LHC Performance Workshop 2017 - 23-26 January 2017

Chamonix 2017 Summary

F. Bordry

1st March 2017

LHC Performance Workshop (Chamonix 2017)

A great workshop after
a great year 2016
to prepare 2017,
and Run 2, LS2, Run3,…
LIU and HL-LHC

Good proposals, overviews and strategies.

Valuable information & discussions

Active participation of LHC Experiments

8 dense sessions,
and… a lot of debates

LHC Performance Workshop (Chamonix 2017)

Session 1: Lessons from 2016
Chair: Matteo Solfaroli
Scientific secretary: Roderik Bruce

Session 2: System Performance
Chairs: Paul Collier, Mike Lamont
Scientific Secretary: Chiara Bracco

Sessions 3: Operation Performance Optimization for Run 2
Chairs: Paul Collier, Mike Lamont
Scientific secretary: Laurette Ponce

Session 4: Full Energy Exploitation
Chair: Oliver Bruning
Scientific secretary: Andrea Apollonio

Session 5: LIU / HL-LHC common ground talks
Chair: Malika Meddahi
Scientific Secretary: Giovanni Iadarola

Session 6: LIU talks
Chair: Giovanni Rumolo
Scientific Secretary: Giulia Bellodi

Session 7: HL-LHC talks
Chair: Lucio Rossi
Scientific Secretary: Daniel Wollmann

Session 8: LS2 talks
Chair: José Miguel Jiménez
Scientific Secretary: Jean-Philippe Tock

CERN Machine Advisory Committee (CMAC13)

Bai Mei	FZ Jülich
Gourlay Stephen	LBNL
Holtkamp Norbert (chair)	**SLAC**
Koseki Tadashi	KEK
Qing Qin	IHEP
Seidel Mike	PSI
Vedrine Pierre	CEA
Nagaitsev Sergei	*FNAL (absent)*
Delille Benoit, Zerlauth Markus (scientific secretaries)	**CERN**

Closed session on Friday 27th January at CERN
CMAC Close out : Friday 27th January at 13h30

CMAC13 charge

- Recommend 2017/2018 running conditions (choice of optics, Beta star …) based on lessons learnt from run 1 and 2016 operation;
- Recommend strategy for time sharing between physics production in view of the global Run2 goal (100-120 fb^{-1}) and operational developments for Run3 and the efficient machine exploitation with LIU/HL-LHC parameters;
- Recommend strategy to reach 14 TeV after LS2 based on the identification of limitations that currently prevent operating LHC at full energy;

- Review the redefined **LIU performance reach recently aligned with HL-LHC needs**;
- Review the HL-LHC ability to reach the **initial (unchanged) performance goals of 3000 fb^{-1} integrated luminosity** (respectively 4000 fb^{-1} for the ultimate configuration), a mean pile-up of 140 (ultimate 200) and around 250 fb^{-1}/year, **taking into account decisions taken during the 2016 re-baselining exercise of the HL-LHC project**;
- Review the LS2 project status, assess the evaluation of resources needs and areas of high risk of schedule overrun.

2nd Cost & Schedule review of LIU and HL-LHC (CMAC12)

(17th -19th October 2016)

www.cern.ch

2nd HL-LHC/LIU Cost & Schedule review 17-18-19 October 2016

Goal : Assess the C&S status of both projects, taking into account baseline changes since the previous C&S review.

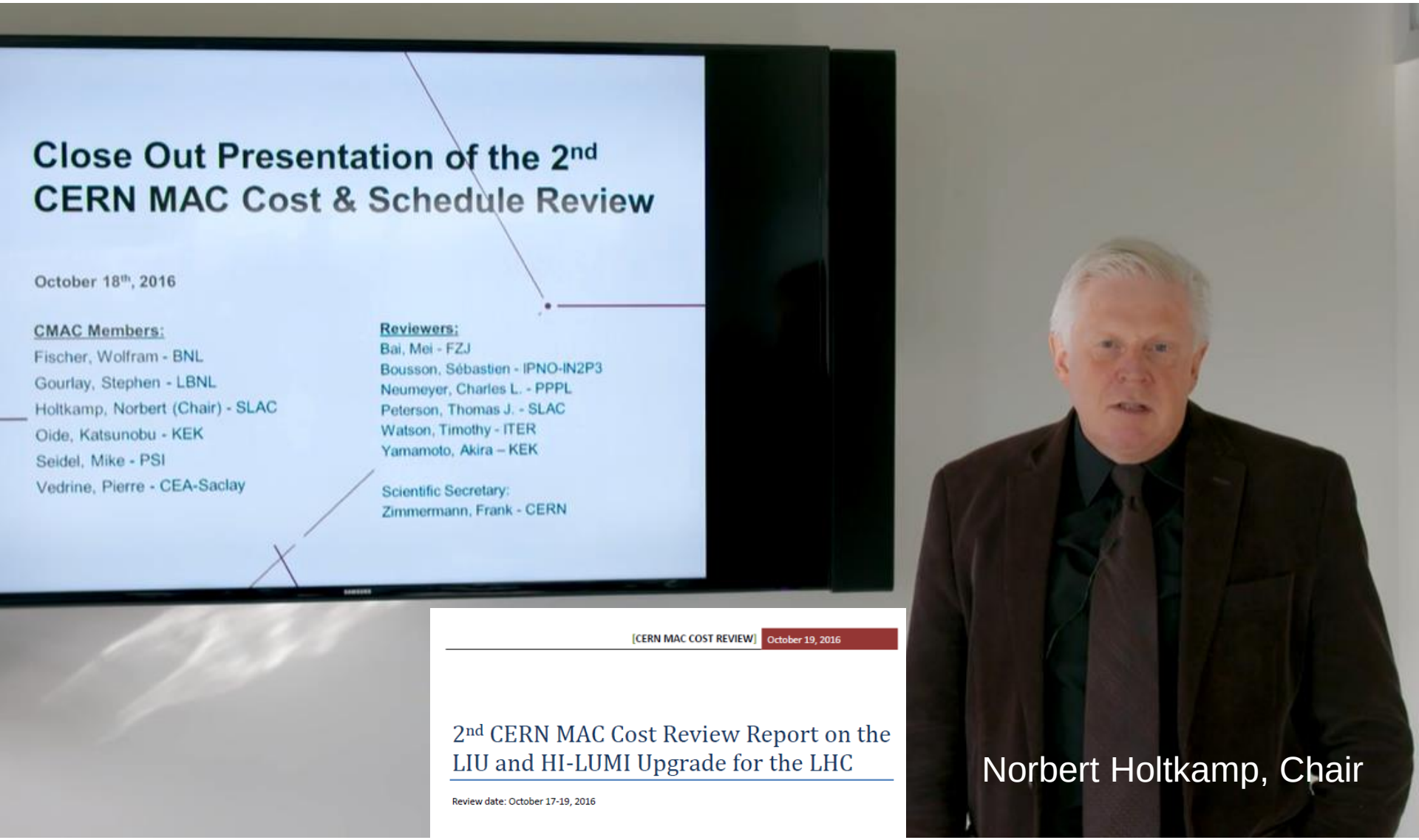
Scrutinize

- Projects status and progress, in particular the identification of critical pieces of hardware on schedule or cost point of view **(where we are);**
- Baseline changes since the previous C&S review, reasons for these changes and impact on the scope, schedule and cost **(what has changed);**
- Change-management methods, and their implementation since the previous C&S review **(how these changes are traced and validated);**
- Global evolution of the cost and schedule of both projects, of the level of risks and uncertainties **(what is the global impact).**

HL-LHC Civil Engineering & Technical Infrastructure WP **(WP 17)** :

1st external review

It was not a technical review !



[CERN MAC COST REVIEW] October 19, 2016

2nd CERN MAC Cost Review Report on the LIU and HI-LUMI Upgrade for the LHC

Review date: October 17-19, 2016

Edited: Norbert Holtkamp

Authors:

CMAC Members: W. Fischer (BNL), S. Gourlay (LBNL), N. Holtkamp (SLAC), K. Oide (KEK / CERN),

Q. Qin (IHEP, did not participate), M. Seidel (PSI), P. Vedrine (CA-Saclay),

Invited Experts: M. Bai (FZJ), S. Bousson (IPNO-IN2P3), C. Neumeyer (PPPL), T. Watson (ITER), A. Yamamoto (KEK / CERN)

Scientific Secretary: F. Zimmermann (CERN)

2nd C&S summary

[CERN MAC COST REVIEW] October 19, 2016

Executive Summary

The review committee again is very impressed with the enormous amount of work that was presented. Both, the LIU team and HL-LHC team continue to perform at a very high level and an enormous amount of work has been accomplished since the last review. Both teams addressed the recommendations from the last review as well and dealt with new challenges which developed over the last eighteen months.

- **"Clean Bill of Health" delivered at the 1st C&S review has been confirmed**

- **LIU and HL-LHC projects on budget and schedule (-2 months);**
  no technical review; to be done in Chamonix'17
- **Actions to key recommendations already implemented (mainly HL-LHC WP17)**
- **Detailed recommendations in the hands of the Project Leaders and WP Leaders**

- **Succession plan for experts in certain critical domains to be addressed**

- **C&S review is a milestone that keeps all teams synchronized and aligned with the project baseline**
- **Frequency of the review set to 18 months (Next C&S review March-April 2018)**

LHC goal for **2016 and for Run 2 and 3**

Integrated luminosity goal:

