Coherent Electron Cooling Simulation

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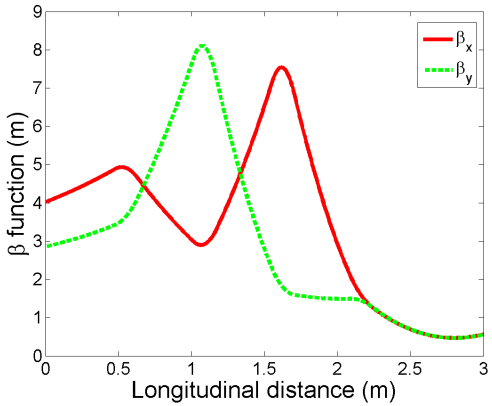
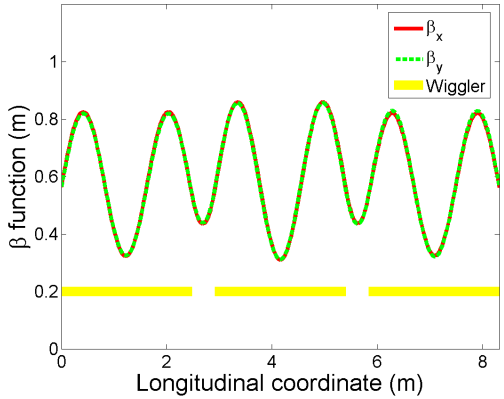
Introduction

- In the Electron-Ion Collider (EIC), Strong Hadron Cooling (SHC) is essential to reach high luminosity. Present baseline approach for SHC is based on Coherent electron Cooling (CeC).
- A general CeC scheme consists of three main sections:
  - Modulator
  - Amplifier
  - Kicker
- Implementations of amplifier
  - Free electron laser (FEL) amplifier.
  - Plasma cascade amplifier (PCA), ongoing experiment at Relativistic Heavy Ion Collider (RHIC).
  - Microbunching instability (MBI) amplifier, microbunched electron cooling (MBEC) for EIC.
- The SPACE code is a parallel, relativistic, three-dimensional (3D) electromagnetic (EM) Particle-in-Cell (PIC) code.

