ARIES

Accelerator Research and Innovation for European Science and Society

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PERIODIC TECHNICAL REPORT

ARIES: 1st PERIODIC REPORT

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For more information on ARIES, its partners and contributors please see http://aries.web.cern.ch

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Delivery Slip

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1. Explanation of the work carried out by the beneficiaries and overview of the progress

1.1 Executive summary

In the first period, **WP1 (Management, dissemination and ensuring sustainability)** had to set-up the Project governance and the required committees and to provide four milestone reports. The first milestone MS3 concerned the formation of all project bodies and was achieved on time. Two more Milestones concerned the organisation of the Project meetings, achieved with the Kick-off meeting that took place at Geneva (CERN) on 4-5 May 2017 (MS1), and with the 1st Annual Meeting that took place at Riga (Latvia) organised by RTU on 22-25 May 2018 (MS4). The last Milestone MS2 concerned the kick-off of the ARIES-TIARA Working Group on Sustainability, which took place in June 2017.

The activities in **WP2 (Training, Communication and Outreach for Accelerator Science)** started with the launch of the Project website http://aries.web.cern.ch/ by Task 2.2, corresponding to MS10. In Task 2.4, the Milestone MS10 related to the definition of the MOOC (Massive Online Open Courde) content and documenting it in a report has been achieved at the end of M12. Survey tools were evaluated and 'Survey Monkey' was identified as an effective tool for carrying out the training survey. The work has been carried out to prepare the draft survey form and a draft contact list of survey participants has been prepared.

WP3 (Industrial and Societal Applications) had two milestones during this period (MS13 and MS14). The first provided a quite detailed summary of the broad range of applications of electron beams up to 10 MeV and the accelerators currently in use. It also discussed possible research area derived technology that could bring improvements to these applications. The second looked at possible future applications that would be of interest to industry. One milestone (MS15) and three deliverables (D3.1, D3.2 and D3.3) are due in the second year and the work necessary to produce these is already underway.

The **WP4 (Efficient Energy Management)** has co-organized the Workshop on Energy for Sustainable Science that took place in Bucharest, hosted by ELI-NP. A session was devoted to ARIES WP4 subjects and organised by the WP Coordinator, corresponding to MS17. The Task 4.2 activities on efficient klystron design have started with the definition of goal parameters and concept defined, and for the neutron moderator of task 4.3 design studies and simulations were started as well. The Workshop on low-loss RF organised by Task 4.4 and corresponding to MS18 was delayed and took place a few days after the end of Period 1 (November 2018). The subject of the Workshop was flux trapping and magnetic shielding; the Milestone was delivered at M19. Procurement of components for a pilot installation of pulsed low-consumption magnets of Task 4.5 is ongoing.

The main result in Y1 for **WP5 (European Network for Novel Accelerators)** was the organization of the European Advanced Accelerator Concepts Workshop EAAC 2017 and of the Kick-off meeting for the new EuroNNAc3 Network, including the preparation of the agenda and the Indico websites for the events. These corresponded to MS22 and MS23. The EAAC proceedings are being published NIM-A (open-access) under the coordination of the WP. Preparation for Deliverable D5.1 has already started; the school organised by Task 5.4 will take place in March 2019.

In Period 1, **WP6 (Accelerator Performance and Concepts)** organized, or co-organized, a total of sixteen workshops, about three times as many events as had been planned. The subjects were, for Task 2: “Beam Quality Control in Hadron Storage Rings and Synchrotrons”, “Space Charge 2017”, “Slow Extraction”, “Pulsed Power for Kicker Systems”, “Space Charge Collaboration”, “FCC Week 2018”. For task 3: “Mini-workshop on Reliability and Availability”, “Accelerator Reliability Workshop 2017”. For Task 4: “Mini-Workshop on Impedances and Beam Instabilities in Particle Accelerators”, “Electron Cloud”, “Limitations of future circular e^+e^- factories”. For Task 5: “LHeC/FCC-eh”, “PERLE”, “Ion Sources and Low Energy Beam Transport into RF Linacs”. For Task 6: “Photon Beams”, “Muon Colliders”, “Channeling”. Altogether, 1054 participants attended the WP6 events; to this number can be added the 465 participants to the large FCC event that was only co-organised by ARIES WP6, to reach the impressive number of 1519 persons from all over the world who took part in ARIES WP6 events during the period 1. The only Milestone was MS26 (Report on 1st annual workshops of all tasks) that was completed in mid-May 2018

In the 1st Period, **WP7 (Rings with Ultra-Low Emittance)** has met all milestones. These consisted of the organisation of three workshops in the main subtask of injection systems for ultra-low emittance rings (Task 7.2 – MS34) technical developments, specifically dedicated to diagnostics systems for ultra-low emittance rings (Task 7.3 – MS35) and the general workshop (Task 7.1 – MS33). Notable technical highlights were the wealth of technical solutions proposed for novel injection schemes and the R&D towards their technical realisation especially in the field of fast pulsed kickers. Diagnostics and feedback systems seem, in many cases, already at a mature state of development to meet the challenges of ultra-low emittance rings. The field is bustling with more than 15 projects active around the world; most of the latest designs were reviewed at the general workshop. Key aspect of novel injection schemes and the operation with negative momentum compaction factor were tested at KARA (KIT) and BESSY-II respectively. These tests were the object of the Deliverable D7.1 in Task 7.4.

WP8 (Advanced Diagnostics at Accelerators) achieved its milestone for the first period (MS39) organising four topical Workshops, one per Task. The first took place in May 2017 on ‘Simulation, Design & Operation of Ionization Profile Monitors’ for transverse profile measurements at hadron LINACs and synchrotrons (33 participants). The second, in January 2018, concerned ‘Emittance Measurements for Light Sources and FELs’. The third one took place in Geneva in May 2018 on ‘Extracting Information from electro-magnetic monitors in Hadron Accelerators’. In June 2018 a fourth workshop on ‘Longitudinal diagnostics for Free Electron Lasers’ was organized in Hamburg focusing on bunch length measurements as this is one of the most important parameters for Free Electron Lasers.

WP9 (Magnet Testing) offers Transnational Access (TA) to the magnet testing at CERN and University of Uppsala. Table 1 gives an overview of the facilities activities in terms of number of projects, users and access units. At CERN MagNet, four projects have been selected and supported, with 22 users and delivering 49% of the total of access units foreseen for the project. The delivery to the Uppsala Gersemi facility of the vertical cryostat system was delayed due to technical difficulties during manufacturing. The complete system was delivered only in March 2018; installation work has been completed by August 2018 and first operation is expected in early 2019.

Facility	No. of projects P1	Total no. of projects Annex 1	No. of users P1	Total no. of users Annex 1	No. of access units P1	Total no. of access units Annex 1

MagNet	4	8	22	40	944	1,920
Gersemi	0	8	0	56	0	2,880

Table 1: Number of projects, users and access units for the magnet testing facilities

WP10 (Material Testing) provides user access to the material testing at CERN and GSI. Table 2 shows the number of projects, users and access units for these facilities. During P1, the CERN HiRadMat provided access to 6 projects with 38 users and was particularly successful, providing more access units than foreseen. This is important because the facility will be stopped at end 2018 for two years of maintenance of the CERN accelerator complex. The second access facility at GSI was in shut-down until June 2018; in this time, it has been contacted by several user groups and finally two proposals were submitted and approved, indicating that the user community prefers to form large scale projects by cooperating already at the proposal stage. Therefore we expect less projects (3-4) covering the total number of access units. Preparation of the experiments of the approved projects is ongoing, while the first project already started with initial beam time.

Facility	No. of projects P1	Total no. of projects Annex 1	No. of users P1	Total no. of users Annex 1	No. of access units P1	Total no. of access units Annex 1
HiRadMat	6	5	38	20	1328	200
UNILAC	2	8	21	48	104	480

Table 2: Number of projects, users and access units for the material testing facilities

WP11 (Electron and proton beam testing) is composed of five facilities offering electron and proton beam testing in KIT, CEA, DESY and STFC. The status of the five facilities is as follows:

- ANKA/KARA @ KIT enabled transnational access for three experiments.
- FLUTE @ KIT enabled access based on a first TNA Proposals.
- IPHI @ CEA has restarted operation with beam only at end of 2017. The first TNA proposal was accepted in Summer 2018 and the experiment performed in October 2018.
- SINBAD @ DESY is still under installation. Its availability in Spring 2019 is confirmed.
- VELA @ STFC has two TNA experiments scheduled, but failure of the photo-injector laser has delayed these experiments until Q1 2019.

The Table below shows the activity in terms of number of projects, users and access units.

Facility	No. of projects P1	Total no. of projects Annex 1	No. of users P1	Total no. of users Annex 1	No. of access units P1	Total no. of access units Annex 1
ANKA	3	8	6	64	180	480
FLUTE	2	8	9	40	56	320
IPHI	1	12	8	72	72	1,440
SINBAD	0	9	0	36	0	630
VELA	1	14	0	56	0	336

Table 3: Number of projects, users and access units for the electron and proton beam testing facilities

WP12 (Radio Frequency Testing) provides user support to radiofrequency testing at the University of Uppsala and CERN. HNOSS had two projects supported with 18 users during the first period, providing 1330 access units out of 2880 committed. Xbox at CERN had two project completed with 13 users and has provided 1680 access units out of 6000.

Facility	No. of projects P1	Total no. of projects Annex 1	No. of users P1	Total no. of users Annex 1	No. of access units P1	Total no. of access units Annex 1
HNOSS	2	4	18	44	1330	2,880
XBox	2	4	13	64	1680	6,000

Table 4: Number of projects, users and access units for the Radiofrequency testing facilities

WP13 (Plasma beam testing) provides plasma beam testing at three facilities, CNRS, CEA and ULUND. During the first period, The Transnational Access APOLLON facility was under preparation for the first experiments, in agreement with the workplan; no Transnational Access was provided during the first period. At LPA-UHI100 facility, the transnational access activity has been opened to a project from Queen's University Belfast. 24% of total access units foreseen for ARIES have been delivered. The laser of the LULAL facility is under repair and the facility could not yet welcome users. A first experiment should start before the end of 2019.

Facility	No. of projects P1	Total no. of projects Annex 1	No. of users P1	Total no. of users Annex 1	No. of access units P1	Total no. of access units Annex 1
APOLLON	0	6	0	48	0	180
LPA-UHI100	1	4	5	40	152	640
LULAL	1	6	0	36	0	480

Table 5: Number of projects, users and access units for the plasma beam testing facilities

In **WP14 (Promoting Innovation)** the deliverable D14.1 "set up of the PoC innovation funding scheme" was achieved almost 6 months in advance. This anticipation has allowed launching the Call for Proposal for the proof-of-Concept Fund already on December 1st, 2017. The deliverable D14.3, "Production of material samples of C-based and metal-diamond composites" due in month 24, has been as well completed almost one year in advance, as the sample production and characterization has been successfully concluded and there was some pressure to complete testing under high-power beam before the closure of the HiradMat test facility. In a similar way, the Deliverable D14.4 "1st length of industrial HTS", due in month 30, is already well advanced and it is expected to be completed ahead of schedule. This Deliverable will follow the successful completion of the Milestone MS45 "First HTS short length produced via new process", which was achieved on schedule. Other Milestones due in the reporting period were MS42 "set-up of Industry Advisory Board", completed on schedule before M12, and MS47 "revised requirement document" on the new accelerator timing system, all these timely submitted. Work is progressing towards the organization of the 1st academia-meets industry event, object of MS43, due in M24.

In **WP15 (Thin Film for Superconducting RF Cavities),** the main activity during the first year concerned task 15.2, which was required to clean and polish with different techniques 100 copper substrates prepared by different partner laboratories. The surface properties had to be measured to evaluate the techniques. This production campaign was defined in the kick-off meeting, covered by MS49 "Organisation of WP15 kick-off meeting" while the first surface preparation was the subject of MS50 "First sample substrates cleaned at INFN for depositing at partners", both Milestones being achieved on schedule. Deliverable D15.1 "Evaluation of cleaning process" reports the results of the measurement campaign. It was achieved with a delay of two months to have some additional time to collect and process data after the end of the measurement campaign. After surface preparation, first depositions took place and were reported in Milestone MS51 "First samples exchanged (system 1 and 2) and deposited at partners". Additionally, tests made with a laser have demonstrated that laser radiation of a Niobium film can increase the grain size and improve on adhesion of the film on a copper substrate. Preparation work is progressing in the other tasks, in particular for the preparation of superconducting film characterisation facilities at IEE, CEA, and STFC.

During the first reporting period, the work in **WP16 (Intense, RF modulated E-beams)** concentrated on the conceptual design of the electron gun and its modulator as well as the design of the test stand. There were no deliverables scheduled and only a single milestone (MS53), due right at the end of the reporting period. MS53 belongs to task 16.3 and constitutes a report on the conceptual layout of gun and modulator, which was finished on time. Likewise, excellent progress was already made in task 16.4 regarding the test stand design, the first stage of which has in fact already been completed, even though the corresponding milestone (MS54) is not due before month 24. A slower progress than expected was made in task 16.2 due to some unanticipated changes in the personnel resources. Nonetheless, significant results were obtained on the integrated set-up of the space charge compensation lens for GSI. The personnel resource issues being solved since the beginning of 2018, the work on task 16.2 regained pace and no impact on the first milestone (MS55), due by month 24, is expected.

After holding its kick-off meeting (reported in MS58), and organizing a fruitful workshop in Turin (Italy), **WP17 (Materials for extreme thermal management)** achieved its first Deliverable, D17.1 "Material Characterization". This was the result of a comprehensive characterization campaign performed at CERN, GSI and POLIMI on a broad spectrum of advanced materials, including recent grades of Molybdenum Carbide – Graphite (MoGr), Thermal Pyrolytic Graphite (TPG), several grades of Carbon Fibre reinforced Carbon (CFC), Isotropic Graphites, Carbon Foams, Glassy Carbon (GC), Copper – Diamond (CuCD), with and without thin-film coatings. Obtained results are paving the way for further materials optimization and future irradiation experiments. Additionally, the Multimat and FlexMat experiments was successfully completed, with the test under the direct impact of highly intense particle pulses of a broad range of materials, ranging from extremely light Carbon Foams to Heavy Tungsten Alloys. All carbon-based materials produced survived the tests and were qualified for use in future high power accelerator applications.

In **WP18 (Very High Gradient Acceleration Techniques),** Task2 has completed the conceptual design of an electron transport line between two accelerating stages, identifying a preferred layout with acceptable impact on beam quality, as reported in Deliverable D18.1 "Enabling multi-stage Laser Wakefield Acceleration". In Task 3 has performed Particle-In-Cell simulations to explore the acceleration in plasma waves driven by exotic beams, followed by a first test of creating Laguerre-Gaussian doughnut beams. These activities were reported in two Milestone reports, MS18.1 (Setup simulation framework for acceleration and radiation generation in wakefields driven by lasers with orbital angular momentum) and MS 18.2 (Setup of experimental facilities for laser wakefield acceleration experiments using laser drivers with orbital angular momentum), both achieved on time. Tasks 4 and 5 have started their theoretical and simulation analysis and are on time for their reporting.

1.2 Summary of exploitable results and an explanation about how they can/will be exploited

WP	Type of exploitation foreground[1]	Description of exploitable foreground (relevant deliverable)	Purpose (How the foreground might be exploited and by whom)	IPR[2]	Potential/expected impact (quantify where possible)	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable, commercial or any other use
3	*GAK*	***Hybrid electron accelerator system for the treatment of marine diesel exhaust gas***	*HERTIS proposal to Social Challenges H2020 call*	*open*	*Reduction of maritime transport pollution*	*Project proposal*	*Maritime transport*	*Short-medium term*
6.2	*GAK*	***Ranked assessment of processes causing performance degradation in hadron storage rings and synchrotrons***	*Implementation of more efficient mitigation approaches, which may be used by any accelerator laboratory*	*open*	*Improved performances of present and future hadron accelerators by better control of degradation processes*	*Reports*	*Beam Dynamics*	*starting today*

[1] Type of foreground: General advancement of knowledge (GAK), Commercial exploitation of R&D results (CERD), Exploitation of R&D results via standards (ERD), exploitation of results through EU policies (EUP), exploitation of results through (social) innovation (INV).

[2] Invention, disclosure, patent, other

6.3	*GAK*	***Compilation and ranking of RAMS standards***	*Spreading the identified best RAMS practices*	*open*	*Feasibility of an Open Data Infrastructure for accelerator reliability*	*Reports and collaboration network*	*Reliability of Accelerators*	*>2 years*
6.4	*GAK*	***Beam-impedance assessments and impedance models***	*Review of existing strategies & methods*	*open*	*Conceptual design of advanced beam feedback systems for future machines*	*Reports and proposals of R&D*	*Beam dynamics, ongoing and future projects*	*>2 years*
6	*GAK*	***Alternative muon-collider concepts***	*Future energy frontier collider for worldwide HEP community*	*open*	*Collider concept for the long-term future and related infrastructure*	*Reports*	*Future projects in high-energy physics*	*>50 years*
6	*GAK*	***Accelerator-based source of intense pulsed Gamma rays – conceptual study***	*An intriguing application of the LHC serving several types of user communities*	*open*	*Future use of LHC (or FCC) complex*	*Reports and collaborations*	*Nuclear physics, material science, high-energy physics*	*>8 years*
6	*GAK*	***Highest-brilliance X-ray FEL based on ERL***	*Next-next generation XFEL*	*open*	*Revolutionize X-ray based science and open up new research possibilities*	*The next frontier XFEL*	*Material science, biology, industry*	*>8 years*

6	*GAK*	***Ultra-thin NEG coating***	*Providing good vacuum and suppressing electron cloud, without increasing impedance*	*tbd (patent)?*	*Improved coating for accelerator vacuum chamber and insertion devices*	*Higher-intensity higher-performance lepton accelerators*	*Electron/positron accelerators, light sources*	*could start today*
10.1	*GAK*	***Development of real-time beam diagnostic system (HRM-BTV)***	*Facility users for all delivered protons to experiments. Could be adapted for other facilities requiring real-time beam profile measurements.*	*other*	*Improved knowledge and categorisation of beam information (beam spot size and beam position) during experiment and during post-experimental analysis*	*Reports*	*Beam Instrumentation & Diagnostics*	*Already in place. Analysis ongoing*
10.1	*GAK*	***Qualification of newly designed BLMs***	*Calibration of BLMs for installation in accelerators*	*other*	*Improve the quality and accuracy of beam loss monitoring systems*	*Reports and new installations*	*Beam Diagnostics*	*Ongoing*
15.2	*GAK*	***Copper polishing***	*Study the effect of different Copper polishing procedures on copper surface*	*disclosure*	*Define a standard procedure for the copper substrates in SRF applications*	*Copper polishing protocol*	*SRF*	*Ready to use*

17	*GAK*	***Advanced knowledge on materials response to energy density deposition***	*New materials solutions for challenging operation conditions at new high power accelerator facilities*	*open*	*Improved material response to high energy density deposition; increase reliability of beam intercepting devices*	*New BID (production targets, collimators, beam dumps) solutions*	*High-power accelerators; thermal management*	*Short and long term*
18	*GAK*	***Multi-stage wakefield acceleration***	*Enable multi-stage laser wakefield acceleration*	*open*	*Make LWFA possible for high energies*	*Multi-stage compact FEL or linear collider*	*Photon science (FEL), high-energy physics (colliders)*	*Long term*

1.3 Progress towards objectives and significant results

WP1 (Management, dissemination and ensuring sustainability)

Objectives: *set up the project governance and the related official bodies, organise the project meetings, set up the communication structure, form a working group on sustainability.*

The Consortium Agreement was signed by all partners, the Governing Board and the Steering Committee for the Project were formed and hold their regular meetings, 2 for the GB and 6 for the SC. The Project kick-off and first annual meetings took place attended by more than 100 people. The ARIES web site is open and a regular ARIES Bulletin is distributed to a list of more than 300 people who participates in the ARIES activities. The Working Group on Sustainability of Accelerator research was formed and organised a first Workshop with industry. 6 Deliverables were produced in the reference period, one more than the contractual agreement, as well as 26 Milestones, one less than foreseen.

WP2 (Training, Communication and Outreach for Accelerator Science)

Objectives: *set up the external communication and outreach of the Project, launch a survey on education and training needs for accelerators in Europe, define a MOOC course (technical platform and contents) on accelerator science and technology.*

The ARIES website was launched and so far had over half a million hits and more than 9,000 unique visitors. More than 15 ARIES articles appeared on the newsletter Accelerating News. A video promoting ARIES for general public was publish on social media, exposed to more than 100,000 people with engagement rates well above average. Drafting of a survey of the provision of education and training in accelerator science in Europe, ready for launch in the next reporting period, was started. The preparation for delivering the Massive Open Online Course on Introduction to accelerator science and technology was completed. The syllabus is being finalised and recording of the first video will take place in early 2019.

WP3 (Industrial and Societal Applications)

Objectives: *complete a study on application of low-energy electron beams, explore new applications in particular in the environmental field.*

The network has produced a comprehensive study on application of low-energy electron beams and has identified and promoted a new application to hybrid electron beam treatment of exhaust gases from ships. A collaboration was formed to support the development of this technology, which has successfully applied to receive funding within the ARIES Proof-of-Concept fund. The collaboration is now preparing to submit a proposal for a wide project under the Societal Challenges pillar of Horizon 2020. Other promoted applications in the environmental field are electron beam sludge hygenization and use of electron beams to produce high-quality organic fertilisers from biogas digestate, the latter being the subject of another proposal in preparation for H2020.

WP4 (Efficient Energy Management)

Objectives: *organise a workshop on sustainable accelerator facilities, explore new high-efficiency power sources, organise a workshop on higher efficiency superconducting RF, study new iron-free quadrupole magnets.*

A general workshop on sustainable accelerator based research facilities co-organised by the Network was successfully held at the ELI-NP facility in Bucharest/Romania. A prototype kladistron, a novel type of high-efficiency RF power source, has been manufactured and is presently under study. A topical Workshop was organised on flux trapping and magnetic shielding techniques to improve efficiency of superconducting accelerating systems. Components were procured and installed for testing of pulsed iron-free quadrupole magnets.

WP5 (European Network for Novel Accelerators)

Objectives: *structure the novel accelerator community, organise a large European event on novel accelerators, organise a school on this topic.*

The Network is reaching at a wide community, with 65 participating institutes and universities, 14 being from outside of Europe. It has organised the main European event on novel accelerator technologies, the European Advanced Accelerator Concepts Workshop which took place at Elba Island in September 2017 and attracted 297 participants (18% female) from 18 different countries, presenting in total 192 talks and 92 posters. Preparation for EAAC19 has already started. A school on High Gradient Wakefield Accelerators has been organised; it will take place in March 2019.

WP6 (Accelerator Performance and Concepts)

Objectives: *organise at least one workshop per Task, identify limitations in the performance of accelerators and propose solutions, analyse and promote new accelerator concepts.*

The Network has organized or co-organized 16 scientific Workshops, reaching a number of 1,054 participants globally attending WP6 events. 22% of participants were coming from outside of Europe. Main scientific outcomes were the identification and ranking of performance degrading mechanisms for hadron storage rings and of novel methods to reduce accelerator impedance such as ultrathin coating; a definition of the optimal design and operational characteristics for particle accelerators to improve the availability; and a validation of accelerator concepts for the long-term future, such as Gamma factories and muon colliders.

WP7 (Rings with Ultra-Low Emittance)

Objectives: *organise one general workshops and two topical workshops, perform a campaign of beam measurement at accelerator test facilities.*

The Network has organised a general workshop with more than 80 participants and two topical workshops, on injectors and specific technologies for low-emittance rings. Experimental tests supporting the development of ultra-low emittance rings were carried out at two different accelerators, KARA and BESSY-II, providing useful insights on operation with negative momentum compaction factor and on the comparison between simulations and measurements for off-energy off-phase injections.

WP8 (Advanced Diagnostics at Accelerators)

Objectives: *organise at least one workshop per Task, start personnel exchange between accelerator laboratories.*

The Network organised four dedicated workshops on specialised subjects, with a number of participants ranging between 30 and 50. Some of the Workshop were co-organised between different

Tasks, to favour the exchange of experience between different accelerator communities. Three exchanges of personnel took place for a period of around 2 weeks each.

WP9 (Magnet Testing)

Objectives: *start the maximum number of projects at MagNet (CERN) without interference with the internal programme, advertise the facility and start user support at the new Gersemi (Uppsala Univ.).*

MagNet welcomed 4 projects, providing 944 access units to 22 users from two European countries. At Gersemi, due to the ongoing construction and preparation of the infrastructure, user support could not start yet. The facility will be operational by mid-2019.

WP10 (Material Testing)

Objectives: *for HiRadMat at CERN, provide the maximum number of access units before the shut-down of the facility for maintenance at end 2018. For GSI M-branch at GSI, advertise the facility and start providing access after the GSI shut-down.*

HiRadMat has provided 1,328 Access Units for material testing, supporting 6 projects. GSI M-Branch was adequately advertised to the community, but because of the GSI accelerator shut-down and of delays in the start-up, the first project could be provided with beam only in June 2018.

WP11 (Electron and proton beam testing)

Objectives: *advertise the new facilities providing access to external users for the first time (IPHI at CEA, ANKA and FLUTE at KIT, VELA at STFC), finalise the infrastructures and provide access to the first user projects. Continue the construction of the new facility SINBAD at DESY.*

IPHI@CEA, ANKA/KARA@ KIT and FLUTE @ KIT received the first user requests. SINBAD @ DESY continues its installation. VELA @ STFC completed commissioning in September 2018 but failure of the photo-injector laser has introduced a further three-month delay to operations.

WP12 (Radio Frequency Testing)

Objectives: *advertise the new facilities providing access for the first time to HNOSS at Uppsala University and Xbox at CERN.*

The new HNOSS facility supported 18 users during the first period and provided 1,330 access units. Xbox at CERN had one project completed with 6 users and has provided 1,680 access units out of 6,000. A second User Project was approved with seven users.

WP13 (Plasma beam testing)

Objectives: *advertise the new facilities providing access for the first time to LPA-UHI100 at CEA and LULAL at Lund University. Complete the installation and commissioning of APOLLON at CNRS.*

The LPA-UHI100 facility has welcomed 4 scientists from Queen's University Belfast providing 152 access units. The laser of the LULAL facility is under repair and the facility could not yet take users; a first experiment should start before the end of 2019. The APOLLON facility is under preparation for the first experiments.

WP14 (Promoting Innovation)

Objectives: *set-up the Proof-of-Concept programme for innovative projects, select the submitted projects and attribute the grants. Set-up the Industry Advisory Board. Produce the first length of high-temperature superconducting cable. Start production of material samples for high-thermal accelerator applications. Complete the specification for a novel timing system.*

The Proof-of-Concept fund was launched and received 10 applications for technology developments finalized to commercial applications. The Evaluation Committee nominated by the Industry Advisory Board (IAB) selected 4 for funding. The IAB was set up to improve and expand collaborations and joint research with industry. Significant technical results were achieved in its three collaborative projects with industry: first lengths of HTS cable produced and successfully tested, a series of novel material samples produced and delivered to the testing facilities, and the specifications of the timing system completed and validated. The first samples of MgB_2 added-material were produced and are currently under characterization for superconductor properties.

WP15 (Thin Film for Superconducting RF Cavities)

Objectives: *set-up the collaboration team, to build/modify deposition and characterisation facilities, set-up a sample exchange procedure and define the surface preparation procedure.*

The full process has been successfully started and the first 50 sample substrates have been produced and polished, 15 samples were jointly deposited and characterised in the participating laboratories. First set of System 1 and 2 samples have been produced and sent to other WP15 participants.

WP16 (Intense, RF modulated E-beams)

Objectives: *developing the concepts and the design for electron gun and modulator and a design for the test stand.*

A preliminary design of the electron gun and a concept for the modulator were developed. A preliminary design for the first stage of the test stand was completed, with the first components already acquired and the facility under preparation.

WP17 (Materials for extreme thermal management)

Objectives: *launch a characterisation campaign of new materials.*

The JRA has launched an extensive characterization campaign of advanced materials, has assessed by simulation the long-term radiation damage in materials for HL-LHC collimators and has selected beam parameters for future irradiation experiments. It has completed two experiments investigating the response of more than 30 advanced materials to high intensity proton beam impact: Multimat and FlexMat, at CERN HiRadMat facility.

WP18 (Very High Gradient Acceleration Techniques)

Objectives: *start simulations on acceleration with exotic laser beams, design an interstage beam transport line for multi-stage acceleration.*

The JRA has produced two milestones on studies of laser wakefield acceleration with exotic laser beams, delivering first results. They consisted in setting up a simulation framework for acceleration and radiation generation in wake fields driven by lasers with orbital angular momentum and setting up an experimental facility for laser wakefield acceleration experiments using laser drivers with orbital angular momentum. An interstage transport beam-line has been designed, including a complete set of simulation and estimates of beam degradation.

1.4 Explanation of the work carried per WP

WP1: Management, dissemination, ensuring sustainability

The objectives of this WP are to ensure the management and coordination of the broad consortium, to guarantee the efficient dissemination of information and generated results, and to define a long-term strategy for sustainability of accelerator research in Europe. The WP includes 3 tasks:

- Task 1.1. Management
- Task 1.2. Internal communication, dissemination, scientific publications and monographs
- Task 1.3. Sustainability of Particle Accelerator Research in Europe

Task 1.1. Management

Consortium management tasks and achievements

The Management Team, composed of a Scientific Coordinator from CERN, a deputy from DESY, an Administrative Manager and a Project Support Office from CERN, set up the project Consortium Agreement, distributed the EC pre-financing, monitored the resource utilisation of the 41 beneficiaries, organised the project Kick-off meeting and prepared the first project amendment to the EC.

The Kick-off meeting took place on 4-5 May 2017 at CERN and consisted of plenary sessions with presentations from all WPs, the first meetings of the Governing Board and the Steering Committee, a dedicated Industrial meeting, as well as parallel sessions per activity or WP. The Kick-off meeting

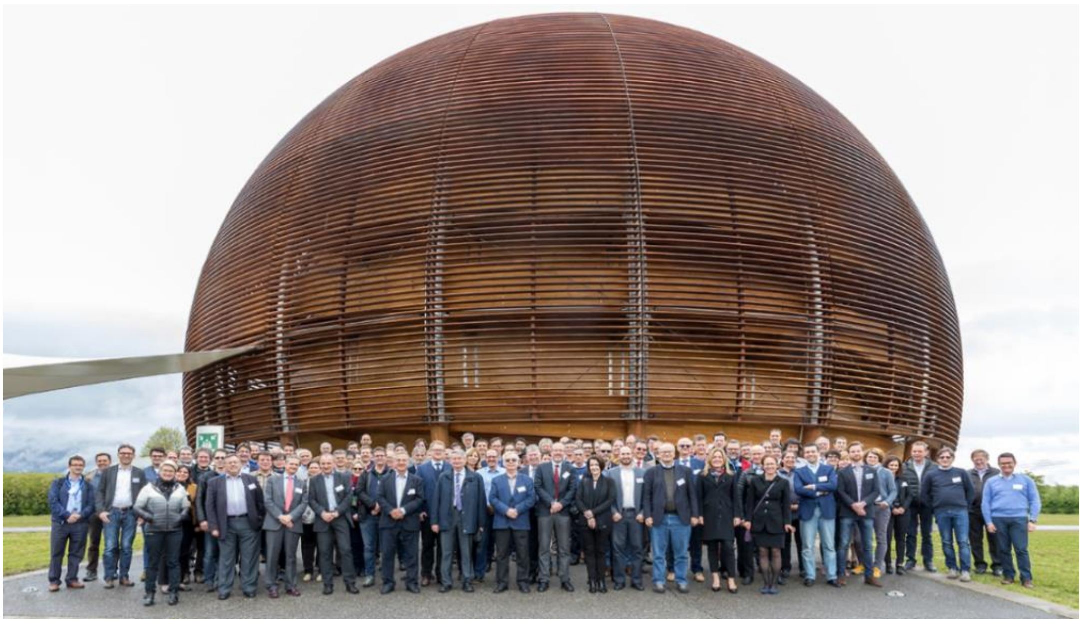


Figure 1: Group picture from the ARIES Kick-off meeting at CERN

gathered a wide audience, with 140 participants from 22 countries, 4 more than the member countries of ARIES, and 19 participants from industry, 14% of total. The large majority of participants (78%) was from outside CERN.

All the project management bodies were formed in the first months of the project:

- The ***Governing Board (GB)***, composed of one representative from each beneficiary is the decision-making and arbitration body of the project. It met for the first time during the Kick-off meeting to endorse the members of the Steering Committee, to nominate the Scientific Advisory Committee and Industrial Advisory Board members and to approve the accession of new partner organisations to the ARIES consortium. A second meeting took place during the ARIES Annual Meeting on 23 May 2018 in Riga.
- The ***Steering Committee (SC)***, with at least one representative per WP, met 6 times in the reference period to discuss general ARIES issues, status of deliverables and milestones, and the scientific progress in each WP.
- The ***Industrial Advisory Board (IAB)***, composed of six representatives of industries not members of ARIES but related to ARIES activities, provides advice on possible societal applications of ARIES technologies and on strategies to maximise their impact on society. It has been nominated at the first meeting of the Governing Board and met for the nomination of the Evaluation Committee of the proof-of-Concept fund and then at the first Annual Meeting.
- 5 ***User Selection Panels (USP)*** were established per each TA work package to review the proposals submitted for transnational access. The list of USP members per WP can be found in *Annex 2*.
- The **Scientific Advisory Committee (SAC)**, composed of external experts from different regions (1 from Asia, 1 from America and 1 for Europe) was formed to advise the Governing Board and the Steering Committee on technical and strategic matters related to the scientific programme of the project.

The 1st ARIES Annual Meeting took place in Riga, Latvia, from the 22nd to the 25th of May 2018, hosted by the Riga Technical University (RTU). Parallel Meetings, the ARIES Governing Board, and a Transnational Access Meeting were organized at the beginning of the week, followed by two days of Plenary Sessions. A meeting of the Steering Committee closed the event on the 25th of May.

The main goals of the meeting were to present the activities of the different ARIES work packages during the first year and to plan the work for the following year. The Meeting was well attended, with 113 participants (23 female, 20.3%) coming from 16 European countries, plus Japan and Russia. 10 participants were from industry (9%) Outreach activities were organised in Riga to promote accelerator technology and scientific cooperation in the dynamic Baltic area and high-level meetings took place with Latvian scientific representatives.

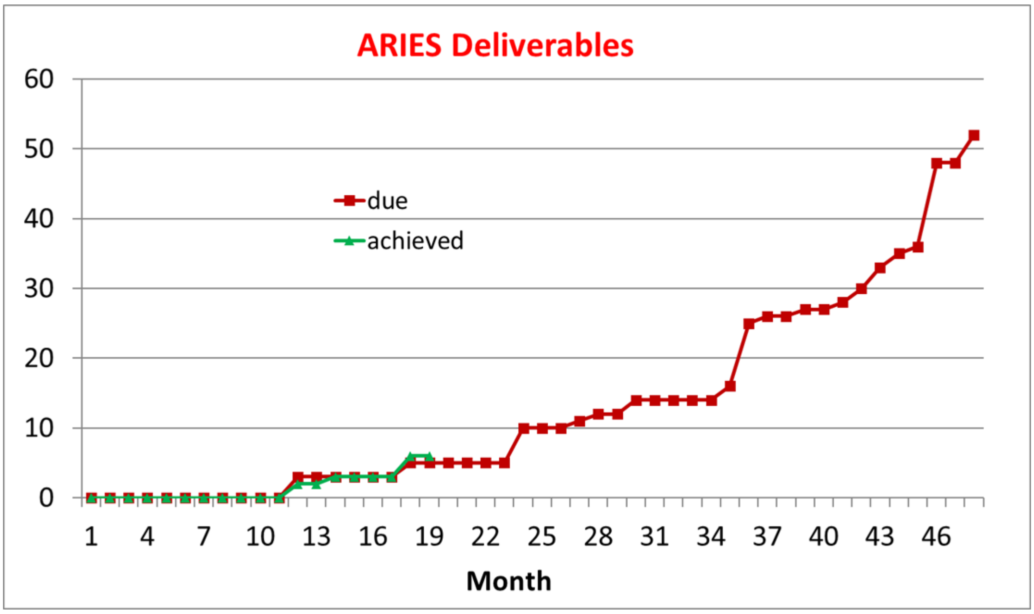
Contractual milestones and deliverables

In the P1 reporting period, Task 1.1 had three milestones to achieve:

- MS1: Kick-off meeting – ACHIEVED
- MS3: Forming all official bodies required by the governance – ACHIEVED
- MS4: 1st Annual Meeting – will take place on 22-25 May at RTU - ACHIEVED

Project planning and status

In the first period of the project, the contractual objectives included the completion of 5 deliverable reports (out of the total 52) and 27 milestones (out of the total 66). 6 deliverables have been achieved in Period 1, one more of the contractual obligations – a set of prototype materials developed with industry that needed to be tested in advance of schedule. Only one Milestone could not be completed in the reference period due to delays in organising a Workshop but was achieved in M19 a few days after the end of Period 1 (details in Section 3.1). The progress of Deliverables and Milestones during the first 18 months is detailed in Figure 2.



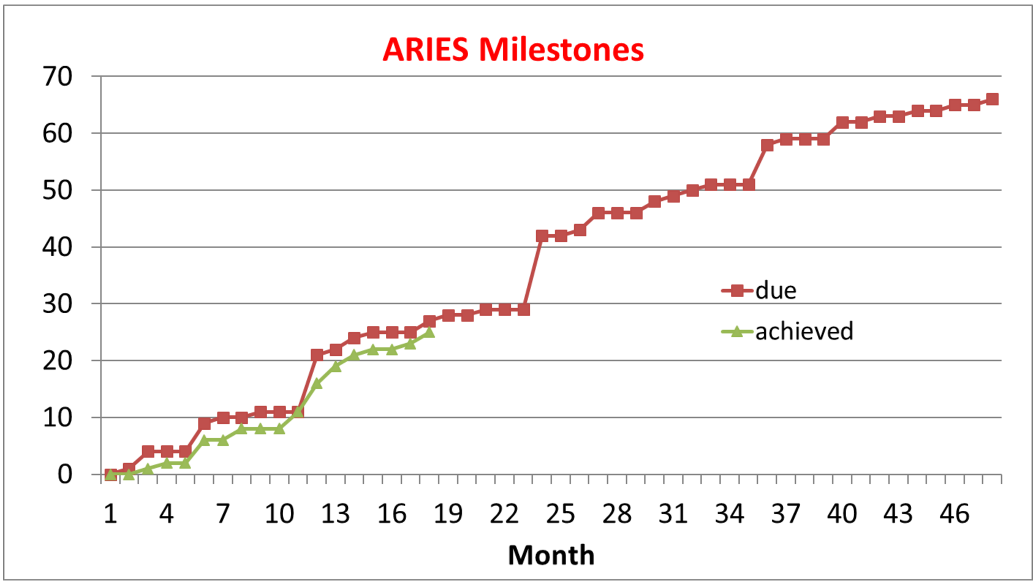


Figure 2: Progress in the Deliverable and Milestones preparation

Problems and solutions

The main problem to be addressed was the low access to some Transnational Access facilities during the first year. A special Steering Committee meeting in September 2018 was devoted to this issue, with the presence of all facility coordinators. The main measure taken were: a) the definition of new channels to advertise the access within the accelerator community, b) the provision of more administrative support to some facilities for a better management of their access, and c) the encouragement to successful facilities to exceed their commitment to compensate for underperforming facilities.

Budget adjustments

The only budget adjustments of the EC contribution in Annex 2 in the first reference period of the project concerned the transfer of the funding for the Proof-of-Concept Fund (see Section of WP14) from CERN that manages the Fund to the four Beneficiaries leading the projects approved by the Evaluation Committee. These are RTU, RHP, CEA and UNILIV that received 50’000 EUR each. The transfer was approved by the Governing Board with electronic vote on 24 July 2018.

Change of tasks between beneficiaries

No changes of tasks between beneficiaries occurred in the first period of the project. The Proof-of-Concept activities became part of the Workplan, attributed to the leading institute.

Changes in the consortium and/or legal status of beneficiaries

The first project amendment was launched by the Consortium in June 2017 to include Fondazione CNI as third party linked to CNI (which was agreed with the EC at the time of the Grant Agreement preparation), as well as to implement other minor modifications such as: a change of distribution between personnel costs and other direct costs for ESS to allow funding of PhD students and an update of the list of partner organisations. The amendment request was approved by the EC on 14 July 2017.

The Austrian Institute of Technology (AIT) and the University of Strathclyde (STRATH) have expressed interest to participate to ARIES activities as partner organisations[3]. The Governing Board endorsed their participation to the following activities:

- AIT will contribute to Task 6.3: Availability and Reliability of Particle Accelerators;
- STRATH will contribute to the networking activities of WP5.

Coordination of activities between beneficiaries and synergies with other projects

The WPs have conducted their own coordination of activities, with the Project Coordination intervening only to advise and promote applications to the Proof-of-Concept Fund and to favour exchanges between participants and transversal initiatives during the Kick-off and First Annual Meetings. Two of the ARIES Network work in close contact with ongoing Design Studies (EuPRAXIA for WP5 and EuroCirCol for WP6). They have coordinated their activities with the Design Studies and co-organised some of the events (Workshops).

Particular attention during the first period was given to coordinating with the AMICI (Accelerators and Magnets Infrastructure for Cooperation and Innovation) project for support to accelerator and magnet technological infrastructures. Two coordination meetings were hold between ARIES and AMICI management to precisely identify the area covered by the two projects, and to outline and solve possible overlaps. The two areas of action are different (accelerator R&D for ARIES, support to accelerator technological infrastructure for AMICI), with accelerator R&D extensively using the technological infrastructure coordinated and supported by AMICI. Possible overlaps might concern development of innovative technologies, with ARIES dealing mostly with low TRL activities and AMICI oriented towards higher TRL. To avoid overlaps and to exploit synergies, the Coordinator of ARIES joined the AMICI Steering Committee, to represent his Laboratory and to allow a close coordination between the two projects. Synergies are evident in the connection with industry and during the first period two common initiatives were organised, a co-innovation workshop with

[3] A partner organisation in ARIES is defined as a participant contributing to the project in cooperation with a beneficiary.

industry at Brussels in February and a meeting on IP management in collaborative projects with industry at CERN in May.

Contacts were also established with the FuSuMaTech FET initiative; here the field of activities is far from the ARIES goals, and a communication line was established to exploit synergies e.g. in HTS superconductors.

The ARIES management has closely followed the establishment of the new LEAPS federation of photon sources. Their programme has a robust accelerator part and discussions took place to be sure that there are no overlaps and that the activities in ARIES and LEAPS can be synergetic.

With other projects oriented towards particle detectors as ATTRACT and AIDA2020 there is no overlap, apart some very specific types of detectors that can be used in accelerators and are not covered by ARIES. The Coordinators of ARIES and AIDA2020 met a few times to exchange experience and to discuss common issues.

Project meetings

All ARIES project meetings are registered on Indico. The meetings that took place during the reporting period are outlined in Annex 1.

Task 1.2. Internal communication, dissemination, scientific publications and monographs

To fulfil its open-science obligations and host its publications, the ARIES project selected the Zenodo platform. A dedicated ARIES section has been created: https://zenodo.org/communities/aries. Zenodo is a general-purpose open-access research data repository, created by OpenAIRE to provide a place for researchers to deposit datasets. Zenodo is a strong supporter of open data in all its forms (i.e. data everyone is free to use, reuse, and redistribute) and takes an incentive approach to encourage publication under an open license.

In order to help the participants to submit directly in Zenodo, a tutorial video was produced in September of 2018 (Figure 3) (https://aries.web.cern.ch/content/aries-zenodo-tutorial). The tutorial focus the importance of open science for European Commission co-funded projects and instructs researchers on how to publish for the ARIES community. In this way, we hope to increase the number of publications submitted, since the process is very simple to follow.

Figure 3: A screenshot of the ARIES Zenodo tutorial, September 2018

A project Intranet was developed for members to use as an online collaborative workspace for communication and dissemination of results: https://espace.cern.ch/project-ARIES-Intranet/SitePages/Home.aspx

Posters for the ARIES meetings (Figure 4, left) were designed and distributed to project members to announce the details of the meetings.

