DOE-NP Accelerator R&D PI Meeting

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Thomas Jefferson National Accelerator Facility
Exploring the Nature of Matter

DOE Headquarters, Germantown 11/14/2016

Recently Funded Projects

- 500kV DC High Voltage Inverted Gun with Load-locked CsK_2Sb Deposition Chamber - Research and Development for Next Generation Nuclear Physics Accelerator Facilities (LAB 12-632) **and** (LAB 14-1082)
- New Photocathode Materials for Electron Ion Colliders - Research and Development for Next Generation Nuclear Physics Accelerator Facilities (LAB 12-632) **and** (LAB 14-1082)
- Cryo-Pumped DC High Voltage Polarized Electron Source - Small Project, DOE Office of Nuclear Physics, (LAB 10-339)

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Recently Funded Projects

Summary of expenditures by fiscal year (FY):

$K	FY10+FY11	FY12+FY13	FY14+FY15	FY16	Totals
a) Funds allocated		$116.0			$116.0
b)Actual costs to date		$116.0			$116.0

LAB 12-632 & LAB 14-1082 - 500kV DC High Voltage Inverted Gun with Load-Locked Csk$_2$sb Desposition Chamber

To extend the “inverted gun” geometry design, to operate at higher voltage, for high bunch charge and high average current EIC cooling applications

$K	FY10+FY11	FY12+FY13	FY14+FY15	FY16	Totals
a) Funds allocated		$44.0			$44.0
b)Actual costs to date		$44.0			$44.0

LAB 12-632 & LAB 14-1082 - New Photocathode Materials for Electron Ion Colliders (used by W&M for plasmonic photocathode studies)

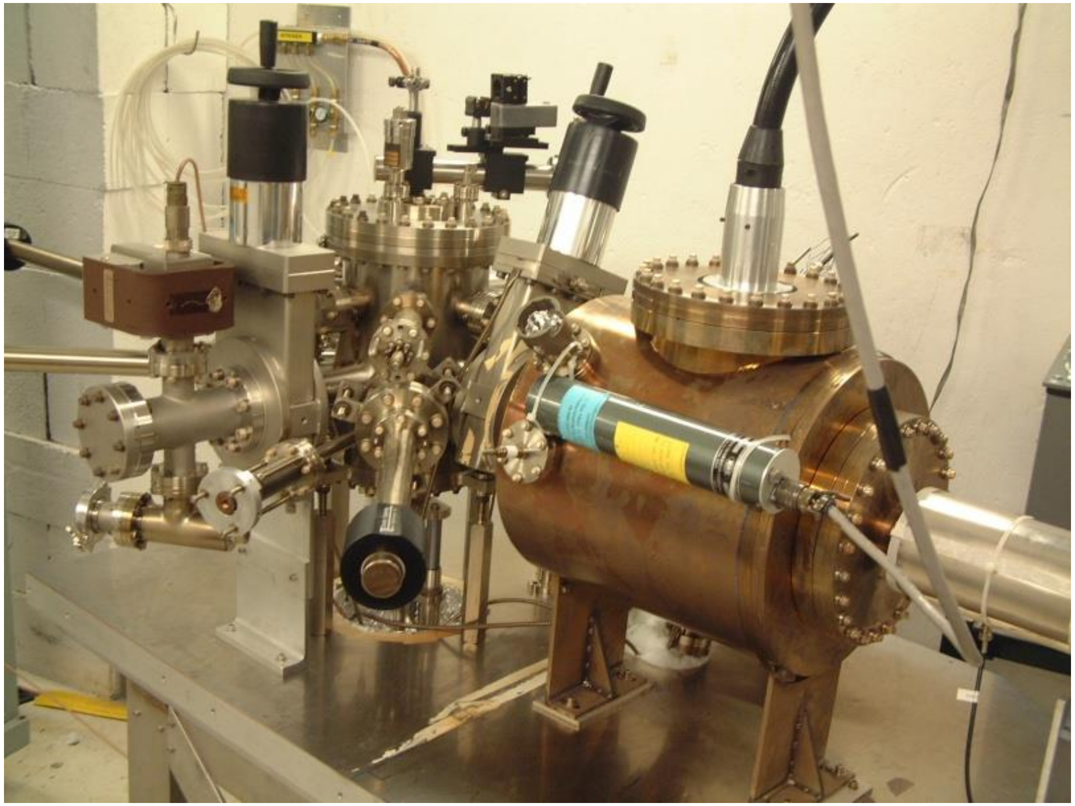
To design a photocathode test stand to measure QE and polarization of new photocathode materials that might help EIC

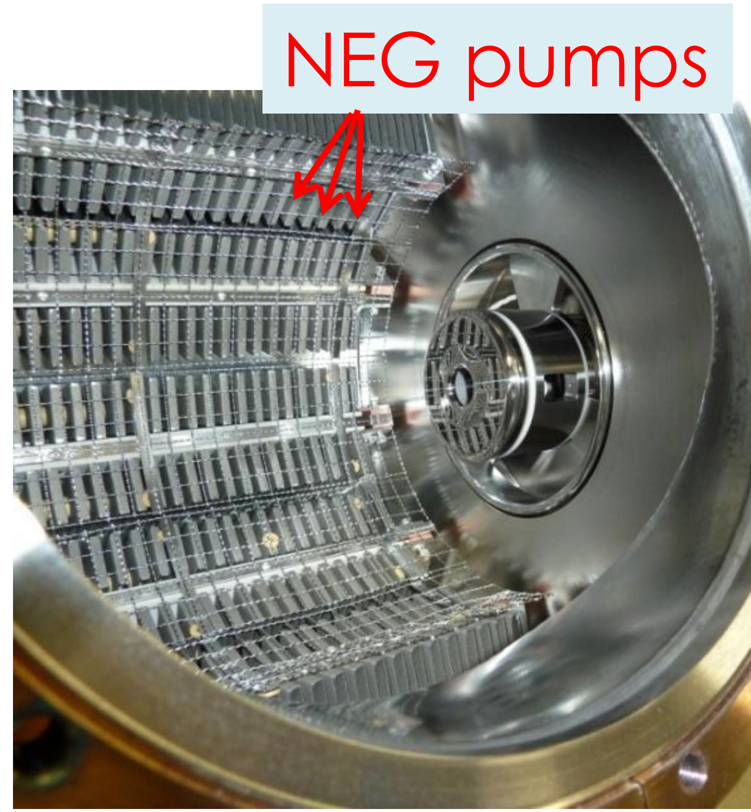
$K	FY10+FY11	FY12+FY13	FY14+FY15	FY16	Totals
a) Funds allocated	$362.0				$362.0
b)Actual costs to date	$361.6				$361.6

LAB 10-339 - Cryo-Pumped DC High Voltage Polarized Electron Source

To improve photogun vacuum and thereby improve lifetime of polarized electron sources, particularly at mA current, i.e., eRHIC

