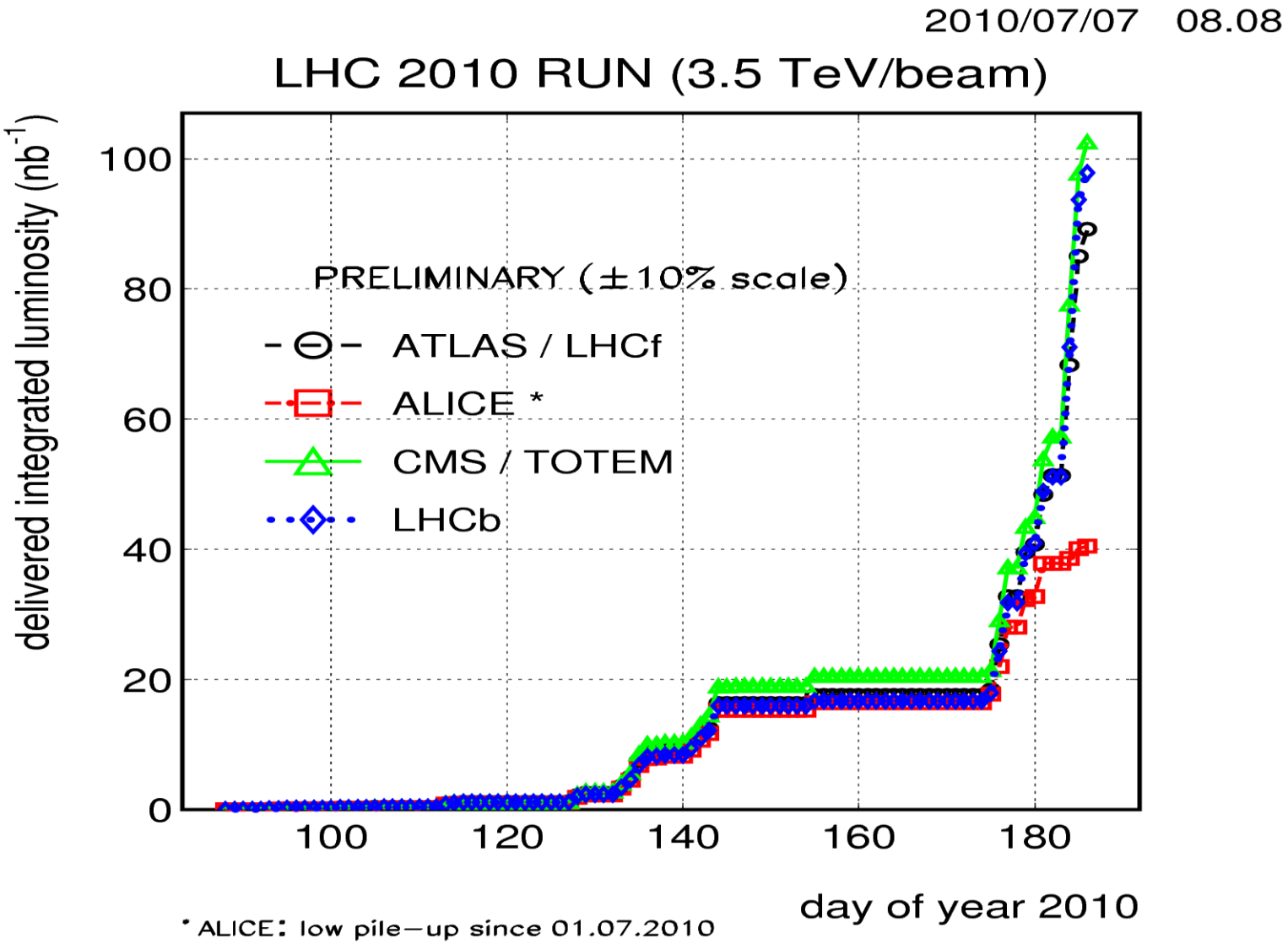
LHC Machine Operational Status and Plans

LHCC, 22nd September 2010

Steve Myers

(On behalf of the LHC team and international collaborators)

