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

Laboratory Directed Research and Development (LDRD) Proposal

Riad Suleiman and Matt Poelker

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# Outline

- Magnetized Cooling
- Electron Beam Requirements
- Generation of Magnetized Beam
- Proposed Measurements:
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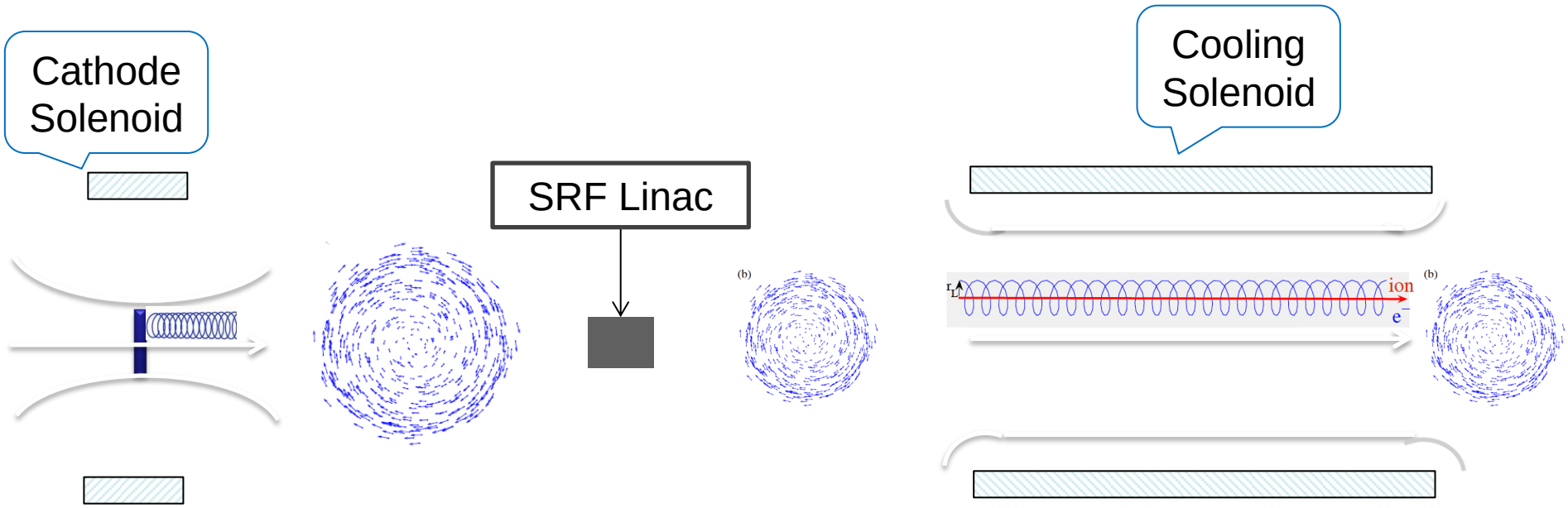
  II. Round-to-Flat Beam (RTFB) transformation
  III. Magnetized beam transport
  IV. Magnetized photocathode lifetime
  V. Beam halo and beam loss
- Work Place: FEL Gun Test Stand
- Budget