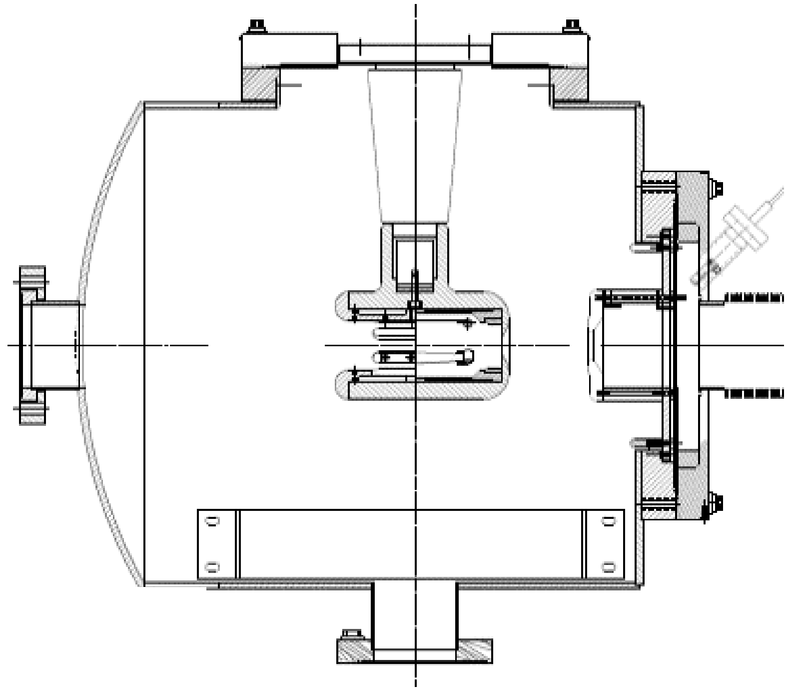
The CEBAF - ILC Inverted Gun



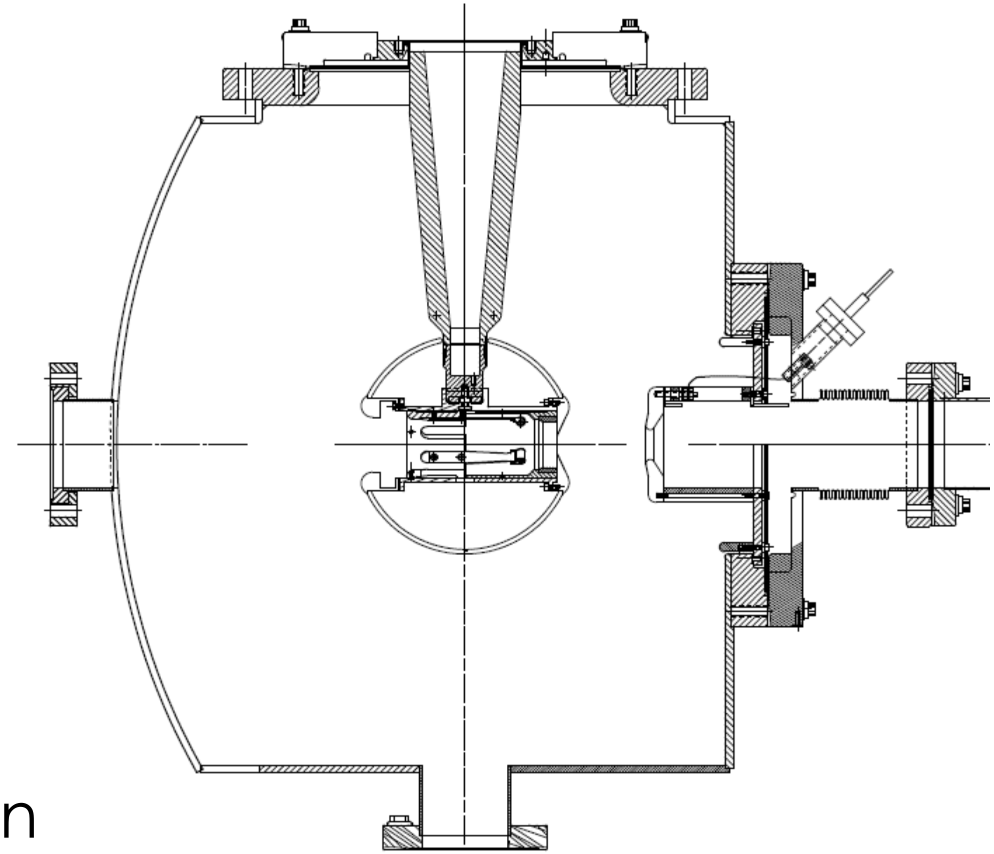


- Load-locked GaAs polarized photogun
- 130 kV at CEBAF, 200 kV at Injector Test Stand
- Gun Vacuum ~ low 10^{-12} Torr

500 kV Photogun?



