Chamonix 2016 – Session 1
Lessons learned

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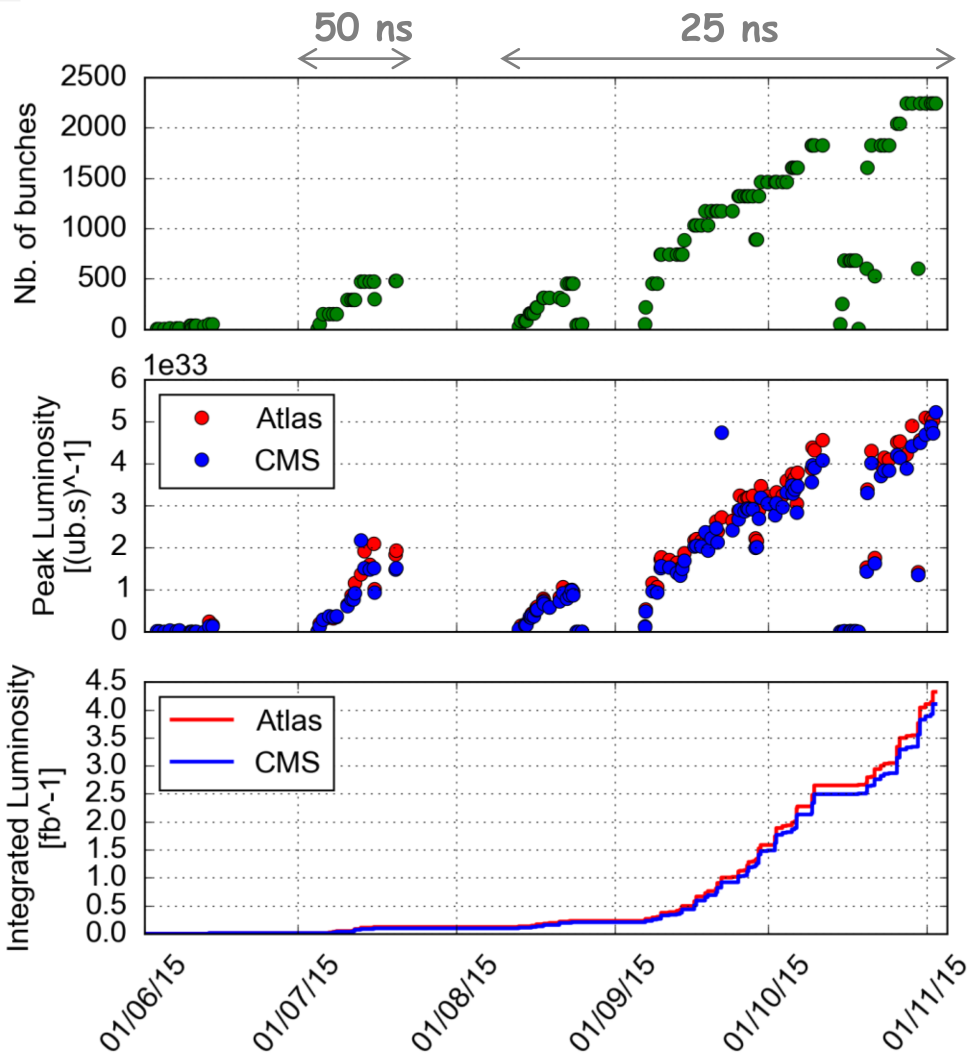
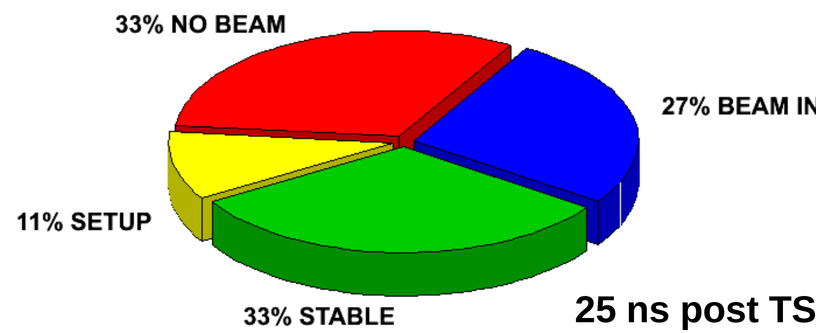
Session 1 – Lessons learned

- Lessons from LHC operation in 2015 – G. Pappoti
- LHC Operation and Efficiency in 2015 – M. Solfaroli
- Machine Protection at 6.5 TeV – J. Uythoven
- Collimation System Performance – B. Salvachua
- RF and Transverse Damper Systems – P. Baudrenghien
- Circuit Performance at 6.5 TeV and beyond – A. Verweij

25 ns – yes we can do it !



