Generation and Characterization of Magnetized Bunched Electron Beam from DC Photogun for JLEIC Cooler

Laboratory Directed Research and Development (LDRD) Proposal

Riad Suleiman and Matt Poelker

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JLEIC Magnetized Beam LDRD

- Generate magnetized electron beam and measure its properties

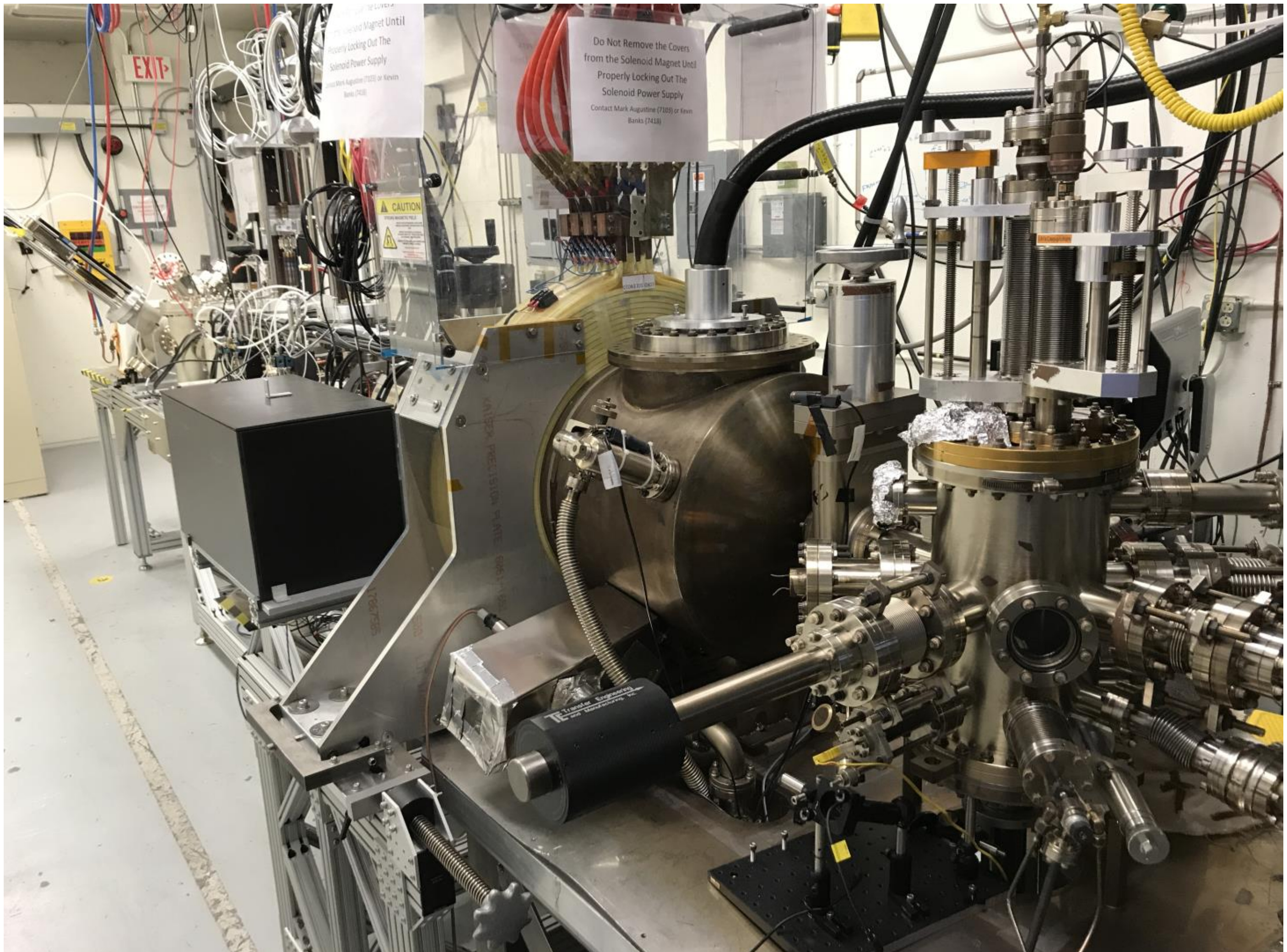
- Explore impact of cathode solenoid on photogun operation

