PROGRESS WITH FCC-EE TUNING

Chromaticity correction and effective lattices

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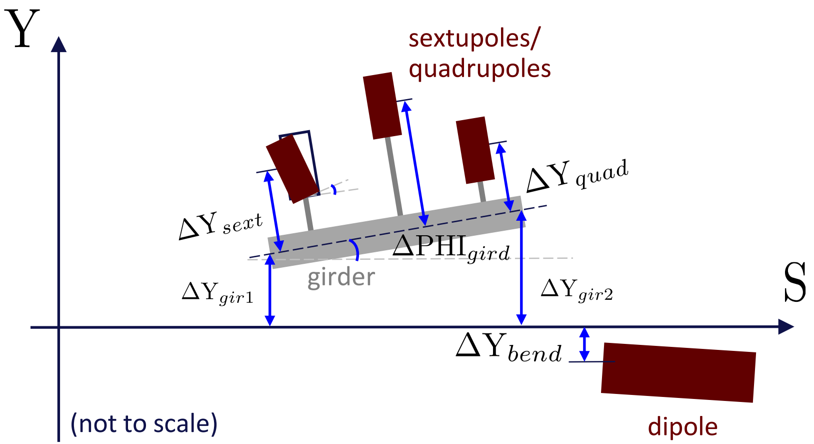
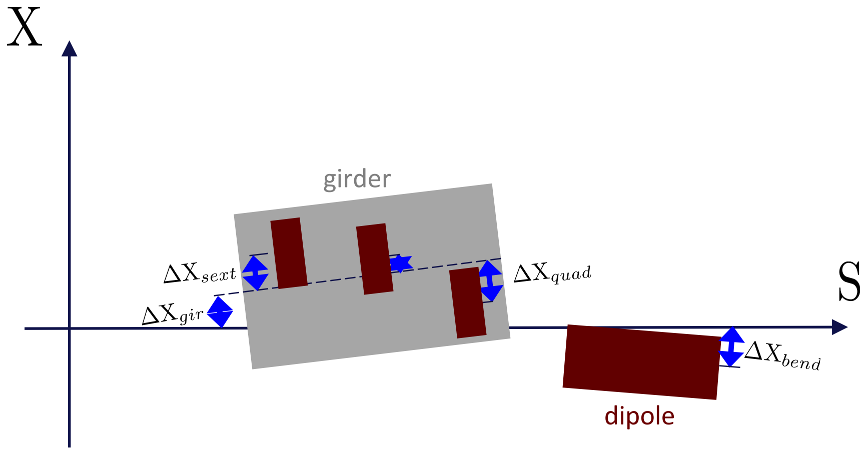
1. University of Liverpool, 2. Cockcroft Institute, 3. CERN, 4. KEK

FCCIS – The Future Circular Collider Innovation Study. This INFRADEV Research and Innovation Action project receives funding from the European Union's H2020 Framework Programme under grant agreement no. 951754.

Assigning girder misalignments





- 2 independent DX and DY misalignments for each end of the girder, and which can be used to calculate DTHETA and DPHI.

