Operating the LHC **with Beam**

(on behalf of the LHC team)

December 18, 2009

Milestones

Date	Day	Achieved
Nov 20	1	Each beam circulating. Key beam instrumentation working.
Nov 23	4	First collisions at 450 GeV. First ramp (reached 560 GeV).
Nov 26	7	Magnetic cycling established (reproducibility).
Nov 27	8	Energy matching.
Nov 29	10	Ramp to 1.18 TeV.
Nov 30	11	Experiment solenoids on.
Dec 04	15	Aperture measurement campaign finished. LHCb and ALICE dipoles on.
Dec 05	16	Machine protection (Injection, Beam dump, Collimators) ready for safe operation with pilots.
Dec 06	17	First collisions with STABLE BEAMS, 4 on 4 pilots at 450 GeV, rates around 1Hz.
Dec 08	19	Ramp colliding bunches to 1.18 TeV
Dec 11	22	Collisions with STABLE BEAMS, 4 on 4 at 450 GeV, > 10^{10} per bunch, rates around 10Hz.
Dec 13	24	Ramp 2 bunches per beam to 1.18 TeV. Collisions for 90mins.
Dec 14	25	Collisions with STABLE BEAMS, 16 on 16 at 450 GeV, > 10^{10} per bunch, rates around 50Hz.
Dec 16	27	Ramp 4 on 4 to 1.18 TeV. Squeeze to 7 m.

Corrector polarity checks

Beam 1

	total	checked	ok	checked ok?	% checked
L1	39	32	32	TRUE	82.05%
R1	38	30	30	TRUE	78.95%
L2	40	33	33	TRUE	82.50%
R2	37	29	29	TRUE	78.38%
L3	31	31	29	FALSE	100.00%
R3	39	0	0	TRUE	0.00%
L4	30	29	29	TRUE	96.67%
R4	33	28	28	TRUE	84.85%
L5	39	32	32	TRUE	82.05%
R5	38	31	31	TRUE	81.58%
L6	29	29	29	TRUE	100.00%
R6	28	28	28	TRUE	100.00%
L7	31	31	29	FALSE	100.00%
R7	30	28	28	TRUE	93.33%
L8	40	34	34	TRUE	85.00%
R8	40	32	32	TRUE	80.00%
	562	457	453	FALSE	81.32%

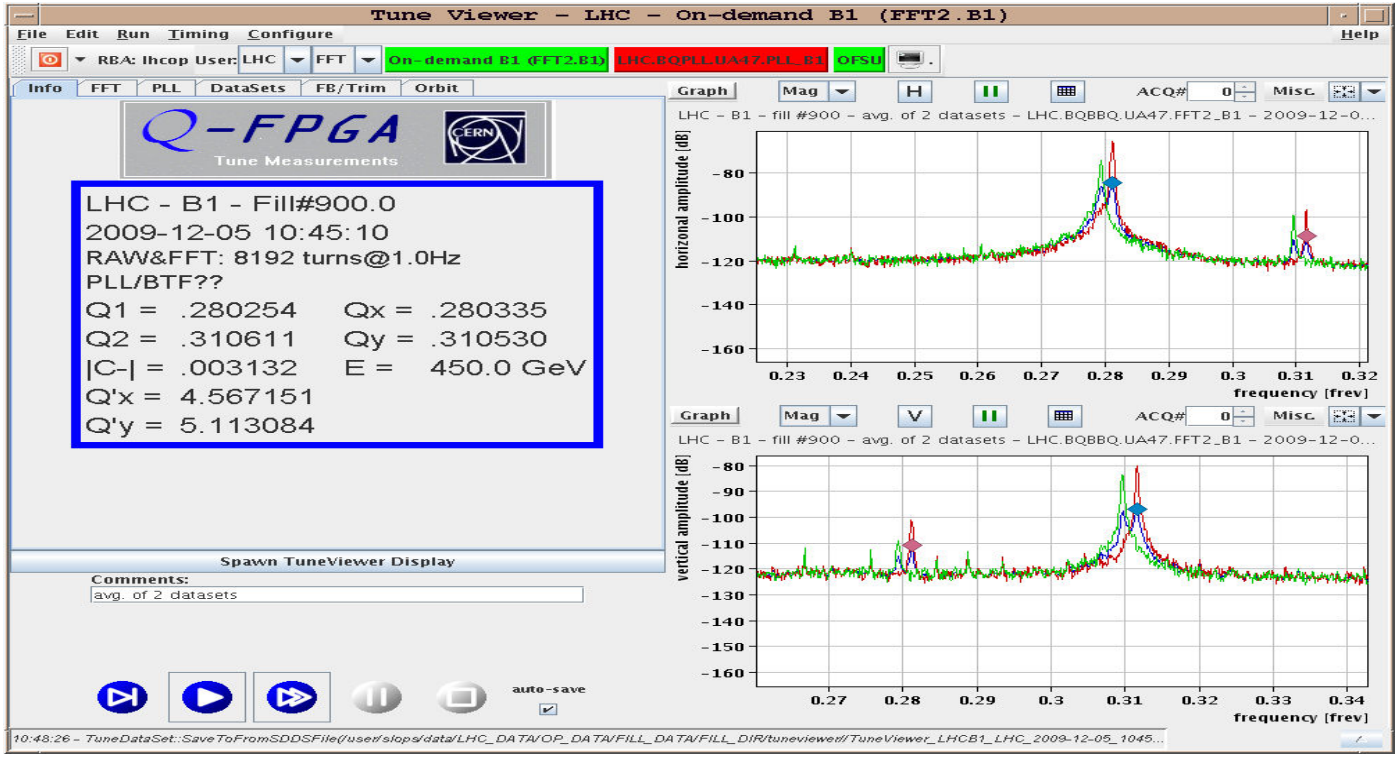
Beam 2:

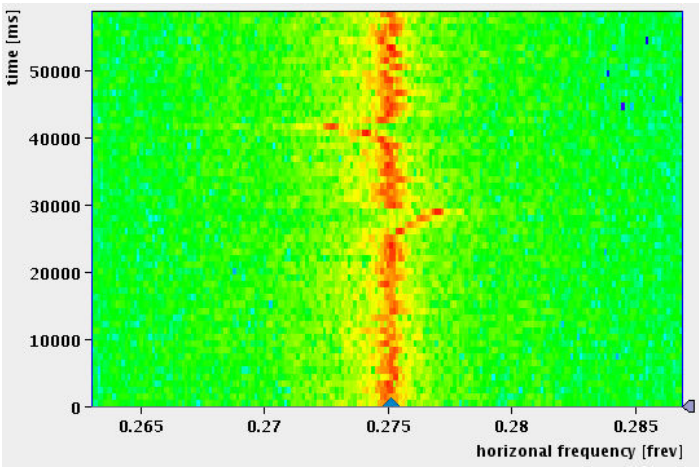
	total	checked	ok	checked ok?	% checked
L1	39	32	32	TRUE	82.05%
R1	38	30	30	TRUE	78.95%
L2	40	31	31	TRUE	77.50%
R2	37	31	31	TRUE	83.78%
L3	31	31	31	TRUE	100.00%
R3	30	29	29	TRUE	96.67%
L4	30	29	29	TRUE	96.67%
R4	29	27	27	TRUE	93.10%
L5	39	32	32	TRUE	82.05%
R5	38	32	32	TRUE	84.21%
L6	29	29	29	TRUE	100.00%
R6	28	28	28	TRUE	100.00%
L7	31	16	16	TRUE	51.61%
R7	30	15	15	TRUE	50.00%
L8	40	0	0	TRUE	0.00%
R8	40	0	0	TRUE	0.00%
	549	392	392	TRUE	71.40%

