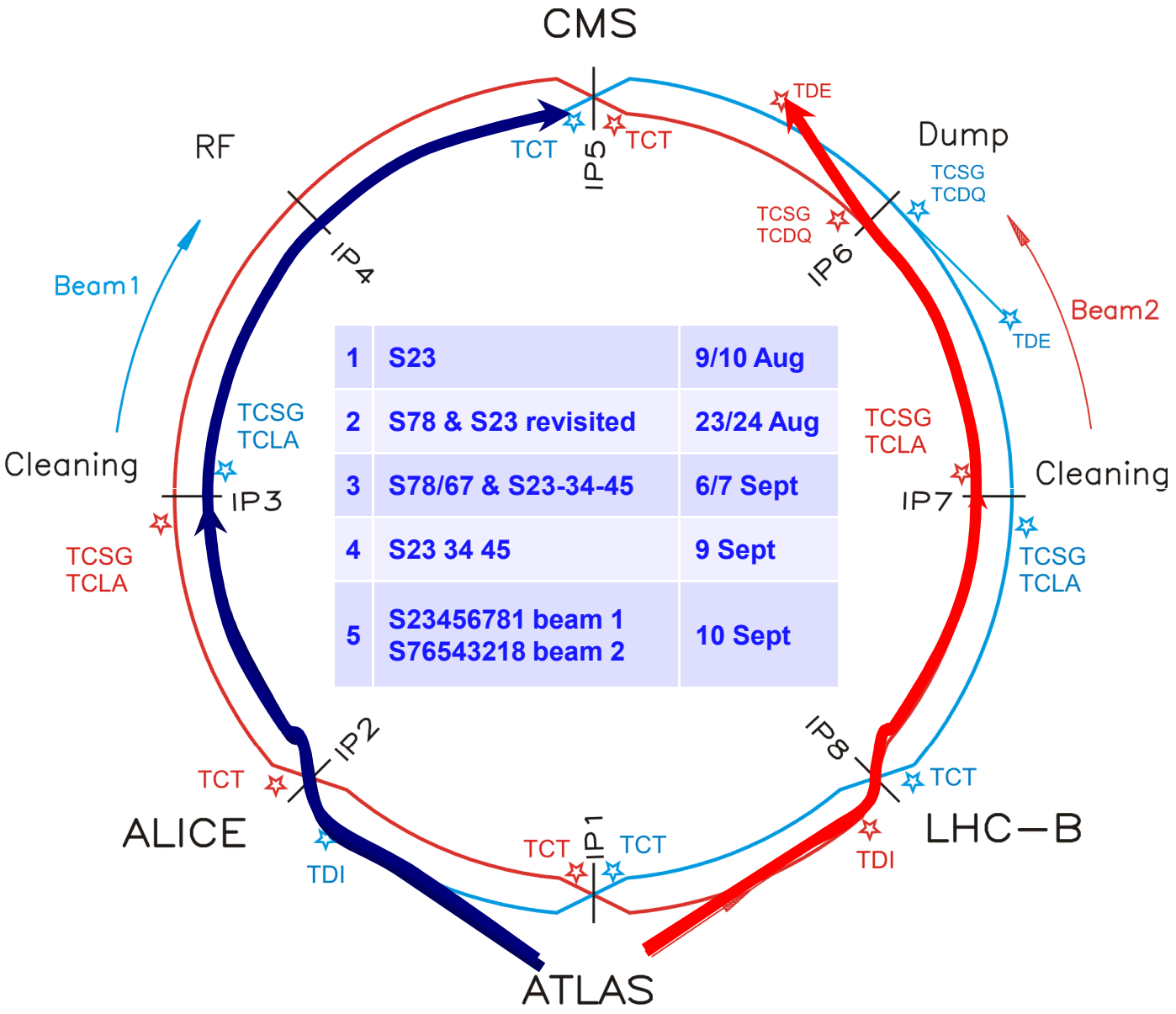
*A line will take us hours maybe;*
*Yet if it does not seem a moment's thought,*
*our stitching and unstitching has been naught.*
*W. B. Yeats*

# LHC Injection Tests


## Mike Lamont on behalf of:

I. Agapov, M. Aiba, M. Albert, R. Alemany Fernandez, G. Arduini, R. Assmann, R. Bailey, R. Billen, L. Bottura, O. Bruning, A. Butterworth, R. Calaga, E. Carlier, P. Collier, B. Dehning, L. Deniau, S. Fartoukh, F. Follin, D. Forkel-Wirth, K. Fuchsberger, R. Giachino, M. Giovannozzi, B. Goddard, J-J. Gras, E. Hatziangeli, P. Hagen, D. Jacquet, L. Jensen, R. Jones, V. Kain, I. Kozsar, T. Kramer, G. Kruk, M. Lamont, J. Lewis, A. Macpherson, M. Meddahi, V. Mertens, S. Page, L. Ponce, B. Puccio, S. Redaelli, C. Roderick, S. Roesler, F. Ronacarlo, M. Sapinski, F. Schmidt, R. Schmidt, R. Steinhagen, M. Strzelczyk, Y. Sun, B. Todd, E. Todesco, R. Tomas Garcia, J. Uythoven, W. Venturini Dalsolaro, Heinz Vincke, Helmut Vincke, E. Veyrunes, J. Wenninger, R. Wolf, C. Zamantzas, F. Zimmermann.

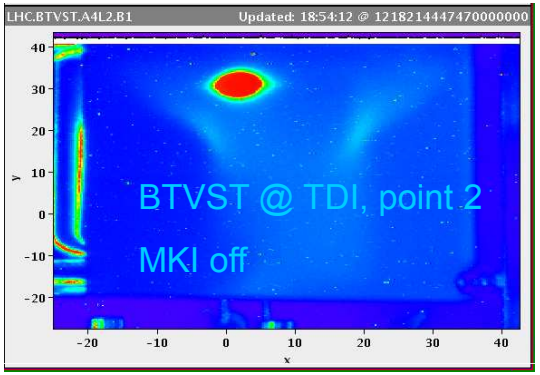
# Injection tests

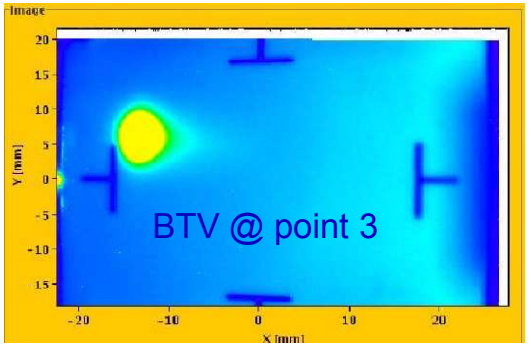



| | | |
|---|---|---|
| 1 | S23 | 9/10 Aug |
| 2 | S78 & S23 revisited | 23/24 Aug |
| 3 | S78/67 & S23-34-45 | 6/7 Sept |
| 4 | S23 34 45 | 9 Sept |
| 5 | S23456781 beam 1<br>S76543218 beam 2 | 10 Sept |

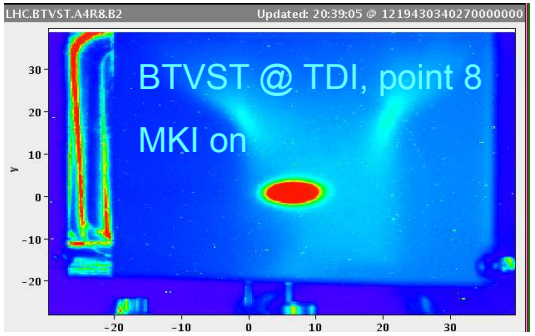
# First Beam in the LHC

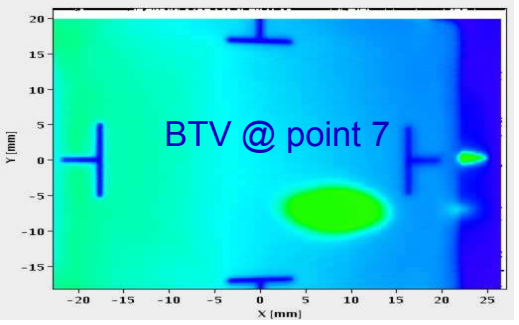
- First **beam 1** in the LHC at point 2: 8th of August 18:54:12 (on TDI)
  - NO THREADING REQUIRED to go to point 3




