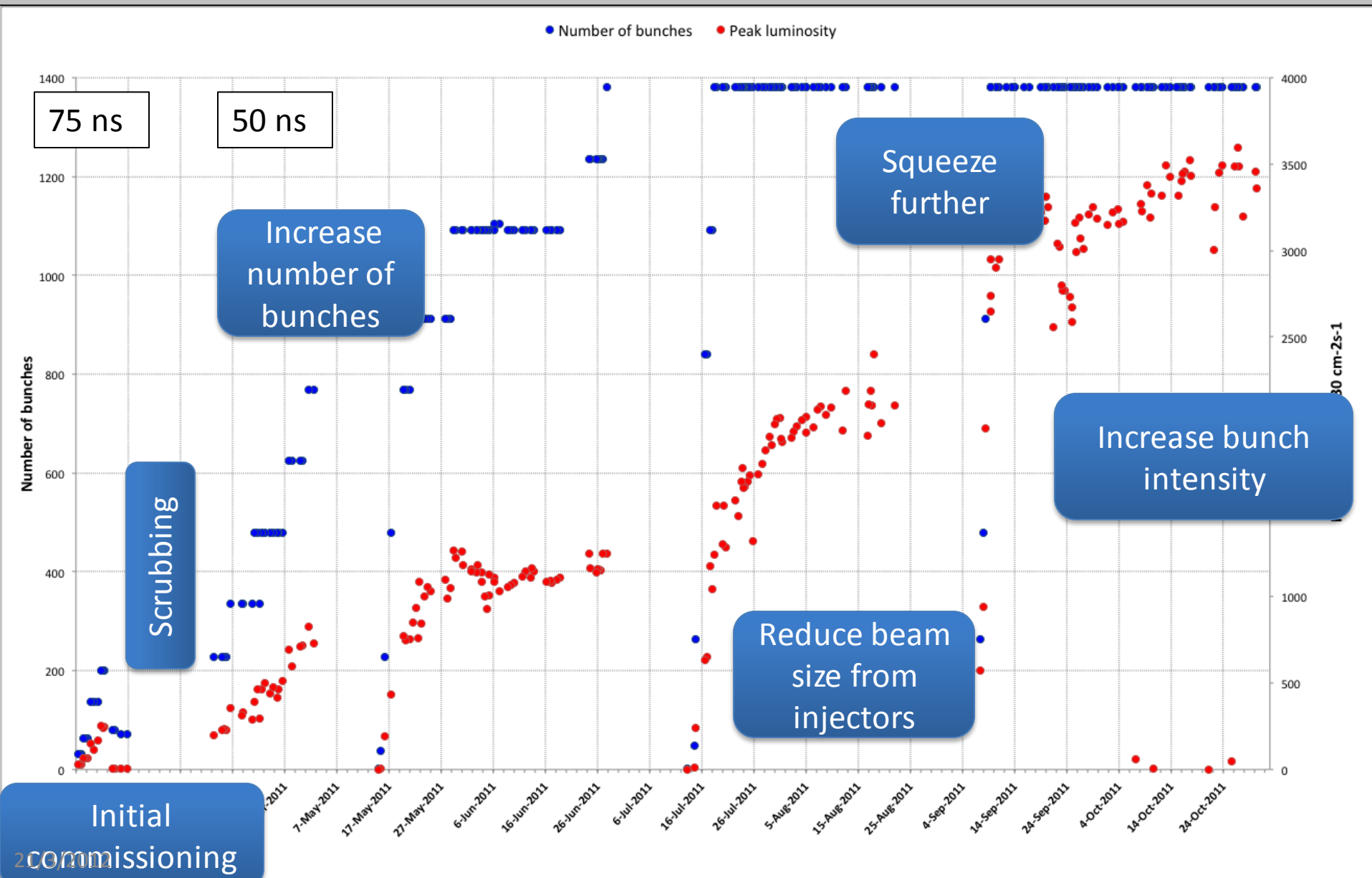


LHC machine status

Mike Lamont
for the LHC team

2011 – recap



2011

- Another remarkable year
- It was nearly always a battle...
- Remarkably no real show stoppers

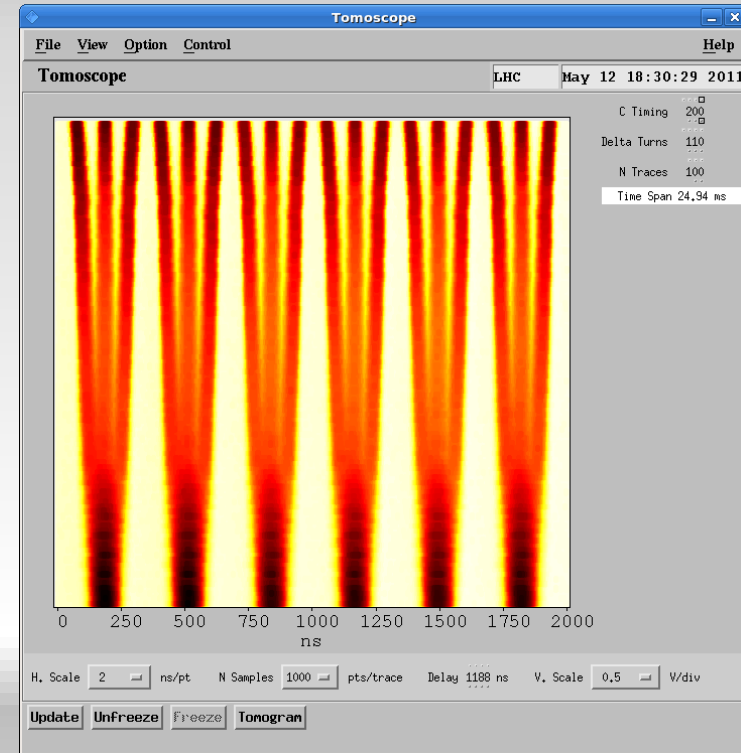
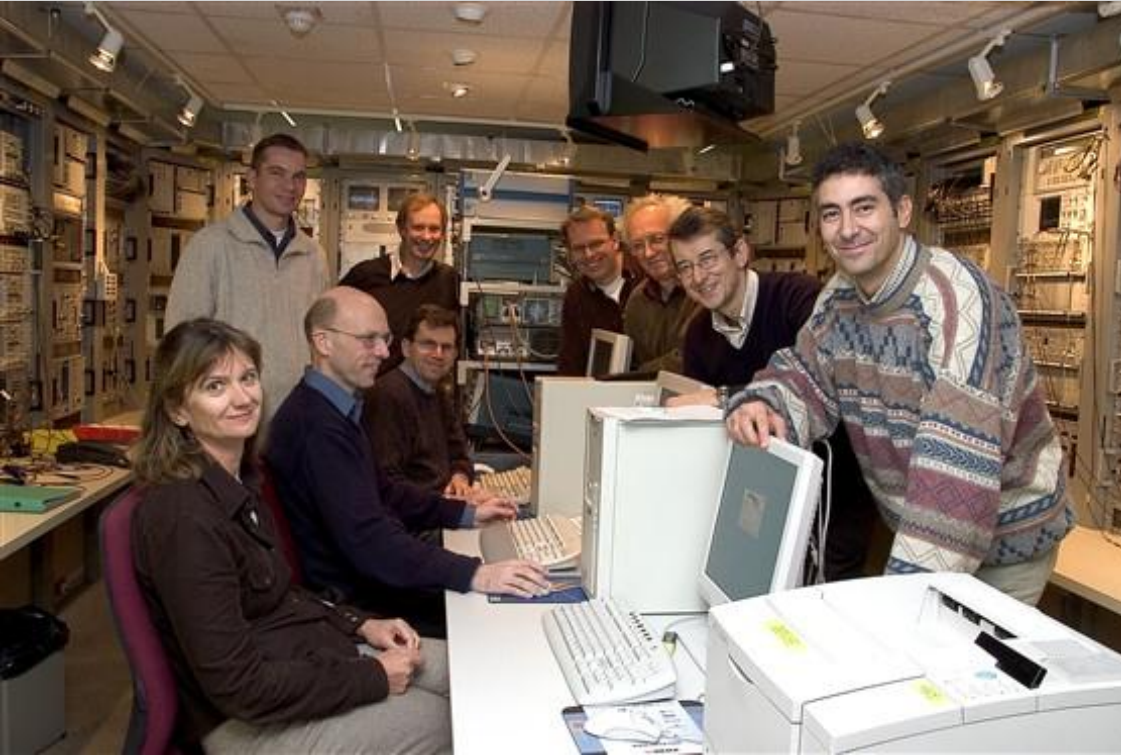
- Successfully took on:
 - Total intensity
 - Bunch spacing
 - Bunch intensity
 - Emittance
 - Beta* & aperture

