JLab-ILC Polarized e-Source R&D

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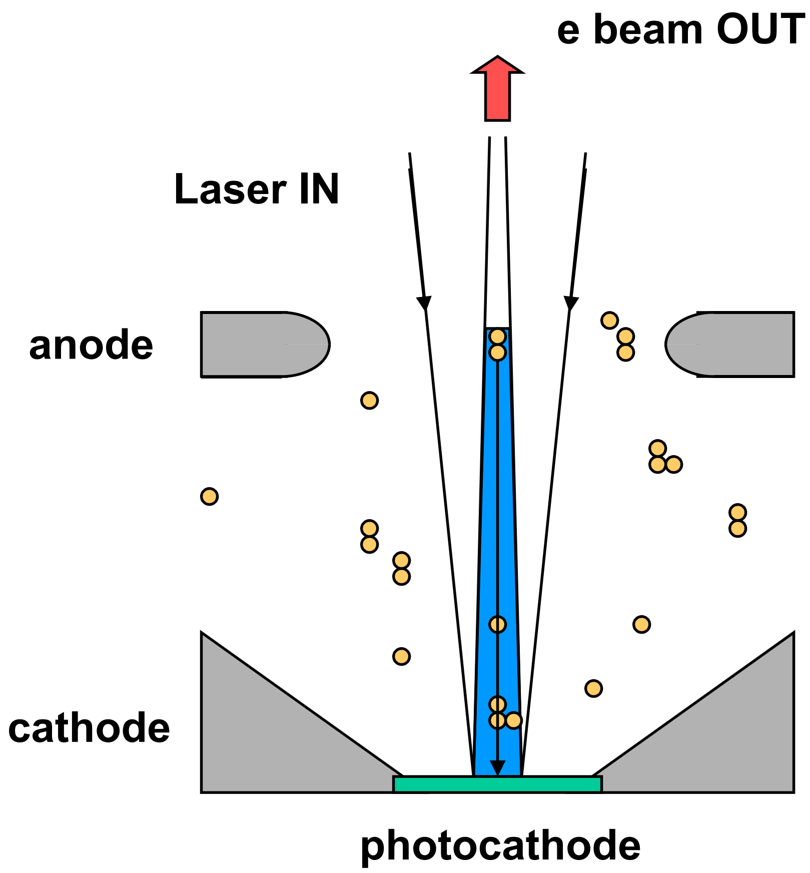
ILC – unique polarized e-beam requirements

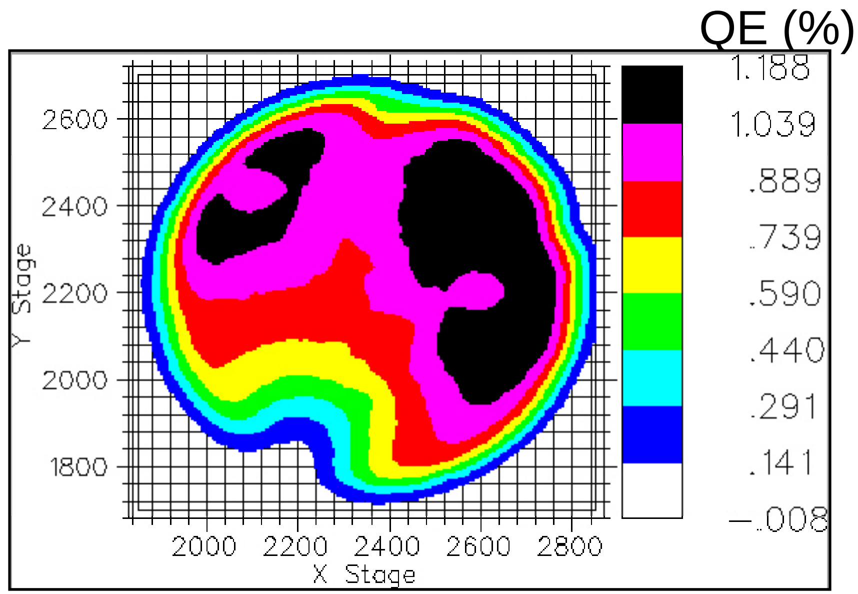
- High Average Current (100uA, ~ 50x SLC ave. beam current)
- High Bunch Charge
- Demanding Time Structure

JLab Expertise

- CEBAF: 10 years experience delivering 100+uA
- Leverage time/money spent building a new CEBAF load locked gun, many features well suited for ILC: improved vacuum, multiple photocathode samples, rapid photocathode replacement

What limits photogun lifetime?



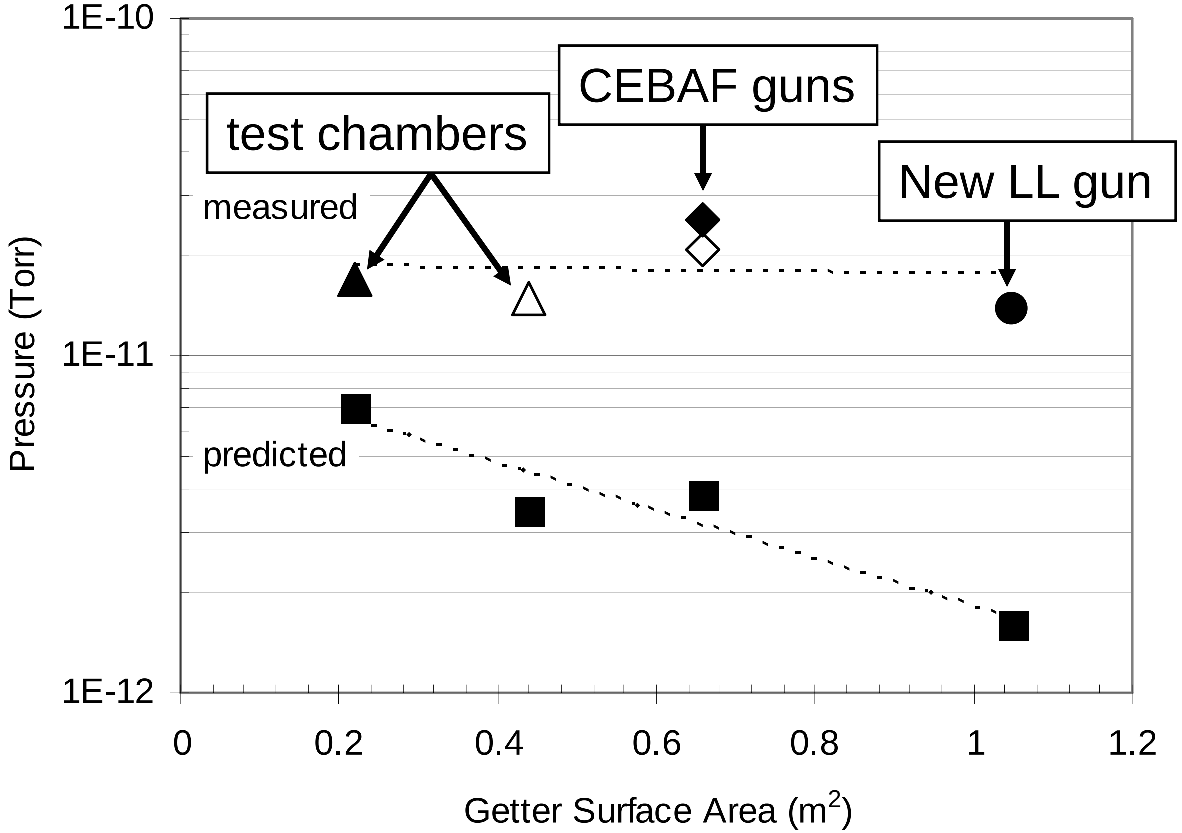


QE scan of photocathode

Proposed R&D for ILC:
- Vacuum Studies
- High Voltage > 200kV
- Cathode/Anode Design

