Magnetized Beam LDRD

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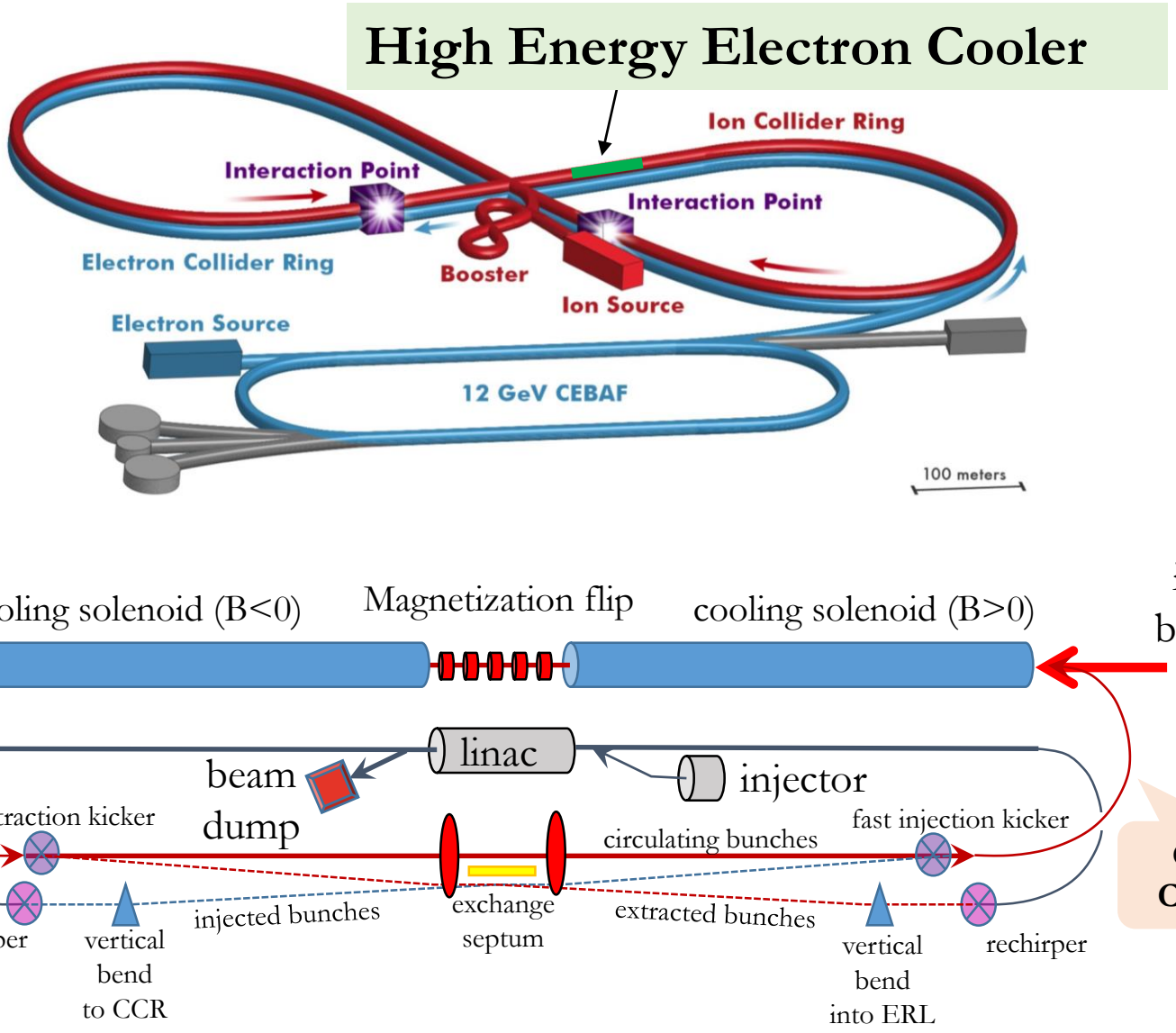
Jefferson Lab Accelerator Advisory Committee Mtg., September 13-15, 2017

