Chamonix 2016 Conclusions

Frédérick Bordry

3rd March 2016

26th January 2016 from Les Aiglons

LHC Performance Workshop (Chamonix 2016)

1st preparation meeting: 1st September 2016

4 general preparation meetings

- **Review 2015 performance: hardware and beam limitations**
- **LHC hardware performance: reliability (MTBF), availability (MTTR) and operational efficiency (Integrated Luminosity). Identify possible areas for improvement**
- **Defined operational scenario for 2016/Run 2 and establish a strategy for Run 2;**
- **Energy increase scenarios (13 TeV towards 14 TeV)**
- **LIU; HJL-LHC (technical review and not Cost & Schedule review)**
- **(E)YETS and Long Shutdown 2 Strategy and Preparation**

Spirit: no status but open questions and scenario discussions

Difficult selection through DHs, Project Leaders and Session Chairs

(125-135 participants per session; overbooking !)

LHC Performance Workshop (Chamonix 2016)

A very fruitful workshop with very good proposals, overviews and strategies.
Valuable information & discussions

Active participation of LHC Experiments

A big thanks to all the chairpersons, 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

CERN Machine Advisory Committee (CMAC11)

Fischer Wolfram	BNL
Gourlay Stephen	LBNL
Holtkamp Norbert (chair)	SLAC
Oide Katsunobu	KEK
Qing Qin	IHEP
Seidel Mike	PSI
Shiltsev Vladimir	FNAL
Vedrine Pierre	CEA
Zimmermann Frank (scientific secretary)	CERN

Closed session on Friday 29th January at CERN

CMAC Close out : Friday 29th January at 13h30

(CERN - Room Georges Charpak)

LHC goal for **2015 and for Run 2 and 3**

Priorities for the 2015 run :

- **Establish proton-proton collision at 13 TeV with 25ns and *low* β* to prepare production run in 2016.**
  Optimisation of physics-to-physics duration
- **Later in 2015: decision on special runs "when and duration" (90m optics): not in the 1st part of the year. Waiting LHCC recommendation**
- **Pb-Pb run: one month at the end of 2015**

The goal for Run 2 luminosity is 1.3 x 10^{34} cm^{-2} s^{-1} and operation with 25 ns bunch spacing (2800 bunches), giving an estimated pile-up of 40 events per bunch crossing.

"A maximum pileup of ~50 is considered to be acceptable for ATLAS and CMS"

LHC goal for **2015 and for Run 2 and 3**

Integrated luminosity goal:

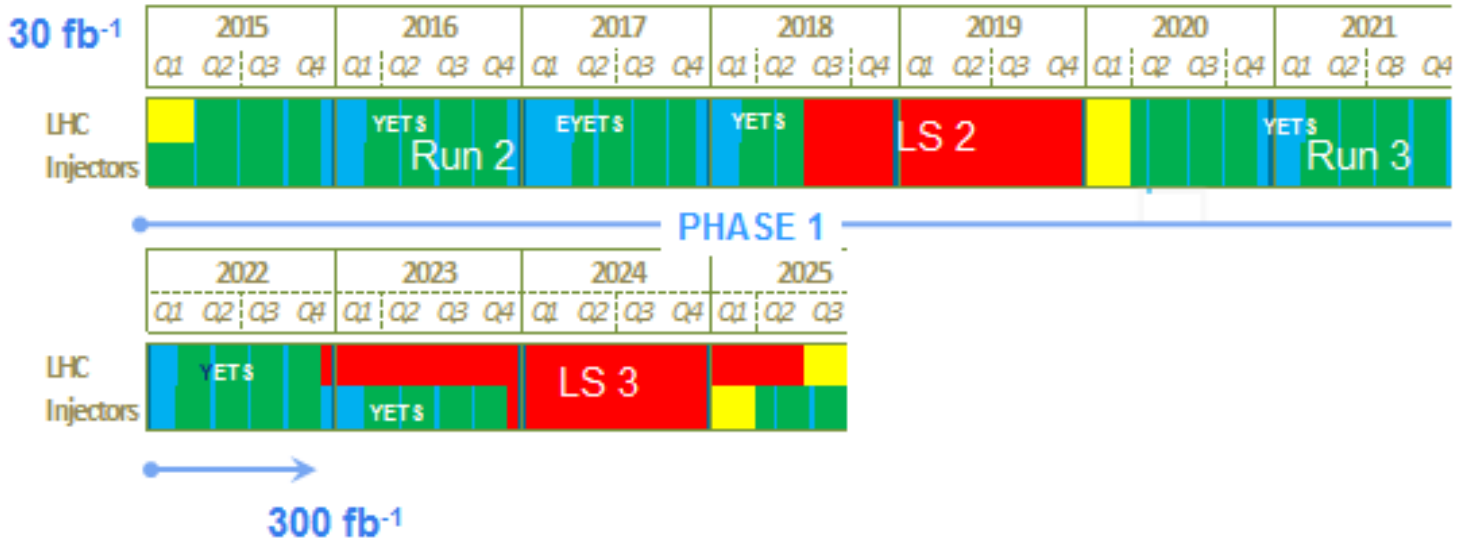
2015 : 8-10 fb^{-1}

"Prediction is very *difficult*, *especially if* it's about the *future*." - Niels Bohr

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

(better estimation by end of 2015)

300 fb^{-1} before LS3



2015 LHC Integrated Luminosity

- The initial projections of integrated luminosity for 2015 were ~ 8-10 fb^{-1}.

Achieved ~ 4.3 fb^{-1}.

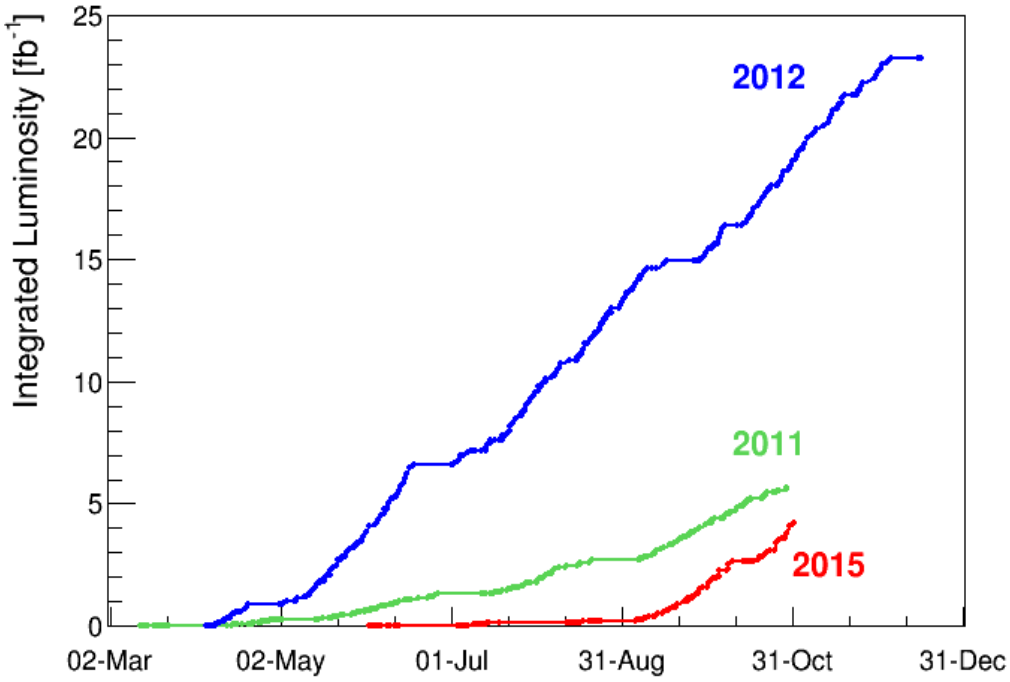
- Slope at the end of the run better than in 2011, and close to 2012 slope

(last week of operation > 1 fb^{-1})

