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EuCARD 2010 Accelerator Technology in Europe

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***Abstract*—Accelerators are basic tools of the experimental physics of elementary particles, nuclear physics, light sources of the fourth generation. They are also used in myriad other applications in research, industry and medicine. For example, there are intensely developed transmutation techniques for nuclear waste from nuclear power and atomic industries. The European Union invests in the development of accelerator infrastructures inside the framework programs to build the European Research Area. The aim is to build new infrastructure, develop the existing, and generally make the infrastructure available to competent users. The paper summarizes the first year of activities of the EU FP7 Project Capacities EuCARD – European Coordination of Accelerator R&D. Several teams from this country participate actively in this project. The contribution from Polish research teams concerns: photonic and electronic measurement – control systems, RF-gun co-design, thin-film superconducting technology, superconducting transport infrastructures, photon and particle beam measurements and control.**

***Keywords*—RF, SRF, superconducting RF, electronic systems, particle accelerators, FEL lasers, photon physics, photonics, elementary particles, large research infrastructures in Europe, European research projects.**

I. Accelerator Infrastructures in Europe

THE YEAR 2009 marked the beginning of a large European infrastructural FP7 project EuCARD – European Coordination of Accelerator R&D, a continuator of the previous project in this research area CARE – Coordination of Accelerator Research in Europe (2004-2009). The aggregated budget of the project is over 30M€. Time span of the project is 2009-2013, thus, it has just entered the second year of its realization [1]. The subject of activities is development, upgrade and transnational access to the European accelerator infrastructures. Large accelerators are today immense machines, whole factories including all kinds of industries like electronics, photonics, material engineering, mechanical engineering, mechatronics, technical physics, chemical engineering, and all sorts of advanced measurement technologies. The project is realized by more than 40 partners. The main partners are the biggest European and National Laboratories having large accelerator infrastructures. A few institutes participate from Poland including: Technical Universities – Warsaw, Wrocław and Łódź, and governmental laboratories – Sołtan Institute of Nuclear Problems in Świerk, Niewodniczański Institute of Nuclear Physics in Kraków. As it is known, our country does not possess yet any accelerator infrastructures, though there are plans to build a National Synchrotron Laboratory in Kraków (just under preliminary phases of design and construction), and National FEL Laboratory – POLFEL (still planned).

Participation in the project enables a facilitated flow of advanced technologies to this country and training of young scientists and engineers. The project embraces five main research and technical themes: high field magnets, beam collimation and materials, linear colliders, superconducting RF technology, and new concepts of acceleration. The research and technical advances of the project are summarized every year during project annual conferences. The meetings, with attendance well over 100, group not only the projects participants but also a few tens of invited guests – who are the top experts from the area of accelerator science and technology. The Annual Conference EuCARD 2010 was organized in Rutherford Appleton Laboratory (RAL-STFC) in Oxfordshire UK in April 2010. The Annual Conference EuCARD 2011 is scheduled in CEA and CNRS Laboratories in Paris. This paper summarizes very shortly the achievements and development directions of the EuCARD project during its first year of activities [2]–[5].

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II. High Field Magnets

The theme ‘high field magnets’ is coordinated commonly by dr Gijs de Rijk from CERN and dr Francois Kircher from CEA. There are 13 partners realizing the theme. The main aim is to reach a completely new level of magnetic field intensity in the new generation of very high field magnets for the next generation of particle accelerators. The field intensity and gradients are key parameters deciding of the quality of the beam. A subject of the project is research, design and construction of a mock-up of a dipole accelerator-grade magnet made of niobium-tin superconductor Nb_3Sn of the maximum field equal or greater than 13 T. Such a magnet with an insert – in a form of additional coils, playing a role of a field booster, may generate a field of 20 T in intensity. This is done, however, at a cost of smaller magnet aperture. Potential applications of this magnet are: test station for high power superconducting cables, the second phase of LHC upgrade, construction of next generation wigglers and undulators for X-ray laser. Such high field magnets in the beam collimators will allow in the future for building smaller, more energy efficient accelerators. The work on high field magnets goes in all major accelerator laboratories. Gijs de Rijk presented developments of construction of 20 T magnets for LHC upgrade. Eric Presbys from Fermilab presented an overview of research and development of high filed magnets of completely new construction and considerably increased field gradient, up to 200 T/m [3].

