LHC BPM system: status, measurement reliability and outlook for 2011

Thanks to all the LHC-BPM team

Content

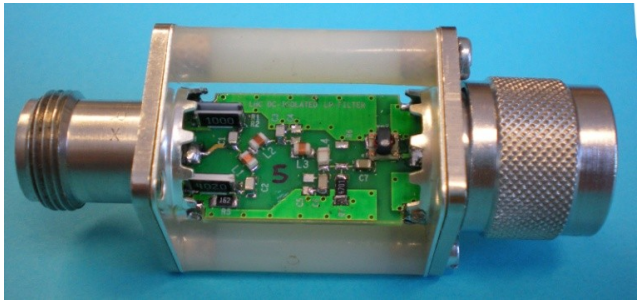
- Performance
  - System availability
  - Closed orbit modes
  - Resolution
  - Stability
- Intensity dependence
- Temperature dependence
- Future measurements/checks
- Conclusions

System availability

- Complex distributed system with good reliability
  - Just a few hours down during the year.
  - FEC reboots are rare.
- Currently (17th Nov), only 3% of channels disabled on OFC (71 out of 2152).
- None of these channels are 'dead':
  - Non-physical offsets
  - Too noisy measurements
- Number quite constant during 2010

3 % missing channels

- 75% correspond to BPMs close to the IR
  - Long coaxial cables (deported electronics)
  - Coupled noise and/or ground loops
- **Cable adapters** will be installed this XMAS stop
- Expect to reduce RMS noise in many channels



- Most of them are strip line monitors (BPMS/SA/SE)
- Beam directivity smaller than sensitivity of electronics (~20 dB vs 35dB).
- With I_{beam}>2e10 p/bunch, B1 bunches can trigger B2 channels and vice versa. (LHC BPM front-end electronics auto-triggered, no timing signals in tunnel).
- During 2011 commission **Synchronous orbit mode** (bunch mask) will reduce this problem.

LHC BPM closed-orbit modes #1

Present:

- **Asynchronous closed-orbit:**
  - Position signal from all bunches (from the auto-triggered front-end cards) enters digital IIR filter. (Filter time constant can be configured).
  - Output of the filter is read-out, calibrated and transmitted at 25Hz
  - Recovered by the OFSU from where YASP gets it (typically at 1Hz)

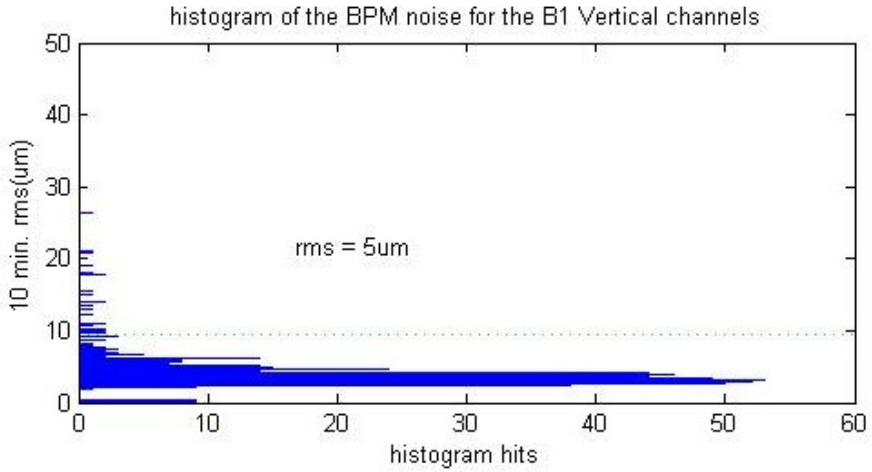
Starting 2011:

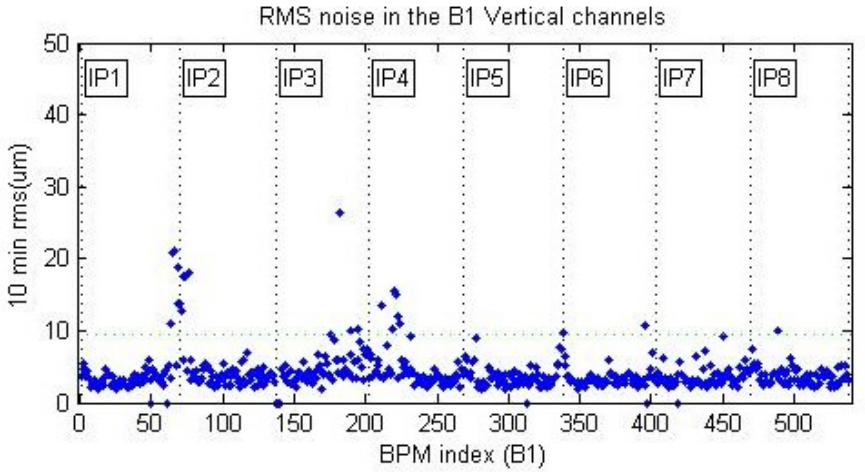
- **Synchronous orbit:**
  - Only bunches from selected slots averaged (225 turns)
  - Initially the mask allows one or all bunches.
  - It requires the phase adjustment of each channel in the DAB module.

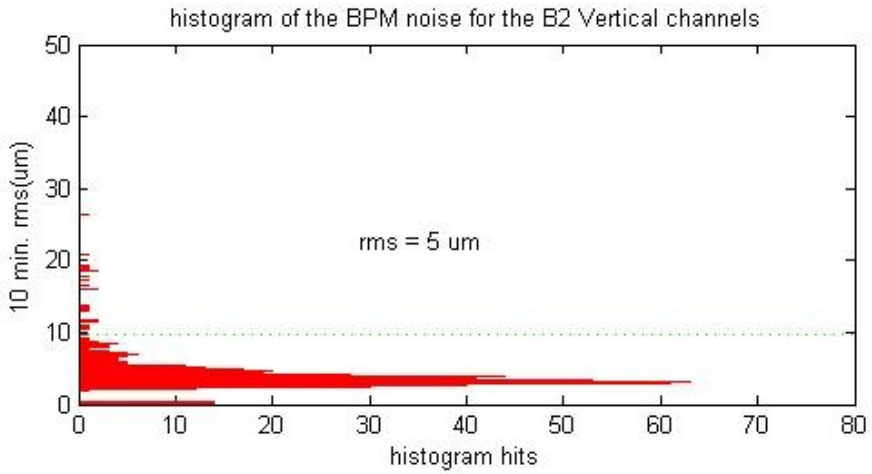
Output from both modes read-out, calibrated and transmitted at 25Hz to OFSU system (YASP update 1Hz) – choice of mode

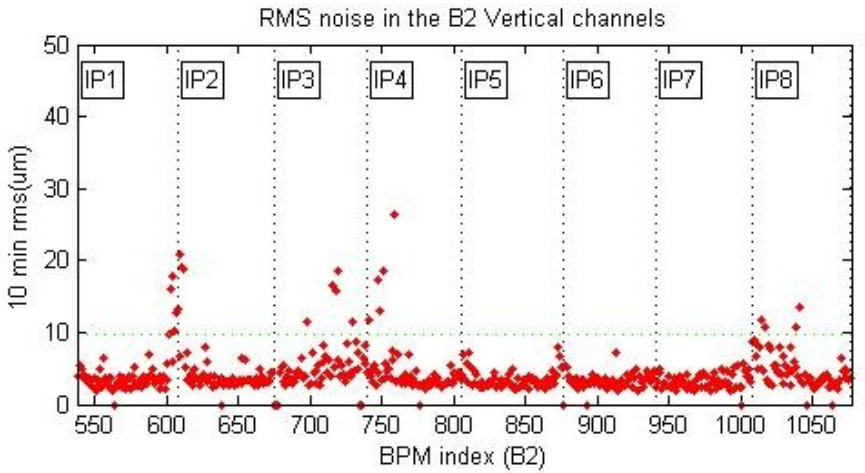
Resolution

- Resolution of LHC BPM system in closed-orbit mode is ~5um.