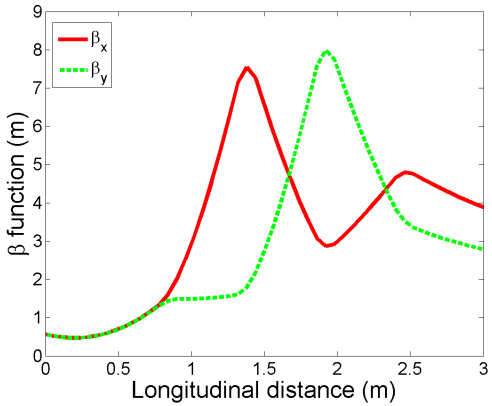
FEL-based CeC simulation



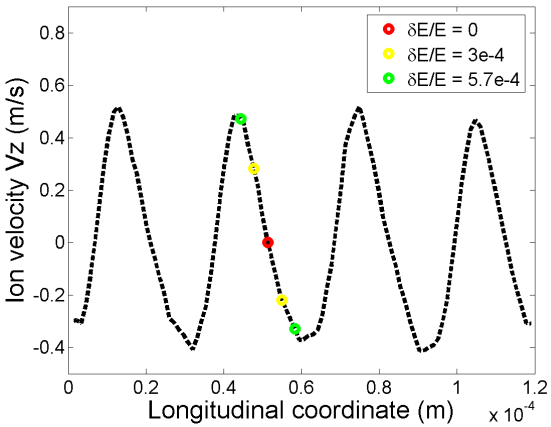
(a) Modulator



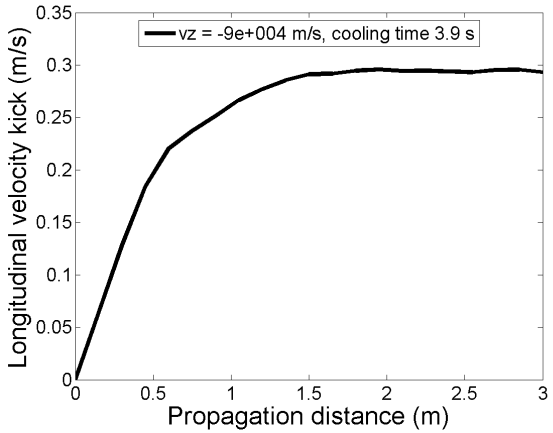
(b) FEL amplifier



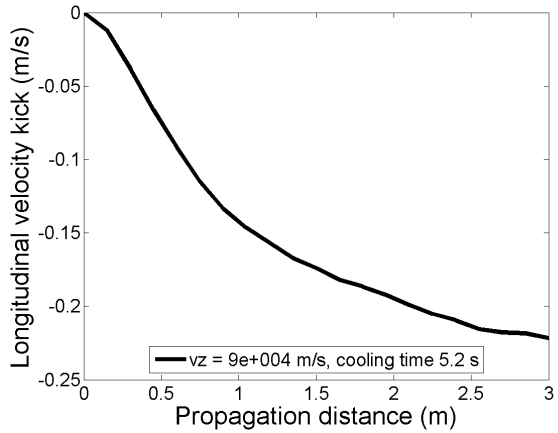
(c) Kicker



(d) Ions at different locations



(e) Ion with lower energy



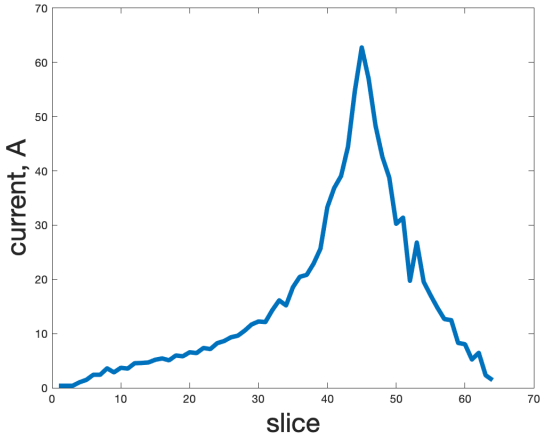
(f) Ion with higher energy

PCA-based CeC experiment

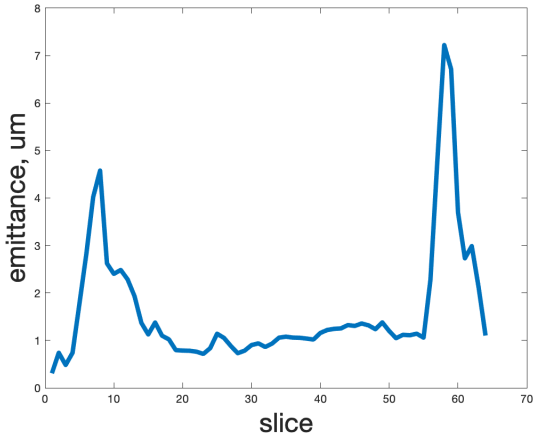
