LHC Utilities & Facilities

WAO 2010 - Daejeong

12/04 – 16/04/2010

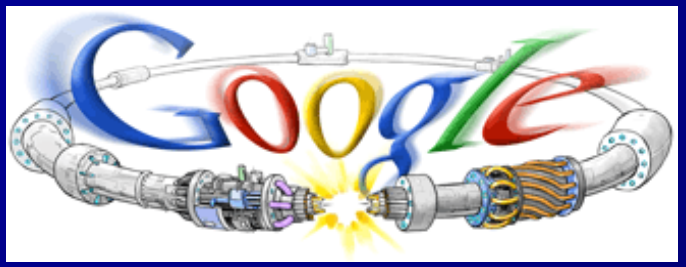
Markus Albert on behalf of LHC Operations

Outline

- Introduction
- LHC Software Architecture
- LHC Sequencer
- LHC Beam Instrumentation & Applications
- Summary

Major Milestones

B1: First turn in 1h



B2: First turn in 1h30

10/09 First beam

20/11 Restart with beam

28/02 Circulating beam

19/03 beams @ 3.5TeV

30/03 first collisions @ 3.5TeV

19/09 Breakdown in S34

Repair & consolidation

Beam operation @ 3.5 TeV per beam
Longest CERN run ever !

LHC parameters

Quantity	number
Circumference	26.659 m
Operating temperature	1.9 K (-271.3 °C)
Number of magnets	9593
Number of main dipoles	1232
Number of main quadrupoles	392
Number of RF cavities	8 per beam
Nominal energy, protons	7 TeV
Nominal energy, ions	2.76 TeV/u
Peak magnetic dipole field	8.33 T
Min. distance between bunches	~7m
Design Luminosity	10^{34} $cm^{-2}s^{-1}$
Number of bunches per p+ beam	2808
Number of protons per bunch (@ start)	1.1×10^{11}
Number of turns per second	11245
Number of collisions per second	600 million

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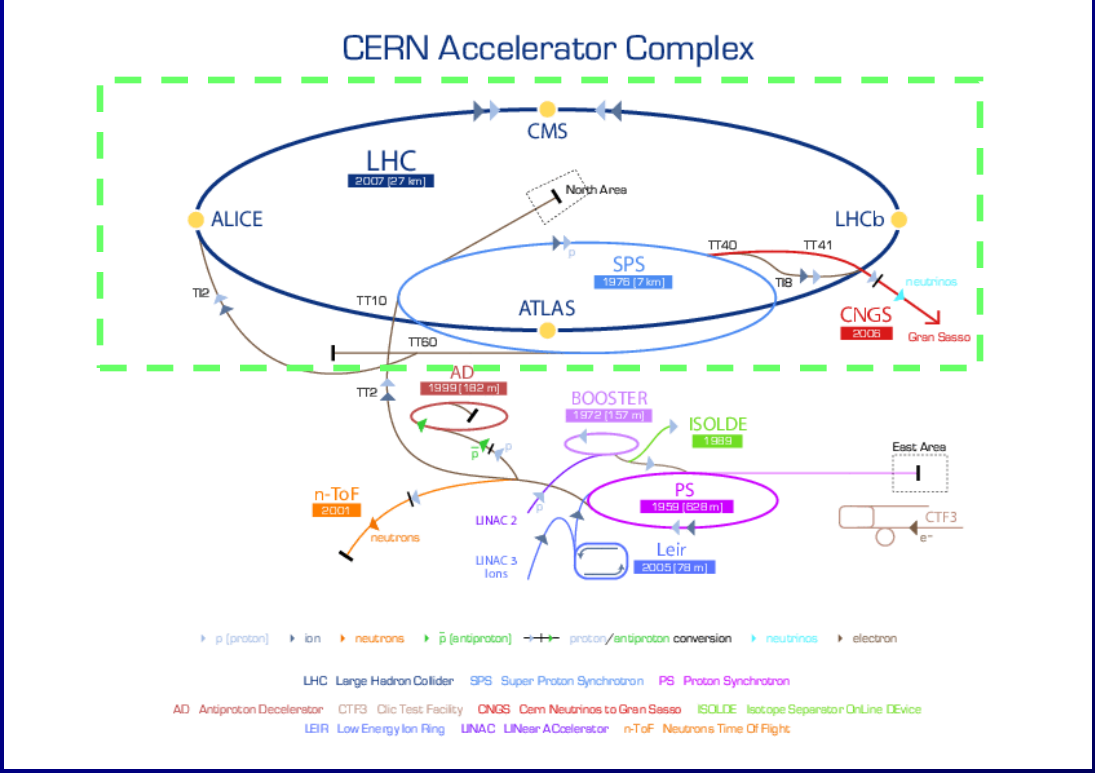
LHC Software Architecture



- Homogeneous software suite to operate LEIR, SPS and its transfer lines and the LHC
- Project shared between controls and operations
- Entirely written in Java

LSA

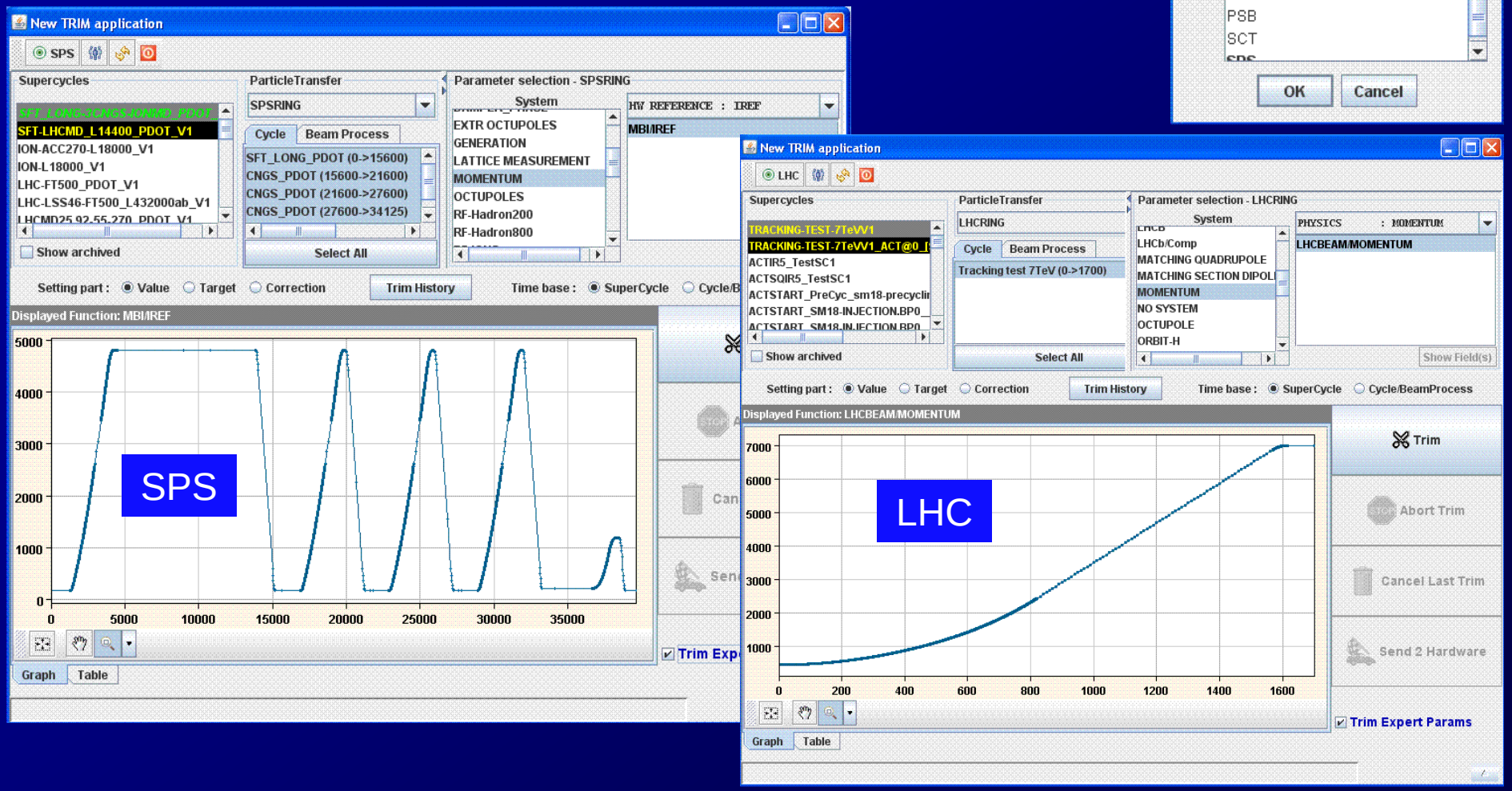
- 2001 : development started in
  motivation: replacement of old SPS control system
- 2005 : included LEIR
- 2006 : successfully introduced @ SPS
  (after 18 months of shutdown !)
- 2008 : LHC start – up
- Ongoing: adaptation to PS

LSA covers

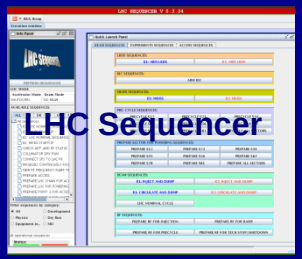
- Optics
  - Information about all devices
  - Machine layout
  - Twiss parameters
- Settings generation
  - Generation of initial settings based on optics
- Settings management & trim
  - Management of values for all parameters
  - Coherent modifications
  - History of changes and rollback
  - Incorporation of LHC actual settings (scalar settings) into ramp functions
- Hardware exploitation
  - Equipment control
  - Sending settings to the hardware
- Services to handle LHC timing events
  - Creation, modification
  - Loading to and unloading from the Timing System
- Equipment & beam measurements

