Beam dynamics study of RF and solenoid fields for PITZ gun without space charge (update)

- Introduction
- Magnification factor analysis with grid image
- Rotation angle analysis
- Summary

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11/19/2015

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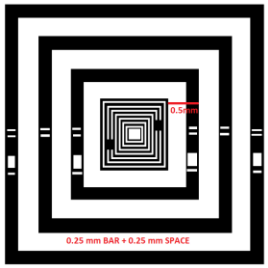
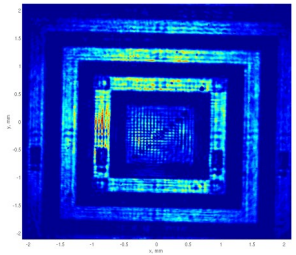
DESY

Introduction

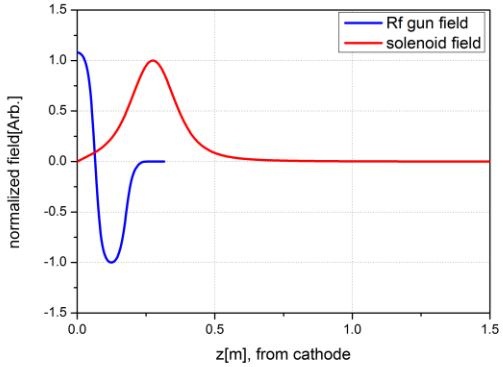
- Motivation: Beam dynamics study of PITZ gun without space charge by experiment and simulation.
- Methods:
  - Experiment: Shape laser by grid, with low bunch charge ~30 pC. By adjusting the solenoid current to get clear beam grid pictures on Low. Scr.1&2&3.





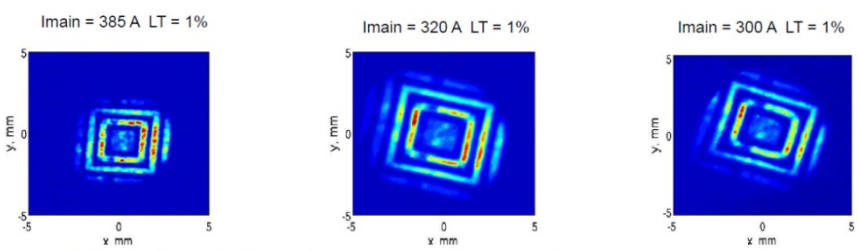
Laser grid on VC2

  - Simulation: RF and solenoid peak fields used in ASTRA simulation are from experiment.

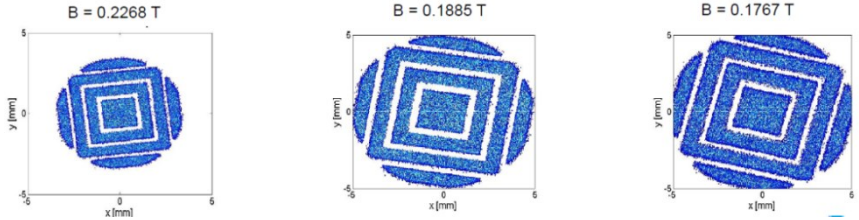


$B_{z,main}$[T]=5.889×10⁻⁴∗I_{main}[A]+7.102 ×10⁻⁵

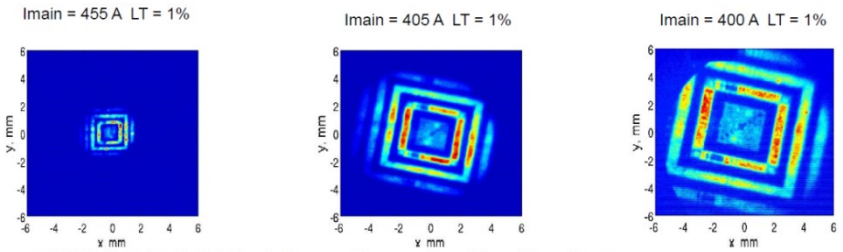
EXPERIMENT P_{gun}=3MW, Ep= 42.2MV/m



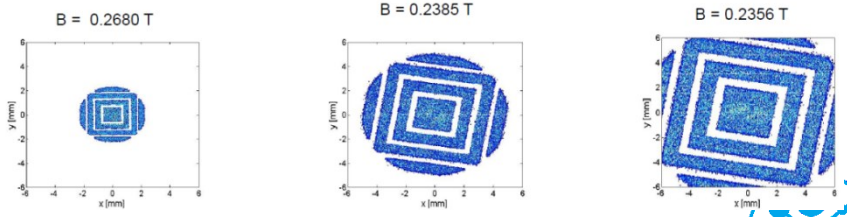
SIMULATION (ASTRA: A Space Charge Tracking Algorithm)



