Particle Initialization and Focusing Field

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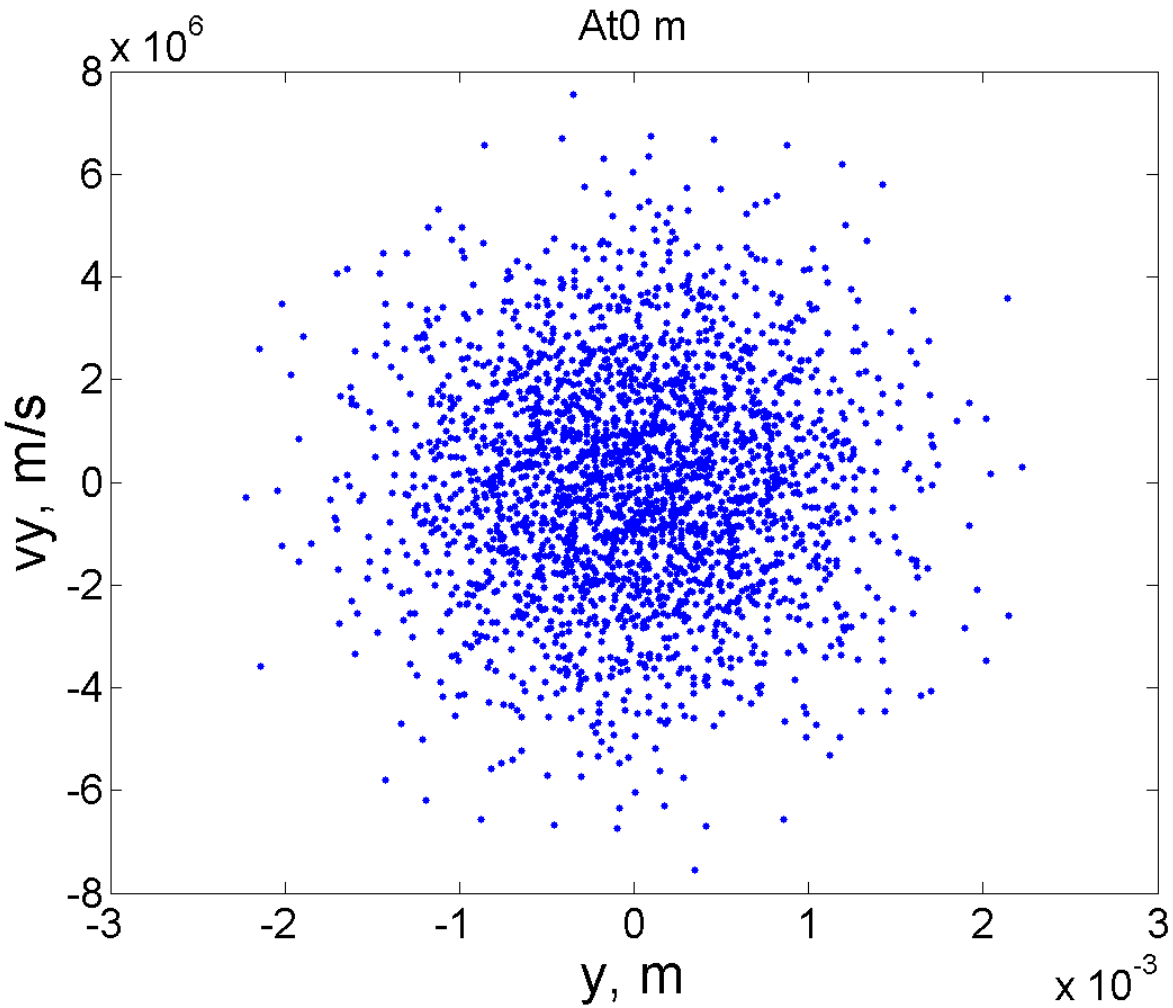
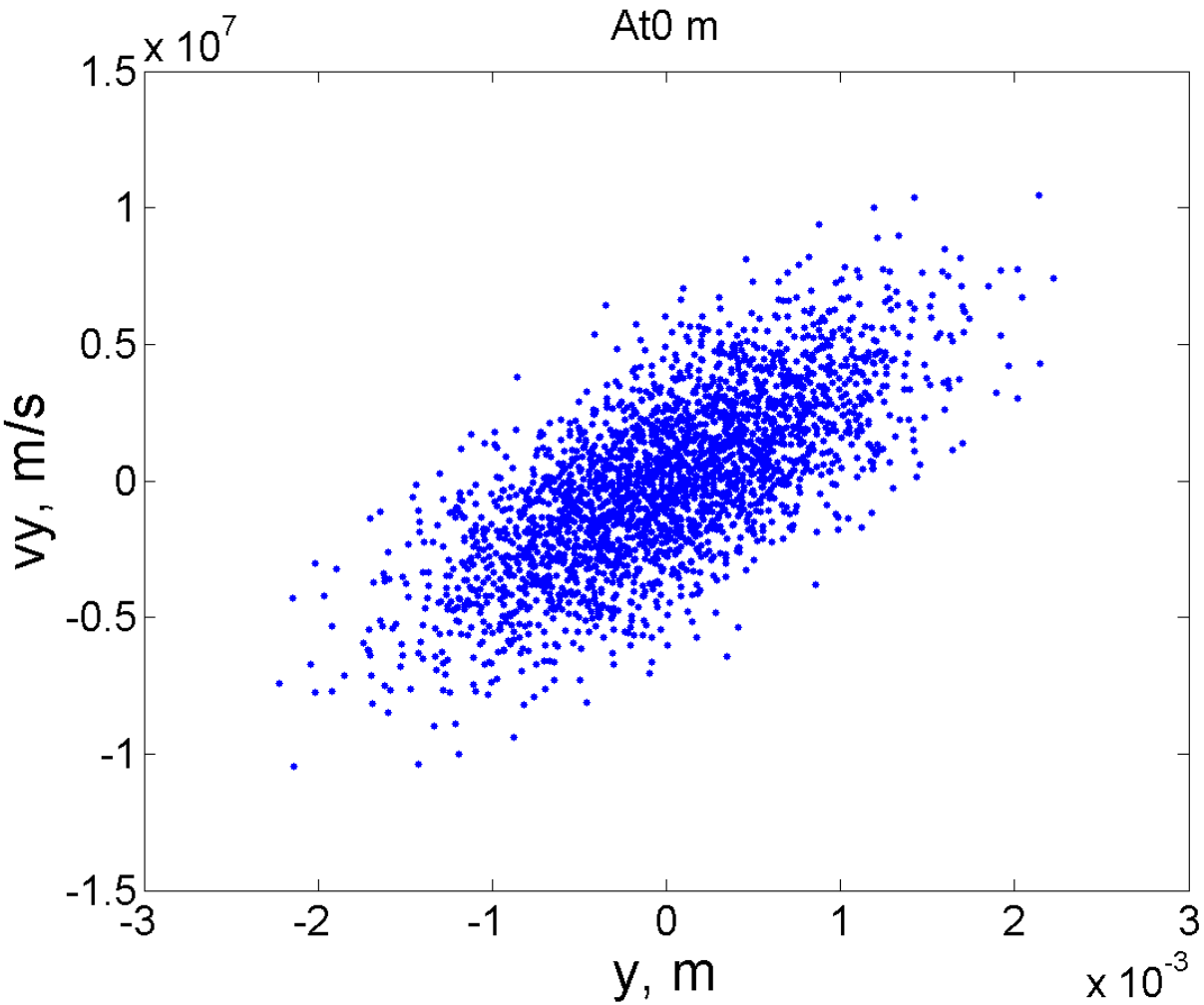
- Quiet start
- Add correct shot noise to θ
- See notes for details
- Implemented in PIC code

