Discussion Topics

Topics

- I will not even try to give a summary of summaries but present selected urgent important topics. There are many more topics which are also very important but not as urgent. All 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

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 still OK
    - **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 intermagnet splice protection
    - Asymetric quench protection
  - Evaluation of the damage
  - Evaluation of the repair time

This question is being pursued following the LMC of 3 February

Splices and Beam Energy: 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.

3.5 TeV requirements

circuit	τ [s]	Condition	Max R_{addit} for RRR_{bus}=100	Max R_{addit} for RRR_{bus}=160
RB	50	GHe with t_{prop}=10 s	80	87
		GHe with t_{prop}=20 s	>100	>100
		LHe without He cooling	58	65
		LHe with He cooling	76	83
RQ	10	GHe with t_{prop}=10 s	>150	>150
		GHe with t_{prop}=20 s	>150	>150
		LHe without He cooling	74	80
		LHe with He cooling	80	84

5 TeV requirements

circuit	τ [s]	Condition	Max R_{addit} for RRR_{bus}=100	Max R_{addit} for RRR_{bus}=160
RB	75	GHe with t_{prop}=10 s	34	37
		GHe with t_{prop}=20 s	46	51
		LHe without He cooling	23	28
		LHe with He cooling	43	48
RQ	15	GHe with t_{prop}=10 s	71	75
		GHe with t_{prop}=20 s	>120	>120
		LHe without He cooling	35	40
		LHe with He cooling	41	47

Remark: better knowledge of RRR_{bus} may give another 10 μΩ margin.

13 kA requirements

circuit	τ [s]	Condition	Max R_{addit} for RRR_{bus}=100	Max R_{addit} for RRR_{bus}=160
RB	100	GHe with t_{prop}=10 s	**11**	12
		GHe with t_{prop}=20 s	13	14
		LHe without He cooling	8	9
		LHe with He cooling	15	21
RQ	20	GHe with t_{prop}=10 s	18	22
		GHe with t_{prop}=20 s	[illegible]	[illegible]
		LHe without He cooling	13	14
		LHe with He cooling	15	17

Conclusion: $R_{addit,RB}$<11 μΩ and $R_{addit,RQ}$<15 μΩ are required for operation around 7 TeV.

Better knowledge of RRR_{bus} will hardly increase these numbers

Two Possible Scenarios 2010-2011

1. Run at 3.5 TeV/beam up to a predefined integrated luminosity with a date limit. Then consolidate the whole machine for 7TeV/beam.
    - Need to determine the needs for the shutdown (resources, coactivity etc)

2. Run until second half 2010 then do minimum repair on splices to allow 5TeV/beam in 2011 (7TeV/beam comes much later)
    - ? Do DN200s at same time
    - ? Will we need to **warm** all sectors in order to re-measure (looks like yes to 7 RB octants from Mike's results, and 8 RQ)
    - ? How many splices will we need to repair to reach the "limit" copper stabilizer resistances (what about the RQs?)

Circuit/ Sector	Temperature spread (K)	Excess resistance spread	Highest remaining excess resistance	Excess resistance limit 90%CL
A12 RB	1.1	13	37	51
A34 RB	1.9	10	35	47
A45 RB	0.9	17	53	78
A56 RB	0.4	9	20	34
A67 RB	0.6	14	31	48

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?

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:

  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
- Goals
  - Check the performance of the present upgrades
  - Check the coherence wrt accelerator performance limitations, detectors, manpowe3r resources, shutdown planning…

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 (ΔQ_{sc} = 0.3)
- In the SPS at injection: ΔQ_{sc} = 0.07! (no fundamental limitation)
- Actual Intensity Limitation in SPS (mitigaton)
  - 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 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?

Comparison: Pros and Cons

- SPL/PS2
  - Con:resources
  - Con: comes very late in the life of the LHC (lever arm of time is low)
  - Con: FT experiments depending on existing injectors (ISOLDE, AD, …)
  - Pro: excess intensity (can this be used in the LHC?)
  - Pro?: Upgrade potential for future projects (non-LHC, neutrinos etc)
- Alternative Scenario (PSB/PS)
  - Pro: resources must be given as high priority
  - Pro: Performance improvement comes sooner
  - Pro: impact on existing FT experiments
  - Neutral: Intensity capability exceeds all out maximum envisaged in LHC

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)
- Other areas of study in view of additional improvements:
  - PS working point control.
  - Pulsing PS faster (26 GeV/c in 1.2 s)
  - Losses at PS extraction (new thin septum or additional thin septum).

