



# SPS Optics & RDT measurements

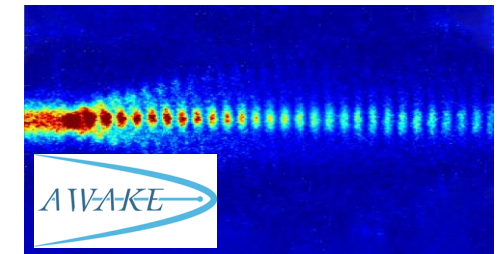
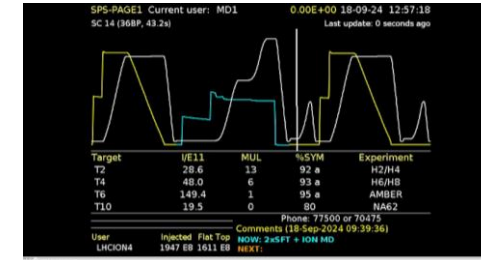
MD Days - 04 February 2025

Joshua Dilly, Ewen McLean, Kostas Paraschou, Panos Zisopoulos

Acknowledgements: SPS OP crew, Tom Levens

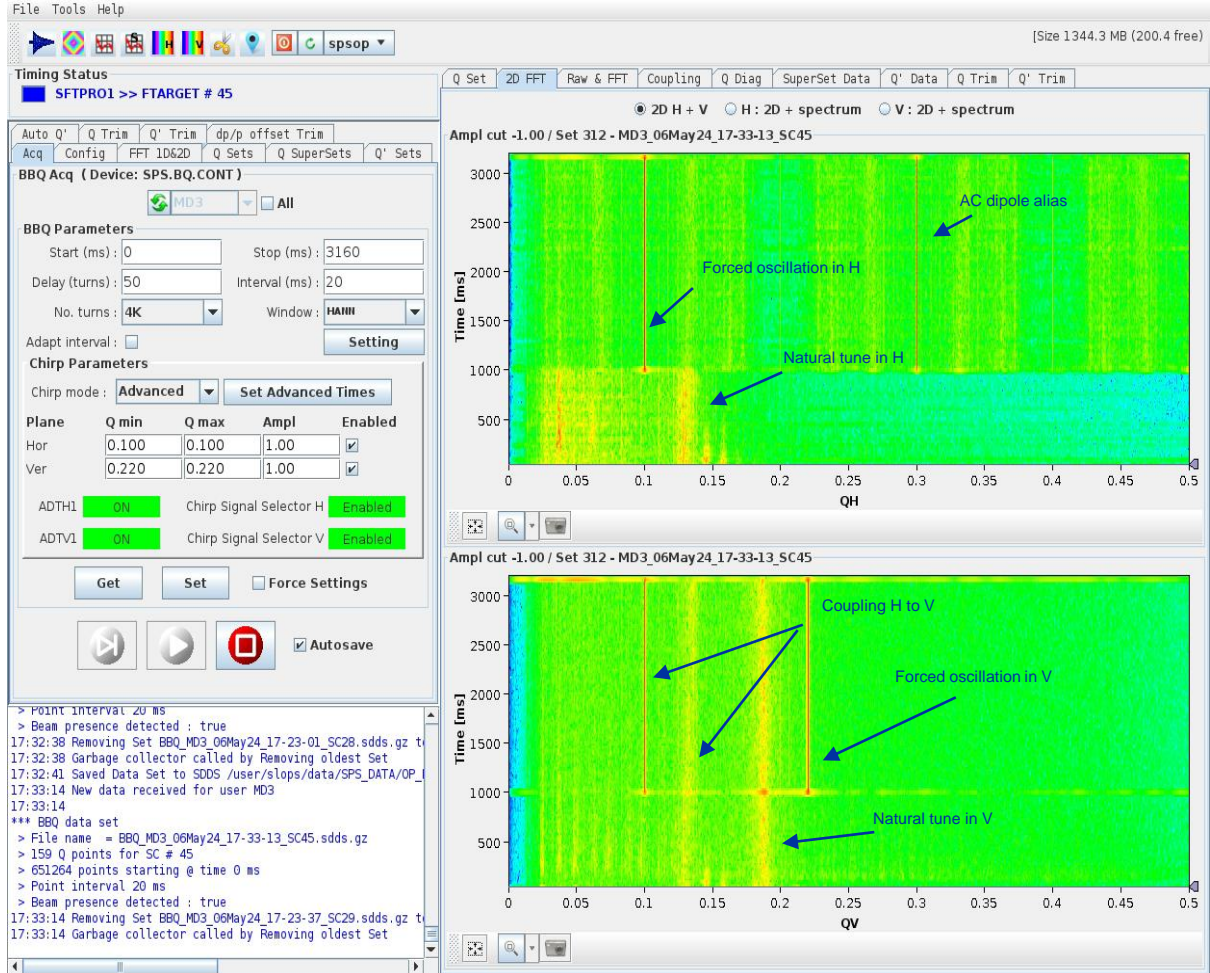
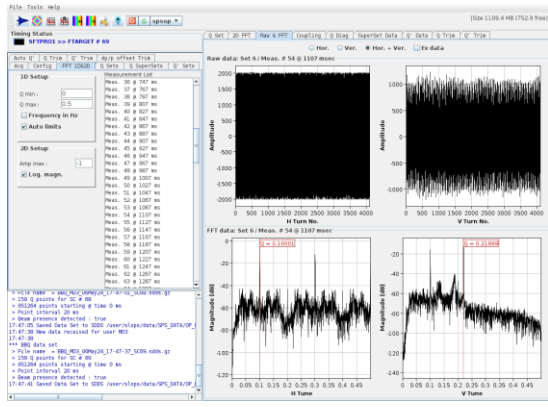
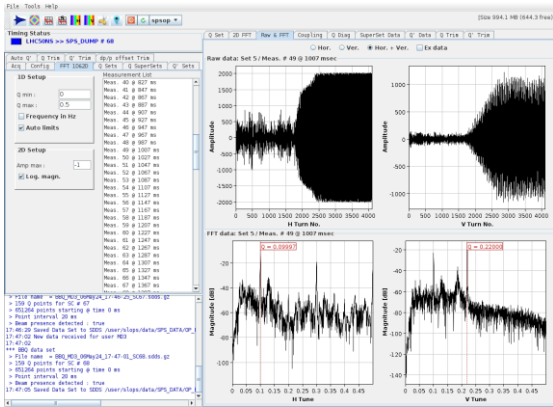
# Why this MD matters?