$\alpha_y = 0$



$\alpha_y = -1$



Bunching factor

- Number of macro-particle : 1e+4
- Representing number : 1e+4
- Number of real particle : 1e+8
- Shot noise from theory : 1e-4
- Shot noise from PIC code : 5e-5

- Up sampling for x, y, p_x, p_y, γ
- Quiet start and add correct shot noise to θ

Up sampling

- Randomly pick one particle
- Find it's nearest neighbor in 5D space of x, y, p_x, p_y, γ
- Randomly add a particle in between these two particles
- Repeat until sufficient number of particles

Simple harmonic motion

- Total energy

$$E_{total} = (mv^2 + kx^2)/2$$

- Linear focusing

$$E = k_1 x$$

-

$$k = k_1 q$$

Simple harmonic motion

- A single particle always follows simple harmonic motion for any liner focusing strength
- Liner focusing strength affects the magnitude and frequency of the simple harmonic motion

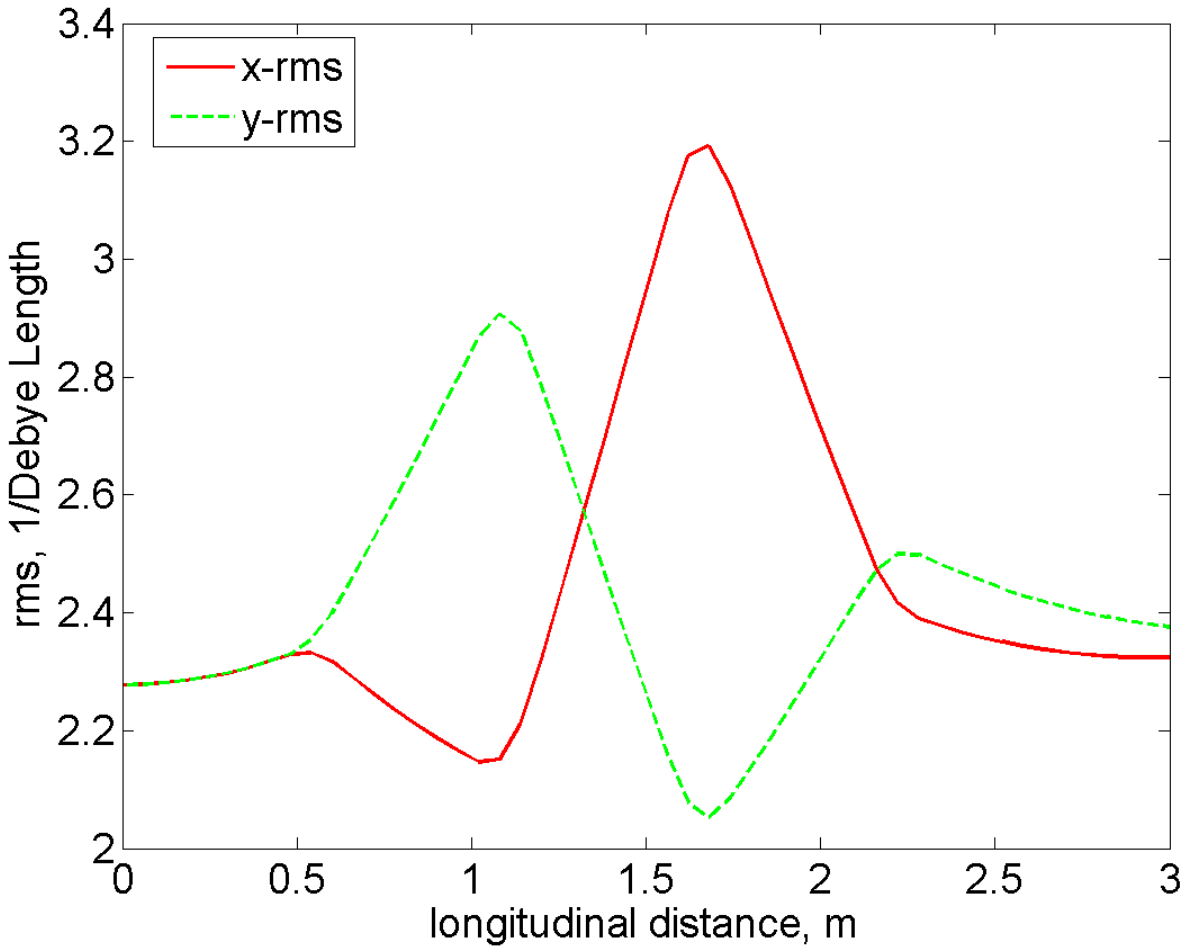
Simple harmonic motion

- For a beam, every particle follows simple harmonic motion if we ignore space charge effect
- If we consider space charge effect, particles may gain or lose energy, and may jump through different orbits in phase space. This effect may cause oscillations.
- Consider the particles with highest total energy. Some of them may gain energy and jump to a orbit with higher energy in phase space. Finally, a few particles may gain very large energy. This explains the tail of particles with very large outwards velocities in our previous simulations using linear focusing field.

