Status of LHC Operations

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for the LHC Commissioning Team

Beam commissioning strategy 2010

1. 450 GeV re-commissioning
2. Machine protection commissioning at 450 GeV
3. Ramp commissioning
4. Establish stable beams at 3.5 TeV
5. Collisions at 3.5 TeV
6. Squeeze commissioning
7. Collisions at 3.5 TeV squeezed
8. Full machine protection qualification

26/03/2010

09/04/2010

M. Lamont

Outline

- The way to stable beams at 3.5 TeV
- Experience from the first Physics fills
- Progress in the commissioning (issues and improvements)
- Plans
- Conclusions

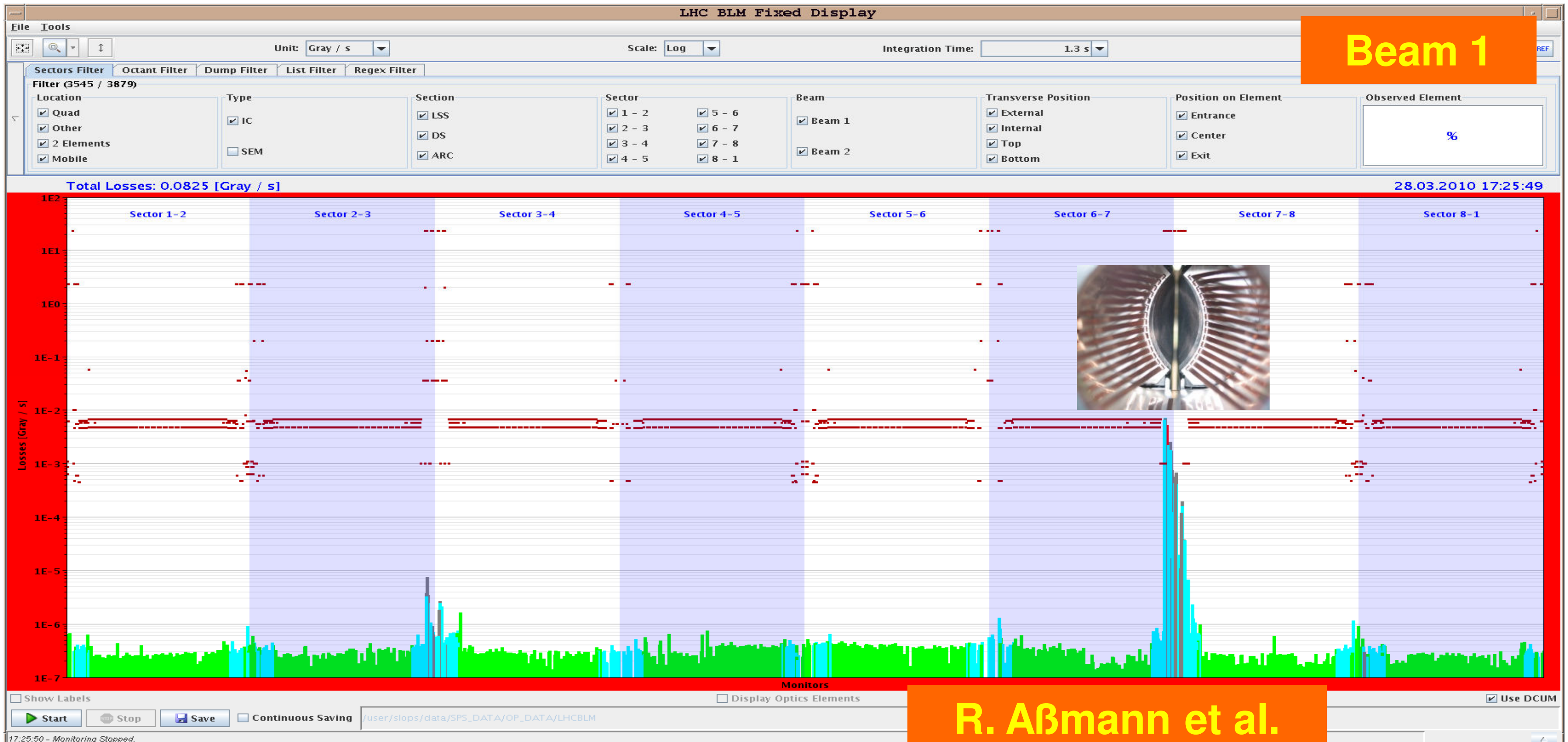
The way to stable beams @ 3.5 TeV

- Stable beams means that LHC and expts. are protected against possible failures by the existing passive protection devices:
  - Protection device and collimator setting-up 3.5 TeV
  - Beam dump set-up 3.5 TeV
  - Verification of proper set-up of the machine protection elements by simulating possible “failure” scenarios

- These steps were completed on Monday 29/3 in preparation for collisions in SAFE conditions on Tuesday 30/3

