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

Laboratory Directed Research and Development (LDRD) Proposal

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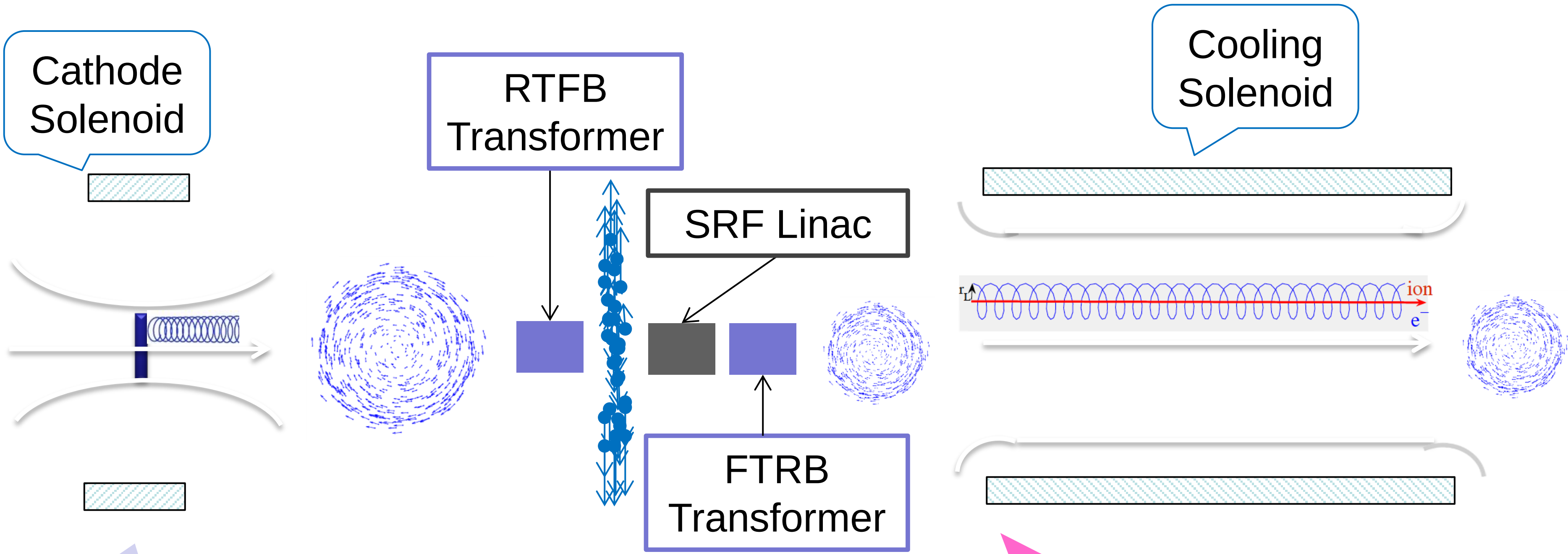
Outline

- Magnetized Cooling
- Electron Beam Requirements
- Generation of Magnetized Beam
- Proposed Measurements:
    I. Mechanical angular momentum
    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

