Discussion Topics

More or Less in order of Sessions

- Can we reduce the nitrogen part of the cool down time (Lucio)
- Continuous measurement of R (nΩ) during "coast", what is a critical increase, and do we have the software for the analysis
  - During a quench can we extract useful information about the state of the copper stabilizers (Paul)
  - nQPS: Potential problem related to radiation weakness of latest version of field-bus chip (MicroFip^{TM})
    - Affects only supervision not protection
    - Temporary workaround for QPS boards available
    - **Long term solution required for all QPS systems**

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 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

Splices and Beam Energy: Statements

- For confident operation at 7TeV we need
  - To replace all splices with new clamped shunted ones!

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

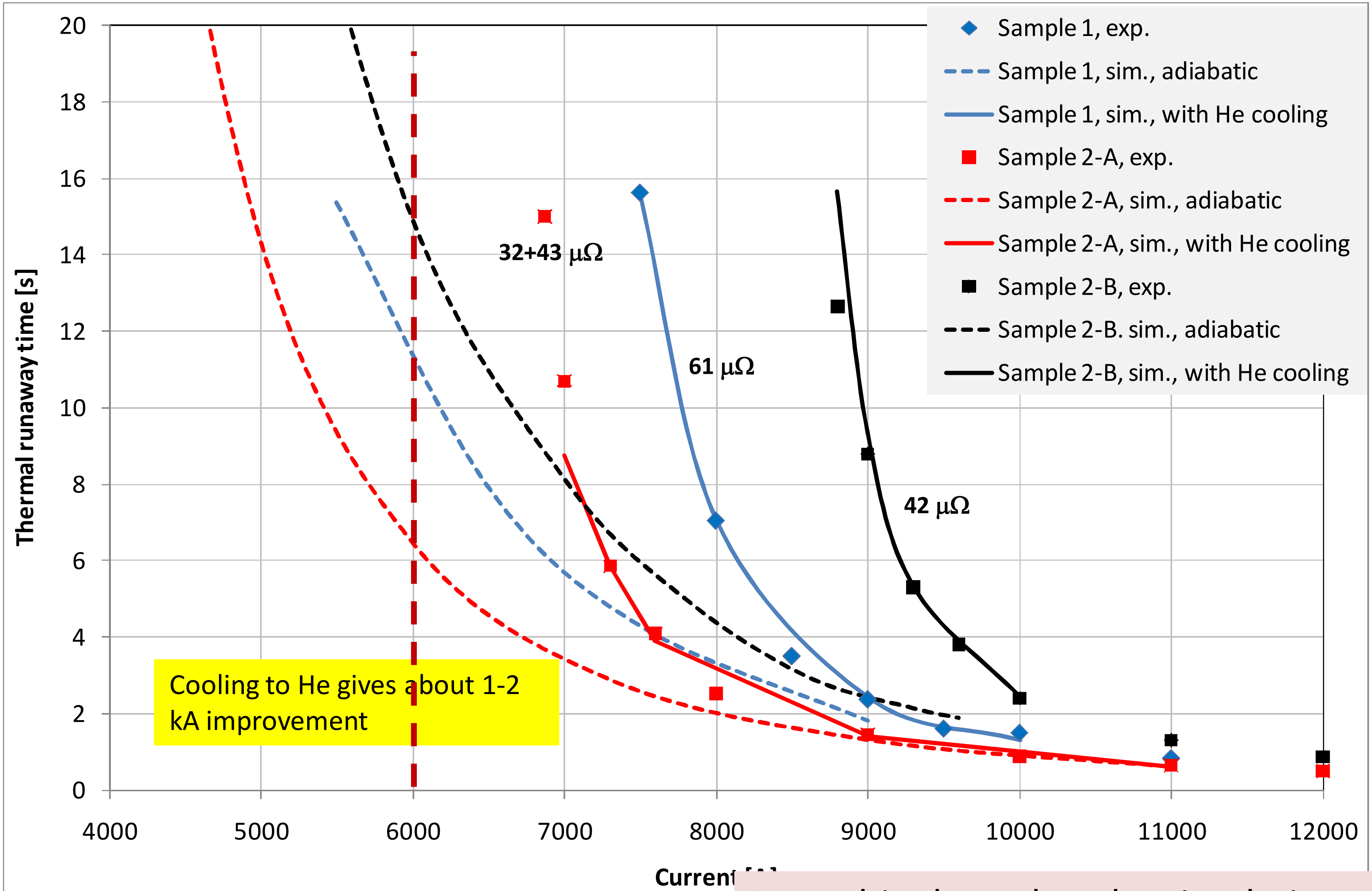
For safe running around 7 TeV, a shunt has to be added on all 13 kA joints, also on those with small R_{addit}. Joints with high R_{addit} or joints with large visual defects should be resoldered and shunted.