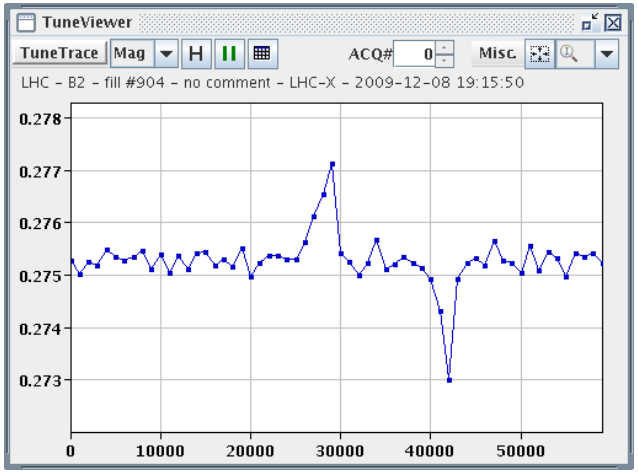
BPM polarity checks

	checked	ok	% ok
Beam 1	1076	1050	**97.58%**
Beam 2	1076	1058	**98.33%**

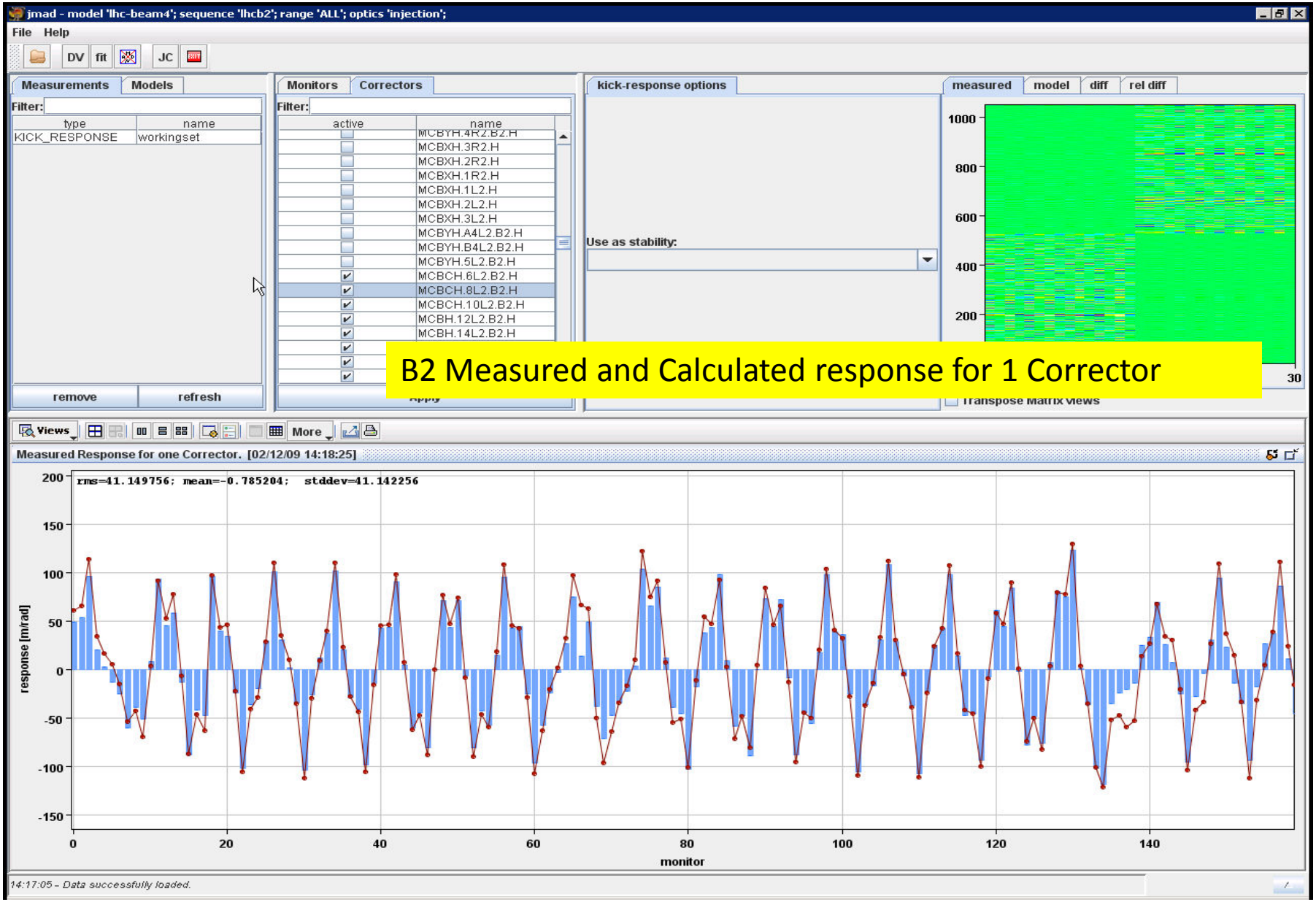
Q Q' C and Q loop





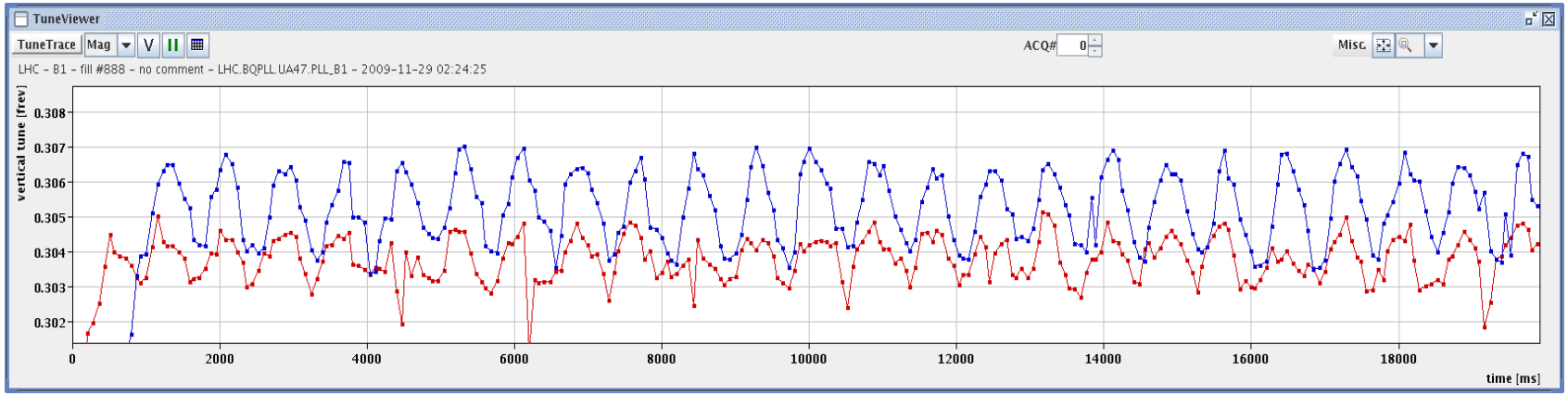


Optics Checks (2nd Dec)



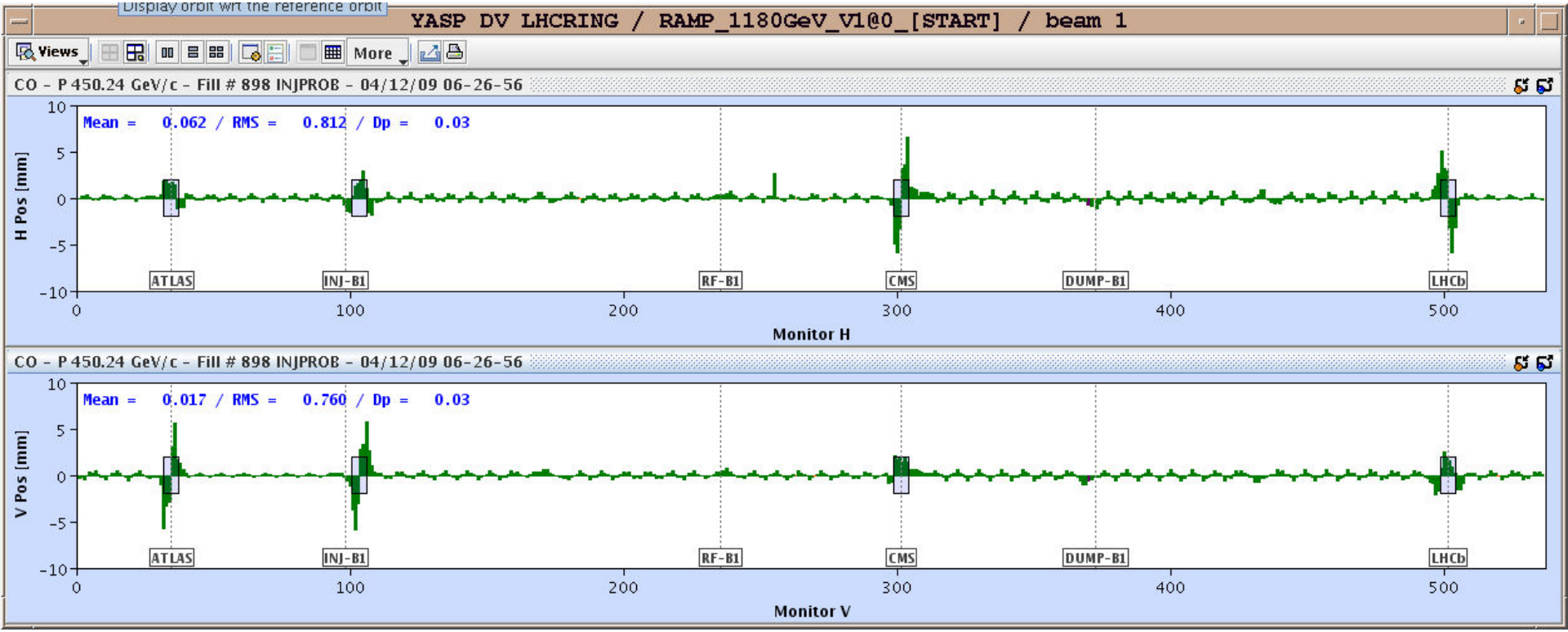
B2 Measured and Calculated response for 1 Corrector

Chromaticity Measurement and Correction

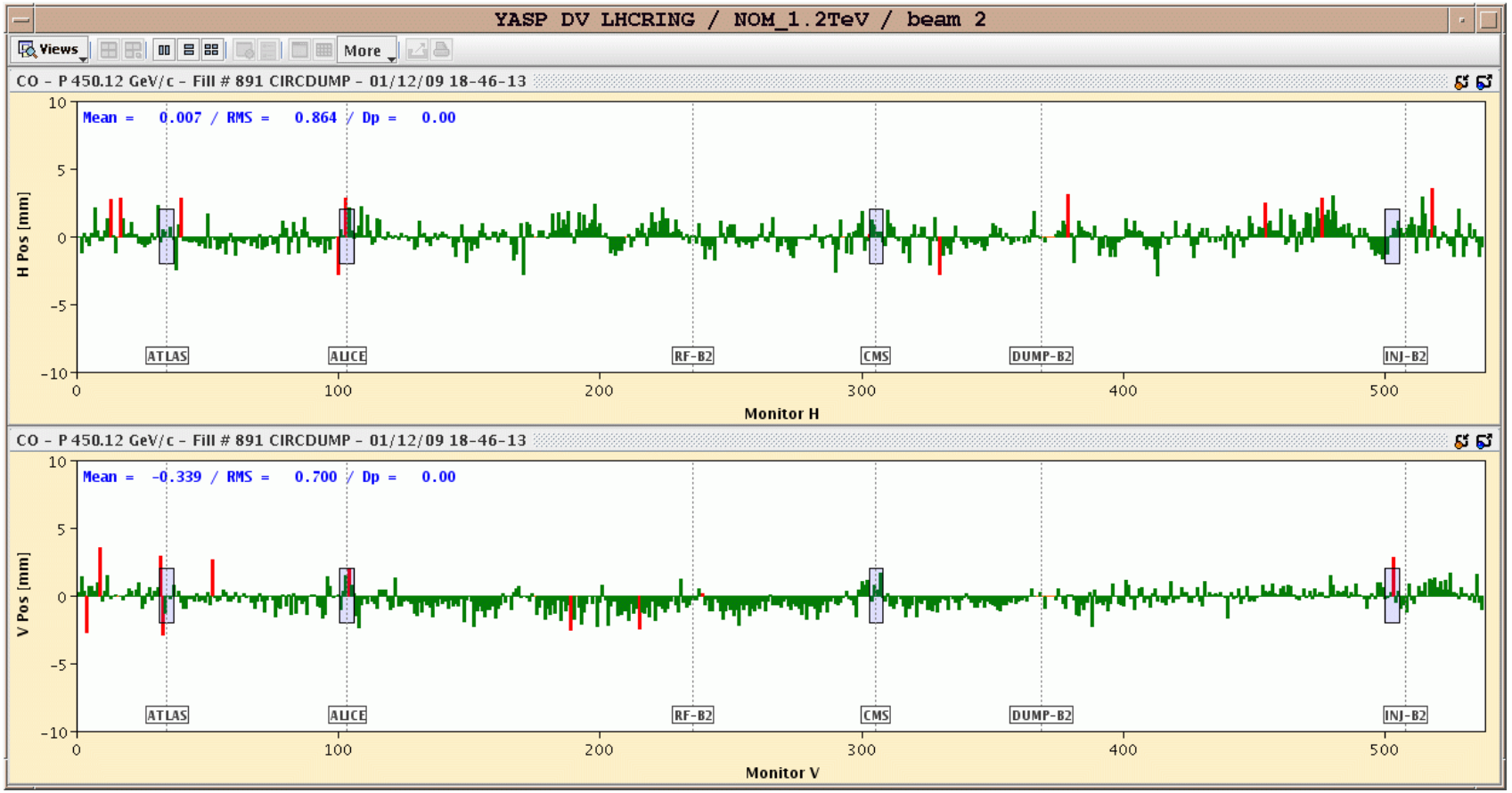


measured Q_v' = 15 using dp/p=1e-4 @2.5 Hz radial modulation,
damper amplitude 1e-3
with dQ_v' = -10 trim
'blue' trace before and 'red' after trim

Separation bumps and crossing angle.

