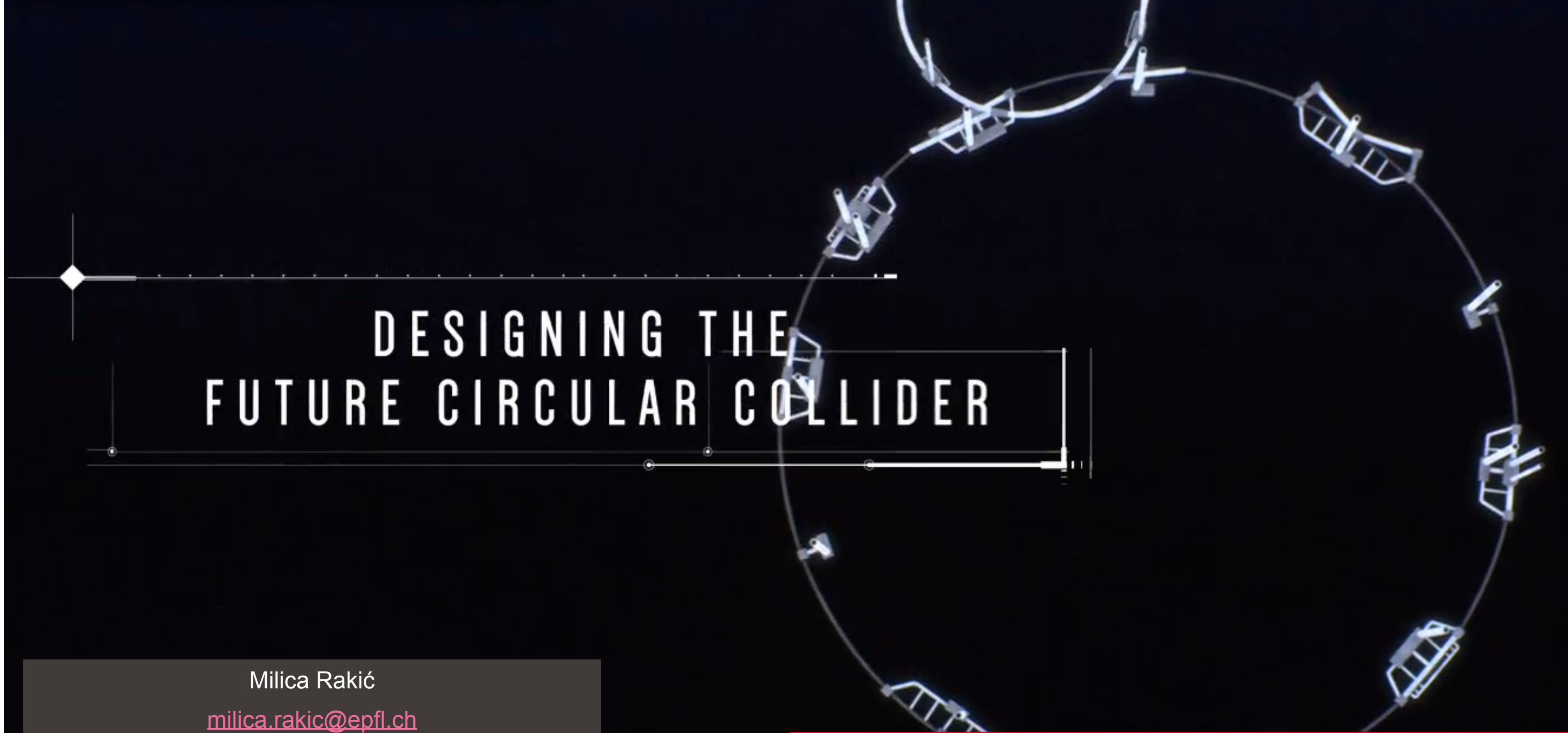
Adjusted tapering schemes for reduction of circuits in PyAT



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Mentors and Supervisors:

Tatiana Pieloni, Felix Carlier and Simon White

EPFL-LPAP FCC-ee Software Framework Meeting - 20.05.2021

Accelerator Toolbox - AT

- The AT core was developed at SLAC by Andrei Terebilo
- Represents a collection of tools used to model storage rings and beam transport in MatLab (PyAT implementation for Python exists)
    - Creation and manipulation of storage ring lattice elements
    - Tracking particles
    - Compute accelerator and beam parameters
- GitHub: https://github.com/atcollab/at

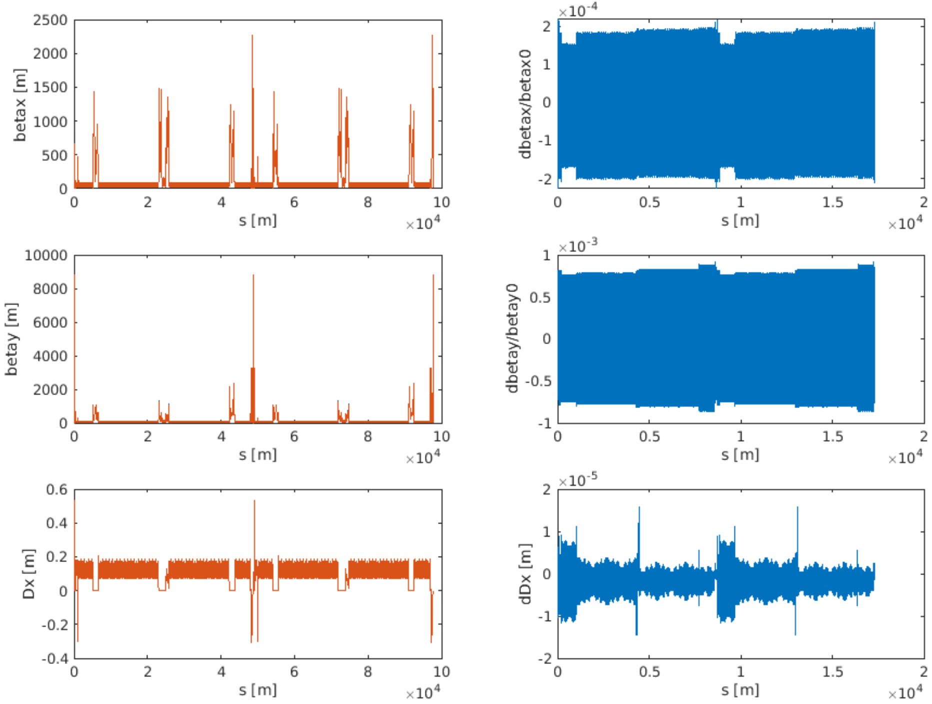


Figure 1: Comparison of the AT and MADX optics. Image credit: S. White.

