RE-DESIGNING OF THE JEFFERSON LAB MAGNETIZED DC HIGH VOLTAGE PHOTOGUN FOR HIGH BUNCH CHARGE OPERATIONS

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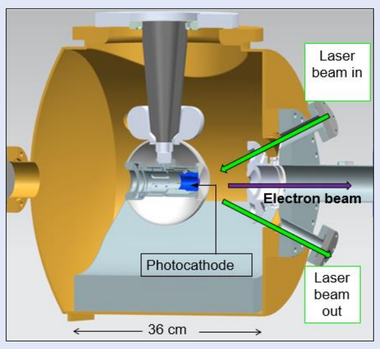
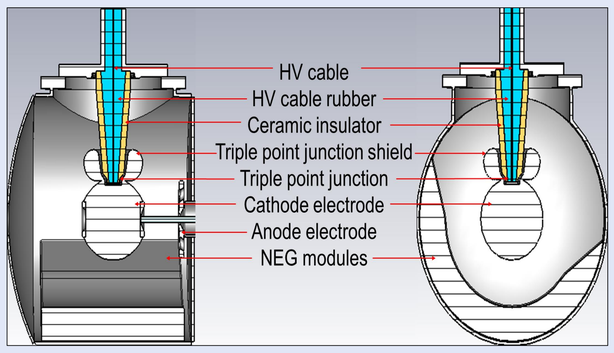
ABSTRACT

Magnetized electron cooling is one of the major approaches towards obtaining the required high luminosity in the proposed Electron-Ion Collider (EIC). In order to increase the cooling efficiency, the design requires to deliver high bunch charge. At Jefferson Lab (JLab) we generated high bunch charge magnetized electron beam using a DC high voltage photogun. We reached the space charge limit at 0.3 nC and extracted only 0.7 nC at the dump due to the lower accelerating electric field (E_z) at the cathode and beam loss. Thus, to reach the high bunch charge goal the original DC high voltage photogun was modified to obtain a higher E_z at the cathode while keeping the beam centered and minimizing the electric field at the insulator-metal-vacuum interface of the cathode electrode. This contribution presents the comprehensive electrostatic design of the modified photogun obtained from the CST simulating software in comparison with original design and simulations done using General Particle Tracer (GPT) software on the beamline with electric field information obtained from the above modeling.

INTRODUCTION

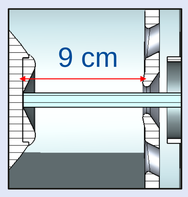
Original DC high voltage photogun



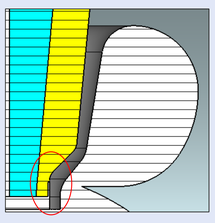


- E_z at the photocathode sets the limit on the maximum charge density extractable from the photocathode
  - Increase E_z at the cathode – by removing the Pierce geometry and decreasing anode-cathode gap
- Inverted insulator and triple point junction shield, asymmetric NEG pumps combine in to introduce asymmetric electric fields in between the anode-cathode gap which then result in deflecting the beam vertically at the exit of the anode, difficulty in beam steering, and ultimately beam losses
  - Find a way to correct the beam deflection with minimum changes on the original design
- Reliable operation at -300 kV high voltage with high quality beam and 10^{-12} Torr scale vacuum without field emission and high voltage breakdown.

Pierce geometry 25º

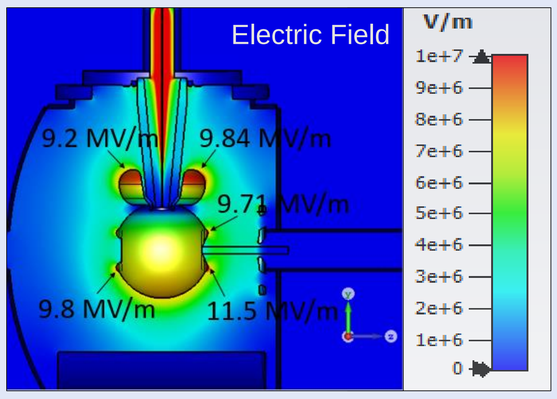


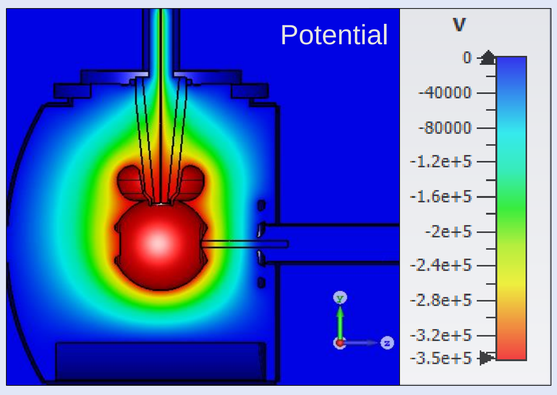
Triple point junction (Insulator, metal and vacuum)