- **Optics Measurements in the SPS:** Measuring optics for all operational beams is essential for understanding machine behaviour and improving beam control.
- **Towards operational optics measurements:** Develop a framework for low-impact & precise operational measurements – Focus on alternatives to free kick excitations
- **OMC Tool integration:** The SPS was the only machine without it, prompting efforts to integrate it into its ecosystem.
- **AC Dipole Excitations in SPS:** No pure AC Dipole available - Revived after many years via BBQ kicker to investigate new measurement capabilities



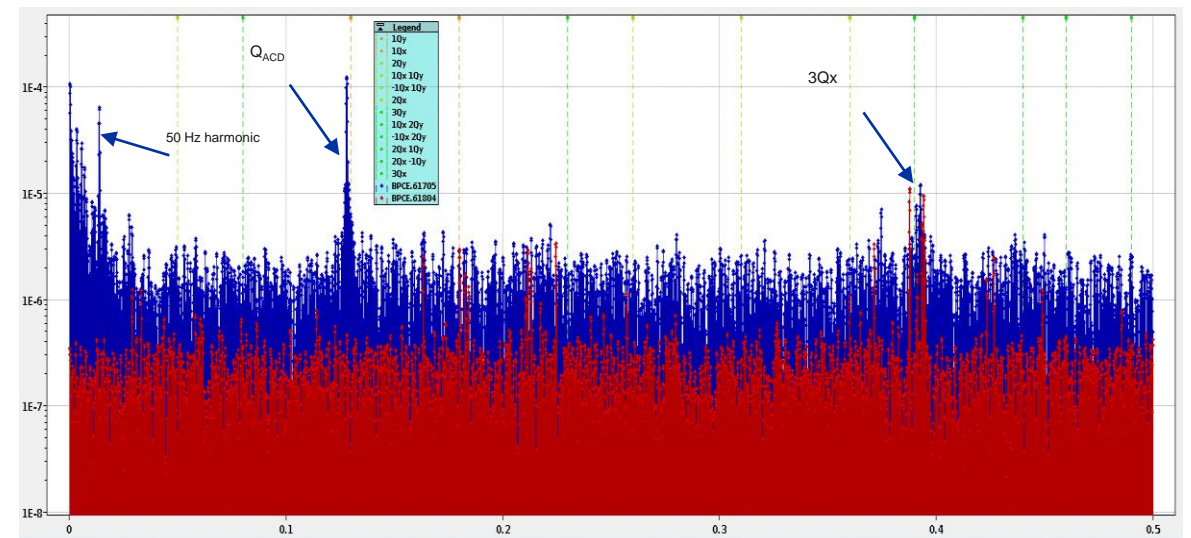
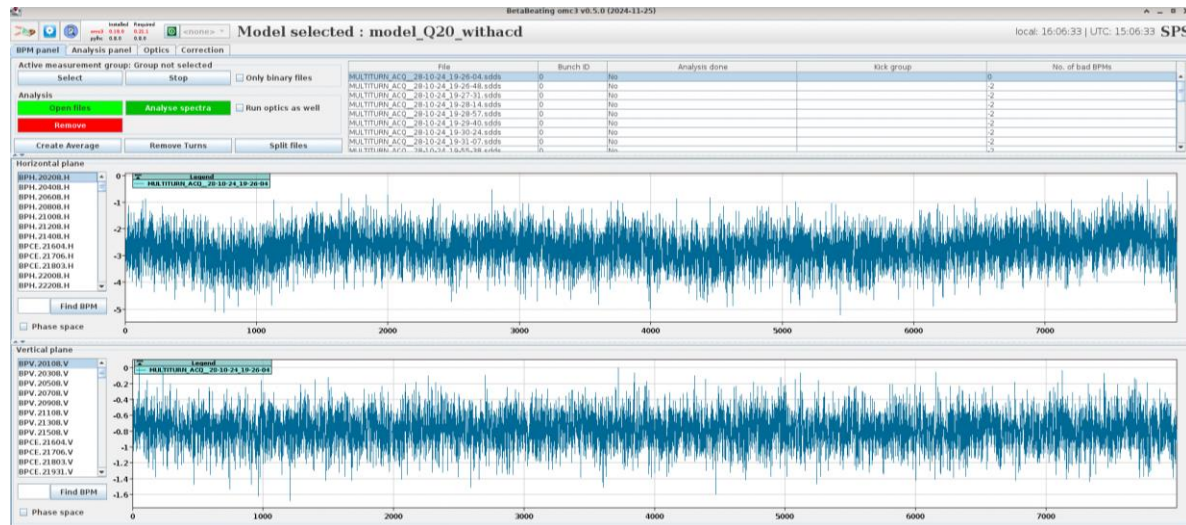
# SPS BBQ as an AC Dipole shaker

- New mode in the BBQ application to allow for **AC-Dipole** excitations
- User can set trigger times, ramp up, ramp down and excitation lengths
- Occasionally AC dipole **aliases** appear in BBQ spectrum – not appearing in the rest of BPMs
- TbT data can be recorded with the MultiTurn application (limited to only 8000 turns for the SPS)



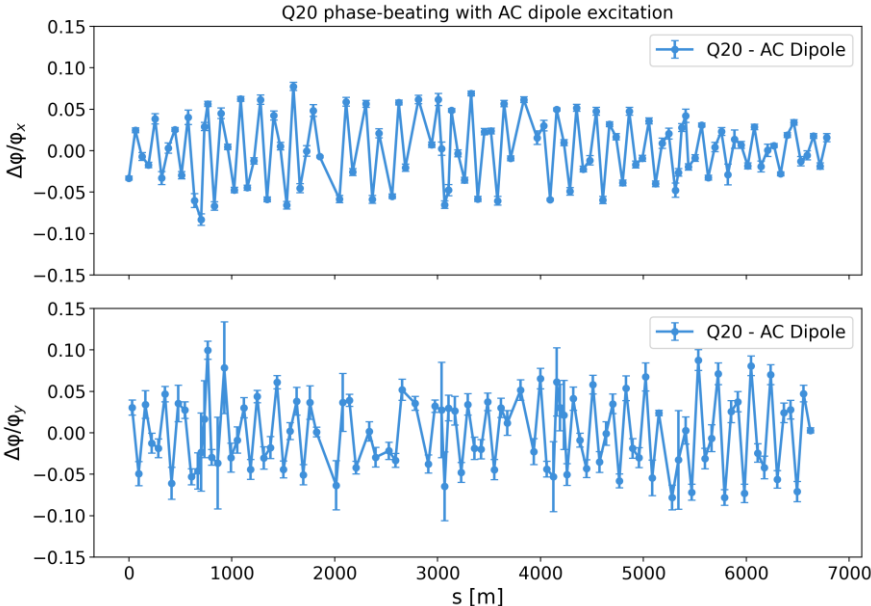
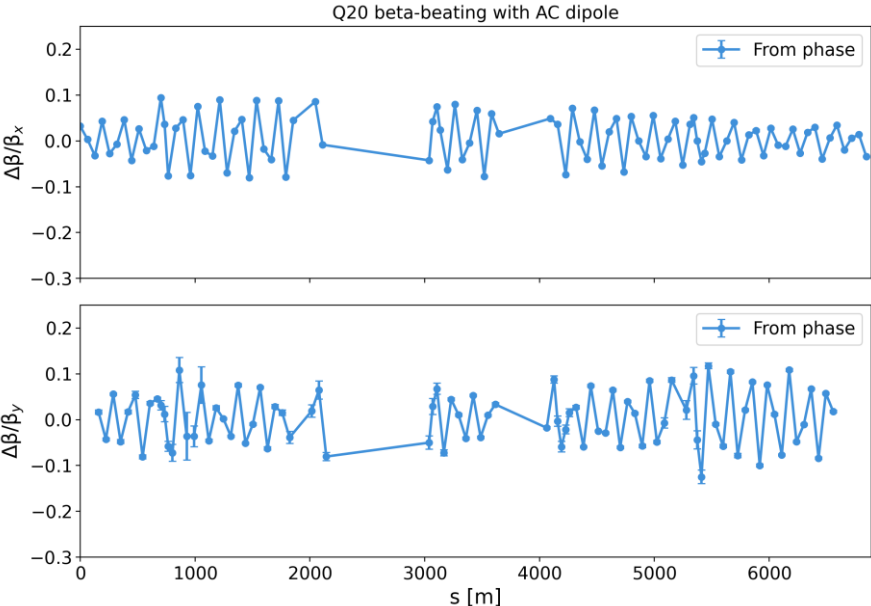
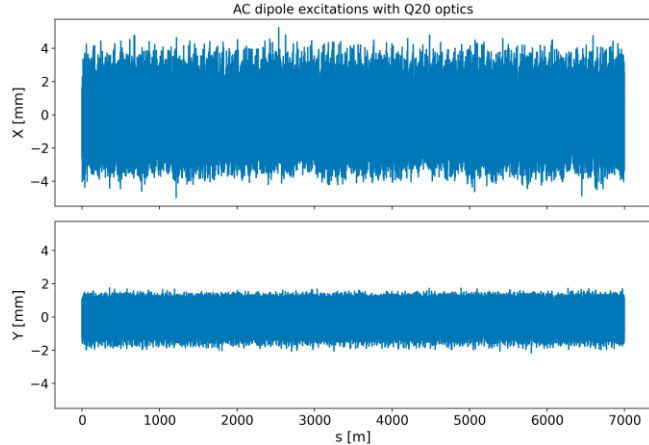
# OMC in the SPS for the first time