A category ARIES (ARI) was created in the "Accelerating News" newsletter to associate the project to this active accelerator-community channel (acceleratingnews.eu). Articles are published on a quarterly basis and, to date, six newsletters including ARIES articles were issued. In total more than 15 ARIES articles were published on Accelerating News. In November of 2018, Accelerating News has 1480 contacts, including e-groups. 'ARIES Transnational Access' performed very well in Accelerating News: it was published in July 2018 and is already one of the most viewed articles. Additionally, visits to the website peak when the newsletter is published.

Recently, an ARIES Bulletin (Figure 4 right) has been created to communicate information on the project to the participants (announcement of meetings, workshops and events, publications, general information). The first issue was distributed in October 2018 and it is foreseen to prepare three to four issues per year.

Figure 4 : ARIES Posters and Bulletin in Period 1

The start of publications under the "ARIES Editorial Series on Accelerator Science and Technology" (printed scientific monographs of 20-50 pages each, distributed to all participating institutes) had to be delayed because of complexities in negotiating the printing contract covering the entire duration of the project. Three tenders were cancelled for different administrative reasons until the final one was successful and the contract was signed in July 2018, for 15 volumes. Six monographs were sent to the printing office, and the first 5 will be distributed in December 2018. These are:

- S. Keckert, Optimizing a Calorimetry Chamber for the RF Characterization of Superconductors;
- R. Kleindienst, Radio Frequency Characterization of Superconductors for Particle Accelerators;
- L. Shi, Higher-Order-Mode-based Beam Phase and Beam Position Measurements in Superconducting Accelerating Cavities at the European XFEL;
- J. Ruuskanen, Predicting Heat Propagation in Roebel Cable Based Accelerator Magnet Prototype;
- F. Carra, Thermomechanical Response of Advanced Materials under Quasi-Instantaneous Heating;
- C.Accettura, Ultra-high vacuum characterization of advanced materials for future particle accelerators.

Task 1.3. Sustainability of Particle Accelerator Research in Europe

The Task started its activity in two directions, the first being the identification of themes and methodologies that could be part of future programmes based on innovation and the second being exploring the ways to organise co-innovation projects with industry.

The first activity was done in coordination with the TIARA Committee that represents the Particle Accelerator R&D community and resulted in a number of discussion meetings. The second activity resulted in the organisation of the Accelerator-Industry Co-Innovation Workshop - Tools and strategies to enhance industry-academia cooperation in the particle accelerator community, which took place at Brussels on February 6 and 7. The programme committee for this Workshop is the first nucleus of the joint TIARA-ARIES working group that is going to develop the subject of accelerator sustainability.

Figure 5: Poster of the Accelerator-Industry Co-Innovation Workshop

The main objectives of the Workshop were to foster discussion on most effective ways to develop co-innovation with industry in Europe, to identify sustainable structures, possible funding schemes and financing mechanisms, to contribute to the definition of new EC instruments to boost co-innovation and to provide a communication platform to all relevant stakeholders: policy makers, academia, industry and scientific management. The Workshop was well attended, with 90 participants coming from 18 countries. 37 participants were from industry, 36 from research centres, 9 from Universities, and 9 from the European Commission. As a general conclusion, this Workshop indicated that, with some active support from the European Commission, accelerator laboratories and projects are now ready to join efforts with industry to propel accelerator technology into the next decade.

Contractual milestones and deliverables

In the P1 reporting period, Task 1.3 had one milestone to achieve:

- MS2: Kick-off Meeting of ARIES-TIARA working-group – ACHIEVED

WP2: Training, Communication and Outreach for Accelerator Science

This NA will provide support and coordination to ongoing accelerator training in Europe, organise a pilot e-learning course on accelerators, and support outreach actions to the general public. The undergraduate e-learning course will become a unique training delivery mode for accelerator science and technology in Europe. The WP includes 4 tasks:

- Task 2.1. Coordination and work package communication
- Task 2.2. Coordination, support and enhancement of communications/outreach activities for accelerators in Europe
- Task 2.3. Coordination, support and enhancement of training activities for accelerators in Europe
- Task 2.4. Provide an e-learning course: introduction to accelerator science, engineering and technology

Task 2.1. Coordination and work package communication

All tasks are on track. The participants are meeting regularly. Both milestones have been met on schedule. Task 2.3 is on track to meet its milestone in M24. All three tasks are on track to meet their deliverables.

Task 2.2. Coordination, support and enhancement of communication / outreach activities for accelerators in Europe

During the first period of the ARIES project, the main activities of the task concerned the launch of the project website, the development and dissemination of a video to present the project, and the teaming up with the Accelerating News newsletter to publish ARIES related articles. Further, we have also begun to collect data for D2.2, by organizing the ARIES Accelerator Communication and Outreach workshop, which addressed the accelerator communication community to share best practices and discuss the future of outreach for accelerators.

The **project website** (Figure 6, https://aries.web.cern.ch/), launched in May 2017, has had over half a million hits and more than 9,000 unique visitors. The website was designed to be accessible to a range of different audiences by providing information tailored to their own unique requirements. Top performing pages include ARIES 'Proof of Concept' and 'Transnational Access'. The Factsheet remains one of the most downloaded items (1021 downloads).

The category ARIES was created in the Accelerating News **newsletter** to associate the project to this already active accelerator community media. The newsletter is available on a dedicated website acceleratingnews.eu. Articles are published on a quarterly basis and, to date, 6 newsletters including ARIES articles were issued. In total more than 15 ARIES articles were published on Accelerating News. 'ARIES Transnational Access' performed very well in Accelerating News: it was published in July 2018 and is already one of the most viewed articles. Additionally, visits to the website peak when the newsletter is published.

A **video** to present the ARIES project to a public non-expert audience was created by the CERN Audiovisual Production Service in 2 formats: short for social medias and long for reference. It was posted on 15/02/2018 on CERN Facebook, Twitter, LinkedIn and Youtube with links to ARIES

Figure 6: A screenshot of the front page of the ARIES website, May 2018

website, FB and LinkedIn accounts to direct some of the traffic towards them. The video was exposed to more than 100’000 people on each of the CERN social media channels and the engagement rates were above average (Twitter) to very good (FB) compared to existing benchmarks. The video was the second most viewed on CERN FB in February when it was released.

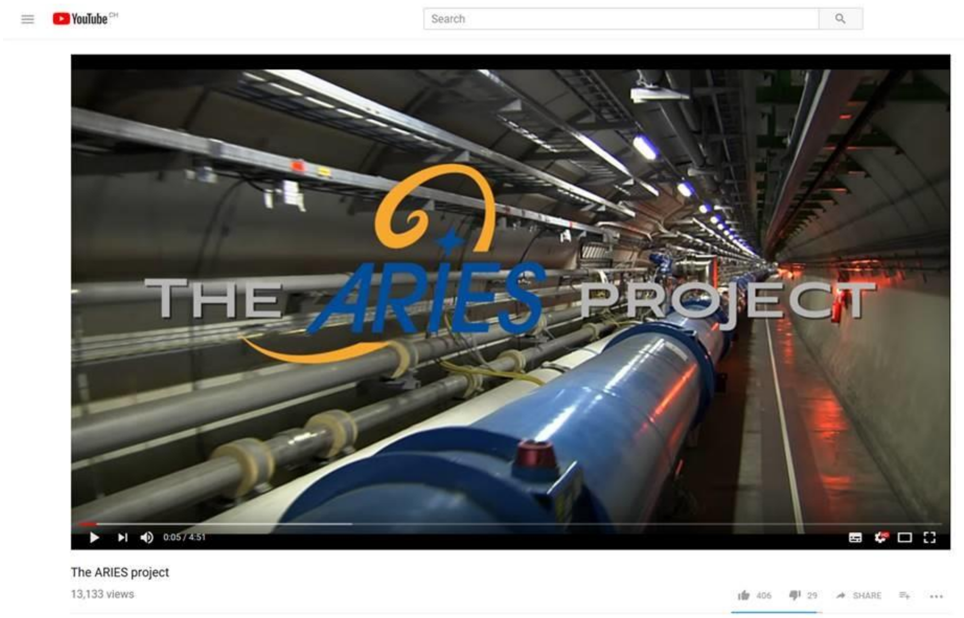


Figure 7: Screenshot from the ARIES video

The **social media** approach followed in ARIES is to reach the followers of the project main partners’ social media channels, whilst creating dedicated ARIES social media channels (primarily Facebook and LinkedIn, as judged more relevant for the communication of a technological EU project). The reason is that it takes a long time to build a followers’ basis, whereas through the ARIES’ partners’ channels, it is possible to reach to a large pool of followers interested in the topics relating to accelerators. This cascading approach has been used for the ARIES presentation video, which was posted on CERN Facebook, Twitter, LinkedIn and YouTube channels and leveraged a great level of interest. This level of interaction is due to CERN's 2.6M Twitter followers and 662K Facebook followers. Other ARIES partners reach similar levels of impact.

Finally, an ARIES Accelerator Communication and Outreach **Workshop** will take place on 5-6 November, at CERN. There are 15 registrations, surpassing the goal of 10 participants. This is an event for the accelerator communication community. It aims to share best practices, through the presentation of case studies, identify resources and assess the needs of the community, in order to make the adequate recommendations for resources and activities in D2.2.

Contractual milestones and deliverables

In the P1 reporting period, Task 2.2 had one milestone to achieve:

- MS10: Project website launched - ACHIEVED

Task 2.3. Coordination, support and enhancement of training activities for accelerators in Europe

The first period activities were dedicated to preparing the ground work for meeting the upcoming milestone and the later deliverable on schedule. A group of interested participants was set up. Four meetings were held to make decisions on the direction of the work. It was decided that the data needed for the report shall be acquired by a formal approach i.e. by carrying out a survey. Survey tools were evaluated and 'Survey Monkey' was identified as an effective tool for carrying out our survey. It is suggested to host the survey via the ESS www infrastructure and capitalize on tools available to ESS, such as easyBI on confluence/JEERA, for analyzing the survey data. The work has been carried out to prepare the draft survey form and a draft contact list of survey participants has been prepared.

Task 2.3 is on track to deliver a report on "coordination of training activities, documenting ongoing and proposed activities and identifying any required additional resources to support the proposed initiatives".

Task 2.4. Provide an e-learning course: introduction to accelerator science, engineering and technology

The first 18 months of the project have been devoted to defining the infrastructure and the course content. This course will be a massive open online course (MOOC). Two committees have been set up: the Technical Committee was dedicated to technical issues such as infrastructure and the Syllabus Committee was in charge of defining the syllabus of the course. Both committees met once a month (by video). Minutes of these meetings were produced and are in the milestone report MS11. A paper was also produced and presented at the International Particle Accelerator Conference (IPAC'18) under reference MOMPL050.

On the technical side, different MOOC platforms have been compared and a large international platform has been found to be the best suited (discussions are under way to seek agreement to host the course). The license to be used for release of the video clips has also been selected, it will be a Creative Commons license (CC-BY-NC-SA). The files will also be available to all interested users. The course will be in English but any interested country or language group will be welcome to translate it if they wish.
On the pedagogical side, the course will be aimed at students toward the beginning of the second cycle (master program) as defined in the European Higher Education Area (so-called Bologna process). The course duration will comprise 10 hours of online video, which is equivalent to

approximately 30 hours of in-class teaching. This course will be split into 4 modules: One introductory module with an online duration of 4 hours and 3 specialization modules of 6 hours each. To complete the course students will have to complete the introductory module and one of the specialization modules. The coordinators of these modules have been identified as well as most of the lecturers. Finalisation of the syllabus details is in progress with recording of the first videos expected in early 2019.

Figure 8 shows the position of the ARIES MOOC in the European Accelerator Education landscape, as defined by ARIES WP2.

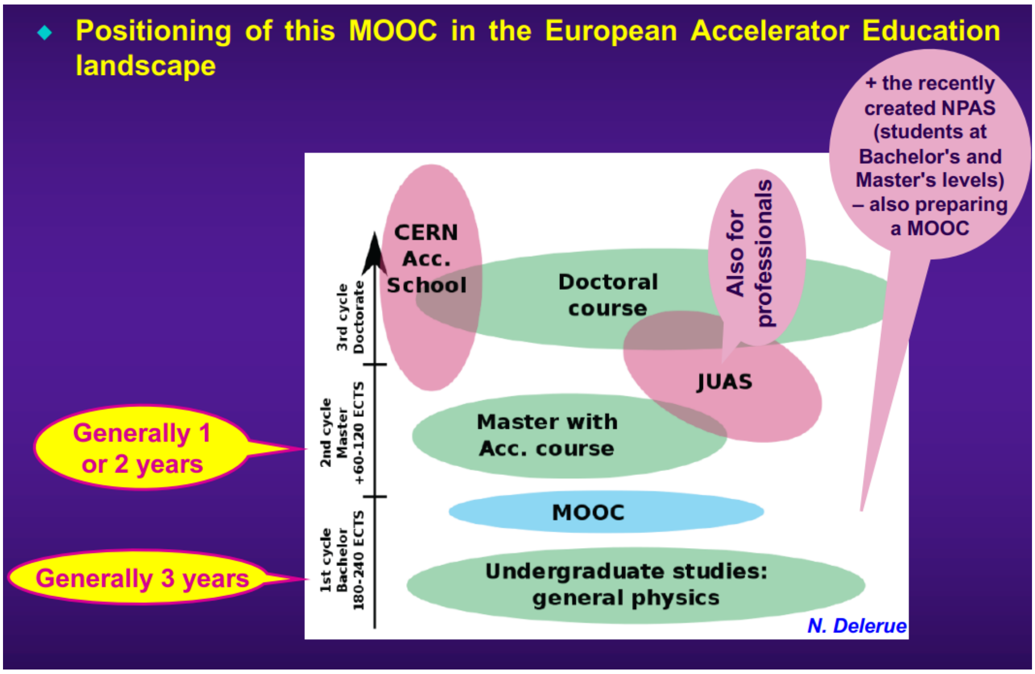


Figure 8: ARIES MOOC in the European Accelerator Education landscape

Contractual milestones and deliverables

In the P1 reporting period, Task 2.4 had one milestone to achieve:

- MS11: Meeting to agree MOOC platform and academic structure and content of e-learning course – ACHIEVED

WP3: Industrial and Societal Applications

This NA studies two important application areas of particle accelerators, with the aim of developing new designs and of improving both cost and performance. The first is the use of electron beams, primarily up to 10 MeV beam energy, for a variety of industrial and emerging environmental applications and second is the production of medical radioisotopes for imaging and the treatment of cancer. The WP includes 5 tasks:

- Task 3.1. Coordination and communication
- Task 3.2. Low energy electron beam applications: new technology development
- Task 3.3. Low energy electron beam applications: new applications
- Task 3.4. Medium energy electron beams
- Task 3.5. Radioisotope production

Task 3.1. Coordination and communication

The coordination and communication task has overseen the activities of the WP and ensured that it is making good progress towards achieving all of its obligations. This has been done through monthly task leaders meetings and by email. It organised the successful WP3 kick-off in Krakow, after the Nutech conference. It encouraged and discussed the production of two Proof-of-Concept proposals and participation in a 3rd, one of which was successful. It is working with an associate partner, the International Irradiation Association (iiA), to produce a webinar to introduce the benefits of electron beams to new industrial users. The first webinar will be introductory and mainly targeted at current γ-source users. Further webinars on more specialist topics for new users are foreseen.

The Task is contributing to two proposals for the last H2020 calls in the Societal Challenges area. The first is for a call on “High-quality organic fertilisers from biogas digestate”, part of a joint EU-Chinese Ministry of Agriculture agreement with both EU and Chinese partners, including industry. The proposal title is: “PHOEBe: Production of High-Quality Organic Fertiliser using Electron Beams”. The second proposal is called “HERTIS: Development of hybrid electron accelerator system for the treatment of marine diesel exhaust gases”. This is using a technology developed by partners in the work package and will be submitted to a two stage call, closing on 16th January 2019.

Task 3.2. Low energy electron beam applications: new technology development

A report on current applications of electron beam accelerators up to 10 MeV energy used in R&D programmes and industrial implementations has been prepared (MS13). There are many of these covering a broad range of industry. The report described possible accelerator design improvements and their role in the enhancement of the radiation technology applications. Possible future developments and new applications were described in a second report (MS14) and it is clear that e-beam technology is capable of providing a sustainable solution to many technological problems. These include:

- the development of polymeric materials with new properties by the application to different materials,
- reduction in the environmental pollution by the degradation of toxic compounds in air, water and soil,
- cracking crude oil to increase the yield of lighter compounds which are the most valuable products,
- increased sale of irradiated foods to reduce the use of toxic chemicals to control insects, and to reduce the risk of disease,

- recovery of rare metals, such as scandium from effluents of hot springs by radiation grafted fibre absorbent (radiation grafted fibres for the recovery of uranium from sea water),
- radiation degradation of natural polymers, such as chitosan, starch and carrageenan to produce plant growth promoters and super-water absorbents for improving agriculture.

Radiation processing in the case of water rich materials is recognized as one of the Advanced Oxidation Technologies (AOT), and can be classified as an industrial process where chemical, physical or biological transformations may occur when materials are exposed to high energy radiation (electron beams in this particular case).

Progress in accelerator development includes more efficient and compact accelerator constructions, new materials for certain accelerator components, new RF devices, superconductivity implementation, and cheaper and more efficient accelerator operation. Amongst other tasks, the concept of a standard electron beam unit for a broad range of technology users could be an important part of the future activity within the accelerator technology development.

In addition, a novel helical accelerator is being designed and prototyped to deliver a low energy (~300 keV) beam from all directions, see Figure 9. This sort of geometry is ideal for treating exhaust gases, for example, flowing through a pipe in the centre of the accelerator.

Collaborations have been formed with ebeam Technologies (Switzerland) and CGN Dasheng (China). Each company is lending an accelerator to a project described in Task 3.1, ebeam to the diesel exhaust gas project and CGN Dasheng to the sewage sludge treatment project.

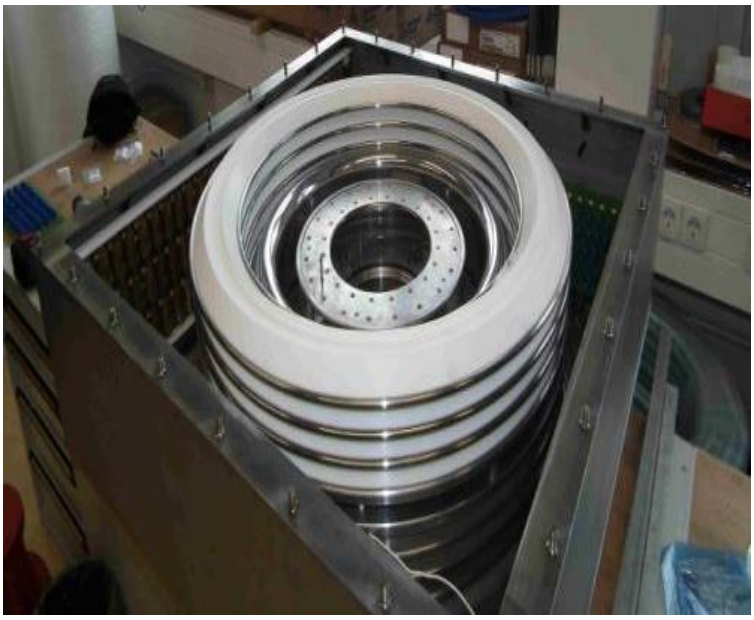


Figure 9: Prototype toroidal accelerator built by Fraunhofer FEP

Contractual milestones and deliverables

In the P1 reporting period, Task 3.2 had one milestone to achieve:

- MS13: Current applications of e-beam accelerators up to 10 MeV - ACHIEVED

Task 3.3. Low energy electron beam applications: new applications

The main activities were related to the elaboration of the basis for ship diesel exhaust gases electron beam treatment. The main source of air pollutants such as NO_x and SO_2 are exhaust gases generated during the combustion of fuels used in power and transport sectors. It is estimated that in 2020 pollution from marine sources will exceed the level of pollution from all land-based sources. The concentration of harmful oxides in the exhaust gas varies with the type of fuel. One of the most commonly used fuels on cargo ships is diesel oil, which exhaust gases contain high concentrations of both NO_x and SO_2, so it is necessary to use a gas purifying method before releasing them into the atmosphere. Removal of nitrogen oxides is a difficult process, often requiring the use of an expensive catalyst (the most commonly used is Selective Catalytic Reduction). Taking into account the increasingly strict regulations on emissions of nitrogen and sulphur oxides, the current methods are insufficient. Therefore, it is necessary to look for new solutions to remove both nitrogen and sulphur oxides with high efficiency and at the same time low cost.

The research is based on the use of hybrid technology combining Electron Beam with Wet Scrubbing to create a synergistic effect and to achieve higher process efficiency. Different wet-scrubbing solutions are used in the current study to optimize the removal of pollutants, while also receiving a post-process liquid that could potentially be recycled. The results of the research revealed that the NO_x removal efficiency, when using a hybrid method with the $NaClO_2$ oxidant, can be higher than 80%. Such high removal efficiency would fulfil the requirement imposed by the law and shows the potential of a method to be scaled-up and commercialized in the future. The optimization of the process during the current stage of the project led to results giving a strong base for future research with other liquid oxidants and also the modification of installation. The working group reported the results at two ARIES organized meetings held in Geneva on December 1st 2017 and in Genova on March 1st 2018.

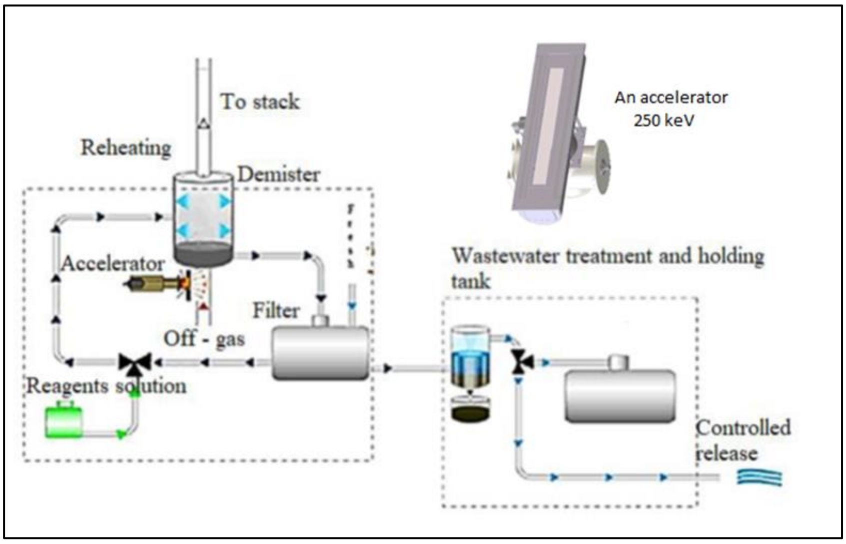


Figure 10: Technological units of the hybrid electron beam technology system

The technology has been selected for the further developments in the frame of a Proof-of-Concept project (ARIES WP14) with leader Riga Technical University and INCT, FEP, HUD and Shipyards in Gdansk and Riga as consortium members.

The third workshop in the Task 3.3 area was AcEL (Accelerated Electrons for Life) focussed on new technology developments in the field of very low energy electrons (80 – 300 keV) for environmental (waste water treatment, seed treatment) and medical applications (virus inactivation for vaccine production, miniaturized sterilization compartments). The aim was to get a deeper understanding of the industrial needs to push the development direction to market relevant topics. On the other hand there are many reservations against irradiation technologies in industry which until now are not involved in such production methods. Therefore important tasks of this workshop were building up trust and reduction in concerns. One important result is the joint signature of a Memorandum of Understanding between Fraunhofer FEP and IPEN (Instituto de Pesquisas Energeticas e Nucleares, Brazil) to develop new applications of low energy electron irradiation focussed on the actual challenges of environmental protection.

The other field of environmental applications being developed in collaboration with ARIES is electron beam sludge hygenization. The workshop entitled "The emerging trends in the sludge treatment" was organized by the Institute of Nuclear Chemistry and Technology on August 27th, 2018, co-financed by WP3 and the Erasmus+ project KA107. Talks on pathogens in municipal sewage sludges and on its beneficial reuse were presented to an audience of 30 experts from five countries.

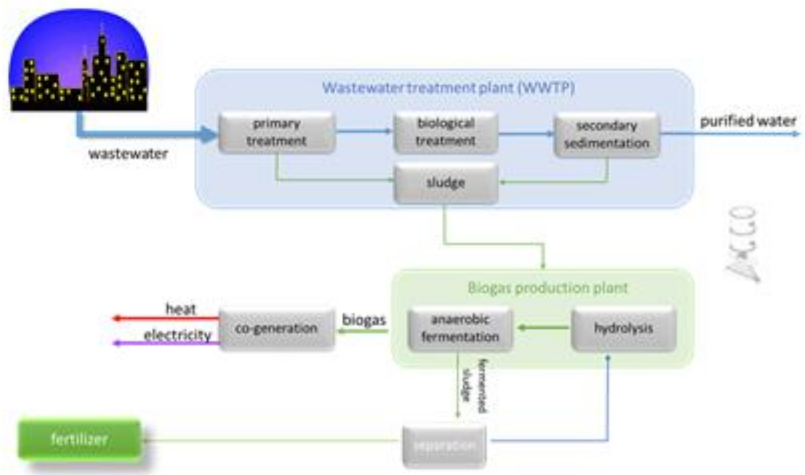


Figure 11: Zero energy hybrid electron accelerator system for biogas and fertilizer production from municipal sludge

Sewage sludge is generated from wastewater treatment plants, is an organic fertilizer and is also a rich source of many macro (N, P, K) and micronutrients essential for soil. As sewage sludge still contains microbes, viruses and worm eggs, which under certain circumstances can be dangerous for human beings and animals, it must be disinfected before it is deposited on to agricultural areas. The hygienized sludge is an ideal medium for nitrogen fixing bacteria like Rhizobium to grow and hence can be converted easily into a bio-fertilizer. Many crops have been tested in actual fields with excellent results. Soil condition improves considerably after application of hygienized sludge. The "zero energy" hybrid process combines the electron beam process with a sludge digester supplying methane to the cogeneration plant which provides electricity for the accelerator and other equipment (Figure 11). The attractiveness of a new technology is particularly important in light of a European Council Decision establishing criteria and procedures for the disposal of waste, which prohibits the deposition of sewage sludge in landfills starting from the year 2016.

Contractual milestones and deliverables

In the P1 reporting period, Task 3.2 had one milestone to achieve:

- MS14: New industrial applications of electron beams- ACHIEVED

Task 3.4. Medium energy electron beams

Task 3.4 has two main objectives, the study of the applications of electron beams up to 140 MeV in the medical and other areas, and the study of the construction of high performance electron linear accelerator up to 140 MeV. Concerning the first objective, several workshops have been organized related to the applications of the medium energy:

- Medical applications, more specifically the use of Very-High Energy Electrons (VHEE) Radiation Therapy (RT) https://www.cockcroft.ac.uk/events/VHEE17/

- Special session in the CLIC 2018 workshop dedicated to applications in: beam instrumentation developments (cavity BPMs, Diamond Cherenkov diffraction beam size monitor, Electro-Optical BPMs, wake field monitors…), irradiation of material and components, plasma lens acceleration, Tera-Hertz radiation developments, VHEE RT. https://indico.cern.ch/event/656356

To achieve the second objective, a first optics design of an electron accelerator at medium energy dedicated to applications called PRAE (Platform for Research and Application of Electrons) has been completed. The construction of the RF gun and the tendering for the linac and its powering (Klystron-modulator) are on-going. The platform is based on an accelerator delivering a high-performance electron beam with energy up to 70 MeV and then upgraded to 140 MeV, over the two successive time phases of the project. A layout is shown in Figure 12. The 50-140 MeV electron energy range will allow the development of radiobiology studies pursuing preclinical studies of new radiotherapy methods aiming for a better treatment of cancer. Over the full energy range, PRAE beams will provide the essential tools to characterize optimize and validate instrumentation techniques for the next generation of detectors used in medical imaging, subatomic physics, particle physics, spatial technology and astrophysics. A general workshop on other possible applications of PRAE took place in Fall 2018: http://workshop-prae2018.lal.in2p3.fr/ .

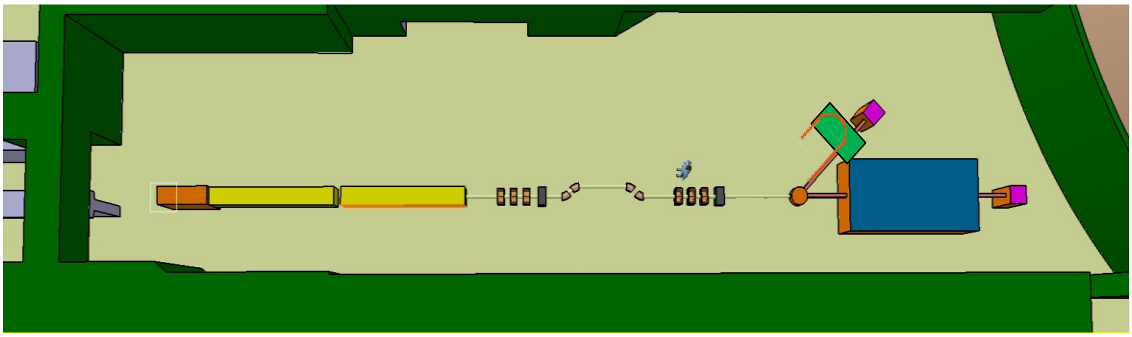


Figure 12: Schematic view of the PRAE accelerator (140 MeV) with the two experimental beam lines

The purpose of the Workshop was to bring together the leading experts of the PRAE domains – accelerator techniques, instrumentation, subatomic physics and radiobiology, to promote PRAE to the research, academic, and industrial communities. The aim was to broaden the PRAE scientific programme, enlarge the user community, and identify new synergies between the participants.

Task 3.5 Radioisotope production

Task 3.5 had no workshops during the period. Development activities to build a compact cyclotron for isotopes production are currently being conducted in CIEMAT. One of them is to optimise the design of an H^- PIG ion source with the aim of maximising the production. The problems with using PIG sources in cyclotrons are stability of current and emittance of the beam. Therefore, a dedicated test facility has been constructed in CIEMAT for the optimization of this kind of ion source. This test bench has been designed to minimize drawbacks such as the high voltage loading spark, low vacuum level and non-stability of glow discharge in the extraction area. The discharge characteristics of the cold cathode PIG ion source has been studied at different arc currents, gas flow rates and magnetic fields. The influence of these and other geometrical parameters such as the distance between the slit opening and the edge of the plasma column in the production of H^- ions is under study in the IST CIEMAT facility. A current of ~450μA has been measured in the beam probe. Beam profile measurements using scintillation ceramic screen materials are in progress.

A creation of the negative hydrogen ion H^- in a PIG ion source, is a multi-step process, where multiple conditions should be achieved. The negative ions are formed by dissociative attachment between vibrational excited gas molecules and very cold electrons. The low binding energy of H^- , around 0.75eV, means that the extra electron is easily detached. There are several channels for this, but one of them has a very large cross section for energies higher than 3 eV. The lifetime of the ion source is due the sputtering of the cathodes as result of bombardment by positive ions. CIEMAT has in mind a new innovation idea of PIG ion source which increase the efficiency, life time and ion currents controlling the kinetic energy of plasma electrons and ions.

In parallel, CERN has progressed in the parameter choice and design of a linac-based compact PET isotope production system to be installed in hospitals. The cost of such a system being directly proportional to the accelerator energy and only slightly dependent on beam current, it has been decided to fix the output energy at 6.5 MeV, the minimum for an efficient production of 18F isotope out of enriched water. To increase the average current, the linac duty cycle has been set close to the maximum achievable by the HF-RFQ design developed at CERN, 20% for a maximum duty of 25%. The final mean current will depend on the ion source current. For a source current of 500 μA and an expected 30% transmission from the RFQ, 30 mA should be available on the target with an expected 18F production rate of 35 patient doses per hour. A scheme of the system is presented in Figure 13.

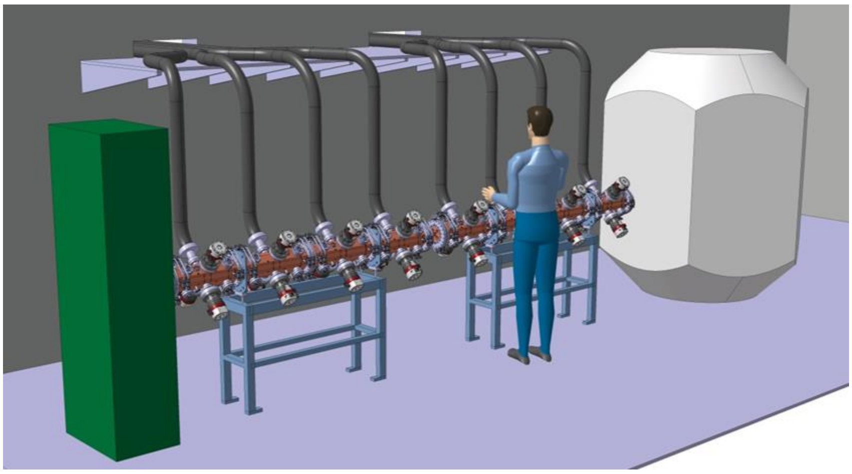


Figure 13: RFQ-based linear accelerator concept for isotope production

WP4: Efficient Energy Management

This NA federates different research centres that perform internal programmes aimed at analysing strategies to save energy. It concentrates on promoting, following and coordinating clear technological solutions towards increasing the efficiency of four critical accelerator sub-systems: Radio-Frequency power sources, superconducting accelerating cavities, pulsed magnets and targets. The WP includes 5 tasks:

- Task 4.1. Coordination and communication
- Task 4.2. High Efficiency RF Power Sources
- Task 4.3. Increasing energy efficiency of the spallation target station
- Task 4.4. High Efficiency SRF power conversion
- Task 4.5. Efficient operation of pulsed magnets

Task 4.1. Coordination and communication

The workshop Energy for Sustainable Research Infrastructures, held November 2017 in Magurele (Romania), was co-organised by the WP4 of ARIES. The workshop showed a large variety of concepts and technologies aimed at improving the sustainability of large research infrastructures. New projects consider sustainable technologies already in the planning phase. This includes for example energy management schemes, heat recovery, energy efficient technologies such as efficient RF production, low loss superconducting cavities, permanent magnets.

The workshop was organised in a collaboration of the European Research Foundation (ERF), CERN, ESS, ARIES-EEM and ELI-NP as the local host. The workshop had 73 participants, mainly from Europe but also from Asia and the US. 31 presentations were given during several plenary and one parallel session. The workshop series will be continued and a next workshop in the series will be organised by PSI in fall 2019, again with the support of the ARIES project.

Contractual milestones and deliverables

In the P1 reporting period, Task 4.1 had one milestone to achieve:

- MS17: Contribute to Workshop on Energy for Sustainable Science - ACHIEVED

Task 4.2. High Efficiency RF Power Sources

The aim of task 4.2 is to deliver a complete design study of a novel RF source at 12 GHz with at least 10 to 20% higher efficiency then the presently existing ones. Intense work is going on in this area thanks to new bunching techniques developed in the framework of the HEIKA collaboration (Bunch-Align-Collect and Core-Oscillation-Method), as well as at CEA with the adiabatic klystron approach (kladistron).

Task 4.2 will initially focus on designing a high efficiency klystron operating in the X-band (12 GHz) with an electron beam power in the range 15-30 MW. The work done so far in task 4.2 was to define the parameters of this klystron, as well as to define the strategy to achieve higher efficiencies than the 45-50% usually achieved for this kind of tubes with a perveance about $1.5\mu A/V^{1.5}$. Initial simulations are now going on with two 1D/2D disk-model codes (AJDISK from SLAC and KlyC from CERN) in order to achieve the highest possible efficiency. Starting from a kladistron design that incorporates the COM method, it seems possible to achieve efficiencies up to 70%. Once this design has been optimized, the next step will be to validate it using 2D/3D simulations based on PIC models (CST and MAGIC2D).

A new bunching technique has been developed at CEA during EUCARD2 project, and a prototype klystron (kladistron) at 5 GHz based on this new idea has been manufactured during this project (Figure 14). Its performances have been measured in the THALES facilities in September 2018 and gave interesting results. However, a parasitic oscillation has been detected. Benchmarking the simulations with the results of the measurements has started. Differences between the simulated model and the real one have been observed, and they will give important insight into the precision and reliability of the simulation methods that will be used for designing the 12GHz klystron.

Moreover, this analysis will be used to mitigate parasitic oscillations in the 12GHz klystron design for this ARIES WP.

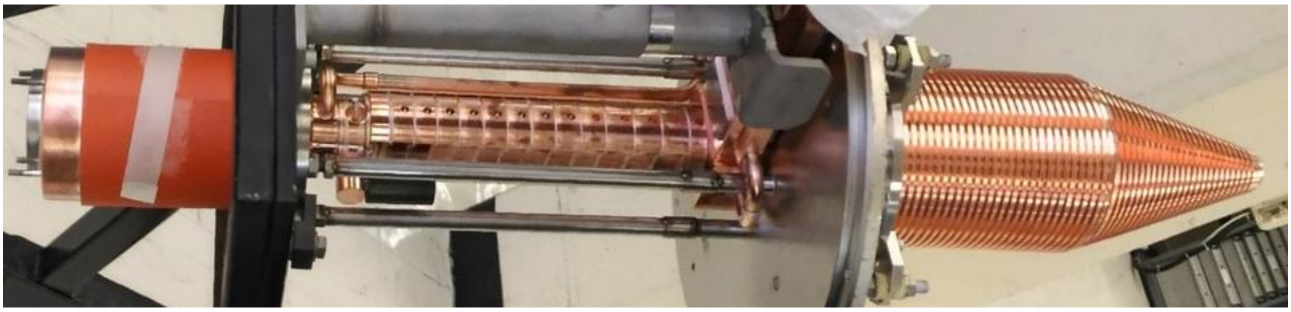


Figure 14: Manufactured kladistron prototype at 5 GHz

We have also observed in our preliminary simulations of the 12 GHz klystron that its efficiency depends not only on the bunching process, but as well on the performances of the output cavity. For instance, a high transit time factor (M parameter) with a reasonable R/Q factor for this output cavity is mandatory to achieve 70% efficiency. At 12GHz, a single gap cavity cannot have such performances and multi-gap cavity has to be considered. Thus, design efforts have been focused on the multi-gap output cavity performances (highest M; R/Q>40; f_0 = 11.994 GHz), using a genetic algorithm and a 2D eigenfrequency solver (COMSOL).

Task 4.3. Increasing energy efficiency of the spallation target station

We have performed Monte-Carlo simulations to investigate a set of geometrical and material changes to the cold neutron source. The resulting moderator design allows for the delivery of a higher cold neutron flux. Most importantly, the presence of an optimized re-entrant hole has a strong influence on the flux of cold neutrons exiting the moderator. The use of 100% ortho-deuterium and low-attenuation structural materials give additional flux gains. We are currently developing the CFD and thermomechanical model of the existing design with the aim to compare the simulated results with current temperature measurements. During the ARIES annual meeting in Riga, Latvia, a contribution has been given regarding the work accomplished on the cold moderator. The geometry for the cold moderator is being prepared for the ANSYS flow solver (geometry and meshing), and material properties are researched, which will be the basis for the CFD simulations. Furthermore, Monte-Carlo particle transport calculations (MCNP6.1) have provided a description of the spatial power deposition in the different materials of the SINQ D2 mode, to serve as a heat source for future CFD calculations. This heat source is currently being implemented in the modeling framework.

Task 4.4. High Efficiency SRF power conversion

The Post-docs hired to perform the studies related to this Task have conducted magnetic measurements at CERN on an existing vacuum vessel, which is meant to accommodate four 5-cell bulk Niobium cavities operating at 704 MHz (Figure 15). The vessel in question will be the outer hull of the four cavity cryo-module. The goal was to measure its magnetic shielding factor and to decide whether the vessel needs to be demagnetized before it can be used. A technical note has been published of magnetic shielding measurements (CERN-ACC-NOTE-2018-0045).

On May 2018 a new post-doc was hired for experimental and theoretical work on flux trapping and

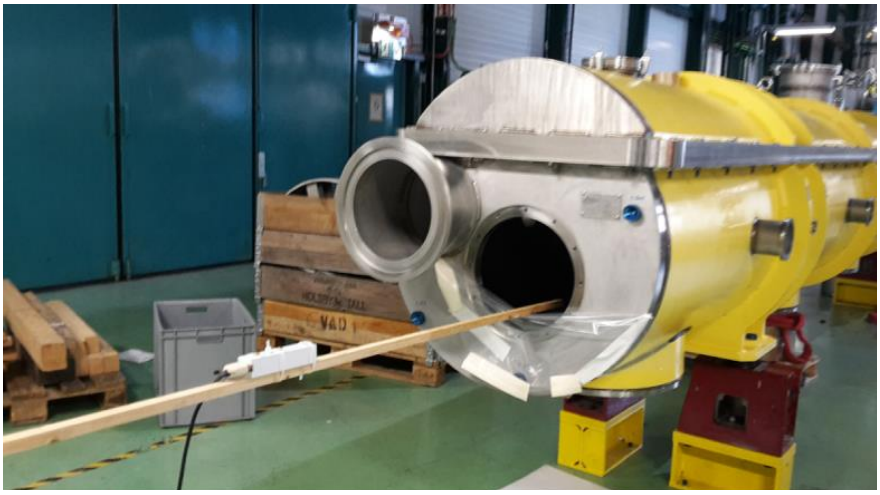


Figure 15: Magnetic field measurements on a cryo-module vacuum vessel with a 3-axis fluxgate mounted on a wooden stick

magnetic shielding. He performed a magnetic field mapping of one of CERN's vertical cryostats and compared the results with his simulations (see Figure 16).

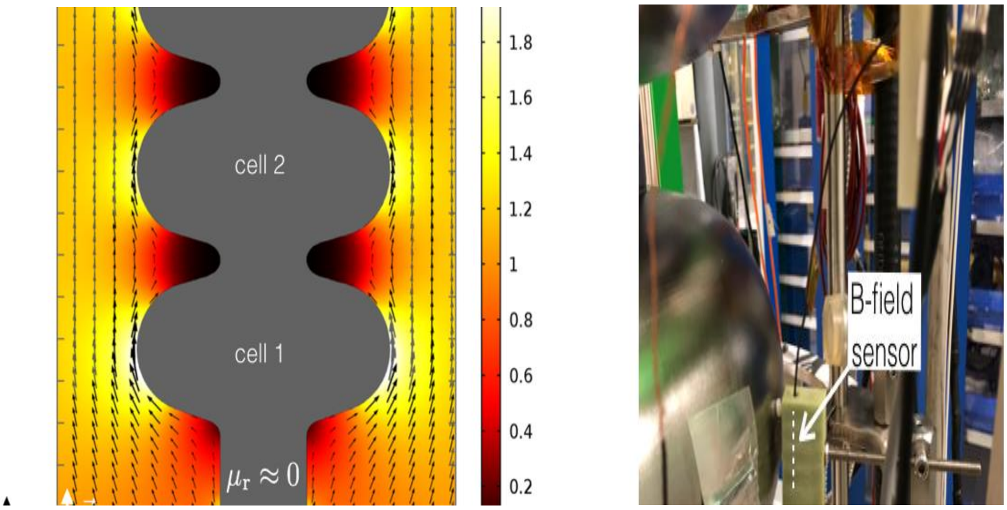


Figure 16: Left: simulated field configuration after cool-down in vertical cryostat, Right: measurement set-up for magnetic fields and temperature

First experiments on flux trapping and the measurement of thermoelectric currents have been conducted using a 704 MHz 5-cell superconducting cavity. A workshop on flux trapping and magnetic shielding was organised with the support of ARIES. It took place on 8-9 November 2018 at CERN with almost 60 registered participants. The outcome of the Workshop will be presented in the next Periodic Report.

Contractual milestones and deliverables

In the P1 reporting period, Task 4.4 had one milestone to achieve:

- MS18: Workshop on Low Loss Superconducting RF – delayed by six months to M19 (November 2018) - ACHIEVED on M19.

