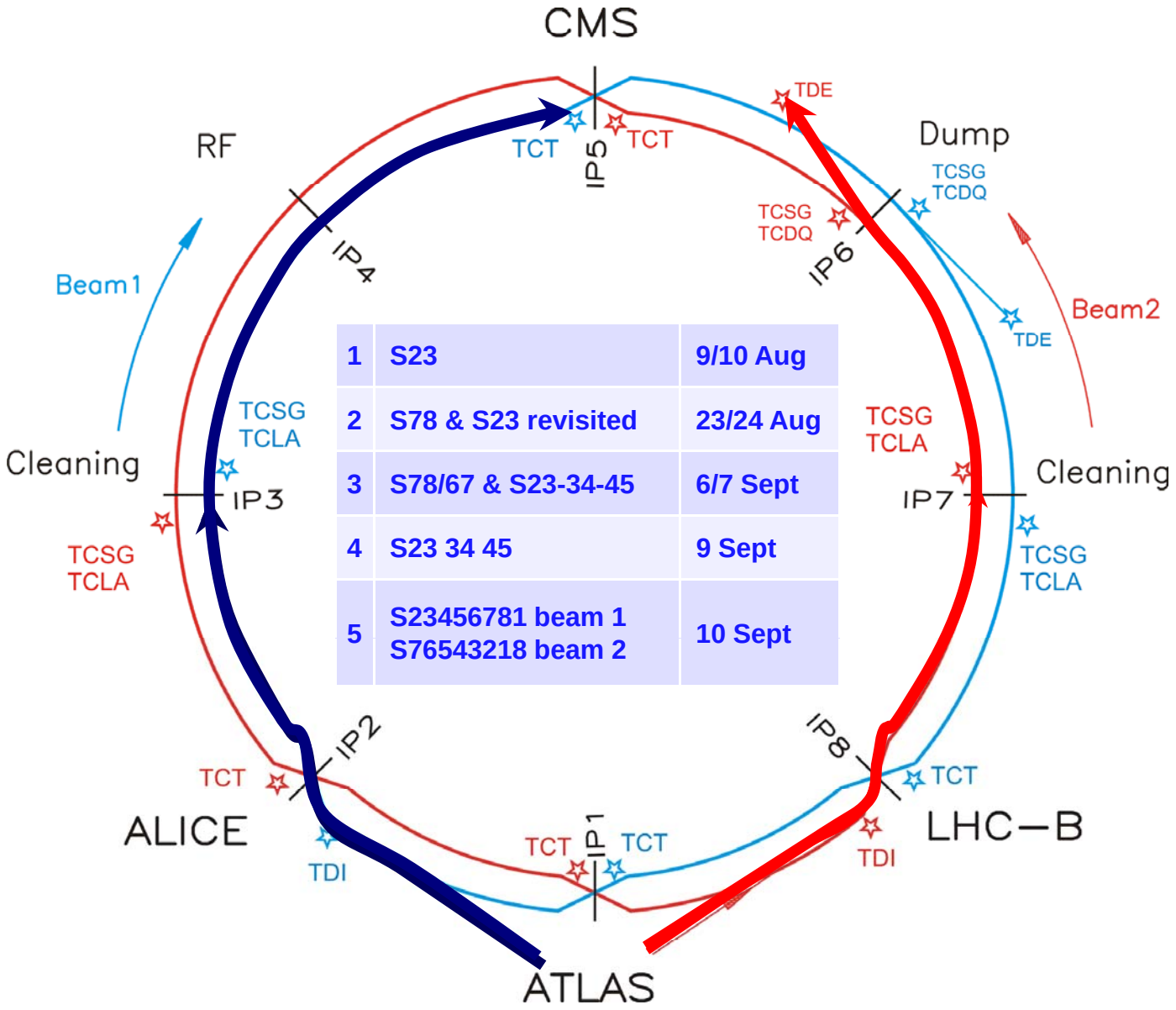
Session 7 - What did we learn with beam in 2008?

Injection tests	Verena Kain
Operational experience with circulating beam	Stefano Redaelli
Beam based measurements in 2008	Rogelio Tomas
Transfer lines and Injection: results from machine studies during beam commissioning	Malika Meddahi
Injection and Beam dump	Brennan Goddard
First Results from the LHC Beam Instrumentation Systems	Rhodri Jones
Controls & software	Eugenia Hatziangeli
First Field Test of FiDeL, the Magnetic Field Description for the LHC	Luca Bottura