- OMC Team implemented the SPS model in OMC tool
- Works with both AC-dipole and single kicks excitations
- Data cleaning is essential for optics measurements - Full support in OMC (SVD, zeros, NaNs etc.)
- MDs were carried out in the SPS for optics measurements with Q20 and Q26 optics



# Measurements with Q20 optics (MD12183)

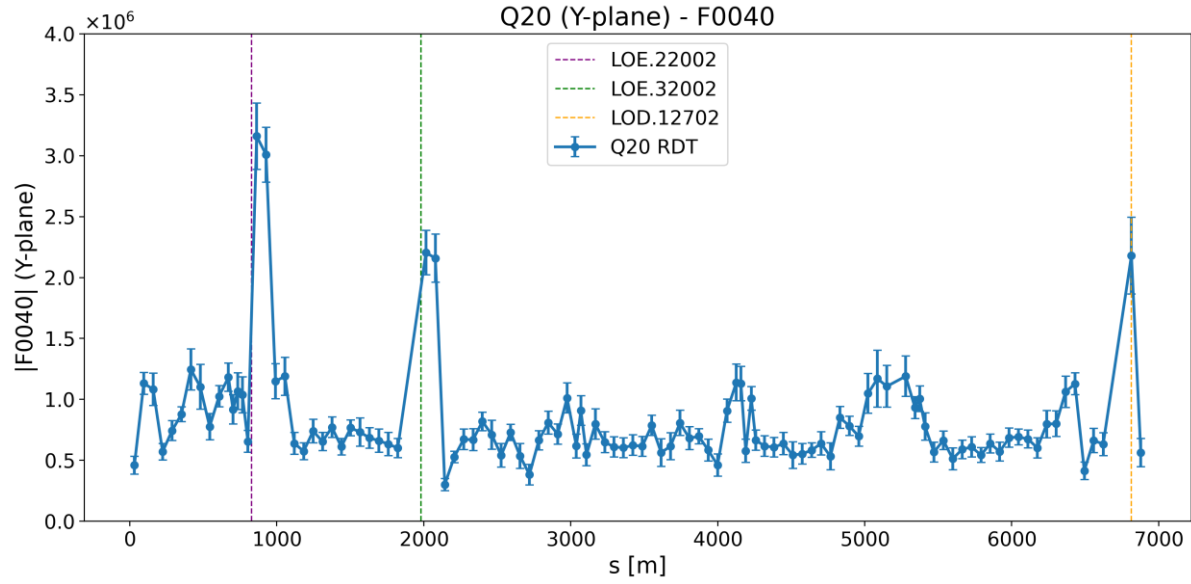
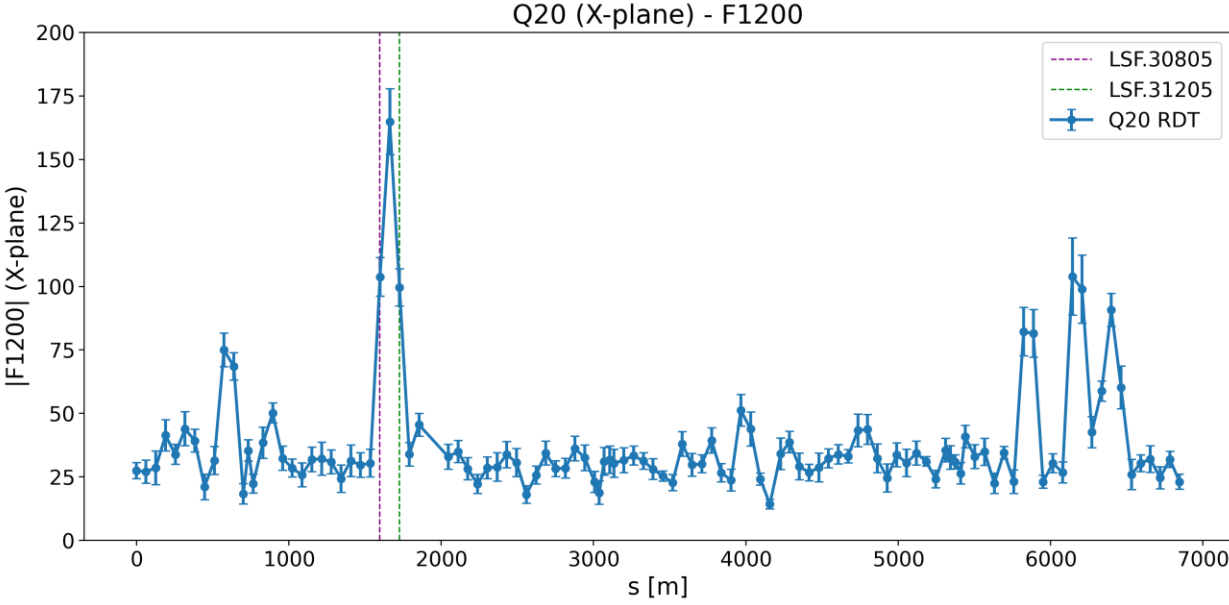
- Measurements with one single pilot (<math>10^{10}</math> ppb) @ FB and excitation with AC dipole
- Good shot-to-shot reproducibility of TbT data with AC-dipole – Issues with some faulty BPMs
- Phase beating around **10%** peak-to-peak
- Beta beating around **20%** peak-to-peak



