LHC: short and long(er) term plans

La Thuile

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Sergio Bertolucci
CERN, Geneva

Topics

- I will not try to cover all the topics discussed in Chamonix, but present selected urgent important topics. The other topics which are also very important will be followed up in the LMC.
    - Running scenarios for 2010-2011
        - Risks
        - Implications
    - Upgrade of the Injector Chain
    - Upgrade of the insertions (IT "phase 1")
    - Future Upgrade Plans
- Since Chamonix (Implementation)

Running Scenarios for 2010-2011

Splices and Beam Energy: Statements

- Simulations for safe current used pessimistic input parameters (RRR……) but have no safety margins
- For 2010, 3.5 TeV is safe
    - **Measure the RRR (asap) to confirm the safety margin for 3.5TeV/beam**
- Without repairing the copper stabilizers, **5 TeV is risky**
- For confident operation at 5TeV we would need
    - Repairs to the "outlier" splices
    - Better knowledge of the input parameters (RRR…)
    - With present input parameters the "limit" splice resistances are **43 μΩ (RB)** and **41 μΩ (RQ)**
      NOTE: these values are close to the limit of the resolution of our measurements made for the RBs at 300K

A Question to better define the risk

- What exactly will happen if we have exceed the “limit” values for the splices while running at 3.5TeV/beam
  - New situation with pressure release valves
  - New dump resistors
  - New QPS protection
    - Fast inter-magnet splice protection
    - Asymmetric quench protection
  - Evaluation of the damage
  - Evaluation of the repair time

This question is being pursued following the LMC of 3 February

7TeV/beam Splices : Statements

- For confident operation at 14TeV we need
  - To replace all splices with new clamped shunted ones!

► F. Bertinelli, A. Verweij, P. Fessia (unaminous)

For safe running around 7 TeV/beam, a shunt has to be added on all 13 kA joints, also on those with small R_{addit}. Joints with high R_{addit} or joints with large visual defects should be resoldered and shunted.

A Cu-shunt with high RRR and a cross-section of 16x2 mm^2 is sufficient, if soldered at short distance from the gap. Experimental confirmation by means of a test in FRESCA should be foreseen.

Comparison of Scenarios

- Scenario 1 (Minimum Risk)
  - Probably the more efficient over the LHC lifetime
    - **+ ALARA**
    - **determine the needs for the shutdown (resources, coactivity etc)**
    - **Re-design/testing of the splices; timing is "reasonable"**
- Scenario 2 (Higher Risk)
  - Reduced running in 2010, long shutdown 2010-2011, delays operation at the highest energy
    - **-- ALARA**
    - **-- Urgently needs a more accurate measurement of warm resistance (thermal amplifier) which has not yet been developed**
    - **? --May need nearly as much shutdown time as scenario 1 and the repair is only good for 5TeV/beam**

What to do if we have an unforeseen stop e.g. S34 vacuum?

Summary

- To achieve an integrated luminosity of $1fb^{-1}$ in 2010/2011 we must reach a peak of luminosity of $2x10^{32}cm^{-2}s^{-1}$ in 2010.
- To do this there must be a rapid progression in stored beam energy in parallel to a lot of commissioning activities.
  - Much faster than in previous machines, with the potential to cause damage !
  - Coupled to an excellent machine uptime.
- Progress will depend on confidence in MPS.
  - Tests … + operational experience.

Beam back in the LHC last evening at 21:00

Upgrades: Foreword

Studies have been launched about one year ago and are ongoing

- Performance Aim
  - To maximize the useful integrated luminosity over the lifetime of the LHC
- Targets set by the detectors are:

  $3000 fb^{-1}$ (on tape) by the end of the life of the LHC

  → $250\text{-}300 fb^{-1}$ per year in the second decade of running the LHC

- Goals
  - Check the performance of the present upgrades
  - Check the coherence of present upgrades wrt
    - » Accelerator performance limitations,
    - » Detector requirements,
    - » manpower resources,
    - » shutdown planning for all activities

Performance: Injector Upgrades

- Present Peak Performance Situation

Intensity Limitations (10^{11} protons per bunch)		
	Present	
Linac2/LINAC4	4.0	
PSB or SPL	3.6	
PS or PS2	1.7	
SPS	~1.2	
LHC	1.7-2.3?	

Conclusion 1: SPS is the bottleneck!

