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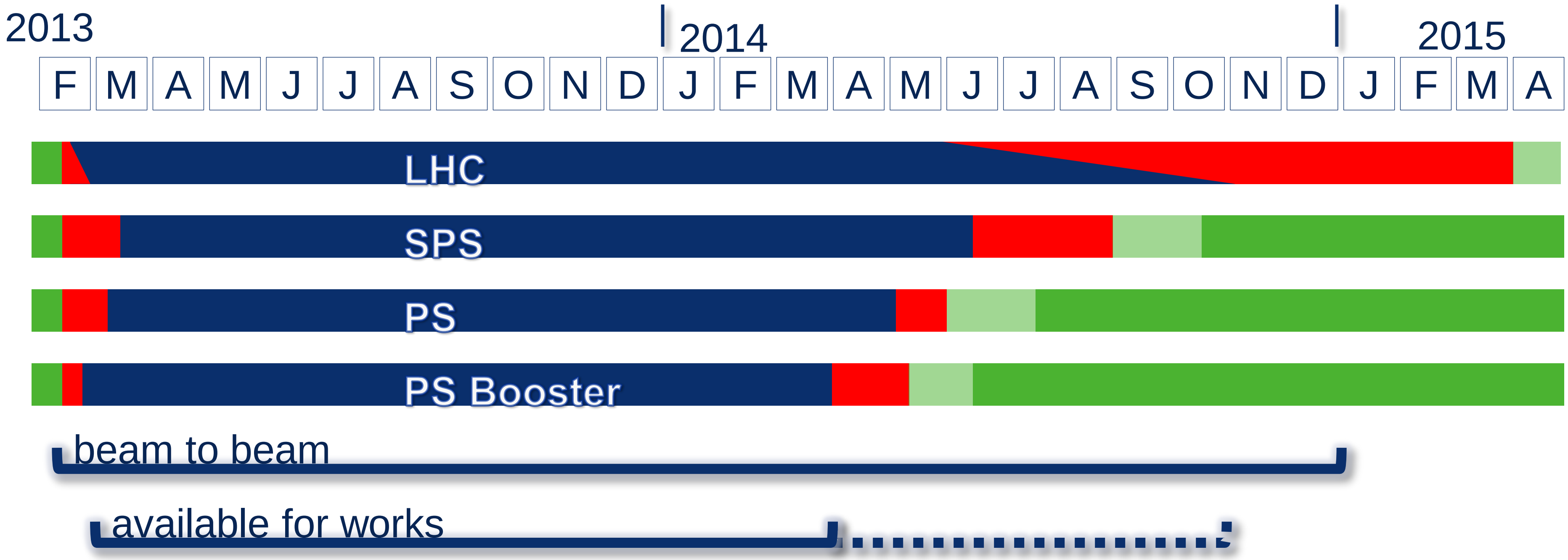
Status & prospects LHC accelerator and HL-LHC plans

High Energy Physics Advisory Panel

Frédérick Bordry

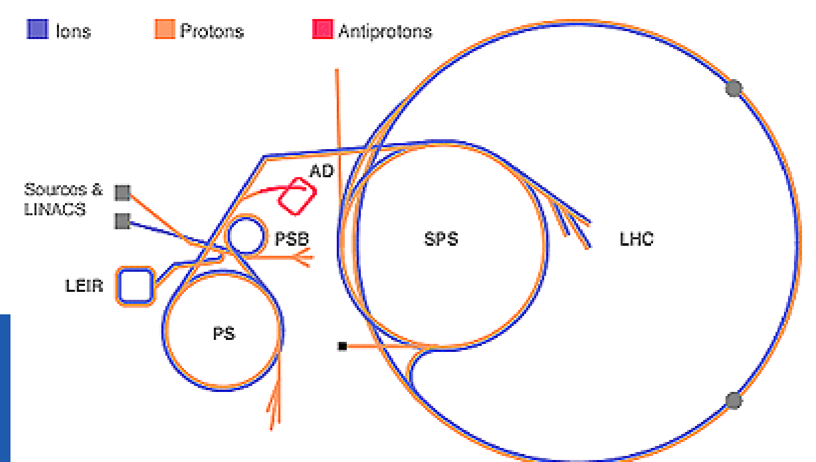
10th December 2015

Long Shutdown LS1 from Feb. 2013 to Mar. 2015

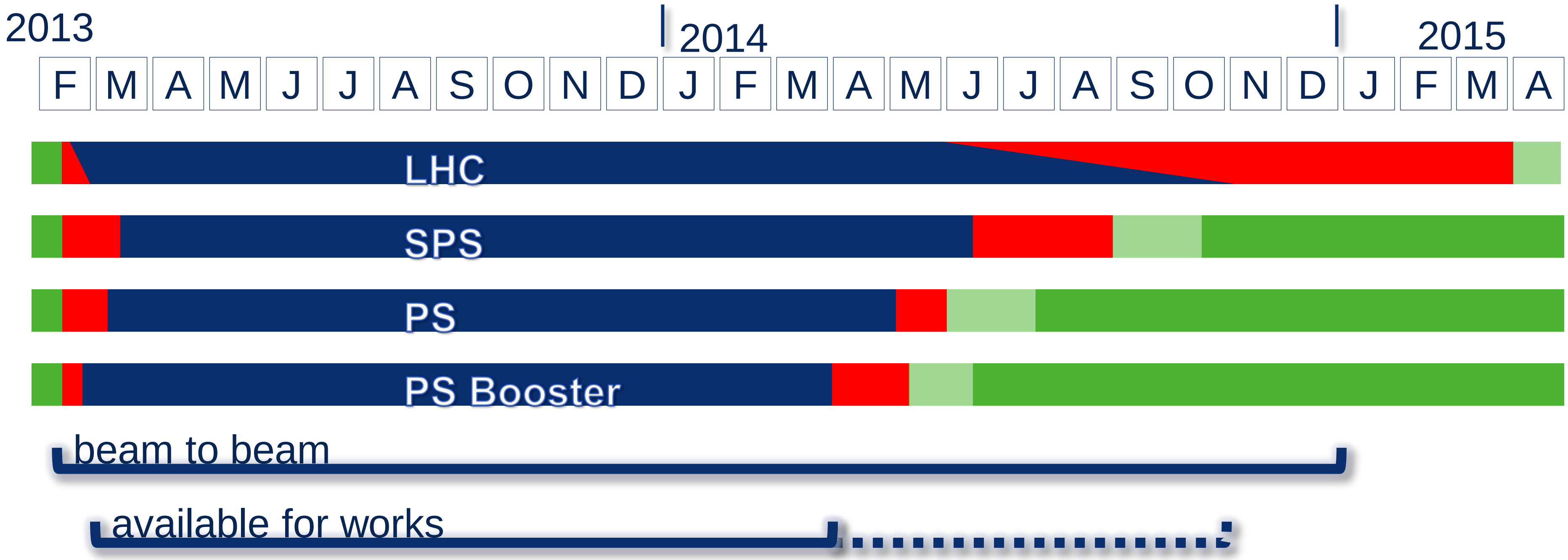


- Physics
- Beam commissioning
- Shutdown
- Powering tests

- ➢ **Prepare the LHC for Operation at Nominal Energy**
- ➢ **Consolidate and Upgrade the LHC and Injector performance**
- ➢ **Major Maintenance Programme**



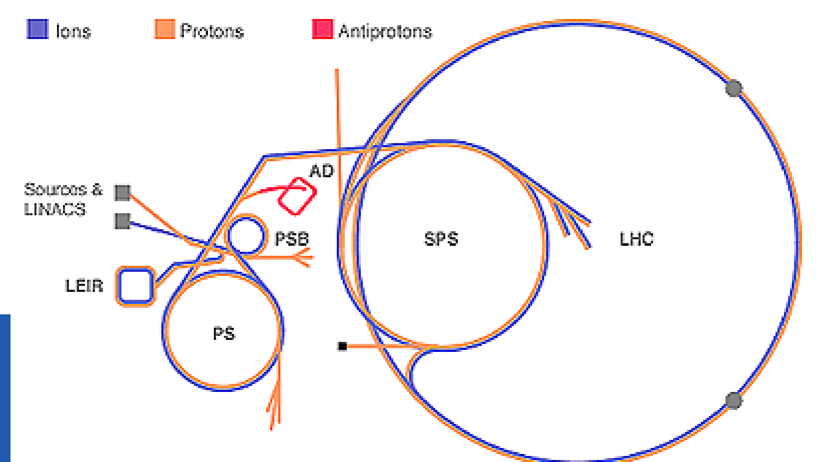
Long Shutdown LS1 from Feb. 2013 to Mar. 2015



- Physics
- Beam commissioning
- Shutdown
- Powering tests

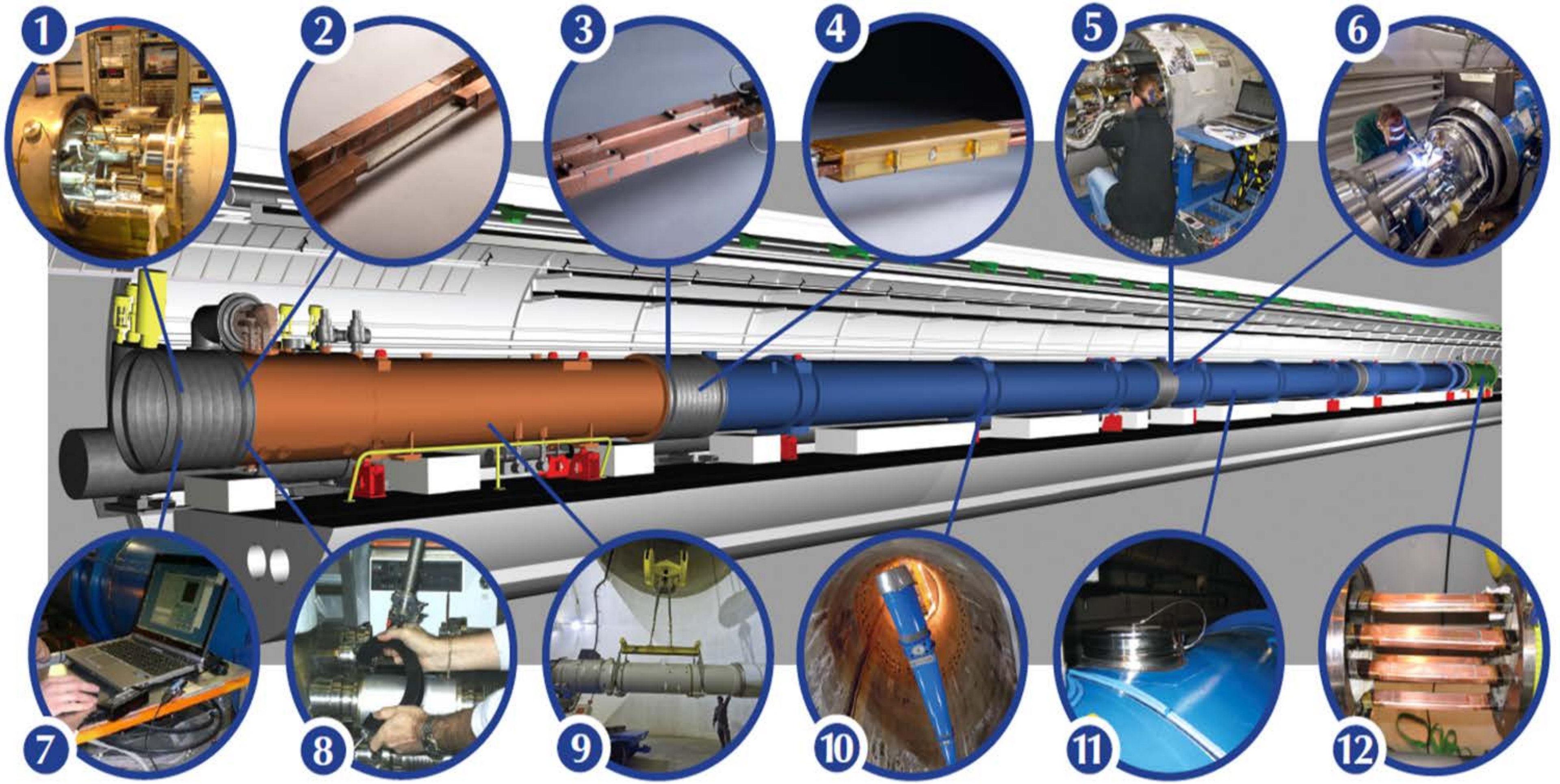
Over 1 Million Hours Worked in the LHC Tunnel

Safety First,
Quality Second,
Schedule Third.



The main 2013-14 LHC consolidations

1. 1695 Openings and final reclosures of the interconnections
2. Complete reconstruction of 3000 of these splices
3. Consolidation of the 10170 13kA splices, installing 27 000 shunts
4. Installation of 5000 consolidated electrical insulation systems
5. 300 000 electrical resistance measurements
6. 10170 orbital welding of stainless steel lines



7. 18 000 electrical Quality Assurance tests
8. 10170 leak tightness tests
9. 3 quadrupole magnets to be replaced
10. 15 dipole magnets to be replaced
11. Installation of 612 pressure relief devices to bring the total to 1344
12. Consolidation of the 13 kA circuits in the 16 main electrical feed-boxes

The main 2013-14 LHC consolidations

SMACC project : Closure of the last interconnection – 18.06.2014

18 000 electrical Quality Assurance tests

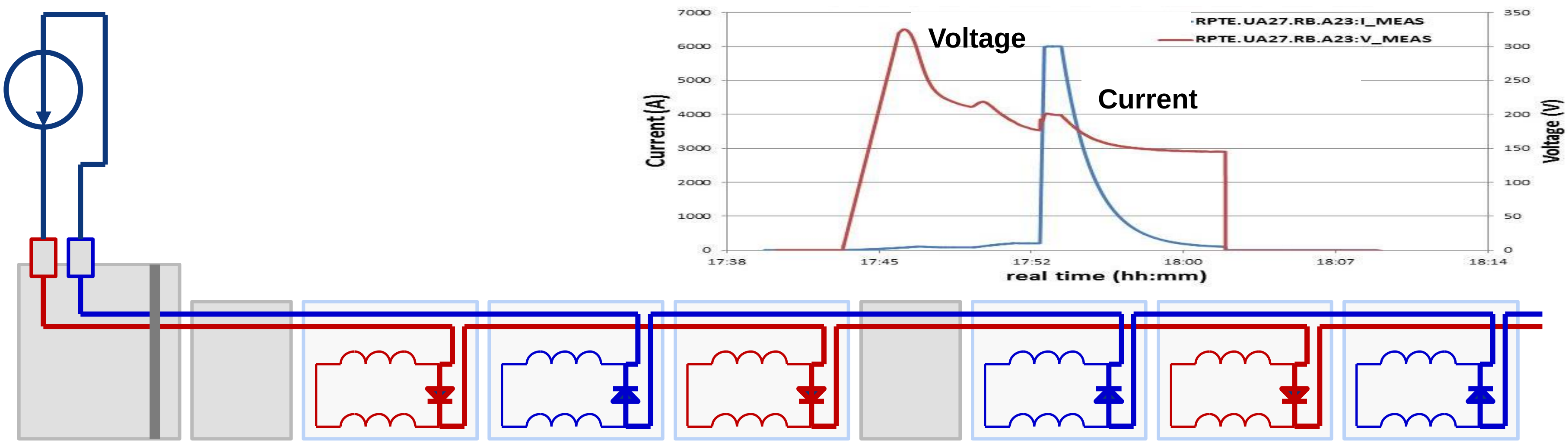
nsolidation of the kA circuits in the 16 in electrical feed- boxes

CSCM: Copper Stabilizer Continuity Measurement

The CSCM is a test to ***fully qualify*** if the main dipole bypass can take over the current if the superconducting circuit quenches. A kind of dry-run of the bypass (very low energy 200 kJ and low time constant 0.2s)

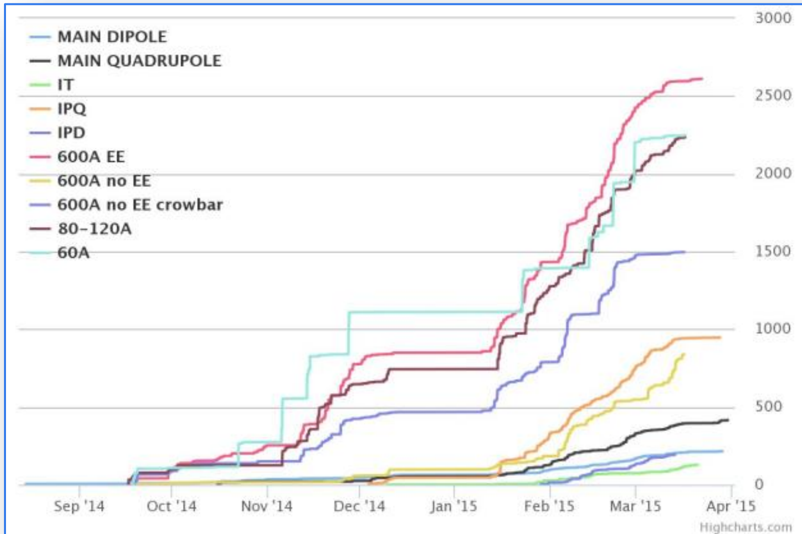
Basic idea

- Stabilize the entire sector at around 20 K, so the magnets and bus are not superconducting. Keep the DFB at 4.5 K.
- Connect the two 6 kA/200 V power converters in series ($\Rightarrow$ 400V)
- Apply several steps of current pulse, up to 11.1 kA (6.5 TeV), τ=100 s

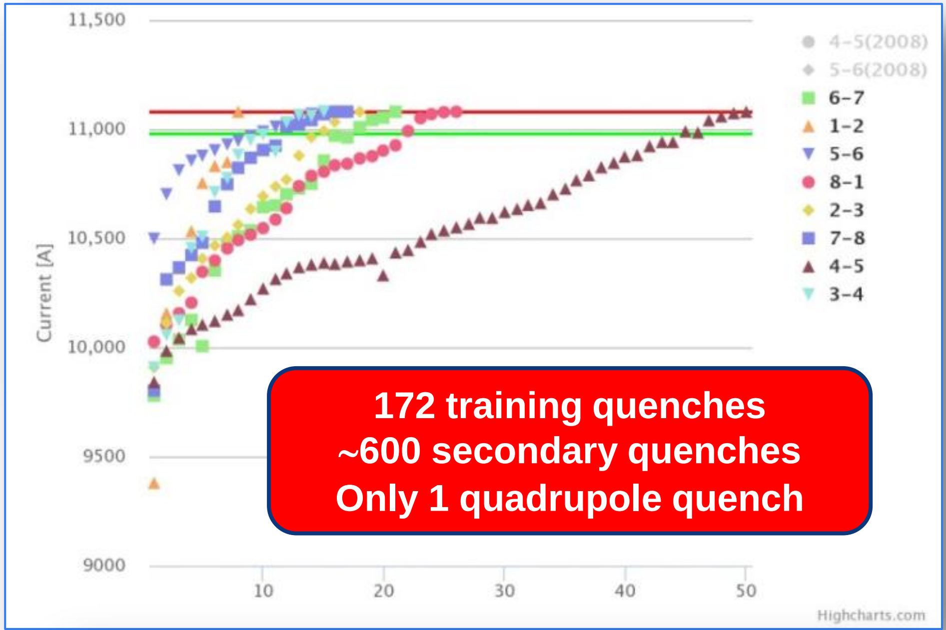


Addition of 1 month on LS1 duration (Quality)

