Orbit Stability Prospects

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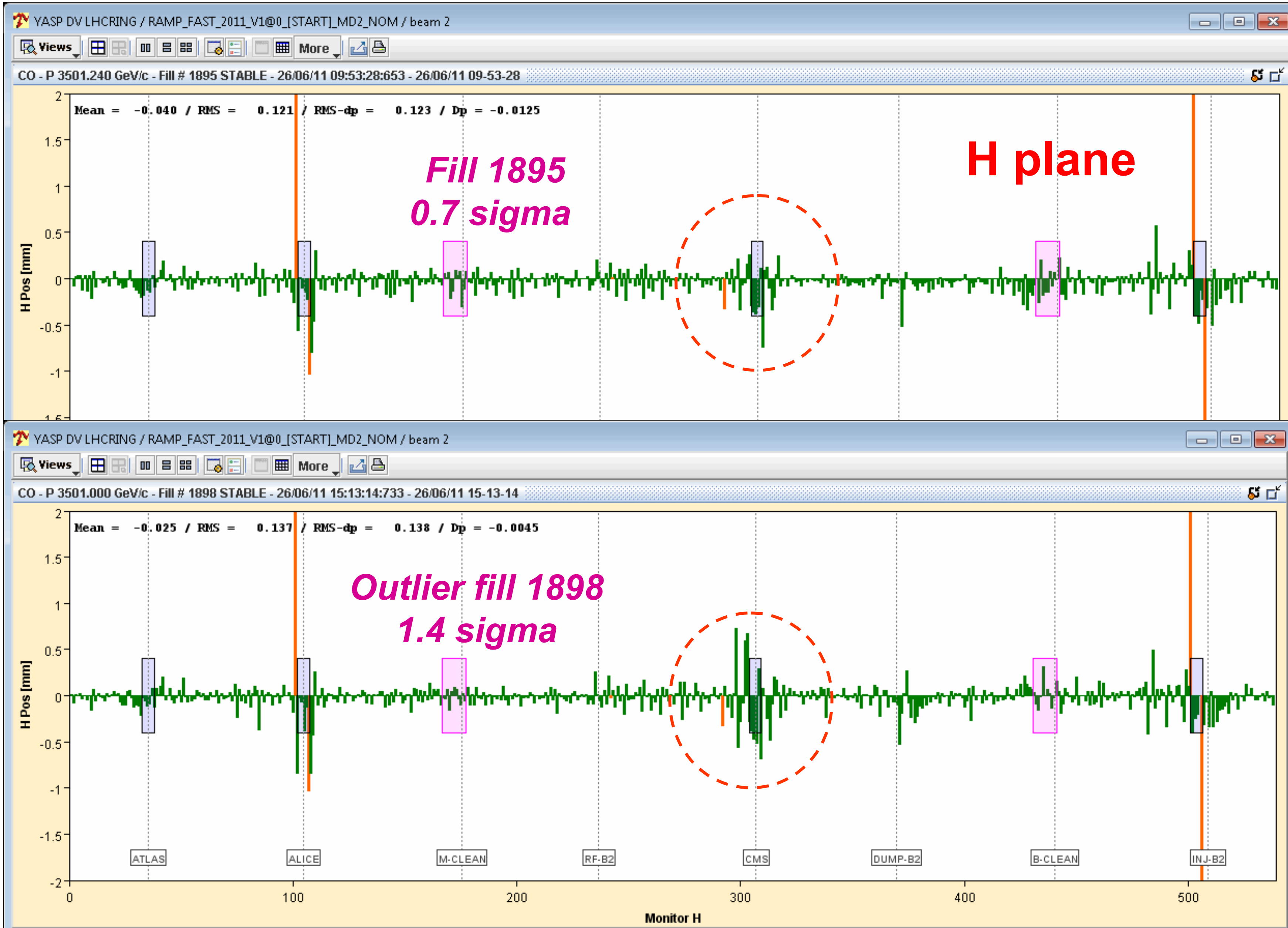
special thanks to: R. Jones, J. Wenninger

Achieved Stability vs. Tolerances
Q: Can the Orbit Stability further improved in the IRs for 2010?