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.

2.2

Correlation experimental and calculated $t_{TR}(I)$ curves.

For each sample the effective heat transfer to the helium is individually fitted



Does this show that the simulations are very pessimistic at < 8kA?

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

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

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 $\mu\Omega$ margin.

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?

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

BLMs

- BLM system is crucial to reach full protection level
  - Beam test to determine safe setting of threshold levels, full application of procedures
- Impressive system performance
- “scraping in SPS is needed”
- “clean injection is critical”
    - Injection efficiency did not receive any attention till now but will have to be optimised (using injection damper etc.) for higher injected currents

Machine Protection etc

- 30kJ in 2009: 30MJ in 2010! (for $2\text{x}10^{31}$)
- Collimation protection is crucial to avoid beam damage
- MD phases have added danger
- Proposal/Authorization/Procedures needed
  - Operational strategy for intensity increase
  - Masking and unmasking interlocks
- HWC 2010 and Beyond (organization)
  - Rudiger to chair a WG and report to LMC

Proposals to the LMC

Optimization of Recovery from Collateral Damage

- Vacuum group had to develop a super clean vacuum cleaner
  - A new methodology was developed and applied for the cleanup process of sector 3-4
  - They have 6 sets of tooling “on the shelf” to intervene in case of need
  - Hope they will remain on the shelf forever !
- Fast Valves need development work
- Additional Rupture discs envisaged

Repairs with Localised Warm up of cold sectors

- Local warm-up is part of baseline, allows local repairs, avoids thermal cycle of whole arc, method must be adapted for PIM issue.
- Example of a repair of the insulation vacuum using localised warm up produces a saving of 17 days (69 to 52)
- X Ray Tomography gives huge leap forward: avoids systematic beam vacuum venting + endoscopy to check PIMs
- “Can we change a magnet without warming up the full arc?”..... Probably yes, but needs development of tools

Safety Session Interesting session, lots of follow up needed

- Follow up of task force on underground safety:
  - Experimental areas are sealed
- Still outstanding
  - Sealing of service areas from the tunnel
  - Alternative He release path
  - Proposal to link access with powering system
  - Do we need a 5^{th} safety coordinator?

Access system and Radiation Monitoring

- No problems with personnel safety but issues with availability of the LHC
  - Never ending story of the MAD
  - Access very slow when there is a large throughput
  - Detailed proposal for consolidation of the access system
    - Reduce the size of the sectors? (more doors)
    - Should the LASS be extended to include other hazards such a electricity, high pressure, lack of oxygen...
  - Introduction of new AET (Avis Execution Travaux)
  - Do we need more people who are trained to give access?

WG needed to provide the functional specifications for new access system

Radiation to Electronics (WoW!!)

