THE EXTREME BEAMS INITIATIVE IN EuCARD-2*

K. Aulenbacher, JGU, Mainz, Germany; M. Biagini, INFN-LNF Italy; M. Eshraqi, ESS, Lund, Sweden; G. Franchetti, J. Struckmeier, GSI, Germany; F. Zimmermann, CERN, Switzerland

Abstract

EuCARD-2 [1] is an Integration Activity on accelerator R&D co-funded within the European Union's 7th Framework Program. The Extreme Beams (XBEAM) network of EuCARD-2 extends, and goes beyond the scope of, the previous Networking Activities of CARE-HHH and EuCARD [2] EuroLumi. XBEAM addresses, and pushes, all accelerator frontiers: luminosity, energy, beam power, beam intensity, and polarization. This is realized through five tasks, which are focusing on Coordination and Communication, Extreme Colliders (XCOLL), Extreme Performance Rings (XRING), Extreme SC Linacs (XLINAC), and Extreme Polarization (XPOL), respectively. This presentation reports the major achievements of the XBEAM activity from 2013 to 2015, and outlines the further plans through 2017.

OVERVIEW

The EuCARD-2 network on Extreme Beams ("XBEAM") aims at advancing on all accelerator frontiers, in particular luminosity, energy, beam power, beam intensity, and polarization. On the high energy and luminosity frontier it is supporting the HL-LHC crab cavity development and the studies of a Future Circular Collider, both of which became official projects thanks to activities in EuCARD, as well as plans for lepton-hadron colliders, and the preparation of SuperKEKB commissioning. At the high-intensity frontier, it is advancing projects like FAIR, the PSI cyclotron enhancement, and the ISIS upgrade, as well as preparing the ESS linac commissioning. Polarization management is improved both at high energy (LHeC, eRHIC, FCC, ILC, CLIC) and for low-energy precision experiments, such as electron storage rings for electric dipole measurements. XBEAM includes the five tasks shown in Table 1. Detailed information can be found on the XBEAM web site at http://cern.ch/xbeam.

In the first 2 years of the EuCARD-2 project, XBEAM has organised or co-organised more than fifteen workshops, as summarized in Table 2. These workshops addressed key questions for extreme colliders, extreme performance rings, extreme linacs, and extreme polarization. The XBEAM workshop achievements were complemented by a proactive outreach and dissemination effort, including numerous invited presentations at high-level conferences, workshops, or universities, several articles in the Accelerating News, the CERN Courier, and the ICFA Newsletter, plus two EuCARD-2 monographs. Some expert exchanges complete the picture.

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Table 1: The Five Tasks of EuCARD-2 XBEAM

Task	Coordinators
1. Coordination and Communication	F. Zimmermann (CERN) and G. Franchetti (GSI)
2. Extreme Colliders (XCOLL)	M. Biagini (INFN) and F. Zimmermann (CERN)
3. Extreme Performance Rings (XRING)	G. Franchetti and J. Struckmeier (both GSI)
4. Extreme SC Linacs (XLINAC)	M. Eshraqi (ESS)
5. Extreme Polarization (XPOL)	K. Aulenbacher (JGU Mainz)

EXTREME COLLIDERS

XCOLL, together with the earlier AccNet-EuroLumi activity of EuCARD, has helped revive the idea of large high-energy circular lepton ("Higgs factory") and hadron colliders. The development and proposals started by AccNet and continued by XCOLL workshops have led to the launch, in February 2014, of an official 5-year "Future Circular Collider" (FCC) study, under a mandate from the CERN Directorate and from ECFA. The SuperKEKB B-factory soon to be commissioned in Japan will test and demonstrate the feasibility of several important features for these proposed future colliders. Impedance issues are one particular concern for both large lepton and hadron colliders, and have been investigated at a dedicated workshop co-organised by XCOLL. The scope of the LHeC study has been extended to include the integration of an electron-hadron collider option within the FCC complex. Novel compact crab cavities, earlier promoted at several workshops in the framework of CARE-HHH and EuCARD-AccNet, have now become a baseline ingredient for the LHC luminosity upgrade. Their continued development is being followed up by EuCARD-2 XBEAM XCOLL. These crab cavities may also be of interest for LHeC and FCC.

EXTREME PERFORMANCE RINGS

XRING has created discussion forums around critical areas of research for advanced storage rings. The first of these has focused on a topic relevant for FAIR, at the workshop "Beam dynamics meets Magnets" in Darmstadt. Experiences at J-PARC and LHC have provided examples for different working models with the following outcome: 1) According to LHC experience and benchmarking of the LHC dynamic aperture [1] theoretical models can correctly predict beam behaviour when the magnets parameters are well known. 2) Only for the LHC project the magnets characterization were determined by the beam-dynamics requirements, whereas in all other projects (J-PARC, RHIC) the beam dynamics calculations primarily studied the effect of given magnetic