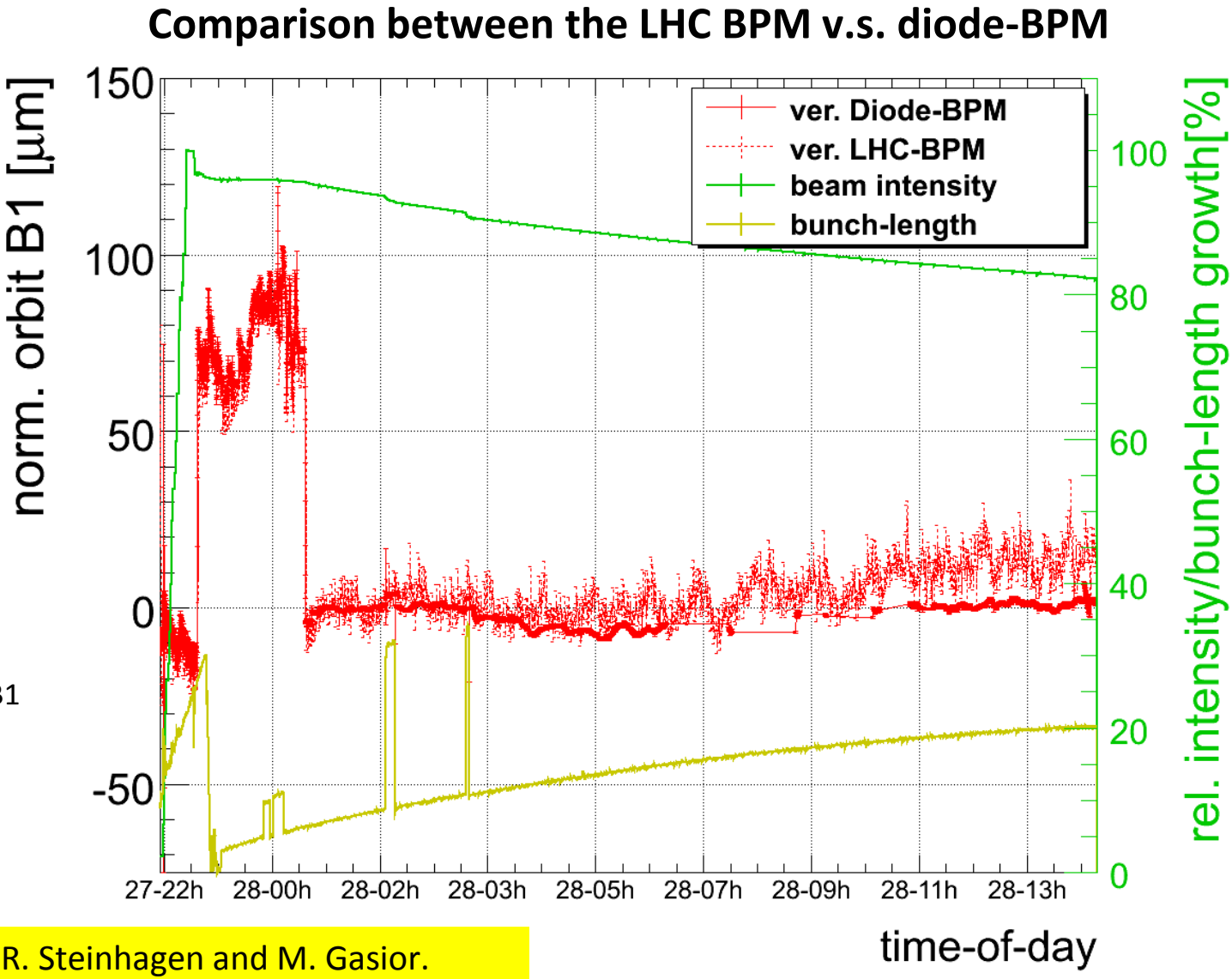








Stability

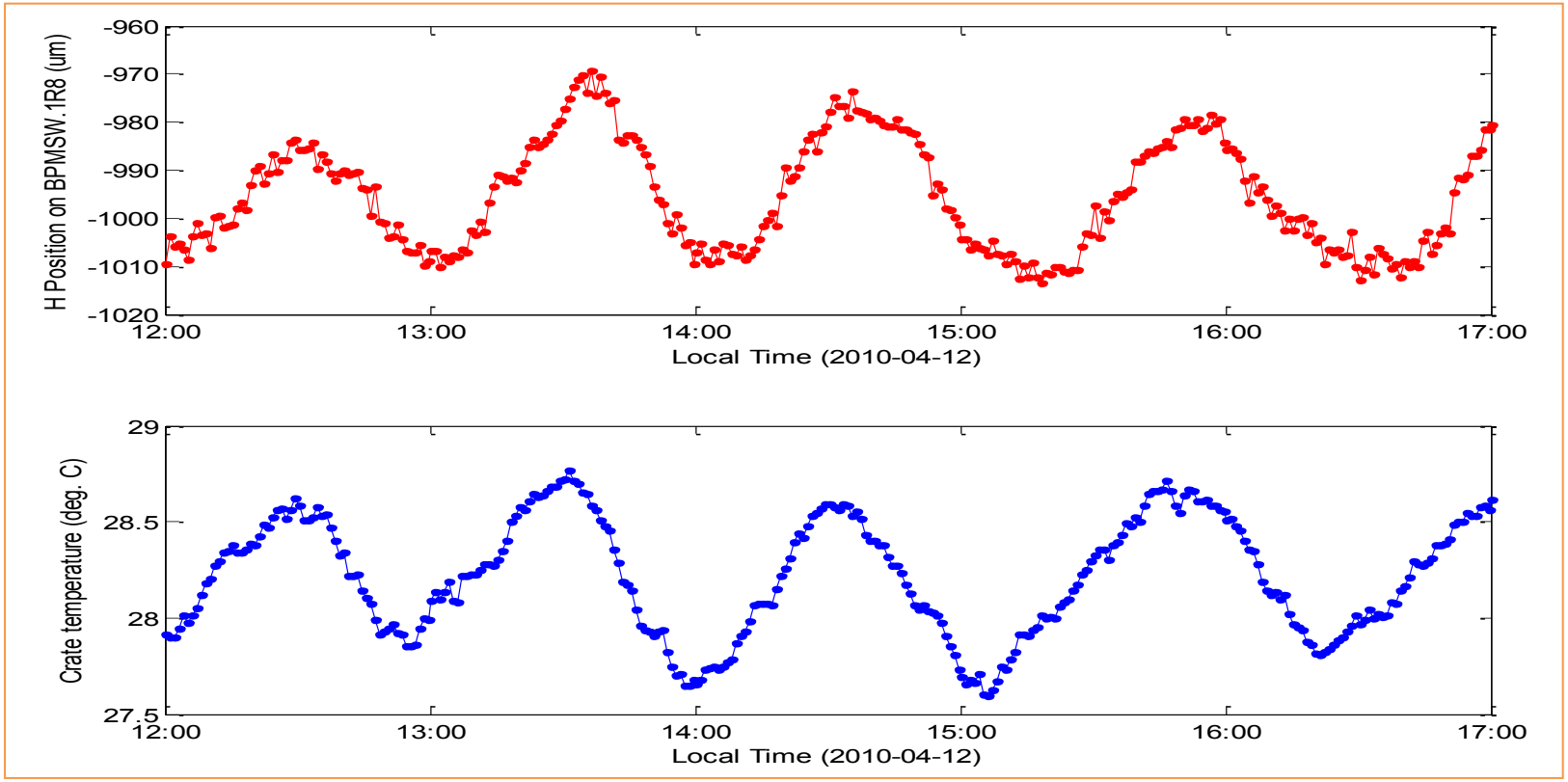


Orbit @ BPMC.8L4.B1

Courtesy of R. Steinhagen and M. Gasior.

Temperature issue #1

- Long term stability limited by ambient temperature dependence
  - Systematic offset in the position measurement
  - Average value: 2.2 ADC bins/deg C (ARC BPM = ~50 um/deg C).
  - ΔTemp in 24h varies from day to day but can be up to 6°C.