Integrated Luminosity on 7th July

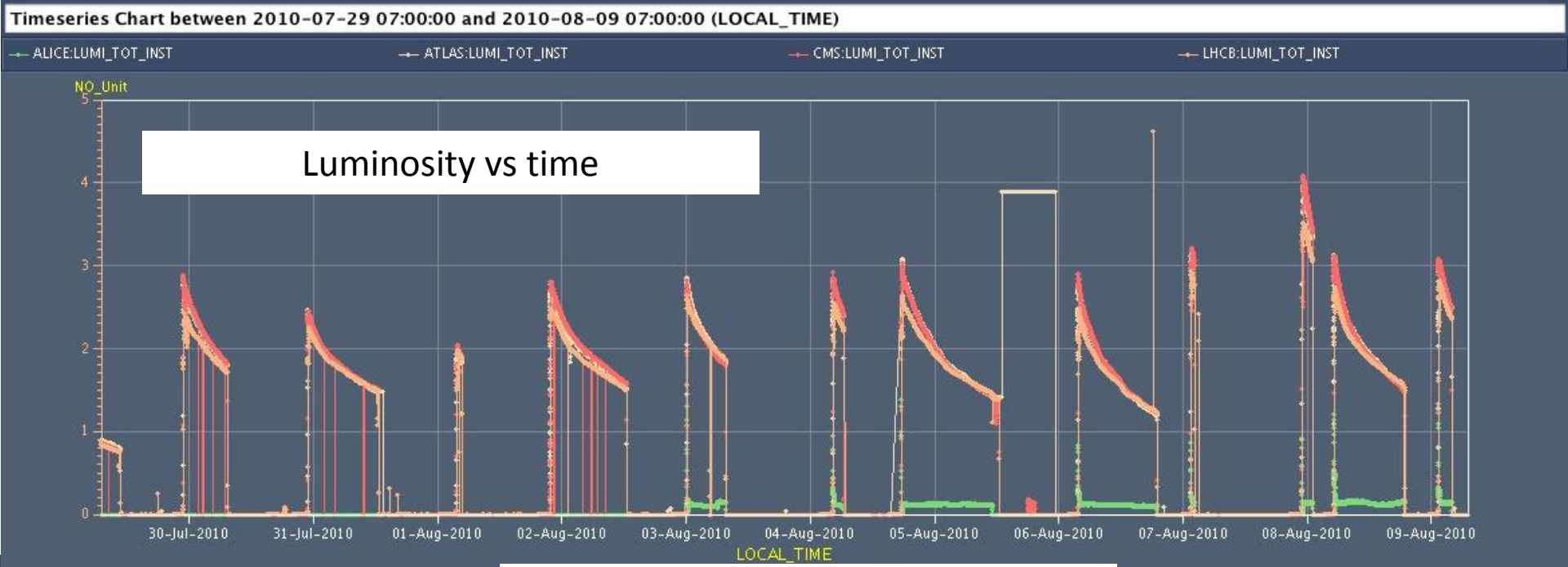


Summary of Luminosity progress

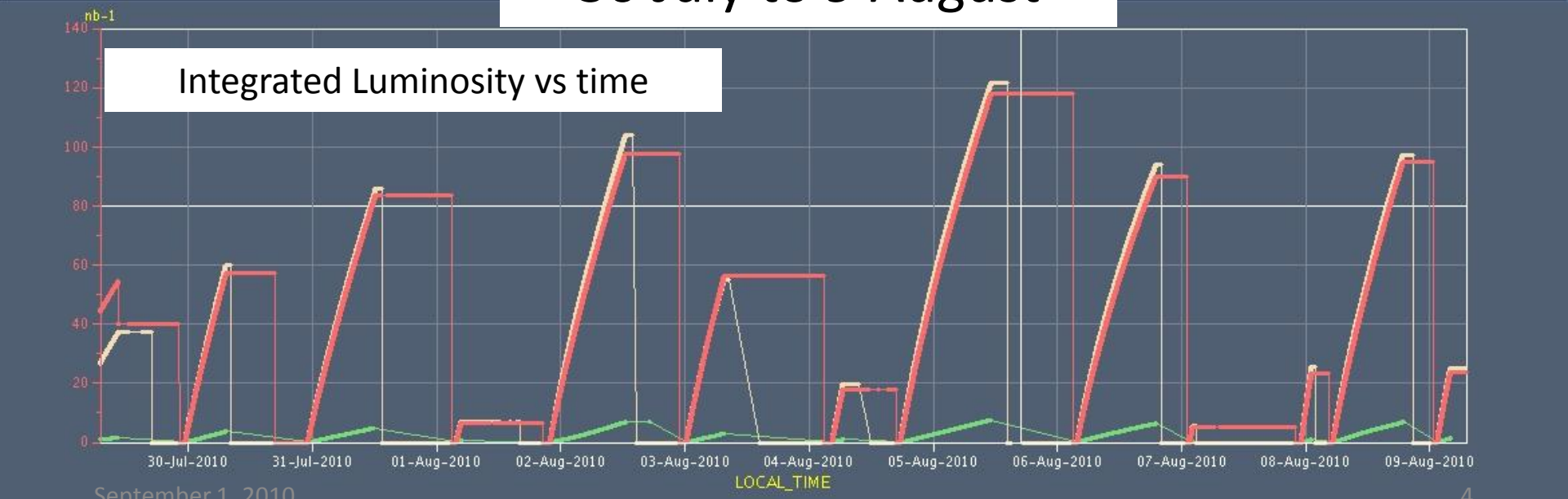
calculated

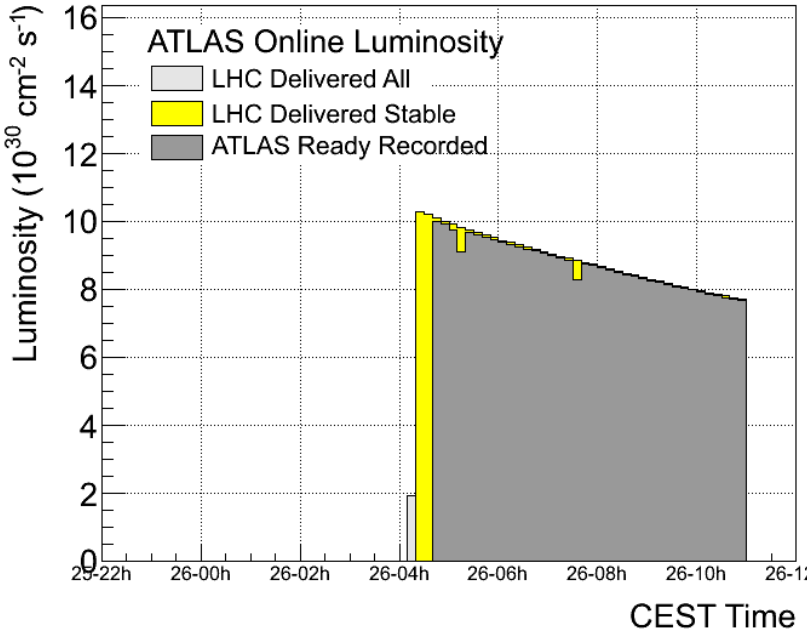
Event	TeV	OEF	β*	Nb	Ib	Itot	MJ	Nc	Peak luminosity	Date
1	3.5	0.2	10	2	1.00E+10	2.0E+10	0.0113	1	8.9E+26	30 March 2010
2	3.5	0.2	10	2	2.00E+10	4.0E+10	0.0226	1	3.6E+27	02 April 2010
3	3.5	0.2	2	2	2.00E+10	4.0E+10	0.0226	1	1.8E+28	10 April 2010
4	3.5	0.2	2	4	2.00E+10	8.0E+10	0.0452	2	3.6E+28	19 April 2010
5	3.5	0.2	2	6	2.00E+10	1.2E+11	0.0678	4	7.1E+28	15 May 2010
6	3.5	0.2	2	13	2.60E+10	3.4E+11	0.1910	8	2.4E+29	22 May 2010
7	3.5	0.2	3.5	3	1.10E+11	3.3E+11	0.1865	2	6.1E+29	26 June 2010
8	3.5	0.2	3.5	6	1.00E+11	6.0E+11	0.3391	4	1.0E+30	02 July 2010
9	3.5	0.2	3.5	8	9.00E+10	7.2E+11	0.4069	6	1.2E+30	12 July 2010
10	3.5	0.2	3.5	13	9.00E+10	1.2E+12	0.6612	8	1.6E+30	15 July 2010
11	3.5	0.2	3.5	25	1.00E+11	2.5E+12	1.4129	16	4.1E+30	30 July 2010
12	3.5	0.2	3.5	48	1.00E+11	4.8E+12	2.7127	36	9.1E+30	19 August 2010

Maximum reached is 10.7×10^{30} $cm^{-2}s^{-1}$



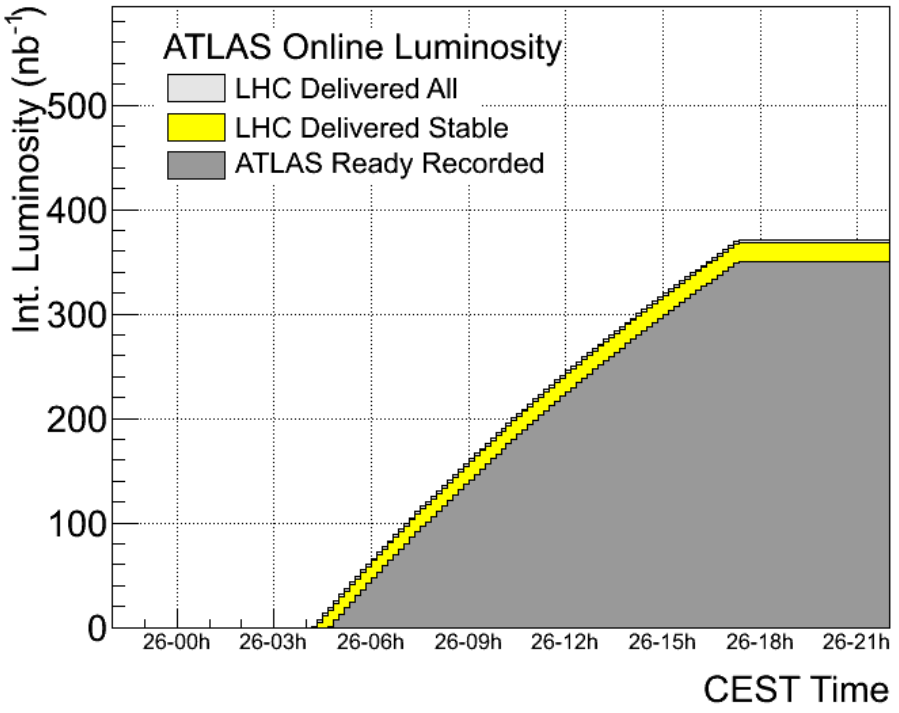
30 July to 9 August



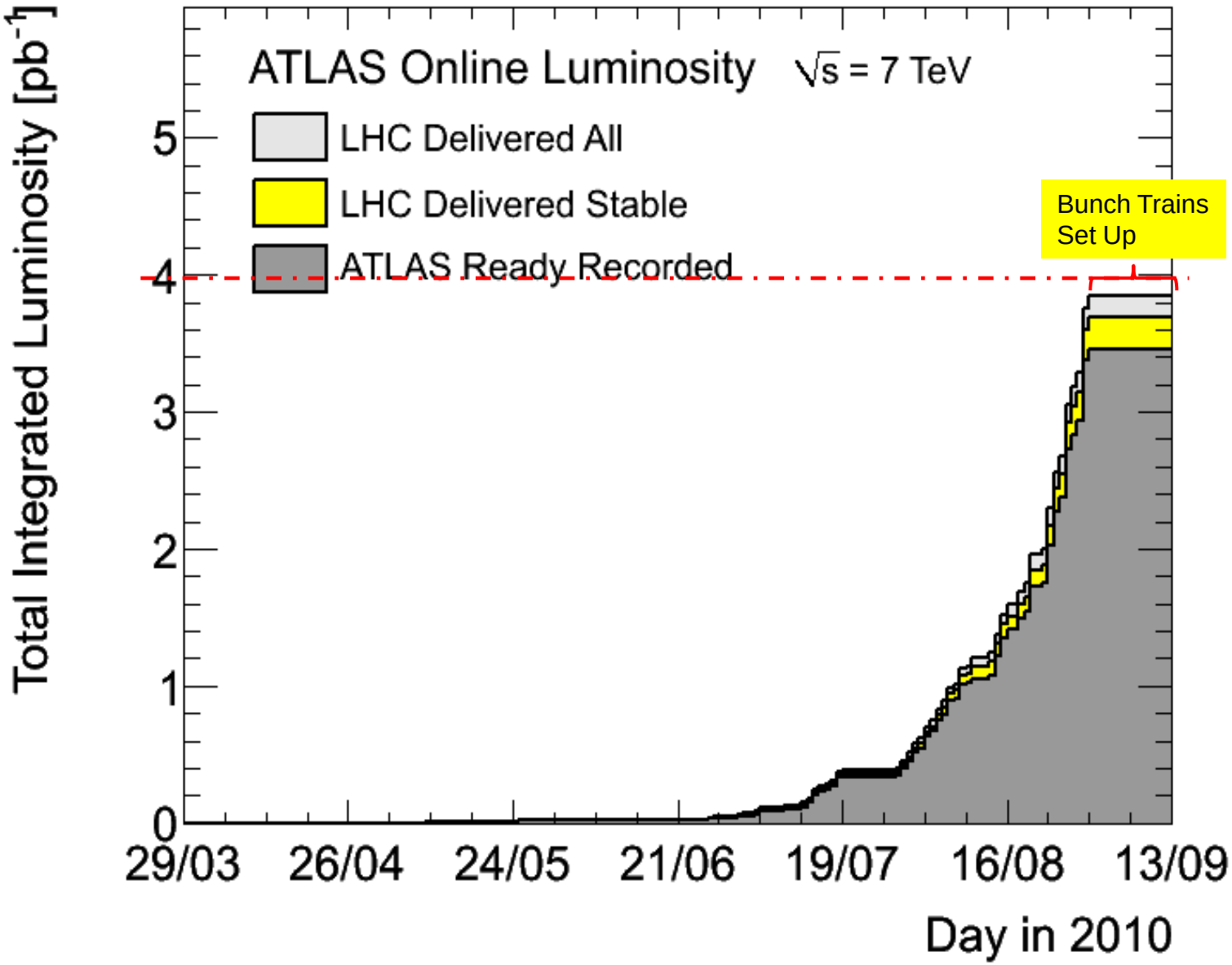


1303 (Aug 26) best fill so far

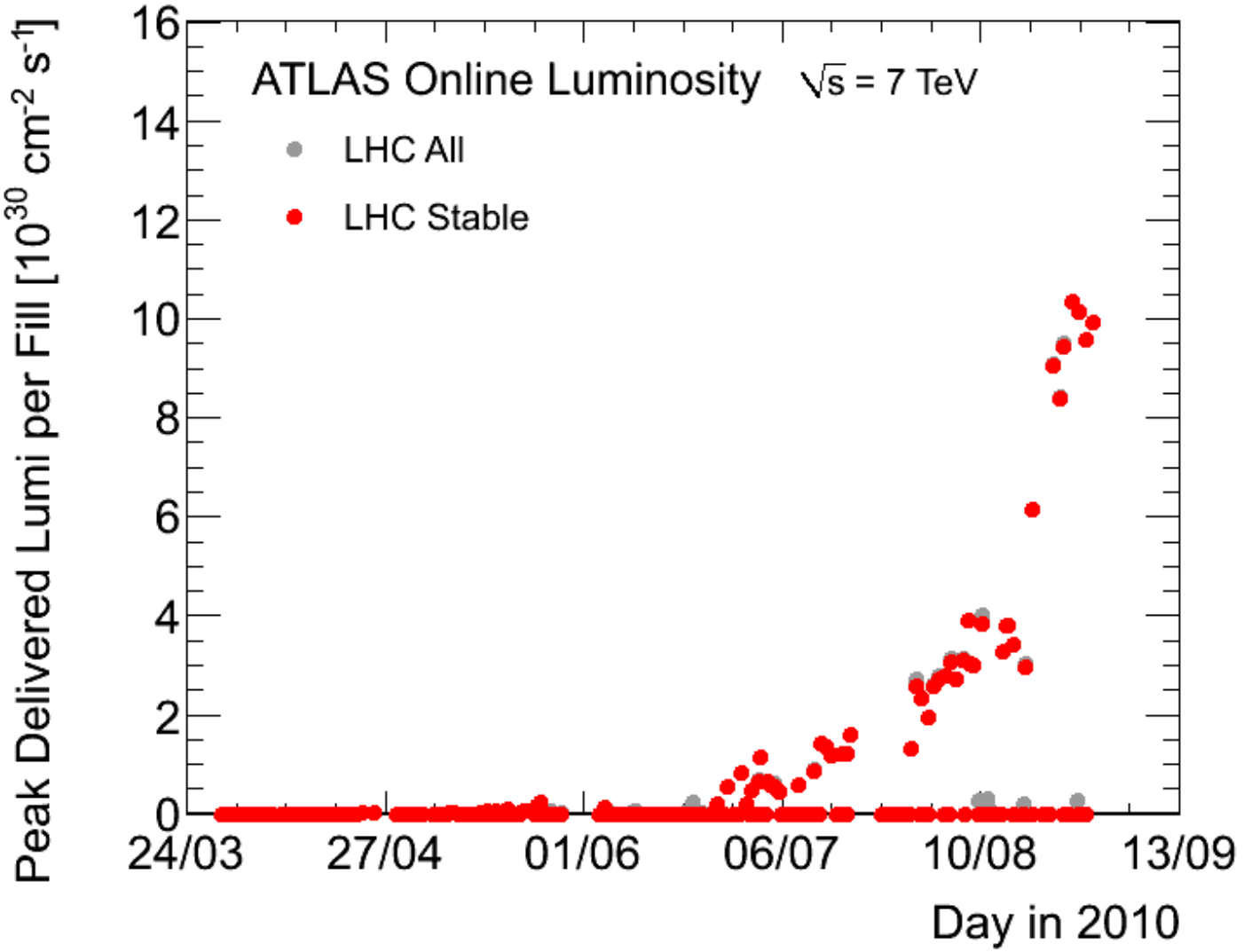
This fill gave integrated luminosity exceeding what was shown in ICHEP Paris



Approaching 4pb^{-1} (TODAY)



Peak Luminosity 31/8/2010



Preparations for 10^{32} ?

