ISBN: 978-3-95450-201-1 doi:10.18429/JACoW-IBIC2018-MOPB02

ARIES-ADA: AN R&D NETWORK FOR ADVANCED DIAGNOSTICS AT ACCELERATORS*

P. Forck†, M. Sapinski, GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany
U. Iriso, F. Perez, ALBA Synchrotron, Cerdanyola del Vallès, Barcelona, Spain
R. Jones, CERN, Geneva, Switzerland
Ch. Gerth, K. Wittenburg, Deutsches Elektronen-Synchrotron, Hamburg, Germany
R. Ischebeck, Paul Scherrer Institut, Villigen, Switzerland

Abstract

Accelerator Research and Innovation for European Science and Society, ARIES, is an initiative funded by the European Union. The activity comprises three major categories: Joint Research Activities; Transnational Access; Network Activities. One of 17 activities is a network related to Advanced Diagnostics at Accelerators, ADA with the task of strengthening collaborations between international laboratories and for coordinated R&D in beam diagnostics. This is performed by organizing Topical Workshops on actual developments and supporting interchange of experts between different labs. Since the start of the project in May 2017 four Topical Workshops were organized, each with 30-45 participants. Future workshops will address actual topics.

THE INITIATIVE ARIES

Accelerator Research and Innovation for European Science and Society, ARIES [1], is an Integrating Activity which aims to develop European particle accelerator infrastructures, co-funded under the European Commission's Horizon 2020 Research and Innovation programme.

Within a four year funding period, the key aim of the initiative ARIES is related to the development of novel concepts and further improve existing accelerator technology. This is realized by improving the performance, availability, and sustainability of particle accelerators, transferring the benefits and applications of accelerator technology to both science and society, and enlarging and integrating the European accelerator community. Moreover, it aims to support innovative technologies with market potential by advancing concepts and designs for medical, industrial and environmental applications of accelerators for the benefits of European society as a whole. The consortium consists of 41 institutions form academia, accelerator laboratories and industry of 18 European countries. The initiative is organized in 17 scientific work-packages of three different categories:

- Within the 5 so called '*Joint Research Activities'* several intuitions are working together on key technologies for accelerators like for super-conducting rf-cavities or very high gradient accelerators.
- As a second branch 5 so called '*Transnational Access'* provides infrastructure for equipment testing like fully equipped test benches for rf-cavities, access to electron and hadron accelerators with a wide range of beam parameters.
- The third branch comprises of 7 *'Network Activities'* which aims for strengthening the collaborations concerning the worldwide accelerator research and development. These activities are related to e.g. the design of novel accelerators, efficient energy management, design of ultra-low emittance light sources, industrial applications, beam diagnostics and novel methods for student education.

THE NETWORK ARIES-ADA

One of the Network Activities is related to '*Advanced Diagnostics at Accelerators'*, ADA [2]. To meet the demands of new accelerator facilities, novel beam instrumentation and diagnostics methods are required. Knowledge exchange between experts from worldwide research institutes is an efficient way of developing such systems efficiently. Topical Workshops with about 20 to 40 international participants ranging from novices to world-leading experts is an excellent way of summarizing state of the art developments in the field and transferring this knowledge to the young generation. A workshop duration of typically two days seems to be adequate to summarize the current status of a dedicated subject, provide the possibility to discuss novel ideas and trigger the collaboration between the participants. The collection of contributions acts as a comprehensive summery of the current R&D status. The subject of the workshops is oriented on actual topics; four of such dedicated workshops were organized in the first 14 month of the funding period (i.e. between May 2017 and June 2018).

The funding form the European Union for ARIES-ADA is administrated by the four beneficiary institutions ALBA, CERN, DESY and GSI. The budget covers mainly the general workshop costs as well as possible additional costs to enable the participations of the worldwide experts. The workshops are announced to the general audience from the ARIES website [1, 2]; key-speakers are invited directly by the workshop organizers.

In addition to the workshops, the exchange of experts for a typical duration of 2 weeks for common discussions and to carry out experiments were organised in the frame of ARIES-ADA to further strengthen the collaboration between the accelerator institutions. Within the first year of ARIES-ADA four of such visits were financed.

* This project has received funding from the European Union's Horizon 2020 programme under Grant Agreement No 730871
† email address: p.forck@gsi.de.

ISBN: 978-3-95450-201-1 doi:10.18429/JACoW-IBIC2018-MOPB02

In the following the Topical Workshops executed within the frame of ARIES-ADA are summarized and an outlook for further events is given; the entire contributions can be found on the cited INDICO pages.

