



**High
Luminosity
LHC**

Status of the HL- LHC project

Lucio Rossi

CERN

HL-LHC project coordinator



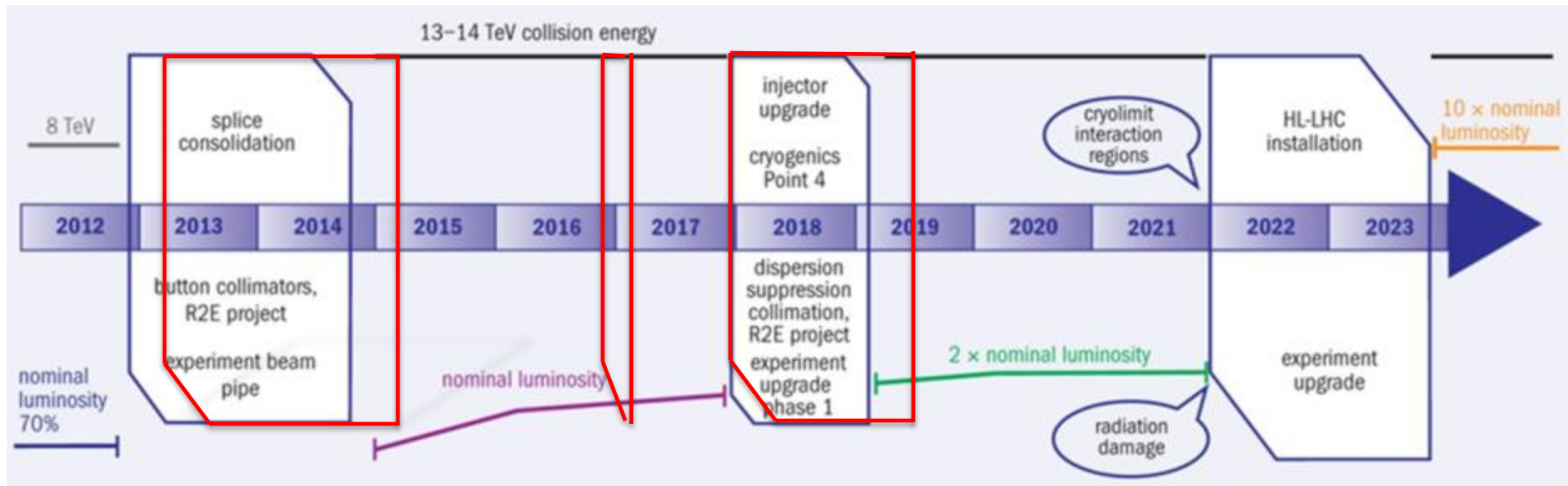
The HiLumi LHC Design Study is included in the High Luminosity LHC project and is partly funded by the European Commission within the Framework Programme 7 Capacities Specific Programme, Grant Agreement 284404.



Content

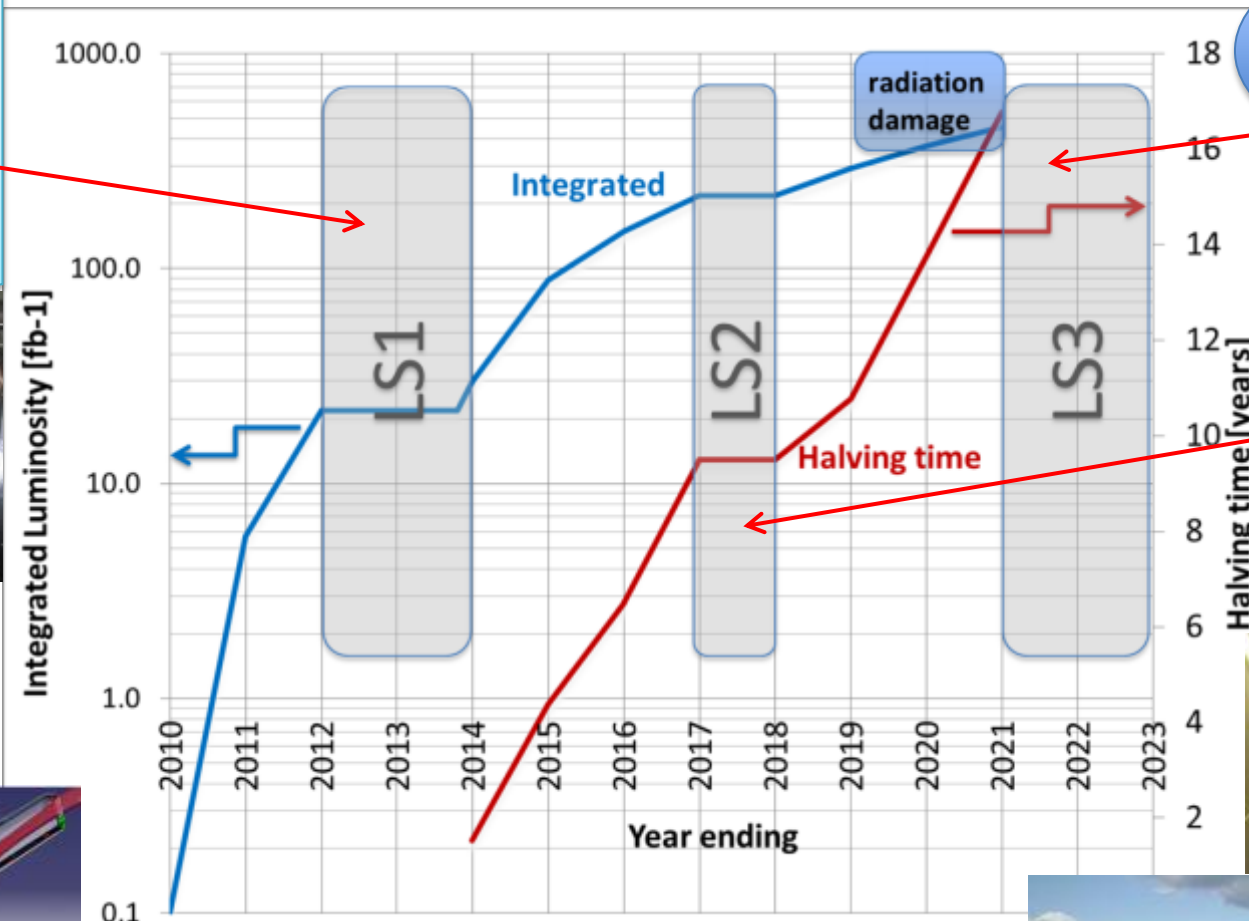
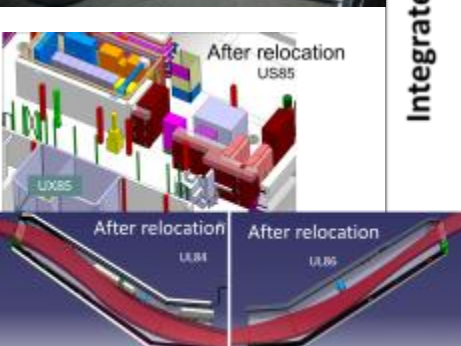
- Recap of the HL-LHC project
- Project management update
 - TC
 - Coordination Group
- CERN context
 - Two branches project and CtC
- EU strategy update context
- Progress of work
- Discussions for in kind-contribution

Change of plan from last year... (official part is till 2015)



2 Reasons for upgrade: Performance & Technical (Consolidation)

Shut down to fix interconnects and overcome energy limitation (LHC incident of Sept 2008) and R2E



Full upgrade

Shut down to overcome beam intensity limitation (Injectors, collimation and more...)