Which scenario is easier?

$\beta^* = 3.5$, Nb = 394, MJ =22.2

$\beta^* = 2.0$, Nb = 226, MJ = 12.8

Unanimous answer

$\beta^* = 3.5$, Nb = 394, MJ =22.2

Plan for getting to 10^{32} before ion run

LMC 18th August.

- Parameters and Conditions
  - Nominal bunch intensity 1.1E11
  - Stick to β* = 3.5 m in all IPs
  - Commission bunch trains
    - Complete re-do of the whole machine protection set-up
  - Go to 150 ns bunch spacing
  - Commission faster ramp (10 A/s)

Additional work for bunch trains

- Completely new set up of all phases of LHC under the new conditions needed for safe operation with high intensity bunch trains
  - Beam transfer (collimation)
  - Emittance control in injectors and during ramp in LHC
  - Transverse damper set up with lower noise
  - Injection with crossing angles (collimators and unsafe beam),
  - Accumulation with crossing angle; long discussions about magnitude of crossing angle
  - Ramp with 10A/s
  - Squeeze (changing crossing angles to collision values)
  - Collisions with crossing angles (collimation)

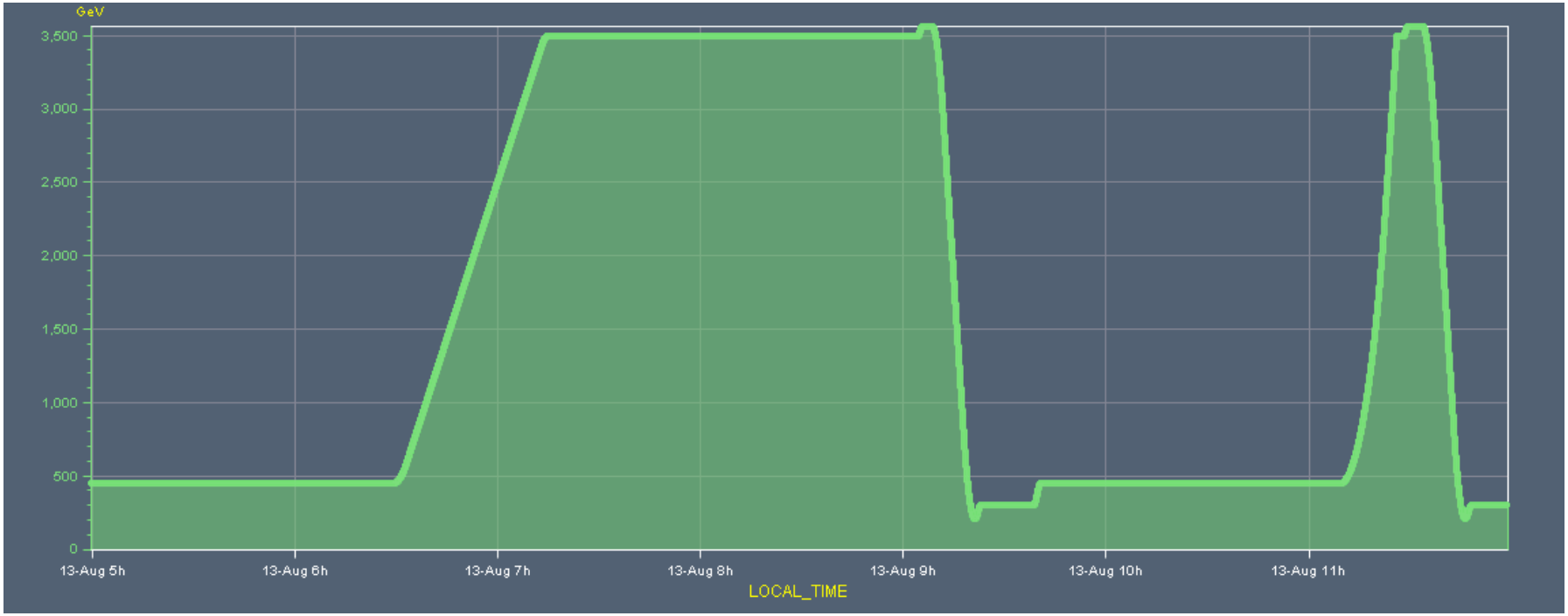
Crossing angles

- External crossing angles
  - IR1: -170 μrad at inj./ramp and -100 μrad in squeeze/collision
  - IR2: +170 μrad at inj./ramp and +110 μrad squeeze+collision
  - IR5: +170 μrad at inj./ramp and +100 μrad in squeeze/collision
  - IR8: -170 μrad at inj./ramp and -100 μrad in squeeze/collision

- Good for beam-beam (do we need it for 150ns ?)
- Bad for aperture and MP (are we ready to do this ?)

- Strategy
  - Start with nominal angles at injection
  - Measure IR apertures
  - Test parasitic beam-beam with lower angles
  - Decide based on this

Test ramp 10 A/s

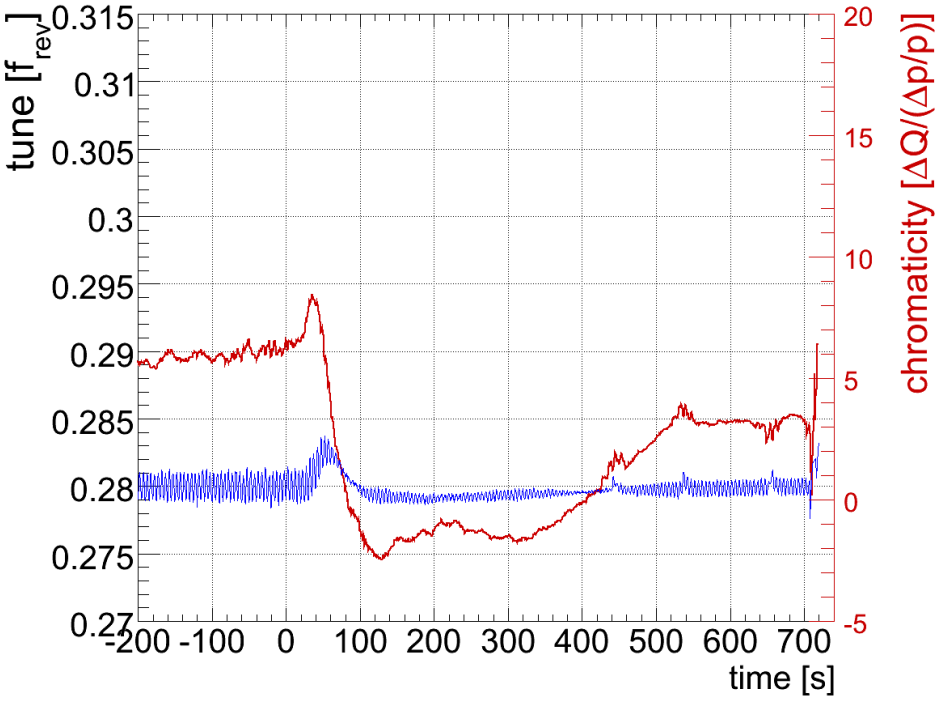


1st attempt reached 1.7TeV
2nd attempt perfect ramp up to 3.5TeV

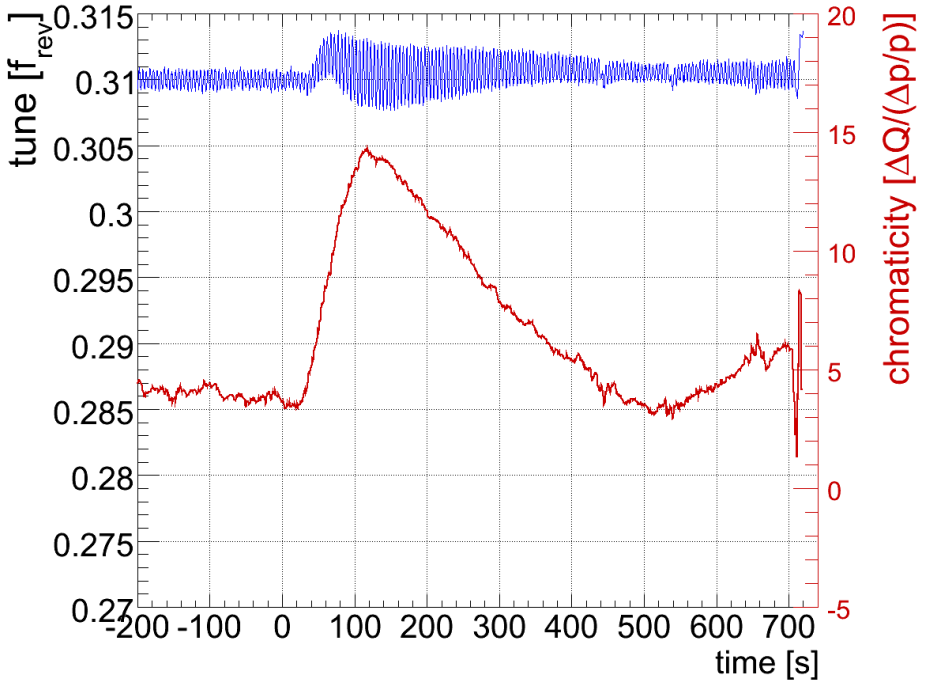
Ramp duration reduced from 46 to 16 minutes

Test ramp at 10 A/s

Orbits, Tunes and Chromaticities measured and automatically corrected during the ramp and stored and fed forward for next ramp