(a) PCA-based CeC layout

- Modulator: 3 m
- 4-cell PCA: 1.8 m, 2.2 m, 2.2 m, 1.8 m
- Kicker: 3 m

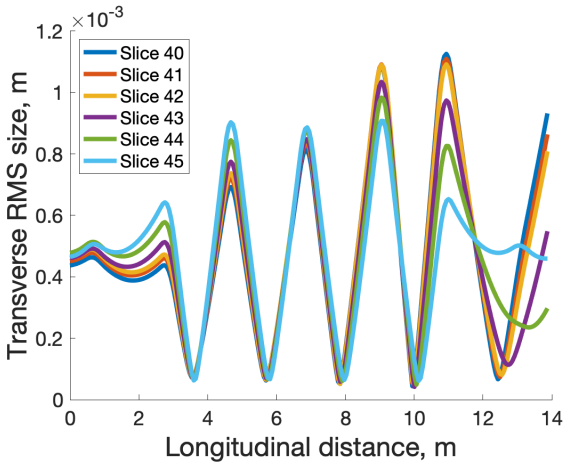
PCA-based CeC simulation



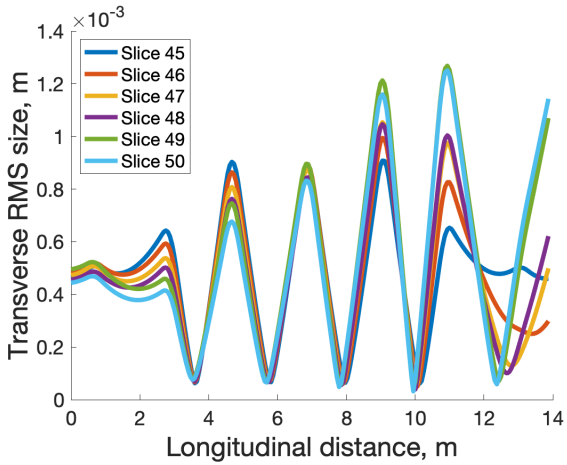
(a) Slice current



(b) Slice emittance

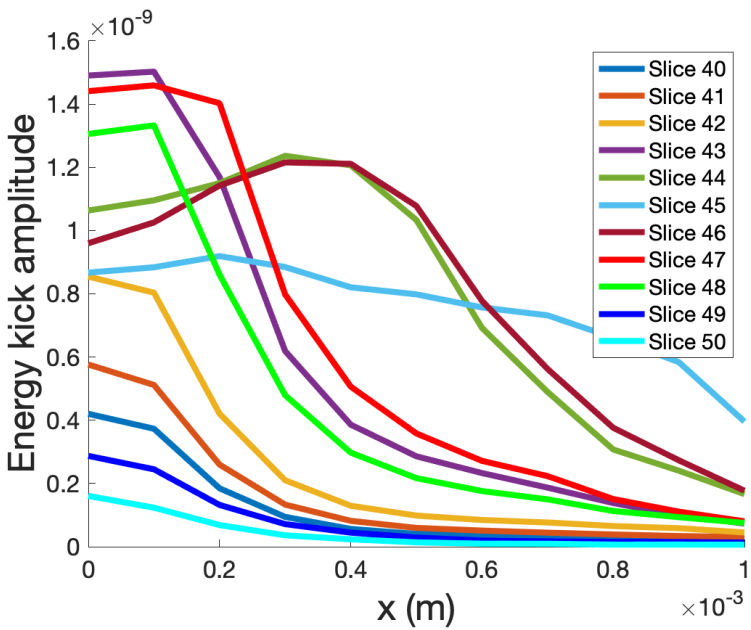


(c) Slice 40-45

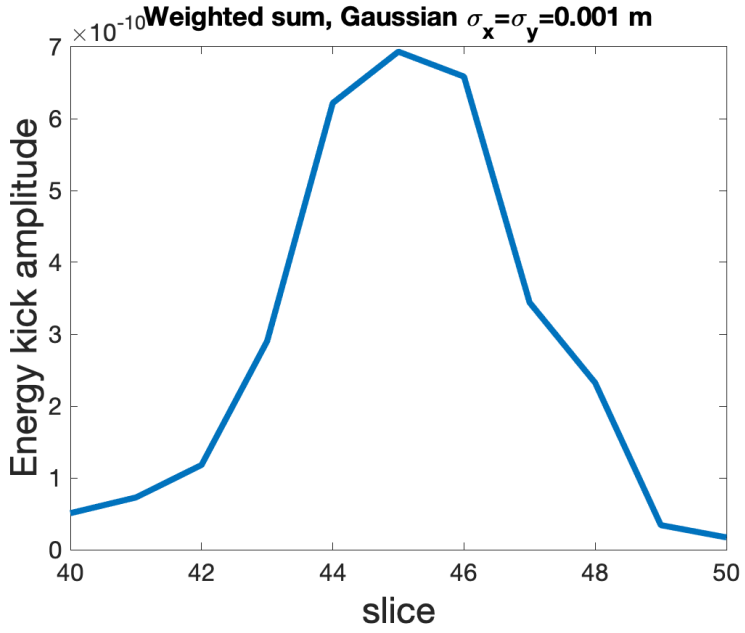


(d) Slice 45-50

PCA-based CeC simulation



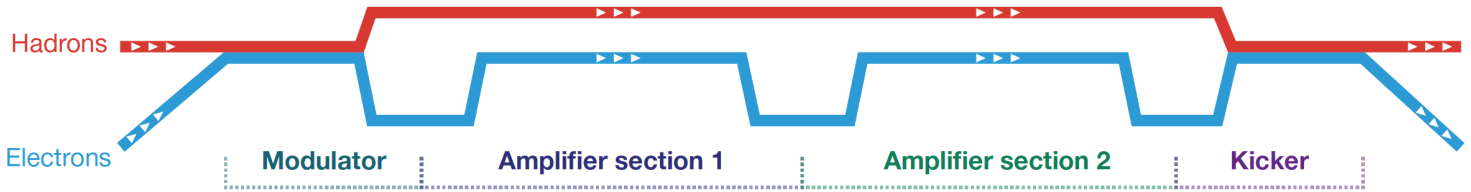
(a)