Topic #1: Improving Gun Vacuum

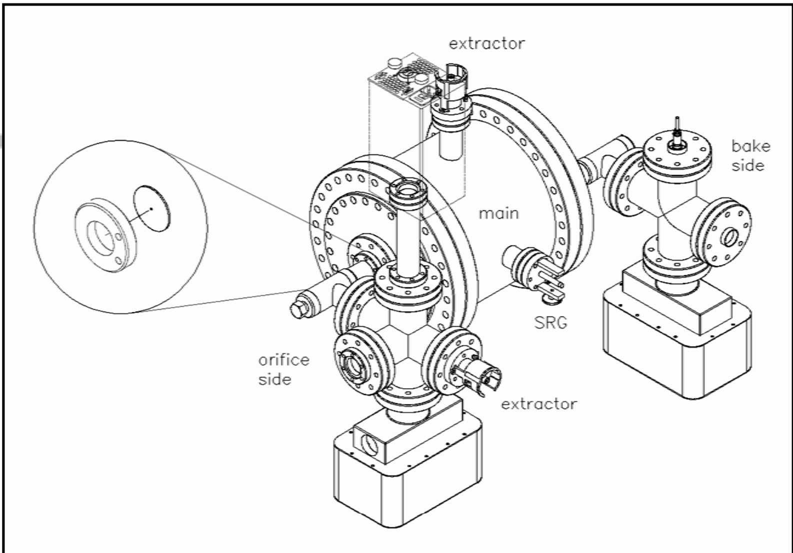
$$\text{Ultimate Pressure} = \frac{\text{Outgassing Rate x Surface Area}}{\text{Pump Speed}}$$



How to explain this discrepancy?

- Outgassing rate higher than assumed "standard" value; 1×10^{-12} Torr·L/s·cm^2?
- NEG pump speed smaller than SAES says?

Measured pressure always much greater than predicted



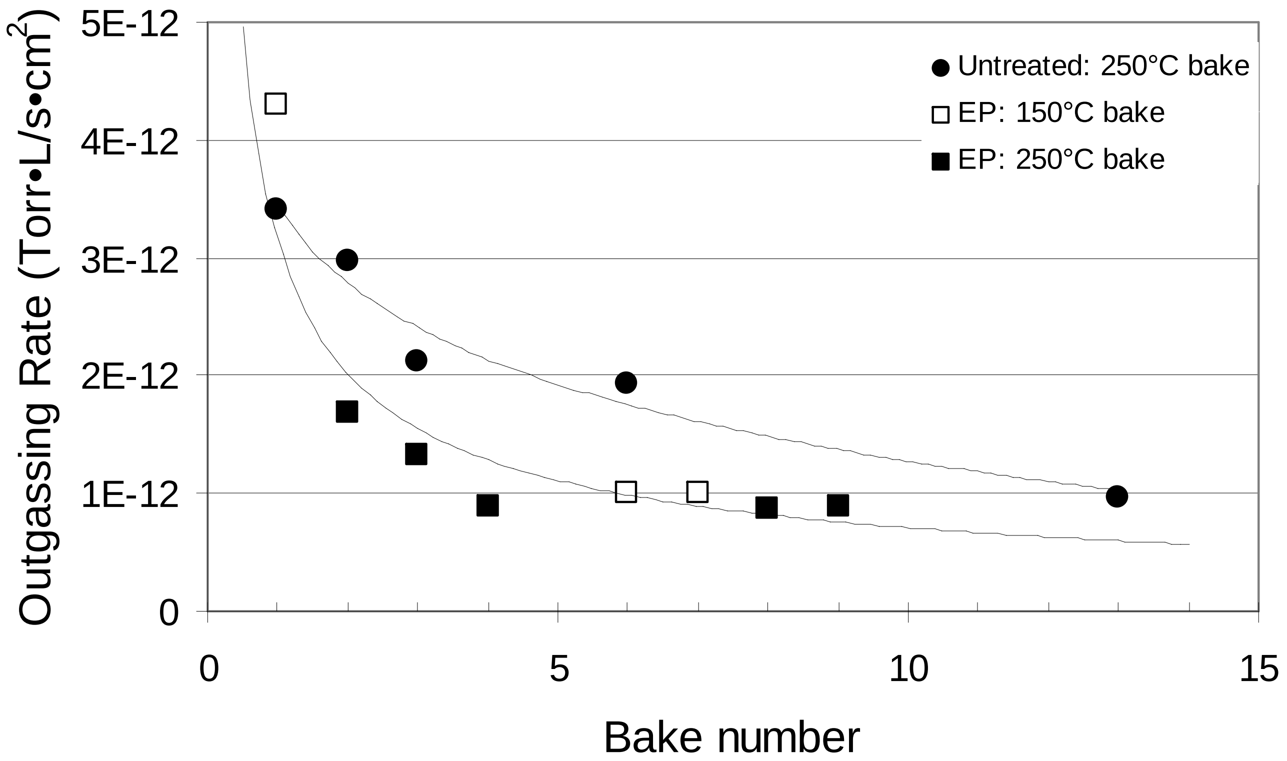
Outgassing Rate

- Orifice and Rate of Rise Methods
- Studied 304, 316L and 6061 Al
- Degreasing/solvent cleaning vs electro-polishing/vacuum firing at 900C

	Preprocessing				In situ bake parameters		Outgassing Rate (Torr·L/s·cm^2)	
Chamber	**t(h)**	**T(°C)**	**EP**	**Surface roughness**	**t(h)**	**T(°C)**	**Orifice Method**	**Rate of Rise Method**
Old 304			**no**	**3.7 μm**	**400**	**250**	**9.7×10^{-13}**	**1×10^{-12}**
New 304			**no**	**3.7 μm**	**180**	**250**	**1.9×10^{-12}**	**2.5×10^{-12}**
EP 304	**4**	**900**	**yes**	**2.1 μm**	**30 then 90**	**150 250**		**8.9×10^{-13}**

"Characterization of the CEBAF 100 kV DC GaAs Photoelectron Gun Vacuum System," M.L. Stutzman, et al., Nucl. Instrum. Meth. A, 574 (2007) p. 213-