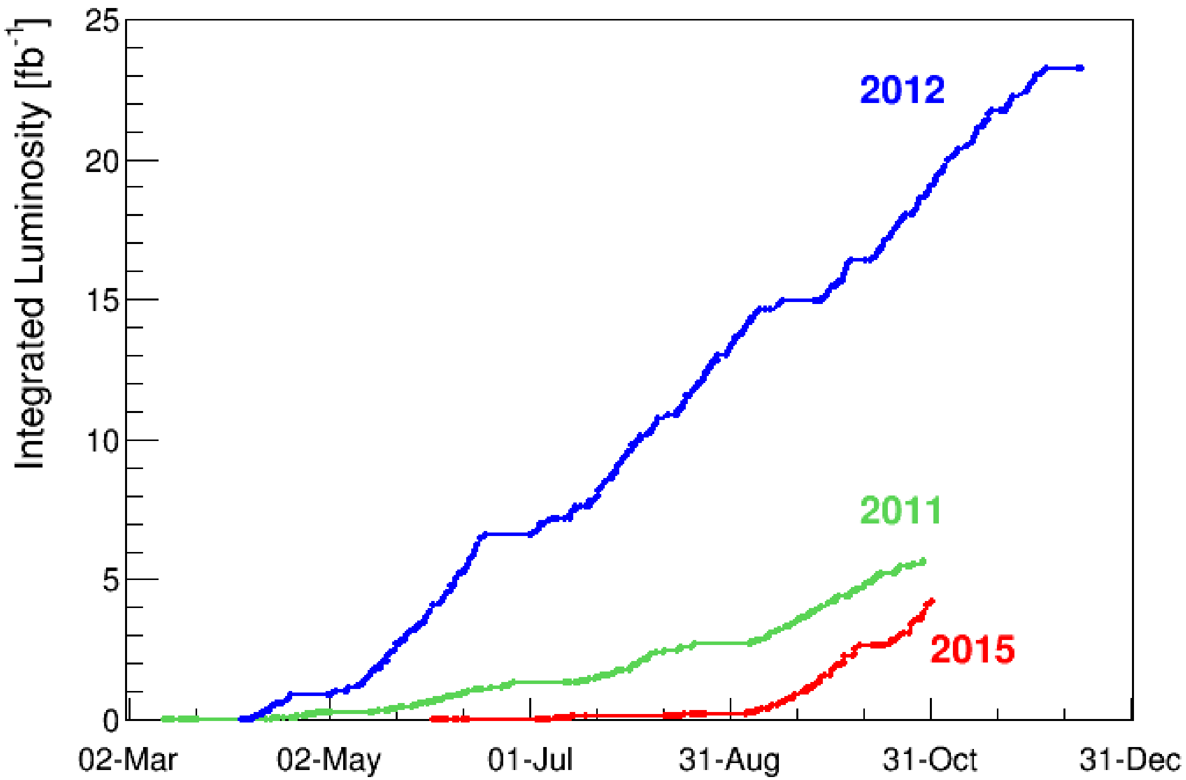
- Invested a lot of time in scrubbing and special physics.
- Intensity ramp-up lasted until the end – and was not completed.
- Real production started in September only.
- Availability for stable beams during 25ns similar to 2012.



25 ns post TS2

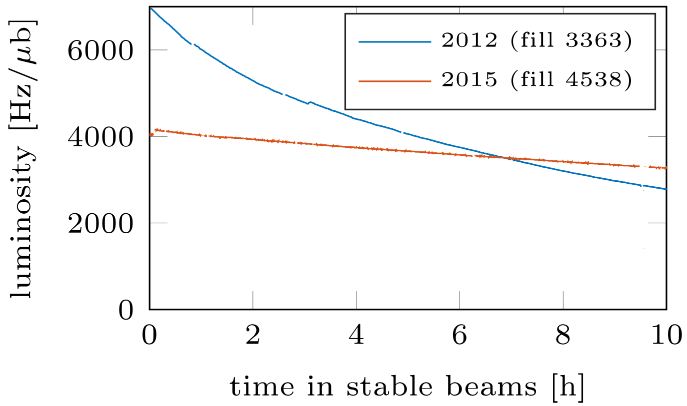
In business for run2

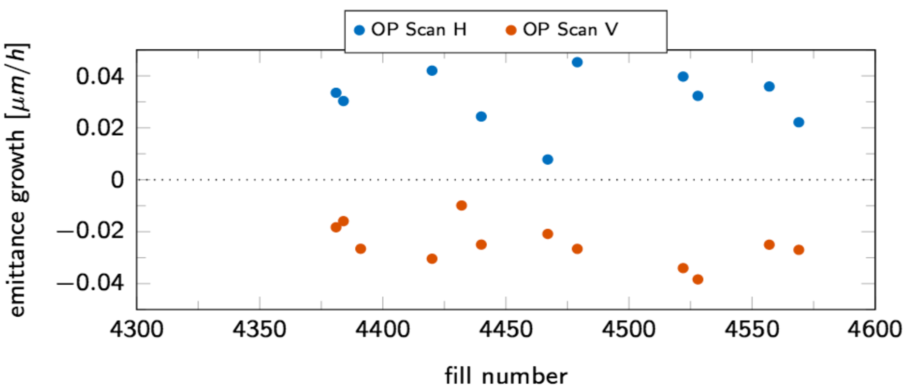
- The target of 5-10 fb-1 may have been missed, but we also lost ~4 weeks of running in 2015.
- In the last week, with 2244 bunches, the performance was similar to 2012 ~ fm^{-1} / week. ***We are in the starting blocks for run2!***



Luminosity & emittance

- Healthy luminosity lifetime ~30-40 h favours long fills (> 20 hours).

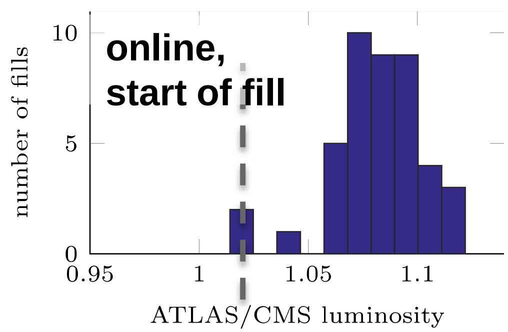


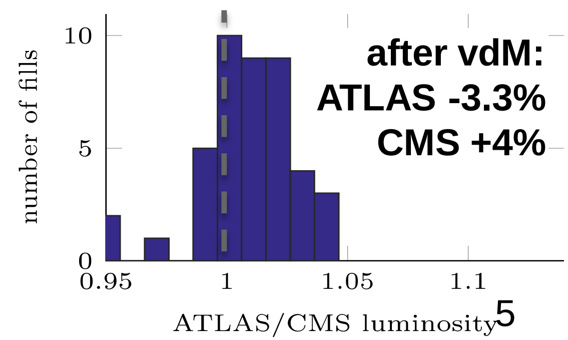


- Synchrotron radiation damping is clearly observable.
  - *Vertical emittance shrinking during fills → contribution to long L lifetime.*

