Triplet movements and beam separation

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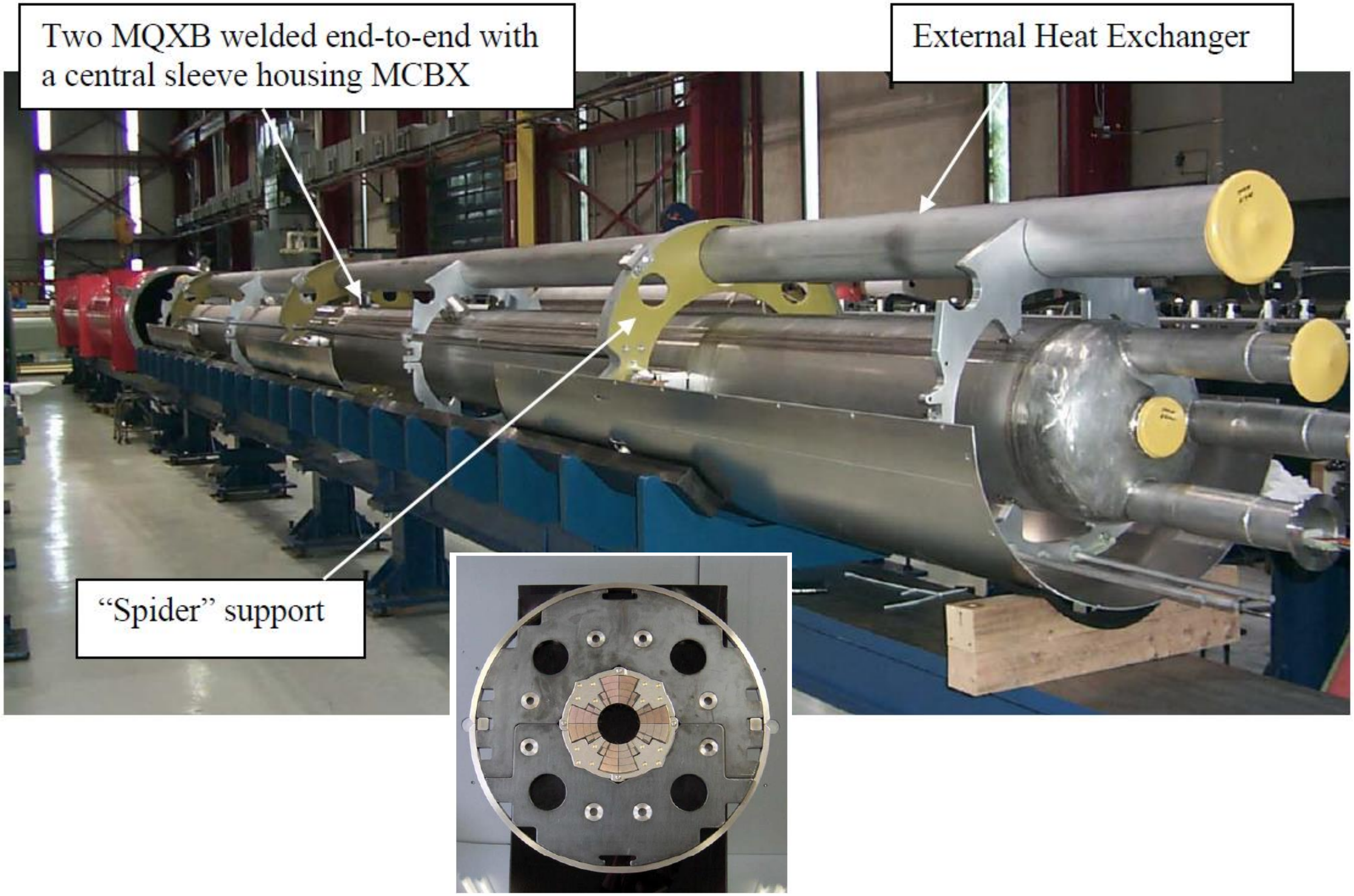
Triplet movements