# Measurements with Q20 optics (MD12183)

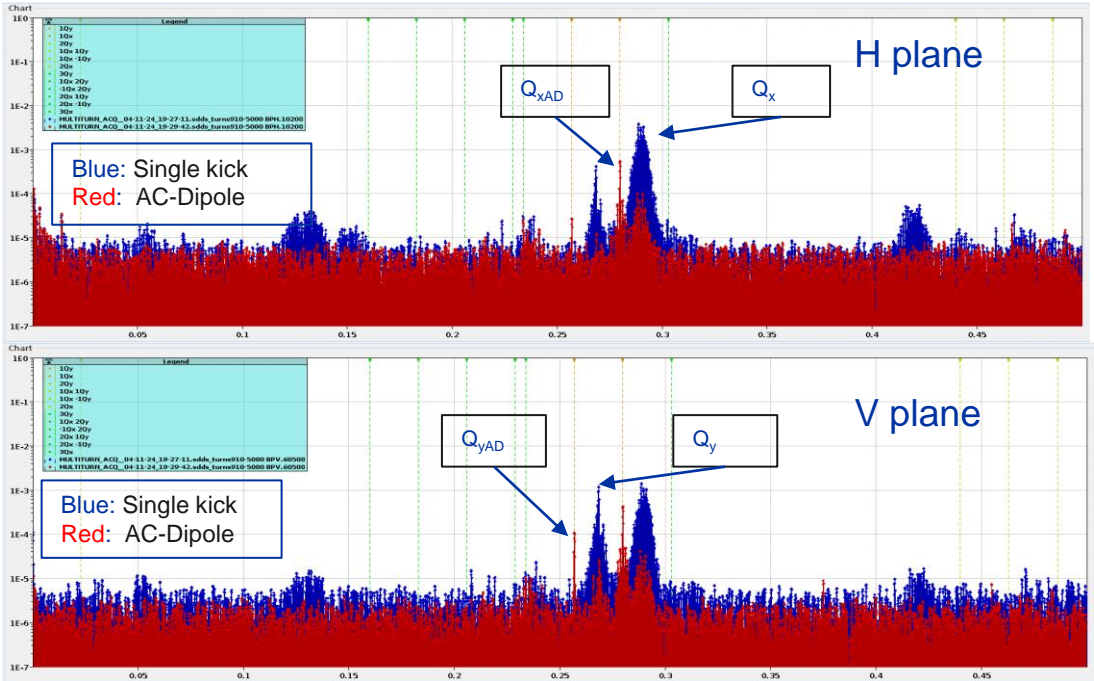
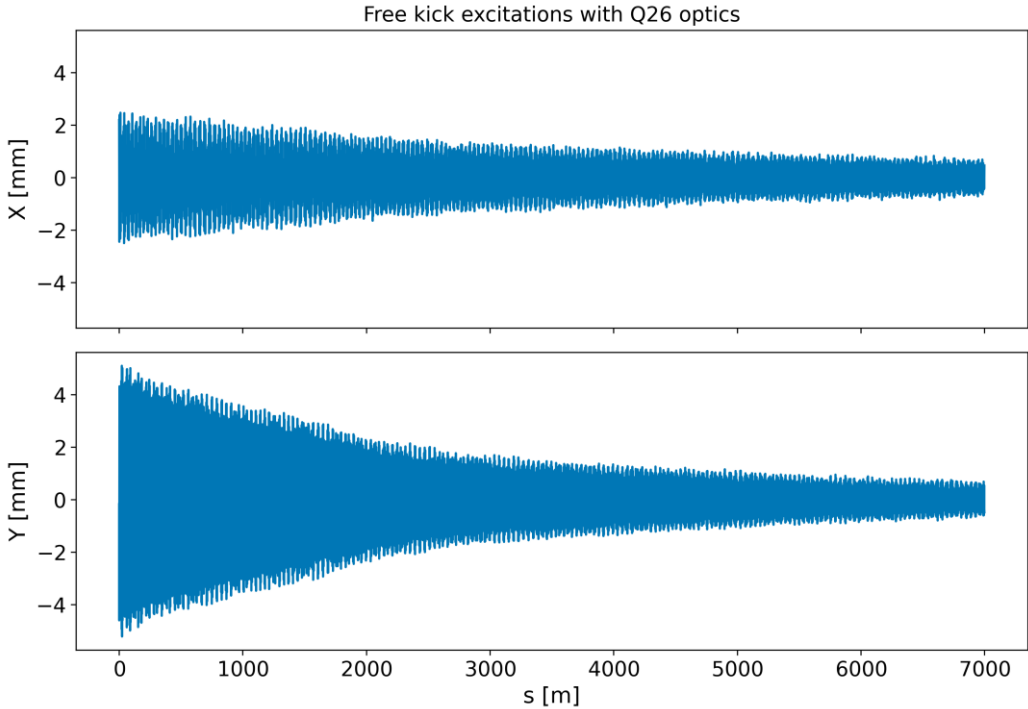
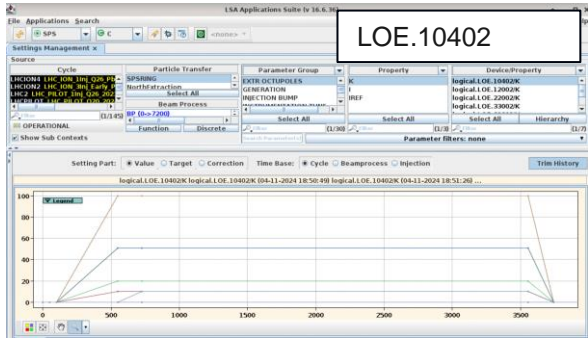
- OMC application allows for the calculation of RDTs on the fly
- Effective method for localizing sources of non-linearities in the lattice
- Various bumps appear in **f1200** & **f0040** RDTs with Q20 optics
- Focused on **f0040** –  $4Q_y$  resonance has been shown to induce beam losses [see Ingrid's [talk](#) in this workshop]
- Interest on **LOE.22002** since this is **not** plugged in - residual fields?

RDT	Resonance (m,n)
F1200	Sextupolar (-1,0)
F0040	Octupolar (0, 4)