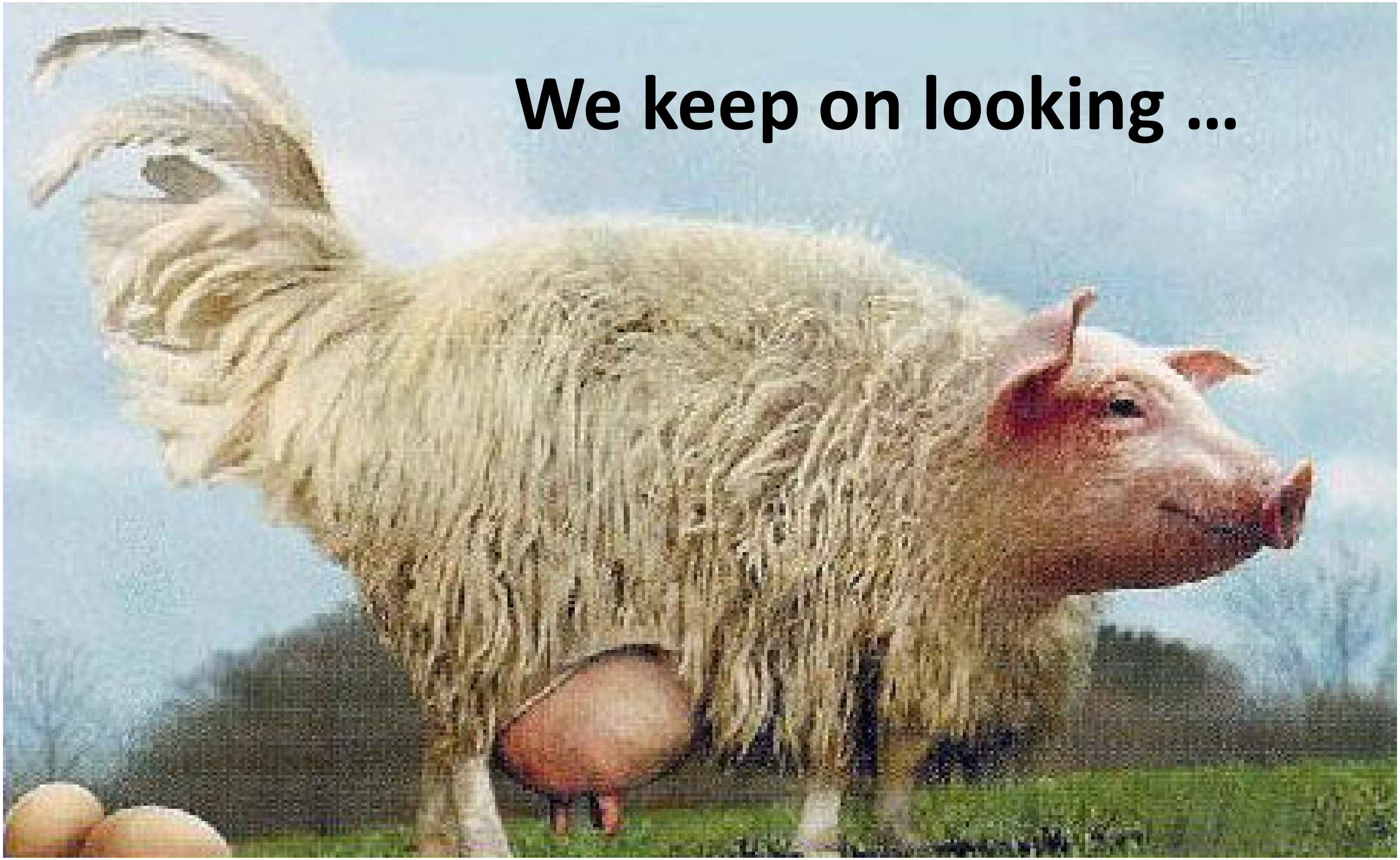
- The detectors attacked the problem at the right time (>10 years ago)
- LHC Present situation is difficult: mitigation
  - Shielding,
  - Relocation to existing areas
  - Redesign of electronics (???)
  - Relocation to newly generated areas (civil engineering)
- Lead times are long (needs evolutionary approach)
- Cost will be very high for generation of new underground areas
  - Superconducting links?

The slide that no-one should ever dare show!

