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

OUTLINE

- SETUP AND MOTIVATION
- EXPERIMENTAL STUDY
- SIMULATION STUDY
- RESULTS
- CONCLUSION

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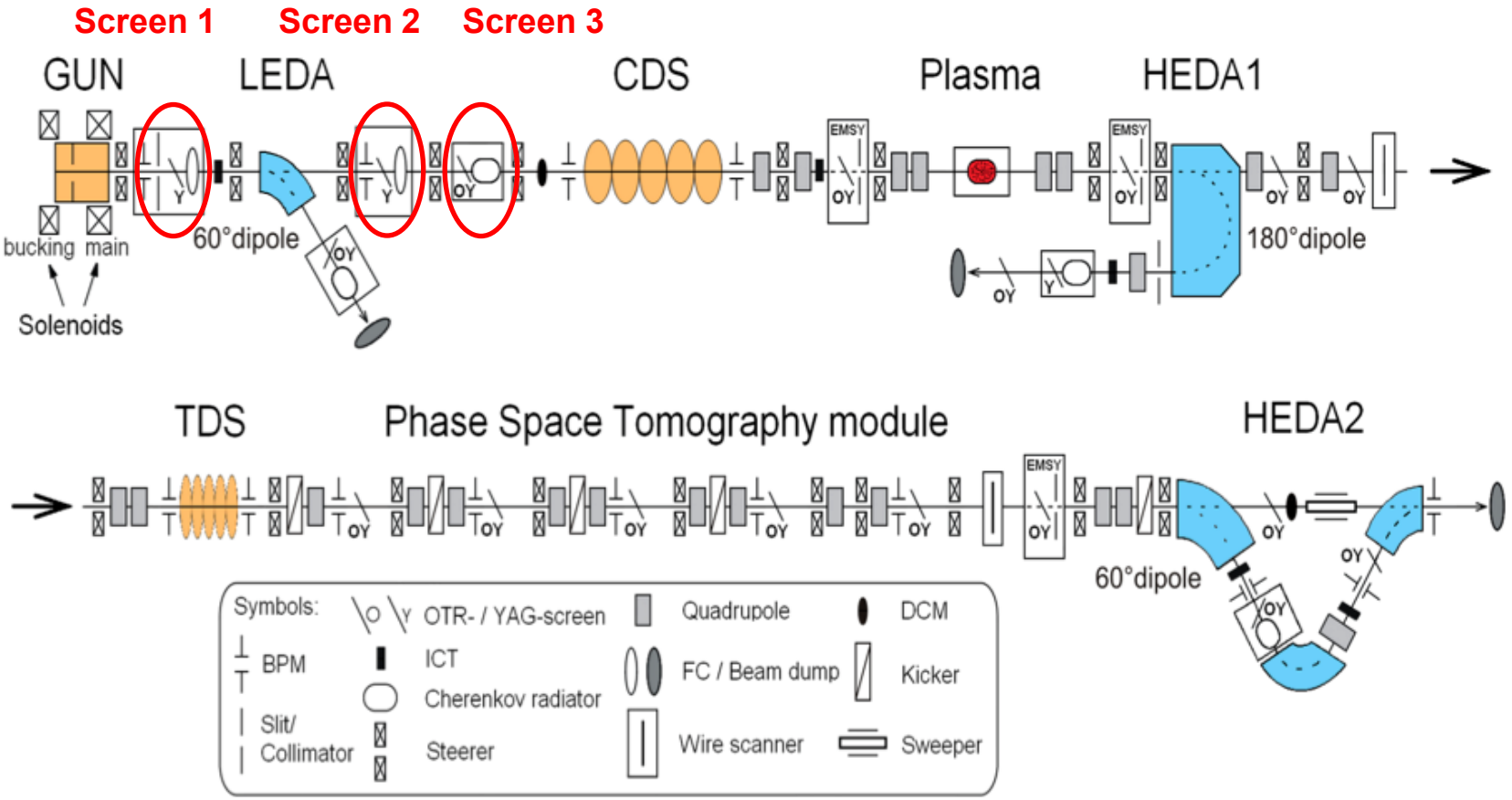
Summer Student Project
Zeuthen, 10/9/2015