CEBAF 130 kV Inverted Gun
"R28" insulator

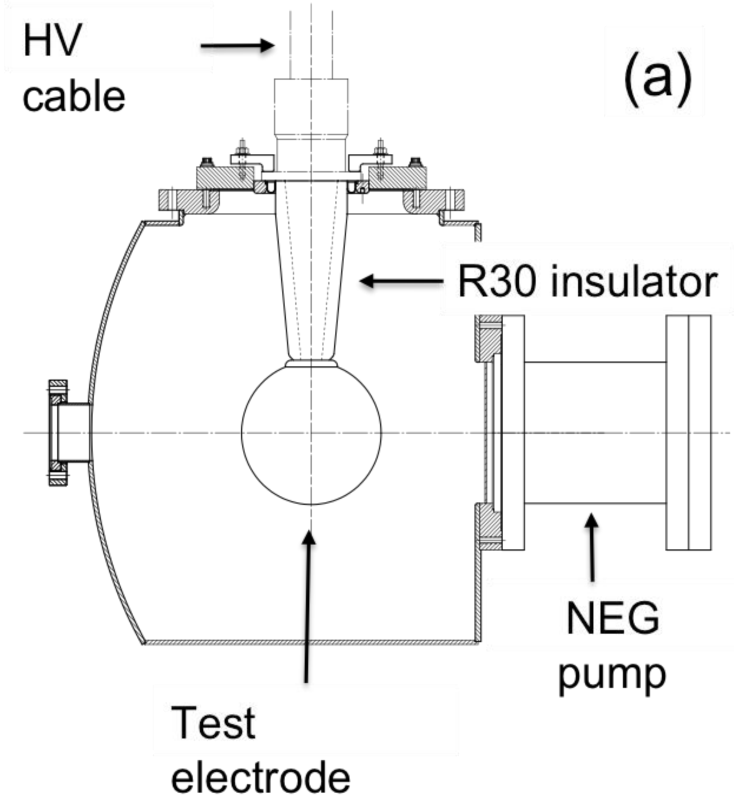


Longer "R30" insulator
Spherical electrode

Slide 6

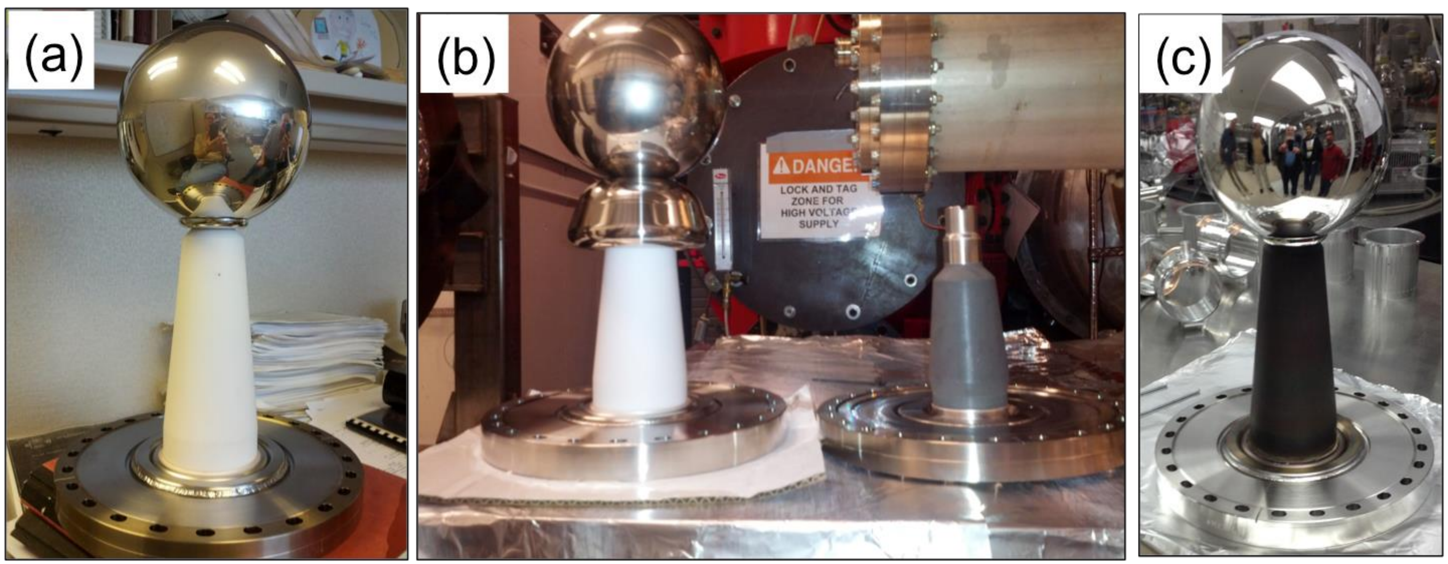
Building the 500 kV Gun

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



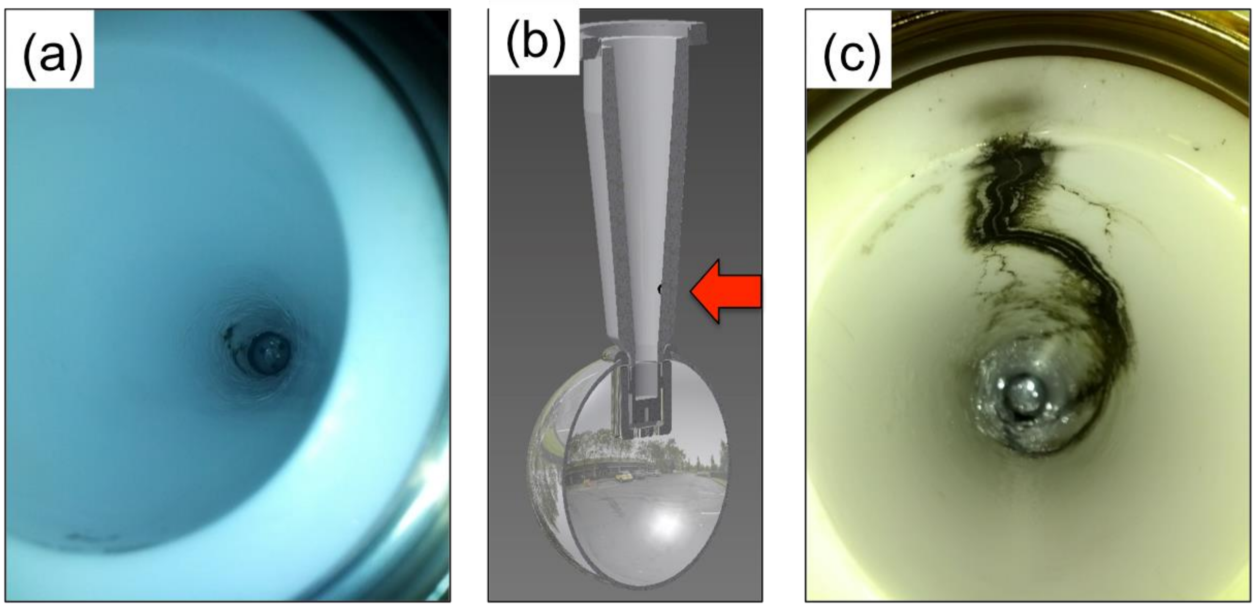
INSULATORS AND SCREENING ELECTRODE

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



BREAKDOWN AT CABLE/INSULATOR INTERFACE

- Problems at the cable junction, atmosphere side



- Note: Field emission was managed via krypton-processing. i.e., voltage first applied with ~10^{-5} Torr krypton added to gun chamber

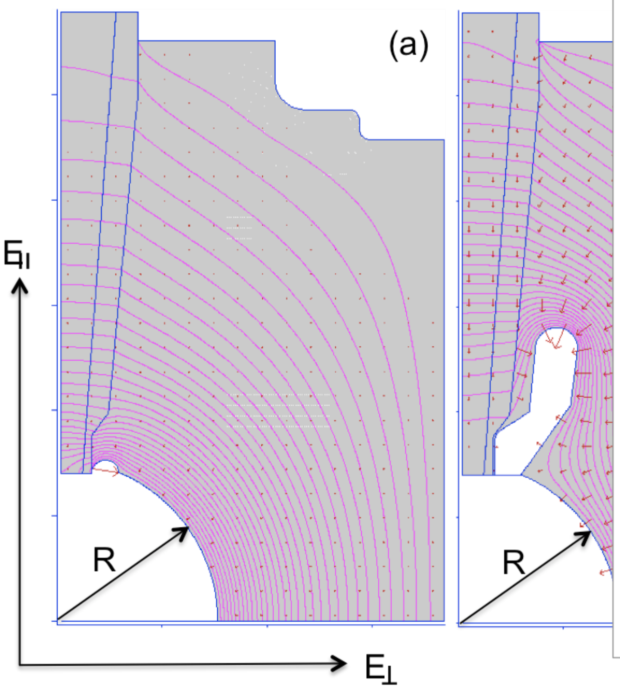
Summary of Tests

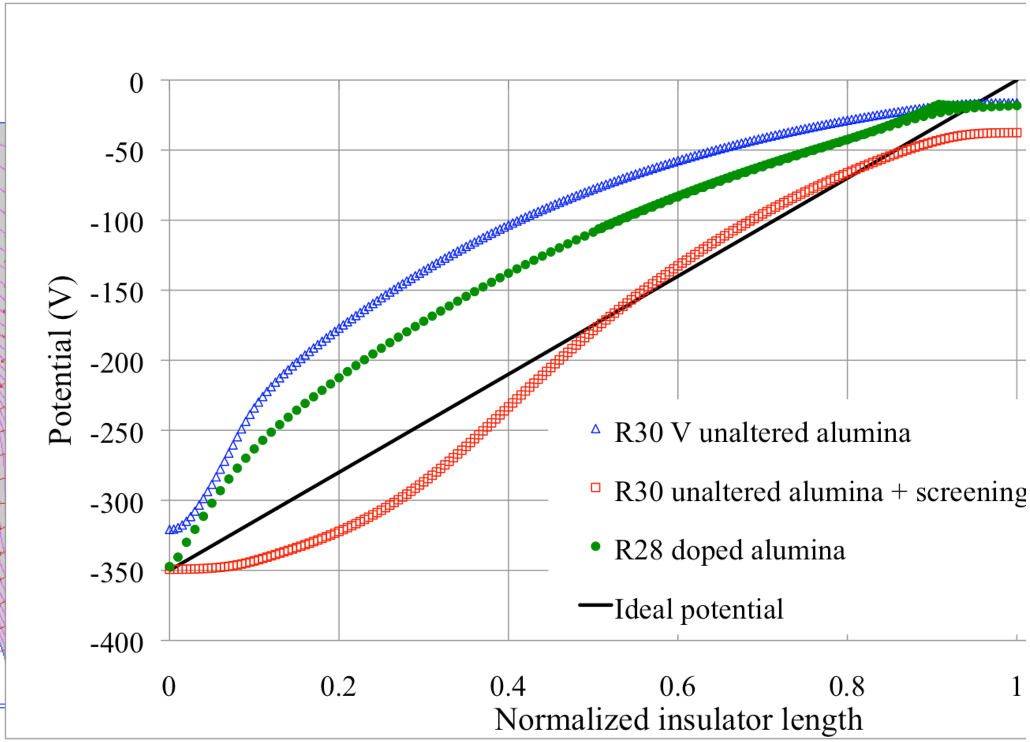
- Two and 1/2 configurations reached our voltage goal

Insulator type	Length (cm)	Transversal resistivity (Ohm-cm)	Dielectric constant $\varepsilon_1/\varepsilon_0$	Maximum voltage (kV)	Performance
R30 sample 1	20	5.0×10^{15}	9.1	329	Breakdown and puncture near high voltage 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 with krypton 4-hr soak, 350 kV in vacuum 4-hr soak. Significant field emission in both cases
R30 ZrO-coated	20	5.0×10^{15}	9.1	340	Breakdown and puncture near ground end
R28 doped	13	7.4×10^{15}	8.4	360	360 kV with krypton 1-hr soak, 350kV in vacuum 5-hr soak, 2 times Minimal field emission in both cases
R30 doped	20			360	Breakdown originating at high voltage end and puncture near ground end

Linear Potential Drop

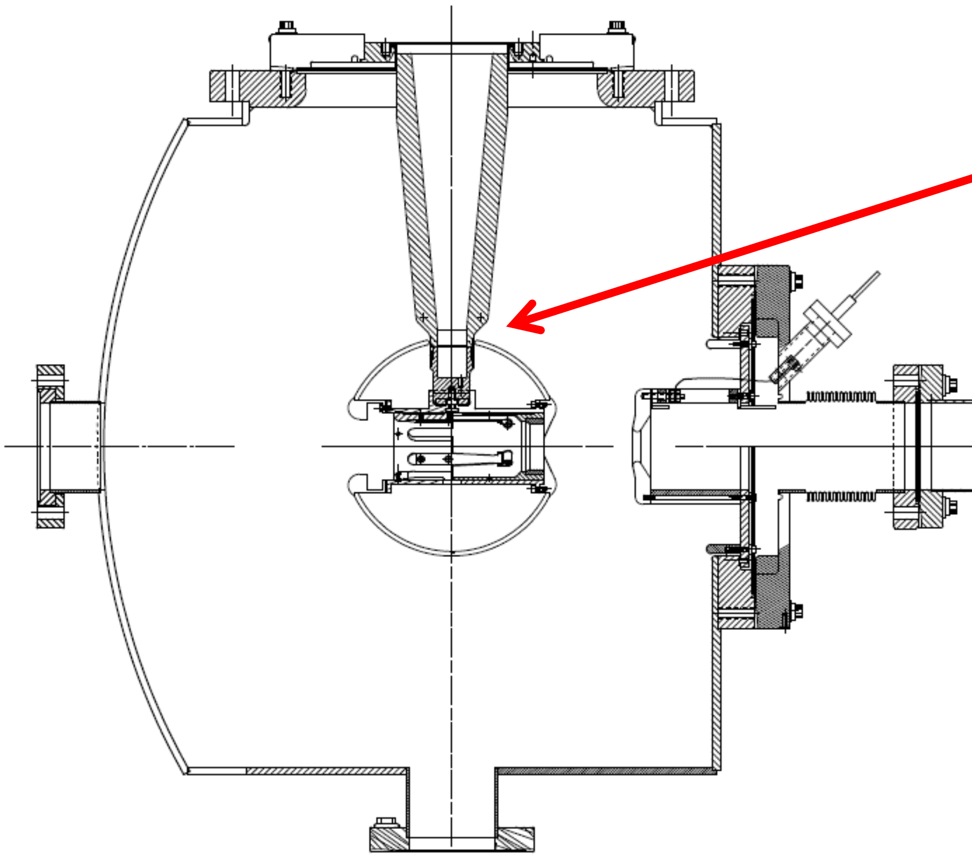
- Want a linear potential gradient along length of the insulator

