Terrestrial tidal energy shifts impact on HLLHC & LHC

26 Feb 2025

Sasha Horney

Thanks to E. Maclean, T. Persson, J. Dilly, M. Hostettler

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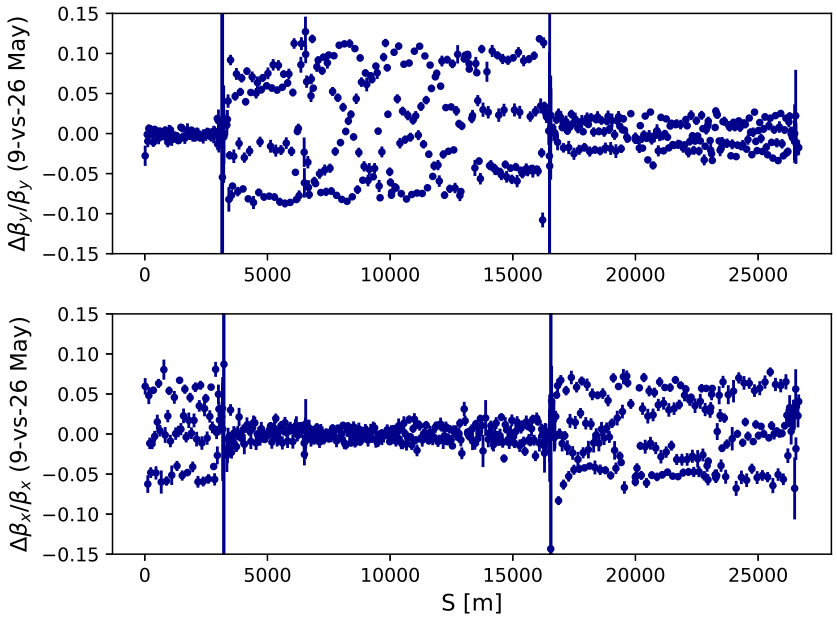

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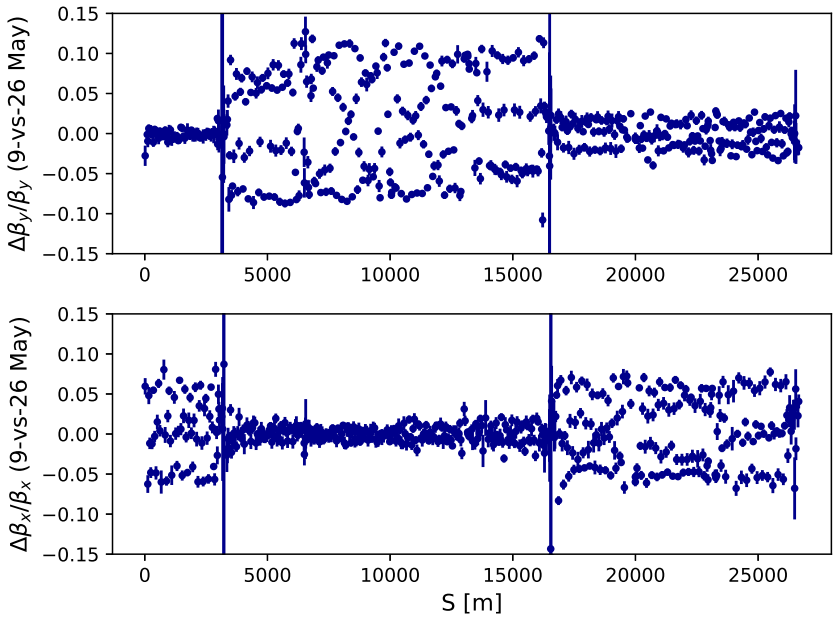

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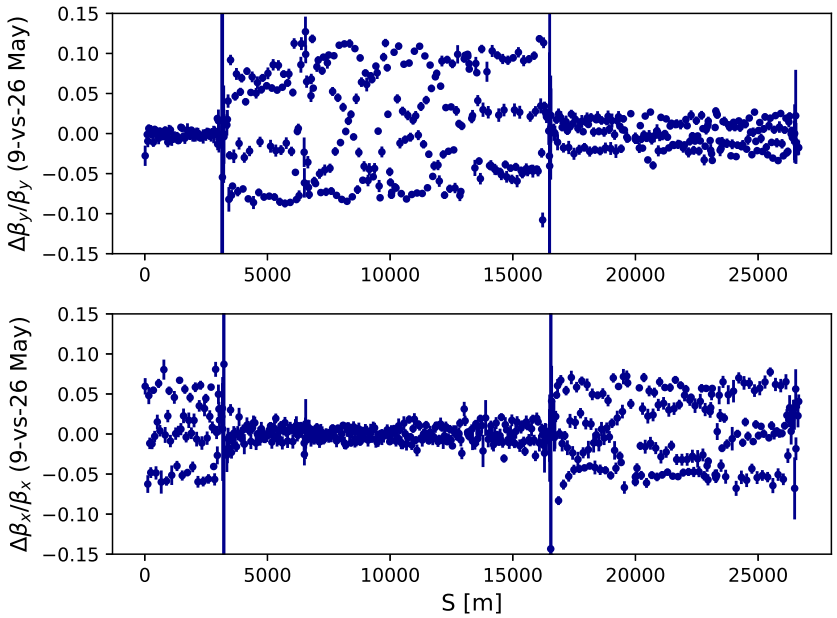
- This effect will be enhanced going to smaller β^*, so even more relevant for HLLHC at end-of-squeeze.



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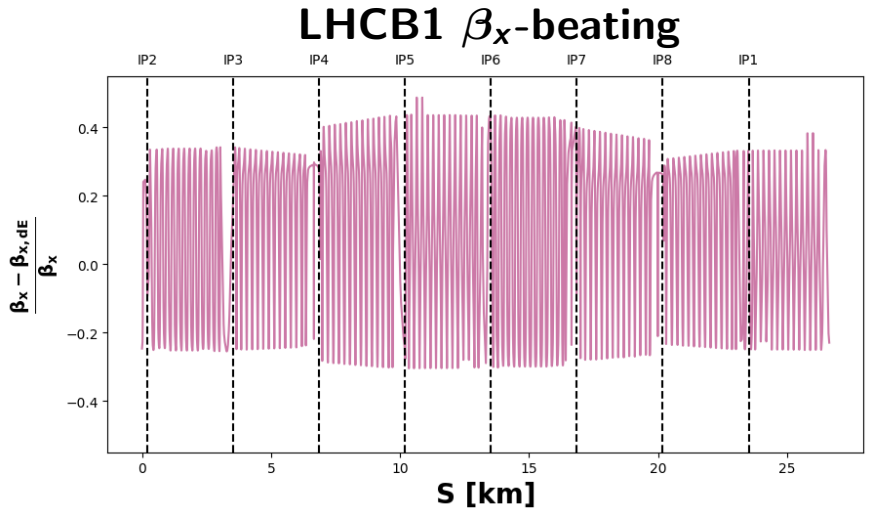