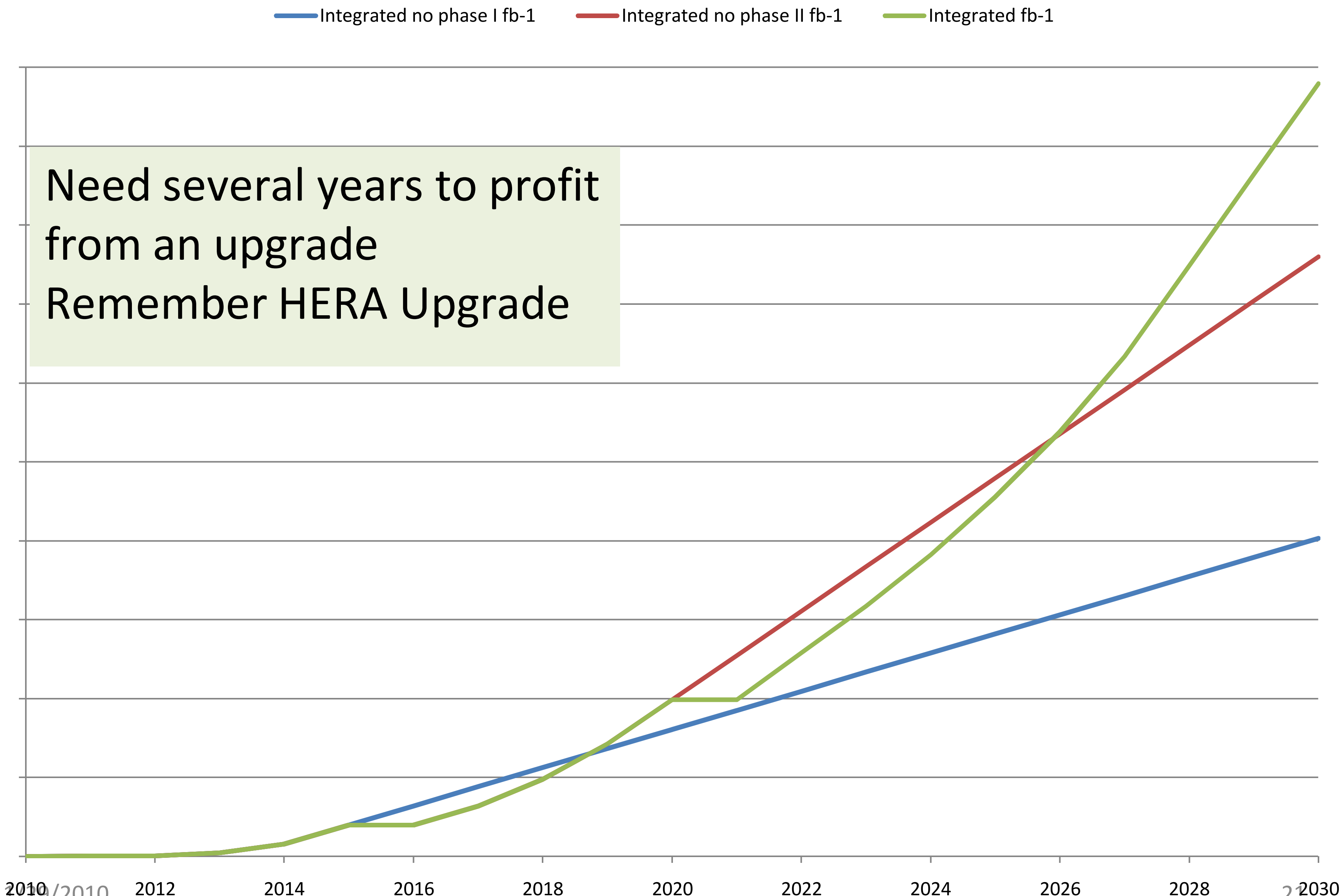
	Material [MCHF]	MANPOWER [FTEs]	decision	Ready
Early shielding/relocation	5÷10	20	Now	2011
Redesign 120/600 Amps	10	15÷20	May 2010	2014
New Shafts and relocation	50÷60	40	June 2010	2014÷2015
Relocation UJs (no new civil engineering)	15	30	2010	2013
4 New UAs	100 MCHF ?	60?	2011?	2015

180—195 MCHF **170 FTEs**

The Perfect Solution



Upgrade or not



Need several years to profit from an upgrade
Remember HERA Upgrade

What added value will SPL/PS2 provide for LHC useful integrated luminosity?

- We finally returned to what Chamonix used to be like: LOTS OF CONFLICT...
- Motivation for LP-SPL/PS2 upgrade
  - Improve reliability of injector chain for LHC era
  - Needed consolidation of existing injectors will give improved reliability
  - Remove main performance limitation
  - Summary of Performance Limitations at present (protons per bunch)
    - PS Booster …> 1.7×10^{11}
    - PS………………. 1.7×10^{11}
    - SPS………………. 1.2×10^{11}
    - LHC……… ?

Highest Priority: Identify the performance limitations in the SPS and the LHC

What added value will SPL/PS2 provide for LHC useful integrated luminosity?

- Design Goals for LP-SPL/PS2 upgrade
  - Increased brightness ($4x10^{11}$ppb, and/or possible lower emittance)
  - Questions:
    1. SPS upgrade which would allow to accelerate this intensity
    2. LHC upgrade to allow luminosity operation with this intensity or with lower emittance
  - Reduction of LHC Filling Time
    - Reduction of 5 minutes per fill!

Highest Priority: Identify the SPS and LHC Upgrades necessary to allow operation with these intensities

These two very high priority items should have been an integral part of the LP-SPL/PS2 study programme.

