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# Accelerator Infrastructure in Europe EuCARD 2011

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***Abstract*—The paper presents a digest of the research results in the domain of accelerator science and technology in Europe, shown during the annual meeting of the EuCARD – European Coordination of Accelerator Research and Development. The conference concerns building of the research infrastructure, including in this advanced photonic and electronic systems for servicing large high energy physics experiments. There are debated a few basic groups of such systems like: measurement – control networks of large geometrical extent, multichannel systems for large amounts of metrological data acquisition, precision photonic networks of reference time, frequency and phase distribution.**

***Keywords*—Electronics and photonics for high energy physics experiments, free electron laser, distributed measurement and control systems, precise timing distribution systems of large space extent, advanced electronic systems, integration of hardware and software.**

## I. INTRODUCTION

THE EuCARD 2011 Annual Conference on the development of the accelerator research infrastructure in Europe was held in Paris on 10-13 May. The venue of the meeting was the IN2P3 institute, a part of the CNRS. Around 150 accelerator researchers participated and 80 papers were presented. The conference covered the following subjects: material engineering – new materials for building accelerator subsystems, building of research infrastructure for measurements of the mass and oscillations of neutrinos, muon electronics, upgrade of existing accelerators, HL-LHC, HE-LHC, building of new infrastructure of large scale, experiments of new physics, plasma wake field and laser accelerators [1-90].

## II. MATERIAL ENGINEERING FOR ACCELERATOR RESEARCH, HIGH ENERGY PHOTONICS AND PHOTON PHYSICS

Accelerator technology uses materials, which are positioned in the vicinity of the particle or photon beams of high intensities. Some materials are subject to interaction with the beam for research purposes. Proper working conditions of the accelerator depend, in a big degree, on the reliability and efficiency of the collimation sub-system. One of the most critical components are collimator jaws. The material should be characterized by a nominal value of the conductivity to improve the stability of RF circuits, high thermo-mechanical stability, ruggedness and resistance to particle radiation, high density (large value of the atomic Z number) to improve the collimation ability. The following composite materials are used: metal-diamond M-CD (with Cu, Mo, Ag, Cu-Cd) and Glidcop. The metal component provides in the composite good thermal stability, good mechanical properties, high softening and melting temperatures. The diamond phase provides high thermal conductance. Sintering of the composite is done in the temperature which does not influence the diamond phase, i.e. is not degrading the diamond micro-crystallites. The Me-CD composites are investigated for their resistance to particle and photon radiation of high intensities.

Glidcop is a composite material consisting of copper and aluminum. Cu builds a metal matrix for hard ceramic particles of aluminum oxide. The addition of aluminum oxide does not have any essential influence on the thermal and electrical properties of Cu in the room temperature. In elevated temperatures, this addition greatly improves Cu parameters. Additionally, aluminum oxide increases Cu resistance to the radiation damage. Glidcop may contain more components, tailoring its properties to the application. These are Mo and Kovar. Some components decrease its thermal dilatation. Addition of Nb increases the strength of Glidcop. Hardness of Glidcop is comparable to the copper-beryllium and copper-tungsten alloys, but the electrical parameters are better. Glidcop is resistant to neutron degradation. It is commonly used for building of RF quadrupoles in accelerators and compact beam absorbers. Properties of the materials for accelerator technology are researched in the HiRadMat experiment under construction in CERN.

The laboratory of high level radiation for material research is using the SPS accelerator beam. The aim is to investigate the influence of intense pulse beams on the materials. The research covers thermal phenomena in materials, material damage below the melting point, evaporation of the material, ablation effects, radiation damage, generation of thermal shocks and propagation of the shock pressure waves. There are predicted searches of new collimator materials, for the development of the LHC accelerator, basic experimental research on materials, hi-rad materials extremely resistant to radiation damage, tests of vacuum components like beam windows, covering layers. Installation of the HiRadMat laboratory has to prevent building of ad-hoc or pirate testing installations for material research near the intensive particle beams, to increase the safety level and enable more systematic research approach.

