



# ARIES

Accelerator Research and Innovation for European Science and Society

Horizon 2020 Research Infrastructures GA n° 730871

## PERIODIC TECHNICAL REPORT

### YEAR 1 REPORT

<b>Grant Agreement number:</b>	730871
<b>Project Acronym:</b>	ARIES
<b>Project title:</b>	Accelerator Research and Innovation for European Science and Society
<b>Start date of the project:</b>	01/05/2017
<b>Duration of the project:</b>	48 months

<b>Period covered by the report:</b>	from 1 May 2017 to 30 April 2018
<b>Periodic report:</b>	Year 1
<b>Date:</b>	29/06/2018
<b>Version:</b>	Final
<b>Project website address:</b>	<a href="http://cern.ch/aries">http://cern.ch/aries</a>
<b>The report is elaborated on the basis of the:</b>	Grant Agreement after Amendment no.1, July 2017

ARIES Consortium, 2018

ARIES Consortium, 2018

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

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 730871. ARIES began in May 2017 and will run for 4 years.

### Delivery Slip

	Name	Partner	Date
<b>Authored by</b>	ARIES Management team with contributions from all Work Package Coordinators and Task Leaders		01/06/18
<b>Edited by</b>	Valérie Brunner, Sabrina El Yacoubi	CERN	15/06/18
<b>Reviewed by</b>	Maurizio Vretenar [Scientific Coordinator]	CERN	25/06/18
<b>Approved by</b>	Steering Committee		14/07/18

## TABLE OF CONTENTS

<b>Summary for publication .....</b>	<b>5</b>
Summary of the context and overall objectives of the project .....	5
Work performed from the beginning of the project to the end of the period covered and the main results achieved so far.....	5
<b>1. Explanation of the work carried out by the beneficiaries and overview of the progress.....</b>	<b>9</b>
1.1 Executive summary .....	9
1.2 Progress towards objectives and significant results .....	14
1.3 Explanation of the work carried per WP .....	16
WP1: Management, dissemination, ensuring sustainability.....	16
WP2: Training, Communication and Outreach for Accelerator Science .....	22
WP3: Industrial and Societal Applications .....	25
WP4: Efficient Energy Management .....	29
WP5: European Network for Novel Accelerators (EuroNNAC) .....	31
WP6: Accelerator Performance and Concepts (APEC) .....	34
WP7: Rings with Ultra-Low Emittance .....	38
WP8: Advanced Diagnostics at Accelerators.....	41
WP9: Magnet Testing (MagNet & Gersemi) .....	44
WP10: Material Testing (HiRadMat & UNILAC).....	47
WP11: Electron and proton beam testing (ANKA, VELA, IPHI, SINBAD & FLUTE).....	53
WP12: Radio Frequency Testing (HNOSS & XBox) .....	59
WP13: Plasma beam testing (APOLLON, LPA-UHI100, LULAL).....	62
WP14: Promoting Innovation.....	67
WP15: Thin Film for Superconducting RF Cavities SRF .....	70
WP16: Intense, RF modulated E-beams .....	74
WP17: Materials for extreme thermal management (PowerMat) .....	78
WP18: Very High Gradient Acceleration Techniques .....	82
1.4 Impact.....	87
<b>2. Deviations from Annex 1 and Annex 2 .....</b>	<b>91</b>
2.1 Deliverables and Milestones .....	91
2.2 Tasks .....	91
2.3 Use of resources .....	91
<b>3. Dissemination and exploitation of results .....</b>	<b>93</b>
Scientific publications .....	93
Dissemination and communication activities.....	94
<b>Annex 1: Project meetings .....</b>	<b>98</b>

---

<i>Annex 2: List of User Selection Panel Members .....</i>	<i>102</i>
<i>Annex 3: List of publications related to Transnational Access.....</i>	<i>104</i>
<i>Annex 4: List of Scientific Advisory Committee Members.....</i>	<i>105</i>
<i>Annex 5: List of Industry Advisory Board Members.....</i>	<i>106</i>

---

## Summary for publication

---

### Summary of the context and overall objectives of the project

Particle accelerators are fundamental engines of discovery and unique tools for understanding the universe and its properties. In addition to their crucial contribution to basic science, they have applications in research fields as varied as life science, condensed matter, energy research, engineering materials and geosciences, environmental science, material science, and cultural heritage. They provide a wealth of data to science and a competitive advantage to their industrial users.

ARIES (Accelerator Research and Innovation for European Science and Society) aims to:

- Develop and further improve the European particle accelerator infrastructure, and identify and promote new concepts;
- provide European researchers and industry with access to top-class accelerator research and test infrastructures;
- enlarge and further integrate the accelerator community in Europe;
- develop a joint strategy for securing sustainable accelerator Science & Technology;
- transfer the benefits and applications of accelerator technology to both science and society.

ARIES brings together a consortium of 41 beneficiaries from 18 countries: accelerator laboratories, technology institutes, universities and industrial partners to jointly address common challenges for the benefit of a number of projects and infrastructures in high-energy physics, as well as in photon and neutron science.

### Work performed from the beginning of the project to the end of the period covered and the main results achieved so far

The priority of **WP1 (Management, dissemination and ensuring sustainability)** has been to set up the project governance and management, including the finalisation of the Consortium Agreement and the definition and kick-off of Governing Board, Scientific Advisory Committee and Industry Advisory Board. Starting the project activities and creating an environment for open collaboration and exchange was achieved in the kick-off meeting organised at CERN in May 2017, which was followed by four meetings of the Steering Committee. The publication platform and strategy were defined and the first Milestones and Deliverables were produced on schedule. A Workshop with industry organised at Brussels in February contributed to defining the role of accelerator industry in the sustainability of particle accelerator research.

**WP2 (Training, Communication and Outreach for Accelerator Science)** has carried out several activities to advance its objectives. 16 tasks and WP meetings were held. The project website, intranet, video, poster, and 10 news articles were delivered. The preparatory work was done for launching a survey of the provision of training in accelerator science in Europe, which will be performed in the next reporting period. A massive open online course (MOOC) in accelerator science is being prepared, targeted at students at the beginning of the second cycle (master program) as defined in the European Higher Education Area (so-called Bologna process). A Technical Committee has identified a MOOC platform and a Syllabus Committee has defined the outline intellectual content of the MOOC.

**WP3 (Industrial and Societal Applications)** has made significant progress towards its aims. In particular, a review of the existing applications of low energy electron beams and the technology used to produce them has been completed, demonstrating the broad range of these applications and their importance to everyday life. New applications, especially in the environmental area, have been identified and are being studied, as are new forms of accelerator technology. The applications of higher energy electron beams have also been studied and their importance again demonstrated. The construction of a high performance accelerator to study these has started. Finally, considerable progress has been made on a number of novel technologies for the production of both existing radioisotopes and novel radioisotopes for medical imaging and cancer therapy.

Depending on the application, many particle accelerators consume considerable power from the public grid. **WP4 (Efficient Energy Management)** aims at improving the efficiency of specific accelerator subsystems and of entire accelerator based research facilities as a whole. Besides organising general workshops on the topic, the work package selected four specific accelerator subsystems for development work aimed at improving efficiency. These include efficient high power RF sources, high efficiency neutron production using a spallation target, low loss beam acceleration in superconducting cavities, and efficient beam guiding using pulsed magnets with energy recovery. A first general workshop was organised with good participation, and all tasks have started their work on the specific subsystems.

The highlight of the first year of activity of **WP5 (European Network for Novel Accelerators)** was the success of the EAAC2017 (European Advanced Accelerator Concepts) Workshop with 300 registered participants, including 91 students. This event was a major step forward in a continuous effort on building and enhancing the advanced acceleration network of more than 50 national laboratories and universities in Europe, Asia and the US. The proceedings are published in NIM-A as open-access. The Kick-off and first Yearly WP meetings took place as a satellite meeting to EAAC2017. Training of young scientists within the Network was an utmost priority, with special student meetings during the Workshop and poster prizes for outstanding student contributions. The future European strategies for electron plasma accelerators and dielectric accelerators defined within the Network resulted in support of the H2020 EuPRAXIA design study, the ALEGRO workshops in Geneva and Oxford and the ACHIP and AXIS projects on dielectric structures.

In the first year of ARIES, **WP6 (Accelerator Performance and Concepts)** organized eleven workshops and networking events, which covered a large spectrum of accelerator technology, design and operation, in its pursuit of raising the technology readiness levels in several key areas linked to accelerator performance. The WP6 workshops attracted a large number of international participants from around the globe. The WP6 workshop results are already helping improve the performance of modern accelerator facilities, including accelerators for medical and material-science applications, and are preparing the design of high-energy accelerators for the long-term future. WP6 also places a high emphasis on outreach activities, on support for students, and on gender diversity.

The **WP7 (Rings with Ultra-Low Emittance)** aims at developing network activity in the accelerator community working on ultra-low emittance rings. This field has seen great progress in the last years promoted by some pioneering projects that resulted in the funding of several upgrade projects in the EU and US. In parallel, R&D activity in damping ring for linear colliders has also continued and new proposal for low emittance damping ring for muon collider have been put forward. WP7 has supported these developments with the organisation of one general workshop and two topical workshops dedicated to injection systems and diagnostics, key technological areas that underpin progress in the design and construction of ever-aggressive low emittance rings. Such workshops have all been well attended with ~80 delegates for the general one and more than 40 for the topical ones.

**WP8 (Advanced Diagnostics at Accelerators)** aims at developing beam instrumentation and diagnostics methods to meet the demands of new accelerator facilities. To improve knowledge exchange between experts from worldwide research institutes three topical workshops were organized, with about 20 to 40 participants ranging from novices to world-leading experts. The first workshop concerned transverse profile measurements at hadron LINACs where non-destructive technologies have to be applied, calling for novel technical solutions accompanied by new simulations. A simulation code that covers a very wide range of applications was jointly developed and benchmarked, and is now available as freeware. The second workshop was dedicated to profile measurements at light sources, where the very small beam sizes calls for novel measurement technologies. The third workshop concerned the measurements of critical parameters at hadron synchrotrons, with some final agreement on improved measurement techniques that should enhance the performance and operation of these accelerators.

The Transnational access activity is organised in **WP9 (Magnet Testing)**, **WP10 (Material Testing)**, **WP11 (Electron and proton beam testing)**, **WP12 (Radio Frequency Testing)** and **WP13 (Plasma beam testing)**. In the first year, the main activity was to set up the User Selection Panels (one per WP, with the exception of WP10 that has two) and to advertise the facilities via the web site, and at Conferences and meetings. The first projects have started, with good results in term of number of projects, of access units and of users for the facilities that are continuing from the previous project EuCARD2. The facilities that are open for the first time under ARIES have been addressing their initial users and are in the process of setting up their procedures for access and usage. During the first year, some facilities were still under development or under construction; they will provide access to users in the coming months.

In the course of the first year of activity, **WP14 (Promoting Innovation)** has launched the Proof-of-Concept (PoC) innovation fund for industry-oriented activities identified within the ARIES project. The procedure for the management of the PoC has been drafted, discussed and agreed, the Call for proposals has been launched, and the Evaluation Committee appointed by the Industrial Advisory Board has been set-up. The Industrial production of materials for extreme thermal management and of two high temperature cable lengths has been completed, and the components produced have been successfully tested. The short High-Temperature Superconductor (HTS) cable lengths present the world record for HTS engineering current density, at a much reduced production cost with respect to previous samples. The document specifying the new accelerator timing system in product grade level has been produced and sent to collaborating company.

Eight research partners from six countries are contributing to the **WP15 (Thin Film for Superconducting RF Cavities)**. The collaboration aims at producing and testing Niobium-coated samples with each sample going through 3 to 5 partners, to use different complementary facilities and to exploit the best expertise available. In the first year, the teams were focused on building or improving their facilities. With the goal of evaluating four different surface preparation techniques. 50 copper samples were cut, then treated at two different partners, and finally sent to all other partners for Niobium deposition and characterisation.

In the first year of the project, the focus of **WP16 (Intense, RF modulated E-beams)** has been on design work. The various components of the electron gun and the test stand have to be carefully designed to meet the initial requirements of high current – up to 10A - modulated at several MHz. Major progress has been achieved regarding the design of the electron gun for space charge compensation, and a preliminary design has been completed. A modulation using a control grid was selected and incorporated into the design, taking care of preserving the electron transverse profile. A conceptual design of the power modulator for the grid modulation has been developed and a low-power prototype based on this concept been built, to be tested in a proof-of-concept experiment that

is ready for commissioning. The design of the test stand for the characterization of the electron gun made excellent progress, with the definition of a staged approach: a first stage for measuring the electron current and transverse profile as generated by the gun; a second stage – including a drift magnet – to study the dynamics and longitudinal profile.

**WP17 (Materials for extreme thermal management)** aims at the development and characterization of novel and advanced materials for demanding thermal management applications at high-energy particle accelerators. After defining its objectives in its kick-off meeting and in a first workshop, the activity focused on a comprehensive characterization campaign on a broad range of advanced materials for applications in beam intercepting devices for particle accelerators. Effects of long-term radiation damage in relevant materials were analysed by simulations, assessing the expected damage in collimators at the end of the operational life of the high luminosity upgrade of the LHC at CERN and leading to the selection of beam parameters for future irradiation experiments. A comprehensive experiment, exposing a broad range of materials to the direct impact of extremely powerful particle beams was successfully completed at the CERN test facility, qualifying certain carbon-based materials, such as Molybdenum Carbide – Graphite (MoGr), for the use in future devices as the collimators for the LHC upgrade.

The **WP18 (Very High Gradient Acceleration Techniques)** explores four very different approaches in the new field of laser acceleration. Each approach aims either to improve parameters of the produced beams that are critical for the intended applications, or to explore new regimes and techniques. A simulation framework and an experimental setup for acceleration and radiation generation in wakefields driven by lasers with orbital angular momentum has been realised, as well as a first attempt at accelerating electrons in a plasma wave excited by laser beams with orbital angular momentum.

---

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

---

## 1.1 Executive summary

ARIES is an Integrating Activity project dedicated to the research, development and innovation of European particle accelerators and their related infrastructure and technology. Over four years, ARIES will pave the way for the future of accelerator science by providing access to top class accelerator infrastructures and by enhancing the use of accelerators for society. It is structured in 8 Networks, 5 Transnational Access Workpackages covering 14 accelerator test facilities, and five Joint Research Activities.

In the first period, **WP1 (Management, dissemination and ensuring sustainability)** had to set-up the Project governance and the required committees and to provide three milestones. The first milestone concerned the Kick-off meeting, which took place at CERN on 4-5 May 2017, and the second was related to the kick-off of the ARIES-TIARA Working Group on Sustainability, which took place in June 2017. The third Milestone consisted in the 1<sup>st</sup> Annual Meeting, which took place in May 2018, shortly after the end of Year 1.

The activities in **WP2 (Training, Communication and Outreach for Accelerator Science)** started with the launch of the Project website <http://aries.web.cern.ch/>, corresponding to task 2.2. In task 2.4, the milestone of having define the MOOC content and documenting it in a report has been achieved at the end of M12.

**WP3 (Industrial and Societal Applications)** had one milestone during this period, MS13. This 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 future applications and possible research area derived technology that could bring improvements to these applications. Two milestones (MS14 and MS15) and one deliverable (D3.1) 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. To carry out the perspective studies foreseen in Tasks 2, 3, 4 and 5 three post-docs were hired by the partners responsible for Tasks 2-4, and a student was hired for Task 5. The 12GHz efficient klystron design started with the definition of goal parameters and concept defined. For the neutron moderator, design studies and simulations were started. Shielding studies and magnetization measurements were started for the high efficiency SRF power conversion. Procurement of components for a pilot installation of pulsed low-consumption magnets is ongoing. The MS19 related to the Workshop has been achieved.

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.

In the first year, complying with community demands, **WP6 (Accelerator Performance and Concepts)** organized, or co-organized, a total of eleven 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”. For Task 5: “LHeC/FCC-eh”, “Ion Sources and Low Energy Beam Transport into RF Linacs”. For Task 6: “Photon Beams”. Altogether, 590 participants attended the WP6 events; to this number can be added the 456 participants to the large FCC event that was only co-organised by ARIES WP6, to reach the impressive number of 1046 persons from all over the world who took part in ARIES WP6 event during the first year. Milestone MS26 (Report on 1st annual workshops of all tasks) was completed in mid-May.

In year 1, **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.

**WP8 (Advanced Diagnostics at Accelerators)** achieved its milestone for the first period. In May 2017 a dedicated workshop took place concerning ‘[Simulation, Design & Operation of Ionization Profile Monitors](#)’ for transverse profile measurements at hadron LINACs and synchrotrons (33 participants). In January 2018 a second workshop was organized to discuss ‘[Emittance Measurements for Light Sources and FELs](#)’. As the beam size at modern light sources continues to decrease, novel measurement technologies have to be developed to keep pace. Various technical solutions were discussed by experts in the field with the aim of establishing common measurement techniques. Milestone (MS39) on the organization of the first year of workshops was successfully achieved.

**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, three projects have been selected and supported, with 15 users and 24% of the total of access units foreseen were delivered. The delivery of the Uppsala Gersemi facility vertical cryostat system was delayed due to technical difficulties during manufacturing. The vertical cryostat, liquid bath insert, valve box, and transfer lines were finally completed during January 2018. Factory tests followed and the complete system was delivered to Uppsala only on 5 March 2018. Two inserts and the control system are scheduled to arrive in May. Installation work has started and is planned to be completed by August 2018.

Facility	No. of projects Y1	Total no. of projects Annex 1	No. of users Y1	Total no. of users Annex 1	No. of access units Y1	Total no. of access units Annex 1
MagNet	3	8	15	40	464	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: Number of projects, users and access units for the material testing facilities shows the number of projects, users and access units for these facilities. During Y1, the CERN HiRadMat provided access to 6 projects with 37 users and was particularly successful, providing more access units than foreseen. This is particularly important in consideration of the fact that 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 during the first year; in this time, it has been contacted by several user groups and finally three proposals were submitted and approved. Preparation of the experiments is ongoing, to be performed during the beam time period 2018/19.

Facility	No. of projects Y1	Total no. of projects Annex 1	No. of users Y1	Total no. of users Annex 1	No. of access units Y1	Total no. of access units Annex 1
HiRadMat	6	5	37	20	616	200
UNILAC	0	8	0	48	0	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. In year 1, some facilities have not started yet due to the ongoing construction of the infrastructure. Table 3 shows the activity in terms of number of projects, users and access units. The status of the five facilities is as follows:

- ANKA/KARA @ KIT already received the first user support.
- FLUTE @ KIT has already been supported the first TNA Proposals.
- IPHI @ CEA has restarted operation with beam only at end of 2017. Two requests are being discussed (proton beam in September, neutrons beginning of 2019).
- SINBAD @ DESY is still under installation. Its availability in Spring 2019 is confirmed.
- VELA @ STFC had a delay in commissioning and the beam will be available only in the last quarter of 2018. Two groups are preparing requests.

Facility	No. of projects Y1	Total no. of projects Annex 1	No. of users Y1	Total no. of users Annex 1	No. of access units Y1	Total no. of access units Annex 1
ANKA	1	8	2	64	48	480
FLUTE	2	8	7	40	56	320
IPHI	0	12	0	72	0	1,440
SINBAD	0	9	0	36	0	630
VELA	0	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. In the Table 4, the number of projects, users and access units are shown for these facilities. HNOSS had one project supported with 5 users during the first period. It had provided 136 access units out of 2880 committed. Xbox at CERN had one project supported with 3 users and had provided 80 access units out of 6000.

