Simulations of CeC with FEL and PCA
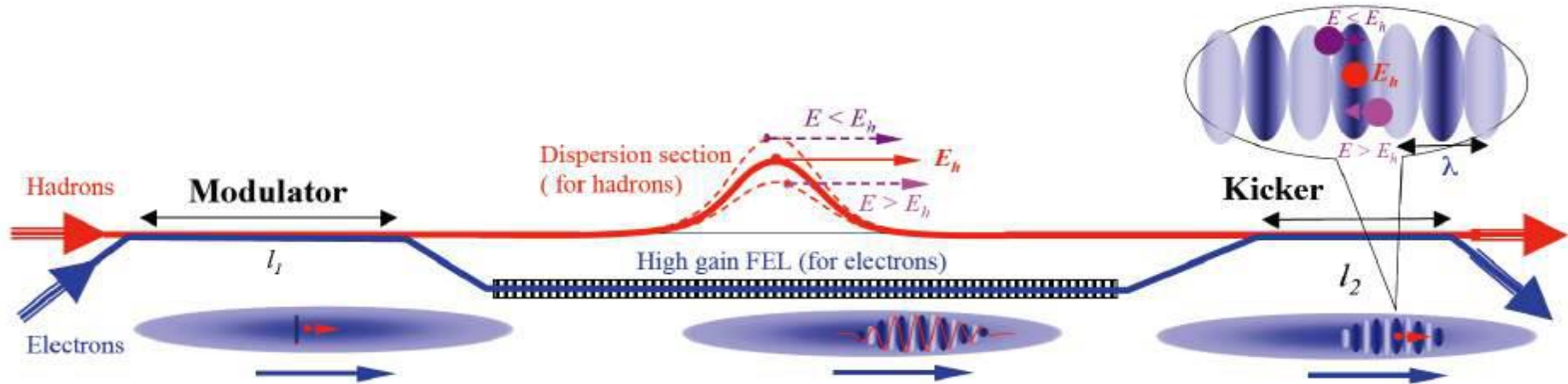
Jun Ma on behalf of CeC team

Collider-Accelerator Department

Brookhaven National Laboratory

BROOKHAVEN
NATIONAL LABORATORY

U.S. DEPARTMENT OF
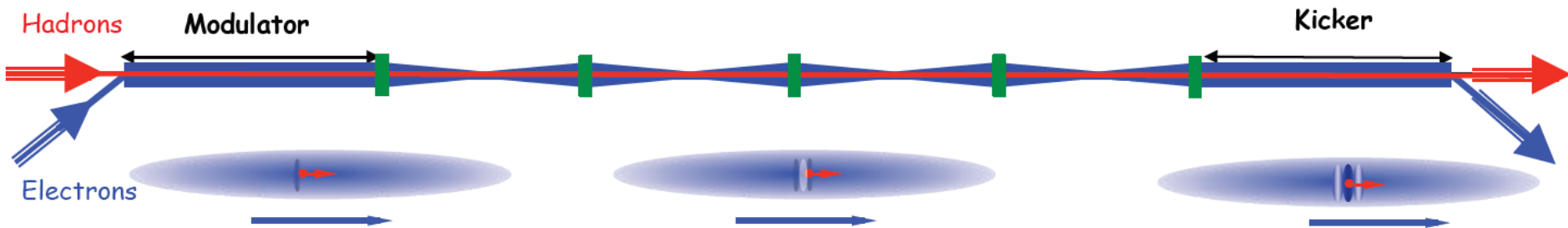**ENERGY**

Outline

- Introduction to coherent electron cooling (CeC) and code SPACE

- Simulations of CeC
    - Algorithm and Verification
    - Modulator
    - Free-electron laser (FEL) amplifier
    - Kicker
    - Plasma-cascade amplifier (PCA)

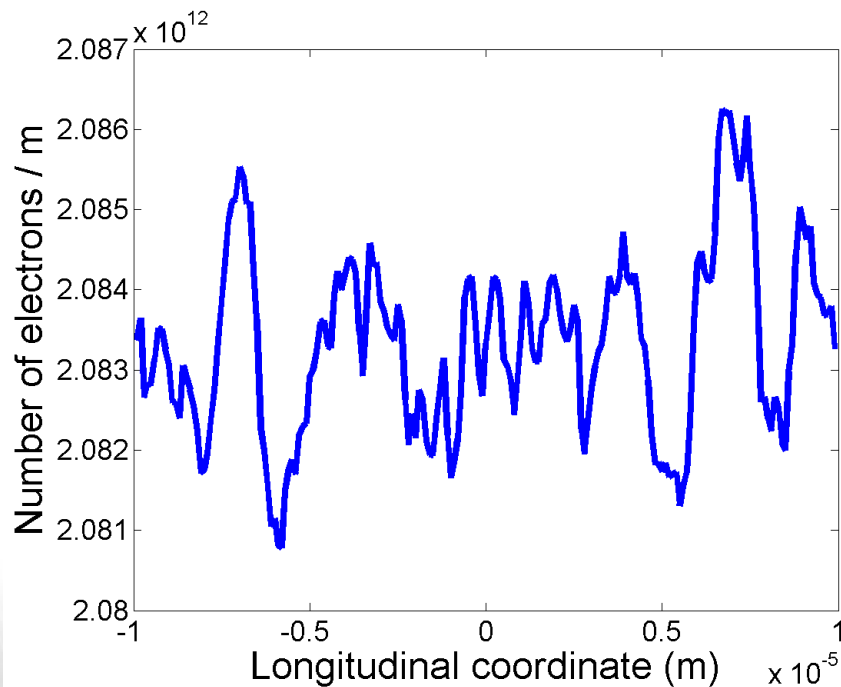# CeC: Modulator, Amplifier, Kicker

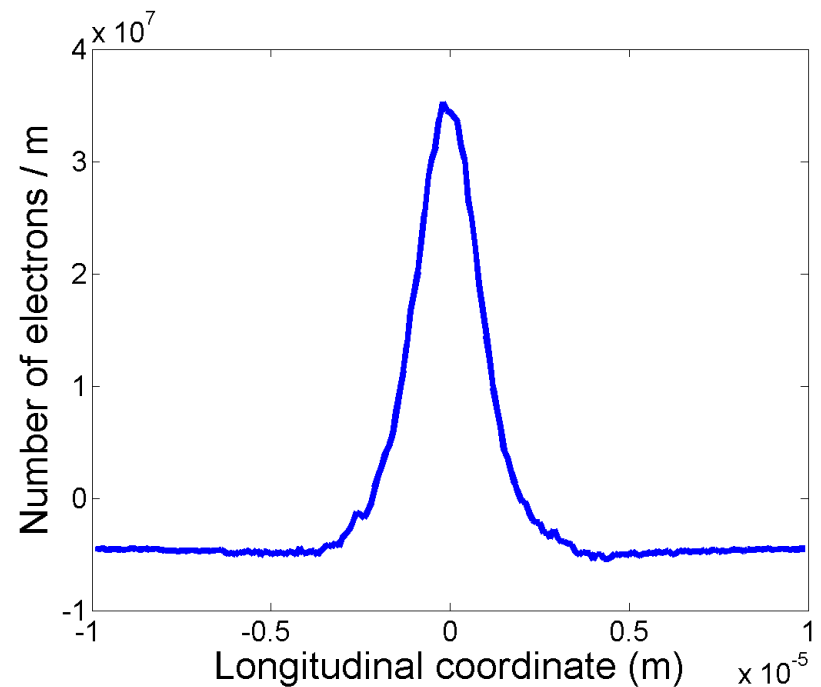CeC with FEL

CeC with PCA

SPACE

- Parallel, relativistic, 3D electromagnetic Particle-in-Cell (PIC) code
- Simulations of relativistic particle beams, beam-plasma interaction and plasma chemistry
- Benchmarked with MAD-X, ELEGANT and Impact-T
- Electrostatic module
  - Traditional PIC method
  - Adaptive Particle-in-Cloud (AP-Cloud) method

