REDESIGN OF THE JEFFERSON LAB -300 kV DC PHOTO-GUN FOR HIGH BUNCH CHARGE OPERATIONS

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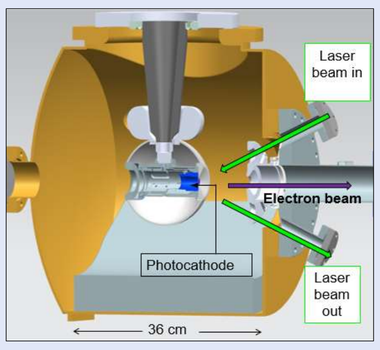
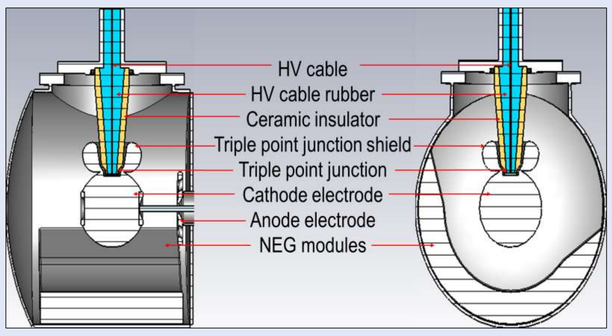
ABSTRACT

Production of high bunch charge beams for the proposed Electron-Ion Collider (EIC) has been a challenging task. High bunch charge (a few nC) electron beam production studies at Jefferson Lab using an inverted insulator -300 kV DC photo-gun showed evidence of space charge current limitations starting at 0.3 nC and reducing the maximum delivered bunch charge to 0.7 nC. The low extracted charge is mainly due to the modest longitudinal electric field (E_z) at the photocathode as well as beam loss. Thus, to reach the few nC high bunch charge goal, the existing DC photo-gun electrode and anode-cathode gap were modified to increase E_z at the photocathode. In addition, the anode aperture was shifted with respect to the beamline longitudinal axis to correct the beam deflection exerted by the non-symmetric nature of the inverted insulator photo-gun. This contribution discusses the electrostatic design of the modified photo-gun obtained using CST Studio Suite's electromagnetic field solver and presents high voltage conditioning results. Beam dynamics simulations performed using General Particle Tracer and the new electrostatic field map obtained from the modified electrodes will also be presented.

INTRODUCTION

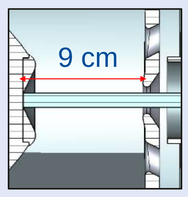
Original DC high voltage photo-gun



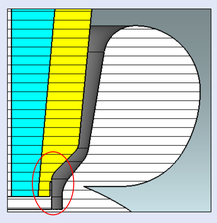


- E_z at the photocathode sets the limit on the maximum charge density extractable from the photocathode
  - Increase E_z at the cathode – by removing the Pierce geometry and decreasing anode-cathode gap
- Inverted insulator and triple point junction shield, asymmetric NEG pumps combine in to introduce 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

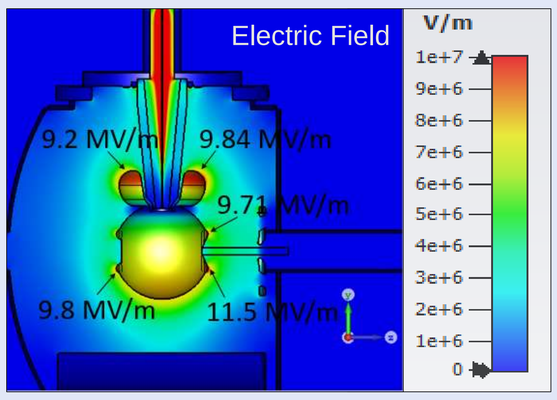


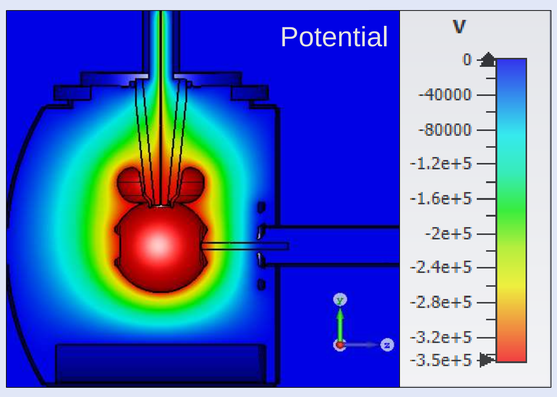
Triple point junction
(Insulator, metal and vacuum)



