Malta, 14th October 2010
Higher Energy LHC workshop

Summary of session 1
Introduction and Overview

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PHYSICS CASE 1,

JAMES WELLS, CAMBRIDGE UNIVERSITY

- For HE-LHC, the emphasis is rather on the widening of the discovery reach, rather than on precision physics, best served by the luminosity upgrade.
- Today, when the LHC has not yet provided information on new physics beyond the Standard Model, the unresolved problem of "Naturalness" is chosen in this talk to illustrate the discovery potential of HE-LHC.
- The Naturalness problem can be stated as follows: in a perturbative QM approach, the expression of the Higgs mass turn out to be have to be expanded versus the Planck mass and exhibits quadratic divergence

$$m_H^2 \sim \frac{\alpha_f}{4\pi}\Lambda^2 \quad \Rightarrow \quad \Lambda^2 \sim M_{Pl}^2\ ? \qquad \frac{M_{Pl}}{m_t} \sim 10^{16}$$

3 approaches to resolve the issue:

1. **"technicolor theories":** new particles, like a Z′ boson around 10 TeV. HE-LHC would **significantly increase the discovery reach**. However, these theories, suffering from a proliferation of bosons, seem less likely given LEP and Fermilab data showing signs of a low mass Higgs.

2. **Extra dimensions:** the large Planck mass becomes a fake: combination of a much smaller mass scale (~1 TeV) multiplied by the large space volume. An observable is the KK gravitons, whose cross-section increases with energy. **Higher energy pays huge dividends!** Many more benefits p

$$\sigma_{allKK} \sim \frac{1}{M_D^2}\left(\frac{E}{M_D}\right)^n \qquad \sigma \sim \frac{1}{E^2}$$

3. **Supersymmetry** introduces superspartners to SM particles. Some are expected in (HE-)LHC due their expected mass range. However, gluino pair production give colliders hope. Perhaps best bet is gaugino + squark production. Suggest careful study of the various prospects at HE LHC. **May be one of principle motivators for HE LHC upgrade.**

PHYSICS CASE 3

JAMES WELLS, CAMBRIDGE UNIVERSITY

Discussion:

- HE-LHC versus LC's: all depends on the processes of interest. LHC will give indications, but, likely, both are needed.
- Could running LHC longer be an alternative to HE-LHC? No
- Is a factor of 2 in energy liable to justify the investment? Fundamental energy scale for gravity is no longer off the scale. We are in the TeV range!
- Are the LHC results to come in the coming years liable to change this analysis? Yes for two of the topics, no for gravity.

Tentative conclusion:

HE-LHC will certainly enhance significantly the detection of extra dimensions. Data from LHC are needed to evaluate the enhancement of the studies of supersymmetry and technicolour.

MOTIVATION, STATUS AND STRATEGY 1,

STEVE MYERS, CERN DIRECTOR OF ACCELERATORS & TECHNOLOGY

The motivation for the HE-LHC study is to prepare a palette of possibilities for the upgrade and development of the world class CERN accelerator complex and maintain it at the energy frontier.

CERN Accelerator Strategy

1. LHC Operation at 7 TeV/beam up to design luminosity
2. HL-LHC for installation in 2020/2021
3. Linear collider TDR for 2016-2020
4. Study HE-LHC as a feasibility study
5. R&D on high power proton drivers
6. CDR for a LHeC (ring-ring, ring-linac)

Discussion:

•Timescale of the HE-LHC feasibility study? 1 to 2 years
•What about ILC? DG insists that we treat all linear collider studies together. Once we have results from the LHC we need to start discussing the direction to take.
•When does the user community enters the game? A HE-LHC workshop shall be organized once the major possible showstoppers are eliminated.

Beam Parameters, Optics and Beam Dynamics Issues 1, *Franck Zimmermann, CERN*

- **For users:** 33 TeVc.m., 2 10 ^{34} cm^{-2}s^{-1}, 50 ns spacing (25 ns is an option), multiplicity 76.
- **Basic accelerator:** rather modest change of the basic LHC nominal parameters: beta* nominal, emittance reduced by 2, bunch charge nominal, injection energy 1TeV, beam half aperture 13mm
- **SR related at top energy:** power/ring 66KW heat load: 2.8 W/m (~*16); damping time 1hr.
- **Beam dynamics:** long-range should be less (12 sig separation);, hence dQ_{bb} at least .02? Long. and transverse emittances to be blown-up continusously; performance not sensitive to beam aspect ratio (round or flat beams)
- **Technology:** low-beta quads challenging, arc quad length will need to be increased.