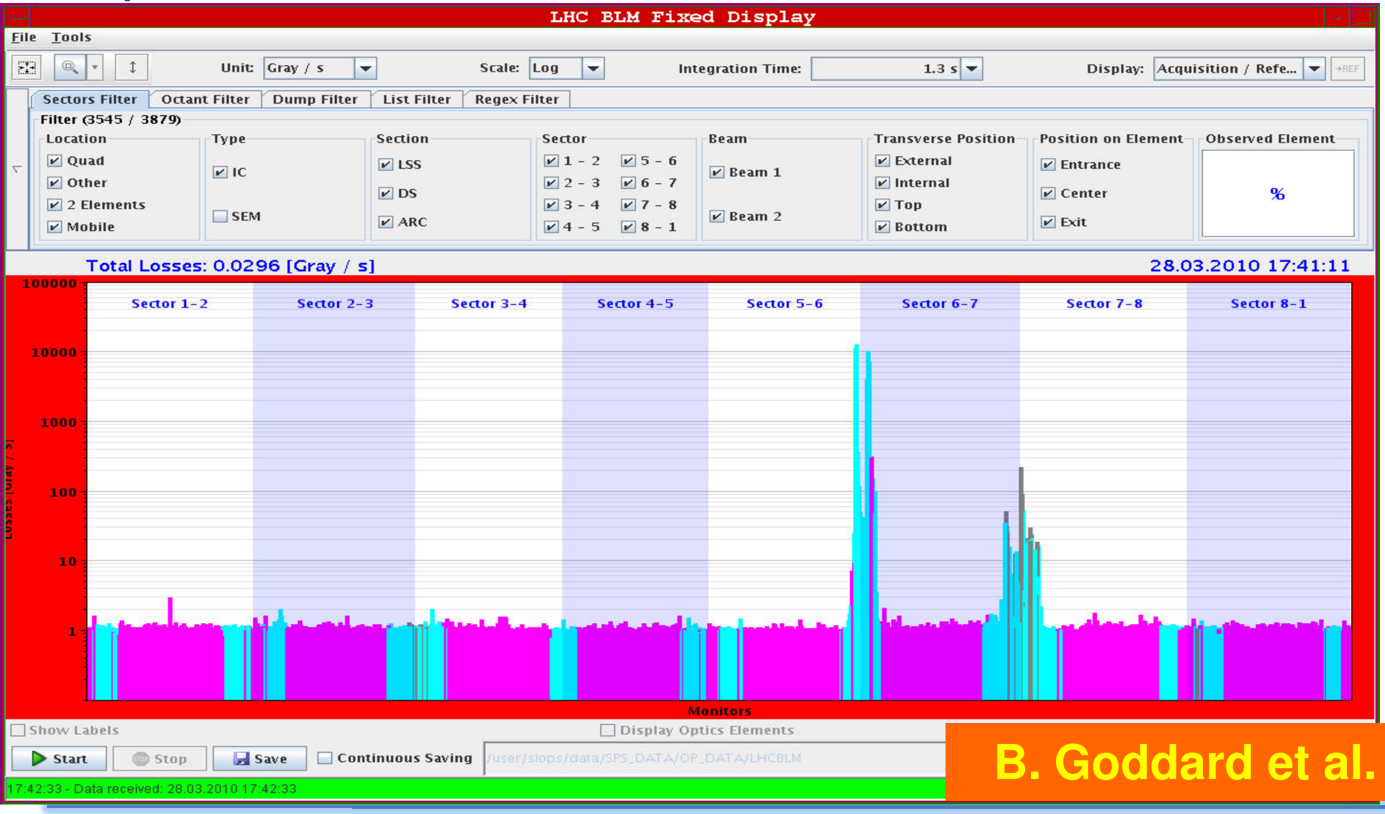
The way to stable beams @ 3.5 TeV

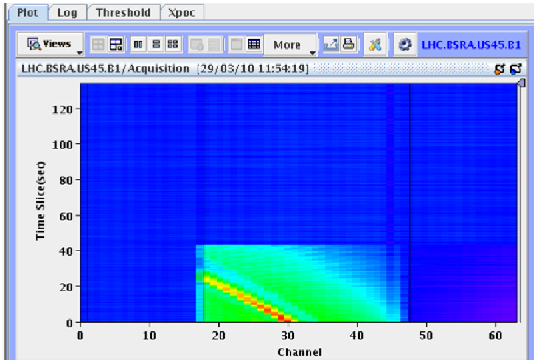
- Scenario with abnormally low beam lifetime created on purpose by operating the machine in an unfavorable working point (3rd order resonance) ➔ losses are catched mainly at the betatron collimation area in LSS7 (designed to stop particles at large oscillation amplitudes)



The way to stable beams @ 3.5 TeV

- Scenario of an unsynchronized dump (i.e. sweep of the fast extraction kicker pulse through the beam) created by switching OFF the RF system and let the beam populating the beam abort gap due to the momentum spread of the beam. Losses are catched primarily by the beam dump protection elements in LSS6.

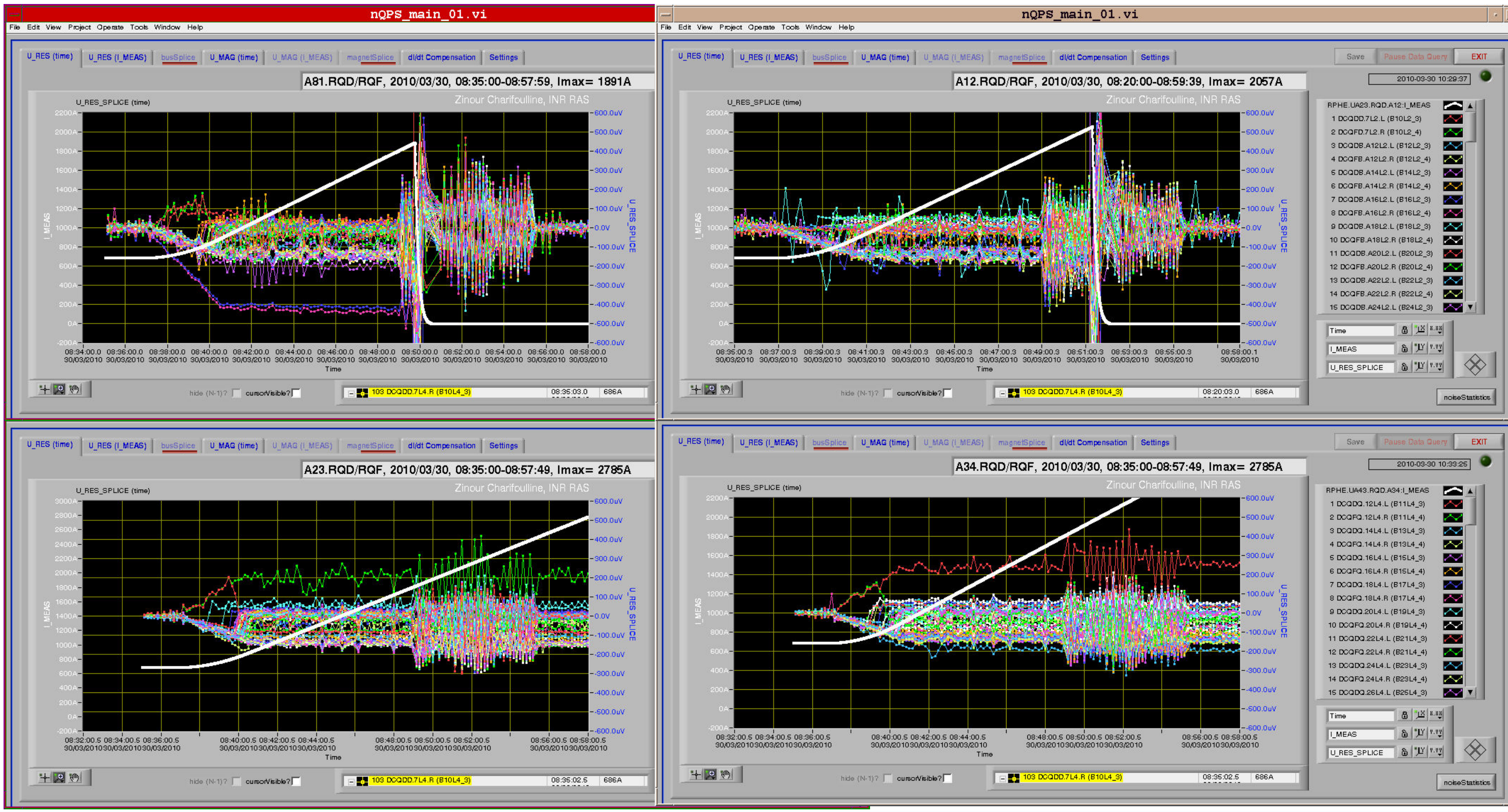




B. Goddard et al.

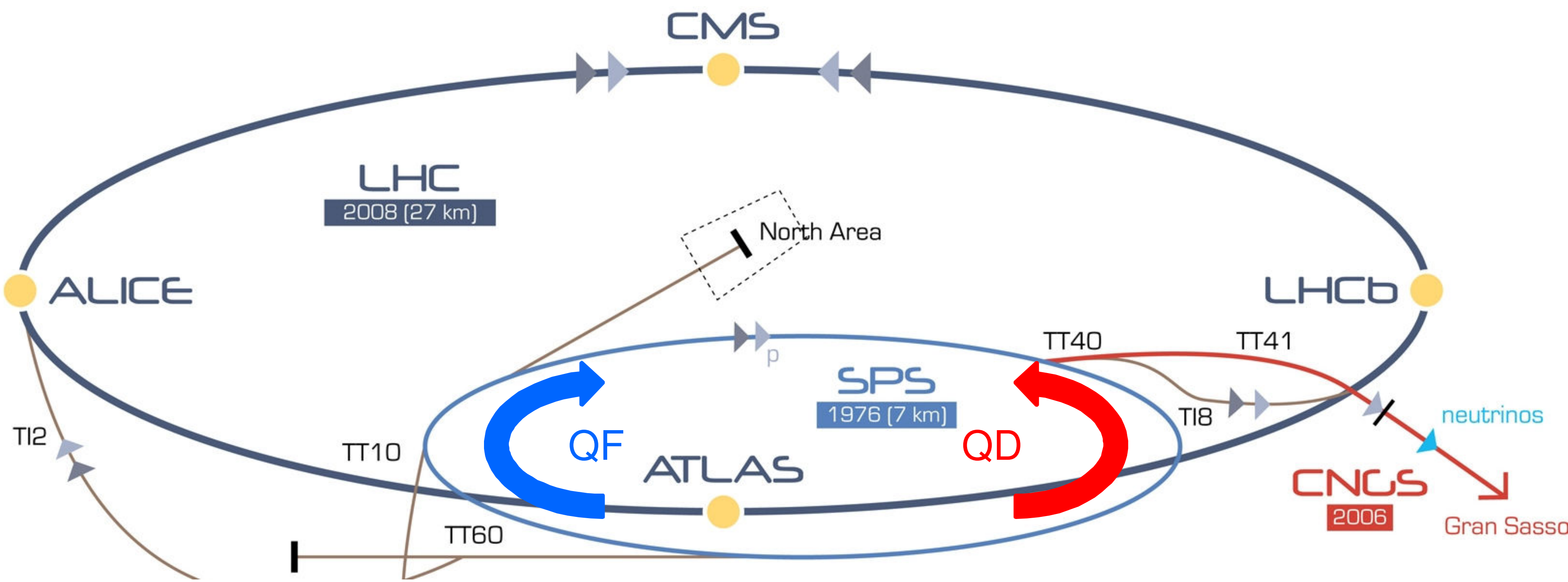
Not quite at 09:17...