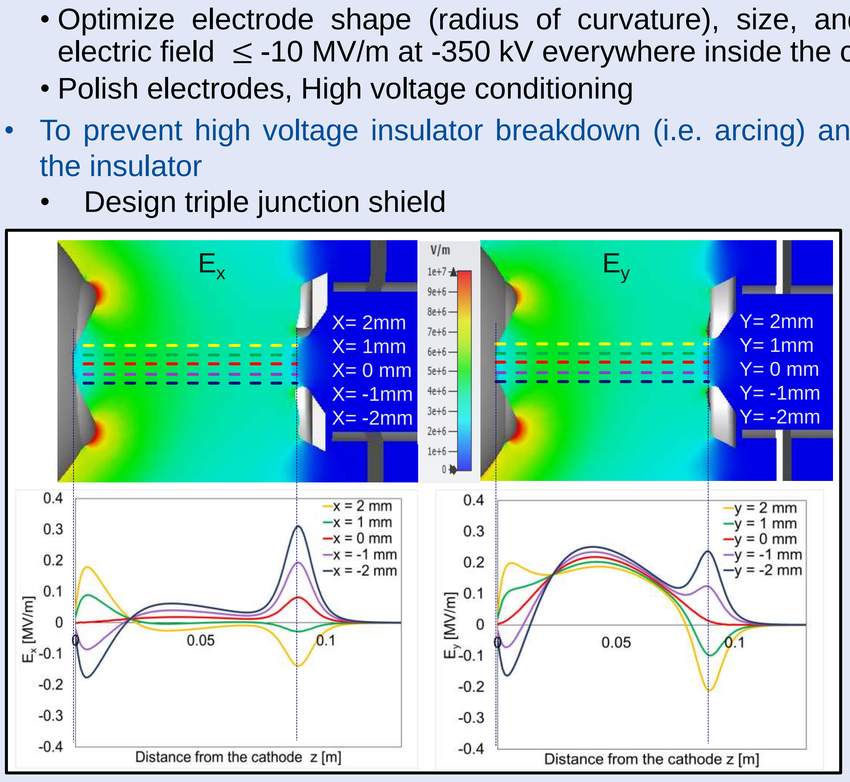
ELECTROSTATIC DESIGN OF THE ORIGINAL GUN

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

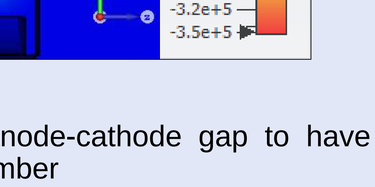




- To minimize field emission to have long photocathode lifetime
  - Optimize electrode shape (radius of curvature), size, and anode-cathode gap to have electric field $\leq$ -10 MV/m at -350 kV everywhere inside the chamber
  - Polish electrodes, High voltage conditioning
- To prevent high voltage insulator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



Beam trajectory

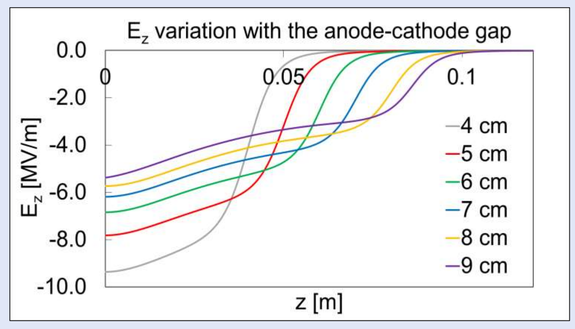


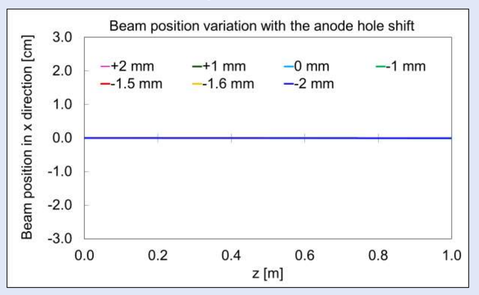
- E_z at the cathode front is -2.5 MV/m
- E_z reached its maximum at z=2 cm and E_x and E_y fields focused at the same position due to the Pierce geometry