JLEIC High Energy Electron Cooler



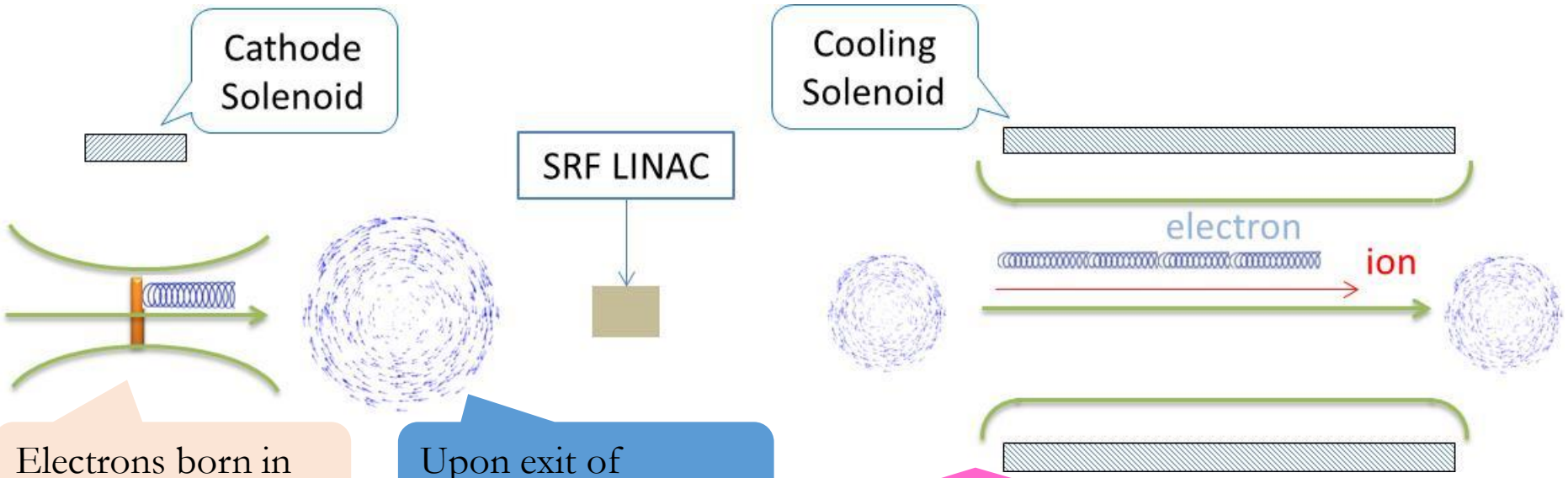
Magnetized Bunched-Beam Electron Cooling

- Ion beam cooling in presence of magnetic field is much more efficient than cooling in a drift (no magnetic field):
  - Electron beam helical motion in strong magnetic field increases electron-ion interaction time, thereby significantly improving cooling efficiency
  - Electron-ion collisions that occur over many cyclotron oscillations and at distances larger than cyclotron radius are insensitive to electrons transverse velocity
- Long cooling solenoid provides desired cooling effect:
  - Counteracting emittance degradation induced by intra-beam scattering
  - Maintaining ion beam emittance during collisions and extending luminosity lifetime
  - Suppressing electron-ion recombination

but putting the electron beam into the cooling solenoid represents a challenge

Magnetized Cooling Schematics

Electron beam suffers an azimuthal kick at entrance of cooling solenoid. But this kick can be cancelled by an earlier kick at exit of photogun. That is the purpose of cathode solenoid



Electrons born in strong uniform B_z

$$\langle L \rangle = \frac{eB_z a_o^2}{4}$$

$a_0 = R_{laser} = 3.14$ mm
$B_z = 0.5$ kG

Upon exit of Cathode Solenoid

$$\langle L \rangle = \gamma m_e \langle r^2 \rangle \dot{\phi}$$

$$\varepsilon_d = \frac{eB_z a_o^2}{8 m_e c} = 36\ \mu\text{m}$$

Upon entering Cooling Solenoid

$$\langle L \rangle = \frac{eB_{cool} r_e^2}{4}$$

$r_e = 0.7$ mm
$B_{cool} = 1$ T

$$\frac{B_{cool}}{B_z} = \frac{a_0^2}{r_e^2}$$

JLEIC Magnetized Source Requirements

Bunch length	60 ps (2 cm)
Repetition rate	43.3 MHz
Bunch charge	3.2 nC
Peak current	53.9 A
Average current	140 mA
Transverse normalized emittance	<19 microns
Cathode spot radius – Flat-top (a_0)	3.14 mm
Solenoid field at cathode (B_z)	0.5 kG

