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ARIES 2018 – Infrastructure, Innovation, Outreach

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***Abstract*—This article has two outreach aims. It concisely summarizes the main research and technical efforts in the EC H2020 ARIES Integrating Activity – Accelerator Research and Innovation for European Science and Society [1] during the period 2017/2018. ARIES is a continuation of CARE, TIARA and EuCARD projects [2-3]. The article also tries to show these results as an encouragement for local physics and engineering, research and technical communities to participate actively in such important European projects. According to the author's opinion this participation may be much bigger [4-27]. All the needed components to participate – human, material and infrastructural are there [4,7]. So why the results are not satisfying as they should be? The major research subjects of ARIES are: new methods of particles acceleration including laser, plasma and particle beam interactions, new materials and accelerator components, building new generations of accelerators, energy efficiency and management of large accelerator systems, innovative superconducting magnets, high field and ultra-high gradient magnets, cost lowering, system miniaturization, promotion of innovation originating from accelerator research, industrial applications, and societal implications. Two institutions from Poland participate in ARIES – these are Warsaw University of Technology and Institute of Nuclear Chemistry and Technology in Warsaw. There are not present some of the key institutes active in accelerator technology in Poland. Let this article be a small contribution why Poland, a country of such big research potential, contributes so modestly to the European accelerator infrastructural projects? The article bases on public and internal documents of ARIES project, including the EU Grant Agreement and P1 report. The views presented in the paper are only by the author and not necessarily by the ARIES.**

***Keywords*—particle accelerators, accelerator science and technology, novel accelerators, high field magnets, superconducting magnets, RF particle guns, particle detectors, high energy physics, applications of particle accelerators, laser and plasma accelerators, community and social implications of ARIES, EC Integrating Introduction**

EUROPEAN Integrating Activity ARIES was established for four years 2017-2021 to develop European particle accelerator infrastructures in wider community and social context (aries.web.cern.ch). This well-defined context counts very much, and was probably one of the main factors which decided of the project approval. These contextual aims are realized in a number of innovative ways, not previously exercised in the European research projects. In this sense ARIES is a kind of a leader to combine research, networking, innovation, pro-community activities, and increasing social impact. ARIES paves the way for the future and new understanding of accelerator science and technology. It researches the key components of future accelerators. It provides access to premium class of European accelerator infrastructures. It strongly emphasizes and tries to enhance the use of accelerators for society. ARIES builds new environment, new ecosystem around the particle accelerator communities.

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I. Research, Innovation, Access, Industry – Academia Interaction, Contribution to Society

ARIES offers uniquely funded grants in Transnational Access Scheme for numerable accelerator research infrastructures. Electron and proton beam testing facilities are available at several European laboratories. ANKA at KIT Karlsruhe offers electron beam 0,5-2,5 GeV with adjustable electron bunch length and operator defined bunch filling pattern. KIT offers also FLUTE facility with electron energies of 7 and 40-50 MeV, bunch length range 1-300 fs, and charge range 1 pC – 3nC per bunch. IPHI CEA Saclay offers a beam of 3 MeV protons of duty cycle 1ms/1Hz to 100mA/CW. Neutron source at low flux is available and 352 MHz RF test facility. SINBAD DESY offers electron bunches 0,1 – 20 pC of charge, few fs in length, and energies to 100 MeV. VELA STFC Daresbury offers electrons of 6 MeV at 10 Hz, with pulses 100 fs. Upgrade will provide electrons 40 MeV and 100 Hz.

ARIES offers uniquely grants to check the proof of concept proposed by smaller groups of research teams, mainly originating from universities and innovative industry. The grants are to foster the innovation and primarily to enhance the impact of accelerator technology in society. The winning proposals were evaluated not only for technical aspects but according their potential applications. Electron beam accelerators were proposed to neutralize the pollution generated by large marine diesel engines (Consortium run by Riga TU). Diamond based innovative composite materials of tailored thermomechanical properties are proposed for power electronics, lasers and collimators for future accelerators (Consortium run by RHP Austria). These patented materials are offered to numerable industries including automotive. Novel manufacturing technology of superconducting RF cavity by ALD was proposed by CEA and Zanon. It is expected that the application of ALD may lead to reduction of construction and operational costs of the largest accelerators such as CLIC, ILC and FCC. Advanced optical imaging system was proposed by Liverpool Uni. for beam diagnostics in synchrotrons, light sources, also for displays and video projectors. Funding of application grants by ARIES shows the maturity of accelerators which enables to look much wider beyond particle physics and explore more fields which are beneficial to the society.