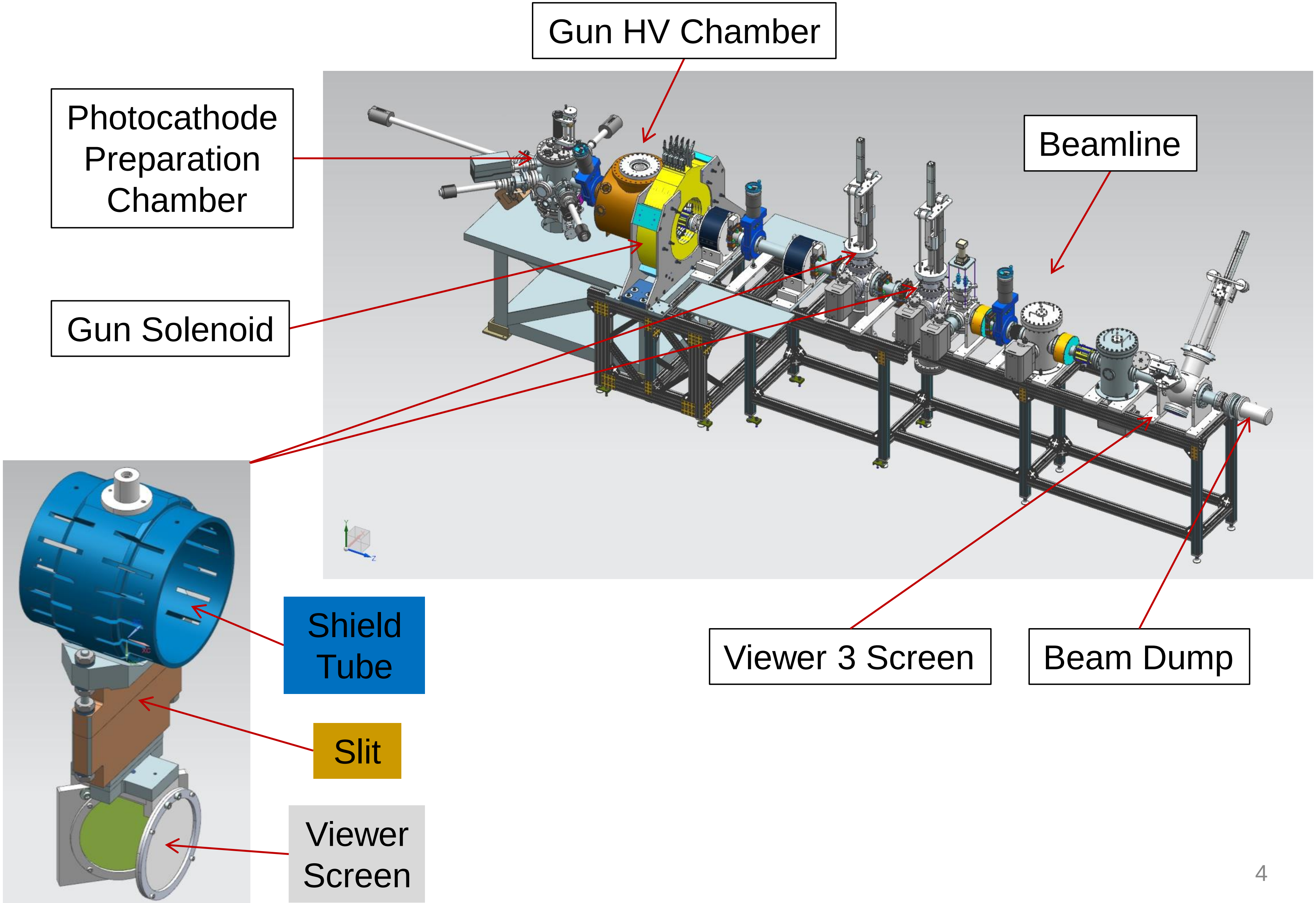
- Simulations and measurements will provide insights on ways to optimize JLEIC electron cooler and help design appropriate source