Note that in Annex 2 the due dates of MS18 and MS19 have been inverted by mistake: MS18 is due at M13 (and not M19), and MS19 at M19 (and not M13).

Task 4.5. Efficient operation of pulsed magnets

The objective of task 4.5 consists in analysing and discussing the efficient operation of a pulsed iron-free quadrupole magnet as alternative to DC magnets. The related study supported by the Network prepares for an experiment to be carried out by the GSI laboratory. The first steps were to evaluate and select the equipment required to improve an existing pulse circuit. Beforehand, some theoretical work and simulations had to be carried out, to determine the requirements for the hardware. This resulted in the decision to produce a current of up to 30 kA in the quadrupole with a maximum voltage of 1.7 kV. Subsequently the current will be increased stepwise to 50 kA. These decisions were followed by the identification of the key components that are high-voltage pulse diodes, pulse-resistors and fast high voltage switches. A diode with a surge current of 52 kA was selected to avoid parallelising diodes for the first tests. Later on two parallel diodes of this type could be used for higher currents. The HVR-pulse-resistor is designed for 80 kA, which is achievable with two diodes. Procurement of these items shown in Figure 17 was done by GSI. Within the next steps the new components will be assembled in the pulse circuit and first tests and measurements can be done with a current of up to 30 kA.

Figure 17: Pulse Diode, Pseudospark-Switch and Resistor (left to right)

The completion of the assembly is planned for December 2018. The first power tests are planned for Q1 2019 and will bethen made available to the Network.

WP5: European Network for Novel Accelerators (EuroNNAC)

This NA continues the corresponding activities developed in EuCARD-2 and gathers the world's leading accelerator laboratories and universities involved in R&D for novel laser-based accelerators. The network will provide the essential European coordination of a wide on-going effort in the field of plasma and dielectric acceleration involving a large number of partners and funding agencies and will connect to similar initiatives in the USA and Asia. The WP includes 5 tasks:

- Task 5.1. Coordination and communication
- Task 5.2. European Strategy Plasma Accelerators
- Task 5.3. European Strategy Dielectric Accelerators
- Task 5.4. European Advanced Accelerator Concepts Workshop (EAAC)
- Task 5.5. Young Scientist Networking and Academic Standards

Task 5.1. Coordination and communication

The growing impact of the WP5 EuroNNAc Network is not only measurable by the growing number of applicants and the great interest in the European Accelerator Concepts Workshop (EAAC), but also in the interest of Institutes to become a member of the network and to receive all information about the network's activities. Nine new members joined during the last year (institutes from Armenia, France, Germany, Italy, Norway, Russia and Switzerland). Altogether, the Network has 65 members, 14 being outside of Europe. The new members are invited for the first time to join the Yearly Meeting in November where remote participation is made possible to allow participation to everyone interested. The registered participants to WP5 activities are presented in Figure 18.

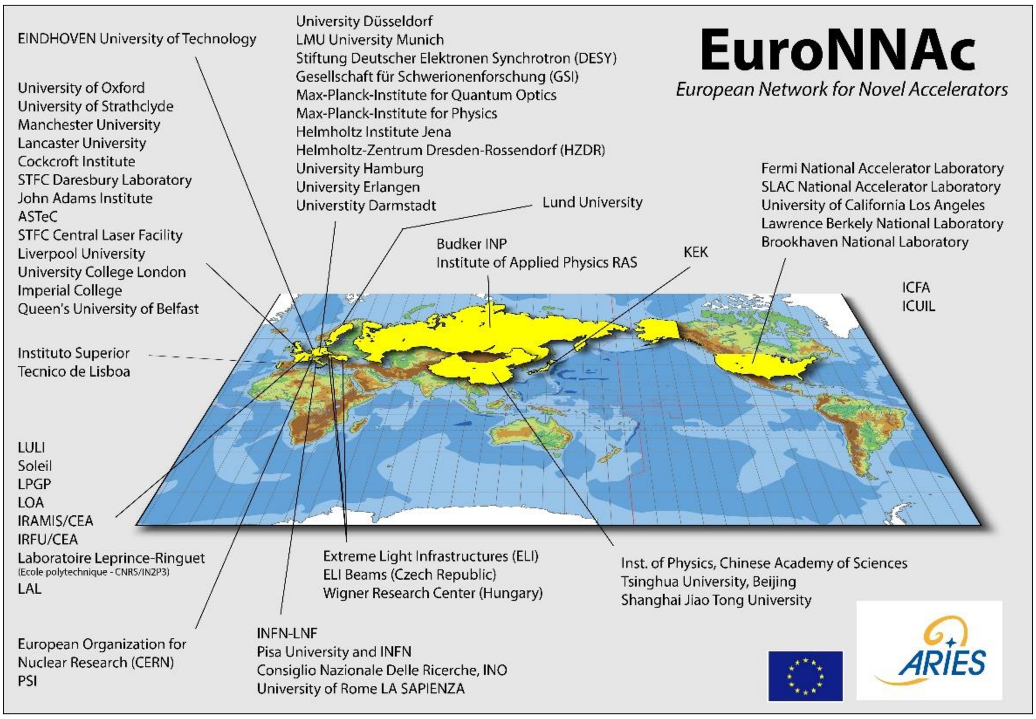


Figure 18: EuroNNAc3 members graphic and additional new members (May 2018)

The nine new members are CANDLE (Armenia), PHLAM Université de Lille (France), FBH Ferdinand Braun Institut (Germany), Forschungszentrum Jülich (Germany), Karlsruhe Institute of Technology (Germany), University of Rome Tor Vergata (Italy), University of Oslo (Norway), JIHT of Russian Academy of Sciences (Russia), University of Bern (Switzerland).

The kick-off meeting that took place in September 2017 (29 participants) decided that the next EAAC19 Conference will take place again at Elba island, with envisioned dates 15.9 – 20.9.2019. A special postdoc price will be awarded during the event. Preparation has started for a final EuroNNAc3 report to be delivered at end of ARIES, in coordination with the ICFA ANA panel to have the non-European perspective. Among the priorities listed for the Network, are:

- Balance ambition and risk for the new acceleration techniques, credibility is the most important asset;
- Focus not only on e+e colliders, but also on e-ion, e-p, gamma collider;
- Get collider experts into novel accelerator R&D officially for conceptual design studies;
- Strengthen university based R&D for novel accelerators;
- Focus on intermediate R&D steps like AWAKE run II and EuPRAXIA construction;
- Improve training of new generation of physicist/engineers/technicians in innovative technologies.

Contractual milestones and deliverables

In the P1 reporting period, Task 5.1 had one milestone to achieve:

- MS22: EuroNNAC3 Kick-Off Meeting - ACHIEVED

Task 5.2. European Strategy Plasma Accelerators

Discussing future European strategies for electron plasma accelerators was pursued through participation and co-organization of the Horizon2020 EuPRAXIA design study and the ALEGRO workshops in Geneva and Oxford. The EuroNNAc input to the European Strategy Group for Particle Physics is being discussed and will be provided within this context of projects and initiatives.

The Horizon2020 Design Study EuPRAXIA (European Plasma Research Accelerator with eXcellence In Applications) will in propose a first European Research Infrastructure that is dedicated to demonstrate exploitation of plasma accelerators for users. Developing a consistent set of beam parameters produced by a plasma accelerator able to drive a short wavelength FEL is one of the major commitments of the EuPRAXIA Design Study. At present, five different EuPRAXIA configurations are under investigation, based on a laser and/or a beam driven plasma acceleration approaches.

Task 5.3. European Strategy Dielectric Accelerators

Discussing future European strategies for dielectric accelerators was pursued through participation and co-organization of the ACHIP and AXSIS projects on dielectric structures. Work is ongoing and strategic future proposals will depend on the results of the projects mentioned above. It is foreseen that a strategic discussion will be conducted from 2020 onwards.

Task 5.4. European Advanced Accelerator Concepts Workshop (EAAC)

Three hundred scientists from all over the world gathered from September 24-30 2017 at the 3rd European Advanced Accelerator Concept Workshop (EAAC_2017) on the Island of Elba in Italy. Specialists from accelerator physics, RF technology, plasma physics, instrumentation and the laser field discussed ideas and directions towards a new generation of ultra compact and cost effective accelerators with ground-breaking applications in science, medicine and industry. At the EAAC senior scientists from various specialties mix with junior experts and a large community of young students, attracted by the promise and success of compact particle accelerators. In 2017 about 70 PhD students presented their work at the EAAC. Besides the reports on scientific achievements the large diversity in gender, age distribution and nationalities made the EAAC 2017 a special event and a great success for the accelerator field.

Figure 19: Participants of the EAAC2017 conference on Elba in September 2017

The EAAC2017 Workshop was supported by the EuroNNAc3 network through the EU project ARIES, INFN as the host organization, DESY and the Helmholtz association, CERN and the industrial sponsors Amplitude, Vacuum_Fab and Laser_Optronic.

The next EAAC will be held on Elba (Italy) 15-21 September 2019. A first Meeting of the Organization Committee is prepared and takes place on 23rd November in Frascati (Italy) as a Satellite Meeting to the EuPRAXIA Yearly Meeting and 4th Collaboration week.

Contractual milestones and deliverables

In the P1 reporting period, Task 5.4 had one milestone to achieve:

- MS23: EAAC and Yearly Meeting EuroNNAc3 - ACHIEVED

Task 5.5. Young Scientist Networking and Academic Standards

The 3rd European Advanced Accelerator Concepts workshop in 2017 marked once again the growing interest in this field with 300 participants, including about 70 students who gave talks and presented 45 posters at poster sessions. As in previous EAAC workshops, poster prizes were awarded to acknowledge outstanding contributions students are making to the field. Three prizes were awarded during a special ceremony at the workshop.

In order to bring students together, a special "student meeting" has been organised by the EuroNNAc students' mentors Bernhard Holzer and Roman Walczak. The students got to know each other, discussed matters such as students' web site, and dedicated novel accelerators school and programs of future EAAC workshops from students' perspective.

The prospect of organizing a meeting of students between EAAC 2019 and 2021 has been discussed. There is no doubt that such a meeting will be beneficial for the student's network, the actual organization of such an event however will strongly depend on the financial support from the student's home institutes and the EuroNNAC network.

The organization and preparation of a dedicated CERN Accelerator School (CAS) on High Gradient Wakefield Accelerators is successfully progressing. The program is finished, the site and the local organizers (IST in Lisbon) are defined and all lecturers accepted the invitation. The Website of the event is ready, posters and invitations are being sent out and the event will be open for application in the first week of November 2018. It will take place in Sesimbra, Portugal 11-22 March 2019. The poster of the school is shown in Figure 20. The school web site is https://cas.web.cern.ch/schools/sesimbra-2019 .

Figure 20: Poster of the CAS School on High Gradient Wakefield Accelerators

WP6: Accelerator Performance and Concepts

This NA aims to reach ultimate performances in future accelerators that are now in the advanced planning or construction phase, by investigating advanced beam stabilization techniques, novel collimation schemes and reliability enhancement measures. It will contribute to the design of the future generation of accelerators, by exploring alternative technologies and concepts. The WP includes 6 tasks:

- Task 6.1. Coordination and communication
- Task 6.2. Beam Quality Control in Hadron Storage Rings and Synchrotrons
- Task 6.3. Reliability and Availability of Particle Accelerators
- Task 6.4. Improved Beam Stabilization

- Task 6.5. Beam Quality Control in Linacs and Energy Recovery Linacs
- Task 6.6. Far Future Concepts & Feasibility

Task 6.1. Coordination and communication

Task 6.1 coordinated WP6 events with several parallel accelerator activities and projects, in particular the global FCC study, the design studies for LHeC and PERLE, the MESA project, the CERN Physics Beyond Colliders working group, the GSI FAIR project, HIC for FAIR, LHC HiLumi and LIU Projects, the European working group on muon colliders, ICFA, the EC co-funded EuroCirCol and EasiTrain, and the other work packages of ARIES. The results of WP6 workshop events were widely communicated, e.g., through invited seminars and through outreach articles in Accelerating News, the CERN bulletin, the ICFA Beam Dynamics Newsletter, and in the CERN Courier. In addition, the WP6 coordinator was invited, by the EU delegation to Japan, to discuss the positive aspects of EU-Japan collaboration in the frame of FCC/EuroCirCol/E-Jade/ARIES at the Tokyo Science Agora 2017 (“Beyond the Boundaries”). Task 6.1 also presented regular WP6 status reports at the quarter-annually ARIES steering meetings. At all workshops, particular emphasis was put on gender diversity and student participation. Figure 21 illustrates the geographical distribution of WP6 workshops participants and the fraction of women in the various events. The material developed in the frame of WP6 will prove an important input to the deliberations for the update of the European Strategy for Particle Physics scheduled in 2019/20.

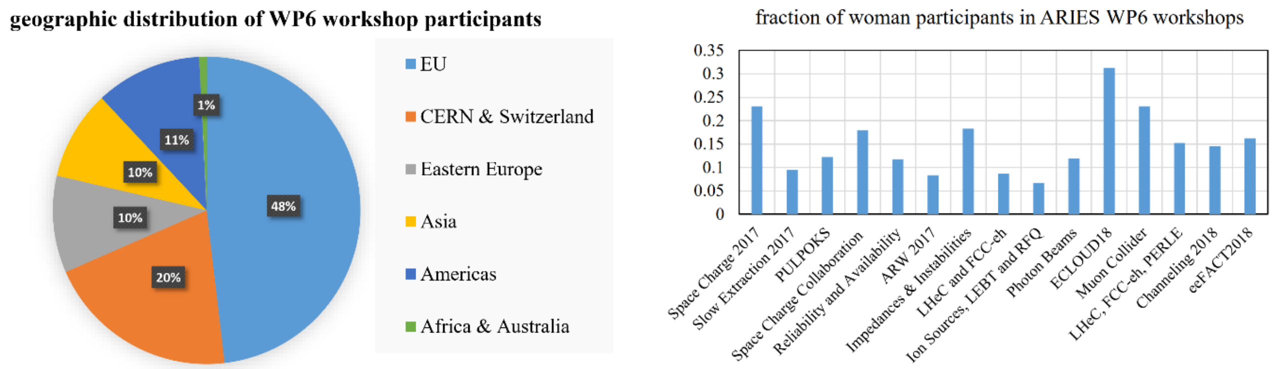


Figure 21: Geographical distribution of WP6 worksop attendees (left) and raction of women participants (right)

Contractual milestones and deliverables

In the P1 reporting period, Task 6.1 had one milestone to achieve:

- MS26: Report on 1st Annual workshops of all tasks - ACHIEVED

Task 6.2. Beam Quality Control in Hadron Storage Rings and Synchrotrons

Task 6.2 organized or co-organized seven workshops, more than anticipated in the proposal. The high rate of workshops demonstrates how much this networking activity is appreciated by the accelerator community, and which needs it fulfils. Task 6.2 workshop topics ranged from beam generation and low-energy transport (ion sources, radiofrequency quadrupoles) over performance limitations of present and future hadron storage rings (space charge, slow extraction, pulsed kicker systems, electron cloud) to future circular colliders. All events were unique (e.g. the workshops on LEBT or on pulsed kicker systems), often breaking new ground, and attracted great worldwide interest. The space-charge studies especially that are the burning issue to control the damaging effect of the incoherent space-charge tune shift have been the centre of the activity, which nicely overlaps with the IOTA program in the US. The interplay of space charge effects and nonlinear optics in circular accelerators has become a central theme for the intensity frontier of CERN and GSI. Figure 22 shows the intriguing form of a fixed line created by a resonance of order 6 in the presence of space charge.

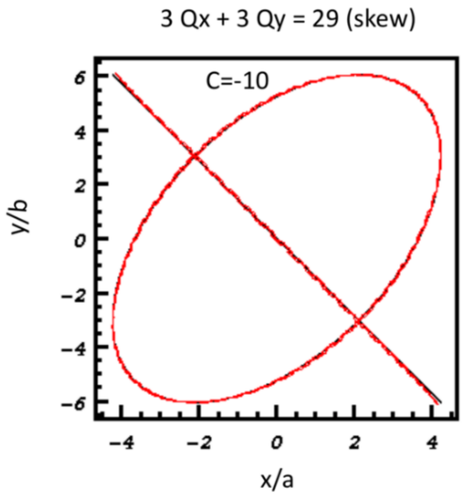


Figure 22: Fixed line created by a resonance of order 6 and space charge.

The US intensity frontier (PIP II at FNAL) will benefit from the international synergy developed by Task 6.2. In particular, the IOTA program will be a partner for studies of electron lenses developed in APEC Task 6.2. The synergy promoted by WP6 Task 6.2 also extends links to pre-existing institutions of global ambition such as ICFA: The Task 6.2 engages in the co-organization of the historical “High Brightness Hadron Beams” conference series, guaranteeing leadership beyond the ARIES mandate.

The activity of the task has seen the completion of the experimental beam dynamics studied initiated with the EuCARD2 network. In August 2018 the full experimental proof of the existence of resonance fixed lines was established. Another activity of the task studied the novel interaction of neutral molecules with a magnetic or electric dipole moment and electro-magnetic fields in the LHC. Task 6.2 has promoted and co-organized meetings for improving synergies between CERN-GSI on the new GSI control system and challenges of using CERN LSA software for storage modes at GSI.

Task 6.3. Reliability and Availability of Particle Accelerators

Task 6.3 held, or co-organized, two workshops: a dedicated mini-workshop on reliability data collection at CERN 18.-21.09.2018 and the larger accelerator reliability workshop ARW2017 at Versailles 15.-20.10.2017. ARW2017 provided a venue for individuals from accelerator communities worldwide to meet and to share their experiences with operating reliable facilities. This helped to proceed towards the task objective of identifying and spreading best practices in reliability engineering between accelerator facilities. The mini workshop at CERN helped to assess the feasibility of an Open Data Infrastructure (ODI) for accelerator reliability. Beside the workshops, a task study compared different approaches for reliability data collection. The oil industry’s OREDA project was chosen as the most suitable model example reliability data sharing in the accelerator community. This approach, documented in EN ISO 14224, was adopted to form the use case model and logical model of the accelerator reliability database.

Concerning human resources, HIT will recruit an early stage researcher before the end of 2018. Assessing the feasibility of the accelerator-reliability information system has been contracted to AIT.

Figure 23: Moments of the RAMS Training Sessions.

ARIES task 6.3 also held two RAMS (Reliability, Availability Maintainability, Serviceability) training sessions. The first training (Fig. 23) took place on 15-18 May 2018. It had 21 participants including seven students. The second training was organized from 9 to 12 October 2018 with 16 participants including four students. About 8% of the participants were women. The training aims at spreading the best practices in reliability engineering to the accelerator community that is one of the objectives of task 6.3. Work to assess the feasibility of reliability data sharing in the accelerator community continued. Two technical notes were published on this topic. The first note presented the findings on different reliability data collections practices in the industry, and the second presented foreseen use cases and use context of the reliability information system. The next step in the feasibility study is to assess interfaces to access the data based on the established use cases. The task will also determine if potential synergies exist with similar activities in the fusion energy community.

Task 6.4. Improved Beam Stabilization

Co-organized jointly with ICFA, an ARIES workshop on Impedances and Beam Instabilities in Particle Accelerators was held in Benevento (Italy) from 18 to 22 September 2017, hosted by the University of Sannio. The task also co-sponsored the ECLOUD18 Workshop at La Biodola in June 2018.

During the first Reference Period, the existing strategies & methods for beam-impedance assessments and impedance models were reviewed. The task determined the minimum thickness of NEG coating which mitigates the electron cloud instability and guarantees a good pumping efficiency while, at the same time, reduces as much as possible the contribution to the beam coupling impedance. For FCC-ee low impedance BPMs and bellows were developed, and advanced beam feedback systems were designed. The maximum electron beam current of 1.7 A for the DAΦNE accelerator at INFN Frascati was examined during a dedicated run. The primary limitation was longitudinal quadrupole oscillations, which could be mitigated by a modification of the synchrotron (dipole) feedback system, using the QPSK modulation detuning in the feedback back end for damping both dipole and quadrupole beam motion (see PRST-AB, 6,052801, 2003). Also simulated was the beam-induced heating of the new DAΦNE vacuum chamber for the Siddhartha experiment without water cooling (Figure 24 right) and with water cooling (Figure 24 left). INFN-LNF is attempting to recruit a postdoctoral researcher before the end of 2018.

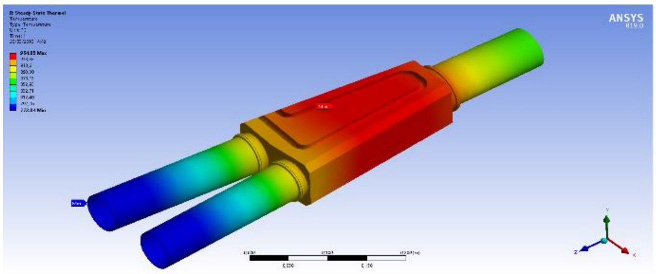


Figure 24: DAFNE vacuum chamber with cooling

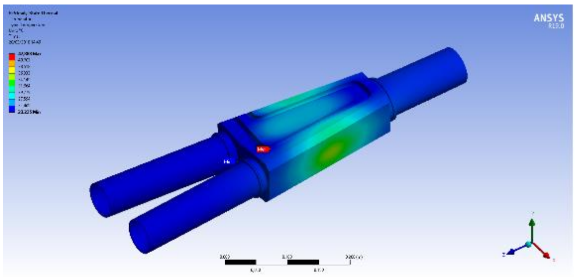


Figure 25: DAFNE vacuum chamber w/o cooling

Task 6.5. Beam Quality Control in Linacs and Energy Recovery Linacs

The field of Energy Recovery Linacs (ERLs) is rapidly developing over the last years. This can be seen in the growing number of planned projects as well as in the growing number of participants in the bi-annual ICFA Advanced Beam Dynamics Workshop on Energy Recovery Linacs. The last ERL Workshop at CERN (Geneva) hosted ~90 participants and took place at the beginning of the ARIES project in June 2017. Even though it was not directly funded by ARIES it was closely related to the goals of this WP. As one outcome one can state that by now ERLs are more seen as drivers for colliders or internal experiments in particle physics and less as drivers for future light sources. Also new applications like electron coolers for hadron rings are currently in focus. There are several projects planned or close to start commissioning as can be seen in Figure 26.

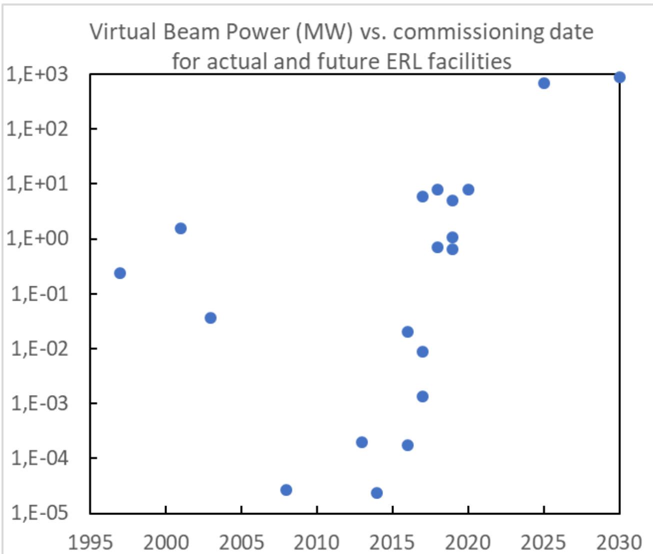


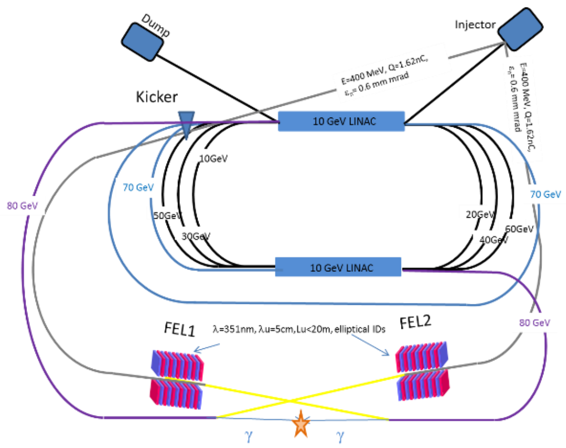
Figure 26: Beam power of current and future ERL projects. Recently many new projects emerged aiming for beam power in the MW range

The next technological step towards high power and high energy ERLs would be the realization of a SRF multi-turn ERL. Some single turn machines exist already, but the multi-turn operation with superconducting cavities would be the next milestone; it is envisaged by a number of projects. During the ERL workshop a data collection of current, future and past ERL projects was initiated, which already is a significant step towards completing the next milestone of the WP (M27: report on: Parameter database for various ERL & Linac facilities). Task 6.5 co-organized three specific workshops. The first two were the LHeC and FCC-eh Workshops in September 2017 at CERN and June 2018 at Orsay, where future ERL-based hadron electron colliders were discussed. The electrons for LHeC would be provided by a high-energy multi-turn ERL. The PERLE project aims at building a test facility for this kind of machine. The third workshop took place at Frankfurt, Germany in February 2018. Here, key performance issues for hadron linacs were discussed. In particular, the workshop examined the injection section of high-current ion linacs. At present an international ERL collaboration is being formed under the leadership of G. Hoffstaetter (Cornell University, USA), with support from ARIES Task 6.5. This formal collaboration shall facilitate exchange of knowledge about ERL technology and personnel between the participating labs and universities, similar to the existing and successful TTC collaboration in SRF technology.

Task 6.6. Far Future Concepts & Feasibility

A first dedicated workshop on "Photon Beams" reviewed the state of the art of gamma-gamma colliders, Compton sources, and Gamma factories and fostered synergies between the different communities. This event was the first topical workshop of Task 6.6, which aims at studying the options and practicality of next and future-generation particle accelerators. The technical agenda included presentations on accelerator design, beam commissioning, laser technology, Free Electron Lasers (FELs), experimental programmes, and fundamental physics questions, with reports on studies and experiences from across the globe. The workshop brought together members from modern Compton sources like ELI-NP in Romania and Thom-X in France (now under construction), from the worldwide Gamma Factory community, FEL experts, laser specialists, atomic physicists, and photon-collider experts from around the world. An elegant generic $\gamma\gamma$ Higgs factory, based on a single one-directional recirculating linac and two FELs, was proposed for the first time (Figure 27, left).

A second topical workshop addressed prospects for Muon Colliders. Several novel concepts could help the muon collider become a reality. These concepts include parametric ionization cooling, low-emittance muon production by positron annihilation (LEMMA scheme), production of low-emittance muon or positron beams using the Gamma Factory concept, and strategies to upgrade large accelerator complexes, like the LHC or the Future Circular Collider (FCC), into a highest-energy muon collider. At the workshop was presented the fascinating option of a 14 TeV muon collider in the LHC tunnel, which could be a cost-effective approach for reaching the ten-TeV scale in lepton collisions. From CERN came the sketch of a possible upgrade of the FCC lepton and hadron-collider complex to a high-energy muon collider, using a combination of Gamma Factory and LEMMA concepts. Indeed, the FCC appears to be the ideal basis for constructing a future 100 TeV muon collider. A retired CERN expert compared the performance of several proposed future lepton colliders, introducing two figures of merit, the luminosity per construction cost and the luminosity per electrical power (Fig. 27, right). At the workshop, a general consensus was reached that the steps forward should include: (1) the design and implementation of a 6D cooling experiment; (2) LEMMA target tests; (3) the Gamma Factory development; (4) the establishment of a particle-physics programme based on high-intensity,



high-energy muon beam, e.g. NuSTORM. At the end of the workshop, the coordinator of the European muon collider study group drew some enthusiastic conclusions and discussed the muon-collider input to the 2019/20 European Strategy Update.

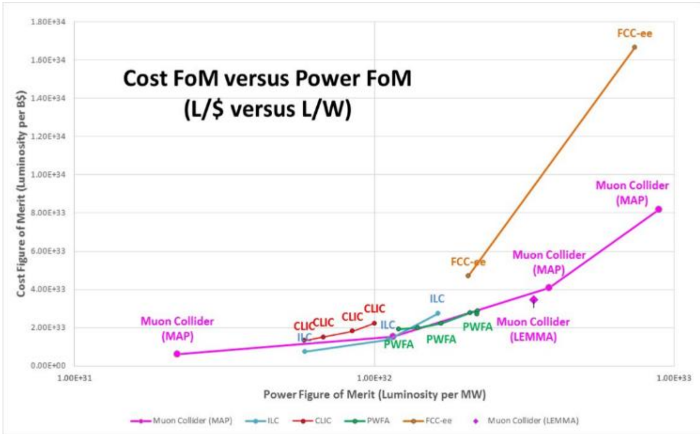


Figure 27: Left:Generic recirculator-based γγ Higgs factory with two FELs. Right: Cost-figure-of-merit versus power-figure-of-merit for future lepton colliders, comparing muon colliders, circular e+e- colliders, and linear e+e- colliders.

Task 6.6 also co-sponsored the international conference "Channeling2018", devoted to the physics of coherent/incoherent interaction of relativistic and nonrelativistic hadrons and leptons in strong electromagnetic fields of various origins and structures, ranging from solid amorphous and crystalline to laser and plasma based ones, and including the interaction of radiation and beams in various structured media as well as meta-materials. The conference started with a "Channeling Primer" for students; it included two mini-workshops "Advanced Generation of THz and X-rays using compact accelerators" and "Channeling in Plasma Physics by Laser and Applications". Channeling 2018 featured 23 invited talks, 81 oral contributions and 93 poster reports.

WP7: Rings with Ultra-Low Emittance

This NA gathers the world-leading laboratories in R&D for low emittance rings (synchrotron light facilities, damping rings for colliders, and advanced factories). It focuses on the specific technical challenges that will need to be tackled for these new rings in the coming years and it will promote and support common beam tests as well as provide a platform for collaborative efforts in the commissioning of new facilities. The WP includes 4 tasks:

- Task 7.1. Coordination and communication
- Task 7.2. Injection Systems for ultra-low emittance rings
- Task 7.3. Beam dynamics and technology for ultra-low emittance rings
- Task 7.4. Beam tests and commissioning of ultra-low emittance rings

Task 7.1. Coordination and communication

Coordination meeting were held at the side of the kick-off and annual meetings. The planning of the network activities has run smoothly, allowing the organisation of relevant workshops in advance. In particular the general workshop at CERN in January 2018 gathered more than 80 participants, outlining the progress in the design of the upcoming facilities, and presenting new designs developing from the standard MBA lattice, and its variation in the Hybrid MBA (HMBA). Novel rings concepts are proposed for PETRA IV, the so called double minus I (DMI) lattice or the double-triple bend achromat (DTBA) proposed at Diamond, with the aim of doubling the number of straight sections of the ring. Of interest also the new project proposals in Thailand and the South-Eastern Initiative for Sustainable Development (SEEIST) for a diffraction limited light source project in the Balkan region. It is interesting to note that the effort in the development of ultra-low emittance damping rings continues, even if now overtaken by the effort in light sources, and a proposal for a new muon collider (LEMMA project, Low Emittance rings for Muon Acceleration) also hinges on a low emittance 45 GeV positron ring design. Albeit the target emittance of 5 nm in a ring of 6.4 km is not extremely challenging, the design proposed is based on the HMBA solution used for the ESRF-EBS upgrade. Examples of ultra-low emittance cell optics are reported in Figure 28.

Optimisation techniques were discussed: the field is still benefitting from two complementary approaches based on Hamiltonian resonance driving term optimisation and fully numerical tools, e.g. multi objective genetic algorithms (MOGA). The main difficulty in these lattice remains the problem of the available dynamics aperture (DA) and momentum aperture (MA). While the consequence of a small MA can be tackled with the use of High Harmonic RF Cavities for bunch lengthening, the small DA remains relatively elusive, and has forced the community to adopt radical technological solutions for the injection problem.

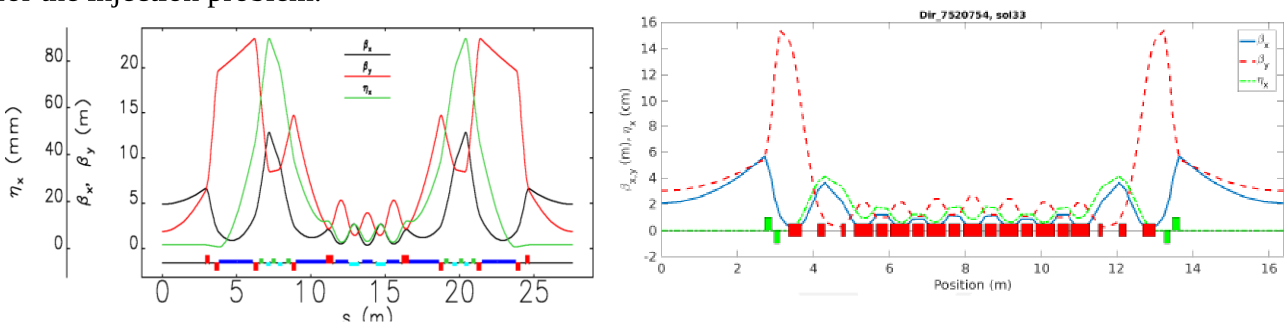


Figure 28: lattice for APS-U (62 pm) and ALS-U (50 pm)

Contractual milestones and deliverables

In the P1 reporting period, Task 7.1 had one milestone and one deliverable to achieve:

- MS33: First general workshop of the RULE network - ACHIEVED
- D7.1: First beam tests for low emittance rings – ACHIEVED

Task 7.2. Injection Systems for ultra-low emittance rings

Injection in the small dynamic aperture associated to ultra-low emittance rings is a key problem in the design and optimisation of such rings. A second non negligible point is the request of achieving a transparent injection that does not perturb the stored beam. These requirements have pushed the development of novel hardware such as the nonlinear kickers (NLK) and the anti-septum magnets (for SLS-II). The NLK concept developed by Bessy-II had been refined and built by SOLEIL and now installed at MAX IV, with excellent results. Figure 29 reports the reduction of the transient oscillations during the kicker pulse.

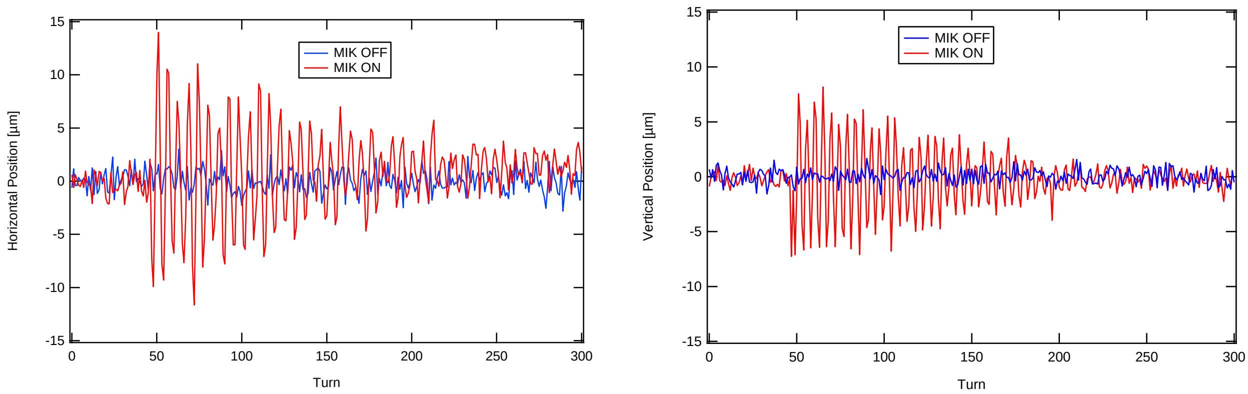


Figure 29: MAX IV beam transient during the injection with NLK: horizontal (left) vertical (right)

Recent studies have shown that in order to push the optics to reach diffraction limited emittances of use for light sources (tens of pm) the standard pulsed orbit bumps becomes unworkable. In this scenario, a large number of new injection schemes has been developed based on on-axis injection, therefore doing without the need of providing a sufficient DA for injection. Schemes based on longitudinal injection were developed at SLS-II, and HEPS, Beijing. Different variants of RF gymnastic are under study at HEPS and SOLEIL. More aggressive schemes rely on the so called swap-out injection, where no accumulation is sought but a whole, full current, freshly prepared beam is injected in a portion of the bunch train while the spent part is kicked out.

Many of these scheme rely on the use of fast pulsed kicker magnets, with rise time, flat top and fall time in the order of few ns. These requests are pushing the boundary of existing technology. A new class of fast (ns) high voltage (20 kV) pulsers based on inductive adders is under development. Thyratron switches seem to be preferred to old thyristor type. These studies form the basis of the injection scheme proposed for the APS-U, ALS-U and HEPS upgrades. The corresponding freedom in the lattice design unleashed by the on-axis injection concept has been fully exploited by such designs, which constitute the cutting-edge frontier of ultra-low emittance rings with emittance in the tens of pm.

Contractual milestones and deliverables

In the P1 reporting period, Task 7.2 had one milestone to achieve:

- MS34: First topical meeting of the RULE network: injector - ACHIEVED

Task 7.3. Beam dynamics and technology for ultra-low emittance rings

The operation of ultra-low emittance ring is underpinned by technological advances in many key subsystem, involving magnets and vacuum systems with small apertures, harmonic RF systems, advanced diagnostics which ensure the correct implementation of the nominal beam optics.

In this framework the first topical workshop on the technology for ultra-low emittance rings has been dedicated to the advancement on beam diagnostics. The workshops was held in concomitance with the DEELS workshop (Diagnostics Experts of European Light Sources) and counted 36 delegates. A large effort is ongoing in the design of diagnostics that help the beam based characterisation of the optics. These consist of high performance beam position monitor (BPMs) that allow the acquisition high resolution low noise orbit and turn-by-turn data, e.g. the pilot tone technique for the ELETTRA BPMs. Main applications refer especially to the measurement of high order spectral lines in the betatron oscillations (ESRF) or the analysis of microbunching instabilities (ANKA).

Tuning techniques based on fast orbit response matrix and fast quadruple BBA were presented. These allowed major operational advancement in operating light sources and, in some cases, the characterisation and the correction of the optics during operation with minimal perturbation of the beam, not to perturb the data taking of very sensitive experiments. Another area of technical improvement is the extension of the functionality of the electronics of classical bunch-by-bunch feedback systems to provide a wealth of diagnostics data for the characterisation of collective instabilities.

Contractual milestones and deliverables

In the P1 reporting period, Task 7.3 had one milestone to achieve:

- MS35: First topical meeting of the RULE network: technology- ACHIEVED

Task 7.4. Beam tests and commissioning of ultra-low emittance rings

Beam time and visit exchange to test low emittance tuning ideas on existing light sources and support for newly commissioning rings are under being considered for the upcoming period. Facilities involved are ANKA, CERN, Diamond, ALBA, SLS, BESSY and the commissioning preparation for ESRF-EBS.

Experimental tests supporting the development of ultra-low emittance rings were carried out to tackle some of the most challenging accelerator physics issues in the operation of such rings. In particular tests for novel injection schemes were carried out at BESSY-II studying off energy off-phase injection phase. Figure 30 shows the comparison between simulations and measurements of the full longitudinal acceptance in a storage ring.

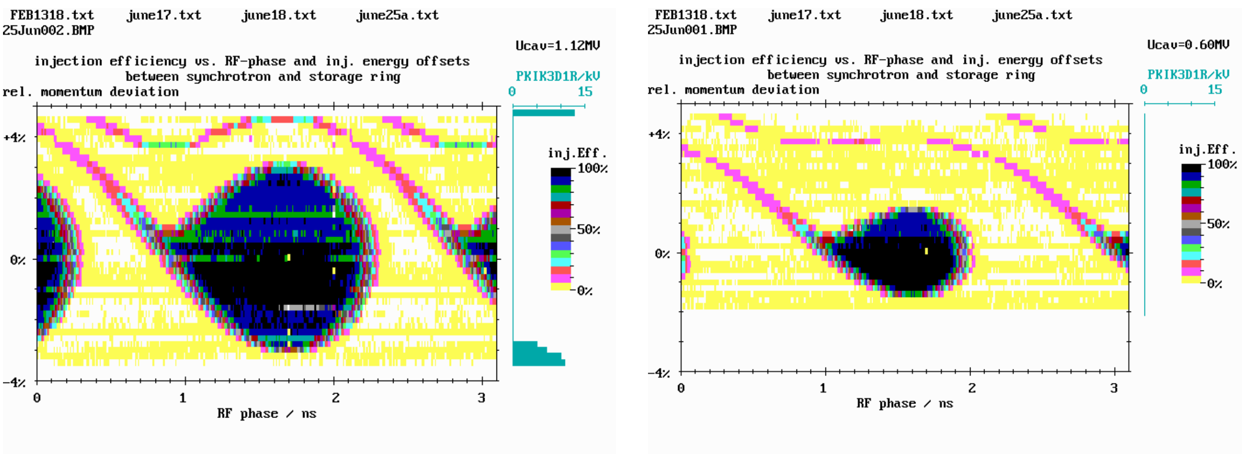


Figure 30: example of measurement of the longitudinal acceptance for different voltages at BESSY-II (1.2 MV left; 0.6 MV right)

The operation with negative momentum compaction factor lattices was studied at the KARA facility at KIT were a dedicated lattice was designed and tested. Injection in the negative α was made at

500 MeV, the normal value for daily operation at KARA. Because of the difficult injection in negative α and of the presence of sextupoles inside the injection bump orbit section, it was not easy and simple to get the first stored beam in the KARA ring in negative α; a stored beam was achieved only after further adjustment of the horizontal correctors. The stored current was less than 10 μA when all the sextupoles were off, and about 30 μA when they were properly optimised. A streak camera image of the bunch train stored in these conditions is reported in Figure 31.

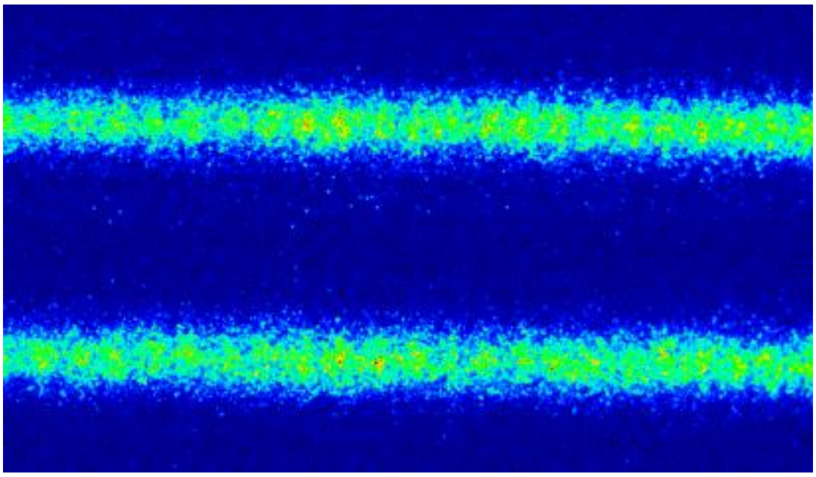


Figure 31: Streak camera image of the beam stored in negative alpha at KARA. Time scales are 100 ms horizontal, 600 ps vertical.

After getting a higher beam current, the experiments will continue aiming at collective effects in the negative α beam. One of the important subjects to study would be the head-tail instability.

Contractual milestones and deliverables

In the P1 reporting period, Task 7.4 had one deliverable to achieve:

- D7.1: First Beam Tests for Low Emittance Rings (M18) - ACHIEVED

WP8: Advanced Diagnostics at Accelerators

This NA will contribute to the enhanced operation of existing facilities and strengthen the design of novel accelerators via the synergetic development of advanced diagnostics tools required to monitor the unprecedented performances required by new accelerator projects in the fields of hadron linacs, hadron synchrotrons, 3rd generation light sources and Free Electron Lasers. The WP includes 5 tasks:

- Task 8.1. Coordination and communication
- Task 8.2. Advanced instrumentation for hadron LINACs
- Task 8.3. Advanced instrumentation for hadron synchrotrons
- Task 8.4. Advanced instrumentation for 3rd generation light sources
- Task 8.5. Advanced instrumentation for FELs

Task 8.1. Coordination and communication

The organization of the workshops and exchange of personnel was coordinated by this task; the details and outcome are reported within the summaries of the other tasks below. The communication was executed through personal meetings, video conferences and e-mail exchange. The results of two Steering Committee meetings were reported in a written manner. A formal collaboration meeting was not deemed necessary as the experienced task leaders regularly met each other throughout the year. The individual workshop programs were put in place by the corresponding task leaders.

