Instrumentation performance in the LHC in 2011 & wishes for 2012

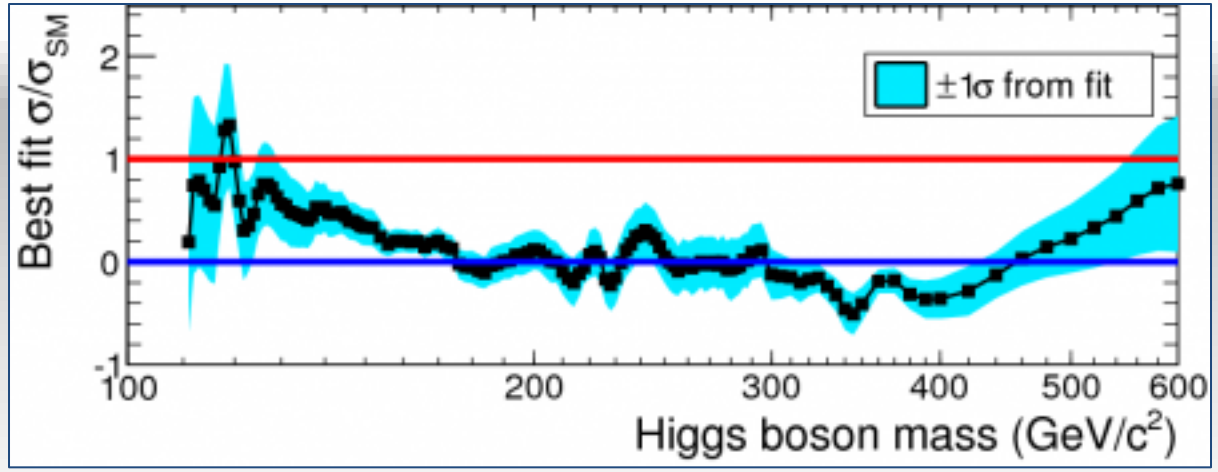
Mike Lamont

Many thanks to Jorg Wenninger, Stefano Redaelli, Verena Kain, Giulia Pappoti, Mirko Pojer, Roderik Bruce, Barbara Holzer, Laurette Ponce for their input

Pre-cursor

"From my side, I have been really impressed this year by the performance of the LHC instrumentation, with many improvements on all sides." EIC X

It has clearly contributed to a very good year.



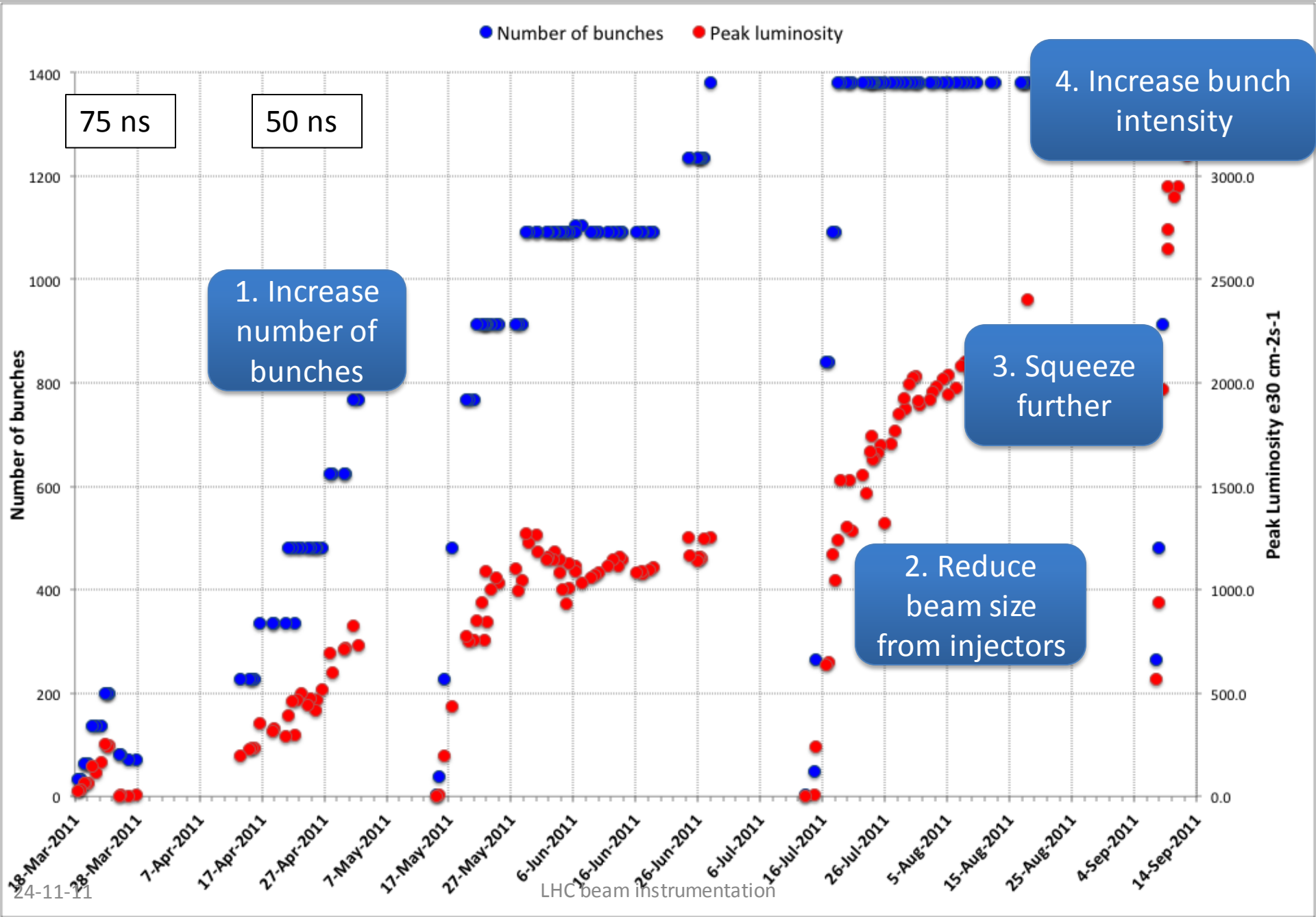
BI playing fields

- **Luminosity production**
  - OP's bread and butter
  - Now with 110 MJ – no messing (please)
  - Moving target as performance and intensity is pushed
- **Routine commissioning**
  - New optics, squeeze, loss maps
- **Machine development**
  - Exotica and interesting stuff
- **Special runs**
  - VdM scans, scrubbing runs
  - Can be very demanding

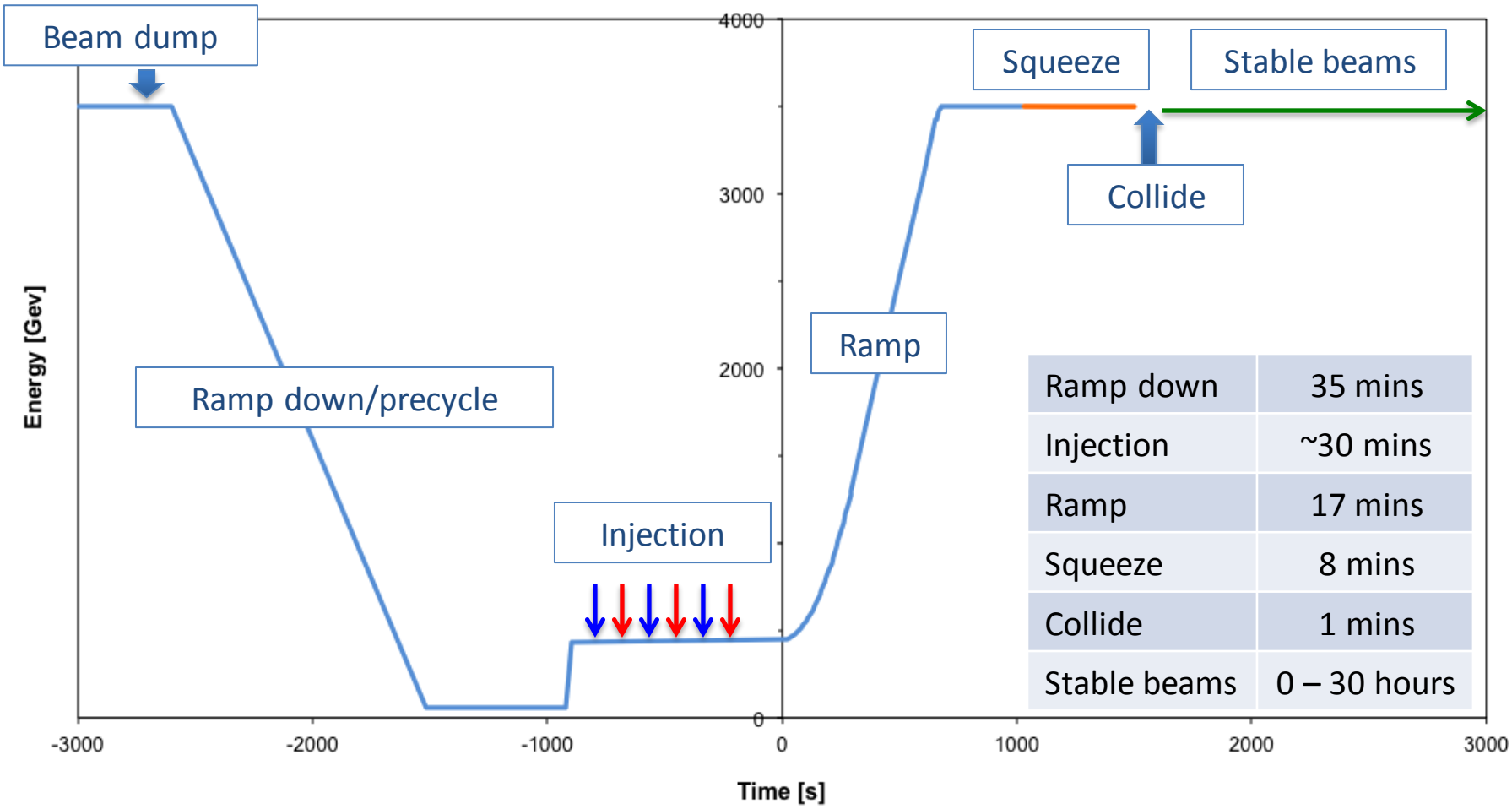
OP's bread and butter

- First priority is getting 110 MJ safely through the cycle
  - QFB
  - OFB & orbit stability with respect to collimators
  - Inputs to machine protection
    - BLMs, SMP, BPF, BPMD…
  - Monitoring
    - Lifetimes, beam loss…
- Second priority is performance
  - Beam loss is normally negligible
  - Emittance from the injectors and emittance blow-up during the LHC cycle is the focus at the moment
    - Bunch-by-bunch, batch by batch

2011


Number of bunches
Peak luminosity
75 ns
50 ns
1. Increase number of bunches
2. Reduce beam size from injectors
3. Squeeze further
4. Increase bunch intensity
Number of bunches
Peak Luminosity e30 cm-2s-1
0
200
400
600
800
1000
1200
1400
0.0
500.0
1000.0
1500.0
2000.0
2500.0
3000.0
18-Mar-2011
28-Mar-2011
7-Apr-2011
17-Apr-2011
27-Apr-2011
7-May-2011
17-May-2011
27-May-2011
6-Jun-2011
16-Jun-2011
26-Jun-2011
6-Jul-2011
16-Jul-2011
26-Jul-2011
5-Aug-2011
15-Aug-2011
25-Aug-2011
4-Sep-2011
14-Sep-2011

A day in the life of the LHC



Ramp down	35 mins
Injection	~30 mins
Ramp	17 mins
Squeeze	8 mins
Collide	1 mins
Stable beams	0 – 30 hours

Preparation for injection

- BPM calibration
- DC BCT calibration
- BLM capture mode for IQC
- Reset BPMDs
- BPM sensitivity to pilot
- Reset BPM turn-by-turn concentrator
- Check BLM MCS settings
- BLM sanity check
- SMP
- Prepare feedbacks for injection

Room for more…

Usually unfolds without too many problems – when there is a problem, there usually is a problem

Injection pilot

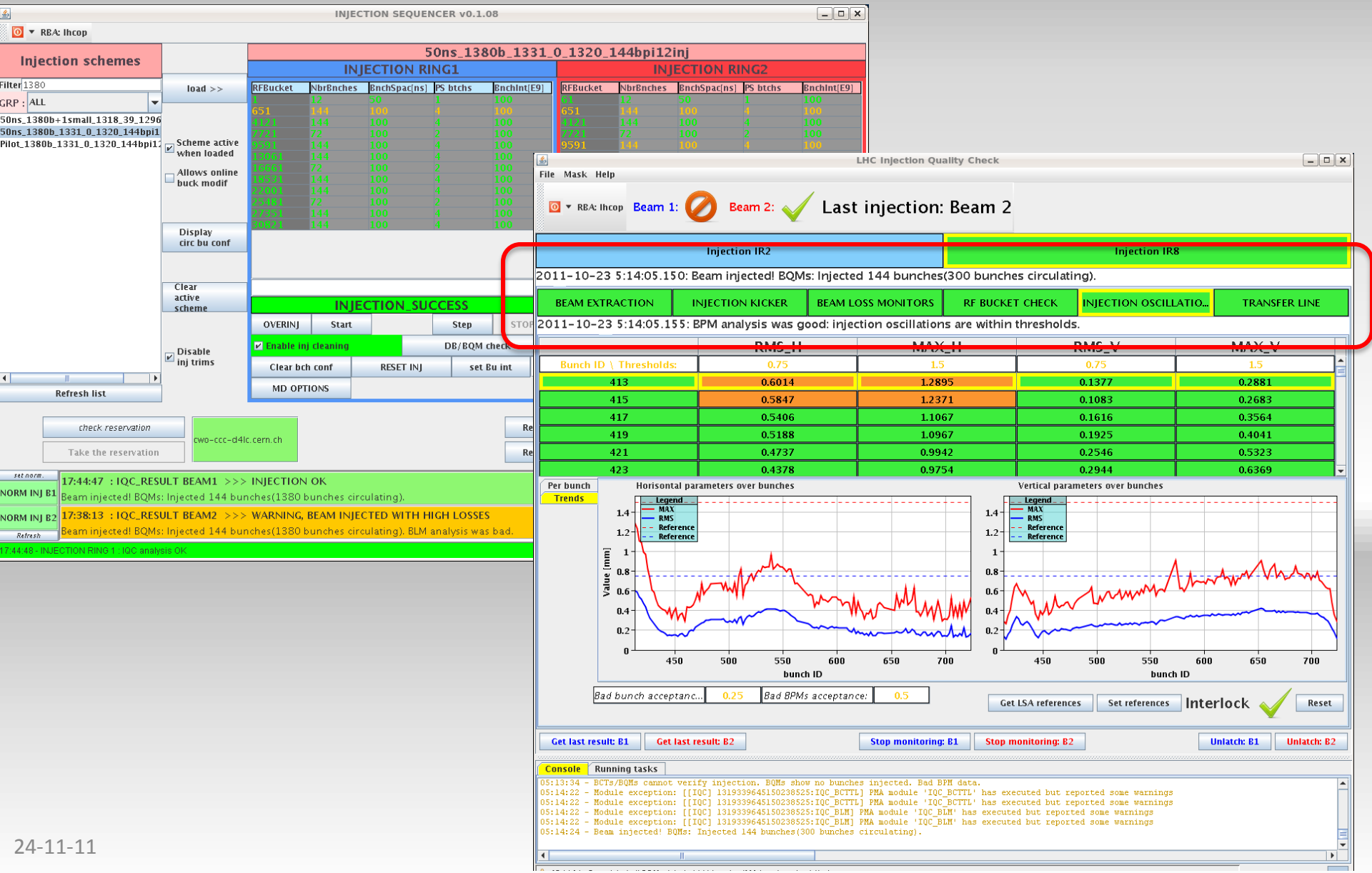
- Check tunes
- Chromaticity via BBQ & RF modulation
- OFB on to correct orbit

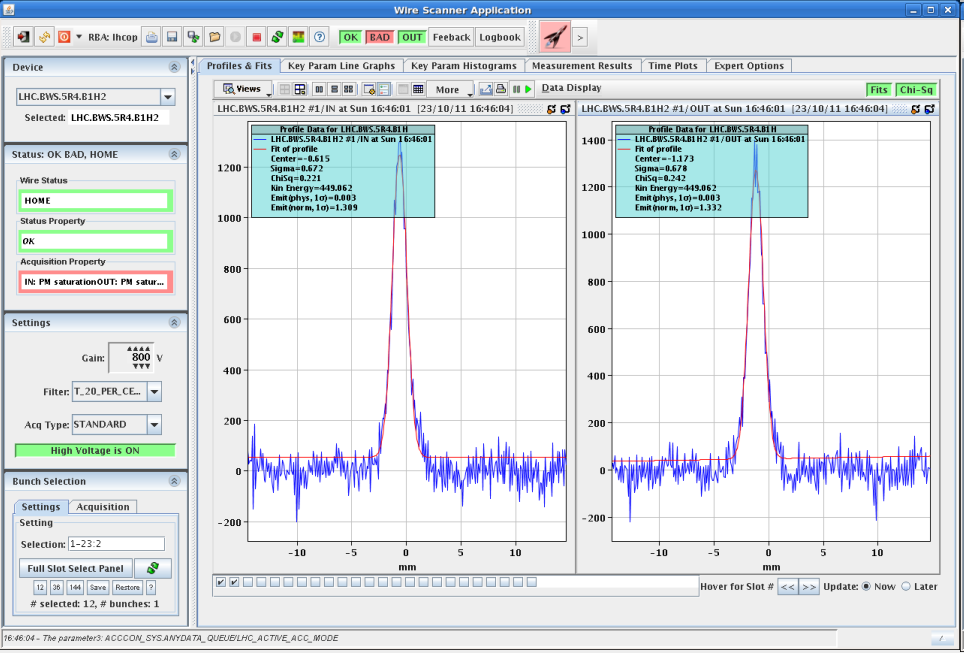
- Prepare for nominal intensity
  - BPM sensitivity nominal
  - BQM nominal attenuation
  - (ABC, IGC, SBF)
  - Circulating bunch configuration

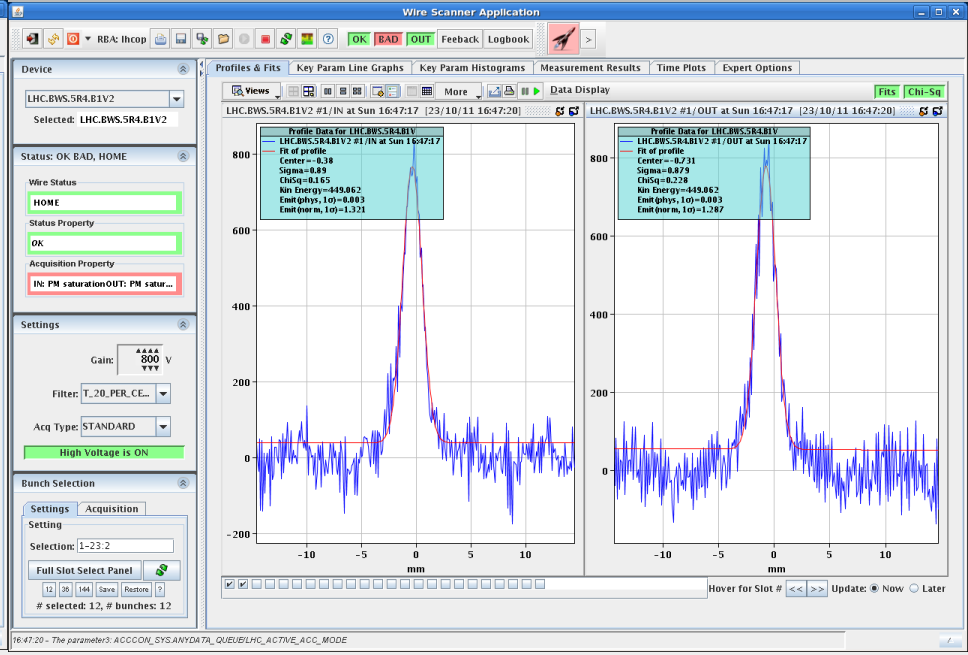
Injection Nominal

- Transfer line trajectory – BPMs – (not using BbB)
- Injection Quality Check
  - Ring trajectory - bunch-by-bunch
  - BLMs
  - WCM@RF for bunch length, filling pattern
- Wire scanners (first 12b + 144b)
- Bunch by bunch BSRT
- Chromaticity
  - Measure with pilot and then trust in FIDEL dynamic correction
- BCTs always
- Orbit/Orbit feedback
- BBQ/Tune feedback

Injection


INJECTION SEQUENCER v0.1.08
RBA: lhcop
Injection schemes
50ns_1380b_1331_0_1320_144bpi12inj
INJECTION RING1
INJECTION RING2
load >>
Scheme active when loaded
Allows online buck modif
Display circ bu conf
Clear active scheme
Disable inj trims
INJECTION_SUCCESS
OVERINJ
Start
Step
Enable inj cleaning
DB/BQM check
Clear bch conf
RESET INJ
set Bu int
MD OPTIONS
Refresh list
check reservation
Take the reservation
17:44:47 : IQC_RESULT BEAM1 >>> INJECTION OK
Beam injected! BQMs: Injected 144 bunches(1380 bunches circulating).
17:38:13 : IQC_RESULT BEAM2 >>> WARNING, BEAM INJECTED WITH HIGH LOSSES
Beam injected! BQMs: Injected 144 bunches(1380 bunches circulating). BLM analysis was bad.
NORM INJ B1
NORM INJ B2
LHC Injection Quality Check
File Mask Help
Beam 1:
Beam 2:
Last injection: Beam 2
Injection IR2
Injection IR8
2011-10-23 5:14:05.150: Beam injected! BQMs: Injected 144 bunches(300 bunches circulating).
BEAM EXTRACTION
INJECTION KICKER
BEAM LOSS MONITORS
RF BUCKET CHECK
INJECTION OSCILLATIO...
TRANSFER LINE
2011-10-23 5:14:05.155: BPM analysis was good: injection oscillations are within thresholds.
Bunch ID \ Thresholds:
0.75
1.5
413 0.6014 1.2895 0.1377 0.2881
415 0.5847 1.2371 0.1083 0.2683
417 0.5406 1.1067 0.1616 0.3564
419 0.5188 1.0967 0.1925 0.4041
421 0.4737 0.9942 0.2546 0.5323
423 0.4378 0.9754 0.2944 0.6369
Per bunch
Trends
Horisontal parameters over bunches
Vertical parameters over bunches
Legend
MAX
RMS
Reference
Value [mm]
bunch ID
Bad bunch acceptanc... 0.25
Bad BPMs acceptance: 0.5
Get LSA references
Set references
Interlock
Reset
Get last result: B1
Get last result: B2
Stop monitoring: B1
Stop monitoring: B2
Unlatch: B1
Unlatch: B2
Console
Running tasks
05:13:34 - BCTs/BQMs cannot verify injection. BQMs show no bunches injected. Bad BPM data.
05:14:22 - Module exception: [[IQC] 1319339645150238525:IQC_BCTTL] PMA module 'IQC_BCTTL' has executed but reported some warnings
05:14:22 - Module exception: [[IQC] 1319339645150238525:IQC_BCTTL] PMA module 'IQC_BCTTL' has executed but reported some warnings
05:14:22 - Module exception: [[IQC] 1319339645150238525:IQC_BLM] PMA module 'IQC_BLM' has executed but reported some warnings
05:14:22 - Module exception: [[IQC] 1319339645150238525:IQC_BLM] PMA module 'IQC_BLM' has executed but reported some warnings
05:14:24 - Beam injected! BQMs: Injected 144 bunches(300 bunches circulating).