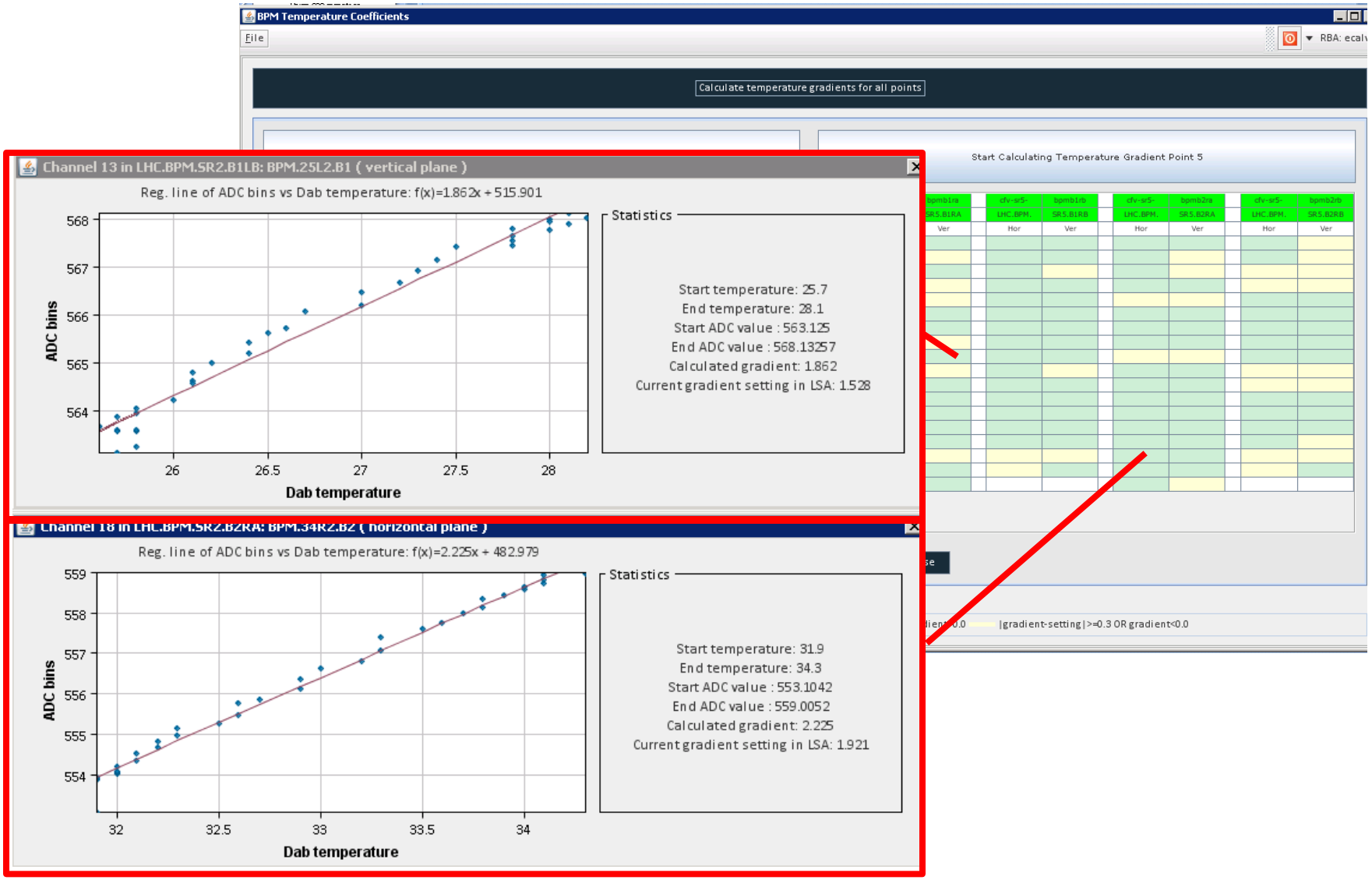


Temperature issues #3

- An expert application was developed:
  - Simulates using calibration signals a centered beam
  - VME fan trays speed is then reduced (reduce air-cooling).
  - Linear fit is applied to the data of each channel. (Gradient values).
  - Low-level server corrects ADC data by applying the gradients found with temperature difference .

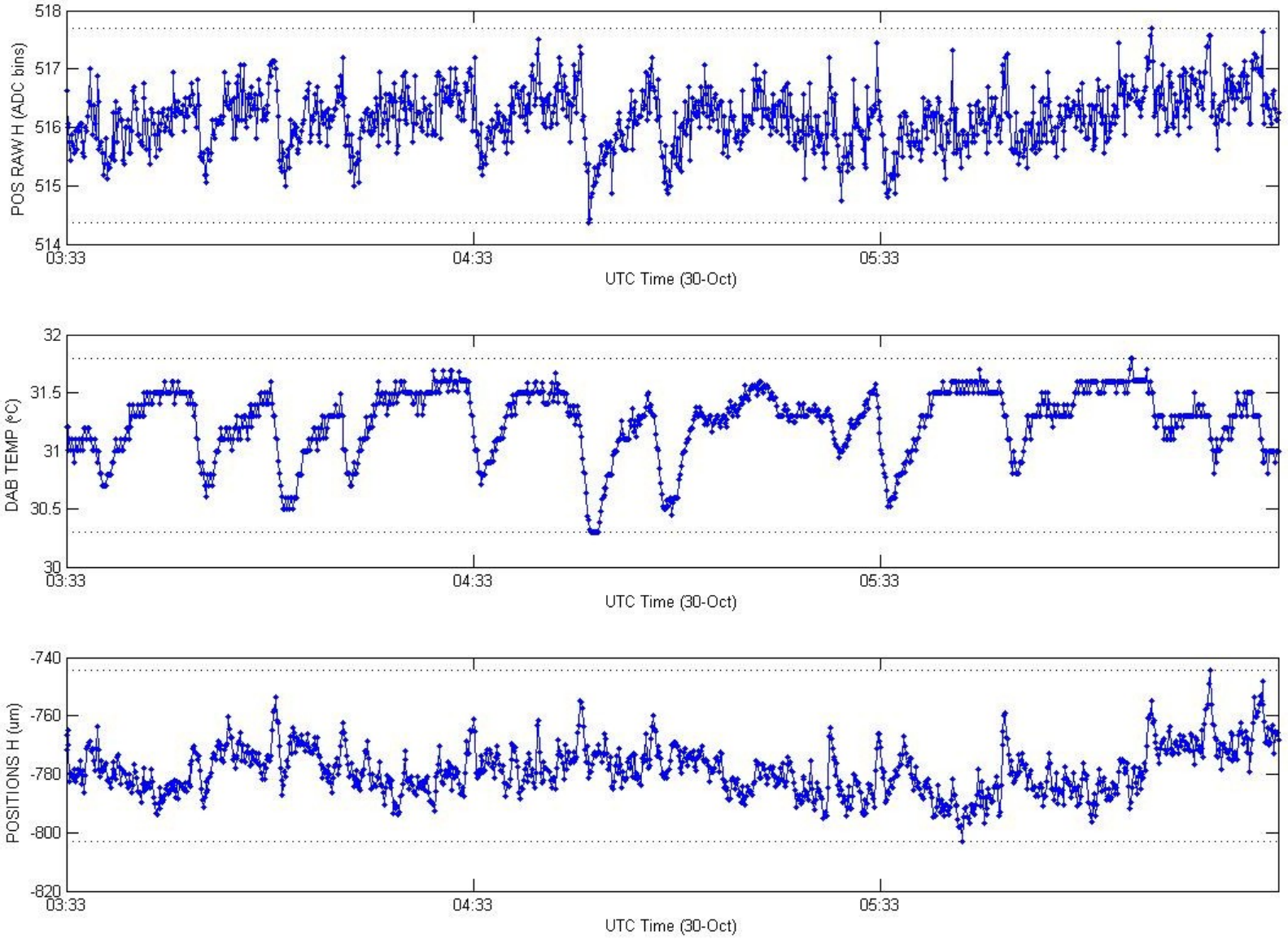
- Procedure has reduced the problem. However:
  - The fan speed reduction allows for calibration in small dynamic range (5 - 6°C)
  - Error non-negligible if temperature too far from the measured points (non-linear behaviour)

Temperature issues #4



Temperature issues #5

BPM.33R8.B2

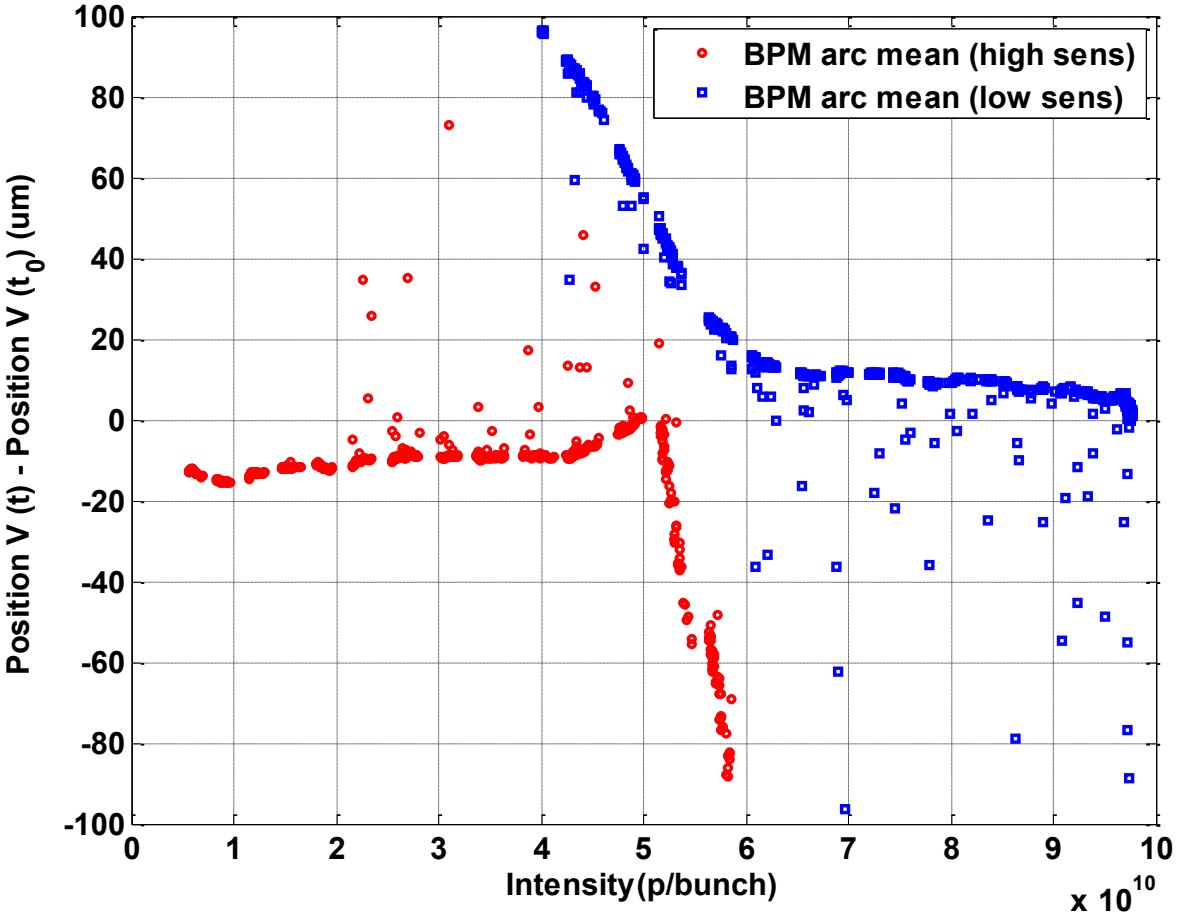


Temperature issues #6

- In order to attenuate further the temperature drifts:
  - Add to LHC sequencer standard BPM calibration
  - Remove long term accumulated temperature variations. (“Reset effect”).
  - Procedure is “safe” – Several checks assure that it will not introduce “bad calibration factors”.
  - Long term, plans to implement “temperature regulated racks”.
    - First prototype received beginning of next year.
    - Complete replacement during long shutdown (2012? / 2013?).