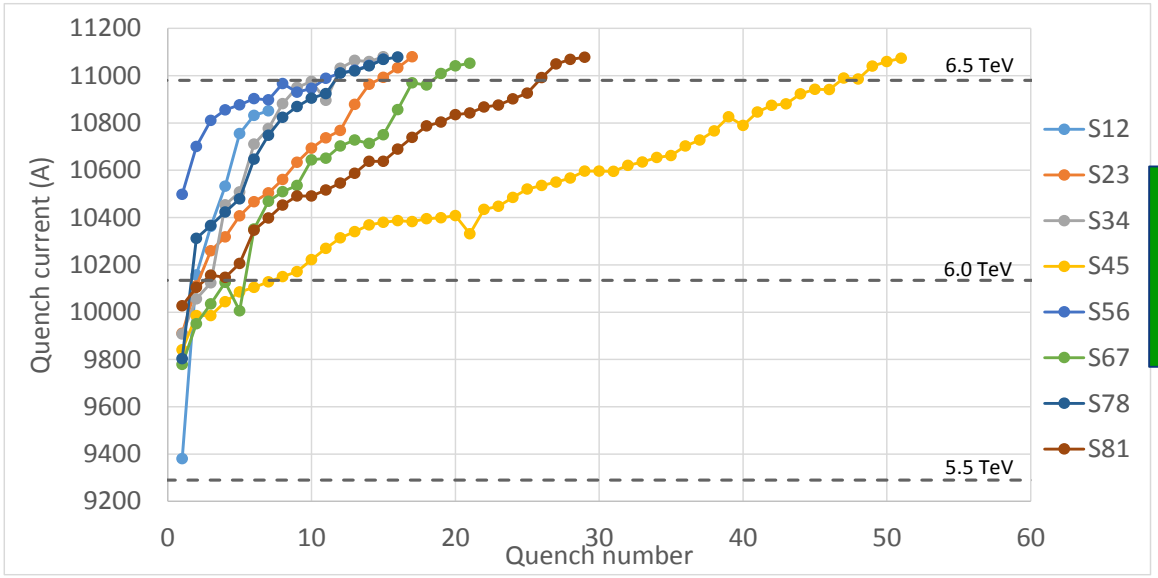
The main reasons for the lower value:

- Start-up delays (~ 4 weeks),

- Availability issues:
  radiation failures on the quench protection tunnel electronics; solved after TS2
- Electron clouds mitigation



Dipole Training Campaign



173 training quenches
~600 secondary quenches
Only 1 quadrupole quench

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

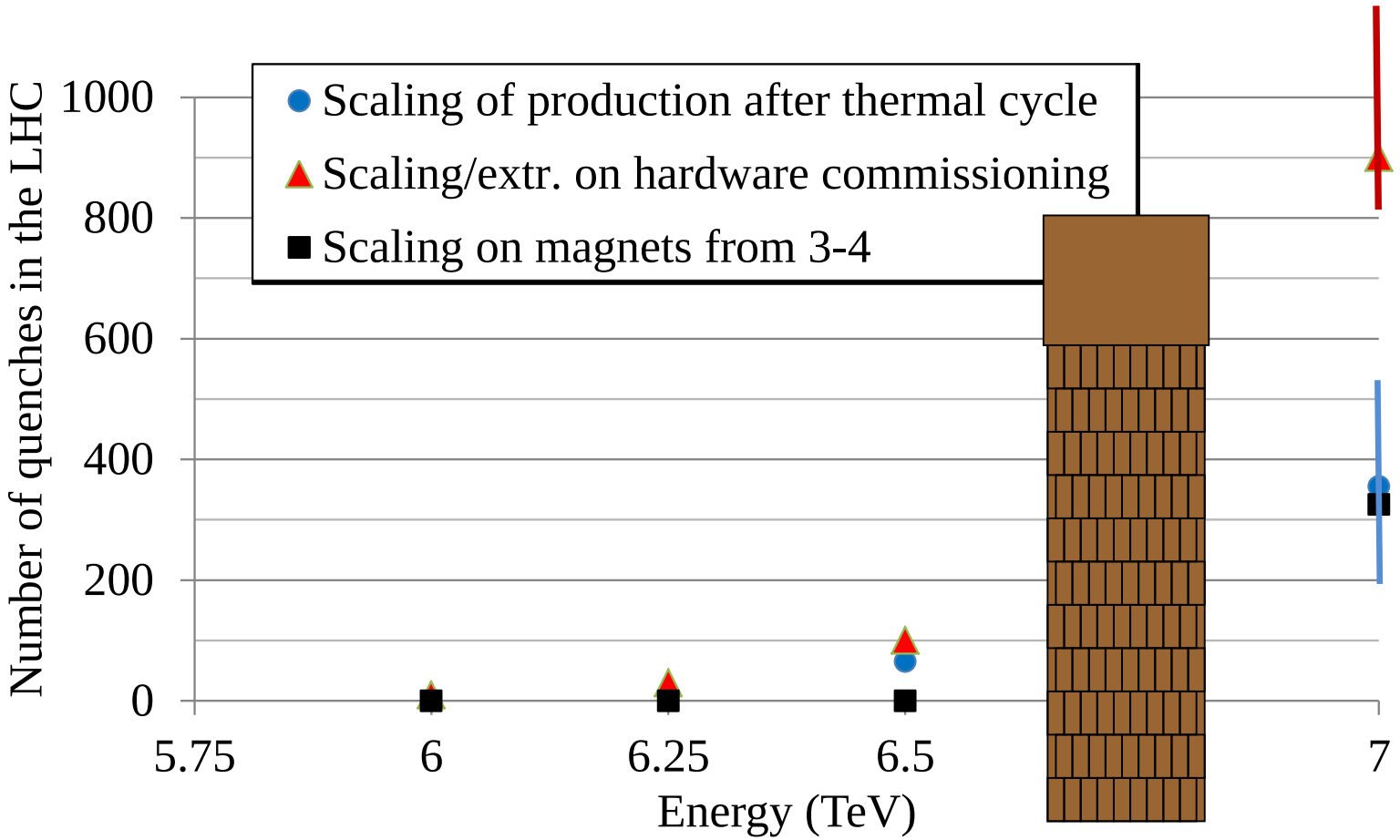
Sector	# Training quench	Flattop quenches
S12	7	0
S23	17	0
S34	15	1
S45	51	0
S56	18	3
S67	22	1
S78	19	3
S81	29	0
Total	171	8

Large variation in number of training quenches per sector

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

Energy of the LHC after 2013-2014 long shut-down

Comparison of different estimates



Towards 7 TeV

A new model for the quench behaviour was established from the 2015 quench campaign.
The new estimates for the number of quenches to reach 7 TeV :

~270 first quenches to go !

Best estimate for 7 TeV (first q. only)

sector	1000	2000	3000	total	Done	to do
12	3	19	7	28	7	21
23	3	12	30	44	17	27
34	2	16	22	40	15	25
45	2	9	62	73	49	24
56	1	8	63	73	16	57
67	3	7	46	56	20	36
78	3	24	46	72	21	51
81	3	5	50	58	28	30
LHC	20	100	325	445	173	272

- The data are compatible with a scenario where after each warm-up we re-start in the same conditions than at the beginning of the previous campaign.
- We could probe the predictions by pushing ~2 sectors towards 7 TeV (future powering campaign).

13 TeV c.m. in 2016

- No change on powering tests

  Each Sector powered to 6.55TeV
  (11080A ;100 A above the operational field)
  To define the length of stay at 6.55 TeV (4h?)

- A training campaign should not proceed before the end of the 2016 run.