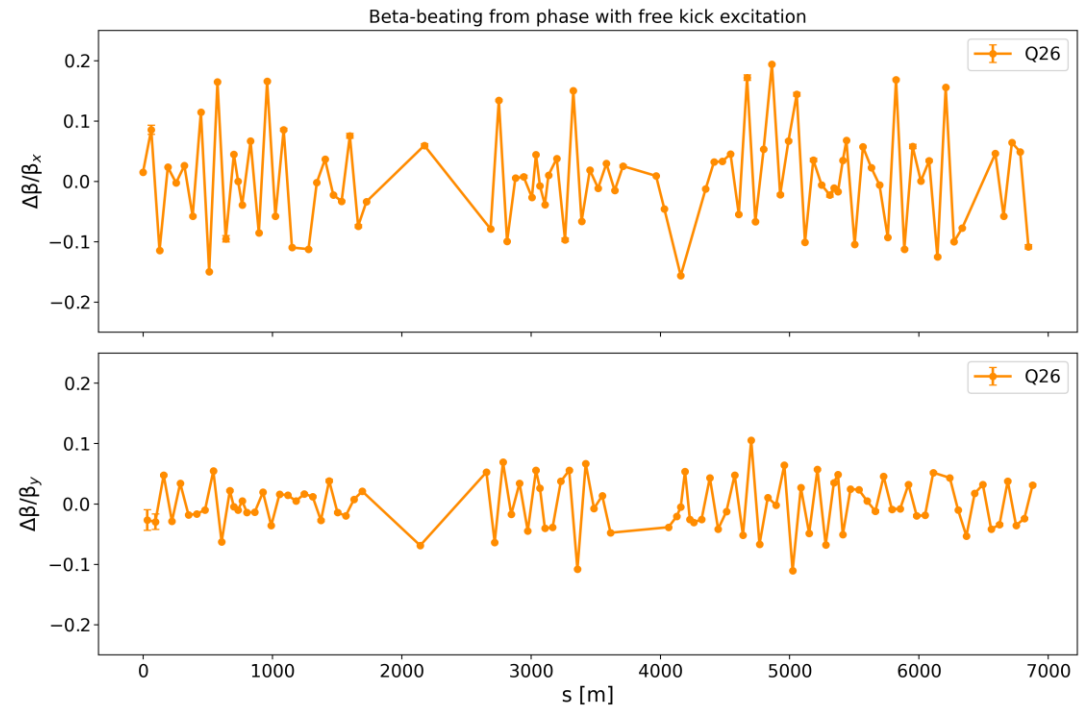
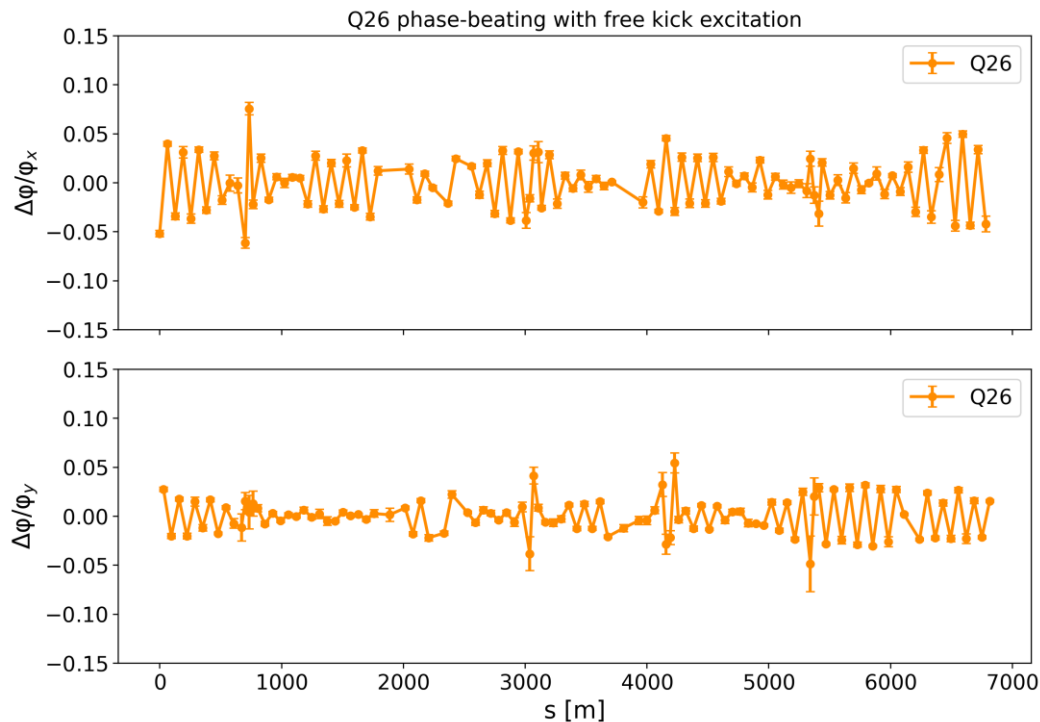
# Measurements with Q26 optics (MD14403)

- New short // MD with single ion bunches & Q26 optics
- Move V tune close to the 4<sup>th</sup> order resonance
- Scan current in extraction octupoles LOE.10402 & LOE.33002
- AC-dipole excitation close to noise plateau
- Tried free kicks to increase S/N – Very long decoherence times!



# Measurements with Q26 optics (MD14403)

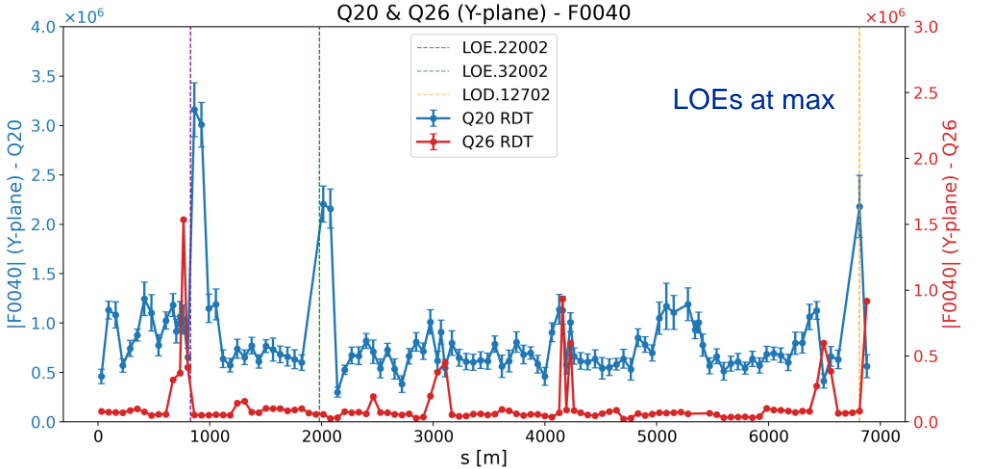
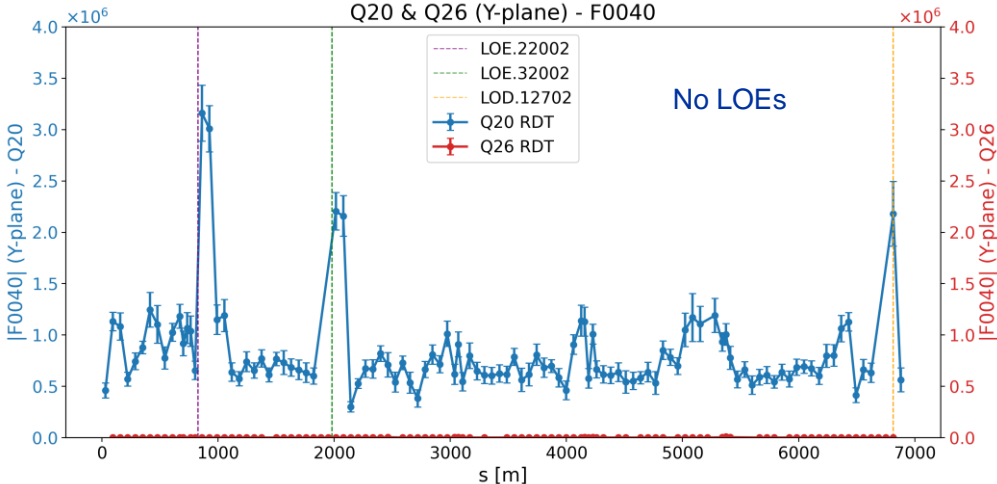
- Measurements with single ion bunches @ FB and excitation with AC dipole
- AC-dipole TbT difficult to analyze due to larger noise content
- Additional complexity from optics – Close to **90°** phase advance BPM to BPM
- Phase beating around **10%** peak-to-peak and **20%** peak to peak beta-beating on par with Q20





