Jefferson Lab Injector Beamline Upgrade

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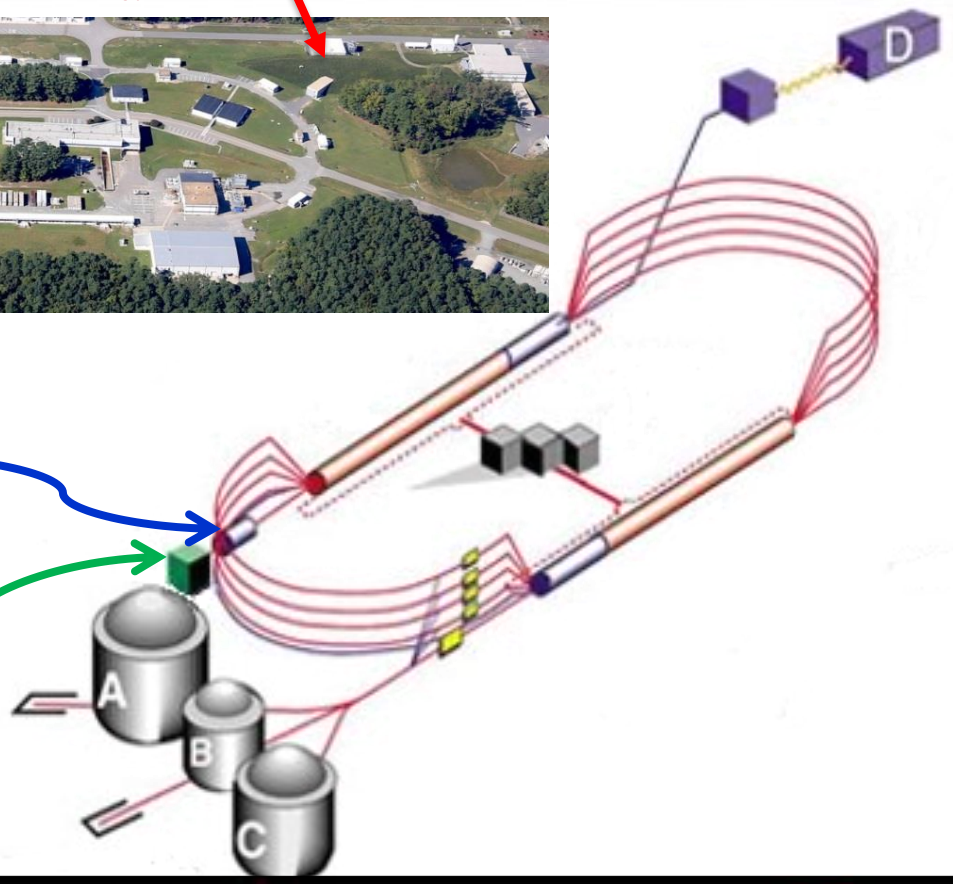
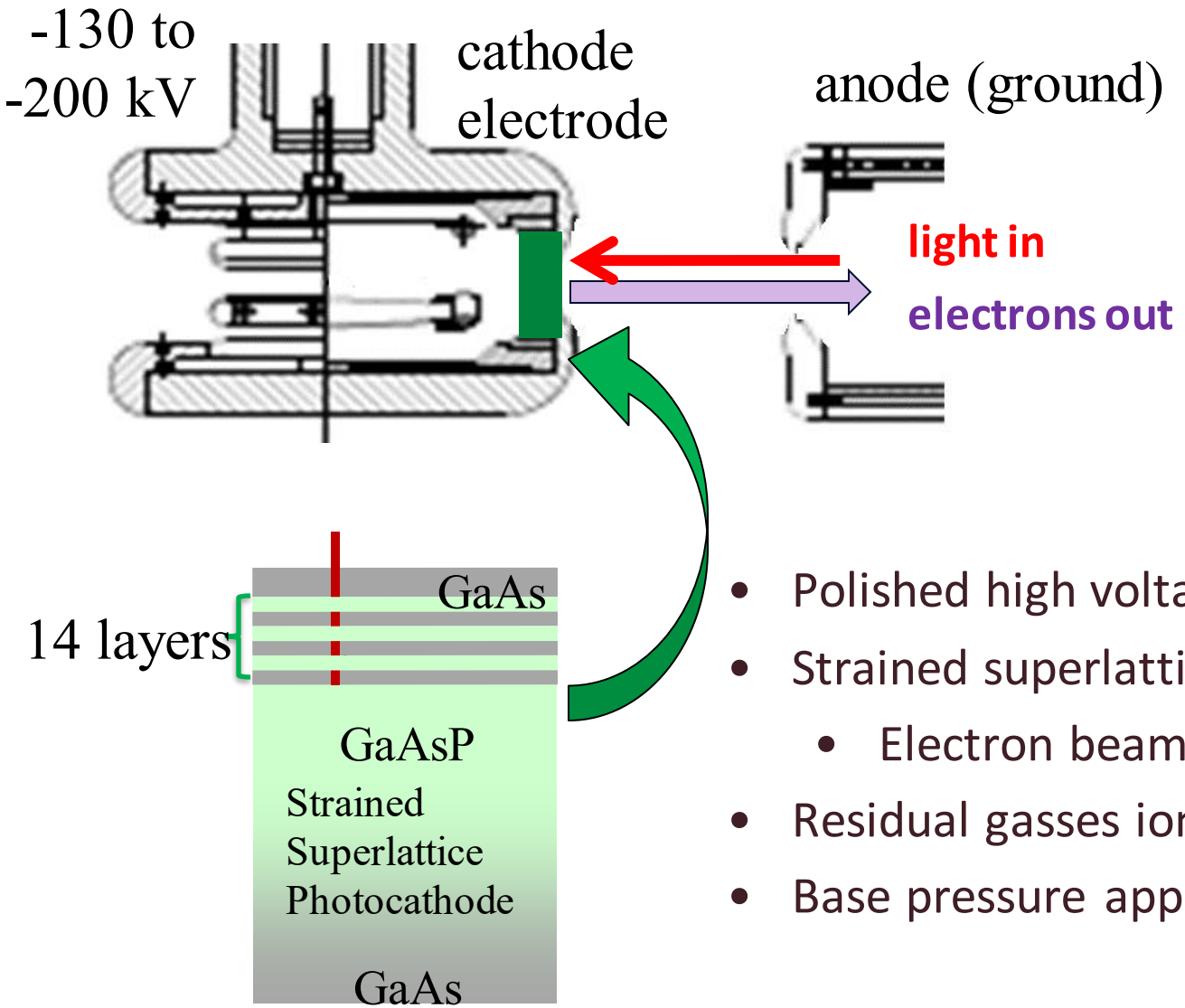
Thomas Jefferson National Accelerator Facility