The LHC powering tests overview



Powering tests were completed at 8 am on Friday 3rd April 2015

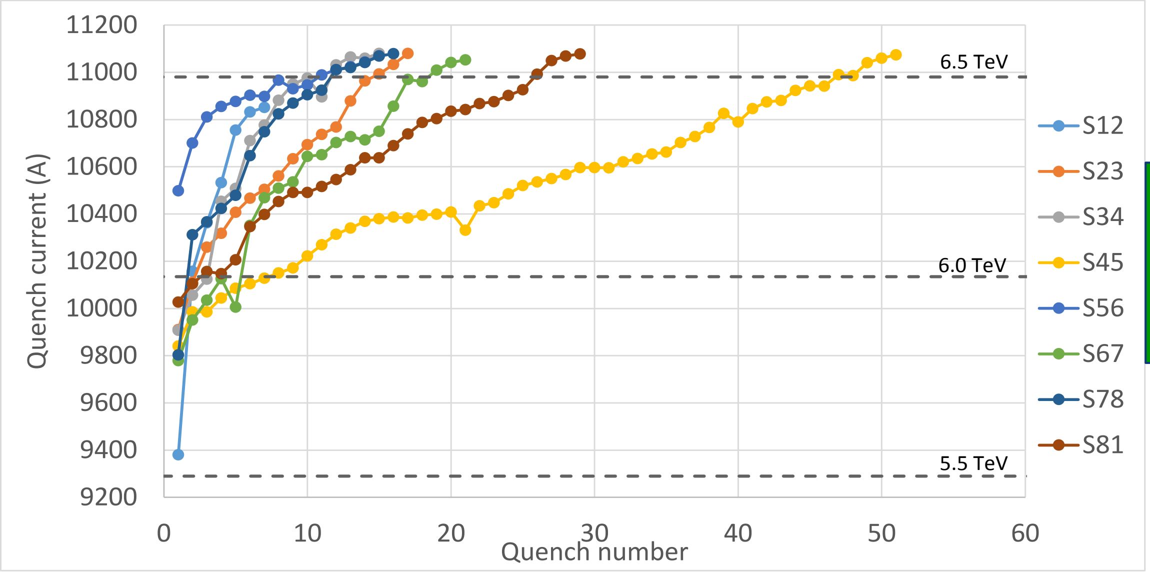


Since September 15th 2014:

1566 superconducting circuits commissioned through execution and analysis of **more than 10.000 test steps** (~13.800 test steps including re-execution)

Circuit	Status	#M Firm 1	#M Firm 2	#M Firm 3	#MQ Firm 1	#MQ Firm 2	#MQ Firm 3	#MQ total	#CQ total
RB.A12	11080 A reached	50	95	9	2	1	4	7	7
RB.A23	11080 A reached	56	58	40	0	2	15	17	17
RB.A34	11080 A reached	44	81	29	1	7	8	16	16
RB.A45	11080 A reached	48	44	62	-	3	48	51	49
RB.A56	11080 A reached	28	42	84	0	0	18	18	17
RB.A67	11080 A reached	57	36	61	0	1	21	22	21
RB.A78	11080 A reached	53	40	61	2	10	7	19	19
RB.A81	11080 A reached	64	24	66	0	3	26	29	26

Dipole Training Campaign



Each Sector Trained to 6.55TeV (11080A)
(100 A above the operational field)

Sector	# Training quench	Flattop quenches
S12	7	0
S23	17	0
S34	15	1
S45	51	0
S56	18	3
S67	22	1
S78	19	3
S81	29	0
Total	171	8

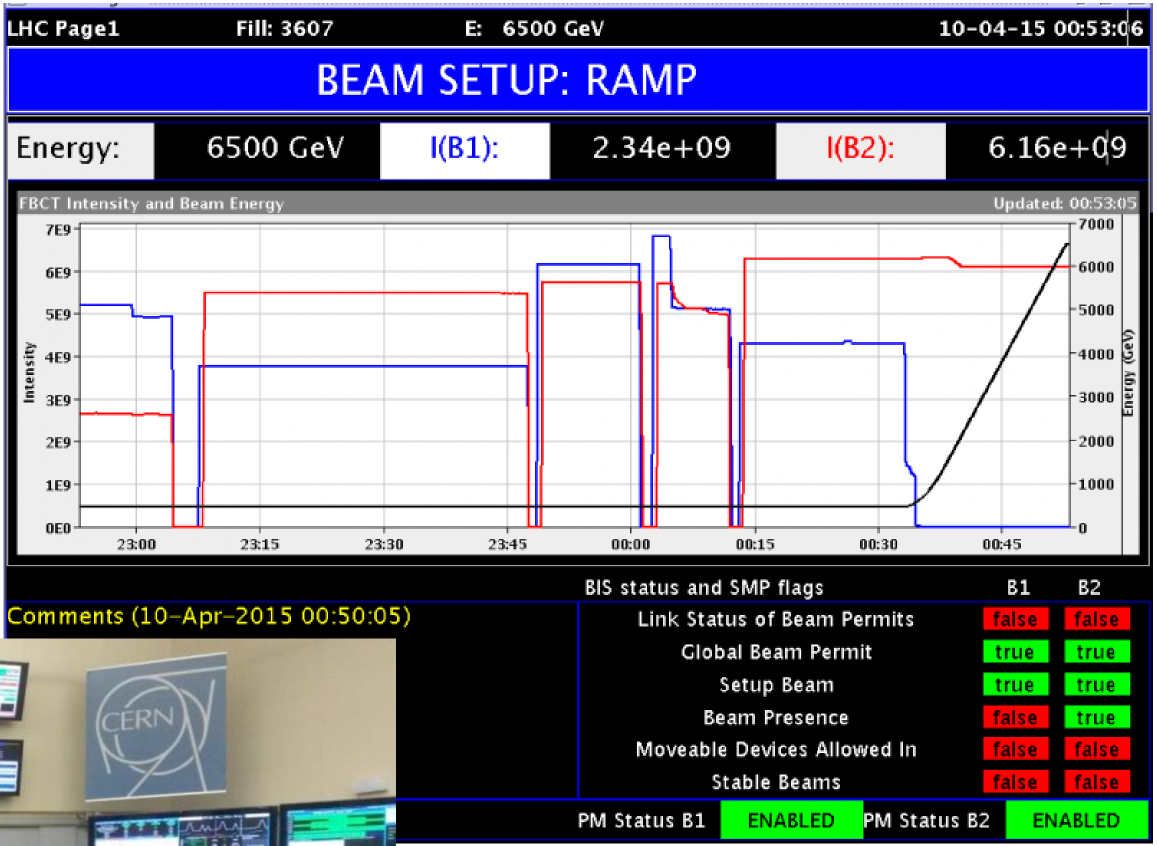
Large variation in number of training quenches per sector

Detailed Analysis in Progress!

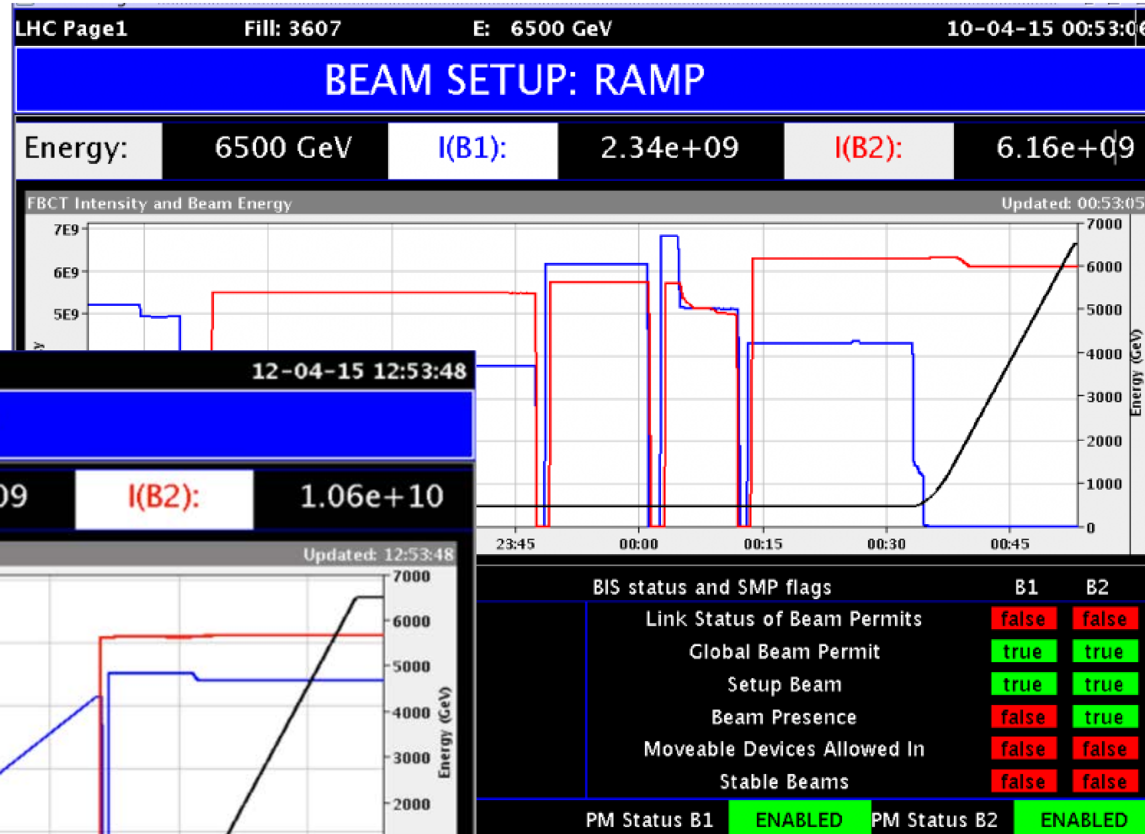
First circulating beams in LHC on Easter Sunday

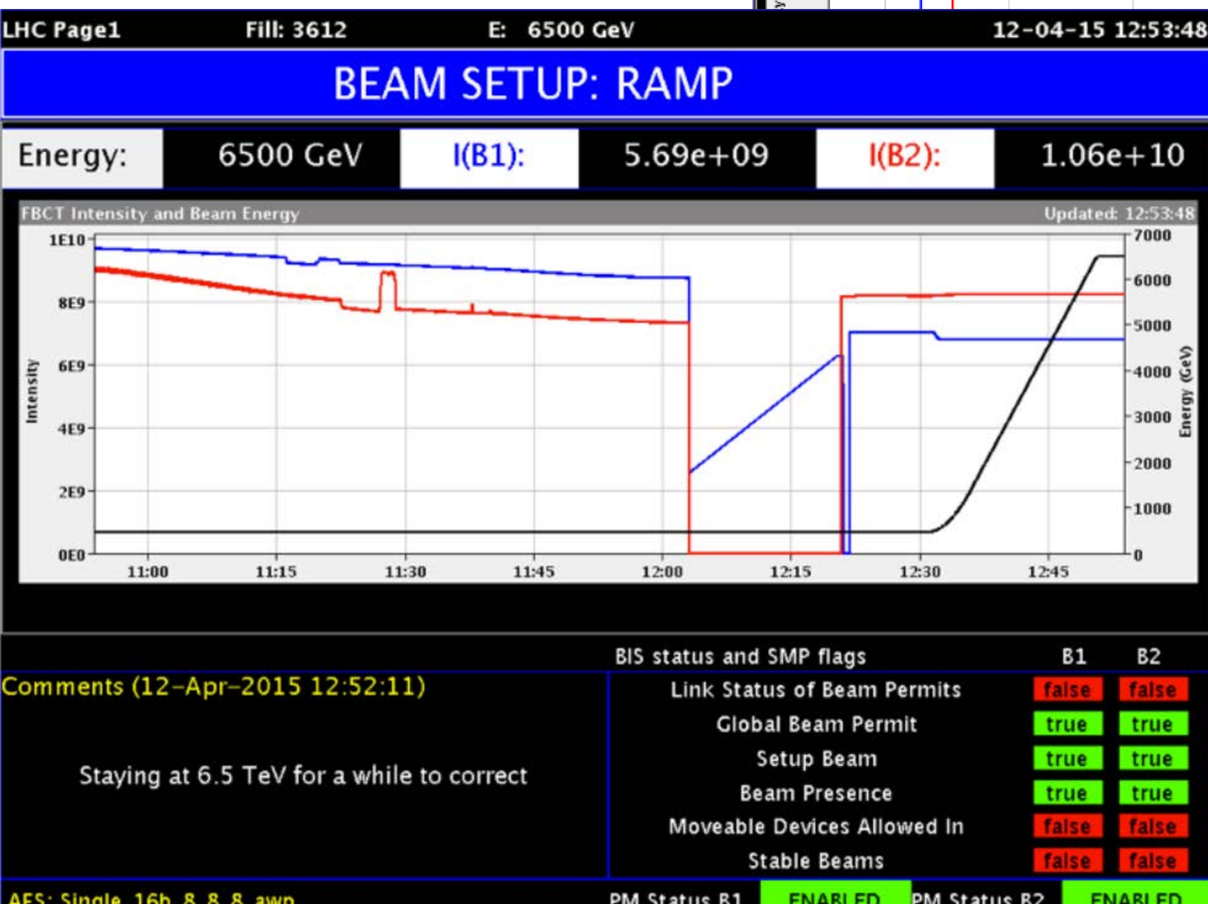
5th April 2015

First beam at 6.5 TeV! (10th April)



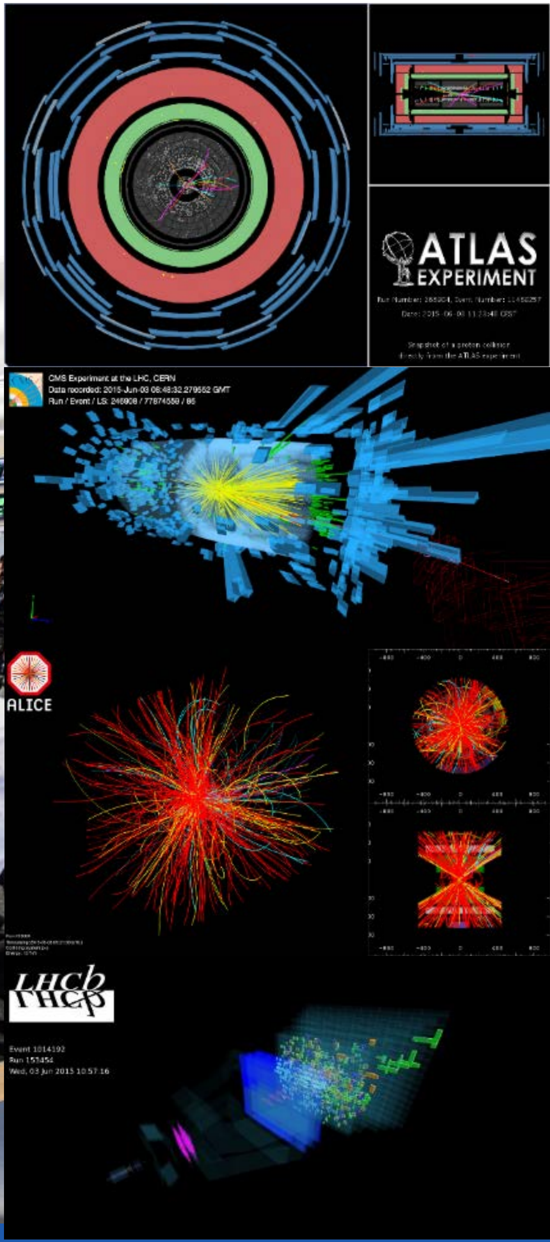
First beamS at 6.5 TeV! (12th April)





LHC experiments are back in business at a new record energy 13 TeV

3rd June 2015



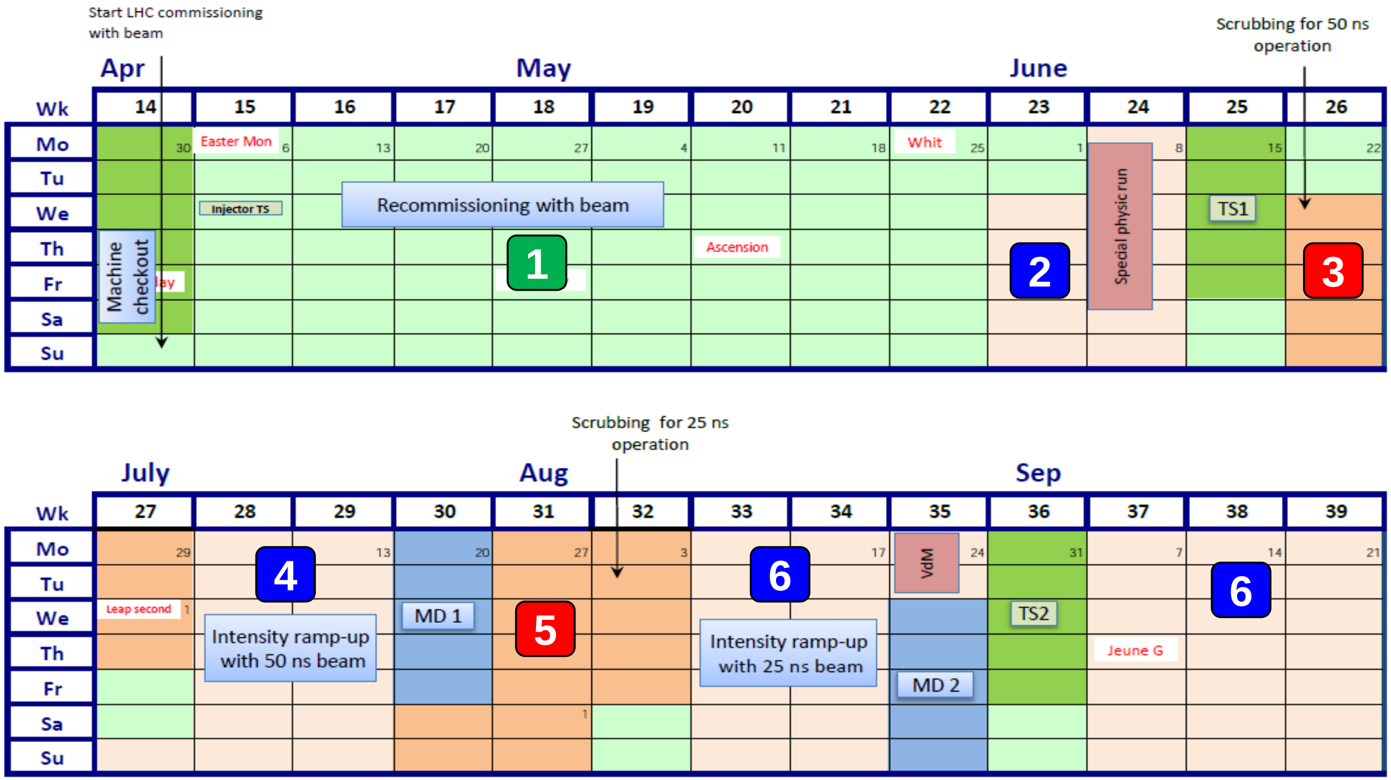
Beam commissioning in two months ☺

13 TeV

- **A lot of lessons learnt and experience from Run 1**
- Excellent and improved system performance **(LS1)**
  - Beam Instrumentation
  - Transverse feedback
  - RF
  - Collimation
  - Injection and beam dump systems
  - Vacuum
  - Machine protection
- Improved software & analysis tools **(LS1)**
- Magnetically reproducibility
- Optically good, corrected to excellent
- Behaving well at 6.5 TeV
  - One additional training quench so far
- Operationally well under control
  - Injection, ramp, squeeze, de-squeeze

Terrific team work

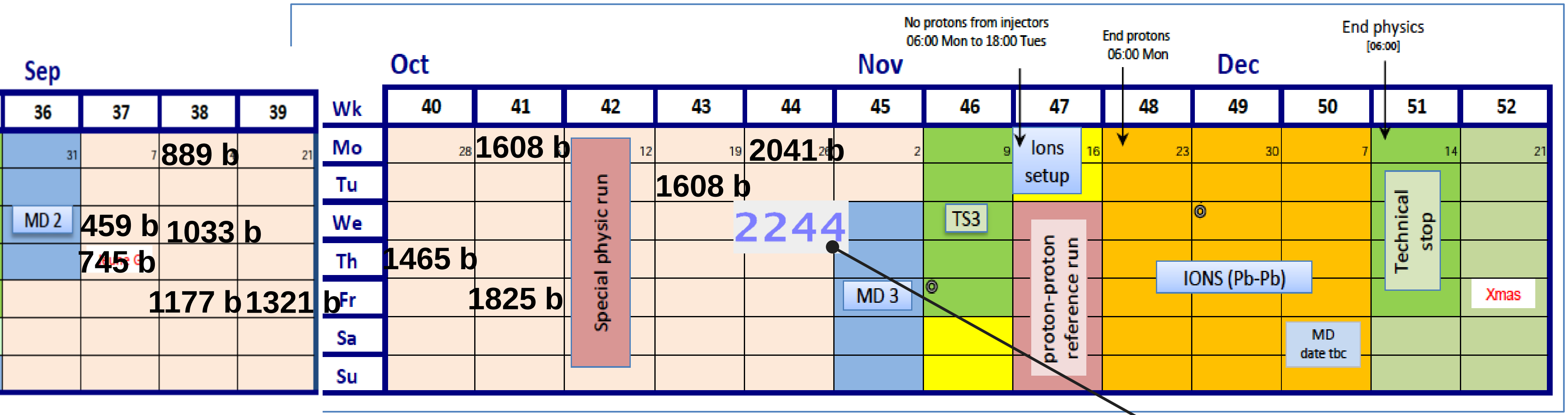
2015 Commissioning strategy

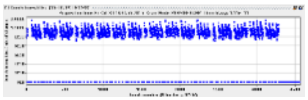


1. Low intensity commissioning – 8 weeks
2. First physics – low number of bunches, LHCf run
3. Electron cloud scrubbing for 50 ns (e-cloud)
4. Physics - intensity ramp-up with 50 ns

