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LHC Machine Status

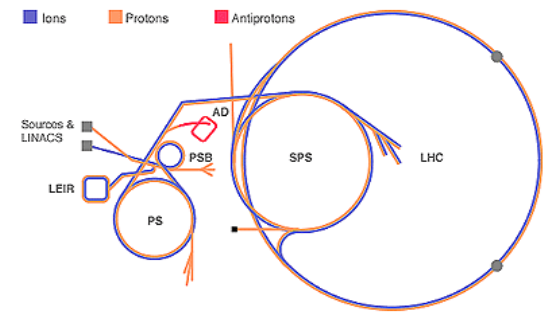
RRB

Frédéric Bordry
25th April 2016



YETS (Year End Technical Stop) 2015-2016

Regular maintenance, mandatory tests, problem fixing and unforeseen issues ... not all plain sailing !



PSB, PS
and SPS

	Jan			Feb				Mar					
Wk	1	2	3	4	5	6	7	8	9	10	11	12	13
Mo	4	11	18	25	1	8	15	22	29	7	14	21	28
Tu					Close PSB				1	SPS DSO test			
We													
Th													
Fr	Year end technical stop				Close Linac2	Close PS	Close SPS		Recommission injectors			G. Friday	
Sa													
Su													

LHC

	Jan			Feb				Mar					
Wk	1	2	3	4	5	6	7	8	9	10	11	12	13
Mo	4	11	18	25	1	8	15	22	29	7	14	21	28
Tu													
We				Year end technical stop									
Th										Powering tests			
Fr								DSO test				G. Friday	
Sa													
Su												Machine checkout	



Status of injectors

- ▶ **Booster:**
 - ▶ All operational beams available
 - ▶ Beam to ISOLDE on schedule
- ▶ **PS**
 - ▶ Beam to nTOF on schedule
 - ▶ Beam to AD and East Area users as foreseen this week
 - ▶ MTE to SPS for North Area
- ▶ **SPS**
 - ▶ **LHC 25 ns in good shape, reconditioning after extraction septum exchange**
 - ▶ Beam to North area users from Friday 22nd April – slight delay
 - ▶ First HiRadmat run of 2016 successfully completed

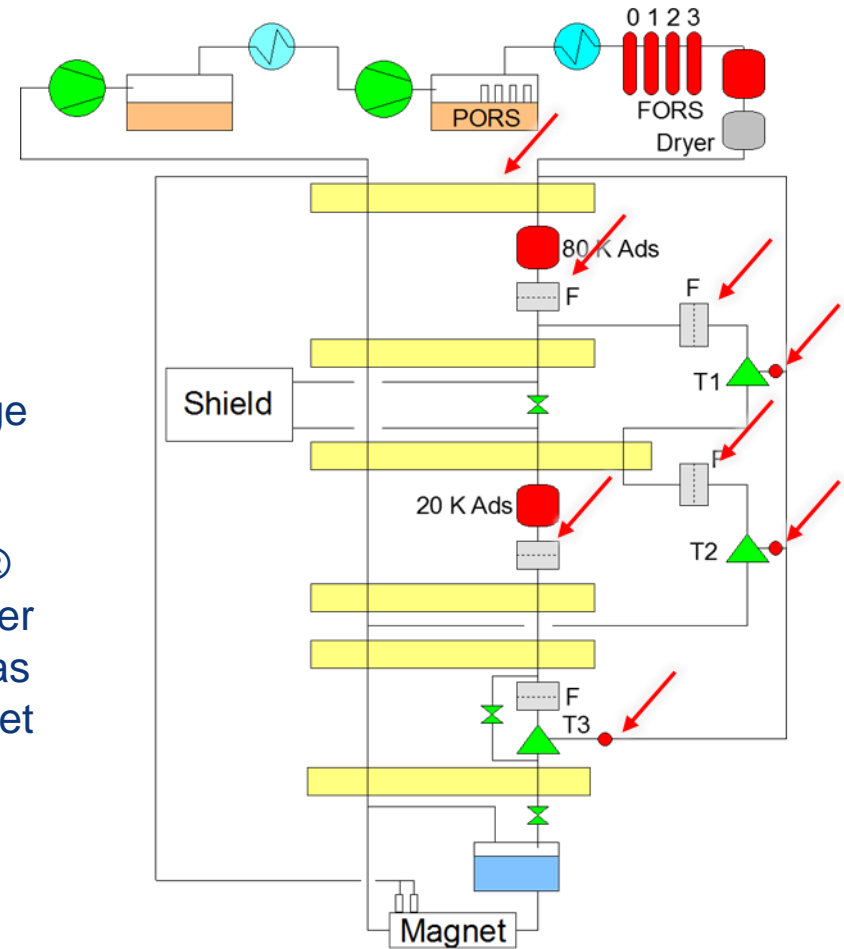
Wk	Apr 14	Apr 15	Apr 16	Apr 17	Apr 18	Apr 19	Apr 20	Apr 21	Apr 22	Apr 23	Apr 24	Apr 25	Apr 26
Mo	4	11	18	25	2	9	Whit 16	23	30	6	13	20	27
Tu								UA9 [24 h]		Cool-down			
We		Technical stop		Injector MD 10 hrs 8 to 18	Injector MD 10 hrs 8 to 18	Injector MD 10 hrs 8 to 18	Injector MD 10 hrs 8 to 18	Injector MD 10 hrs 8 to 18	Injector MD 10 hrs 8 to 18	Technical stop ITS2 36 hrs	Injector MD 10 hrs 8 to 18	Injector MD 10 hrs 8 to 18	Injector MD 10 hrs 8 to 18
Th					Ascension					COLDEX 24 hrs			
Fr					May Day comp								
Sa													
Su				1st May									

Beam to AD
 Start NA setup
 ISOLDE, nTOF, EA setup
 Start ISOLDE
 nTOF physics
 Start NA proton
 physics
 Start AD physics
 Start physics East Area
 Start LEIR

CMS Cold-Box Contamination 2015

- 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.

