CERN

European Organization for Nuclear Research
Organisation Européenne pour la Recherche Nucléaire

Thursday 28 January 2010

Session 8 - LHC Upgrade Plans for the first long Shutdown

(Convener: Oliver Bruning,
Paolo Fessia)

Outline of the session

7 presentations:

- Overview of IR upgrade scope and challenges

  Ranko Ostojic
- Injector complex upgrades

  Maurizio Vretenar
- Optics Challenges & Solutions for the LHC Insertions Upgrade Phase I

  Stephane Fartoukh
- Hardware challenges and limitations for the IR upgrades

  Stephan Russenschuck
- Planned upgrade activities in IR4 for the 2014/15 shutdown

  Ed Ciapala
- Summary of the collimation upgrade plans

  Ralph Assmann
- Integration issues in the tunnel and impact on general LHC systems

  Sylvain Weisz

The goals as reported

IR UPGRADE

- Provide more flexibility for focusing of the LHC beams in the ATLAS and CMS insertions, and enable reliable operation of the LHC at 2 10^{34} $cm^{-2}s^{-1}$.
- No modifications to the MS magnets and cryo system
- Significant challenges still exist on the hardware and optics side.

Linac4

- Linac4 will replace aging Linac2
- Linac4 will allow reaching the nominal LHC intensity in PS single batch mode and the ultimate intensity out of PS in double batch mode

IR 4 (RF) upgrades

- ACN: Improve capture, minimize losses for large emittance beams from SPS with large injection errors: not sure yet if really required (200 MHz upgrade in SPS might be better solution)
- ADT: Transverse Damper system upgrade: not sure if really required. Need beam experience!
- New cryo power plant in point 4 to establish RF cryo autonomy from sector 4-5 and make equal cryo capacity between sector 3-4 and 4-5 : significant benefit for operationa!
- Other upgrade options: Crab cavities & higher harmonic RF system

Collimation upgrade

- Phase 2 collimation aims to be compatible with nominal and ultimate intensities. Present installed phase I system is compatible to less then 50% of nominal intensity (depending on assumptions on beam lifetime).
- Phase 2 installation requires new secondary collimator jaws in IR3 and IR7; new-additional tertiary collimators and absorbers and new cryo collimators in the DS
- Planning for installation in 2014-15 requires decision in 2010 and production in 2011