Conveners: Mike Lamont & Stefano Redaelli

Injection tests

Verena Kain



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 S76543218 beam 2	10 Sept

Injection tests

Verena Kain

Remarkably useful exercise

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

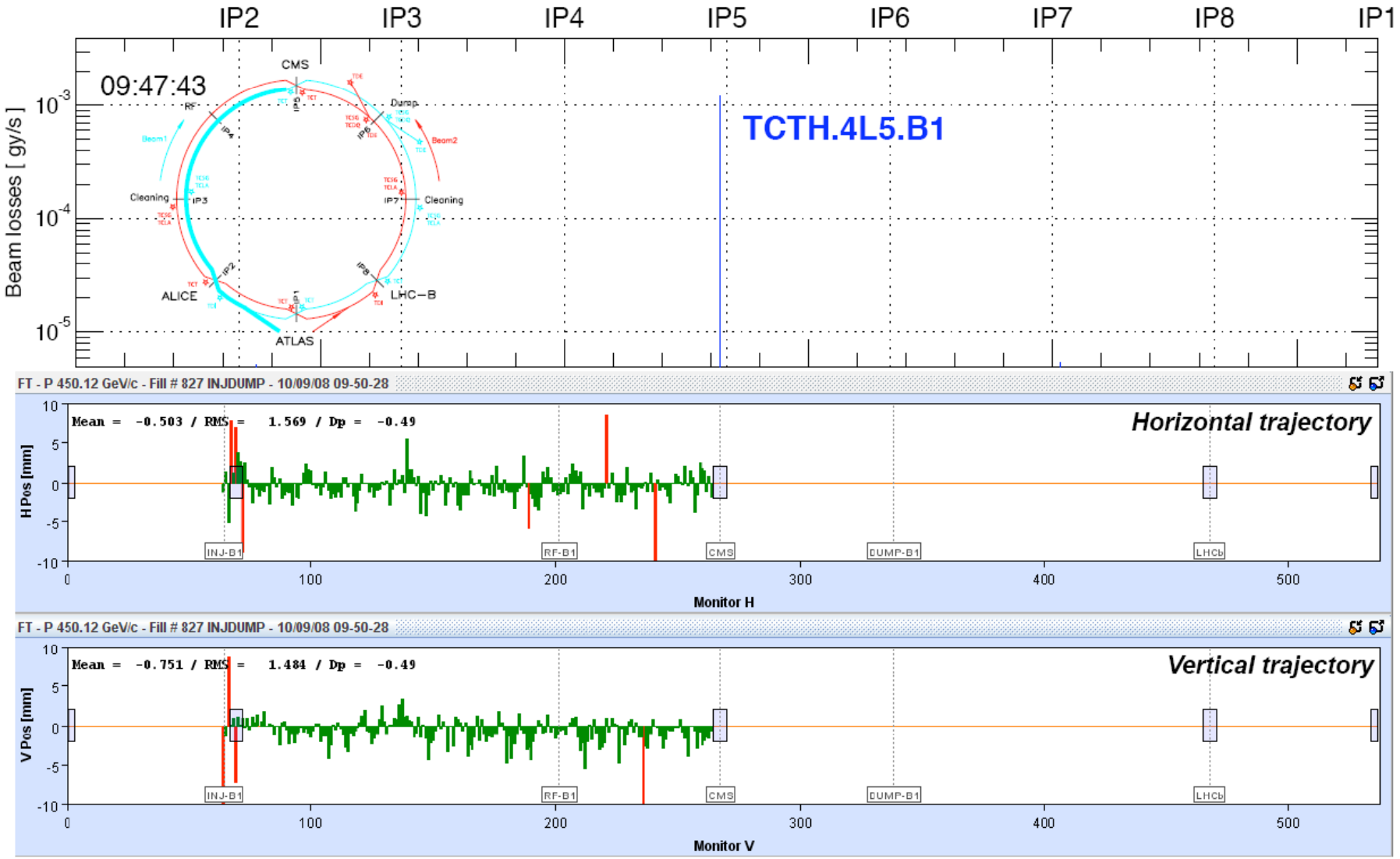
Injection tests

Verena Kain

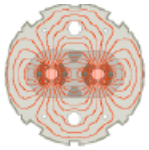
- Beautiful set of measurements performed
  - Aperture, polarity checks, dispersion, kick-response optics checks
  - First quenches, beam loss maps…
- From a beam perspective, the LHC looks good:
  - Alignment
  - Aperture
  - Field quality
  - Reproducibility
  - Stability
- Powerful analysis tools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

Led seamlessly to the first turn…

Example: Beam to CMS



Milestones of 60 hours of LHC beam



First turn!
10:26

TDI-B2 out
13:34

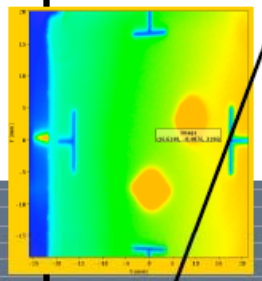
TDI-B1
out
09:35

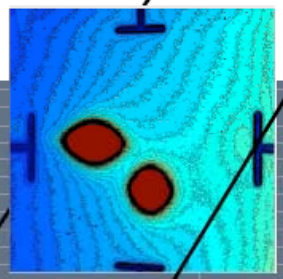
First turn!
14:59

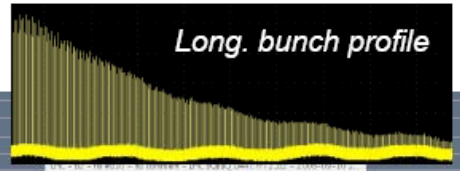
Circulating beam:
300+ turns
First tune meas.

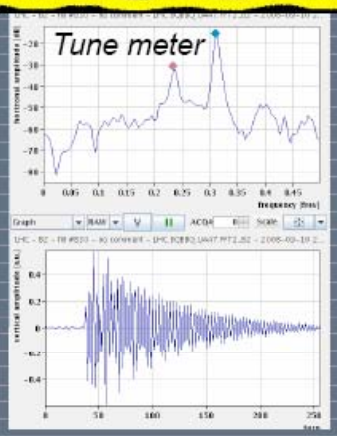
Beam captured!
Circulating>15min

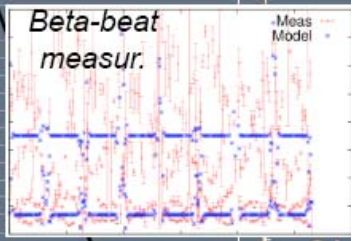
Detailed
measurements







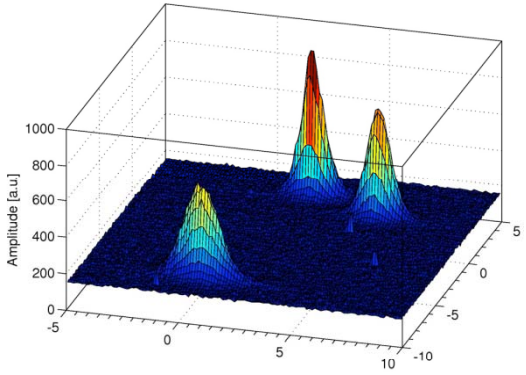


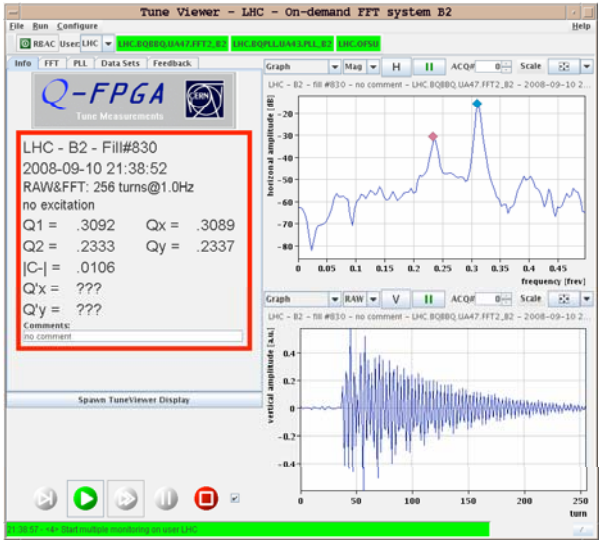


An early commissioning thrash

Stefano Redaelli

- Instrumentation commissioning
  - Screens, Beam Loss Monitors, Wire Scanners
  - Q meter, Beam Position Monitors, BCTs
- Measurements
  - Tune, coupling and chromaticity
  - Closed orbit
  - Beta beating and aperture
- RF
  - Capture, initial commissioning
  - RF settings and beam momentum
- Beam dump
  - including first emergency dump





Qx = 0.3803 / 0.3015 (nom = 0.2800)
Qy = 0.3066 / 0.2441 (nom = 0.3100)
Coupling ≈ 0.07 / 0.06 (uncorrected)
| Qx' | ≈ | Qy' | ≈ 30 units (preliminary)

Quite remarkable.

