EPFL

Effective model for orbit distortion in spin simulation in FCC-ee

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Acknowledgements to Alain Blondel, David Sagan, Eliana Gianfelice-Wendt, Tessa Charles, Jörg Wenninger, Werner Herr, and all colleagues

Introduction

- Precise center-of-mass collision energy calibration using resonant depolarization in the FCC-ee
- Energy scans should be done to ensure that sufficient level of the equilibrium polarization can be achieved for the energy calibration.
- Effective models are created to simulate realistic orbits and check their effects on the polarization level

Spin Polarization Simulations

- The Tao program[1] in Bmad is useful for the lattice control, the parameters examination and the polarization simulation.
- Bmad distribution has been successfully compiled and setup on LXPLUS, making HTCondor accessible for simulation.

FCC-ee sequence version 217

Circumference (km)	97.756
Beam energy (GeV)	45.6
β_x^* (m)	0.15
β_y^* (mm)	0.8
ϵ_x (nm)	0.27
ϵ_y (pm)	1
Synchrotron tune Q_s	0.025
Horizontal tune Q_x	269.139
Vertical tune Q_y	269.219

Table 1: Main FCC-ee parameters at Z energy

1. Tao Simulation Program, https://www.classe.cornell.edu/bmad/tao.html

Effective models

- The process of determining corrections for fully misaligned lattices is lengthy and currently not easily achieved.
- Effective models with realistic orbits are built for demonstration purposes.
- Small errors are generated using truncated Gaussian distributions.

An example

Type	$\sigma_{\Delta X}$ (μm)	$\sigma_{\Delta Y}$ (μm)	$\sigma_{\Delta S}$ (μm)	$\sigma_{\Delta PSI}$ (μrad)	$\sigma_{\Delta THETA}$ (μrad)	$\sigma_{\Delta PHI}$ (μrad)
Arc quadrupole	0.1	0.1	0.1	2	2	2
Arc sextupole	0.1	0.1	0.1	2	2	2
Dipoles	0.1	0.1	0.1	2	0	0
IR quadrupole	0.1	0.1	0.1	2	2	2
IR sextupole	0.1	0.1	0.1	2	2	2

three offsets
+
three angular misalignments

σ : standard deviation of the Gaussian distribution

Table 2: An example of error settings used in the energy scan

Matching parameters to retrieve the design value

“Data”
(parameters to be optimized)

$Q_{x,y,s}$

$\square_{x,y}$ at IPs

x, z at IPs

“Variables”
(parameters to be varied)

strengths of RF quadrupoles

phase of RF cavities

merit function

$$\mathcal{M} \equiv \sum_i w_i \left[\delta D_i\right]^2 + \sum_j w_j \left[\delta V_j\right]^2$$

weights

functions of data
and variables

Distribution of the Orbit Distorsions

- Different errors are generated from the same error settings.
- 100 seeds are generated from the error setting in Table 2.

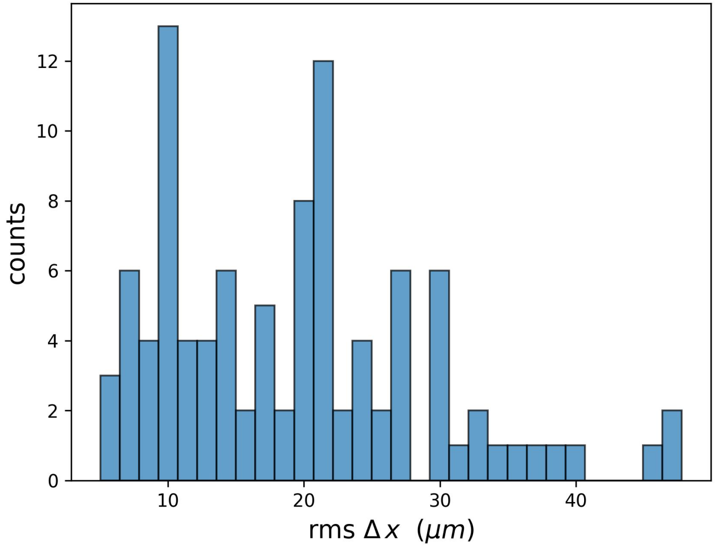

Figure 1: Distribution of rms horizontal orbits of 100 produced errors using the settings in Table 2

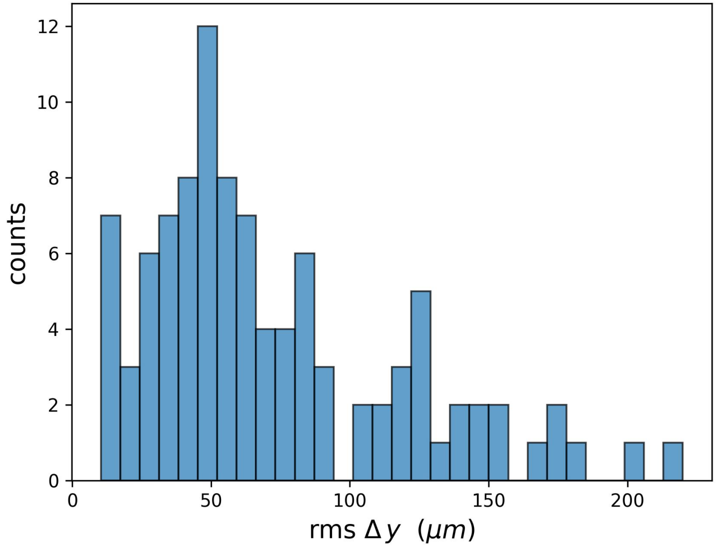

Figure 2: Distribution of rms vertical orbits of 100 produced errors using the settings in Table 2

