LHC Status

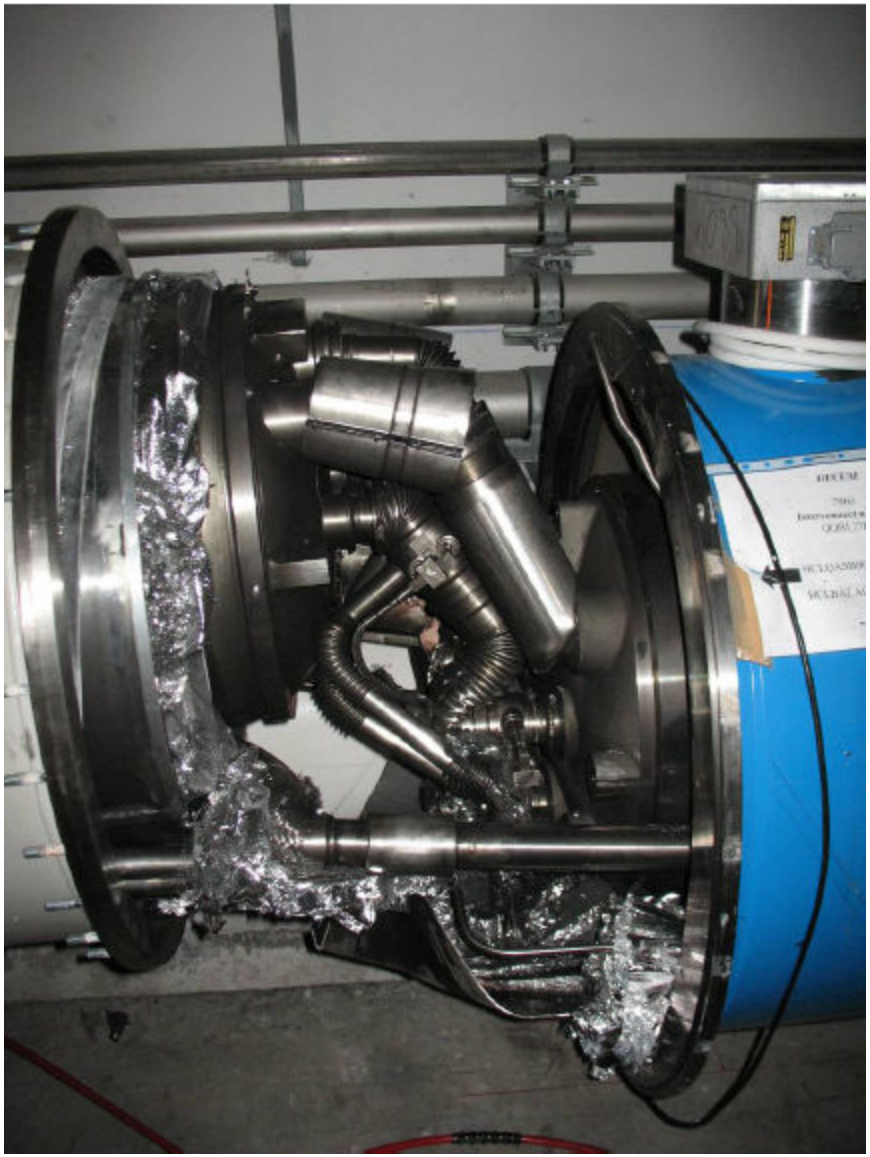
26th November 2009

Steve Myers

LHC is back!

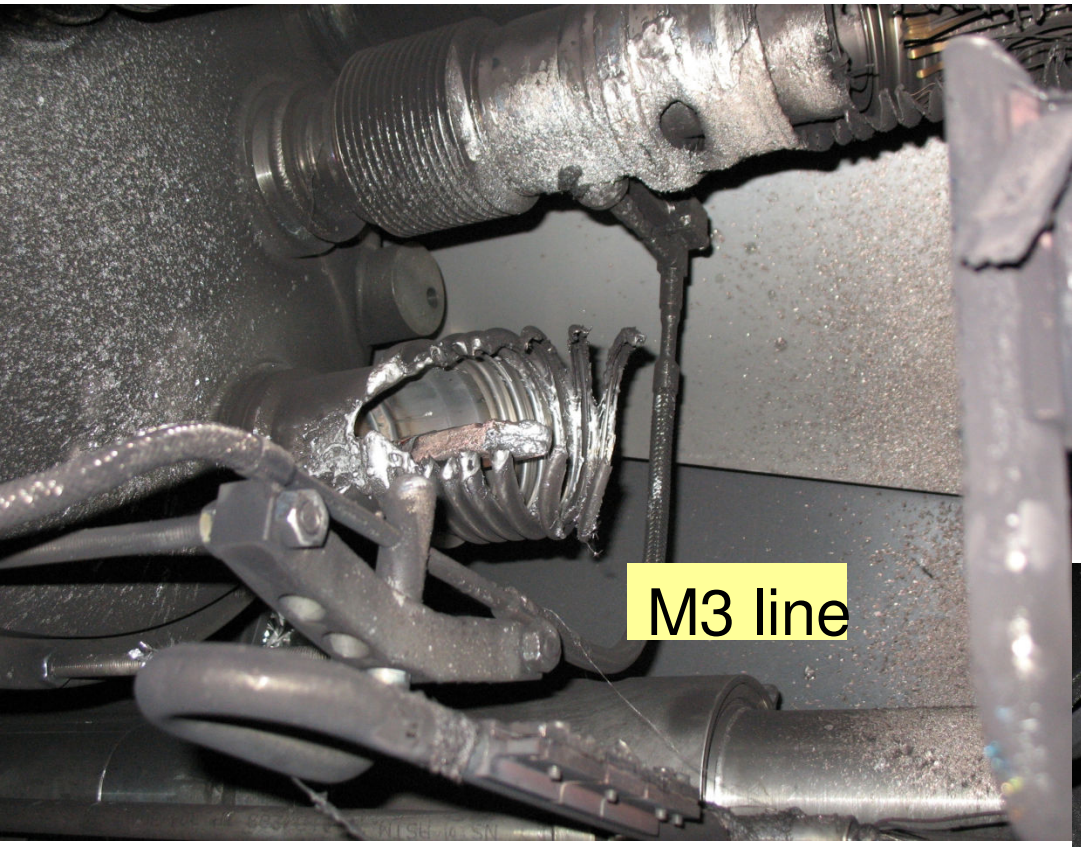
From the dark days after September 19, 2008 to the bright days of late November 2009

From This!

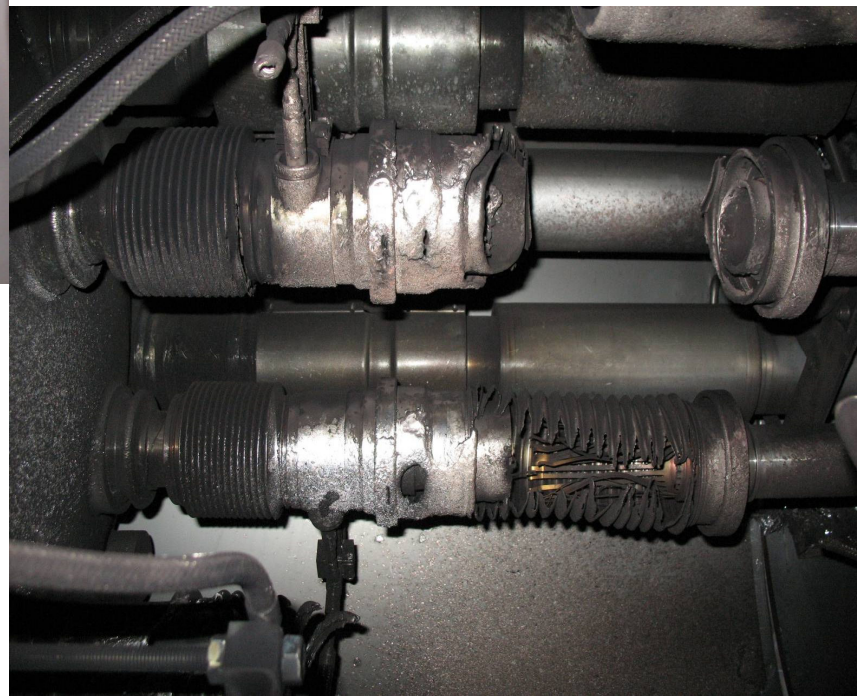


From This!

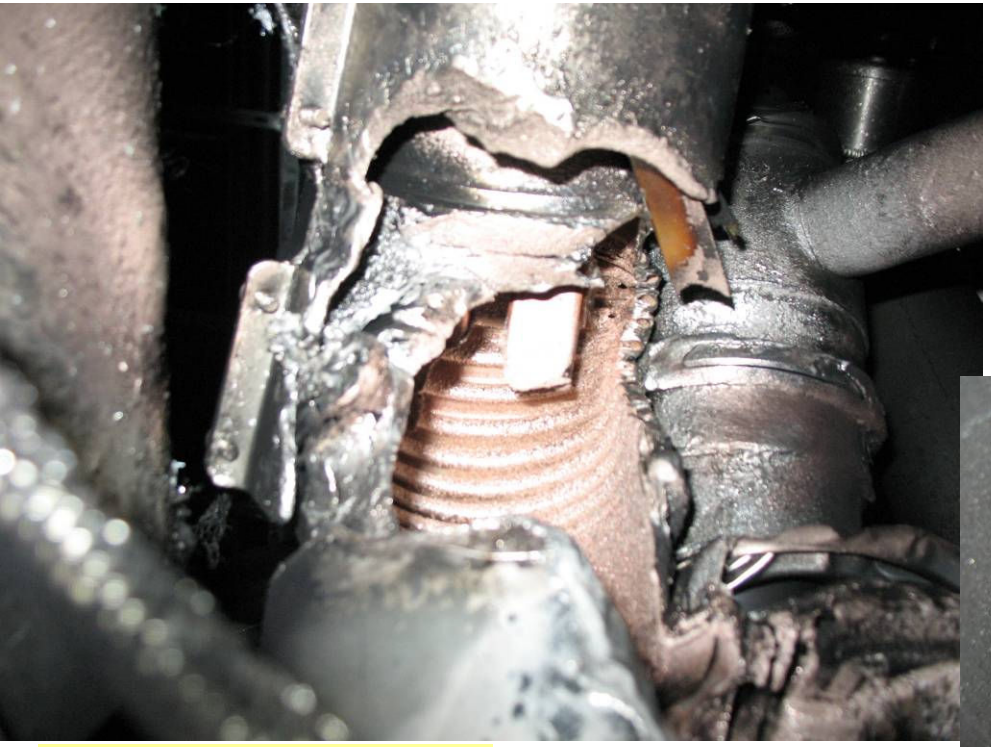
Electrical arc between C24 and Q24



V lines



From This!

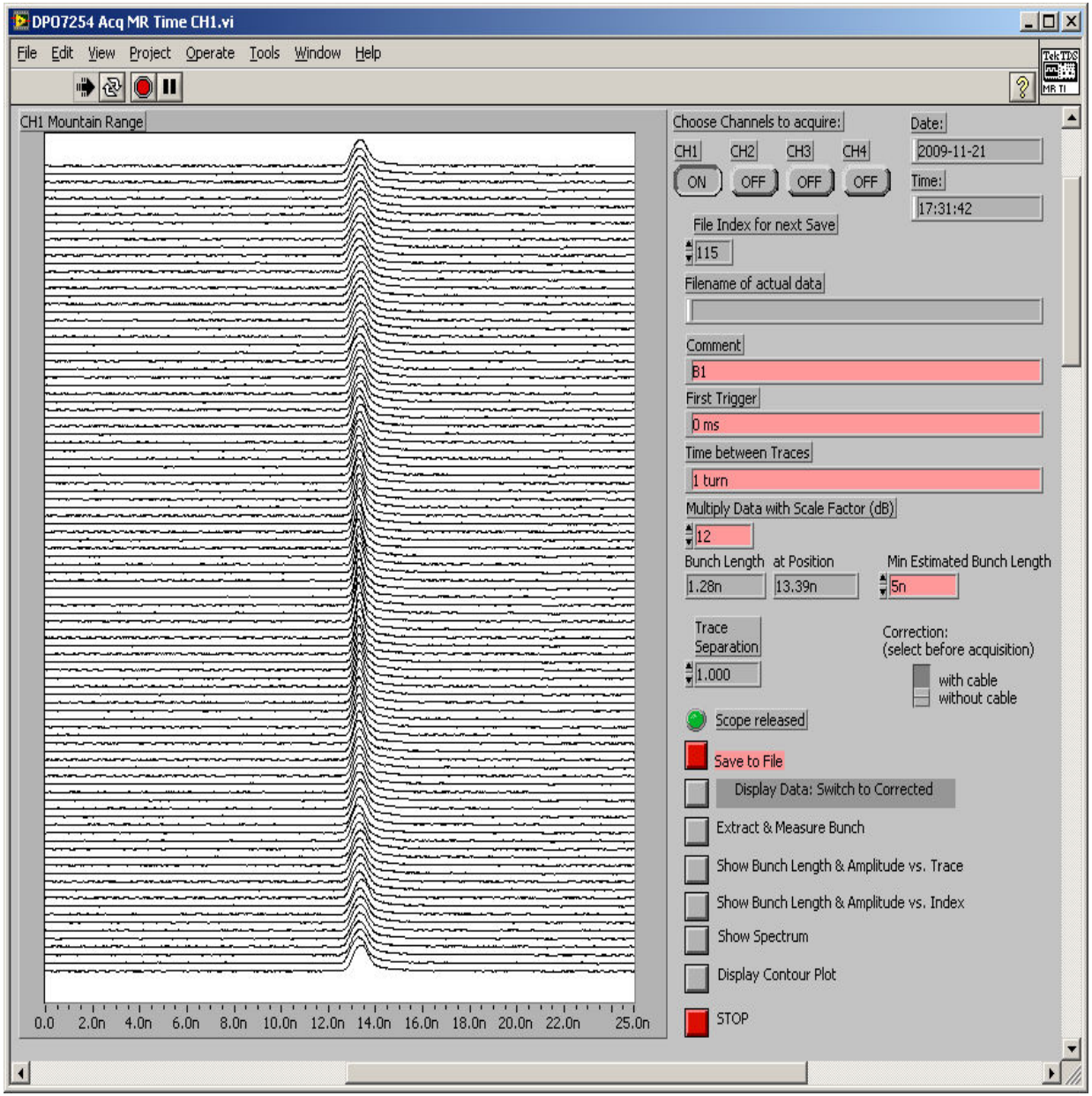


QQBI.27R3 M3 line

QBBI.B31R3 M3 line


From This!