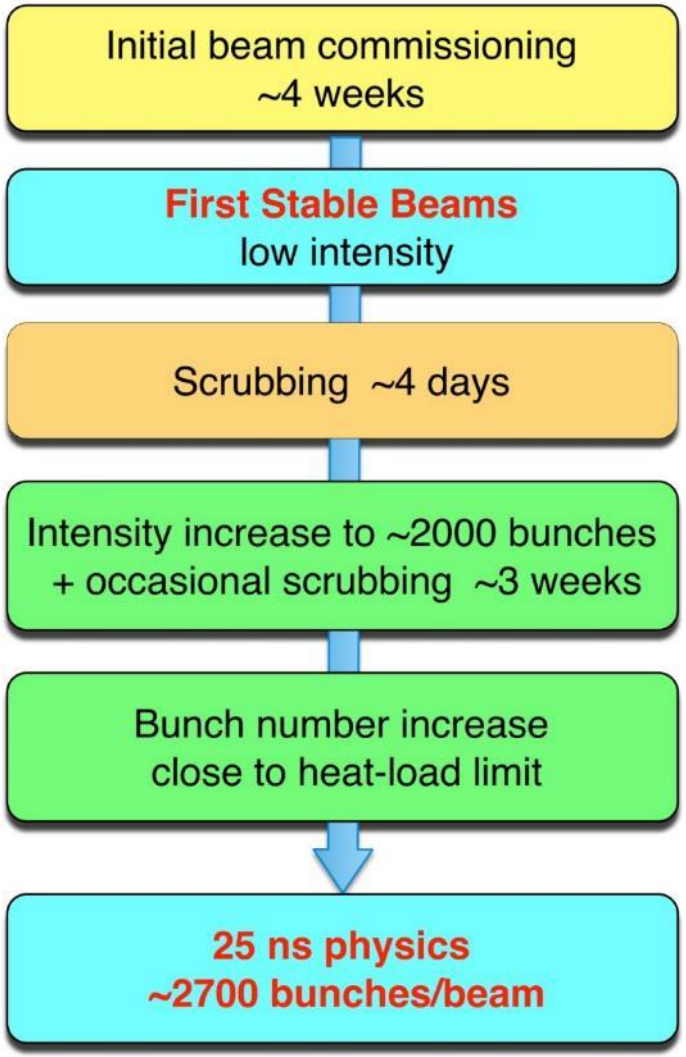
- Perform a quantitative risk analysis on the basis of a modest training campaign of one or two sectors

  just before or during the EYETS or end of 2017 ?

1st step of Full Energy Exploitation of the LHC mandate – Oliver Bruning (assessment by end 2016)

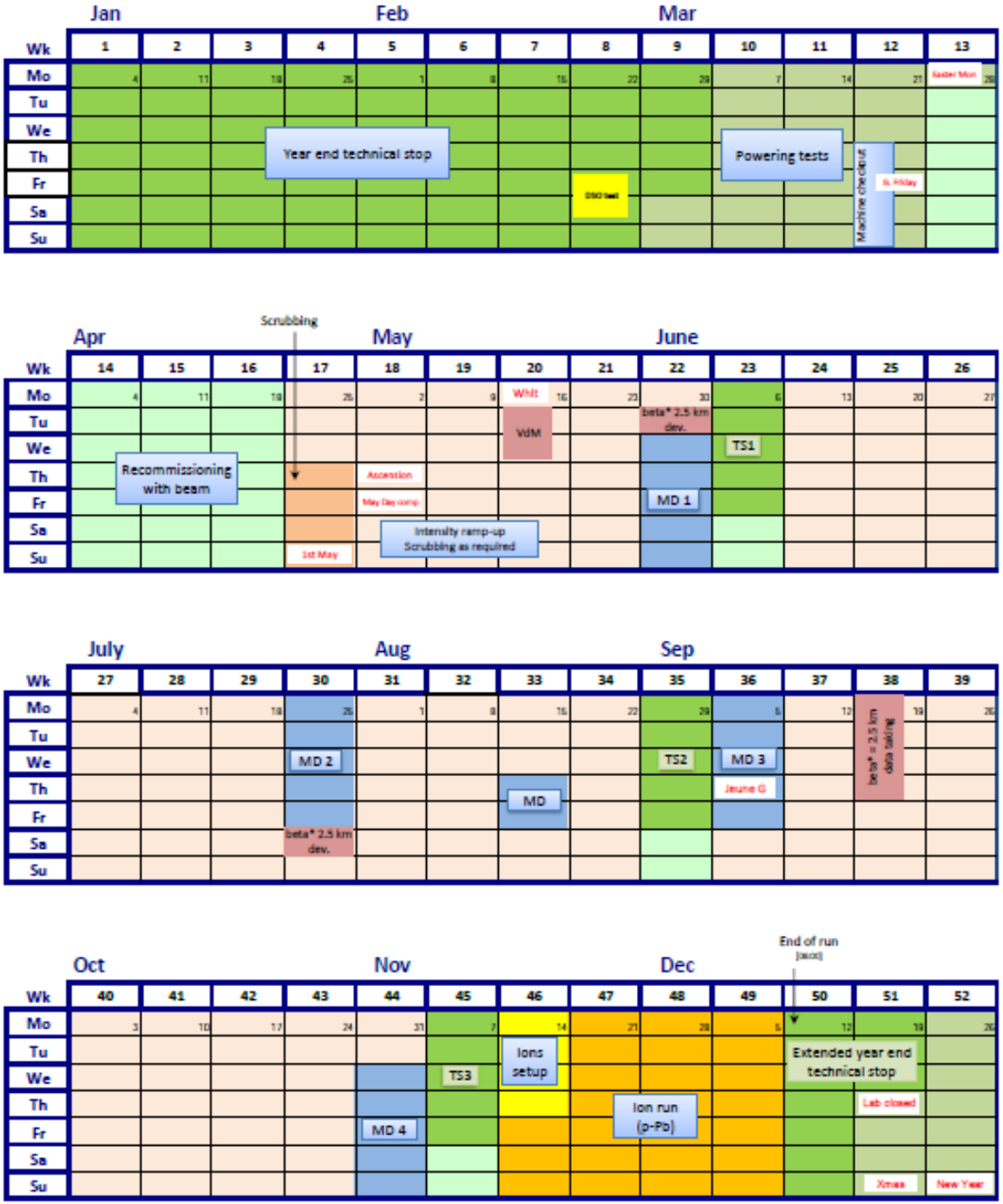
Proton-Proton Plans for 2016

- ✓ **Stable Safe Operations**
  - ➢ Don't compromise on machine safety!
  - ➢ Don't do anything to compromise machine reproducibility
- ✓ **Electron Cloud under control**
  - ➢ Short dedicated scrubbing
  - ➢ Continue during intensity ramp-up
- ✓ **6.5 TeV, 40 (50) cm β***
  - ➢ Keep an eye on availability
- ✓ **Nominal 25ns beam, 2748 bunches, 288 bpi**
  - ➢ May push later to shorter bunches & BCMS
- ✓ **Good! Availability**
  - ➢ Sustained effort to trace faults
  - ➢ Keep avoidable interruptions to production running to a minimum
- ✓ **Excellent Operational Efficiency**
  - ➢ Combined ramp/squeeze
  - ➢ Work on injection process



LHC schedule 2016
(after LMC 24th Feb. 2016)