LP-SPL/PS2

- Resources
  - 1250MCHF (in my opinion erring on the lower side)
  - 1600 man-years (same comment)
  - Peak of around 300 extra people per year
  - In parallel with
    - Consolidation of present injector chain
    - Consolidation of LHC (splices, cryo, radiaton to electronics, LINAC4, Inner triplet phase 1, 2...)

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
  - The PS tunnel is an intensity limitation but not for LHC beam
  - Only the yokes of the main PS magnets are 51 years old
  - Consolidation programme includes all experimental areas
    - Should this and the cost of removal of these areas be included in the cost of the new injectors?

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).

Set up a study for this very interesting option

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.

Implementation

- In general:
  - Three to four years are considered necessary to develop and build the new hardware required for the increase of the PSB extraction energy.
  - One long (eight months) or two short shutdowns to install the new hardware.

Summary of Intensity Limits

Intensity Limitations (10^{11} protons per bunch)			
	Present	SPL-PS2	2GeV in PS
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	1.2	1.2
LHC	?	?	?

Faster and Cheaper

Session 8 Upgrade Plans for Long Stutdown

- IT Upgrade Optics
  - What is the improvement with respect to present?
- IR4 Upgrades
  - 200MHz (ACN) justification is very weak
  - Cryo upgrade attractive
  - Crab cavity studies ongoing; keep the space
- Collimation: clear proposal for phase 2
  - Present intensity "limitation" is soft, needs to be redefined
  - 48 magnets to be displaced (cryo collimators)
  - Approve soon: break point summer 2011
  - Completion 2014-2015

Session 8: Integration Issues

- Planning is 9 months for IT phase 1, idem for matching sections

Session 8 Upgrade Plans for Long Shutdown

- IT Upgrade
  - Goal: reliable operation at $2x10^{34}cm^{-2}s^{-1}$, intensity < ultimate and > nominal

Very similar to "ultimate"

  - ? Same resources for splice consolidation and IT upgrade
  - Present design; matching magnets D2-Q6 remain unchanged but if redesigned should be good for phase 2

Tough Questions:

1. Will the phase 1 upgrade produce an increase in 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?

Session 9 Future Upgrade Scenarios

- Parameter Space beyond $10^{34}cm^{-2}s^{-1}$
  - Very clear presentation of parameter dependence
  - Intensity the most important parameter, beta not the way to go
- Limitations on Higher Intensities (Reality Check!!)
  - Many, many many problems with higher intensities
  - Upgrade should be limited to ultimate intensity
  - Should also develop luminosity scenarios for limitations in total intensity and intensity/bunch (2^{nd} reality check)
- Crab Cavities (nice logo!)
  - Only efficient for low betas around .25m
  - Should continue with the studies (machine protection...)

Session 9 Future Upgrade Scenarios

- Luminosity Optimization and Leveling
  - For LHC high luminosities, the luminosity lifetime becomes comparable with the turn round time.. Low efficiency
  - Need leveling (very efficient for operations if we can make it work)
    - Beta*, crossing angle and crabs, bunch length (NO!)
- What do the experiments want?
  - 3000fb^{-1} (on tape)
  - And a clear plan for the technical developments ffor the next 5-6 years
  - How to give LHCb 5x10^{33}cm^{-2}s^{-1}

Session 9 Future Upgrade Scenarios

- Estimates of Integrated Luminosity (crystal ball)
  - 30fb-1 (2014), 100fb-1 (2016)
  - 100fb-1/year after 2019

We will be able to give better estimates this time next year for the next 5 years

