

# Status of high intensity polarized electron gun project at MIT-Bates



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# General Information

- Polarized electron guns utilize GaAs photo cathodes.
- When polarized laser beam strikes the cathode, polarized electrons are ejected.
- Photocathodes must have atomically clean surface and they must be activated by heating to about 600°C and applying Cs and NF<sub>3</sub> to the surface.
- UHV conditions are required in the gun. Any traces of gases (excluding hydrogen and noble gases) poison the crystal.

# eRHIC (Linac-ring version)

Requires a polarized electron source with an extremely high current ( at least 10 mA).

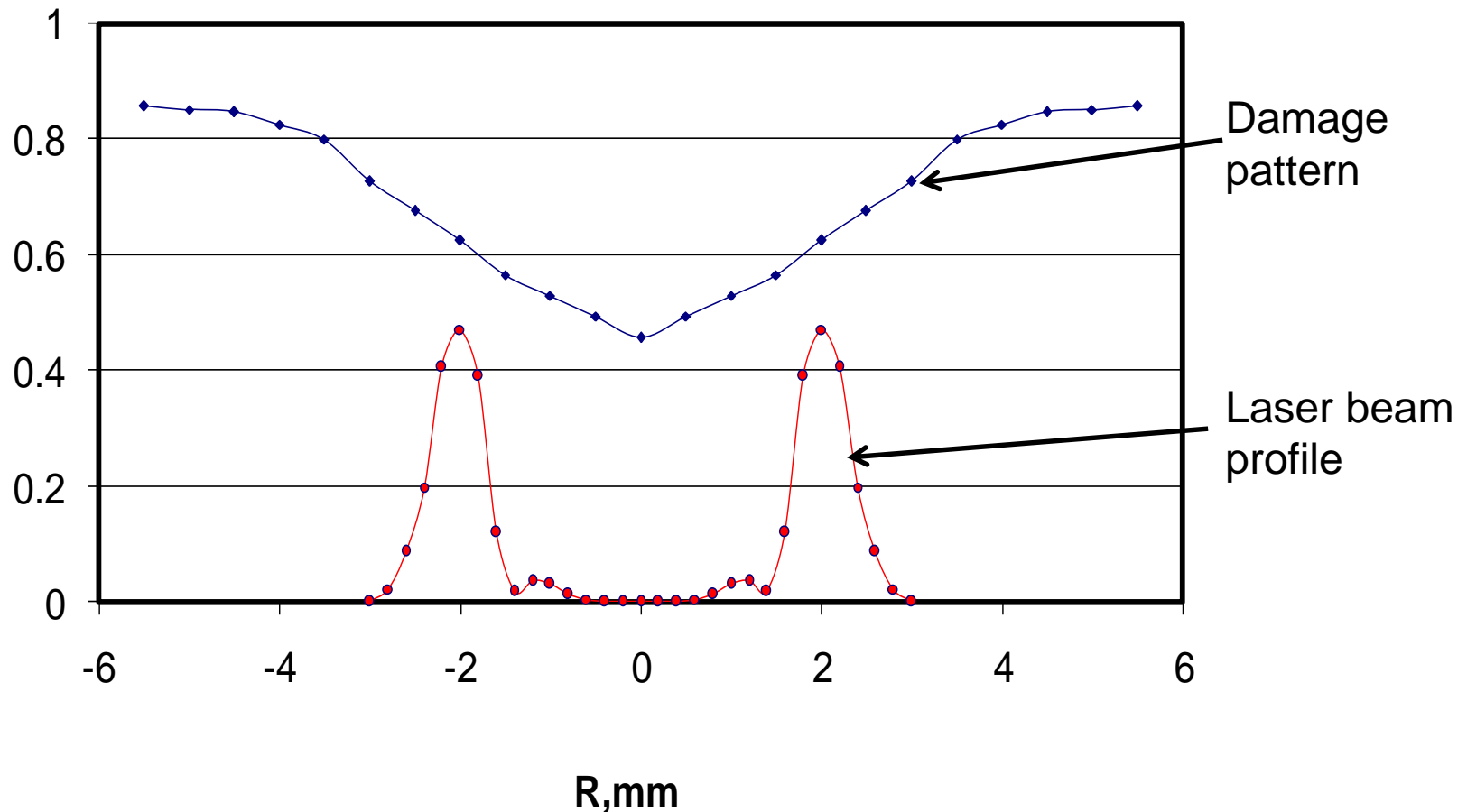
- Modern state-of-the-art guns produce  $\sim 100\text{-}200\ \mu\text{A}$
- Average current of  $\sim 1\ \text{mA}$  achieved in tests at JLab and Mainz;
- Average current of up to 10 mA achieved at Mainz with very short lifetime (needs active cathode cooling)

Main problem – ion back bombardment.

Anode hole acts like a focusing lens for ions.

Ion damage is most severe at the center of the cathode.

# Ion damage mostly the center of cathode (Bates results)



# High Intensity Polarized Electron Gun

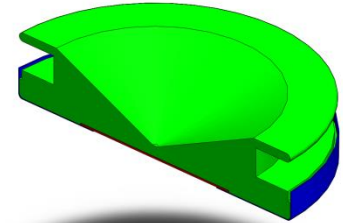
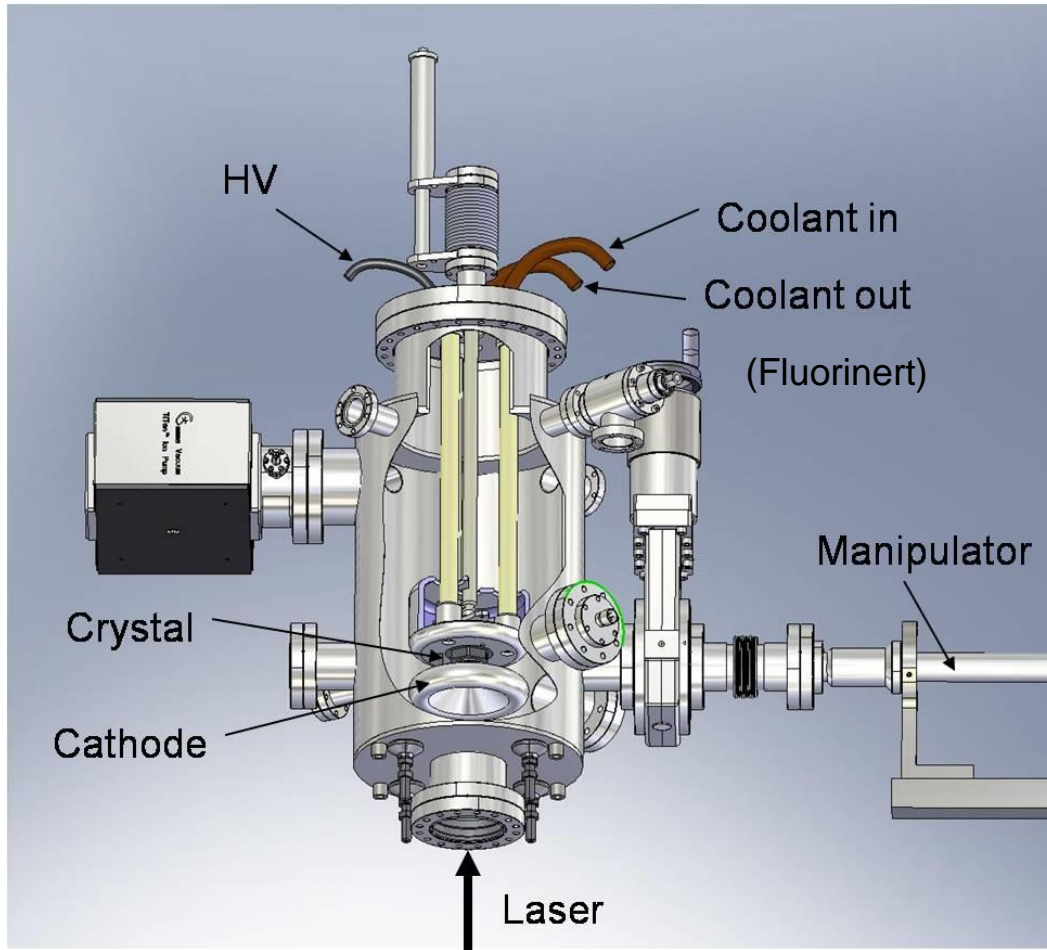
**The principal points to achieve high average current:**