Discussion

- Might be worth looking at pushing injection energy as high as possible, due to aperture reasons (say 3TeV).
- 40mm bore considered acceptable for SSC, although this is indeed a challenge. Field quality is a driving force which has to be balanced with available aperture.
- Should we assume smaller emittances from the beginning, also for magnet design.
- dQ_{bb} of 0.03 seems optimistic at a design stage. Performance actually not much dependent on this hypothesis.

Tentative conclusion:

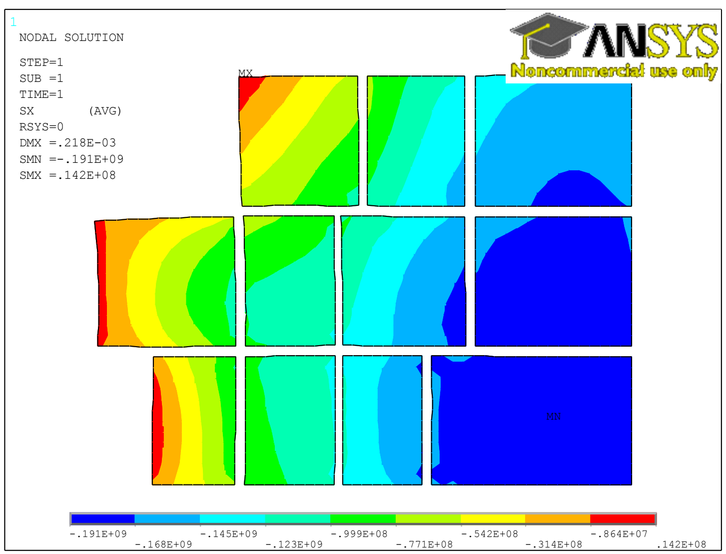
From the machine design and beam dynamics point of view, HE-LHC does not appear at first view especially challenging. The SR damping and a weaker long-range beam-beam effect are both favourable.

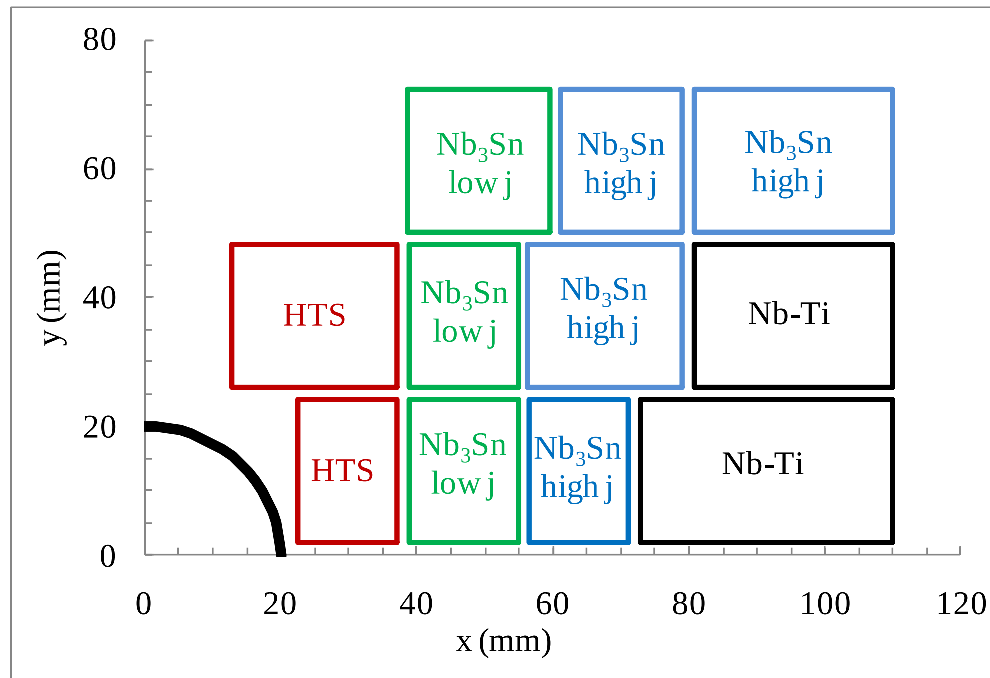
Magnet concepts and cost evaluation 1,

Ezio Todesco, CERN

- Constraint: margin, cost & transverse size
  - One needs 25 T short sample magnet for the usual margin of 20%
  - Grading of the superconductors material to decrease cost.
  - Operational current of 350-400 A/mm^2 to have "compact" coil
- HTS
  - Bi2212 appears the only possibility; YBCO much too expensive and not adapted, at least now.
- Design
  - Two-in-one structure with distance between beams enlarged to 30 mm to avoid crosstalk, magnets cooled at 1.9K.