Algorithm: Extract Signal

- Two simulations with identical initial distribution
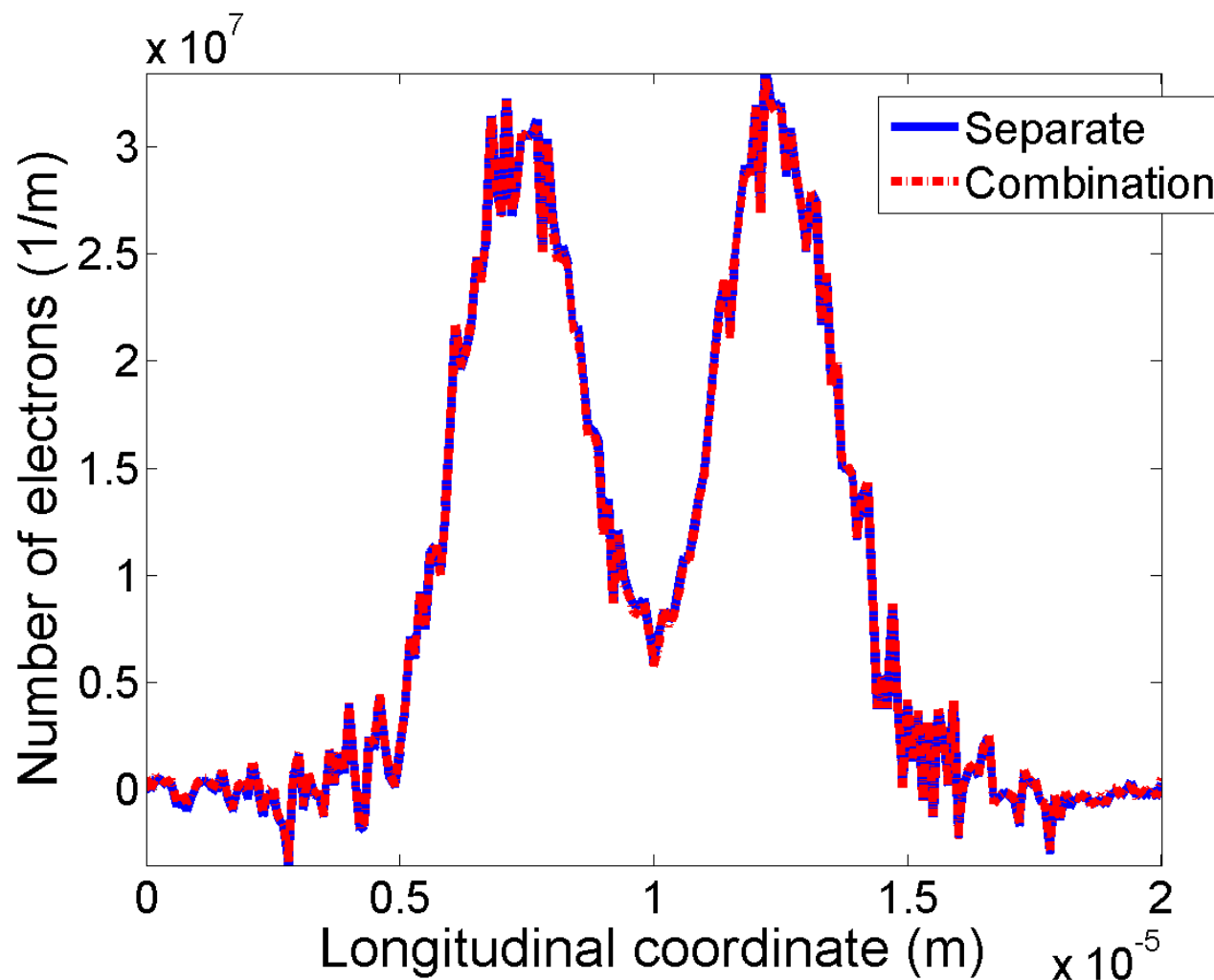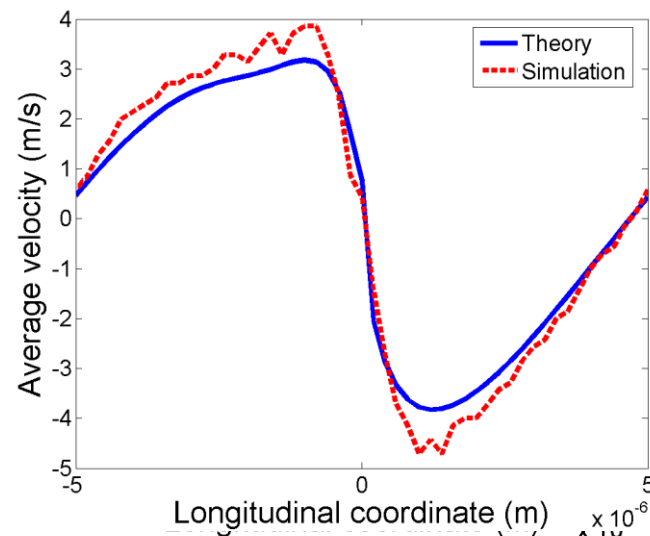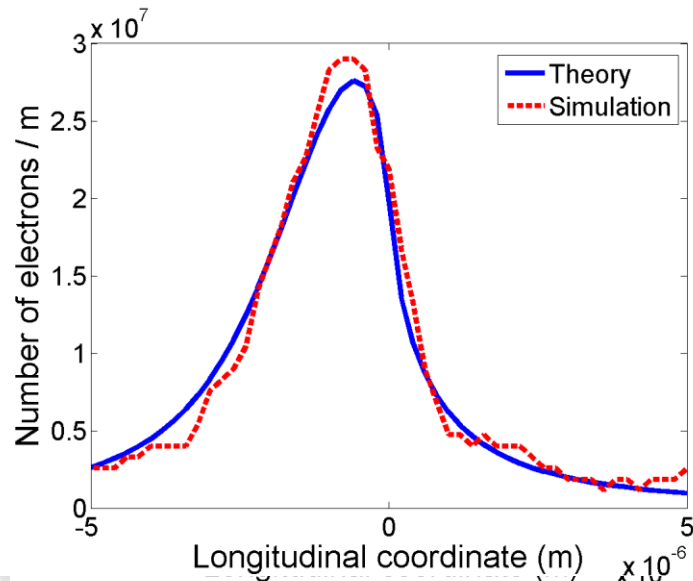- One without ion, one with ion
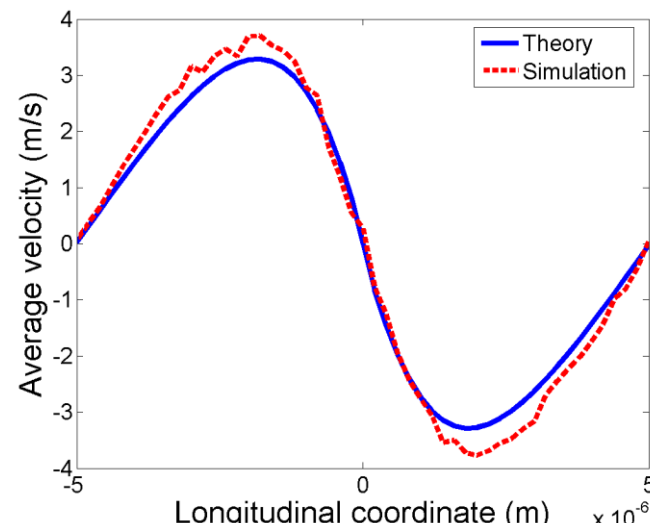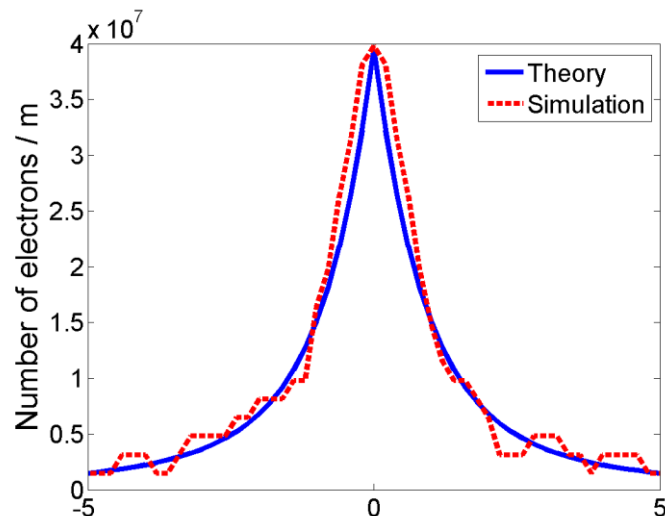- Take difference

