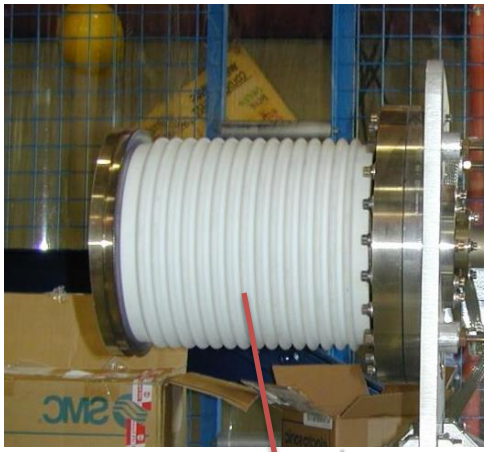
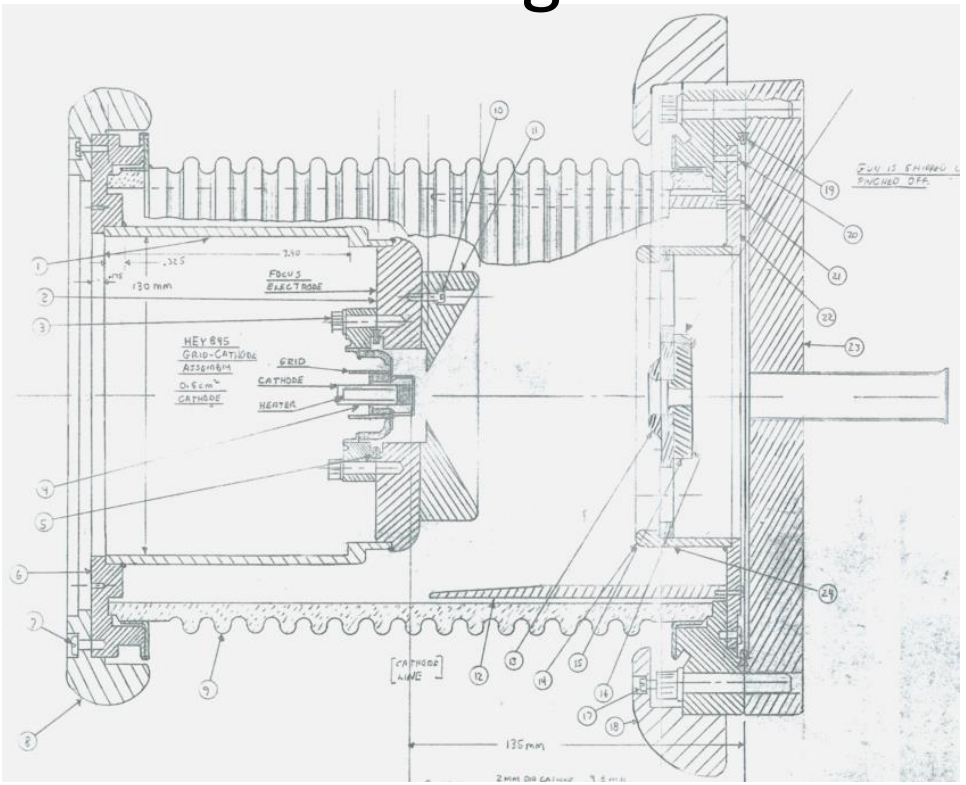
CEBAF's First Electron Source

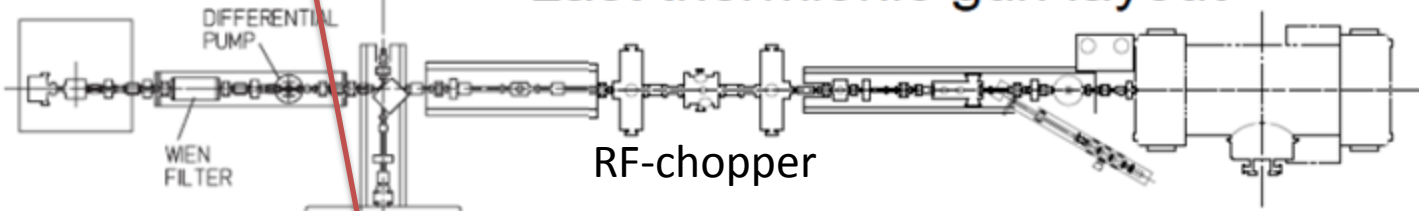
100kV Unpolarized thermionic gun

- Make beam by running current through the filament biased at 100kV
- Use "grid" to turn beam ON/OFF, i.e., create machine-safe macropulses
- Apertures to improve emittance
- Use RF "chopper" to create RF structure





Last thermionic gun layout



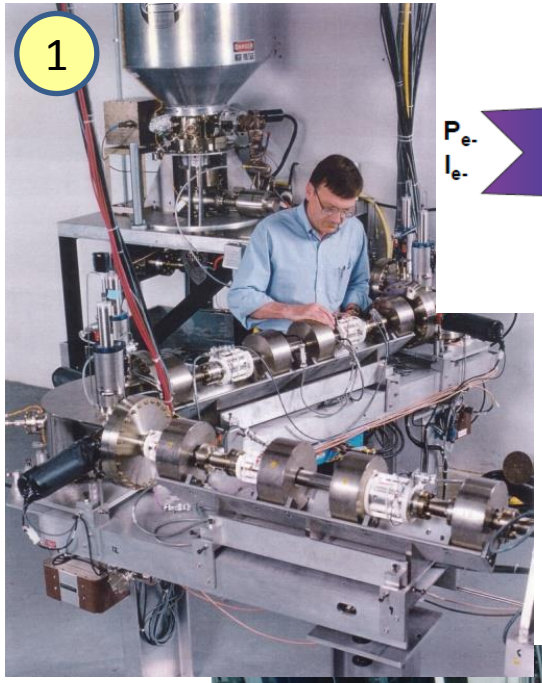
Polarized GaAs photosource

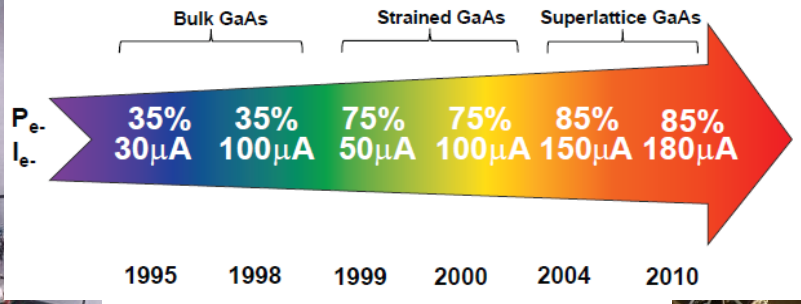
RF-chopper

Thermionic source

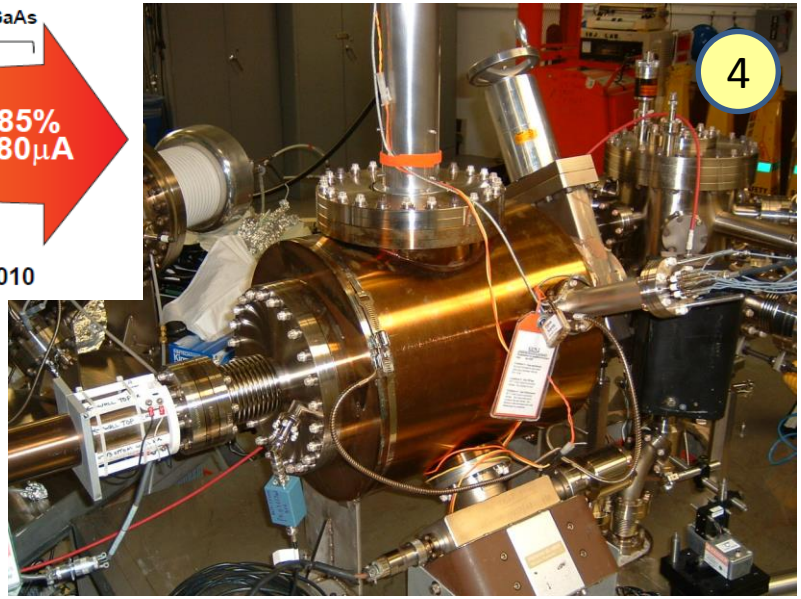
This gun was loaned to Hampton University