Development of the accelerators requires application of multi-cable, superconducting, very high power transmission lines. Aggregated supply currents powering a section of a big accelerator are of the order 200 kA. Single cables lead current of 1 – 15 kA. Application of high temperature superconductors (HTS) in the cable saves energy for cooling. Critical temperature $T_c$ for the superconductivity of materials used in accelerator technology is as follows: Nb-Ti 5K, $Ni_3Sn$ 9K, $MgB_2$ 40K, Y-123 (YBCO) 90K, Bi-2223 (BISCO) 110K. HTS are manufactured only in tapes (with exception of $MgB_2$), thus new conceptions are researched to build mutually isolated cables. The cable construction consists of a few (usually

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three) superconducting tapes, interlaced with copper stabilized and twisted helically. The structure, resembling a twisted pair conductor, of the dimensions 2*4mm, carries 2*600 A. A single structure is embedded in a package together with strength members of the outer diameter 6mm. The construction as a twisted pair eliminates the EMI coupling. High current cable contains 25 pieces of twisted pair. The cables are placed in a semi flexible pipe cryostat (1.5 m of bending radius). Round wires including $MgB_2$ have a composite structure including a Cu core covered with internal thin Fe cladding and external thick Ni or Monel cladding. The $MgB_2$ wires are fully embedded in the external cladding. The composite wire has 1.2mm in diameter, There are also tested wires of the same dimensions but only with Ni or Monel matrix and internal $MgB_2$ embedded superconducting wire channels. The $MgB_2$ wires are of different diameter and different lot (from 10 to 100). This structure is stabilized by electro-deposition of Cu on the outer surface. Critical current for such wires, assuming magnetic field 0.5 T, and critical temperature 25K, is around 0.5 kA. Now, a prototype energy, high power transmission line is build spanning 20 m. The aim is to build before 2014 the full powering system with cables spanning 500 m – from the surface down to the accelerator tunnel.

## III. Muon Electronics and Neutrino Factories

The aim of the research is to measure the mass, and mass hierarchy for three species of neutrinos (electron, muon and taon) and anti-neutrinos, as well as neutrino oscillation phenomena and mixing angles between them. Now, the best estimates give the minimal mass difference between the neutrinos for 0.04 eV, and particle mass confinement for 1 eV. The neutrino is the least understood particle of the standard model (SM). The density of sun neutrinos on the Earth surface is $6.5{*}10^{10}\mathrm{cm}^{-1}$. A general aim of the neutrino research is to understand the differences between the quark and lepton sectors.

Neutrino factory is a fundamental and the most powerful tool now to research neutrino oscillations. These oscillations is the first effect outside the SM. The neutrino factory bases on the possibility to produce, cool, accelerate and store the muon beam of big intensity. The technique used for neutrino factory is nearly the same as for the muon collider. A high power (a few MW) proton accelerator provides a stream of a few nanosecond bunches aiming at a target made of high Z number material (Hg, Ti). The target is inside a strong field 20 T solenoid, in order to differentiate between positive and negative muons. Interaction beam – target produces pulsed beam of charged pions (mesons $\pi$), which decay in weak interactions to the muons of both signs (like anti-muon and muon neutrino or vice versa) and of big emittance. The transverse emittance is reduced in a process called ionization muon cooling. The non-relativistic muons have relatively short lifetime 2.2 $\mu$s. Relativistic muons can live at least 10 times longer, if not over 100 times. The muons are re-accelerated to the relativistic energies in an accelerator of fixed field and alternating gradient (FFAG) and then gathered in an accumulation ring. After a determined lifetime by the energy, the muons decay and produce both kinds of neutrinos and anti-neutrinos (electron and muon).

An alternative method of muon-neutrino beam production, however of smaller intensity than in the neutrino factory, is directly from the proton beam (which is called a super beam technique), or from a beam of radioactive ions (radionuclides) in an accumulation ring in the process of beta decay (a technique called beta beam). Both research infrastructures are considered in Europe, however, in the case of the neutrino factory, not earlier than in 2020+. A neutrino factory with a beam of $10^{20}$/year and energy 50GeV allows for its transmission to several thousand km. Now, an experiment is under preparation to transmit the neutrino beam for 130km from CERN to Frejus. There is exploited an experiment CNGS, spanning from CERN to Gran Sasso. The neutrino experiments, apart from neutrino generators, require neutrino detectors. Detectors use (unfortunately very rare) interaction mechanism of neutrino with the nucleus, which leads to the generation of photons and nuclear changes. The detectors have large dimensions from many kT to MT and detect Czerenkov radiation (liquid scintillator) or transmutation – nuclear changes in the chain Lithium-Argon. The detectors cooperate with multichannel measurement systems.