- JLab will have direct experience magnetizing high current electron beam

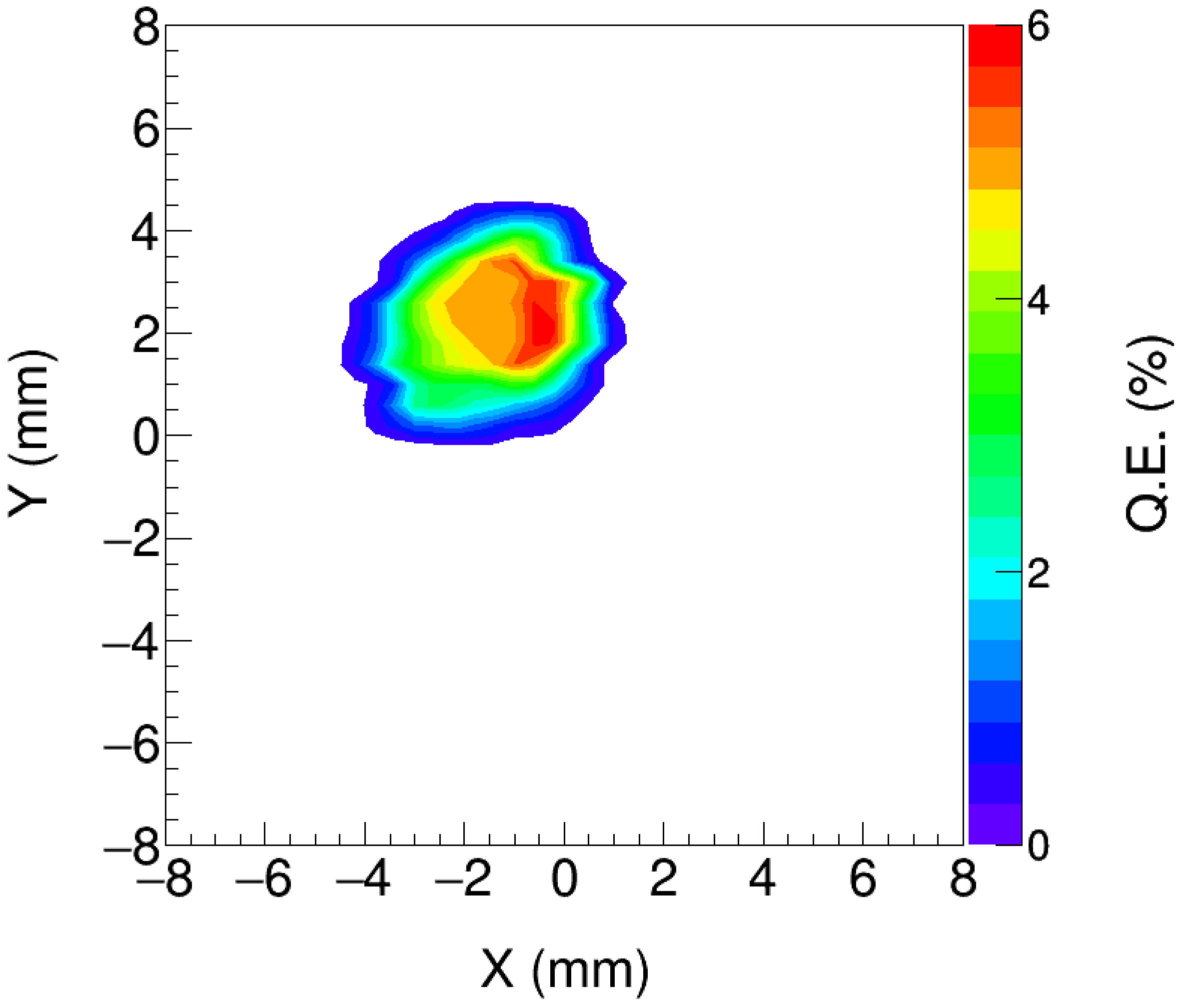
Magnetized Electron Source at GTS

- K_2CsSb Photocathode Preparation Chamber, Gun, Solenoid and Beamline are all operational




Gun HV Chamber
Photocathode Preparation Chamber
Beamline
Gun Solenoid
Shield Tube
Slit
Viewer Screen
Viewer 3 Screen
Beam Dump