Intensity dependence #2

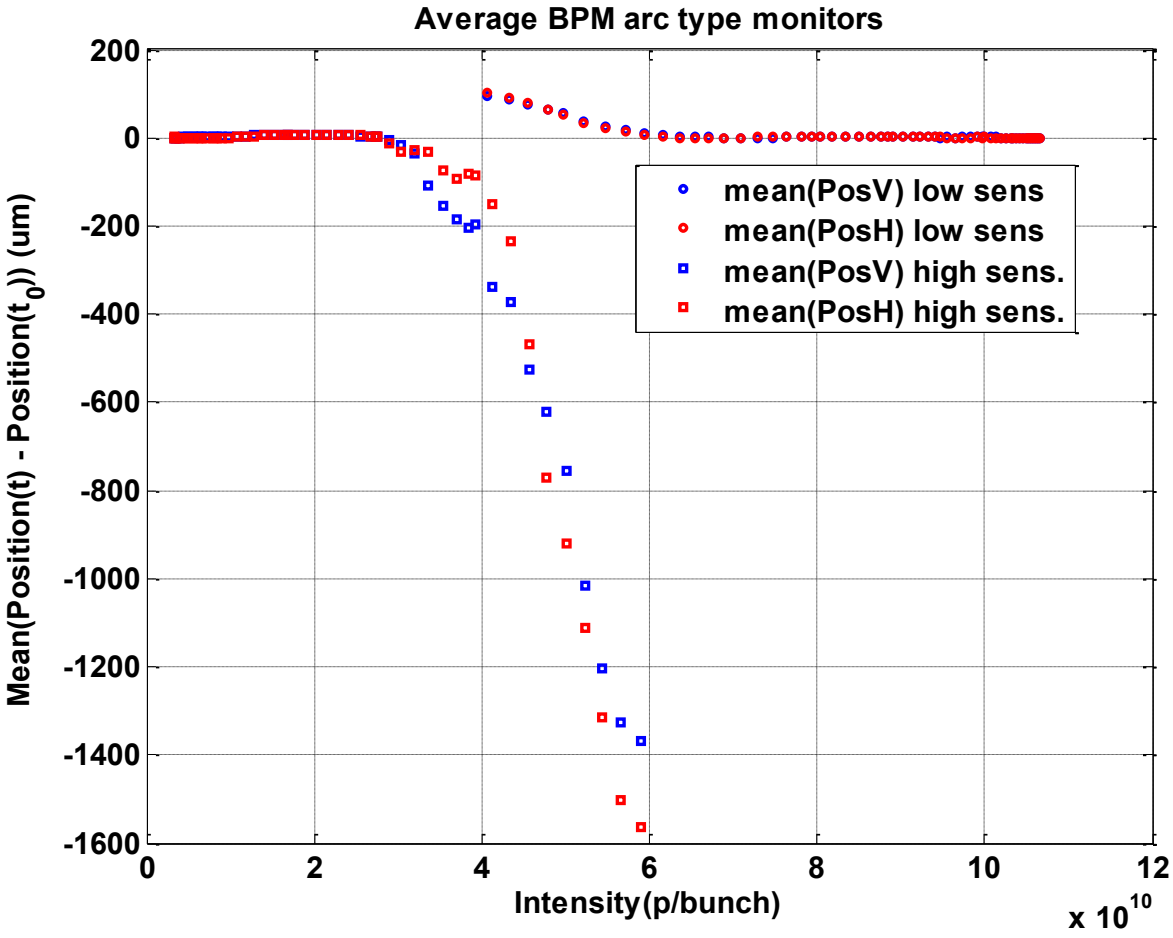
- MD on 28th of May - **Beam 2** scraping with collimators (point 7)
- Calibrating beam position versus bunch intensity.



- Switching between high and low gain every 10s.
- Optimum switch point 5e10p/bunch.
- Drift on the orbit due to intensity <40um.

Intensity dependence #4

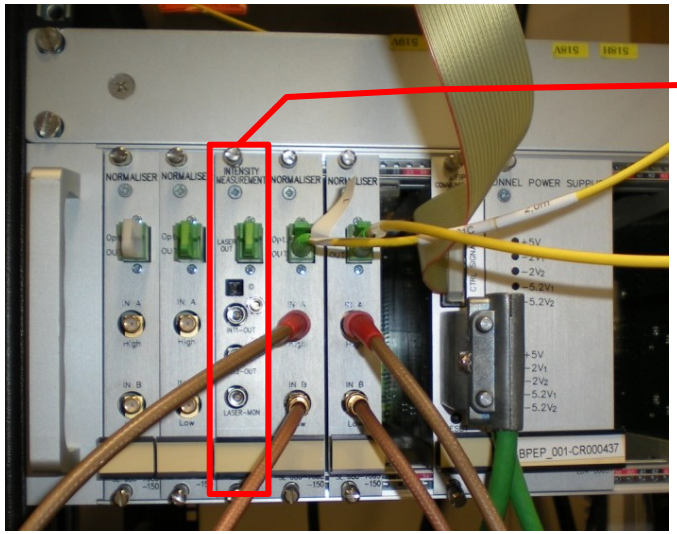
- MD on 8th of June - **Beam 1** scraping with collimators (point 7)
- Calibrating beam position versus bunch intensity.

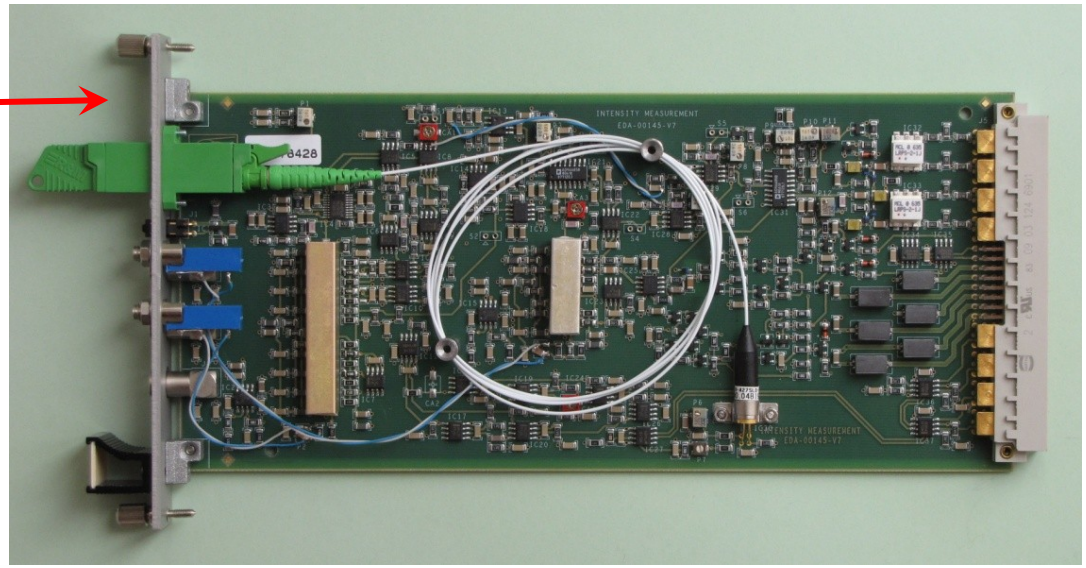


- One test with complete scraping per sensibility mode.
- No optimal switch point !
- Switching @4e10, the maximum drift was ~300um.

Intensity issues

- The Front-end cards for Beam 1 and Beam 2 are identical.
- B1 behavior was caused by a small impedance mismatch at the input of the intensity module.
- Solving this issue would require : *→ Decision to be taken!*
  - Replacing the intensity card by termination card. (Possibly this shutdown).
  - Producing new cards with better impedance matching (Long term).





3 main lines of defence against BPM errors and faults

- Pre-checks without beams using the in-build calibration unit → Done ✔
  - Test the electronics (not the cabling neither the monitors).
  - Eliminates dead BPMs, detects noisy or misbehaving channels.
  - Removes electronic offsets
  - Provides the electronic sensibility of each channel.
- Pre-checks with Pilot and Intermediate beams → Needs integration
  - Forced slow COD-driven betatron oscillation with rotating phase
  - Idea: “Every non-moving position reading indicates a dead BPM”
  - Test the complete acquisition chain (including monitors and cabling).
  - Tests also calibration factors.
- Continuous data quality monitoring through Orbit Feedback → Done ✔
  - Detect spikes, steps and BPMs that are under verge of failing

Conclusions

The global performance of the system is very good.

In 2011:

- Synchronous orbit implementation will solve double trigger issue.
- Long cable adapters will reduce the RMS noise.
- BPM calibration procedure in the sequencer will reduce the temperature induced offsets.

- To decide if this Xmas shutdown the intensity modules should be removed.

- A temperature regulated racks prototype will be evaluated. (Future operational installation during the long shutdown).

Thank you !