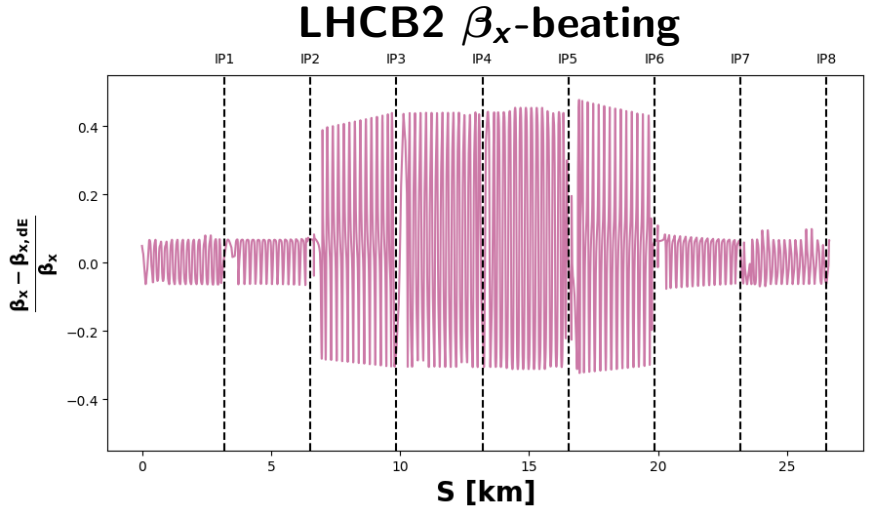

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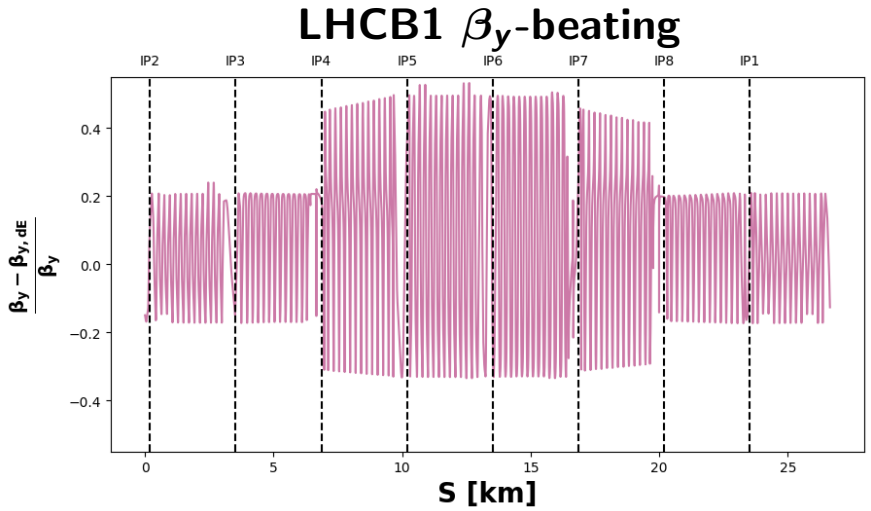
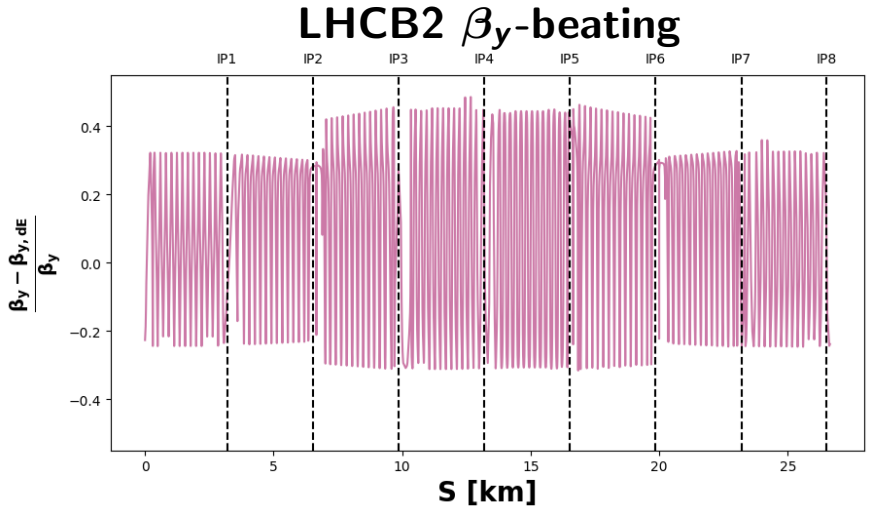
- Same approach used to study original error in 2022 - done for 15cm β^* (round optics) & saw v. large impact for typical scale of energy errors experienced during LHC commissioning.





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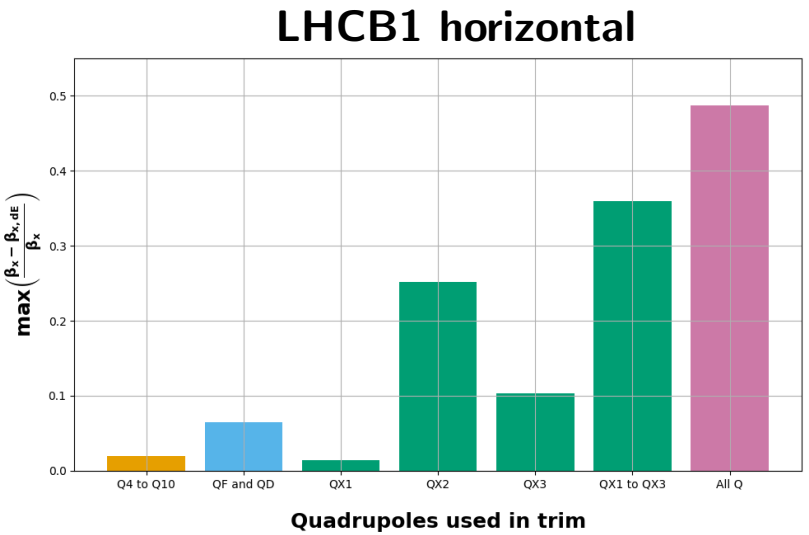

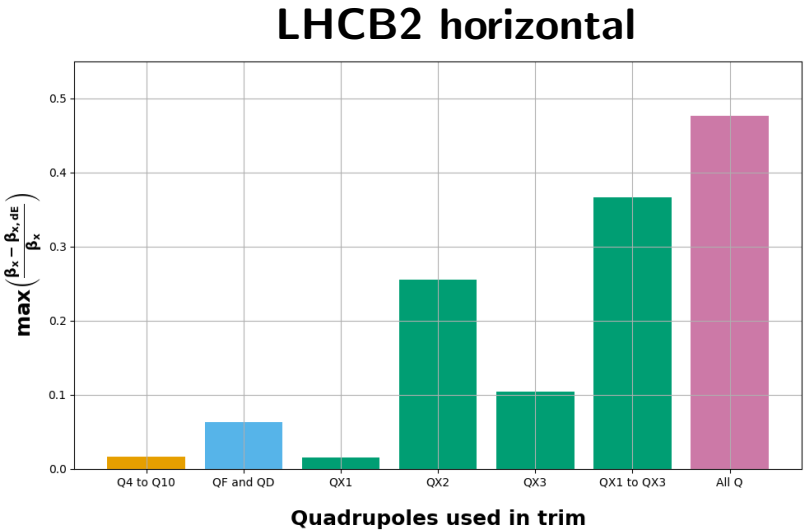

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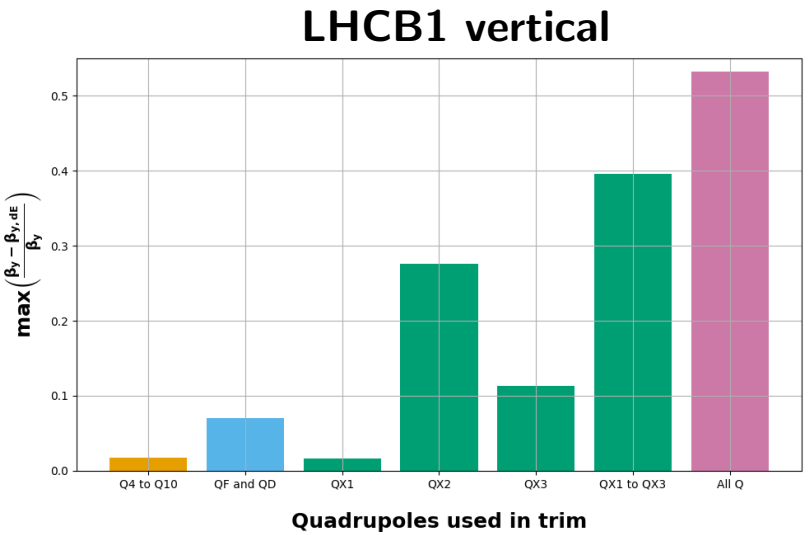