- We know since last year that the LHC triplet positions are sensitive to the temperature of the IT thermal shields (50K-80K).
  - *In 2015 we had to switch on the orbit FB in stable to keep to orbit in place.*
  - *The driving triplet was in R8.*
- In 2016, contrary to 2015, the changes were much slower and the orbit amplitudes (in a fill) generally smaller (factor 2-3), despite the large β in the triplet of IR1 that dominated this year.
  - *In 2016 the driving triplet is in R1.*
- Temperature variations lead to radial displacements of the triplet magnets of **~10's of μm** that in turn induce orbit drifts and separations of the beams at the IPs.
  - *The movements can be observed, at least qualitatively, with the **Wire Position System (WPS)**.*
  - *Mitigated with OFB in stable beams. The OFB mitigates well the impact of a triplet movement on the machine, but it cannot correct locally the IP shifts very well. Regular re-optimizations must be performed at the concerned IP → see later !*

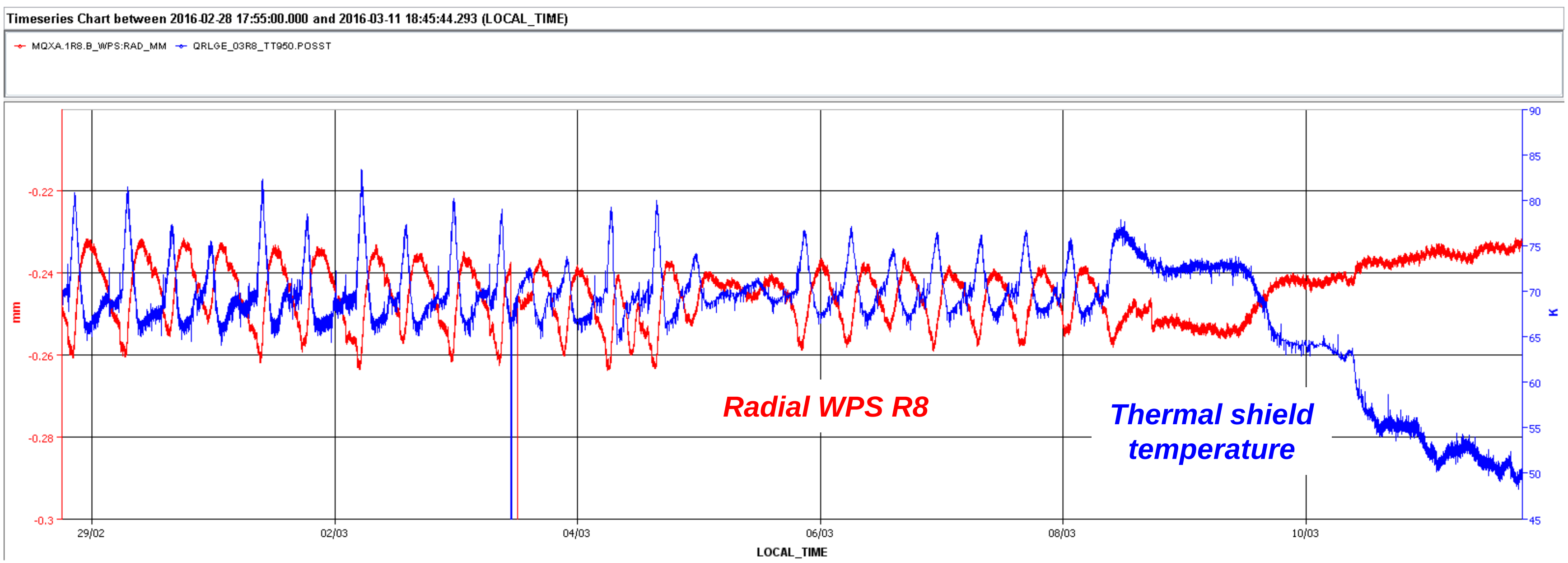
Triplet support

- Triplet spider support.



