Introduction to Electron Guns for Accelerators

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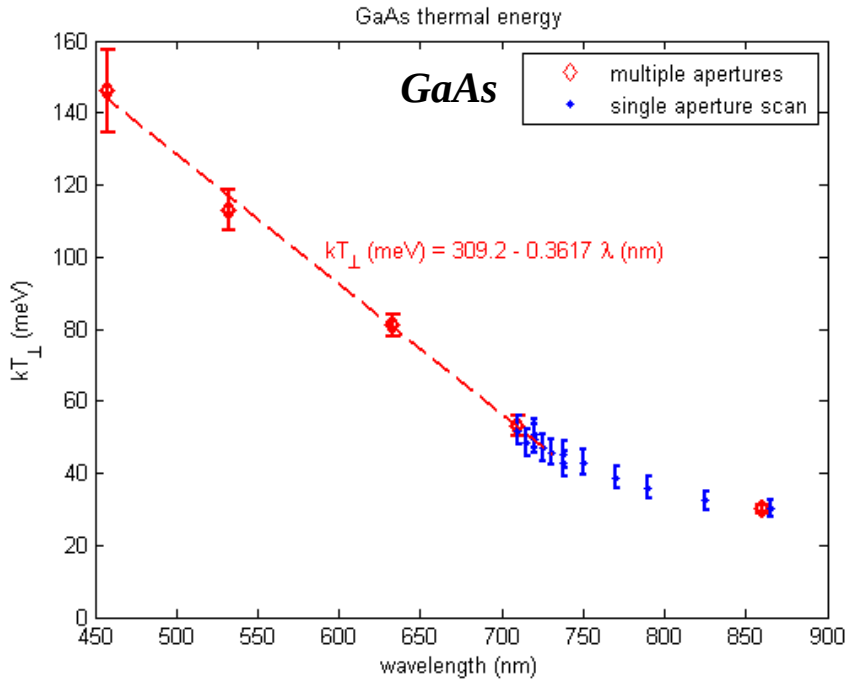
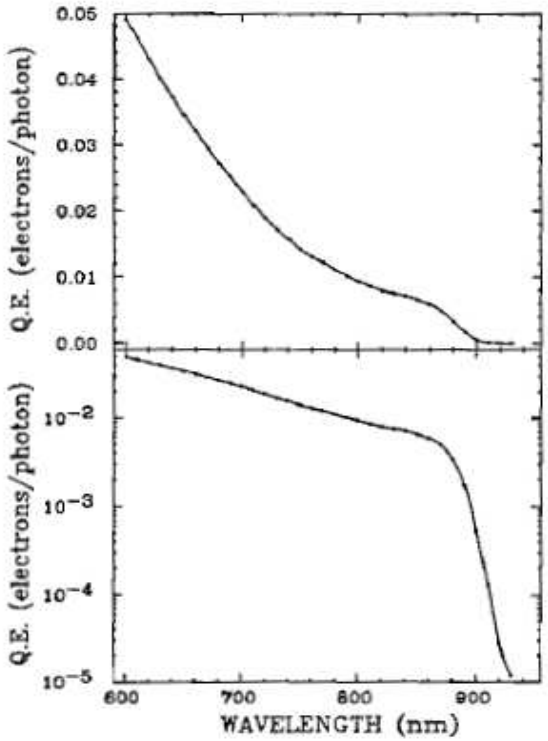
Outline

- The Basics
- Cathodes
- Details of Different Accelerator Guns
  - RF Guns
  - SRF Guns
  - DC Guns
  - Polarized Electron Guns
- Photoemission Guns
  - High Voltage
  - Vacuum
  - Laser System