   Characterize high intensity operation (≈ repeat 4 TeV @ 6.5 TeV)
5. Electron cloud scrubbing for 25 ns (e-cloud)
6. Physics - ramp-up intensity for 25 ns operation

End of 2015: 25 ns physics run





October 28th, 2244

- Resume of the intensity ramp up after TS2
  - *First driven by machine protection validation*
  - *Then driven by cryo system operation (> 1600 bunches)*
- Special physics run (90 m optics)
  - *back to lower beam intensity for commissioning and production → step down for 25 ns physics run*
- Ions run to conclude the year:
  - *Including intermediate energy run with proton at 2,51 TeV*

2015 LHC Luminosity

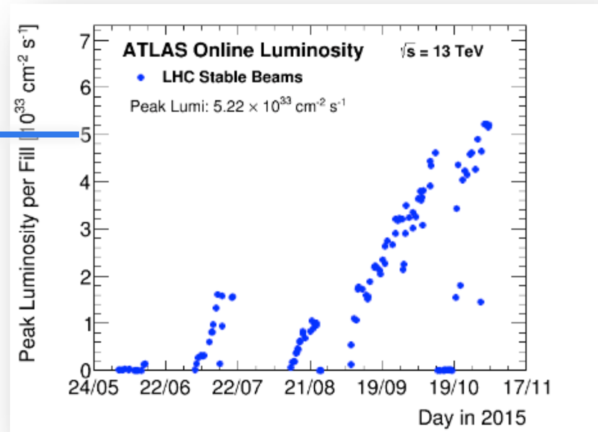
ATLAS

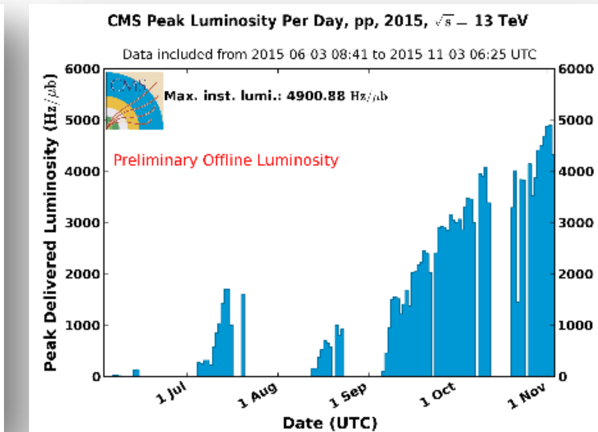
CMS

Peak

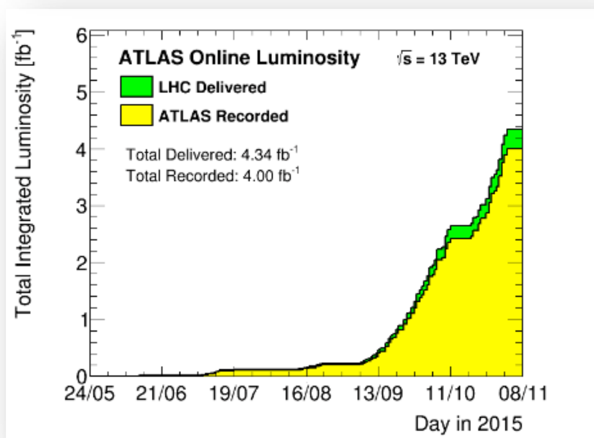
$5 \times 10^{33}\ cm^{-1}\ s^{-1}$

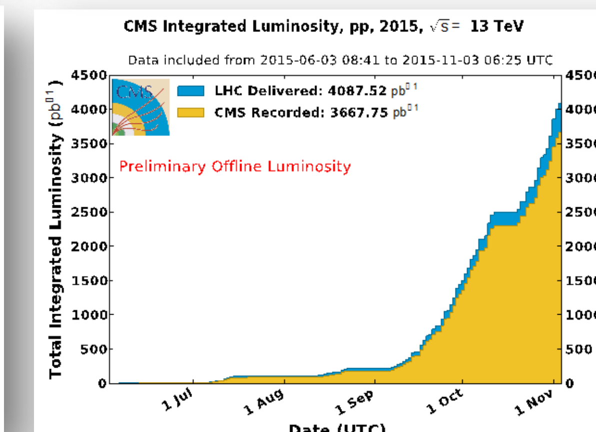
Design $10^{34}\ cm^{-1}\ s^{-1}$





Integrated



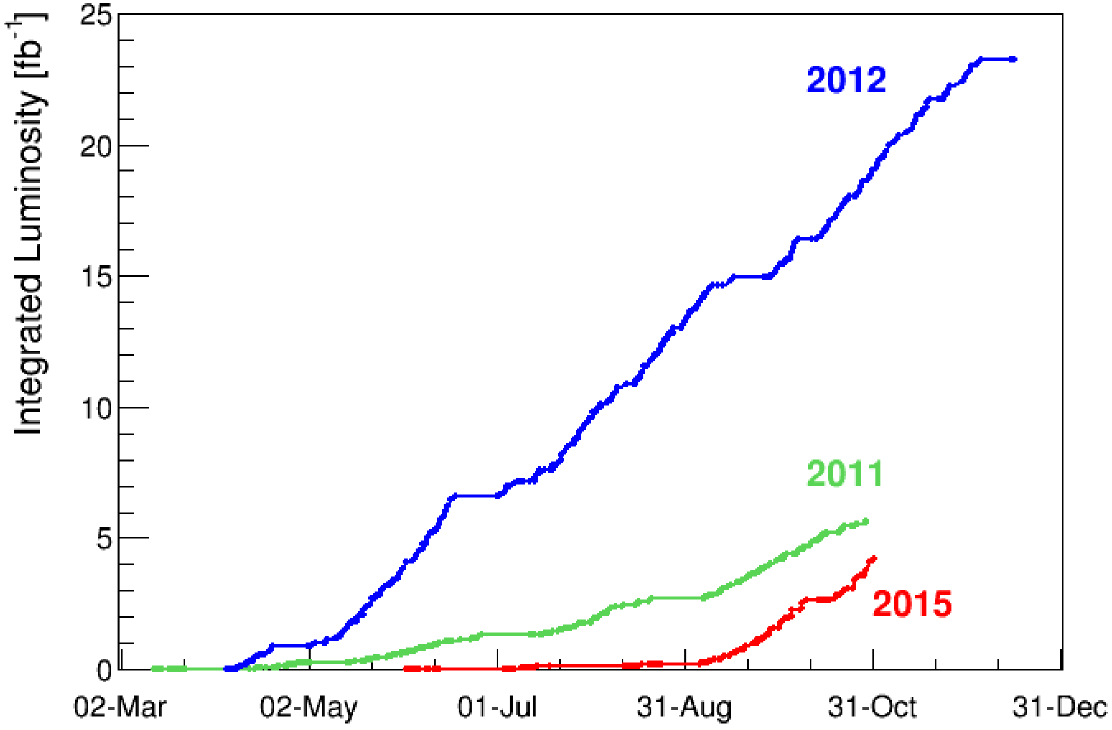


2015 LHC Integrated Luminosity

- **The initial projections of integrated luminosity for 2015 were ~ 8-10 fb^{-1}.**
- **Achieved ~ 4.3 fb^{-1}.**
- **Slope at the end of the run better than in 2011, and close to 2012 slope (last week of operation > 1 fb^{-1})**

The main reasons for the lower value:

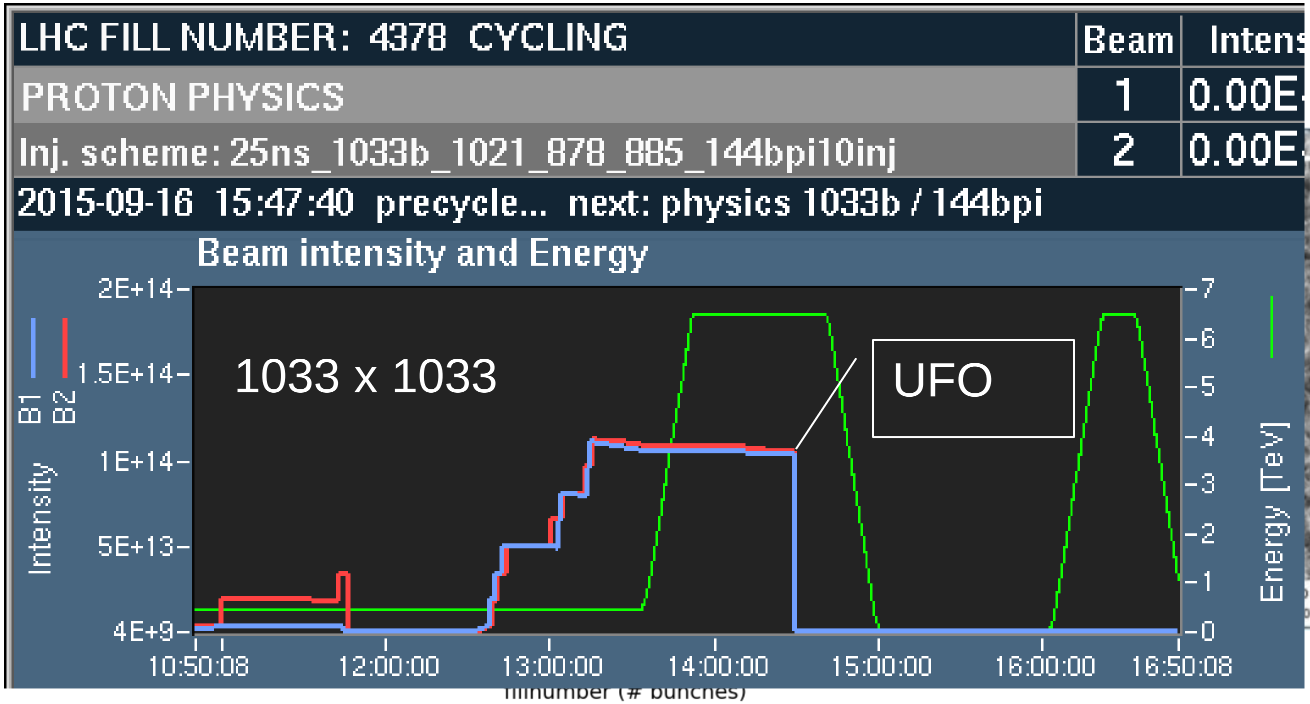
- Start-up delays (~ 4 weeks),
- Availability issues (radiation failures on the quench protection tunnel electronics; solved after TS2),
- Electron clouds mitigation

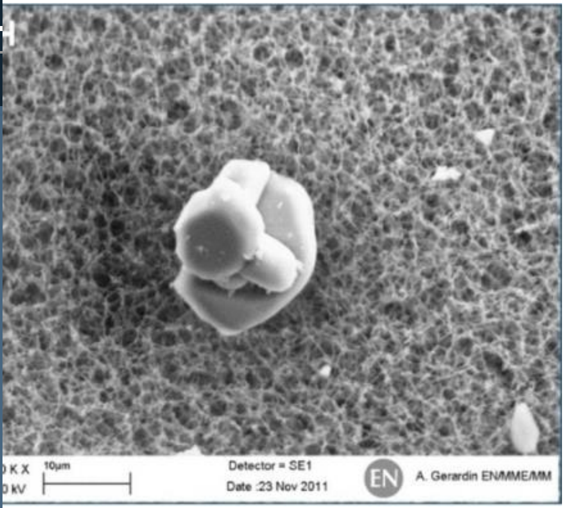


UFOs

There are with us, they are many of them, they are large !

- **UFO events observed quite often** during operation at 6.5 TeV

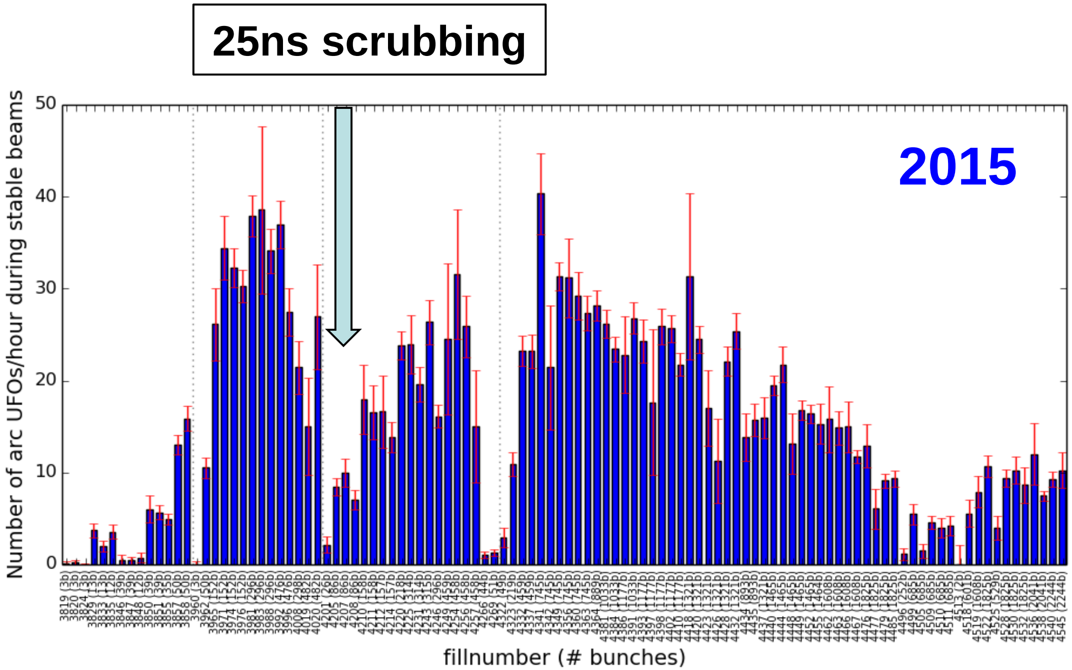


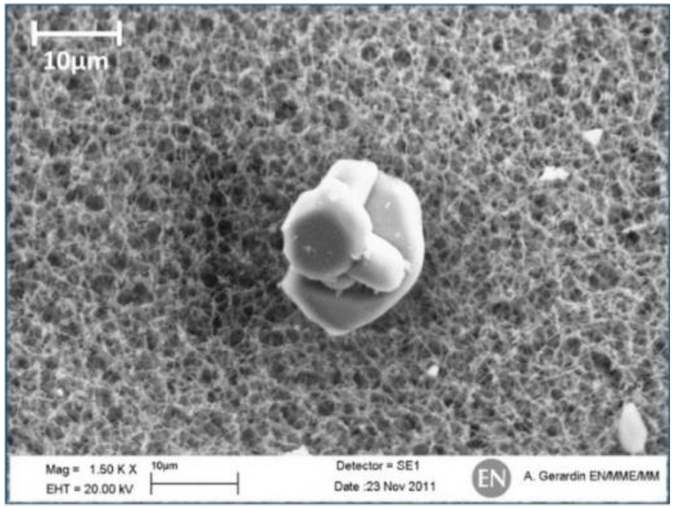


UFOs

There are with us, they are many of them, they are large !

- **UFO events observed quite often** during operation at 6.5 TeV
- **Conditioning** is observed on the UFO rate in spite of the increasing number of bunches
- **BLM thresholds** being optimize to find a **good compromise between availability and quench protection**

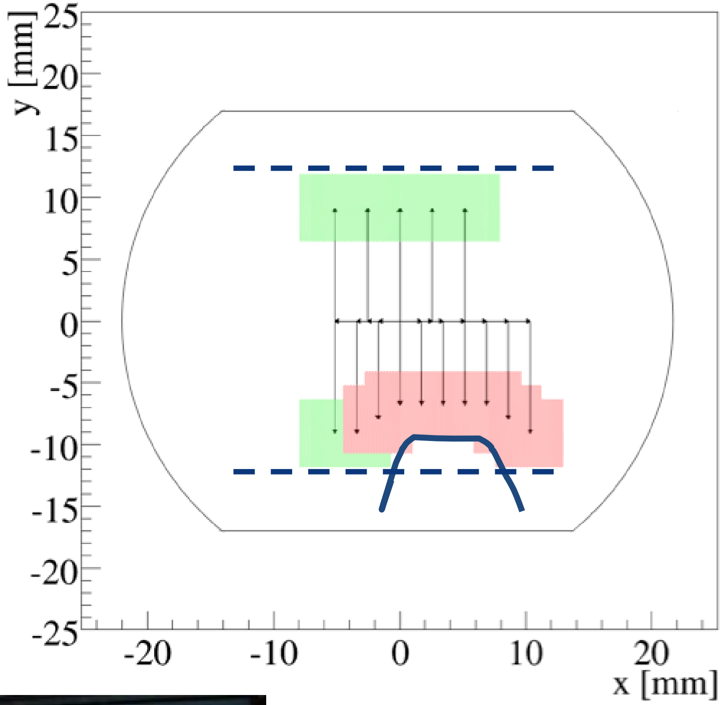




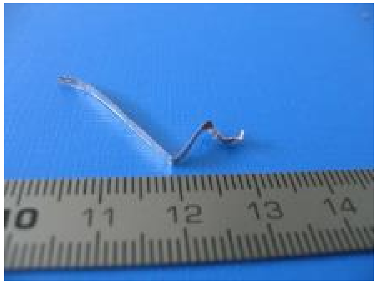
The bad 'surprise' : aperture restriction (ULO)

Aperture restriction:

- A position with anomalous beam losses was located on beam 2 in the arc between LHCb and ATLAS only few days after commissioning.
- Measured at injection and 6.5 TeV
- An aperture restriction due to an was found by scanning the beam position.
- Reference orbit is bumped by +1mm in V and -3mm in H at 15R8.
- 2015 not a limiting aperture for operation