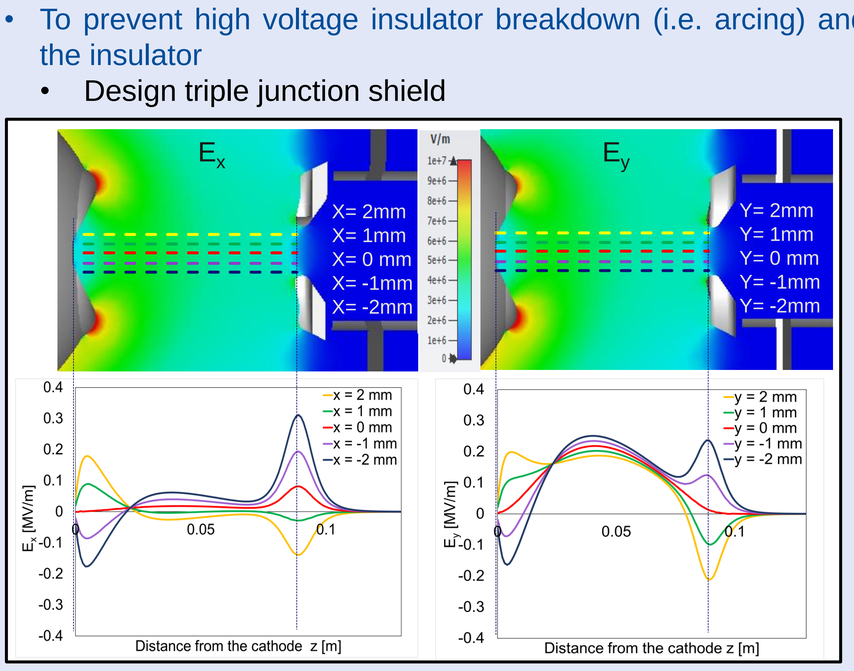
ELECTROSTATIC DESIGN OF THE ORIGINAL GUN

-350 kV at the cathode, 0 V at the anode

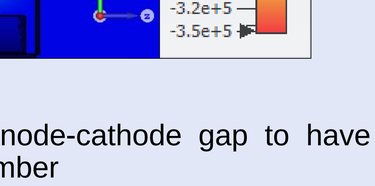




- To minimize field emission to have long photocathode lifetime
  - Optimize electrode shape (radius of curvature), size, and anode-cathode gap to have electric field $\leq$ -10 MV/m at -350 kV everywhere inside the chamber
  - Polish electrodes, High voltage conditioning
- To prevent high voltage insulator breakdown (i.e. arcing) and linearize the potential across the insulator
  - Design triple junction shield



Beam trajectory

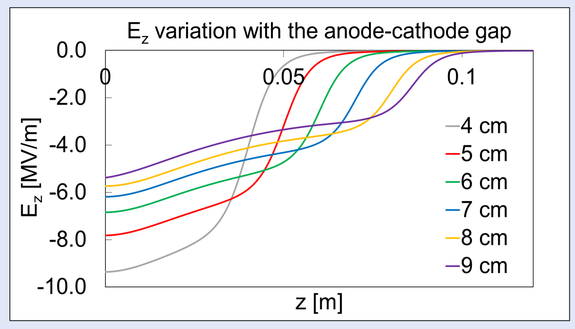


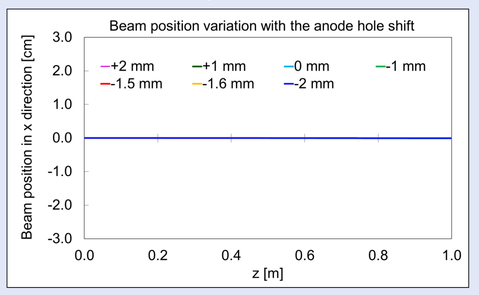
- E_z at the cathode front is -2.5 MV/m
- E_z reached its maximum at z=2 cm and E_x and E_y fields focused at the same position due to the Pierce geometry

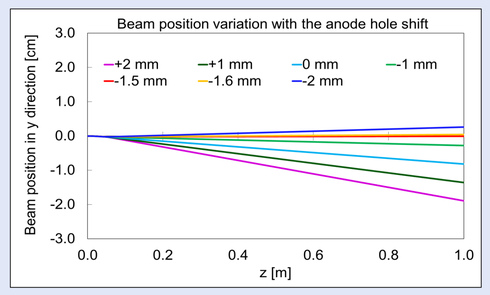
- Asymmetry in E_x
  - Beam deflect 3 mm at z=1 m
  - Due to the asymmetry in placing the NEG pumps at the bottom of our gun chamber
- Huge asymmetry in E_y
  - Beam deflect 3.3 cm at z=1 m
  - Due to the inverted insulator and triple point junction shield