Achieved Stability vs. Tolerances

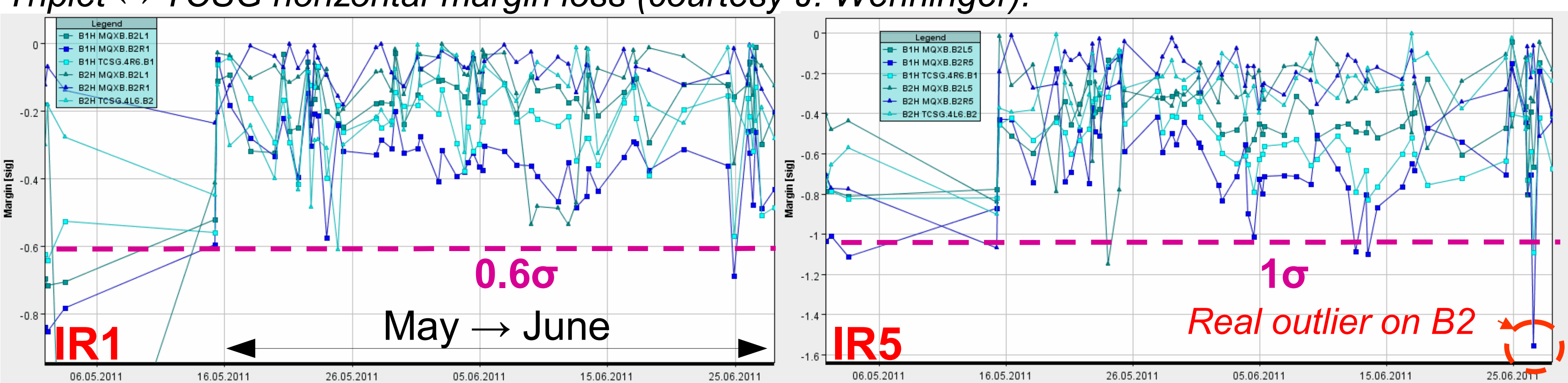
➔ Long-range collimator requirements are effectively peak-to-peak tolerances
- $1\sigma_{pp}$@'TCT↔TSCG' translates to 250 µm or 0.5% at the given BPMs!!
- Target requirements are beyond the initial BPM design (1998)

➔ Known systematic on temperature, intensity and bunch filling pattern
- Several improvement have been and will be put in place to mitigate these
- Still, day-to-day calibrations vary by 200-300 µm (~7 ADC bins)
  - a) remaining uncertainty of the calibration & system stability
  - b) this is the error one should expect if calibrations are skipped for >24h

➔ Present performance is in line with the initial BPM system design
- Noteably, achieved 1 σ reproducibility vs. allocated 2.5 σ tolerances

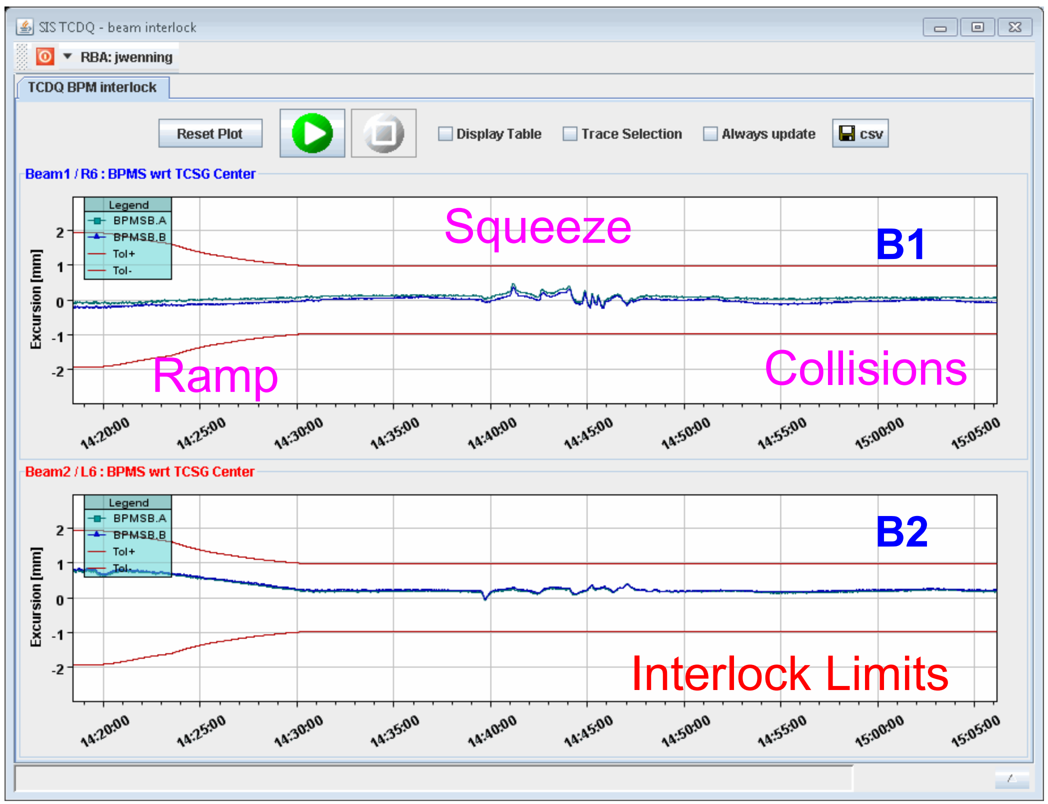
→ can these be re-distributed/accounted in a different way?