Misalignments and field errors used in these simulations

Type	ΔX (μm)	ΔY (μm)	ΔPSI (μrad)	ΔS (μm)	ΔTHETA (μrad)	ΔPHI (μrad)	Field Errors
Arc quadrupole*	50	50	300	150	70	70	$\Delta k/k = 2 \times 10^{-4}$
Arc sextupoles*	50	50	300	150	70	70	$\Delta k/k = 2 \times 10^{-4}$
Dipoles	1000	1000	300	1000	-	-	$\Delta B/B = 1 \times 10^{-4}$
Girders	150	150	-	1000	-	-	
IR quadrupole	100	100	250	200	70	70	$\Delta k/k = 2 \times 10^{-4}$
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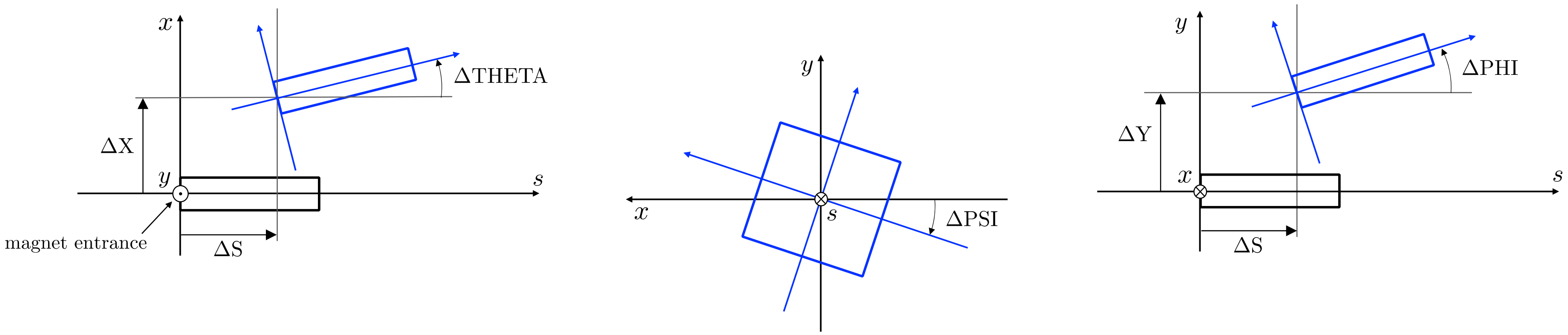
* misalignment relative to girder placement

Misalignments are randomly distributed via a Gaussian distribution, truncated at 2.5 sigma.



FCC-ee emittance tuning results – without chromaticity correction

RMS misalignment and field errors tolerances:

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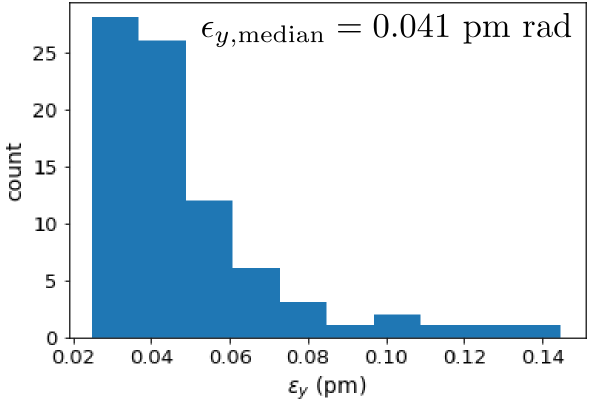
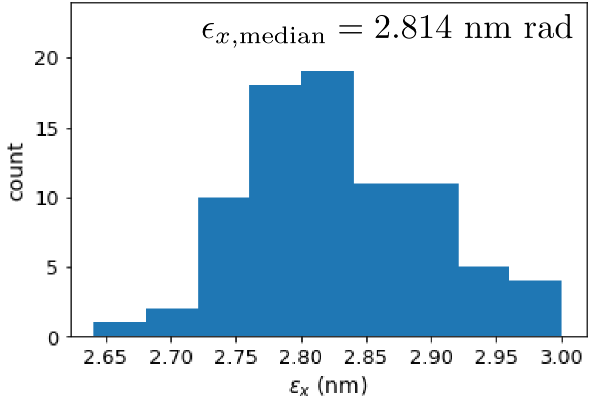
Note: BPM errors not included

ttbar (182.5 GeV) 4IP lattice,
after correction strategy:





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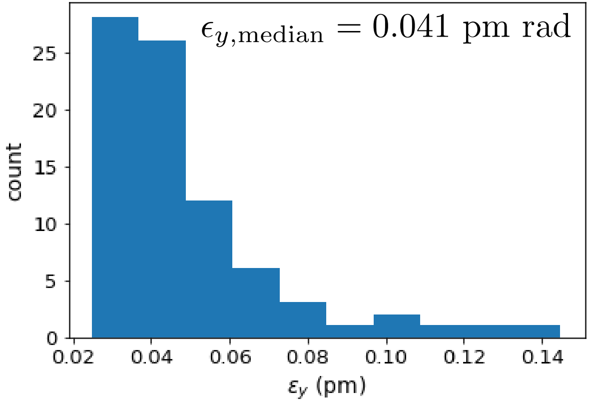