Consolidation works performed during YETS 2015-2016

- Replacement the **primary oil separator system**
- Replacement of the **coalescers system**
- Replacement of the **activated charcoal** in warm adsorber
- Replacement of the **high pressure piping** between the surface compressor station and the underground cold-box
- **Chemical cleaning of the cold box circuits**
- Replacement the **20 K and 80 K adsorbers**
- Repair of **liquid nitrogen pre-cooler** heat exchanger
- Repair of the damaged **cryogenic valve CV273** in the experimental cavern

All works completed and equipment commissioned
The cooling down of the CMS magnet is ongoing:

- Started from 165 K (09 April 2016)
- No liquid nitrogen pre-cooler used

Cold box cleaning: USC

350+10+8 grams of Breox

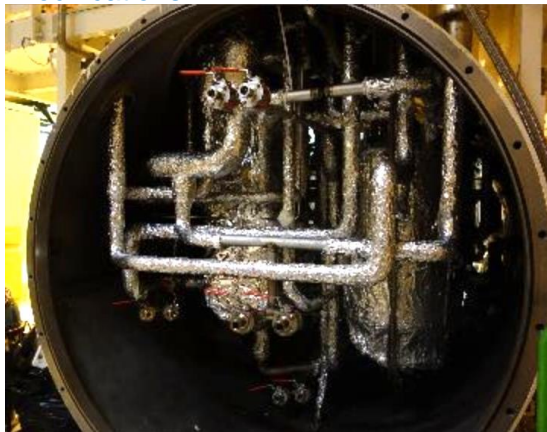
Cold box shunts & taps



Warm-end of cold box modifications



Heat exchanger tapings (taken out)



Cold-end of cold box modifications

Cleaning machine components



Commissioning finished 25 Jan.

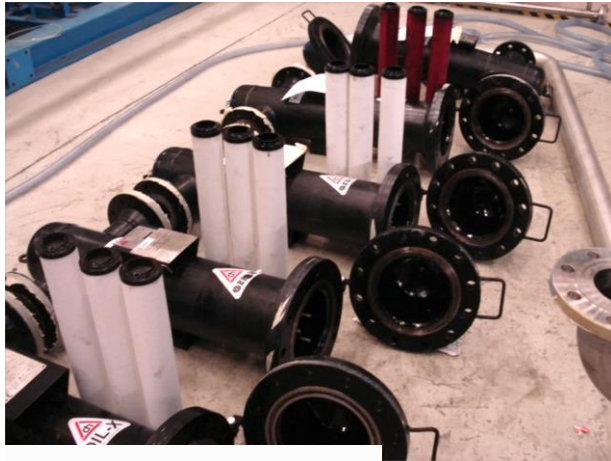
Fluid circulation in cct 1 started 25 Jan

Following the drying procedure, the outgassing rate of the cleaning liquid is very low (less than 100 ppm over several days). Most of the contaminated items (O-rings etc.) are replaced

Cryogenics: Oil removal system & adsorbers

Surface compressor hall

Old Coalescers: removed



New Coalescers:



Old PORS: removed



New PORS

pressure tested at A.L. factory



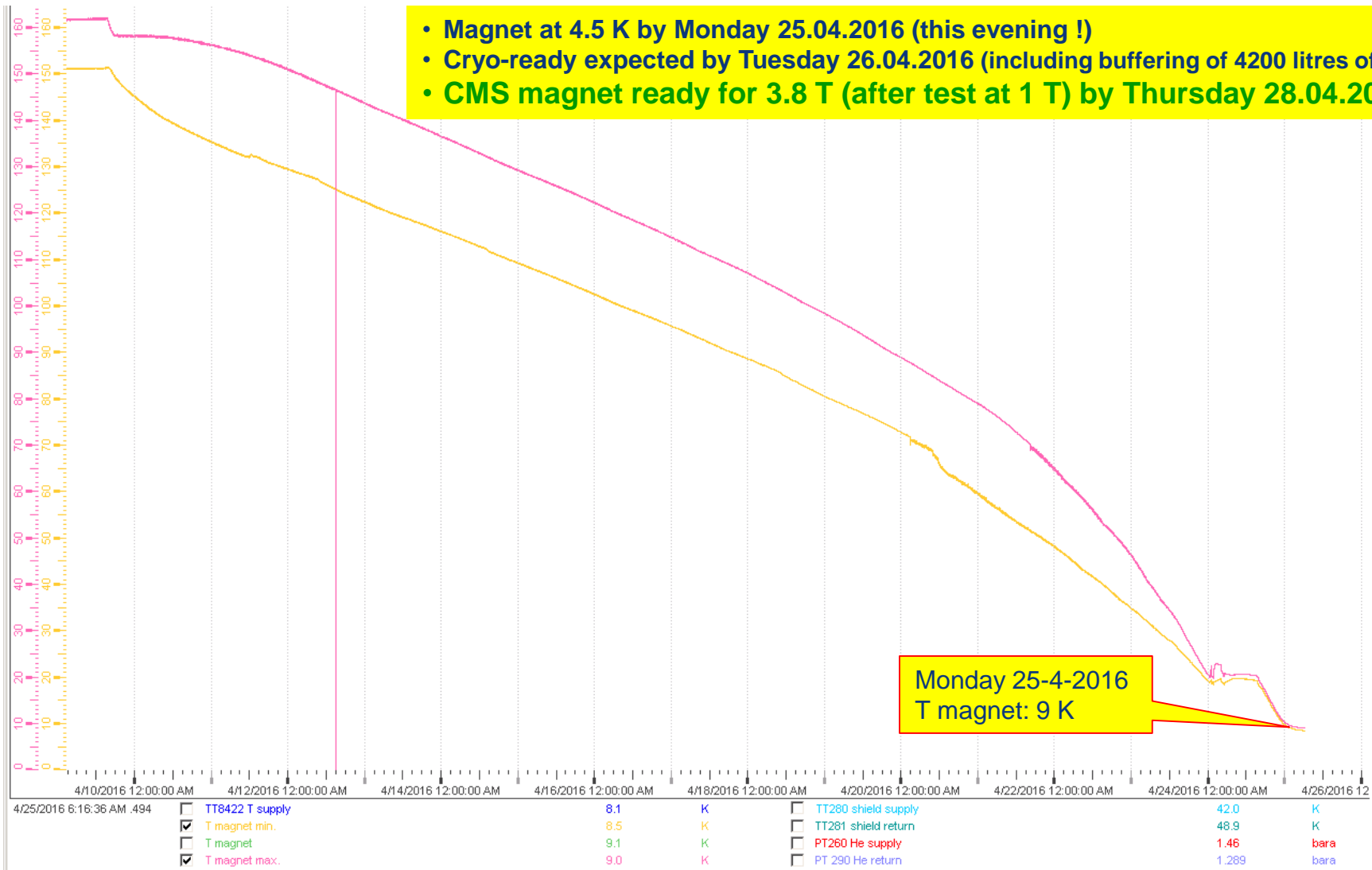
Replacement the primary oil separator and the coalescers system



Fantastic combined works and team spirit between CMS and A&T groups.

CMS Magnet cooling down progress

- Magnet at 4.5 K by Monday 25.04.2016 (this evening !)
- Cryo-ready expected by Tuesday 26.04.2016 (including buffering of 4200 litres of LHe)
- CMS magnet ready for 3.8 T (after test at 1 T) by Thursday 28.04.2016



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

✓ **13 TeV, 40 (50) cm β^***

- Keep an eye on availability

✓ **Nominal 25ns beam, 2748 bunches, 288 bpi**

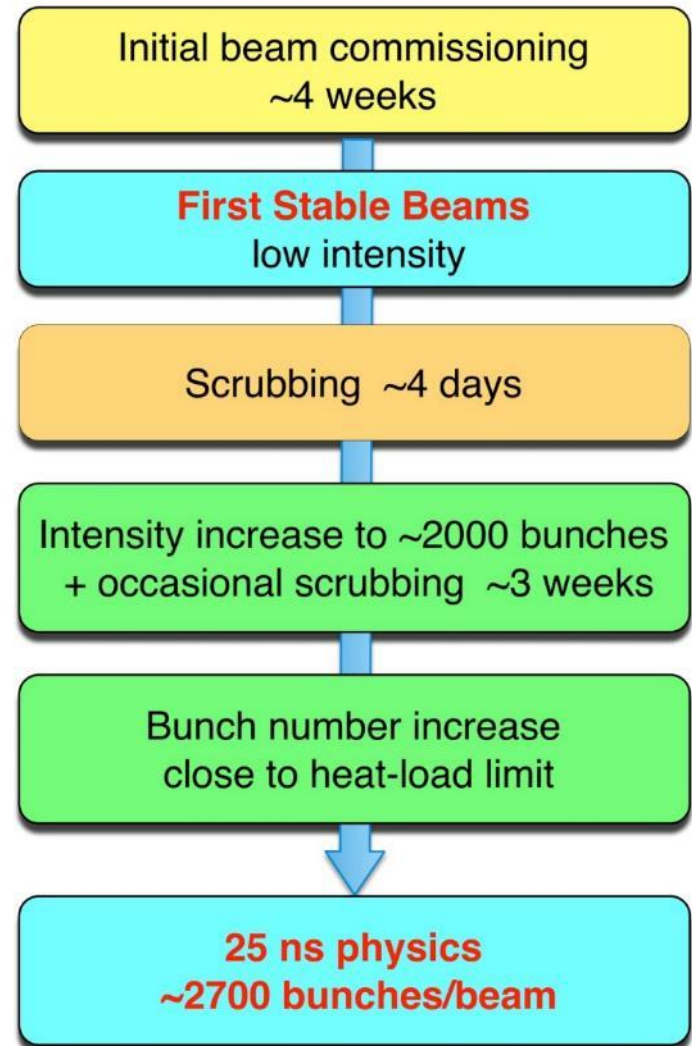
- May push later to shorter bunches & BCMS