2016 : ~ 25 fb^{-1} at 13 TeV c.m

Run2: ~100 fb^{-1}

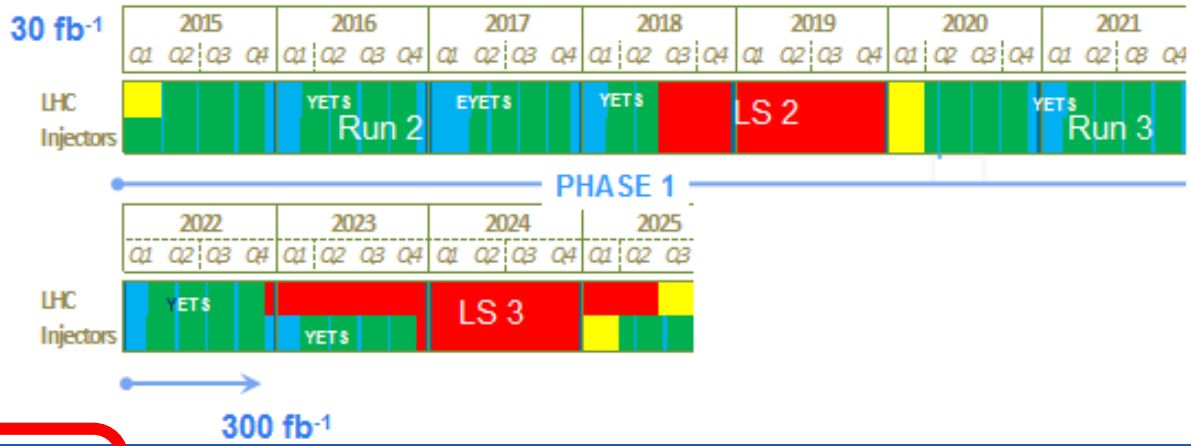
Prepare for (or go to) 14 TeV operation

300 fb^{-1} before LS3

Chamonix'16 recommendations

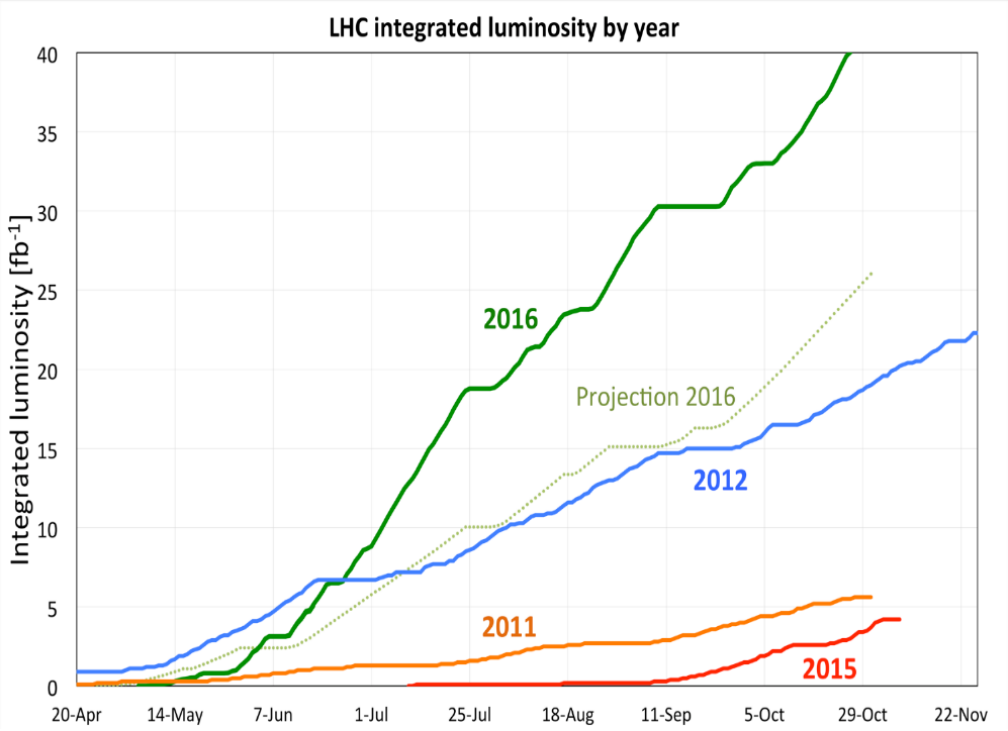
Peak luminosity

> 1 x 10^{34} cm^{-2}s^{-1}

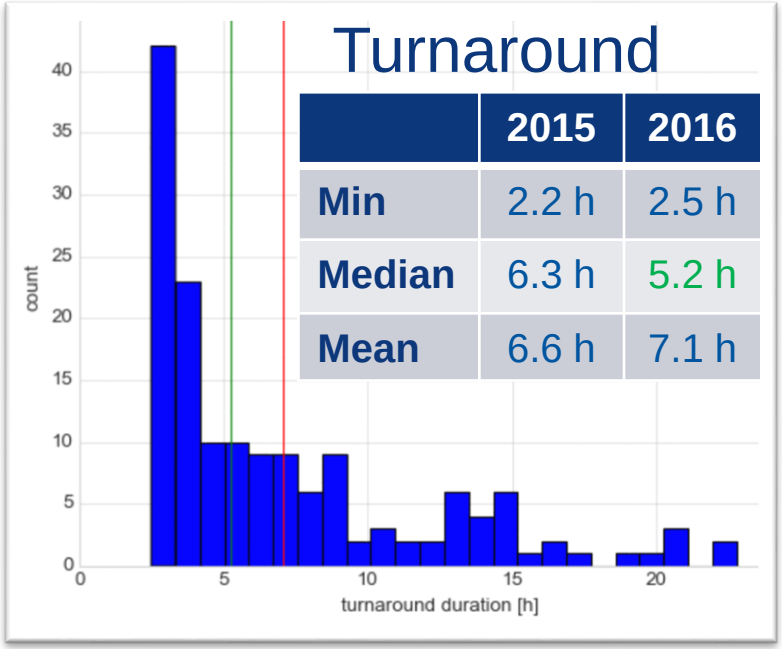


2016 main achievements

- Achieved **stable operation with high intensity beams** in presence of e-cloud (increase of bunch intensity for scrubbing was limited by SPS beam dump non-conformity)
- Established stable operation at **reduced (40 cm) beta***
- **Identified working point** for beam stability (chromaticity, octupoles, transverse damper, tune separation, coupling)
- **Deployed** routine operation with **high brightness** beam for high luminosity (Batch-Compression-Merging-and-Splitting, BCMS)



LHC operation in 2016

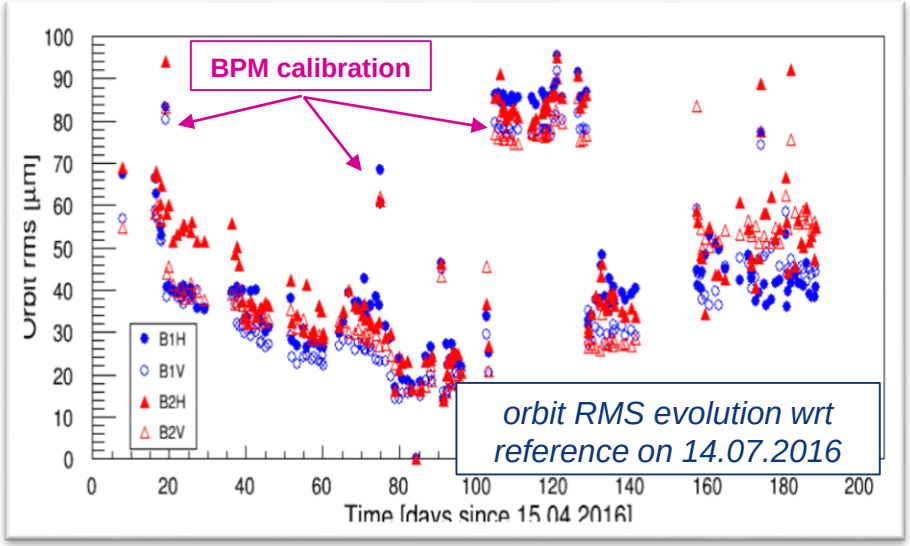


Turnaround

	2015	2016
Min	2.2 h	2.5 h
Median	6.3 h	5.2 h
Mean	6.6 h	7.1 h

The LHC is a **remarkably reproducible** machine, in particular at 13 TeV

- Q: ± 0.002
- Q': ~ ± 2
- Coupling: ~ ± 0.002
- Arc orbit: ± 20-50 µm



Improvements foreseen for **2017**:

- Enhanced Combined Ramp and Squeeze
- New (faster) energy ramp
- Beam parameter optimization

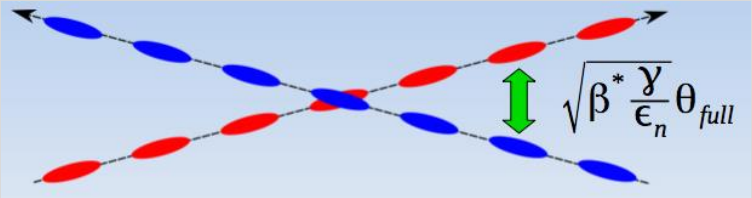
2016 Beam quality in collisions

- E-cloud (still present) defines machine settings with practically no margin
- 8b+4e scheme confirmed stable operation in presence of e-cloud

Losses exceeding burn-off are observed in the first hours of stable beams → The mechanism is not fully understood, but it might be linked to combination of noise and beam-beam effect

Crossing angle successfully reduced during the year

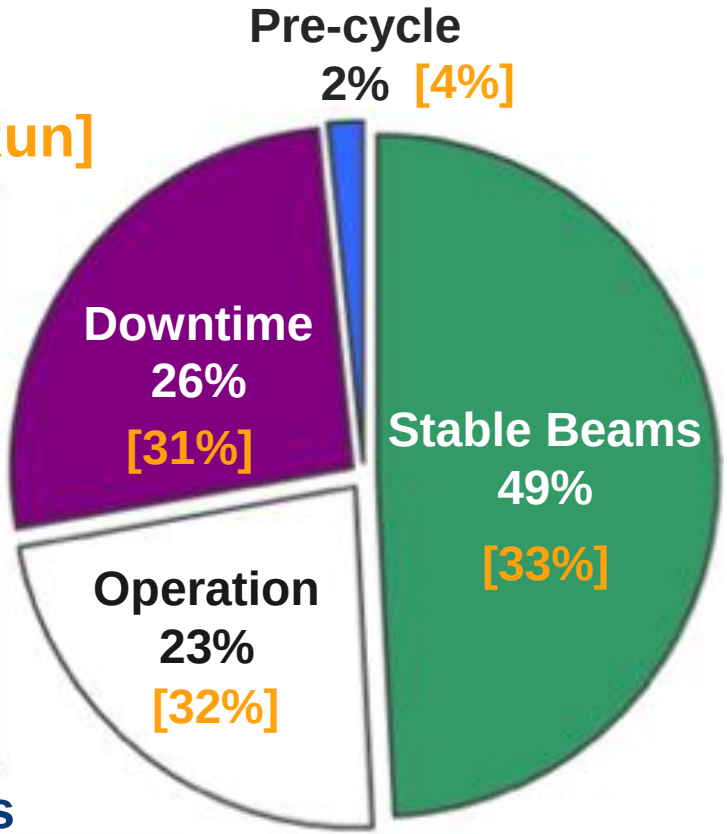
- Acquired operational experience with reduced crossing angle
- Fundamental limit still not reached



Few tests on luminosity levelling by separation in IP1/5 to gain experience on beam stability in such conditions → **No show stopper** due to beam-beam interactions with transverse offset

2016 Availability

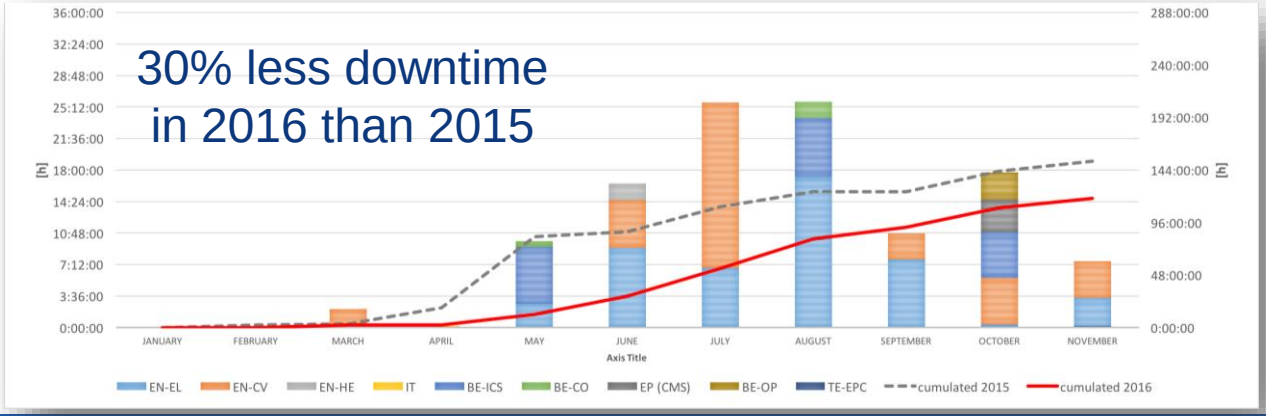
[2015 - 25 ns Run]



Remarkable availability:

- **Increased** operational efficiency
- **Enhanced** system availability
- **New** pre-cycle strategy

Downtime of technical infrastructures



Non-availability of beams from the injector complex is the largest source of LHC downtime