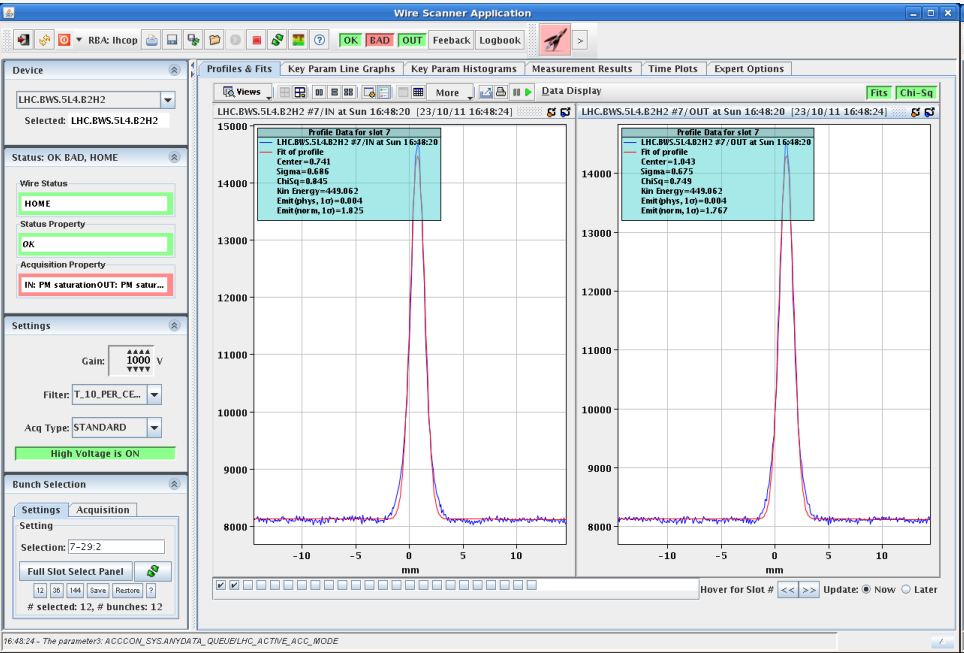


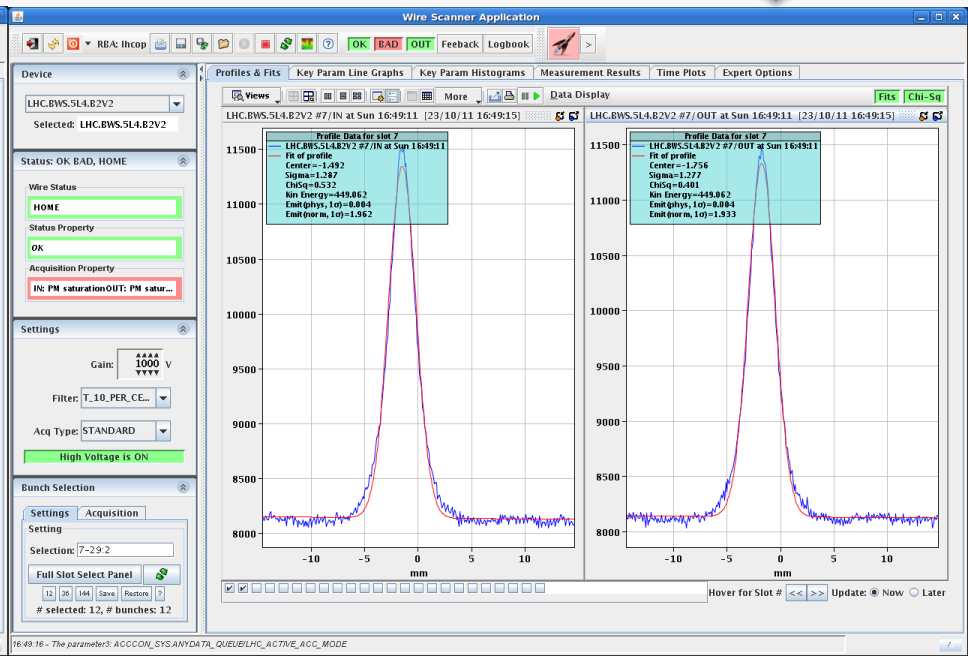


Beam 1 emittance ~1.3 microns

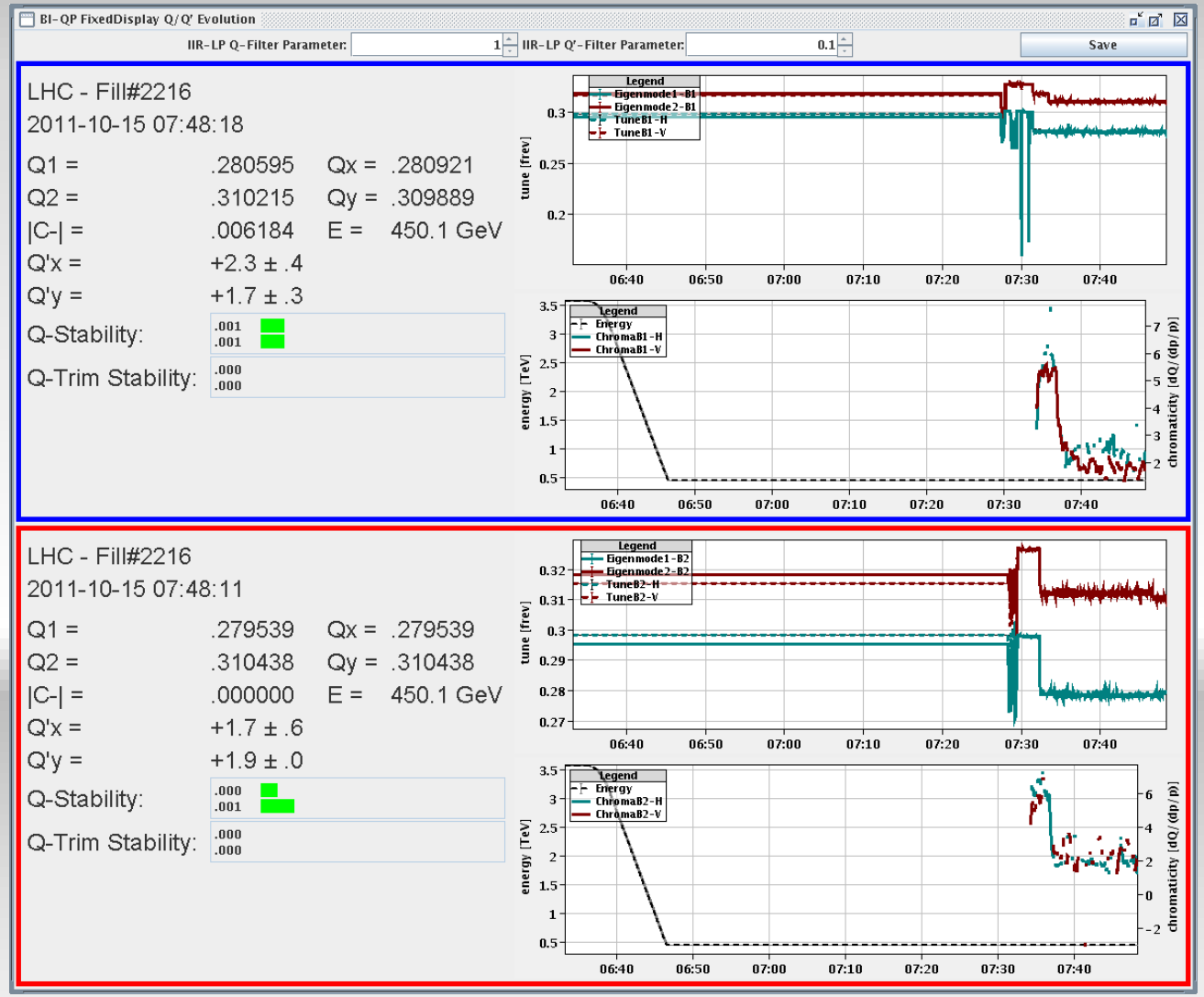
?