- (Fake) luminosity imbalance triggered machine studies that revealed a waist offset of 20cm at the IPs:

  β^* = 84 cm (not 80 cm)

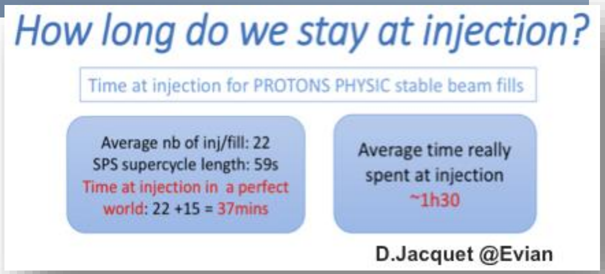


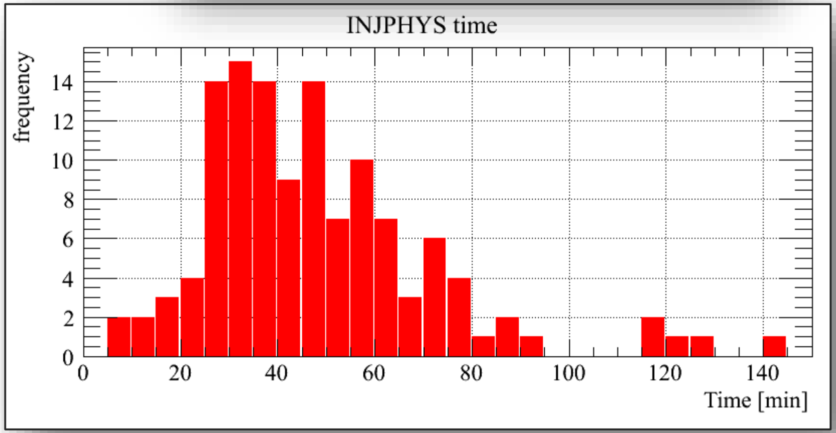


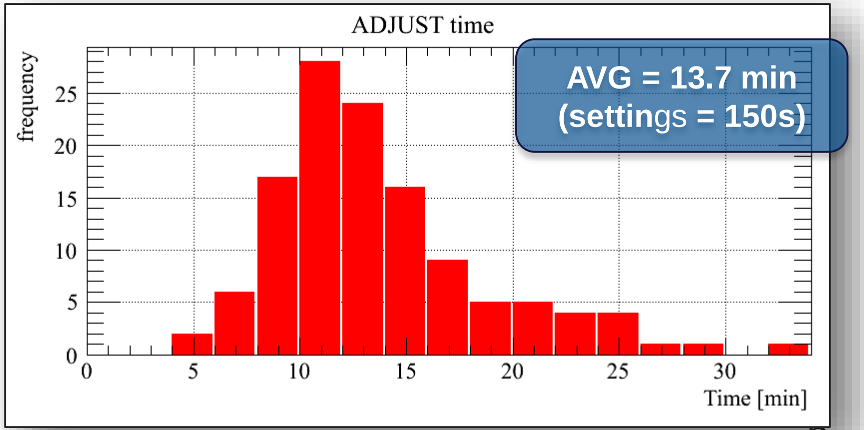
Cycle & efficiency

Where can we gain **time**?

- **Injection** remains a phase where we spend much more time than the theoretical time. There are many reasons → to be improved in 2016.
- **Ramp and squeeze** are highly optimized – clockwork. We can only gain by combining ramp & squeeze: we will squeeze to 3m during the 2016 ramp.
- **Adjust** (going into collision): we could gain 5-10 mins on average. Discussions with LPC & experiments initiated to move faster to stable beams.

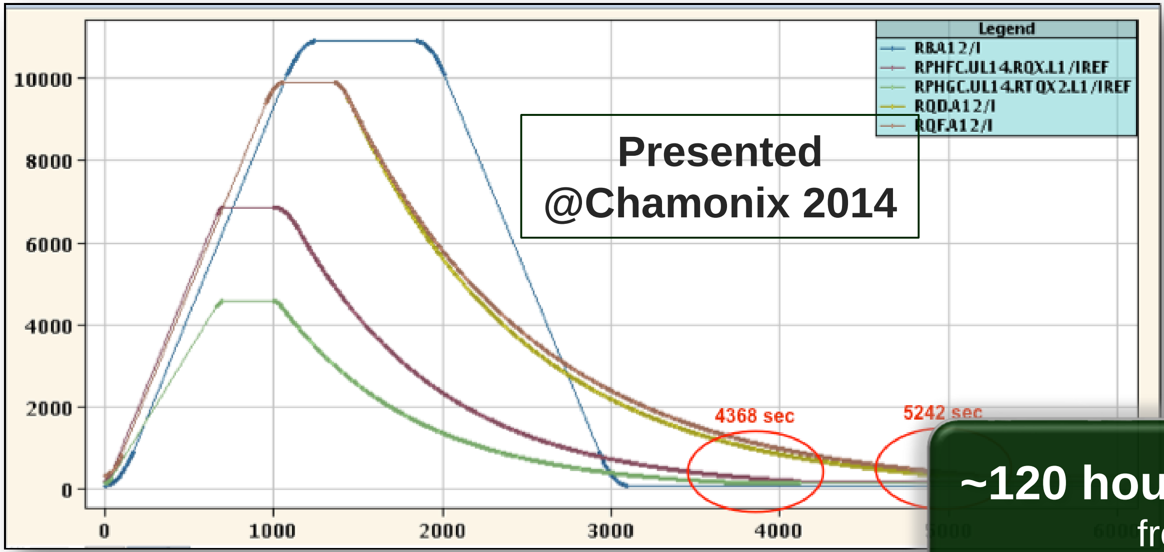






Pre-cycle

✧ **230 pre-cycles** of whole LHC done in 2015



The pre-cycle & rampdown strategy was already adapted in 2015 as compared to run 1.