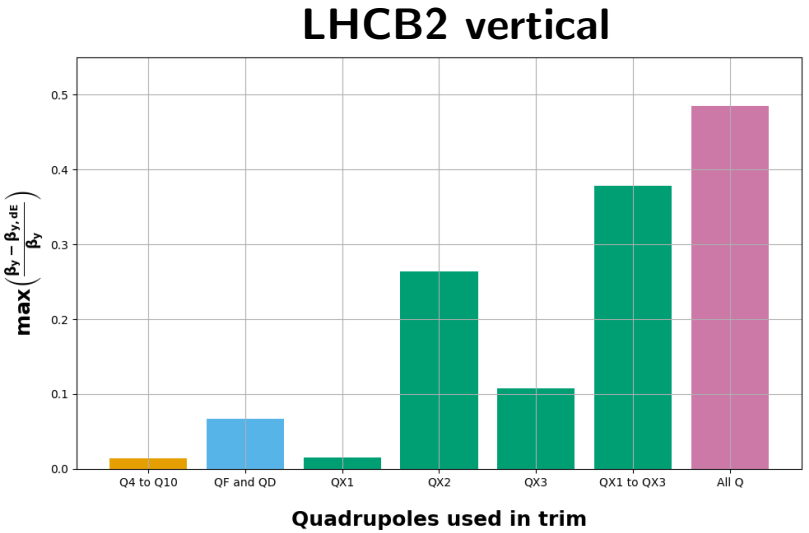

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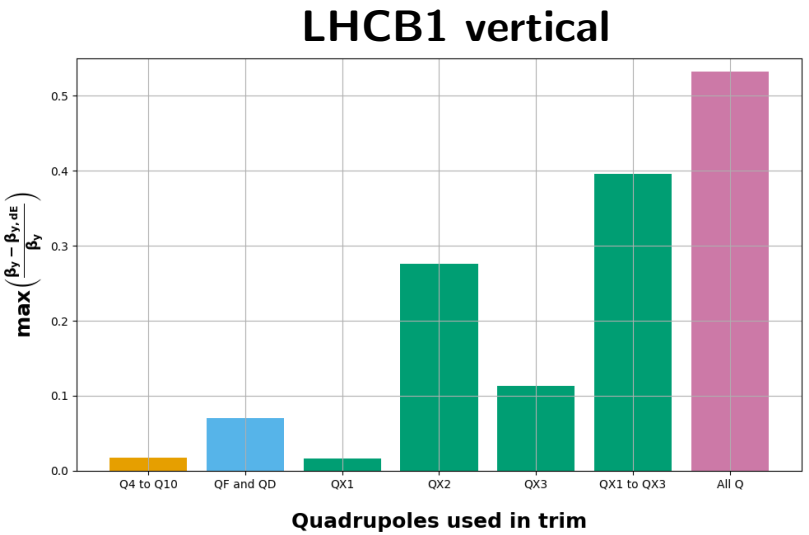
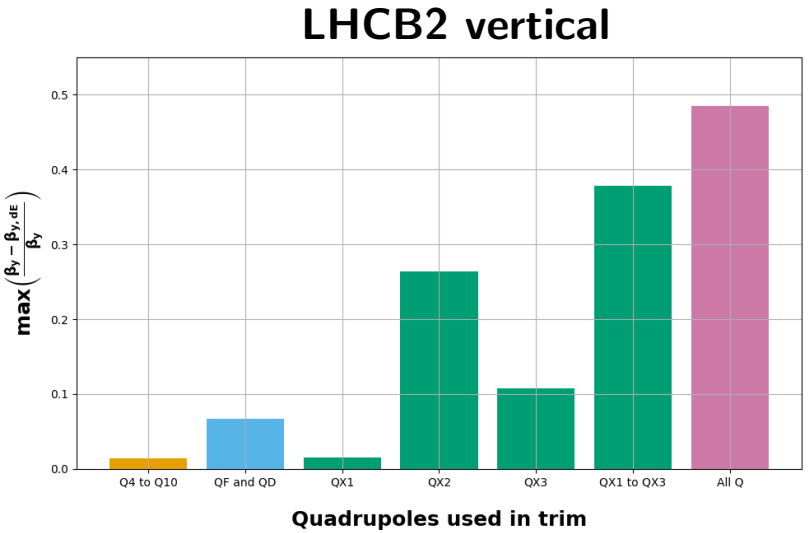
- Investigated main sources of β-beating by comparing maximum β-beating produced, out of the quads powered found that it was the inner triplet ones.

- This was consistent for both horizontal and vertical β-beating and, more specifically Q2.

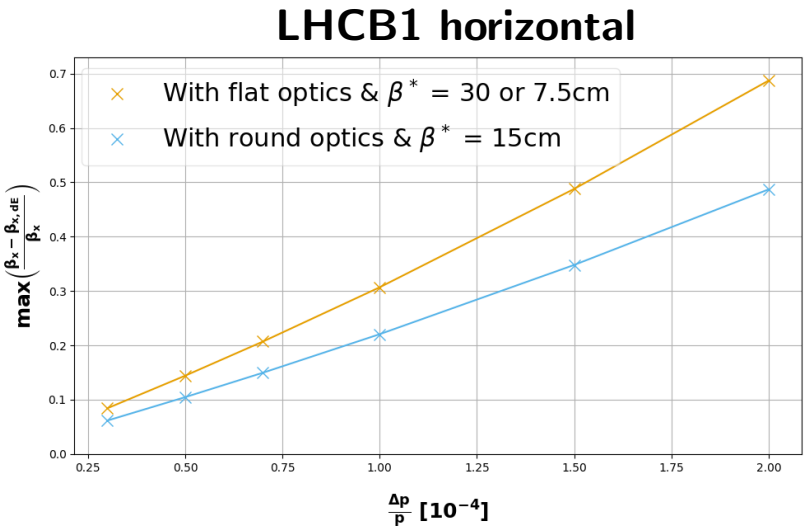
- Should be noted that non-negligible ($>$5%) β-beating was produced by arcs.

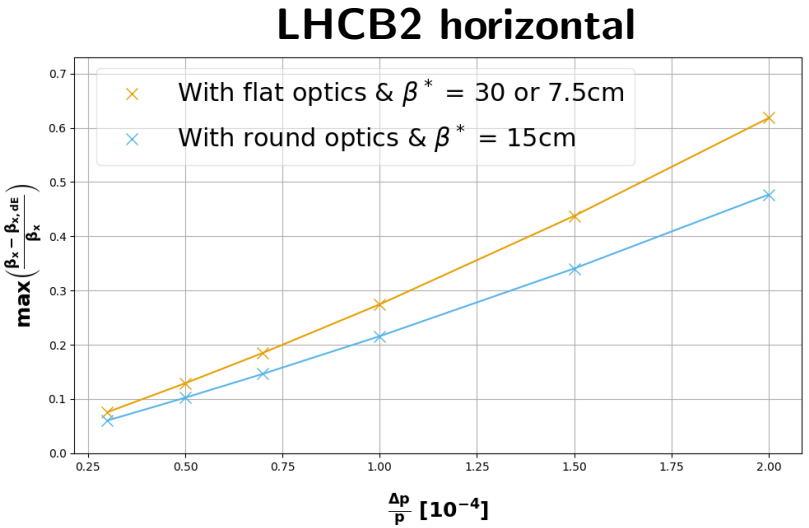




Flat vs Round Optics

- The difference in flat ($\beta^* = 30/7.5$cm) vs round optics ($\beta^* = 15$cm) was also checked.





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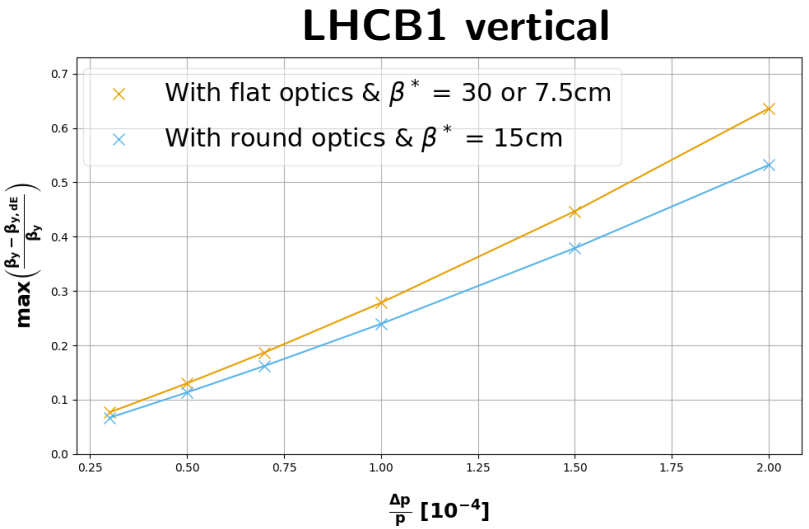
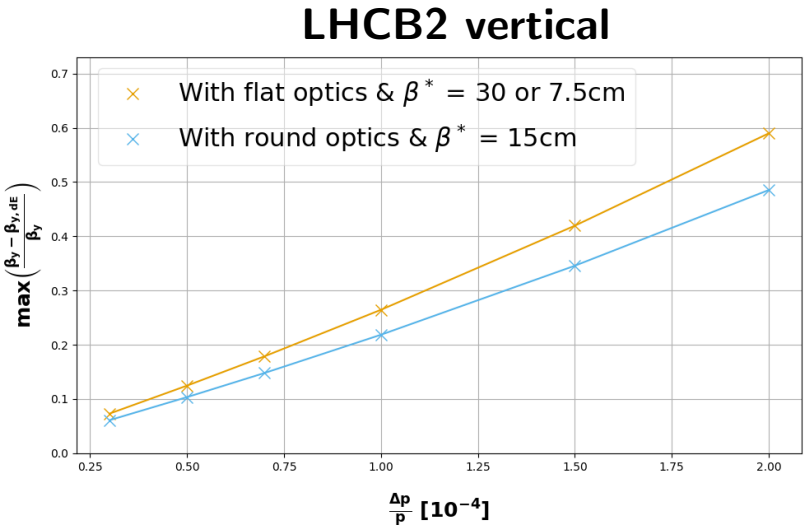
- It was found that with flat optics there was maximum β-beating as expected.