Realization of ARIES confirms that the accelerators are at a critical time of their evolution path. Rough estimate reveals more than $3*10^4$ particle accelerators working in different applications across the globe, including health, agriculture, environment protection, waste disposal and transmutation, security and numerable different industries, including specialized and mass production. ARIES acts on three platforms of accelerator science and technology: sustainability, innovation, and community. These three areas complement themselves in a balanced way. Continuity of HEP research at the discovery frontier requires a lot of developments in accelerator science and technology. One of the prohibiting factors are increasing costs. Thus, the research goes on the size, cost and power consumption by these infrastructures, preceding the design, implementation and funding. In the domain of sustainability ARIES develops new ideas, concepts, technologies, but also politics and roadmaps to change present and future generations of particle accelerators. These future accelerators have to be operated, serviced and maintained by new generation of researchers and engineers. ARIES helps to train early career accelerator researchers and engineers to maintain fast rate of continuity at the discovery edge.

One of the ways to promote innovation is to undertake directly and actively common actions, by such projects like ARIES, with industrial partners. Such actions are focused on specific developments, relevant to hi-tech industries. Some of these fields include: material engineering for applications various industries, high temperature superconductors, high power superconducting cables, radiation resistant materials, high temperature and mechanical stress resistant materials, graphitic volume materials and coatings, diamond like materials, advanced and new generation electronics and software. Innovation is combined in a broader sense with the community. ARIES combines cooperative actions of several tens of direct partners and countries with even more of associated institutions. The partners, belonging to both academia, research institutes and industry, create together a unique combination of experience in the relevant field of the largest accelerator infrastructures with the intellectual potential of the key universities. This mixture of experience and visions for the future is submerged in the strict market-oriented approach of the high-technology industry.

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

- develop, demonstrate novel concepts and further improve the European particle accelerators;
- 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 continues to publish and contributes to the periodic Accelerating News [28], a newsletter designed for global particle accelerator communities. The newsletter was started by FP6 CARE project, as part of the online media system accompanying then the project. The newsletter gained a large popularity on the web and the editors have decided to continue the editorial effort throughout EuCARD and EuCARD2. Now the Accelerating News AN is a standalone web publication coordinated by CERN but of worldwide extent. ARIES is, among other relevant projects, one of the most active contributors. Accelerating News covers such subjects like: new accelerator technologies, visits to particular laboratories, interviews with key accelerator scientists, reports from accelerator conferences, projects mid-term and final reviews, technical news and research discoveries, meetings with industry during innovation days, outreach and educational activities.

Accelerator science and technologies are exercised in Poland at different level in several academic and research institutes like NCNR in Świerk, INP in Kraków, INCT in Warsaw, and also at some universities, for example in Warsaw, Kraków, Kielce, Opole, Łódź, Wrocław, and some other places. Warsaw and Kraków centres have their own small accelerator infrastructures. Both of them also design and manufacture accelerator components for international partners to be integrated in large European accelerator centres like CERN, FAIR, ESS/Lund, DESY, JINR, and other places. A variety of components are also manufactured for different infrastructures of similar research demands and technical requirements like high field magnets, materials resistant to intense neutron radiation, free electron lasers - FELs, tokamaks, other HEP experiments, including hot plasma and astroparticle physics. A number of smaller university groups distributed across the country is contributing actively through material engineering research, numerous simulations and modelling in the field of accelerator science, design and tests of new generation of high power and low level RF systems, novel solutions to advanced electronics systems, cryogenic systems, atomic clock distribution systems and solving ultra-precise synchronization over large distributed accelerator research infrastructures.

II. Activities Oriented on Community and Society

Management, dissemination and ensuring sustainability provides governance and area for collaborative communication. It embraces: progress monitoring, topical and plenary meetings, outreach and dissemination events, structuring the accelerator community, and industrial workshops.

