# SUMMARY OF SESSION 1: INTRODUCTION AND OVERVIEW

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## PROGRAM OF SESSION 1

This workshop being the first discussion opportunity for this very ambitious LHC energy upgrade (HE-LHC), session 1 was dedicated to setting the scene and browsing through the most significant challenges:

- The physics case, by James Wells/Cambridge University, UK.
- Motivation, status and strategy for HE-LHC studies, by Steve Myers/CERN
- Beam parameters, optics and beam dynamic issues, Frank Zimmermann/CERN
- Magnet concepts and cost evaluation, Ezio Todesco/CERN
- Relevant studies for VLHC/SSC, Uli Wienands/SLAC
- Detector plans and constraints for HE-LHC, Marzio Nessi/ATLAS

This summary attempts at underlining the salient aspects, summarizing discussions and drawing provisional conclusions.

## THE PHYSICS CASE

*James Wells*

### *The salient points*

The added value of HE-LHC would be to extend the discovery range; precision physics is best served by the luminosity upgrade. This extension of discovery range is illustrated in this presentation by the "Naturalness" problem: in the SM, the expression of the Higgs mass, expanded versus the Planck mass, exhibits a quadratic divergence. Three approaches allow resolving this issue:

- Technicolor theories, now less likely with LEP and Fermilab results showing signs of a low Higgs mass. HE-LHC would significantly extend the discovery reach for these theories.
- Extra-dimensions, where the mass scale can be reduced and convergence restored. Higher energy pays huge dividends to observe the KK graviton.
- Supersymmetry: the extended capability to detect supersymmetric particles may be one of the principle motivations for HE-LHC.

### *The discussion*

- HE-LHC versus CLIC/ILC?: their respective capabilities depend in detail on the processes of interest. HE-LHC is good for discovery of strongly interacting particles, CLIC/ILC for weakly interacting.
- Could running longer the LHC at its nominal energy give a similar reach extension? No.
- Is a major investment yielding only a factor of two in energy justified? Yes, because energy gains explore new territory, e.g., by approaching or exceeding the gravity energy scale.
- Can the LHC results expected in the years to come change this analysis? Yes.

### *Tentative conclusions*

The strength of the HE-LHC is to enhance significantly the detection of new physics at the energy frontier. Its precise impact on the ideas discussed -- technicolor-like theories, supersymmetry, and extra dimensions -- will need to be reassessed in a few years, based on the LHC results.

## MOTIVATION, STATUS AND STRATEGY FOR HE-LHC

*Steve Myers*

### *The salient points*

Beyond the goal of operating the LHC at its nominal parameters, CERN is engaged in a number of projects or studies to prepare the future: luminosity upgrade of the LHC (HL-LHC) for installation around 2020, technical design report for a linear collider scheduled for 2016-2020, the subject of this workshop i.e. the HE-LHC study, R&D on high-power proton linacs, as well as a conceptual design study of an electron-proton option for the LHC.

### *The discussion*

- What is the timescale for the HE-LHC study? 1 to 2 years.
- ILC versus CLIC? CERN option is to treat all LC studies together. LHC results will make the case for one or the other.
- When will the users enter the HE-LHC study? An open HE-LHC workshop will be organized as soon as the major possible showstoppers are eliminated.

### *Tentative conclusions*

This workshop kicks off the HE-LHC studies, open to global collaborations. All workshop participants are thanked for their interest and contributions.

## BEAM PARAMETERS, OPTICS AND BEAM DYNAMIC ISSUES

*Frank Zimmermann*

### *The salient points*

The major parameters for the users are: 33 TeV cm energy, 50 ns bunch spacing, with 25 ns spacing kept as an option, a luminosity of 2 $10^{34}$ $cm^{-2}s^{-1}$, yielding a multiplicity of 76. The basic accelerator parameters suffer mild changes: similar optics, same bunch charge, emittance reduced by a factor of 2, injection at 1 TeV, beam half-aperture of 13mm. The significant difference is the radiated light that reaches 2.8 W/m and produces a much reduced damping time of 1 hour. Emitances will need to be kept constant by heating. Damping is favourable for beam dynamics, reducing the adverse effect of the beam-beam interactions. A larger beam-beam limit can be anticipated and values up to 0.03 (three times nominal) are being considered.