To This



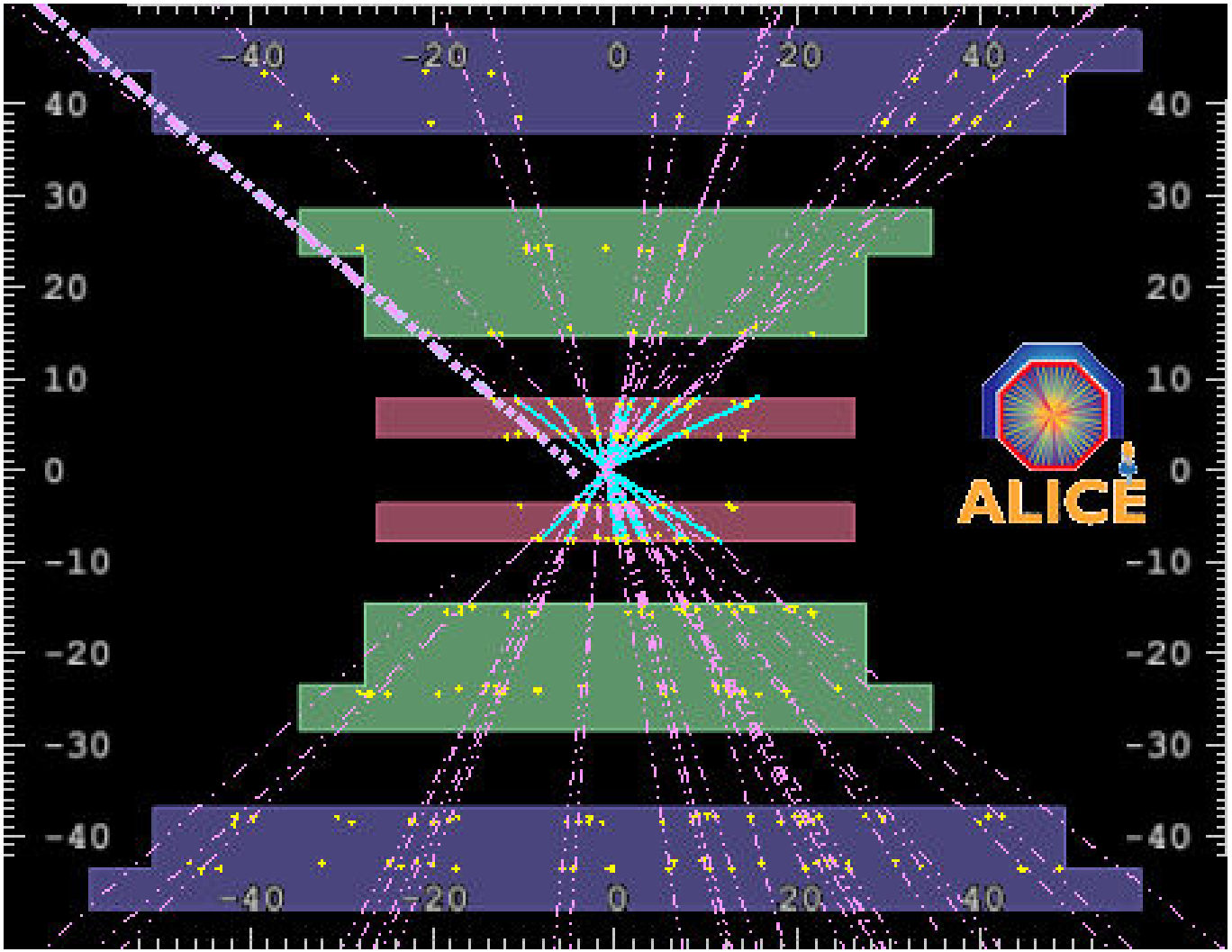
Beam is circulating and stable

- magnets
- power supplies
- vacuum
- RF
- cryogenics
- all infrastructure
- optics
- injection

and This

ALICE

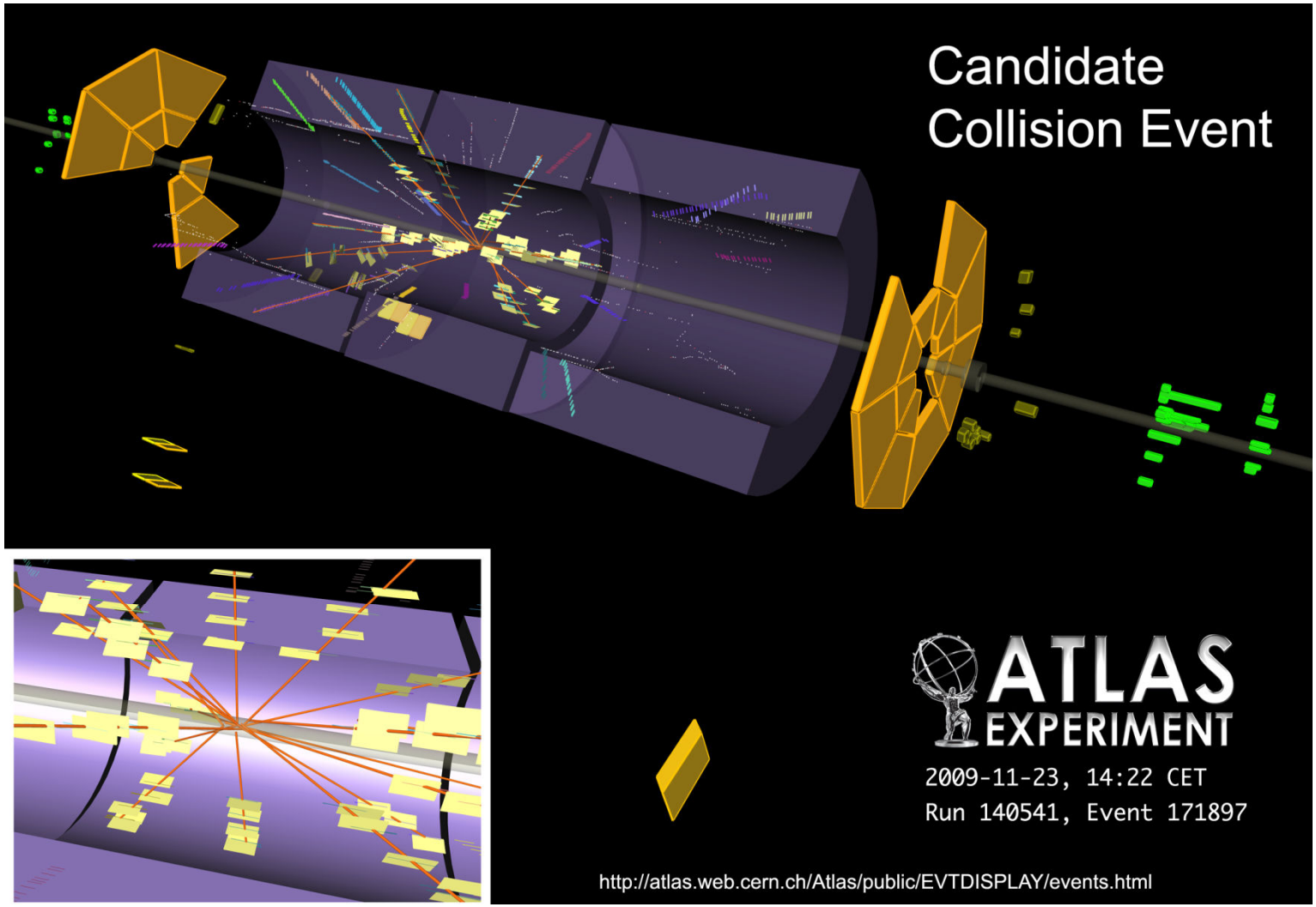
Monday 23, Nov



and This

ATLAS

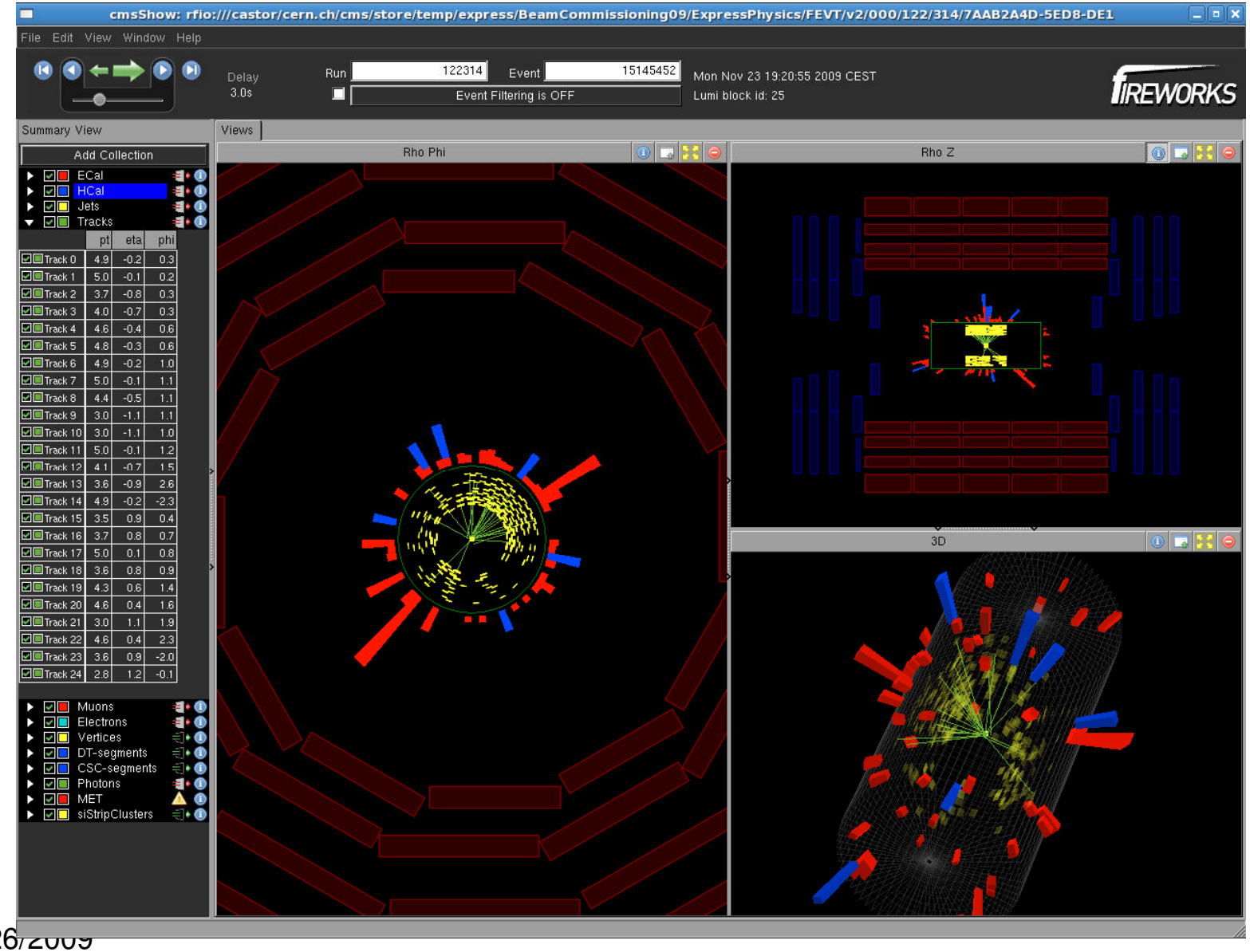
Monday 23, Nov



and This

CMS

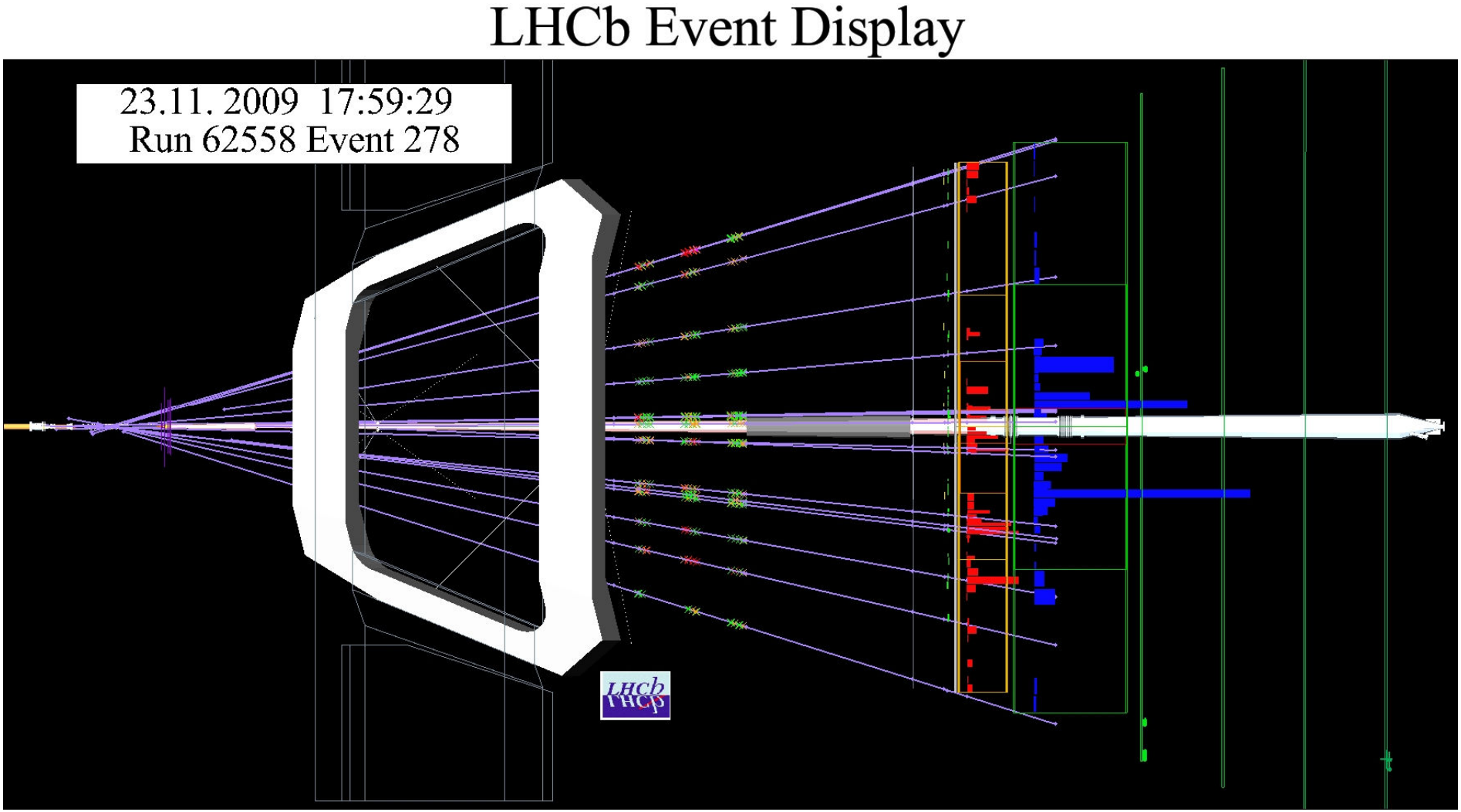
Monday 23, Nov



and This

Monday 23, Nov

LHCb



LHC is back! How was it done?

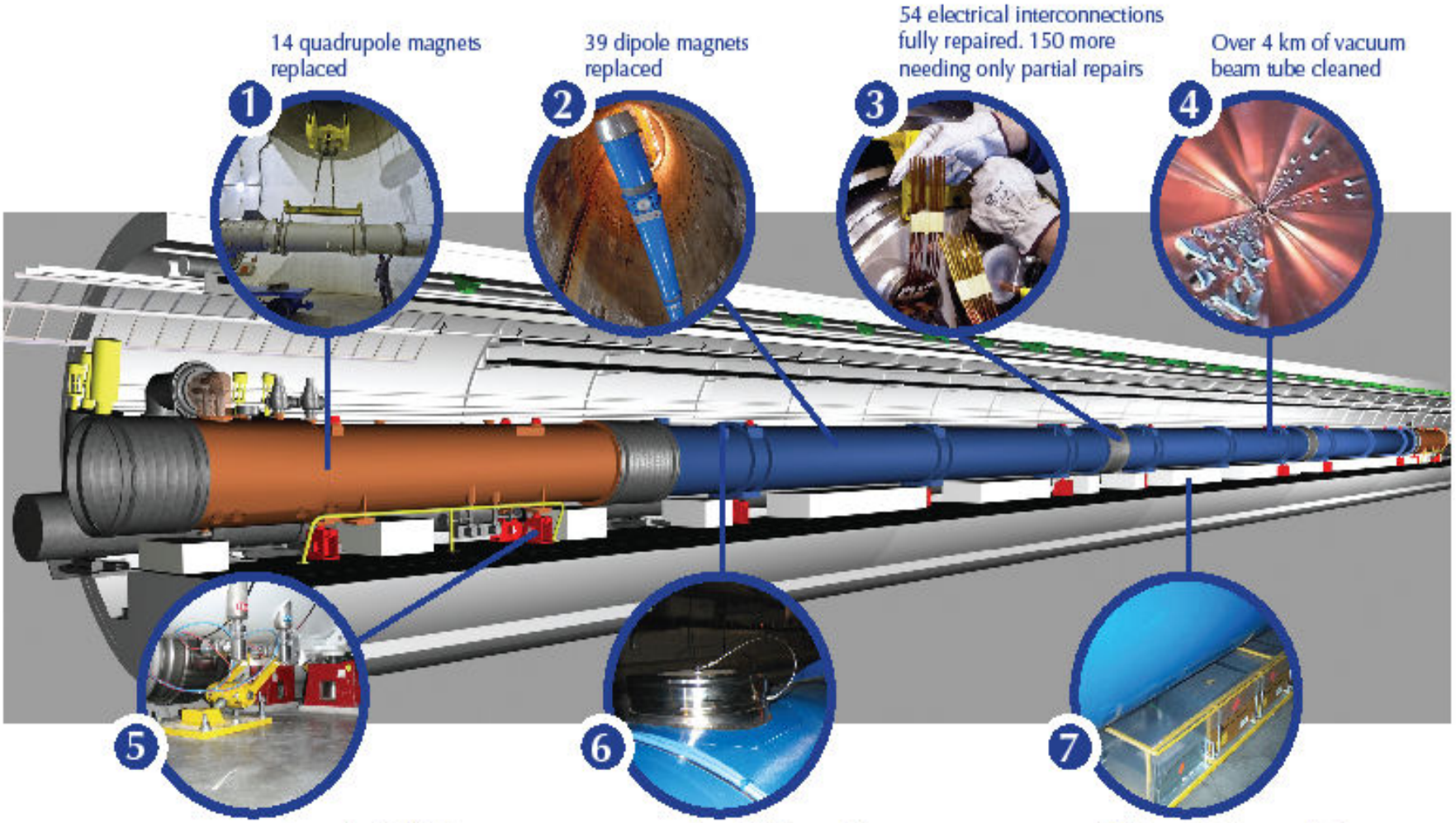
Five Phases

1. Repair of sector 34
2. Consolidation and Avoidance of collateral damage
3. Hardware Commissioning
4. Preparations for Beams (long term)
5. Operation with Beams