Contractual milestones and deliverables

In the P1 reporting period, Task 8.1 had one milestone to achieve:

- MS39: Report on 1st Annual workshops of all tasks - ACHIEVED

Task 8.2. Advanced instrumentation for hadron LINACs

In May 2017 a Topical Workshop took place at GSI concerning 'Simulation, Design & Operation of Ionization Profile Monitors' with 33 participants from Europe, North America and Asia. It was undertaken as a common event of Task 8.2 and 8.3. An Ionization Profile Monitor (IPM, Figure 32) is based on spatially resolving the ions or electrons generated from residual gas ionisation through beam impact. These monitors deliver the beam profile in a non-destructive manner with a spatial resolution of typically 50 µm and time gating down to the 10 ns level. They are installed at both hadron synchrotrons and LINACs. Due to the increase in the beam power of future LINACs (e.g. at CERN, ESS, FAIR, ISIS) these IPMs will substitute the traditional invasive wire-based diagnostics. Even though the principle is well known, there are many technical challenges for the stable, reliable operation of such beam instrumentation. The experience and technical solutions from installations all over the world were presented by the experts in the field, with the results extensively discussed and the related contributions serving as a comprehensive catalogue of such systems.

The main purpose of the workshop was to introduce the community to a recently completed simulation code called IPMSim, https://twiki.cern.ch/twiki/bin/view/IPMSim/. This code was produced with the input of several experts to simulate the related physical processes (cross section for electron and ion production) under various conditions (beam distribution, space charge, external field configurations) from non-relativistic beams at LINACs to highly energetic beams at synchrotrons. The code features a modern programming style, a user-friendly GUI and can easily be expanded to include new physical models and applications. The code is freely available and its benchmarking was successfully demonstrated by the experts. Further extensions of the code (e.g. for Beam Induced Fluorescence Monitors) are currently underway. Possible experimental verifications of such simulations were put forward at this workshop and many have now been performed.

As foreseen in the ARIES proposal, an exchange of personnel was made possible, with an expert from Fermilab (USA) staying at GSI for several weeks to discuss IPM related topics and possible improvements to these systems. The second exchange of personnel took place in May 2018 with a GSI employee to work at the UK DIAMOND Light Source on topics related to closed orbit feedback. Additionally, short term visits are encouraged and supported to strengthen the scientific collaboration and exchange.

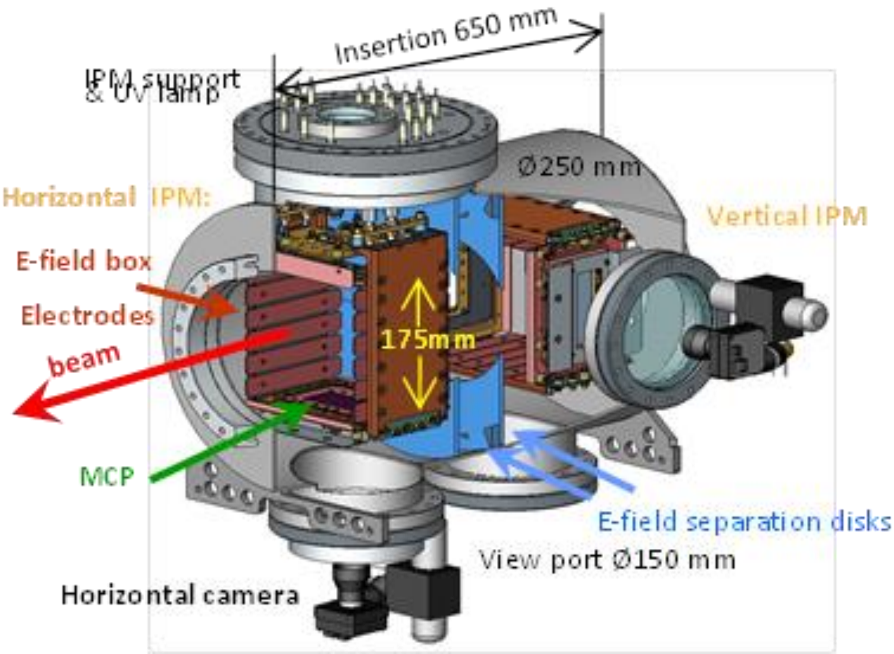


Figure 32: Typical installation of a horizontal and vertical IP monitor

Task 8.3. Advanced instrumentation for hadron synchrotrons

The Topical Workshop on ‘Simulation, Design & Operation of Ionization Profile Monitors’ was organized as a common event between Task 8.2 and Task 8.3 as the topic was of relevance to both hadron LINACs and synchrotrons (see the summary above). This was an ideal opportunity to bring together experts from LINACs and synchrotrons to solve common issues.

A second dedicated workshop with 32 participants on ‘Extracting Information from electro-magnetic monitors in Hadron Accelerators’ took place from 14th to 16th of May 2018. The goal was to strengthen the collaboration between the beam dynamics and beam instrumentation community as both have to contribute to a correct interpretation of advanced beam measurements. Additionally, people working at 3rd generation light sources participated as the topic is equally important for the electron- and hadron synchrotrons.

The workshop focused on various measurement methods of lattice parameters at synchrotrons, such as the machine tune and chromaticity. Recent results concerning betatron-function measurement and beta-beating determination were discussed. The different methods used for optics measurements were summarized in an overview talk. It was shown that part of the progress is related to improvements of the achievable accuracy of the BPM readout. The applicability of methods leading to significant noise reduction of the BPM data was demonstrated in several contributions. Moreover, the determination of advanced parameters such as intensity dependent tune shift and tune spread determined via quadrupolar oscillations are currently a ‘hot topic’ and were intensively discussed between instrumentation and beam dynamics experts. A comparison between simulations and measurements at CERN PS shows a good correspondence as had been clearly depicted in one of the contributions.

Further on, Schottky signal analysis was discussed in several contributions. This method enables an observation of many parameters without any influence on the beam. The applicability for coasting and bunched beam for daily operation and detailed machine studies was discussed. Recently, the advanced Schottky system at LHC was realized and enable now online measurements e.g. of tune and chromaticity. Using Schottky analysis it is possible to perform BPM-based position measurements for a coasting beam. Those contributions serve as a comprehensive collection of the standard and advanced applications.

Task 8.4. Advanced instrumentation for 3rd generation light sources

The Topical Workshop ['Emittance Measurements for Light Sources and FELs'] was held at ALBA (Barcelona, Spain) in January 2018, organized by Task 8.4 with the collaboration of Task 8.5. The Workshop addressed the challenges that this community is facing with such measurements for the next generation of ultra-low emittance machines. One day was devoted to emittance measurements at synchrotron light sources, and the second day to measurements at Free Electron Lasers. Experts working on emittance measurements for other types of machines such as hadron synchrotrons and Laser Plasma Accelerators were also invited to discuss possible synergies between the different communities.

For synchrotron light sources, the review of present techniques using synchrotron radiation showed that beam sizes down to the 2-3µm level can be measured through the careful design and choice of the instrumentation. These techniques include direct imaging techniques (X-ray pinhole cameras, Compound Refractive Lenses, or in-air X-ray detectors) and techniques based on the analysis of light coherence (visible light interferometers). Since this is at the limit for the beam sizes foreseen for the next generation of low emittance rings, the benefits of more complex techniques such as X-ray diffraction/interferometry and Heterodyne Speckle Fields (HNFS) were also deeply discussed during the workshop. The conclusion of the workshop was that these techniques will need specific beamlines foreseen for their operation.

For Free Electron Lasers, beam sizes are typically measured using invasive methods through the interaction of the beam with movable obstacles, such as Optical Transition Radiation screens or wire scanners. It was shown that using lithographic techniques, wires as thin as 1 µm can now be manufactured, which allow the measurement of beam sizes down to 500 nm. In addition to discussing the current status of techniques such as laser wire measurements or Optical Diffraction Radiation Interferometry, the workshop also addressed new, innovative techniques such as those making use of Cherenkov Diffraction Radiation.

As foreseen in the ARIES proposal, an exchange of personnel was organized within this task, with an expert from Univ. Milano staying at the ALBA synchrotron to discuss about the HNFS technique and to perform tests in an ALBA beamline.

Task 8.5. Advanced instrumentation for FELs

The Topical Workshop 'Emittance Measurements for Light Sources and FELs' was organized as a common event between Task 8.4 and Task 8.5. See summary under the section for Task 8.4.

In June 2018 the Topical Workshop 'Longitudinal Diagnostics for Free-Electron Lasers' took place at DESY (Hamburg, Germany) with 45 participants. The workshop aimed at both fostering joint developments of longitudinal diagnostics for femtosecond electron bunches and bringing together experts working on beam instrumentation and detector development. Several participants working in the field of Laser Plasma Accelerators contributed to the workshop as these novel short-bunch accelerators are facing even higher demands on time resolution. The topic of transverse deflecting structures (TDS) was intentionally excluded as there exists a strong collaboration between CERN, PSI and DESY on the development of an X-Band TDS with regular meetings. The workshop was organised in five working groups with the goal of exchanging ideas, planning joint collaborations or measurement campaigns. The first day of the workshop was devoted to discussions within these working groups. On the 2nd and 3rd day the working group coordinators reported the discussion results and the participants presented their contributions in poster sessions.

Compression Monitors and THz Detectors: The intense coherent THz and IR part of diffraction or edge radiation emitted by the electron bunches is commonly used as a compression monitor for a feedback on the accelerator phase. The THz/IR beam transport, attenuation and detection need to be optimized depending on the bunch charge, profile and repetition rate. Further improvements of a multi-array Schottky diode detector developed by TU Dresden as a THz spectrometer were identified.

Electro-Optical Diagnostics: Electro-optical techniques are limited in time resolution but are fully non-invasive. Different read-out schemes were discussed to achieve single-bunch resolution at MHz repetition rates. Joint experiments are planned.

THz Streak of the primary electron beam: The goal of this working group was to discuss possibilities to streak the electron beam in a micro-structure operating at terahertz frequencies. The aim is to improve the resolution of radio frequency deflectors by increasing both frequency and deflecting fields. The application to low-energy beams has been presented, and further studies at higher-energy facilities are planned.

KALYPSO and fast digitization: The KALYPSO (Karlsruhe Linear detector for MHz-rePetition rate SpectrOscopy) linear detector system has been developed as a flexible digitizer board to be compatible with different front-end electronic standards for many applications. Requirements for the next improved version were defined by the various applications of the linear detector board.

Laser Heater operation and diagnostics: The aim was to share experience of laser heater operation and optimization for the suppression of micro-bunching instabilities gained at different facilities. The cathode material of the photo-injector, e.g. Cu or Ce_2Te, seems to have an influence on the micro-bunching instabilities and, therewith, on the operation of the laser heater. Further joint studies are planned.

WP9: Magnet Testing (MagNet & Gersemi)

This work package provides Transnational Access to the magnet testing facilities: MagNet and Gersemi. The WP includes 2 tasks:

- Task 9.1. MagNet
- Task 9.2. Gersemi

Task 9.1. MagNet

The MagNet is a facility situated at CERN. Magnet test stands are part of a large installation including a facility for radiofrequency cavities and superconducting links. The installations shares the cryogenics and handling services. The magnet test benches are working at low temperature using LHe at 1.9 or 4.2 K, while the superconducting link test stand requires cooling with He gas between 5-50 K. Although we have horizontal and vertical installations, R&D projects can be accommodated only in the vertical cryostats, as the horizontal benches developed in-purpose for the LHC type magnets would require a large investment for bench modification. The test stands are then composed by 5 vertical cryostats and 1 feed box for SC link. The installations were completed few years ago with a cryogen free cryostat allowing to test instruments up to 4.2 K. Powering capacities are up to 30 kA and magnets of large size: up to 4 m long and 600 mmm diameter can be tested. Finally, the installations are run by a well-trained team of experts in superconductivity and cryogenics allowing users to perform their test and make with the help of the team diagnostics and data interpretation.

Description of the publicity concerning the new opportunities for access

The opportunities for ARIES has been advertised by direct contact with our regular user group leaders from the previous project EUcard2. The opportunities offered by Aries TNA were presented deeply in two special occasion during the 1st and 2nd International Workshop on Superconducting Magnet Test facilities: once in Geneva at CERN and once in Brookhaven at Brookhaven National Laboratory.

Description of the selection procedure

WP9 has a common Selection Panel for both tasks 9.1 and 9.2. The entire panel has expertise in superconducting magnets. The selection panel is made of experts coming from 4 different laboratories among the worldwide community; Tatsushi Nakamoto (KEK, Japan), Gianluca Sabbi (LBL, USA), and the two work package leaders Marta Bajko (CERN), Roger Ruber (Uppsala University).

Proposals are accepted at any time of the year and within less than 2 weeks the adjudication is done. The selection criteria is mainly based on feasibility with the installations at MagNet and Gersemi and according to the test planning. In addition, we look after projects that can be combined with CERN program, scientific interest of the experiment, involvement of institutes or universities not being part of the community. Promotion of diversity, multiculturality and multidisciplinarity is an asset.

Description of the Transnational Access activity

User projects and experiments

MagNet	**User-projects**		**Total no. of users benefitting from the TA**	**Units of access** (1 hour)
	Eligible submissions	Selected		
Period 1 (M1-M18)	4	4	22 (12 financial support)	944

Foreseen for project (M1-M48)	8	40	1,920

Scientific output of the users at the facility

ARIES-CERN-MagNet-2017-01: The SuShi Project aims to evaluate a third technology (multilayer NbTi/Nb/Cu sheet), and then test further aspects of a Superconducting Shield Septum (SuShi). The background is the Future Circular Collider (FCC), which requires novel technologies for many of its subsystems, including the beam extraction system. A zero-field cooled superconducting magnetic shield was proposed to realize a high field (3–4 T) compact septum magnet. Two candidate technologies (MgB2 and HTS) have already been tested in the framework of the EuCARD-2 TNA program, and the first gave very positive results (2.6 T field shielded by a wall thickness of 8.5 mm). Two young scientists and their group leader installed their shield fabricated in Hungary inside a CERN magnet to be tested at low temperature. The magnet was cooled down to 4.2 K with LHe and during the powering test with a dedicated magnetic measurement system, this shielding capacity was proven. This material is the 3rd one tested. Measurements with a magnetic measurement probe allowed gathering important information towards a complete design composed by the shield and the superconducting magnet. The results were presented at a scientific seminar at CERN on 3 October 2018. (https://indico.cern.ch/event/760359/). The measurements carried out at TNA MagNet are reported in a paper (https://arxiv.org/abs/1809.04330) accepted for publication in IEEE TAS.

ARIES-CERN-MagNet-2017-02: The AHVT Project aims the development and realization of hardware and software to perform high voltage (HV) tests in an automatic and reliable way on superconducting coils. The HV test are typically done to verify the insulation integrity. The first test of the system has been carried out at the TNA but yet without magnet. The next test are planned with magnet in 2019.

ARIES-CERN-MagNet-2018-01: The Mag-DAS Project aims at implementing distributed optical fiber sensors for the monitoring of superconducting facilities. The focus is on high-field magnets, but the same technology is applied also to the monitoring of superconducting links. Regarding magnets, distributed optical fiber sensors are used to locate quenches by monitoring temperature variation and/or detecting the acoustic wave induced during the event. Regarding the superconducting link, the sensors are used to monitor the thermal uniformity of the cryostats. Fibers of two different technology were installed into the Superconducting Link developed at CERN and built in industry. With the help of these sensors both local temperature profiles and temperature distribution along the 60 m long cryostat was measured in the range of 5-50 K. The project leader and a doctoral student from the University of Padua spent a week in recording and analyzing in place the data.

ARIES-CERN-MagNet-2018-02: CRYO PAL project's objectives are to develop and to test fiber optic temperature sensors based on photonic crystal for cryotemperature range. The sensor will be based on a multimodal fiber optic. The sensing element will be a Photonic Crystal made by a Colloidal Crystal Assembly of nanoparticles (mainly polymers and eventually their hybrids). The sensing principle relies on the variation due to the temperature of the refractive index of the nanoparticles and the changes of the reticular dimension of the photonic crystal. During the first test slot at MagNet for maximizing the experimental session two type of optical sensors were tested in the cryogen free cryo cooler: Long Period Grating and microstructured FBG. Part of the test have been realized but due to a technical problem of the cryocooler and the need of a new type of connector the test has been shortened.

User meetings

No user meetings occurred in the reporting period.

Task 9.2. Gersemi

Gersemi is a versatile vertical cryostat system for testing superconducting magnets or cavities.

It is designed for characterizing the performance of superconducting devices in either a saturated or sub-atmospheric liquid helium bath with a useful diameter of 1.1m and height of 2.8m. Gersemi is in direct and closed loop connected to a cryogenic plant providing liquid helium and a sub-atmospheric pumping system enabling operation in the range 1.8 to 4.5~K. The facility is presently under construction and planned to reach operational state before the end of 2018.

Two 2'000 A power converters with energy extraction units will be available. A data acquisition and quench monitoring & protection system will also be available. Mechanical and electric workshop services are available in-house to assist with installation and maintenance.

Description of the publicity concerning the new opportunities for access

Publicity for the facility is available on the ARIES web site. Furthermore, access to the facility was advertised at two public meetings were the community gathers: the ARIES Kick-off Meeting (Geneva, May 2017), and the TTC Meeting (Milan, February 2018).

Description of the selection procedure

The WP9 USP oversees the approval of TA applications at work package level. The composition of the USP and the selection procedure are described in section *Task 9.1 – Description of the selection procedure*.

Description of the Transnational Access activity

User projects and experiments

Gersemi	**User-projects**		**Total no. of users benefitting from the TA**	**Units of access** (1 hour)
	Eligible submissions	Selected		
Period 1 (M1-M18)	0	0	0	0
Foreseen for project (M1-M48)	8		56	2,880

Scientific output of the users at the facility

No Transnational access activity has been provided yet because the delivery of the vertical cryostat system ordered in 2016 was delayed due to technical difficulties during manufacturing; it was finally completed only during January 2018. Factory tests followed and the complete system was transported to Uppsala in several parts between March and May 2018. Installation work was completed during June, and a first commissioning phase started end June with some minor equipment still missing from the manufacturers delivery scope. This revealed some minor bugs in the control software which were quickly fixed. During August a second commissioning phase was started continuing into September. This revealed a cold leak in the liquid helium circuit. After extensive testing the so-called valve box cryostat was opened and the leak could be located at a cold valve. The valve was dismounted and shipped back to the sub-contractor of the manufacturer.

At present manufacturer and sub-contractor are discussing the status of the valve. A cold leak test is foreseen in the week 26-30 November at the sub-contractor's premises.

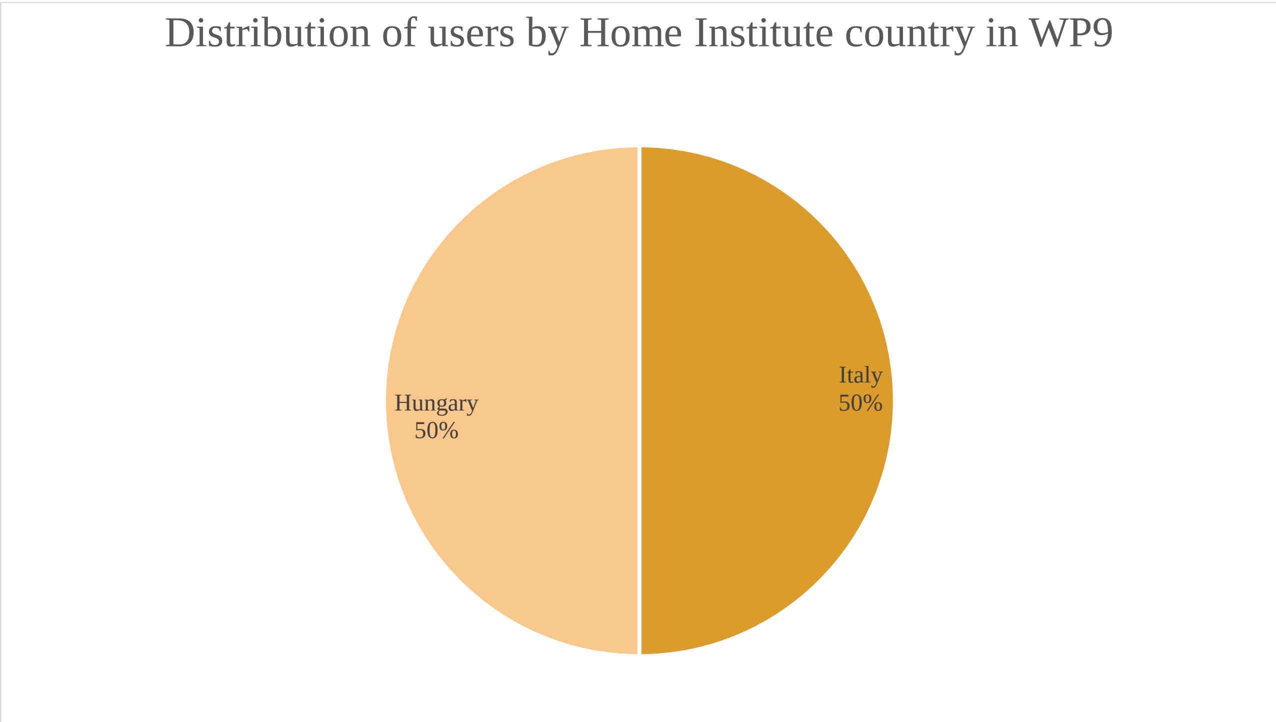
The present estimate is that a repaired valve should be received before the end of 2018, allowing to re-assemble the valve box cryostat and resume commissioning in January 2019. Present plan is to complete commissioning during the first half of 2019 after which the facility will be operational and available to users.

User meetings

No user meetings occurred in the reporting period.

Distribution of users by home institute country in WP9

Out of the total number of 22 user projects supported by MagNet in this reference period, 50% were from Italy and 50% from Hungary.



WP10: Material Testing (HiRadMat & UNILAC)

This work package provides Transnational Access to the material testing facilities: HiRadMat and UNILAC. The WP includes 2 tasks:

- Task 10.1. HiRadMat
- Task 10.2. UNILAC

Task 10.1. HiRadMat

HiRadMat (High Irradiation to Materials) is a facility at CERN designed to provide high-intensity pulsed beams to an irradiation area where material samples as well as accelerator component assemblies can be tested. HiRadMat uses the extracted beam from the CERN-SPS (Super Proton Synchrotron) with up to a few 10^{13} protons/pulse to a momentum of 440 GeV/c. The fast (single turn) extracted beam is transported into the HiRadMat experimental area where the test setup of materials will be installed. The beam spot size at the focal point at the experiment can be varied from 0.5 to 2 mm^2 to offer sufficient flexibility to test materials at different deposited energy densities. The facility can also provide heavy ion beams like Pb82+ with a beam energy of 177.4 GeV/nucleon (36.9 TeV per ion) resulting in a pulse energy of up to 21 kJ. HiRadMat as a dedicated facility for material and component testing with LHC type particle beams parameters is unique today.

The facility was initially contemplated as a test bed for collimator related issues. Within the years since commissioning, the research topics have gradually been extended to other elements of accelerator technologies, like for instance testing/validating beam diagnostic systems, all supported by granting beam time to external users.

Within the past EUcard2 and current ARIES European Programmes, several user teams using Transnational Access could take advantage of the facility. Researchers primarily from all over Europe, but also from the US and Japan, gained access to the facility amounting to more than 3000 Transnational Access hours (2700 during EUCARD2 alone). Users of the facility have access to all available infrastructures at CERN and receive technical support from CERN. Apart from the irradiation area this also includes a preparation area with easy access, a control room, the support on logistics like transport, installation and radiation-protection monitoring as well.

Description of the publicity concerning the new opportunities for access

HiRadMat and the opportunities for access has been publicised at the different conferences and meetings and via publications: a) NUFACT2017, 25 – 30 September 2017, Uppsala University, Sweden; b) publication in Accelerating News, "HiRadMat: testing materials under high radiation", Issue 23, 7th Dec 2017; c) HiRadMat USER DAY 19th April 2018, CERN, Switzerland; d) 6th Beam Telescopes and Test Beams Workshop, 16 – 19 January 2018, EHT, Zurich, Switzerland; e) High Power Targetry Workshop, 4 – 8 June 2018, East Lansing, Michigan, USA.

Description of the selection procedure

HiRadMat holds Scientific Boards (SB), when necessary, to review requested proposals for beam time. The SBs goal is to review the scientific merit of the proposals with focus on the significant contribution towards the advancement of the state-of-the-art knowledge on materials, components and systems associated with particle accelerators and the physical sciences. Within the ARIES framework a HiRadMat SB was held on 15th September 2017 to review experimental requests for 2018. Previous SB were also held in 2014 and 2016. No SBs were held in 2018 because 2018 marks the end of the proton run before the CERN Long Shutdown.

Upon SB approval, Technical Boards (TB) are held regularly in order to discuss the 'technical' aspects of the experiments, e.g. safety, design, pulse requests. Several TBs were held previously to discuss the relevant 2018 HiRadMat experiments; 12th December 2017 [HRMT19 (BLM2), HRMT47 (ATLASPixRad)], 22nd January 2018 [HRMT38 (FlexMat)], 3rd May [HRMT43 (BeGrid2)].

Description of the Transnational Access activity

User projects and experiments

As host facility, support is provided by the HiRadMat team to all experimental users. The project begins with design and cross-checks of integration models prior to any experiment entering the HiRadMat facility. During the installation phase, support is available from expert teams at CERN, including transport, survey, measurement techniques, beam diagnostics and radiation protection. During beam time the HiRadMat team facilitates the operation where support is also provided by the beam operators from the SPS (Super Proton Synchrotron), as HiRadMat uses beam extracted directly from the CERN-SPS.

During Period 1 of ARIES, HiRadMat successfully provided its facilities expertise to all TA projects agreed in the 2017/2018 period. Each experiment completed beam time by the end of the 2018 proton run where a total of 1328 TA hours was used.

HiRadMat	**User-projects**		**Total no. of users benefitting from the TA**	**Units of access** (1 hour)
	Eligible submissions	Selected		
Period 1 (M1-M18)	6	6	38	1328
Foreseen for project (M1-M48)	5		20	200

Scientific output of the users at the facility

ARIES-HiRadMat-2017-01: *HRMT19-BLM2*
(480 Access Units, project ongoing)

Project studied the signal linearity and response, calibration, saturation and comparison of different types of Beam Loss Monitors (BLMs).

The project continued from 2015 and has continued to benefit from TA support throughout 2017 and 2018. The project gained vital data for the analysis of BLMs, with dedicated and parasitic beam time. This project team consisted of 9 members from CERNs Beam Instrumentation and The European Spallation Source ERIC, Lund, Sweden. The members who benefitted from the TA support were from the field of Physics and Engineering & Technology.

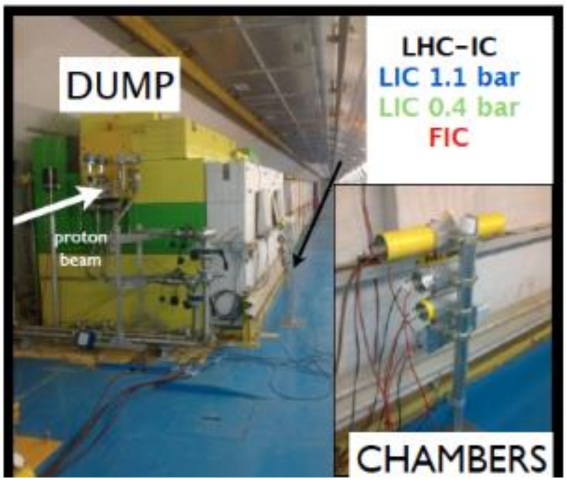


Figure 33: Example of BLM set-up in the experimental area.BLMs are positioned on and near the Beam Dump.

The project received dedicated beam time as well as parasitic beam time during 2018. Successful calibration of different ionization chambers was achieved. Tests confirmed the necessary design that will be produced for future installation. Publications are ongoing and the current ones have been reported in the TA report.

ARIES-HiRadMat-2017-02: *HRMT21-RotCol (88 Access Units)*

A rotatable collimator designed at the SLAC National Accelerator Laboratory, as part of the US-LARP collaboration, was tested. The collimator was designed to have up to 20 surfaces, where the collimator could rotate in case of surface damage caused by beam. The experiment aimed to demonstrate the rotation functionality of the collimator rotation mechanism after high intensity, high energy, beam pulses had been fired onto the collimator surfaces. The goal was to determine the surface damage caused by an iterative number of beam pulses, to determine the integrity of the control of the cooling pipes after beam impact and jaw rotation, and to determine the surface effects of the beam on the jaw of the collimator.

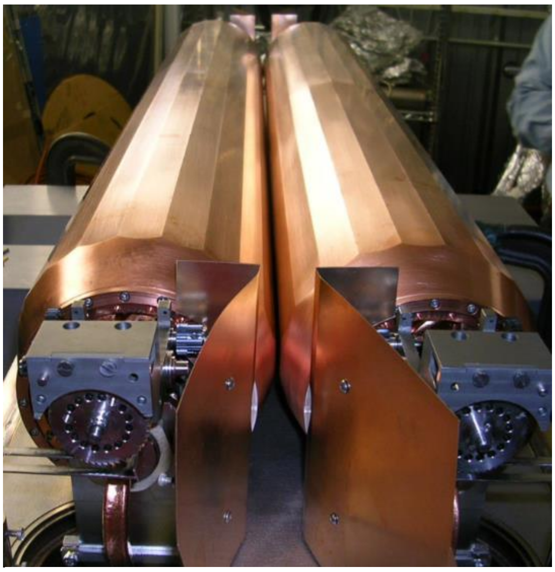


Figure 34: Example of SLAC Rotatable Collimator

This project consisted of a core team of 16 members from CERN, SLAC National Accelerator Laboratory (USA) and University of Malta (Malta). The teams' scientific field of expertise consisted of Physics, Engineering & Technology and Information & Communications Technology.

All proton pulses were delivered successfully to the experiment. The rotatable jaw was fully functional after the experiment, the integrity of the cooling pipes was demonstrated and there was no fixation/sticking of the jaws. PIE will continue.

Currently a publication on the work is under review and further publications are expected.

ARIES-HiRadMat-2017-03: *HRMT41-ATLASPixel (88 Access Units)*

The effects of accidental beam loss scenarios for the ATLAS tracking detectors for HL-LHC were studied. TWO IBL Pixel 3D modules and ONE ITk Strip DAQload without readout were tested, where the damage thresholds were measured. High intensity 288 bunch pulse destroyed the detector resulting in minimal PIE being possible, however a new damage threshold of 10^{13} protons/cm^3 was estimated (greater than previous thresholds measured).

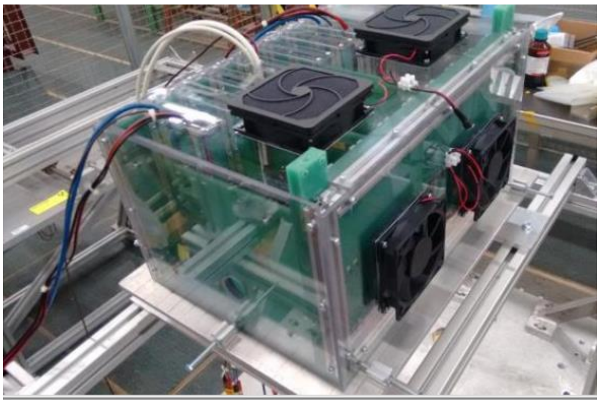


Figure 35: HRMT41 experimental box

HRMT47-ATLASPixRad (completed 2018): Continued TA support provided for the continuation of experimental analysis of the ATLAS tracking detectors. ONE IBL planar pixel module and TWO ITk DAQload CNM strip modules were tested. Damage thresholds were not met enabling PIE to be performed for all modules.

Figure 36: IBL module with cooling attached

The ATLAS project involved a multi-collaborative effort with several institutes around the world. The dedicated scientific team consisted of 11 members. These members were from INFN Bologna (Italy), INFN Genova (Italy), IFIC Valencia (Spain), Institute of High Energy Physics, Chinese Academy of Sciences, Beijing (China) and Petersburg Nuclear Physics Institute (Russia). The experimental team are experts in the field of Physics and Engineering & Technology.

The studies of ATLAS resulted in the damage threshold for the ATLAS tracker modules being identified, at approximated 10^{13} protons. This has provided further information regarding their use for future HL-LHC beam loss scenarios.

ARIES-HiRadMat-2017-04: *HRMT38-FlexMat* (296 Access Units, project ongoing)

Tested the dynamic response of intense proton beam induced shock for low density, high damping carbon materials and for composite carbon targets including high stiffness and high damping materials. Impact tests were performed with increasing beam pulse intensity up to nominal value (288 bunches, 1.2e11 p/b). On- and off-line techniques to monitor the response and possible failure limits of simple and composite targets were used in combination with hydrodynamic calculations of pressure and shock wave velocities in individual materials. The project team consisted of 11 members from GSI (Germany) with expertise in Physics, Engineering.

The results from *in situ* beam time measurements are ongoing. To note, different grades of carbon and carbon composite materials were successfully tested with proton beam and the results have highlighted the different response of the materials under similar beam impacts. This has provided information on the most suitable materials for use in proton targets, beam catchers, beam windows for high powered accelerators.

Once the experimental tank is released from HiRadMat by radiation protection PIE measurements are to be performed and thus further results are expected. The publications have been highlighted in the relevant TA report and further publications are expected.

ARIES-HiRadMat-2017-05: *HRMT36-MultiMat* (64 Access Units, completed 2017)

Investigated multi-materials for the HiLumi upgrade. This project was in collaboration with the LHC Collimation project and was a multi-collaborative effort. The experiment was designed to test various material specimens of different material types, e.g. coatings, anisotropic materials, foams), that have the potential to be used in collimator and beam intercepting devices. The materials were tested with high intensity, high energy, pulses utilising the maximum proton pulse offered by HiRadMat (288 bunches at ~3.46×10^{13} protons per pulse). The project team consisted of 21 members from CERN, University of Malta (Malta), Brevetti Bizz Srl (Italy), Politecnico di Milano (Italy) and The University of Huddersfield (UK), with expertise in Physics, Engineering & Technology and Materials Sciences.

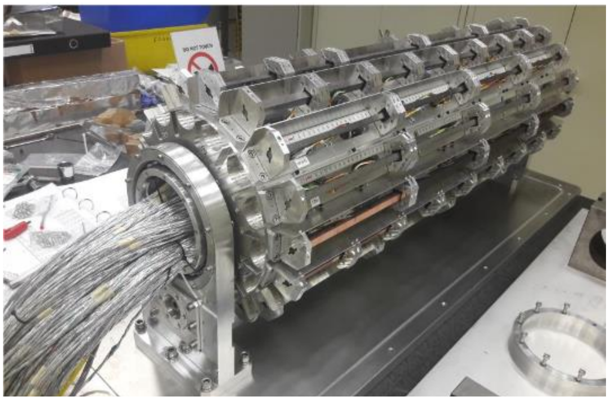


Figure 37: Illustration of the HRMT36 experimental tank, with multiple target stations shown on a rotatable barrel

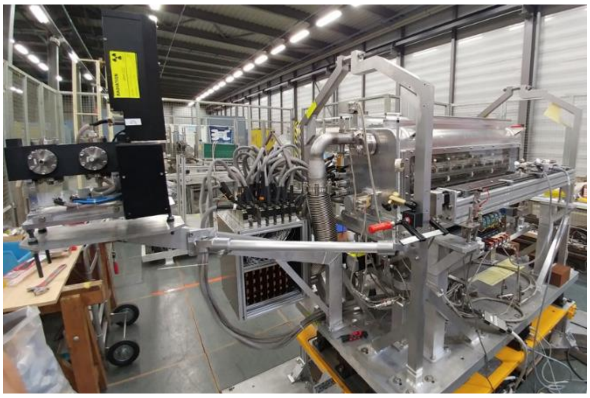


Figure 38:HRMT36 experimental tank with BTV/BPKG attached on the HRM table

HRMT36 concluded a successful 2017 experimental campaign. The proton beam delivered was stable and repeatable and the online measurements systems were successful. Data processing and PIE is ongoing. Initial observations were that all carbon-based materials survived all proton intensity impacts, Silicon-Carbide materials failed unexpectedly, plastic permanent deflections were induced on high-Z materials and surface damage was induced on coatings. The dynamic behaviour of the coatings enabled validation of the material choices for LS2 installations.

Further results are expected to be published in the future.

ARIES-HiRadMat-2018-01: *HRMT43-BeGrid2* (312 Access Units, project ongoing)

Experiment designed to further understand the thermal shock response of conventional materials (beryllium, graphite, silicon, glassy carbon and titanium alloys) and novel materials (electro-spun materials, metal foams.) used for accelerator beam windows and secondary particle production targets. This experiment built on the previous BeGrid (HRMT24) experiment by increasing the beam pulse intensity to even higher levels on beryllium specimens than what was requested in HRMT24. In addition, new and novel material specimens (as well as beryllium) in both non-irradiated and previously proton-irradiated conditions were tested. The primary goal was to understand the failure mechanisms, limits and flow behaviour of the various material specimens and to compare and contrast the thermal shock responses of previously irradiated materials to their non-irradiated counter-parts. The experimental set-up comprised of multiple arrays of specimens, each exposed to different beam intensities. Online diagnostics were performed (strain/temperature gages, LDV system, and camera systems) to monitor the experiment in real-time. PIE is planned, involving measuring out-of-plane permanent plastic deformation of the specimens with a profilometer as well as advanced microscopic imaging systems (SEM, EDS, EBSD) to analyse the microstructural evolution of the specimens. The project team consisted of 9 members from Rutherford Appleton Laboratory (UK), FNAL (USA), UK Atomic Energy Authority, KEK (Japan) and RAL/STFC (UK) with expertise in Physics, Engineering.

HRMT43 received beam on 1st – 2nd October 2018, and therefore no results are yet available. However, the full programme was completed and all requested beam pulses were delivered. Publications on the experiment and results are anticipated.

User meetings

Date	*Meeting*	*Venue*	*Total number of participant*	*N. of users attending*	*Link*
2017.05.01	Users meeting	CERN	14	7	https://indico.cern.ch/event/639690/
2017.06.22	Users meeting	CERN	15	8	https://indico.cern.ch/event/647936/
2017.08.10	Users meeting	CERN	9	3	https://indico.cern.ch/event/658538/
2017.09.14	Users meeting	CERN	8	3	https://indico.cern.ch/event/665044/
2017.09.15	Scientific Board	CERN	25	13	https://indico.cern.ch/event/657996/
2017.12.12	Technical Board	CERN	13	6	https://indico.cern.ch/event/683966/
2018.01.22	Technical Board	CERN	13	6	https://indico.cern.ch/event/683970/
2018.04.19	User Workshop	CERN	48	28	https://indico.cern.ch/event/705237/
2018.05.03	Technical Board	CERN	15	4	https://indico.cern.ch/event/704916/
2018.06.22	User Meeting	CERN	12	8	https://indico.cern.ch/event/738222/
2018.07.04	User Meeting	CERN	11	7	https://indico.cern.ch/event/740290/
2018.07.18	User Meeting	CERN	12	8	https://indico.cern.ch/event/743362/
2018.07.25	User Meeting	CERN	12	8	https://indico.cern.ch/event/743384/
2018.08.01	User Meeting	CERN	9	5	https://indico.cern.ch/event/747895/
2018.08.09	User Meeting	CERN	9	5	https://indico.cern.ch/event/749309/
2018.08.15	User Meeting	CERN	10	6	https://indico.cern.ch/event/750613/
2018.08.22	User Meeting	CERN	9	5	https://indico.cern.ch/event/751908/
2018.09.05	User Meeting	CERN	9	5	https://indico.cern.ch/event/755357/
2018.09.13	User Meeting	CERN	10	6	https://indico.cern.ch/event/757362/
2018.09.25	User Meeting	CERN	9	6	https://indico.cern.ch/event/758643/
2018.10.03	User Meeting	CERN	5	3	https://indico.cern.ch/event/763022/
2018.10.10	User Meeting	CERN	6	4	N/A

Task 10.2. UNILAC

The Universal Linear Accelerator UNILAC of the GSI Helmholtz Centre for Heavy Ion Research (Darmstadt, Germany) provides ion beams of all elements (from protons up to Uranium) in the energy regime between 3.6 to 11.4 MeV per nucleon.

UNILAC M-branch offers three ion beamlines (M1, M2 and M3) dedicated to in-situ and/or online materials analysis during sample irradiation:

M1 beamline

- High-resolution scanning electron microscopy (HRSEM) to monitor beam-induced surface and elemental (EDX) changes.
- Ultra-high vacuum (UHV) irradiation chamber including atomic force and scanning tunnelling microscopy (AFM/STM)
- High energy Time-of-Flight Secondary Ion Mass Spectrometry (ToF SIMS)

M2 beamline

- Four-circle X-ray diffractometer (XRD) for in-situ monitoring of crystallographic and structural beam-induced changes without removing the sample during beam breaks

M3 beamline

- A multi-purpose chamber including a heating and cooling stage; sample irradiations at a temperature between 20 and 1,000 K and under various gas atmospheres are possible
- Optical spectroscopy (FTIR, UV/Vis, and Raman) and thermal imaging by a fast IR camera
- Residual gas analyzer (RGA)
- Free ports to attach user equipment

Description of the publicity concerning the new opportunities for access

The new possibility of transnational access of the GSI UNILAC M-branch is now posted on a dedicated web page at GSI.de. It informs about the access opportunities and provides a link to the ARIES web page. In addition, the information was spread at several international conferences and received very positive response.

Description of the selection procedure

A two-step selection process is established: first the user groups submit proposals to the Materials Science Program Advisory Committee of GSI (Mat-PAC). This committee evaluates the scientific merit of all proposals related to material science and recommends (or not) beam time to the scientific director of GSI.

The approved groups which request TNA, submit in a second step the proposal including a detailed working plan to the ARIES TNA user selection panel of GSI UNILAC M-Branch (USP). The USP consists of the TNA facility coordinator (Dr. Daniel Severin) and two international experts (Prof. Jie Liu (IMP Lanzhou) and Prof. Maik Lang (University of Tennessee)). On April 27, 2018 the constituent meeting took place at GSI and the general procedure was discussed. Two proposals were pre-evaluated and final approval is foreseen via e-mail circulation procedure and or video conference.

Description of the Transnational Access activity

User projects and experiments

Because of the shut-down of GSI accelerators in 2017 and 2018 until summer, this TNA has been active only for 3 months during the first Reporting Period.