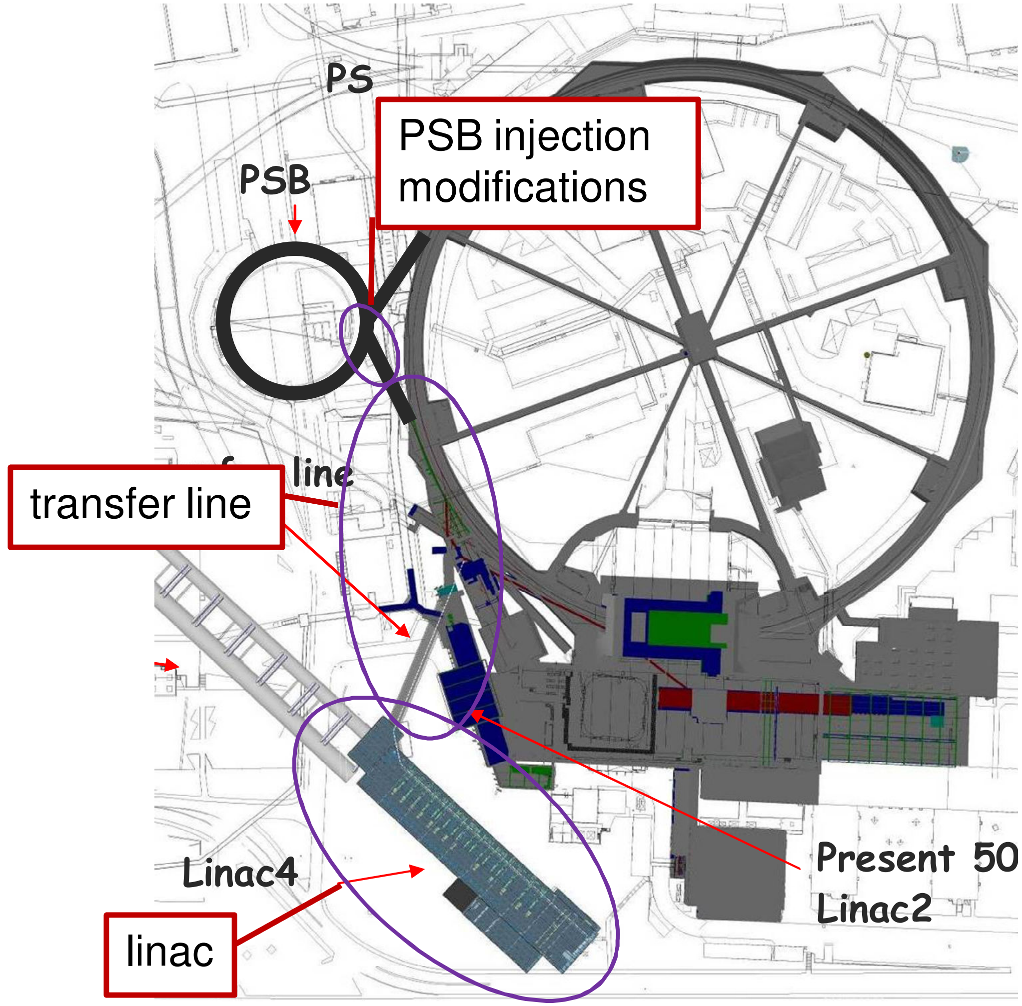
Extension of the Linac4 Project

Maurizio Vretenar

The "Linac4 Project" is composed of 3 parts:

1. Construction and commissioning of Linac4 *(up to Linac4 dump).*
2. Construction of the transfer line, connection to Linac2 line, upgrade of the measurement lines *(up to PSB wall, LBE dump)*.
3. Modification of PSB injection region for H^-, 160 MeV *(commissioning of PSB with Linac4).*

➔ *requires 8 month stop of proton operation for the LHC!*



Performance Tables

Limitations are highlighted in yellow; values to be demonstrated are in italic.

LHC INJECTORS WITH LINAC2		Nominal LHC Double Batch	Expected Maximum Double Batch	Original proposal, 1997 Nominal	Original proposal, 1997 Ultimate
PSB out ($\varepsilon^* \leq 2.5\ \mu m$)	ppr	1.62 x10^{12} *(1bunch/ring)* ↓ *(6 bunches, h=7)*	1.8 x10^{12} *(1bunch/ring)* ↓ *(6 bunches, h=7)*	1.05 x10^{12} *(1bunch/ring)* ↓ *(8 bunches, h=8)*	1.8 x10^{12} *(1bunch/ring)* ↓ *(8 bunches, h=8)*
PS out, per pulse	ppp	9.72 x10^{12}	10.8 x10^{12}	8.4 x10^{12}	14.4 x10^{12}
PS out, per bunch ($\varepsilon^* \leq 3\ \mu m$)	ppb	1.35 x10^{11} *(72 bunches)* ↓ *15% loss*	1.5 x10^{11} *(72 bunches)* ↓ *15% loss*	1.0 x10^{11} *(84 bunches)* ↓ *no loss*	1.7 x10^{11} *(84 bunches)* ↓ *no loss*
SPS out	ppb	1.15 x10^{11}	*1.27 x10^{11}*	1.0 x10^{11}	1.7 x10^{11}