Phase 1 and 2
Repair and Consolidation

Phase 1 +2

The LHC repairs in detail



CERN

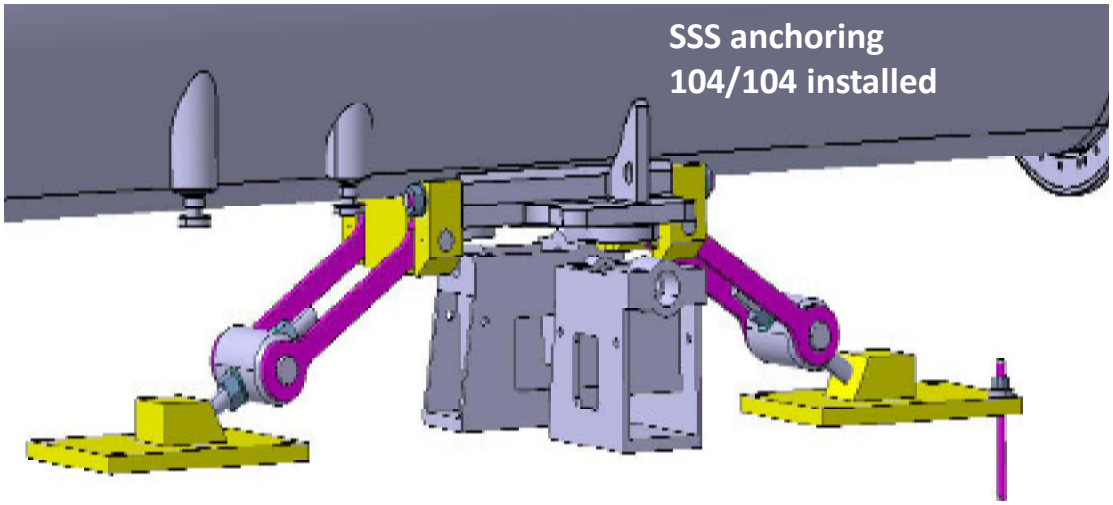
+ cryogenics!

sector 3-4 : Magnet repair in SMI2

15

Last Repaired Magnet (SSS) going down (30/4/2009)

Magnet protection and anchoring

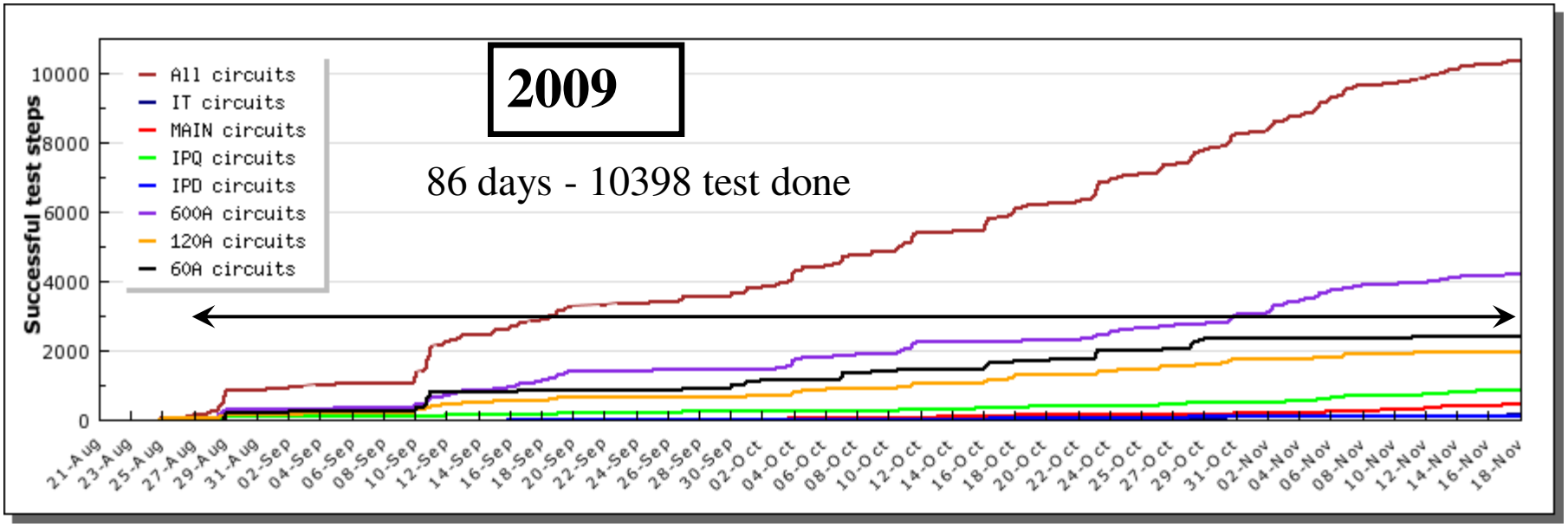


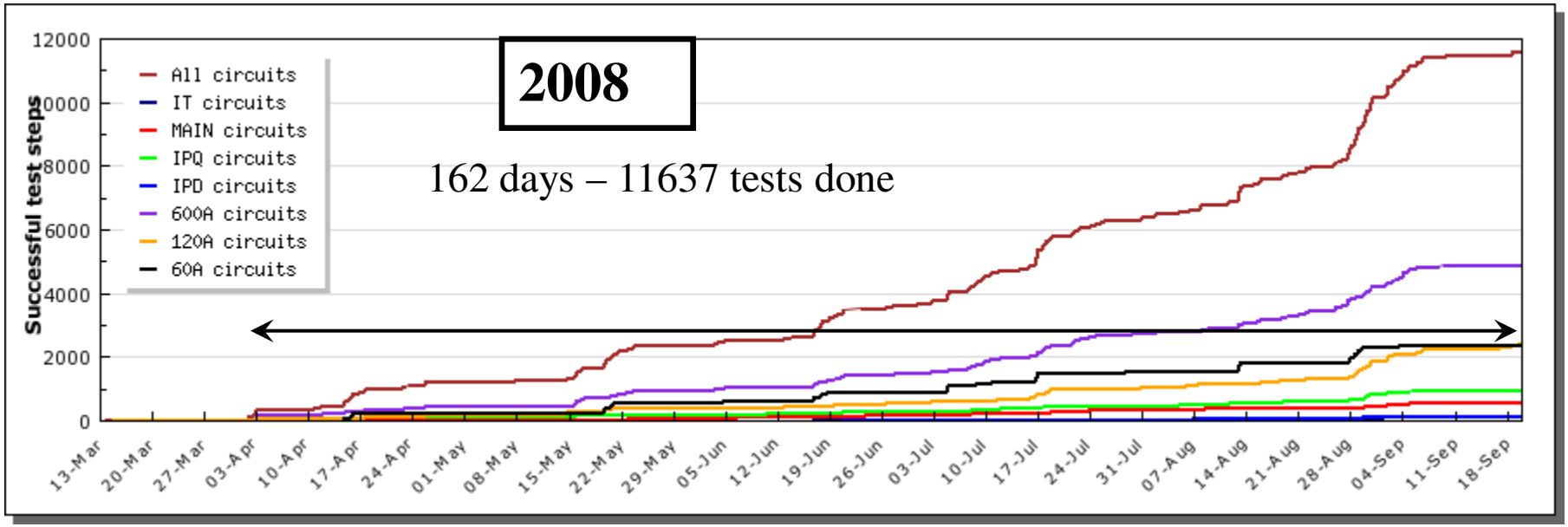
Phase 3
Hardware Commissioning

"Hardware commissioning" is essentially the electrical qualification (ELQA) and commissioning of the electrical circuits (magnets, power converters, current leads, protection systems, …)

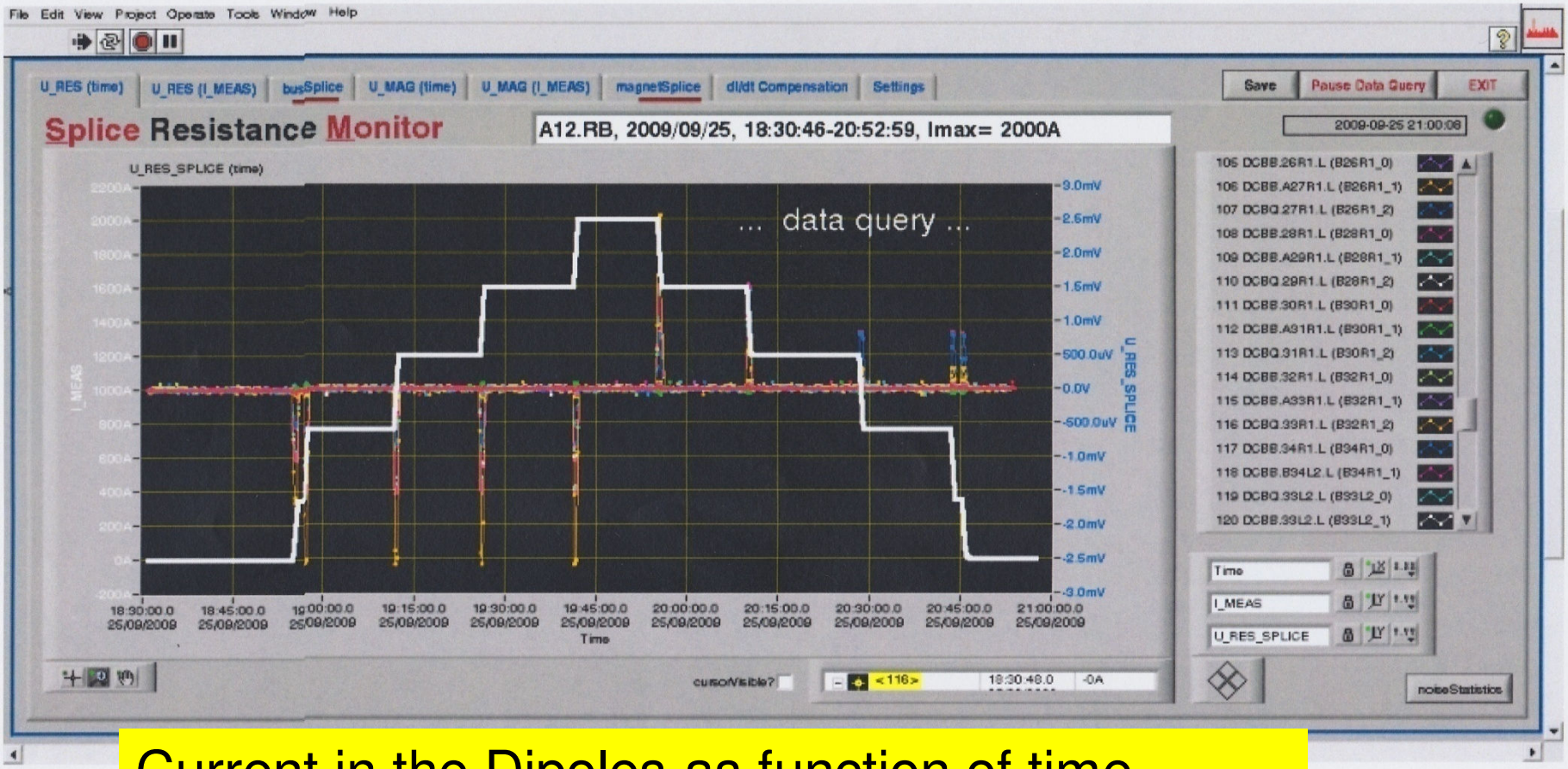
- **About 10000 magnets**
- More than **50 different types of magnets**
- Magnets can be **powered in series** or **individually**
- **1618 electrical circuits** grouped into nine "**Electrical Circuit Types**" (eight for circuits with superconducting magnets, one for circuits with normal conducting magnets)
- There are **more than a thousand current leads** installed in the DFBs (to bring the current from the warm into the cold)

