DESY/TEMF Meeting – Status 2012

PIC Simulation for the Electron Source of PITZ

DESY, Hamburg, 17.12.2012

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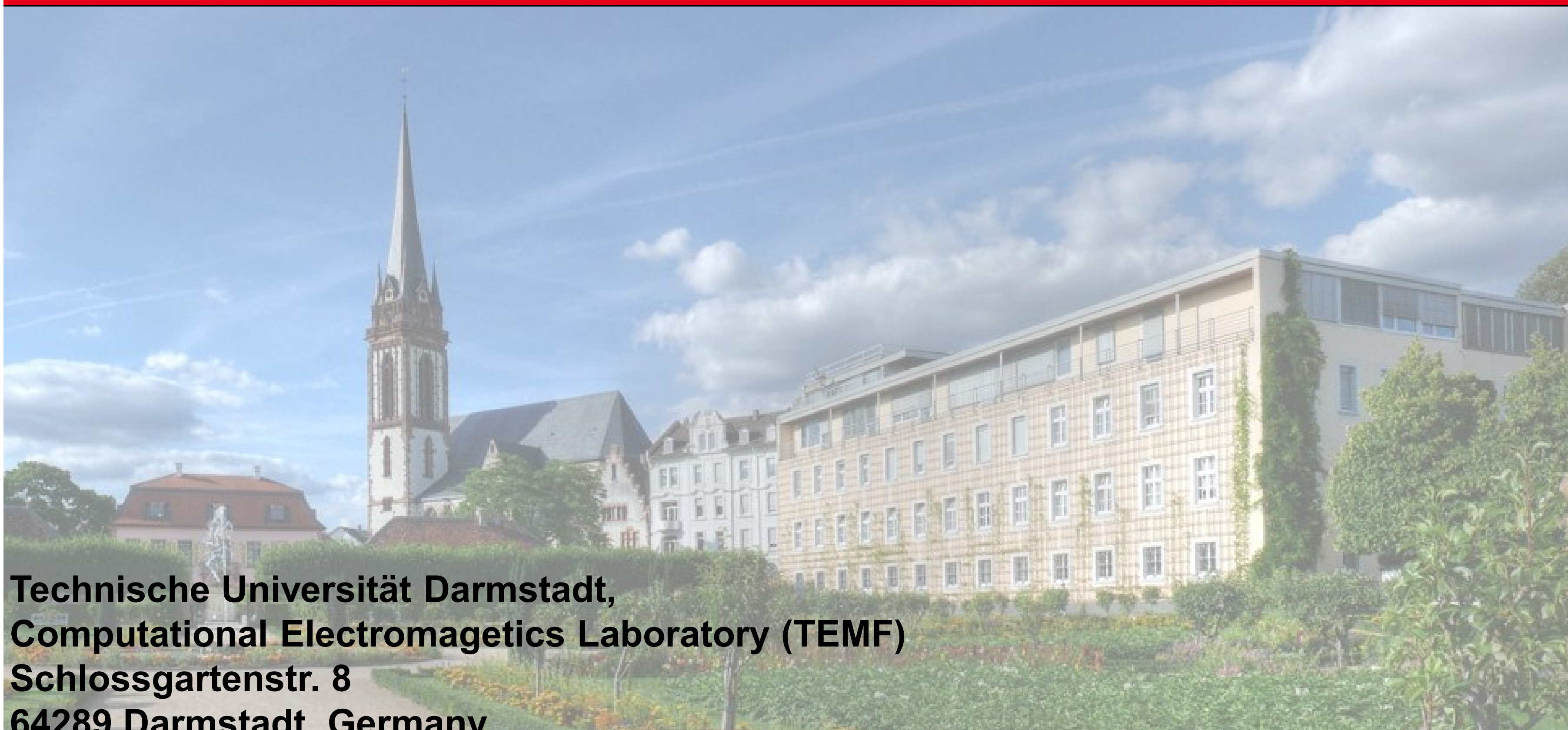

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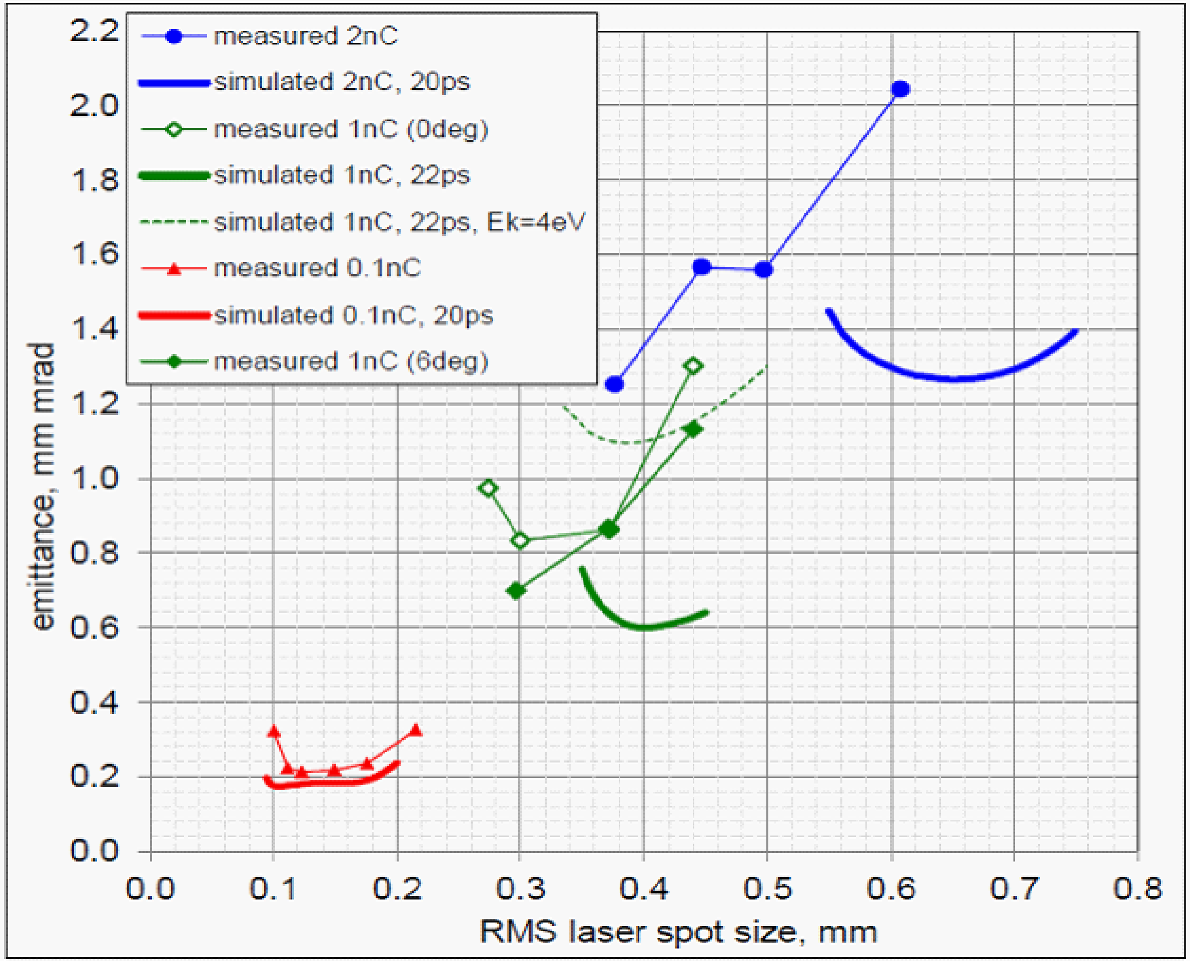
Motivation & Introduction