Training, communication and outreach for accelerator science concerns training improvement, communication and outreach for accelerator community, and includes relevant web resources – open and intranet, posters, video, social media, news and articles. Survey on training in accelerators is expected to show the distribution of knowledge and the needs for activities. The accelerator courses are targeted at students doing master program. The courses are a component of larger open online educational platform devoted to accelerator science, technology and applications. The future of communication and outreach for accelerators requires constant channelling of the best practices between the communication officers of the European accelerator infrastructures and physics centres. The continuous task is to increase the effectiveness of outreach activities for particle physics, light sources accelerators and their bounds to the society.

Industrial and societal applications activity traces and reviews existing applications of low energy electron beams. This includes technologies of beam generation and applications in material processing, sterilization, environmental technologies, medicine, agriculture, safety and other ones. The

issues of concern are public acceptance and their potential barriers, legal regulations and infrastructure safety and reliability. New forms of accelerator technology are related with new applications especially in environment protection. Higher energy electron beam accelerators add to the low energy beam applications. Traditional and novel radioisotopes are fabricated by more compact and efficient accelerator machines for medical imaging and cancer therapy.

Efficient energy management is a key factor for all accelerator applications and their infrastructures. Large energy consumption is considered differently for research and industrial uses. Big accelerators use several multi MW klystrons. Novel high-efficiency RF sources are considered like kladistrons. Energy efficiency concerns all components and processes of these infrastructures like energy recovery from the used beam and from the pulsed magnets, novel low-loss materials, optimized construction of cold neutron sources, flux trapping, magnetic shielding, increased efficiency of spallation targets, higher efficiencies of superconducting cavities, more efficient beam transport, etc.

European network for novel accelerators works continuously on advanced accelerator concepts. ARIES adds to this effort by building and enhancing the advanced accelerator network of more than 50 national laboratories and universities in Europe, Asia and the US. The activities include well organized training of young scientists, preparing students meetings. Electron plasma and dielectric accelerators are considered for intense developments in cooperation with relevant projects like EuPRAXIA, ACHIP and AXSIS, and ALLEGRO workshops. High gradient wakefield accelerators are subject to schools attracting young researchers to this emerging field.

Accelerator performance and concepts is a networking activity organizing workshops and periodic topical meetings. These events cover most of the critical issues related to accelerator technology, design and operation. Networking contributions add effectively to the increase of accelerator performance, modern facilities and infrastructures. This concerns research accelerators but also facilities for medical and material science and engineering applications. The main aim is to prepare the design of high energy accelerators for the long term future. There are considered future concepts like super intense photon beams for gamma-gamma colliders, Compton sources and gamma factories. These various ideas contribute to building strong relations between apparently different accelerator communities. Muon collider is considered as an effective alternative for high energy colliders.

Rings with ultra-low emittance is concerned with particle beams of the ultimately high quality. Emittance lowering is of key issue for infrastructures upgrades. Research is carried on damping ring for linear colliders including muon colliders. Emittance lowering is related to injection and diagnostic systems. Critical issues concerning emittance lowering and beam commissioning strategies are tested on existing infrastructures, including KARA/KIT and BESSY-II/HZB.

Advanced diagnostics at accelerators embrace watching the status of the beam and the machine. Beam quality monitoring concerns transverse profile measurements with the usage of non-destructive technologies. Beam profiles are measured at accelerators and at light sources. Very small beam sizes require application of novel measurement technologies. Critical parameters of hadron synchrotrons are measured with the aim to enhance the performance and operation of these accelerators. Different techniques of bunch length measurements are compared for optimal choice in the LINAC based light sources.

Testing of magnets, materials, electron and proton beams, RF equipment, and plasma beams is generally concerned with building of test facilities supporting the construction of accelerator infrastructures. Testing facilities are available to outside users using the schemes of the transnational access TA. The most attractive testing facilities are for material and magnets, vertical cryostats, and several others.

