LHC orbit system, performance and stability

LHC Beam commissioning workshop,
Evian, 19./20. Jan 2010

Kajetan Fuchsberger

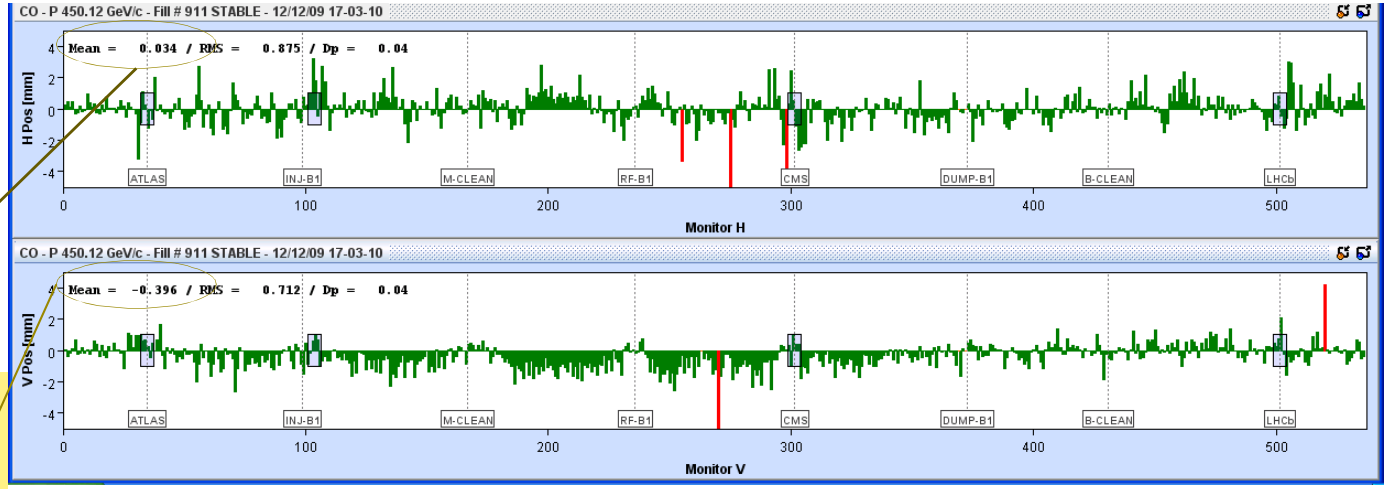
Thanks for Help and discussion:
J. Wenninger, R. Steinhagen, T. Baer, S. Redaelli and many others.

Outline

- Actual golden orbit and correction improvements.
- Orbit evolution during stable periods
- Comissioning Status:
  - BPM- and COD- polarity checks
  - Orbit Feedback
- Summary, Open Issues

Santa Claus golden orbit

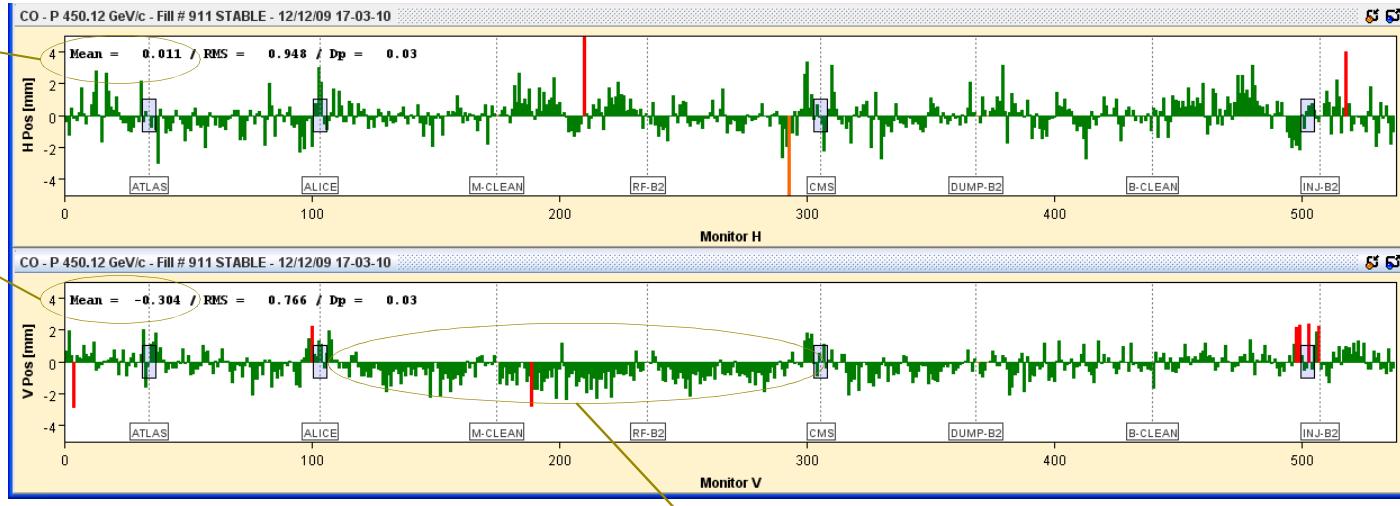
B1



Rms:
0.7 to 1.0 mm

H: nicely centred
(mean < 40 µm)