Triplet ↔ TCSG horizontal-margin loss (courtesy J. Wenninger):



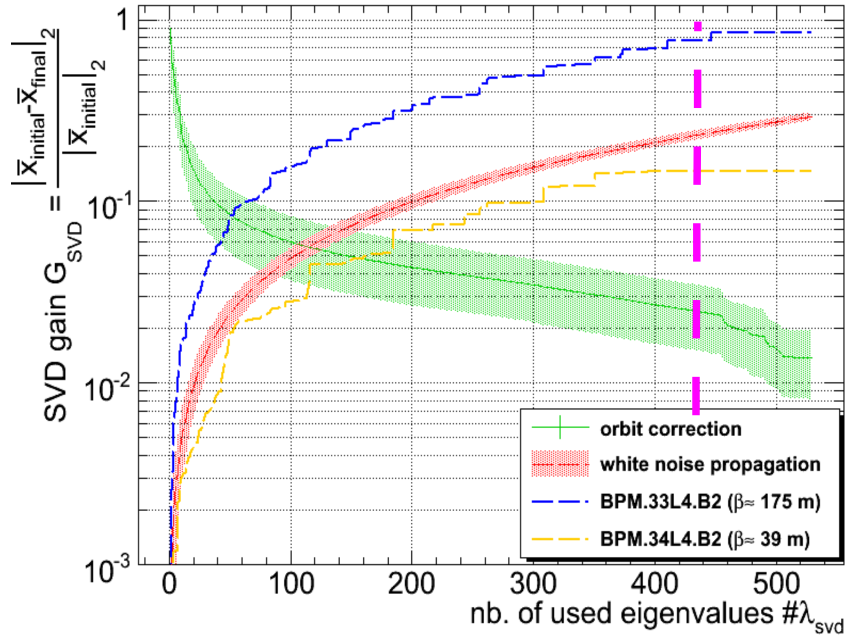
Orbit Correction & Feedback Strategy I/II

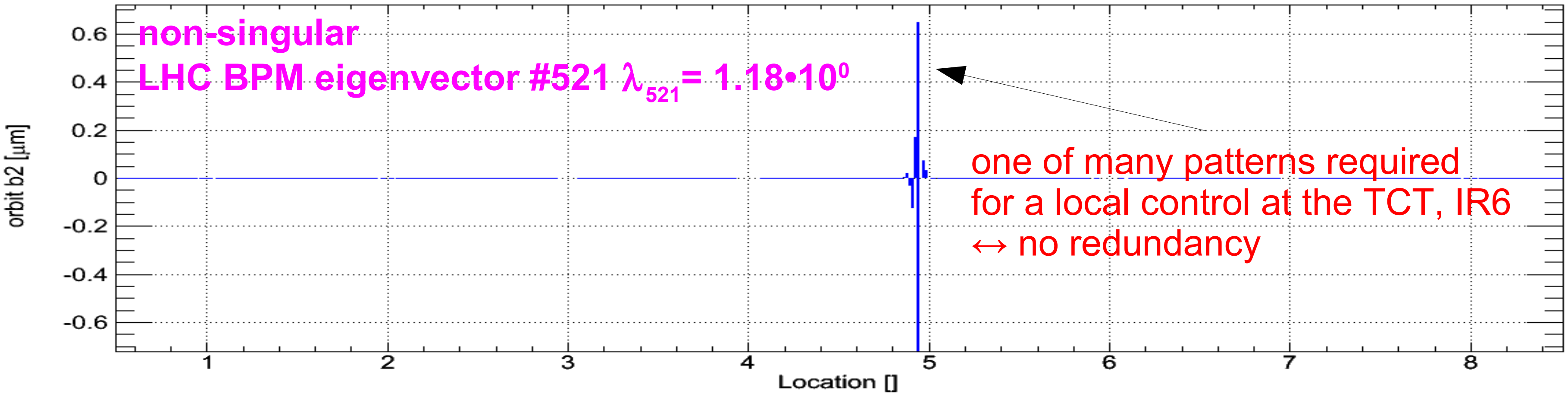
- Presently we deliberately limited the overall correction bandwidth and locality
  a) localised bumps are explicitly removed, i.e. the orbit control is not applied on a per BPM or collimator basis but on the average over a given region.
  b) Orbit-FB bandwidth is (artifically) limited to below 0.1 Hz:



- There is enough margin to further minimise these transients through more regular feed-forward and/or adaptive bandwidth scheduling

- In principle, a more local control can be achieved but makes the corrections more sensitive and dependent on performance and errors of individual BPMs





BPM Improvements

- Removed LSS intensity cards → provides larger overlap of sensitivity ranges (probably a non-issue for targeted larger bunch intensities)
- 'Synchronous orbit' mode e.g. triggering on non-colliding bunches can further reduce filling-pattern dependences and spurious triggers due reflections for directional coupler BPMs (BPMSes)
  → basically there, but needs further integration (i.e. injection sequencer)
- Temperature stabilised racks: massive undertaking of removing, disconnecting, installing and reconnecting 32++ existing racks, cooling water infrastructure, 2200 fiber connections → requires a long shutdown

Provided the presently achieved 200-300 μm reproducibility is not sufficient:

- More robust BPM electronics → non-trivial, but being looked into:
  - Diode-based Orbit acquisition
  - BPM signal commutators to remove systematic offset drifts
- additional redundancy* in critical locations:
  - additional acquisition chains on the same pick-up
  - Additional pick-ups!!