Of note

- Operational robustness
 - Precycle, injection, 450 GeV, ramp & squeeze & collisions routine
- Machine protection
 - Unpinned by superb performance of machine protection and associated systems
 - Rigorous machine protection follow-up, qualification and monitoring
- **Routine collimation of 110 MJ LHC beams** without a single quench from stored beams.

Beam from injectors

Excellent performance – years in the preparation



Best in 2011 with 50 ns:

- $\sim 1.45 \times 10^{11}$ ppb
- ~ 2.3 microns into collision

Design with 25 ns:

- 1.15×10^{11} ppb
- Normalized emittance 3.75 microns

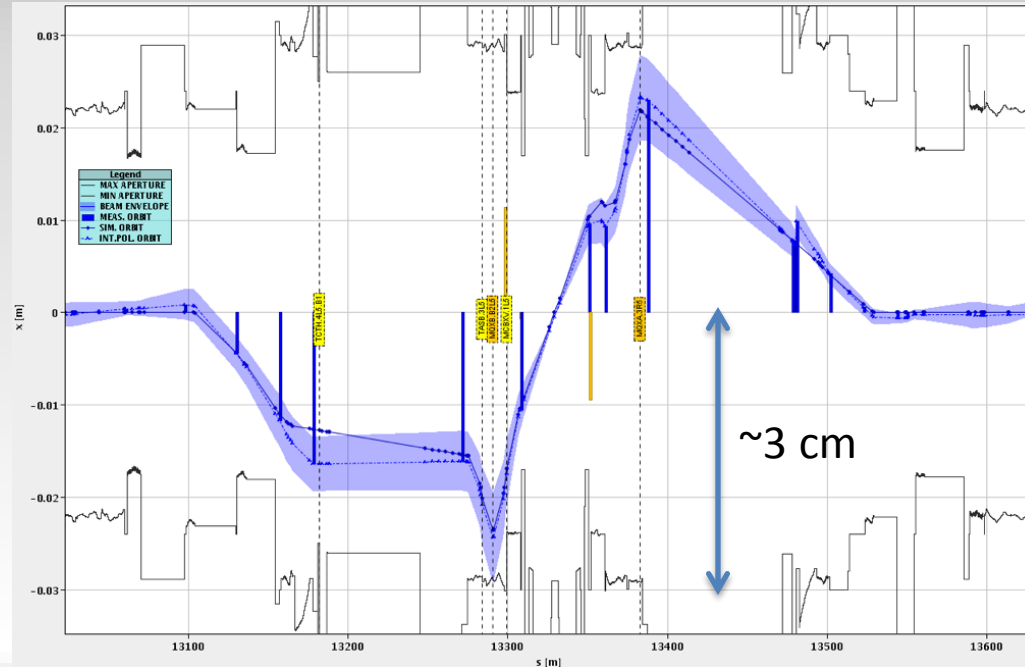
IR1 and IR5 aperture at 3.5 TeV

2011's "platinum mine"

TeV

CMS

IR	Plane	Type of bump in standard optics	Aperture [σ]
1	H	Separation	19.8 – 20.3
1	V	Crossing	18.3 – 18.8
5	H	Crossing	19.8 – 20.3
5	V	Separation	> 20.3



Stefano Redaelli

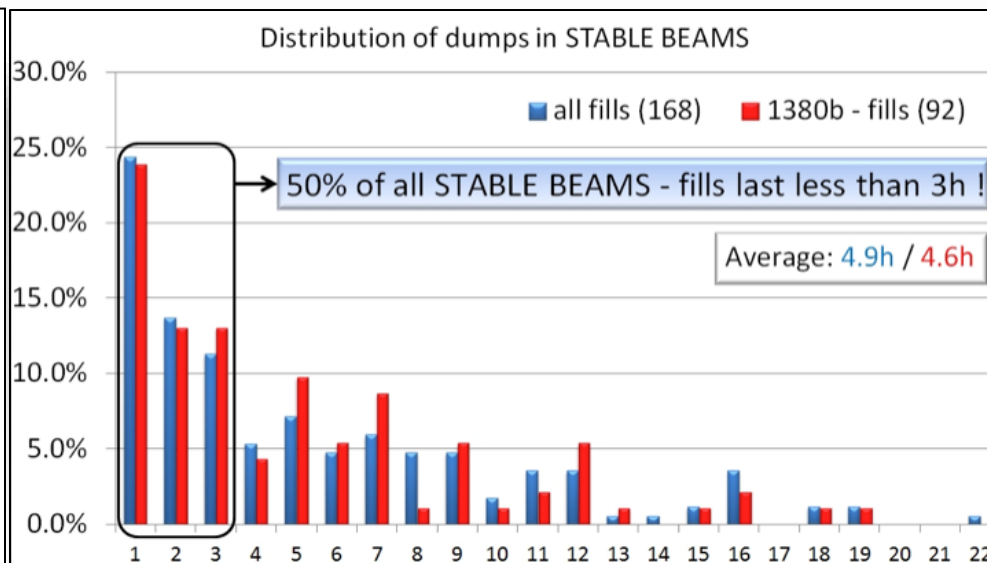
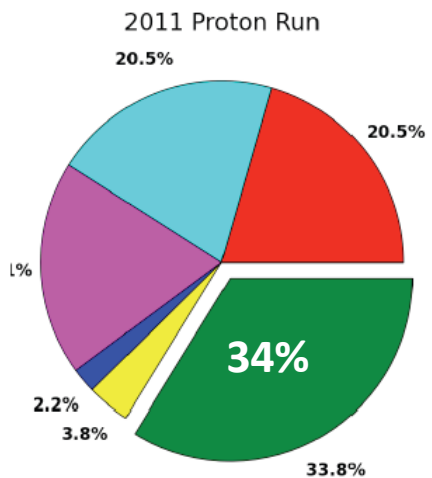
~600 m

