Production of Magnetized Electron Beam from a DC High Voltage Photogun

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Motivation

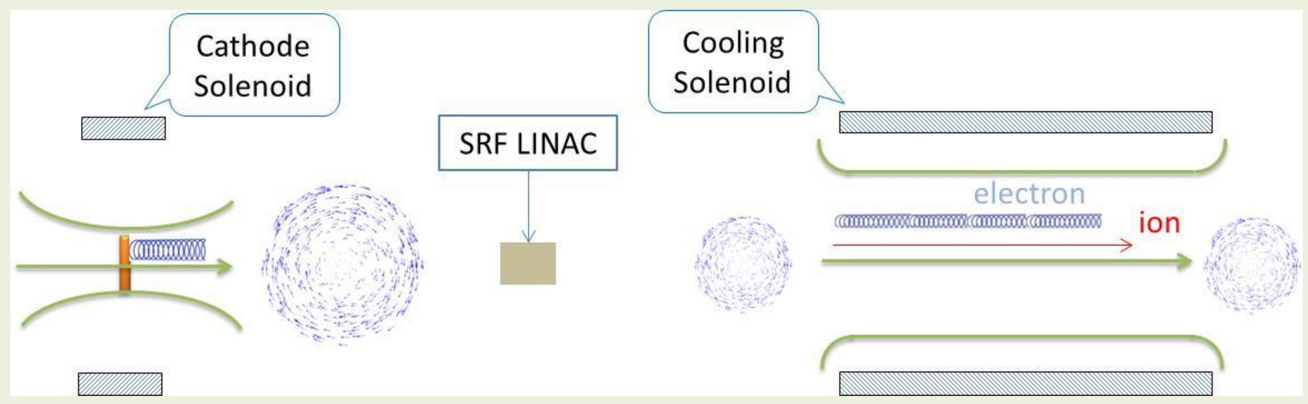
Jefferson Lab Electron Ion Collider (JLEIC) bunched magnetized electron cooler is part of Collider Ring and aims to counteract emittance degradation induced by intra-beam scattering, to maintain ion beam emittance during collisions and extend luminosity lifetime.

Magnetized 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
- Cooling rates are determined by electron longitudinal energy spread rather than electron beam transverse emittance as transverse motion of electrons is quenched by magnetic field
- Magnetic field suppresses electron-ion recombination

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 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

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

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

Upon entering Cooling Solenoid

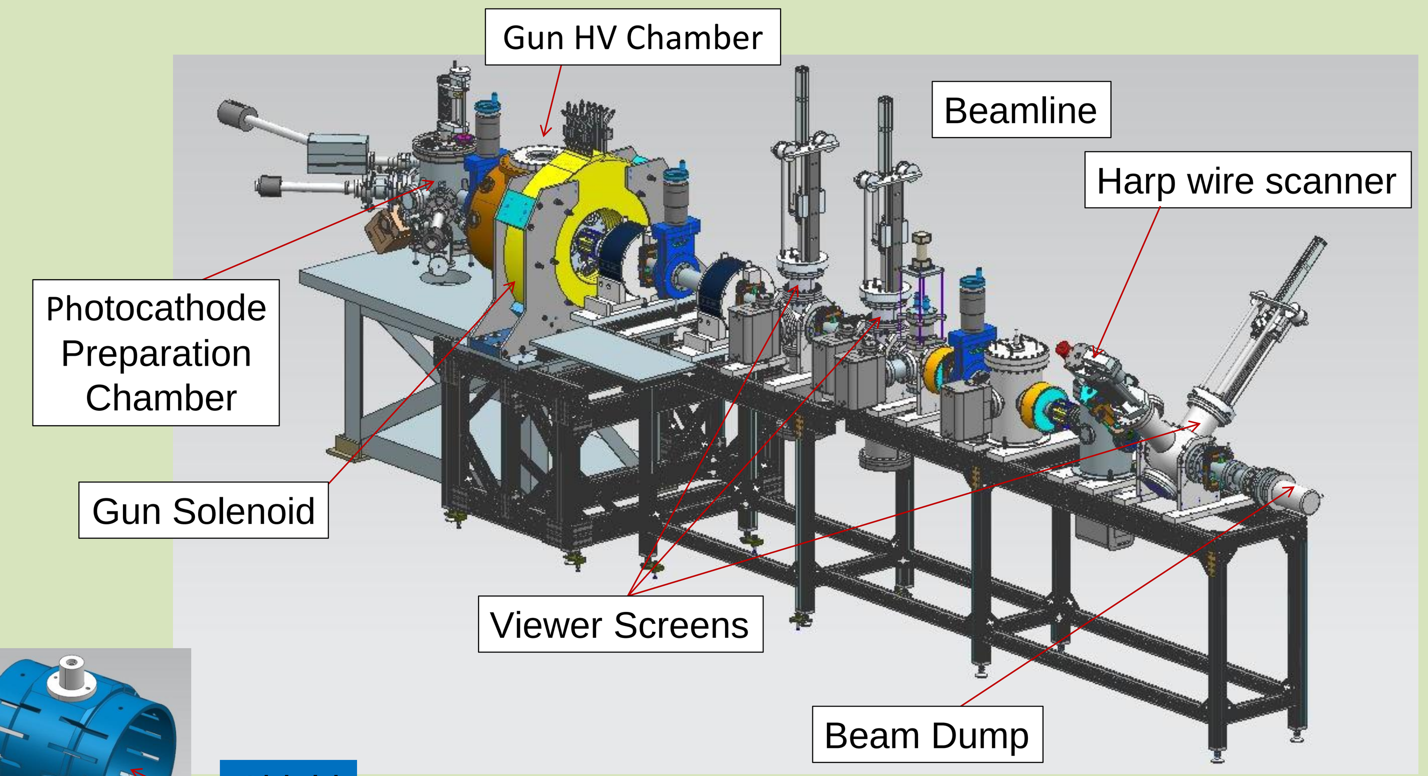
$$\langle L\rangle = \frac{eB_{cool} r_e^2}{4}$$