Beam based measurements

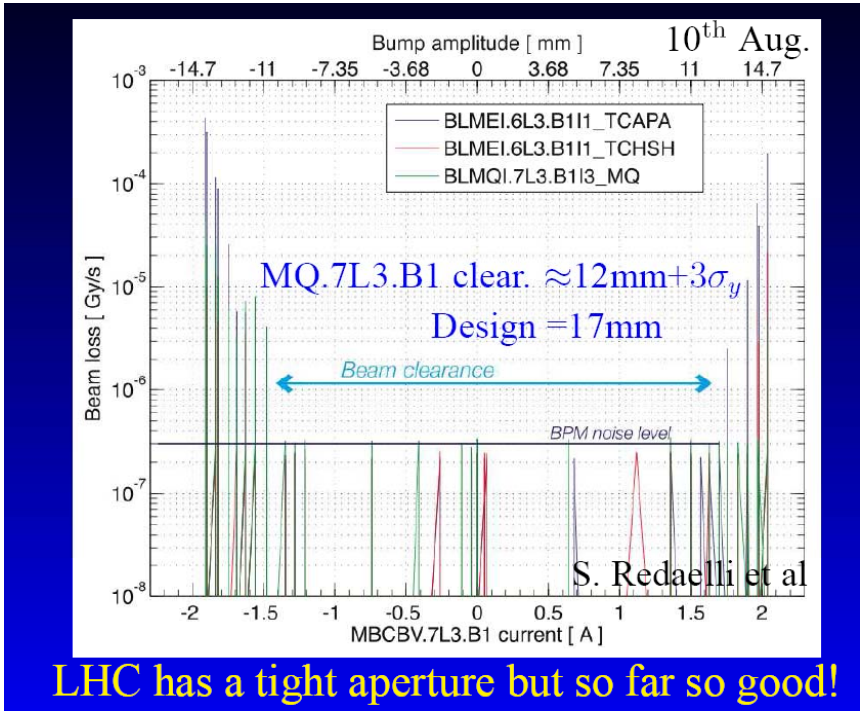
In-depth analysis performed given only minimal data

Powerful techniques have be implemented to help identify optics errors and possible aperture problems

- Aperture
  - Free betatron oscillation scans
  - Closed orbit bumps at specific locations
- Polarity checks
  - correctors, quads, higher order circuit
  - database & cabling errors
- Beta beating
- Coupling

