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MILESTONE REPORT

PRESENTATION FOR SCHOOLS AND EDUCATED PUBLIC OF THE SCOPES OF THE HL-LHC AND TECHNOLOGY SPIN OFFS

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Abstract:

This report consists of two summary documents. Part A gives a summary on the outreach activities of the project so far as well as a general presentation template to be used by project members when presenting the HL-LHC project. Part B presents some of the new technology developments done in the frame of HiLumi LHC and their potential applications.
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The HiLumi LHC Design Study is included in the High Luminosity LHC project and is partly funded by the European Commission within the Framework Programme 7 Capacities Specific Programme, Grant Agreement 284404. HiLumi LHC began in November 2011 and will run for 4 years.

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PART A

1. OUTREACH ACTIVITIES

The project has been incredibly active in outreach activities. Outreach has been enhanced with lectures and public talks, mostly by the Project Coordinator. Prof. Dr. Lucio Rossi has given about 50 outreach talks with an average audience of 280 people of different ages and different backgrounds, including science festivals, schools and universities. The countries of the talks ranged from US to Japan, including several places in Europe. The list of events is available: http://goo.gl/4REsq. Some talks had an audience of an impressive number of 2000-4000 people. The talks are now available in CDS under Task 1.6. Industry Outreach.

Figure 1: Leaflet for a public talk in Hamburg
The Project Coordinator was also featured in more than 10 articles in public newspapers, e.g. Giornale del Popolo, scientific magazines as well as the Management newsletter. He gave several interviews to national television.

A general presentation has been also prepared by the Project Coordinator to ease the work of the project member when giving an outreach talk on the scopes of the HL-LHC project. The presentations are available in English, German and Italian from the public website.

1.2. SELECTED ARTICLES FROM THE MEDIA ON HL LHC OR INTERVIEWS WITH LUCIO ROSSI

Figure 2: Excerpt from Corriere
CULTURA L’UOMO AI PIEDI DELL’UNIVERSO

La certezza del mistero

I segni, gli errori, le svolte. E alla fine l’imprevisto che getta nuova luce sull’ignoto. Per il fisico Lucio Rossi è questo il senso della scoperta del bosone di Higgs e di quelle “caratteristiche inattese” che rimettono in moto gli scienziati.

di Ugo de Giacomo

Figure 3: An article in TEMPI
Il Cern ha stanato il “bosone di Higgs”

Il più grande acceleratore del mondo, il Large Hadron Collider (LHC) di Ginevra ha mantenuto la promessa e l'ipotesi di Higgs è diventata realtà. L'esperimento ha permesso di scoprire una nuova particella subatomico, che è il Bosone di Higgs.

Risultati straordinari, che hanno avuto un impatto notevole sul campo della fisica e sulla comprensione del mondo fisico. Il Cern ha stanato il “bosone di Higgs”, un passaggio storico nel campo della fisica e nella ricerca scientifica.

Figure 4: Article in Giornale del Popolo
A caccia dell’infinitamente piccolo

Lucio Rossi, fisico del Cern fa il punto sulle ricerche nel sofisticato laboratorio di Ginevra dell’acceleratore di particelle strumenti per aiutare a curare i tumori.

Il problema è che ci sono tanti tumori, e i tumori sono così piccoli che è quasi impossibile metterli a puntino con i raggi X. Ma c’è una tecnica, chiamata tomografia aonde, che usa onde di aghi di luce per scansionare il corpo e vedere internamente. Questo è molto utile per lo studio dei tumori, ma non è sufficientemente preciso per la ricerca medica. Per questo motivo, la ricerca medica è un campo molto interessante per i fisici.

È questo il punto in cui entra la ricerca nel Laboratorio di Ginevra dell’acceleratore di particelle. I fisici stanno sviluppando nuovi strumenti che potrebbero aiutare a curare i tumori in modo più preciso.

Le ultime ricerche hanno messo in luce che i tumori possono essere più piccoli di quanto si pensa, e che i metodi tradizionali di diagnosi non sono sufficientemente precisi per rilevare questi piccoli tumori. Per questo motivo, la ricerca medica è una delle aree più interessanti per i fisici.

Figure 5: Article in Liberta
PART B

2. INTRODUCTION

Development of new technologies and software is a crucial component of the HL-LHC upgrade. Some of these technologies have a large potential to find applications outside of high-energy physics. This report will present some of the new developments done in the frame of HiLumi LHC and potential applications.

2.1. NEW TECHNOLOGIES AND APPLICATIONS

To reach the ambitious goals of the HiLumi LHC project, development of new technologies is crucial. Several of these technologies and software have already been developed, many of which can find use outside of high-energy physics (HEP). The new technologies are developed for the next generation of research accelerators and will find their main applications outside of the HEP field in other accelerators applications. However, some of them also have potential applications spanning much wider.