TS1 - TS2 : stable beams 58 %
TS2 - TS3 : stable beams 54 %

LHC Limitations

SPS beam-dump

Nb of bunches per injection limited to 96

Total number of bunches: 2200

LHC Injection kickers

Outgassing from ceramic

Bunch population limited to around 1.1 x 10^{11}

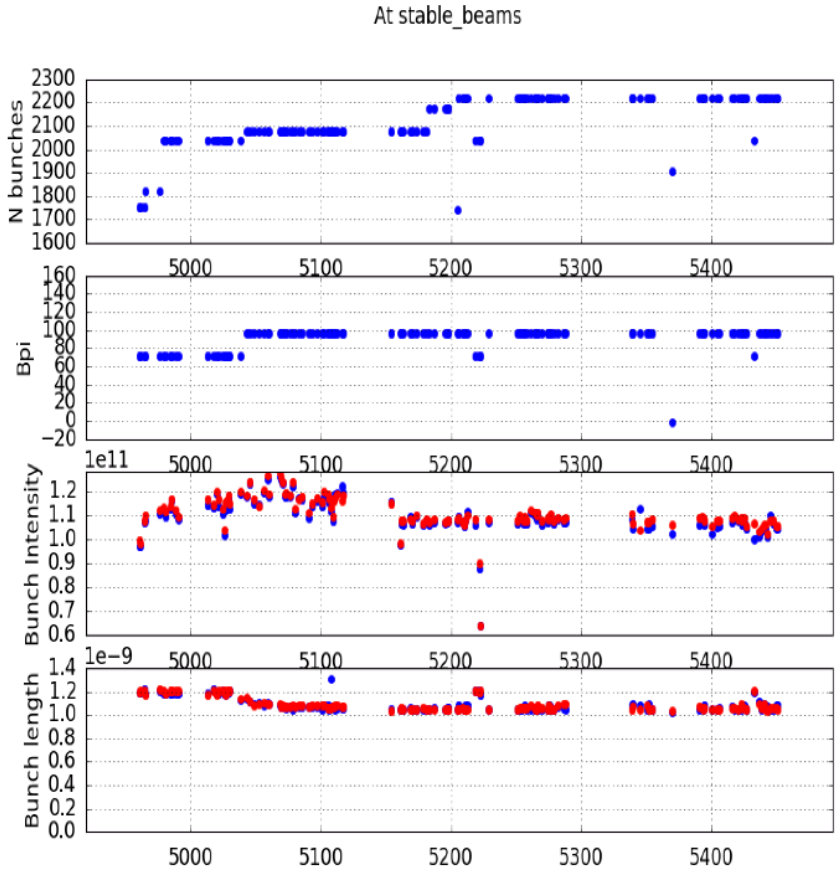
Electron cloud

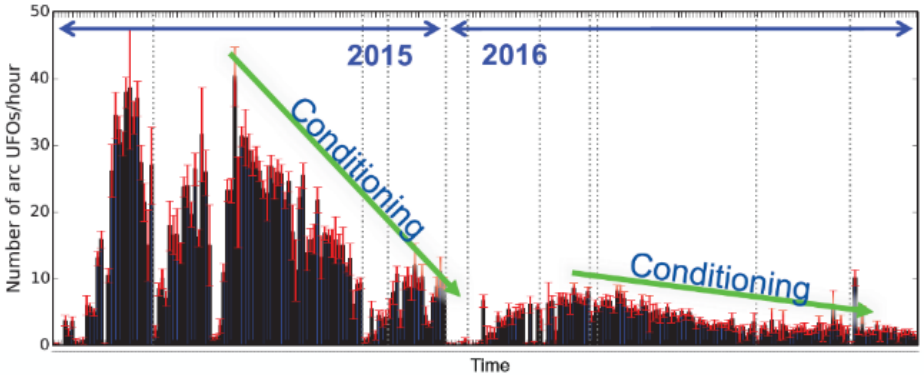
Still significant heat-load within cryogenic limits

Dynamics – well handled by cryogenics feed-forward – no impact on operations in the present conditions

UFOs

Frequency has happily conditioned down





Injection kickers & Beam dump

Injection kickers

- dynamic pressure rise between MKI8D and Q5 limiting number bunch intensity in 2016: increased pumping installed during EYETS
- MKI2D replaced during TS3 2016: ~200 hours conditioning with beam required

Beam dump (LBDS)

- caused less downtime than in 2015 despite 30% more time being spent at 6.5 TeV.
- two generators of the horizontal dilution kickers (MKBH) failed within a week: consolidation of HV switches and generators are under study plus examination of re-triggering strategy

Cryogenics

Excellent availability of 98.6% thanks a number of targeted improvements:

- feed-forward played a crucial role in smoothing the thermal reactions related to the start of collisions and the beam dump

The heat loa
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$cm^{-2}s^{-1}$
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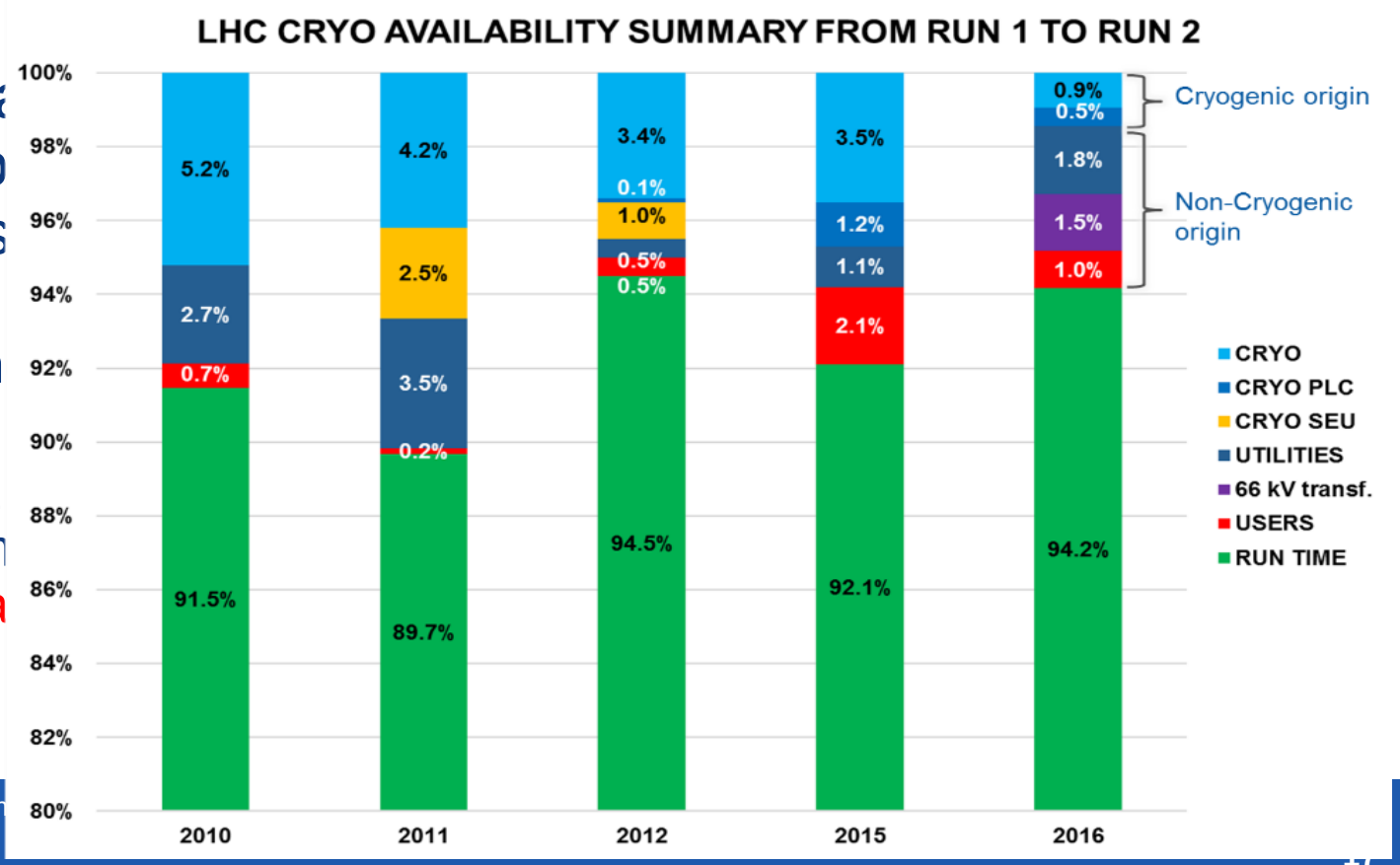

Injectors

The performance of the LHC injectors in 2016 was overall a success as confirmed by the production of high quality BCMS beams which allowed the LHC to reach a beyond design peak luminosity.

Availability generally good but major events caused a total downtime of 360 hours for the LHC

Looking forward to:

- Replacement of the SPS internal dump
- Improved fault tracking
- BCMS and further developments

Magnet circuit performance

LHC magnet circuits and the associated systems recorded an excellent performance in 2016.

But

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N onver e warm
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electrical perturbations.

Cool down started February 15th

2017 scenarios

	Nominal	BCMS	BCMS+
Beta* (1/5) [cm]	40	40	33
Half crossing angle [urad]	185	150	170
No. of colliding bunches	2748	2544	2544
Proton per bunch	1.1e11	1.2e11	1.2e11
Emittance into SB [um]	~3.2	~2.3	~2.3
Bunch length [ns]	1.05	1.05	1.05
Peak luminosity [$cm^{-2}s^{-1}$]	~1.1e34	~1.7e34	~1.8e34
Peak pile-up	~28	~48	~52
Luminosity lifetime [h]	~24	~15	~14

2017 plans

- Keep pushing performance and **availability (~50%)**
- BCMS beams (Smaller emittance though cycle; lower electron cloud heat load; faster intensity ramp-up; lower total beam current; lower losses; better for R2E... pile-up ?) **=> maximize integrated luminosity**
- Starting with ATS optics; β^* = 40 cm and later towards 33 cm

  (would deploy HL-LHC optics and open up the exploration of its possibilities)

  => expect to reach 1.7 to 1.9 10^{34} cm^{-2} s^{-1} (inner triplet cooling limit ?)

- Look forward to HL-LHC without compromising present performance: ATS, beta* levelling, RF full de-tuning, electron cloud,...
- Look forward to the post-LS2 LIU era and how to exploit the potential

2017 special runs ?

- 5 TeV pp reference run (for Pb-PB and p-Pb physics analysis)
  - LHCC should recommend if to do at end of 2017 or end of 2018 just before the ion run
  - LHCC should define the duration: 7-10 days or 4-5 days of stable days

- High β* run at low energy (900 GeV/2 TeV ?)
  (TOTEM and ATLAS(ALFA)
  - 2018 or Run 3 ?
  - To schedule 1 day of machine time in 2017 to investigate possibilities ?