2016:
a production
year

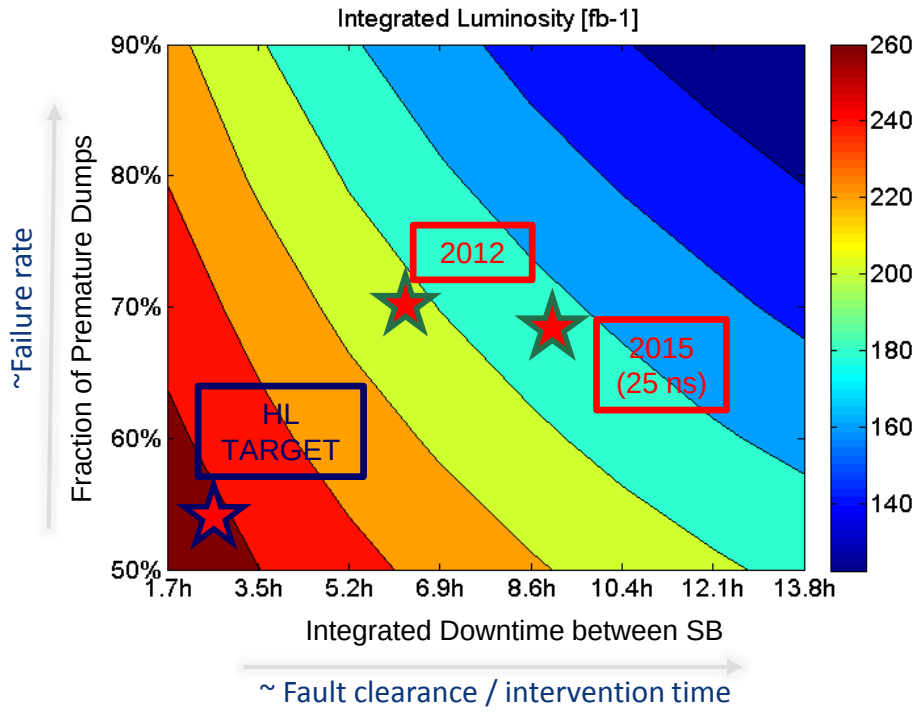


Maximizing physics output of the LHC

- Dependability of LHC systems is one of key drivers of physics output (integrated L)
- While machine safety cannot be compromised, one of priorities for future years (and conception of HL-LHC, FCC) will be to maximize system availability to meet physics goals
- Availability is the only means to increase integrated luminosity once a machine is levelled
- Past experience is key to understanding of equipment failures (root cause) and assessing impact and cost of mitigations

Availability

Monte-Carlo simulation of HL-LHC performance based on availability achieved in 2012 / 2015



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

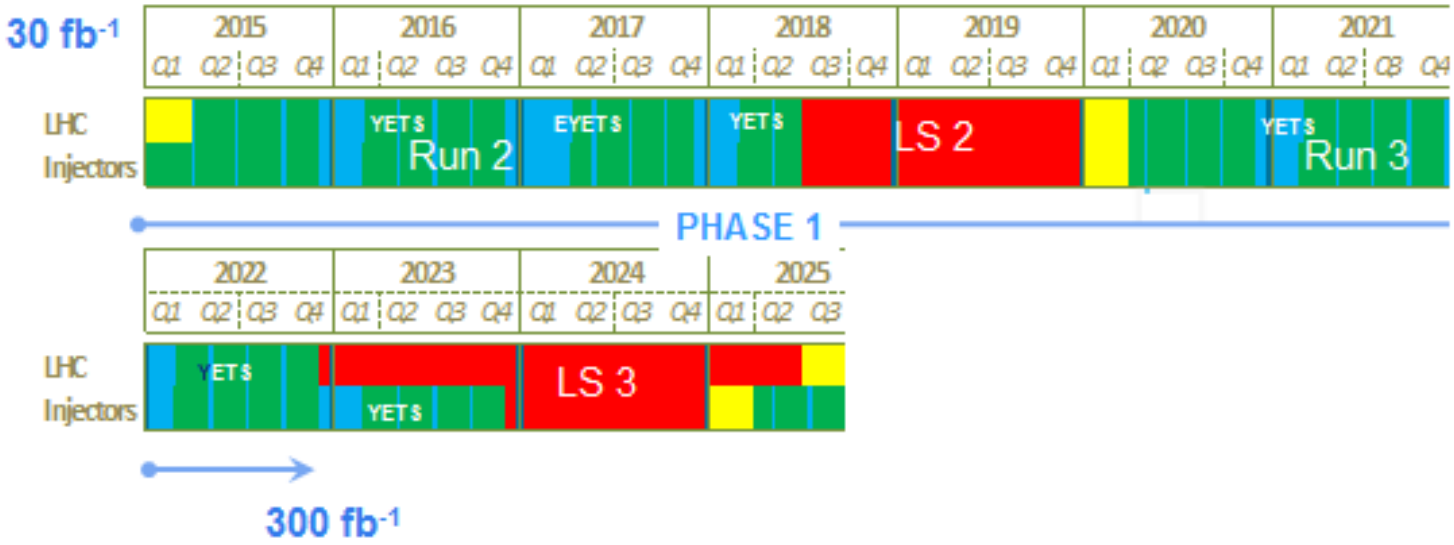
Integrated luminosity goal:

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

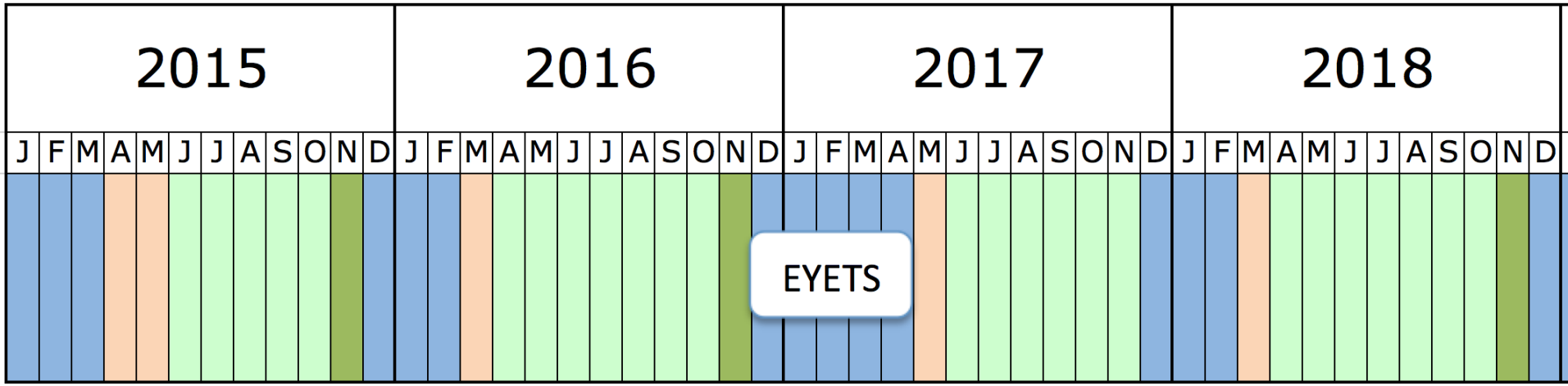
Run2: ~100 fb^{-1}

Prepare for (or go to) 14 TeV operation

300 fb^{-1} before LS3



Run 2

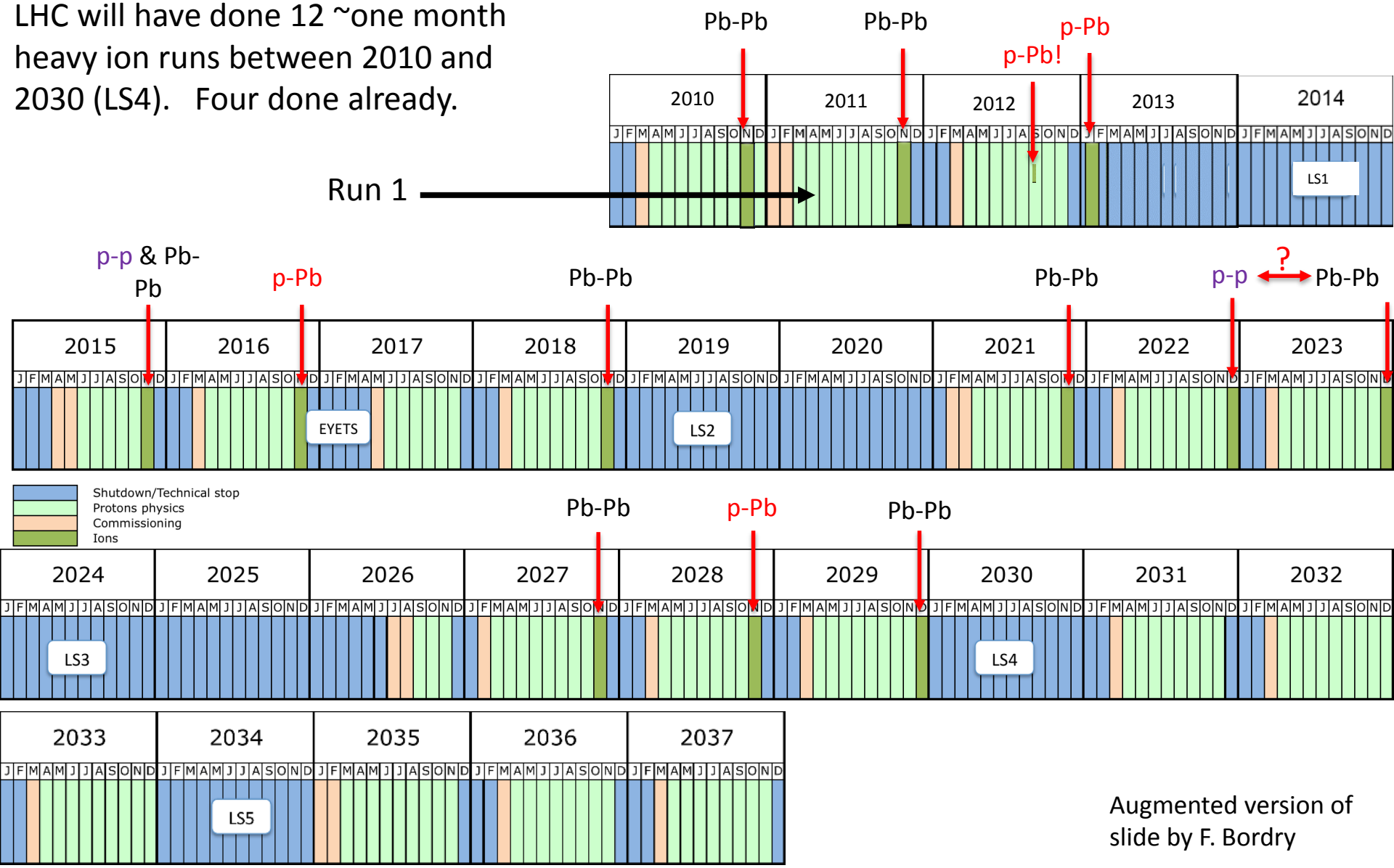


Shutdown/Technical stop
Protons physics
Commissioning
Ions

- EYETS –19 weeks – CMS pixel upgrade
- Assume machine stays cold during EYETS (ULO ?)
- Ion runs in 2016 and 2018

LHC heavy-ion runs, past & approved future
+ species choices according to ALICE 2012 LoI (could evolve if required)

LHC will have done 12 ~one month heavy ion runs between 2010 and 2030 (LS4). Four done already.



Augmented version of slide by F. Bordry

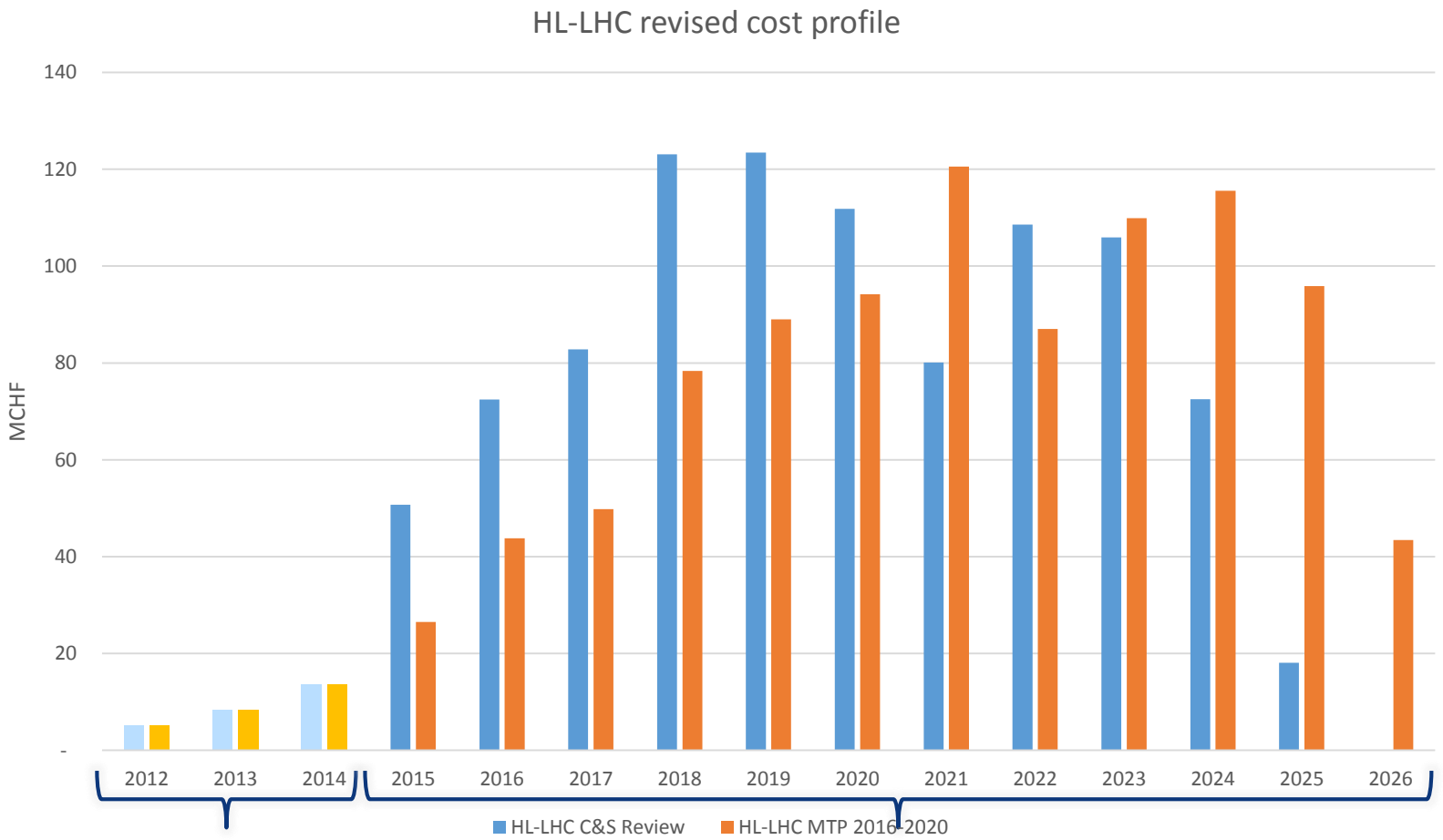
www.cern.ch

1st Cost & Schedule review of LIU and HL-LHC

9-11 March 2015 ; Chair: N. Holtkamp (CMAC 10)

The goal of the cost and schedule review of the LIU and HL-LHC projects was to assess the status and risks of both projects