Facility	No. of projects Y1	Total no. of projects Annex 1	No. of users Y1	Total no. of users Annex 1	No. of access units Y1	Total no. of access units Annex 1
HNOSS	1	4	5	44	136	2,880
XBox	1	4	3	64	80	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 year, 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 year. At LPA-UHI100 facility, the Transnational access activity has been opened to external users. 4 scientists from Queen’s University Belfast had access to the electron source at LPA-UHI100 facility during 1 project. 24% of access units foreseen have been delivered.

Facility	No. of projects Y1	Total no. of projects Annex 1	No. of users Y1	Total no. of users Annex 1	No. of access units Y1	Total no. of access units Annex 1
APOLLON	0	6	0	48	0	180
LPA-UHI100	1	4	5	40	152	640
LULAL	0	6	0	36	0	480

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

**WP14 (Promoting Innovation)** had one deliverable (D14.1) “set up of the PoC innovation funding scheme” to achieve. This deliverable, due month 12, was indeed completed with almost 6 months in advance. This has allowed launching the Call for Proposal already in December 1st, 2017. No other deliverables were due in the reporting period. However, we can anticipate that the D14.3, “Production of material samples of C-based and metal-diamond composites” due in month 24, is almost 1 year in advance, as the scope of sample production and characterization, has been virtually successfully concluded. By the same token, the deliverable D14.4 “1st length of industrial HTS”, due month 30, can be considered well progressing to conclusion before the deadline. Milestones were MS42 “set-up of Industry Advisory Board”, completed on schedule, and MS47 “revised requirement document”, recently submitted.

In **WP15 (Thin Film for Superconducting RF Cavities)**, preparation of copper substrates for deposition was identified as the main goal for 1<sup>st</sup> year. To meet this goal, 50 samples were prepared at CERN by cutting them from the same copper sheet. Then 25 samples were treated at CERN with SUBU, other 25 samples were sent to INFN and treated there with EP, SUBU, EP+SUBU and tumbling. All prepared samples were sent to partners for the Nb film deposition and following characterisation of the films. A few more samples were sent to RTU for exploring the laser polishing. The deposition facilities at INFN, University Siegen and STFC were updated and commissioned; sample deposition started in March-April 2018. RTU is exploring the film characterisation method based on the exoelectron electron emission compared to thermally stimulated electron emission. In parallel, two superconducting characterisation facilities were built or updated and commissioned at IEE and CEA. HZB and CERN are designing a new sample holder for SRF test that can be used on both facilities. Milestone MS49 (organisation of kick-off meeting) and Milestone MS50 (First sample substrates cleaned at INFN for depositing at partners) were completed on schedule. Deliverable D15.1 (Evaluation of cleaning process) 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.

During the first year, 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 or milestones scheduled during the reporting period. However, considerable progress was made in task 16.3 toward the conceptual layout of gun and modulator, constituting the next milestone (MS53) due by month 18. 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 smaller progress than

expected was made in task 16.2 due to unanticipated changes in the personnel resources at GSI and IAP. 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, no impact on the first milestone (MS55) of task 16.2, 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)** first deliverable (D17.1) on Material Characterization was achieved. This was done in 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 experiments such as FlexMat at CERN and an irradiation campaign of coated and uncoated MoGr samples at GSI. Additionally, the Multimatt experiment was successfully completed at HiRadMat, 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 studied in the frame of PowerMat survived and were qualified for use in future BID, most notably collimators for the high luminosity upgrade of the LHC (HL-LHC).

**WP18 (Very High Gradient Acceleration Techniques):** In Task2 (2 stage injection), the conceptual design of the electron transport line has been completed, and a preferred version was identified. In Task 3 (exotic laser beams), the Particle-In-Cell simulations were started, followed by a first test of creating Laguerre-Gaussian doughnut beams. In Task4 (dielectric laser acceleration) the hiring of additional personnel to perform the work programme has been completed, the simulation efforts are continuing, and the design of the experiment was started. In Task5 (spectral charge frontier) the theoretical study and benchmarking of injection schemes are ongoing. The Milestone MS18.1 (Setup simulation framework for acceleration and radiation generation in wakefields driven by lasers with orbital angular momentum) was achieved on time in Month 6 and Milestone MS 18.2 (Setup of experimental facilities for laser wakefield acceleration experiments using laser drivers with orbital angular momentum) was achieved on time on Month 12.

---

## 1.2 Progress towards objectives and significant results

**WP1 (Management, dissemination and ensuring sustainability):** The Consortium Agreement was signed by all partners, the Governing Board and the Steering Committee for the Project were formed and had their regular meeting accordingly to the rules defined in the Consortium Agreement. The Project kick-off meeting took place and the first Annual Meeting was organised. The Working Group on Sustainability of Accelerator research was formed and organised a first Workshop with industry.

**WP2 (Training, Communication and Outreach for Accelerator Science):** The project communications infrastructure and tools were set-up (web site and social media). 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.

**WP3 (Industrial and Societal Applications)** has organised the Workshop foreseen by MS13 and has started the activities of all Tasks. A new applications identified in the WP has led to an application for funding to the ARIES Proof-of-Concept Fund.

The main objective for **WP4 (Efficient Energy Management)** during the first year was the co-organisation of a general workshop on sustainable accelerator based research facilities. This workshop was successfully held at the ELI-NP facility in Bucharest/Romania. For the four tasks the main objective was to hire post-docs or students for their specific projects, to define detailed parameters and to start design work, which was successfully achieved.

**WP5 (European Network for Novel Accelerators)** aimed for an efficient coordination of the European novel accelerator community. A central service (EuroNNAc office) to the novel accelerator community is provided and an exchange platform is installed by implementing workshops and a coordinated European strategy. All future Workshops and meetings are scheduled. Planning of a further specialized school for novel accelerators to be held in 2019 has started.

**WP6 (Accelerator Performance and Concepts)** has started the identification and ranking of performance degrading mechanisms for hadron storage rings and synchrotrons and of novel methods to reduce accelerator impedance; and a definition of the optimal design and operational characteristics for particle accelerators to improve the availability. In the reporting period, WP6 has carried out eleven workshops, whose discussions prepared the ground for meeting its ambitions.

The main objectives of **WP7 (Rings with Ultra-Low Emittance)** during the reporting period were the organisation of the workshops, supporting the activities identified in the tasks of the work package. These have all been carried out as planned. The corresponding milestones consisted in reports which were duly produced for (MS33-MS34) and the report for MS35 is in preparation (due in Year 2). No deliverables are yet foreseen in the present reporting period. No changes in the lists of milestones and deliverables in Annex 1 are expected.

In **WP8 (Advanced Diagnostics at Accelerators)**, dedicated workshops on three specialised subjects were organized. The first workshop was organized as a common event of Task 8.2 and 8.3, whilst the second was a common event of Task 8.4 and 8.5. The third dedicated workshop is organized by Task 8.3 but will have contributions from both the hadron and electron community. Two exchanges of personnel for a period of around 2 weeks took place with a third exchange shifted to June 2018 due to visa problems.

The objectives for **WP9 (Magnet Testing)** at CERN was to accommodate as fast as possible 3 selected projects and start testing while keeping the CERN internal deadlines unchanged. At Gersemi,

due to the ongoing construction and preparation of the infrastructure, the user support at the facility has not started yet. The facility will be operational by the end of 2018.

In **WP10 (Material Testing)**, the deliverables for the first period of HiRadMat was to provide access for materials testing and to provide a minimum quantity of 200 Access Units. 600 Access Units have been provided and 5 projects have been approved. GSI M-Branch facility objectives for the first period were the announcement of the TNA program waiting for the start of operation.

**WP11 (Electron and proton beam testing)** objectives for the first period were essentially to finalize the infrastructure in order to provide user support by the end of 2018. IPHI, ANKA/KARA@ KIT and FLUTE @ KIT received the first user requests. IPHI @ CEA will resume operation at end of summer. SINBAD @ DESY is still under installation. VELA @ STFC had a delay in commissioning and will restart operation soon.

In **WP12 (Radio Frequency Testing)**, the primary objectives were to advertise the new user facilities and to set up the selection committee. They have been achieved, and the experimental programme is slowly starting.

The objectives of the **WP13 (Plasma beam testing)** were to set-up the selection panel and to advertise the access to the facilities. APOLLON is starting operation, LIDYL has welcomed the first users and the LULAL facility had some delays in providing user support due to the service equipment repair and preparation for experiments.

**WP14 (Promoting Innovation)** has evaluated within the Proof-of-Concept fund a series of ten technology developments finalized to commercial applications. The Industry Advisory Board to improve and expand collaborations and joint research with industry was set up. 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 main objective of **WP15 (Thin Film for Superconducting RF Cavities)** was to 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 samples have been produced and jointly measured in the participating laboratories.

The main objectives of **WP16 (Intense, RF modulated E-beams)** were the development of the concepts and the design for electron gun and modulator and the development of the 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)** had several main objectives that were achieved in year 1. The extensive characterization campaign of advanced materials was reported in D17.1. The assessment by simulation of long-term radiation damage in materials for collimators and the selection of beam parameters for future irradiation experiments were completed, as was Multimat, a comprehensive experiment on 18 different materials at CERN HiRadMat facility.

**WP18 (Very High Gradient Acceleration Techniques)** has met two contractual milestones, both concerning the studies of laser wakefield acceleration with exotic laser beams, and first results have been produced. 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.

## 1.3 Explanation of the work carried per WP <sup>1</sup>

### 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. It included 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 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.

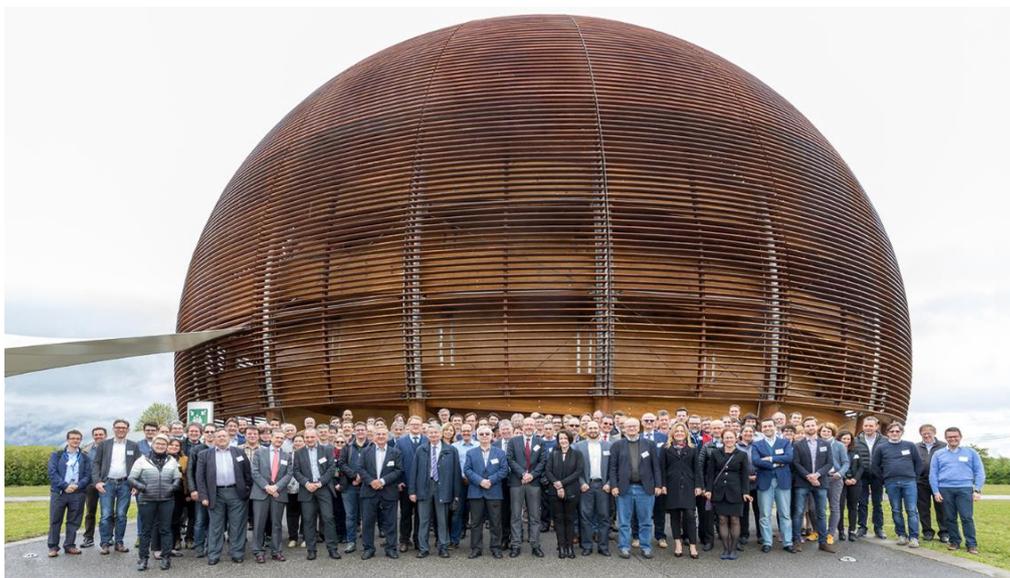


Figure 1: Group picture from the ARIES Kick-off meeting at CERN.

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

---

<sup>1</sup> The partners carrying out the work in each task are mentioned in the text or can be found in brackets.

- 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.
- The **Steering Committee (SC)**, with at least one representative per WP, met 4 times in the first year of the project to discuss the status of deliverables and milestones and the scientific progress in each WP.
- The **Industrial Advisory Board (IAB)**, composed of 6 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.

### Contractual milestones and deliverables

In the Y1 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: 1<sup>st</sup> Annual Meeting – will take place on 22-25 May at RTU

### Project planning and status

In the first year of the project, the contractual objectives included the delivery of 3 deliverable reports (out of the total 52) and 21 milestones (out of the total 66). 2 deliverables and all 21 milestones due in this period have been achieved. The status of the delayed deliverables and milestones is detailed in *Section 3.1*.

The Figure 2 below reports the progress in the preparation of the Milestones. Some initial delays were compensated, and by M13 all Milestones were achieved, as well as a Milestone due only in the second year and delivered in advance.

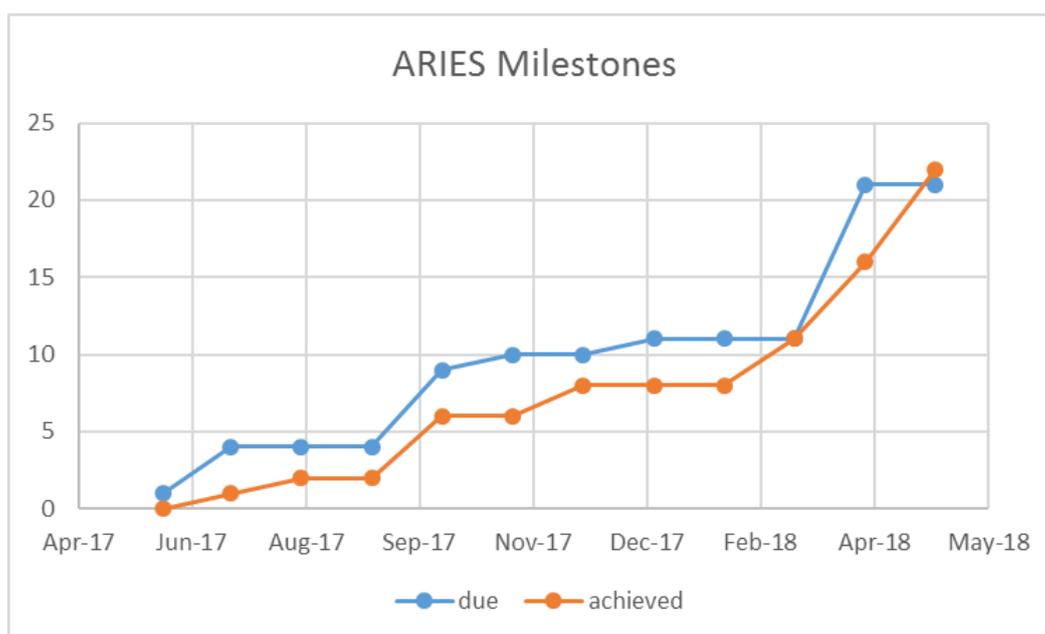


Figure 2: Progress in the Milestones preparation

### Problems and solutions

No particular problems occurred during the first year of the project.

### Budget adjustments

No budget adjustments of the EC contribution in Annex 2 occurred in the first year of the project.

### Change of tasks between beneficiaries

No changes of tasks between beneficiaries occurred in the first year of the project.

### 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. These were: 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<sup>2</sup>. 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.

<sup>2</sup> A partner organisation in ARIES is defined as a participant contributing to the project in cooperation with a beneficiary.

---

## 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 Meeting. 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 year 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 held 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 with high TRL. To avoid overlaps and to exploit synergies, a close coordination is put in place with the Coordinator of ARIES being a member of the AMICI Steering Committee. Synergies between the two projects can be exploited in the connection with industry and already during the first year two common initiatives were organised, a co-innovation workshop with 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.

### 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

For its publications, the ARIES project selected Zenodo and a dedicated ARIES section has been created: <https://zenodo.org/communities/aries>

Zenodo is a general-purpose open access research data repository. It was created by OpenAIRE and CERN to provide a place for researchers to deposit datasets. It launched in 2013, allowing researchers in any subject area to upload files up to 50 GB. Zenodo is a strong supporter of open data in all its forms (meaning data that anyone is free to use, reuse, and redistribute) and takes an incentives approach to encourage depositing under an open license.

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

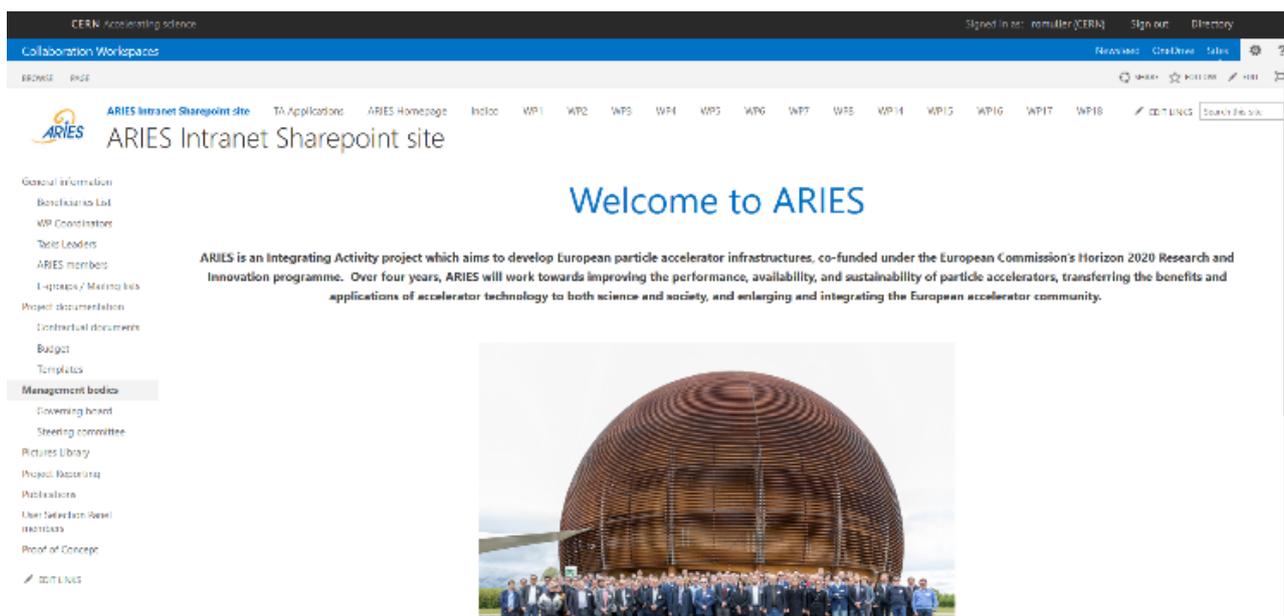


Figure 3: A screenshot of the ARIES intranet, May 2018

A **poster** for the first ARIES Annual Meeting was designed and distributed to project members to announce the details of the meeting. A category ARIES was created in the Accelerating News newsletter to associate the project to this already active accelerators' community media. The newsletter is available on a dedicated website [acceleratingnews.eu](http://acceleratingnews.eu). Articles are published on a quarterly basis and to date four newsletters including ARIES articles were issued. In total more than 10 ARIES articles were published on Accelerating News. As of May 2018, the *Accelerating News* mailing lists contains 1455 subscribers.

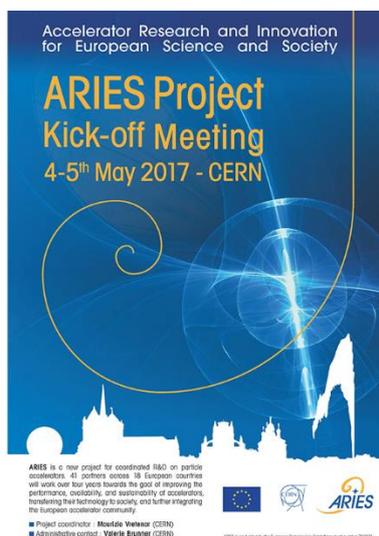


Figure 3: Poster of the ARIES Kick-off meeting

During the first year, no monographs were produced waiting for the attribution of the printing contract.

### 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 4 Poster of Figure 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 Y1 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 year 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. The **project website** (<https://aries.web.cern.ch/>) was launched in May 2017, and to date has had **over 1/3 of a million hits and more than 6,000 unique visitors**. The website was designed to be accessible to a range of different audiences by providing information tailored to their own unique requirements.



Figure 5: A screenshot of the front page of the ARIES website, May 2018.