Objects found in the past in the LHC vacuum chambers



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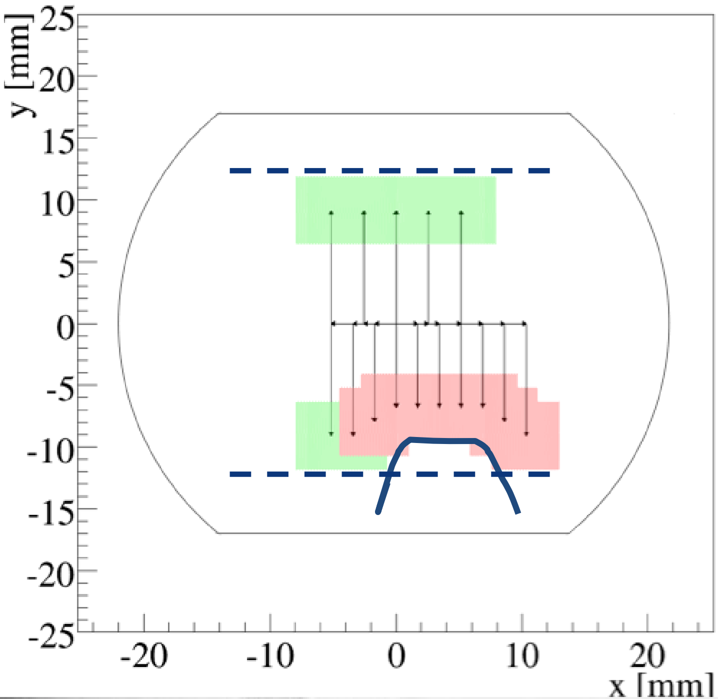
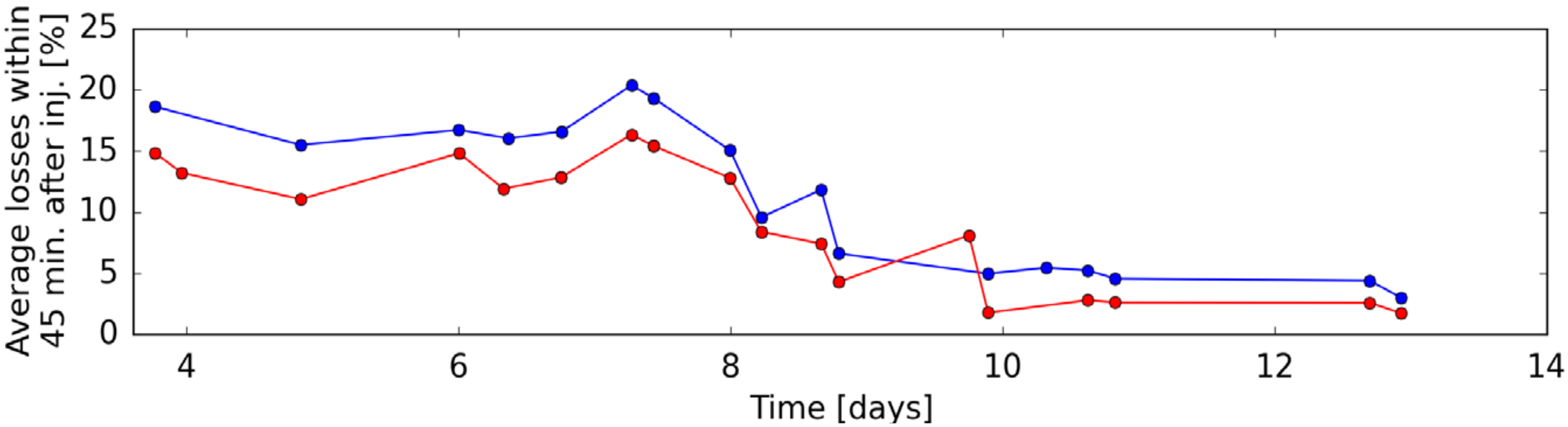


- **Opening the magnet to remove this object would take 2-3 months !**
- **=> Not planned for YETS (Year End Technical Stop)**

Scrubbing @ 25 ns bunch spacing

- Some issues :
  - Higher Order Modes heating of the injection collimator and kickers
  - Number of injections limited by same components

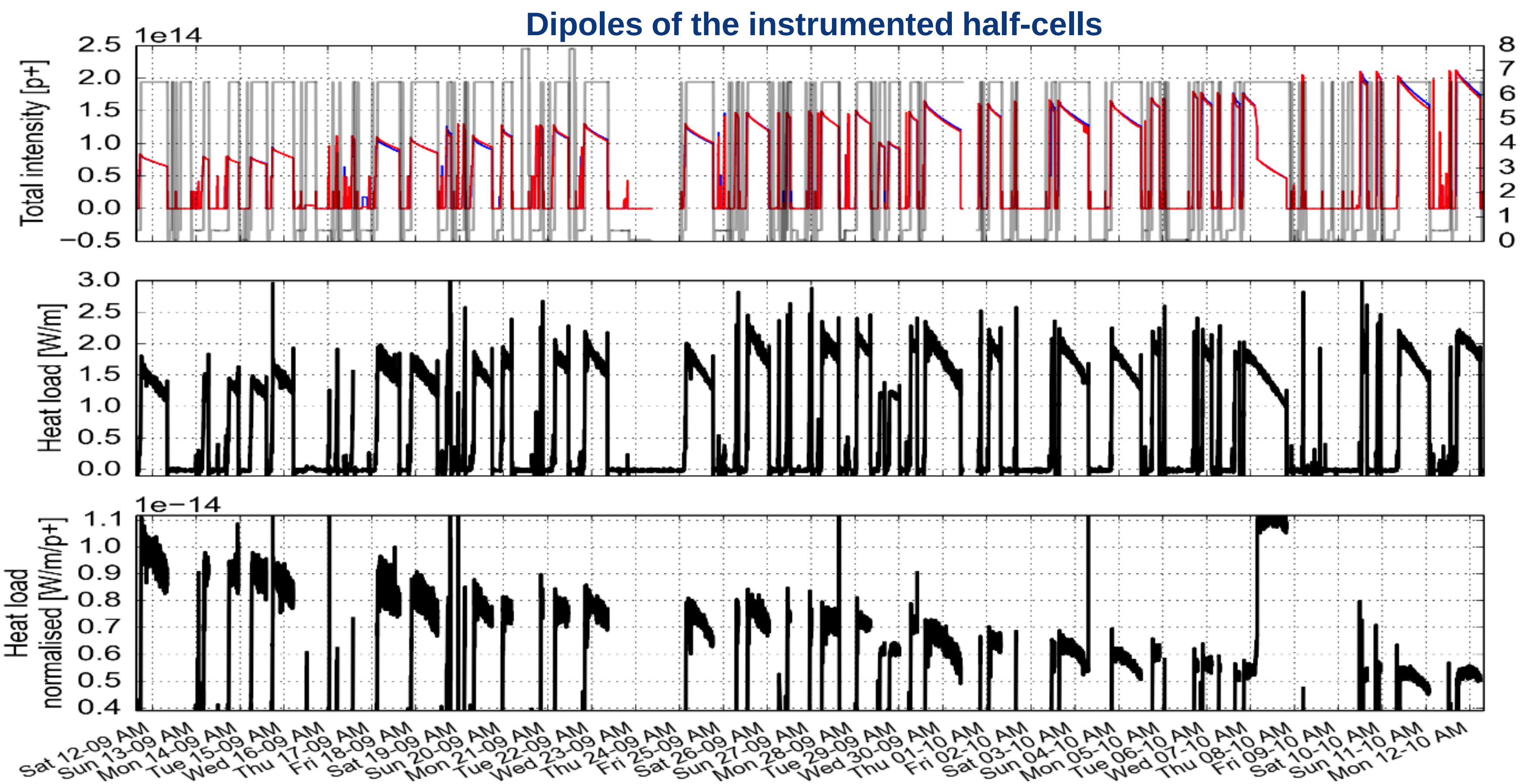
  - Injection speed in general limited by time response of the cryogenic system



Heat Load Evolution – E cloud

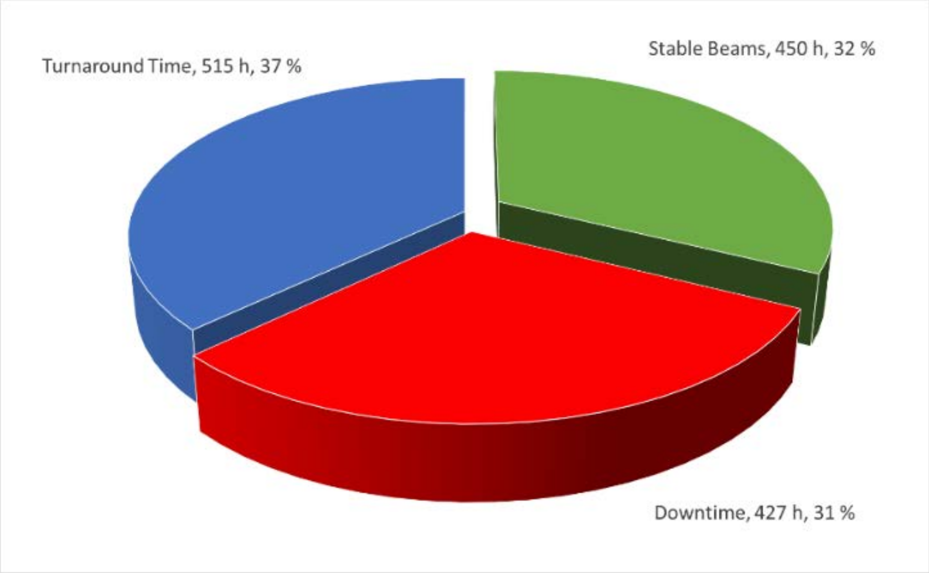
Scrubbing observed with physics fills at 6.5 TeV

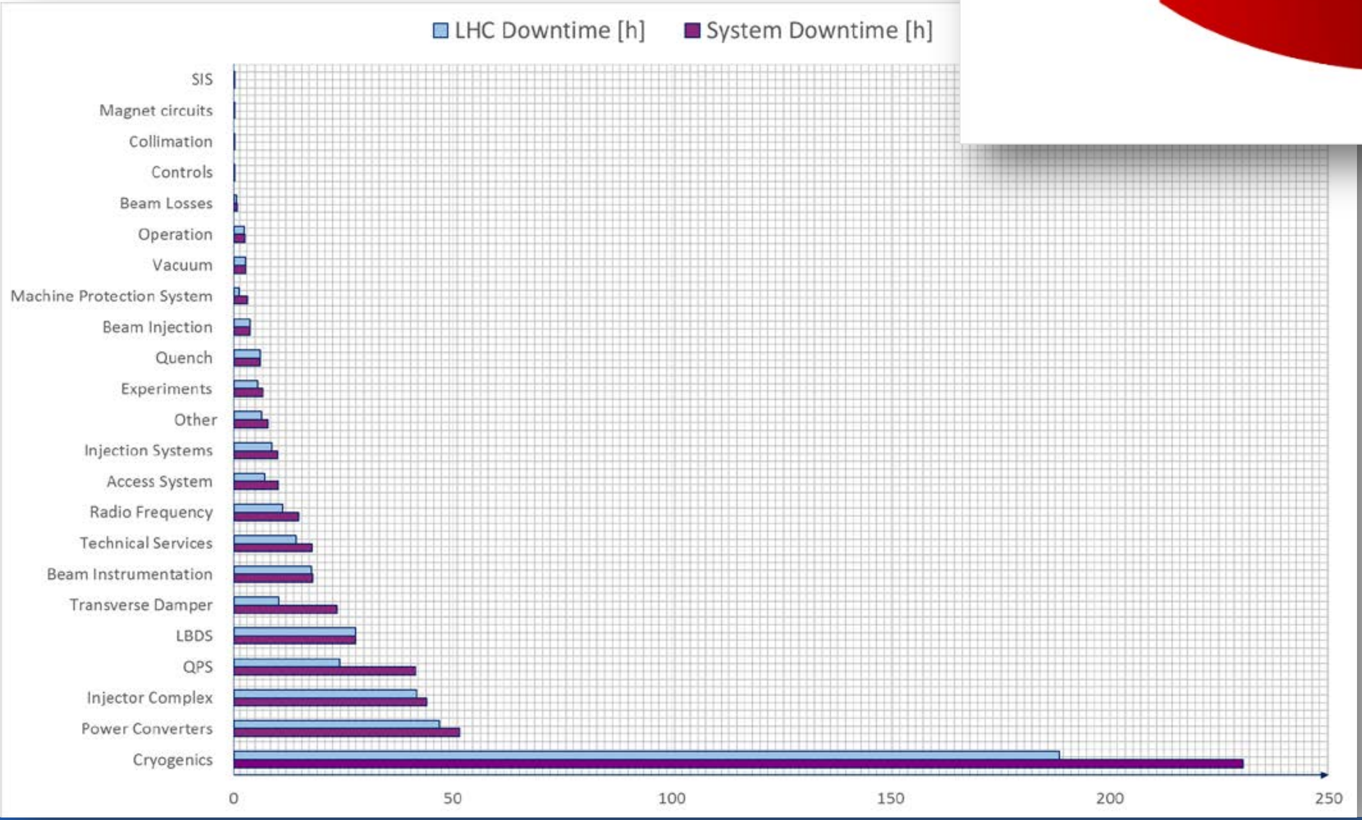
- → Hopefully gaining margin to further increase the number of bunches
- → **Scrubbing "memory" kept** while running with 25 ns beams - **deconditioning** was observed after few weeks of low e-cloud operation



2015 LHC Machine availability

Statistics for 25 ns run from September 7 to November 3





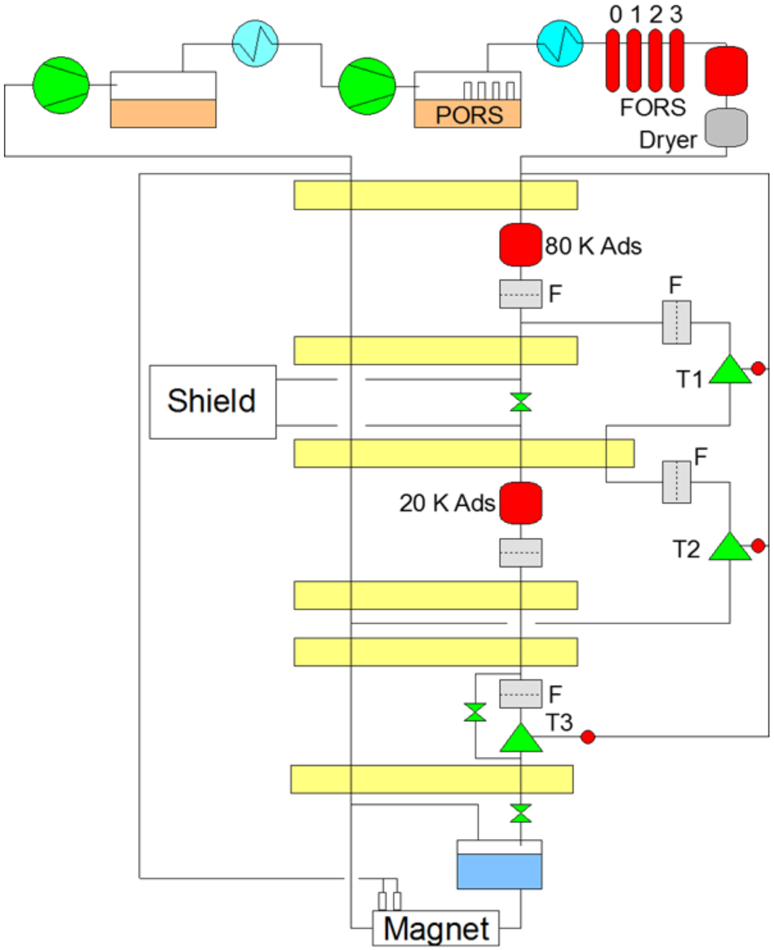
CMS Cold-Box Contamination: *Introduction*

- In 2004, during commissioning of the system at the surface, about 2 litres of Breox were “spilled” in the cold box (wrong manipulation). The system was cleaned with isopropyl alcohol. It was afterwards very difficult to get the cleaning solvent out.

- During commissioning of compressor station, an under-dimensioning of the oil separator system has been identified.

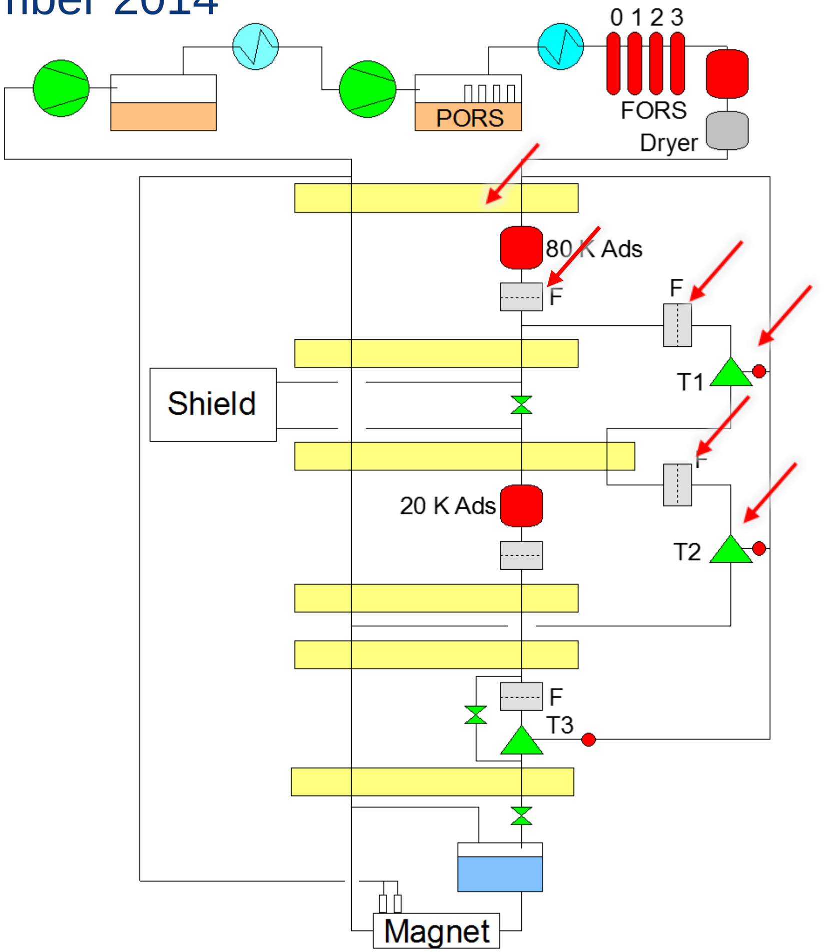
- At that moment the oil separator system was not upgraded, but a 4th coalescer added to the system.

- **The refrigerator system operated through Run 1 (≈10 years), with only minor problems.**



CMS Cold-Box Contamination: *Summary of events*

- CMS refrigerator has been re-started in November 2014 after the LS1 maintenance;
- Mid March first sign of contamination, at that moment blamed on air / water-pollution. ***Procedures applied: sub-system regenerated***.
- Beginning of May contamination identified at three different points. ***Procedures applied: System stopped, samples taken and complete regeneration***.
- After re-start of system almost **immediate contamination measured** at same points. Confirmed by result analysis of samples. ***Procedures applied: System stopped***.
- Analyse shows compressor oil (Breox®) <u>milligram </u>(mg) traces.

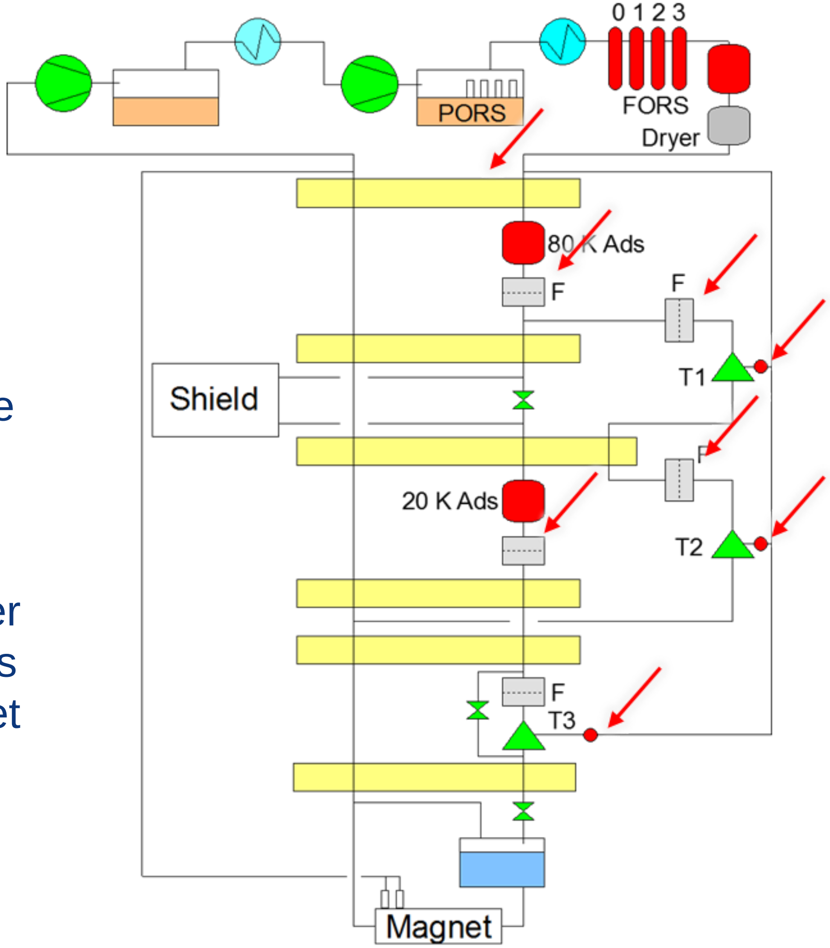


CMS Cold-Box Contamination: *What is causing these problems?*

- Breox® (compressor oil) was found on
  1. Outlet filter 80K and 20 K adsorbers
  2. Inlet filter T1
  3. Inlet filter T2
  4. Turbine gas bearing inlet filters

- Breox® is thought to diminish the heat exchange surface of the first heat-exchanger.