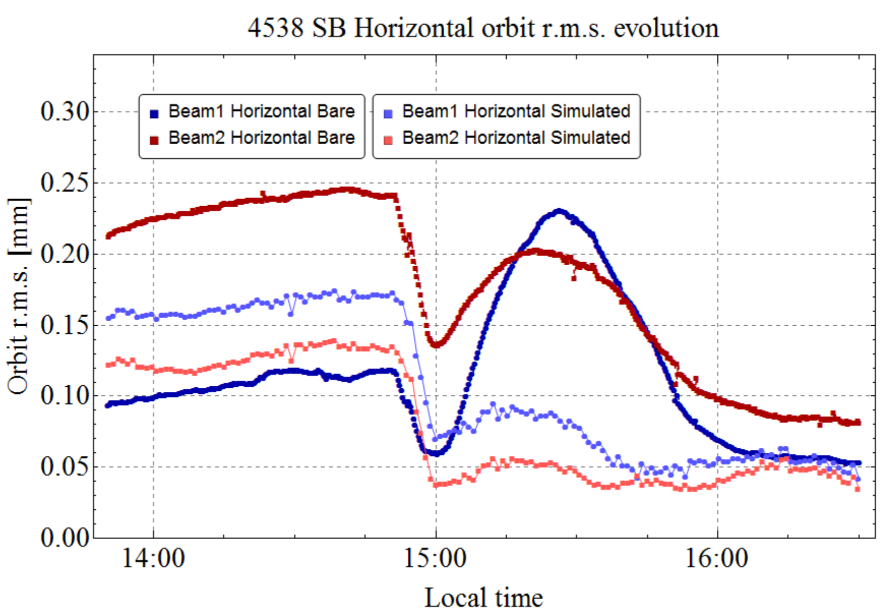
IR8 - 2015

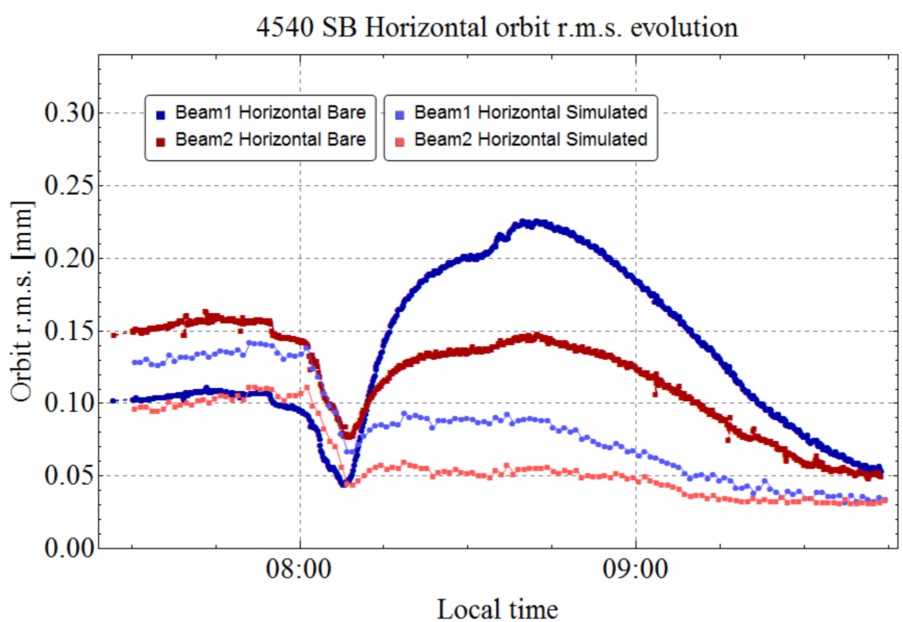
- The triplet movement in IR8 revealed for the first time the important sensitivity to the thermal shield temperature (or another hidden parameter behind it). And with its large amplitude and fast changes ‘spoiled’ many measurements.
- In IR8 the problem came from a regulation valve that did not move correctly (not repaired, mitigated by a change of operating point).



IR8 - 2015

- The WPS provided excellent semi-quantitative monitoring of the CM movements.
- Attempts to simulate the orbit change with the WPS data yield good qualitative agreement, but the amplitude of the orbit movements is off by ~ factor 2 – depends on the phase.