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- The proposal (from Felix and Josh) to solve this by basing the orbit set-up on the initial optics measurements is very much needed for HL

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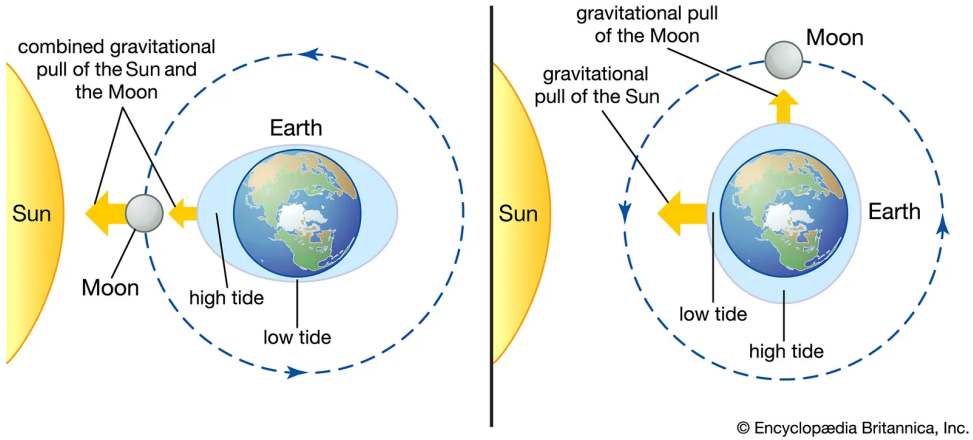
• Terrestrial tides change the beam energy through the gravitational deformation of the earth and, by extension, the accelerator. This changes the path length, and the resultant mismatch between between RF frequency and this new circumference, leads to energy drifts - more info can be found in Jorg's talk



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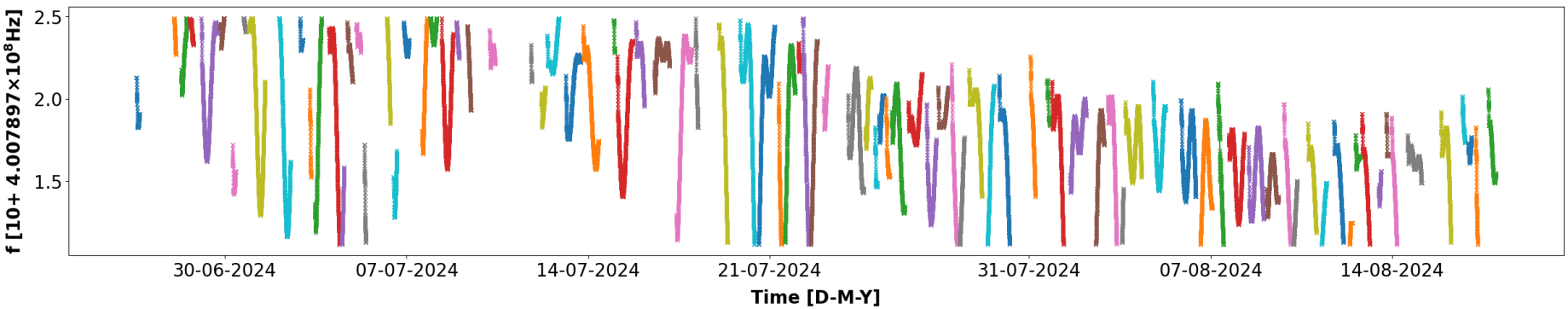
- For these studies LHCB1 and LHCB2 are similar so focussed on LHCB1.



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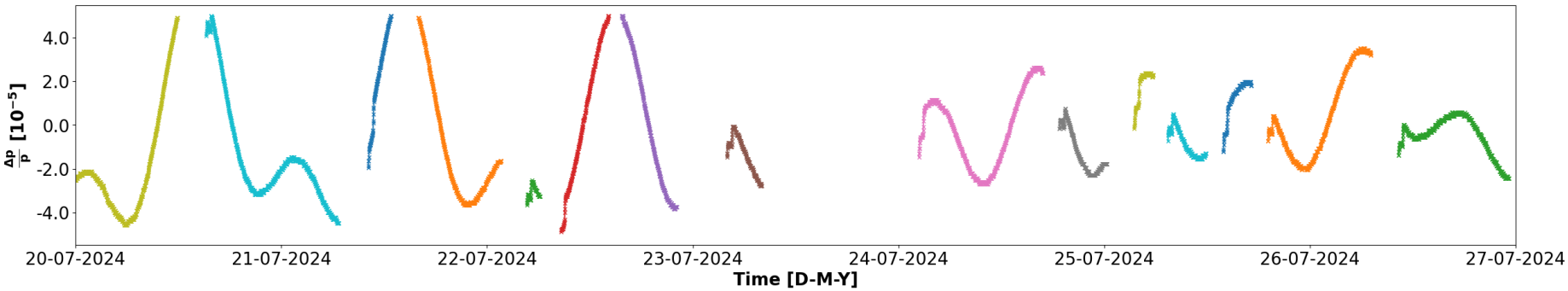
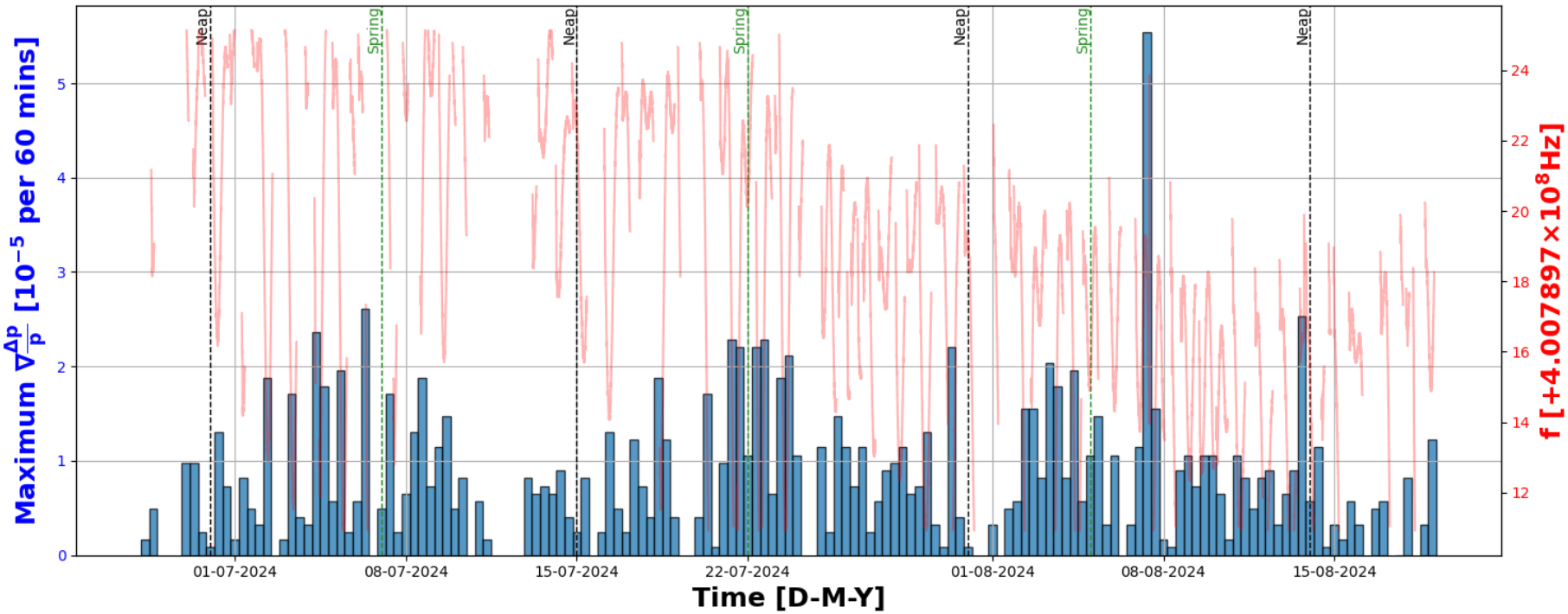
- This led to the following plot where maximum $\frac{\Delta \mathrm{p}}{\mathrm{p}}$ can be seen to be around 4×10^{-5}.