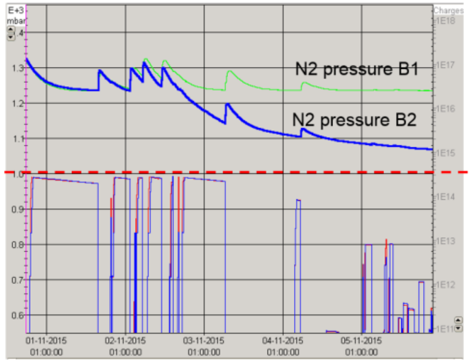
~120 hours (5 days) gained in 2015 from precycle&rampdown

We cannot do without pre-cycle…

- …but in 2016 another gain of **4-5 days** could be achieved by pre-cycling to **3.5 TeV** (and not 6.5 to TeV).
- This has consequences for injection (different fields after ramp-down or pre-cycle): **will be tested during beam commissioning** (trivial to back off).

MPS “topics” in 2015

- mDQQBS radiation induced failures.
  - *No safety, repair during TS2.*
- TDI absorber failures > 400 deg.
  - *Limit on no. injected bunches.*
- BLM threshold changes
  - *Weigh unnecessary UFO dumps vs protection.*
- Doublet beam for scrubbing
  - *Issues with interlock BPMs*.
- Beam dump block N2 pressure.
  - *Discovered a weakness in the surveillance of the dump*.



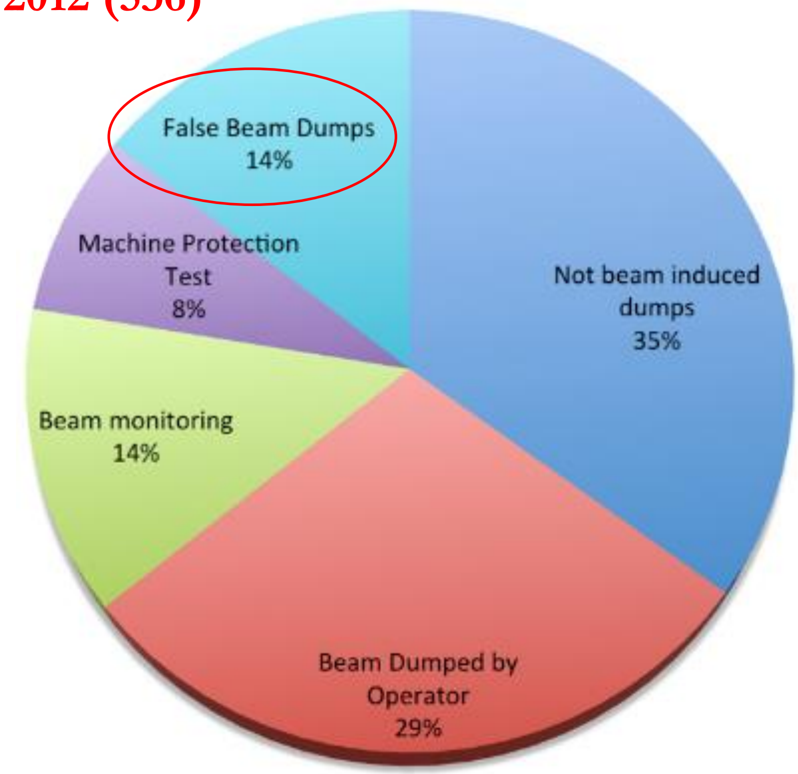
Efficient and fast reactions, mitigations were put in place.

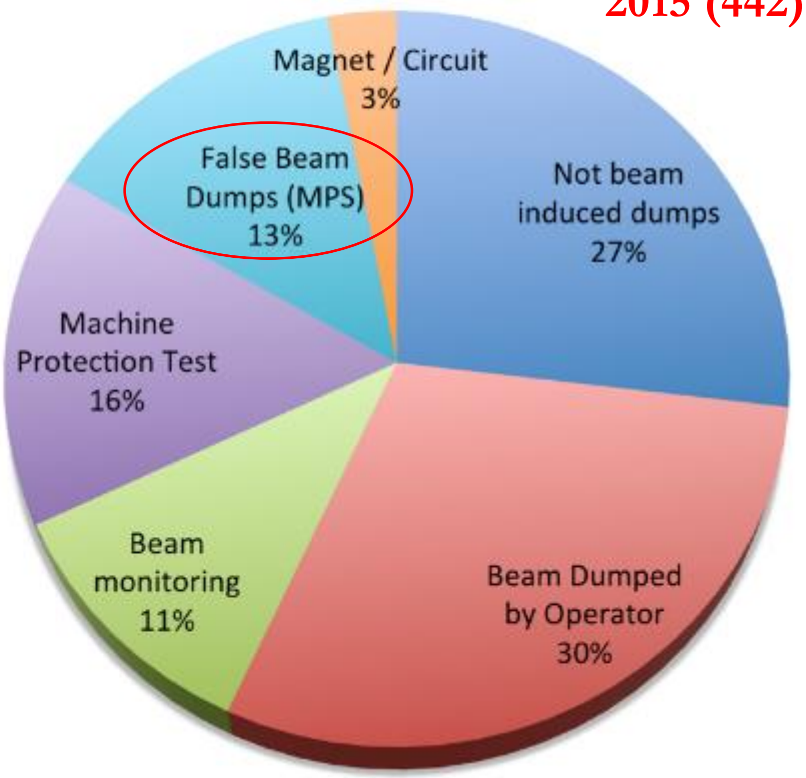
No problems during the intensity ramp up of the LHC in 2015.