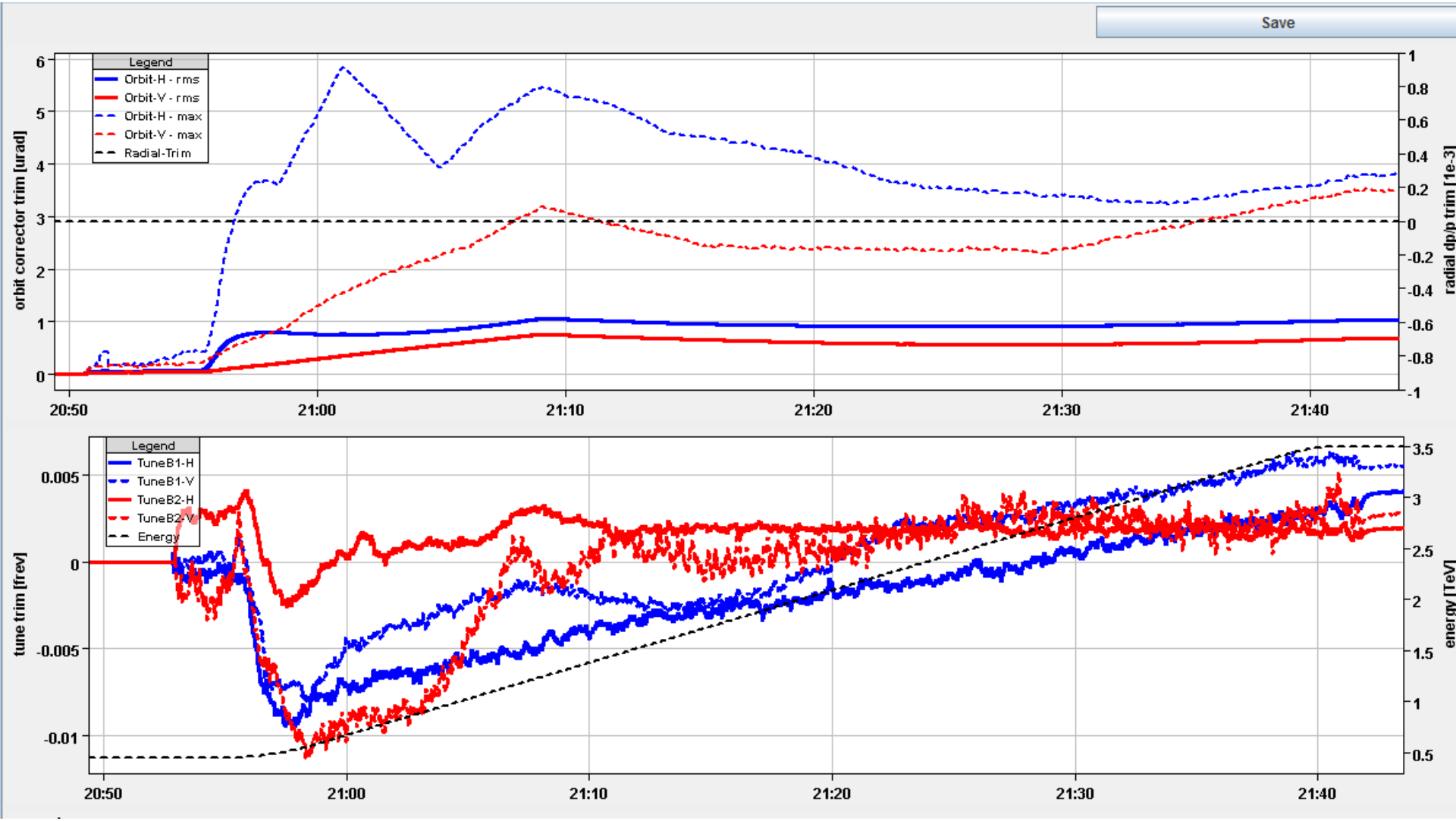
B1 horizontal



B1 vertical

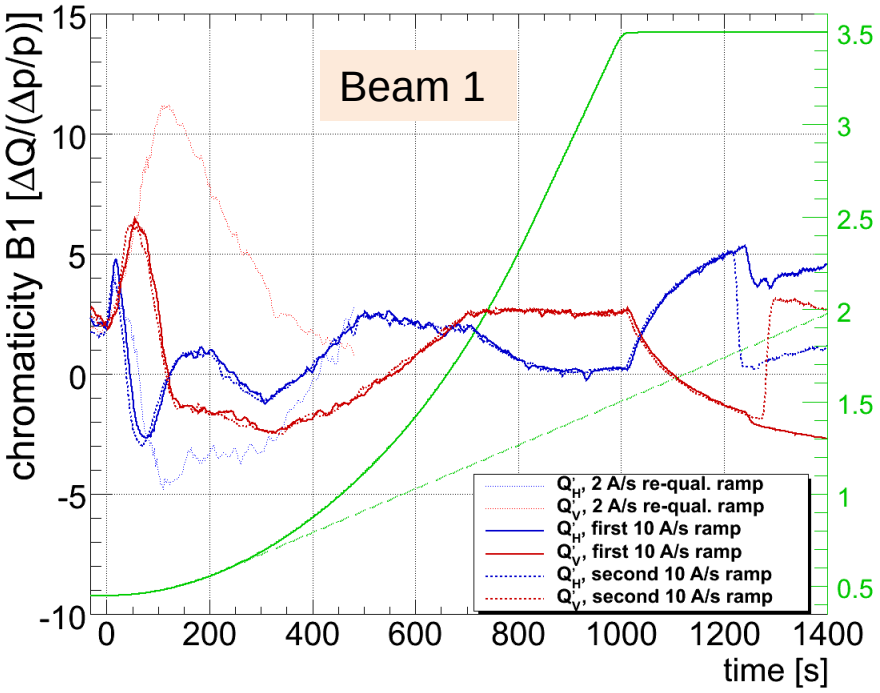
Thursday 19.8.

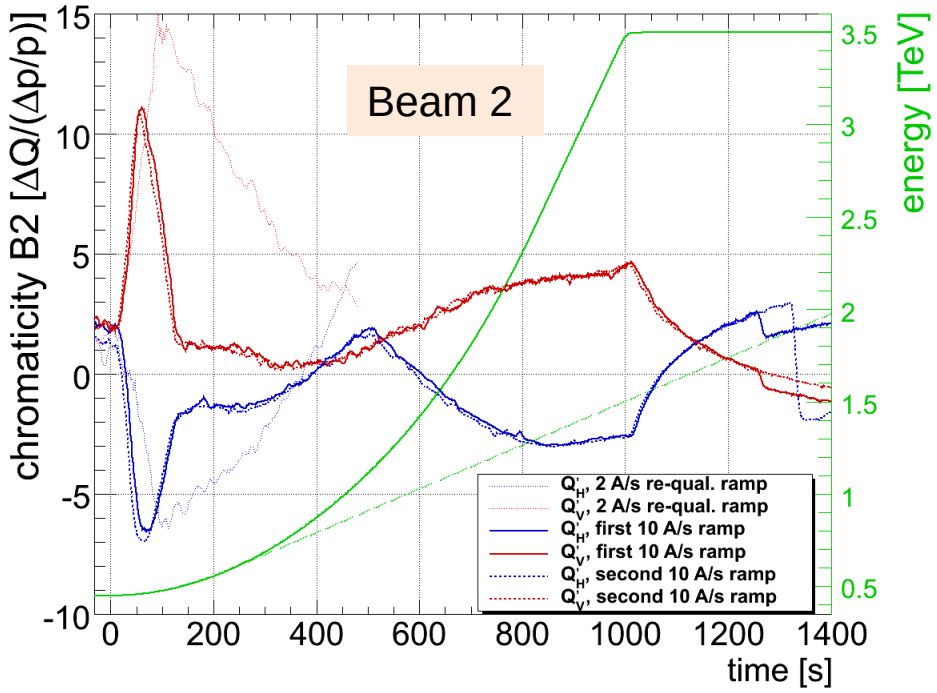
- Feedback during ramp:



Ramp with 10 A/s

- Chromaticity during the ramp reproducible (RS)

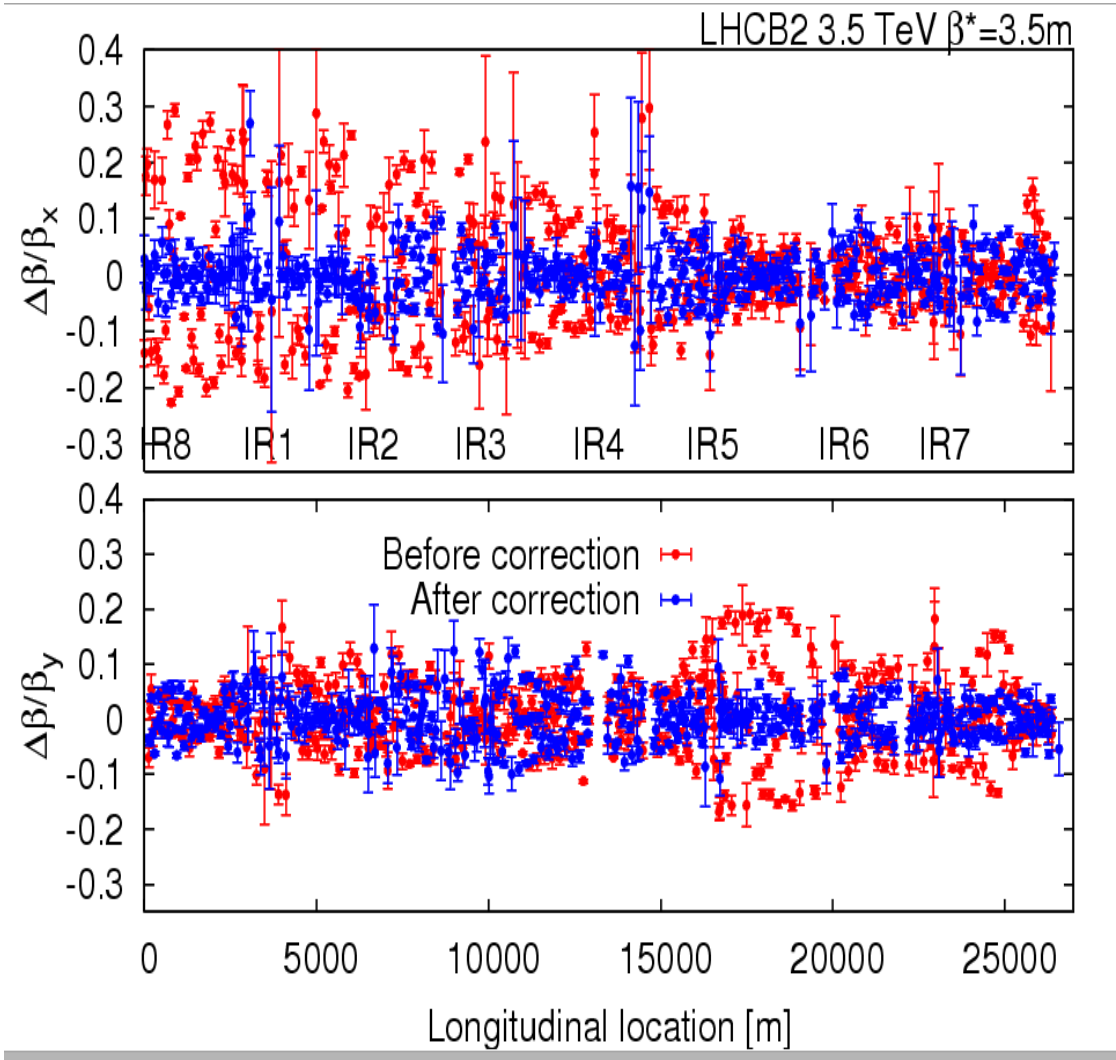




Correction of Beta beating (Wednesday 8th Sep)