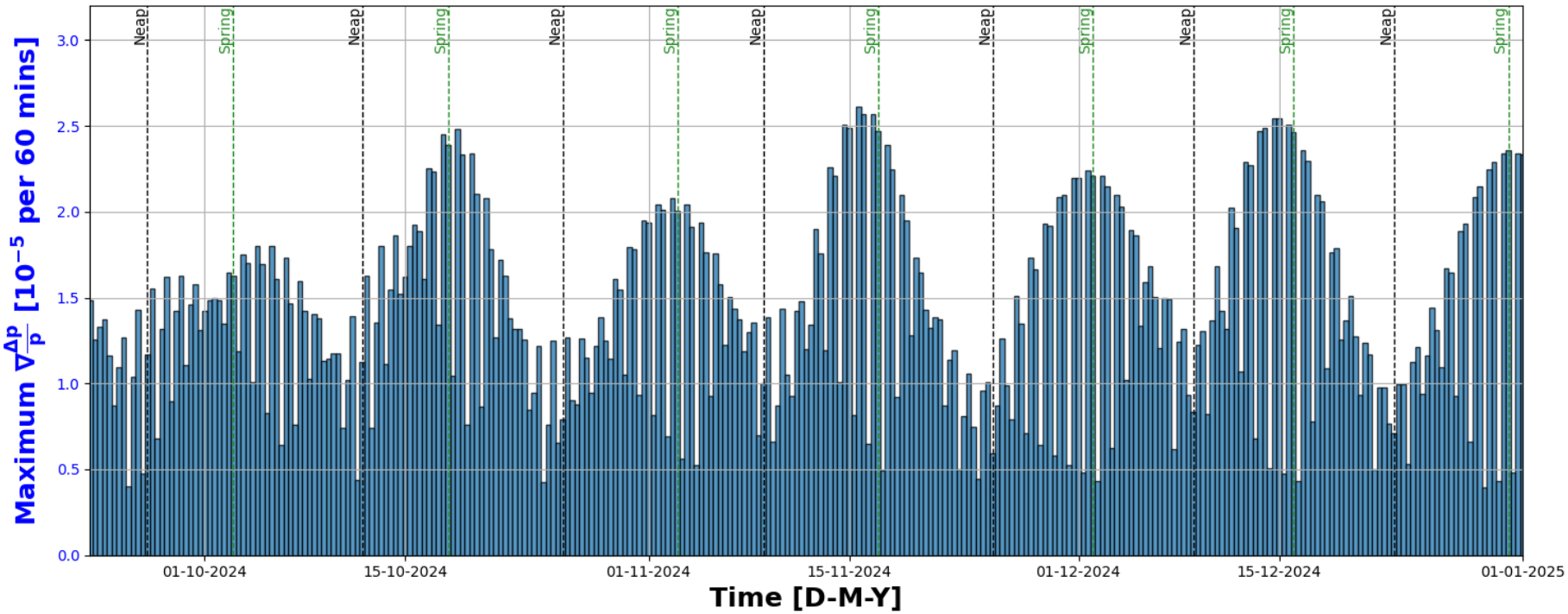
Terrestrial tides

- It is expected that the maximal change in $\frac{\Delta p}{p}$ would happen during spring tides which can somewhat be seen here despite the sparsity of data.



Terrestrial tides

• Predicted $\frac{\Delta p}{p}$ trims taken from YASP make the trends are clearer, and there does appear to be maximal change during spring tides (these will happen in mid and late April this year).



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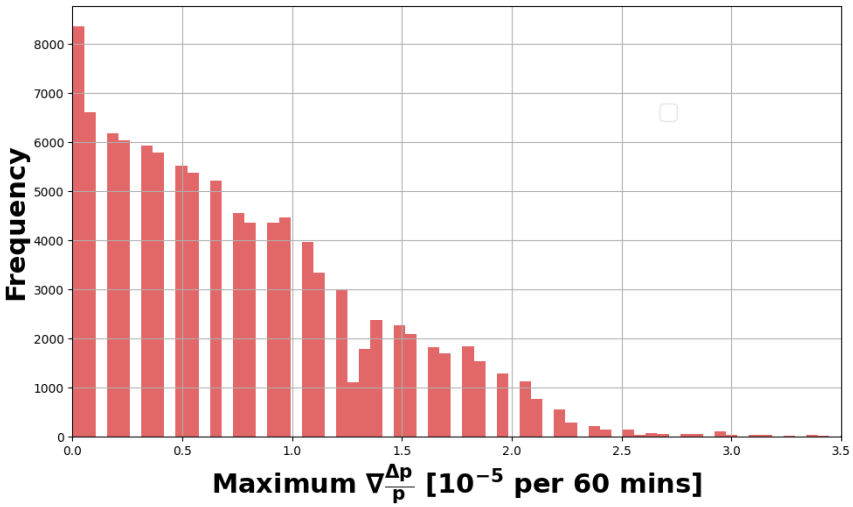
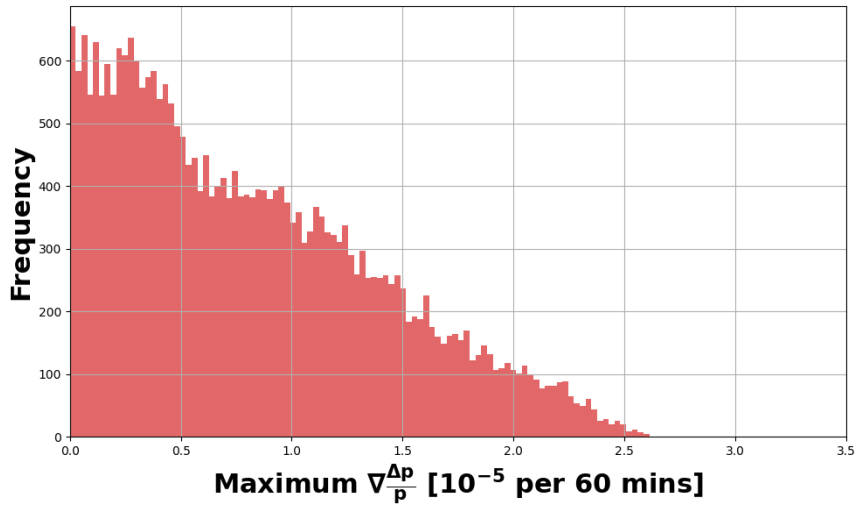
- A similar distribution was produced from the analysis, despite the difference in sample size.



(a) Maximum change in $\Delta p/p$ over a 60 minute period with a sample size of around 7 months



(b) Maximum change in $\Delta p/p$ over a 60 minute period with a sample size of around a 200 days

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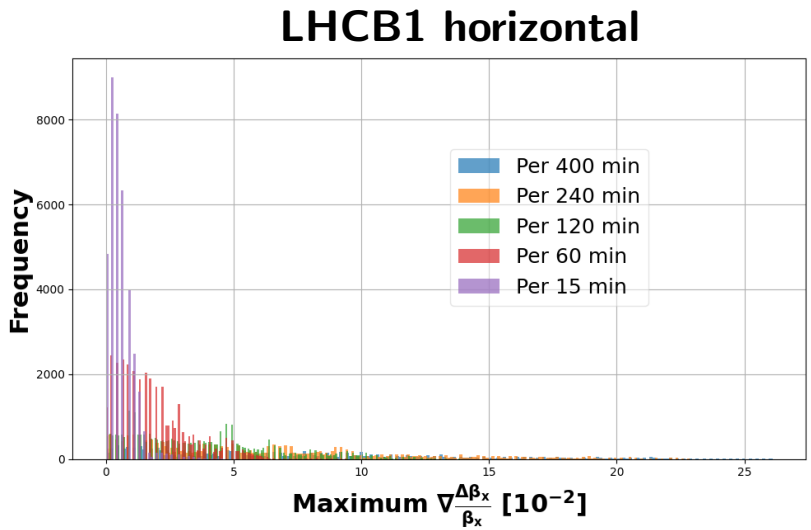