Thermal emittance

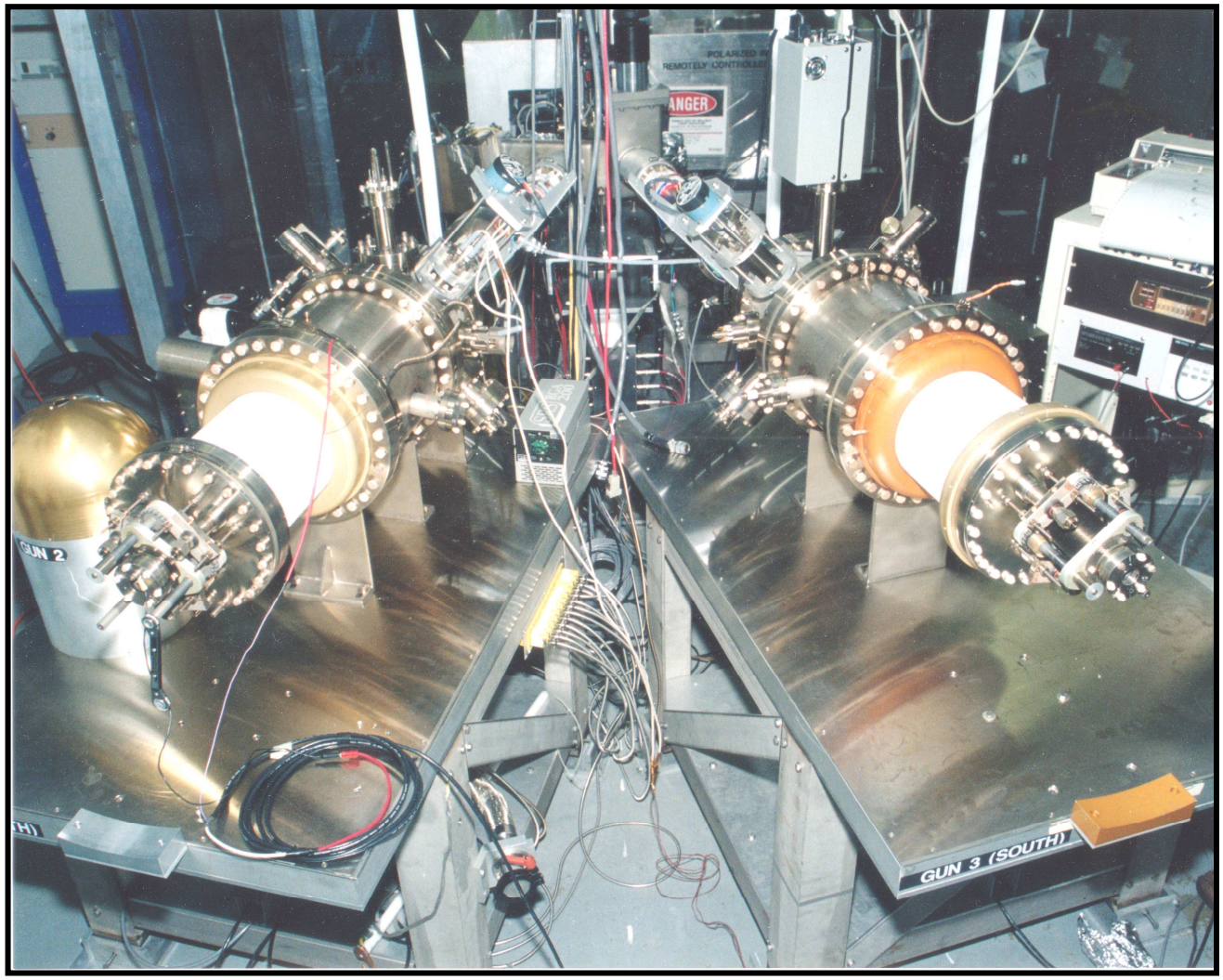




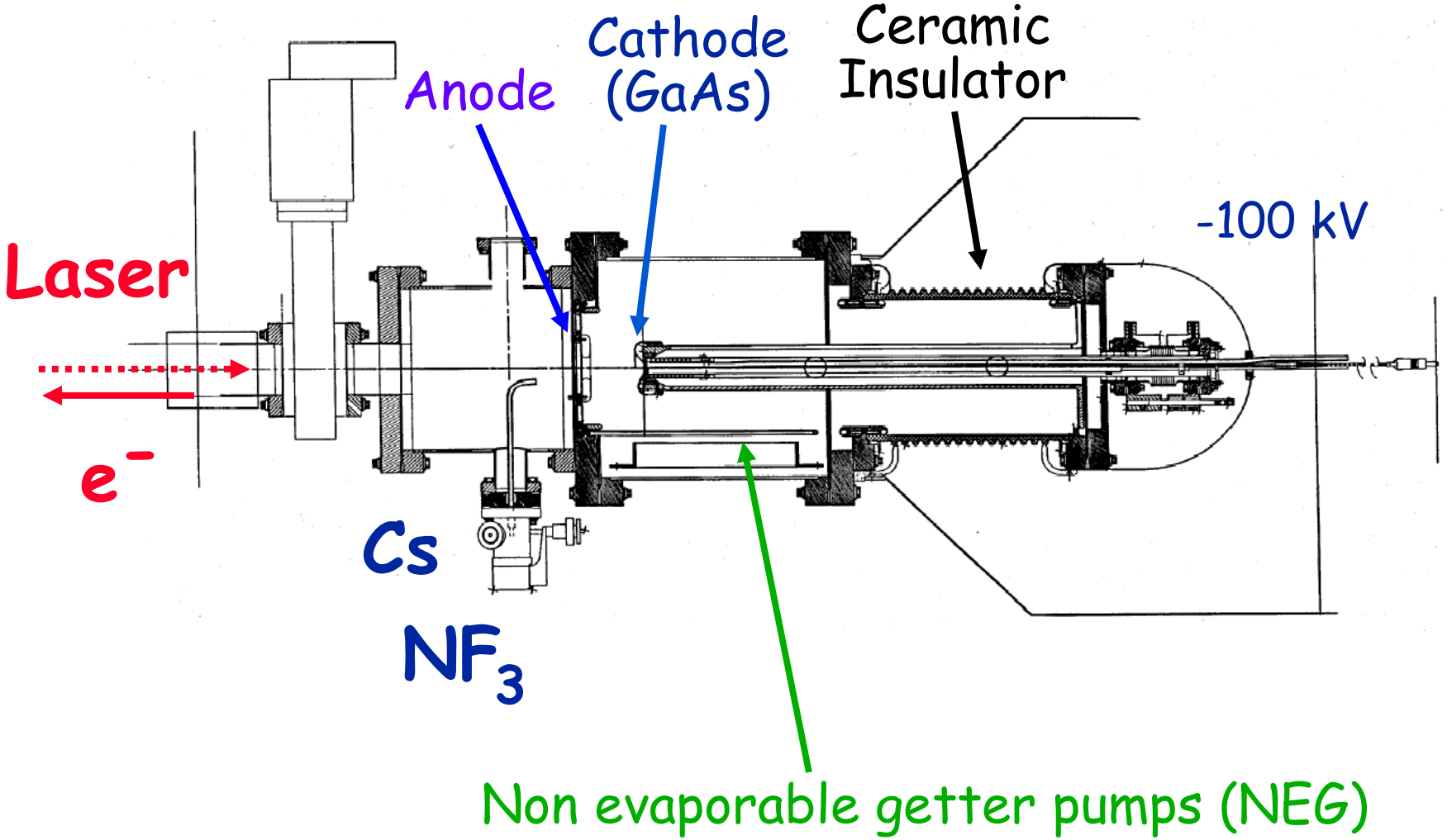
- $kT_{\perp}$ = ***120 meV*** at ***520 nm***
- or ***0.5 mm-mrad*** per ***1 mm*** rms
- GaAs still best overall performance
  Beam emittance ∝ sqrt(kT)

The lowest kT occurs at the worst QE!!

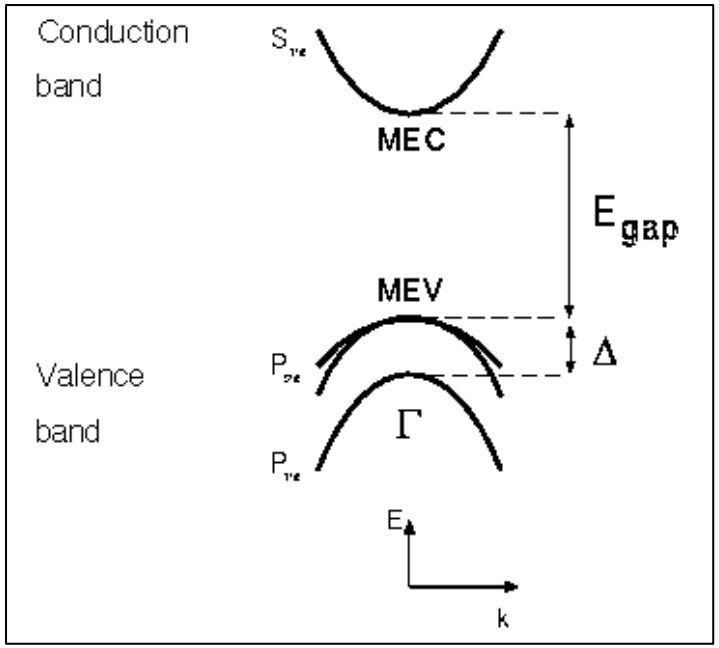
Jefferson Lab 100kV DC Polarized Electron Source

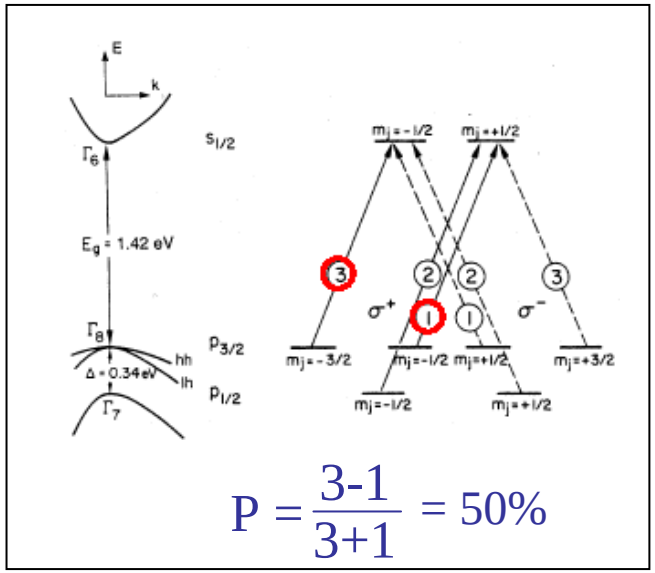


Gun Chamber


Anode
Cathode
(GaAs)
Ceramic
Insulator
-100 kV
Laser
e⁻
Cs
NF3
Non evaporable getter pumps (NEG)