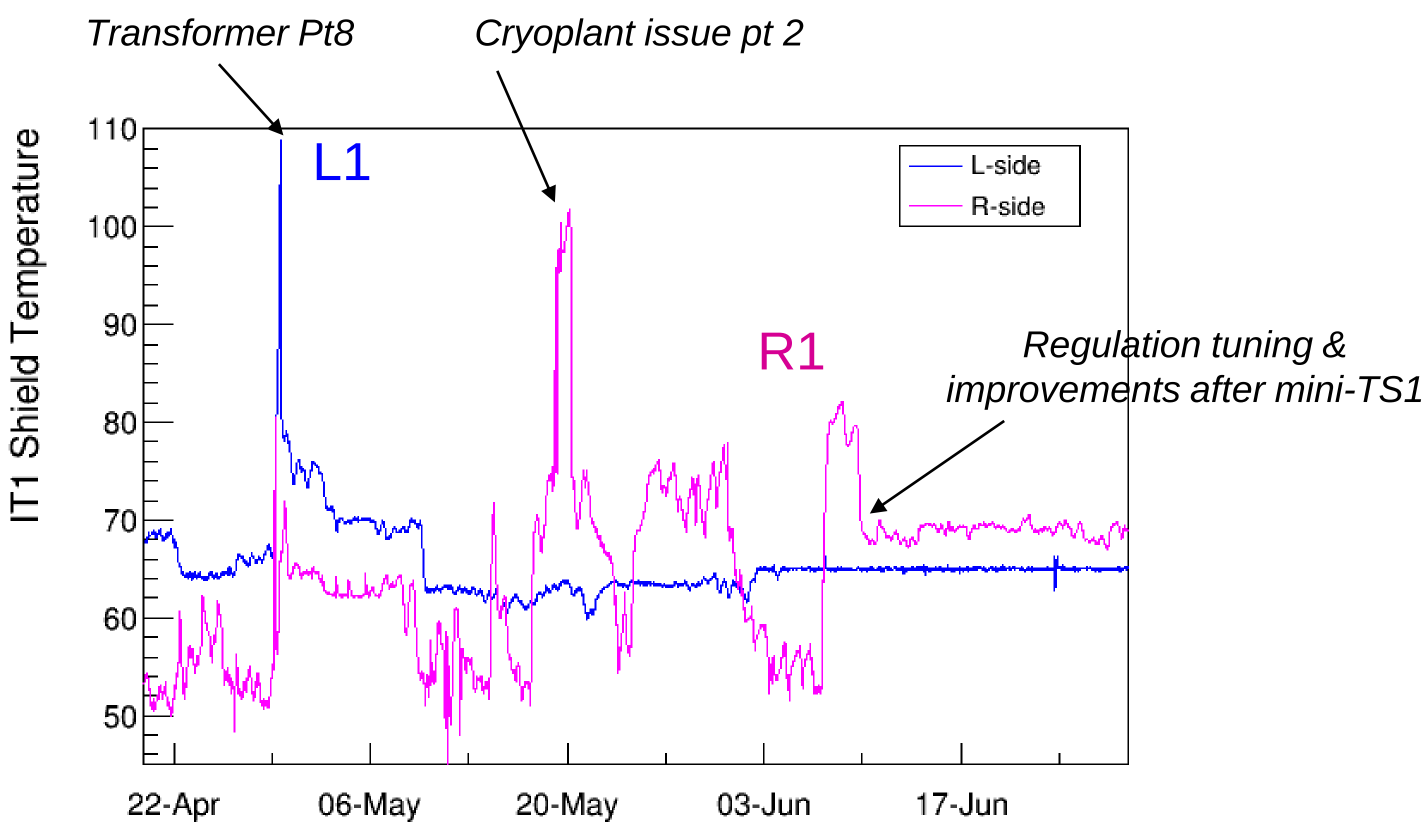




A. Gorzawski

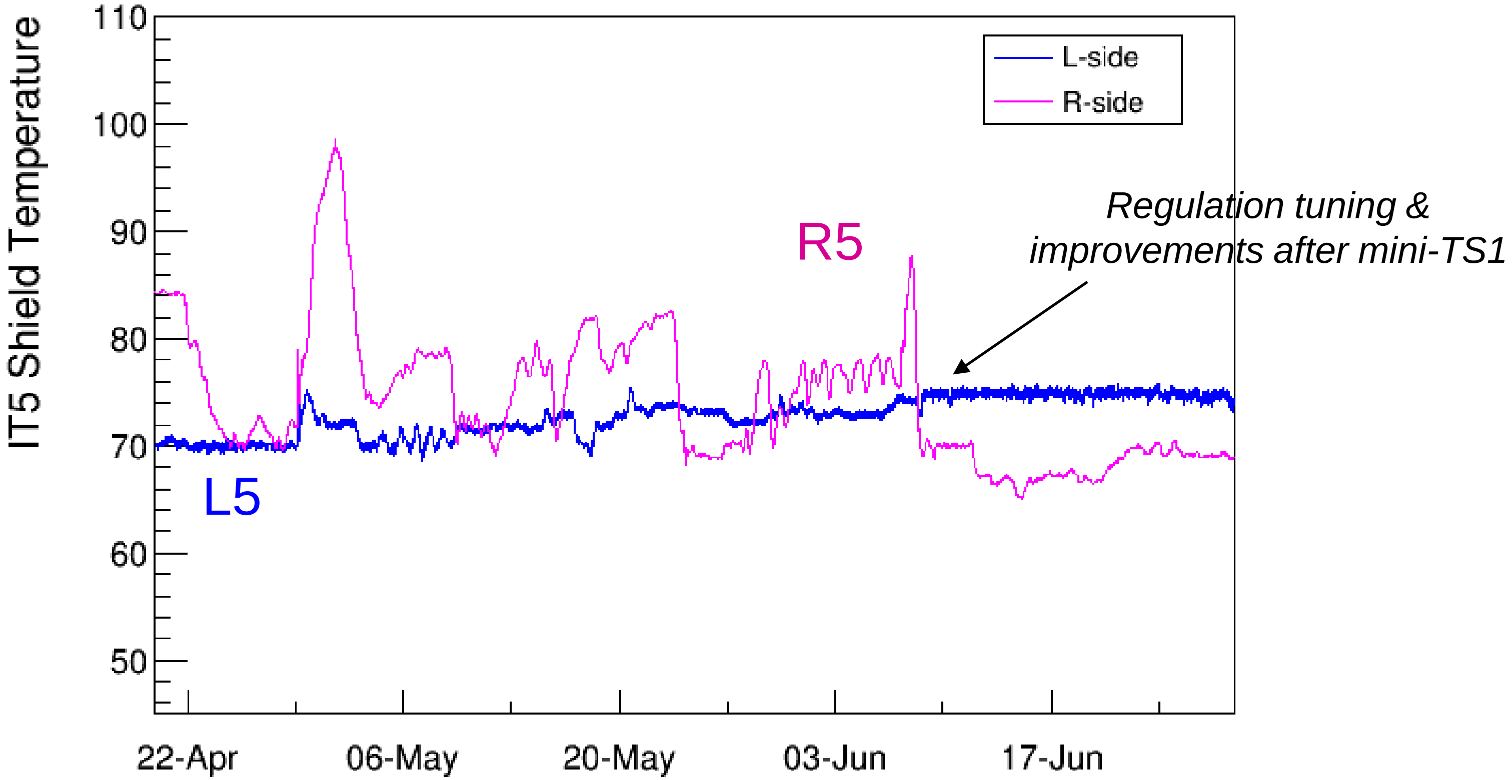
Triplet thermal shield – IT1

- In 2016 the IP1 triplet thermal shield temperatures varied significantly over time, in particular in **R1**. This triplet is ‘behind’ S12 with its high e-cloud load.
- IT **L1** was strongly affected by the ‘fouine’ transformer event: large pressure wave and high temperature that led to a transverse movement of ~170 μm of one the magnets.
  - *Magnet moved back with motorized jacks. The magnet has settled in the new position.*



Triplet thermal shield – IT5

- Temperatures are rather stable in IR5.
  - *Same scales for IT1 and IT5 !*
- L1 ad L5 were always ok, stable to ~5K.