Intensity issues

Spare slides

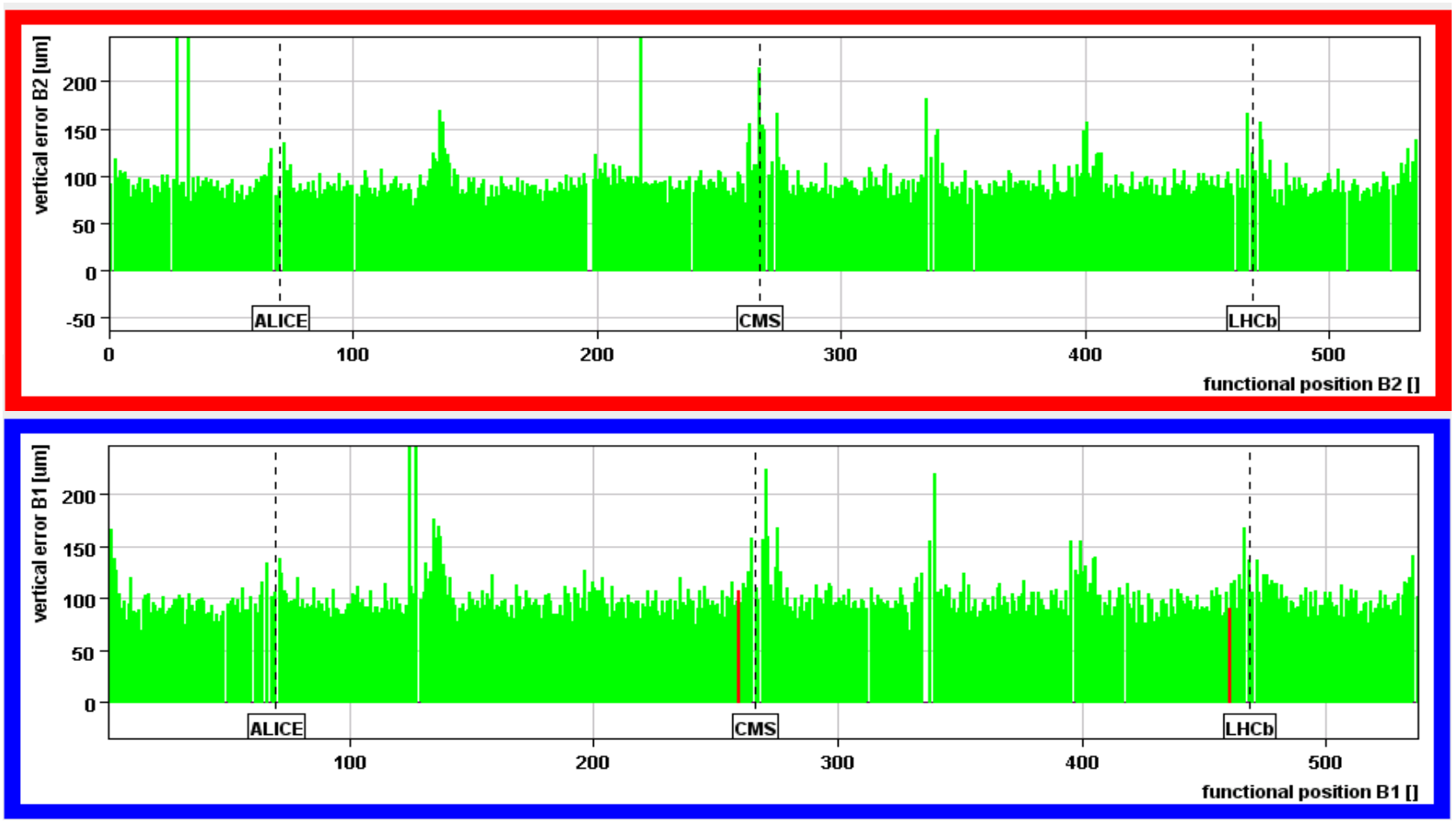
Interventions

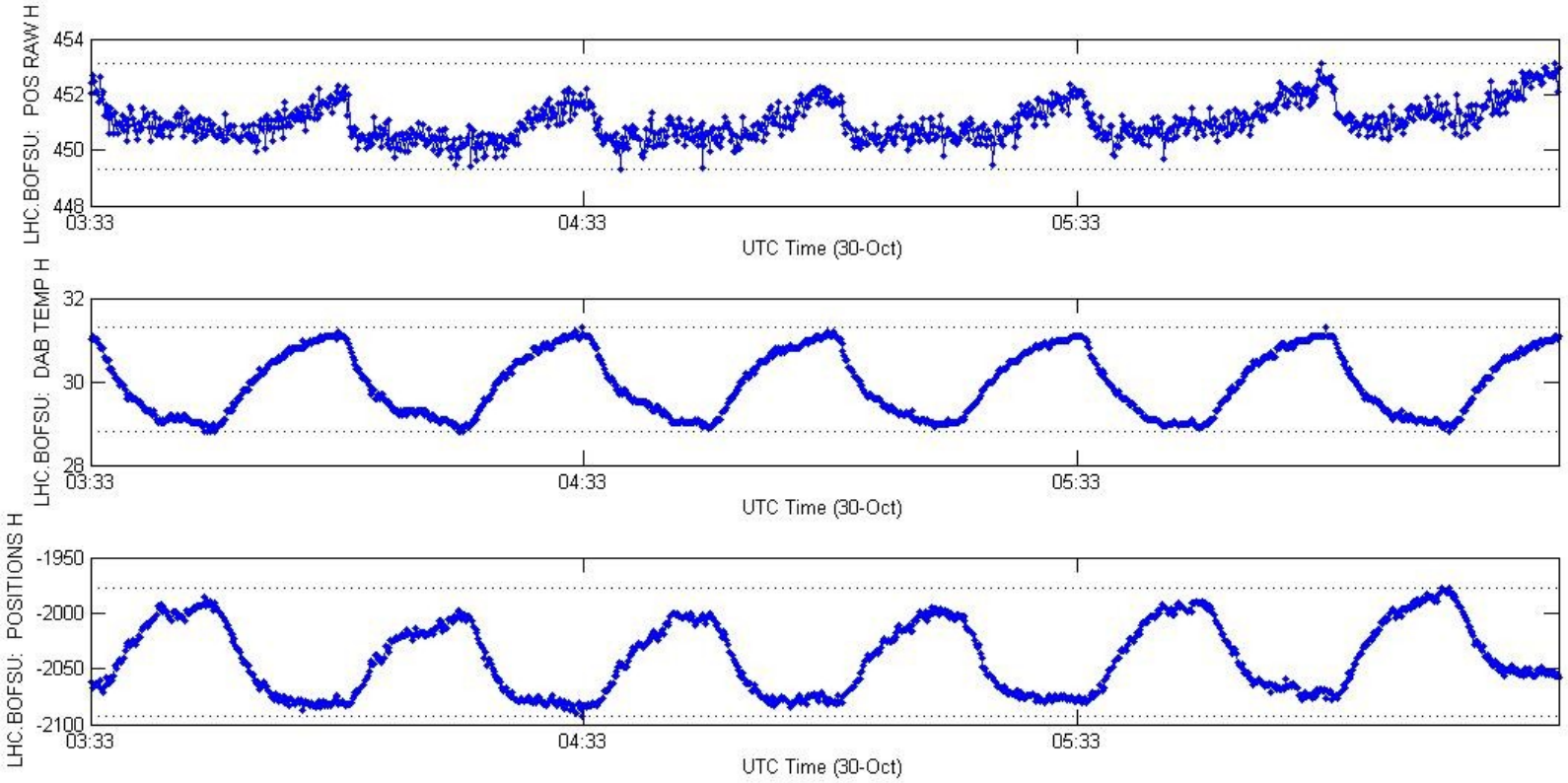
- Almost no calls from the CCC
- Typical interventions:
  - 3 VME crate P.S. replaced
  - 1 VME CPU replaced.
  - 16 DAB cards replaced (11 in the same campaign in April, only 1 after then). -> youth errors
  - 5 WBTN replaced
  - 1 BYPMD crate replaced
  - 2 inverted polarities
  - 5 bad contacts at the flange level
  - 2 defects inside the cryostat
  - 1 time power disjunctors trip on the tunnel