Beam 2 emittance ~1.8/1.9 microns

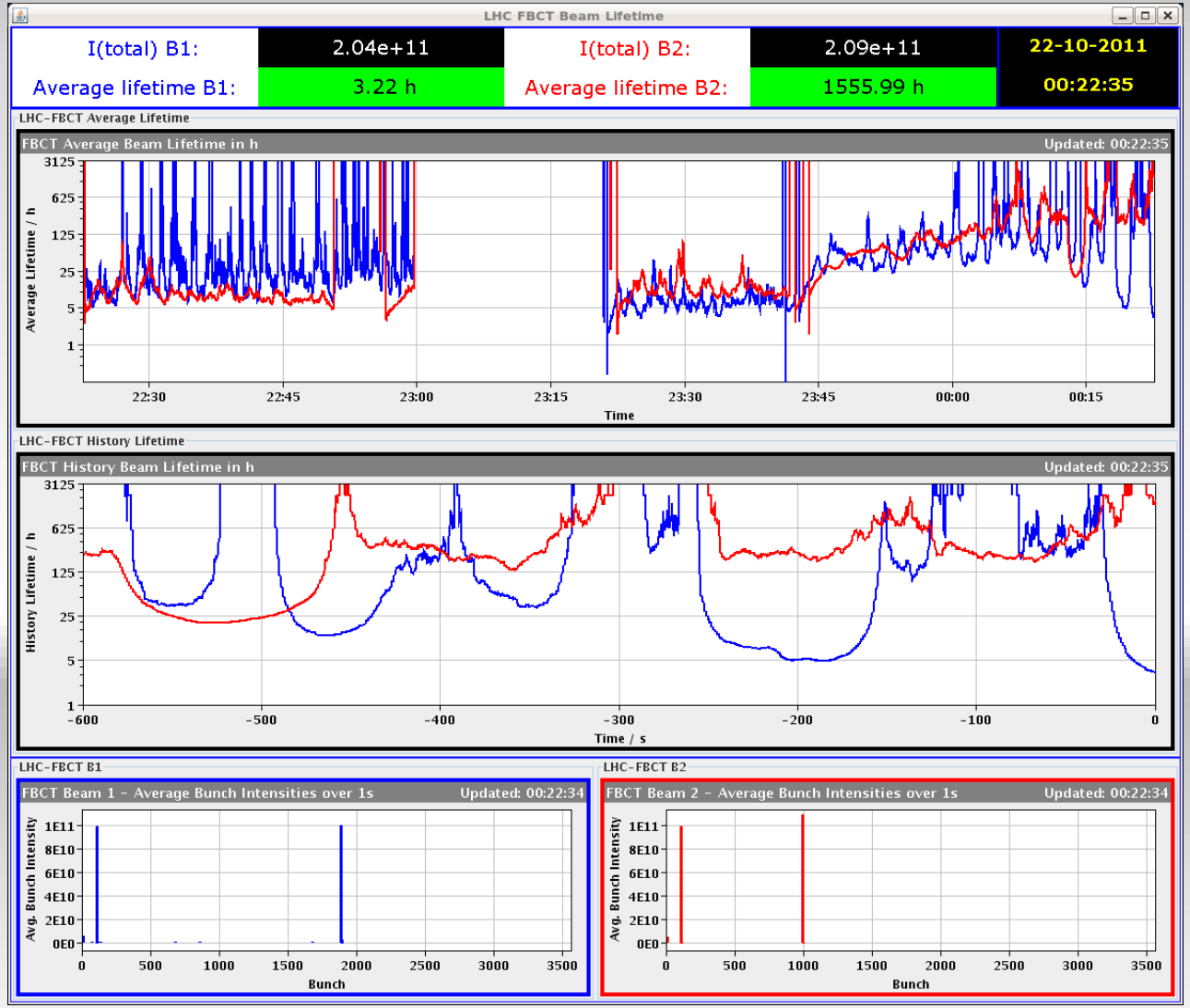




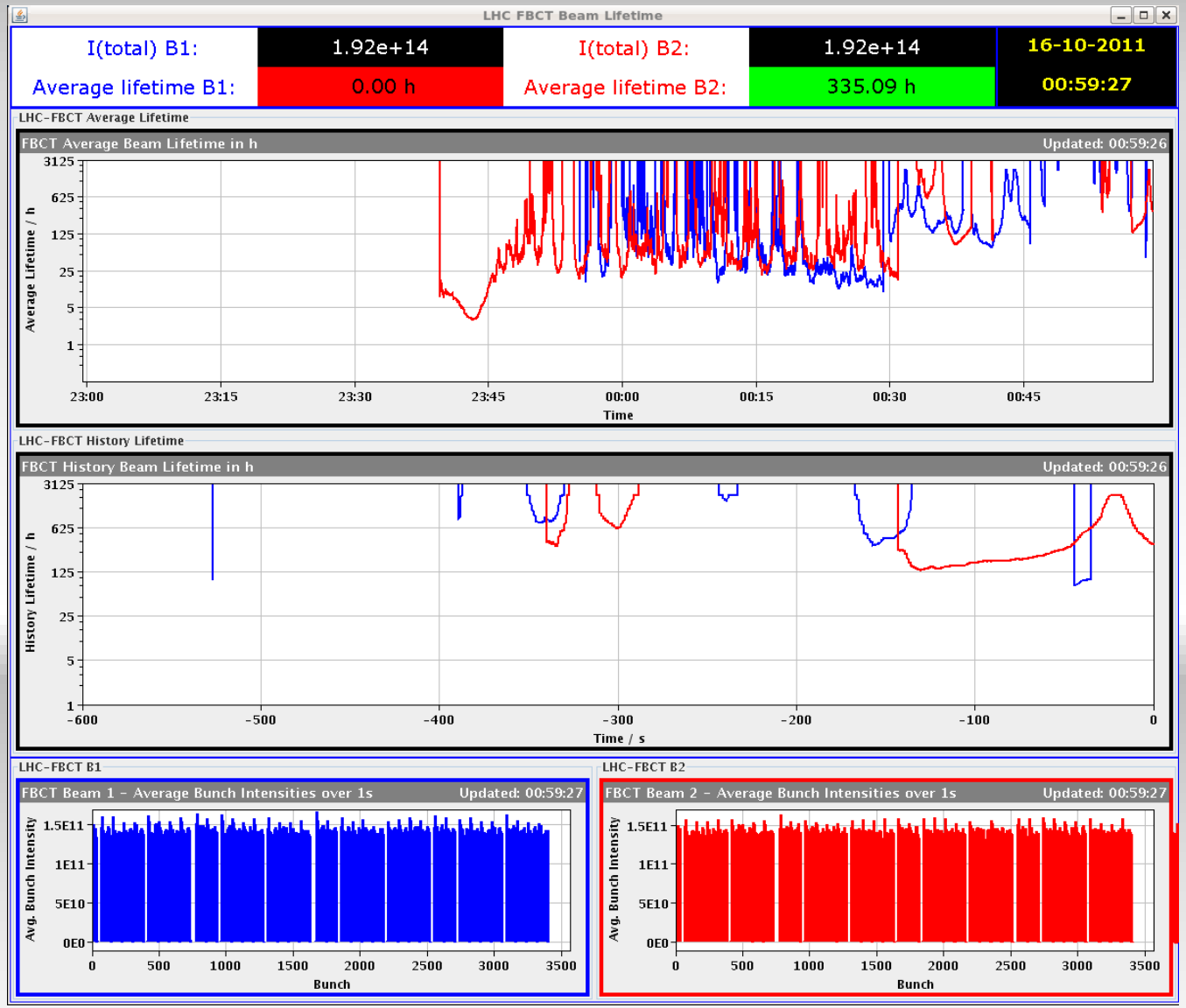
Chromaticity measurement

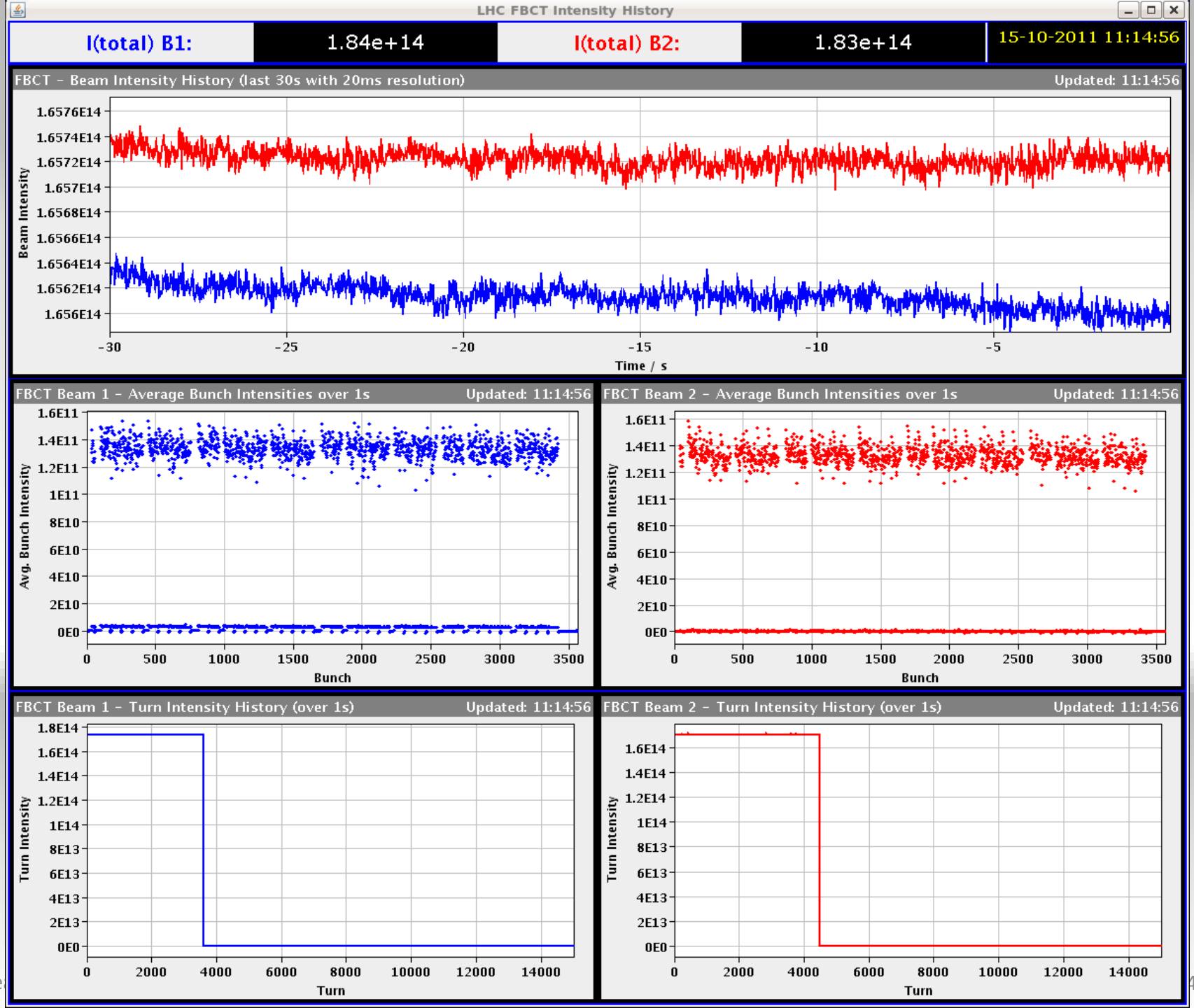


Lifetime – 2 bunches



Lifetime – the challenge

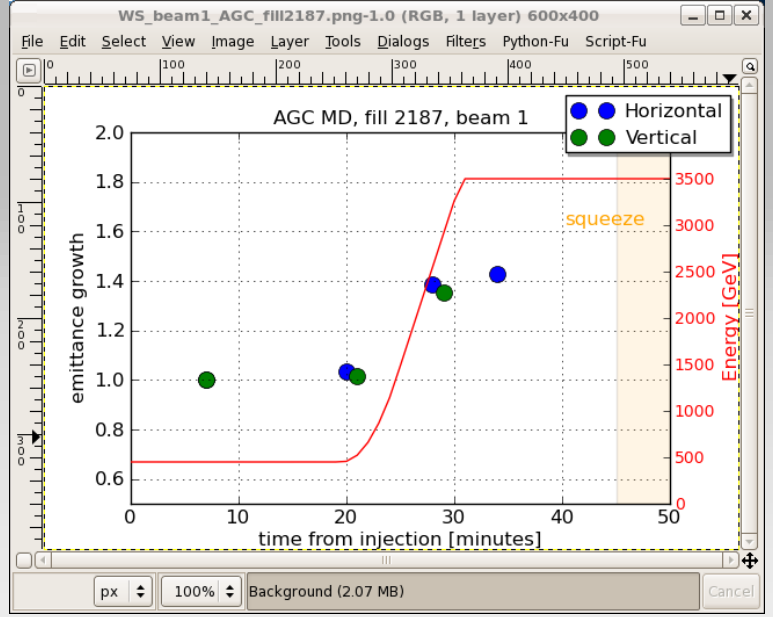


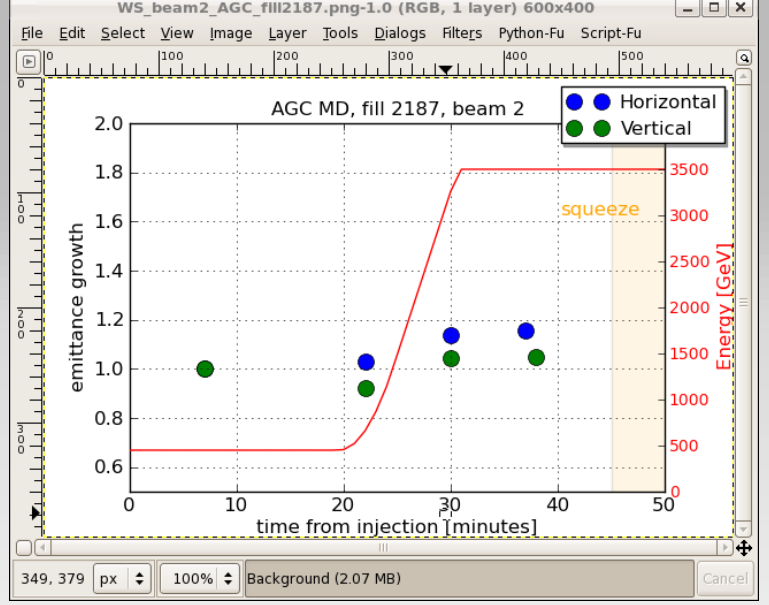

LHC FBCT Intensity History
I(total) B1:
1.84e+14
I(total) B2:
1.83e+14
15-10-2011 11:14:56
FBCT – Beam Intensity History (last 30s with 20ms resolution)
Updated: 11:14:56
Beam Intensity
1.6576E14
1.6574E14
1.6572E14
1.657E14
1.6568E14
1.6566E14
1.6564E14
1.6562E14
1.656E14
-30
-25
-20
-15
-10
-5
Time / s
FBCT Beam 1 – Average Bunch Intensities over 1s
Updated: 11:14:56
Avg. Bunch Intensity
1.6E11
1.4E11
1.2E11
1E11
8E10
6E10
4E10
2E10
0E0
0
500
1000
1500
2000
2500
3000
3500
Bunch
FBCT Beam 2 – Average Bunch Intensities over 1s
Updated: 11:14:56
Avg. Bunch Intensity
1.6E11
1.4E11
1.2E11
1E11
8E10
6E10
4E10
2E10
0E0
0
500
1000
1500
2000
2500
3000
3500
Bunch
FBCT Beam 1 – Turn Intensity History (over 1s)
Updated: 11:14:56
Turn Intensity
1.8E14
1.6E14
1.4E14
1.2E14
1E14
8E13
6E13
4E13
2E13
0E0
0
2000
4000
6000
8000
10000
12000
14000
Turn
FBCT Beam 2 – Turn Intensity History (over 1s)
Updated: 11:14:56
Turn Intensity
1.6E14
1.4E14
1.2E14
1E14
8E13
6E13
4E13
2E13
0E0
0
2000
4000
6000
8000
10000
12000
14000
Turn

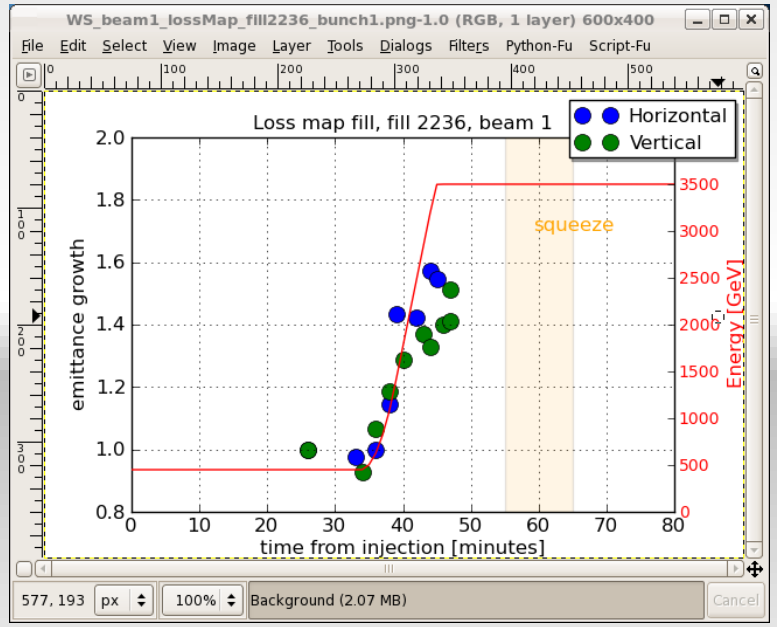
Ramp & squeeze

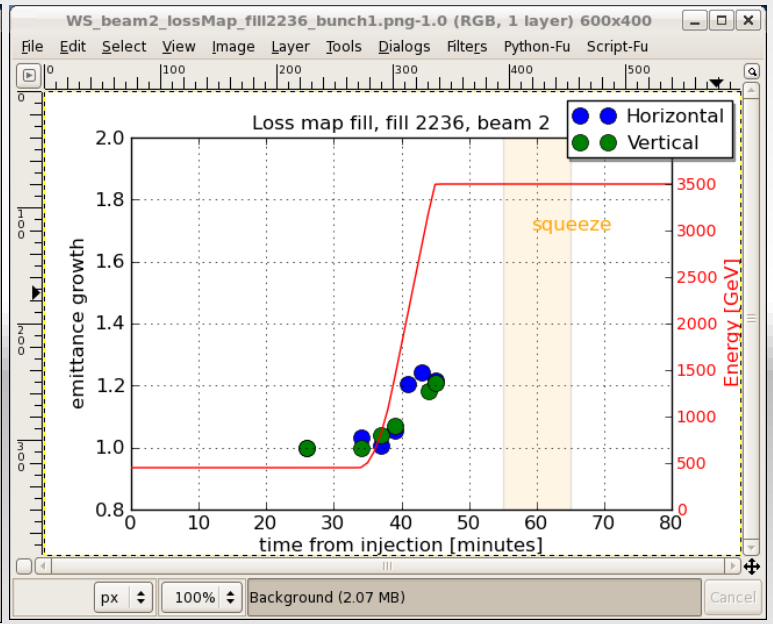
We are in your hands

- BBQ/tune feedback
- Orbit feedback
- Monitoring:
  - BLMs always, the orange screen the wake-up
  - lifetimes
  - bunch lengths (RF's WCMs)/blow-up
- With normal intensities – essentially blind on beam size



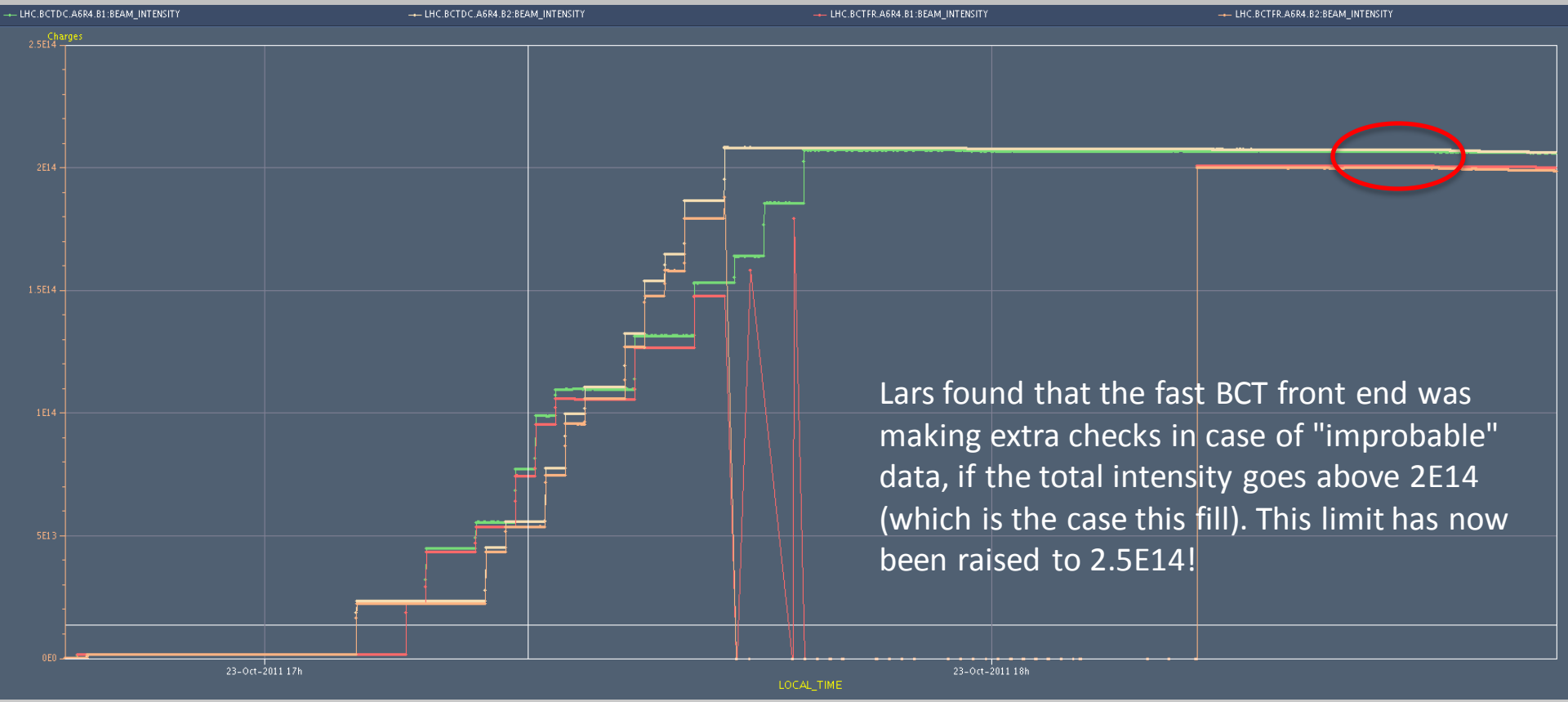






Attempt to measure emittance blow-up in ramp with wire scanners – by hand!

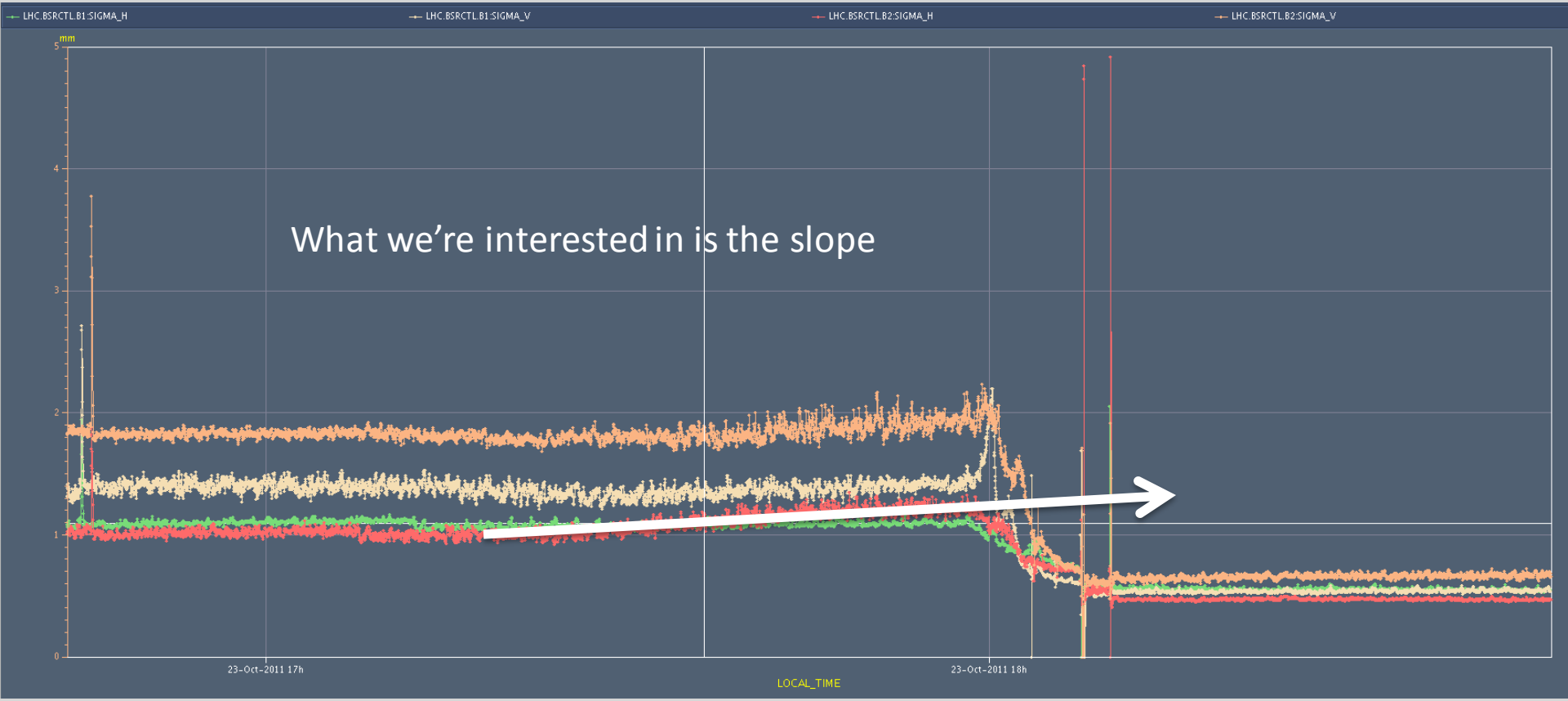
BCTs



Lars found that the fast BCT front end was making extra checks in case of "improbable" data, if the total intensity goes above 2E14 (which is the case this fill). This limit has now been raised to 2.5E14!

- Bunch pattern dependence & saturation of the DCCT
  - Modified DCCT feedback loop, wall-current bypass & front-end amplifiers
  - Uncertainty in the absolute DCCT calibration now at the 0.1% level
- Satellite bunches and unbunched beam
  - Produces uncertainty in cross-calibration of FBCT with DCCT
  - LDM & data from experiments used to ensure this is well below 1%