HELMHOLTZ ASSOCIATION

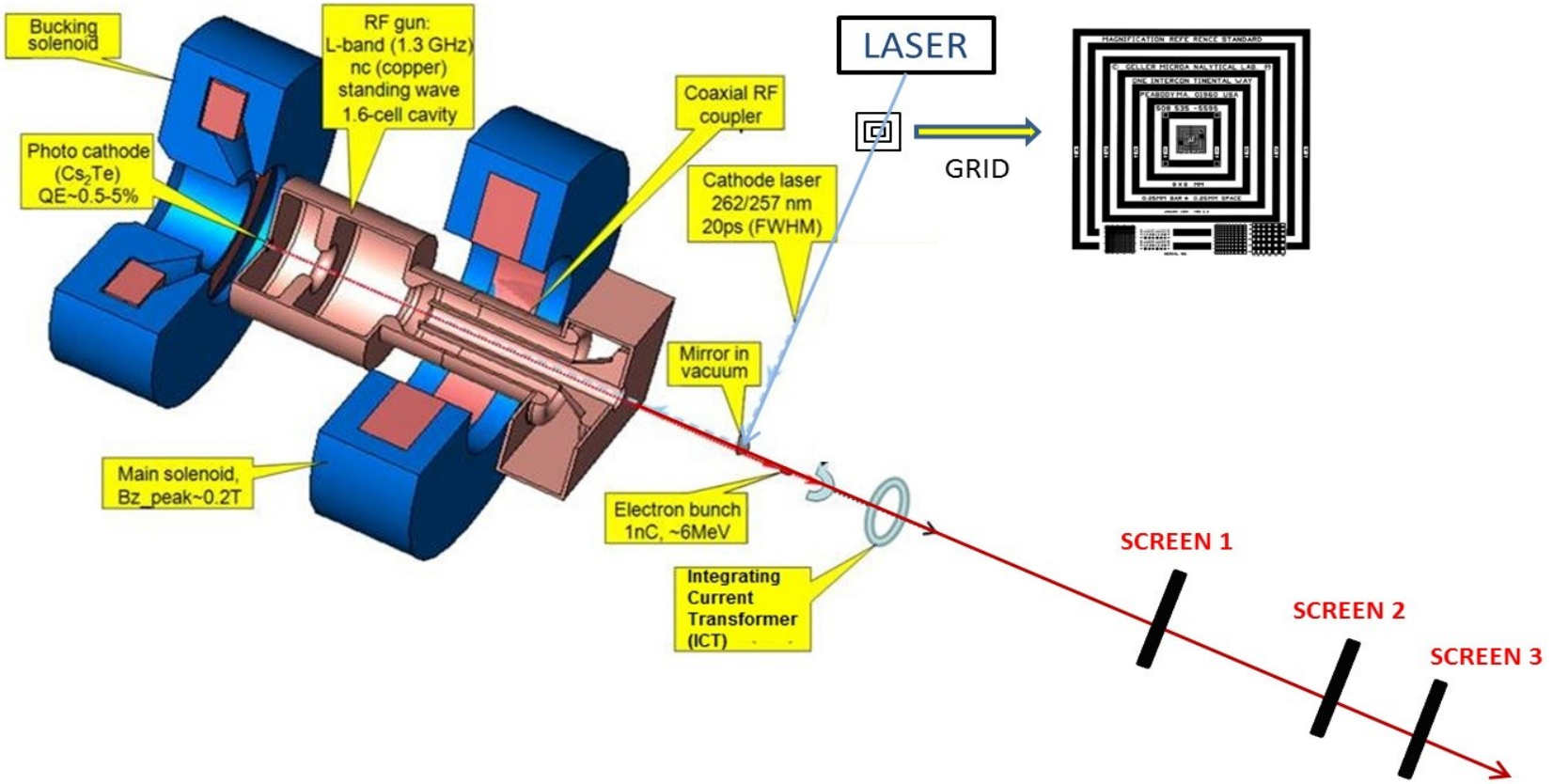
DESY

PITZ beamline

Electron source can be used as an electron microscope.



Experimental SETUP



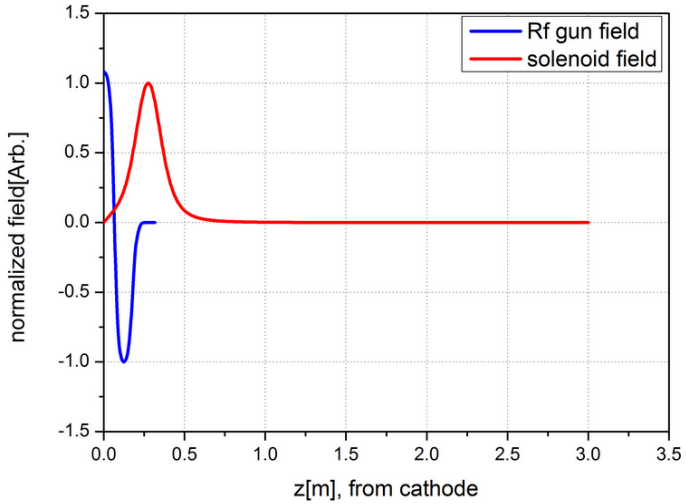
MOTIVATION

- Calibration formula for the longitudinal magnetic peak field

  (S. Rimjaem, September 2009)

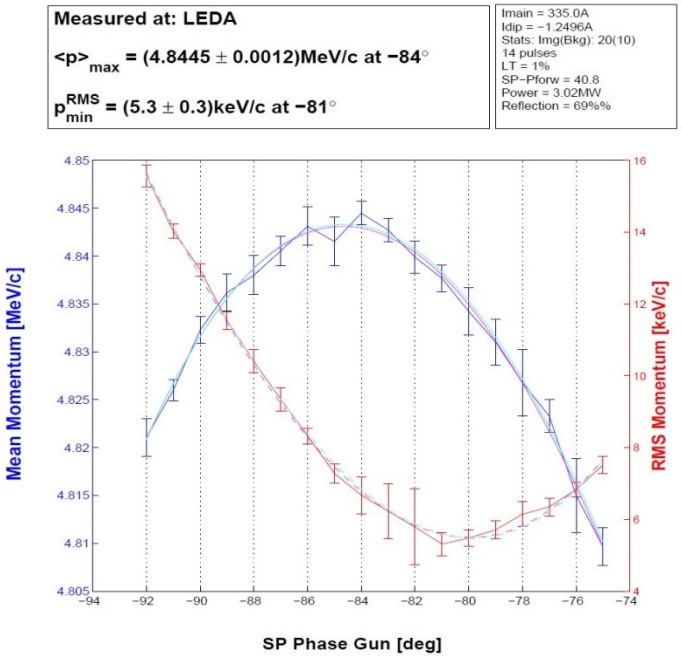
$$B_{z,main}[T] = 5.889 \times 10^{-4} * I_{main}[A] + 7.102 \times 10^{-5}$$

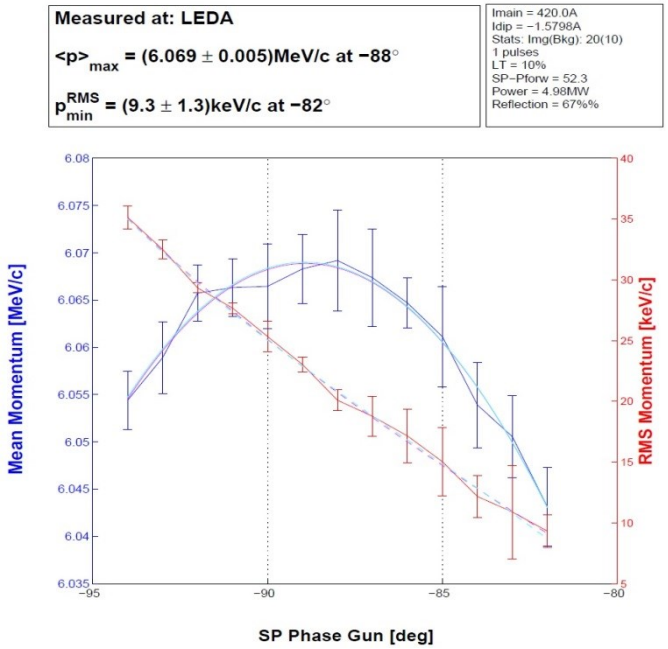
- verify the consistency of this formula
- experiment study and a simulation of the RF and solenoid fields



