Last RRB 17/10/2011

LHC Status

RRB,

CERN

Monday 23rd April 2012

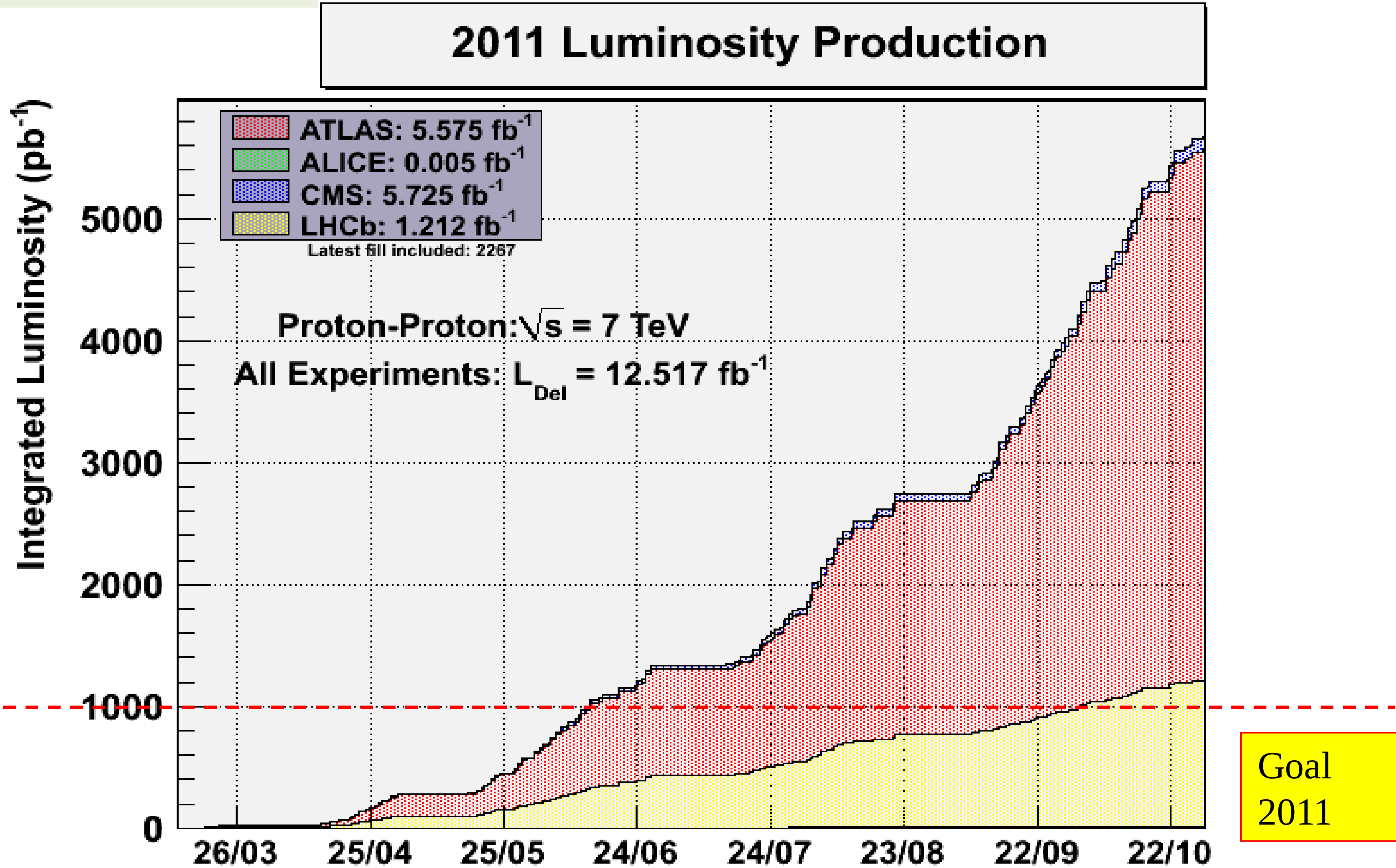
Steve Myers

Topics

- Performance at end of 2011
- Chamonix 2012
- Start-Up in 2012
- Present performance and some issues encountered

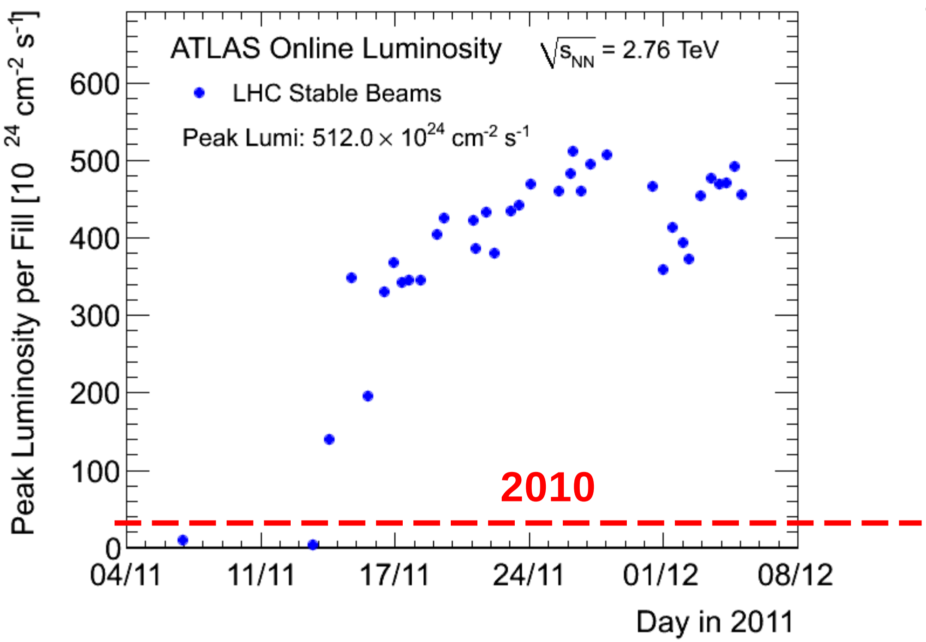
Performance in 2011

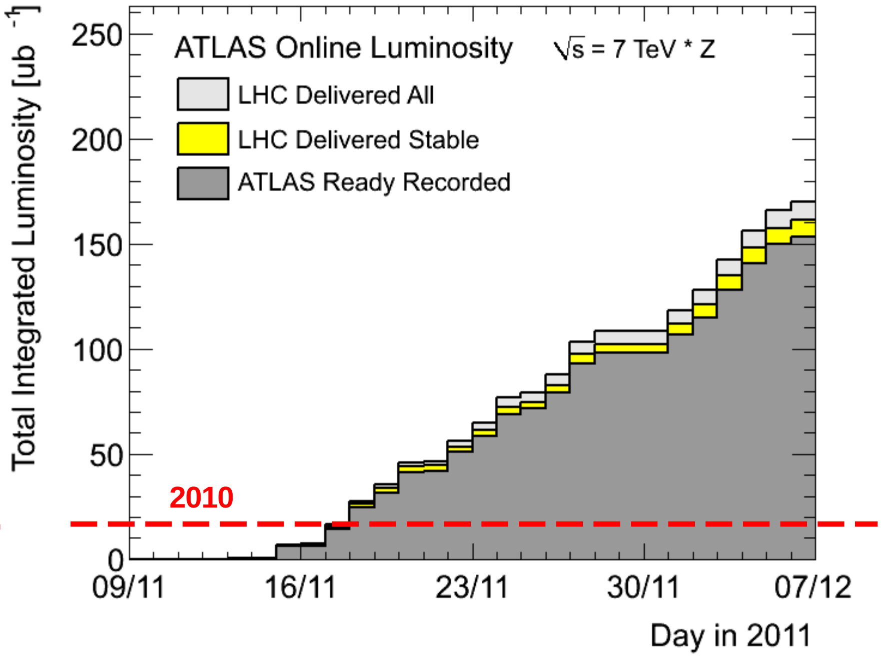
Protons



Goal
2011

Peak and Integrated luminosity





356 bunches

In 2010:

Peak ~18E24; Integrated ~18ub-1
Max 137 bunches, larger β*, smaller bunch intensities

Chamonix 2012

Sessions

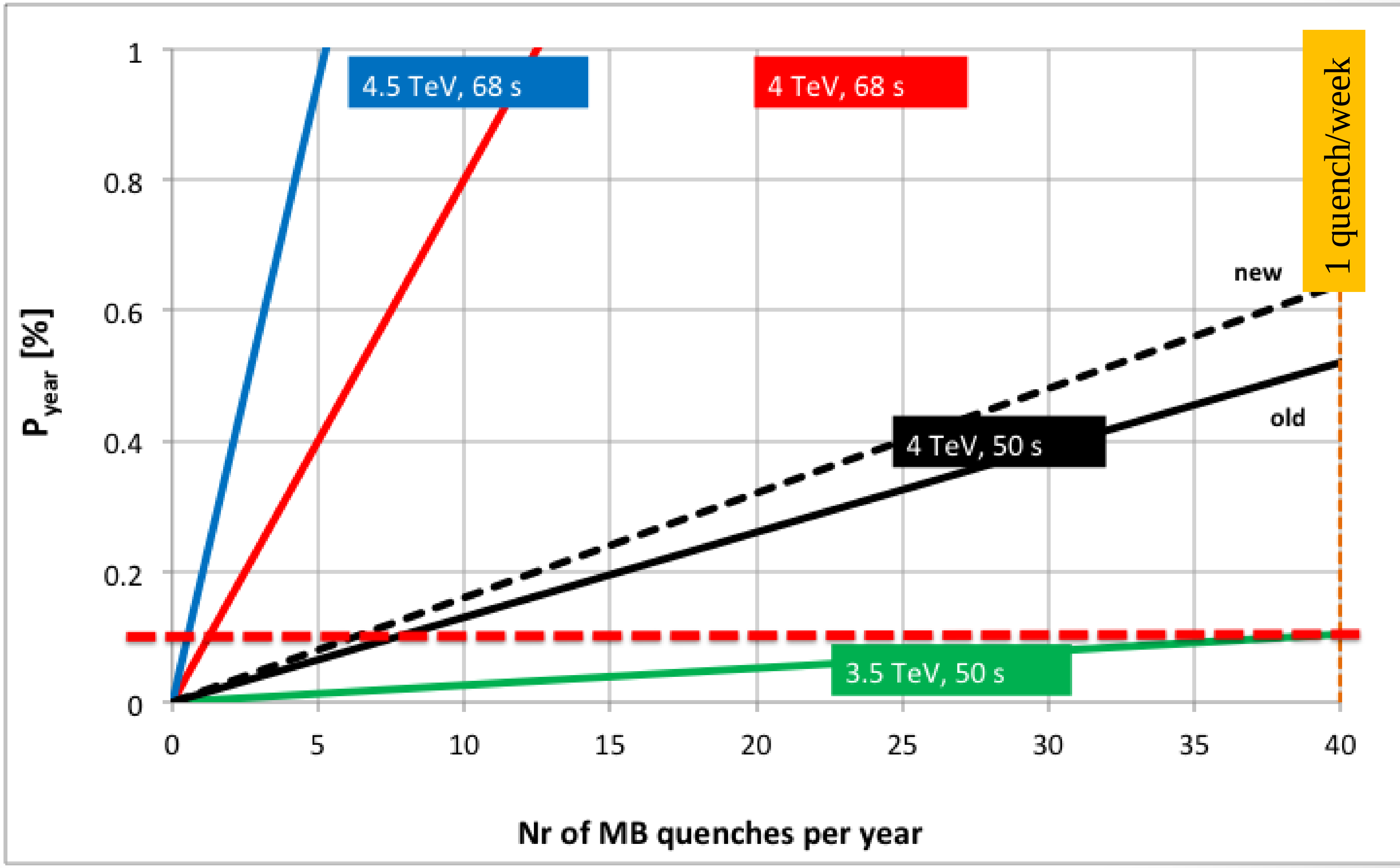
1. Lessons from 2011: M.Lamont/C. Bracco
2. Machine Studies: R. Assmann/G. Papotti
3. Strategy for 2012: J. Wenninger/R. Tomas Garcia
4. Strategy for 2012: O.Bruning/L. Ponce
5. LS1: …….F. Bordry/K. Foraz
6. LS1: …….F. Bordry/K. Foraz
7. After LS1…..R. Schmidt/M. Pojer
8. LHC Related Projects and Studies: R. Garoby/L. Ponce
9. LHC Related Projects and Studies: L. Rossi/R. De Maria
10. Proposals for Decisions: S. Myers/F. Zimmermann