Electron Polarization





Bulk GaAs

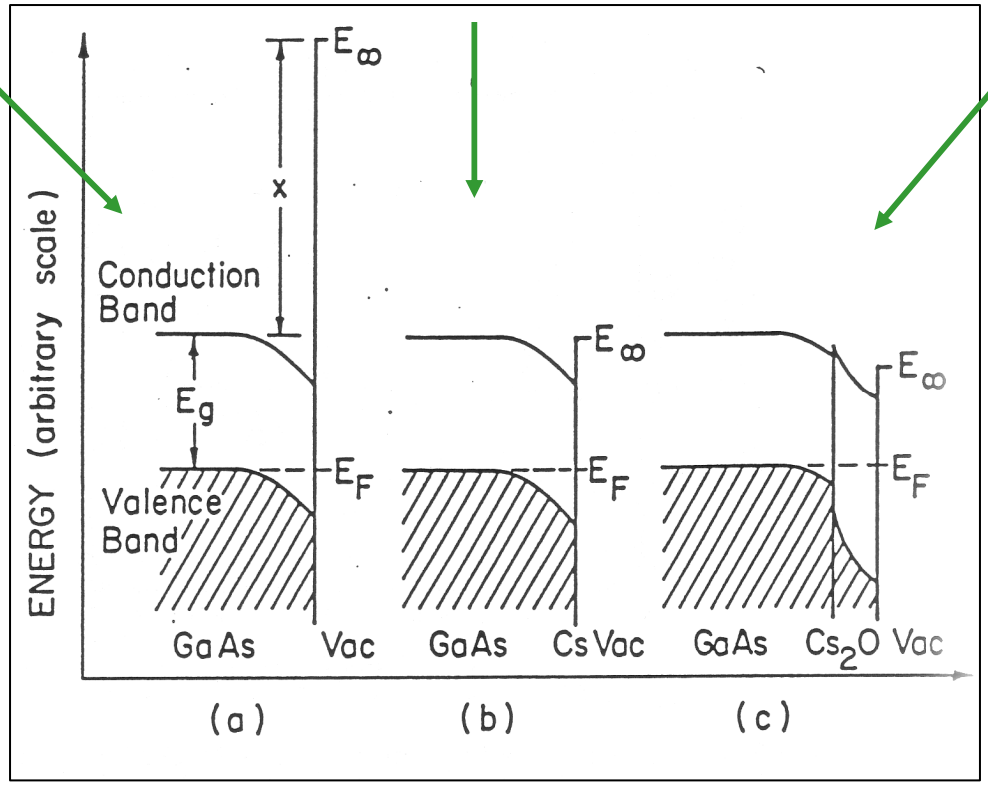
- Circularly polarized light at energy Egap (less than Egap + Δ) excites three electrons in one spin state for every one in the opposite spin state
- Theoretically 50% polarization, actually ~35% polarization
- First used at SLAC, then Jlab, Mainz, Bates

GaAs Surface Preparation

Bare GaAs surface;
Large work function.
No electrons

Alkalai (Cs) reduces
work function.
Some electrons

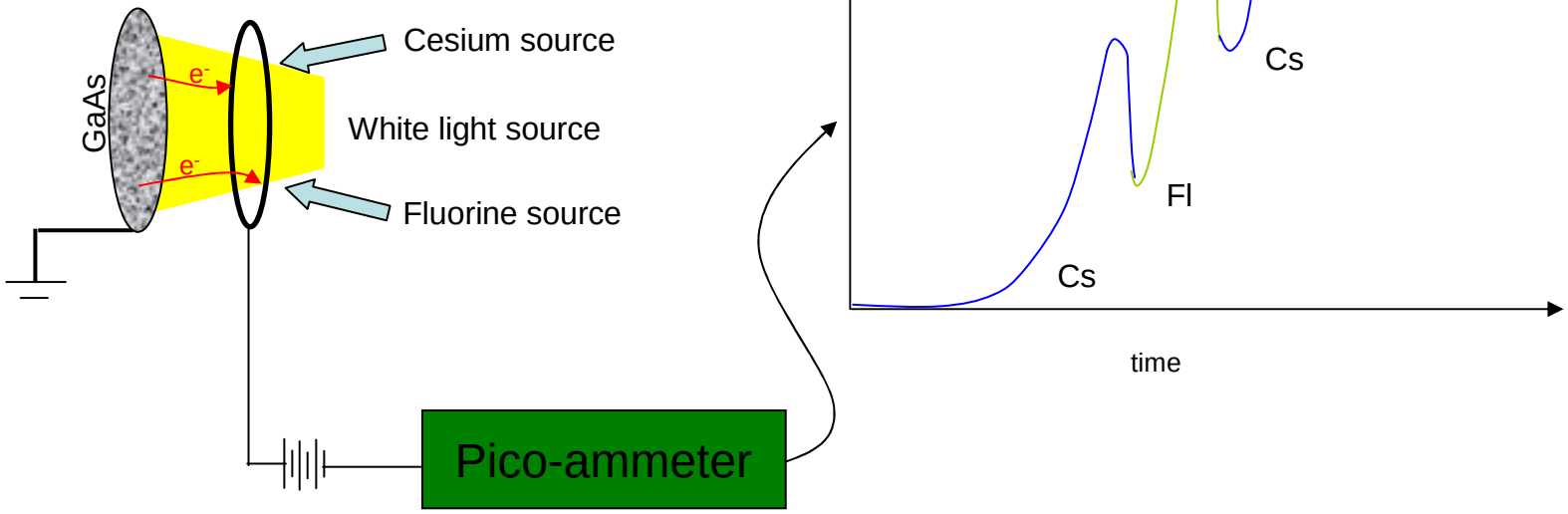
Cesium + Oxidant (O_2 or NF_3)
"Negative Electron Affinity".
Many electrons