MTP – HL-LHC revised cost profile

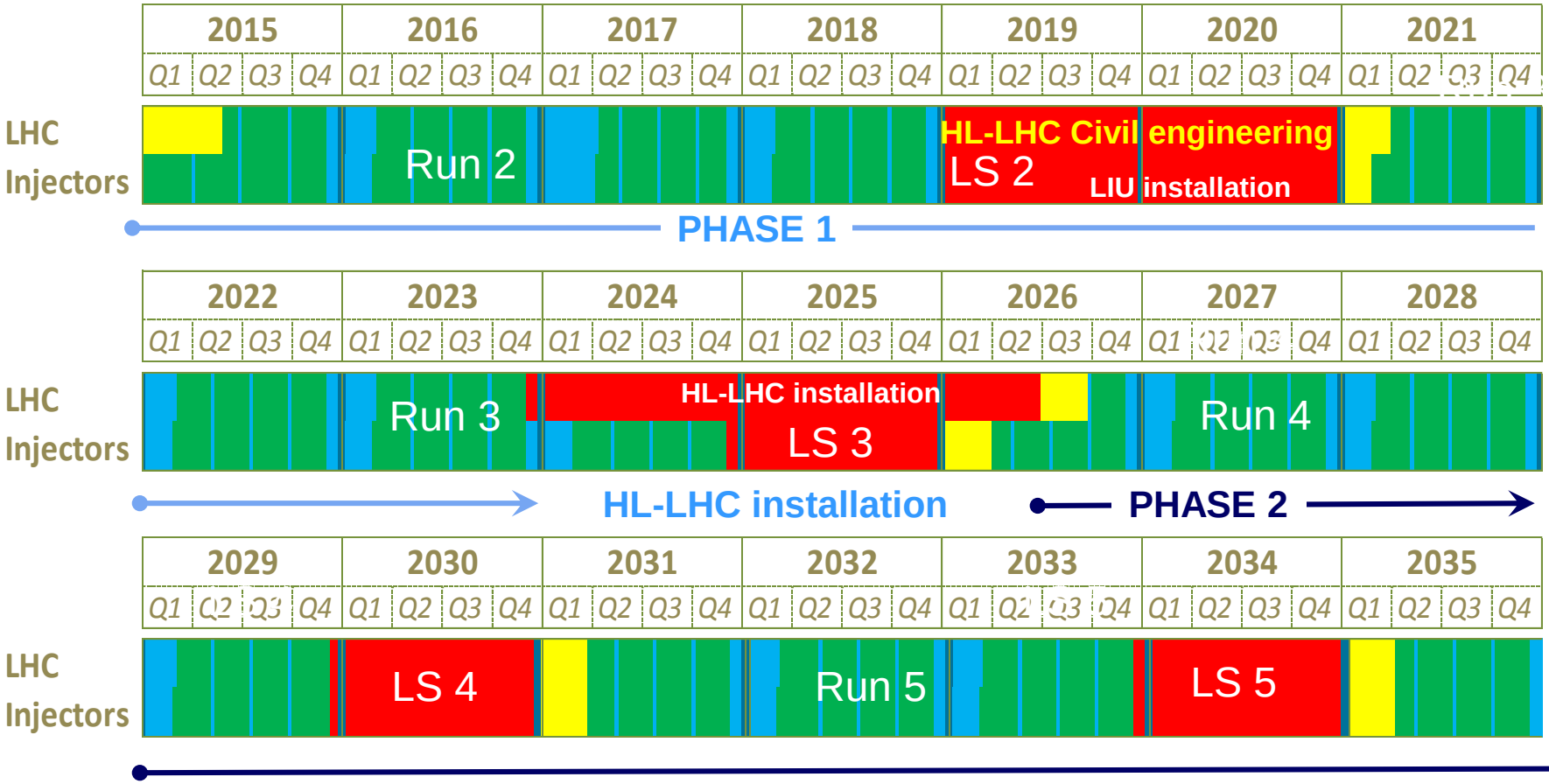


R&D phase: 27 MCHF

Construction phase: 950 MCHF

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



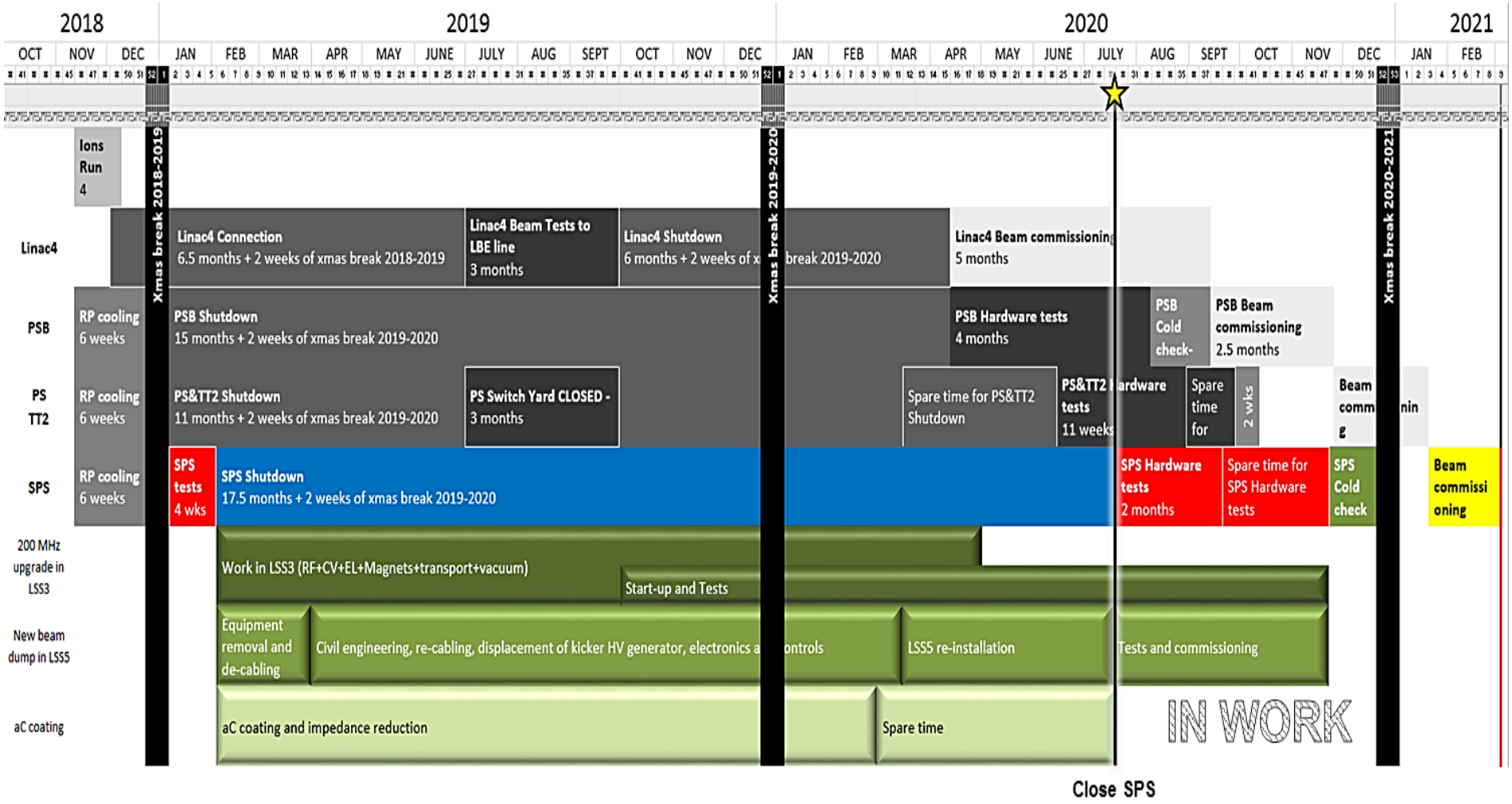
2nd HL-LHC/LIU Cost & Schedule review 17-18-19 October 2016

- Goal : Assess the C&S status of both projects, taking into account baseline changes since the previous C&S review.
- Scrutinize
  - Progress of both projects, in particular identify critical elements of the PBS w.r.t. schedule or cost
  - Baseline changes - their impact on the scope, schedule and cost – Change management methods
  - Evolution of global C&S, risks level and uncertainties
- HL-LHC Civil Engineering & Technical Infrastructure WP – 1st external review