EXPERIMENT P_{gun}=5MW, Ep= 53.75 MV/m



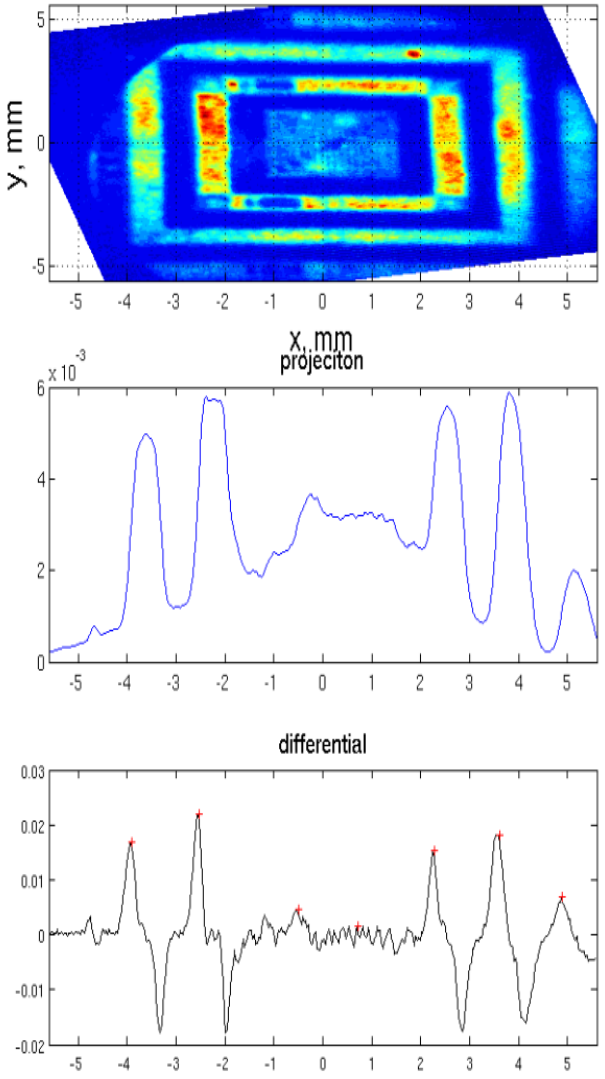
SIMULATION (ASTRA: A Space Charge Tracking Algorithm)



Magnification factor analysis method

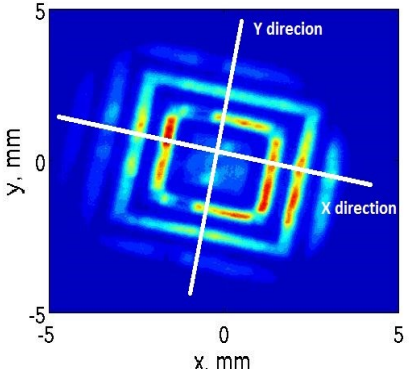
- Rotation of the image.
- Projection of the image in x-axes.
- Calculation of the differential of projection.
- Computation of the magnification factor with the grid edge to edge distance.