$E_a > 0$ $E_a \approx 0$ $E_a < 0$

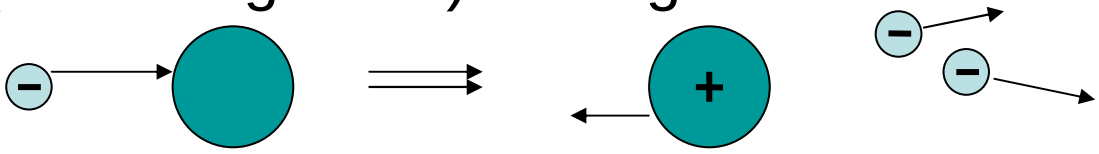
Cathode Activation Yo-Yo

1. Chemical etch
2. Mount on wafer holder
3. Load into vacuum system
4. Atomic hydrogen clean
5. Heat clean
6. activate



Vacuum Requirements for GaAs

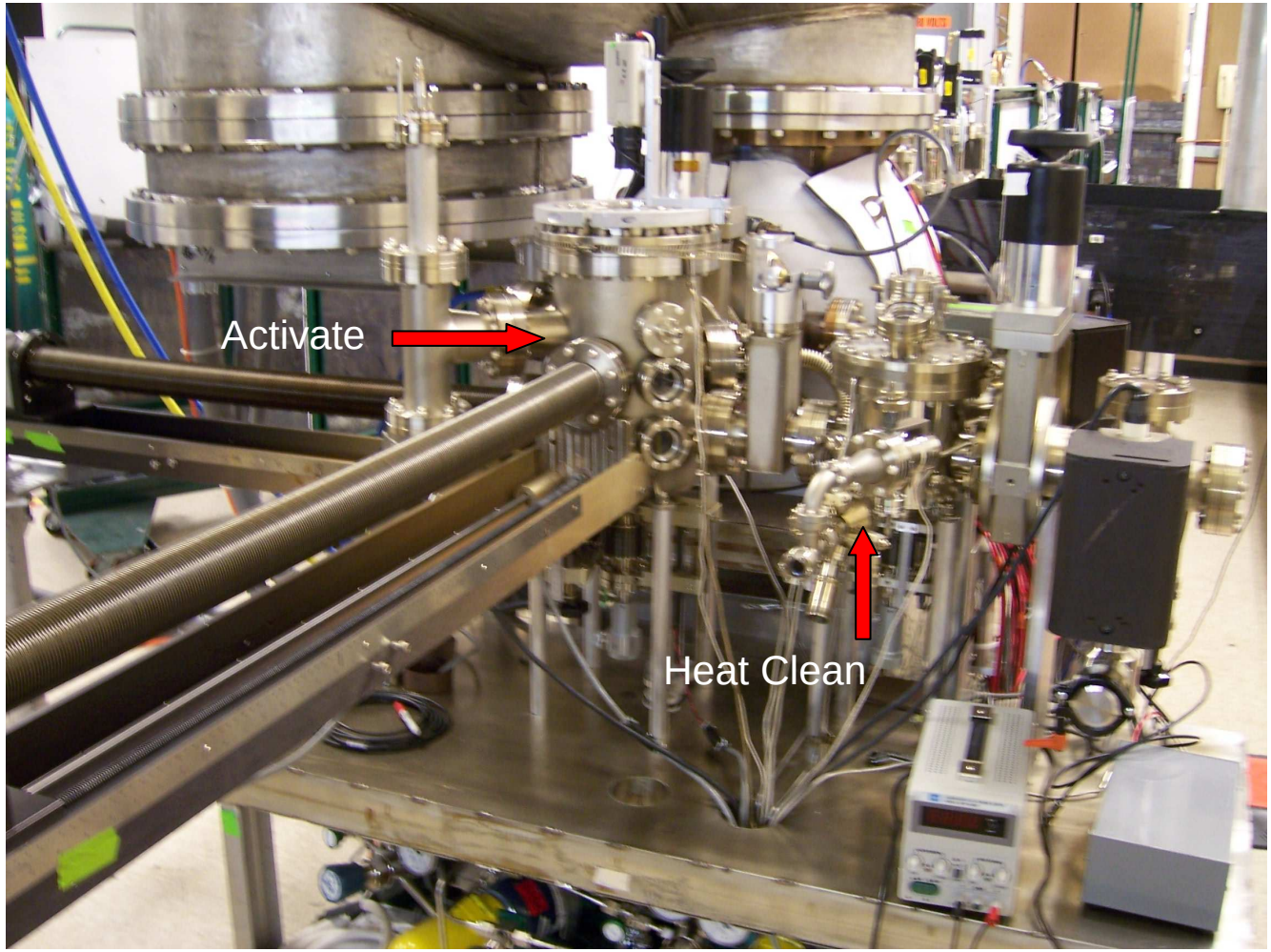
- Surface Chemistry
  - Reacts with residual gasses
  - Oxide forms on GaAs during heat processes if water is present
- Ions (residual gasses) damage cathode



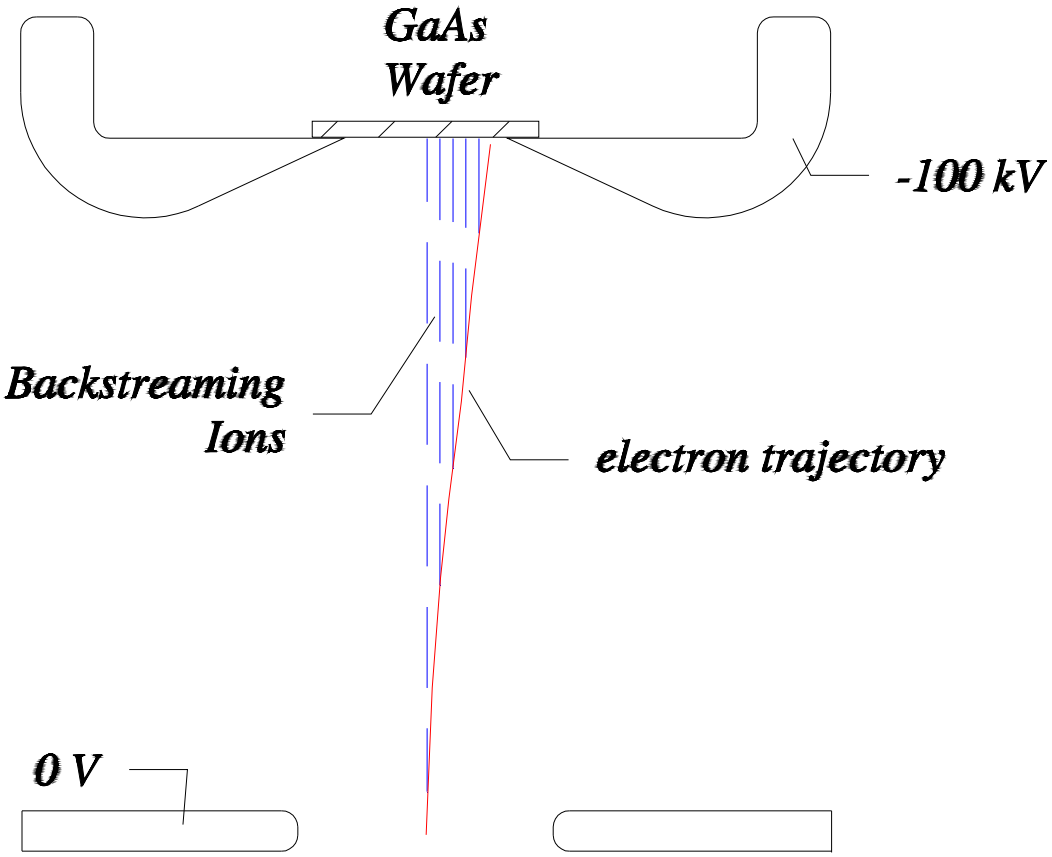
- Excellent (<1x10^{-11} Torr) vacuum obtained through
  - Pumping
    - Getter (chemical) and ion pump
  - Clean materials with low outgassing rates
    - Stainless steels, copper, ceramics
  - Leak Check
  - Bake

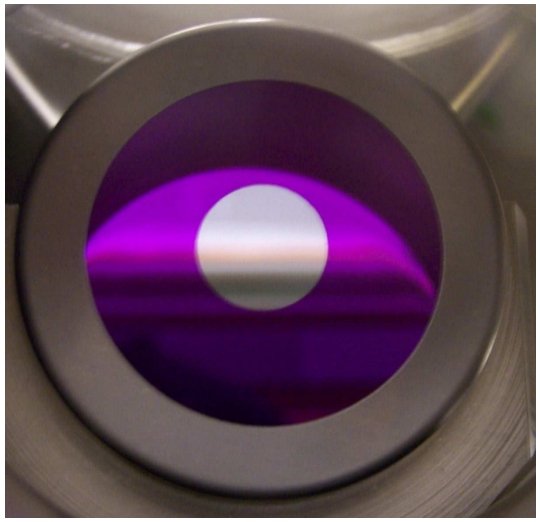
Arrays of NEG pumps provide the best vacuum conditions