Distribution of Maximum Orbits

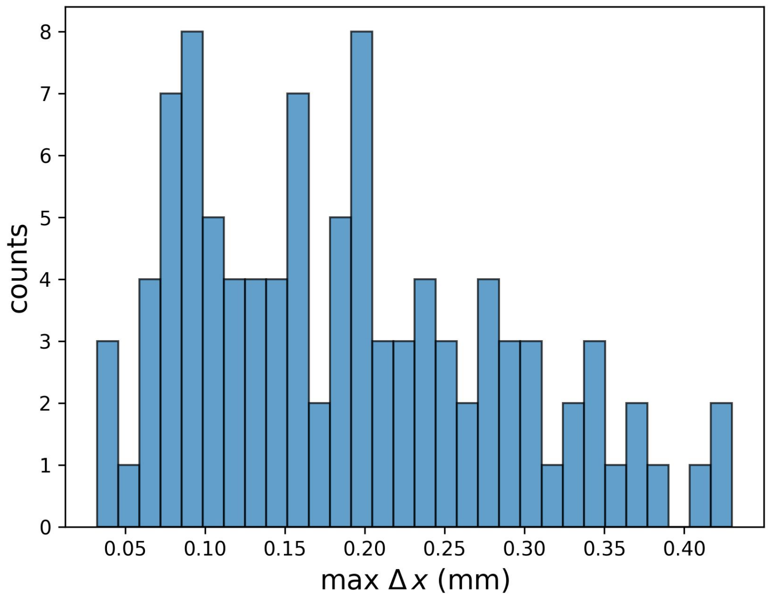

Figure 3: Distribution of maximum horizontal orbits of 100 produced errors using the settings in Table 2

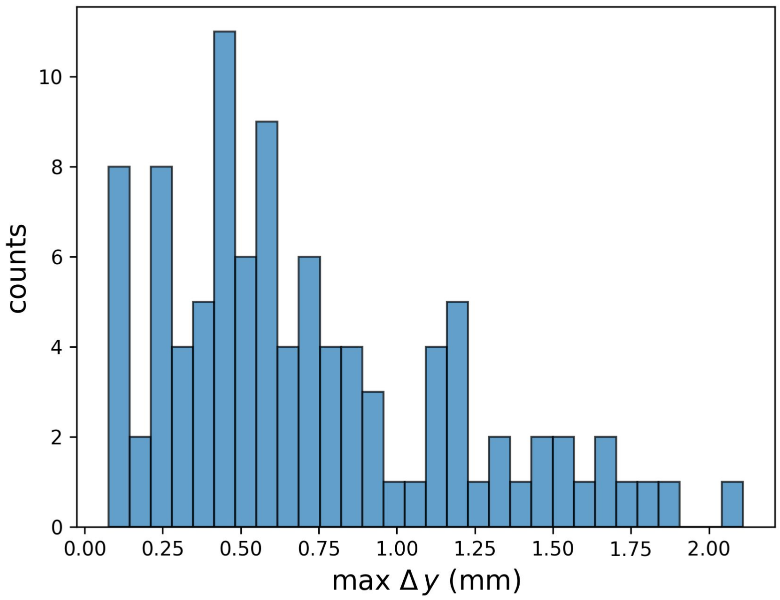

Figure 4: Distribution of maximum vertical orbits of 100 produced errors using the settings in Table 2

Distribution of rms Beta-Beating

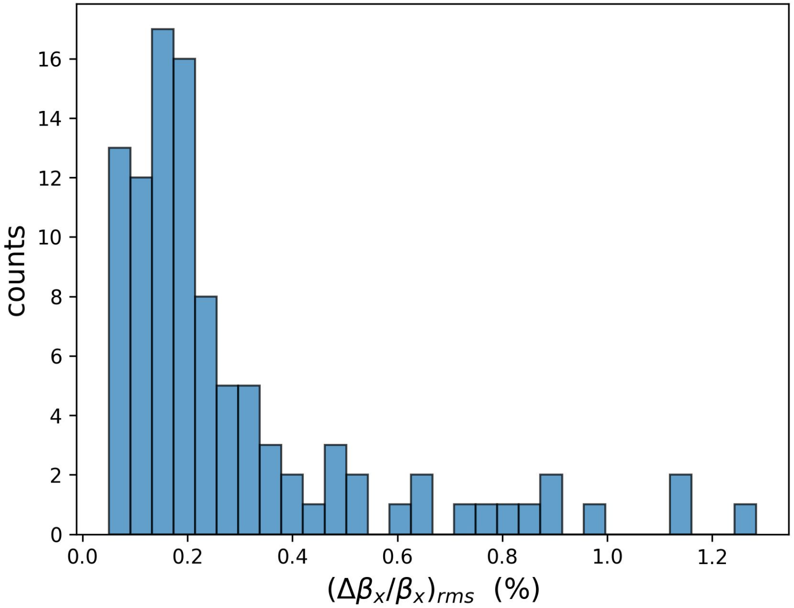

Figure 5: Distribution of horizontal beta-beating of 100 produced errors using the settings in Table 2

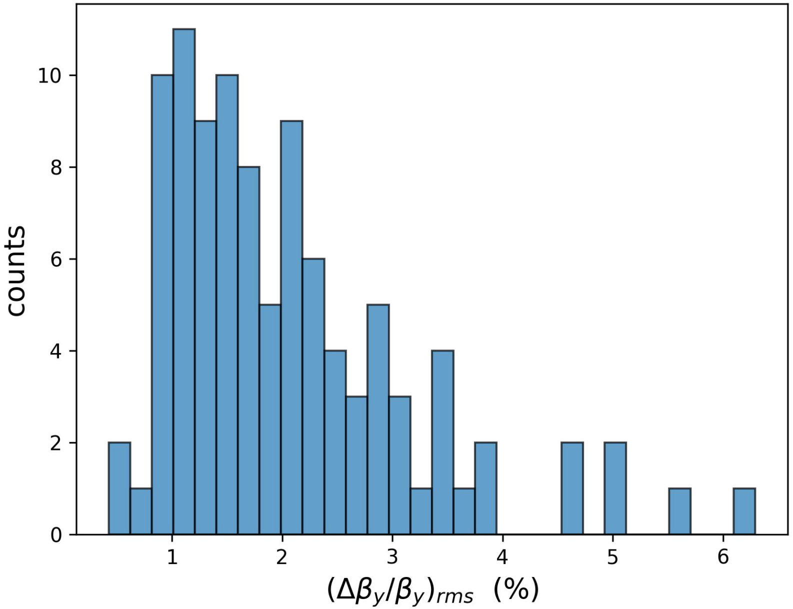

Figure 6: Distribution of vertical beta-beating of 100 produced errors using the settings in Table 2