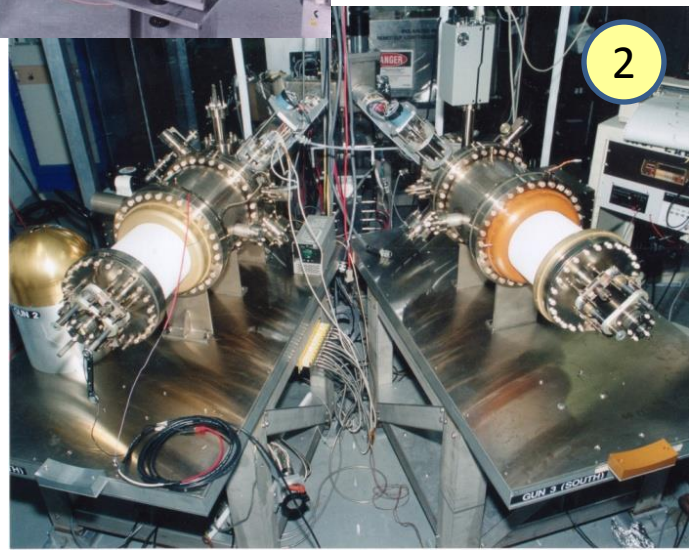
CEBAF polarized photoguns





Endless (?) quest for perfection





Describe a “good” DC HV photogun

- NO high voltage problems, operates reliably at desired voltage for years, NO field emission, NO HV breakdown
- Photocathode has high yield, quantum efficiency (QE)
- Photocathode provides high current for a long time (good lifetime)
- Photocathode provides high polarization (when needed)

Two Kinds of DC HV Photoguns

Vent and Bake, or vent/bake

- Simple gun with one photocathode
- Activate the photocathode inside the HV chamber – this often leads to problems (field emission and Zero QE)
- Days to weeks to replace a photocathode
- CEBAF quit using vent/bake gun about 10 years ago
- LERF uses this type of photogun

Load-locked

- More complicated and costly, with multiple chambers serving different purposes. Takes awhile to “get it right”
- Photocathode dirty work happens outside of the HV chamber, inside a prep chamber that holds many spare photocathodes
- Only hours to replace the photocathode
- Once all problems solved, gun can be happy for years

Photogun Inventory at JLab

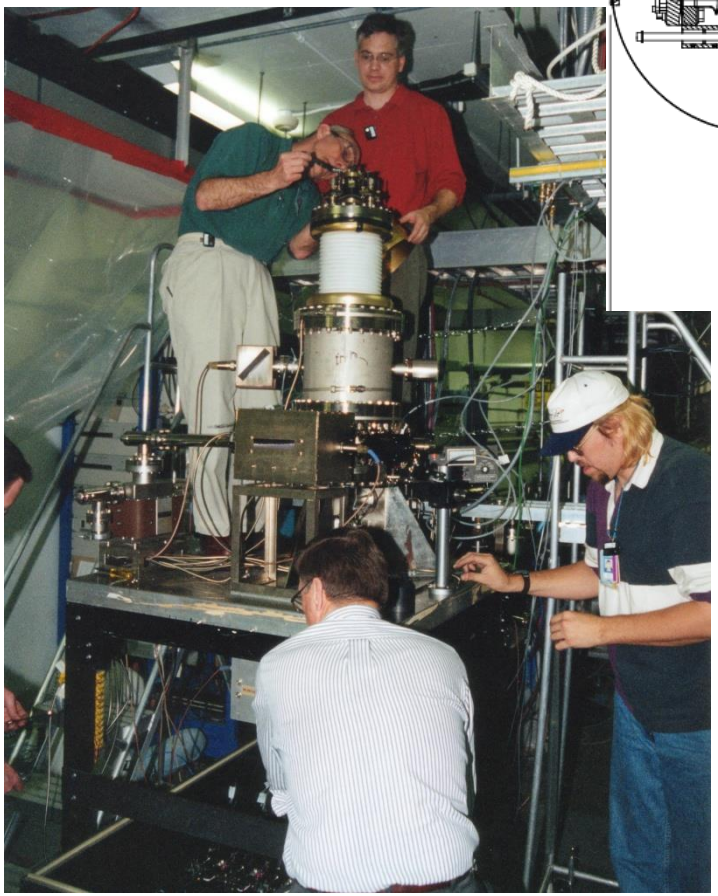
Vent and Bake guns

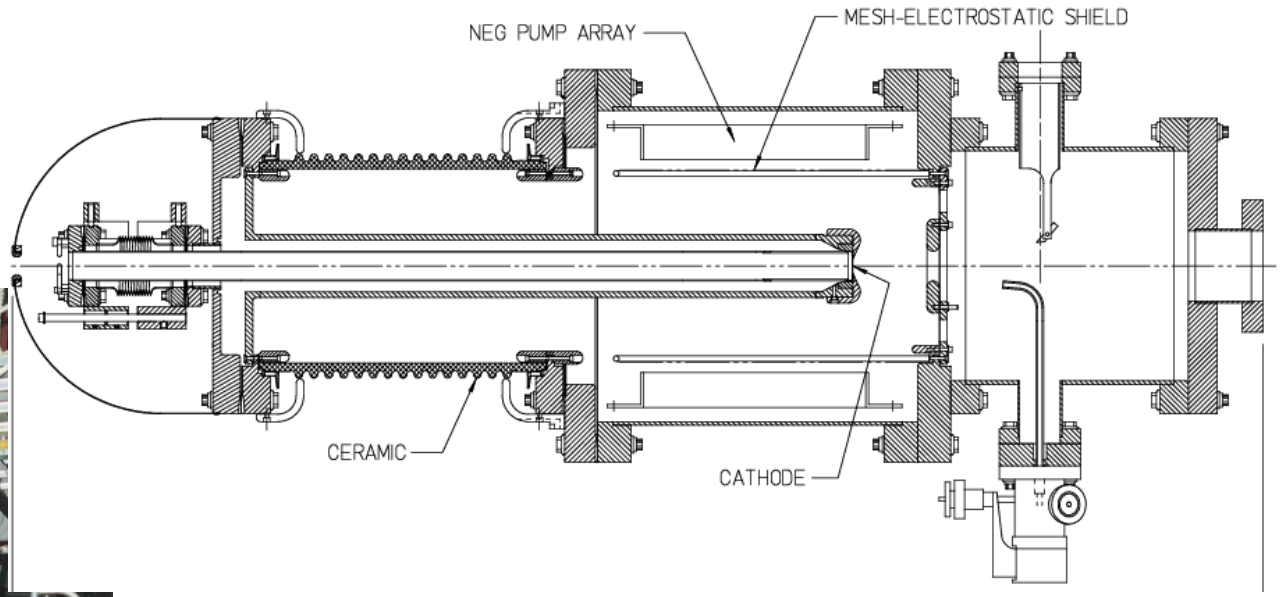
- 350 kV LERF production gun
- 100 kV Gun3 at CEBAF, not used
- Lots of parts on shelf to make more of these guns, but prefer not to use this style anymore. Most labs use load-locked gun designs…

Load-locked

- 130 kV CEBAF production load locked gun, with inverted insulator
- 200 kV CEBAF-style gun, our spare for CEBAF, and used at old Test Cave for some R&D where we pushed it to higher voltages compared to CEBAF gun
- Trying to build a 350 kV inverted gun, it is challenging
- LERF spent money on two 500 kV gun designs but did not build them (pictures of designs follow)