- Large area cathode.
- Ions tend to damage the central area of the cathode – ring-shaped emission pattern.
- Active cathode cooling.
- Very small beam losses could be allowed near the gun (  $<10^{-6}$  ).

# Additional requirements

- Heat-cleaning and activation compromise vacuum condition, they should be done in a separate chamber (preparation chamber).
- It takes months to achieve good vacuum, so gun chamber and preparation chamber should never be vented. New cathodes should be loaded into the system via load lock.

# Cathode cooling

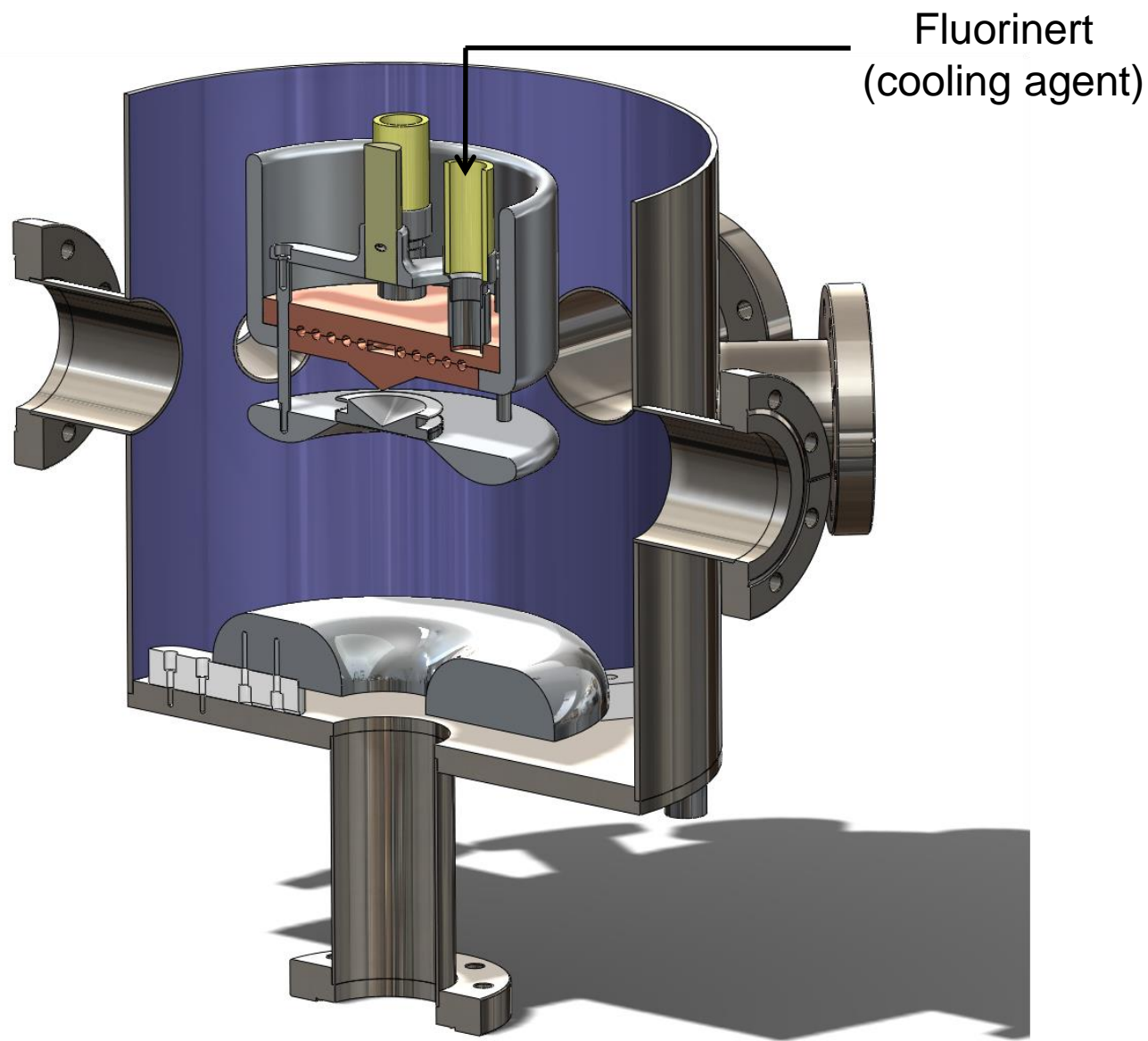


Cathode puck (Moly)