*N.B. SL sources have for this reason about 2-4x the BPM for the same phase advance

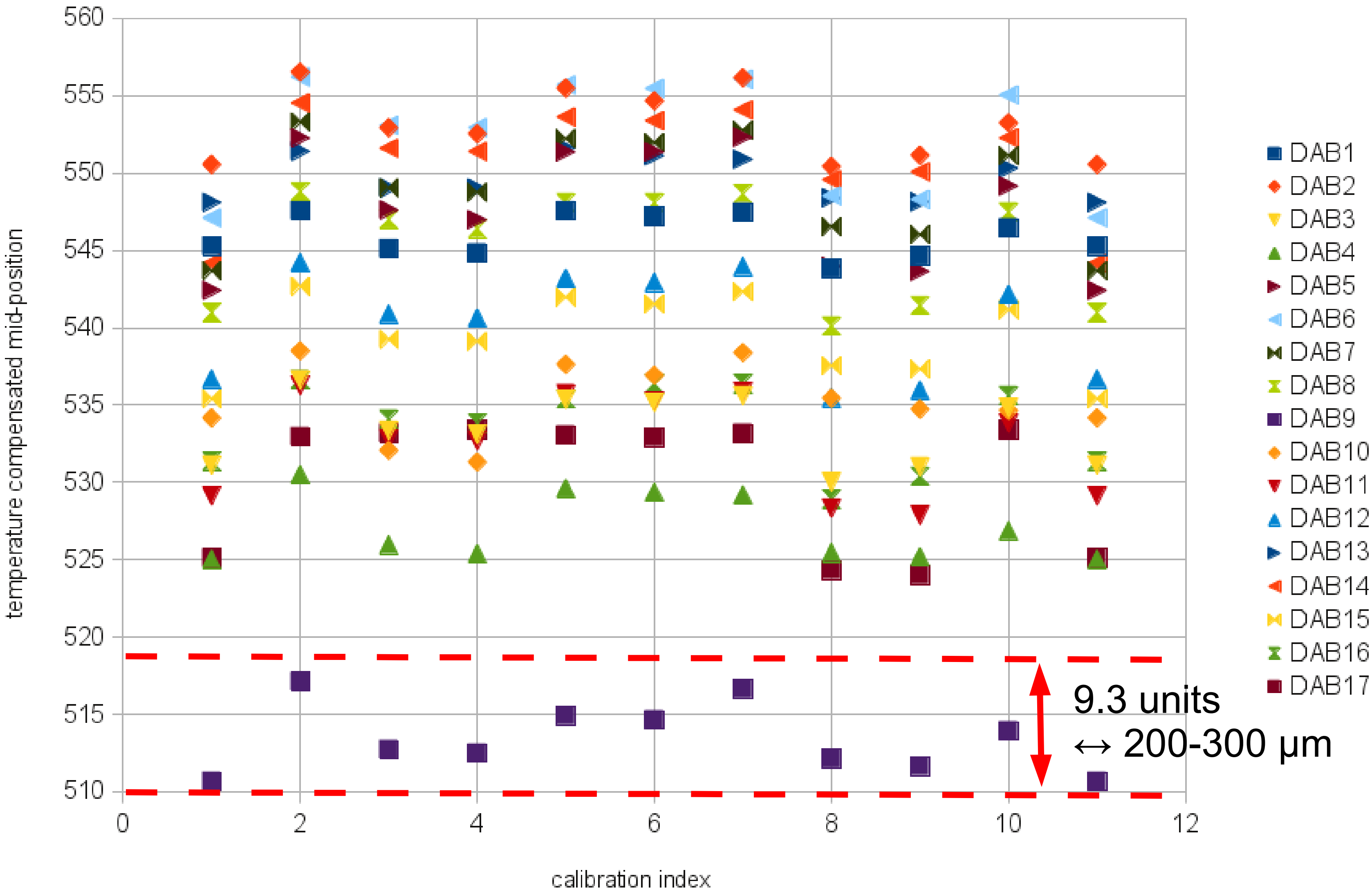
Conclusions

- Achieved measured fill-to-fill orbit stability of about ≤ 1 σ over the past two month of physics which was better than the allocated 2.5 (/1.6) σ margin between the TCT and dump protection...
  - Could one consider leveraging this by basing the tolerances on the actually achieved rather than specified beam parameter stability?!?
  - Orbit interlock de-facto enforces these tight tolerances
- Orbit stability ultimately limited by the performance and BPM systematics
- Little margin to gain on BPM performance this year – any major accuracy improvement would require additional hardware and machine modifications, i.e. temperature controlled racks, additional acquisition chains & pick-ups.
- Nevertheless, there is some margin to improve certain specific items:
  - feed-forward corrections and adaptive feedback bandwidth → squeeze
  - 'synchronous-orbit' → bunch-filling pattern and spurious triggers that plague the directional couplers in the IRs