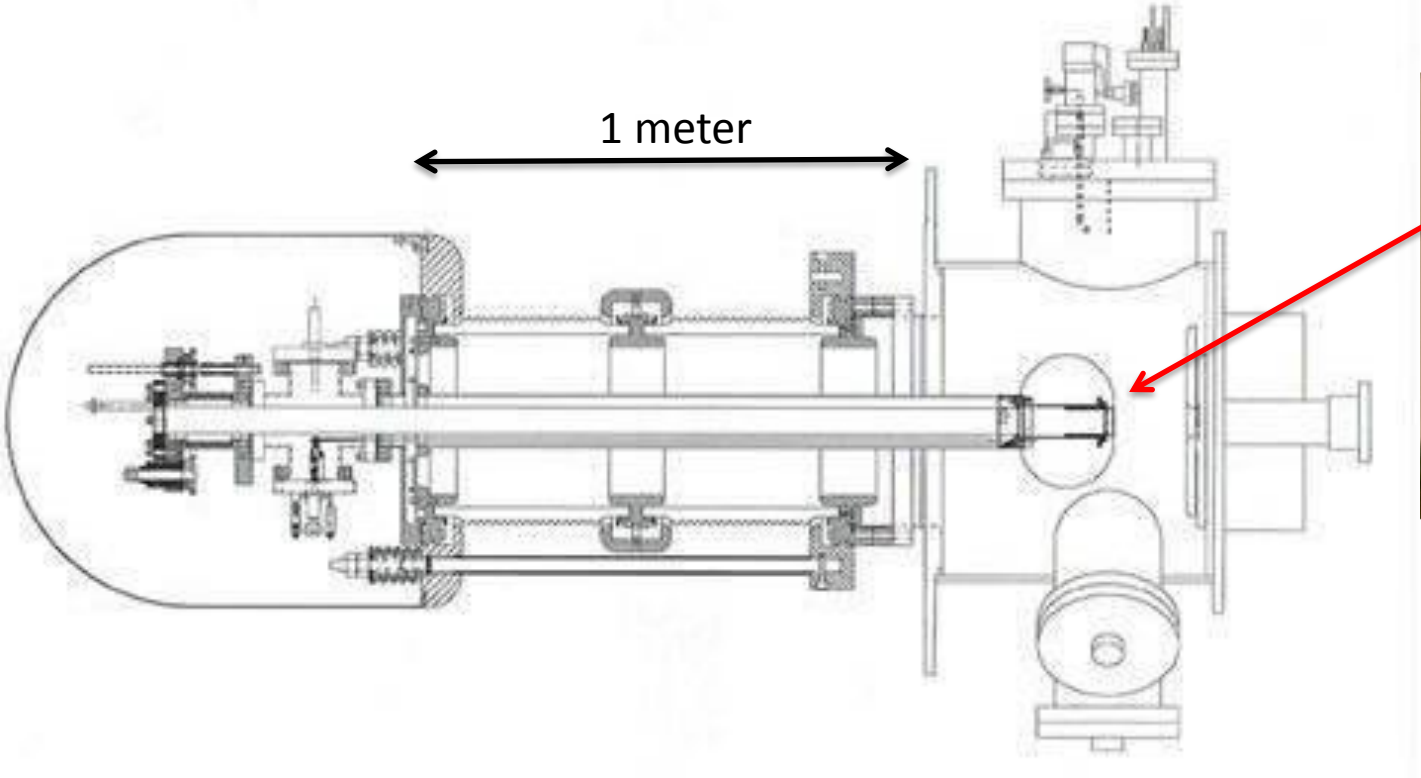
CEBAF's Vent and Bake Gun

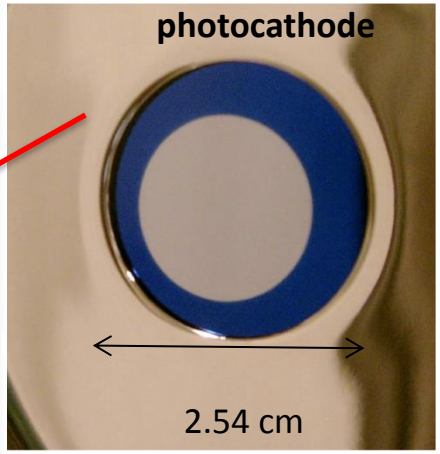




- One of these still lives at CEBAF injector : "Gun3"
- Hasn't been used in years
- 5 days to replace photocathode