III. Collimation of a Particle Beam

The theme ‘collimation and materials’ is coordinated by dr Ralph Assmann from CERN and dr Jens Stadlmann from GSI. There are nine participants. The future accelerators require strong, energy efficient and much more precise than today, collimation of the beam. Such a high precision collimation will be a must for the upgraded LHC accelerator and for the new accelerator complex under construction, FAIR in GSI. The theme embraces the following subjects: particle beam modeling, precise calculations of energy deposits, material behavior under the influence of energetic beam – and in particular under the shock wave (incidental loss of the beam), radiation damage, implementation and tests of warm and cold collimators.

A modified beam crossing, called crab-crossing, with the usage of crab-cavities, the construction of the crab-cavities themselves, were subjects of digest presentations delivered by Rama Calaga from Brookhaven and Graeme Burt from University of Lancaster. The crab-cavities optimize the field distribution for the beam crossing point increasing the luminosity in the focus. A considerable increase in the beam luminosity was obtained in an experiment conducted in INFN, which was presented by Catia Milardi. An analogous experiment in FAIR at GSI with superconducting collimators was presented by Peter Spiller.

IV. Linear Colliders

The theme 'linear colliders' is coordinated by dr Grahame Blair from Royal Holloway, Univerity of London and dr Erik Jensen from CERN. There are eleven partners. The subjects embrace development of planned large international accelerator infrastructures – CLIC and ILC. CLIC – a compact linear collider has been under intense development for more than a decade in CERN, in warm RF technology, initially for 30 GHz, now for 12 GHz. The acceleration scheme in CLICK is two-beam. A decelerated high intensity 3 GHz beam gives its energy to the accelerated 12 GHz beam. ILC is a project of immense linear collider of 40 km in length, and working in cold SRF TESLA like technology. There are investigated in this work package common problems for both machines CLIC and ILC including beam transmission and stability. The theme embraces the following issues: design and construction of highly efficient distributed circuits of power extraction and transfer from the powering to the powered beam (this research is done for the CTF3 phase of work on CLICK), demonstration of a practical HOM damping circuit in the presence of beam alignment errors, simulations of break downs and cavity quenching, diagnostic equipment for the beam, ultra-precise synchronization network of the time resolution better than 20 fs, ultra-precise system of beam stabilization and focusing with the aimed space resolution better than 1 nm for the linac and 0,1 nm for the beam waist. These systems will be built as laboratory demonstrators designed for thorough tests at several locations in Europe including, among others, PETRA III in DESY.

V. Superconducting RF Technology

The theme superconducting RF technology (SRF) is coordinated by dr Olivier Napoly from CEA and dr Olivier Brunner from CERN. There are 15 partners. This is the biggest work package of the project. The research subjects are all aspects of the superconducting techniques used for generation, support and stabilization of accelerating RF field of high power – of the order of hundred kW and high intensity – of the order of tens MV/m. The theme embraces: theories, models, materials, superconducting thin-films, distribution of HP-RF, measurement and control circuits and networks – LLRF, higher order modes – HOM. Large costs of ultrapure bulk niobium resonators are the cause of search for alternative technologies, in particular superconducting thin film layers. The parameters of concern for thin films are: purity, uniformity of covering of complex internal surface of the cavity, smoothness, large dimensions of flat grains or mono-crystalline character, lack of impurities on grain boundaries.

The bulk material cavities must eventually be subject to high quality industrial mass production. The basis are here reliable, repeatable and fast techniques of cavity cleaning. Now, the superconducting hadron linacs of the current generation base nearly totally on the bulk cavities of the increasingly high quality. The SRF theme contains also research and construction of HP RF couplers to the cavities. The coupler has a ruggedized mechanical construction going through all thermal regions from the outside of the cold mass to the very cavity.

Next version of the LLRF system is tested using the new generation of ATCA standard of telecommunication crates and racks. One of the useful features of ATCA is an intelligent power management system IPMS, a kind of modern and extended hot-swap feature. Such a system in the first development stage is tested in DESY's FLASH. An alternative for further development of the LLRF (much cheeper) is a fully distributed, rack-less system based on FPGA-DSP and embedded GPP. In parallel, there are carried out tests of using measurement signal from HOM circuits to directly diagnose the beam.