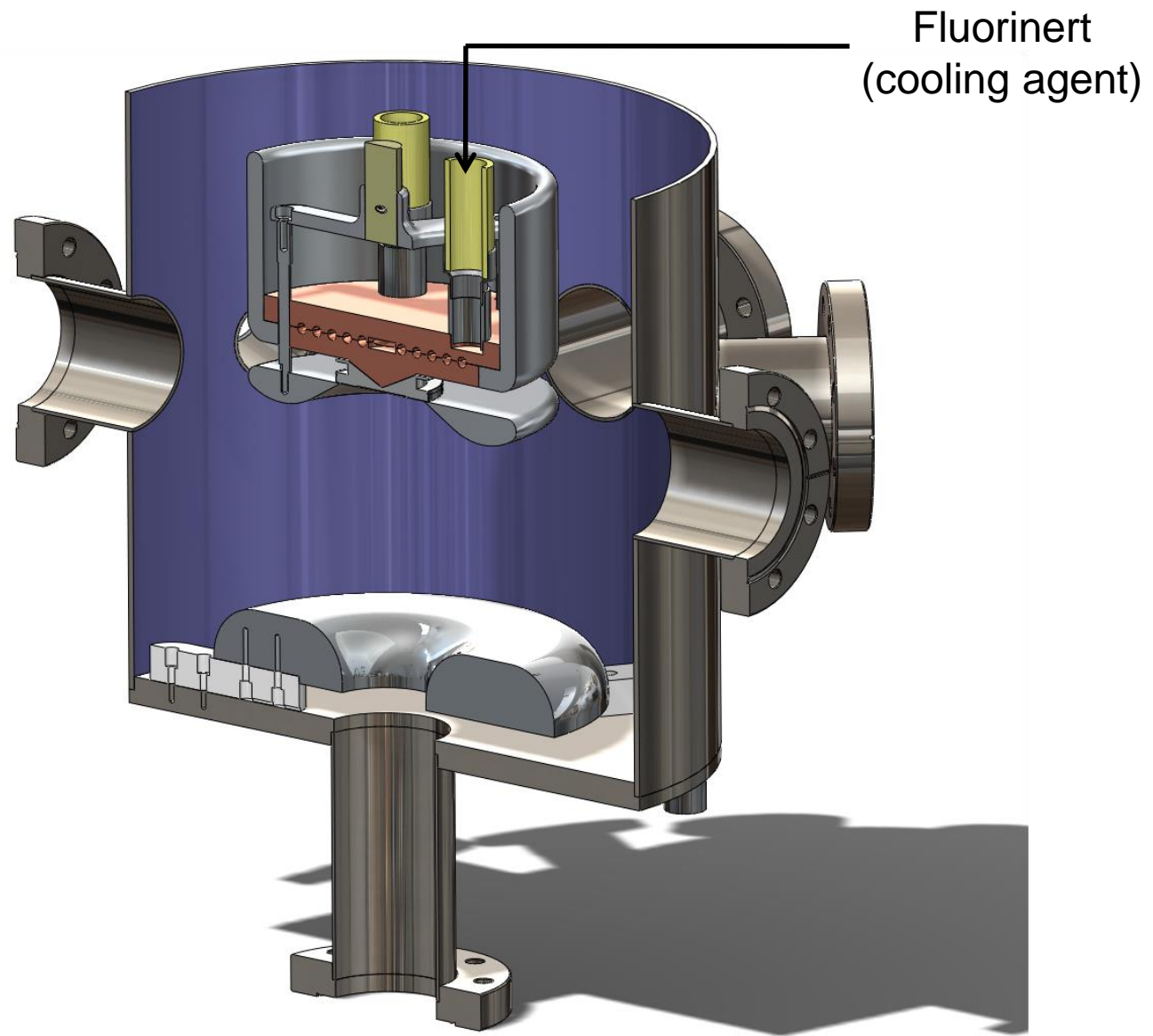
Heat exchanger

# Cathode – anode assembly

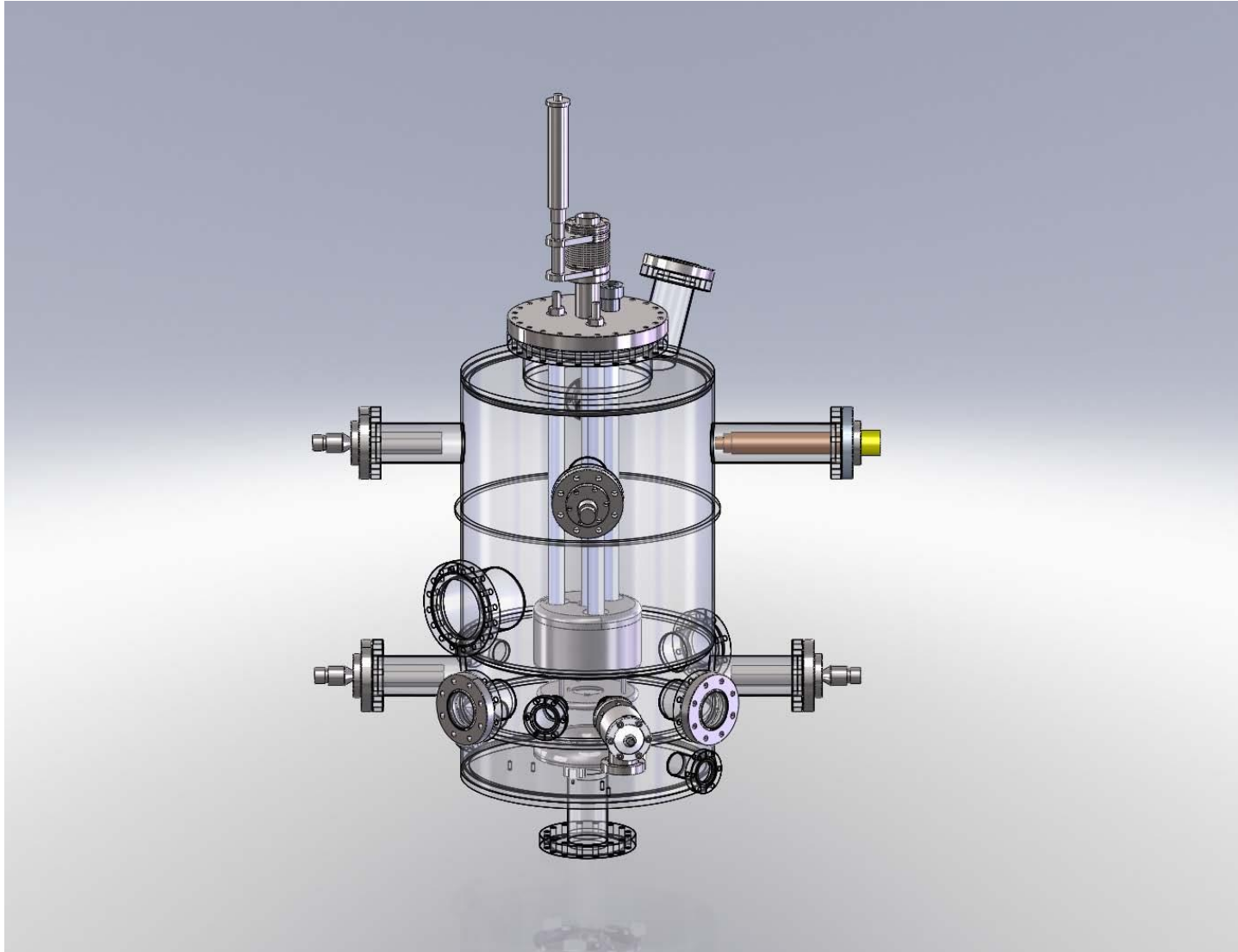




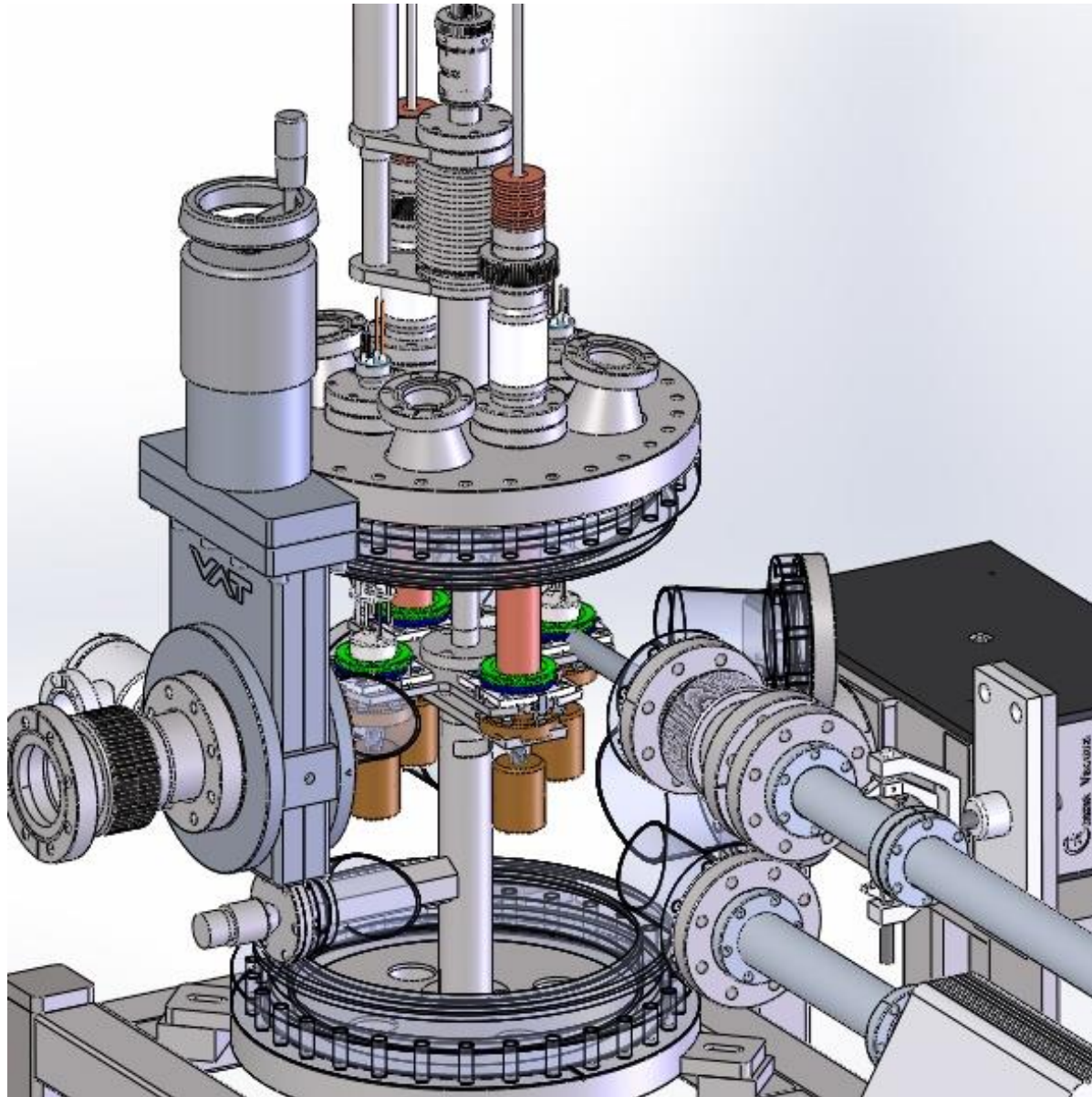
# Cathode – anode assembly



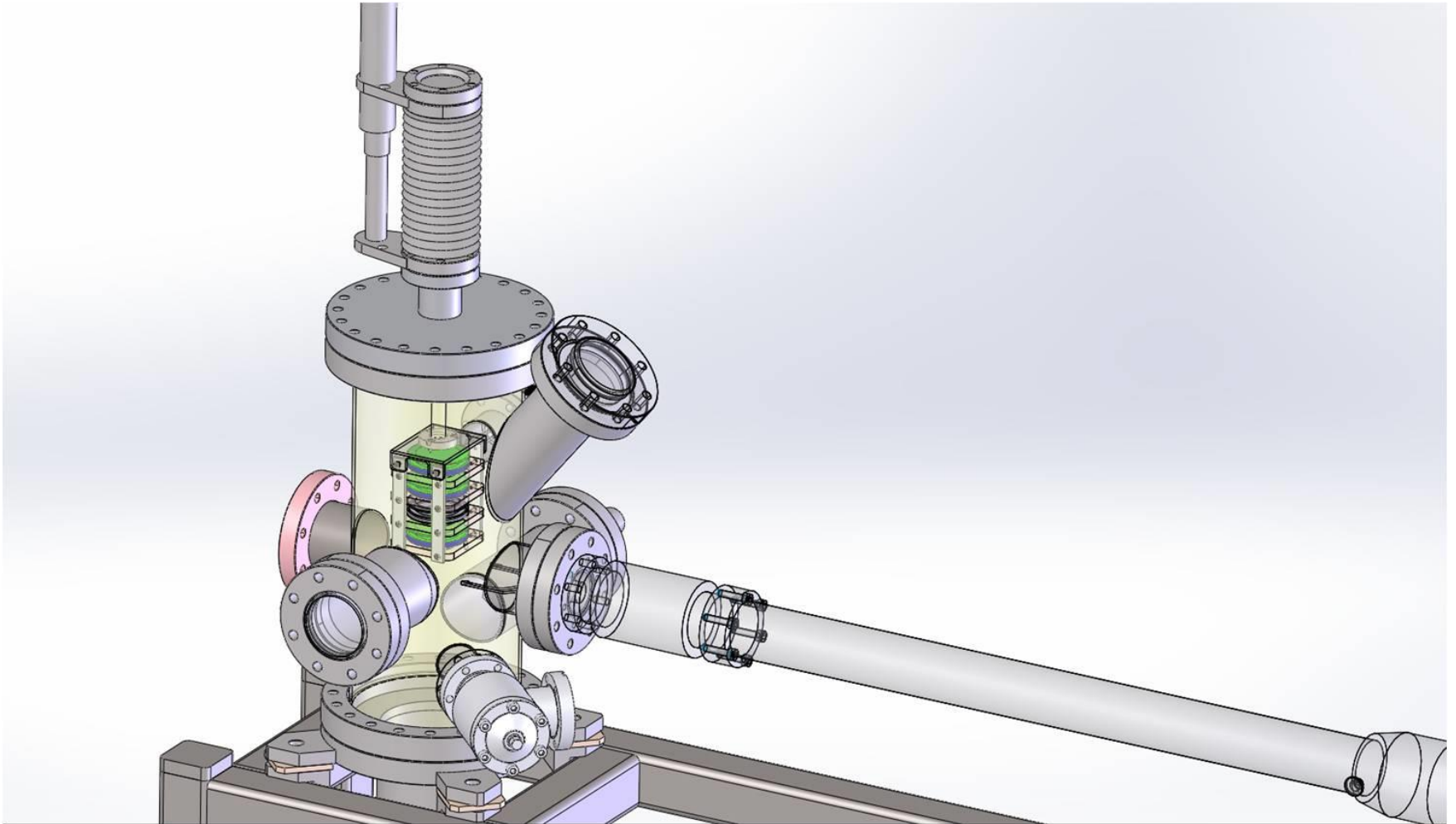
# Gun chamber

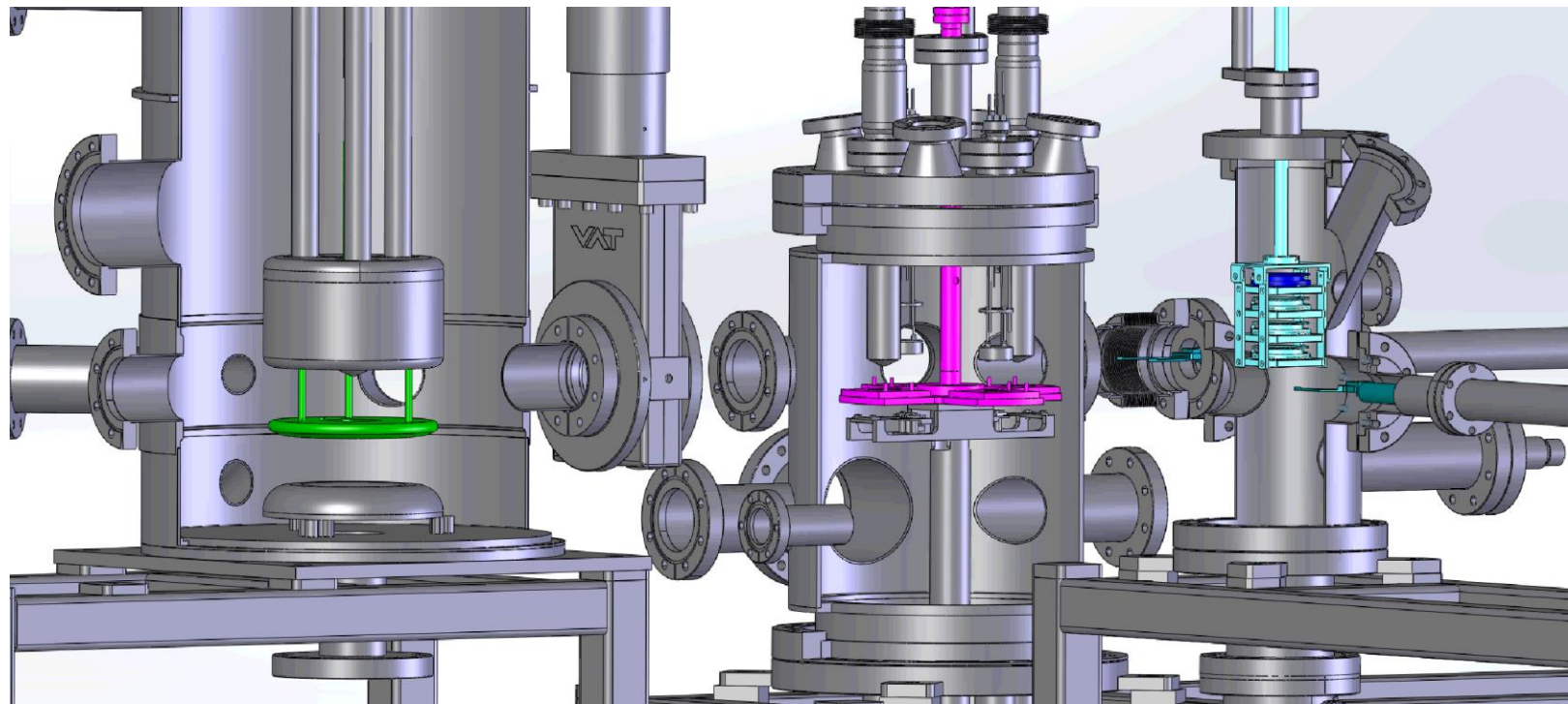


# Preparation chamber

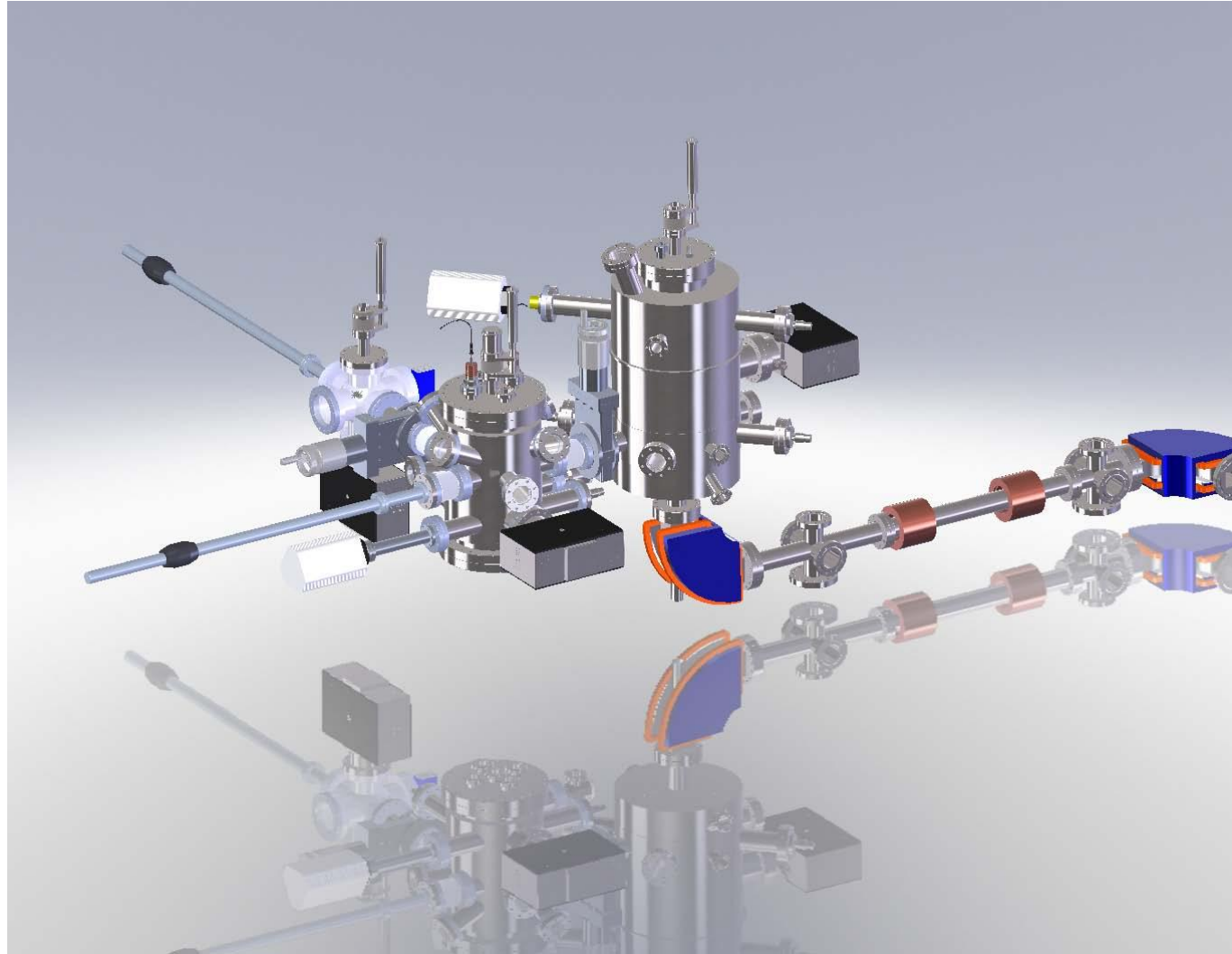