- Ramp started at 08:37 ➔ Oscillation observed on the new QPS system signals in all sectors but reducing in amplitude the further we get from point 1 ➔ trip of Main Quadrupoles in Sector 81 followed by those in Sector 12 within few minutes

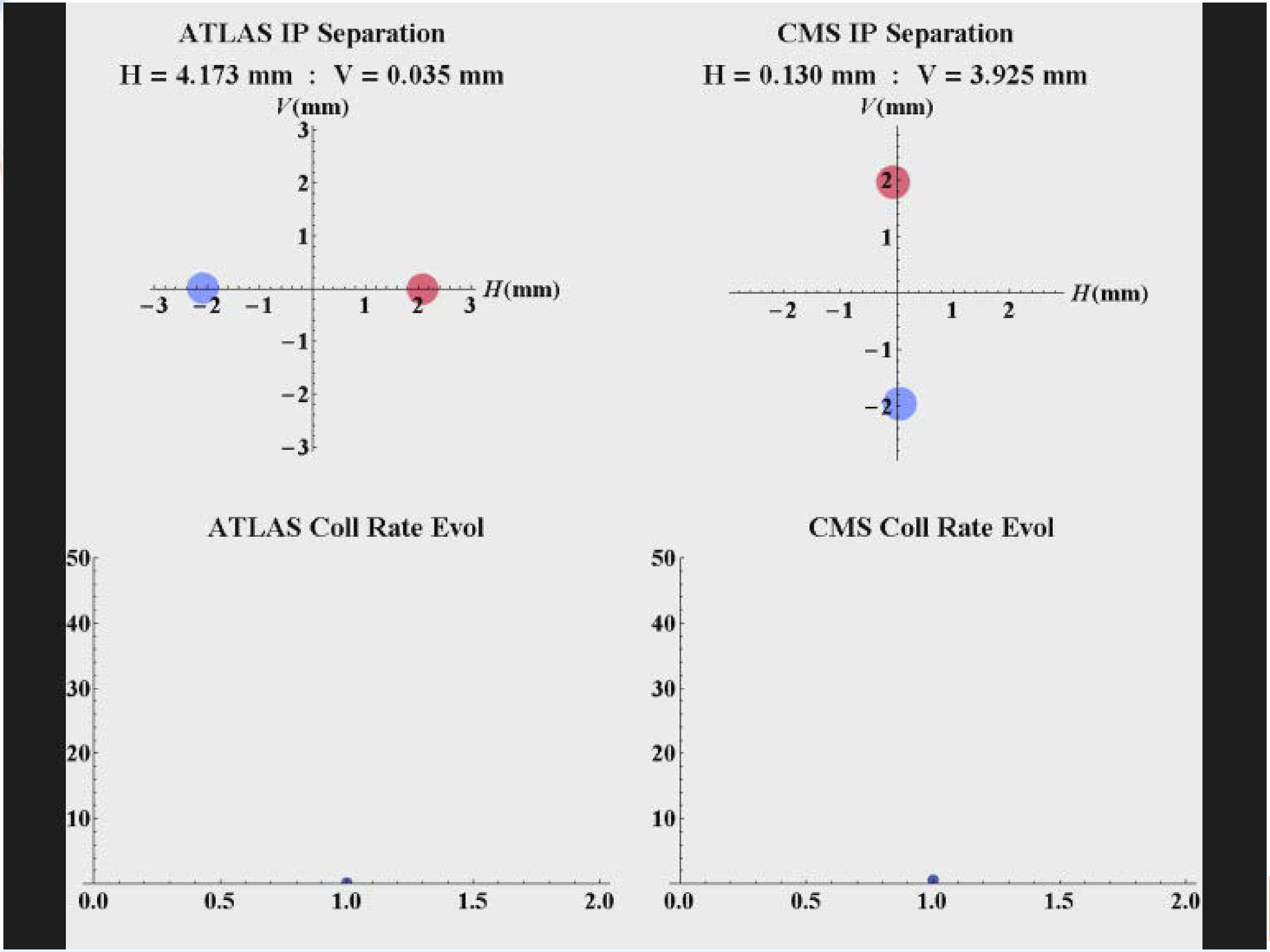


Not quite at 09:17...

- at the same time trip of the QF circuit in the SPS while the QD circuit continued to pulse
- ➔ transformer effect in this case SPS is the primary and LHC is the secondary at the origin of the oscillation ➔ interlock preventing powering one of the main families put back in service the following day