- 90 m-like β* run with maximum luminosity
  (TOTEM and ATLAS(ALFA)
  - LHCC: 2018 ? Duration : ~1-2 weeks including setup

LHC Energy Exploitation

Full Energy Exploitation of the LHC mandate – Chair: Oliver Bruning

Main scope and goal:

Part of a general study that is divided into 3 parts:

I. Implications for pushing the LHC to 7 TeV (nominal energy)
II. Implications for pushing the LHC to 7.7 TeV (ultimate energy)
III. Implications and feasibility for pushing the LHC beam energy beyond ultimate by replacing some of the LHC magnets with 11T magnets

Chamonix'17 session addressed Part I :

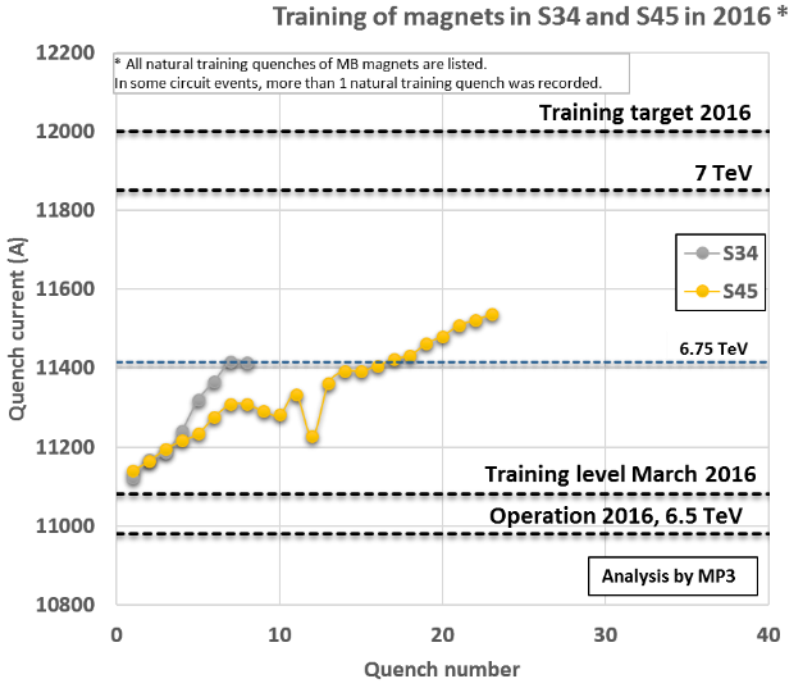
Time required for training all magnets to 7TeV

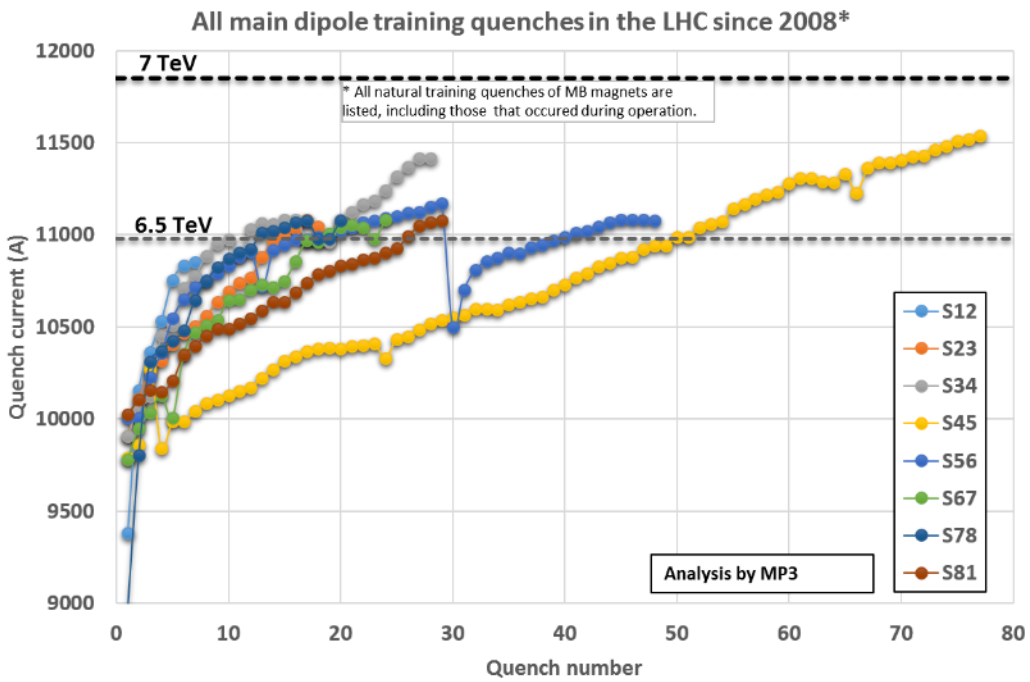
➔ provide robust data to the management for estimating the performance reach if the LHC is pushed to 7TeV before LS2

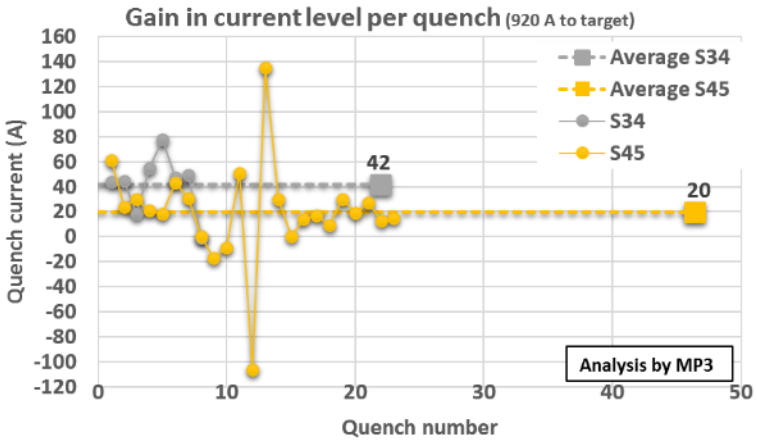
Perform training campaigns in S34 and S45 before EYETS 16/17

➔ Explore if there are any 'unforeseen' obstacles when training a large fraction of the machine to 7TeV

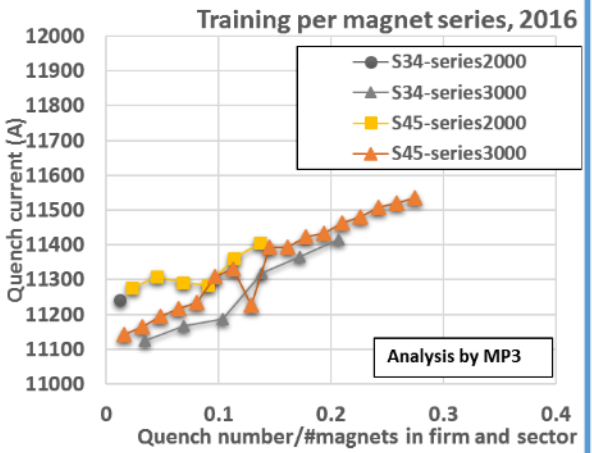
MB Training campaign 2016, December 5 - 14







	Training quenches December 2016		
	Series 1000	Series 2000	Series 3000
RB.A34	1	1	6
RB.A45	0	6	17
total	1	7	23



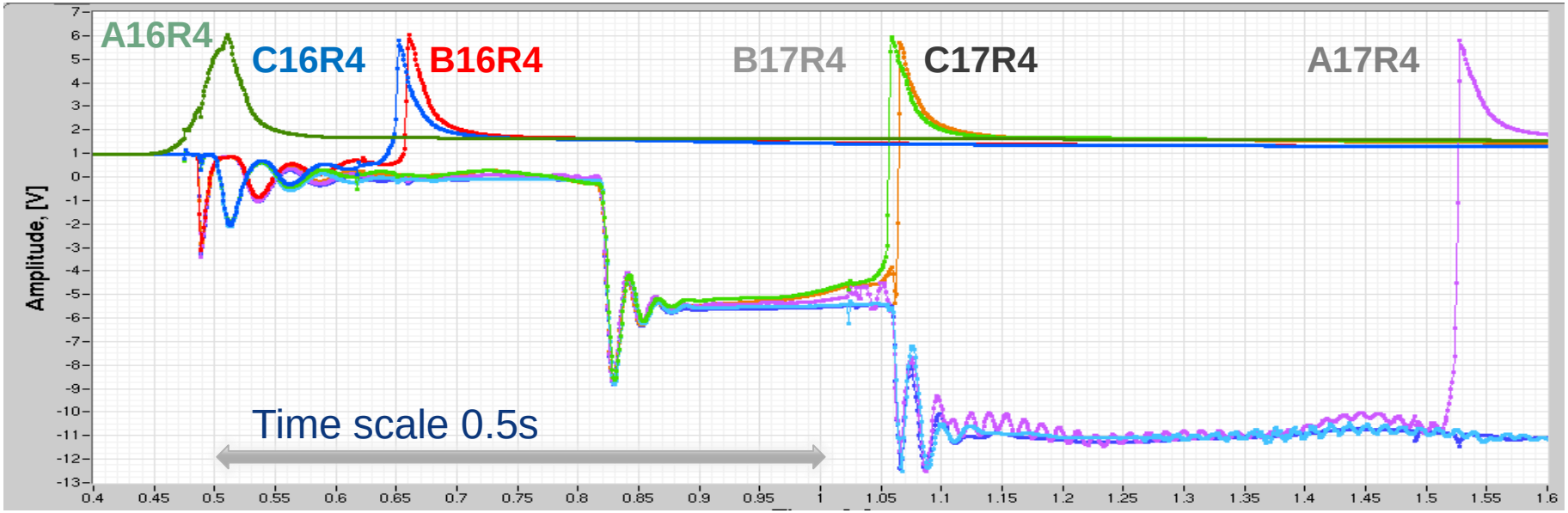
LHC Energy Exploitation

Observations from the training campaign:

Multiple magnet quenches during a given training quench event:

- Multiple training quenches and / or EM coupling (timescale < 1s)
  + heat propagation at lower current ➔ multiple quenches.
- Possible cascade effect for quenches at higher magnet current.

Example: I=11521 A with 6 quenches triggered by nQPS and iQPS



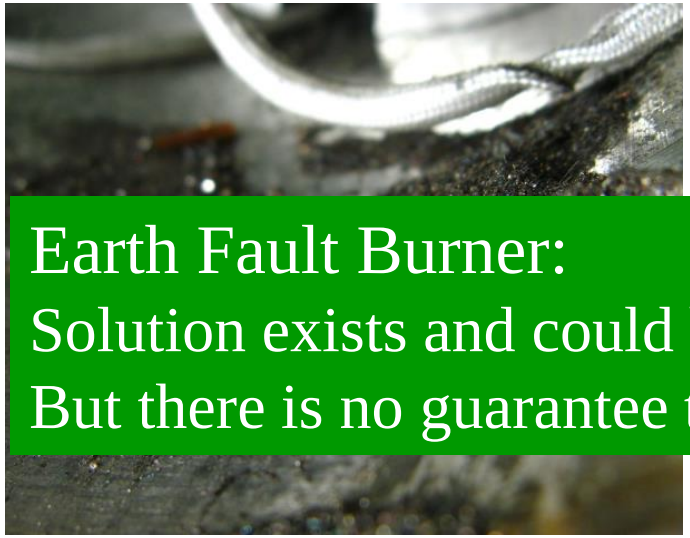
LHC Energy Exploitation

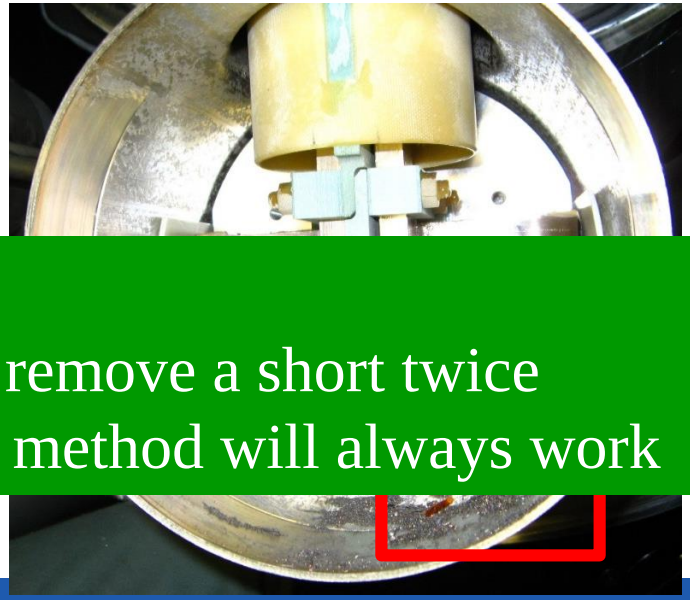
Unforeseen obstacles:

Short in the diode box following a training quench:

=> released energy during quench at high energy is capable of displacing debris that has collected in the diode box

=> Second incident during training in ca. 252 quenches (but had also 5-6 shorts before LS1)





Earth Fault Burner:
Solution exists and could by now remove a short twice
But there is no guarantee that this method will always work

Beam energy : **Run 2 @ 13 TeV c.m.**

NO change of beam energy in 2017 and 2018

Goal is to prepare the LHC to run at 14 TeV during Run 3.