- Optimum machine parameters (laser spot size, gun phase): experiment ≠ simulations
- Difference in the optimum laser spot size is bigger for higher charges (good agreement for 100pC)
- Artificial increase of the thermal kinetic energy at the cathode (from 0.55eV to 4eV) did not improve the situation

talk from M. Krasilnikov,Zeuthen, 2011

Motivation & Introduction

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- Main procedures in CST

- Simulations for gun-cavity & solenoids (CST-MWS & EMS)
- Tune & Calibrate external fields referring to ASTRA import data
- PIC simulations at a short distance of (60~130) mm (CST-PS)
- Beam qualities comparison between PIC simulations and ASTRA
- Continue PIC simulations with finer grid resolutions ($\Delta x, \Delta y, \Delta z \ll 0.05$mm)
- Broaden the calculation domain as far as possible
- Check the results using different particle distributions
- Investigations with inhomogeneous particle distributions
- Investigate the influence of cathode (material, impurities …)
- Optimizations & Repeat simulations with refined parameters

Motivation & Introduction

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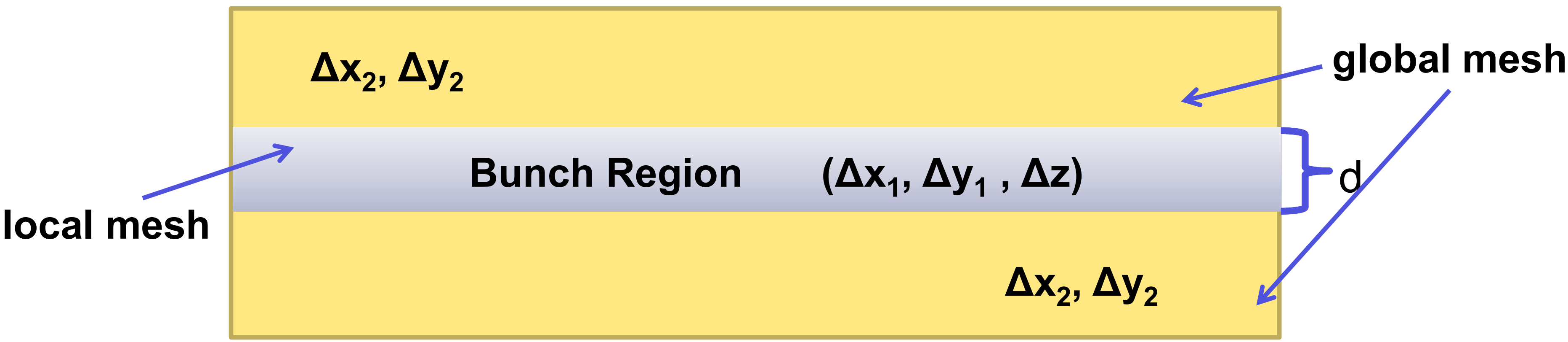
- Grid resolution demands for PIC simulations



Part of the calculation domain

- Δx_1& Δy_1 & Δz « 0.05 mm
- d = $2X_{rms}$
- Δx_2 & $\Delta y_2 \approx (2\sim3)\times 0.05$mm

- By properly choosing Δx_2 & Δy_2 outside the bunch region, there will be mesh-saving solutions to broaden the calculation domain in PIC simulations as far as possible.

3D CST Simulation-Field Simulation

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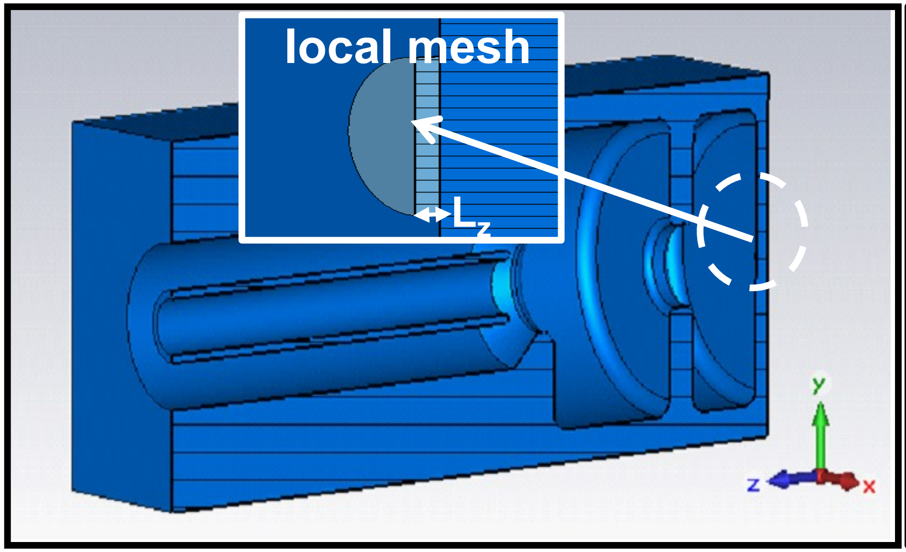
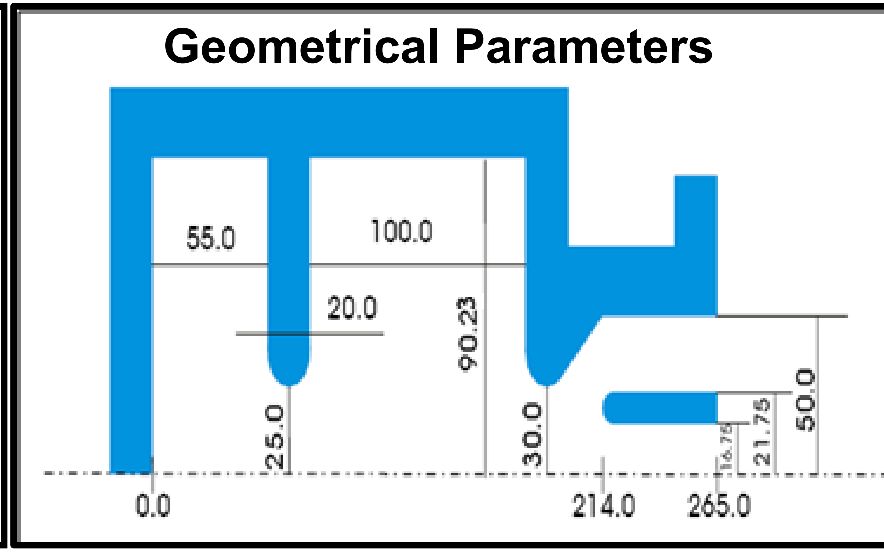
- Setup 1 for Gun-Cavity Simulation (CST-MWS)





Local mesh properties

- A cylinder, not included in the simulation, only for mesh refinement at the cathode.
- $L_z = \Delta z$ (mesh resolution in z, 0.01mm-0.05mm).
- Δx & Δy should be comparable with Δz (0.01mm-0.05mm).