Addition margin allowed squeeze to $\beta^* = 1 \text{ m}$

– big success – $3.3 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$

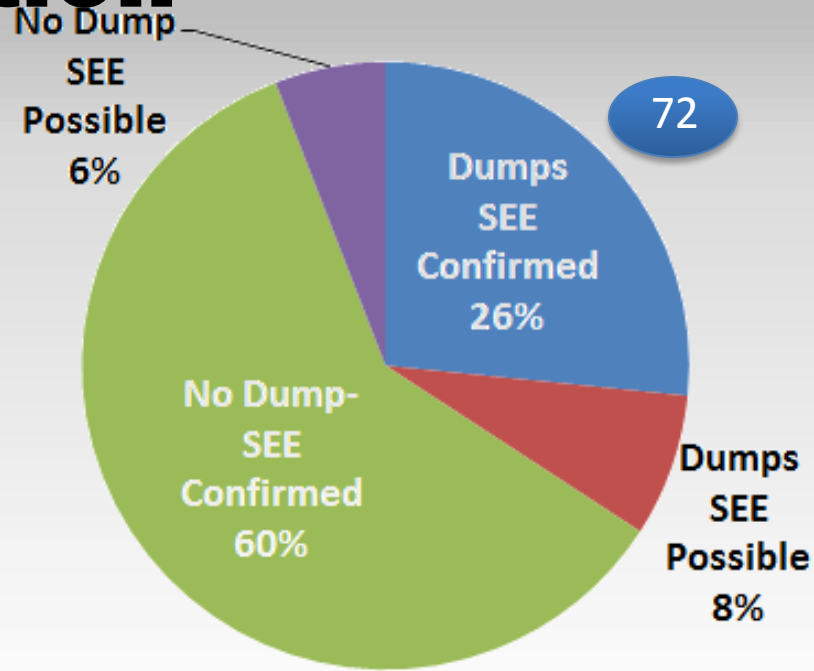
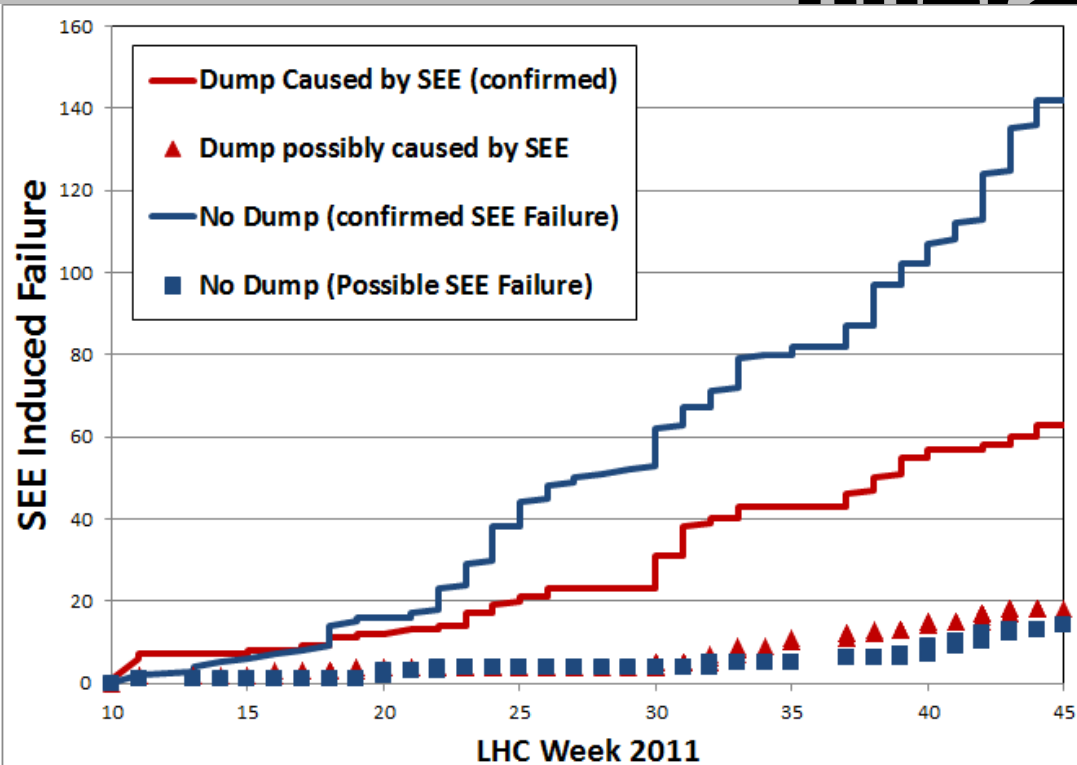
Operation efficiency

- Overall efficiency
 - Pretty good considering that this is the LHC
 - Overall time in stable beams 34%
- Premature dumps
 - 50% of all STABLE BEAMS fills lasted less than 3 hours



SEE failures during 2011

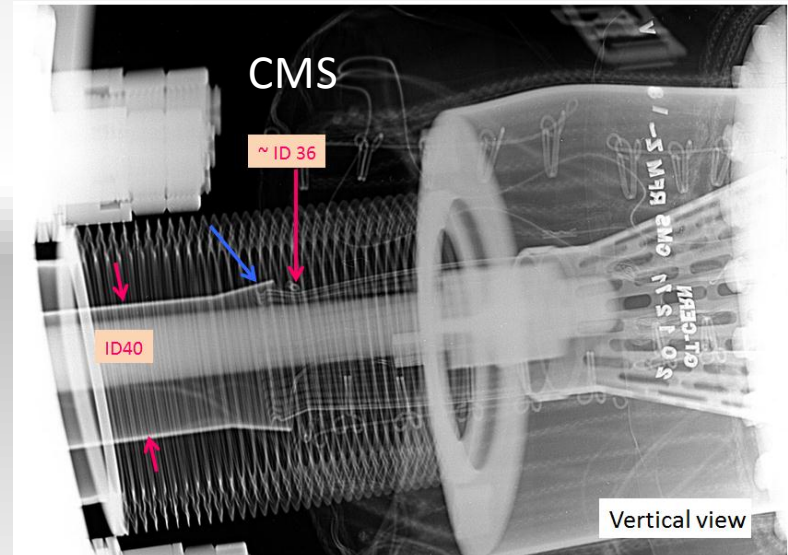
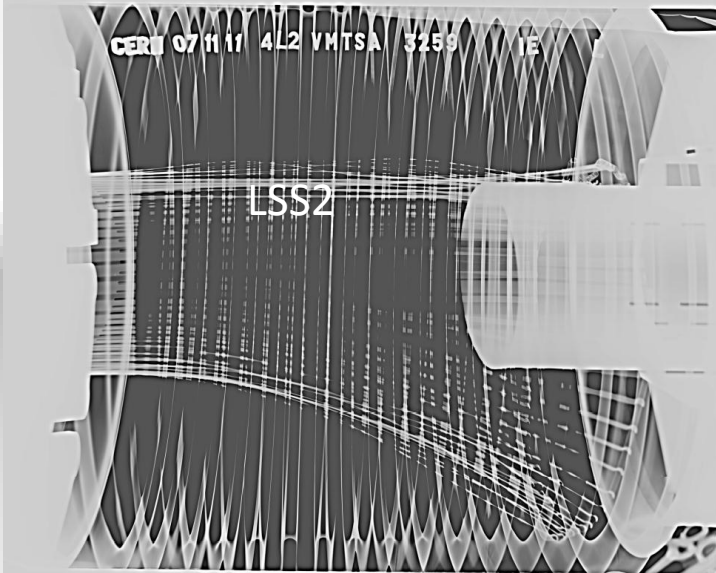
operation