- First **beam 2** in the LHC at point 8: 22nd of August 20:39:05 (on TDI)
  - NO THREADING REQUIRED to go to point



# Preparation & Testing 1/2

- Beam Dump system
- Injection system
- Synchronization and timing
- Beam Interlock System
- Collimators & absorbers
- Beam Instrumentation
  - BLMs, BPMs, screens, BCT, radiation monitors…
  - full deployment & testing of complete acquisition chain
- Cold circuits
  - ramp, squeeze, pre-cycle  etc. on cold sectors as they became available

**Months in advance** →

Dry Runs

Machine Checkout

Hardware Commissioning

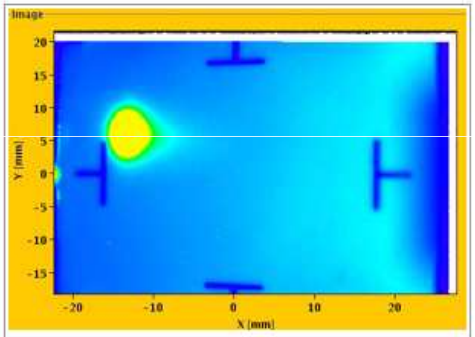
# Preparation & Testing 2/2

- Deploy and check magnet model (FiDeL)
  - provides on a circuit by circuit basis
  - full-blown transfer function model for main magnets
  - simplified transfer function model for correctors
  - full-blown b3, b5 errors for the MB's (static + dynamic)
- Software & Controls
  - settings, parameter control, optics, magnet model, equipment control & monitoring, logging, database, sequencer, orbit correction, fixed displays…
  - Stress test controls…

# Results – some examples

Home 11.08.2008

## LHC synchronization test successful



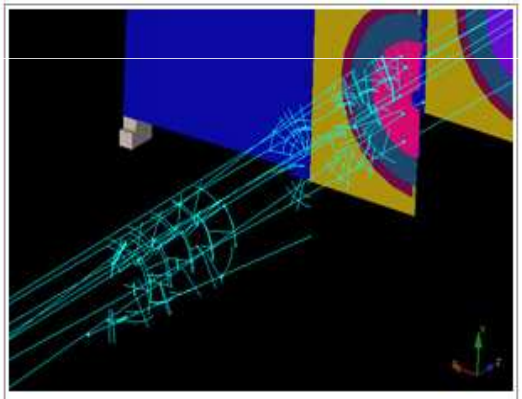

Particles in the LHC. The yellow spot shows a bunch of a few particles arriving at point 3 of the LHC ring.

The synchronization of the LHC's clockwise beam transfer system and the rest of CERN's accelerator chain was successfully achieved last weekend. Tests began on Friday 8 August when a single bunch of a few particles was taken down the transfer line from the SPS accelerator to the LHC.

After a period of optimization, one bunch was kicked up from the transfer line into the LHC beam pipe and steered about 3 kilometres around the LHC itself on the first attempt. On Saturday, the test was repeated several times to optimize the transfer before the operations group handed the machine back for hardware commissioning to resume on Sunday.
The anti-clockwise synchronization systems will be tested over the weekend of 22 August.

Home 25.08.2008

## Final LHC Synchronization Test a Success



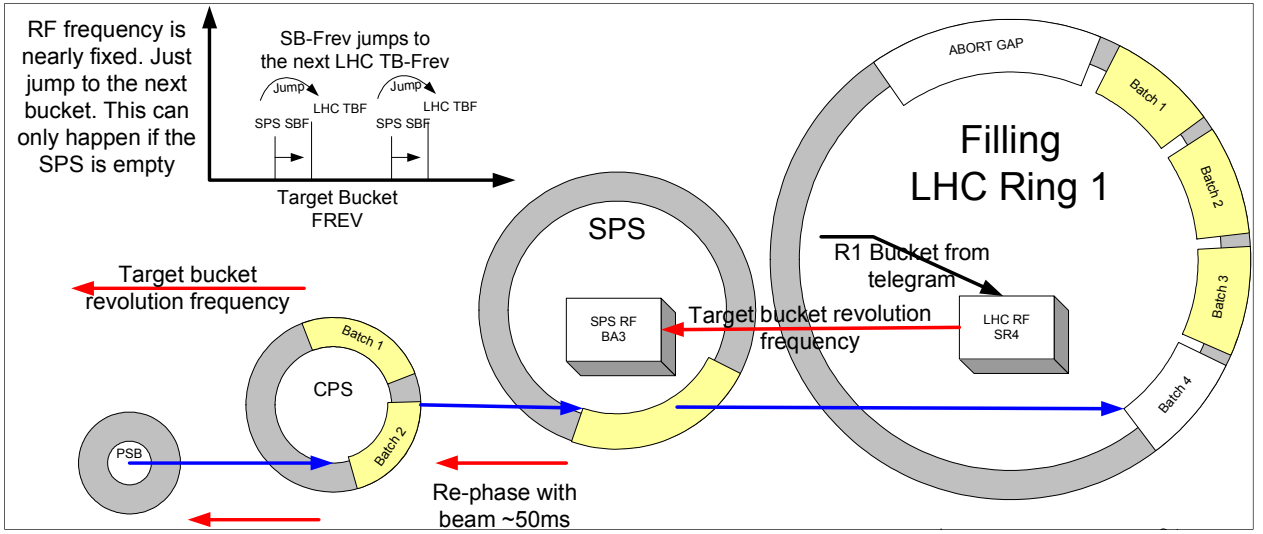
Particle tracks seen in the LHCb vertex detector (VELO) and triggered by the experiment's calorimeter during synchronization tests last weekend

Geneva, 25 August 2008. CERN has today announced the success of the second and final test of the Large Hadron Collider's beam synchronization systems which will allow the LHC operations team to inject the first beam into the LHC.

Friday evening 22 August, a single bunch of a few particles travelled down the transfer line from the Super Proton Synchrotron (SPS) accelerator to the LHC. After a period of optimization, one bunch was kicked up from the transfer line into the LHC beam pipe and steered counter-clockwise about 3 kilometres around the LHC.