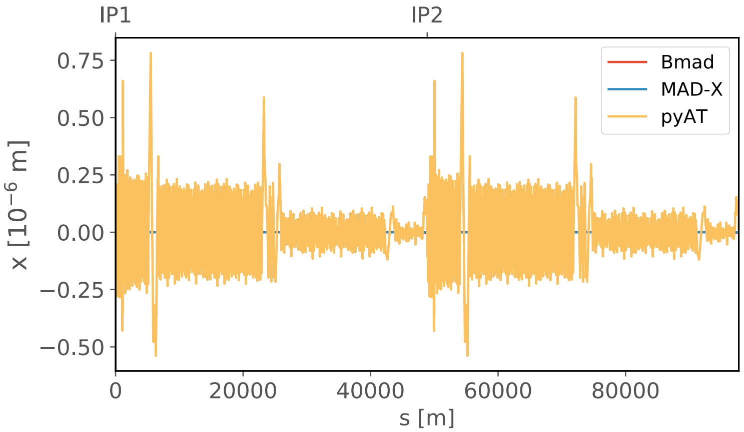
Historical warmup

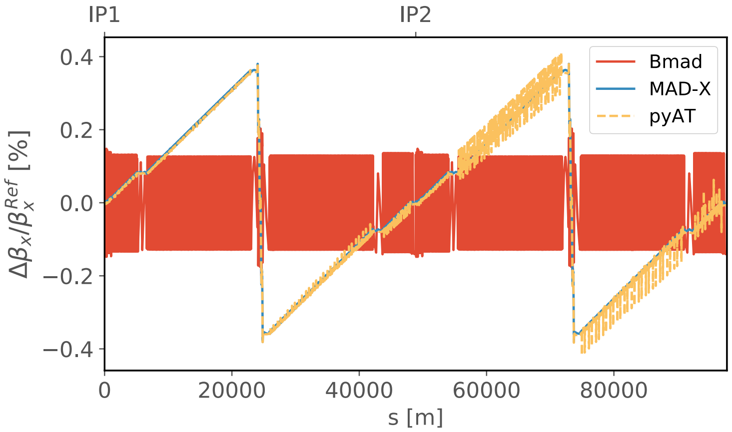
- Initially:
  - PyAT had no tapering implementation
  - PyAT had no feature of optics calculation with included synchrotron radiation
- Currently:
  - Individual tapering and optics with radiation were tested
  - Individual matching to 6D orbit
  - Looking at more simplified tapering for Higgs lattice

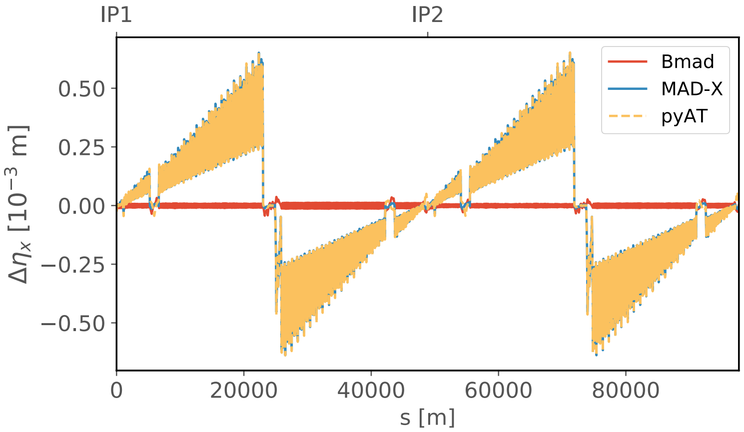
→ Developed by S.White

Optics with radiation in PyAT

- Comparison with Bmad and MAD-X
- Perfect tapering scheme:
  - Good reproduction of optics functions
  - Need to improve the tapering for energy and hardware considerations
- Images source: F. Carlier







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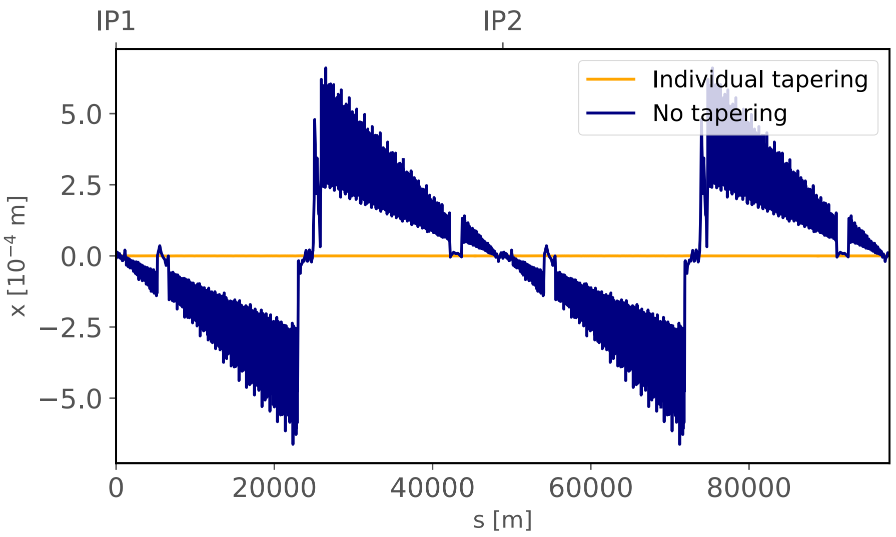
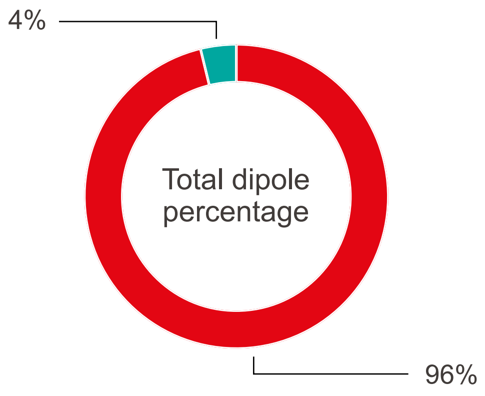
Perfect tapering in PyAT