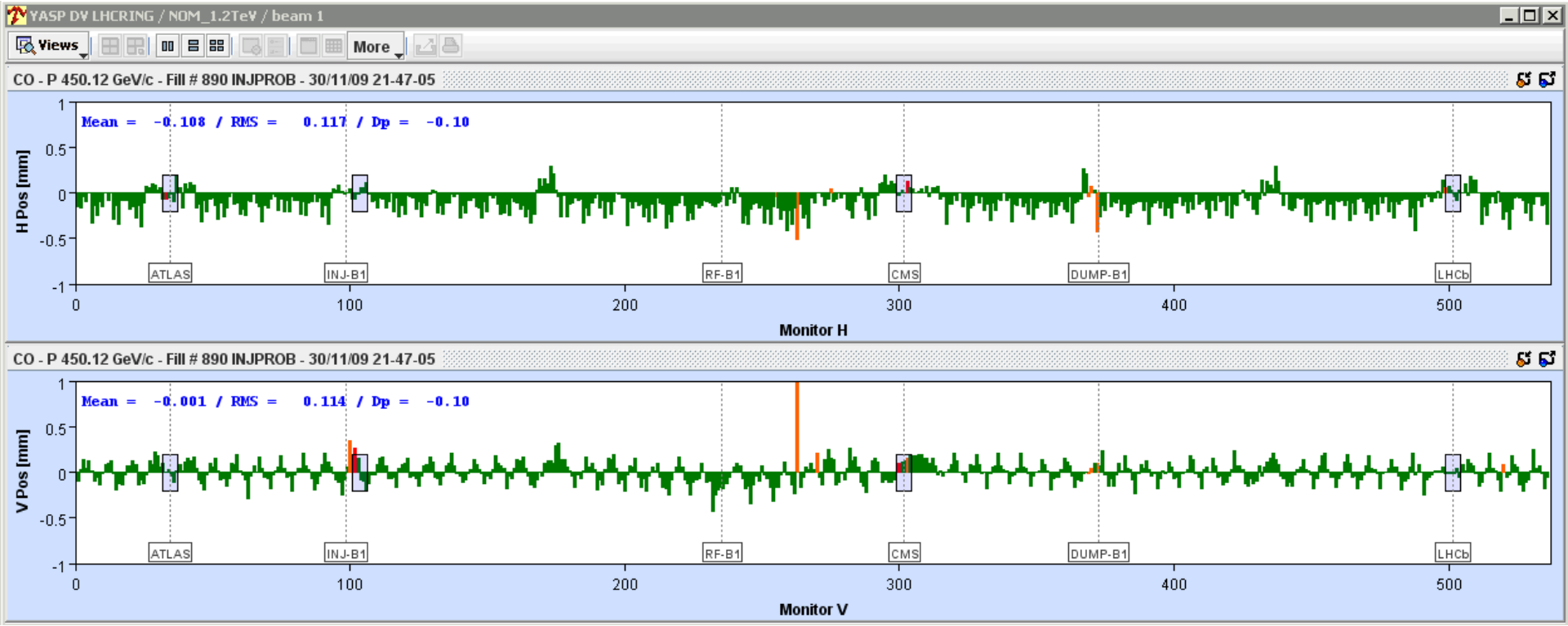


Orbits – golden “Santa Klaus”



CMS solenoid ramp up

Orbit difference CMS ON – CMS OFF

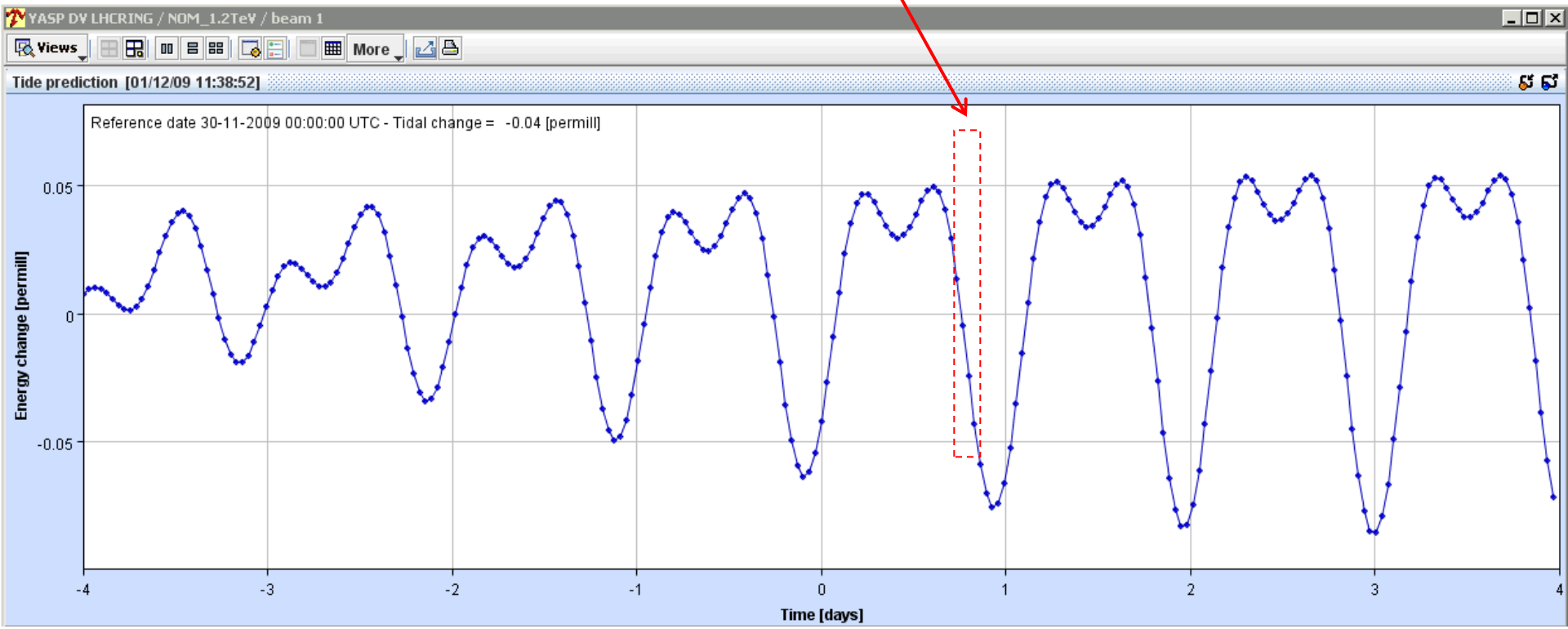


dp/p error change by ~ 0.1 per mill…

?? CMS solenoid changes the beam energy??

NO! But Earth tides do!

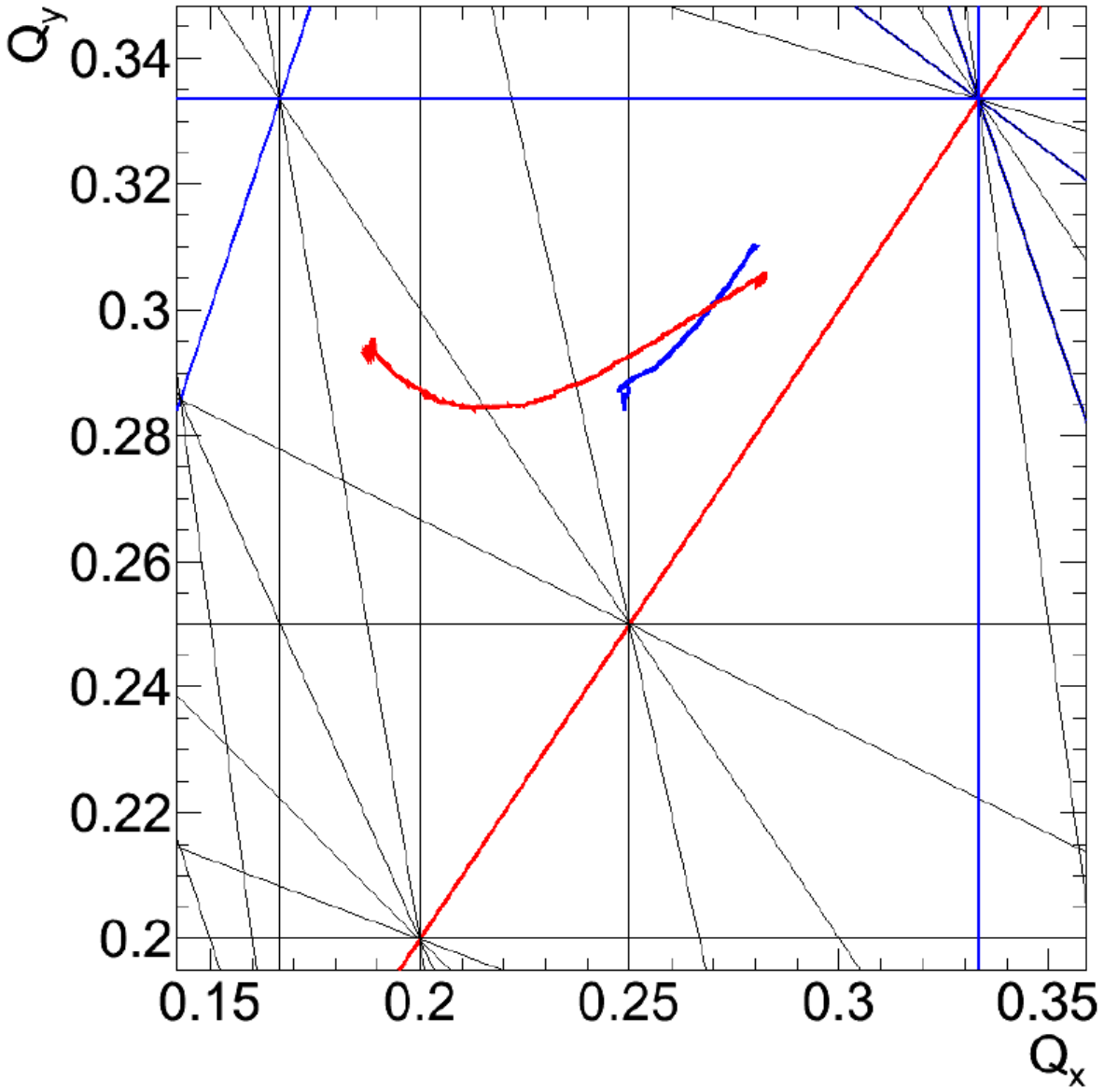
Ramp up coincided with large tidal change – good agreement !
Tidal swing corresponds to ~ 15 Hz.



LHC measures influence of tidal forces 10 days after 1st Beam!