- Cornell University demonstrated 65 mA and 2 nC, but not at same time, and non-magnetized

- Fermilab Magnetized Photoinjector Laboratory:
  - Pulsed NCRF gun with Cs_2Te photocathode and UV laser (λ=263 nm)
  - Bunch charge: 0.5 nC and bunch length: 3 ps
  - 0.5% duty factor (average current: 7.5 μA)
    - Bunch frequency: 3 MHz
    - Macropulse duration: 1 ms
    - Number of bunches per macropulse: 3000
    - Macropulse frequency: 5 Hz

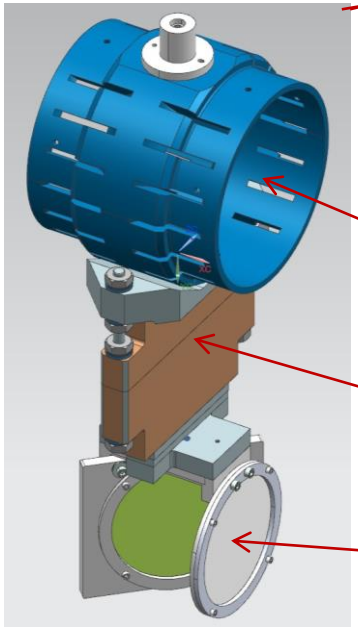
Magnetized Source Schematics

Photocathode Preparation Chamber

Gun HV Chamber

Beamline

Gun Solenoid



Shield Tube

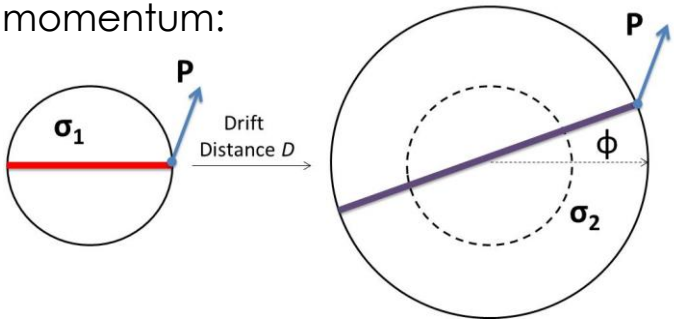
Slit

Viewer Screen

Viewer 3 Screen

Beam Dump

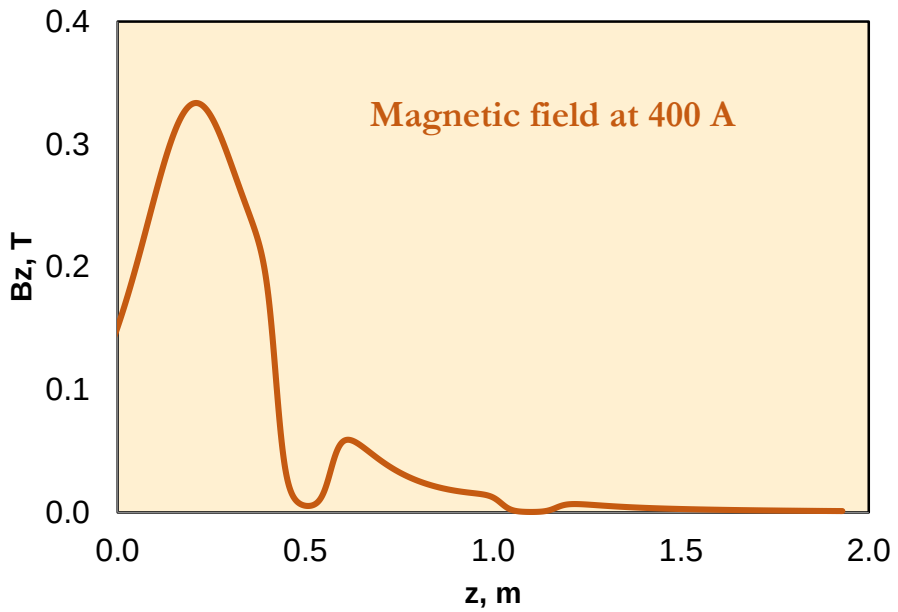
Use slit and viewscreens to measure mechanical angular momentum:

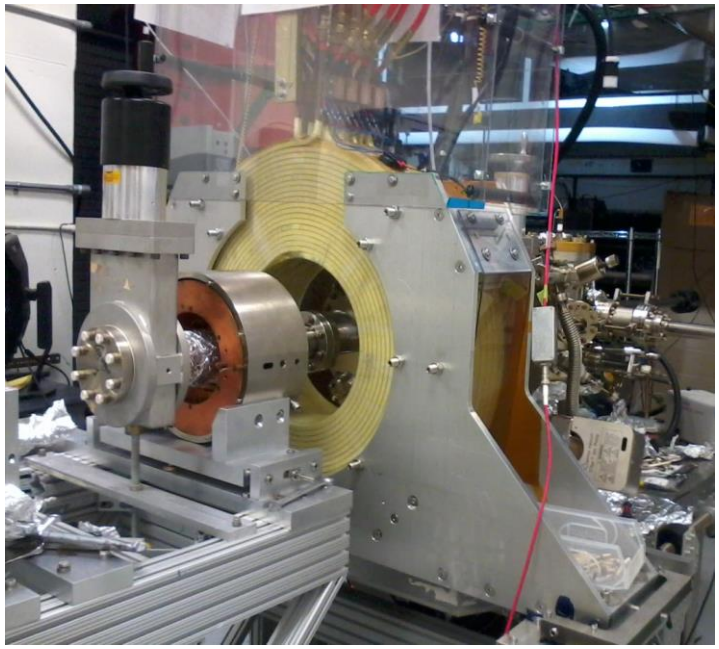


$$\langle L \rangle = 2 p_z \frac{\sigma_1 \sigma_2 \sin\varphi}{D} = e B_z a_o^2$$

B_z: solenoid field at photocathode
a_0: laser rms size
φ: rotation (sheering) angle

Gun Solenoid

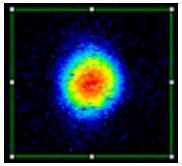


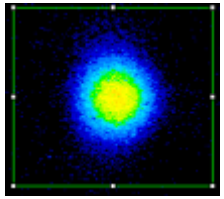


- Using spare CEBAF Dogleg magnet power supply (500 A, 80 V)
- Learned that gun solenoid **can** influence field emission
- First trials with gun at high voltage and solenoid **ON** resulted in new field emission and vacuum activity
- Procedure to energize solenoid without exciting new field emitters