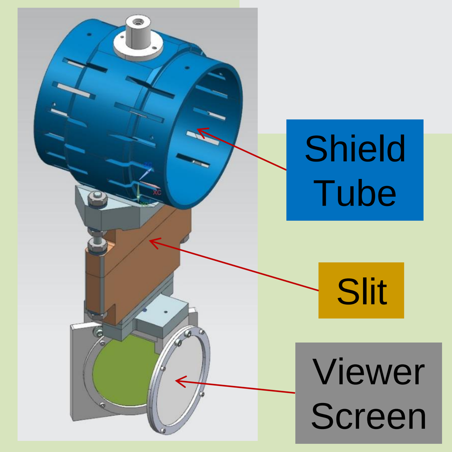
$r_e = 0.7$ mm
$B_{cool} = 1$ T

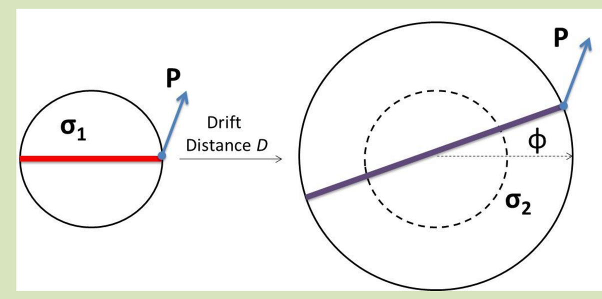
$$\frac{B_{cool}}{B_z} = \frac{a_0^2}{r_e^2}$$

Bunch length	60 ps (2 cm)
Repetition rate	43.3 MHz
Bunch charge	3.2 nC
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)	500 G

Experimental Overview







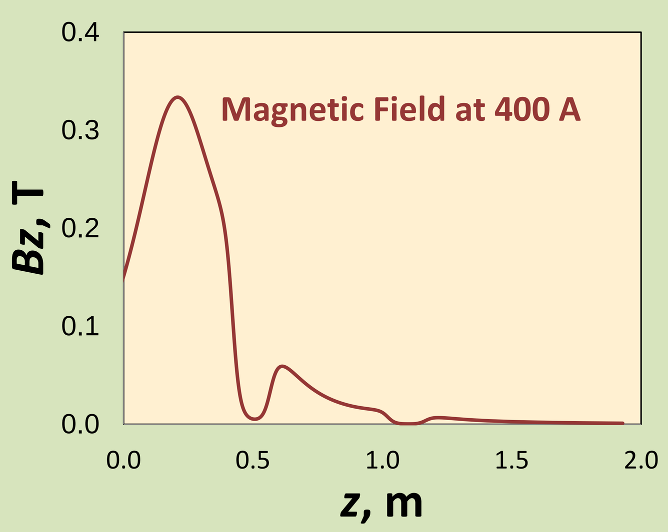
$$\epsilon_d = \frac{eB_z a_0^2}{2m_e c} = \frac{\langle L\rangle}{2m_e c}$$