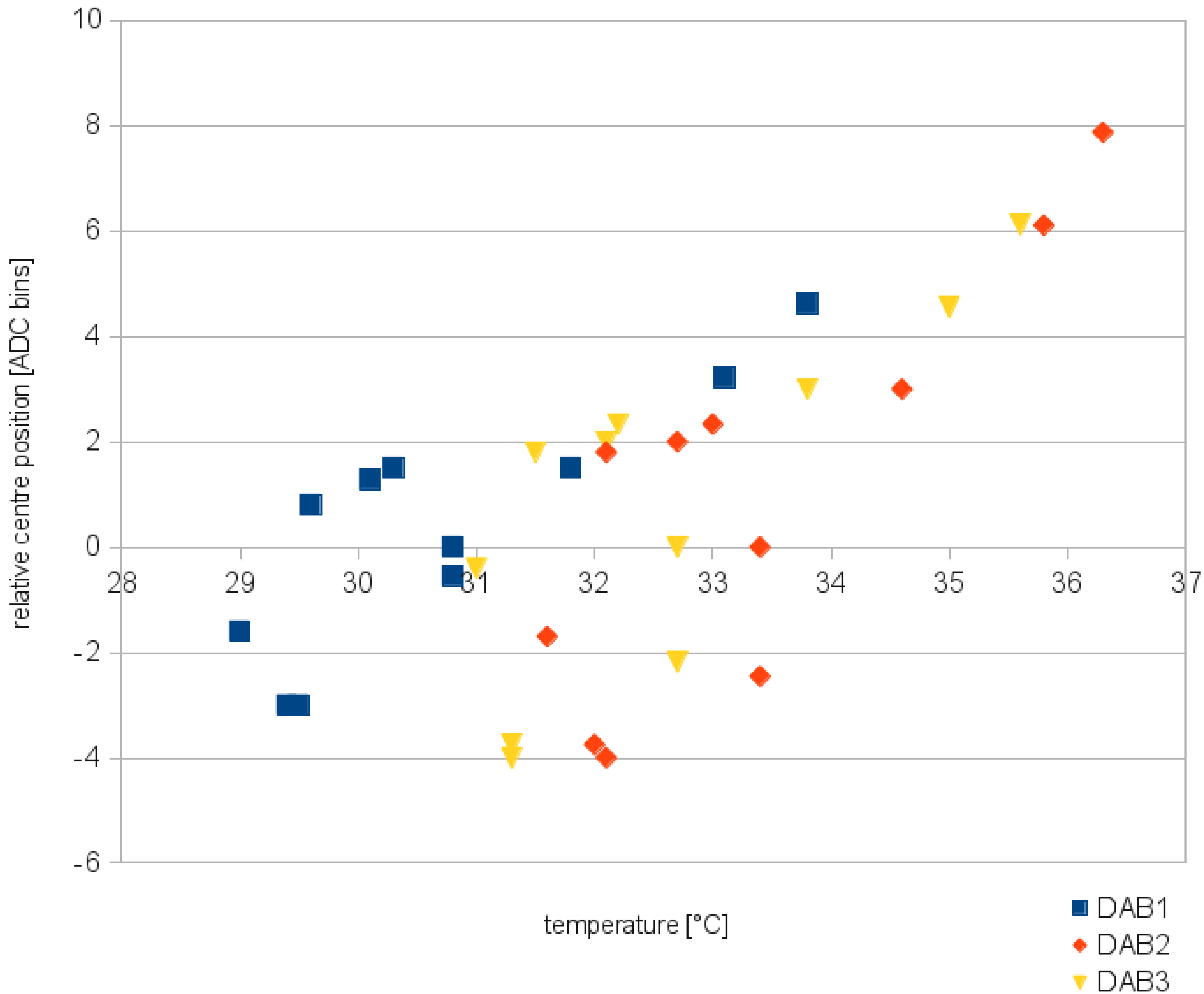
Additional slides

Residual DAB Calibration Stability

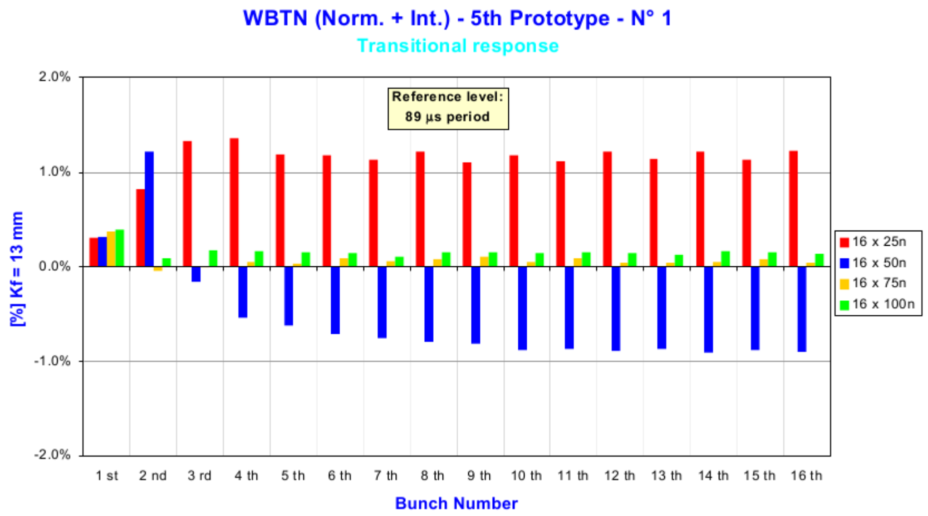
- From LSA... (compensated for DAB reference temperature & coefficients)

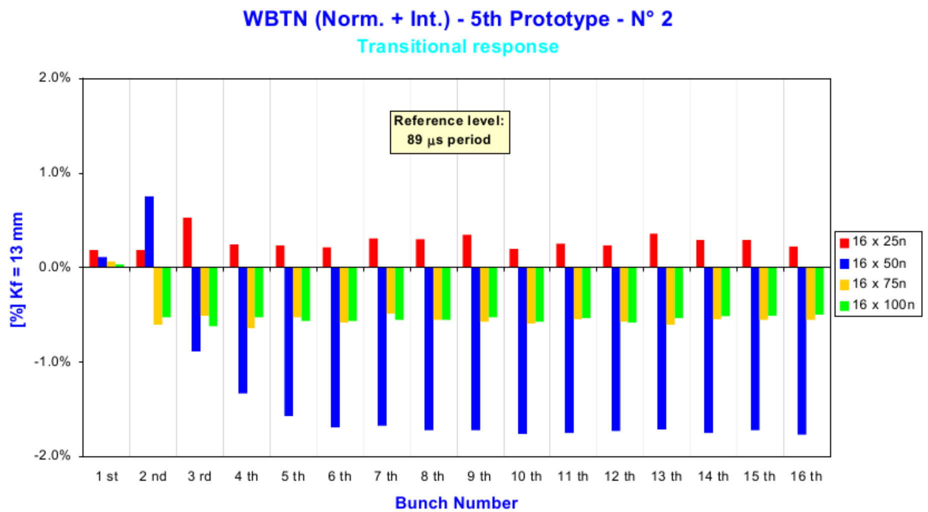