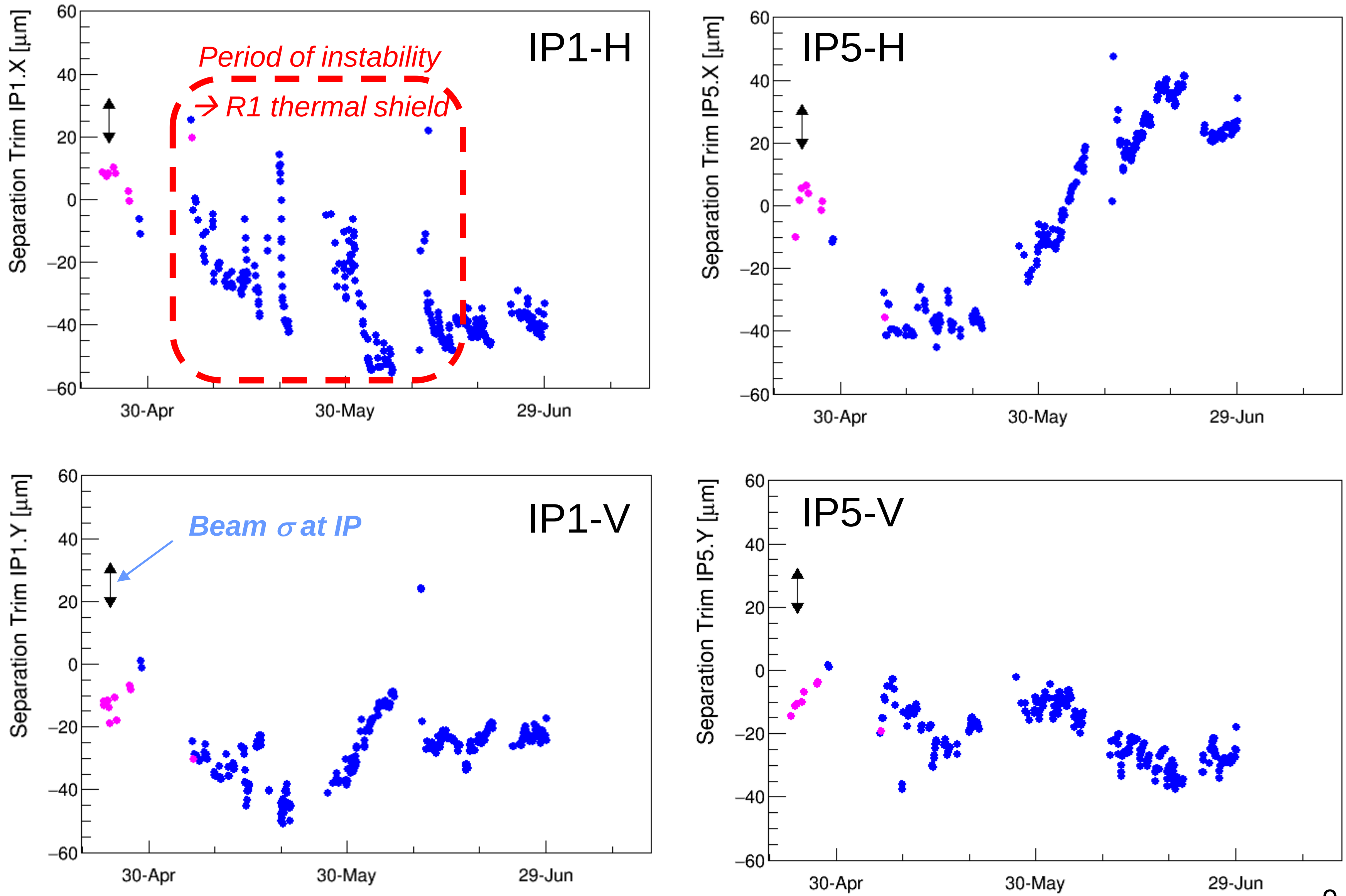


Impact on orbit

- The triplet movements generate deflections (→ orbit perturbations) inside the triplet. Such a perturbation can only be properly corrected with the triplet MCBX (HV) correctors.
- Unfortunately the QPS system on the MCBX does not appreciate the OFB very much → fake trips due to voltage spikes.
  - *Since 2010 the MCBX are excluded from the OFB configuration following a few tests that ended with power aborts.*
- The best correction the OFB can provide (ultimate orbit correction in terms of orbit rms) will close the perturbation around the triplet at the Q4 & Q5 → leaves a local bump.