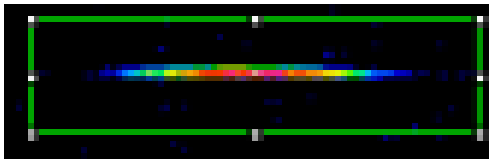
Slit and Viewscreen Measurement

0 G at photocathode

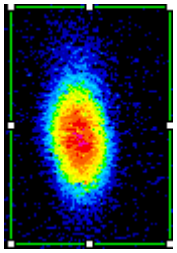


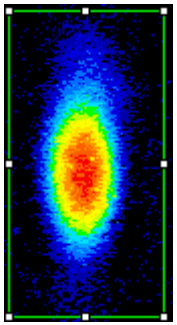


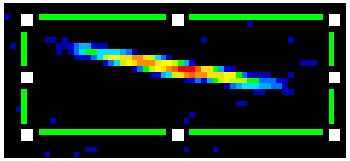
Beamlet observed on downstream viewer



1511 G at photocathode

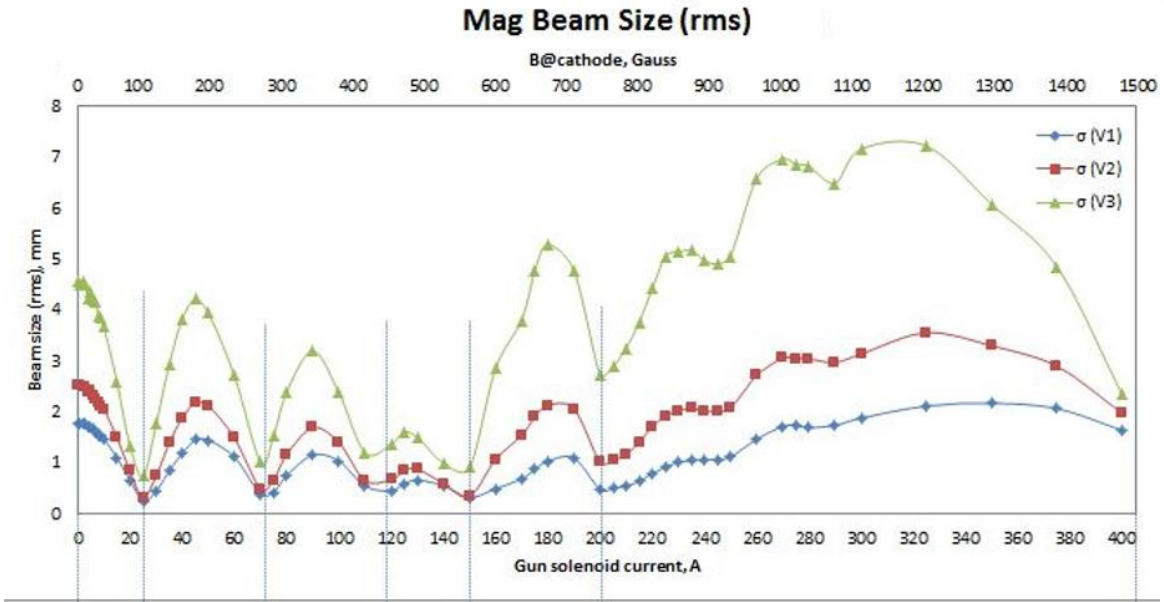




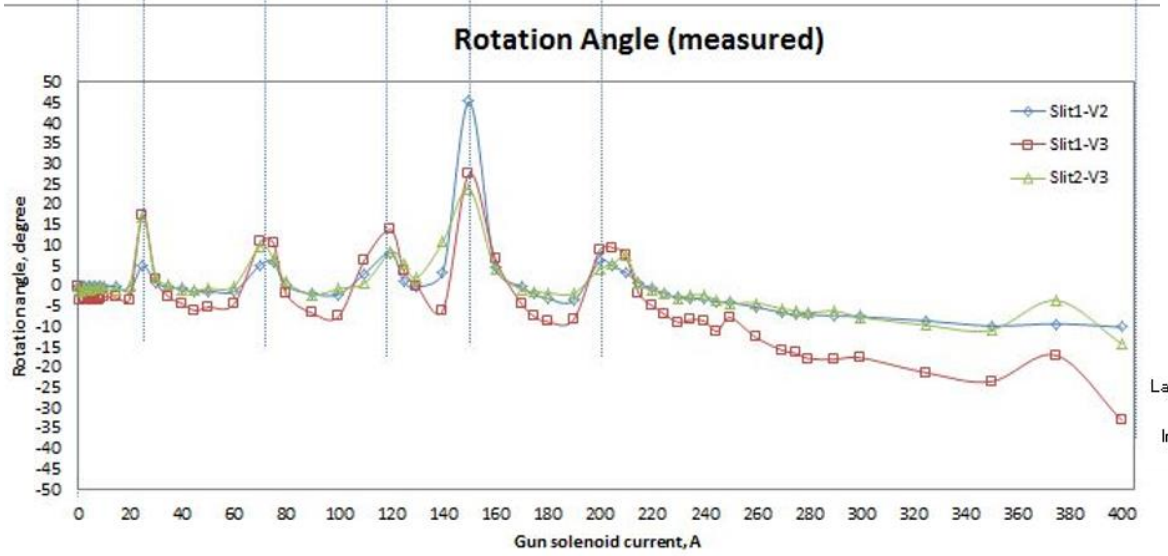