Load lock system for introducing new wafers



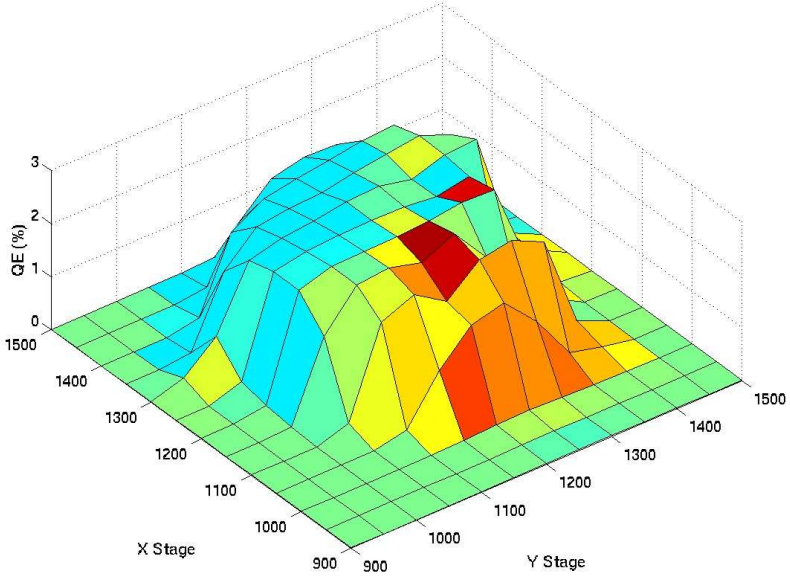
Vacuum and ion backstreaming

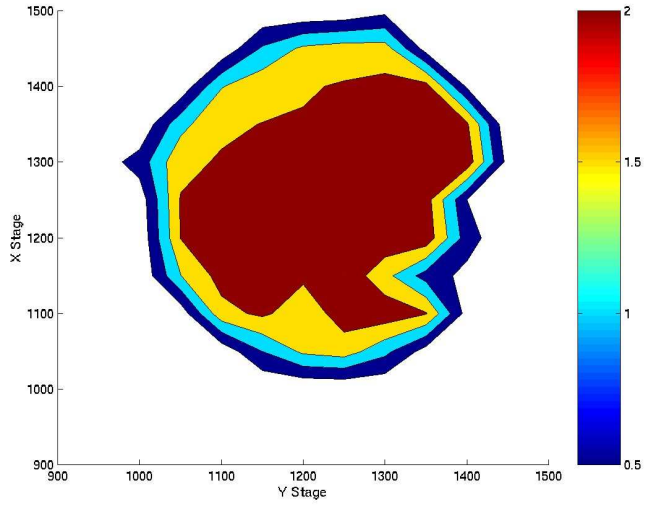




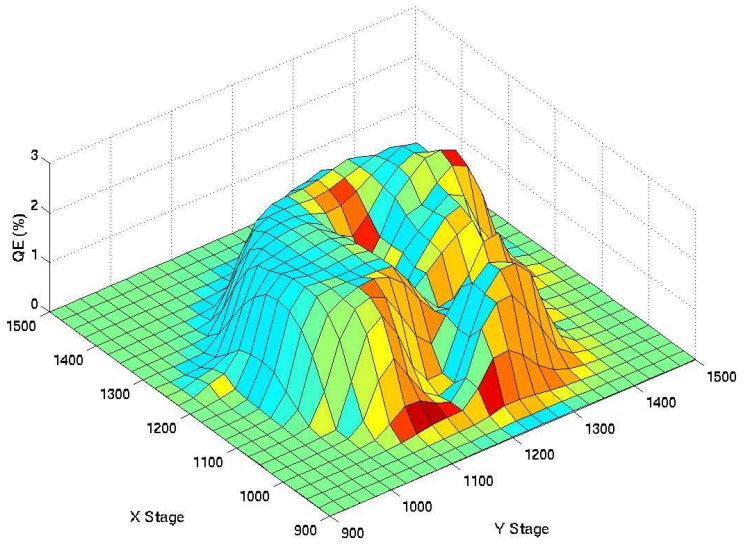
Ion backstreaming is a cause of poor cathode lifetime