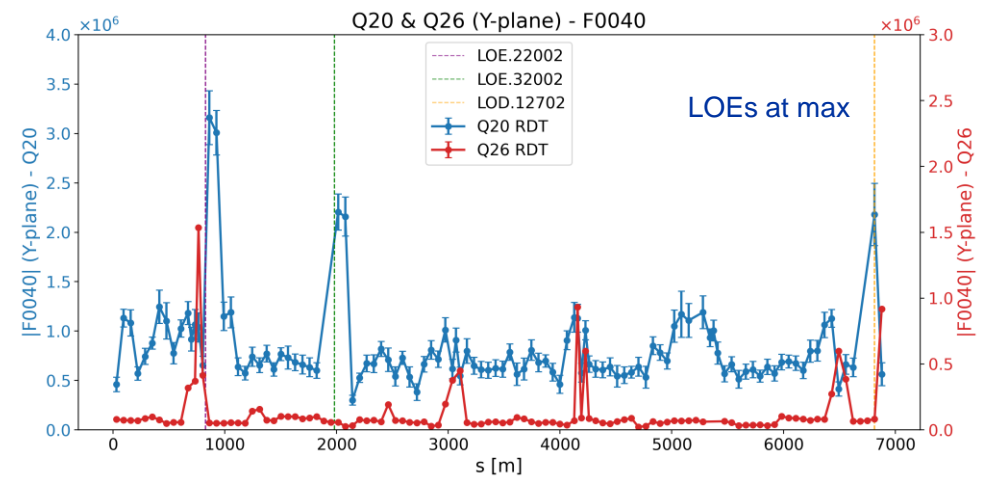
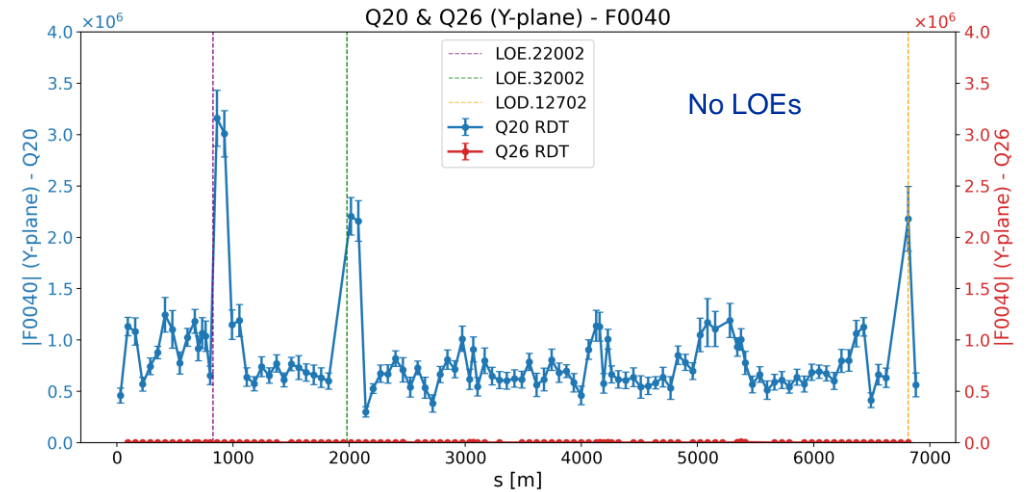
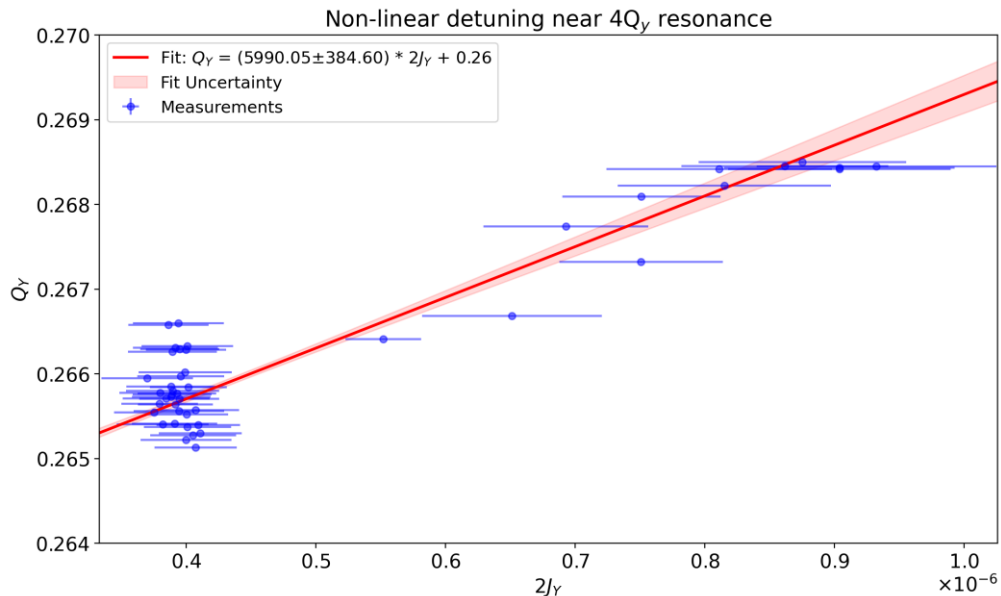
# Measurements with Q26 optics (MD14403)

- RDTs measurements did not reproduce Q20 findings
- Most likely scenario: Noise & other artifacts in BPMs during Q20 MD and the OMC's routine for locating RDTs led to spurious measurements – Needs to be clarified!



# Measurements with Q26 optics (MD14403)

- RDTs measurements did not reproduce Q20 findings
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- LNOs scans provided the opportunity for detuning analysis with OMC – Needs tune drift correction



# Conclusions

- **For the first time optics measurements with OMC + AC Dipole combo in the SPS**
- **Q20 & Q26 optics beating around 20% peak to peak**
- **Sextupolar & Octupolar RDTs measured around the machine**
- **Indications for octupolar perturbations were dismissed**
- **Identified issues to be addressed in the future**

# Plans for 2025 run

- **Refine SPS instance in OMC to allow further optics measurements (e.g. coupling)**
- **Can we improve ADT excitation for better S/N ratio?**
- **Optimize OMC search algorithms for resonances in the presence of noise & correct for tune-drifts**
- **Follow-up request to register TbT data for a larger number of turns in the SPS**
- **Simulations development with XSUITE on-going**
- **Repeat measurements in short parallel MDs and expand with non-linear chromaticity & tune-shift with amplitude**

Thank you for your attention

# Extras

# What is an AC-dipole?

- Dipole magnet that shakes the beam continuously for a fixed amount of time
- Forced oscillations!
- Resonant excitation -> Need to approach the natural frequencies of the beam
- Routinely used in PSB, PS and LHC for optics measurements and beam dynamics applications
- It was last used in the SPS in 2004!