- US Department of Energy, 12 GeV electrons, recirculating linear accelerator
- Up to 90% polarization from DC photoemission source
- Electron currents to 200μA beam (CW) to four experimental halls



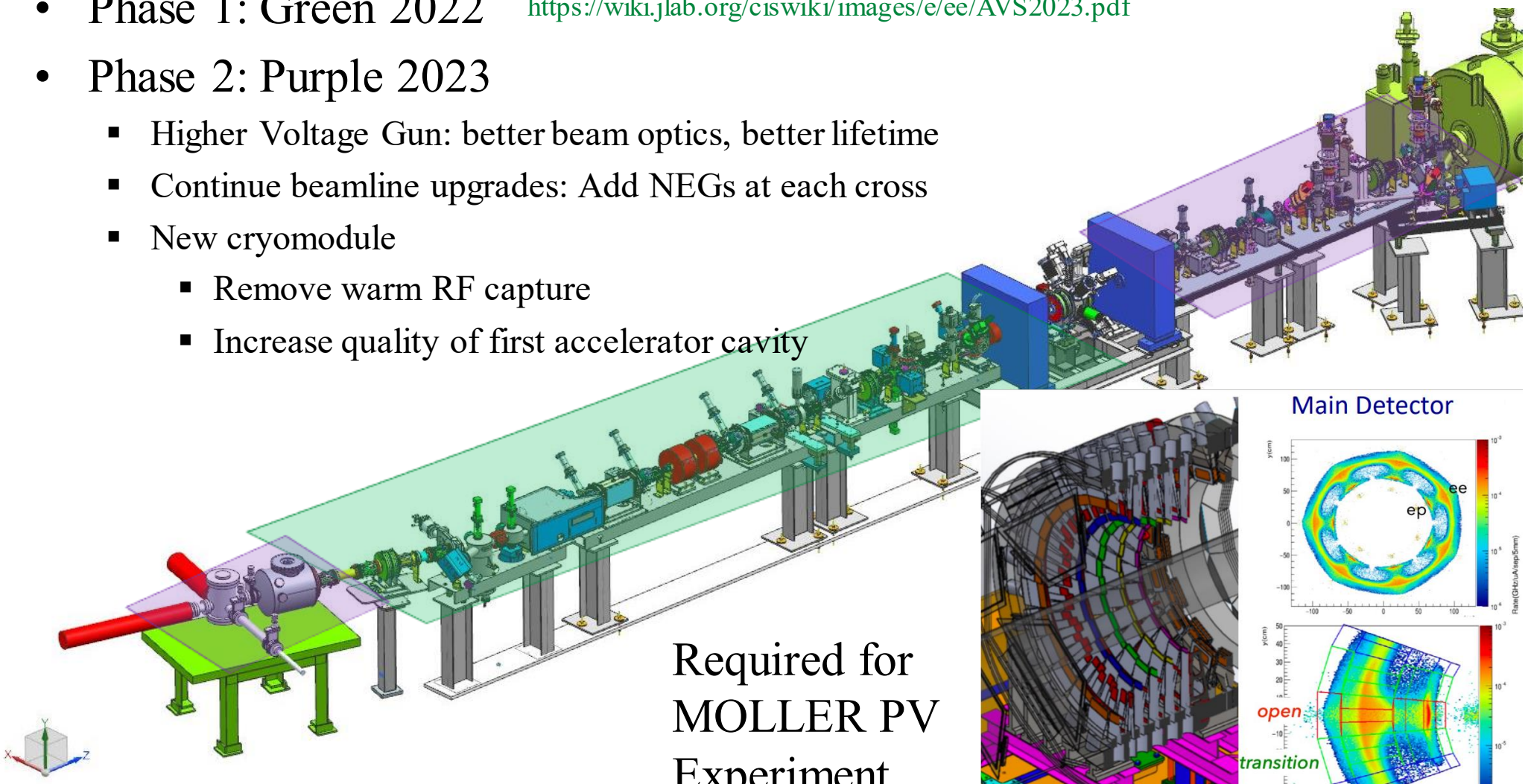
DC Photoemission Source



- Polished high voltage electrodes
- Strained superlattice GaAs/GaAsP photocathode
  - Electron beam polarization ~90%
- Residual gasses ionized, limit operational lifetime
- Base pressure approaching XHV: P ~ 2×10^{-12} Torr