Preference to make the change in energy in a single step.

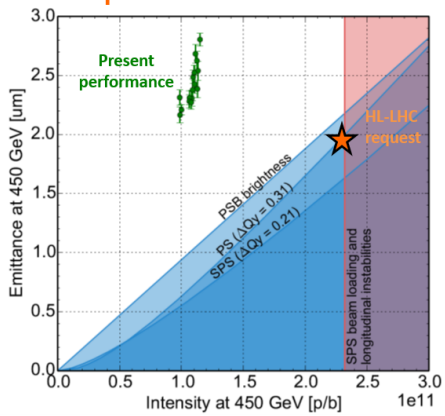
Study how to reinforce the insulation (and to clean) during LS2 the electrical part connecting the dipole bypass diode. Powering tests before and during LS2 should be defined

Working group was set up after Chamonix'17 workshop:
How ?, How long ?, How much ?

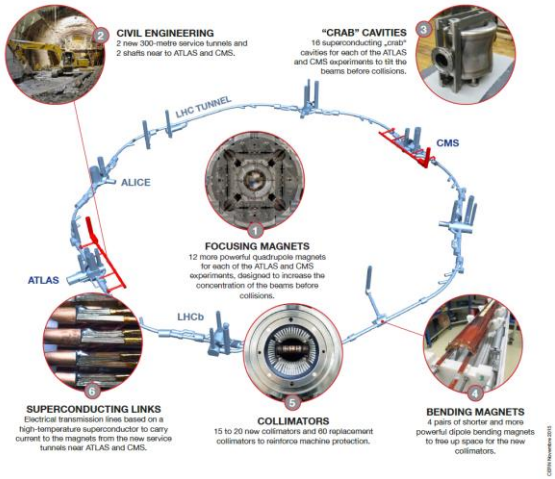
LIU & HL-LHC project

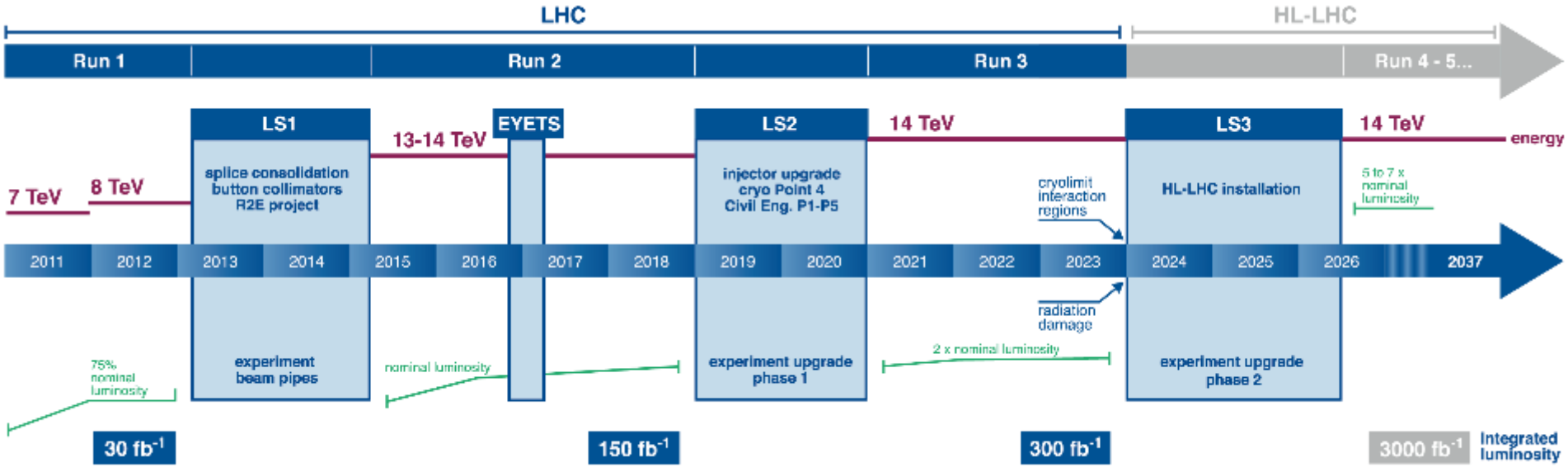
formal approval by CERN Council (June 2016)

LIU performance reach for protons with SPS impedance reduction

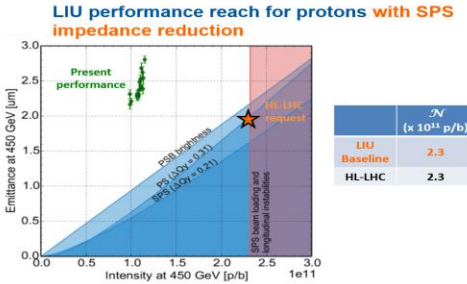


	$\mathcal{N}$ (x 10^{11} p/b)	ε (μm)
LIU Baseline	2.3	2.2
HL-LHC	2.3	2.1





LIU and HL-LHC common grounds



	$\mathcal{N}$ ($\times 10^{11}$ p/b)	ε (μm)
LIU Baseline	2.3	2.2
HL-LHC	2.3	2.1

Baseline and beam parameters - protons

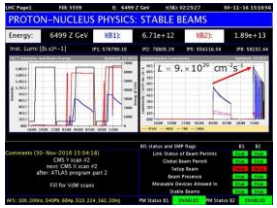
HL-LHC

- The present **baseline is compatible with the integrated luminosity goal** (250 fb^{-1}/year, luminosity levelled at $5x10^{34}$ $cm^{-2}s^{-1}$) relying on LIU to deliver bunches with **$2.3x10^{11}$ p/bunch**
- Several **options** are being studied to **further increase performance** (BCMS+, 80b trains, dynamic crossing angle to further push β*) and for **risk mitigation** (flat beams, 8b+4e, 200 MHz main RF)

LIU

- The **baseline upgrades** (including SPS impedance reduction, following C&S Review 2015) allow reaching **beam parameters compatible with HL-LHC requirements**
- Main **risk factors** (PS longitudinal instabilities and SPS losses at low energy) are being investigated in order to define **suitable mitigation measures**

LIU and HL-LHC common grounds



Baseline and beam parameters - ions

HL-LHC

- The **baseline upgrade meets the goal of accumulating 2.85 nb^{-1}** in each Pb-Pb run (with 3 experiments; 10nb-1 before LS4). This relies on the injectors providing beams with **50 ns** bunch spacing and bunch intensities of **1.9x10^{8} ions/bunch**
- Specific **upgrades on the collimation system**, i.e. new collimators in the dispersion suppressors of IR2 and IR7, will be **implemented in LS2**
- **LHCb** expectations for post-LS2 still need to be clarified

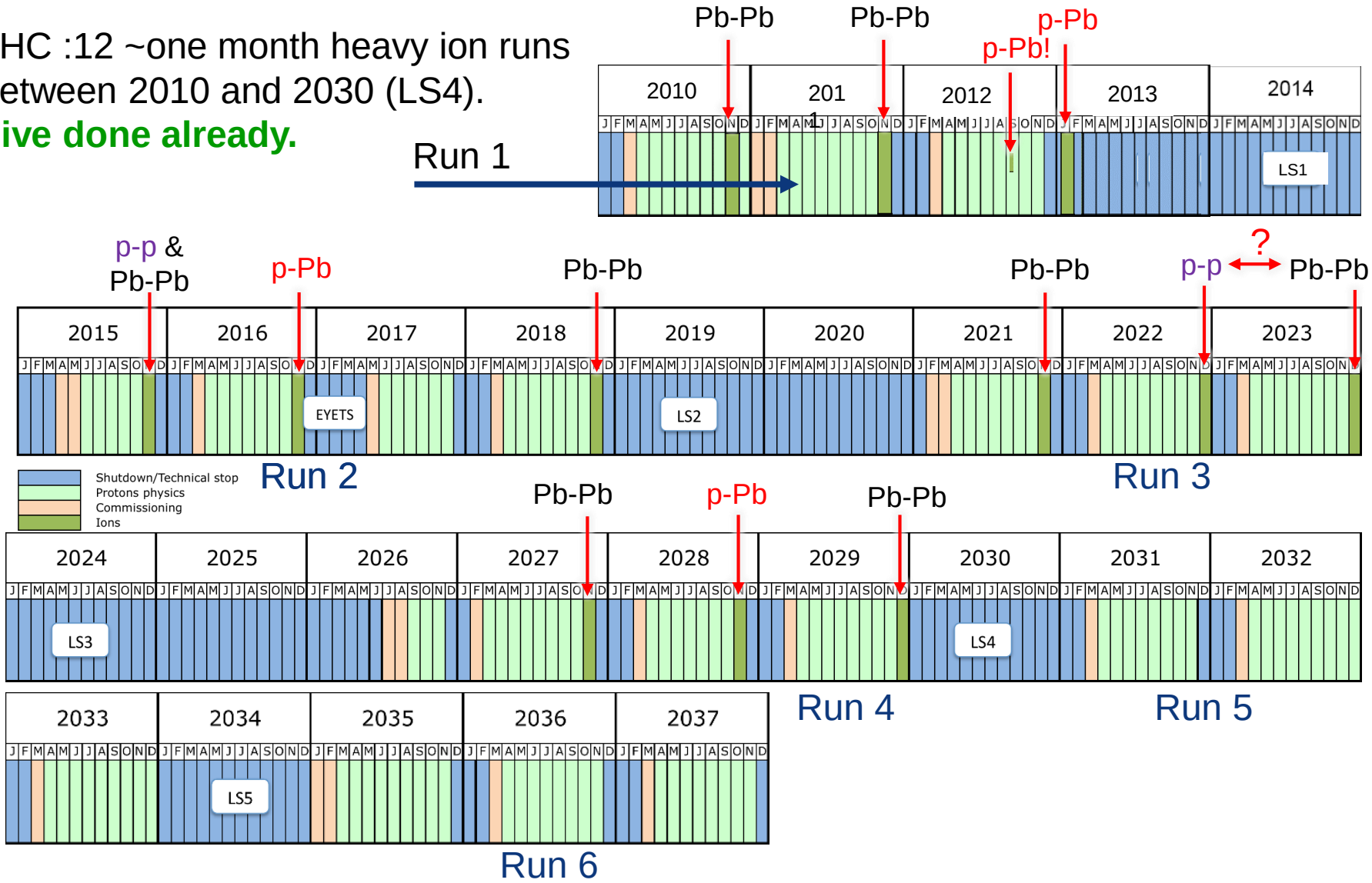
LIU

- Ion **chain restarted earlier in 2016** to allow for extended period for **studies** and machine **optimization** → **doubled intensity per PS batch** injected in the LHC
- **Earlier start** of ion chain **requested also for 2018**
- This performance together with the implementation of **momentum slip-stacking** in the SPS after LS2 (new low-level RF), allows meeting the **HL-LHC requirement.**
- Investigate **swapping 2021 ion run with 2023 p-p reference** to have more time to commission SPS slip-stacking

LHC heavy-ion runs, past & future

LHC :12 ~one month heavy ion runs between 2010 and 2030 (LS4).

Five done already.