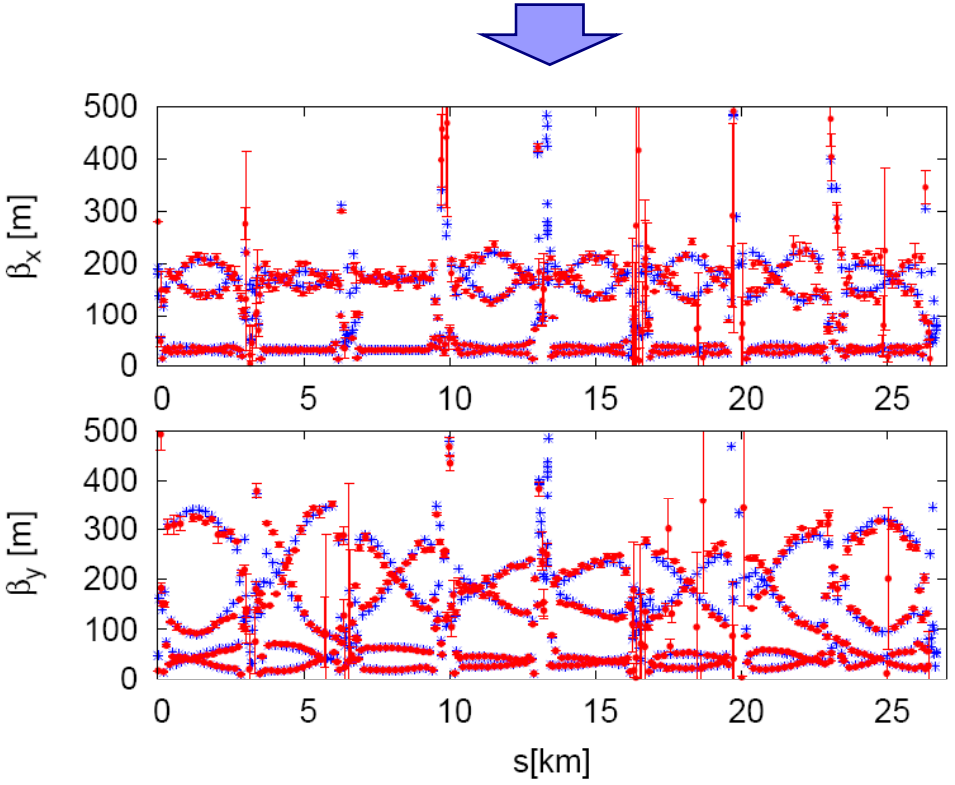
Rogelio Tomás Garcia

Beam based measurements - examples



Rogelio Tomás Garcia

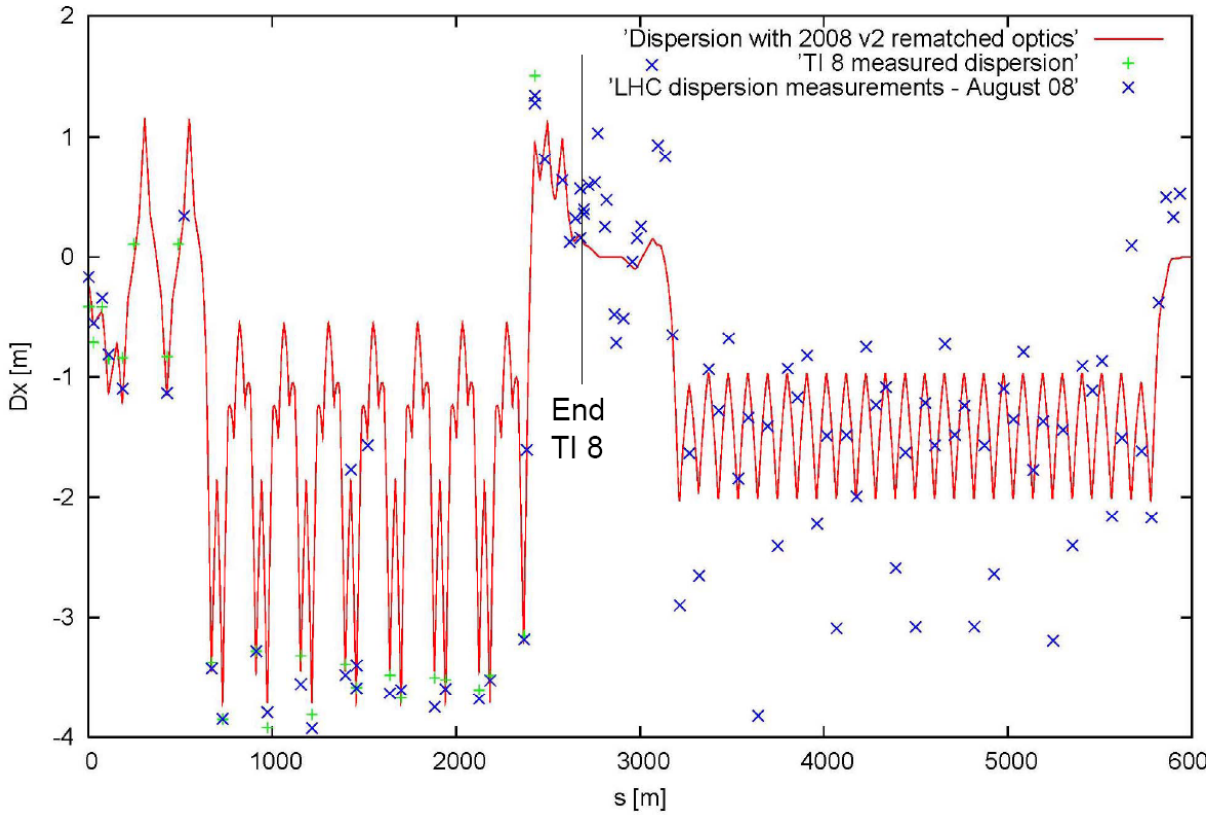
Beta beating measurements just with a single file with 90 turns



mqtli.7r3.b2 cabling problem identified via the segment-by-segment approach as the leading error of the machine

One problem – dispersion at end of TI 8

Spurious dispersion generated at the end of TI8 propagating into the LHC – would lead blow-up of injected beam if not resolved



- Very through checks performed of alignment and elements
- Alignment and corrector settings included in model
- Additional BPMs installed
- Dispersion free steering included in YASP
- Full TI 8 to LHC model to be used

Malika Meddahi

Injection system

Brennan Goddard

Critical system – damage potential of 450 GeV LHC beam well established

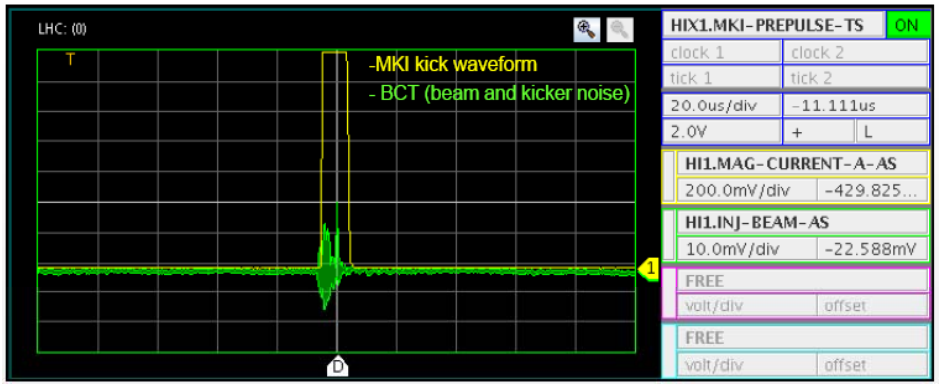
	Beam 1 (TI2/P2)	Beam 2 (TI8/P8)
Transfer line optics	OK	Still question of dispersion match
Injected beam aperture	OK (after vac. re-alignment)	OK
Kicker synchronisation	OK (rough)	OK (rough)
Injection element strengths	OK	OK
Beam instrumentation checks	OK	OK
Check injection stability	Started (data to evaluate)	OK
Interlocks	Started	Started
Circulating beam aperture	To do	To do (TDI moved in - OK)
Injection steering	To do	Started (rough)
Kicker waveform measurement	To do	To do
Detailed optics matching to LHC	To do	To do
Injection protection systems setup	To do	To do
Injecting onto Xing/sep bumps	To do	To do
Abort gap keeper	To do	To do

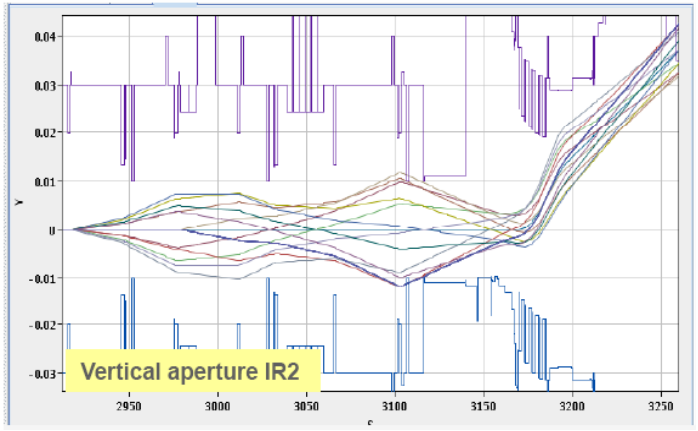
Maybe 40-50% through initial (pilot) beam commissioning

Injection System

Brennan Goddard

- MKI kicker strengths look perfect
- MSI septum strengths look perfect
- SPS extraction & LHC injection kicker timing-in worked fine
- Injection region aperture checks OK
  - except 10 mm vertical realignment of vacuum valve assembly
- Short-term (1 h) stability v. good at injection point
- Some concern about MKI flashovers with beam
  - strategy for operation to be established