To obtain the field ratio we need, the radius of half cell was tuned by ~70μm

Field Simulation

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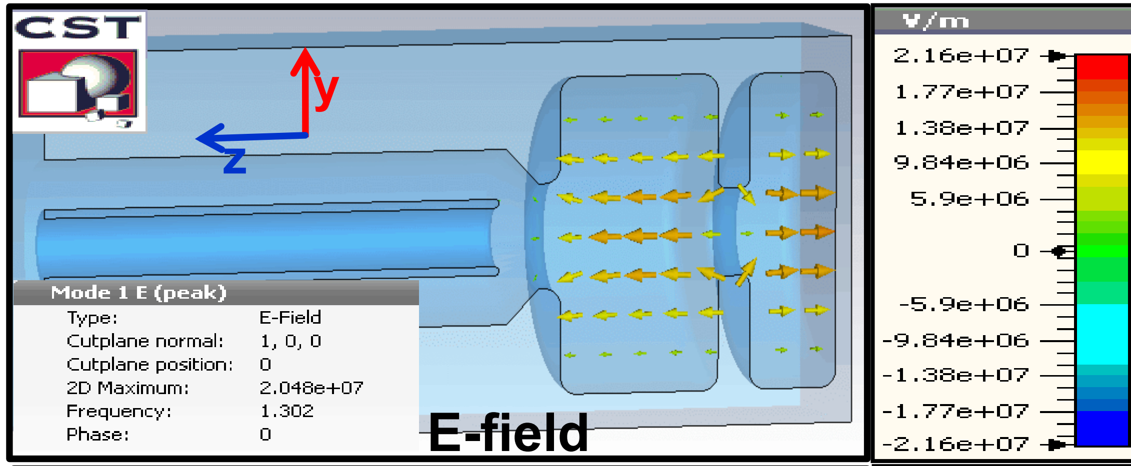
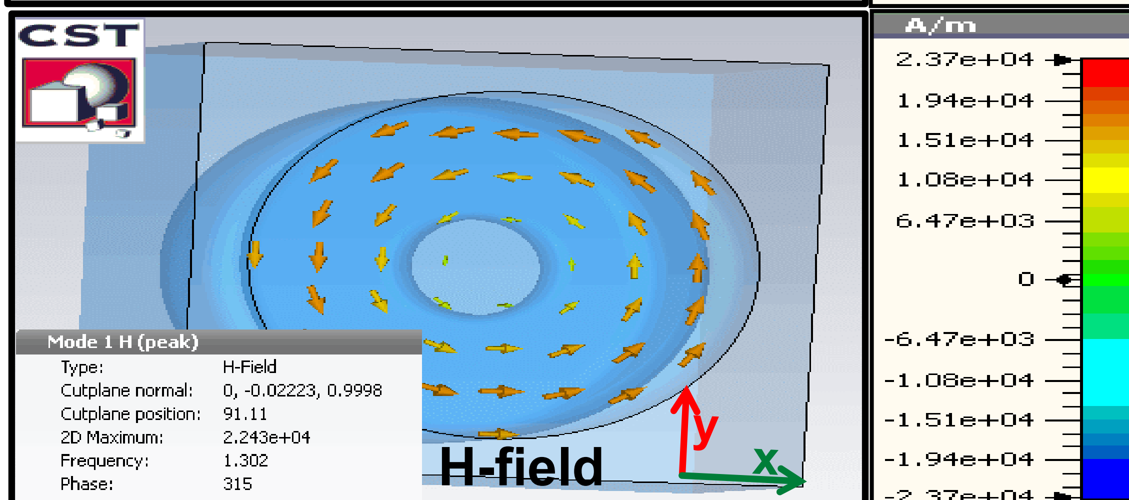
- Gun-Cavity Simulation Results

Parameters	Values
[redacted]	
Accuracy	1e-6
[redacted]	
Lines/wavelength	120
[redacted]	
Mesh resolution	0.125mm
[redacted]	
Duration	60h
[redacted]	
Frequency separation	3.6MHz
[redacted]	
Frequency	~1.301GHz





Field Simulation

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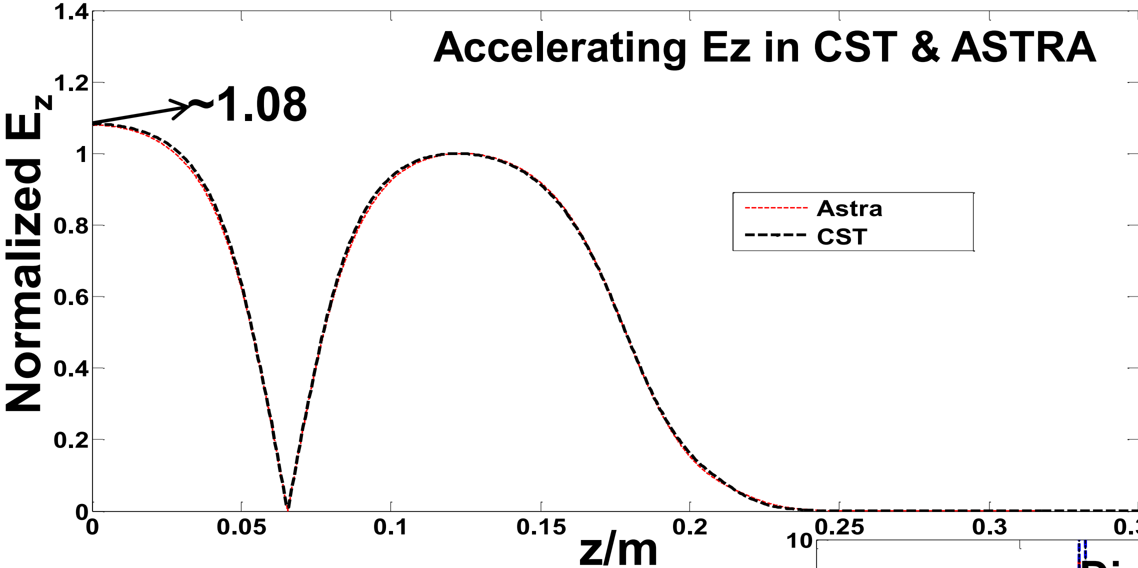
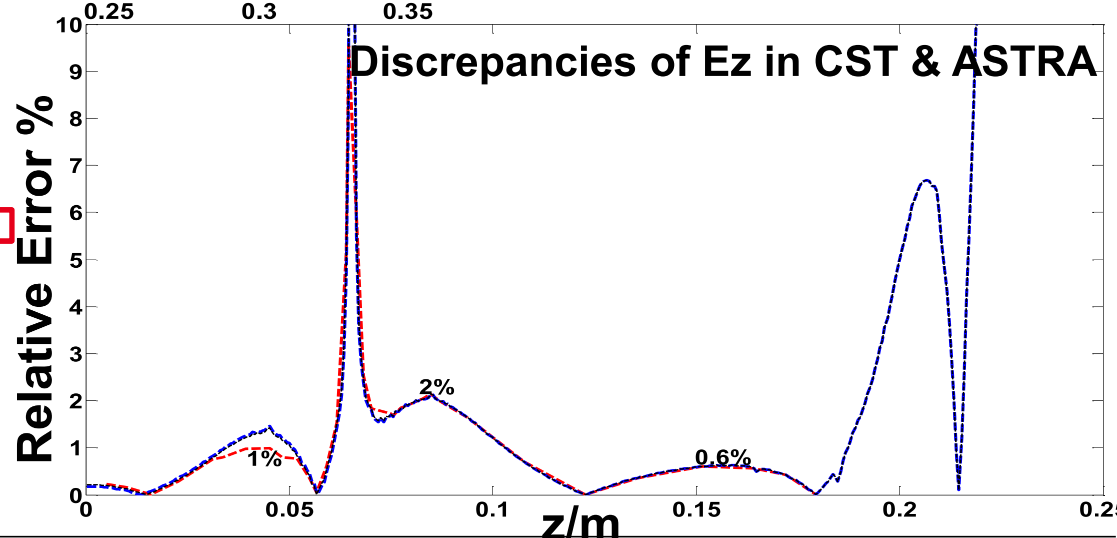