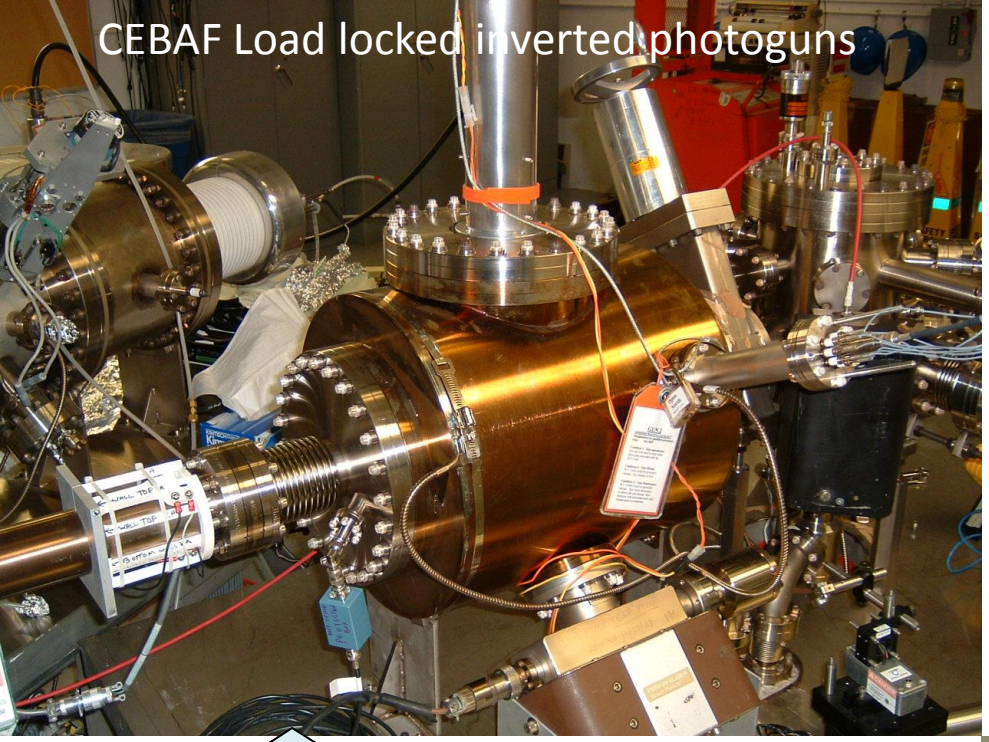
This is LERF's photogun





- One month to replace photocathode
- Lifetime < 500C
- 10mA means 864C/day

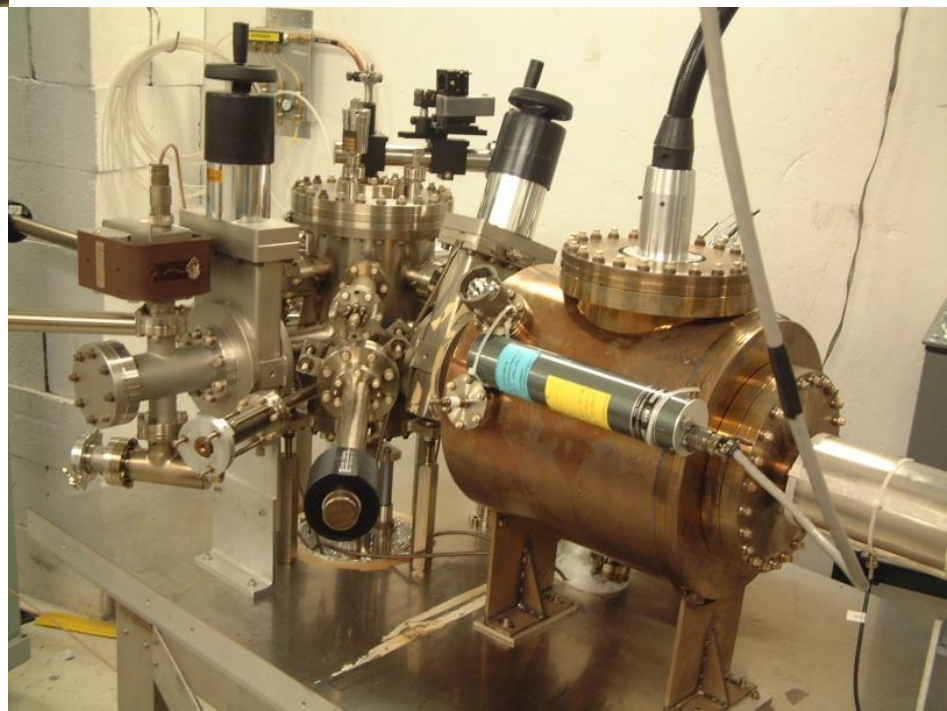
CEBAF Load locked inverted photoguns



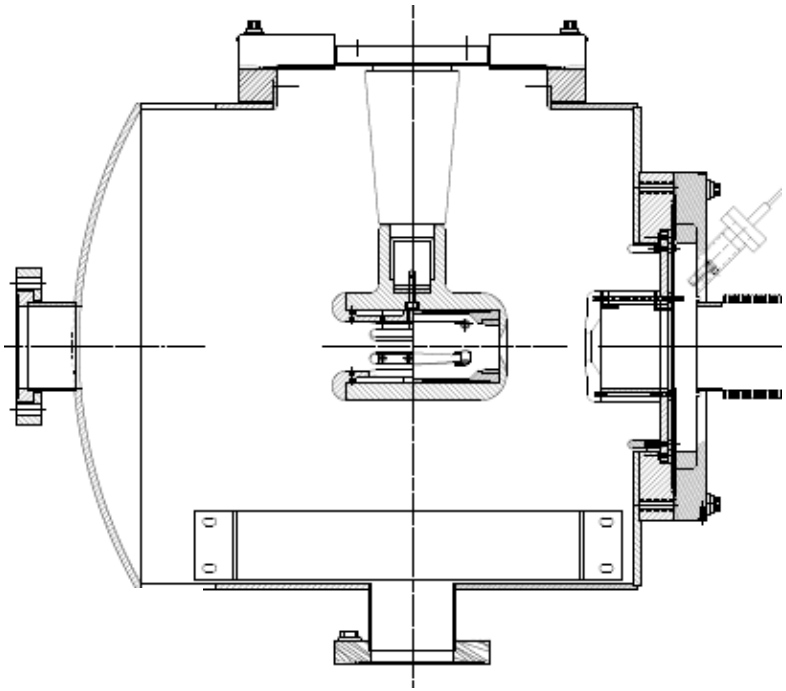
- Load locked Inverted Gun #1 at CEBAF
- Operational since July, 2009
- Stainless steel electrode
- Operated at 100kV for HAPPEx, PVDIS and PRex (70C @ 150uA)
- Operated at 130kV for Qweak (70C @ 300 uA), improved transmission
- Expected better lifetime….puzzling

Paid for by ILC

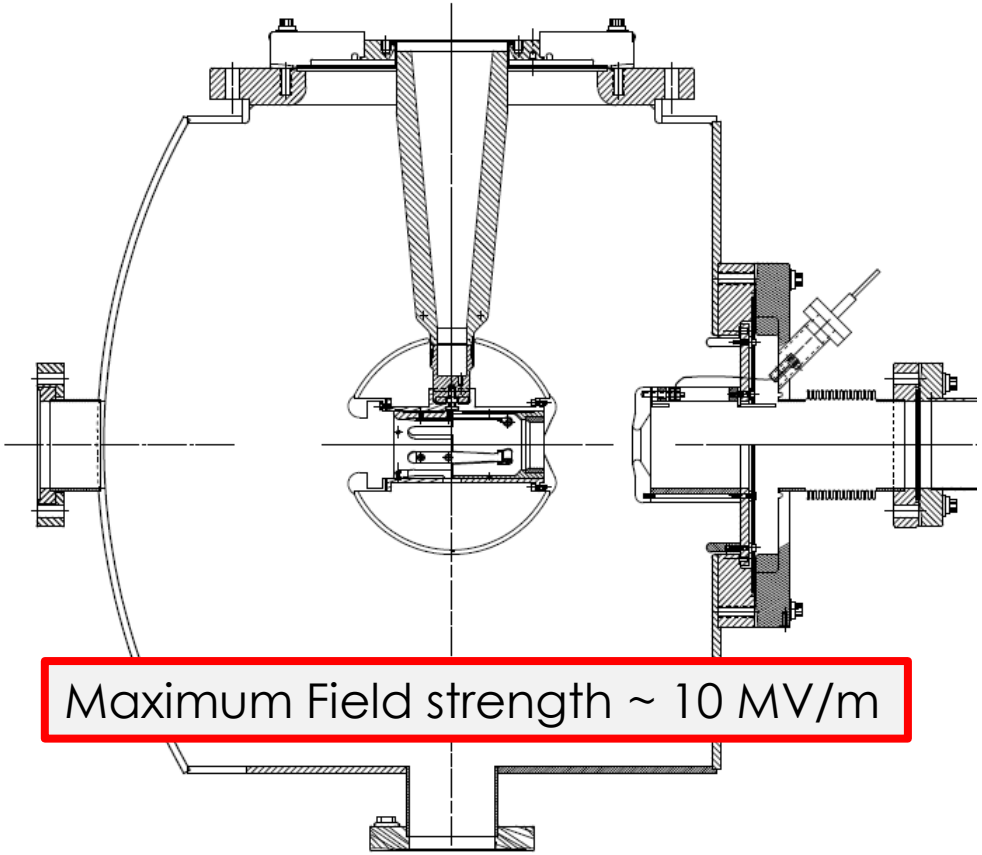
- Load locked Inverted Gun #2 at Test Cave
- Large grain niobium electrode
- Problematic field emission at 140kV
- Repeated BCP treatment, no measurable field emission at 225kV
- Have since demonstrated many months of beam delivery at 200kV
- Our spare gun……