$$MF = \frac{Calculated\ distance}{Real\ distance}$$

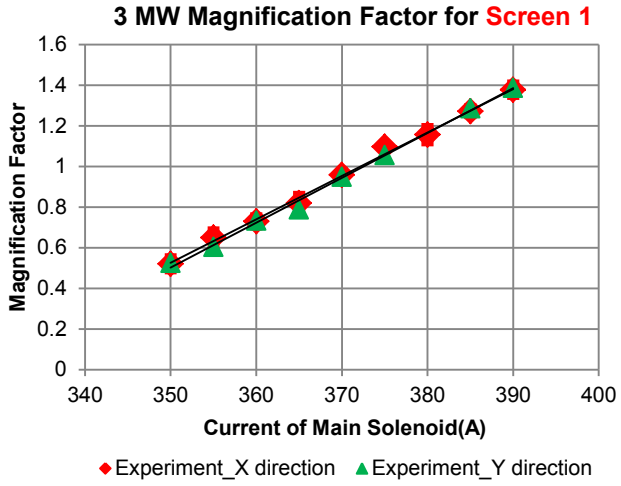


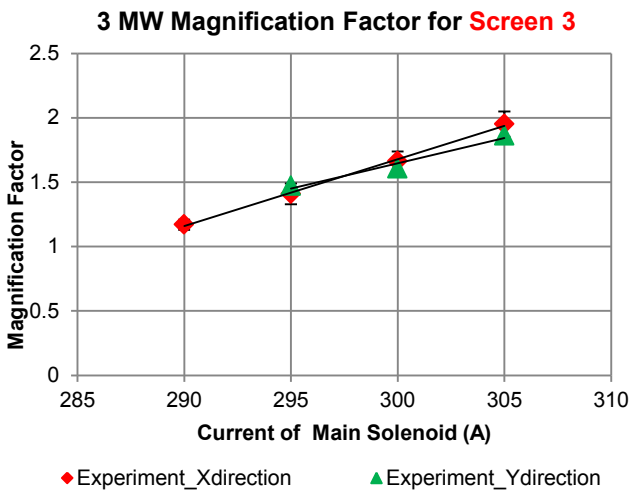
Magnification factor for two directions

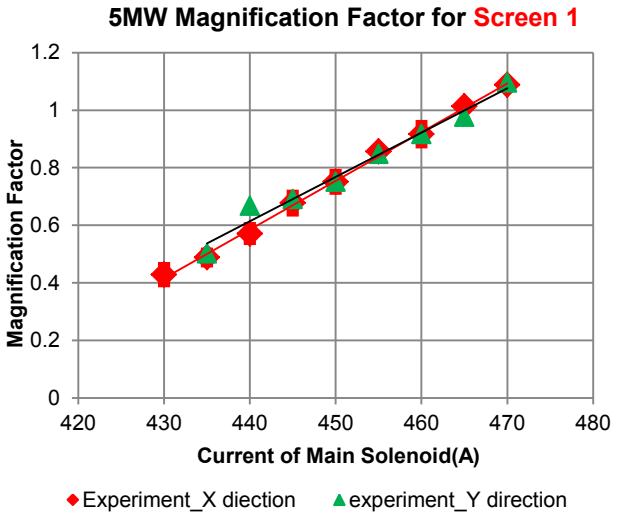
3 MW

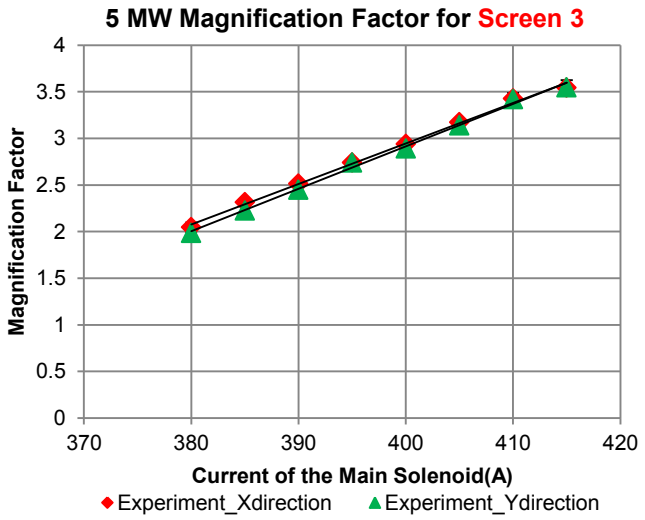


5 MW



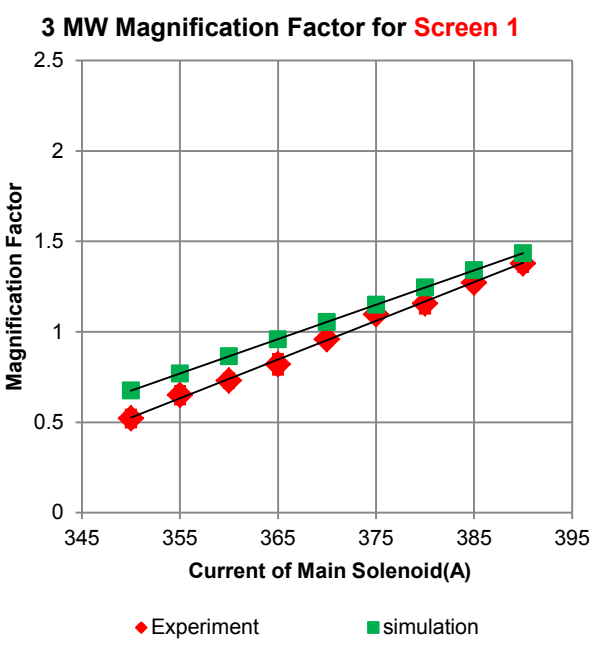


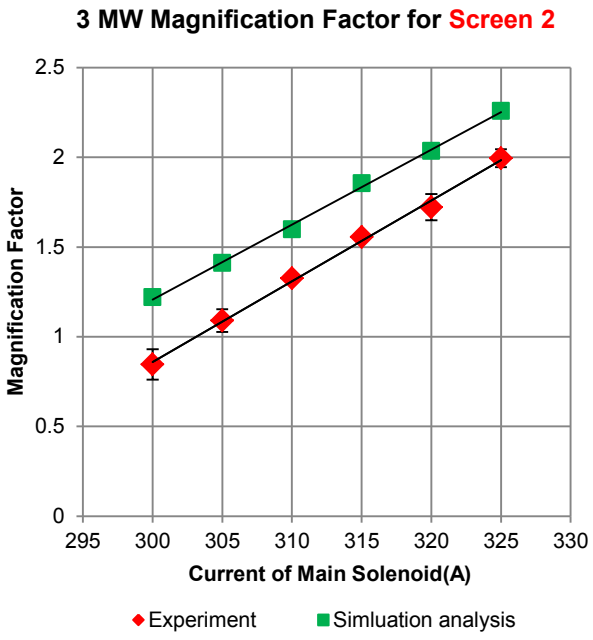


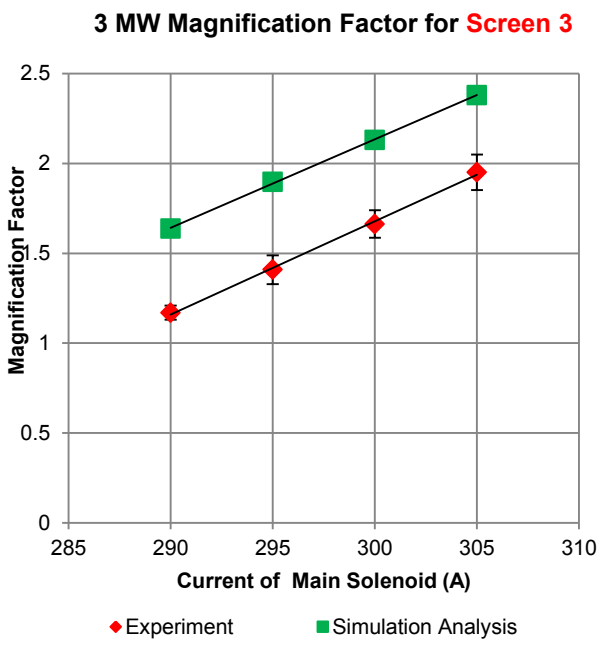


- The magnification factor for two directions are same.