Powering Tests overview





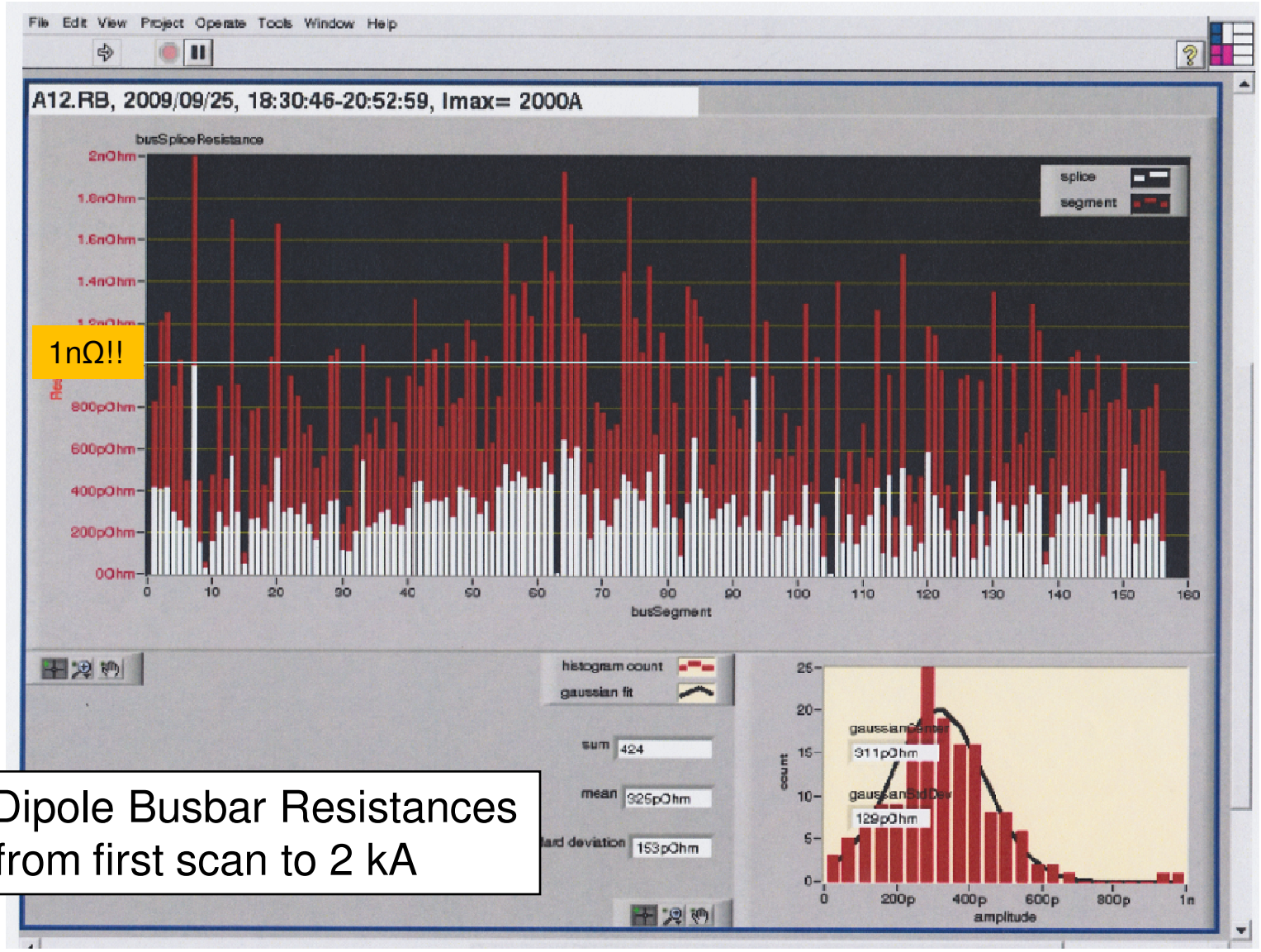
Pyramid for Splice Mapping



Current in the Dipoles as function of time

Splice Mapping of Dipoles

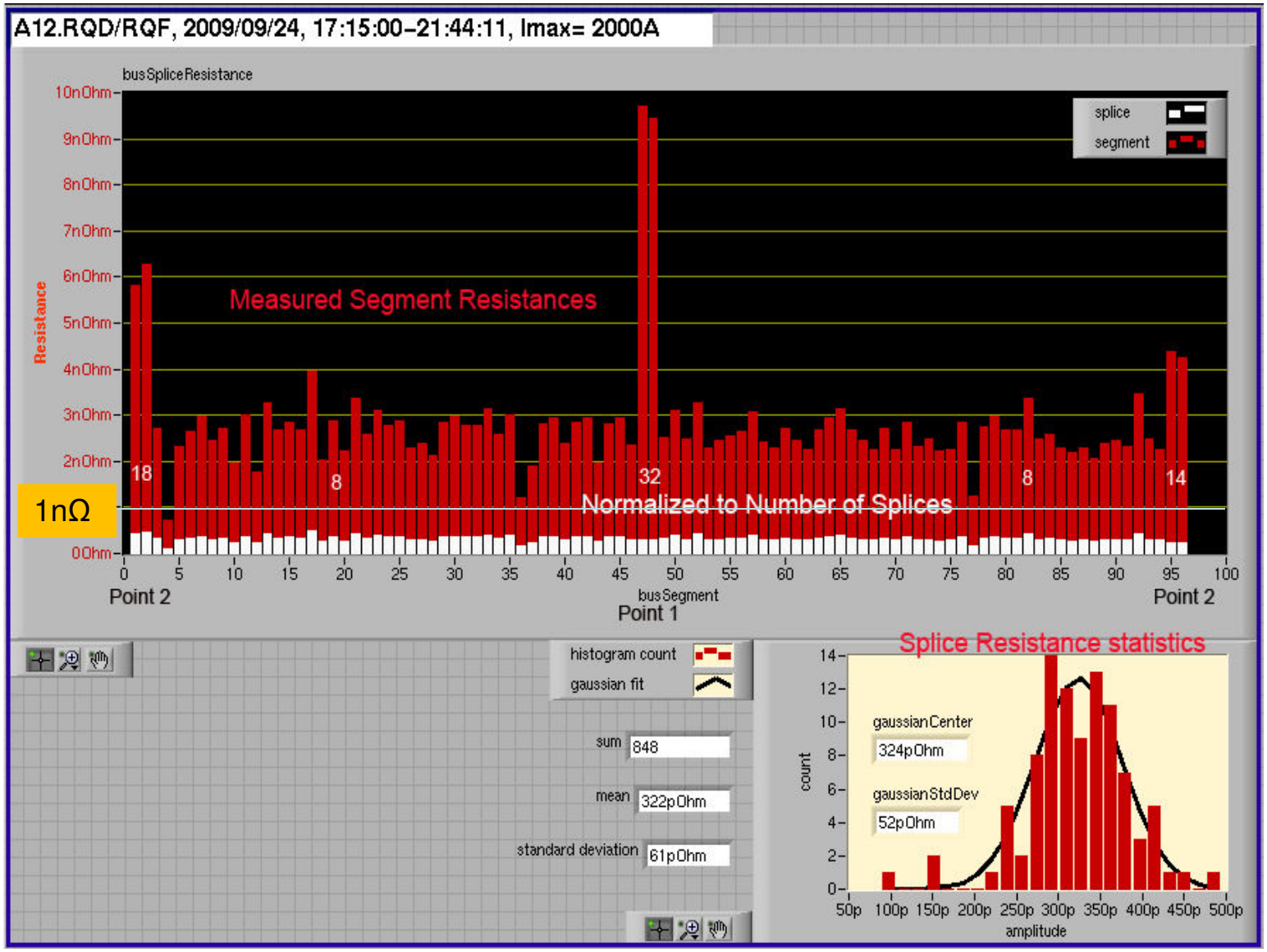
QPS team

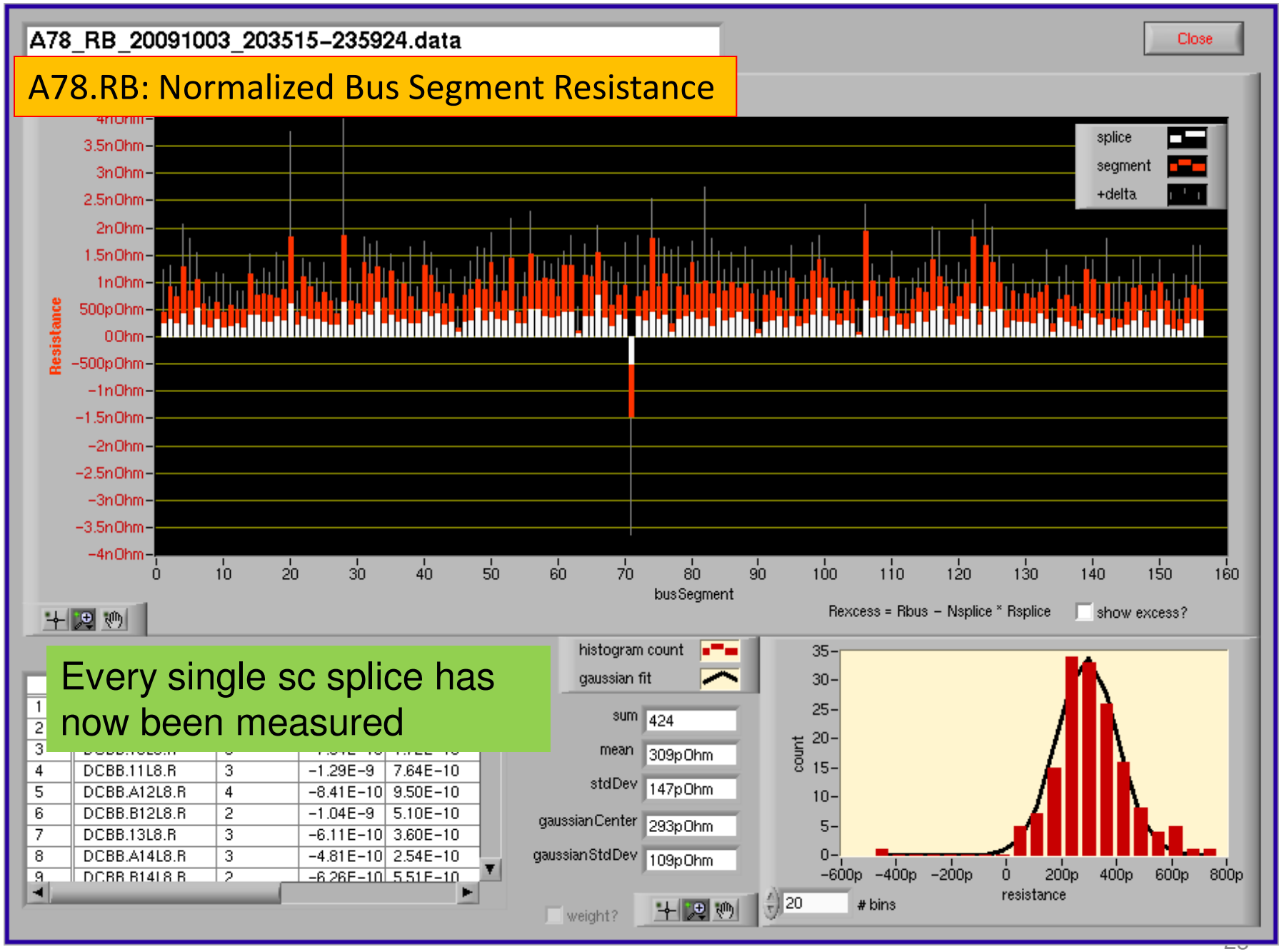


First Dipole Busbar Resistances from first scan to 2 kA

Splice Mapping of Quadrupoles

QPS team




A78_RB_20091003_203515-235924.data
Close
A78.RB: Normalized Bus Segment Resistance
splice
segment
+delta
Resistance
busSegment
Rexcess = Rbus – Nsplice * Rsplice
show excess?
Every single sc splice has now been measured
histogram count
gaussian fit
sum 424
mean 309pOhm
stdDev 147pOhm
gaussianCenter 293pOhm
gaussianStdDev 109pOhm
weight?
count
resistance
20
bins
4 DCBB.11L8.R 3 -1.29E-9 7.64E-10
5 DCBB.A12L8.R 4 -8.41E-10 9.50E-10
6 DCBB.B12L8.R 2 -1.04E-9 5.10E-10
7 DCBB.13L8.R 3 -6.11E-10 3.60E-10
8 DCBB.A14L8.R 3 -4.81E-10 2.54E-10

Phase 5
Preparation for Beam

- Started a long time ago in 2001!! (after the closure of LEP and using the ex-LEP staff)

LHC Commissioning Committee (LCC 1)

(S.Myers/F. Ruggiero/O.Bruning)

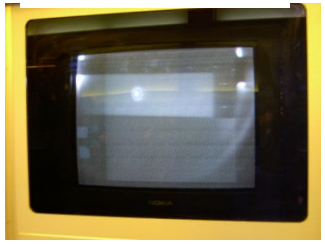
http://lhc.web.cern.ch/lhc/lcc/lcc.htm

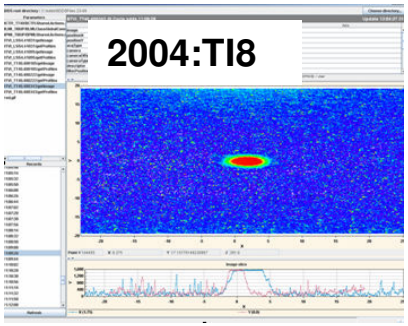
Mandate February 14, 2001

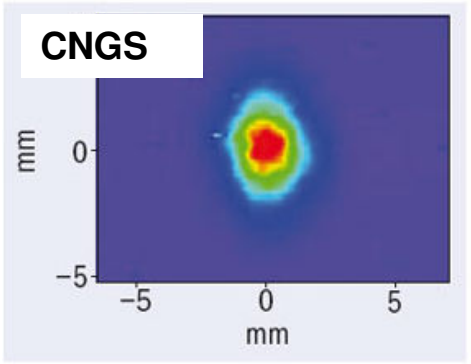
- Prepare beam commissioning and operation of the LHC collider
- Establish commissioning milestones based on the overall planning.
- Evaluate and maximise the performance of the injectors.
- Organise and evaluate experience with other relevant machines
- Prepare a detailed scenario and create a competent and appropriately experienced and trained team for initial commissioning.
- Examine and specify special software requirements pertaining to machine commissioning and operation.
- Plan and examine the results of MD experiments pertaining to the machine and its injectors
- Proposals of design changes to equipment groups on topics pertaining to commissioning, operation or performance of the machine.

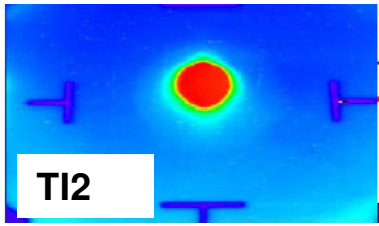
Prep: beam tests through the years

2003:TT40

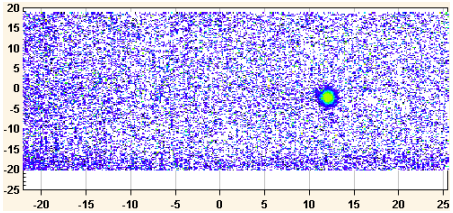




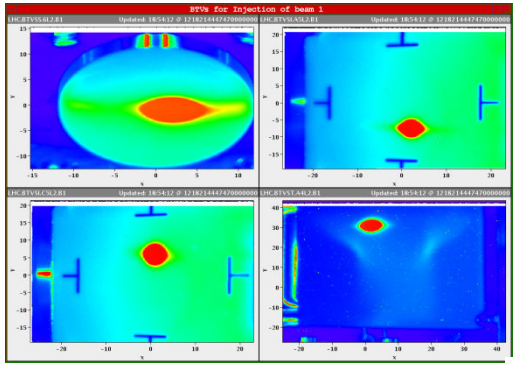




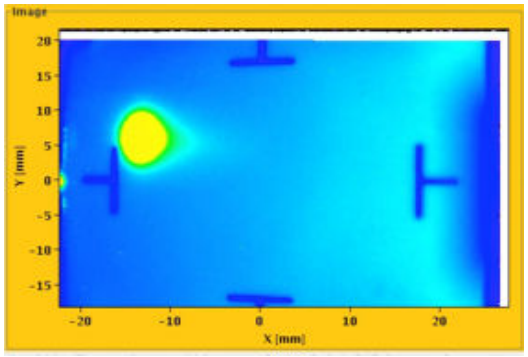
2005: FIRST HOLE (SPS)



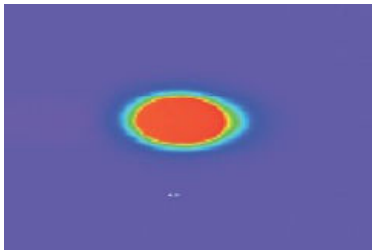
2008: FIRST BEAM TO LHC



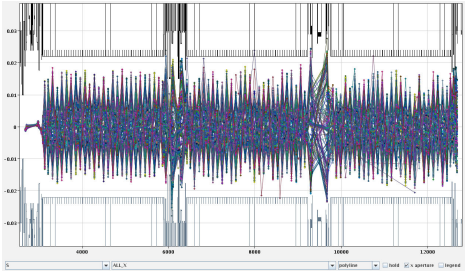
2008: FIRST BEAM TO IR3

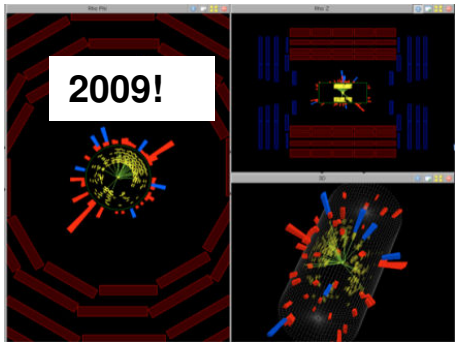


2009: FIRST IONS TO LHC



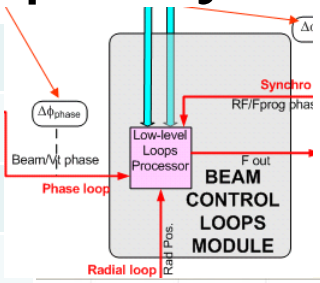
2009: Sectors test

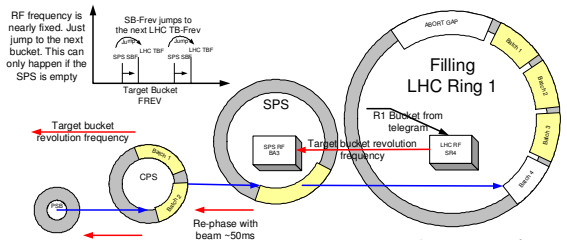


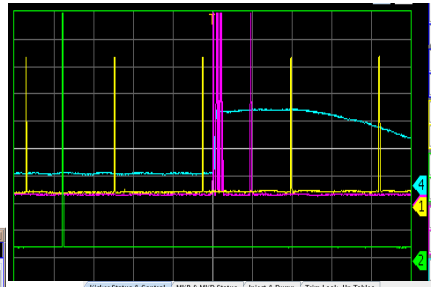


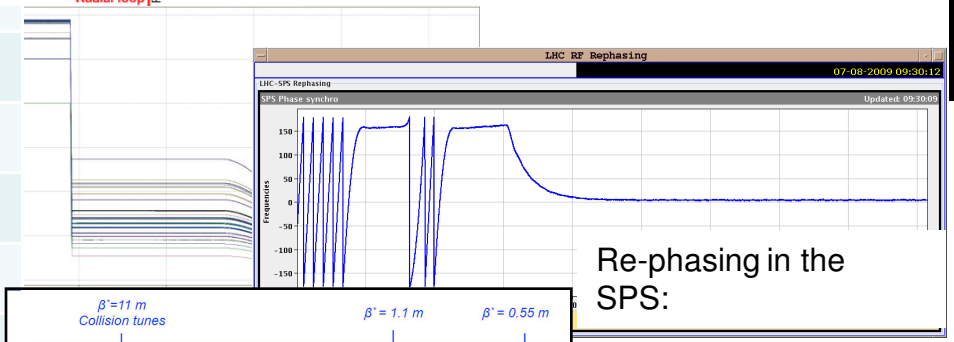
Prep: dry runs and checkout

- Extraction
- Transfer lines
- Injection
- RF, injection sequence
- Timing System
- Beam Interlock System
- Collimators
- Vacuum
- Interlocks, SIS
- BLMs, BPMs
- BTV, BCT
- Beam dump
- PGCs
- Magnet model
- Sequencer, alarms
- Controls, logging, DBs
- LSA, optics model, YASP

