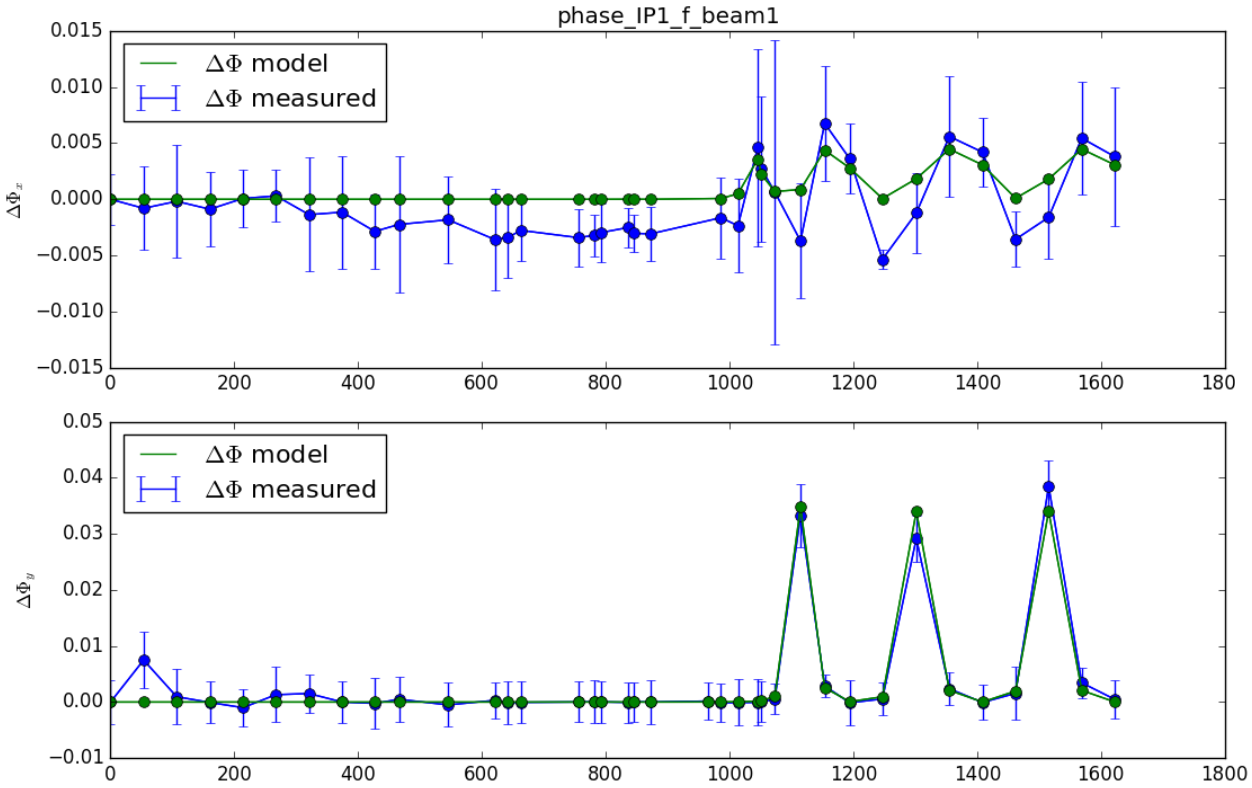
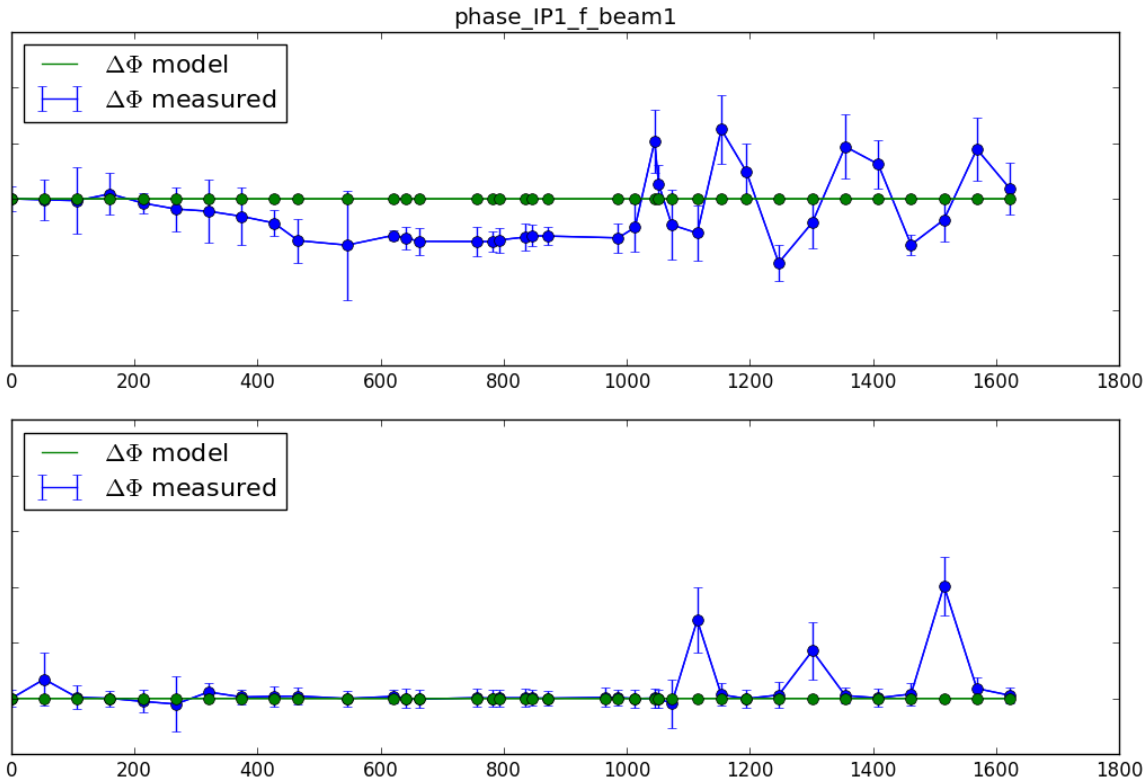
Results form operation and MDs and implications for HL-LHC: Linear corrections