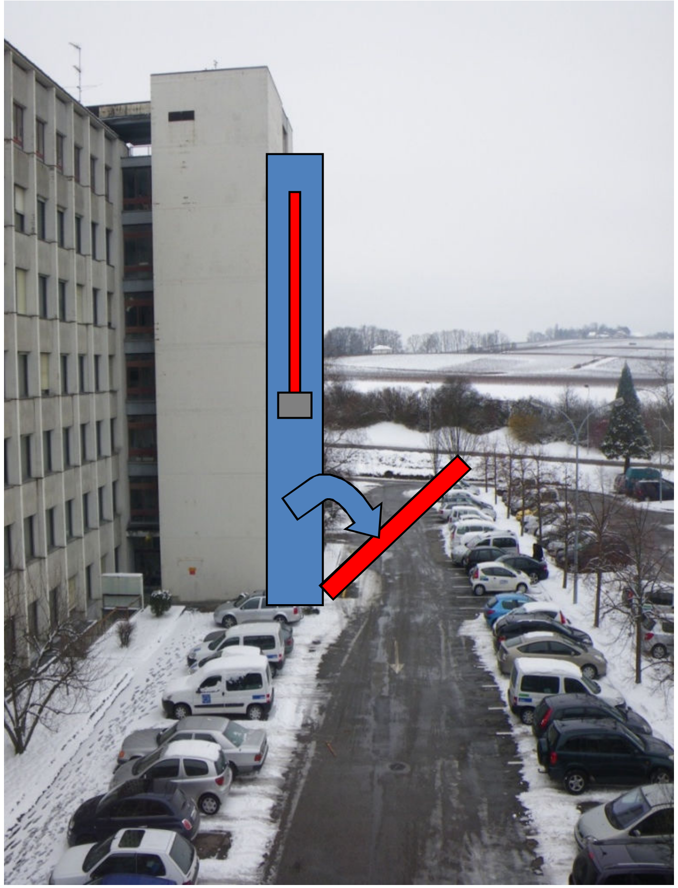
LHC INJECTORS WITH LINAC4		Nominal LHC Single batch	Maximum Single batch	Maximum Double batch	Single batch + PS h=14, 12 bunches scheme
PSB out ($\varepsilon^* \leq 2.5\ \mu m$)	ppr	3.25 x10^{12} *(2bunch/ring)* ↓ *(6 bunches, h=7)*	3.6 x10^{12} *(2bunch/ring)* ↓ *(6 bunches, h=7)*	1.8 x10^{12} *(1bunch/ring)* ↓ *(6 bunches, h=7)*	*3.6 x10^{12}* *(3bunch/ring)* ↓ *(12 bunches, h=14)*
PS out, per pulse	ppp	9.72 x10^{12}	*10.8 x10^{12}*	*12.3 x10^{12} (scaled 1998 limit, 206ns bunches)*	*14.4 x10^{12} (lower ΔQ in single batch)*
PS out, per bunch ($\varepsilon^* \leq 3\ \mu m$)	ppb	1.35 x10^{11} *(72 bunches)* ↓ *15% loss*	*1.5 x10^{11} (72 bunches)* ↓ *<15% loss*	*1.7 x10^{11} (72 bunches)* ↓ *20% loss*	*2.0 x10^{11} (72 bunches)* ↓ *20% loss*
SPS out	ppb	1.15 x10^{11}	*>1.3 x10^{11}*	*1.37 x10^{11}*	*1.6 x10^{11}*
Goal:		Nominal intensity in single batch: shorter filling time, lower losses and emittance growth.		Potential for ultimate intensity out of PS in double batch.	Potential for > ultimate with a new PS scheme (in PSB: new recombination kicker, new RF gymnastics).

Maurizio Vretenar

Triplet upgrade: Main points

- A conceptual design for the Phase-1 Upgrade, in line with the general constraints, is at hand. Due to the fact that the LHC dipole cable is readily available, the magnets and other equipment can be built, under reasonable assumptions, by **the end of 2014** **(date to be reviewed)**.
- But past experience showed 5 years from design to production and some components still require significant development (e.g. nested dipole magnets)
- ***The available resources at CERN and worldwide for the construction of the magnets and other equipment for the Phase-1 Upgrade are limited.*** *The collaborations with European and US laboratories, which bring in their expertise and resources, have been formalised and are in effect.*
- Separate cryogenic systems for the triplets in IR1 and IR5, together with new underground areas, if available around 2015-16, would considerably ease the installation and improve the performance of the new triplets. Such investment is necessary for further IR upgrades.
- The new triplets provide considerable flexibility for beam collisions in ATLAS and CMS insertions. Several ways are open to reach stable operation at a luminosity of $2\ 10^{34}\ cm^{-2}s^{-1}$.