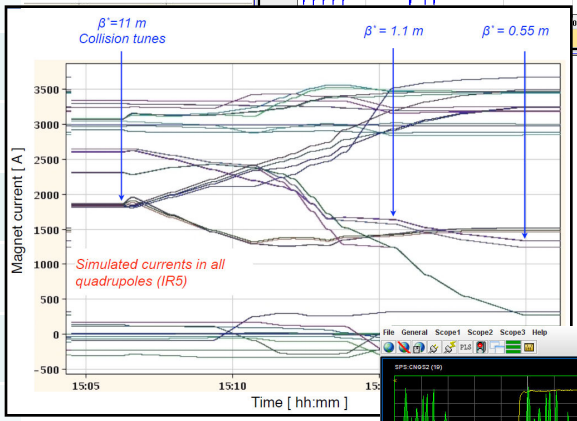


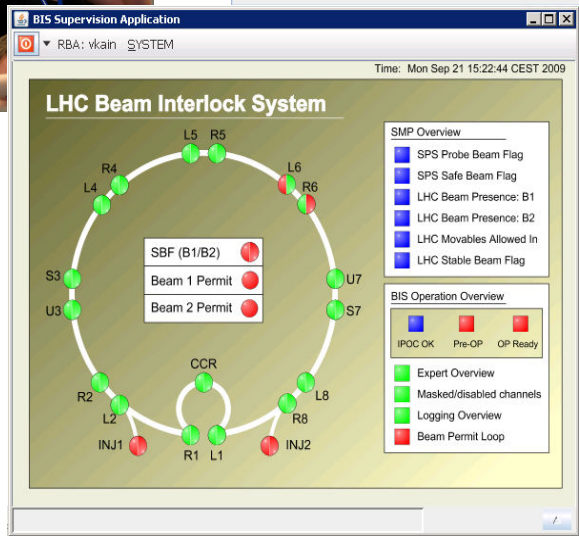




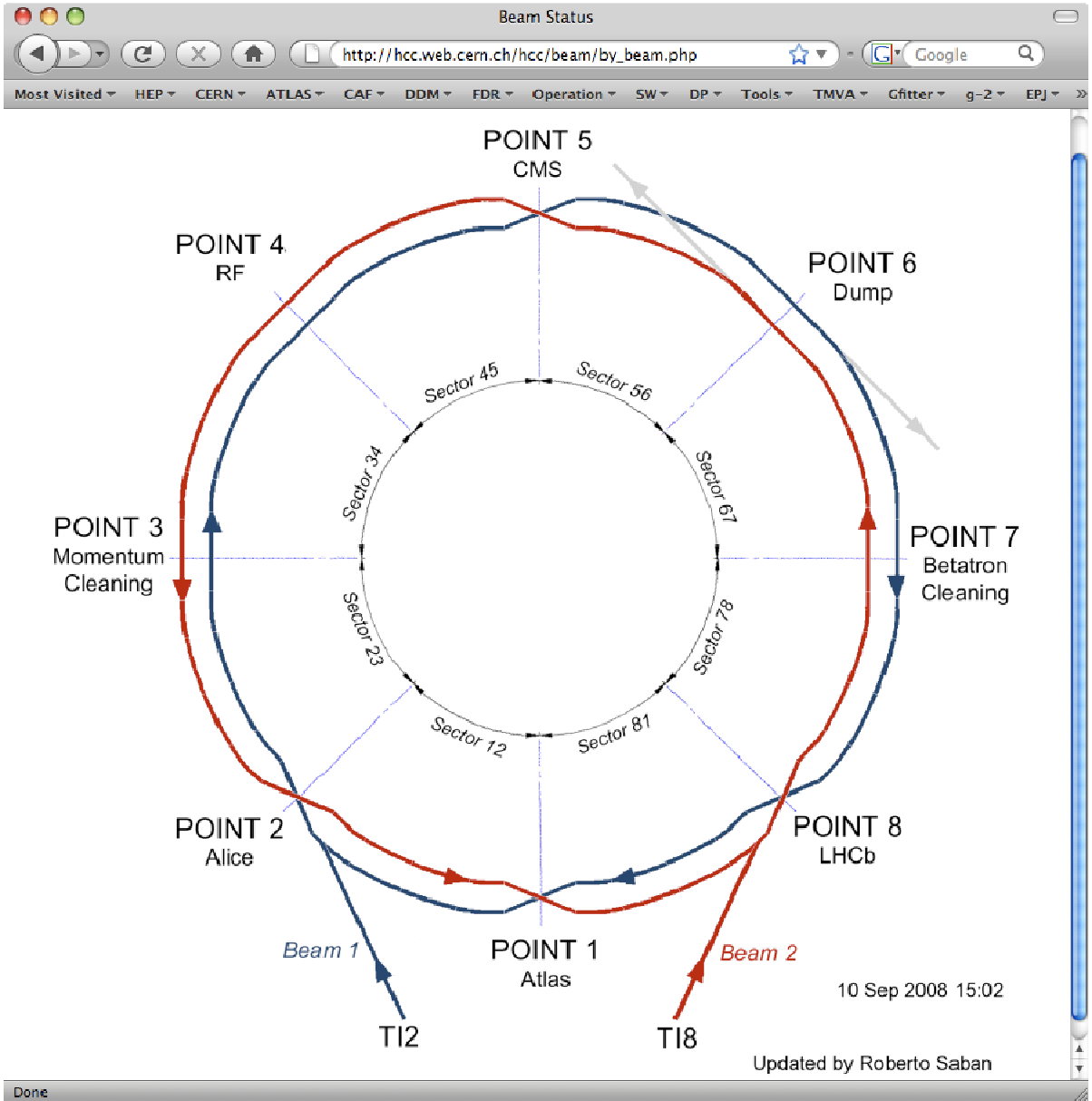


Re-phasing in the SPS:





Phase 5 Operation with Beam

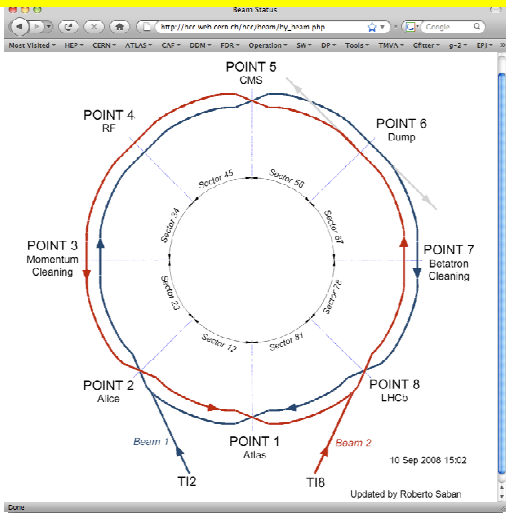


Friday November 20

18:30 Beam 1

- 19.00 beam through CMS (23, 34, 45)
  - beam1 through to IP6 19.55 Starting again injection of Beam1
  - corrected beam to IP6, 7, 8, 1
- 20.40 Beam 1 makes 2 turns
  - Working on tune measurement, orbit, dump and RF
  - Beam makes several hundred turns (not captured)
    - Integers 64 59, fractional around .3 (Qv trimmed up .1)
- 20.50 Beam 1 on beam dump at point 6
- 21.50 Beam 1 captured

2h10 for 27km: 12.5km/h average speed



22:15 Beam2

- 23.10 Start threading Beam2
  - Round to 7 6 5 2 1
- 23.40 First Turn Beam2
  - Working on tune measurement, orbit, dump and RF
  - Beam makes several hundred turns (not captured)
    - Integers 64 59, fractional around .3 (Qv trimmed up .05)
- 24.10 Beam 2 captured

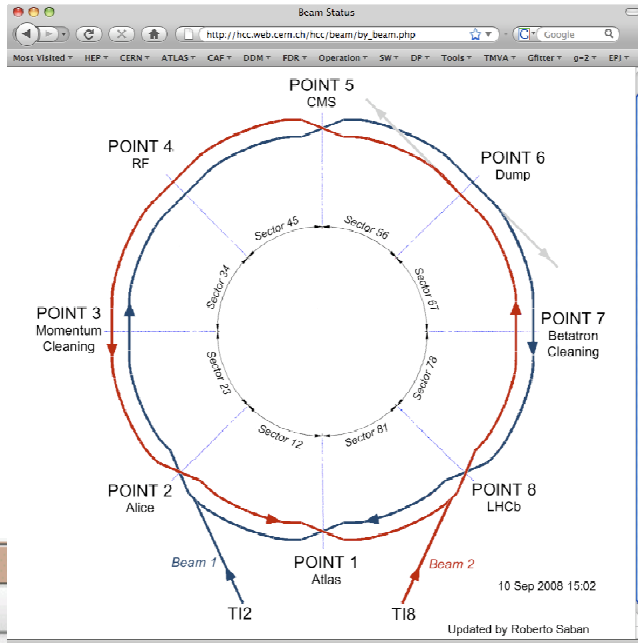
1h25 for 27km: a bit faster

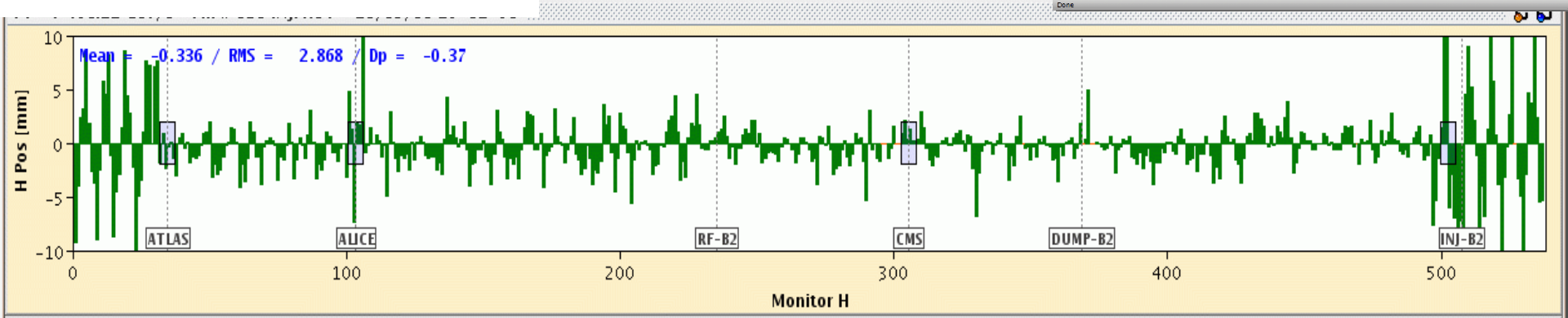
Beam threading

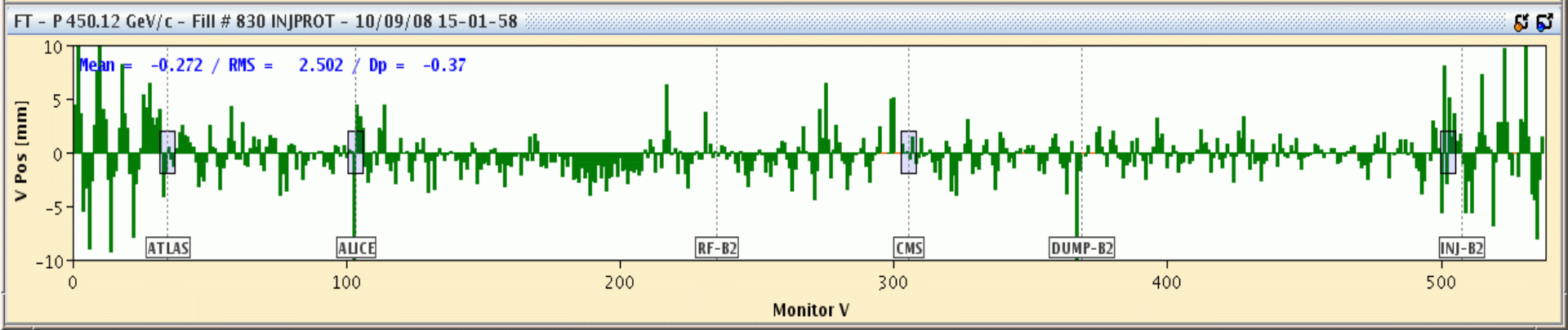
Threading by sector:

- One beam at the time
- Beam through 1 sector (1/8 ring), correct trajectory, open collimator and move on.