Major Decisions Needed

- Safe Beam Energy for 2012
- Priorities for the 2012 run
  - Proton-proton (integrated luminosity)
  - Proton-ion
  - Machine Studies
- Date of Start of LS1
- «Ready for beam» date after LS1
- High energy and luminosity after LS1

Update on burn out probability calculations

- Additional resistance in by-pass diode stacks (discovered during 2011 run) needs to be taken into account



New Information during 2011

- Thermal amplifier tests have been excluded for time and risk reasons
- Multiple quenches due to EM coupling have been eliminated
  - Snubber capacitors (are) very effective in 2011
  - Modification of Power converters passive filters
  - Modification of the energy extraction
- RRR measurements adds margin
- Balance of anomolous resistances adds margin
- Not a single beam induced quench during stable beams in 2011

CONCLUSION (risk factor = Probability * Impact)

- We consider the probability of a splice burn out at 4 TeV/beam in 2012 to be less than or equal to the probability in 2011 at 3.5TeV/beam
- Following the improvements made in 2009, the impact is now somewhat less than the 14 month shutdown resulting from the previous accident

Major Decision Needed

- Safe Beam Energy for 2012
- Priorities for the 2012 run

Proposal: operation at 4TeV/beam

  - Proton-ion
  - Machine Studies
  - Date of Start of LS1
  - «Ready for beam» date after LS1

Safe Beam Energy for 2012

Consequences of operating at 4.0 TeV per beam as compared to 3.5 TeV

- Higher peak (integrated) luminosity ($\approx$ 15%)
- Higher Higgs cross-section (20-30%)
- Possibly allows beta* of 0.6m

2012 Priorities Proposed

1. The LHC machine must produce enough integrated luminosity to allow ATLAS and CMS to independently discover the Higgs before the start of LS1.

2. We must also prepare for the proton-lead ion run at the end of the year.

3. We must (in 2012) do the necessary machine experiments to allow high energy, useful high luminosity running after LS1.

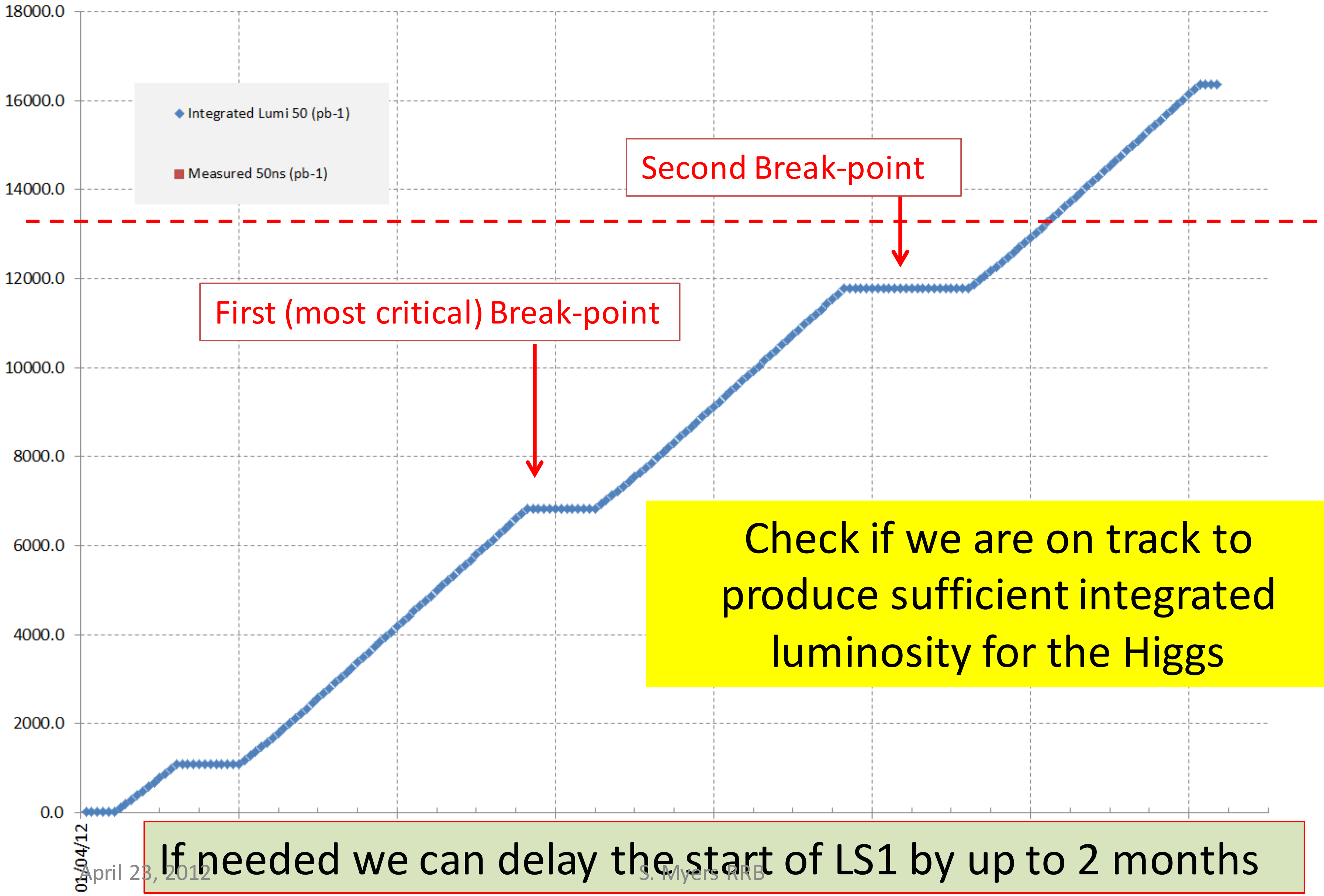
Pile up and 25ns

Integrated luminosity needed for Discovery of Higgs

Year	fb-1	signal (in σ)	Beam Energy	

These numbers come from my simplistic arithmetic. However both ATLAS and CMS said they would like MORE. Of course when we reach 13.3fb-1 we are NOT going to stop!

2012 Measured vs Predicted Integrated Luminosity



Check if we are on track to produce sufficient integrated luminosity for the Higgs

If needed we can delay the start of LS1 by up to 2 months

The Path to High Luminosity

- Beta* of 0.6 seems possible
- Tighter collimation settings

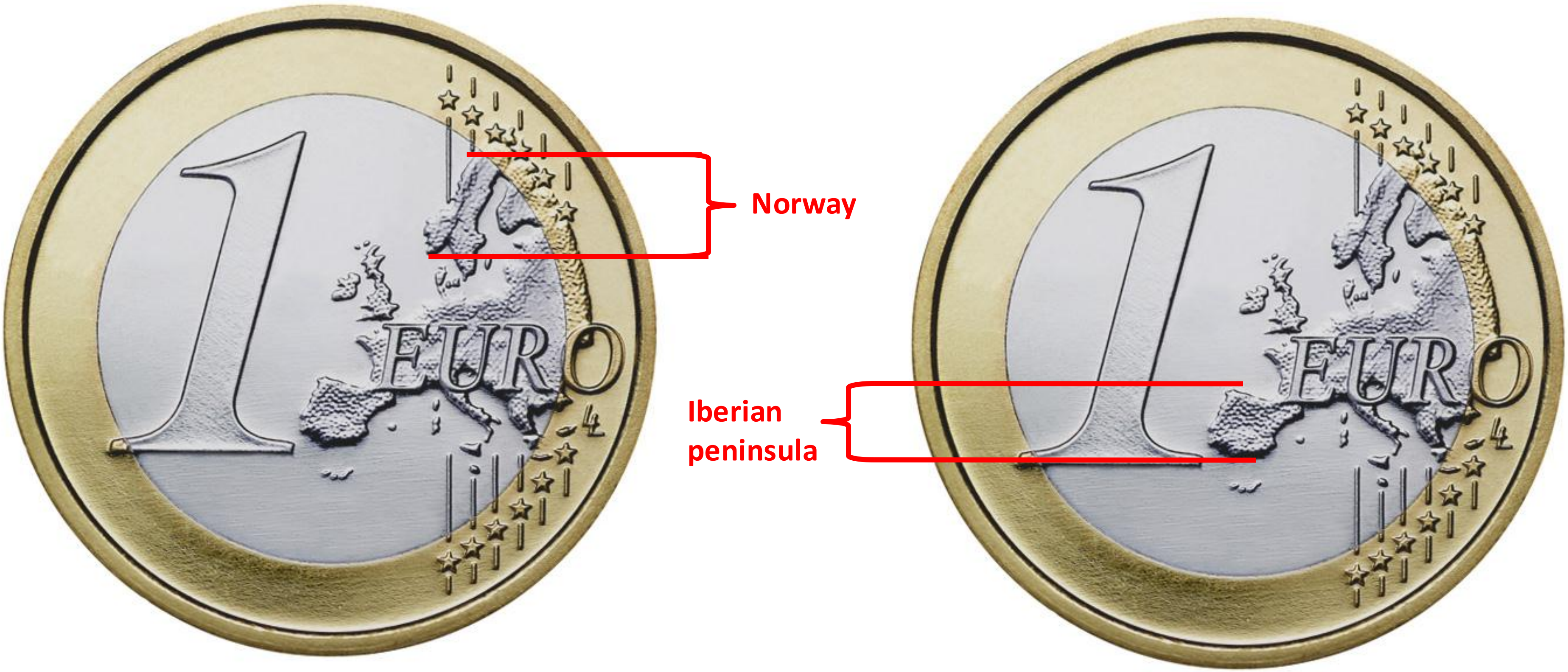
- Question
- Should we take conservative path (changing the parameters adiabatically or should we immediately go for the «final» configuration

Proposal from the operations group to start operation at 0.6m and tight collimation settings

2012 run configuration

- Energy – 4 TeV
  - Low number of quenches (as in 2011) assumed
- Bunch spacing - 50 ns
- Collimator settings – tight
  - As discussed – NB not yet proven operationally
- Atlas and CMS beta* - 60 cm
  - with 70 cm and 90 cm as fallbacks
- Alice and LHCb beta* - 3 m
  - Natural satellites versus main bunches in Alice

How tight?



Intermediate settings (2011):
~3.1 mm gap at
primary collimator

Tight settings:
~2.2 mm gap at
primary collimator

Prepare for the proton ion run towards the end of 2012

Will be continued in parallel with the proton running. The operating energy must be decided based on efficiency of operation

Target p-Pb performance in 2012 (ATLAS/CMS)

Main choice:	**Units**	**200 ns**	**200ns**	**100 ns**	**100**
Beam energy/(Z TeV)	*Z* TeV	3.5	4	3.5	4
Colliding bunches		356	356	550	550
β^*	m	0.7	0.6	0.7	0.6
Emittance protons	µm	3.75	3.75	3.75	3.75
Emittance Pb	µm	1.5	1.5	1.5	1.5
Pb/bunch	10^8	1.2	1.2	0.8	0.8
p/bunch	10^{10}	1.15	1.15	1.15	1.15
Initial Luminosity L_0	10^{28} cm^{-2} s^{-1}	**6.2**	**8.3**	**6.4**	**8.5**
Operating days		**22**	**24**	**22**	**24**
Difficulty (subjective)		**0.9**	**1**	**0.9**	**1**
Integrated luminosity	µb^{-1}	**15.4**	**22.4**	**15.9**	**23.1**

Integrate luminosity by scaling from 2011.
Average Pb bunch intensities from best 2011 experience.
Proton bunch intensities conservative, another factor 10 ????
Proton emittance conservative, another factor 1.37 ??
Untested moving encounter effects, possible reduction factor 0.1 ??