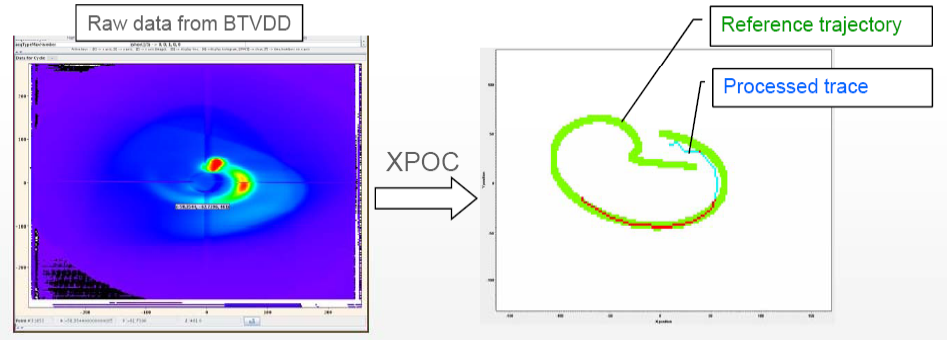
Beam Dump

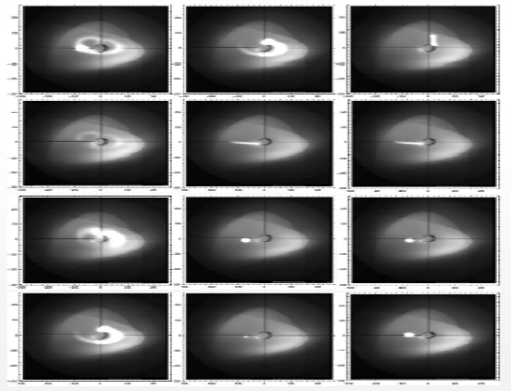
Brennan Goddard

Absolutely critical – painstaking tests must be performed

	Beam 1 (TD/UD68)	Beam 2 (TD/UD62)
Inject and dump setup	OK	OK
Circulate and dump setup	To do	OK
Dump region aperture	To do	Started (some phases)
Detailed kicker synchronisation	To do	To do
Extraction element strengths	Started (corrected MSD)	Started (corrected MSD)
Beam instrumentation checks	Started	Started
Interlocks (BPMSA, TCDQ, …)	To do	To do
Sweep waveform measurement	To do	To do (parasitic looks OK)
Dump protection systems setup	To do	To do
PM and XPOC	Started	Started
Tracking tests	Started (2 sectors only)	Started (2 sectors only)
Abort gap keeper	Started	Started

Maybe 10-20% through initial (pilot) beam commissioning





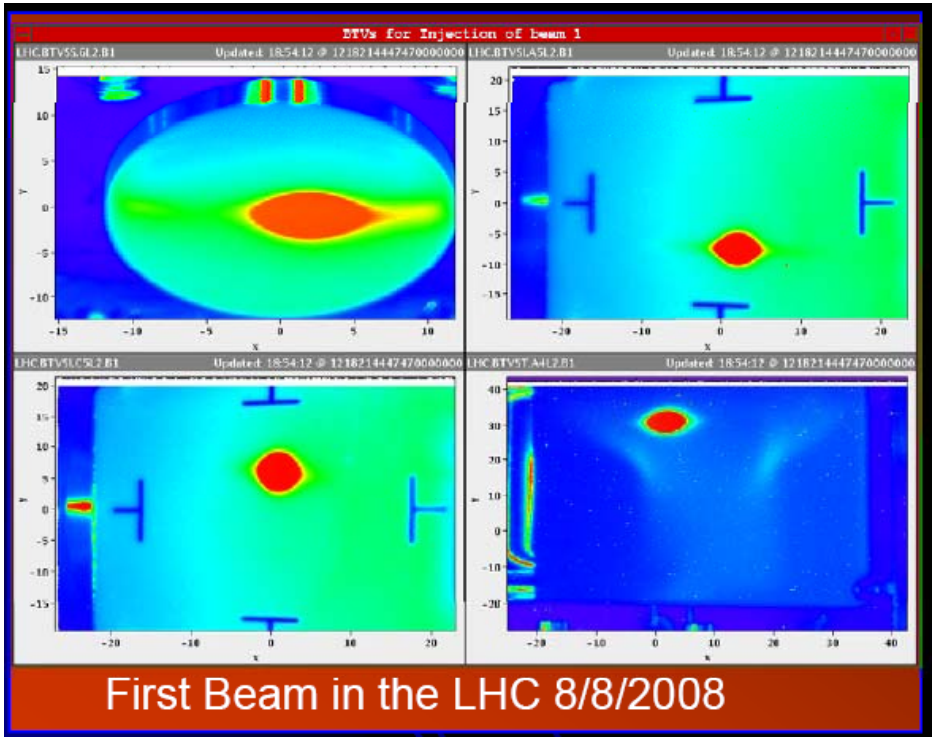
Beam Dump

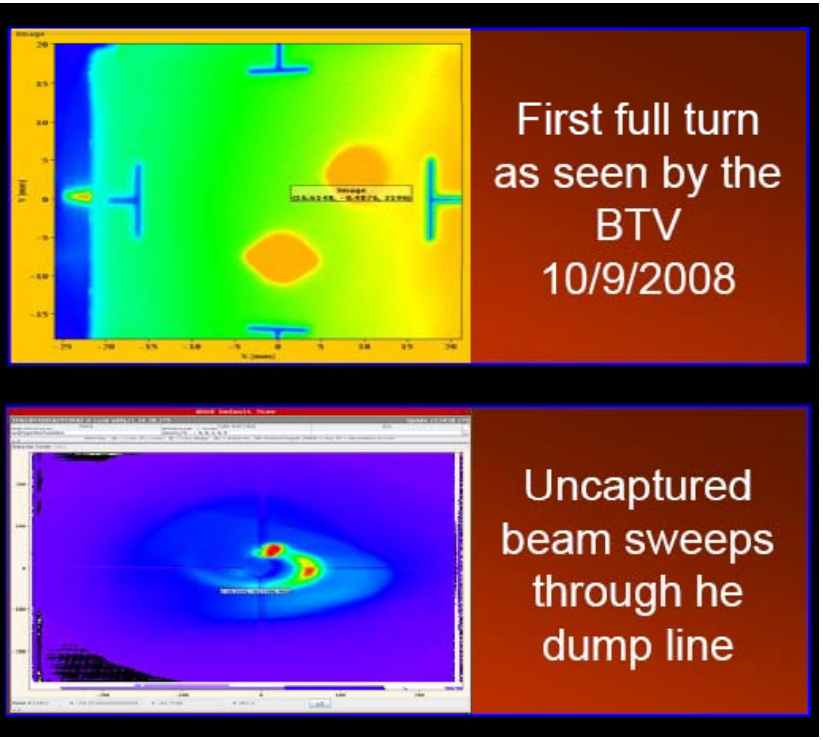
Brennan Goddard

- Dump element strengths and synchronization looks good
- Dump region aperture measurements
  - No obvious problems so far – and “loss free” extractions performed
- Dump diagnostics - XPOC Analysis – in good shape
- Sweep characterization and “asynchronous” dumps
  - rogues gallery collected, work in progress
- Sequencing and special machine modes
  - worked well
- Some operational aspects to be addressed
  - **complicated systems with a lot of dependencies**
- Still a lot to do
  - **transfer line and injection beam tests in 2009** will speed up ring beam commissioning