Simulation and experiment results for 3 MW



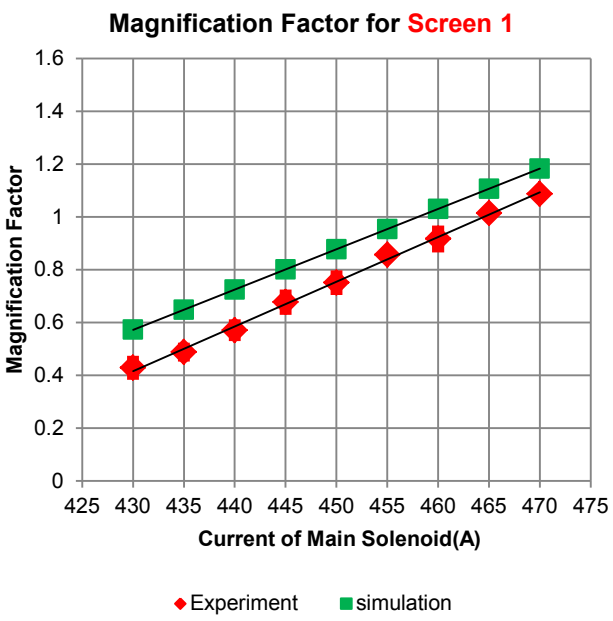


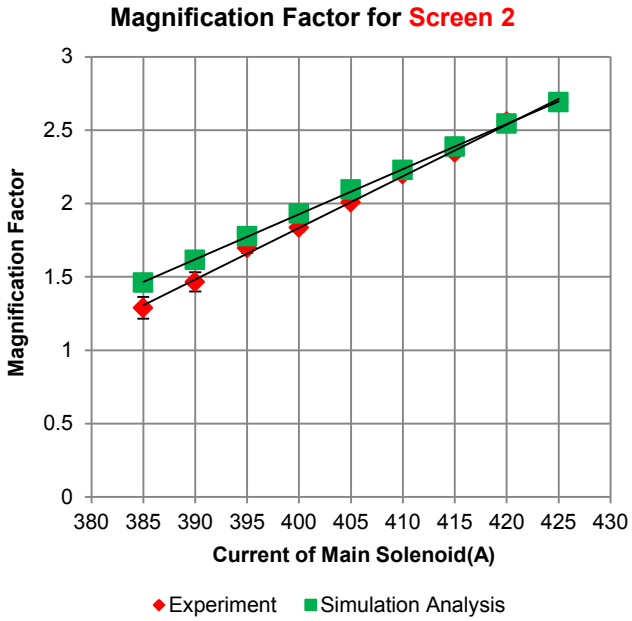


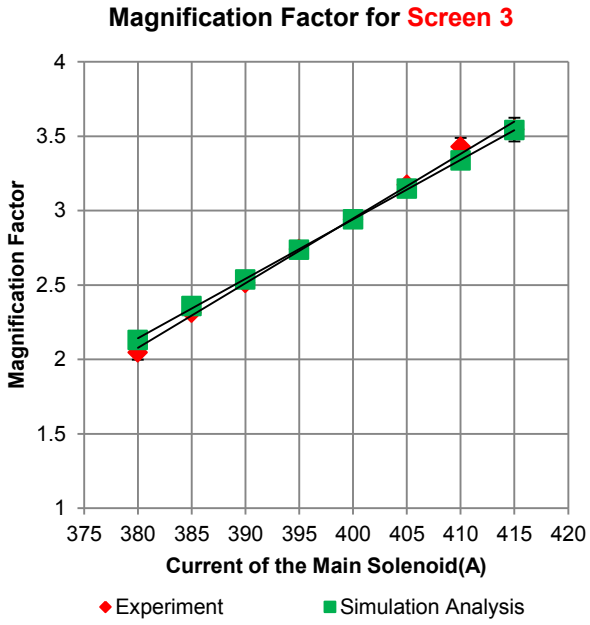
Z= 0.803m Z= 1.379m Z= 1.708m

- The magnification factor from simulation are bigger than the experiment results.
- The current for solenoid used in the experiment from 290 A ~ 390 A.