Upon exit of Cathode Solenoid

Upon entering Cooling Solenoid

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

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

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

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

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

σ_e = 0.95 mm
B_{cool} = 2 T

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

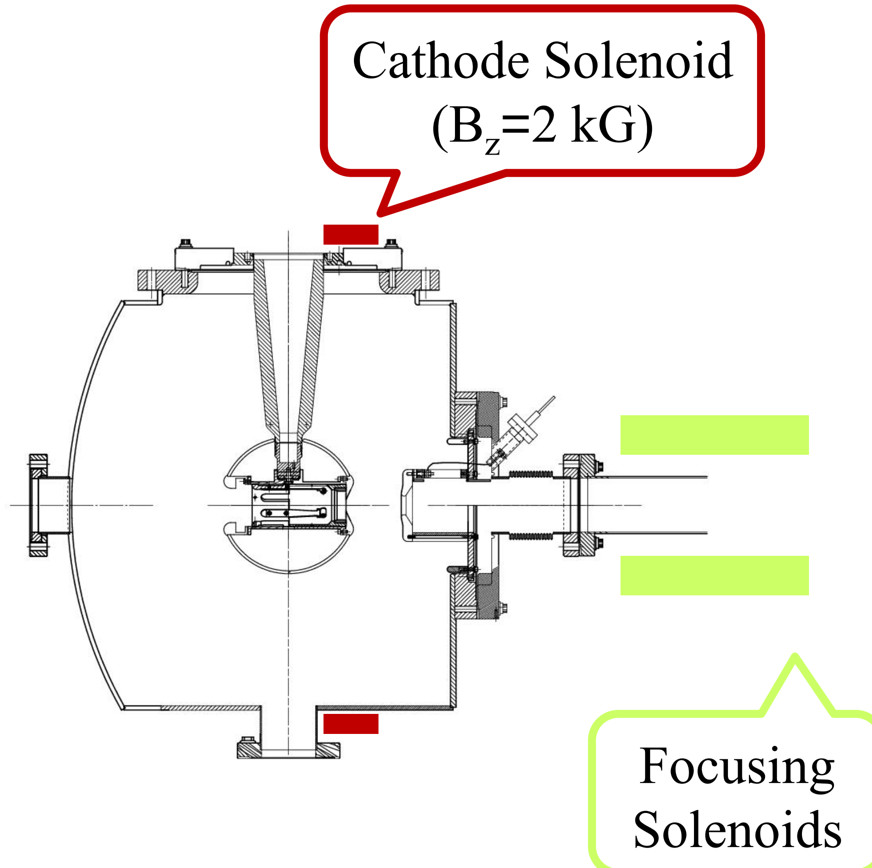
Bunched Magnetized Gun Requirements

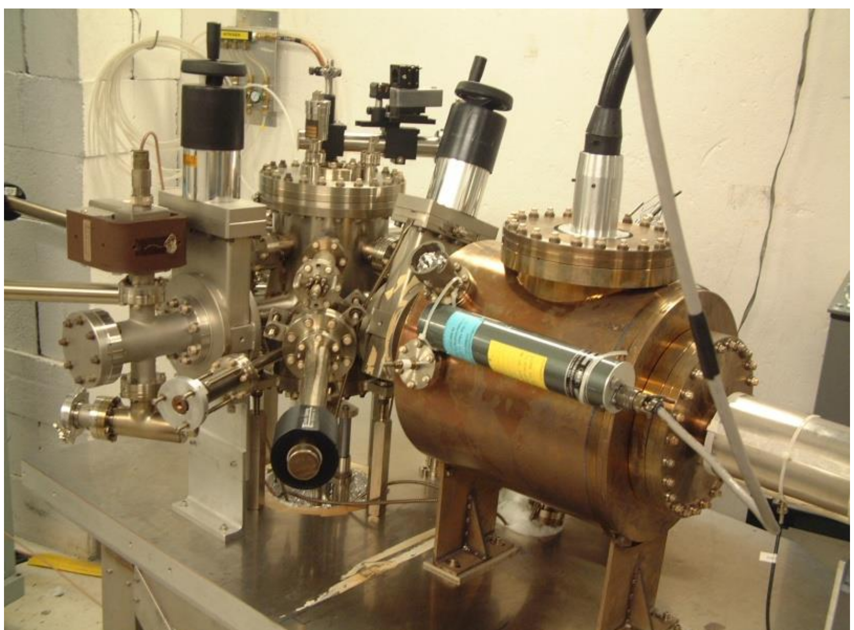
Bunch length	100 ps (3 cm)
Repetition rate	476 MHz
Bunch charge	420 pC
Peak current	4.2 A
Average current	200 mA
Emitting radius (a_0)	3 mm
Transverse normalized emittance	10s microns
Solenoid field at cathode	2 kG