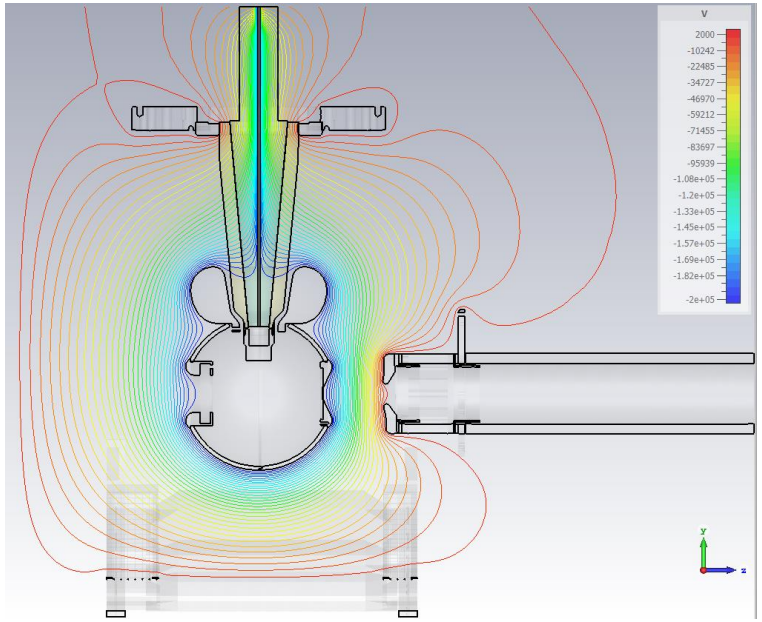
Injector Upgrade: Phases 1 & 2

- Phase 1: Green 2022 https://wiki.jlab.org/ciswiki/images/e/ee/AVS2023.pdf
- Phase 2: Purple 2023
  - Higher Voltage Gun: better beam optics, better lifetime
  - Continue beamline upgrades: Add NEGs at each cross
  - New cryomodule
    - Remove warm RF capture
    - Increase quality of first accelerator cavity



Required for MOLLER PV Experiment

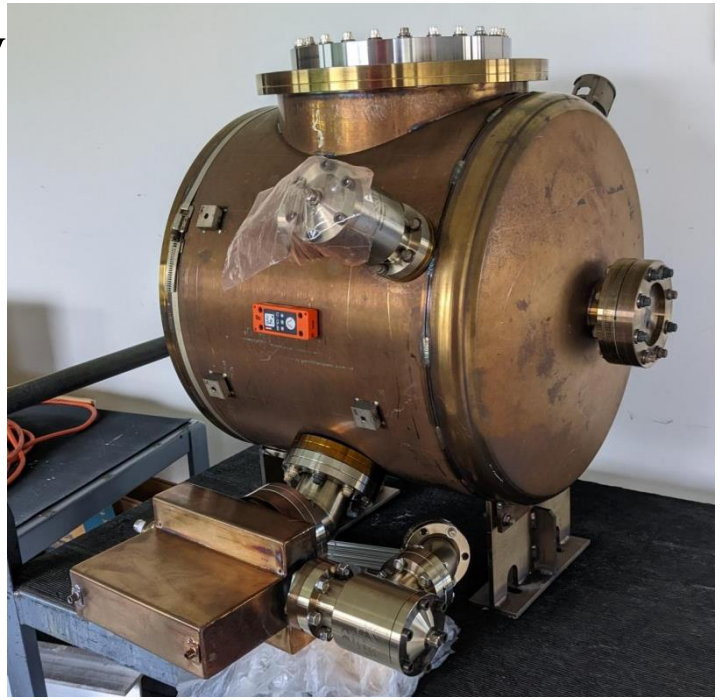
Gun upgrade



Current gun:130 kV, 15” (38cm) diameter
New gun: 200 kV, 18” (46cm) diameter

NEG coated, heat treated,
New NEGs with less particulates

Cleanroom assembly



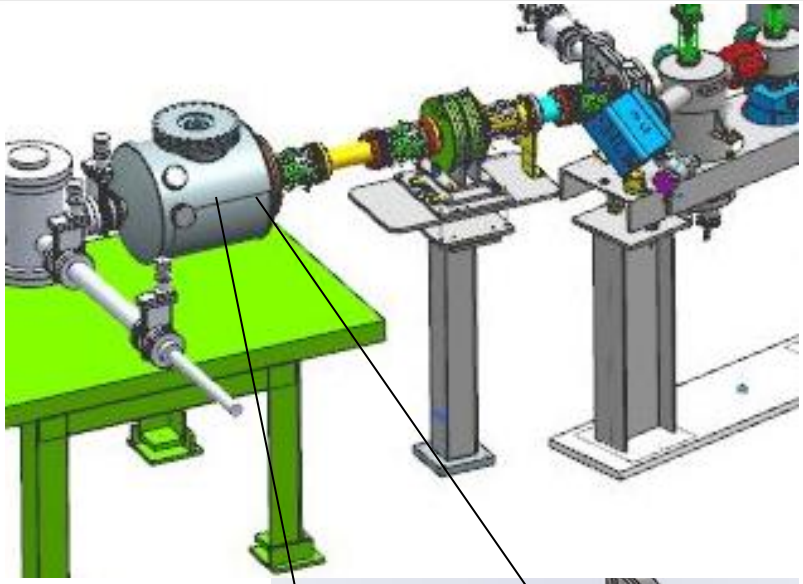
J. Vac. Sci. Technol. A **36**, 031603 (2018)

