

# (Non-) Linear Optics studies at IOTA

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Acknowledgments:

S. Antipov, M. Benedikt, F. Carlier, J. Dilly, E. Fol, E.H. Maclean, L. Malina,  
T.H.B. Persson, J. Coello de Portugal, A. Garcia-Tabares, G. Stancari, A. Wegscheider

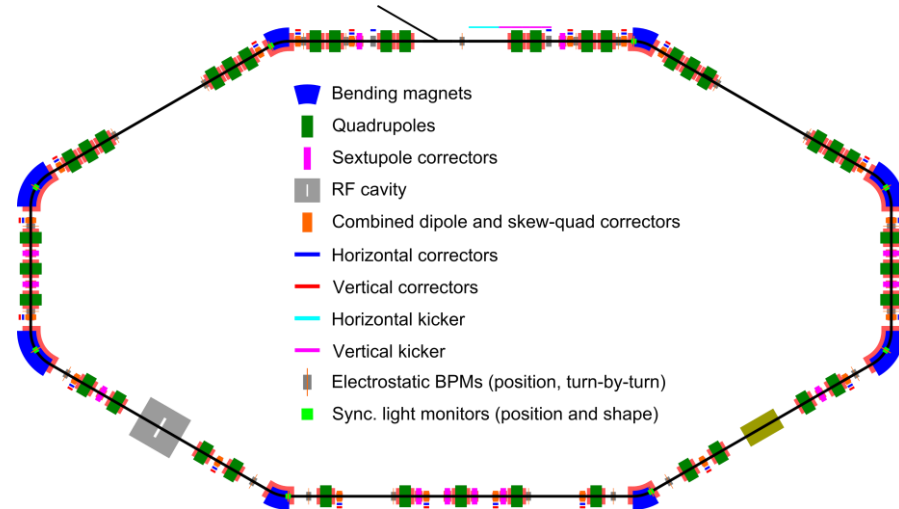


3/11/2015

FAC/IOA Collaboration Meeting

# The IOTA ring

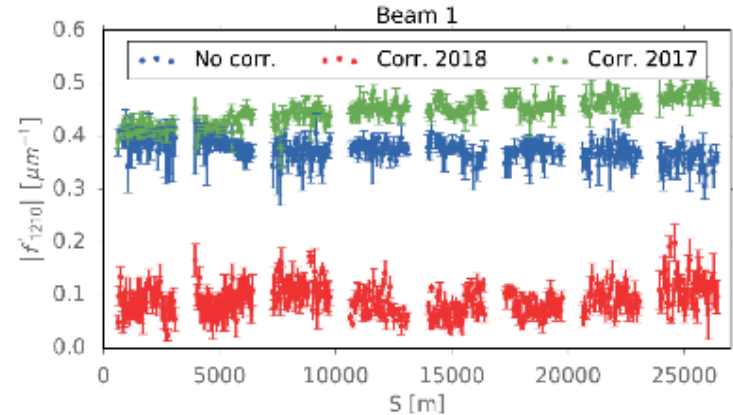
- The IOTA ring/octagon is a unique accelerator
- In terms of experimental program:  
octupole channel, nonlinear insert, OSC, e-lens, ...
- But also for optics studies:
  - Good control over  $\beta$ -function required down to the % level [1,2]
  - Similarly so for coupling due to working point on the diagonal (in certain modes of operation)
  - Inherently nonlinear while not driving resonances



- [1] A. Valishev et al., Beam physics of integrable optics test accelerator at Fermilab, IPAC2012, TUPPC090  
[2] S. Antipov et al., Single-particle dynamics in a nonlinear accelerator lattice: attaining a large tune spread with octupoles in IOTA, 2017 JINST 12 P04008

# Resonance Driving terms as a diagnostic tool

- Goal of the proposed study is to measure resonance driving terms (RDT) in the IOTA ring
- Localized measure of the distortion in phase space due to particular resonance
- Longitudinal variation of amplitude of RDT used to determine sources of nonlinearities and potentially correct for
- A tool used in many accelerators such as SPS, LHC, Tevatron, RHIC, Diamond, ESRF, ...

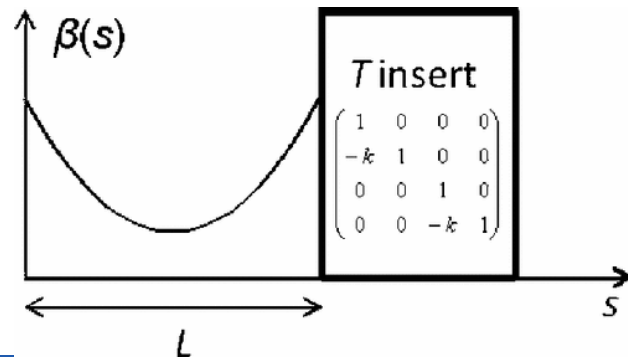


F. Carrier et al., Correction of skew octupoles with Resonance Driving Terms

$$\begin{aligned}
 h_x^- &= x - ip_x = \sqrt{2I_x} e^{i(2\pi\nu_x N + \psi_{x_0})} \\
 &- 2i \sum_{jklm} j f_{jklm} (2I_x)^{(j+k-1)/2} (2I_y)^{(l+m)/2} \\
 &\times e^{i[(1-j+k)(2\pi\nu_x N + \psi_{x_0}) + (m-l)(2\pi\nu_y N + \psi_{y_0})]}
 \end{aligned}$$

