LHC Machine Status

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for the LHC team

2012 run configuration

- Energy – 4 TeV
  - Low number of quenches (as in 2011) assumed
- Bunch spacing - 50 ns
- Tight collimator settings
  - Aperture plus tight settings have allowed us to squeeze to 60 cm
- Atlas and CMS beta* - 60 cm
- Alice and LHCb beta* - 3 m
  - Natural satellites versus main bunches in Alice
  - Tilted crossing in LHCb

Of note

- Operational robustness
  - Precycle, injection, 450 GeV, ramp & squeeze & collisions routine
    - beam instabilities with high bunch currents
    - beam losses if tails and/or big beams from injectors
- Machine protection
  - Unpinned by superb performance of machine protection and associated systems
  - Rigorous machine protection follow-up, qualification and monitoring
  - Injecting up to 144 bunches per shot from the SPS – 1.8 MJ
  - Still enjoying routine collimation of 140 MJ beams without a single quench from stored beams

Bunch spacing

Performance from injectors – exit SPS

Bunch spacing	From Booster	Protons per bunch (ppb)	Emittance H&V [mm.mrad]
150	Single batch	1.1×10^{11}	1.6
75	Single batch	1.2×10^{11}	2.0
50	Single batch	1.45×10^{11}	3.5
50	Double batch	1.7 to 1.8×10^{11}	~2.0
25	Double batch	1.2 to 1.3×10^{11}	~2.7

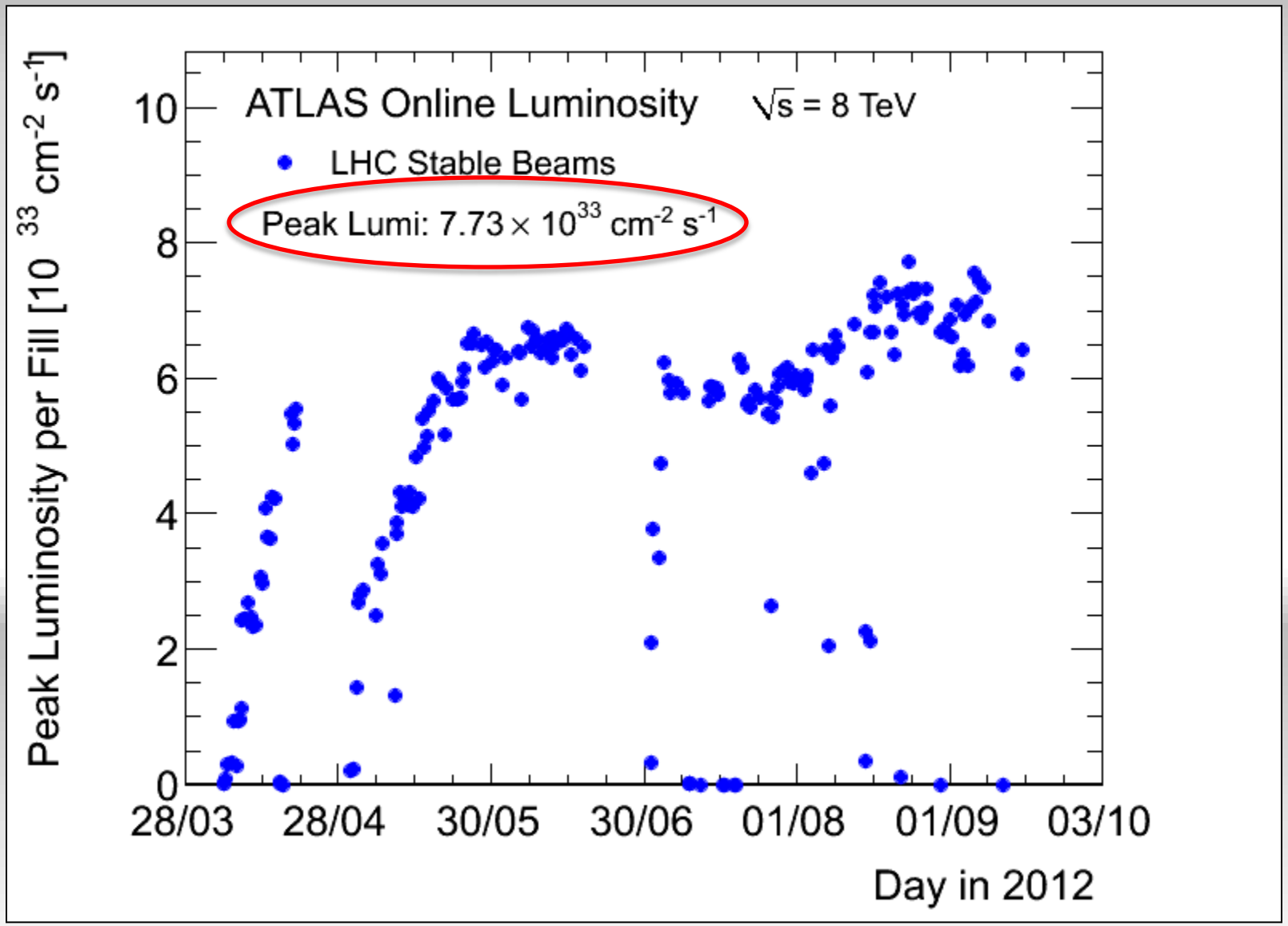
$$L = \frac{N^2 k_b f}{4\pi\sigma_x\sigma_y} F = \frac{N^2 k_b f \gamma}{4\pi\varepsilon_n \beta^*} F$$

2012 records (so far) courtesy ATLAS

Peak Stable Luminosity Delivered	7.73×10^{33} cm^{-2}s^{-1}	Fill 2998	12/08/24, 02:07
Maximum Luminosity Delivered in one fill	237.32 pb^{-1}	Fill 2692	12/06/02, 01:55
Maximum Luminosity Delivered in one day	259.39 pb^{-1}	Sunday 22 July, 2012	
Maximum Luminosity Delivered in 7 days	1350.14 pb^{-1}	Sunday 10 June, 2012 - Saturday 16 June, 2012	
Maximum Colliding Bunches	1380	Fill 2660	12/05/24, 13:17
Maximum Peak Events per Bunch Crossing	71.55	Fill 2825	12/07/10, 02:52
Maximum Average Events per Bunch Crossing	69.49	Fill 2825	12/07/10, 02:52
Longest Time in Stable Beams for one fill	22.8 hours	Fill 2692	12/06/02, 05:10
Longest Time in Stable Beams for one day	21.5 hours (89.7%)	Saturday 18 August, 2012	
Longest Time in Stable Beams for 7 days	91.8 hours (54.6%)	Sunday 22 July, 2012 - Saturday 28 July, 2012	
Fastest Turnaround to Stable Beams	2.13 hours	Fill 2472	12/04/05, 15:46