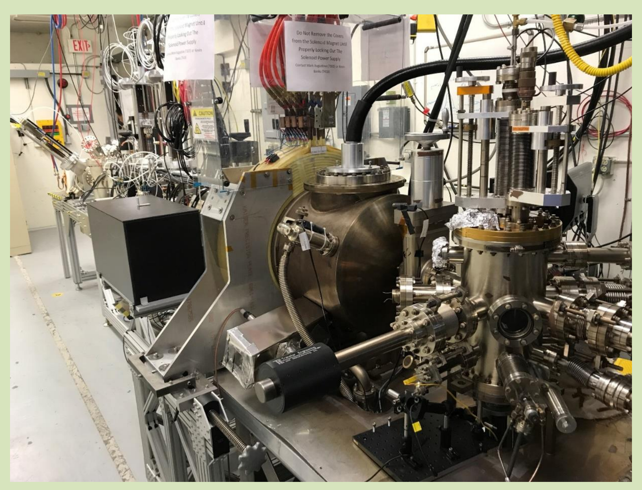
$$=> \langle L\rangle = 2\epsilon_d m_e c$$

- Use slit and viewscreens to measure beam size and rotation angle
- Use wire scanner (harp) to measure drift emittance and evaluate beam magnetization

P: transverse momentum
σ: beam rms size
Φ: rotation (sheering) angle
$\langle L\rangle$: canonical ang. momentum
ϵ_d: drift/magnetized emittance
B_z: long. mag. field at cathode
a_0: laser rms size