ELECTROSTATIC DESIGN OF THE MODIFIED GUN

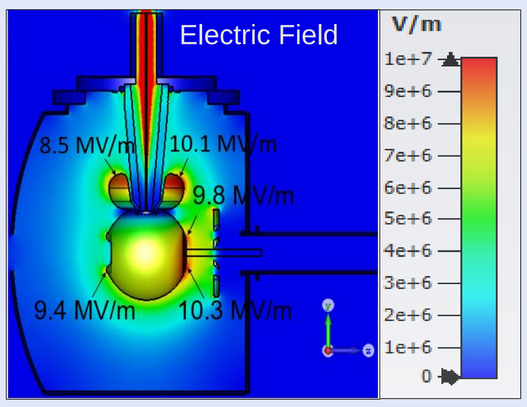
- To increase E_z at the cathode
  - Removed the Pierce geometry- flat cathode and flat anode front
  - Reduced anode-cathode gap to 5 cm (E_z at the cathode -7.82 MV/m)
- To correct the beam deflection with minimum changes on the original design
  - Y deflection - shift anode -1.6 mm in vertical direction
  - X deflection - replace existing NEGs with thinner strips



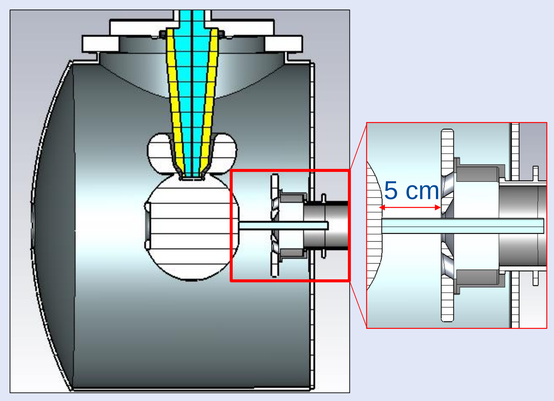


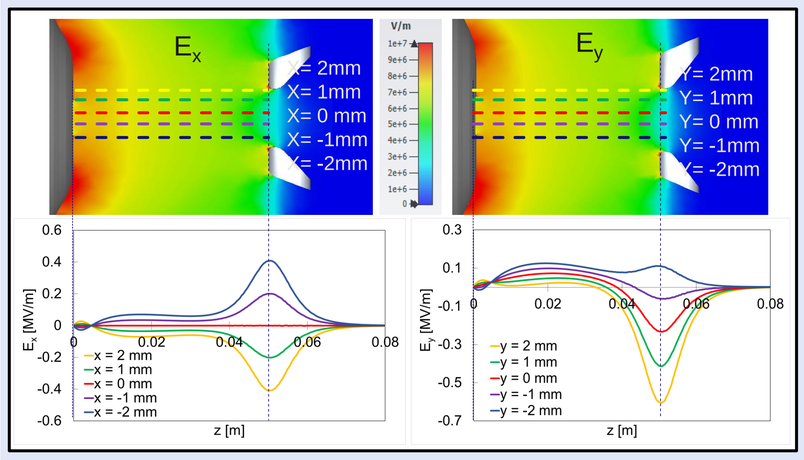


-350 kV at the cathode, 0 V at the anode

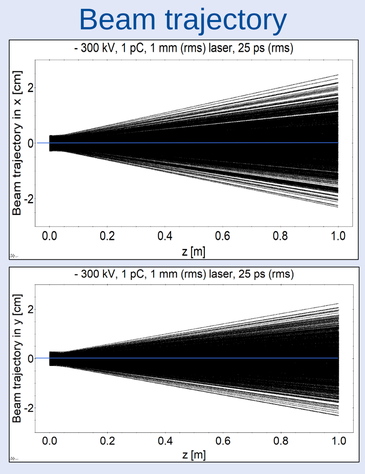


Finalized mechanical design





Beam trajectory



GPT simulations with the modified gun for the magnetized (0.075 T at the cathode) and non-magnetized (0 T at the cathode) beam

Parameter	Value
Gun high voltage [kV]	-300
Pulse width, Gaussian (FWHM) [ps]	75
Laser spot, Gaussian (rms) [mm]	1.64
Bunch charge [nC]	0.01 to 14

SUMMARY AND OUTLOOK

- Increased E_z up to -7.82 MV/m from -2.5 MV/m by removing the Pierce geometry and decreasing anode-cathode gap to 5 cm from 9 cm
- Discovered a smart way to get rid of the beam deflection just by lowering the anode hole by -1.6 mm which will be implemented in CEBAF polarized photogun
- This will be a huge advantage for all the photoguns to minimized the beam loss at the exit of the anode
- Charge extracted from the cathode increased with the modified gun (from 4.6 nC to 10.2 nC for the maximum bunch charge delivered)
- Planning to repeat the measurements with the modified photogun

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