PERFORMANCE

Peak luminosity



Peak luminosity

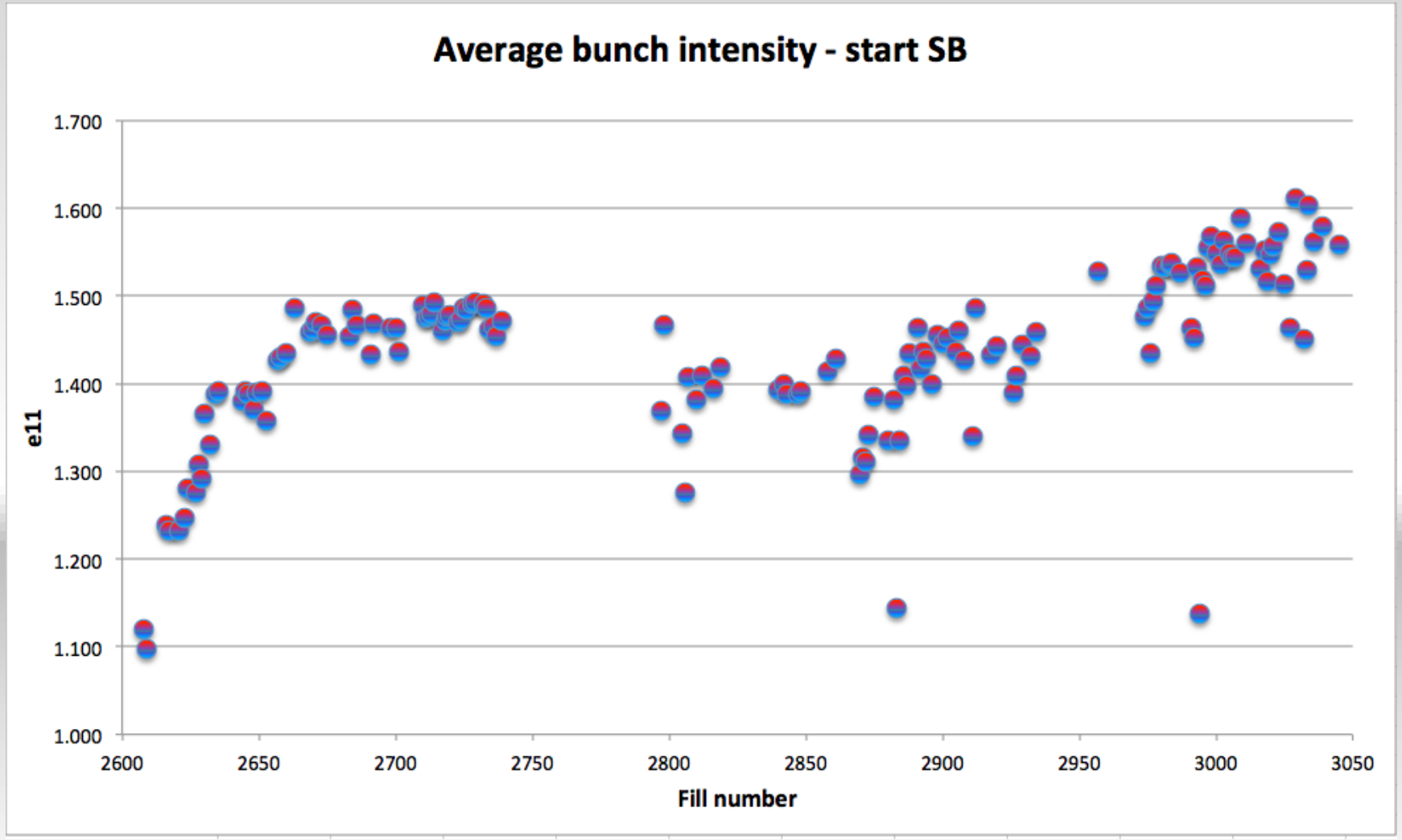
	Fill 2998 – Aug 24th	Design (7 TeV)
Average bunch current [ppb]	1.6×10^{11}	1.15×10^{11}
Number of colliding bunches	1368	2808
Emittance [mm.mrad]	~2.3	3.75
Peak luminosity [$cm^{-2}\ s^{-1}$]	7.73×10^{33}	1×10^{34}
Peak <Events>/BX	36.66	19.02

This is not bad.