- © Systems hit: QPS, Cryogenics, Power converters, Collimation, Interlock systems, UPS, Access
- © UJ14/16 most critical

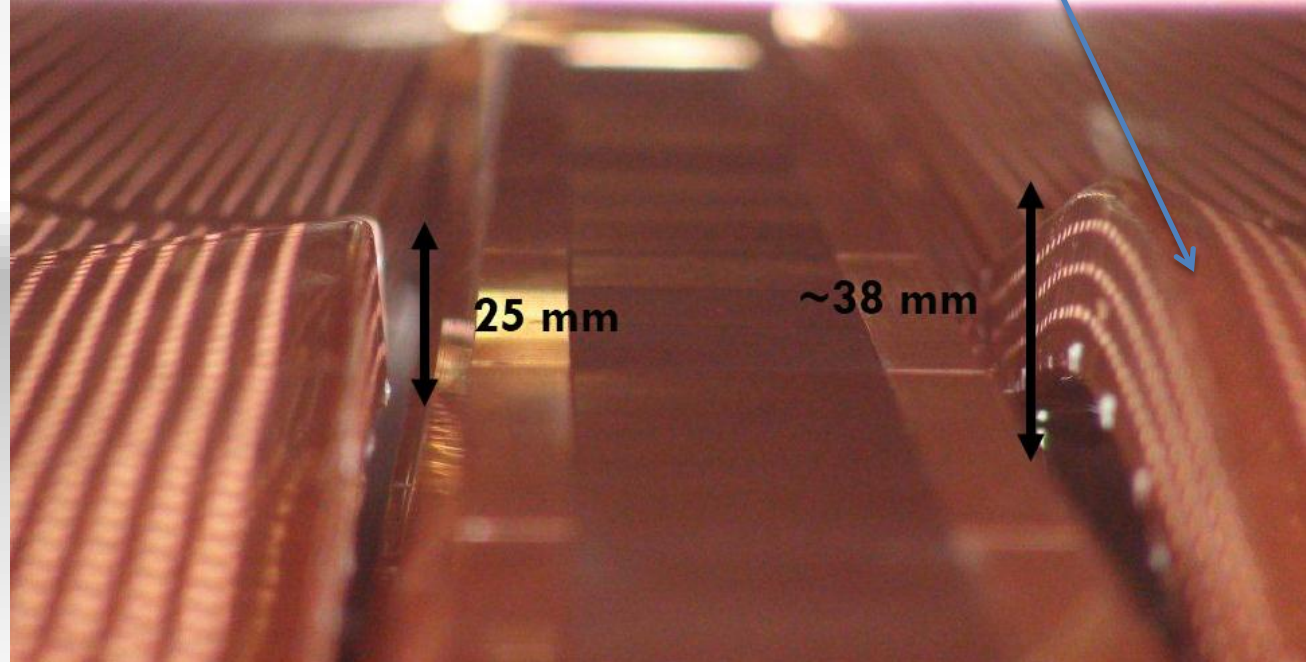
Vacuum

- Unexpected pressure rise (10^{-6} mbar) observed in LSS2 & LSS8 and close to CMS:
 - bad RF contact (x-rays inspection)
- Interventions done in 2 & 8 & CMS to resolve RF finger issues
 - shouldn't be a problem in 2012.

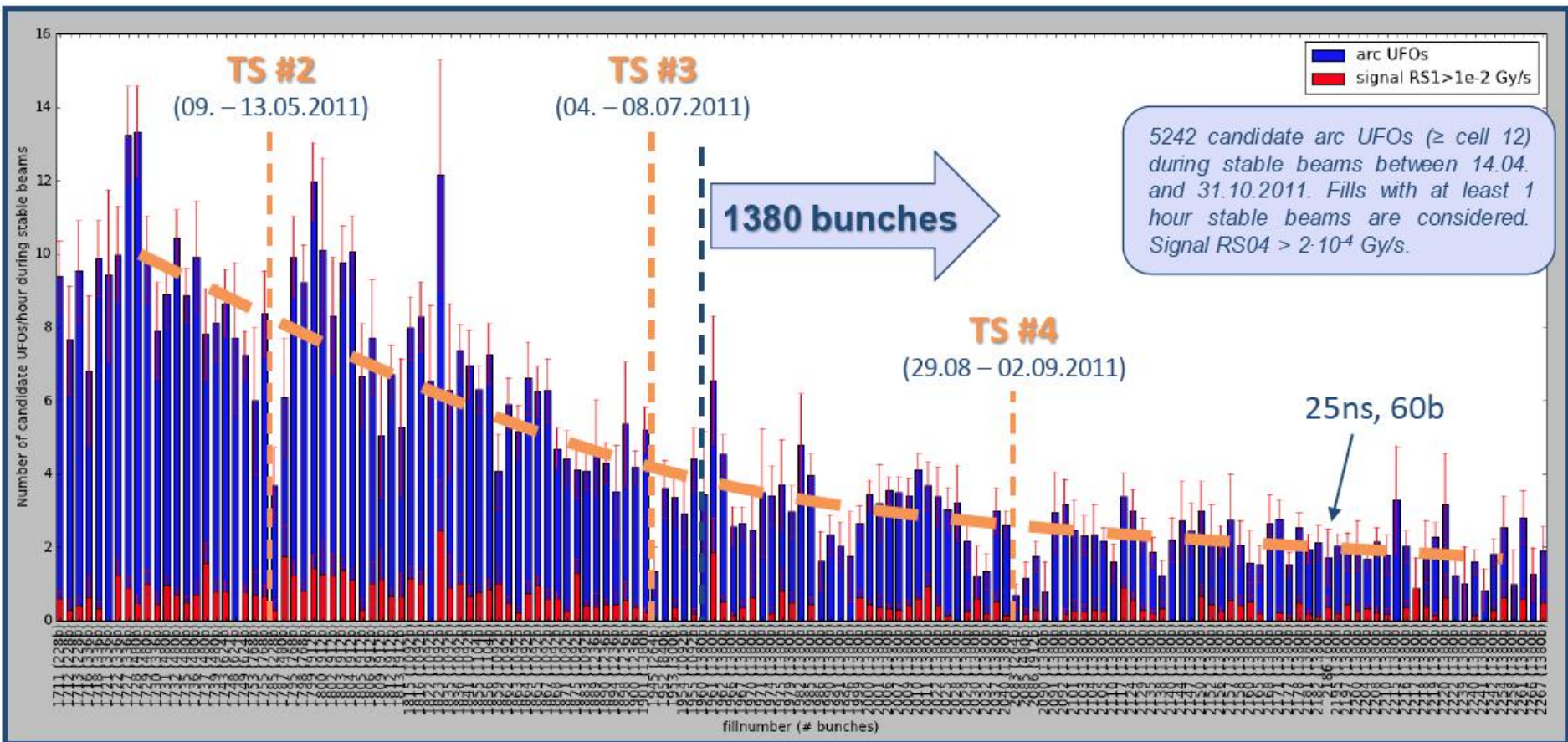


Injection collimators

beam screen heating



UFO rate 2011



Decrease of UFO rate from ≈ 10 UFOs/hour to ≈ 2 UFOs/hour.