SPS Bottleneck

- Other injectors are limited by a fundamental limitation, the space charge effect ($\Delta Q_{sc} = 0.3$)
- In the SPS at injection: $\Delta Q_{sc} = 0.07$! (no fundamental limitation)
- Actual Intensity Limitation in SPS (mitigation)
    - Electron cloud (vacuum chamber coating)
    - Transverse Mode Coupling Instability (Impedance reduction and/or transverse feedback)
    - RF effects such as beam loading etc (redesign of existing RF or build new system)

Immediately after Chamonix a hardware task force has been set up to investigate the removal of this SPS bottleneck (led by Volker Mertens)

Injectors Performance (Availability)

- From the LINAC2 to the SPS we have ageing machines
  - We need consolidation or replacement
- Proposed scenario (White Paper, 2006) is to replace LINAC2, PSB and PS
  - LINAC4, SPL, and PS2
- Recent study shows time scale for operation of the PS2 is at earliest 2020 and likely 2022.
  - Conclusion 2: We need to aggressively consolidate the existing injector chain to allow reliable operation of the LHC until at least 2022.
  - Task force set up late last year. (Simon Baird)
- BUT: **Resources** needed for the consolidation of the existing injectors are in direct competition with those needed for the construction of SPL/PS2
- Question: What would be the LHC performance implications of not constructing SPL/PS2??

Summary of Intensity Limits

Intensity Limitations (10^{11} protons per bunch)		
	Present	SPL-PS2
Linac2/LINAC4	4.0	4.0
PSB or SPL	3.6	4.0
PS or PS2	1.7	4.0
SPS	1.2	>1.7?
LHC	1.7-2.3?	1.7-2.3?

It would be wonderful to be able to afford these additional margins and flexibility! Also an asset to CERN for future high intensity proton project proposals

Performance Limitations without SPL/PS2

- Alternative scenario to SPL/PS2
  - Consolidate existing injectors for the life of the LHC (2030)
  - During the same consolidation, improve the performance of PSB/PS as injectors for the LHC
- New “Idea”
  - Increase the extraction energy of the PSB which allows increase of the injection energy of the PS.
  - 2GeV injection energy in the PS allows ~3×10^{11} ppb with the same space charge tune shift (preliminary study presented in Chamonix)

“Project” set up immediately after Chamonix

Intensity Limits

Intensity Limitations (10^{11} protons per bunch)			
	Present	SPL-PS2	2GeV in PS
Linac2/LINAC4	4.0	4.0	4.0
PSB or SPL	3.6	4.0	3.6
PS or PS2	1.7	4.0	3.0
SPS	1.2	>1.7?	>1.7?
LHC	1.7-2.3?	1.7-2.3?	1.7-2.3?

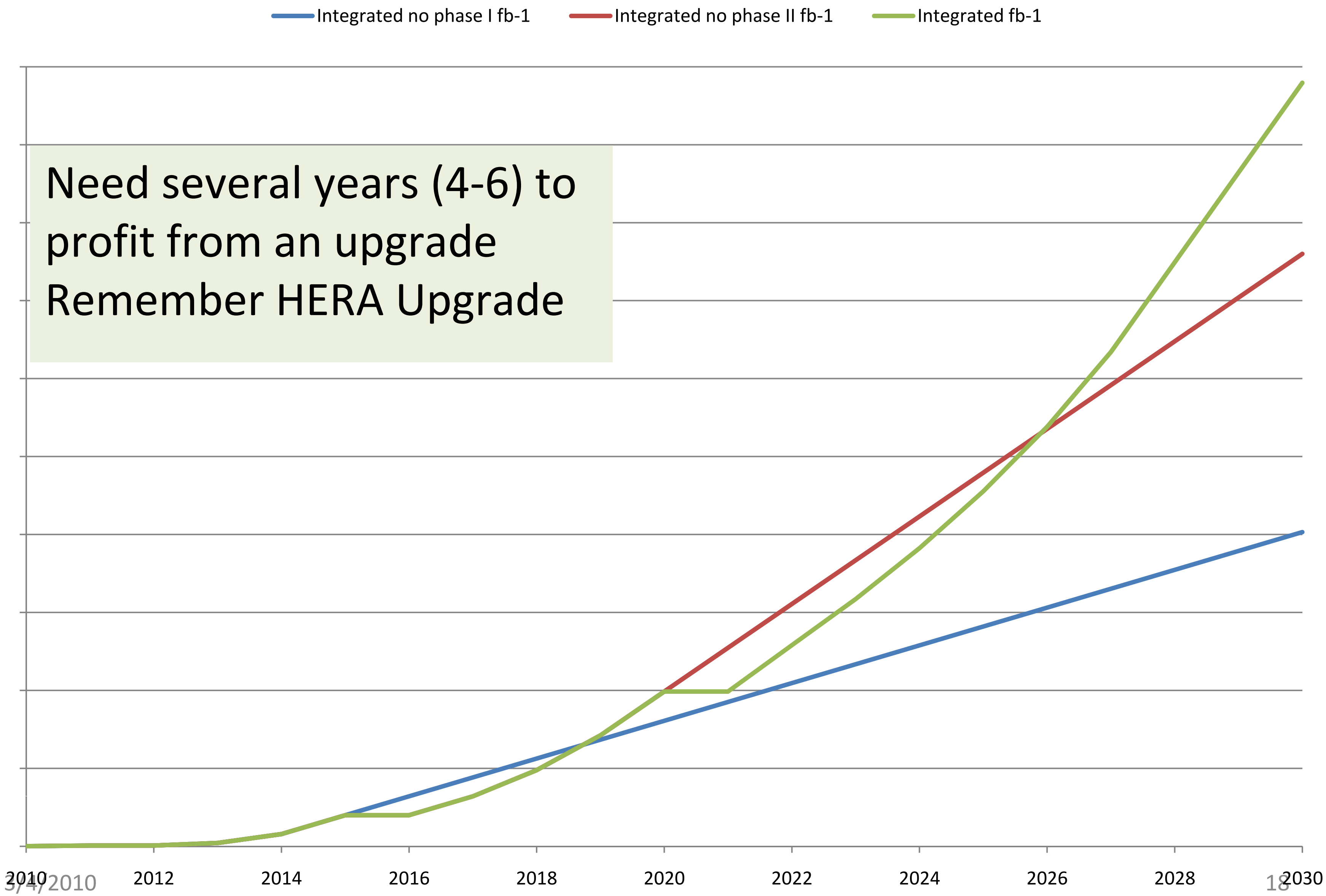
Running Present injector Chain for > 20 years