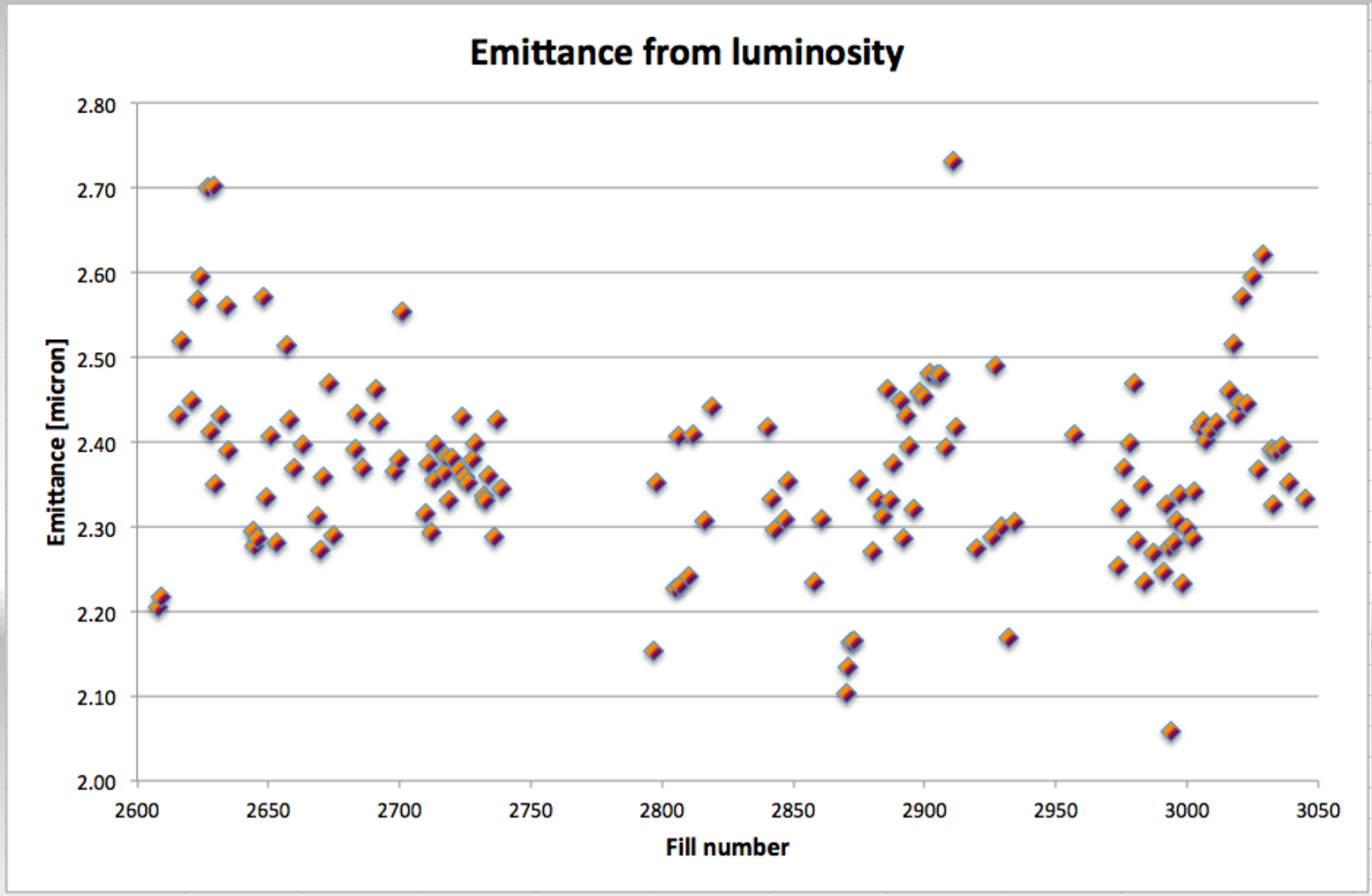
- 50 ns beam from injectors
  - Bunch current
  - Emittance
- Squeeze to 60 cm
- Acceptable beam losses through the cycle
- Instabilities supressed using octupoles and high chromaticity