Individual vs no tapering	$\Delta\epsilon_x$	$\Delta\eta_x$	$\frac{\Delta\beta}{\beta^{Ref}}$
IP1	1.905E-10	-4.919E-08	-3.6958E-05
IP2	1.905E-10	-5.491E-08	-3.6959E-05



First exploration of simplified tapering

- Identification of 100 microns figure of merit for maximum orbit (K.Oide)
- Identification of most important lattice families (supplied by K.Oide)
  - Main arc dipoles at sextupole-free sections B1
  - Main arc dipoles at long sextupole sections B1L
  - Main arc dipoles at short sextupole sections B1S
- All other dipole families were kept as are (e.g. dispersion suppressors, connecting arc, IP upstream and downstream)
- For B1, B1S and B1L average tapering was employed, all other dipoles received individual tapering



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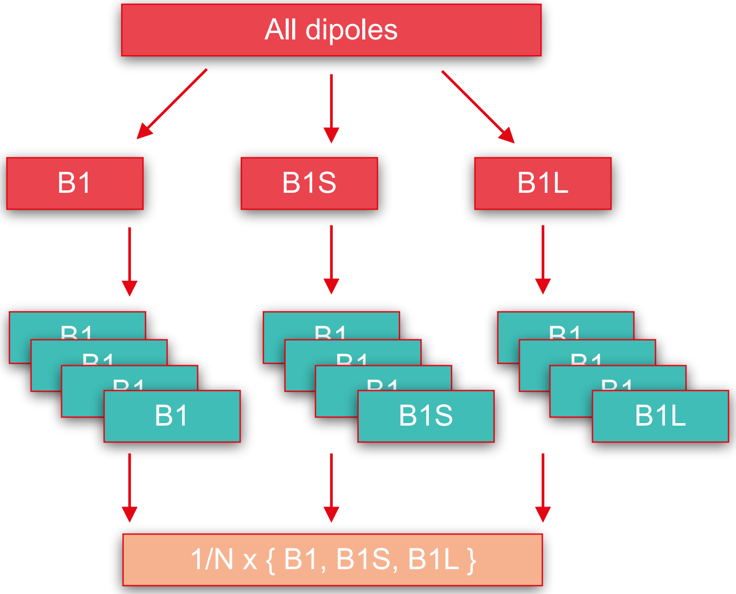
First exploration of simplified tapering

- Reasons for looking into simplified tapering:
  - Tapering of individual magnets is expensive
  - Successful simplified tapering for Higgs physics lattice can greatly reduce costs
  - Valuable input for future dipole magnet design phase
- Average tapering entailed:
  - Individual tapering of all dipoles, quadrupoles and sextupoles
  - Segmenting three main dipole families in 4 section based on RF and IP positions
  - Further segmentation into number-adjusted sub-families
  - Taking values from individual tapering and averaging them over sub-families
  - Applying obtained values to dipole strengths of chosen families