- (0-55) mm, RE ≤ 1%
- (55-75) mm, A approaches to 0
- (75-105) mm, RE≤ 2%
- (105-185) mm, RE ≤ 0.6%

Relative **E**rror %=

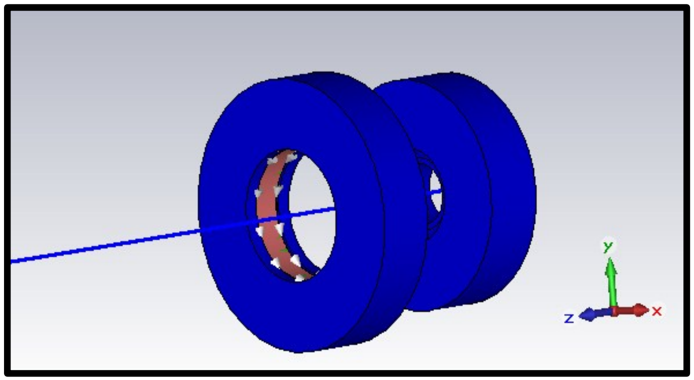
Abs[A_{cst}-A_{astra}]/A_{astra}*100%

A: Amplitude of E_z

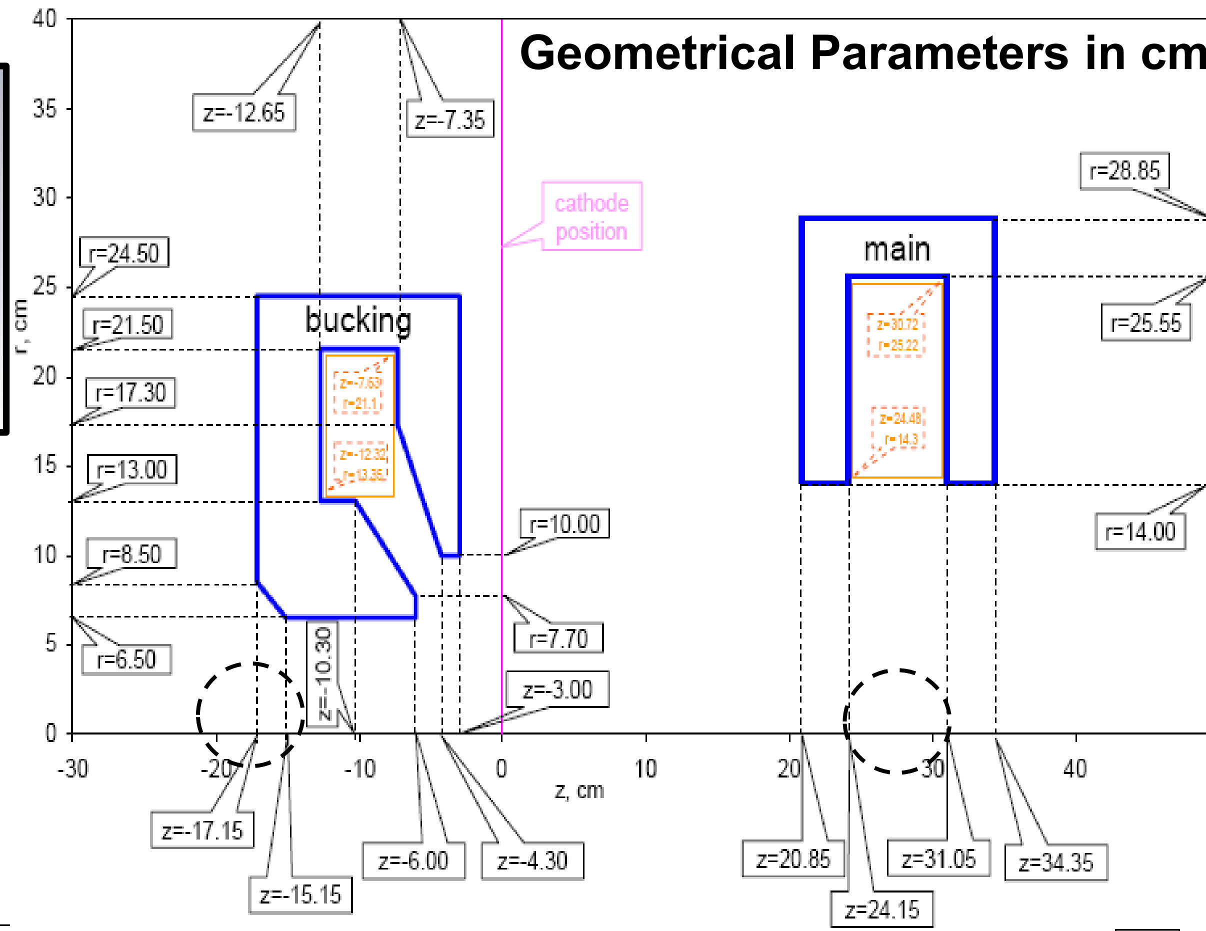


Field Simulation

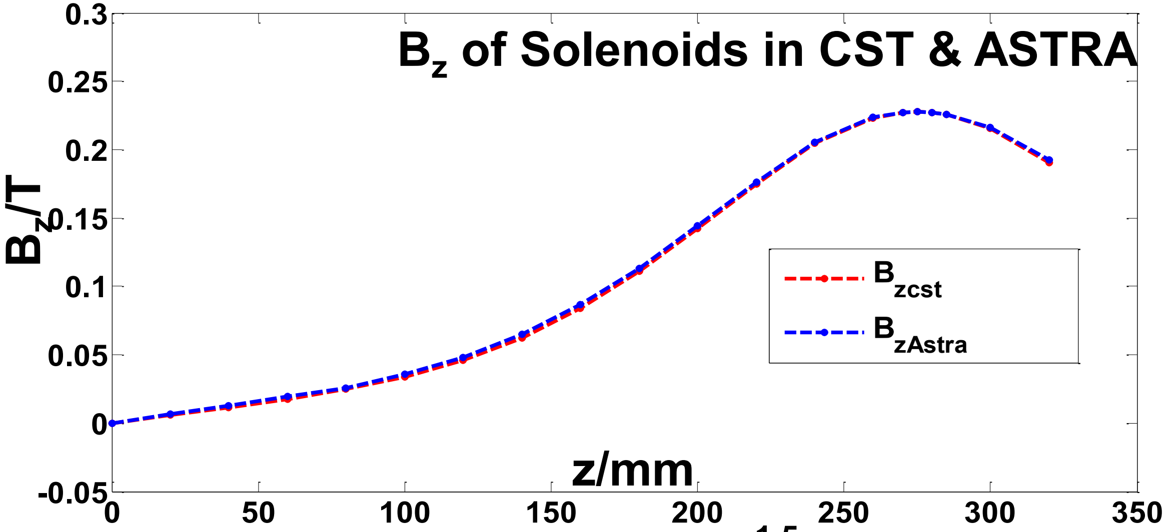
- Setup 2 for Solenoids Simulation (CST-EMS)