# Magnetized Cooling




Electrons born in uniform $B_z$

$$\langle L \rangle = eB_z a_o^2$$

$a_0 = R_{laser} = 3$ mm
$B_z = 2$ kG

Upon exit of Cathode Solenoid

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

$$\varepsilon_d = \frac{eB_z a_o^2}{2m_e c} = 528\ \mu m$$

Upon entering Cooling Solenoid

$$\langle L \rangle = eB_{cool}\sigma_e^2$$

$\sigma_e = 0.95$ mm
$B_{cool} = 2$ T

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

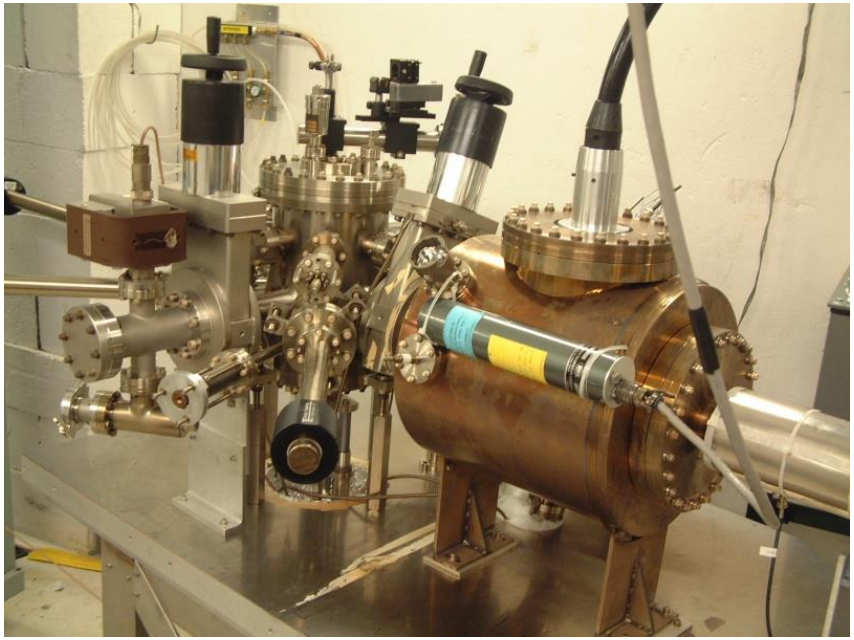
# Bunched Magnetized Gun Requirements

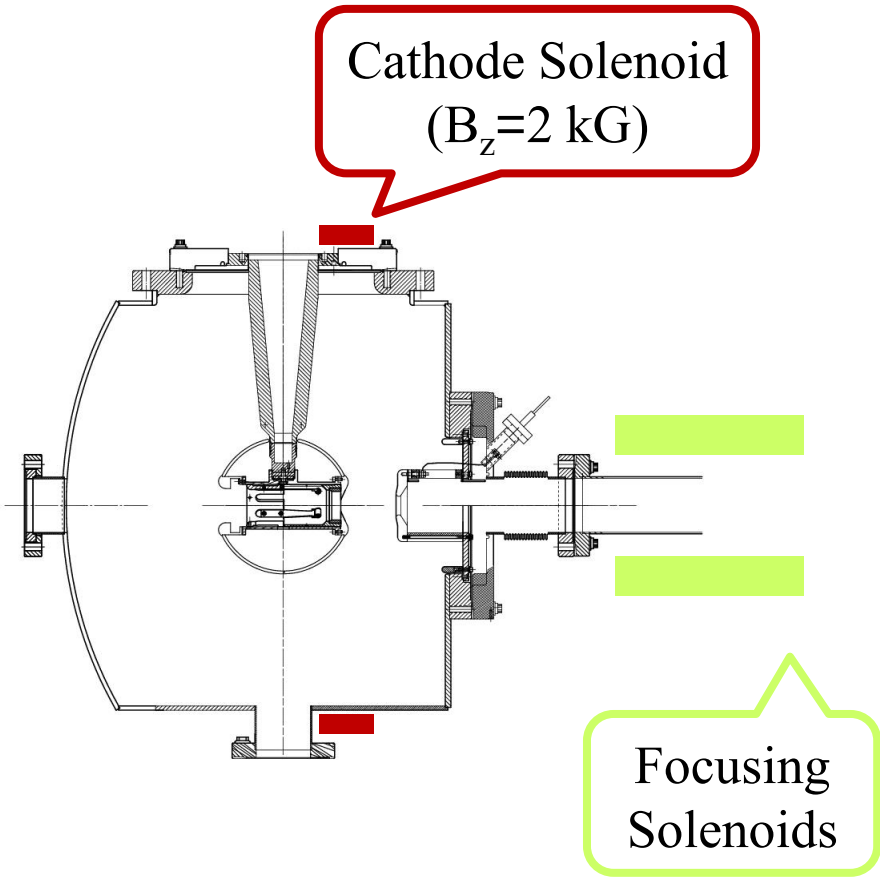
| | |
|---|---|
| Bunch length | 100 ps (3 cm) |
| Repetition rate | 476 MHz |
| Bunch charge | 420 pC |
| Peak current | 4.2 A |
| Average current | 200 mA |
| Emitting radius ($a_0$) | 3 mm |
| Transverse normalized emittance | 10s microns |
| Solenoid field at cathode | 2 kG |