A key part of the system designed for the muon and neutrino science is the MICE experiment in the RAL. Ionization cooling of the generated muon beam of large emittance is necessary in order to enable efficient acceleration of the beam and then collide the bunches of negative and positive muons or the generation of the neutrino beam in the muon decay process. After generation, cleaning, cooling, diminishing of the energy dispersion, and re-accelerating of the muons, the beam is structured into well space defined bunches. The cooling takes place in 6 dimensions of geometry and momentum. The level of muon beam re-acceleration is 0.2-2000GeV.

## IV. Accelerators: RF, SRF, Plasma and Laser

The development of the LHC accelerator (superconducting RF machine working in the MHz frequency range) is planned beyond the year of 2030. The first upgrade will depend on the obtained results with the full power 14TeV colliding beams, and will very probably take place still in this decade. The first upgrade is referred to as the HL-LHC (high luminosity) and concerns the increase of the luminosity twice, at only slightly bigger energy. This development process for the HL-LHC will be continued in this and the next decade. The HE-LHC machine (high energy) is a new proton collider of the collision energy over 33 TeV (now 7 TeV and soon 14 TeV) and the luminosity $2{*}10^{34}$ (now $1{*}10^{34}$). The required field of the dipole magnets in 16.5 T (now 8 T) at smaller aperture of 4cm (now 5cm). HL-LHC would require a new injector with energy 1.5 TeV (now around 0.5 TeV). The cost of HE-LHC is estimated roughly as 5 times the LHC at two times bigger energy. It is considered than some components or infrastructure of the HL-LHC may be reused for the HE-LHC, like cold factories. However, they will be 20 years old when the decision will be taken, thus nothing is sure. It is also not sure if the LEP tunnel will be able to accommodate bigger cryogenic devices. The main accelerator pipe is expected to have around 1m in diameter instead 60cm like today. It is not sure if the new detectors will fit to the existing caverns occupied now by CMS, ATLAS, LHCb and ALICE. It is estimated that the aggregated power for the new SRF HE-LHC accelerator and detectors will be very close to 1TW.

The development of infrastructure for European accelerator technology follows three main pathways: improving parameters of the existing linac and collider infrastructure and building of new one, development of RF technologies – cold and warm, tests of the ideas for plasma wake and laser accelerators. Most of the activities are coordinated in Europe by the ACCNET research accelerator network by relevant working groups EuroLumi, RFTech and EuroNNAC. The EuroLumi network covers the research areas concerning the beam dynamics, magnets, collimation for such infrastructures like FAIR, LHC injector, and accelerator complex in CERN. The research projects which are realized now are: increase of energy, improving the quality of the magnets in the collision region (better focusing of the beams, radiation and thermal hardness of the magnets), increase of the beam quality (collimation, luminosity, stability, emittance). RFTech concerns common topics for such infrastructures like: CLIC, ILC, EXFEL, FLASH and embraces klystron development, high RF power distribution, design of high power RF couplers and resonant cavities, including crab cavities which shift transversely the particle bunches, LLRF system, accumulation rings. Requirements for the future LLRF system are: keep the RF signal phase stability better than 0,03° and amplitude 0.03%. The LLRF has to include embedded diagnostics and fulfill strict conditions for the accelerator availability.

The development of the cavities requires maximization of the field gradient, minimize the costs, minimize the impedance, optimize the efficiency. EuroNNAC searches for synergy between such branches like lasers, plasma technology, accelerators, very fast technologies from femto to atto. The task is to prepare a proposal for the EC of a laser-plasma, accelerator research infrastructure, which would be able to confirm a conceptual idea to build a new class of particle accelerators.

Threshold of the electrical breakdown for metal cold microwave resonant accelerating cavities (working in the frequency domain 1–3 GHz) is now estimated approximately for not more than 50 MV/m (TESLA technology), and warm ones (working in the frequency range 10–30 GHz) for over 200 MV/m (CLIC technology). These values are not to be increased considerably. The alternative is to create dynamically a stable, for the flight time of the particles, acceleration channel in the plasma, by means of a particle or a laser beam. The used frequency band is 10–100 THz, and the field intensity 30–300 GV/m. The periodic accelerating channel in plasma is created by axial shift by the wake field of particles or photons of the electrons to a minute distance. A channel cleared of electrons is just the accelerating tunnel. Now, a number of laboratories in Europe demonstrated successful and acting laser – plasma accelerating experiments, with the channels spanning several cm, and boosting the electron beam energy at lest twice. Not yet experiments were performed outside electrons. The closest aim is to build, fully basing on laser and plasma technology, medium energy accelerator or booster following high energy accelerator.