Concerted program of investigations, simulations, tests with beam ...

Christmas stop



- **The big 5:** Cryogenics, Cooling and Ventilation, Electricity, Vacuum, Magnets and protection
- Plus many, many other activities
- Huge amount of work performed to ensure a reliable operation in 2012:
 - Maintenance, consolidation, upgrades...
- No major concerns during the break
- From the machine side a duration of 13 weeks (from beam ON to beam OFF) is realistic (no margin but no shortcuts)

R2E 2012

- ~30-50 dump events expected...
- Mitigation actions over Xmas:

Shielding

Point 1: RBs/UJs



Relocation

Point 1: Fire detectors

Points 4 & 6: cryogenics CPUs relocated from UX to UL

Point 5: Civil engineering (ducts in UL557, vault along 20 m)

UPS relocated from UJ56 to UL557

PIC relocated from UJ56 to USC55

Point 8: Ethernet racks (startpoint) (from US85 to UL86)

WIC & timing racks (from US85 to UA83)

QURCb & rack EYQ (from US85 level 2 to US85 level 0)



2011 to 2012

- Well organized, productive **Xmas technical stop**
 - Lot of R2E related work
 - Plus consolidation and improvements of many systems
- **Vacuum** consolidation to address successfully diagnosed causes of instabilities in 2011
- **Injection collimators** issues diagnosed and understood - spare in preparation - fingers crossed in the meantime
- **Cool-down** of machine exactly on schedule - cryogenics demonstrating full mastery...
- Very smooth **hardware commissioning** including careful quench-less commissioning of main circuits to 4 TeV
- **Well oiled Machine checkout** final tests and preparation for beam

2012 strategy

4 TeV

$\beta^* = 0.6\text{m} \rightarrow 0.7\text{m} \rightarrow 0.9\text{m}$

50 ns

$\int \text{Ldt} = 5 \text{ fb}^{-1}$ in June?

$\int \text{Ldt} = 15-19 \text{ fb}^{-1}$

SEE dumps=30-50

Pile-Up=26-35

LHCb $\int \text{Ldt} = 1.5 \text{ fb}^{-1}$

$L_{\text{peak}} = 5-6.8 \cdot 10^{33} \text{ cm}^{-2}\text{s}^{-1}$

TCP gap=2.2mm

SPS $\epsilon = 2 \mu\text{m}$

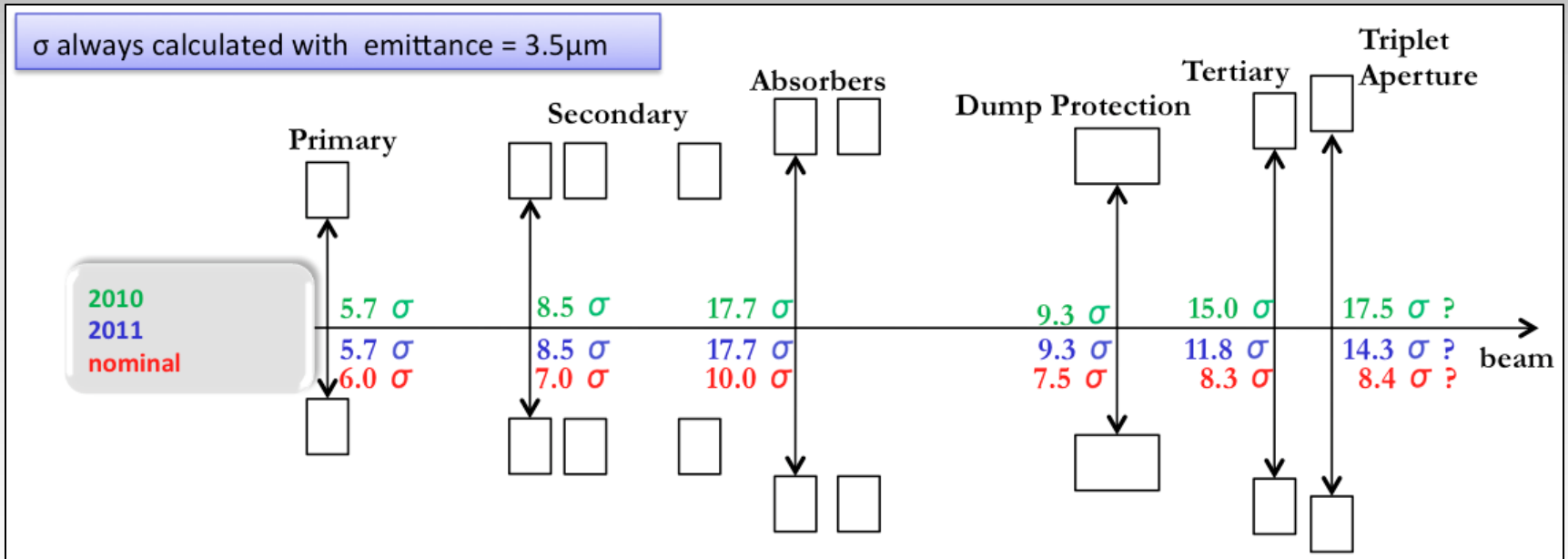
SPS $N_p = 1.6 \cdot 10^{11}$

p-Pb: 3.5 TeV or 4 TeV

$\beta^* = (0.6, 0.6, 0.6, 3)\text{m}$

$\int \text{Ldt} = 15-23 \text{ nb}^{-1}$

Collimator settings 2012



Collimation hierarchy has to be respected in order to achieve satisfactory **protection and cleaning**.

Aperture plus tight settings allows us to squeeze even further..

2012: tight settings

	σ
TCP 7	4.3
TCSG 7	6.3
TCLA 7	8.3
TCSG 6	7.1
TCDQ 6	7.6
TCT	9.0
Aperture	10.5

How tight?