LS1

- Planning is in very good shape
- CMS «ready for beam» September 2014 (2 months later than originally planned)
- After LS1 we need to quickly get back into operation with high energy and high luminosity.
  - Re-training
  - UFO induced quenches

Beam Energy after LS1

- Strong recommendation
- Goal: Around 6.5TeV/beam is safer and more efficient for data production in 2015(<100 training quenches estimated)
- We are still aimimg to reach 7TeV/beam after 2015

UFOs and Magnet quenches

- Estimated number of beam dumps per year
  - 108 (50ns), many more with 25ns
- What to do?
  - High priority for studies and tests related to UFOs and quench levels
  - Detailed Proposal to come from the Machine Protection Team

Summary of Proposals/Decisions

- Safe Beam Energy for 2012... 4TeV
- Priorities for the 2012 run
  - Proton-proton (integrated luminosity) HIGGS
  - Proton-ion
  - Machine Studies...UFOs and Quenches
    - Prepare 25ns
- Date of Start of LS1..determined at lumi break-points
- «Ready for beam» date after LS1 (1st September 2014.. CMS)
- After LS1: Around 6.5TeV/beam to reduce the number of re-training quenches

CERN Machine Advisory Committee Recommendations

Report of the 5th Meeting of the CERN Machine Advisory Committee held on 10 - 13 February 2012

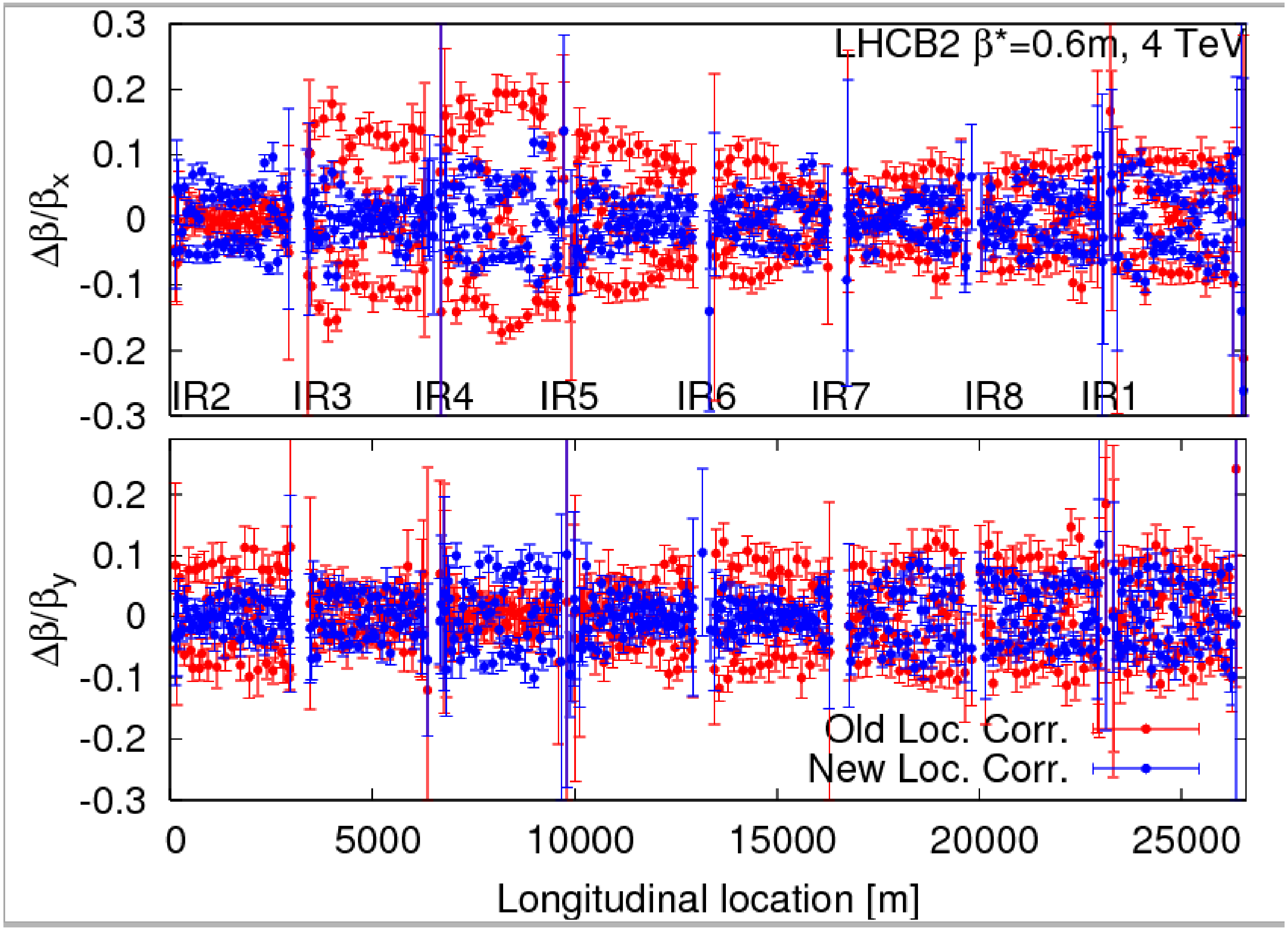
The recommendations are in line with our proposals from Chamonix. All recommendations are being followed up at present. The list of recommendations is attached to this presentation.

- The fifth meeting of the CERN Machine Advisory Comm… 10 - 13 February 2012. The following memb… (INFN), R. Brinkmann (DESY), W. Fi… Seeman (SLAC), V. Shilt… …Oide (KEK) was …
- … …ely preceded this meeting and the … …ast the last two days of the Chamonix … …any excellent presentations and the lively discussions at … …amonix workshop on LHC operation and plans for future operation and upgrades formed the basis for the deliberations of the MAC and this report.
- The Committee is very impressed by the outstanding performance of LHC in both proton and heavy ion operations, greatly exceeding expectations, and congratulates the entire LHC team.

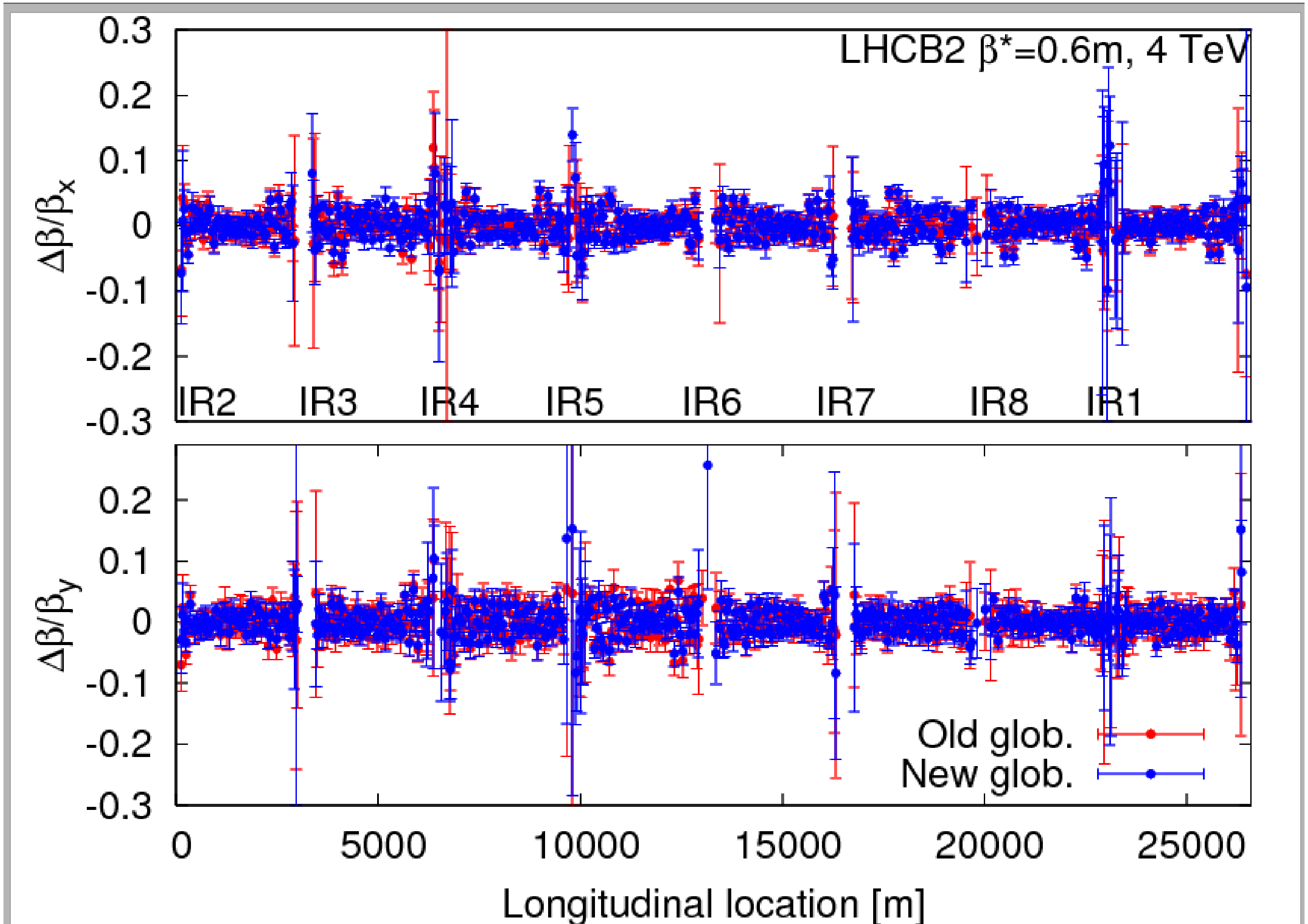
2012 Start Up

- Hardware commissioning
- Optics and machine validation
- Physics with intensity build up