Previous setting

- 0m - 0.4715m : Drift
- 0.4715m - 0.6285m : Q1, K1=-2.102
- 0.6285m - 1.0215m : Drift
- 1.0215m - 1.1785m : Q2, K1=6.713
- 1.1785m - 1.5715m : Drift
- 1.5715m - 1.7285m : Q3, K1=-7.661
- 1.7285m - 2.1215m : Drift
- 2.1215m - 2.2785m : Q4, K1=3.383
- 2.2785m - 3m : Drift

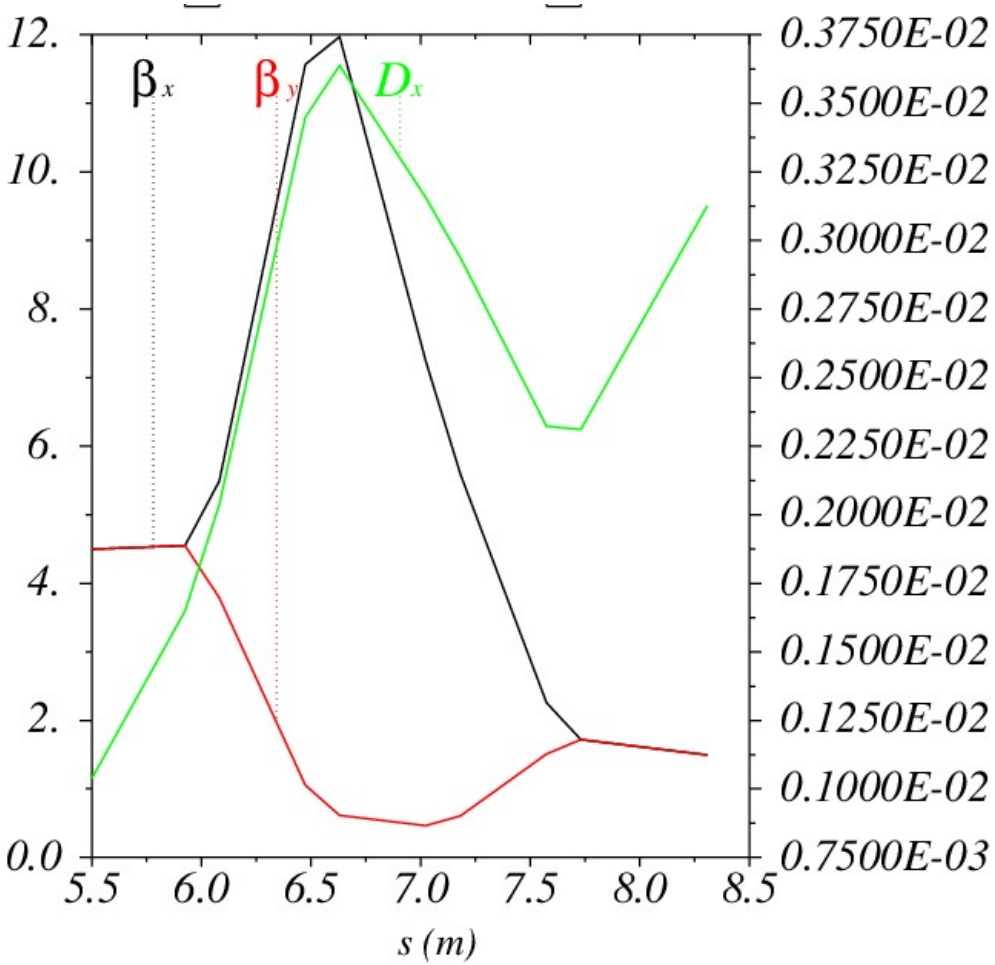
RMS change


x-rms
y-rms
rms, 1/Debye Length
longitudinal distance, m
3.4
3.2
3
2.8
2.6
2.4
2.2
2
0
0.5
1
1.5
2
2.5
3