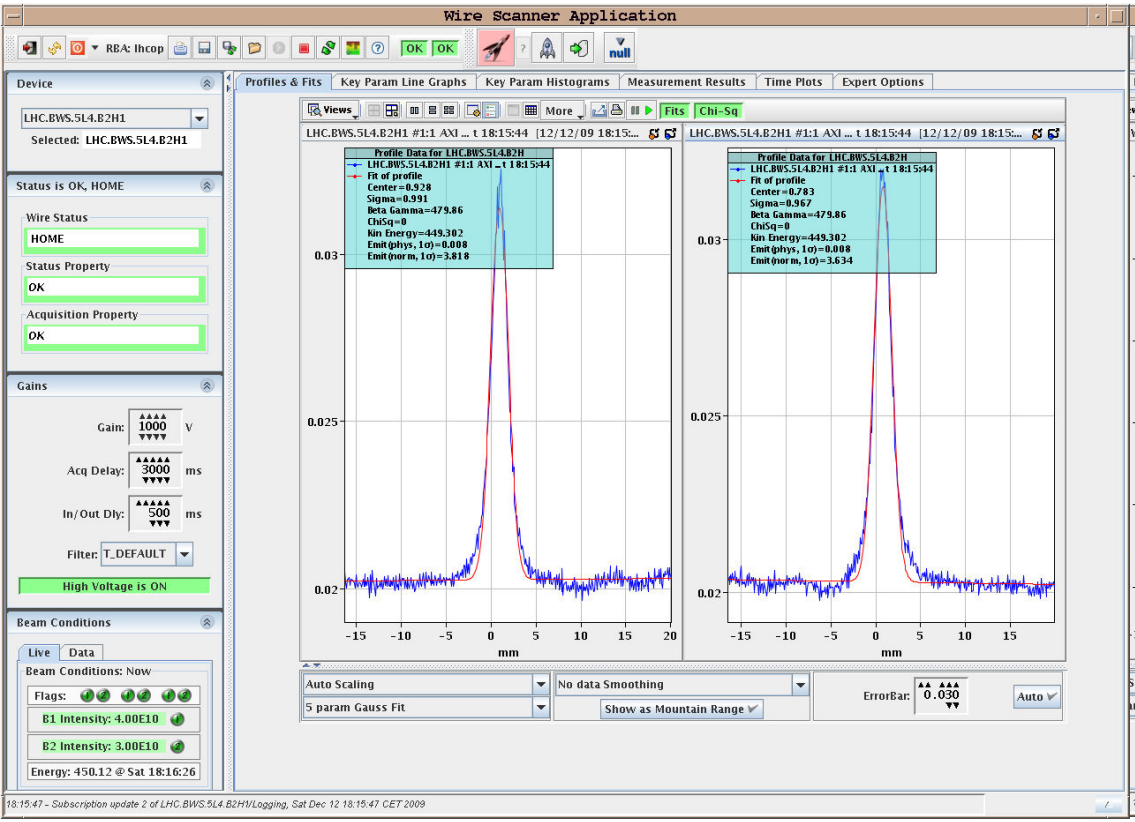
Third Ramp to 1.18 TeV

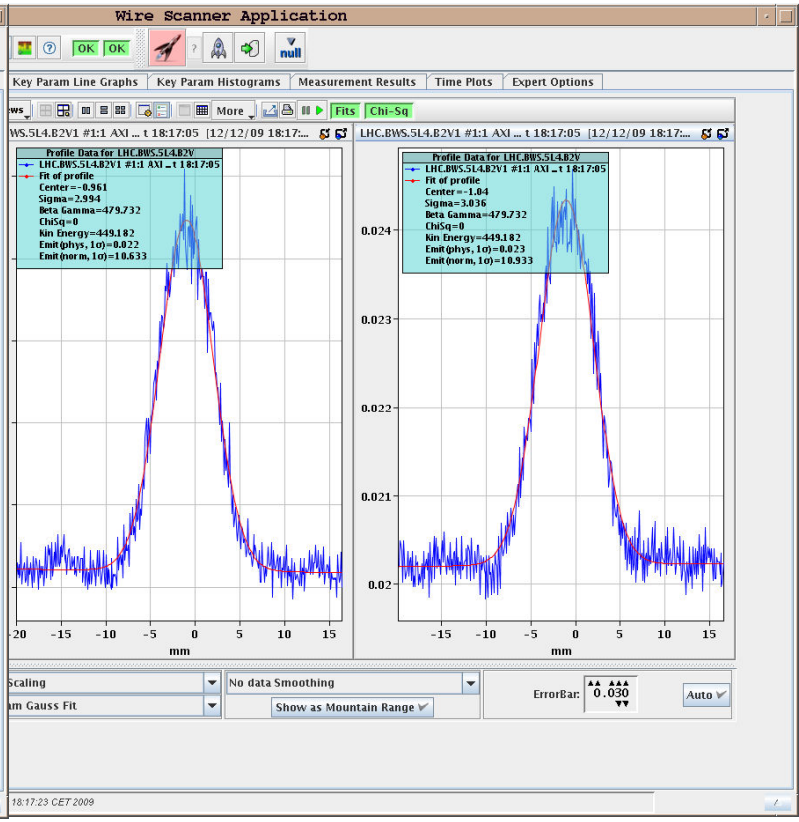
Tune variations during ramp
Beam 1
Beam 2