The most interesting, but still very futuristic idea is to build a fully laser based particle accelerator, where the accelerating medium is directly the optical field. Comparing this solution with classical RF accelerators and plasma ones, the frequency of optical field considered for this purpose is from 150 THz to 3 PHz, and the required intensity of the accelerating optical beam should be in the range 10–100 TeV/m and in the future even PV/m.

At low intensities, the laser beam is propagated in mater in a linear way, and the movement is governed by the local value of the refractive index.

Increasing the optical beam intensity to the level $10^8$–$10^{10}$ W/cm$^2$ the materials start to reveal optical nonlinearity in a form of additional nonlinear refractive index which value depends on the E field intensity. The nonlinearity is expressed by such phenomena like generation of second harmonic wave, and next higher harmonics too.

At the beam intensities of $10^{12}$ W/cm$^2$ and above some materials are ionized by the beam and then may form plasma. The plasma in such a form, for this levels of optical field intensities, may behave as an amorphous material, optically homogeneous, which is optically linear. After ionization, the classical, electron based, optical nonlinearity of the transmission medium disappears, but only for a range of optical field intensities.

Further increase of the optical field intensity to the level of $10^{18}$ W/cm$^2$ causes that the plasma electrons start to show again nonlinear properties. This is the level of electron relativistic nonlinearity (optical relativistic condition). A single period of the optical wave accelerates electrons to the relativistic velocities. The electrons are subject to reaction of the nonlinear, magnetic Lorentz force from the laser beam. This effect may be used for direct acceleration of electrons by the laser beam. Applying practically this technology, it would be possible to decrease the current dimensions of the accelerators by a factor of 100 if not around 1000.

Increasing the beam intensity to the level $10^{23}$ W/cm$^2$, the protons start to behave relativistically in the vicinity of the optical field. This condition is called super-relativistic. The laser beam is able to accelerate relativistically protons, and for even higher intensities also ions, heavier and heavier with the increase of the beam intensity. The super-relativistic case (accelerating protons) is much more interesting for accelerating techniques, than the relativistic case (accelerating electrons), because leads directly to many different applications of compact accelerators, including research, technical, industrial and biomedical. In particular, in the future there are expected compact, thus cheap, medical accelerators for carbon ions, for cancer therapy.

Increasing the laser beam intensity even further, one expects to reach a level called the polarization of vacuum. The first stage is a virtual polarization of vacuum and then strong polarization. According to the Maxwell laws, the photon beams in the vacuum do not interact with each other. However, according to the quantum electrodynamics, despite a very small cross section for this effect, the light scatters light in the vacuum. This light-light dissipation effect was predicted by Heisenberg in 1930. The laser beam of high intensity leads to vacuum polarization along its pathway. The induction of polarization originates from virtual particles – electrons and coupled positrons, hidden in the vacuum and revealed, hidden and revealed, again and again by the intense enough optical field of the beam.

Increasing the beam intensity further to the level called the Schwinger intensity, which is equal to $10^{29}$ W/cm$^2$ for optical wavelengths, the polarization of the vacuum changes from virtual to real. The polarization is so strong that the virtual pairs of electron-positron change to real particles not hidden any more by the vacuum. They are real particles accompanying the beam. The optical field generates real matter along the beam. This leads to electrical breakdown of the vacuum. It is predicted that the vacuum breakdown effect may be obtained also for smaller intensities, but for shorter optical wavelengths, like for the gamma rays. Thus, the Schwinger intensity is a function of wavelength.