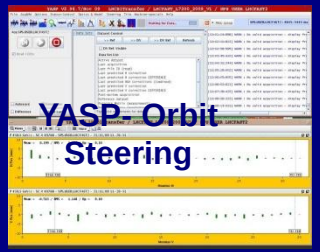
Generic applications

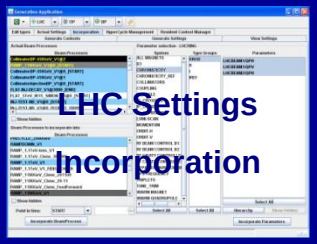
Data model & business logic are common for all accelerators
→ we can reuse applications

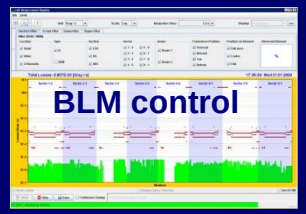


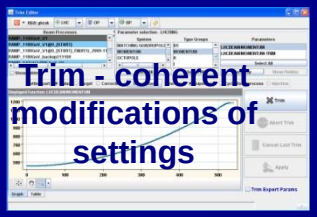

Equipment state control


LHC Sequencer

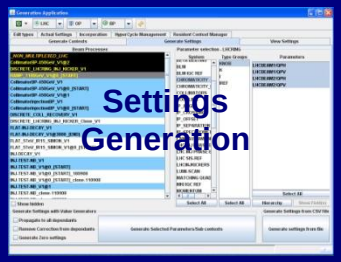

YASP- Orbit Steering


LHC Settings Incorporation

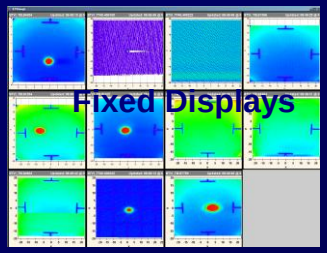

BLM control


Trim - coherent modifications of settings


SIS


Settings Generation


LSA


Fixed Displays

~40 GUI applications depending on LSA

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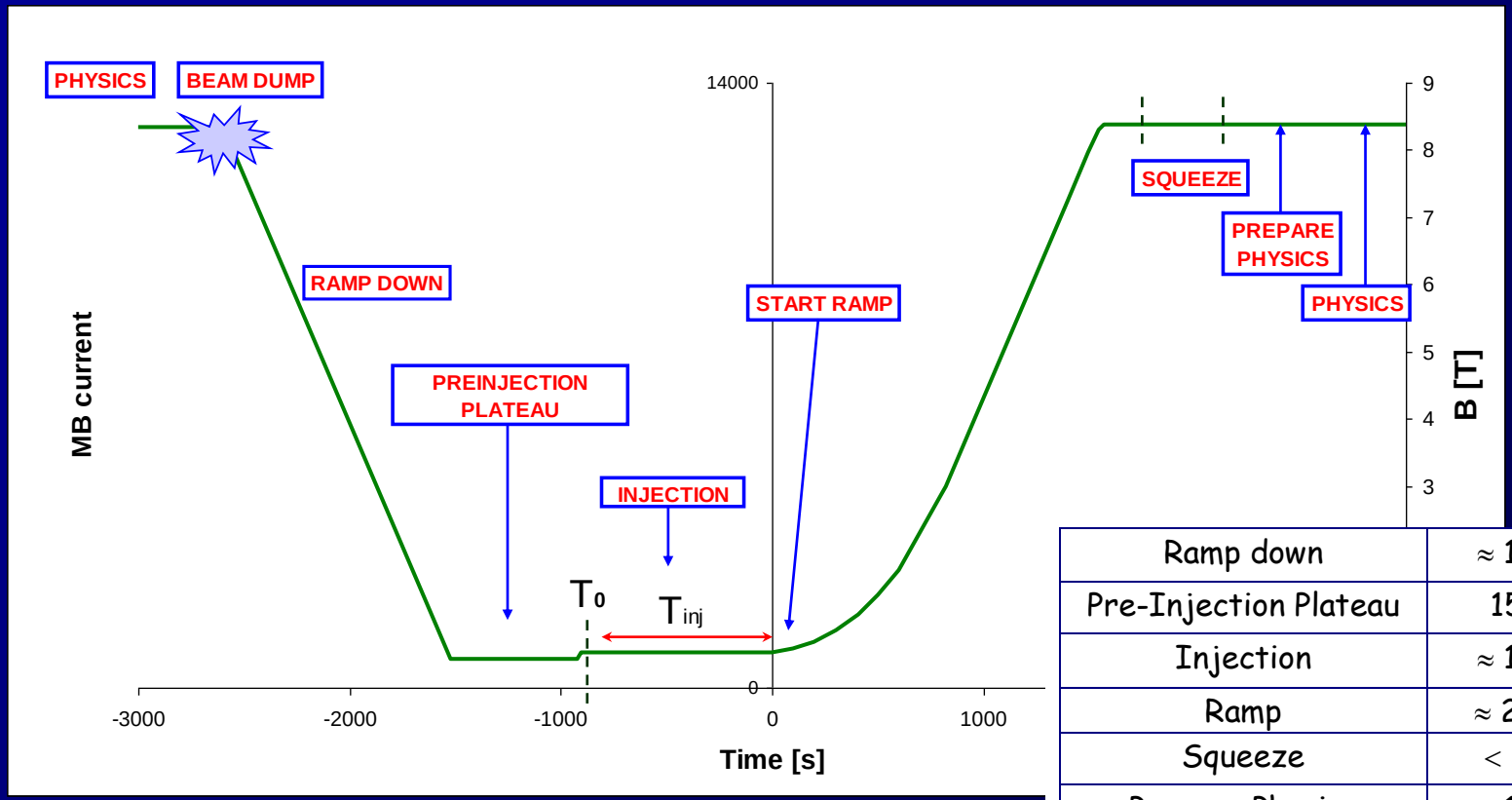
The LHC Sequencer

Application to drive the LHC through its duty cycle

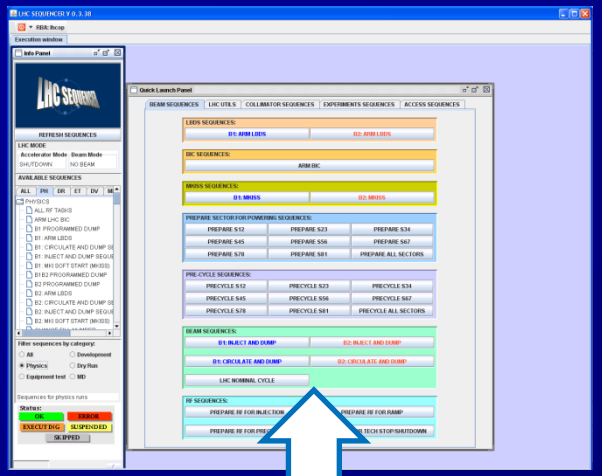


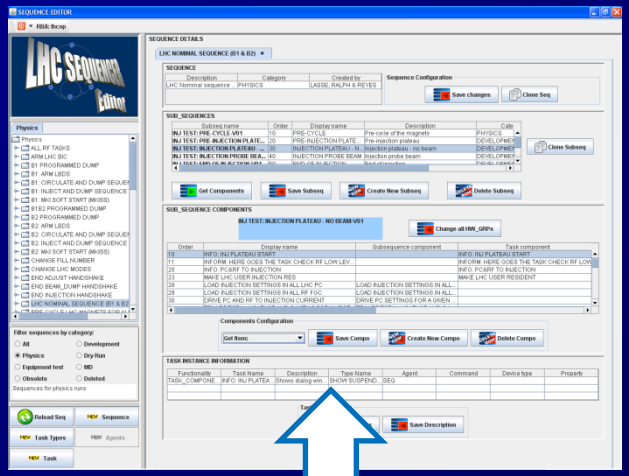
Ramp down	≈ 18 Mins
Pre-Injection Plateau	15 Mins
Injection	≈ 15 Mins
Ramp	≈ 28 Mins
Squeeze	< 5 Mins
Prepare Physics	≈ 10 Mins
Physics	10 - 20 Hrs

LHC Sequencer - Architecture

Editor GUI

Execution GUI





Beam interlock

Sequencer Core (Java)

DB (Oracle)