A separate task is upgrade of the RF-gun, either in warm or in cold versions. A cold construction is compatible with superconducting linac. The RF-gun should have a big brilliance and small emittance. Research on new solutions to ELBE RF-gun are carried out in Forschung Zentrum Dresden-Rossendorf. Research on PITZ RF-gun is carried out in BESSY. One of the fundamental issues of the cold RF-gun is construction of the photocathode, transport of the photon beam to photocathode, difficulties with field measurements in the photocathode cavity.

VI. New Accelerator Concepts

The theme 'new particle accelerator concepts' is coordinated by dr Marica Biagini from INFN and dr Rob Edgecok from RAL. There are five participants. New accelerator methods embrace: beam crossing in the crab waist, FFAG accelerators – non-scalable, fixed-field, alternating-gradient, and plasma wave acceleration. A plenary talk on plasma wave acceleration was prepared by Allen Caldwell of Max Planck Institute of Physics. Brigitte Cross of CNRS presented EuroLEAP project concerning the construction of plasma wake accelerator. The European project was compared to American one BELLE, realized in Lawrence Berkeley Laboratory [4].

VII. European Neutrino Network

The Neutrino network is coordinated by dr Vittorio Palladino from INFN and dr Silvia Pascoli from IPPP of Durham

Fig. 1. Participants of EuCARD 2010 Conference - European Coordination of Accelerator Research and Development, RAL, Oxfordshire.

University. The aim of the network is to help the European community to structure its activities, to modernize and develop the neutrino research infrastructures. The network is a liaison with the EUROnu project to build a high-intensity neutrino beam factory and investigate neutrino oscillations. The network community discusses preparations for future neutrino experiments including superbeams, betabeams and neutrino factories.

VIII. European Accelerator Network

Accelerator Network AccNet is coordinated by dr Frank Zimmerman from CERN and dr Alessandro Variola from CNRS-LAL. It contains two topical groups – EuroLumi and RFTech. The coordination activities concern future upgrade of the LHC and integration and structuring of accelerator R&D in Europe.

The LHC gathers now the results from 7GeV energy collisions, in the mass centre. The LHC designers are looking into the future and propose several upgrade paths of its development. Dr Roland Garoby from CERN presented a work of the SLHC-PP design group, combined with the upgrade of the machine to the Super-LHC of multiplied luminosity.

The ILC machine will use the resonators of increased field gradient and of construction similar to the TESLA solution. Dr Eckhard Elsen from DESY presented developments in the maximum obtainable gradients in 3GHz superconducting bulk niobium RF cavities. These developments are furthered by the ILC-HiGrade project.

TheAccNet has recently organized a workshop on proton propelled plasma – wave accelerating scheme [5].

IX. Access to Accelerator Infrastructures

Accelerators and FELs of high energies are big machines under construction only in a few locations in Europe. A fundamental condition for the equalized and homogeneous development of these technologies is an easy and wide access to the unique research infrastructures. The aim of the project is working out sensible procedures of facilitated access, for competent research teams, via for example by decent granting system. The following experiments were embraced by transnational access grants – MICE in RAL and HiRadMat in CERN.

X. EuCARD – Dissemination, Dommunication and Outreach

The research and technical results of EuCARD are published on the own information website cern.ch/eucard. Dissemination of the results embraces several layers of activities – professional, research, academic, industrial, publications, communications and outreach. The publications layer contains, in particular, printing a new editorial series of research and technical monographies on all themes combined directly or indirectly with EuCARD. The publisher of this series is Warsaw University of Technology and CERN [6]–[14].

Prof. Tord Ekelof from Uppsala University presented a group of essential issues combined with the participation of universities in large European projects like CARE, EuCARD, TIARA and similar. The projects are dominated in a natural way, administratively, logistically and financially by the largest laboratories possessing accelerator infrastructures. However, a lot of researchers is recruited for these projects from the universities. The design of R&D in such fields which require large infrastructures, such as accelerator science, requires taking into account, in a balanced way, all involved communities.

Dr Roy Aleksan from CEA-Paris and ESGARD presented a next initiative by the European accelerator science community to launch a new TIARA project on Test Infrastructure and Accelerator Research Area. The project aims at structuring the community and integration of national research groups on a common European platform, inside the ERA initiative.