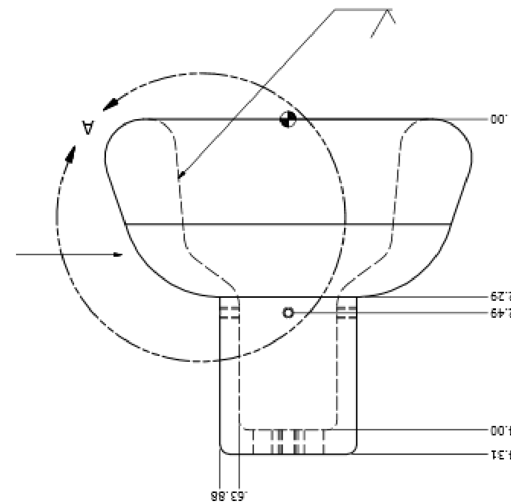




- Note - POISSON does not accurately model the mildly-conductive feature of the black insulator

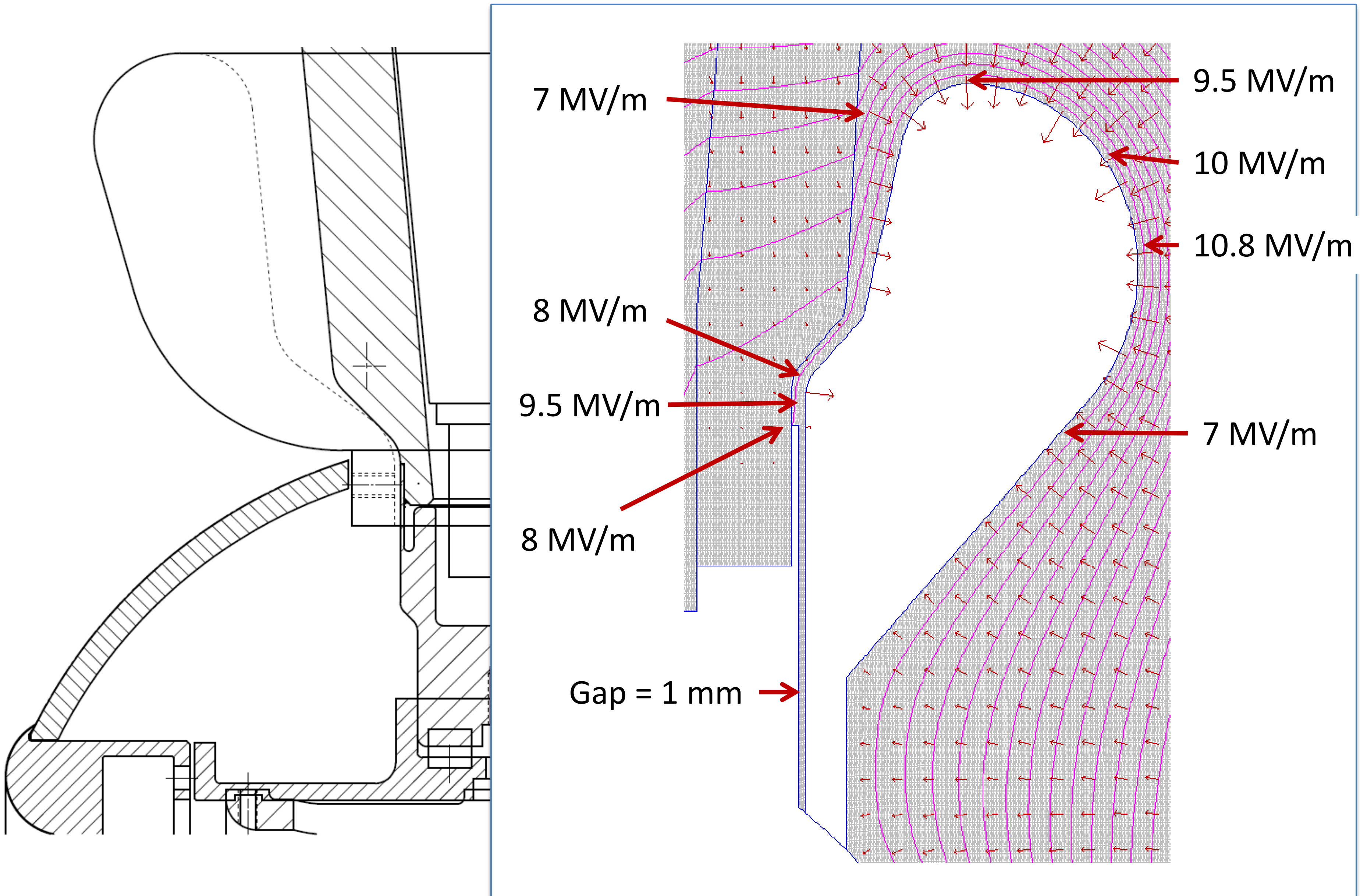
- Combine the two features that provided incremental success: screening electrode and doped black R30 insulator





- Replaced dummy ball with electrode that can hold photocathode

The gap between shed and insulator



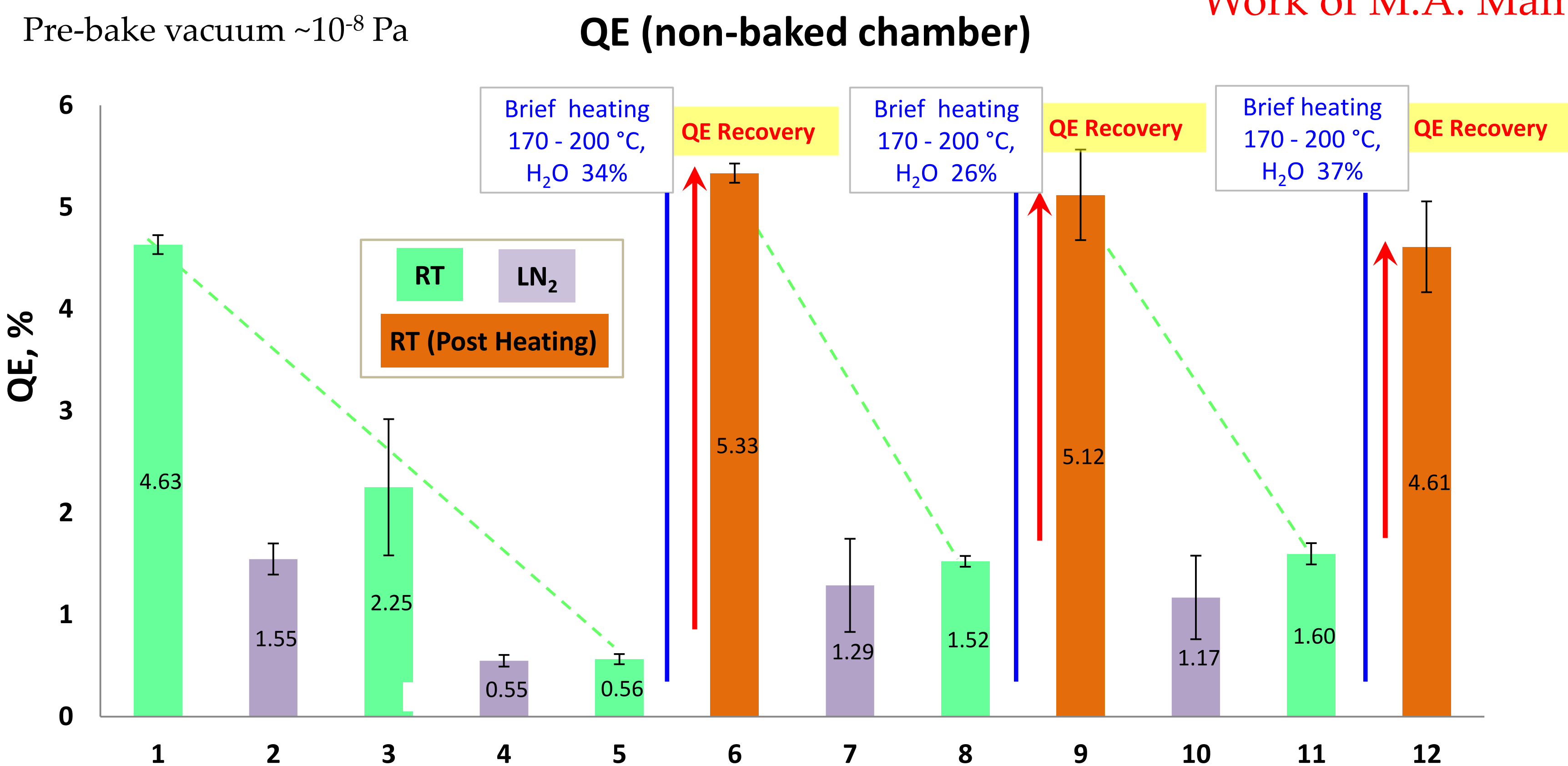
CsK_2Sb DEPOSITION CHAMBER

- Effusion source, compact, high capacity
- Contains both Cs and K species, co-deposition
- Photocathodes grown on stalks