Optics B2 – New Local Correction



Optics B2 – New Correction…

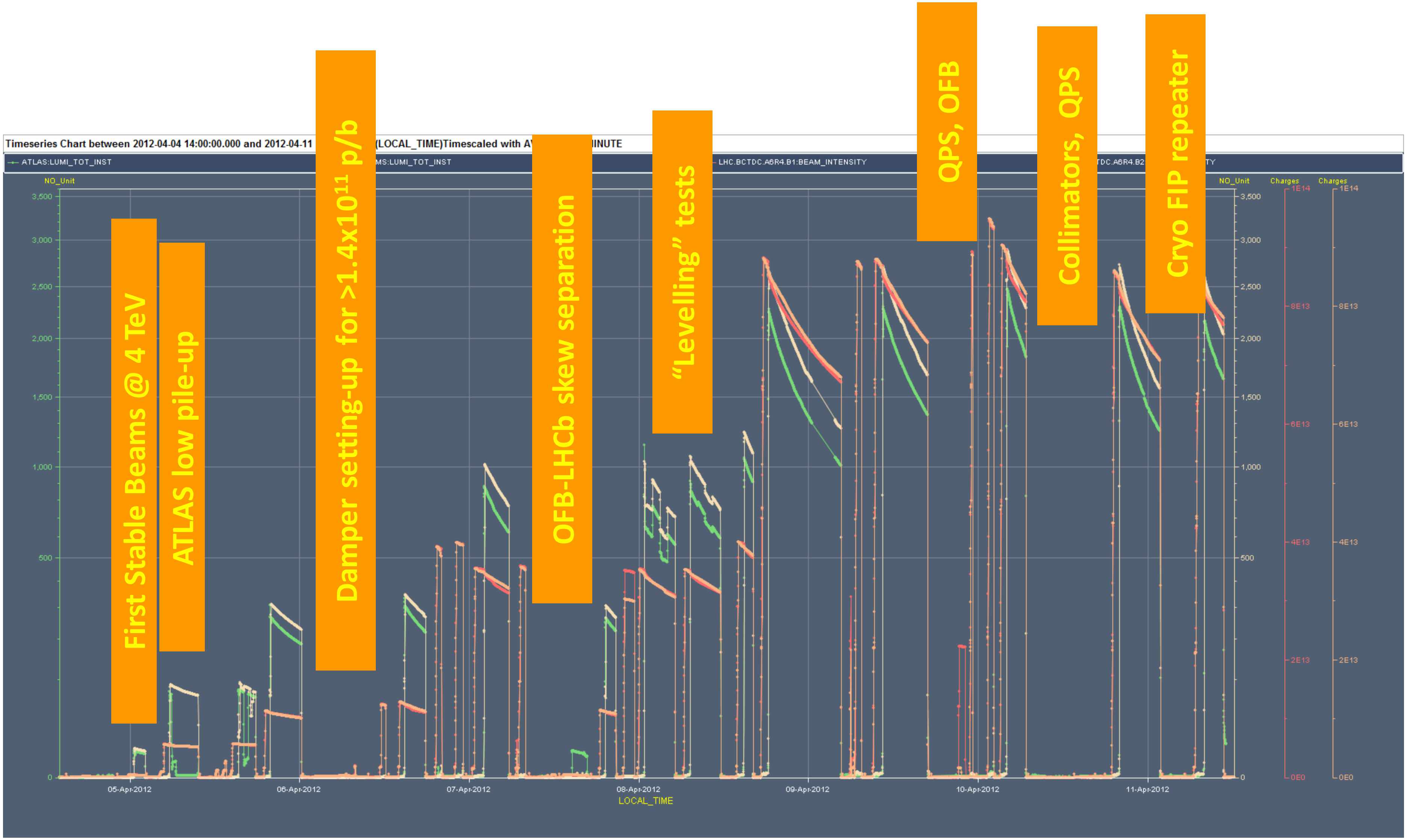


Plan for Intensity ramp-up

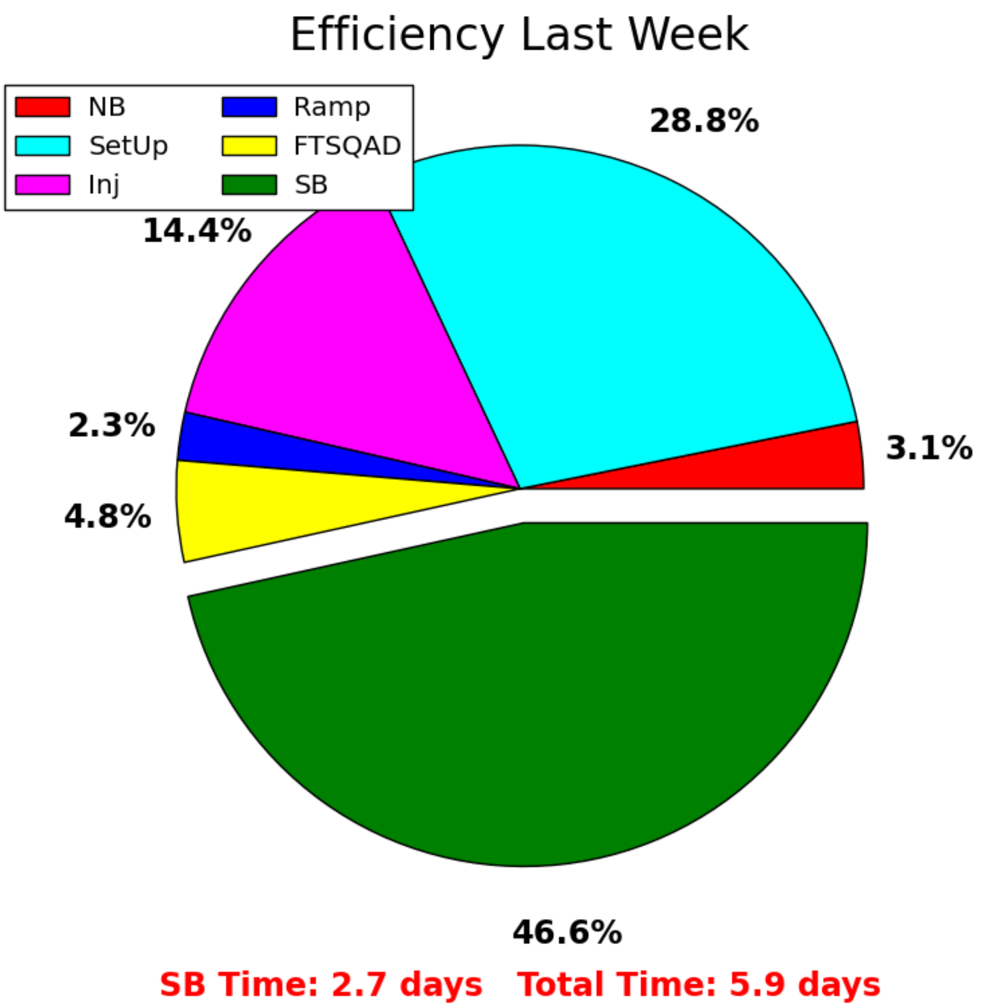
- 3b for MPS
- 2-3 fills and 4-6 hours with 48b, 84b, 264b (cycle validation)
- 3 fills and 20 hours with 624b, 840b, 1092b, 1380b (intensity/lumi related problems)
- MP checklists after 84b, 624b, 840b, 1092 bunches
- Regular checklists every two weeks when operating with 1380b

Bunches	Max number of bunches injected	Alice
3	1	Main-main
48	12	Main-satellite
84	36	Main-satellite
264	36	Main-satellite
624	72	Main-satellite
840	108	Main-satellite
1092	108	Main-satellite
1380	144	Main-satellite

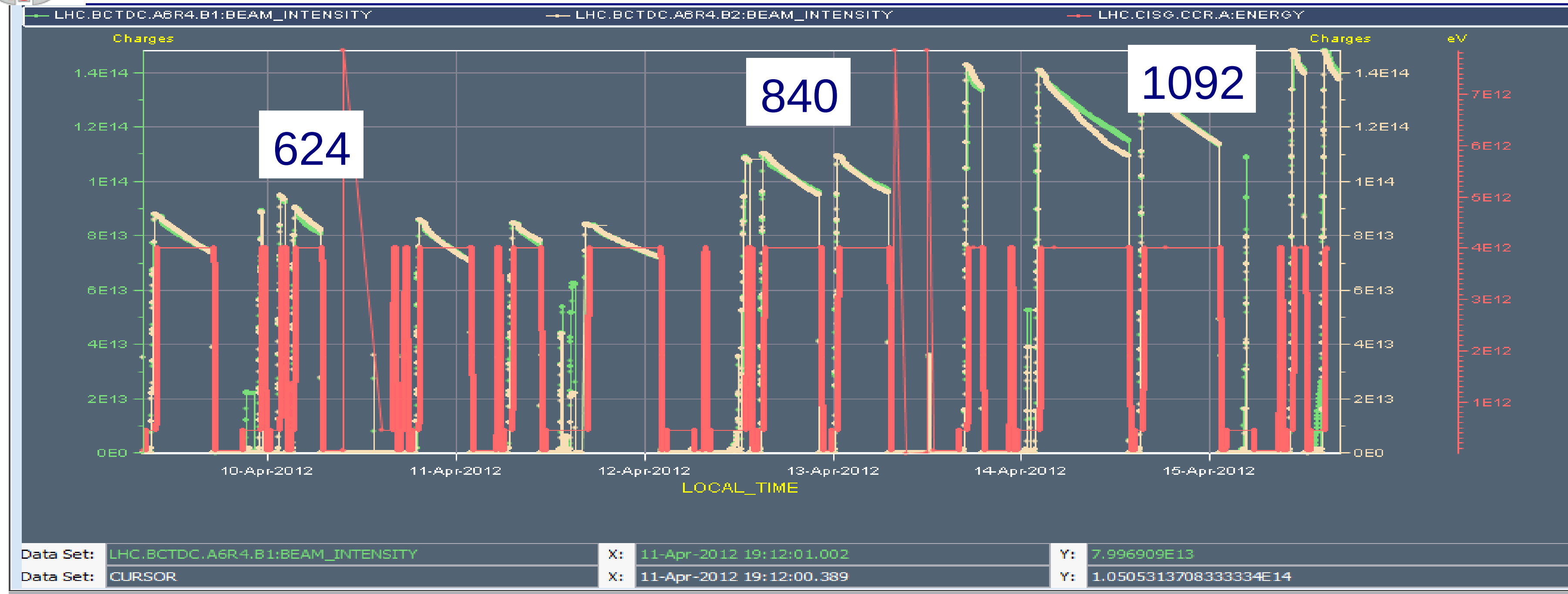
First week with Beams

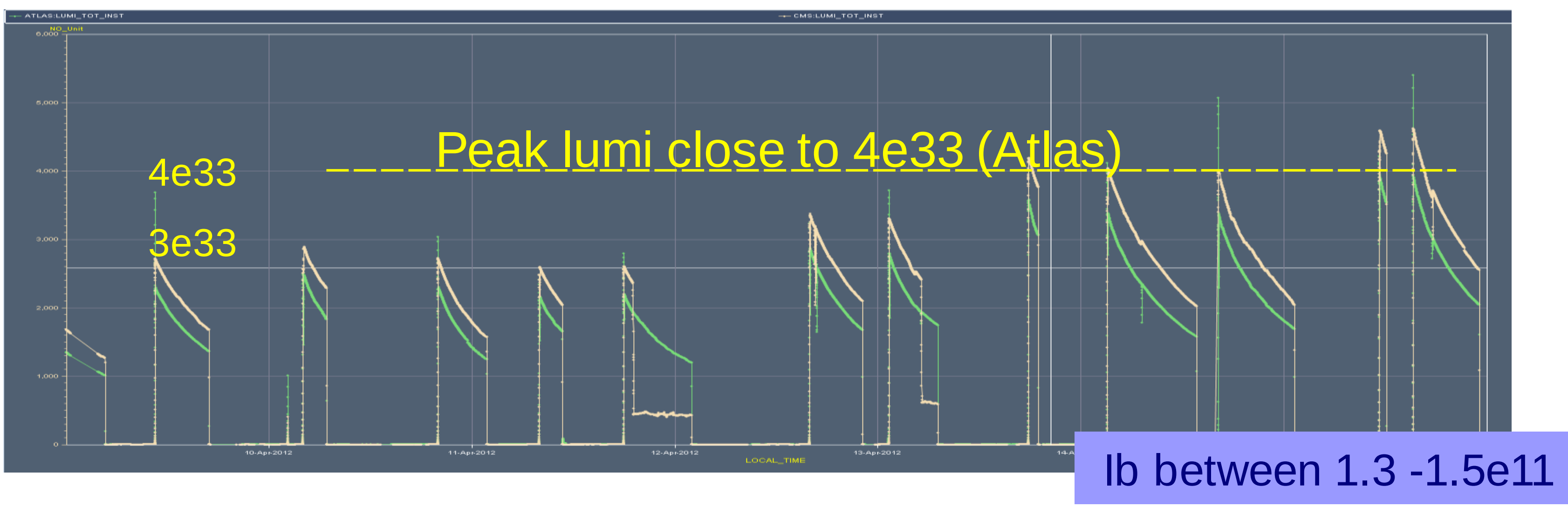


Week 15: 47 % of time in Stable Beams



Second Week– week 15





Some of the Issues

Beam Life time

- Life time low during squeeze and when going into collision
  - Feed forward of orbit corrections by J.Wenninger (ongoing?)
  - Loosing the tails when going into collision

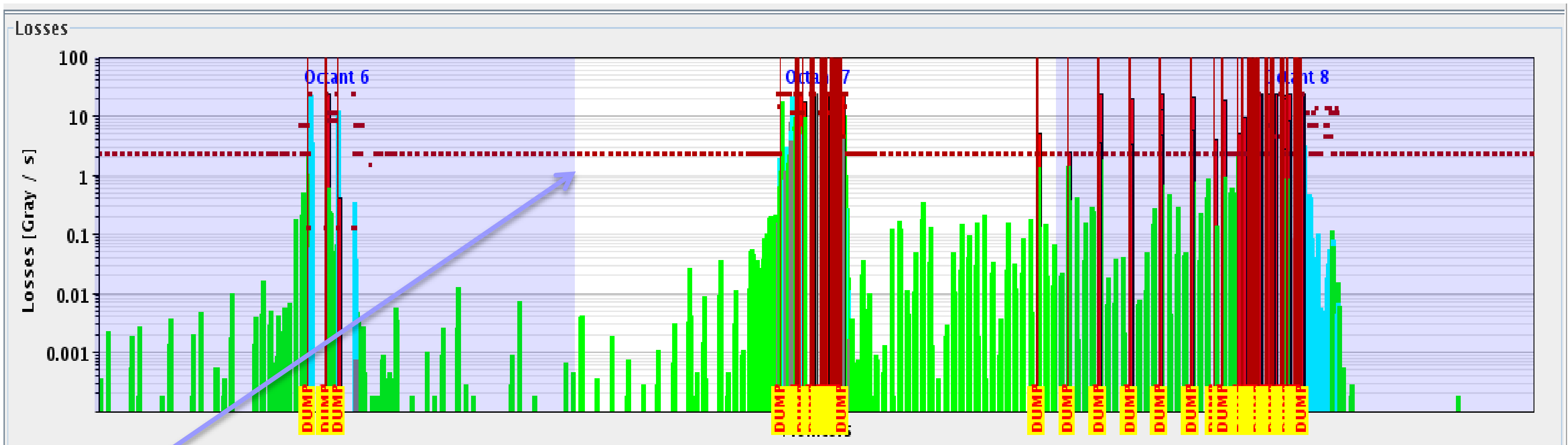
lifetime … during squeeze / … during adjust