Residual DAB Calibration Stability Correlation with Temperature



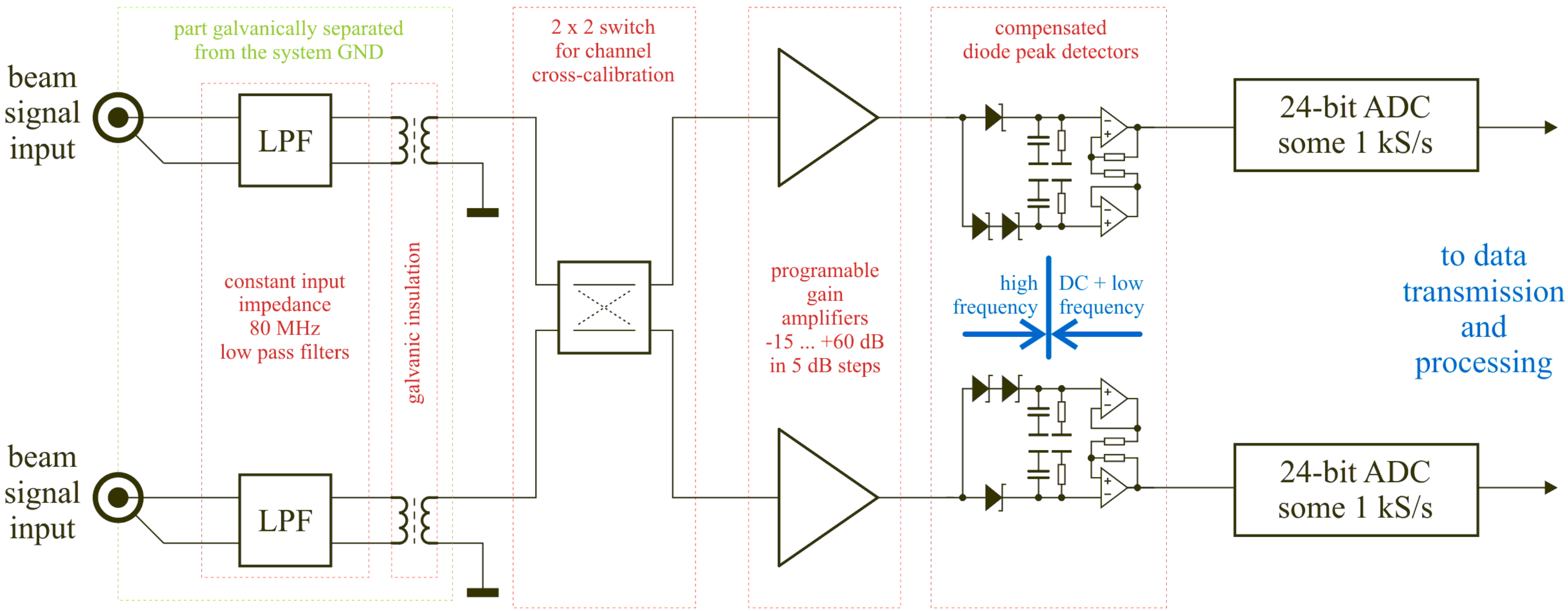
- Largely compensated by choosing the proper calibration mode, small asymmetries remain since true filling pattern contains e.g. gaps to accommodate injection and dump kicker rise-times