Sequences

Power converters

Collimators

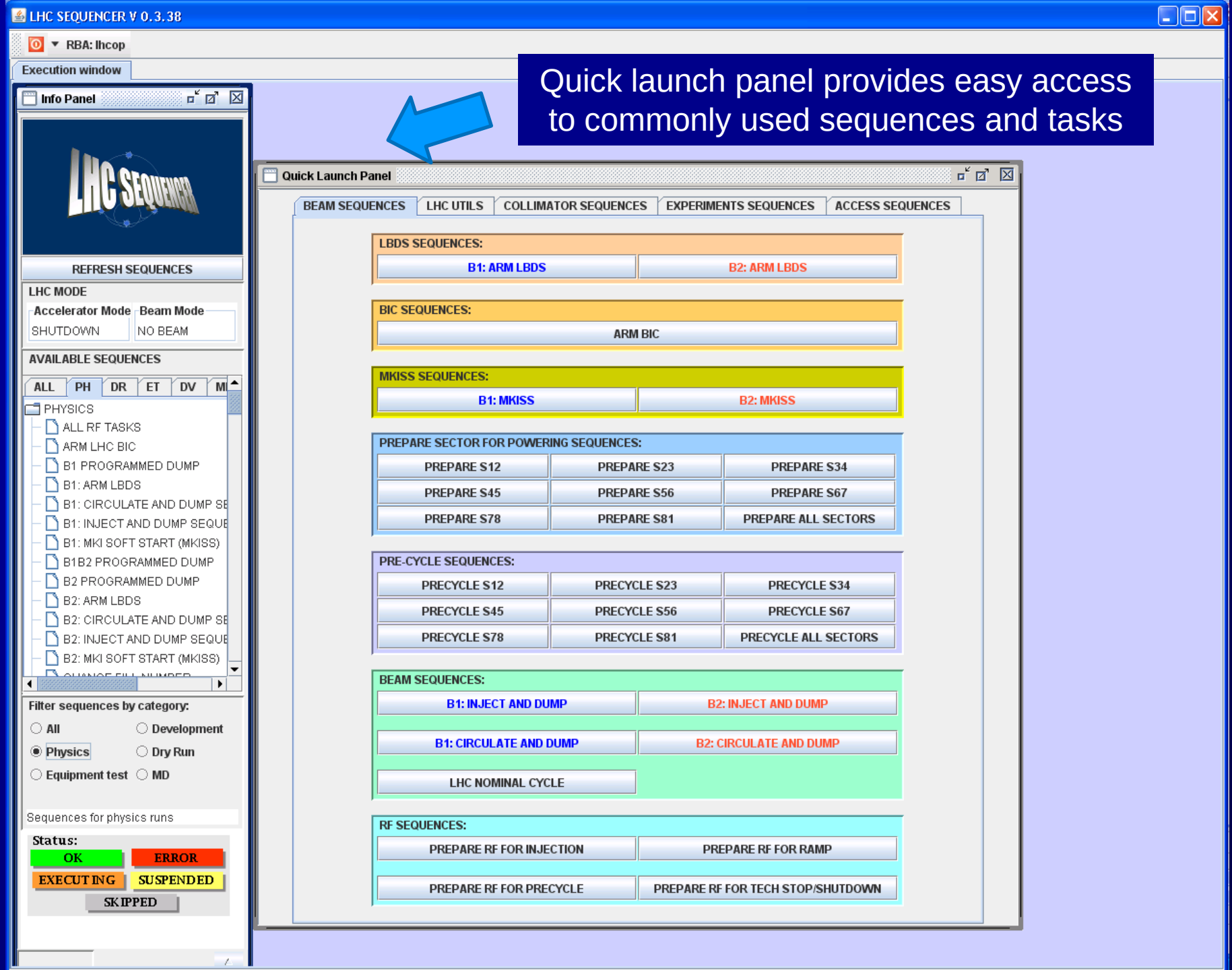
Injection system

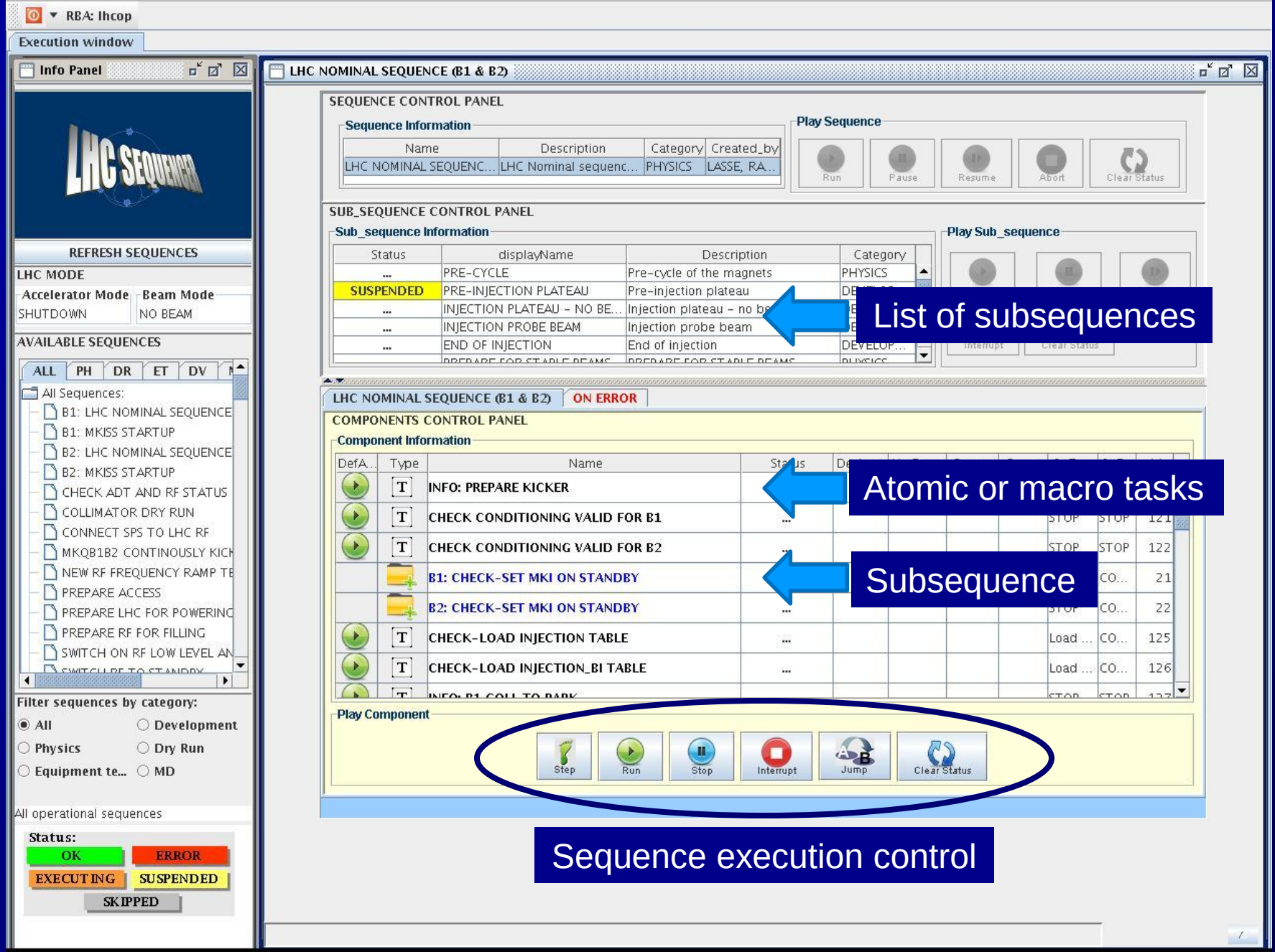
etc

RF

Beam dump system

Beam instrumentation


LHC SEQUENCER V 0.3.38
RBA: lhcop
Execution window
Info Panel
LHC SEQUENCER
REFRESH SEQUENCES
LHC MODE
Accelerator Mode
Beam Mode
SHUTDOWN
NO BEAM
AVAILABLE SEQUENCES
ALL
PH
DR
ET
DV
PHYSICS
ALL RF TASKS
ARM LHC BIC
B1 PROGRAMMED DUMP
B1: ARM LBDS
B1: CIRCULATE AND DUMP SE
B1: INJECT AND DUMP SEQUE
B1: MKI SOFT START (MKISS)
B1B2 PROGRAMMED DUMP
B2 PROGRAMMED DUMP
B2: ARM LBDS
B2: CIRCULATE AND DUMP SE
B2: INJECT AND DUMP SEQUE
B2: MKI SOFT START (MKISS)
Filter sequences by category:
All
Development
Physics
Dry Run
Equipment test
MD
Sequences for physics runs
Status:
OK
ERROR
EXECUTING
SUSPENDED
SKIPPED
Quick launch panel provides easy access to commonly used sequences and tasks
Quick Launch Panel
BEAM SEQUENCES
LHC UTILS
COLLIMATOR SEQUENCES
EXPERIMENTS SEQUENCES
ACCESS SEQUENCES
LBDS SEQUENCES:
B1: ARM LBDS
B2: ARM LBDS
BIC SEQUENCES:
ARM BIC
MKISS SEQUENCES:
B1: MKISS
B2: MKISS
PREPARE SECTOR FOR POWERING SEQUENCES:
PREPARE S12
PREPARE S23
PREPARE S34
PREPARE S45
PREPARE S56
PREPARE S67
PREPARE S78
PREPARE S81
PREPARE ALL SECTORS
PRE-CYCLE SEQUENCES:
PRECYCLE S12
PRECYCLE S23
PRECYCLE S34
PRECYCLE S45
PRECYCLE S56
PRECYCLE S67
PRECYCLE S78
PRECYCLE S81
PRECYCLE ALL SECTORS
BEAM SEQUENCES:
B1: INJECT AND DUMP
B2: INJECT AND DUMP
B1: CIRCULATE AND DUMP
B2: CIRCULATE AND DUMP
LHC NOMINAL CYCLE
RF SEQUENCES:
PREPARE RF FOR INJECTION
PREPARE RF FOR RAMP
PREPARE RF FOR PRECYCLE
PREPARE RF FOR TECH STOP/SHUTDOWN