Normally a cold-box having suffered such a Breox® pollution is stopped to be cleaned. This was however impossible in the CMS case, and the installation was kept alive with regular 80K adsorber and turbine inlet filters regenerations. When judged necessary the turbine filters were exchanged for new ones.



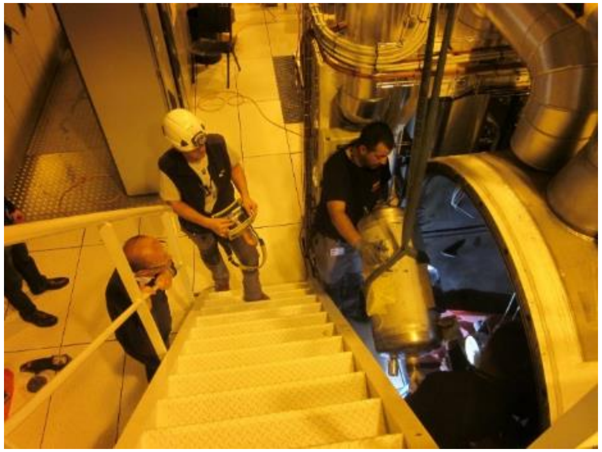
Of the integrated (p-p) luminosity delivered to CMS in 2015, about 73% of the data is taken under nominal field conditions;

CMS cryogenic issue: YETS (Year End Technical Stop) consolidations

- Cleaning of the cold box circuits: procedure and cleaning medium compatible with cavern environment.
- Installation of a new high-pressure line in CMS pit.
- Consolidation of the oil removal system:
  - New high-pressure primary oil separator
  - New coalescers for the final oil removal system
- Repair of a bended cryo-valve on the 6000-l LHe buffer in the UX cavern (damaged during LS1)
- Repair of the leaky LN2 pre-cooler
- Additional boosting of the cryoplant with the connection of a 11’000-l LHe mobile reservoir (feasibility under study).

CMS Cold-Box: *YETS clod-box cleaning*

- Change the 80 K and 20 K adsorbers (remove polluted equipment which cannot be cleaned)



Earlier removal of 80 K adsorber

- Clean cold-box equipment from Breox® : which solvent to use?
  1. Solvent shall adsorb Breox compressor oil, but not attack cold-box equipment
  2. It shall be possible to remove the solvent from the cleaned volumes
  3. Solvent shall be used in underground area

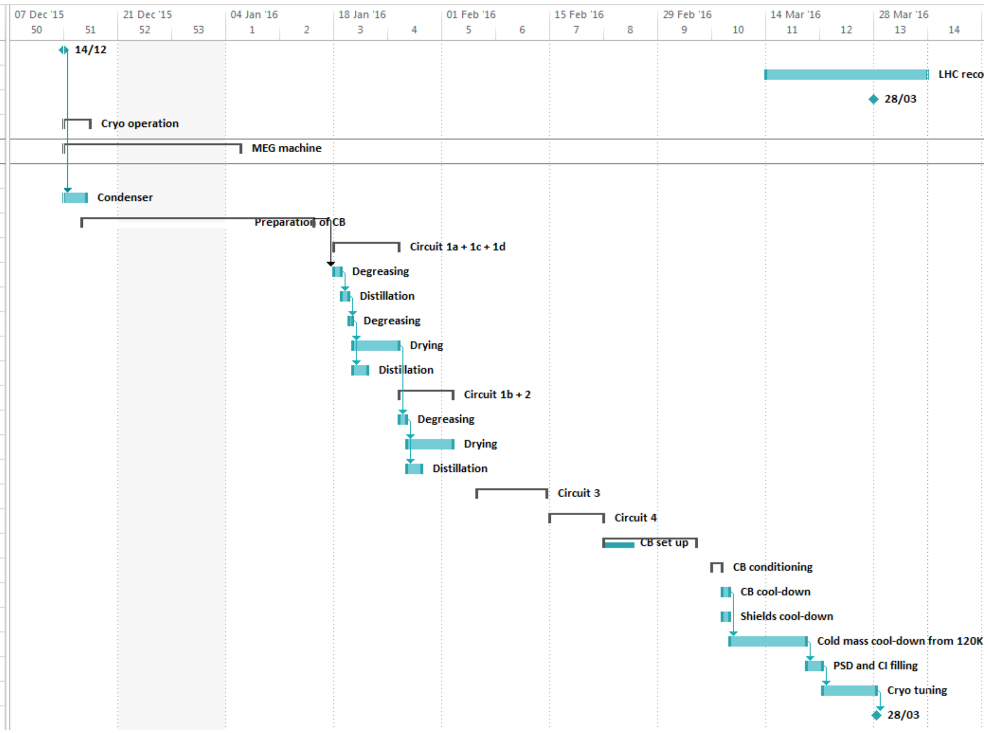
Adequate solvent has been selected, machinery to circulate the solvent though the cold-box equipment has been ordered, safety measures have been implemented;

CMS Cold-Box: *YETS planning*

A first review took place on the proposed measures discussed above, and a second one of the risks which these interventions could bring to the system. Both reviews supported the proposed measures.

A preliminary planning was established, but has to be finalized after the completion of the cleaning procedure of the first sub-system.

Task Name	Duration	Start	Finish
Field OFF	0 days	Mon 14/12/15	Mon 14/12/15
LHC recommissioning with beam	16 days	Mon 14/03/16	Sun 03/04/16
Field ON	0 days	Mon 28/03/16	Mon 28/03/16
Cryo operation	**3.25 days**	**Mon 14/12/15**	**Thu 17/12/15**
MEG machine	**7 days**	**Mon 14/12/15**	**Tue 05/01/16**
Safety equipement installed			
Condenser	3 days	Mon 14/12/15	Wed 16/12/15
Preparation of CB	**12 days**	**Wed 16/12/15**	**Fri 15/01/16**
Circuit 1a + 1c + 1d	**6.5 days**	**Mon 18/01/16**	**Tue 26/01/16**
Degreasing	1 day	Mon 18/01/16	Mon 18/01/16
Distillation	1 eday	Mon 18/01/16	Tue 19/01/16
Degreasing	0.5 days	Wed 20/01/16	Wed 20/01/16
Drying	6 edays	Wed 20/01/16	Tue 26/01/16
Distillation	2 edays	Wed 20/01/16	Fri 22/01/16
Circuit 1b + 2	**5 days**	**Tue 26/01/16**	**Tue 02/02/16**
Degreasing	1 day	Tue 26/01/16	Wed 27/01/16
Drying	6 edays	Wed 27/01/16	Tue 02/02/16
Distillation	2 edays	Wed 27/01/16	Fri 29/01/16
Circuit 3	**5.25 days**	**Fri 05/02/16**	**Sun 14/02/16**
Circuit 4	**5 days**	**Mon 15/02/16**	**Sun 21/02/16**
CB set up	**2 wks**	**Mon 22/02/16**	**Fri 04/03/16**
CB conditioning	**1.1 days**	**Mon 07/03/16**	**Tue 08/03/16**
CB cool-down	1 day	Tue 08/03/16	Wed 09/03/16
Shields cool-down	1 day	Tue 08/03/16	Wed 09/03/16
Cold mass cool-down from 120K	10 edays	Wed 09/03/16	Sat 19/03/16
PSD and CI filling	2 edays	Sat 19/03/16	Mon 21/03/16
Cryo tuning	1 wk	Mon 21/03/16	Mon 28/03/16
Cryoready ON	0 days	Mon 28/03/16	Mon 28/03/16

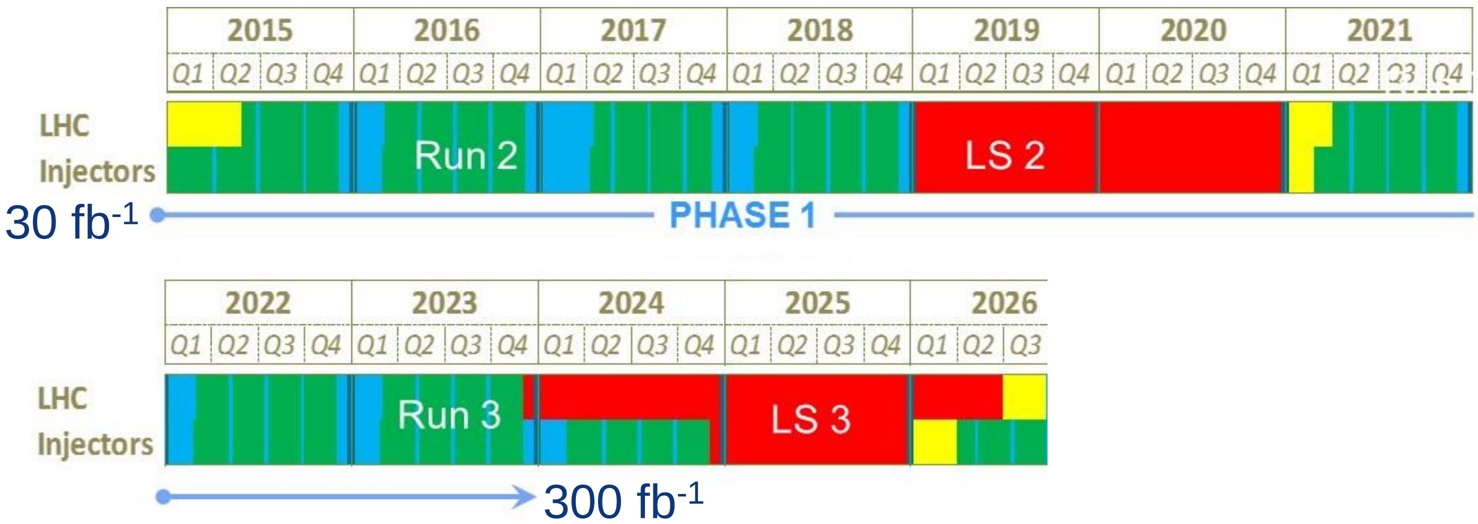


LHC goal for Run 2 and 3

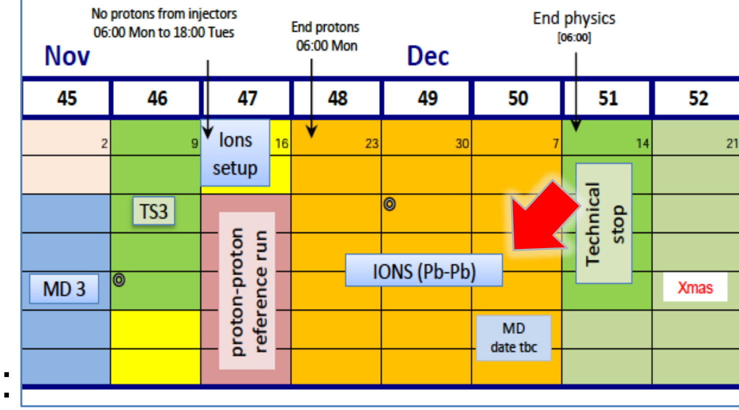
Integrated luminosity goal:

Run2: ~100-120 fb^{-1}

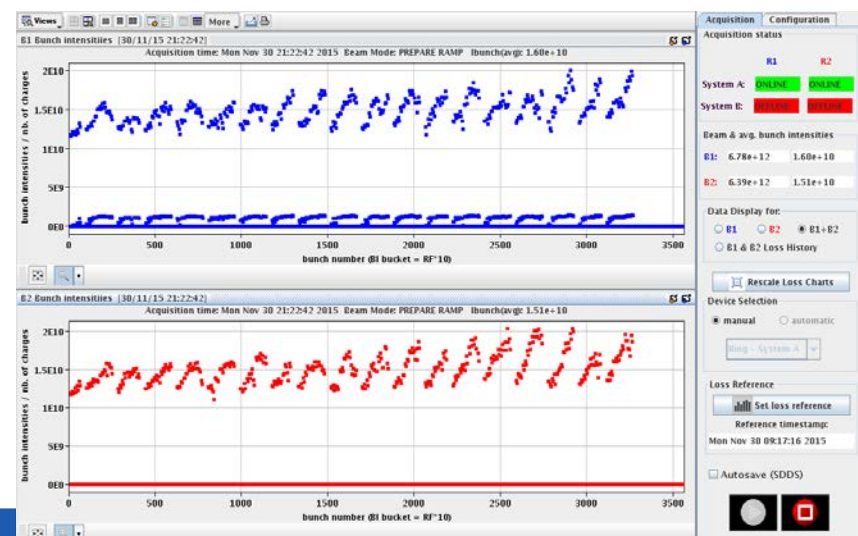
~ 300 fb^{-1} before LS3



End of 2015: Lead-Lead physics run

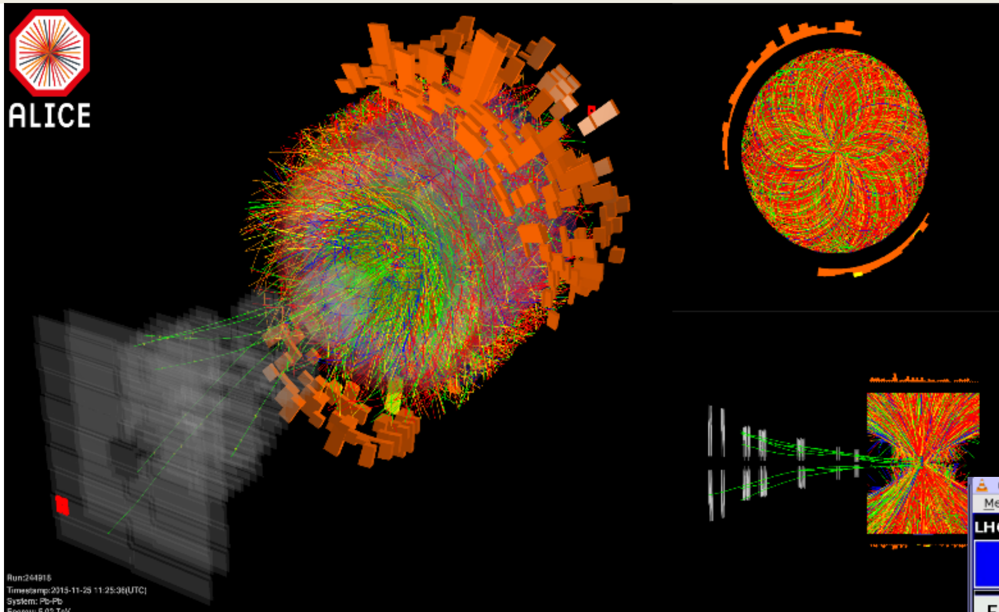


- After TS3, restart for ions physics run
- Intermediate energy run with protons at 2.51 TeV :
    - *Full cycle commissioning: combined ramp and squeeze, optics, Machine protection validation....*
    - *Intensity ramp up: up to 1800 bunches per beam*
- 3 weeks of Pb-Pb collisions:
    - *Again full validation of a new cycle at 6.37 ZTeV: Alice pre-squeeze, squeeze, ALICE crossing reversal + IP shift....*
    - *Now operating with 518 bunches per beam*



11 Nov – First Pb-Pb STABLE BEAMS

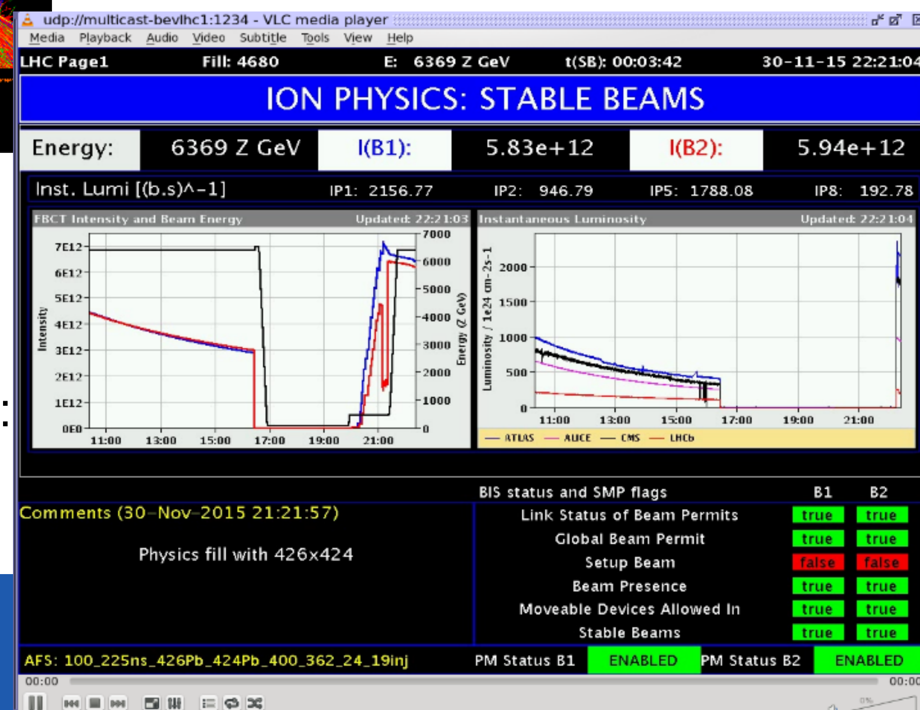
First Pb-Pb Stable Beams at 5.02 *A* TeV = 1.045 PeV



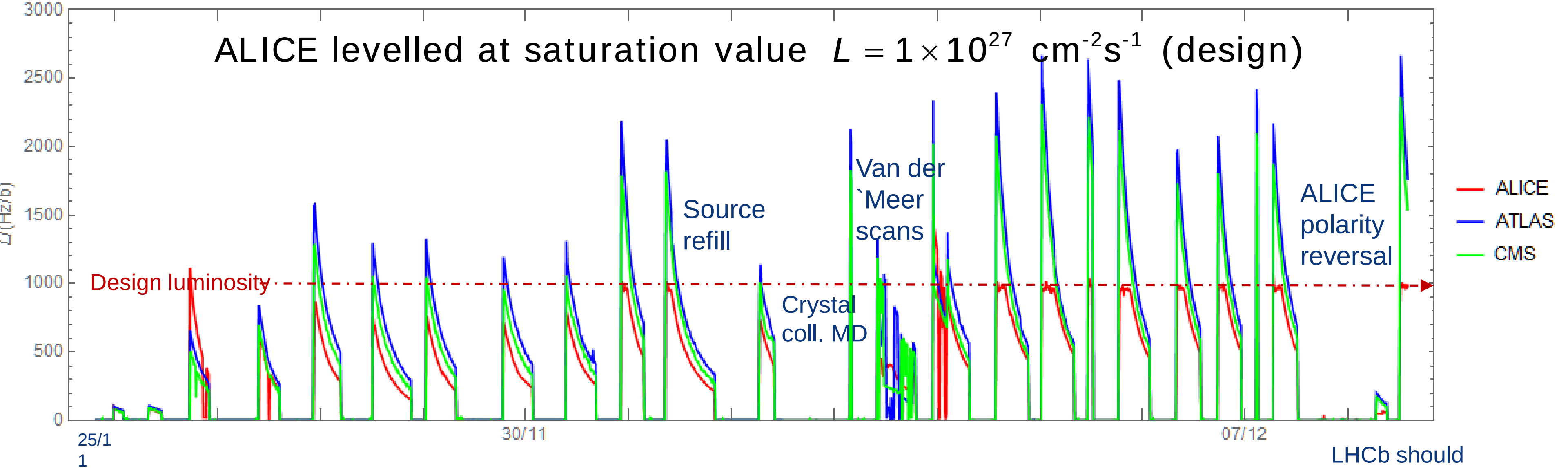
ALICE event with TPC and muon spectrometer

- **Design peak lumi:** 1×10^{27} cm^{-2}s^{-1}:
  - *ALICE already leveled at design lumi*
  - *ATLAS/CMS aready beyond*

- Delivered lumi so far (2.5 weeks of physics):
  - *ALICE 280 μb^{-1} ; ATLAS/CMS 410 μb^{-1}*
  - *Target for 2015 ions run :300 - 500 μb^{-1}*