Promoting innovation in ARIES is the umbrella for Proof-of-Concept grants to industry and university consortia. The subjects of proposals are identified within the ARIES project. Several proposals won the grants including MgB_2 hot pressed and additive manufactured samples for HTS high current density power cables. HTS cables of high transmission efficiency are critical for next generation SRF accelerator systems and infrastructures. Key issue are cable parameters like length, mechanical ruggedness, maximum current density, and mass production costs. Next generation accelerator timing system requires unprecedented phase stability at the level of fs.

Thin films for SRF cavities are developed to decrease the immense costs of bulk niobium structures. Major aim is to improve the surface quality (measured by the lowest roughness without scratches) by etching, polishing, electro-polishing, electroplating, cleaning with sulfamic acid and butanol. Electroplating is a pitting free technique. Thin niobium layers were treated with laser beam to increase monocrystalline grain sizes and improve the film adhesion on the copper substrate.

Intense RF-modulated E-beams are generated in electron guns. The requirements are for 10 A electron currents modulated at several MHz, with space charge compensation and preservation of transverse beam profile. Modulation is done by specially shaped control grid. The full model includes a drift magnet which enables beam dynamics and longitudinal profile to be measured.

Materials for extreme thermal management are used for new generation of accelerators but also for numerable other demanding thermal interaction applications. In particle accelerators they serve for building of beam intercepting devices. Effects of long term radiation damage are analysed. Experiments on exposing a range of materials to the direct impact of high power particle beams are conducted. The materials included molybdenum carbide – graphite, carbon-fibre composited, flexible graphite and graphite foams.

Very high gradient acceleration techniques explore several methods like multi-stage laser based electron transport line with laser plasma beam creation, transport and injection into a second stage. Acceleration of electrons are considered also in twisted plasma waves with orbital angular momentum. Ideas of dielectric accelerators are under simulation and experimental tests. High gradients means multiple GV/m obtained in plasma rather than tens or even hundreds of MV/m obtained in warm and cold cavities of more or less classical construction.

III. Outreach, Sustainability, Dissemination, Access, Communication, Interaction, Training, Workshops

Here we understand all activities combined with communications, dissemination, outreach, education, training, professional advertising, and all information interaction with

the community, and recently also with the society, including social media of all levels professional and open. This approach has changed completely during a few recent years with the advent of successive EU FP programs and projects. The emphasis was shifted towards wider communities, training of young researchers, social media and interaction with society. Interaction with society justifies and supports, in a different and new way, realization of such a high technology project like ARIES. Outreach is done on several levels of the project – by the project itself on a general platform and by particular topical work packages. The aim and target of these activities is different, yet equally important. ARIES defines some of these activities in the following way: The social media approach followed in ARIES is to reach the followers of the project main partners' social media channels, whilst creating dedicated ARIES social media channels (primarily Facebook and LinkedIn, as judged more relevant for the communication of a technological EU project). The reason is that it takes a long time to build a followers' basis, whereas through the ARIES' partners' channels, it is possible to reach to a large pool of followers interested in the topics relating to accelerators. This cascading approach has been used for the ARIES presentation video, which was posted on CERN Facebook, Twitter, LinkedIn and YouTube channels and leveraged a great level of interest. Other ARIES partners reach similar levels of impact. Social media play more and more important role in creating the broader opinion of the science and research and their roles in society development. European projects, but also large professional associations and institutions take these changing outreach conditions very seriously into account. I wish that the relevant local institutions involved in accelerator research take the same outreach and dissemination paths of active interaction with the society.

A unique feature of ARIES and its predecessors CARE, EuCARD, and EuCARD2 is continuous and periodic publishing of a series of scientific and technical monographs related to the project. During the P1 period of ARIES the following booklets were published:

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

During these projects more than 50 volumes have been published internationally contributing to the development of accelerator technology, also changing the traditional face of infrastructural projects, and also widening their standard extent of tasks. Most of the monographs are Ph.D. theses related to the mentioned projects. Some of the monographs are research reports from the particular work packages and from the whole projects, summarizing their achievements. The monographs are available via the project web portals, via the CERN's Document Server CDS, and also via the Publishing Office of Warsaw University of Technology.