UNILAC	**User-projects**		**Total no. of users benefitting from the TA**	**Units of access** (1 hour)
	Eligible submissions	Selected		
Period 1 (M1-M18)	2	2	21	104

Foreseen for project (M1-M48)	8	48	480

Scientific output of the users at the facility

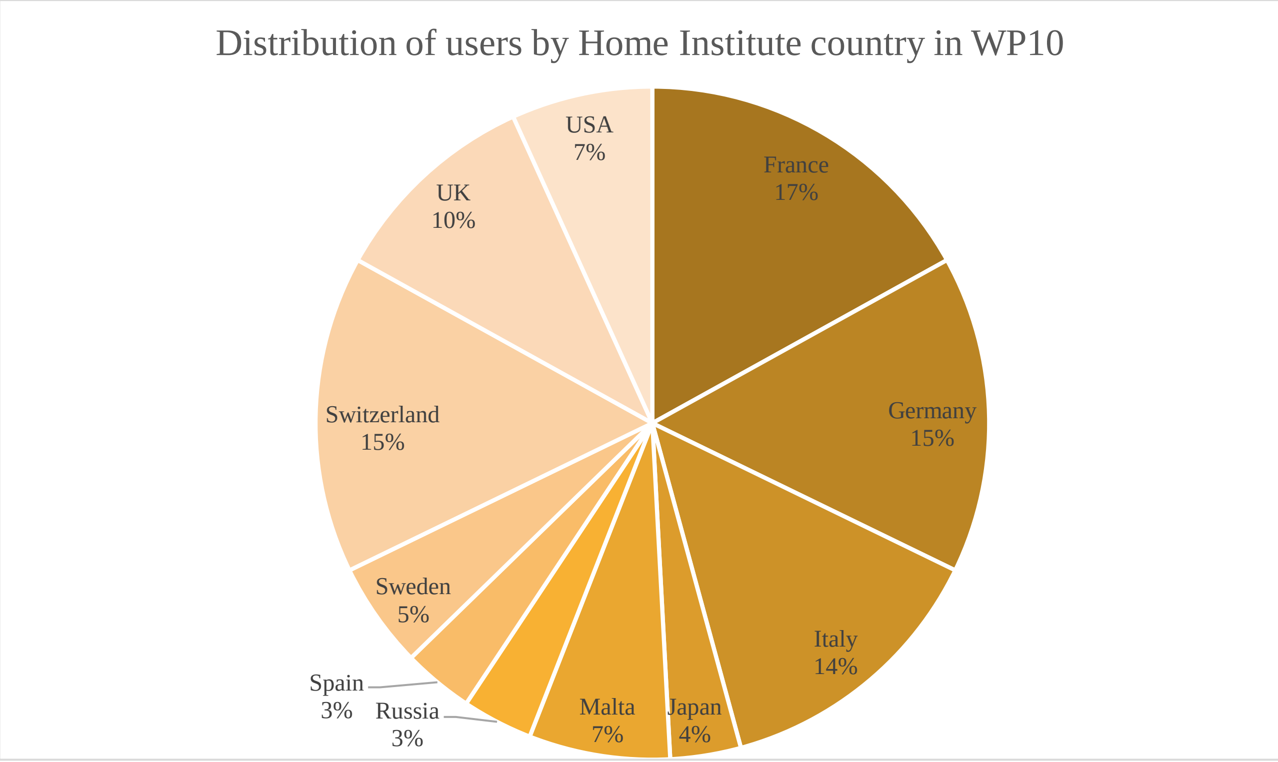
Data are still under evaluation and the second beam time block in Feb. – March 2019 is needed to complete the data sets.

User meetings

No user meetings occurred in the reporting period.

Distribution of users by home institute country in WP10

The chart below shows the distribution of users at HiRadMat and UNILAC material testing facilities by the country of the user's home institute.



WP11: Electron and proton beam testing (ANKA, VELA, IPHI, SINBAD & FLUTE)

This work package provides Transnational Access to the electron and proton beam testing facilities: ANKA, VELA, IPHI, SINBAD and FLUTE. The WP includes 5 tasks:

- Task 11.1. ANKA
- Task 11.2. FLUTE
- Task 11.3. IPHI
- Task 11.4. SINBAD
- Task 11.5. VELA

Task 11.1. ANKA (presently called KARA)

The Karlsruhe Research Accelerator (KARA) at the Karlsruhe Institute of Technology (KIT) is used as a synchrotron radiation source (ANKA) and a test facility providing a unique test environment for accelerator R&D. The KIT accelerator complex consists of a 53 MeV microtron, a 500 MeV booster synchrotron and a 2.5 GeV storage ring named KARA equipped with state-of-the-art beam diagnostics. This is the core of the KIT accelerator technology platform which allows research in accelerator physics and instrumentation at the accelerator proper or using the emitted synchrotron radiation. Users accessing KARA through the ARIES-TA11 will profit from the existing user office and support procedures as well as the workshops assisting experimental installations.

Accelerator studies at the KARA profit from its flexible lattice, large energy range (0.5 - 2.5 GeV), adjustable filling pattern and bunch lengths (50 ps down to a few ps in a dedicated short bunch operation mode), and the fully synchronized, fast, transversal and longitudinal beam diagnostics. The latter includes novel single-shot, high repetition rate electro-optical longitudinal bunch profile monitoring and in-house developed detector systems (e.g., THz detectors) with bunch-by-bunch and turn-by-turn multi-channel readout. Several installed superconducting insertion devices in different section allow the study of nonlinear beam dynamics. One is the prototype of superconducting damping ring wiggler proposed for the CLIC damping rings.

In preparation of user experiments, a working point with negative momentum compaction factor is currently being implemented and characterized.

Description of the publicity concerning the new opportunities for access

The KIT synchrotron light source is well known as a user facility for experiments using this KIT light source at different beamlines. In addition to the implementation of the ARIES application procedure KIT upgraded its online proposal submission platform ANNA (since more than 15 years well known for ANKA) with new functionalities for accelerator research experiments at KARA. KIT promoted the activities for ARIES and TNA possibilities at international conferences and workshops on accelerators and terahertz research, e.g. IPAC17, IPAC18, ESLS-WS17, DEELS 2018, TW-DULER 2018, via a special advertisement leaflet for WP11.

Description of the selection procedure

The User Group Leaders are invited to contact the facility coordinator before beginning the formal application process in order to discuss the technical aspects and feasibility of the project, the suitability of the proposal's draft and the eligibility of the user group. This resolves eligibility issues and gives feedback to rejected applicants before the formal application procedure. The User Group Leader should download, complete and send the ARIES TA application form to ARIES-TA@cern.ch

Each facility, following its own selection procedure to assess technical feasibility, will forward the recommended project for decision of the WP11 User Selection Panel based on scientific quality. Proposals are evaluated based on scientific merit whilst taking into consideration the availability of the facility and similar facilities in the users' home country.

Description of the Transnational Access activity

User projects and experiments

Three user projects of "**Optics measurements with TxT data**" were carried out during the reporting period based on a proposal of CERN and Uppsala University. These projects were in the field of beam dynamics and beam diagnostics. The beam dynamic measurements with the CLIC SC Wiggler were carried out at KARA. Users from Uppsala University measured the tune-shift with the wiggler's field at KIT, the users from CERN participated in an experiment on tune and chromaticity measurements remotely. They used a novel method to measure chromaticity. The results agree well with the traditional chromaticity measurements. KIT supported the experiments with a scientist and the operating team of the KIT facility. The results obtained are relevant for the design and operation of future accelerators like CLIC, ILC or ultra-low emittance rings.

ANKA	**User-projects**		**Total no. of users benefitting from the TA**	**Units of access** (1 hour)
	Eligible submissions	Selected		
Period 1 (M1-M18)	3	3	6	180
Foreseen for project (M1-M48)	8		64	480

Scientific output of the users at the facility

Measurement results of the user project "Optics measurements with TxT data" were presented at the ARIES annual meeting in Riga: "Optics characterisation at ANKA including the high wiggler field" by Panagiotis Zisopoulos (CERN and Uppsala University) et al. (CERN, KIT).

User meetings

No user meetings occurred in the reporting period.

Task 11.2. FLUTE

FLUTE (Ferninfrarot Linac- Und Test Experiment) is a new compact and versatile linear accelerator test facility at KIT. It is currently under final commissioning in collaboration with the Paul Scherrer Institute (PSI, Villigen, CH) and DESY (Hamburg, D). Its focus is on accelerator physics and technology including systematic studies on the generation and dynamics of ultra-short electron bunches, in addition to photon science experiments with intense, ultra-short terahertz (THz). FLUTE consists of a 7 MeV photo-injector, a 41 MeV S-band linac and a D-shaped chicane to compress electron bunches covering a large bunch charge range, from 1 pC to 3 nC, and bunch lengths from 500 fs down to a few fs. FLUTE is providing users short electron bunches with beam energies of 7 and 41 MeV. The spectral bandwidth of FLUTE's THz radiation generated with a repetition rate of 10 Hz, covers the range of 0.1-100 THz with up to 5 GW THz pulse power, and up to 3 mJ THz pulse energy. Various diagnostic sections equipped with state-of-the-art diagnostics before and after the linac as well as in the bunch compressor allow access to all beam parameters. The in-house R&D program at FLUTE includes the investigation of space charge and coherent radiation induced effects, bunch compression, and systematic comparison of simulation code results with measurements. Furthermore, FLUTE will serve as a test bench for advanced accelerator diagnostics, synchronization and stabilization schemes, reliability, and innovative instrumentation. It is envisioned to also provide intense, femtosecond, terahertz radiation with focused electric fields up to GV/m for applications in accelerator physics, materials science, life sciences, and medicine. To prepare the first user experiment at FLUTE, the required equipment was installed and commissioned (Figure 39).

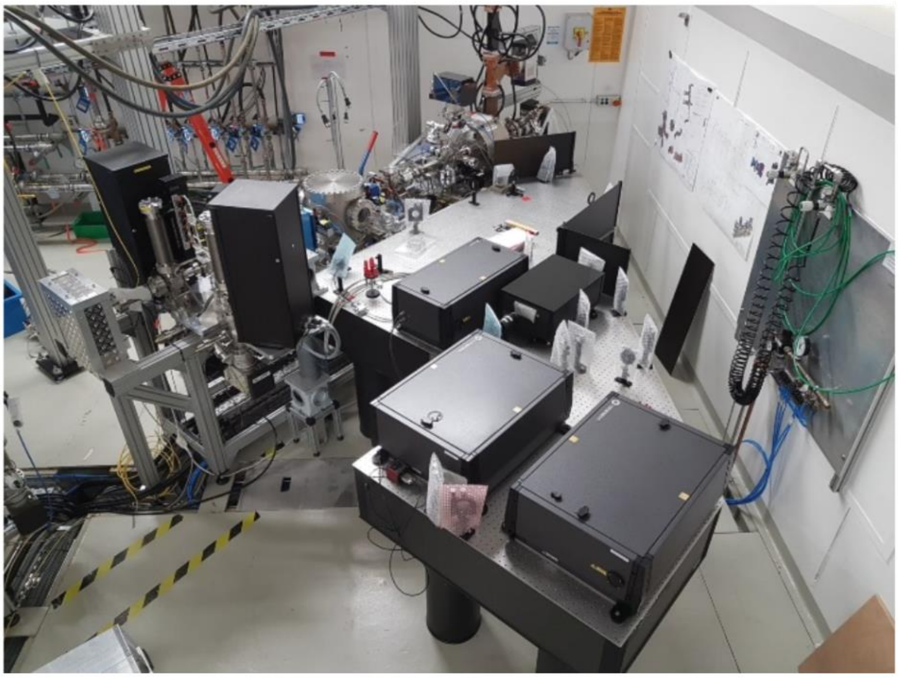


Figure 39: View in the experimental hall on the FLUTE configuration for the 7 MeV electrons (in the back from right to left): photon injector, solenoid, BMP, ICT, quadrupole magnet, round metal vacuum chamber for SRR experiments of PSI, two screen monitors

Description of the publicity concerning the new opportunities for access

FLUTE was advertised at the same time and using the same channels as the KIT light source, the KIT accelerator test facility KARA, profiting as well of the submission platform ANNA.

Description of the selection procedure

The WP11 USP oversees the approval of TA applications at work package level. The composition of the USP and the selection procedure are described in section *Task 11.1 – Description of the selection procedure*.

Description of the Transnational Access activity

User projects and experiments

To measure ultra-short electron bunch length, PSI and University of Bern plan a linear mapping of the longitudinal axis onto the transverse plane by THz streaking using a micro-structured split ring resonator (SRR). To prepare this first experiment at FLUTE, KIT supported the installation and commissioning of the vacuum chamber made by PSI (2 days, 2 users) and the design, installation, adjustment of the THZ generation by University of Bern (5 days, 2 users and 3 days 3 users) for several campaigns of the upcoming SRR experiments. These experiments were planned to be a proof of principle of a novel longitudinal diagnostic tool within several stages.

FLUTE	**User-projects**		**Total no. of users benefitting from the TA**	**Units of access** (1 hour)
	Eligible submissions	Selected		
Period 1 (M1-M18)	2	2	9	56

Foreseen for project (M1-M48)	8	40	320

Scientific output of the users at the facility

Installation of the user experiment and the first measurements carried out are essential for the development of a new longitudinal diagnostics tool with fs time resolution. No publication yet.

User meetings

No user meetings occurred in the reporting period.

Task 11.3. IPHI

The High Intensity Proton Injector, IPHI, is located in the premises of the Accelerator, Cryogenics and Magnetism Division (DACM) at CEA Saclay. IPHI is a beamline composed of an ECR ion source, a Low Energy Beam Transport line, a 6 m long 352 MHz Radio-Frequency Quadrupole and two Medium Energy diagnostic lines. Built in CEA Saclay with the collaboration of IPN Orsay and CERN, IPHI will be able to provide a 3 MeV proton beam with peak intensities between 1 and 100 mA and duty cycles between 1 ms / 1 Hz up to continuous wave. This very high intensity proton beam will be unique in Europe.

The 352 MHz Radio-Frequency power used by IPHI is provided by two TH2089B continuous wave klystrons, each delivering an RF power up to 1 MW, and one TH2179A pulsed klystron optimized for working at the ESS duty cycle (3.5 ms pulses at 14 Hz), with a peak RF power of 2.2 MW and an average power of 210 kW. This RF system has been upgraded and is now operational. In addition to the IPHI accelerator, the 352 MHz RF power will also be distributed to two other vaults, where it could be used for dedicated experiments.

The IPHI proton beam can be used to develop and test high intensity beam diagnostics or beam devices (for example beam profile measurements or beam choppers) and perform beam dynamics studies (for example study space charge effects at 3 MeV). IPHI can also be used as a neutron source. Neutrons could be produced with the current beam stop (up to 10^9 n/s), or using a Beryllium target (up to 10^13 n/s). These neutrons could be used to optimize neutron moderators, test neutron diagnostics, or for irradiation purposes. RF power for external users can be provided to test RF components (RF windows, RF power loops, DTLs, etc).

Description of the publicity concerning the new opportunities for access

The possibility to access IPHI within the ARIES project has been advertised at several occasions during workshops (for example at workshops on compact neutron sources held in Jülich in October 2017 and in October 2018) and conferences (for example at the IPAC conference held in Vancouver in May 2018).

Description of the selection procedure

The WP11 USP oversees the approval of TA applications at work package level. The composition of the USP and the selection procedure are described in section *Task 11.1 – Description of the selection procedure*.

Description of the Transnational Access activity

User projects and experiments

After upgrading the IPHI cooling system in 2017 and restarting the beam in December 2017, the IPHI beam was used for internal experiments in Spring 2018 and a first experiment within the ARIES program took place only in October 2018. The experiment consisted in testing a Beam Position Monitor (BPM) designed by ESS Bilbao (Spain) for the European Spallation Source (ESS). The performance of the BPM and its electronics has been evaluated for different beam currents and pulse lengths. The beam current was changed from 0.4 mA up to 50 mA and the system performance evaluated for this range.

The system response for beam pulse lengths from 300 μs up to 3 ms was verified successfully. The position and phase resolution has been verified and position measurements were successfully compared to already existing IPHI BPM's. Time-of-flight measurements were performed and measurements proportional to the beam energy from pulse to pulse could be monitored. It was possible to identify improvements to be implemented on the ESS BPM system before the manufacturing of all the ESS electronics units to improve its performance.

IPHI	**User-projects**		**Total no. of users benefitting from the TA**	**Units of access** (1 hour)
	Eligible submissions	Selected		
Period 1 (M1-M18)	1	1	8	72
Foreseen for project (M1-M48)	12		72	1,440

Scientific output of the users at the facility

The first experiment at IPHI having been performed very recently, there is no publication yet of the results

User meetings

No user meetings occurred in the reporting period.

Task 11.4. SINBAD

SINBAD ("Short Innovative Bunches and Accelerators at Desy") is an electron linear accelerator R&D facility located at the DESY lab in Hamburg, Germany. The facility is currently under construction and will be available to users early 2019.

The linac will accelerate electron bunches of 0.1-20 pC charge to 100 MeV kinetic energy, compressing them to only a few fs in bunch length.

Electron bunches are, for example, ideally suited for injection into advanced acceleration scenarios, such as plasma wakefield or laser acceleration in dielectric structures.

In the context of the TNA-program, access to the experimental site of the linac will be granted. Users will receive support prior to their visit to the facility (ie via vacuum guidelines and synchronization), and will be assisted by DESY staff during the preparation and operation of the facility during the experiment.

Description of the publicity concerning the new opportunities for access

The possiblity for TNA is communicated at the ARIES EuroNNAC Network and at conferences and workshops.

Description of the selection procedure

The WP11 USP oversees the approval of TA applications at work package level. The composition of the USP and the selection procedure are described in section *Task 11.1 – Description of the selection procedure*.

Description of the Transnational Access activity

User projects and experiments

Access to the SINBAD-ARIES linac will be possible as planned from spring 2019 onwards. The installation of the gun area is currently ongoing with the linac region following in fall 2018. The general purpose technical infrastructure for the TNA-users at the experimental site is being developed.

SINBAD	**User-projects**		**Total no. of users benefitting from the TA**	**Units of access** (1 hour)
	Eligible submissions	Selected		
Period 1 (M1-M18)	0	0	0	0
Foreseen for project (M1-M48)	9		36	630

Scientific output of the users at the facility

Transnational access activity has not started yet.

User meetings

No user meetings occurred in the reporting period.

Task 11.5. VELA

VELA (Versatile Electron Linear Accelerator) is a high performance, modular injector facility located at the STFC Daresbury Laboratory and capable of delivering a highly stable, highly customisable, short pulse, high quality electron beam to a series of test enclosures. The facility delivers a capability for the cutting edge development and qualification of advanced accelerator systems, enabling industry to expedite their technology development from prototypes to market ready products.

The VELA facility comprises an S-Band Photo-injector, which is capable of delivering up to 250 pC of bunch charge at 6 MeV, with micron level beam emittance performance. The copper photo-cathode is driven by a UV laser which delivers a pseudo-Gaussian profile of 1 mm FWHM at the cathode. RF power is delivered to the RF Gun via a 10 MW klystron which is powered by a modulator, all of which is housed on the VELA injector enclosure roof. The electron beam is then transported through a beam diagnostics line comprising wall current monitor, pepper pot, YAG screens, Faraday Cup and slit/strip line BPMs, and a transverse deflecting cavity, before exiting into the two experimental enclosures.

Description of the publicity concerning the new opportunities for access

Access to the facility is communicated by STFC's website, social media, calls for proposals, and via attendance and presentations at meetings, workshops and conferences. Due to the delay and uncertainty in availability in year 1, promotion of the ARIES TNA access programme for VELA has been minimal, although highlighting of other facilities covered by TNA has been more extensive.

Description of the selection procedure

The WP11 USP oversees the approval of TA applications at work package level. The composition of the USP and the selection procedure are described in section *Task 11.1 – Description of the selection procedure*.

Description of the Transnational Access activity

User projects and experiments

Following delays to the commissioning phase, the VELA facility began User exploitation experiments in September 2018, with two ARIES TNA experiments scheduled for beamtime. Unfortunately, failure of a critical component in the photo-injector laser has introduced an additional delay, and the ARIES TNA experiments have been provisionally re-scheduled for January/February 2019. Further beamtime allocations will be available to the TNA programme in 2019.

VELA	**User-projects**		**Total no. of users benefitting from the TA**	**Units of access** (1 hour)
	Eligible submissions	Selected		
Period 1 (M1-M18)	1	1	0	0
Foreseen for project (M1-M48)	14		56	336

Scientific output of the users at the facility

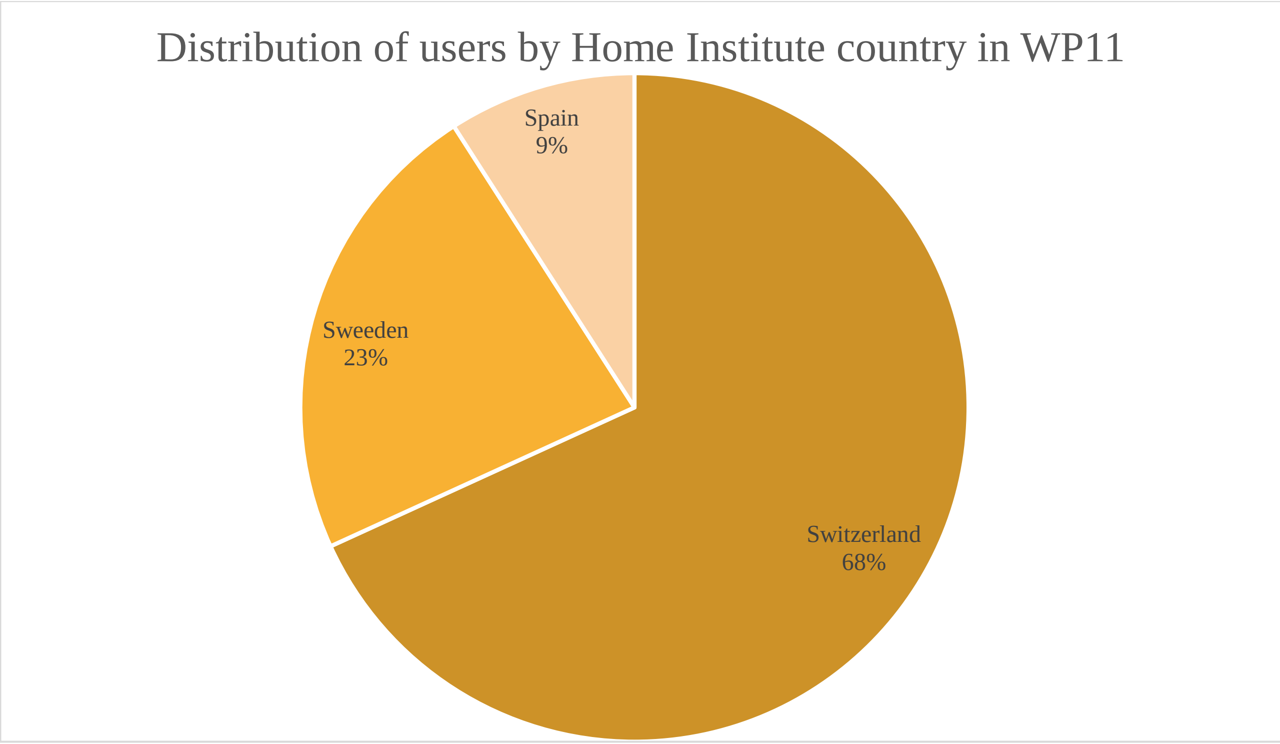
Transnational access activity has not started yet.

User meetings

No user meetings occurred in the reporting period.

Distribution of users by home institute country in WP11

The chart below shows the distribution of users at ANKA, VELA, IPHI, SINBAD and FLUTE electron and proton beam testing facilities by the country of the user's home institute.


Distribution of users by Home Institute country in WP11
Spain
9%
Sweeden
23%
Switzerland
68%

WP12: Radio Frequency Testing (HNOSS & XBox)

This work package provides Transnational Access to the radio frequency testing facilities: HNOSS and XBox. The WP includes 2 tasks:

- Task 12.1. HNOSS
- Task 12.2. XBox

Task 12.1. HNOSS

HNOSS (High power RF test stand with horizontal cryostat) is a versatile horizontal cryostat system for testing superconducting cavities located at the FREIA Laboratory, Department of Physics and Astronomy, Uppsala University, Sweden. HNOSS is designed for high power RF testing of up to two superconducting accelerating cavities simultaneously, each equipped with helium tank, fundamental power coupler and tuning system. HNOSS is used to characterise the performance of superconducting accelerating cavities like used in the new state-of-the-art accelerators like ESS, LHC upgrade and advanced FEL projects. HNOSS is connected to a cryogenic plant providing liquid helium and a sub-atmospheric pumping system enabling operation in the range 1.8 to 4.5K. The capacity to test two devices simultaneous makes it world unique as the only other existing facility, HoBiCAT at the HZ Berlin, Germany, is fulltime used for the development of the bERLinPro project.

Description of the publicity concerning the new opportunities for access

The HNOSS facility was advertised at the ARIES meetings and at workshops and conferences.

Description of the selection procedure

WP12 has a common Selection Panel for the two tasks 12.1 and 12.2. All of the Panel has expertise in RF with a mixture of specializations to cover the superconducting HNOS and normal-conducting Xboxes. The criteria for choosing the members of the User Selection Panel (USP) were that they should be from among the worldwide RF community with one member from the Americas, Asia, and Europe each. In addition, they should represent one member each from superconducting RF, normal conducting RF, and RF manufacturing technologies. The final panel consists of Jiaru Shi (Tsinghua University, China), Vyacheslav Yakovlev (Fermi National Laboratory, USA), Kenneth Österberg (Helsinki University, Finland), and the two work package leaders Walter Wuensch (CERN), Roger Ruber (Uppsala University). Due to the difference in time and space between the members, one meeting was organized by video-conferencing while discussions were conducted by e-mail.

The USP received two requests for User Projects, one for each facility, during period 1. After due consideration the USP accepted the proposals. Thereafter the facility management accepted the proposals and started discussions with the User Group Leader to implement the project.

Description of the Transnational Access activity

User projects and experiments

HNOSS	User-projects		Total no. of users benefitting from the TA	Units of access (1 hour)
	Eligible submissions	Selected		
Period 1 (M1-M18)	2	2	18	1330

Foreseen for project (M1-M48)	4	44	2,880

Scientific output of the users at the facility

The first project consisted in the test of a high-beta elliptical cavity. The power coupler was installed onto the cavity in a clean room at CEA Saclay and the assembly transported to Uppsala during July 2017. During November 2017, two people from the User Group visited Uppsala for discussions and installation of the cavity frequency tuning system. During January-February 2018 the cavity was inserted into the HNOSS cryostat. This was followed by a second visit of two people from the User Group in February to install the doorknob onto the power coupler.

The high power RF system consisting of a high voltage pulse modulator and klystron RF amplifier have been kindly lent by ESS. Unfortunately, due to a technical problem with the klystron amplifier, its shipment to Uppsala was delayed until mid-January 2018. At the same time, the original high voltage pulse modulator already sent by ESS in summer 2017 had to be returned and was replaced with another modulator in February while the klystron slow control system had to be replaced in March. ESS staff visited Uppsala in mid-April to switch-on and condition the klystron.

In June, the whole installation was completed and the high power RF system commissioned. Testing of the cavity followed. First the power coupler was conditioned with RF power at room temperature and short pulse lengths. Then the cavity and coupler were cooled down with the cavity reaching 2 K followed by RF conditioning of power coupler and cavity up to 300 kW. Some outgassing and X-ray radiation occurred at intermediate field, but disappeared after a few hours of operation (conditioning). A maximum accelerating gradient of 16 MV/m was reached with an incident RF power of 290 kW. The effect of Lorenz force detuning was visible at high field, with a variation of the field amplitude on the flat top of the pulse. In July the cavity was warmed up to room temperature to modify the connection of the frequency tuner drivers. Mid August the cavity was cooled down again to 2K and the tests repeated with a proper control of the frequency tuner. The fast piezo driven tuner proved to be effective in counter-working the effects of Lorenz force detuning.

User meetings

Date	***Meeting***	***Venue***	***Total number of participants***	***Number of users attending the meeting***
6-8/11/2017	Installation	Uppsala	2 + 5	2
12-14/02/2018	Installation	Uppsala	2 + 5	2
25-56/09/2018	De-installation	Uppsala	2 + 5	2

Task 12.2. XBox

The Xboxes are klystron-based X band test stands located at CERN in Geneva, Switzerland. The test stands are dedicated to the testing and development of high-gradient accelerating structures and high-power RF components. At present there are three Xboxes: two with each powered by a 50 MW/1.5µs/50 Hz klystron and the third is powered by four 6 MW/5µs/400 Hz klystrons combined in pairs.

The Xboxes were constructed and are being used to high-power test the main linac accelerating structures and novel RF components for the Compact Linear Collider (CLIC). The test stands are just as useful for developing high gradient and power structures for X-band FELs, Compton/Thomson sources and as potential test units of RF units used in high-performance compact linacs.

Access to the Xboxes is granted in two modes: Primary access is given to accelerating structures and RF components powered by RF directly, and parasitic access is given to experiments dedicated to projects such as high gradient research and diagnostic developments.

Description of the publicity concerning the new opportunities for access

The primary means of publicity and information have been announcements and dedicated slides during presentations at international events in which the high-gradient RF community are present. For example the presentations given at MeVArc2018 https://indico.cern.ch/event/680402/, HG2018 https://indico.cern.ch/event/675785/ and ISDEIV2018 http://www.isdeiv2018.org/index.html. These presentations and announcements link directly to the ARIES Xbox web pages. An announcement poster has been prepared and has been displayed at numerous events as well.

Description of the selection procedure

The WP12 USP oversees the approval of TA applications at work package level. The composition of the USP and the selection procedure are described in section *Task 12.1 – Description of the selection procedure*.

Description of the Transnational Access activity

User projects and experiments

The first User Project was a spectrometer-based diagnostic system for measurement of electron and light emission from high-gradient cavities. It was installed in Xbox-1 and operated during 1680 access hours. It was installed, commissioned and then operated remotely.

The experiment was designed and built by the University of Uppsala. The group at the University of Uppsala is very active in the field of high-gradient research, for example it has built and carried out studies of field emission in an in-situ miniaturized set-up which is installed inside the chamber of an electron microscope. The experiment installed in Xbox-1 and the in-situ system provide complementary data on high-gradient effects. The equipment is shown in Figure 40. **Error! Reference source not found.**Once the system was fully commissioned by Uppsala personnel, masters and PhD students as well as post-docs and staff operated the system and carried experiments remotely from Uppsala.

The second User Project is to high-power test a PSI-built new barrel open cavity X-band RF pulse compressor and a novel Tsinghua University multiple cavity correction cavity chain, which forms near-flat pulses from the exponentially decaying cavity pulse compressor shape. These two devices will operate together to bring a significant improvement in high-power handling capability, efficiency and pulse shaping capability.

The first User Project operated during a multi-month 24/7 running period resulting in 1680 access hours. There were six users in the first User Project, one travelled to CERN and the rest participated remotely. There are four users in the second User Project.

XBox	User-projects		Total no. of users benefitting from the TA	Units of access (1 hour)
	Eligible submissions	Selected		
Period 1 (M1-M18)	2	2	13	1680
Foreseen for project (M1-M48)	4		64	6,000

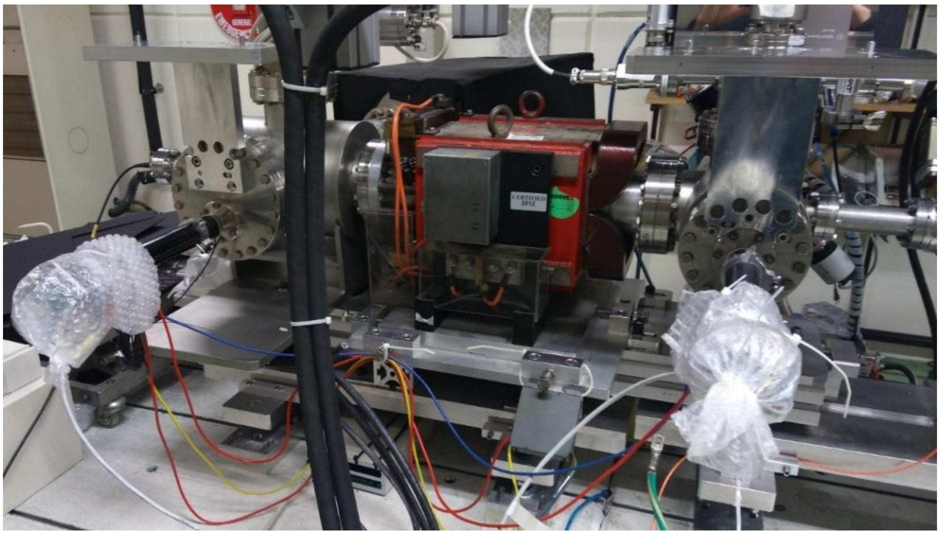


Figure 40: The spectrometer-based high-gradient experiment now underway in Xbox-1

Scientific output of the users at the facility

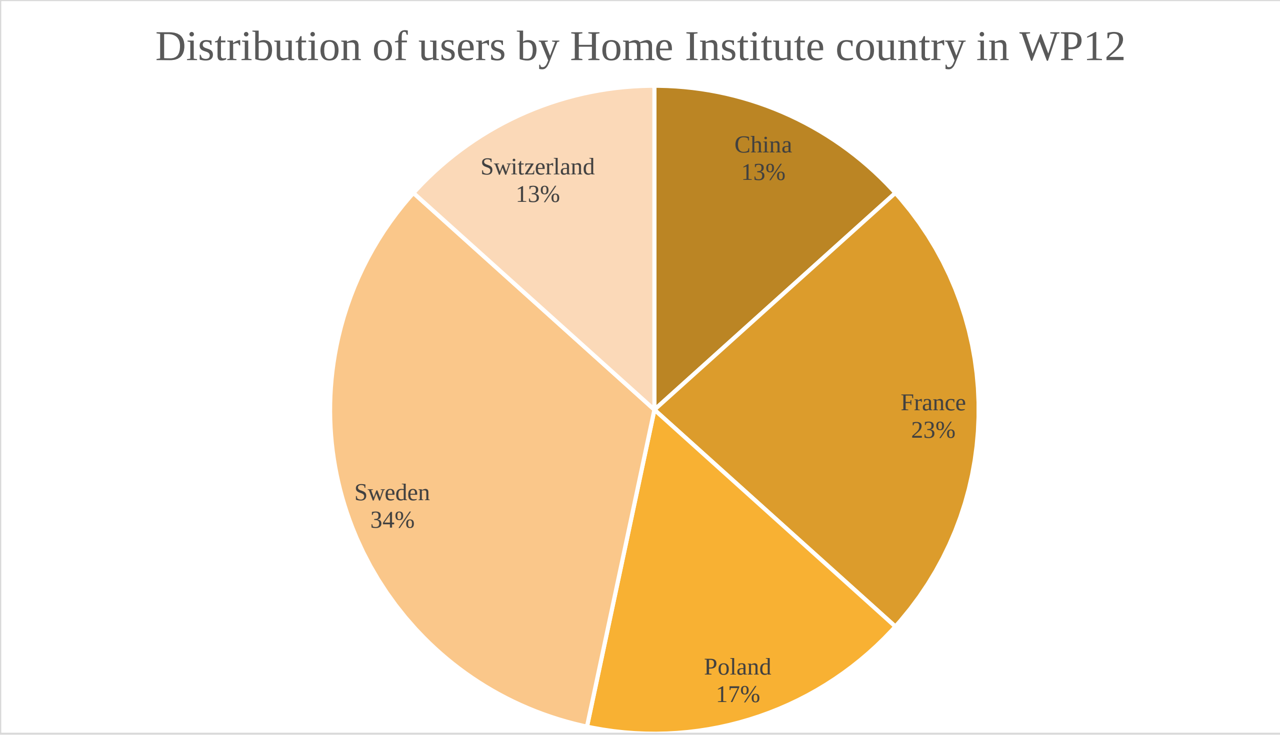
The first User Project has been completed and the final report is under preparation. Data analysis is continuing and it is expected that scientific publications will be written in the coming months.

User meetings

No user meetings occurred in the reporting period. WP12.2 does not hold any dedicated user meetings due to the diversity of the user community, but does take advantage of international meetings as explained in section 1.2.

Distribution of users by home institute country in WP12

The chart below shows the distribution of users at HNOSS and XBox radio frequency testing facilities by the country of the user's home institute.


Distribution of users by Home Institute country in WP12
China
13%
France
23%
Poland
17%
Sweden
34%
Switzerland
13%

WP13: Plasma beam testing (APOLLON, LPA-UHI100, LULAL)

This work package provides Transnational Access to the plasma beam testing facilities: APOLLON, LPA-UHI100 and LULAL. The WP includes 3 tasks:

- Task 13.1. APOLLON
- Task 13.2. LPA-UHI100
- Task 13.3. LULAL

Task 13.1. APOLLON

LULI is the host of APOLLON laser facility and of APOLLON MUST-LPA beamline. APOLLON is a unique new multi-PW facility, based on a Ti-sapphire laser technology.

The dedicated electron beamline, named APOLLON MUST-LPA, will be developed and equipped with state-of-the-art instrumentation to diagnose spatial and spectral beam profiles or measure emittance, pulse duration and charge. ARIES users may test novel electron acceleration concepts to optimize electron bunch parameters for specific applications, test innovative methods to measure its characteristics or to manipulate it, study electron beam – plasma coupling processes (including synchronization and stability), etc.

Description of the publicity concerning the new opportunities for access

APOLLON is a new facility and its electron beam line will for the first time become available in the frame of the ARIES access program. General information, such as general description and pictures, was provided for the communication channels of the ARIES project. The future availability of access was advertised at several conferences e.g. IPAC2017, EAAC2017, and EUPRAXIA meetings. Targeted users are mainly, but not exclusively, advanced accelerator development researchers.

Description of the selection procedure

A User Selection Panel (USP) common to WP13 facilities was constituted. The APOLLON selection procedure follows the steps announced on the ARIES website.

Step1-Informal request: The User Group Leaders contact the facility coordinator before beginning the formal application process in order to discuss the technical aspects and feasibility of the project and the eligibility of the user group.

Step2-Application form: The User Group Leaders download, fill and submit centrally the application form on the ARIES website. Application forms are directed to the relevant TA WP coordinator. The user groups interested in beam tests at one of the WP13 TA facilities must request access by submitting (in writing) to the ARIES WP13 User Selection Panel (USP) a description of the work that they wish to carry out for testing of and the names, nationalities and home institutions of the users.

Step3- Selection procedure: APOLLON proceeds with periodic calls. After submission, proposals are sent to at least one of the external experts of the USP for reviewing, based on scientific merit, impact, feasibility and ability of the users' team to carry out the proposed work. After reception of reviews, selected proposals by the USP are submitted to the APOLLON programme committee. The User Group Leader is contacted by the ARIES TNA Office regarding the outcome of the selection.

The ranking of the proposals from the ARIES User Selection Panel WP13 will be handed over to the APOLLON Local Selection Committee that will allocate the time for each project. To avoid overlaps with the LASERLAB project, the ARIES Transnational Access covers only the electron beam part of the facility; the common Local Committee will check that the requested access is not covered by LASERLAB. Users will have access to the APOLLON MUST-LPA beamline after acceptation of a written proposal by the USP and scheduling by the LULI program committee.

Description of the Transnational Access activity

User projects and experiments

Apollon is getting prepared for commissioning experiments in the fall 2018, starting with electron acceleration experiments. 1st User experiments are foreseen in 2019

APOLLON	**User-projects**		**Total no. of users benefitting from the TA**	**Units of access** (1 hour)
	Eligible submissions	Selected		
Period 1 (M1-M18)	0	0	0	0
Foreseen for project (M1-M48)	6		48	180

Scientific output of the users at the facility

Transnational access activity has not started yet. The complex installation of APOLLON has experienced some delays and commissioning of the laser beam in the experimental area is planned to start only in October 2018, with first tests of electron acceleration scheduled for December. Commissioning of the electron beam with the properties proposed for ARIES access is scheduled for February-March 2019. The official start of the facility for ARIES users is expected in May 2019.

User meetings

No user meetings occurred in the reporting period.

Task 13.2. LPA-UHI100

LPA-UHI100 installation provides ARIES users access to an electron beamline operating around 75 MeV and an experimental area dedicated to laser-driven electron acceleration studies in plasma media.

The radioprotection has been specifically dimensioned for electron acceleration and the survey is insured by radioprotection service from CEA. The LPA-UHI100 is equipped with control and diagnostics of the laser beam crucial to control the electron beam properties such as a deformable mirror linked to a wavefront sensor to optimise the spatial profile of the laser, and a set of different focusing parabola for various range of intensities. Two types of gas target can be provided, a gas jet and a variable length gas cell. A magnetic spectrometer is available for electron spectrum characterization. The LPA-UHI100 is strongly linked to APOLLON laser facility through the Equipex CILEX. Part of the scientific program that will be developed in the long focus area (HE0) is currently in preparation on LPA-UHI100. ARIES users may test new concepts or diagnostics using LPA-UHI100, benefitting from the higher repetition rate and larger number of shots available, before implementing them at APOLLON MUST-LPA operating at higher energy.

The facility is operated by a team of 2 technicians, 2 engineers and 1 local co-investigator in charge of the access in the experimental room. Users receive complete technical and scientific assistance, from the conceptual design of the experiment to its realization. A workshop is accessible during campaigns, as well as administrative assistance if needed.

Description of the publicity concerning the new opportunities for access

The UHI100 facility is well known among laser facility users. It has been delivering laser driven electrons for several years but the electron beam produced by laser wakefield is newly available in the frame of the ARIES access program. Information, such as general description and pictures, was provided for the communication channels of the ARIES project. The access was advertised at several conferences e.g. IPAC2017, EAAC2017, and EUPRAXIA meetings. Targeted users are not only advanced accelerator development researchers but also others scientists interested in using the electron beam, e.g biologists for irradiation of DNA samples.

Description of the selection procedure

The WP13 USP oversees the approval of TA applications at work package level. The composition of the USP and the selection procedure are described in section *Task 13.1 – Description of the selection procedure*.

Description of the Transnational Access activity

User projects and experiments

The project selected at LPA UHI100 in 2017-2018 is linked to the development of positron sources and improved characterisation of the electron beam. This field is of general interest for advanced accelerators development and particularly for the development of positron injectors for future high energy accelerators.

A team from Queen's university Belfast proposed to use the electron beam (up to 200MeV) to generate an electron-positron source from quantum cascade in a high Z- converter. The aim of the experiment was to characterise the emittance of the positron source. The users, assisted by the local team, have put a lot of effort on the positron source generation and optimisation, from conversion of a stabilised electron beam by laser-plasma acceleration in a gas cell. A positron beam has been generated but the charge density was not sufficient to characterise the emittance of the positron source directly. The emittance was indirectly measured from the secondary electron source generated at the same time as the positron one. The source size of the positron beam has also been indirectly characterized by measuring the electron source size via obscuration of the source. Preliminary results are shown in Figure 41.

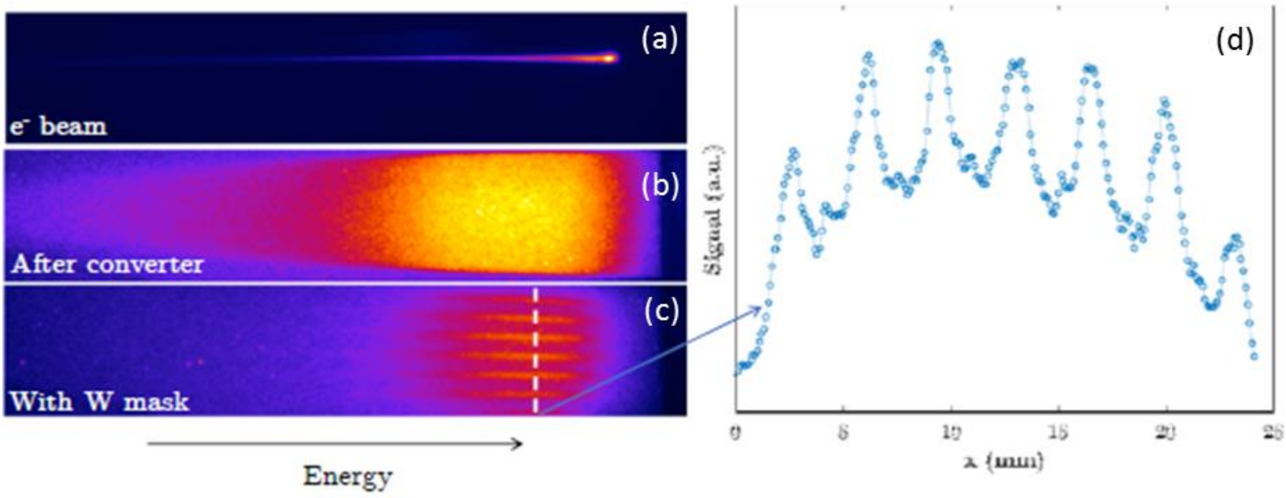


Figure 41: (a) typical electron beam spectrum from Laser-Plasma acceleration in a gas cell at UHI100-LPA, (b) secondary electron beam after the converter, (c) secondary electron beam through the Tunsgten mask, (d) profile through the dashed line from fig.(c)

LPA-UHI100	User-projects		Total no. of users benefitting from the TA	Units of access (1 hour)
	Eligible submissions	Selected		
Period 1 (M1-M18)	1	1	4 + 1 remote	152
Foreseen for project (M1-M48)	4		40	640

Scientific output of the users at the facility

Experimental data are under analysis, and will be correlated to numerical simulations to get access to the emittance characterisation of the positon source. These results should be published this year, the manuscript on the 1st campaign at UHI100 is in preparation. A presentation was given by Aaron Alejo (Generation of positrons using laser-plasma electron beams) at the 1st ARIES annual meeting in RIGA (May 2018).