A **poster** for the first ARIES Annual Meeting was designed and distributed to project members to announce the details of the meeting. A category ARIES was created in the Accelerating News newsletter to associate the project to this already active accelerators’ community media. The newsletter is available on a dedicated website [acceleratingnews.eu](http://acceleratingnews.eu). Articles are published on a quarterly basis and to date four newsletters including ARIES articles were issued. In total more than 10 ARIES articles were published on Accelerating News. As of May 2018, the Accelerating News mailing lists contains 1455 subscribers.

A video to present the ARIES project to a public non-expert audience was created by CERN Audiovisual Production Service in two 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 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.

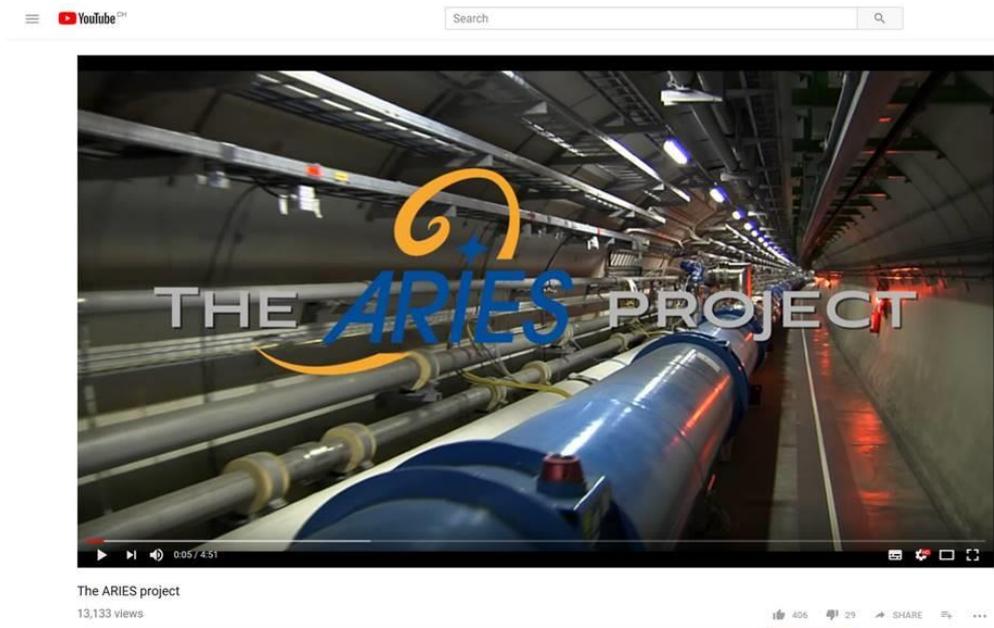


Figure 6: Screenshot from the ARIES video

The social media approach followed in ARIES is to reach to 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 thanks to the ARIES’ partners it is possible to reach to a large pool of followers interested on the topics relating to accelerators.

For example CERN has 2.6M Twitter followers and 662K Facebook followers. Other ARIES partners reach similar levels of magnitude in followers already.

With almost none dedicated actions but through referencing in the main posts on partners’ social media channels, the ARIES Facebook gained 44 followers whilst the LinkedIn on 35.

This cascading approach has been used for the ARIES presentation video which was posted on CERN FB, Twitter, LinkedIn and YouTube channels and leveraged a great level of interest.

**Contractual milestones and deliverables**

In the Y1 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 year 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. Three 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 year of the project has 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 half of the lecturers. Finalisation of the sub-module lecturers and syllabus details is in progress.

### **Contractual milestones and deliverables**

In the Y1 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 will study 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 3 Proof-of-Concept proposals and participation in a 4<sup>th</sup>. It is working with an associate partner, the 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  $\gamma$ -source users. If this works, further webinars will be undertaken on more specialist topics for new users.

It is leading a proposal to one of the final H2020 calls in the Societal Challenges area, on “High-quality organic fertilisers from biogas digestate”. The plan is to propose the use of electron beams. This call is part of a joint EU-Chinese Ministry of Agriculture agreement and must have both EU and Chinese partners, including industry. The work is at an early stage, but the proposed proposal title is: PHOEBE: Production of High-Quality Organic Fertiliser using Electron Beams.

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

A report on current applications of electron beam accelerators up to 10 MeV used in R&D programs and industrial implementations has been prepared. The material can be the basis for future perspectives of accelerator design improvements and their role in the enhancement of the radiation technology applications share of the global economy and social well-being. There is no argument that e-beam technology is capable of providing a sustainable solution to solve any technological problem but many beneficial effects have been demonstrated by studies done both in research laboratories and the industrial implementation of radiation processing:

- 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 absorbent for improving agriculture.

Radiation processing in the case of water rich materials can be 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).

The report is written to describe and evaluate the field of EB technology practical applications and the future prospects for accelerator technology implementation. It will help to evaluate new solutions for radiation facilities and accelerator technology development. Progress in accelerators developments includes more efficient and compact accelerator constructions, new materials for certain accelerator components, new RF devices, superconductivity implementation, 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.

### **Contractual milestones and deliverables**

In the Y1 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 off gases electron beam treatment. The main source of air pollutants such as NO<sub>x</sub> and SO<sub>2</sub> 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 off-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<sub>x</sub> and SO<sub>2</sub>, 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 expensive catalyst (the most commonly used is Selective Catalytic Reduction). Taking into account the more and more strict regulations on emissions of nitrogen and sulfur oxides, the current methods are insufficient. Therefore, it is necessary to look for new solutions to remove both nitrogen and sulfur 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<sub>x</sub> removal efficiency, when using hybrid method the NaClO<sub>2</sub> oxidant, can be higher than 80%. Such high removal efficiency would fulfill the requirement imposed by the law and shows a 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 1<sup>st</sup> 2017](#) and in [Genova on March 1<sup>st</sup> 2018](#).

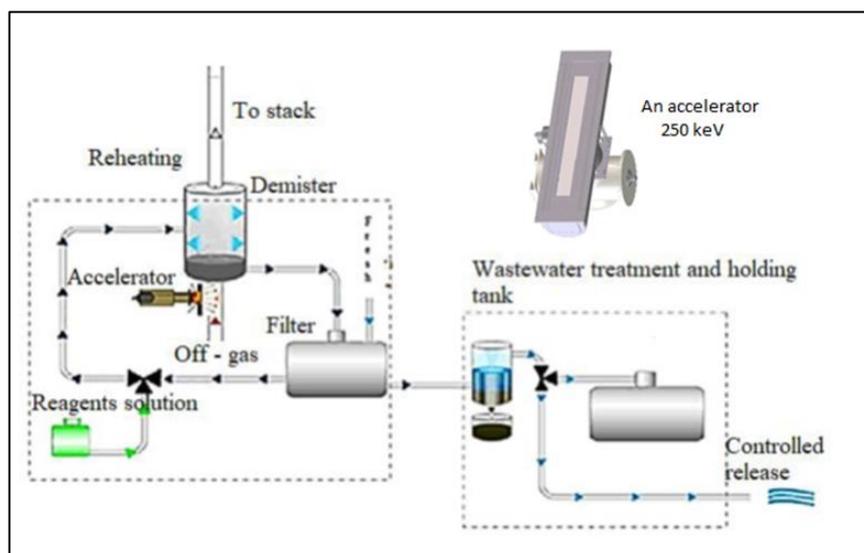


Figure 7: Technological units of the hybrid electron beam technology system

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 deeper understanding of 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 ENERGÉTICAS E NUCLEARES, Brazil) to develop new applications of low energy electron irradiation concerning actual challenges of environmental protection.

### 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 CLEAR use for 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/overview>

The second objective is progressing well, a first optics design of an electron accelerator at medium energy dedicated to applications 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 2. In the energy range 30-70 MeV, PRAE will contribute to unravel the proton radius puzzle with the ProRad experiment. The 50-140 MeV electron energy range will allow developing 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 the other possible applications of PRAE is being organized for Fall 2018 at Orsay.

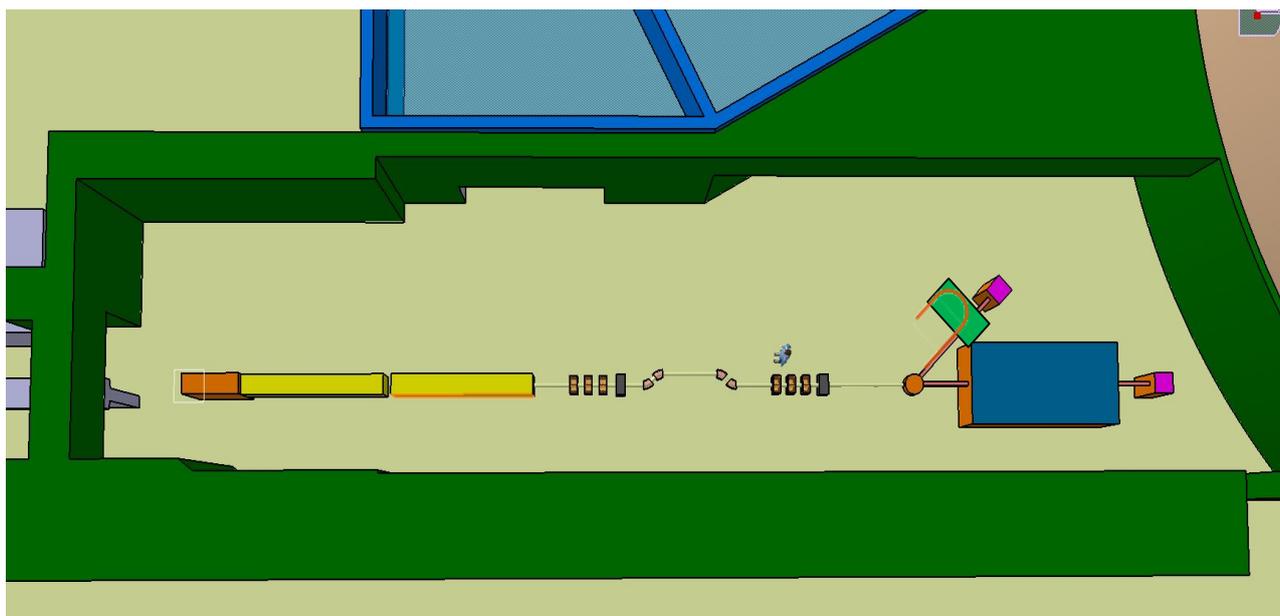


Figure 8: Schematic view of the PRAE accelerator (140 MeV) with the two experimental beam lines

### 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  $\sim 450\mu A$  has been measured in the beam probe. Beam profile measurements using scintillation ceramic screen materials are in progress.

A numerical code to simulate the particle tracking of  $H^-$  ion source extraction has been performed using a macro structure. The magnetic and electric field are calculated by Opera-3D software and TOSCA module.

---

## 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, 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 s.c. 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 Y1 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 with at least 10 to 20% higher efficiency than 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). It has been decided that task 4.2 will 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, that could be used for the “Compact Light” project. 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  $1.5\mu\text{A}/\text{V}^{1.5}$ . Initial simulations are now going on with two freely available 1D/2D disk-model codes (AJDISK, developed at SLAC by A. Jensen, and KlyC, developed at CERN by I. Syratchev) 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). Thanks to the recent fabrication of a 5 GHz kladistron in the scope of the previous Eucard2 project, we will have a solid benchmark to calibrate these simulations.

### 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. For this we are acquiring the scientific and technical skills for turbulent flows, thermal transfers, modelling strategies and two-phase flows. This will be supplemented by a formal training on the modelling tools, available in ANSYS, which are used in the present project.

### Task 4.4. High Efficiency SRF power conversion

The Post-docs hired to perform the studies related to this Task have conducted magnetic measurements on an existing vacuum vessel, which is meant to accommodate four 5-cell bulk Niobium cavities operating at 704 MHz. 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. The measurement set-up is shown in Figure 9.

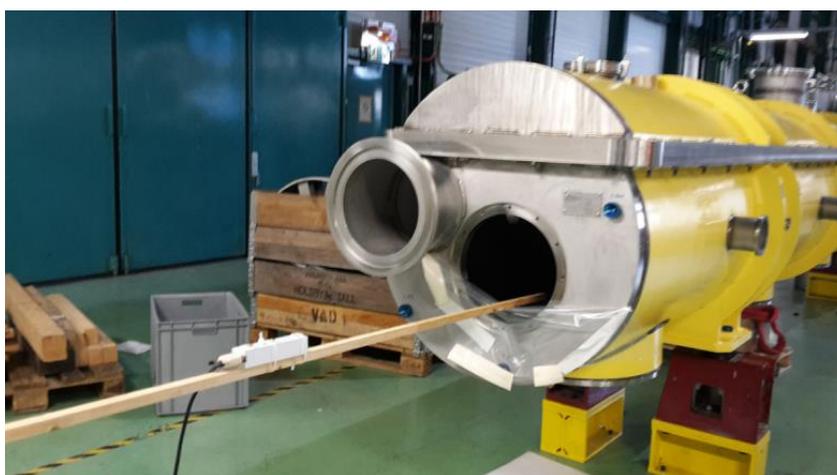


Figure 9: Magnetic field measurements on a cryo-module vacuum vessel with a 3-axis fluxgate mounted on a wooden stick.

The results indicated a shielding factor of 2-3 with a very low magnetization which contributes on average 13 uT on axis, which is roughly 1/3 of the ambient magnetic field. Peak values of up to 80 uT have been measured around the top weld of the top part of the vessel, but as they decline rapidly within a few cm, they are not considered detrimental. The detailed results have been summarized in report, which will soon be published as a CERN technical note.

### Task 4.5. Efficient operation of pulsed magnets

The objective of task 4.5 is the efficient operation of a pulsed iron-free quadrupole magnet as alternative to DC magnets. The first steps were to evaluate, choose and procure decisive hardware to improve the existing pulse circuit. Beforehand, some theoretical work and simulations had to be carried out, to determine the requirements for the hardware. In our next step the pulsed circuit shall 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 a market survey

for the key components which are high-voltage pulse diodes, pulse-resistors and fast high voltage switches. The diode ABB D2601N was selected with a surge current of 52 kA 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. The pseudospark-switch TDI1-200K/25 is capable of 200 kA and therefore sufficiently dimensioned for future developments beyond the planned tests. Procurement of these items shown in Figure 10 is done. 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 10: Pulse Diode, Pseudospark-Switch and Resistor (left to right)*

## **WP5: European Network for Novel Accelerators (EuroNNAC)**

This NA will continue 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.

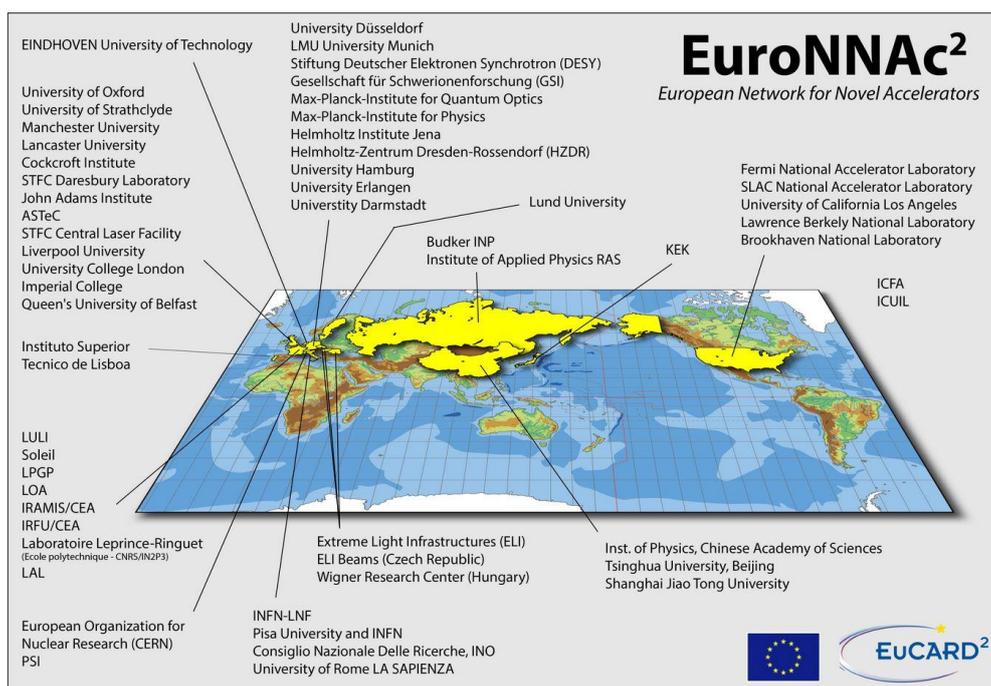


Figure 11: EuroNNAc3 members graphic and additional new members (May 2018)

### Contractual milestones and deliverables

In the Y1 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. 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 October 2019 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 AXISIS 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 12: 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.

### **Contractual milestones and deliverables**

In the Y1 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, dedicated novel accelerators school and programs of future EAAC workshops from students’ perspective.

At the Yearly EuroNNAc meeting 2017, a proposal to establish a prize for an outstanding early career researcher in the field of novel accelerators was approved. Roman Walczak, Bernhard Holzer and Ralph Assmann will prepare a proposal of the procedure. It is foreseen that the first prize will be announced at EAAC 2019.

In parallel to the networking activity, the main emphasis at present is the training and education in novel acceleration techniques. While being of general importance for the students, this initiative

follows as well a request (deliverable) defined within the ARIES framework. The organisation and preparation of this big event is already under way and a first version of the program has been defined: Under the umbrella of the CERN Accelerator school a special lecture series on "High Gradient Acceleration Techniques" will be organised in spring 2019 in Portugal. The program covers the full spectrum of dielectric and plasma based acceleration concepts and includes in addition of the theoretical part, actual design work of the student that – under the leadership of tutors – will work on realistic problems. About 120 participants are expected.

A prospect of organizing a meeting of students between EAAC 2019 and 2021 (there will be CAS school as described above between EAAC 2017 and 2019) 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.

## WP6: Accelerator Performance and Concepts (APEC)

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 LHeC design study, 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, 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. A number of publications in peer-reviewed journals and conference proceedings testify to the fruitfulness of the ARIES WP6 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.

### Contractual milestones and deliverables

In the Y1 reporting period, Task 6.1 had one milestone to achieve:

- MS26: Report on 1<sup>st</sup> 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 5 workshops, five times more than anticipated in the proposal. The high rate of workshops demonstrates how much this networking activity is appreciated by the community, and which needs it fulfills. 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) 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 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 USA current development with IOTA program. The interplay of space charge effects with nonlinear circular accelerators is now central for the intensity frontier of CERN and GSI. Figure 1 shows the intriguing form of a fixed line created by a resonance of order 6 in the presence of space charge.

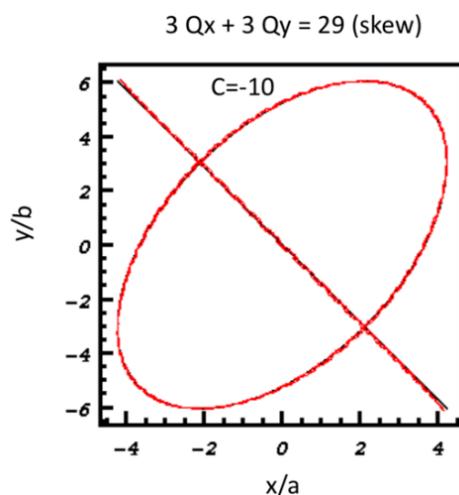


Figure 13: Fixed line created by a resonance of order 6 and space charge.

The United States 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 APEC 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.

### 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 in summer 2018. Assessing the feasibility of the accelerator-reliability information system has been contracted to AIT.

### Task 6.4. Improved Beam Stabilization

Co-organized jointly with ICFA, an ARIES International Workshop on Impedances and Beam Instabilities in Particle Accelerators was held in Benevento (Italy) from 18 to 22 September 2017, and hosted by the University of Sannio.