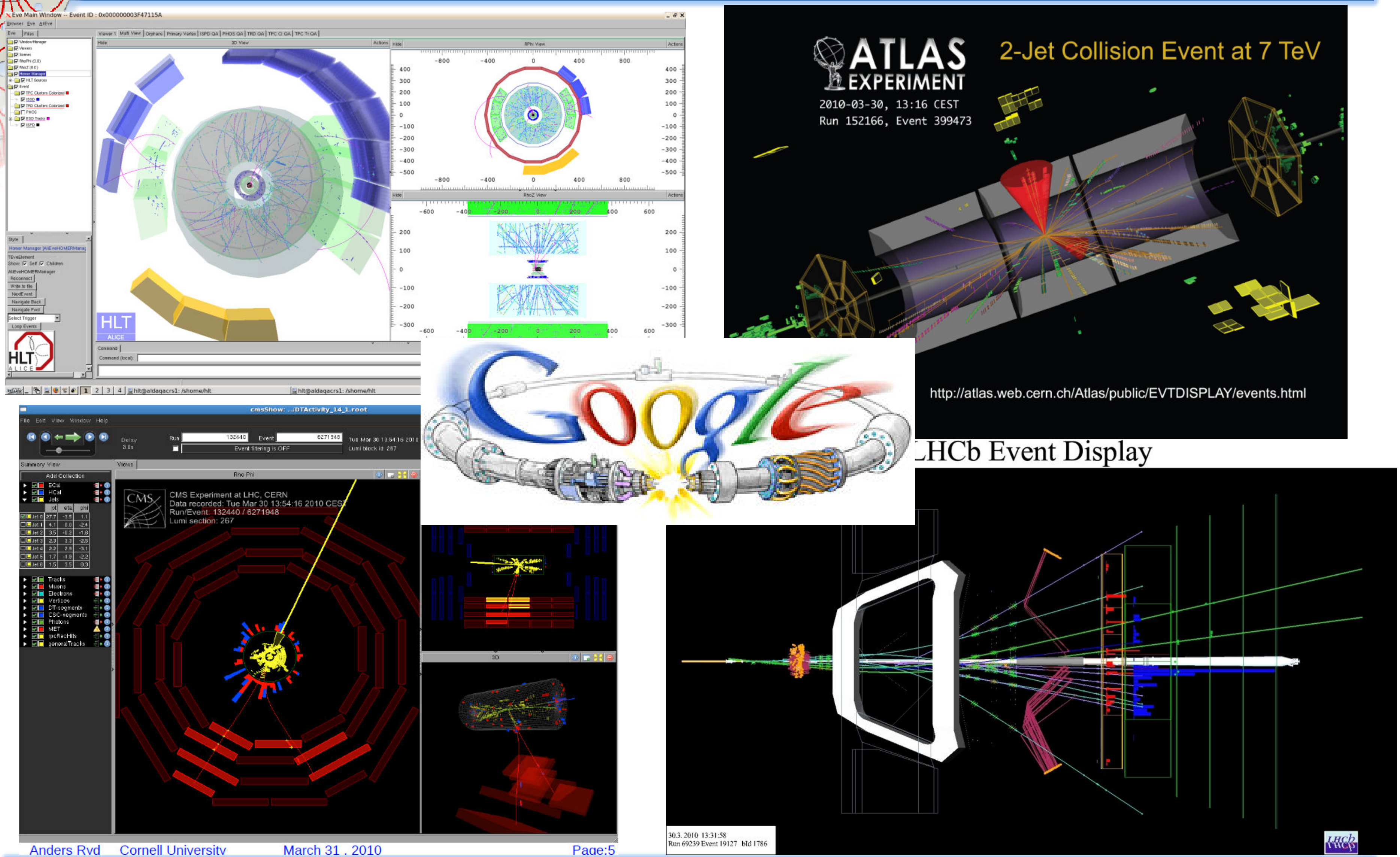


Yes, we can!!!



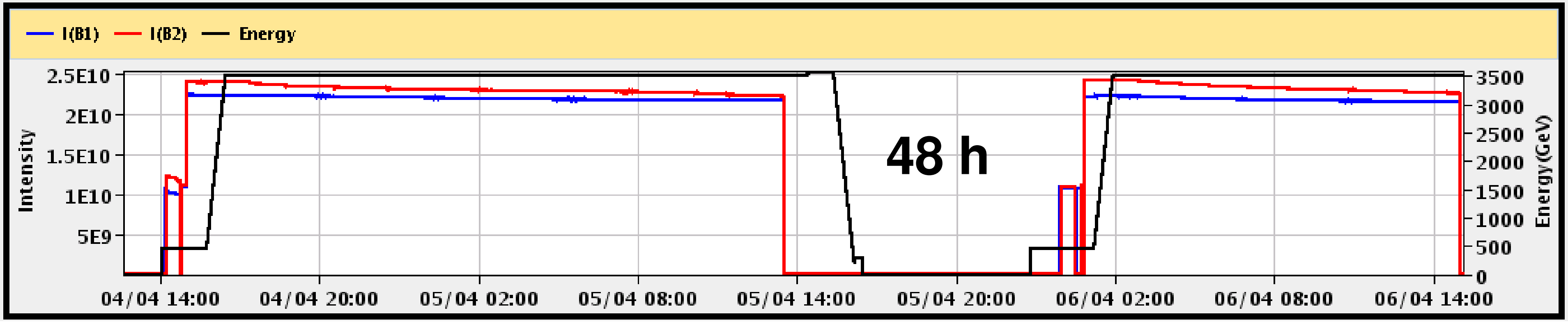
J.-J. Gras

Yes, we can!!!

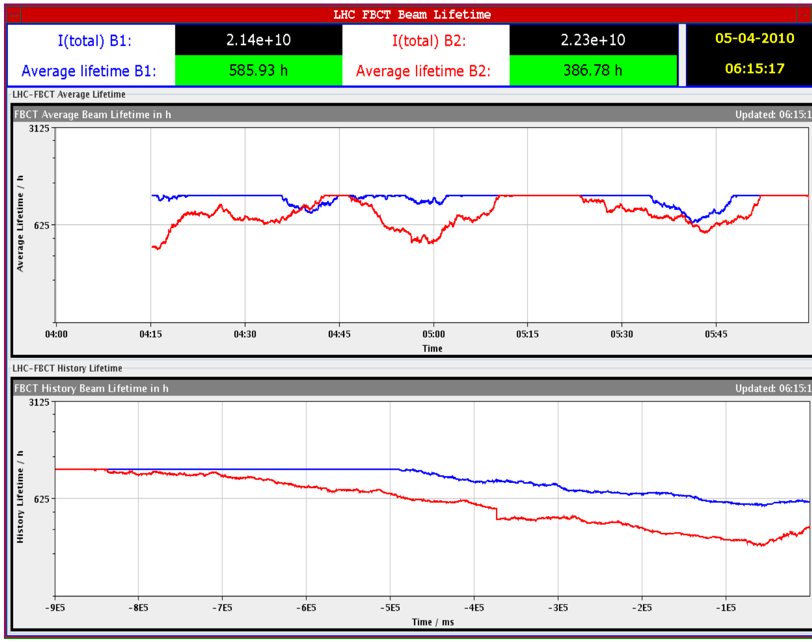


Eve Main Window -- Event ID : 0x000000003F47115A
HLT
ALICE
ATLAS
EXPERIMENT
2-Jet Collision Event at 7 TeV
2010-03-30, 13:16 CEST
Run 152166, Event 399473
http://atlas.web.cern.ch/Atlas/public/EVTDISPLAY/events.html
Google
LHCb Event Display
cmsShow: ../DTActivity_14_1.root
CMS Experiment at LHC, CERN
Data recorded: Tue Mar 30 13:54:16 2010 CEST
Run/Event: 132440 / 6271948
Lumi section: 267
30.3.2010 13:31:58
Run 69239 Event 19127 bld 1786
Anders Ryd
Cornell University
March 31 , 2010
Page:5