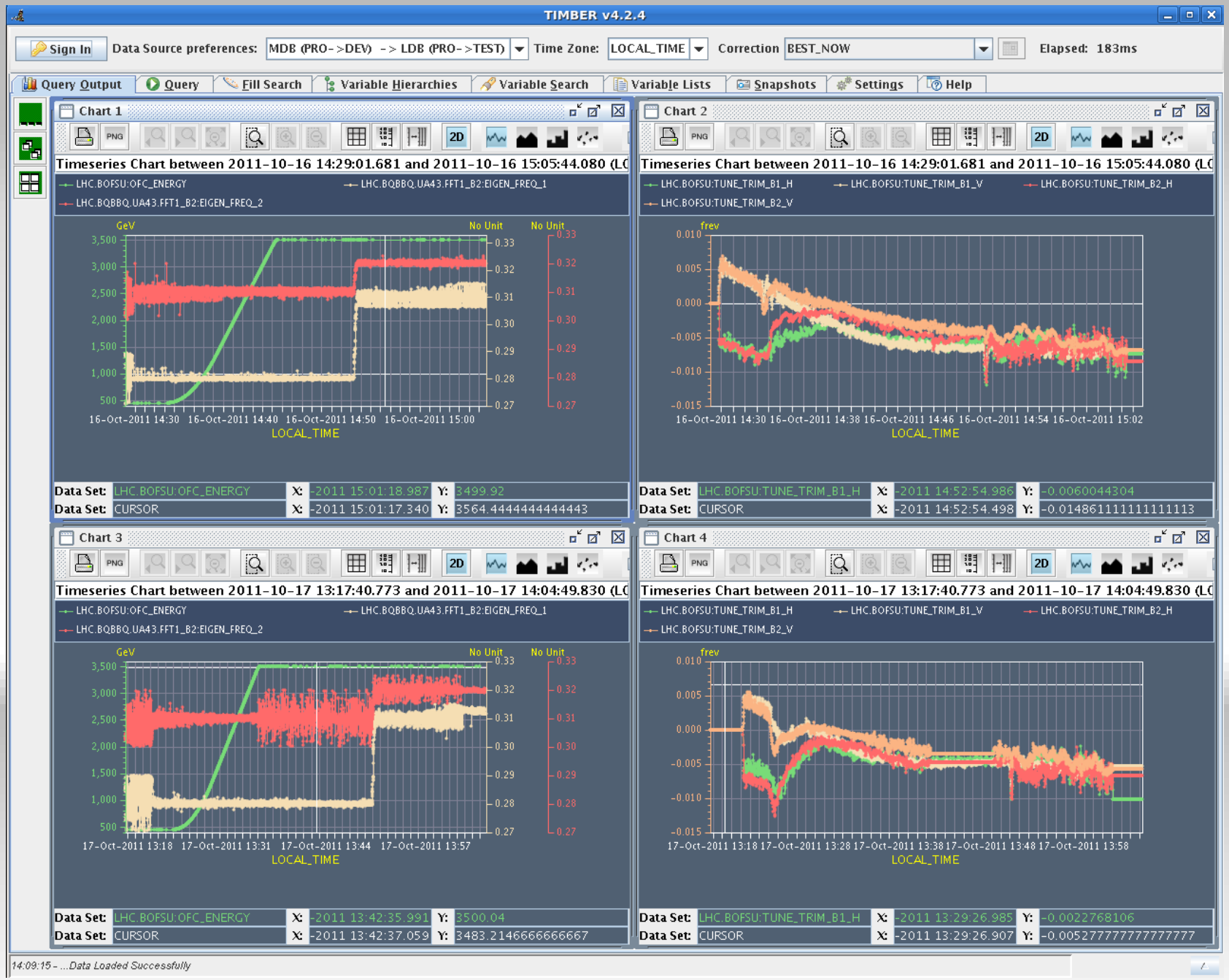
BSRT – ramp & squeeze



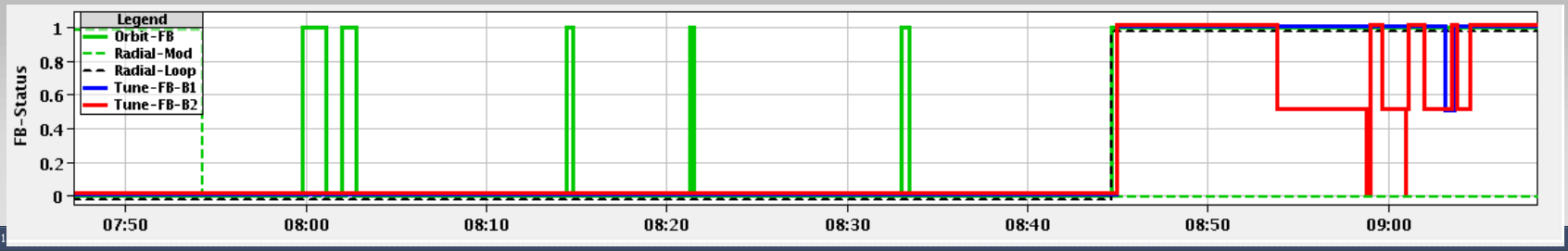
BBQ

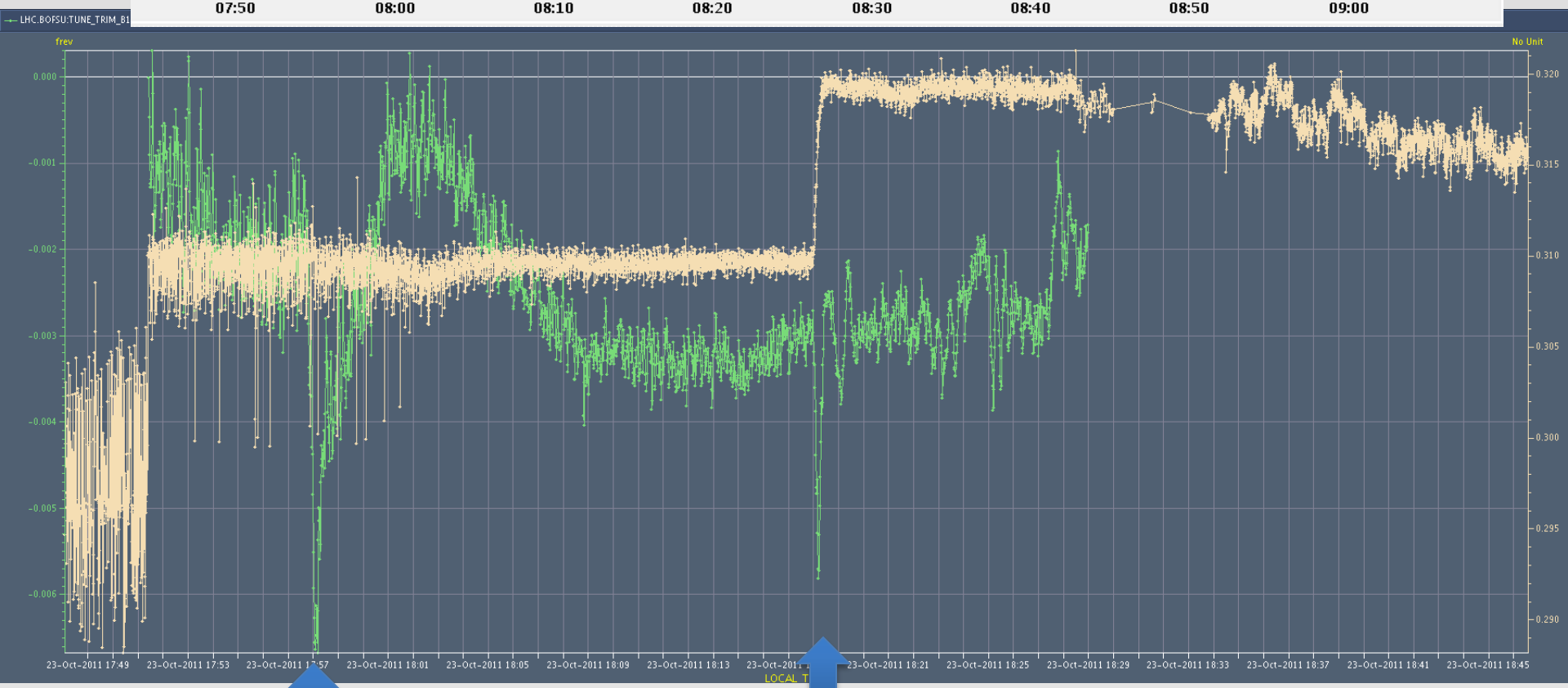
QFB ON

Start Squeeze


TIMBER v4.2.4
Sign In
Data Source preferences: MDB (PRO->DEV) -> LDB (PRO->TEST)
Time Zone: LOCAL_TIME
Correction BEST_NOW
Elapsed: 183ms
Query Output
Query
Fill Search
Variable Hierarchies
Variable Search
Variable Lists
Snapshots
Settings
Help
Chart 1
Timeseries Chart between 2011-10-16 14:29:01.681 and 2011-10-16 15:05:44.080 (LC
LHC.BOFSU:OFC_ENERGY
LHC.BQBBQ.UA43.FFT1_B2:EIGEN_FREQ_1
LHC.BQBBQ.UA43.FFT1_B2:EIGEN_FREQ_2
GeV
No Unit
No Unit
16-Oct-2011 14:30
16-Oct-2011 14:40
16-Oct-2011 14:50
16-Oct-2011 15:00
LOCAL_TIME
Data Set: LHC.BOFSU:OFC_ENERGY X: -2011 15:01:18.987 Y: 3499.92
Data Set: CURSOR X: -2011 15:01:17.340 Y: 3564.4444444444443
Chart 2
Timeseries Chart between 2011-10-16 14:29:01.681 and 2011-10-16 15:05:44.080 (LC
LHC.BOFSU:TUNE_TRIM_B1_H
LHC.BOFSU:TUNE_TRIM_B1_V
LHC.BOFSU:TUNE_TRIM_B2_H
LHC.BOFSU:TUNE_TRIM_B2_V
frev
16-Oct-2011 14:30
16-Oct-2011 14:38
16-Oct-2011 14:46
16-Oct-2011 14:54
16-Oct-2011 15:02
LOCAL_TIME
Data Set: LHC.BOFSU:TUNE_TRIM_B1_H X: -2011 14:52:54.986 Y: -0.0060044304
Data Set: CURSOR X: -2011 14:52:54.498 Y: -0.014861111111111113
Chart 3
Timeseries Chart between 2011-10-17 13:17:40.773 and 2011-10-17 14:04:49.830 (LC
LHC.BOFSU:OFC_ENERGY
LHC.BQBBQ.UA43.FFT1_B2:EIGEN_FREQ_1
LHC.BQBBQ.UA43.FFT1_B2:EIGEN_FREQ_2
GeV
No Unit
No Unit
17-Oct-2011 13:18
17-Oct-2011 13:31
17-Oct-2011 13:44
17-Oct-2011 13:57
LOCAL_TIME
Data Set: LHC.BOFSU:OFC_ENERGY X: -2011 13:42:35.991 Y: 3500.04
Data Set: CURSOR X: -2011 13:42:37.059 Y: 3483.2146666666667
Chart 4
Timeseries Chart between 2011-10-17 13:17:40.773 and 2011-10-17 14:04:49.830 (LC
LHC.BOFSU:TUNE_TRIM_B1_H
LHC.BOFSU:TUNE_TRIM_B1_V
LHC.BOFSU:TUNE_TRIM_B2_H
LHC.BOFSU:TUNE_TRIM_B2_V
frev
17-Oct-2011 13:18
17-Oct-2011 13:28
17-Oct-2011 13:38
17-Oct-2011 13:48
17-Oct-2011 13:58
LOCAL_TIME
Data Set: LHC.BOFSU:TUNE_TRIM_B1_H X: -2011 13:29:26.985 Y: -0.0022768106
Data Set: CURSOR X: -2011 13:29:26.907 Y: -0.005277777777777777
14:09:15 - ...Data Loaded Successfully

Tune feedback - corrections

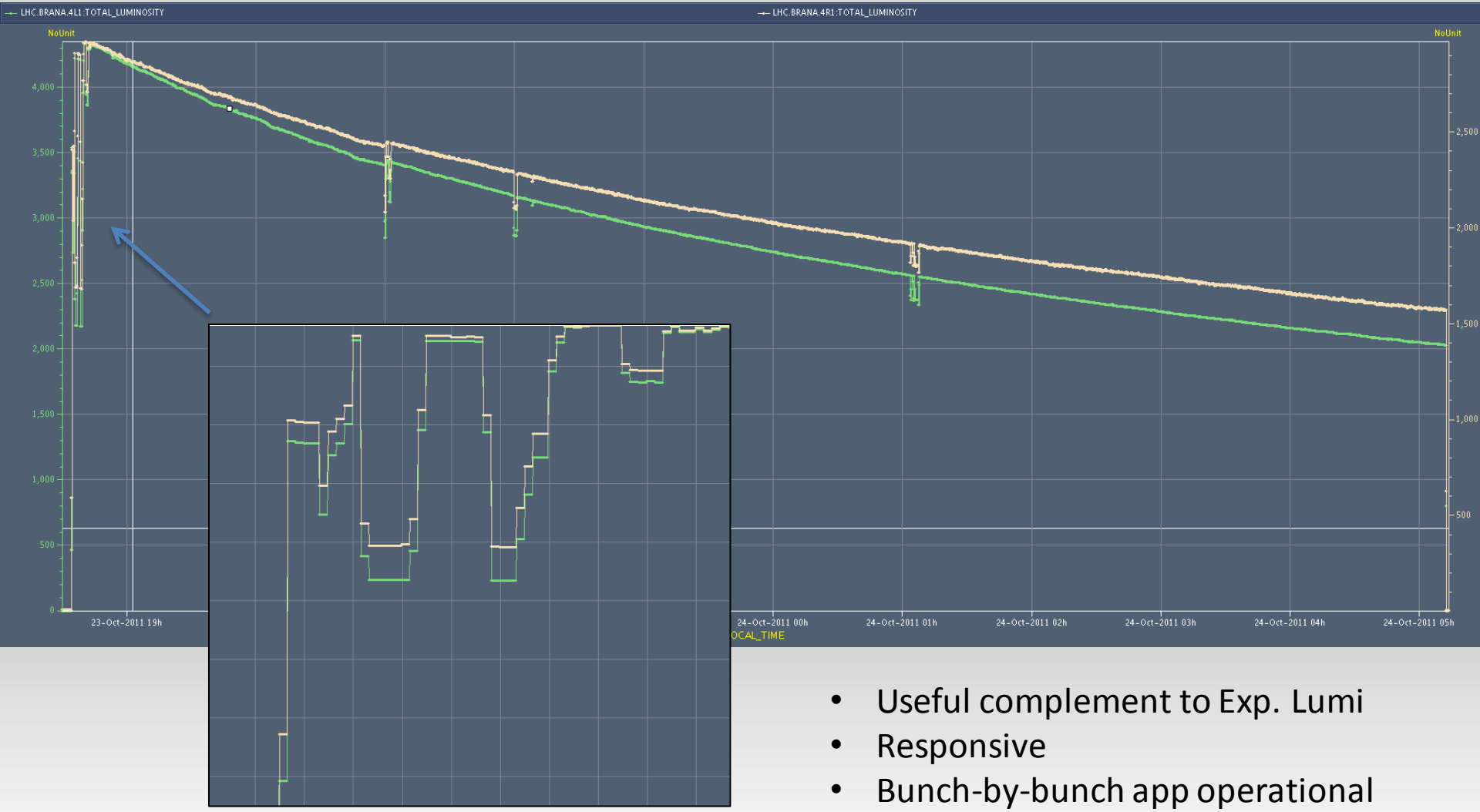




Snapback – good job

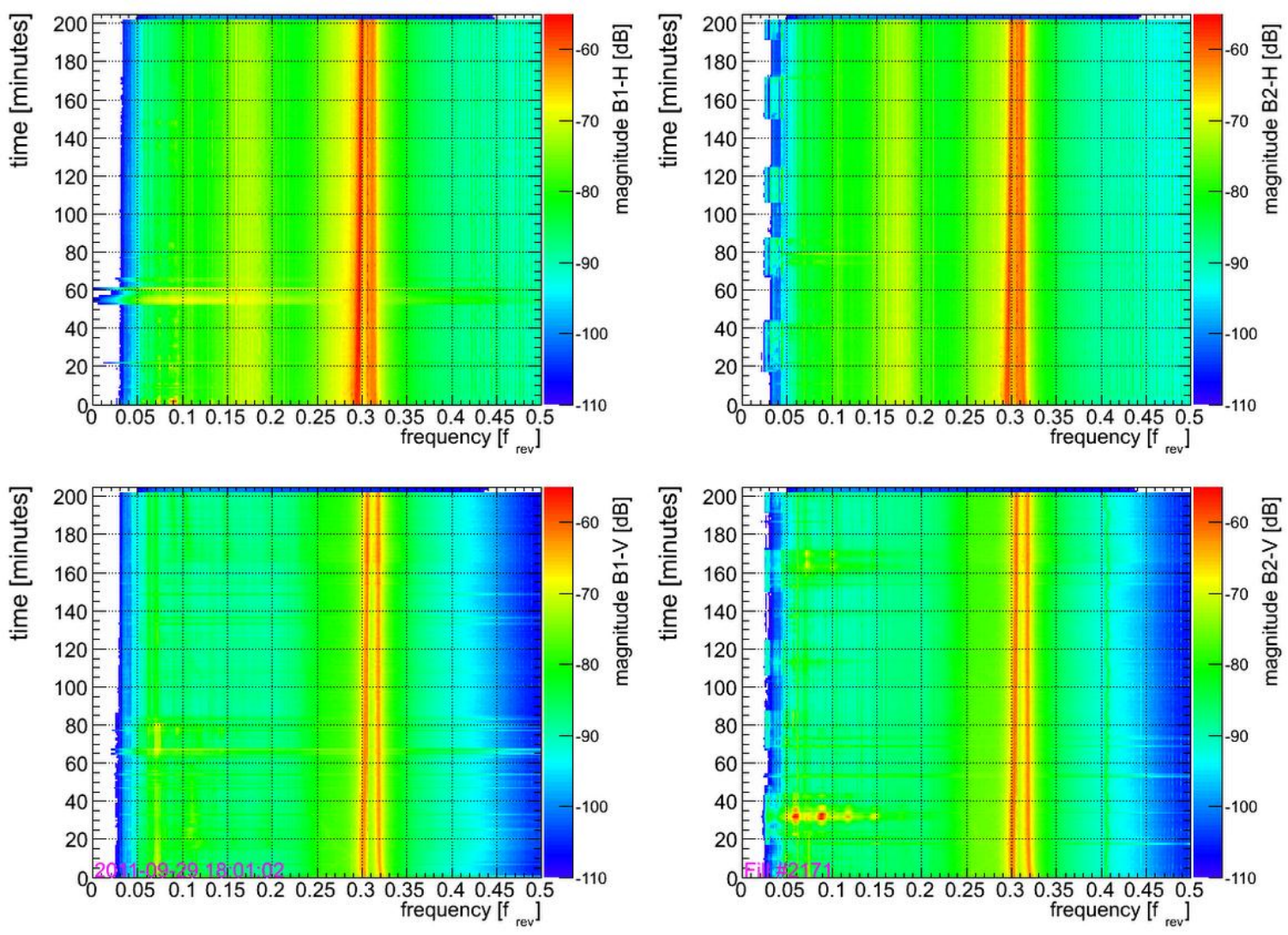
Tune change – start of squeeze

Collisions - BRAN

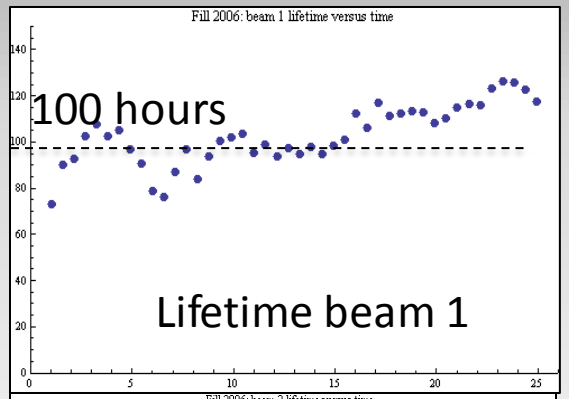


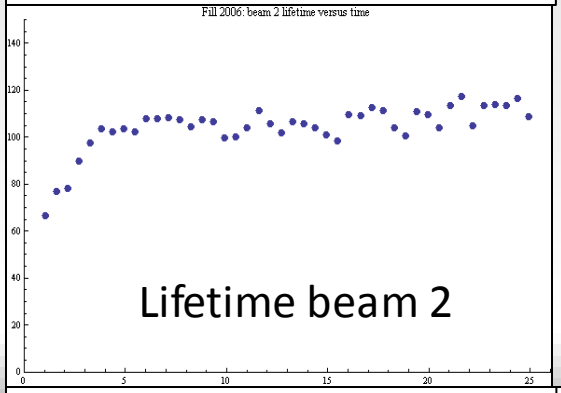
- Useful complement to Exp. Lumi
- Responsive
- Bunch-by-bunch app operational