# Generation of Magnetized Beam

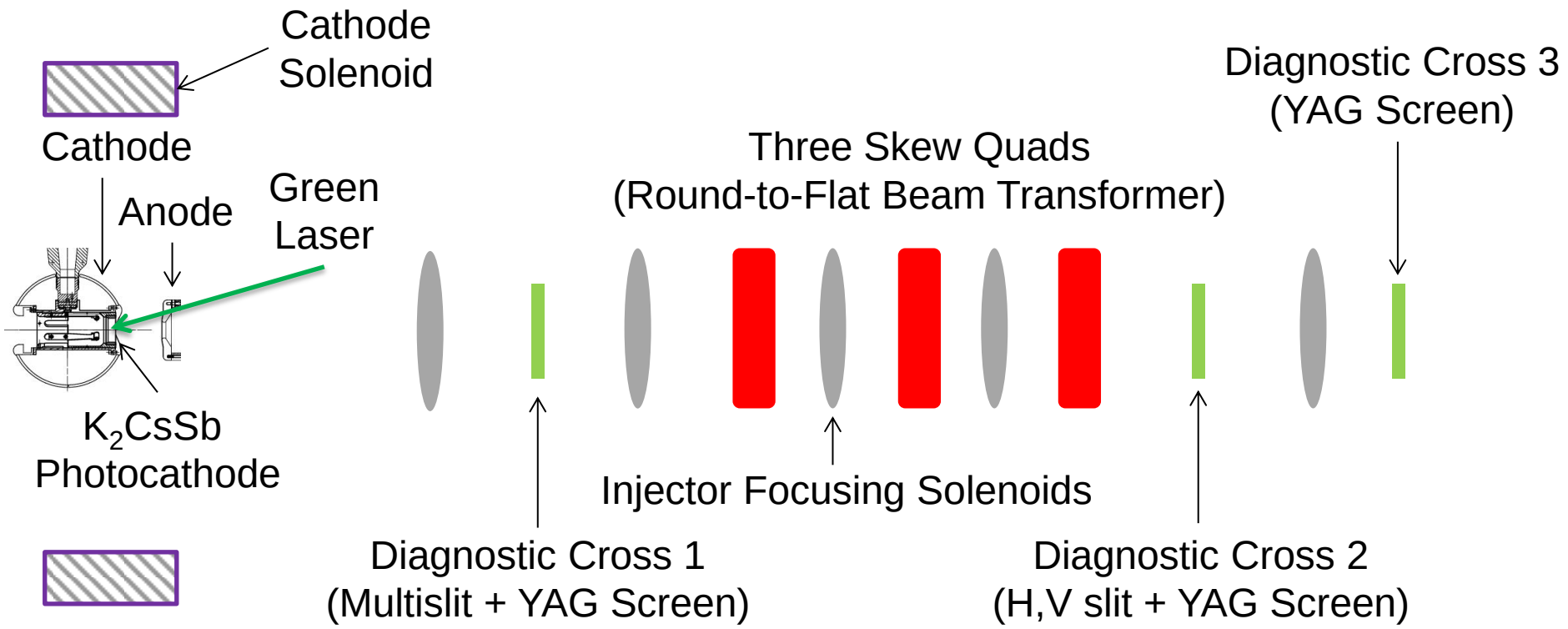
I. Cathode Solenoid:
- To produce magnetized beam

II. Injector Focusing Solenoids:
- For magnetized beam transport
- To compensate space-charge emittance growth





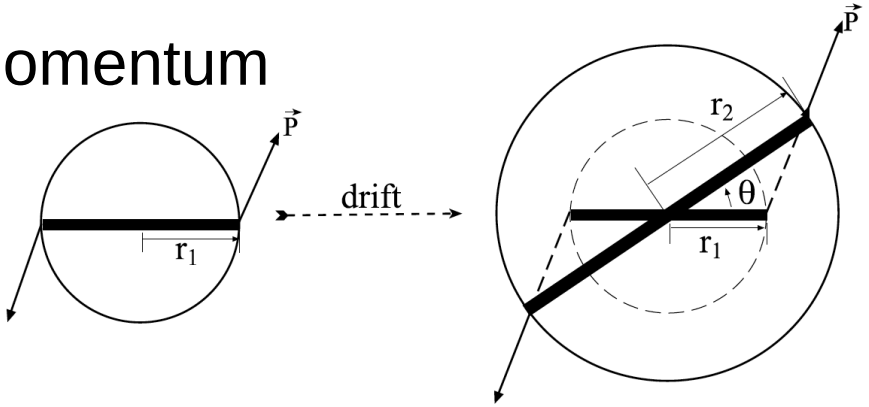
# Proposed Beamline




- Generate magnetized beam:
  - $a_0$ = 0.1 – 3 mm, $B_z$ = 0 – 2 kG
  - Bunch charge: 1 – 500 pC
  - Bunch length: 100 – 1000 ps
  - Repetition Rate: 4.76 – 476 MHz
  - Average beam currents up to 30 mA
  - Gun high voltage: 200 – 350 kV