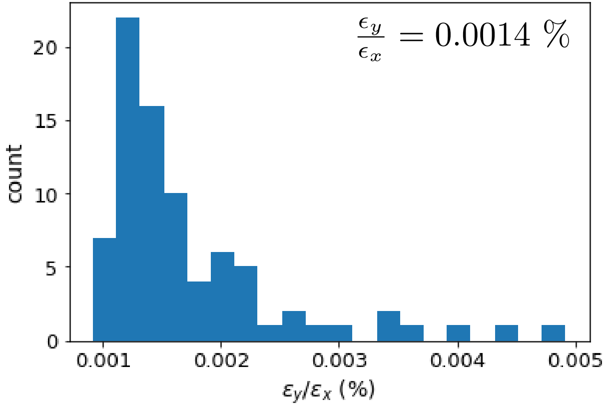

FCC-ee emittance tuning results – without chromaticity correction

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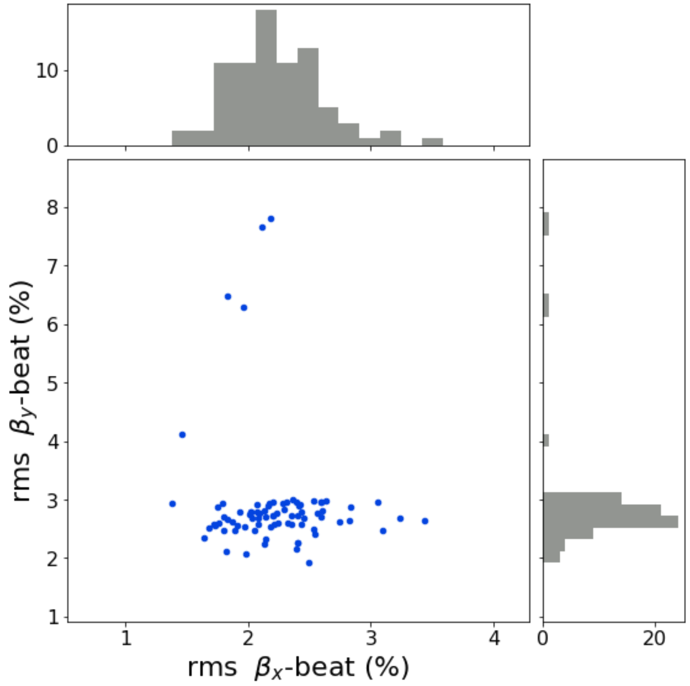

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Adding chromaticity correction…

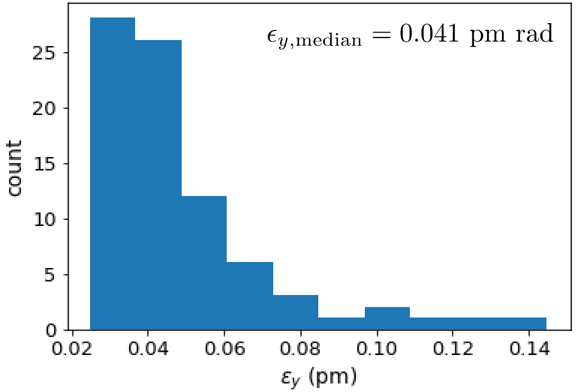
Chromaticity correction

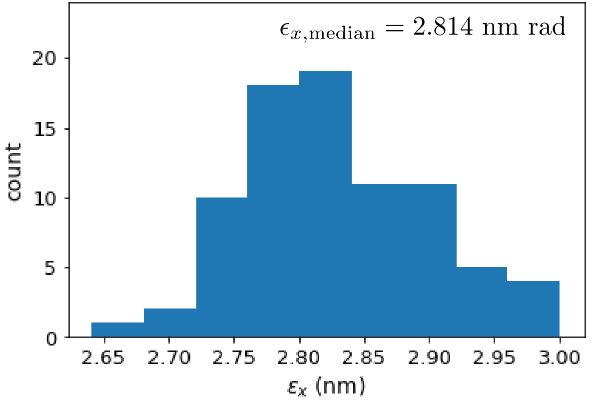
Chromaticity corrected with tunable factor applied to arc sextupoles. Same factor applied to all sextupoles of each type.