13.12.2009: Wire Scans During STABLE Beams

Beam2 horizontal: Beam2 vertical



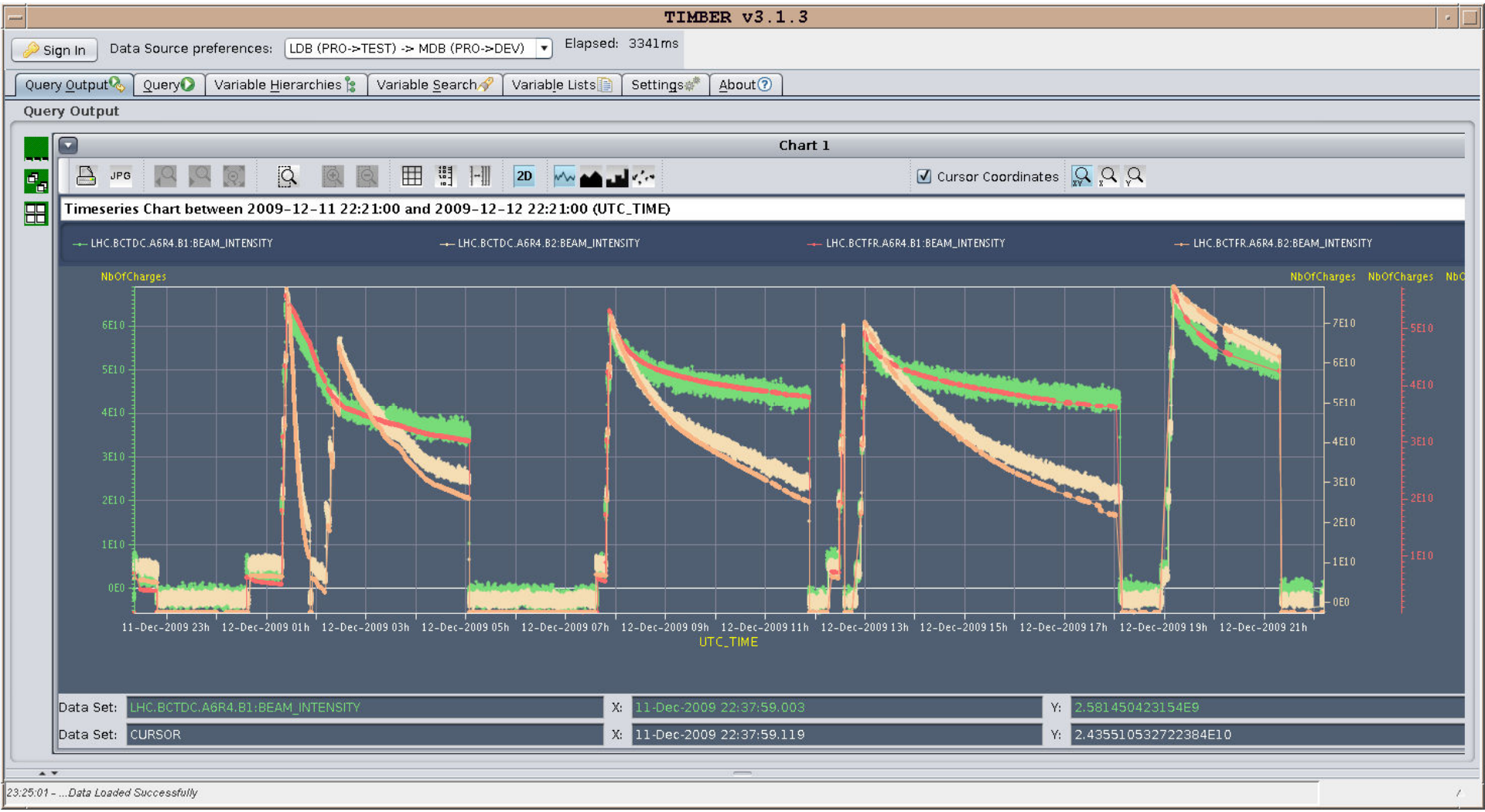


Comparing beam size from wire with synchrotron light monitor

Wire: σ_x = 0.98mm σ_y = 3.0mm

BSRT: σ_x = 1.10mm, σ_y = 2.7mm ➔ ca factor 2 between σ_y and σ_x

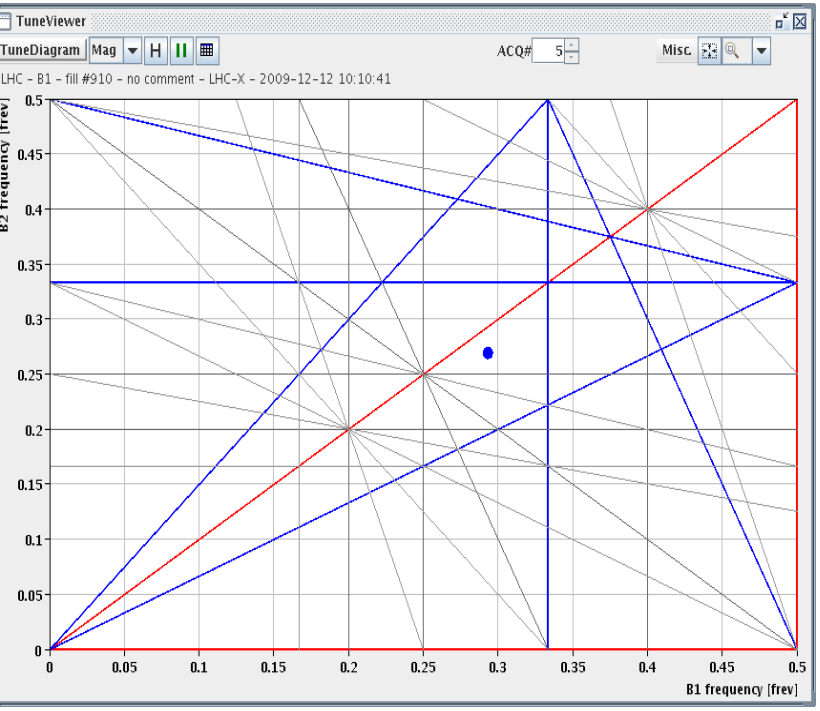
13.12.2009: 24 hours running - currents

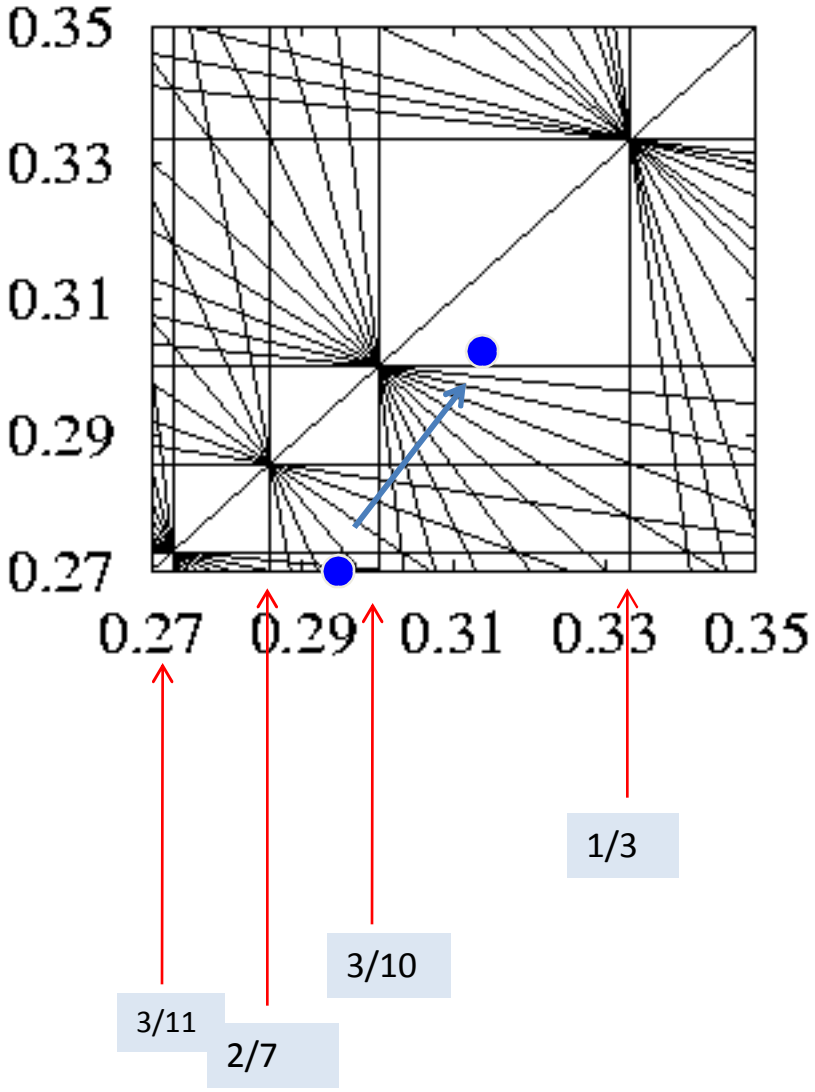


Oliver

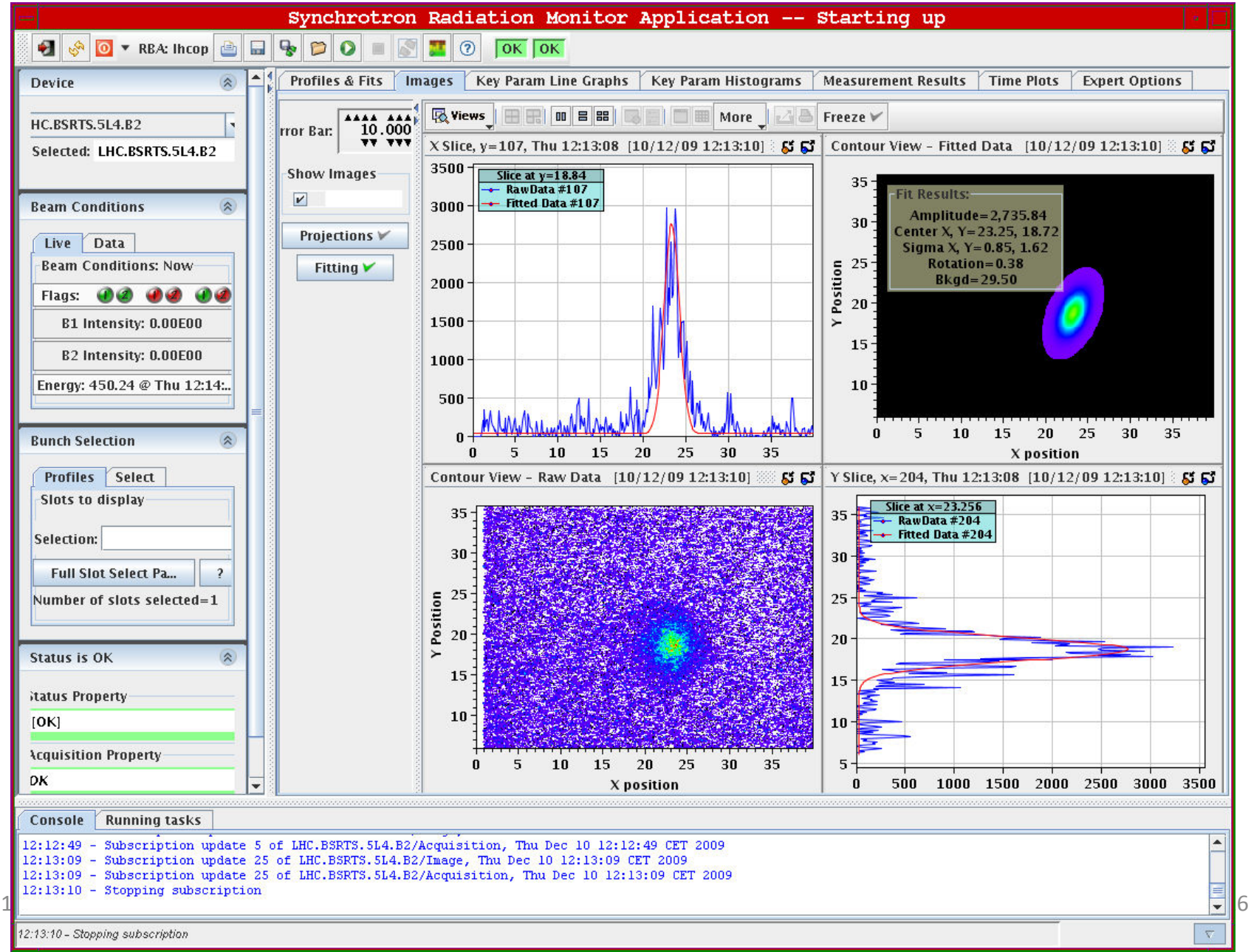
13.12.2009: Tune Adjustments for Beam2

B1: $Q_x = 0.293$, $Q_y = 0.269$; lifetime = 26h
B2: $Q_x = 0.297$, $Q_y = 0.267$; lifetime = 5h
B1: $Q_x = 0.293$, $Q_y = 0.269$; lifetime = 25h
B2: $Q_x = 0.312$, $Q_y = 0.305$; lifetime = 12h



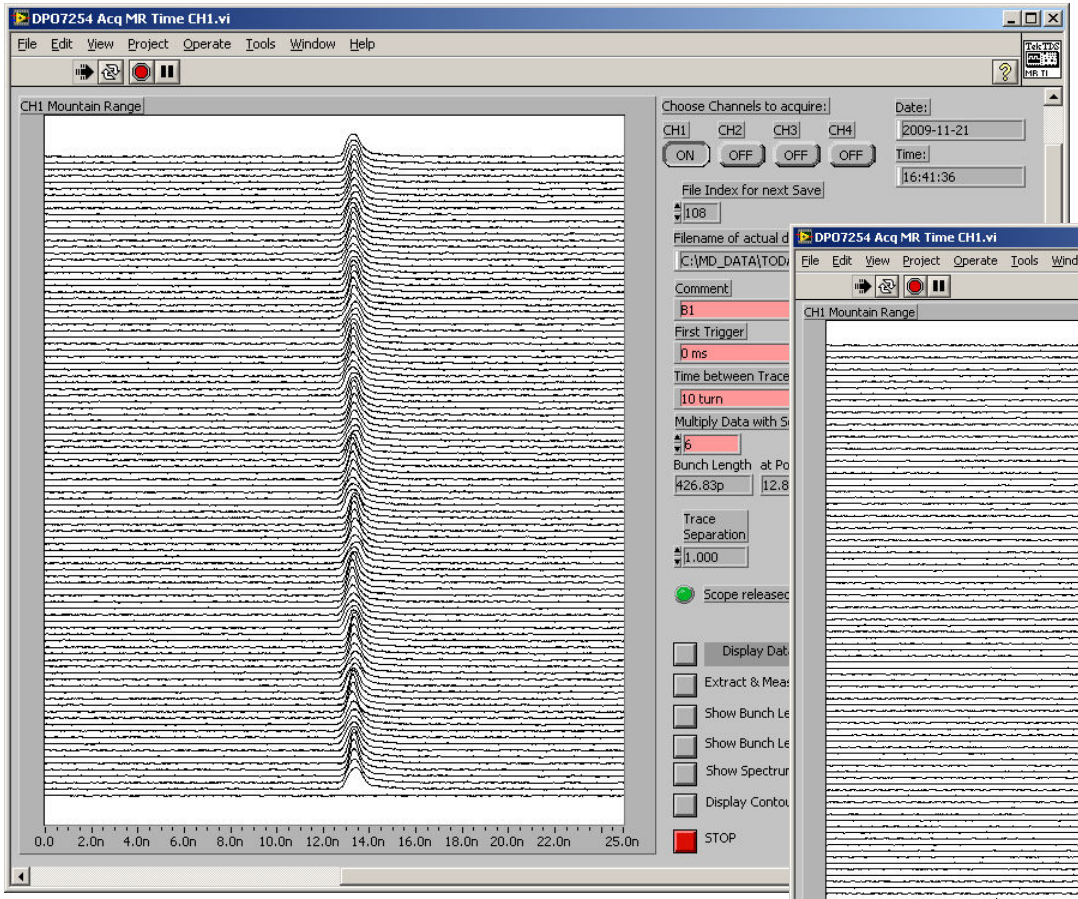


BSRT on beam 2

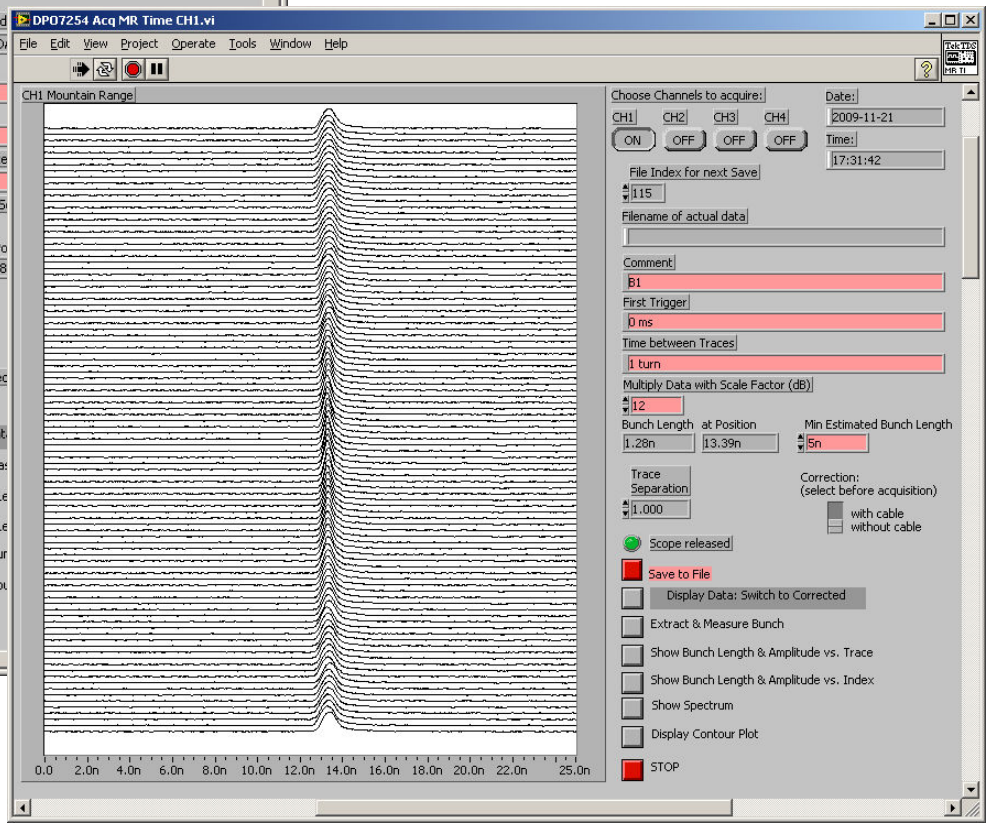


The “RF guys” (Ed and his merry men)