The 350 kV Photogun



CEBAF 130/200kV
Inverted Gun

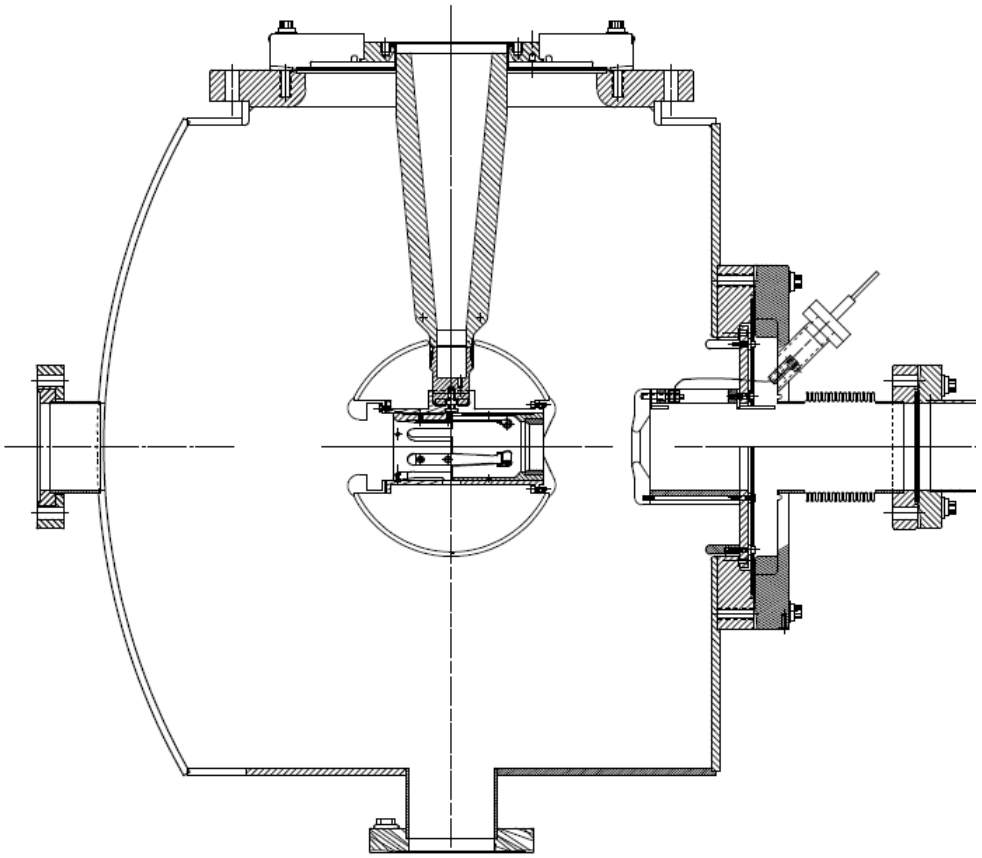


Maximum Field strength ~ 10 MV/m

- Longer "R30" insulator
- Spherical electrode
- Thin NEG sheet to move ground plane further away

Slide 9

WHY BUILD A 350 KV PHOTOGUN?

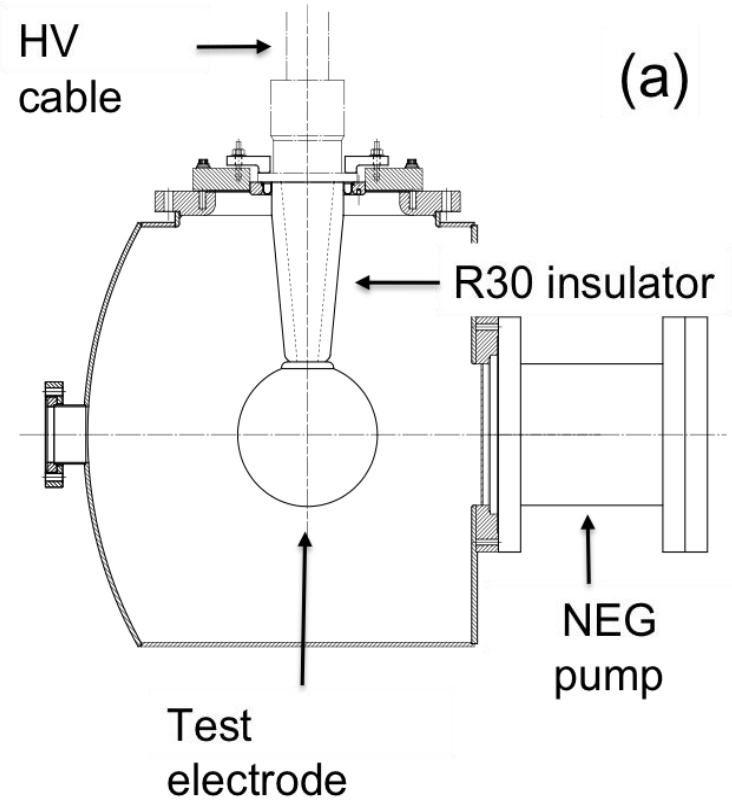


- UITF: compact injector, no capture section, beam straight into ¼ CM
- Use it at LERF: load locked gun for 24/7 high current beam delivery
- Magnetized beam demonstration
- For experiments that need high bunch charge, like experiment to minimize Coherent Synchrotron Radiation

Slide 10

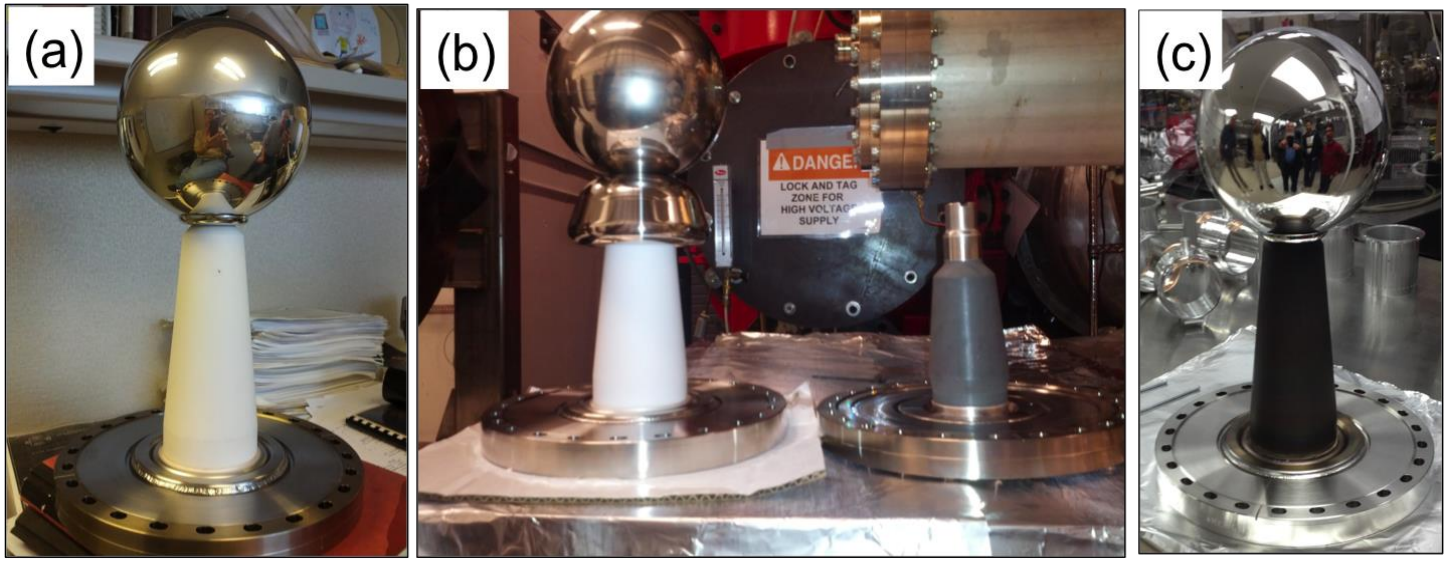
BUILDING THE 350 KV GUN

- Start with "dummy" electrodes and test different insulators and cathode screening electrode



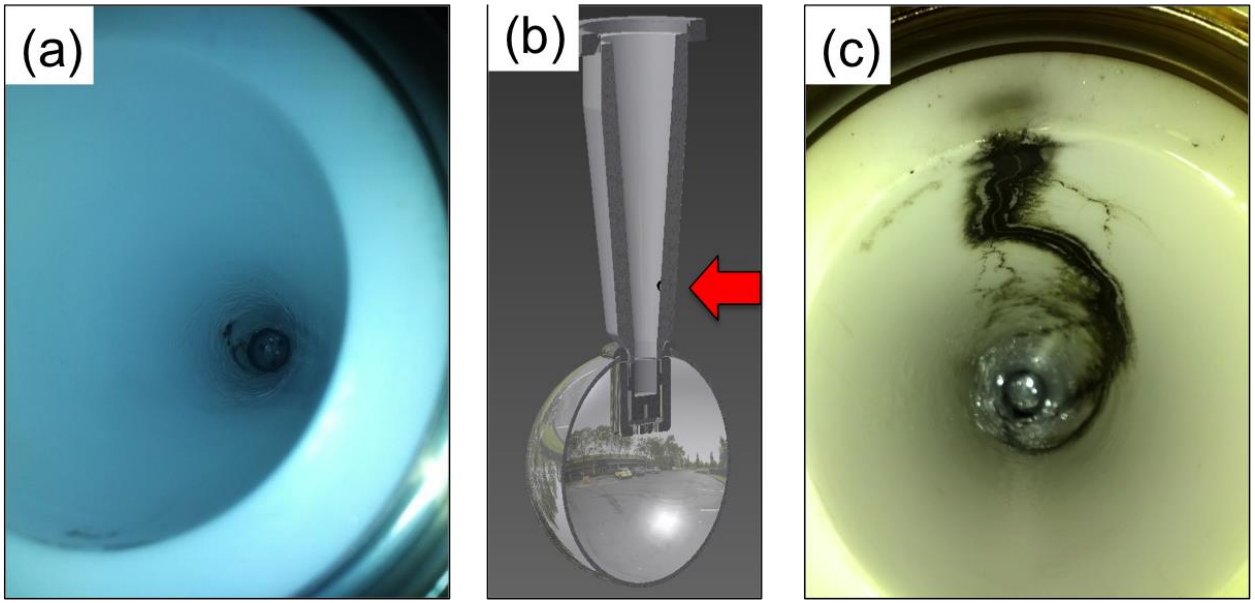
Insulators and Screening electrode

- Longer R30 insulators, conventional alumina
- Short R28 insulator, bulk resistivity, mildly conductive
- ZrO-coated R30 insulator, also mildly conductive
- dummy electrode and with a screening electrode