Julie Coupard, LIU Coordination
Katy Foraz, LS2 Project Planning Coordinator

Session 8: (E)YETS and Long Shutdown 2 Strategy and Preparation

LIU Activities during LS2, highlight of changes with respect to last year

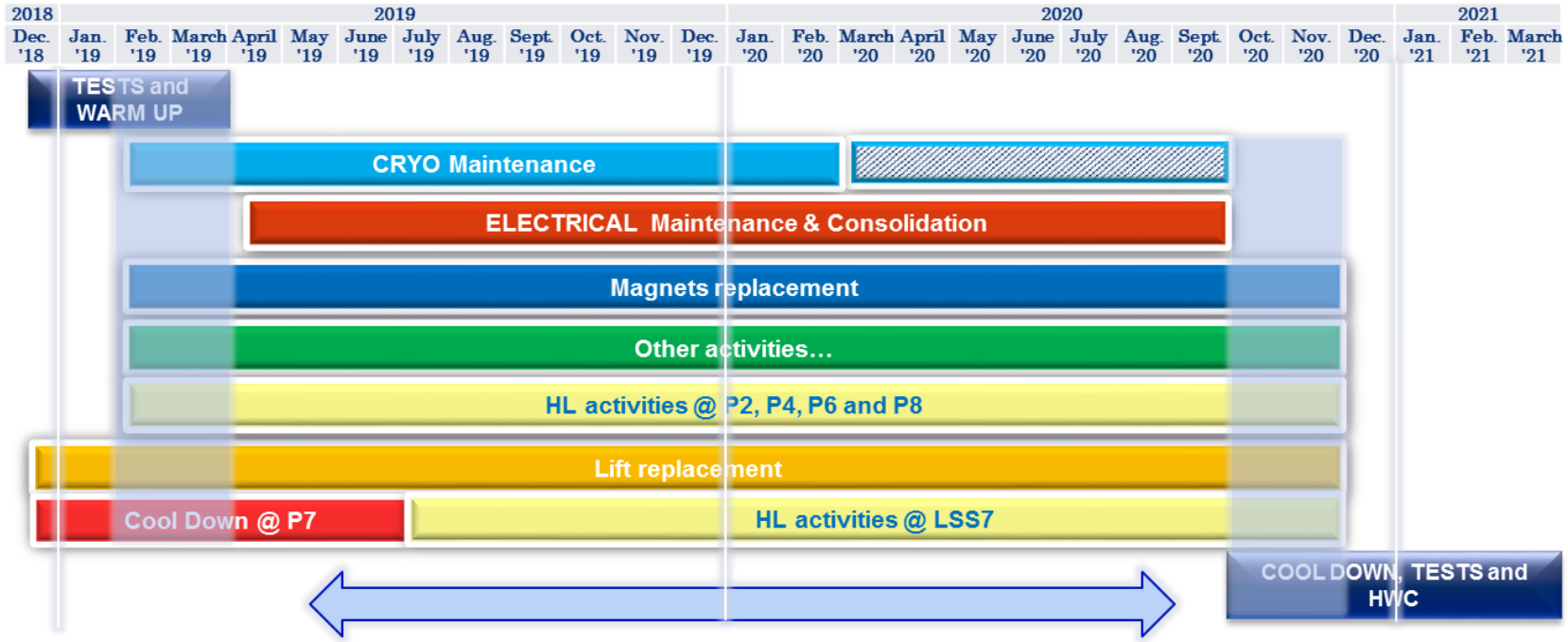


Katy Foraz, LS2 Project Planning Coordinator
Mirko Pojer, LS2 Plan Data Quality Manager

Session 8: (E)YETS and Long Shutdown 2 Strategy and Preparation

Framework schedule from EYETS 2016 to LS2

Draft Master Schedule skeleton is defined…



Depending on the cool down and warm up sequence,

the available window for the activities is between **18** to **22 months**

Session 8: (E)YETS and Long Shutdown 2 Strategy and Preparation

LHC Experiments Activities during LS2

Cooling and Ventilation

ALICE

- New
- Poss
- O2 c
- TPC
- Vent

ATLAS

- Ren
- Refu
- Stud
- Upg

CMS

- Upgr
- Elimi
- Add
- Wate
- Com

LHCb:

- New

Electrical distribution & cabling

ALICE

- 2 x 2.
- Large
- 12k o
- Signif cables

ATLAS

- Upgra
- Upgra
- Conso
- Cablin

CMS

- Upgra
- Electr

LHCb

- Power

Survey

ALICE

- Significa re-install
- Close co
- Metrolog

ATLAS

- Usual ac
- Survey
  - Du
  - NJ
  - BI

CMS

- Opening

Handling

ALICE

- Opening beginnir
- Special
- Installat

ATLAS

- On top NSW in
- Transpor
- JD shield 2016 to
- Transpor

Beam Pipe

ALICE

- New
- Bake-
- Remo LS2.

ATLAS

- No n
- But f

Safety & Radiation

ALICE

- Safety

ATLAS

- Work pa and dur
- Study c

Civil engineering

ALICE

- New visitor center (2016/2017)
- Baseline for O2 computing facility is a commercial container (choice end 2016). Infrastructure and noise protection needed.

ATLAS

ncluding the exisiting clean room

(1000 m2)

s lab space for Phase 2 build/maintenance

overwritten by HL-LHC buildings

extraction/lowering by “crawler crane”

tion of new housing.

’ and to transformer

perated, stored or become radioactive waste

e place in the underground

ector parts, with some components being radioactive.

oncrete blocks from the shielding.

To complete the filling of PLAN tool

(coactivities, ressources,…)

To identify the resources needed and resources providers :

- who does what and when?
- who pays what?

CMAC11 messages

All members of the CMAC want to congratulate the CERN team on its accomplishment throughout the year. Most impressive was the successful completion of the Long Shutdown 1 allowing world record energy operation at 6.5 TeV per beam and 25 nsec bunch spacing. Only its highly dedicated staff made all this possible.

The major upgrade projects, LIU and HL-LHC continue to be very well-integrated into the overall goal of substantially improving LHC performance over the next decade.

The excellent presentations given during the Chamonix 2016 Workshop provide the basis for this report. They were informative and comprehensive and we thank all the speakers and organizers of the workshop.

Finally, we want to express wholehearted congratulations from the CMAC to the whole CERN team for a tremendous achievement during 2015 and we look forward to future progress reports.

We appreciate the format of the workshop and believe that this is a very efficient way of communication, inside and outside of CERN. It helps the MAC to understand all the relevant issues and at the same time to interact with the experts.

CMAC11 recommendations

2016 Planning and Beyond: "The Production Year"

R1: Continue to operate at 6.5 TeV

R2: Minimize the number of configuration changes

R3: Use the availability tool to optimize consolidation investments

LHC Beam Dynamics and High Luminosity Operation

R4: The emittance blowup at the LHC will be the major limitation on the peak luminosity before LS2. Estimate the emittance growth by each source, such as the remaining electron cloud, TMCI, IBS, external noise, etc. Making use of turn-by-turn instruments may provide useful information for this purpose.

R5: Explore the possibility of a wideband transverse feedback in the LHC, as it can suppress TMCI/e-cloud instability without increasing the nonlinearity in the lattice, especially for the BCMS injection.

LHC Intensity Limits, Scrubbing

R6: Further develop the 5+20 ns beams as a scrubbing tool in the LHC until higher intensity beams are available from the LIU upgrade.

CMAC11 recommendations

Collimation, Machine Protection, UFO's and ULO

R7: Utilize the good performance of the collimation system for tighter settings at the beam and more aggressive β* configurations.

R8: Continue refining the various interlock systems to reduce the number of false or unnecessary beam dumps.

R9: Mitigate the impact of UFO's for the BLM system, which could occur at higher rate with increased beam intensity.

Cryogenics

R10: Develop a long-term plan to raise the overall availability of the cryogenics system to 98%.

Magnet Performance and Risk

R11: A training campaign should not proceed before the end of the 2016 run.

R12: Perform a quantitative risk analysis on the basis of a modest training campaign of one or two sectors.

Injector Performance

R13: Machine studies are suggested in the injectors, which can lead to understand the beam loss mechanics, emittance enhancement, and improve the transmission at high beam intensity.