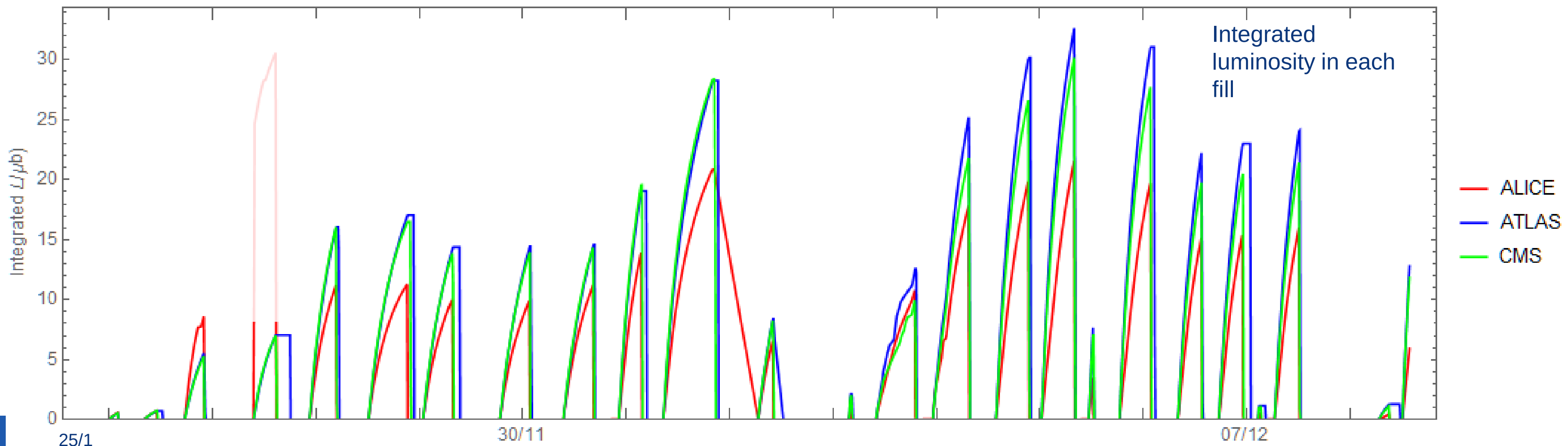


Luminosity to 14:30 8 Dec 2015



LHCb should have about 2% of ATLAS

13 days



The European Strategy for Particle Physics
Update 2013

*Europe's top priority should be the **exploitation of the full potential of the LHC**, including the high-luminosity upgrade of the machine and detectors with a view to collecting **ten times more data than in the initial design, by around 2030**. This upgrade programme will also provide further exciting opportunities for the study of flavour physics and the quark-gluon plasma.*

HL-LHC from a study to a PROJECT

300 fb^{-1} → 3000 fb^{-1}

including LHC injectors upgrade **LIU**

(Linac 4, Booster 2GeV, PS and SPS upgrade)

Strategic Plan for U.S. Particle Physics

Particle Physics Project Prioritization Panel (P5) – May 2014

Building for Discovery

Strategic Plan for U.S. Particle Physics in the Global Context

Report of the Particle Physics Project Prioritization Panel (P5)

Near-term & Mid-term High-energy Colliders

LARGE HADRON COLLIDER

- **The HL-LHC is strongly supported and is the first high-priority large-category project in our recommended program. It should move forward without significant delay to ensure that accelerator and experiments can continue to function effectively beyond the end of this decade and meet the project schedule.**
- *Recommendation 10:* ***Complete the LHC phase-1 upgrades, and continue the strong collaboration in the LHC with the phase-2 (HL-LHC) upgrades of the accelerator and both general-purpose experiments (ATLAS and CMS). The LHC upgrades constitute our highest-priority near-term large project.***

Goals and means of the LHC Injectors Upgrade: LIU project

Increase intensity/brightness in the injectors to match HL-LHC requirements

⇒ Enable Linac4/PSB/PS/SPS to accelerate and manipulate higher intensity beams (efficient production, space charge & electron cloud mitigation, impedance reduction, feedbacks, etc.)

⇒ Upgrade the injectors of the ion chain (Linac3, LEIR, PS, SPS) to produce beam parameters at the LHC injection that can meet the luminosity goal

Increase injector reliability and lifetime to cover HL-LHC run (until ~2035) closely related to consolidation program

⇒ Upgrade/replace ageing equipment (power supplies, magnets, RF…)

⇒ Improve radioprotection measures (shielding, ventilation…)

Courtesy of Malika Meddahi

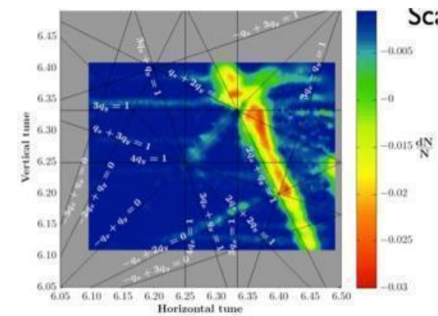
LS2 : (2019-2020), LHC Injector Upgrades (LIU)

LINAC4 – PS Booster:

- H^- injection and increase of PSB injection energy from 50 MeV to 160 MeV, to increase PSB space charge threshold
- New RF cavity system, new main power converters
- Increase of extraction energy from 1.4 GeV to 2 GeV

PS:

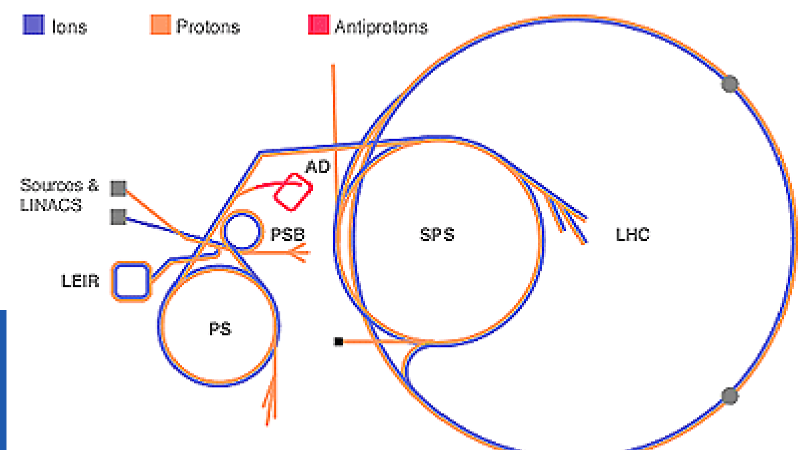
- Increase of injection energy from 1.4 GeV to 2 GeV to increase PS space charge threshold
- Transverse resonance compensation
- New RF Longitudinal feedback system
- New RF beam manipulation scheme to increase beam brightness



SPS

- Electron Cloud mitigation – strong feedback system, or coating of the vacuum system
- Impedance reduction, improved feedbacks
- Large-scale modification to the main RF system

These are only the main modifications and this list is far from exhaustive



Goal of High Luminosity LHC (HL-LHC):

The main objective of HiLumi LHC Design Study is to determine a hardware configuration and a set of beam parameters that will allow the LHC to reach the following targets:

Prepare machine for operation **beyond 2025 and up to 2035-37**

Devise beam parameters and operation scenarios for:

- enabling a total integrated luminosity of **3000 fb^{-1}**
- implying an integrated luminosity of **250-300 fb^{-1} per year**,
- design for **μ ~ 140 (~ 200)** (➔ peak luminosity of **5 (7) 10^{34} cm^{-2} s^{-1}**)
- design equipment for 'ultimate' performance of **7.5 10^{34} cm^{-2} s^{-1}** and **4000 fb^{-1}**

=> Ten times the luminosity reach of first 10 years of LHC operation

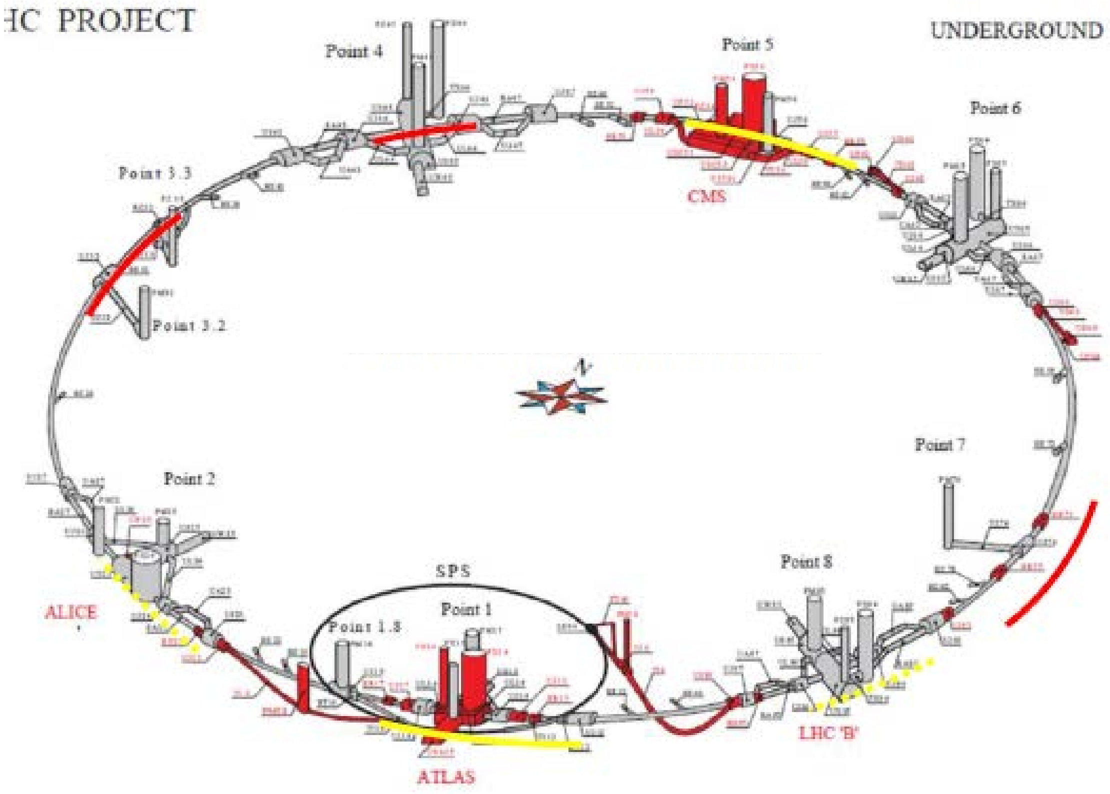
LHC Upgrade Goals: Performance optimization

Luminosity recipe :

$$L = \frac{n_b \cdot N_1 \cdot N_2 \cdot \gamma \cdot f_{rev}}{4\pi \cdot \beta^* \cdot \varepsilon_n} \cdot F(\phi, \beta^*, \varepsilon, \sigma_s)$$

- ➔1) maximize bunch intensities ➔ Injector complex
- ➔2) minimize the beam emittance LIU ⇔ IBS
- ➔3) minimize beam size (constant beam power); ➔ triplet aperture
- ➔4) maximize number of bunches (beam power); ➔ 25ns
- ➔5) compensate for 'F'; ➔ Crab Cavities
- ➔6) Improve machine 'Efficiency' ➔ minimize number of unscheduled beam aborts

The HL-LHC Project



- New IR-quads Nb_3Sn (inner triplets)
- New 11 T Nb_3Sn (short) dipoles
- Collimation upgrade
- Cryogenics upgrade
- Crab Cavities
- Cold powering
- Machine protection
- …

Major intervention on more than 1.2 km of the LHC

Squeezing the beams: High Field SC Magnets

Quads for the inner triplet

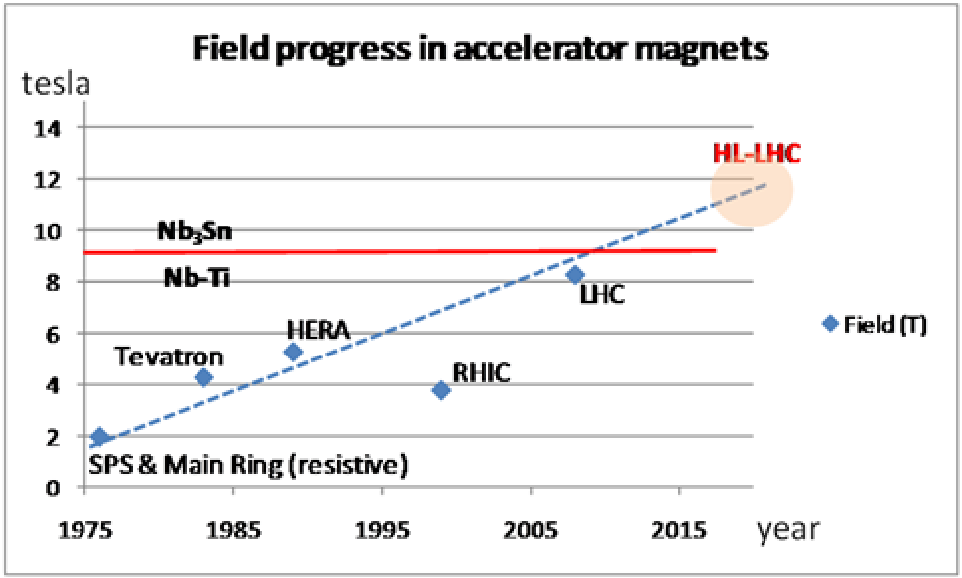
Decision 2012 for low-β quads

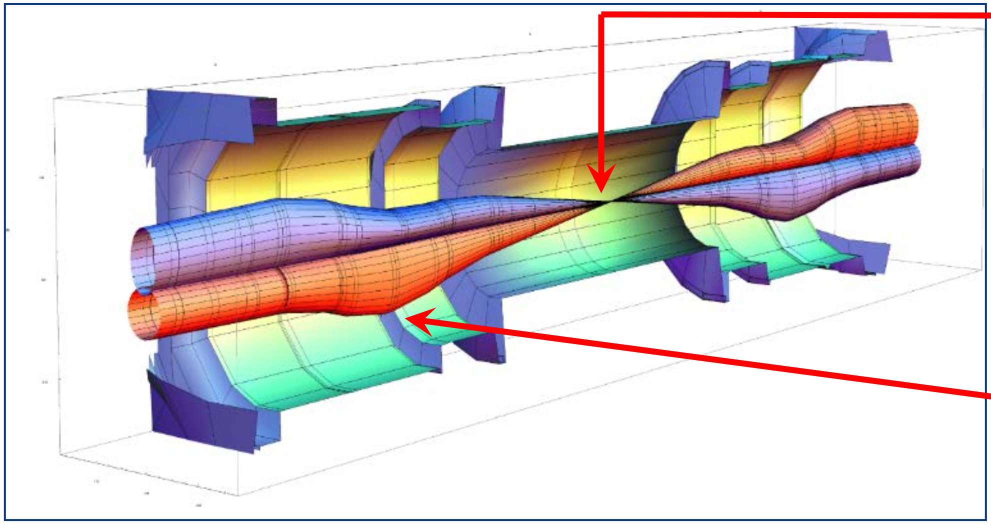
Aperture ∅ 150 mm – 140 T/m

(B_{peak} ≈12.3 T) operational field, designed for 13.5 T

=> Nb_3Sn technology

(LHC: 8 T, 70 mm)



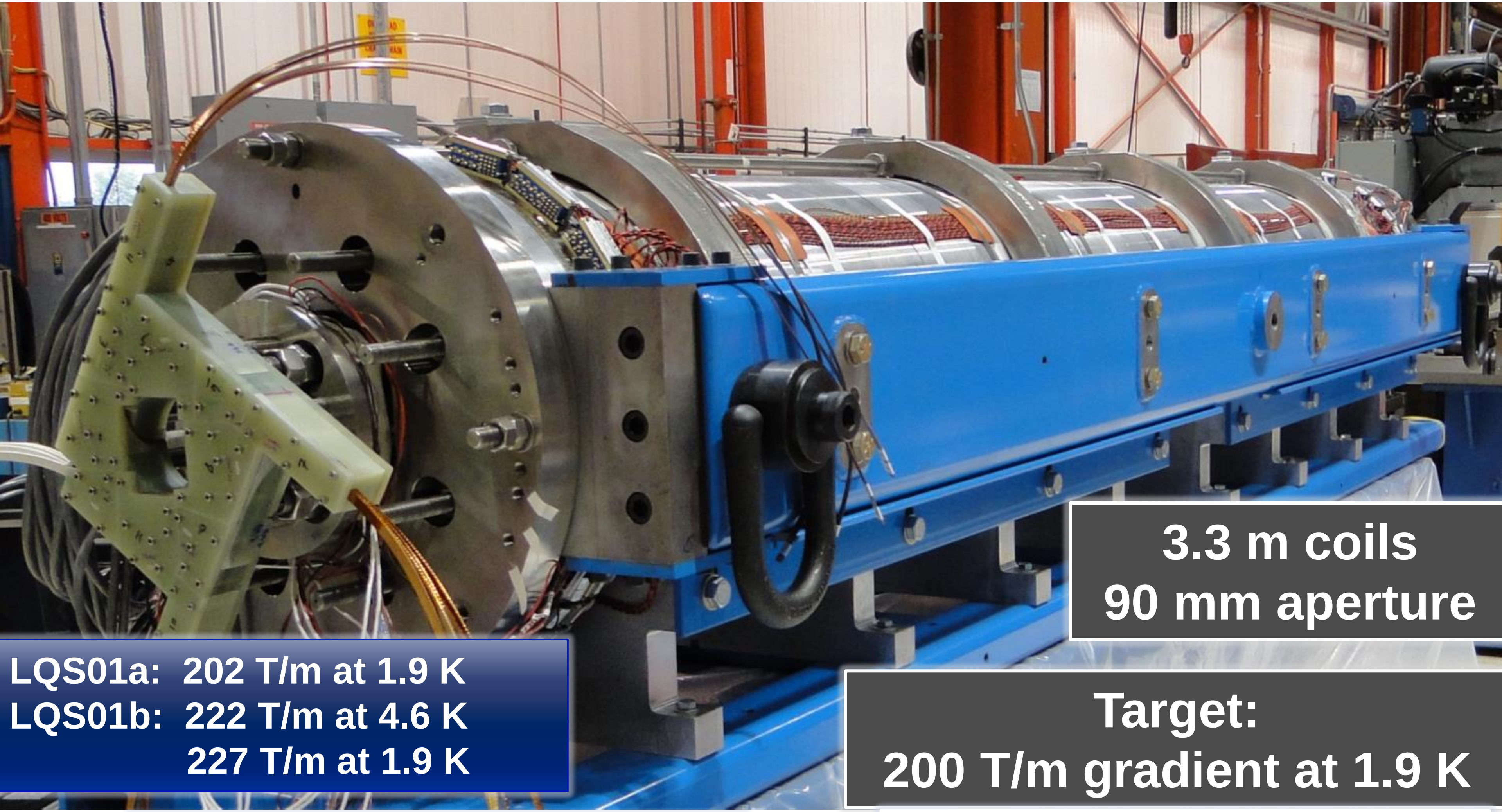


	$\beta_{triplet}$	Sigma triplet	β*	Sigma*
Nominal	~4.5 km	1.5 mm	55 cm	17 um
HL-LHC	~20 km	2.6 mm	15 cm	7 um

Quadrupoles of LARP

Courtesy: G. Ambrosio FNAL and G. Sabbi , LBNL

LARP



3.3 m coils
90 mm aperture

LQS01a: 202 T/m at 1.9 K
LQS01b: 222 T/m at 4.6 K
227 T/m at 1.9 K

Target:
200 T/m gradient at 1.9 K

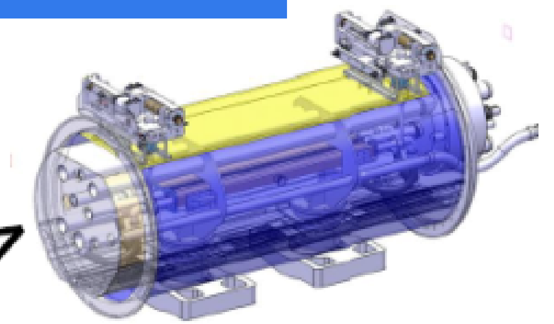
LQS02: 198 T/m at 4.6 K 150 A/s
208 T/m at 1.9 K 150 A/s
limited by one coil