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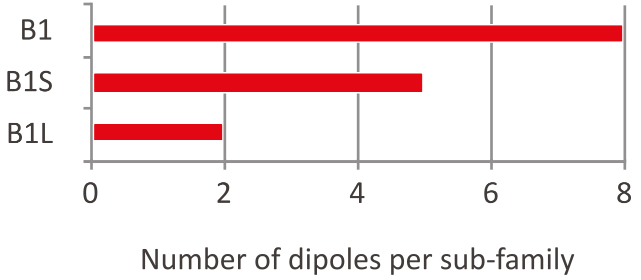
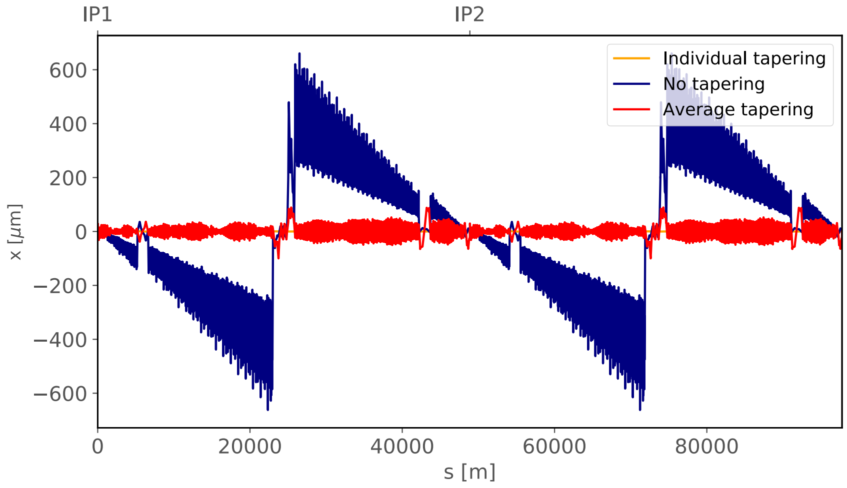
Simplified tapering for 50 micron orbit

- Results on orbit and optics, given for different number of dipoles per one averaged group:
  - Average tapering for small number of dipoles per sub-family shows good results
  - Half arc splitting into around 100 sections





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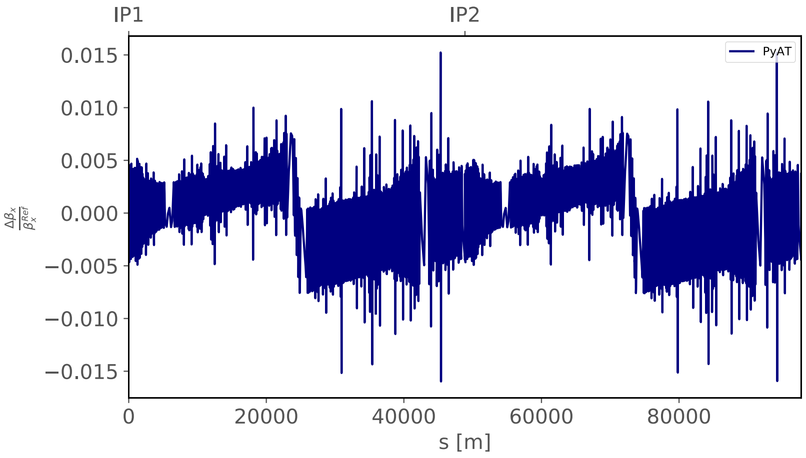
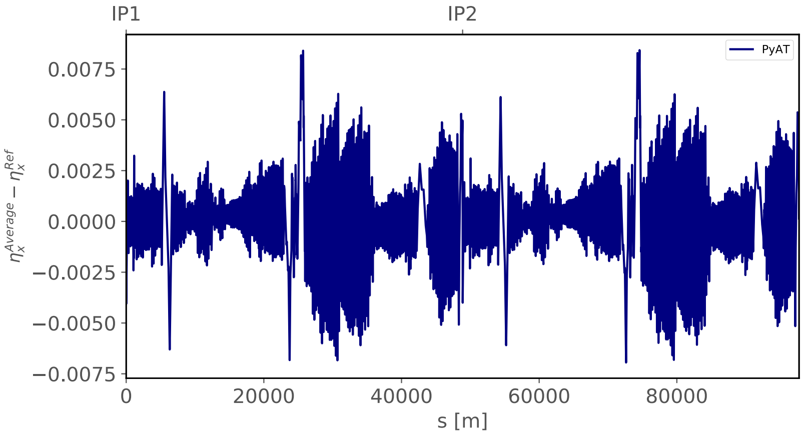
Simplified tapering for 50 micron orbit