BBQ – beam-beam modes

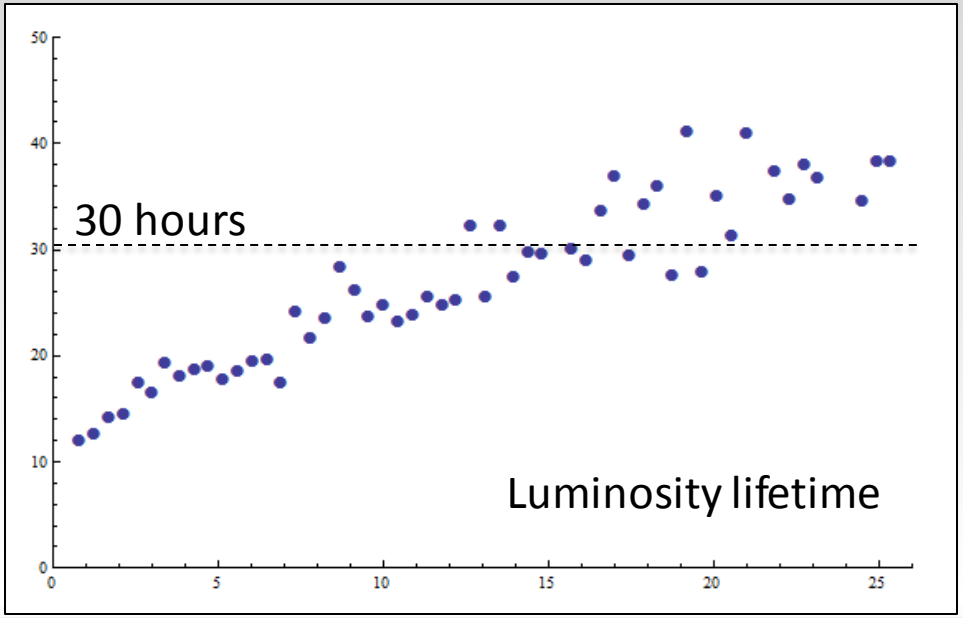


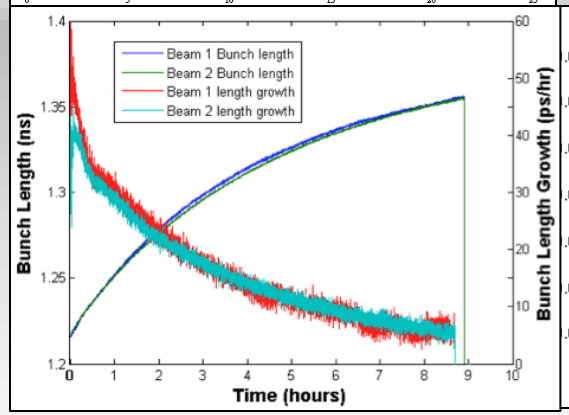
Fill 2006: Luminosity lifetime

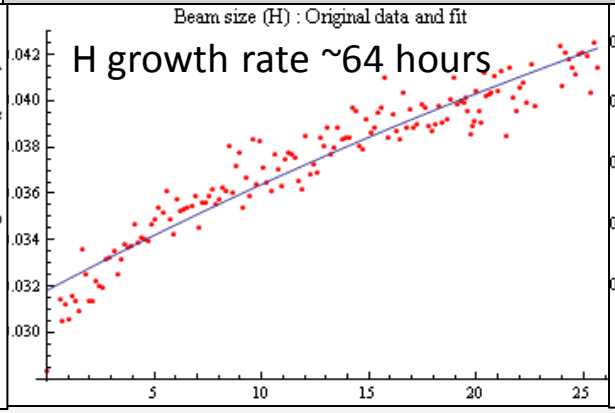


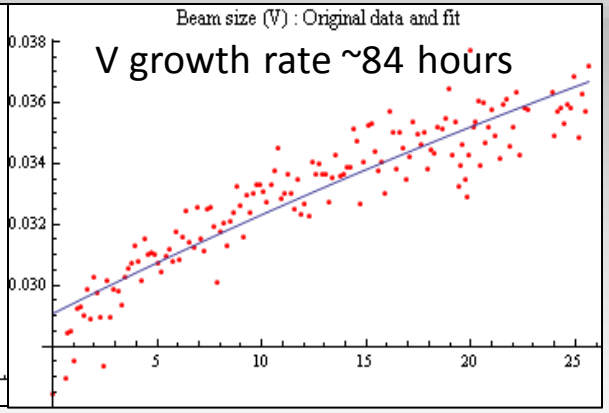


A “typical” fill that lasted 26 hours and delivered 100 pb^{-1}

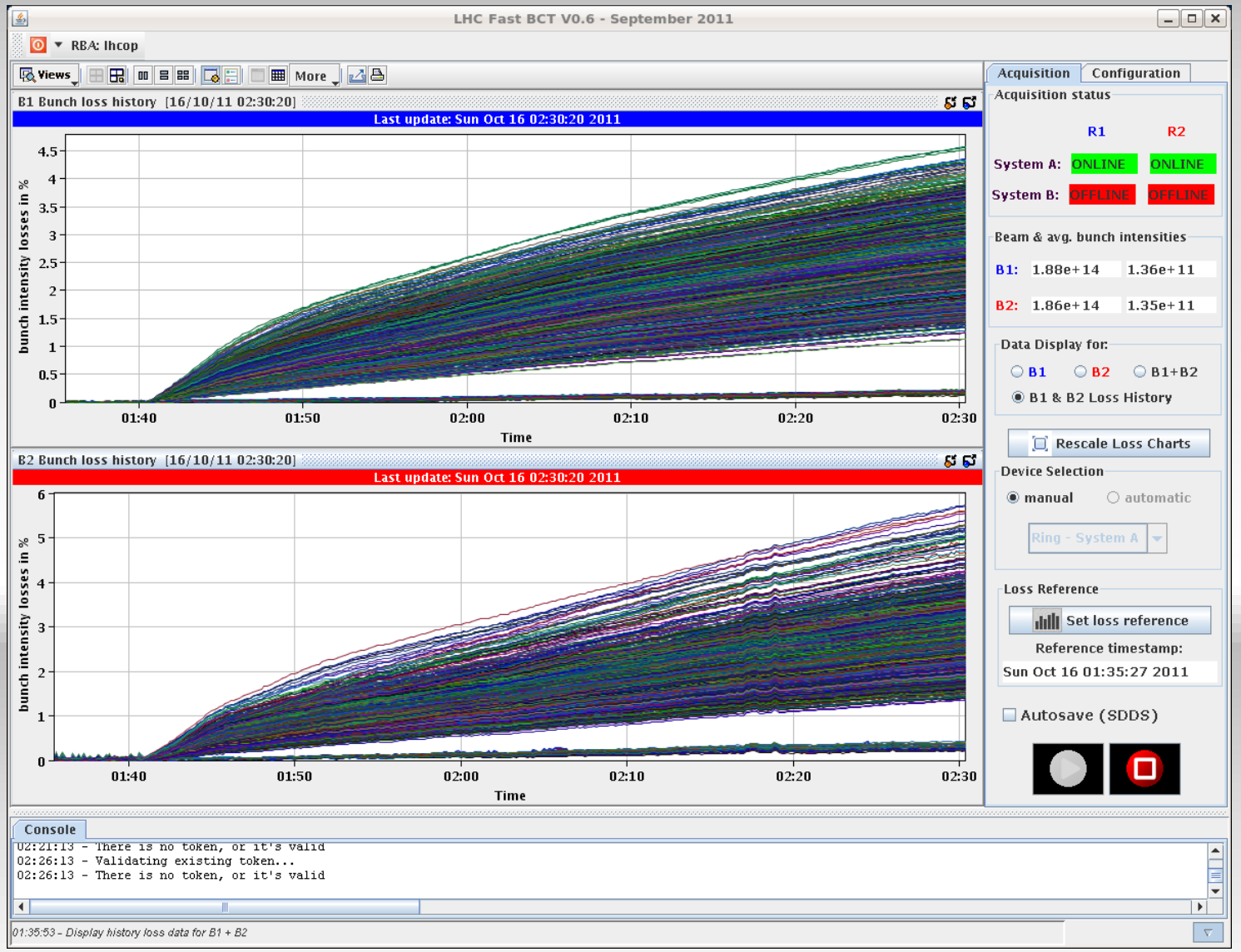




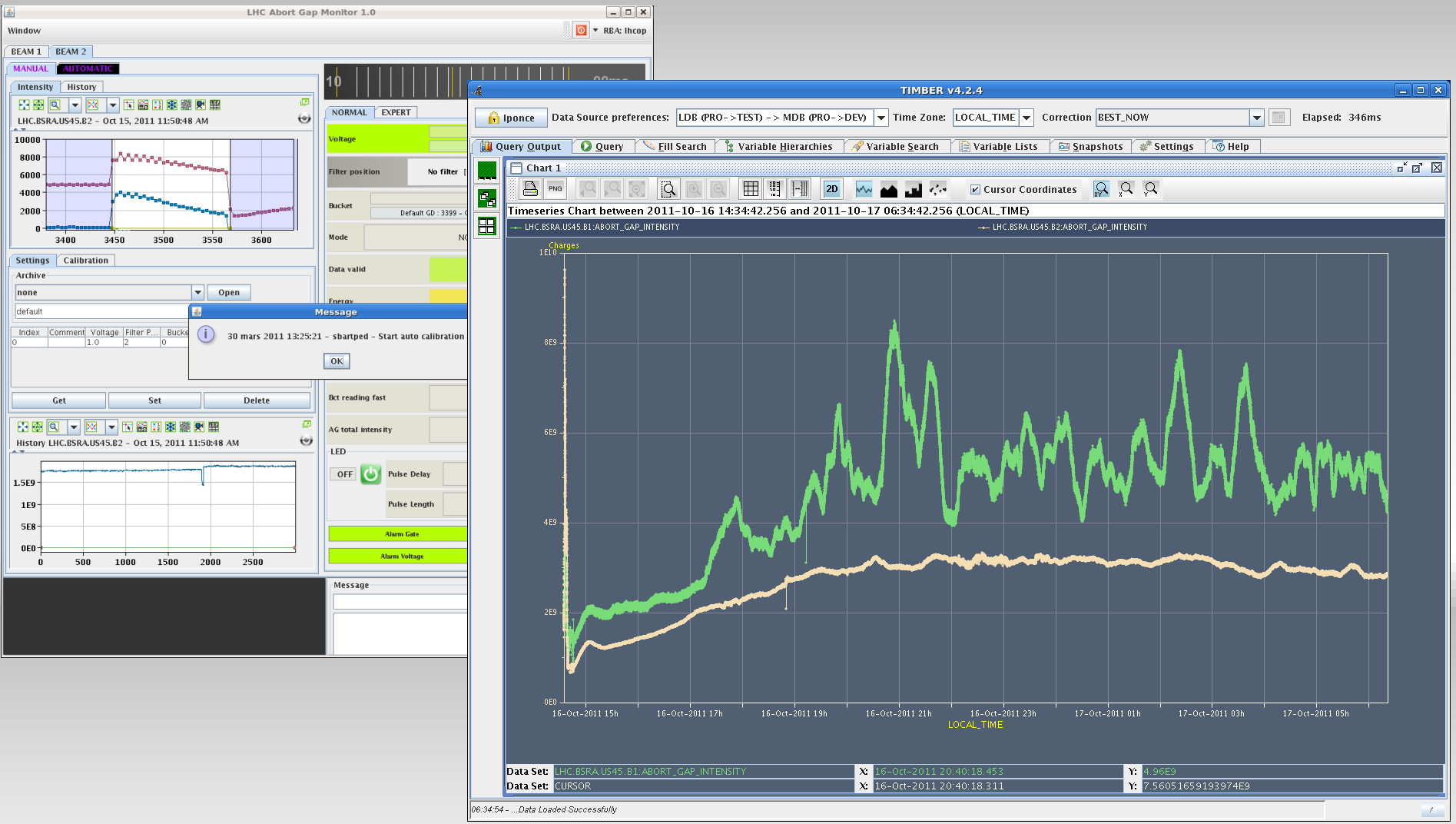




BbB FBCT in collisions



BSRA



Important for machine protection, very useful diagnostic for RF problems

Beam 1 orbit in stable beams fill 2105

- 03:00 t = 0 hours
  - Start of stable collisions

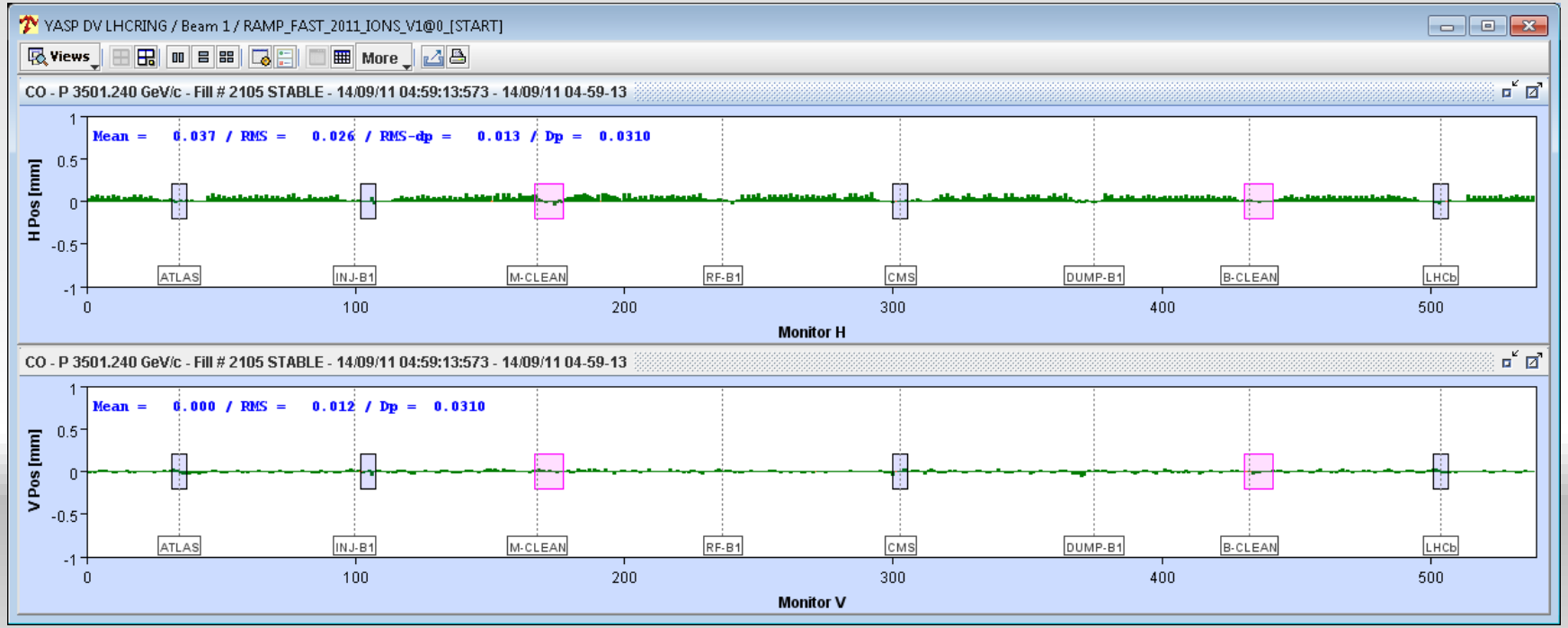
This sequence courtesy: Jorg Wenninger

Beam 1 orbit in stable beams fill 2105

- 04:00 t = 1 hours.
  - Tides showing up in horizontal, small ‘features’ around IR3.

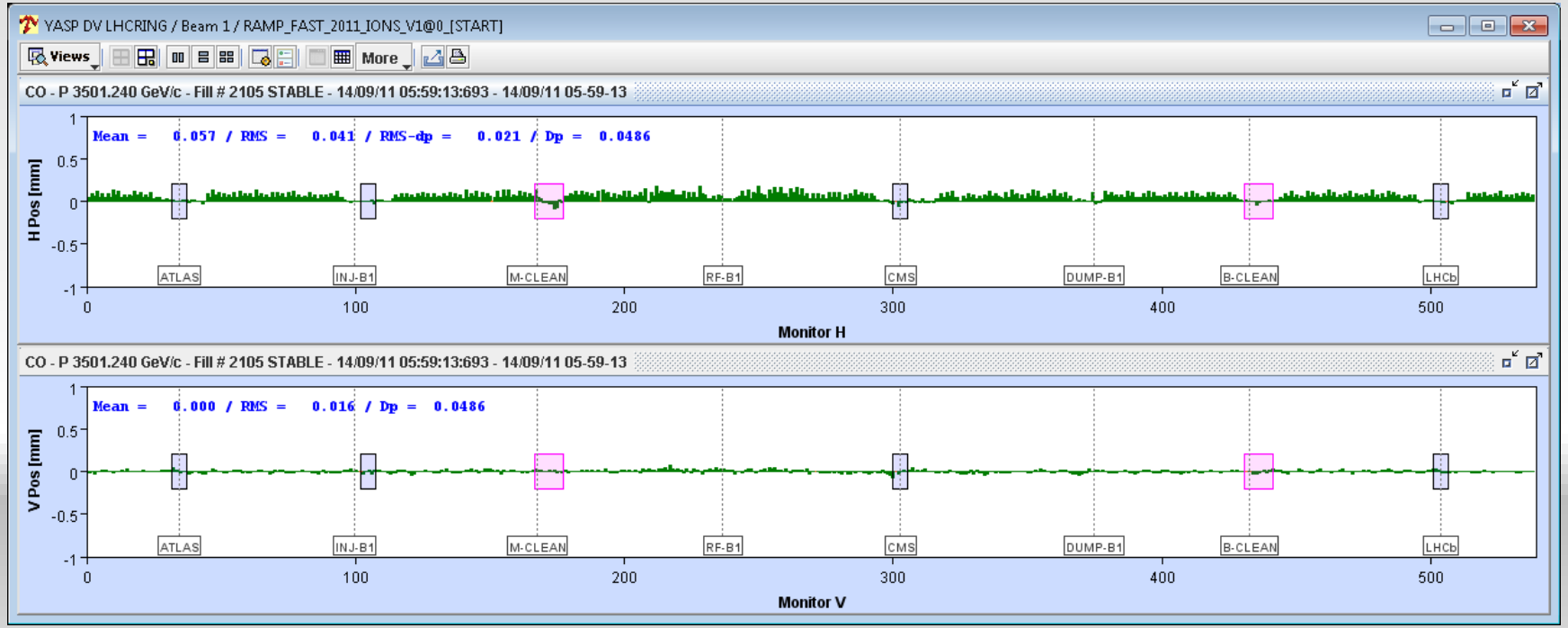
Beam 1 orbit in stable beams fill 2105

- 05:00 t = 2 hours.
  - More tides.



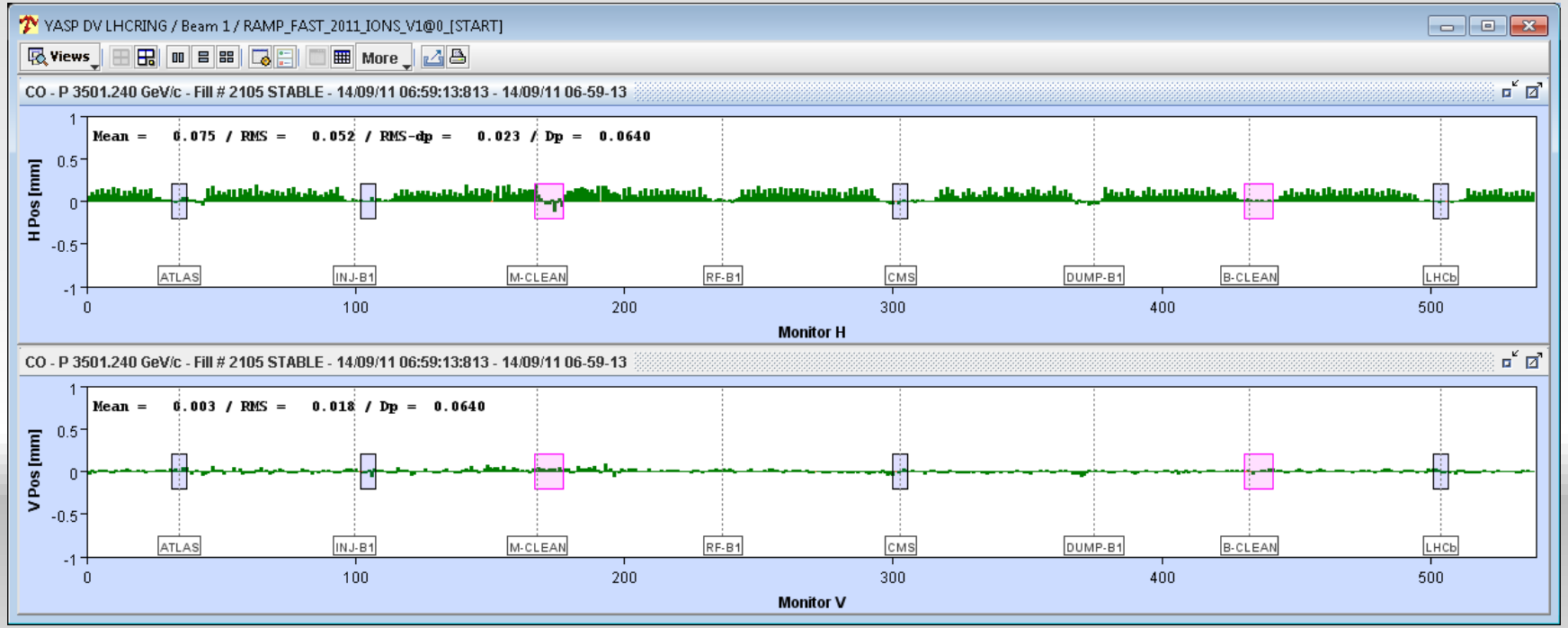
Beam 1 orbit in stable beams fill 2105

- 06:00 t = 4 hours.
  - New moon.



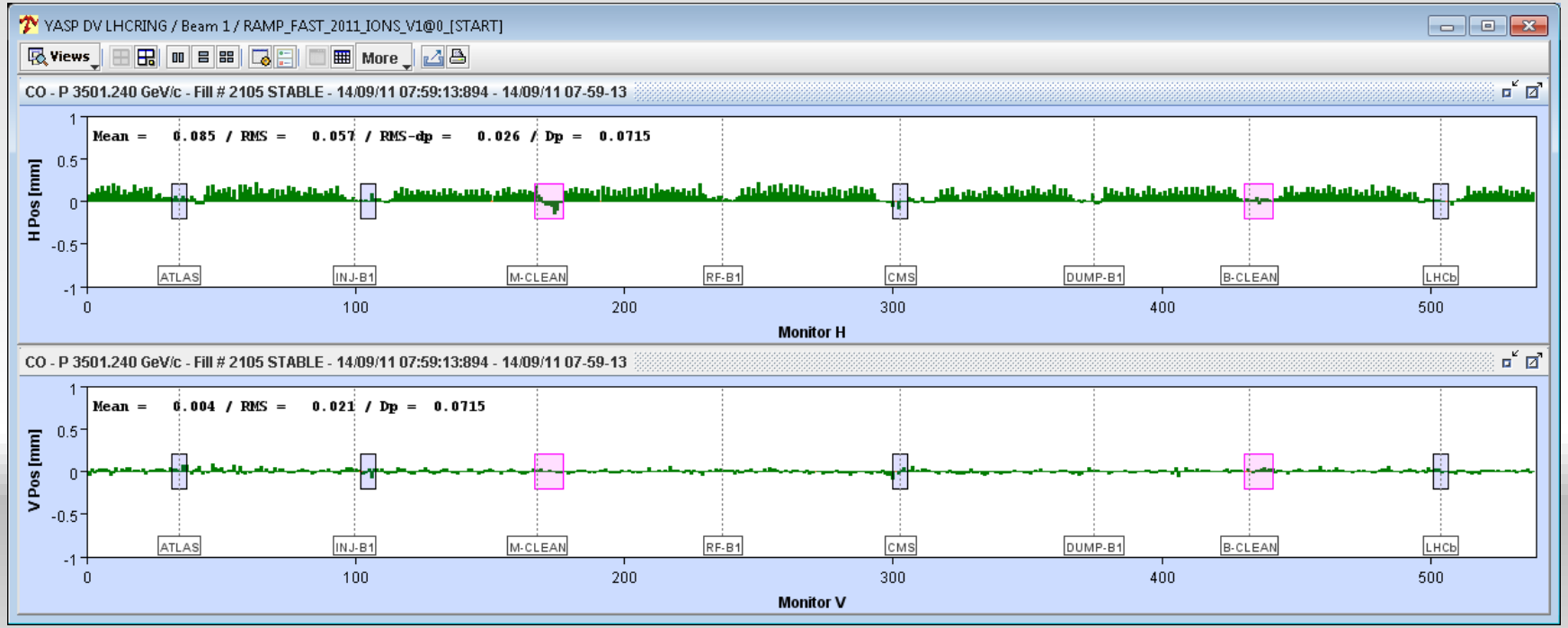
Beam 1 orbit in stable beams fill 2105

- 07:00 t = 5 hours.
  - Shift hand-over..



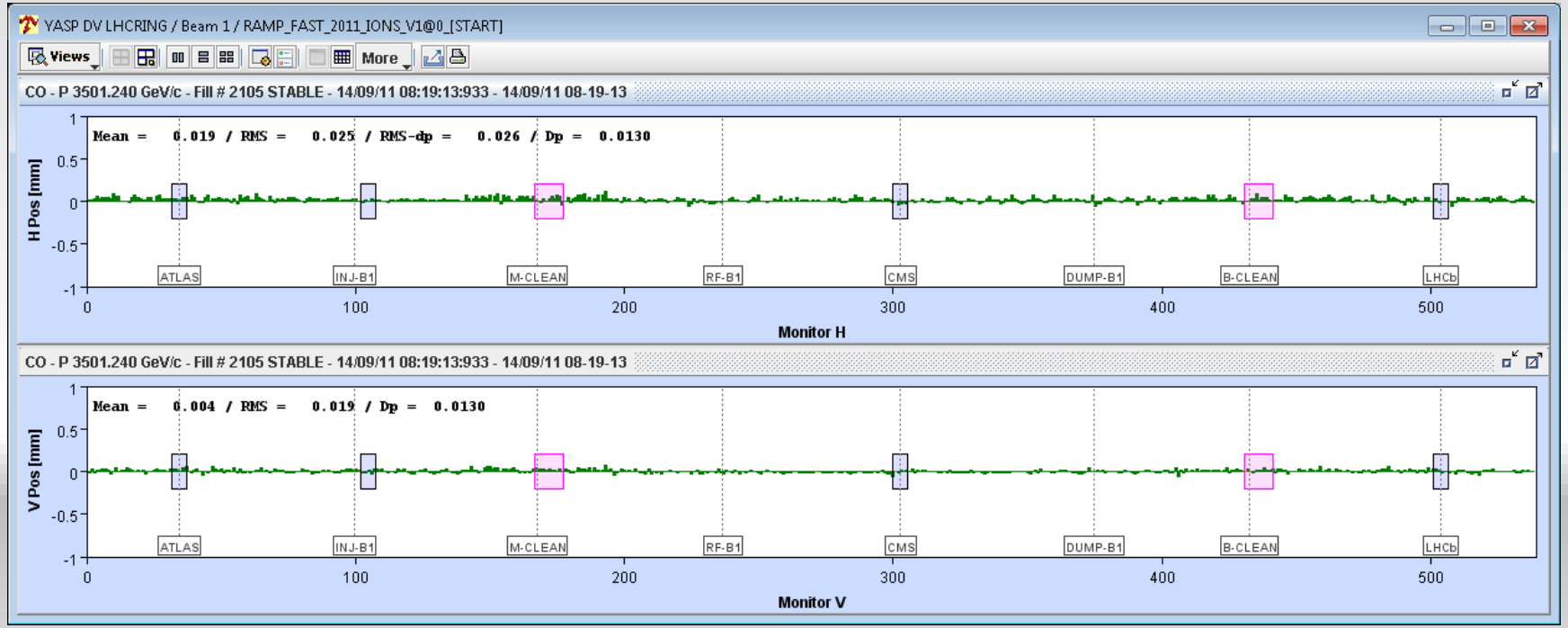
Beam 1 orbit in stable beams fill 2105

- 08:00 t = 6 hours.
  - Coordinators arrive..



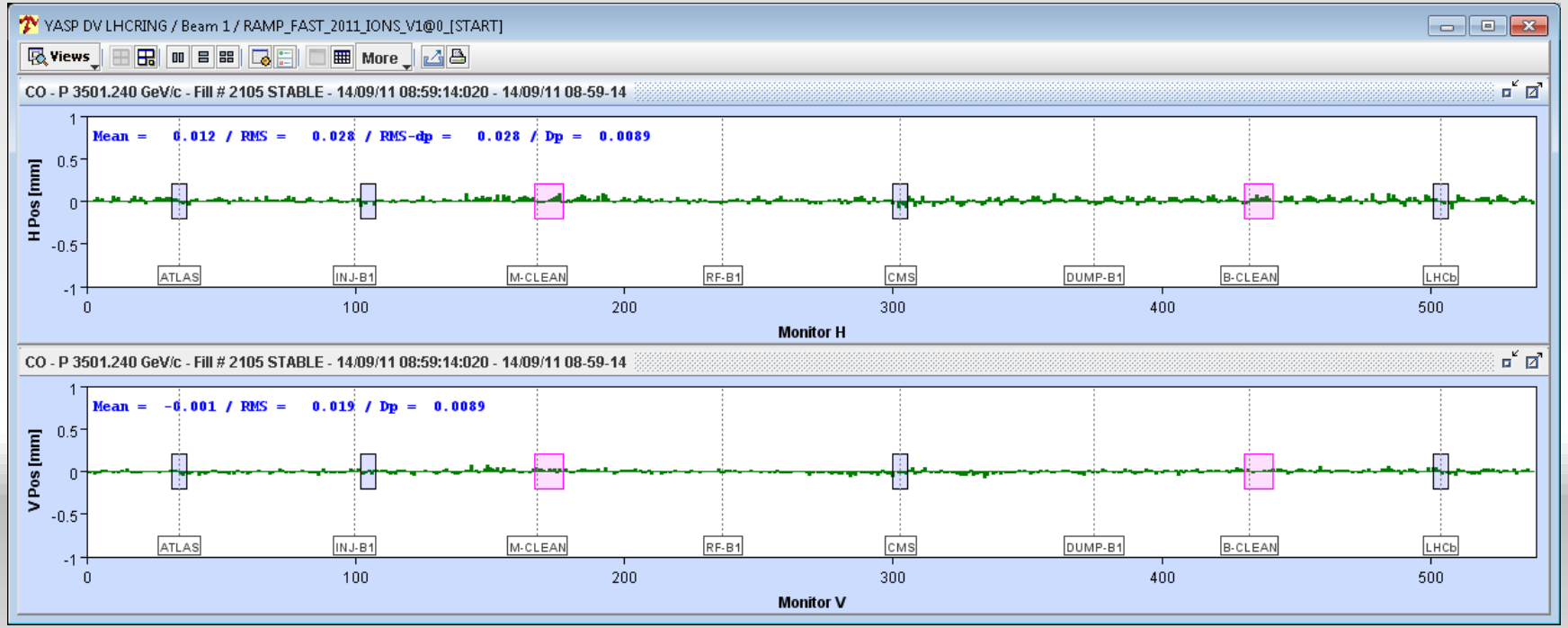
Beam 1 orbit in stable beams fill 2105

- 08:20 t = 6.3 hours.
  - RF frequency correction to compensate tides.