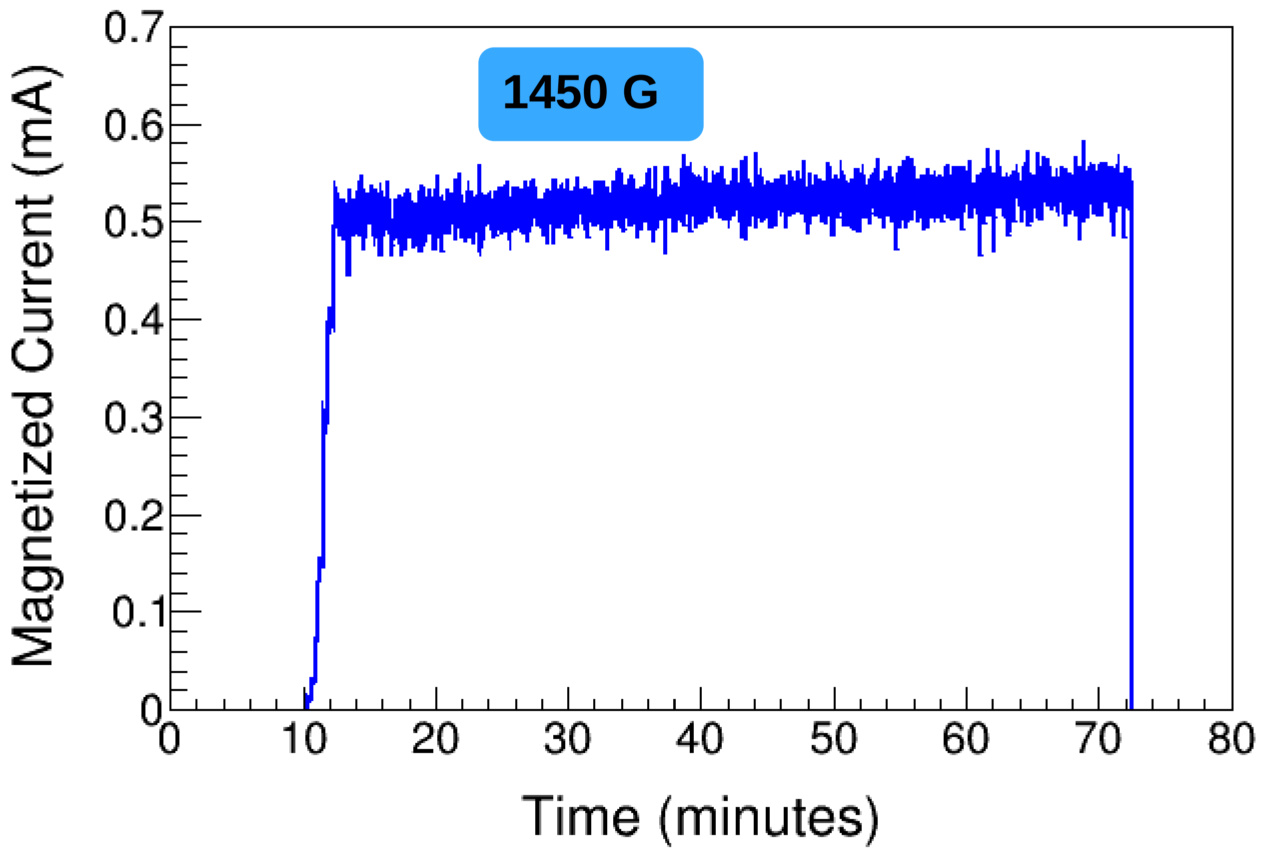
K_2CsSb Quantum Efficiency ~ 6%



- K_2CsSb grown with a mask – limit photocathode active area (3 mm diameter) to reduce beam halo
- Active area can be offset from electrostatic center
- 5 mm active area also available
- Entire photocathode can be activated too