LIU and HL-LHC common grounds

Protection devices in the whole accelerator chain will be upgraded for beams with higher intensity and brightness. Main examples:

- **SPS internal dump** will be replaced with a re-designed version with improved shielding and vacuum performance
- **TCDI collimators** in the SPS-to-LHC transfer lines will be replaced with longer and more robust devices
- **TDI injection dumps** will be replaced with re-designed versions featuring better impedance, cooling and vacuum
- A large fraction of **LHC collimators** will be replaced with low impedance ones

Crab cavity tests in the SPS

- This will allow testing for the **first time** crab cavities in a **high current and high energy proton machine**
- After one year of fabrication the project is **on track** for installation in 2017- 2018 YETS but **schedule is tight.** Anyway important to have this test facility during Run 3 to advance crab cavity commissioning.

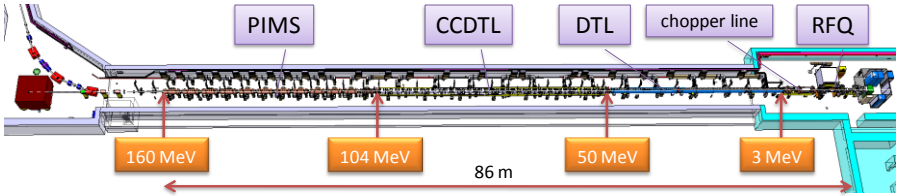
LIU

LIU-ions PS injectors

Unprecedented performance of Linac3 and LEIR in 2016

- Higher current from Linac3 thanks to bottleneck removal after source
- 40% more current out of LEIR thanks to space charge mitigation

Need of adequate tools and additional support from the operations team for beam monitoring and tuning



Linac4

In November 2016, Linac4 served the **Half Sector Test (HST)** with 15 mA of 160 MeV H^- beam

- Quality of the Linac4 beam (e.g. phase/energy stability) to be improved to complete the HST measurement campaign

Actions identified to control emittance from source and improve the transmission through Linac4 to realistically reach 30 mA

Reliability run in 2017, relying on support from equipment groups, must begin in time and is crucial to prove future operation of Linac4

LIU

LIU-PSB

PSB will be ready for an early 160 MeV connection to Linac4 by mid 2017

HST (temporary) and the Stripping Foil Test Stand (permanent) installed in Linac4 during summer 2016

HST has already provided relevant outcome (e.g. discovery of design/fabrication issues and mitigation, preparation of controls and applications, test of instrumentation)

De-cabling campaign going well and completion of new main power converter building completed

10 modules of Finemet cavities used operationally in Ring4 throughout 2016

LIU-PS

Most activities (2 GeV injection, magnets, instrumentation) in execution phase of procurement, manufacturing, installation

LHC beam with 2e11 p/b demonstrated at PS extraction (large transverse emittance, nominal longitudinal emittance) with the fraction of upgrades presently in place

→ **2017 will aim at understanding and producing higher current with required beam quality**

LIU

LIU-SPS

All activities (200 MHz renovation, LSS5 dump, impedance reduction + partial a-C coating , protection devices) on track

Proton beam performance

Inclusion of impedance reduction in LIU baseline allows reaching desired HL-LHC beam parameters at extraction

Losses at injection important bottleneck being studied in synergy with PS performance to define clear mitigation strategy (Q22 optics)

Ion beam performance

LIU single bunch parameters demonstrated at SPS extraction

Slip stacking crucial (and high risk) to meet HL-LHC requirements.

If not: reduction by almost a factor 2 the number of bunches and then 30-40% less integrated luminosity

LIU safety and Radiation Protection (RP) aspects

Safety documentation being produced for all identified LIU Safety Packages

RP LIU Work Packages actively working on critical items, such as Linac4 connection, new dumps, new intercepting devices

Waste handling:

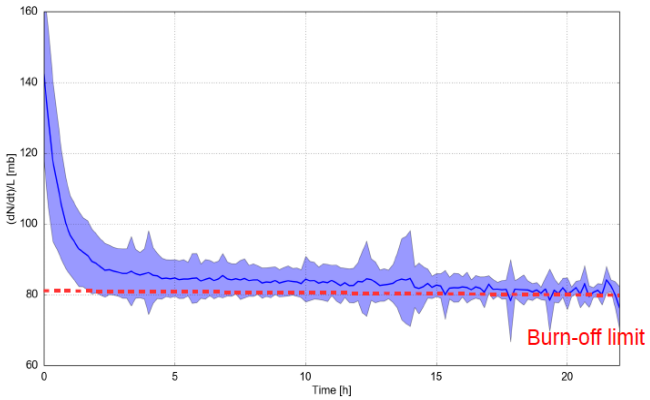
Conventional waste inventory to be filled in

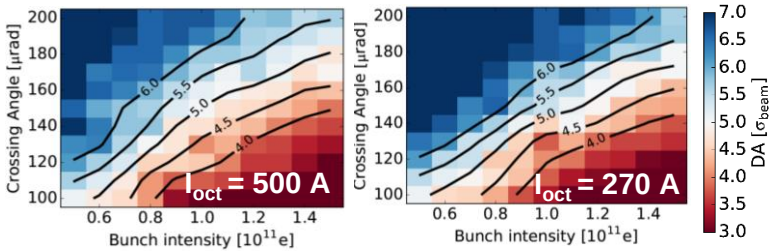
Strategy for radioactive waste management defined

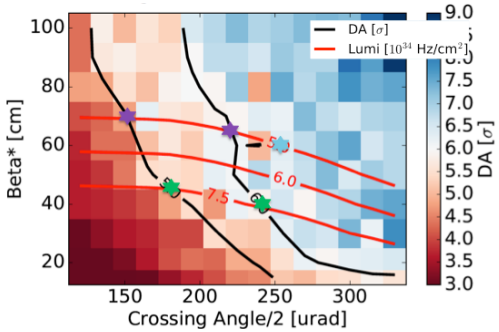
HL-LHC

HL-LHC: performance sensitivity to parameters change

- Luminosity decreases at start of SB **faster than expected** → source not understood.
- Reduction of dynamic aperture < **dynamic aperture (DA) < 5 σ** leads to reduced beam life time.
- Simulations indicate sources of DA reduction :
  - **High octupole currents** → adjust crossing angle
  - **LHCb polarity** → adjust working point
- **Beam beam wire compensators** (LRBB) could **improve dynamic aperture by 1 – 2 σ** → 2017 and 2018 Tetst!
- **Reduction of crossing angle** during **beta* leveling** → increased leveling time → increase in **integrated luminosity** (1-2 %); reduction of **pile up density** (10 – 15 %)
- Using the above methods may **allow re-establishing** the margins for **old baseline**.
- **Gain operational experience** in LHC using some mitigations after successful validation in MDs.





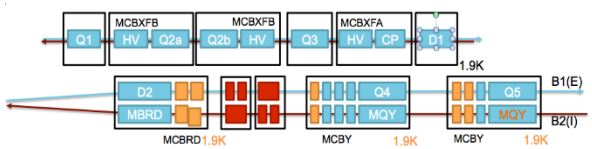


Nominal and ultimate scenario (2.2e11p/bunch). Full crabbing (190urad) achievable with aggressive DA = 5σ

HL-LHC

Can we simplify the correctors and magnet circuits for HL-LHC?

- HL-LHC requires **extra corrector strength** for orbit adjustments at crab cavities and un-anticipated needs → additional correctors in MS.
- Possible simplifications for **Q4 / Q5 corrector** circuits:
  - **3 instead of 4** correctors → no change of crossing plane; no additional CC.
  - Powering of two correctors in **one circuit** → possible impact on availability



- Compensate reduction of DA at beta*=15 cm by
  - **Additional sextupole** correctors in Q10 (IP1 / 5);
  - **Disconnect focusing sextupoles** in Q14 (under study to identify additional impacts);
- ATS optics requires **170 T/m for Q5** left of IP6 (MQY) (today's limit at 4.5 K 160 T/m) → go to 1.9 K (baseline) or push magnet @ 4.5 K during HW commissioning.
- 120 A trim in **Q2a/b of triplet** avoided by including **response functions** in magnetic model.

Review of the present non-conformities in view of HL-LHC

- **Existing non-conformities** in magnet system are well documented by MP3.
- HL-LHC will be **more sensitive** to missing circuits than current LHC, due to telescopic squeeze → **consolidation before HL-LHC era**.
- **Time evolution** of non-conformities not know → **Re-testing** of some **critical non-conformities** foreseen in coming **hardware commissioning** campaign**.**
- Future **nested triplet orbit correctors** will be **more robust** → larger operational margins.

HL-LHC

Vibration: is it still an issue?

Transvers movement of magnetic center in LHC triplets magnets due to excavation with

- Road header **well below** tolerable levels.
- Hydraulic hammers (operating at 8 Hz) reaching in-tolerable levels → use **less effective tools** OR **modify operating frequency**.

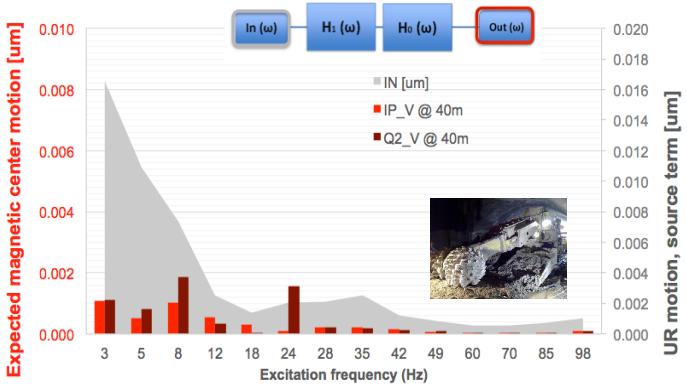
No emittance growth observed due to low frequency noise **with transvers damper.**

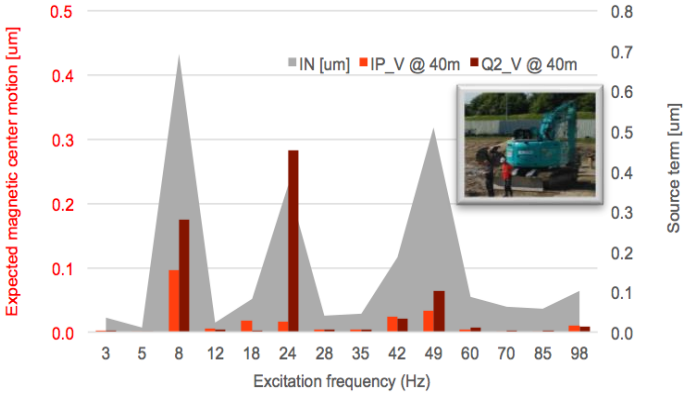
Seismic stations installed around all C.E. areas and operational since 12.2016 → sufficient time to **record reference data** before start.

Active beam feedback possible to mitigate **cold mass movements**, requiring installation of additional corrector magnets.

HL-LHC C.E. schedule provides more than **six months margin** and only upper part of shaft excavation takes place during beam operation.

Background noise due to geothermic project will be added to the current models.





HL-LHC

Need for beam halo depletion in the HL-LHC era
Collimation is still a limit

Active halo control would allow **controlling diffusion speed** and **distributing losses** over time. **Overpopulated tails** (33 MJ outside 3.5 σ) combined with **fast failures** (e.g. by crab cavities) can cause high **losses into aperture** / collimation system.

Halo control via **e-lens** might be necessary to **mitigate fast failures (CC) and loss spikes**. → **SPS crab cavity tests are essential**

Program: 1. Complete technical solution. 2. **Review of technical design** foreseen for autumn 2017. 3. Evaluate **alternative methods**.

Low impedance secondary collimators (CFC) stabilize HL-LHC beams → **Prototype** collimators (MoGr, MoGr + TiN, MoGr + Mo) are being **installed** in LHC to **measure impedance** effects.