Applied through MAD-X Match function. Two optimization variables (sextupole strength knobs for SF and SD) and two objectives (chromaticity in x and y).

Chromaticity correction added

No chromaticity correction:





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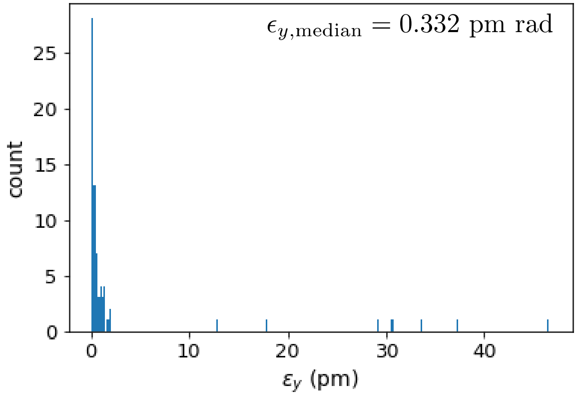

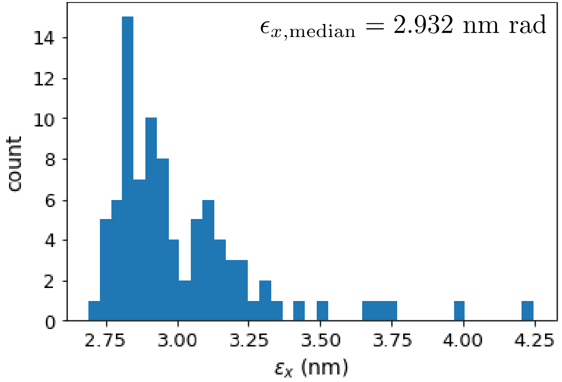

Chromaticity correction clearly increases the emittance in both planes.

Chromaticity correction added

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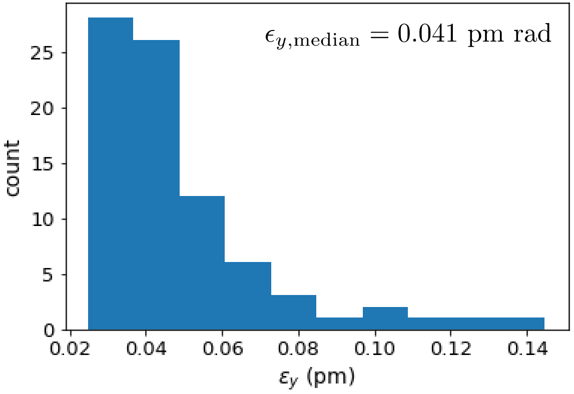