Norway

Iberian peninsula



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

**Tight settings (2012):
~2.2 mm gap at
primary collimator**

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

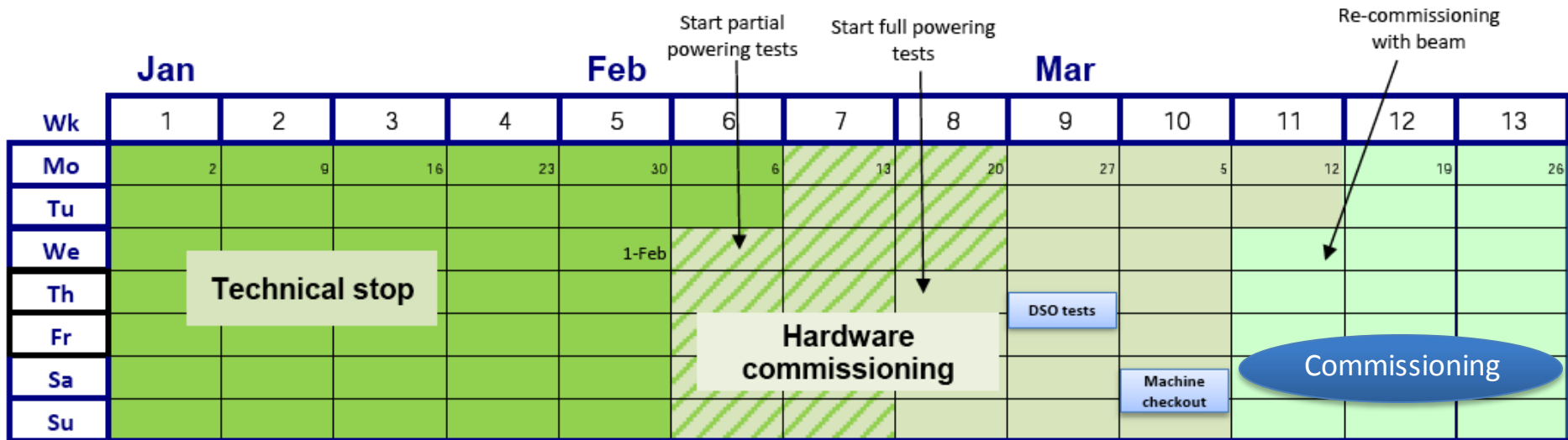
Bunch spacing

Performance from injectors

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	1.6×10^{11}	2.0
25	Double batch	1.2×10^{11}	2.7

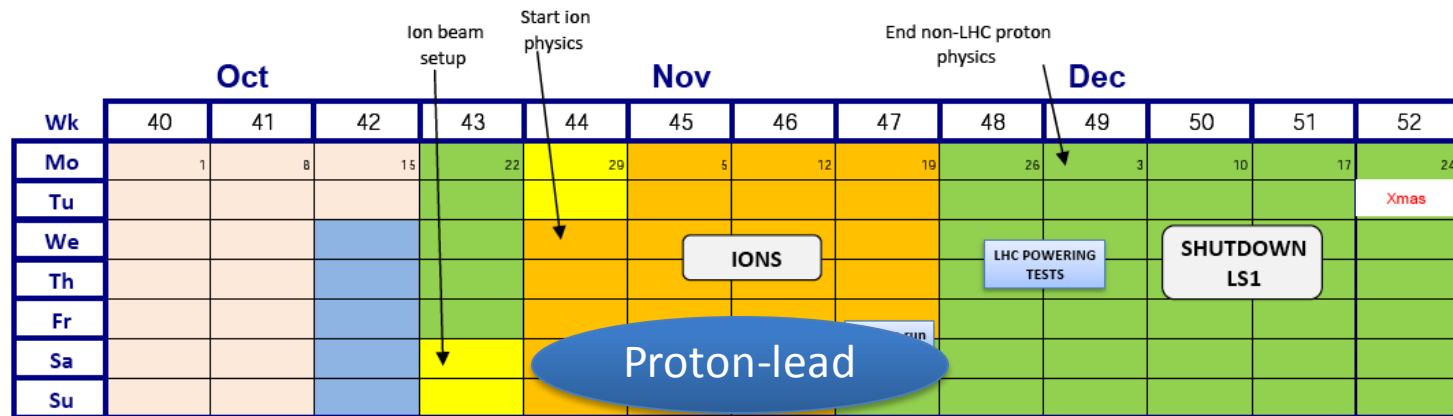
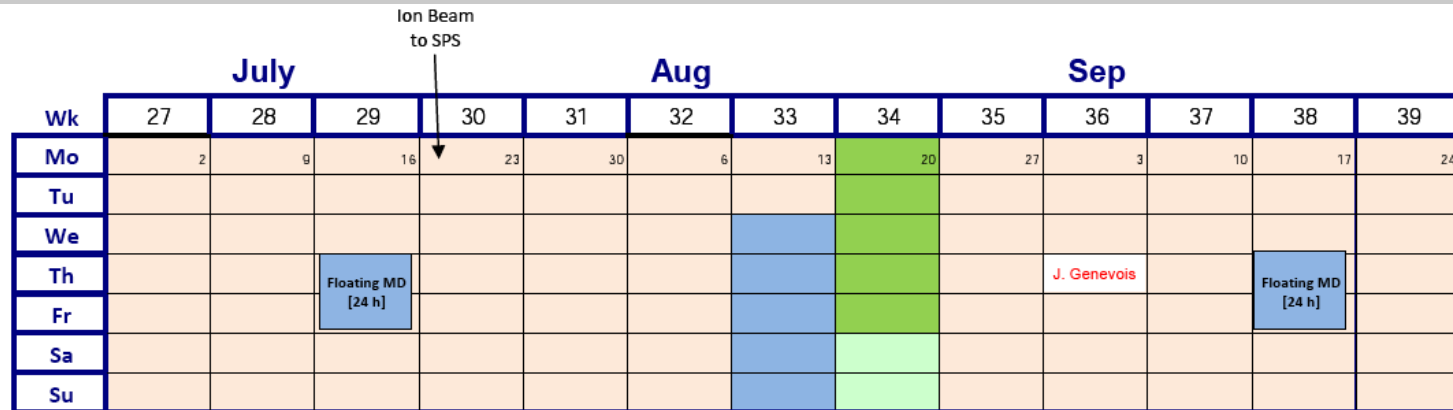
$$L = \frac{N^2 k_b f}{4 p s_x s_y} F = \frac{N^2 k_b f g}{4 p e_n b^*} F$$

2012 LHC schedule Q1/Q2



36th International Conference on High Energy Physics
 4 - 11 July 2012
 Melbourne Convention and Exhibition Centre

2012 LHC schedule Q3/Q4



- Technical Stop
- Recommissioning with beam
- Machine development
- Ion run
- Ion setup

Special runs (TOTEM etc.) to be scheduled

Special runs

High beta* runs for ALFA and TOTEM
Van der Meer scans

2012 - breakdown

	Days
Machine check-out	2
Commissioning with beam	21
Machine development	22
Technical stops	20
Scrubbing (25 ns)	3
Technical stop recovery	6
Initial intensity ramp-up	~21
Proton running	~126
Special runs	~8
Ion setup	4
Ion run	24