Bunch intensities

Up to an average bunch intensity of ~1.7e11 ppb at 450 GeV

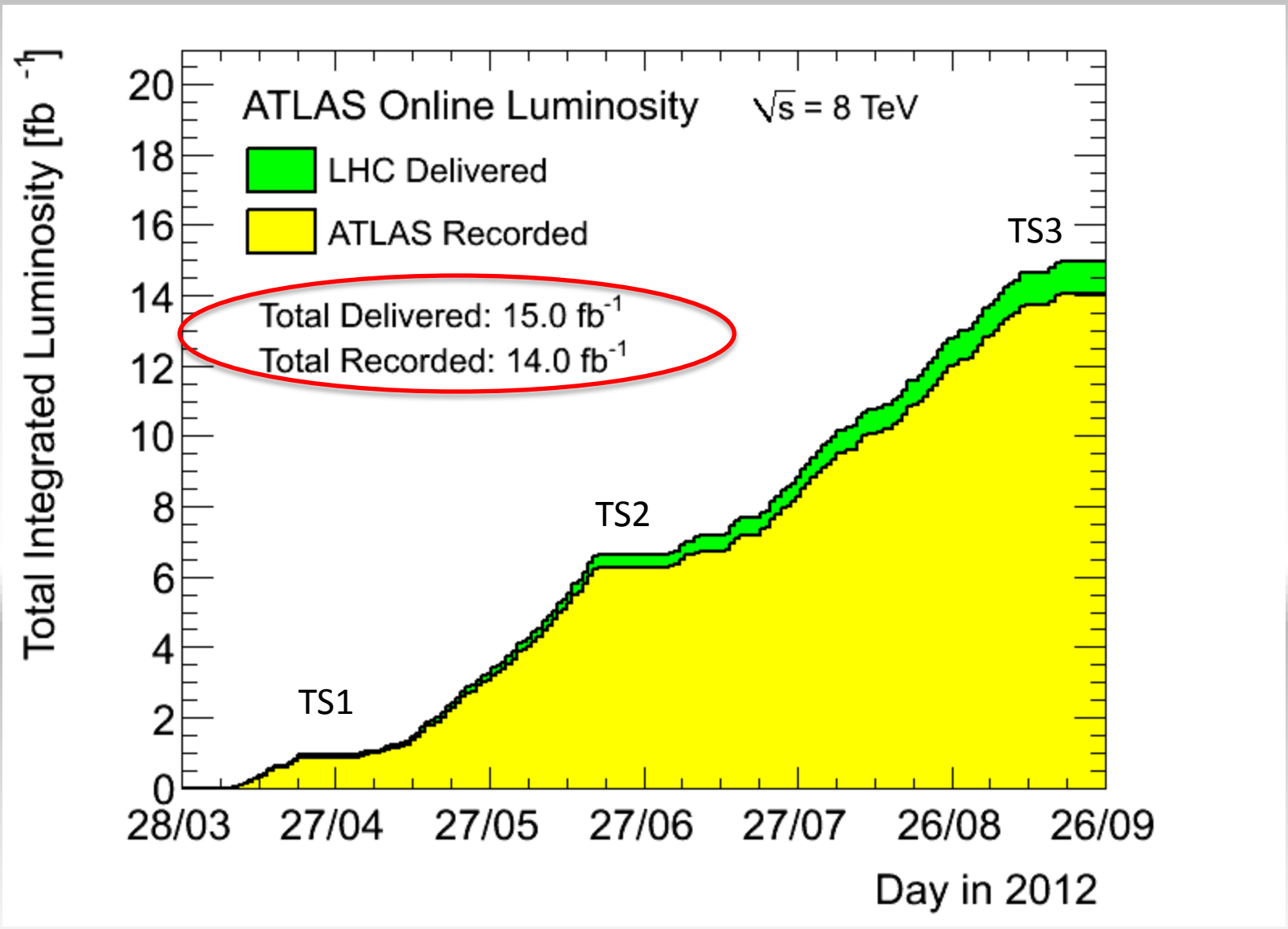


Emittances



Thanks to the injectors…

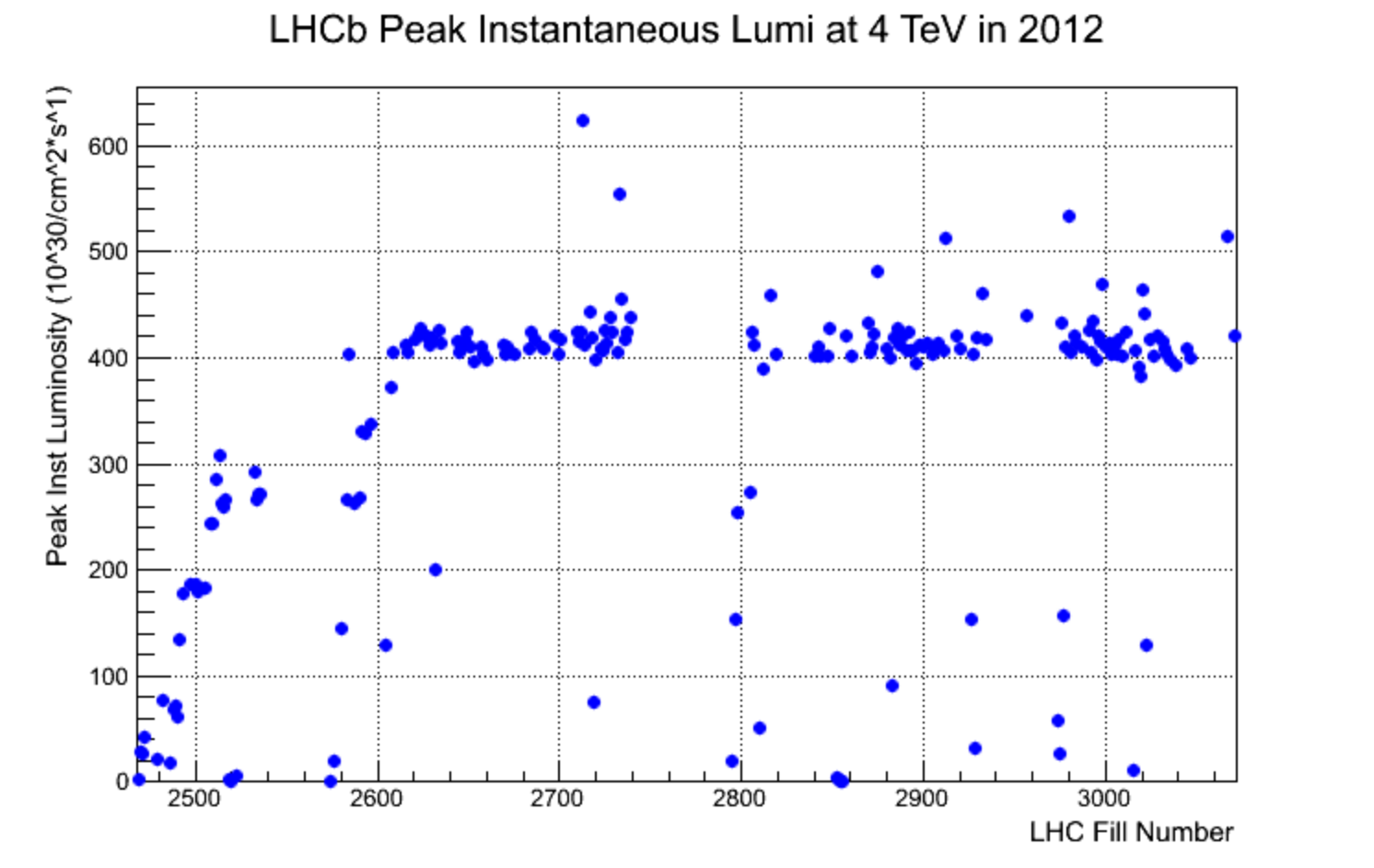
Integrated luminosity CMS/ATLAS



Integrated luminosity

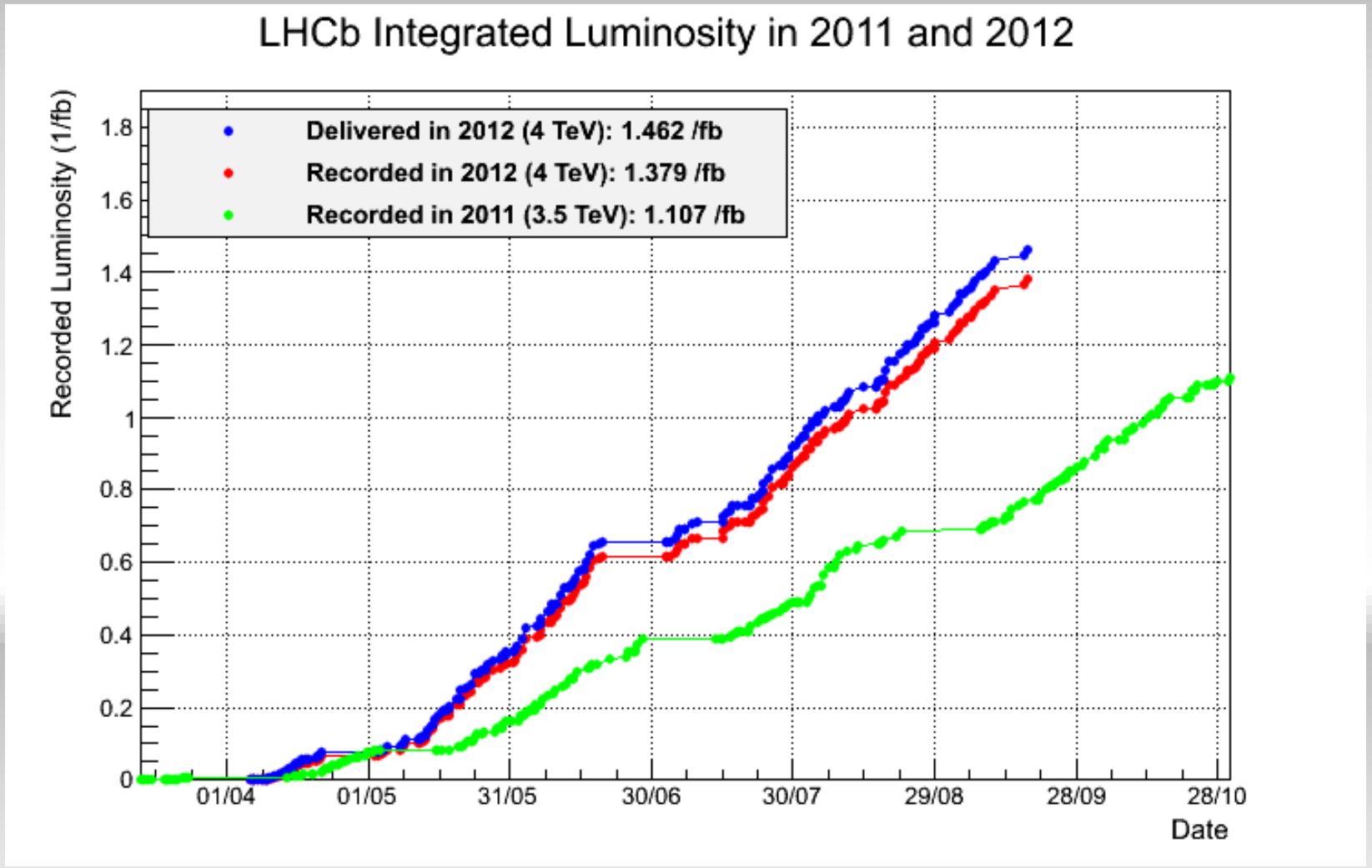
- Increase in peak luminosity not reflected in increased integrated rates (which are still pretty good…)
- Issues:
  - Struggle with beam instabilities – significant change of operating point at start of August (octupoles, chromaticity)
  - Beam quality from injection
    - Good but absolute peak performance difficult to maintain
    - Occasionally not so good – tails, big beams – constant attention
  - Beam induced heating: e.g. synchrotron light telescope…
  - Time outs: CMS, cryogenics, wire scanner…
- It is still a big machine.
- And we still rely on LINAC2, Booster, PS, SPS, TI …

Peak luminosity LHCb



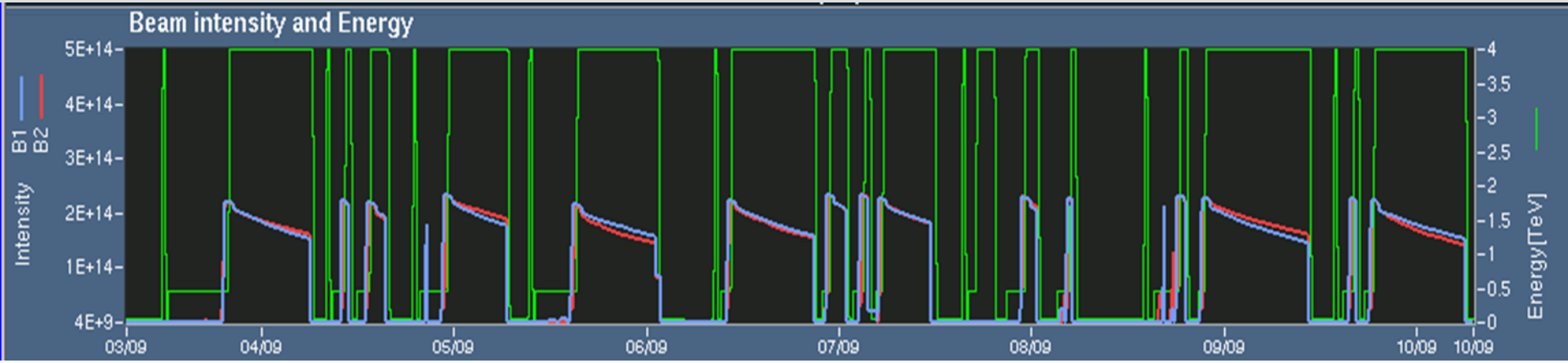
Levelled by transverse separation

Integrated luminosity LHCb



ALICE: ~2.9 pb^{-1} delivered – suffering somewhat from vacuum issues and low satellite populations

A typical week



Week 36: 3rd to 10th September

Delivered luminosity 1.02 fb^{-1} compared with a maximum of 1.35 fb^{-1}

Week 36

Fill	Lumi [e33]	pb^{-1}	Stable beams	Dump