Physics

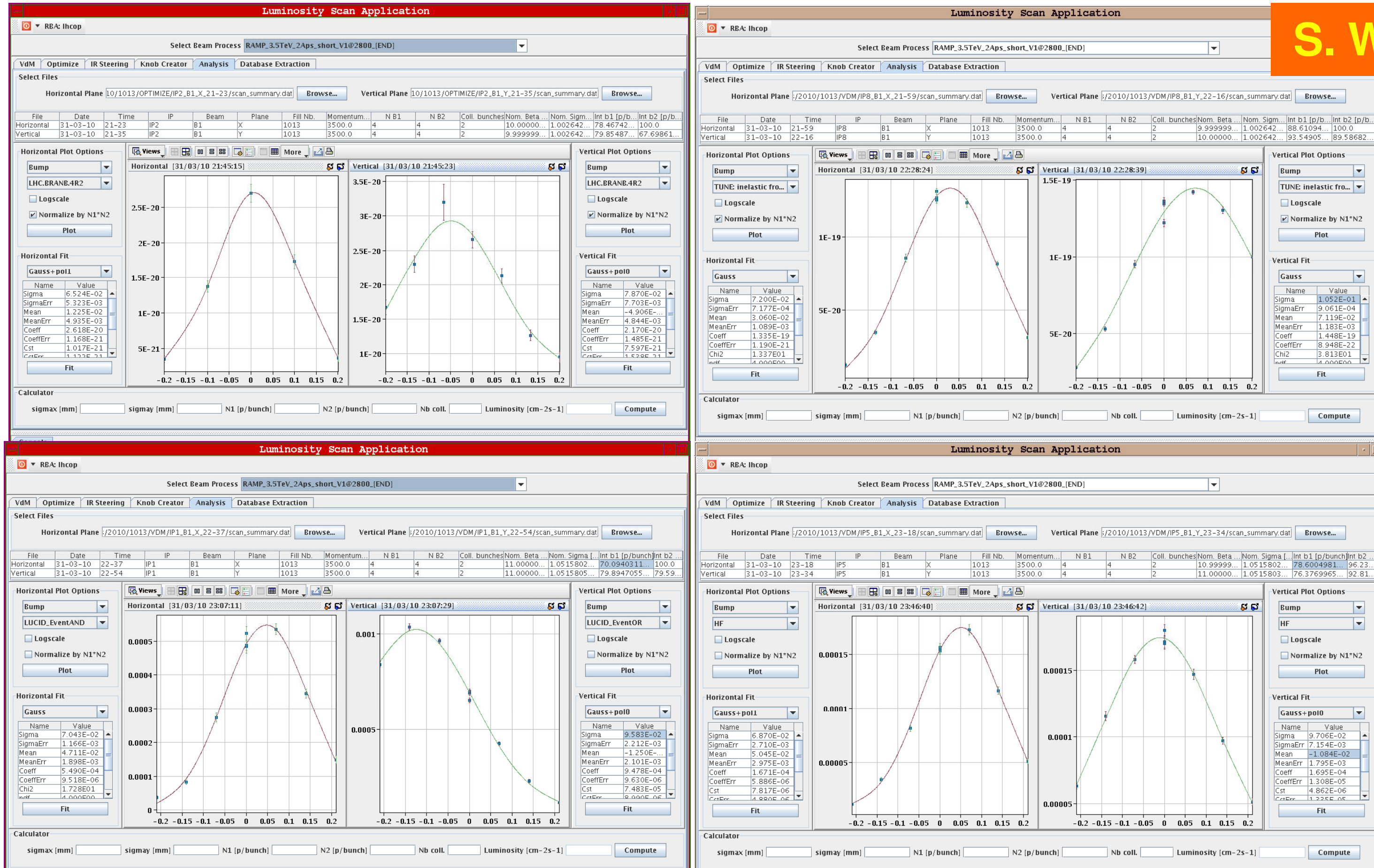


- We can produce long fills **but we did not manage to have a programmed dump yet**
- Beam lifetime is excellent (>100 h)
- From LHC Physics Coordinator @ LMC (07/04/2010):
  - Accumulated order of 300 μb^{-1}/expt
  - Several million inelastics on tape
  - Inelastic rates typically up to ~120 Hz when optimized and ~1.1e10 p/bch, small emittance
  - Luminosity life time seen well above 20h !



Physics

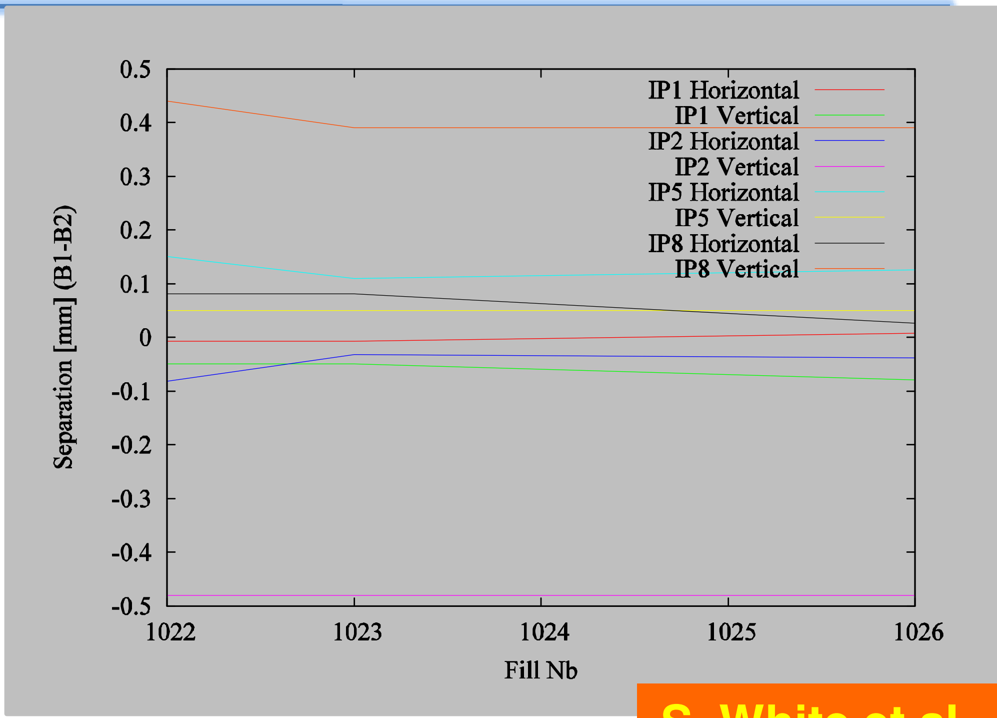
S. White et al.



Trim to separation bump IP1: HB1:0.045 mm, VB1:-0.062 mm / VB2=0.062 mm
Trim to separation bump IP2: HB1:0.012 mm, VB1:-0.215 mm / HB2= -0.05 mm, VB2=0.235 mm
Trim to separation bump IP5: HB1:0.025 mm, VB1:-0.01 mm / HB2:-0.025 mm
Trim to separation bump IP8: HB1:0.03 mm, VB1:+0.175 mm / VB2: -0.175 mm

Physics

- Stability within 50 μm for the separation in the last fills after correction to the same reference orbit. To be confirmed with more statistics
- Need to follow-up on some observations of longitudinal movements of the collision point by ~40 ps (~1 cm) made by the experiments