Jaime Maria Coello de Portugal – Martinez Vazquez

Flat optics MD

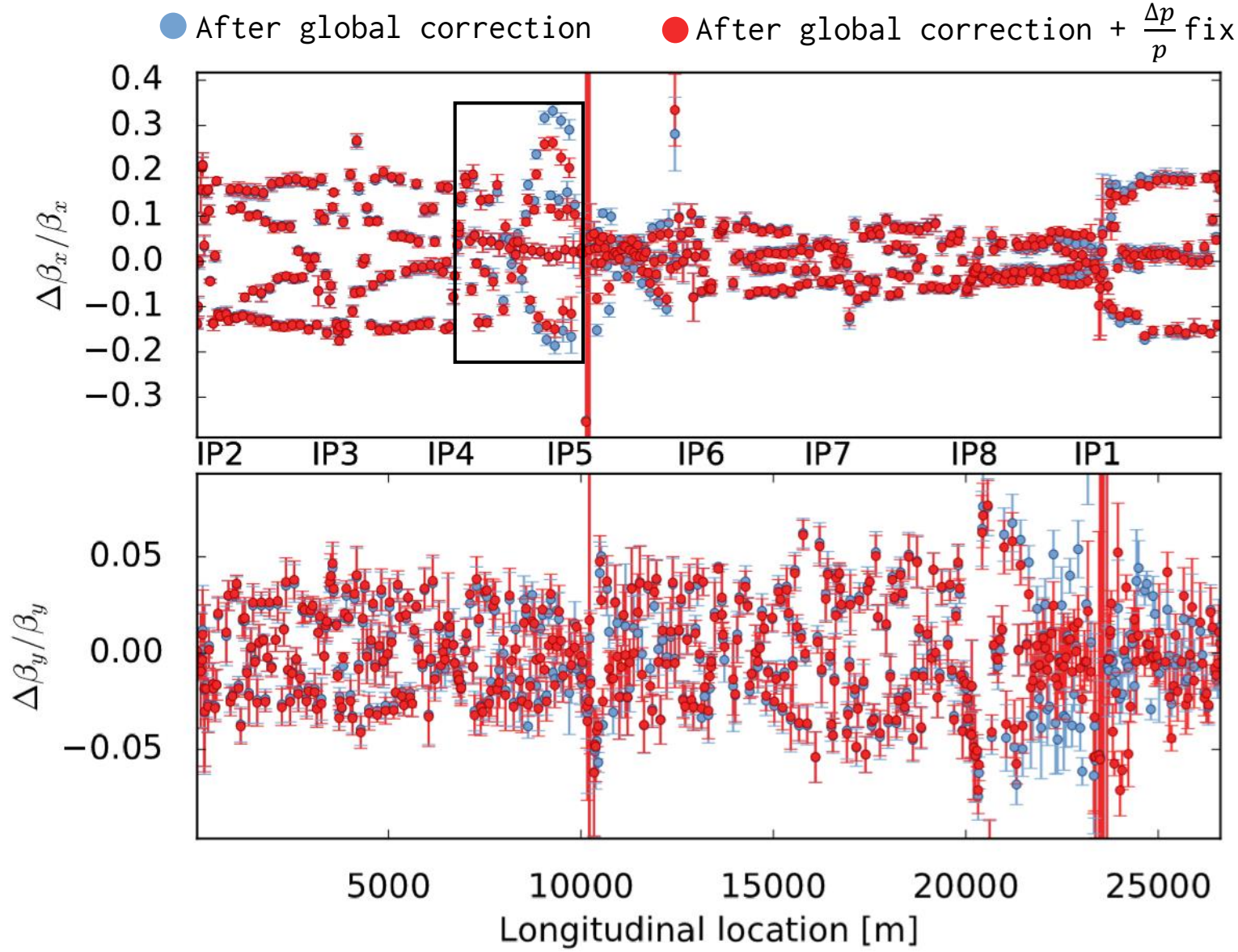
- Clear local error found in IP1 vertical plane





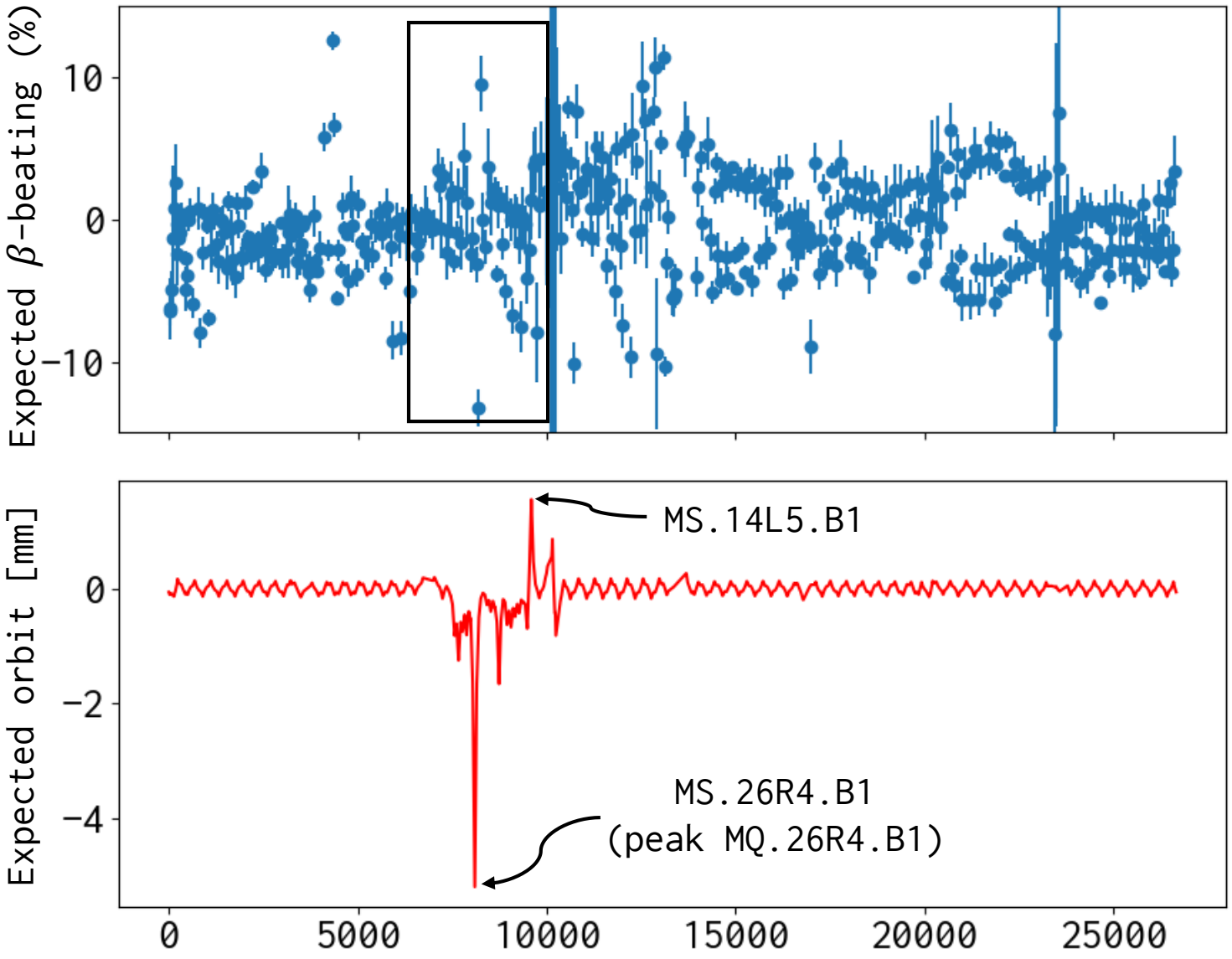
- Matched using the automatic tool
- Only matched beam 1 and then checked that beam 2 more or less OK with ADT-kicks
- Errors differ from round optics