Beam 1 orbit in stable beams fill 2105

- 09:00 t = 7 hours.
  - Small betatron oscillation in horizontal.



Beam 1 orbit in stable beams fill 2105

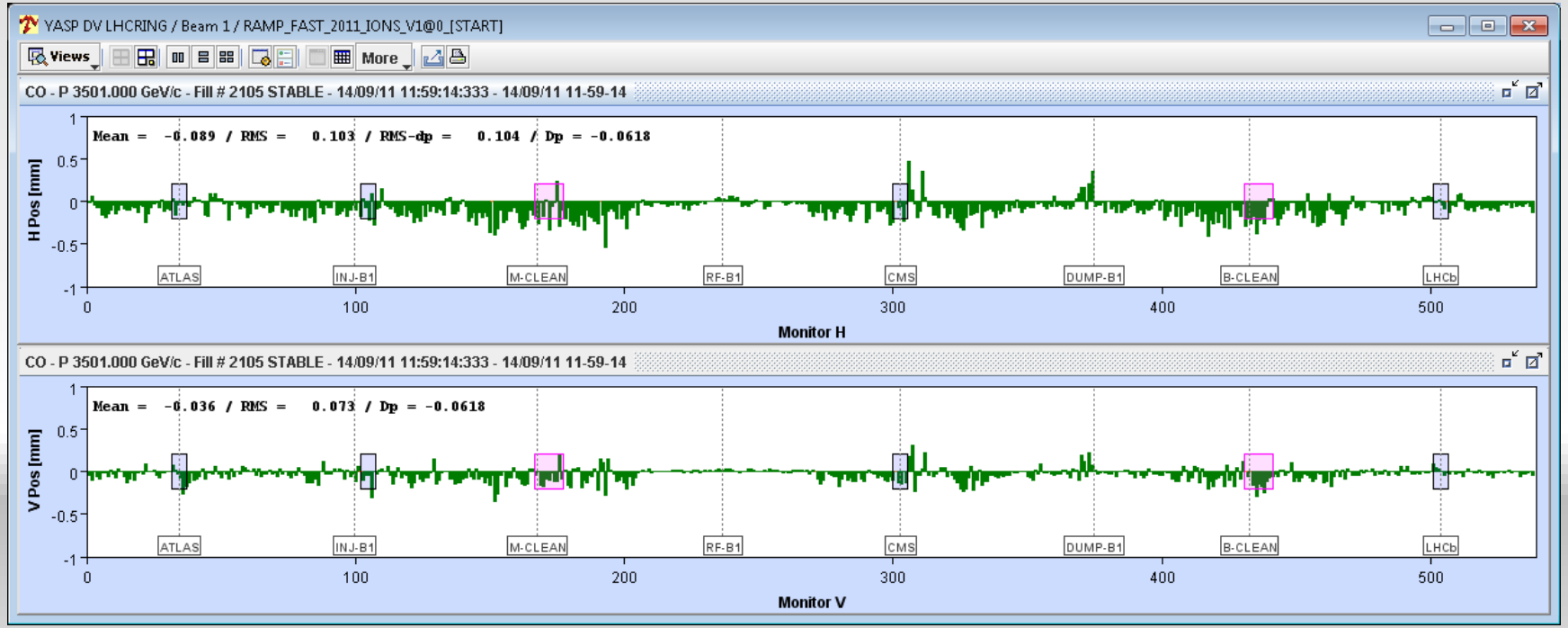
- 10:00 t = 8 hours.
  - Nice day, temperature is rising.

Beam 1 orbit in stable beams fill 2105

- 11:00 t = 9 hours.
  - It is going to be hot.

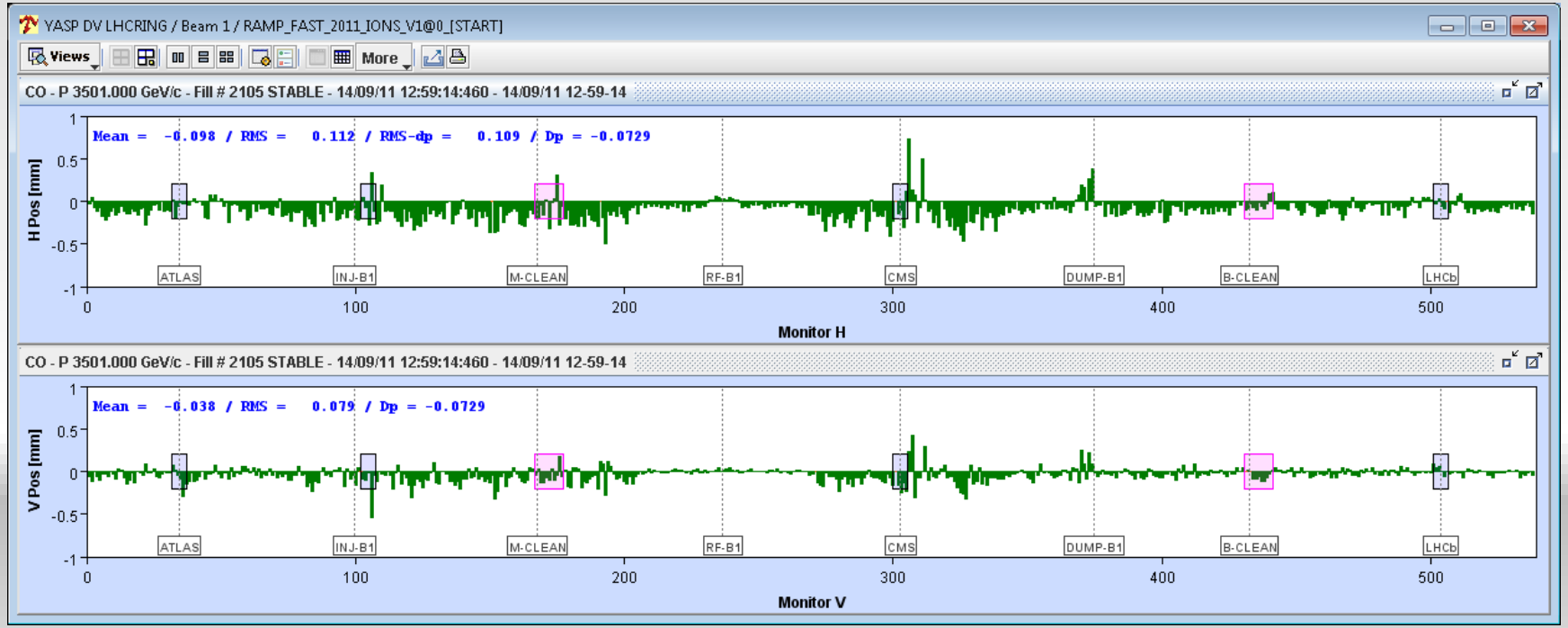
Beam 1 orbit in stable beams fill 2105

- 12:00 t = 10 hours.
  - High noon.



Beam 1 orbit in stable beams fill 2105

- 13:00 t = 11 hours.
  - Time for a fresh beer.

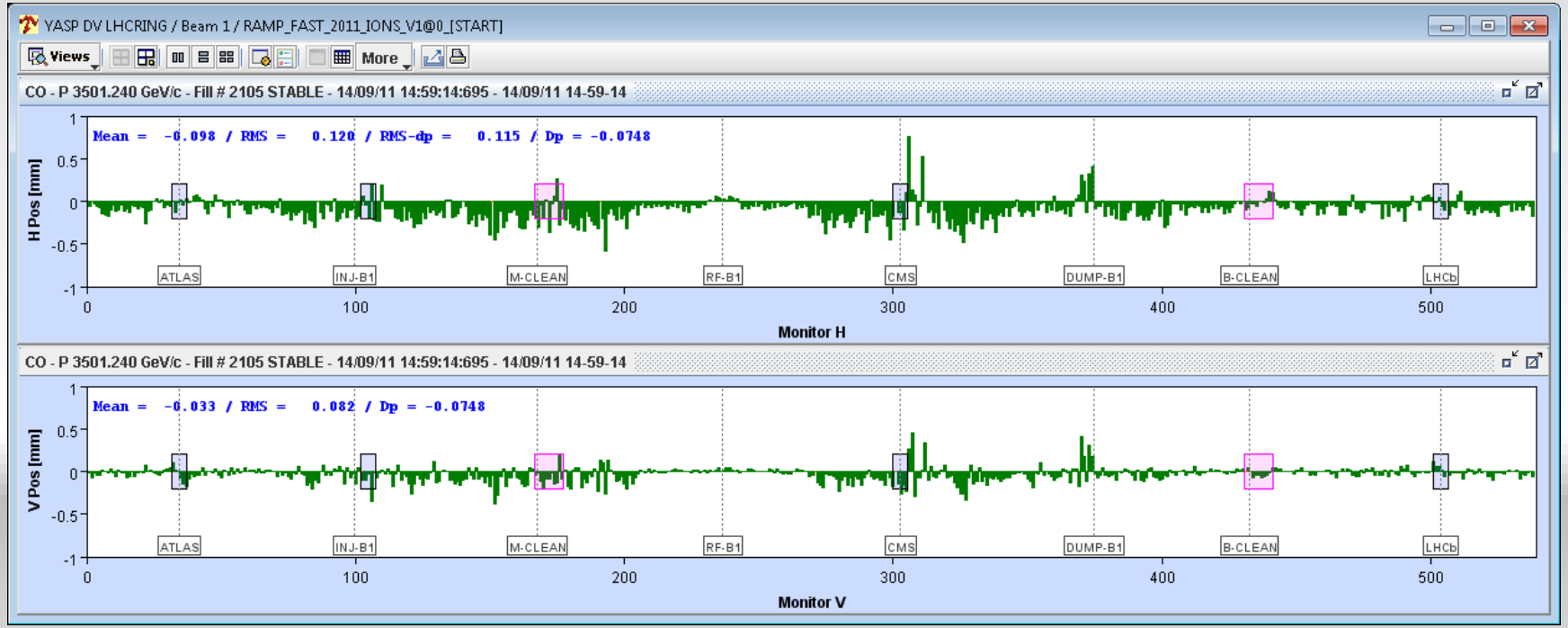


Beam 1 orbit in stable beams fill 2105

- 14:00 t = 12 hours.
  - LMC.

Beam 1 orbit in stable beams fill 2105

- 15:00 t = 13 hours.
  - LMC…

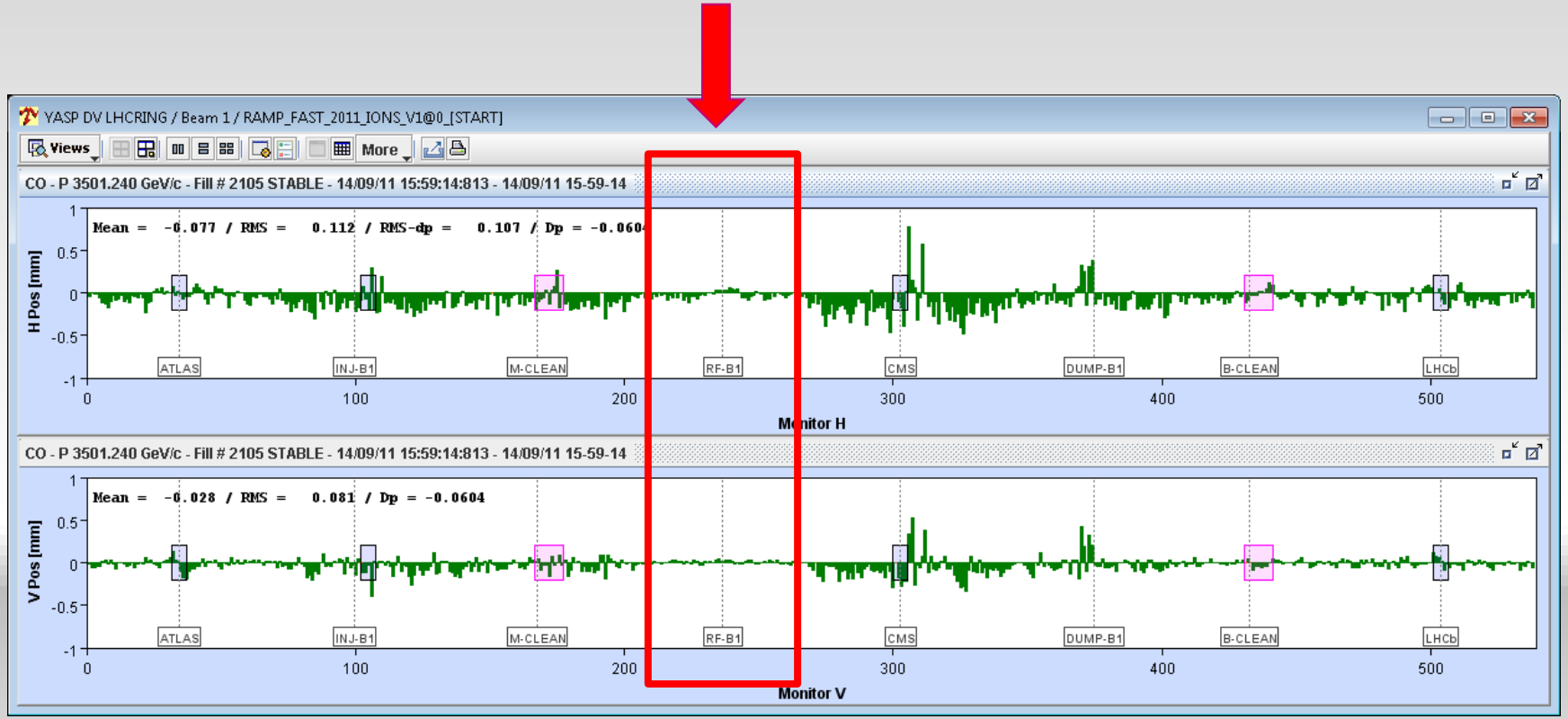


Beam 1 orbit in stable beams fill 2105

- 16:00 t = 14 hours.
  - LMC…

Beam 1 orbit in stable beams fill 2105

- 16:00 t = 14 hours.
  - Can we have more of those ?



WISH LIST/ISSUES FOR 2012

BPMs

Pretty good overall, excellent performance of arc BPMs, ability to reproduce orbit shown in the fact that collimator set-up remains valid throughout the year (validated via loss maps)

- Insertion BPM calibration – point 5 in particular – questionable readings & stability (temperature)
  - Orbit in fact stable but worry about reaction of OFB
  - Important for the beta* reach.
  - See below…
- Disabled BPMs (~20) – not bad – have redundancy
  - Management of disabled BPMs could be better (persist & reload)
- Automated quality checks with bumps – to be deployed – pick out the bad ones

BPMs

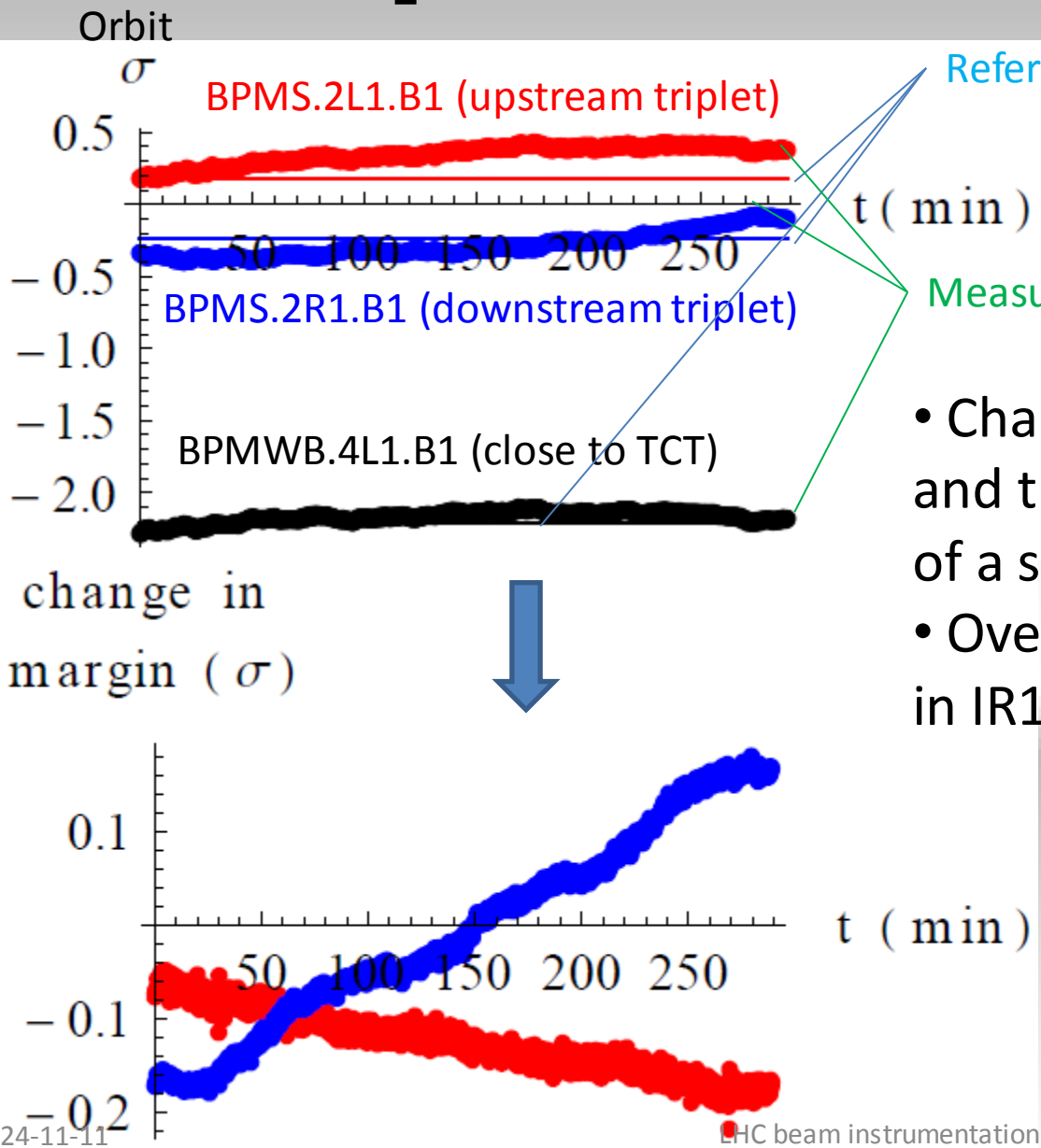
- Multi-turn mode very useful of course:
  - Would like full capacity (100,000 = n_turns*n_bunches) for bunch-by-bunch and turn-by-turn buffers of LHC BPMs
- BPMDs
  - No redundancy
  - Better diagnostics would be nice

Orbit stability

- Orbit fluctuations make up largest part of margin TCT-aperture
- Considering relative change between BPMs close to TCT and aperture bottleneck wrt reference orbit from collimation setup
- End result important part of calculation of possible beta*

Roderik Bruce

Example: fill 2158, IR1 B1 hor.