Reduction of phase advance (dump kickers to tertiary) or use of **more robust jaw material** allow for **tighter collimator settings** → nearly recover beta*=15 cm!

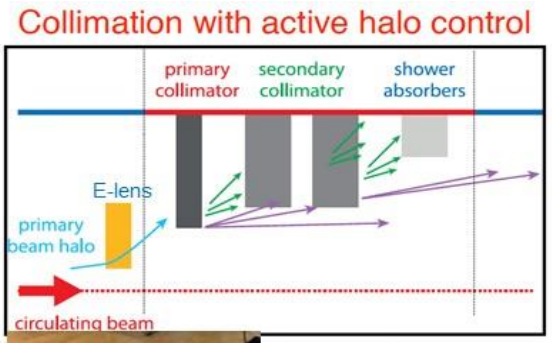
Implementing **BPM buttons** in **all new collimators**: reduction of setup time

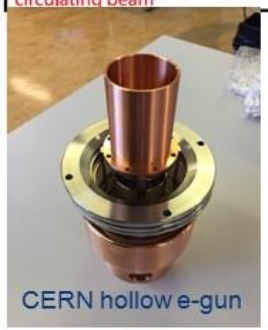
In IP7 dispersion suppressor installation of **TCLD + 11 T dipoles** during LS2 will provide factor 3-4 margin (baseline) for protons.

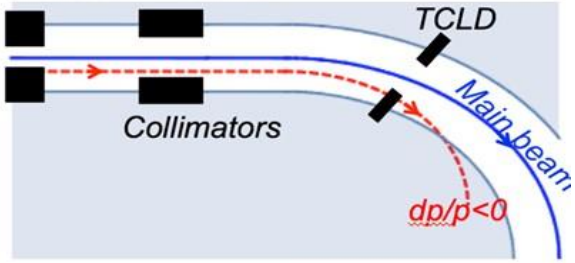
For ion operation cleaning is worse and we need to increase minimal allowed beam lifetime to 48 min factor 4. Doable, but if not possible:

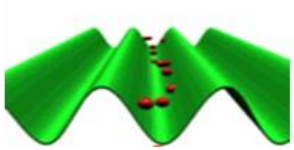
- Install second set of TCLDs + 11 T in IP7 DS (not in baseline).
- **Use crystal collimators to improve cleaning by factor ~3 (further studies required)**.

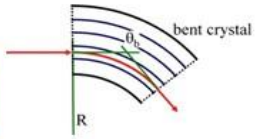
Increased power load from ion debris mitigated by TCLD collimators (in Connection Cryostat) in IP2.











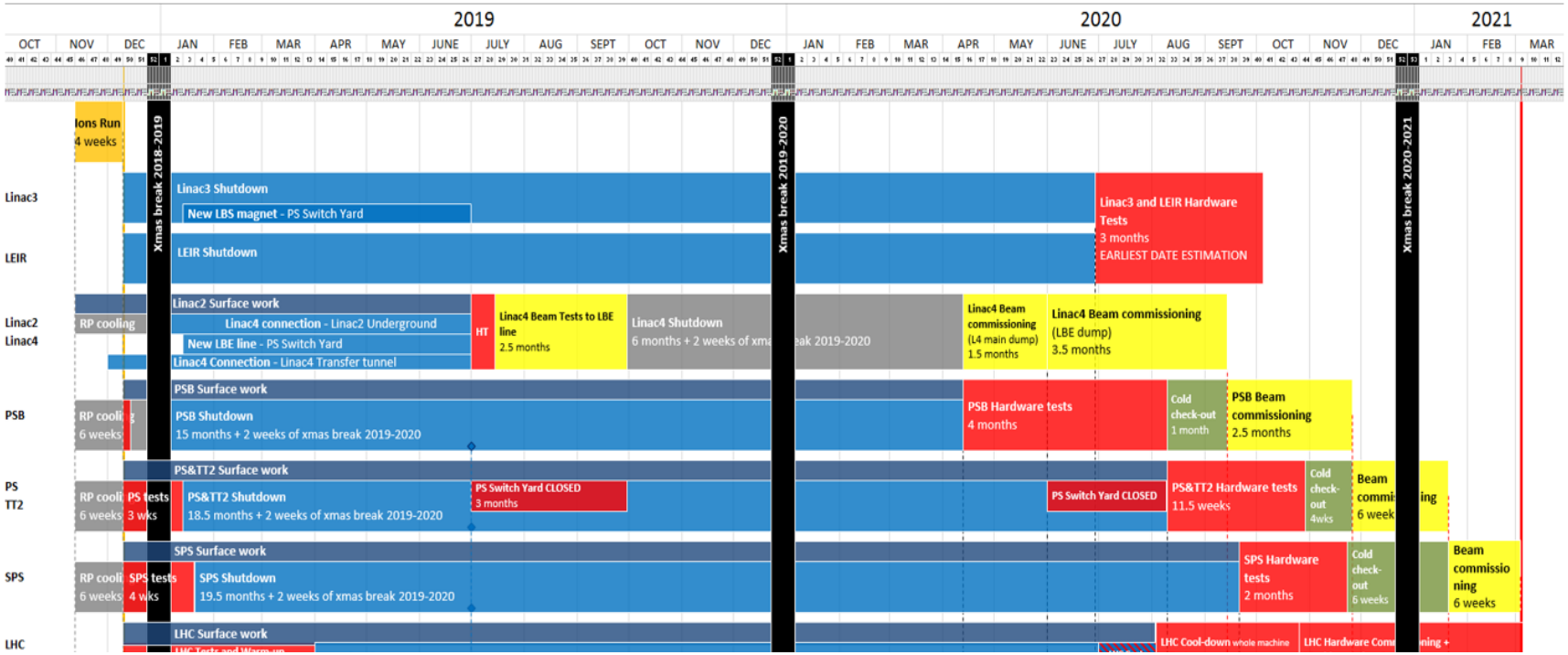
Schedule

LS2 2019-2020

PS Complex and SPS

LS2

1687788 v.1.0 | ACC-PM-MS-0002 v.1.0 Released

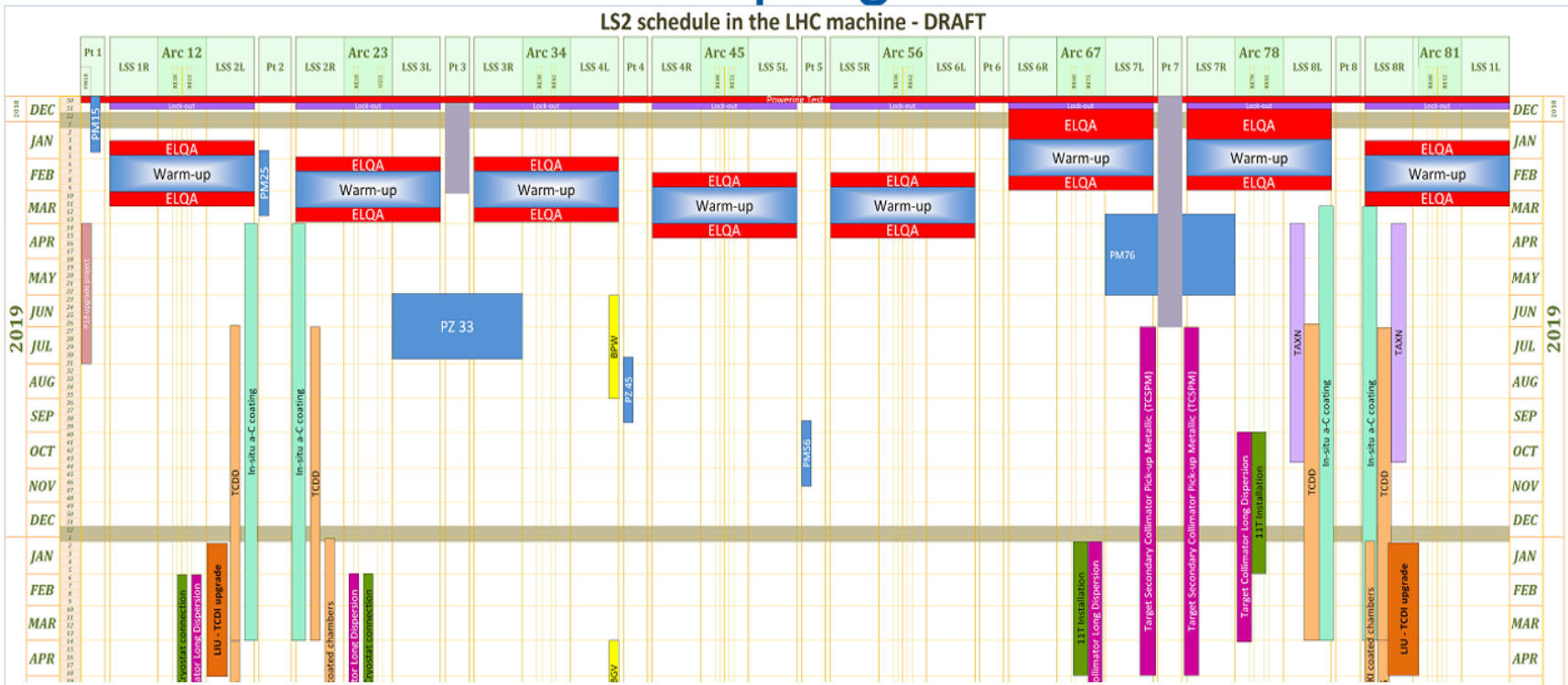


PLAN version 2 will be the reference for the LS2 schedule.

Additional projects shall be detailed and be compatible with the LIU.

The LS2 Master Schedule will be based on the **component availability** as communicated by Equipment owners (including acceptance tests).

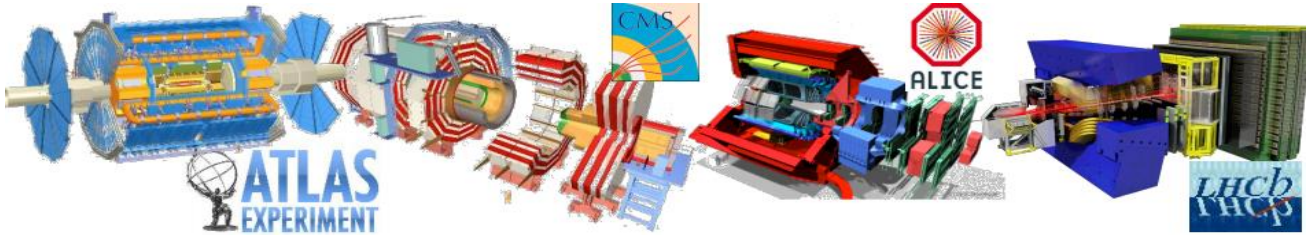
LHC-LS2 schedule in progress



Requests shall be inserted in **PLAN version 2** by **end March'17**, approval expected by June'17.

HL-LHC activities well identified, **schedule and sequencing in 2017**.

Approval process of PLAN items initiated in 2017 will be **completed by Q1-2018**, allowing the release of the draft of the LHC-LS2 schedule, identifying the critical path(s).



Experiments' activities towards and during LS2

- **Significant** work on going and foreseen for each of the **4 Experiments** in LS2.
- Large involvement is needed from the CERN **A&T Sector** for the upgrade and maintenance of Infrastructures: primary electricity, cooling, general services, Data networks, etc.
  - Reinforcement of teams (4 new engineers and 4 new Technicians) to help experiment in the area management;
  - Work ongoing in the LETEM to optimize the development of these works.

- Still many open points in the activities reported (or not reported) in PLAN.
- Experiments need help from A&T Experts to finalise PLAN activities.