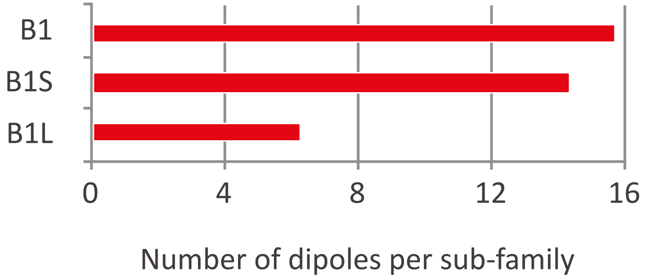
- Results on orbit and optics, given for different number of dipoles per one averaged group:
  - Beta beating becomes more drastic
  - Half arc splitting into around 100 sections

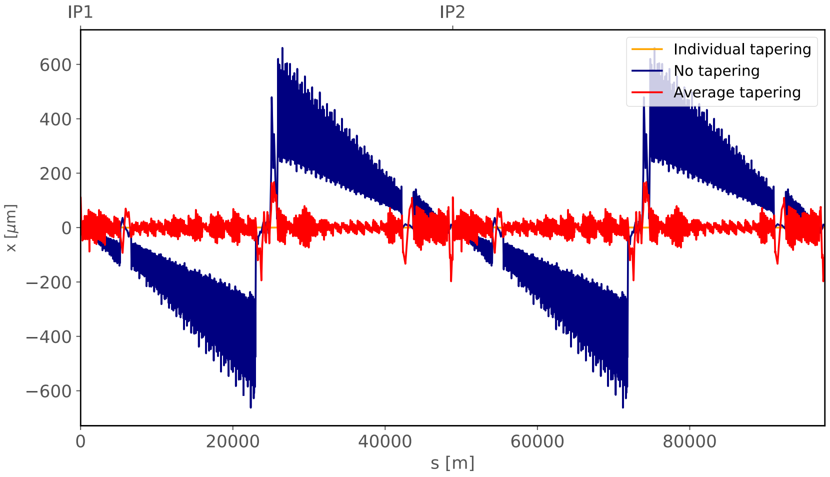




Simplified tapering for 100 micron orbit

- Results on orbit and optics, given for different number of dipoles per one averaged group:
  - Half arc splitting into around 40 sections