# Load lock

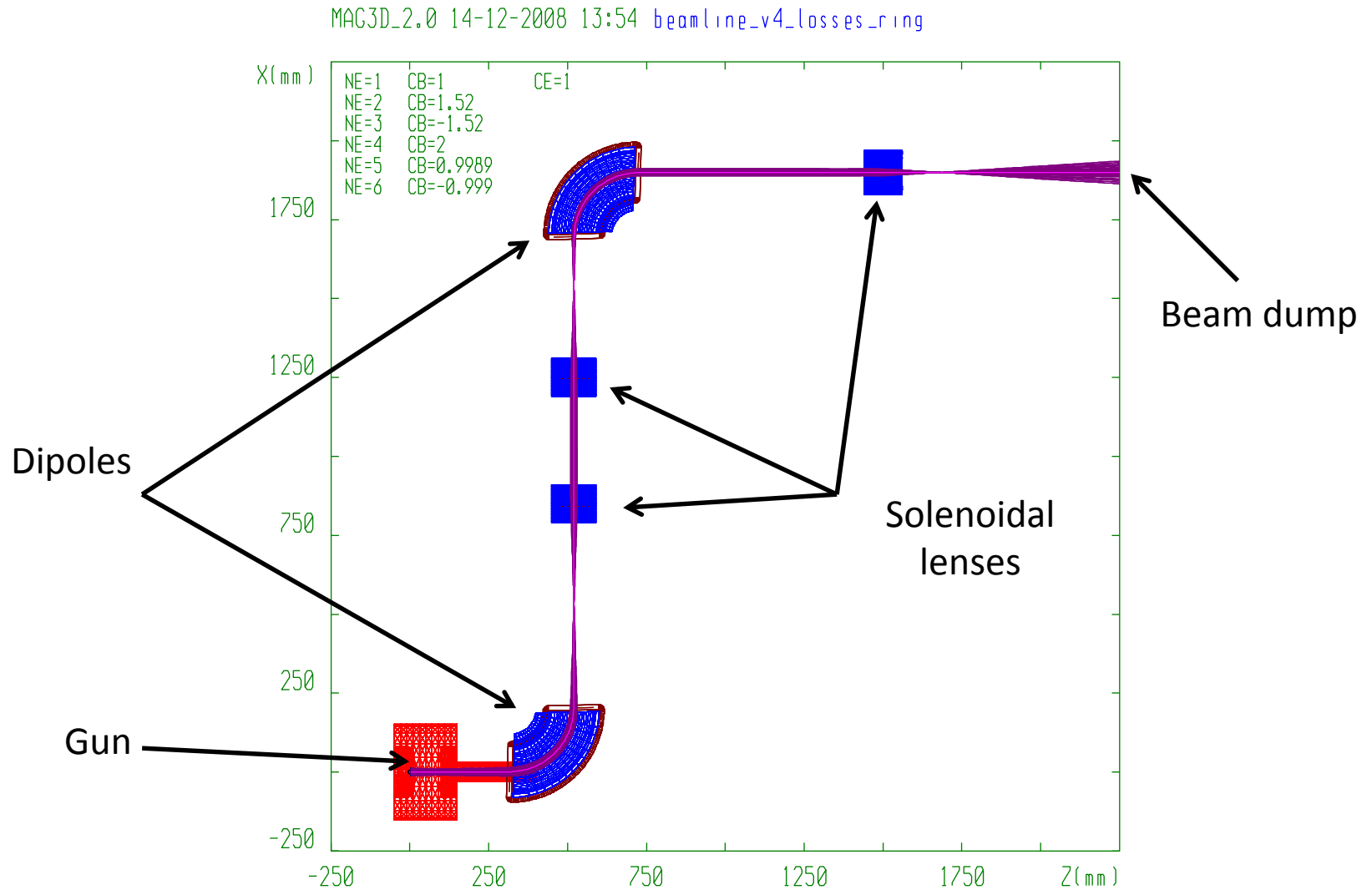




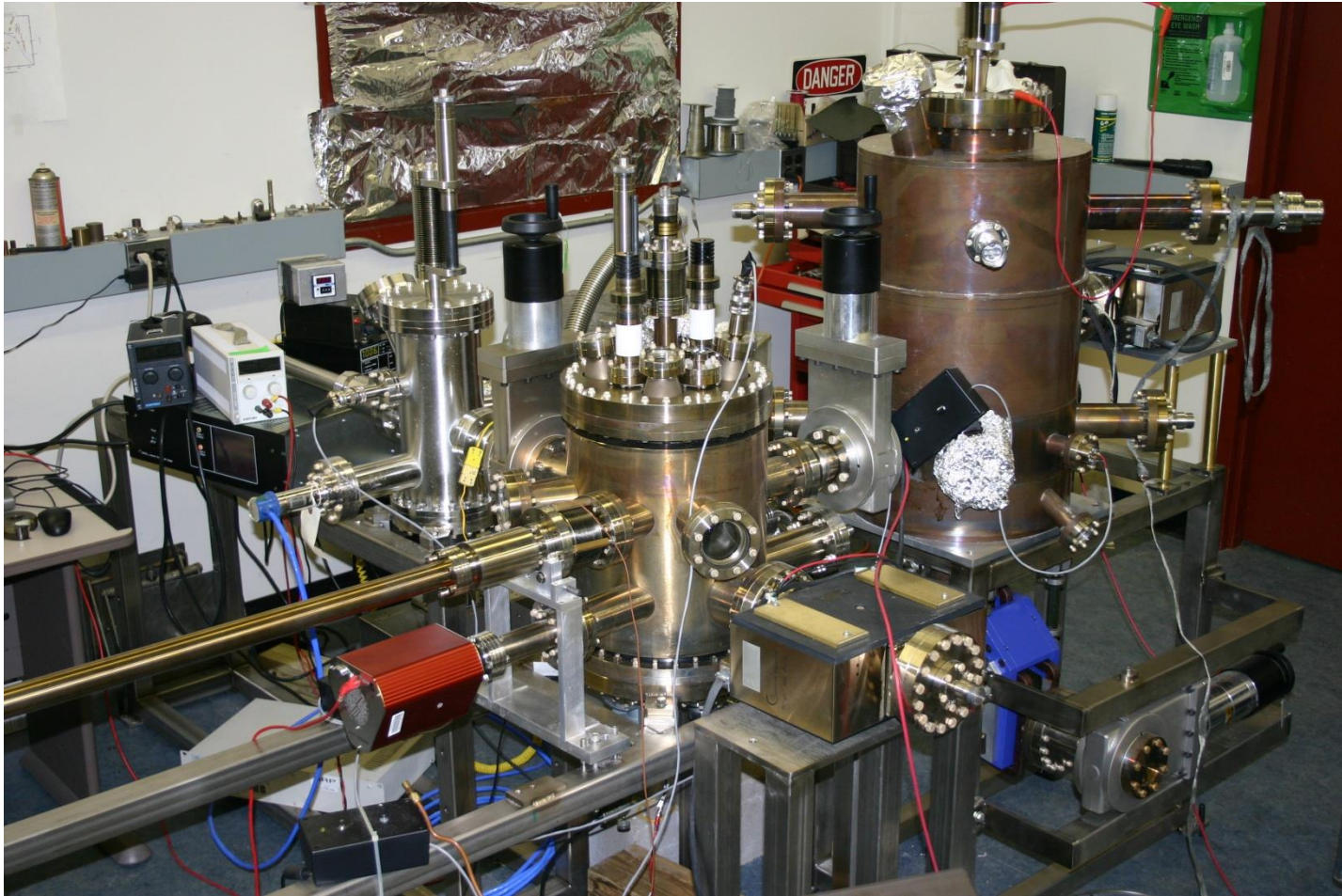
# Gun + beam line



# Beam line. Pipe aperture $\sim \pm 34$ mm.



# Gun + beam line

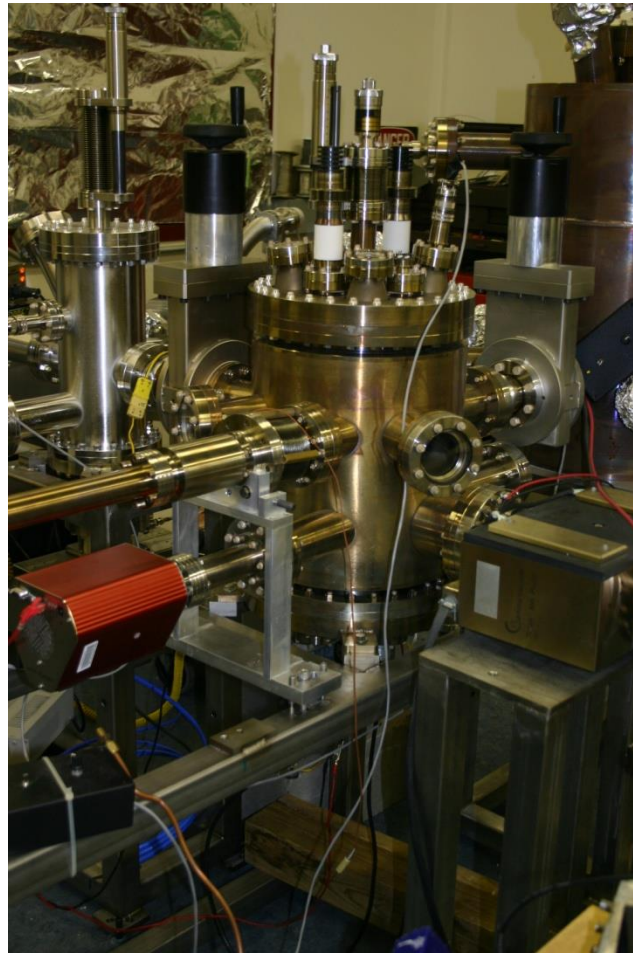




# Gun chamber



# Prep. chamber



# Vacuum features of the chambers

- Gun chamber: 100 l/s Ion pump with 400 l/s NEG and 4 additional 400 l/s NEG.