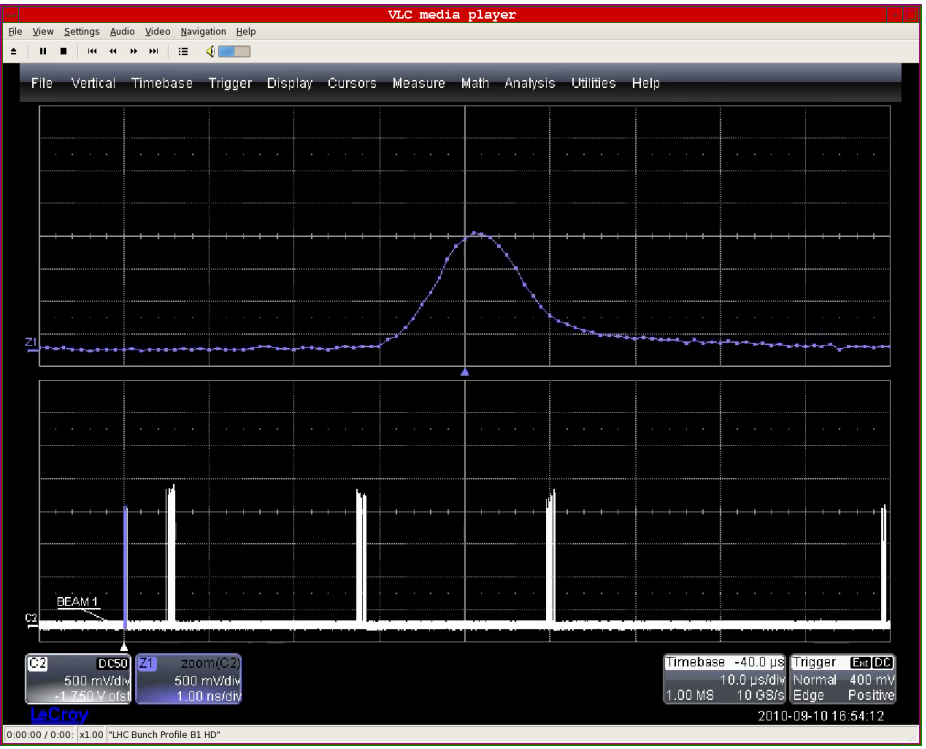
- Squeeze B2
- Brief optics studies on B2
  - Global correction
  - 100 quads !
  - Impressive results !

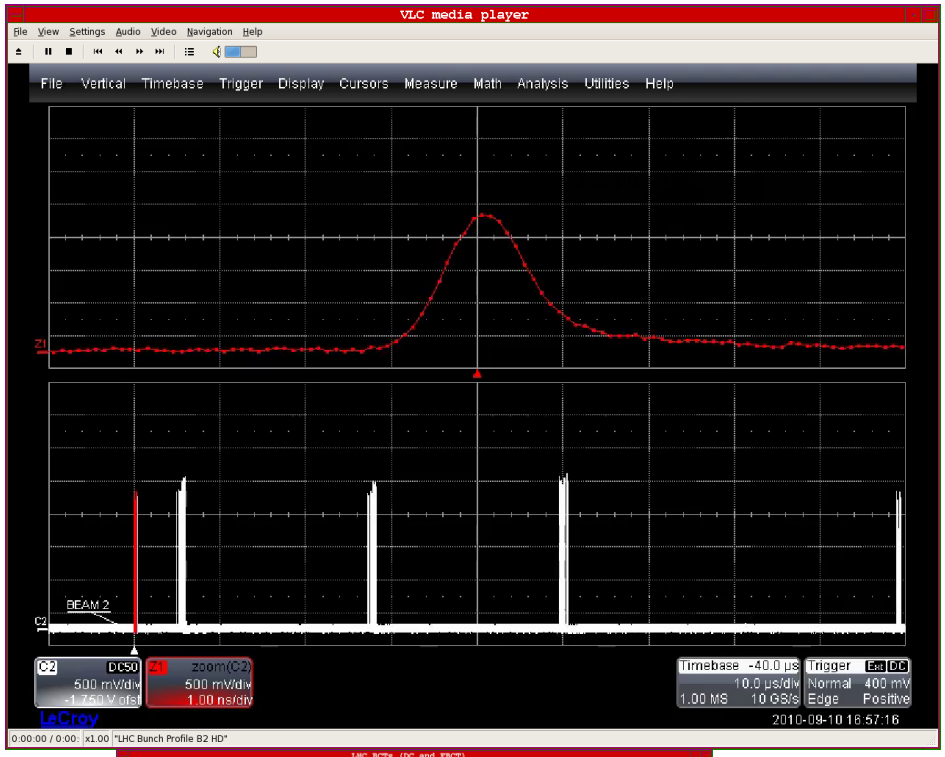
IP1	**3.22 0.22**	**3.62 0.40**
IP2	**3.83 0.61**	**3.43 0.26**
IP5	**3.67 0.07**	**3.28 0.25**
IP8	**3.26 0.10**	**3.51 0.09**