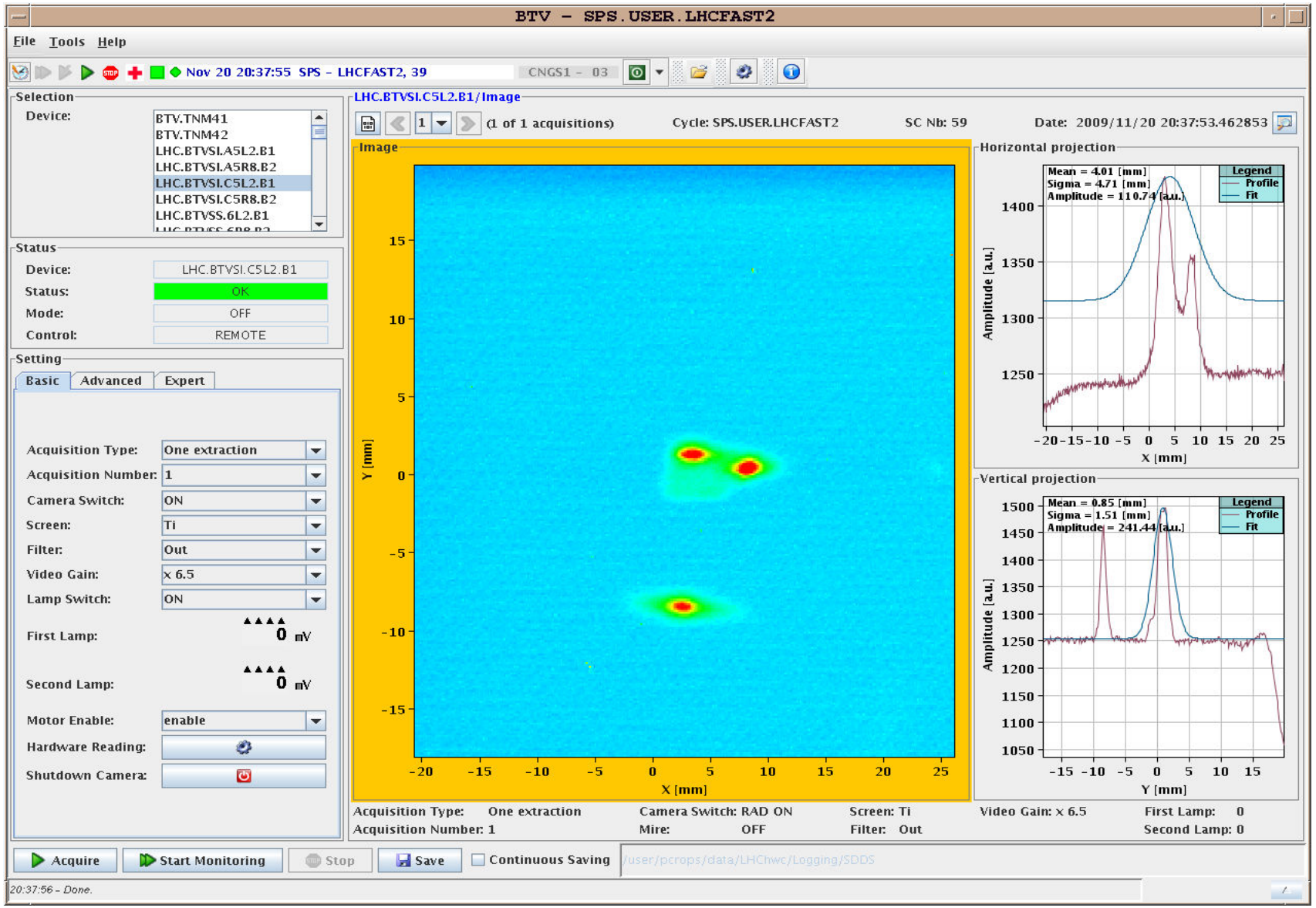
Beam 2 threading







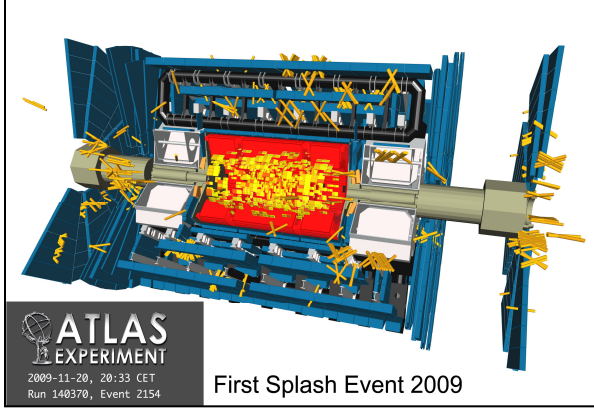
Friday: 8:15pm: Beam 1 First 2 turns



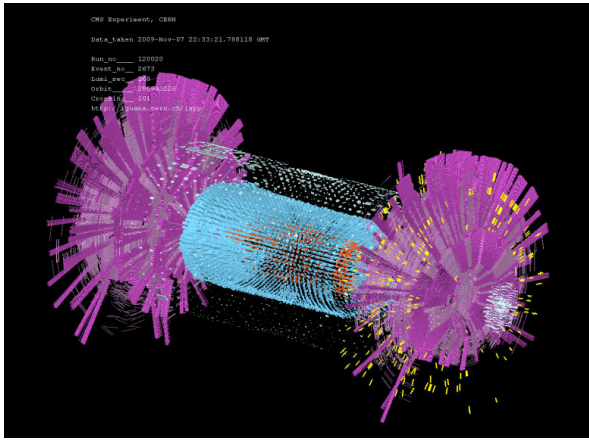
First circulating Beam in LHC in 2009

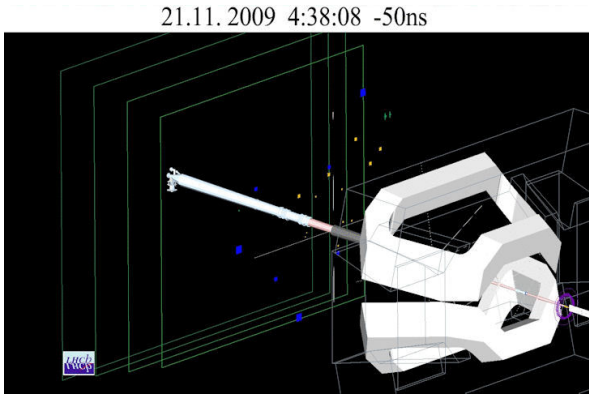
Saturday - Beam 1

- Splashes for experiments overnight Friday/Saturday
- Beam 1 again from 16.00
  - RF fine tuning
  - Beam Instrumentation on tune, orbit and more
- Circulate and not dump
  - Lifetime 10h
- From 19.00
  - Dispersion and Chromaticity
- Kick response (with circulating beam) overnight
- Concern about transformer in point 8!
  - 20ms earth leak (800A) – to be watched