field errors. XRING has also extended several networking activities inherited from EuCARD(-1). Two Space Charge collaboration meetings, organized by XRING at CERN, brought together accelerator physicists from Europe and USA to discuss issues on codes and experiments. The XRING space-charge discussions have triggered new developments e.g. regarding the effect of artificial noise due to the PIC field solvers [3]. A second "Beam dynamics meet Magnets" event (BeMa2015) organized at PSI, has, among other topics, addressed challenges of wiggler magnets for light sources and gantries for medical accelerators. During the Advanced Optics Control workshop at CERN in 2015, supported by XRING and XCOL, optics-control experts discussed the recent development in the field, from current and future colliders to light sources, EDM rings and nonlinear manipulations. Highly specialized techniques such as resonance driving term measurements or MOGA were highlighted along with a careful look at the LHC's linear and nonlinear optics. Following the success of SpaceCharge 2013, a second workshop was recently organized at Oxford with emphasis on the role of the next generation of beam dynamics experiments, and renowned interest in the fundamental origin of space charge induced structure resonances.

EXTREME LINACS

XLINAC addresses the challenges posed by linear accelerators of high power and/or high energy: considering the vulnerability of their components and the high power contained in the beam or in the RF system, efficient and timely commissioning is of great interest. The purpose of the first XLINAC workshop in April 2014 was to bring together beam physicists, beam diagnostics experts and operators, in order to foster an enhanced knowledge exchange and improved communication between these three communities. The workshop demonstrated that a detailed commissioning plan is needed a few years ahead of the actual commissioning, and one should not rely on diagnostics which itself needs significant beam time to debug. An optimum ratio between longitudinal and transverse diagnostic devices needs to be determined. Specific goals should be defined for each particular commissioning objective, with dedicated-time limits and a decision path for passing on to the next phase. Most importantly, dual applications of the same device as well as the sharing of devices between different laboratories can reduce the cost and design efforts. This requires an early identification of synergies in terms of diagnostics needs. Similar beam energies out of RFQs and DTL tanks would increase the possible synergies between projects. XLINAC plays a pivotal role through fostering the pertinent information exchange, the joint inter-laboratory planning, and the introduction of common standards.

EXTREME POLARIZATION

XPOL covers all kinds of polarization phenomena in particle accelerators. It is coordinating the on going polarization efforts for existing and planned projects. The first XPOL workshop at Mainz in February 2014 concentrated on lepton accelerators, covering a large number of issues, ranging from the 100-MeV (MESA-like) energy range, over polarization treatment at existing synchrotrons like ELSA (GeV range) and larger (single or double) polarized electron/ion colliding machines, such as eRHIC or LHEC (with electron energies between a few and tens of GeV), up to high energy linear machines such as the ILC. Discussion topics included spin generation, spin transport, accurate measurement of spin vector, contributions from universities, milestones accomplished, the road ahead, and open issues for linear and circular machines. The future challenges for the polarization treatment have been formulated in the form of four "key questions," namely: (1) Is it possible to intensify the interaction between experimental physicists and accelerator experts answer whether or not spin capability must be included in specific accelerator designs? (2) What is the most efficient "quality control" for newly proposed polarization measurement methods with advertised precision at the per mid level? (3) What is the further potential of precise spin control in storage rings for fundamental physics? (4) Does the expected scientific output justify investing in R&D efforts on anti-proton polarization? The XPOL activities undertaken so far provide a solid basis for intensifying discussions on the above four key questions within the next couple of years.

UNIVERSITIES MEET LABORATORIES

Extreme Beams and EuCARD-2 as a whole have also contributed to removing the barriers separating universities and laboratories through a dedicated workshop hosted by Frankfurt University [4]. In this workshop representatives from many countries discussed the standing of accelerator science in the academic world, the ranking criteria for research at laboratories and universities, education in accelerator technology and physics, and the interplay between universities and laboratories.

OUTLOOK

The activities of Extreme Beam will continue along with EuCARD-2 through mid 2017. At least 10 more workshops will be organized until then. Upcoming soon are the XCOLL LHeC and XLINAC "LLRF & beam dynamics in hadron linacs" workshops in June, which are followed by the XRING "beam dynamics meets diagnostics" and XPOL "electron EDM ring" workshops in September 2015. Other future events will look at the far frontier of accelerators (XCOLL), revisit the plans for

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hadron linac commissioning (XLINAC), review EDM rings for protons and deuterons (XRING), and study polarization needs for FCC/CepC and LHeC (XPOL).