Generation of Magnetized Beam

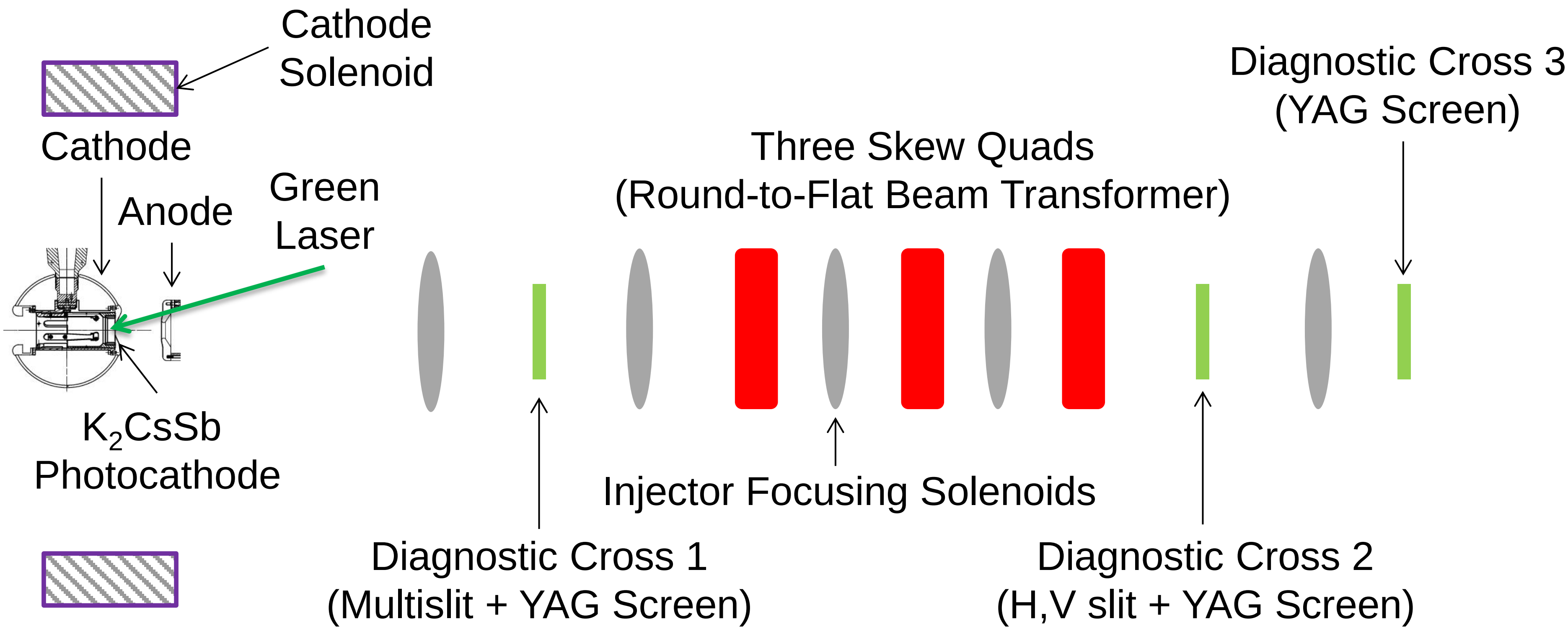
I. Cathode Solenoid:
- ➢ To produce magnetized beam

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





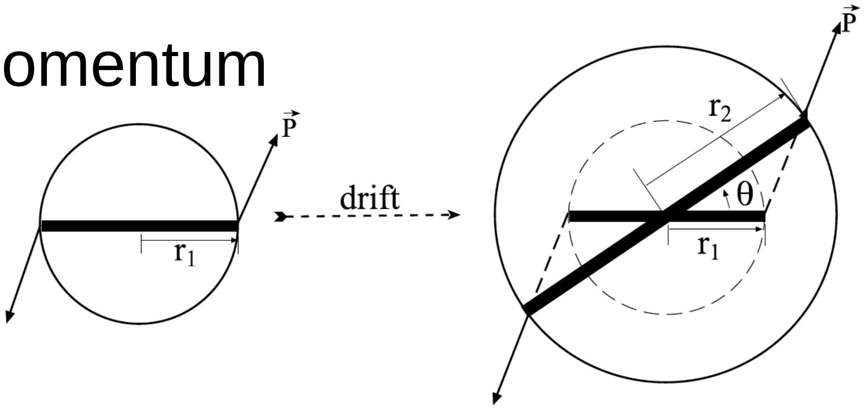
Proposed Beamline



- 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)

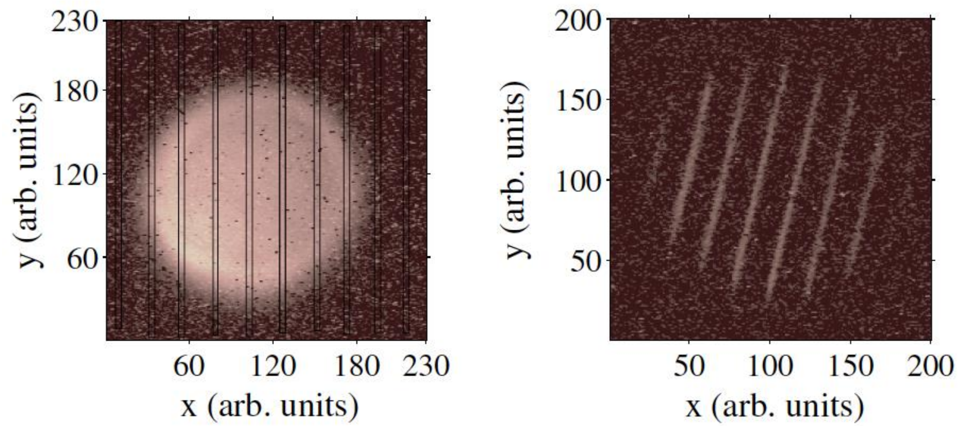


σ_1 beam radius measured at Diagnostic Cross 1
σ_2 beam radius measured at Diagnostic Cross 2
D drift between two crosses
p_z beam longitudinal momentum

