SIMULATION STUDY OF THE MAGNETIZED ELECTRON BEAM

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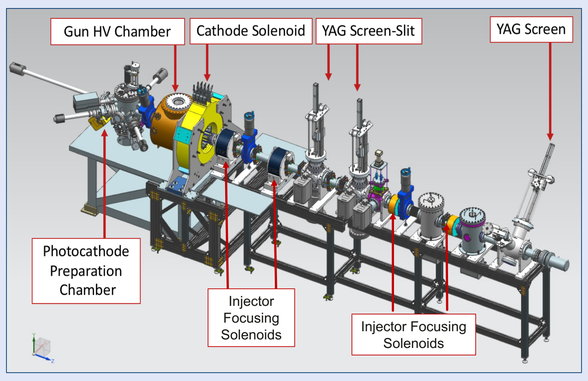
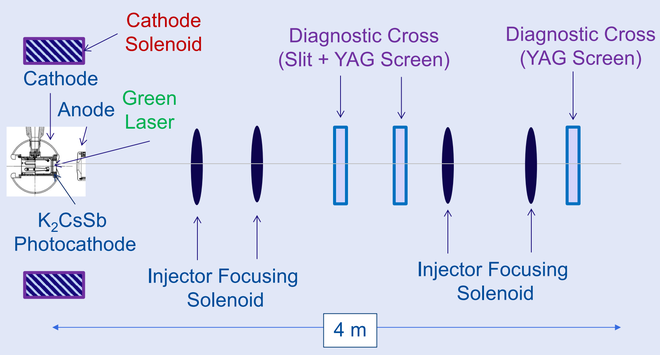
INTRODUCTION

Electron cooling of ion beams is important for electron ion colliders to obtain the required high luminosity. Cooling can be enhanced using a magnetized electron beam where the cooling process occurs inside a solenoid field. This presentation describes a comparison of measured and predicted values of electron beam size and rotation angle along the beamline for different magnetizing photogun solenoid settings, using ASTRA and GPT software and a magnetized electron beam generated from a DC high voltage photogun. In addition, ASTRA simulations helped inform the importance of using an accurate magnetic field map by modelling the mismatch oscillations that arise in the magnetizing solenoid.

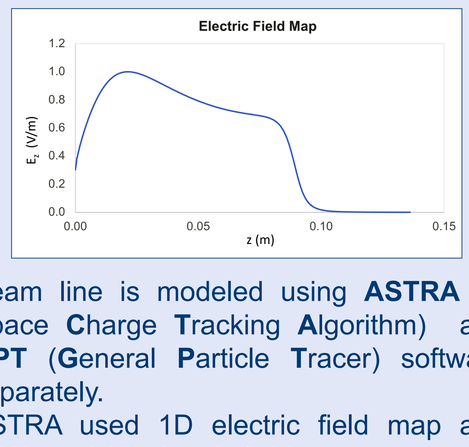
Beam Line

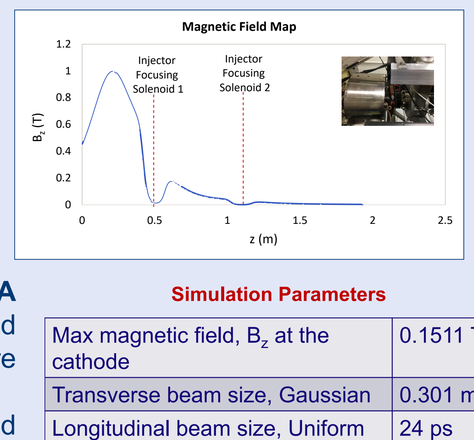




Gun Test Stand consists of a K_2CsSb photocathode preparation chamber, DC high-voltage photogun operating at -300 kV, cathode solenoid magnet to magnetize the beam, and a beamline with two YAG screen-slit combinations at 0.5 m and 2.0 m, a YAG-screen at 3.75 m, four injector focusing solenoids, steering magnets, harp, and beam dump.

Modelling





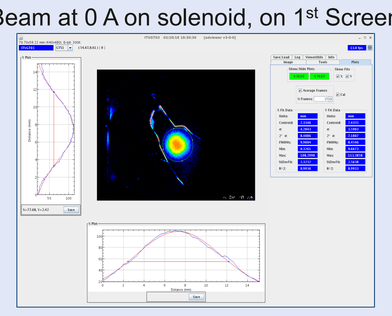
- Beam line is modeled using **ASTRA** (**A** **S**pace **C**harge **T**racking **A**lgorithm) and **GPT** (**G**eneral **P**article **T**racer) software separately.
- ASTRA used 1D electric field map and GPT used 2D electric field map.
- Magnetic field map is distorted by metal housing of the nearby focusing solenoids.
- **MATLAB** is used to post-processing and calculate beam sizes and rotation angles.