Peak Performance: Luminosity

$$L = \gamma \frac{f_{rev} n_b N_b^2}{4\pi \epsilon_n \beta^*} R$$

Beam current

energy

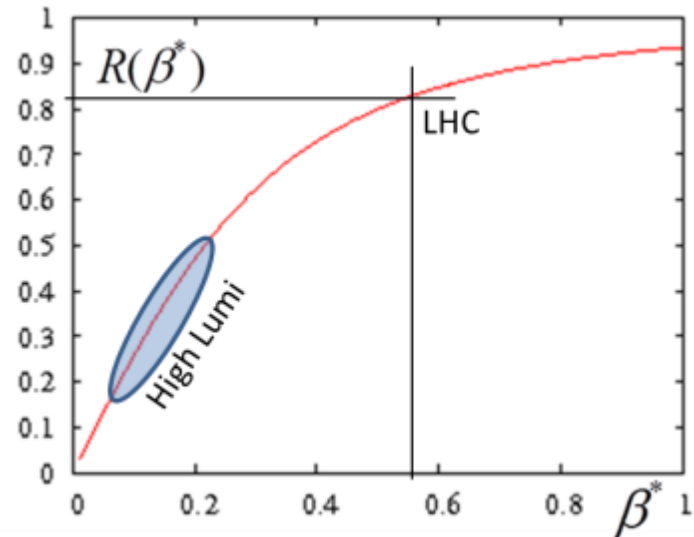
Beam size

$$R = \frac{1}{\sqrt{1 + \left(\frac{\theta_c \sigma_s}{2\epsilon_n \beta^* \gamma}\right)^2}}$$

Beam current and emittance: involve Inj chain and whole ring
 β^* involve «only» 2 IRs, 600 m (but ATS...)

$$L_0 = 1 \cdot 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$$

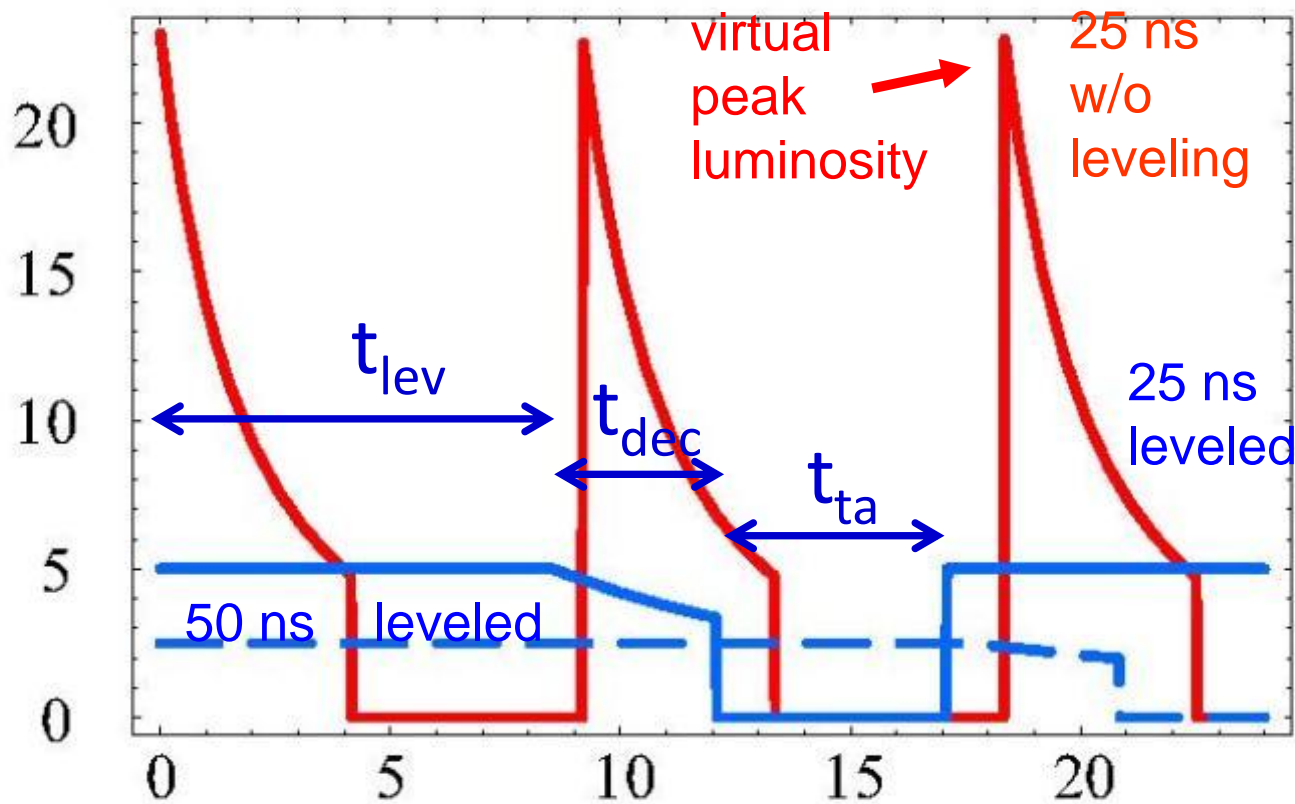
LHC has been designed for L_0
All systems have singularly designed tentatively for ultimate $2L_0$ (almost...)