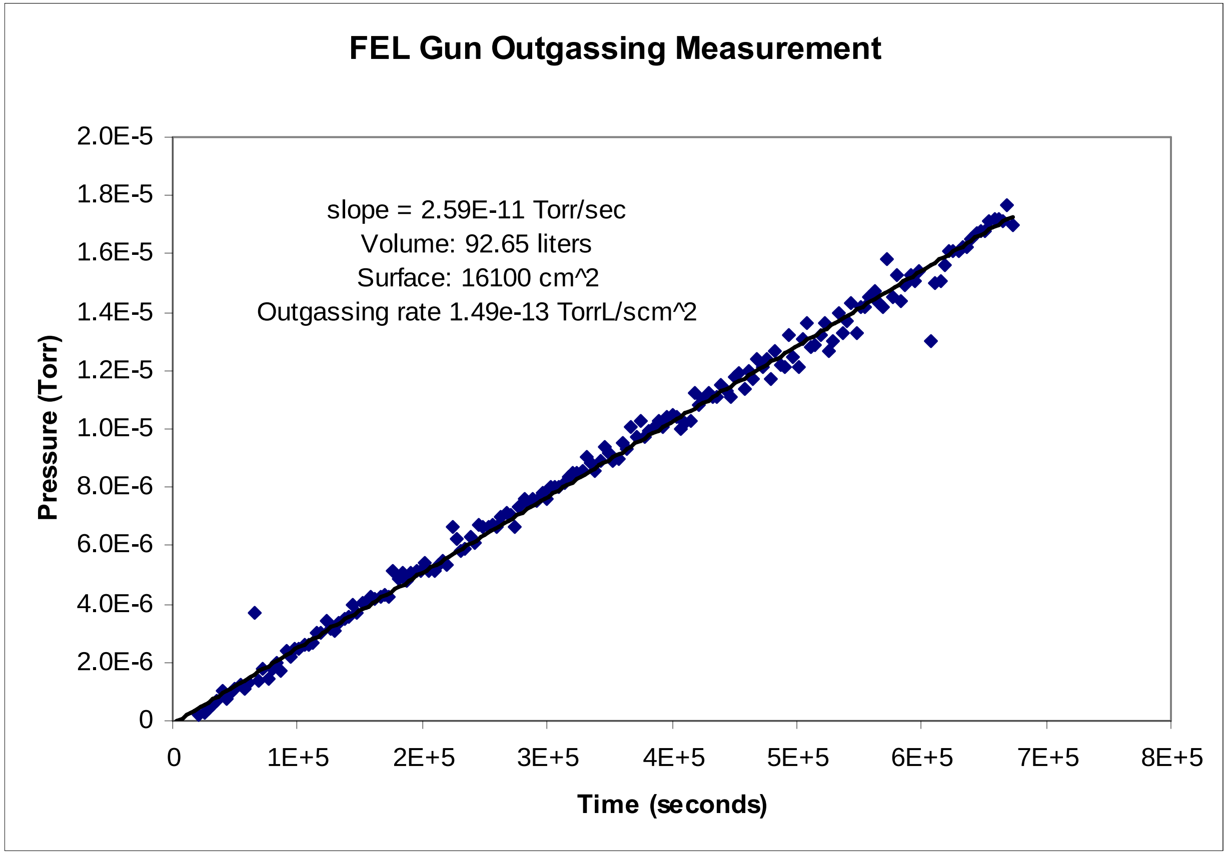
Benefit of EP and Vacuum Firing



- Electropolishing and vacuum firing provides low rate with fewer bakes
- Extremely low values (e.g., 10^{-14} to 10^{-15}) reported in literature elude us
- Conclusion: We have the "industry-standard" outgassing rate ~ 1×10^{-12} Torr·L/s·cm^2

Recent High Temperature Bake of JLab FEL Gun

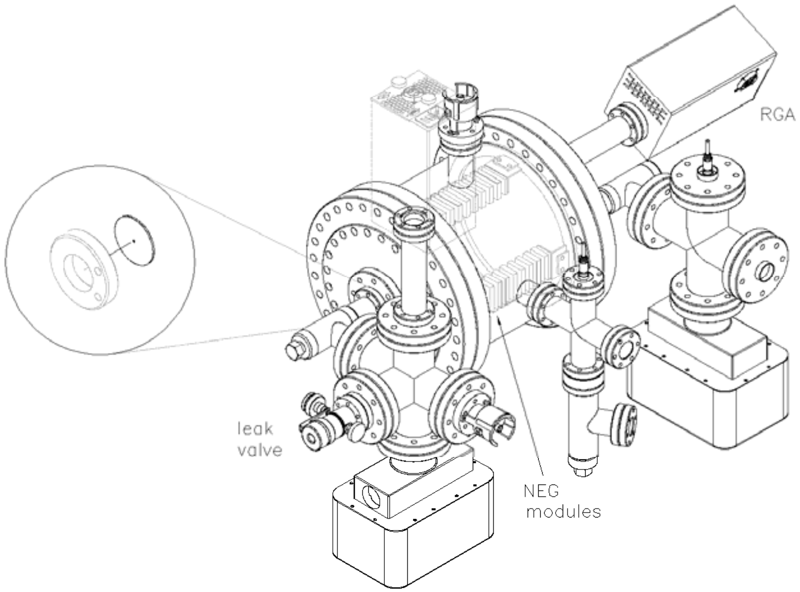
316 LN Stainless Steel, Baked at 400°C for 10 days
Vacuum inside, hot air outside, Strip heaters instead of hot air guns
Outgassing rate: 1.49×10^{-13} Torr L/s cm^2

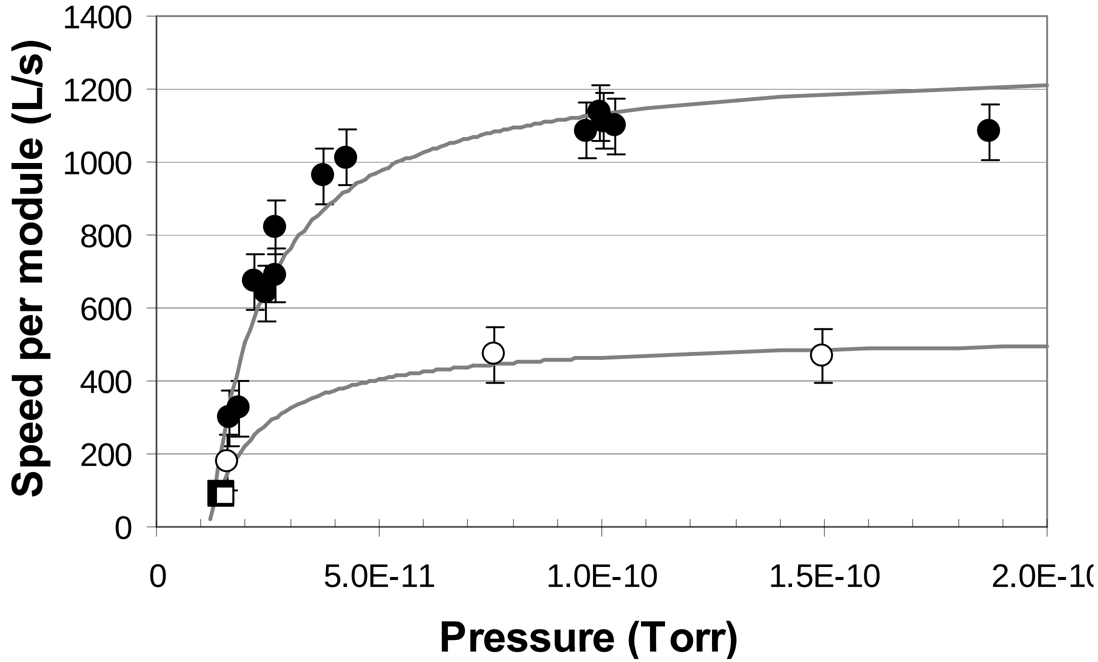


Lessons for CEBAF/ILC?

- We should have vacuum fired our end flanges
- Welding introduces hydrogen
- 250C for 30 hours not adequate