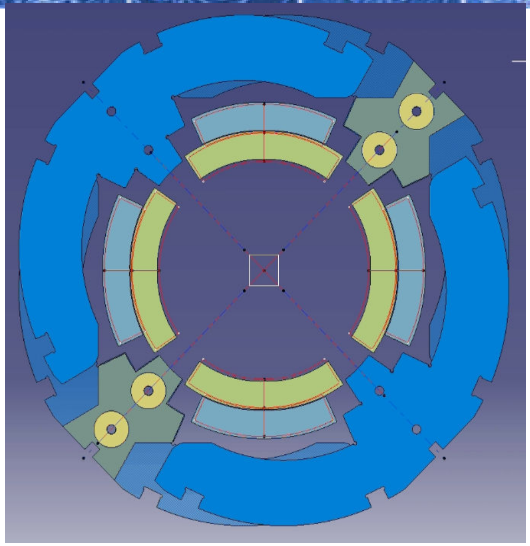
Vertical Collaring (Hardly Possible for 10-m-long Magnets)

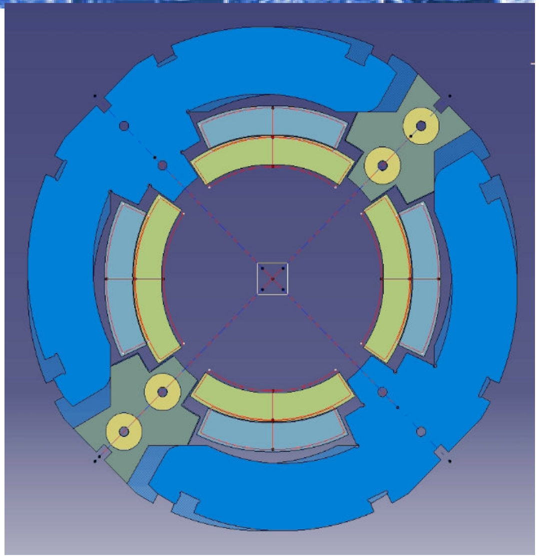


Stephan Russenschuck

Horizontal Collaring

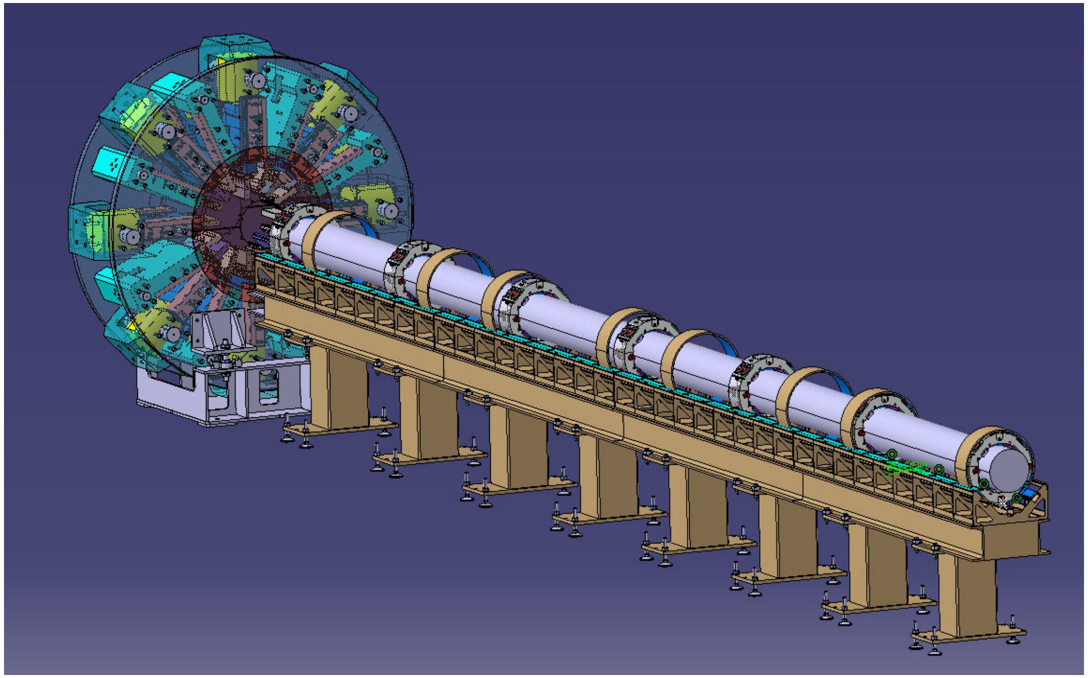
Self-locking collars

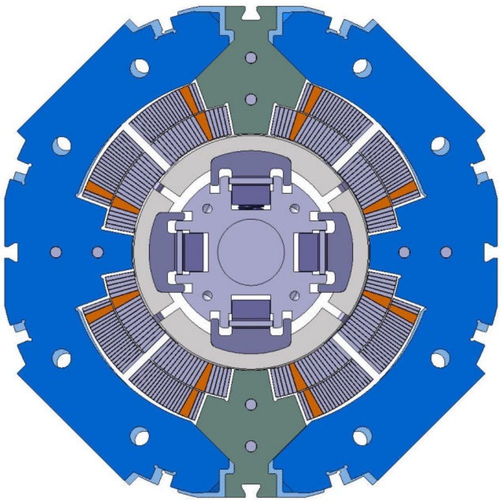




Stephan Russenschuck

Collaring Press





Assembly mandrel

Main points from Optics design:

Stephane Fartoukh

- **A new overall optics** is needed for the chromatic correction of the new IT. **This means an almost new machine to be re-commissioned.**

- **A palette of solutions is possible in collision, between two extreme configurations, each of them hitting at least one hard limit given by the LHC ring @ 7 TeV:**

→ **β* = 30 cm → 40 cm:** lower β* hardly limited by **gradient limits** (lattice sextupole, IR quads) and then **MS aperture**.

→ **Full crossing-angle = 410 → 560μrad:** higher X-angle hardly limited by **MCBY/MCBC strength**

→ Giving a peak luminosity between **2×10^{34} cm^{-2}s^{-1} and 3×10^{34} cm^{-2}s^{-1} @ ultimate intensity.**

- **While the aperture of the new IT is clearly not questioned, the IT layout shall still be optimized keeping in mind these two extreme configurations:**

→ **Double plane MCBX** highly desirable for the quality of the orbit correction in the new IT, but also to decouple it from the generation of the X-scheme, otherwise a X-angle of 560 μrad is out of reach (sLHC-PR30).

→ **Minimize the number of parasitic b-b encounters:** QDXS moved on the non-IP side of D1, solution with N-lines?

→ Further optimize the **Field Quality of the new IT** (targets still to be finalized and a good compromise to be found) with a **particular concern for D1** (e.g. a factor of 5 missing for a2/b3 comparing the requirements and the first offer).

- The next step is to decide **what is the most likely configuration to "guaranty a reliable operation of the machine with a peak lumi ≥ 2×10^{34} cm^{-2}s^{-1} @ ultimate intensity".**

→ Why did we push for a wide aperture for the new IT?.. Certainly for beam-beam, collimation, but not necessarily β* !

→ **β* ~ 40 cm (→ 35 cm ?)** seems then to be the most promising option, **with a X-angle of ~13 → 16σ still to be fine tuned** for beam-beam, collimation efficiency and impedance (n1/n2), but also debris coming from the IP.