Today there are around 15,000 accelerators in use around the world. Accelerators themselves have a wide range of applications and about half of the world’s accelerators are used as ion implanters, for surface modification and for sterilization and polymerization. Other applications are: material analysis and modification through spectrometry especially in environmental science, medical treatment and isotope production. For cancer therapy with proton or ions in particular, the European community is already collaboration extensively with the high-energy physics community through the ENLIGHT network coordinated by CERN.

Technologies with spin-off potential developed in the frame of HiLumi LHC, are presented on the following pages, a presentation for industry explaining the technologies in more detail will be made available on the HiLumi LHC webpage and some of the technologies will be marketed through the Knowledge Transfer Group at CERN. A few of the technologies have already also been showcased to the European industry at CERN’s stand at the Hannover Messe, one of the biggest industrial fairs in Europe.

2.1.1. Beam Dynamics Simulation Codes (WP2)

MAD (Methodical Accelerator Design) code developed at CERN since more than 20 years, is widely used for the design of accelerators worldwide. The advanced design of HL-LHC has required an enhancement of these codes, adding additional modules to the code to describe specific components such as crab cavities and beam-beam wire compensators. Mad-X, with the new modules, is released open source, is easy to extend, and the software with the new modules and enhancements will be available together with user guides and examples at: http://cern.ch/madx

2.1.2. Superconducting Technology for Magnets (WP3)

HL-LHC will make extensive use of superconducting technology, materials which at very low temperature transport current with zero resistivity. Progress has been done on using Nb3Sn superconducting technology, which could double the field from the well-established Nb-Ti conductors from 8 to 16 T in accelerator dipoles, and have the potential of getting 50% more
gradient in a quadrupoles. In addition it is the first accelerator magnets based on a novel mechanical structure, bladders and keys technique developed in Berkeley. The technology could benefit applications which require high magnetic fields and/or compact devices. The technologies could benefit research applications such as future circular colliders with high energy and fusion based on magnetic confinement such as the International Thermonuclear Experimental Reactor (ITER) based on Nb₃Sn with lower current densities and the proposed follow up project DEMOnstration Power Plant (DEMO). An example of this is the use by the EC commission Agency EFDA for a prototypical wide aperture dipole (named EDIPO¹) of the high current density conductor developed by USA LARP program for HiLumi LHC. This is the first attempt of fusion community of using high Jc Nb₃Sn. In addition Nuclear Magnetic Resonance (NMR) spectroscopy and Magnetic Resonance Imaging (MRI) at high fields could have a benefit from these technologies. The most striking example is the use in NMR high field magnet, by the largest European group in this sector, Bruker Biospin (please have a look at official name), of the the special Nb₃Sn. Developed also with the support of various EC programmes: FP6-CARE, FP7-EuCARD and finally FP7-HiLumi the PIT (powder-in-tube) Nb₃Sn technology has been an innovation pushed originally by University of Twente and then by CERN, CEA, and other EU Institutes in view of the HiLumi LHC has been turned into an industrial product made initially by the Dutch company SMI and then developed and industrialized by Bruker European Advanced Superconductor (BEAS gmbh).

2.1.3. Crab Cavities (WP4)

The use of transverse deflecting cavities (AKA crab cavities), is proposed to correct the geometric effects of the wider crossing angles as a consequence of reduced beam sizes. By using a pair of cavities per beam on either side of each of high luminosity collision points, it is expected that one can recover approximately 70% of the luminosity that would otherwise be lost. Together with industry (Niowave Inc. Michigan) three concepts have been prototyped and successfully tested beyond the specification, in a simple configuration without external interfaces. These new cavities are approximately 1/4 the size of a conventional cavity, provide at least a factor of two higher performance and have a wide spacing of the operating mode and the higher order (unwanted) RF modes. Some of the work on the Crab Cavities have been carried out in the frame of EuCARD another CERN coordinated FP7 project. At the moment in the European partners of HiLumi the development of their cryostat, called cryomodule, which is a key and complex component of the crab cavity system making the interface with the external environment is under way. Applications outside HEP lie in the accelerator community to deflect particle beams, in particular in:

- Light sources: for pulse compression of synchrotron light and emittance exchange between transverse & longitudinal planes
- Electron-Ion colliders: for the purpose of luminosity gain & levelling and
- LINACS: for fast switching of bunches between different experiments
- Medical accelerators for performing beam scanning and to assist gantries