- Setting the residual $\frac{\Delta p}{p}$ in the model accounts for another 5% peak β-beating
- But β-beating in arc 45 remains uncorrected (also seen in 10cm round optics*)
- Our normal global corrections seem to have little effect in this region.
- Try to do a correction with orbit bumps in the sextupoles?

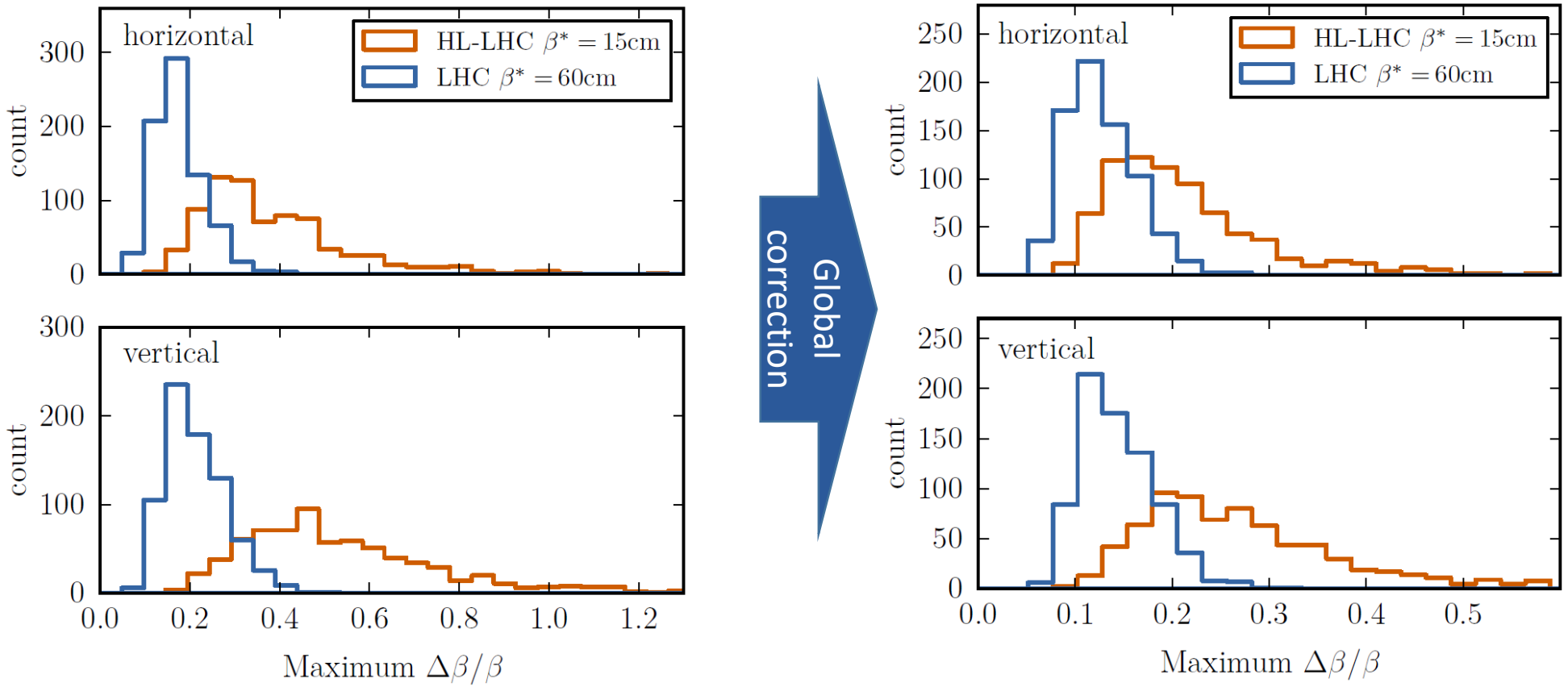


*https://cds.cern.ch/record/2290899/files/CERN-ACC-2017-0088.pdf?

- Perform the typical global correction using non-common quads
- But including all the π-bumps in the 45 arc
- The β-beating is expected to vanish in the region
- …but an orbit of up to 5.2mm is needed in MS.26R4.B1
- Using 4 combined bumps for strong and weak sextupoles in R4 and L5 does not seem to work…
- Deeper investigation of possible local errors around 26R4 needed



- The global correction as we use it now also seems to be more challenging in the HL-LHC*:



*https://cds.cern.ch/record/2290899/files/CERN-ACC-2017-0088.pdf?