Research activities of Task 6.4 include:

- Reviewing existing strategies & methods for beam-impedance assessments and impedance models: studying of the minimum thickness of a NEG coating to mitigate the electron cloud instability, guaranteeing a good pumping efficiency while, at the same time, reducing as much as possible the contribution to the coupling impedance.
- Developing and evaluating novel methods to reduce accelerator impedance: studying low impedance BPMs and bellows for FCC-ee.
- Simulating the heating of the new DAFNE vacuum chamber for Siddartha experiment without water cooling (Figure 14) and with water cooling (Figure 15).

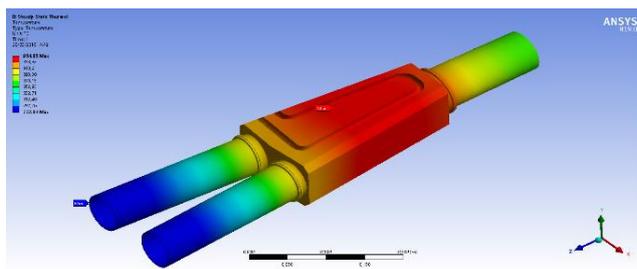


Figure 14: DAFNE vacuum chamber w/o cooling

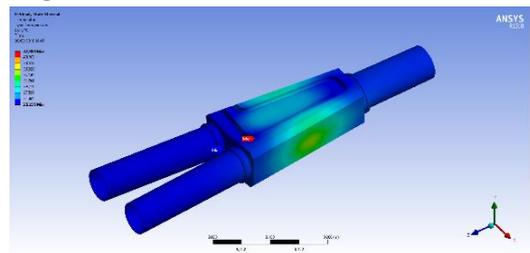


Figure 15: DAFNE vacuum chamber with cooling.

- Conceptual design of advanced beam feedback systems for FCC-ee, presented at the FCC Week 2018.
- Tests of peak e- beam currents stored during the KLOE-2 experiment (1.7 A). The beam current was predominantly limited by longitudinal quadrupole oscillations, which were controlled by a special technique implemented in the synchrotron (dipole) feedback system of DAFNE. This technique uses the *QPSK* modulation detuning in the feedback back end for damping both dipole and quadrupole beam motions.

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

The field of Energy Recovery Linacs (ERLs) is developing more quickly since the last years. This can be seen in the growing number of planned projects as well as 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 just at the beginning of the funding period of ARIES in June 2017. Even though it wasn't directly funded by ARIES it was closely related to the goals of this WP. As one outcome one can state, that ERLs are more seen as drivers for colliders or internal experiments in particle physics by now and not anymore as drivers for future light sources. Also new applications like electron coolers for hadron rings are in focus currently. There are several projects planned or close to start commissioning as can be seen in Figure 16. 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 to reach and is envisaged by a number of projects. During the ERL workshop a data collection of current, future and past ERL projects was initiated (credits to O. Brüning), which is already a significant step towards completing the next year's milestone of the WP (M27: report on: Parameter database for various ERL & Linac facilities). Task 6.5 co-organized two specific workshops. The first one was the LHeC and FCC-eh Workshop in September 2017 at CERN, 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 is aiming on building a test facility for that machine. The second workshop took place at Frankfurt, Germany in February 2018. Here issues on conventional linacs for hadrons have been discussed. In particular, the workshop was related to injection section of high current ion linacs.

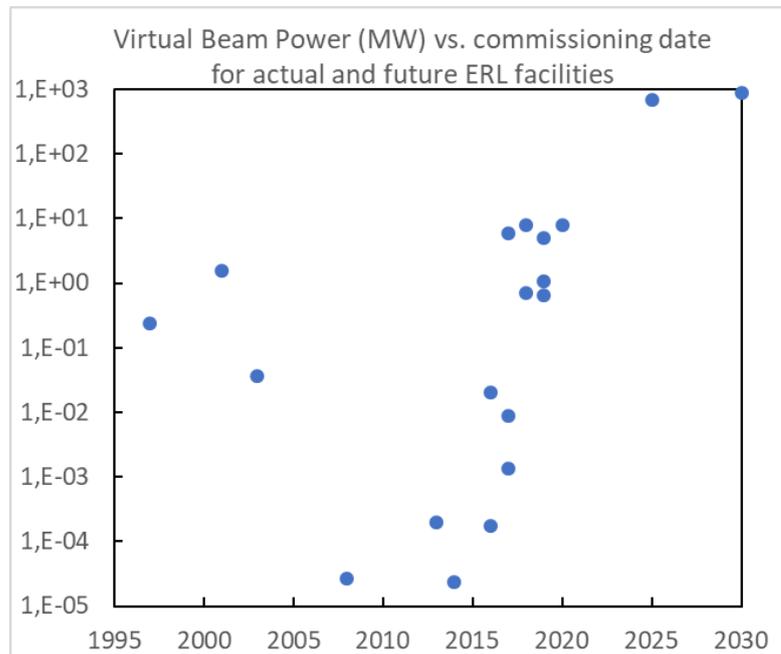


Figure 16: Beam power of current and future ERL projects. It can be seen, that during the last years a lot of new projects emerged, which will be commissioned soon and aim for beam power in the MW range.

### Task 6.6. Far Future Concepts & Feasibility

A dedicated workshop on “Photon Beams” reviewed the state-of-the-art 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 17).

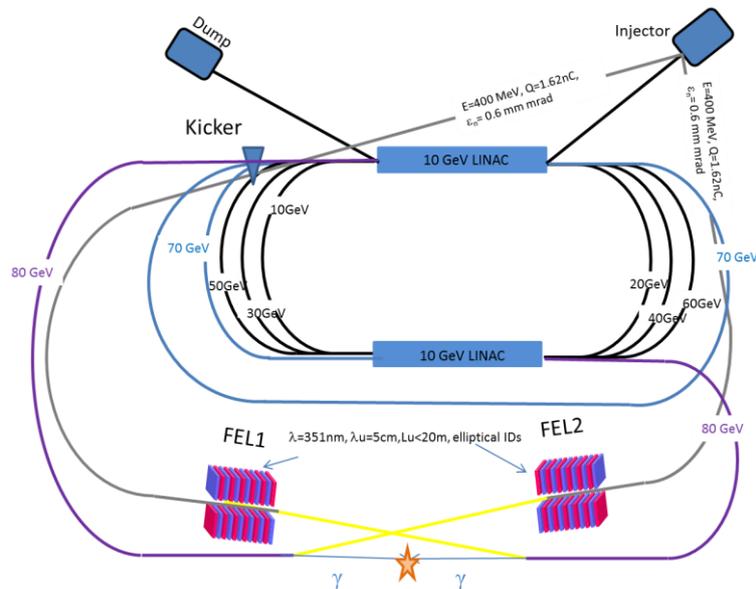


Figure 17: Generic recirculator-based Higgs factory with two FELs (A. Meseck).

Human resources: A postdoc was recruited in May 2018 at INFN Padova with a one year contract.

## 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 meetings 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 organisation of the general workshop at CERN in January 2018, saw more than 80 delegates. Progress in the design of the upcoming facilities, show 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 18.

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.

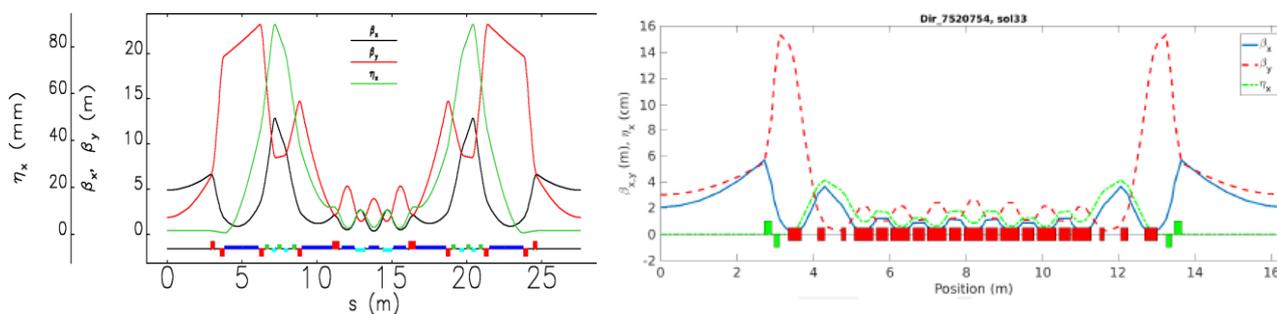


Figure 18: lattice for APS-U (62 pm) and ALS-U (50 pm)

### Contractual milestones and deliverables

In the Y1 reporting period, Task 7.1 had one milestone to achieve:

- MS33: First general workshop of the RULE network - [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 19 reports the reduction of the transient oscillations during the kicker pulse.

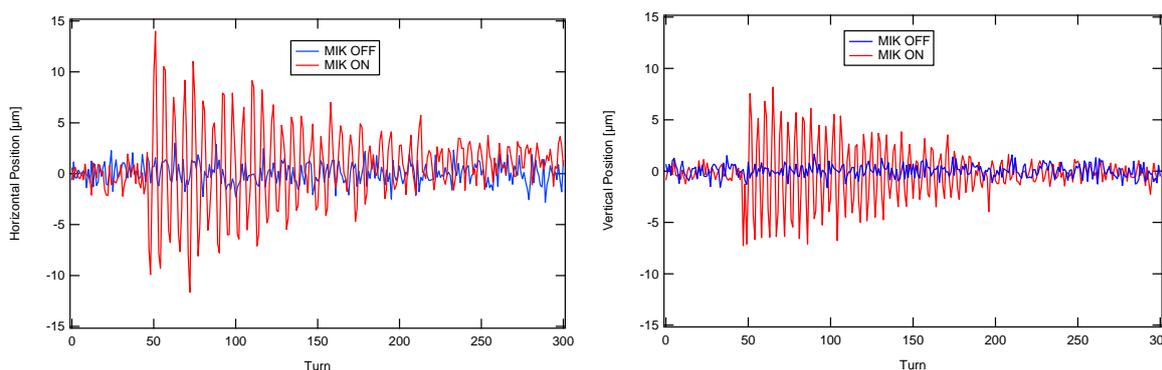


Figure 19: MAX IV beam transient during the injection with NLK: horizontal (left) vertical (right)

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. Thyatron 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, that constitute the cutting-edge frontier of ultra-low emittance rings with emittance in the tens of pm.

### Contractual milestones and deliverables

In the Y1 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.

#### **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.

### **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, 3<sup>rd</sup> 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 3<sup>rd</sup> 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 Y1 reporting period, Task 8.1 had one milestone to achieve:

- MS39: Report on 1<sup>st</sup> Annual workshops of all tasks - [ACHIEVED](#)

#### **Task 8.2. Advanced instrumentation for hadron LINACs**

In May 2017 a Topical Workshop (task leader GSI) 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) 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  $\mu\text{m}$  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 was planned for February 2018 with a GSI employee to work at the UK DIAMOND Light Source on topics related to closed orbit feedback.

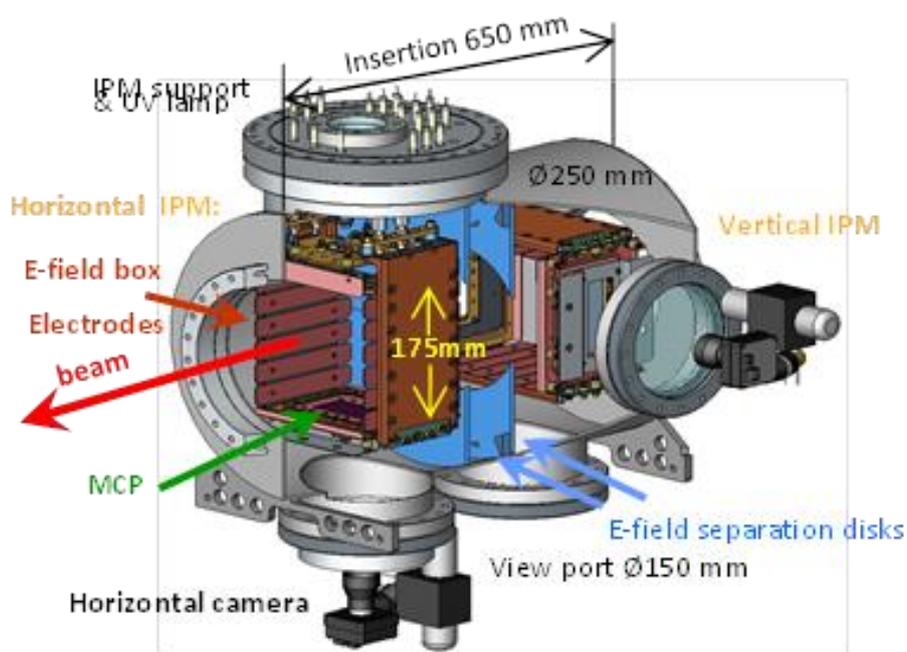


Figure 20: Typical installation of a horizontal and vertical IP

### 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 (task leader GSI) and Task 8.3 (task leader CERN) 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 electromagnetic monitors in Hadron Accelerators’](#) took place from 14<sup>th</sup> to 16<sup>th</sup> of May 2018. (This workshop had to be shifted slightly outside of the report period due to clashes with other workshops and conferences held in spring 2018.) The goal was to strengthen the collaboration between the beam

dynamics and beam instrumentation community as both communities have to contribute to a correct interpretation of advanced beam measurements. Additionally, people working at 3<sup>rd</sup> 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 show 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 (task leader ALBA) with the collaboration of Task 8.5 (task leader DESY). 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 2-3 $\mu\text{m}$  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  $\mu\text{m}$  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 M. Siano (Univ. Milano) staying at ALBA 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 (task leader ALBA) and Task 8.5 (task leader DESY). See summary under the section for Task 8.4.

The next event will be a Topical Workshop on '[Longitudinal diagnostics for FELs](#)' organised for June 2018. The bunch length and longitudinal distribution are some of the most important parameters to be measured for these 4<sup>th</sup> generation light sources. The results of this workshop will be summarized in the next annual report.

## **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 mm 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 EUcard-2. It is planned to be done also in the next conferences in the field of superconductivity and magnet technology.

### **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 essentially based on feasibility with the installations at MagNet and GSI 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, teams that promotes diversity, multicultural and multidisciplinary of a team 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		
Year 1 (M1-M12)	3	3	15	464
Foreseen for project (M1-M48)	8		40	1,920

### Scientific output of the users at the facility

The two first projects just started and yet they could not entirely analyse all data and publish but definitively is their plan to do so.

1. 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 (MgB<sub>2</sub> 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). The team of 2 young scientists and their group leader spend time with us in the test facility to install their shield fabricated in Hungary inside a magnet that is CERN property and was foreseen 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 3<sup>rd</sup> one tested.
2. 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. Fibbers of two different technology were installed into the Superconducting Link developed at CERN and built in the industry for the HL-LHC project of CERN. With the help of the fibres 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 came to the initial preparations while a doctoral student from the University of Padua spent a week in recording, analysing in place the data.
3. 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.

## 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 where 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		
Year 1 (M1-M12)	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.

#### User meetings

No user meetings occurred in the reporting period.

## 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 450 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<sup>2</sup> 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, 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 as high-performance instrumentation for tests and measurements during the experiments.

### Description of the publicity concerning the new opportunities for access

HiRadMat and the opportunities for access has been publicised at the following conferences/meetings/articles:

- NUFACT2017, 25-30 September 2017, Uppsala University, Sweden.
- HiRadMat USER DAY 19<sup>th</sup> April 2018, CERN, Switzerland.
- Publication in Accelerating News, “HiRadMat: testing materials under high radiation”, Issue 23, published 7<sup>th</sup> Dec 2017; <http://acceleratingnews.web.cern.ch/article/hiradmat-testing-materials-under-high-radiation>

### 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 15<sup>th</sup> September 2017 to review experimental requests for 2018. Previous SB were also held in 2014, 2016.

## Description of the Transnational Access activity

### User projects and experiments

As host facility, support is continuously provided by the HiRadMat team to all users. The project begins with the design and cross-checks of the integration 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, the TA projects received 6 projects. Each project plan was successfully completed where a total of 616 TNA hours was used. HiRadMat is currently on track to deliver the agreed Access Units to the experiments associated with the ARIES project.

**HRMT19** aims to study the signal linearity and response, calibration, saturation and comparison of different types of Beam Loss Monitors (BLMs).

This project has continued from 2015 and has gained vital data in the analysis of BLMs. For the duration of TA under WP10.1, 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.

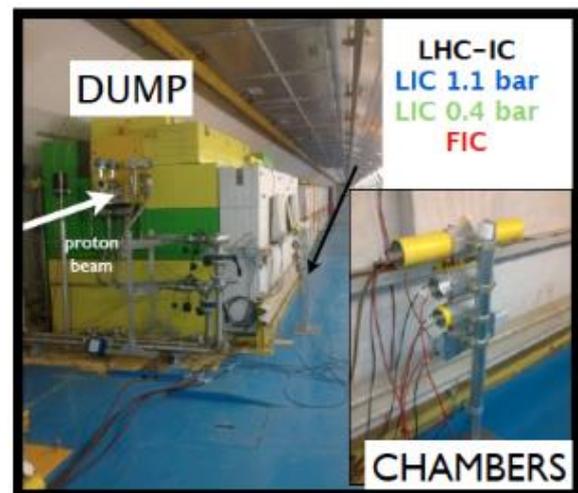


Figure 21: Example of BLM set-up in the experimental area. BLMs are positioned on and near the Beam Dump.

**HRMT21-RotCol** tested a rotatable collimator designed at the SLAC National Accelerator Laboratory, as part of the US-LARP collaboration. 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, 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 (in case of ejecta with LHC-type aperture) on the jaw of the collimator, for example fixation of the jaw due to the material debris. 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.

**HRMT41- ATLAS Pixel** aims to study the effects of accidental beam loss scenarios for the ATLAS tracking detectors for HL-LHC. This project involves 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 aim of **HRMT38: FlexMat** is to test the dynamic response to 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 will be performed with increasing beam pulse intensity up to nominal value (288 bunches,  $1.7 \times 10^{11}$  p/b or higher). On- and off-line techniques to monitor the response and possible failure limits of simple and composite targets will be 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

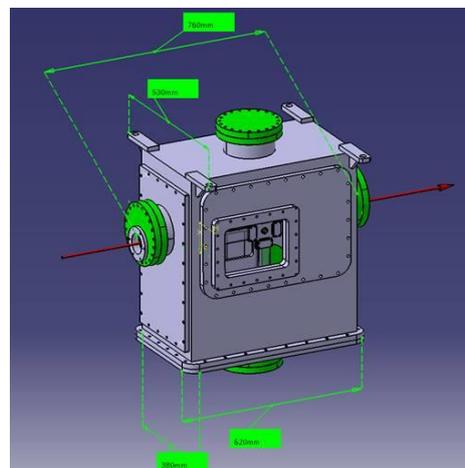


Figure 22: HRMT38 experimental chamber

**HRMT36: MultiMat** aimed to investigate 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 at high intensity, high energy, pulses utilising the maximum proton pulse offered by HiRadMat (288 bunches at  $\sim 3.46 \times 10^{13}$  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 23: Illustration of the MultiMat experimental tank where the multiple target stations are shown on a rotatable barrel.