Multiple error sources case 1

β_x^* (m)	0.15
β_y^* (mm)	0.8
$x_{\mathrm{ip}1,4}$ (μm)	-0.18
$z_{\mathrm{ip}1,4}$ (μm)	0.02
$x_{\mathrm{ip}2,3}$ (μm)	-0.27
$z_{\mathrm{ip}2,3}$ (μm)	-0.02
Synchrotron tune Q_s	0.0247
Horizontal tune Q_x	269.139
Vertical tune Q_y	269.219

rms orbit	Δx_{rms} (μm)	32.2
	Δy_{rms} (μm)	42.2
max orbit	$\Delta x_{\max}$ (mm)	0.26
	$\Delta y_{\max}$ (m)	0.44
beta-beating	$(\Delta\beta_x/\beta_x)_{\mathrm{rms}}$ (%)	0.18
	$(\Delta\beta_y/\beta_y)_{\mathrm{rms}}$ (%)	1.7
emittance	ϵ_x (nm)	0.271
	ϵ_y (pm)	0.33

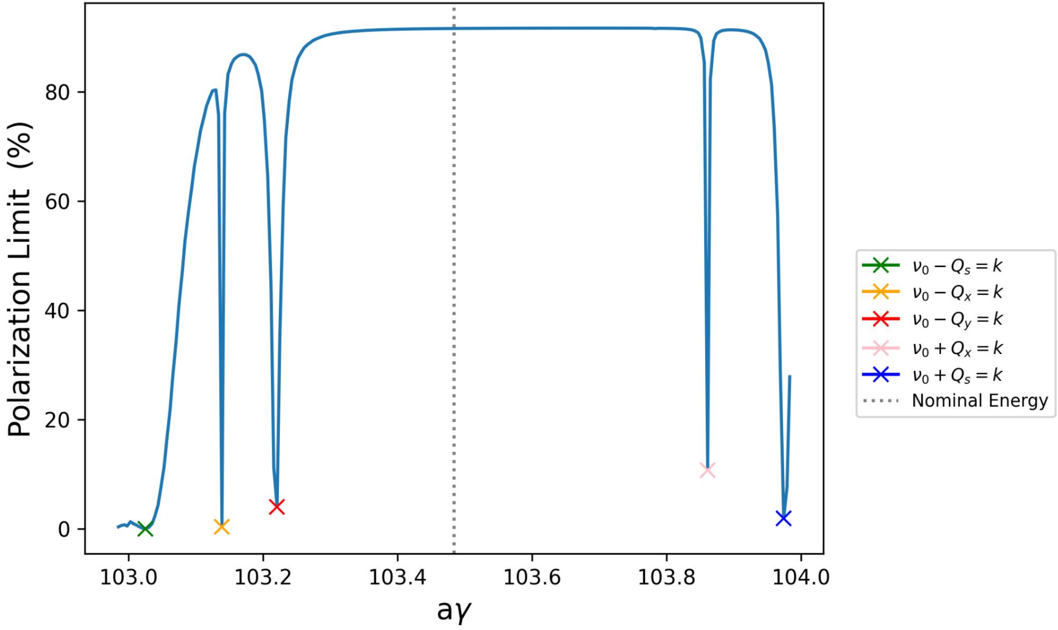