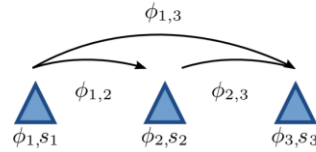
# Aiming to measure what shouldn't be there

- Ideally we will not see any RDTs present in IOTA although very nonlinear
  - NL-insert should not drive any resonances
  - Sextupolar RDTs to be expected from the chromaticity sextupoles in the T-insert
- Initially focus on measuring sextupolar and octupolar RDTs
- First measurements/assessments can be done parasitically to some other studies by reanalysing BPM turn by turn data
- Results should provide input for future simulations and potential corrections

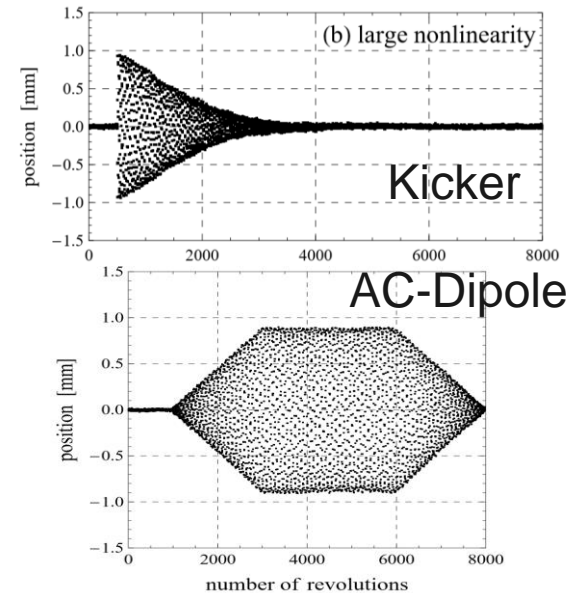


# Linear optics studies

- Extracted Turn by turn data also allows for fast linear optics measurements complementary to the previous LOCO measurements
- Assessing the local coupling and correction of interest not only for non linear integrable optics but also later on for OSC
- One particular challenge for the measurements
  - Potential way of overcoming decoherence could be the use of running the kicker magnets with oscillating current (AC-Dipole configuration)



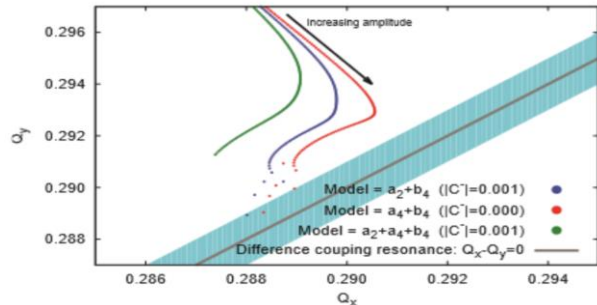
$$\beta_1^{\text{meas}} = \beta_1^{\text{mod}} \frac{\cot \Delta\phi_{12}^{\text{meas}} - \cot \Delta\phi_{13}^{\text{meas}}}{\cot \Delta\phi_{12}^{\text{mod}} - \cot \Delta\phi_{13}^{\text{mod}}}$$



From R. Miyamoto, [FERMILAB-Thesis-2008-48](https://arxiv.org/abs/2008.0448)

# Further studies on coupling

- In addition, the possible occurrence of an amplitude dependent closest tune approach could be studied

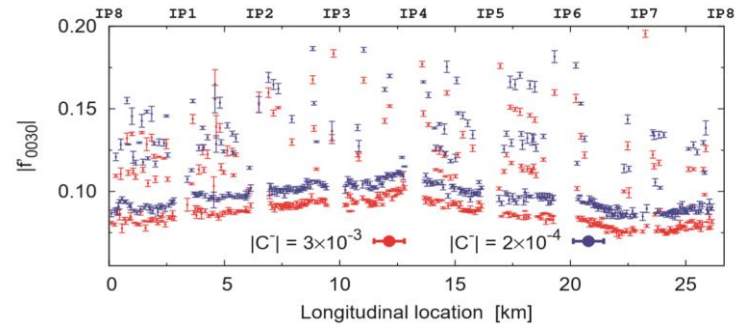


E.H. Maclean et al., Amplitude dependent closest tune approach generated by normal and skew octupoles, IPAC 2017, WEPIK091

$$\Delta Q_{min} \approx 2 \sqrt{\kappa^2 + h_{1111} \kappa a_1 \bar{a}_2 - h_{1111}^2 / 32 (a_2 \bar{a}_2 - a_1 \bar{a}_1)^2} \quad [3]$$

with  $\kappa$  being the linear closest tune approach,  
 $h_{1111}$  octupolar amplitude detuning term,  
 $a_{1,2}$  phase space coordinates

- Similarly, the impact of local coupling on RDTs but also in combination with NL-insert possibly of interest



E.H. Maclean et al.,  
 Effect of linear coupling on nonlinear observables at the LHC, IPAC 2017, WEPIK092

[3] R. Tomás et al., Amplitude dependent closest tune approach, PRAB 19, 071003 (2016)

# Conclusion

- Focus of the proposed study is measuring resonance driving term in IOTA
  - Unique in that it is very nonlinear while ideally no RDT present
- Output of the proposed study hopefully valuable input for further studies and corrections
- Comments/ input are very welcome

**Thank you for your attention!**