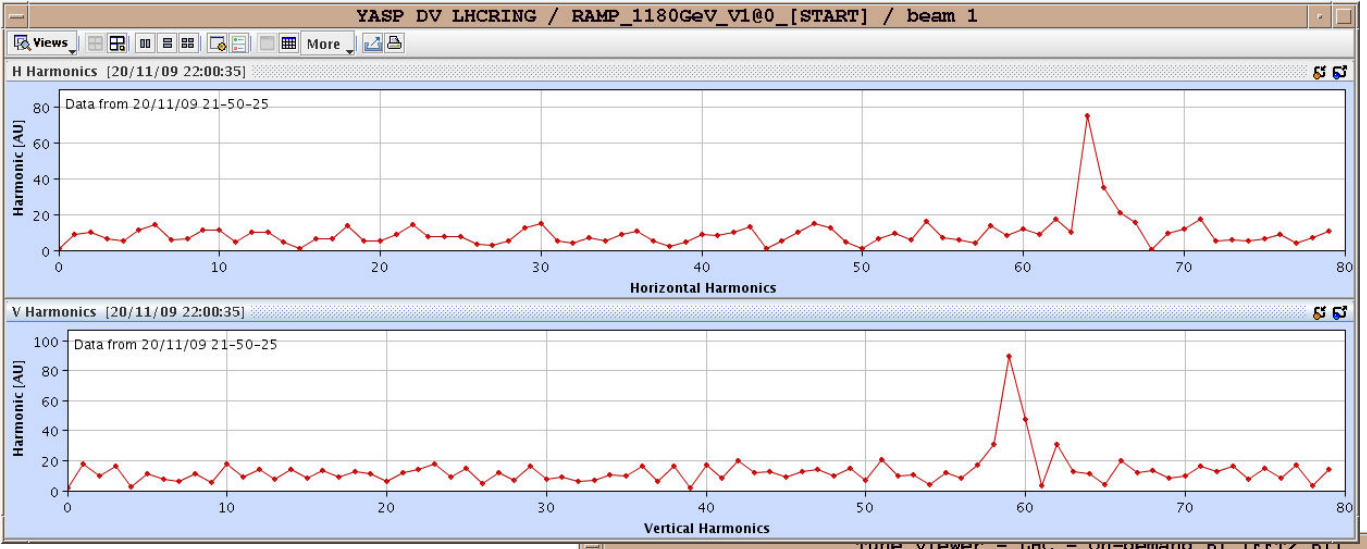
First Splash Event 2009



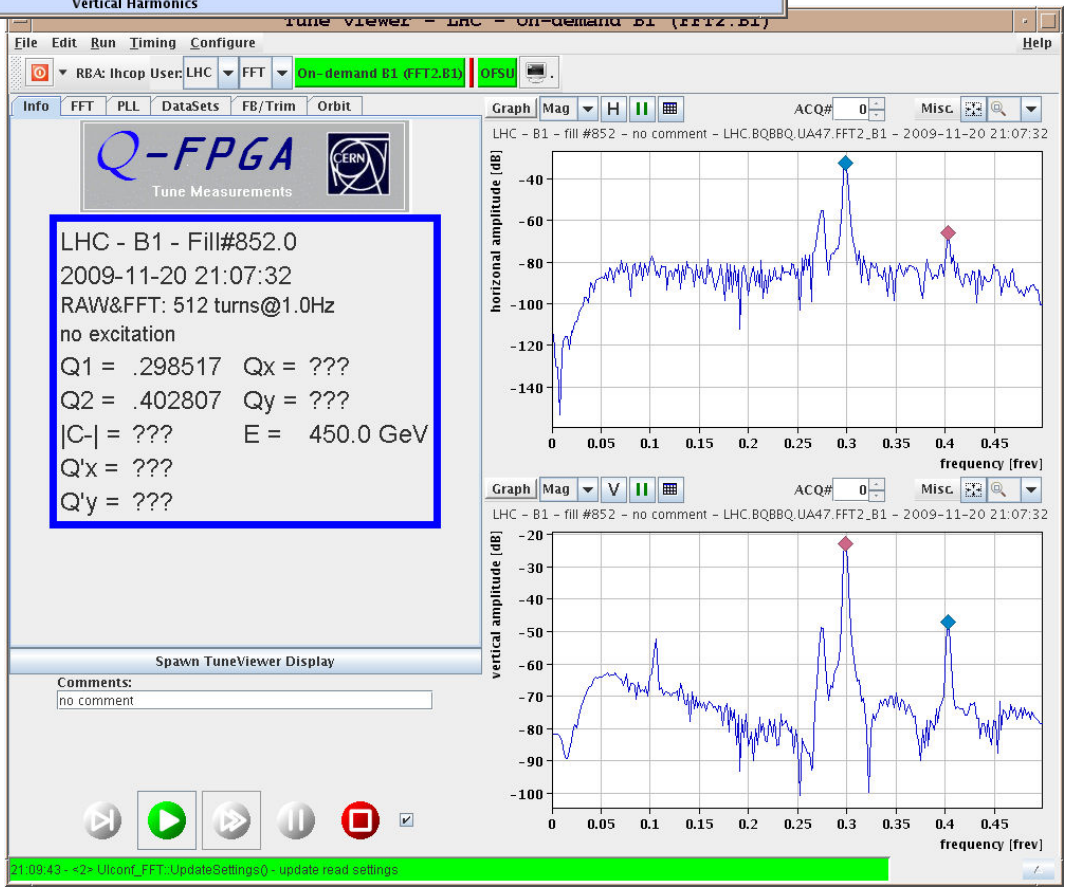


Tunes

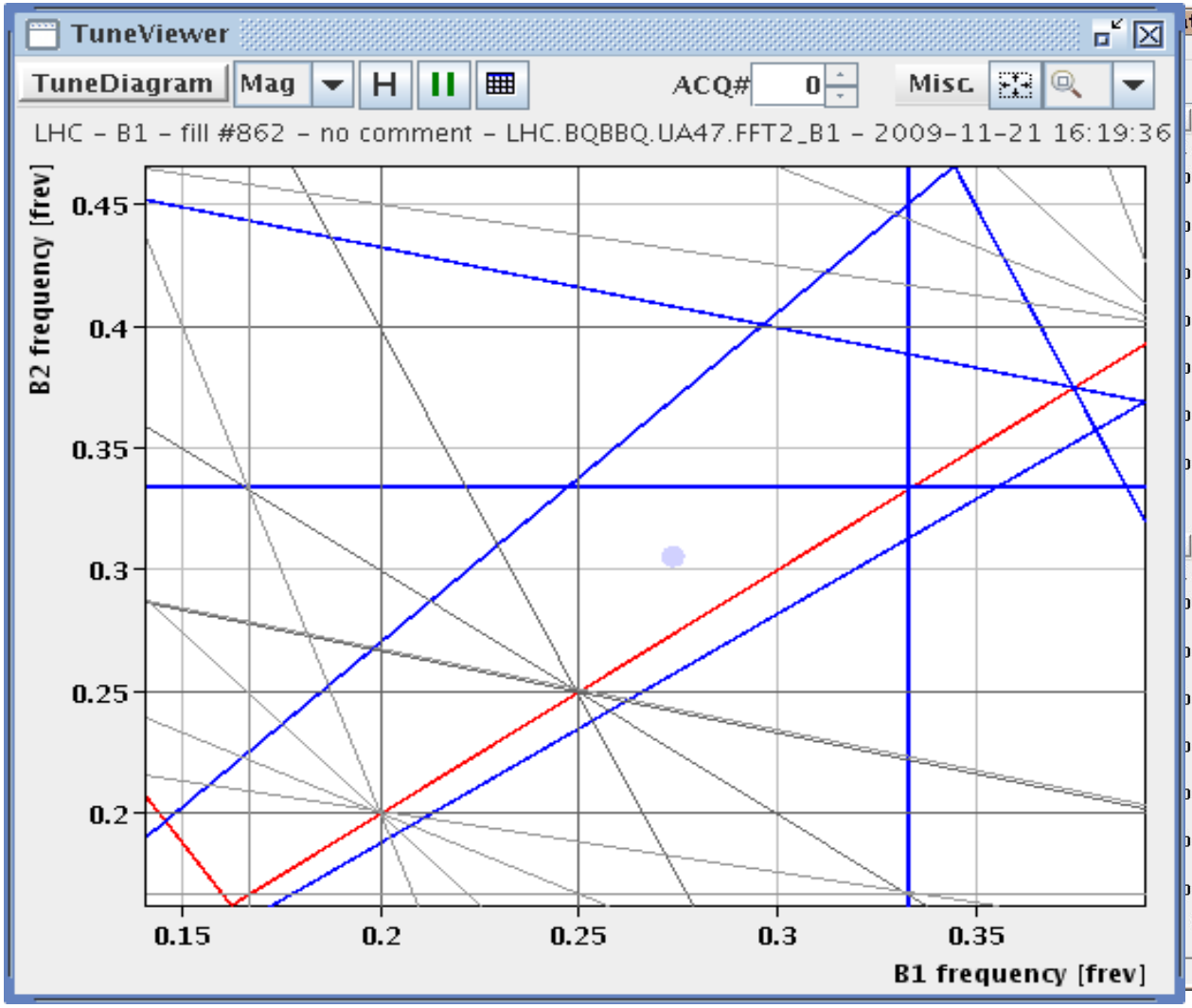
Integer

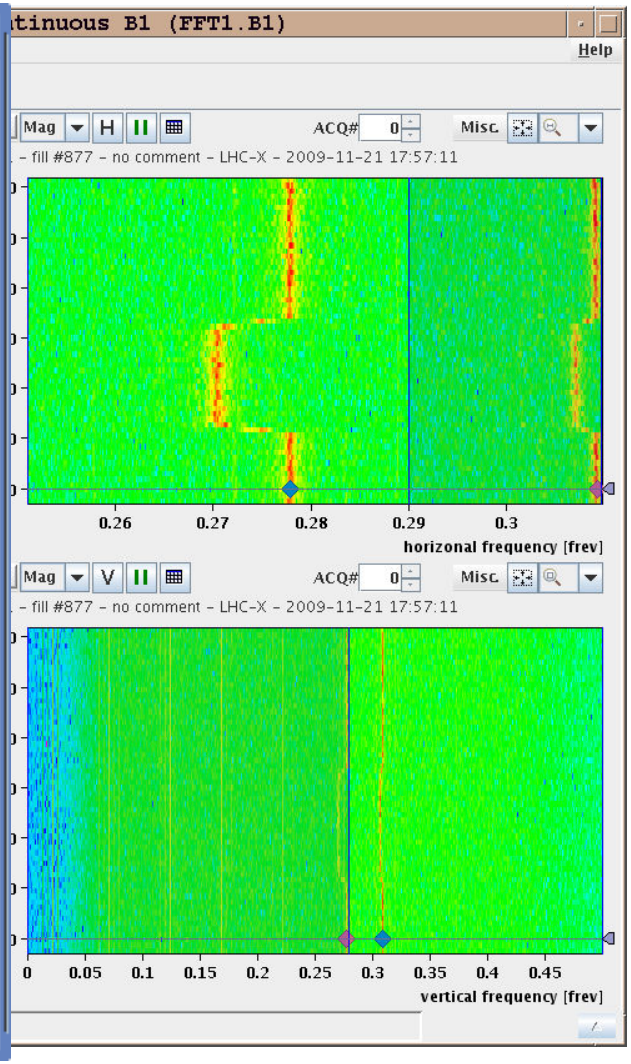


Non-Integer

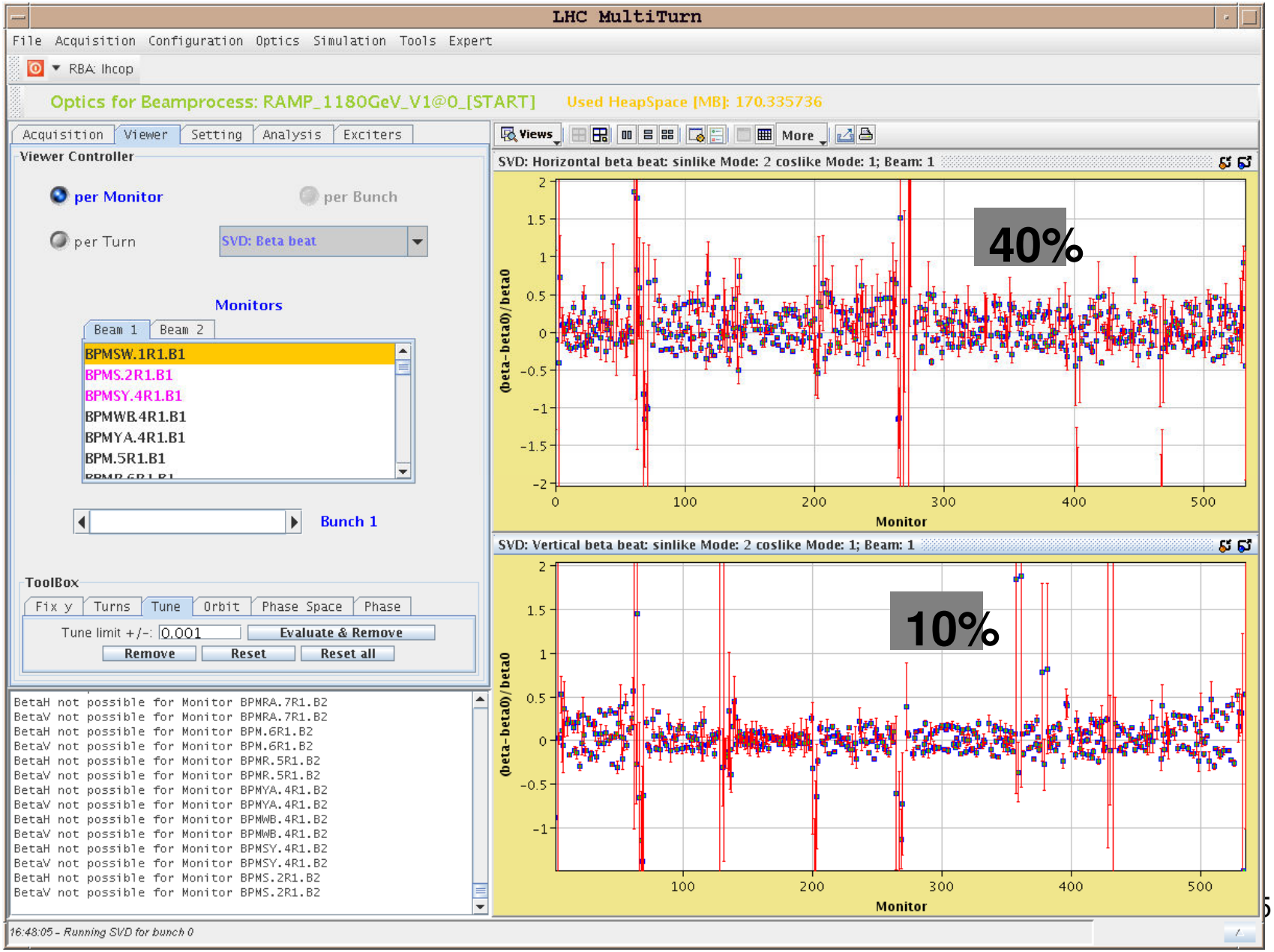


Tune measure and trim

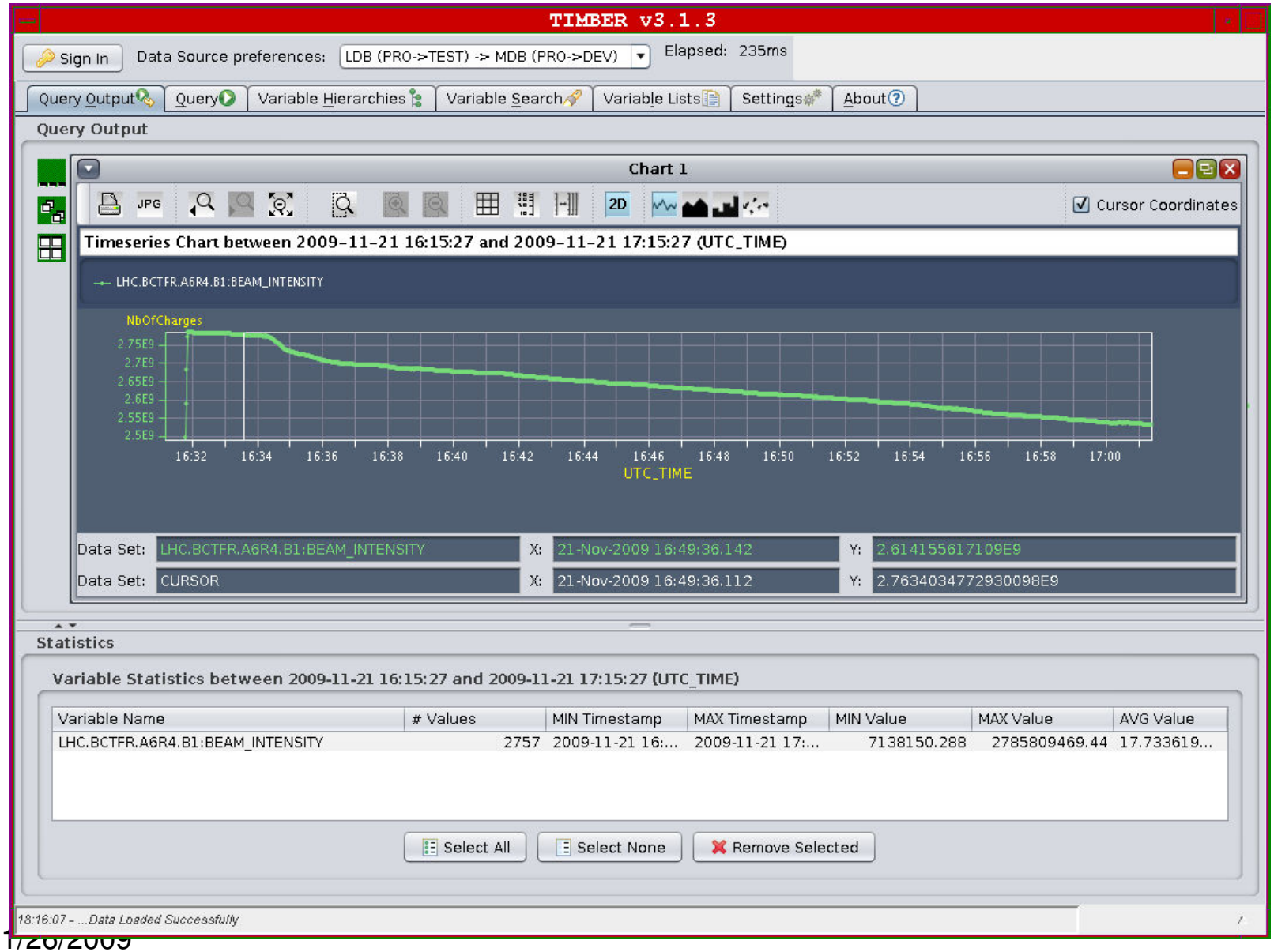




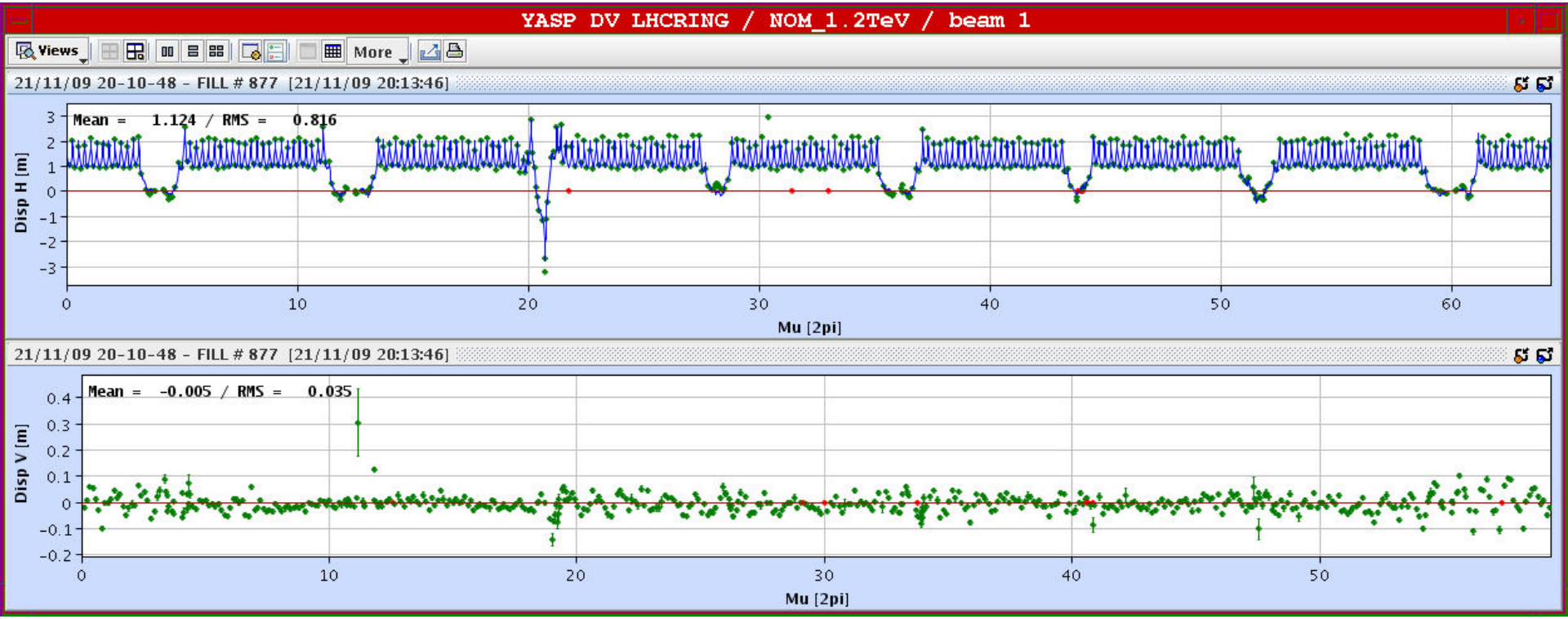
Beta-beat


LHC MultiTurn
File Acquisition Configuration Optics Simulation Tools Expert
RBA: lhcop
Optics for Beamprocess: RAMP_1180GeV_V1@0_[START]
Used HeapSpace [MB]: 170.335736
Acquisition Viewer Setting Analysis Exciters
Viewer Controller
per Monitor
per Bunch
per Turn
SVD: Beta beat
Monitors
Beam 1 Beam 2
BPMSW.1R1.B1
BPMS.2R1.B1
BPMSY.4R1.B1
BPMWB.4R1.B1
BPMYA.4R1.B1
BPM.5R1.B1
Bunch 1
ToolBox
Fix y Turns Tune Orbit Phase Space Phase
Tune limit +/-: 0.001
Evaluate & Remove
Remove Reset Reset all
BetaH not possible for Monitor BPMRA.7R1.B2
BetaV not possible for Monitor BPMRA.7R1.B2
BetaH not possible for Monitor BPM.6R1.B2
BetaV not possible for Monitor BPM.6R1.B2
BetaH not possible for Monitor BPMR.5R1.B2
BetaV not possible for Monitor BPMR.5R1.B2
BetaH not possible for Monitor BPMYA.4R1.B2
BetaV not possible for Monitor BPMYA.4R1.B2
BetaH not possible for Monitor BPMWB.4R1.B2
BetaV not possible for Monitor BPMWB.4R1.B2
BetaH not possible for Monitor BPMSY.4R1.B2
BetaV not possible for Monitor BPMSY.4R1.B2
BetaH not possible for Monitor BPMS.2R1.B2
BetaV not possible for Monitor BPMS.2R1.B2
16:48:05 - Running SVD for bunch 0
Views
More
SVD: Horizontal beta beat: sinlike Mode: 2 coslike Mode: 1; Beam: 1
40%
(beta-beta0)/beta0
Monitor
SVD: Vertical beta beat: sinlike Mode: 2 coslike Mode: 1; Beam: 1
10%
(beta-beta0)/beta0
Monitor

BCT – lifetime around 10h

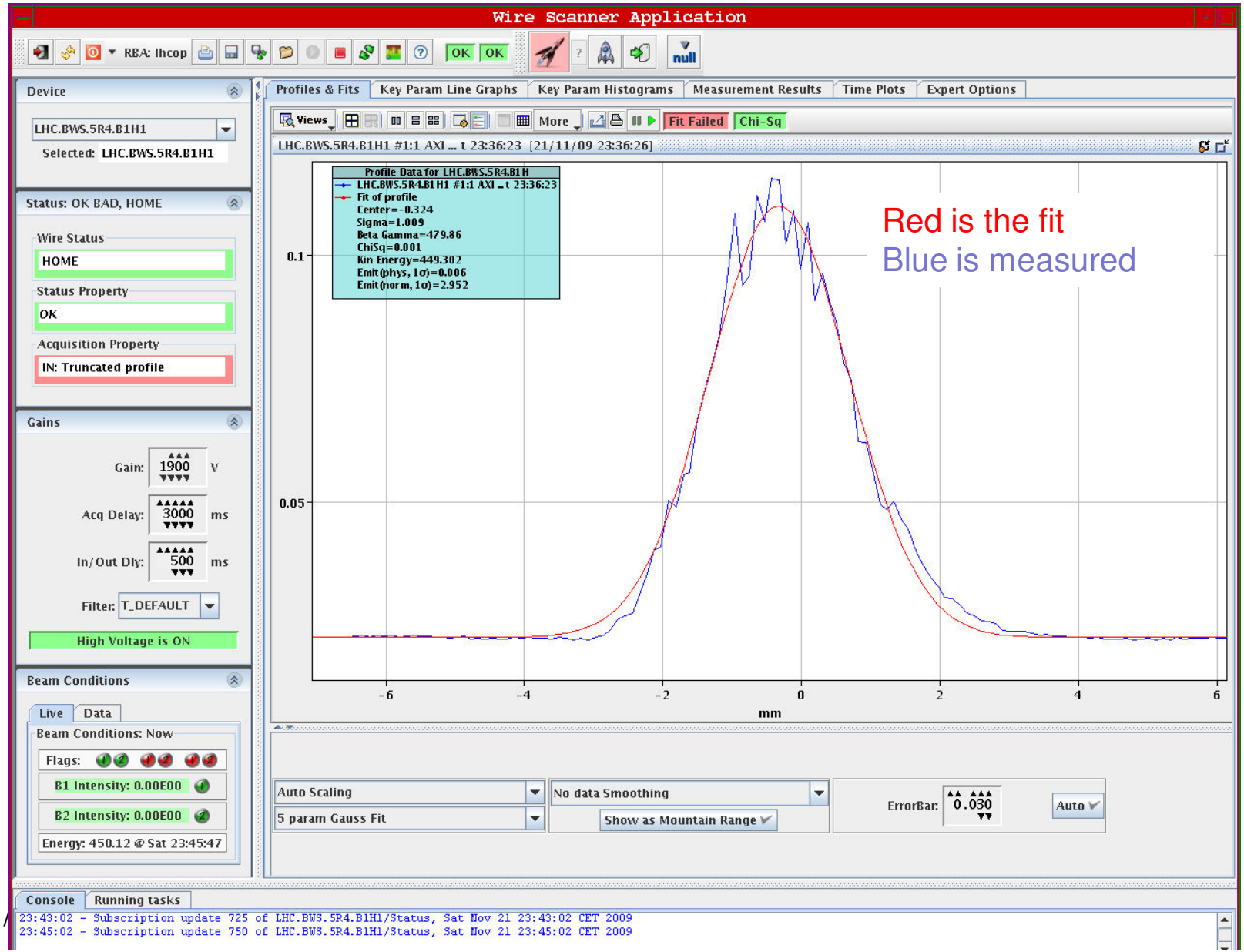


Dispersion B1



Green dots are measured: blue line calculated

Wire scan


Wire Scanner Application
RBA: lhcop
OK
OK
null
Device
LHC.BWS.5R4.B1H1
Selected: LHC.BWS.5R4.B1H1
Status: OK BAD, HOME
Wire Status
HOME
Status Property
OK
Acquisition Property
IN: Truncated profile
Gains
Gain: 1900 V
Acq Delay: 3000 ms
In/Out Dly: 500 ms
Filter: T_DEFAULT
High Voltage is ON
Beam Conditions
Live
Data
Beam Conditions: Now
Flags:
B1 Intensity: 0.00E00
B2 Intensity: 0.00E00
Energy: 450.12 @ Sat 23:45:47
Profiles & Fits
Key Param Line Graphs
Key Param Histograms
Measurement Results
Time Plots
Expert Options
Views
More
Fit Failed
Chi-Sq
LHC.BWS.5R4.B1H1 #1:1 AXI ... t 23:36:23 [21/11/09 23:36:26]
Profile Data for LHC.BWS.5R4.B1H
LHC.BWS.5R4.B1H1 #1:1 AXI ...t 23:36:23
Fit of profile
Center=-0.324
Sigma=1.009
Beta Gamma=479.86
ChiSq=0.001
Kin Energy=449.302
Emit(phys, 1σ)=0.006
Emit(norm, 1σ)=2.952
Red is the fit
Blue is measured
0.1
0.05
-6
-4
-2
0
2
4
6
mm
Auto Scaling
5 param Gauss Fit
No data Smoothing
Show as Mountain Range
ErrorBar: 0.030
Auto
Console
Running tasks
23:43:02 - Subscription update 725 of LHC.BWS.5R4.B1H1/Status, Sat Nov 21 23:43:02 CET 2009
23:45:02 - Subscription update 750 of LHC.BWS.5R4.B1H1/Status, Sat Nov 21 23:45:02 CET 2009