First BIG UFO in the arc – 92 % dump threshold

MKI point 8 magnet D break down

- About 50 bunches on the TDI, some grazing
- Quench of several downstream magnets
- See presentation Mike Barnes

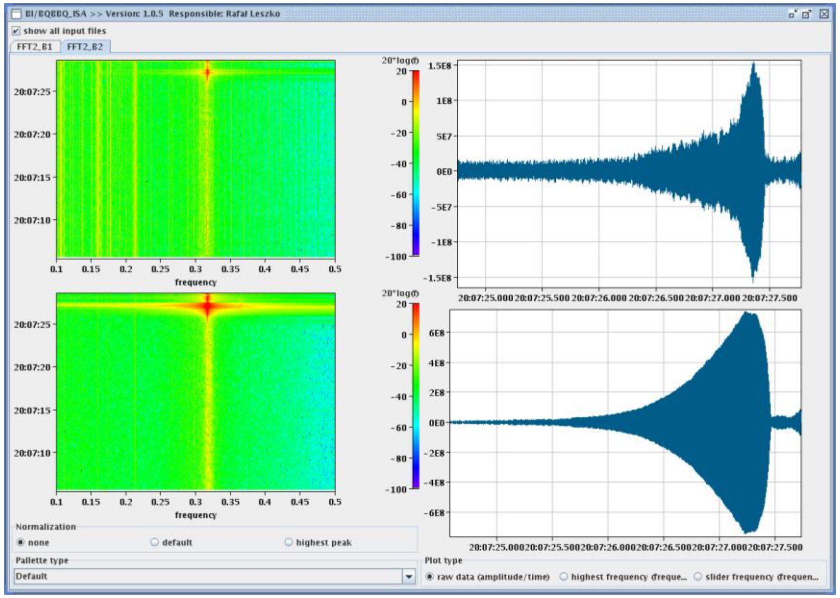
Beam 2



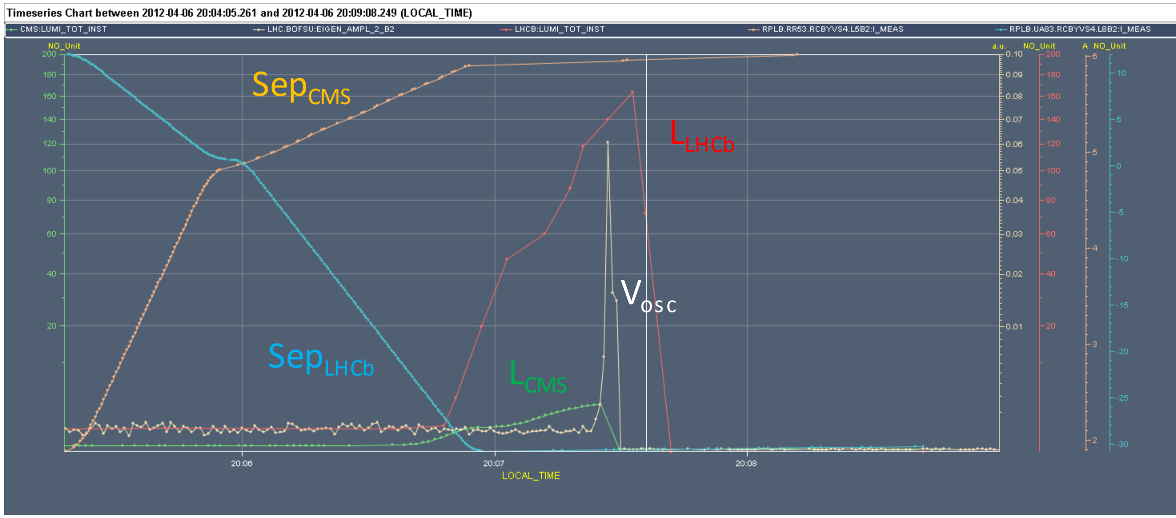
dump threshold

Issues: LHCb skew crossing

- When it goes wrong:
  - Instabilities observed when going in collision with 264 bunches and mostly during the rotation of the LHCb crossing plane.



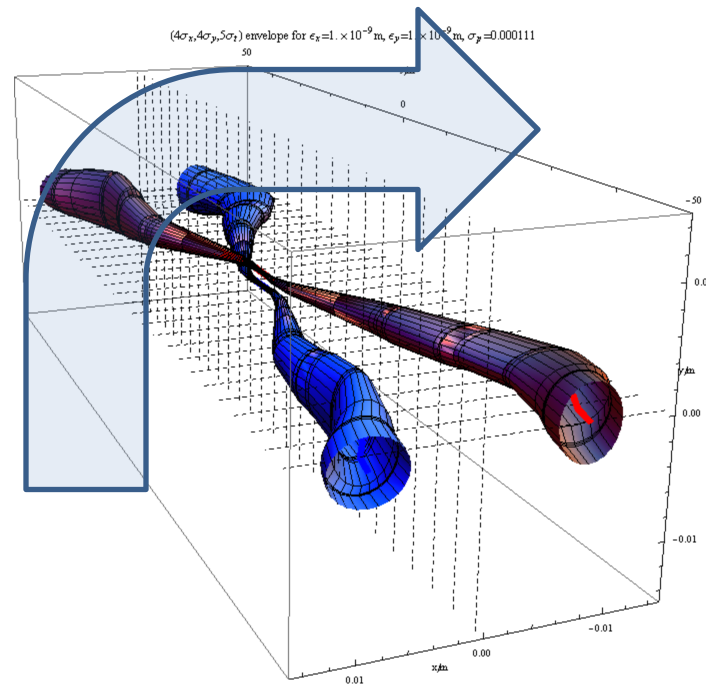
  - Observation of high collision rates in LHCb during this process and well before the end of the collision process (220 s)



- Corrected

Issues: LHCb skew crossing

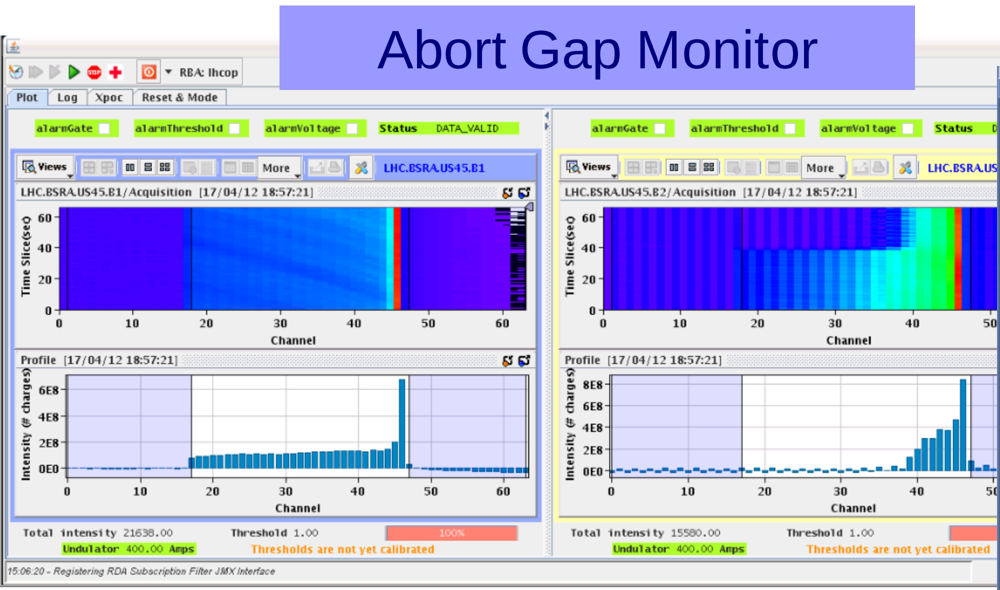
- Quite some gymnastics:
  - 0 – 40 sec:
    - V half-separation -650 um ➔ -100 um
  - 40 – 60 sec:
    - V half-crossing angle 0 ➔ + 90 urad
  - 100 sec – 220 sec:
    - create H half-separation 0 ➔ + 42 um to get the beams in the skew levelling plane
    - collapse horizontal crossing angle -> 0 urad

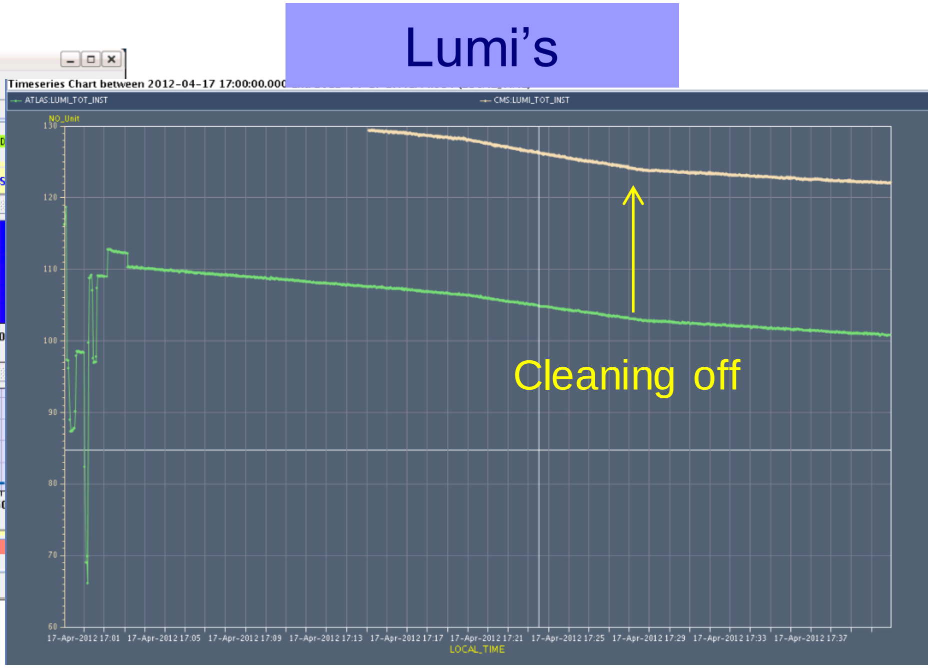


R. Alemany, B. Holzer, R. Versteegen

Abort gap cleaning in collision

- Operationally checked with 36 bunches in the machine at 4 TeV with colliding beams
- Cleaning does affect the lumi when cleaning applied – confirms 2011
- Approved edms doc with procedures
  - Edms no. 1204352, released
  - Only clean when required and then clean strongly
  - Brush up on diagnostics but cleaning functionality is there using the new application