# Proposed Measurements

1. Measure mechanical angular momentum (skew quads off)

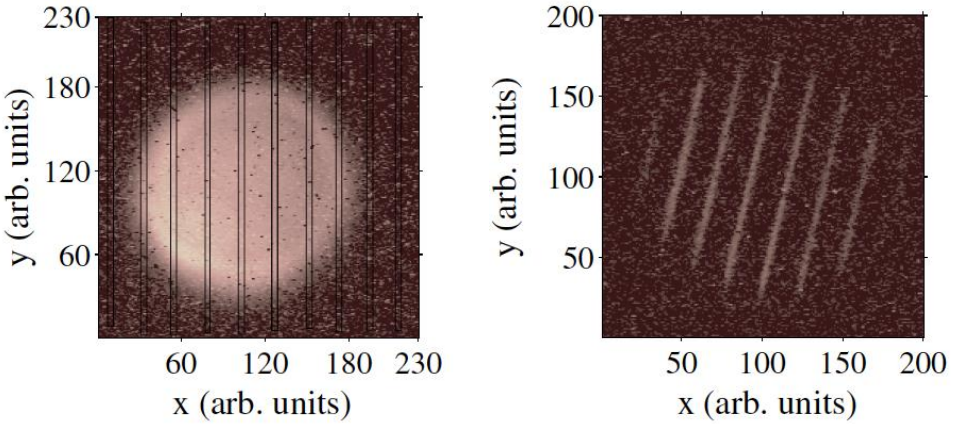



$\sigma_1$ beam radius measured at Diagnostic Cross 1
$\sigma_2$ beam radius measured at Diagnostic Cross 2
*D* drift between two crosses
$p_z$ beam longitudinal momentum

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

- Angular rotation ϕ is measured from beam image at Cross 2 when multislit is inserted at Cross 1

Example of mechanical measurement at Fermilab (Piot et al.)



2. Use three skew quads – RTFB Transformer – to generate a flat beam with transverse emittance ratios of:

$$\frac{\varepsilon_x^n}{\varepsilon_y^n} = \frac{\varepsilon_d}{\varepsilon_{th}} >> 1$$

- Measure horizontal and vertical emittances using slit method
- Cross 2 will be equipped with a horizontal and vertical slits
- Measure size of emittance dominated beamlets passed through slits, after drift distance *D*, with YAG viewer in Cross 3
- Assume horizontal beam radius measured at Cross 2 is $\sigma_{2h}$ and horizontal radius of beamlet at Cross 3 is $\sigma_{3h}$ when vertical slit is inserted at Cross 2, then horizontal emittance is

$$\varepsilon_x^n = \gamma \sigma_{2h} \sigma_{3h} / D$$

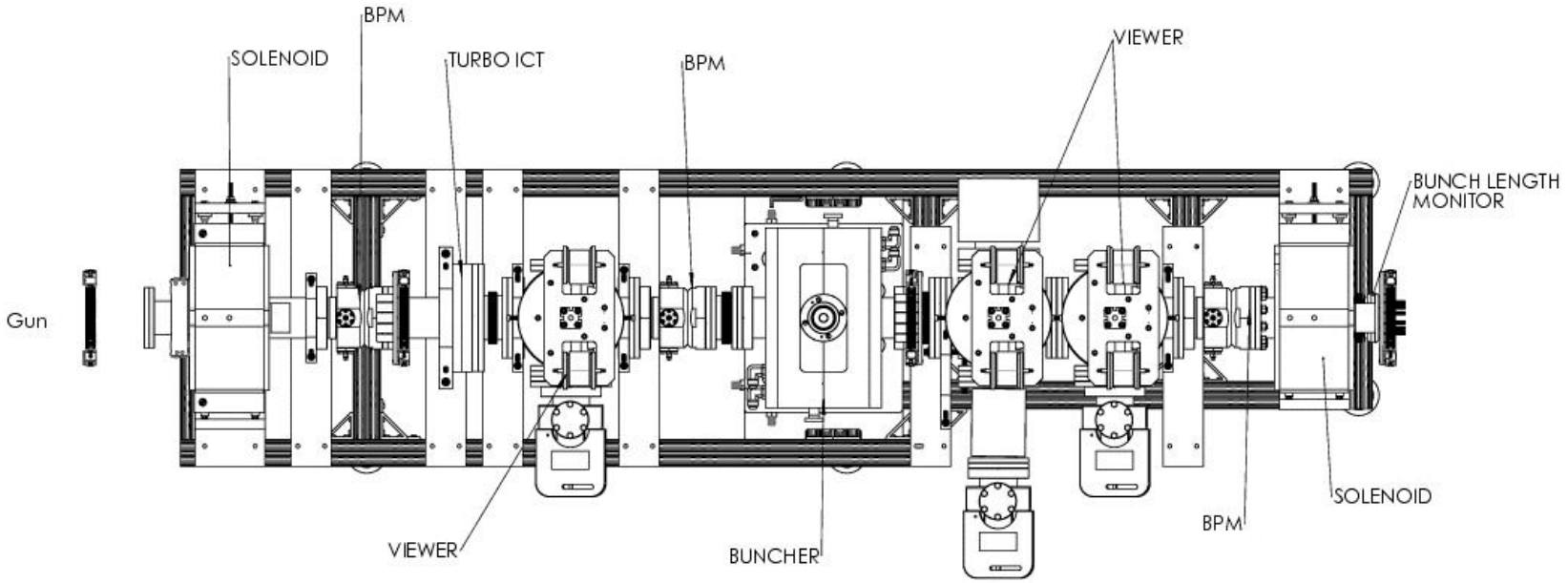
- Similarly, measure vertical emittance using horizontal slit