Figure 7: Energy scan with error settings listed in Table 2

Orbit deviation

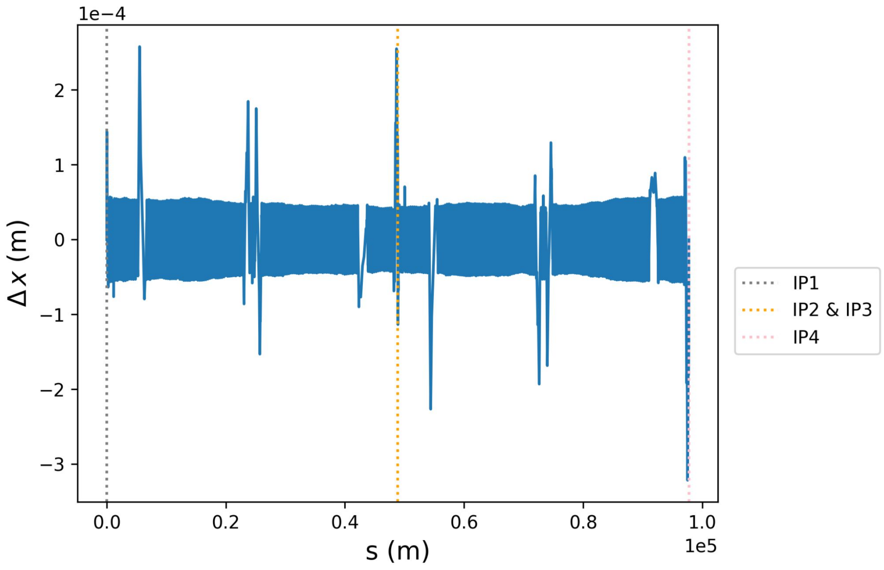

Figure 8: Variation of horizontal orbit deviation in case 1

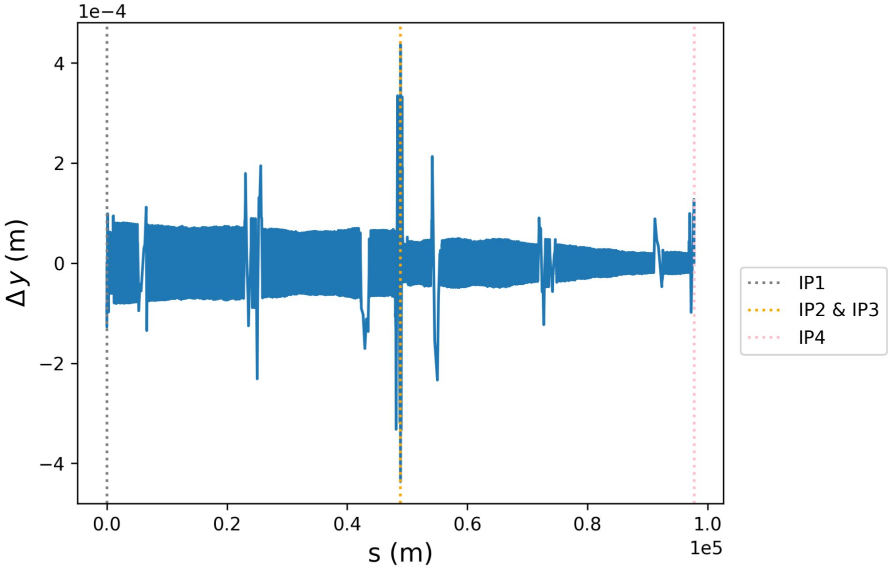

Figure 9: Variation of vertical orbit deviation in case 1

Beta-beating

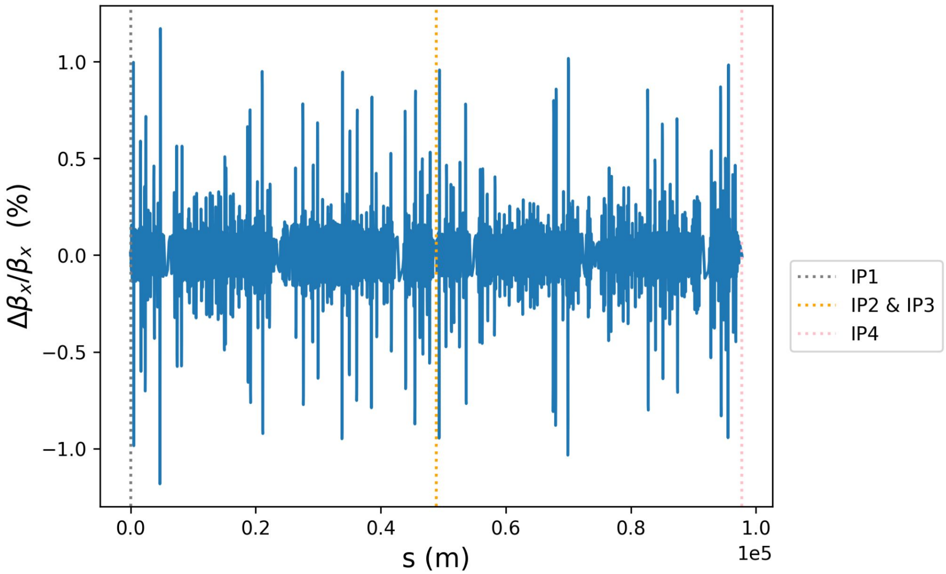

Figure 10: Variation of horizontal beta-beating in case 1

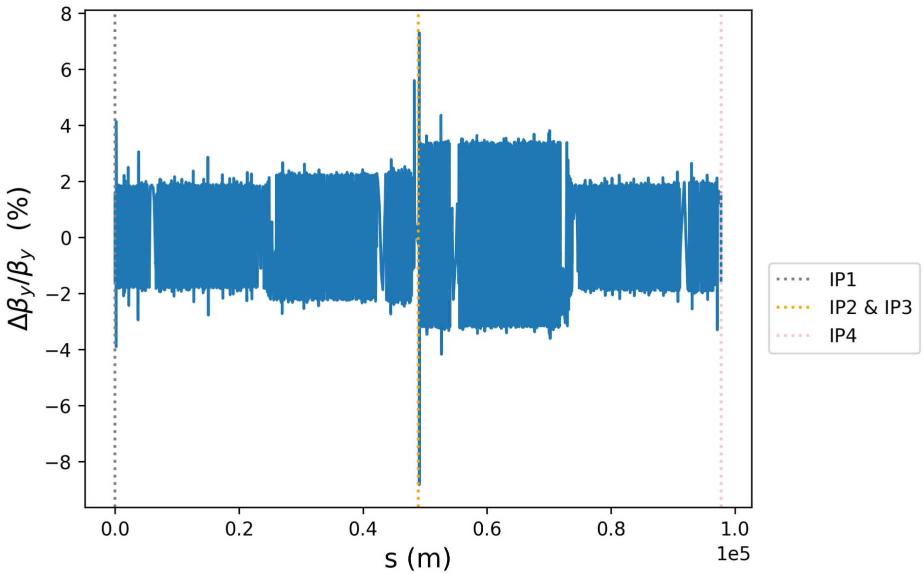

Figure 11: Variation of vertical beta-beating in case 1

Horizontal dispersion

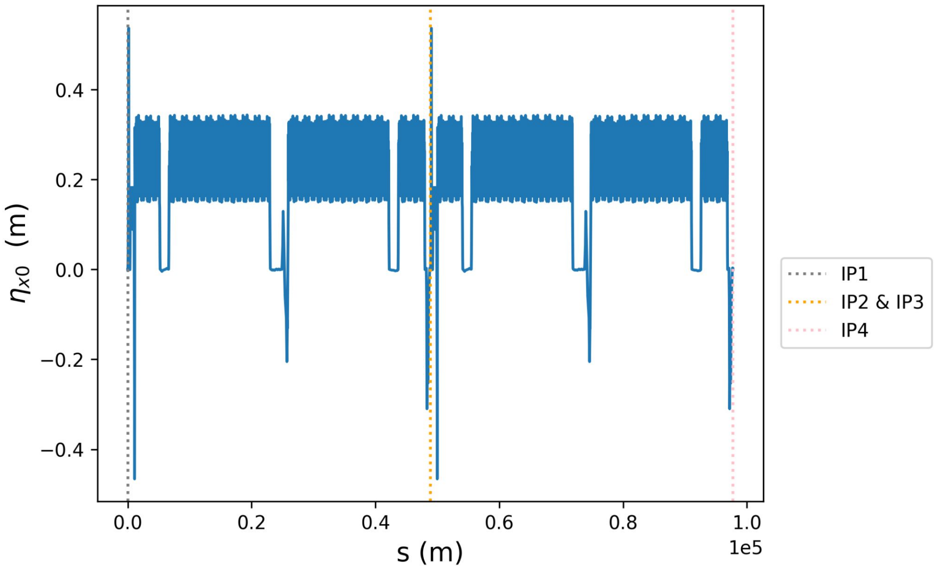