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

- 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 σ_{2h} and horizontal radius of beamlet at Cross 3 is σ_{3h} when vertical slit is inserted at Cross 2, then horizontal emittance is

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

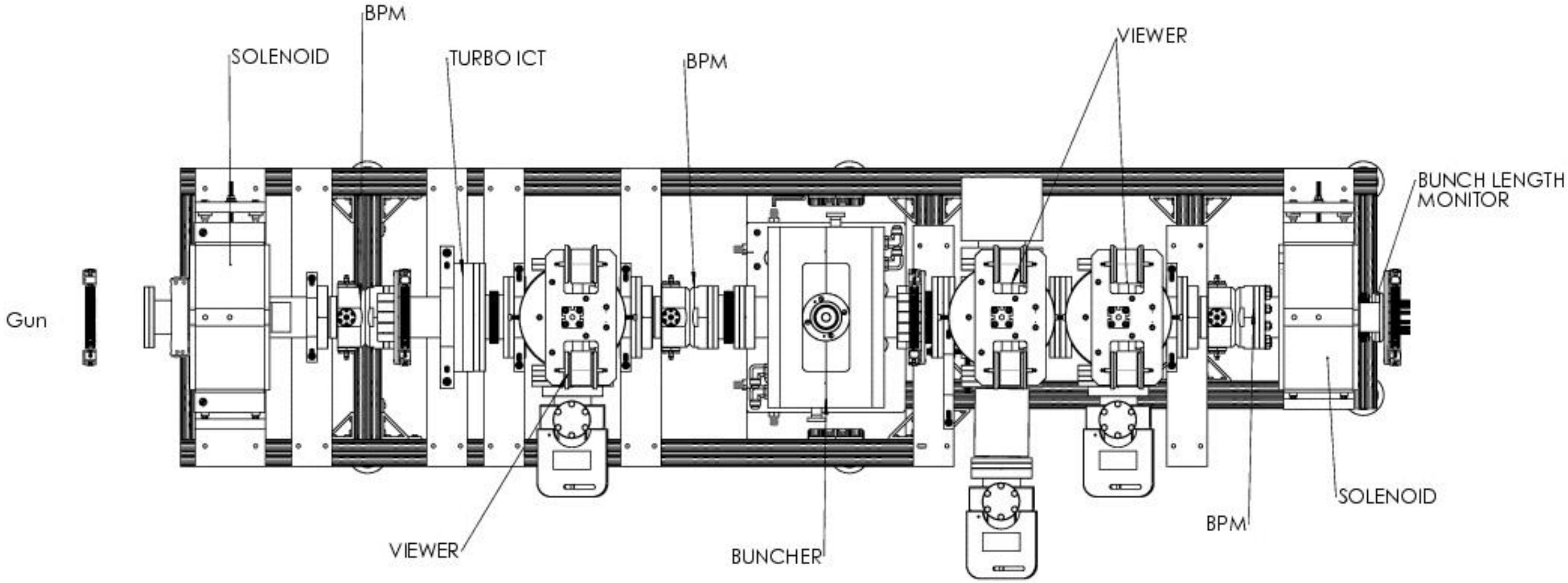
- Similarly, measure vertical emittance using horizontal slit

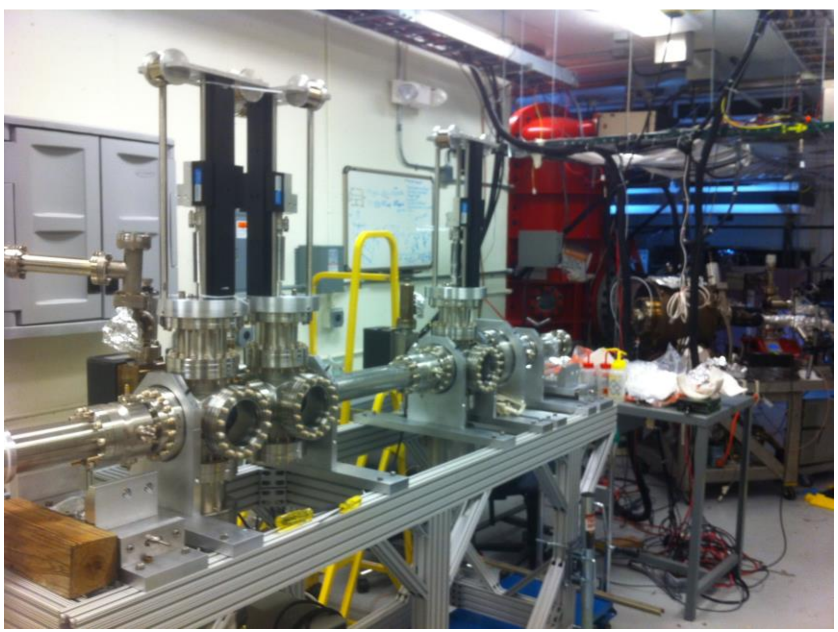
3. Generate very high currents magnetized beam and study beam transport and RTFB transformation versus electron bunch charge