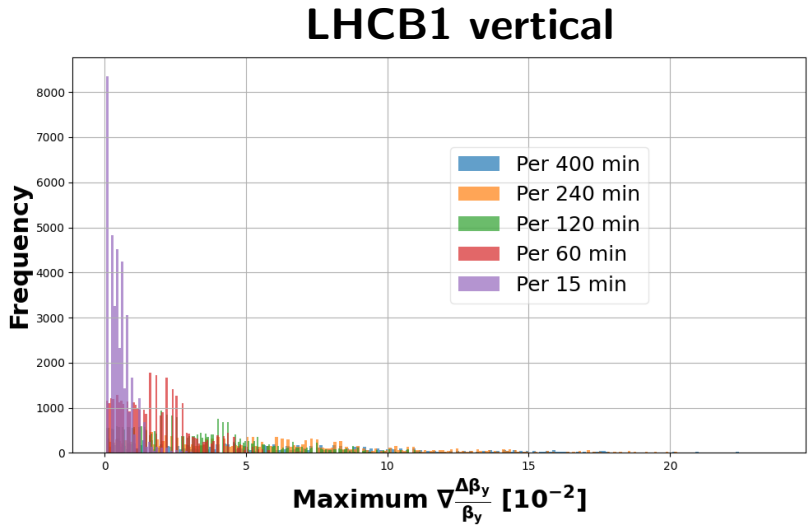

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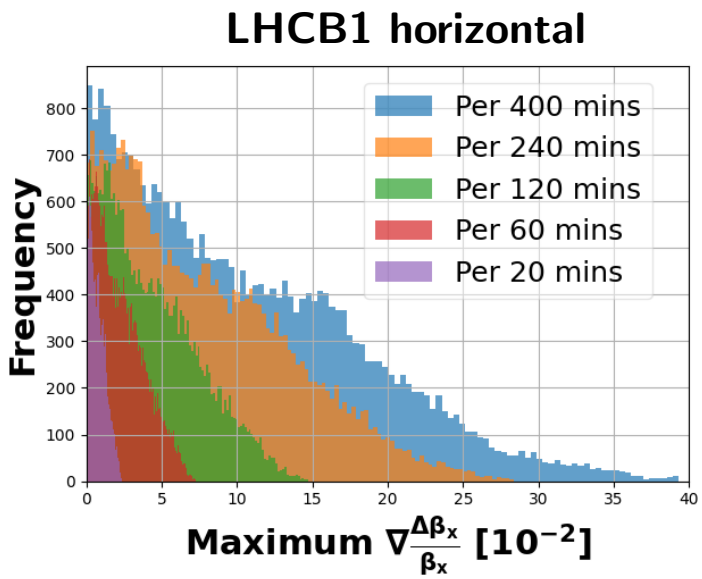
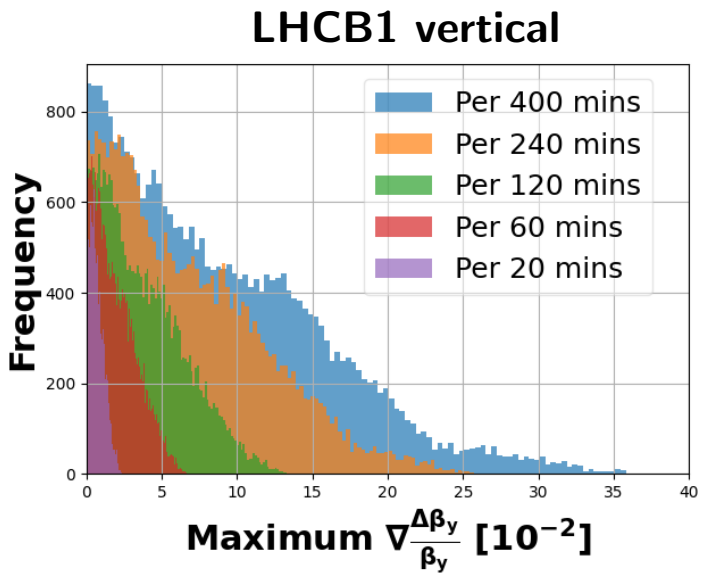
- It is clearer to see using the YASP prediction that with the change within a longer interval increased both the frequency maximal value of the change in β-beating but beyond 400 mins it starts to saturate





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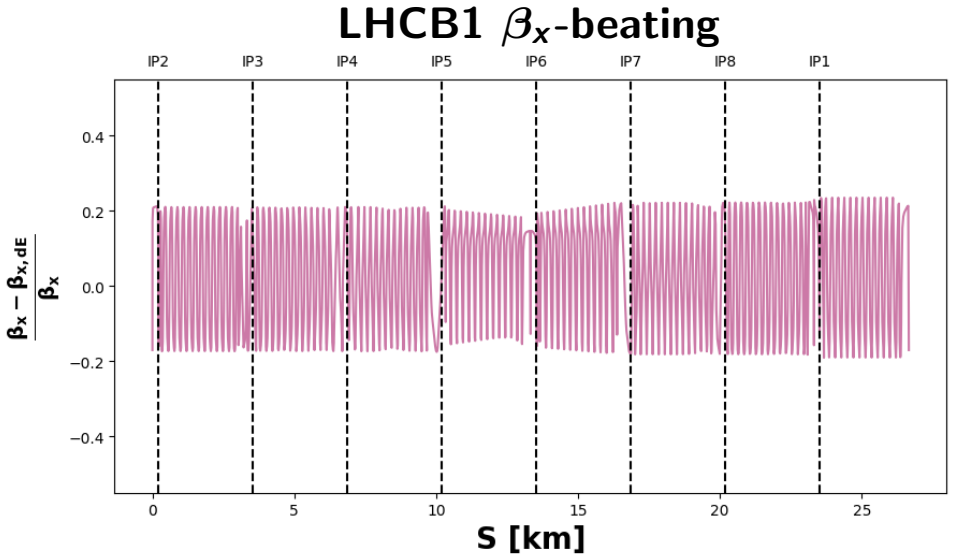
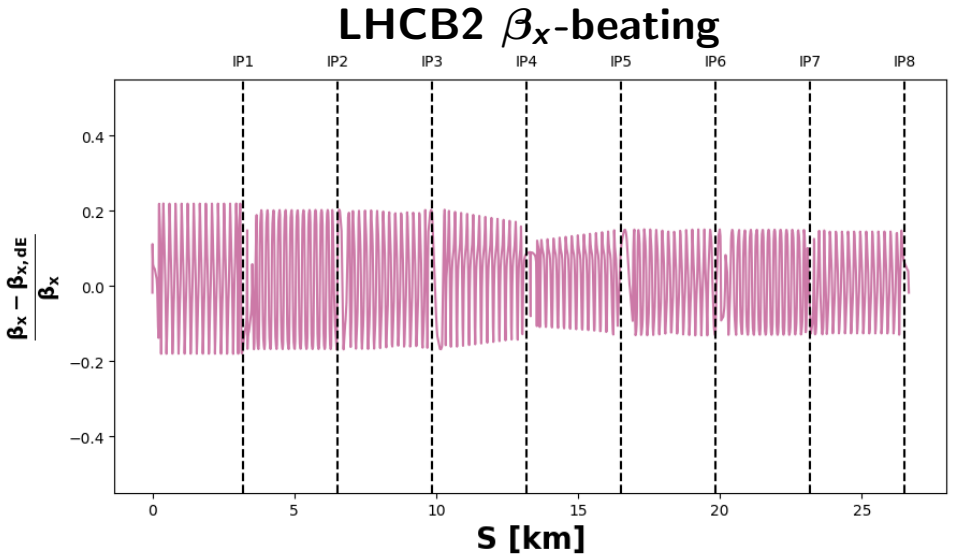
• Likely need to start to use the radial-loop feed-back during HL-LHC optics commissioning..?

2025 LHC β-beating

- Due to non-negligible β-beating produced, simulated the effect on 2025 flat optics.