3025	6.19	133	9h39m	Trip of RQF.A23: non destructive SEU
3027	6.35	25	1h19m	Failure of optical link in BLM system.
3029	6.95	120	6h46m	FMCM triggered the beam dump (electrical glitch)
3032	6.18	117	8h58m	OP
3033	7.06	145	9h40m	OP
3034	7.55	34	1h26m	RF trip
3036	7.14	102	5h34m	Inner triplet trip – dumped on BLMs
3039	7.44	19	48m	QPS: lost comms. with RCS.A67B1 switch controller
3045	7.35	178	12h13m	OP
3047	6.85	146	10h46m	OP

Good peak luminosity
Long productive fills

Week 36 - main timeouts

Mon AM	Lost cryogenics in sector 78. QRL vacuum gauge spurious reading Access in point 7 for replacing vacuum PLC	5:40
Mon PM	MCOX and skew octupoles checks in shadow of 18kV cable intervention in SPS	~8:00
Wed	Electrical glitch captured by FMCM of RD1.LR5 Access required for QPS	1:27
Thurs AM	QPS (RQS/RSS controller) problem - access required twice	6:18
Friday	- Trip and reset of the RQX5.R5 power converter - Problem on the RQX5.R5 QPS reset – access required	2:20
Sat AM	RCS.A67B1 QPS switch controller; Access required	2:35
Sat 05:00	Motor for the demineralised water pump (pump for all of sector 23 and 34) changed.	8:00
Sun AM	QPS – access required RQD/RQF.A56 controller can't be reset	2:50
Mon AM	Access for the power cycle of a QPS controller on the main dipoles	~2:00