Figure 12: Original horizontal dispersion

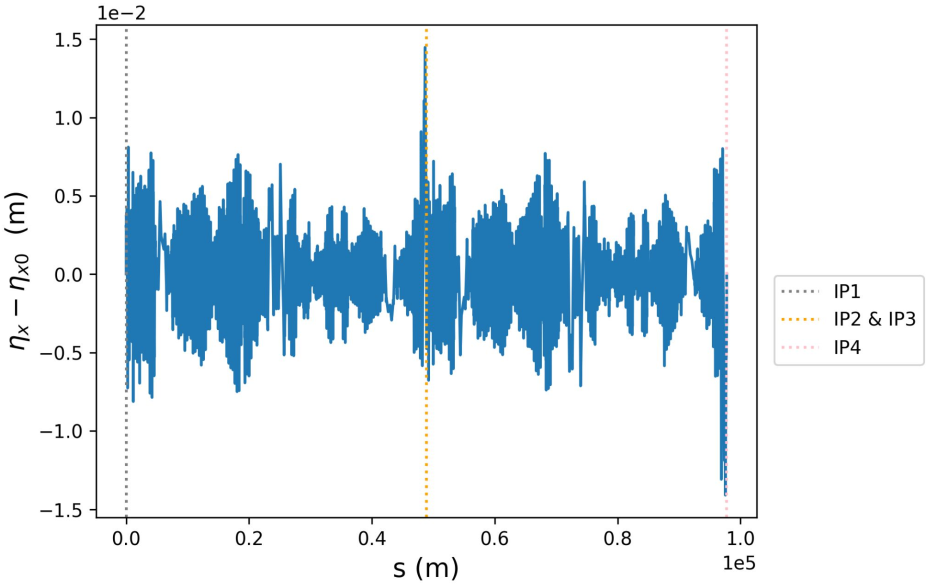

Figure 13: Variation of horizontal dispersion in case 1

Vertical dispersion

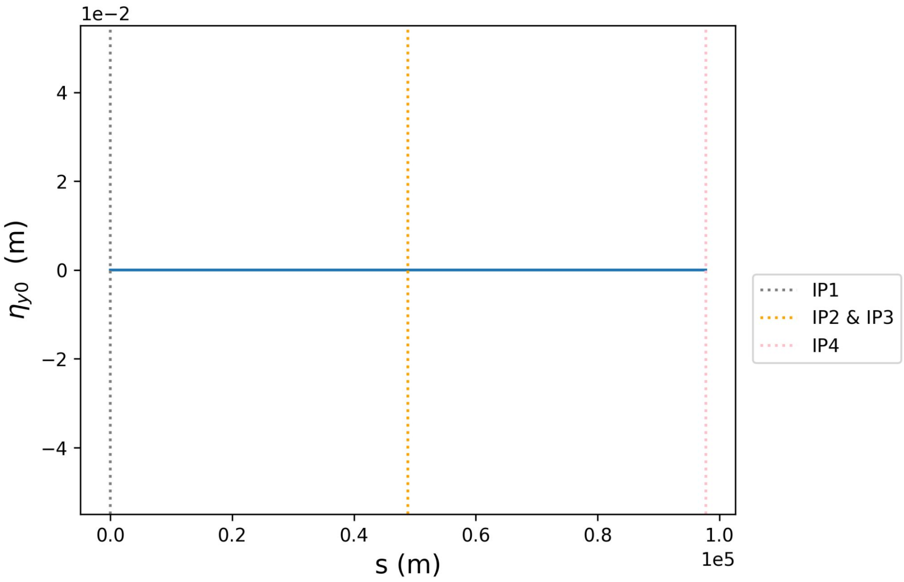

Figure 14: Original vertical dispersion

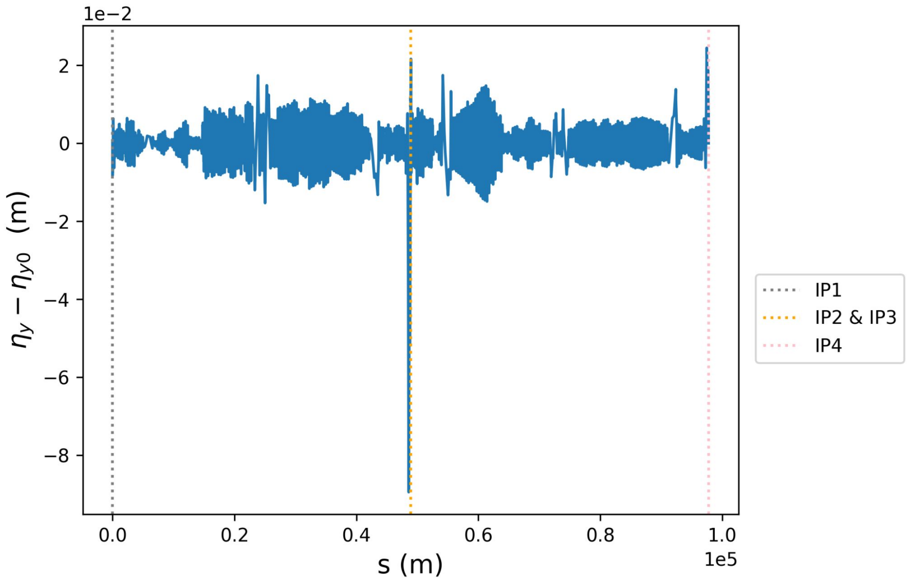

Figure 15: Variation of vertical dispersion in case 1

Multiple error sources case 2

β_x^* (m)	0.15
β_y^* (mm)	0.8
$x_{ip1,4}$ (μm)	0.44
$z_{ip1,4}$ (μm)	0.06
$x_{ip2,3}$ (μm)	0.65
$z_{ip2,3}$ (μm)	0.06
Synchrotron tune Q_s	0.0247
Horizontal tune Q_x	269.139
Vertical tune Q_y	269.219