✓ **Good Availability**

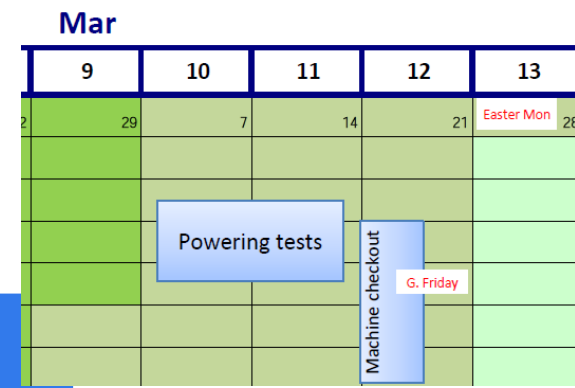
- Sustained effort to trace faults
- Keep avoidable interruptions to production running to a minimum

✓ **Excellent Operational Efficiency**

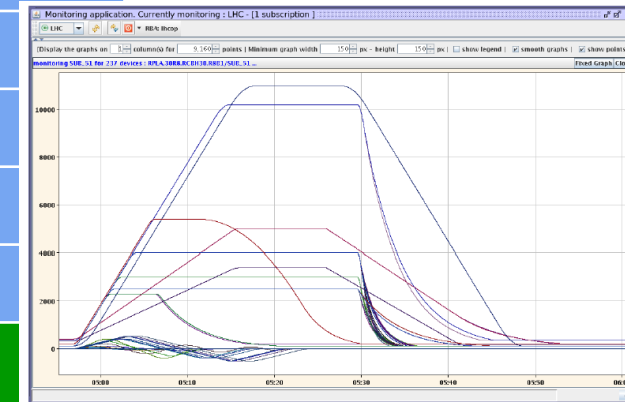
- Combined ramp/squeeze
- Work on injection process



Powering test Status (19th March 2016)



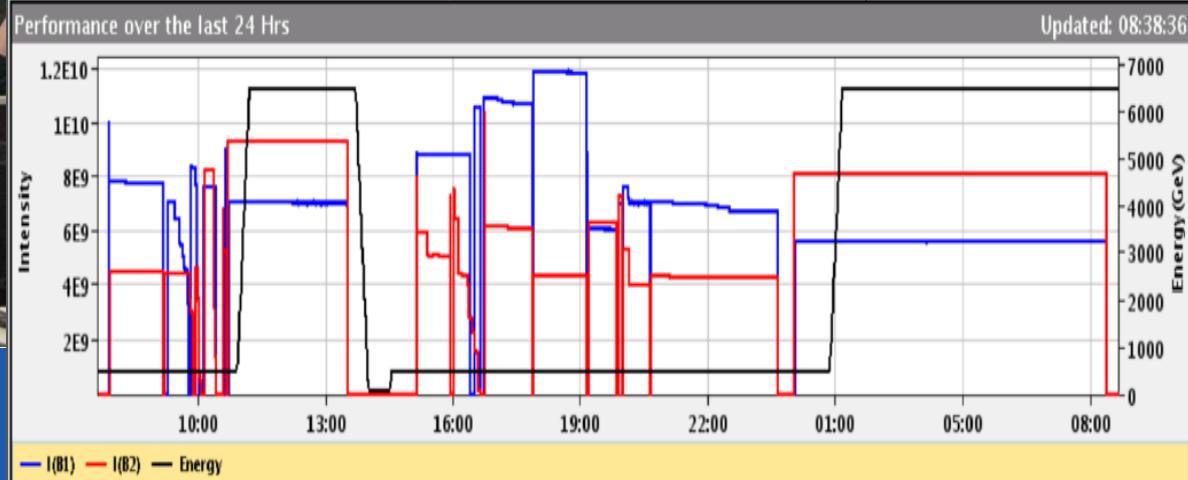
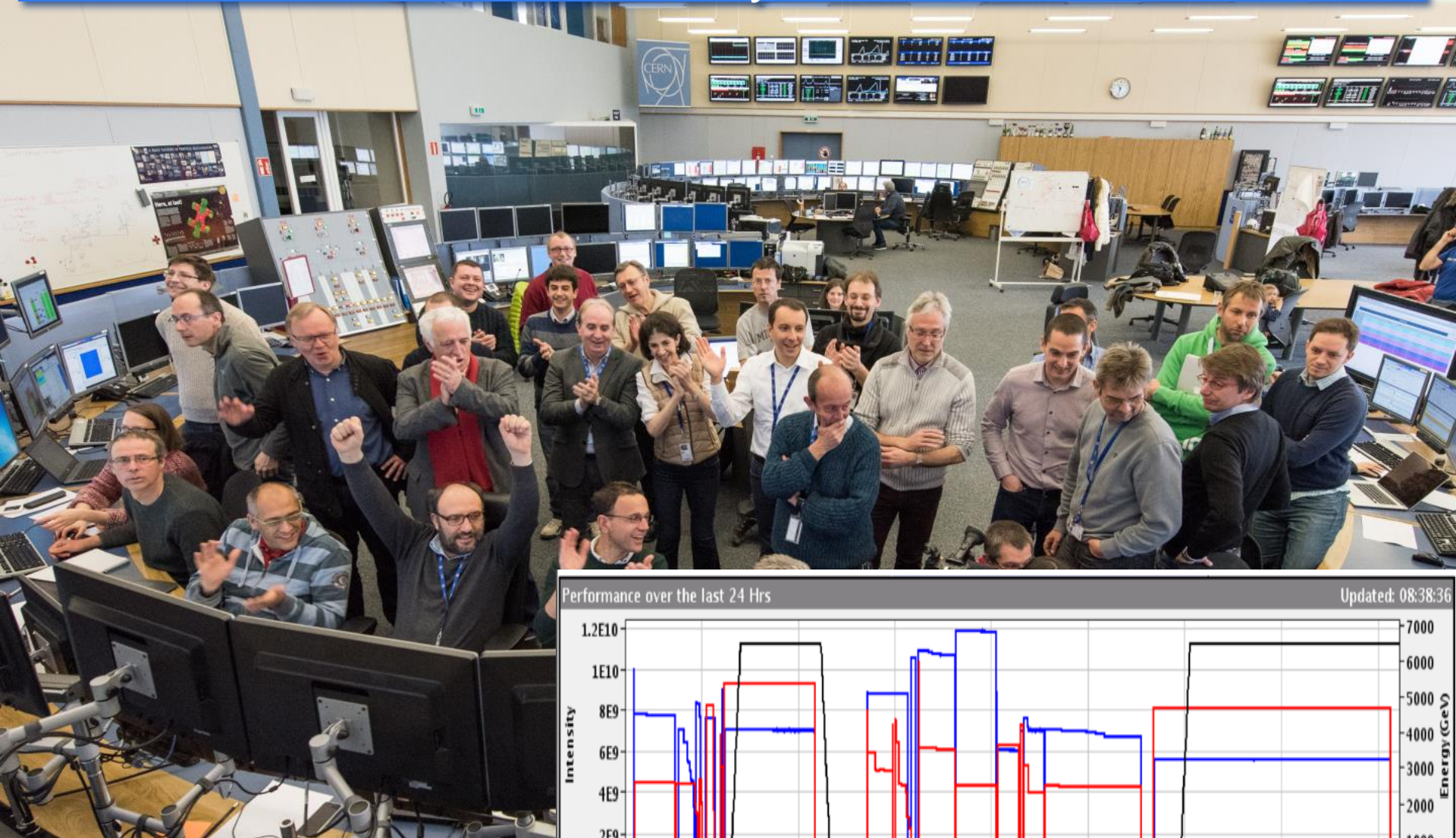
Circuit type	Number of circuits	Completion [%]
RBs	8	100% – only 2 quenches above 6.5 TeV
RQs	16	100% – no quench
ITs	8	100%
IPQ/IPD	94	100%
600 A	412	100%
120-60 A	1049	100%
Total		100% (8592 successful tests)