  - *The OFB protects perfectly the other IRs from the perturbation, but not the local IR where the triplet movement occurs.*

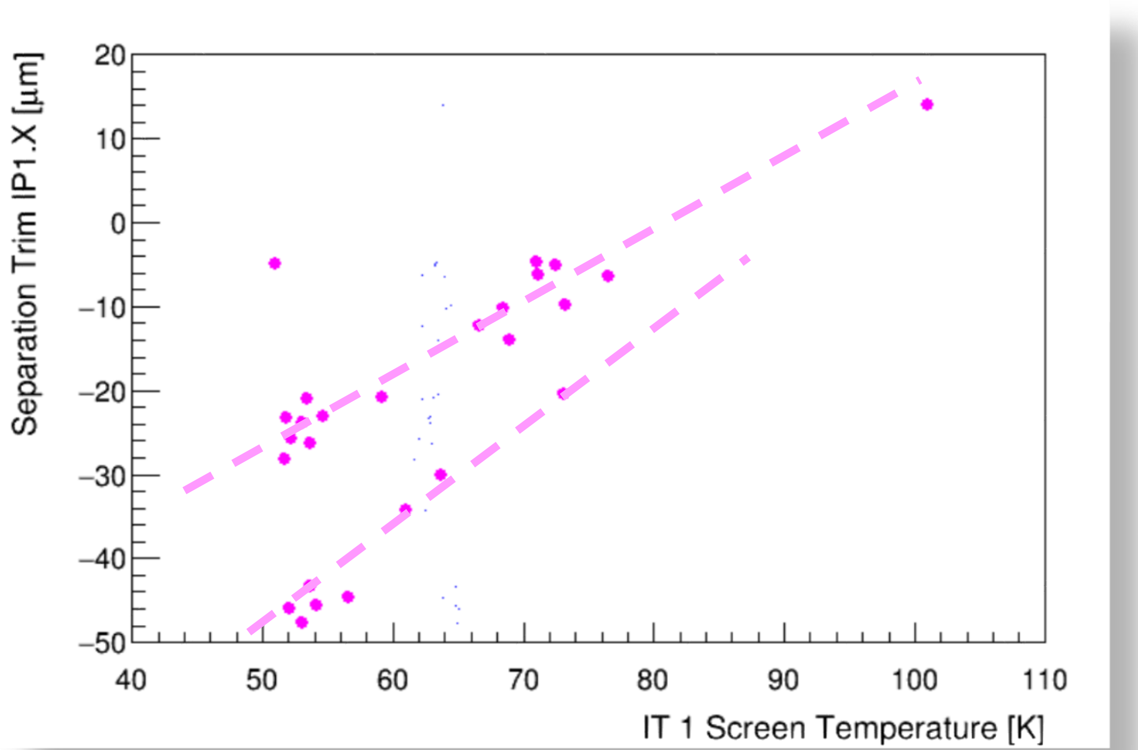
- The evolution of the corrections that have to be applied to bring beams head-on versus time evolve due to ground motion, but also carry the signature of the thermal shield temperature → next slide

Beam separation trims 1 & 5



IT R1 correlation

- There is a reasonable correlation between start of fill separation data and R1 triplet temperature after mid-May.
  - *Two groups of points corresponding to different time intervals.*
- The slope is ~ **0.8-1.2 μm / K**.