- The chamber walls are thin (~ 3 mm) to reduce outgasing.
- The chamber and most of the parts have been prebaked to 400°C before the final assembly.
- Bake-out at 250°C after the final assembly.
- Vacuum ~  $1 \cdot 10^{-11}$  (all Hydrogen)
- Prep. chamber: 100 l/s Ion pump with 400 l/s NEG and 2 additional 400 l/s NEG.
- Vacuum ~  $2 \cdot 10^{-11}$  (all Hydrogen)

# BUDGET

FY	From BNL	From DOE	Actual cost to date
07-09	\$444 K		\$444 K
10-11	\$150 K	\$586 K	\$736 K
12-13		\$388 K	\$388 K
14-15		\$500 K	\$500 K
16		\$130 K	
Total	\$594 K	\$1474 K	\$1765 K

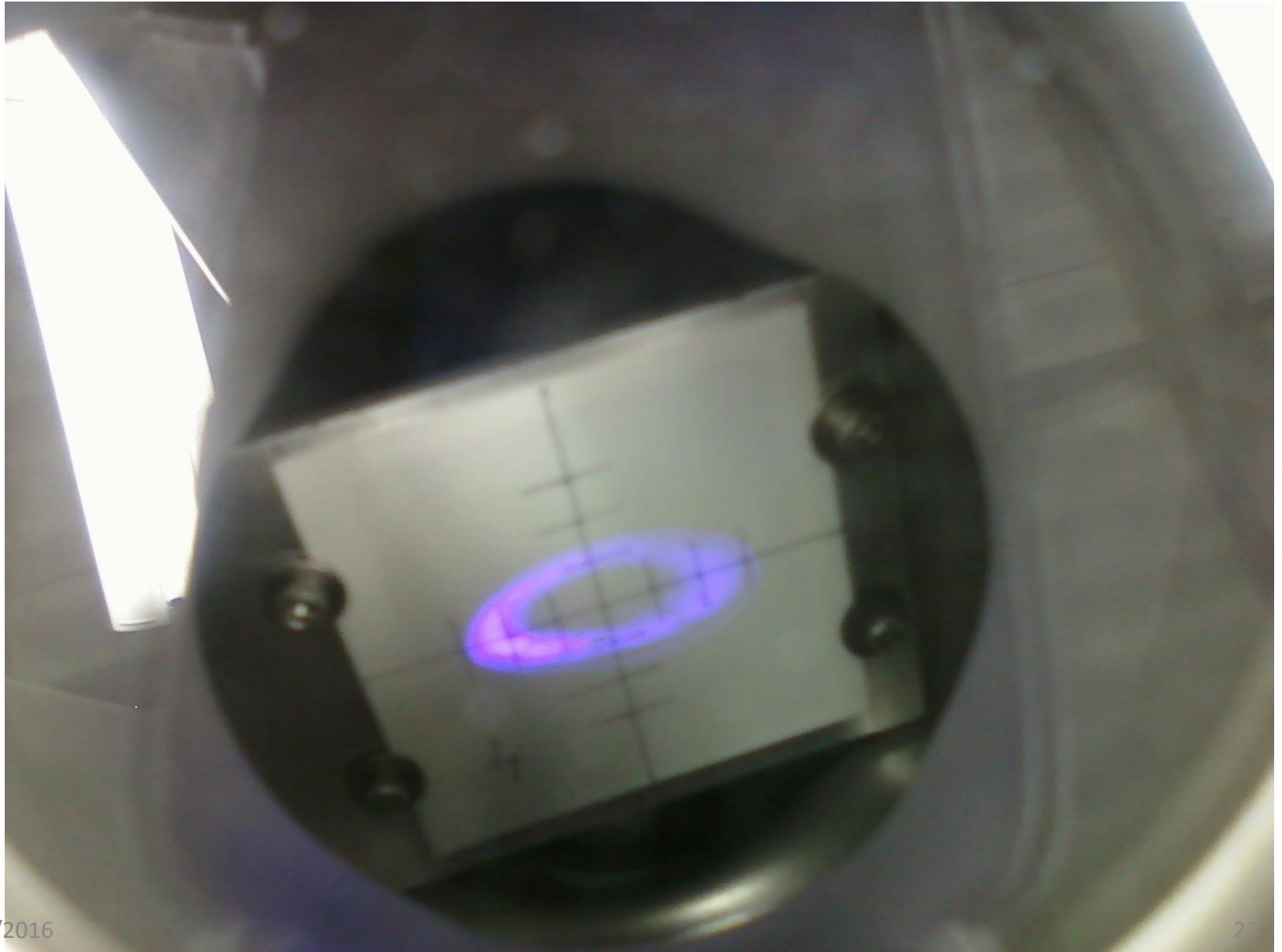
# PROJECT PROGRESS

- FY 2007-2009 - preliminary simulations and tests. Beam simulations through the gun and entire beam line. Emphasis – no beam losses near the gun. Tests of active cooling. HV tests.
- FY 2010-2011 – gun chamber and preparation chamber built and assembled. Load lock and beam line designed, and manufacturing began.
- FY 2012-2013 – load lock build and assembled. Beam line and unbiased beam dump built.
- FY2014-2015 – beam line and beam dump completed. First beam tests.