User meetings

Date	*Meeting*	*Venue*	*Total number of participants*	*Number of users attending the meeting*
11.12.2017	Technical meeting to prepare the experiment	CEA Saclay	4	1 in video conf.
17.10.2018	Technical meeting to discuss next proposal	CEA Saclay and remote	5	3 in video conf

Task 13.3. LULAL

LULAL (Lund University Laser Acceleration Laboratory) is located at the Lund High Power Laser Facility which is a major infrastructure for research using advanced ultra-short and ultra-intense lasers. It is part of the Lund Laser Centre (LLC), which is the largest unit in the Scandinavian countries in the field of lasers. The research at LLC encompasses a wide range of disciplines ranging from medicine to physics. It also includes laser activities at the 3 GeV synchrotron at the MAX IV Laboratory. The LLC is characterised by its interdisciplinary nature, fostering a strong exchange of ideas, techniques and resources. The laboratory houses one of the most intense ultrafast lasers in Europe. The research at LULAL specialises in laser-driven beams of coherent and incoherent x-rays, fast ions and high-energy electrons. In particular, the facility is instrumental for a strong and very successful research programme on laser-based particle acceleration.

Description of the publicity concerning the new opportunities for access

The facility was advertised at the ARIES meetings, at different workshops and conferences, and via the Network WP7 EuroNNAc.

Description of the selection procedure

The WP13 USP oversees the approval of TA applications at work package level. The composition of the USP and the selection procedure are described in section *Task 13.1 – Description of the selection procedure*

Description of the Transnational Access activity

User projects and experiments

A few unexpected problems with the laser have occurred, forcing to change the amplifier and to start negotiations with the company. A first experiment should start before the end of the year, for 180 hours. Two additional experiments are in discussion with groups from Vilnius and STFC. The facility is definitely behind schedule.

LULAL	User-projects		Total no. of users benefitting from the TA	Units of access (1 hour)
	Eligible submissions	Selected		
Period 1 (M1-M18)	1	1	0	0
Foreseen for project (M1-M48)	6		36	480

Scientific output of the users at the facility

Transnational access activity has not started yet.

User meetings

No user meetings occurred in the reporting period.

Distribution of users by home institute country in WP13

Only one experiment took place for WP13 in Period one, with all users coming from UK.

WP14: Promoting Innovation

This JRA includes a number of actions aimed at promoting innovation in the accelerator community. These include a Proof-of-Concept (PoC) scheme that will provide resources and visibility to innovative and promising technologies, the setting-up of an Industry Advisory Board to increase the effectiveness of market-pull initiatives, and the organization of an industrial workshop on ARIES technologies with potential industrial applications. Moreover, this JRA will directly support three co-innovation actions with industry, aimed at the development of higher performance and lower cost high-temperature superconducting cables, of new graphitic materials and coatings, and of a standardized multi-platform timing system. The WP includes 6 tasks:

- Task 14.1. Coordination and communication
- Task 14.2. Proof-of-Concept (PoC) innovation fund
- Task 14.3. Collaboration with industry
- Task 14.4. Industrial production of materials for extreme thermal management
- Task 14.5. High Temperature Superconducting (HTS) innovative process for accelerator magnet conductor
- Task 14.6. Industrialisation of REDNet Accelerator Timing System for Industrial and Medical Applications

Task 14.1. Coordination and communication

Task 14.1 is the usual task of coordination and communication, and activities related are documented by the organization of the general WP Meetings, administrative meeting, task meetings as reported in the table in Appendix. WP14 has also contributed to the organisation of the Accelerator-Industry Co-Innovation Workshop - Tools and strategies to enhance industry-academia cooperation in the particle accelerator community, which took place at Brussels on February 6 and 7. The WP14 Coordinator participated to the Programme Committee, and WP14 advertised the event to the industry community of ARIES, contributing to its success.

As part of the communication task during Period 1 was organized at CERN in May 2018 a workshop on Intellectual Property Rights, in collaboration with H2020 project AMICI (https://indico.cern.ch/event/723985/). The title of the Workshop was "AMICI-ARIES workshop on Intellectual Property in collaborating activities between Research and Technical Infrastructure and Industry". The management of the IP is in general a main ingredient in the Co-Innovation activities (or in all cases joint projects are performed) and from a very general point of view, it is generally accepted that standard common practices and procedures should be agreed. This was the motivation for organizing a mini-workshop on IP with the goal to identify standard procedures from the experience of large labs, get on them the feedback from industry, and possibly converge on possible IP management schemes to be applied to future EC projects. Some general conclusions are available on the web site of the Workshop.

Task 14.2. Proof-of-Concept (PoC) innovation fund

The Proof-of-Concept fund foreseen in the Workplan for Period 1 has been set-up. The PoC fund is used to demonstrate commercial viability of some selected technologies investigated in the frame of ARIES, and to support them by market assessments, evaluations and business plans. The innovation criteria for eligibility, selection and award of PoC fund have been drafted during the summer 2017, then discussed at several Steering Committee meetings and in WP14 context, agreed and eventually approved by the ARIES project management in autumn 2017.

A PoC call for proposal was launched in December 2017 and advertised to all ARIES participants, with call deadline fixed at March 28th, 2018 (the call poster is shown in Figure 42). An independent Evaluation Committee (EvCo), chaired by the WP Coordinator, was appointed by the ARIES Industry

Figure 42: PoC call for proposals poster

Advisory Board (IAB). The EvCo carried out and completed the evaluation of the 9 submitted proposals by May 28th, 2018, preparing a report that was sent to the Steering Committee for review on May 29th, 2018. Following the attribution of the grants to the four projects selected by the EvCo, the Governing Board has approved by electronic vote during summer 2018 the reallocation of funding between ARIES beneficiaries corresponding to the PoC allocations.

The monitoring process for the funded projects has been as well defined during summer 2018, together with the administrative procedure to be followed by the beneficiaries to access the grants. The letters to the four successful bidders containing all instructions on monitoring and administrative procedures were sent by the Project Coordinator on 16 August 2018. They contained a draft Agreement document checked and approved by the CERN Legal Service that had to be sent back to the Coordinator with the appropriate signature to allow the budget transfer to take place. So far, all signed Agreements have been received and the projects have started. The Deliverable D14.1 provides full details of the process that was implemented and of the supporting motivations.

The four selected projects, each funded with 50’000 Euros, and their leading institute (member of ARIES) are:

1. Riga Technical University, “Development of an hybrid electron accelerator system for the treatment of marine diesel exhaust gas.”
2. RHP, “Investigation of new methods for the manufacturing of copper diamond composites with tailored thermo-physical properties”.
3. CEA, “Atomic layer deposition: an innovative approach for next generation particle accelerators”
4. University of Liverpool, “Accelerator Diagnostic using innovative Adaptive Optics”.

The main features of the four projects are presented below.

The project proposed by Riga Technical University, aims to address the problem of the SOx produced by the marine diesel motors. The current technological solutions, e.g. scrubbers, are not able to efficiently and economically address the threshold limitations for the SO_2 and NOx emissions. Stringent regulations are going to be implemented in the next future that will strongly impact the shipping industry. To address this problem, an ARIES partner, the Institute of Nuclear Chemistry and Technology in Warsaw, Poland, has developed and laboratory tested a system based on treatment of the exhaust gases with an electron beam, which coupled to traditional scrubbing could reduce the NOx and SO2 well below the future legal limits (Figure 43). The system can be implemented as a retrofit to existing diesels. The Evaluation Committee of PoC has considered that this idea has a good potential for applying accelerator technology to “real-life” problems for reducing the emission from marine diesel exhaust gases. The PoC shall help a proof-of-principle test on a real marine diesel located on-shore at a shipyard, an economic analysis of the cost and benefits of this technology, and the formation of a Consortium of industrial and academic partners to further develop this idea.

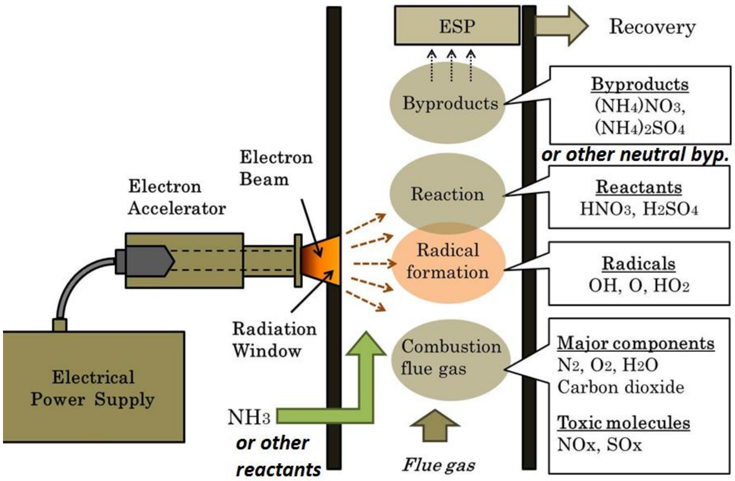


Figure 43: Scheme of the hybrid electron accelerator system for treatment of marine diesel exhaust gases

The project proposed by RHP is a proof of concept of a new processing technology for Metal Diamond materials with high-quality thermal performance. The EvCo has considered promising its application into two areas:
a) applications already identified and which can be handled with todays used manufacturing technology, such as thermal management for electronics, cooling plates/systems for lasers, collimators for the LHC accelerators (if made components are made in several segments).
b) applications which have not been assessed up to now or where up to now Metal Diamonds have not been tested because of issues with the size or shape of the materials, such as components for Fusion, manufacturing of grinding wheels, metal-diamond claddings on components like drill heads for deep drilling, complex geometries or multimaterials which could not be covered by the available processing technologies up to now (e.g. large housings for electric components with local inserts).

The project proposed by CEA addresses the difficulty for future accelerators in meeting the requirements of higher Q-value and maximum electric field with the current SRF technology. The technology is now approaching the material's intrinsic limits (~78% of theoretical maximal limit) of the Niobium superconducting elements. New materials and new nanostructures offer significantly better materials properties than those used in the current generation of devices, strongly needed to boost the performance far beyond what is currently achievable and reduce the operational and production cost of superconducting RF systems, making them more accessible to small scientific and industrial accelerators. It is proposed to study two complementary approaches based on an industry scalable synthesis technic that can be realistically applied to accelerator scale, the focus being on applying already developed Atomic Layer Deposition chemistries to single cell cavities that will be tested at CEA-Saclay and CERN. The PoC funds will enable the proof of concept and optimization of established Atomic Layer Deposition recipes and structures on monocellules for future scale up to multicell cavities. Atomic Layer Deposition, as a surface functionalization technique, has also many other potential applications for particle accelerator in general: low secondary electron yield thin films, charging management on ceramics, diffusion barriers and seed layers, gather coatings inside tubes.

The project proposed by the University of Liverpool, seeks to support the development of advanced optical imaging systems based on Digital Micro-mirror Devices (DMDs), which are directly relevant to the field of charged particle beam diagnostics and have significant potential for commercial exploitation. A DMD is a light processing system that is routinely used commercially in optical products such as video projectors and displays; its potential in the field of optical diagnostics for charged particle beams is yet to be fully realized. The project will initially focus on developing Optical DMD Interferometry (ODI) and Optical Phase-Space Mapping (OPSM), two techniques demonstrated experimentally without a DMD that can be substantially improved by the introduction of a DMD. Alongside these studies, a realistic simulation model of a DMD based optical imaging system will also be developed to enable simulations to be completed with any associated optical system, investigating and developing opportunities to apply DMDs in a range of beam diagnostics scenarios, from large-scale research infrastructures to small medical facilities. The project will produce DMD-based applications expected to have a strong commercial impact, and will provide beyond the state-of-the-art diagnostics to the international accelerator community and the numerous sectors they support, from manufacturing and research through to security and medicine.

Contractual milestones and deliverables

In the P1 reporting period, Task 14.2 had one deliverable to achieve:

- D14.1: Set-up of the Proof-of-Concept innovation funding scheme - ACHIEVED

Task 14.3. Collaboration with industry

The Task 14.3 task links the activity of the industrial partners and ARIES beneficiaries and also provides support actions for PoC management. This is done by the appointing of the Industrial Advisory Board (IAB), which, in turn provides the resources and expertise for the Evaluation and Selection of the projects submitted for Proof-of-Fund.

Scope of the Task 14.3 is also the management of ARIES industry events, and the support with IP management. In this respect, the Task has supported the PC into the organization of an Accelerator-Industry Co-innovation Workshop in Brussels, on 06-07/02/2018, whose scope was to bring together the main actors (EC, academy, industries) involved into the accelerator technology sector innovation developments.

New collaboration opportunities have been appearing: in the investigation for new accelerators (Muon colliders), the necessary new technology development for spallation target has been overlapping contiguous technology fields as Accelerator Driven System, radioisotopes production and HEP. Technical contacts have been taken and new possibility of collaboration (JRC, Karlsruhe) have materialised.

The preparation of the first industrial event, which is among the objectives of the Task 14.3, and which is due by M24, has started after the summer in collaboration with Wigner institute (hosting organization of the event) and STFC.

The collaboration and synergies with WP17 has expanded through the organization by WP14 of a dedicated session during the annual WP17 meeting, in La Valletta. WP14 has organized in that occasion a special discussion on neutron spallation technology. This technology is an essential ingredient of muon colliders, which are promising candidate for the next generation of accelerator machines, but also of Accelerator Driven systems and radioisotopes machines. JRC Karlsruhe and INFN Frascati have joined CERN to have technical discussion and possible investigate possibilities of collaboration.

Contractual milestones and deliverables

In the P1 reporting period, Task 14.3 had one milestone to achieve:

- MS42: Appointing of an Industrial Advisory Board (IAB) - ACHIEVED

Task 14.4. Industrial production of materials for extreme thermal management

The Task 14.4 in WP14 is integrated with the activities going on in WP17 (PowerMat). Target is to explore composite combining properties of graphite or diamond (low ρ, high λ, low α) with those of metal and transition metal-based ceramics (high R_m, good γ). Also, it is foreseen to investigate materials like Silver-diamond (AgCD), Copper-diamond (CuCD), Molybdenum-graphite (MoGr). The samples made of ceramic-graphite and copper-diamond (Figure 44) for applications in particle beam intercepting devices and luminescence screens were all produced and characterized well in advance of the planned schedule, in order to coordinate with WP17 the technical development.

The production objective of one sub-task is the production of a number of samples of MgB_2 by Additive Manufacturing on Cu substrate. The industry partner (RHP, Austria) has defined the development of the process and the road map to arrive till the point of characterize samples for checking the super-conducting properties. Few samples have then been produced after the summer, and delivered to UNIGE for superconducting properties characterization.

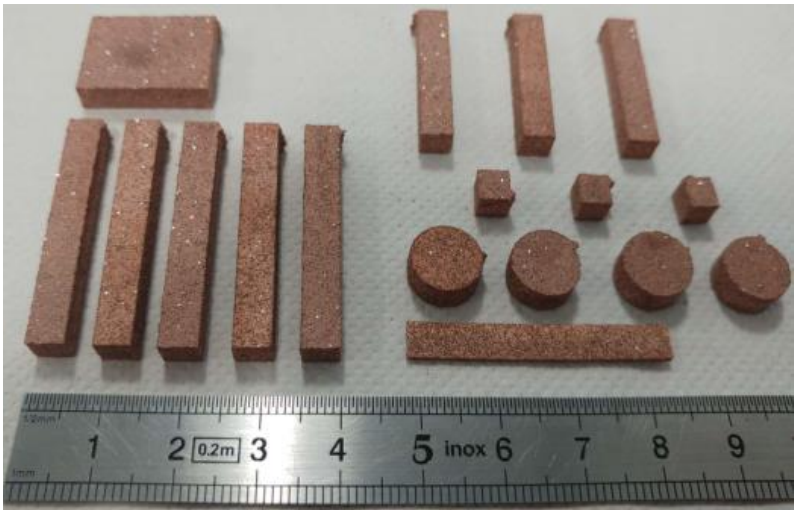


Figure 44: 17 samples of Copper-Diamond produced for thermophysical characterization at CERN

Contractual milestones and deliverables

In the first reporting period, Task 14.4 had no deliverables to achieve but it has completed in advance one deliverable due in M24 (April 2019):

- D14.3: production of material samples of carbon-based composites and metal-diamond composites - ACHIEVED

Task 14.5. High Temperature Superconducting (HTS) innovative process for accelerator magnet conductor

To develop the next generation of accelerators, it is crucial to demonstrate industrial production potentials of superconductor cables with current density capabilities improved by a factor 2, while the overall cost of production is decreased of the same factor.

So far more than 1 km of 12 mm Roebel tape has been produced, with large part of this largely exceeding the target of critical currents. At today, the 1st HTS short length, by original program due in month 14, has already been produced in month 8. The first long length of industrial produced High Temperature Superconductor is just in these days being completed, so much in advance of the original due time in month 30. The system developed for EUcard2 has been reviewed and adapted to manufacture HTS coated conductor depositing REBCO on a 50 μm thick substrate, half the previous thickness of 100 μm. The use of such thin stainless tape is an absolute novelty in the panorama of coated conductor. BHTS has adopted the equipment and the process and has obtained tapes with record current density; a subtle unexpected issue of the bi-directional bending (bi-stable effect) has been solved. In more than one short length values of 900-1200 A/mm2 at 4.2 K , 18-20 T have been obtained, well above the ARIES minimum target value of 800 A/mm2. The goal will be now the production of longer lengths and their characterisation.

Figure 45: A 12 mm tape produced by BHTS using the new method

Contractual milestones and deliverables

In first Reporting Period, Task 14.5 had one milestone to produce on M14, which was achieved on time.

- MS45: First HTS short length produced via new process - ACHIEVED.

Task 14.6. Industrialisation of REDNet Accelerator Timing System for Industrial and Medical Applications

CERN together with Cosylab has designed and implemented a generic accelerator main timing system in the scope of the MedAustron project. This Real Time Event Distribution Network is in use at the facility, successfully irradiating patients today. The objective of Task 14.6 is to investigate with potential actors in the market, the use of the concept and the implementation of an adapted variant of the system for a generic industrial or medical project. According to plan, and in cooperation with an identified interested user, the updated system requirements have been produced in M12 and submitted to the industrial partner.

The submitted document reports the high-level requirements for a generic particle accelerator main timing system (Figure 46) and explains how the requirements can be effectively managed. It describes how the main timing system steers the actions of the individual particle accelerator components at specified points in time so that the sequence of actions results in the production of particle beams, via a sequence of actions specified by the particle accelerator operators. The actions are triggered by the main timing system in real-time during the operation of the particle accelerator.

The specified system aims at being used in a small and medium sized medical, industrial and research particle accelerators (up to several thousands of equipment components that can be geographically distributed up to some kilometres). It is not constrained to a specific hardware- or software platform and is specifically developed to fit any class of particle accelerator.

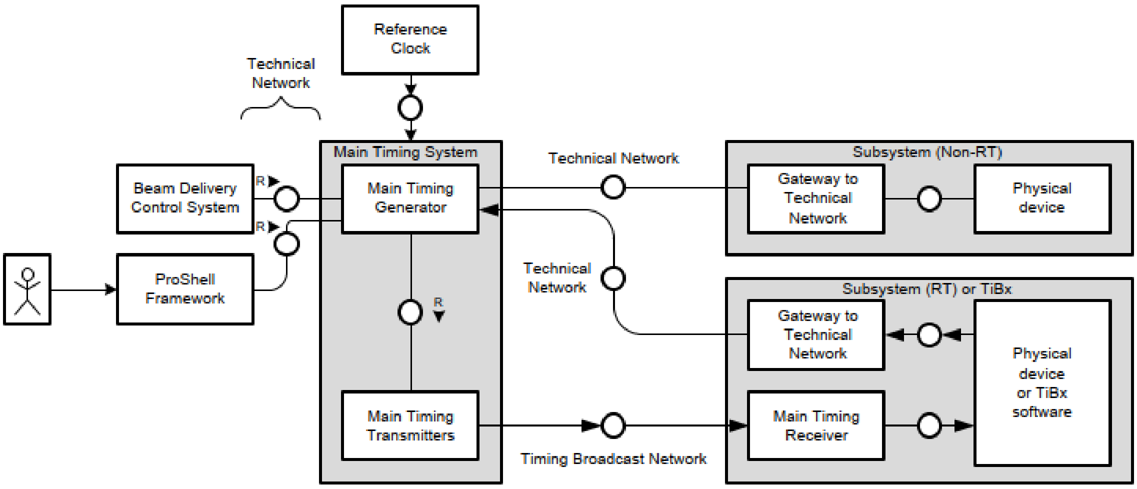


Figure 46: Concept and scope diagram of the accelerator Main Timing System (MTS)

Contractual milestones and deliverables

In the P1 reporting period, Task 14.6 had one milestone to achieve:

- MS47: Reviewed requirements document - ACHIEVED

WP15: Thin Film for Superconducting RF Cavities SRF

This JRA federates a large number of laboratories and universities for a breakthrough in thin film coating technology of superconducting accelerating cavities. Conventional bulk Niobium technology is very close to its theoretical peak performance; this activity will test and improve different coatings (Nb3Sn, NbN on Cu) to achieve quality factor and surface resistance equal or higher than bulk Niobium and 20% increase of RF critical field. The participating teams have an expertise in different fields (thin film deposition, surface analysis, superconductivity, RF, etc.) and joining them together is expected to provide the critical mass for breakthrough achievements. The WP includes 4 tasks:

Task 15.1. Coordination and communication

Task 15.2. Substrate surface preparation

Task 15.3. Thin film deposition and analysis

Task 15.4. Superconductivity evaluation

Task 15.1. Coordination and communication

The WP15 Kick-off meeting was held on 5th May 2017 during the ARIES Kick-off meeting at CERN in Geneva, Switzerland (Milestone MS49). The participants have agreed on principles of collaboration within WP15 and a programme of the work for the 1st year. The main purpose of this meeting was to create a team of working collaboration where every partner is included to reach common goals. A specific attention was paid to include the partners who are new to the TF STF field such as RTU and IEE. It was agreed on who is doing different parts of work, how the sample will be transported, and time schedule. Particularly, the first year was focused on sample substrate preparation and its impact on quality of the Nb film and its superconducting properties. In the period M12-M18 the deposition of two other superconducting materials has started: System 1 (Nb_3Sn) and System 2 (NbN).

Apart from the WP15 Kick-off meeting, six other WP15 meetings were organised within the reporting period. To coordinate the WP15 progress, the Task 15.1 partners have had regular e-mail exchange, phone conversations and meetings at various conferences and workshops.

Contractual milestones and deliverables

In the P1 reporting period, Task 15.1 had one milestone to achieve:

- MS49: Organisation of WP15 kick-off meeting - ACHIEVED

Task 15.2. Substrate surface preparation

The first part of Task 15.2 activity consisted in the cleaning and polishing of 50 planar copper samples with 4 different procedures. During the WP15 kick-off meeting it was decided that all samples for the 1st year program would be produced from the same sheet of OFE copper and 4 different polishing treatments would be investigated. Following this plan, the activity can be resumed as follows:

- 50 samples with a size of 53mm x 53 mm were cut at CERN from the same copper sheet. 25 samples were sent for cleaning and treatment to INFN and 25 samples were left for cleaning and treatment at CERN.
- 25 copper planar samples were treated at CERN with a SUBU (Chemical Polishing of Cu with a solution of Sulphamic Acid and Buthanol) solution. At INFN the other 25 samples were divided

in 4 different batches, one for each treatment investigated: SUBU solution, Electropolishing (EP), SUBU+EP and Tumbling.

- For each treatment batch a surface characterization was done, consisting in a roughness evaluation, Scanning Electron Microscopy scope Microscopy and Energy Dispersive X-Ray Spectroscopy.
- Surface characterizations show that SUBU reduces roughness more than the other treatments, but produces pitting on the surface. On the contrary, EP treated surface does not present pitting, but roughness is influenced by the dynamic of the process. The simple mechanical polishing process reduces the initial surface roughness, but introduces small scratches on the surface.
- The polished samples were packaged in wafer boxes under nitrogen atmosphere and sent to the WP15.3 partners for the Nb thin film deposition.

A set-up was built and commissioned at RTU for laser polishing of the samples. Four untreated samples cut from the same copper plate were sent from CERN to RTU for laser polishing.

Figure 47: An overview of the polishing treatments configuration used: A) Tumbling, B) SUBU, C) Electropolishing

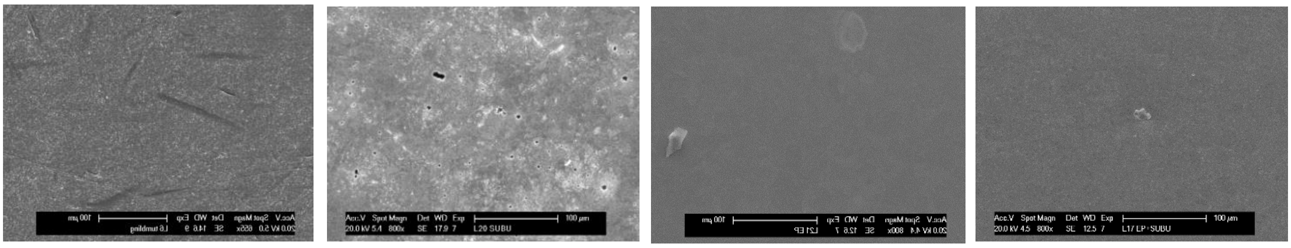


Figure 48: The Surface micrographs of the 4 different treatments A) Tumbling, B) SUBU, C) EP, D) EP+SUBU

After depositing a Niobium film on the samples, subsequent film characterization (Task 15.3), and superconductivity evaluation (Task 15.4), the overall analysis led to conclusion that the preferable surface treatment for the following 3 years of the project are **EP** and **SUBU5** (see Deliverable D15.1). Several tests on copper planar samples and on Nb-Cu electron beam welding samples were done in order to identify the right set-up and procedure for the chemical polishing and Electro Polishing samples for the QPR.

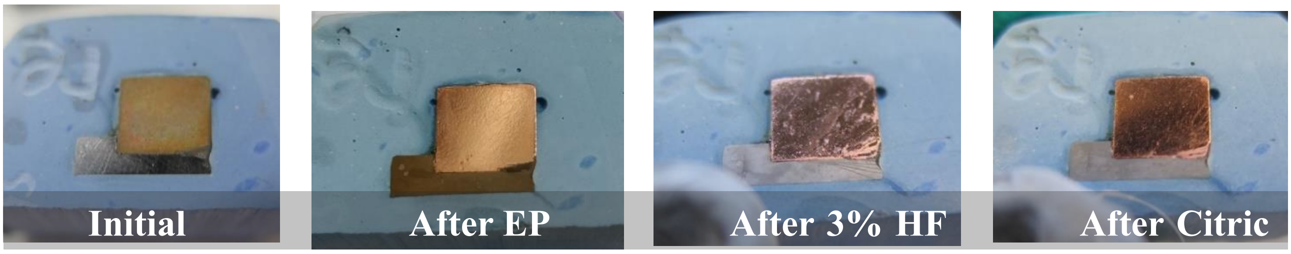


Figure 49 Nb-Cu EB welding sample after EP. The Nb oxide layer, growth during the EP, preserve the Nb from etching.

Contractual milestones and deliverables

In the P1 reporting period, Task 15.2 had one deliverable and one milestone to achieve:

- D15.1: Evaluation and cleaning process - ACHIEVED
- MS50: First sample substrates cleaned at INFN for depositing at partners - ACHIEVED

Task 15.3. Thin film deposition and analysis

The task of deposition was pursued by STFC, INFN and University of Siegen. For the first set of deposition it was decided to use a deposition method that is available at all three centres. Therefore planar DC magnetron was chosen. Although the deposition configuration is different from one centre to another, the deposition parameters were set to be comparable as follows:

At STFC:
- Substrate heated at 650 °C for 12 hours
- Deposition Temperature 650 °C
- DC Magnetron
- Deposition Power: 400W
- Current: 0.97A Voltage: 411V
- Base pressure: <10^{-9} mbar
- Deposition pressure (Kr): 10^{-3} Torr
- Target / Substrate distance = 10 cm
- Substrate rotation at 4 rpm
- Substrate kept at ground potential
- Film thickness: 3 µm

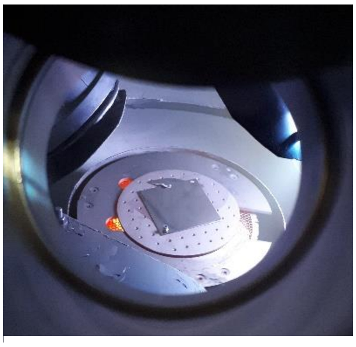


Figure 50: Copper substrate during Nb deposition at STFC

- **At LNL/INFN**:
  - Base Pressure = 8.6 x10^{-8} mbar (at 650 °C)
  - Magnetron Current = 2.1 A (current density 0.027 A/cm^2)
  - Argon Pressure = 5x10^{-3} mbar
  - Sample Temperature = 650 °C
  - Process time = 20 min
  - Thickness = 3 µm
  - Deposition rate = 150 nm/min
  - Distance target-sample = 10 cm
  - Baking time = 60 h
  - Chamber baking Temperature = 250 °C

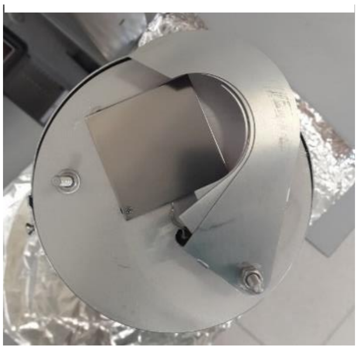


Figure 51: Copper substrate after Nb deposition at LNL

- **At University Siegen**
  - Chamber Baking Temperature = 650 °C

- Baking Time: 1.25 h
- Base Pressure: 1.22x10^{-5} hPa @ 650 °C
- Deposition Temperature: 650 °C
- Argon Pressure: 1.5x10^{-2} hPa
- Target / Substrate distance = 6 cm
- Target Power: 400 W
- Current: 1.34 A, Voltage: 298 V
- Process Time: 20 min
- Film thickness: 3 µm

Figure 52: View into the open coating tool at University Siegen

Each has deposited one sample from each group of substrates prepared by LNL and CERN as described in task 15.2. The delay in film characterisation was due to problems that each centre encountered in setting up and reconfiguration of their deposition systems to have similar conditions so samples from each centre can be compared directly.

In the first six months of the 2nd year the deposition of samples has took place at STFC and at University of Siegen.

At STFC, Nb_3Sn was deposited on both copper and single crystal sapphire as single and double layer of Nb_3Sn/Nb. Only those high temperature above 600 °C resulted in superconducting thin films. Deposition at room temperature resulted in very small grain highly columnar structure which did not show any superconducting property. Post anneal of these film did not make any change either in it superconducting property nor in the film microstructure. Post annealing also resulted a matrix crack to appear on the entire surface.

At Siegen, NbN was deposited on Si and copper. In all cases stoichiometric NbN was not achieved. With the progression from low N_2% to high N2%, the grains go from being very faceted to far more rounded in shape at higher N_2%. The grains can also be seen to decrease in size with increasing N_2%. In the cross section views, the grain growth is seen to be very columnar, with a slight change to smaller columns between 25 to 50%. The film thickness is also found to drastically decrease with increasing N_2%.

Some preliminary tests were performed at RTU on influence of laser radiation on adhesion of Nb/Cu structures. It was preliminary concluded that laser irradiation affects not only the adhesion of coating, but increase the ductility and grain size of the coating. The magnetisation measurements of first samples demonstrate also some improvement of superconducting properties.

Exploration of application of photo- and thermostimulated exoelectron emission for characterising of the Nb film on Cu substrates has also started at RTU. Measurements of first set of 14 samples were completed, the result analysis is ongoing.

Contractual milestones and deliverables

In the P1 reporting period, Task 15.3 had one milestone to achieve:

- MS51: First samples exchanged (system 1 and 2) and deposited at partners- ACHIEVED

Task 15.4. Superconductivity evaluation

Task 15.4 comprises AC/DC and RF testing of samples that were manufactured and characterized in the preceding Tasks 15.2 and 15.3. Since the project has not arrived at this stage, the preparation of the different testing devices at the respective institutes is described below.

At IEE Bratislava a custom-made, high amplitude AC susceptometer insert developed at IEE has been refurbished and adapted for measurements at liquid helium temperatures. Development of a sample holder and of a new experimental set-up for B_{c1} measurements on planar thin film samples has started. Preliminary characterization of trial thin film samples in standard AC susceptometer in the PPMS test station was performed.

At CEA-Saclay the stable operation of the local AC-magnetometer has been pushed up to 130 mT. In order to further increase this value it is planned to incorporate a ferrite for field focusing.

Figure 53: local AC-magnetometer at Saclay

At STFC a radiofrequency (RF) cavity and cryostat dedicated to the measurement of superconducting coatings at 7.8 GHz has been updated to operate with a closed-cycle refrigerator. With emphasis on fast turn-around time for sample measurements the updated facility will allow low power RF surface resistance measurements. Ongoing commissioning is planned to be completed by the end of November 2018.

At CERN an upgraded version of a quadrupole resonator (QPR, device for RF sample testing at different frequencies and arbitrary temperatures) has been fabricated and is planned to be commissioned in mid-2018.

At HZB the identification of systematic errors in the parameter space of the QPR has advanced: It was found that microphonics in the quadrupole rods can lead to mode cross talk and thus significant bias in the calorimetric surface resistance measurement. It was also found that even a small temperature gradient along the sample surface could falsify measurements. It is planned to find ways to either eliminate or mathematically correct these errors.

The sources of systematic errors have been further investigated and additional sources have been identified and partly eliminated: The impact of RF leakage into the coaxial gap has been underestimated all along – in particular at the highest mode of 1.285 GHz. Even tiniest amounts of RF power that propagate to the metallic flange at the bottom of the coax gap will create significant heat and thus an offset in the calorimetric measurement when it interacts with the flange's million times higher normal conducting surface resistance as compared to the BCS resistance of the sample. An Nb coating of the flange is planned to minimize this error.

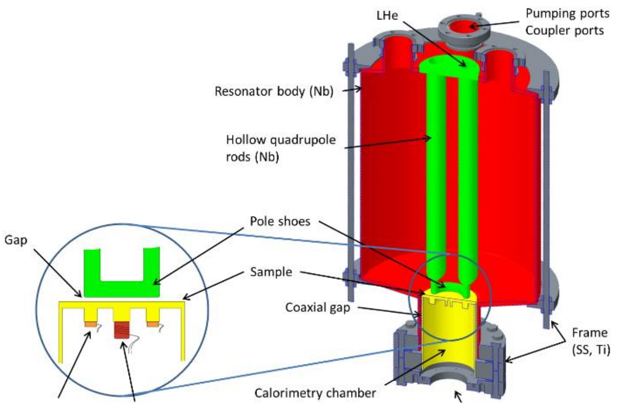


Figure 54: Cross section of calorimetry chamber and quadrupole resonator

At the same time a detachable sample has been tested, and further sources of errors identified.

The manufacture order of 5 full-Nb samples, and 5 composite Nb/Cu samples for the QPR has been placed with the manufacturing company. Significant effort had to be put into developing an EB-welding step of copper to niobium which is required for the composite samples. The welds and their responsiveness to the cleaning procedures used within WP15 have been investigated by INFN Legnaro. A sample weld has been sent to Riga Univ. for Laser treatment.

Contractual milestones and deliverables

In the P1 reporting period, Task 15.4 had one milestone to achieve:

- MS51: First samples exchanged (system 1 and 2) and deposited at partners- ACHIEVED

WP16: Intense, RF modulated E-beams

This JRA will jointly develop the most critical component of an electron-lens system, the RF modulated electron beam generation system. Electron lenses are proposed for space charge compensation in low energy synchrotrons and beam cleaning and compensation of beam-beam effects in high energy colliders. This activity will develop and build a prototype for the required electron beams currents up to 20 A modulated with changing spatial and longitudinal profile at a bandwidth of 2 to 5 MHz, values that are outside of the reach of any presently available technology. The WP includes 4 tasks:

- Task 16.1. Coordination and communication
- Task 16.2. System Integration
- Task 16.3. Electron Gun and Power Modulator
- Task 16.4. Test Stand and Beam Diagnostics

Task 16.1. Coordination and communication

This task covers the internal coordination among the partners contributing to WP16 only. The coordination was ensured by five WP Meetings (see Appendix) and by several bi-lateral meetings and exchanges of information.

Task 16.2. System Integration

Within the scope of Task 16.2 the boundary conditions for the integration of an electron lens for space charge compensation (SCC) into a low energy hadron synchrotron and the development of an RF-modulated electron gun with respect to the hadron beam dynamics have been defined. As a first step towards a technical layout of the electron lens, a numerical model taking into account the geometrical boundaries of the hadron synchrotron has been set up. First beam dynamics studies of the electron beam have been performed in order to estimate the required magnetic field strength and to evaluate the influence of the vacuum tube on the elliptical beam in the main solenoid (Figure 55).

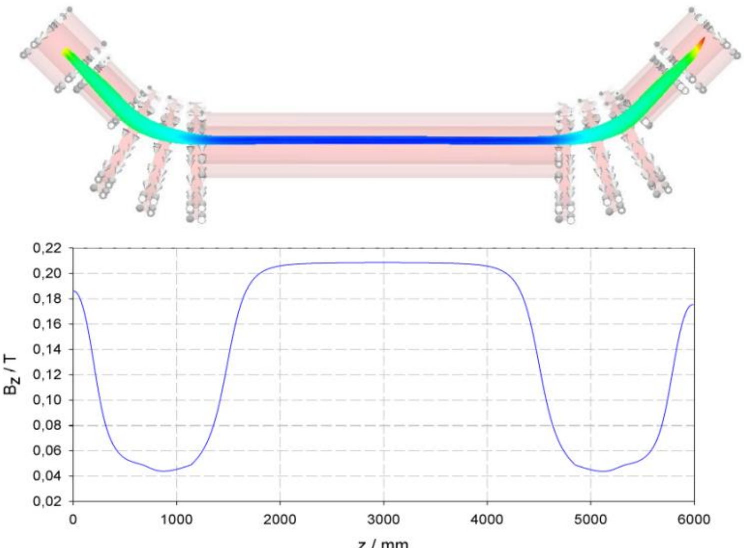


Figure 55: Simulation of electron beam transport in an SCC lens and magnetic field along the lens, serving as a basis for the technical layout of the GSI SCC lens

The results of the numerical model using CST-PS® are currently benchmarked with the codes WARP and BENDER. As a next step towards the layout of the electron lens, the specifications of the main solenoid were defined and a magnet design study on the technical realization was initiated.

The interaction of the hadron beam with the electron beam and the resulting (partial) compensation of the space charge tune shift using the example of the SIS18 at GSI are being studied by the associated partner TUD. Preliminary results indicate that, besides a matched transverse profile, an alternative approach might be pursued using a homogeneous transverse profile. This option will be taken into account in the gun design.

Contractual milestones and deliverables

In Period 1 there were no Milestones or Deliverables.

Task 16.3. Electron Gun and Power Modulator

The conceptual layout of the RF-modulated electron gun and power modulator has been completed and reported in MS53. The design of both components is defined by the requirements on the electron beam for the SCC lens at GSI. These requirements can be summarized as follows: (i) maximum electron beam currents of 10 A; (ii) Gaussian profile (or, in a later stage, homogeneous profile) with elliptical cross section in the x-y plane; and (iii) modulation option to create a prescribed longitudinal current profile matching the hadron bunches.

Regarding gun design, the required maximum currents could easily be achieved for extraction voltages of 16 kV according to Child's law. Yet, the extracted current has to be modulated to follow the longitudinal hadron bunch profile. The modulation shall be realized using a grid. While this choice is mandatory to reduce power dissipation in the modulation circuit, it entails higher electron currents extracted from the cathode to compensate for beam loss on the grid. Consequently, higher extraction voltages are needed. Still, it is possible to reach the required current densities in the order of 3.2 A/cm^2 by standard thermionic dispenser cathodes based on barium oxide. Cathode and grid are designed to have a Gaussian shape to achieve a Gaussian transverse electron beam profile, as required for matching the SIS18 transverse hadron beam profile. Figure 56 shows the simulated transverse beam profile behind the grid. For this design, a grid voltage of 2.5 kV to 3 kV is required to suppress the residual electron current below 5%.

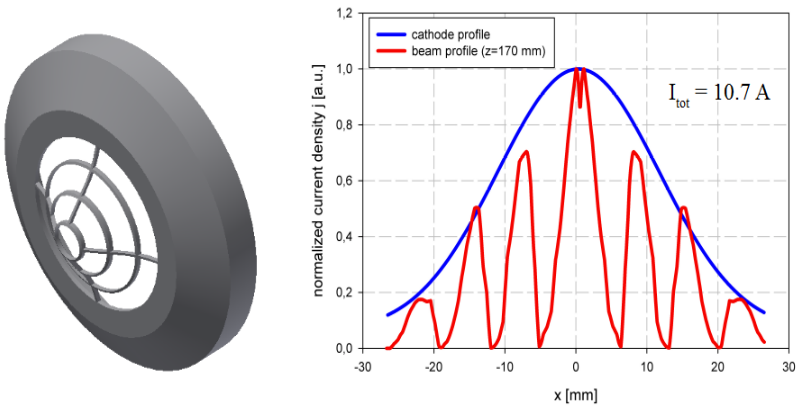


Figure 56: Drawing of final grid design and resulting transverse electron beam profile for U_a=30 kV and B_z=0.4 T

The gun will be positioned in the homogeneous field at the centre of a solenoid. An additional air coil quadrupole will be integrated into the solenoid to create an elliptical cross section of the beam right at the extraction point. The advantage of this solution compared to the production of an elliptical cathode is the flexibility in adjusting the ellipse's aspect ratio.

The major components of the complete electron gun set-up are the round Gaussian shaped cathode and grid, an anode, and a magnet system including solenoid and quadrupole air coils are shown in Figure 57. To confirm the electrical and thermal properties of the gun design, an electron gun dummy is presently being built. It will in particular be used to verify simulations of heat load on the grid due to beam loss. Based on the results, the engineering design of the gun will then be worked out.

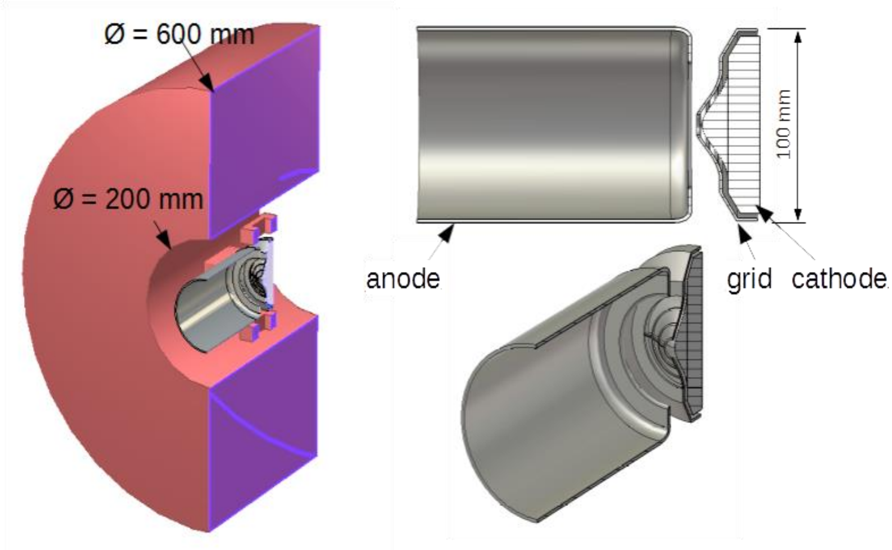


Figure 57: Schematic layout of the electron gun inside the magnet system (left) and cross section of gun (right)

The concept for the modulator is mainly determined by the frequency and bandwidth requirements dictated by the evolution of the longitudinal current profile of the hadron beam during a complete SIS18 cycle. For SCC during injection, bunch creation, and the beginning of acceleration, the electron beam has to follow the hadron beam's changing charge distribution and time structure, which results in a frequency range from 400 kHz to 1 MHz at a bandwidth of about 10 MHz.