Data acquisition

- Data for 3 MW and 5 MW Gun power
- LEDA scan to define the beam momentum





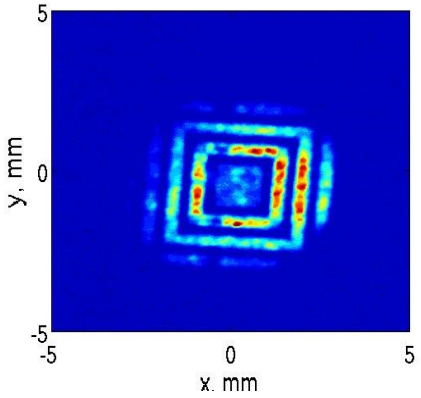
- Gun setting to MMMG (Maximum Measured Momentum Gain) phase
- Record images in LOW.Scr1, LOW.Scr2, LOW.Scr3 for different solenoid currents.

Study for 3 MW Gun power

- EXPERIMENT

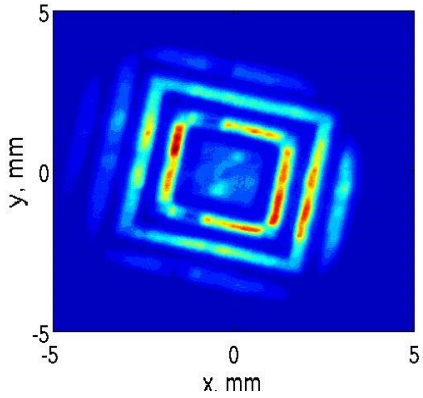
Low Screen 1

Imain = 385 A LT = 1%



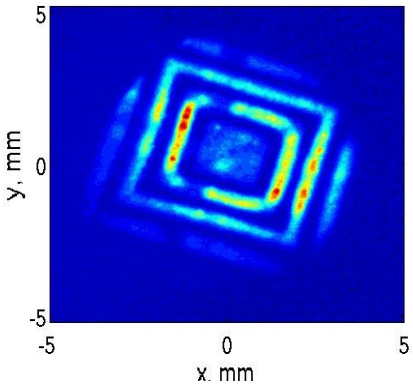
Low Screen 2

Imain = 320 A LT = 1%



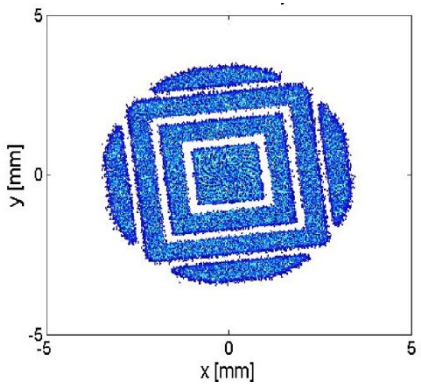
Low Screen 3

Imain = 300 A LT = 1%

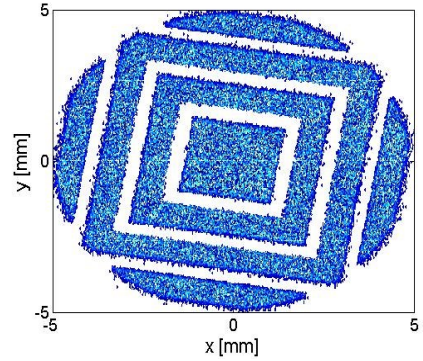


- SIMULATION (ASTRA: A Space Charge Tracking Algorithm)