Distinguishing QE Drop due to Contamination

Work of M.A. Mamun

Pre-bake vacuum ~10^{-8} Pa

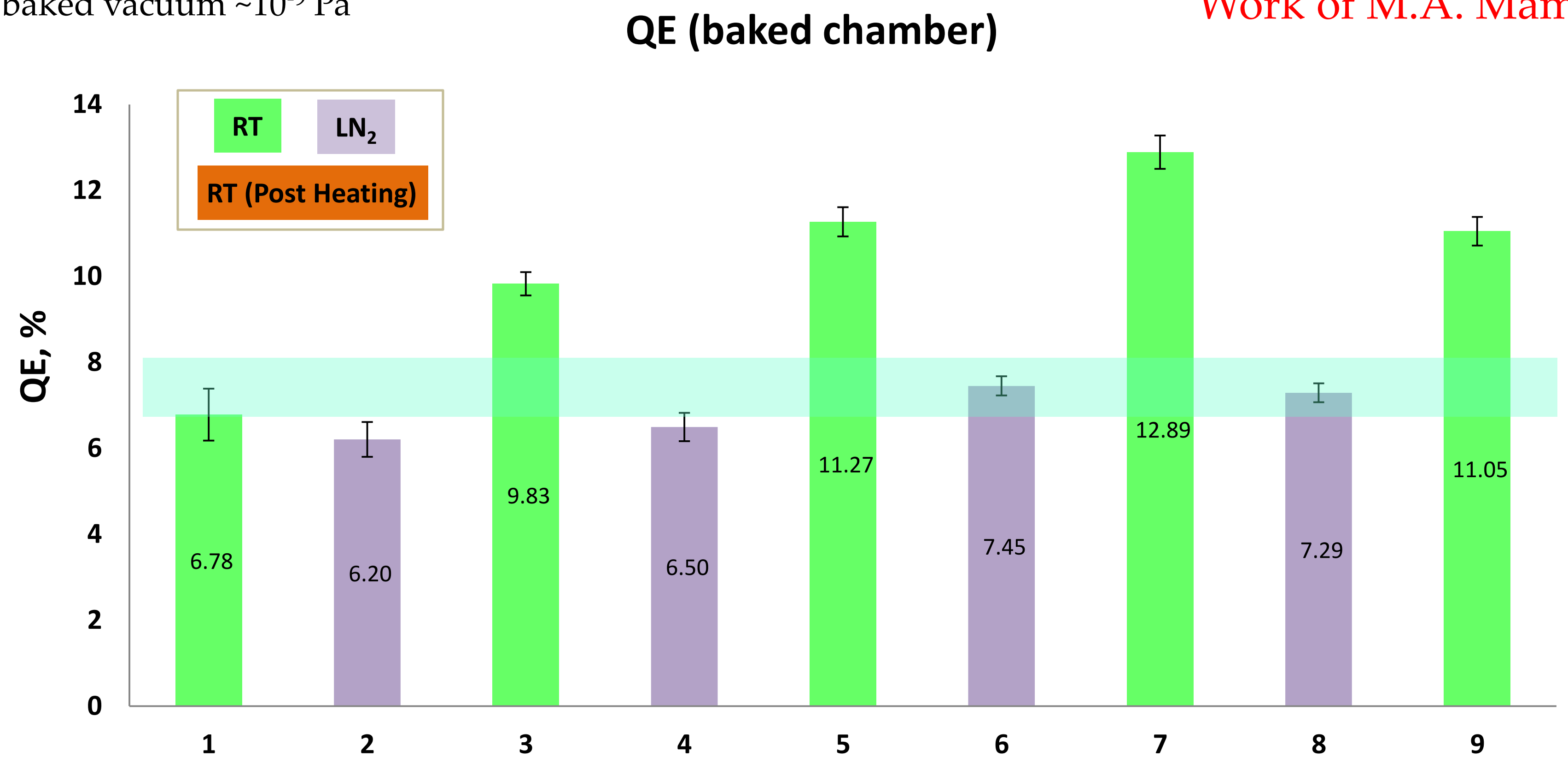


- **Systematic decrease in QE at RT** in **repeated cooling events**
- Considerable increase in water partial pressure during brief heating was observed
- **Rejuvenation of QE** by brief heating at 170-200 °C was consistently observed in the non-baked system which can be considered as a **signature of water adsorption**

Reproducible QE - Cryocooled Photocathode

baked vacuum ~10^{-9} Pa

Work of M.A. Mamun

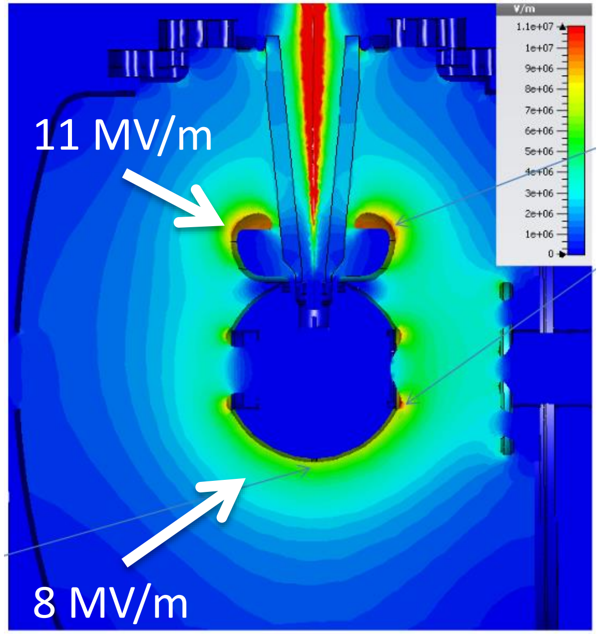


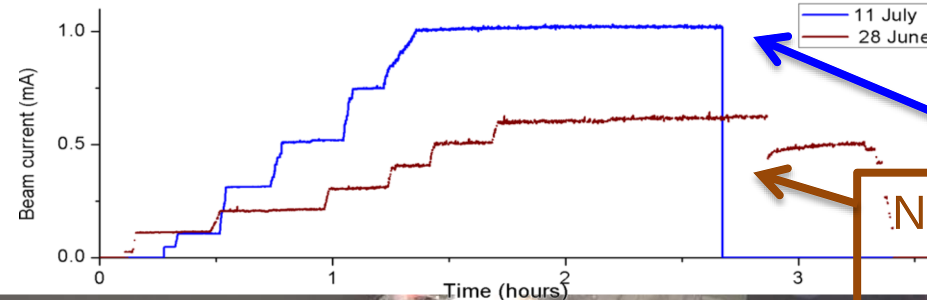
- The QE at RT **did not show any decrease** between **repeated cooling** events
- **QE at Liquid N_2** temperature (77 K) showed **similar QE every time** it was cooled
- **Initial QE rise** due to **stoichiometric optimization**
- We did our spectral response and temperature analysis from this phocathode.