REFERENCES

[1] http://eucard2.web.cern.ch/
[2] http://eucard2.web.cern.ch/content/eucard
[3] I. Hofmann and O. Boine-Frankenheim, Phys. Rev. ST Accel. Beams 17, 124201 (2014); O. Boine Frankenheim, *et al.*, Nucl. Instrum. Methods Phys. Res., Sect. A 770, 164 (2015); F. Kesting and G. Franchetti, arXiv:1503.04646.
[4] indico.gsi.de/conferenceDisplay.py?confId=2843

Table 2: EuCARD-2 XBEAM Workshops

Workshop	Dates	Location	Co-organisers	Particpants	Web site
TLEP6	10/2013	CERN, Geneva	-	84 participants (USA: 5, Asia: 11, Mexico: 3, Europe: 66)	http://indico.cern.ch/conferenceDisplay.py?confId=257713
SuperKEKB commissioning	11/2013	KEK Japan	ICFA	68 participants (Europe: 7, USA: 8, Japan: 51, China: 1, Russia: 2)	http://kds.kek.jp/conferenceDisplay.py?confId=12760
"Beam Dynamics meets Magnets "	12/2013	Darmstadt, Germany	HICforFAIR	84 participants (Japan: 3, USA: 2, Europe: 79)	https://indico.gsi.de/conferenceDisplay.py?confId=2352
LHC crab-cavities 13	12/2013	CERN	-	68 participants (Europe: 7, USA: 8, Japan: 51, China: 1, Russia: 2)	http://indico.cern.ch/conferenceDisplay.py?confId=269322
LHeC 2014	01/2014	Chavannes, Switzerland	ECFA, NuPECC	109 participants (USA: 14, Asia: 4, Africa: 3, Latin America: 2, CERN: 48, Europe: 37)	http://indico.cern.ch/event/278903
Spin Optimization at Lepton Accelerators	02./2014	Mainz, Germany	-	23 (Mainz, DESY, U. Munich, U. Bonn, U. Hamburg, U. Heidelberg), US: 2 (BNL))	https://indico.mitp.uni-mainz.de/conferenceDisplay.py?confId=18
Future Circular Colliders Study Kickoff	02/2014	CERN, Geneva	-	341 participants (Americas: 37, Asia: 19, Africa: 1. CERN: 140, Europe: 144)	http://indico.cern.ch/e/fcc-kickoff
Commissioning of Proton Linacs	04/2014	ESS, Sweden	-	31 (Europe: 30, America: 1)	http://indico.esss.lu.se/indico/conferenceDisplay.py?confId=164
Impedance 2014	04./2014	Erice, Italy	ICFA, etc.	52 (Americas: 10, Asia: 4, Russia:1, Europe: 37)	http://indico.cern.ch/conferenceDisplay.py?confId=287930
SC Collaboration Meeting 2014	05/2014	CERN, Switzerland	-	28 (CERN: 14, Germany: 8, UK: 1, USA: 5)	http://indico.cern.ch/event/292362/
MulCoPim14	09/2014	Valencia, Spain	ESA, VSC	147 (Germany: 10, Canada: 7, China: 5, Spain: 65, USA: 16, France: 13, The Netherlands: 7, Italy: 3, UK: 12, Russia: 4, Switzerland: 5)	http://www.mulcopim.org/
Channeling 2014	10/2014	Capri, Italy	INFN, EPS, etc.	145 (Europe: 60, Russia 51: Ukraine: 6, Armenia: 13, America: 4, Belarus: 4, Japan: 7)	http://www.lnf.infn.it/conference/channeling2012/
Circular e^+e^- Colliders – Higgs Factory	10/2014	Beijing, China	ICFA, CAS	97 (Europe: 14, Asia: 55, USA: 17, Russia: 10, Africa: 1)	http://hf2014.ihep.ac.cn/
Beam Dynamics meets Magnets II	12/2014	Bad Zurzach, Switzerland	GSI	74 (Asia: 3, USA: 11, Europe: 60)	http://indico.psi.ch/conferenceDisplay.py?confId=3033
Advanced Optics Control	02/2015	CERN	CERN, ICFA,…	49 (CERN: 27, other Switzerland: 1, France: 2, Germany: 7, Japan: 1, Russia: 1, Spain: 2, UK: 5, USA: 3)	https://indico.cern.ch/event/349643/
Space Charge 2015	03/2015	Oxford, UK	-ICFA, CI, JAI, IOP, STFC	55 (Canada: 1, CERN: 13, China: 5, France: 2, Germany: 5, Japan: 3, Sweden: 2, UK: 17, US: 7)	http://www.cockcroft.ac.uk/events/SpaceCharge15/
Future Circular Collider	03/2015	Washington, USA	IEEE, US DOE, CERN	340 (USA: 120; CERN: 93, Germany: 20, China 16, UK: 16, Italy: 12, France: 11, Russia: 11, Japan:10, Switzerland : 10. Spain: 6)	http://cern.ch/fccw2015
LLRF and Beam Dynamics Mutual Needs in Hadron Linacs	06/2015	Lund, Sweden	ESS		http://indico03.esss.lu.se/indico/event/310/
LHeC 2016	06/2015	CERN & Chavannes	ECFA, NuPECC		https://indico.cern.ch/event/356714/
Search for Electron EDM in Electrostatic Storage Ring	09/2015	Mainz, Germany	-		http://indico.mitp.uni-mainz.de/conferenceDisplay.py?confId=38
Beam Dynamics meets Diagnostics	11/2015	Firenze, Italy			https://indico.gsi.de/conferenceDisplay.py?confId=3509

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