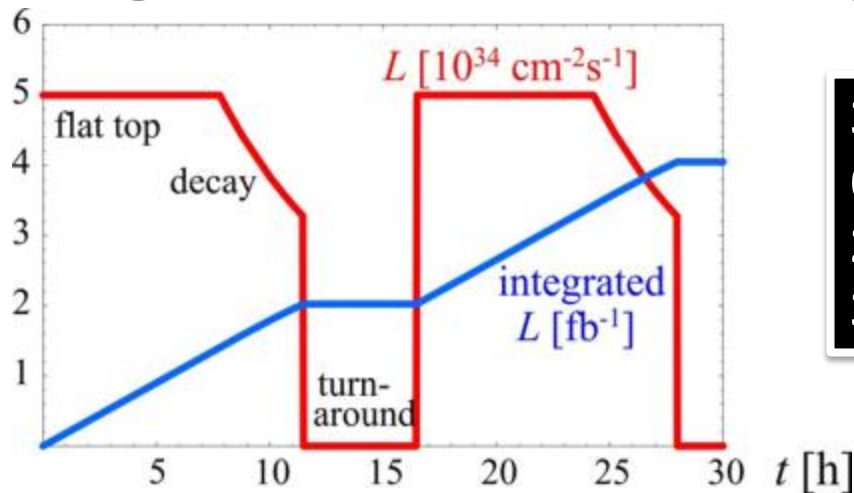
The final performance: $\int L dt$

This requires levelling (\ll virtual lumi)

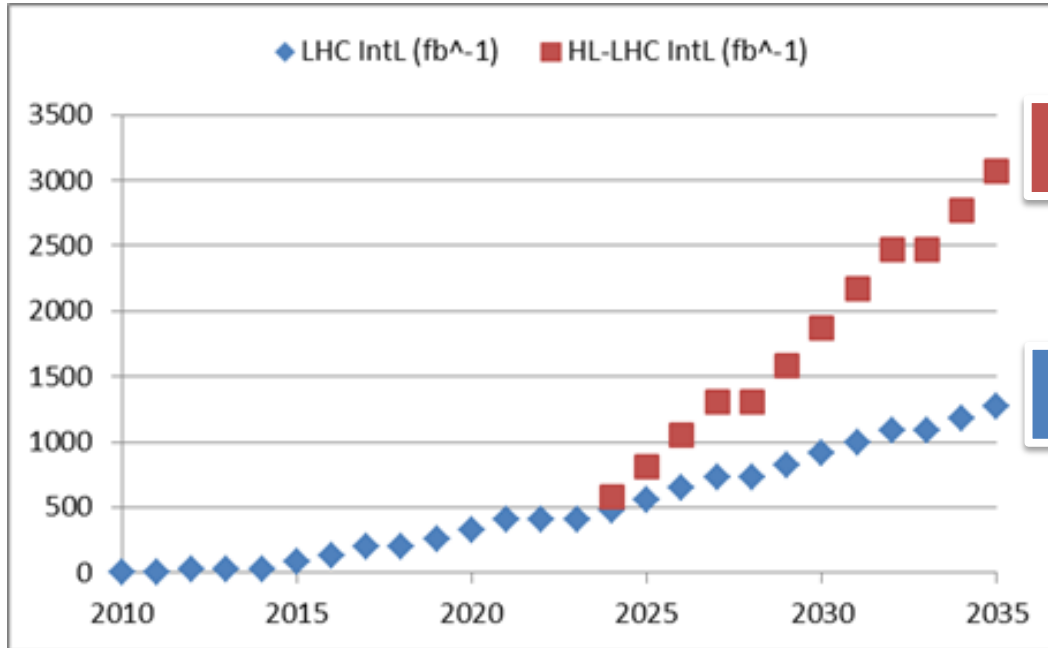
This requires availability and reliability



Final goal : 3000 fb⁻¹ by 2030's...



3 fb⁻¹ per day
60% of efficiency
250 fb⁻¹ /year
300 fb⁻¹/year as «ultimate»



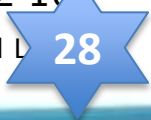
Full project

Enhanced consolidation

Official Beam Parameters

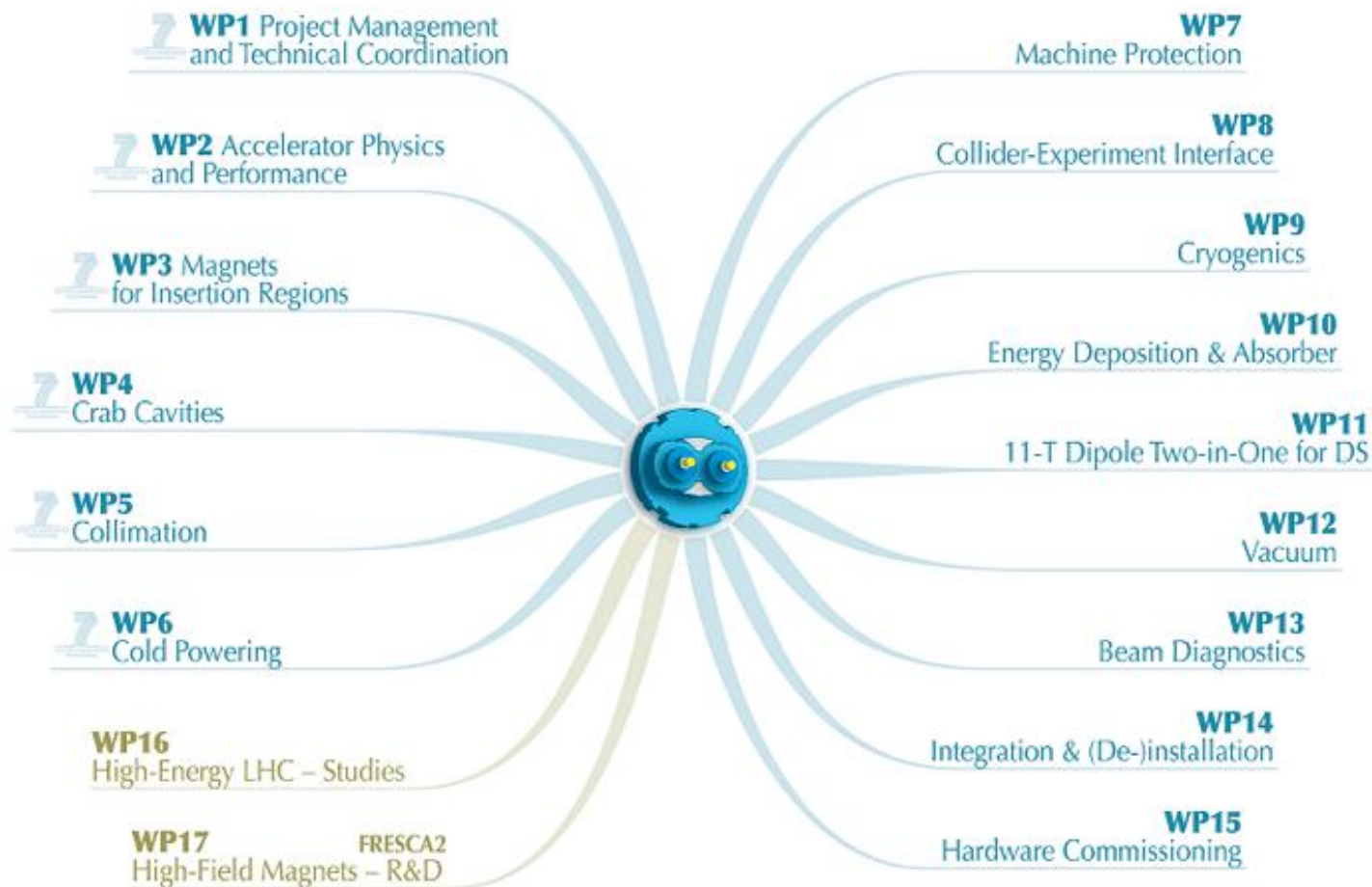
(see PLC by O.Bruning)

