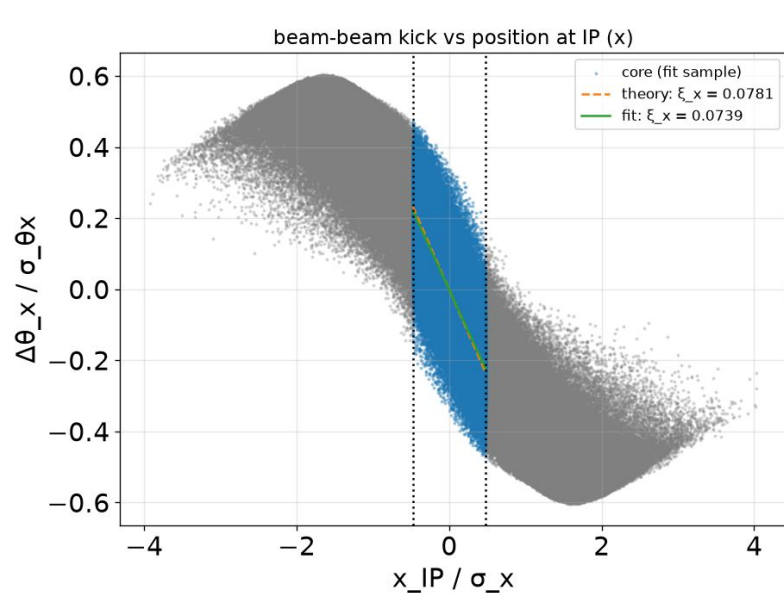


Goals: Simulating a Muon Collider in WarpX:

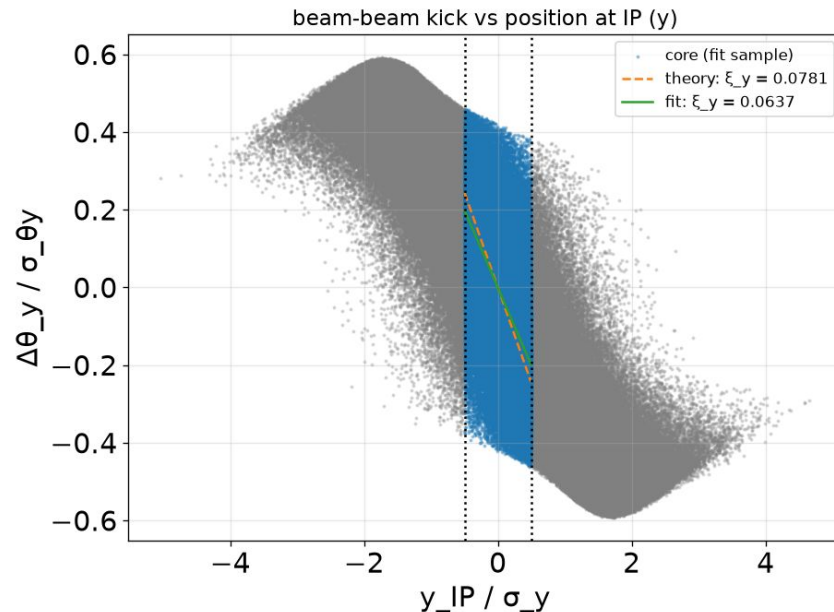
- Deploying WarpX for a muon collider, including beam-beam effects
- Testing modifications for the code that need to correctly model muon behavior, including QED effects
- Visualizations of collisions
- Understanding muon collider performance under different parameters.

File (everything in subdirectory Source/Particles/ElementaryProcess/)	Description of change
QEDInternals/QedChiFunctions.H	Add mass scaling in computation of Schwinger field χ : $\chi \propto (m / m_e)^3$
QEDInternals/QuantumSyncEngineWrapper.H	Propagate input mass through everything that calls χ
Input file change	Numerical integrals of $T(\chi)$ [a modified Bessel function] normally has a pre-computed table; Since χ can now range over orders of magnitude, we have to modify the range over which $T(\chi)$ is computed.
QEDPhotonEmission.H	WarpX 'cleans' low energy photons by dropping photons under a certain energy, computed using the mass of the electron. This threshold needs to be lowered for heavier lepton.
PICSAR [Particle In Cell Scalable Application Resources] dependency: quantum_sync_engine_core.hpp, gamma_functions.hpp	PICSAR library is used to compute dN/dt [# photons/time] and hard codes the electron mass, so this has to be updated to pass through as well.