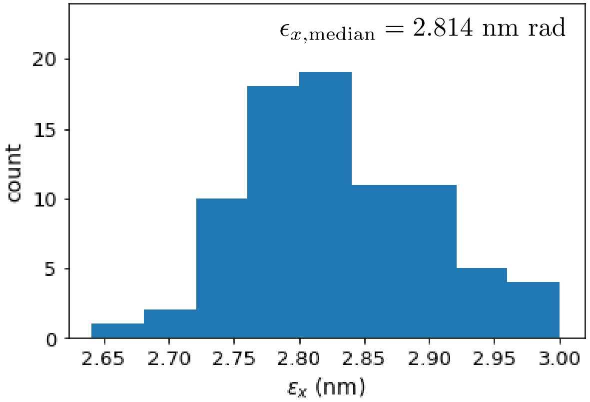

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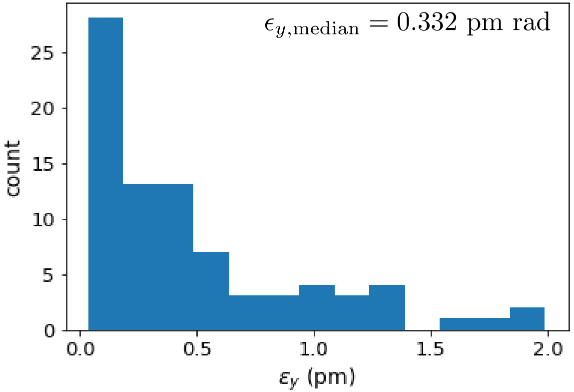
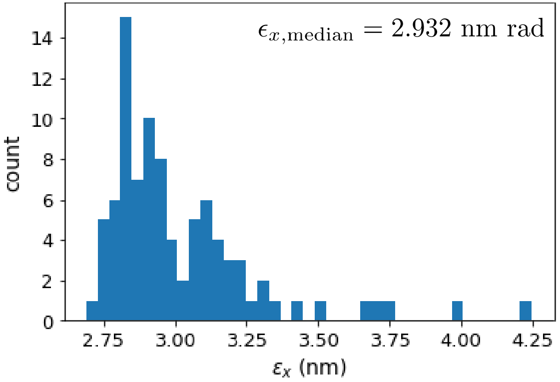


Highest 8 emittances removed, to better view lower end of distribution.



Chromaticity correction clearly increases the emittance in both planes.

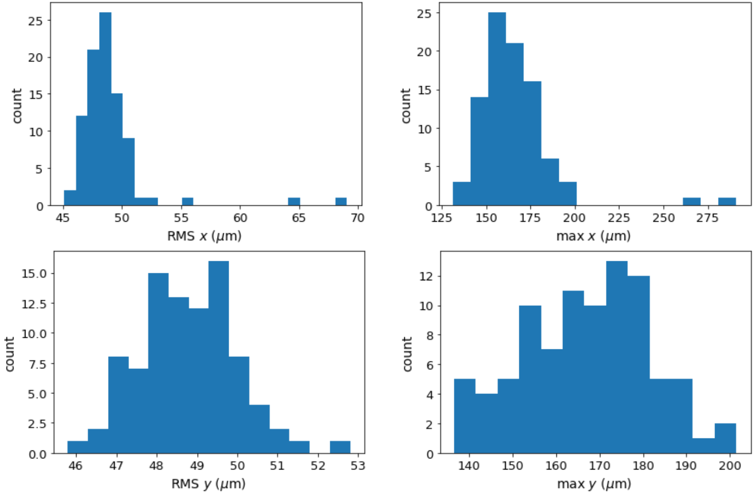
Adding chromaticity correction

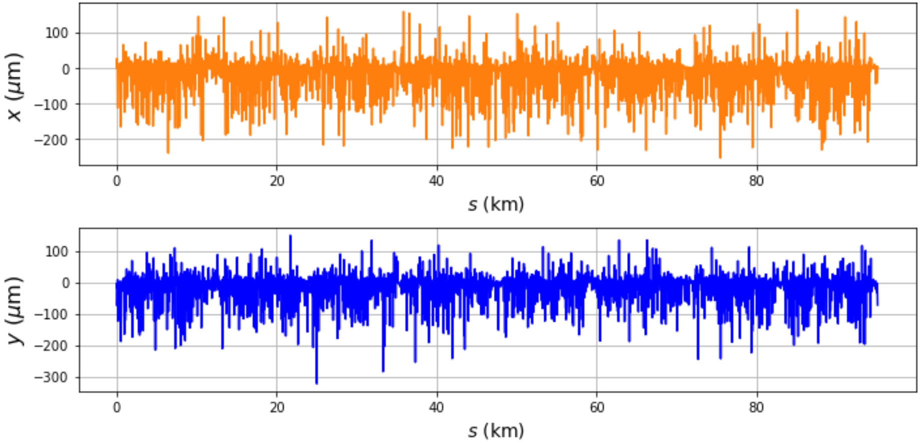
Multiple variations attempted:

- Chroma corr added at the end of original correction algorithm
- Chroma corr scattered throughout final stage of correction algorithm (sextupoles at full strength)
- Chroma corr performed, followed by a recalculation of the coupling+dy correction resp. mat.