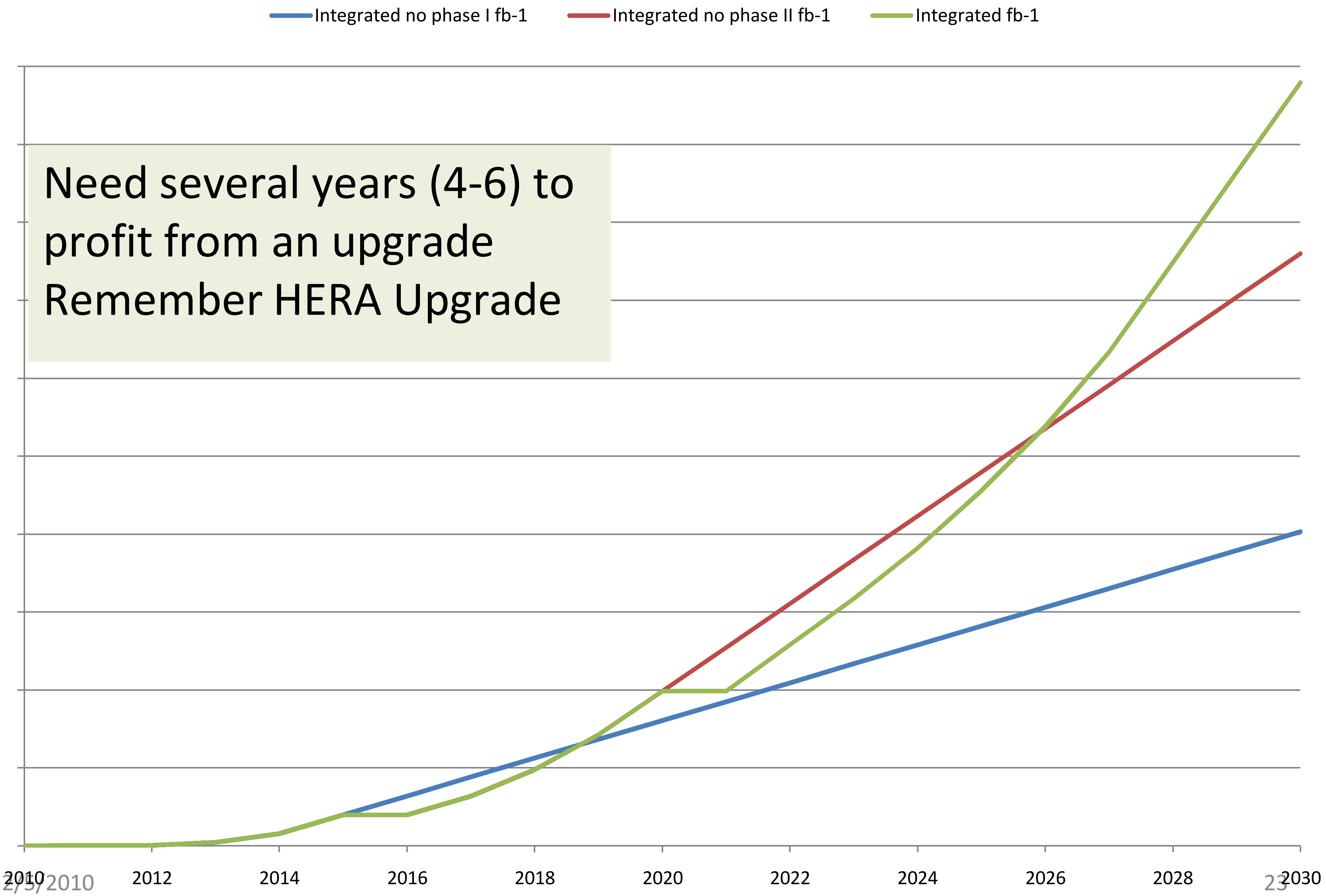
To increase the PSB extraction energy

- PSB:
  - Main magnets
  - Main power supply
  - RF
  - Septa and kickers
- Transfer and measurement line
  - Magnets
  - Septa and kickers
  - Power converters