Background

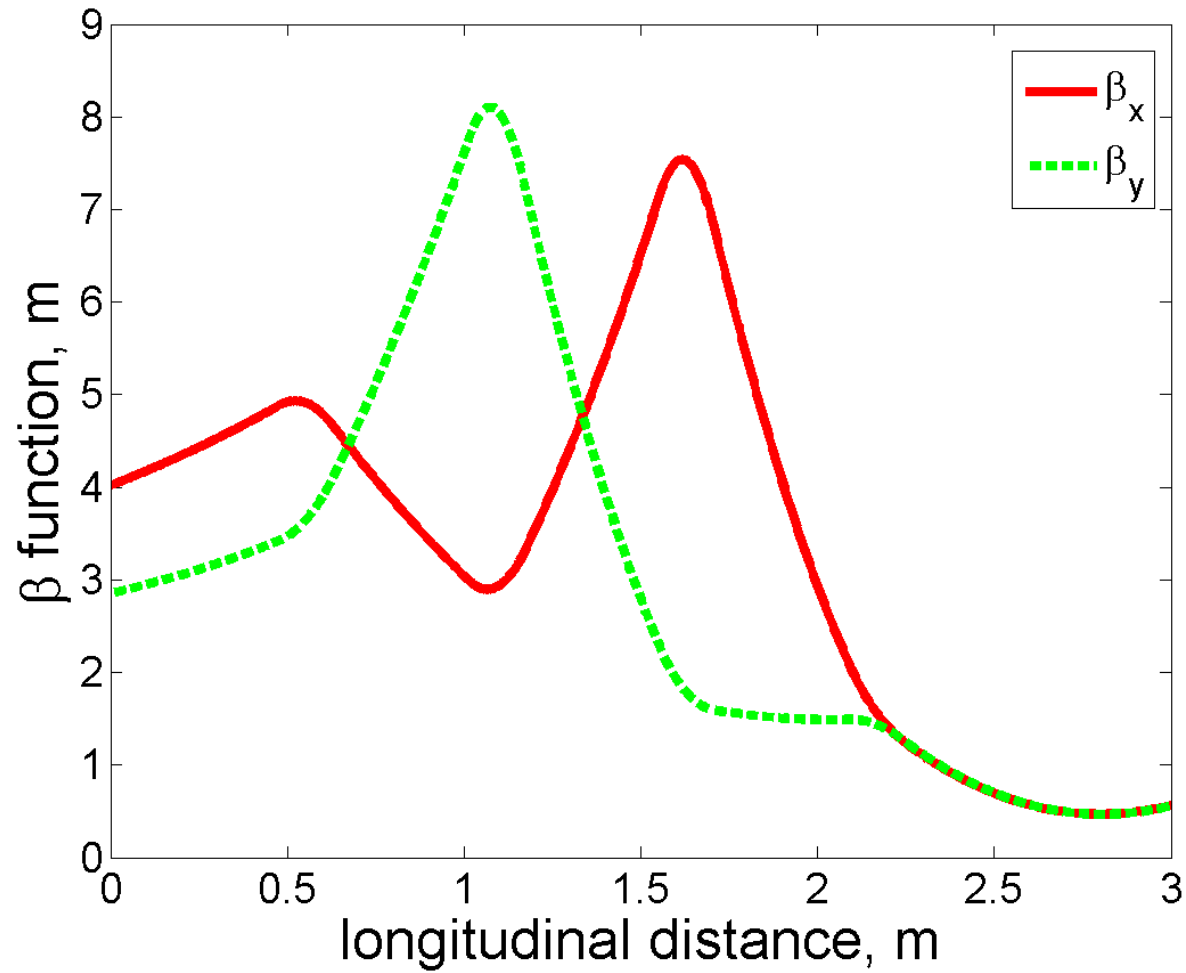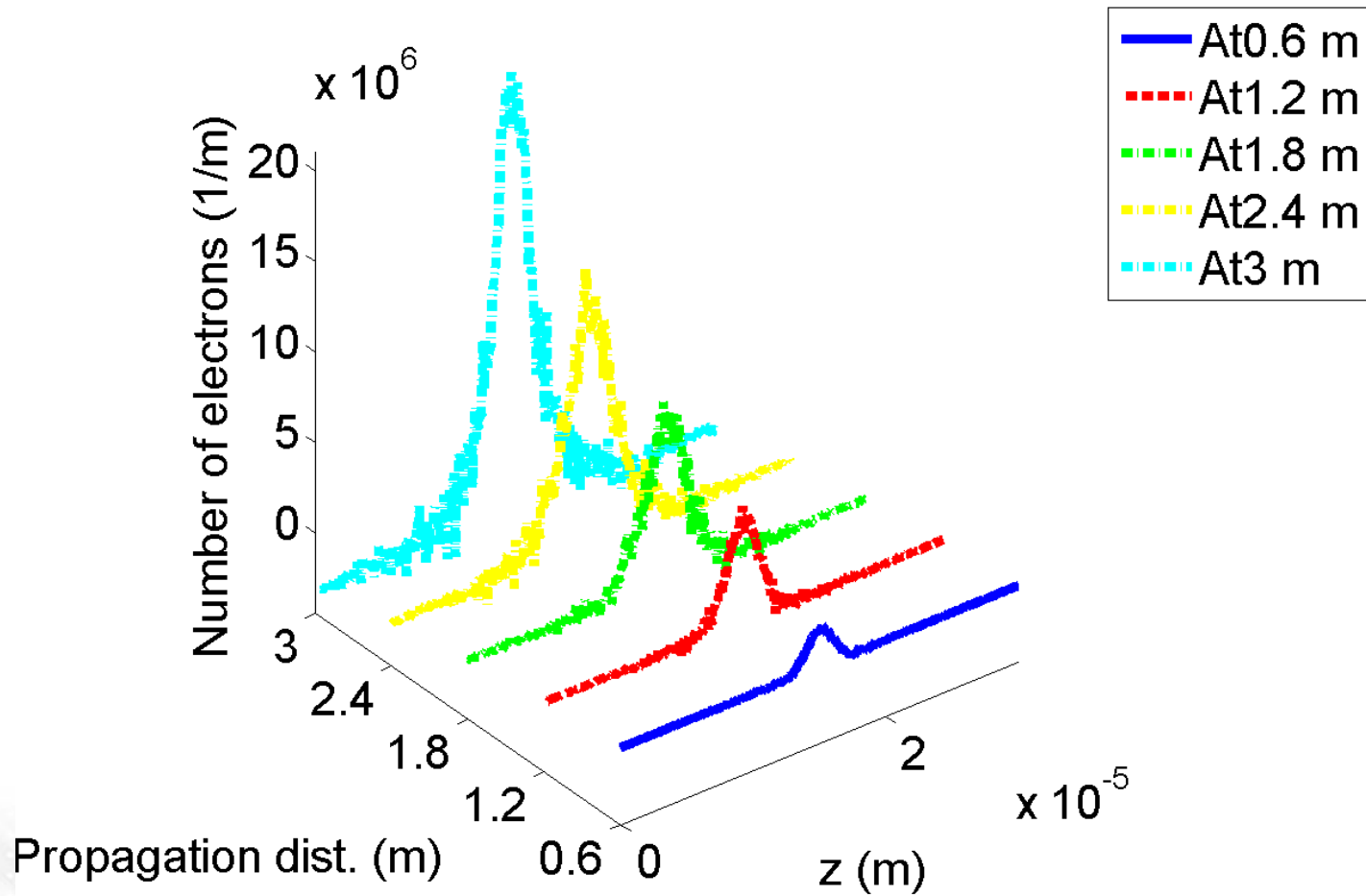Signal