Main bend circuits:

- 6 circuits without quenches up to 6.55 TeV (11080A) and 4h at 6.55 TeV
- Sector 2-3: one quench at 11040 A (6.5 TeV – 10980 A) and OK (new magnet)
- Sector 5-6: one quench at 11076 – (magnet quenched in 2008 at 10976 A)

First circulating beams in LHC in 2016 on Easter Friday 25th March 2016

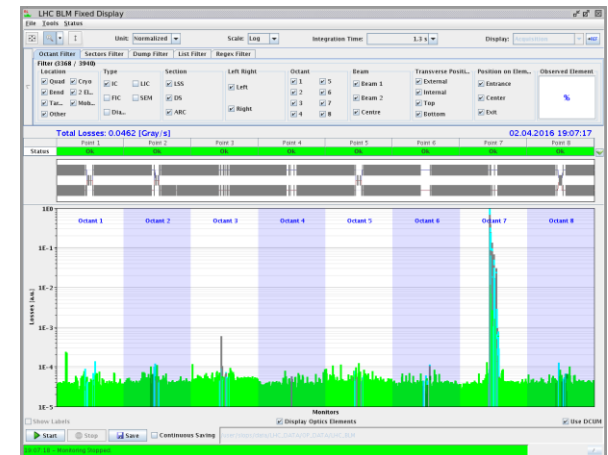


Milestones 2016

Friday 25 th March	First beam. RF capture
Saturday 26 th March	First ramp to 6.5 TeV
Sunday 27 th March	Squeeze to 0.4 m and optics measurements
Thursday 31 st March	Optics correction at 6.5 TeV (flat-top+squeeze)
Wednesday 6 th April	Nominal bunch to flat-top
Friday 8 th April	Nominal bunches into collisions
Tuesday 12 th April	Quiet beams
Sunday 17 th April	Aperture measurement (collision)
Thursday 21 st April	72 bunch injection to 444 bunches/beam
Friday 22 nd April	First Stable Beams – 3 bunches/beam

Progress 1

- Combined ramp and squeeze in place
- Optics measured and corrected through cycle
- Aperture measured through cycle
- Collimators set-up through cycle
- Full set of loss maps performed
- RF, transverse dampers, beams dumps, injection and transfer lines, feedback systems fully commissioned
- Machine protection re-commissioned and fully qualified
- ULO measured at 450 GeV
 - in similar orientation to end 2015
 - bump in place throughout cycle
- New injection protection devices (TDIs) look good; barely discernible impedance