Pos. of Main	276 mm
[redacted]	
Cur. of Buck	~-31 A

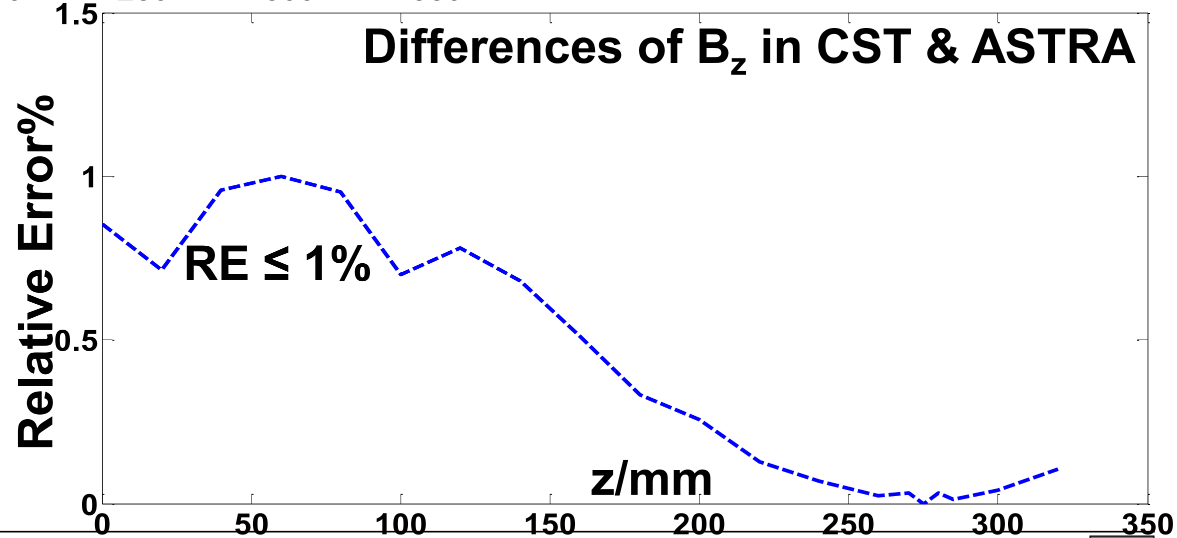


Field Simulation



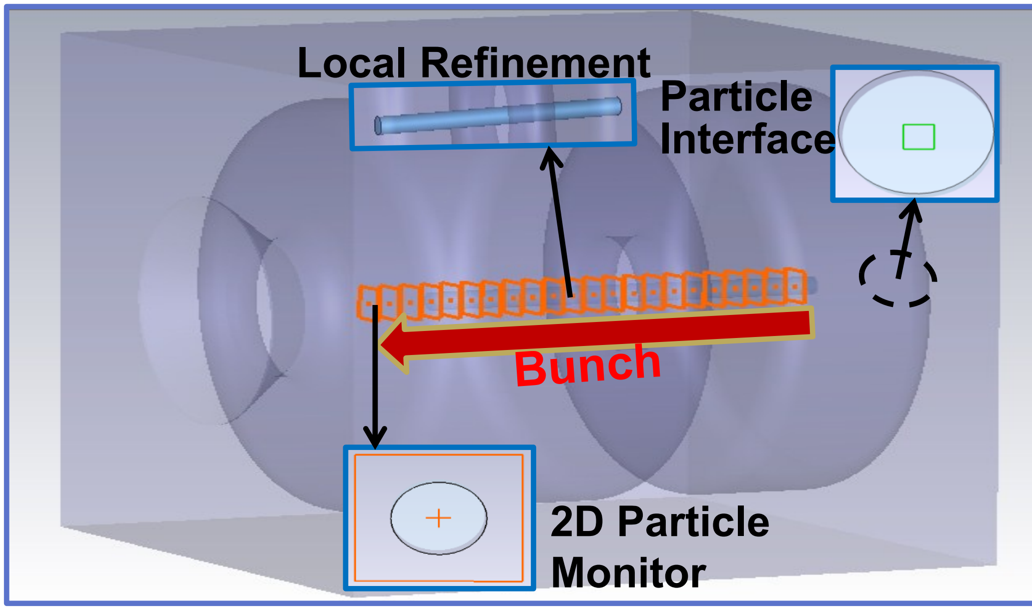
B_{zmax}=0.2279T

B_{z0}~10^{-7}T



PIC Simulation

- Setup 3 for PIC Simulation (CST-PS)



Bunch parameters & External fields data

Parameters	ASTRA	CST
[redacted]		
Bunch radius	0.4mm	0.4mm
[redacted]		
Bunch length	21.5ps	21.5ps
[redacted]		
Macro Nos.	500k	500k
[redacted]		
E_z at cathode	60.58MV/m	60.58MV/m
[redacted]		
B_{zmax}	0.2279T	0.2279T
[redacted]		
Ez profile	Δ=1%~2%	
[redacted]		

- Simulation time: ≤700ps so far
- Mini. mesh step=(0.12~0.07) mm so far
- Lines/λ=100~120, meshcells≥115Million
- 1-PIC Position Monitor
- 18-2D Particle Monitors along the beam line from 6mm to 132mm so far

PIC Simulation

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- ASTRA Particle Import

Particles
$z=0,\ t\epsilon(t_0,t_1)$

Astra2Cst

Particles
$t=0,\ z\epsilon(z_0,z_1)$

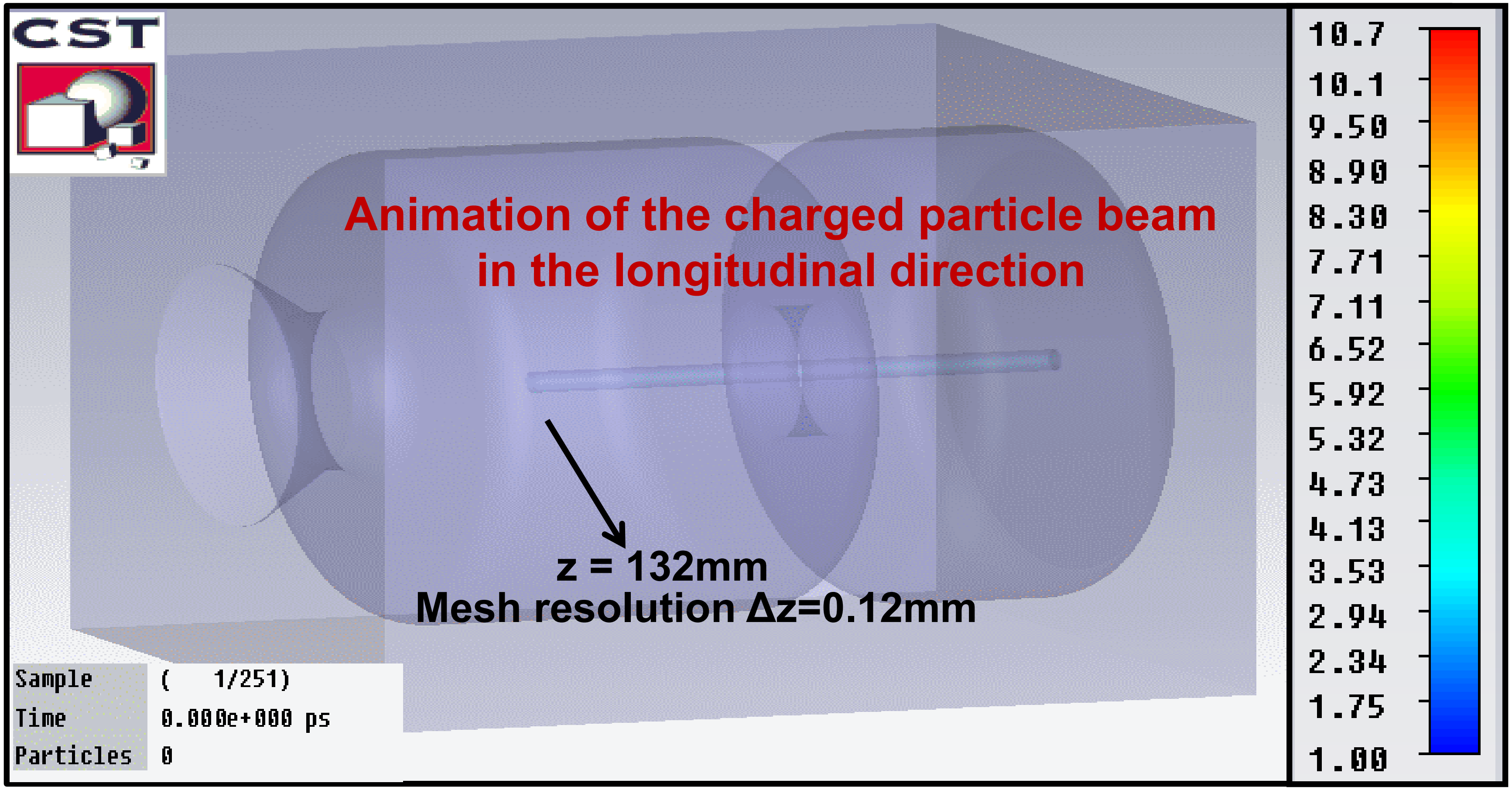
Particle Interface
(CST-PS)