Beam Size Oscillation

Gun solenoid magnetizes beam but also focuses beam



Rotation angle influenced by Larmor oscillation in gun solenoid

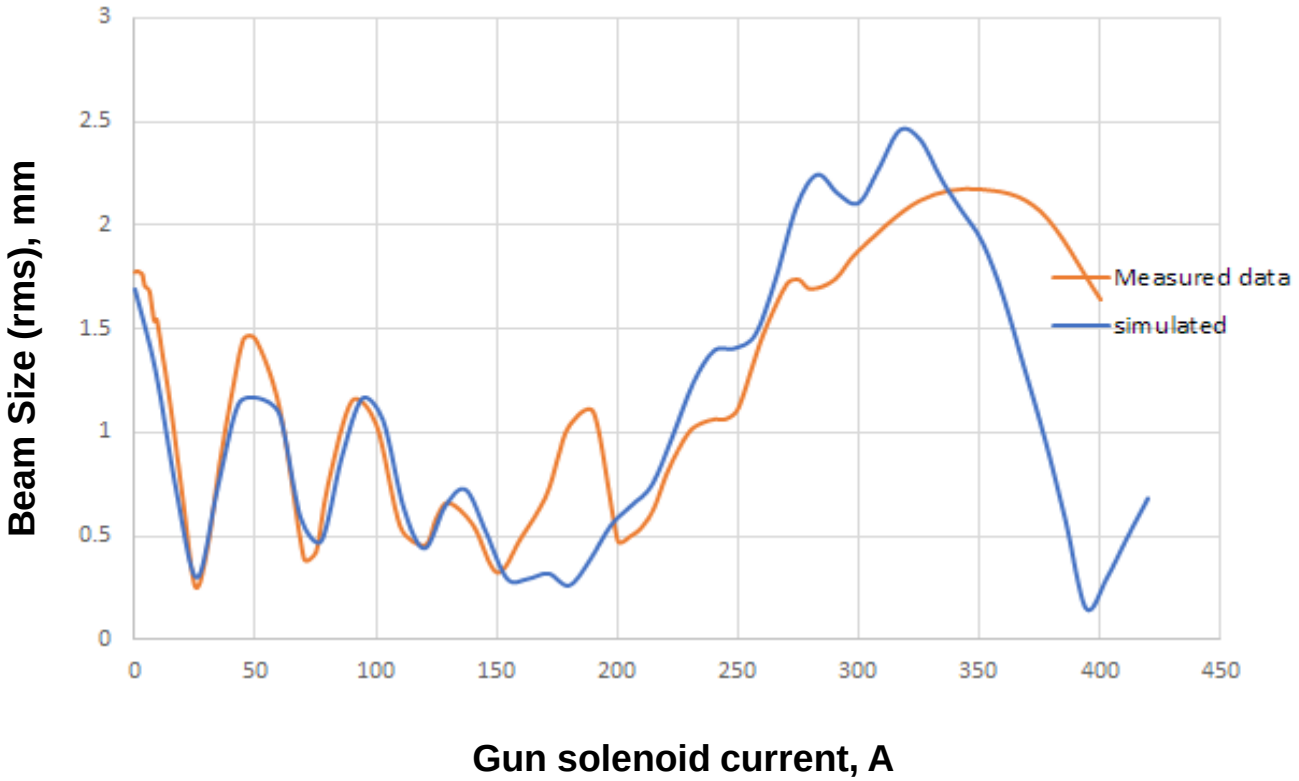


Three curves correspond to measurements at three beamline viewers

Laser spot size (rms), mm:	0.106		
for=>	S1-V2	S1-V3	S2-V3
Inter viewer distance, m:	0.5	2.2965	1.7965
Gun HV:	300 kV		