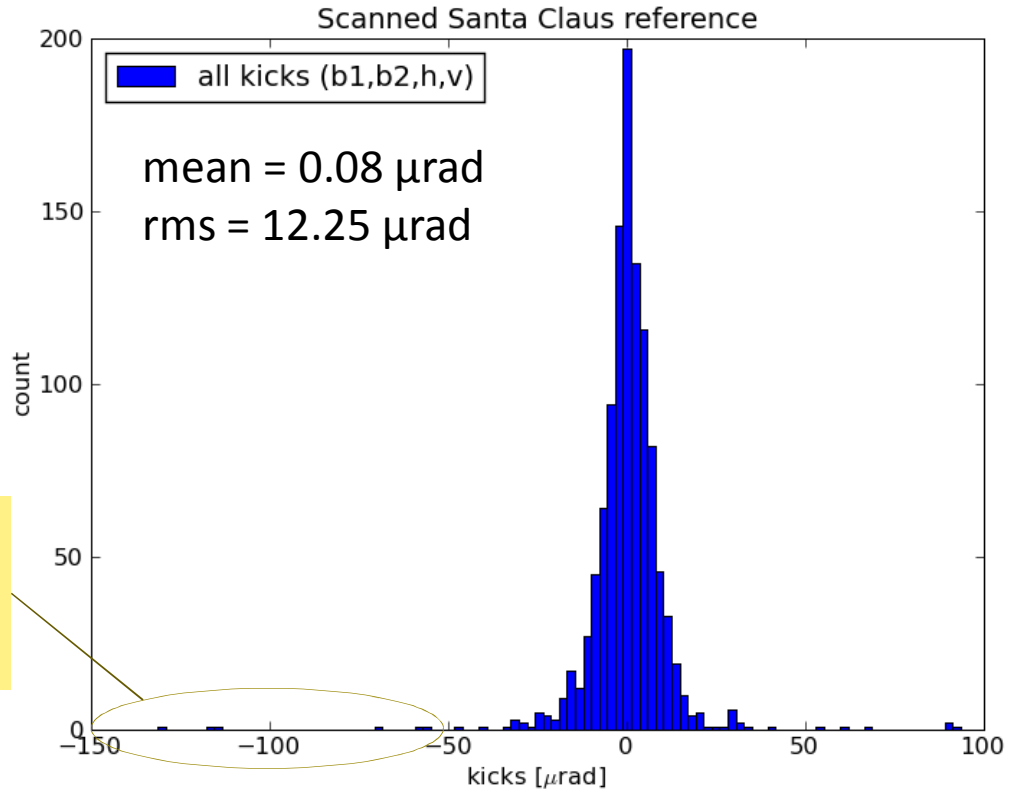
B2



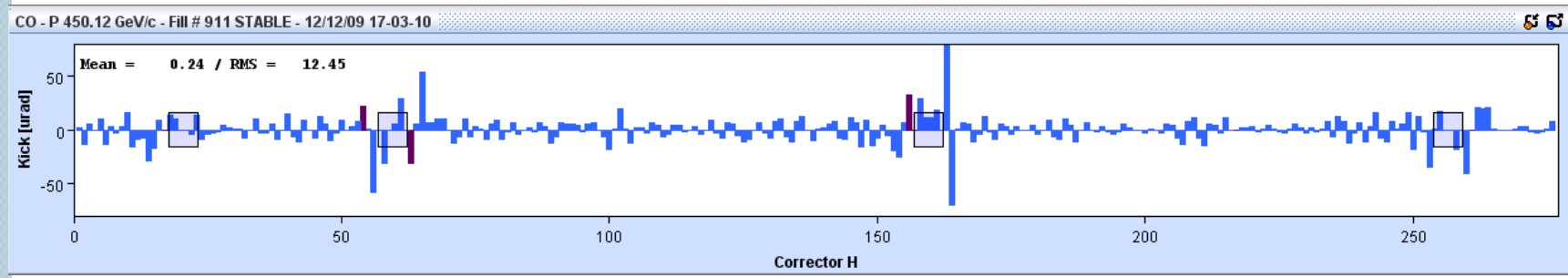
V: bit larger offset
(mean: 300...400 µm)

Vertical offsets of up ~ 1 mm in arcs 23, 34, 45

Corrector strengths



Large corrections result from IP scanning.
Not scalable to 7TeV.

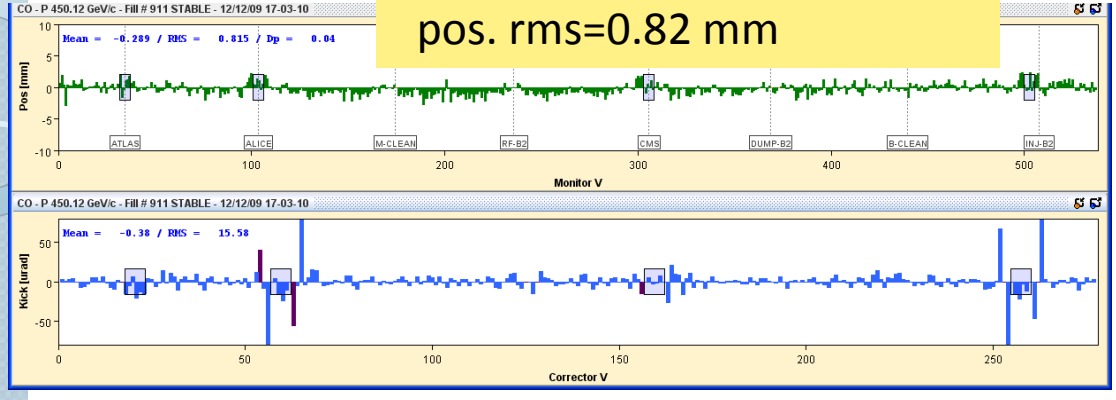


B1, H (Example)

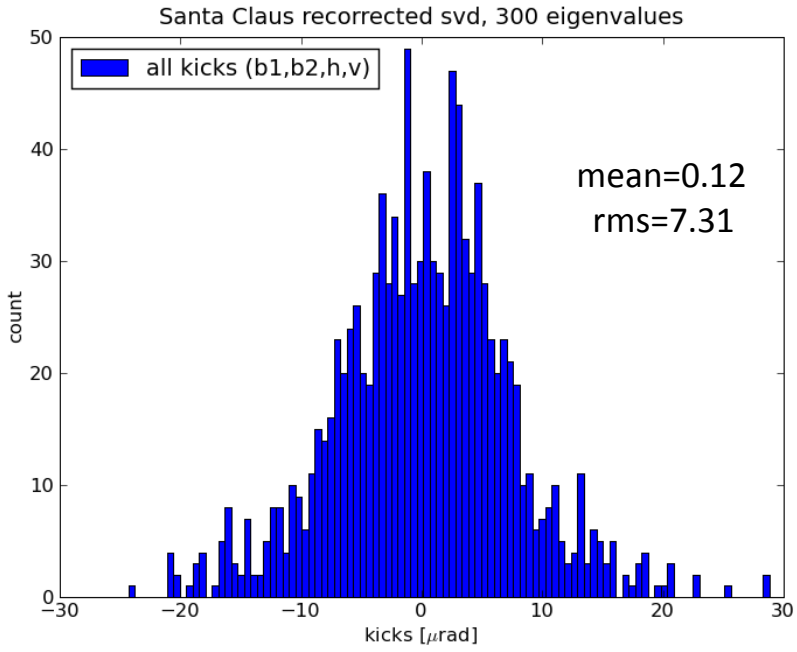
Correction – can we do better?

Example: B2, V

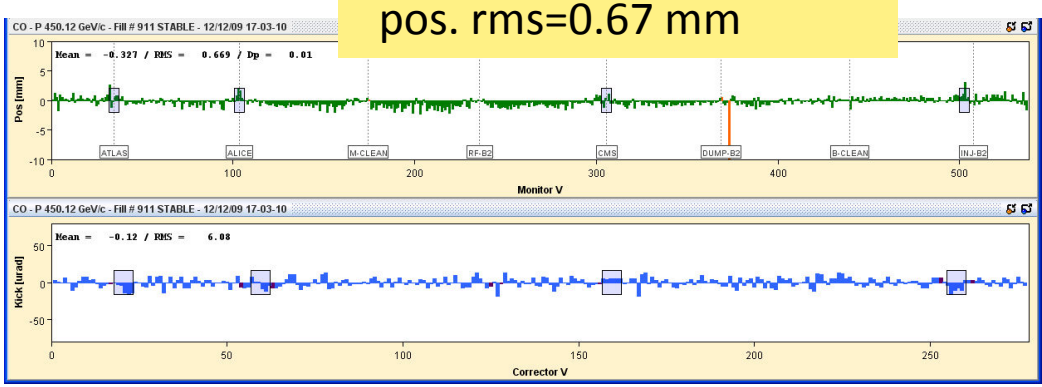
Original golden orbit:
pos. rms=0.82 mm



SVD correction on bare, 300 Eigenvalues



After correction:
pos. rms=0.67 mm

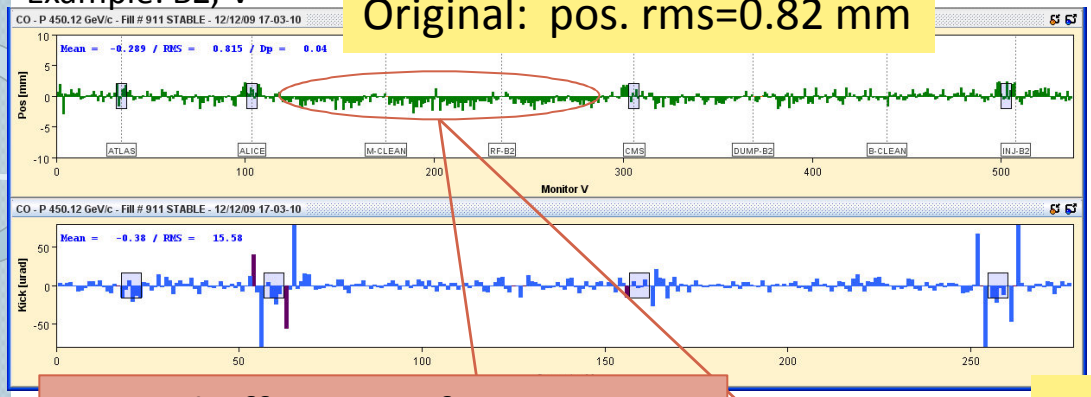


All kicks below 30 µrad.
rms reduced from 12.25 to 7.31 µrad

… even more?