Saturday morning – point 2

W36: lost fills above 450 GeV

Timestamp	Beam Mode	Fill Number	Loss reason
04-SEP-12 10.58. AM	ADJUST	3026	UFO on MKI.D5L2 above 200% of dump threshold, BLM at several magnets were above threshold, triggered also ALICE BCM.
07-SEP-12 03.43 AM	ADJUST	3035	Losses when going into collisions, while luminosity is just coming up. Beam oscillating on B1V. The overall loss is not so high, dumped on TCSG IR7 0.6 s RS.
08-SEP-12 05.09 AM	SQUEEZE	3041	QF/QD Sector 2 - water pump motor
08-SEP-12 07.13 PM	ADJUST	3044	high beam losses going into collisions - high Q'
09-SEP-12 07.13 PM	SQUEEZE	3046	Very fast loss towards end of squeeze - not clear

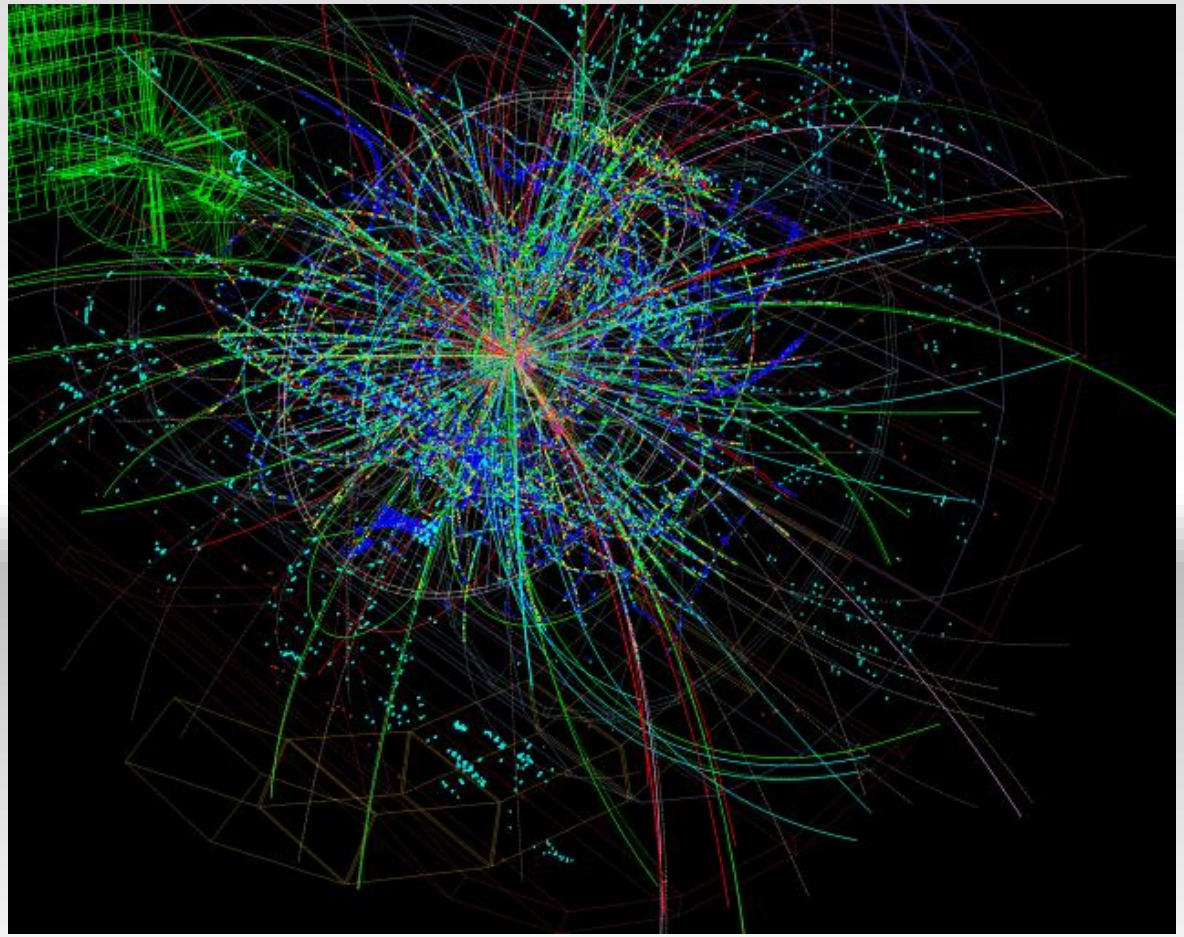
Overall picture:

- Good/excellent performance, both instantaneous and per fill
- Mixture of technical problems
- Still some lost fills to high beam losses

ALSO OF NOTE

Successful proton-lead pilot fill in preparation for the 4 weeks run in the new year

ALICE 2.4M events during stable beam and another 0.7M events with the tracker during non stable beam time



CMS: in total 2.2M events collected in 4.5 hours

Pilot was unsqueezed with low number of bunches – still work to do

Target p-Pb performance in 2013

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

Machine development

- Beam dynamics:
  - collective effects, instabilities, beam-beam, impedance
  - Longitudinal dynamics
- Optics:
  - ATS, Q20, high beta*: 1 km successfully tested
  - Beta* levelling
  - low emittance options from injectors
- Collimation, beam loss, quench tests
- Emittance growth,
- System development
  - Beam instrumentation, RF, transverse damper, injection
- Electron cloud, 25 ns

Have focused on performance improvements and, importantly, looking at issues that will impact performance post-LS1

Operational development

- RF: longitudinal batch-by-batch blow-up
  - Potentially reduced transverse blow-up from intra-beam scattering at 450 GeV
- h=9 low emittance option from PS successfully tested
  - Possible pre-cursor for low emittance 25 ns beam
- Q20
  - Change of working point in SPS
  - Offering increased longitudinal stability and in turn better transverse beam quality
  - Now operational
- Transverse damper
  - Selective anti-damping, abort gap cleaning, gated excitation for tune measurement, increase bandwidth…
- Etc.,etc.