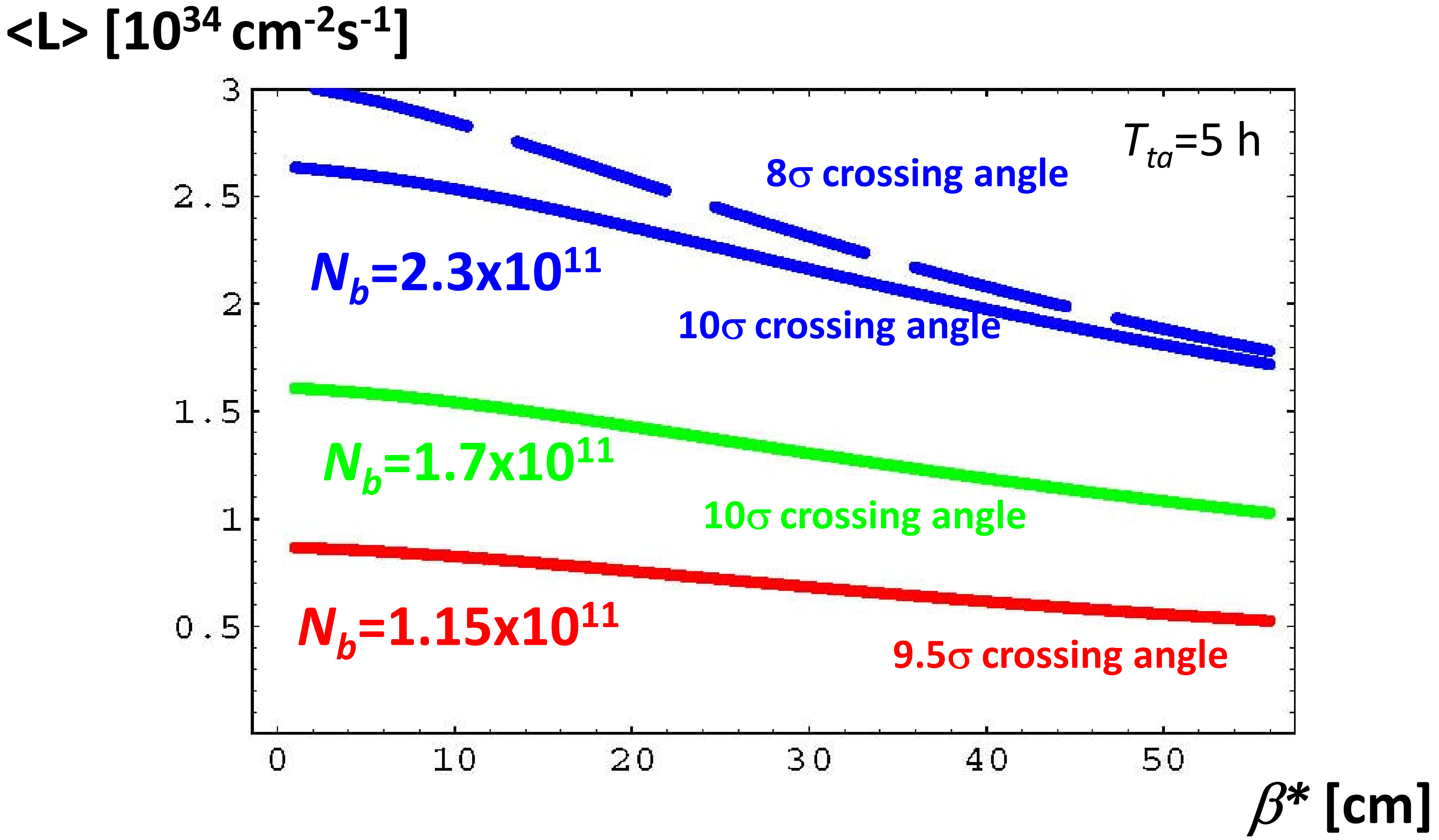
THANKS

- Tjitske for a superb organization
- Pierre Charrue and the CERN micro club
- CERN Directorate (75% present)
- President of Council (Michel Spiro; this is a first!)
- Session Chairs and Scientific Secretaries
- Speakers
- Most importantly the participants

See you next year; same time, same place

Safe Home

<*L*> vs. β* - the KEY PLOT



beam intensity is much more important than *β**

Can LHC swallow > ultimate intensities ?

- Ultimate intensity is challenging for the LHC. Many systems at technological limits with little or no margin.
- Long (incomplete) list of required LHC work collected:
  - "New" RF system, possibly requiring civil engineering.
  - New DSL in IR3, review of potted magnets, radiation damage.
  - Two new cryoplants (assuming one installed for ultimate).
  - Essentially all protection devices to be replaced with more robust designs, possibly requiring also layout changes.
  - Upgrade of the beam dump system. Additional hardware.
  - Half of the phase 1 collimation system to be reviewed (replaced).
  - Remote handling mandatory in parts of the machine.
  - Additional service galleries?
  - Absolute filters and modifications of ventilation system.
  - Additional shielding in some areas.
  - Upgrade of permanent vacuum bake-out system.