rms orbit

max orbit

beta-beating

emittance

Δx_{rms} (μm)	24.2
Δy_{rms} (μm)	148
Δx_{max} (mm)	0.35
Δy_{max} (mm)	1.47
$(\Delta\beta_x/\beta_x)_{rms}$ (%)	0.26
$(\Delta\beta_y/\beta_y)_{rms}$ (%)	2.8
ϵ_x (nm)	0.269
ϵ_y (nm)	0.165

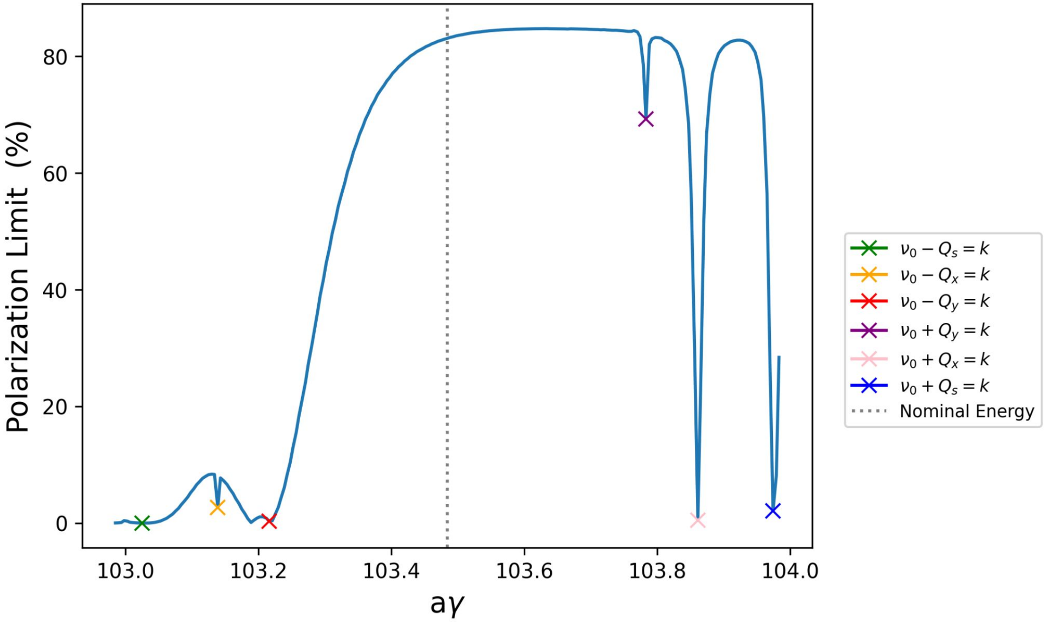

Figure 16: Energy scan with error settings listed in Table 2

Orbit deviation

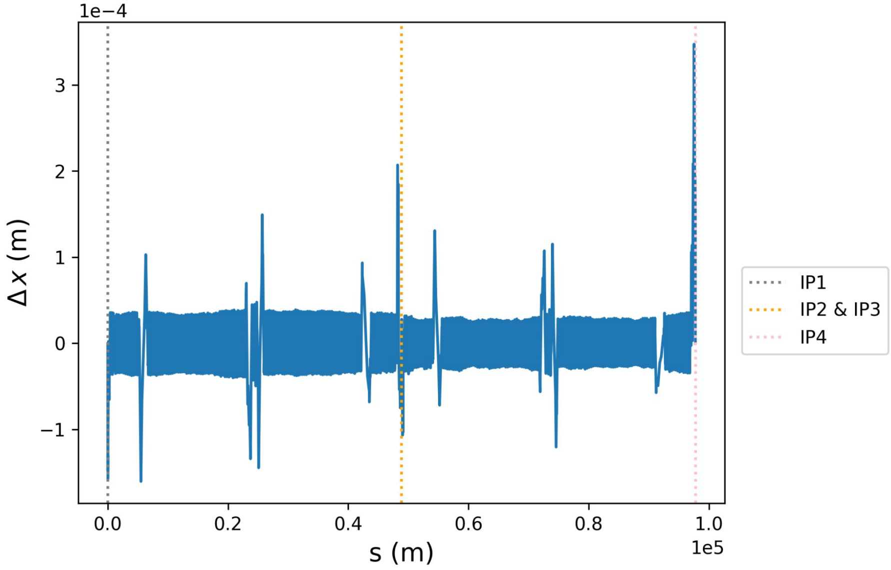

Figure 17: Variation of horizontal orbit deviation in case 2

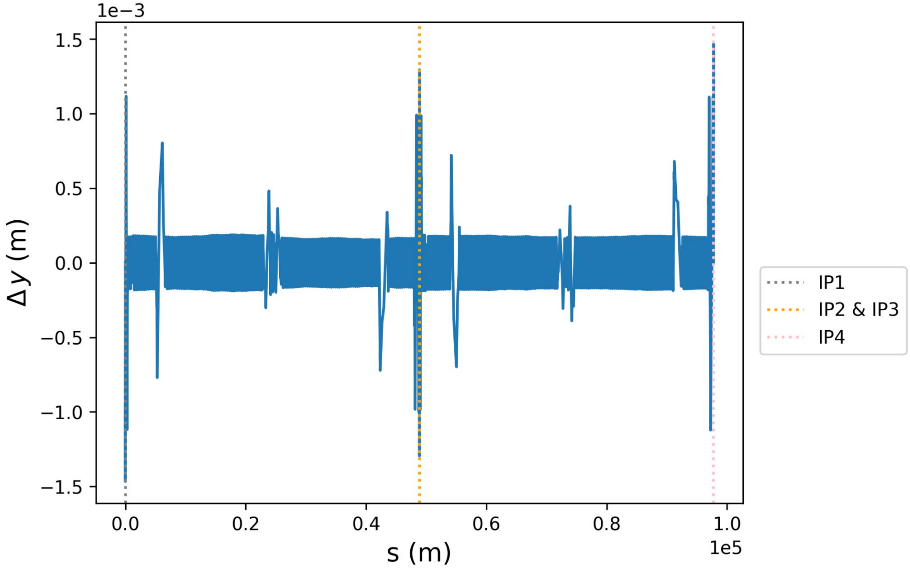

Figure 18: Variation of vertical orbit deviation in case 2