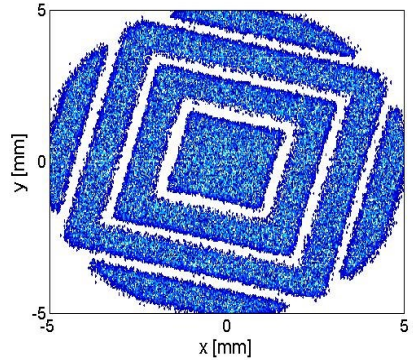
B = 0.2268 T



B = 0.1885 T



B = 0.1767 T

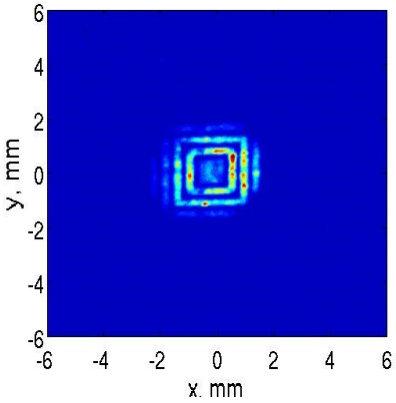


Study for 5 MW Gun power

- EXPERIMENT

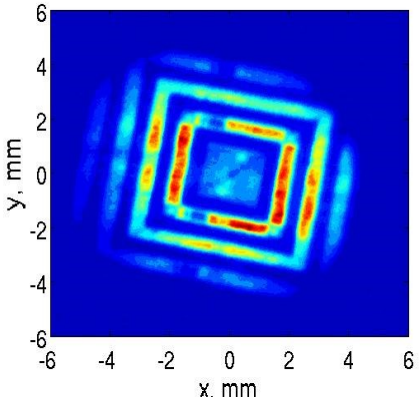
Low Screen 1

Imain = 455 A LT = 1%



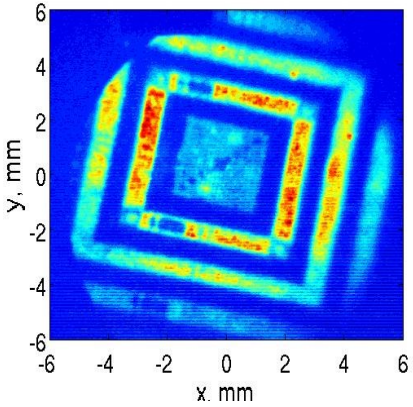
Low Screen 2

Imain = 405 A LT = 1%



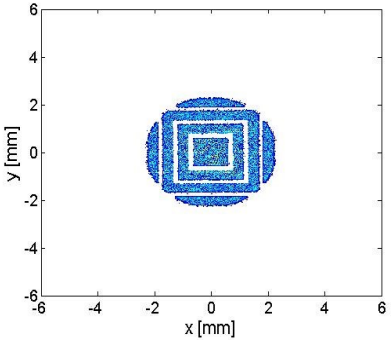
Low Screen 3

Imain = 400 A LT = 1%

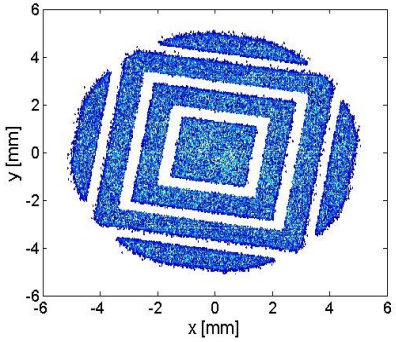


- SIMULATION (ASTRA: A Space Charge Tracking Algorithm)

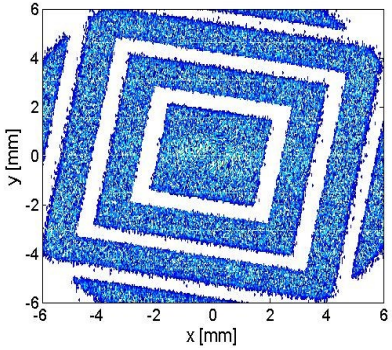
B = 0.2680 T



B = 0.2385 T



B = 0.2356 T

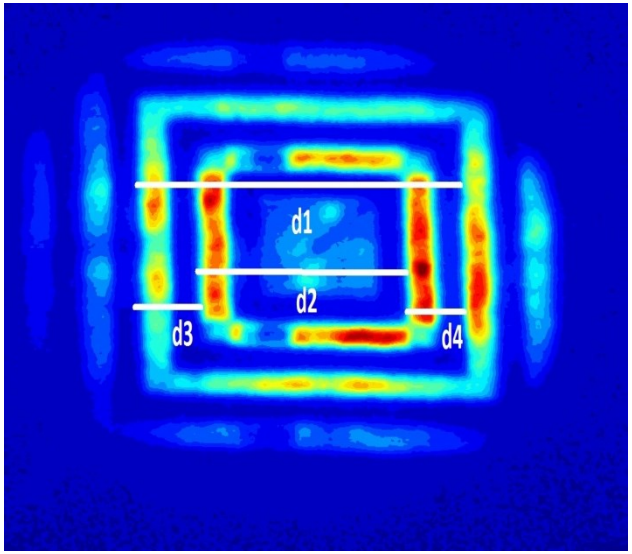


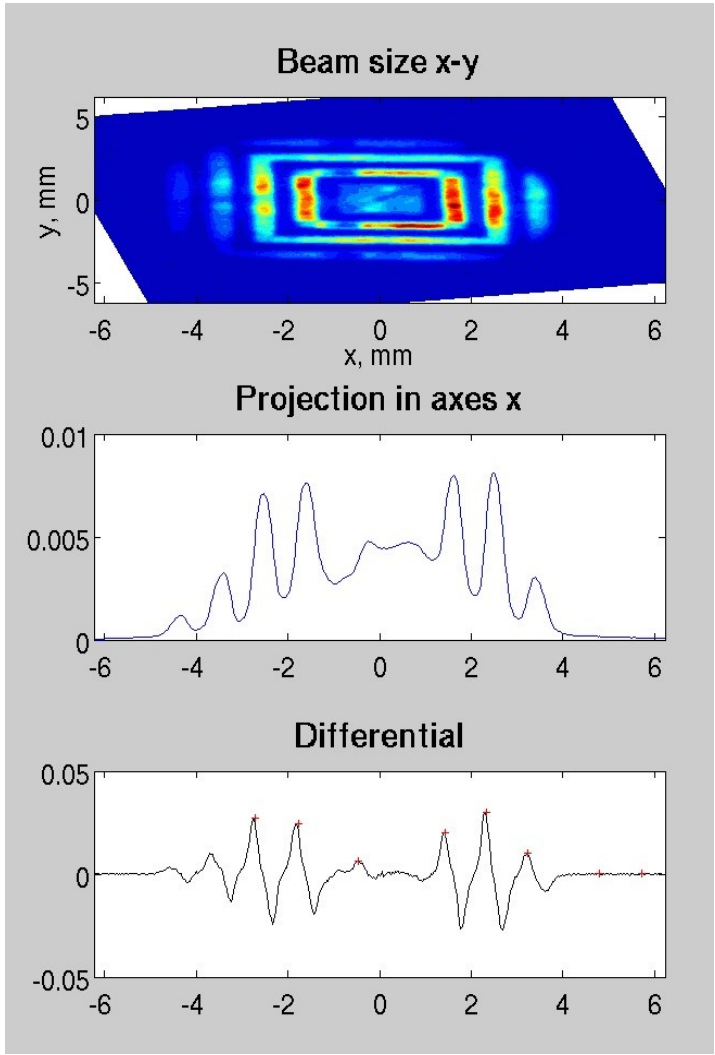
Data analysis

- Rotation of the image
- Projection of the image in x-axes
- Calculation of the differential of projection.
- Peaks are used for measure the distances d1, d2, d3, d4
- Computation of the magnification factor using the formula:

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

- Std is used for estimation of the error.