2025 LHC β-beating

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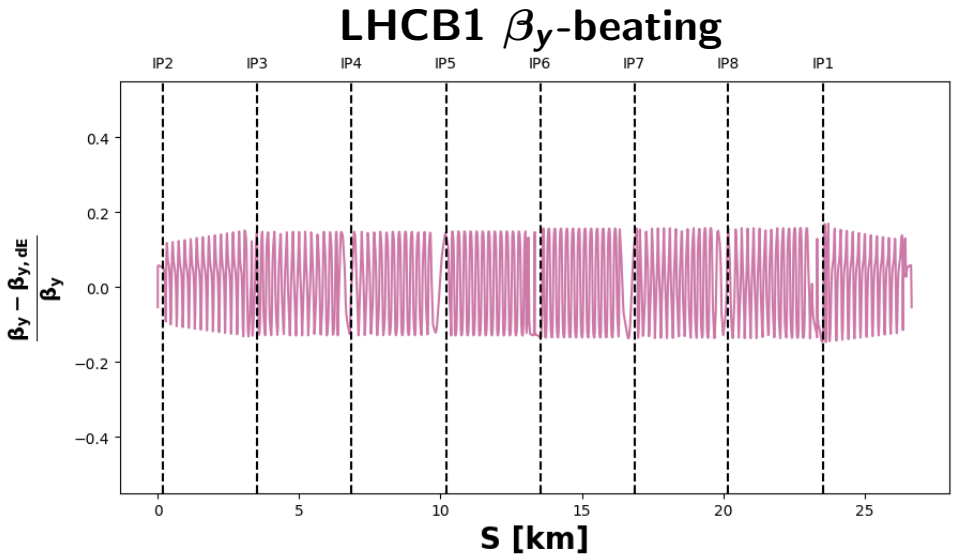
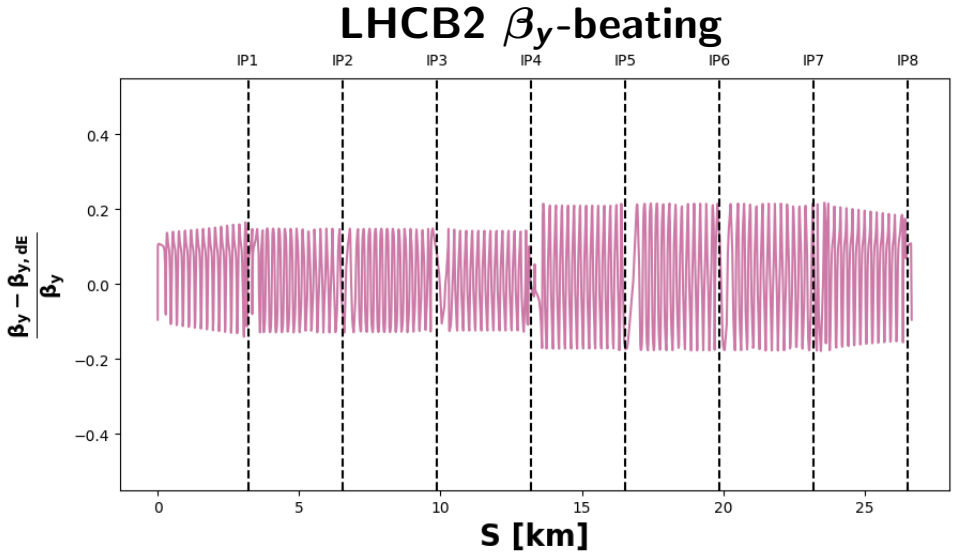
- β-beating was about half the magnitude of HLLHC, still significant. Interestingly no jumps at IP1/5 like in HLLHC though...





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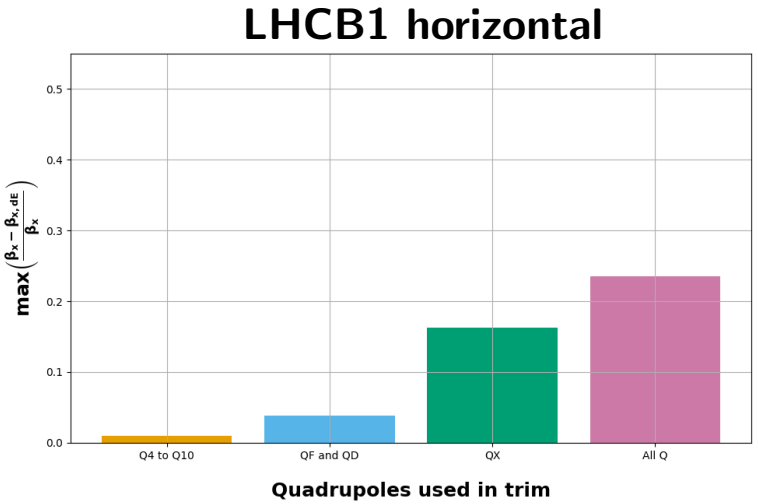

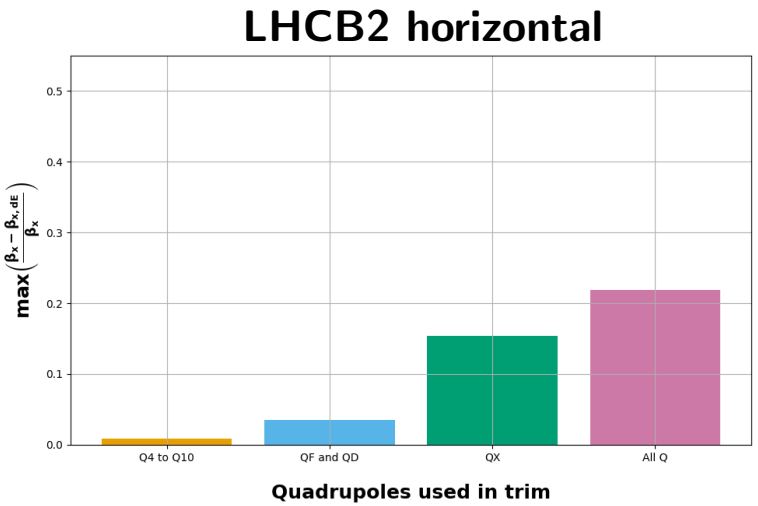

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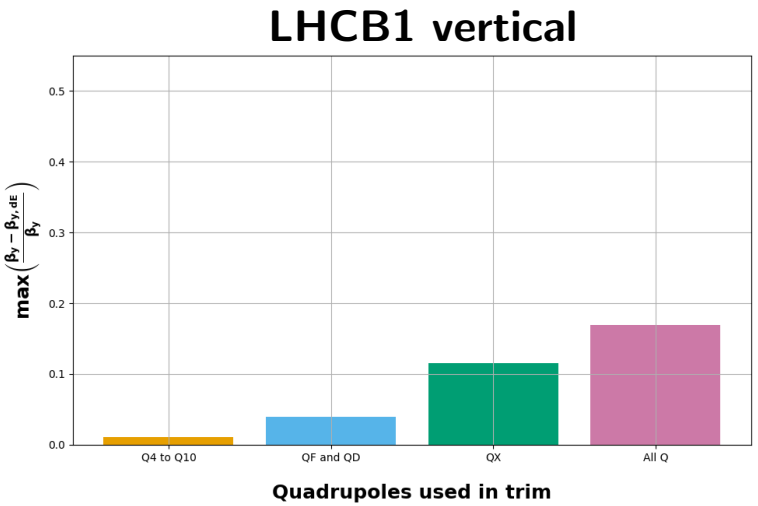