Work of M. Mamun and Y. Wang

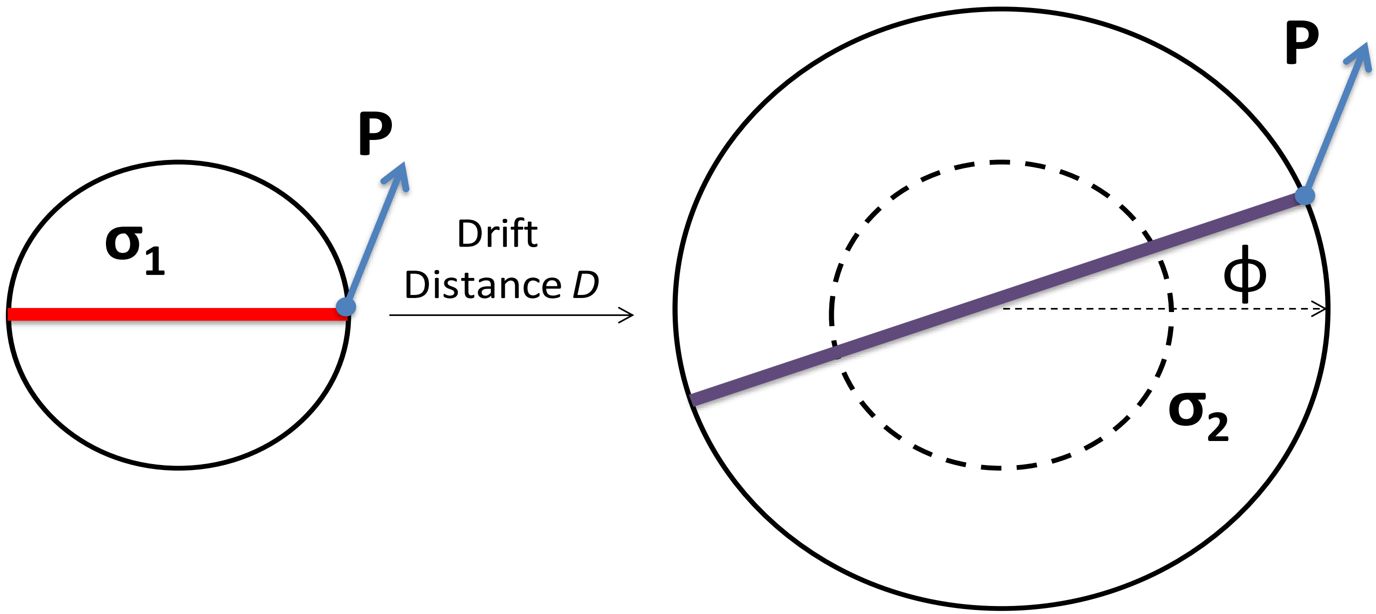
High Current Magnetized Beam



- ➢ Delivered 0.5 mA dc
- ➢ Plan for 5 mA by end of summer

Measuring Beam Magnetization

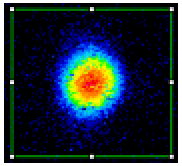
- Use slit and viewscreens to measure mechanical angular momentum:

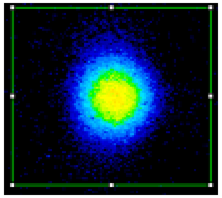


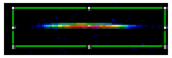
$$\langle L \rangle = 2p_z \frac{\sigma_1 \sigma_2 \sin\phi}{D} = eB_z a_o^2$$

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

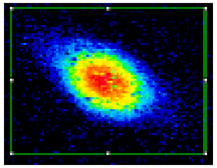
0 G
at photocathode

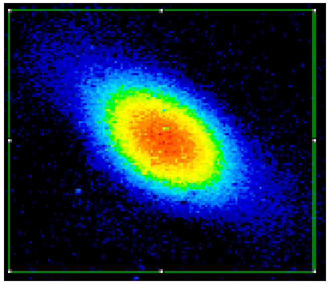


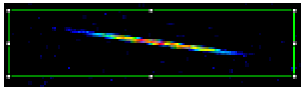


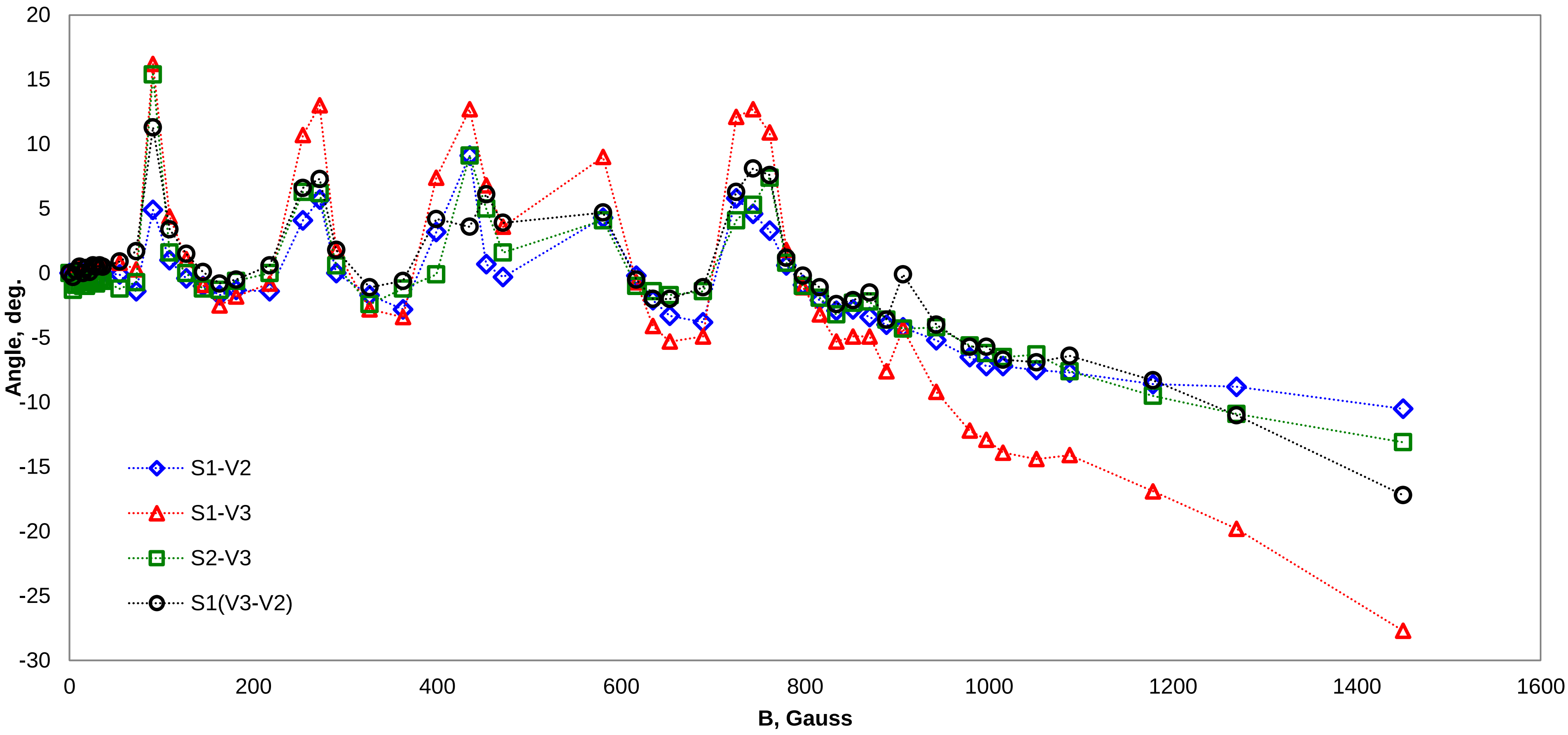


1088 G
at photocathode





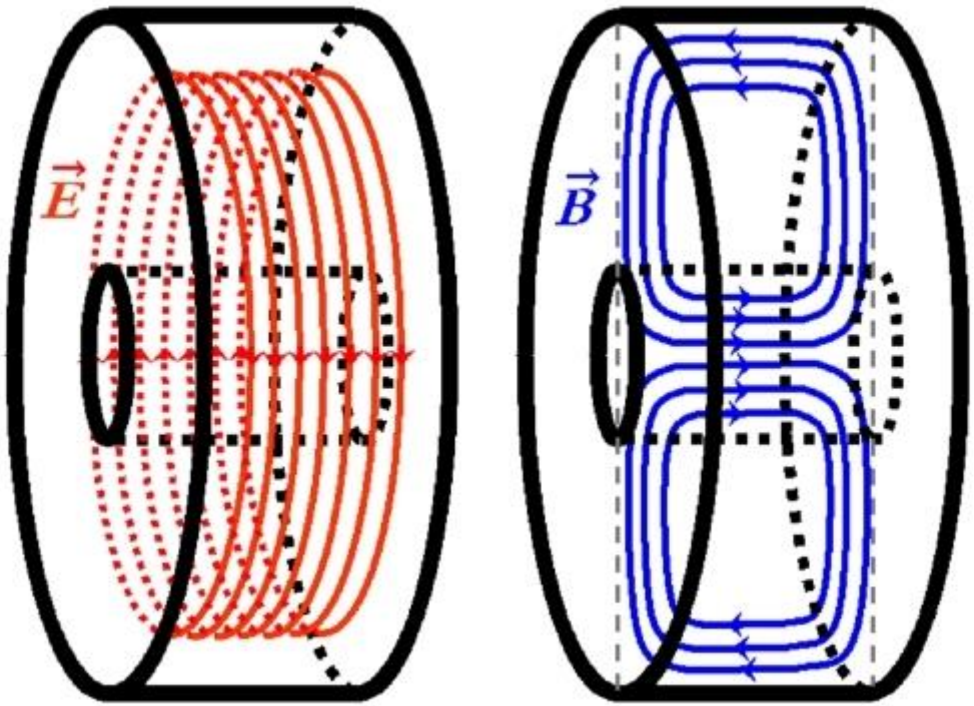




Work of M. Mamun

TE_{011} Cavity: non-invasive technique

- New non-invasive technique to measure beam magnetization
- Filed inventor disclosure entitled “Non-invasive RF Cavity to Measure Beam Magnetization”



Summary and Outlook

- 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

- Continue to characterize magnetized beam and cross check measurements with simulation
- Install RF pulsed laser
- Demonstrate 32 mA
- Build and install TE_{011} cavity at GTS to measure beam magnetization in collaboration with Brock and SRF Institute

Next: Funded Phase-II SBIR with Xelera, to develop rf-pulsed dc high voltage thermionic gun to be installed at GTS in 2019