Simulation and experiment results for 5 MW



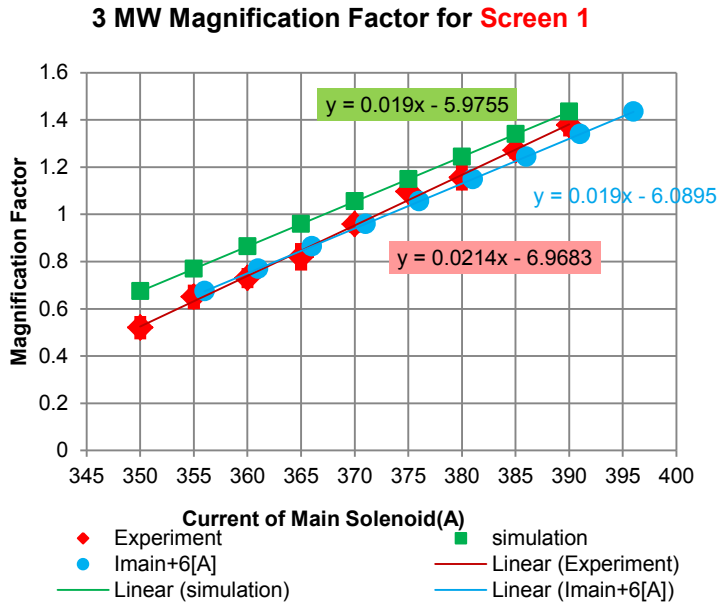


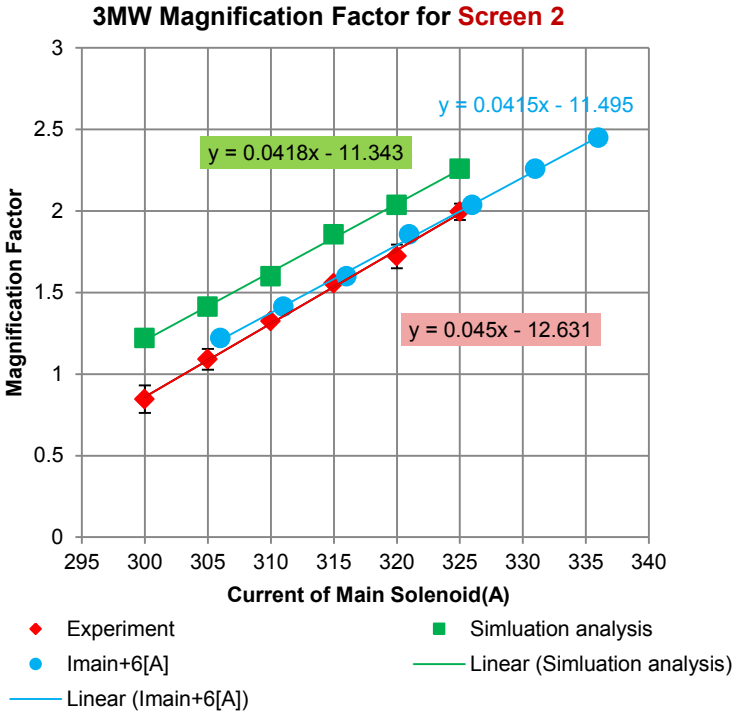


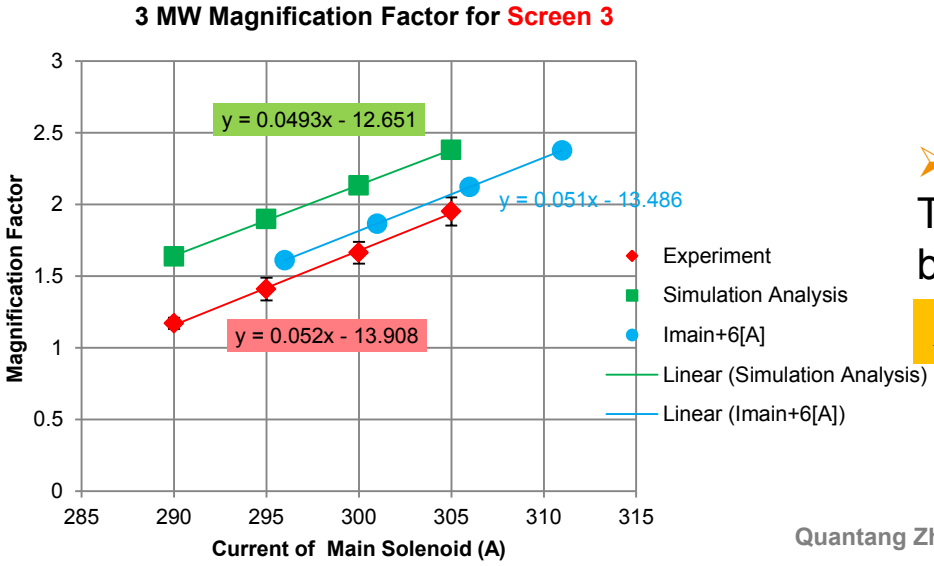
- The magnification factor from simulation are consistent with the experiment results for Screen2 and 3, but for Screen1 still bigger than the experiment results.
- The current for solenoid used in the experiment from 380 A ~ 470 A.

Analysis for 3MW : shift Imain +6[A]