Parameter	nominal	25ns	50ns	
N	1.15E+11	2.2E+11	3.5E+11	6.2 10¹⁴ and 4.9 10¹⁴ p/beam
n _b	2808	2808	1404	→ sufficient room for leveling (with Crab Cavities)
beam current [A]	0.58	1.12	0.89	
x-ing angle [μrad]	300	590	590	
beam separation [σ]	10	12.5	11.4	Virtual luminosity (25ns) of
β* [m]	0.55	0.15	0.15	L = 7.4 / 0.35 10 ³⁴ cm ⁻² s ⁻¹
ε _n [μm]	3.75	2.5	3.0	= 21 10 ³⁴ cm ⁻² s ⁻¹ ('k' = 5)
ε _L [eVs]	2.51	2.5	2.5	
energy spread	1.20E-04	1.20E-04	1.20E-04	Virtual luminosity (50ns) of
bunch length [m]	7.50E-02	7.50E-02	7.50E-02	L = 8.5 / 0.33 10 ³⁴ cm ⁻² s ⁻¹
IBS horizontal [h]	80 -> 106	20.0	20.7	= 26 10 ³⁴ cm ⁻² s ⁻¹ ('k' = 10)
IBS longitudinal [h]	61 -> 60	15.8	13.2	
Piwinski parameter	0.68	3.1	2.9	
geom. reduction	0.83	0.35	0.33	
beam-beam / IP	3.10E-03	3.9E-03	5.0E-03	(Leveled to 5 10 ³⁴ cm ⁻² s ⁻¹ and 2.5 10 ³⁴ cm ⁻² s ⁻¹)
Peak Luminosity	1 10 ³⁴	7.4 10³⁴	8.5 10³⁴	
Virtual Luminosity	1.2 10 ³⁴	21 10³⁴	26 10³⁴	
Events / crossing (peak & leveled L)	28	210	475	140 140



1 project – 1 structure: HL-LHC

FP7 HiLumi Design Study just covers part of it



Structure and Management

	Description	Coordinator	Co-coordinator
WP1	Project Management and Technical Coordination	Lucio Rossi, CERN	Oliver Brüning, CERN
WP2	Accelerator Physics and Performance	Stéphane Fartoukh, CERN	Andy Wolski, UNILIV
WP3	Magnets for Insertion Regions	Ezio Todesco, CERN	GianLuca Sabbi, LBNL
WP4	Crab Cavities	Erk Jensen, CERN	Graeme Burt, UNILAN
WP5	Collimation Project	Stefano Redaelli, CERN	Grahame Blair, RHUL
WP6	Cold Powering	Amalia Ballarino, CERN	Francesco Broggi, INFN

WP7	Machine Protection	Rudiger Schmidt, CERN	Jorg Wenninger, CERN
WP8	Collider-Experiment Interface	Helmut Burkhardt, CERN Austin Ball, CMS Marzio Nessi, ATLAS	Daniel Lacarrère, CERN
WP9	Cryogenics	Laurent Taviani, CERN	Rob Van Weelden, CERN
WP10	Energy Deposition & Absorber	Francesco Cerutti, CERN	Nikolai Mokhov, FNAL
WP11	11 T Dipole Two-in-One for DS	Mikko Karppinen, CERN	Alexander Zlobin, INFN
WP12	Vacuum	Roberto Kersevan, CERN	Mark-Antony Gallilee, CERN
WP13	Beam Diagnostics	Rhodri Jones, CERN	
WP14	Integration & (De-)installation	Sylvain Weisz, CERN	
WP15	Hardware Commissioning	Mirko Pojer, CERN	
WP16	High-Energy LHC - Studies	Lucio Rossi, CERN	Frank Zimmermann, CERN
WP17	High-Field Magnets – R&D FRESCA2	Gijs de Rijk, CERN	François Kircher, CEA

Technical Coordinator	Herman Schmickler, CERN
Project Safety Officer	Thomas Otto, CERN
Deputy TC, QA and Risk Management	Isabel Bejar Alonso, CERN
FP7 HiLumi LHC Administrative Manager	Svetlomis Stavrev, CERN
Dissemination and Outreach	Agnes Szeberenyi, CERN
Administrative Support	Cécile Noels, CERN

WP 1 : Project Management



- Scientific Advisory Committee (not appointed)
⇒ CERN Machine Advisory Committee
(T. Roser, BNL, chair)
- Task 1.2 Parameter and Lay-out Committee
(O. Bruning, chair). Installed by April
- Task 1.3 QA plan
 - Work in progress (I. Bejar Alonso)
 - Study of the LHC QAP and identification of the documents to be updated.
 - Comparison of the LHC QAP with the QAP for other research infrastructures today under study/construction on CERN site.
 - Comparison of the LHC QAP with the quality assurance guide for project management of the DOE (DOE G 413.3-2) and other DOE guides for the design and construction of research facilities.

WP1 – Project Management – cont.2



- Task 1.4 : radiological impact : to be started
- Task 1.5 Liaison with:
 - Detector Upgrade
 - Many contacts (also in Experiment Coll. Meet.)
 - HL-LHC Coordination Group (mandate by CERN Directorate) to coordinate consolidation/upgrades in the LHC machine (and Injectors) after LS1. Chaired by HL-LHC coordinator.
3 meetings: ⇒ **New concepts of pile up volume density**
 - Agreement on the nominal design pile up: 140 (200 max)
 - Inclusion of Alice and LHCb plan and Forward detector plan
 - See talk of H. Burkhardt, Friday morning
 - 30 Nov 2012: day workshop on Collider-Experiments interface
 - LHC Injector Upgrade :
 - Two one-day workshops ⇒ **«Agreed» parameter list HL-LIU**
 - See talk by M. Meddahi on Friday

WP1 – Project Management – cont.3



- Task 1.6 : Dissemination (Kate \Rightarrow Agnes)

- Release on CERN Courier
- Release on Acc-News
- > 10 outreach talks



- Task 1.6 Information to Industry

- Talks to CERN ILO forum, To Euspen, to German Industry@CERN
- Workshop on SC Technologies (Magnet, SCRF, Cryostats)

4-5 December @ CERN ,

> 20 firms



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WP1 – Project Management



- Technical Coordination
& HL-LHC technical committee
TC: Hermann Schmickler (CERN)
 - I. Bejar Alonso (CERN)
 - Th. Otto (Safety officer)
 - D. Duret (budget and resources plan)
- Coherent set of hardware systems
- Define technical system PBS, ES, QAP, ECR...
- (Remote) Handling radioactivated components