The proposed design of the power modulator is based on calculations and two different design stages. In these design stages, prototype modulators were designed, built (see Figure 58), and tested in the proof-of-concept experiment with a small commercial electron gun set up at IAP.

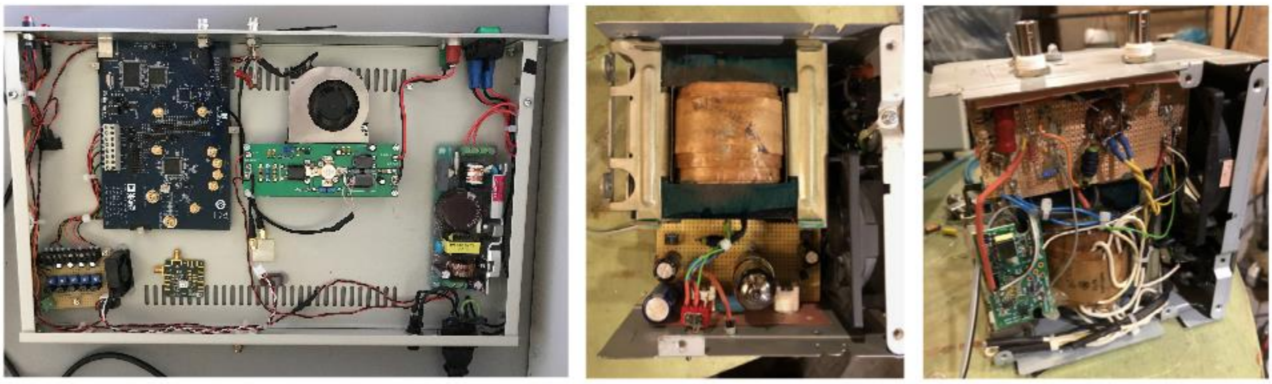


Figure 58: Prototype of first stage modulator (left) and vacuum valve amplifier of second stage modulator (middle, right)

The purpose of the final power modulator is to apply an alternating voltage with a defined signal form for a defined frequency range to the grid of the SCC gun. To a fixed grid voltage of 3 kV for complete electron current depression, the AC signal of the modulator is added with opposite polarity to reduce the DC component. This results in an alternating electron beam current.

The tests on the prototypes of each design stage lead to improvements and finally a full definition of the power modulator. The block diagram of the final modulator layout is presented in Figure 59.

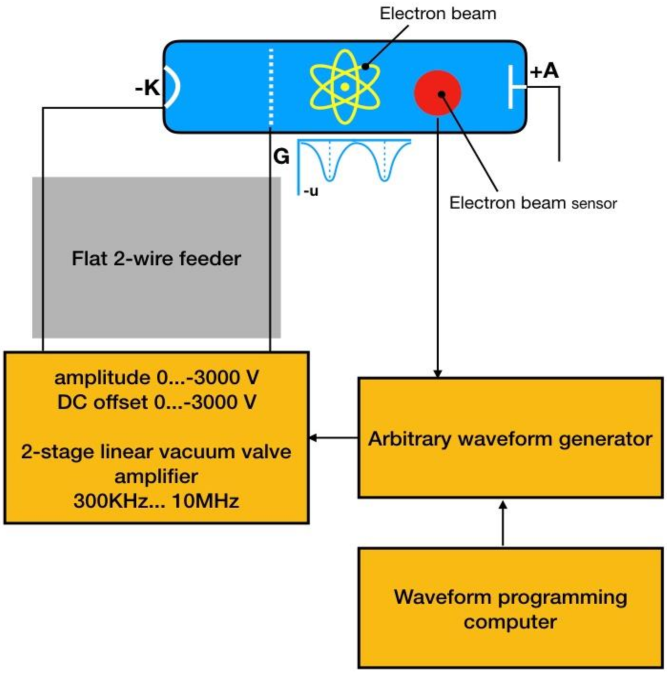


Figure 59: Block diagram of final modulator design

According to the test results, waveform auto tuning could help to assure a stable signal form. This option will be studied in parallel to the development of the final modulator, as it opens the path for using the measured longitudinal profile of the hadron beam to tune the electron current profile.

Contractual milestones and deliverables

In the P1 reporting period, Task 16.3 had one milestone to achieve:

- MS53: Conceptual layout of electron gun and power modulator completed - ACHIEVED

Task 16.4. Test Stand and Beam Diagnostics

Applications of electron beams in electron lenses demand electron beams with appropriate transverse and longitudinal distributions. In particular, compensation of space charge in a hadron beam, as in the GSI SCC lens, requires an electron beam with longitudinal and transverse profiles matching those of the hadron beam. In a similar way, the CERN Hollow Electron Lens (HEL) for enhanced halo diffusion in the frame of the HL-LHC project (see for example S. Redaelli, http://lss.fnal.gov/archive/2015/conf/fermilab-conf-15-135-ad-apc.pdf) requires a hollow transverse electron beam profile fitting the LHC beam. A test stand facility is being set up at CERN to characterize both the SCC and the HEL gun, especially with respect to the dynamics of the intense electron beam and its modulation. Therefore, the requirements for testing the electron guns for both applications are taken into account in the test stand design.

The test stand will be constructed in two stages: The first stage allows characterization of the gun itself by measuring the electron gun current yield versus cathode temperature and anode voltage, and by measuring the current density profile in the transverse planes. It includes two solenoids, one for the gun and one for the collector, one diagnostics box with a pin-hole Faraday cup and a YAG monitor, as well as the necessary data acquisition systems and control software. The layout of the first stage is shown in Figure 60. The second stage will include a drift solenoid in between the gun and collector solenoids (see Figure 61), for studying beam dynamics (deformations in the transverse plane during transport through the drift solenoid, compression due to increasing magnetic fields, and RF modulation to shape the beam in the longitudinal plane), and to benchmark computer models. The second stage will also allow testing of electron beam diagnostics like BPMs or other diagnostics devices that may be required for the final installation of the SCC gun in the hadron accelerator.

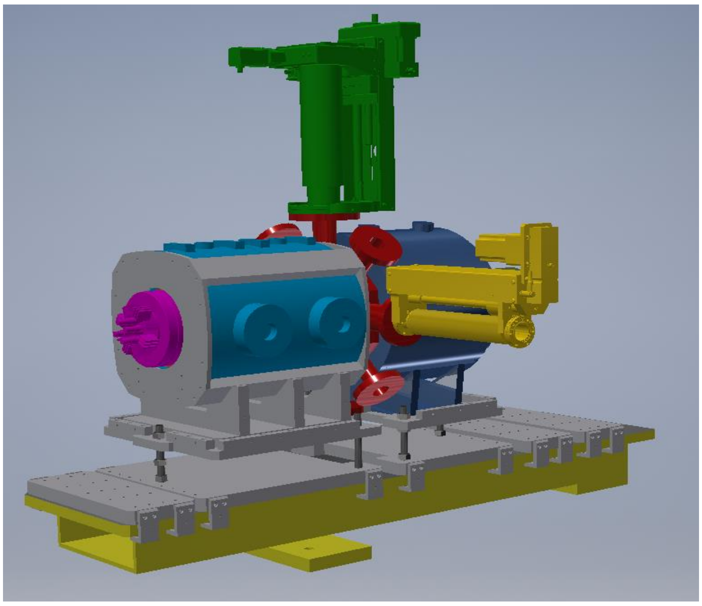


Figure 60: Layout of first stage of electron gun test stand

The dynamics of the electron beam in the test stand has been modeled using CST®. Measurements of the hollow gun and comparisons with simulated results will allow validating and benchmarking computer codes with experimental techniques.

It should be noted that the first stage of the test-stand is almost entirely founded by the HL-LHC project of CERN. Equipment and hardware is being installed and should be commissioned by the end of 2018. It is expected to be running by the first quarter of 2019. ARIES contributes to the second stage.

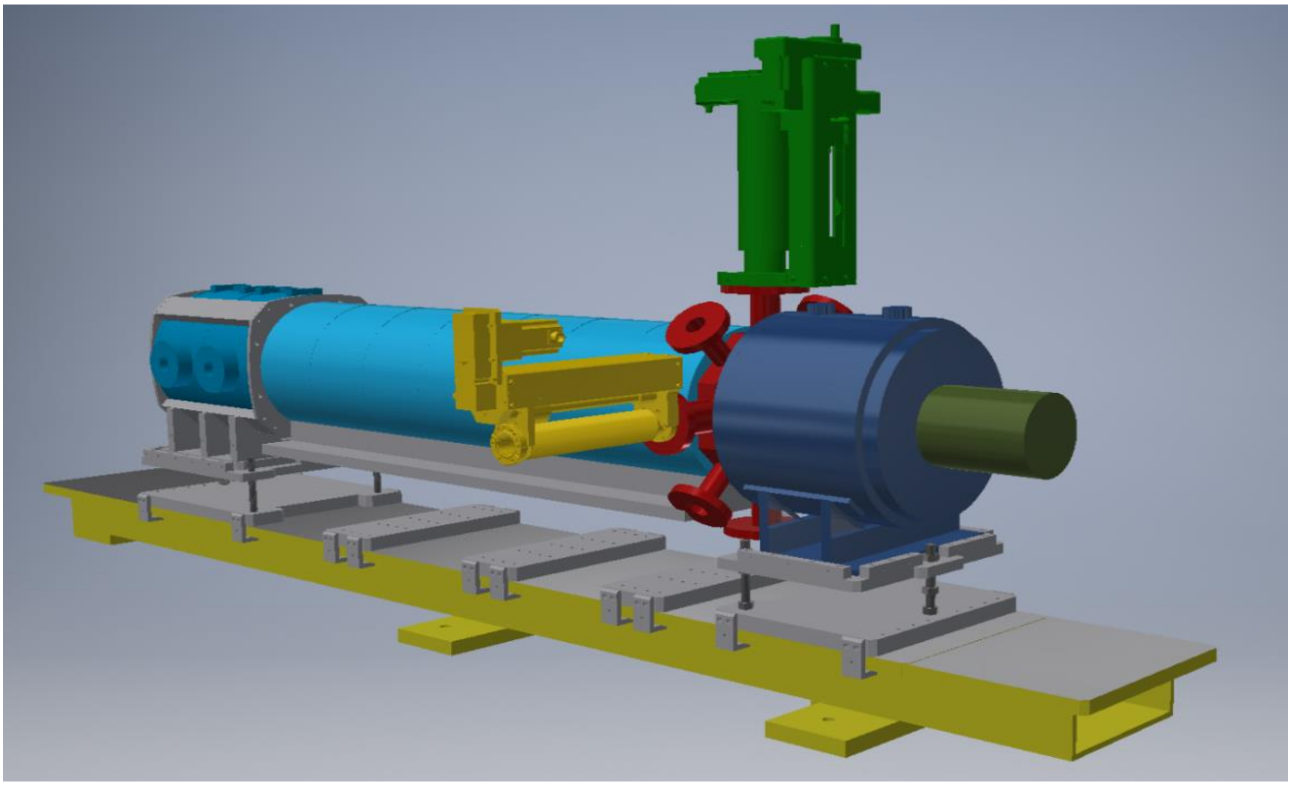


Figure 61: Layout of second stage of electron gun test stand

Contractual milestones and deliverables

In Period 1 there were no Milestones or Deliverables.

WP17: Materials for extreme thermal management (PowerMat)

This JRA will study and develop graphitic materials and electrically conductive coatings, resisting the impact of high intensity particle beams. For the first time, it will use thermomechanical dynamic testing under very high intensity laser pulses and laser-driven particle beams and it will perform thermomechanical modelling of innovative materials in extreme loading conditions. It will analyse applications of the new materials to accelerator devices beyond collimators and to industrial domains such as high-end electronics, avionics, gas turbines, aerospace, advanced braking systems. The WP includes 5 tasks:

- Task 17.1. Coordination and communication
- Task 17.2. Materials development and characterization
- Task 17.3. Dynamic testing and online monitoring
- Task 17.4. Simulation of irradiation effects and mitigation method
- Task 17.5. Broader accelerator and societal application

Task 17.1. Coordination and communication

The kick-off meeting of WP17 took place at CERN in Geneva, Switzerland on the 5th May 2017, following the ARIES kick-off meeting, with 24 attendees representing all beneficiaries.

The first PowerMat workshop was organized in Turin (Italy) on 27th and 28th November 2017, with 30 participants from several Laboratories, Universities, small companies. Each session was dedicated to a specific task of WP17, and to task 4 in WP14 (Promoting Innovation). One of the workshop main goals was the presentation and discussion of results related to the latest developments of novel and advanced materials based on carbon and diamond. An important session was dedicated to dynamic tests of advanced materials, with specific attention to experiments performed at CERN HiRadMat facility, including the recently completed MultiMat experiment, which saw the participation of personnel from GSI, UoM and Brevetti Bizz through ARIES Transnational Access.

The 1st WP17 Annual meeting was hosted by the University of Malta in Valletta, Malta, on 28th and 29th of October 2018. All beneficiaries of the WP17 were represented and the ongoing work on evaluation of results of the two experiments performed at HiRadMat by teams from CERN and GSI was presented. CERN, GSI, POLIMI and POLITO presented updates on characterization of carbon materials and coatings, preparation of the irradiation experiments to be performed in spring 2019 at GSI, status of simulations of the long-term radiation damage in HL-LHC collimators and, in collaboration with WP14, status of the production of new graphite and diamond based composites. ELI-NP presented the status of the high-power laser facility and the development of the interaction chamber for experiments on materials in extreme conditions in Bucharest. External collaborators were invited and presented interesting contributions on molecular dynamics simulations of radiation damage in carbon materials and on high power targets at JRC and for ADS applications.

Contractual milestones and deliverables

In the P1 reporting period, Task 17.1 had one milestone to achieve:

- MS58: Organisation of PowerMat kick-off meeting - ACHIEVED

Task 17.2. Materials development and characterization

The activities started with an extensive characterization campaign of a broad range of advanced materials, based on carbon allotropes, for applications in future particle accelerators. These materials comprise both novel materials, currently under development, as Molybdenum Carbide – Graphite (MoGr) and Copper – Diamond (CuCD), as well as commercially available graphitic materials, also including thin-film coatings. This campaign permitted to identify a number of improvements and optimization steps to be implemented in the production processes, with additional measurements to be performed in the second year.

Microstructures analyses were performed at CERN by scanning electron microscopy (SEM) and X-ray diffraction (XRD), evidencing materials key features and phase structures. Thermophysical and mechanical properties of several MoGr grades (as in Figure 62), CuCD and Thermal Pyrolytic Graphite (TPG) were measured at CERN in preparation for experiments at HiRadMat.

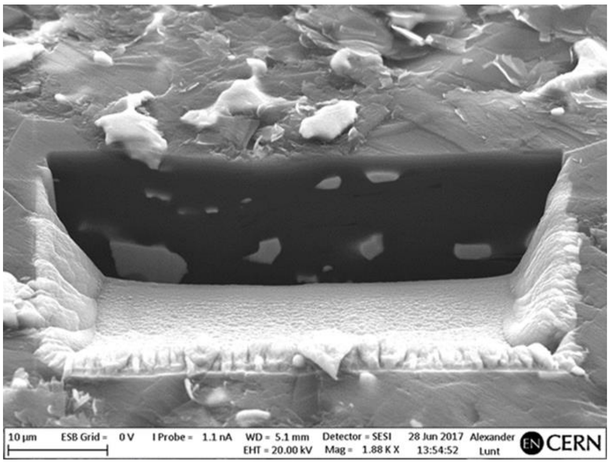


Figure 62: SEM image of MoGr after diamond paste polishing. The pocket and flat surface are obtained by Focused Ion Beam (FIB) in view of additional detailed SEM imaging. CERN

Progress was made in selecting and characterizing the material samples to be irradiated at GSI. In total, 32 coated and uncoated samples were prepared, which will be irradiated with different fluencies in order to assess the evolution of material properties as a function of the induced displacement damage. Two different geometries have been foreseen (Figure 63): 1mm thick samples for thermo-mechanical and microscopic characterization and 0.15 mm thick samples for electrical conductivity.

Figure 63: Sample holders for GSI irradiation campaign and thin sample (0.15mm) for electrical conductivity measurements

The pristine samples were characterised in different ways, including measurements of electrical conductivity, thermal diffusivity, and elastic modulus. This was complemented by a qualitative assessment of the bulk-coating interface using FIB-SEM imaging. In addition, different techniques for assessing the adherence of the thin-film coatings were tested. Thermo-mechanical simulations were carried out in order to estimate the temperatures and stresses in the samples during ion irradiation.

At GSI, investigations, including Raman spectroscopy, laser flash analysis, micro-indentation, impact indentation and three point bending tests were performed on a wide range of commercially available advanced graphitic materials: these included several isotropic graphite grades, 2D and 3D Carbon fibre-reinforced Carbon (CFC) FC, graphitic foams, glassy carbon and TPG. These activities prepared a solid fundament for the FlexMat experiment performed in May-June at CERN HiRadMat facility.

UHV performance was measured at CERN on samples of MoGr and CuCD.

At POLIMI, a methodology was developed to thermomechanically characterize coatings by the combined use of Brillouin Spectroscopy (BS) and Substrate Curvature (SC) techniques. The surface roughness of CFC and MoGr samples coated with molybdenum did not allow to apply this method straightforwardly (Figure 64). A number of countermeasures were identified and should allow to overcome this limitation in future investigations.

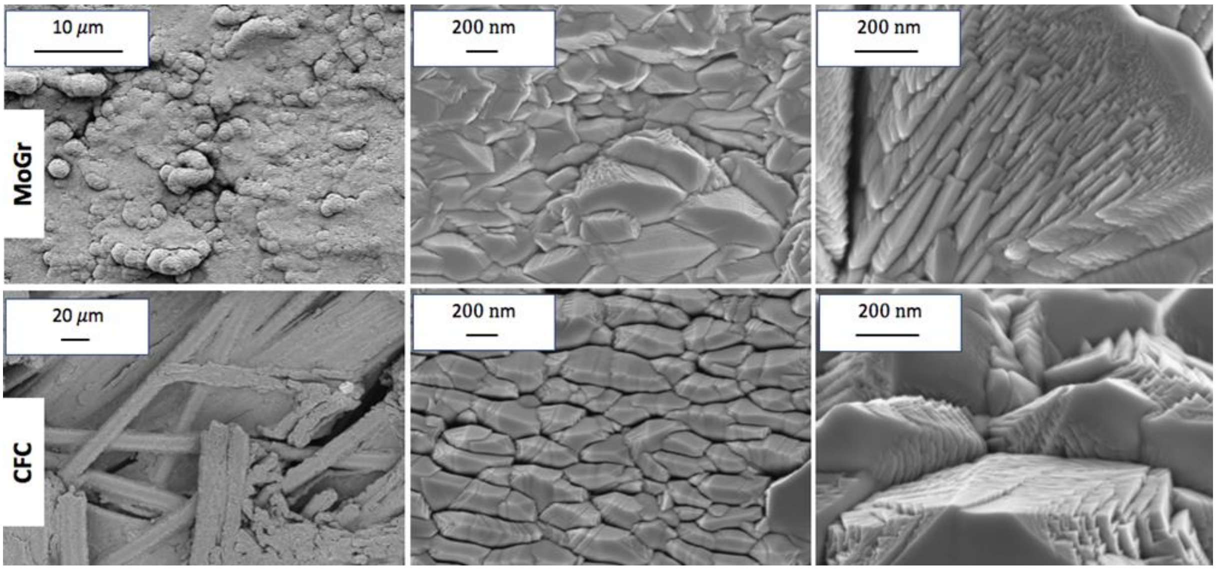


Figure 64: SEM images of Mo coatings on MoGr and CFC substrates from POLIMI

Contractual milestones and deliverables

In the P1 reporting period, Task 17.2 had one deliverable to achieve:

- D17.1: Material characterization - ACHIEVED

Task 17.3. Dynamic testing and online monitoring

The 1st period of the project saw the successful completion of the Multimat and FlexMat experiments at HiRadMat (Figure 65), which took place in the first two weeks of October 2017 and in May-June 2018 respectively. For the MultiMat experiment the reusable, rotatable barrel hosted in the test bench allowed to test samples of 18 different materials and three thin-film coatings under proton pulses extracted from CERN Super Proton Synchrotron (SPS), at energy densities exceeding those expected in the High Luminosity upgrade of the LHC (HL-LHC). The target stations were instrumented with strain gauges, pressure sensors and thermal probes in order to acquire the dynamic response of the materials and benchmark the numerical results of the simulations. The experiment was concluded with more than $2 \cdot 10^{15}$ protons delivered on target: all carbon-based materials survived impacts up to maximum intensities; the online instrumentations worked very reliably, making a wealth of data available for post-processing. For FlexMat experiment a new experimental chamber was designed with a complex system of kinematic mirrors and moving axes for non-contact monitoring of target response by Laser Doppler Vibrometry. This allowed to obtain very high quality data for radial velocities in response to high intensity proton beam impact on a large class of materials for high power targets, beam dumps and beam windows applications. For both experiments, the first analyses indicate a very good agreement with the numerical and analytical predictions.

Figure 65: View of the test-benches of WP 17 HiRadMat experiments: MultiMat -CERN (left); FlexMat- GSI (right)

At POLITO, work progressed to define the size and shape of specimens and loading conditions required to completely describe the mechanical response of relevant materials under the extreme regimes induced by the impact of high-energy particle beams. Priority was given to carbon-based materials: specifically MoGr and 3D CFC. The feasibility of dog-bone specimens with threated ends was checked, obtaining good results for both materials (Figure 66). This allowed investigating mechanical response by using a single geometry. Selected loading conditions permit to reach strain-rates in the range of $10^{-3}÷10^{3}$ s^{-1} from room temperature (RT) up to high temperatures, by using an ad-hoc induction heating system.

The problem posed by material oxidation at high temperature is being addressed by a vacuum/inert chamber which is currently under fabrication. Because of materials brittle behaviour, a detailed study of the gripping system was performed so to avoid fracture during the specimen mounting because of minor misalignments. For the high strain-rate test, a new Hopkinson Bar setup was designed and realized to adapt to low strength materials. Preliminary tests were performed on MoGr samples, previously inspected at CERN by x-ray and 3D Computed Tomography (CT) scans to study the presence and distribution of defects inside the specimens and correlate this to the dynamic test results. Initial tests in quasi-static conditions at RT exhibit a large scatter in results: the correlation between defects and material strength is currently under investigation.

Figure 66: Dedicated holders for tensile tests showing dog-bone material specimens. POLITO

At GSI, all materials investigated within the FlexMat, HiRadMat experiment were also exposed to nanoindentation impact with strain rates in the order of 10^2 s^{-1}. The dynamic behaviour at the grain scale, investigated by nanoindentation will be correlated with the dynamic response at the macroscale in the FlexMat experiment, to understand the role of grain boundaries and interfaces in composite materials in wave damping and dynamical hardness.

Contractual milestones and deliverables

In the P1 reporting period there were no Milestones or Deliverables.

Task 17.4. Simulation of irradiation effects and mitigation method

During the 1st reporting period, different objectives of Task 17.4 were addressed, including the assessment of long-term radiation damage in HL-LHC collimators (both in the bulk absorber material and Mo thin-film coatings) and the selection of beam parameters for irradiation experiments.

Based on particle shower simulations and Beam Loss Monitor measurements from 2015-2018, updated estimates of collimation losses expected in the HL-LHC era were derived, which are essential for determining the cumulative radiation damage until the end of the collimator lifetime. The new scaling suggests that the number of protons lost in the HL-LHC (betatron) collimation system will be more than a factor of ten less than originally expected. The studies also indicate that beam losses at injection energy can yield a non-negligible contribution to the displacement damage in primary collimators. The shower simulations show that, for collimators made of MoGr, a few 10^{-1} Displacements Per Atom (DPA) will be reached in primary collimators, and a few 10^{-4} DPA in the most exposed secondary collimator. The peak DPA in the Mo coating of secondary collimators is estimated to be a few 10^{-3}.

The studies described above provided the basis for establishing the requirements for an irradiation campaign of coated and uncoated MoGr, CfC and Graphite samples, planned for 2019 at GSI and supported by Transnational Access. The irradiation test aims in quantifying the long-term degradation of material properties in the HL-LHC era (electrical conductivity etc.). Among the available GSI beam options, ^{48}Ca or ^{40}Ar ions were found to be some of the most suitable ion species in order to reach similar DPA levels as in the HL-LHC. Radiation damage simulations with FLUKA indicate that a few tens of hours of irradiation time with 4.8 MeV/u ^{48}Ca or ^{40}Ar beams (flux of 5×10^9 ions cm^{-2} s^{-1}) are needed to induce DPA values of a few 10^{-3} in Mo coatings. Although lighter ions like ^{12}C would offer the advantage of penetrating deeper into the bulk of samples (larger irradiated volume), the required irradiation time would be ten times longer in order to reach comparable DPA values and not compatible with the time allotted for the campaign.

Progress was also made in selecting and characterizing the material samples to be irradiated at GSI. In total, 32 coated and uncoated samples were prepared, which will be irradiated with different fluences in order to assess the evolution of material properties as a function of the induced displacement damage. Two different sample geometries have been foreseen: 1mm thick samples for thermo-mechanical and microscopic characterization and 0.15 mm thick samples for electrical conductivity. The pristine samples were characterised in different ways, including measurements of the electrical conductivity, thermal diffusivity, and elastic modulus. This was complemented by a qualitative assessment of the bulk-coating interface using FIB-SEM imaging. In addition, different techniques for assessing the adherence of the thin-film coatings were tested. Thermo-mechanical simulations were carried out in order to estimate the temperatures and stresses in the samples during ion irradiation.

Task 17.5. Broader accelerator and societal applications

One important objective of task 17.5 is to explore societal applications of novel materials in challenging domains such as advanced engineering, medical imaging, quantum computing, energy efficiency, aerospace, and thermal management. In this context, development of diamond-reinforced composites for luminescence screens has started and optimization paths for metallic matrix and diamond doping are being tested. First screens with optimized matrix, diamond size and doping were produced in close collaboration with RHP Technology and WP14. First quantification of luminescemnce signal induced by a 4.8 MeV/u Xe ions and 440 GeV proton beams were performed during experiments at M-branch beamline at GSI and at HiRadMat at CERN.

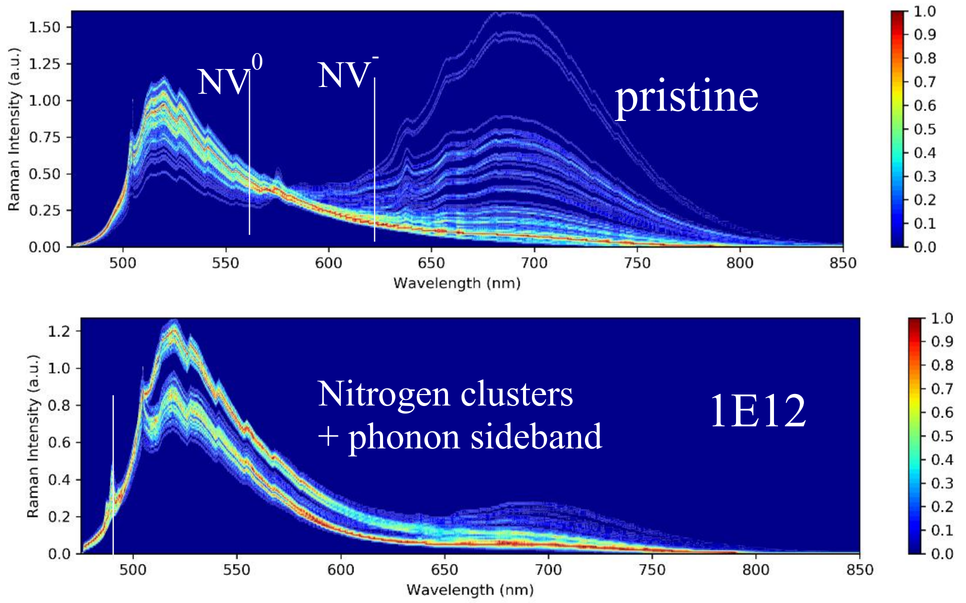


Figure 67: Photoluminescence spectra of copper-diamond composite screens: as pristine material (top) and after irradiation with a fluence of 1 x1012 , 4.8.MeV/u Bi ions/cm2 (bottom)

WP18: Very High Gradient Acceleration Techniques

This JRA federates the leading teams in the field of novel laser-based acceleration techniques, well-known experts in numerical simulation of plasma accelerators, highly competent teams for magnet development, and world-class facilities. The activity will cover four key topics, complementary to other ongoing initiatives and with a huge impact on future Laser Wakefield Accelerators (LWFA): design construction and test of interstage module for multi-stage LWFA, LWFA with exotic laser beams (non-gaussian, twisted, etc.), design construction and test of a dielectric structure for acceleration using ultra-THz lasers, and numerical and experimental studies to extend the charge limit of LWFA. The WP includes 5 tasks:

- Task 18.1. Coordination and communication
- Task 18.2. Enabling multi-stage LWFA
- Task 18.3. LWFA with exotic laser beams
- Task 18.4. Laser driven dielectric accelerator
- Task 18.5. Pushing back the charge frontier

Task 18.1. Coordination and communication

The four technical tasks are managed separately by the task leaders, and do not depend directly on each other. In particular, achievement of milestones and deliverables of one task do not condition those of another task. Proper coordination is done through regular phone and in person meetings of variable frequency, in particular for the preparation of Milestones and Deliverables.

Task 18.2. Enabling multi-stage LWFA

In Laser-Wakefield Accelerators (LWFA) dephasing and beam-depletion make the use of multiple acceleration stages necessary in order to reach multi-GeV electron beams. Besides, on the low energy end, a first injection stage before further acceleration allows to uncouple the injection mechanism from the acceleration and consequently a better tuning of the plasma structures. Such 2-stage acceleration experiment is being considered at the multi-petawatt laser facility CILEX, with transport of electrons from an all-optical injector in the non-linear (blowout) regime to a booster in the linear regime.

A lattice design of the two stage compact, sufficiently achromatic, isochronous, and astigmatic transfer line has been found, for the envisaged CILEX operating point of 200MeV (Figure 68). First start-to-end simulations, i.e. tracking studies of electrons generated in a laser plasma injector with an electron bunch distribution from PIC simulations (SMILEI code) were performed (Figure 69). Preliminary tolerance studies have been initiated and will be pursued. From exploratory two-dimensional modelling of the electromagnets and 3D modelling of the permanent dipoles it appears that all magnets are be feasible. The needs for beam diagnostics are currently evaluated. An adaptation of a slightly higher energy is currently being studied in order to reduce CSR (Coherent Synchrotron Radiation) and accommodate the use of the spectrometer bend magnet currently under design. Depreciation rules for equipment might make justification of the entire magnet cost difficult.

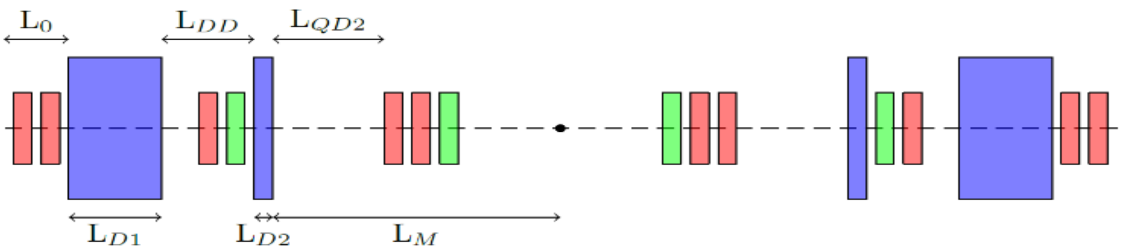


Figure 68: Lattice design of the interstage transport line for 200 MeV. Quadrupoles in red, dipoles in blue and sextupoles in green

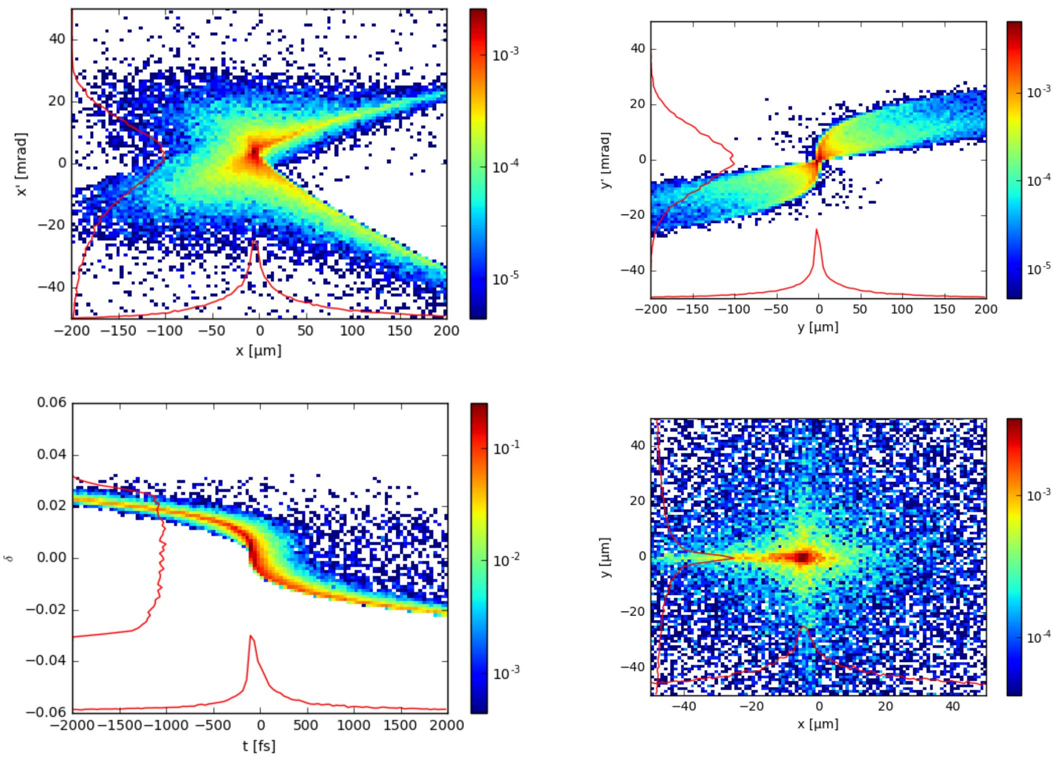


Figure 69: Simulated phase space portrait of a 200MeV electron beam created in a laser plasma injector after passage of the interstage transport line ("start-to-end simulation)

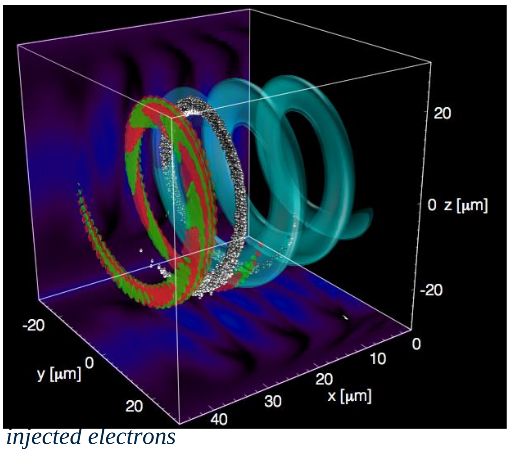
Contractual milestones and deliverables

In the P1 reporting period, Task 18.2 had one deliverable to achieve:

- D18.1: Enabling multi-stage Laser Wakefield Acceleration (LWFA)- ACHIEVED

Task 18.3. LWFA with exotic laser beams

LWFA experiments typically use intense Gaussian laser pulses to drive the plasma waves where acceleration takes place. Recent theoretical work showed that plasma wakefields driven by using non-Gaussian, twisted laser pulses with orbital angular momentum are adequate for high gradient positron acceleration and for the generation of exotic electron bunch. Although very promising, the use of intense lasers with orbital angular momentum for plasma acceleration and related compact betatron radiation sources, remains nearly unexplored from experimental, theoretical and numerical perspectives.



injected electrons

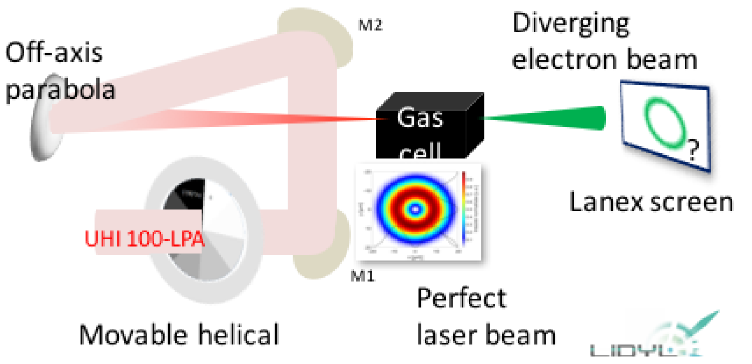


Figure 70: Experimental setup at CEA Saclay to test LWFA with beam with OAM

This task employs the full PIC code OSIRIS to explore plasma acceleration driven by exotic laser pulses with orbital angular momentum. In addition of having the code running in local computer clusters at Instituto Superior Técnico we have successfully installed OSIRIS in the TIER-0 computer cluster SuperMUC at the Leibniz research centre in Munich, Germany. We have already successfully tested and used OSIRIS in these computing sites and demonstrated that it can now be used to perform plasma acceleration simulations. We have also ensured that laser injection algorithms into the simulation can adequately model exotic lasers, which is critical for the completion of this task. Plasma acceleration simulations driven by twisted light with orbital angular momentum and explore its evolution in the plasma have been performed (Figure 71). In parallel, an experimental setup has been devised at CEA Saclay using a helical phase plate to create a laser beam with OAM (Figure 70).

We discovered a new acceleration regime in which a higher order Laguerre-Gaussian laser pulse can drive a twisted plasma wave containing orbital angular momentum, using theory and simulations. The unprecedented dynamics of the accelerated particles leads to the generation of vortex electrons that have quantized angular momentum levels. These beams could lead to novel radiation sources and probe new magnetic properties of matter using electrons that are not accessible to conventional Gaussian electron beams.

In 2017, we have identified an optical scheme that can generate laser intensity peaks with controllable and adjustable velocity in vacuum (Optica 4, Issue 10, pp. 1298-1304 (2017)). This is achieved by inducing a combination of longitudinal chromatism and temporal chirp on the laser beam. Such exotic laser beams could provide very useful for laser-driven particle acceleration, for instance by facilitating the injection of charges in the accelerating plasma structure thanks to gradually-accelerating laser pulses, or by providing a way to mitigate dephasing of charges in this accelerating structure. We have designed the optical elements required to generate such beams, and tested these elements by using new spatio-temporal measurement techniques. An experiment is ongoing on the UHI100 laser at CEA Saclay to get direct experimental evidence of the control of the laser intensity peak velocity in vacuum through this scheme.

Numerical studies of laser wakefield electron acceleration with such beams are in preparation. We have already included these lasers in the OSIRIS simulations and explored their evolution in vacuum, confirming that there is a large flexibility to control the velocity of the peak of the intensity of these beams. The new simulation tool is fully operational in 2D geometries and is ready to explore the self-consistent evolution of these beams in the plasma for the first time.

Contractual milestones and deliverables

In the P1 reporting period, Task 18.3 had two milestones to achieve:

- MS63: Setup simulation framework for acceleration and radiation generation in wakefields driven by lasers with orbital angular momentum - ACHIEVED
- MS64: Setup of experimental facilities for laser wakefield acceleration experiments using laser drivers with orbital angular momentum - ACHIEVED

Task 18.4. Laser driven dielectric accelerator

At DESY, work is ongoing to prepare for first dielectric laser acceleration (DLA) experiments at the ARES linear accelerator (Figure 72). The past quarter has predominantly focused on the infrastructure layout as well as finalizing the choice of laser to drive the accelerating fields in our DLAs. Specifically, we will now acquire a Holmium YLF laser with 2 mJ /pulse, 5 kHz repetition rate, and pulse length of ~2 ps. The laser will initially be located in the ARES photocathode laser lab to reduce integration times for e.g. synchronization and transport.

In parallel, several other preparatory steps are underway, including the development of an experimental chamber to house first DLA experiments, the development of diagnostics to measure sub-micron beams, and simulations to optimize the ARES lattice to achieve appropriately-sized beams for these structures. We have also began developing a damage threshold test stand to test bulk material and future DLA structures.

Finally, the design of first grating-based DLAs has been realized and have confirmed collaborations with European and American groups so secure the delivery of both Silicon and Quartz structures. We have also began investigating photonic-bandgap fiber DLAs which have significant advantages from beam dynamics perspectives. We have reached out to Philip Russel (the father of photonic bandgap fibers) to begin a collaborative effort; he will visit in February 2019.

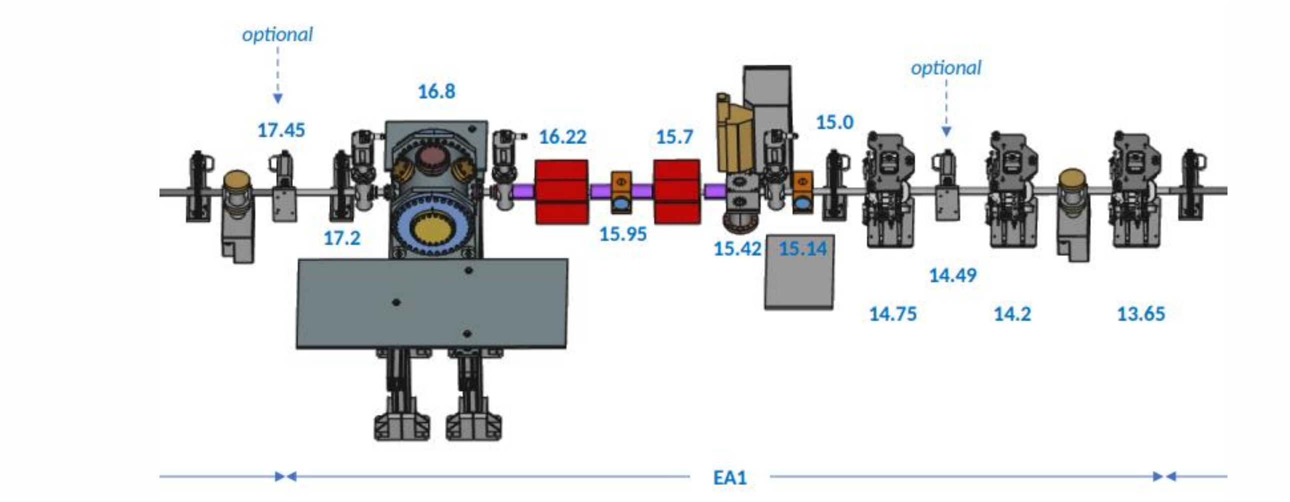


Figure 72: A schematic of the ARES linac for first DLA experiments is illustrated. The electron beam passes through a focusing triplet (right-to-left) and is focused in the experimental chamber located at 16.8 m downstream of the photocathode

Contractual milestones and deliverables

In the P1 reporting period, Task 18.4 had no Milestones or Deliverables.

Task 18.5. Pushing back the charge frontier

The beam charge in laser-plasma accelerators is about three orders of magnitude lower than in conventional accelerators, and this low charge is a major bottleneck of laser-plasma accelerators, which hinders the development of many applications. It questions in particular the pertinence of using laser-plasma accelerators for high energy physics. This task aims at improving the spectral intensity of the electron bunch, i.e. the charge per unit of momentum and solid angle.

A variety of strategies are explored. Experimental and simulation efforts have first focused on the compensation of the energy chirp in the bunch through a tailored density downramp transition in the plasma. A doubling of the spectral intensity has been demonstrated at LOA (France) [Phys. Rev. Lett. **121**, 074802], and sets also the record for this figure of merit at this installation.