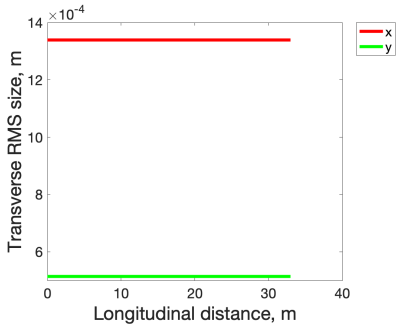
(b)

- Amplitude of the energy kick for slices in the electron beam (left) and weighted sum of the energy kick amplitude with the probability density function of Gaussian distribution (right). The RMS of the Gaussian distribution is set at 1e-3 m, which is the expected ion beam size in the CeC experiment

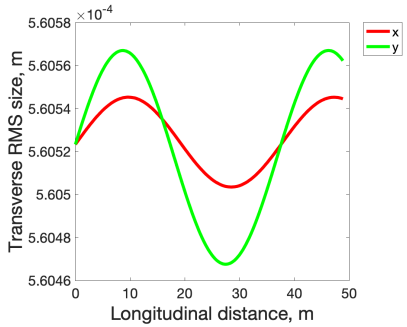
EIC MBEC with continuous focusing



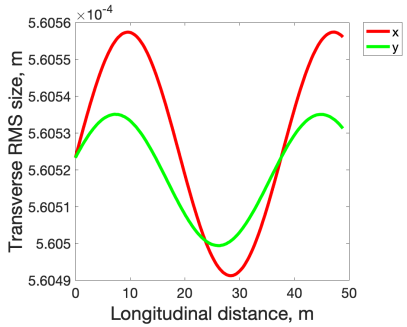
(a)