Example: B2, V

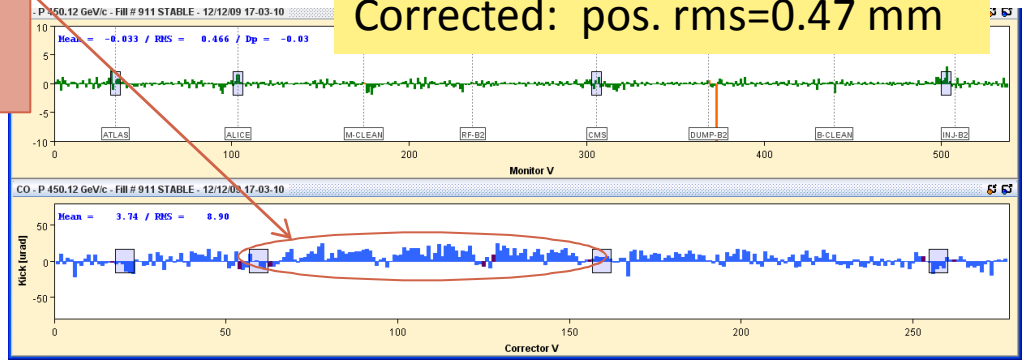
Original: pos. rms=0.82 mm

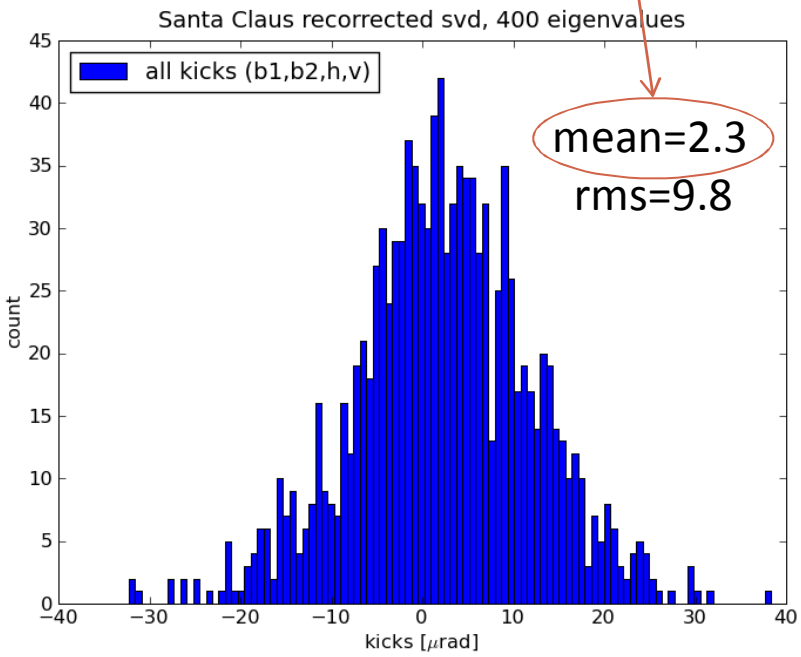


SVD correction on bare, 400 eigenvalues

Vertical offset transforms into systematic kick-offset.

Corrected: pos. rms=0.47 mm



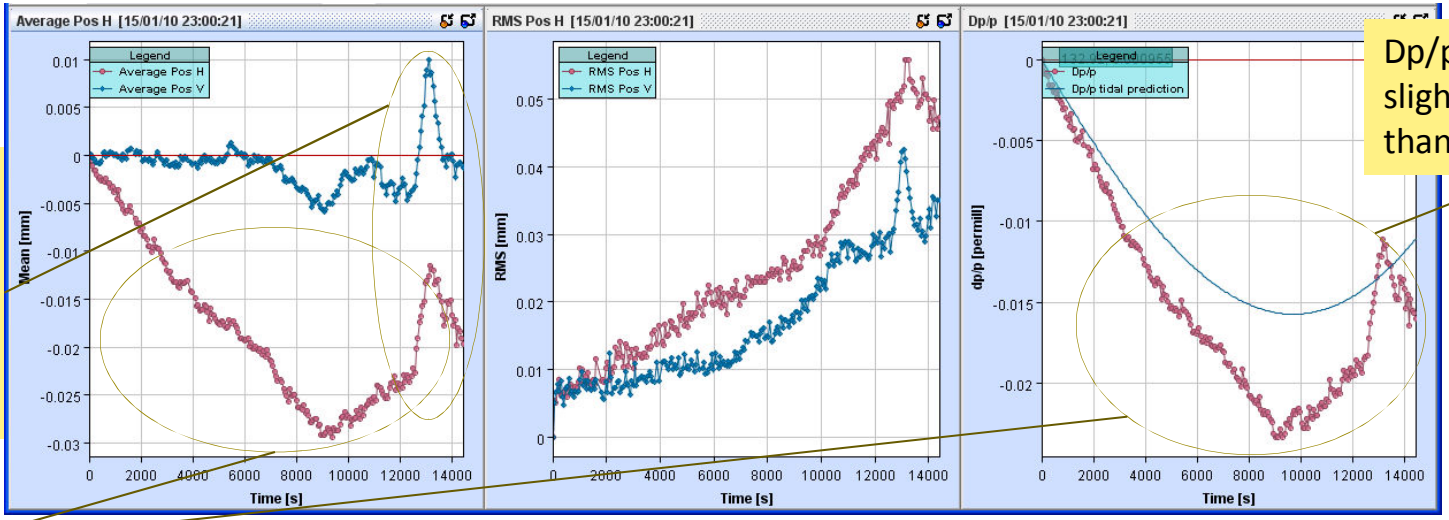


Source of vertical offset in arcs should be confirmed before correcting:

- Real offset? (e.g. Systematic quadrupole misalignment)
- BPM misalignment/wrong readings?
- Proposal: Check with aperture to distinguish.

Stable beams @ 450GeV

B1

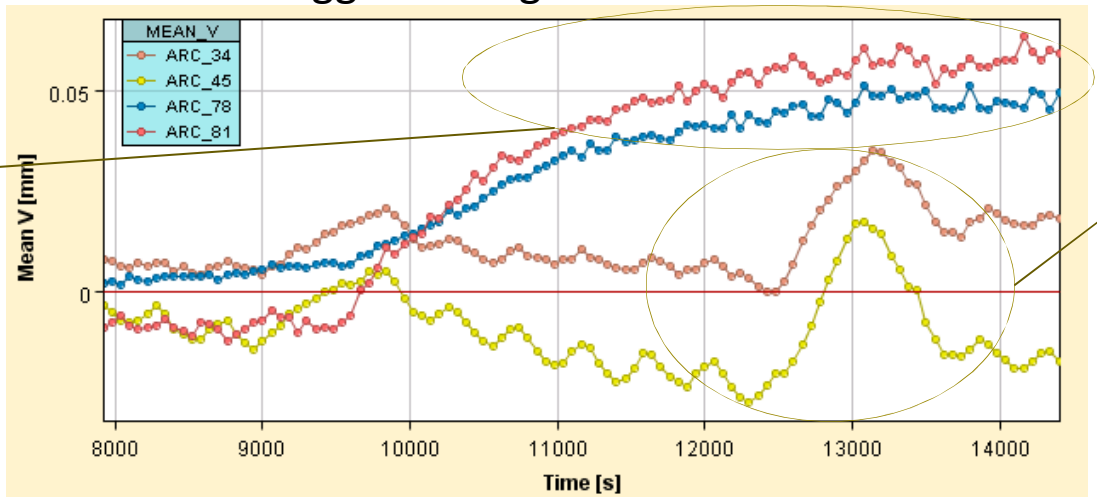


Perturbations visible in both beams, both planes,
... But not in all sectors

Dp/p change slightly larger than prediction.