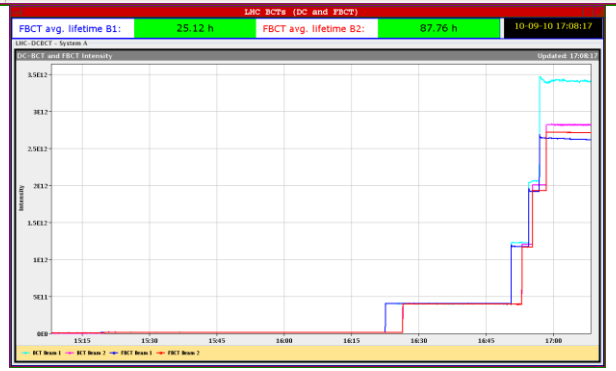


Friday 10.9

- 17.00 Inject 1 train of 4, then 3 trains of 8, both beams

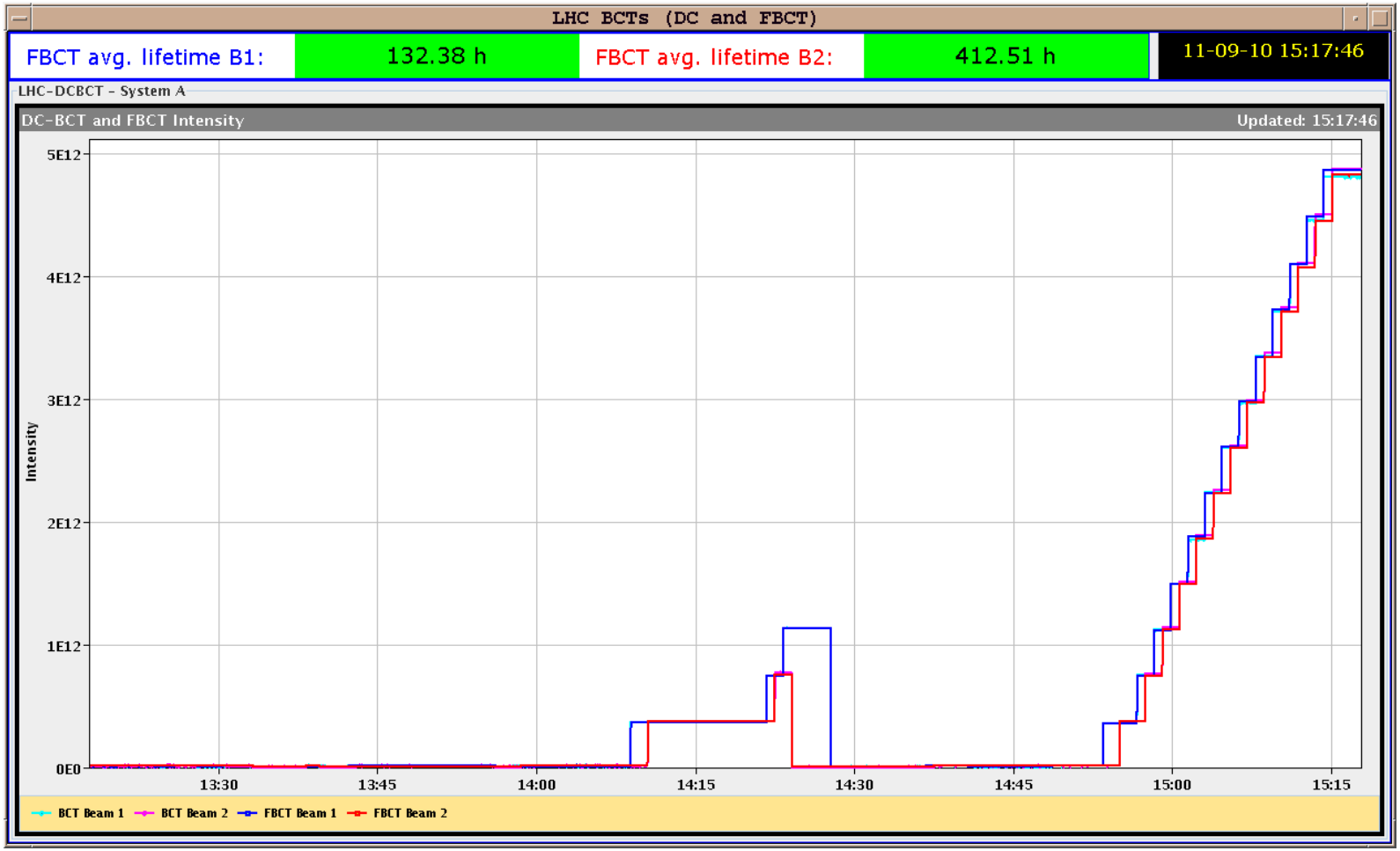






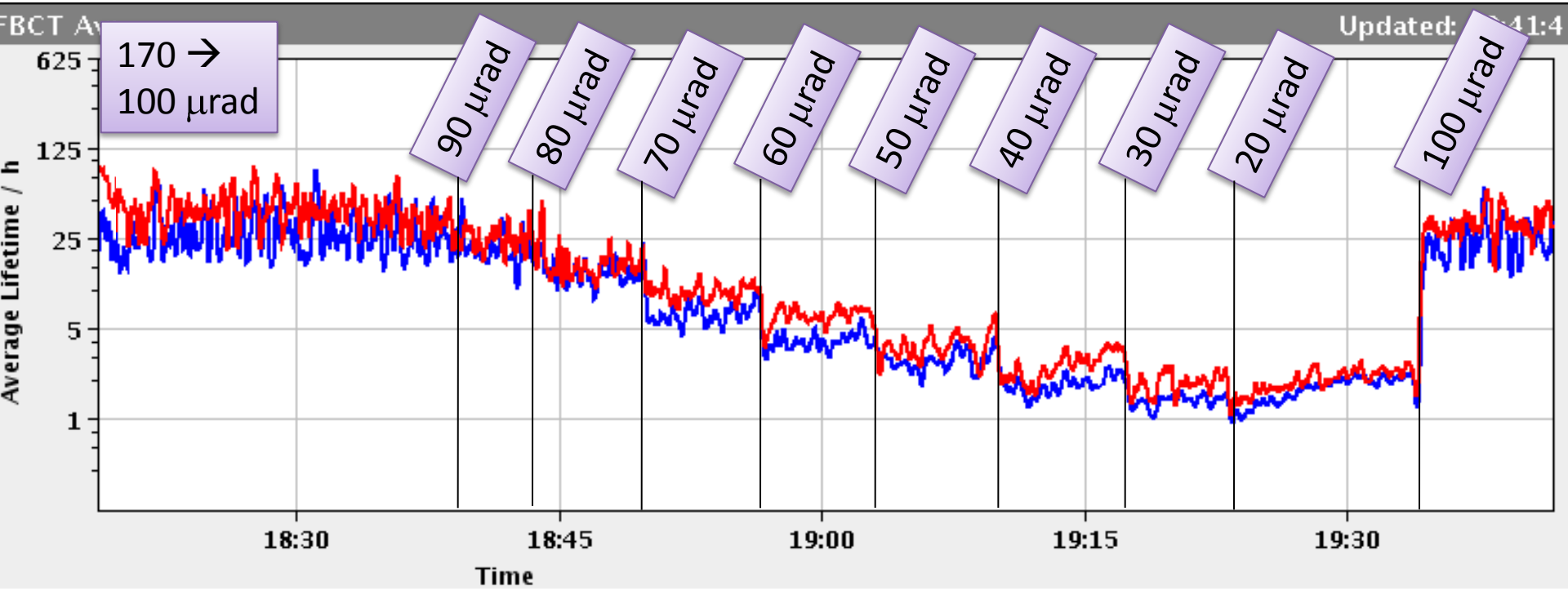
Saturday 11.9

- RF setting up
  - Finally the complete injection sequence of 13x4 bunches per beam was executed and went smoothly with very little uncaptured beam



Lifetime when Reducing Crossing Angle

3 batches of 8 bunches each, spacing 150 ns → up to 6 LR interactions per bunch



Conclusion: **Minimum required crossing angle is ~100 μrad in 2010.**

Measured 450 GeV Aperture

Beam / plane	Limiting element	Aperture [σ]
Beam 1 H	Q6.R2	12.5
Beam 1 V	Q4.L6	13.5
Beam 2 H	Q5.R6	14.0
Beam 2 V	Q4.R6	13.0

- Predicted aperture bottlenecks in triplets (n1=7) do not exist.
- “Measured” n1 = 10 – 12 (on-momentum) instead design n1 = 7
- “We discover the aperture gold mine for performance”

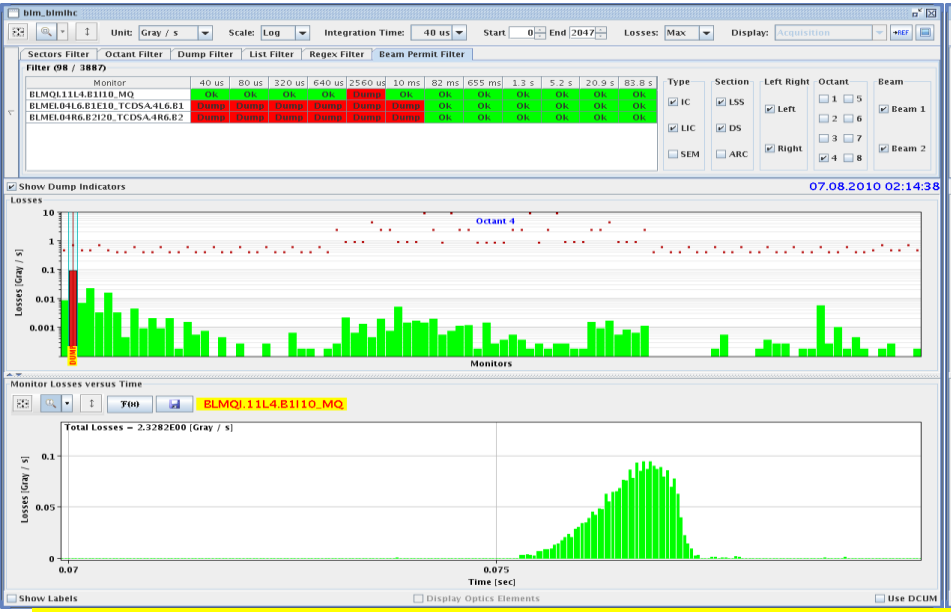
Conclusion from Aperture

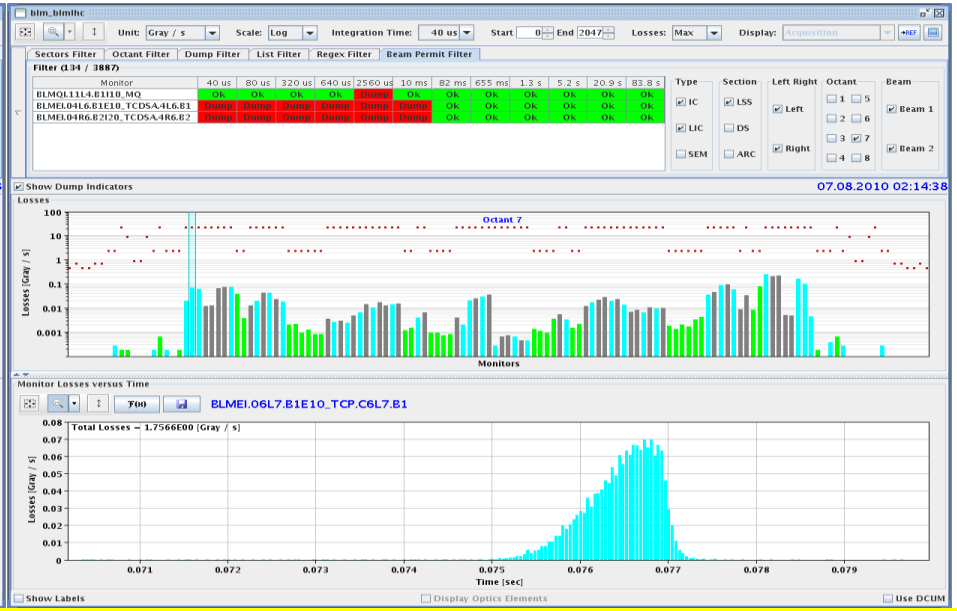
- **Plenty of aperture at triplets: > 13 σ (n1 > 10)**
- Can open tertiary collimators, e.g. to 13 σ at injection.
- **Can stay with 170 μrad crossing angle at injection.**
- Can also review settings for injection protection → Relax?
- We will measure aperture also at top energy with 3.5 m beta*. If (when) similar margins found , this will open the door for smaller beta* with same risk level.

Unexplained Beam Losses

Losses with almost identical loss characteristics

- ~~4~~ 5 unexplained beam losses (dump provoked by the Beam loss monitoring system)
- 1 unexplained beam loss while moving Roman Pots
- 1 beam loss provoked by a wire scan



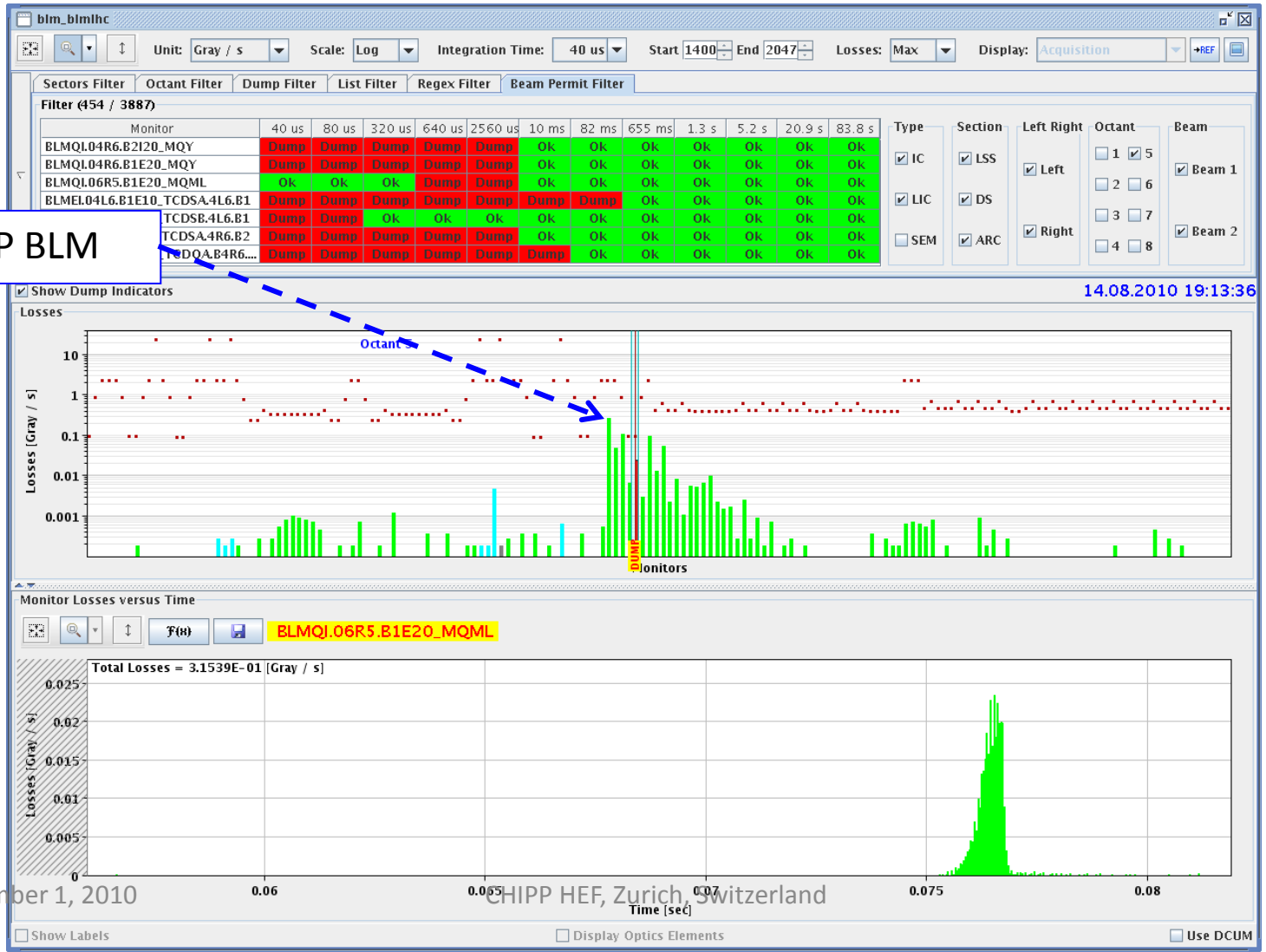


- Suspicion is that debris if falling into the beam provoking a small beam loss seen by the BLM which triggers the beam dump (machine protection works well)

Proposal to verify the thresholds of the BLMs by doing a “quench” test.