ARIES coordinates its activities with the accelerator community at several levels, including communication, discussions, organization, logistics, interaction with relevant bodies and institutes, other projects like AMICI, planning and innovation. In particular coordination is done with TIARA Committee that represents the Particle Accelerator research and development community. The discussions with TIARA concern the current performance of the community, relevance of ARIES contributions, and primarily planning for the near and medium term development of the community via realization of the planned, accepted and forthcoming projects. Project continuity and community sustainability is here of the key issue. Generally the coordination task is closely combined with several basic policies like the identification of subjects and technologies that could be part of future programmes based on innovation, and exploring the ways to organise co-innovation project with industry. Relevant planning and realizations towards these policies, plus close coordination with other relevant community and society bodies, are a solid guarantee of the sustainability and continuation. Tools and strategies are considered to enhance industry-academia cooperation in the particle accelerator community. To keep the coordination alive, dynamic, and to develop the subject of accelerator sustainability, a permanent joint TIARA-ARIES work group was established. TA-WG consists of key representatives of ARIES beneficiaries and other decision makers which were active previously in the European ESGARD Committee.

ARIES and its WPs organize periodically and frequently general and topical workshops related to accelerator science and technology. Massive online open courses MOOC were defined to serve the broader accelerator community. Survey Monkey tool was adopted for carrying out the training surveys. Industrial relations required provision of a detailed digest of wide range of applications of electron beams up to 10 MeV and the accelerators currently in use. These applications may require up-to-the-date modifications, improvements and upgrades, which involves continuous professional training and permanent communication between research groups and industry, preferably in the form of workshops and topical meetings. Apart of improvements, the workshops and trainings look also into new applications that would be of interest to industry. Energy for sustainable science is of concern and subject to workshops due to ever increasing energy consumption by not only the largest accelerator infrastructures. The energy related considerations and trainings, including lowering losses and increasing the efficiency, concern all parts of research and industrial accelerator infrastructures. Low energy consumption and pulsed modes of work, together with energy recovery are considered to be key paths for development.

ARIES promotes knowledge on advanced accelerator concepts. Large infrastructures are planned ahead for several decades. The decision processes concerning the choice of concept, working principles, choice of components, localization and finances, human resources, realisability, risk analysis, etc. take long time and are slowly changing towards the final choice. ARIES plays a role of the junction point to trace the developments for short, medium and long time choices of research level accelerator technology for the future. This

coordination is done in close cooperation with relevant permanent and temporal or networking European bodies active in accelerator science and technology like EuroNNAC network, and EAAC workshops. One of the methods to widen the impact outside of the direct project extent is to organize joint workshops with other projects active in accelerator science and technology, but also accelerators as tools for high energy physics, material science and engineering, and other relevant areas. Additive manufacturing advanced technologies are used for accelerator applications. Scintillation screens and optical technologies are used for transverse profile measurements. HTS magnets and components are more and more frequently used not only for accelerator magnets.

ARIES is now one of the most effective engines in research on accelerator performance improvement and development. Organized worldwide topical workshops, and dynamically organized mini-workshops, turned out to be the most effective tool to communicate and proliferate the development ideas and the results of current implementations laboratory tests. Narrow, in depth topics of the workshops were: Beam Quality Control in Hadron Storage Rings and Synchrotrons, Space Charge, Electron Cloud, Slow Extraction, Pulsed Power for Kicker Systems, FCC Week, LHeC/FCC-eh, Reliability and Availability of Accelerator Infrastructures, Synchronization and Timing in accelerator infrastructures, Impedances and Beam Instabilities in Particle Accelerators, Limitations of future circular e+e- factories, Ion Sources and Low Energy Beam Transport into RF Linacs, Photon Beams, Muon Colliders, Injection for Ultra Low Emittance Rings, Diagnostics, Feedback systems and Measurements of Accelerators. Impact of this approach for research results exchange and future activity planning is very big since interested audience usually participates in all listed smaller meetings, adding together to quite big numbers, and contributing effectively towards the development of the community and investigated ideas. Novel injection schemes are tested at operation with negative compaction factor in several accelerator infrastructures like KIT and BESSY. Some of the workshops are indirectly associated with access to the laboratories including magnets testing, RF, material testing and beam testing (CERN, GSI, Uppsala, KIT, CEA, STFC). Testing facilities embrace also plasma beams and combined accelerator – plasma technologies. These facilities serve experiment development purposes but also checking new ideas, and training young researchers.