Performance

- The resolution of the BPM system in bunch by bunch basis is <100 um

RMS from the Orbit Feedback GUI




LHC.BOFSU: POS RAW H
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UTC Time (30-Oct)
LHC.BOFSU: DAB TEMP H
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UTC Time (30-Oct)
LHC.BOFSU: POSITIONS H
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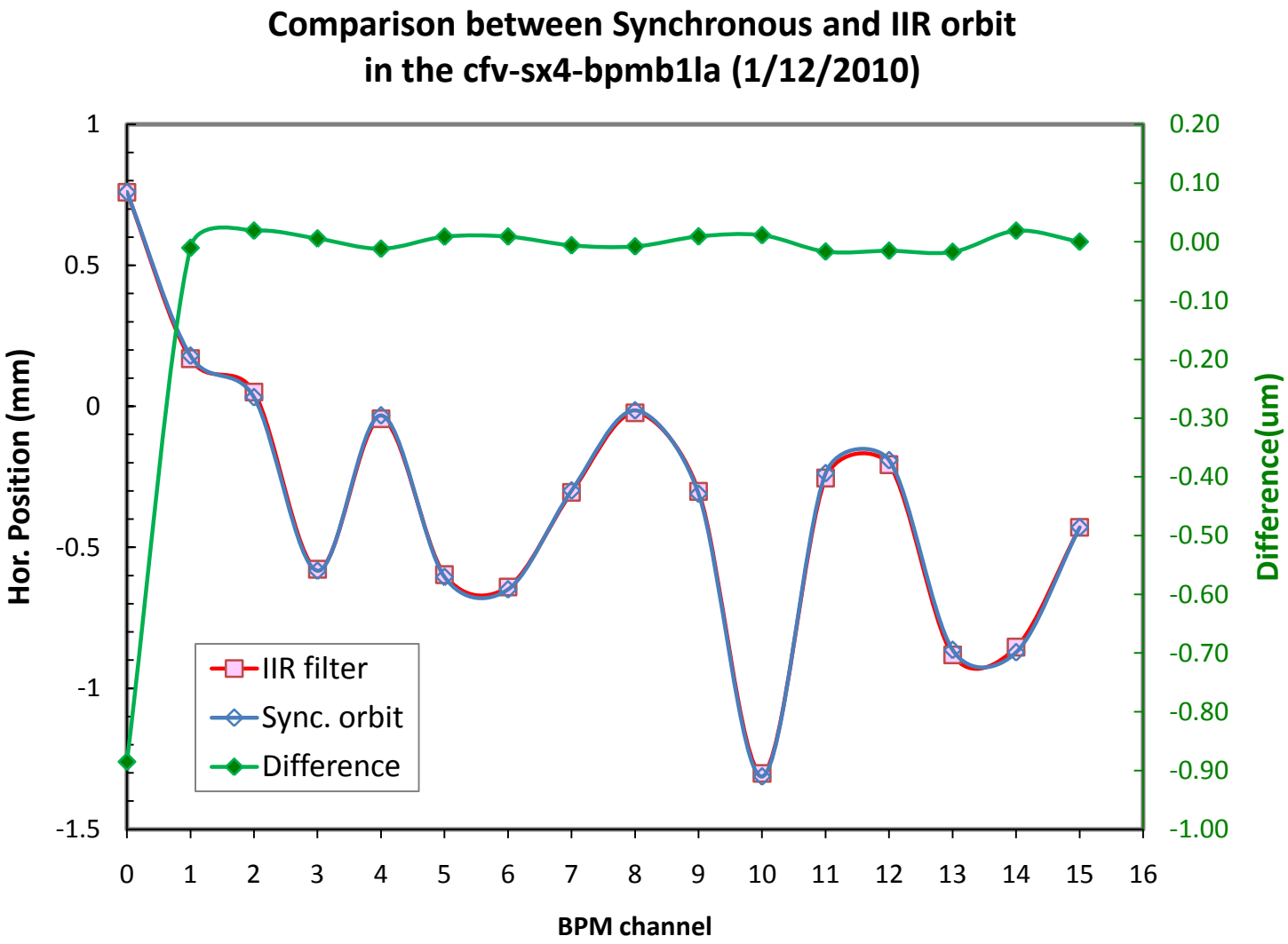
LHC BPM closed-orbit modes #1



LHC BPM orbit modes

	Slot 1	Slot 2	Slot 3	…	Slot 3564
Turn i+1	0.211				
Turn i+2	0.225				
…	…				
Turn i+N	0.208				

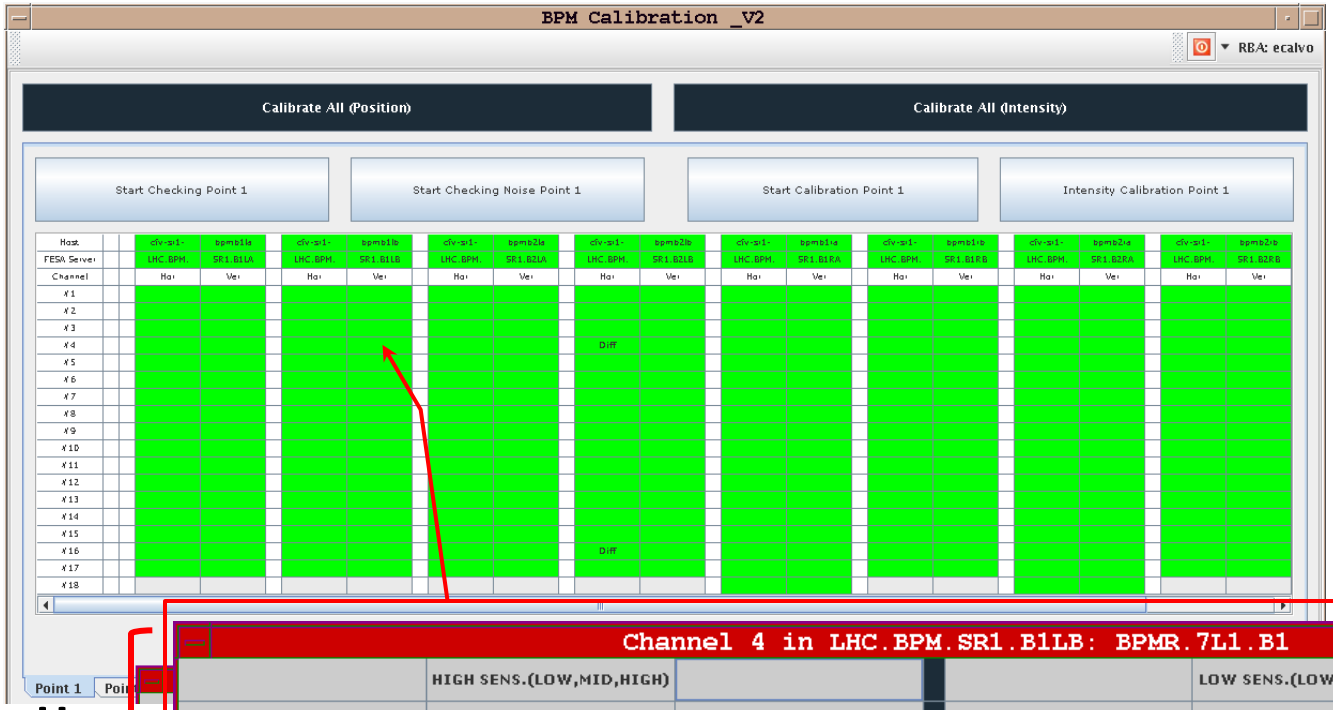
The mask will allow only the bunches in the first slot to be averaged.

$\sum$ Sum $1/N_{TOTAL}$ = **sync. orbit**

Sum $1/N_1$	Sum $2/N_2$	Sum $3/N_3$	…	Sum $3564/N_{3564}$

= **bunch sync. orbit** (vector)

BPM calibration



H plane

V plane

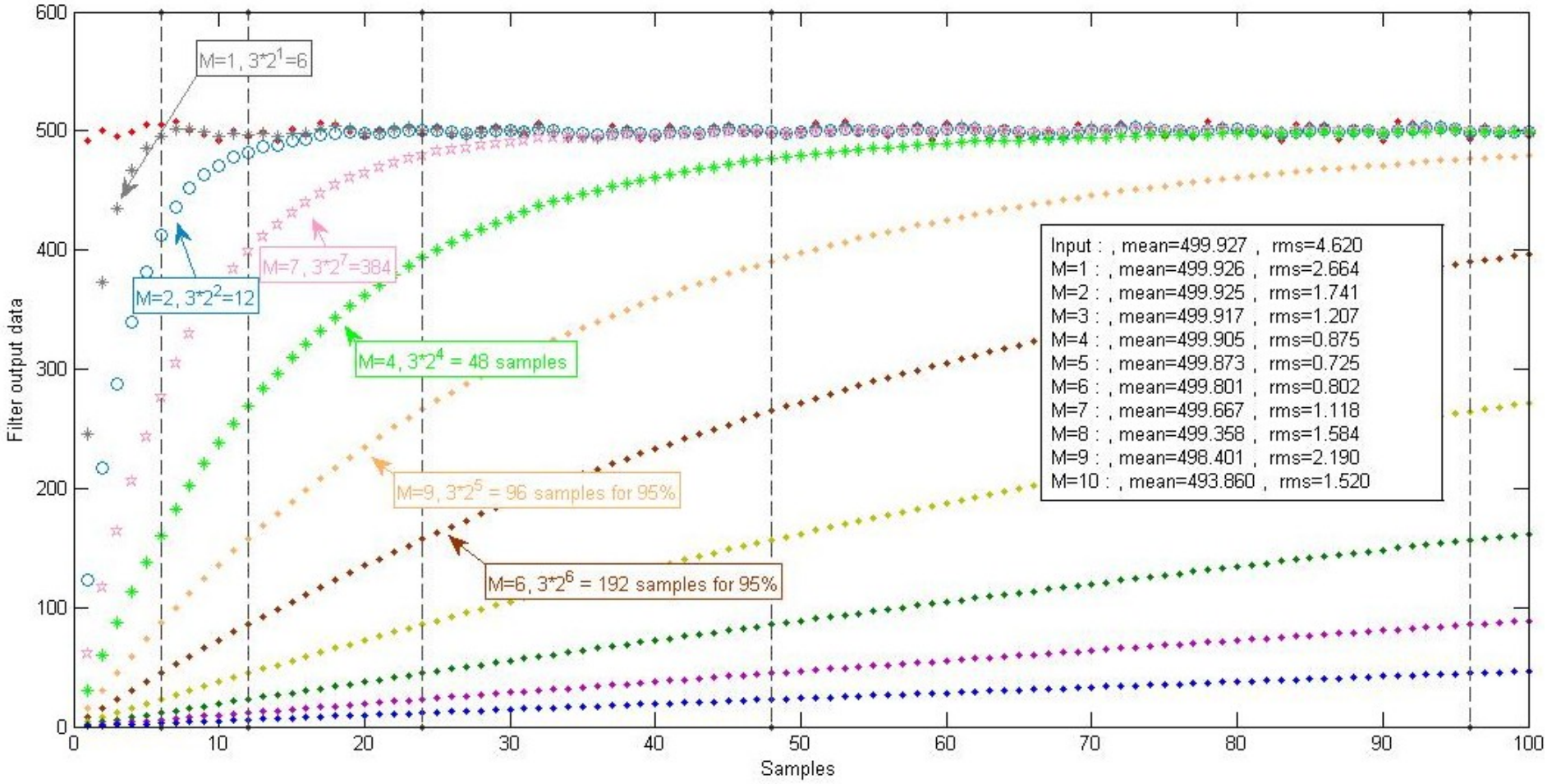
Channel 4 in LHC.BPM.SR1.B1LB: BPMR.7L1.B1