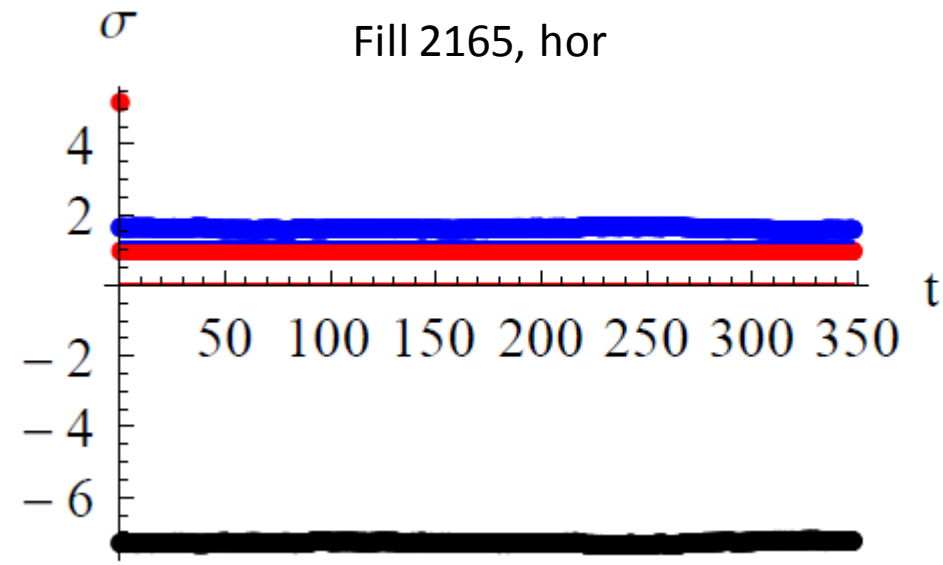


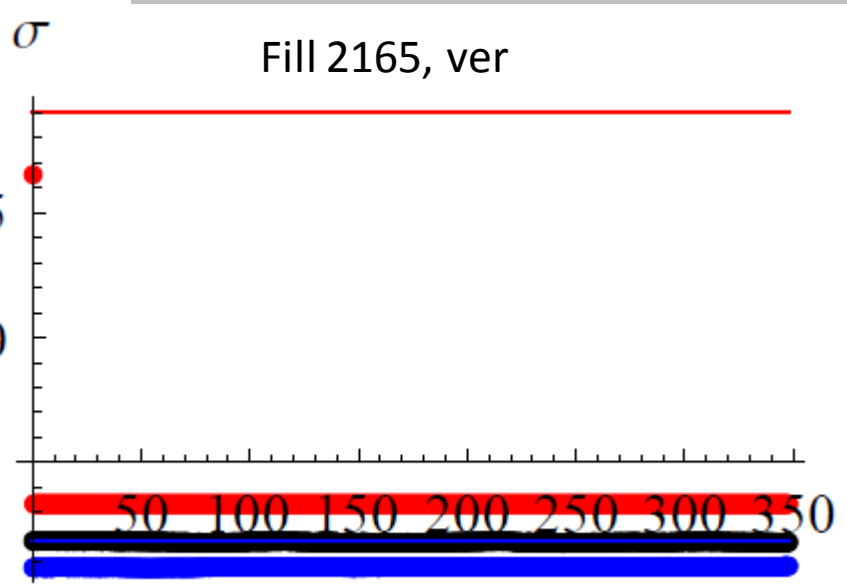
Reference orbits from TCT setup

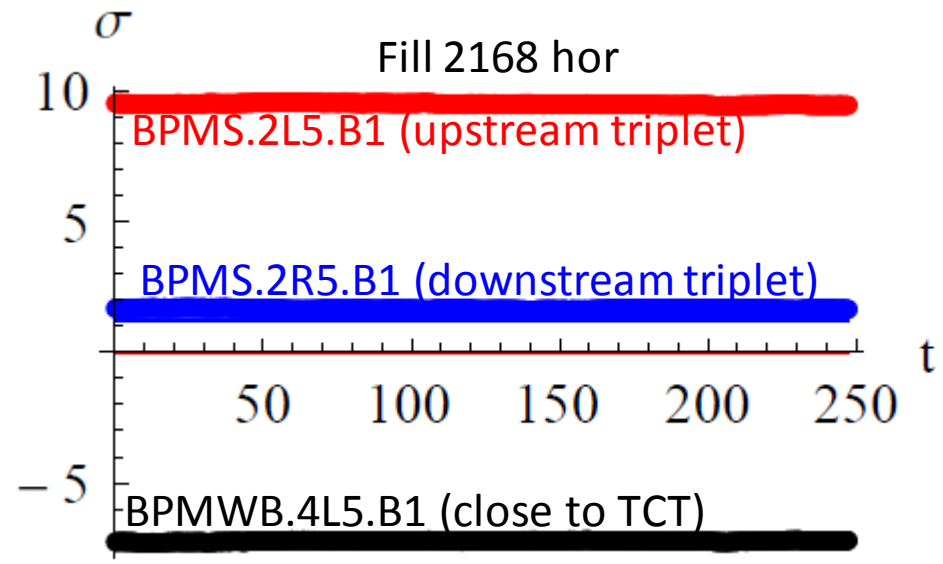
Measured orbits during stable beams

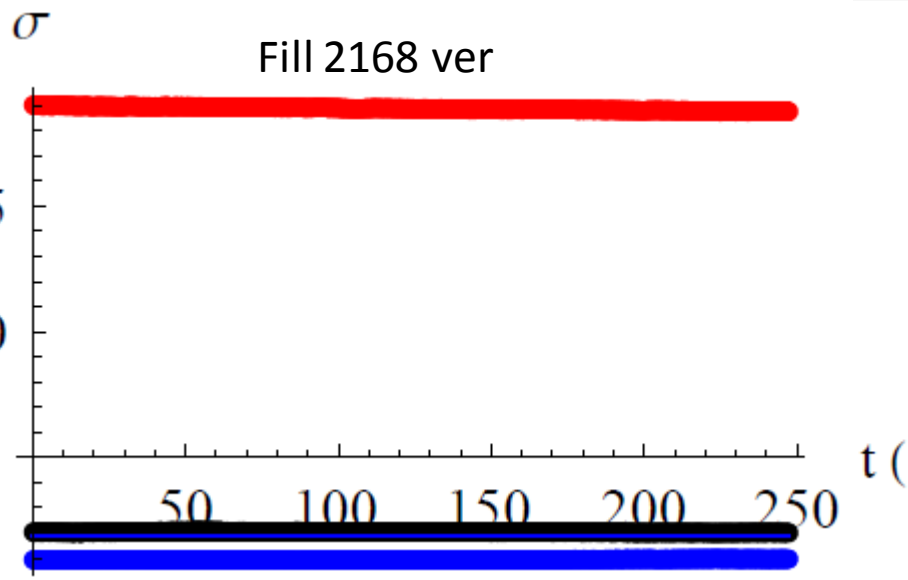
- Change in margin between TCT and triplets stay within fractions of a sigma
- Overall very good performance in IR1

IR5, B1


σ
Fill 2165, hor
4
2
−2
−4
−6
50 100 150 200 250 300 350
t


σ
Fill 2165, ver
15
10
50 100 150 200 250 300 350

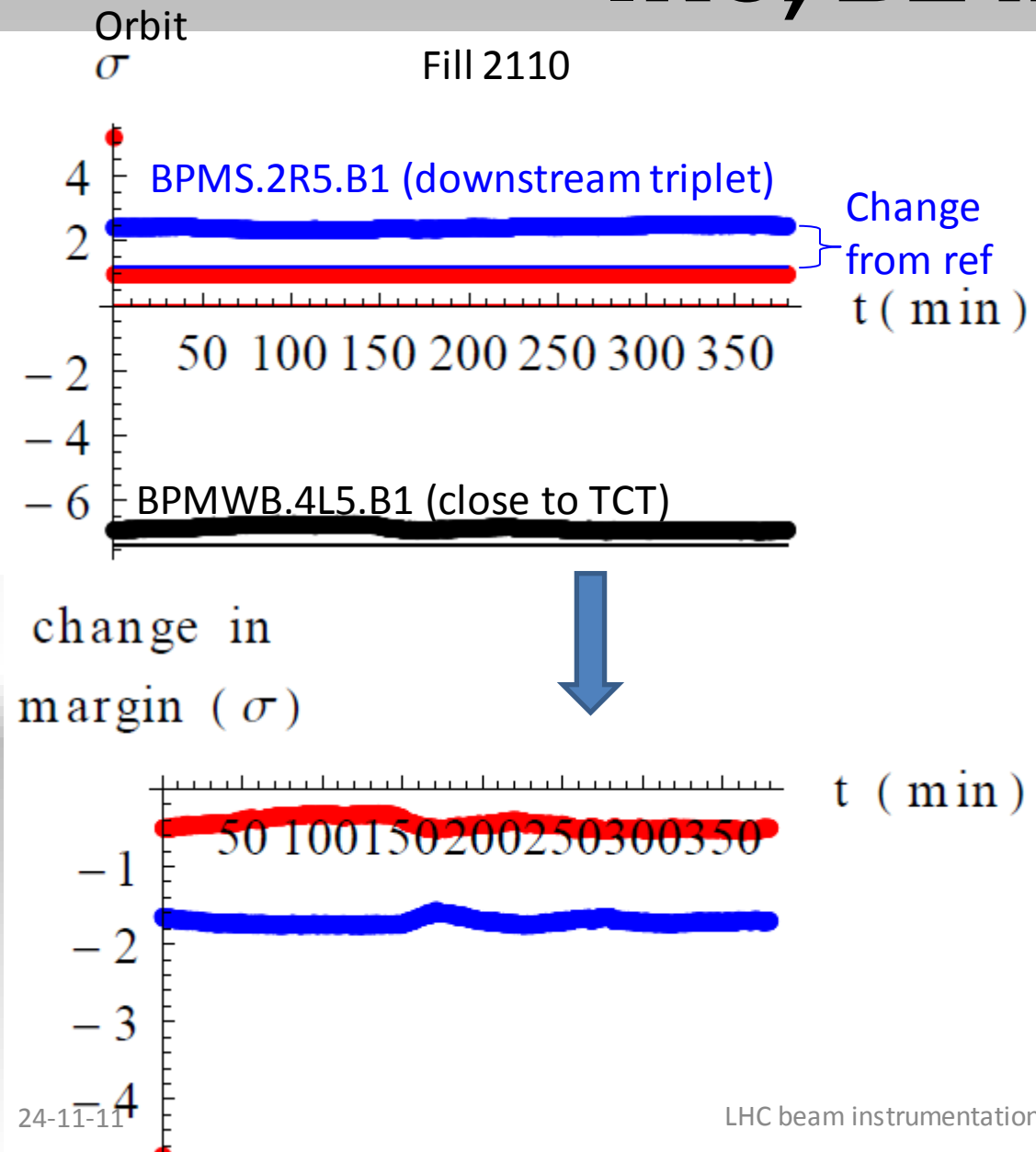

σ
Fill 2168 hor
10
5
−5
BPMS.2L5.B1 (upstream triplet)
BPMS.2R5.B1 (downstream triplet)
BPMWB.4L5.B1 (close to TCT)
50 100 150 200 250
t


σ
Fill 2168 ver
15
10
50 100 150 200 250
t (

BPMS.2L5.B1

- BPMS.2L5.B1 jumps by >10mm between fills. Off in hor when seems OK in ver and vice versa
- Even when excluding the fills with unphysical drifts at this BPM, a 1.7 sigma margin is needed in IR5. Larger than presently assumed.
- Should we exclude this BPM from all analysis?

IR5, B1 hor



- Also BPMS.2R5.B1 gives large offsets
- Example: stable orbit with ~1.7 sigma reduction in margin throughout fill.
- Are the drifts real?
  - Ongoing work: correlation between planes and beams to identify unphysical drifts

BLMs

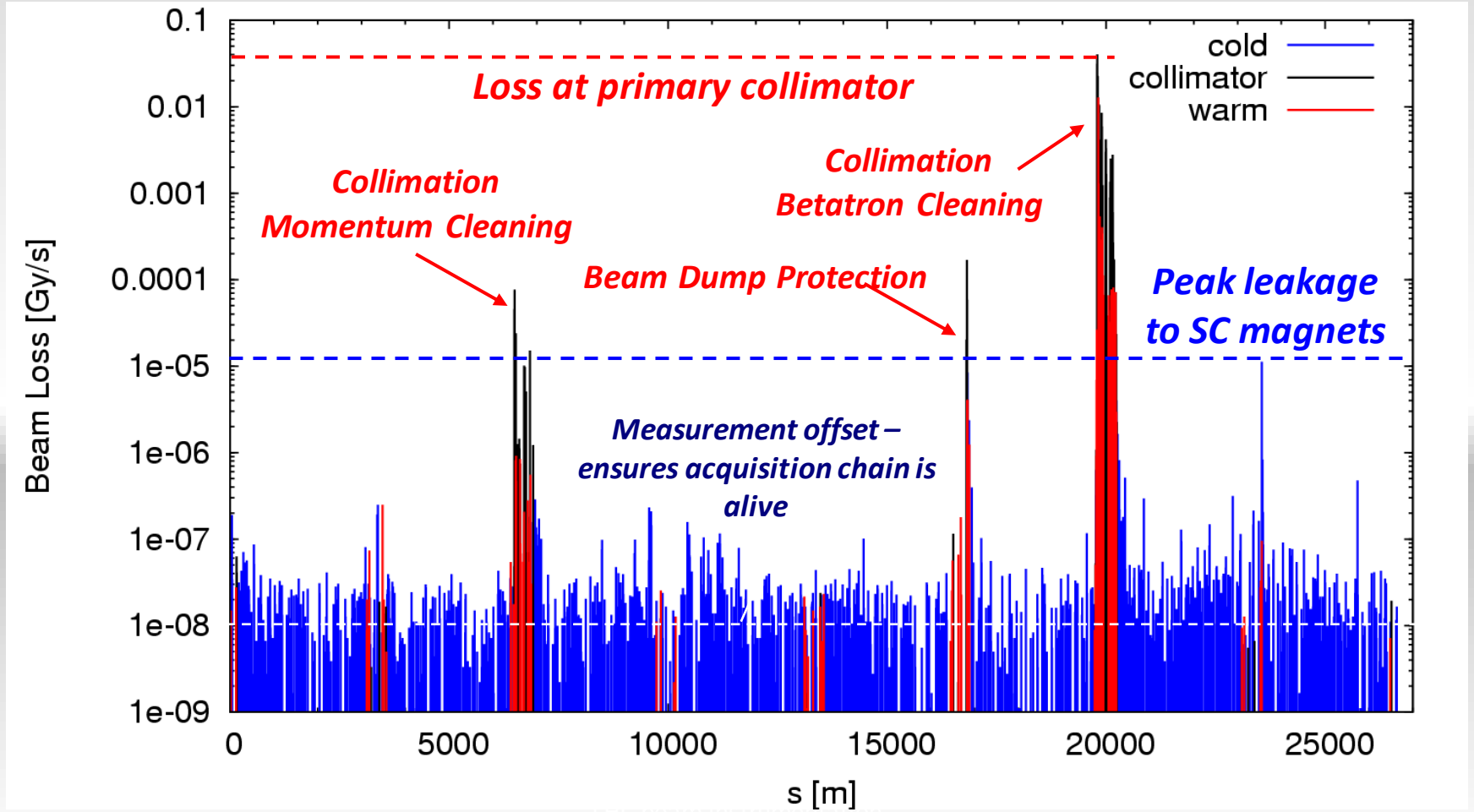
General consensus is “marvellous”.
Remarkably good performance for such a huge system.

- Machine protection role performed impeccably
- Threshold management - fine
- Application software – very good indeed
- Possibilities:
  - Gated BLM signal and "study" buffers to distinguish losses from individual trains (if not bunches) and from the abort gap.
  - Lifetime from calibrated losses
- Operational diamond monitors – beautiful potential
  - Reduced diamond buffer for injection around injection trigger (to be picked up online - IQC)
  - diamond detectors at the TCP locations

“The Diamond Monitors gave an unprecedented insight into the time structure of the beam losses resolving the LHC RF frequency of 400MHz as well as the nominal bunch separation of 25ns.”

BLMs & Collimation

- Full collimation setup
  - BLM system used both for setting-up and qualifying
  - Beam cleaning efficiencies ≥ 99.98% ~ as designed



Observing Fast Losses

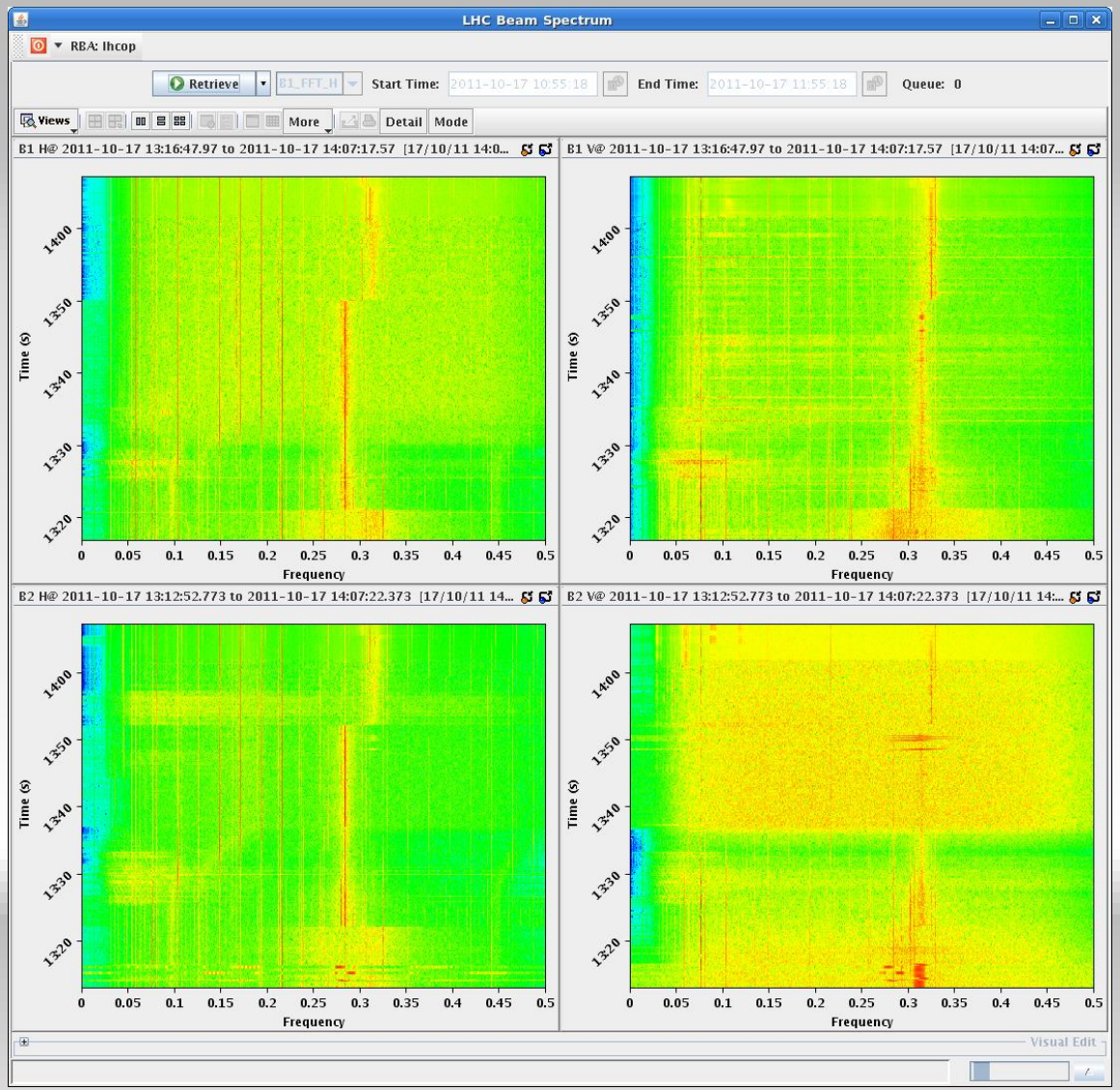
- 7th July 2010 – BLMs request beam dump as result of fast (ms) beam loss
  - Since then 35 beam dumps requested due to similar losses
  - Believed to be caused by "Unidentified Falling Objects" or UFOs
  - Subsequent study showed more than 5000 candidates - most well below threshold
  - UFO rate during physics fills is now ~5 per hour

Etc. Etc.

BBQ/feedback

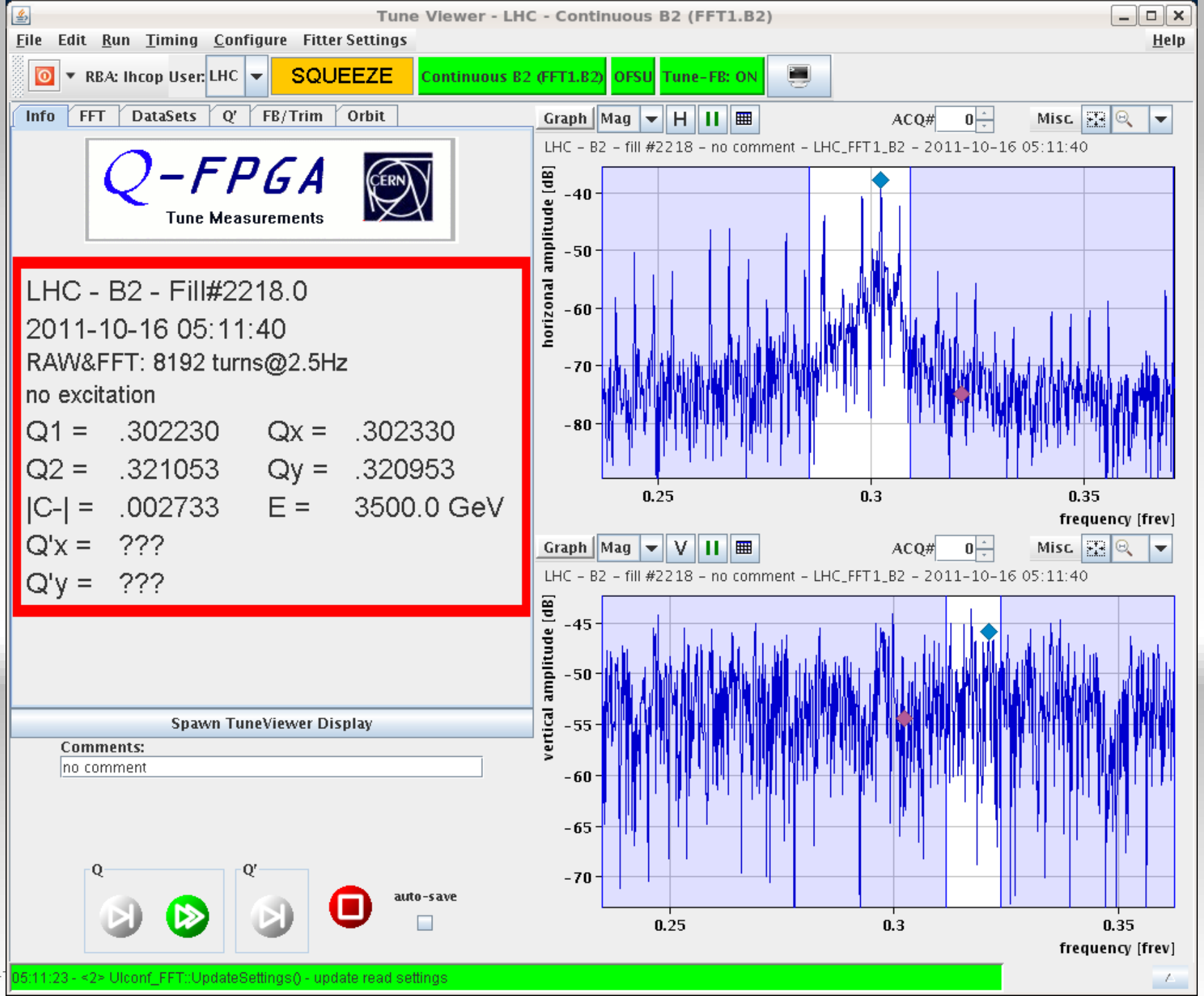
Wonderful job - mandatory for ramp & squeeze – but...!