Flat optics MD tune jitter

- 60/15cm optics
- Only beam 1 as beam 2 AC-dipole was not working

	Tune jitter [10^{-5}]					
	40cm 2016	40cm 2017	30cm (200m arcs)	25cm (600m arcs)	Ballistic optics 2017	Flat optics 60/15cm
Beam 1 x	5±2	6±2	0±32	3±2	0.9±0.4	**2.3±1.3**
Beam 2 x	4±2	4±2	3±2	1.7±0.8	0.8±0.4	-
Beam 1 y	2.4±1.0	3.0±1.2	1.7±0.8	4±2	0±0.8	**0±1**
Beam 2 y	8±4	0±20	2.1±1.1	2.6±1.3	1.7±0.7	-
W. Average	3.8±1.5	3.9±1.7	2.1±1.0	2.6±1.1	0.8±0.4	-
Sim. Beam 1 x	1.85	1.82	2.22	3.07	1.04	-
Sim. Beam 1 y	1.83	1.81	2.22	3.01	1.01	-

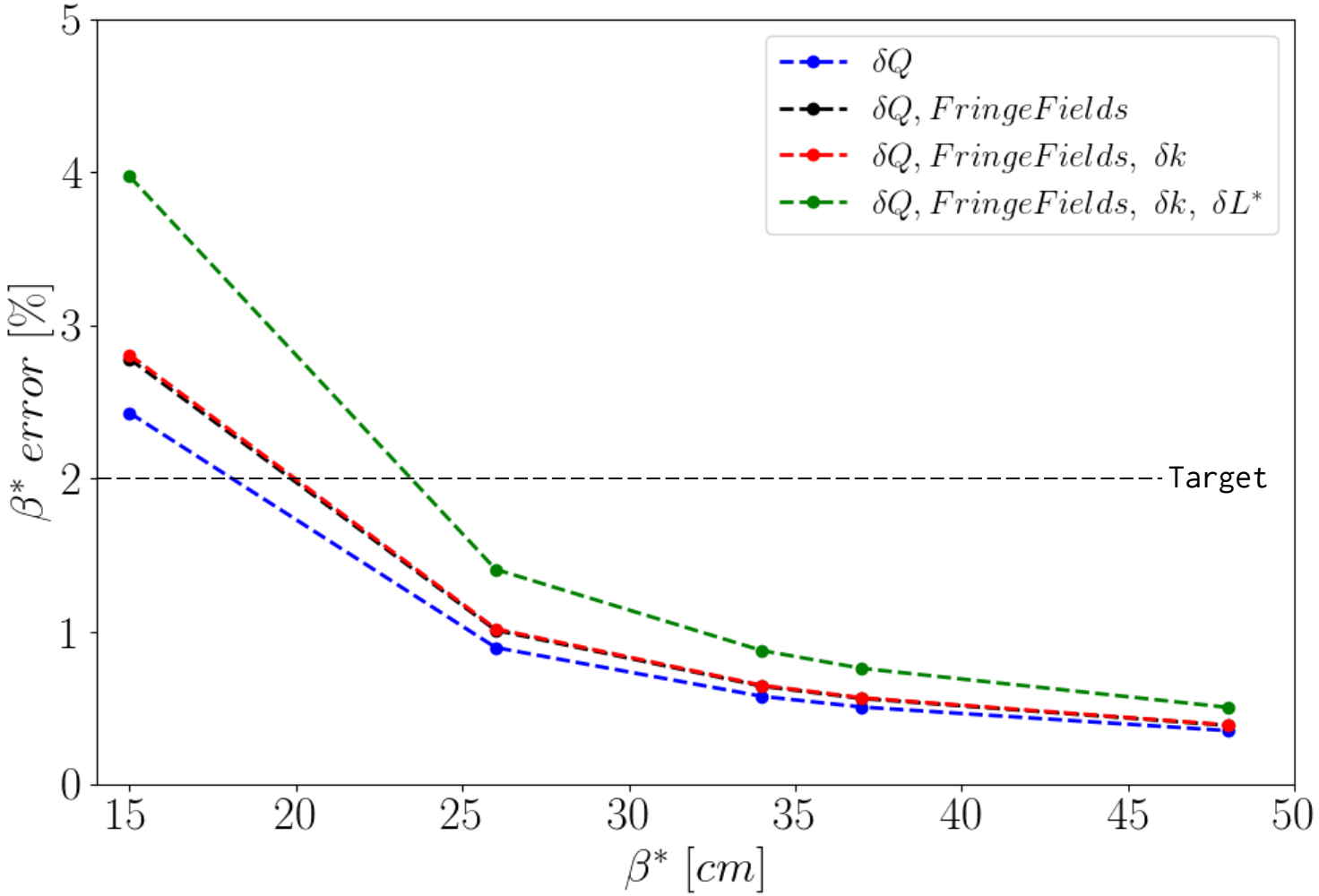
*

- For HL-LHC at 15cm with the upgraded power supplies in the ATS bends* → Beam 1 tune jitter [10^{-5}] x: 2.77 (4.13 without upgrade)
  Beam 1 tune jitter [10^{-5}] y: 2.75 (4.05 without upgrade)