Difficulty: chroma correction corrects chromaticity well, but increases coupling (by a lot).
Applying additional coupling correction changes the chromaticity -> An iterative procedure is necessary.

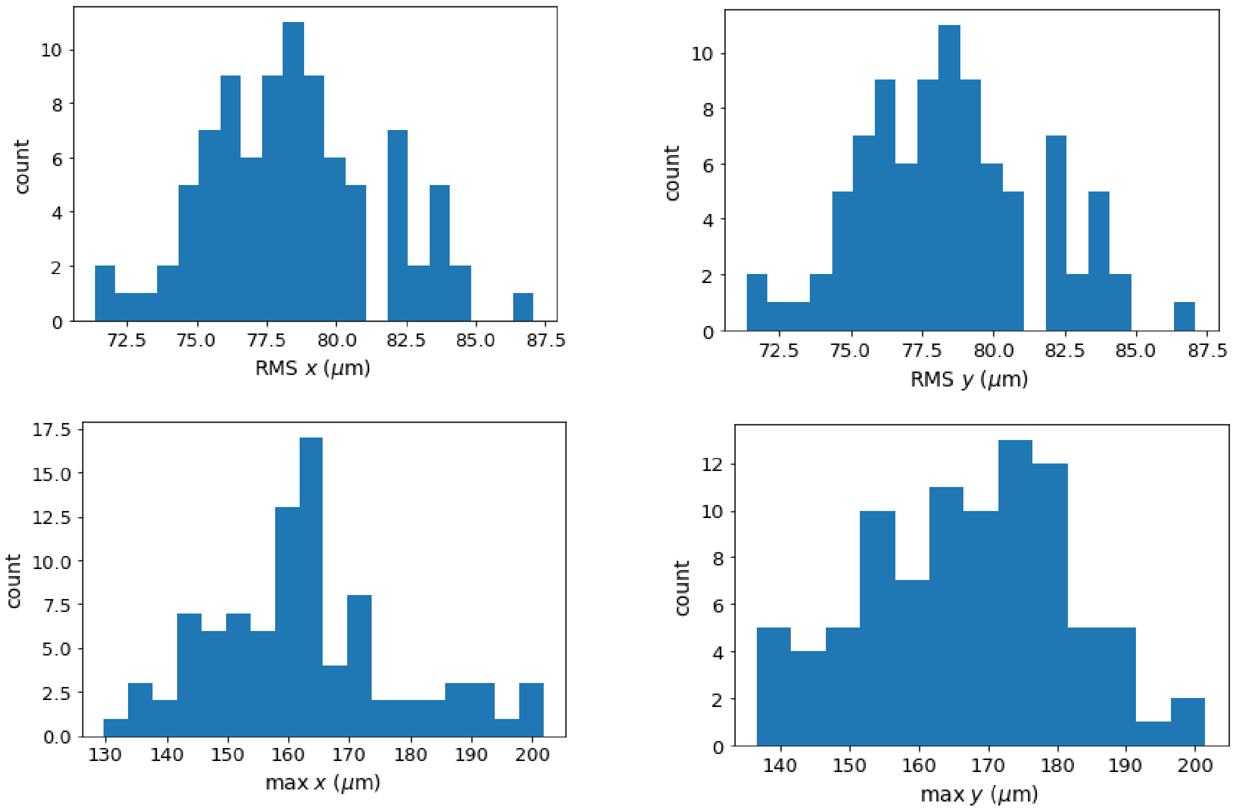
RMS horizontal orbit and max orbit distortion, after corrections (without BPM errors):





Orbit distortion through arc sextupoles after correction

Note: BPM errors not included!