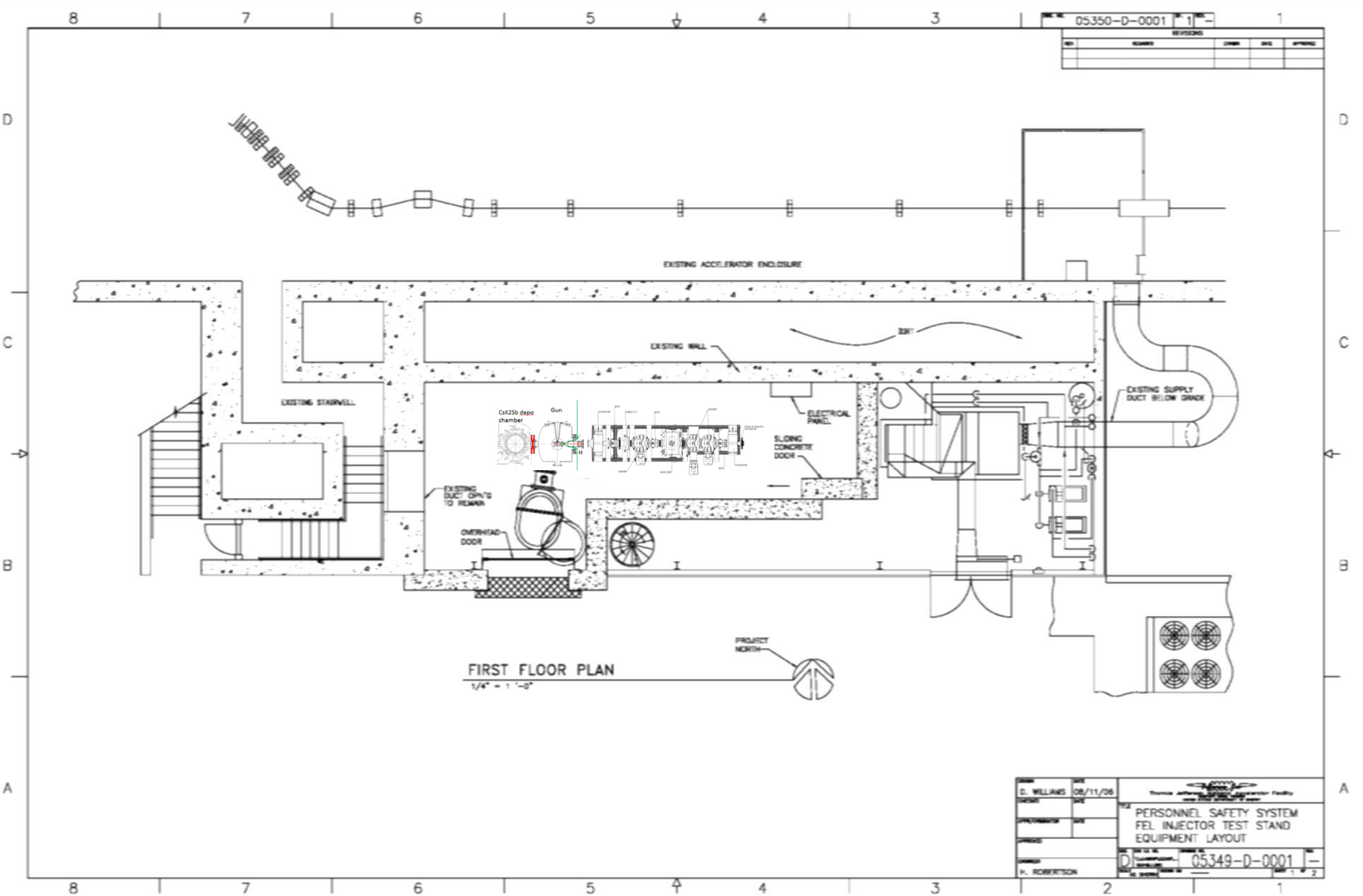
4. Measure photocathode lifetime versus solenoid field at high currents (up to 30 mA) and high voltages (200 – 350 kV) limited by HV supplies we have

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