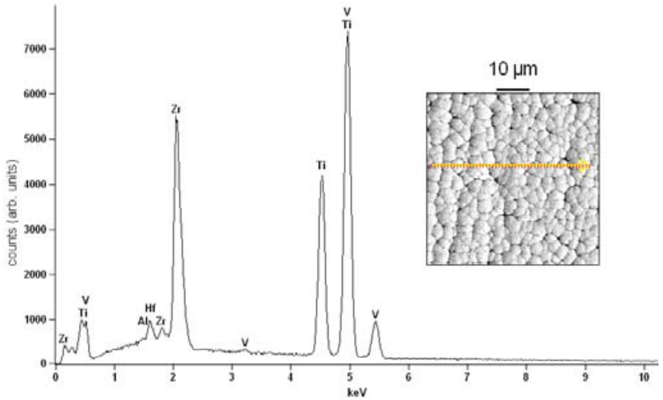
NEG Pump Speed

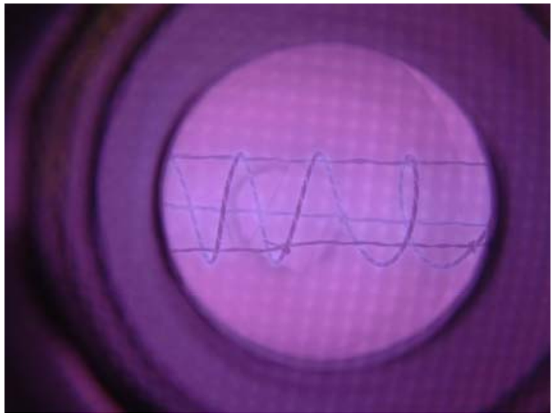


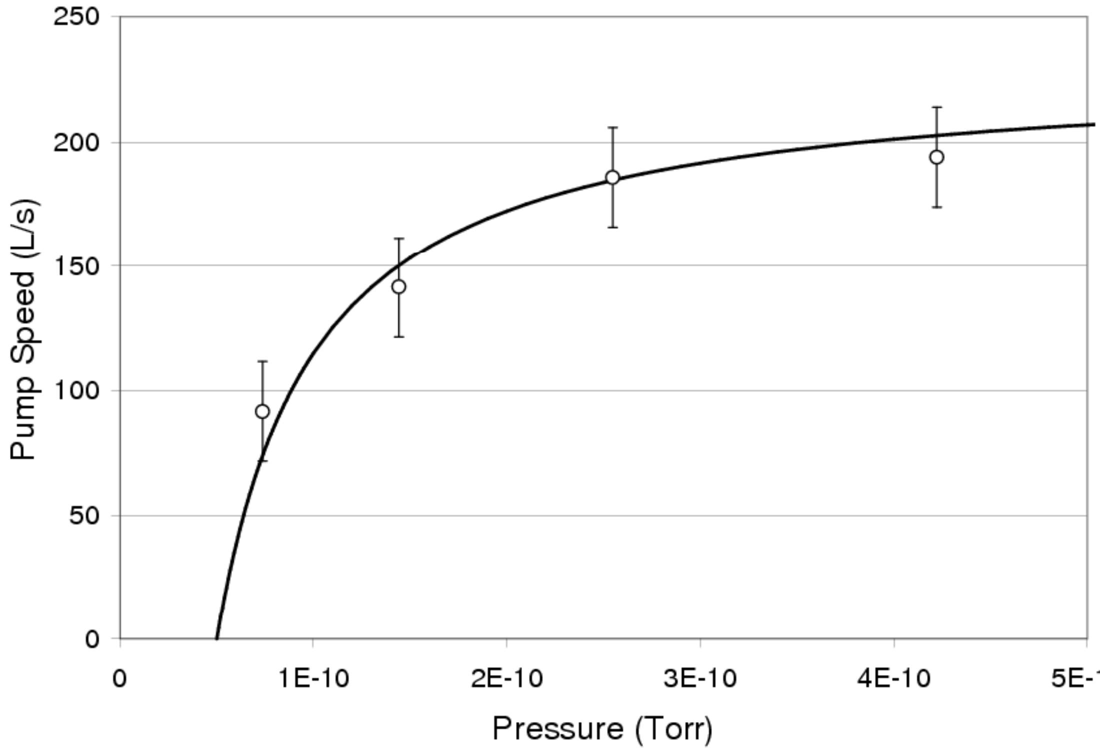


- Full NEG activation better than passive activation via bake
- NEG pump speed very good, at least at high pressure
- Conclusion: Can't explain reduced pump speed at low pressure – a real effect? More likely an indication of gauge limitations