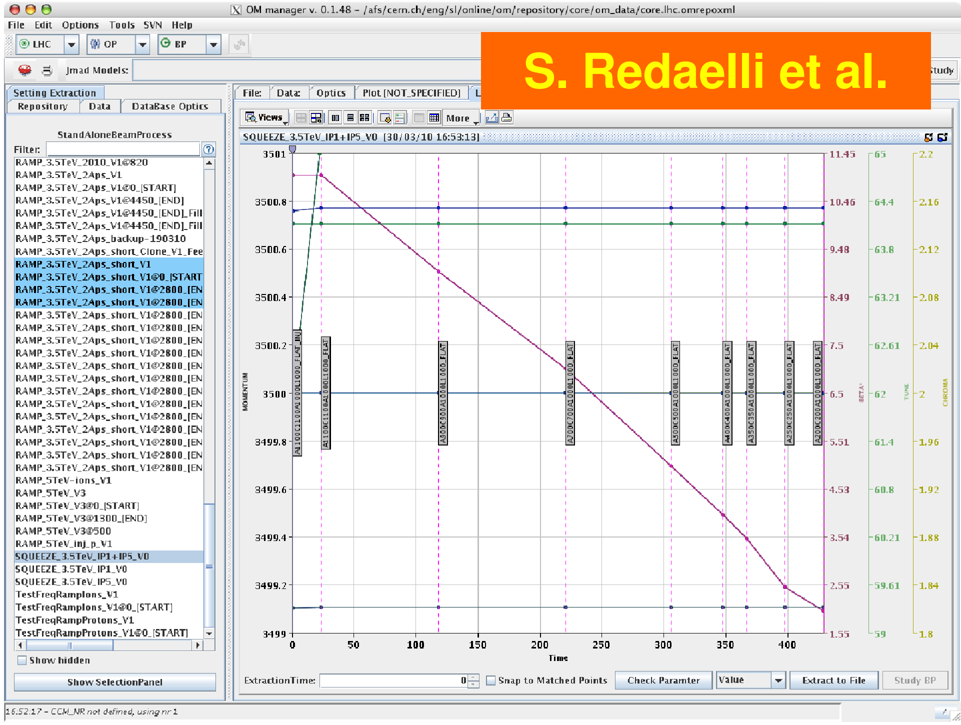


S. White et al.

Squeeze

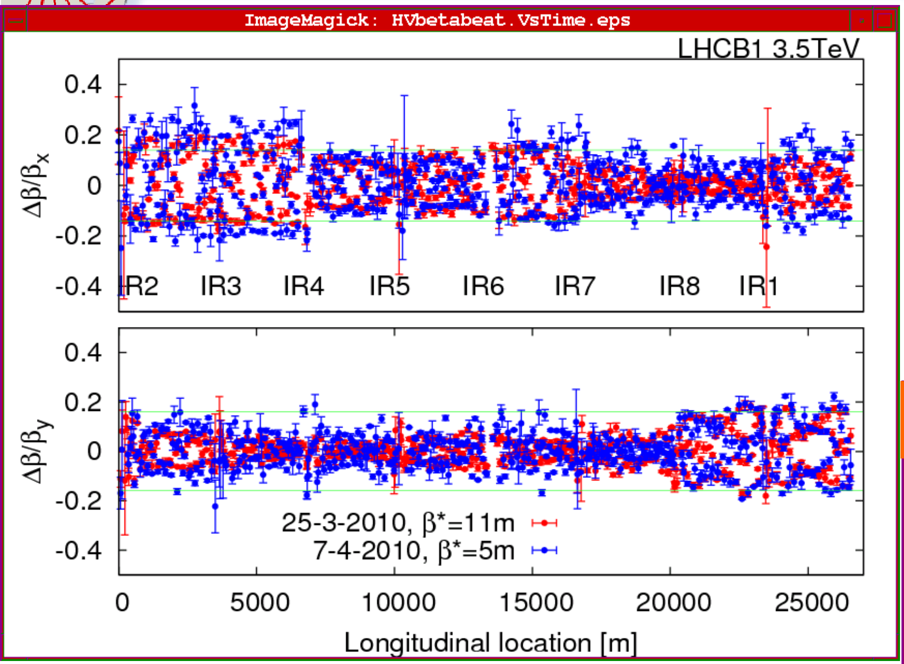
- Start of the tests of the combined squeeze in IR1 and IR5 to 2 m on 1/4 and continued on 7/4 ➔ Need to do Pt 2 and 8
- Collimators at physics settings
- Tunes, orbit, chromaticity, coupling measured and corrected at each step

Time [s]	β*
0	11 m. tunes 0.28/0.31
23	11 m. tunes 0.31/0.32
118	9 m.
221	7 m.
306	5 m. TCTs in to 2 m settings
348	4 m.
367	3.5 m. skipped
398	2.5 m
429	2.0 m.

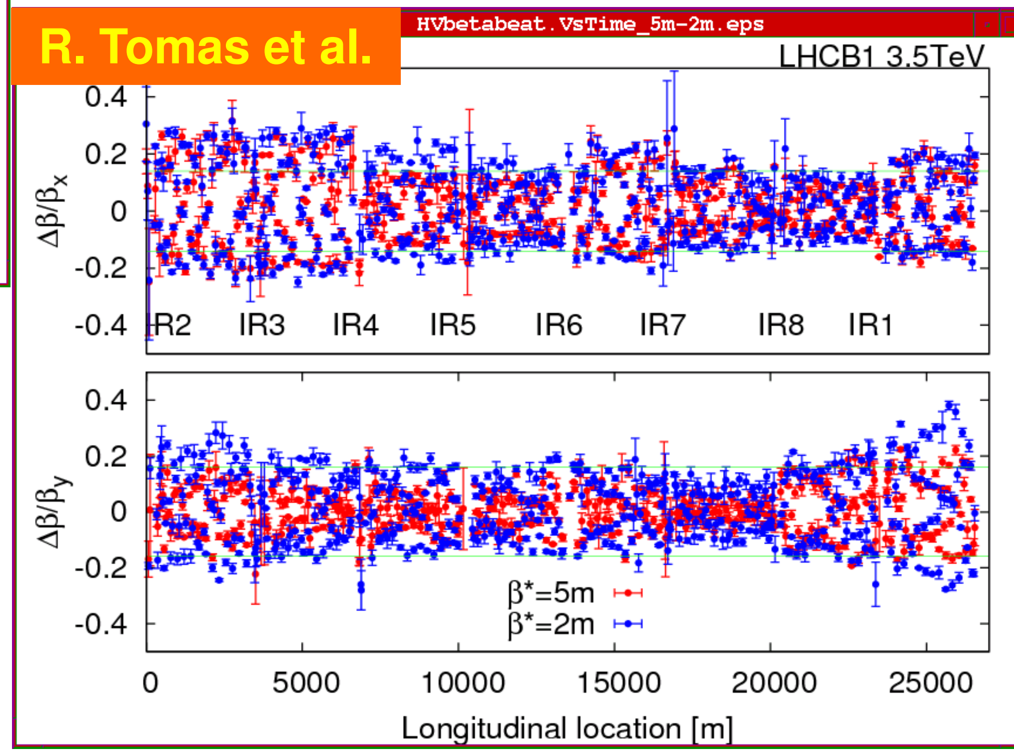


- No significant lifetime issues during the process ➔ machine parameters under control

Squeeze

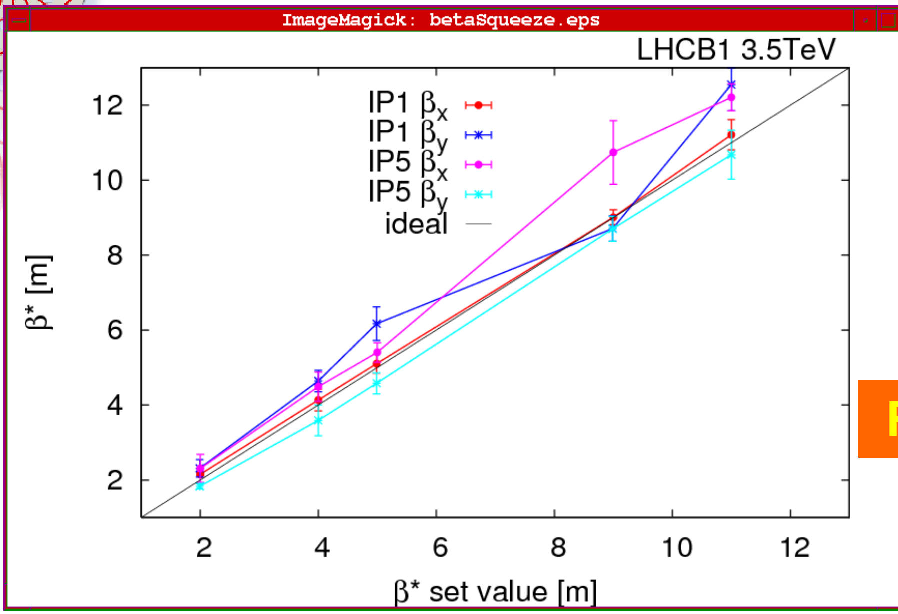


- Some β-beating (for the uncorrected machine) observed in particular for beam 1 and at lower β^* reaching 30 to 40% in V-plane