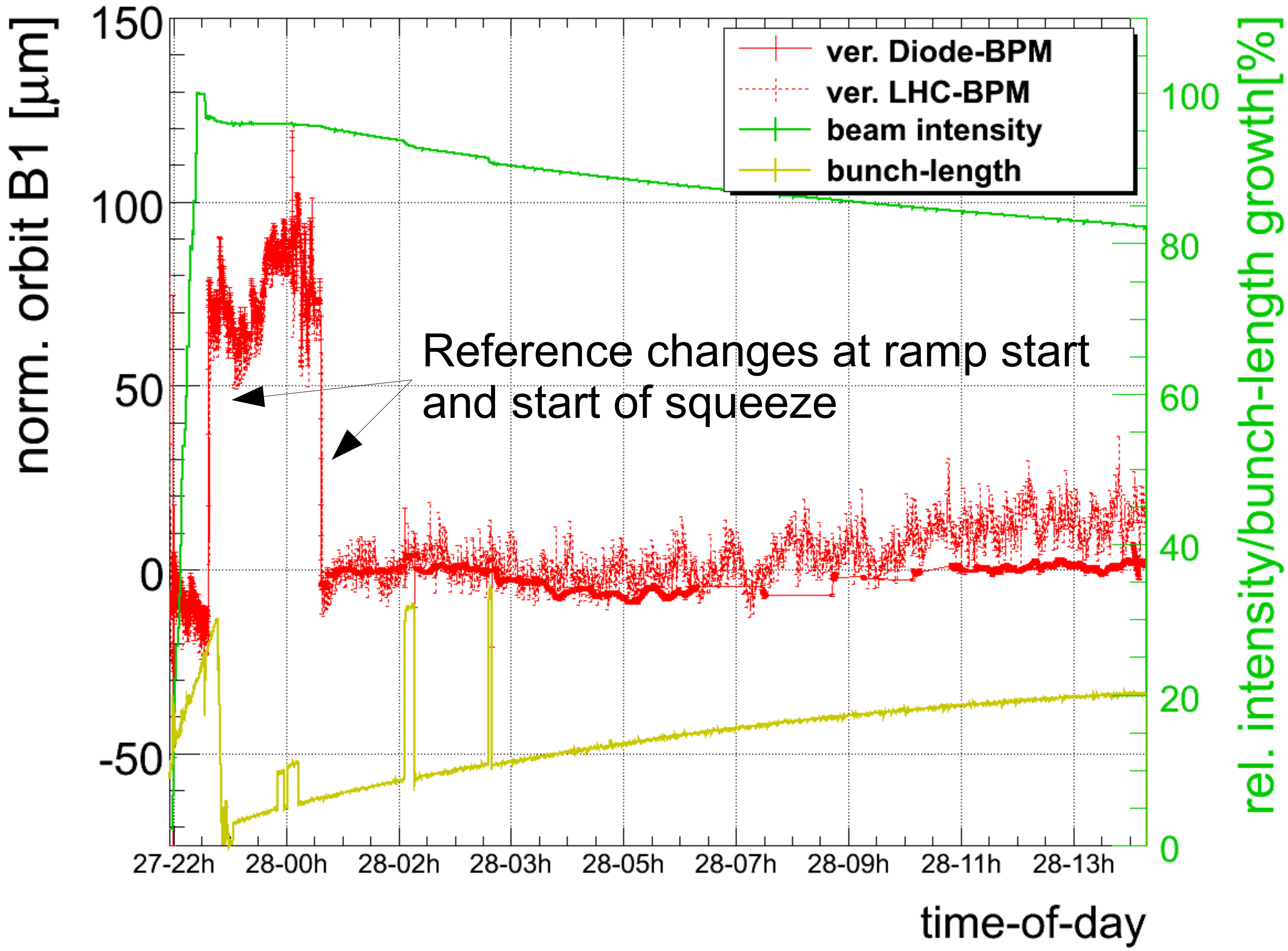
Diode ORbit Acquisition System Functional Diagram