LHC Nominal sequence

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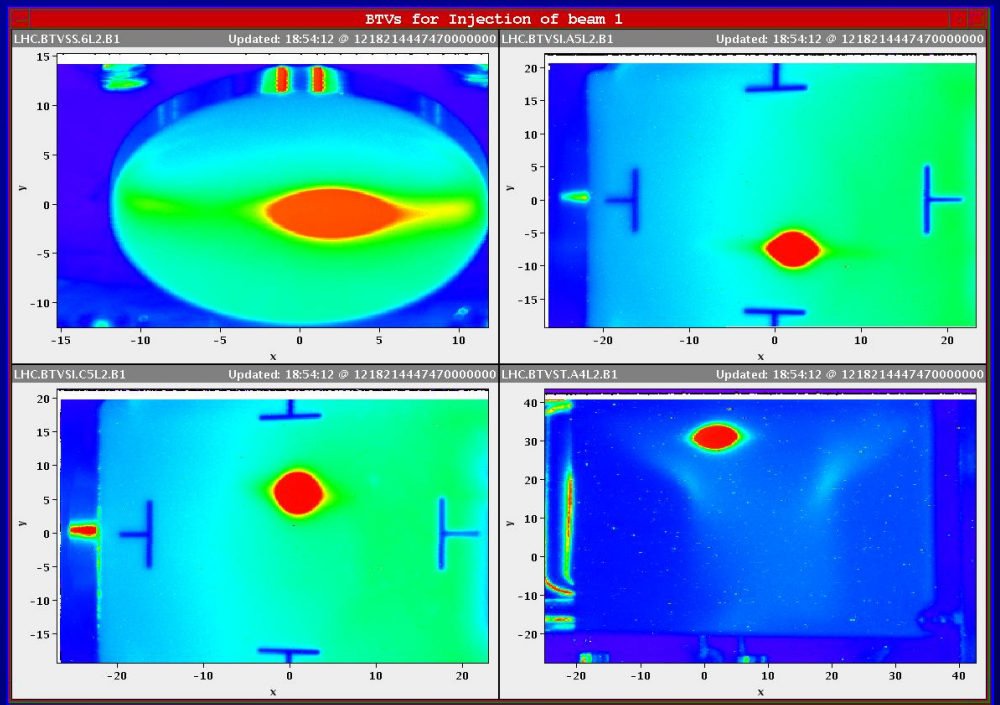
LHC BTV System

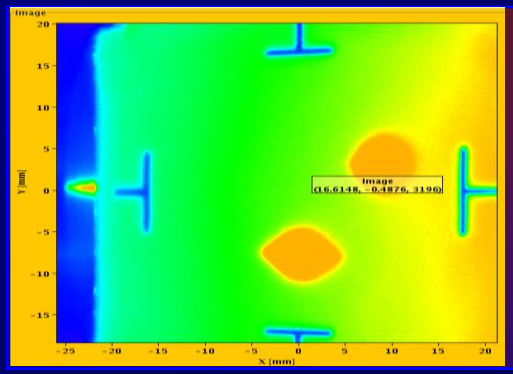
- 18 BTV in LHC transfer lines SPS - LHC
- 13 BTV in LHC ring
- 6 BTV in LHC dump lines

Both video link and digitised data acquired on first shot !

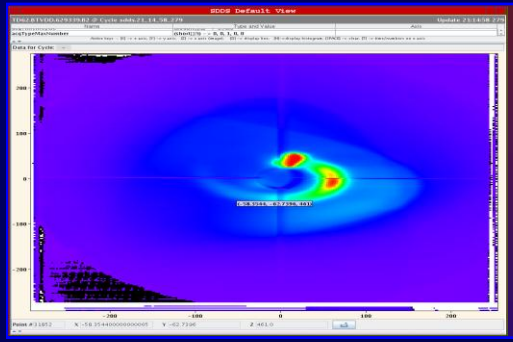
Each BTV has 2 screens:
1mm Al_2O_3:Cr (scintillator)
12 µm Ti foil (OTR)



First Beam in the LHC 8/8/2008



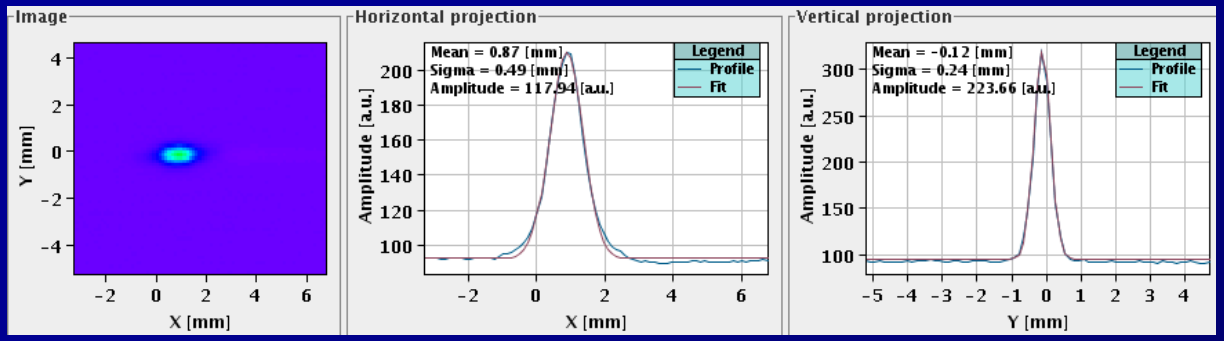
First full turn as seen by the BTV 10/9/2008



Uncaptured beam sweeps through he dump line

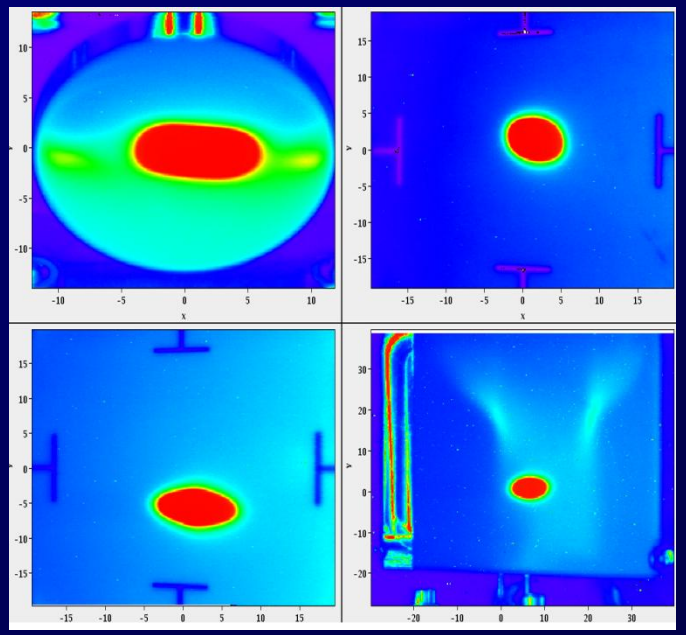
LHC BTV System

Used to check steering and optics in transfer lines



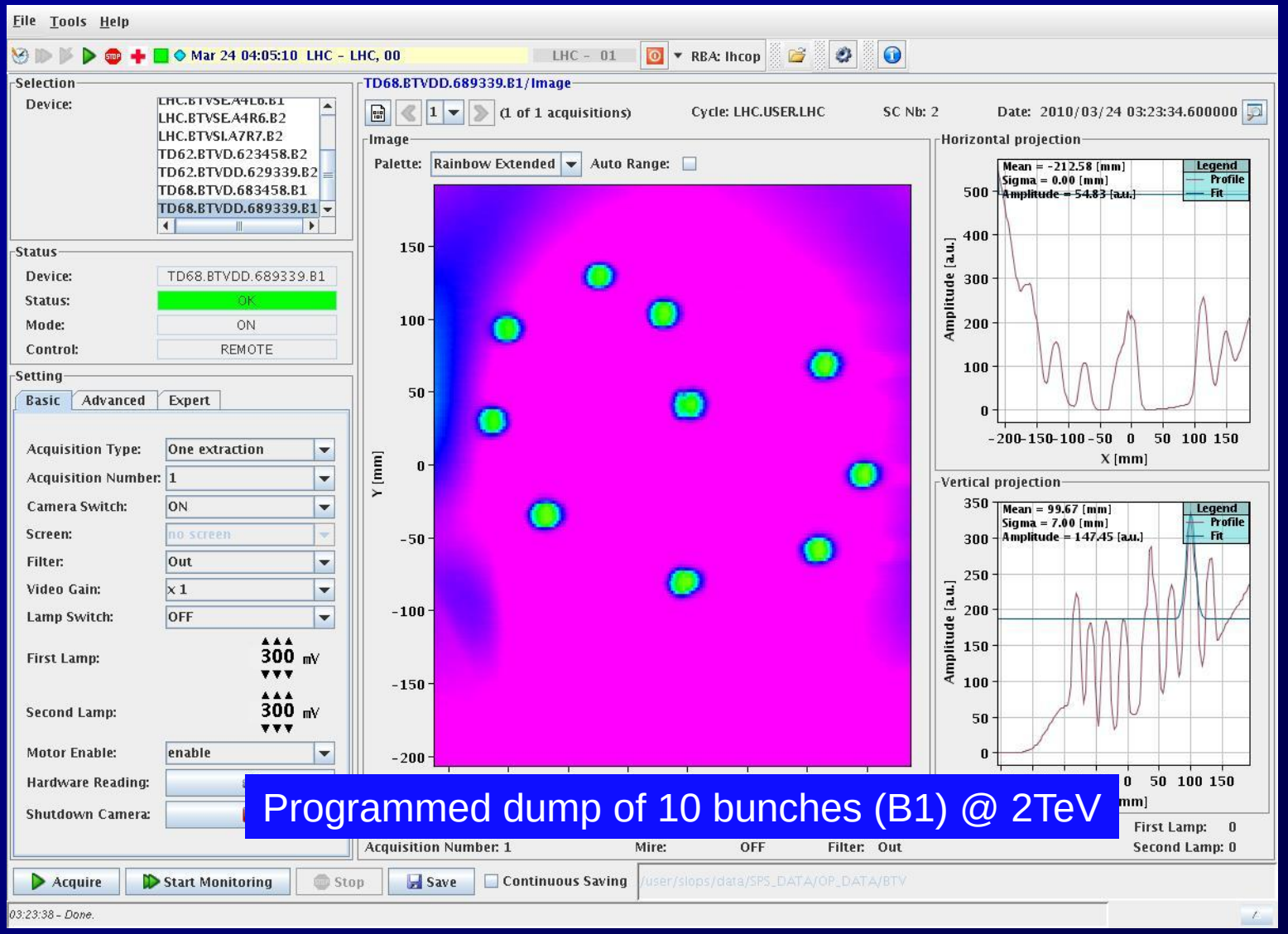
OTR image of beam in TI8 (B2)