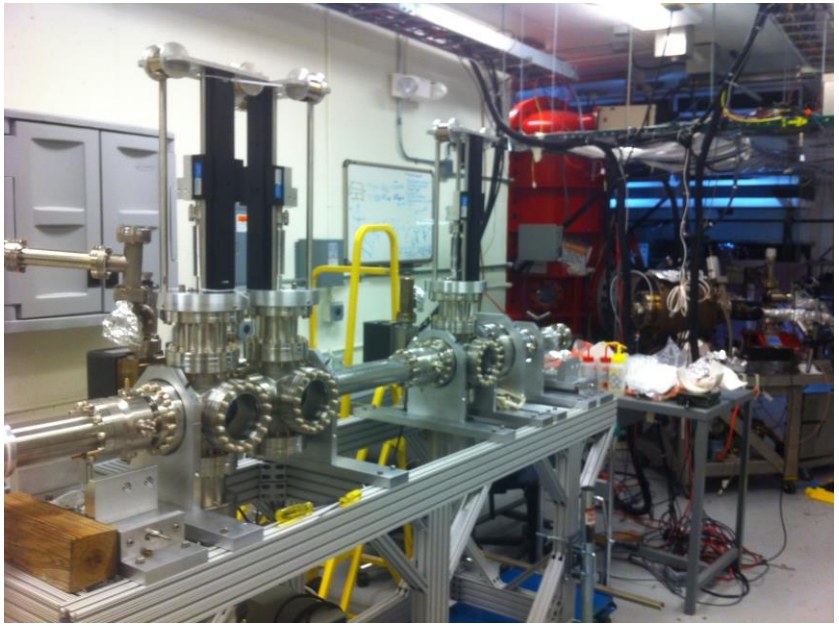
3. Generate very high currents magnetized beam and study beam transport and RTFB transformation versus electron bunch charge