**Simulations by Davide Gamba*

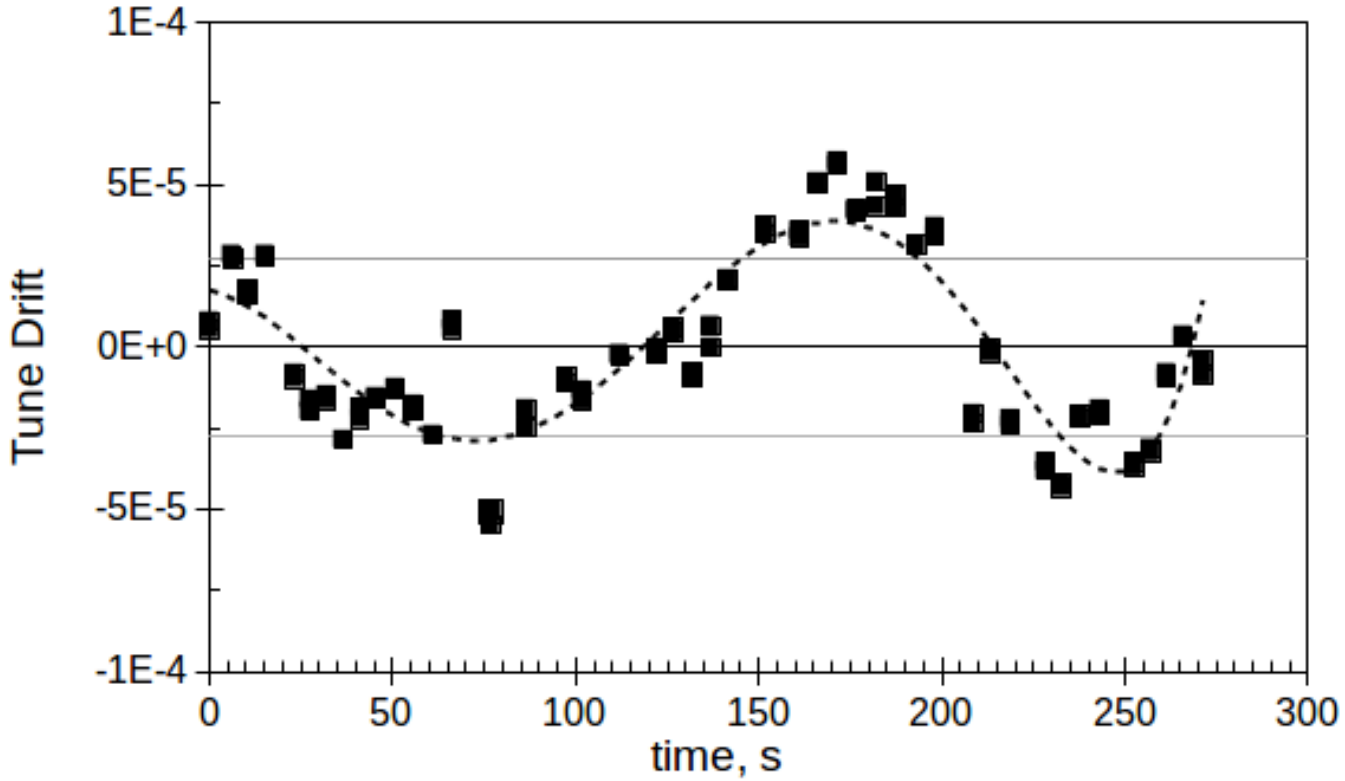
Update on HL-LHC local corrections

- β-beating in the IP with $2.5 \cdot 10^{-5}$ tune stability
- Trimming only the innermost part of Q1
- In RMS, the target* of 2% β^* error would produce around 5% luminosity imbalance between IP1 and 5
- Still far away from the target for 15cm optics
- The proposed upgrade of the ATS bends power supplies to class 0 will be critical to reach ~$2.7 \cdot 10^{-5}$ tune jitter according to Davide's simulations (not far from the $2.5 \cdot 10^{-5}$ assumed here)



*https://cds.cern.ch/record/2290899/files/CERN-ACC-2017-0088.pdf?

- A oscillation in the tune of a 100s period has been observed in the LHC*
- Measured at flattop (1m)



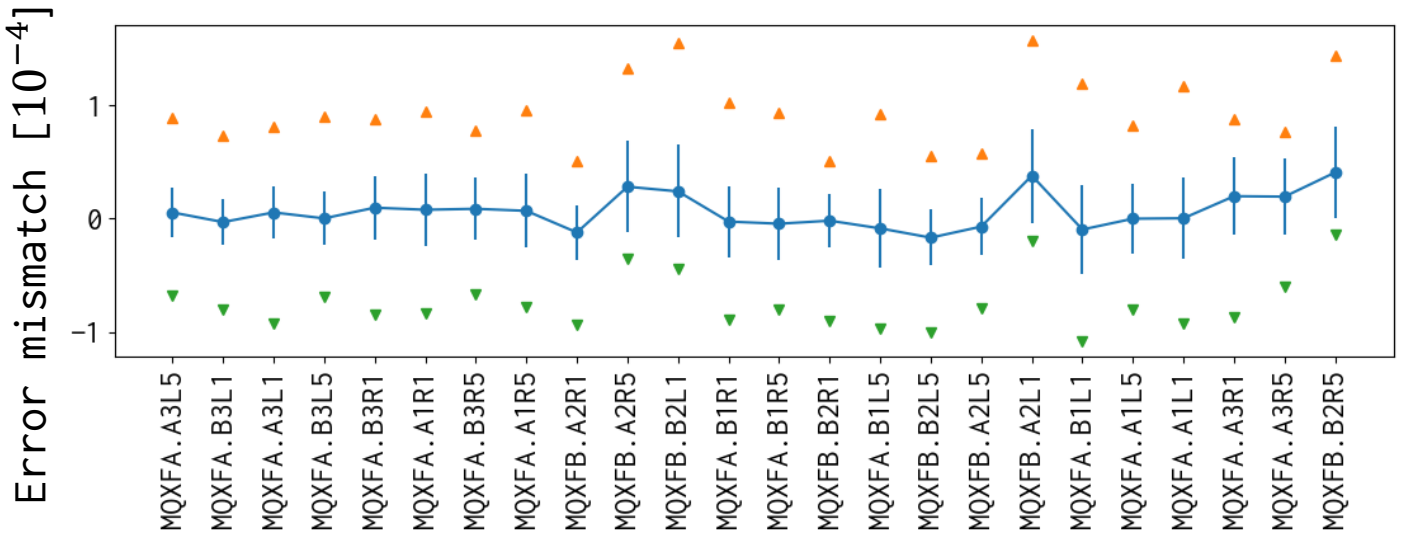
- If it is enhanced in HL-LHC, it could challenge the K-modulation measurements