NEG Coating

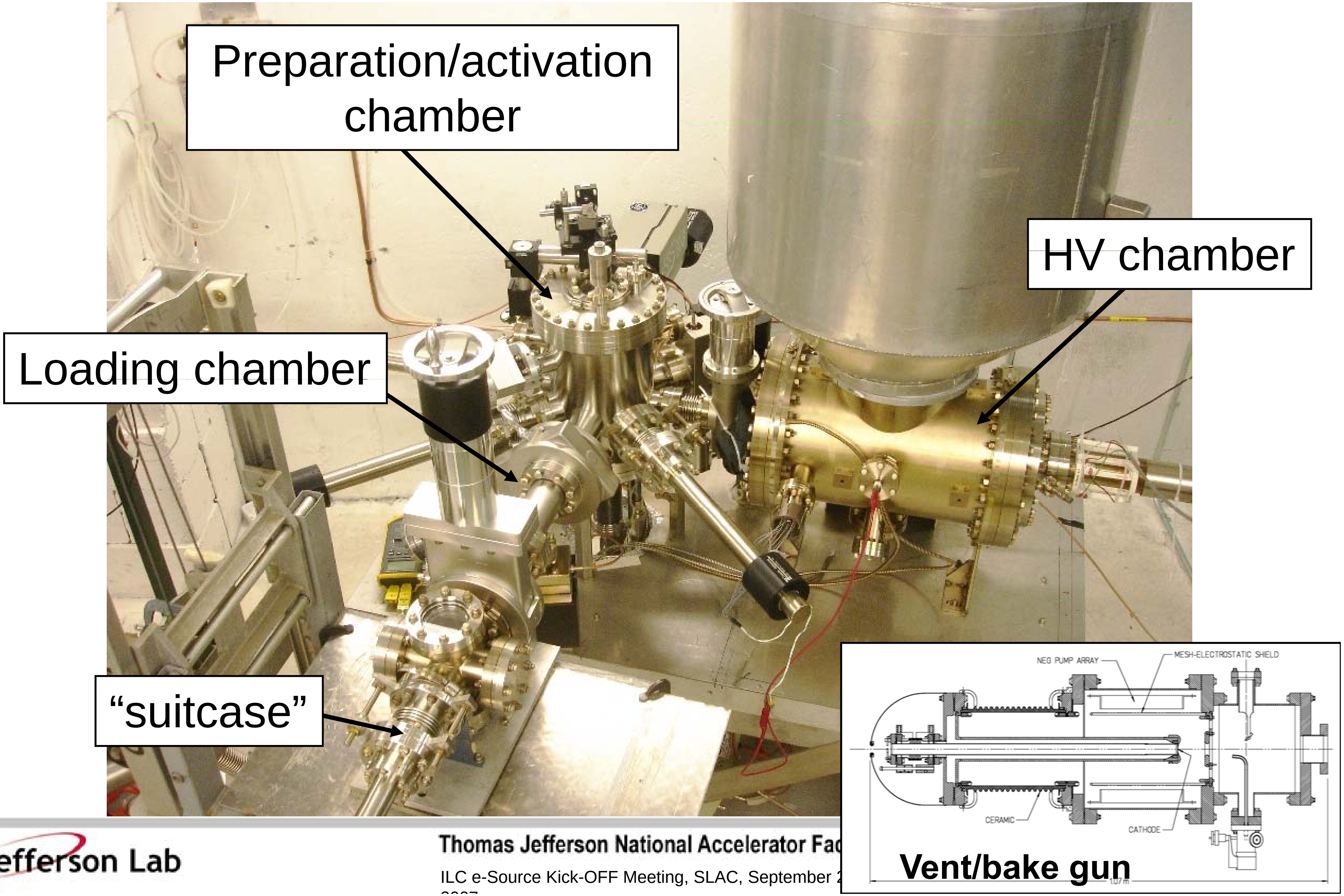






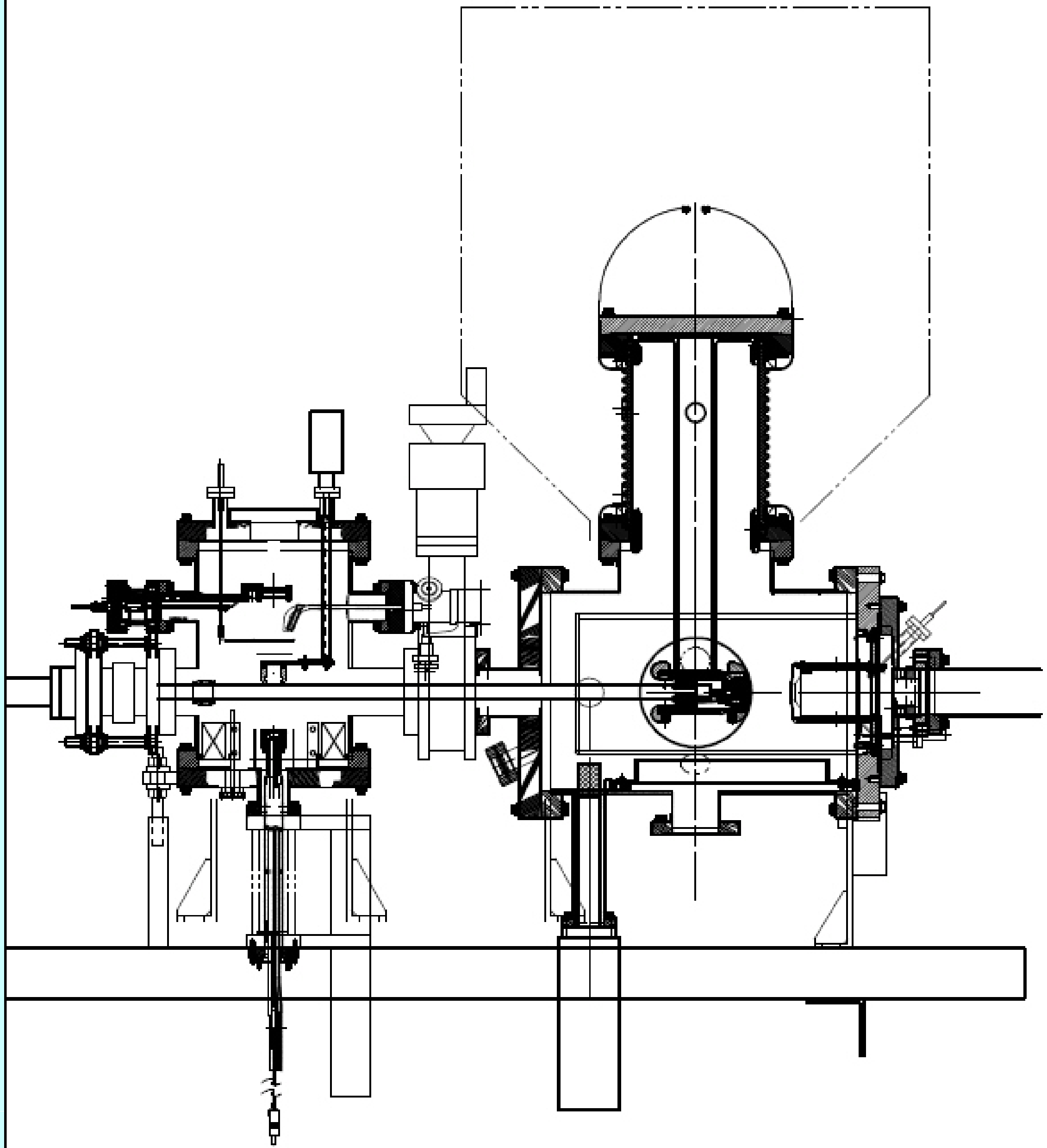
NEG coating turns a gas source into a pump
~0.02 L/s·cm^2 : Modest pump speed can be improved

New CEBAF load-locked gun

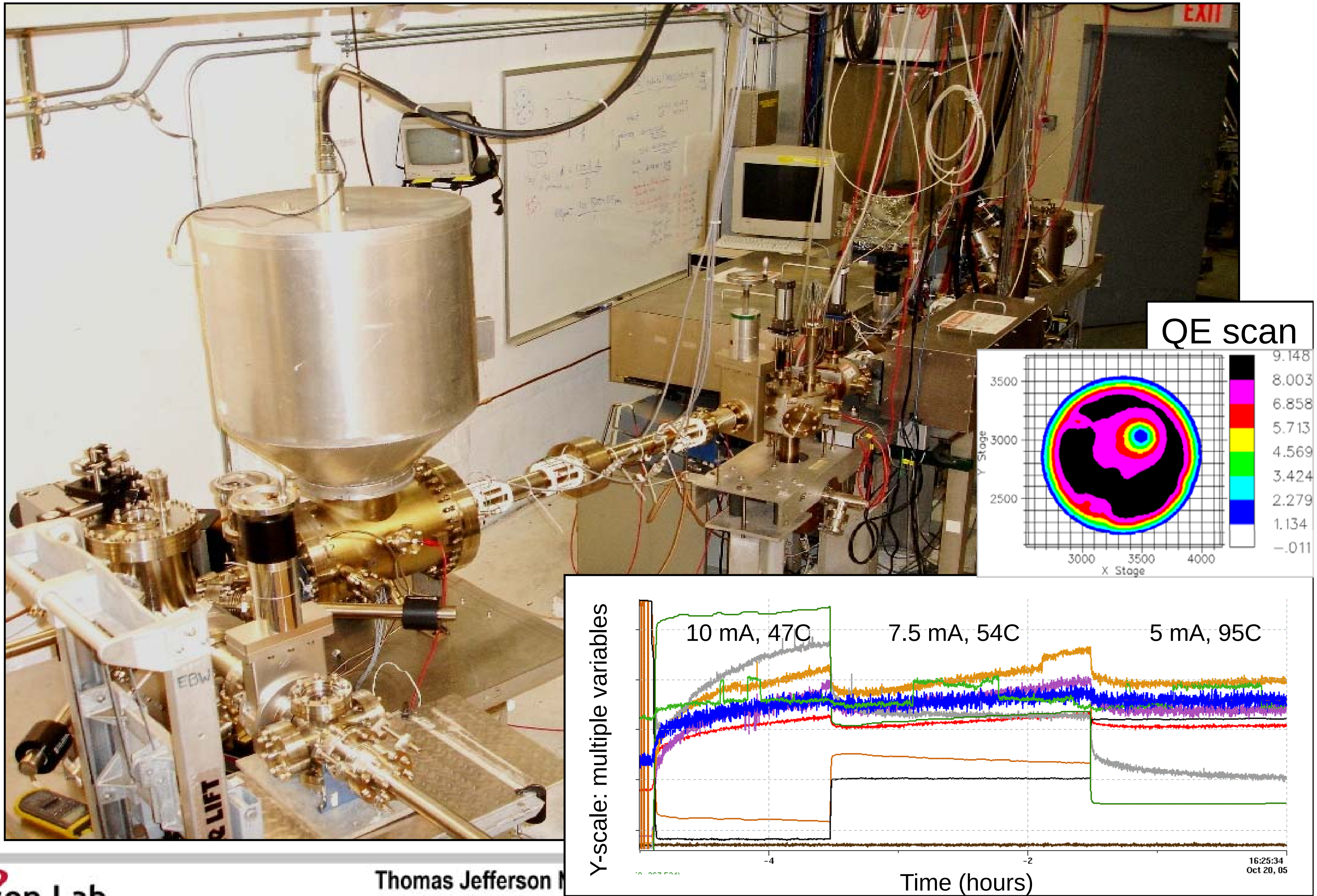


Key Features:

- Smaller surface area
- Electropolished and vacuum fired to limit outgassing
- NEG-coated
- Never vented
- Multiple pucks (8 hours to heat/activate new sample)
- Suitcase for installing new photocathodes (one day to replace all pucks)
- Mask to limit active area, no more anodizing