Probing the vacuum with the optical field (generally the EM field) has a deep research sense, as an alternative to build very large RF accelerator infrastructures. Though very high power lasers are also quite big. It is not excluded that the vacuum hides unknown fields, apart of well known, instantly appearing and disappearing, virtual particles like coupled electrons and positron pairs. One of these fields may be the searched Higgs field which gives mass to the elementary particles. Other field may the one which makes the world probably opaque to the photons more energetic than $10^{22}$–$10^{23}$ eV. There are a few more candidates for these unknown fields. The vacuum is densely filled with neutrinos. The vacuum may be filled by other very light, much lighter than electron, and not yet detected particles of dark matter very weakly interacting. Other candidates are WIMPs – weakly interacting massive particles. The next candidate is an anti-gravitational (or negative pressure) field of the dark energy. All these fields, if there are any, may densely permeate, though at very small intensities, the vacuum, as we understand the vacuum now. Despite very weak coupling of the laser beam to these fields, at sufficiently high intensities and perhaps also high enough photon energies (hardly available today), it would be possible to reveal at least some of these fields and particles. If the field of dark energy exists, and permeates the space, it may consist with very weak fields coupled only to the lightest particles. Intense photon beam, polarizing the vacuum, in the presence of unknown fields may lead to the generation of the second harmonic wave.

The next mechanism which may lead to the generation of high intensity and high quality (monochromatic, spatially coherent and of very high luminosity but low emittance) gamma beams is relativistic back reflection of a very intense optical beam from high intensity and very energetic electron beam. This technique tries to combine the achievements of accelerator and laser technologies and to combine them into a single gamma light source. Such energetic gamma beams would enable research on photo-nuclear effects.

The aim of activities of the European network on new accelerators is to prepare the assumptions and first set of requirements for a large, pan-European research project on laser plasma accelerators. This project would be submitted to the EC, before the year 2013. The project would request financing a pilot infrastructure of a laser accelerator within the European Framework Program FP8. The project assumptions is as follows: building a full scale demonstrator of a FEL basing on the plasma accelerating, reliable work of plasma accelerators for energies around 1 GeV, generation of high quality beam of energy 10 GeV from plasma accelerators, positron acceleration in the field of gradient GV/m, building of a demonstrator using proton beam to create an accelerating channel in plasma.

## V. New Generation of Medical Accelerators

The current technology of medical accelerators, where they are giant and expensive machines, makes them exceptional and of non-numerous localizations. The logistics and management of therapy in such big ‘medical factories’, requires large concentration of patients around such radiotherapy centers. Next generations of laser plasma accelerators are necessary of much smaller dimensions and costs, which would generate electron, positron, proton and coal ion beams for medical purposes. Electron beam of 100 MeV energy is generated by a laser beam transmitted through a narrow supersonic stream of plasma. To make the generator more compact, the plasma may be contained in an optical capillary. Proton beam of 10 MeV energy is generated by a pulsed laser beam impinging on a 1 $\mu$m thick metal foil. The RF gradient in an accelerating microwave cavity is usually smaller than 100 MV/m. In a plasma cavity, dynamically structured in a periodic way by a proton beam or a laser beam, is bigger than 100 GV/m, thus three orders of magnitude. The dimensions of the RF cavity working at around 1 GHz is approximately 1 m. The dimension of a dynamically generated plasma cavity is a few cm. The parameters of electron beam, produced now in prototype laser – plasma accelerators are increasingly good. The beam is stable. Two laser beams allow for the control of many parameters of the accelerated electron beam. The beam mono-chromaticity is dE/E<1% and may be tuned in the range 1 – 10%. The beam energy is tuned in the range 20–300 MeV. The charge in a single bunch is from 1 to a few tens of pC. The length of the bunch is 1.5 fs (RMS) and may be tuned. Femtosecond electron pulse induces DNA destruction in the cancerous cells. The photons and protons cause single tears in the DNA helix. The carbon ions cause double tears in the DNA helix of cancerous cells, which are irreparable.

Now, 95% of cancer radiotherapies is done by X radiation (gamma knives). Comparing the deposited dose from three different radiotherapy sources: 20MeV electrons, 8 MeV X and 230 MeV protons one may conclude, that the energy deposited by the protons is maximal 30 cm deep in the tissue, at only small deposit on the body surface. Changing proton energy it is possible to change the therapeutic depth. Both electrons and X rays give large energy deposits on the patient’s body. The electrons, at the listed energy, penetrate to the depth of 10 cm. The dose of X-rays, of the listed energy, on the depth of 30 cm falls below 10%. The X-ray radiotherapy requires the usage of multi-beam and multi-angle technique. The beams cross precisely in the point under therapy, under several angles, avoiding too big surface doses. The electron beam of 250 MeV energy deposits the dose homogeneously to the depth more than 40cm. This case also requires application of multi-beam – multi-angle technique in order to maximize the dose in a particular point inside the body. For the three above radiotherapy sources, and the treated point situated deep inside the patient's body, the worst conditions are offered by X-rays, because the dose is the biggest on the surface and exponentially decays with the depth in the tissue. The simulations comparing the same radiotherapy conditions on prostate done by laser generated electron beam of 250MeV and X-rays show large savings of the adjacent tissues, of several tens of %, in the case of electron beam irradiation, and next several tens % savings, in case of proton beam irradiation. The best deposit of the dose is with the proton beam. The maximum dose deposit and the depth of this deposit is a simple function of the proton energy.