Super Position Principle

Verification
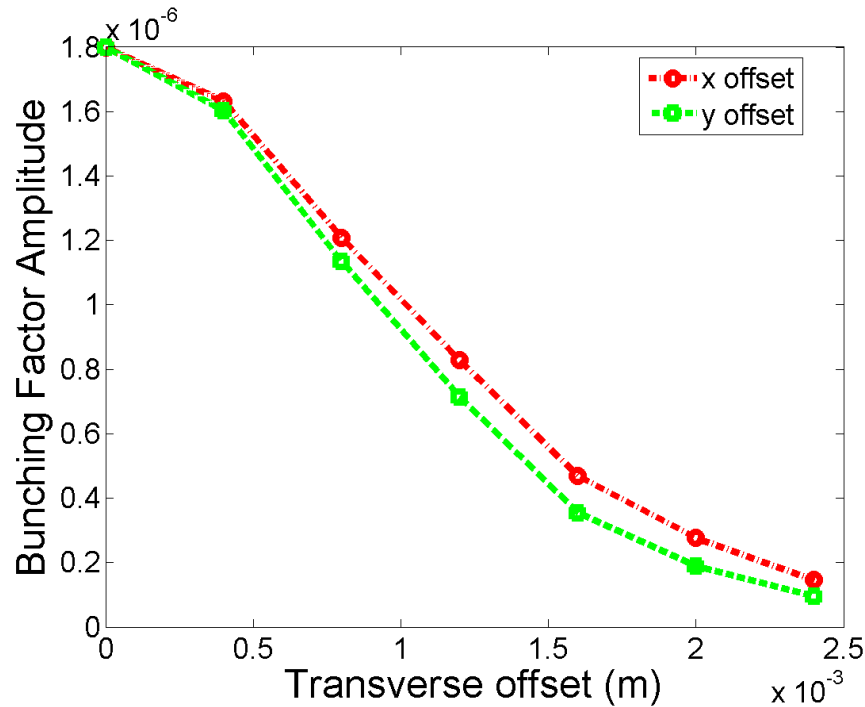

Compared with theory

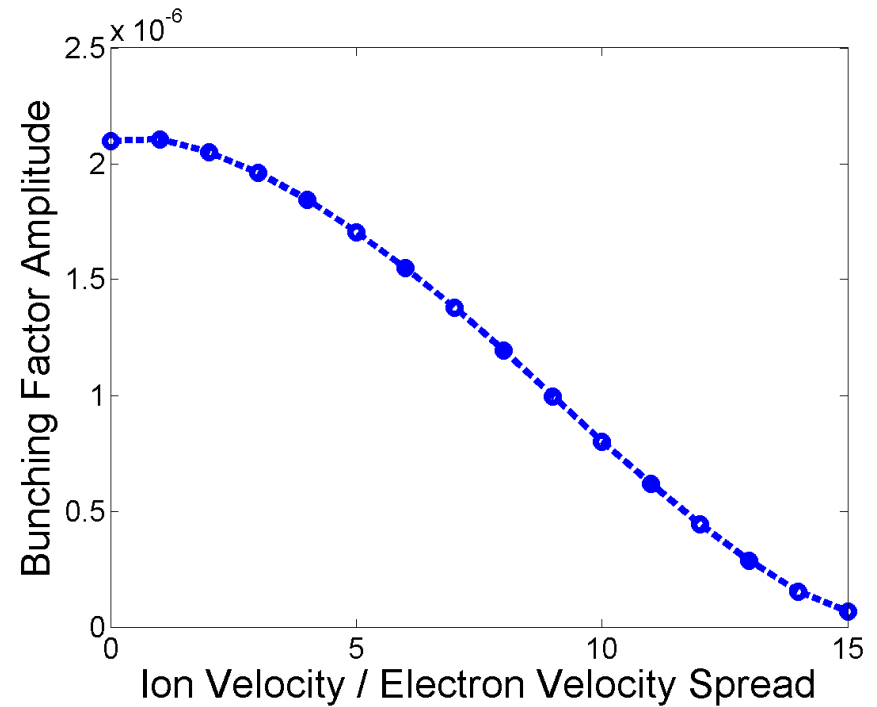# Modulator: Beam Envelope

Modulator: Density Modulation

Bunching Factor

$$b \equiv \frac{1}{N_\lambda} \sum_{k=1}^{N_\lambda} e^{i\frac{2\pi}{\lambda_{opt}} z_k}$$
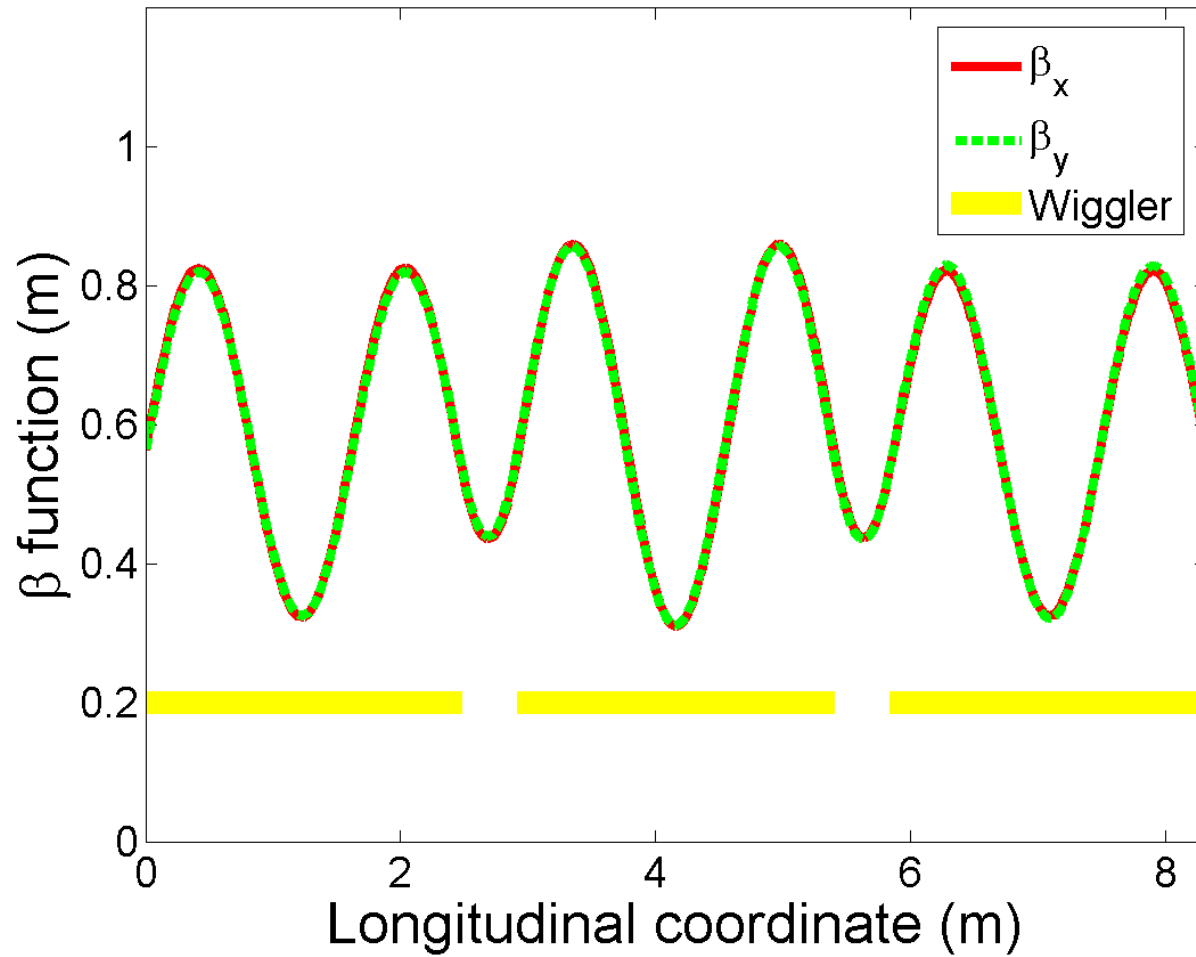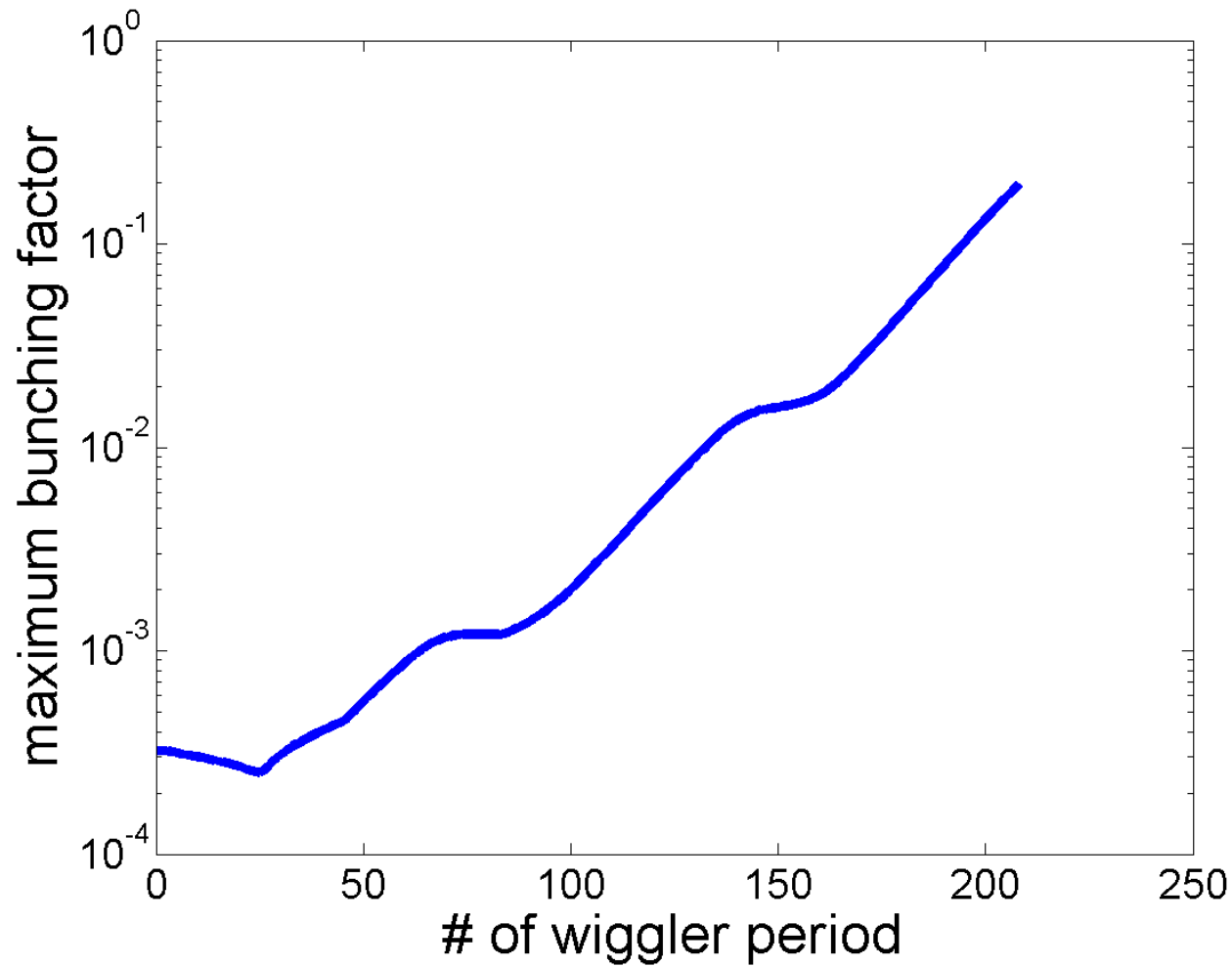