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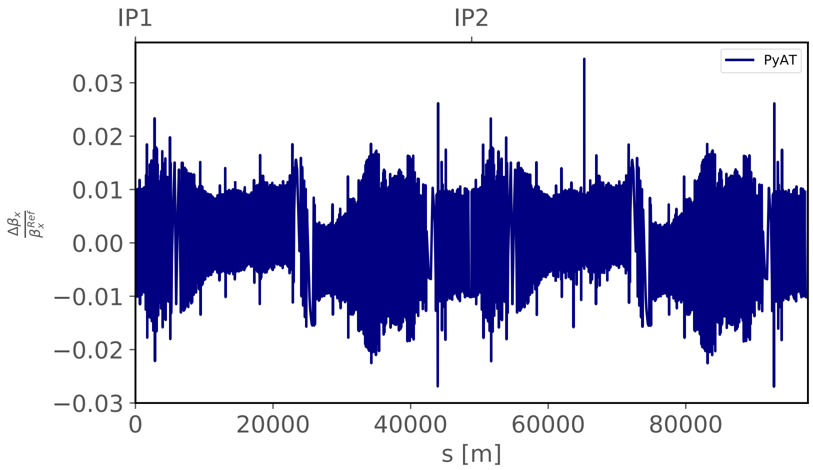
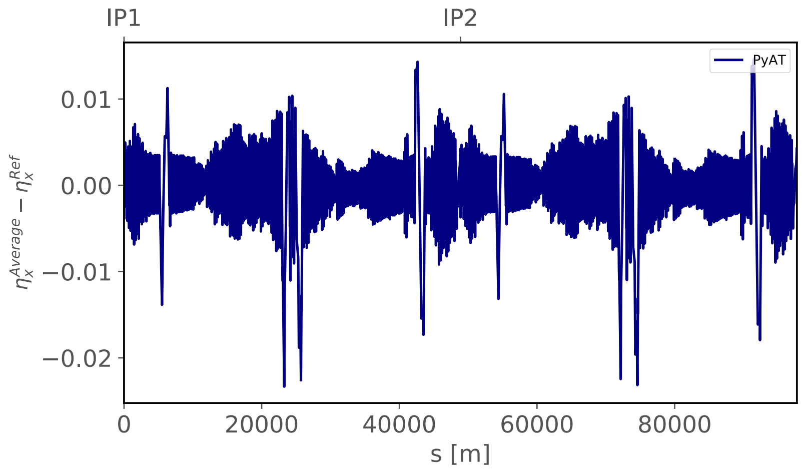
Simplified tapering for 100 micron orbit

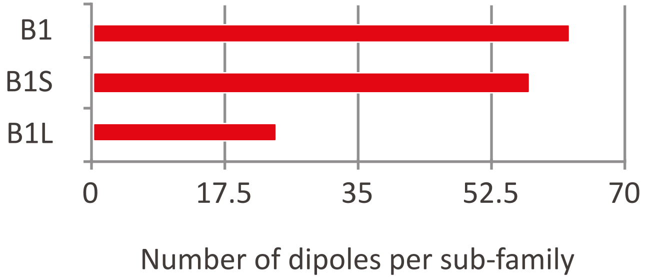
- Results on orbit and optics, given for different number of dipoles per one averaged group:
  - Half arc splitting into around 40 sections
  - 10x increase in dispersion from 50 micron orbit
  - 2x increase in beta from 50 micron orbit