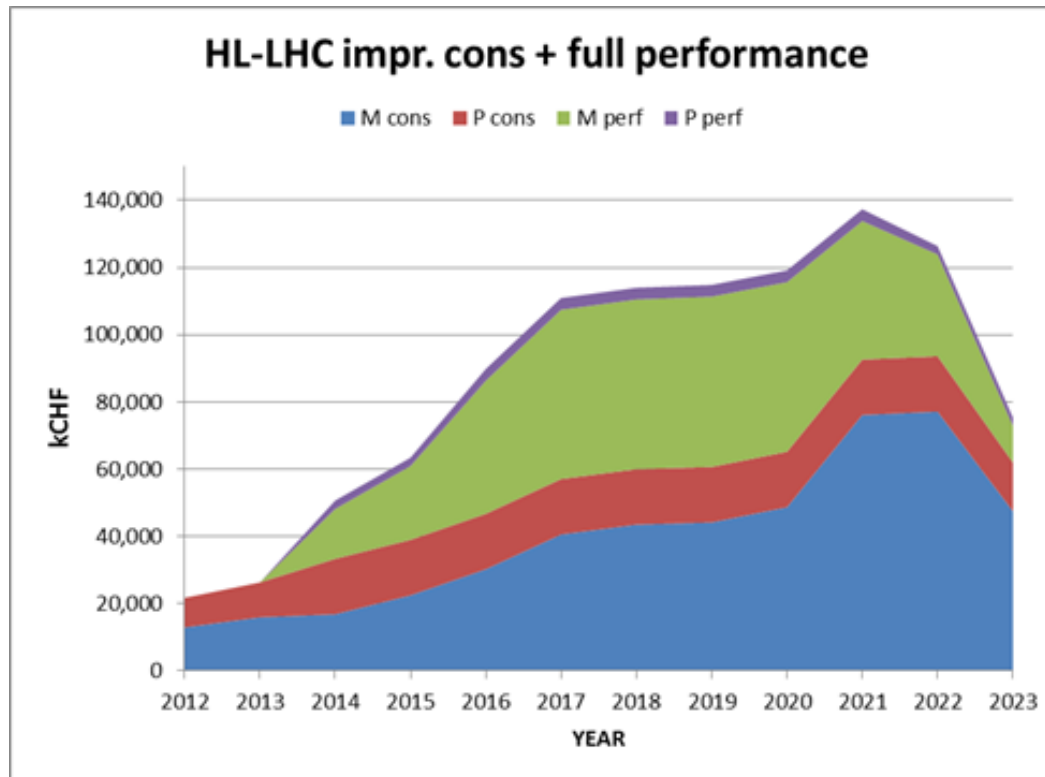
CERN Context

- Resources for engineering and construction will be available after LS1
- HiLumi DS, LARP, Eucard for Design and R&D
- Other projects appearing on the scene
 - Secure resource for study, engineering and **integration** is being pursued vigorously
 - HiLumi serves a large community already in place and is synchronized to the Detector Upgrade.
 - HiLumi is a step forward but is ALSO the natural evolution of LHC. The technical reasons for the upgrade will never disappear and a better performance may even anticipate the technical limitations

HiLumi: Two branches (with overlap)

- **Enhanced Consolidation upgrade ($1000-1200 \text{ fb}^{-1}$)**
 - Magnet rad. damage and enhanced cooling
 - Cryogenics (P4, IP4, IP5) with separation Arc from RF and from IR
 - Collimation
 - SC links (in part)
 - QPS and Machine Prot.
 - Kickers
 - Interlock system
- **Full performance upgrade (3000 fb^{-1})**
 - Maximum low- β Quads aperture
 - Crab Cavities
 - HB feedback system (SPS)
 - Advanced collimation systems
 - E-lens (?)
 - SC links (all)
 - R2E and remote handling for 3000 fb^{-1}

Preliminary budget estimate

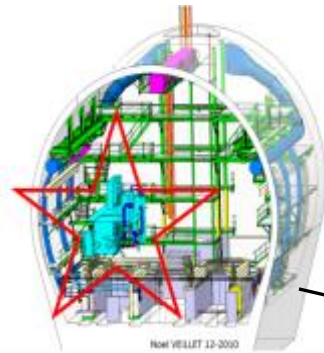


	Improving Consolidation	Full performance	Total HL-LHC
Mat. (MCHF)	476	360	836
Pers. (MCHF)	182	31	213
Pers. (FTE-y)	910	160	1070
TOT (MCHF)	658	391	1,049