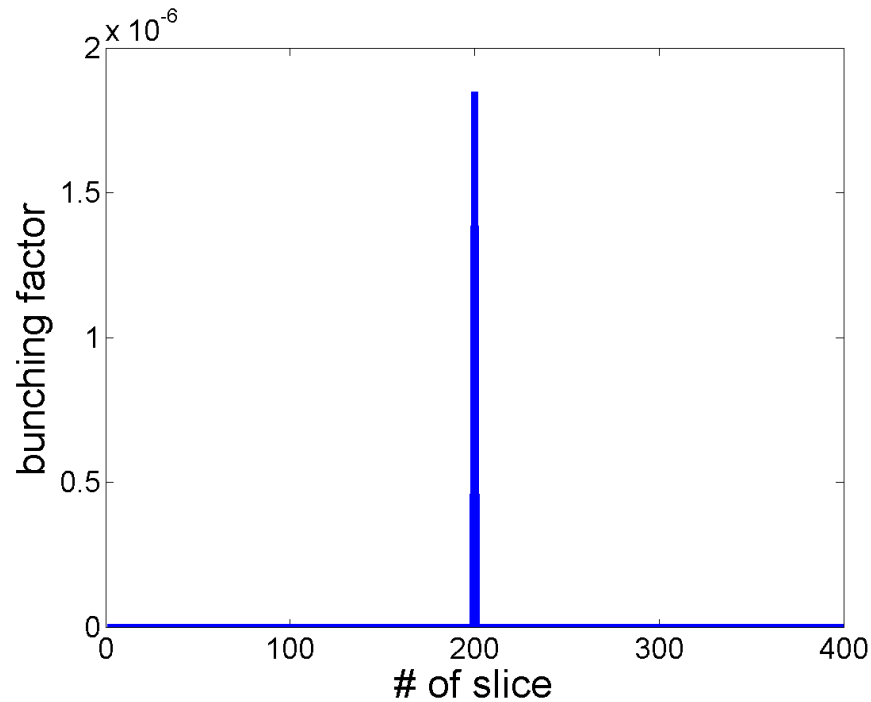Dependence on Transverse offsets

Dependence on Longitudinal velocity
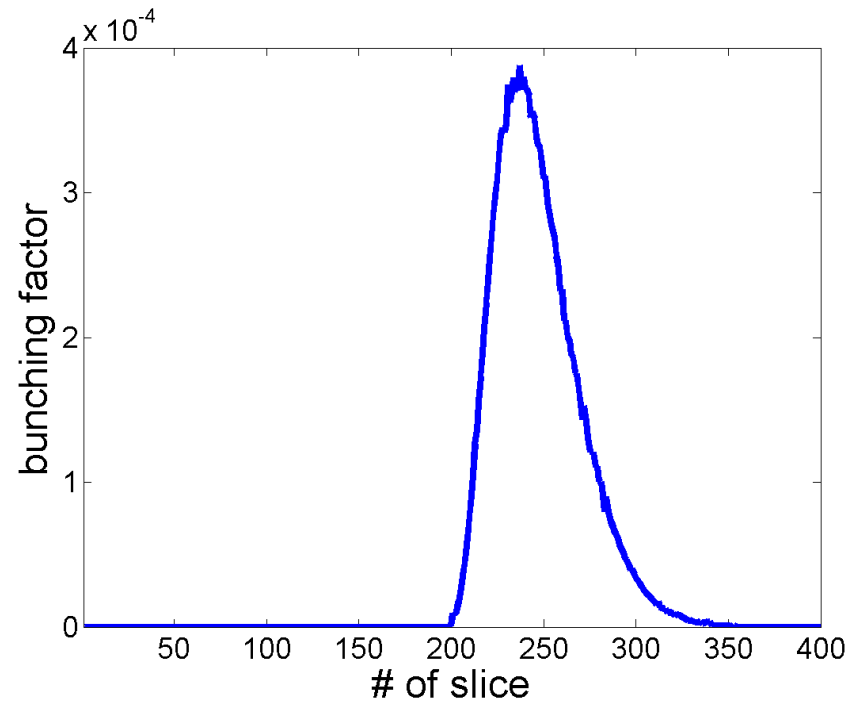
FEL: Beam Envelope (GENESIS)

FEL: Shot Noise (GENESIS)
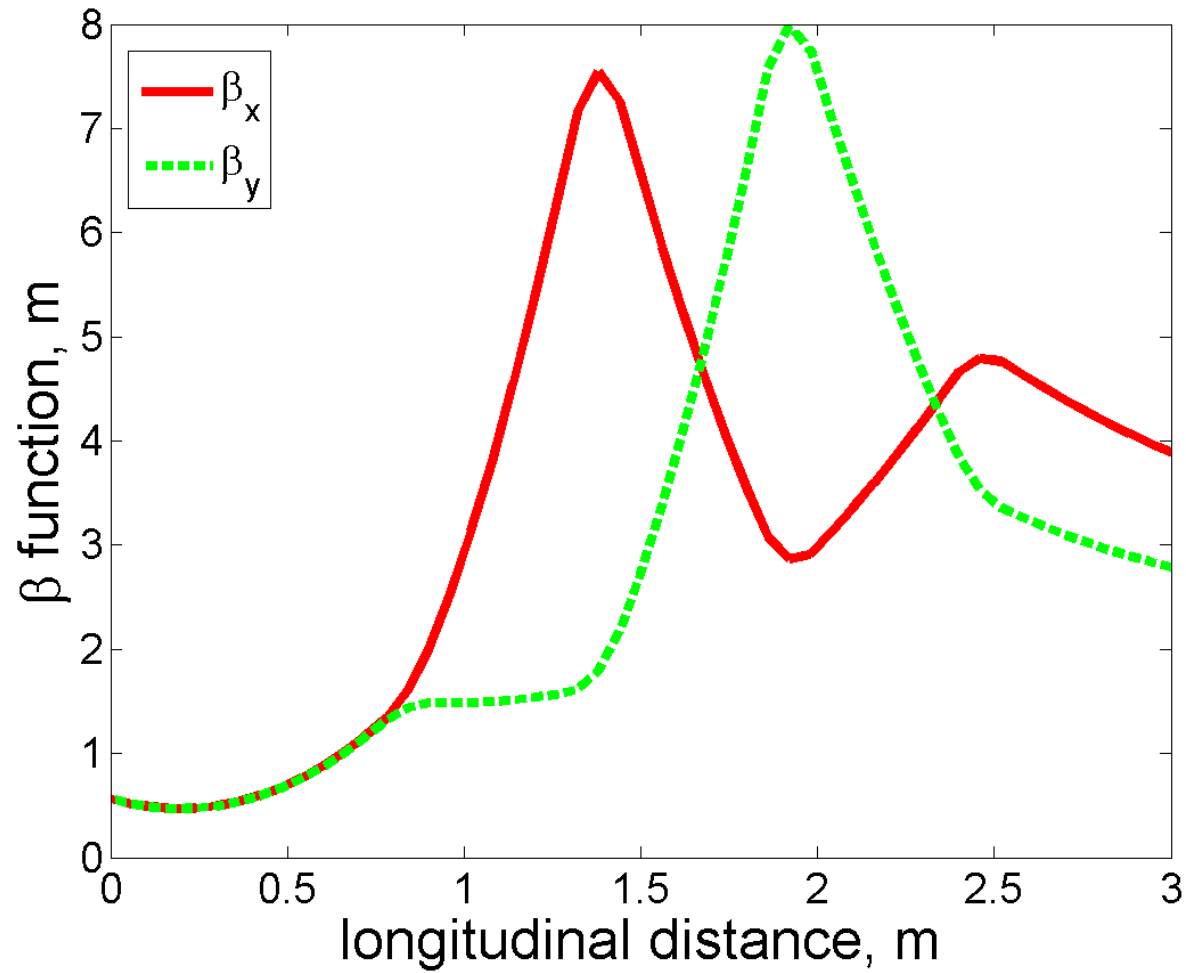
FEL: Growth of Signal (GENESIS)
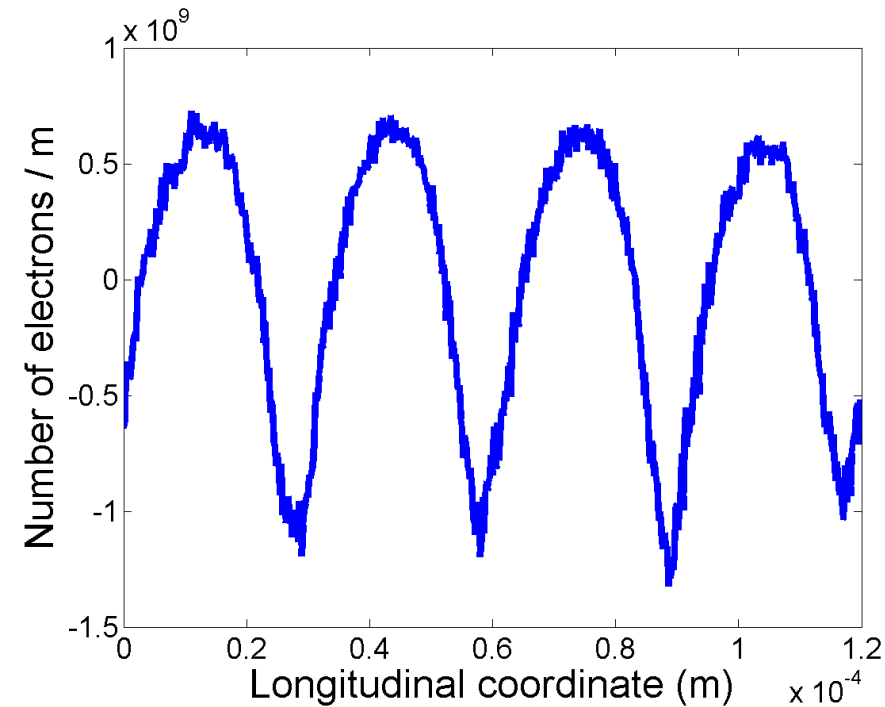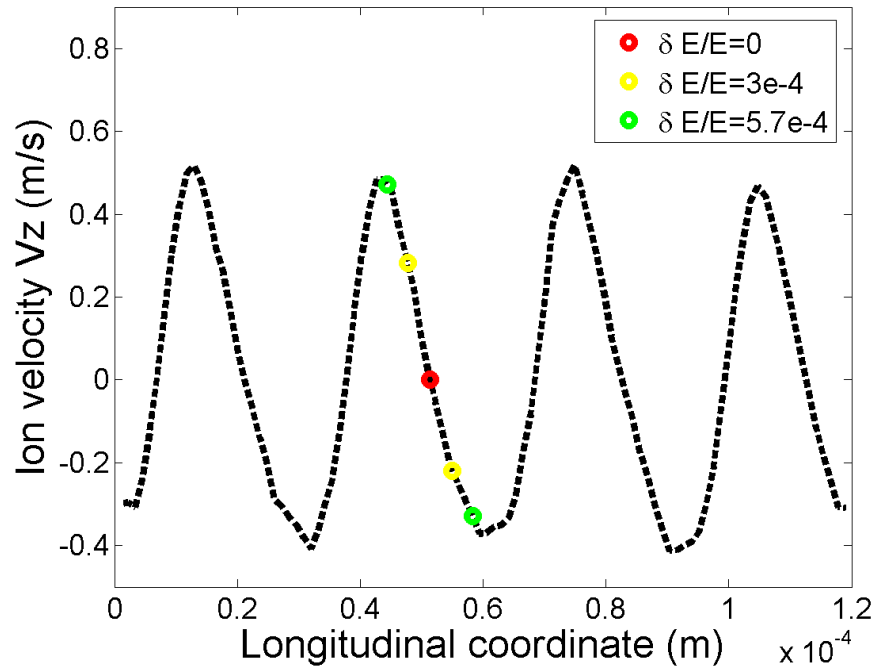