High Voltage Breakdown

Problems at the cable junction, atmosphere side



puncture

Short to ground

Summary of Insulator Tests

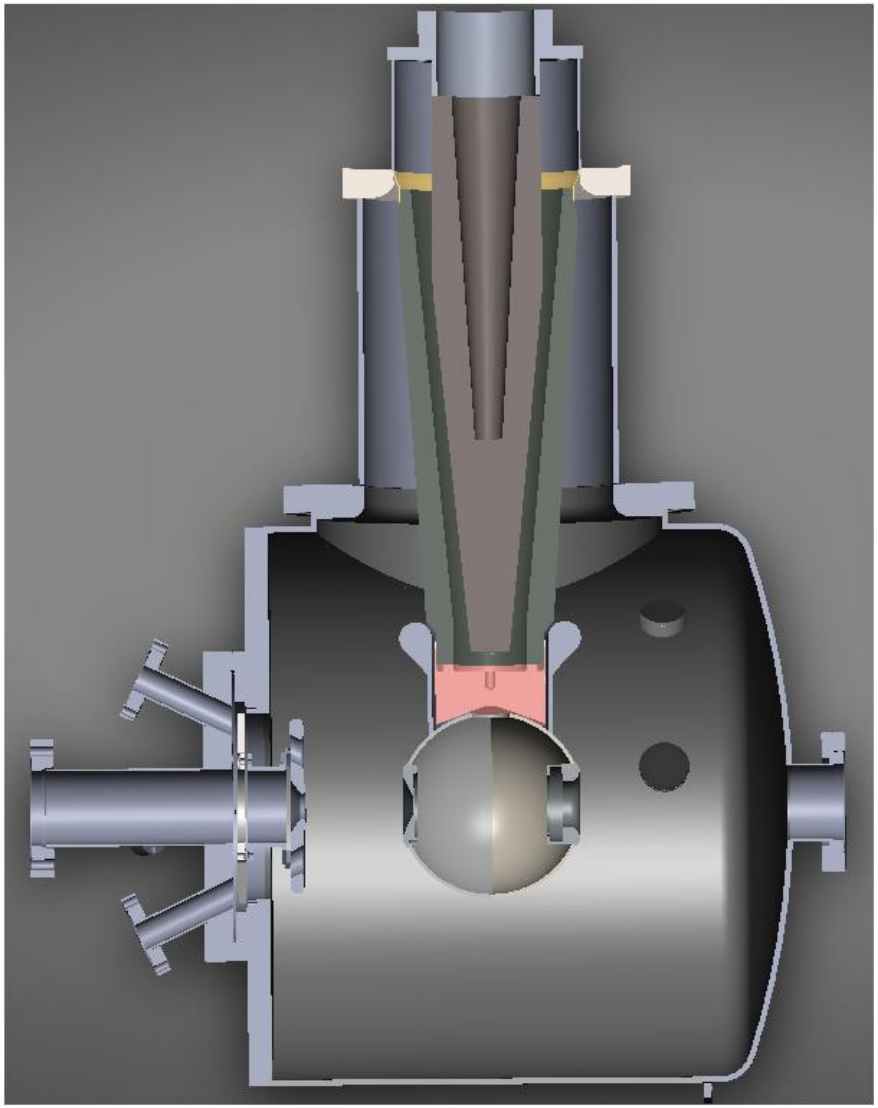
Two configurations reached our voltage goal

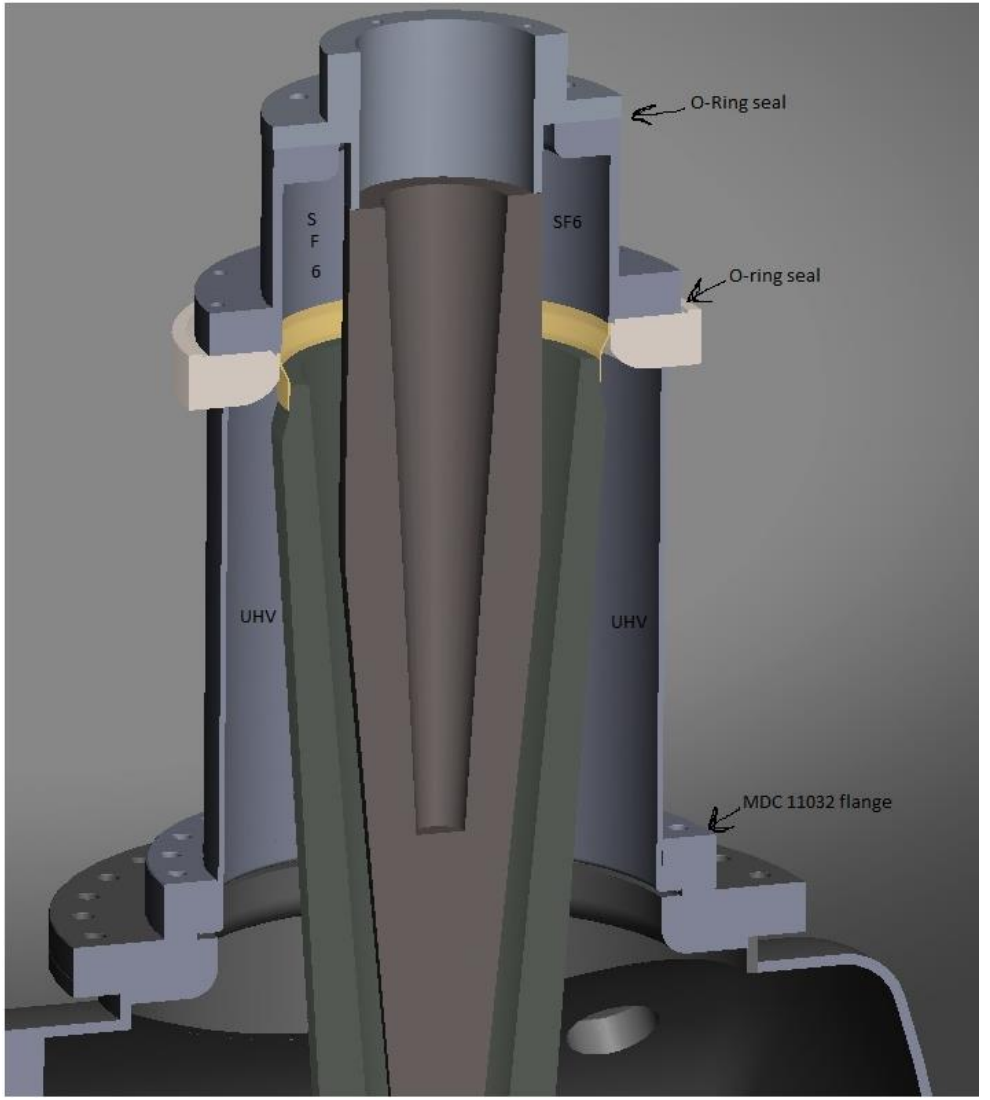
Insulator Type	Length (cm)	Transversal resistivity[a] (Ohm-cm)	Dielectric constant* $\varepsilon/\varepsilon_0$	Maximum voltage (kV)	Performance
R30 sample 1	20	5.0×10^{15}	9.1	329	Breakdown and puncture near HV end
R30 sample 2	20	5.0×10^{15}	9.1	300	Breakdown
R30 with additional screening electrode	20	5.0×10^{15}	9.1	375	370 kV sustained in multi-hour test, significant field emission
R30 ZrO-coated on vacuum side	20	5.0×10^{15}	9.1	340	Breakdown and puncture near ground end
R28 doped	13	7.4×10^{11}	8.4	365	360 kV sustained in multi-hour test, minimal field emission

[a]Provided by the manufacturer.