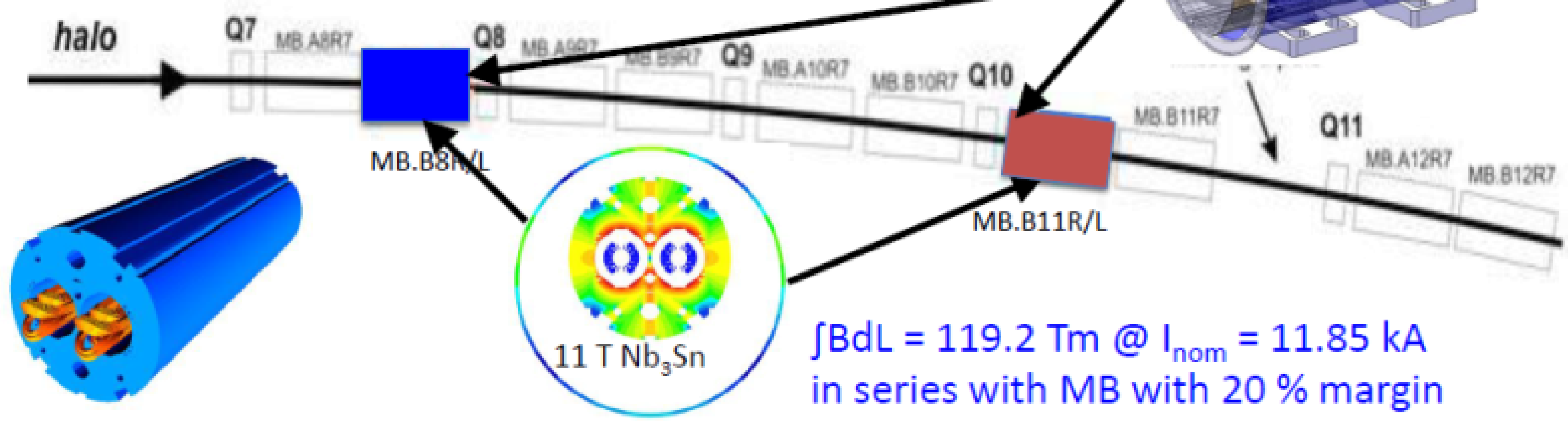
LQS03: 208 T/m at 4.6 K
210 T/m at 1.9 K
1st quench: 86% s.s. limit

CERN

LS2 : collimators and 11T Dipole

- LS2 2017-18: Point-~~3~~,7 & IR-2
- LS3 2020+: IR1,5 as part of HL-LHC



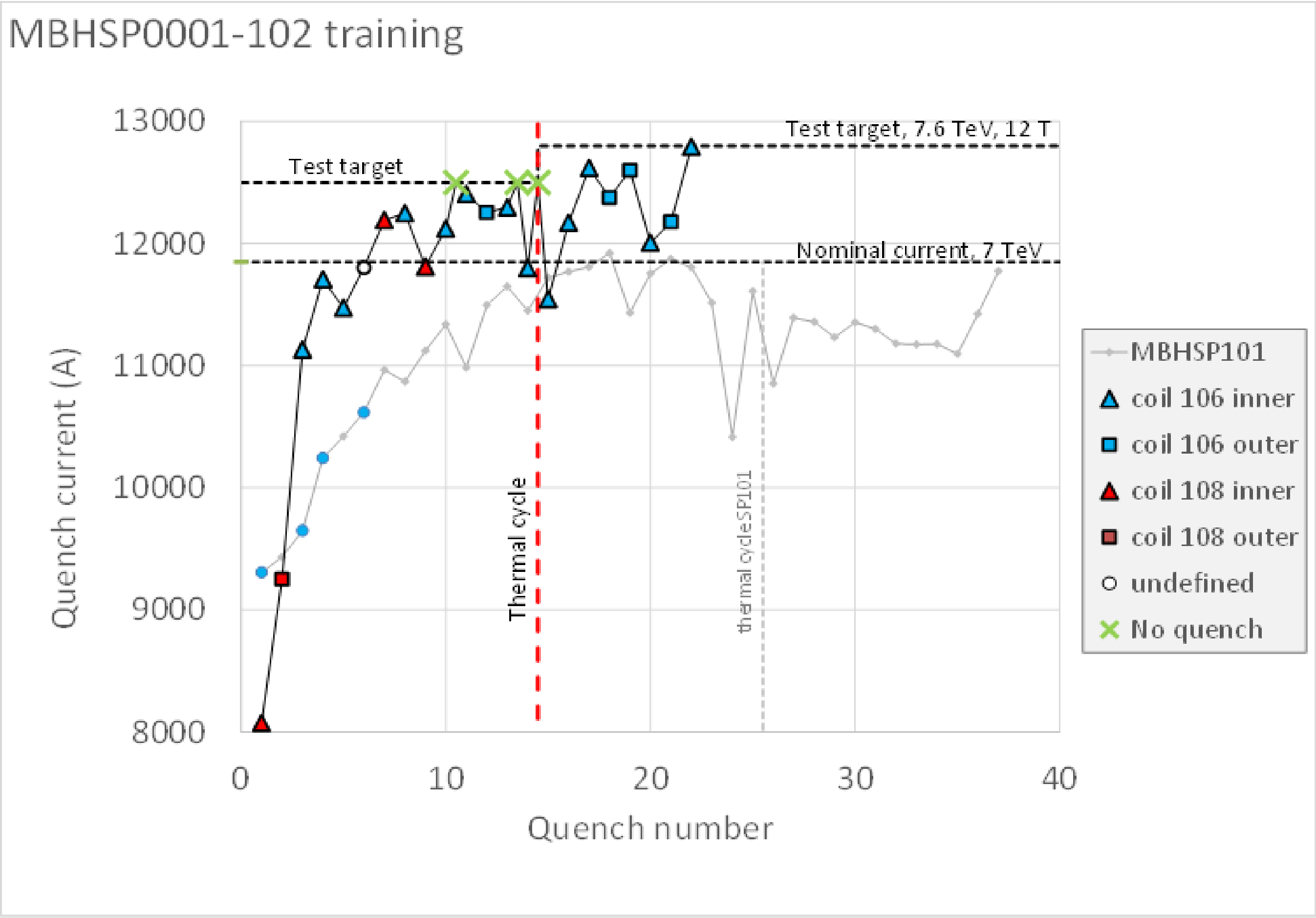


$\int BdL$ = 119.2 Tm @ I_{nom} = 11.85 kA
in series with MB with 20 % margin

LS2: 12 coldmass + 2 spares = 14 CM
LS3: 8 coldmass + 2 spares = 10 CM
Total 24 CM

LS2: 24 coldmass + 4 spares = 28 CM
LS3: 16 coldmass + 4 spares = 20 CM
Total 48 CM

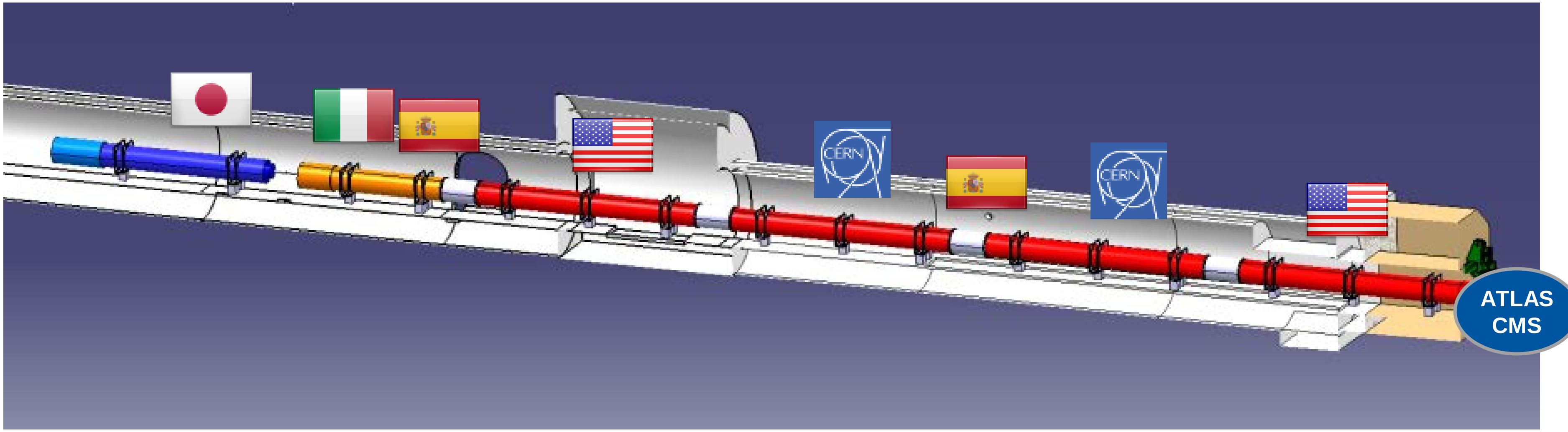
11 T Magnet – **Nb3Sn** technology
Status on recent developments &tests at CERN

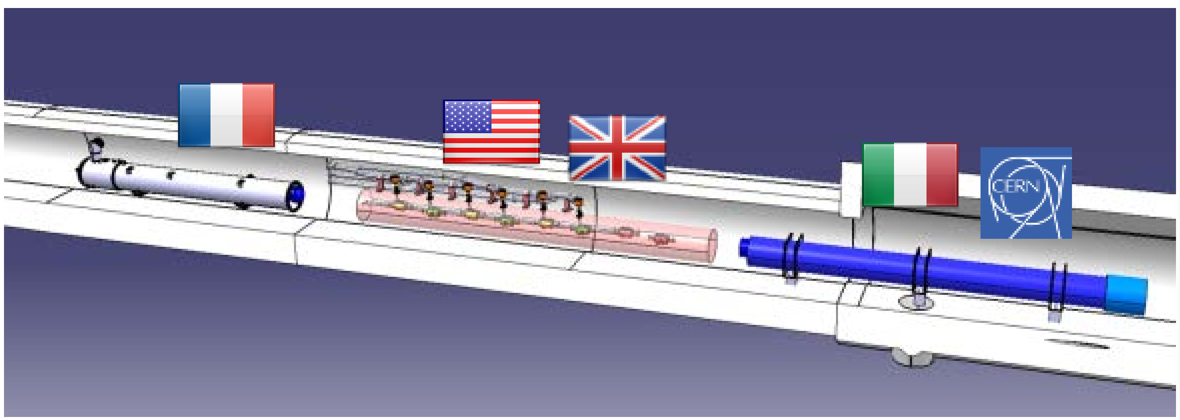


Courtesy of Frédéric Savary

In-kind contributions and collaborations for design, prototypes, production and tests

Discussions are ongoing with other countries, e.g Canada,…





Q1-Q3 : R&D, Design, Prototypes and in-kind **USA**
D1 : R&D, Design, Prototypes and in-kind **JP**
MCBX : Design and Prototype **ES**
HO Correctors: Design and Prototypes **IT**
Q4 : Design and Prototype **FR**

CC : R&D, Design and in-kind **USA**

CC : R&D and Design **UK**

Cost & Schedule review of LIU and HL-LHC

(March 2015)

Cost and Schedule Review Committee

CMAC Members:

Brinkmann, Reinhard	DESY (Deutsches Elektronen-Synchrotron)
Fischer, Wolfram	BNL (Brookhaven National Laboratory)
Gourlay, Stephen	LBNL (Lawrence Berkeley National Laboratory)
Holtkamp, Norbert (Chair)	**SLAC (SLAC National Accelerator Laboratory)**
Oide, Katsunobu	KEK (高エネルギー加速器研究機構)
Qin, Qing	IHEP (Institute of High Energy Physics)
Roser, Thomas	BNL (Brookhaven National Laboratory)
Seeman, John	SLAC(SLAC National Accelerator Laboratory)
Shiltsev, Vladimir	FNAL (Fermi National Accelerator Laboratory)

Reviewers:

Neumeyer, Charles L.	PPPL (Princeton Plasma Physics Lab)
Petersen, Bernd	DESY (Deutsches Elektronen-Synchrotron)
Seidel, Mike	PSI (Paul Scherrer Institute)
Vedrine, Pierre	CEA-Saclay (Commissariat à l'énergie atomique et aux énergies alternatives)
Yamamoto, Akira	KEK (Kō Enerugī Kasokuki Kenkyū Kikō)

Conclusion

C&S review committee side

Executive Summary - The first sentence of the 4 first paragraphs

Executive Summary

The review committee is very impressed with the enormous amount of work that was presented.

A very competent, engaged and effective management team is in place to manage both projects.

The Project Management tools used at CERN are state of the art, well utilized and well understood by the management team as well as all the personnel the review committee talked to.

The QA and QC programs are well established, flexible and effective.

LIU : Cost Summary

Total cost / MCHF	**186***
Uncertainty / %	**-10 / +15**
Uncertainty / MCHF	**167 - 214**
Uncertainty	**Class 2**
% complete	**17% (31 MCHF)**
Total FTE / CERN	**691**
Total FTE / MPA	**194**

*Does not include LINAC4

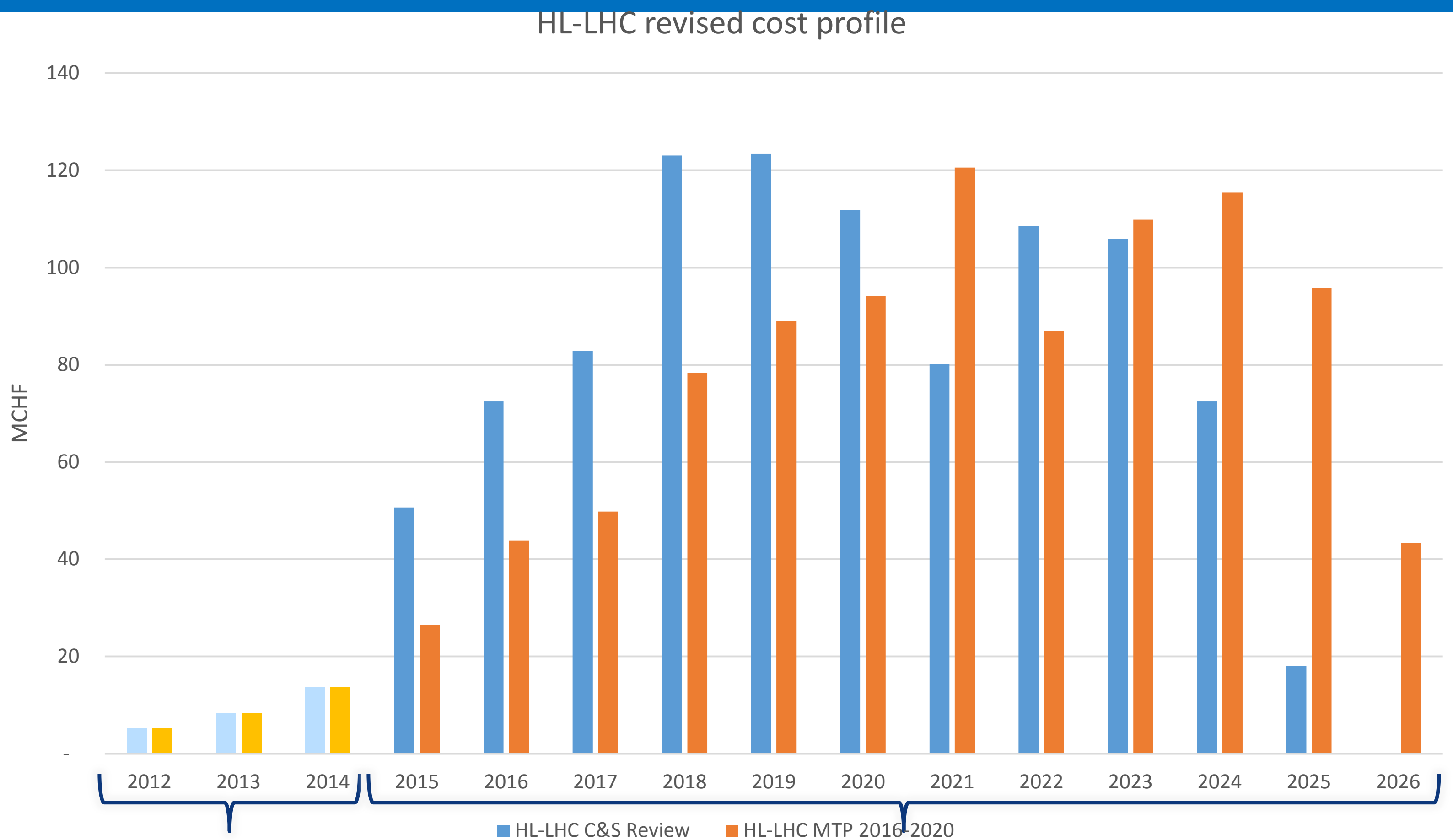
- Budgets are correctly assembled and adequate
- Schedule is generally well defined and realistic
- Some options for savings, deferrals or deletion (<15 MCHF)
- Scope on IONS is not well enough defined which leaves uncertainty in the design
- Significant ramp up of effort in the next 2 years requires close tracking of resources
- General concern about retiring expertise/ expertise availability

HL-LHC : Cost Summary

Total cost / MCHF (original estimate 2011)	**833**
Total cost / MCHF (new estimate)	**949 Construction phase 27 R&D phase**
Uncertainty / %	**-15 / +22**
Uncertainty / MCHF	**-142 / +208**
Uncertainty	**On average Class 3**
% complete	**R&D phase**
Total FTE / CERN	**1660**
Total FTE / MPA	**946**

- Budgets are correctly assembled and adequate, but uncertainty varies between class 1 and 5
- Schedule is generally well defined and realistic
- Some options for savings, deferrals or deletion (see table later)
- More expensive workpackages have generally less uncertainty (apart from Civil Engineering).
- Unlikely that uncertainty on the negative site will materialize to the degree assumed.
- General concern expertise availability **(new contract policy should help)**
- Late information on cost / risk of Civil Engineering creates major risk that needs to be retired asap

MTP – HL-LHC revised cost profile



R&D phase: 27 MCHF

Construction phase: 950 MCHF

LHC roadmap: schedule beyond LS1

LS2 starting in 2018 (July) => 18 months + 3 months BC
LS3 LHC: starting in 2023 => 30 months + 3 months BC
Injectors: in 2024 => 13 months + 3 months BC

(Extended) Year End Technical Stop: (E)YETS

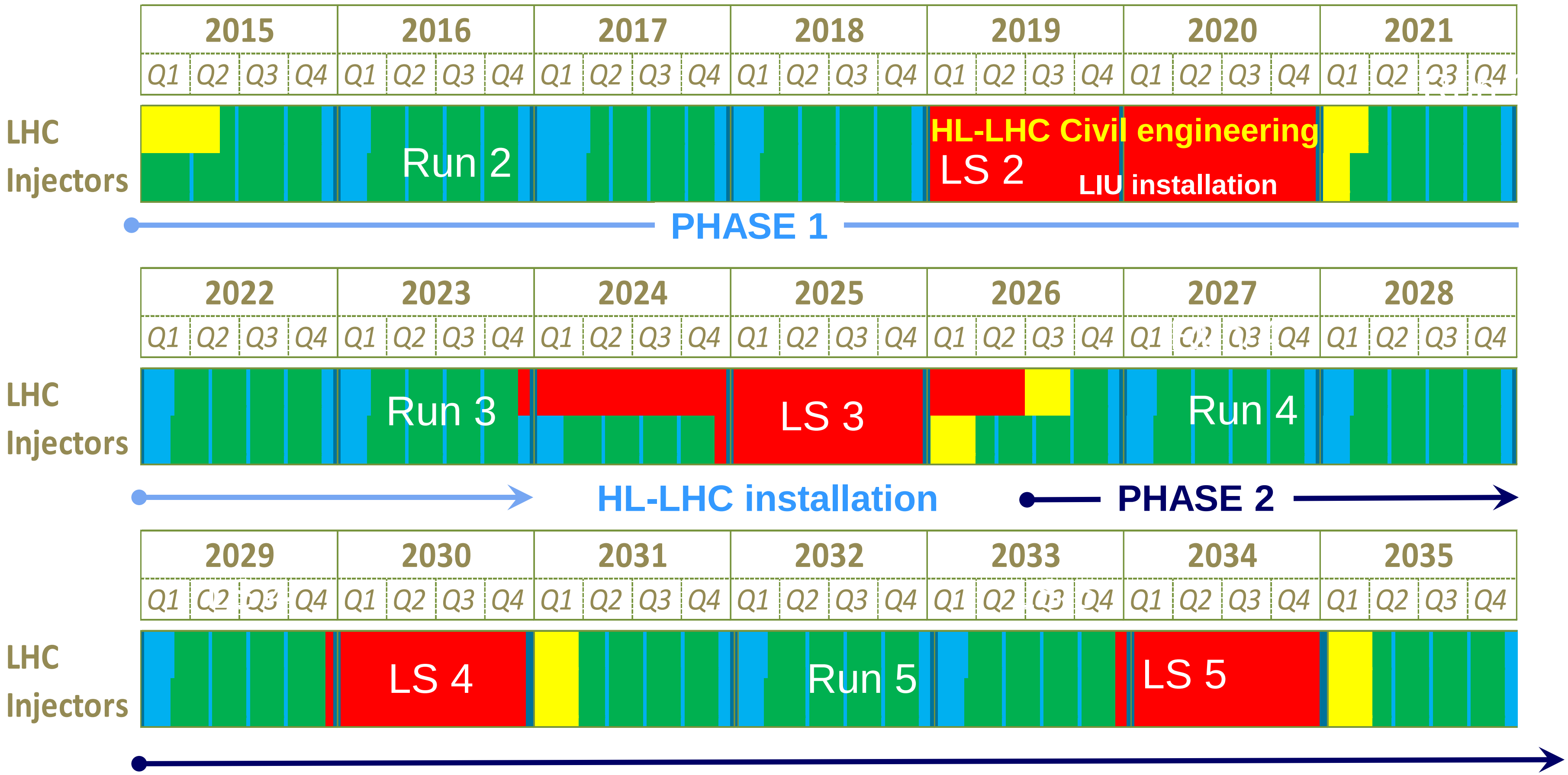
- Physics
- Shutdown
- Beam commissioning
- Technical stop