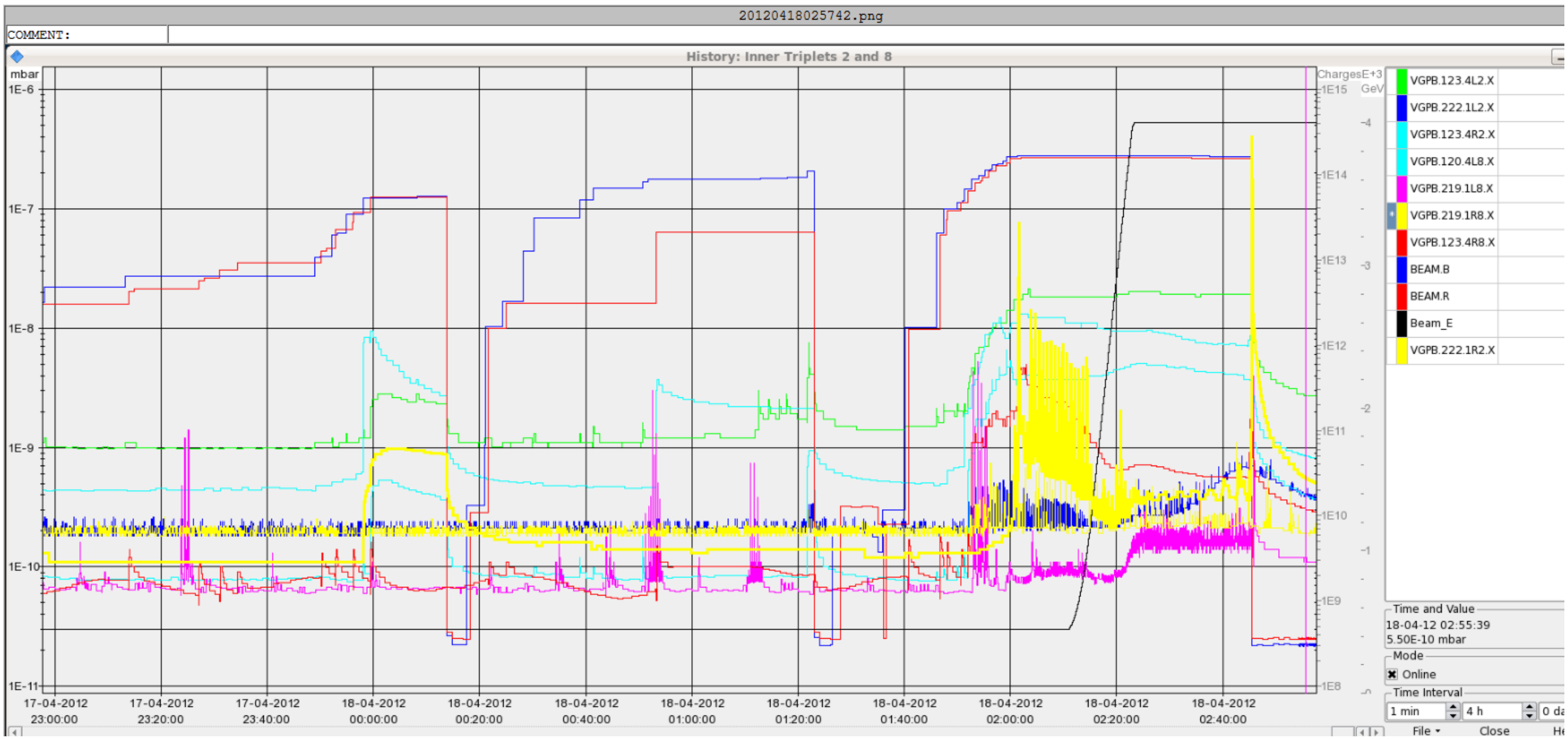




Vacuum spike 1380 bunches

In the middles of collision beam process we had a beam dump due to a vacuum spike in 1R8 that provoked valve closure

Vacuum spike VGPB.219.1R8 at 1.8E-7



ATLAS and CMS Luminosity

LMC 18.04.2012

EM,BG

- 2011 luminosities @ Lumi Days 2012
  - ATLAS and CMS report total integrated luminosity for 2011 with a difference of order 10%
- Lumi Days: launched comparison on standard candle (Z->$\mu\mu$):
  - Very preliminary results today
- 2012
  - Current online numbers differ by ~18%
  - CMS online luminosity known to be high by 8-10% from preliminary pixel studies
  - VdM scans with squeezed optics were carried out on Monday: very preliminary results

From Lumi Days Report at LMC124 (BG)

- One of the most remarked parts of the workshop…
- Preliminary results:
  - ATLAS (see Mark Tibbetts' talk): **5.61 fb^{-1}**
  - CMS (see Jeroen Hegeman's talk): **6.1 fb^{-1}**

Using pixel cluster count

- Beware that these measurements require the extrapolation from the recorded luminosity to the delivered
  - Correcting for periods where the luminosity is not measured by an experiment e.g. from stable beams to when the inner detector is ready
  - Hence the uncertainty on these measurements is expected to be larger

on recorded

?)

CMS

ference

consistent with

ry large error

s hard to

easurement

Pixel luminosity for 2011: systematics

Huge improvement made by the LHC BCNWG
See contributions by F. Ferro-Luzzi and C. Barschel
in the 2012 lumi days

Source	Uncertainty (%)
Stability across pixel detector regions	0.3
Pixel gains and pedestals	0.5
Dynamic inefficiencies	0.4
Length-scale correction	0.5
Beam width evolution	0.6
Beam intensity - DCCT	0.3
Beam intensity - FBCT	0.5
Beam intensity - Ghosts	0.2
Scan-to-scan variations	1.5
Afterglow	1.0
Total	2.2

K-modulation

Beam	Plane	β^* IP1 (m)	β^* IP5 (m)
B1	H	1.20 ± 0.20	1.13 ± 0.15
B1	V	1.05 ± 0.13	1.20 ± 0.20
B2	H	1.14 ± 0.10	1.10 ± 0.20
B2	V	1.17 ± 0.18	1.06 ± 0.11

AC dipole

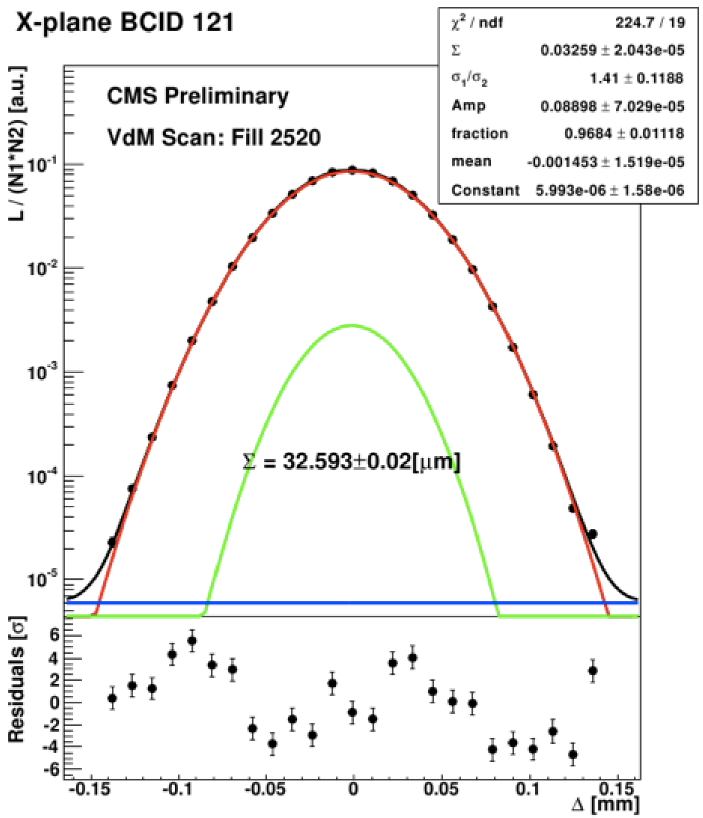
Beam	Plane	β^* IP1 (m)	β^* IP5 (m)
B1	H	0.97 ± 0.05	1.00 ± 0.05
B1	V	1.04 ± 0.17	0.95 ± 0.11
B2	H	1.01 ± 0.10	0.95 ± 0.13
B2	V	1.05 ± 0.06	0.98 ± 0.10

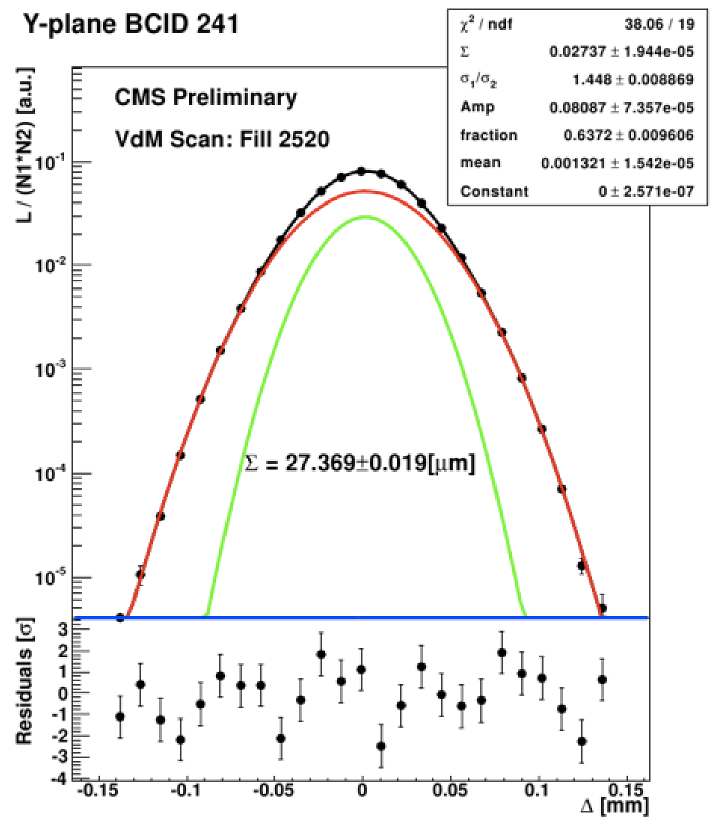
From Rogelio

2012 Luminosity

- CMS Online published luminosity so far ~18% higher than ATLAS
- Both values expected to be known at the 10% level from extrapolation of 2011 calibrations
- Earlier estimates based on the pixel/HF comparison indicated CMS is 7% high (online Luminosity figures are another 2% higher since they are not corrected for afterglow)
  - This has been communicated to ATLAS/LHC
- CMS decided not to apply any correction until VdM scan on Monday

VdM Scan 2012: Very Preliminary Results from CMS





- Example fit results (one BCID). The V-plane looks good, the H-plane shows an oscillatory structure in the residuals for all bunches, most pronounced in first scan

Conclusions

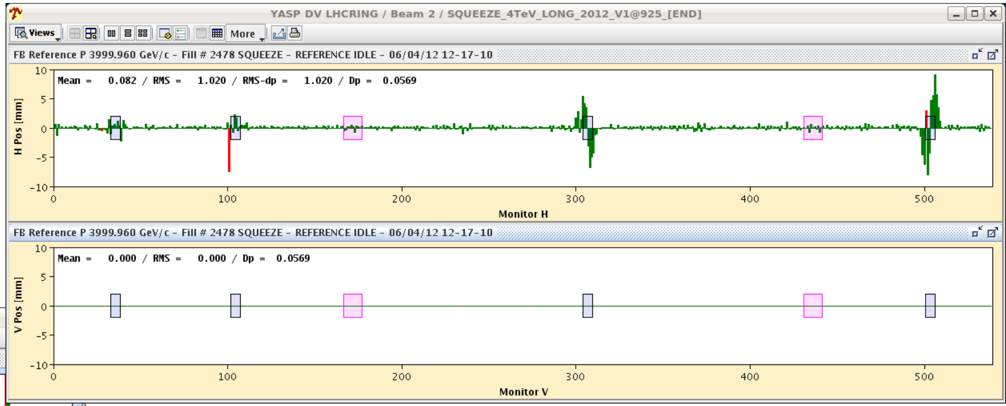
- The 8% difference in 2011 delivered luminosity seems to be confirmed by further studies based on physics candles
- The CMS online luminosity is going to be revised downwards after performing VdM calibrations
- ATLAS initial analysis indicate an underestimated online luminosity
  - The exact extent will be known after complete analysis of VdM data and presented at next LMC
- Final decision on possible mitigation measures of a residual difference should be postponed to next LMC

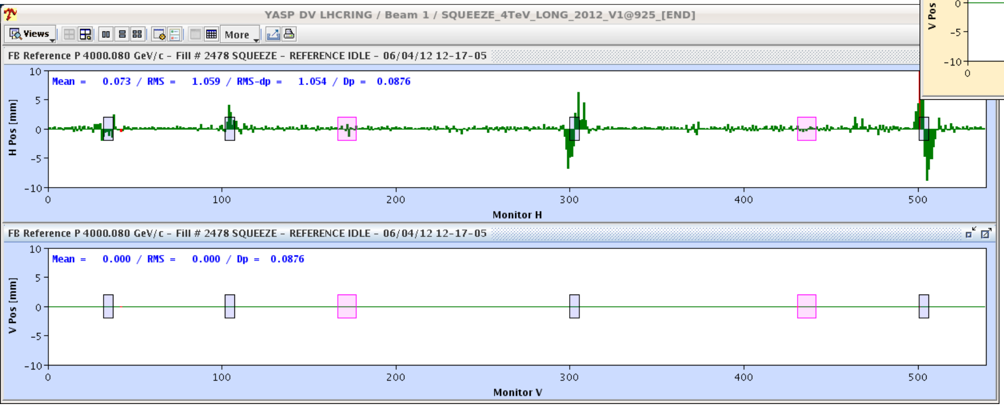
v/d Meer scans

- Took in total 31 hours (instead of 2 shifts?)
- Longer than foreseen due to difficult start
  - Low bunch intensities hard to produce stable, refilling
  - Fill lost due to RCBV17.R7B1 tripped, caught by the SIS.
  - Access Alice
- Experiments working hard on analysing the data…