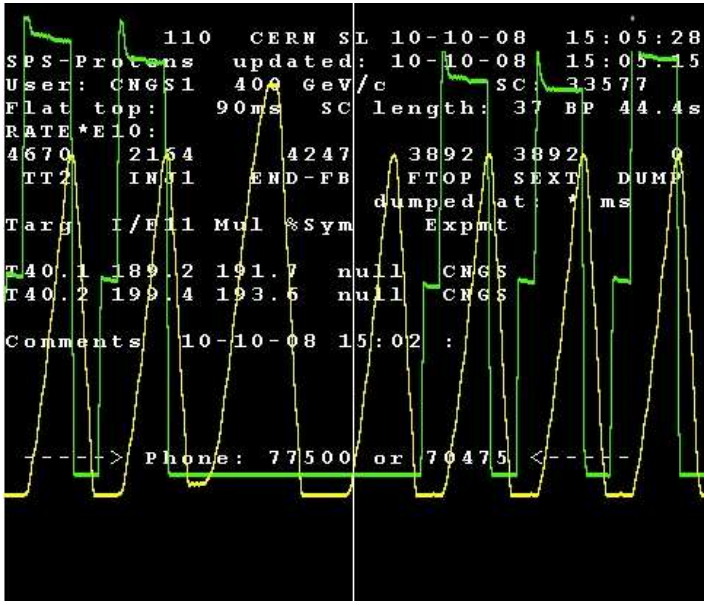
# Injection/RF synchro

Injection requests, RF pre-pulses etc





Deployed, tested, tested, tested…

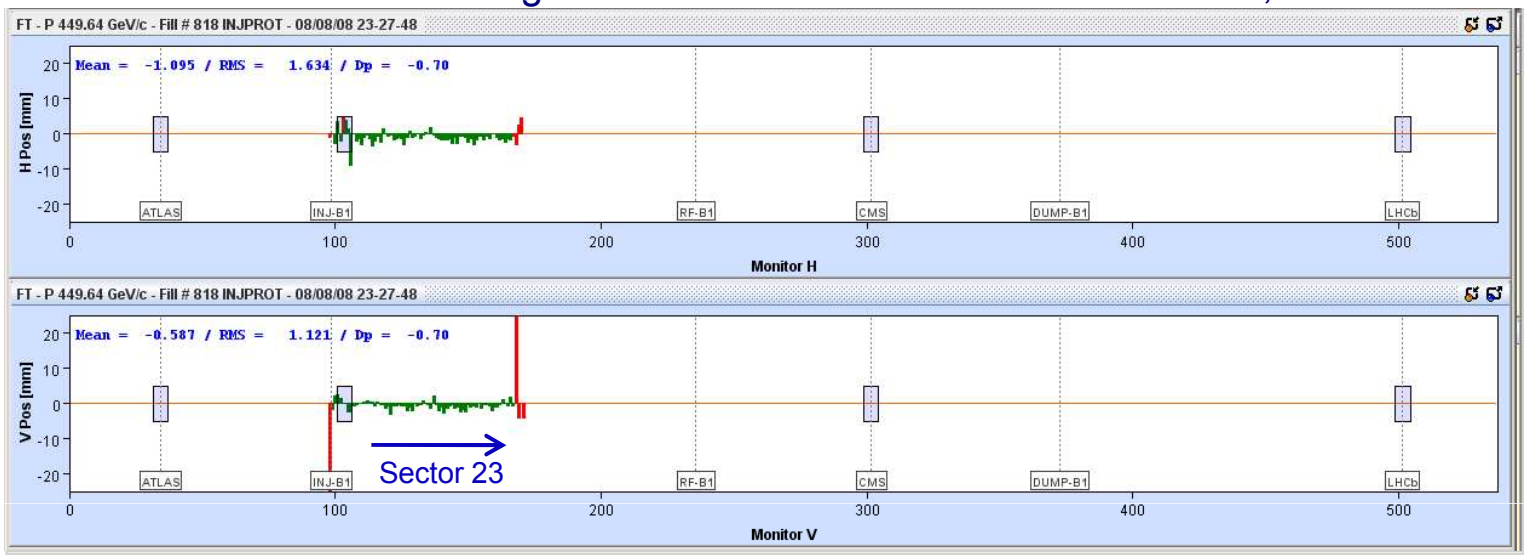



… interleaved injection into LHC while delivering beam to CNGS

# First Trajectories

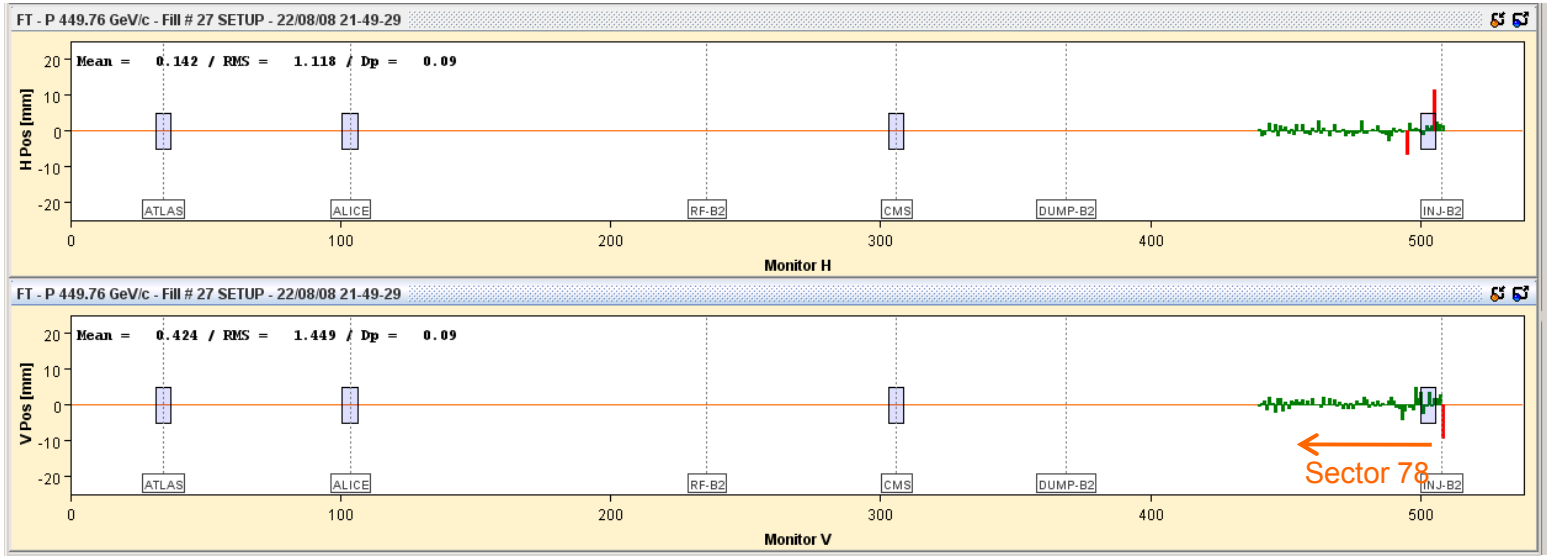
Beam 1: after some steering

H rms: 1.6 mm, V rms: 1.1 mm