- Primary application: beam-based col. jaw centering using in-built buttons



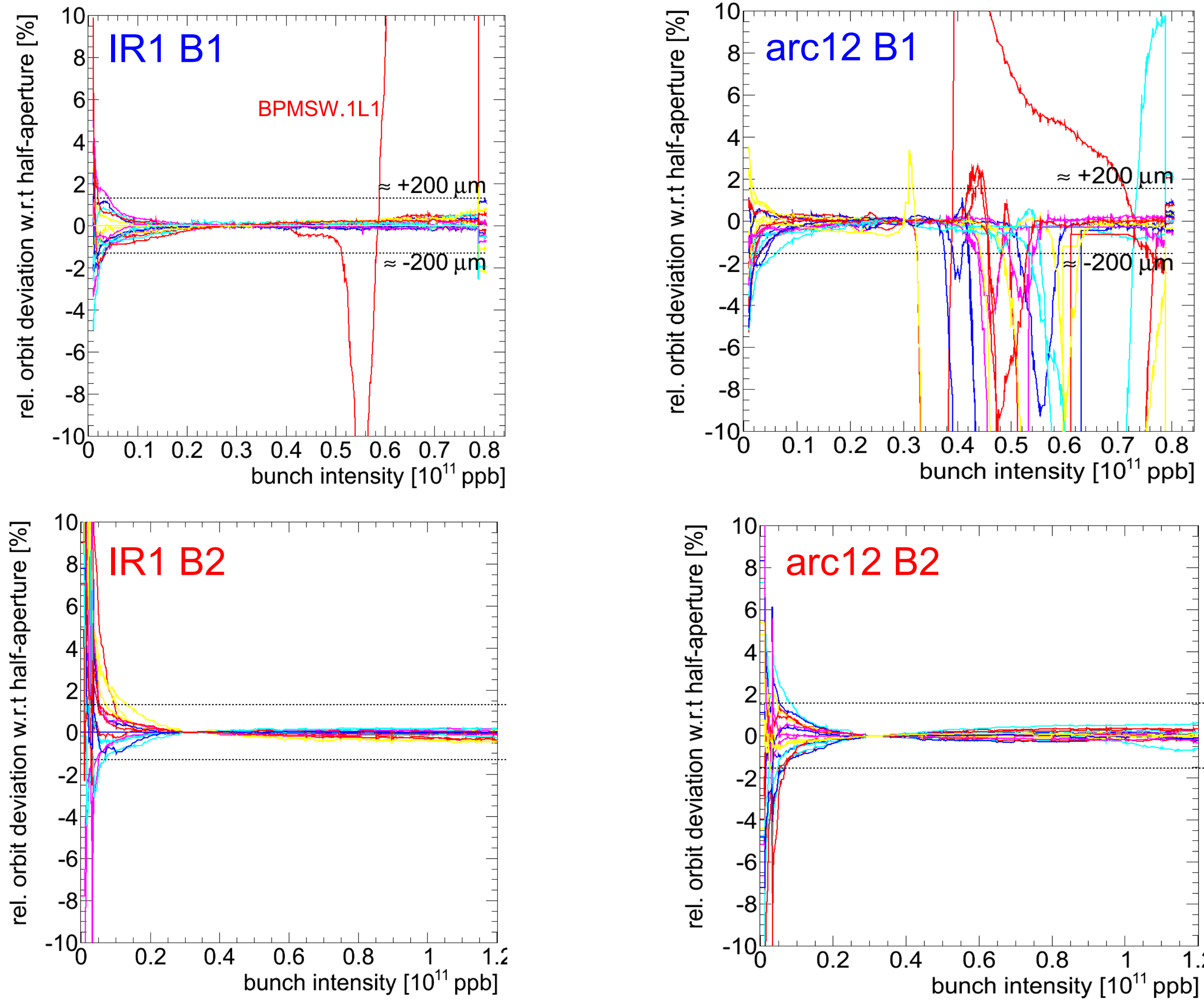
- Excellent μm-level resolution and stability
- Still, no "silver bullet" solution (yet) due to important non-linear systematic for off-centre beams → require further investigation

Orbit Stability during one LHC Fill



- Orbit stability during physics < 5 µm over 15 hours (Orbit-FB 'off')
  - new high-accuracy diode-based beam position monitor system: Δx_{res} < 0.5 µm

Residual LHC BPM Dependence on Intensity II/IV
High-Sensitivity Mode



Residual LHC BPM Dependence on Intensity III/IV
Low-Sensitivity Mode (standard operation)

- Better 'B1 vs. B2' symmetry for LSS BPM after intensity card removal
  - Only a few specific channels dropping out a earlier … to be investigated