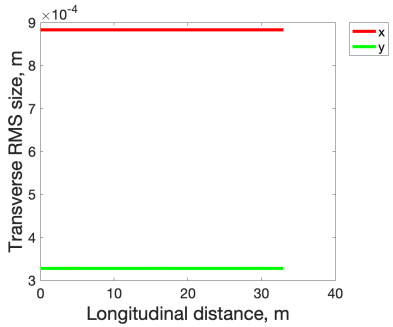
(b) Modulator



(c) Amplifier 1



(d) Amplifier 2

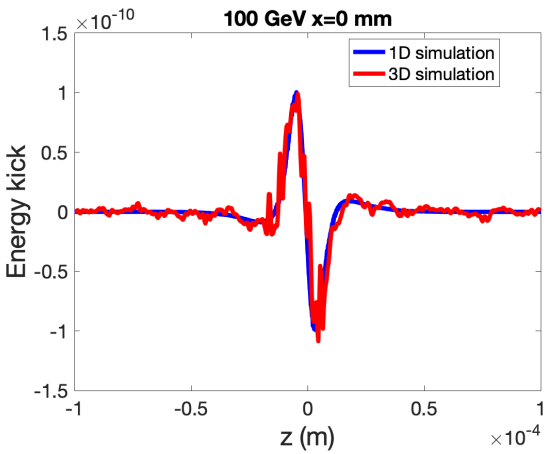


(e) Kicker

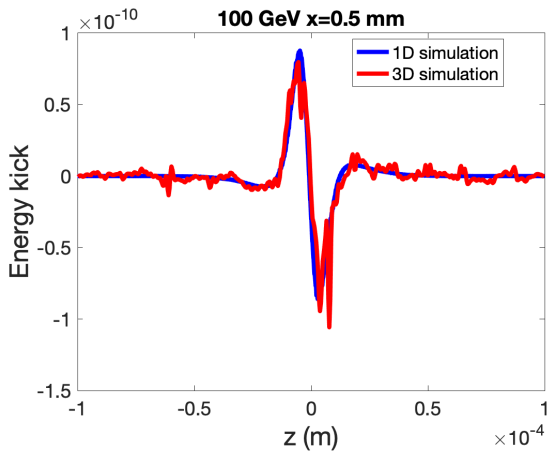
EIC MBEC with continuous focusing

- Turn off transverse space charge in 3D simulation, and compare with 1D simulation

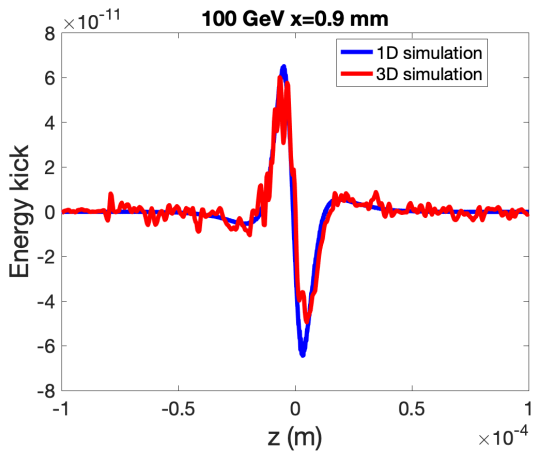
* 1D simulation from W. F. Bergan.



(a)

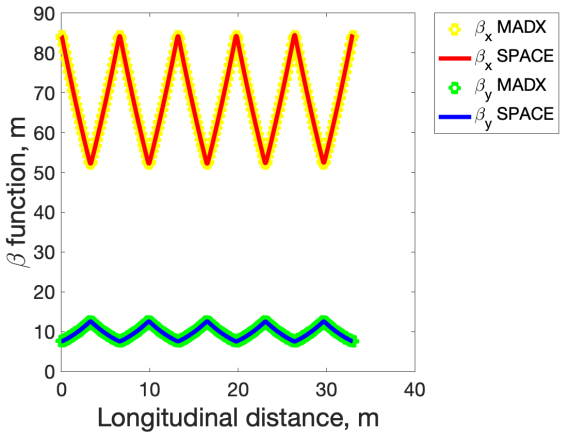


(b)