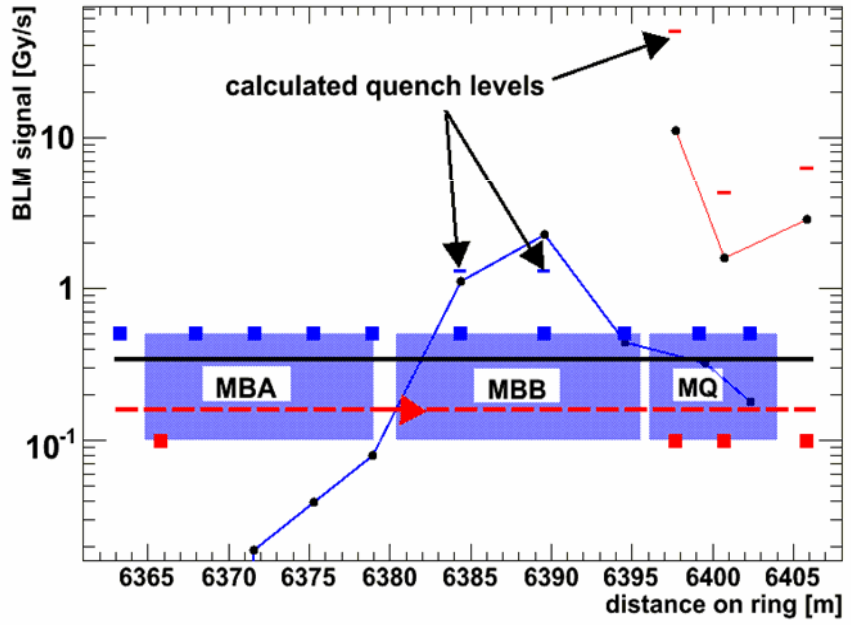

Beam 2: after some steering

H rms: 1.1 mm, V rms: 1.4 mm



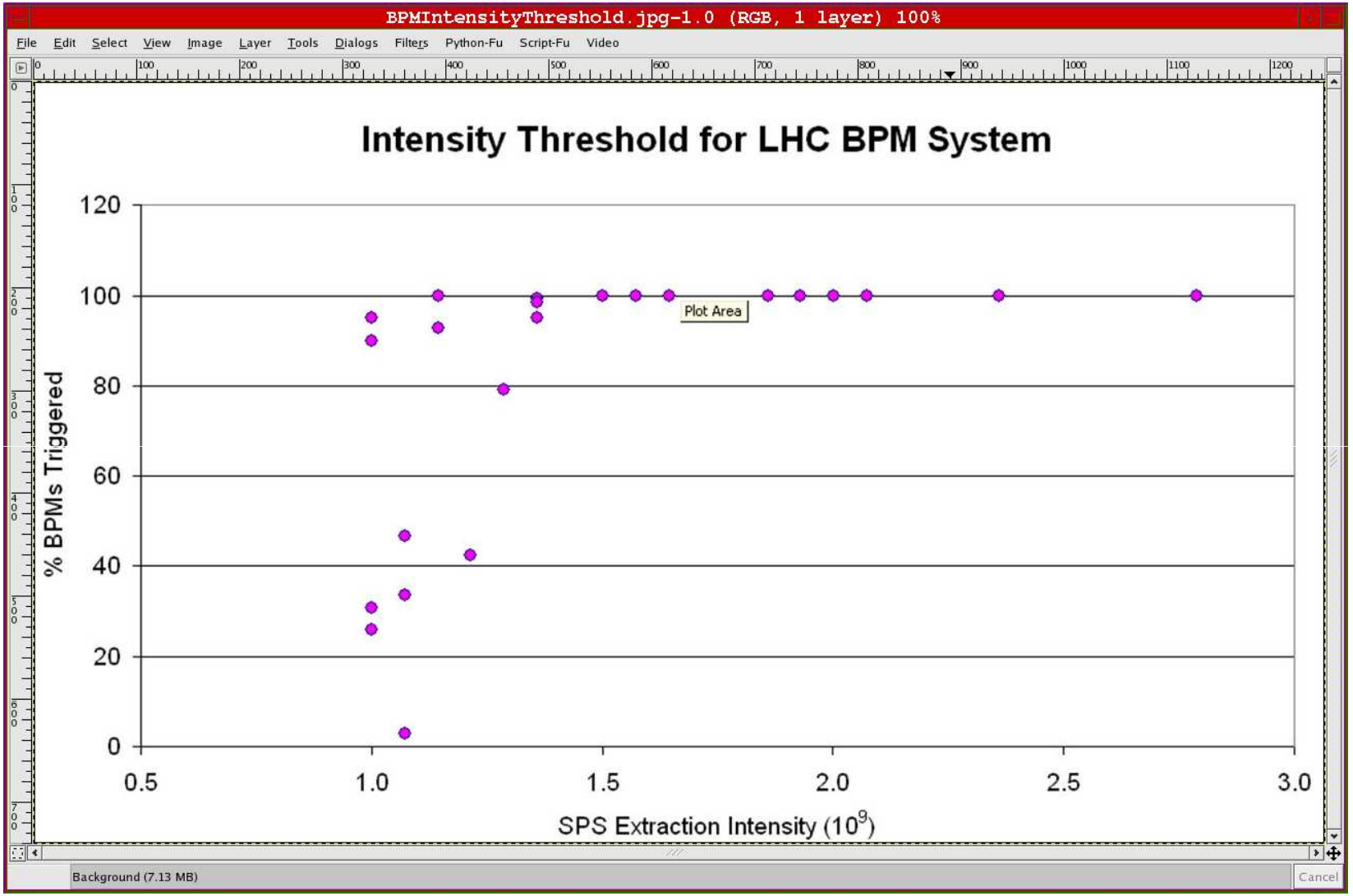
# Quench levels

**Quenchinos** …a quench of MB.A10.R2 was induced with 2e9 protons – a new lower limit for a beam induced quench at 450 GeV. This was achieved by steering the beam directly into the magnet concerned – not a typical scenario.