Fitting the beam-beam parameter thru WarpX data



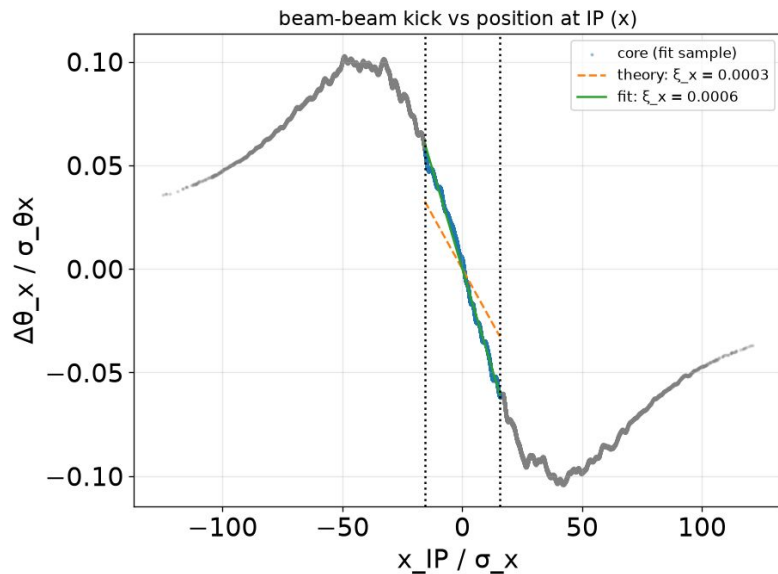
muon1 · 31139098



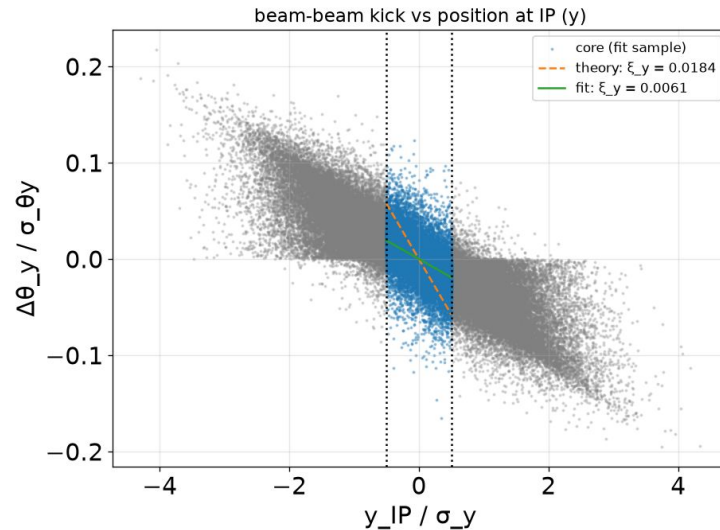
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Theory:
$$\xi_x = \frac{N r \beta_x^*}{2\pi \gamma \sigma_{x,\text{eff}} (\sigma_{x,\text{eff}} + \sigma_y)}$$

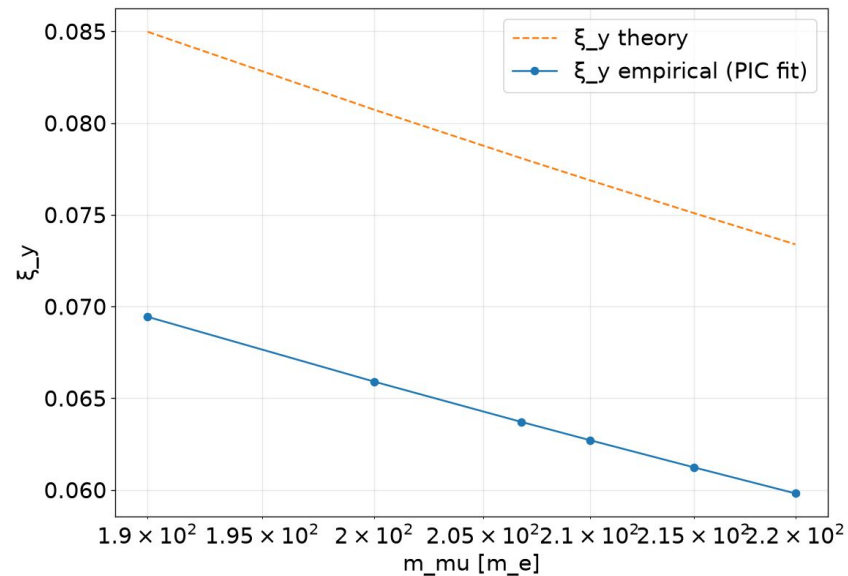
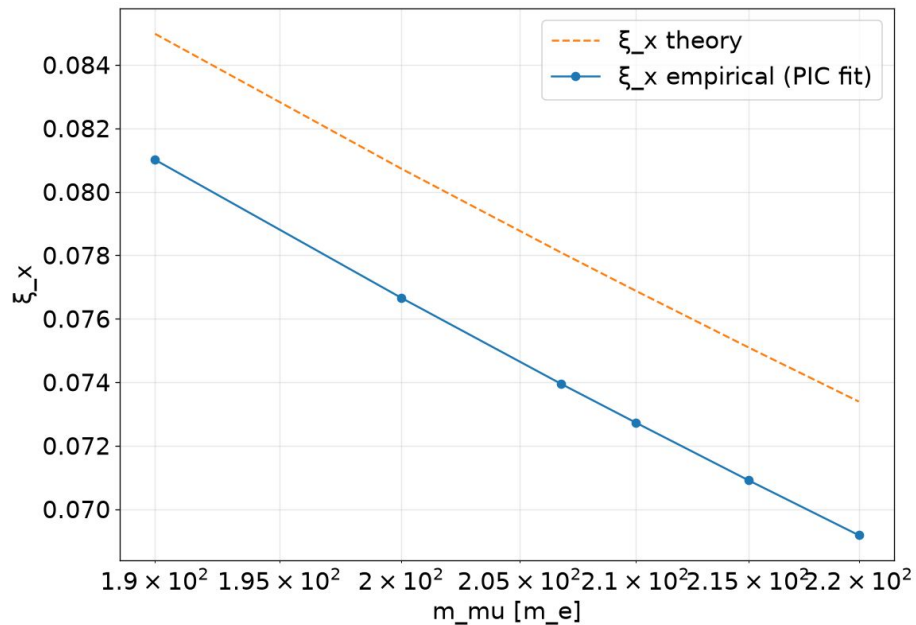
Validating beam-beam parameter fitting: FCC collider