- Preliminary design (no structure, everything is glued)
  - 8 T with Nb-Ti, up to 15 T with Nb_3Sn, the last 5 T with Bi2212
  - Below the Nb_3Sn limit for degradation (200 MPa) !!
  - Field quality should not be too much critical due to the large ratio coil size/aperture





Horizontal stress in the coil at 20 T operational field [from A. Milanese]

- Many challenges ...
  - The cable (HTS) at 400 A/mm2
  - The magnet with hybrid coils
- Cost
  - Nb_3Sn 4 times more expensive than Nb-Ti
  HTS 16 times more expensive than Nb-Ti.
  - 1200 dipoles → 5500 M$
  About five times the LHC for 2.5 times the field

Discussion

- Stray fields OK
- Protection, max voltage (due to higher required current) not studied
- Bi an issue under radiation (produces Polonium): consequence?
- What is the timeline for a 25T magnet? Today, one can predict for 15T, not for 25T.
- Can the margin of 20% be reduced?: perhaps, but not at this stage.
- Shouldn't we reconsider the tunnel since it is a major constraint for HE-LHC; its cost was .35BCHF in 1980.
- What would be the consequence of being the almost only customer on the HTS market, presently almost inexistant?

Tentative conclusion:

The initial study of a 25 T magnet shows that the mechanical stresses and the field quality should not be major issues. This was not given. However, serious issues like hybrid coils, protection, voltage to ground,…must be studied to establish the feasibility.

There is confidence that the construction of a 17 T Nb3Sn magnet for the HE-LHC time line can be made.

The HTS coils needed to reach 20T to 25T open a range of issues.

Relevant studies from SSC & VLHC 1,
Uli Wienands, SLAC

Magnet aperture
- SSC with 50 mm magnets @ 2 TeV ≈ same dyn. ap. as LHC
- mid-cell correctors a la Neuffer can help
- VLHC: 40 mm

Injection energy
- For 40-mm SSC, 1 TeV considered too low.
- For 50-mm SSC, 2 TeV considered possibly unnecessary (–> 1.5 TeV)

Synch. radiation
- SSC diffusion model may be useful in estimating gas loads
- VLHC and HE-LHC similar in deposited W/m and damping time.
- VLHC photon stops likely not applicable to HE-LHC (geometry)
- Damping may raise ξ, but not a whole lot
- VLHC would need to heat up beams (bunch length, stability!)

Flat-beam collider
- Doublet IR likely easier (except QD0!) than triplet IR
  - β^ lower, or longer L*, or smaller β*

e-cloud, radiation, bunch length
- not much beyond LHC

Relevant studies from SSC & VLHC 2,

Uli Wienands, SLAC

Discussion

SLHC beam screen temperature was 80K. Why?

Came from a balance of cooling efficiency and heat load.

Tentative conclusion:

References are given on reports touching common issues of HE-LHC and VLHC, such as the flat beam option.

A High Energy LHC machine. Experiments' first impressions 1, *Marzio Nessi, CERN*

For the experiments, the question of HE-LHC will be better answered in summer 2011.

Energy will buy much more, because rare physics cross-sections, and in particular if large mass objects are involved, will be boosted. More energy available to create heavy objects !!

After a few years of enthusiasm for the high energy regime, for sure physicists will ask (because then they will be used to the HL-LHC) to run with high luminosity too.

The LHC detectors will be at least partly obsolete or irradiated by the time of HE-LHC. They will require major upgrades. Major RP issues will be encountered from 2016. Change of culture needed. In ATLAS showstoppers due to the heavy irradiation cannot be excluded.
*Why not a **new detector**, in addition to ATLAS and CMS (16-18 years needed)?*

A High Energy LHC machine. Experiments' first impressions 2, *Marzio Nessi, CERN*

Discussion

Any scope for changing the magnetic configuration?
Would stay the same in both ATLAS and CMS.

Tentative conclusion:

The user community will need to be associated to the study from 2011.