MPS dumps

Beam dump causes 2015 versus 2012

above injection





- False beam Dumps by Machine Protection Systems stable (LBDS, PIC, BLM, BIC, SIS, QPS, FMCM):

14 % in 2012 ➔ 13 % in 2015: OK

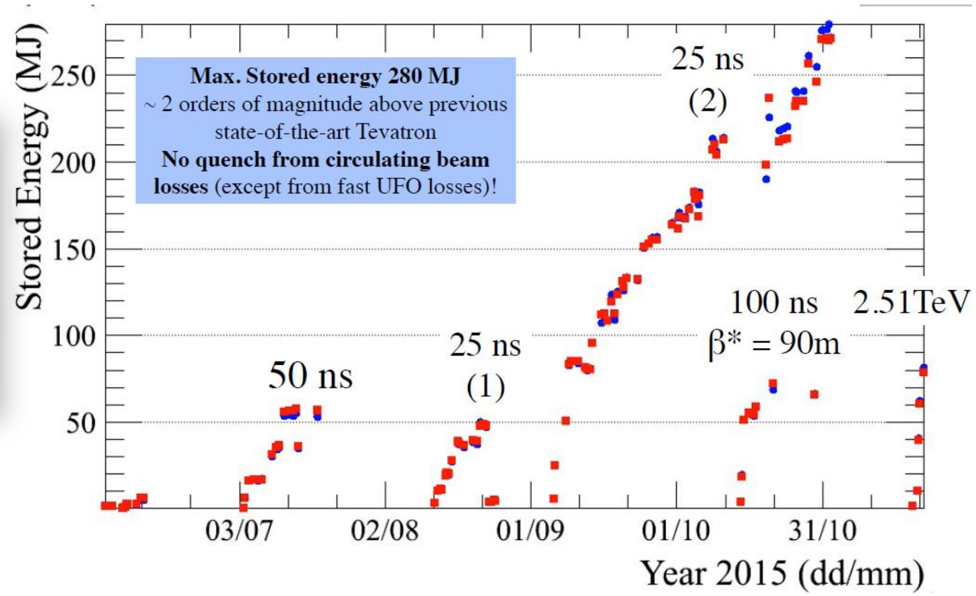
MPS in 2016

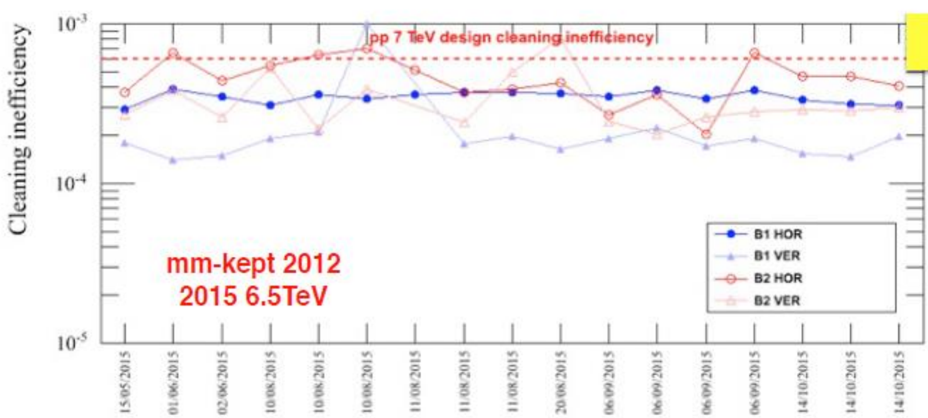
- Intensity ramp up in 2016 is likely to be similar than in 2015. In particular because of the smaller b* of 40-50 cm:
  - *Much less aperture and margins,*
  - *Potential instabilities.*
- Initial ramp up to ~500 bunches cannot go much faster as we need time & fills to monitor the evolution and performance. One or two fills are not sufficient…
- From 500-1000 bunches, ramp up speed is generally defined by our capacity to handle e-cloud, beam stability, etc.
  - *Duration at high intensity is very likely not defined by MP, see 2012 and 2015 !*

Collimation – cleaner than ever

The stored energy reached 270 MJ (360 MJ design) at 6.5 TeV

– still no quench of a magnet due to cleaning losses.