All useful long term developments

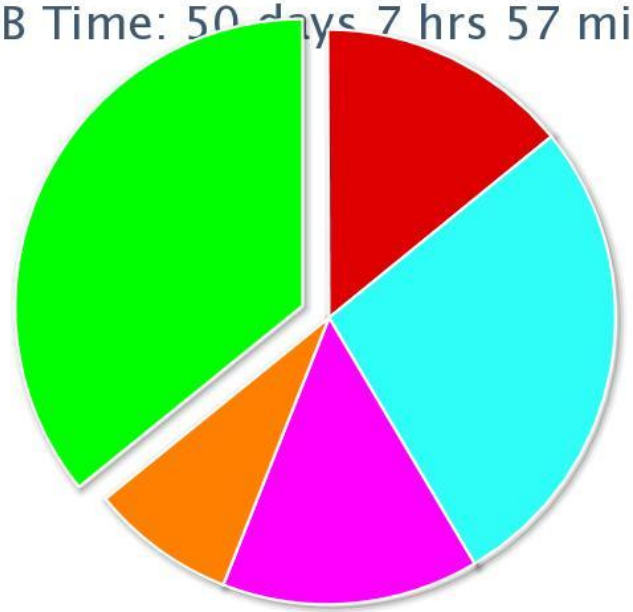
AVAILABILITY & ISSUES

This year – so far

Mode: Proton Physics

Fills: 2469 – 3084 [509 Fills]

SB Time: 50 days 7 hrs 57 mins



Access – No beam : 14.13%

Machine setup : 27.34% Beam in : 14.49%

Ramp + squeeze : 8.18% Stable beams: 35.86%

Run Availability

Based on LHC Physics Schedule

Total Run Time	140 days 8 hrs 13 mins	
Cryo Availability	129 days 21 hrs 30 mins	92.6 %
Fault Downtime	34 days 6 hrs 26 mins	24.4 %

Recent Availability

Total Run Time	5 days 8 hrs 29 mins	
Cryo Availability	2 days 22 hrs 34 mins	54.9 %
Fault Downtime	2 days 14 hrs 18 mins	48.5 %

Recent Faults: The top 5 list

Fill	Duration	System
3074	66:19	Cryogenics/Cold compressor
3081	1:36	Injection/Hardware
3075	1:03	Collimator/Hardware
3076	0:43	Collimator/Hardware
3080	0:41	PS/No beam

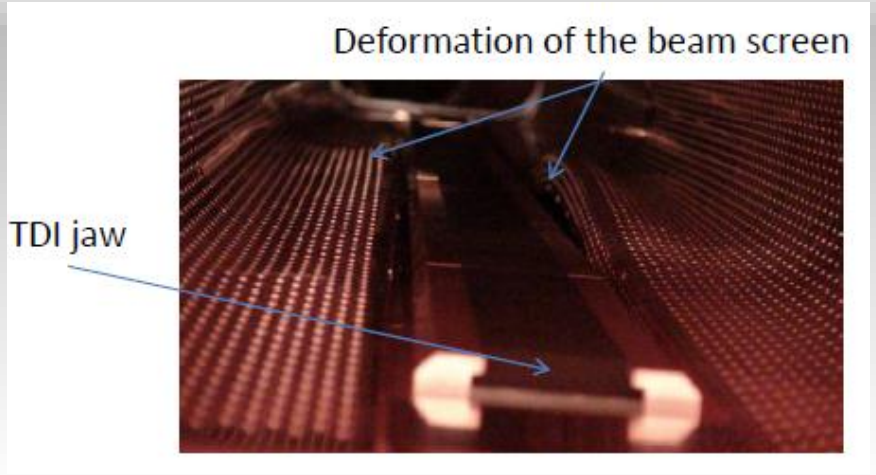
Issues

- SEUs
  - impact considerably reduced following sustained program of mitigation measures
- Beam induced heating
  - Synchrotron radiation telescope mirror assembly seriously distorted – invention and replacement required (last TS)
  - Replacement of injection kicker last week
- UFOs
  - Occasional dumps following adjustment of BLM thresholds at appropriate timescales
  - Potentially serious problem at higher energies – investigations continue

Beam induced heating

- Many devices are heating at a faster rate following the bunch intensity ramp-up
  - Actions are/should be planned to be taken in LS1 to prepare safe and smooth running:
  - Cooling for all near beam equipment (in particular BSRT, TDI, ALFA, HPS, AFP)
  - Consolidation of RF contacts
  - Analysis of suspected non-conformities (TCPB6L7, Q6R5…)
- Systematic analysis of available pressure and temperature stored before LS1 to detect other issues