Load Locked Gun and Test Beamline

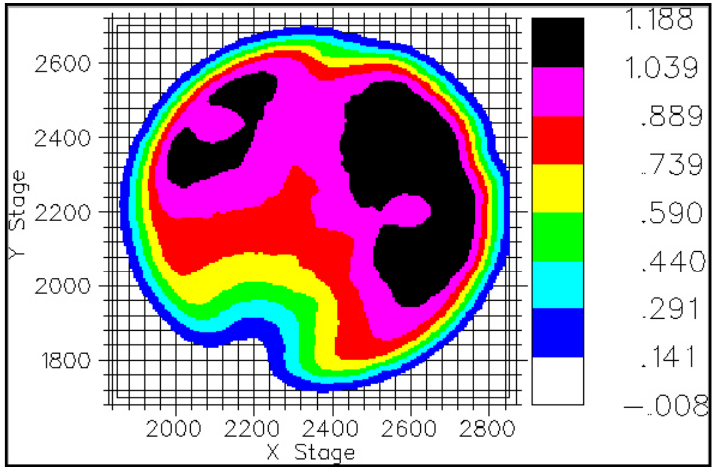


1mA from High Polarization Photocathode*

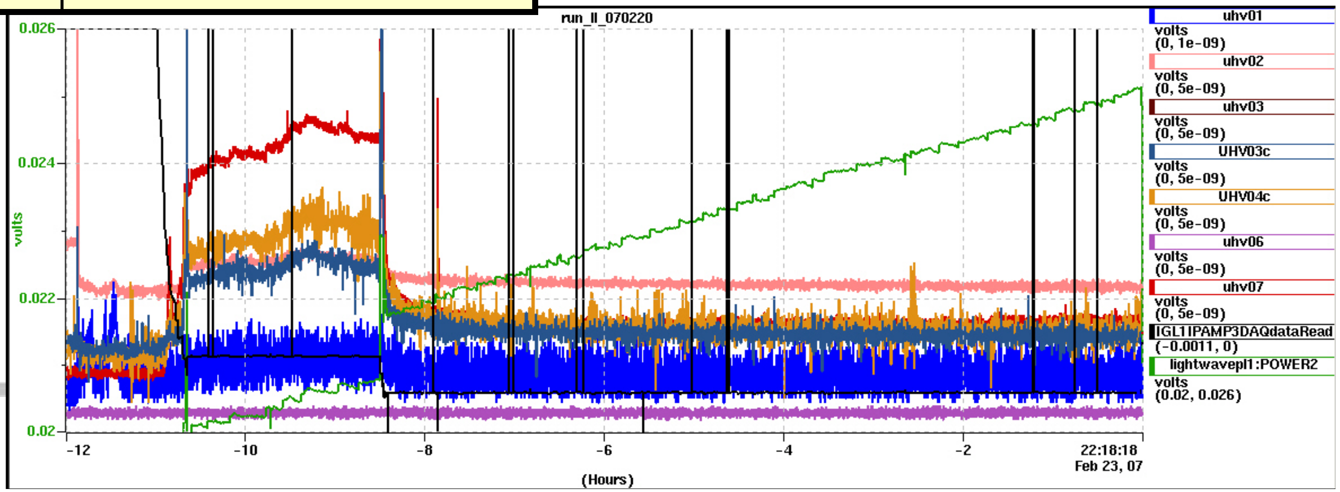
Parameter	Value
Laser Rep Rate	499 MHz
Laser Pulselength	30 ps
Wavelength	780 nm
Laser Spot Size	450 mm
Current	1 mA
Duration	8.25 hr
Charge	30.3 C
Lifetime	210 C
Charge Lifetime	160 kC/cm^2

* Note: did not actually measure polarization

High Initial QE



Vacuum signals
Laser Power
Beam Current



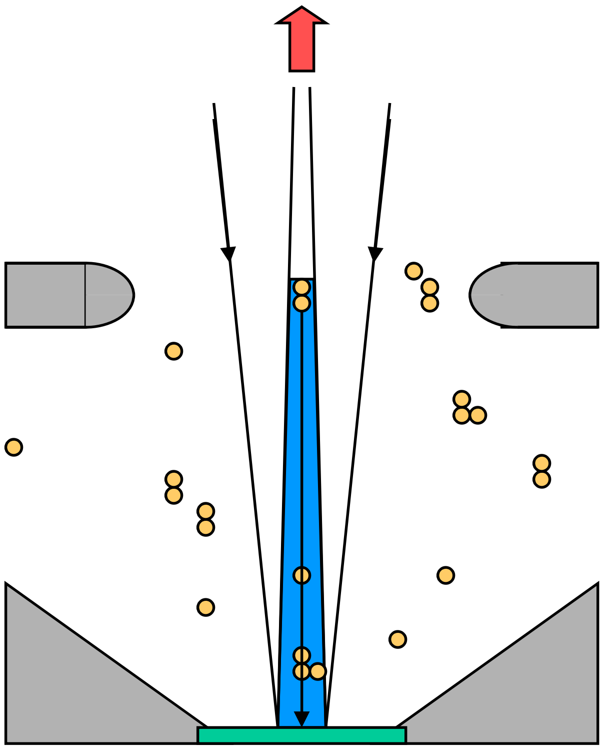
Vacuum R&D Summary

- Limit outgassing via high temperature 400°C bakeout
  - Can chamber be vented and still maintain low outgassing rate following 150°C, 250°C bake?
- Construct gauge that can accurately measure pressure below $1x10^{-11}$ Torr (modified Helmer gauge)
  - STTR proposal?
- Improve NEG coating process, to boost pump speed per unit area.
  - 0.02 L/s·cm^2 versus 1 L/s·cm^2 reported in literature

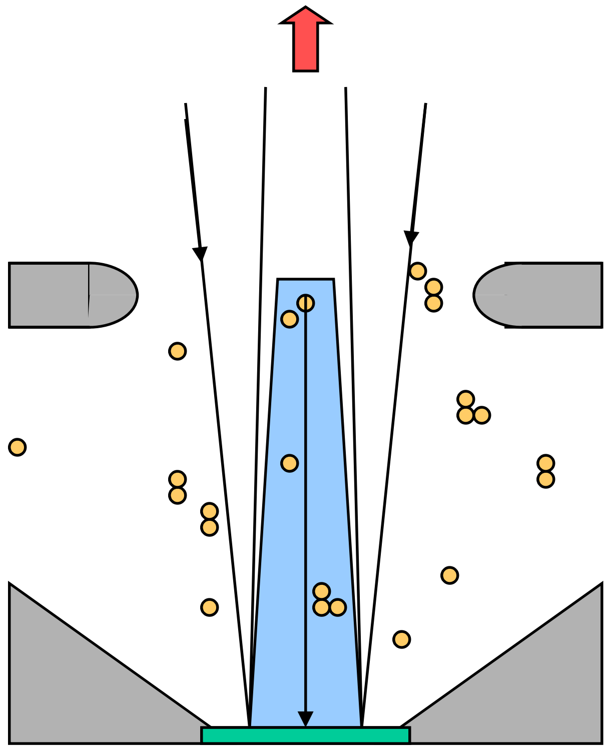
Improve Lifetime with Larger Laser Spot?