	HIGH SENS.(LOW,MID,HIGH)			LOW SENS.(LOW,MID,HIGH)	
horFiltOrbitRaw	horFiltOrbitRawSpread	horFiltOrbitErrRate	horFiltOrbitRaw	horFiltOrbitRawSpread	horFiltOrbitErrRate
(62,553,995)	(2.70,2.75,3.24)	(0,0,0)	(55,553,968)	(2.14,1.88,2.00)	(0,0,0)
(64.0,553.0,993.0)			(61.0,559.0,973.0)		
verFiltOrbitRaw	verFiltOrbitRawSpread	verFiltOrbitErrRate	verFiltOrbitRaw	verFiltOrbitRawSpread	verFiltOrbitErrRate
(70,589,993)	(2.55,2.16,1.85)	(0,0,0)	(78,585,956)	(2.63,2.08,1.87)	(0,0,0)
(71.0,589.0,9[illegible])			(82.0,591.0,972.0)		
(3-100,500-600,920-1022)	(<5,<5,<5)	(<20%,<1%,<20%)	(3-100,500-600,920-1022)	(<5,<5,<5)	(<20%,<1%,<1%)

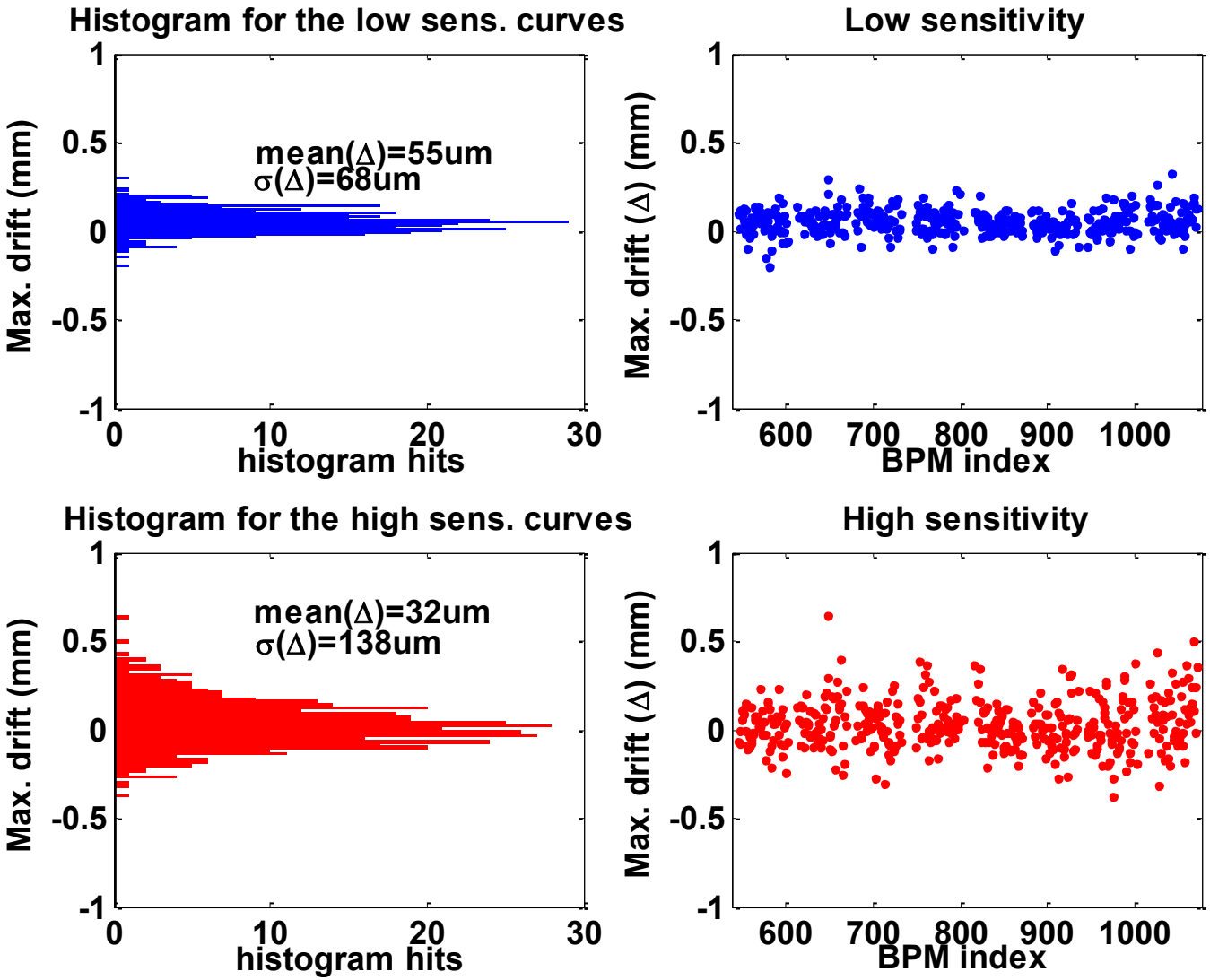
Checks in offset, spread, and number of bad acquisitions