Input Data for ASTRA:

Lt=21.5E-3	Species='electrons'
rt=2E-3	Dist_z='p'
LE=0.00055	Dist_pz='i'
sig_x=sig_y=0.4	Dist_y=Dist_x='r'
Q =1	Dist_px=Dist_py='r'
Ipart=500,000	Ref_zpos=0.0

PIC Simulation

- Preliminary results



PIC Simulation

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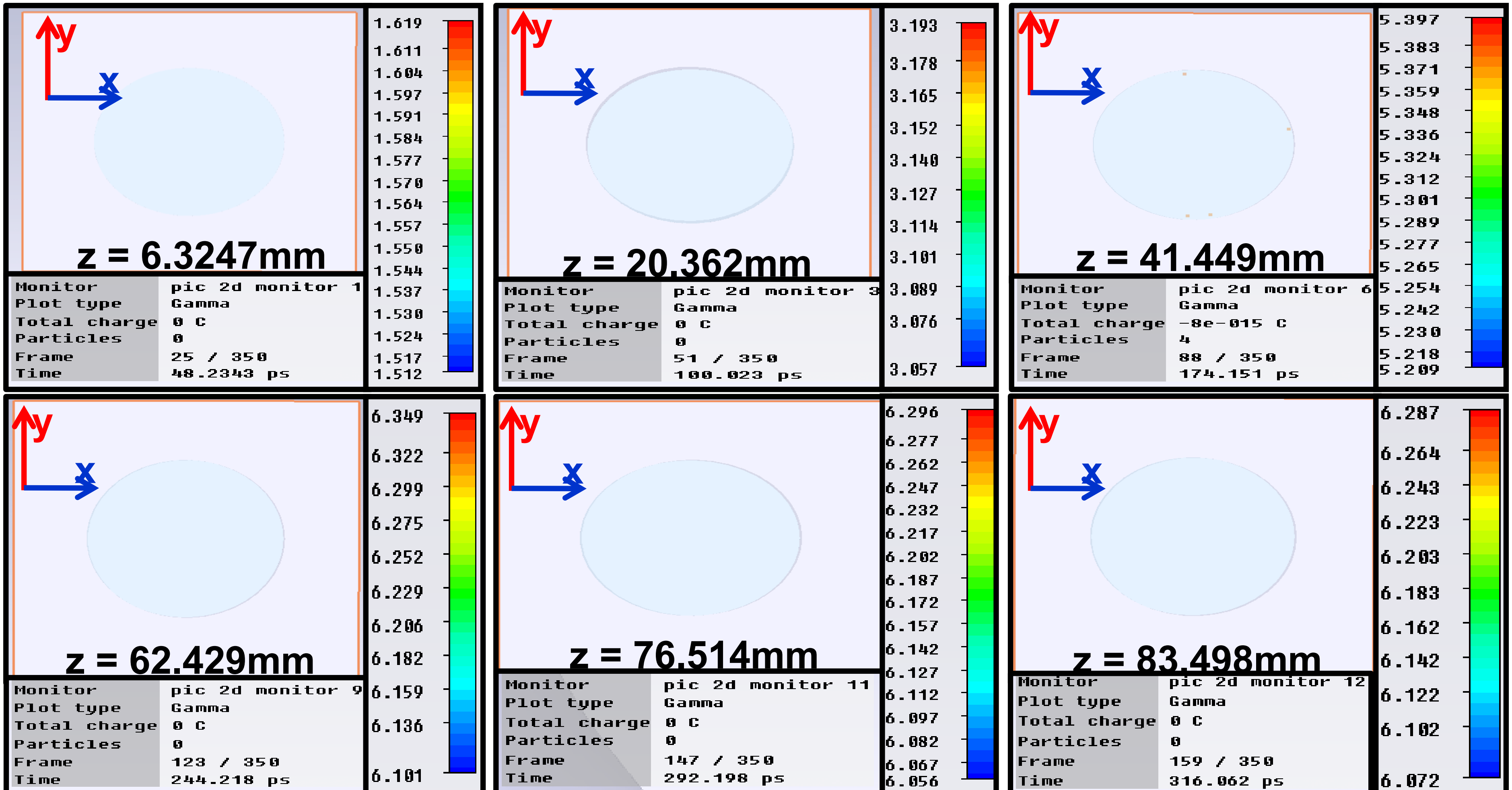
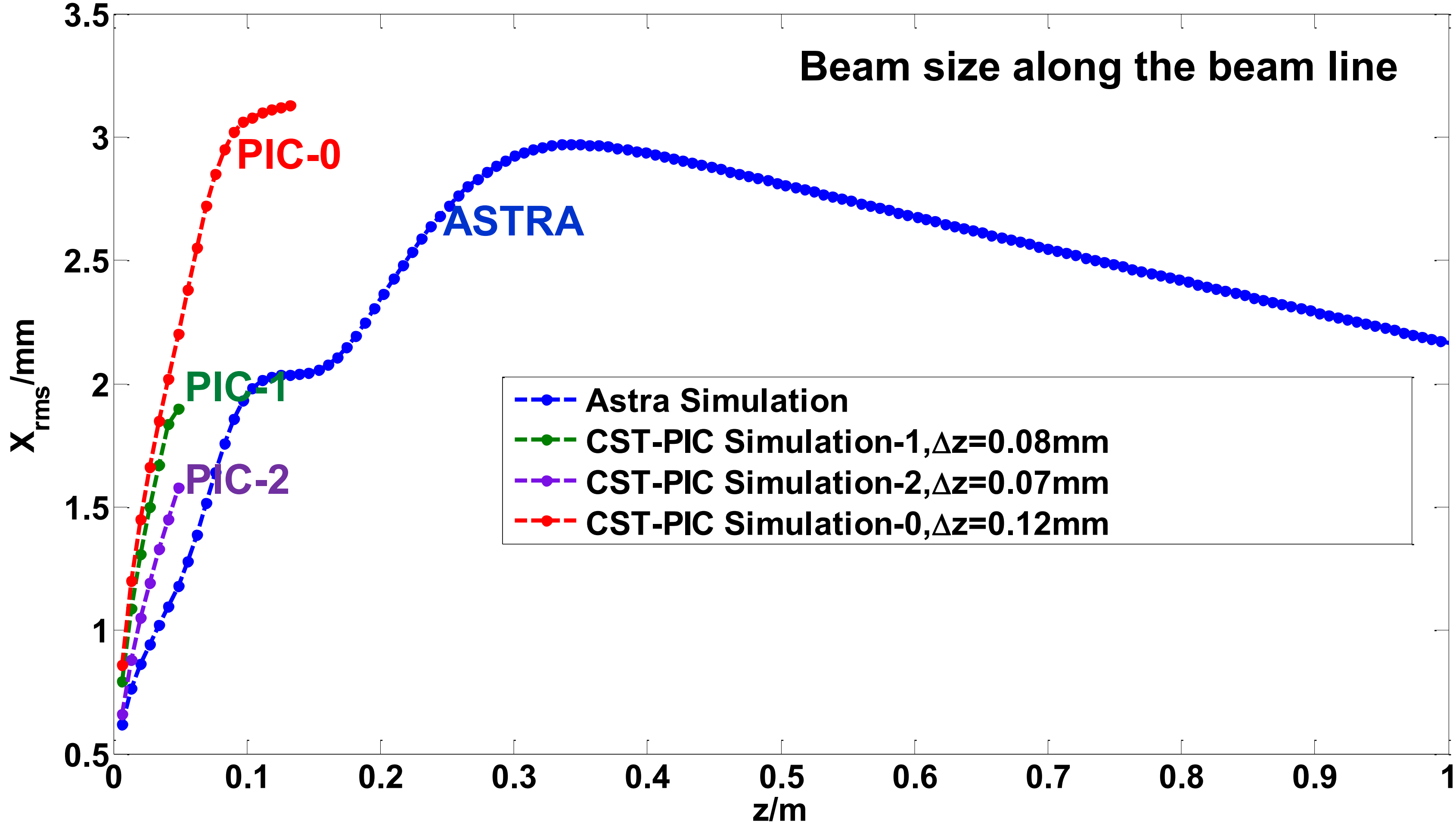
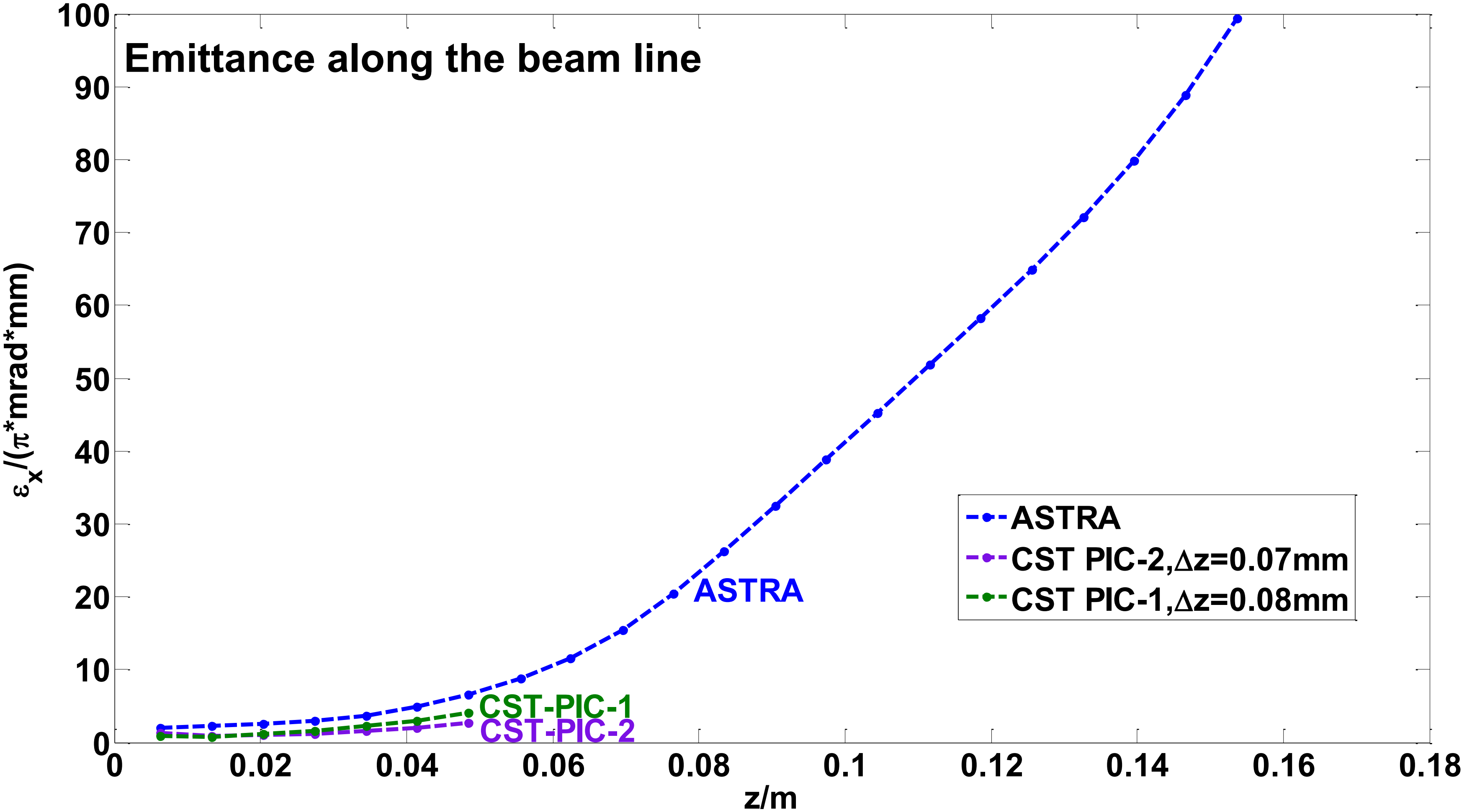
Animation of the transverse particle distributions