DEPO CHAMBER AT GUN TEST STAND

Always something to fix: Valve between gun and depo chamber leaked, working distance between puck and chemical sources too large, no mask to limit active area

300 kV Inverted Gun and CsK_2Sb Photocathode

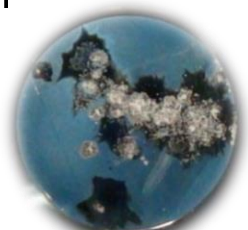


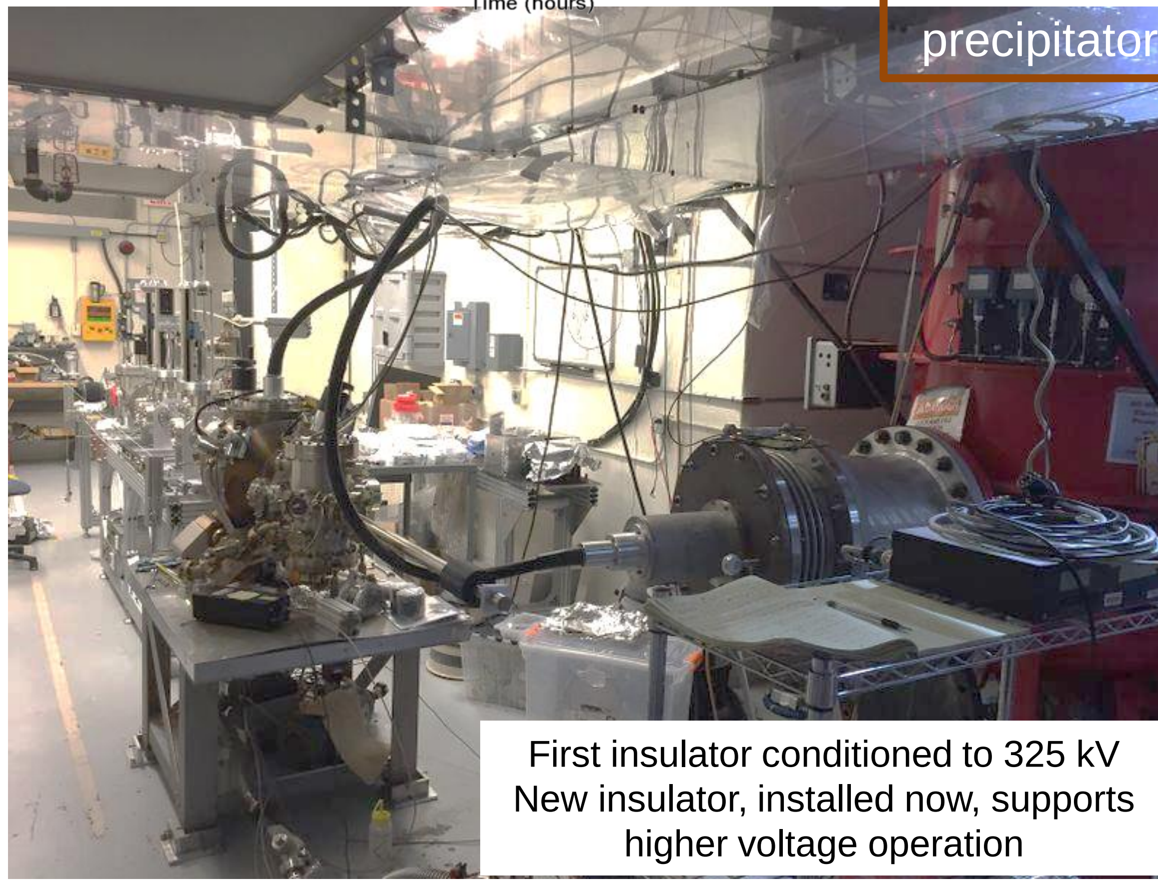


1mA

Need mask and precipitator

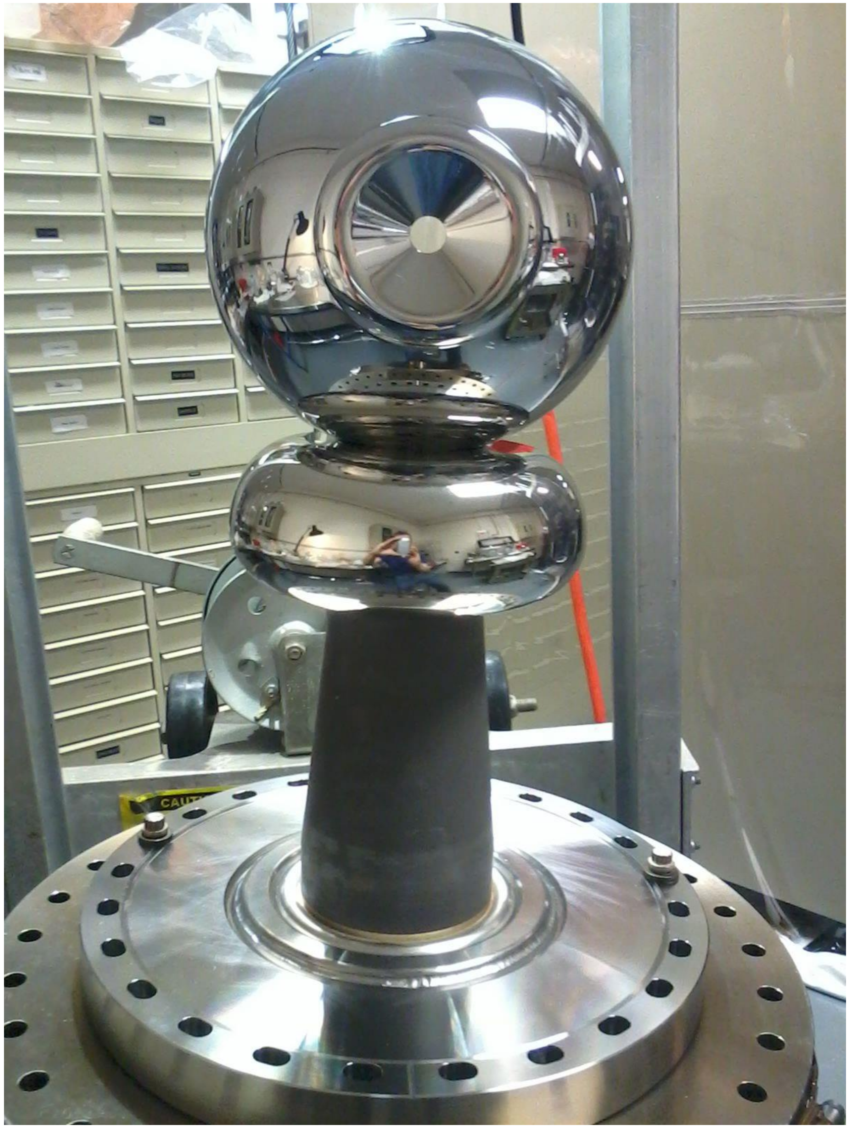
Learning how to use the new photocathode





First insulator conditioned to 325 kV
New insulator, installed now, supports higher voltage operation

500 kV Gun



500 kV Gun

Barrel-Polished Electrodes

- Gun electrodes traditionally polished using sand paper and diamond paste
- Tedious process, takes about 30 days to complete
- Now performed in 1 day using SRF barrel polishing machine