(Best Solution – Improve Vacuum, but not easy)

Bigger laser spot, same # electrons, same # ions



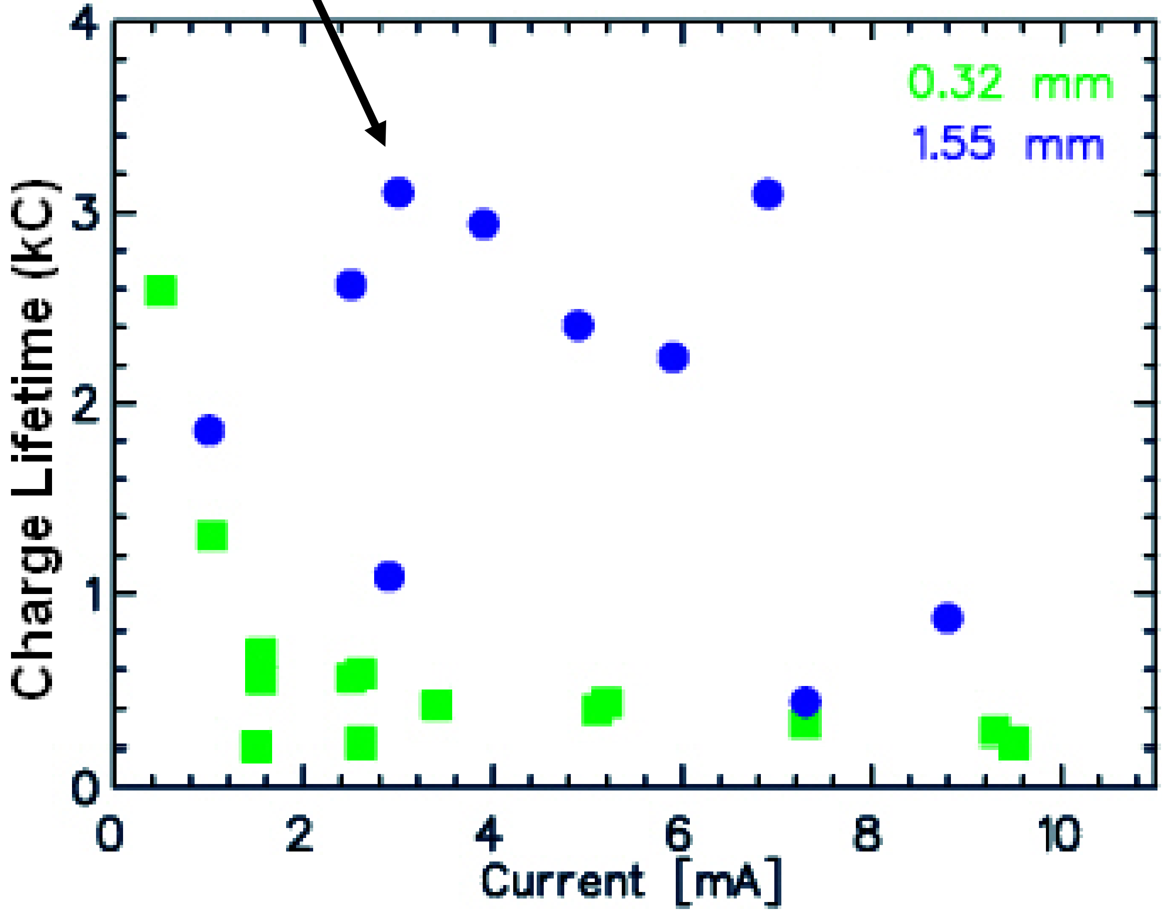
Ionized residual gas strikes photocathode



Ion damage distributed over larger area

Lifetime with Large/Small Laser Spots

Tough to measure large Coulomb lifetimes with only 100-200 C runs!



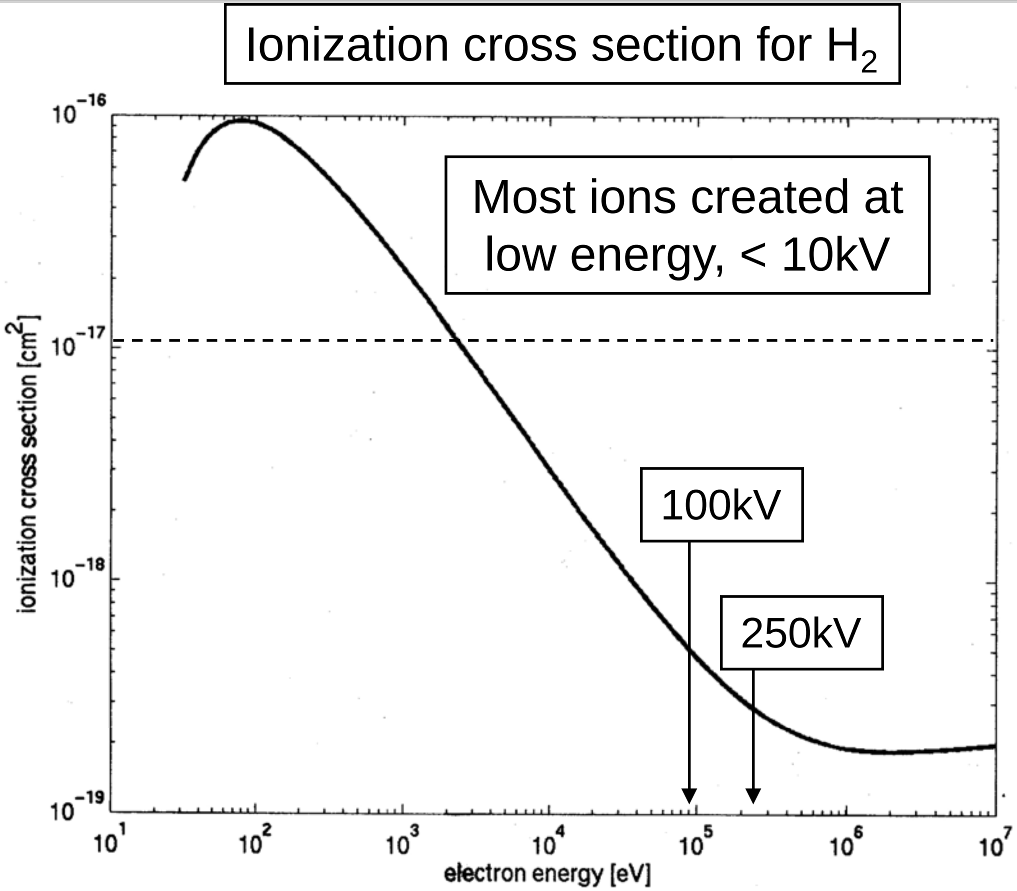
Factor of 5 to 10 improvement with larger laser spot size

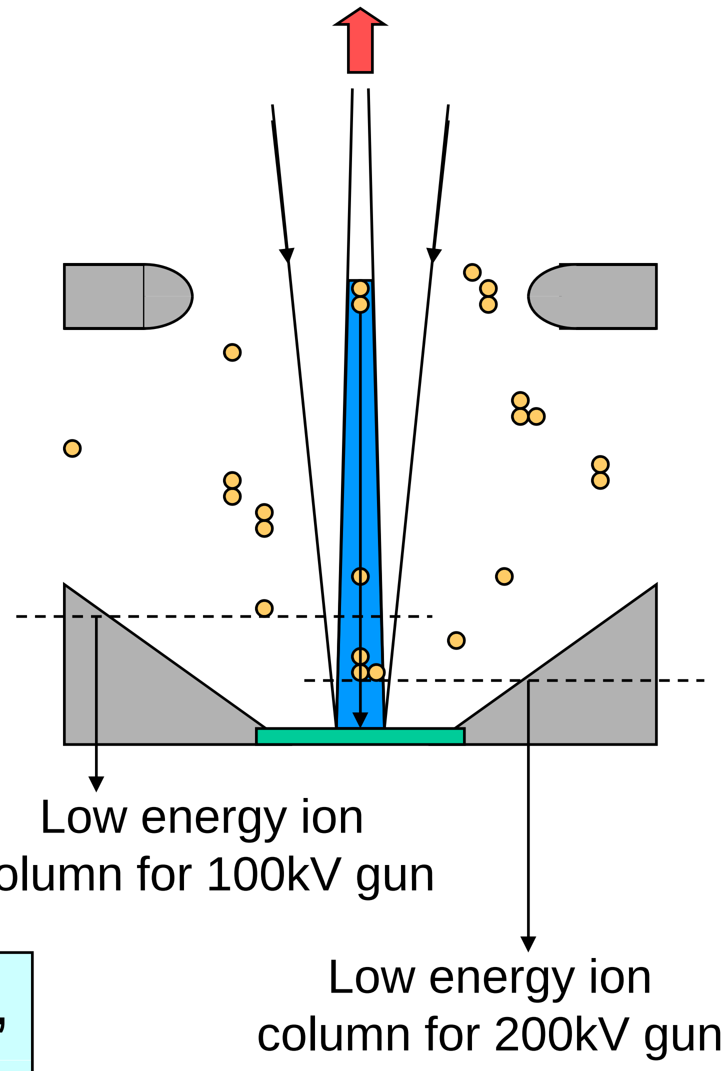
Expectation:

$$\left[\frac{1500}{350}\right]^2 \approx 18$$

"Further Measurements of Photocathode Operational Lifetime at Beam Current > 1mA using an Improved 100 kV DC High Voltage GaAs Photogun," J. Grames, et al., Proceedings Polarized Electron Source Workshop, SPIN06, Tokyo, Japan