XI. Rutherford Appleton Laboratory

RAL is a national laboratory where there are located several large infrastructures including: ISIS neutron source and synchrotron light source of the third generation DIAMOND. Scientific director of RAL dr Mike Poole presented research program of the laboratory for the coming years. Susan Smith presented participation of RAL in international projects including ALICE and EMMA.

XII. Conclusion

Organization of the conferences by EU FP projects in particular leading laboratories of the beneficiaries which participate actively in the research and have large accelerator infrastructure is very profitable for strengthening of integration processes among the European research communities.

Participation in such large projects of the research and technical representatives of governmental and academic laboratories from this country is very profitable for the unavoidable future development of relevant technologies in Poland. Accelerator technology is a key factor in development of the nuclear medicine (proton and carbon ion therapy), nuclear power and atomic industries (isotope transmutation) and other branches of national economy [15]–[18].

References

[1] J. P. Koutchouk, R. Aleksan, and K. Kahle, "Accelerator R&D gets a collaborative boost," *CERN Courier*, vol. 49, no. 9, pp. 16–18, November 2009.

[2] K. Kahle, "EuCARD: mixing neutrinos, crab cavities, magnets and more," *CERN Courier*, vol. 50, no. 5, p. 8, June 2010.

[3] "US niobium-tin superconducting magnet reaches 200 T/m," *CERN Courier*, vol. 50, no. 1, p. 6, January/February 2010.

[4] "BELLA will boost plasma accelerator research," *CERN Courier*, vol. 50, no. 1, p. 8, January 2010.

[5] "Workshop pushes proton driven plasma wakefield acceleration," *CERN Courier*, vol. 50, no. 2, p. 7, March 2010.

[6] R. Romaniuk, "New Editorial Series by Publishing Office of Warsaw University of Technology with CERN on 'Accelerator Science and Technology'," *Elektronika*, no. 8, pp. 306–307, 2009.

[7] R. S. Romaniuk and J. P. Koutchouk, *Editorial Series on Accelerator Science and Technology*. Warsaw University of Technology Publishers and CERN, 2009-2010.

[8] J. Sekutowicz, *Multi-cell superconducting structures for high energy e+ e- colliders and free electron laser linacs*, ser. Editorial Series on Accelerator Science and Technology. Warsaw University of Technology Publishers and CERN, 2010, vol. 1.

[9] K. Poźniak, *TRIDAQ detector systems for high energy physics experiments*, ser. Editorial Series on Accelerator Science and Technology. Warsaw University of Technology Publishers and CERN, 2010, vol. 2.

[10] Z. Szadkowski, *Triggers for the Pierre Auger Observatory, the current status and plans for the future*, ser. Editorial Series on Accelerator Science and Technology. Warsaw University of Technology Publishers and CERN, 2010, vol. 3.

[11] R. Aleksan and O. Napoly, *Coordinated accelerator research in Europe*, ser. Editorial Series on Accelerator Science and Technology. Warsaw University of Technology Publishers and CERN, 2009, vol. 4.

[12] H. Mais, *Some topics in beam dynamics of storage rings*, ser. Editorial Series on Accelerator Science and Technology. Warsaw University of Technology Publishers and CERN, 2009, vol. 5.

[13] G. Sterbini, *An early separation scheme for the LHC luminosity upgrade*, ser. Editorial Series on Accelerator Science and Technology. Warsaw University of Technology Publishers and CERN, 2010, vol. 6.

[14] T. Czarski, *Complex envelope control f pulsed accelerating field in superconducting cavities*, ser. Editorial Series on Accelerator Science and Technology. Warsaw University of Technology Publishers and CERN, 2010, vol. 7.

[15] R. Romaniuk, "Free electron laser in Poland," *Electronics and Telecommunications Quarterly*, vol. 55, no. 4, pp. 669–682, 2009.

[16] R. S. Romaniuk, "POLFEL - free electron laser in Poland," *Photonics Letters of Poland*, vol. 1, no. 3, pp. 103–105, 2009.

[17] ——, "Realization of CARE and EuCARD projects in ISE-WUT; accelerator and FEL research, development and applications in Europe," *Electronics and Telecommunications Quarterly*, vol. 55, no. 3, pp. 419–431, 2009.

[18] W. Ackerman *et al.*, "Operation of a free electron laser from the extreme ultraviolet to the water window," *Nature Photonics*, vol. 1, pp. 336–342, June 2007.