Monday Midday

Status both beams at midday Monday

- Lots of successful BI system commissioning
- RF capture and phase loop on
- Orbit, Q, Q', coupling measured and corrected to first order
- Lifetimes ~10h
- Dispersion remarkably good
- Beta beating measured
- Kick response almost done for beam 1

Monday afternoon

- **Both beams circulating in LHC. Hands off by OP for half an hour.**
- Transverse Steering into collision using BPMs through 1 and 5.
- **Hands off by OP for half an hour**

- **Recorded collision events in ATLAS and CMS**

- From 16:00
  - Two beams in LHC at buckets 1 and 8911
  - **Quiet beams for ALICE**
  - Then 2 beams in LHC at buckets 1 and 26701
  - **Quiet beams for LHCb**

- **Recorded collision events in ALICE and LHCb**

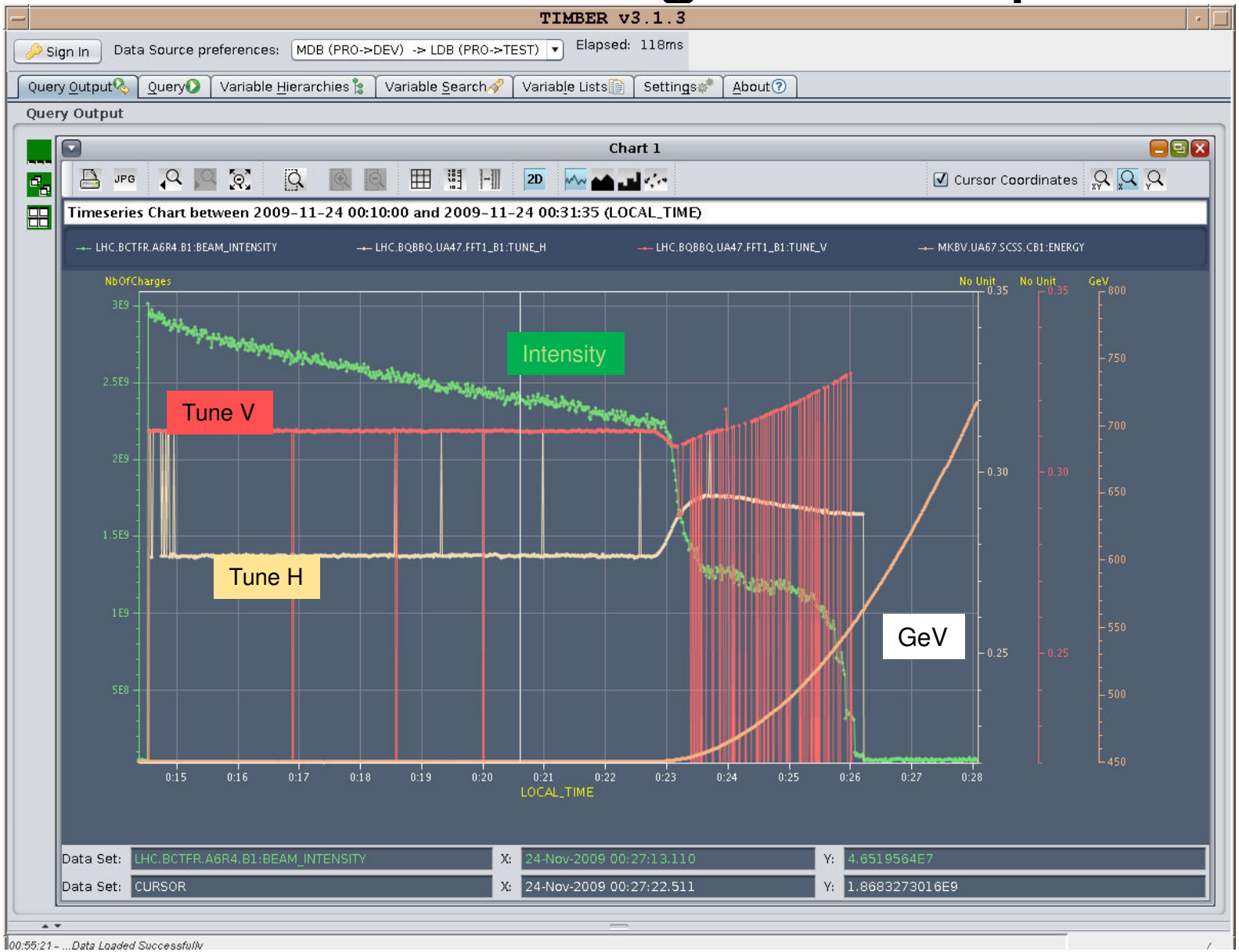
- From 19.00
  - Beam 2 back in bucket 1
  - 2 beams in for collimation set up
  - Quickly steer IR5 (with new knob) and IR1
  - **Quiet beams for 15' for CMS and ATLAS**

Monday

- From 19.30 to 22.30 – first collimator set up (20 collimators done)
- Dump debunched beam
  - All losses on TCDS and TCDQ – looks good

– First test ramp just after midnight
  - Beam 1
  - Beam to 560 GeV
    – Some losses at start
    – Then stable
    – Then losses (3rd order resonance)

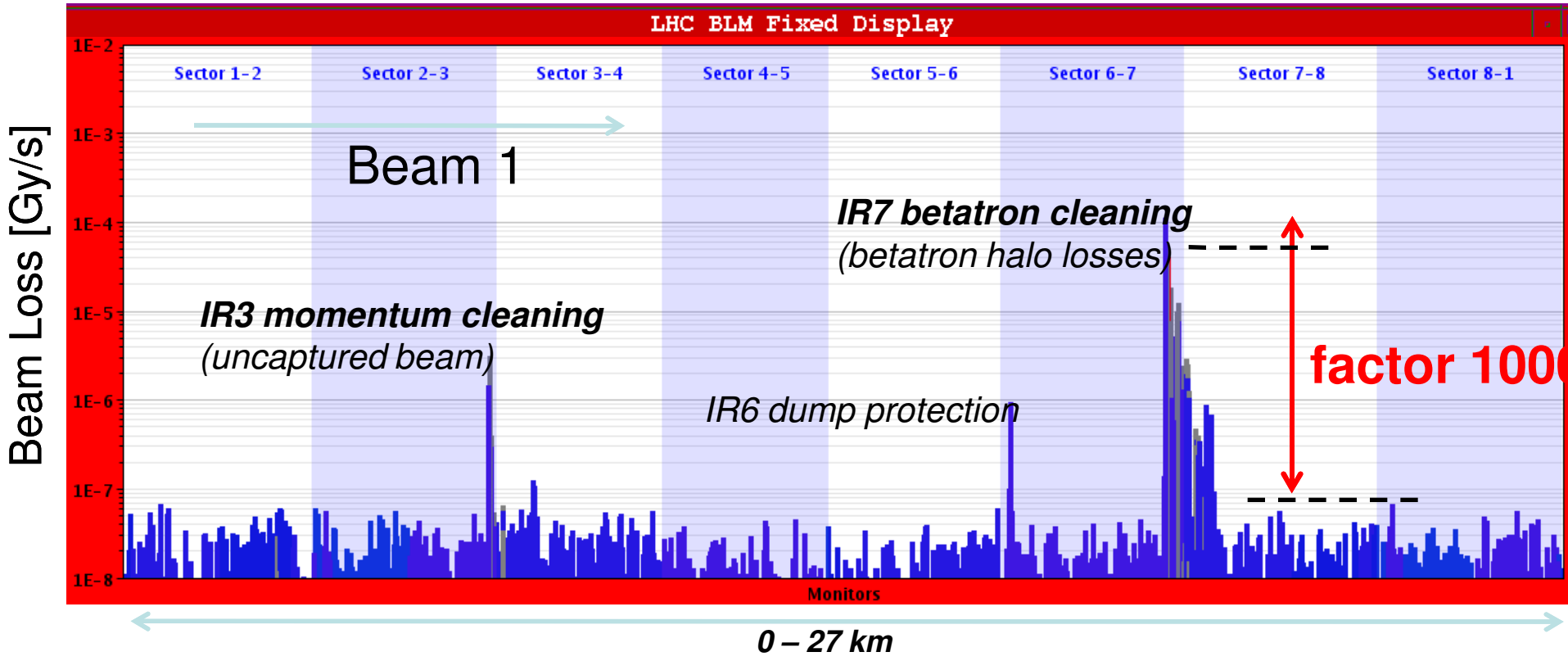
Tunes during the ramp



First Multi-Stage Betatron and Momentum Collimation

21/100 coll. beam-based aligned to nominal settings for trial ramp 24.11.2009 (others coarse).

IR7	*Primary:*	***5.7 σ***	*Secondary:*	*~10 σ*	*Tungsten absorber:*	*10 σ*
IR3	*Primary:*	***8.0 σ***	*Secondary:*	*~10 σ*	*Tungsten absorber:*	*10 σ*
IR6	*TCS:*	*~7.0 σ*	*TCDQ:*	*~8.0 σ*		



- No unexpected losses in arcs, experimental insertions, …
- Initial cleaning efficiency: **> 99 %**

Status

Vacuum leak in the PS: at the wire scanner
now fixed and pumping down

- Great progress so far
  - Thorough preparation is paying off
- Need to consolidate
  - Pre-cycle not operational yet (probably is now as I speak)
  - Energy mismatch SPS-LHC
  - Revisit and consolidate linear optics
  - Beam dump beam commissioning
  - Get data on 450GeV machine
    - Beta-beating
    - Kick response
    - Aperture BT issues
- Get experimental solenoids on
- Machine Protection
- Ramps (tune control feedback)

In conclusion

This has been a truly remarkable seven days for CERN. Things have moved so fast that it has been hard to separate fact from fiction –facts have often seemed too good to be true.

It's been a week of many firsts. Monday was the first for two captured beams in the LHC. Also first time the LHC has functioned as a particle accelerator. First for the highest energy proton-proton collisions ever produced at CERN:

I'd like to express my heartfelt thanks and congratulations to all those who have done such a great job in bringing the LHC to life this week, and to all the unsung heroes who worked untiringly for the past 14 months to bring us from the dark days of late September last year, to where we are today. It has been a herculean effort, with no fewer than five distinct phases: repair; consolidation; hardware commissioning; preparing for beam; and finally operation. Each phase deserves equal merit.

The final phase has been highly visible, and widely reported around the world, but without phases one to four, the final phase would not have been possible.

One of the remarkable successes of the LHC start-up this year has been the cryogenic system. With all the excitement of beam this week, it would be easy to overlook the fact that the LHC has been stably cold, almost without a glitch, since 8 October. That alone marks tremendous progress since last year.

The new magnet protection systems have also been a revelation. The faulty connection that failed on 19 September had a resistance of 220 nano-Ohms. Today, we measure splice resistances and monitor them to less than one nano-Ohm. And the splices will be protected with this system

To accomplish all this, teams from CERN rolled up their sleeves and worked tirelessly to get the job done. They were joined by people, whose help was spontaneously offered, from partner labs and institutes around the world. My sincere thanks go to all of them.

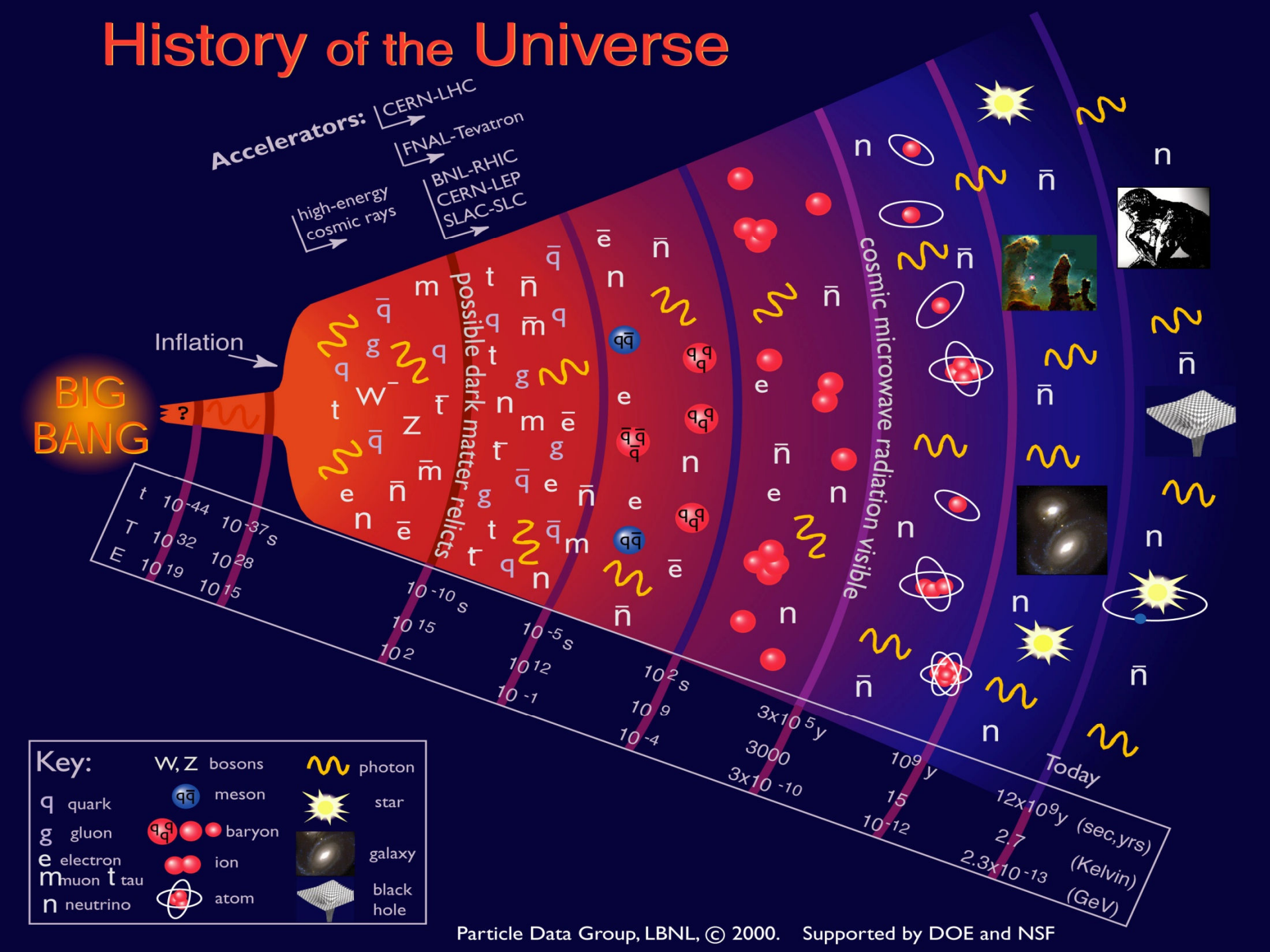
There are a few more groups of people that I'd personally like to acknowledge. In the CERN control centre, there are four islands. One is for the LHC, the others control and monitor the technical infrastructure of CERN, the PS complex and the SPS. For the LHC to work, all of them have to be working smoothly, and they were. The injector complex even managed to take lead ions all the way into the LHC at the first attempt, boding well for the end of the 2010 run. And the 'RF guys' put in a sterling effort to capture beams from the word go, and to accelerate at the first attempt.

Last but not least then there are all the other CERN services that have to come together to make things work: the GS department for access and safety systems; HR and FP for showing great flexibility in time of need; and SC for diligently ensuring that all safety aspects are fully covered, to name but three. The media service were also very successful in fending off many of the journalists .

A magnificent team effort.

Thank you!

History of the Universe



- sustained exponential development for more than 79 years
- progress achieved through repeated jumps from saturating to emerging technologies
- superconductivity, key technology of high-energy machines since the 1980s