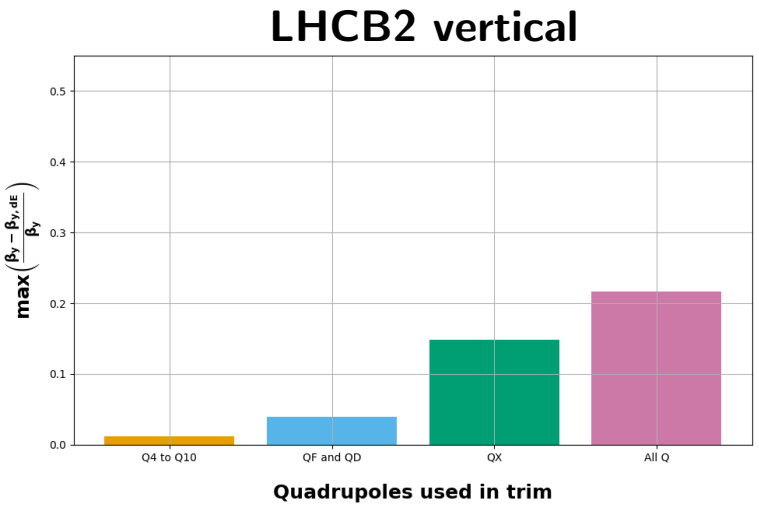

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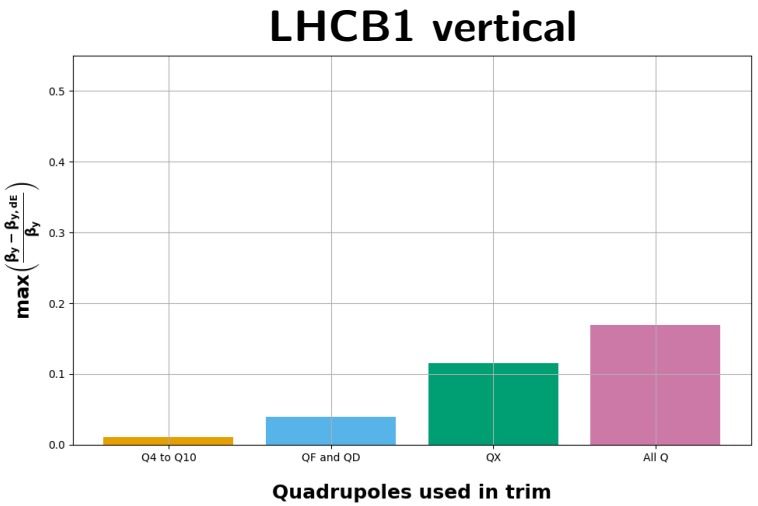
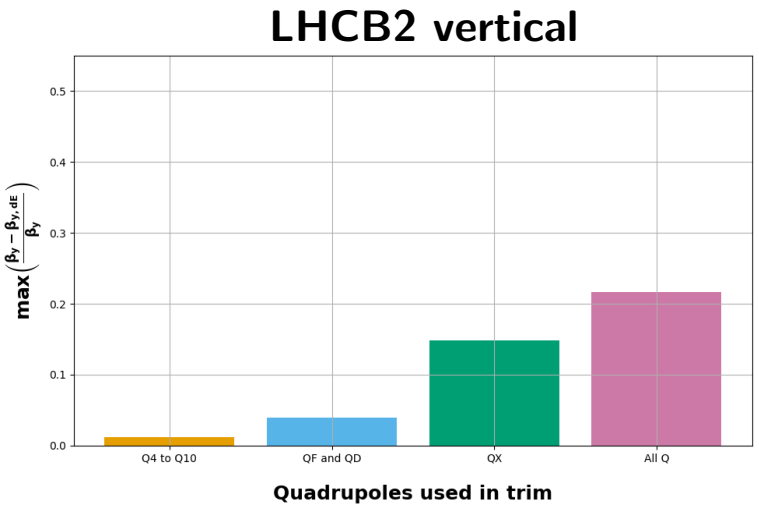
• To check the method - two different approaches were adopted. One was using the CORRECT macro in MAD-X to correct orbit back to reference after adding a Δp/p trim, and the other was to use Rogelio's manual script to scale the quads. These were similar order of magnitude.





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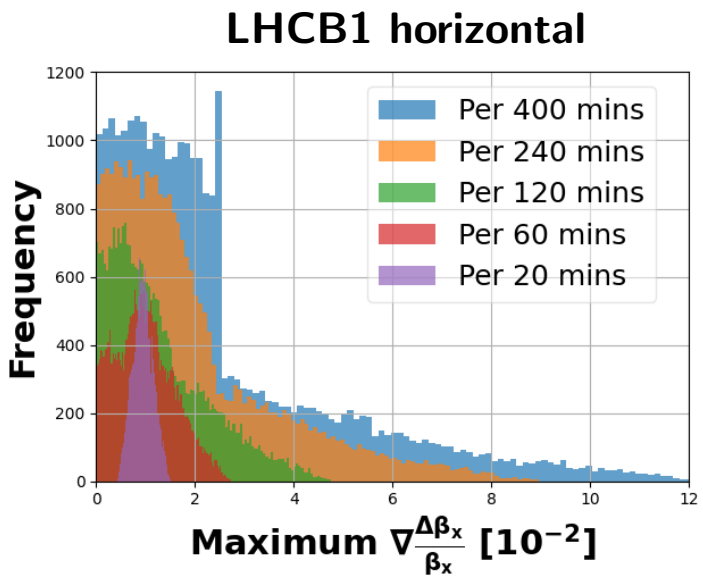

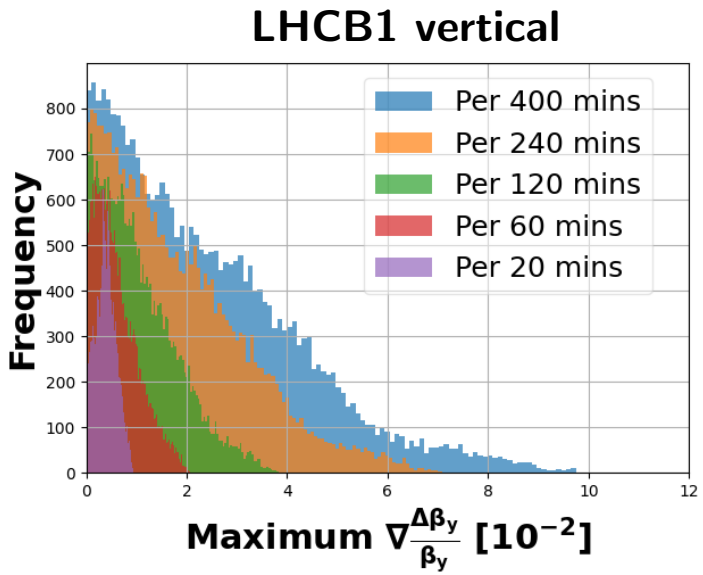

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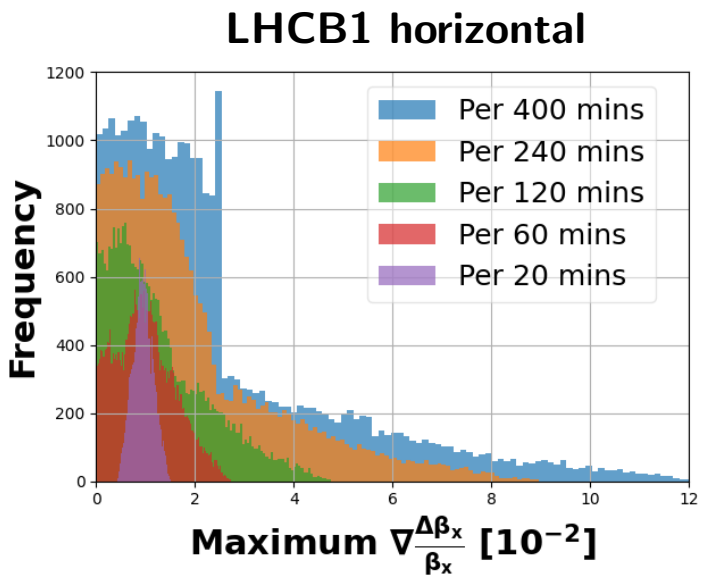
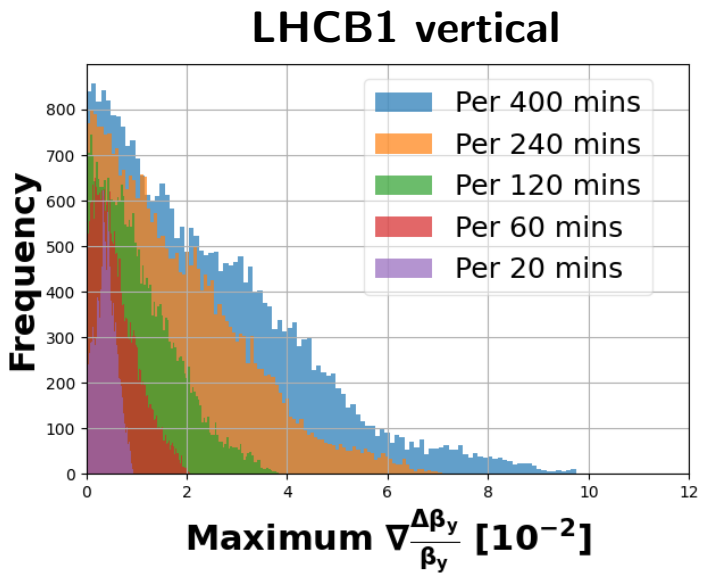
- It can be seen that the predicted change in the β-beating is non-negligible even for the LHC.





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• Mael has shared a script so next can investigate the impact on FCC-ee

Thanks for your attention!
Any questions?

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