# PROJECT PROBLEMS

- Gun chamber, preparation chamber, load lock manufacturing and assembly – not a glitch. Excellent vacuum conditions. Reliable cathode transfer between chambers (good illumination and observation conditions). Very high QE ( $\sim 2\%$  at  $\lambda=805$  nm) has been achieved. However, the dark lifetime of the cathode in the gun is short (less than 100 hours).
- Beam line assembly – successful. Beam tuning through the beam line – the shape of the beam in a full agreement with simulations.
- Beam dump bake out – first problem. The solder in the assembly melted venting the chamber. Lost NEG. Tight budget makes such accidents time consuming (delivery time 6 weeks).
- Beam tests – real problem. The lifetime is much shorter than in old generation guns even at low current.

# Beam on BeO target



# SECOND TRY

- Most likely the problem is a fluorinert leak into the gun chamber. The molecules are very compact and penetrate through very narrow cracks, they are too heavy to be detected with RGA, and they are chemically active.
- The gun was vented and the problem addressed. Preparation chamber was vented as well to fix minor problems. Reassembly and rebake.
- A whole bunch of accidents:
  - Gasket failure during bake out (twice)
  - Magnetic manipulator support system putting pressure on the gasket during alignment, causing leak and venting both gun and preparation chamber
  - Ceramic support standoff for Cs strips creaked shortening the strips to the ground (another 6 weeks delivery item).
  - Leak in the brazing in the beam dump.
  - After multiple activations NEGs in preparation chamber saturated.



# WHY DO WE HAVE THESE ACCIDENTS ?

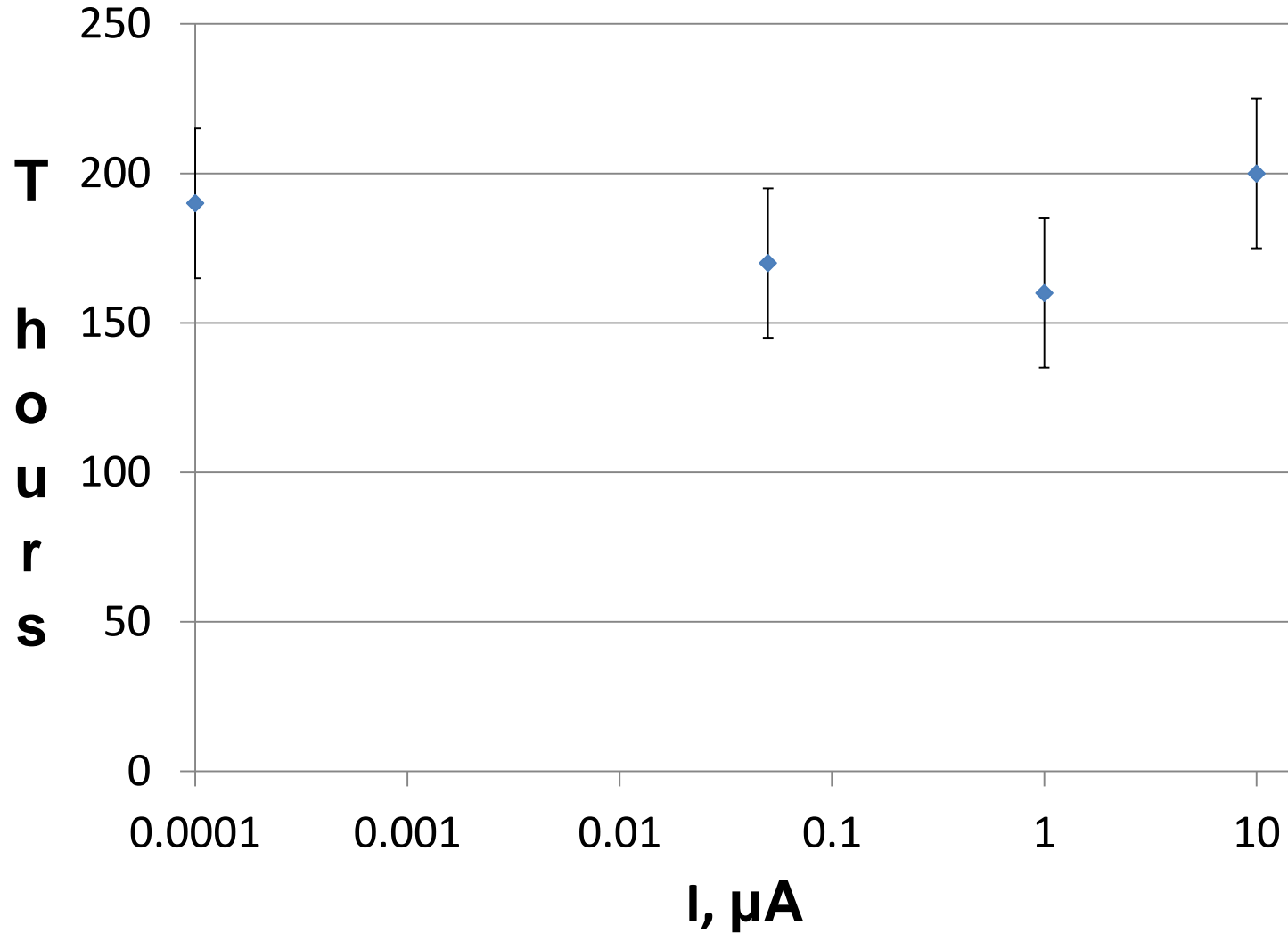
This gun is a prototype. It took several tries to lick out all the bugs. Any modification or accident are very costly (require re-bake). Any bake-out is a risk and a heavy load on equipment.

We operate on a very tight budget.

All successful Polarized Gun projects: SLAC, Bates (SAMPLE), Jlab  
required

EXPERTIZE + FUNDING

# Lifetime measurements



# CURRENT STATUS

- We believe that we have built a very good gun.
- However, currently it is not in the best shape. There were leaks, they were fixed, but not all chambers have been re-baked. Most likely, some NEG's lost the pumping speed. One of the ion pumps in the beam line failed. The leak valve for NF3 barely works.
- The gun location may prevent running a high intensity beam (radiation).
- With the current level of financing we can only continue the beam tests.
- Ideal scenario: disassemble the installation, replace all failing parts, all hardware and reassemble in the radiation-protected area. It will take ½ of a year and significant financing.