fcc · 31065432



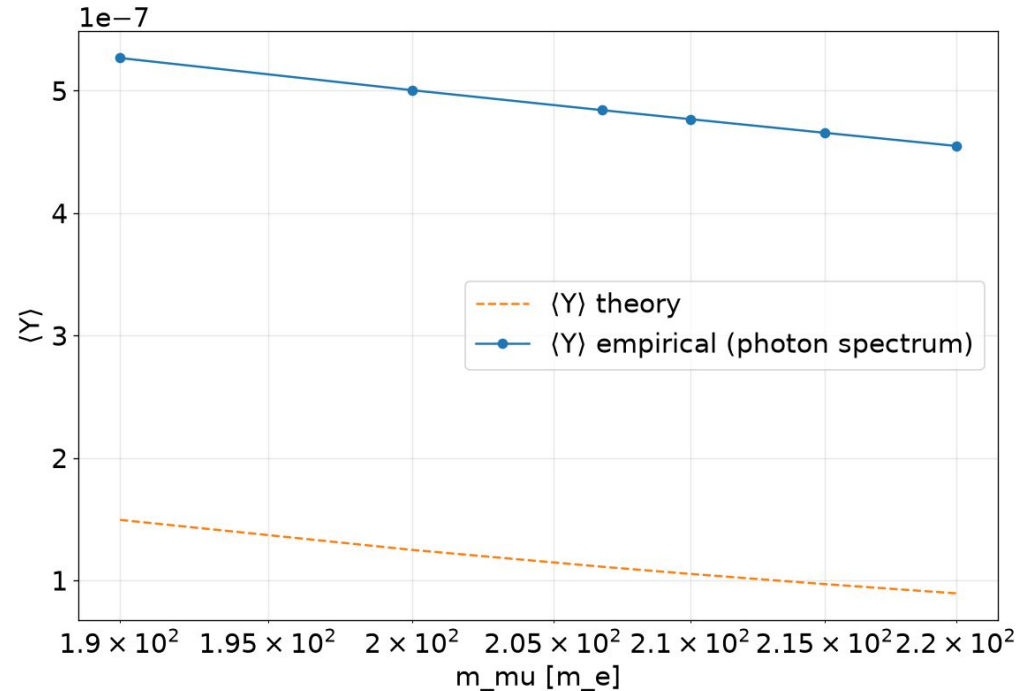
Lepton mass vs. beam-beam parameter



Preliminary study of quantum parameter ($Y \ll 1$)

$$\langle \Upsilon_{\text{theory}} \rangle = \frac{5}{6} \frac{r_{\mu}^2 \gamma N}{\alpha \sigma_z (\sigma_x + \sigma_y)}$$

$$\langle \Upsilon_{\text{emp}} \rangle = \frac{15}{4\sqrt{3}} \frac{\langle E_{\gamma} \rangle}{E_{\text{beam}}}$$



Appendix: Muon Collider specifications

Parameter	Unit	version	
		relaxed	target
Center of mass energy	TeV	10	
Geometric Luminosity ¹	$10^{34} \text{ cm}^{-2} \text{ s}^{-1}$	5.77	19.2
Beam energy	TeV	5	
Relativistic Lorentz factor		47322	
Circumference ²	km	≈ 10	
Dist. of last magnet to IP	m	6	
Repetition rate	Hz	5	
Bunch intensity (one bunch per beam)	10^{12}	1.80	
Injected beam power per beam	MW	7.2	
Normalized transverse rms emittance	μm	25	
Longitudinal norm. rms emittance	eVs	0.025	
Relative rms momentum spread	10^{-3}	0.3	1
RMS bunch length in space	mm	5	1.5
RMS bunch length in time domain	ns	.017	0.005
Twiss betatron function at the IP	mm	5	1.5
Energy loss per turn ³	MeV	≈ 27.2	
Integrated RF gradient ⁴	MV	30	

Table 6.1: Assumptions for the main parameters used in the design of a 10 TeV muon collider.