Based on two good results, we purchased long R30 doped insulators but….
Sadly, our recent test of R30 doped was a disappointment, puncture at 360 kV
Conclusion: both good results cited above a result of beneficial geometry

Plan Z: use big insulators purchased by FEL





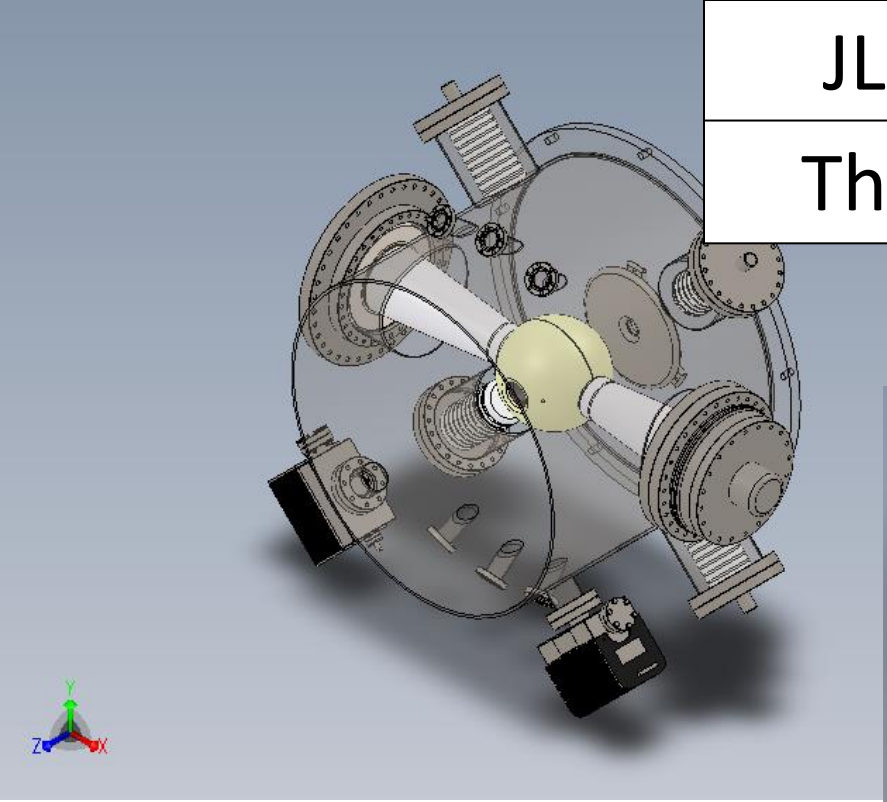
Longer insulator, adopt beneficial “shed”-style geometry, insulator + receptacle + SF6

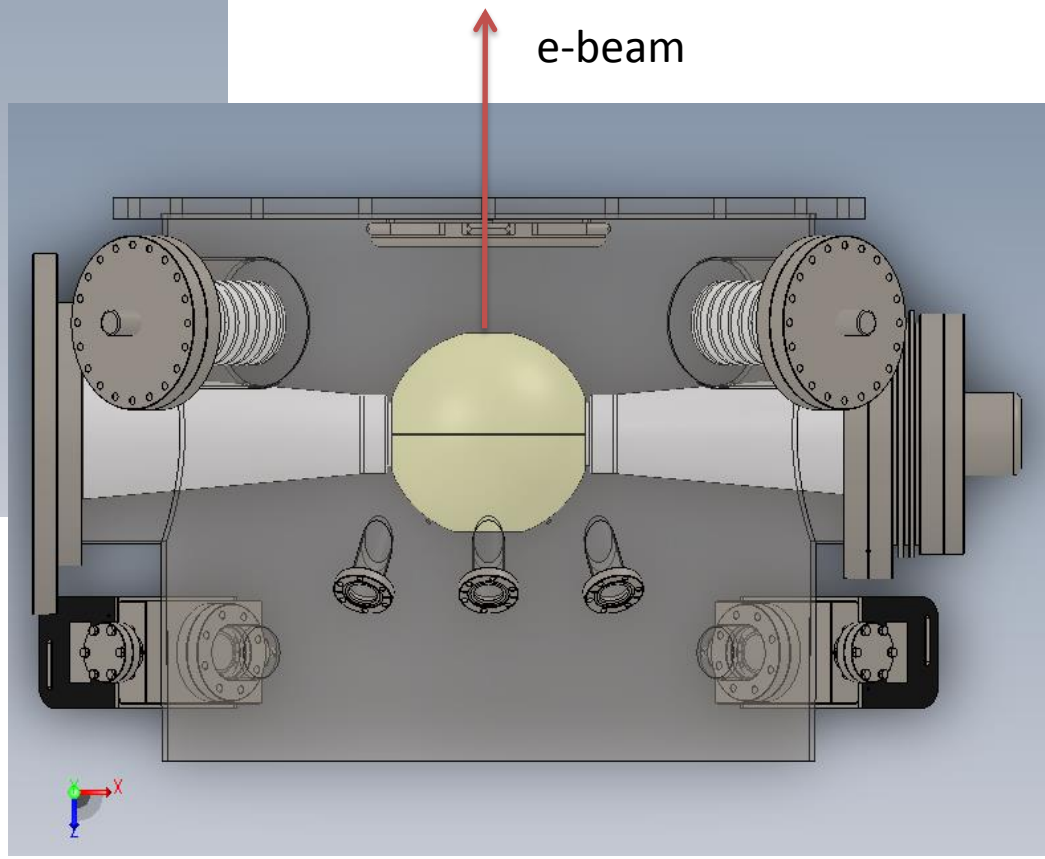
Before the FEL's financial collapse, they spent money on load-locked gun designs.

a) Inverted gun geometry, which they ultimately abandoned in favor of….
b) Copy successful Cornell and JAEA designs