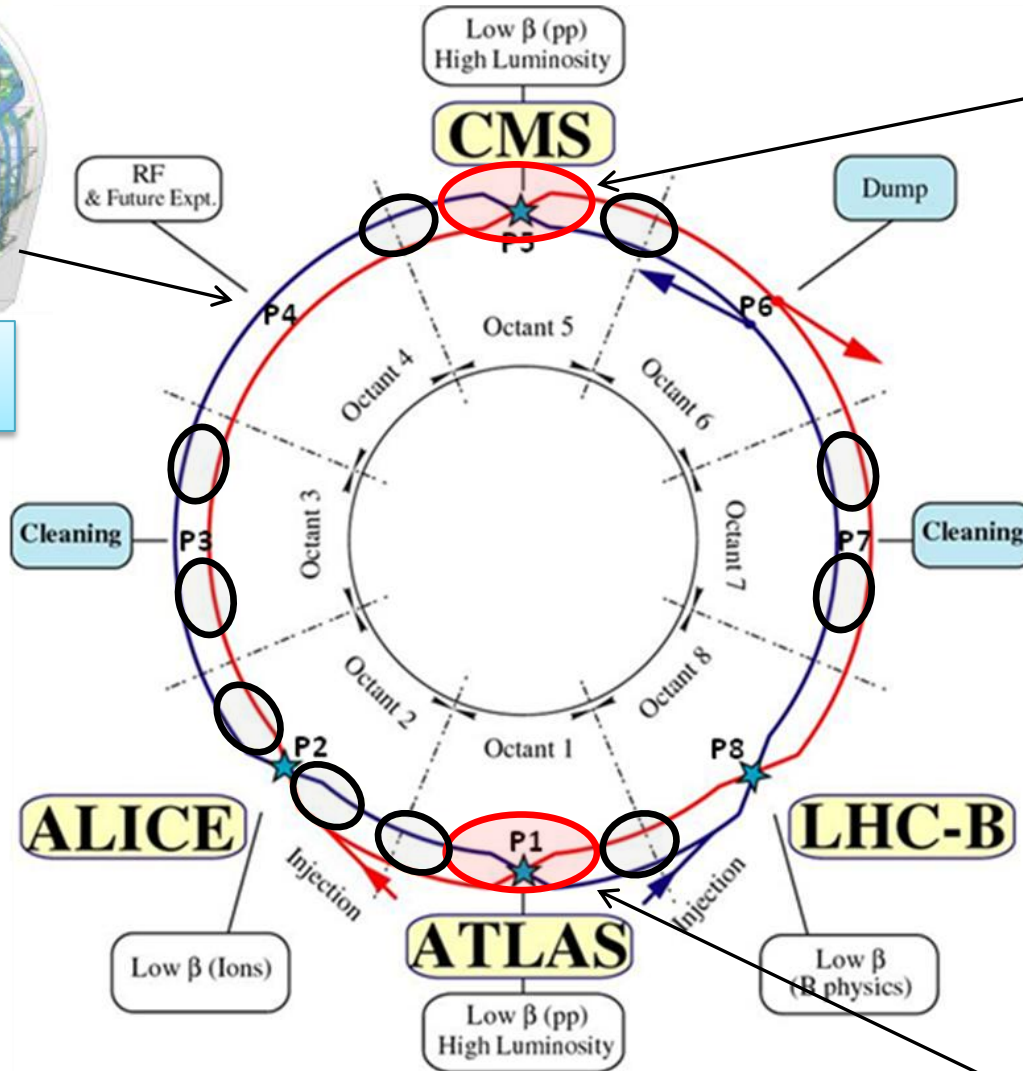
European Strategy Update

- Open symposium in Cracow 10-12 Sept
- July 2012: submission of documents:
 - CERN-ATS-2012-236
High Luminosity Large Hadron Collider - A description for the European Strategy Preparatory Group
 - CERN-ATS-2012-237
High Energy LHC - Document prepared for the European HEP strategy update
- We work hard to make HL-LHC “unavoidable”: much return in Physics and Accelerator Technology for little (extra)money
- **HL-LHC is the test bed (on real scale) of new advanced technology: 11T and 13 T Magnets, CCs, new collimation concepts, new diagnostics, SC Links, advanced modelling at the highest energy, all working on a ~ 1 GJ beam... (vacuum, cryogenics, kickers, protections...)**

1.2 km of new equipment in the LHC...



6.5 kW@4.5K cryoplant



2 x 18 kW @4.5K cryoplants for IRs

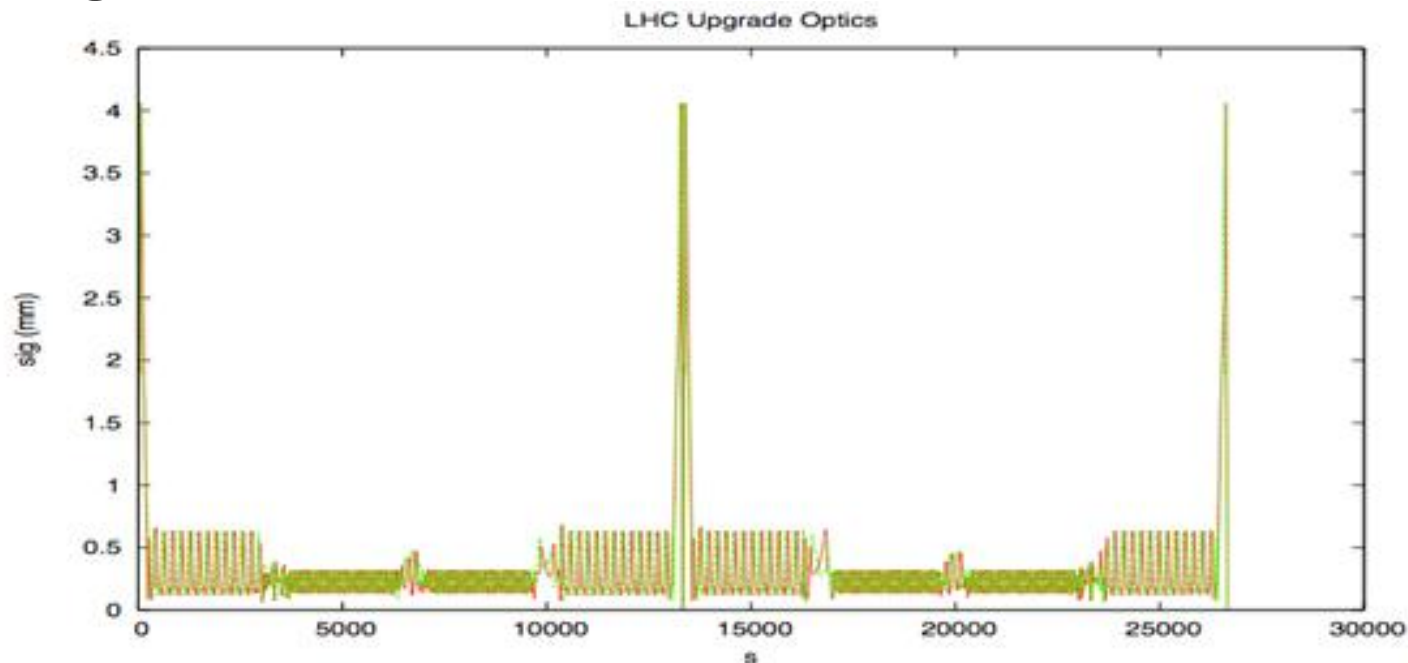


Technical Progress (incomplete ...) - 1

• WP2




- **ATS is fully proved** ($\beta^* = 15$ cm «easy», room for 10-12 cm); optics layout (many magnets to change); field errors (also CC)... Strong contribution from EU and LARP...