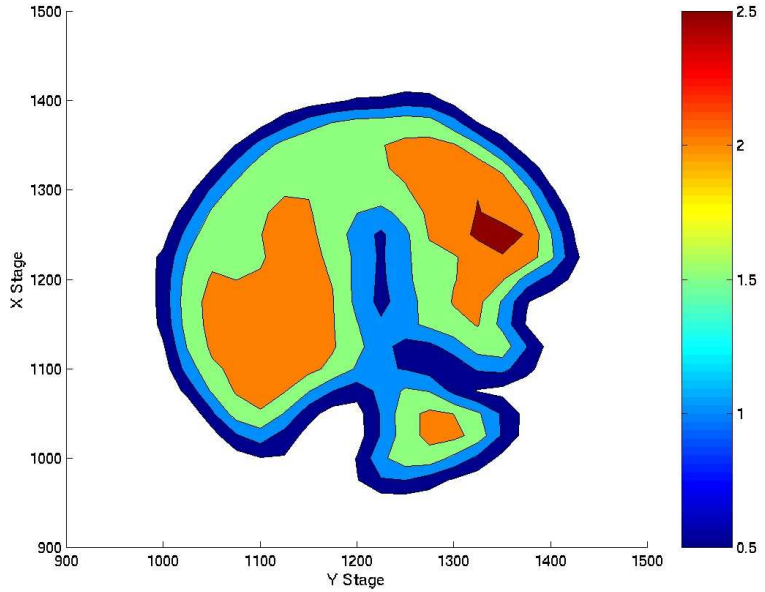
QE map before beam



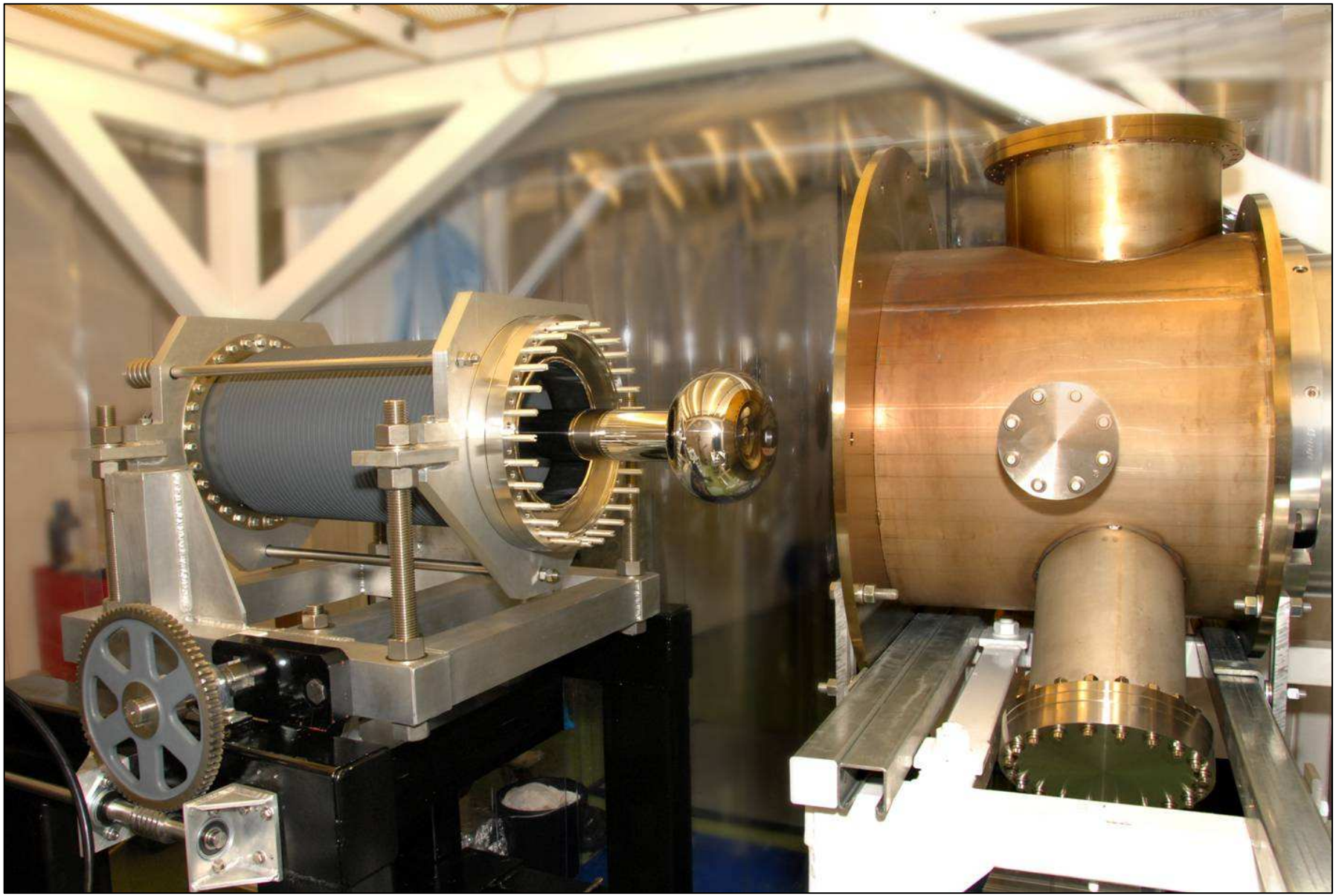


QE map after beam

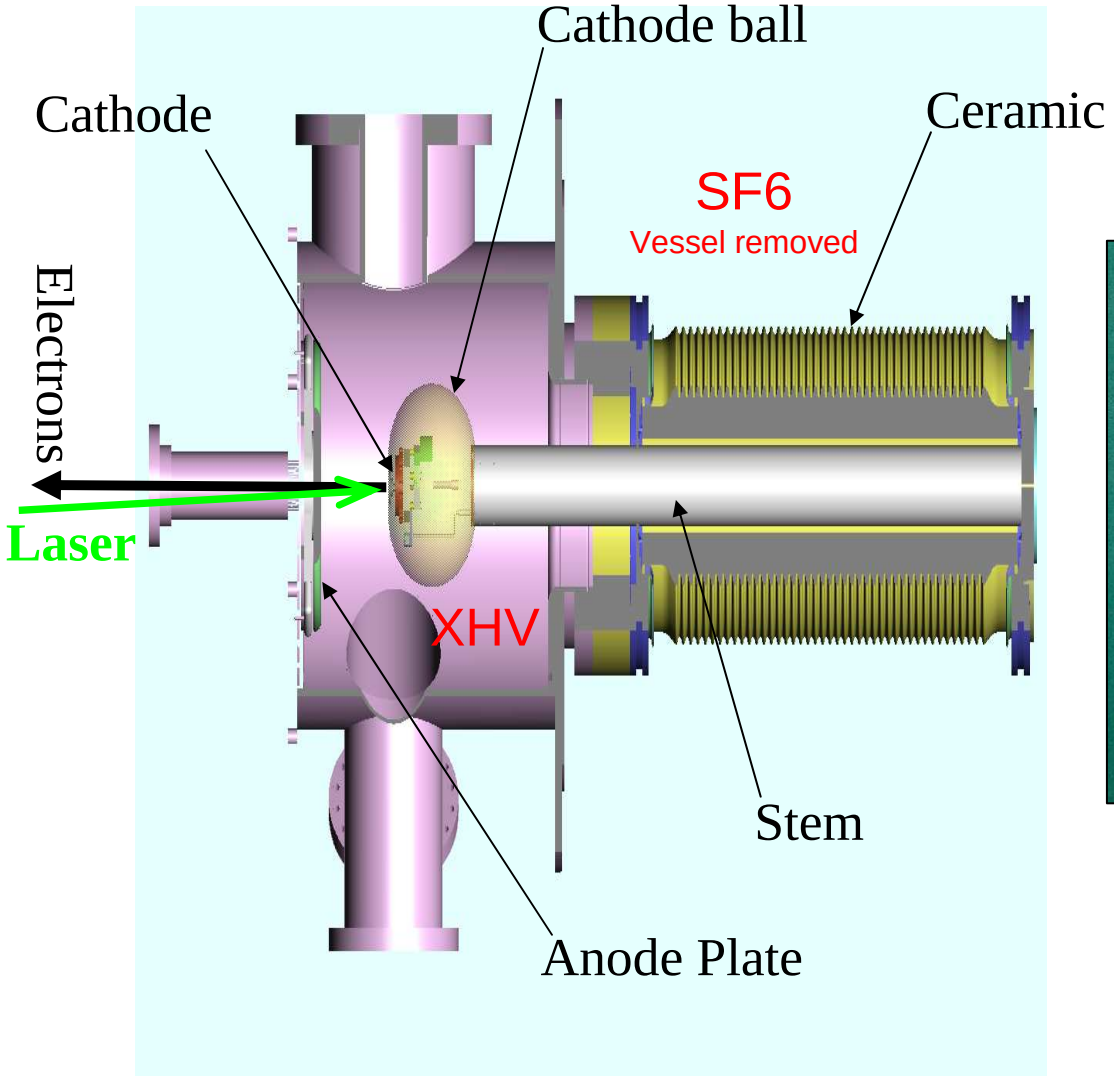




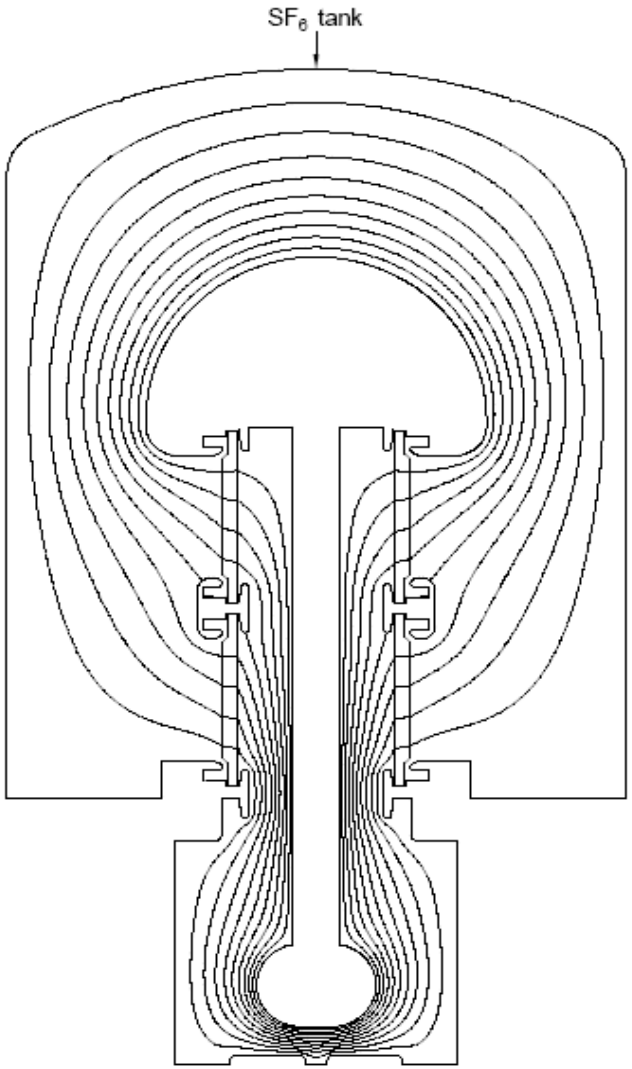
Daresbury Lab DC Photoemission Gun

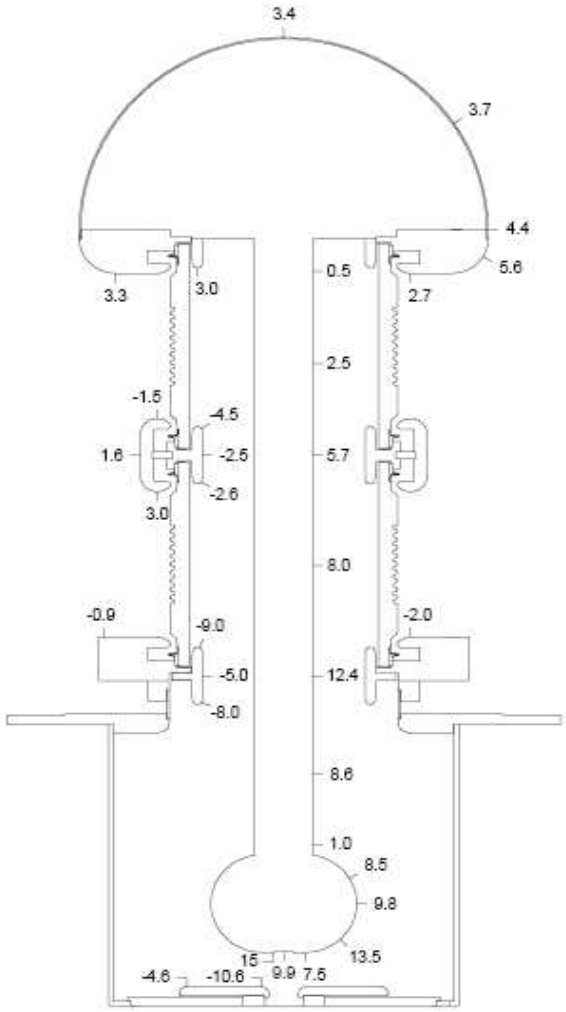


Gun Assembly



- JLab design Cs:GaAs cathode
- 500 kV DC supply
- Target transverse emittance: ~3 mm mrad





SF6 holds off 6MV/m at 1 atm

Insulators provide several functions:

•Isolate the HV electrodes from ground

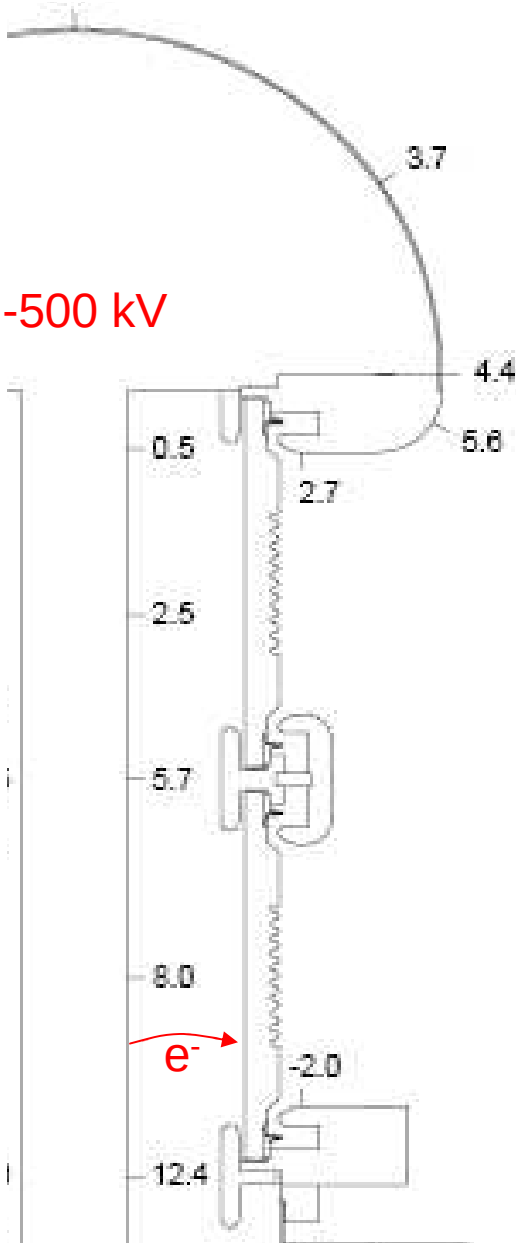
•Mechanical strength

•Ultra high vacuum

Only a few vendors worldwide available

Expensive

Long lead times



Problems with this geometry

The fields on the central support tube become quite high as it passes thru the flange at the bottom of the insulator

Electrons can be generated at sharp points or dust and accelerated into the insulator. The charge can build up and punch a hole thru the insulator.

Still trying to find an insulator design that has some resistivity to bleed off this charge

Inverted Gun Design

Breidenbach, et al, NIM A, 350 (1994)