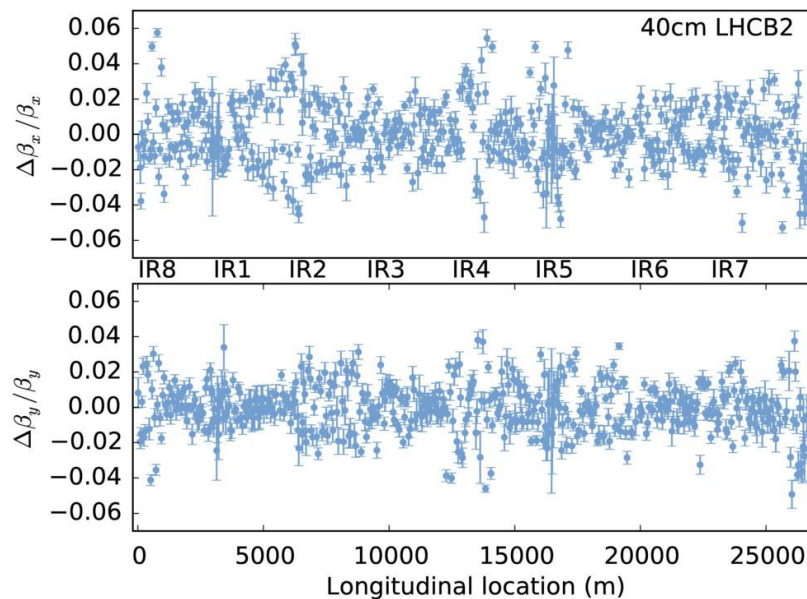
Progress: Squeeze to 40 cm

- Optics measured and corrected to unprecedented levels
- Aperture at 40 cm measured carefully: tight as expected but sufficient
- TOTEM and AFP Roman pots commissioned and set-up for insertion during 40 cm operation

Measured beta* in ATLAS and CMS



IP	B_{IP}	$\beta_{IP\ err}$	w	w err
ip1b1.X	0.399	0.002	0.047	0.009
ip1b1.Y	0.404	0.001	-0.009	0.009
ip1b2.X	0.396	0.001	0.009	0.011
ip1b2.Y	0.411	0.004	0.072	0.010
ip5b1.X	0.400	0.000	-0.009	0.008
ip5b1.Y	0.403	0.002	-0.028	0.010
ip5b2.X	0.409	0.005	0.070	0.013
ip5b2.Y	0.399	0.002	-0.025	0.011
Average	0.403	0.002	0.016	0.010
RMS β -beat in %	<u>1.4</u>			

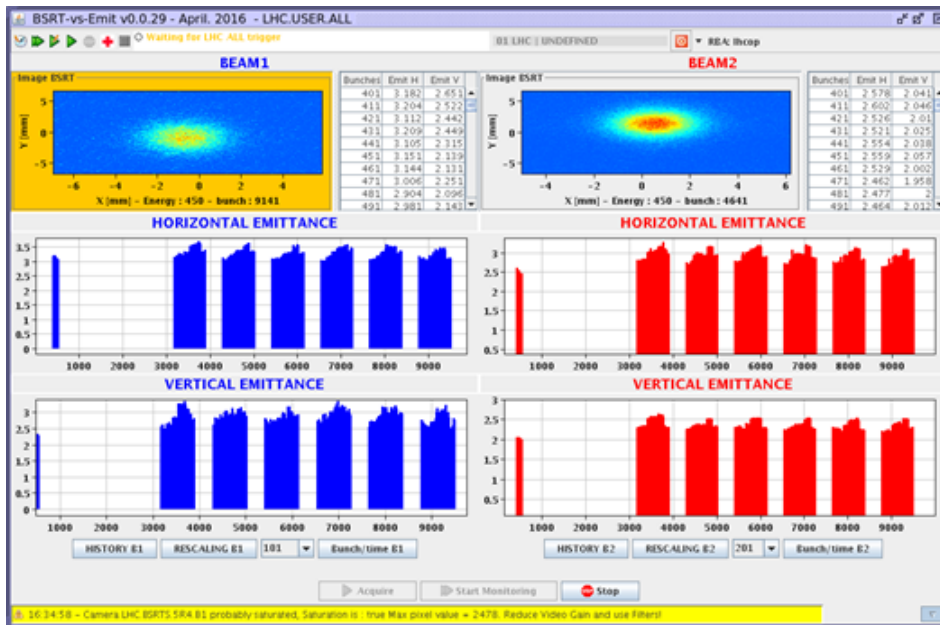


Impressive level of correction:
RMS beta beating ~1.4%

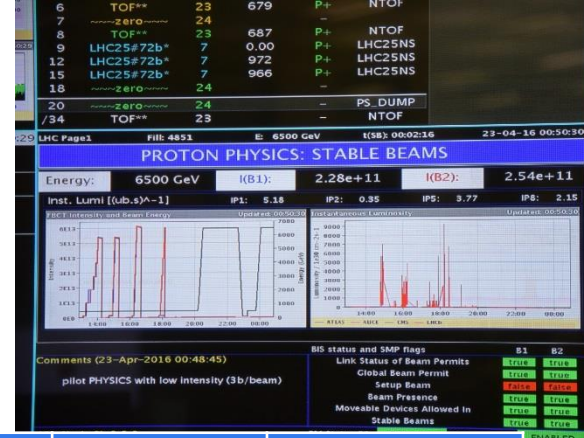
Progress: Initial multi-bunch tests

Initial multi-bunch tests encouraging

- Injection of 444 bunches
- Electron cloud de-conditioning over YETS looks acceptable