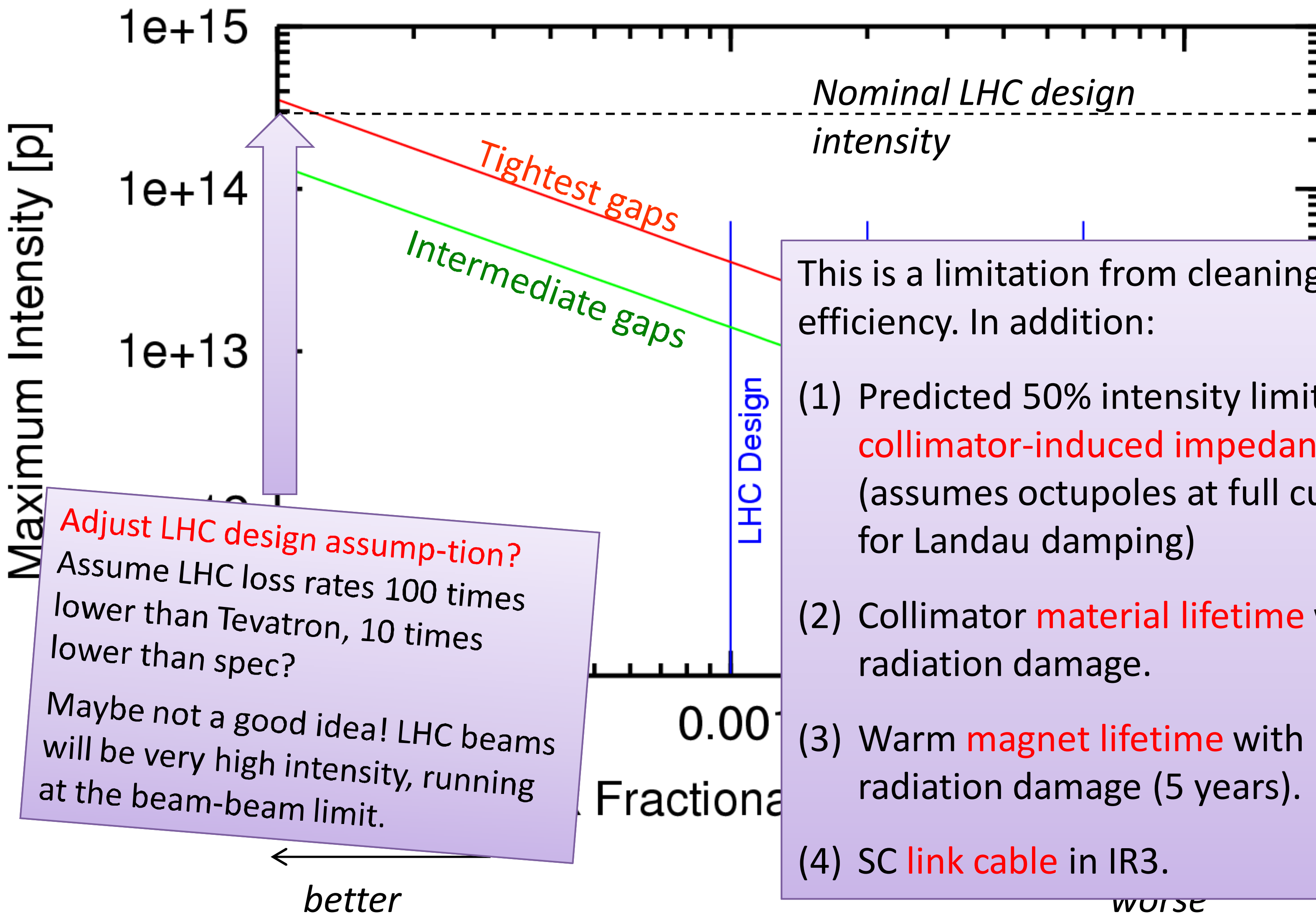
- **Further steps in this direction** shall not be forgotten **to restore operational margins on the "non-IT side"**, also because possibly easy (??) or already needed for the nominal machine:

→ Re-commission **the lattice sextupoles and Q7/Q9's (MQM @1.9K) at higher than nominal current.**

→ Install **warm orbit corrector at Q4** (~1 Tm) to reinforce the MCBY's for IP steering and Vernier scans @ 7 TeV.

Phase 1 Intensity Limit vs Loss Rate at 7 TeV

Loss map simulations and LHC design values



This is a limitation from cleaning efficiency. In addition:

(1) Predicted 50% intensity limit from collimator-induced impedance (assumes octupoles at full current for Landau damping)

(2) Collimator material lifetime with radiation damage.

(3) Warm magnet lifetime with radiation damage (5 years).

(4) SC link cable in IR3.

Adjust LHC design assump-tion?
Assume LHC loss rates 100 times lower than Tevatron, 10 times lower than spec?

Maybe not a good idea! LHC beams will be very high intensity, running at the beam-beam limit.

10

IR	Hardware	#	Justification	Construction	Infrastructure
1	TCLP installed	2	Interaction debris for **nominal luminosity**	OK	prepared
	TCTH, TCTVA moved	4	Phase 1 IR upgrade (if change in D2-D1 region)	OK	move
	TCT (new type?) installed	4	Phase 1 IR upgrade (reduced aperture in matching section)	new	new
2	TCTH installed	2	Improve **signal acceptan**		new
	TCRYO installed	2	R		new
3	TCSM				prepared
	Shift p magnet				
	TCRYO				new
5	TCLP ins				epared
	TCTH, TC		D1 region)	OK	move
	TCT (new		IR upgrade (reduced aperture in matching section)	new	new
6	TCLA installed	2	**Reduce quench risk** after TCDQ	new	new
7	TCSM	22	**Lower impedance (1/2), faster setup (h → s), longer lifetime (x 3), lower R2E (1/6 – 1/2)**	new	prepared
	Shift positions of 24 SC magnets by 3m, 3cm		Space for collimators at critical loss locations		
	TCRYO installed	4	**Better efficiency (x 15-90)** with collimators in SC dispersion suppressor	new	new

Total work (machine and experiment requests):

- 64 locations modified.
- 52 collimators + ~ 10 spares to be constructed.
- 22 new infrastructures.
- 8 infrastructures to be moved.
- 48 SC magnets to move in IR3 and IR7 (can be staged, 12 at a time).