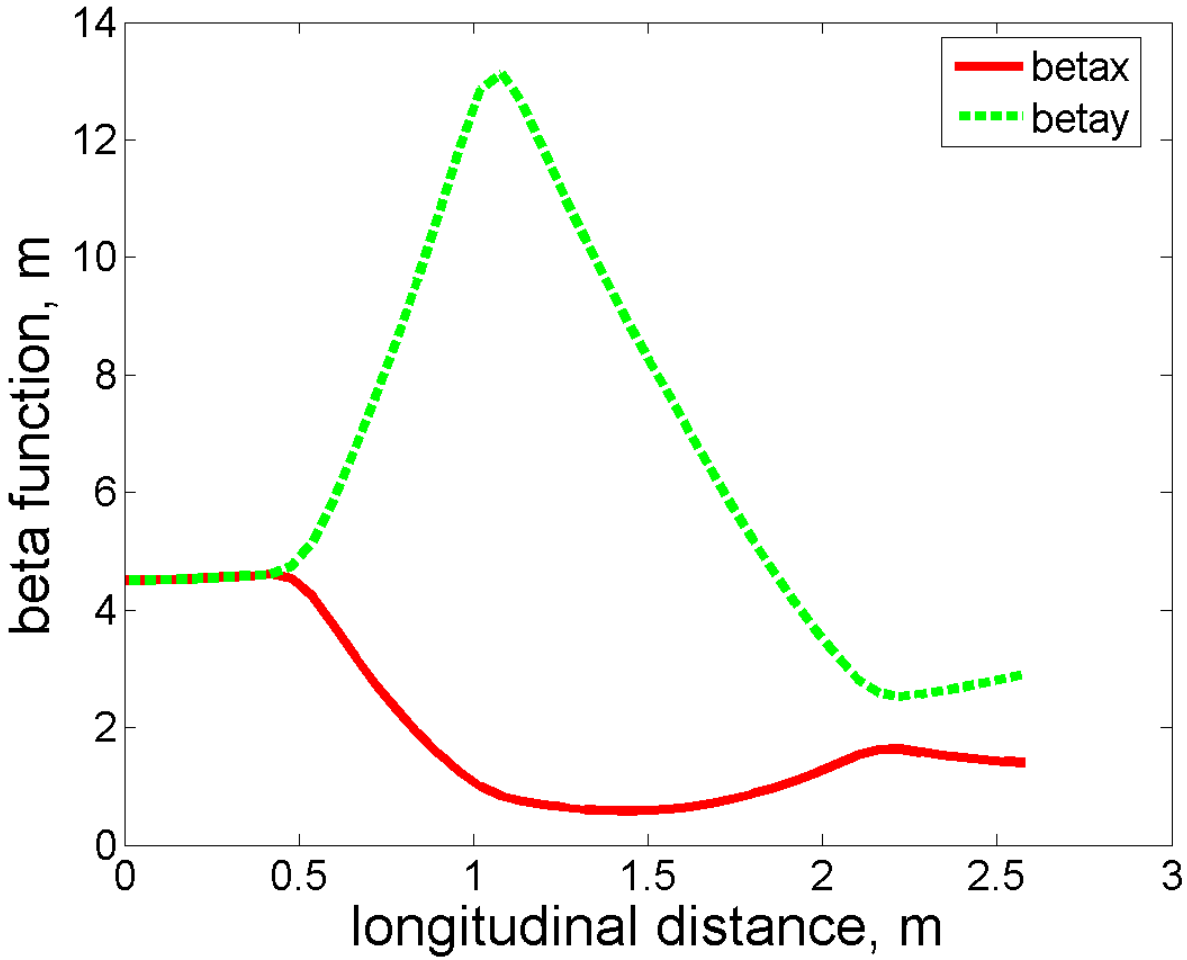
New setting

- 0m - 0.4245m : Drift
- 0.4245m - 0.5815m : Q1, K1=-7.56277
- 0.5815m - 0.9745m : Drift
- 0.9745m - 1.1315m : Q2, K1=8.50925
- 1.1315m - 1.5245m : Drift
- 1.5245m - 1.6815m : Q3, K1=0.698665
- 1.6815m - 2.0745m : Drift
- 2.0745m - 2.2315m : Q4, K1=-8.30714
- 2.2315m - 3m : Drift