Great start

Thanks to years of planning, testing & HW commissioning within the BI Group, with the help of many other Groups & external collaborators

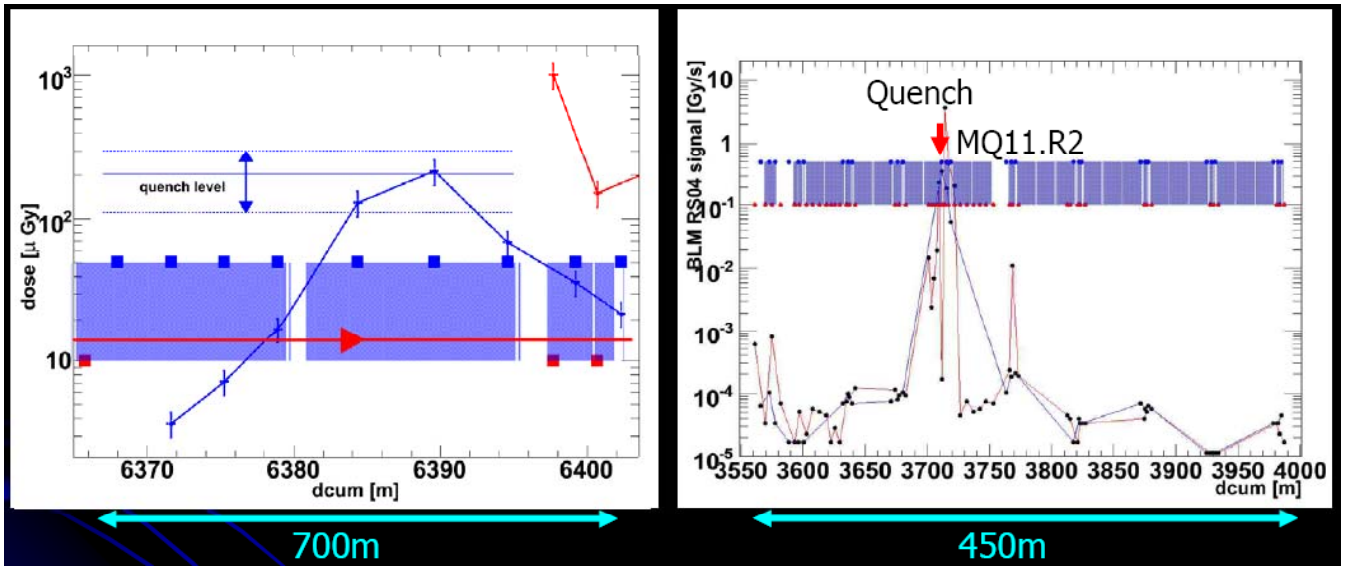




Beam Loss Monitors

Rhodri Jones

- Worked well from first injection tests
  - Logging issues (linked to data rates) sorted out early on
  - Data concentration
    - on-demand capture & continuous monitoring tested
- 2009 sees hardware re-installation & modifications, software and FPGA extensions

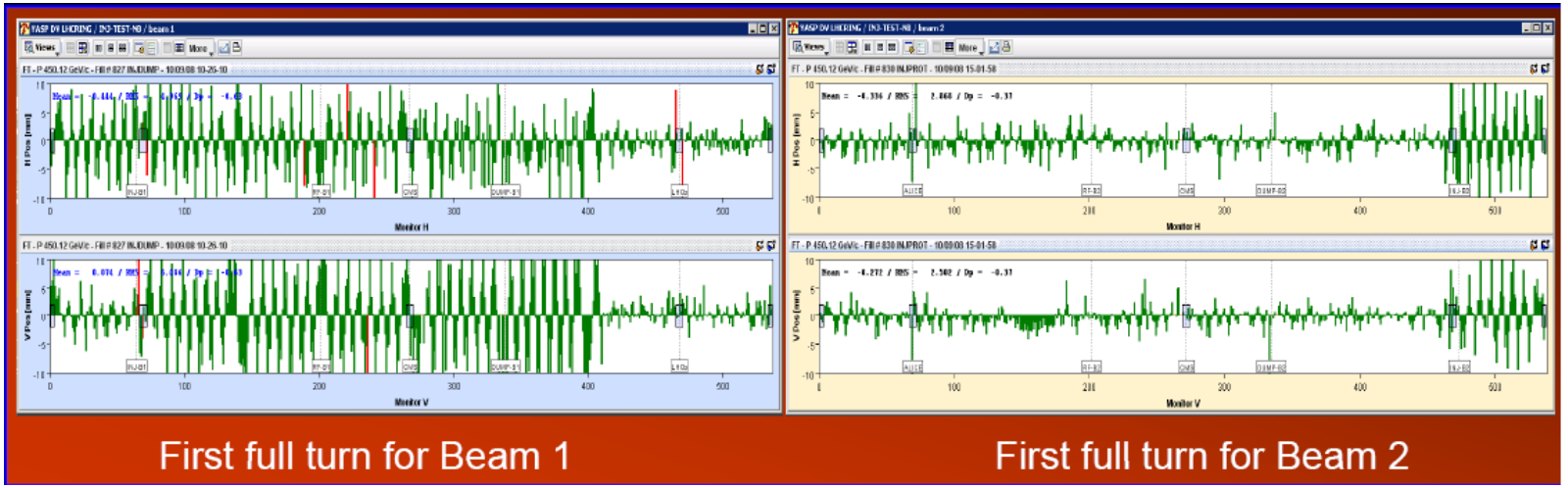


2 beam induced triggers of quench protection system during injection tests

Beam Position Monitors

Rhodri Jones

- Asynchronous bunch by bunch (FIFO) mode
  - Used for threading & first few 100 turns
  - Worked first time on both beams for injection tests & on 10th September
- Asynchronous orbit mode
  - Provided filtered data for 1Hz orbit update to YASP & feedback controller
  - Routed full turn for Beam 1, first full turn Beam 2
  - Worked as soon as beam was circulating for more than a few seconds