LHC BPM orbit modes

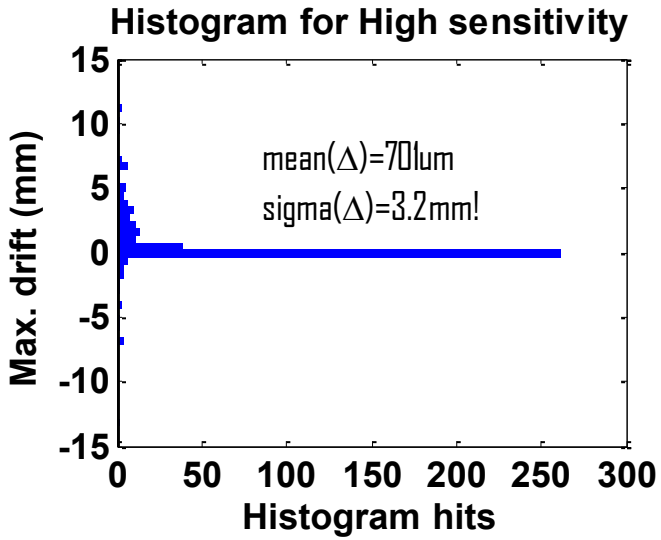
- IIR time constant effect

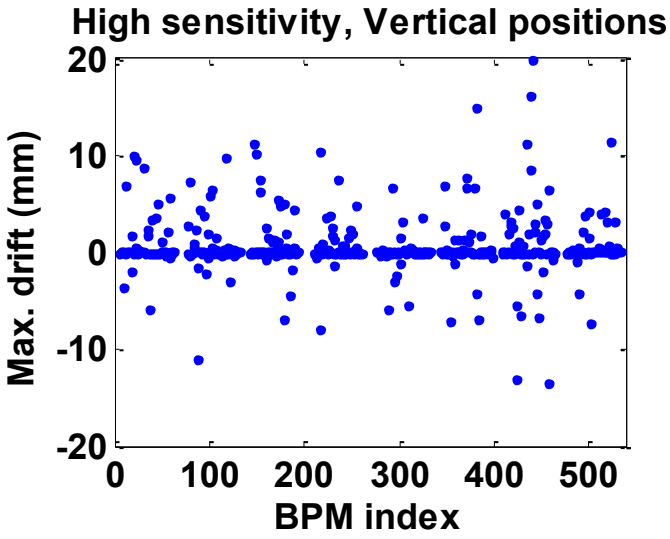


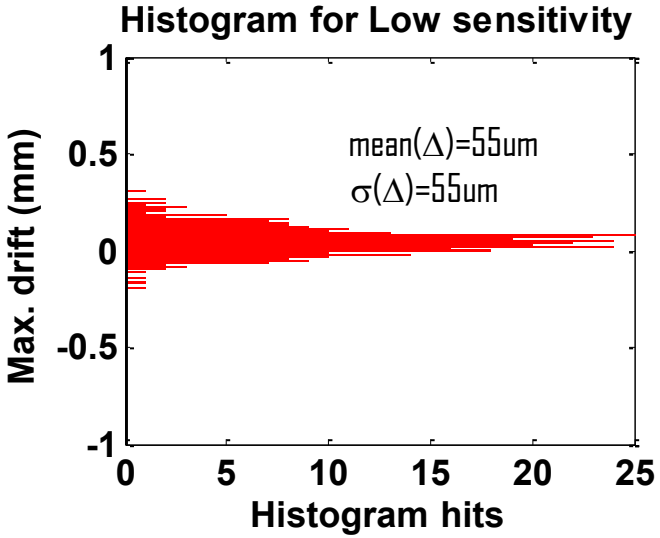
Intensity dependence #3

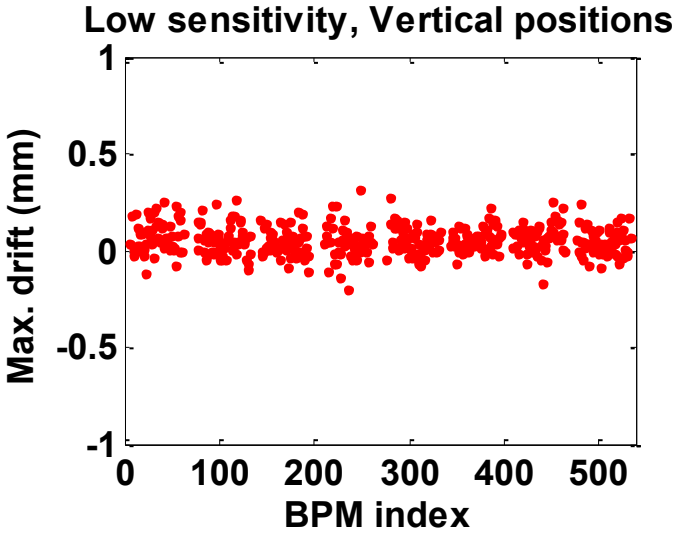


Intensity issues



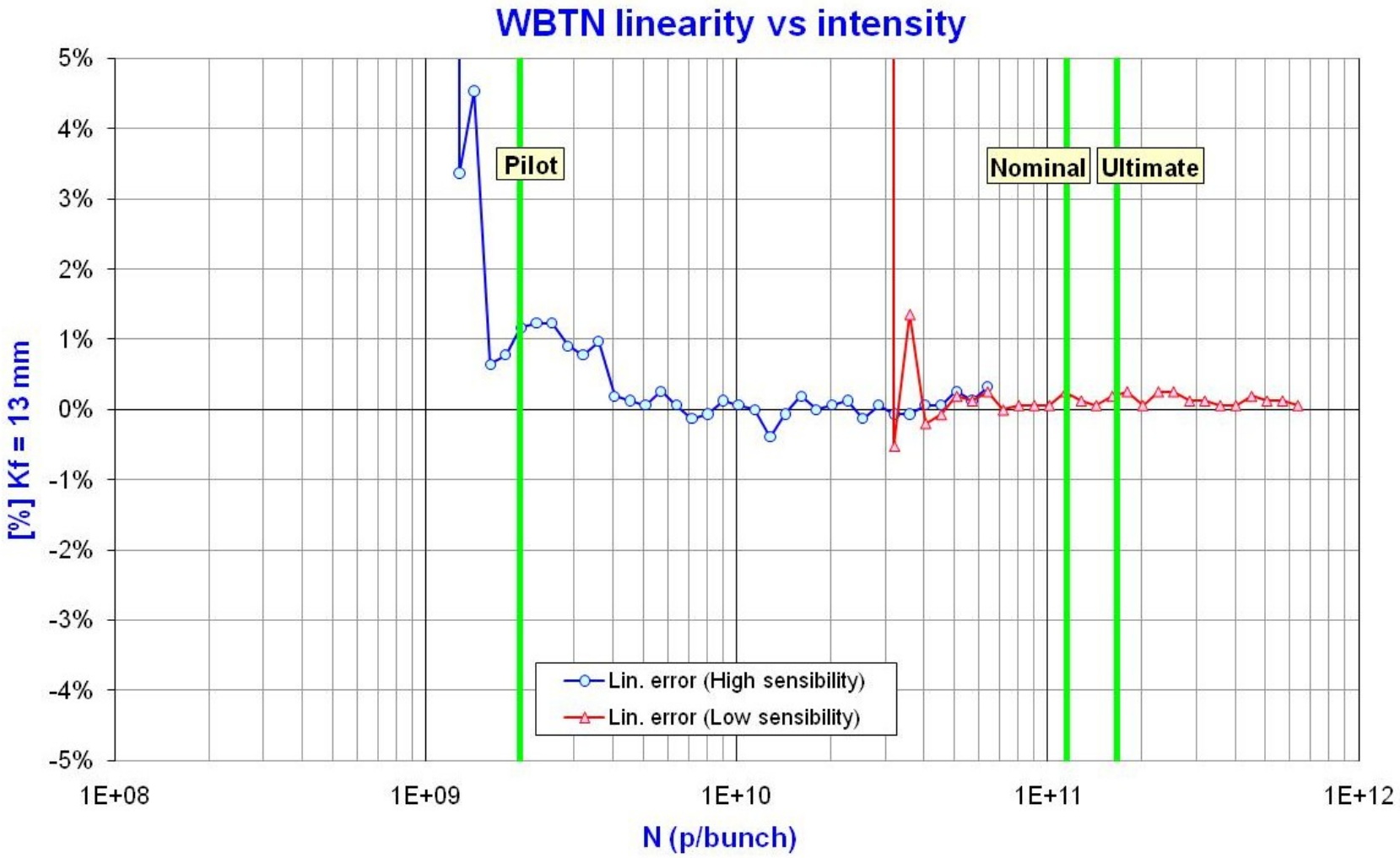




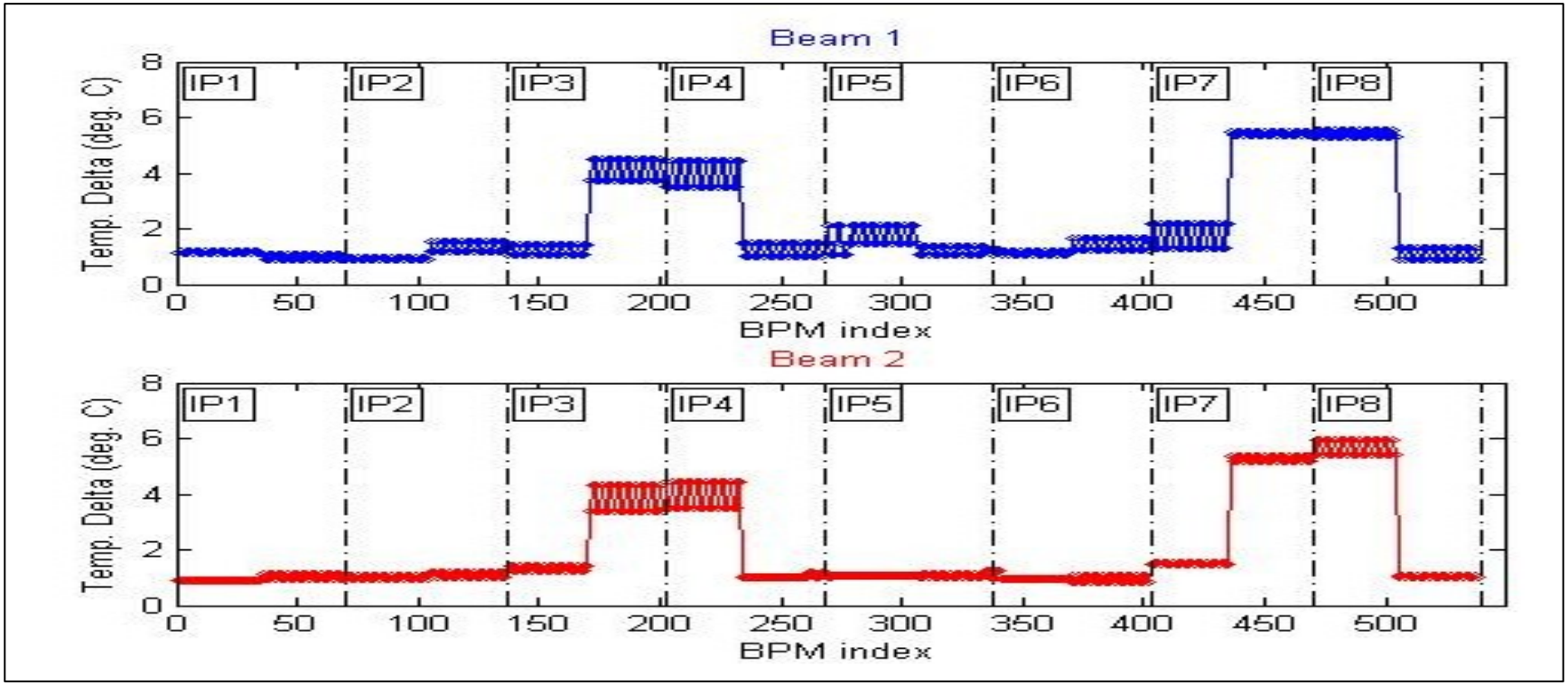


Intensity dependence

- Linearity error as function of beam intensity qualified for each installed card .



Temperature issue #2



Temperature variation (over 24h) for each BPM (12 April 2010)

Depending on the day, we observe different drifts in different points.

(This would limit our accuracy if we do not calibrate the system often enough)