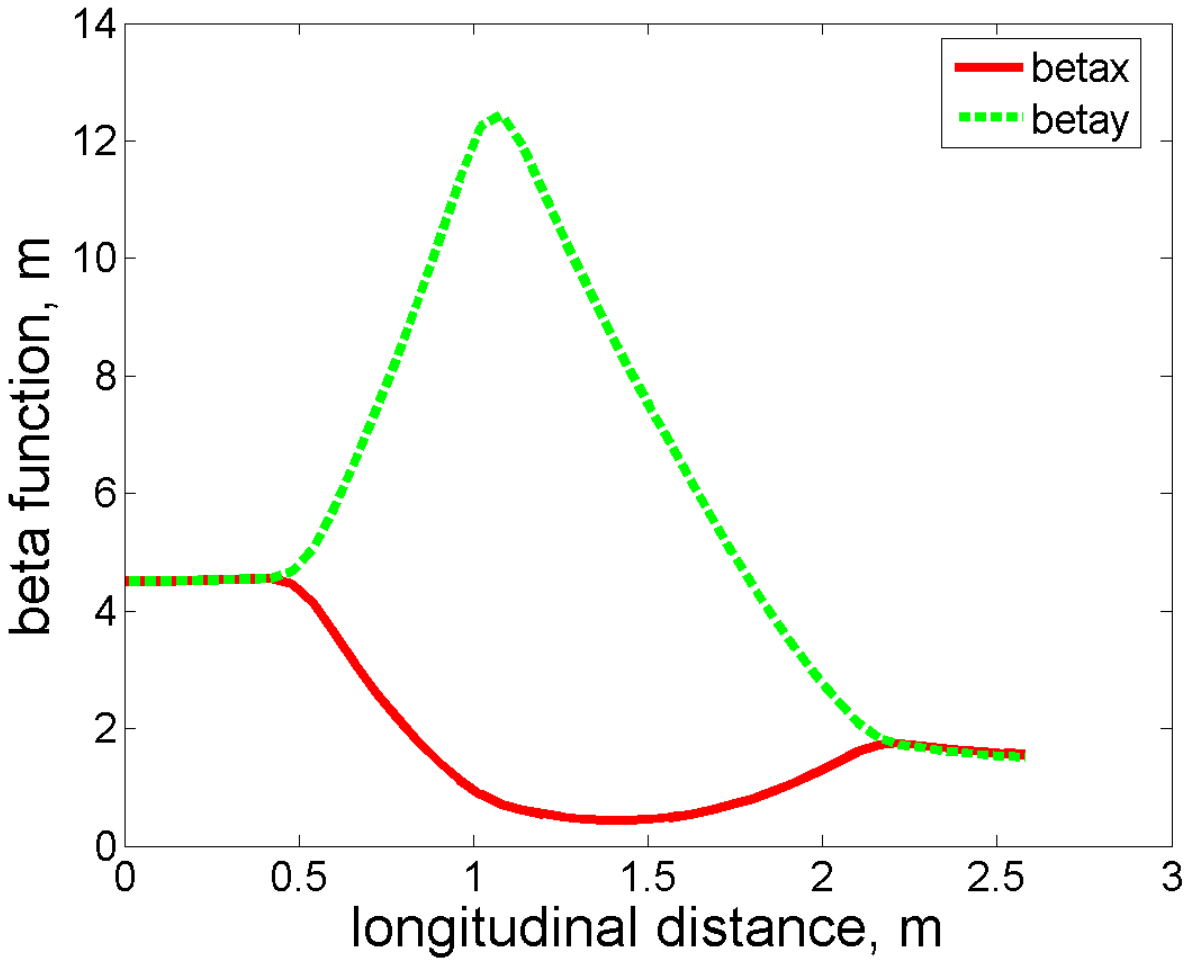
Theory β change



Simulation β change



Simulation β change, reduce charge by 100

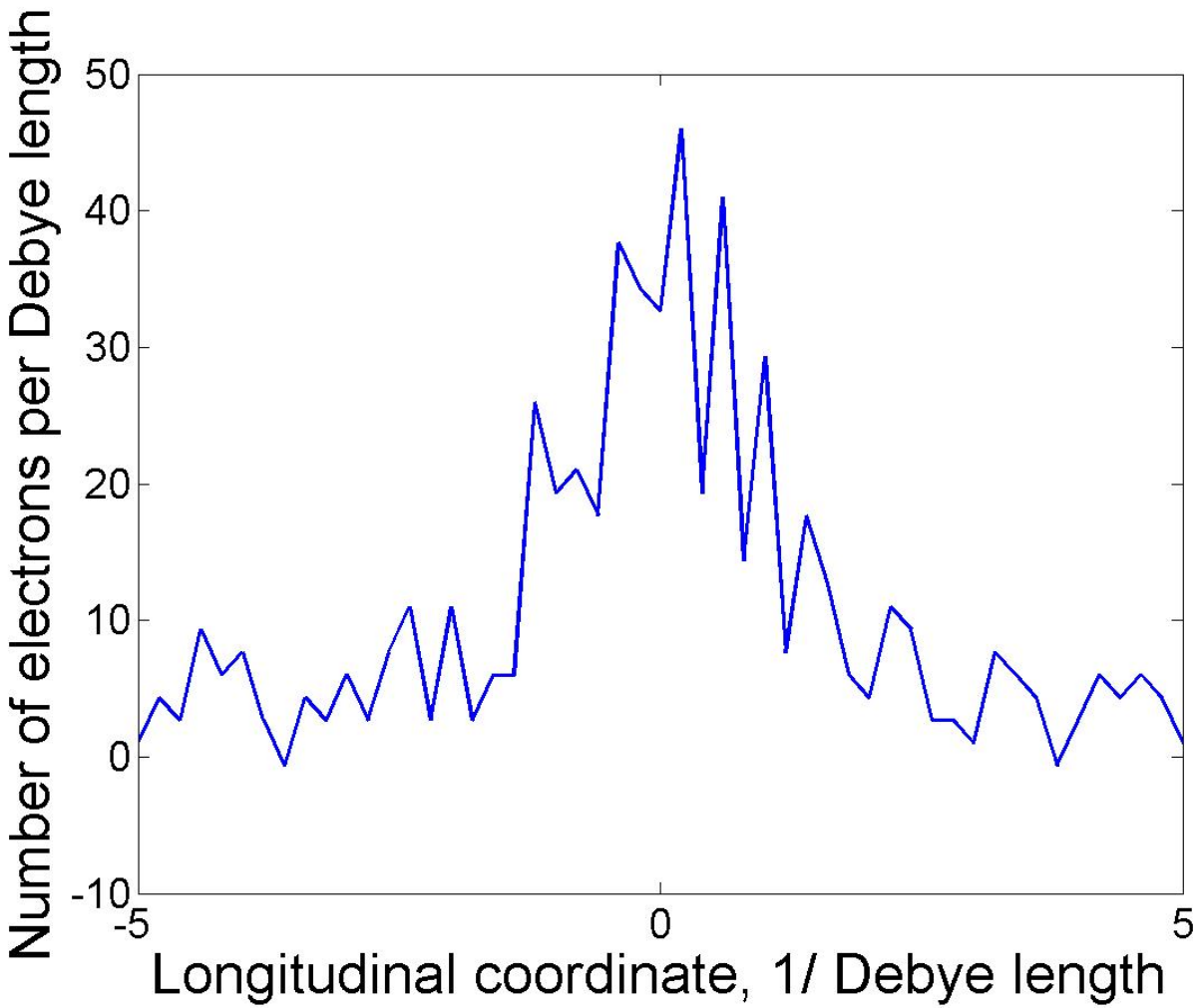


- β_x in theory is β_y in PIC simulation
- β_y in theory is β_x in PIC simulation
- $\vec{x} \times \vec{y} = -\vec{z}$ in theory
- $\vec{x} \times \vec{y} = \vec{z}$ in PIC simulation

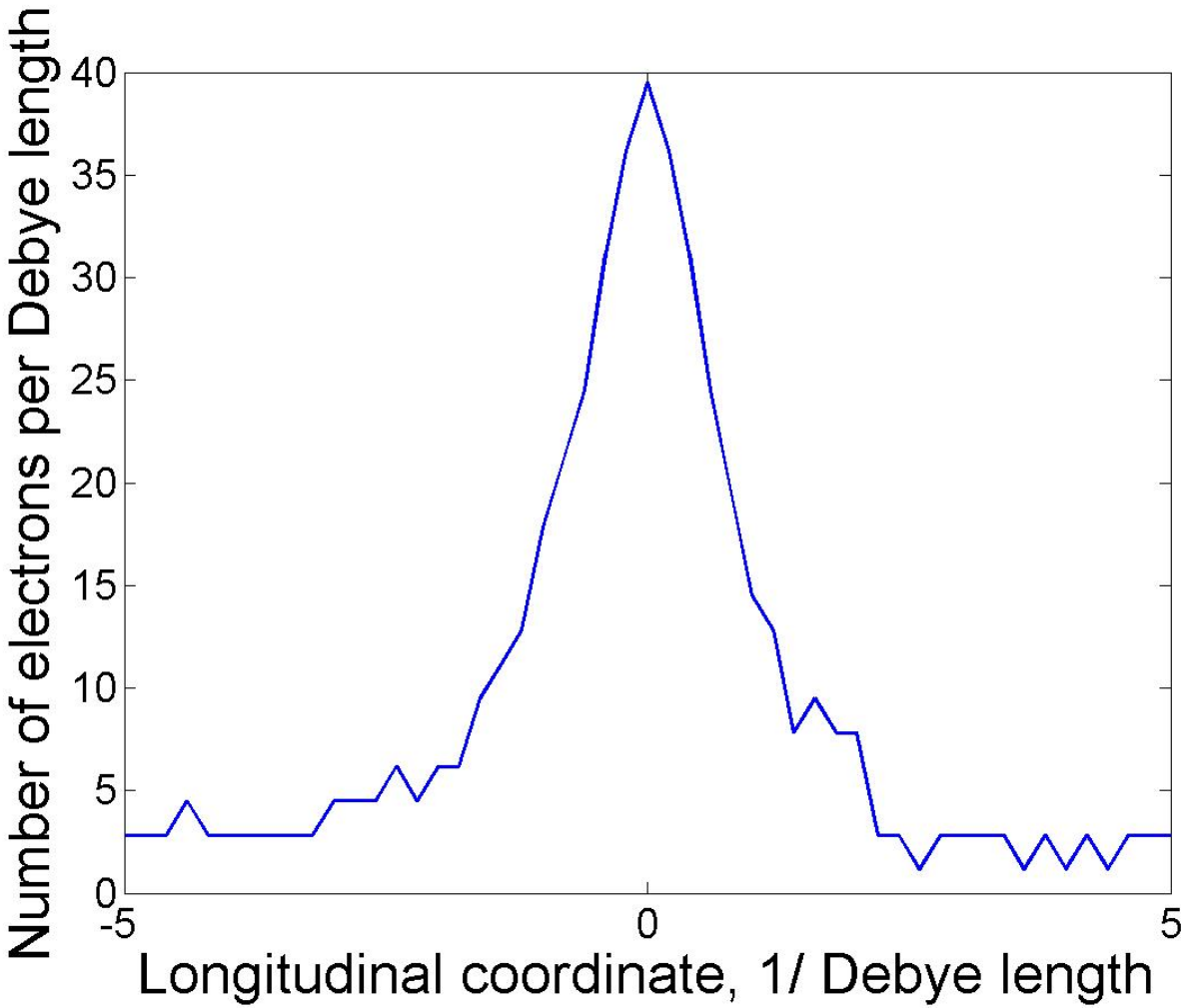
Setting

- 1 real ion
- Mesh refinement: 5, 20 grids / Debye Length
- Number of real particle : 1e+7
- Number of macro-particle : 1e+5, 1e+7
- Representing number : 1e+2, 1