CMAC11 recommendations

LIU (LHC Injectors Upgrade)

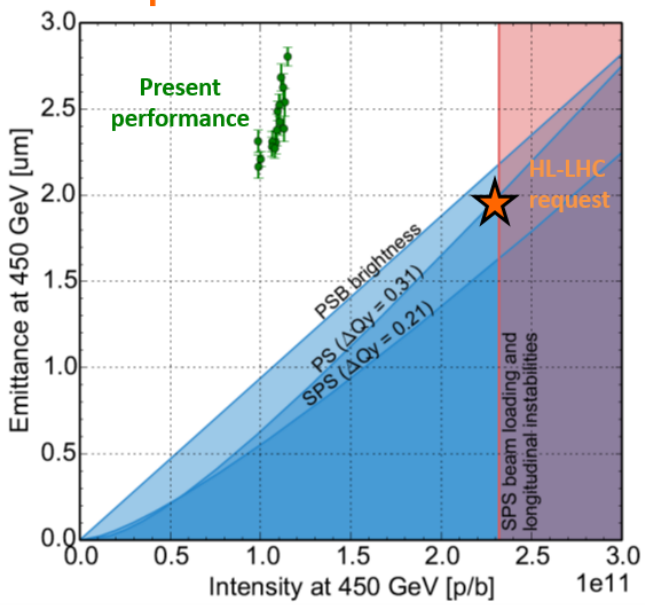
R14: Match the LIU beam parameter goals and the HL-LHC requirements to each other.

R15: Secure adequate human resources to support the design, testing and commissioning of the large number of RF and LLRF systems for the injectors.

HL-LHC (High Luminosity LHC Project)

R16: In preparation for the cost review in October 2016, develop a decision matrix for all ongoing changes and alternatives.

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

Conclusions

LHC is operational at 13 TeV c.m. (> 4fb-1 in 2015) and with 25ns beams (2x2244 nominal bunches)

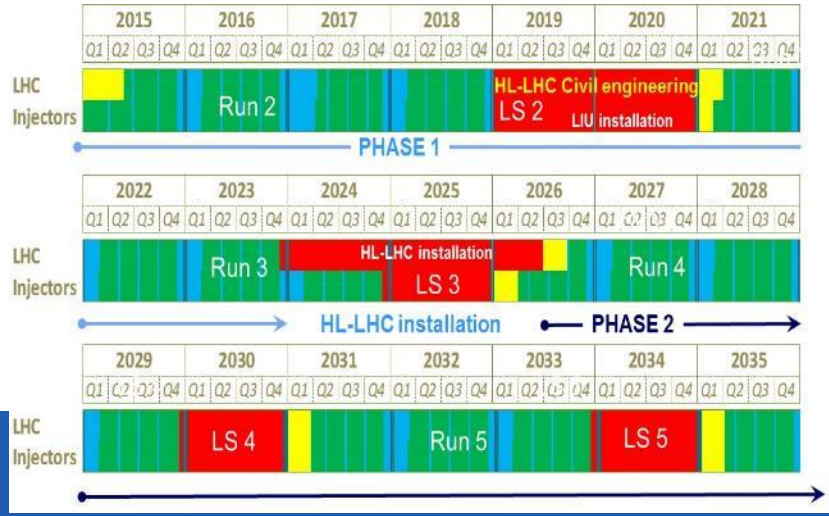
2016 : production mode at 13 TeV ; ~25 fb^{-1}

- **25 ns operation**
- **β^* = 40 cm in ATLAS and CMS ; 3m in LHCb ; 10m in ALICE**
- **Going towards combining ramp & squeeze**
- **Rapid intensity ramp up should be possible**

  Nominal design luminosity $1x10^{34}$ cm^{-2} s^{-1} should be reached
- **Optimisation of the integrated luminosity (availability)**

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

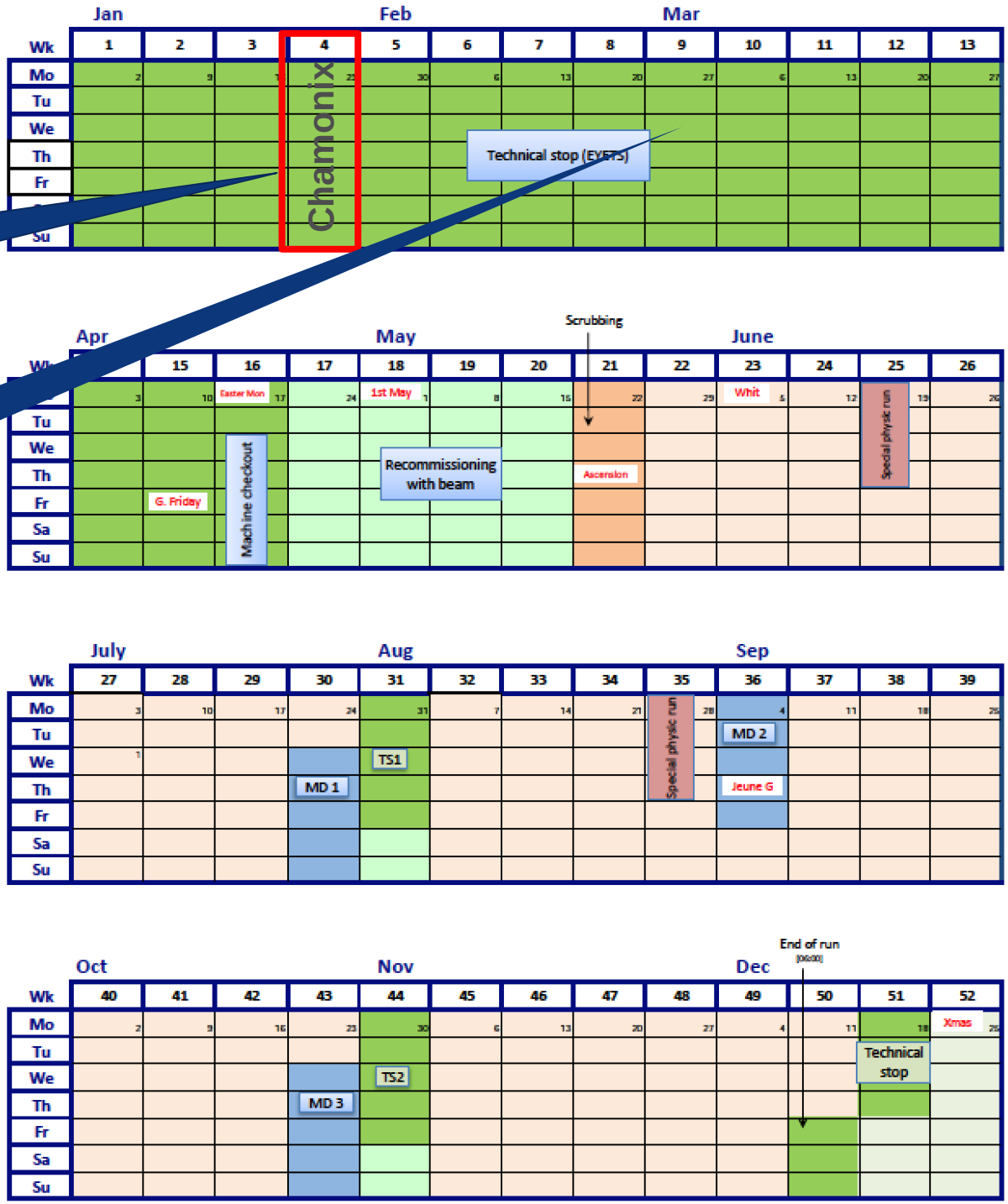
LHC Injector Upgrade (LIU => LS2)
and High Luminosity LHC (HL-LHC =>LS3)
well defined and now in construction phase



2017

Chamonix
23rd -26th January

Summary session of the LHC Performance Workshop - Chamonix 2017: Wednesday 1st March 2017



2016 winning numbers

13	25	27	48	40	+	25
TeV	**ns**	**bunches**		**cm**		**fb^{-1}**

Thanks for your attention

www.cern.ch