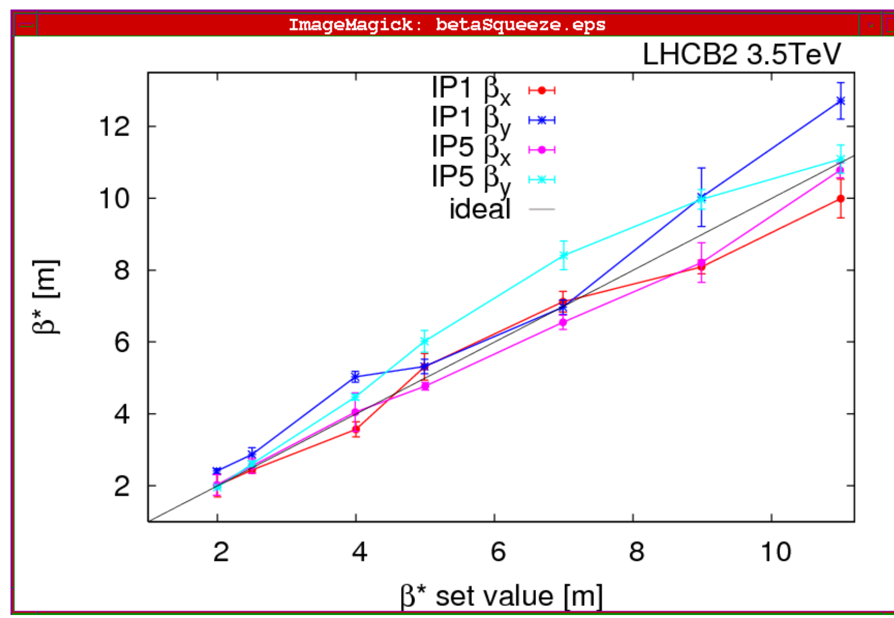
- Tolerance = 20% ➔ i.e. 10% modulation in beam size with respect to expectations.
- Present results not bad at all for an uncorrected machine!!
- ...and in particular for a superconducting machine

Squeeze



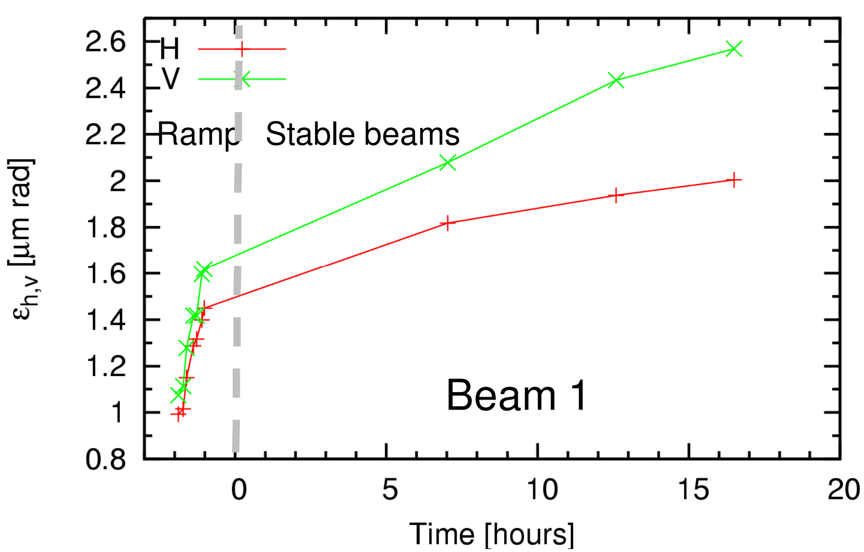
- β* @ IP1-5 close to expectations (within 20 %) for an uncorrected machine

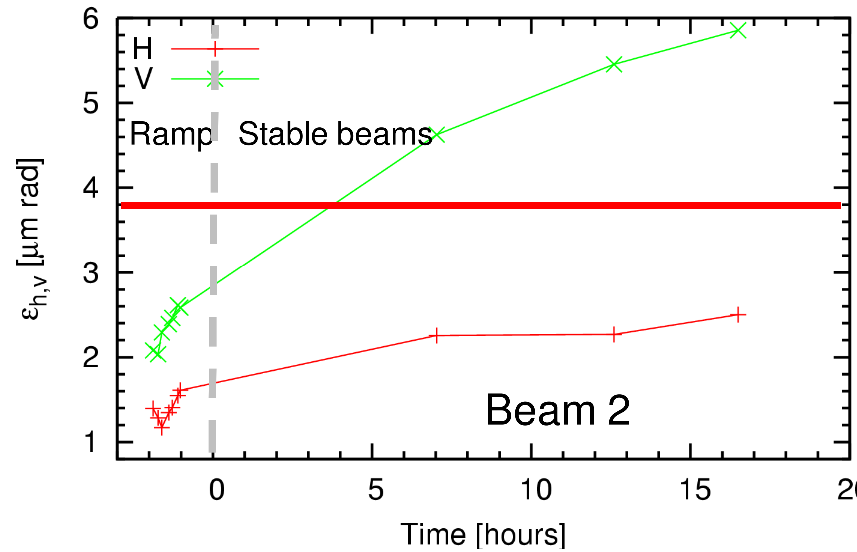
R. Tomas et al.



Emittance preservation

- Protons never forget....differently from leptons

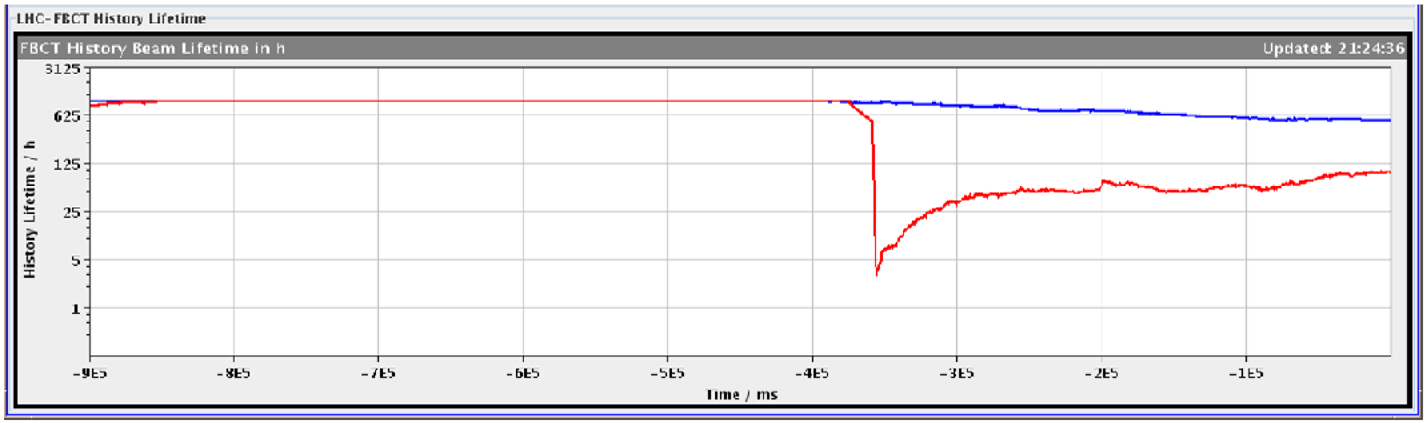




- After reduction of the beam momentum spread after optimization of the RF capture which resulted in better lifetime at injection
- Indications that emittance growth is due to coupling chromaticity – energy spread. Worse for beam 2 due to the presence of beam excitation close to the working point ("hump"). Improvements: further energy spread reduction & chromaticity minimization at injection and during the ramp ➔ ongoing