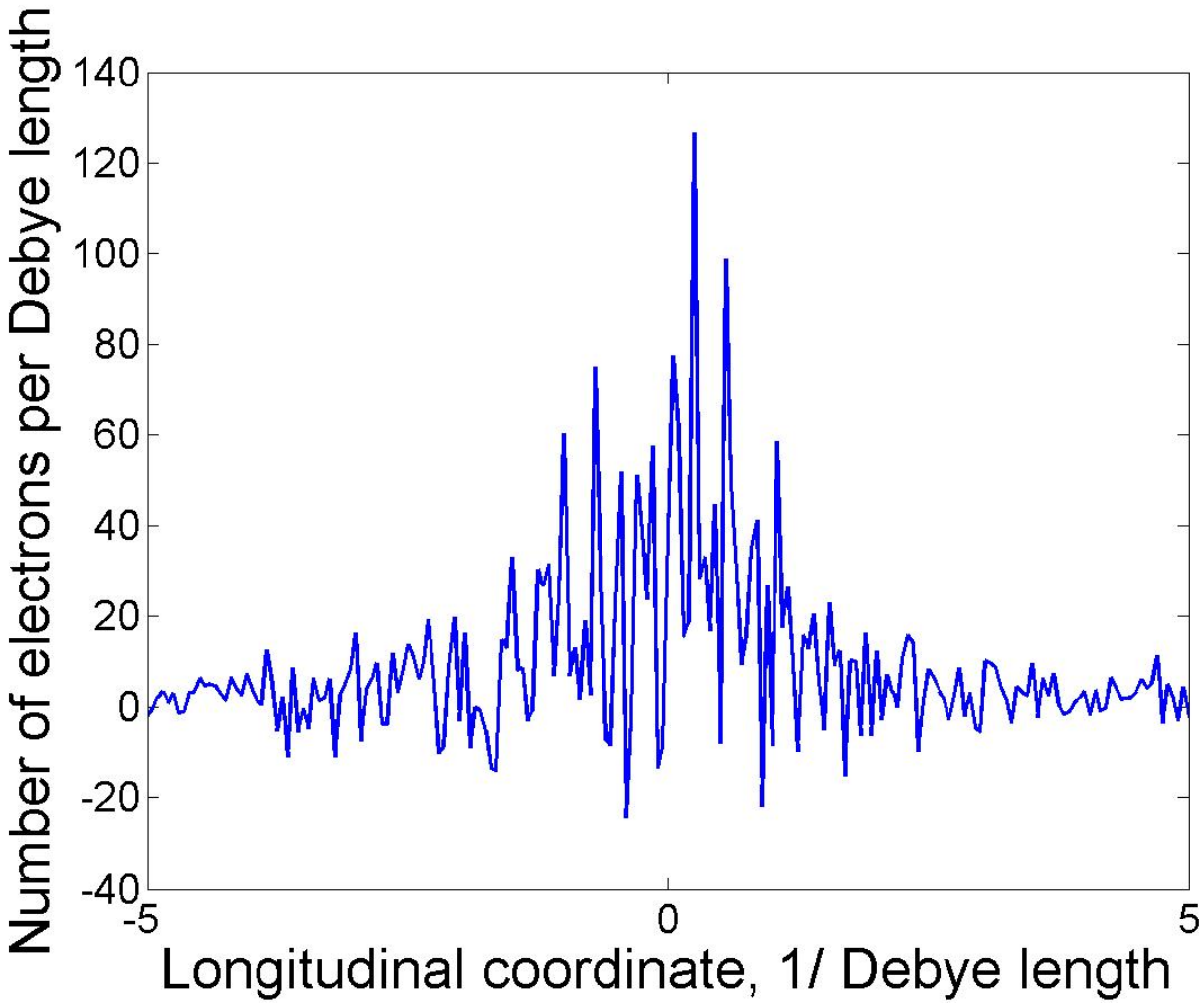
5 grids / Debye Length, rep=1e+2



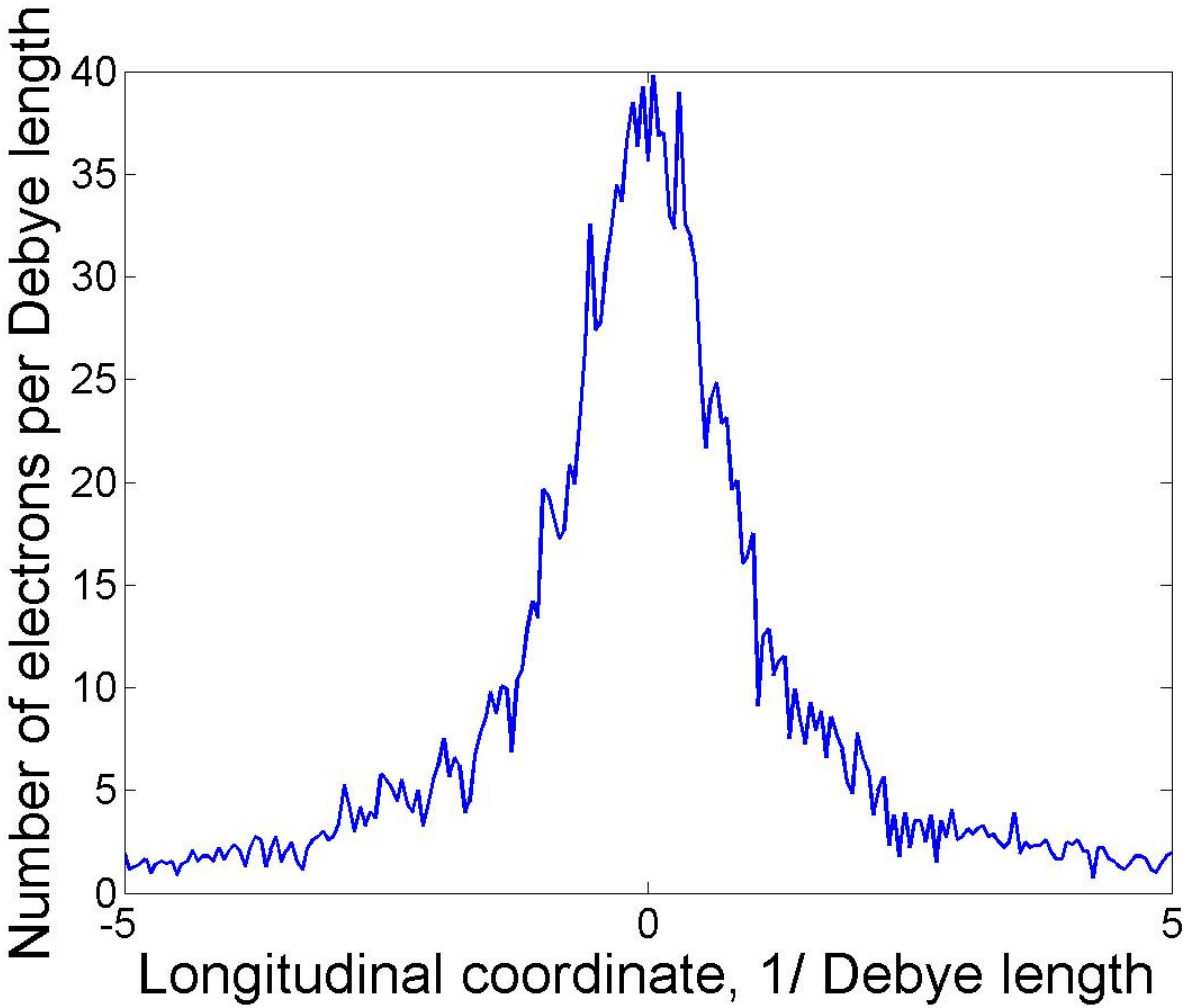
5 grids / Debye Length, rep=1