Screens showing two beams in the LHC



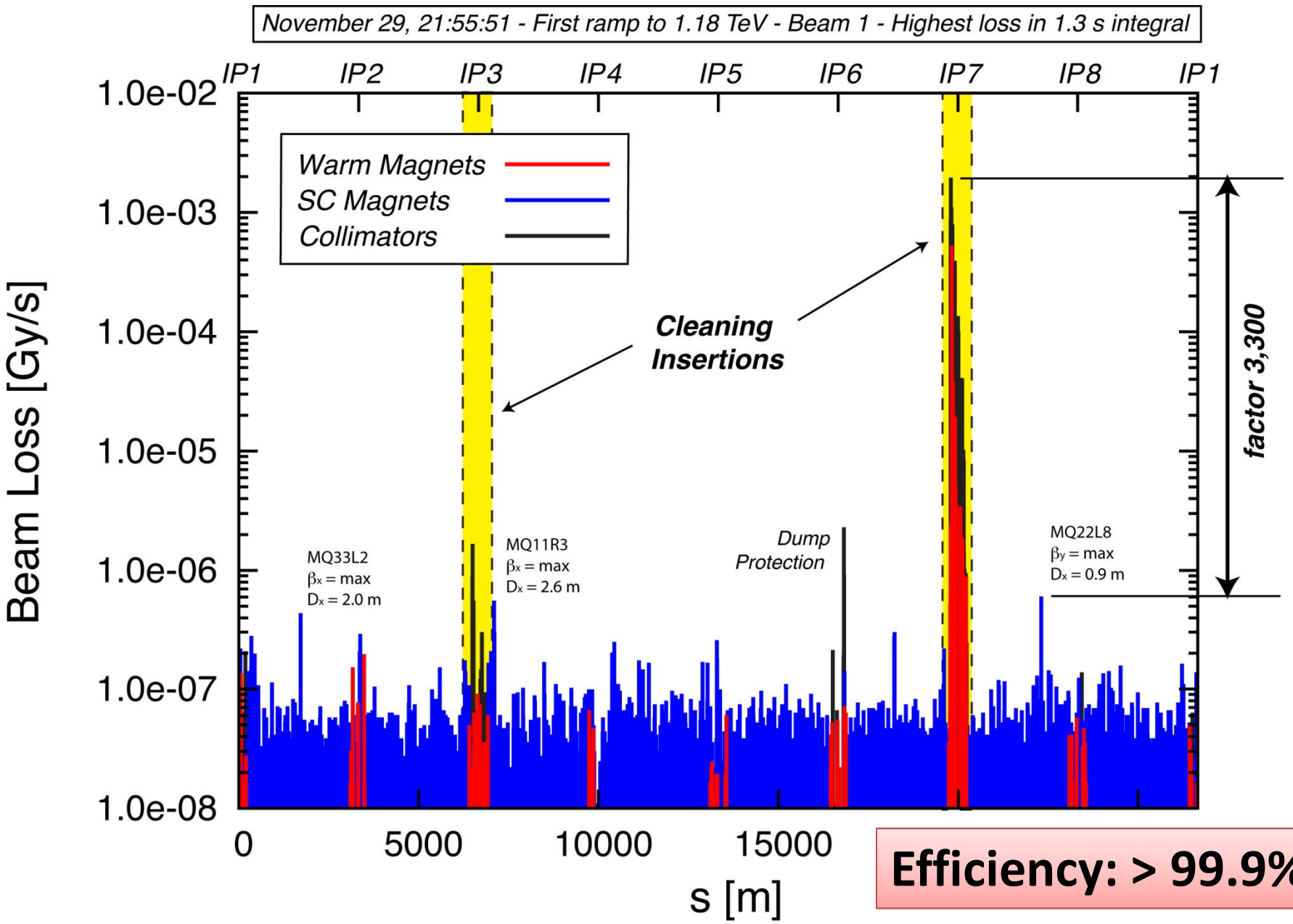
Phase loop Off



Phase Loop On

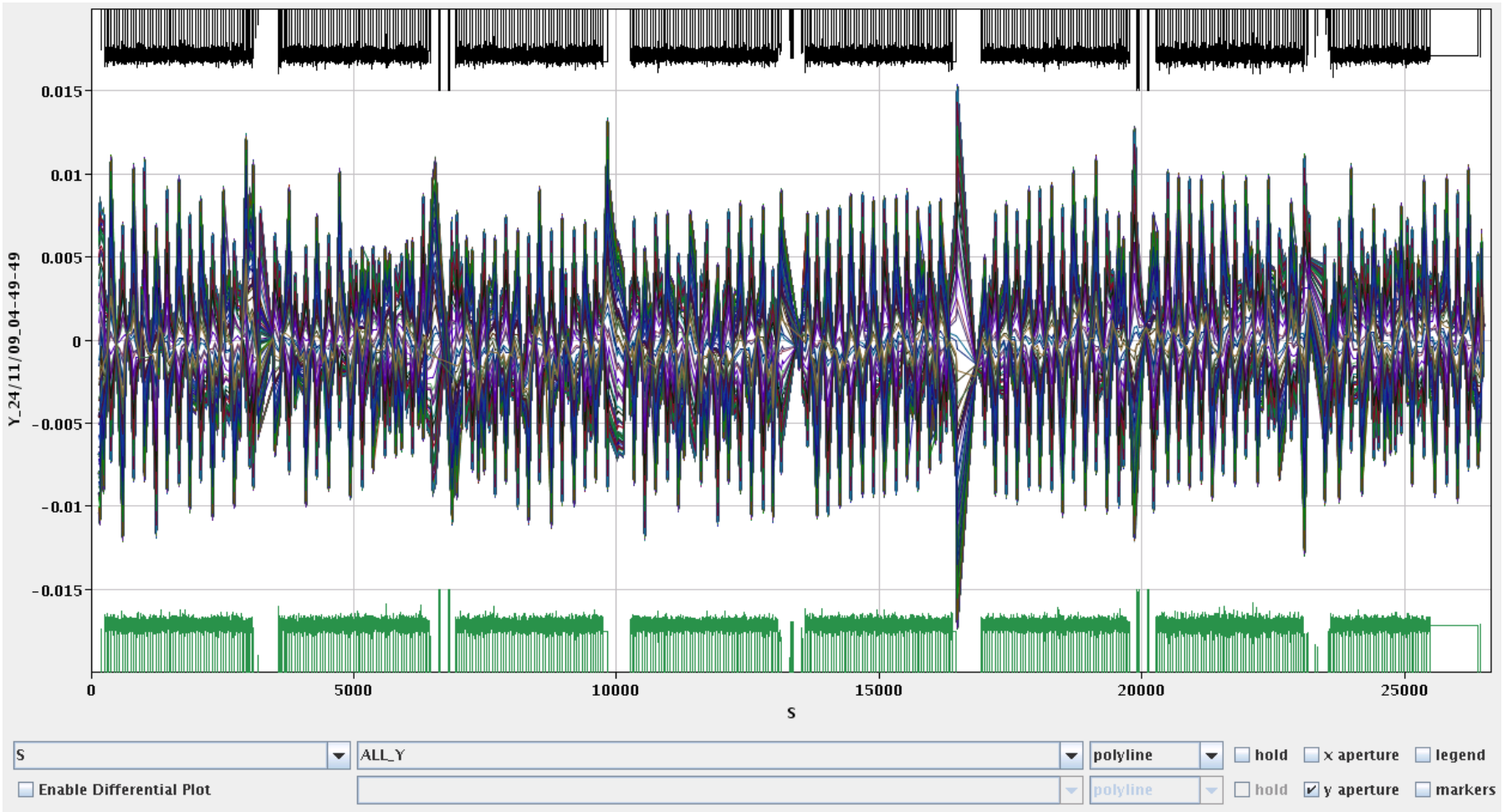
Ralph A

Collimation after beam based set up



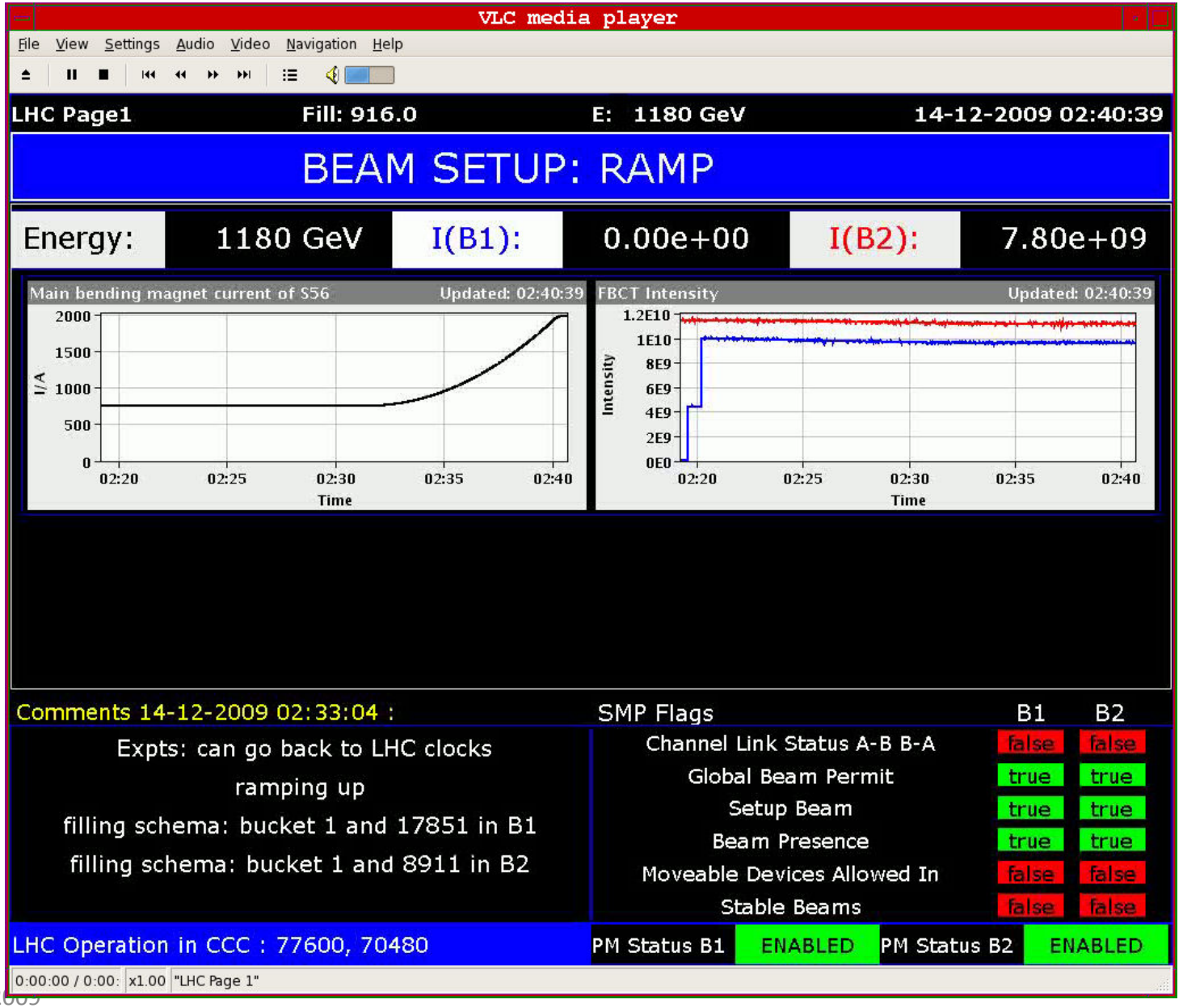
Efficiency: > 99.9%