Goal of 3'000 fb-1 by mid 2030ies

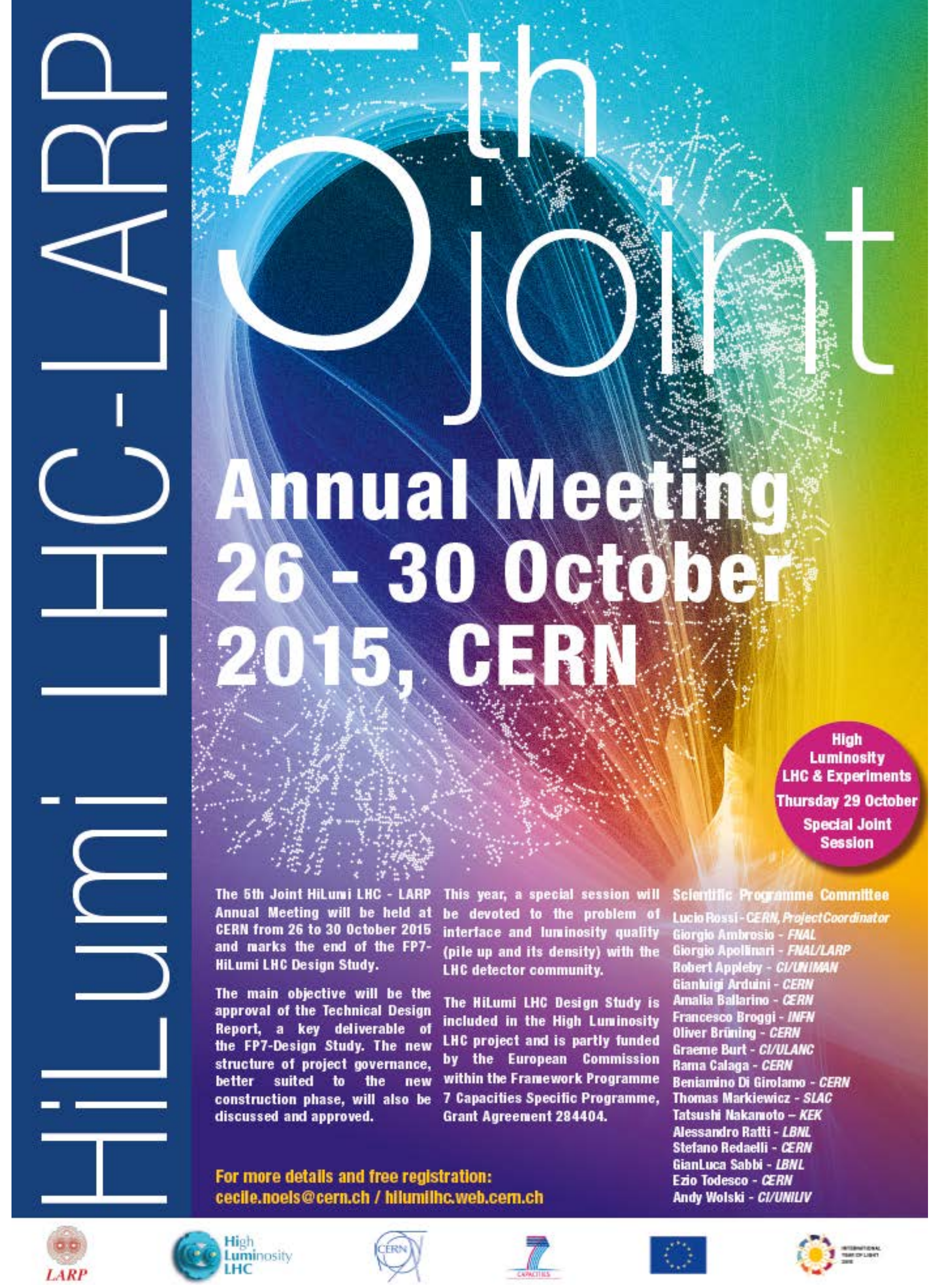
LHC roadmap: according to MTP 2016-2020

LS2 starting in 2019 => 24 months + 3 months BC
LS3 LHC: starting in 2024 => 30 months + 3 months BC
Injectors: in 2025 => 13 months + 3 months BC

Physics
Shutdown
Beam commissioning
Technical stop

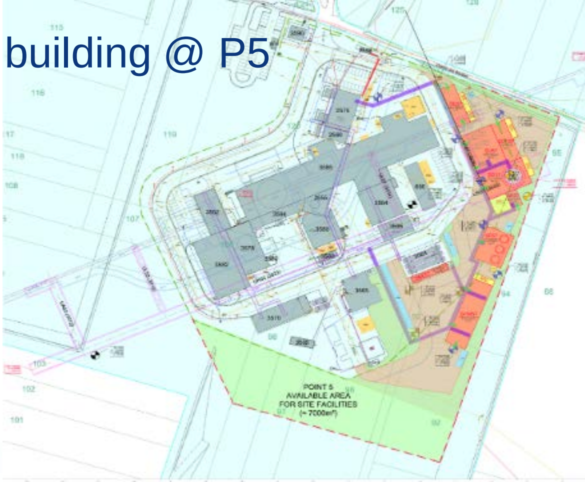


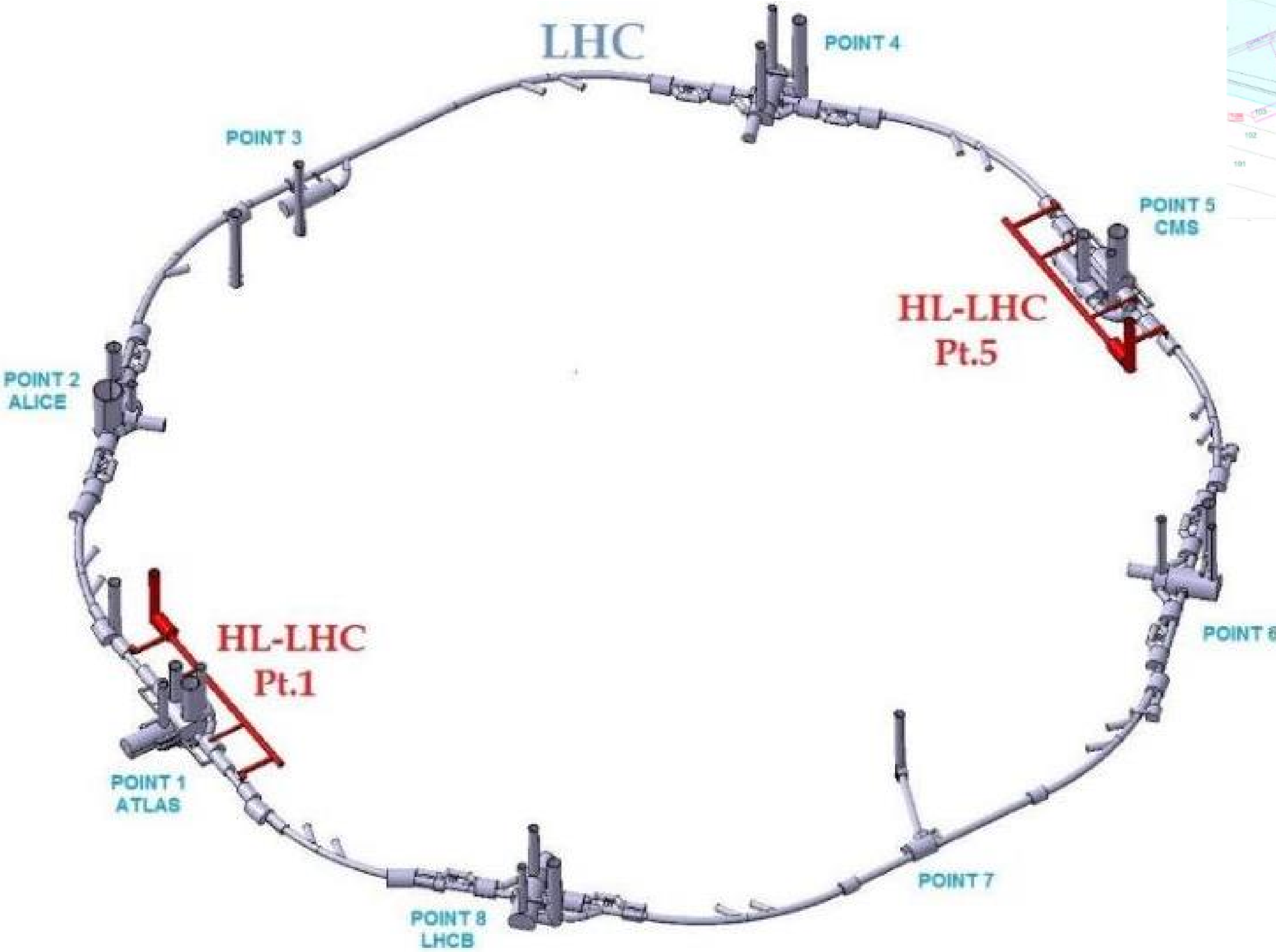

HiLumi LHC-LARP
Daresbury Laboratory, UK
3rd Joint Annual Meeting
11-15 November 2013
High Luminosity LHC Project Kick-off Monday 11 Nov. Special Event
Organizing Committee:
L. Rossi – CERN, Project Coordinator
O. Brüning – CERN, Deputy Project Coordinator
J. Double/C. Noels – CERN, Projects Support
R. Appleby – CI/UNIMAN, Chairperson
D. Angal-Kalinin – STFC
S. Boogert – JAI
G. Burt – CI/ULANC
A. Dexter – CI/ULANC
K. Hock – CI/UNILIV
L. Kennedy/S. Waller – STFC
A. Wolski – CI/UNILIV
The HiLumi LHC Design Study project
is organizing its 3rd Annual Meeting in collaboration with LARP. The meeting will review the progress in design and R&D of the FP7 HiLumi work packages, as well as other work packages. The main scope will be to provide a solid ground for the preparation of the High Luminosity LHC Conceptual Design Report, a key deliverable of the Design Study, due in the first part of 2014.
To mark the recent approval of the High Luminosity LHC project by the CERN Council as first priority for CERN and Europe, a special event called the HL-LHC Project Kick-off will be organized on the afternoon of Monday 11th November, with the participation of directors of the major stakeholders of the project.
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.
For more details and free registration:
http://cern.ch/hilumilhc
High Luminosity LHC
LARP
Science & Technology Facilities Council


HiLumi LHC-LARP
5th joint
Annual Meeting
26 - 30 October 2015, CERN
High Luminosity LHC & Experiments Thursday 29 October Special Joint Session
The 5th Joint HiLumi LHC - LARP Annual Meeting will be held at CERN from 26 to 30 October 2015 and marks the end of the FP7-HiLumi LHC Design Study.
The main objective will be the approval of the Technical Design Report, a key deliverable of the FP7-Design Study. The new structure of project governance, better suited to the new construction phase, will also be discussed and approved.
This year, a special session will be devoted to the problem of interface and luminosity quality (pile up and its density) with the LHC detector community.
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.
Scientific Programme Committee
Lucio Rossi - CERN, Project Coordinator
Giorgio Ambrosio - FNAL
Giorgio Apollinari - FNAL/LARP
Robert Appleby - CI/UNIMAN
Gianluigi Arduini - CERN
Amalia Ballarino - CERN
Francesco Broggi - INFN
Oliver Brüning - CERN
Graeme Burt - CI/ULANC
Rama Calaga - CERN
Beniamino Di Girolamo - CERN
Thomas Markiewicz - SLAC
Tatsushi Nakamoto – KEK
Alessandro Ratti - LBNL
Stefano Redaelli - CERN
GianLuca Sabbi - LBNL
Ezio Todesco - CERN
Andy Wolski - CI/UNILIV
For more details and free registration:
cecile.noels@cern.ch / hilumilhc.web.cern.ch
LARP
High Luminosity LHC

HL-LHC : Civil Engineering

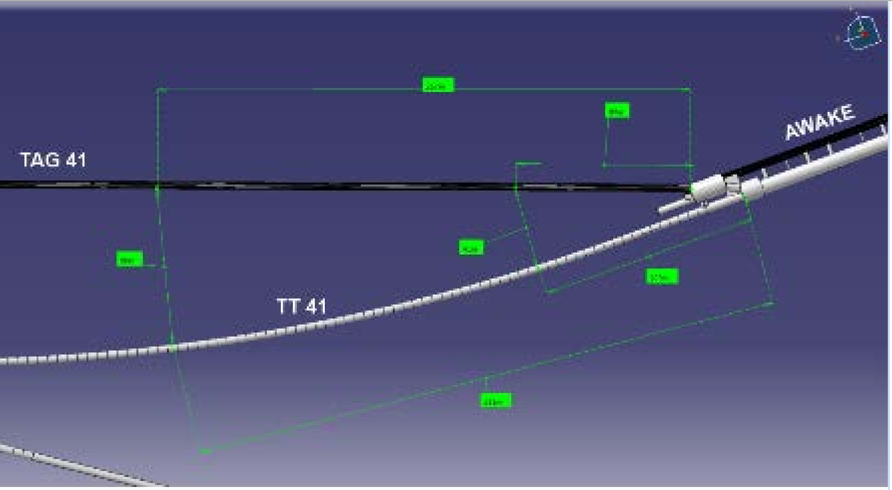
Surface building @ P5

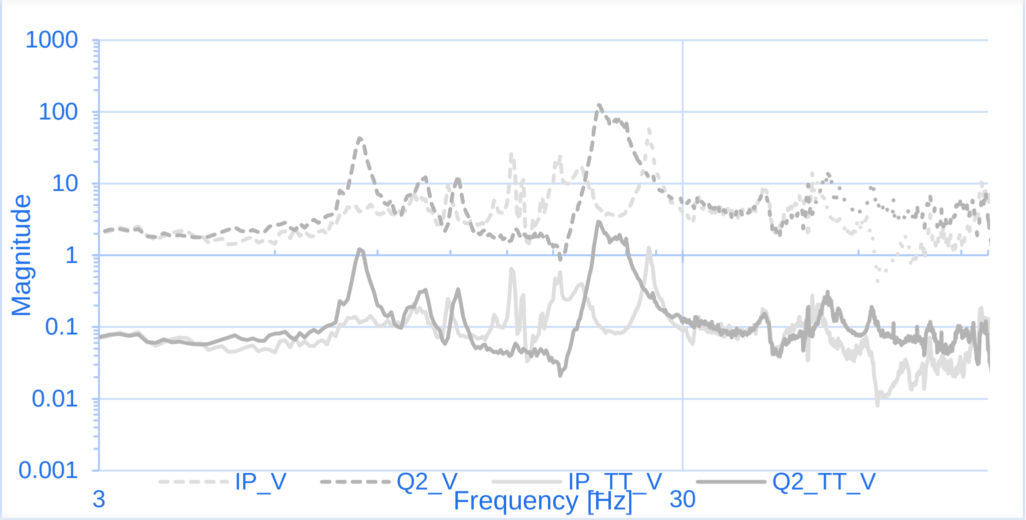




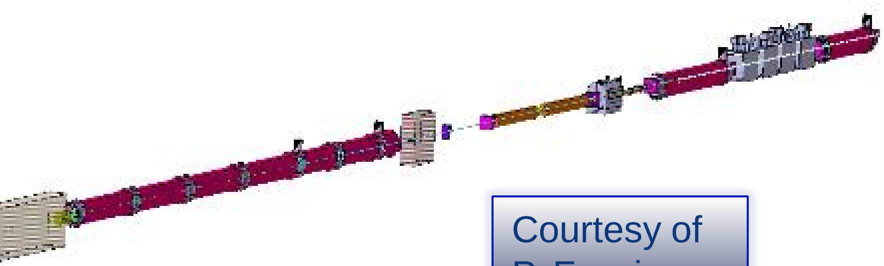
Integration: vibration, machine integration, double decker and more

Vibration studies and measurements



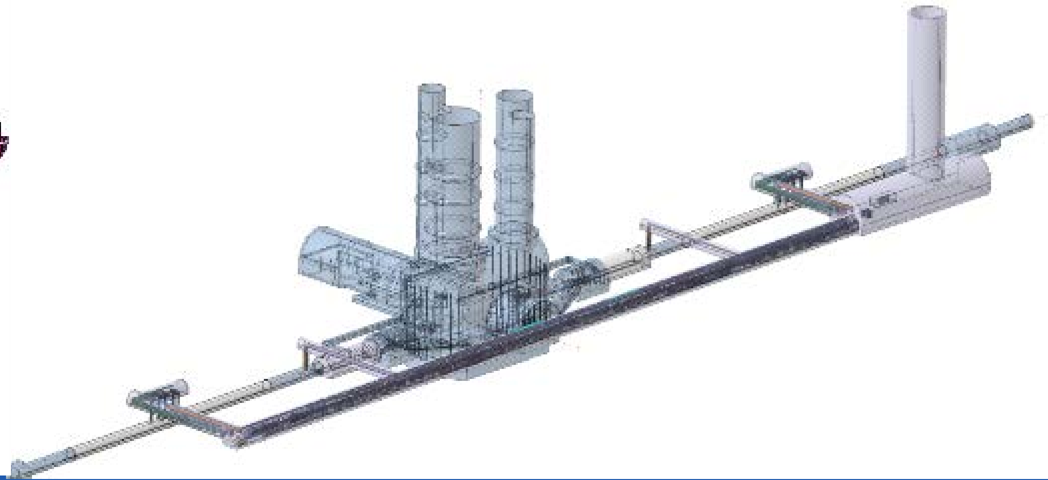


Machine lay-out



Courtesy of
P. Fessia

Double Decker: lay-out and service integration (for WP17)



Conclusions

LHC is operational at 13 TeV c.m.
and with 25ns beams (2x2244 nominal bunches)

From 2016 in production mode

- **6.5 TeV, machine scrubbed for 25 ns operation**
- **β^* = 40 cm in ATLAS and CMS**
- **Rapid intensity ramp up should be possible**
- **Nominal design luminosity 1×10^{34} cm^{-2} s^{-1} should be reached (expectation to go up to ~1.2×10^{34} in 2016)**

RUN 2 goal : 100 fb^{-1} and to reach 300 fb^{-1} at the end of RUN 3

LHC Injector Upgrade (LIU => LS2) and High Luminosity LHC (HL-LHC =>LS3) well defined and now in construction phase

-**Full exploitation of the LHC with optimised planning out to 2035.**

Thanks for your attention