3 MW





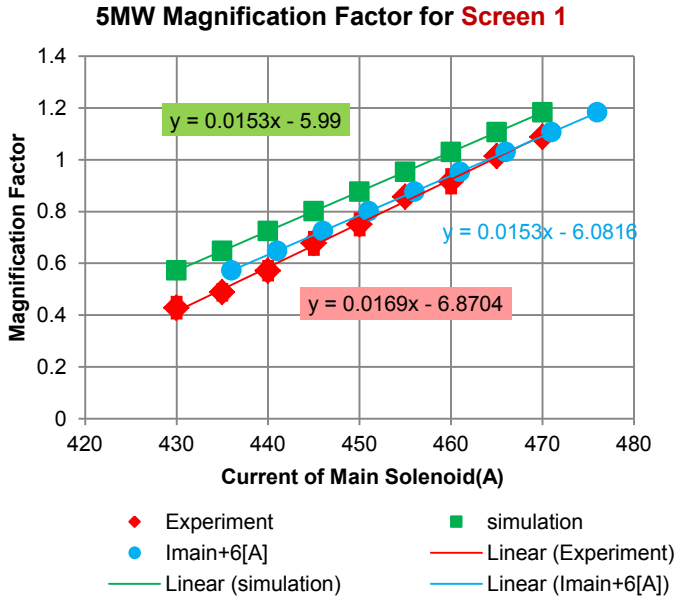


- **For 3 MW in the gun, for screen 1&2:**

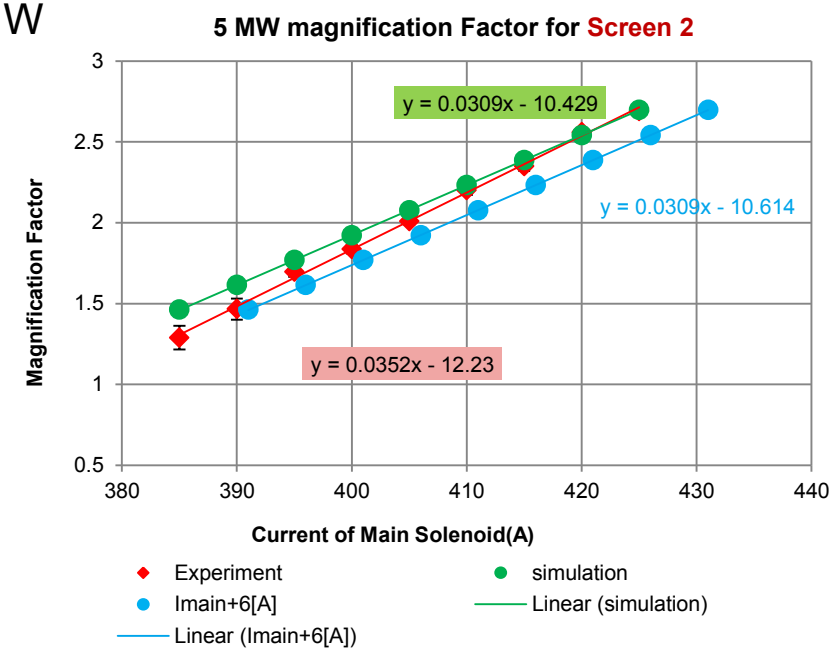
The solenoid fields and current formula can be calibrated very well as follows:

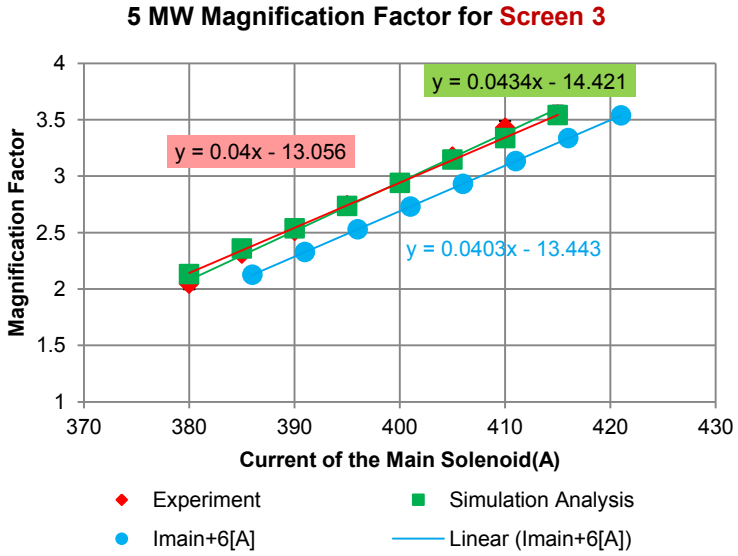
$$B_{z,main}[\mathrm{T}]=5.889\times10^{-4}*(I_{main}\ \mathbf{-6})\ [A]+7.102\times10^{-5}$$

Analysis for 5 MW: shift Imain +6[A]



5 MW





- **For 5 MW in the gun:**

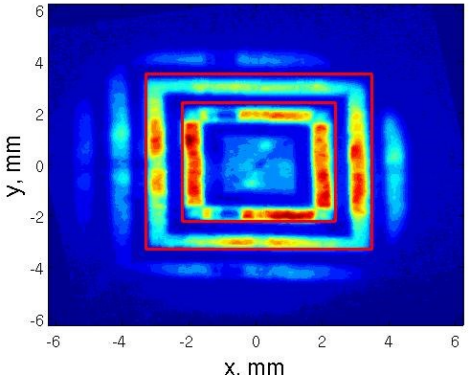
For Screen 1, the same with 3MW in the gun, Imain➔-6 A.

For screen 2 and 3, the results with measured Imain are more consistent than with Imain shift.

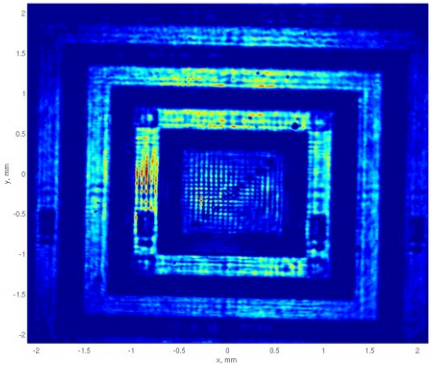
Rotation angle analysis

- Rotate the image and make the grid fit to the square, define the rotation angle.