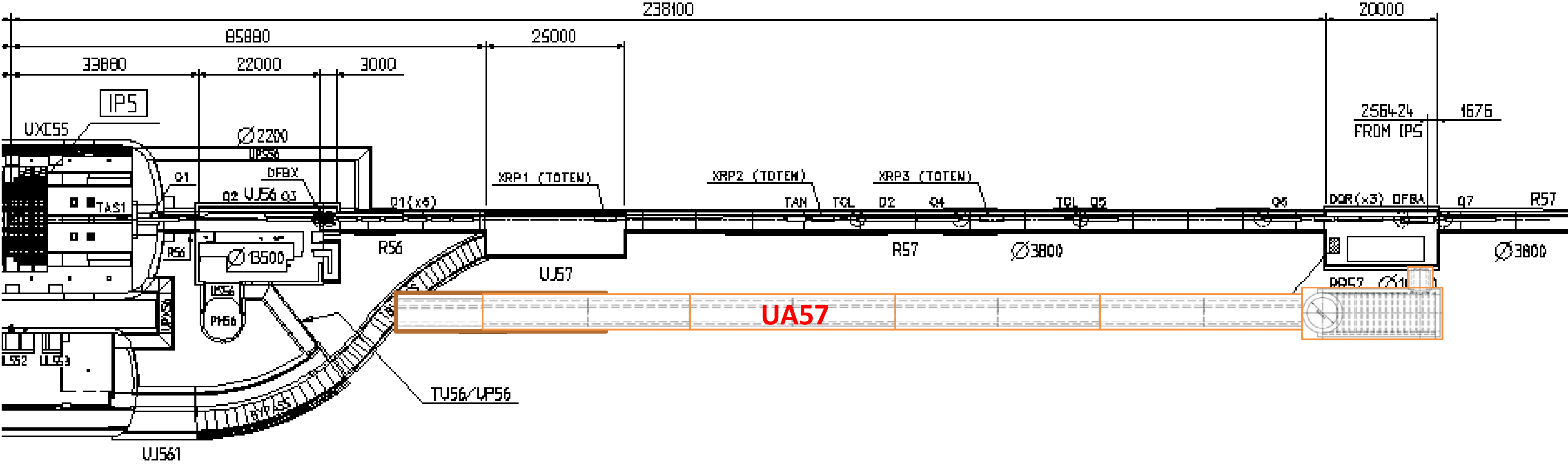
Timing and cost in machine availability

Overall shut down planning required for the next years before Phase 1 upgrade implementation!

- Planning with other required interventions (e.g. splice consolidation).
- How can we assure that we can plan for sufficient running time between the various required shutdowns?
- How many and what interventions can be made in parallel?
- Resource requirements for total interventions?
- How quickly do we think can we reach nominal and ultimate beam parameters (when do we need to be ready with Phase 1)?
- Best timing and earliest practical implementation date for Phase 1?
- Shall we revise the scope of the Phase 1 upgrade if we change the installation date (e.g. allow for modification in the MS)?

Upgrade	Ready f...		... to be ...n
IR...			...ng
			...going
R... ACN... IR4 c... Crab... 800 M...			...ce ...on
Collir...			...gn
Other Infra... upgra...	...ing 3.5 years from t0	to be matched with tunnel activities	Summer 2010 studies Implementation 2012