Aperture checks with free oscillation

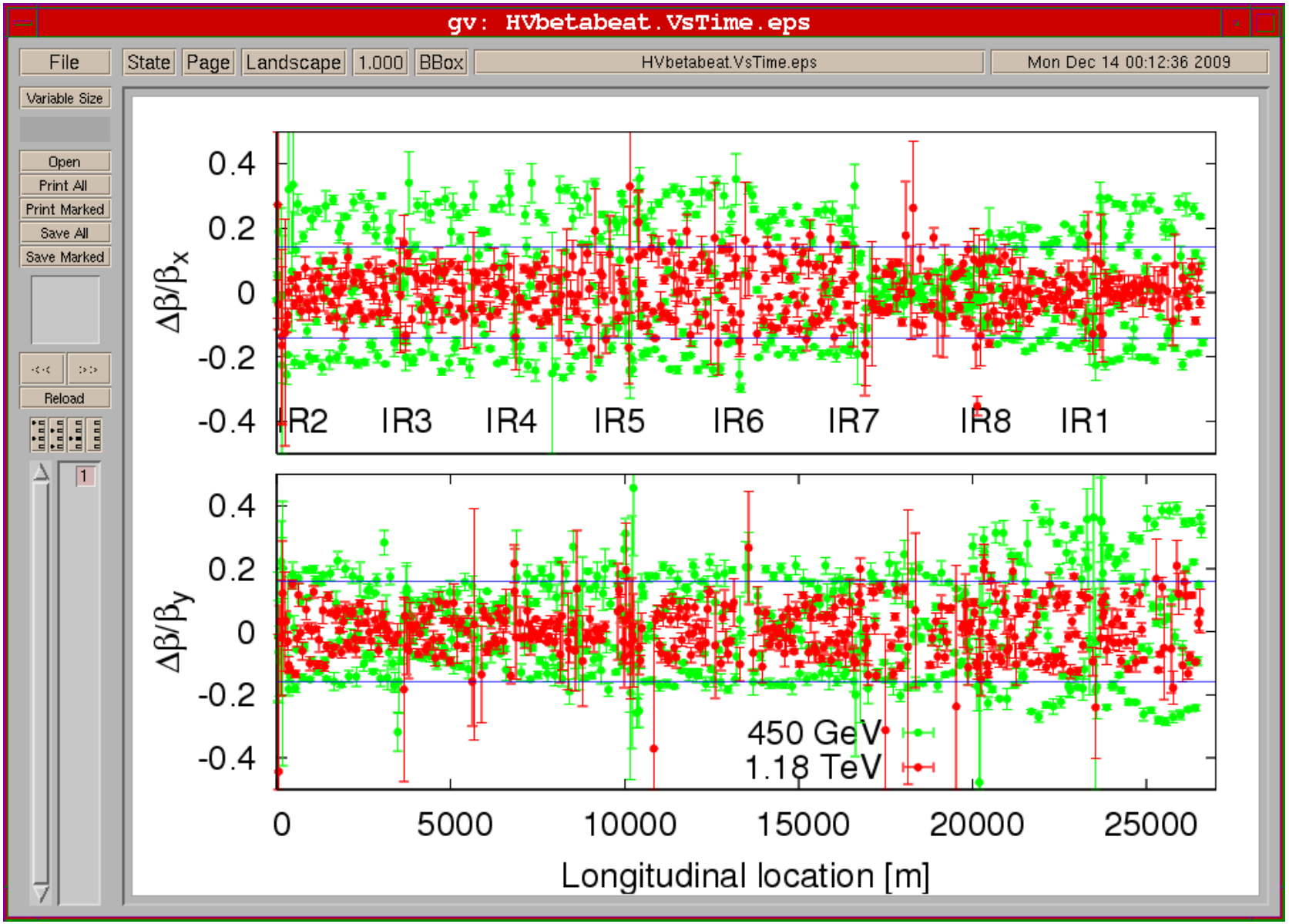


Dispersion…WoW

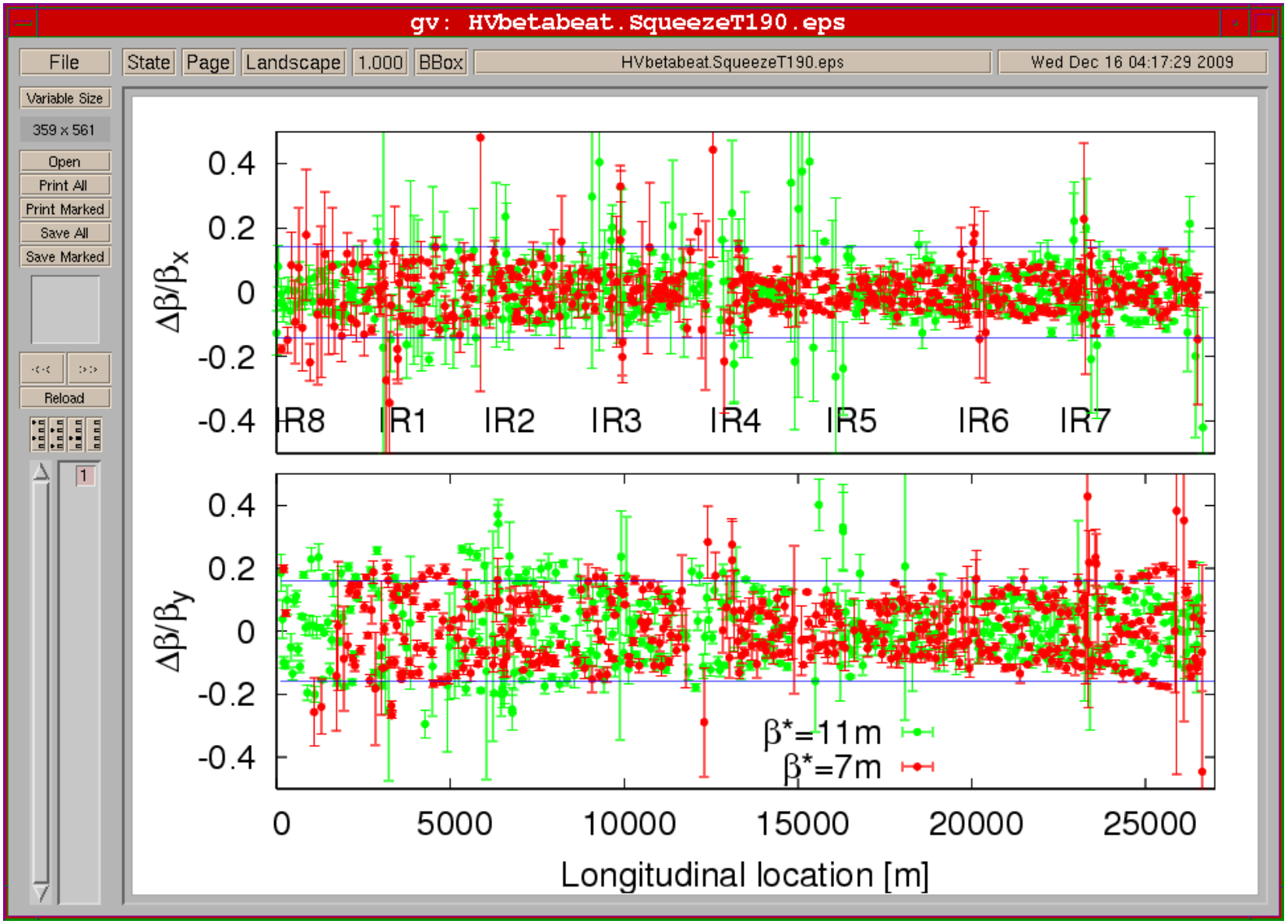
Ramp 2 on 2 to 1.18 TeV



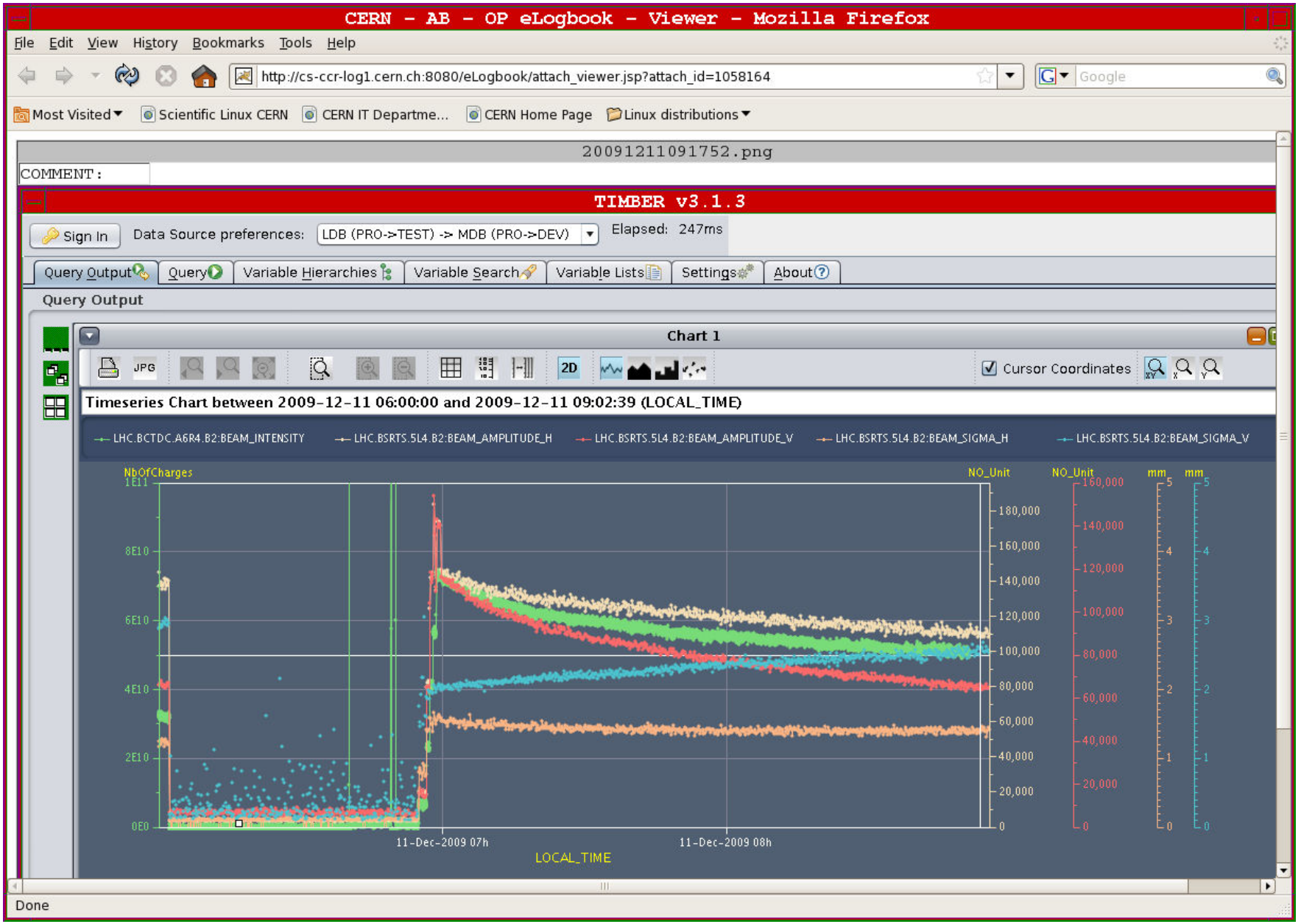
Beta-beat comparison 450 GeV and 1.18 TeV