Injection of B2



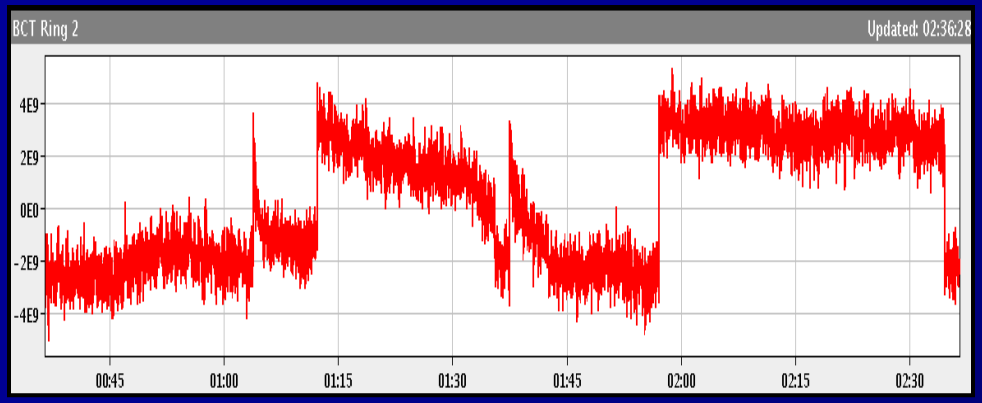
Verification of beam alignment in injection channels

LHC BTV System – beam dump



Programmed dump of 10 bunches (B1) @ 2TeV

LHC BCT - System



First circulating beam in ring 2, 12/09/2008

2 DC – BCT systems per ring

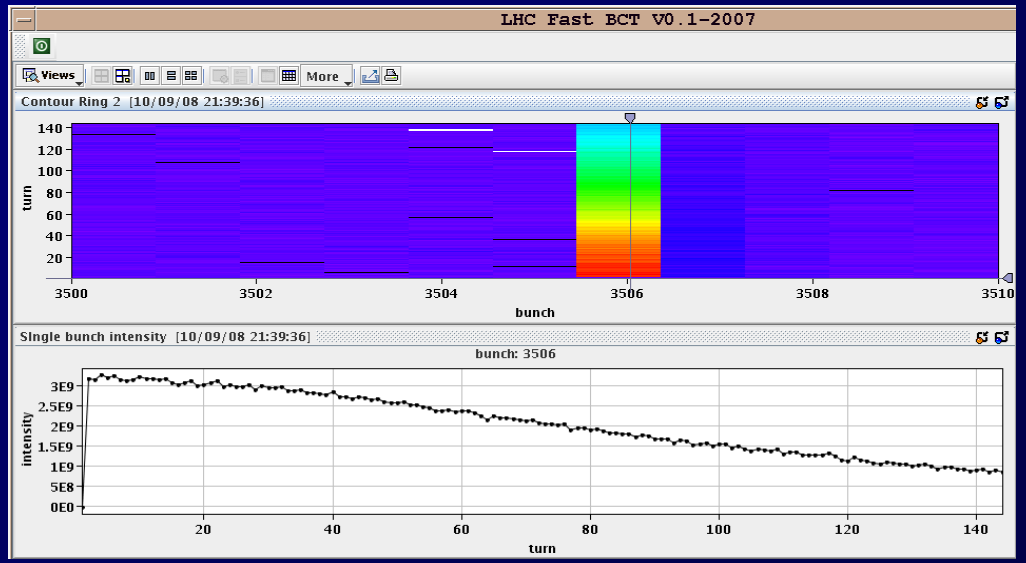
- few 10^9 to 5×10^{14} protons (~3mA to ~900mA)
- Published @ 1Hz for general applications