Issues: Orbit feedback

- Critical tool to guarantee good collimation efficiency and machine protection
- Intermittent problems with orbit feedback
- H or V reference in the OFC zeroed for both beams, crashes of the OFSU

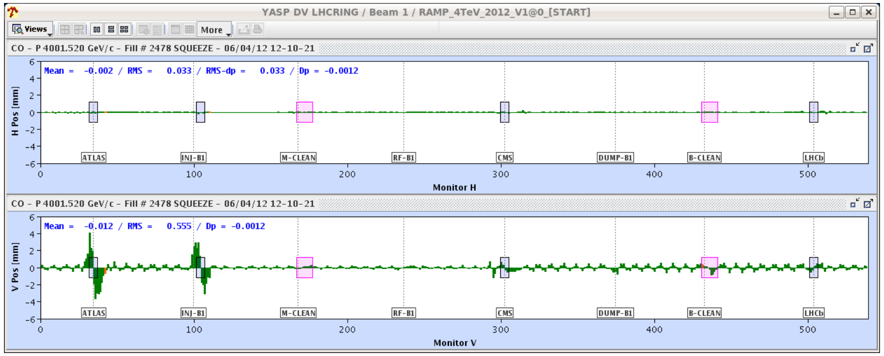


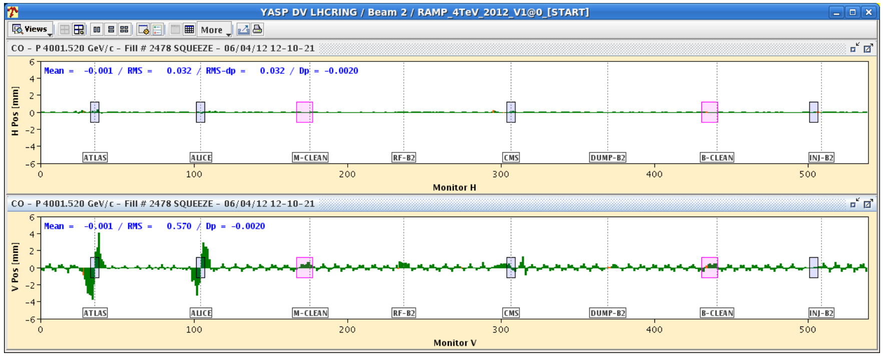


Fill #2478 - squeeze

Issues: Orbit feedback

- Orbit feedback suppressed the crossing angle in point 1 and 2 in approximately 170 s. BLM caught the event and dumped properly.
- Additional interlocks recognizing these failure modes have been implemented but solution of this problem is MANDATORY.





Fill #2478 - squeeze

TSCG

- TCSG.5L3.B1 left jaw collimator blocked yesterday morning
- The issue was traced back to a mechanical problem with a roller screw on one motor axis.
- The repair would requires realistically half a day and could hardly be done immediately. We therefore propose to continue the operation without moving the left jaw from the its injection settings. The other jaw can be "ramped" with the usual functions (one-sided cleaning at top energy).
- Expect a small effect on the system performance
  - validate these new settings with off-momentum loss maps at flat-top (both signs) – done – loss maps OK

STOP PRESS

Summary Week 16 & MD Report

- Machine coordinators: R. Assmann & J. Uythoven
- MD coordination: R. Assmann, G. Papotti, F. Zimmermann

- Highlights:
  - v/d Meer scans: ALICE, ATLAS, CMS, LHCb
  - Improvements LHC orbit (Joerg)
  - Commissioning abort gap cleaning at 4 TeV
  - Injection 144b
  - Completion intensity ramp: 1380b
  - Increase bunch intensity: 1.4e11 p/bunch
  - New highest LHC luminosity: **$5.6\ 10\times^{33}\ cm^{-2}\ s^{-1}$** (average ATLAS, CMS)
  - New highest stored energy: 120 MJ
  - First LHC MD in 2012

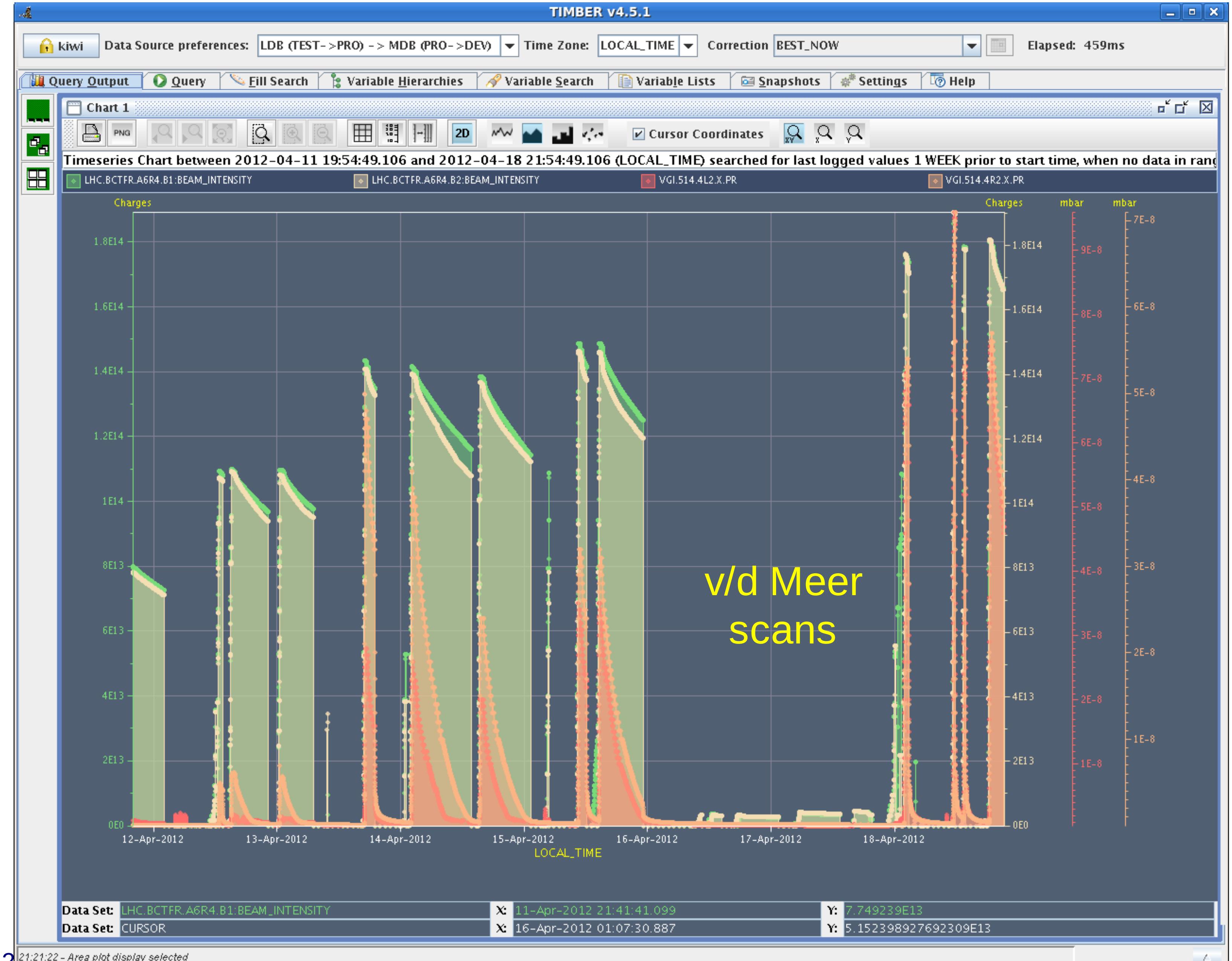
Issues Encountered

- Injection kicker pre-pulse problem b2.
- Disabled ROF.A81B2 until TS.
  - The current of other octupoles increased to compensate.
- Overload problem on COLSA.
- Debunching problem for b1.
- Instability when separating beams for length scale calibration.
- World FIP problem
- Injection steering (MSI)
- ADT amplifier – 1 oo 4 off B1 vertical
- TDI problem
- HV interlock from BLM system

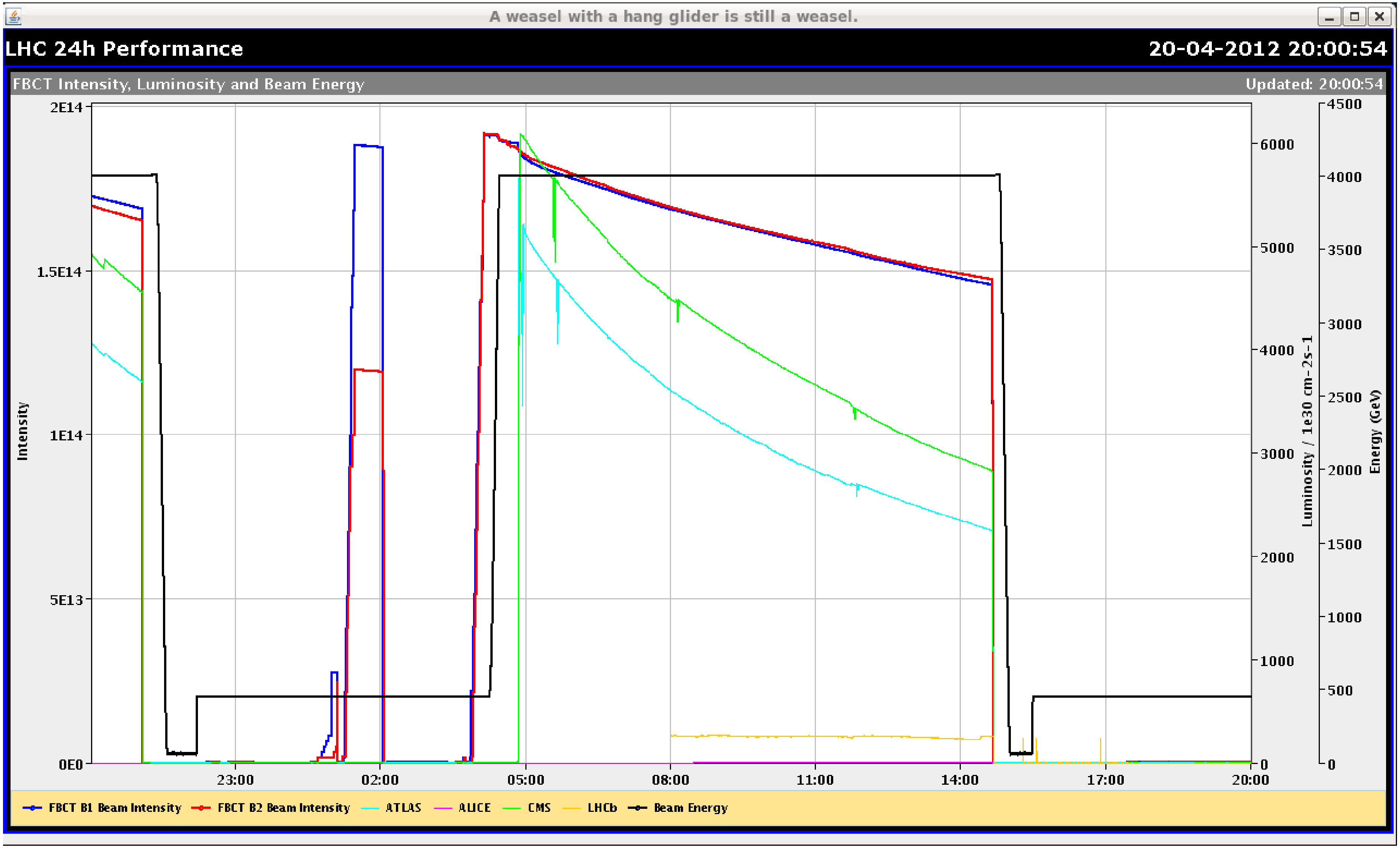
Injection kicker pre-pulse problem B2

- Injection pre-pulse shifted, causing injection BETS to inhibit beam injection
- 144 bunches on the TDI
  - As beam to the core of TDI, not grazing, no magnet quenches
- During tests the inhibition re-appeared once
- Lengthened kicker resonant charging by 100 μs to prevent problem occurring
  - Continue investigations to understand cause of shift