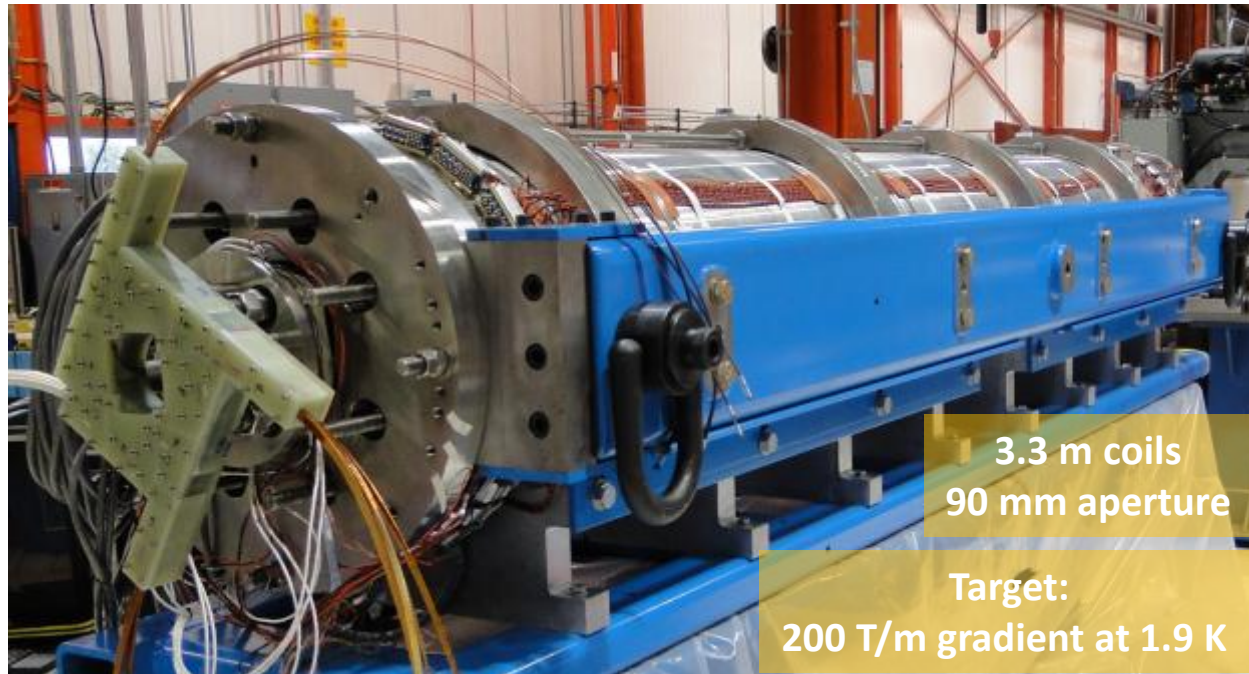


typical ATS collision optics with IR1 and IR5 squeezed down to $b^* = 10$ cm

Technical Progress (incomplete ...) - 2

- WP3 
- LARP: HQ (1m-120 mm) and LQ3 (3.6 m -90 mm), very positive.
- **Aperture 150 mm, 4.5+4.5 m long, W-shielded, more rad-dam limited than heat depo limited, new plan for LARP+CERN**
- EU (CEA, INFN)+ JP


LQS03: **208 T/m** at 4.6 K
210 T/m at 1.9 K
1st quench: 86% s.s. limit



3.3 m coils
90 mm aperture

Target:
200 T/m gradient at 1.9 K

Technical Progress (incomplete ...) - 3

- WP4 
- First CC (from UK) arrived at CERN, near under test!
- ODU-SLAC CC also very near, BNL under way
- Interest from Fermilab for cryomodulization



Jan 2012

UK – Cockcroft Int. –Lancaster U.



First test : Nov.@CERN

May 2012

Finished cavity at Niowave


From virtual
to actual
reality!

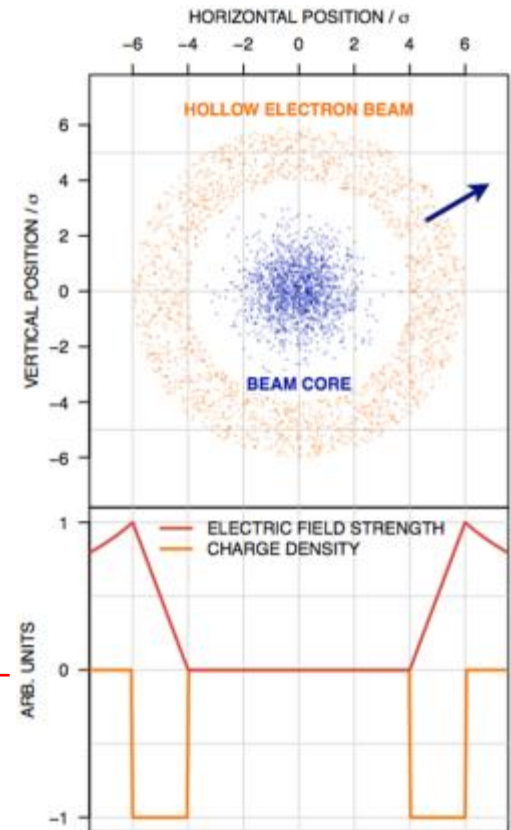
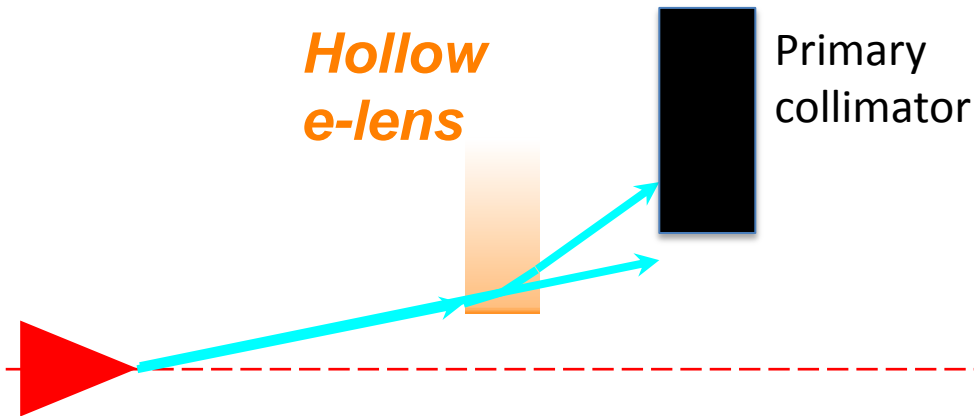


USA (ODU-SLAC)




Technical Progress (incomplete ...) - 4

- WP5 
- Assessment of collimation needs in LHC after LS1 (Cryocollimators...): review in April 2013
- New Material test (HiRadMat)
- New concepts : Crystals, e-Lens



Technical Progress (incomplete ...) - 5

- WP6 

SEVENTH FRAMEWORK PROGRAMME
- first proto 20 m – 20 kA under test at CERN!

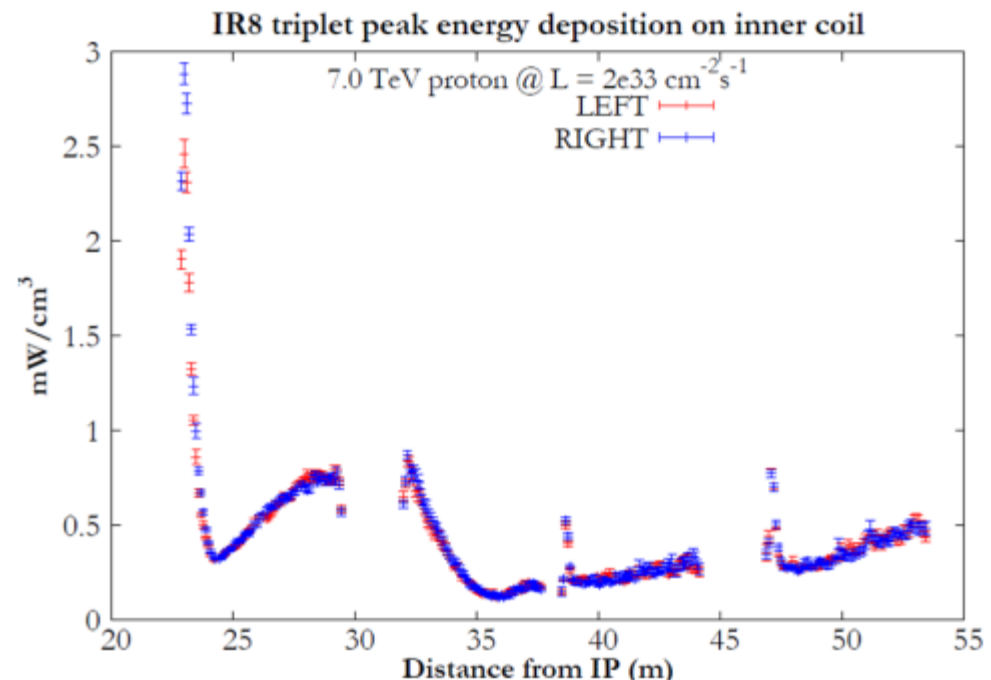


Technical Progress (incomplete ...) - 6

- WP7 (Mach. Protection)
 - Start analysis CC protection
- WP8 (Collider-Experiment Int.)
 - Starting now after endorsement from
Coordination Group: 30 NOV Workshop
- WP9 (Cryogenics)
 - SPS cryogenic zone (Coldex) under revamping
 - Work for SC link and P4 progressing