2 Fast – BCT systems per ring

- Bunch to bunch on turn by turn basis
- Total beam intensity

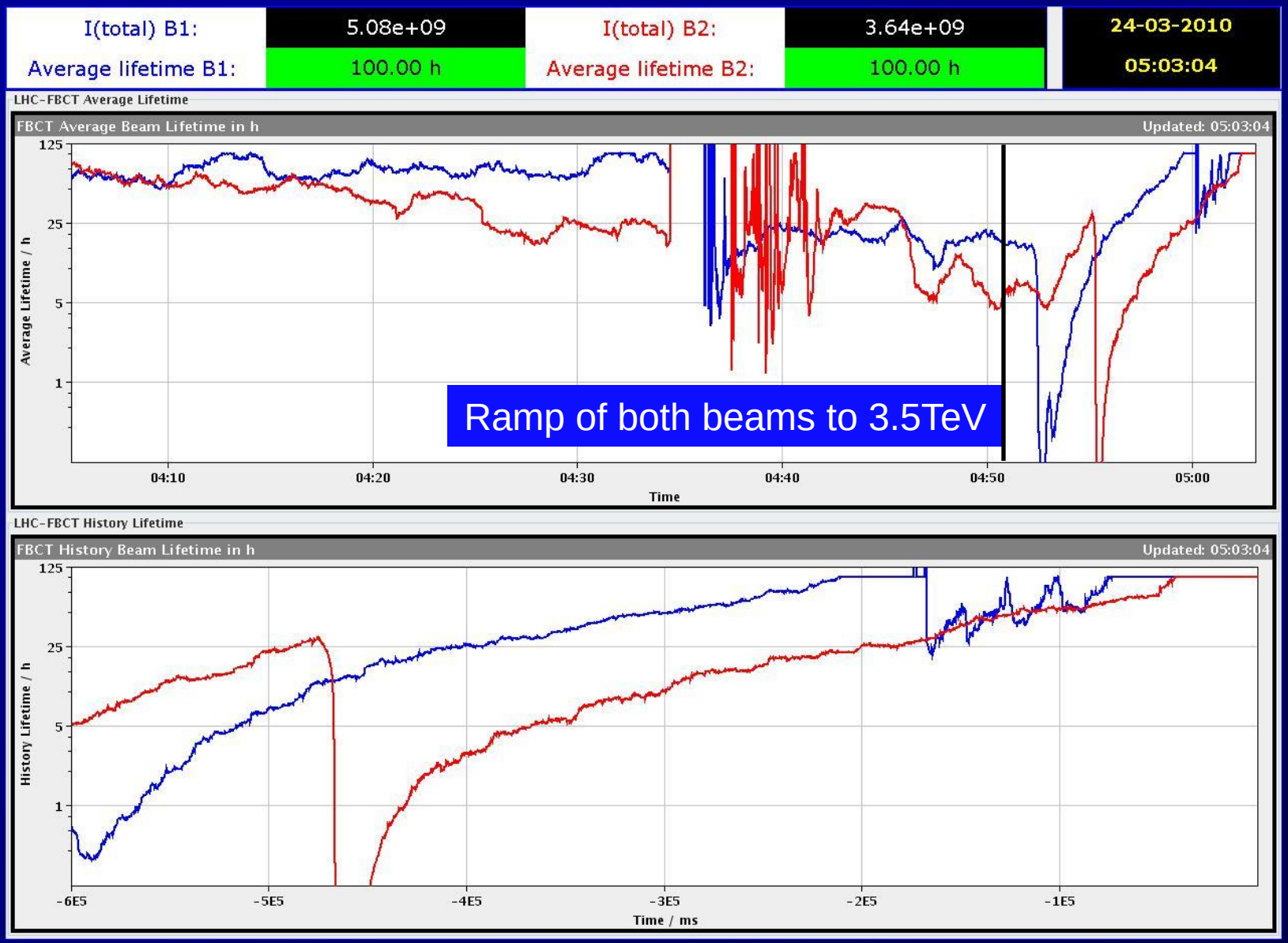
→ Total beam lifetime

→ Beam presence flag



Bunch intensity of captured B2, 10/09/2008

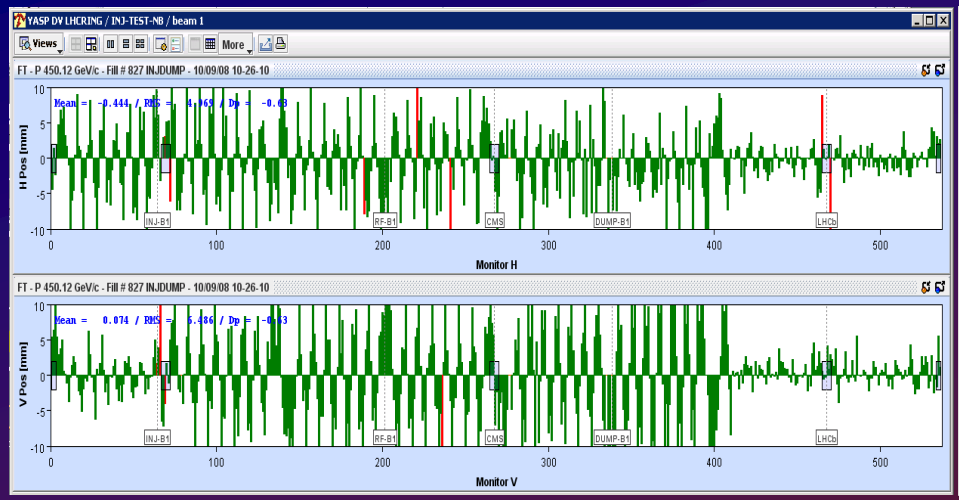
LHC Fast BCT - Lifetime



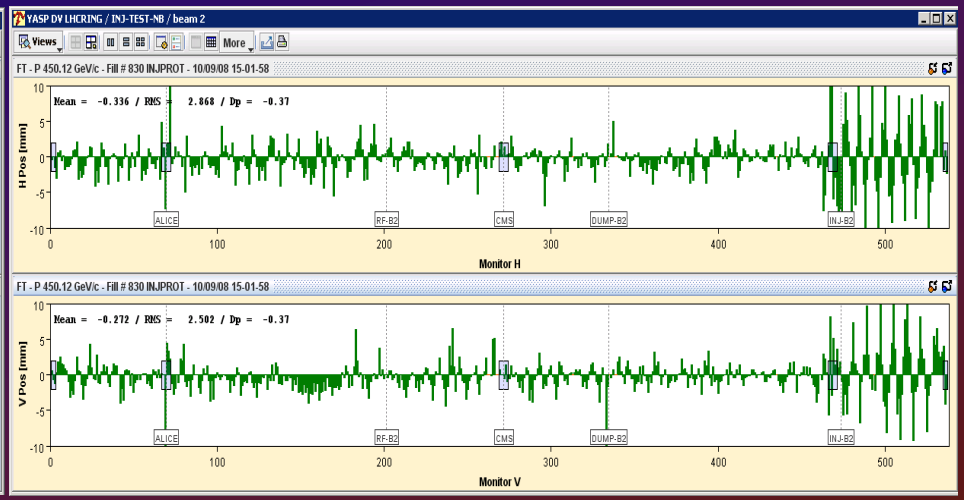
LHC BPM - System

1054 beam position monitors, measure in both H and V plane

1. Asynchronous bunch by bunch mode
   - Beam threading and first few hundred turns
   - Worked first time on both beams for injection tests & on 10th Sep 2008
2. Asynchronous orbit mode
   - Provided filtered data for 1Hz orbit update to YASP & FB controller
   - Worked as soon as beam was circulating for more than a few seconds



First full turn - Beam 1



First full turn - Beam 2

YASP - LHC Trajectory & Orbit Steering

One of the most powerful software tools of the LHC control system. It is used to control :

Trajectory

FIFO: self triggered mode for threading or trajectory measurements of empty ring (single bunch)

CAPTURE: triggered mode where the bunches/buckets must be configured

Closed Orbit

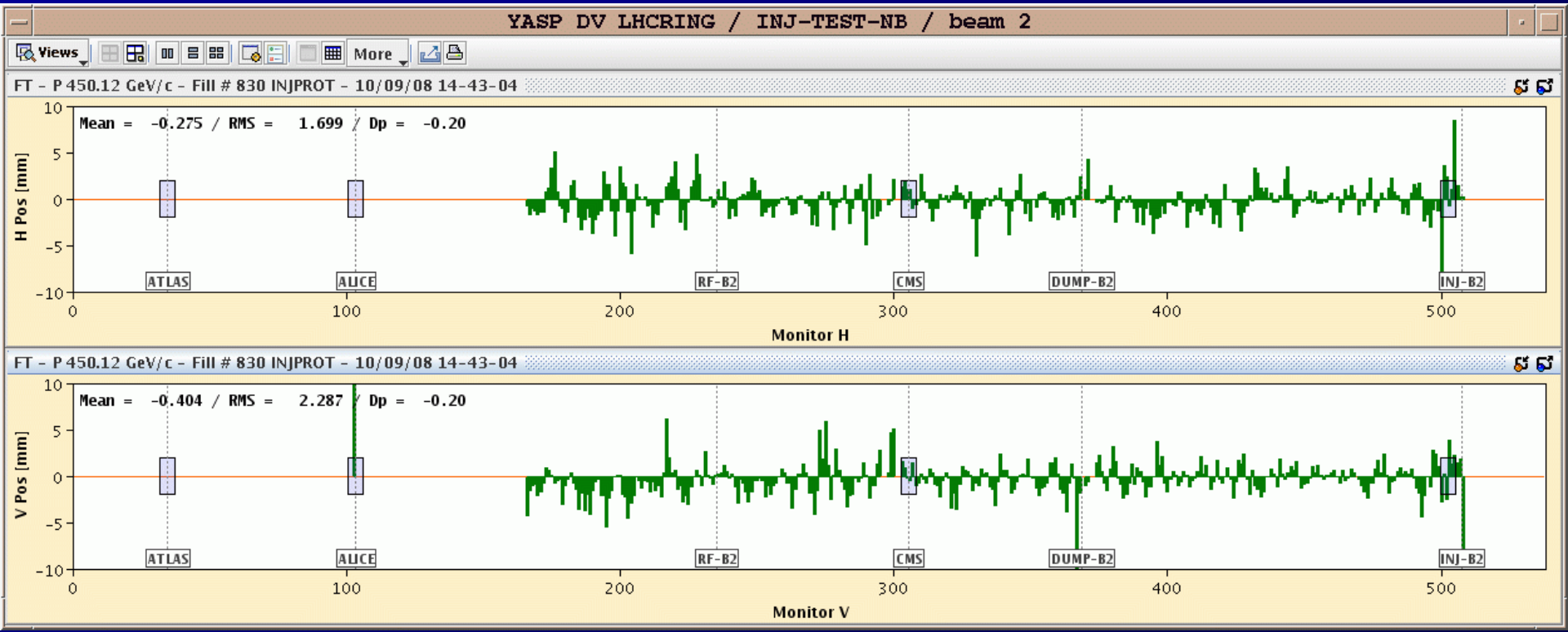
1Hz: one orbit
(averaged over 224 turns/20 ms)

Average - 1s: all orbits acquired during one second are averaged.
Data is returned at 1 Hz.

Average - 10s: all orbits acquired during 10 s are averaged.
Data is returned at 0.1 Hz

YASP – B2 around the ring

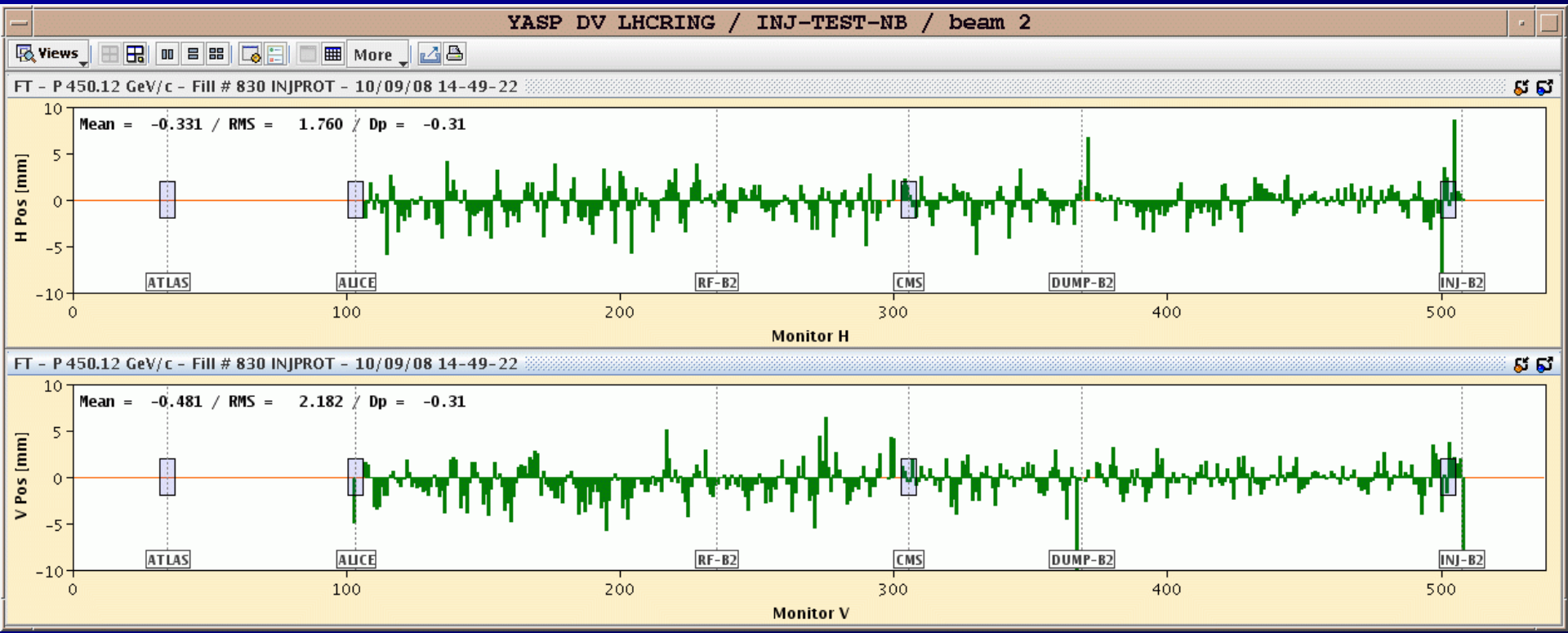
1. Beam to TDI
2. Beam to IR7
3. Beam to IR6
4. Beam to CMS
5. Beam to IR3