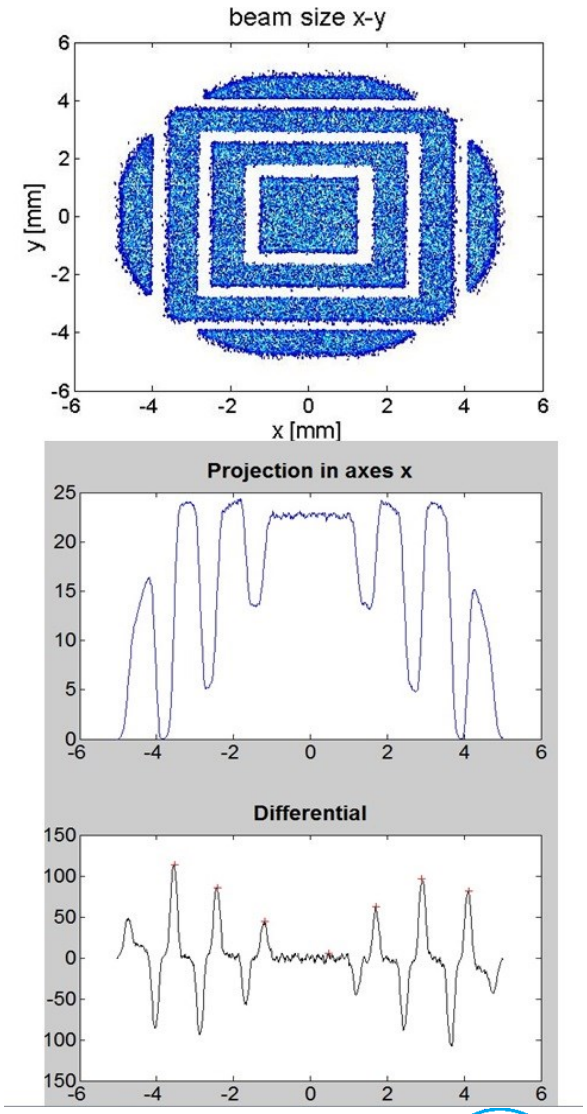
Simulation Analysis

- Very low charge
- Gaussian longitudinal and uniform transverse distribution.
- Beam modulated by the grid
-

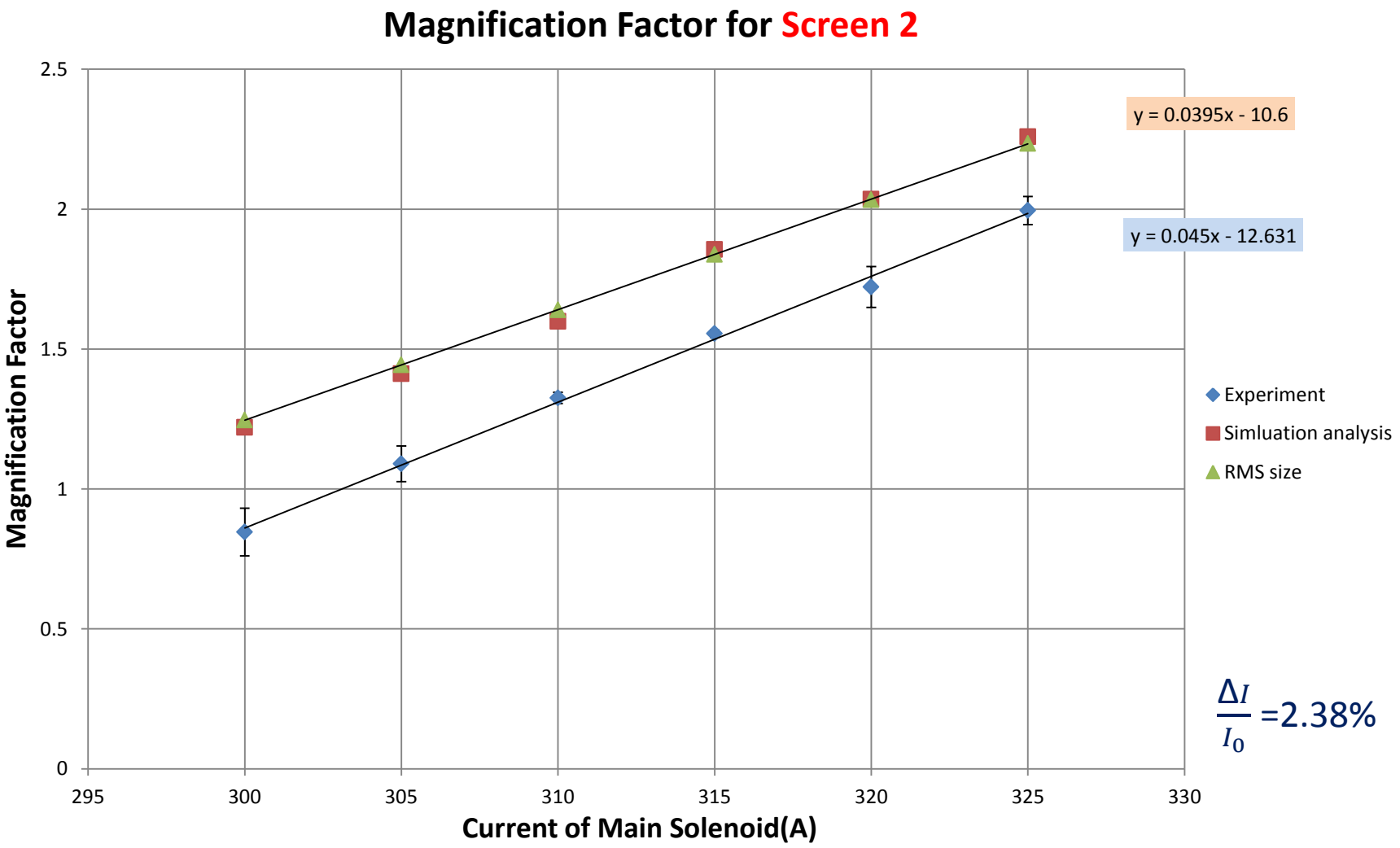
Gun Power	Max. Beam momentum	Electric field
3 MW	4.8 MeV /c	42.2 MV/m
5 MW	6.07 MeV /c	54.4 MV/m

- Imaging at Low Screen2, Low Screen3
- Magnetic field is computed by the formula:
- $B_{z,main}[T] = 5.889 \times 10^{-4} * I_{main}[A] + 7.102 \times 10^{-5}$.