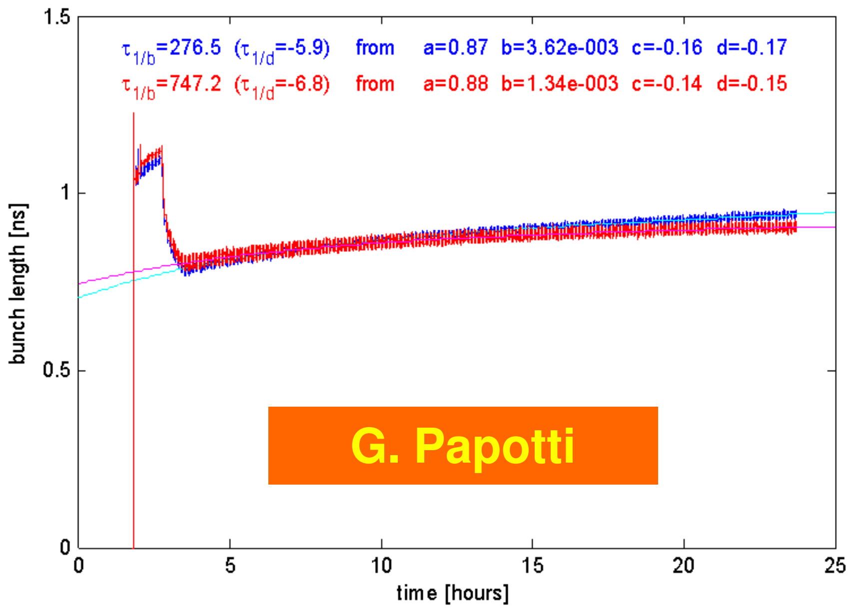
Emittance preservation

- Minimizing blow-up is important to:
  – maximize luminosity
  – Minimize losses when moving in collimators at 3.5 TeV:

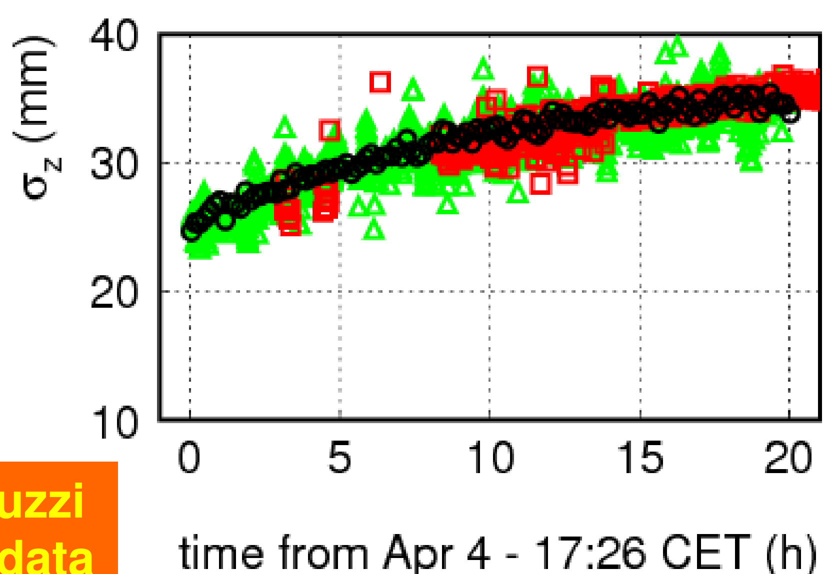


- ε_H and ε_V for Beam 1 and ε_H for Beam 2 below nominal for 17h! BUT bunch intensity is low and emittance growth is beyond specification.

Emittance preservation



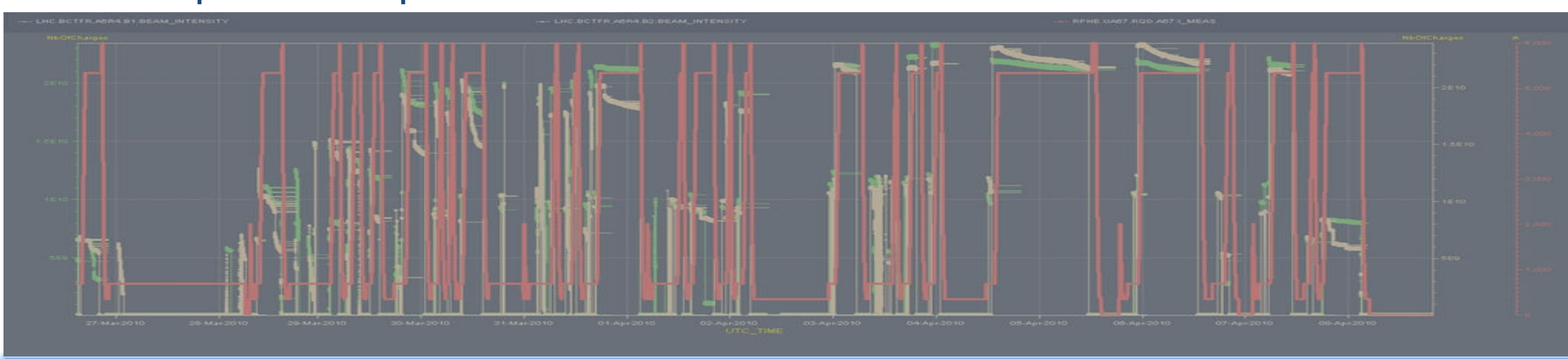
- Longitudinal emittance blow up is also observed ➔ bunch length increase during the physics fill (time constant ~ 6-7 hours)
- Consistent with Intra Beam Scattering (F. Zimmermann)
- ➔ ε_L controlled blow-up during the ramp



M. Ferro-Luzzi from expt. data

Systems availability

- System availability is remarkable but every problem at high energy costs time ➔ need to ramp down and cycle the magnets ➔ turn around time is larger than 4 hours ➔ increasing the ramp speed can only help (ongoing)
- Issues encountered during the past two weeks:
  - Vacuum leak on the bellows of the movable stoppers in the injection transfer lines (replaced)
  - Cryo stop in point 4
  - Some spurious triggers of the QPS observed on the main quadrupoles
  - Current lead temperature controls failures
  - Operational procedures



Next two weeks…

Continued system commissioning and consolidation

↓

Establish squeezed (β^* ~ 2 m.) stable, safe beams

↓

Probe higher intensities at injection

↓

Operations consolidation

↓

Preparation of increased intensity into stable beams

M. Lamont

In parallel the required modifications for increasing the ramp rate of the main circuits from 2 A/s to 10 A/s are ongoing and preliminary test have been performed successfully yesterday

Conclusions

- We have demonstrated that the machine can operate in stable beam mode and deliver hours of quiet data taking for the experiments at 3.5 TeV:
  - Luminosity production has started but we have some orders of magnitude to go...
  - We have not yet had a programmed dump
- Although at low intensity we are progressing in the understanding and control of the beam parameters (in particular lifetime and emittance preservation)
- Optics under control also during the squeeze although some tuning might be required
- We are testing/optimizing our procedures: weaknesses have been found during operation with low intensity and eliminated

Conclusions

- We are increasing the complexity of the operation step-wise and without compromising on safe operation
- Next steps:
  - Completion of the commissioning of the squeeze
  - Stable beams with squeezed optics
  - Bunch intensity increase

- Thanks to all the teams involved
- Thanks to the Physics Coordinator and to the experiments for the fruitful collaboration and feedback