The main scientific purpose of **HRMTX: BeGrid2** is to further the understanding of thermal shock response of conventional materials (beryllium, graphite & titanium alloys) and novel materials (electro-spun materials, glassy carbon, metal foams, etc.) used for accelerator beam windows and secondary particle production targets. This experiment builds 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 will be included in the test matrix. The primary goal is to understand the failure mechanisms, limits and flow behaviour of the various material specimens as well as compare and contrast the thermal shock responses of the previously irradiated materials to their non-irradiated counter-parts. The experimental set-up will comprise of multiple arrays of specimens, each exposed to different beam intensities. Online diagnostics will include strain/temperature gages, LDV system, and camera systems to monitor the experiment in real-time. Offline examinations will involve 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

HiRadMat	User-projects		Total no. of users benefitting from the TA	Units of access (1 hour)
	Eligible submissions	Selected		
Year 1 (M1-M12)	6	6	37	616
Foreseen for project (M1-M48)	5		20	200

#### Scientific output of the users at the facility

- **Results from HRMT19: BLM2**

HRMT19 will continue to be supported by TA into 2018. Therefore the ongoing work will contribute with final publications made at the end of the project. From the research of 2017 three different ionization chambers will continue to be tested at different location in HiRadMat in order to optimise the system.

- **Results from HRMT21: RotCol**

The initial results of HRMT21 are promising. The full proton pulses were provided by HiRadMat@SPS leading to a successful completion of the experimental beam run. From the initial observations the rotatable jaw was functional after experiment, the integrity of the cooling pipes were demonstrated and there was no fixation/sticking of the jaws. Post irradiation analysis of the experiment is required, and thus no scientific publications are currently available. However, the experiment and initial observations were presented at the HL-TCC meeting on the 3<sup>rd</sup> August 2017 (<https://indico.cern.ch/event/657422/>)

- **Results from HRMT41: ATLAS Pixel**

The studies of ATLAS will continue into 2018 and therefore no publishable results are yet available.

- **Results from HRMT38: FlexMat**

The studies of FlexMat will continue into 2018 and therefore no publishable results are yet available.

- **Results from HRMT36: MultiMat**

HRMT36 was the last experiment to take beam, and concluded a successful 2017 experimental campaign. The proton beam delivered was stable and repeatable and the online measurements systems were successful. Data processing is ongoing and post irradiation analysis will be done when

the experiment is released by radiation protection. 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 damaged was induced on coatings.

Full results will be published which are currently ongoing.

- **Results from HRMT43: BeGrid2**

BeGrid2 experiment will start in 2018; therefore no publishable results are yet available

#### User meetings

<i>Date</i>	<i>Meeting</i>	<i>Venue</i>	<i>Total number of participants</i>	<i>N. of users attending the meeting</i>	<i>Link</i>
2017.05.01	Users meeting	CERN	14	7	<a href="https://indico.cern.ch/event/639690/">https://indico.cern.ch/event/639690/</a>
2017.06.22	Users meeting	CERN	15	8	<a href="https://indico.cern.ch/event/647936/">https://indico.cern.ch/event/647936/</a>
2017.08.10	Users meeting	CERN	9	3	<a href="https://indico.cern.ch/event/658538/">https://indico.cern.ch/event/658538/</a>
2017.09.14	Users meeting	CERN	8	3	<a href="https://indico.cern.ch/event/665044/">https://indico.cern.ch/event/665044/</a>
2017.09.15	Scientific Board	CERN	25	13	<a href="https://indico.cern.ch/event/657996/">https://indico.cern.ch/event/657996/</a>
2017.12.12	Technical Board	CERN	13	6	<a href="https://indico.cern.ch/event/683966/">https://indico.cern.ch/event/683966/</a>
2018.01.22	Technical Board	CERN	13	6	<a href="https://indico.cern.ch/event/683970/">https://indico.cern.ch/event/683970/</a>
2018.04.19	User Workshop	CERN	48	28	<a href="https://indico.cern.ch/event/705237/">https://indico.cern.ch/event/705237/</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 Mat-PAC met September 19-21, 2017.

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. The three 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**

No transnational access activity has been provided yet. GSI beam time blocks are foreseen for second half of 2018 and 2019.

UNILAC	User-projects		Total no. of users benefiting from the TA	Units of access (1 hour)
	Eligible submissions	Selected		
Year 1 (M1-M12)	0	0	0	0
Foreseen for project (M1-M48)	8		48	480

**Scientific output of the users at the facility**

No transnational access activity has been provided

**User meetings**

No user meetings occurred in the reporting period.

## 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

ANKA (Angströmquelle Karlsruhe) at the Karlsruhe Institute of Technology (KIT) is a synchrotron radiation facility providing a unique test environment for accelerator R&D. The ANKA 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 ANKA 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.

### Description of the publicity concerning the new opportunities for access

ANKA 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](mailto: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

One user project “**Optics measurements with TxT data**” was carried out during the reporting period based on a proposal of CERN and Uppsala University. This project was in the field of beam dynamics and beam diagnostics. The first beam dynamic measurements with the CLIC SC Wiggler were carried out at KARA. One user from Uppsala University measured the tune-shift with the wiggler's field at KIT, one user 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		
Year 1 (M1-M12)	1	1	2	48
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” are 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 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.

**Description of the publicity concerning the new opportunities for access**

FLUTE was advertised at the same time and using the same channels as ANKA, 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 will be proof of principal of a novel longitudinal diagnostic tool within several stages.

FLUTE	User-projects		Total no. of users benefiting from the TA	Units of access (1 hour)
	Eligible submissions	Selected		
Year 1 (M1-M12)	2	2	7	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 (SACM) 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 is being upgraded and will be fully operational in the second semester of 2018. 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 a workshop on compact neutron sources held in Jülich in October 2017) 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

In 2017, the IPHI cooling system, designed to evacuate about 1 MW of power that will be dissipated into the Radio-Frequency Quadrupole (RFQ) when operated at full power, was finalized and put into operation. This work included changing water seals at the RFQ level, checking and starting the pumping system for the four cooling loops, and changing the heat exchanger.

After these modifications, the cooling system was put into operation and validated. This allowed restarting the IPHI accelerator in December 2017, at a duty cycle of a few per mil allowed by the RF conditioning of the Radio-Frequency Quadrupole (RFQ).

IPHI	User-projects		Total no. of users benefitting from the TA	Units of access (1 hour)
	Eligible submissions	Selected		
Year 1 (M1-M12)	0	0	0	0
Foreseen for project (M1-M48)	12		72	1,440

**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 11.4. 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 possibility 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		
Year 1 (M1-M12)	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

In Year 1 of the ARIES programme, the VELA facility has been unavailable to users. The VELA facility shares its physical location and some infrastructure with the CLARA FEL testbed, currently under development. The phased schedule of the CLARA facility has required extensive modification, with a knock-on impact on the availability of VELA. The VELA facility is now scheduled to be available for users, including those applying through TNA, for a three-month period from September until December 2018. 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		
Year 1 (M1-M12)	0	0	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.

## 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 HNOSS 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 year 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		
Year 1 (M1-M12)	1	1	5	136 (=17x8)
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 transported to Uppsala during July 2017. During November 2017, two people from the User Group visited Uppsala for discussions and installation of the cavity 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.

### User meetings

<i>Date</i>	<i>Meeting</i>	<i>Venue</i>	<i>Total number of participants</i>	<i>Number of users attending the meeting</i>
6-8/11/2017	Installation	Uppsala	2 + 5	
12-14/02/2018	Installation	Uppsala	2 + 5	

### 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/5 µs/400 Hz klystrons combined in pairs.

These 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 will be granted in two modes: Primary access will be given to accelerating structures and RF components powered by RF directly. Parasitic access will be 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 during the first year have been announcements and dedicated slides during presentations at international events in which the high-gradient rf community are present. See for example the presentations given at HG2017 held in Valencia, Spain <https://indico.cern.ch/event/589548/contributions/2614207/> and the CLIC workshop held at CERN <https://indico.cern.ch/event/656356/contributions/2864080/>. These presentations and announcements link directly to the ARIES Xbox web pages.

## 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 is a spectrometer-based diagnostic system for measurement of electron and light emission from high-gradient cavities. It has been installed in Xbox-1 and is being commissioned now. It is capable of being operated remotely and the system will be fully exploited over the coming months.

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. A photograph of the equipment is shown in Figure 24.

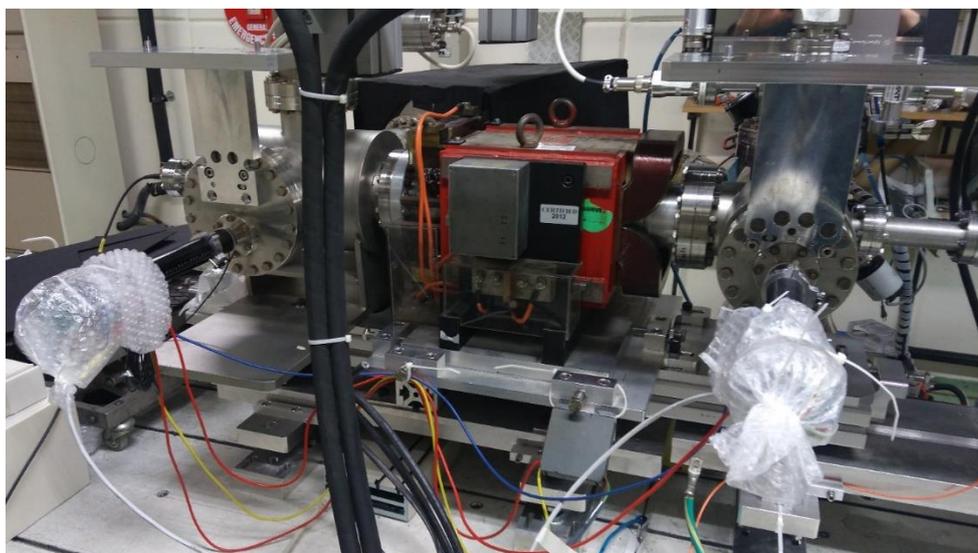


Figure 24: The spectrometer-based high-gradient experiment now underway in Xbox-1.

For the set-up period one user travelled to CERN under the TNA. Once the system is fully commissioned, masters and PhD students as well as post-docs and staff will carry out experiments remotely from Uppsala.

WP12.2 target is to have four User Projects over the four year of the ARIES program, so having the first User Project under commissioning at the end of the first year is satisfactory. The experiment has not yet accumulated many access units but will soon enter a multi-month 24/7 running period so the access units will soon begin accumulating. There are approximately six users in the first User Project so far but since the experiment operates remotely, further masters and PhD students will use the system and the data produced.

XBox	User-projects		Total no. of users benefitting from the TA	Units of access (1 hour)
	Eligible submissions	Selected		
Year 1 (M1-M12)	1	1	3	80 – ongoing, commissioning underway
Foreseen for project (M1-M48)	4		64	6,000

### Scientific output of the users at the facility

The first User Project is currently under commissioning so research results cannot yet be reported.

### 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.

## 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 acceptance 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. 1<sup>st</sup> 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		
Year 1 (M1-M12)	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.

#### 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*.

### User projects and experiments

The users 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 25.

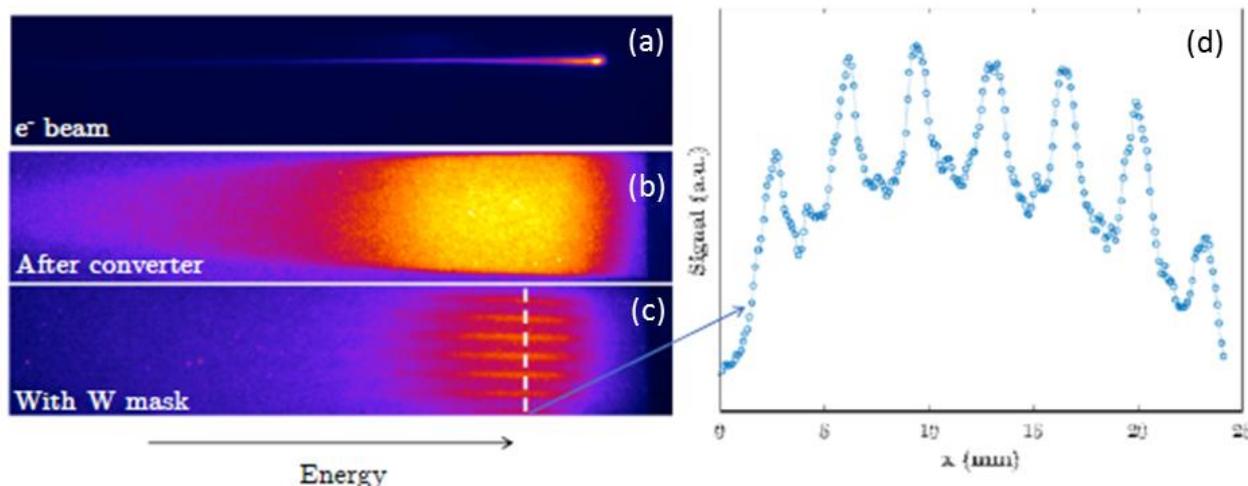


Figure 25: (a) typical electron beam spectrum from Laser-Plasma acceleration in a gas cell at UHI100-LPA, (b) secondary electron beam after the converter, (c) secondary electron beam through the Tungsten mask, (d) profile through the dashed line from fig. (c) of

LPA-UHI100	User-projects		Total no. of users benefiting from the TA	Units of access (1 hour)
	Eligible submissions	Selected		
Year 1 (M1-M12)	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 positron source. These results should be published this year.

### 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.

### 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

LULAL	User-projects		Total no. of users benefitting from the TA	Units of access (1 hour)
	Eligible submissions	Selected		
Year 1 (M1-M12)	0	0	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.

---

## 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 below. As part of the communication task, it would be worth mention the participation to the organization of an industrial event, in Brussels, on February 2018. This will be however detailed in the description of Task 14.3.

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

The Proof-of-Concept funding has been set-up. PoC fund should be used to demonstrate commercial viability of selected technologies investigated in the frame of ARIES, and supported by market assessments, evaluations and business plans. The innovation criteria for eligibility, selection and award of PoC fund have been drafted already during the summer 2017, then discussed at several Steering Committee meetings and in WP14 context, agreed and eventually approved by the ARIES project management. The Call for proposal was opened and published on Dec. 1<sup>st</sup>, 2017 (the poster is shown below). The good result so far is demonstrated by the number of proposals that have been submitted (9 valid, 1 rejected). These proposals are at the moment into an evaluation process that is planned to continue until end of April 2018. The monitoring progress of the funded project developments will be discussed during the final award phase of the projects, that will happen before the summer 2018.

### Contractual milestones and deliverables

In the Y1 reporting period, Task 14.2 had one deliverable to achieve:

- D14.1: Set-up of the Proof-of-Concept innovation funding scheme - [ACHIEVED](#)



Figure 26: PoC call for proposals poster

### 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.

Eventually, Task 14.3, in collaboration with AMICI, is organizing a [workshop in CERN](#), on May 16<sup>th</sup> 2018, to address with experts from CERN, STFC, DESY, INFN, and with interested industries involved into the ARIES and AMICI, the matter of protection and dissemination of IPR.

#### Contractual milestones and deliverables

In the Y1 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 very much integrated with activities going on in WP17 (PowerMat). Target is to explore composite combining properties of graphite or diamond (low  $\rho$ , high  $\lambda$ , low  $\alpha$ ) with those of metal and transition metal-based ceramics (high  $R_m$ , good  $\gamma$ ). Also, it is foreseen to investigate materials like Silver-diamond (AgCD), Copper-diamond (CuCD), Molybdenum-graphite (MoGr). The production objective of one sub-task is the production of a number of samples of  $MgB_2$  by Additive Manufacturing on Cu substrate. For the time being the industry (RHP, Austria) that has responsibility into the development of the process has defined the road map to arrive till the point of characterize samples for checking the super-conducting properties.

### 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 1<sup>st</sup> 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/mm<sup>2</sup> at 4.2 K, 18-20 T have been obtained, well above the ARIES minimum target value of 800 A/mm<sup>2</sup>. The goal will be now the production of longer lengths and their characterisation.



Figure 27: A 12 mm tape produced by BHTS using the new method.

### 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. The 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 an industrial or medical project. According to plan, and in cooperation with an identified interested party, the updated system requirements have been produced in month 12.

#### Contractual milestones and deliverables

In the Y1 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 (Nb<sub>3</sub>Sn, Nb 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 5<sup>th</sup> 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 1<sup>st</sup> 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. It was agreed on who is doing different parts of work, how the sample will be transported, and time schedule. Particularly, 1<sup>st</sup> year work was focused on sample substrate preparation (as written in ARIES programme) and its impact on quality of the film and its superconducting properties.

Apart from the WP15 Kick-off meeting, three other WP15 meetings were organised within the reported year. 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 Y1 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 year of activity of Task 15.2 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 first year activity can be resumed with the following points.

- 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 SUBU 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 Electrode 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.

After depositing a Nb film on the samples, subsequent film characterization (Task 15.3), and superconductivity evaluation (Task 15.4), the overall analysis will allow to conclude if and what surface treatment is preferable for the following 3 years of the project (Deliverable D15.1).



Figure 28: An overview of the polishing treatments configuration used: A) Tumbling, B) SUBU, C) Electropolishing

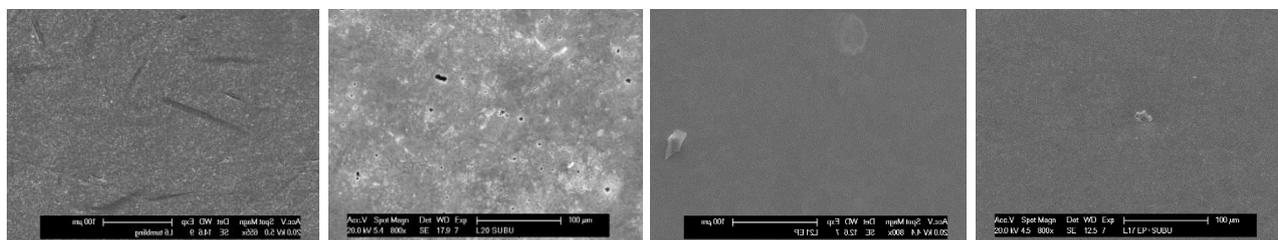


Figure 29: The Surface micrographs of the 4 different treatments A) Tumbling, B) SUBU, C) EP, D) EP+SUBU.

## Contractual milestones and deliverables

In the Y1 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 and areas 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  $\mu\text{m}$

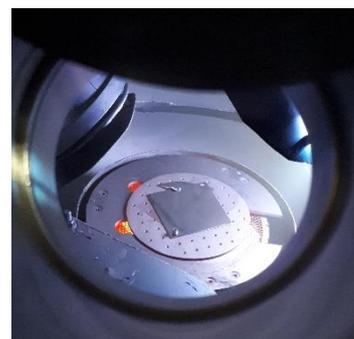


Figure 30: Copper substrate during Nb deposition at STFC

- **At LNL/INFN:**

- Base Pressure =  $8.6 \times 10^{-8}$  mbar (at 650 °C)
- Magnetron Current = 2.1 A (current density 0.027 A/cm<sup>2</sup>)
- Argon Pressure =  $5 \times 10^{-3}$  mbar
- Sample Temperature = 650 °C
- Process time = 20 min
- Thickness = 3  $\mu\text{m}$
- Deposition rate = 150 nm/min
- Distance target-sample = 10 cm
- Baking time = 60 h
- Chamber baking Temperature = 250 °C



Figure 31: Copper substrate after Nb deposition at LNL

- **At University Siegen**

- Chamber Baking Temperature = 650 °C
- Baking Time: 1.25 h
- Base Pressure:  $1.22 \times 10^{-5}$  hPa @ 650 °C
- Deposition Temperature: 650 °C
- Argon Pressure:  $1.5 \times 10^{-2}$  hPa
- Target / Substrate distance = 6 cm
- Target Power: 400 W
- Current: 1.34 A, Voltage: 298 V
- Process Time: 20 min
- Film thickness: 3  $\mu\text{m}$



Figure 32: 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 surface analysis will be carried out in the second year of programme. 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.

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 of the coating. This work will continue next year.

### 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.



Figure 33: local AC-magnetometer at Saclay

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.