Budget

FY16	$339,211
FY17	$265,850
FY18	$285,966
Total	**$891,027**

As of today, spent 65%

Materials and Supplies:

1. TE_{011} copper pillbox cavity
2. Three skew quadrupoles
3. Laser components
4. Travel to conferences

Labor:

1. Mechanical designer for TE_{011} cavity
2. ASTRA and GPT modeling (Fay Hannon)
3. Postdoc

Sajini Wijethunga, student from ODU started her Ph.D. thesis on magnetized beam (advisor: Jean Delayen, funded by 75% JLab + 25% ODU)

Questions to be addressed in your June 28th presentation

Could the authors please provide a reasonably detailed spreadsheet of 2018 purchases, categorized in terms of, for example, the main items to be purchased and their cost?

In accordance with the rules for LDRD funded projects, it is essential that the project be fully completed in 2018; review your plan and milestones to ensure this will be the case.

- LDRD Goals and Purchases (this year remaining direct money – $10k parts and $54k labor):
  1. 32 mA HV Power Supply: cables ordered – complete
  2. RF Laser: Diode laser ordered – complete
  3. High Bunch Laser: mirrors, synchronization electronics – $10k
  4. Round to Flat Beam Transformation: three skew quads – need to design and procure – $9k (use labor money)
  5. TE_{011} Cavity: requested $20k in 2018

MILESTONES

Year 1 Milestones

- Q1 (Oct, Nov, Dec):
  1. HV condition gun to 350 kV and build K_2CsSb preparation chamber ☑
  2. Design beamline, locate magnets and diagnostics at optimum positions ☑
  3. Design cathode solenoid magnet ☑

- Q2 (Jan, Feb, Mar):
  1. Connect existing beamline to gun and instrument beamline ☑
  2. Procure cathode solenoid magnet ☑
  3. Design and procure slits ☑

- Q3 (Apr, May, Jun):
  1. Commission exiting beamline with beam ☑
  2. Measure photocathode lifetime at ~~5~~ 1 mA and ~~350~~ 350 kV (non-magnetized) ☑
  3. Relocate new spare CEBAF dogleg power supply to GTS ☑

- Q4 (Jul, Aug, Sep):
  1. Install cathode solenoid magnet ☑
  2. Assemble new beamline and commission with beam ☑

Year 2 Milestones

- Q1 (Oct, Nov, Dec):
  1. Generate magnetized beam ☑
  2. Measure mechanical angular momentum vs magnetization and laser size on photocathode ☑
  3. Benchmark simulation against measurements ☑

- Q2 (Jan, Feb, Mar):
  1. Measure mechanical angular momentum vs magnetization and laser size
  2. Benchmark simulation against measurements

- Q3 (Apr, May, Jun):
  1. Measure photocathode lifetime vs magnetization at 5 mA and 300 kV
  2. Study beam halo and beam loss vs magnetization
  3. Design TE_{011} cavity to measure beam magnetization

- Q4 (Jul, Aug, Sep):
  1. Measure mechanical angular momentum vs bunch charge
  2. Generate very high currents magnetized beam and study beam transport vs electron bunch charge
  3. Design and procure three skew quads

Year 3 Milestones

- Q1 (Oct, Nov, Dec):
  1. Commission TE_{011} cavity with beam
  2. Install three skew quads
  3. Generate flat beam with skew quads – RTFB Transformer – and measure horizontal and vertical emittances using slit method

- Q2 (Jan, Feb, Mar):
  1. Measure RTFB transformation versus electron bunch charge
  2. Use simulation to quantify how good or complete RTFB transform

- Q3 (Apr, May, Jun):
  1. Change to HV Supply of 32 mA and 200 kV

- Q4 (Jul, Aug, Sep):
  1. Measure photocathode lifetime vs magnetization at 32 mA and 200 kV
  2. Study beam halo and beam loss vs magnetization