2.1.4. Development of New Composite Materials (WP5)

There are considerable challenges of the HL-LHC in terms of beam energy, beam intensity and machine impedance with small collimator gaps. New composite materials have been developed (and are under further development) in the frame of EuCARD, HiLumi LHC and EuCARD-2 to achieve unprecedented thermo-mechanical and electric properties. Molybdenum-Graphite (Mo-Gr) materials in particular, developed together with European industry, provides several benefits such as a very high melting point, low density, outstanding thermal conductivity, very low thermal expansion, in addition they are highly stable (forms MoC_{1-x} carbides) with good electrical conductivity, while maintaining fair mechanical strength. There are many potential applications of the newly developed Mo-Gr materials, which can be further expanded thanks to the unique tailoring possibilities of the materials. Some identified potential applications are: thermal management of power electronics, fusion engineering, high temperature aerospace applications, solar energy applications and advanced braking systems. The new materials have already been showcased at CERN’s stand at the Hannover Messe, Europe’s biggest industrial fair.

2.1.5. State-of-the-art simulations (WP5)

In order to characterize the collimation performance at the LHC, we need to follow the proton path along the machine and understand loss locations. This demands continuous development of tracking tools. Several HiLumi LHC partners contribute bringing in different contributions. These tools push the limits of parallel CPU usage. Tools developed for collimation studies can now be used for other machines. For one high-statistics simulation case, one could typically have 0.034 light-years of particle paths to simulate.

2.1.6. High-precision collimators (WP5)

Small gaps required for precise settings around small beam size (σ ≈ 150 µm at 7 TeV) pose many design and mechanical challenges:

- Optimized jaw design for minimum deformation in presence of beam heating
- Jaw flatness over 1 meter = 40 µm
- 5 µm minimum step size
- Mechanical reproducibility of settings < 20 µm

The LHC collimators are sophisticated high-precision devices designed to work in high-radiation and UHV environment. Designed to handle 0.5 MJ losses. High-precision collimators themselves have a narrow field of application. However, the range of high precision methods and techniques needed to design and construct them could be useful in many other fields. More than 130 LHC collimators have been built in European industry. The know-how has been transferred and this collaboration and performance will be improved for HL-LHC.

2.1.7. Cold powering System for the High Luminosity upgrade (WP6)

The project aims at developing a new way for transferring current to the superconducting magnets of the LHC accelerator. More specifically, the project relies on:

- Development of long electrical transfer lines based on High Temperature Superconductors, having a critical temperature above that of the Nb-Ti alloy presently used in the LHC machine, and able to carry unprecedentedly transferred DC currents of up to above |150| kA at about 25 K.
• Development of a Cold Powering System comprising the electrical transfer from room temperature to the helium environment and based on cooling with helium gas, with potential energy saving if compared with a conventional system based on use of liquid helium.

The full system is designed to enable operation of the superconducting part with a significant temperature margin, at the advantage of a safe operation, and to allow powering of magnets via power converters and distribution feed boxes located at remote distance – far away from the radiation environment of the tunnel.

The main achievements from the point of view of technological development are:

• The development of the first PIT (Powder-In-Tube) MgB₂ round wire with superconducting and mechanical characteristics that make it suitable for use in high-current cables. This is the result of a collaboration between CERN and Columbus Superconductors, a company located in Genova-Italy, which manufactured the wire. This activity started in 2008, a first successful wire configuration was tested at CERN in July 2012, and continuous progress has been made since then in the direction of producing round conductor with improved characteristics.

• Development and measurement at CERN of a 20 m long MgB₂ electrical transfer line transferring 20 kA at 24 K. This demonstrator was developed at CERN for the HiLumi LHC project, and it is also part of the activity performed in the framework of a collaboration agreement between CERN and the IASS Institute, in Potsdam. The IASS Institute proposes such type of MgB₂ line, cooled at about 20 K by liquid hydrogen, as an innovative way for long-distance transport of GW of green power. One WP in the FP7 project Best Paths that is starting now, will focus on this application of the SC links of HiLumi LHC. The main partners are CERN, KIT, IASS of Potsdam (Institute for Advanced Sustainability Studies), Columbus, Nexans and RTE, where the three last are companies, respectively working in the field of superconductors, cables and cabling systems, and operating electric transmission.

• Another indirect application is the fact that MgB₂ round wires open the possibility for new applications of this superconductor that has moderate field but is low cost and medium temperature. For example in Italy is foreseen a new type of Fusion machine (called Ignitor) based on superconducting coils made out of this type of superconductor.

3. CONCLUSION

Several new technologies have been developed in the frame of HiLumi LHC. The way the technologies might find their way to industry and useful applications varies case-by-case. For HiLumi LHC, some current and foreseen routes to exploitation are: software released as open source, technologies developed in close collaboration with industry, use in other research projects, and in addition some technologies are already marketed to the wider European industry through technology transfer mechanisms.