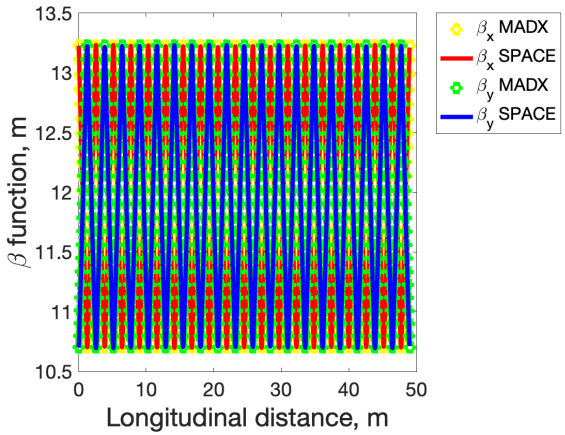


(c)

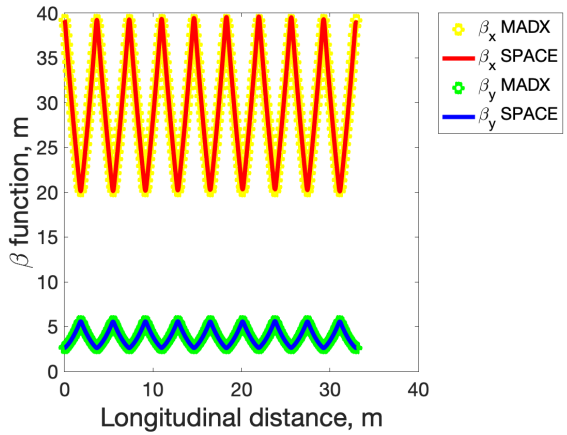
EIC MBEC with quadrupole focusing



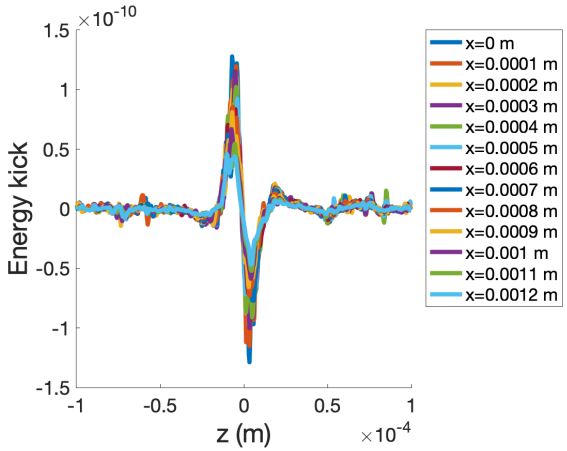
(a) Modulator



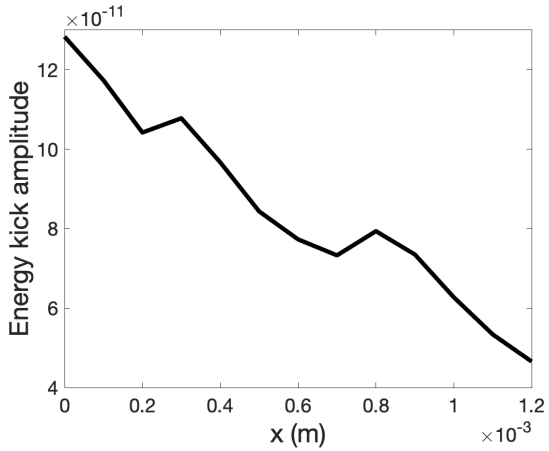
(b) Amplifier



(c) Kicker



(d) Cooling



(e) Cooling

Summary

- Cooling is needed to reach high luminosity in EIC
- The SPACE code has been benchmarked with theory
- Simulation of FEL-based CeC
  - Predict local cooling time
- Simulation of PCA-based CeC
  - Based on CeC experiment
- Simulation of EIC MBEC
  - Continuous focusing, compare with 1D simulation
  - Quadrupole focusing, predict cooling performance

Thank You