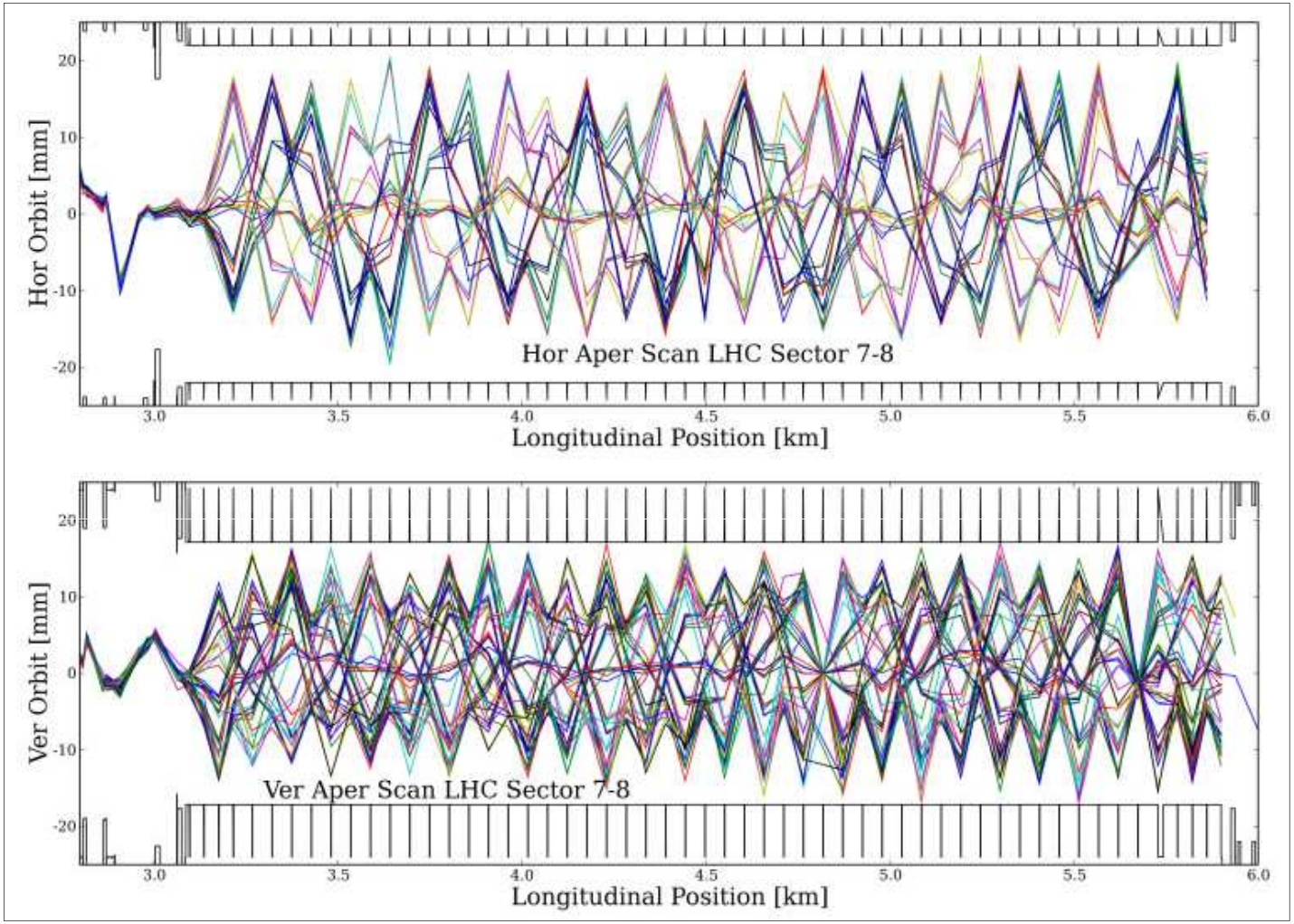

BLM response at location of first quench

# Rapid redefinition of probe beam




Rhodri Jones

# Aperture scans - routine

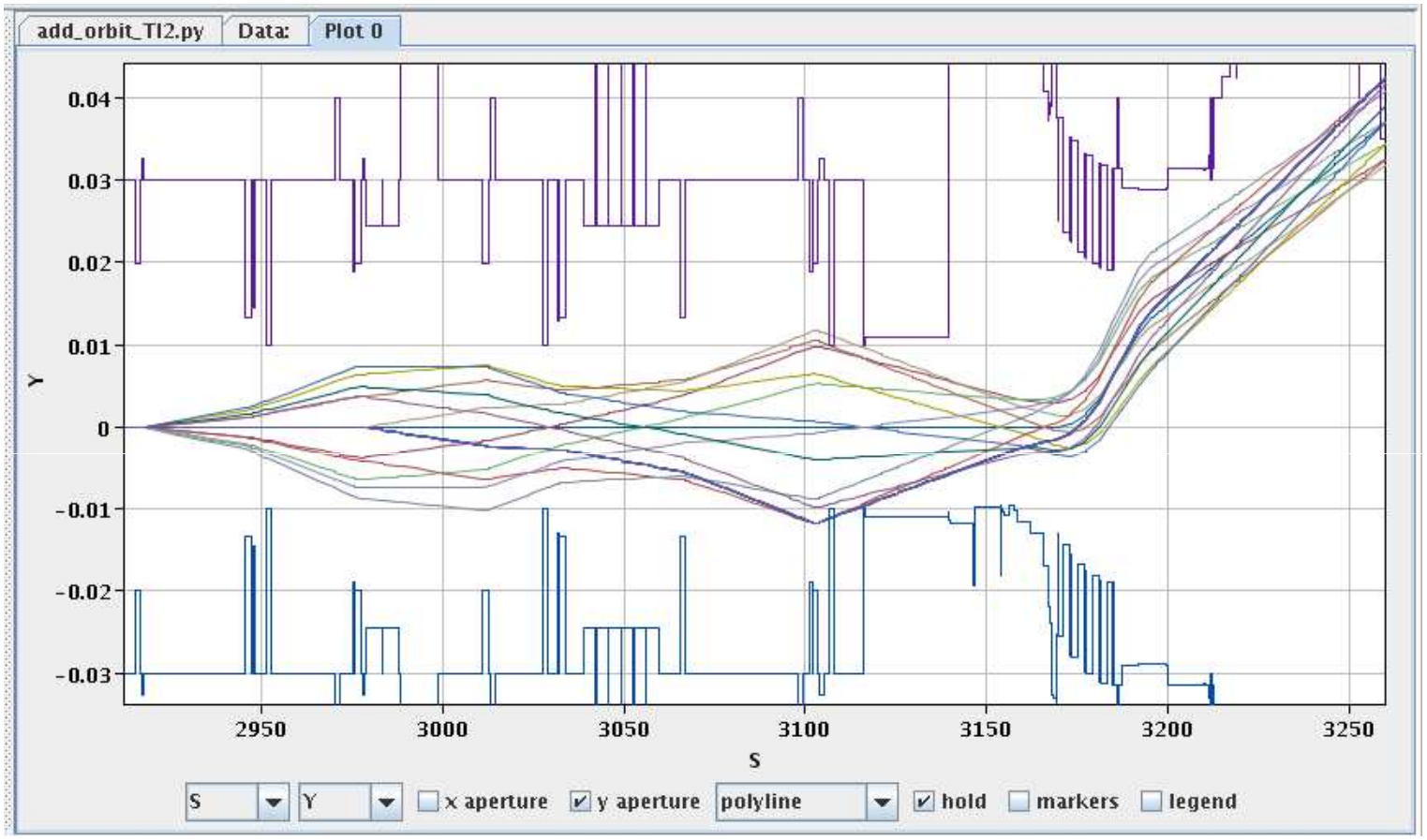



- Horizontal aperture is around ±18 mm (confirmed value measured in first injection test).
- Vertical aperture is around ±12 mm (slightly larger than in first injection test).

I. Agapov, R. Calaga, S. Redaelli, R. Tomàs, M. Giovannozzi et al.

# Injection aperture measurements

On-line model

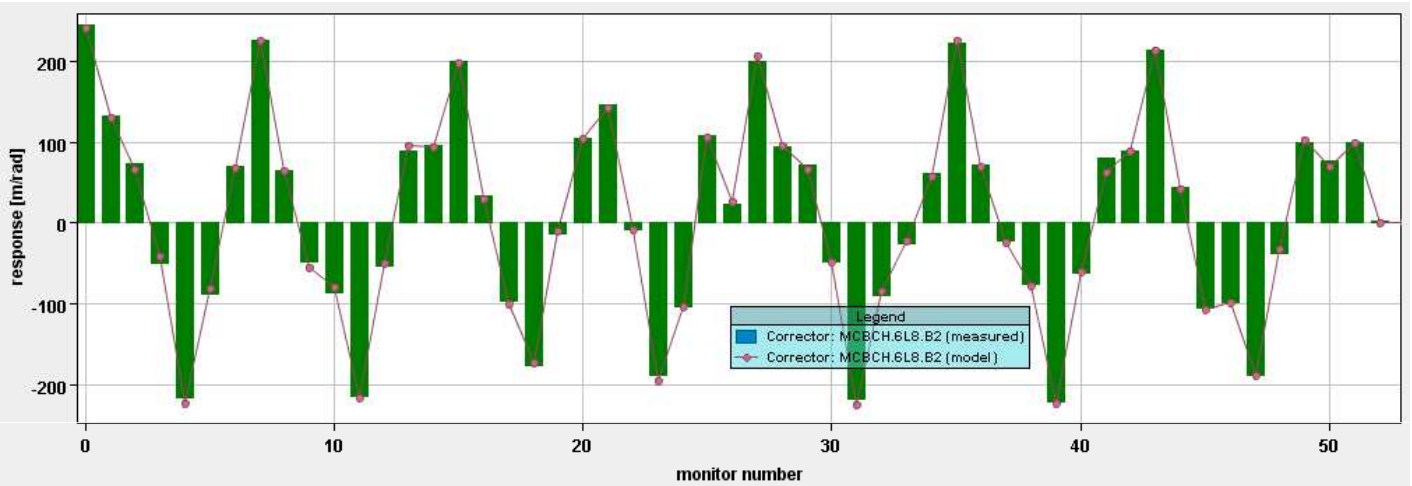


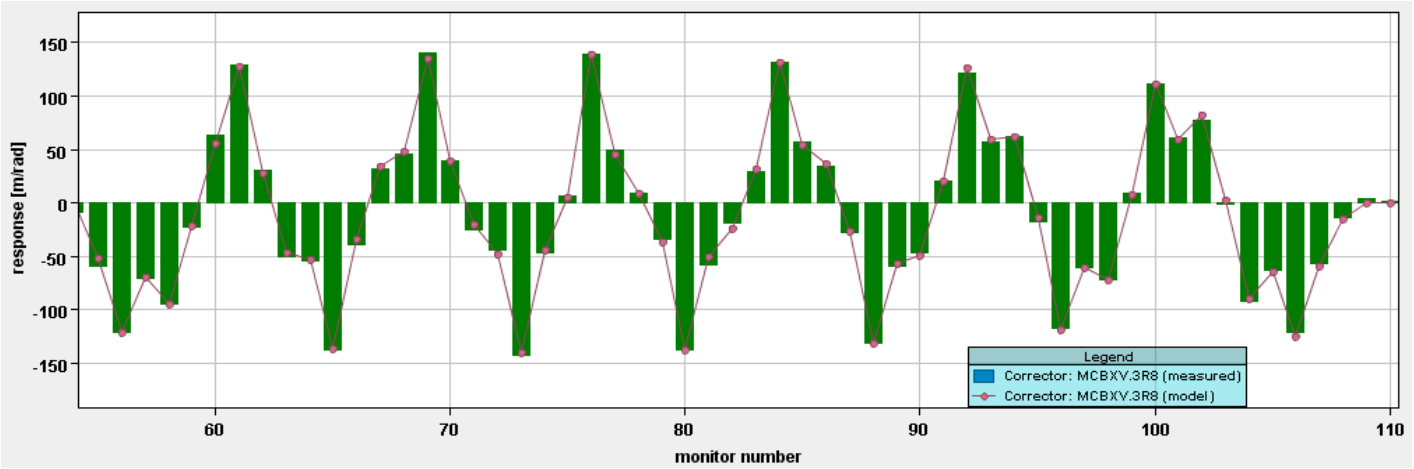

For example, vacuum valve assembly between MSI and Q5 found displaced & realigned – now looks good.

