

## TOWARDS A STRATEGY FOR FUTURE PROJECTS IN HIGH-ENERGY PHYSICS (EUROPEAN PERSPECTIVE)\*

J. ENGELEN

CERN, CH-1211 Geneve 23, Switzerland

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This write-up is a very brief ‘telegram style’ summary of a much more extensive talk delivered at the Conference. The subject of the talk is of current topical interest, in particular because the CERN Council has installed a Strategy Group with the mandate to formulate a strategy for European high energy physics. The recommendations of the Strategy Group will be discussed during a special session of CERN Council in Lisbon, Portugal, on July 14 2006.

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The views expressed in this article are personal but have, of course, emerged from discussions with many colleagues, in particular at CERN. In how far they will be shared by CERN Council, is for the future to tell.

### **The Large Hadron Collider (LHC), the imminent ‘next step’**

The strategy discussion should take into account the Large Hadron Collider (LHC) programme, with the LHC starting operation in 2007.

The LHC will collide protons at a Centre-of-Mass energy of 14 TeV (a factor of 7 larger than the highest energy available now at the Tevatron at Fermilab) and with a luminosity of  $10^{34} \text{ cm}^{-2}\text{s}^{-1}$  (two orders of magnitude larger than the Tevatron, which collides protons and anti-protons). Thus the LHC will allow large steps into new territory.

The installation of the accelerator in the former LEP tunnel with a circumference of 27 km is in full swing, with several activities going on in parallel. The cryogenic distribution line has been completed, pressure tested

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and cold tested for several of the eight LHC sectors and installation is proceeding in the other sectors; completion is foreseen before the end of 2006. Magnet installation is now proceeding routinely at or above the nominal rate of 25 magnets per week, to be finished by March 2007. Alignment and inter-connect work is ramping up. Many other activities (cryogenics, RF, power generation, current distribution *etc.*) are going on in parallel with the aim of closing the machine in the second half of 2007 and start the commissioning phase, to be followed as soon as possible, by the beginning of physics operations. The next ‘reference date’ is end 2008 when a luminosity of  $n$  fb (with  $n > 1$ ) should have been integrated by the ‘general purpose’ experiments ATLAS and CMS.

The status and planning of the experiments is consistent with the LHC machine schedule, briefly sketched above. They will be ready for beam when the LHC is ready to provide it, albeit with ‘initial detectors’, that will have to be completed to full capacity (mainly in the area of triggering and data acquisition) beyond the start-up date, because several items have been ‘staged’, mainly for budget(-profile) reasons.

Computing at the LHC requires a new approach: the Worldwide LHC Computing Grid (WLCG), based on a ‘tiered’ architecture. More than 10 PBytes of new data will be created per experiment per year. The enormous computing needs as well as the need to guarantee smooth worldwide access to these data will be satisfied by WLCG: ‘the Grid’ will consist of 100,000 of today’s fastest processors, of many PetaBytes of disk storage and tape storage. The infrastructure is presently being developed into a ‘service’ and various successful ‘service challenges’ have demonstrated that WLCG will be available in time.

In 2010/2011 ATLAS and CMS should have first results of the exploration of the new domain made accessible by the LHC, in particular on: the Higgs sector of the Standard Model and beyond, on Supersymmetry, on extra dimensions and, maybe, on unexpected new phenomena. It is clear that these results will point the way and determine the future course of high energy physics at the energy frontier.

It is widely accepted that full support to the LHC project in all aspects (machine, detectors, computing) is the first priority for European high energy physics and therefore for CERN.

### **Beyond the LHC, the next ‘next step’**

It is likely that the LHC results will underline the interest of fully exploiting the LHC, even beyond the nominal luminosity of  $10^{34}$  cm<sup>-2</sup>s<sup>-1</sup>. Therefore a possible luminosity upgrade to  $10^{35}$  cm<sup>-2</sup>s<sup>-1</sup> is under consideration. In order to effectively implement a luminosity upgrade decision, to be

taken in 2010/2011, it will be necessary to perform a detailed study of such an upgrade now and identify and perform the necessary R&D work. Furthermore, before even considering a luminosity upgrade, efficient running of the LHC complex, *i.e.* including the injector complex (Linac2, PS Booster, PS, SPS), should be guaranteed. In addition to an ongoing ‘consolidation’ effort, replacements of Linac2 and, on a somewhat longer term the PS are under consideration.

These issues are studied by a CERN Working Group (‘Proton Accelerators for the Future’ — PAF) chaired by R. Garoby, complemented by a Working Group on related physics issues (‘Physics Opportunities at Future Proton Accelerators’ — POFPA) chaired by J. Ellis.

An initial recommendation is to replace the proton linac at the beginning of the chain, called Linac2, by a higher intensity and higher energy  $H^-$  linac, Linac4 (160 MeV) to remove a well known bottle-neck in the proton acceleration chain. A decision on Linac4 can be taken soon.

A further possibility is the replacement of the Proton Synchrotron (operational since 1959) by a more modern, higher energy machine. One possibility is building a machine with fast-ramping superconducting magnets, reaching an energy of 50 GeV. (Such a machine would allow an interesting fixed target programme, with several 100 kW 50 GeV proton beams, *cf.* POFPA Working Group).

Specific changes to the hardware of the LHC itself are required, in addition to improvements of the injector complex, to reach an ‘ultimate’ luminosity of  $10^{35} \text{ cm}^{-2}\text{s}^{-1}$ . In particular the ‘insertion quadrupoles’ at both sides of the high luminosity interaction points should provide lower  $\beta$  and therefore higher field gradients.

This is an incomplete and sketchy description of possible future developments, but the bottom line is that a vigorous R&D programme should be started now for decisions on implementation of one or more of these options, around 2010/2011, to be followed more or less directly by construction activities. The R&D should address: fast ramping superconducting magnets; high current density superconductors (higher than what is presently achievable with NbTi).

### Linear electron–positron collider; CLIC

A high energy electron-positron collider is an attractive option for deepening and broadening the new insights to be gained at LHC. Whether the presently foreseen superconducting RF technology will be used (allowing, as presently understood, an ultimate energy of 1 TeV in the CM) or whether the ‘warm’ novel CLIC technology (allowing 3 TeV) is to be preferred depends on LHC results and of course also on accelerator R&D results. Studies

are pursued in the framework of GDE (the Global Design Effort for a TeV linear collider) and in the framework of the CTF3 collaboration. A decision on which way to go will be taken in 2010/2011.

### **A neutrino factory**

A neutrino factory would require a dedicated high power proton driver. A detailed design study of a neutrino factory has not been performed yet, resources for such a study will hopefully be found soon, such that optimal scenarios and R&D programmes can be defined. One possible solution for such a driver is the Superconducting Proton Linac (5 GeV), considered by the PAF Working Group. The ‘physics case’ for the neutrino factory will be more precisely defined in the light of the results of the neutrino physics programme presently in progress in Japan, the USA and at CERN.

### **Summary**

An ambitious R&D programme as indicated above (fast ramping SC magnets; high current density SC cables, high field quadrupoles and dipoles; Linear Collider technology, both cold and warm; neutrino factory design study with R&D programme following from such a study) should be pursued in the coming years in order to be ready for construction decisions in 2010/2011 based on R&D results, on results of the present neutrino programme and on LHC results.