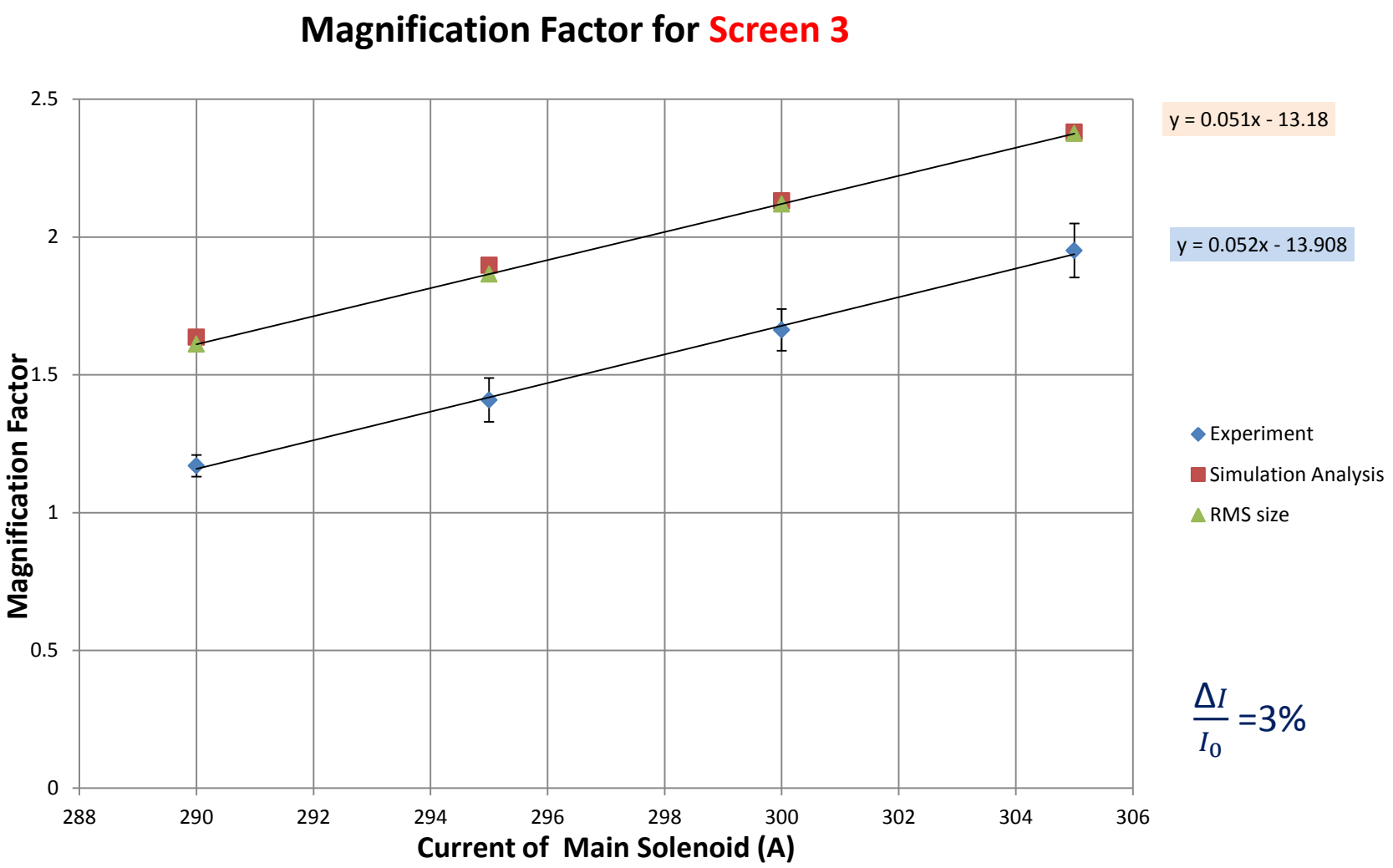
  I_{main} : solenoid current from experiment
  B_z : magnetic field of solenoid in simulation
- Study of Larmor angle (ASTRA output).
- rotation of the output coordinate system
- Calculation of Magnification factor
  - $MF = \frac{Calculated\ distance}{distance\ from\ the\ grid}$
  - $MF = \frac{RMS\ beam\ size\ in\ the\ screen}{initial\ RMS\ beam\ size}$