*Sergey Antipov, collimator impedance MD

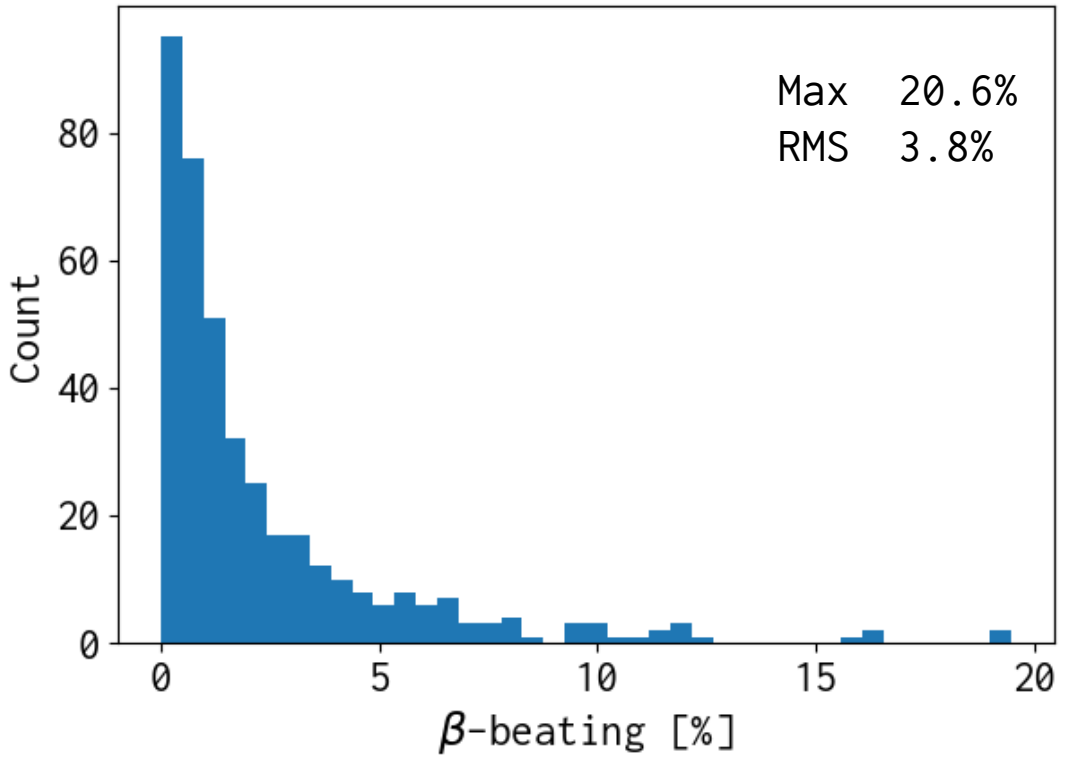
Update on HL-LHC local corrections

- Simulations performed using HL-LHC 1.2 lattice
- Removed the trim in Q2a and applied sorting (pairing magnets with similar errors in Q2a and Q2b)
- 15cm round optics
- 10 units of B2R error in the IR1 and IR5 triplet quadrupoles
- 2mm uniform longitudinal misalignments
- Added the noise in the simulated K-mod measurement corresponding to $2.5 \cdot 10^{-5}$ tune resolution
- Also added 10^{-3} noise to the phase measurement in the focusing BPMs

- The new automatic correction approach gets close to the limit given by the β^* measurement resolution
- The correction is only limited by tune resolution/accuracy
- The correction identifies quadupole errors within 1 unit:

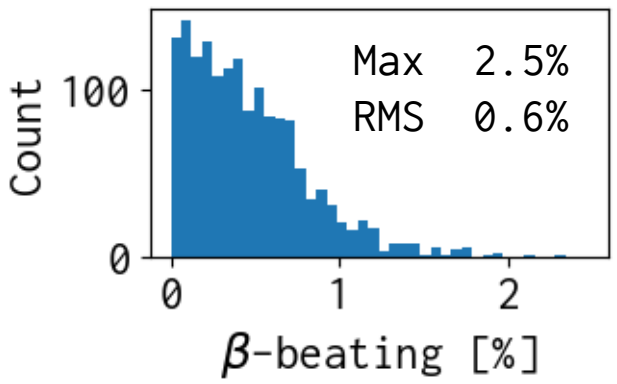


β-beatings in IP1 and IP5

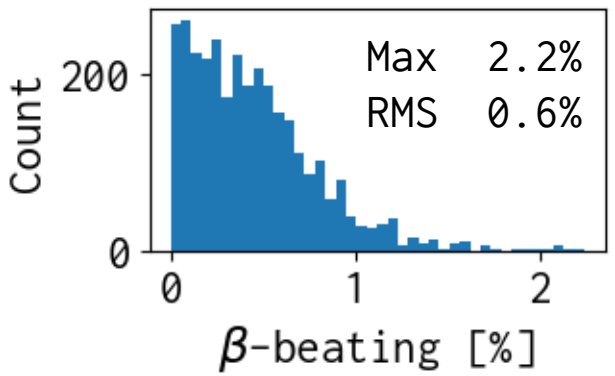


β-beatings in important elements

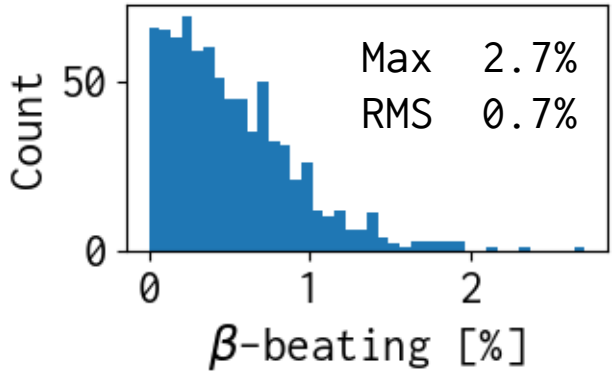
Q2



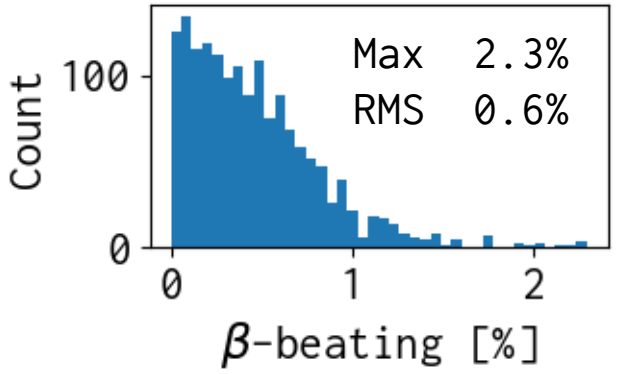
Crab cavities



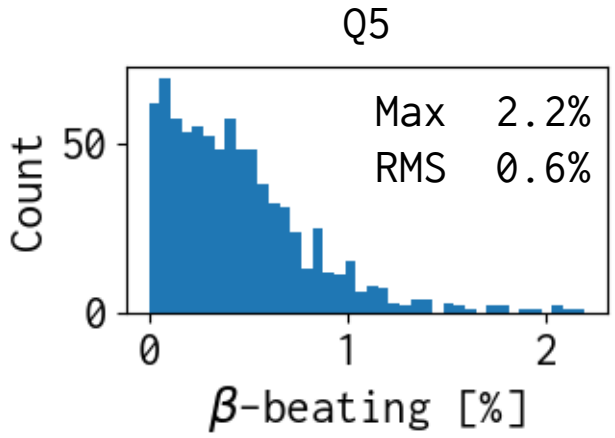
TAXS



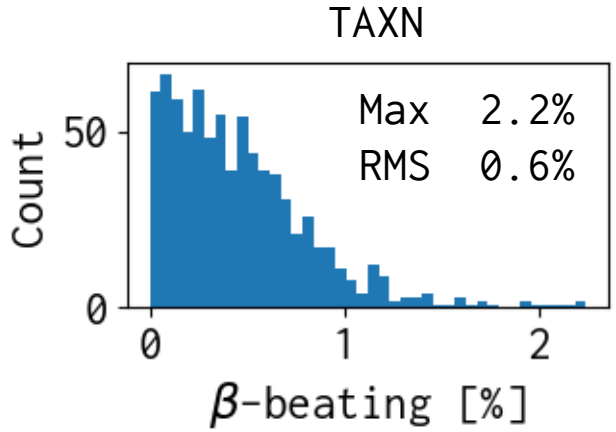
Q3



Q5



TAXN



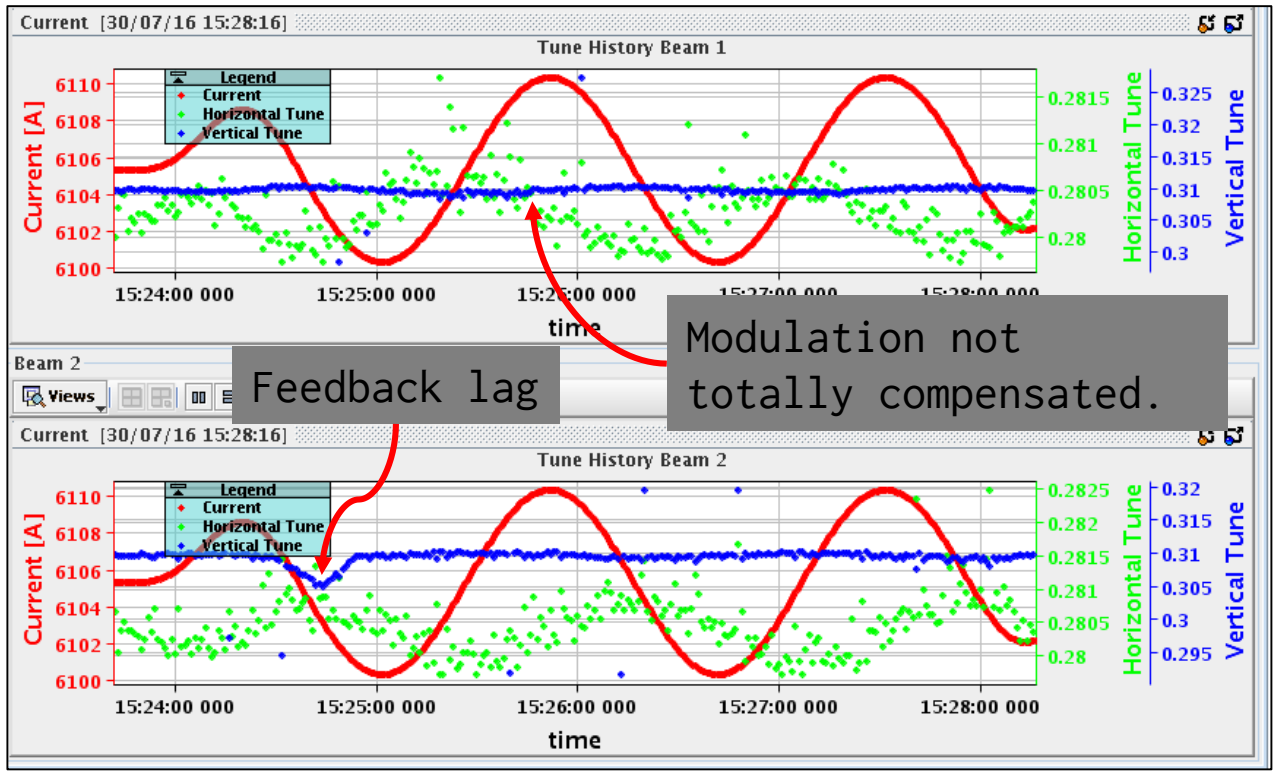
Conclusions

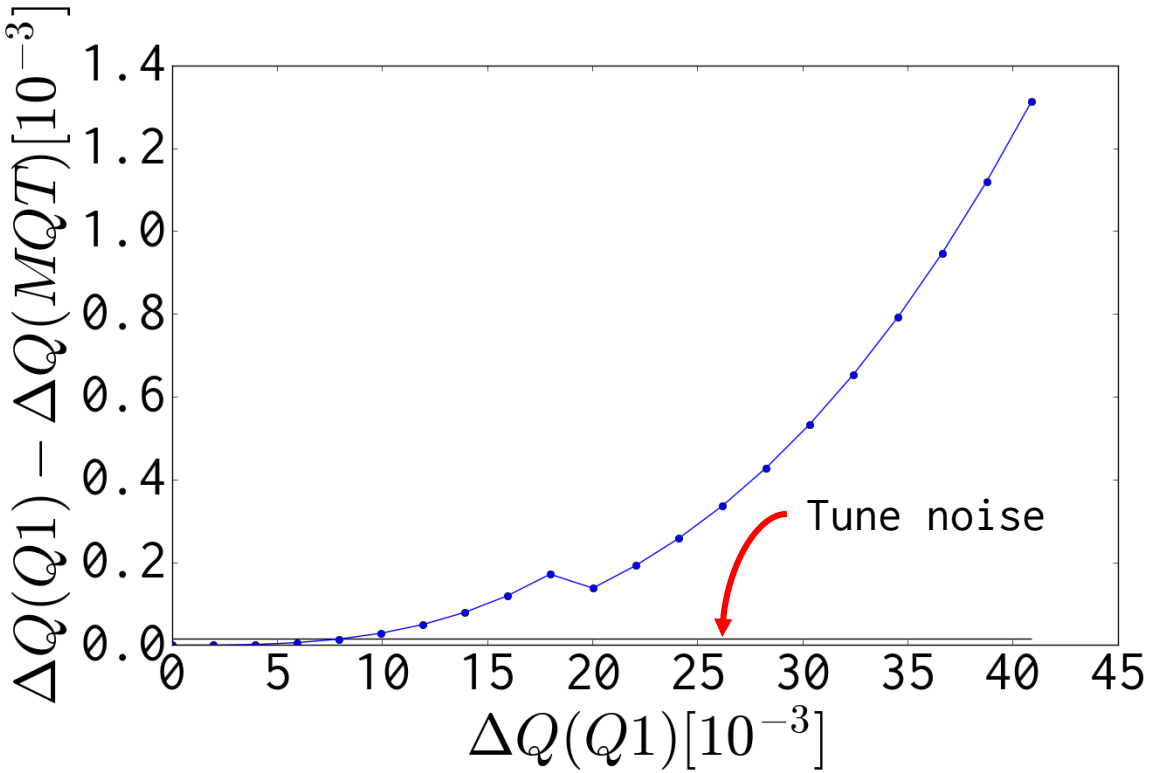
- Local triplet errors differ from round optics
- The β-beating of arc45 might be corrected using orbit bumps, deeper analysis needed
- Upgrading the telescopic bends power supplies to class 0 will be critical to even get close to the desired β^* precision
- The automatic local correction tool is now able to correct to the measurement level at 10 units of B2R
- No significant β-beating leaks to the rest of the machine