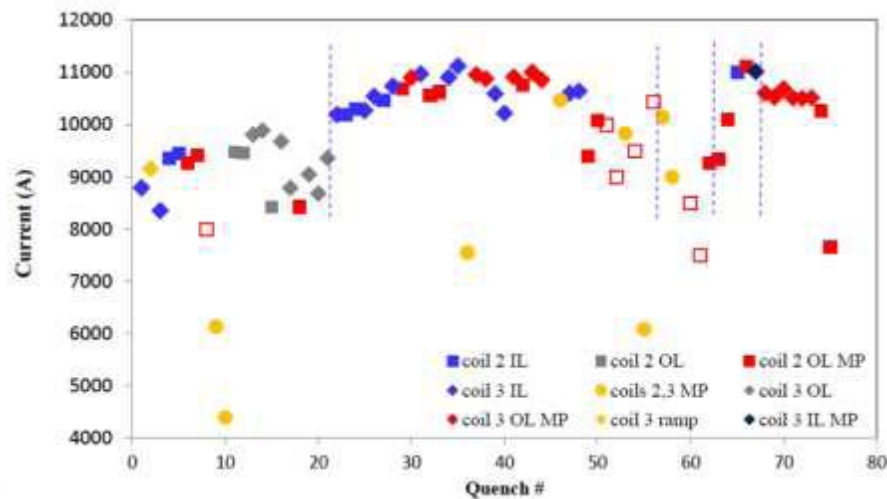
Technical Progress (incomplete ...) - 7

- WP10 (Energy depo)
- Support to all studies
- Leading role in IP8 study for LHCb upgrade: no need of TAS for $2e33$ of luminosity



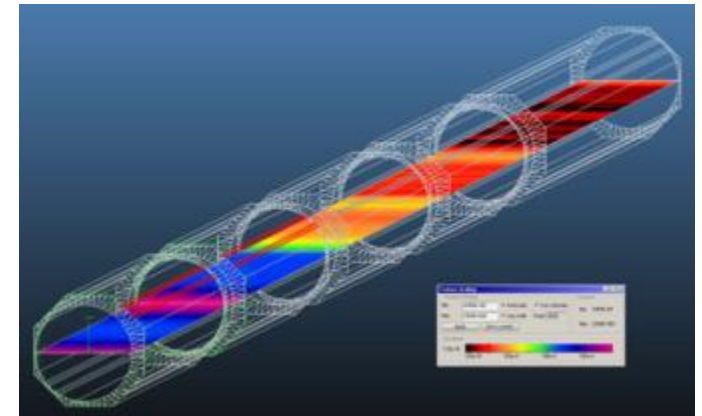
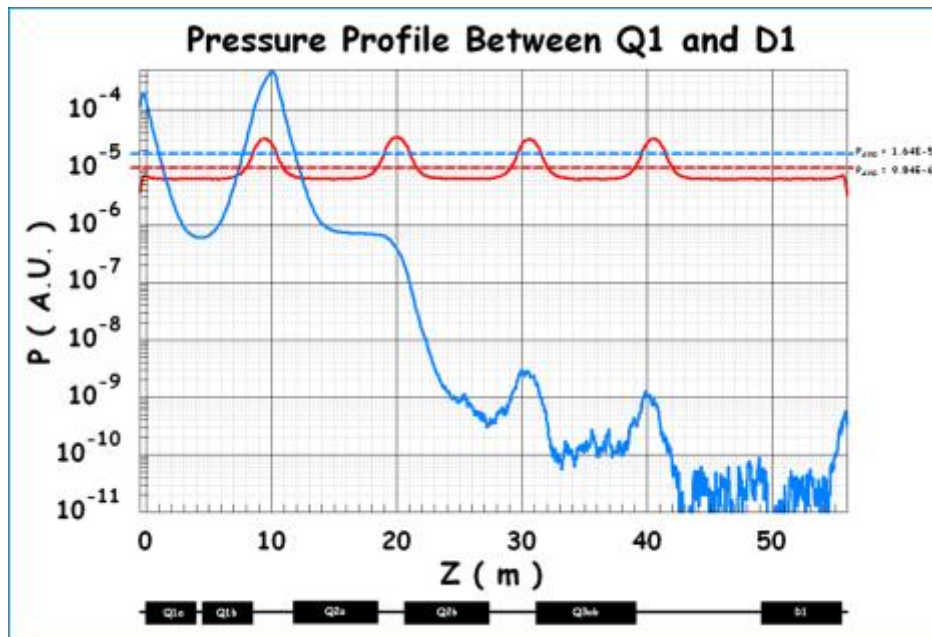
Technical Progress (incomplete ...) - 8

- WP 11 (11 T dipole)
- 2 m long single bore: test in June/July 2012
10.4 T at low di/dt ,
95% of the goal, coil damage recognized
new 1 m single bore to test in February
Then one 2 m single bore and then 2in1



Technical Progress (incomplete ...) - 9

- WP12 (Vacuum)
- Careful study undergoing (for molecular flow and Synchr.Rad.): no issue for the moment



The integrated flux along the ~ 7700 mm-long orbit is $F=2.84E+17$ ph/s, and the integrated power is $P=0.88$ W, for the nominal HiLumi current of 860 mA.

Even for a SR-induced outgassing yield $\eta(\text{molec/ph})=1.0E-4$ the corresponding gas load Q_{SR} is $Q_{SR}=1.158E-6$ mbar·l/s, giving an average pressure rise of $\sim 1.1E-11$ mbar, well below the pressure limit of $6.7E-10$ mbar.

Technical Progress (incomplete ...) - 10

- WP13 (Beam Diagnostic) just starting
- WP14 (de)Installation and Integration
- WP15 HWC

- WP16 (HE-LHC Study): Begins in 2013,
 - FP7-Eucard2 – WP10 approved: start in May 2013
- WP17 : High Field Magnet (technology R&D and 130 mm – 13 dipole for Test station) under FP7 Eucard WP7.

Discussing in-kind contribution (secure Full Performance Upgrade)

- DOE: extremely positive: **on 10 July 2012 first public sentence to prepare plan for 200 M\$ contribution** (project in addition to LARP R&D)
- Japan: progressing, **proposing 20-50 MCHF** with also infrastructure renewal in KEK...
- Others? Any possibility welcome!

**Progress are enormous:
however we are not engaging all available resources!**