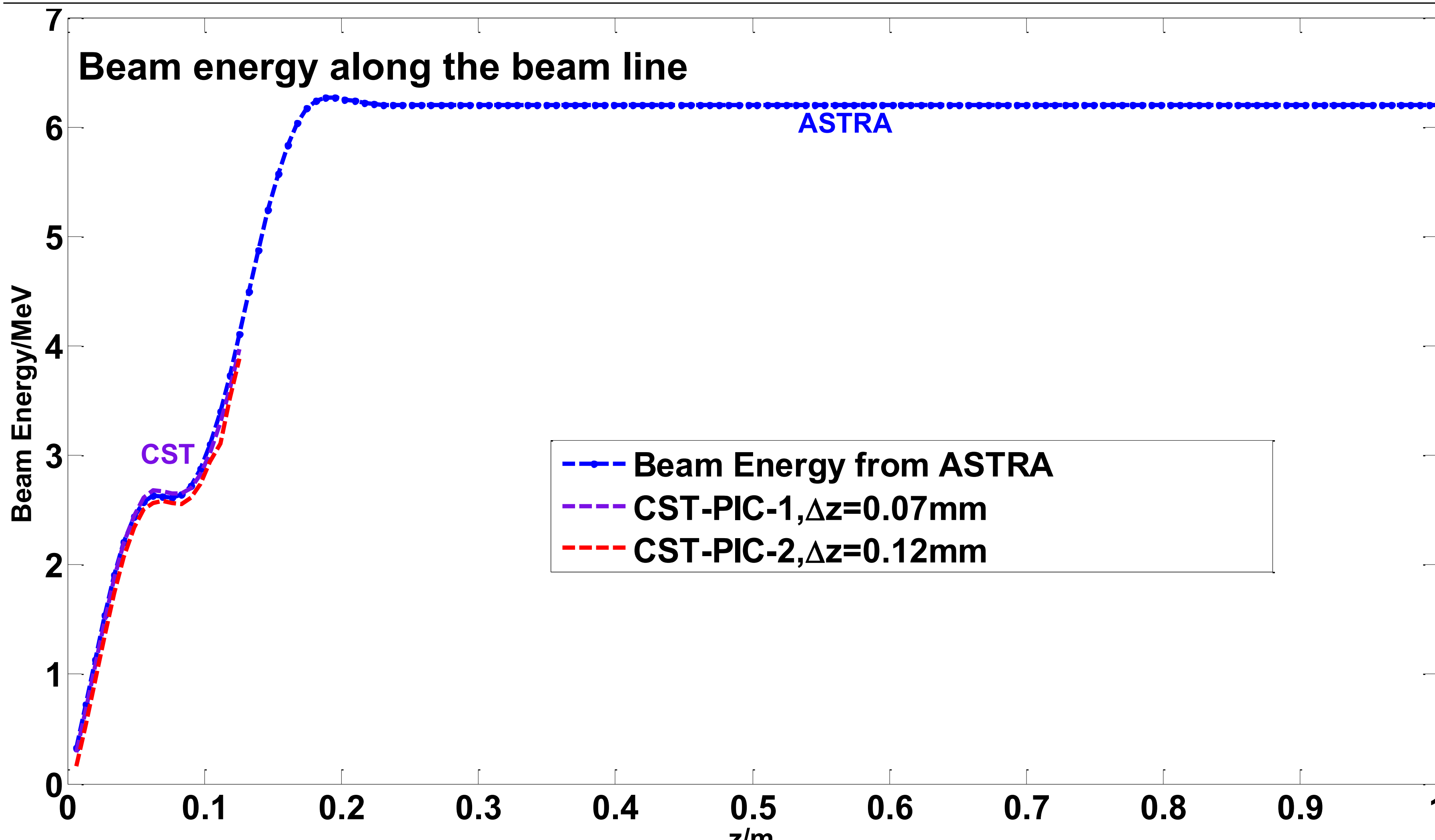
PIC Simulation



PIC Simulation



PIC Simulation



Discussions

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- Interpolation in PEC

- **Cause**

  Difference of the grid resolution around the cathode between field simulation & PIC simulation.

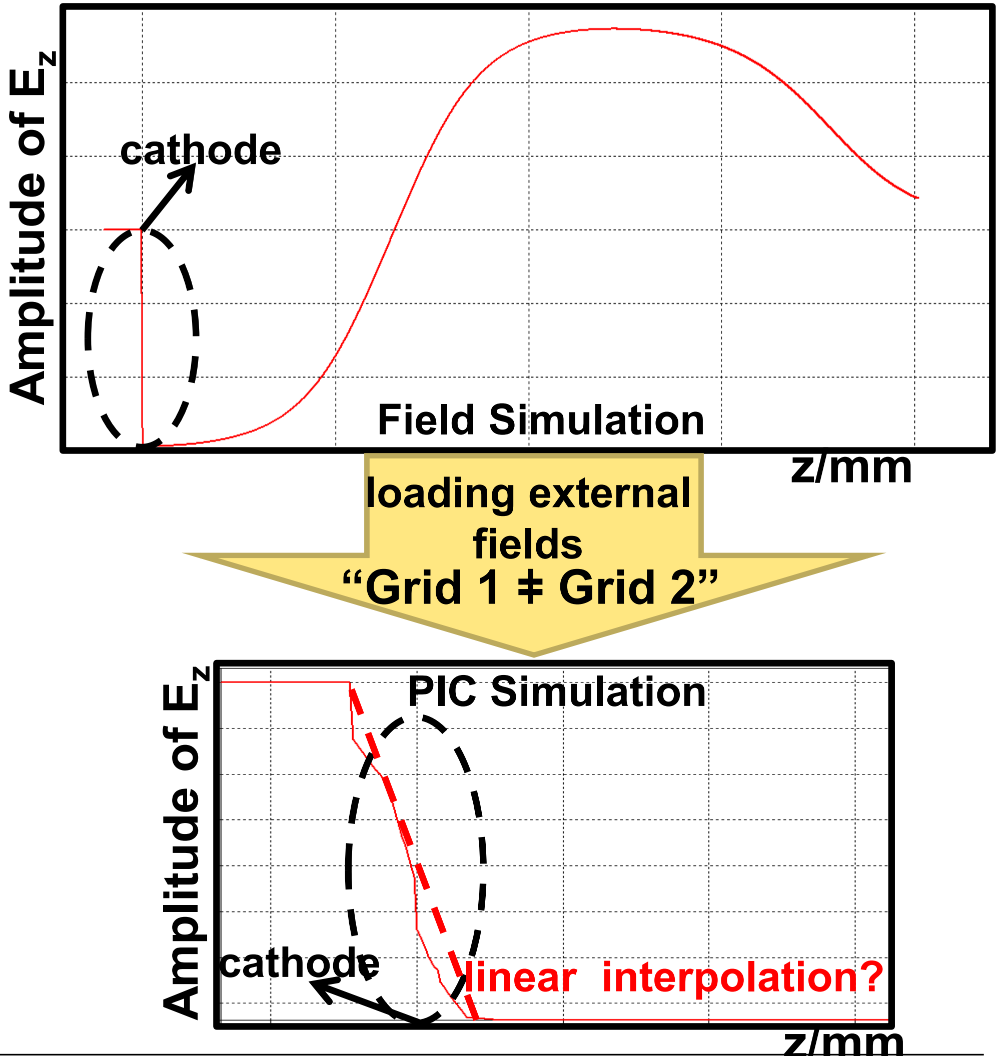
- **Outcome**

  E_z at the cathode was changed by automatic interpolation.

- **Solutions**

  -Keep the grid settings exactly the same around the cathode. But the field simulations turn to be much slower because of the very small grid.

  -Make the interpolation take place inside the cathode by shifting the back plane. But it will somehow change the eigenmode a little bit.



Summary & Further Steps

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- Summary

- PIC Simulation results at a short distance of 60mm downstream from the cathode showed possibilities of convergence to ASTRA simulation in terms of the beam radius by use of a finer mesh resolution (Q=1nC, grid resolution $\Delta z \approx 0.07$mm so far). But the current resolution is still not enough.
- Still no good agreement with ASTRA on the beam emittance at a short distance of 60mm by improving the grid resolution.
- Eigenmode convergence when setting local resolution as $(\Delta x, \Delta y, \Delta z) < 0.05$mm is relatively very slow.

- Steps in the near future

- Continue PIC simulations by enhancing the grid resolutions.
- Broaden the calculation domain as far as possible (60mm~200mm, Δx, Δy, $\Delta z \ll 0.05$mm).
- Check the simulations with different particle distributions(r=0.3mm).
- Investigate the cases with inhomogeneous particle distributions at the cathode.

Thank you for your attention!