Main contribution of horizontal orbit change: tidal dp/p change

Sectors with biggest change:

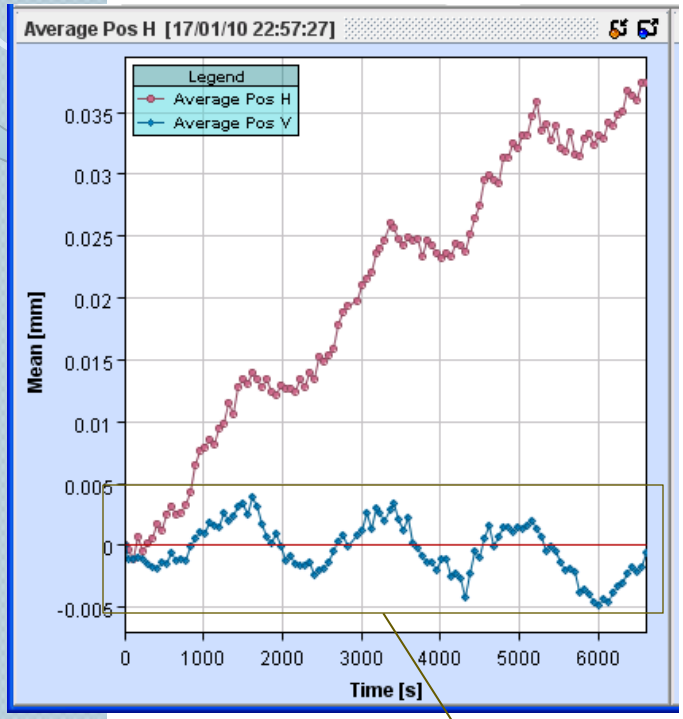


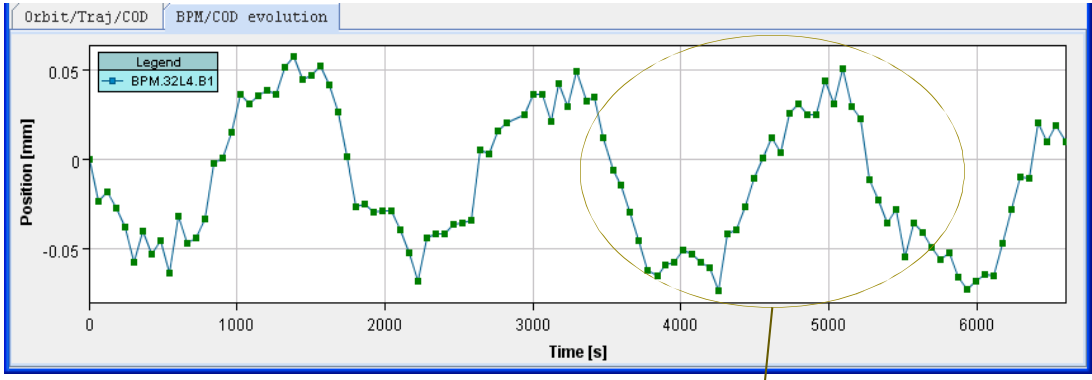
50 µm shifts of mean in arcs 78,81

Hump only in arcs 34,45

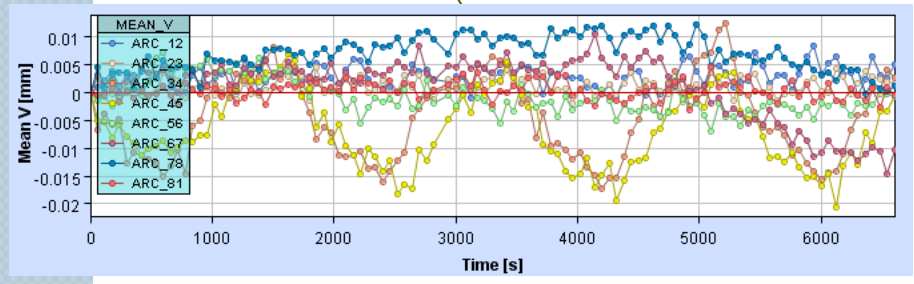
Data: 8. Dec 2009
02:00 to 06:00
(one sample per minute)

Stable beams @ 1.18TeV





Amplitude: ~ 100 µm peak to peak on single monitor.

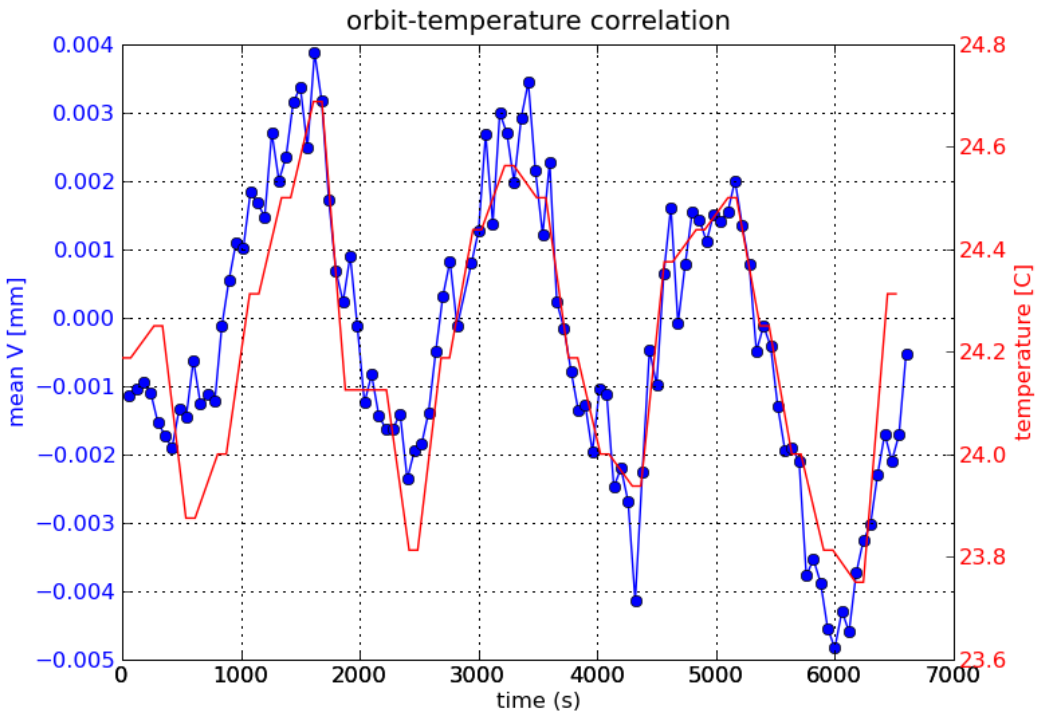


...and again its arcs 34, 45!
(This time oscillation with T ca. ½ h)

Data: 16.Dec.2009
03:40 to 05:30
(one sample per minute)

DAB temperature dependence

Oscillations are correlated with temperature of DAB cards:



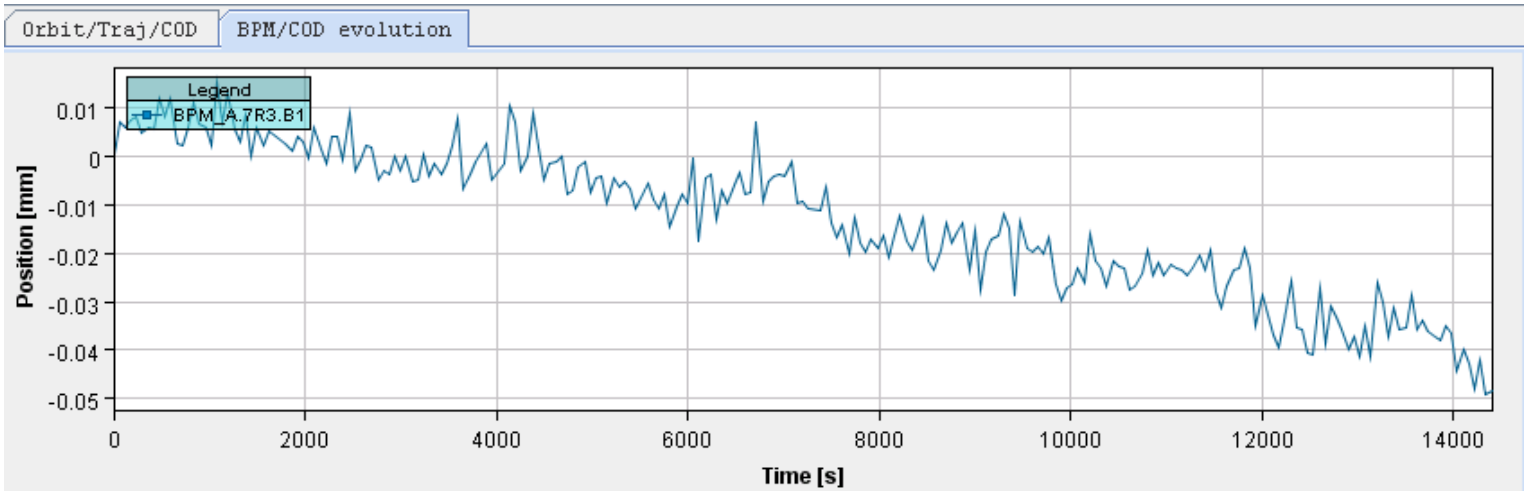
Data: 16.Dec.2009
03:40 to 05:30
(one sample per minute)

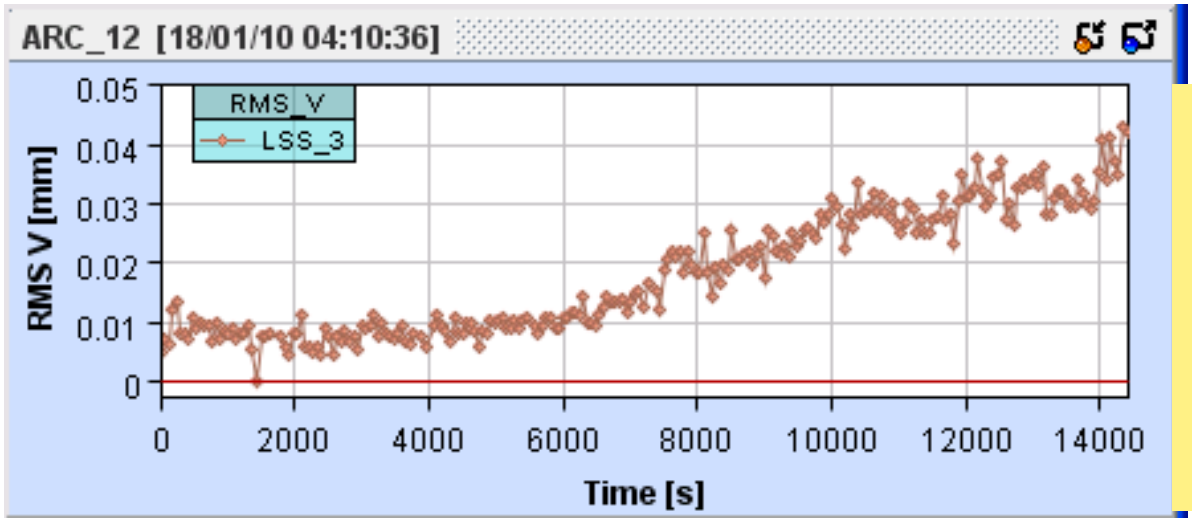
Effect was observed and documented already in 2008 and is followed up by BI. Possible strategies:

- **short-term**: monitoring of DAB temperature and corresponding calibration drifts, recalibration each fill (sequencer?)
- **Medium-term**: compensate the position by the known DAB temperature drifts within the feedback controller
- **Long-term**: prototyping of an BPM crate temperature control to stabilize these drifts at the source, ongoing.

Stability in LSS3

Example BPM (V):





max drift ~ 50 µm/4h:

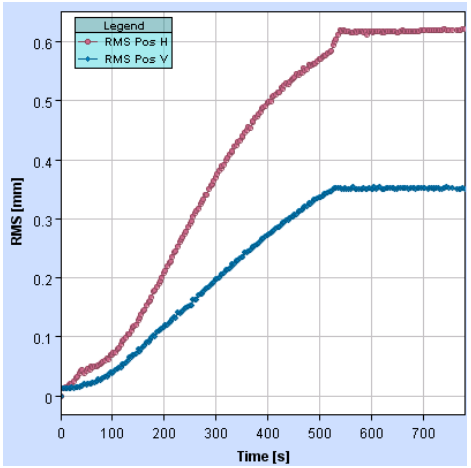
→~150 µm/12h

(collimation requirement: max 300 um)

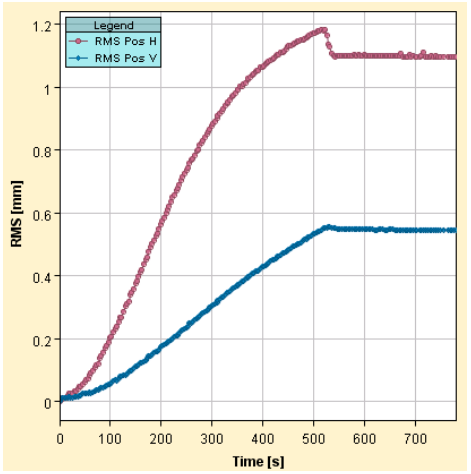
Data: 8.Dec.2009
02:00 to 06:00
(one sample per minute)