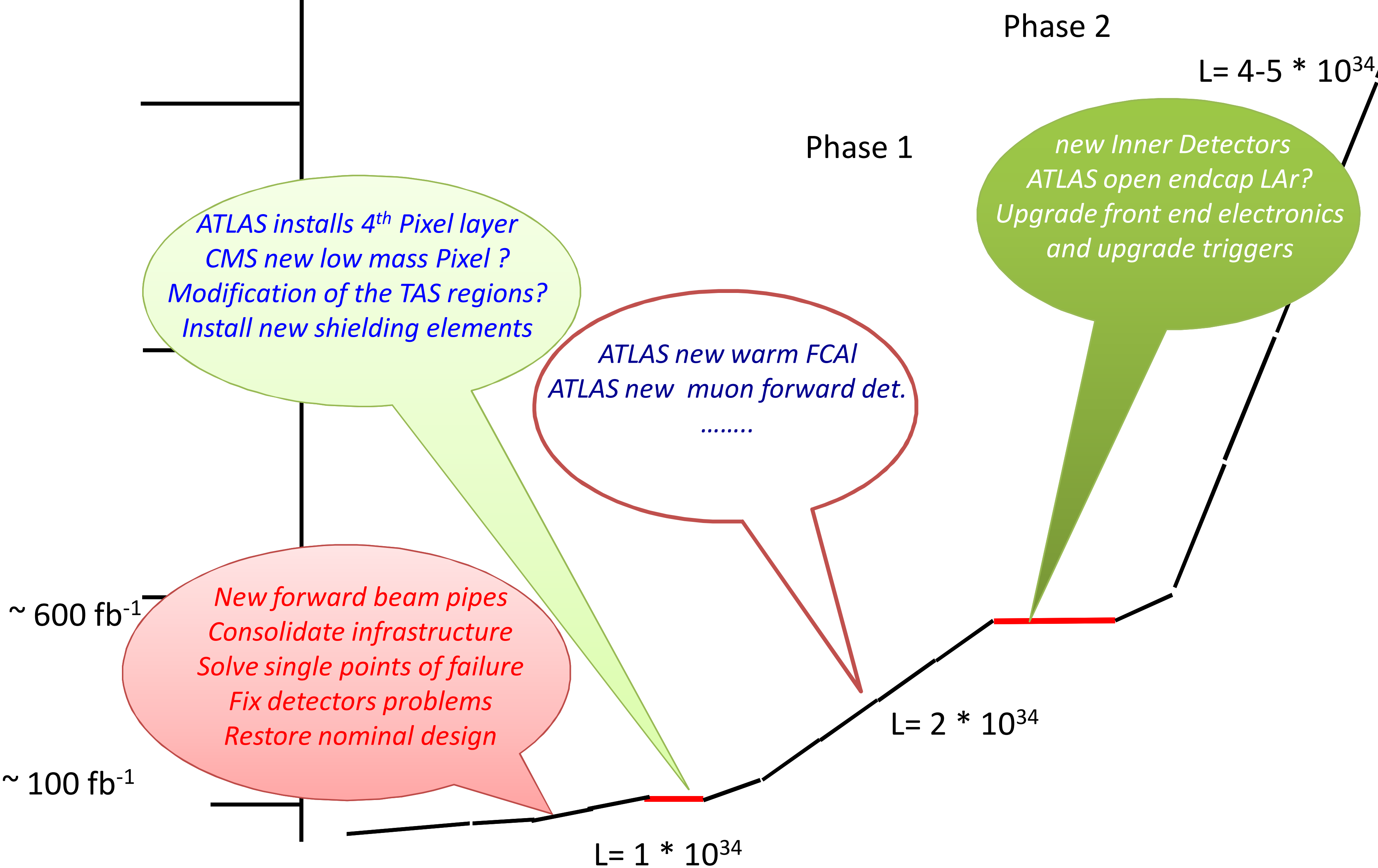
Detectors

The experiments feel now it is very important to have a basic scenario for all what concerns beam periods and shutdown periods over the next 5-6 years, at least until the LINAC 4 is installed and is operational. Actions on the detectors need to be anticipated with enough time for preparation.