~150 days

50 ns performance estimate

4 TeV, 50 ns, 1380 bunches, 1.6×10^{11} , 2.5 microns
150 days of proton physics (assuming similar efficiencies to 2011)

Beta* [cm]	Collimators	Peak Lumi [$\text{cm}^{-2}\text{s}^{-1}$]	Int. Lumi [fb^{-1}]	Pile-up	Increase in peak
90	Intermediate	5.1×10^{33}	12.1 – 14.5	26	
70	Tight	6.2×10^{33}	14.7 – 17.6	31	+22%
60	Tight	6.8×10^{33}	16.2 – 19.3	35	+10%

25 ns performance estimate

4 TeV, 25 ns, 1380 bunches, 1.6×10^{11} , 2.5 microns
140 days of proton physics (extra scrubbing required)

Beta* [cm]	Collimators	Peak Lumi [$\text{cm}^{-2}\text{s}^{-1}$]	Int. Lumi [fb^{-1}]	Pile-up
80	Tight	3.8×10^{33}	8.3	10

Conclusion: 25 ns not competitive with 50 ns

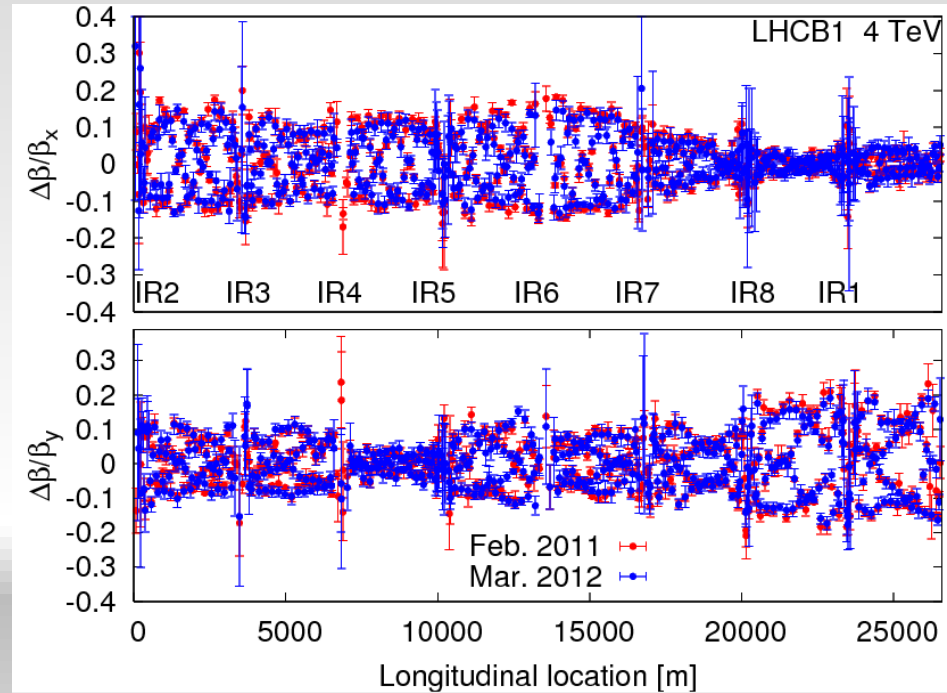
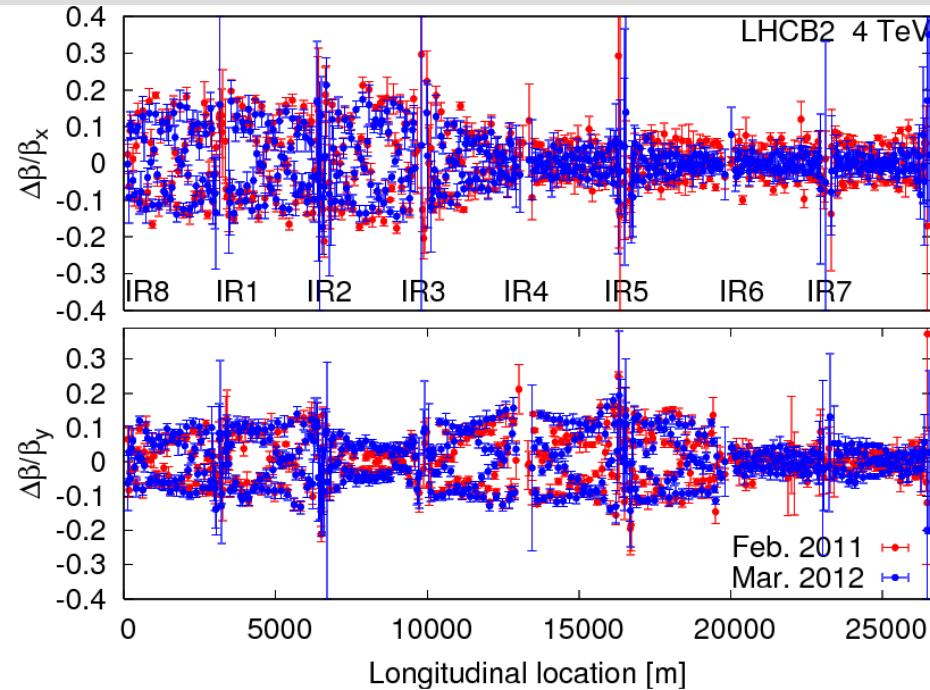
Present status

Beam taken for the first time in 2012 a week ago

Date	Milestone
Wed 14.03	LHC ready for injection
	Beam 1 injected
Thu 15.03	Both beams captured, orbit and Q adjusted
	Optics measured and corrected at 450 GeV
Fri 16.03	Both beams at 4 TeV
Sat 17.03	Beam 1 squeezed to 0.6 m
Sun 18.03	Both beams squeezed to 0.6 m
	Separation and crossing angles on
Mon 19.03	Beam Instrumentation, Ramp & squeeze
	Aperture measurement
Tues 20.03	RF, injection