JLab FEL 500kV inverted gun

They bought 6 long insulators

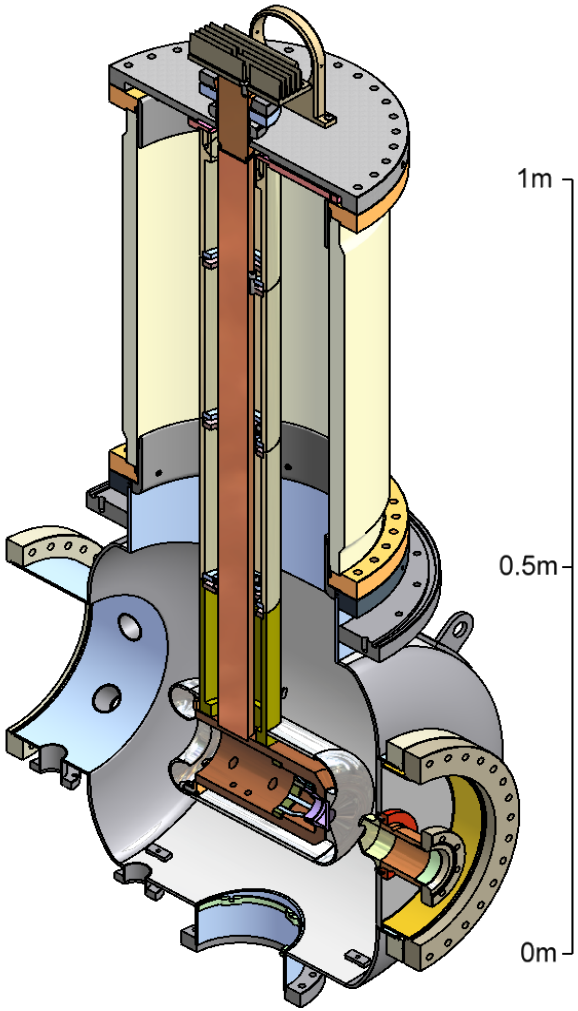


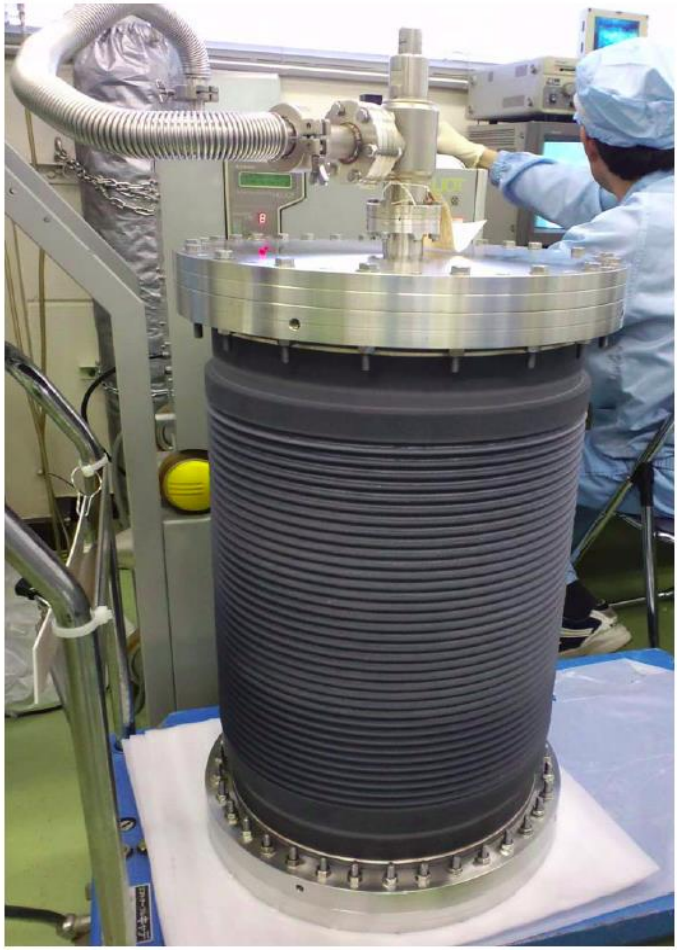


- Condition to 600kV, operate at 500kV
- 3x bigger inverted insulator compared to CEBAF gun
- One insulator for HV: one for cooling
- Niobium electrode – no diamond paste polishing
- Work in-progress

Courtesy: M. Marchlick, G. Biallis, C. Hernandez-Garcia, D. Bullard, P. Evtushenko, F. Hannon, and others from JLab-FEL

Jlab FEL adopted a similar design



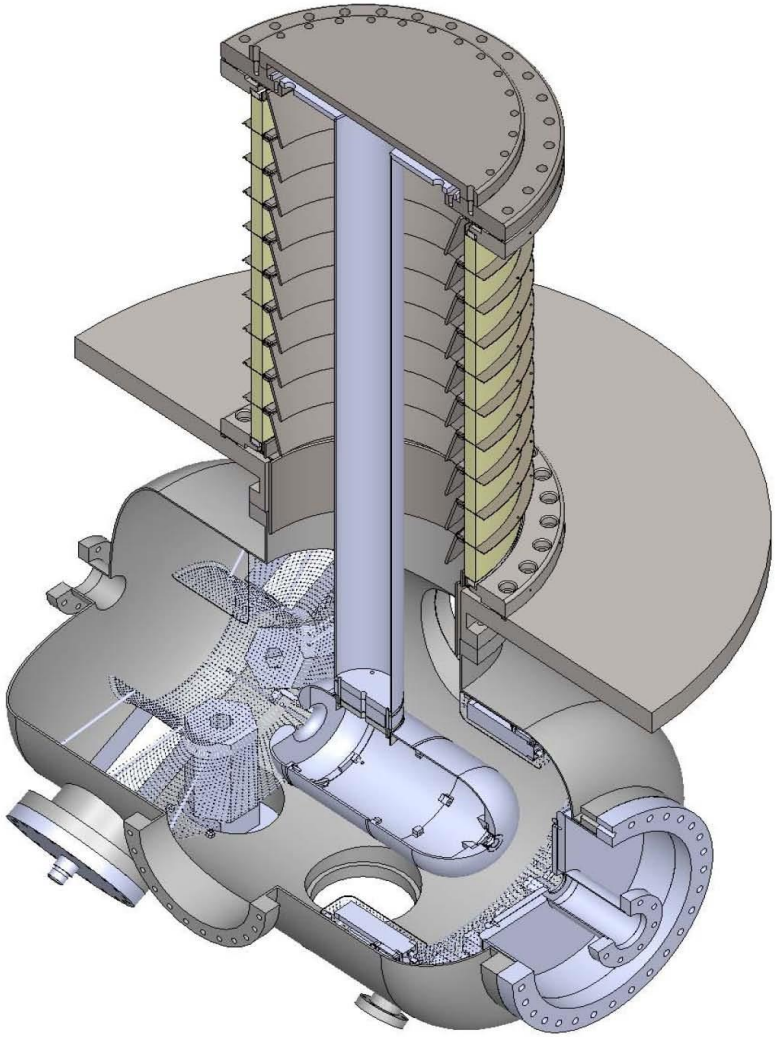


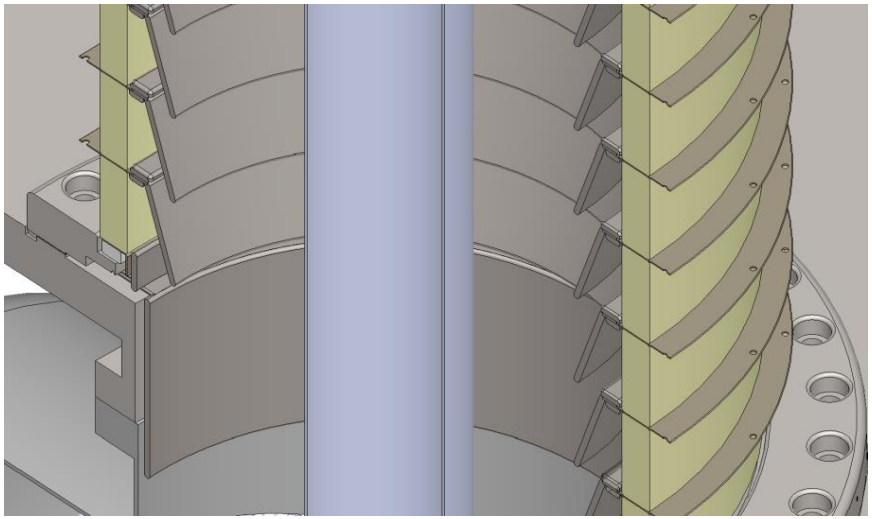
- Ceramic with bulk resistivity and improved braze design installed
- Measured resistivity of 6.45 x 10^{10} Ohm-cm gives 30 μA current draw at 500 kV
- Ceramic by Morgan, brazing and welding by Kyocera

Cornell University 400 kV gun

Courtesy Bruce Dunham, Cornell

Jlab FEL adopted a similar design





- High DC voltage >= 500kV
  - ✓ CockCroft Walton power supply
  - ✓ Segmented insulator with guard rings
  - High voltage testing
- Electrodes and vacuum
  - Cathode and anode electrodes
  - ✓ Low outgassing material (titanium)
  - NEG pumps

Jlab FEL bought this insulator

Courtesy N. Nishimori, Japan Atomic Energy Agency