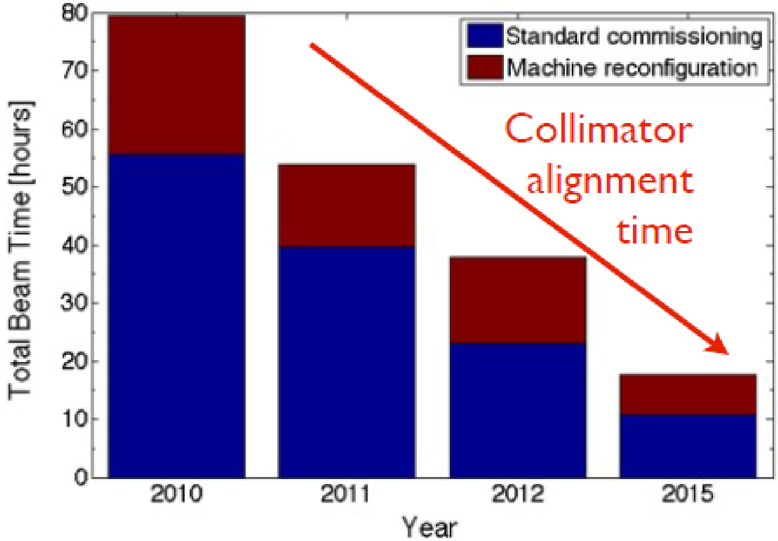
2015 Run

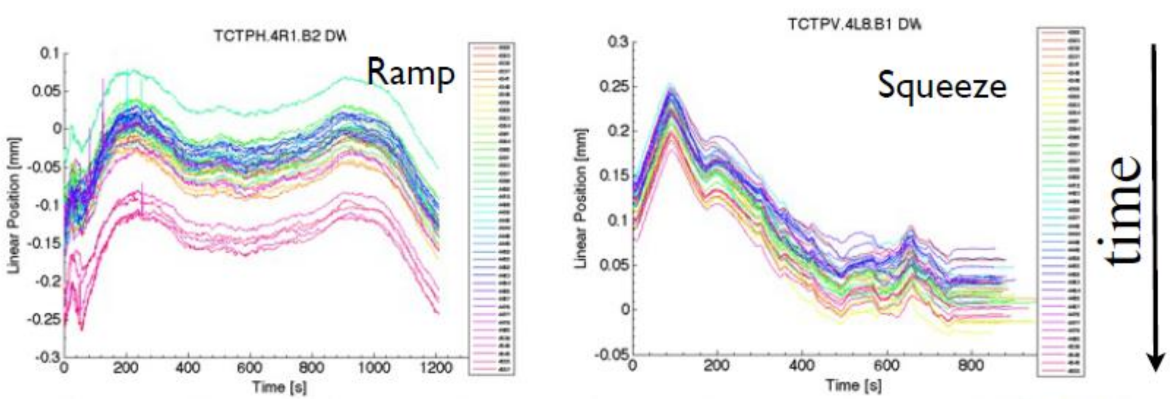
Remarkable cleaning stability with 6.5TeV beam, thanks to the excellent machine reproducibility

= magnets, collimators, instrumentation, feedbacks

Collimation – faster than ever

- Thanks to experience and automation the collimation setup and validation time was reduced by more than a **factor 4** since 2010.
- In 2015 80% of the collimators were aligned with BLMs, 20% with BPMs.





- Systematic orbit offsets in the collimators during the cycle (ramp, squeeze) will be corrected in 2016…
- Preparing to interlock the beam position in collimators at lowest β^*.

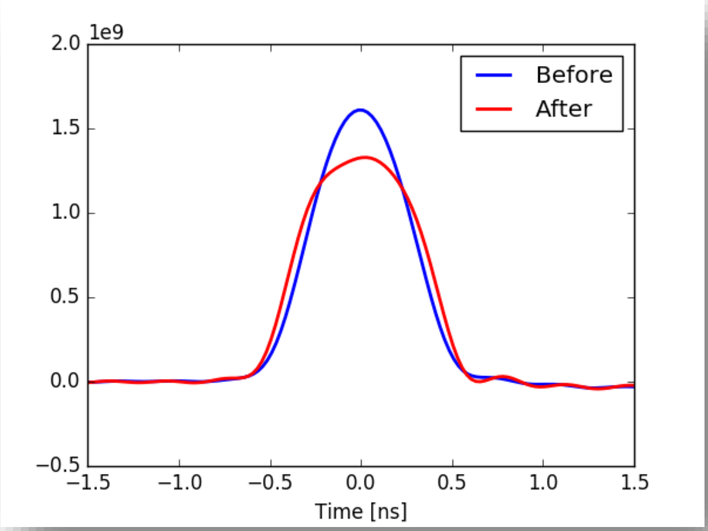
RF – stability

- The **single-bunch threshold** has been measured: nominal bunch intensity (1.1E11 p) will be unstable below 0.85 ns with 10 MV RF.
- No coupled bunch instability was observed so far (2244b).

Stability threshold

N_b (p per bunch) in E11	10 MV	12 MV	14 MV
0.9 ns	1.18	1.41	1.65
1 ns	2.00	2.40	2.80
1.1 ns	3.22	3.87	4.51
1.2 ns	4.98	5.97	6.97
1.3 ns	7.43	8.91	10.4

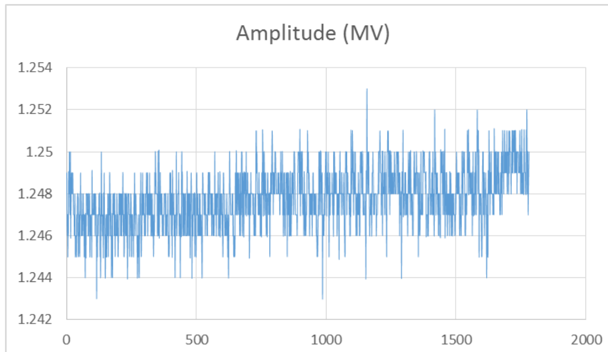
- To avoid bunch instabilities at the end of long fill due to shrinking from synch. radiation, the bunch length should be controlled (blow-up) during the fills – also a demand by some experiments (keep bunch length ~ constant.
- Tests were performed in 2015, to be made operational in 2016.