Optics measurement at 4 TeV

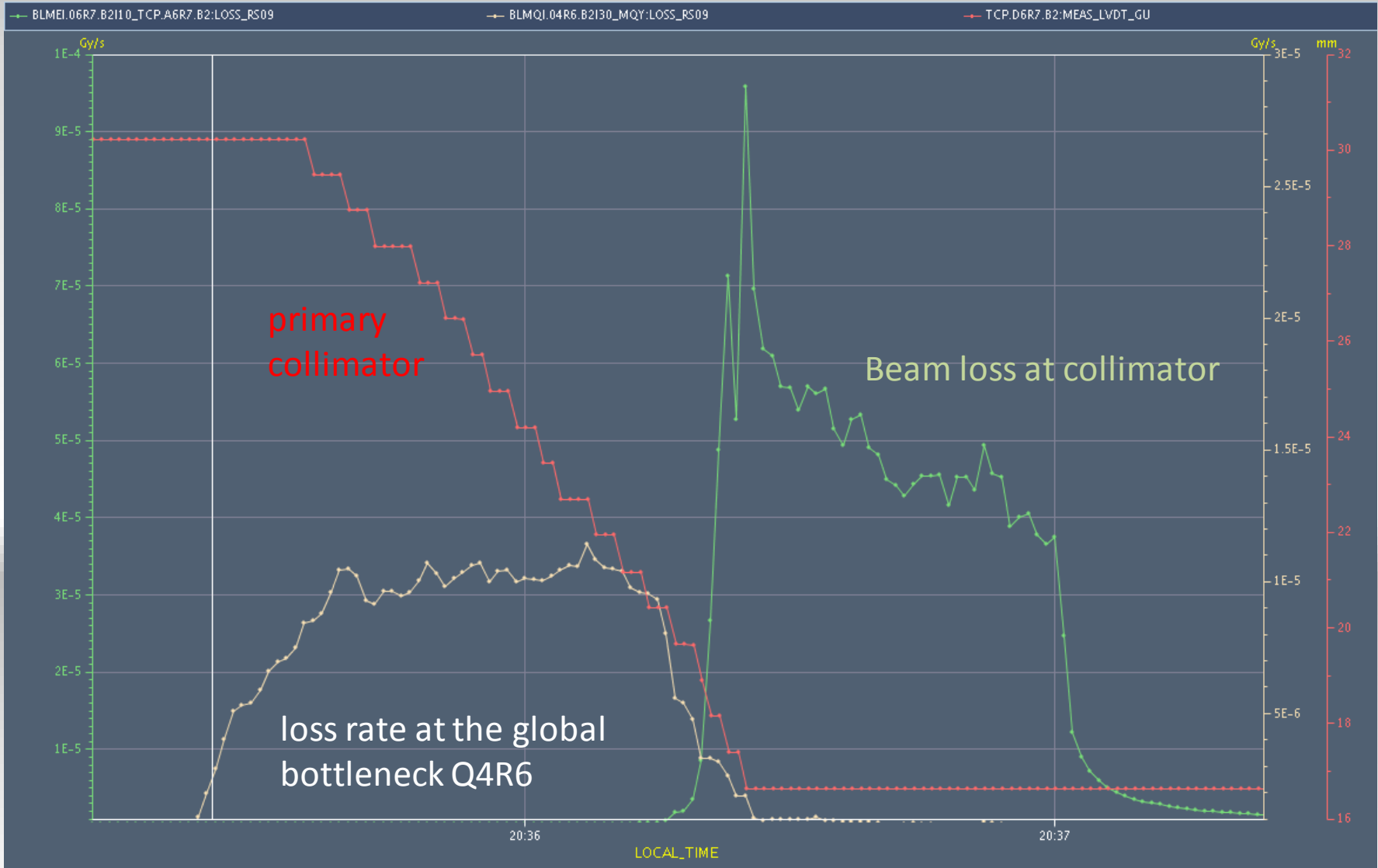
Flat-top before squeeze



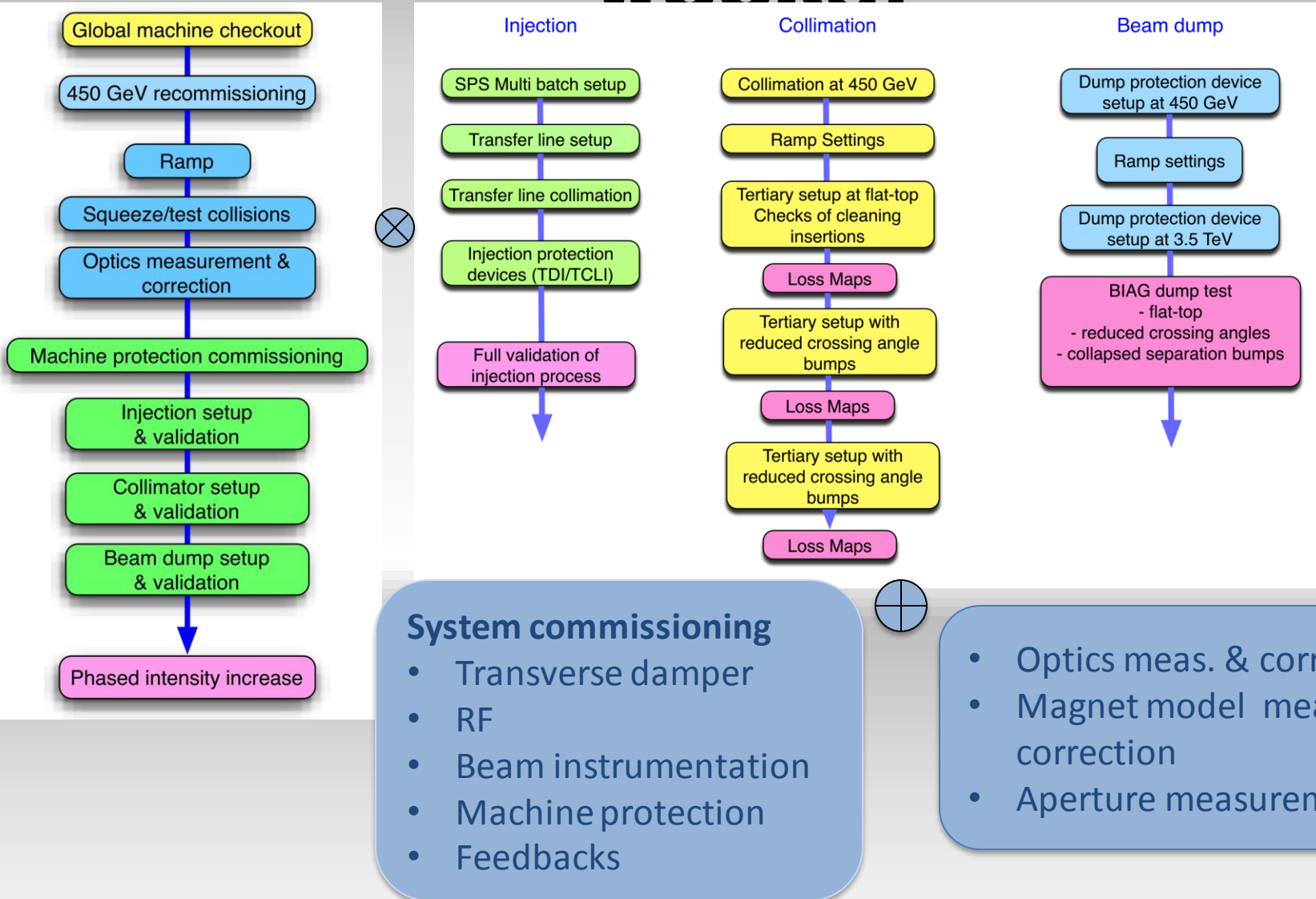
Almost unbelievable reproducibility of magnetic machine

Aperture measurements at 450 GeV

Using transverse damper to generate constant losses with single bunch



Initial commissioning (3 weeks)



Progressing well - machine in good shape

Conclusions

- Good performance in 2011 from working on all available parameters
- Very definitely exploring the effects of high intensity beams
 - SEUs, beam induced heating, vacuum instabilities...
 - Operational efficiency suffering as a result
- Main gain in 2012 is use of tight collimator settings and reduced beta*
 - 5 to 6 x 10³³ cm⁻²s⁻¹ and 15 fb⁻¹ should be possible
- Hope for improved operational efficiency
 - R2E mitigation measures etc.
 - but partially countered by increased peak performance
- Commissioning progressing well - another long, interesting year in prospect...