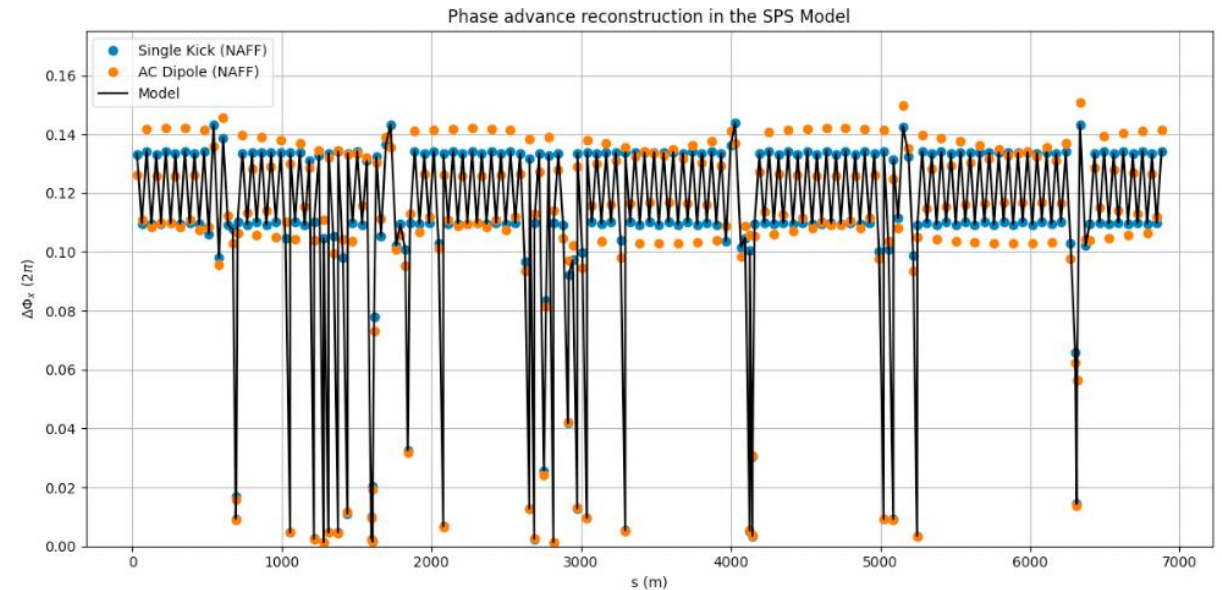
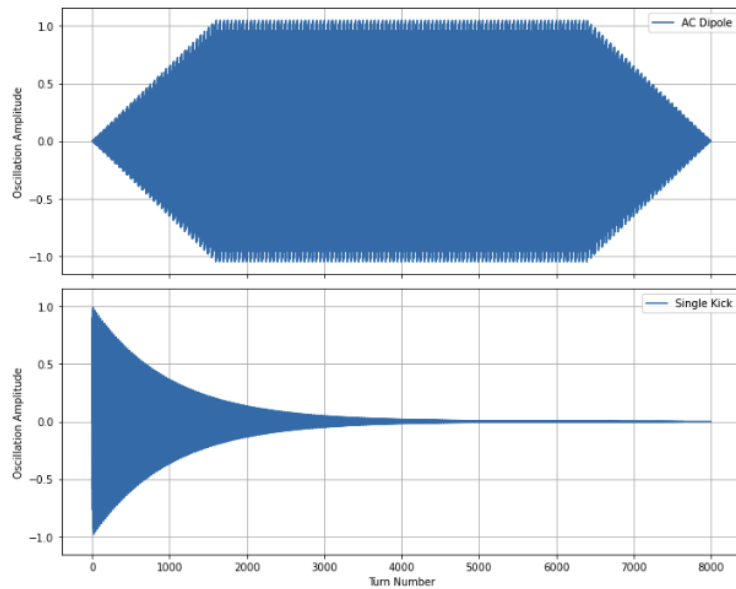
AC Dipole

Beam

# AC-dipole: Pros & Cons

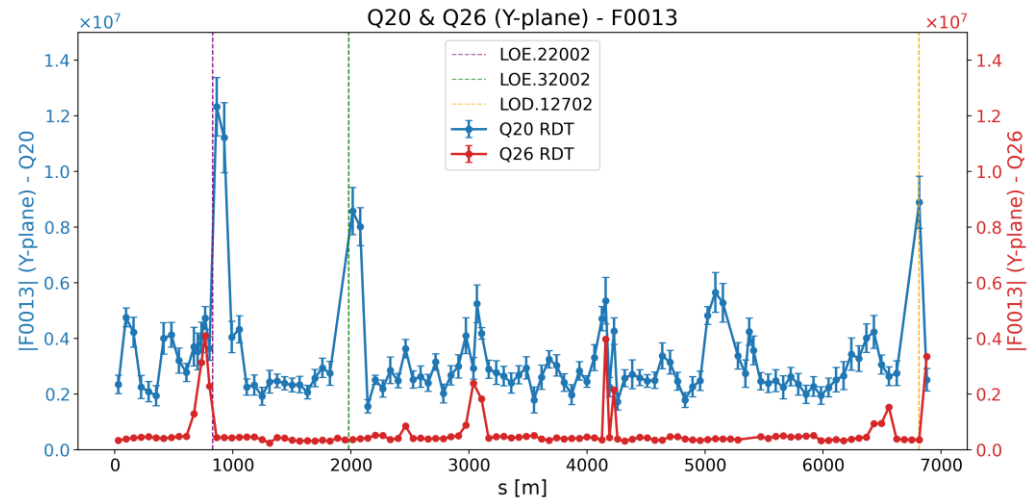
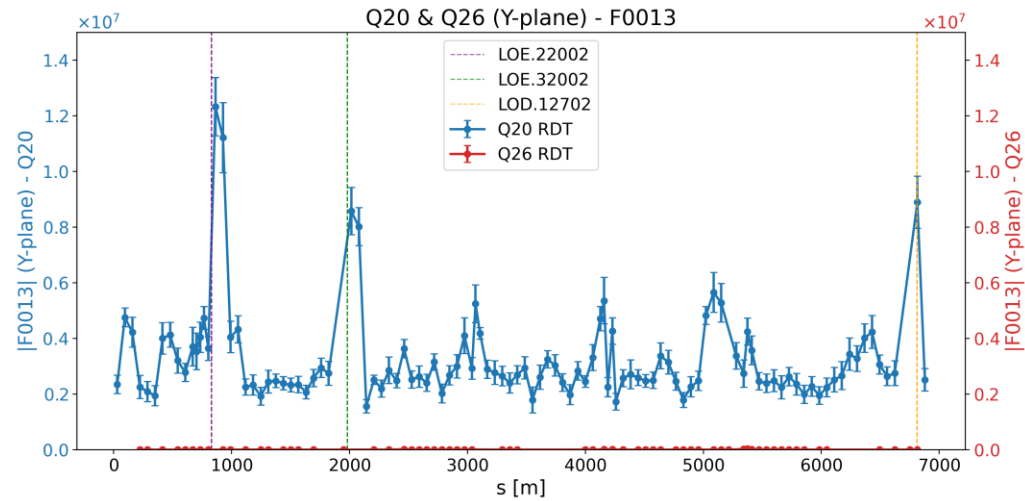
- ✓ Not destructive for the beam
- ✓ "Infinite" TbT data cheat code!
- ✓ AC dipole frequency can be easily changed
- ✓ Can achieve better S/N with respect to traditional kicks

- !! Extra work might be required to make it truly transparent to the beam
- !! Prone to noise from electronics
- !! Complicates frequency spectra
- !! It acts as a gradient error – small optics beating!