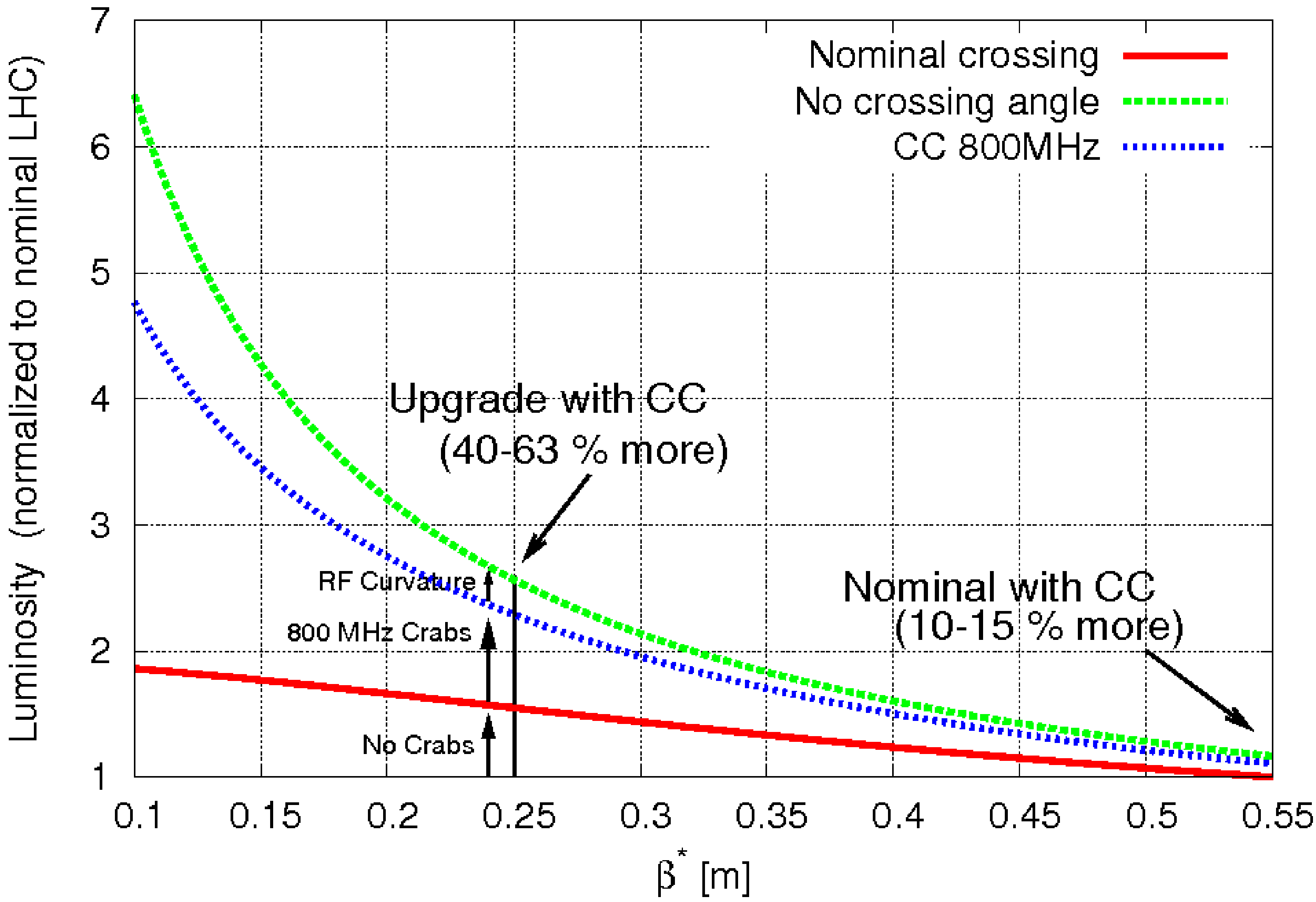
LHC and sLHC operation schemes must be designed to allow running of LHCb after 2020 with $L=5*10^{33}$

LHC and sLHC operation schemes must be designed to allow heavy ion operation and short periods (few weeks/year) of pp with $L<5*10^{31}$ in IP2

Detector Activities



Crab cavities – gain as a function of



Conclusions

At a luminosity level of $10^{35}cm^{-2}s^{-1}$, whatever the scenario, the luminosity lifetime becomes close to operations "time constants" (cycling and filling, travel time to remote buidings and repairs,…).

Hence, **luminosity leveling** could be raised as a requirement for all scenarios. Leveling is also useful for the machine: peak energy deposition, beam-beam effect, operation efficiency.

Accordingly, the performance goal of Phase II would become $L_{average} \sim 5$ to $6\ 10^{34}\ cm^{-2}s^{-1}$, almost constant over one shift (multiplicity ~ 100 for 25 ns spacing).

Projecting

Pushing to nominal in 2016 and taking a couple of years to get to get to ultimate
[potential to push phase 1 upgrade not included]