TOTEM event in stable beams (V B1)

- Very similar time structure than the 4 events with losses on SC magnets – loss map less localized than during alignment event.

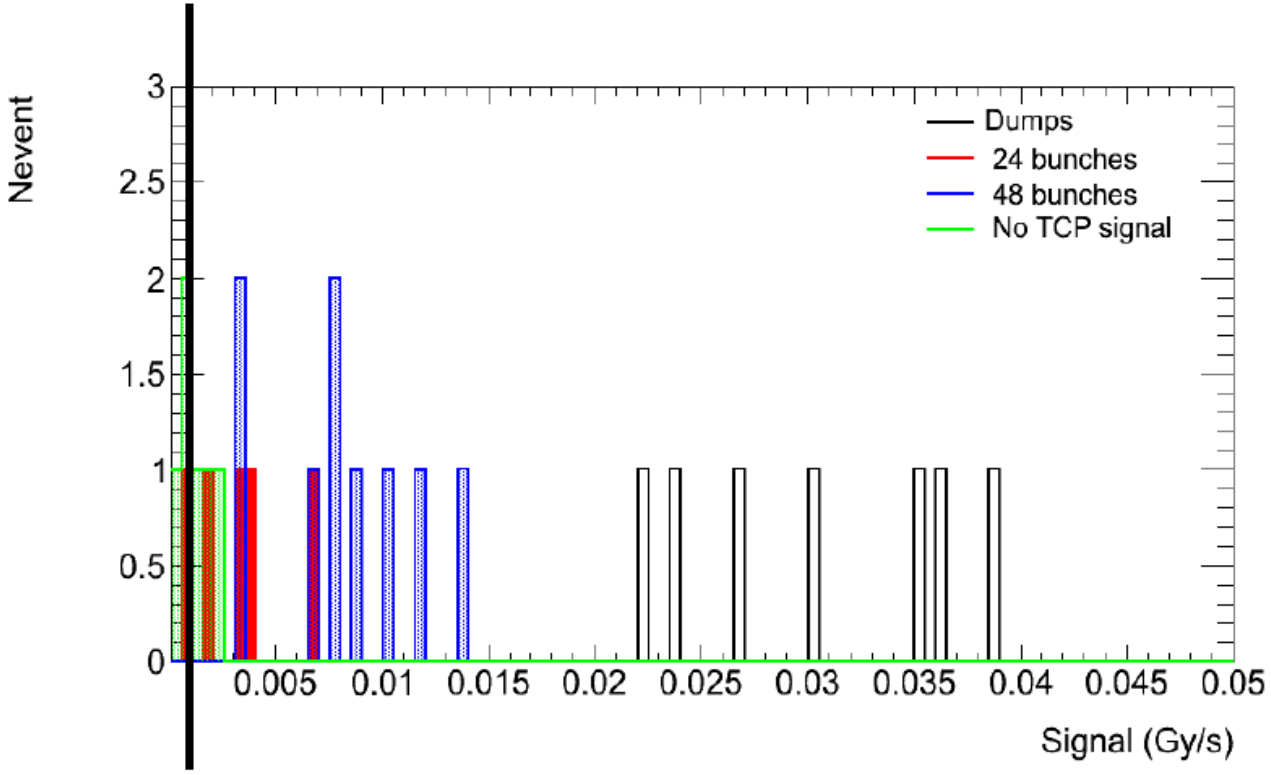


Update on UFOs (fast BLM event in SC regions)

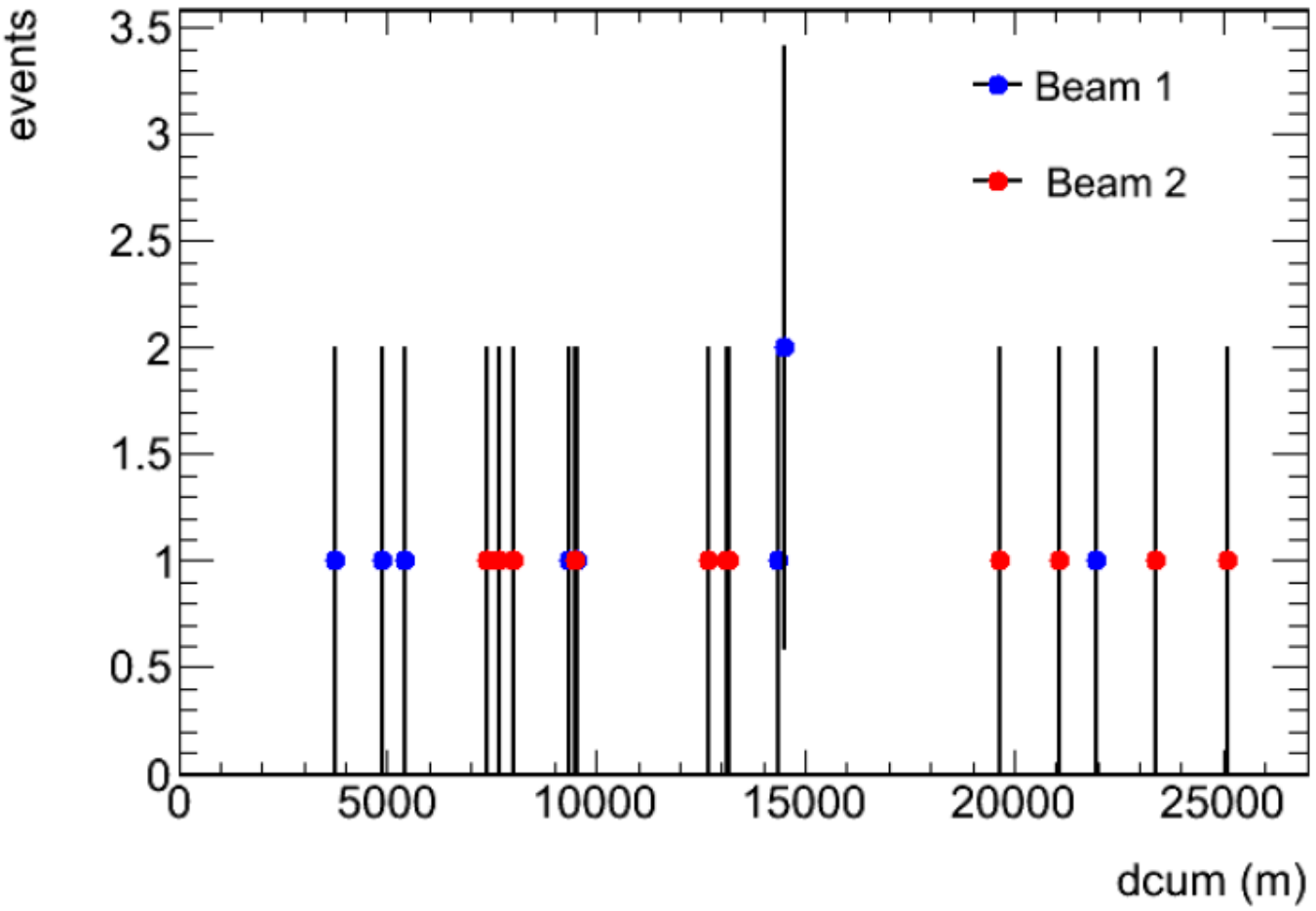
- 7 beam dumps due to fast (~ ms scale) losses in SC regions, triggered by the BLMs
- Search for similar events, but that did not trigger a beam dump, using the data logged in TIMBER.
  - The analysis was concentrated on the period with 24 and 48 bunches.

Sub-threshold UFOs

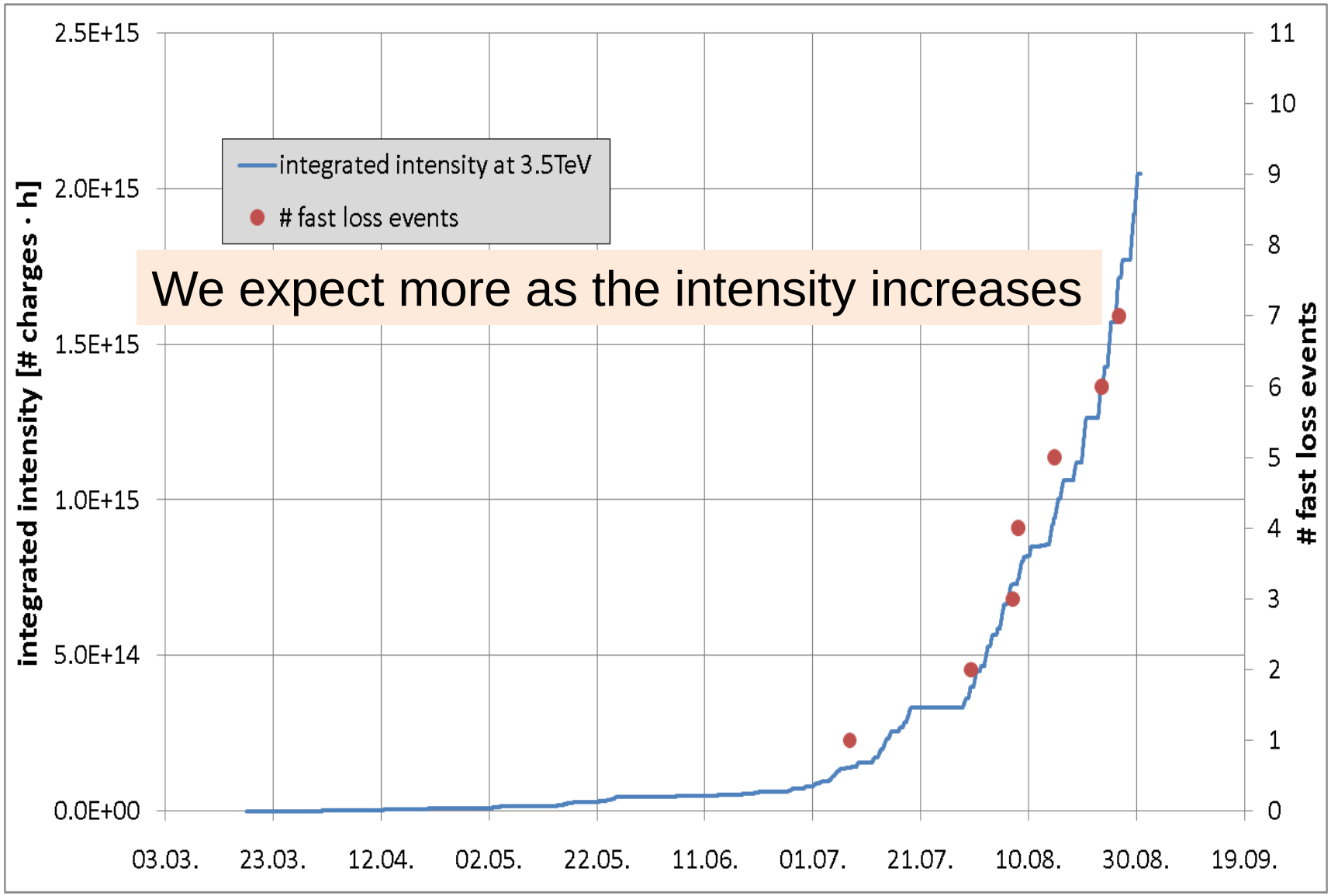
- Total of 228.6 hours of stable beam have been analyzed:
  - 141.3 hours (24 bunches) ==> 0.0566 evts/hour
  - 87.3 hours (48 bunches) ==> 0.1260 evts/hour