CMAC13 messages

First and foremost, the CMAC members offer their congratulations to the entire CERN team on its accomplishment throughout the year. Most impressive is the integrated Luminosity production during the year which reached 40 fb-1 .

The major upgrade projects, LIU and HL-LHC, progressed well and have now integrated the re-baselining made during summer 2016.

The excellent presentations given during the Chamonix 2017 Workshop were informative and comprehensive. Thank you to all the speakers and organizers of the workshop.

We appreciate the format of the workshop and believe that this is a very efficient way of communication, within the LHC team and to external groups. It helps the MAC to understand all the relevant issues and at the same time to interact with the experts. We recommend that the senior management share the charge to the MAC early with the presenters and that they then try to address the particular questions in their talks wherever relevant.

CMAC13 recommendations

Run 2 Operation

R1: Employing the ATS optics as the baseline for 2017 is highly preferable to gain operation experience for HL-LHC. It seems reasonable to start ATS operation at β^* of 40 cm with somewhat tighter collimator settings.

R2: Make a plan to go to smaller β^* with ATS to gain experience with the telescopic β squeeze operation. β^* below 33 cm is not preferred by experimenters due to pileup rate unless leveling is routinely used to mitigate.

R3: Continue the intensive study on e-cloud. For e-cloud in quadrupoles, pursue studies including intensity dependence measurement as planned in MD in 2017.

Availability, Technical Infrastructure, Collimation, Machine Protection

R4: Implement those measures that are needed in any case for HL-LHC as soon as possible (e.g.: ATS optics, fully detuned RF, leveling via β*)

R5: Reevaluate allocated MD time in 2017 to align with the highest priorities given (Luminosity production & preparation for LS2). If necessary extend.

R6: Investigate the cause of varying electron cloud driven heat loads. Use information gained from warm up of sector 1-2.

CMAC13 recommendations

Cryogenics, Magnet Performance, Risk, Testing before LS 2

R7: Perform a quantitative risk analysis of the impact of potential problems caused by magnet training and develop a mitigation plan. Study the possibility to remove debris in all the magnets, to clean and better insulate the diode boxes and establish the necessary time and resources needed to do it.

R8: Perform the full training campaign to 7 TeV at an appropriate moment during LS2 to allow a sufficient margin to recover from unknown events and balance the impact of possible magnet problems with the gain expected at 7 TeV

Injector performance and LIU

R9: Address the two presently existing intensity limitations for respectively HL-LHC protons and ions:

- current limit in the PS and SPS
- slip stacking of SPS

CMAC13 recommendations

High Luminosity Project (HL-LHC)

R10: Execute all necessary experiments, with and without beam, during CY17 which can impact major activities for LS2.

R11: Define a strategy to either intrinsically reduce the heat load stemming from the e-cloud. In case that is not possible, evaluate the maximum possible heat load that could be cooled in the shield and develop a strategy to do that.

Preparation for LS 2

R12:Identify major scope additions as soon as possible

LHC schedule 2017

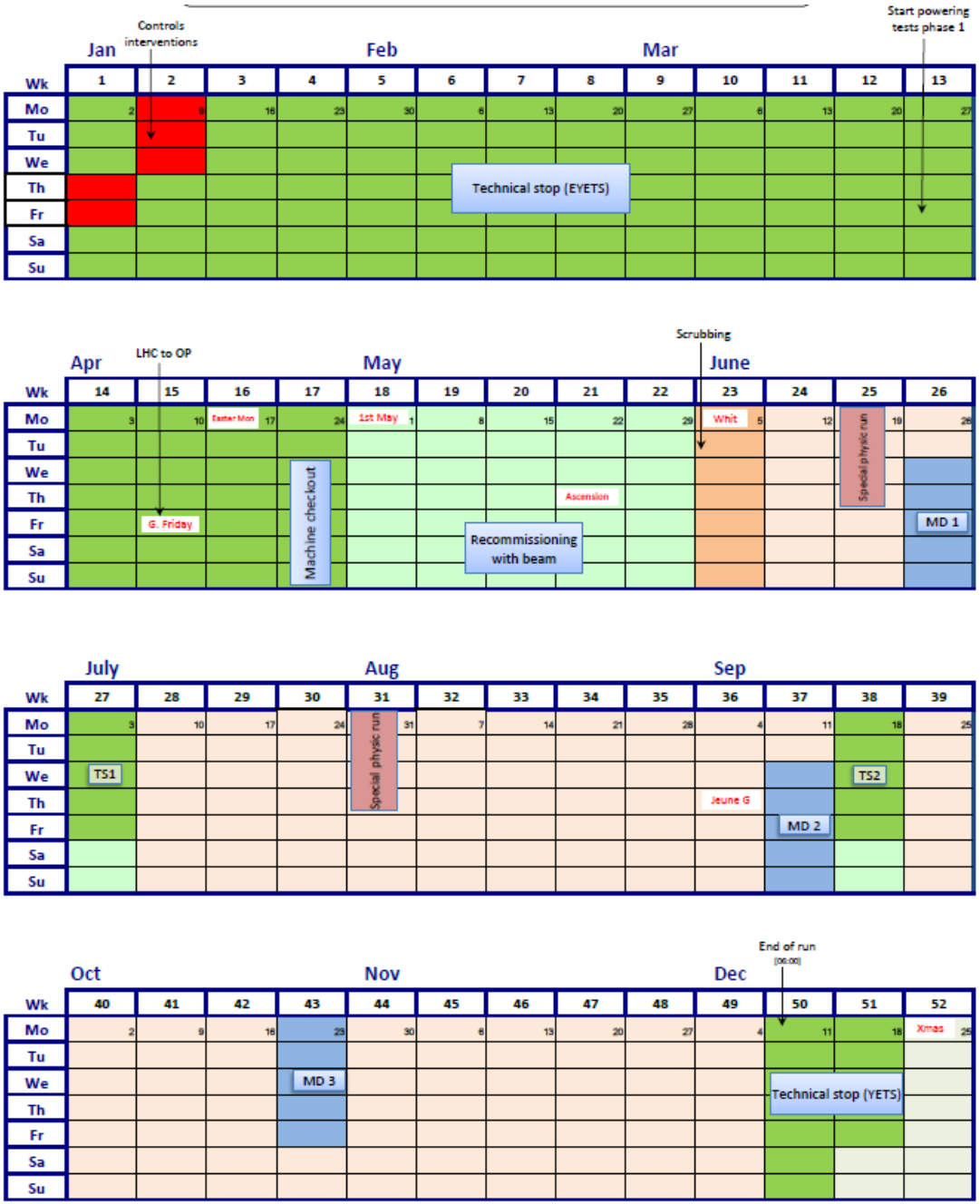
a new production year at 13 TeV

Goal 45fb^{-1}

keeping the LHC availability close to 50% (stable beams)

Initially 15 days of MD; later during 2017 according integrated luminosity : + 3 days ?

Special runs: VdM scans,… and … LHCC recommendations



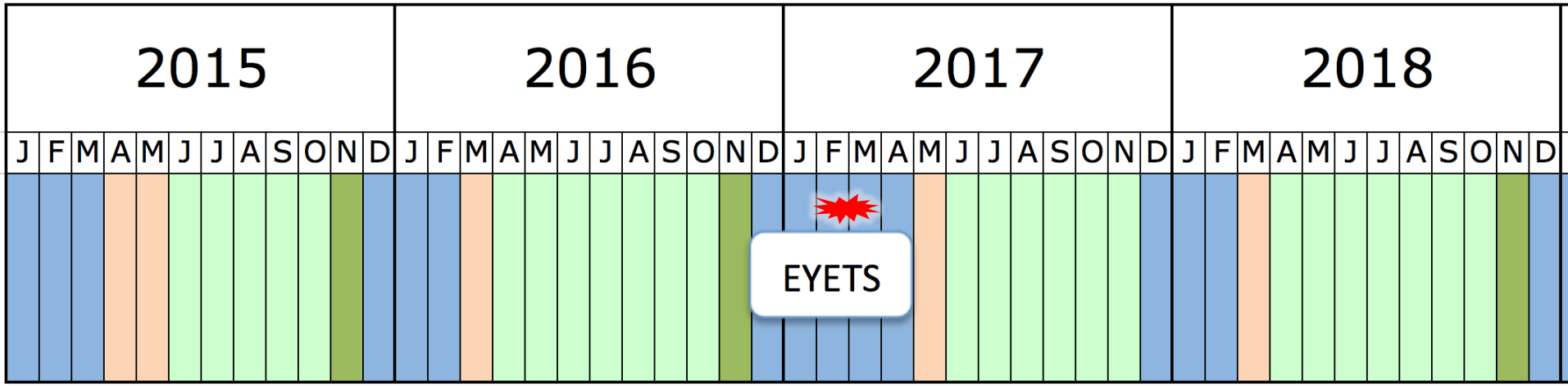
LHC schedule 2017 (version 0.6) : summary table

Phase	Days	Ratio to total beam time
Commissioning & Intensity ramp up	35	15%
Scrubbing	7	3%
Proton Physics at 13 TeV	**145**	**65%**
Special Physics Runs	***8***	***4%***
Machine Developments (MD)	15 (+3 ?)	7%
Technical Stops (TS1 & TS2)	10	4%
Technical Stop Recovery	4	2%
Total	224	100%

2016 Proton Physics : 164 days

Run 2 and Run 3

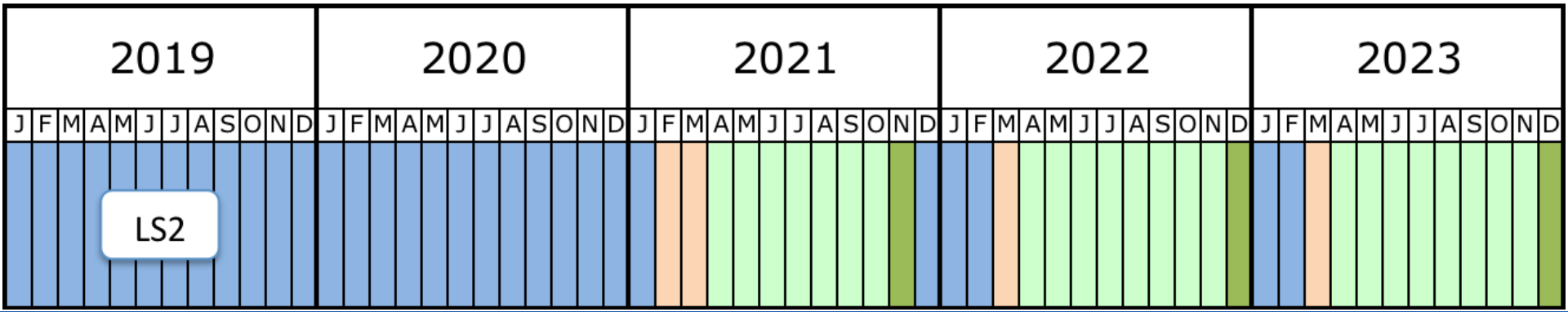
Ion runs end of 2018 (Pb-Pb)



Shutdown/Technical stop
Protons physics
Commissioning
Ions

>120 fb^{-1} (13 TeV)

Σ 300 fb^{-1} (14 TeV ?)



Chamonix'16: - no proceedings
- executive summary per session

Chamonix'18
29th January 2018 – 1st February 2018

Wednesday 1st March 2018: Summary session

3rd LIU/HL-LHC Cost & Schedule review
26th March – 28th March 2018

Thanks for the inputs to session chairs and scientific secretaries

Thanks to CMAC and scientific secretaries

A big thanks to all the speakers together with all persons involved to prepare the presentations and thanks to all participants for the open and live discussions.

Many thanks to Evelyne for the practical organisation

Thanks for your attention

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