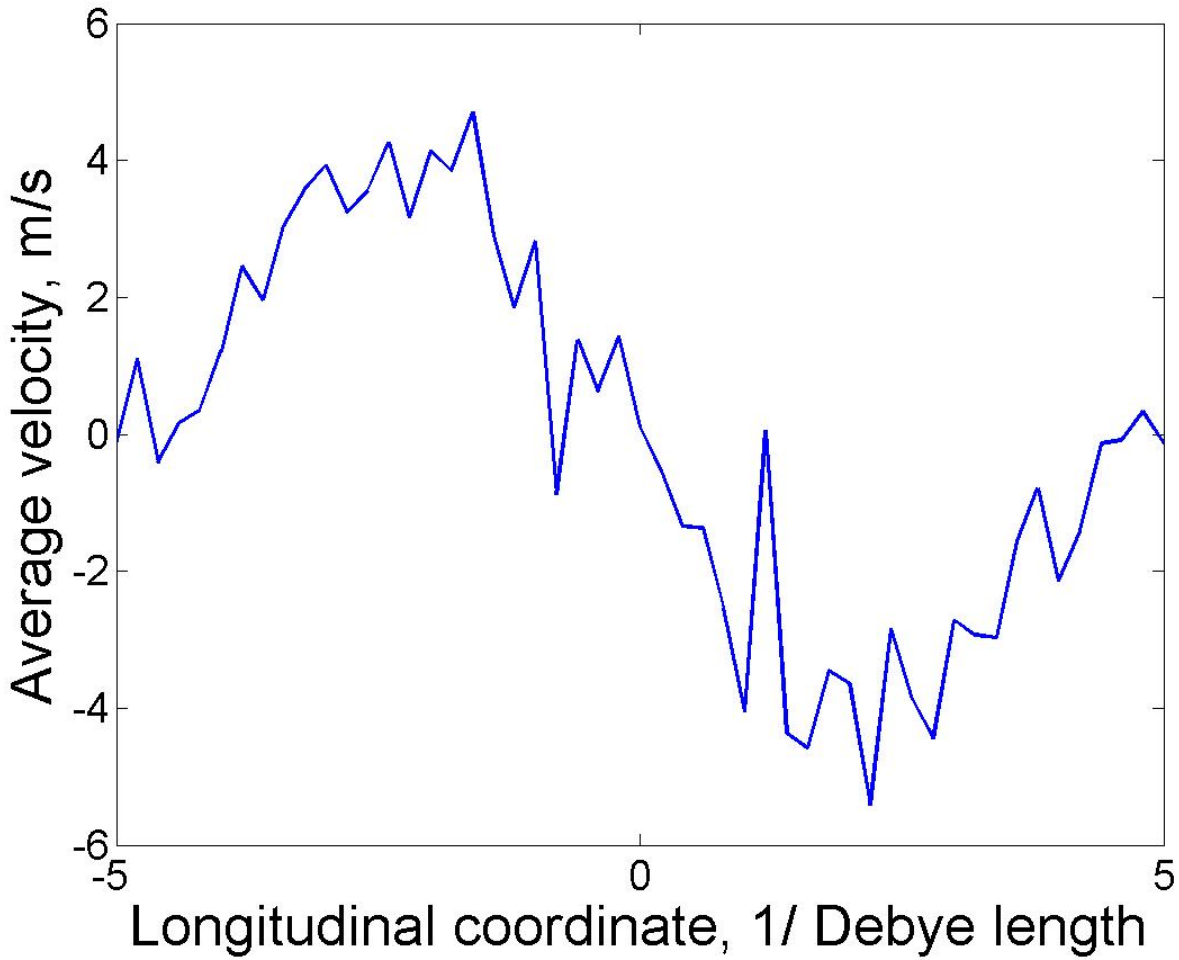
20 grids / Debye Length, rep=1e+2



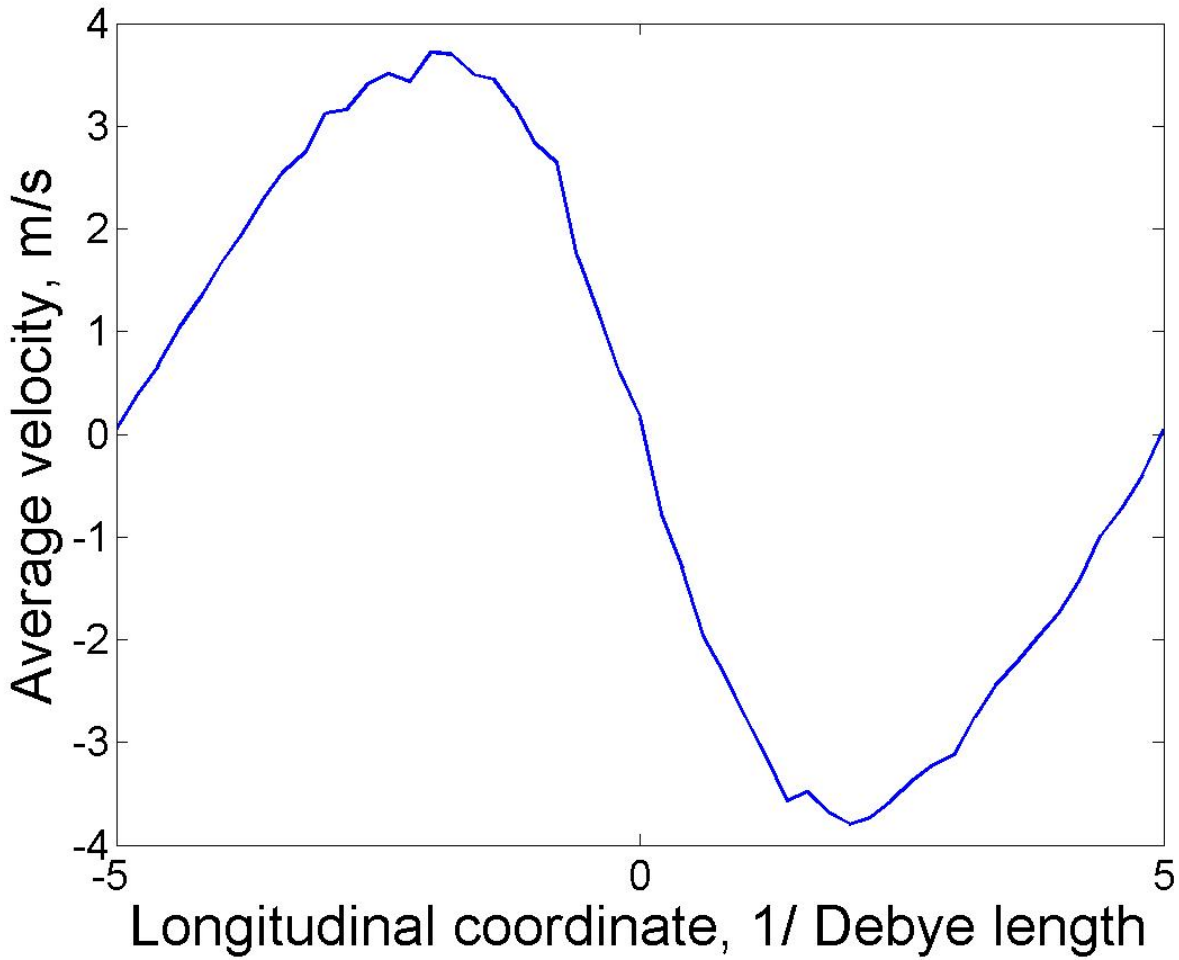
20 grids / Debye Length, rep=1