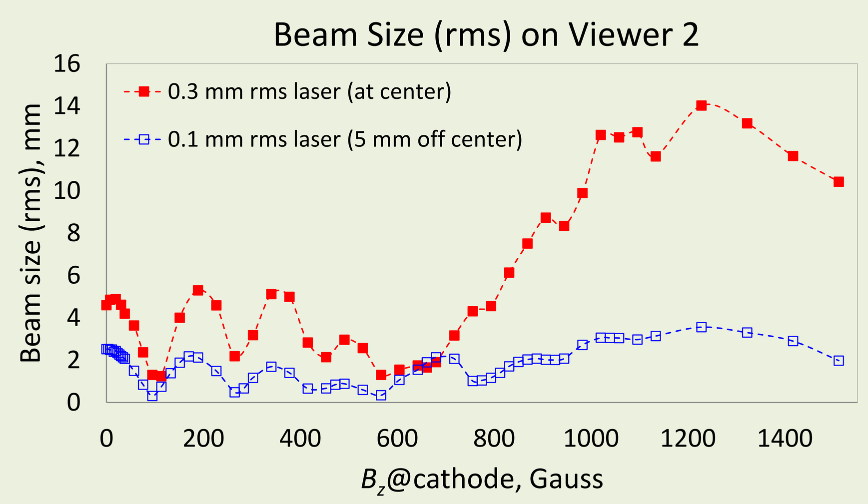
Gun Solenoid

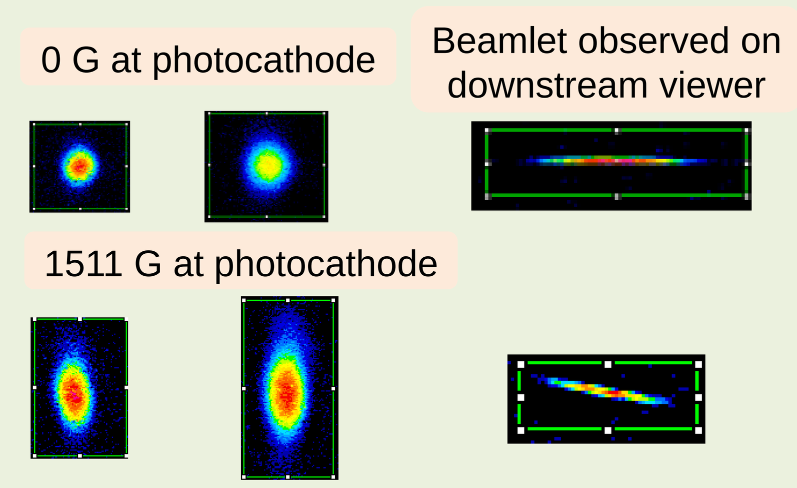


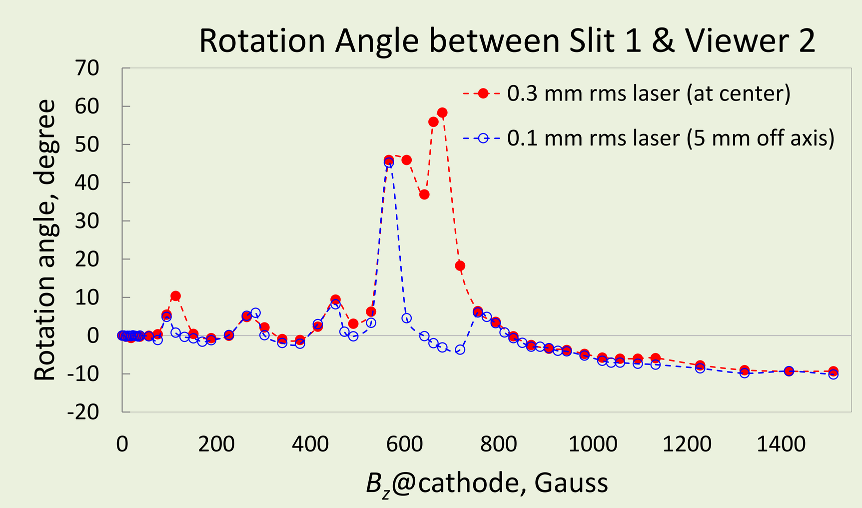


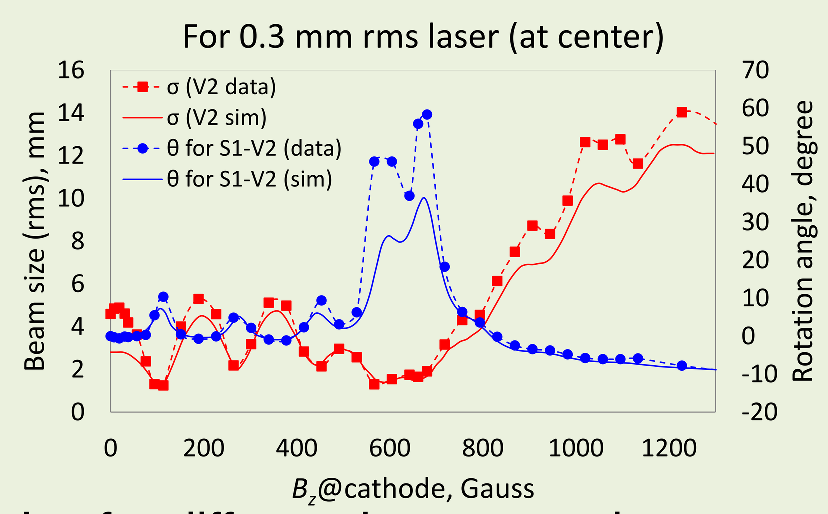
- Using spare CEBAF Dogleg magnet power supply (400 A, 80 V)
- Learned that gun solenoid **can** influence field emission
- First trials with gun at high voltage and solenoid **ON** resulted in new field emission and vacuum activity
- Procedure to energize solenoid without exciting new field emitters

Magnetization Measurements









- Measured beam sizes and rotation angles for different laser spot sizes
- Rotation angles are influenced by Larmor oscillation in gun solenoid
- Making good progress in simulating magnetized beam using ASTRA & GPT

Summary & Plans

- K_2CsSb Photocathode Preparation Chamber, Gun HV 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
- Delivered 4.5 mA DC magnetized beam
- Installed Harp to measure emittance
- Installed a gain-switched drive laser, to generate mA magnetized beam with RF structure
- Run bunch charge up to 3 nC using the regenerative amplifier laser and characterize the space-charge effect on beam magnetization
- Measure drift emittance and angular momentum
- Install and test TE_{011} cavity to measure beam magnetization
- Switch to 32 mA 225 kV HV power supply

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