At entrance

At exit

Kicker: Beam Envelope
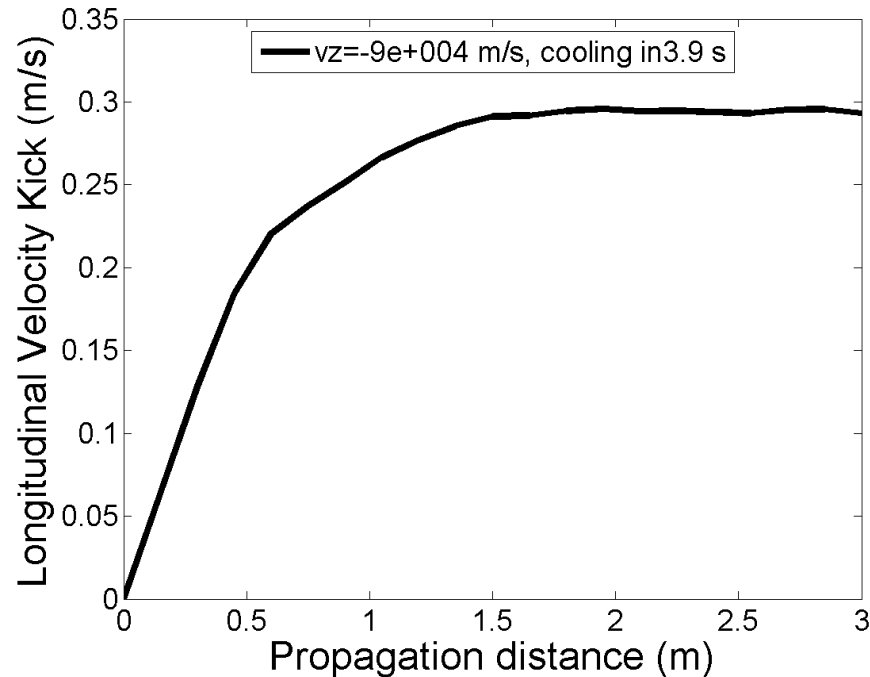
Kicker: Cooling Force
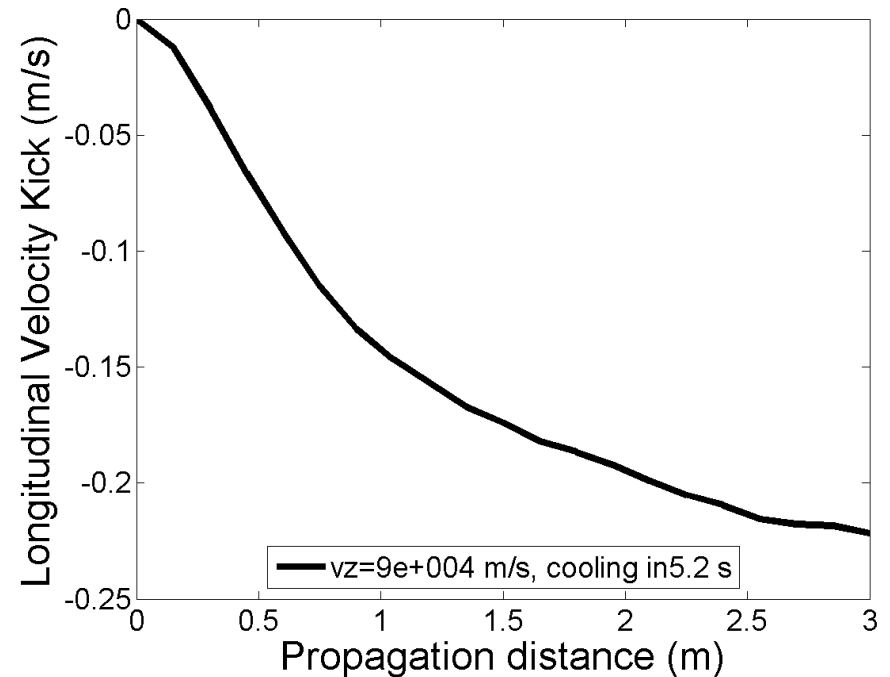

Amplified Signal

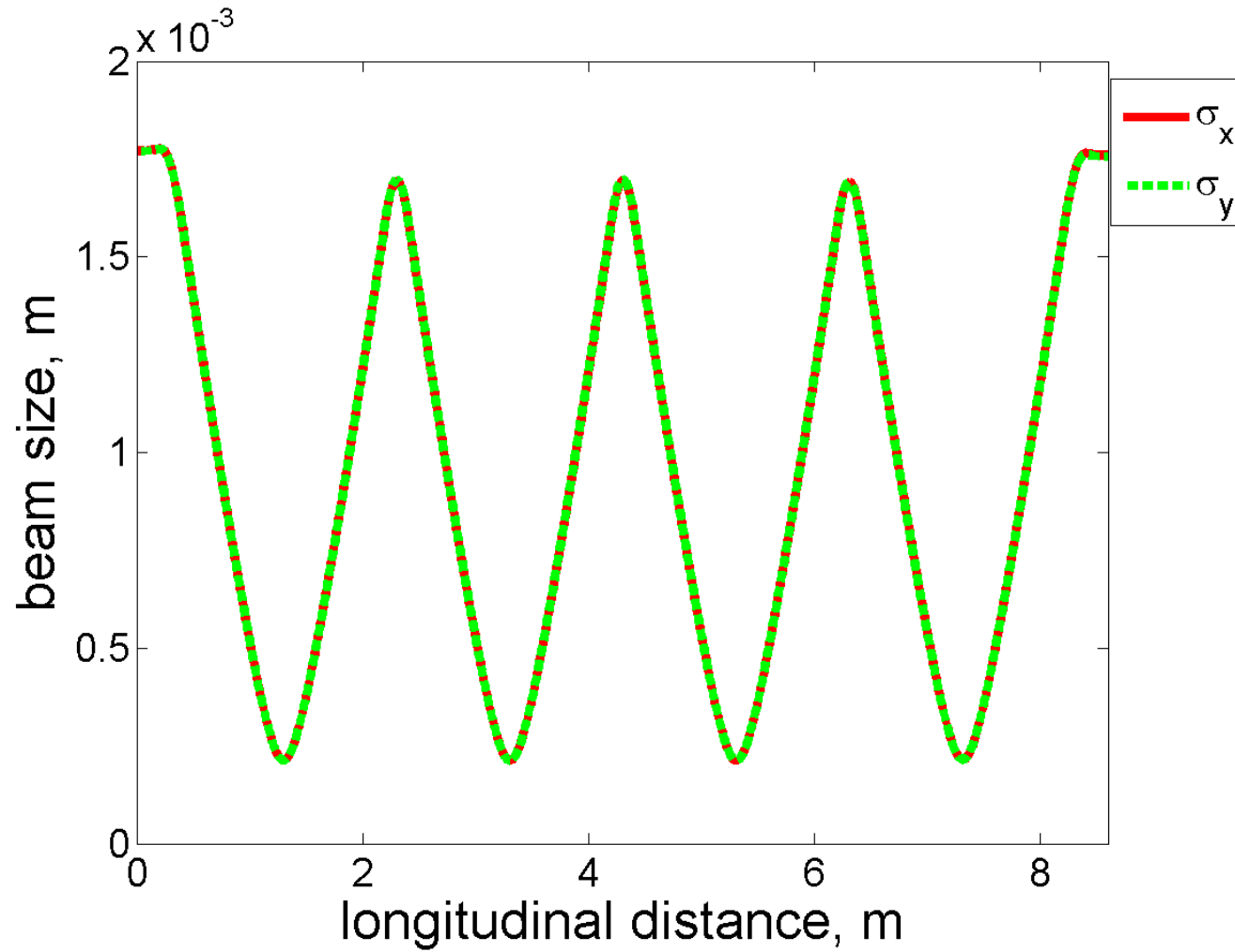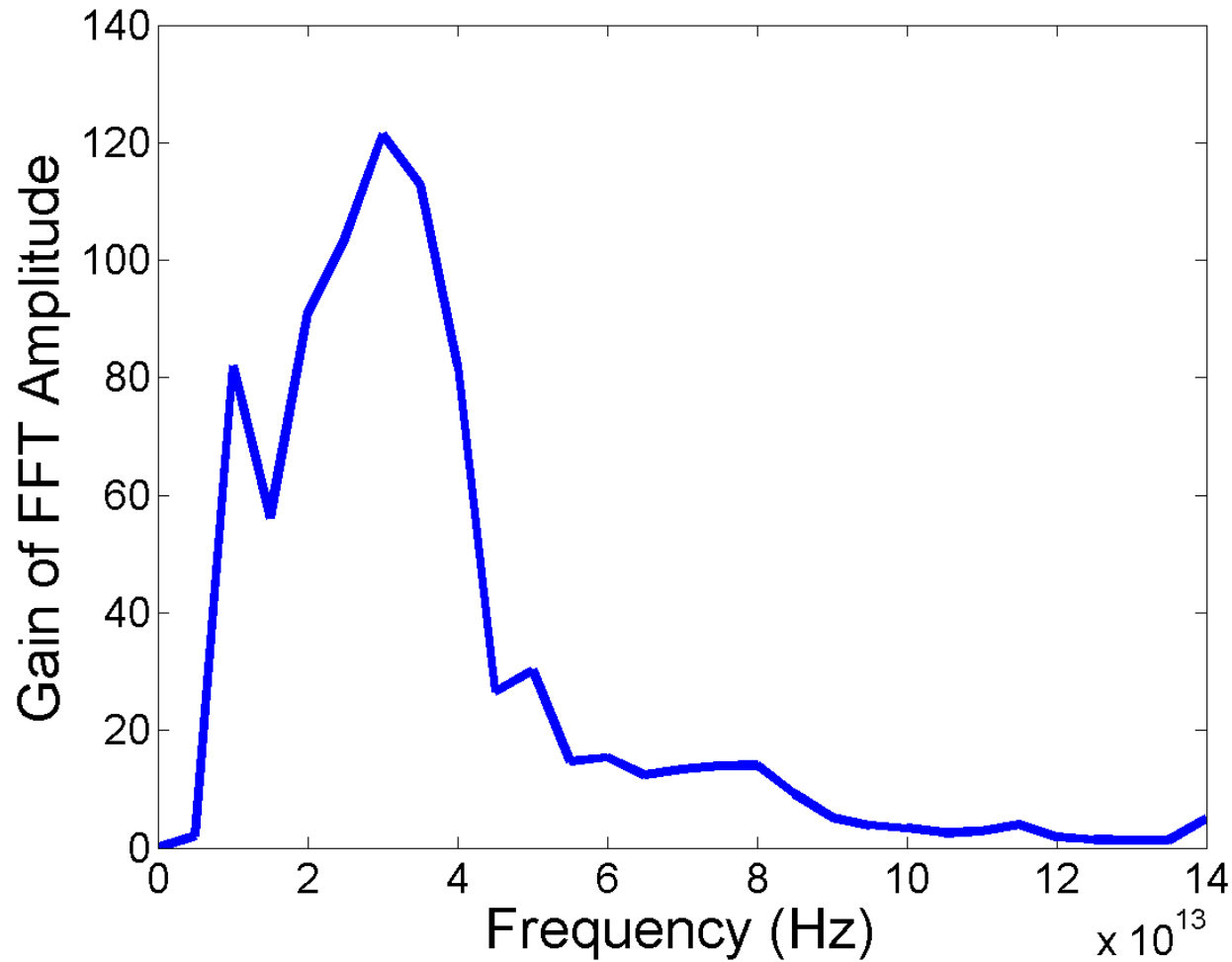Velocity Kick