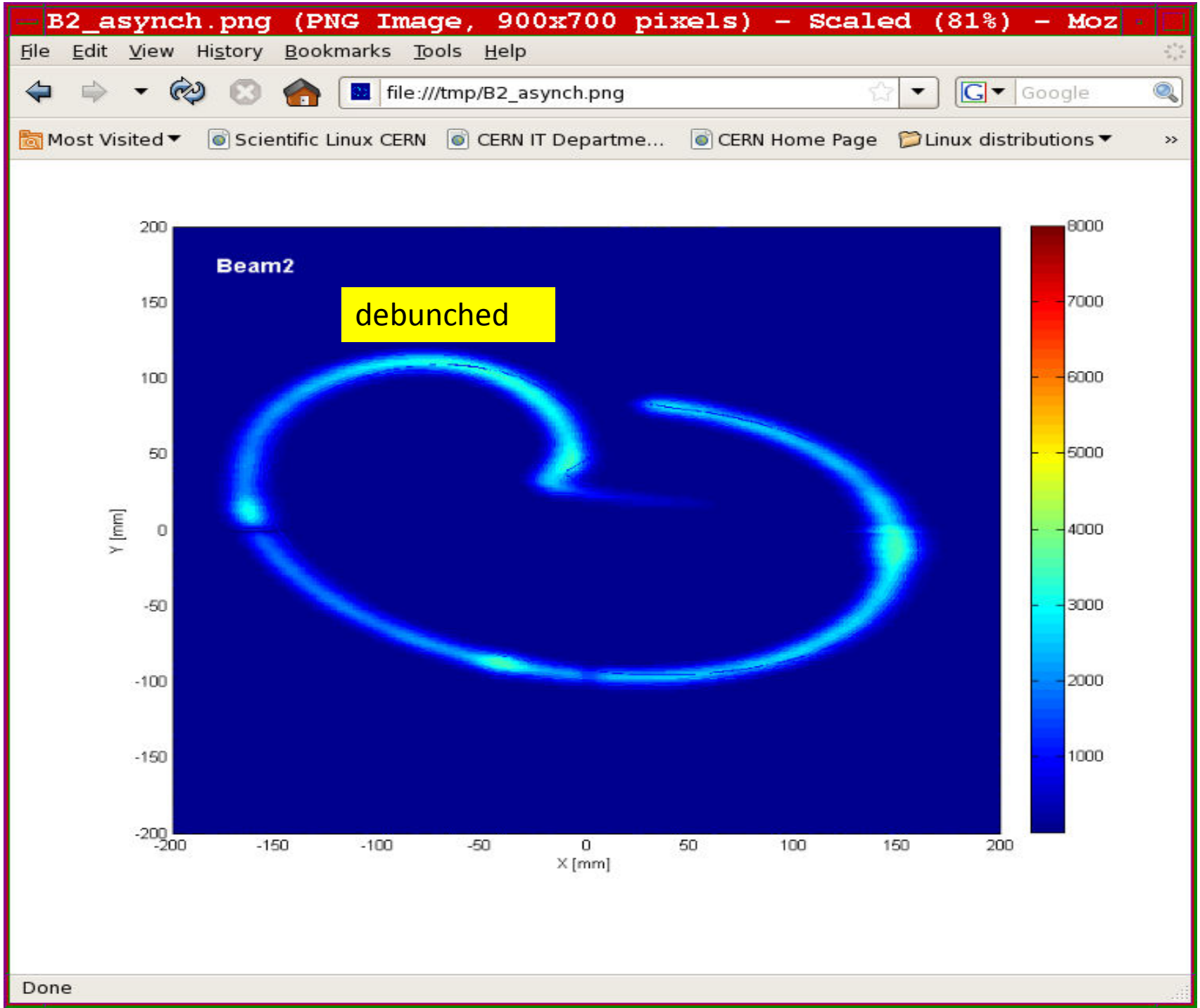


Beta-beat comparison 11m and 7m



Food for thought – V blow up of beam 2




B2_asynch.png (PNG Image, 900x700 pixels) – Scaled (81%) – Moz
File Edit View History Bookmarks Tools Help
file:///tmp/B2_asynch.png
Google
Most Visited
Scientific Linux CERN
CERN IT Departme...
CERN Home Page
Linux distributions
Beam2
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Y [mm]
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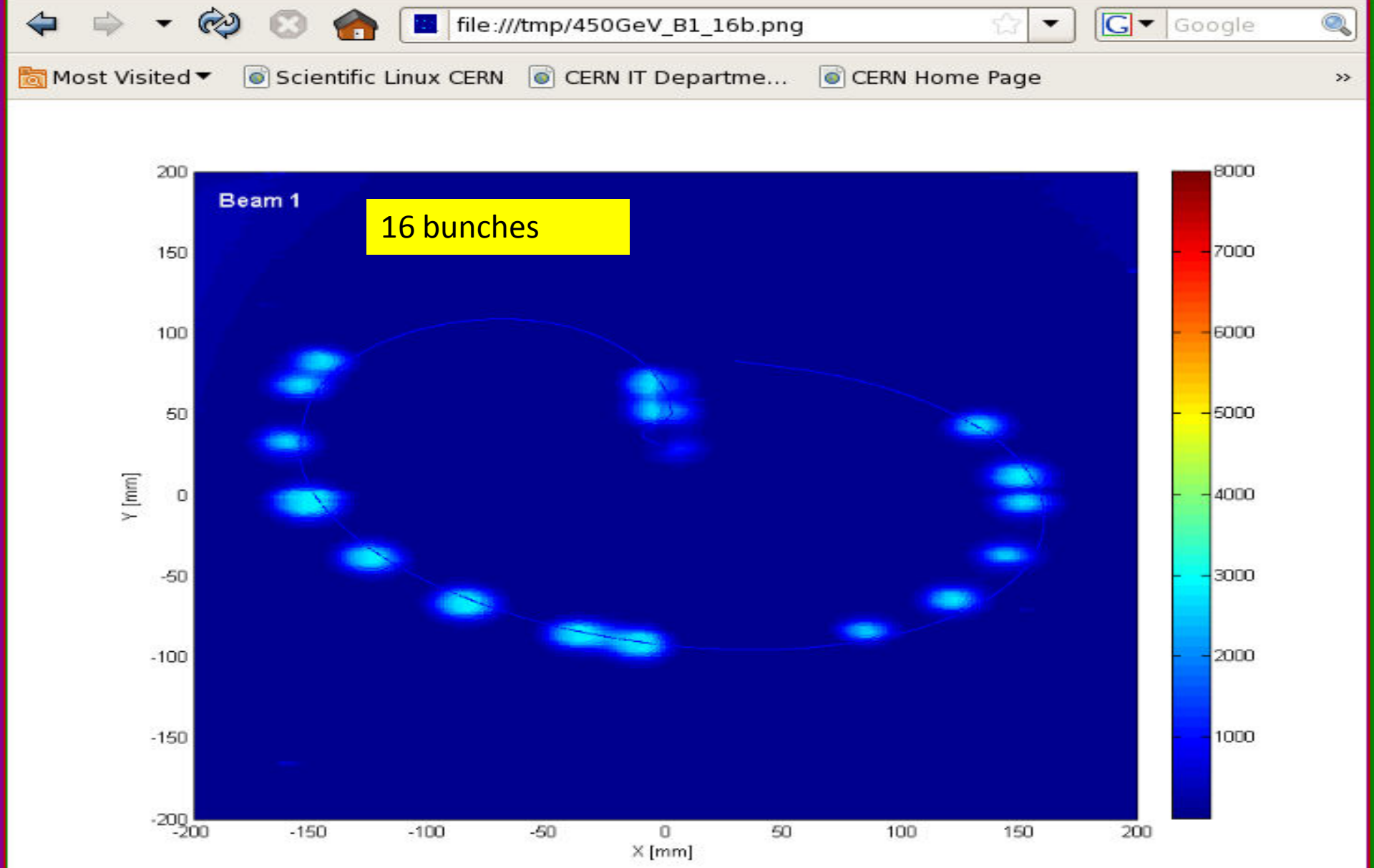
200
150
100
50
0
-50
-100
-150
-200
8000
7000
6000
5000
4000
3000
2000
1000
Done

Brennan and Verena (with baby soon to come)



System commissioning

- Plenty of systems worked as needed on day 1
- Planning was adjusted on a daily basis for critical systems
  - Beam Instrumentation
  - Acceleration (RF)
  - Injection
  - Extraction
  - Collimation
  - Kick response campaign
  - Aperture measurement campaign
  - Optics measurements
  - Machine protection
  - Collisions
  - Ramp
  - Squeeze

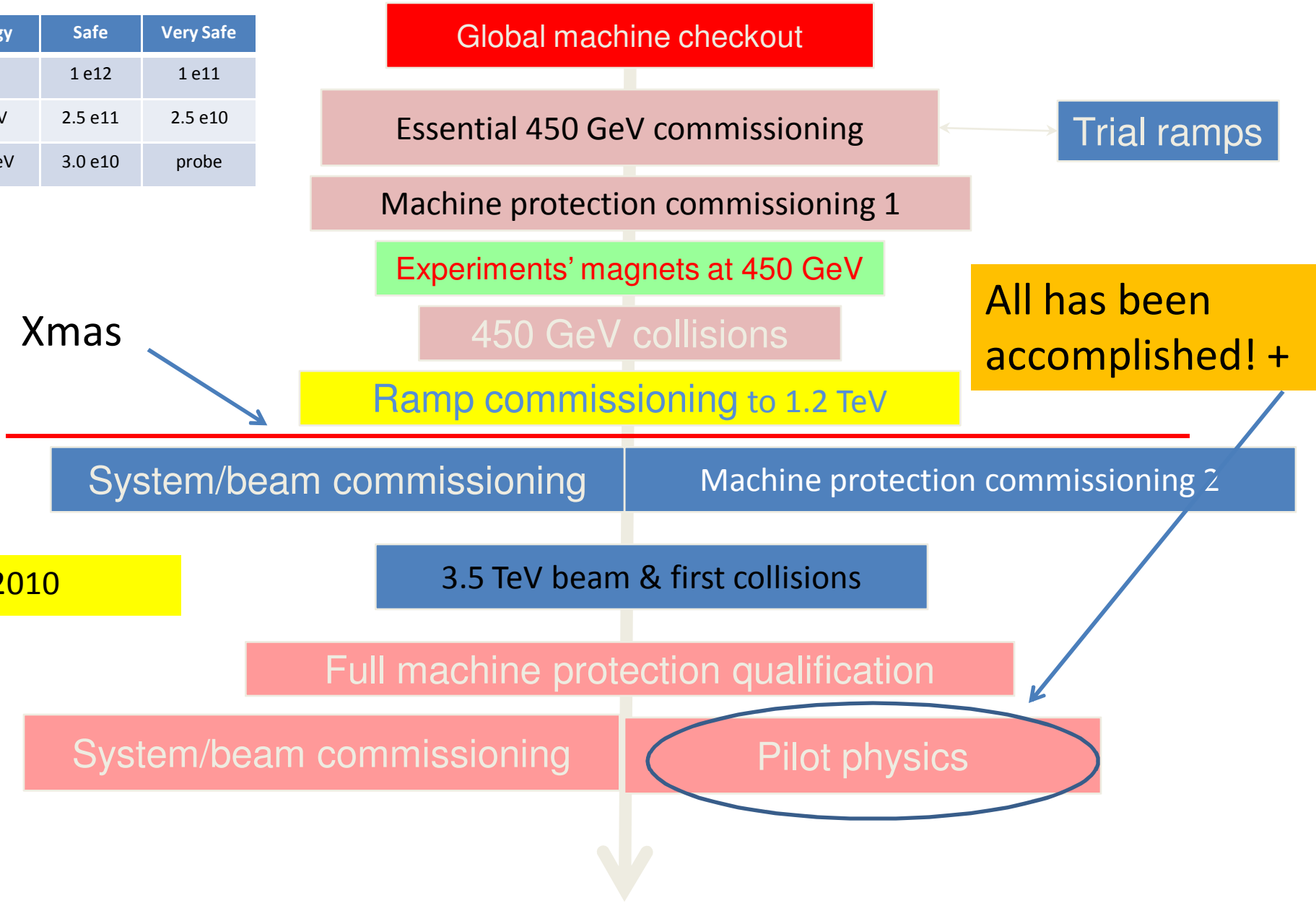
and don't forget

Magnets
Power supplies
Cryo
vacuum
Controls
Electrical distribution
Cooling
Access
nQPS
…
…

Mike's cunning plan

Beam commissioning strategy

Energy	Safe	Very Safe
450	1 e12	1 e11
1 TeV	2.5 e11	2.5 e10
3.5 TeV	3.0 e10	probe



Summary

LHC is back!

26 days of highly successful beam commissioning due to

- meticulous planning
- High availability of all accelerator and detector components

In conclusion

It has been a truly remarkable 24 days. Things have moved so quickly that it has been hard to keep up with the progress.
Many firsts for the LHC and the detectors

On the longer time scale, it has been a fantastic effort, with five impressive phases:
1) repair; 2) consolidation; 3) hardware commissioning; 4) preparation for beam; and 5) beam operation.

The final phase has been highly visible, and widely reported throughout the world, but would not have been possible without the other phases.

From the CERN management, we would like to express our sincere thanks and congratulations to all of you who have done such a great job in bringing the LHC BACK!

I wish you

- A good rest
- a great Christmas with your families
- A very happy new year

And please come back in 2010 fully recharged for the next phase

While waiting for Questions…

A little black Christmas humour