At **ASTeC** a radiofrequency (RF) cavity and cryostat dedicated to the measurement of superconducting coatings at 7.8 GHz has been commissioned. With emphasis on fast turn-around time it is planned to upgrade the facility to operate with a closed-cycle refrigerator by June 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.

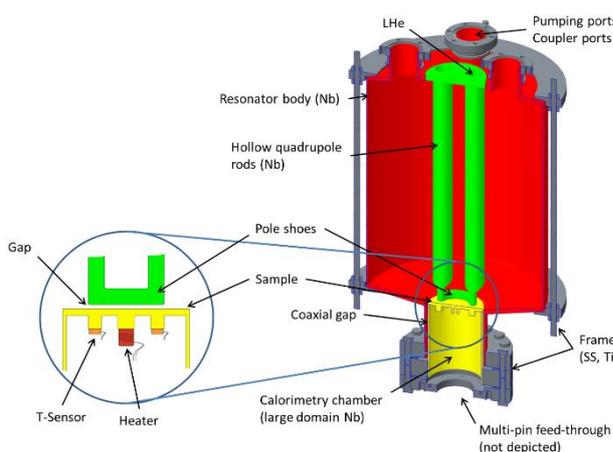


Figure 34: Cross section of calorimetry chamber and quadrupole resonator

## 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

Since WP16 is a JRA, this task covers the internal coordination among the partners contributing to the WP16 only. Therefore, no objectives are set for this task and no results have to be reported.

### 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.

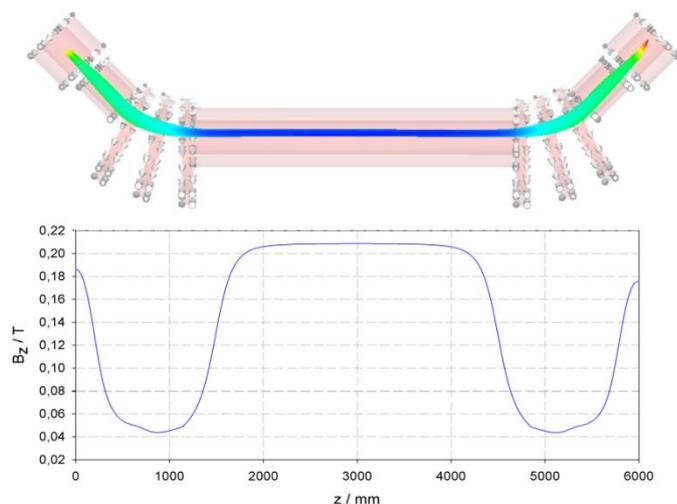


Figure 35: Simulation of electron beam transport in an SCC lens and magnetic field along the lens, serving as a basis for the technical layout of the GSI SCC lens.

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 and first beam dynamics studies of the electron beam have been performed in order to estimate the required magnetic field strength (see Figure ) and to evaluate the influence of the vacuum tube on the elliptical beam in the main solenoid. The interaction of the hadron with the electron beam and the resulting (partial) compensation of the space charge tune shift using the example of SIS18 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.

### Task 16.3. Electron Gun and Power Modulator

The design of the RF-modulated electron gun for the space charge compensation lens (SCC gun) is in progress. A basic gun design meeting the predefined beam current and profile requirements has been completed, which constitutes a major step towards the conceptual layout. The next challenge in

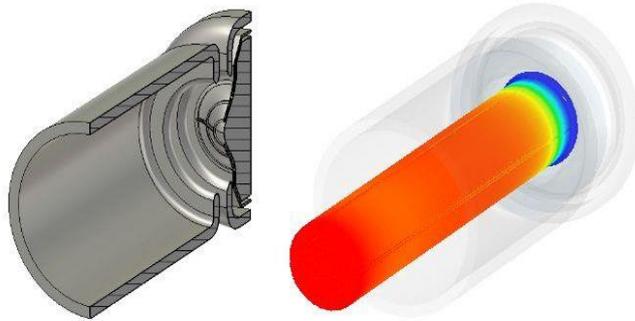


Figure 36: Prototype design of gridded electron gun (left) and simulated beam extraction using CST® (right).

the gun design is the modulation of a 10 – 20 A electron beam with at least 25 keV beam energy. If the modulation is performed by full anode voltage, as it has been done in electron lenses so far, the resulting power requirements are excessive. Therefore, the modulation by a control grid close to the cathode of the SCC gun is presently under study (see Figure ). Since the application requires a defined shape of the transverse current density profile special care has to be taken in the grid design. The beam modulation has been studied numerically for different grid structures in order to determine

current density profile, total current emitted, and grid voltage required to depress the beam current and load on grid. Especially the last two parameters are very important for the final design of the power modulator.

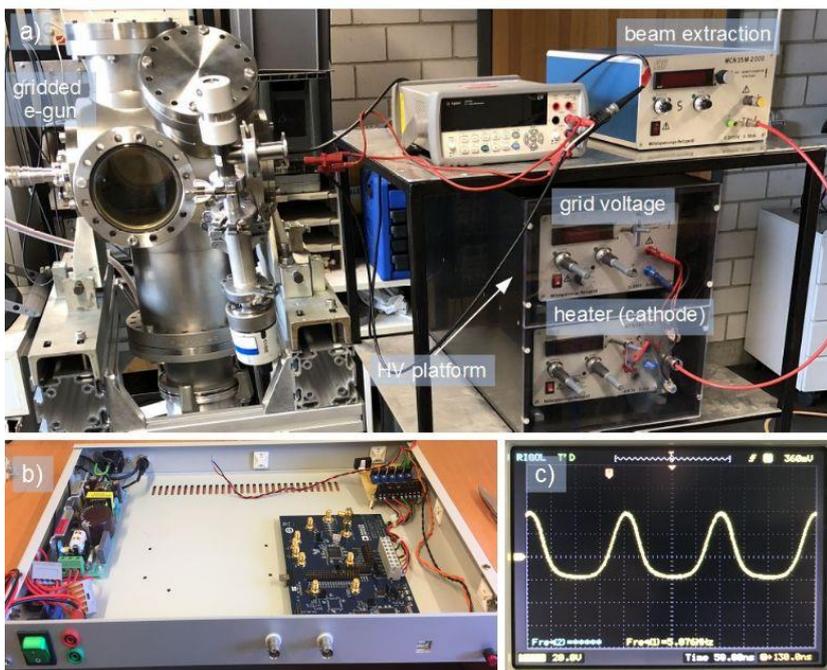


Figure 37: a) Test stand at IAP to test performance of b) prototype driver stage of power modulator which generates required waveform c).

In addition to the design of the SCC gun, a proof-of-concept experiment with a low-current gridded gun was set up at IAP (see Figure ). It serves primarily to benchmark the simulation tools and to verify the performance of the low power modulator stage that was designed and build by RTU. The final modulator includes several stages and is designed for two versions: a low power version (250V, 3mA) for the proof-of-concept experiment and a full power version (2500 V, 0.1 A) for the SCC gun. The low power generator output displayed in **Error! Reference source not found.** is an 8 MHz Gaussian waveform signal with up to 60 V from the driver stage currently under testing at RTU. The

complete low-power modulator will be used to drive the proof-of-concept experiment at IAP during the next months.

Before the electron beam is qualified at the CERN test stand, the electron gun will also be commissioned at IAP. Therefore, another experimental set-up is under preparation which provides the possibility to perform basic functional checks of the SCC gun and its modulator at IAP.

## 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 LHC 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 . The second stage will include a drift solenoid in between the gun and collector solenoids (see Figure ), 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.

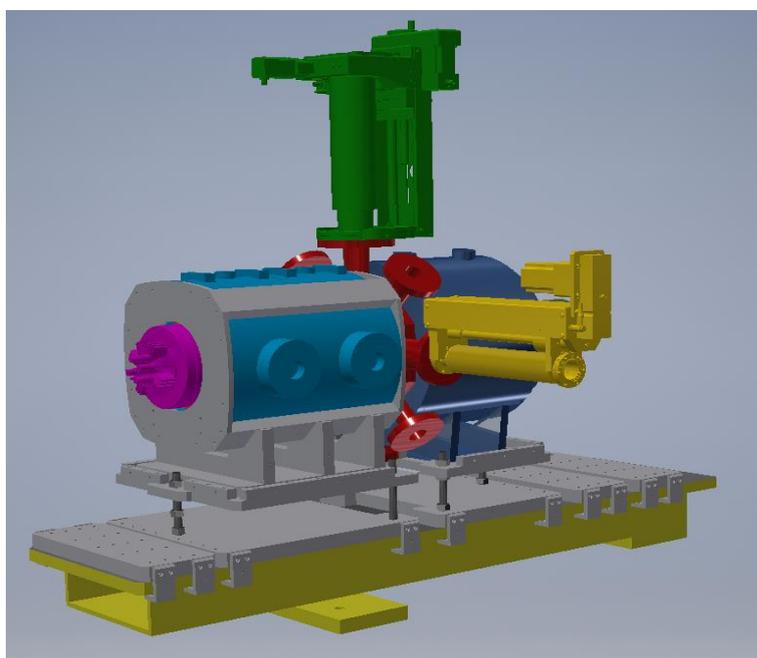


Figure 38: Layout of first stage of electron gun test stand.

The staged approach will simplify and speed up commissioning of the test facility and its sub-systems, such as cooling, high power, high voltage, vacuum, control, interlocks and safety, as well as diagnostics tools and data acquisition systems. Measurements of an existing gun, designed for the HEL, will allow validating the test stand by comparing the results with measurements performed at FNAL and computer codes (CST® and WARP).

The first stage of the test facility is planned to be installed by the end of 2018. After commissioning it is expected to be running by the first quarter of 2019. The present status is as follows:

- Gun and collector solenoids were recuperated and commissioned at CERN.
- High current power supplies have been acquired by CERN and will be commissioned during 2018.
- The design of the diagnostic box including pin-hole Faraday Cup and YAG screen is completed.

The dynamics of the electron beam through the first stage test stand (hollow electron gun, solenoids, vacuum chambers) has been modeled using the CST® package.

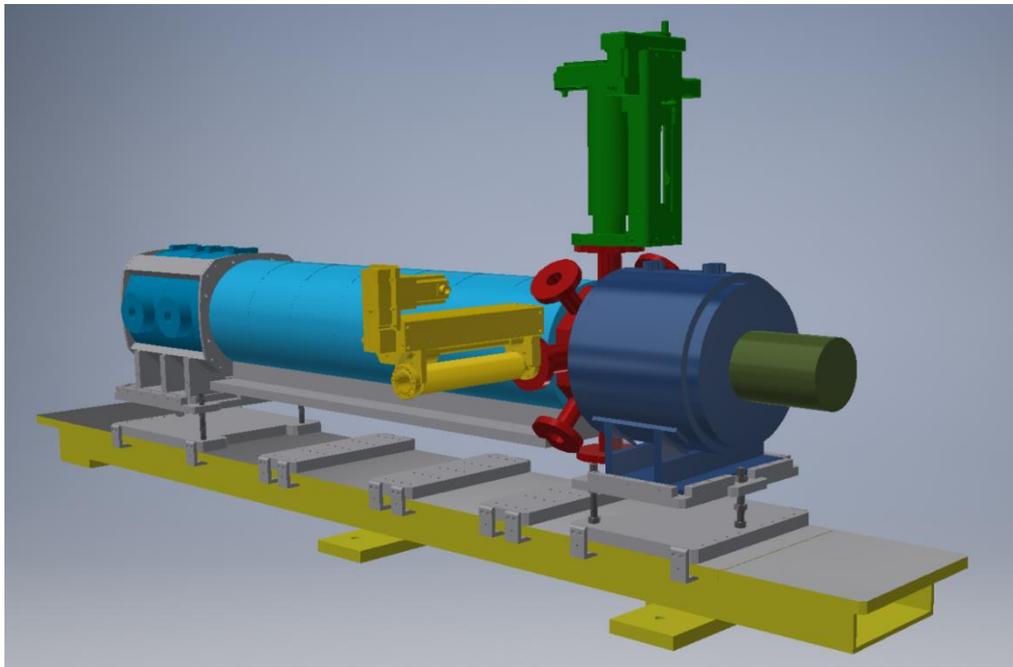


Figure 39: Layout of electron gun test stand.

## 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 5<sup>th</sup> May 2017, following the ARIES kick-off meeting, with 24 attendees representing all beneficiaries.

The first PowerMat workshop was organized in Turin (Italy) on 27<sup>th</sup> and 28<sup>th</sup> November 2017, with 30 participants from several Laboratories (CERN, GSI, ELI-NP, Kurchatov Institute), Universities (POLITO, POLIMI, UoM) and small companies (BrevettiBizz, RHP-Technology). 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 workshop also allowed to review recent results of radiation damage studies performed at GSI, CERN and POLIMI, and to agree on a plan for simulations and experiments to be performed in the coming months, in various facilities in Europe and USA.

### Contractual milestones and deliverables

In the Y1 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

An extensive characterization campaign of a broad range of advanced materials, based on carbon allotropes, for applications in future particle accelerators was started in year 1. 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 year 2.

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, CuCD and Thermal Pyrolytic Graphite (TPG) were measured at CERN, confirming the advantages of MoGr.

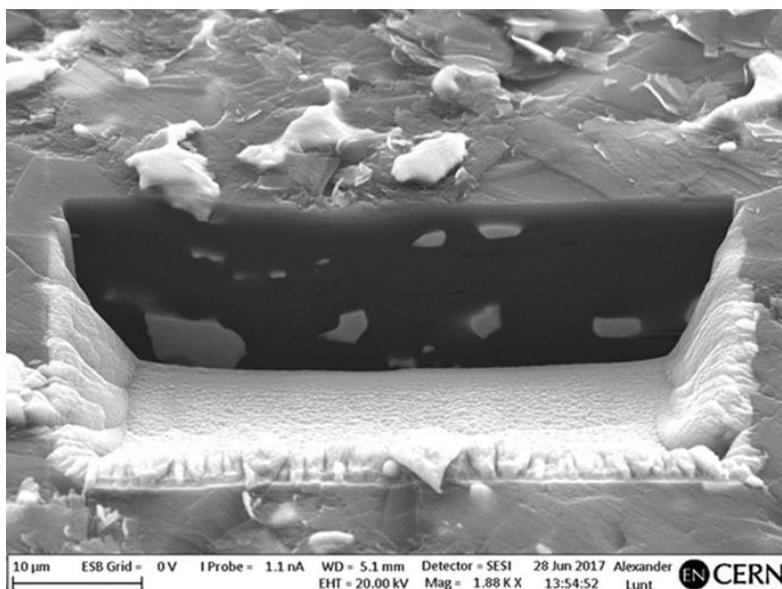


Figure 40: SEM image of MoGr after diamond paste polishing. The pocket and flat surface are obtained by Focused Ion Beam (FIB) in view of additional detailed SEM imaging. CERN

At GSI, investigations, including Raman spectroscopy, laser flash analysis, micro-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 to be performed in May-June at CERN HiRadMat facility with TA support from ARIES.

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. A number of countermeasures were identified and should allow to overcome this limitation in future investigations.

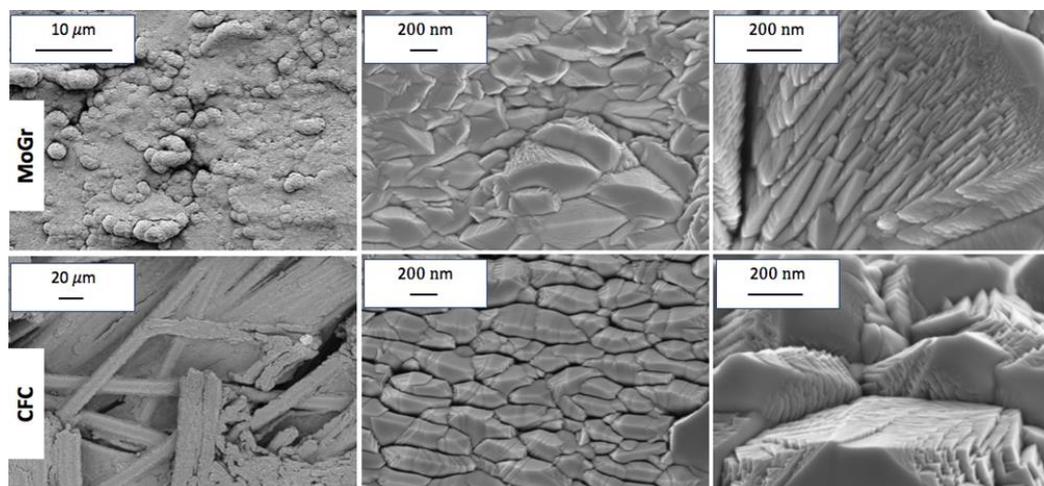


Figure 41: SEM images of Mo coatings on MoGr and CFC substrates. POLIMI

### Contractual milestones and deliverables

In the Y1 reporting period, Task 17.2 had one deliverable to achieve:

- D17.1: Material characterization - [ACHIEVED](#)

### Task 17.3. Dynamic testing and online monitoring

Year 1 saw the successful completion of the Multimater experiment at HiRadMat, which took place in the first two weeks of October 2017. 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. The first analyses indicate a very good agreement with the numerical and analytical predictions.

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 threaded ends was checked, obtaining good results for both materials. This allowed investigating mechanical response by using a single geometry. Selected loading conditions permit to reach strain-rates in the range of  $10^{-3} \div 10^3 \text{ s}^{-1}$  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 42: Dedicated holders for tensile tests showing dog-bone material specimens. POLITO

### Task 17.4. Simulation of irradiation effects and mitigation method

During year 1, 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 2015-2017, 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 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 samples, planned for 2018 at GSI, 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,  $^{48}\text{Ca}$  ions were found to be 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  $^{48}\text{Ca}$  beams (flux of  $5 \times 10^9$  ions  $\text{cm}^{-2} \text{s}^{-1}$ ) are needed to induce DPA values of a few  $10^{-3}$  in Mo coatings. Although lighter ions like  $^{12}\text{C}$  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.

Task 17.4 also contributed to the analysis of the Multimat experiment in HiRadMat through a comprehensive set of energy deposition studies for different specimens and beam spot sizes.

### Task 17.5. Broader accelerator and societal application

One important objective of PowerMat 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 and experiments are being studied.

First screens with optimized matrix, diamond size and doping were produced in close collaboration with RHP Technology and WP14. These new materials are undergoing characterization and will be tested with ion beam within the 2018 irradiation campaign at GSI.

---

## 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. The two milestones of this workpackage in this reporting period have been met successfully.

### 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 (cf. **Error! Reference source not found.**). 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 (cf. **Error! Reference source not found.**). 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 CRS 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.

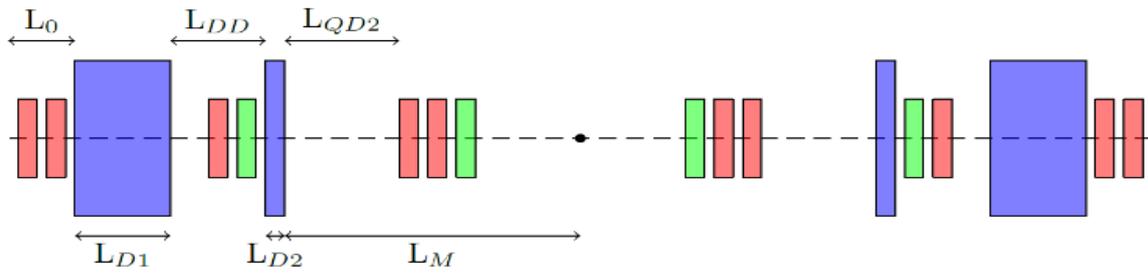


Figure 43: Lattice design of the interstage transport line for 200 MeV, Quadrupoles are in red, dipoles in blue and sextupoles in green.