Kicker: Cooling Time

Lower energy ion

Higher energy ion

- Realistic calculation of cooling time should include random kicks from surrounding ions and electrons
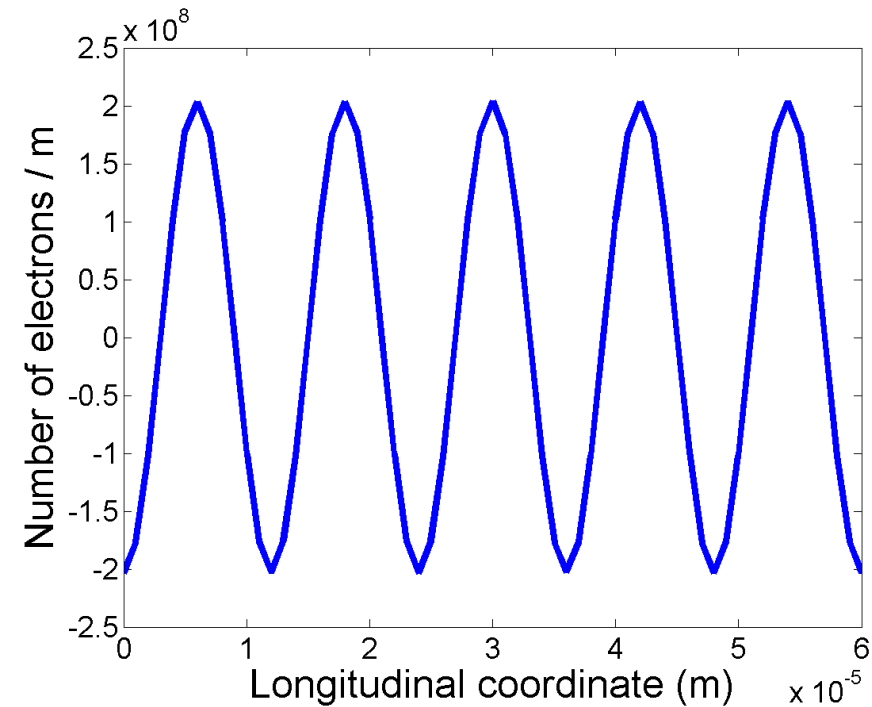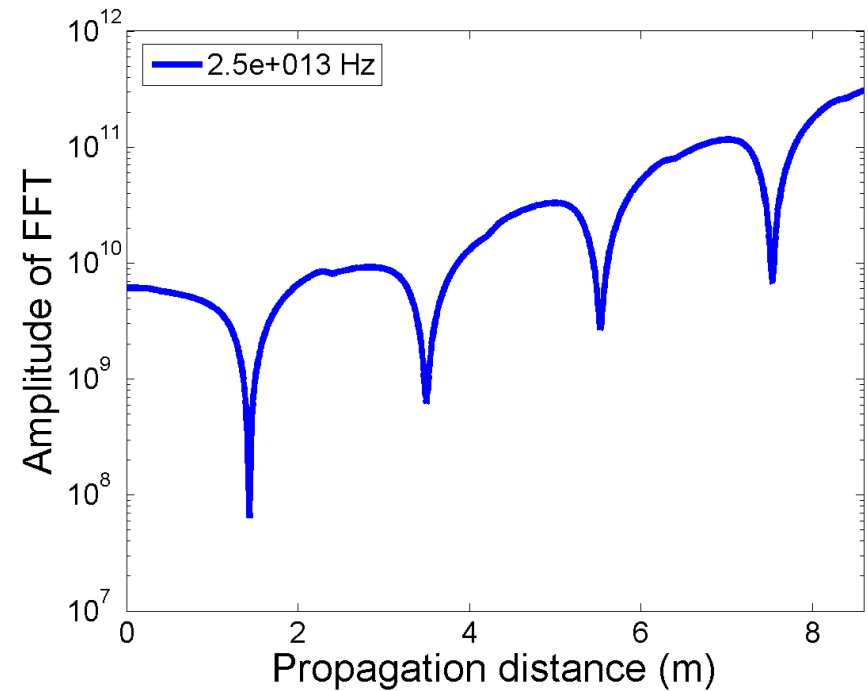
PCA: Beam Envelope

PCA: Spectrum of Gain

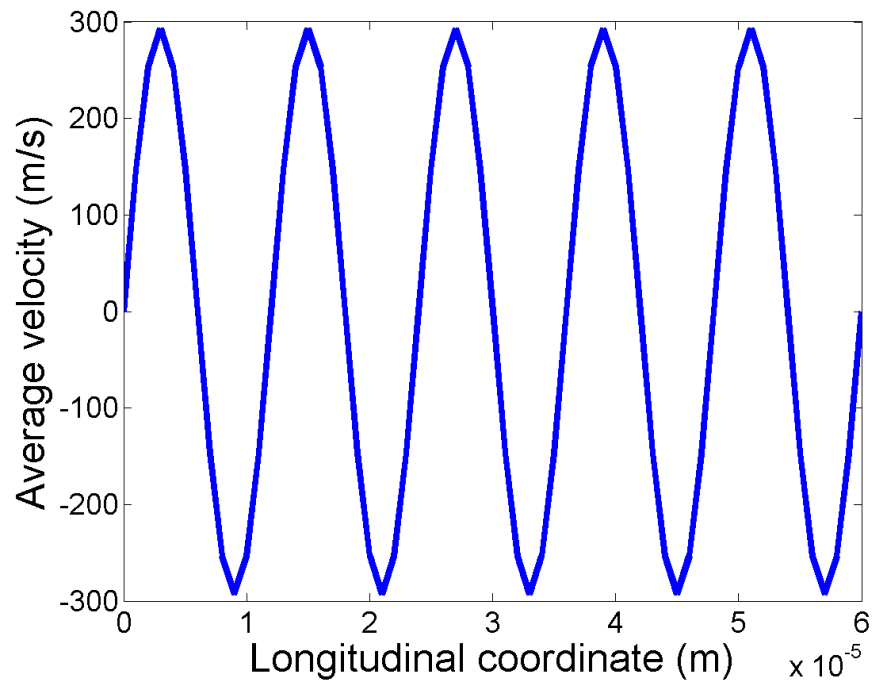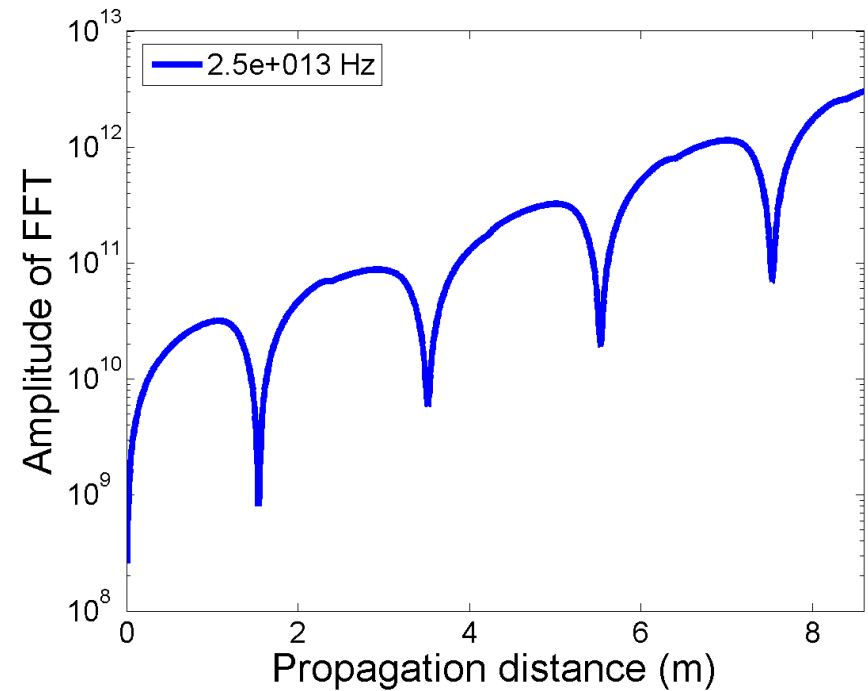# PCA: Initial Density Modulation