Simulation Parameters

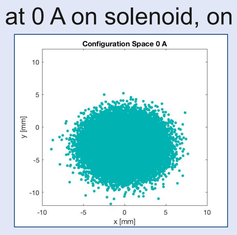
Max magnetic field, B_z at the cathode	0.1511 T
Transverse beam size, Gaussian	0.301 mm
Longitudinal beam size, Uniform	24 ps
Gun voltage	300 kV
Horizontal offset of the laser	0 mm
Vertical offset of the laser	0.5 mm
Mean transverse energy	0.130 eV

Beam Profile

Measurements:
Beam at 0 A on solenoid, on 1st Screen

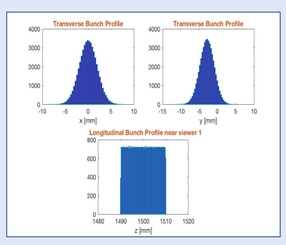


ASTRA:
Beam at 0 A on solenoid, on 1st Screen

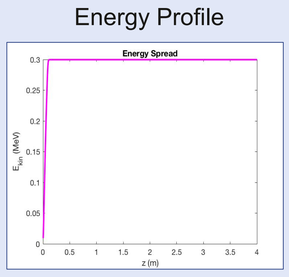


ASTRA: Beam at 0 A on solenoid, on 1st Screen

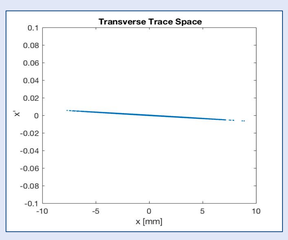
Beam Profile

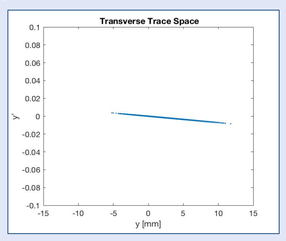


Energy Profile

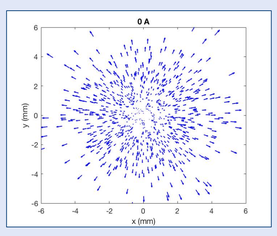


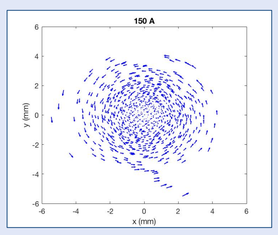
Trace Space





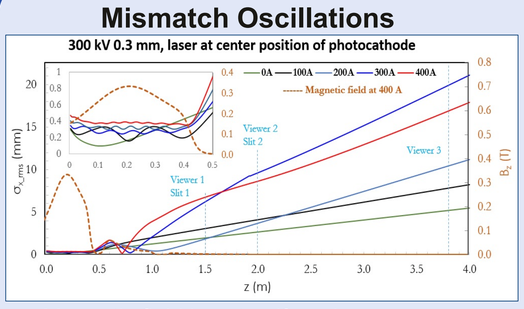
ASTRA: Beam Rotation





ASTRA Simulation Results

Mismatch Oscillations



- Magnetic field is not uniform in *z*.
- Thus, no transverse equilibrium occurs and unbalanced forces inside the magnetic field cause the mismatch oscillations.
- Larmor frequency increases with the B field.

General formula to find the rotation angle :

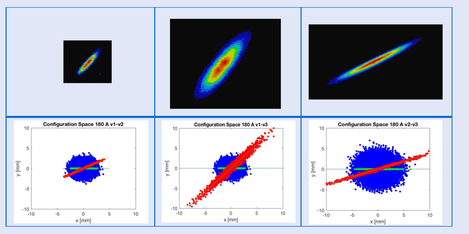
$$\varphi_{rot} = tan^{-1}\left(\frac{\dot{\theta}z/v_z}{1 - z/f}\right)$$

Converging $\alpha > 0, z > f \rightarrow \frac{\pi}{2} < \varphi_{rot} < \pi$
At waist $\alpha = 0, z = f \rightarrow 0 < \varphi_{rot} < \frac{\pi}{2}$
Diverging $\alpha < 0, z < f \rightarrow 0 < \varphi_{rot} < \frac{\pi}{2}$

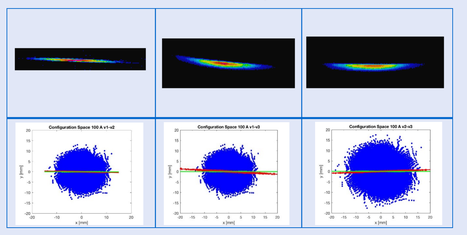
$\dot{\theta}$-rotation from magnetization, z-drift length, v_z-velocity in z direction, f-focal length