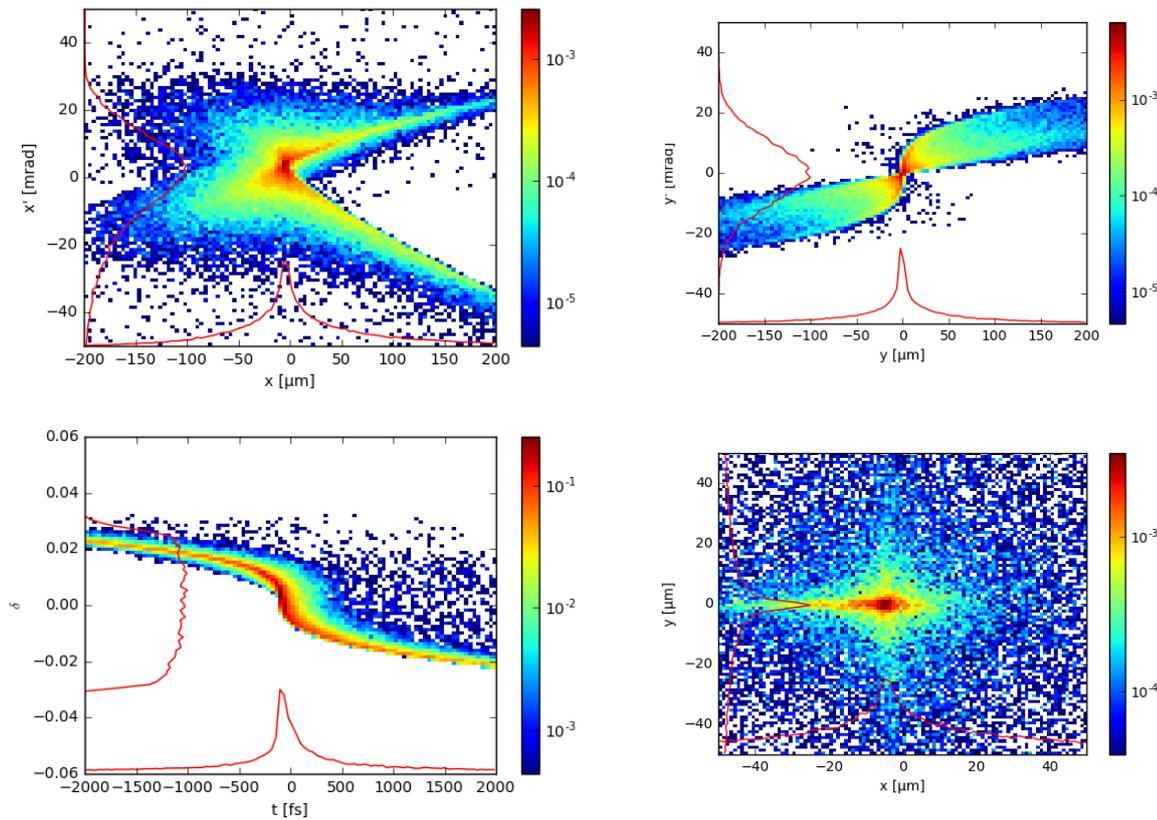


Figure 44: Simulated phase space portrait of an 200MeV electron beam created in a laser plasma injector after passage of the interstage transport line ("start-to-end simulation")

### 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 an experimental, a theoretical and numerical perspectives.

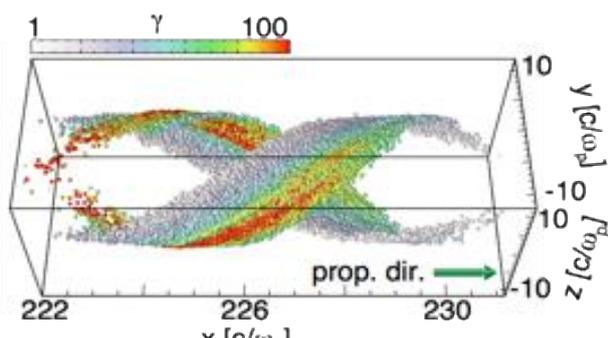


Figure 27: Laser wakefield acceleration of self-injected electrons

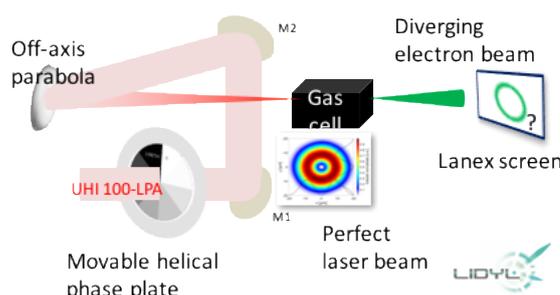


Figure 46 Experimental setup at CEA Saclay to test LWFA with beam with OAM

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. In parallel, an experimental setup has been devised at CEA Saclay using a helical phase plate to create a laser beam with OAM (**Error! Reference source not found.**).

### Contractual milestones and deliverables

In the Y1 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

Dielectric structures have made outstanding progress over the last years, profiting strongly from advances in modern lasers and nano technology. The activity of this Task covers solutions and approaches in Laser Driven Dielectric Structures. Dielectric laser acceleration (DLA) is one way to circumnavigate the Lawson-Woodward theorem, which tells you that you cannot get a significant acceleration of charged particles by a plane electro-magnetic wave. For example, by injecting a laser beam sideways into a dielectric structure with suitable phase pattern, one can accelerate the electrons along the axis with the laser's electric fields, pretty much as in a travelling wave RF cavity, however at micrometre wavelength and length scales.

Work has focused so far on the elaboration of scheme for DLA experiment on the ARES Linac at DESY in view of a beam test with the goal of achieving an acceleration of 100 MeV in a single dielectric structure (. Studies for the optimal laser injection scheme – on-axis or transverse – are still ongoing. Materiel robustness test with first prototypes of DLA structures have been performed and show encouraging results

When the electron bunch is much longer than the laser wavelength, electrons are accelerated AND decelerated. In order to increase the acceleration yield, it is foreseen to impart an energy modulation laser-wavelength scale on the electron beam, and then to translate this to a phase-density modulation via a chicane. Full simulations of the linac part (Astra) and DLA (VSIM, CST) show that a substantial gain in acceleration yield seems feasible. This scheme hinges on precise submicron beam synchronisation which could be facilitated by the use of the same laser source for the photogun and the DLA.

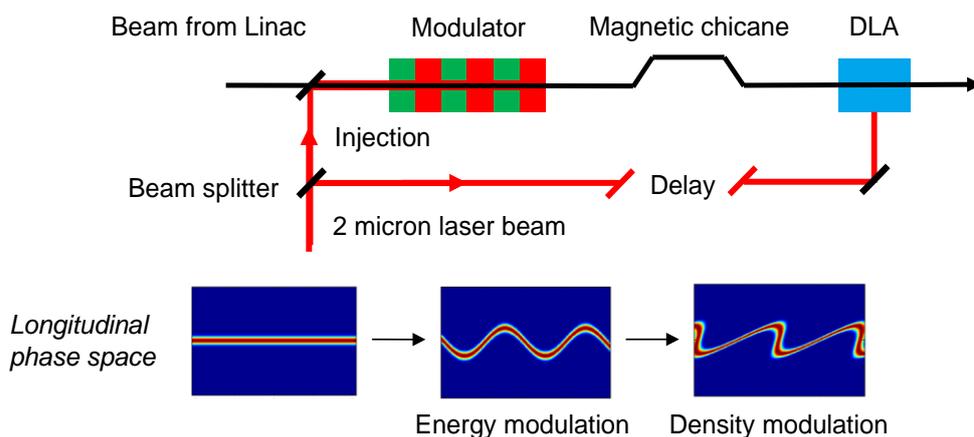


Figure 47: Experimental scheme for electron beam modulation in an undulator and chicane and subsequent dielectric laser acceleration (2µm) at the ARES linac at DESY

### Task 18.5. Pushing back the charge frontier

The beam charge in laser-plasma accelerators is about 3 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 injection efficiency of electrons into the plasma accelerating structure.

There is a variety of strategies to increase the spectral intensity, i.e. the bunch charge per unit of momentum and solid angle. Experimental and simulation efforts have focused so far 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 (**Error! Reference source not found.**) at LOA (France), and sets also the record for this figure of merit at this installation.

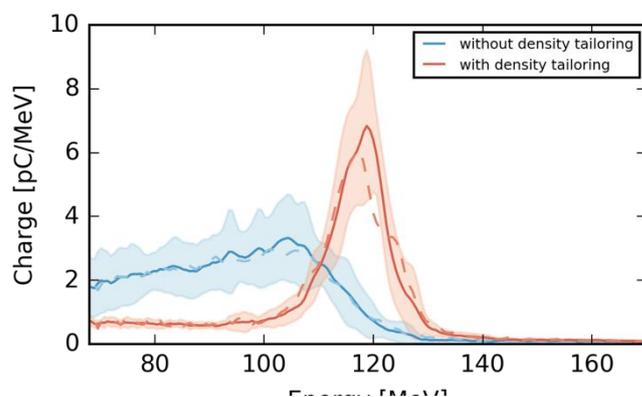
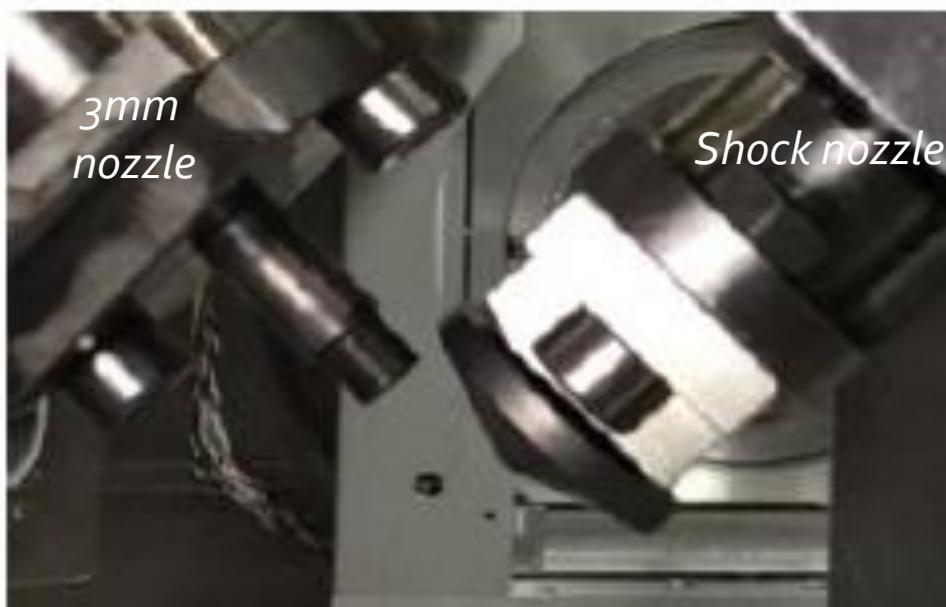


Figure 48: Gain in spectral intensity of LWFA accelerated electrons bunches by a density downramp (LOA)

Since simulations have shown that the height of the density step is the most influential parameter, future experimental activates 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 (33MeV) which may lead to high spectral intensities of electron bunches at 300MeV. This is to be explored in the near future.



*Figure 49: Two nozzle experiment at CEA Saclay UHI100 Laser*

## 1.4 Impact

The main impact factors identified 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**

The TNA objectives remain valid, although initial progress is slow for the new facilities that are accessible for the first time in ARIES.

### **Synergies and complementarities between accelerator facilities in Europe**

The impact during the first year has been particularly important, with a higher than expected participation to the Workshops and events organised by the Networks, and with additional requests from institutes willing to participate in the ARIES activities. The integration of industrial partners is particularly successful, with new collaborations forming and a large industry participation in ARIES events (kick-off meeting and co-innovation workshop).

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

Innovation remains strong, in particular in the fields of high-temperature superconductors, new materials, and superconducting coatings. In the pure scientific domain, new accelerator designs have appeared, as an innovative muon collider design, which are actively studied and supported by ARIES.

### **Co-innovation with European industry**

Co-innovation will be a key factor for future accelerator projects. This impact was enhanced during the first year of ARIES, thanks to the successful Workshop on co-innovation and to the participation of industry in new initiatives, for example in the frame of the Proof-of-Concept fund that was extremely successful.

### **Training of new generation of scientists and engineers**

ARIES is perfectly in line with its training objectives, with the Massive Online Open Course on Accelerator Technology in the advanced preparation phase, with the priority given to training of the new generations by the ARIES Networks, and by the hiring of students and post-docs in the Networks to be in charge of the prospective studies foreseen by the workplan.

### **Knowledge sharing across fields and between academia and industry**

The knowledge sharing is high after the first year of activity. Most of the Workshops organised by the Networks are multidisciplinary, attracting different communities, as are the general project events that are intended to favour exchanges and cross-fertilisation between different communities active in accelerator science.

### **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**

The WP3 has the potential to have a larger than expected industrial and societal impact. The global marine production of SO<sub>2</sub> and NO<sub>x</sub> 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.

Work is underway on the use of electron beams to treat sewage sludge. As well as increasing the efficiency for biogas production and making clearer, more valuable fertiliser, this can also deal with the increase in anti-microbial resistance (AMR) from the treatment. This is a major world-wide concern. As well as destroying the bacteria and viruses, electron beams may also be able to break up the antibiotics themselves. The accelerators could be used at either the treatment plant or at the major sources of the bacteria and antibiotics, hospitals and pharmaceutical companies.

The use of intense X-ray microbeams for cancer radiotherapy (MRT) shows great potential and is one of the few areas that could bring a step-change in cancer therapy. Currently, however, these beams can only be produced using light sources such as the ESRF. This makes the treatment impractical. However, the WP will study the production of these beams using a compact 140 MeV linac instead. This may make it possible to introduce it into larger hospitals.

Radioisotopes are already used extensively for medical imaging and some therapy. However, they have a lot of potential that is currently not being exploited because of the technology used to produce them. The WP is studying a number of new technologies that could bring substantial improvements. These include more compact accelerators that could be used in hospitals to produce shorter half-life PET isotopes, such as <sup>11</sup>C. This would be a major improvement as essentially all organic molecules contain carbon and it would be much easier to target specific organs in the body. In addition, the potential of therapeutic radioisotopes is large, but many of these are difficult to make with existing technology. Two new accelerator types are being developed that could significantly improve this situation.

#### **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 11 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 lively discussions in the events of all tasks, and the large number of workshops demanded by the European accelerator community, have highlighted the strong need for this type of NA, as had been foreseen. 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. This

prospect guarantees a strong role of WP6 in terms of impact. 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)

The “Expected Impacts” highlighted in Annex 1 are still relevant to HiRadMat. A key highlight is the benefit of TA funding to the continued functioning and upgrade of the facility. HiRadMat can continue to grow with an increase of external users as well as an increase of users from multiple institutes from different areas of the physical sciences, including accelerator physics, condensed matter physics, materials science and engineering technology.

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

Due to non-availability of three out of the five facilities and to the reduced activity of the remaining two, the impact of this WP has been lower than foreseen.

The ANKA facility is now referred to as the KIT light source. The storage ring obtained its own name and is called KARA (KARlsruhe Research Accelerator). The remaining information from Annex 1 is still relevant and does not need to be updated.

#### WP12: Electron and proton beam testing (ANKA, VELA, IPHI, SINBAD & FLUTE)

Due to non-availability of three out of the five facilities and to the reduced activity of the remaining two, the impact of this WP has been lower than foreseen.

#### WP15: Thin Film for Superconducting RF Cavities SRF

Within the 1<sup>st</sup> year the WP15 partners have agreed on detailed 1<sup>st</sup> year plan of work, where each of 50 samples goes through 3-5 partners, who are performing different parts of the study. A few

deposition and characterization facilities were modified or updated, and a few others were built, all is in operation by now. The WP15 partners learned how to work in such collaboration.

#### WP16: Intense, RF modulated E-beams

At the end of the first year, the impact of WP16 as described in Annex 1 is still up to date. In particular, electron lenses for space charge compensation and halo diffusion enhancement continue to be requested by the accelerator community. However, with more detailed results on the expected performance of electron lenses for space charge compensation becoming available, the requirements may need to be adapted. In particular, new results on the usage of homogeneous transverse profiles for space charge compensation will be incorporated in the concept for the space charge compensation gun, leading to an even more versatile device.

#### WP17: Materials for extreme thermal management

In its first period, WP17 progressed in line with expectations, conducting an extensive characterization campaign on carbon-based materials at CERN, GSI and POLIMI and performing a successful experiment. 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. Deviations from Annex 1 and Annex 2

During the first year of the project, there have been minor delays in one deliverable and in some milestones and tasks, which do not have any major impact on the overall achievement of the project's objectives in any of the WPs.

### 2.1 Deliverables and Milestones

Deliverable	Delay	Impact
D15.1	Minor delay (2 months) due to larger amount of work required to set-up and commission the deposition and characterisation facilities	None
Milestone	Delay	Impact
MS26	A few weeks delay due to time conflict with several other events in April (FCC week, eRHIC design review, IPAC'18,...)	None

### 2.2 Tasks

Task	Deviation <sup>3</sup>	Justification	Impact on other tasks
Task 8.3	Minor delay	The foreseen workshop had to be shifted to May 2018 due to time constraints with competing workshops and conferences	None
HiRadMat38: FlexMat	1 year	Experimental team suffered problems with experimental set-up. Experiment re-scheduled for 2018	None
Task 11.5 Delivery of TNA/ Access units on VELA	Minor delay	Non-availability of facility through Year 1. Full allocation of access units (336) will be made available during the remaining programme.	Condenses delivery of agreed VELA TNA units within remaining ARIES programme

### 2.3 Use of resources

#### WP7: Rings with Ultra-Low Emittance

The person-months used in WP7 is in line with a uniform spending profile. Spending from budget allocated to beneficiaries responsible for the WP7 tasks has started with the funding of the organisation or the workshop.

<sup>3</sup> Ahead of schedule / Minor delay / Significant delay

#### WP8: Advanced Diagnostics at Accelerators

The resources (in term of financial budget) were used to organize the workshops, to cover travel expenses for some of the participants and to fund the exchange of personnel. The first year's budget is largely spent. The actual work of workshop organization was executed by the task leaders and the personnel of the beneficiary institutes involved.

#### WP10: Material Testing

WP10.1 provided more personnel per month due to the nature of the facility, i.e. preparation, installation, beam time, removal. This involved many teams, including transport, survey, radiation protection, data acquisition experts, beam instrumentation experts, beam operators.

#### WP11: Electron and proton beam testing

Due to the known no-availability of the facility, no resources for WP11.5 have been required to support user-group selection processes or beamtime support. Resource spend to date has therefore been restricted to attendance at project kick-off and annual meetings.

#### WP18: Very High Gradient Acceleration Techniques

Use of resources vary strongly from task to task. All task leader report use of resources, some below some above what would be expected from a uniform spending profile. This is natural due to the different degrees of complexities of the tasks and the difference in due-date for the deliverables.