Orbit change during ramp

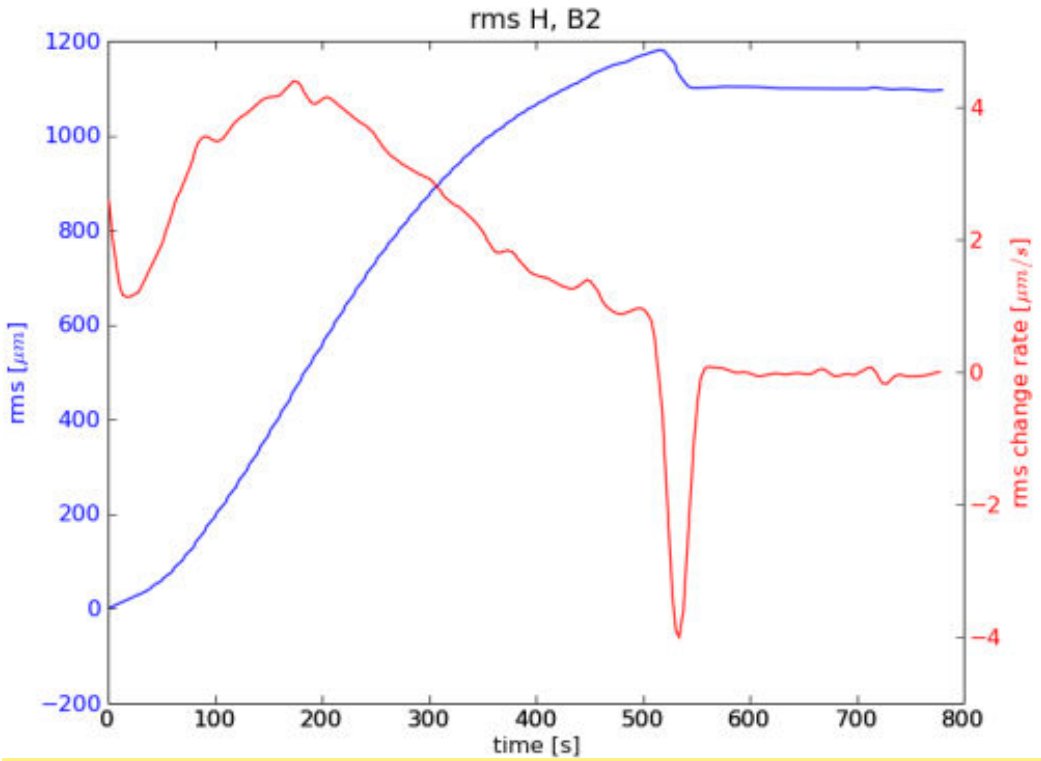
B1: max rms ~ 0.65 mm



B2: max rms ~ 1.2 mm



rms change rate (example: H, B2):



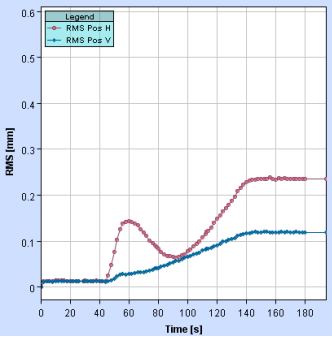
- Maximal change rates < 5 µm/s
- predicted up to 15 µm/s during snapback (R. Steinhagen)
- Feedback necessary for 3.5 TeV

Data: 16. Dec 2009
00:49 to 01:02
(one sample per minute)

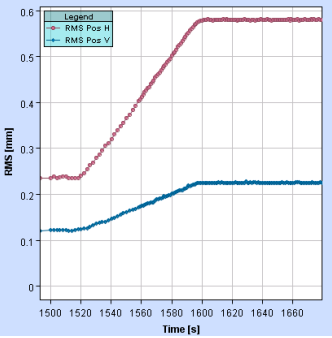
Orbit change during squeeze (IP 5)

B1: max rms ~ 0.6 mm

11→9 m

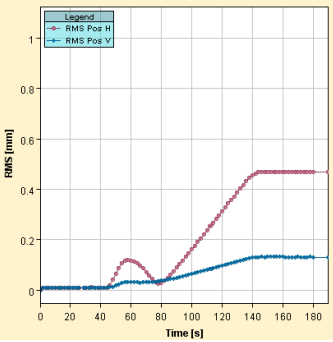


9→7 m

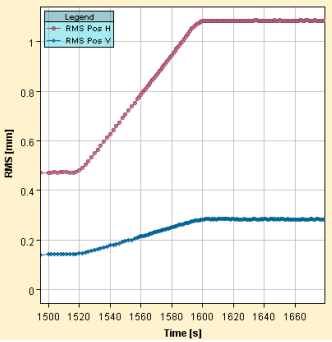


B2: max rms ~ 1.1 mm

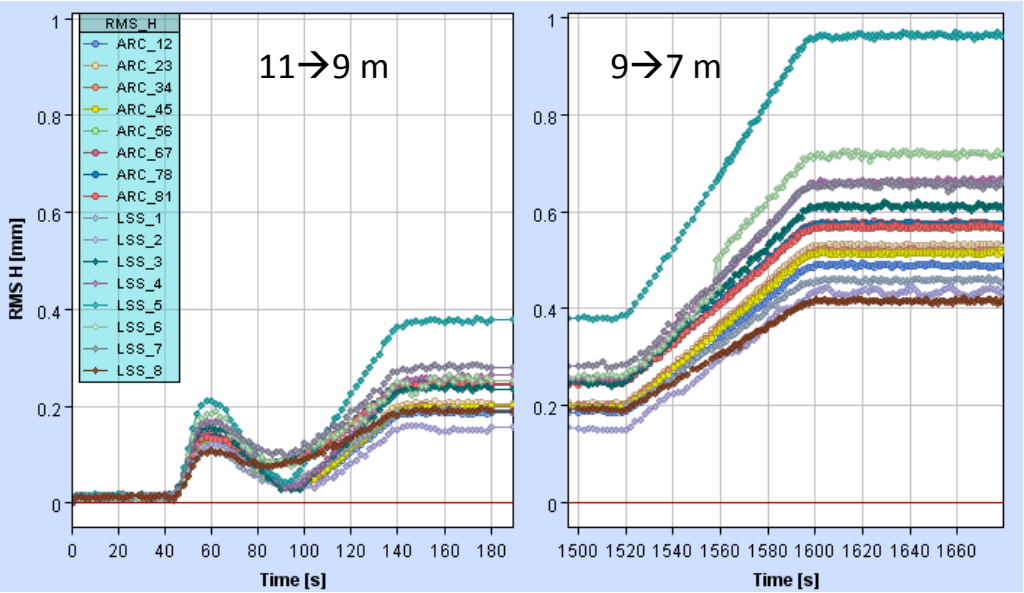
11→9 m



9→7 m



- Rather smooth changes,
- Distributed over all sectors
- Feedback necessary



Data: 16. Dec. 2009
02:27 to 02:54
(one sample per minute)

BPM- and COD- polarity checks

BPMs:

	total	checked	ok	%checked	% ok
Beam 1	1076	1076	1050	**100,00%**	**97.58%**
Beam 2	1076	1076	1058	**100,00%**	**98.33%**

Work on all BPM issues already ongoing by BI

CODs (without MCBX):

	total	checked	ok	%checked	% ok
Beam 1	508	483	483	**95,08%**	**100,00%**
Beam 2	508	371	371	**73,03%**	**100,00%**

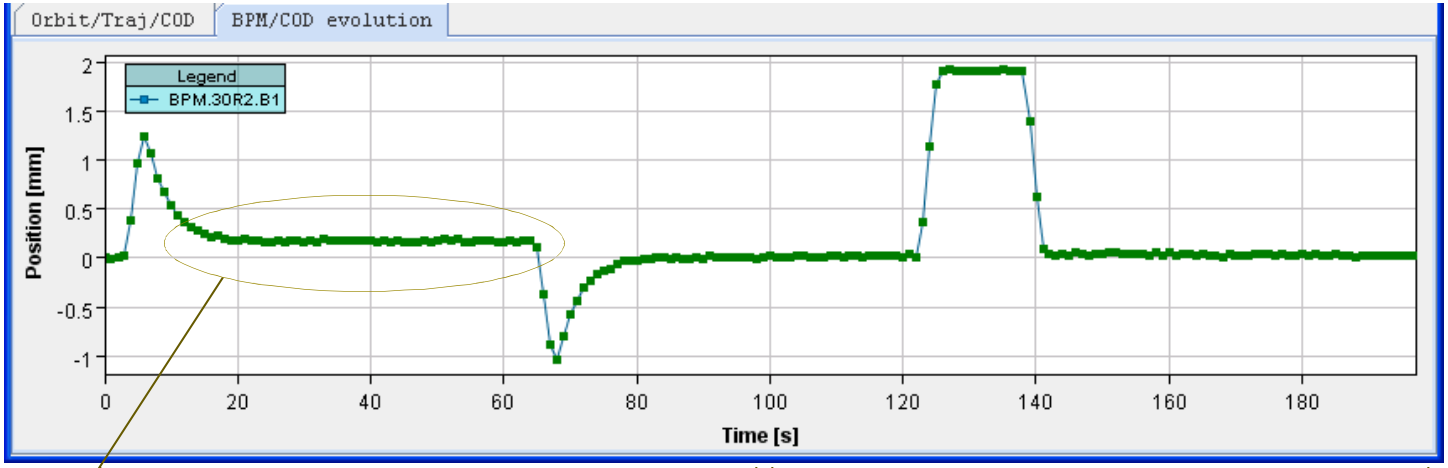
Also MCBX should be systematically checked.
(At least one of them seemed to be inverted)