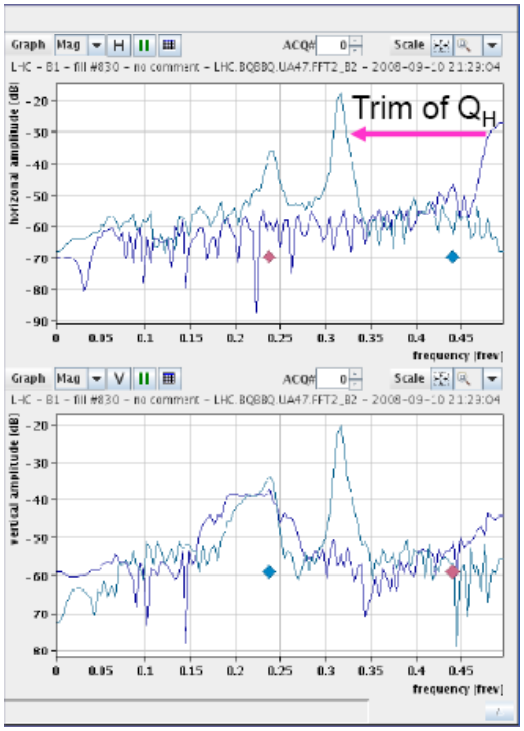


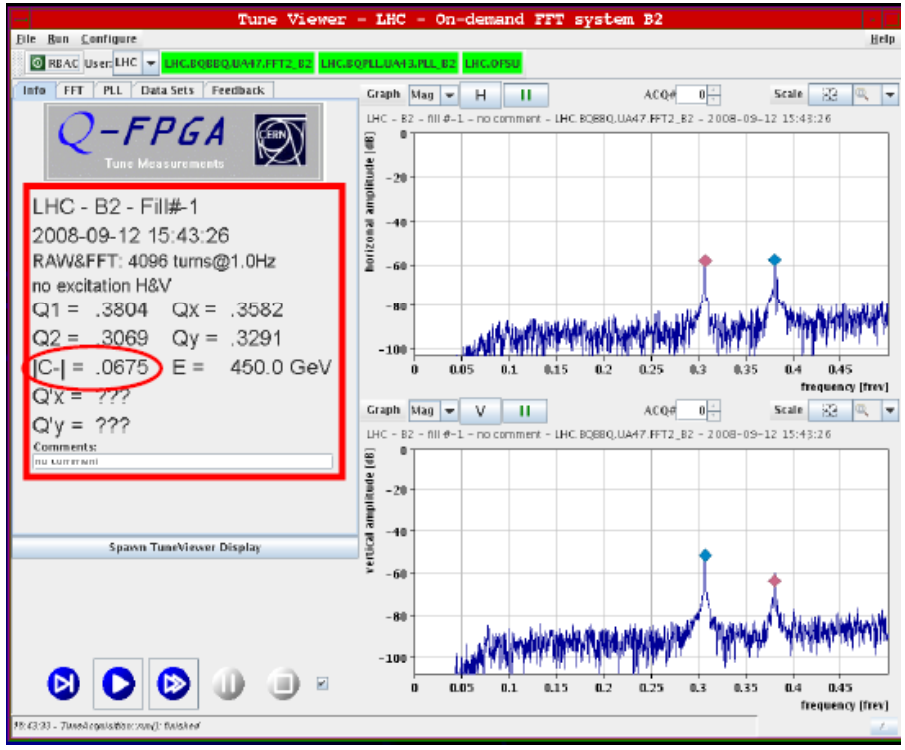
Under pinning most optics and aperture measurements

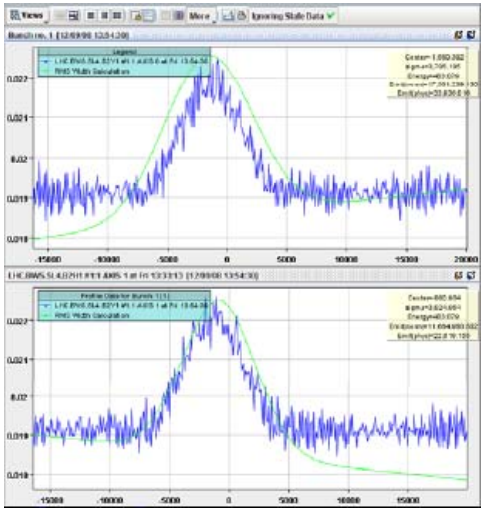
BI - also commissioned

Rhodri Jones

- BBQ Tune Measurement Systems
- BBQ Tune On-Demand system
- BCTs
- Wire scanner







BI – to do

Rhodri Jones

- Next Steps - still a lot to do!
  - Main Shutdown Work
    - BPM & BLM consolidation with considerable dismounting & remounting
  - Improvements to the synchrotron light monitor optical layout
  - Installation of US-LARP luminosity monitors (fast ionization chambers)

- Commissioning in 2009
  - Full (re)commissioning of the already tested systems
  - Systematic measurements & fine timing
  - Commissioning of:
    - Synchrotron light monitor, abort gap monitor, Tune Q' modulation
    - PLL measurement & Q with RF
    - Orbit, tune, coupling and chromaticity feedback systems
    - Schottky & finally Luminosity monitors!

Controls

Eugenia Hatziangeli

- Testing essential
  - Infrastructure & components, individual systems, full scale integration tests
- Component deployment on other machines as precursor
  - Sequencer, Software Interlock system, fixed displays, alarms, analog acquisition…
- Timing and synchronization
  - Complex, de-bugged successfully during injection tests
- Logging
  - Terrific through-put, hardware, CPU, software upgrades required, but generally successful in deal with huge volumes of data
- Middleware
  - CMW/JMS: many issues resolved