Initial signal

Amplification of signal

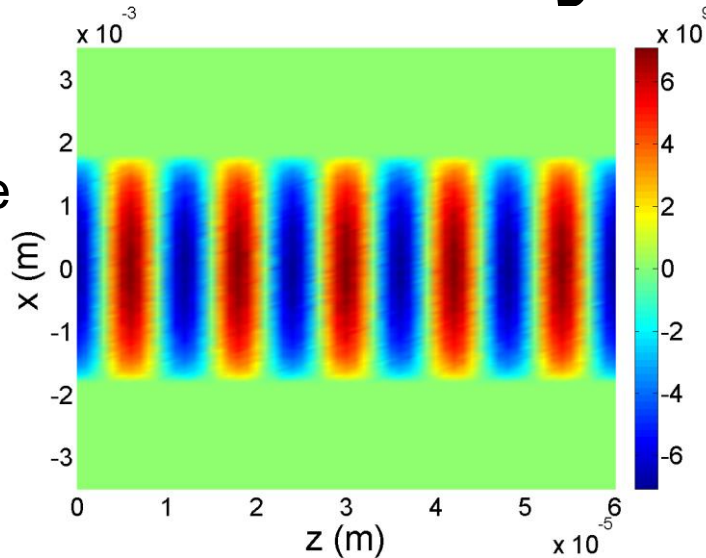# PCA: Initial Velocity Modulation
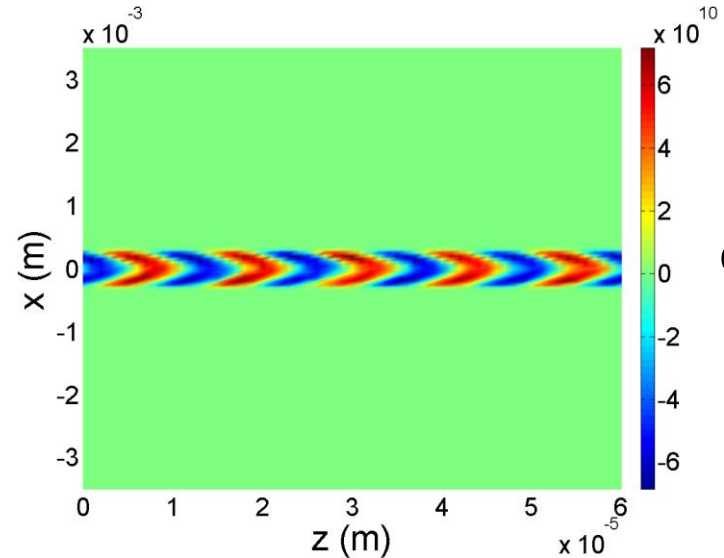

Initial signal

Amplification of signal
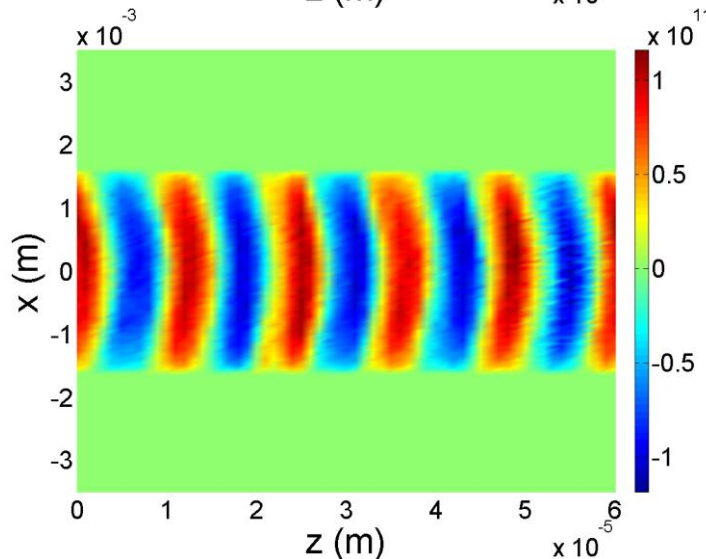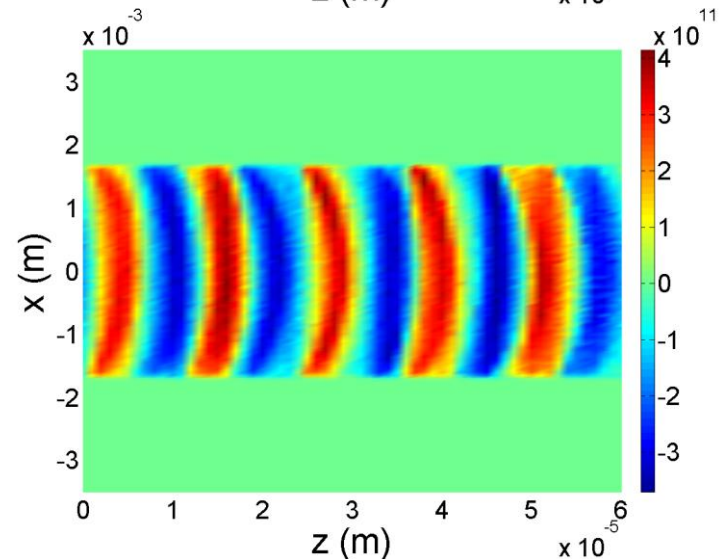
PCA: Beam Dynamics

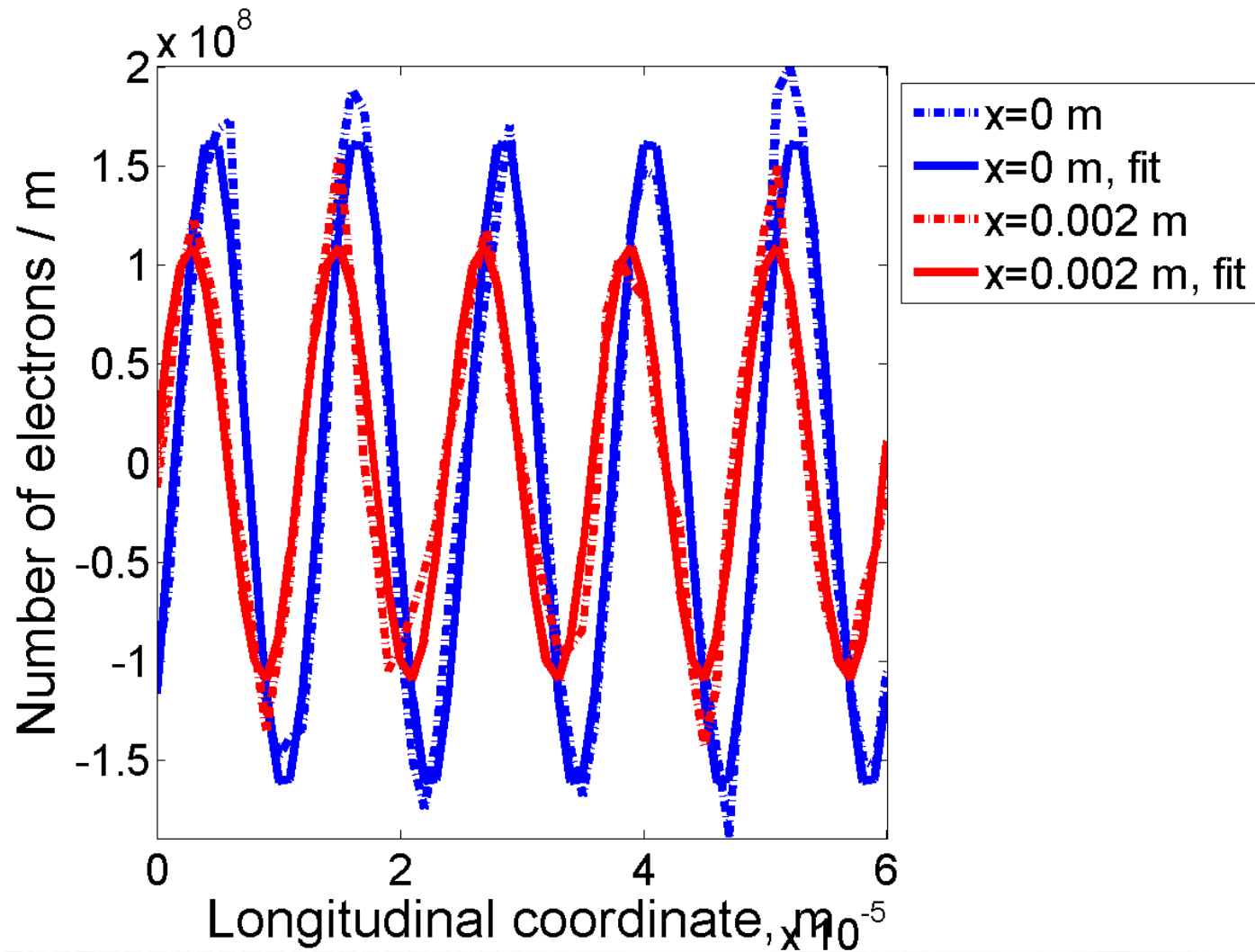Entrance of 1st Cell

Middle of 2nd Cell

End of 3rd Cell

End of 4th Cell

PCA: Central and Edge

Phase difference 45 degree

Conclusion

- SPACE simulations have been benchmarked with theory and other codes

- Start-to-end simulations have been performed for CeC with FEL and cooling time has been predicted

- PCA process has been explored and characterized

- Simulation study will continue supporting CeC design and experiment

Thank You