Proton therapy is now the fastest growing radiotherapy technique, together with the carbon ion therapy. There exist over 30 proton therapy centers and 3 carbon ion therapy centers now in the world. Prescribing the proton therapy is now strictly controlled because of its cost. Dimensions of the therapeutic factory stem from the required very high localization precision of the ballistic beam on the patient's body. Thus the length of the collimated beam is considerable. The precision of magnetic optics is very high. The beam has to be transmitted to the patient and the operator (computer system) has to be able to manipulate the beam around the patient, with the use of a large scanner called the gantry.

Medical publications estimate (January 2011), that the proton therapy may be favorable even for 15–20% of patients requiring radio therapeutic actions. This concerns mainly the cancers of eye, digestion system, lungs, and prostate. In the European scale it is around 200 000 patients. The current therapeutic capability is 8000 patients annually. In the global scale, over 10 million people acquire annually a cancer. Over 6 million undergoes radiotherapy. Estimating that only 10% may be subject to proton therapy, it means that there is a need for at least 500 proton therapy centers. Such a center consists of the proton source like a cyclotron, synchrotron or synchrocyclotron. The source has the following parameters: power 0.5 MW, beam energy 250 MeV, weight 100–400 tons, dimensions 2–4m for cyclotron, 10 m for synchrotron, and cost 10M€. Protons are transmitted to the treatment rooms via the proton lines. The lines end with the isocentric scaning arm – a gantry. The gantry dimensions are 5–20 m and weight 120–600 tons. Positioning accuracy of the beam is around 1 mm. The center possesses also preparation rooms, treatment rooms and auxiliary space. The part of the building containing the source and proton lines, as well as treatment room has to be isolated against ionizing radiation. The isolation are concrete walls, 3 m thick. The cost of the whole hadron therapy center is around 250–300 M€.

If one were able to replace the classical proton accelerator set with the laser based accelerator, the construction of the hadron therapy center would change in the following way: the source is a laser chain, (weight 1–2 tons, power 10 kW), the source and laser beam lines do not require ionizing radiation protection. The radiation protection is needed only in the vicinity of the radiation converter, situated near the patient. Thus they are much smaller and confined. Isocentric gantry is smaller, has 2 m in diameter and weights 1–2 tons.

## VI. EuCARD 2 – 2013–2026

The European accelerator research community prepares a submission of an infrastructural project to the next Framework Program FP8. Fundamental research in the RF accelerator sector embrace increase of the luminosity, energy, and beam power, but also the polarization issues. For the electron beam it is necessary to decrease the emittance in the synchrotron light sources, accumulation rings, decay rings, decelerators and lepton colliders. Energy optimization of accelerators concerns their balanced and energy efficient development. The research on energy recovery from the used beam after the experiment, and on effective acceleration methods have the aim to avoid the exponential growth of energy demand in the future accelerators. The research on new technical solutions concern the construction of hadron machines and their parts (strong magnets, collimators, wigglers, undulators), SRF and NRF machines and plasma-laser accelerators. The research on plasma wake field accelerators may lead in Europe to building a relevant practical research infrastructure in this field. The research on application of accelerators may lead to their much wider usage in the industry, health protection, energy production and safety.

## VII. Conclusions, Acknowledgements, Future

The European research community of accelerator science, including high energy photonics and photon physics is well structured due to common realization of large EC projects. The first project CARE – Coordination of Accelerator R&D in Europe was realized within the EU FP6. The EU FP7 Project EuCARD is an extremely successful undertaking. It engages several hundred European researchers.

Polish accelerator community gains a lot from the cooperation within CARE and EuCARD. The author would like to thank EuCARD management in CERN for extremely efficient cooperation.

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