WORKSHOP ON IPM OPERATION AND SIMULATION

In May 2017 a Topical Workshop took place at GSI (Darmstadt, Germany) concerning *'Simulation, Design & Operation of Ionization Profile Monitors'* [3] with 33 international participants. 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 µm and time gating down to the 10 ns level. They are installed at both hadron synchrotrons and LINACs. Due to the increase in the beam power of future LINACs (e.g. at CERN, ESS, FAIR, ISIS) these IPMs will substitute the traditional invasive wire-based diagnostics. Even though the principle is well known, there are many technical challenges for the reliable operation of IPMs.

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.

Figure 1: Participants of the Topical Workshop executed in May 2017 at GSI.

One purpose of the workshop was to introduce the community to a recently completed simulation code called IPMSim [4, 5], which is freely accessibly. 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. Further extensions of the code (e.g. for Beam Induced Fluorescence Monitors) are currently included [6]. As different codes are produced by various laboratories, a common set of beam parameters were agreed on to perform such benchmarking between those codes. Possible experimental verifications of such simulations were put forward at this workshop and many have now been performed.

This workshop acted as a follow-up of a previous workshop held at CERN in February 2016 [7]. Due the large interest in this field, a third workshop will be executed at J-PARC (Tokai, Japan) in September 2018 [8].

WORKSHOP ON EMITTANCE MEASUREMENT AT LIGHT SOURCES

The Topical Workshop *'Emittance Measurements for Light Sources and FELs'* [9] was organized at ALBA (Barcelona, Spain) in January 2018 with 37 participants. 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. Due to the importance of the topic, a detailed summary of this workshop is given as an invited talk at this conference [10].

Figure 2: Participants of the Topical Workshop executed in January 2018 at ALBA.

For synchrotron light sources, the review of present techniques using synchrotron radiation showed that beam sizes down to the 2-3µm level can be measured through the careful design and choice of the instrumentation. These techniques include direct imaging techniques (X-ray pinhole cameras, Compound Refractive Lenses, or in-air X-ray detectors) and techniques based on the analysis of light coherence (visible light interferometers). Since this is at the limit for the beam sizes foreseen for the next generation of low emittance rings, the benefits of more complex techniques such as X-ray diffraction/interferometry and Heterodyne Speckle Fields (HNFS) were also deeply discussed during the workshop. A further conclusion of the workshop had been that these techniques 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 demonstrated that wires as thin as 1 µm can now be manufactured by lithographic techniques, which allow the

ISBN: 978-3-95450-201-1 doi:10.18429/JACoW-IBIC2018-MOPB02

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 Cherenkov Diffraction Radiation.

WORKSHOP ON DIAGNOSITCS USING ELECTRO-MAGNETIC DETECTORS

A Topical Workshop with 32 participants on *'Extracting Information from electro-magnetic monitors in Hadron Accelerators'* [11] took place in May 2018 at CERN (Geneva, Switzerland) with 32 participants. 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 3rd generation light sources participated as the topic is equally important for the electron- and hadron synchrotrons.

Figure 3: Participants of the Topical Workshop executed in May 2018 at CERN.

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.

WORKSHOP ON LONGITUDINAL MEASUREMENTS AT FELS

In June 2018 the Topical Workshop '*Longitudinal Diagnostics for Free-Electron Lasers*' [12] took place at DESY (Hamburg, Germany) with 45 participants. The workshop aimed at both fostering joint developments of longitudinal diagnostics for femtosecond electron bunches and bringing together experts working on beam instrumentation and detector development. Several participants working in the field of Laser Plasma Accelerators contributed to the workshop as these novel short-bunch accelerators are facing even higher demands on time resolution. The topic of transverse deflecting structures (TDS) was intentionally excluded as there exists a strong collaboration between CERN, PSI and DESY on the development of an X-Band TDS [13] with regular meetings.

Figure 4: Participants of the Topical Workshop executed in June 2018 at DESY.

The workshop was organised in 5 working groups with the goal of exchanging ideas, planning joint collaborations or measurement campaigns. The first day of the workshop was devoted to discussions within these working groups. On the 2nd and 3rd day the working group coordinators reported the discussion results and the participants presented their contributions in poster sessions.

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

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

THz Streak of the primary electron beam: The goal of this working group was to discuss possibilities to streak the electron beam in a micro-structure operating at terahertz frequencies. The aim is to improve the resolution of radio frequency deflectors by increasing both frequency and deflecting fields. The application to low-energy beams has now been presented [14], and further studies at higher-energy facilities are planned.