Magnification Factor for 3 MW gun power

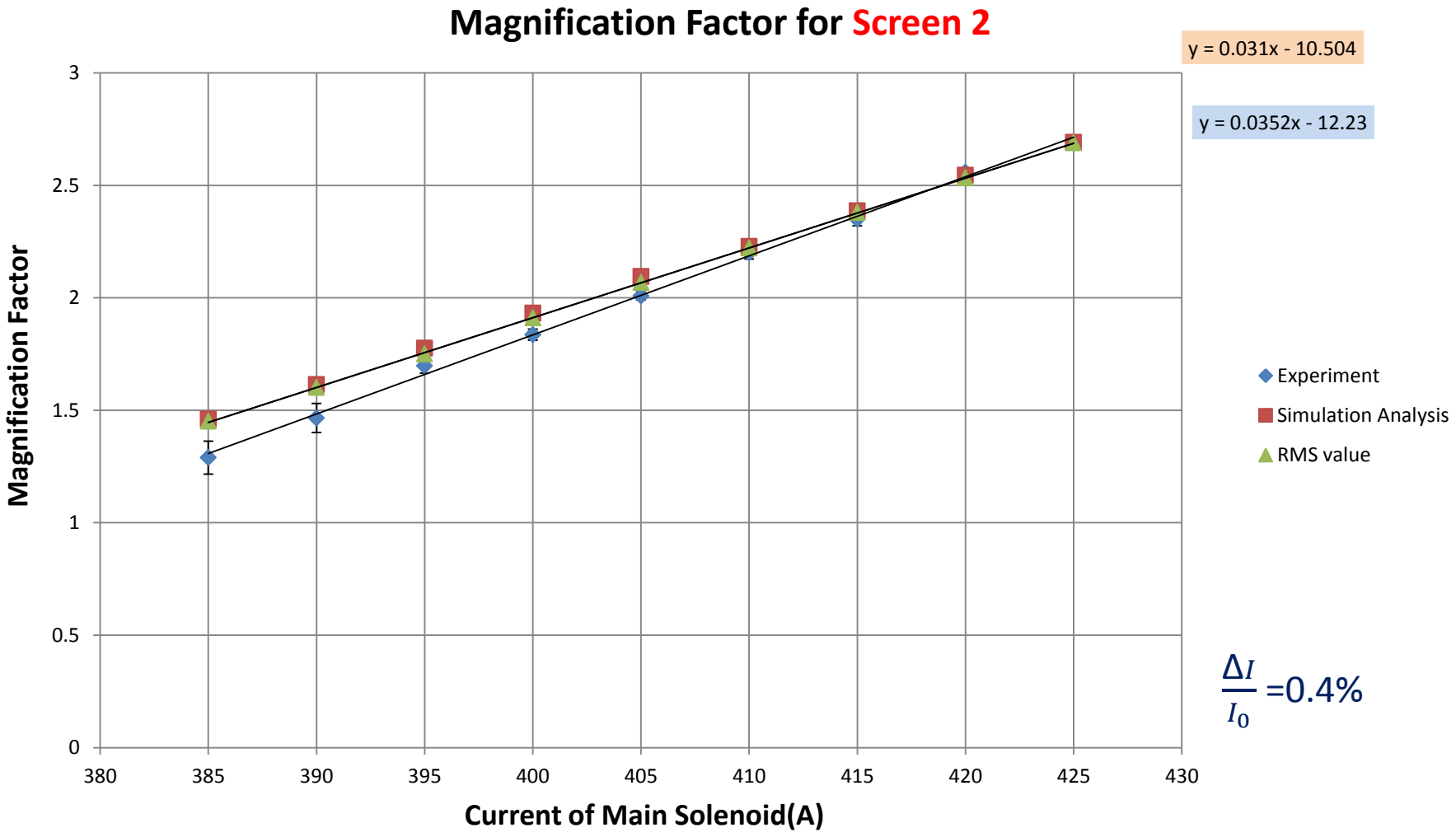


Magnification factor for 3 MW gun power



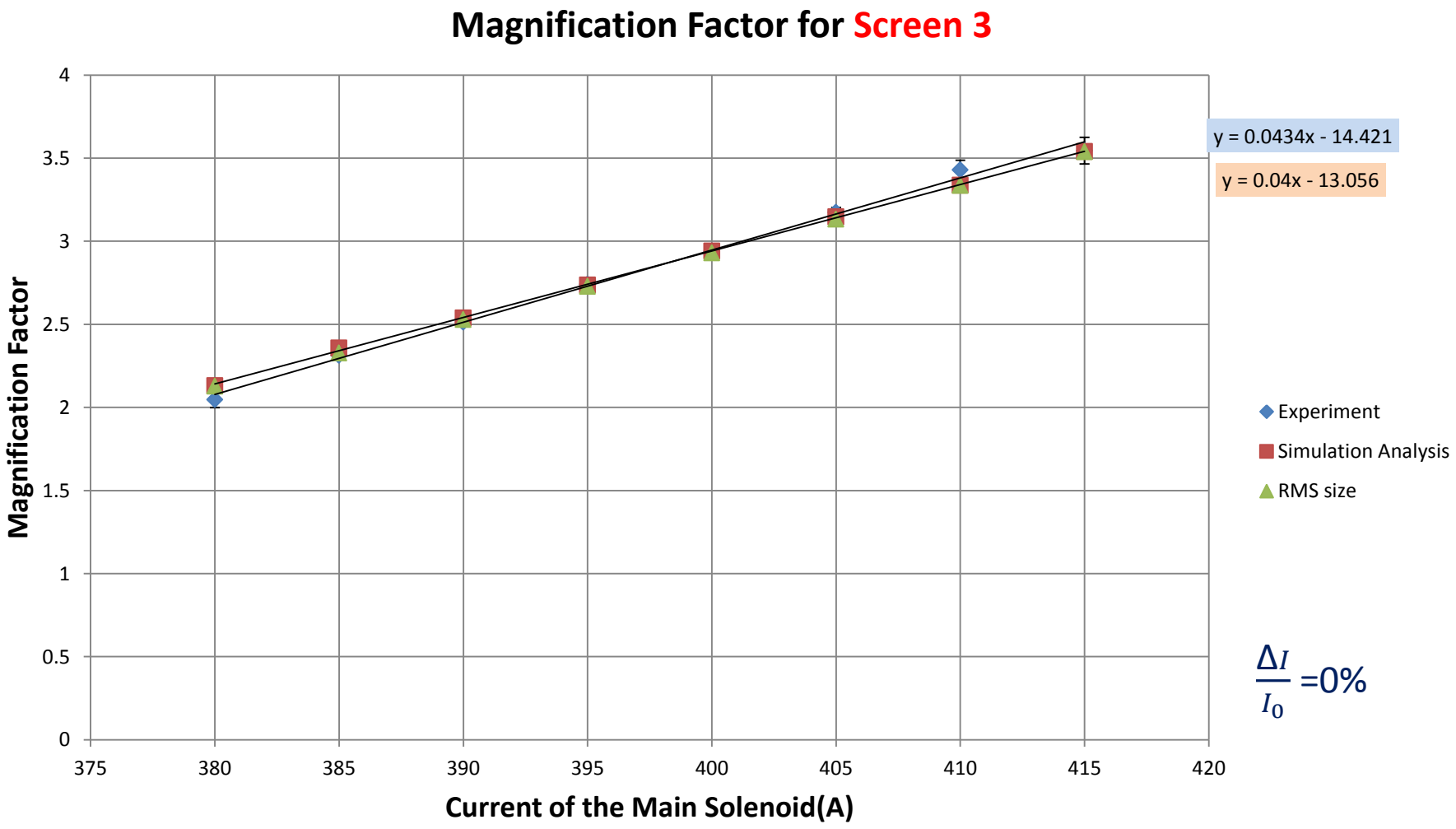
$$\frac{\Delta I}{I_0} = 3\%$$

Magnification Factor for 5 MW gun power



$$\frac{\Delta I}{I_0} = 0.4\%$$

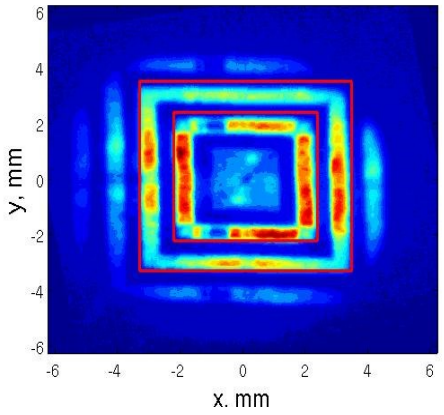
Magnification factor for 5 MW gun power

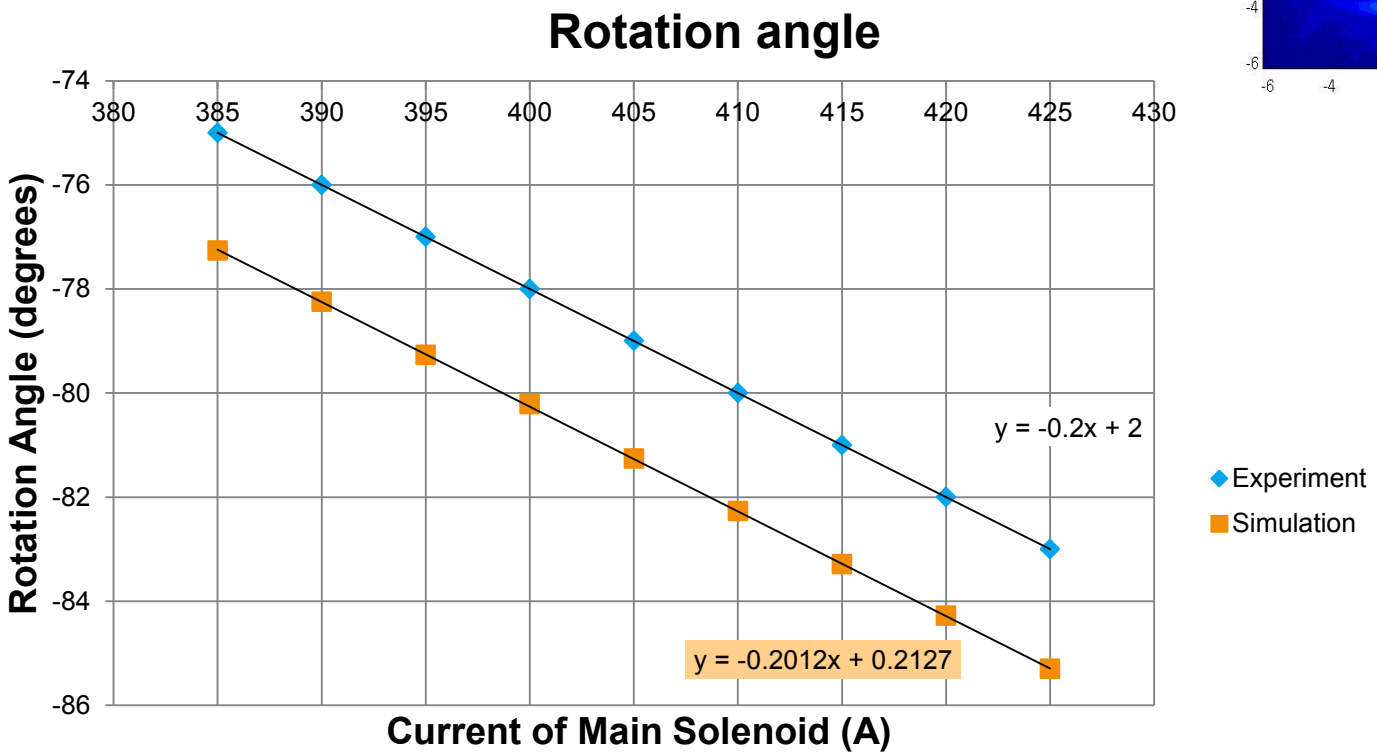


$$\frac{\Delta I}{I_0} = 0\%$$

Rotation angle for 5 MW gun power in the Low Screen 3

- Larmor angle as an output of ASTRA simulation
- Rotation angle of experimental data calculated by Matlab





SUMMARY

- Experiment and simulation study have been conducted for 3 MW and 5 MW Gun power.
- Magnification factor and rotation angle have been studied.
- Simulation and experimental results have been compared.
- For 3 MW Gun power there are discrepancies (~3%) between the experiment and the simulation.
- For 5 MW Gun power the calibration formula is consistent.
- Rotation angle of the grid image in experiment differs from the simulation.

Acknowledgment

- Quantang Zhao
- PITZ group
- Gernot Maier and Katrin Varschen
- All the summer students!

THANK YOU FOR YOUR ATTENTION!