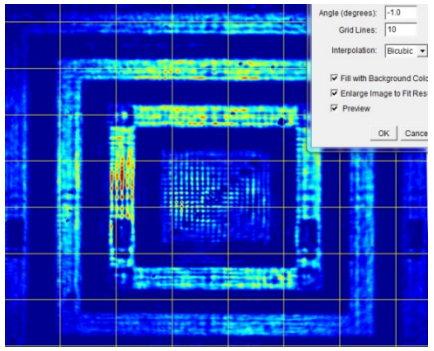
- From simulation: use the larmor angle From ASTRA.



Error from laser grid image on VC2

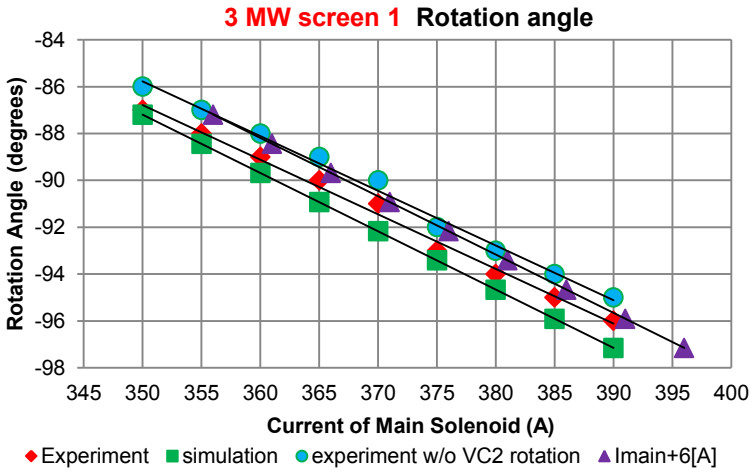


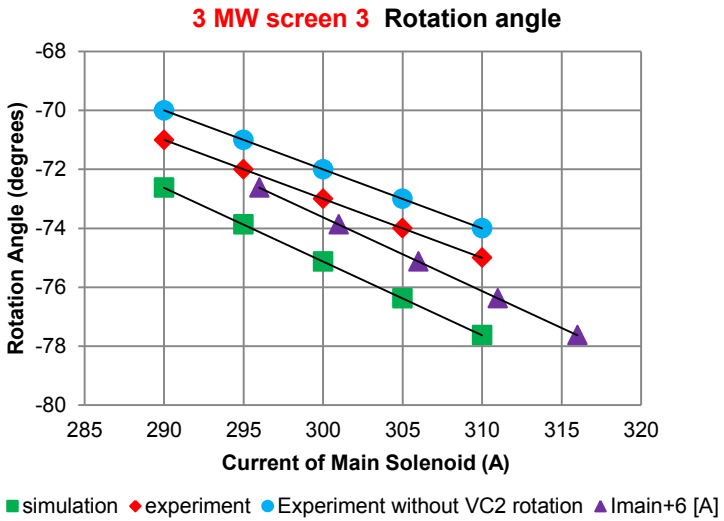
1 degree rotation



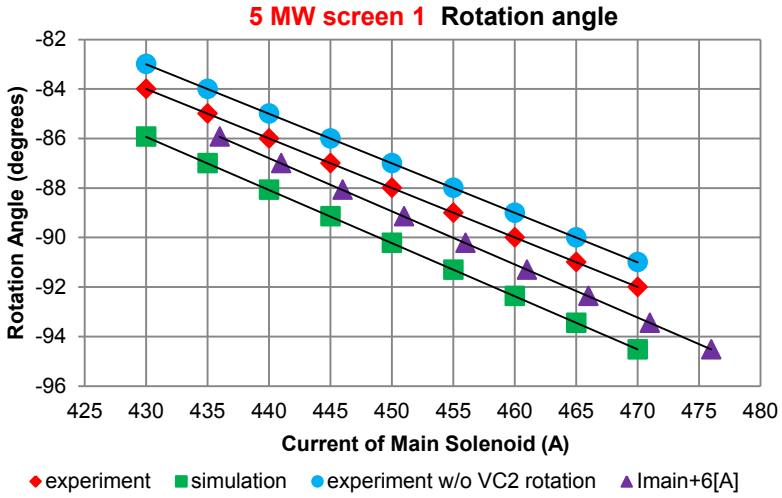
Rotation angle analysis results

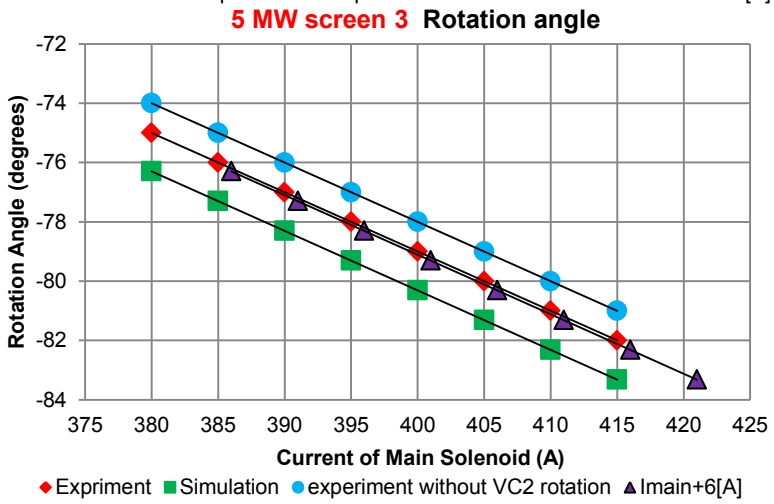
3 MW





5 MW





- Imain shift 6 A ~ rotation angle changes about 1 degree, laser grid ~ 1 degree error.
- The rotation angle with Imain+6[A] seems to be more consistent to the experiment with laser grid error.