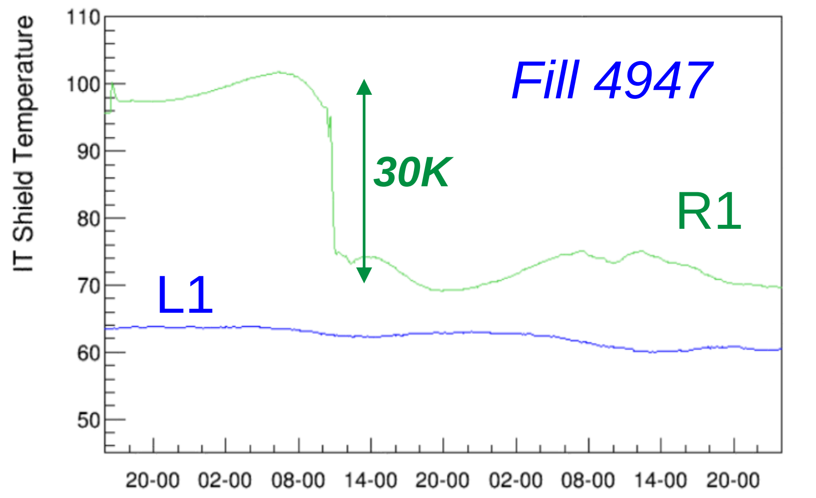


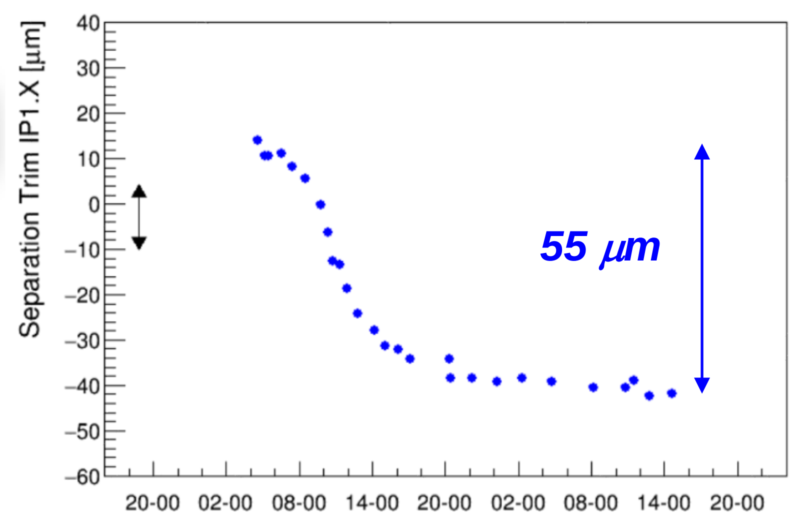
R1 temperature ‘jump’ in stable beams

- During a 36 hour fill, the IT R1 was brought back to its nominal temperature during the fill (following a problem of the cryo plant).
- The overall change of 55 µm for 30K (**1.8 µm/K**) is a factor ~ two larger than the slope of the previous slide.

Typically ~1.5 µm separation / K

- Valid for all triplets?
- Cryo is now maintaining the T of all thermal shields within 2 K.





Summary

- Over the last 2 years we had two clear cases where temperature variations on the thermal shield induced triplet radial movements of some 10's of micrometers.
  - *The sensitivity of beam separation to temperature is established for one triplet.*
  - *The root cause is not understood as no significant thermal effect is expected at those temperatures.*
- The cryo team is now well aware of the problem. They have changed the regulation of the thermal shields during the technical stop and are now maintaining the temperature within ~ 2K → no more problems.

‘Best’ rms correction

- Simulation of a 1 μrad kick @ Q1.L1 with maximal correction when MBCX are excluded (as usual) from the correction. The beam separation at the IP is ~not corrected. A <u>small residual crossing angle</u> is also introduced.
  - *The correction eventually closes the kick perturbation perfectly just outside of the triplet (Q4-Q5) → no effect on the ring, leaves only the local perturbation.*