Corrected lattice proxy

Corrected lattice proxy

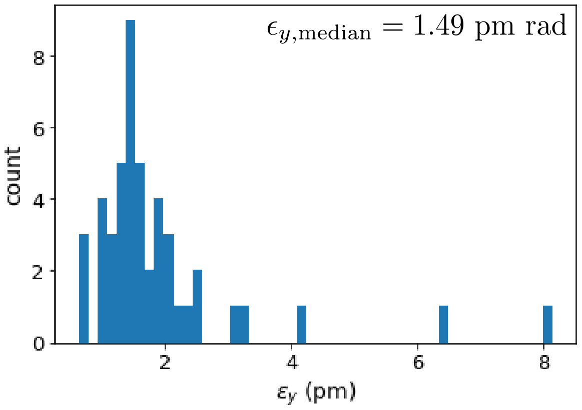
Requests for a lattice that resembles a fully corrected lattice to allow other studies to continue.
Relies on making assumptions about the level of correction that will be achievable. However, these corrected lattices are needed for the other studies to progress.

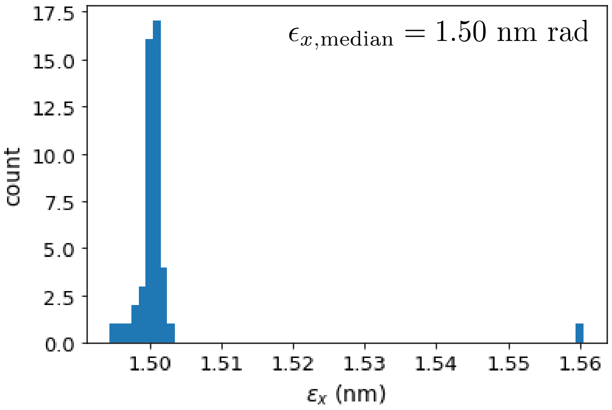
Another approach to generating an 'effective lattice':

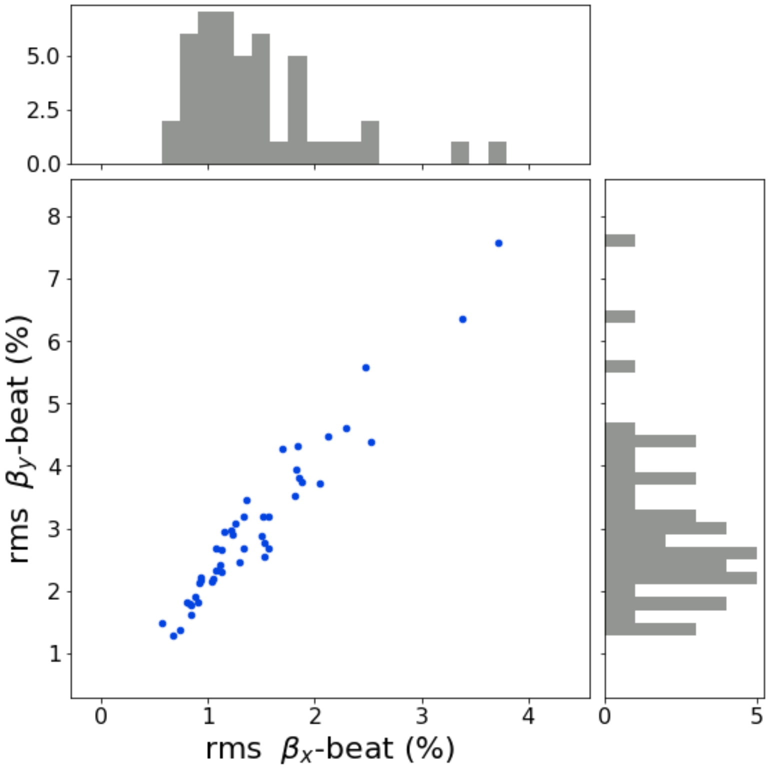
1. Correction algorithm applied to lattice with 10% misalignments. (Results in a median vertical emittance of 0.0002 pm and design horizontal emittance of 1.513 nm).

2. Begin rotating quadrupoles to intentionally introduce coupling. Two sets of lattices produced at 0.1% coupling and 0.2% coupling. (Results in a median vertical emittance of 1.49 pm.)