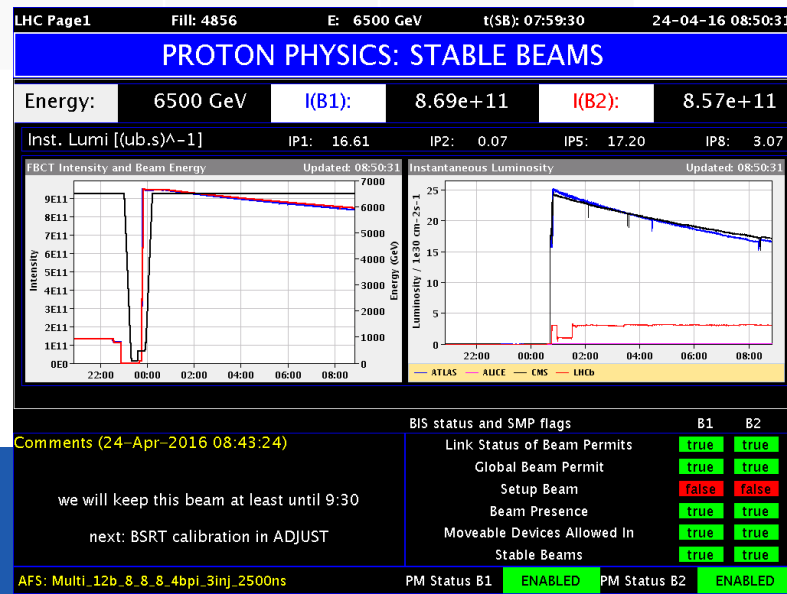


LHC pilot physics



Date	Fill no.	Bunches	Bunches colliding	Peak lumi $\text{cm}^{-2}\text{s}^{-1}$	Stable beams	Integrated lumi
Sat 23 April	4851	3	2	5.2e30	3h52	64 nb^{-1}
Sat 23 April	4852	3	2	5.9e30	2h34	49 nb^{-1}
Sun 24 April	4856	12	8	2.5e31	8h25	0.6 pb^{-1}
Mon 25 April	4861	12	8			

- Monday 25th: 25 ns injection tests with up to 288 bunches down the lines from the SPS
- Scrubbing thereafter for around 4 days targeting 2000+ bunches with 288 bunches per SPS batch



Scrubbing and intensity ramp-up

- ▶ Re-establish 2015: ~2000 bunches conditions during dedicated 4 day run (450 GeV)
- ▶ **Intensity ramp-up (288b) phase 1:**
 - ▶ below the heat load limit
 - ▶ remedial scrubbing as required
 - ▶ 3-12-48/72-288-570-860-1200-1700
 - ▶ ~7 steps – ~ 3 days per step => ~ 3 weeks
- ▶ **Phase 2: (maximal) scrubbing during Stable Beam**
 - ▶ ~2000 to 2748
 - ▶ Small increments in number of bunches (“mini-steps”) playing on batch gap

	May					June						
	16	17	18	19	20	21	22	23	24	25	26	
Scrubbing												
ing	18	25	2	9	Whit	16	23	30	6	13	20	27
					VdM		beta* 2.5 km dev.					
			Ascension					TS1				
			May Day comp				MD 1					
		1st May		Intensity ramp-up Scrubbing as required								

LHC schedule 2016

2016:
a production
year

	Jan				Feb				Mar				
Wk	1	2	3	4	5	6	7	8	9	10	11	12	13
Mo	4	11	18	25	1	8	15	22	29	7	14	21	28
Tu													
We													
Th													
Fr													
Sa													
Su													

Annotations: Year end technical stop (Feb 4-6), Powering tests (Mar 10-12), Machine check-up (Mar 12-13), Easter Mon (Mar 28)

	Apr			May				June					
Wk	14	15	16	17	18	19	20	21	22	23	24	25	26
Mo	4	11	18	25	1	8	15	22	29	6	13	20	27
Tu													
We													
Th													
Fr													
Sa													
Su													

Annotations: Scrubbing (Apr 17), Recommissioning with beam (Apr 14-16), Accession (May 18), May Day comp (May 19), Intensity ramp-up / Scrubbing as required (May 20-21), beta* 2.5 km dev. (Jun 22), TS1 (Jun 23), MD 1 (Jun 24)

	July				Aug				Sep				
Wk	27	28	29	30	31	32	33	34	35	36	37	38	39
Mo	4	11	18	25	1	8	15	22	29	6	13	20	27
Tu													
We													
Th													
Fr													
Sa													
Su													