I.Agapov, B.Goddard, J.Uythoven, M.Meddahi, V.Mertens

# Optics S78 - Arc

## Systematic kick-response measurements

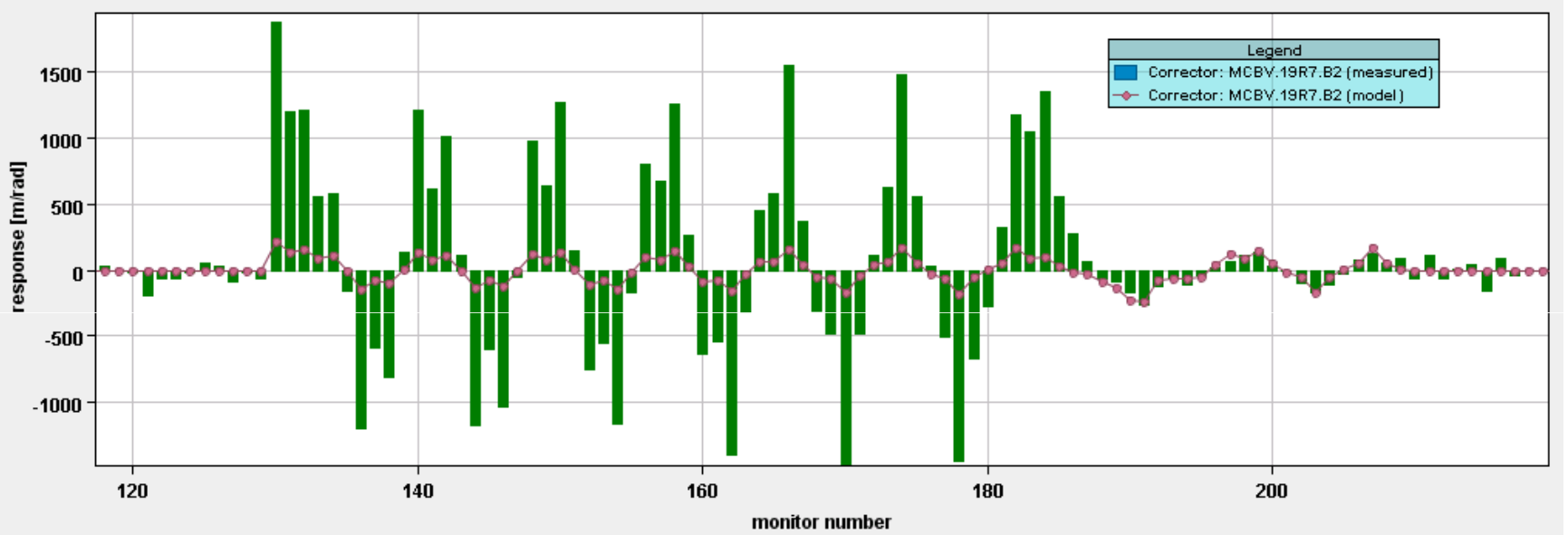



K. Fuchsberger / J. Wenninger

# Optics analysis

ALOHA – Java version implementation of LOCO kick-response analysis




For example, polarity of Q6 – point 7 – fixed very quickly!

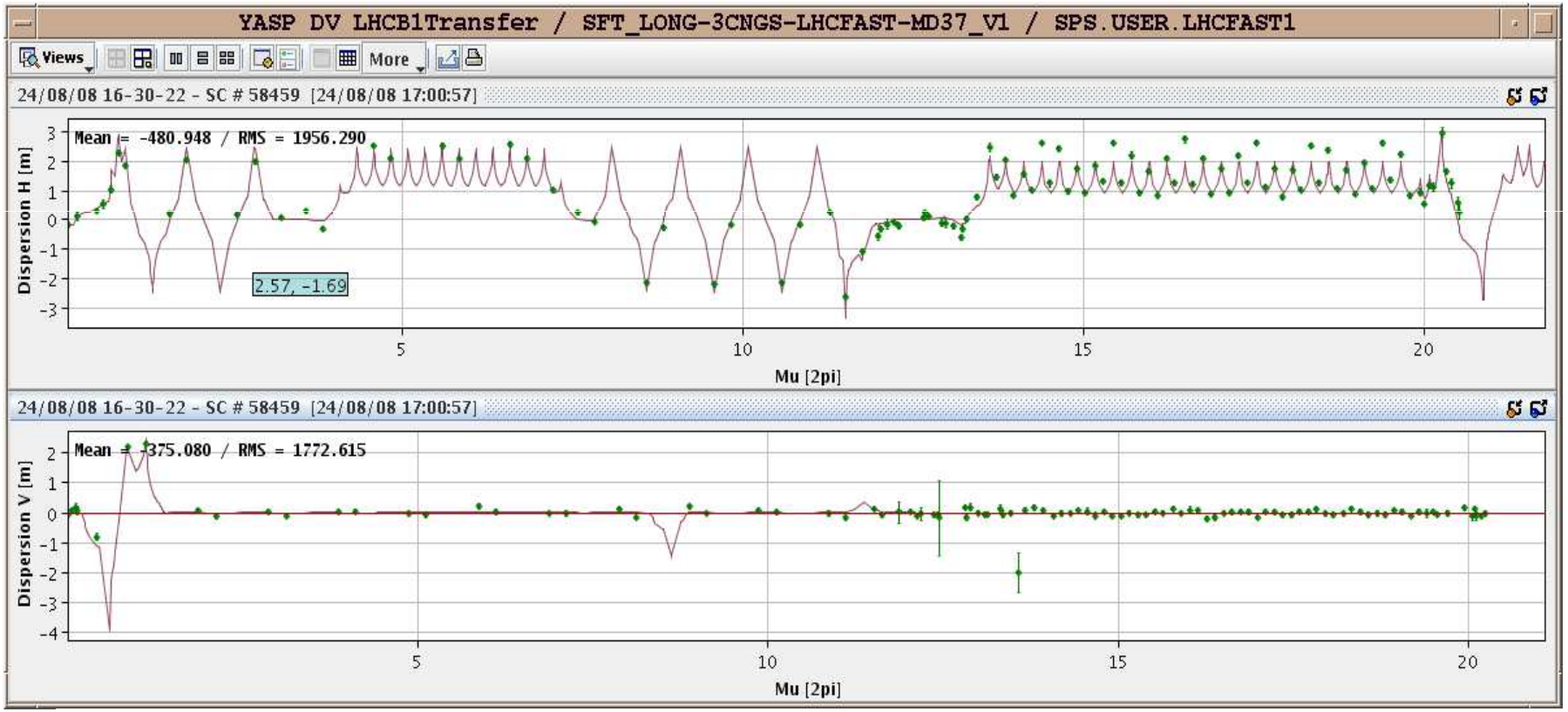
Kajetan Fuchsberger

# Dispersion measurements

Changes of polarity of the odd trim quads solved point 3 issue

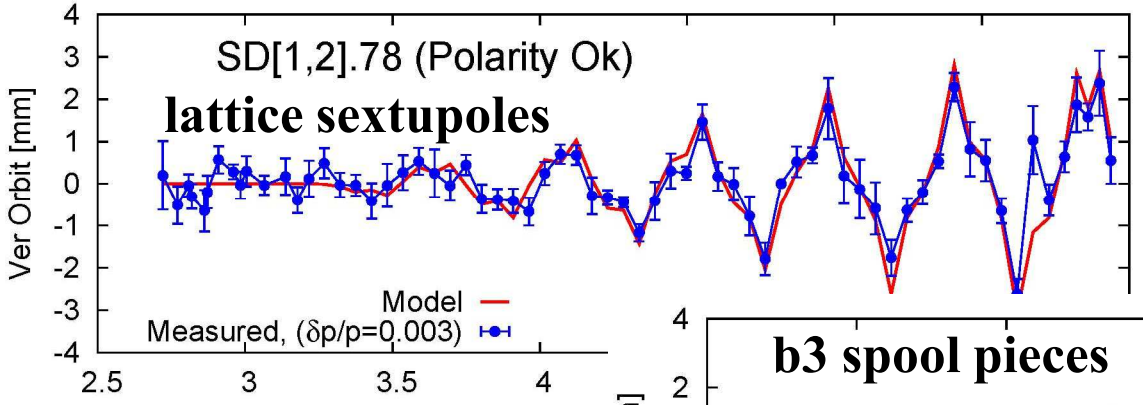
(Stephane Fartoukh)