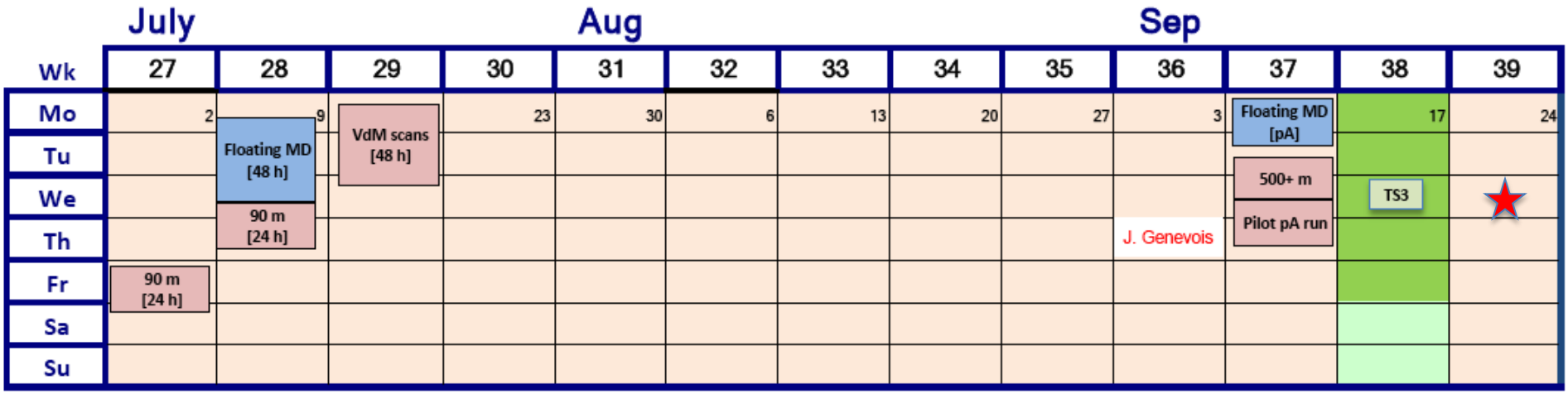
Benoit Salvant



Courtesy: Mike Barnes TE/ABT

REST OF THE RUN

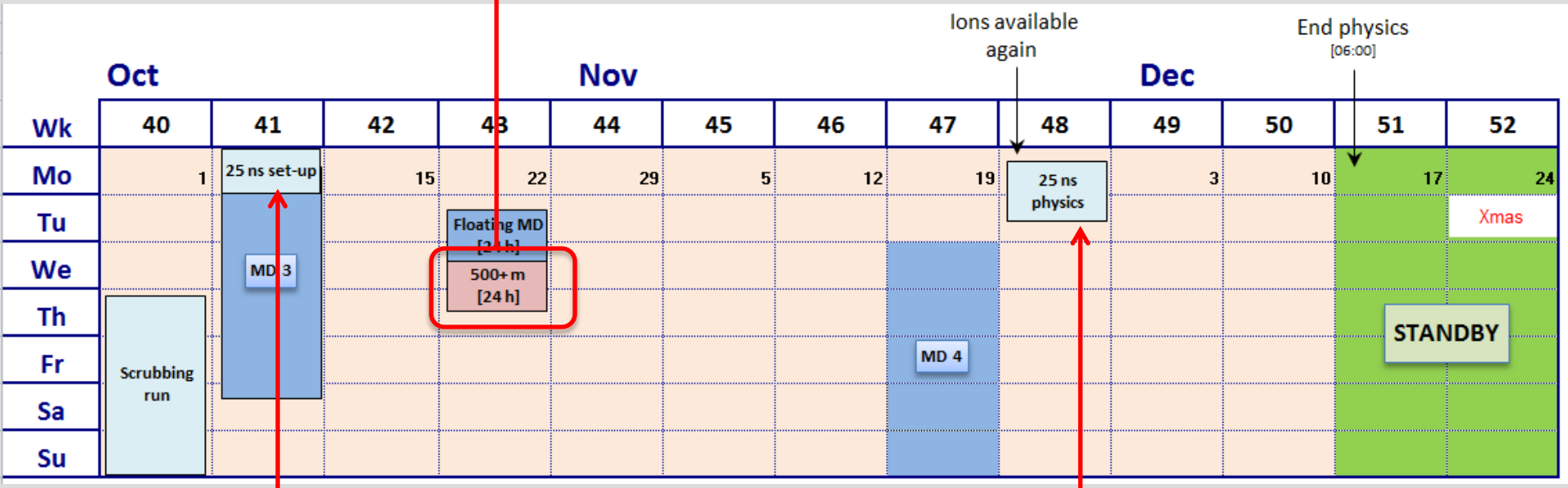
Q3 2012



- TS3 saw successful replacement of injection kicker and BSRT mirror
- Very rocky recovery from TS3 - weekend lost to cryogenics problems at point 8
- Intensity ramp-back-up starts today

Q4 2012

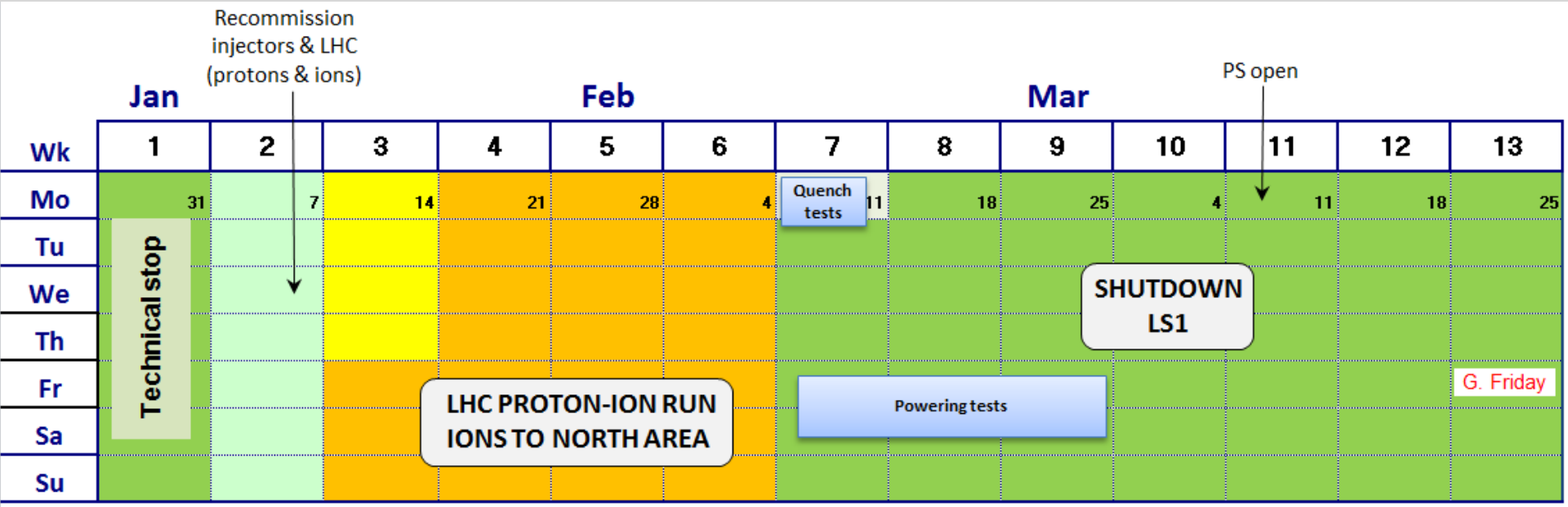
TOTEM/ALFA
1 km physics



~3 shifts – 25 ns setup
for MD and physics

Possible 25 ns physics

2013



Should be an interesting week

LHC 2012/13 – what's left

Phase	Days left
MD	10
Scrubbing for 25 ns	3+1
25 ns physics (tbc)	~1
Proton physics	~64
Special runs (beta*=1 km)	1
Ion setup 2013	4
Ion run 2013	24

~9 weeks

Peak proton-proton performance not expected to increase significantly.
Will back off slightly and concentrate on maximizing integral.
Another 10 fb^{-1} would be very good going…

Conclusions

- Despite some ups and downs, the LHC's performance continues to be remarkable
- This thanks to a continued high level of commitment from all teams involved
- Instantaneous and short term integrated luminosity rates exceed expectations
- Over the longer term integral limited by:
  - availability
  - lack of full mastery of high beam/bunch currents
  - effects of high beam currents
- Challenging program in store for the remains of the run