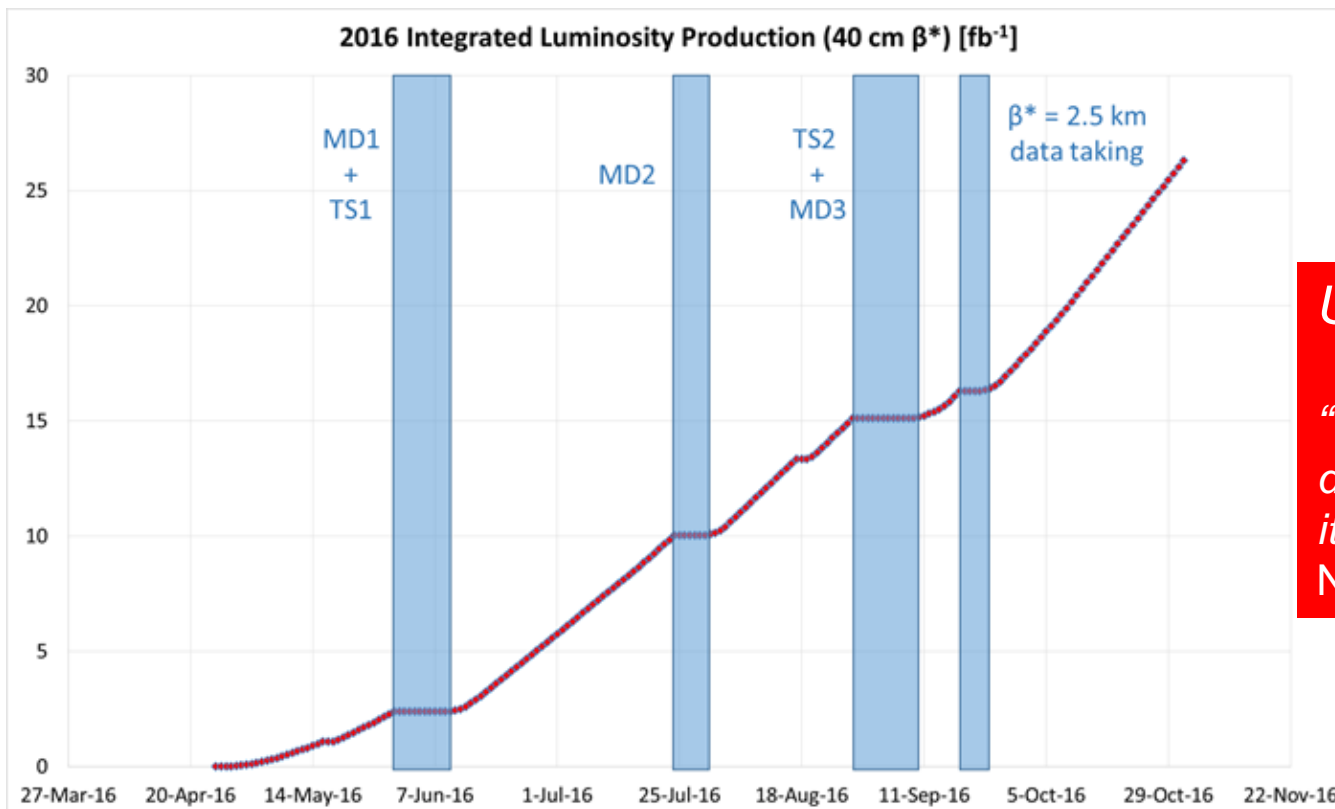
Annotations: beta* 2.5 km dev. (Jul 30), MD 2 (Jul 30), MD (Aug 33), TS2 (Sep 35), MD 3 (Sep 36), Jeune G (Sep 36), beta* 2.5 km dev. (Sep 38)

	Oct				Nov				Dec				
Wk	40	41	42	43	44	45	46	47	48	49	50	51	52
Mo	3	10	17	24	31	7	14	21	28	5	12	19	26
Tu													
We													
Th													
Fr													
Sa													
Su													

Annotations: End of run (Nov 50), Extended year end technical stop (Nov 50-51), Lab closed (Dec 51), Ion run (p-Pb) (Dec 47-48), Xmas (Dec 51), New Year (Dec 52)

LHC goal for 2016

Integrated luminosity goal:
2016 : $\sim 25 \text{ fb}^{-1}$ at 13 TeV c.m



Usual caveat ...

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

LHC goal for 2016 and for Run 2 and 3

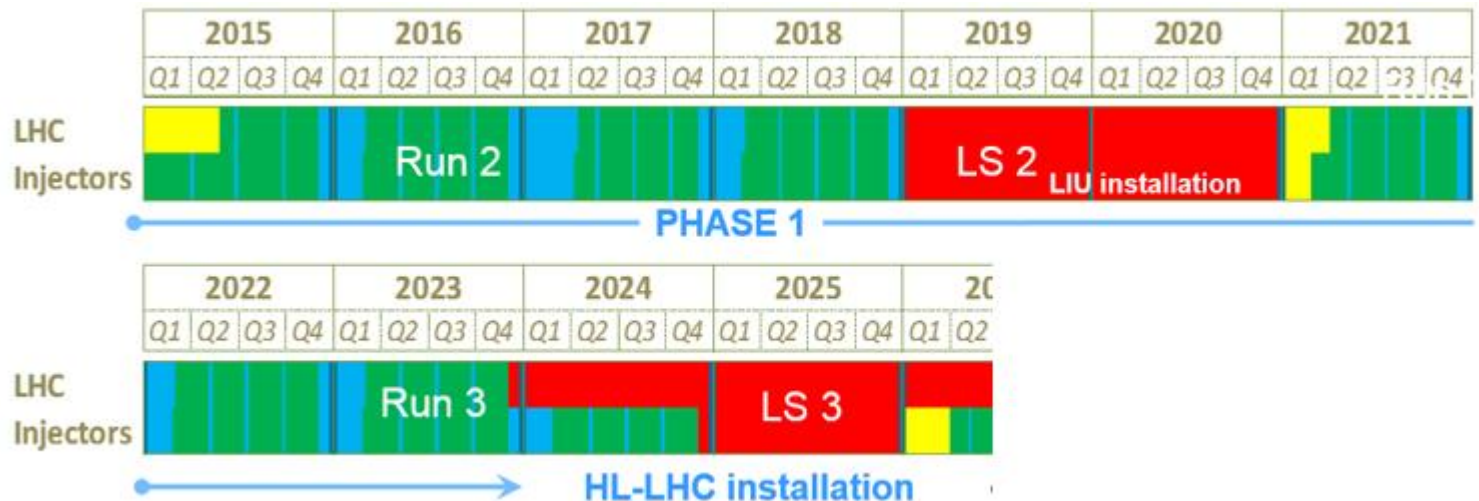
Integrated luminosity goal:

2016 : $\sim 25 \text{ fb}^{-1}$ at 13 TeV c.m

Run2: $\sim 100 \text{ fb}^{-1}$

Prepare for (or go to) 14 TeV operation

300 fb^{-1} before LS3





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