Space for the evolution of the high luminosity insertions

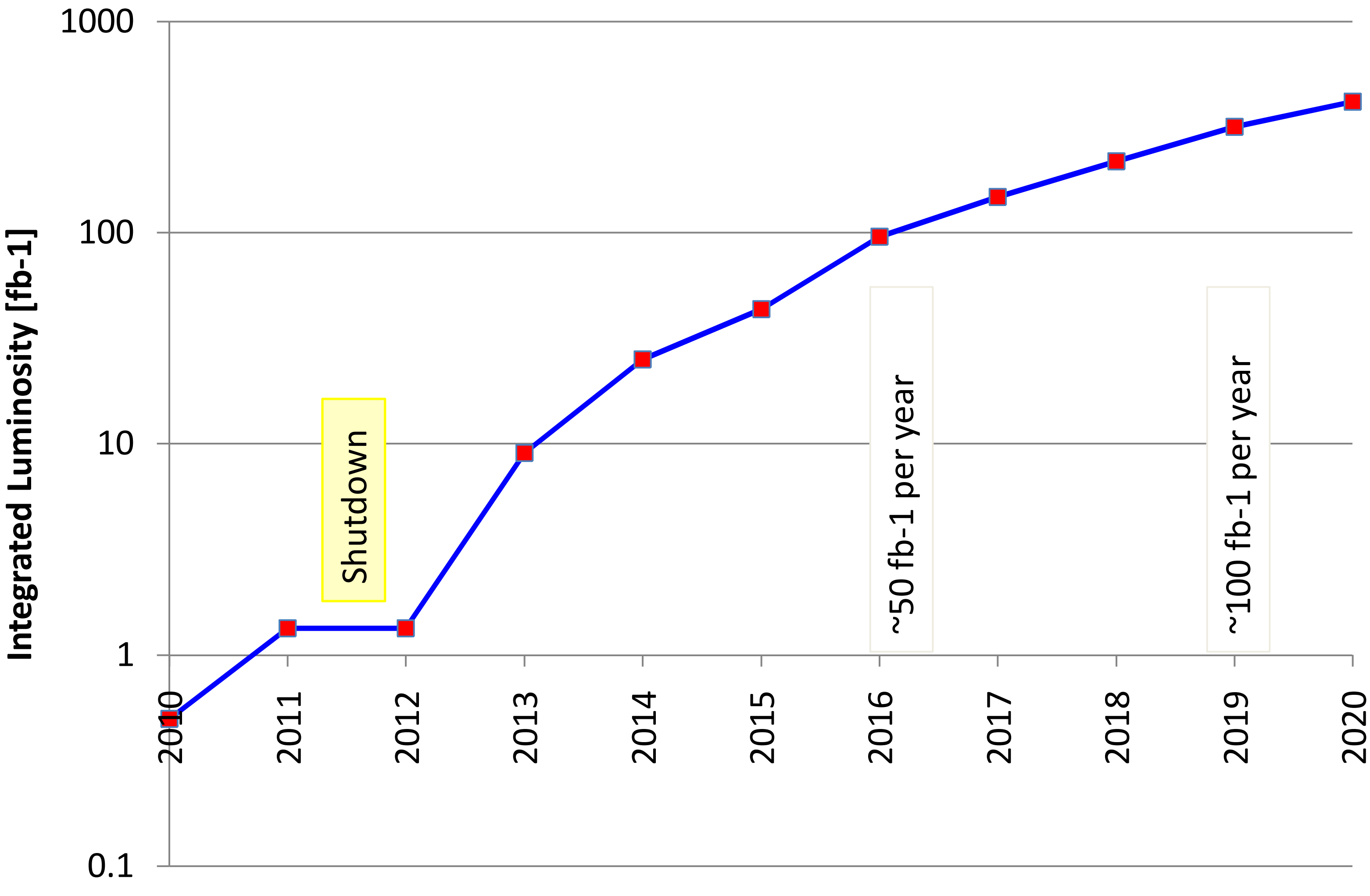


- It is clearly a very important investment (ca. 2 years and 40 MCHF)
- But can we do without it?

Long term SEE mitigation, IR upgrade phase-1 & phase-2, local Crab Cavity with dogleg, additional cryogenics, etc…

- Should be discussed at the mid-April workshop that Roberto announced?

Projecting



Mike Lamont

Main Questions:

- Is the Phase 1 upgrade still a reasonable option in 2015 given the current delays (Sept 19 & splice consolidation) and the projection of reaching ‘only ’ 50 fb^{-1} compared to a triplet lifetime of 300 fb^{-1} ?
- Can the injector complex deliver ultimate beam intensities in time for the planned Phase 1 upgrade (2014/2015)?
- Can / should we revise the planning for installation by 2014 / 2015? If yes for what parts of the Phase 1 upgrade (LINAC4, Collimation, RF, Triplet, civil engineering)
- To what extend will a long shutdown for the splice consolidation impact on the Phase 1 upgrade planning (only 1.5 years of operation between 2 long shut downs)?
- Need decisions rather soon as orders and collaboration agreements are being fixed!