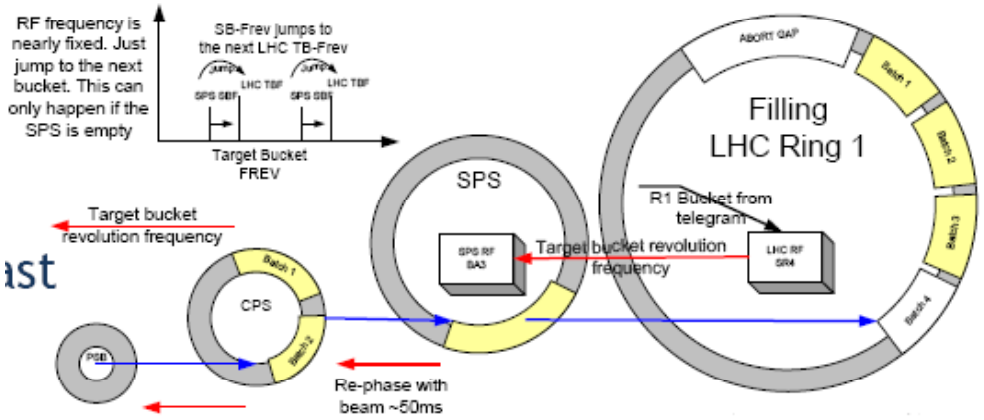
Controls

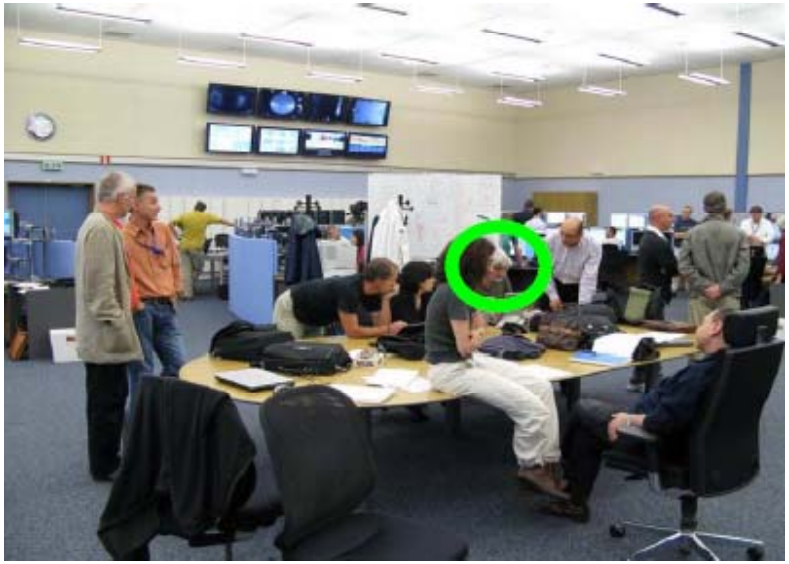
Eugenia Hatziangeli

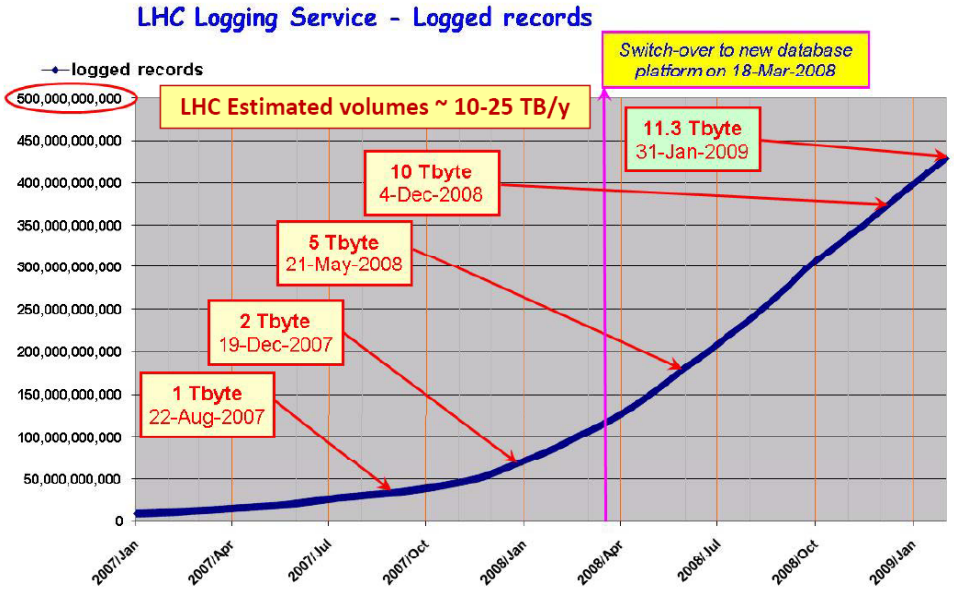
- LSA – core software
  - Machine settings management, magnet model, interfaces to equipment and instrumentation, machine cycle etc. etc. Worked well.
- Role Based Access Control (RBAC)
  - Prevent unauthorized access to LHC equipment and instrumentation - successfully deployed
- 2009
  - Same again and more…
  - Need to (re)deploy existing and new functionality
  - **Test, test, test.**

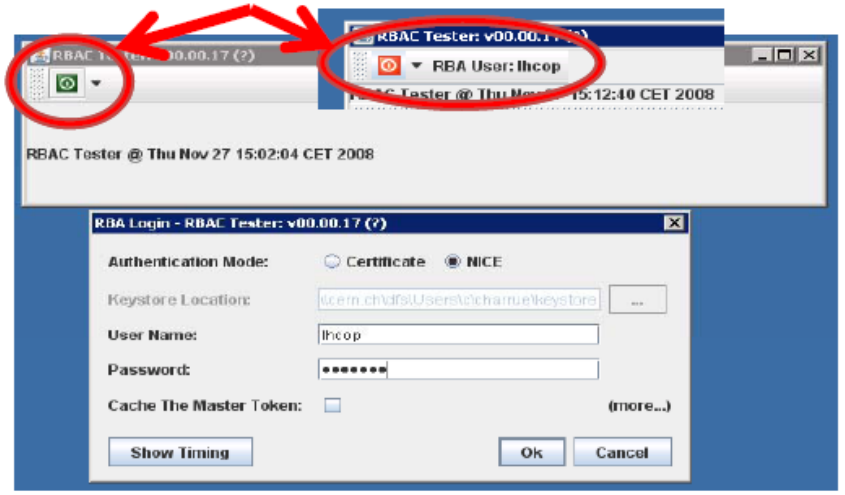
Controls

Eugenia Hatziangeli









Note power and flexibility, modern software development environment, databases, FPGAs …

Fast turnaround on problems

FIDEL

- FIDEL provides
  - Full-blown transfer function model for main magnets
  - Simplified transfer function model for correctors (linear + saturation)
  - Full-blown b3, b5 errors for the MB's (static + dynamic)
- On a circuit-by-circuit basis

FiDeL is an integral part of the LHC controls (LSA)

To the best of our knowledge this is the **most advanced model of the magnetic field in an accelerator magnet**, based on most recent advances in the physical understanding and the largest measurement database ever available

FIDEL

Luca Bottura

- Luca looked at:
  - Momentum, tune, coupling, beta beating, chromaticity and compared beam measurements with predictions
  - …
  - And concluded…

We are in the right ball park for all settings!

Non-nominal cycles are most likely the reason for the reproducibility issues observed.

The work is not over

- Complete this review of the results (**beam vs. expected**)
- Create a **database of reference data** and model parameters. Document. *Tidy-up and check, check, check…*
- **The ramp !!!** Verify settings, check tracking, try on dry-runs
- Tidy-up optics, revise settings and iterate on model, especially for **insertion quadrupoles** (MQM, MQY), and **trims** (MQT, MQWB)
- Complete **cycling prescriptions**, *indoctrinate operators*
- New data (**measurements**) of magnets where we expect issues such as MQM, MQY, MQT, MQW, simulate trim and squeeze
- Consolidate the **FiDeL support team**, by maintaining a *sensitivity to values of the order of 1 unit*

Conclusions

- Preparation, testing and beam based milestones are important.
- We have a beautiful machine.
- There is still a lot to do.
- Carefully.

Acknowledgements