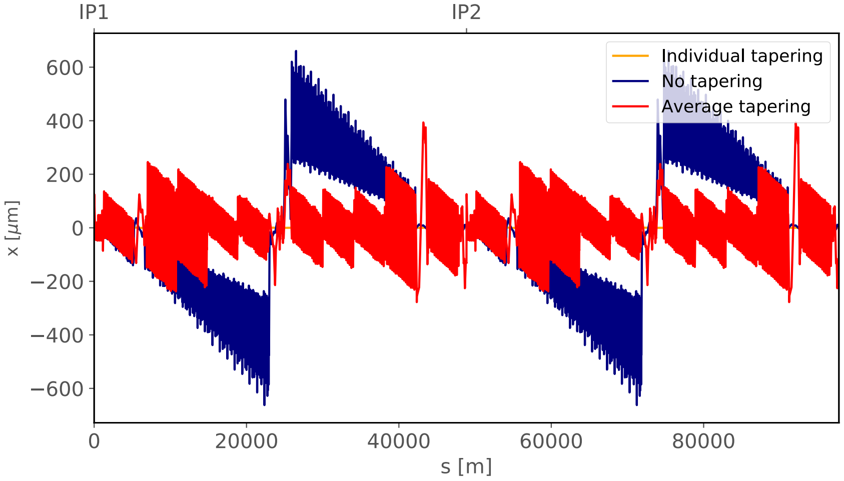




Simplified tapering for 200 micron orbit

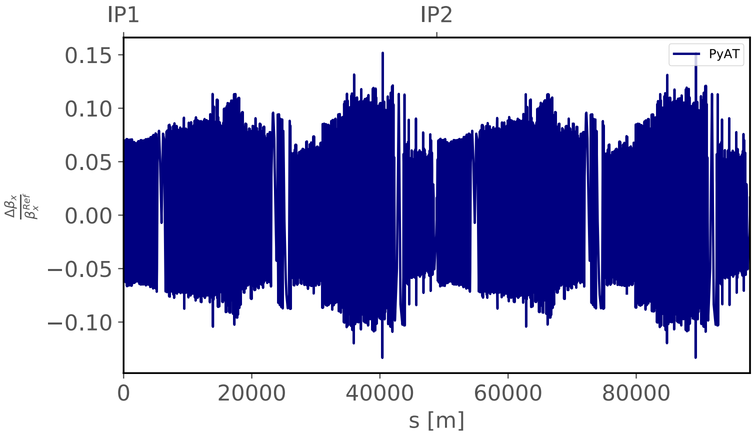
- Results on orbit and optics, given for different number of dipoles per one averaged group:
  - Average tapering for larger amount of dipoles changes the picture
  - Half arc splitting into around 10 sections

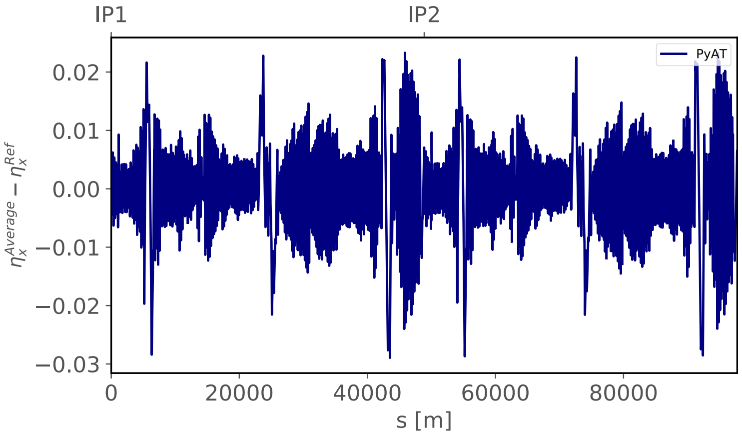




Simplified tapering for 200 micron orbit

- Results on orbit and optics, given for different number of dipoles per one averaged group:
  - Half arc splitting into around 10 sections
  - 2x increase in dispersion from 100 micron orbit
  - 10x increase in beta from 100 micron orbit
  - Need for rematching the optics and correction of dispersion (next steps in future studies)





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First exploration of simplified tapering

- Statistics:

	Number of dipoles per sub-family			ϵ_x		$\frac{\Delta\beta}{\beta^{Ref}}$		$\Delta\eta_x$	
	B1	B1S	B1L	Average	Individual	IP1	IP2	IP1	IP2
50 μm	6	5	2	6.583E-10	6.295E-10	3.7243E-03	3.7244E-03	1.39E-04	1.35E-04
100 μm	16	14	6	9.547E-10	6.295E-10	9.61E-03	9.62E-03	5.25E-05	6.56E-05
200 μm	63	58	25	6.348E-10	6.295E-10	1.652E-02	1.651E-02	6.15E-04	6.17E-04

Conclusion

- Current PyAT developments:
  - Successful tapering
  - Successful implementation of optics calculations with synchrotron radiation (reference E.Forest)
  - Focusing on further exploring:
    - Optics function degradation below 15%
    - Large distortion of dispersion function
- Moving on:
  - Preforming the matching (optimisation) for the dipoles using averaged state as initial condition
  - Performing orbit optimisation with orbit correctors
  - Rematching optics after alternative tapering scheme