Orbit Feedback – status

- Tested in „All or nothing“ fashion → works ;-)
- Bandwidth as expected (0.1 Hz).
  Going to 0.5 or 1 Hz should not pose (big) problems.
- Open issues:
  - Recalculation of response matrix in OFSU to move dynamic load away from OFC
  - Improvement of reference-orbit management (integration with steering)
  - Automated switching between optics (creation of timing tables + testing)
  - Finish integration in the relevant sequences + testing
  - Test of SVD++ algorithm (High EVs fast, lower EVs slow)
  - Long-term solution for MCBX:
    - trips due to small acceleration rate
    - Currently disabled by default

Orbit feedback - demonstration

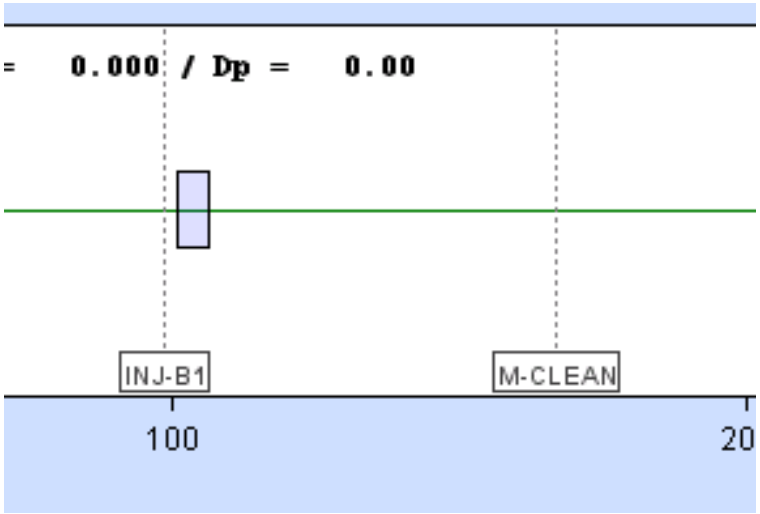
horizontal bump with target 2mm @ BPM.30R2.B1



OFB on

OFB off

200 µm steady-state error due to using only 400/520 eigenvalues



Data: 16.12.2009, 16:30

Summary / Issues

- Orbit
  - Very stable (V drift ~ 15µm/h)
  - Better Corrections possible. Should spend some time to establish a better global correction (and avoid strong local corrections) before setting up Collimators.
  - Understood ‚features‘:
    - Tides
    - DAB-temperature dependence around Pt 4 (100 µm peak to peak)
  - Open issues:
    - Drifts between Pt7 and Pt1 (maybe also temperature?)
    - Vertical offsets in arcs 23,34,45. Proposal: check with aperture if orbit is centered or not.
  - No experience with squeezed optics (triplet movements become more important)
  - Switch of BPM high/low sensity: Check resulting orbit change. When/how to switch?
- BPMs, CODs
  - Finish COD polarity checks (incl. MCBX)
  - BPM issues already followed up by BI
- Orbit feedback
  - Basically operational, time needed for testing
  - Essential for ramp and squeeze (Stefano, Walter)

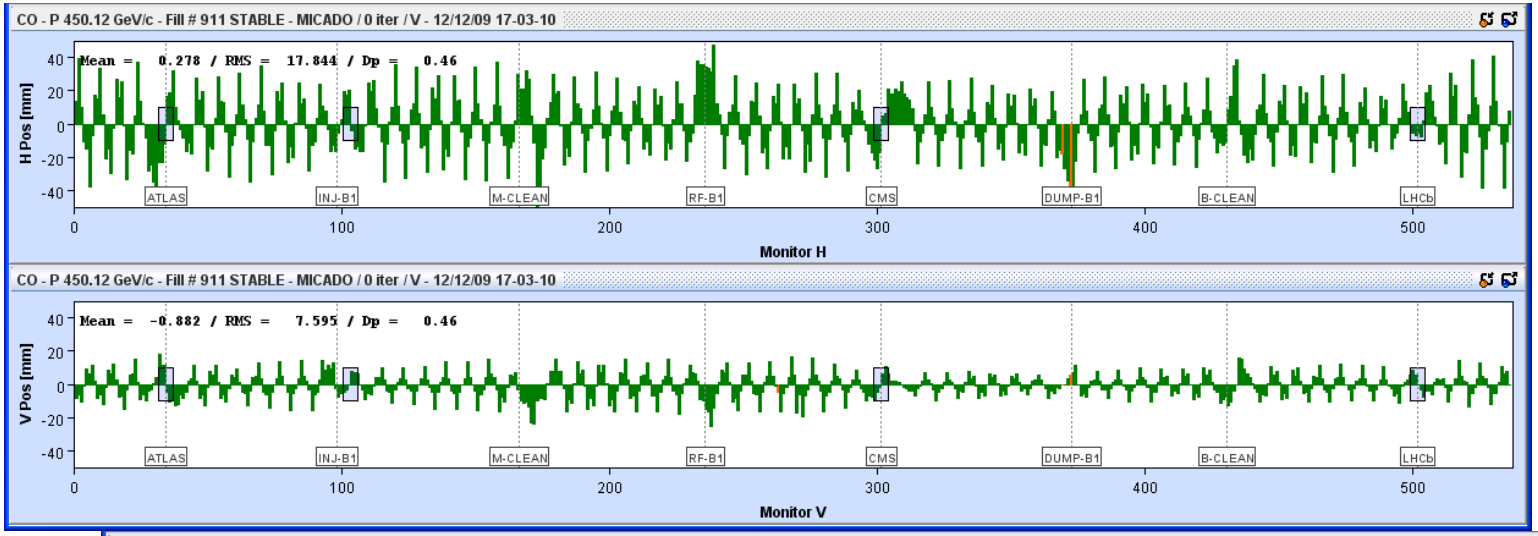
Thank You!