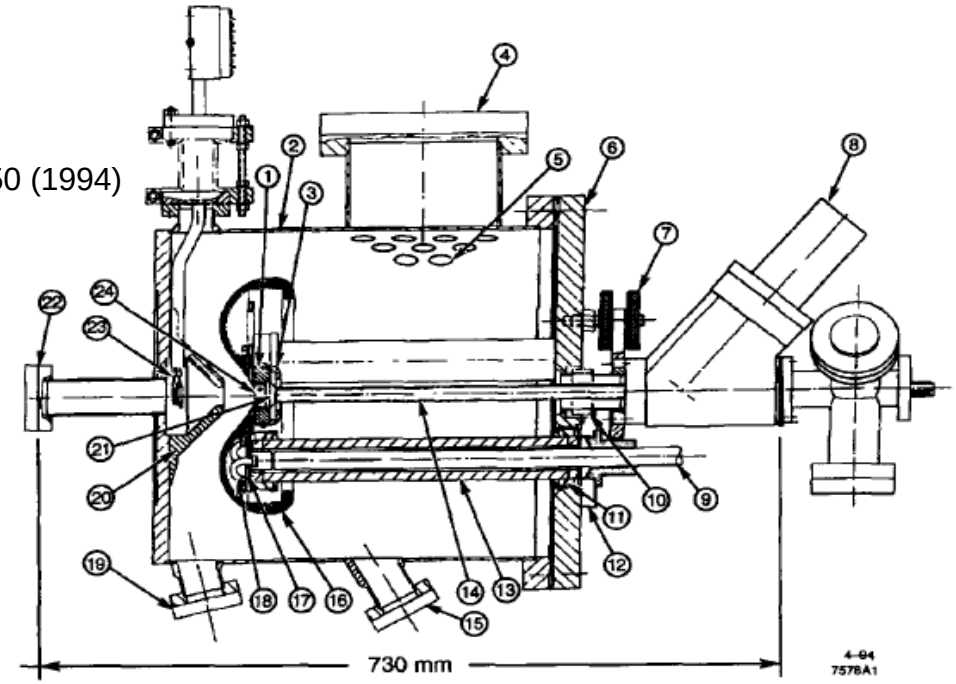
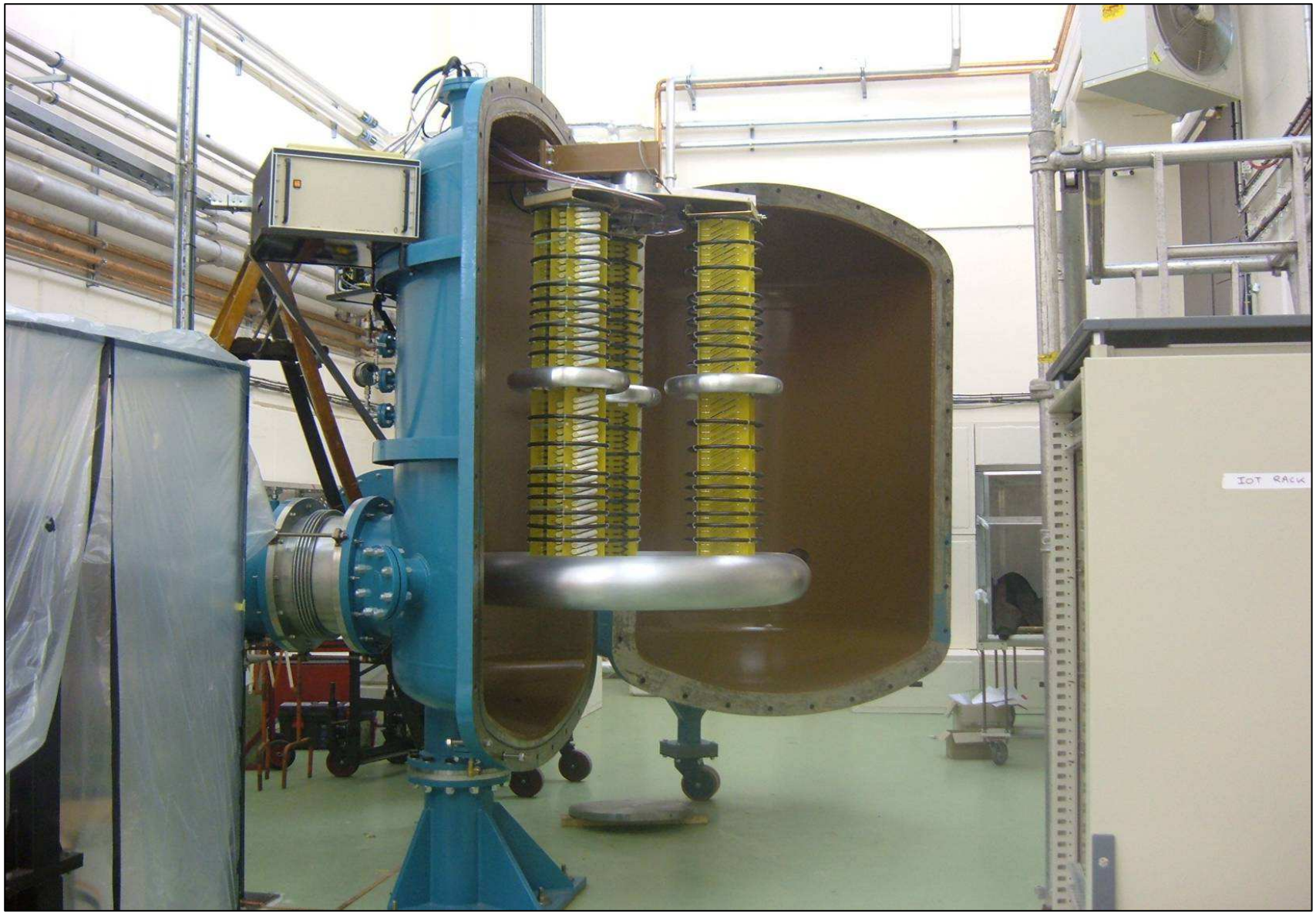
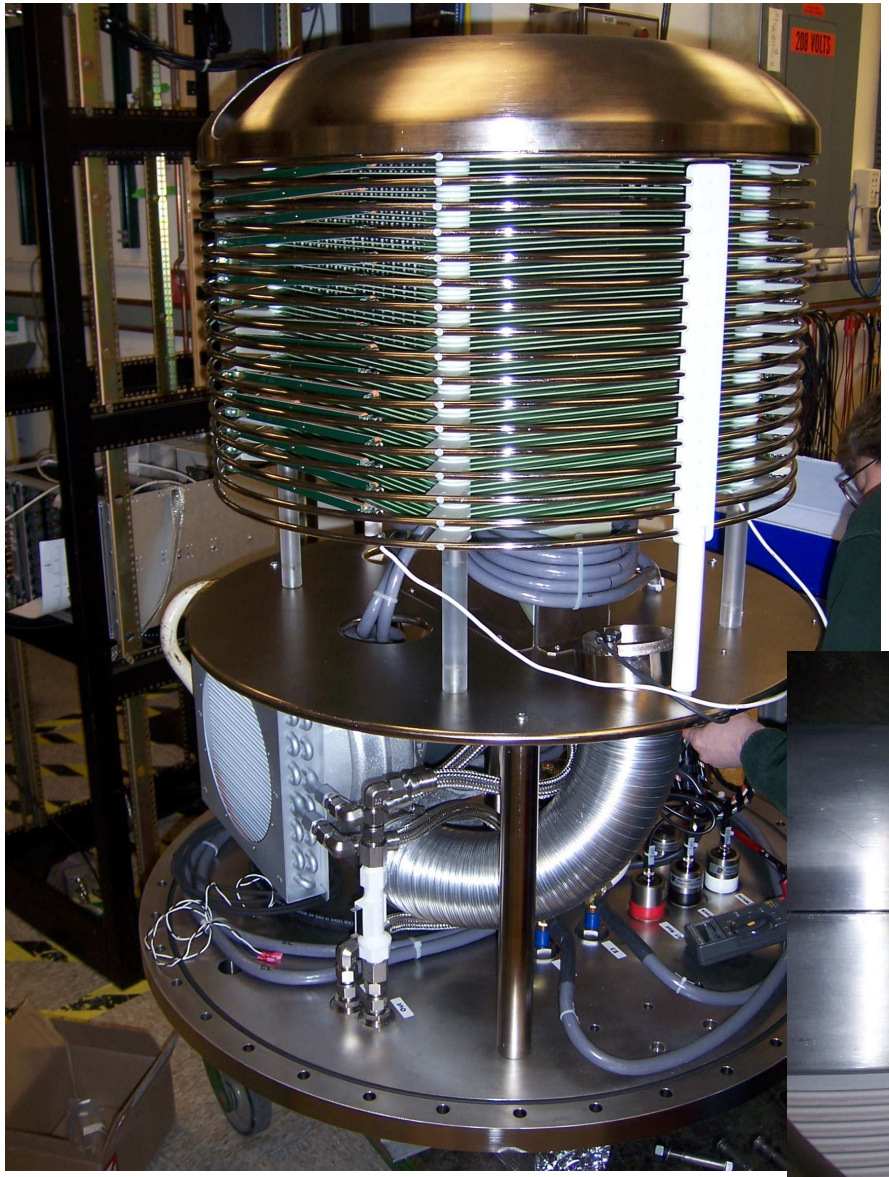


Fig. 1. Gun: (1) docking mechanism and puck holder, (2) gun body, (3) shield rings, (4) ion pump port, (5) pumping holes, (6) end flange, (7) jacks for aligning transporter to puck holder, (8) access valve, (9) high voltage cable, (10) bellows, (11) Kovar weld ring, (12) gas seal flange, (13) ceramic insulator, (14) transporter rod (only in place while changing photocathode), (15) docking window, (16) cathode electrode, (17) support plate, (18) gas tubes, (19) illumination window, (20) anode electrode, (21) puck, (22) exit port to beam line, (23) cesiator, (24) photocathode.

X-ray tube have been made like this for a long time – up to 350 kV

500kV Power Supply





New Technology for HV Power Supplies

(Kaiser Systems)

750kV, 100 mA

Each circuit board produces 100mA, 12.5 kV

Cost: ~ $10 per watt, $750,000

Comparison of different gun types for accelerators

	SC RF	NC RF	DC
Avg Power	M	L	H
Peak Power	M	H	L
Charge/bunch	M	H	L
Vacuum	XHV	HV	HV-XHV
Laser	Huge	Monster	Big
Cathodes	Metal, Metal(SC), antimonides	Metal, antimonides	Any
Cost	Enormous	Huge	depends