Topic #2: Increasing Gun Voltage





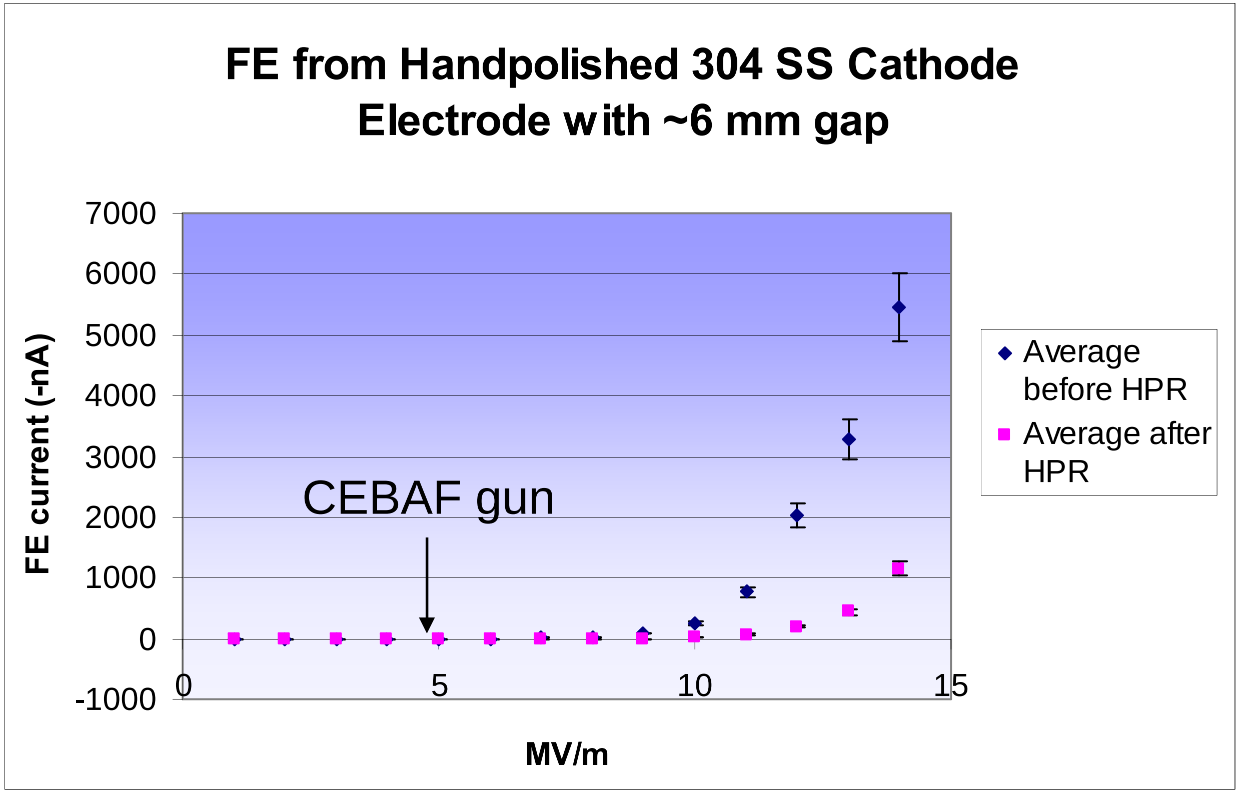
Hypothesis: Double the gun voltage, halve the # of “bad” ions, improve lifetime by 2

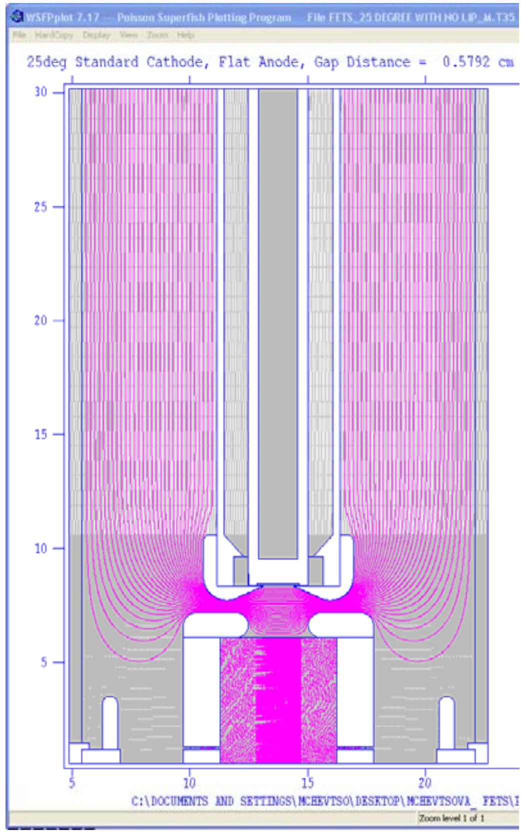
Must Eliminate Field Emission

Cornell Technique, high pressure rinsing (B. Dunham ERL07)

Recent tests at JLab with shaped electrodes support Cornell results

Work of M. Chetsova K. Surles-Law





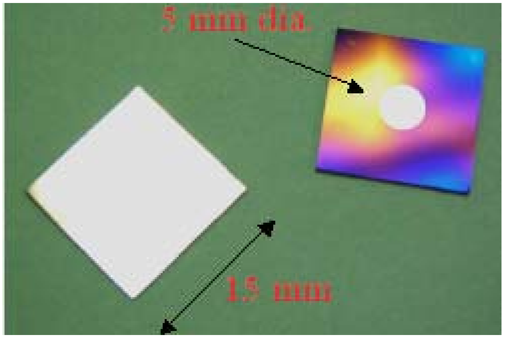
High Voltage R&D Summary

- Field Emission reduction via high pressure rinsing, and if necessary, using coatings
- Reduce complexity, cost and size of ceramic insulators. Exploit medical x-ray source technology
- Lifetime studies at injector test cave using duplicate load locked gun: observe improved lifetime at higher gun voltage
- Other reasons to increase gun voltage….

Topic #3: Cathode/Anode Design

We learned at CEBAF that it is extremely important to manage ALL of the extracted beam

– Anodized edge: beam from outside 5 mm active area can hit beampipe walls, degrade vacuum, reduce operating lifetime



A better way for ILC?

Suggest multivariate optimization of:

– Cathode/anode optic
– First few meters of beamline, including SHB

Goals of Multivariate Optimization

- Create cathode/anode optic with small aberration across large photocathode active area, with very little beam loss. What to optimize?
  - Size of cathode electrode diameter, size of photocathode active area
  - Size of laser beam: lowest possible current density but with adequate emittance
  - Cathode/anode shape for adequate focusing
  - Cathode voltage/gradient: higher voltage to reduce space charge and provide possibility of extracting higher peak current with more narrow laser pulsewidth, to reduce SHB requirements

JLab-ILC Polarized e-Source R&D

- Vacuum R&D on-going
- Lifetime measurements at high current and 225kV will begin soon
- Graduate student to learn technique of multivariate optimization
- ..
- ..
- ..
- Begin scaling/modifying CEBAF load lock gun design for ILC parameters
- Jlab vested interest in ILC gun program – push gun voltage