Rotation angle variation of a diverging beam - 180 A

Slit 1-Viewer 2 | Slit 1-Viewer 3 | Slit 2-Viewer 3

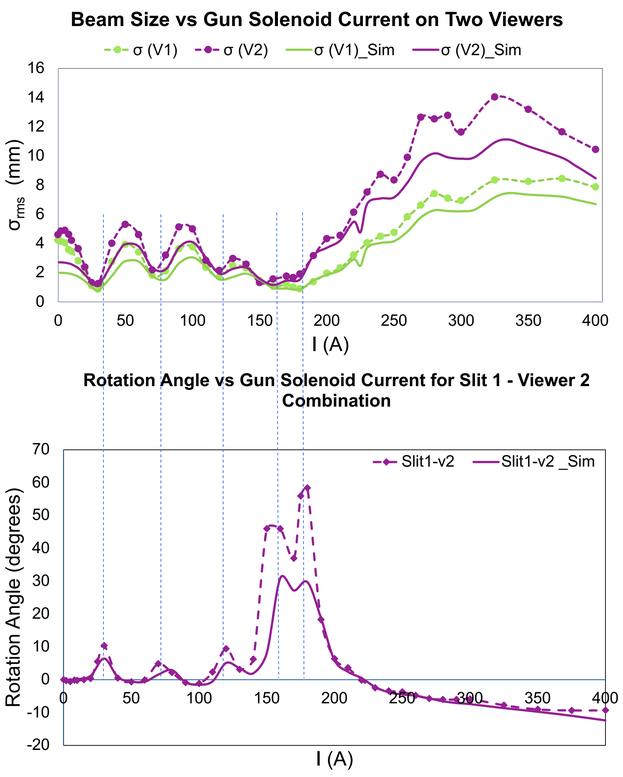


Rotation angle variation of a converging and diverging beam - 100 A

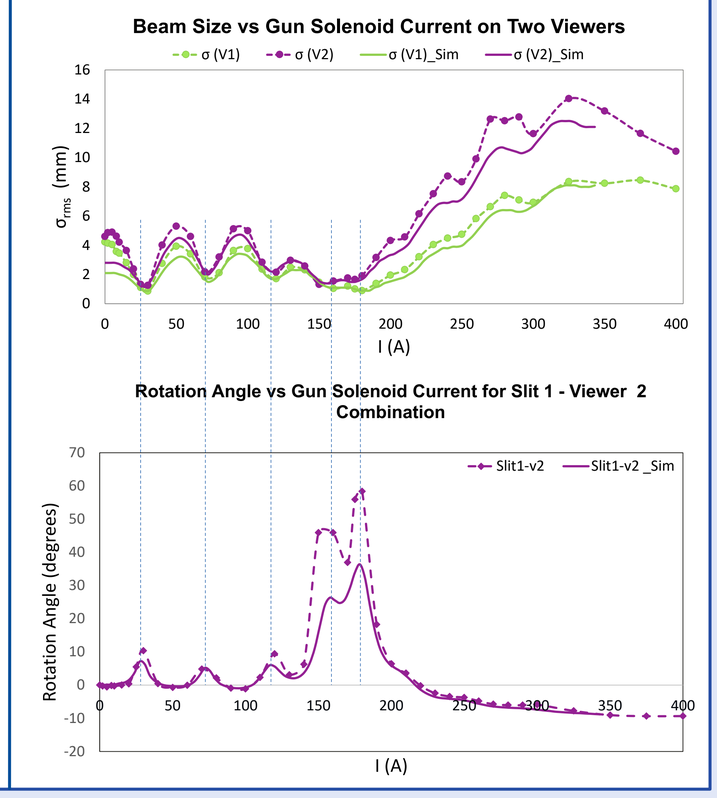


Measurements vs Simulations (ASTRA & GPT)

ASTRA



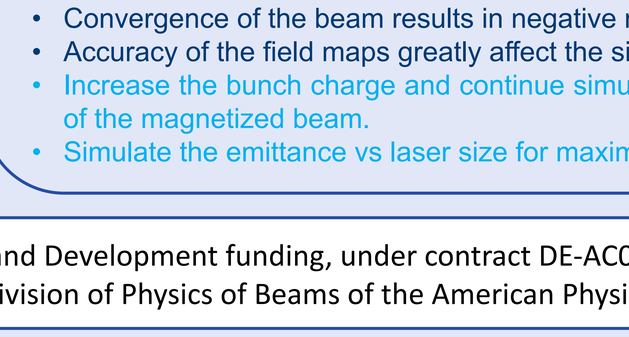
GPT



- GPT and ASTRA show same variations with the measurements.
- Gun solenoid magnetizes the beam but also focuses the beam.
- Rotation angle influenced by Larmor oscillations in the gun solenoid.
- Negative angles occurs due to the beam convergence.
- Other slit–viewer combinations showed the same pattern.

ASTRA Simulation Results Cont'd

Simulation results depend significantly on the field maps



Beam gets kicked off axis quickly, use steering magnets to bring on axis

Summary and Outlook

- Successfully simulated the magnetized beam using ASTRA and GPT software showing good agreement with the measurements.
- Beam sizes and rotation angles oscillate rapidly due to focusing and de-focusing effects.
- Mismatch oscillations occurred due to the non-uniform magnetic field map which results to unbalanced forces inside the magnetic field.
- Convergence of the beam results in negative rotation angles.
- Accuracy of the field maps greatly affect the simulation results.
- Increase the bunch charge and continue simulations on space charge effect of the magnetized beam.
- Simulate the emittance vs laser size for maximum gun solenoid current.

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