Summary

- The beam transverse dynamics without space charge for 3 MW in the gun and 5 MW in the gun is different. The reason of this discrepancy is not clear yet.

  ?? Solenoid field: different solenoid current range, quadrupole field error of solenoid….

  ?? RF field: non linear transverse RF field and multipole fields ….

- One possible and reasonable formula of solenoid field and current from above analysis as follows, which should be certified by further study.

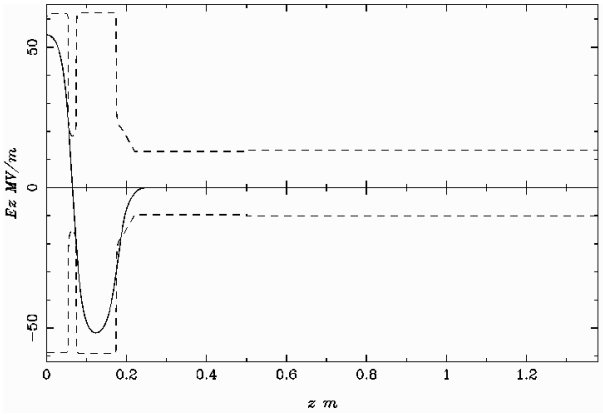
  $B_{z,main}$[T]=5.889×10^{-4}∗(I_{main} **-6**) [A]+7.102 ×10^{-5}

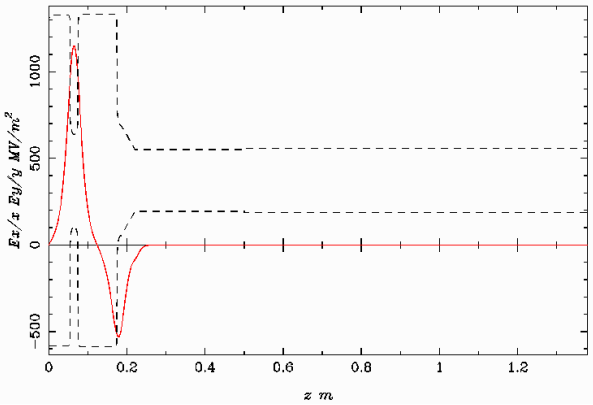
→The difference of magnification factor from simulation and experiment for screen 3(3MW &5 MW) should come from the irregular transverse RF field. The screen 1 is near the gun, which has less effect than screen 3 from this kinds of RF filed like coupler kick.

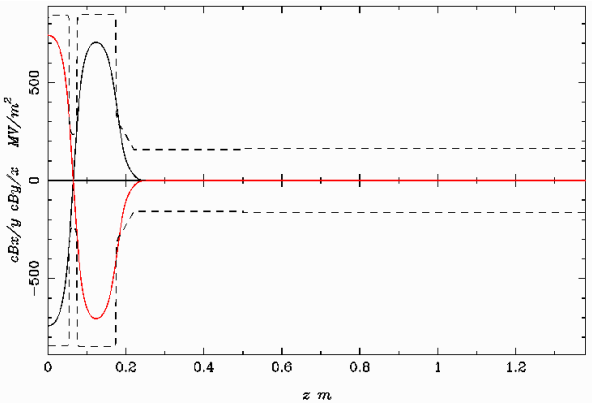
- Field and current formula for solenoid should be investigated firstly, and then take solenoid field as a reference for further study of RF field.

Backslide

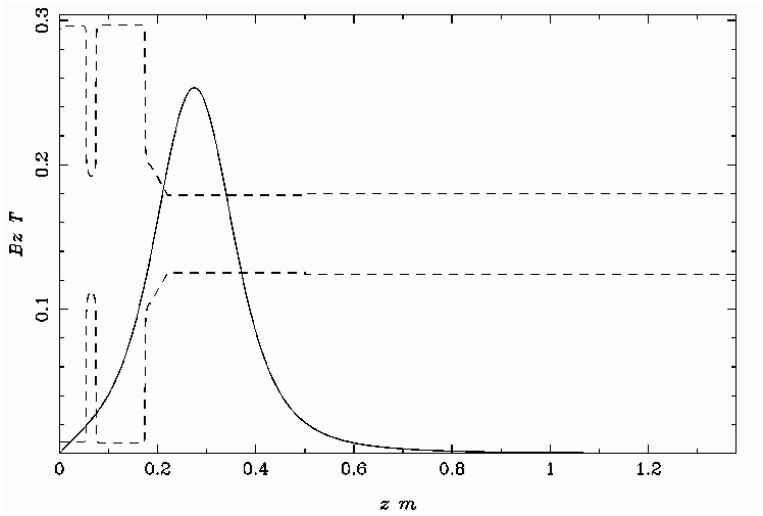
Gun RF fields used in ASTRA simulation







Solenoid fields used in ASTRA simulation



Transverse fields