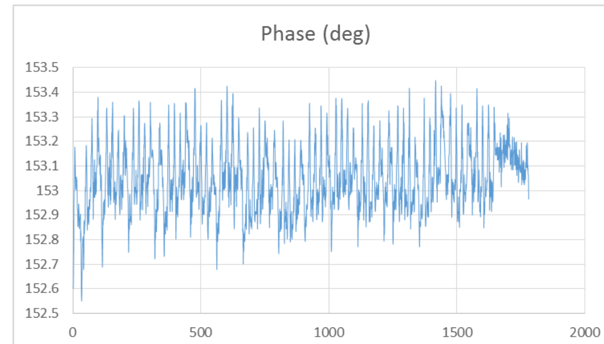


RF – beam loading

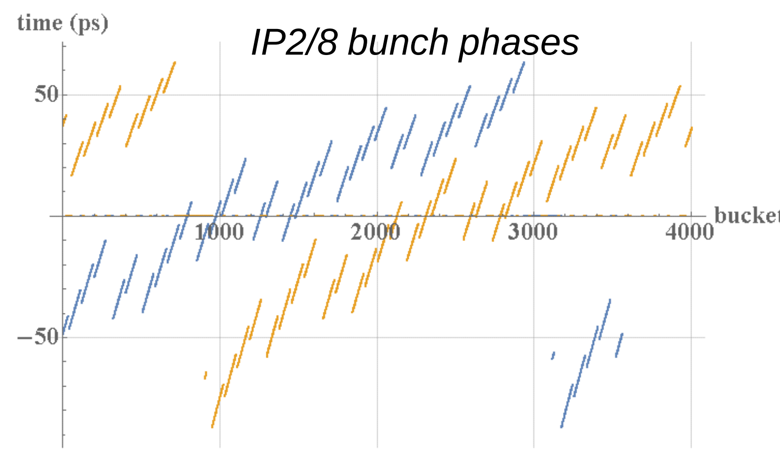
- So far we have operated the LHC RF with full compensation of the transient beam loading in the cavities: $V(t) = V_0$
- As a consequence beam-loading is invisible in amplitude, barely visible in phase (0.5 deg pk-pk) → large power transients for the klystrons !

Nov 2nd, 2015. Fill 4565. 2244 b. Cav4B1



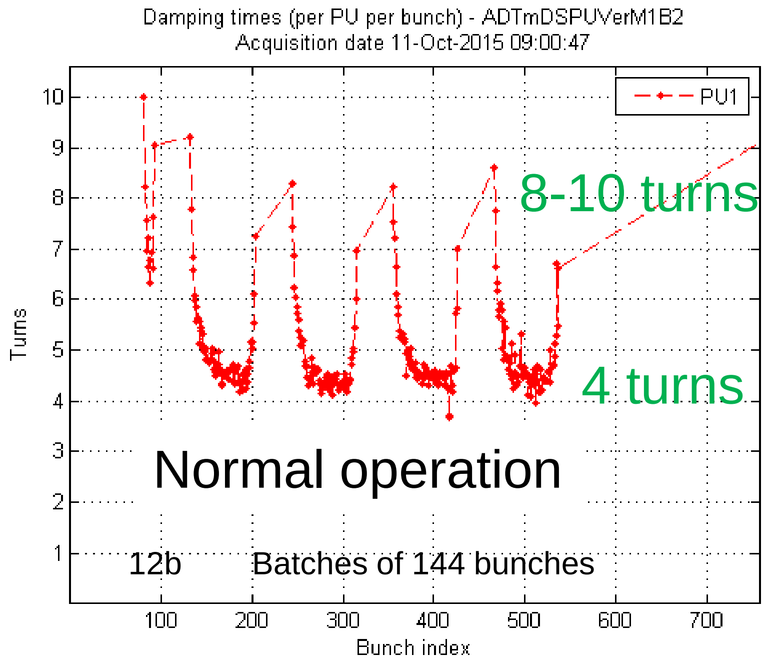


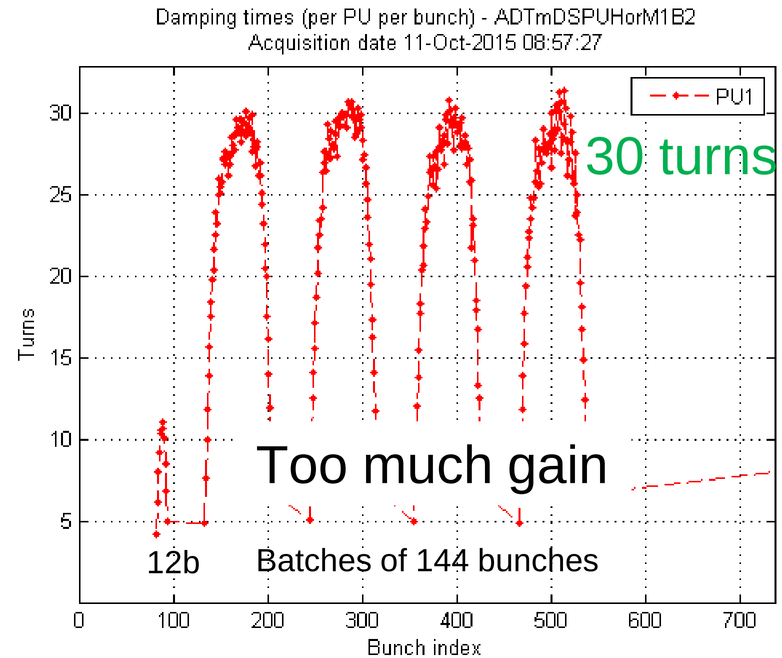
- An alternative scheme keeps the voltage constant over a turn with a modulation of the phase → limits the power transients in the klystrons.
  - But it induces phase modulation of the bunches.
- Scheme to be tried soon…



Transverse Damper

- The LHC cannot be operates at high intensity without transverse damper ADT (fast bbb feedback system) – key system.
- The ADT is continuously improved, one major item is better diagnostics of the damper itself, the other one is the capability of providing bbb and tbt data over all bunches.