Distribution along the ring



Correlation of Number of fast Losses with beam Intensity



Outlook for the second half of this week

- **Bunch trains (with stable beams)!**

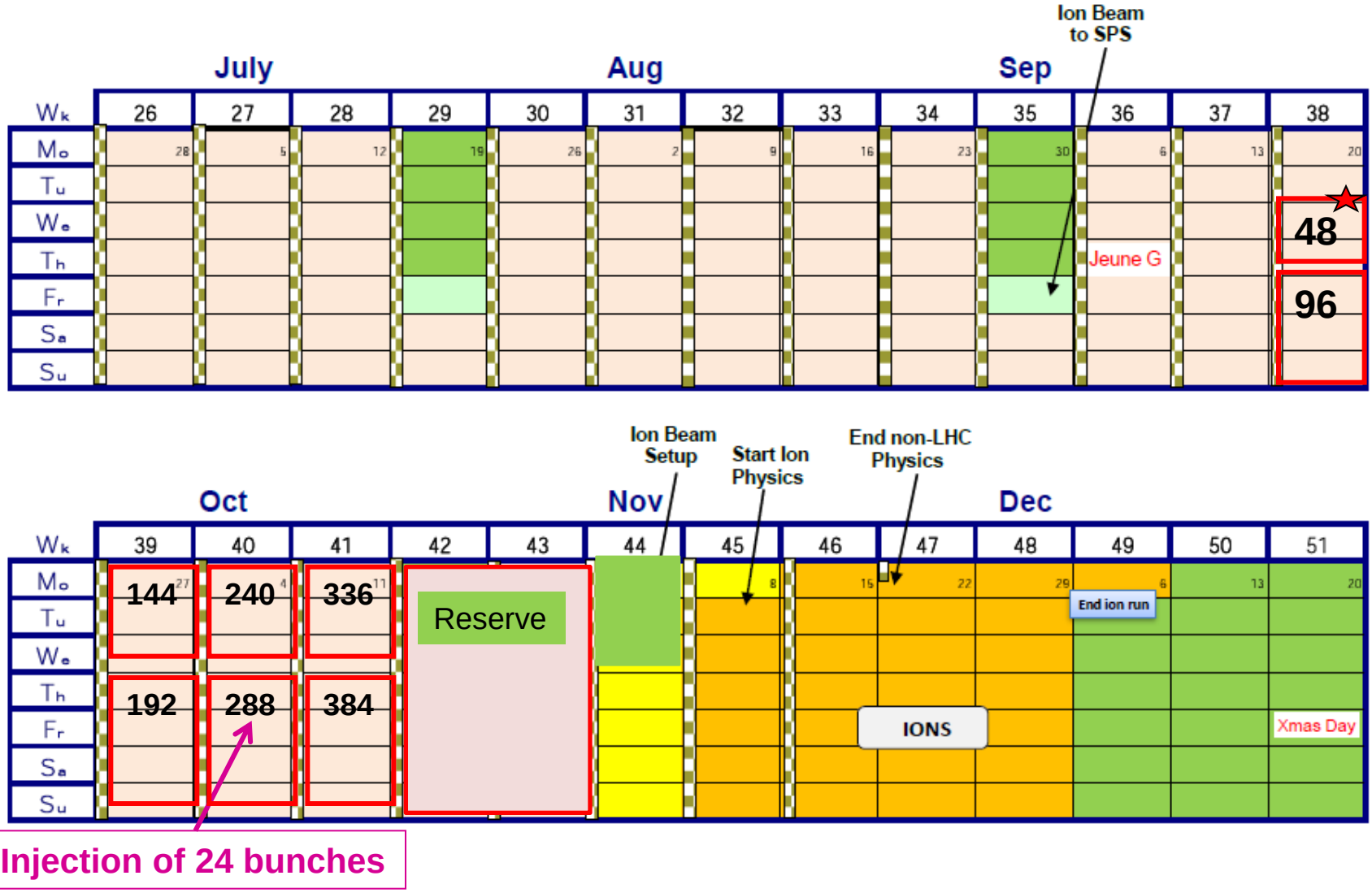
Reconsidering rate of MJ increase

- Following the external review of the machine protection system
  - Considering speeding up the increase of MJ per week to 2 instead of 1
  - Could allow some time before the ion run for slight reduction of the beta* or increase in the number of bunches

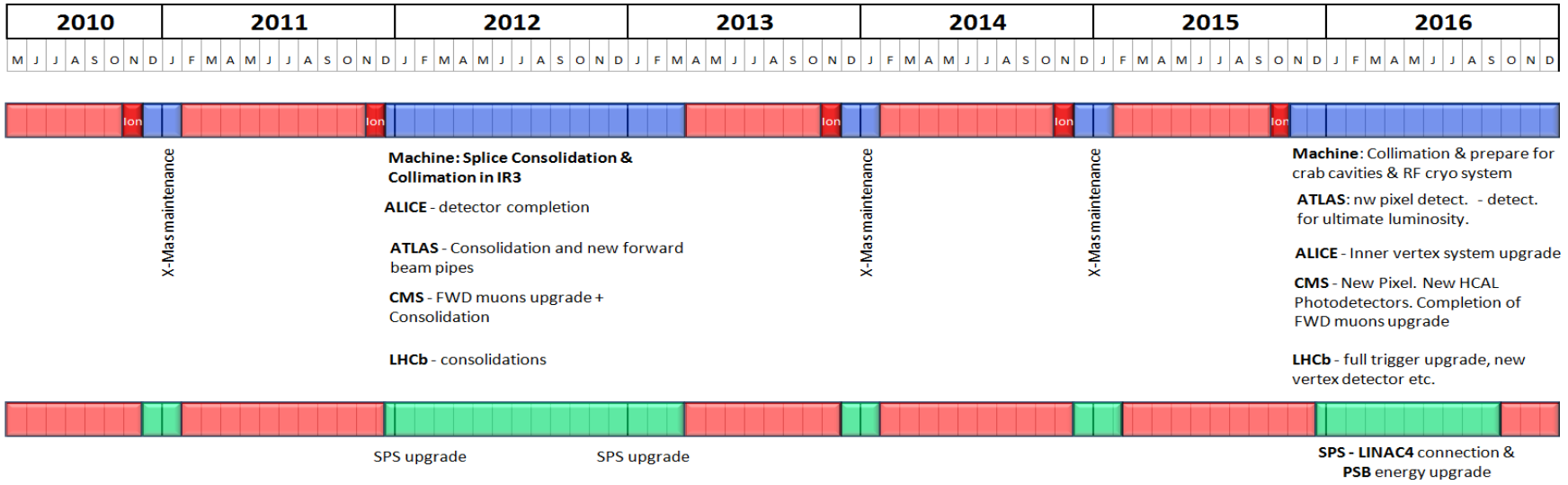
Intensity increase

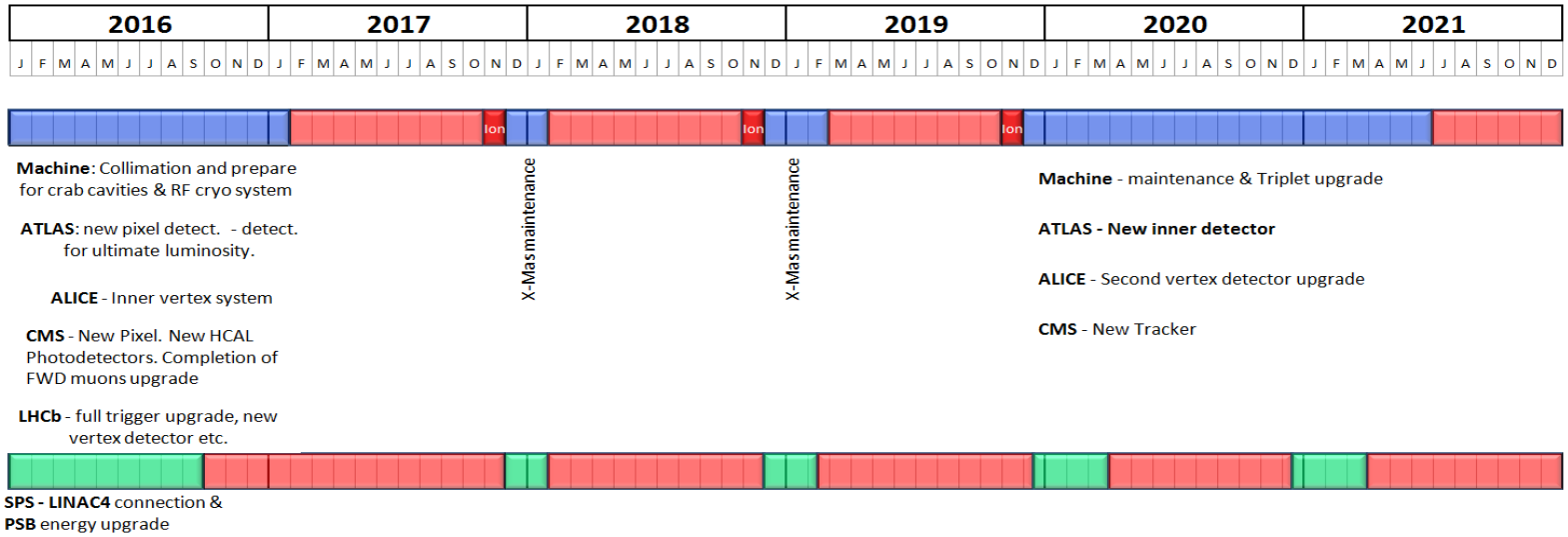
- Intensity increase roadmap
  - Start train operation with 3x8 (or equivalent) – 2 fills, stabilize the sequence. Then move on to 6x8 (or equivalent).
  - 3 fills at a given intensity. Integrated physics time of ~20 hours.
  - Intensity step 48 bunches (+- 10%).
  - A checklist will be defined with the requirements for increasing the intensity.
  - Follow up on review items – as appropriate/possible.
  - Injection: significant change as we are now injecting unsafe beam.
    - Very careful monitoring of abnormal injections.

Aggressive Schedule (short term)



The 10 year technical Plan





Acknowledgements

The progress and performance of the LHC machine is striking.

It is a great personal pleasure to acknowledge this success, due to the excellence and hard work of a wonderful team.

Thank You for your attention

SPARES