Courtesy: J. Wenninger

YASP – B2 around the ring

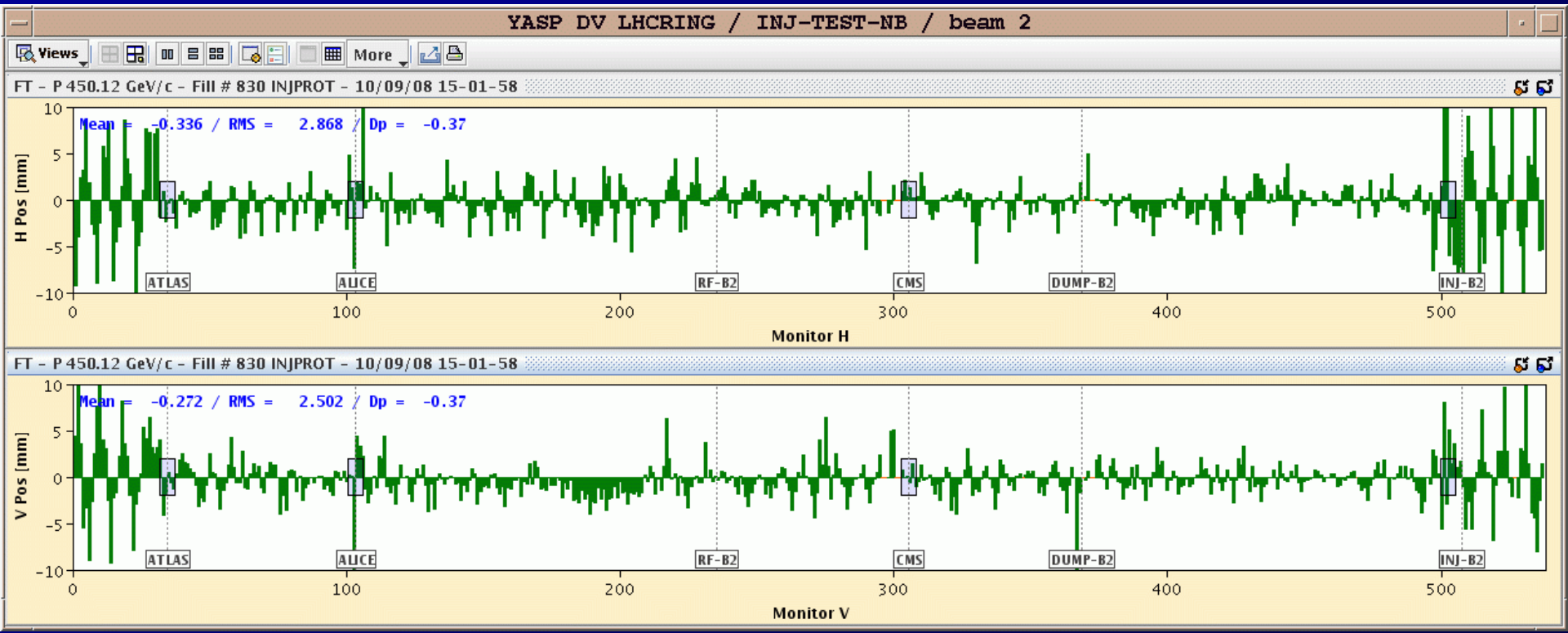
1. Beam to TDI
2. Beam to IR7
3. Beam to IR6
4. Beam to CMS
5. Beam to IR3
6. Beam to ALICE



Courtesy: J. Wenninger

YASP – B2 around the ring

1. Beam to TDI
2. Beam to IR7
3. Beam to IR6
4. Beam to CMS
5. Beam to IR3
6. Beam to ALICE
7. Beam to ATLAS
8. **Beam to LHCb – First Turn !**



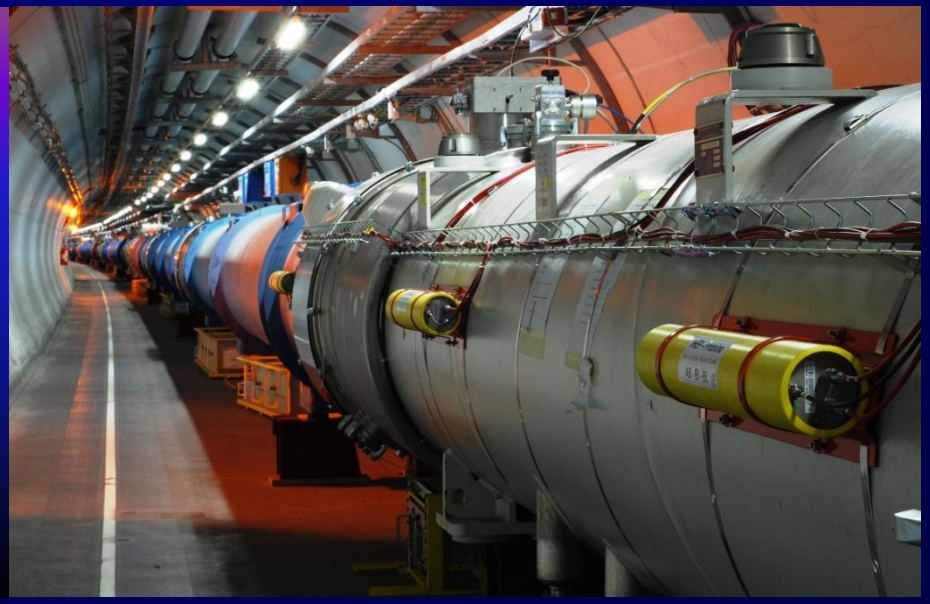
Courtesy: J. Wenninger

LHC BLM - System

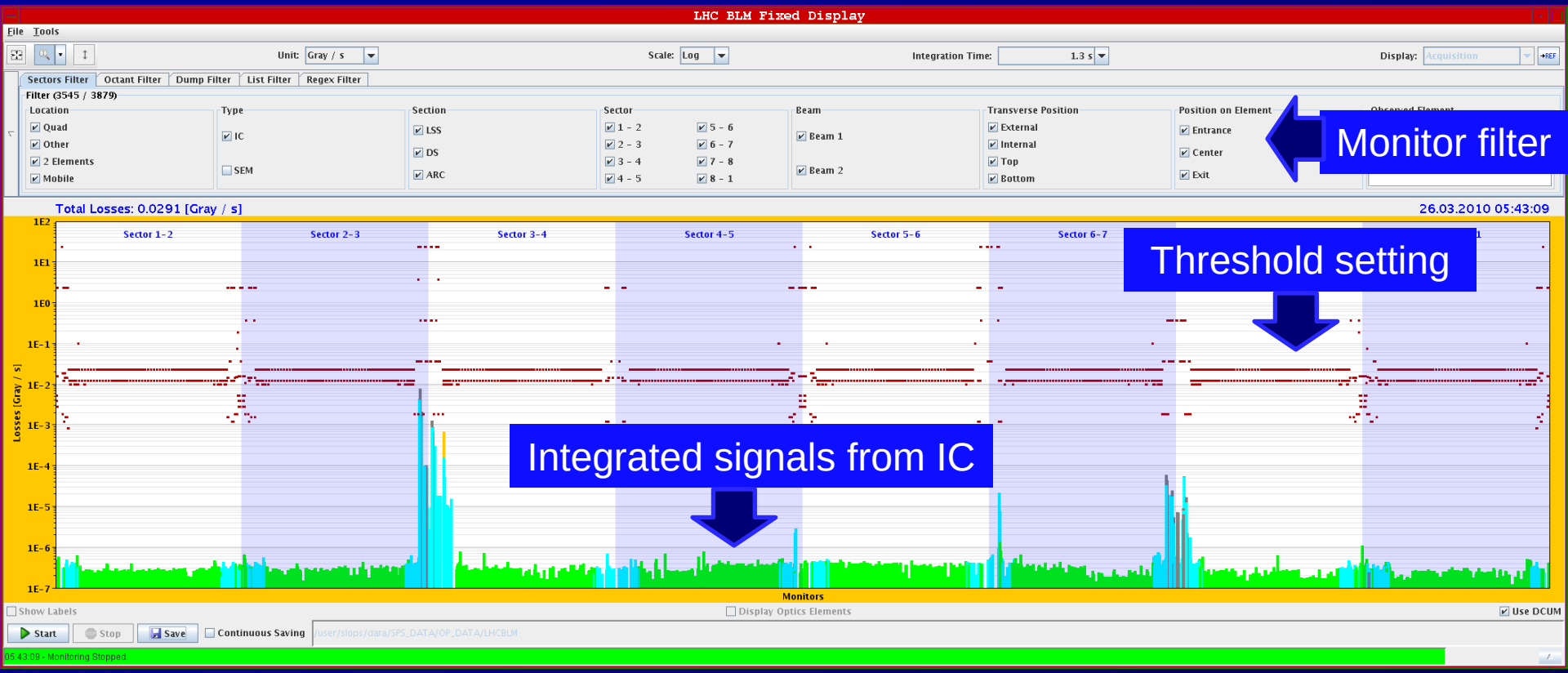
Threefold purpose:

- Protect LHC equipment against damage
- Avoid beam induced magnet quenches
- Loss observation for machine parameter tuning (collimator set-up, aperture studies, etc.)