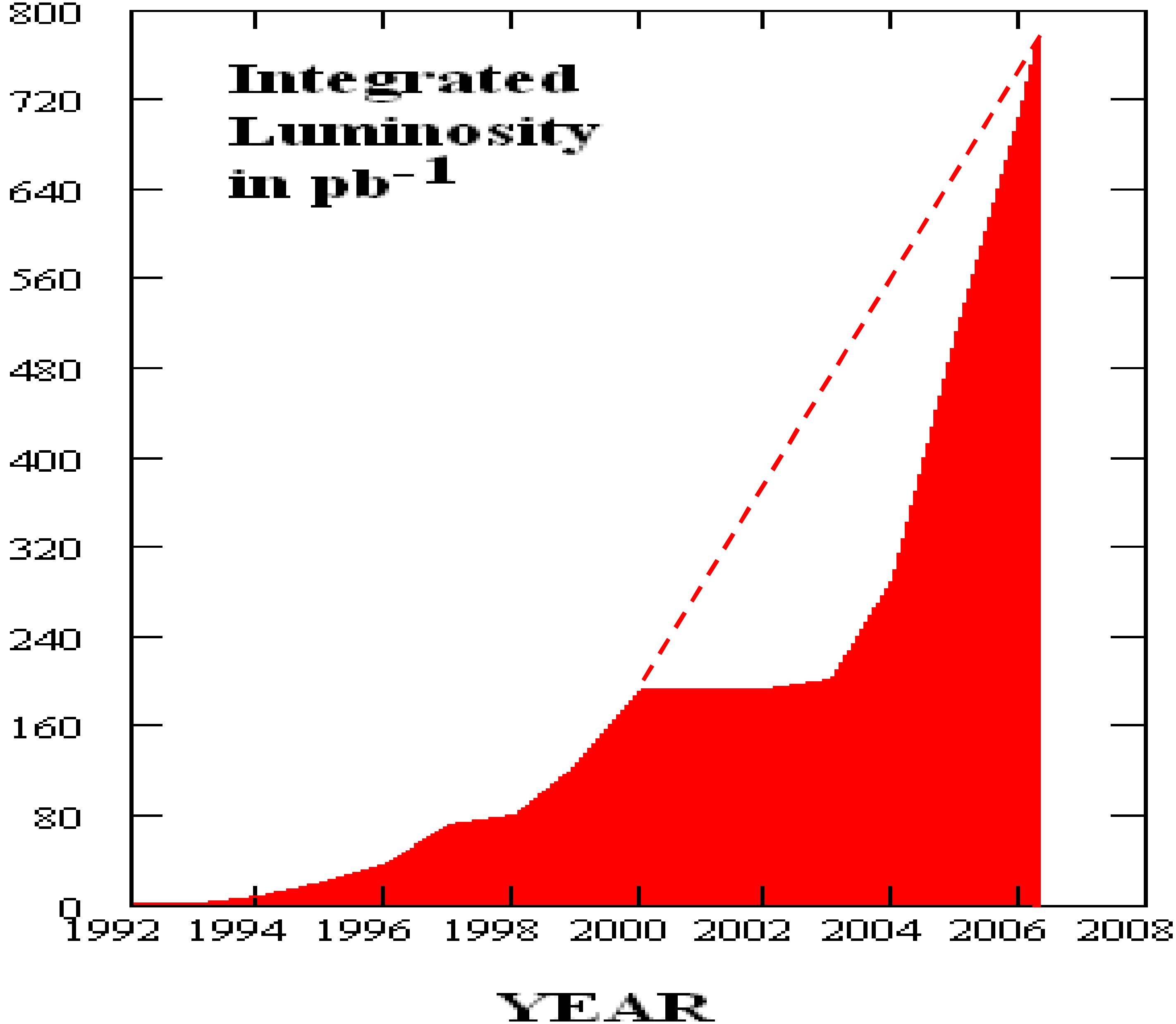
- PS injection:
  - Septum and kicker
  - Injection slow bump

NB: in this proposal the extraction energy for the ISOLDE beams is unchanged.

IR/Optics Upgrade or not



HERA II



Integrated Luminosity in pb^{-1}
800
720
640
560
480
400
320
240
160
80
0
1992
1994
1996
1998
2000
2002
2004
2006
2008
YEAR

Insertion Upgrade Plans

- IT Upgrade “phase 1”
  - Goal: reliable operation at $2x10^{34}cm^{-2}s^{-1}$, 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

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 $5x10^{34}$ 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
- 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