Beta-beating

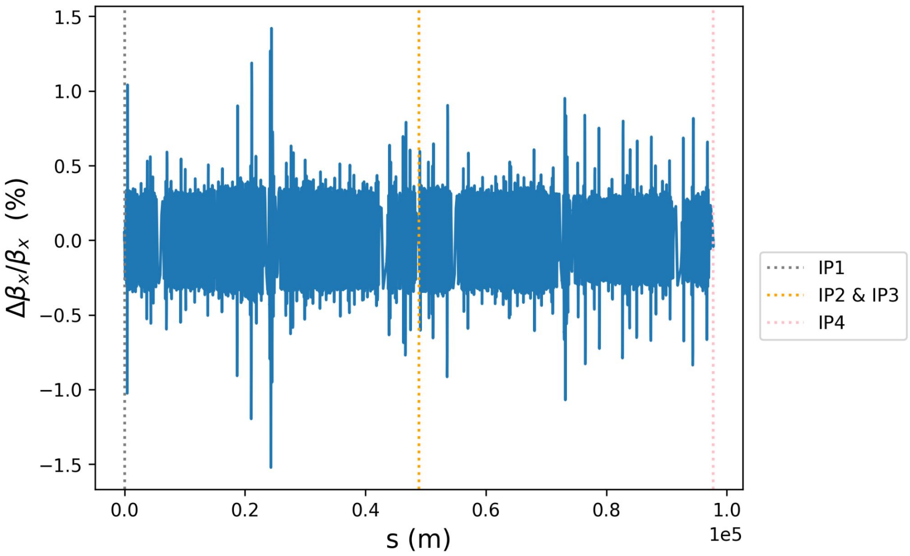

Figure 19: Variation of horizontal beta-beating in case 2

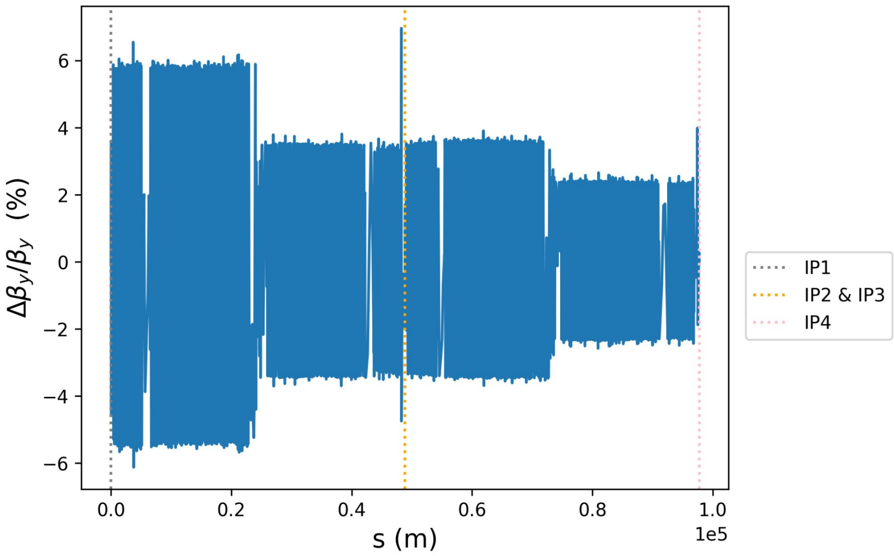

Figure 20: Variation of vertical beta-beating in case 2

Horizontal dispersion

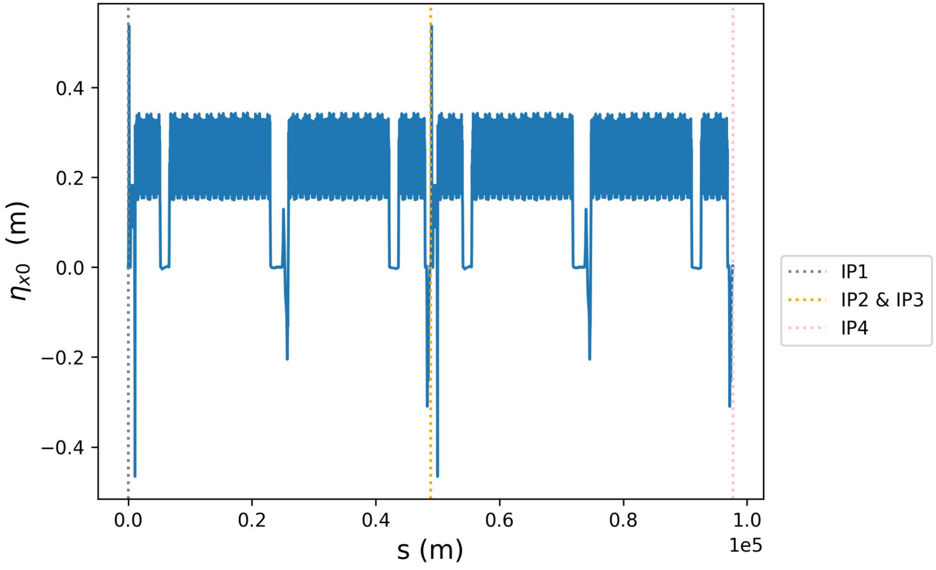

Figure 21: Original horizontal dispersion

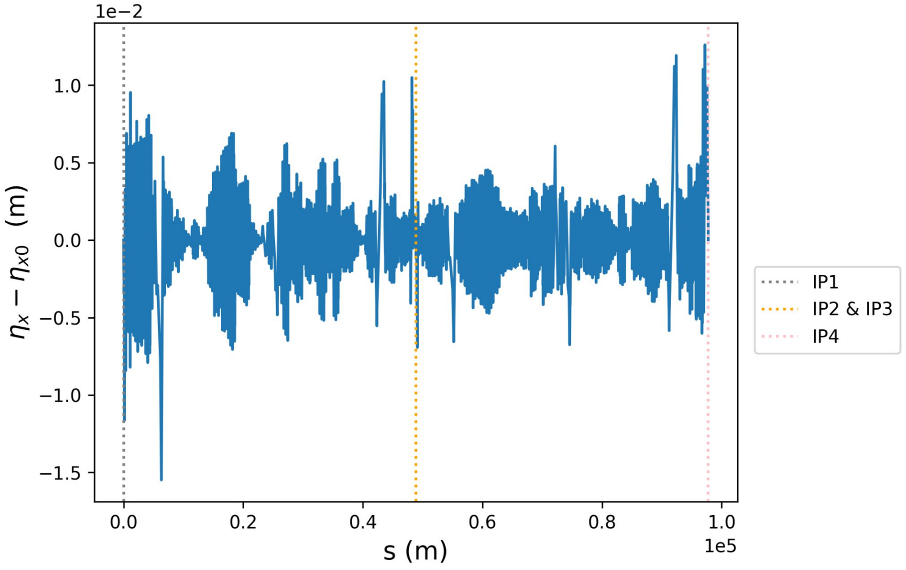

Figure 22: Variation of horizontal dispersion in case 2

Vertical dispersion

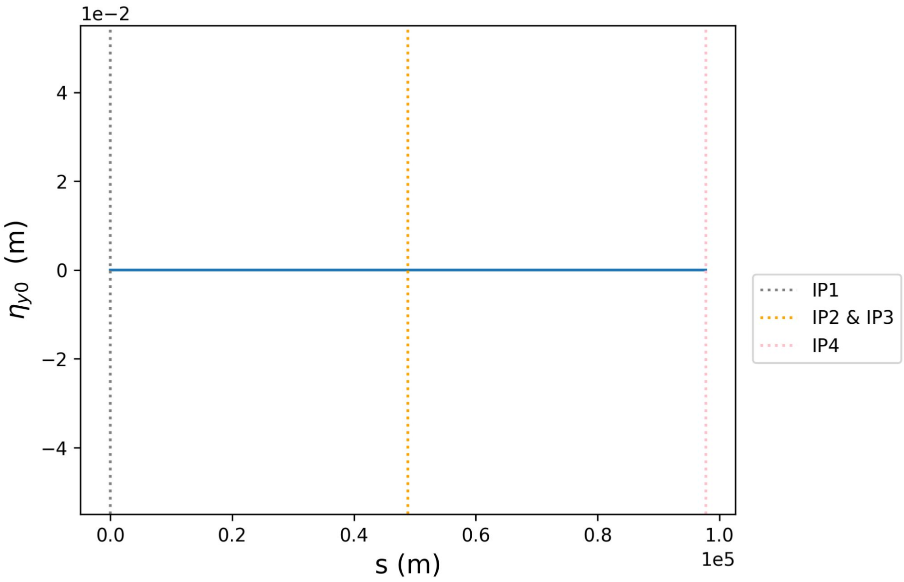

Figure 23: Original vertical dispersion

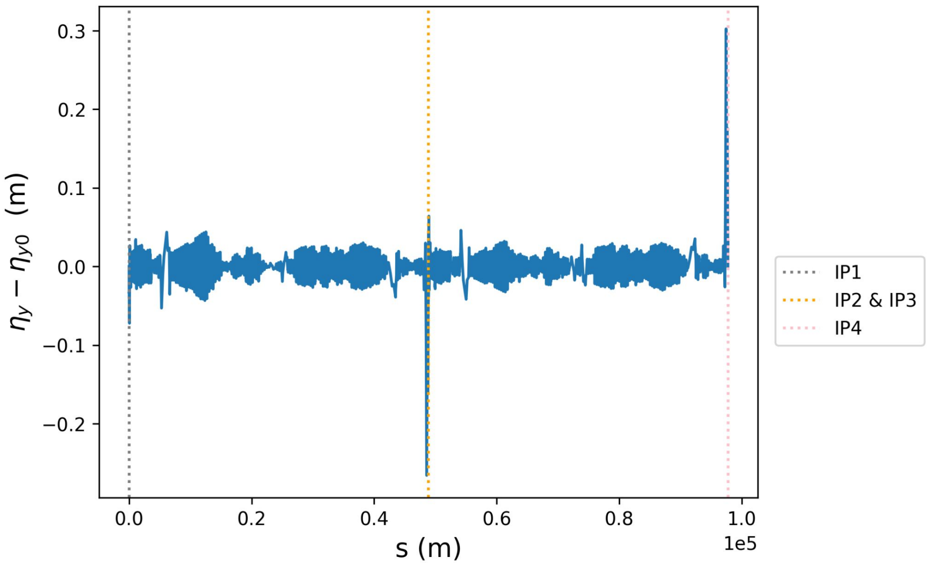

Figure 24: Variation of vertical dispersion in case 2

Summary

- Effective models are created to simulate the realistic orbit and their effect on spin polarization level
- An efficient way for spin polarization simulation as a proof of concept

Topics for discussion

- Hard to match the parameters in the presence of large errors
- Increase the variables for the parameter matching
- Better control of the emittance in the effective models
- A more robust and refined model generation method that offers greater control of the orbit

Thank you!