4000 beam loss monitors
(Ionization chamber, SEM)
mostly around quadrupoles
12 different integration times
(40μs – 83s)



LHC BLM – Online Display



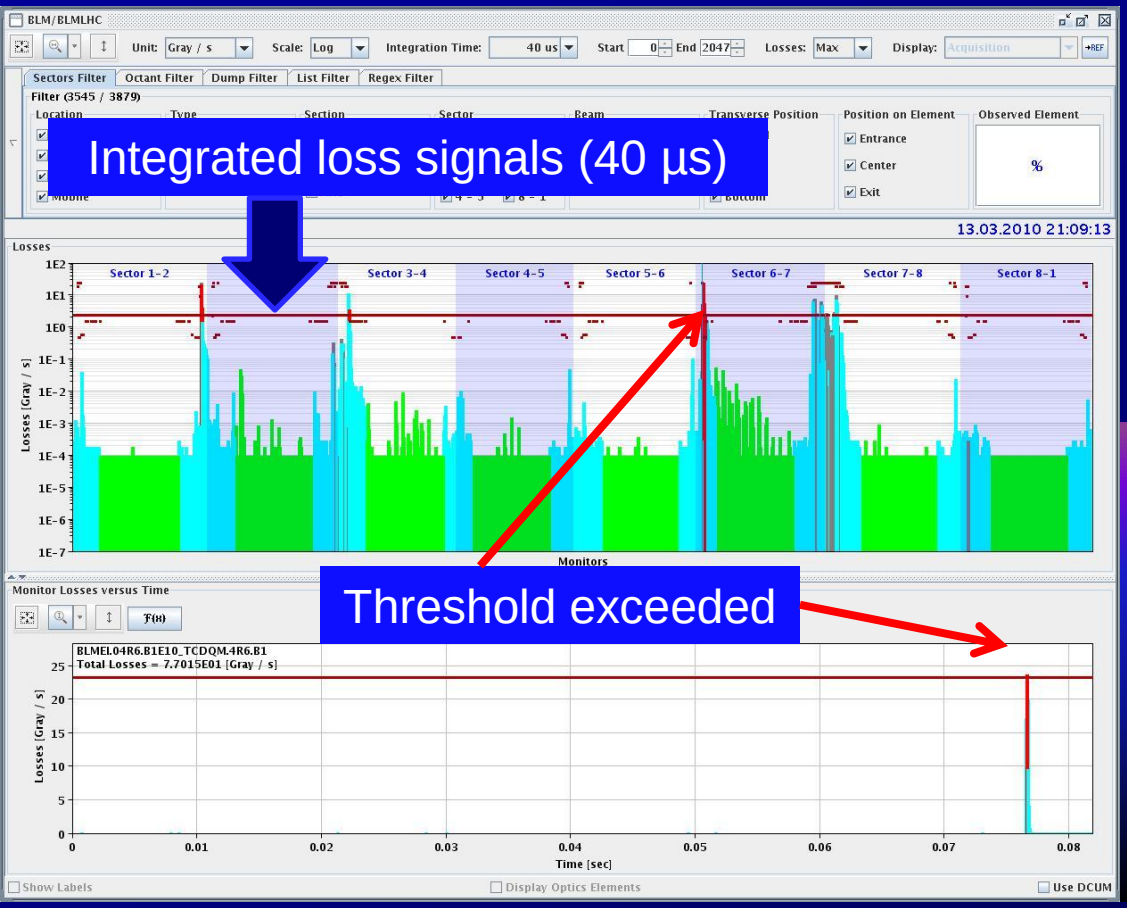
Beam loss monitor readings (Gray/s) along the ring (integration time : 1.3 s)

Updating @ 1Hz

Losses units: Gray/s, % or normalized

Linear or logarithmic scale

LHC BLM – Capture Display



BLM capture data

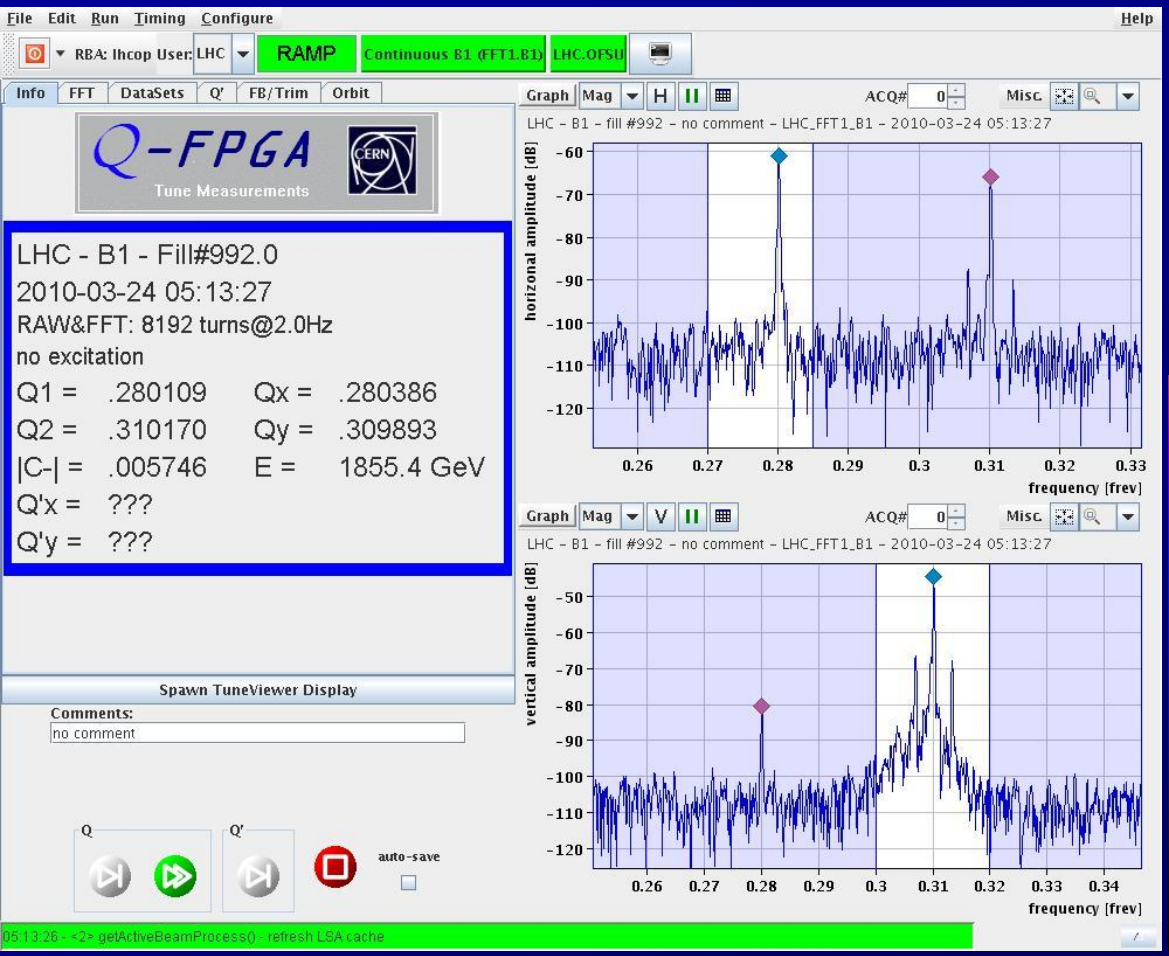
- Triggered by timing event
- Integration time: 40µs, 1.3s
- Loss readings of
  - all selected monitors
  - Single monitor vs. time

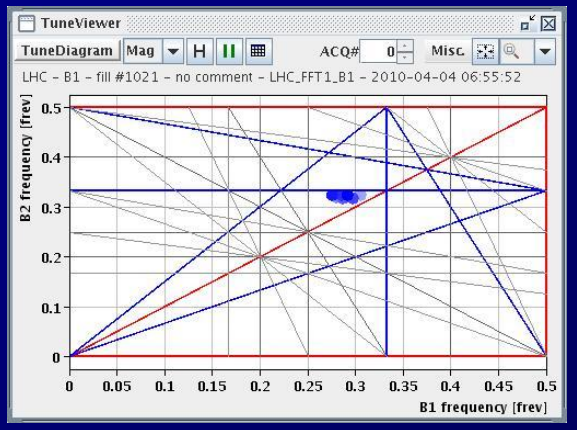
LHC - Q, Q' & Coupling

3 independent acquisition chains per beam relying on base-band-tune (BBQ) method

- Passive beam spectra observation (no excitation)
  - → data logging for post mortem analysis
  - → fixed displays in CR
- "On demand" acquisition with excitation by:
  - tune kickers (MKQA)
  - fast frequency sweeps ('chirp' signals) via the transverse damper
- PLL tune operation, using the transverse damper as excitation source

LHC – Q, Q', Coupling Viewer





- Acquisition of all 3 Q-chains
- Integrated Q, Q' trim facility using LSA services
- Q' measurement
- FB control
- Various data displays
- Lots of expert options...

One of the work-horse applications !

LHC – Feedbacks

Q – feedback is now routinely in use during ramps (not yet with PLL)

Summary

- Very powerful software tools paired with state of the art beam instrumentation were one of the main ingredients for the efficient and fast progress during beam commissioning.
- Meticulous testing of application software and instrumentation before first beam payed off for beam commissioning.
- Involvement of operations in the development of control room software tools is highly beneficial.

Thank you !

Questions ?