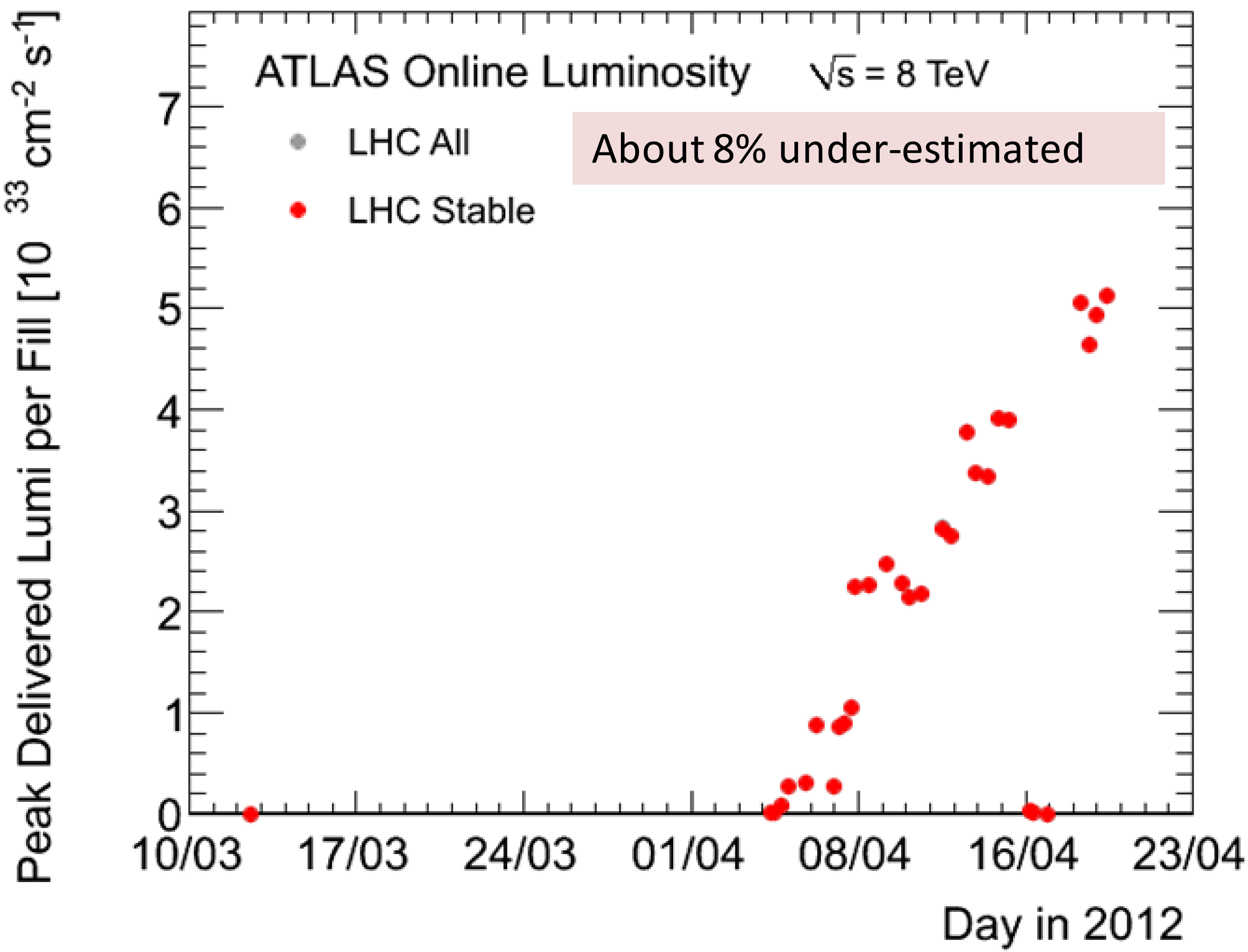
Intensity Ramp (& Vac L2): 1380 bunches

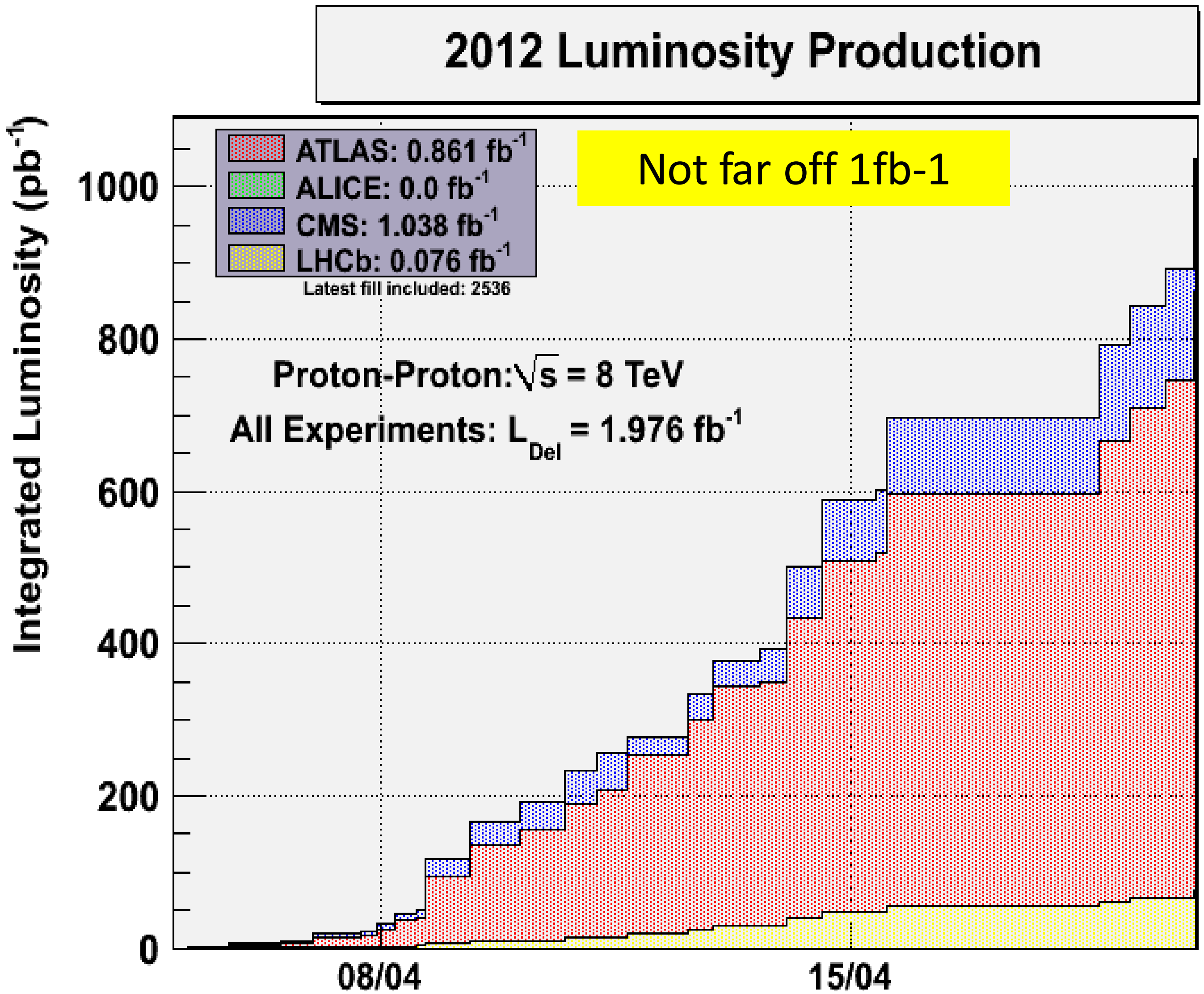


Luminosity Fill Friday (Last Before MD)



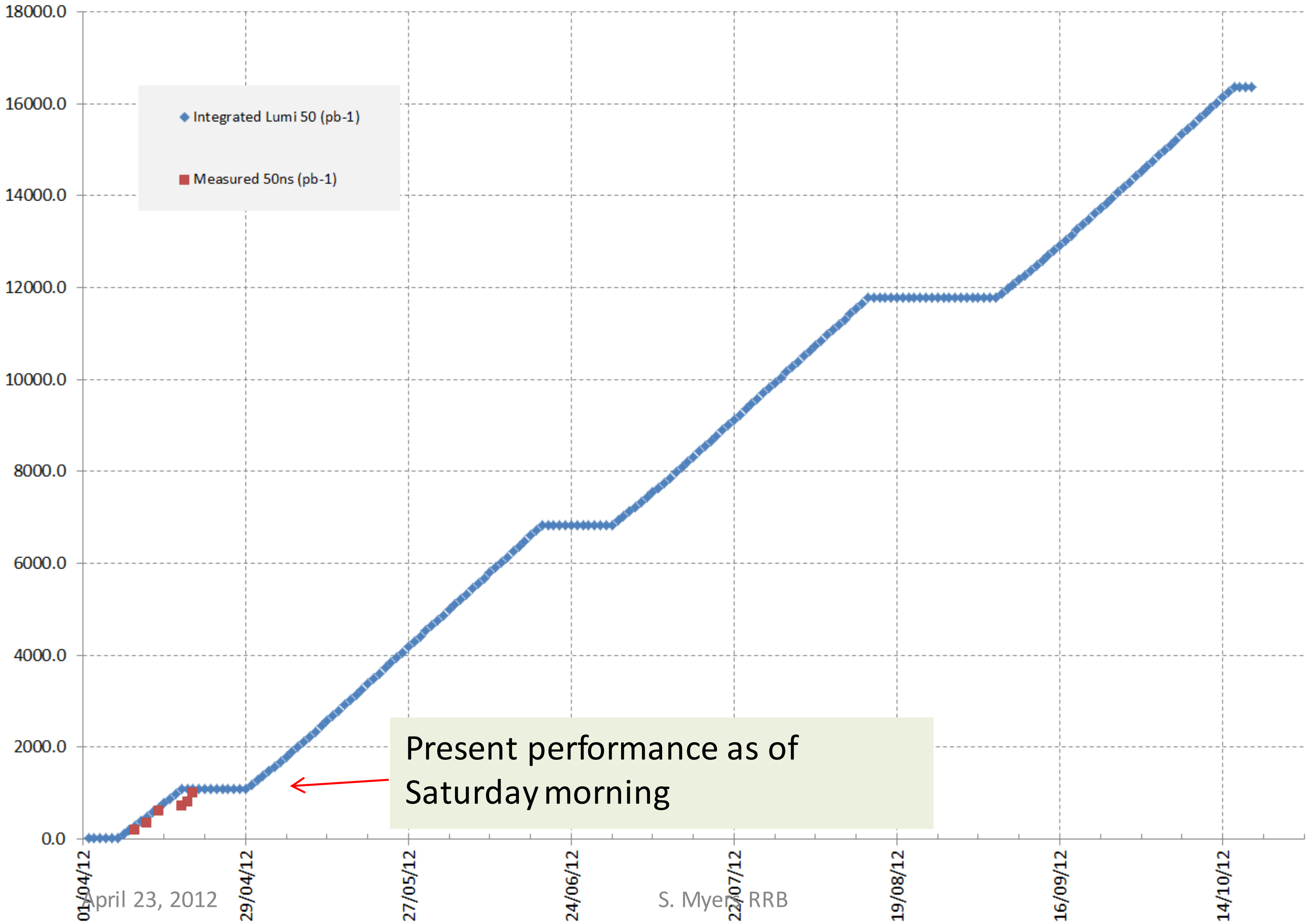
Peak Luminosity





2012 Luminosity Production
ATLAS: 0.861 fb-1
ALICE: 0.0 fb-1
CMS: 1.038 fb-1
LHCb: 0.076 fb-1
Latest fill included: 2536
Not far off 1fb-1
Proton-Proton: √s = 8 TeV
All Experiments: L_Del = 1.976 fb-1
Integrated Luminosity (pb-1)
1000
800
600
400
200
0
08/04
15/04

2012 Measured vs Predicted Integrated Luminosity



Questions??