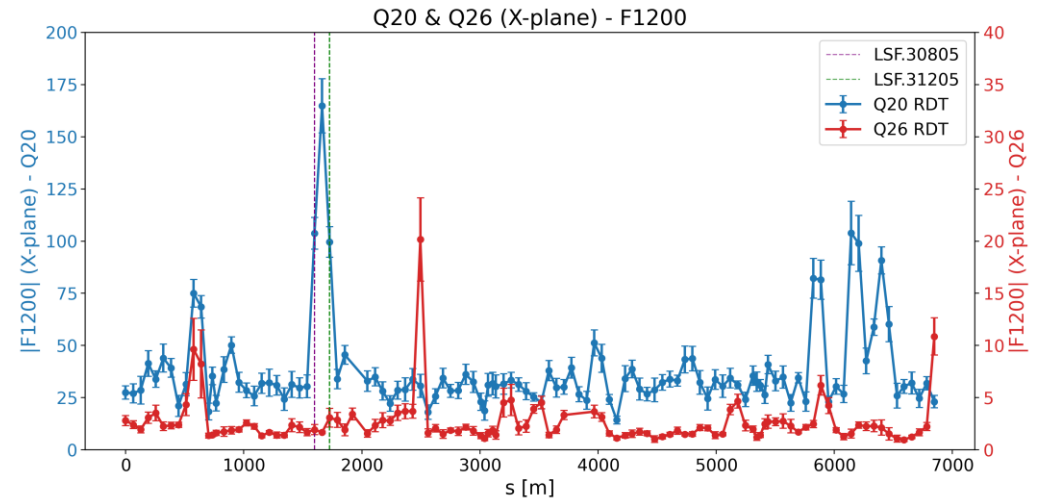
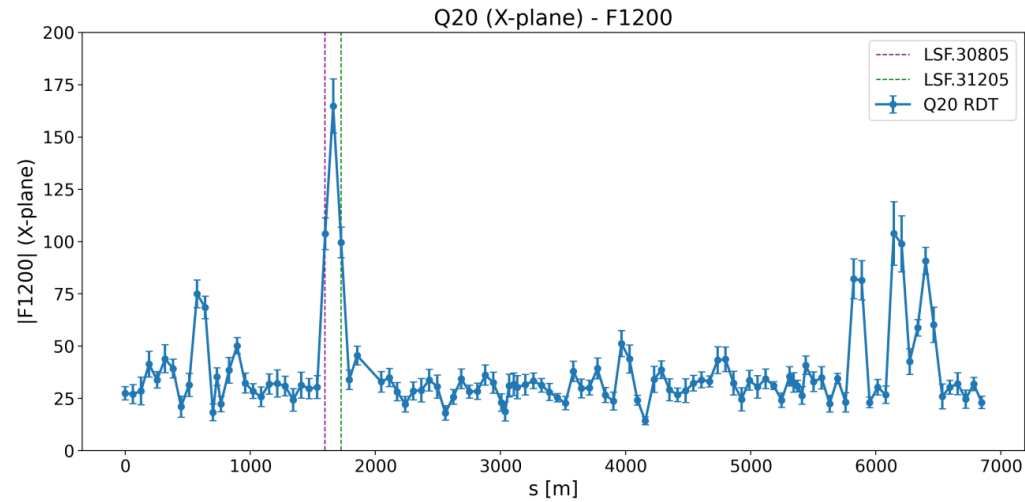




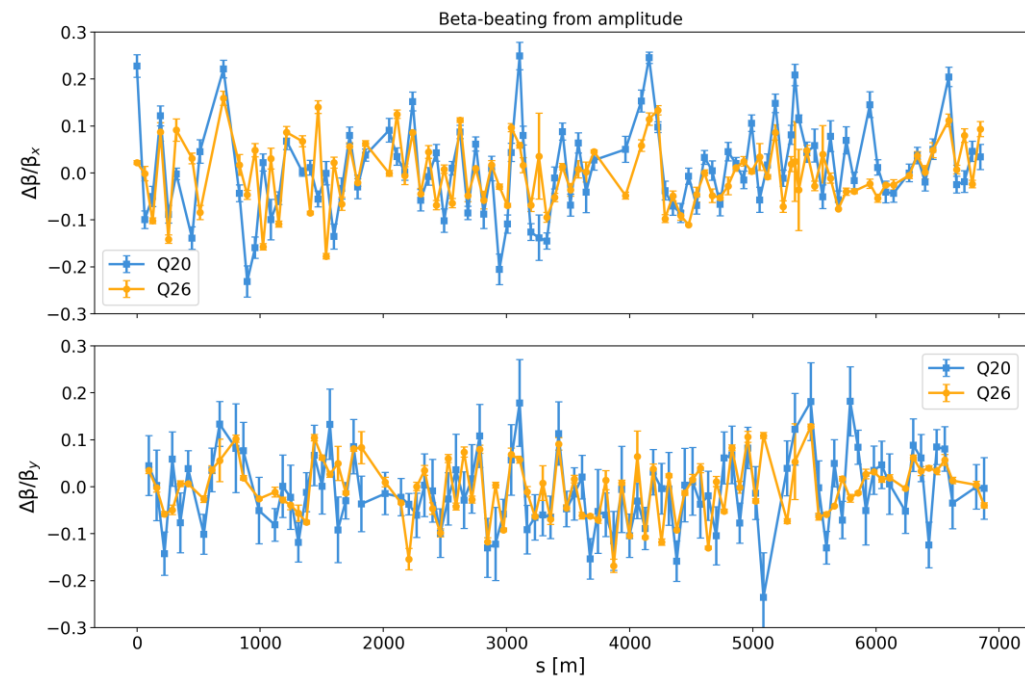
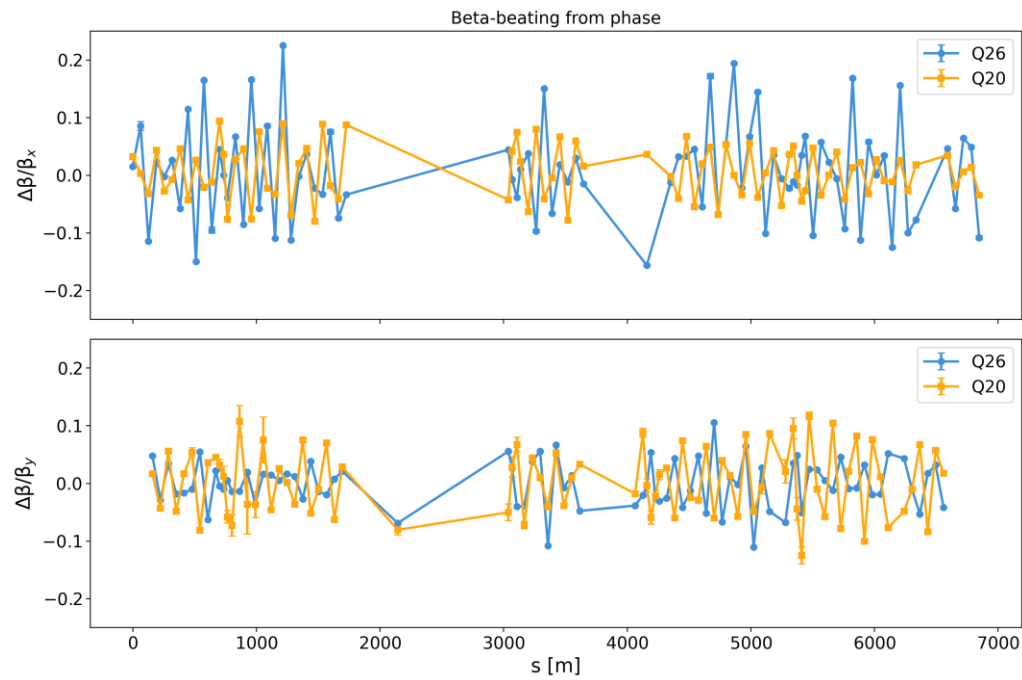
# f0013 with Q20 & Q26



# f1200 with Q20 & Q26



# Beta beating Q20 & Q26





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