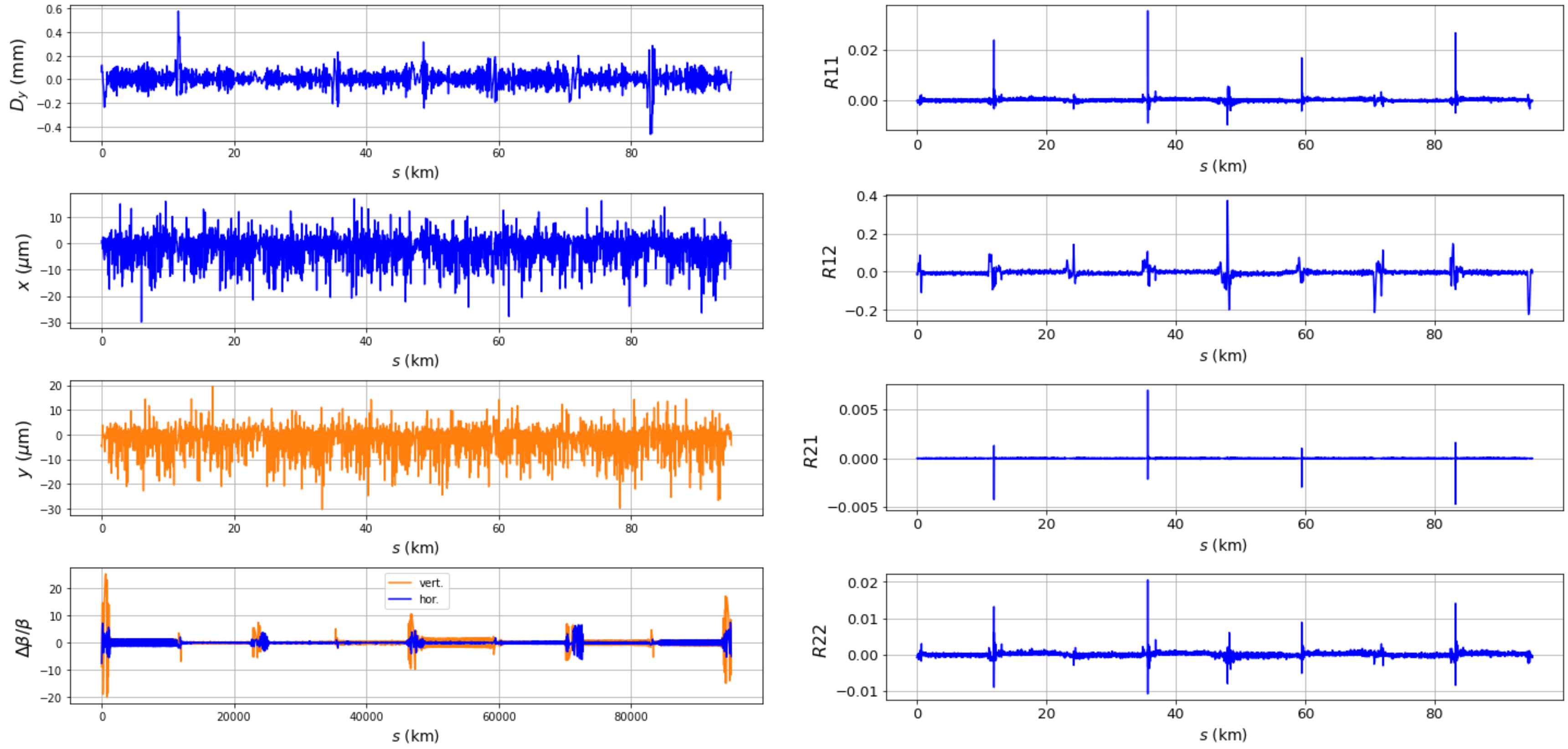
Corrected lattice proxy (0.1% coupling)







Effective lattice (0.1% coupling), ttbar 4 IP lattice:



Conclusions

- Progress made in incorporating chromaticity correction. DA calculations to be performed next.
- Orbit correction identified are critical for successful chromaticity correction that maintains reasonable vertical emittance.
- Effective lattices (or proxy lattices) created to achieve specific coupling ratios of 0.1% and 0.2%.