- Very detailed list of consolidation items to ensure reliable running of the present injector chain
  - Machines, experimental areas, services and infra-structure
- Points of Note
  - Consolidation programme includes all experimental areas
    - Doing this for the SPL/PS2 upgrade will incur substantial additional resources

Possible Improvements in Existing Injector Chain: Summary

- Increase PSB (PS injection) energy to 2 GeV
  - Possibility to generate LHC bunches of up to 2.7×10^{11} p (or even up to 3×10^{11} p) with 25 ns spacing.
- Time line for implementation of new PSB extraction energy:
  - Three to four years (design and construction of new hardware)
  - One to two shutdowns (hardware installation)

IR/Optics Upgrade or not



Insertion Upgrade Plans

- IT Upgrade "phase 1"
  - Goal: reliable operation at $2 \times 10^{34} cm^{-2} s^{-1}$, intensity < ultimate and > nominal

    Very similar to "ultimate"
  - ? Same resources for splice consolidation

Tough Questions:

1. Will the phase 1 upgrade produce an increase in useful integrated luminosity?
   - Installation time and recomissioning a new machine afterwards
2. Do we have the resources to complete on a time scale which is reasonable with respect to phase 2?

Task force set up immediately after Chamonix (Lucio Rossi) 4-5 weeks to answer above questions (mid-end March). Task force will then define the parameters for sLHC

Future Upgrade Scenarios "Phase 2"

- Luminosity Optimization and Levelling
  - For LHC high luminosities, the luminosity lifetime becomes comparable with the turn round time.. Low efficiency
  - Preliminary estimates show that the useful integrated luminosity is greater with
    - a peak luminosity of 5-6x10^{34} cm^{-2} s^{-1} and luminosity levelling
    - than with 10^{35} and a luminosity lifetime of a few hours
  - Luminosity Levelling by
    - Beta*, crossing angle, crab cavities, and bunch length

Detector people have also said that their detector upgrade would be much more complicated and expensive for a peak luminosity of 10^{35} due to

- Pile up events
- Radiation effects

Some additional Remarks

- Collimation (highest priority after the splice repair)
- Radiation to Electronics

- We also need to study
  - How to give LHCb $5x10^{33}cm^{-2}s^{-1}$
  - Higher luminosity with lead collisions (ALICE)

Conclusions

- The Luminosity Targets set by the detectors are:
    - 3000fb^{-1} (on tape) by the end of the life of the LHC
    - → 250-300fb^{-1} per year in the second decade of running the LHC
- The Upgrades needed to attack these goals are
  - SPS performance improvements to remove the bottleneck
  - Aggressive consolidation of the existing injector chain for availability reasons
  - Performance improvement of the injector chain to allow phase 2 luminosities
  - a newly defined sLHC which involves
    - luminosity levelling at ~5-6x 10^{34}cm^{-2}s^{-1} (crab cavities etc…)
    - At least one major upgrade of the high luminosity insertions