Circuit status

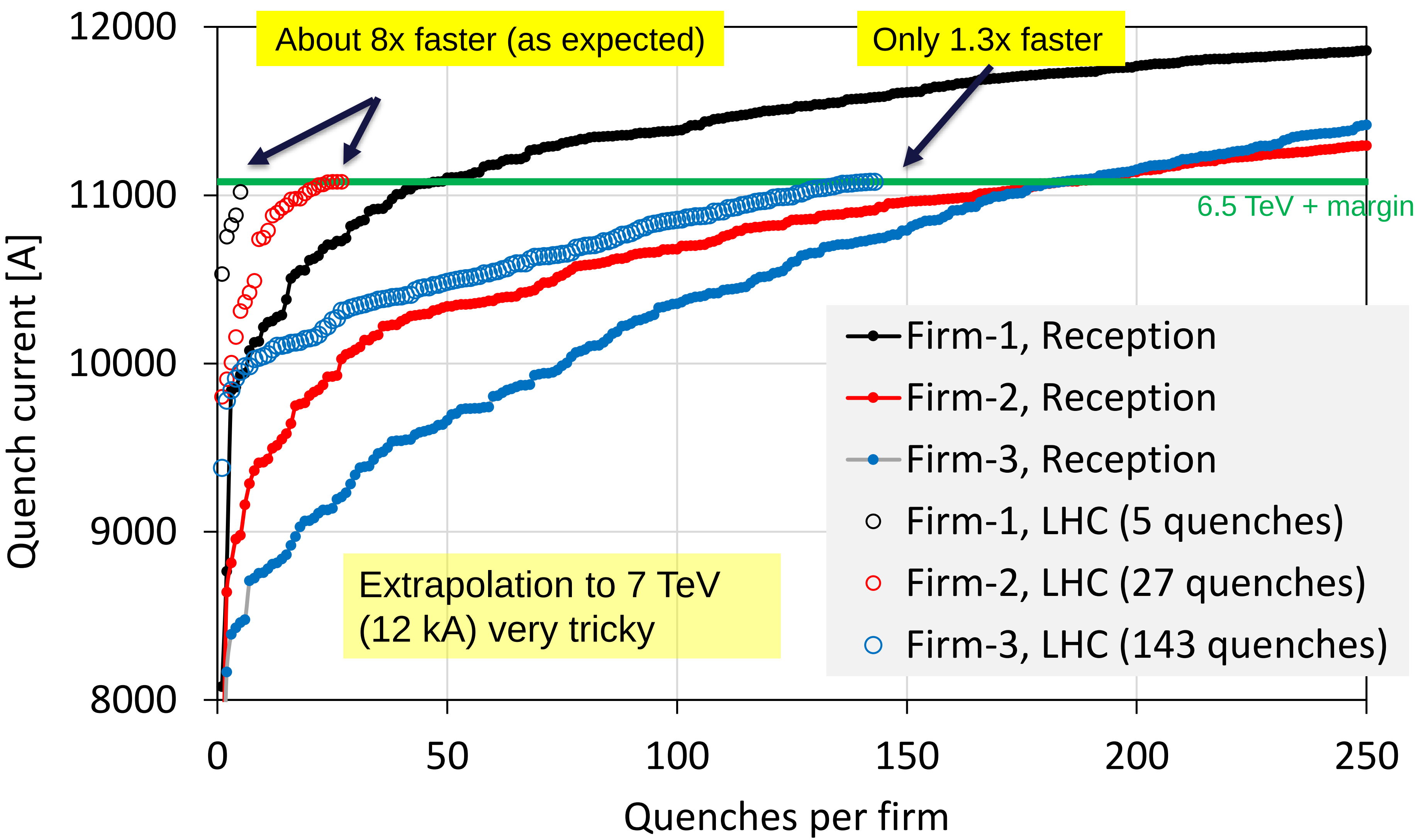
- It are not just the dipoles that quenched, but with the exception of some circuits that are limited in current, the situation is good.

no. quenches

	Nr. of magnets	2008	2009	Feb 2013	2014/5
60 A	752	2	3	0	**23**
80-120 A	1476	37	38	4	**23**
120 A triplet	40	0	1	0	**4**
600 A	6518	140	0	77	**154**
600 A triplet	56	26	4	14	**37**
IPD	18	13	0	10	**4**
IPQ	220	49	0	68	**31**
IT mains	32	0	0	4	**2**
RQ	794	2	0	0	**2**
RB	1232	30	0	0	**175**

- During the 2015 run we have lost a sextupole spool circuit of B2 in S78 – short circuit (when mains are powered).
  - *Backup: spread the correction over the 7 other sectors (non-local).*

Dipoles – Re-training in tunnel



The road to 7 TeV

- A new model for the quench behaviour was established from the 2015 quench campaign. The new estimates for the # quenches to reach 7 TeV :
  ~270 first quenches to go !

Best estimate for 7 TeV (first q. only)

sector	1000	2000	3000	total
12	3	19	7	28
23	3	12	30	44
34	2	16	22	40
45	2	9	62	73
56	1	8	63	73
67	3	7	46	56
78	3	24	46	72
81	3	5	50	58
LHC	20	100	325	445

Done	to do
7	21
17	27
15	25
49	24
16	57
20	36
21	51
28	30
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).


Mera peak, 6.5 km high


Kun, 7 km high