- Challenging: had to deal with a huge range of intensities
  - "Tune measurements with large intensities: we should be finally able to measure the tunes and the chromas with more than a pilot!"
- Saturation (?) with 1380 x 1.4e11
  - Peaks disappear into the noise floor
- Peak jumping
  - And tripping the QT circuits
- Uncomfortable coexistence with transverse feedback
  - Don't use ADT on first 12b or equivalent?

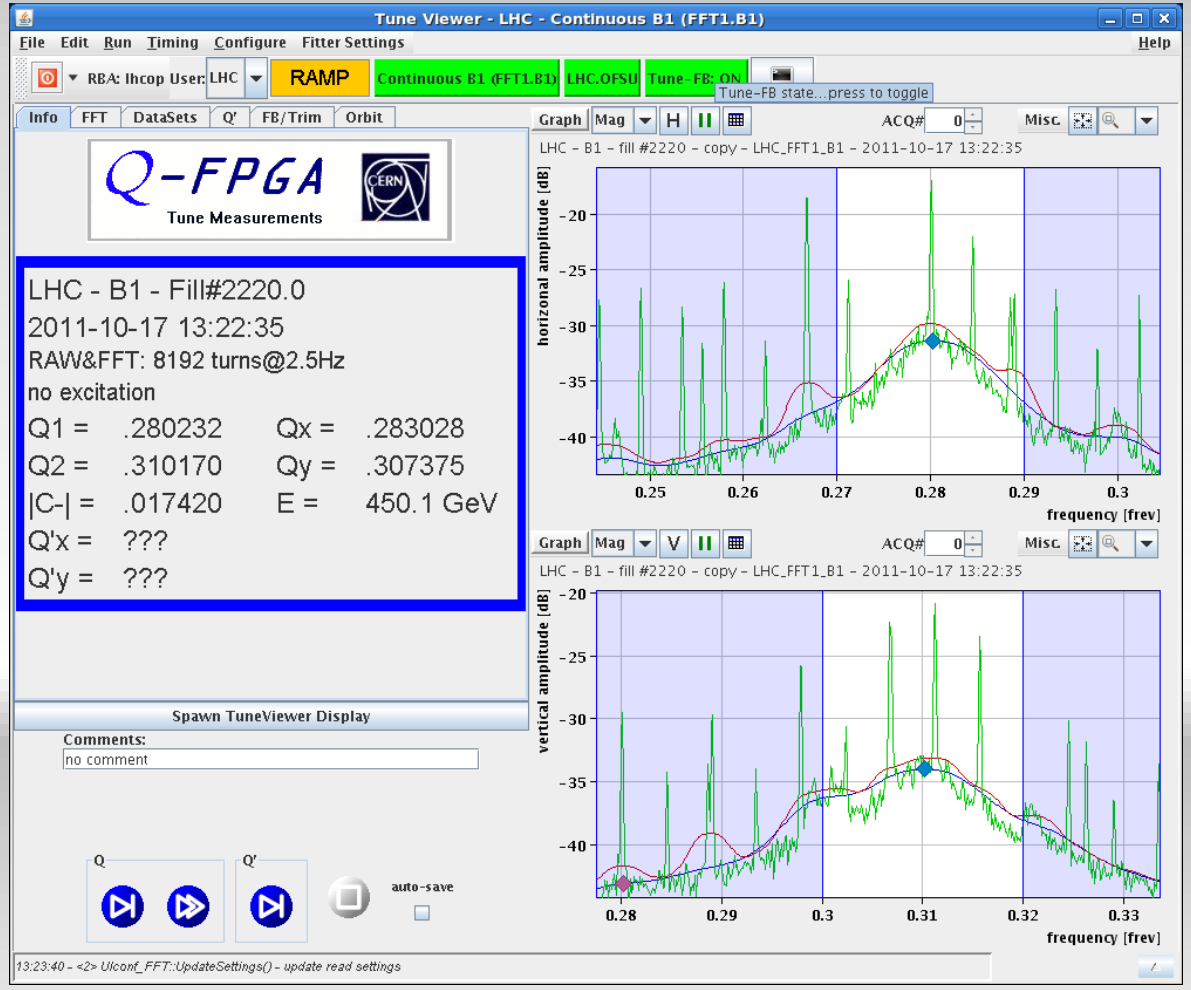


Lost significant S/N ratio for B2V during the last ramp (see spectra).
Chirping (at 1% level) helped to recover the signal.

Ralph

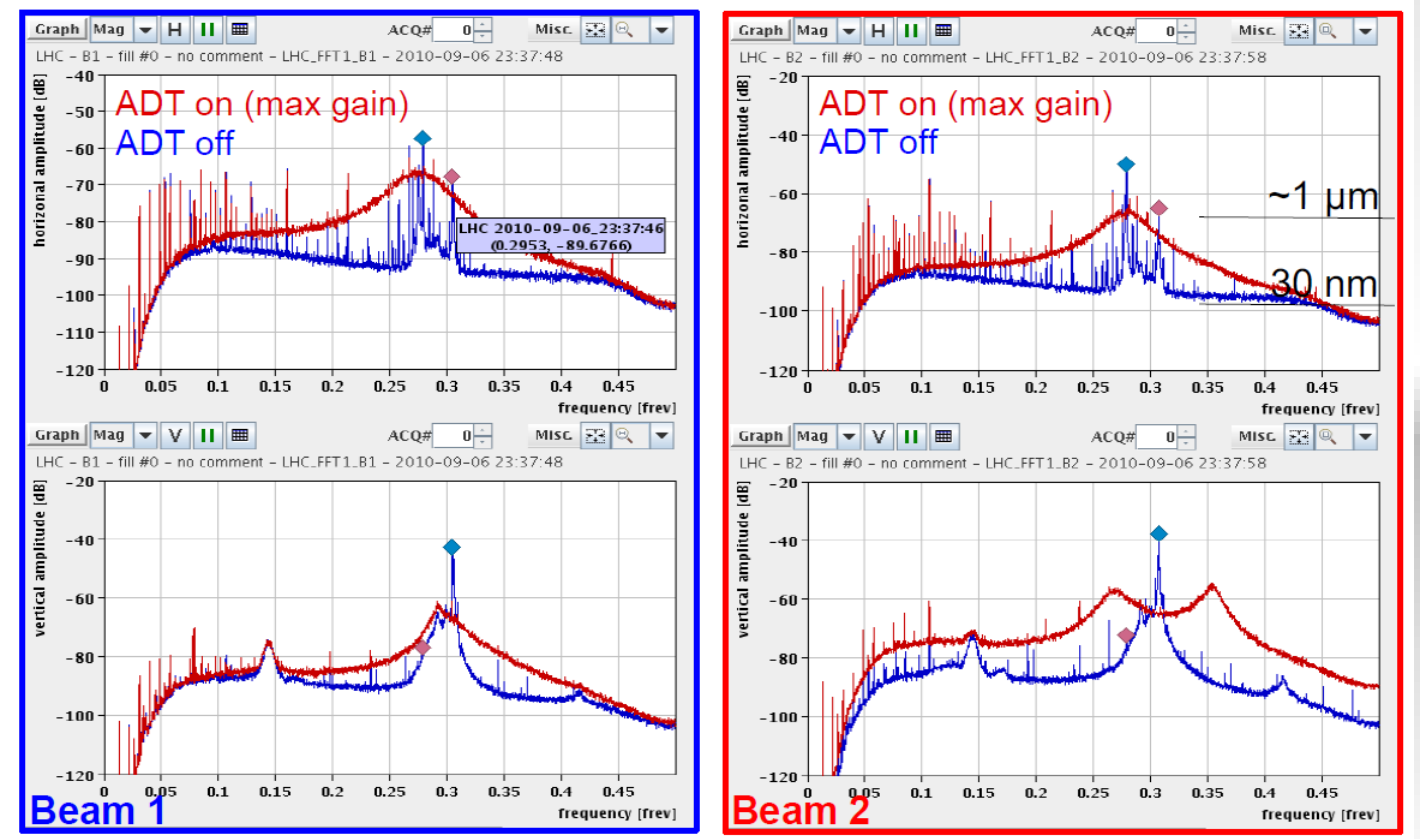

Tune Viewer - LHC - Continuous B2 (FFT1.B2)
File Edit Run Timing Configure Fitter Settings Help
RBA: lhcop User: LHC
SQUEEZE
Continuous B2 (FFT1.B2)
OFSU
Tune-FB: ON
Info FFT DataSets Q' FB/Trim Orbit
Q-FPGA
Tune Measurements
CERN
LHC - B2 - Fill#2218.0
2011-10-16 05:11:40
RAW&FFT: 8192 turns@2.5Hz
no excitation
Q1 = .302230 Qx = .302330
Q2 = .321053 Qy = .320953
|C-| = .002733 E = 3500.0 GeV
Q'x = ???
Q'y = ???
Spawn TuneViewer Display
Comments:
no comment
Q
Q'
auto-save
Graph Mag H ACQ# 0 Misc
LHC - B2 - fill #2218 - no comment - LHC_FFT1_B2 - 2011-10-16 05:11:40
horizonal amplitude [dB]
-40
-50
-60
-70
-80
0.25
0.3
0.35
frequency [frev]
Graph Mag V ACQ# 0 Misc
LHC - B2 - fill #2218 - no comment - LHC_FFT1_B2 - 2011-10-16 05:11:40
vertical amplitude [dB]
-45
-50
-55
-60
-65
-70
0.25
0.3
0.35
frequency [frev]
05:11:23 - <2> UIconf_FFT::UpdateSettings() - update read settings

The peak finding challenge



Tune Feedback & Active Damping

- BBQ noise-floor raised by 30 dB
  - wide tune peak → reduces tune resolution from 10^{-4} → ~10^{-2}
  - Impacts reliable tune (and coupling) measurement & feedback
  - Incompatible with chromaticity measurements using small Δp/p-modulation
- Only solution found so far is to run damper with lower gain



QFB miscellaneous

- Setting for different intensities/ peak finding strategies etc in LSA?
  - Need to be able to see what the feedback is actually using.
- Change reference still clunky
  - should be able load Q(t) as we do everything else.
- “Using about 1% of application functionality”
- Tune diagram fixed display would be nice

Brief Summary on Feedback and Q/Q' Issues during 2010

Ralph Steinhagen

- Genuine OFC software bugs and deficiencies/errors in FB logic
  → shaken-out and fixed (by July) and running stably ever-since
- False-positive Quench-Protection-System trigger on real-time trims
  - Several back-and-forth iterations until R. Denz suggested to increase the dead-time for the U_{res} evaluation from 20 to 190 ms → now OK
  - After RQT[D/F] experience we never dared to use sextupoles and MCBX
    → circuits may become critical for orbit stability with small β*
- Unannounced kernel updates and IT's denial-of-service attacks during beam operation → Caused some real beam dumps and down-time!
  - Necessary but should be coordinated and done during e.g. technial stops!
- Most remaining issues related to instrumentation quality and FB integration:
  - Tune-FFT: Locking on interferences → filter chain rejecting non-tune lines
    ~~Tune-PLL operation OK but not (yet) as robust as the previous one (e-blow-up)~~
  - Transverse damper/abort-gap-cleaning interference → not resolved!
  - Operational failures → improving integration & automation in sequencer

- Most 'teething' problems sorted and should be OK for 2011 operation, but...

Wire scanners 1/2

Heavily used and the only trusted source of an "absolute" emittance measurement

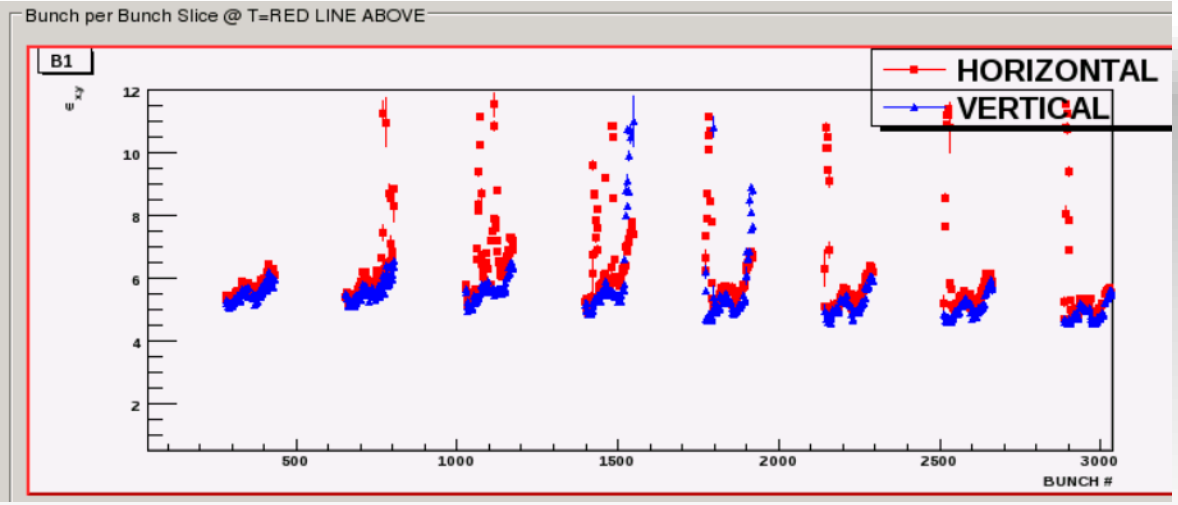
- Application (not BI!)
  - Log the emittances!!!
  - Use measured optics please
  - "the wire scanners have really a painful interface: it never works, you have to set values by hand, no guidelines, no really working defaults."
  - "instructions for settings like attenuation, voltage etc. to use depending on measurement to make, or automatic selection of appropriate settings? One button: measure all? Easier selection of bunches?"
  - Persist settings and re-load
  - Default pre-selection
  - Display of results: make it easier to compare the different bunches measured (all in one list or graph)?
  - Add a button to copy results to logbook (including list for bunches)?

Wire scanner 2/2

- Is the measurement performance (systematic variations depending on filter and voltage settings, beam positions etc.) and total error of measurement ok?
  - see CERN-ATS-Note-2011-049 MD for tested performance
- Timing event driven acquisition up the ramp
  - Wire scans automated through sequencer tasks and timing tables and/or other tools?
  - OP (Verena) would help for tools in case.

BSRT

- **“Precious information”**
- Expert application! There are still too many specialist applications which are not accessible from the CCM menu: the BSRT, for example, although I really appreciate the incredible step up made by Federico.
- Absolute calibration required!
- Long time to scan through bunches - performance of bunch to bunch emittance measurements (gating on few bunches to speed up the measurement …).



BSRA

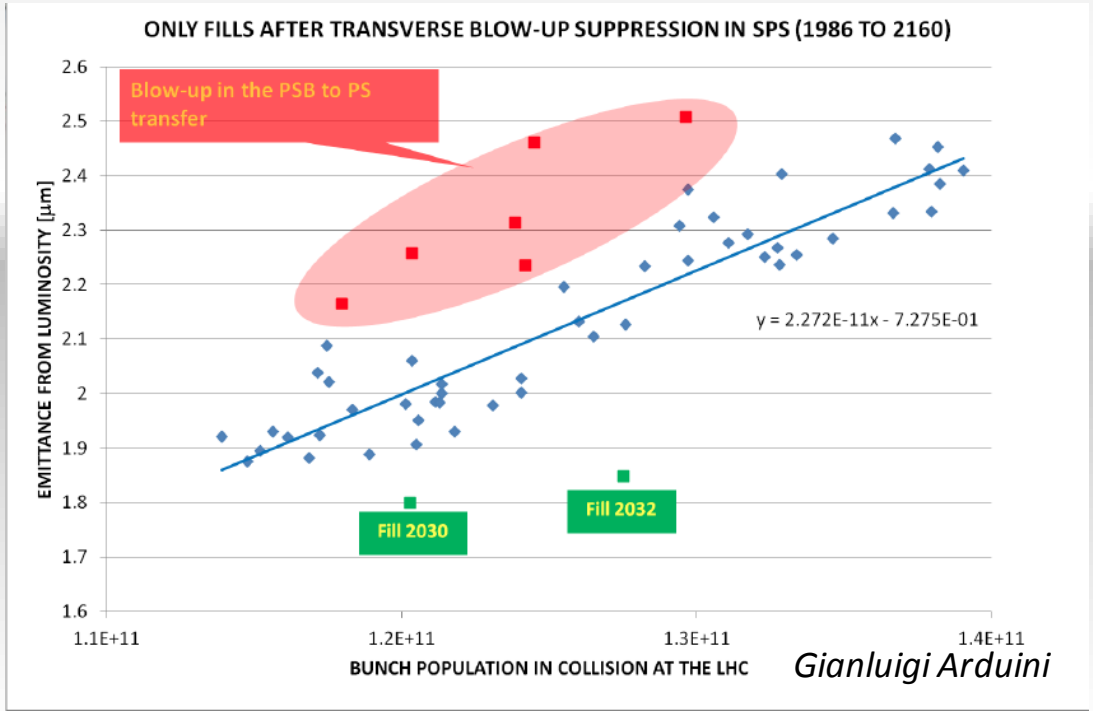
- Abort gap population becomes critical
- Reliability and calibration important
  - Calibration and definition of appropriate thresholds.
- Now wired up the announcer
  - Strategy to be defined.

BGI

- Need to commission BGI for protons.
- Need absolute (or relative) emittance measurements for physics beam intensities including during the ramp and optics squeeze to diagnose emittance increases
- Transfer from expert device to operational device?

Beam from the injector chain

- Need to able to track performance through PSB, PS, SPS and to the LHC
  - Intensity
  - Emittances
  - Longitudinal characteristics



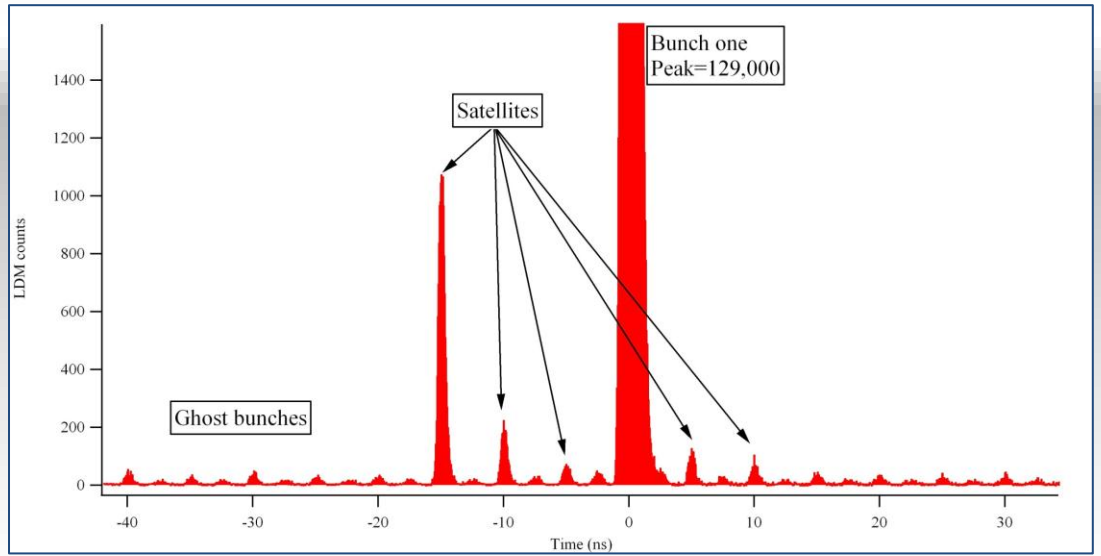
Gianluigi Arduini

DBCT & FBCT

- Calibration
  - lots of work done
  - difference between F and D – which one do we trust?
- Beam lifetime calibration of the FBCT data could be improved.
- Occasional front-end lock-ups

LDM

- Cool stuff and very useful (“GOLD” according to LPC)
- Expert application
- Could really do with a fixed display with zoom features
- Enhance satellites from PS incoming – important next year to monitor this carefully



Schottky

- Impressive MD tool but not exploited by OP
- Getting the Schottky operational for tune measurements?

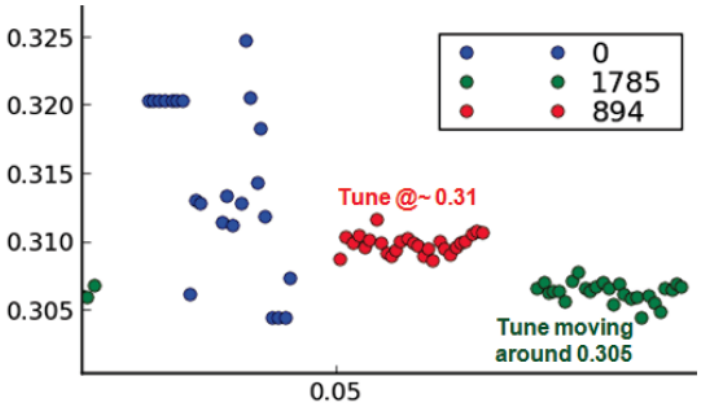


Figure 7: Schottky Tune measurement for pilot bunch (blue), nominal bunch with 1 collision (red) and nominal bunch with 2 collisions (green).

"only instruments in the LHC capable of measuring bunch by bunch tunes, and are extensively used for this purpose during machine development periods."

Bunch by bunch?

Thibaut's list from Evian

- Beam Position Monitors
  - Injection oscillations
  - Multi-turn acquisition for beating etc.
- Head-Tail monitors
  - Instability studies
- Longitudinal measurements: WCM, LDM
- Transverse beam size measurements:
  - Wire Scanners
  - Synchrotron Light
- Schottky monitors
- Luminosity monitors
- Fast BLM's

Pretty good shape

Miscellaneous

- RELEASE MANAGEMENT!
  - FBCT, OFB
- PARAMETER CONTROL!
  - OFB gain, for example
- Some applications are then not limited to a unique user, with the consequence that they can be accessed from several consoles, with conflicts possibly generated
- Remember DIP!

Conclusions

I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind; *Kelvin*

- Great performance overall
  - instrumentation has allowed a profound understanding of the machine and paved the way for the impressive performance increase
- Key operational issues
  - IR BPMs
  - QFB with high intensities & TFB
  - Emittance growth
  - Machine protection!
  - Expert versus operational…