In overall, the use of resources of the WP18 is slightly below what would be expected from a uniform spending profile

### 3. Dissemination and exploitation of results

#### Scientific publications

WP2	
N°	Author(s), Title, References, Date, Link
1	Delerue et Al., A Massive Open Online Course on Particle Accelerators, IPAC'18 MOPML050, <a href="https://doi.org/10.5281/zenodo.1252189">https://doi.org/10.5281/zenodo.1252189</a>
WP6	
1	G. Guillermo, M. Ady, R. Kersevan, F. Zimmermann, D.C. Sagan, R. Cimino, E. La Francesca, <a href="#">Comparing Behaviour of Simulated Proton Synchrotron Radiation in the Arcs of the LHC with Measurements</a> , Proc. IPAC'17 Copenhagen
2	K. Ohmi, N. Kuroo, K. Oide, D. Zhou, and F. Zimmermann, <a href="#">Coherent beam-beam instability in collisions with a large crossing angle</a> , <b>Phys. Rev. Lett.</b> <b>119</b> , 134801 (2017)
3	F. Zimmermann, <i>Future Colliders for Particle Physics – “Big and Small”</i> , Proc. EAAC'17, La Biodola, 24-30 September 2017, <b>Nucl. Instr. Methods A</b> <a href="https://doi.org/10.1016/j.nima.2018.01.034">https://doi.org/10.1016/j.nima.2018.01.034</a> (2017)
4	G. Guillermo, D. Sagan, and F. Zimmermann, <i>Examining mitigation schemes for synchrotron radiation in high-energy hadron colliders</i> , <b>Phys. Rev. Accel. Beams</b> <b>21</b> , 021001 (2018)
5	M. Migliorati, E. Belli, M. Zobov, <i>Impact of the resistive wall impedance on beam dynamics in the Future Circular e+e- Collider</i> , <b>Phys. Rev. Accel. Beams</b> <b>21</b> , 041001 (2018)
6	M. Benedikt and F. Zimmermann, <a href="#">Proton Colliders at the Energy Frontier</a> , invited article for Special Kai Siegbahn Issue of <b>Nucl. Instr. Methods A</b> (2018)
7	S. Fartoukh, M. Giovannozzi, D. Missiaen, E. Todesco, F. Zimmermann, <a href="#">Considerations on a Partial Energy Upgrade of the LHC</a> , ARIES-2017-001; CERN-ACC-2017-096 (2017)
WP7	
1	R. Bartolini et al. <a href="#">The Double Double Bend Achromat upgrade at Diamond: from design to commissioning</a> , <b>PRAB</b> , <b>21</b> , 050701, (2018)
WP17	

1	Guardia-Valenzuela, J et al, Development and properties of high thermal conductivity molybdenum carbide - graphite composites, <i>Carbon</i> <b>135</b> (2018) 72-84, 10 April 2018, <a href="https://zenodo.org/record/1246742#.WvmthaSFNaQ">https://zenodo.org/record/1246742#.WvmthaSFNaQ</a>
2	Carra, F, Thermomechanical Response of Advanced Materials under Quasi Instantaneous Heating, PhD Thesis, Politecnico di Torino, 2017, <a href="https://zenodo.org/record/1240450#.WvmuCaSFNaQ">https://zenodo.org/record/1240450#.WvmuCaSFNaQ</a> / Thesis EuCARD-2?

## Dissemination and communication activities

WP2	
Type <sup>4</sup>	Author(s), Title, References, Date, Link
Poster	Delerue et Al., A Massive Open Online Course on Particle Accelerators, IPAC'18 MOPML050, 30 <sup>th</sup> April 2018
Video	<a href="#">The ARIES project</a>
Press article	<a href="#">Accelerator-Industry Co-Innovation Workshop</a>
Press article	<a href="#">Different techniques of emittance measurements for SLS and FELs</a>
Press article	<a href="#">Taking accelerators on board: Exploring uncharted waters with ARIES</a>
Press article	<a href="#">Workshop for extreme thermal management materials</a>
Press article	<a href="#">HiRadMat: testing materials under high radiation</a>
Press article	<a href="#">Workshop shines Light on Photon-Beam Interactions</a>
Press article	<a href="#">Accelerating health and space research</a>
Press article	<a href="#">ARIES to launch innovation fund</a>
Press article	<a href="#">ARIES and Industry</a>

<sup>4</sup> Press article, Newsletter, Presentation Workshop/Conference, Presentation other events, Poster, Other

Press article	<a href="#">From EuCARD-2 to ARIES</a>
<b>WP3</b>	
<b>Type<sup>5</sup></b>	<b>Author(s), Title, References, Date, Link</b>
Presentation	Zwolińska, E., Sun, Y., Chmielewski, A. G., Licki, J., Pawelec, A., Bułka, S., Zimek, Z., Removal of NO <sub>x</sub> and SO <sub>2</sub> 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
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
Poster	Przybytniak, G., Rzepna, M., Sadło J., Effect of ionizing radiation on the properties of PBAT. International Conference on Developments and Applications of Nuclear Technologies (NUTECH-2017), 10-13.09.2017, Cracow, Poland
Poster	Gryczka, U., Migdał, W., Bułka, S., Chmielewska-Śmietanko, D., Ptaszek, M., Jarecka-Boncela A., Application of low energy electron beam in elimination of plant pathogens from ornamental bulbs. International Conference on Developments and Applications of Nuclear Technologies (NUTECH-2017), 10-13.09.2017, Cracow, Poland
Poster	Sudlitz M., Zimek, Z., Chmielewski, A. G., Głuszewski, W., Irradiation of wastewater from Solvay process. International Conference on Developments and Applications of Nuclear Technologies (NUTECH-2017), 10-13.09.2017, Cracow, Poland
Poster	Wójcik, M., Chmielewska, D., Migdał W., Electron beam for preservation of water-damaged paper. International Conference on Developments and Applications of Nuclear Technologies (NUTECH-2017), 10-13.09.2017, Cracow, Poland
Poster	Chmielewska, D., Wójcik, M., Migdał, W., Sadło, J. Kopec, K., Application of different methods for evaluation of paper properties after decontamination with electron beam irradiation. International Conference on Developments and Applications of Nuclear Technologies (NUTECH-2017), 10-13.09.2017, Cracow, Poland
Presentation other events	Chmielewski, A. G., Environmental applications of electron accelerators –gaseous pollutants, The Summer School " Advanced application of electron beam accelerators " in cooperation with IAEA within ARIES project, 19-23.06.2017, Warsaw.
Presentation other events	Chmielewski, A. G., EU project “Accelerator Research and Innovation for European Science and Society (ARIES)”, The Summer School " Advanced application of electron beam accelerators " in cooperation with IAEA within ARIES project, 19-23.06.2017, Warsaw.

<sup>5</sup> Press article, Newsletter, Presentation Workshop/Conference, Presentation other events, Poster, Other

Presentation	J. Portillo Casado, Low Energy Electron Beam Irradiation of Liquids for Medical Applications, Workshop “Accelerated Electrons for Live”, 2017-11-07
Presentation	Frank-Holm Roegner, Cleaning and Sterilization for hygiene-pertinent production, Workshop “Accelerated Electrons for Live”, 2017-11-07
Presentation	Frank-Holm Roegner, Electron Beam Treatment of Seeds - environmental friendly with future potential, Workshop “Accelerated Electrons for Live”, 2017-11-07
Presentation	Frank-Holm Roegner, Water treatment using low energy electrons - Potentials and Challenges, Workshop “Accelerated Electrons for Live”, 2017-11-07
Presentation	J. Portillo Casado, SteriHealth, New flexible basis for on-site sterilization with e-beam, Workshop “Accelerated Electrons for Live”, 2017-11-07
<b>WP4</b>	
<b>Type<sup>6</sup></b>	<b>Author(s), Title, References, Date, Link</b>
Presentation	M.Seidel et al, <a href="#">Energy Efficiency of Accelerators in the European Programs Eucard2 and ARIES</a> , 11.11.2017, Magurele
Presentation	C.Marchand, <a href="#">Development of Efficient Klystrons</a> , 11.11.2017, Magurele
CERN Int. report	Sotirios Papadopoulos, Suitbert Ramberger, Magnetic measurements of the vacuum vessel for the High-Gradient four cavity cryomodule (2018)
<b>WP5</b>	
Newsletter	CERN Bulletin: EAAC workshop showcases advanced accelerator progress, <a href="http://cerncourier.com/cws/article/cern/70365">http://cerncourier.com/cws/article/cern/70365</a> , 10 Nov 2017
Website	EuroNNAc Homepage, <a href="http://www.euronnac.eu/">http://www.euronnac.eu/</a> , 22.05.2018
<b>WP6</b>	
Presentation Workshop	F. Hug, ERL recirculation optics for MESA, ICFA Advanced Beam Dynamics Workshop on Energy Recovery Linacs, Geneva, Switzerland, 2017

<sup>6</sup> Press article, Newsletter, Presentation Workshop/Conference, Presentation other events, Poster, Other

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, Batavia, USA 2018.
Newsletter	Panos Charitos, Accelerator reliability training help for experts, (APEC 6.3), <b>Accelerating News, no. 22</b>
Newsletter	M. Zanetti and F. Zimmermann Workshop shines Light on Photon-Beam Interactions (APEC 6.6), <b>Accelerating News, no. 23</b>
<b>WP6</b>	
Poster	D. Vilsmeier, “A Modular Application for IPM Simulation“, at the International Beam Instrumentation Conference (IBIC), August 23 <sup>rd</sup> , 2017
Presentation Workshop	K. Satou, “Simulation and Progress in Ionization Profile Monitors for High Intensity Proton Beam”, at the International Beam Instrumentation Conference (IBIC), August 23 <sup>rd</sup> , 2017
Presentation Workshop	U. Iriso, “Summary of Workshop on Emittance Measurements for Light Sources and FELs”, at the Topical Workshop on Diagnostics for Ultra-Low Emittance Rings (TW-DULER), April 19 <sup>th</sup> 2018.
<b>WP17</b>	
Press article	A. Bertarelli, Workshop for extreme thermal management materials, Accelerating News issue 23, December 2017 <a href="https://acceleratingnews.web.cern.ch/article/workshop-extreme-thermal-management-materials">https://acceleratingnews.web.cern.ch/article/workshop-extreme-thermal-management-materials</a>

## Annex 1: Project meetings

<i>Date</i>	<i>Meeting</i>	<i>Venue</i>	<i>WP</i>
04-05.05.2017	<a href="#">ARIES Kick-off meeting</a>	CERN	All
05.05.2017	<a href="#">Governing Board – Kick-off meeting</a>	CERN	All
05.05.2017	<a href="#">1<sup>st</sup> ARIES Steering Committee meeting</a>	CERN	All
05.05.2017	<a href="#">Industrial Meeting / Kick-off meeting</a>	CERN	All
20.07.2017	<a href="#">ARIES-AMICI Coordination meeting</a>	Video	All
10.08.2017	<a href="#">Accelerator application to the ship exhaust gases treatment</a>	CERN	All
26-30.08.2017	<a href="#">Workshop on Ions for Cancer Therapy, Space research and Material Science</a>	Crete	All
05.09.2017	<a href="#">2<sup>nd</sup> ARIES Steering Committee meeting</a>	CERN	All
09.11.2017	<a href="#">Co-innovation Workshop Programme Committee Meeting</a>	CERN	All
22-23.11.2017	<a href="#">Industry workshop Programme Committee Meeting</a>	CERN	All
01.12.2017	<a href="#">ARIES Meets Industry – accelerator application to the ship exhaust gases treatment</a>	CERN	All
07.12.2018	<a href="#">Co-innovation Workshop Programme Committee Meeting</a>	CERN video	All
13.12.2017	<a href="#">3<sup>rd</sup> ARIES Steering Committee meeting</a>	CERN	All
08.01.2018	<a href="#">Co-innovation Workshop Programme Committee Meeting</a>	CERN video	All
06-07.02.2018	<a href="#">Accelerator-Industry Co-Innovation Workshop</a>	Brussels	All
01.03.2018	<a href="#">Electron beam treatment of marine diesel exhaust gases – Consortium meeting</a>	Genova	All
06.03.2018	<a href="#">4<sup>th</sup> Steering Committee meeting</a>	CERN	All
<b>WP2: Training, Communication and Outreach for Accelerator Science</b>			
05.05.2017	<a href="#">Kick-off WP2 meeting</a>	CERN	WP2
31.05.2017	<a href="#">WP2.4 Meeting</a>	Vidyo	WP2
14.06.2017	<a href="#">Task 2.2 kick-off discussion</a>	Vidyo	WP2
17.07.2017	<a href="#">ARIES Task 2.3 meeting</a>	Vidyo	WP2
06.09.2017	<a href="#">Task 2.4: Syllabus committee</a>	Vidyo	WP2
06.09.2017	<a href="#">ARIES Task 2.2 meeting #2</a>	Vidyo	WP2
18.09.2017	<a href="#">Task 2.4 Technical Committee #1</a>	Vidyo	WP2
16.10.2017	<a href="#">Task 2.3 - Meeting #2</a>	Vidyo	WP2
17.10.2017	<a href="#">Task 2.4 Syllabus Committee #2</a>	Vidyo	WP2
19.10.2017	<a href="#">Task 2.4 Technical Committee #2</a>	Vidyo	WP2
14.11.2017	<a href="#">Task 2.2 Meeting #3</a>	Vidyo	WP2
28.11.2017	<a href="#">Task 2.4 Syllabus Committee #3</a>	Vidyo	WP2

06.12.2017	<a href="#">Task 2.3 - Meeting #3</a>	Vidyo	WP2
12.12.2017	<a href="#">WP2 Task Leader Meeting</a>	CERN	WP2
19.01.2018	<a href="#">WP2.4 Syllabus Committee #4</a>	Vidyo	WP2
<b>WP3: Industrial and Societal Applications</b>			
24-26.07.2017	<a href="#">Very High Energy Electron Radiotherapy</a>	Daresbury	WP3
13-14.09.2017	<a href="#">ARIES WP3 kick-off</a>	AGH, Krakow	WP3
6-7.11.2017	<a href="#">Accelerated Electrons for Life (AcEL)</a>	Sao Polo	WP3
01.12.2017	<a href="#">ARIES Meets Industry – accelerator application to the ship exhaust gases treatment</a>	CERN	WP3
22-26.01.2018	<a href="#">CLIC Workshop 2018</a>	CERN	WP3
Monthly	WP3 Task leaders meeting	video	WP3
<b>WP4: Efficient Energy Management</b>			
05.05.2017	<a href="#">WP4 Kick-off meeting</a>	CERN	WP4
<b>WP5: European Network for Novel Accelerators (EuroNNAC)</b>			
24-30.09.2017	<a href="#">3<sup>rd</sup> EAAC workshop</a>	Elba	WP5
30.09.2017	<a href="#">EuroNNAc 3 Yearly Meeting 2017</a>	Elba	WP5
<b>WP6: Accelerator Performance and Concepts</b>			
05.05.2017	<a href="#">WP6 APEC Steering Meeting</a>	CERN	WP6
11-13.09.2017	<a href="#">LHeC and FCC-eh Workshop</a>	CERN	WP6
18-22.09.2017	<a href="#">Mini-Workshop on Impedances and Beam Instabilities in Particle Accelerators</a>	Benevento	WP6
18-21.09.2017	<a href="#">Mini-workshop on Reliability and Availability</a>	CERN	WP6
4-6.10.2017	<a href="#">Space Charge 2017 Workshop</a>	Darmstadt	WP6
15-20.10.2017	<a href="#">Accelerator Reliability Workshop 2017 (ARW2017)</a>	Versailles	WP6
9-11.11.2017	<a href="#">Slow Extraction workshop</a>	CERN	WP6
27-28.11.2017	<a href="#">Photon Beams Workshop 2017</a>	University of Padova	WP6
28.02-2.3.2018	<a href="#">Workshop on Ion Sources and Low Energy Beam Transport into RF Linacs</a>	Frankfurt am Main	WP6
12-14.03.2018	<a href="#">Pulse Power for Kicker Systems (PULPOKS)</a>	CERN	WP6
12-14.03.2018	<a href="#">2nd Space Charge Collaboration Meeting</a>	CERN	WP6
9-13.04.2018	<a href="#">FCC Week 2018</a>	Amsterdam	WP6
<b>WP7: Rings with Ultra-Low Emittance</b>			
05.05.2017	<a href="#">WP RULE Kick-off meeting</a>	CERN	WP7
27-30.08.2017	<a href="#">Topical Workshop on Injection and Injection Systems</a>	Bessy II Berlin	WP7
15-17.01.2018	<a href="#">7th Low Emittance Rings Workshop</a>	CERN	WP7
18-19.04.2018	<a href="#">DEELS 2018</a>	Diamond Light Source	WP7

19-20.04.2018	<a href="#">Topical Workshop on Diagnostics for Ultra-Low Emittance Rings</a>	Diamond Light Source	WP7
<b>WP8: Advanced Diagnostics at Accelerators</b>			
22-24.05.2017	<a href="#">ARIES Topical Workshop on ‘Simulation, Design &amp; Operation of Ionization Profile Monitors’</a>	GSI, Darmstadt	WP8
29-30.01.2018	<a href="#">Topical Workshop on “Emittance Measurements for Light Sources and FELs</a>	ALBA	WP8
<b>WP14: Promoting Innovation</b>			
08.06.2017	<a href="#">WP14 Meeting</a>	CERN	WP14
26.06.2017	<a href="#">Task14.5 HTS Meeting</a>	CERN	WP14
25.08.2017	<a href="#">Budget Implementation</a>	CERN	WP14
18.10.2017	<a href="#">ARIES Task14.5 Conductor meeting</a>	CERN	WP14
30.11.2017	<a href="#">WP14.5 HTS meeting</a>	CERN	WP14
07.12.2017	<a href="#">WP14 KoM meeting</a>	CERN	WP14
05.03.2018	<a href="#">PoC discussion meeting</a>	CERN	WP14
20.03.2018	<a href="#">PoC discussion meeting</a>	CERN	WP14
22.03.2018	<a href="#">PoC discussion meeting</a>	CERN	WP14
27.03.2018	HiRadmat and MgB2 telecom	CERN	WP14
26.04.2018	<a href="#">WP14.5 HTS meeting</a>	CERN	WP14
<b>WP15: Thin Film for Superconducting RF Cavities SRF</b>			
05.05.2017	<a href="#">WP15 Kick-off meeting</a>	CERN	WP15
22.06.2017	<a href="#">ARIES Task 15.1 meeting 2</a>	Vidyo	WP15
17-19.07.2017	WP15 meeting held during SRF2017	Lanzhou	WP15
20.10.2017	<a href="#">ARIES WP15 Meeting</a>	CERN	WP15
16.03.2018	<a href="#">WP15 Meeting 4</a>	video	WP15
<b>WP16: Intense, RF modulated E-beams</b>			
03.05.2017	<a href="#">ARIES WP16 Kick-off Meeting</a>	CERN	WP16
01.12.2017	<a href="#">WP16 Task 4 meeting: parameters for test stand</a>	CERN	WP16
30.04.2018	<a href="#">WP16 meeting: test stand and preparation of annual meeting</a>	video	WP16
<b>WP17: Materials for extreme thermal management</b>			
05.05.2017	<a href="#">ARIES WP17 (PowerMat) Kick-off Meeting</a>	CERN	WP17
27-28.11.2017	<a href="#">1st Workshop of ARIES WP17 PowerMat</a>	Politecnico di Torino	WP17
<b>WP18: Very high gradient acceleration techniques</b>			
08/12/2018	WP18.2 meeting (in person)	Ecole Polytechnique, Palaiseau, France	WP18

---

13/02/2018	WP18.2 meeting (in person)	Ecole Polytechnique, Palaiseau, France	WP18
28/03/2018	WP18.2 meeting (in person)	Ecole Polytechnique, Palaiseau, France	WP18
04/04/2018	WP18.5 meeting (in person)	Ecole Polytechnique, Palaiseau, France	WP18
05/04/2018	WP18.3 meeting (in person)	CEA, Saclay, France	WP18
18/04/2018	WP18.2 meeting (in person)	Ecole Polytechnique, Palaiseau, France	WP18

## Annex 2: List of User Selection Panel Members

Name	Home Institution	Home Institution Town, Country	External / internal members
<b>WP9: Magnet Testing</b>			
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
<b>WP10: Material Testing</b>			
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
<b>WP11: Electron and proton beam testing</b>			
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
<b>WP12: Radio Frequency Testing</b>			
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
<b>WP13: Plasma beam testing</b>			
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

---

## 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