The MCBX issue

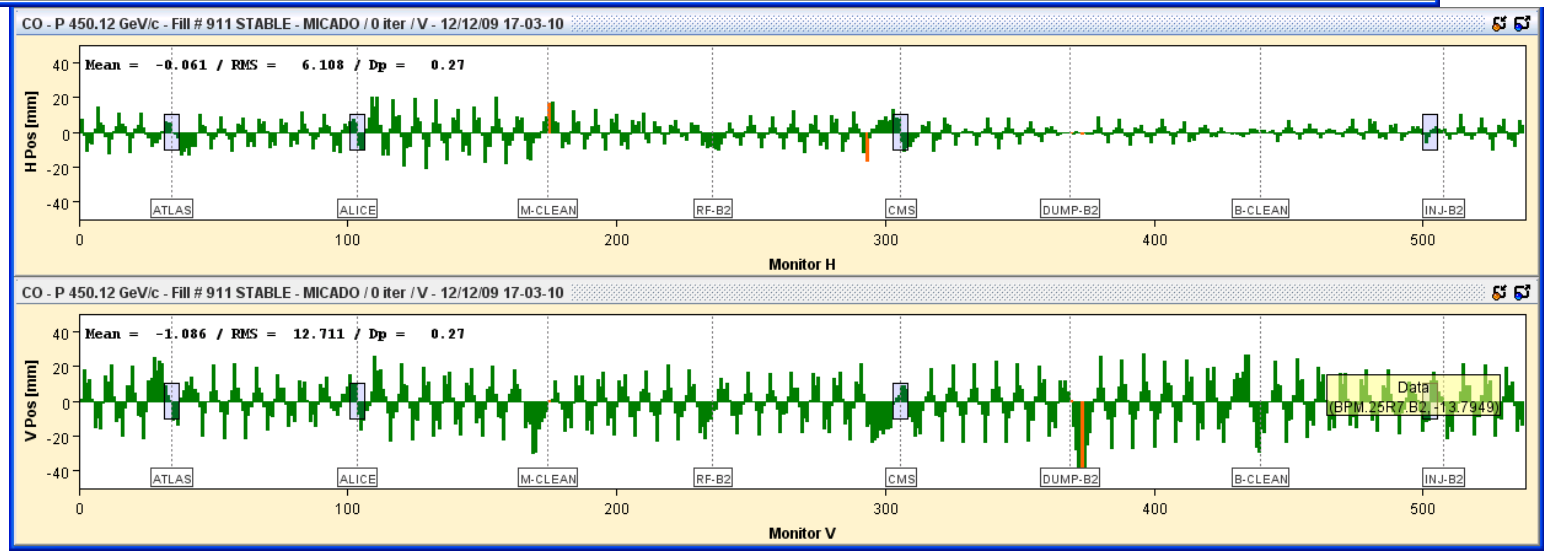
- MCBX trips:
  - low allowed acceleration rate in QPS
  - 'single byte' UDP error:
- FB usage of MCBX corrector magnets is disabled (on OFC as well as FGCs)
- OFC already programmed not to send packets if any value is out of range 2010: additional PC-Gateways & FGC level checks (Q. King & S Page)
- Long-term strategy of using MCBX magnets by OFB needs to be re-evaluated!
- OFB is as fast as the slowest COD -> MCBX would slow the feedback down by factor 10 or more. Acceleration detection is possible but would either come half-a-sample too late or significantly slow down the overall feedback performance.
- The smaller beta* the more likely are triplet shifts being the dominant factor to the global orbit stability -> should compnsat locally.
- Disable all BPMs/CODs in the common region (decouple rings) and correct what's left in the common region at the end of the ramp/squeeze?
- Improvement of QPS for MCBX magnets possible?

Bare orbit (calculated)

B1

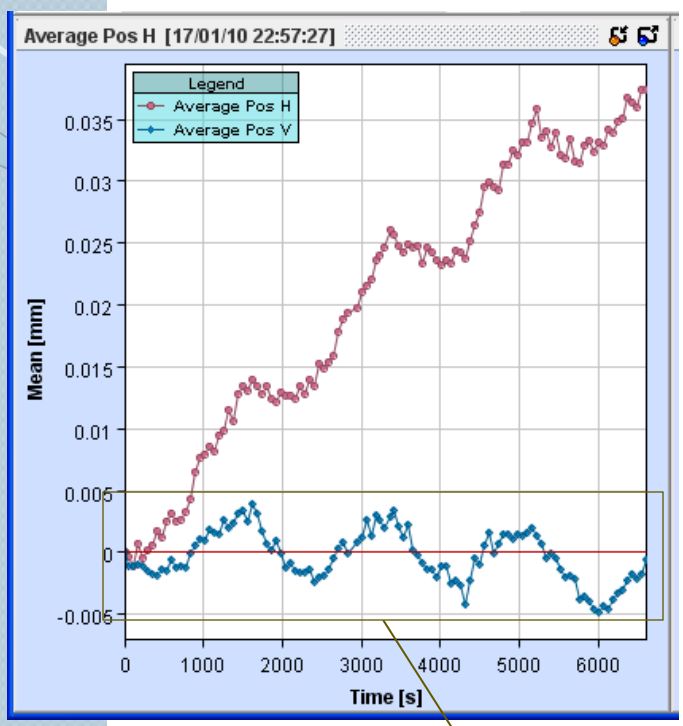


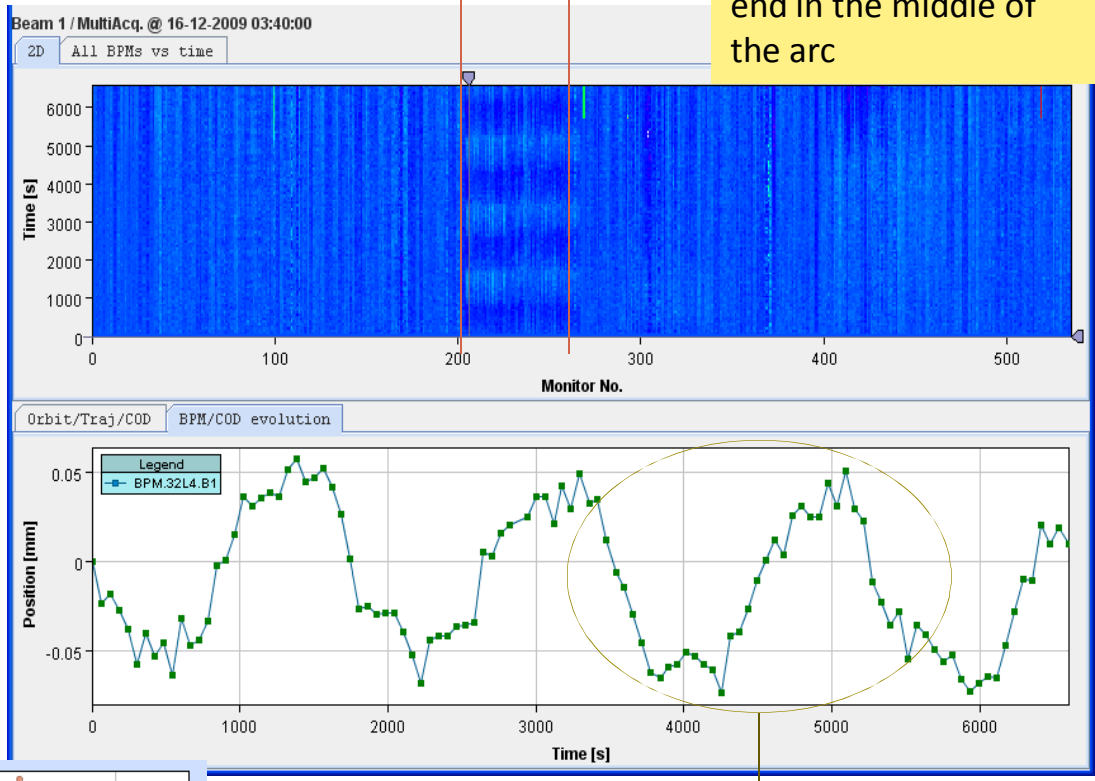
B2



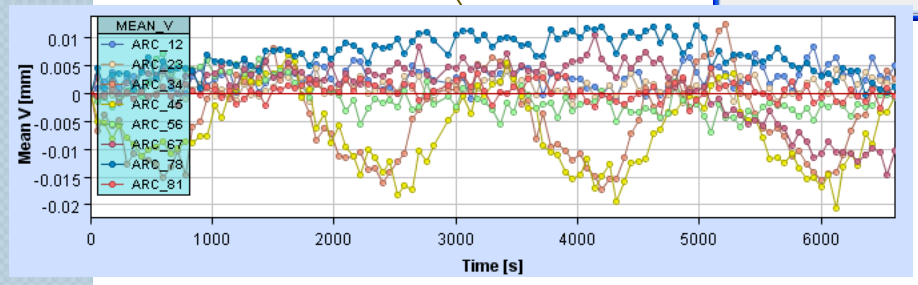
Largest rms:
B1-H (17.8mm)
Smallest:
B2-H (6.1mm)

Stable beams @ 1.18TeV





Oscillations start and end in the middle of the arc



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...and again its arcs 34, 45!
(This time oscillation with T ca. ½ h)

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03:40 to 05:30
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