Sector 23 - Results from weekend 23/24 of August

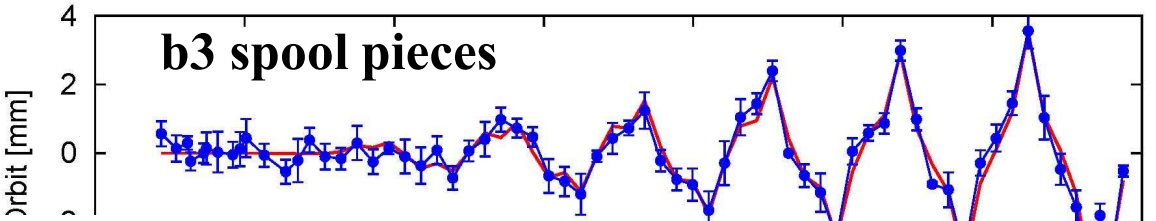


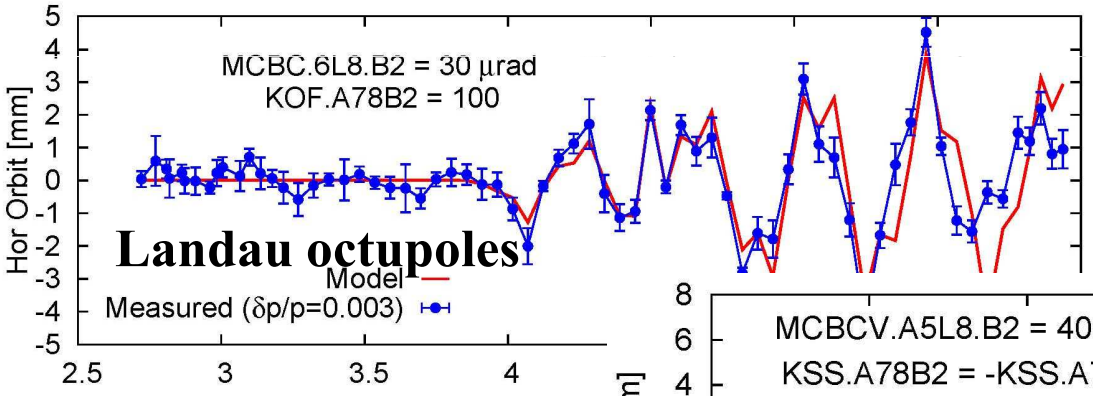

M.Meddahi, I.Agapov, B.Goddard, V.Kain, T.Risselada, V.Mertens et al

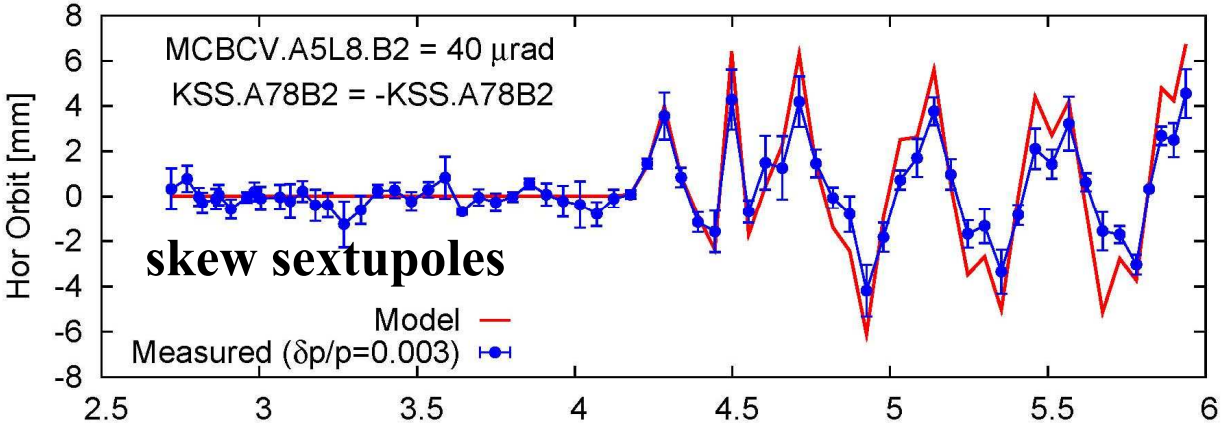
# Higher-order polarity checks




several polarity errors found

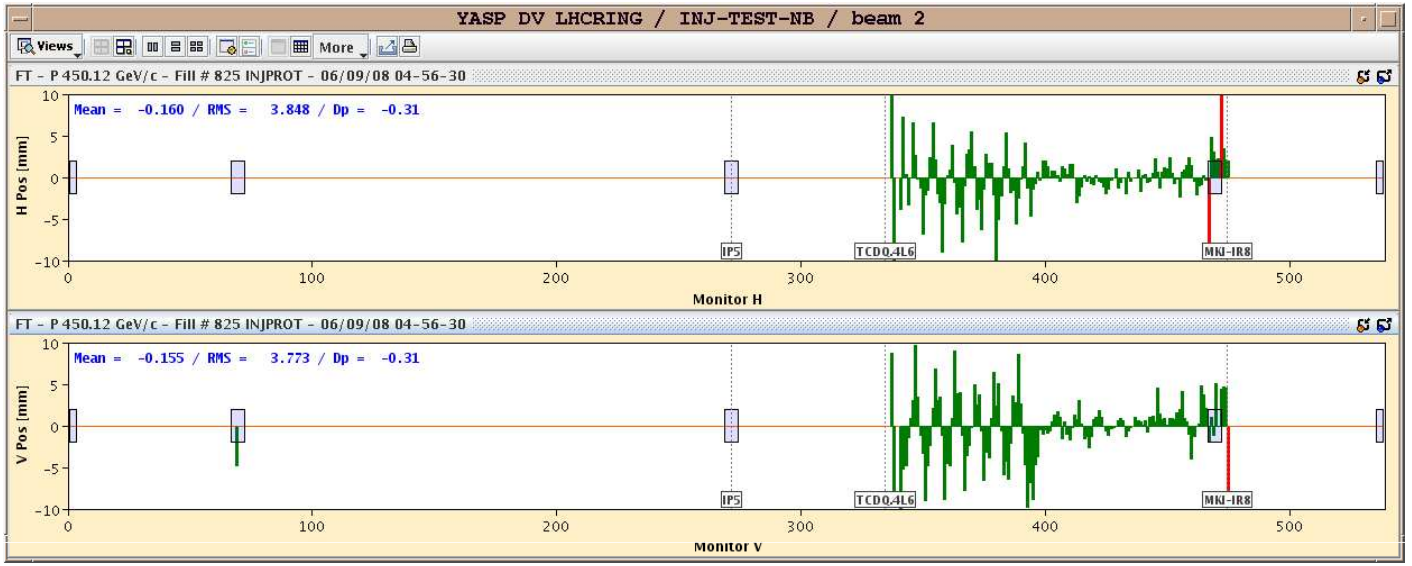


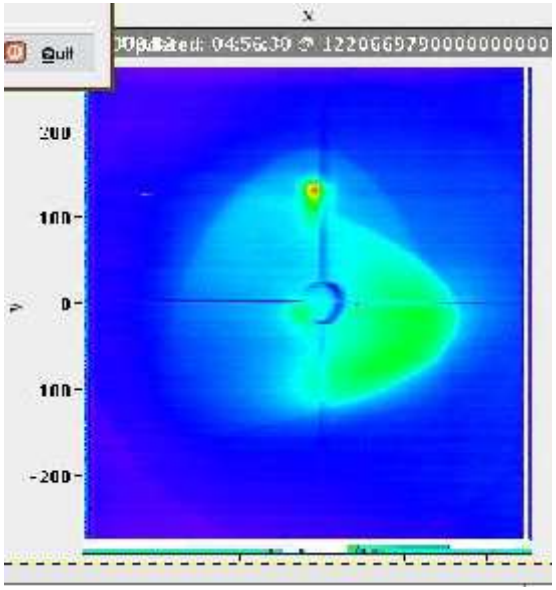



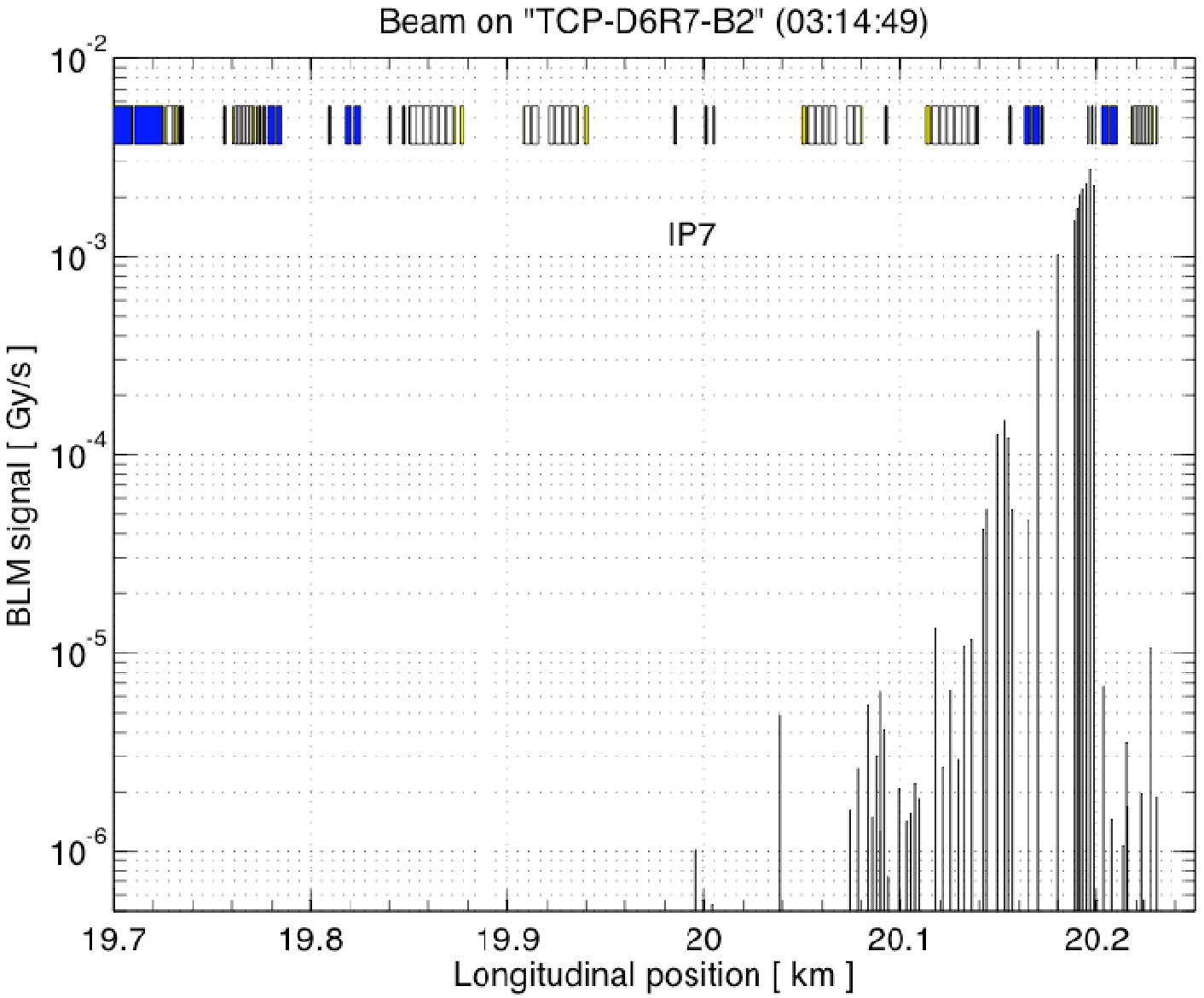

***sub-pilot-intensity single-pass measurements sufficiently sensitive to verify the polarity and the strength of (almost) all circuits!***

# Beam dump


YASP DV LHCRING / INJ-TEST-NB / beam 2
Views
More
FT - P 450.12 GeV/c - Fill # 825 INJPROT - 06/09/08 04-56-30
Mean = -0.160 / RMS = 3.848 / Dp = -0.31
H Pos [mm]
IP5
TCDQ.4L6
MKJ-IR8
Monitor H
FT - P 450.12 GeV/c - Fill # 825 INJPROT - 06/09/08 04-56-30
Mean = -0.155 / RMS = 3.773 / Dp = -0.31
V Pos [mm]
IP5
TCDQ.4L6
MKJ-IR8
Monitor V


Quit
200
100
0
-100
-200

# Beam Loss Maps - Collimators




Beam 2

# Conclusions 1/2

- Long term, painstaking preparation resolved a large number of issues:
  - System tests, dry runs, cold circuit tests etc…
- Important pre-cursors included:
  - Hardware commissioning & machine checkout
  - Access system qualification
  - Beam Interlock System deployment
- Important sub-systems were deployed and tested successfully with beam:
  - Controls, injection, RF, beam dump, machine protection, collimation, communication with experiments, magnet model, beam instrumentation

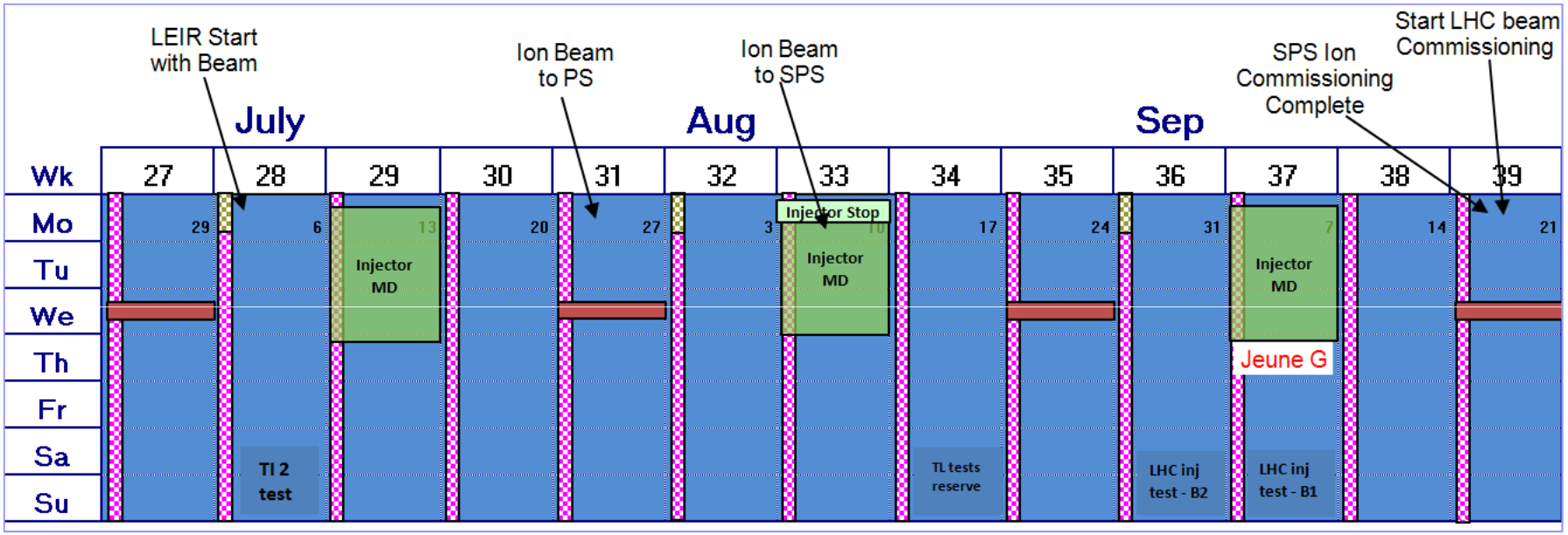
# Conclusions 2/2

- Beautiful set of measurements performed
  - Aperture, polarity checks, dispersion, kick-response optics checks
  - First quenches, beam loss maps…
  - Excellent performance of beam instrumentation
- Powerful analysis tools have allowed verification of:
  - Optics, magnetic model, magnet polarities..
  - Response of instrumentation to beam
  - Response of magnets to beam
- From a beam perspective, the LHC looks good (so far):
  - Alignment
  - Aperture
  - Field quality
  - Reproducibility
  - Stability

The tests acted as important milestones and…

# … led seamlessly into a interesting few days

# 2009




We look forward to doing it again later this year