### *The discussion*

- It would be valuable to foresee increasing the injection energy to 3 TeV, to maximize aperture
- A 40 mm bore was originally considered an acceptable challenge for the SSC. A compromise must be found between small aperture and high field quality.
- Is it safe to assume an emittance two times lower than nominal to define the magnet aperture?
- Isn't the assumed beam-beam limit optimistic? In fact, the performance does not depend much on it.

### *Tentative conclusions*

From the machine design and beam dynamics point of view, HE-LHC does not appear at first view especially challenging. The synchrotron radiation damping and a weaker long-range beam-beam effect are both favourable.

## MAGNET CONCEPTS AND COST EVALUATION

*Ezio Todesco*

### *The salient points*

A preliminary investigation of a 20 T magnet, with 20% margin, shows that a composite coil of Nb-Ti (8T), $Nb_3Sn$ (+7T) and Bi2212 (+5T), where $Nb_3Sn$ is graded, provides the required field when cooled at 1.9K. The field quality is not really an issue, given the large coil size/aperture ratio. The strains are below the degradation limit of 200 MPa. Operational currents of about 400 $A/mm^2$ allow "compact" coils. The magnet design is a two-in-one structure with a beam separation enlarged to 300 mm to avoid crosstalk. A number of significant challenges have to be addressed, e.g. HTS with suitable current density, complexity of a hybrid coil and its protection, etc. A realistic estimate of the cost of 1200 dipoles is about 5.5 B$, i.e., 5 times the LHC dipole cost.

### *The discussion*

- Are stray fields acceptable? Yes.
- What is the impact of the higher voltage to ground? To be studied.
- Bi is an issue under radiation: Polonium is produced and the consequences must be evaluated.
- What is the timeline for a 20 T magnet? A time line can be defined for a 15 T $Nb_3Sn$ magnet, not for this hybrid concept that is pure R&D now.
- Can the 20% margin be reduced? Not at this stage.
- What would be the consequence of being the major HTS customer on the market? Good question.
- Given the extremely high cost of HTS (50% of the cost), a new longer tunnel for a HE-LHC built of $Nb_3Sn$ magnets (without HTS) could become the economical solution, in addition to being more flexible.

### *Tentative conclusions*

The initial study of a 20 T magnet shows that the mechanical stresses and the field quality should not be major issues. However, serious issues like hybrid coils, and protection, must be studied to establish the feasibility. There is confidence that the construction of a 15 T $Nb_3Sn$ magnet for the HE-LHC time line can be made. The HTS coils needed to reach 20 T open a range of technical and cost issues.

## RELEVANT STUDIES FOR VLHC/SSC

*Uli Wienands*

### *The salient points*

There is a trade-off between magnet aperture and injection energy. For the SSC, aperture between 40 and 50 mm were considered, with injection varying between 1 and 2 TeV. Neuffer's non-linear mid-cell correction scheme was considered essential for 1 TeV injection even with 50-mm dipoles. The synchrotron radiation of HE-LHC is similar to that of VLHC. However, discrete photon stops as considered for VLHC are most likely not applicable, given the different geometries. The SSC diffusion model may be useful in estimating the gas loads. The SR damping may indeed increase the beam-beam limit, but perhaps not so much. Flat beams were investigated, with a simpler doublet instead of the triplet final focus. Other studies have not been conducted much beyond that of the LHC.

### *The discussion*

Why 80K foreseen for the beam screen of SLHC? It came from a balance between cooling efficiency and heat load.

### *Tentative conclusions*

The cost optimization must include both the magnet aperture and the injector requirements. A number of references are given on reports touching common issues between HE-LHC and VLHC. A very relevant one is that on the flat beam option.

## DETECTOR PLANS AND CONSTRAINTS FOR HE-LHC

*Marzio Nessi*

### *The salient points*

A higher energy LHC will buy much more, because rare physics cross-sections, in particular if large mass objects are involved, will be boosted. Of course, with the experience gained after years of running at an upgraded luminosity, it is likely that users will require a combined energy and luminosity upgrade. By the time of HE-LHC, the detectors will be obsolete and highly irradiated. Major RP issues will have to be faced, from 2016. Related show-stoppers may not be excluded in ATLAS. The option of a new detector, in addition to ATLAS and CMS could be a way out, letting the present LHC detectors cool down. In fact, the question of the HE-LHC will be best addressed in summer 2011.

### *The discussion*

- Would ATLAS and CMS change their magnetic configurations? No

### *Tentative conclusions*

It is important to associate the user community to the HE-LHC study from 2011.