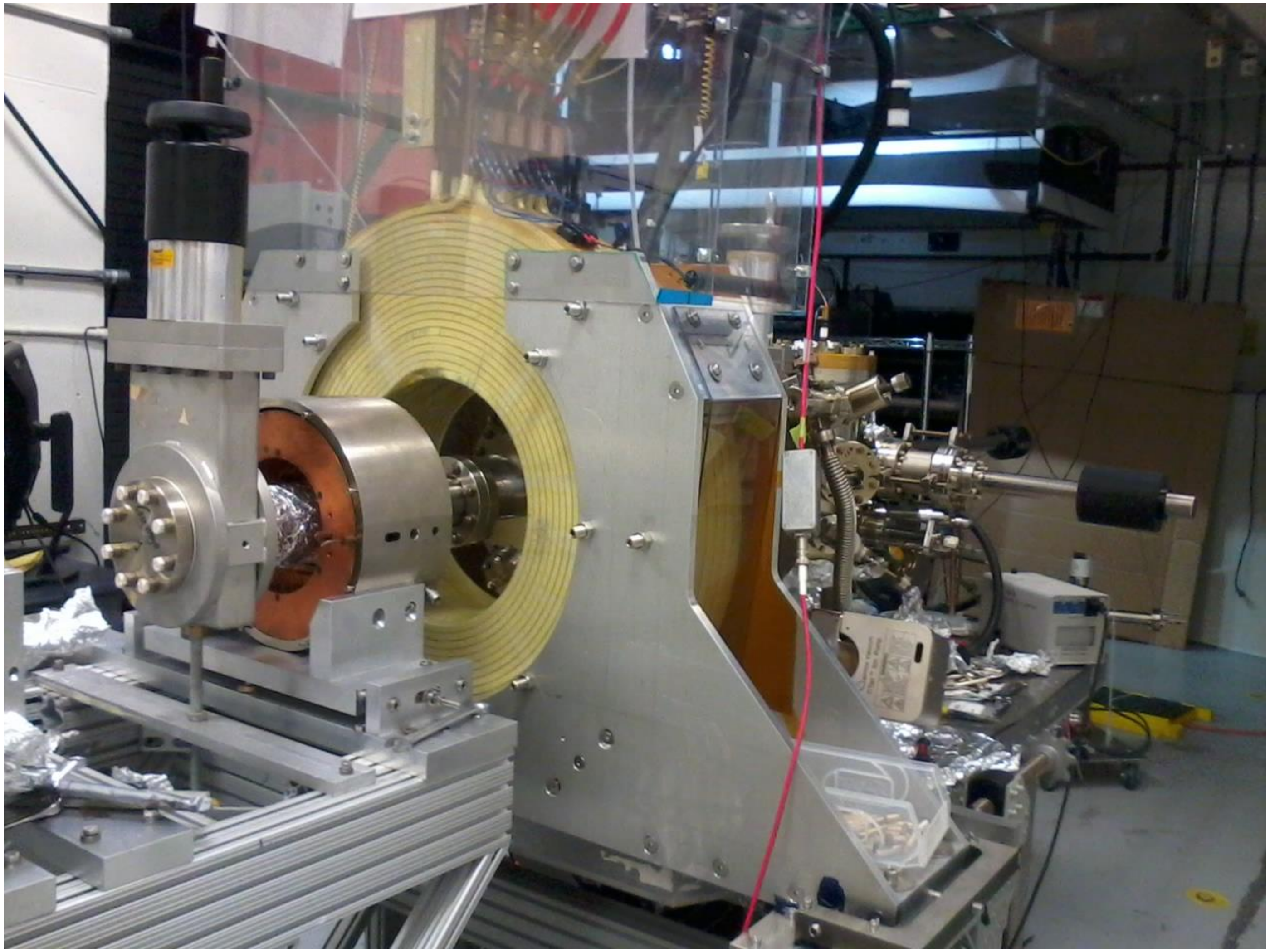
From machine shop

30 minutes with plastic cones

30 minutes with corncob

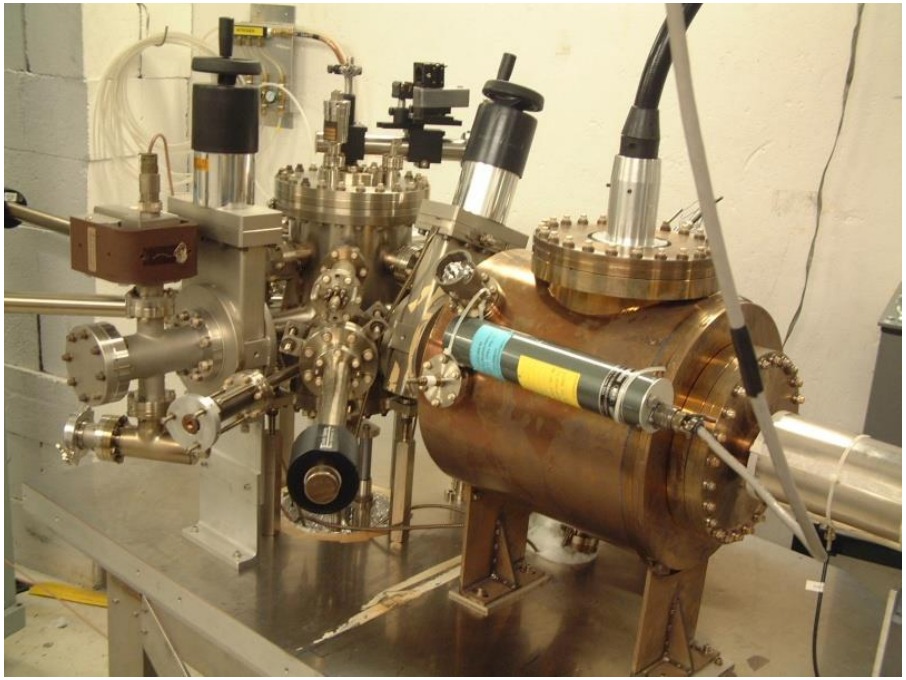
Work by Don Bullard

Magnetized Beam Tests



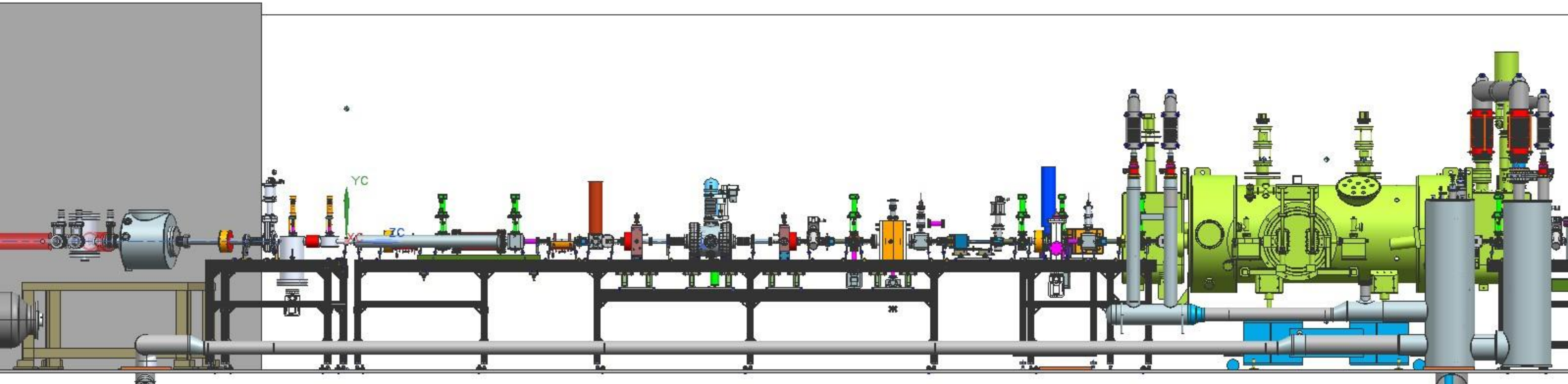
Fixed the gun and deposition chamber, added solenoid