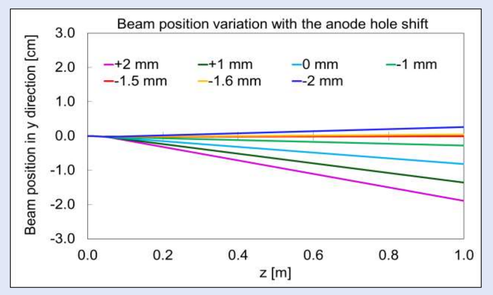
- Asymmetry in E_x
  - Beam deflect 3 mm at z=1 m
  - Due to the asymmetry in placing the NEG pumps at the bottom of our gun chamber
- Huge asymmetry in E_y
  - Beam deflect 3.3 cm at z=1 m
  - Due to the inverted insulator and triple point junction shield

ELECTROSTATIC DESIGN OF THE MODIFIED GUN

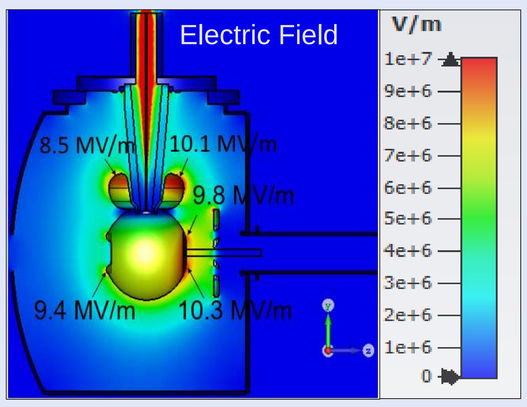
- To increase E_z at the cathode
  - Removed the Pierce geometry- flat cathode and flat anode front
  - Reduced anode-cathode gap to 5 cm (E_z at the cathode -7.82 MV/m)
- To correct the beam deflection with minimum changes on the original design
  - Y deflection - shift anode -1.6 mm in vertical direction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



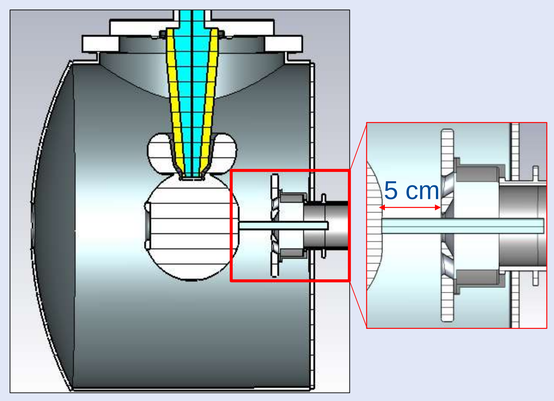


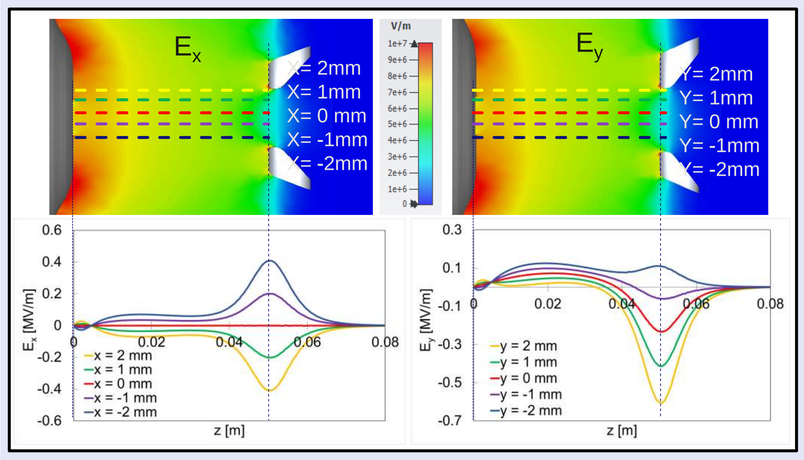


-350 kV at the cathode, 0 V at the anode

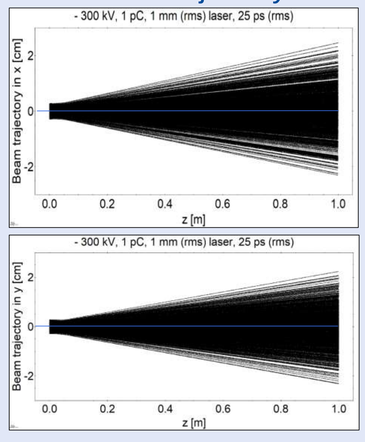


Finalized mechanical design





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 photo-gun
- This will be a huge advantage for all the photo-guns 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)
- Modified parts have already been built, polished and ready to assemble.

Acknowledgement: The U.S. Department of Energy, Office of Science, Office of Nuclear Physics under contract DE-AC05-06OR23177, JSA initiatives fund program and Laboratory Directed Research and Development program

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