ARIES promotes in a very active way cooperation, interaction and outreach with industry. This is done on several platforms, all of them serving the effective development of innovation, knowledge transfer, communication, encouragement, education and training, and building effective links potentially leading to cooperation and development of applications. ARIES has set-up the Industry Advisory Board and promoted meetings are planned on Academia – Industry Cooperation. The research – industry activities are not theoretical but concern, among others, manufacturing of several classes of advanced new materials (HTS and thermally rugged) needed in industry for critical applications in power generation, potentially also in space applications. ARIES enables extended testing facilities for nearly all critical components of accelerator infrastructures. Materials, components and beam testing facilities are accessible, make the project more open and reliable for relevant partners, including industry.

Every year ARIES summarizes its achievements during the annual meetings. The meetings gather over 100 participants not only directly associated with the project. The meetings are designed in such a way so as not only to show in depth project realization paths and current status but also bring these results on a broader accelerator science and technical backgrounds. This approach encourages much wider audience and gets much more useful for the accelerator community. Keynote and invited speakers are presenting the key areas from accelerator technology which have to be solved to maintain proper rate of the development of infrastructures. This includes also new technologies which, after fulfilling their current promises, may completely change the development of particle accelerators in several decades. Such promises, however not yet fully confirmed, are hidden in plasma and laser accelerators. ARIES contributes to the research confirming initially theses abilities, together with other relevant projects like EuPRAXIA [29] and AWAKE [30]. All these projects have at the foundation accelerator technology. Closer combination of electron and proton beams with energetic laser beams, hot and ordered plasma and other high energy technologies leads to new scientific possibilities and to construction of new research tools.

IV. Knowledge Management and Open Access

ARIES, as a part of the H2020 Programme, fully complies with the framework rules for participation and dissemination. EC Grant Agreement GA defines the details and particulars of access to results and background, as well as ownership of results. Consortium Agreement CA defines in details the implementation of these principles and possible access rights granting during the project duration. Background needed for carrying out the project is always identified and agreed by the beneficiaries before the start of activities. Background is defined as the resources which may have to be made accessible and/or available to other beneficiaries. CA defines also the access rights for use of ARIES results for research purposes beyond the project duration.

ARIES is not a project which participates actively and directly in research experiments. ARIES project and all its activities do not generate open research data, neither they develop open source research software. Some of networking activities and joint research activities involve modelling and simulations which are necessary for infrastructure development. The latter include: electron guns, neutron spallation sources, non-linear beam dynamics, material irradiations, and plasma.

Open access to ARIES results is realized according to long tradition of accelerator community. Conference proceedings are published on Indico and JACoW – Joint Accelerator Conference Website. JACoW is an international collaboration that publishes the proceedings of accelerator conferences held around the world, whereby all conferences agree to the policies and requirements for Open Access publication. ARIES makes use of Gold and Silver Open Access publishing standards. Peer reviewed publications are directly submitted to open-access journals, in particular to PRL or PRA&B. ARIES self-archives the publications in open repositories like ArXiv or inSpireHEP.net, but also in CERN CDS publication database -

using ZENODO digital repository. H2020 results are integrated on a common platform OpenAIRE.

Open access is provided not only to results and publications but also to developed hardware. Open hardware license was introduced by CERN several years ago and was widely adopted by the scientific community. Knowledge Transfer Group at CERN coordinates the OHL activities and advices on relevant actions. In particular the CERN OHL is open to the industry. Participation in OHL and other directed actions are pointed at dissemination of results to industry. Cooperation with industry is using existing numerable Technology Transfer networks and an activity generated by ARIES – Academia meets Industry, with the following aims:

- disseminate information on results and technologies developed in the frame of the project to European industry;
- gather market information that may be used to motivate and to encourage industries to develop innovative products, using accelerator technologies;
- scout for technologies suitable for further R&D that could be eligible for the internal ARIES Proof of Concept fund, informing the academic participants and industries about this interesting possibility.

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