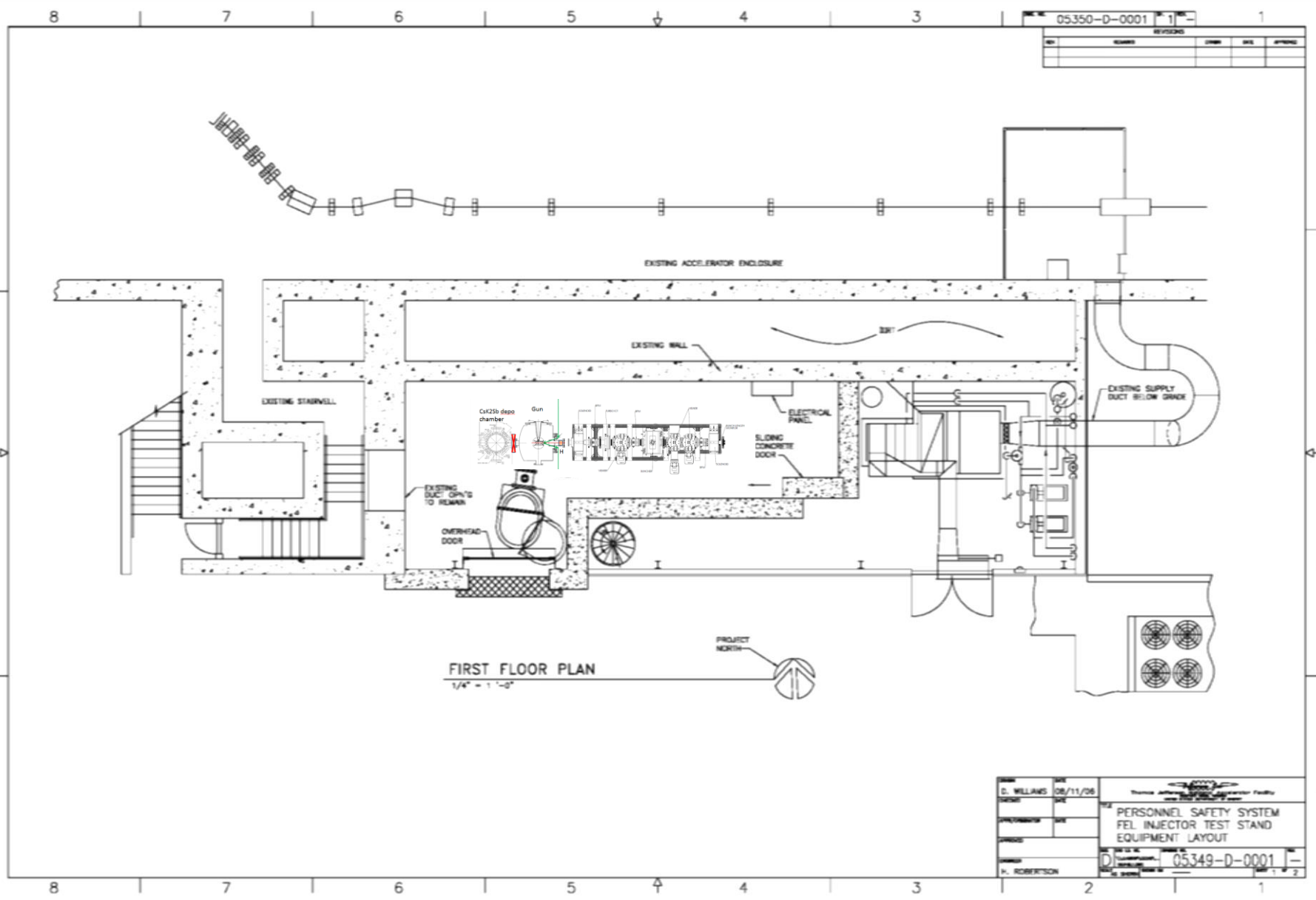
4. Measure photocathode lifetime versus solenoid field at high currents (up to 30 mA) and high voltages (200 – 350 kV) limited by HV supplies we have

5. Study beam halo and beam loss versus magnetization:
   I. Monitor vacuum using ion pumps with very sensitive current readback
   II. Measure radiation with x-ray detectors placed around gun and beamline
   III. Measure beam intercepted at floating anode

# FEL Gun Test Stand




05350-D-0001
EXISTING ACCELERATOR ENCLOSURE
EXISTING WALL
EXISTING STAIRWELL
CsK2Sb depo chamber
Gun
ELECTRICAL PANEL
SLIDING CONCRETE DOOR
EXISTING SUPPLY DUCT BELOW GRADE
EXISTING DUCT GPM'S TO REMAIN
OVERHEAD DOOR
PROJECT NORTH
FIRST FLOOR PLAN
1/4" = 1'-0"
D. WILLIAMS 08/11/06
H. ROBERTSON
PERSONNEL SAFETY SYSTEM
FEL INJECTOR TEST STAND
EQUIPMENT LAYOUT
05349-D-0001

# Budget

| Procurements | |
|---|---|
| | |
| **Item** | **Approximate Cost ($k)** |
| Solenoid magnet or Helmholtz coil-pair | 50 |
| Power supply for gun magnet (500A/150V) | 50 |
| Skew quadrupole magnets (x3 sets) | 15 |
| Cameras | 2.4 |
| PC for cameras | 1 |
| Switcher | 1 |
| YAG viewer | 1 |
| Multislit (1) | 4 |
| Single slit (x2) | 8 |
| Stepper motor translation stages | 10 |
| 50% postdoc | 75 |
| **Total** | **217.4** |
| | |
| Labor | |
| | |
| Magnet design | 2 wk |
| Mechanical design for magnets | 2 wk |
| Mechanical design for slits | 2 wk |
| ASTRA modeling | 12 wk |