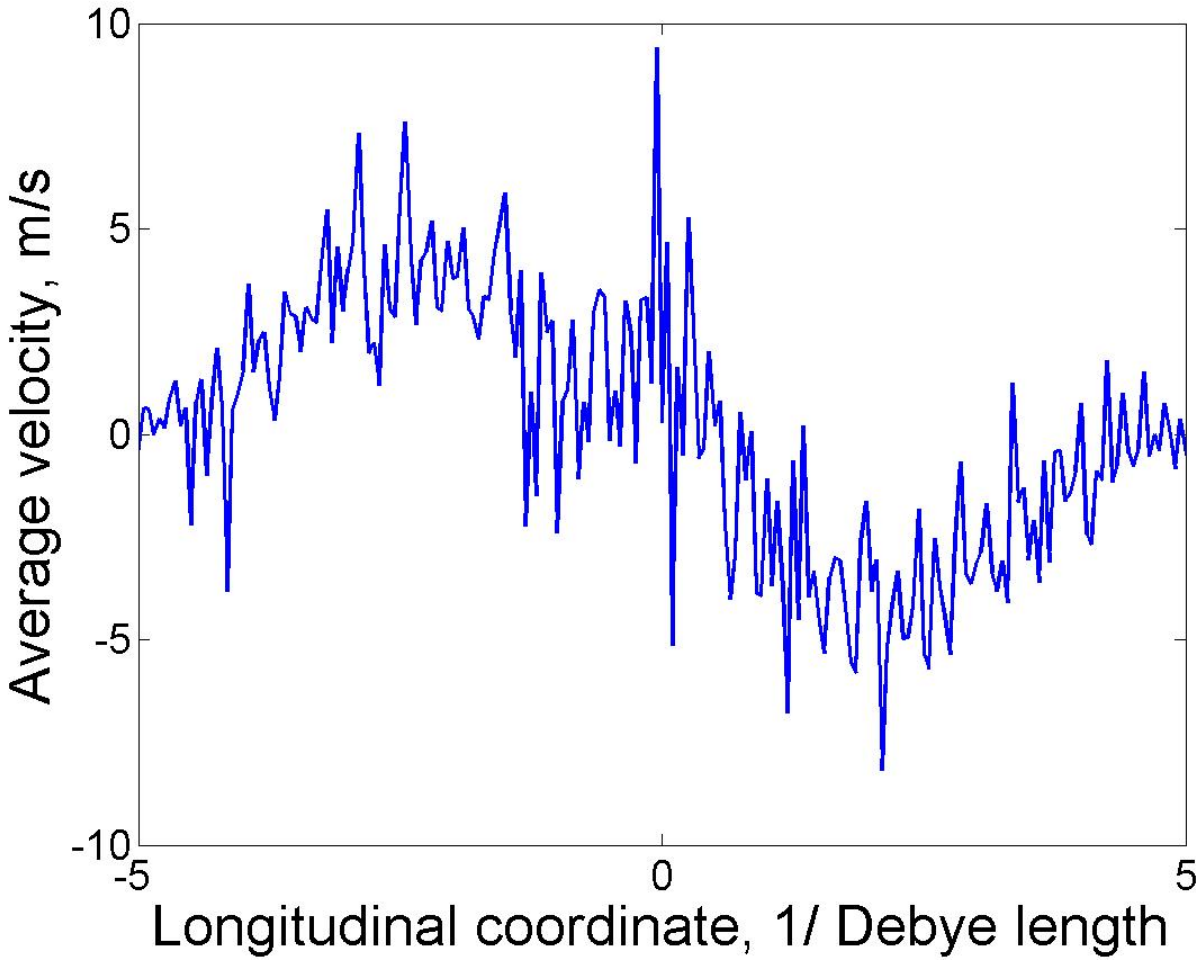
5 grids / Debye Length, rep=1e+2



5 grids / Debye Length, rep=1



20 grids / Debye Length, rep=1e+2



20 grids / Debye Length, rep=1