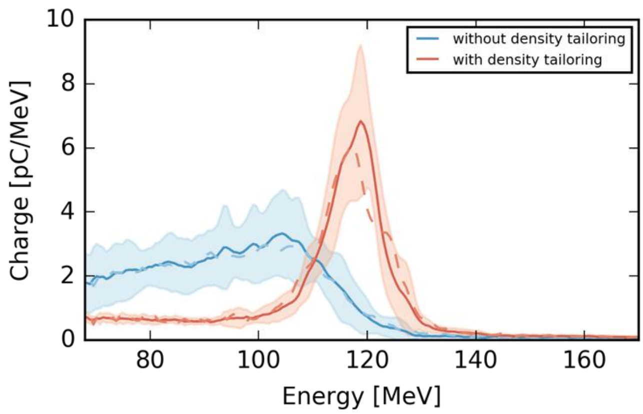


Figure 74: Gain in spectral intensity of LWFA accelerated electron bunches by energy-chirp compensation in a density downramp

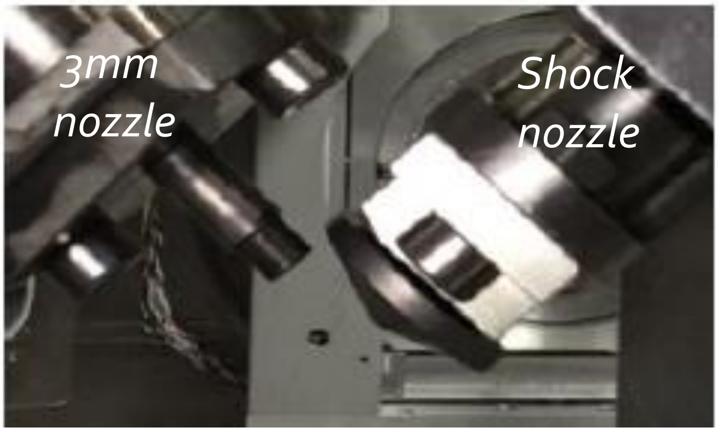


Figure 73: Two nozzle experiment at CEA Saclay UHI100 Laser

A second strategy is to optimize the injection process. Simulations have shown that the height of the density step is the most influential parameter in density transition injection [Plasma Phys. Control. Fusion 60, 034005 (2018)], future experimental activities will focus on increasing this plasma density contrast. In seminal experiments at CEA Saclay with two nozzles producing strongly different plasma densities yield promising results at low energies (33 MeV) which may lead to high spectral intensities of electron bunches at 300 MeV. The setup was recently optimized in simulations and the new setup will be tried out in the near future.

Contractual milestones and deliverables

In the P1 reporting period, Task 18.5 had no Milestones or Deliverables

1.5 Impact

Progress beyond the state of the art and expected potential impact (including the socio-economic impact and the wider societal implications of the project so far)

The main impact factors identifies in Annex 1 are here reported and commented. They all remain relevant, with impact in some fields being reinforced and extended.

Wider access to research infrastructures

For the first time, ARIES offers an enlarged and multi-purpose access to 14 European accelerator test infrastructures. Although some of the most advanced facilities are still in construction and others have experienced technical problems, 5,714 units were already provided to 129 users from 20 different projects, proving the validity of the principle and its capacity to attract new users.

Synergies and complementarities between accelerator facilities in Europe

The intense integration action carried on by the Networks via the organisation of several Workshops and events has already brought results as the identification of alternative high-energy projects that are based on the know-how and experience of different laboratories, the definition of common strategies for the upgrade of synchrotron light facilities, and the identification of common instrumentation needs and tools. The JRA's have fully exploited and enhanced the complementarities between laboratories, in particular for the common development of new superconducting coatings and of new materials.

Fostering of innovation in Research Infrastructures and development of high-risk high-gain technologies

Several ARIES programmes have a strong innovation content, in particular in the fields of high-temperature superconductors, new materials, superconducting coatings, and plasma wakefield acceleration. Breakthroughs in these technologies might have a strong impact on the European accelerator infrastructure, in particular in terms of size and cost of future infrastructures. Furthermore, during this initial period new innovative accelerator designs have been promoted and supported by ARIES, as the muon collider design which might constitute an alternative to larger scale lepton colliders.

Co-innovation with European industry

Strategies to improve co-innovation were discussed at a special Workshop in February, which has attracted a wide industry participation. Future join programmes are under discussion and in active preparation, as is the case of the new system for ship exhaust treatment. The Proof-of-Concept fund of ARIES was a success, with four innovative projects selected out of the 9 submitted.

Training of new generation of scientists and engineers

ARIES is in line with its training objectives: the Massive Online Open Course on Accelerator Technology in the advanced preparation phase, the Workshops organised by the ARIES Networks attract a wide participation from PhD students and young post-docs, and the Networks have completed their recruitment of students and post-docs to perform the perspective studies foreseen in the Workplan.

Knowledge sharing across fields and between academia and industry

The Workshop organised by the Networks are highly multidisciplinary, with the goal of attracting different communities. An example is the recent WP6 Workshop aimed at joining the accelerator performance experts with the teams studying how to improve accelerator availability.

Sustainability of accelerator R&D

ARIES is in line with its sustainability objectives, having started together with other committees and projects (TIARA, AMICI, FuSuMaTech, etc.) and with industry a reflection on the future strategy for ensuring sustainable collaborative R&D in accelerator S&T in Europe in the medium-to-long term after the end of the ARIES project.

Other substantial impacts

Joint programming in accelerator science and technology and leveraging of national funding: some of the ARIES Networks were essential in preparing recent successful proposals at the national level.

Strengthening competitiveness and growth of European companies: some of the ARIES innovations (e.g. marine diesel exhaust cleaning, radioisotope production in hospitals) might have a strong economic impact and are being developed with companies that are engaged from the initial phase.

Other additional impacts as highlighted by some of the Workpackages

WP3: Industrial and Societal Applications

WP3 has the potential to have a larger than expected industrial and societal impact thanks to some promising technologies identified and promoted by Network.

The global marine production of SO_2 and NO_x are due to exceed the land production by 2020 and the only current potential solution able to deal with both of these, plus other organic contaminants, is the use of electron beams. The project to study this process and a novel accelerator solution is making good progress and tests are planned with a marine diesel engine soon. The other environmental application being developed is a “zero energy” plant for municipal waste sludge treatment with an electron accelerator, which provides electricity to supply the accelerator and produces safe organic fertilizer.

The use of intense X-ray microbeams for cancer radiotherapy (MRT) shows great potential and is one the few areas that could bring a step-change in cancer therapy. Currently, however, these beams can only be produced using large synchrotron light sources, making the treatment impractical. The WP is presently studying production with a compact 140 MeV linear accelerator, making possible its introduce into hospitals.

Radioisotopes for medical imaging and some therapy have a lot of potential that is currently not being exploited because of the cumbersome production technology. The WP is studying a number of new technologies that could bring substantial improvements from compact accelerators that could be used in hospitals to produce shorter half-life PET isotopes, such as ^{11}C.

WP5: European Network for Novel Accelerators (EuroNNAC)

The WP5/EuroNNAc continues its impact by supporting scientific exchange in the field of novel accelerators, by fostering common projects and strategies, by stimulating peer-reviewed open publication processes and by supporting the education and training of the next generation of highly trained scientists.

WP6: Accelerator Performance and Concepts

The work carried out by WP6 and, especially, the results of the 14 workshops organized in the reporting year confirm the impact anticipated in the Annex 1, namely that WP6 will produce and explore novel concepts to improve performance of all accelerators, including those for basic research, for applied research, and for medical and industrial applications. WP6 is developing design and operational strategies to improve availability of accelerators, impacting all types of accelerators. The time scale expected for reaching the objectives declared in Annex 1 appears reasonable, based on the "natural" progress in the community and on the liveliness of the NA events. For the topics of space charge and optics control, the WP is likely to make a considerable impact on the US R&D program IOTA, which is constructed, specifically, for overcoming accelerator performance limitations at the intensity frontier.

WP7: Rings with Ultra-Low Emittance

The WP7 is a network activity tasked with fostering the exchange of ideas and staff working in the accelerator community on the development of ultra-low emittance rings. In this sense the successful organisation of well attended workshop is a measure of the impact of the WP7 activity. In line with the impact expected, these workshops provide a framework and support to achieve stable ultra-low emittances in high-intensity electron-positron rings via common design work, measurements and tests. The workshops have focussed the discussion on the development of lattice design and critical components like injection kickers, and diagnostics. Further key systems will be the object of upcoming topical workshops on pulsed kickers, high gradient magnets, improved vacuum design and beam optimisation, to ensure emittances in the 100-200 ps range, in line with the ambitions established for WP7 on the ARIES project.

WP8: Advanced Diagnostics at Accelerators

The Topical Workshops organised to date have had a high impact on the development of the beam instrumentation under discussion, as well as for the use of such instrumentation for accelerator optimization and operation. The relevance of such workshops can be measured through the interest shown for each event (30 – 40 participants) and their attraction to a worldwide audience. Further common developments, such as the simulation code for the IPM development, were initiated during these workshops, with new members joining such collaborative efforts. The ongoing exchange of personnel is not only of direct benefit to the person concerned, but helps to strengthen the collaboration between the participating institutions, greatly facilitating efforts, and thus the efficiency, for R&D in this field.

WP10: Material Testing (HiRadMat & UNILAC):

During the 18 months of the ARIES framework, WP10.1 (HiRadMat) has continued to benefit from TA funding enabling the ongoing function and upgrade of the facility. A key goal was to provide its irradiation facility and services to both internal (CERN) users and external institutes. Of the TA experiments undertaken, all utilised the wider facilities offered through HiRadMat and its collaborations, i.e. experimental design, metrology/survey, installation, beam profile analysis and DAQ support. Throughout 2017 and 2018, HiRadMat welcomed an increase of experimental users from external institutes from the area of physical sciences, including accelerator physics, condensed matter physics, materials science and engineering technology. TA support was provided to 50% of the users in 2017 and 40% of the users in 2018 highlighting a good proportionality of usage of the HiRadMat facilities by external institutes. Similarly, approximately 40% of protons delivered to the experiments during P1 were provided to TA projects. The increased workload from P1 has emphasised the exploitation of HiRadMat by different institutes with different design goals and requirements, as described in

WP14: Promoting Innovation

The Proof-of-Concept fund is promoting four innovative projects that will facilitate the development of products that may hit the market in different ways: reduction of environmental pollution, new materials, compact accelerators, and improved diagnostics. A world record of critical current on a HTS cable has been reached, while at the same time the cost of production have been reduced. Critical technologies were transferred to industry in the sector of software for accelerators: a timing system developed originally for the CERN accelerators is now made available for exploitation of the European medical machines.

WP15: Thin Film for Superconducting RF Cavities SRF

The WP15 research on thin films is progressing well towards facilitating the development of RF cavities with higher acceleration field and higher Q-factor, both intended to allow reducing the construction, infrastructure and operation cost of particle accelerators.

WP17: Materials for extreme thermal management

Applications of materials developed in the WP are expected to bring benefits to domains as optical monitoring, medical imaging and quantum computing, particularly through the exploitation of the properties nitrogen-vacancy centres in diamond induced by particle irradiation. A young generation of Bachelor, Master and Ph.D. students profit from the training opportunities at different beneficiaries sites and develop knowledge and skills related to material design and characterization which will be very useful for future careers in industry. The development and use of high thermal performance materials, with low mass density and excellent resistance to thermal shock, has become an enabling technology in a broad range of industrial and research applications extending the potential impact of WP activities.

2. Dissemination and exploitation of results

Scientific publications

N°	Author(s), *Title*, References, Date, Link
WP2	
1	Delerue et Al., A Massive Open Online Course on Particle Accelerators, IPAC'18 MOPML050
WP3	
1	Z. Zimek, Pre-feasibility Study of setting-up an Electron Beam R&D Facility, INCT Report B, 1/18, Warsaw, 2018
2	M. Siwek, A. G. Chmielewski , Process engineering aspects of diesel engine off gases treatment, INCT Report B, 2/18, Warsaw, 2018
WP5	
1	R. Assmann et al. Status and objectives of the dedicated accelerator R&D facility ¨SINBAD" at DESY,
2	R. Assmann et al. An Adiabatic Phase-Matching Accelerator
WP6	
1	G. Guillermo, M. Ady, R. Kersevan, F. Zimmermann, D.C. Sagan, R. Cimino, E. La Francesca, *Comparing Behaviour of Simulated Proton Synchrotron Radiation in the Arcs of the LHC with Measurements*, Proc. IPAC'17 Copenhagen
2	K. Ohmi, N. Kuroo, K. Oide, D. Zhou, and F. Zimmermann, *Coherent beam-beam instability in collisions with a large crossing angle*, **Phys. Rev. Lett**. **119**, 134801 (2017)
3	F. Zimmermann, *Future Colliders for Particle Physics – "Big and Small"*, Proc. EAAC'17, La Biodola, 24-30 September 2017, **Nucl. Instr. Methods A** (2017)
4	G. Guillermo, D. Sagan, and F. Zimmermann, *Examining mitigation schemes for synchrotron radiation in high-energy hadron colliders*, **Phys. Rev. Accel. Beams 21**, 021001 (2018)

5	M. Migliorati, E. Belli, M. Zobov, *Impact of the resistive wall impedance on beam dynamics in the Future Circular e+e− Collider*, **Phys. Rev. Accel. Beams 21**, 041001 (2018)
6	M. Benedikt and F. Zimmermann, *Proton Colliders at the Energy Frontier,* invited article for Special Kai Siegbahn Issue of **Nucl. Instr. Methods A** (2018)
7	S. Fartoukh, M. Giovannozzi, D. Missiaen, E. Todesco, F. Zimmermann, *Considerations on a Partial Energy Upgrade of the LHC*, ARIES-2017-001; CERN-ACC-2017-096 (2017)
8	E. Belli, G. Castorina, M. Migliorati, G. Rumolo, B. Spataro, M. Zobov, *Single bunch instabilities in FCC-ee*, 9th International Particle Acceleration Conference, pp. 3336-3339, Vancouver, BC, Canada, May 2018. doi: 10.18429/JACoW-IPAC2018-THPAK052.
9	E. Belli, P. Costa Pinto, M. Migliorati, G. Rumolo, T. F. Sinkovits, M. Taborelli, *Electron cloud studies in FCC-ee*, 9th International Particle Acceleration Conference, pp. 374-377, Vancouver, BC, Canada, May 2018.
10	A. Drago, *Feedback Systems for Multibunch Beam Diagnostics and Instabilities Suppression*, CERN Yellow Reports: Conference Proceedings, Vol. 1/2018. CERN-2018-003-CP (CERN, Geneva, 2018), pg. 39-43.
11	F. Zimmermann, *LHC- and FCC-Based Muon Colliders*, IPAC18 Vancouver, **IOP J. Phys.: Conf. Ser. 1067**, 022017 (2018)
12	G. Guillermo Cantón, F. Zimmermann, G.H.I. Maury Cuna, E. D. Ocampo, *Electron Cloud Build Up for LHC Sawtooth Vacuum Chamber*, Proc. IPAC 18, Vancouver
13	M. Benedikt, F. Zimmermann, *FCC: Colliders at the Energy Frontier*, Proc. IPAC18, Vancouver
14	M.A. Valdivia Garcia, D. El Khechen, K. Oide, F. Zimmermann, *Quantum Excitation due to Classical Beamstrahlung in Circular Colliders*, Proc. IPAC18, Vancouver
15	J.L. Abelleira et al., *High-Energy LHC Design*, IPAC18, **IOP J. Phys.: Conf. Series 1067**, 022009 (2018)
16	F. Hug, M. Arnold, T. Bahlo, N. Pietralla, *Beam-based Alignment of SRC Cavities in an Electron Linac*, Proc. IPAC18, published in **IOP J. Phys.: Conf. Series 1067**, 03202 (2018)
17	G. Franchetti, *Sum Resonance with Space Charge*, 61st ICFA ABDW on High-Intensity and High-Brightness Hadron Beams HB2018, Daejeon, Korea. Pag. 226-230
18	A. Preinerstorfer, H. Humer, P. Böhm, T. Gruber, A. Niemi, and J. Gutleber, *Bibliography and state of the art of reliability information systems*

19	A. Preinerstorfer, H. Humer, P. Böhm, T. Gruber, A. Niemi, and J. Gutleber, *Information system use cases and use context of an open reliability information system*,
20	F. Zimmermann, *Challenges for Future Circular e+e- Colliders*, Proc. eeFACT2018 Hong Kong (2018)
21	F. Zimmermann, *Report from ARIES Muon Collider Workshop in Padua*, Proc. Muon Collider Worskhop, Padua (2018)
22	F. Zimmermann et al., *FCC-ee Operation Model, Availability and Performance*, Proc. eeFACT2018 Hong Kong (2018)
23	M. A. Valdivia Garcia, F. Zimmermann, *Optimized Monochromatization for direct Higgs Production in Future Circular e+e- Colliders*
24	F. Zimmermann, *Accelerators in the 21st century*, EPJ Web of conferences
WP7	
1	R. Bartolini et al. The Double Double Bend Achromat upgrade at Diamond: from design to commissioning, **PRAB, 21**, 050701, (2018)
WP8	
1	P. Forck, M. Sapinski, U. Iriso, F. Perez, R. Jones, Ch. Gerth, K. Wittenburg, R. Ischebeck, *ARIES-ADA: An R&D Network for advanced Diagnostics at Accelerators*, Proceedings of the International Beam Instrumentation Conference IBIC, Shanghai September 2018, www.jacow.org
WP17	
1	Guardia-Valenzuela, J et al, **Development and properties of high thermal conductivity molybdenum carbide - graphite composites**, *Carbon* **135** (2018) 72-84, 10 April 2018,
2	Carra, F, **Thermomechanical Response of Advanced Materials under Quasi Instantaneous Heating**, PhD Thesis, Politecnico di Torino, 2017, https://zenodo.org/record/1240450#.WvmuCaSFNaQ
3	Bertarelli, A et al, **Dynamic testing and characterization of advanced materials in a new experiment at CERN HiRadMat facility**, *J. Phys.: Conf. Ser.* **1067** (2018) 082021, September 2018
4	C. Accettura, Ultra-high vacuum characterization of advanced materials for future particle accelerator
WP18	
1	J. Vieira, J. T. Mendonça, and F. Quéré, Optical Control of the Topology of Laser-Plasma Accelerators, Phys. Rev. Lett. 121, 054801

2	A. Döpp, C. Thaury, E. Guillaume, F. Massimo, A. Lifschitz, I. Andriyash, J.-P. Goddet, A. Tazfi, K. Ta Phuoc, and V. Malka, Energy-Chirp Compensation in a Laser Wakefield Accelerator, Phys. Rev. Lett. 121, 074802
3	F. Massimo, A. F. Lifschitz, C. Thaury and V. Malka, Numerical study of laser energy effects on density Phys. Control. Fusion 60 034005 (2018)

Dissemination and communication activities

Type[4]	Author(s), *Title*, References, Date, Link
WP2	
Poster	Delerue et Al., A Massive Open Online Course on Particle Accelerators, IPAC'18 MOPML050, 30th April 2018
Video	The ARIES project
Press article	High thermal performance materials
Press article	Discussing a future strategy for muon colliders
Press article	How to access free of charge state-of-the-art accelerator testing facilities across Europe?
Press article	ARIES first annual meeting in Riga
Press article	And the winners of the ARIES Proof-of-Concept fund are…
Press article	Accelerator-Industry Co-Innovation Workshop
Press article	Different techniques of emittance measurements for SLS and FELs
WP3	
Presentation	Zwolińska, E., Sun, Y., Chmielewski, A. G., Licki, J.,Pawelec, A., Bułka, S., Zimek, Z., Removal of NO_x and SO_2 from exhaust gases using a hybrid electron beam method. International Conference on Developments and Applications of Nuclear Technologies (NUTECH-2017), 10-13.09.2017, Cracow, Poland

[4] Press article, Newsletter, Presentation Workshop/Conference, Presentation other events, Poster, Other

Presentation	Chmielewski, A. G., Flue gas treatment using electron beam technology – status and challenges, International Joint Conference on Environmental and Light Industry Technologies (IJCELIT 2017) 23-24.11.2017 r. Budapest, Hungary
WP4	
Presentation	M.Seidel et al, Energy Efficiency of Accelerators in the European Programs EUcard2 and ARIES, 11.11.2017, Magurele
Presentation	C.Marchand, Development of Efficient Klystrons, 11.11.2017, Magurele
CERN Int. report	Sotirios Papadopoulos, Suitbert Ramberger, Magnetic measurements of the vacuum vessel for the High-Gradient four cavity cryomodule CERN-ACC-NOTE-2018-0045 (2018)
WP5	
Newsletter	CERN Bulletin: EAAC workshop showcases advanced accelerator progress, http://cerncourier.com/cws/article/cern/70365 , 10 Nov 2017
Website	EuroNNAc Homepage, http://www.euronnac.eu/, 22.05.2018
Website	CAS High Gradient Accelerator School https://cas.web.cern.ch/schools/sesimbra-2019
Website	Yearly Meeting https://indico.cern.ch/event/749424/
WP6	
Presentation Workshop	F. Hug, ERL recirculation optics for MESA, ICFA Advanced Beam Dynamics Workshop on Energy Recovery Linacs, Geneva, Switzerland, 2017
Poster	F. Hug, Application of Non-Isochronous Beam Dynamics in ERLs for Improving Energy Spread and Stability, IPAC, Copenhagen, Denmark, 2017
Presentation Workshop	F. Hug, Beam stability and energy spread at MESA, 650. Heraeus Seminar on Energy Recovery Linacs, Bad Honnef, Germany, 2017

Presentation other events	F. Hug, MESA - an ERL project for particle physics experiments, Invited talk at University Frankfurt, Germany, 2017
Presentation Workshop	F. Hug, Welcome and ARIES Overview, Miniworkshop on Ion Sources, LEBT and RFQ Matching, Frankfurt, Germany, 2018
Pres. Workshop	G. Franchetti, Resonant dynamics in presence of space charge, Fermilab Workshop on Megawatt Rings & IOTA/FAST Collaboration Meeting, Bativa, USA 2018.
Newsletter	Panos Charitos, Accelerator reliability training help for experts, (APEC 6.3), **Accelerating News, no. 22**
Newsletter	M. Zanetti and F. Zimmermann, Workshop shines Light on Photon-Beam Interactions (APEC 6.6), **Accelerating News, no. 23**
Newsletter	M. Zanetti and F. Zimmermann, Discussing a future strategy for muon colliders (APEC 6.6), **Accelerating News, no. 26**
Pres. Workshop	M. Migliorati, M. Zobov, Impedance and instabilities in lepton colliders, International Workshop on Impedances, International Workshop on Impedances and Beam Instabilities in Particle Accelerators, Benevento (Italy), 18 - 22 September, 2017.
Pres. Workshop	A.Drago, Transverse Feedback Systems for Multibunch Beam Diagnostics and Instabilities Suppression, International Workshop on Impedances, International Workshop on Impedances and Beam Instabilities in Particle Accelerators, Benevento (Italy), 18 - 22 September, 2017.
Pres. Workshop	E. Belli, Impedance model and single beam collective effects for FCC-ee, FCC Week 2018 April 11, 2018 – Amsterdam.
Pres. Workshop	A.Drago, FCC-ee Feedback System Design Update, FCC Week 2018 April 11, 2018 – Amsterdam.
Pres. Workshop	A. Mostacci, Experimental challenge in linear and circular accelerators driven by impedance issues, ECLOUD’18, 3-7 June 2018, Italy, La Biodola Bay, Isola d’Elba
Pres. Workshop	E. Belli, SEY measurements of coated surfaces with different coating thickness, ECLOUD’18, 3-7 June 2018, Italy, La Biodola Bay, Isola d’Elba.
Pres. Workshop	A. Drago, Intra-bunch Feedback System development at DAFNE, ECLOUD’18, 3-7 June 2018, Italy, La Biodola Bay, Isola d’Elba.

Pres. Workshop	E. Belli, NEG coating for FCC-ee, eeFACT2018 Sep 25, 2018 – Hong Kong.
Pres. Workshop	E. Belli, Single-beam instabilities in FCC-ee, eeFACT2018 Sep 25, 2018 – Hong Kong.
Pres. Workshop	G. Franchetti, Sum resonances with Space charge, 61st ICFA Advanced Beam Dynamics Workshop on High-Intensity and High-Brightness Hadron Beams , Daejeon, Korea, 17-22 June, 2018 Invited Talk.
Pres. School	F. Zimmermann, Linear Lepton Colliders, Circular Lepton Colliders, Circular Hadron Colliders and Beyond, Helmholtz School and Workshop, JINR Dubna (CALC2018), 22 July -1 August 2018
Pres. Meeting	F. Zimmermann, Beyond LHC – Future Circular Colliders, 20th Annual RDMS CMS Collaboration Conference, Uzbekistan, 12-15 Sept. 2018
Pres. School	F. Zimmermann, Machine Aspects of Future e+e- Colliders, Machine Aspects of Future pp Colliders, Pisa School on Future Colliders, 18 September 2018.
Pres. Workshop	F. Zimmermann, Future Circular Colliders, KIT workshop 'The Future of Particle Physics: A Quest for Guiding Principles', Karlsruhe 1-2 October 2018.
Newsletter	P. Charitos, F. Zimmermann, Future Circular Collider (FCC) Week2018, **CFA Beam Dynamics Newsletter no. 74** (2018)
Newsletter	M. Zanetti, F. Zimmermann, Muon Collider Workshop 2018, **ICFA Beam Dynamics Newsletter no. 74** (2018)
WP14	
Poster	Jennifer Toes, ARIES PoC poster, October 2017
Newletter, Accelerating News	Romain Muller, The winners of the PoC Funds, July 2018
WP17	

Press article	A. Bertarelli, Workshop for extreme thermal management materials, Accelerating News issue 23, December 2017 https://acceleratingnews.web.cern.ch/article/workshop-extreme-thermal-management-materials
Press article	A. Bertarelli, **High thermal performance materials**, Accelerating News issue 26, October 2018 https://acceleratingnews.web.cern.ch/article/high-thermal-performance-materials

Annex 1: Project meetings

Date	Meeting	Venue	WP
04-05.05.2017	ARIES Kick-off meeting	CERN	All
05.05.2017	Governing Board – Kick-off meeting	CERN	All
05.05.2017	1st ARIES Steering Committee meeting	CERN	All
05.05.2017	Industrial Meeting / Kick-off meeting	CERN	All
20.07.2017	ARIES-AMICI Coordination meeting	Padova (Italy)	All
10.08.2017	Accelerator application to the ship exhaust gases treatment	CERN	All
26-30.08.2017	Workshop on Ions for Cancer Therapy, Space research and Material Science	Crete	All
05.09.2017	2nd ARIES Steering Committee meeting	CERN	All
09.11.2017	Co-innovation Workshop Programme Committee Meeting	CERN	All
22-23.11.2017	Industry workshop Programme Committee Meeting	CERN	All
01.12.2017	ARIES Meets Industry – accelerator application to the ship exhaust gases treatment	CERN	All
13.12.2017	3rd ARIES Steering Committee meeting	CERN	All
06-07.02.2018	Accelerator-Industry Co-Innovation Workshop	Brussels	All
01.03.2018	Electron beam treatment of marine diesel exhaust gases – Consortium meeting	Riga	All
06.03.2018	4th Steering Committee meeting	CERN	All
22-25.05.2018	1st Annual Meeting in Riga	Riga	All
23.05.2018	Governing Board meeting	Riga	All
25.05.2018	5th Steering Committee meeting	Riga	All
10.09.2018	Preparation meeting: 2nd ARIES Annual Meeting in Budapest	Video	WP1
11.09.2018	6th Steering Committee meeting	CERN	All
04.12.2018	7th Steering Committee meeting	CERN	All
WP2: Training, Communication and Outreach for Accelerator Science			
05.05.2017	Kick-off WP2 meeting	CERN	WP2
31.05.2017	WP2.4 Meeting	Vidyo	WP2
14.06.2017	Task 2.2 kick-off discussion	Vidyo	WP2
17.07.2017	ARIES Task 2.3 meeting	Vidyo	WP2
06.09.2017	Task 2.4: Syllabus committee	Vidyo	WP2
06.09.2017	ARIES Task 2.2 meeting #2	Vidyo	WP2
18.09.2017	Task 2.4 Technical Committee #1	Vidyo	WP2
16.10.2017	Task 2.3 - Meeting #2	Vidyo	WP2
17.10.2017	Task 2.4 Syllabus Committee #2	Vidyo	WP2
19.10.2017	Task 2.4 Technical Committee #2	Vidyo	WP2
14.11.2017	Task 2.2 Meeting #3	Vidyo	WP2

28.11.2017	Task 2.4 Syllabus Committee #3	Vidyo	WP2
06.12.2017	Task 2.3 - Meeting #3	Vidyo	WP2
12.12.2017	WP2 Task Leader Meeting	CERN	WP2
19.01.2017	WP2.4 Syllabus Committee #4	Vidyo	WP2
22.05.2018	WP2 General Meeting	Riga	WP2
05.06.2018	Task 2.3 - Meeting #4	CERN	WP2
01.10.2018	WP2 Task Leader Meeting	Vidyo	WP2
31.10.2018	WP2 Task Leader Meeting	Vidyo	WP2
2-11/11/2018	Accelerator Communication and Outreach workshop	CERN	WP2
WP3: Industrial and Societal Applications			
13-14.09.2017	ARIES WP3 kick-off	AGH, Krakow	WP3
24-26.07.2018	Very High Energy Electron Radiotherapy	Daresbury	WP3
6-7.11.2017	Accelerated Electrons for Life (AcEL)	Sao Polo	WP3
01.12.2017	ARIES Meets Industry – accelerator application to the ship exhaust gases treatment	CERN	WP3
22-26.01.2018	CLIC Workshop 2018	CERN	WP3
Monthly	WP3 Task Leaders meeting	Video	WP3
22.05.2018	WP3 Annual Meeting, Riga	Riga	WP3
27.08.2018	Workshop of the emerging trends in the sludge treatment	Warsaw	WP3
10-11.09.2018	Development of hybrid electron accelerator system for the treatment of marine diesel exhaust gases – technical meeting	Riga	WP3
11-12.10.2018	Development of hybrid electron accelerator system for the treatment of marine diesel exhaust gases - Project kick-off meeting	Warsaw	WP3
8-9.10.2018	PRAE International Workshop	Orsay	
15-19.10.2018	Regional Training Course “Radiation processing for advanced polymeric materials” c/c IAEA	Warsaw	WP3
26.10.2018	Webminar: “Radiometals in Theranostics Applications: Present and future perspectives”	Online	WP3
29-30.11.2018	Phoebe meeting – H2020 proposal preparation	Warsaw	WP3
WP4: Efficient Energy Management			
05.05.2017	WP4 Kick-off meeting	CERN	WP4
8-9.11.2018	TTC/ARIES topical workshop on flux trapping and magnetic shielding	CERN	WP4
WP5: European Network for Novel Accelerators (EuroNNAC)			
24-30.09.2017	3rd EAAC workshop	Elba	WP5
30.09.2017	EuroNNAc 3 Yearly Meeting 2017	Elba	WP5

23.11.2018	EuroNNAc3 Yearly Meeting 2018 https://indico.cern.ch/event/749424/	Frascati	WP5
WP6: Accelerator Performance and Concepts			
05.05.2017	WP6 APEC Steering Meeting	CERN	WP6
11-13.09.2017	LHeC and FCC-eh Workshop	CERN	WP6
18-22.09.2017	Mini-Workshop on Impedances and Beam Instabilities in Particle Accelerators	Benevento, Italy	WP6
18-21.09.2017	Mini-workshop on Reliability and Availability	CERN	WP6
4-6.10.2017	Space Charge 2017 Workshop	Darmstadt, Germany	WP6
15-20.10.2017	Accelerator Reliability Workshop 2017 (ARW2017)	Versailles, France	WP6
9-11.11.2017	Slow Extraction workshop	CERN	WP6
27-28.11.2017	Photon Beams Workshop 2017	Padova, Italy	WP6
28.02-2.3.2018	Workshop on Ion Sources and Low Energy Beam Transport into RF Linacs	Frankfurt/Main, Germany	WP6
12-14.03.2018	Pulse Power for Kicker Systems (PULPOKS)	CERN	WP6
12-14.03.2018	2nd Space Charge Collaboration Meeting	CERN	WP6
9-13.04.2018	FCC Week 2018	Amsterdam, The Netherlands	WP6
23.05.2018	2nd ARIES WP6 APEC Steering Meeting	Riga, Latvia	WP6
03-07.06.2018	ECLOUD18	Elba, Italy	WP6
27-29.06.2018	LHeC and FCC-eh and PERLE Workshop	Orsay, France	WP6
02.-0.3.07.2018	Muon Collider Workshop 2018	Padova, Italy	WP6
23.-28.09.2018	Channeling 2018	Ischia, Italy	WP6
24.-27.09.2018	eeFACT2018	HKUST, Hong Kong	WP6
10-12.12.2018	APEC Accelerator Performance and Concept Workshop	Frankfurt	WP6
WP7: Rings with Ultra-Low Emittance			
05.05.2017	WP RULE Kick-off meeting	CERN	WP7
27-30.08.2017	Topical Workshop on Injection and Injection Systems	Bessy II Berlin	WP7
15-17.01.2018	7th Low Emittance Rings Workshop	CERN	WP7
18-19.04.2018	DEELS 2018	Diamond Light Source	WP7
19-20.04.2018	Topical Workshop on Diagnostics for Ultra-Low Emittance Rings	Diamond Light Source	WP7
WP8: Advanced Diagnostics at Accelerators			
29-30.01.2018	Topical Workshop on “Emittance Measurements for Light Sources and FELs	ALBA	WP8

14-16.05.2018	Extracting information from Electro-Magnetic Monitors in Hadron Accelerators	CERN	WP8
22-24.05.2018	ARIES Topical Workshop on 'Simulation, Design & Operation of Ionization Profile Monitors'	GSI, Darmstadt	WP8
25-27.06.2018	8th Topical Workshop on Longitudinal Diagnostics for FELs	DESY, Hamburg	WP8
12-14.11.2018	Topical Workshop as common event of Task 8.3 and 8.4: New Generation of Beam Position Acquisition and Feedback Systems	ALBA	WP8
WP14: Promoting Innovation			
08.06.2017	WP14 Meeting	CERN	WP14
26.06.2017	Task14.5 HTS Meeting	CERN	WP14
25.08.2017	Budget Implementation	CERN	WP14
18.10.2017	ARIES Task14.5 Conductor meeting	CERN	WP14
30.11.2017	WP14.5 HTS meeting	CERN	WP14
07.12.2017	WP14 KoM meeting	CERN	WP14
05.03.2018	PoC discussion meeting	CERN	WP14
20.03.2018	PoC discussion meeting	CERN	WP14
22.03.2018	PoC discussion meeting	CERN	WP14
27.03.2018	HiRadmat and MgB2 telecom	CERN	WP14
26.04.2018	WP14.5 HTS meeting	CERN	WP14
02.05.2018	WP14.4 meeting (in RHP)		WP14
16.05.2018	IPR Workshop	CERN	WP14
15.06.2018	PoC - Projects presentation	CERN	WP14
06.08.2018	PoC legal framework meeting	CERN	WP14
17.09.2018	WP14.5 Meeting	CERN	WP14
25.09.2018	WP14.3 telco	CERN	WP14
18-19.10.2018	WP14.3 participation to WP17 annual meeting in La Valletta	Malta	WP14
9.11.2018	WP meeting with Cosylab and Avo-Adam	CERN	WP14
WP15: Thin Film for Superconducting RF Cavities SRF			
05.05.2017	WP15 Kick-off meeting	CERN	WP15
22.06.2017	ARIES Task 15.1 meeting 2	Vidyo	WP15
17-19.07.2018	WP15 meeting held during SRF2017	Lanzhou	WP15
20.10.2017	ARIES WP15 Meeting	CERN	WP15
16.03.2018	WP15 Meeting 4	Vidyo	WP15
22.05.2018	5th WP15 meeting in Riga	Riga	WP15
31.08.2018	6th WP15 Meeting	Vidyo	WP15
11.10.2018	7th WP15 meeting	Padova	WP15

WP16: Intense, RF modulated E-beams			
03.05.2017	ARIES WP16 Kick-off Meeting	CERN	WP16
01.12.2017	WP16 Task 4 meeting: parameters for test stand	CERN	WP16
10.04.2018	ARIES WP16 Meeting	CERN	WP16
30.04.2018	WP16 meeting: test stand and preparation of annual meeting	Vidyo	WP16
22-23.05.2018	WP16 Parallel Meeting	Riga	WP16
8-9.11.2018	WP16 meeting	Frankfurt	WP16
WP17: Materials for extreme thermal management			
05.05.2017	ARIES WP17 (PowerMat) Kick-off Meeting	CERN	WP17
27-28.11.2017	1st Workshop of ARIES WP17 PowerMat	Politecnico di Torino	WP17
28-30.10.2018	1st Annual Meeting of the ARIES WP17	Malta	WP17
WP18: very high gradient acceleration techniques			
08.12.2017	WP18.2 meeting	Palaiseau	WP18
13.02.2018	WP18.2 meeting	Palaiseau	WP18
28.03.2018	WP18.2 meeting	Palaiseau	WP18
04.04.2018	WP18.5 meeting	Palaiseau	WP18
05.04.2018	WP18.3 meeting	Saclay	WP18
18.04.2018	WP18.2 meeting	Palaiseau	WP18
03.05.2018	WP18.2 meeting	Palaiseau	WP18
22.05.2018	WP18 meeting – Full WP review	Riga	WP18

Annex 2: List of User Selection Panel Members

Name	Home Institution	Home Institution Town, Country	External / internal members
WP9: Magnet Testing			
GianLuca Sabbi	Lawrence Berkeley National Laboratory (LBNL)	Berkley, USA	USP external member
Tatsu Nakamoto	High Energy Accelerator Research Organization (KEK)	Tsukuba, Japan	USP external member
Roger Ruber	Uppsala University (UU)	Uppsala, Sweden	USP internal member
Marta Bajko	European Organization for Nuclear Research (CERN)	Geneva, Switzerland	USP internal member
WP10: Material Testing			
Nick Simos	Brookhaven National Laboratory (BNL)	New York, USA	USP external member
Bernie Riemer	Oak Ridge National Laboratory (ORNL)	Oak Ridge, USA	USP external member
Yacine Kadi	European Organization for Nuclear Research (CERN)	Geneva, Switzerland	USP internal member
Jie Liu	Institute of Modern Physics, Chinese Academy of Sciences -IMPCAS	Lanzhou, China	USP external member
Maik K. Lang	University of Tennessee	Knoxville, USA	USP external member
Daniel Severin	GSI Helmholtz Centre for Heavy Ion Research	Darmstadt, Germany	USP internal member
WP11: Electron and proton beam testing			
Florencia Cantargi	Centro Atómico Bariloche, CNEA	Bariloche, Argentina	USP external member
Joel England	SLAC National Accelerator Laboratory	Menlo Park, USA	USP external member
Noel Jakse	SIMAP - Laboratoire de Science et Ingénierie, Grenoble INP	Grenoble, France	USP external member
Peter Michel	Helmholtz-Zentrum Dresden-Rossendorf (HZDR)	Dresden, Germany	USP external member

Jerome Schwindling	Commissariat à l'énergie atomique et aux énergies alternatives (CEA)	Gif-sur-Yvette, France	USP internal member
Robert Ruprecht	Karlsruhe Institute of Technology (KIT)	Karlsruhe, Germany	USP internal member
Ulrich Dorda	Deutsches Elektronen-Synchrotron DESY	Hamburg, Germany	USP internal member
Anthony Gleeson	Science and Technology Facilities Council (STFC)	Swindon, UKL	USP internal member
WP12: Radio Frequency Testing			
Jiaru Shi	Tsinghua University	Beijing, China	USP external member
Österberg Kenneth	Helsinki University	Helsinki, Finland	USP external member
Vyacheslav P. Yakovlev	Fermi National Accelerator Laboratory	Batavia, USA	USP external member
Roger Ruber	Uppsala University (UU)	Uppsala, Sweden	USP internal member
Walter Wuensch	European Organization for Nuclear Research (CERN)	Geneva, Switzerland	USP internal member
WP13: Plasma beam testing			
Patric Muggli	Max Planck Institute for Physics (MPP)	München, Germany	USP external member
Laslo Veisz	Umeå University	Umeå, Sweden	USP external member
Danilo Giulietti	University of Pisa	Pisa, Italy	USP external member
Sandrine Dobosz-Dufrenoy	Commissariat à l'énergie atomique et aux énergies alternatives (CEA)	Gif-sur-Yvette, France	USP internal member
Olle Lundh	University of Lund	Lund, Sweden	USP internal member
Brigitte Cros	Centre national de la recherche scientifique (CNRS)	Paris, France	USP internal member

Annex 3: List of publications related to Transnational Access

TA Project Acronym	Publication Year	Authors	Title	References	Publication type	Peer reviewed	DOI	Open Access
ARIES-HiRadMat-2017-01	2017	Y. Kadi, A. Fabich, F. Harden	HiRadMat Facility Experimental Program	NUFACT2017	Presentation	No	No	Yes
ARIES-HiRadMat-2017-01	2018	F.Harden, Y.Kadi	HiRadMat Facility Overview		Presentation	No	No	Yes
ARIES-HiRadMat-2017-01	2018	V. Grishin *et al.*	BLM2 at HiRadMat		Presentation	No	No	Yes
ARIES-HiRadMat-2017-01	2018	V. Grishin *et al.*	A Family of Gas Ionization Chambers and SEM for Beam Loss Monitoring of LHC and Other Accelerators	RuPAC2018	Conference proceedings	Yes	Yes	Yes
ARIES-HiRadMat-2017-01	2018	F.Harden, Y.Kadi, N. Charitonidis	HiRadMat: A Unique Facility Testing Materials with High Power Pulsed Beam	HiRadMat User Day	presentation	No	Yes	Yes
ARIES-HiRadMat-2017-02	2018	F. Carra *et al.*	The HRMT21 - RotCol experiment	HiRadMat User Day	presentation	No	Yes	Yes
ARIES-HiRadMat-2017-03	2018	A. Lapertosa *et al.*	ATLAS PixRad experiment: 2017 results & 2018 plans	HiRadMat User Day	presentation	No	Yes	Yes

ARIES-HiRadMat-2017-04	2018	D. Schmitt	Impact response of high-performance carbon-based materials	1st Annual Meeting of the ARIES WP17	Masters Thesis	No	Yes	Yes
ARIES-HiRadMat-2017-04	2018	P. Simon, M. Tomut *et al.*	First results of FlexMat experiment at HiRadMat- response of target and beam dump materials to beam impact	ARIES, wp17 1st Annual meeting, Malta, 29.10.18	presentation	No	Yes	Yes
ARIES-HiRadMat-2017-05	2018	A. Bertarelli *et al.*	Dynamic testing and characterization of advanced materials in a new experiment at Cern Hiradmat facility		Conference proceedings	Yes	Yes	Yes
ARIES-HiRadMat-2017-05	2018	M. Pasquali *et al.*	The HRMT-36 Experiment (MultiMat)	HiRadMat User Day	presentation	No	Yes	Yes
ARIES-FREIA-HNOSS-2017-01	2018	H. Li *et al.*	First High-Power Test of the ESS High Beta Elliptical Cavity at FREIA	Proceedings of LINAC2018, Beijing, China, Proton and Ion Accelerators and Applications	conference paper	No	Yes	Yes

Annex 4: List of Scientific Advisory Committee Members

Name	Home Institution	Home Institution Town, Country
Lia Merminga	Stanford Linear Accelerator Center (SLAC)	Stanford, USA
Pantaleo Raimondi	European Synchrotron Radiation Facility (ESRF)	Grenoble, France
Akira Yamamoto	High Energy Accelerator Research Organization (KEK)	Tsukuba, Japan

Annex 5: List of Industry Advisory Board Members

Name	Institution	Home Institution Town, Country
John Allen	Elekta Ltd	Crawley, United Kingdom
Thomas Eriksson	GE Healthcare	Uppsala, Sweden
Jean-Luc Lancelot	Sigmaphi, PIGES (French Industrialists for Large Scientific Equipment Association)	Vannes, France
Julio Lucas	Elytt Energy	Madrid, Spain
Francis Martin	International Irradiation Association	Ludlow, United Kingdom
Michael Peininger	RI Research Instruments GmbH	Bergish Gladbach, Germany