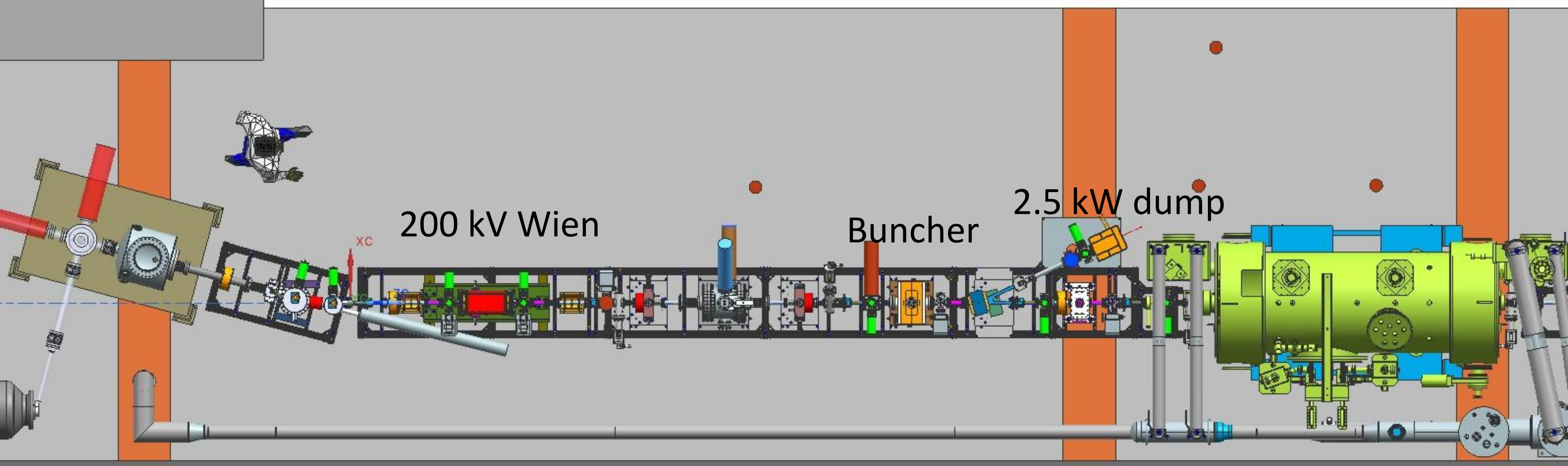
350 kV Gun at Injector Test Facility

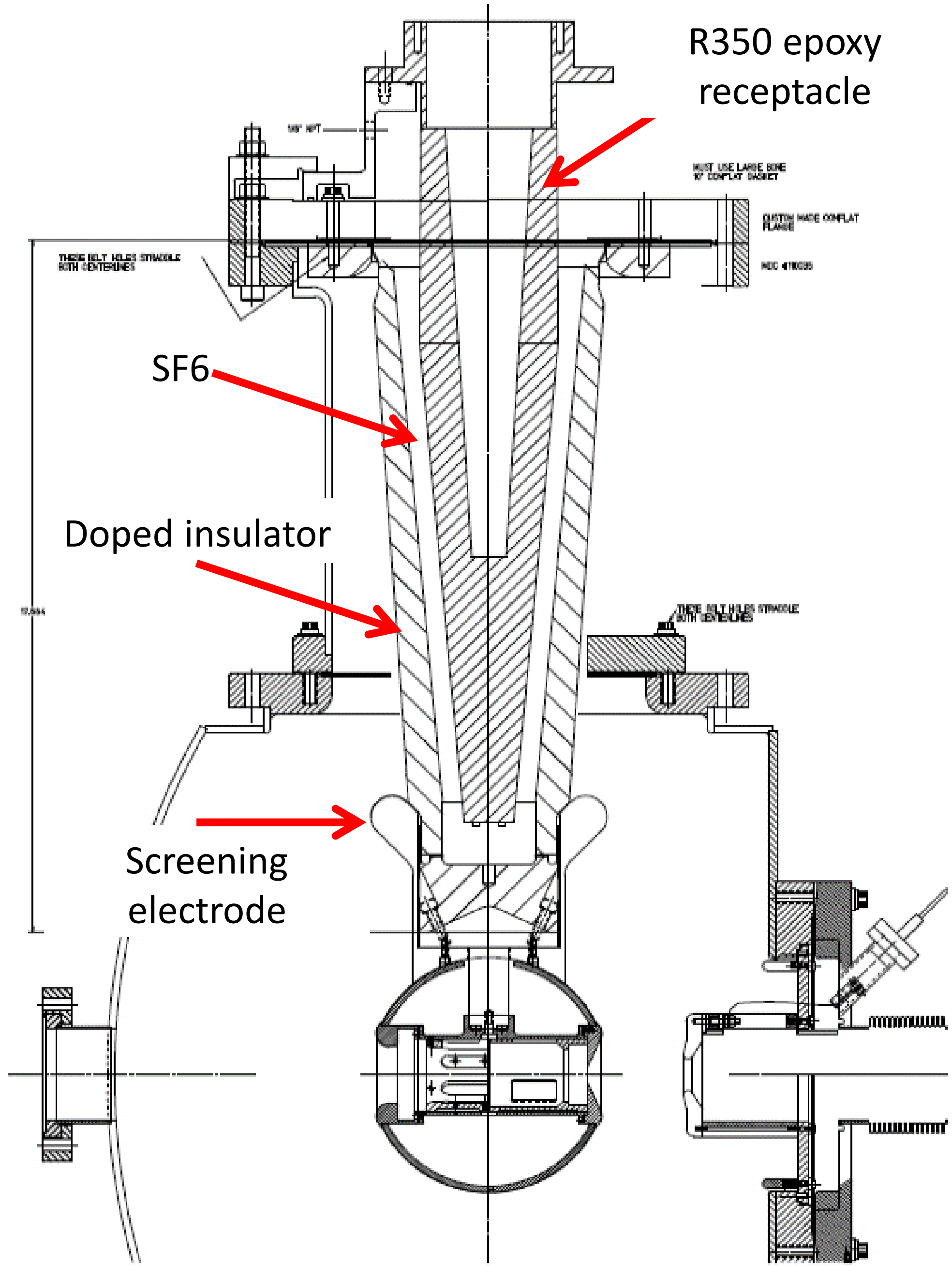


Old and New inverted guns
Vacuum low 10^{-12} Torr
Working on the beamline now

kV beamline at Injector Test Facility



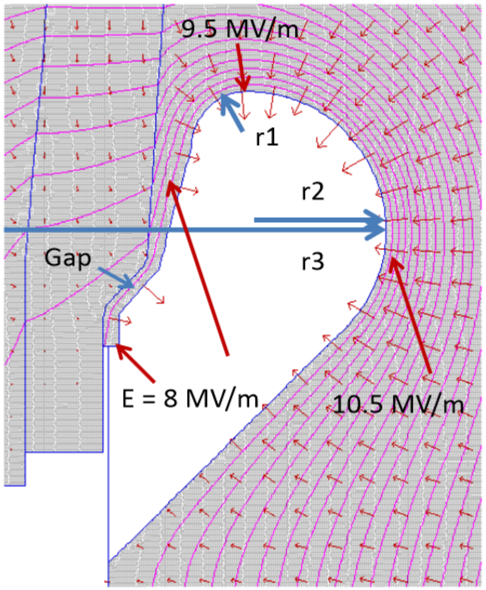




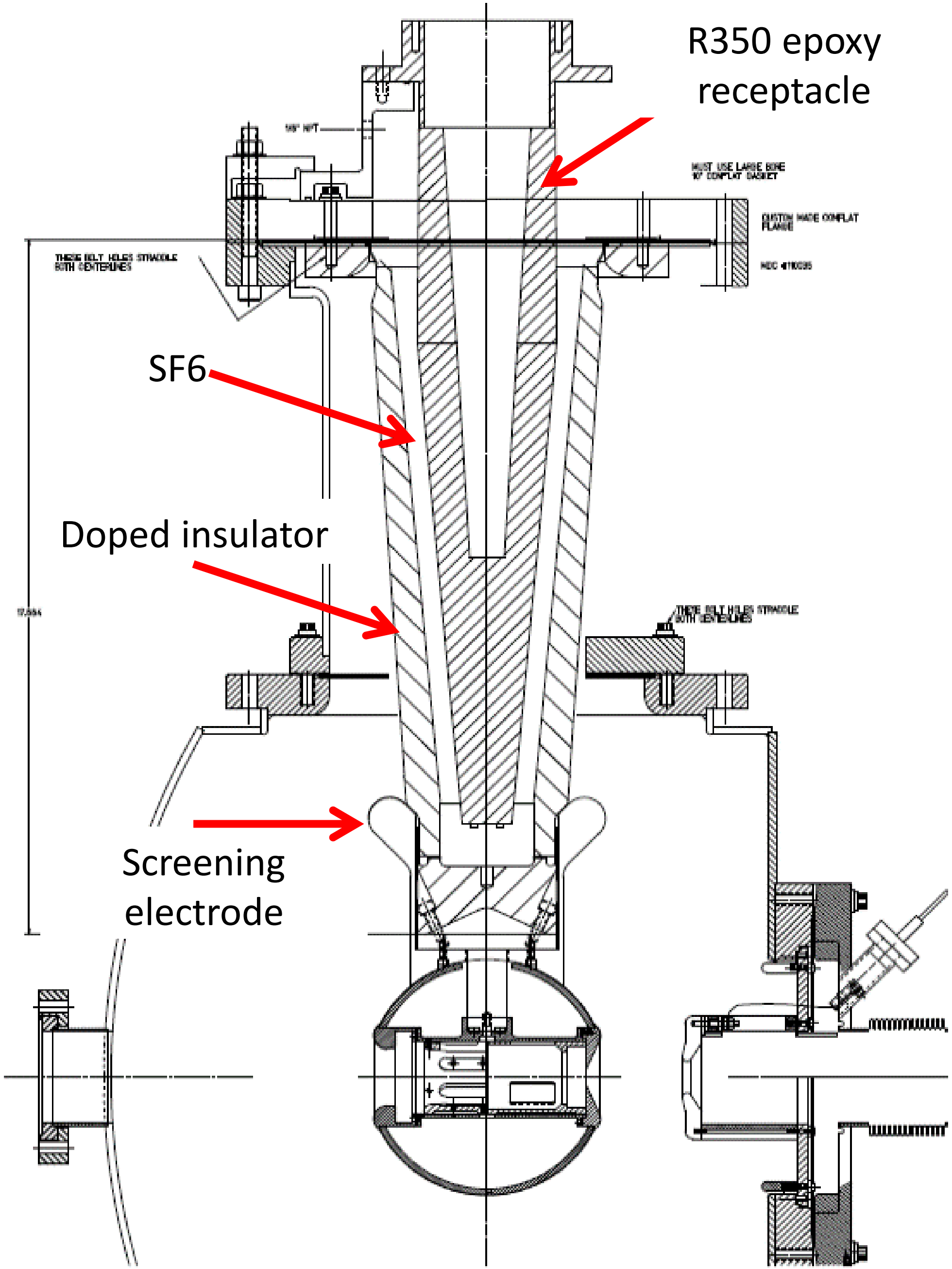
Plan Z

- Our plan to reach 500 kV
- Combination of long doped insulator and shed, SF6 and epoxy receptacle
- And likely a different vacuum chamber

- r1 = 1 cm
- r2 = 2.5 cm
- r3 = 9.5 cm
- 3 mm gap



Work of Yan Wang



Plan Z

- We have the big insulators
- Cables in Receptacles: very reliable
- Receptacles in SF6: very reliable
- Use cold SF6 to remove heat from photocathode

Thank You

- Will continue to work on 500 kV inverted gun, CsK_2Sb deposition chamber (and Cryopumped gun)
- Magnetized beam tests
- We can revisit high current (mA) lifetime tests with polarized beam but need support