Alternatives: K-modulation with tune feedback?

- K-modulation with tune feedback, would allow bigger k trims -> Limited by β-beating coming from MQTs, Q1 and cross terms.
- Not total compensation of the modulation and lag observed:

Measurement

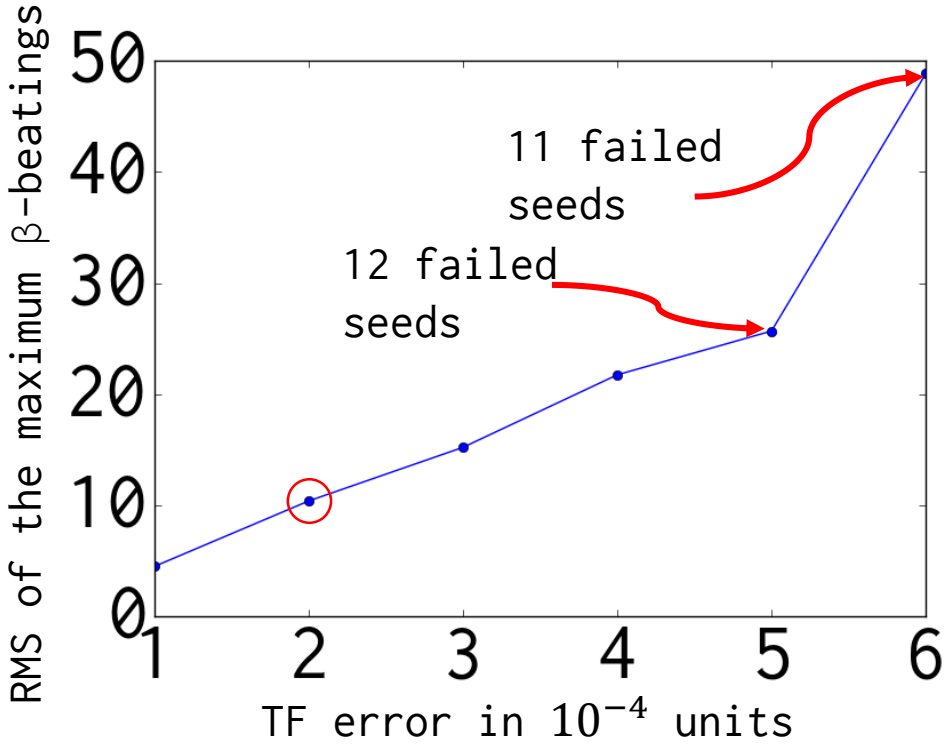


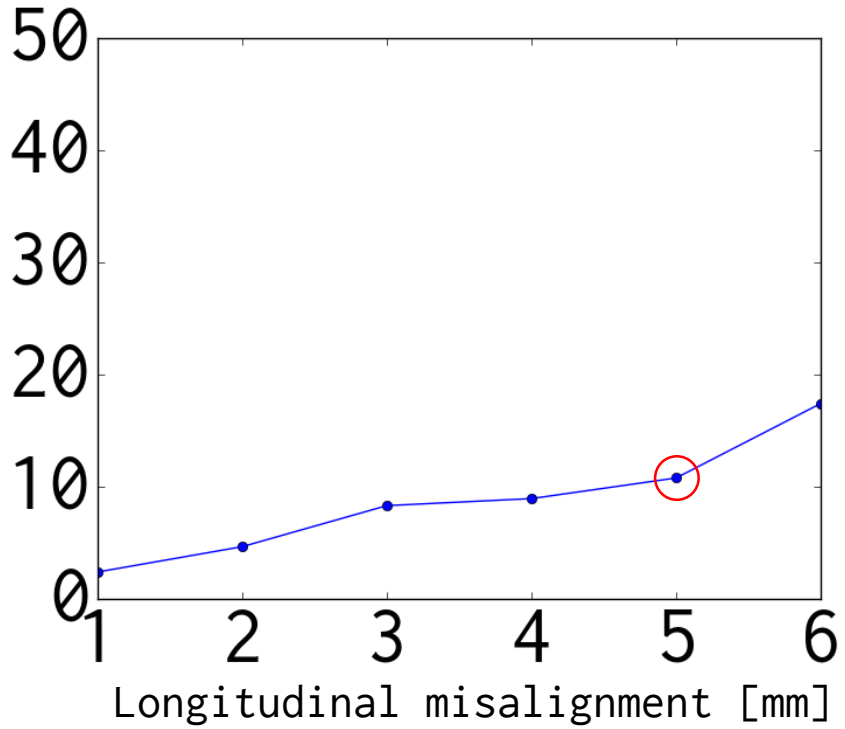


- Very complex alternative, it is unclear if it works.

Effect of triplet transfer function and misalignment errors

- Effect of the errors in the triplet without correction
- 50 seeds per point.
- Independent Gaussian errors in all the quadrupoles of the triplets (IR1/5).





- 2 units of field error correspond to 5mm longitudinal misalignment (round 20cm optics).

- More or less half of the local error corrected
- Around 4% β-beating corrected in RMS
- Too much degeneration because of the lack of constraints from beam 2?