ISBN: 978-3-95450-201-1 doi:10.18429/JACoW-IBIC2018-MOPB02

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

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

FUTURE WORKSHOPS

The next workshop with the title *'New Generation of Beam Position Acquisition and Feedback Systems'* [15] will take place at ALBA in November 2018. This three days event is a 'double workshop' as it will bring the experts from hadron and electron community together in a common session to discuss closed orbit feedback achievements and the challenges at hadron and ultra-low emittance electron synchrotrons. The second and third day is separated into 'Hadron BPM Analog and Digital Electronics' and 'Fast Feedback Systems for Electron Synchrotrons' discussing the special requirements of both communities.

A workshop on '*Optical Profile Measurements by Scintillation Screens*' will take place in Krakow in April 2019. It can be regarded as an update event of workshop organized in 2011 at GSI [16].

Further subjects of interest are related to the commissioning of hadron LINACs and longitudinal and transverse emittance measurements. For these LINACs methods for automatic beam steering will be discussed. For hadron synchrotrons the control of beam stability and advanced machine parameter determination including halo diagnostics is of major concern. For the electron synchrotron the requirements and related control for beam stability and impedance contributions is an important topic. For the LINAC-based light sources feedback system on an inter-pulse reaction will be discussed as well as methods for reliability determination. These workshops will be planned with about lead-time of about half a year prior to the execution to include actual developments accounting for the beam instrumentation needs. Proposals from the community for further subjects are welcome.

CONCLUSION

Due to the funding by the European Union, Topical Workshops can be organized on actual beam instrumentation developments and usage of such diagnostics. The relevance of such workshops is obvious as typically 20 to 40 worldwide experts are interested to discuss about one dedicated subject in a more detailed manner as can be realized at a regular conference. The familiar atmosphere with senior and young scientist forces discussions about layout details, which are normally not presented at large conferences and contribute to the successful design and operation of beam diagnostics. Moreover, the workshops served as a platform for young scientists to present their work and to mingle with experienced experts. The resulting collection of high quality contributions serves as a comprehensive reference summarising the actual status and the proposals for further developments. The workshops are generally open to the accelerator physics community; the workshop topics are oriented on actual developments and open questions within the community.

The exchange of personnel is not only of direct benefit to the person concerned, but helps to strengthen the collaboration and increases the efficiency for beam diagnostics R&D.

ACKNOWLEDGEMENTS

The steady efforts by M. Vretenar (CERN) acting as the ARIES project leader are highly acknowledged; he and his team led ARIES to a successful program. The competent contributions by all participants and the lively discussions leading to successful workshops are warmly acknowledged. This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 730871.

REFERENCES

[1] https://aries.web.cern.ch/.

[2] https://aries.web.cern.ch/content/wp8

[3] http://indico.gsi.de/event/5366/.

[4] https://twiki.cern.ch/twiki/bin/view/IPMSim/.

[5] M. Sapinski *et al.*, "Ionization profile monitor simulations status and future plans", in *Proc. IBIC'16*, Barcelona, Spain, Sep. 2016, pp. 521-524. doi:10.18429/JACoW-IBIC16-TUPG71

[6] D. Vilsmeier, P. Forck, and M. Sapinski, "A modular Application for IPM simulations", in *Proc. IBIC'17*, Grand Rapids, MI, USA, Sep. 2017, pp. 335-338. doi:10.18429/JACoW-IBIC17-WEPCC07

[7] https://indico.cern.ch/event/491615/.

[8] https://conference-indico.kek.jp/indico/event/55/.

[9] https://indico.cells.es/indico/event/128/.

[10] U. Iriso *et al.*, 'Summary of emittance measurements workshop for SLS and FELs', presented at IBIC'18, paper WEOC01, this conference.

[11] https://indico.cern.ch/event/705430/.

[12] https://indico.cern.ch/event/702602/.

[13] P. Craievich *et al.*, "Status of the PolariX-TDS project", in *Proc. IPAC'18*, Vancouver, BC, Canada, May 2018, pp. 3808-3811. doi:10.18429/JACoW-IPAC18-THPAL068

[14] D. Zhang *et al.,* "Segmented Terahertz Electron Accelerator and Manipulator (STEAM)", *Nature Photonics,* vol. 12, pp. 336–342, 2018. doi:10.1038/s41566-018-0138-z

[15] https://indico.cern.ch/event/743699/.

[16] https://www-bd.gsi.de/ssab.