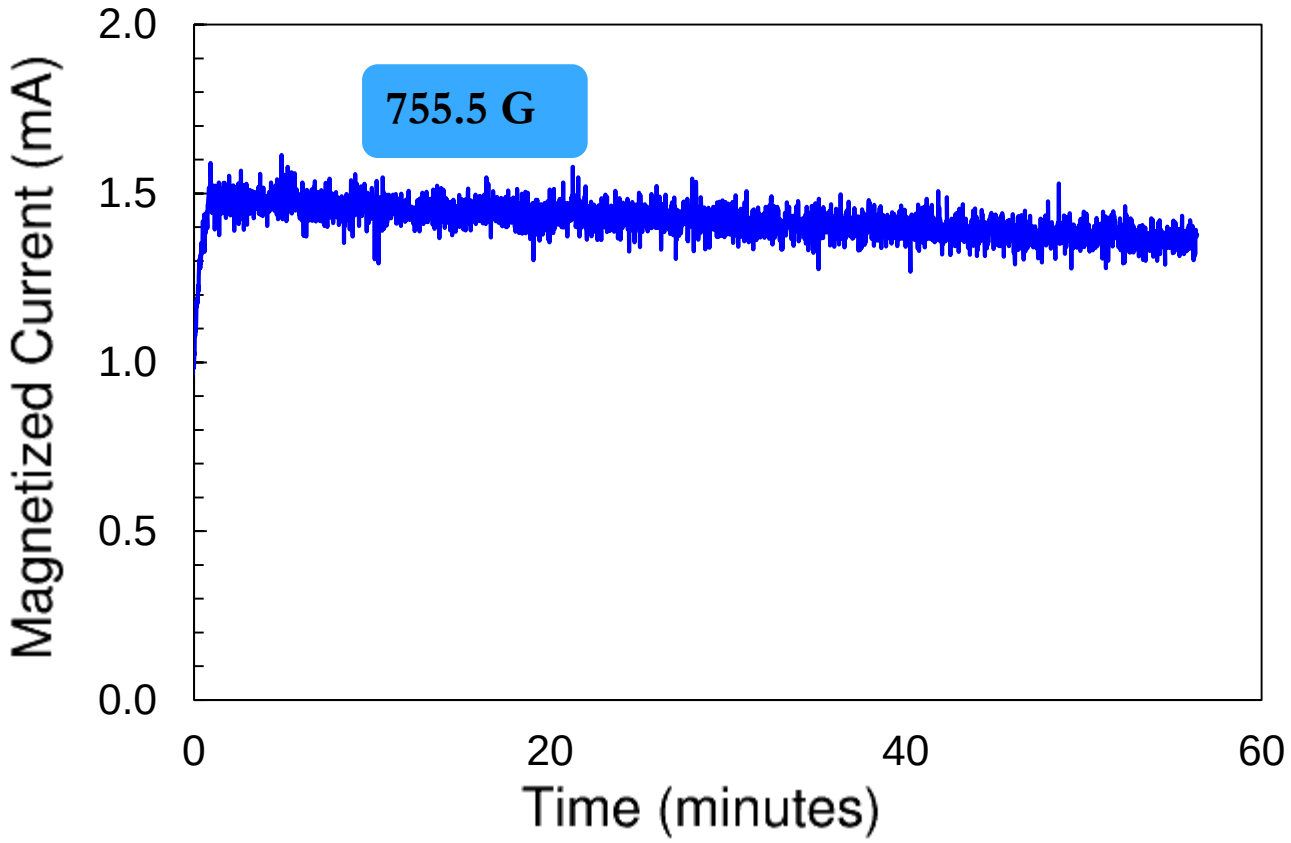
Beam Sizes on Viewer 1

Making good progress in modeling our apparatus and beam motion



Sajini's work

High Current Magnetized Beam



- Delivered 1.5 mA DC magnetized beam (QE limited, 0.3%)
- Investigating the efficacy and necessity of installed dc ion-clearing electrodes to stop ions in beamline from reaching gun and causing HV arcs

Summary

- K_2CsSb Photocathode Preparation Chamber, Gun, Solenoid and Beamline are all operational
- Photogun operates reliably at 300 kV
- Cathode solenoid can trigger field emission but we have learned how to prevent this
- Have successfully magnetized electron beam and measured rotation angle
- Preparing to install a modelocked drive laser, to generate mA magnetized beam with RF structure
- Then switch to 32 mA 225 kV HV power supply….

Thanks to the people involved in this team work:

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ODU Graduate Students