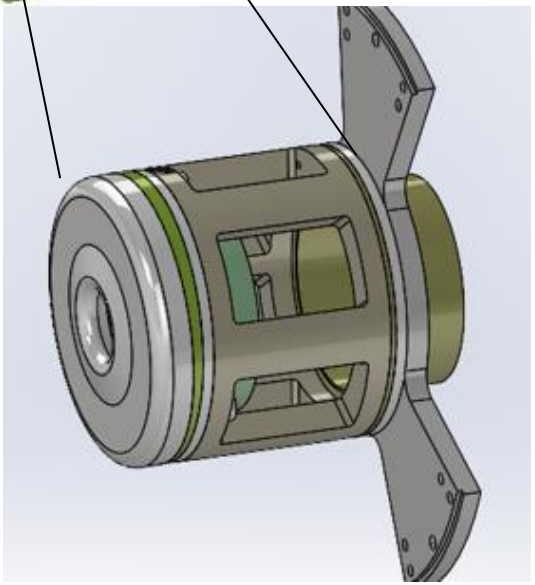
Next generation NEG pumps

WP1250 ST707 pumps
Metallic particulates
Activation @ 38A -> shorts

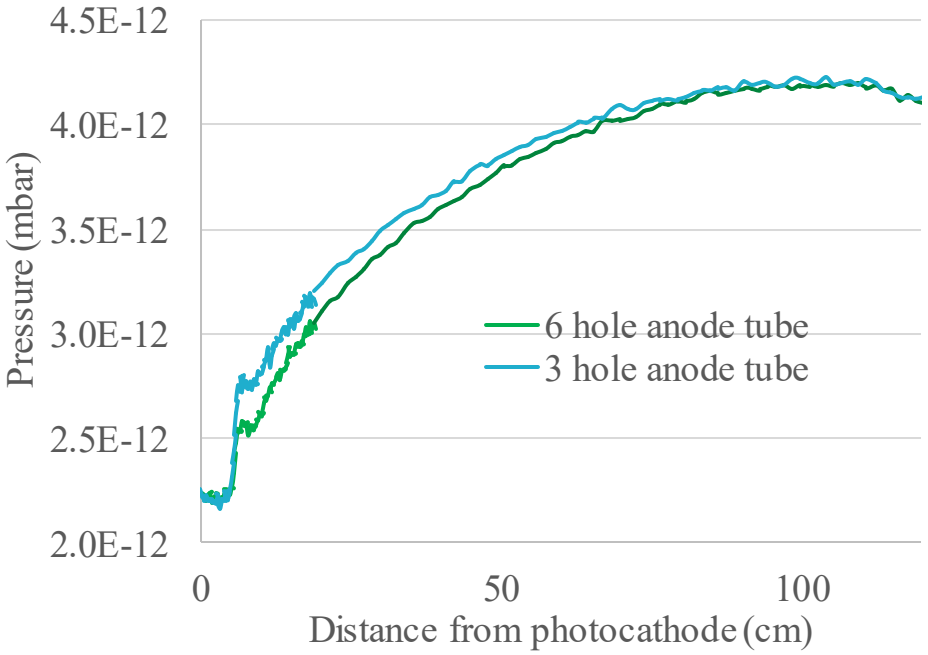
Newer generation UHV ZAO
minimal particulate generation
Heaters -> good activations

Modeling driven improvements

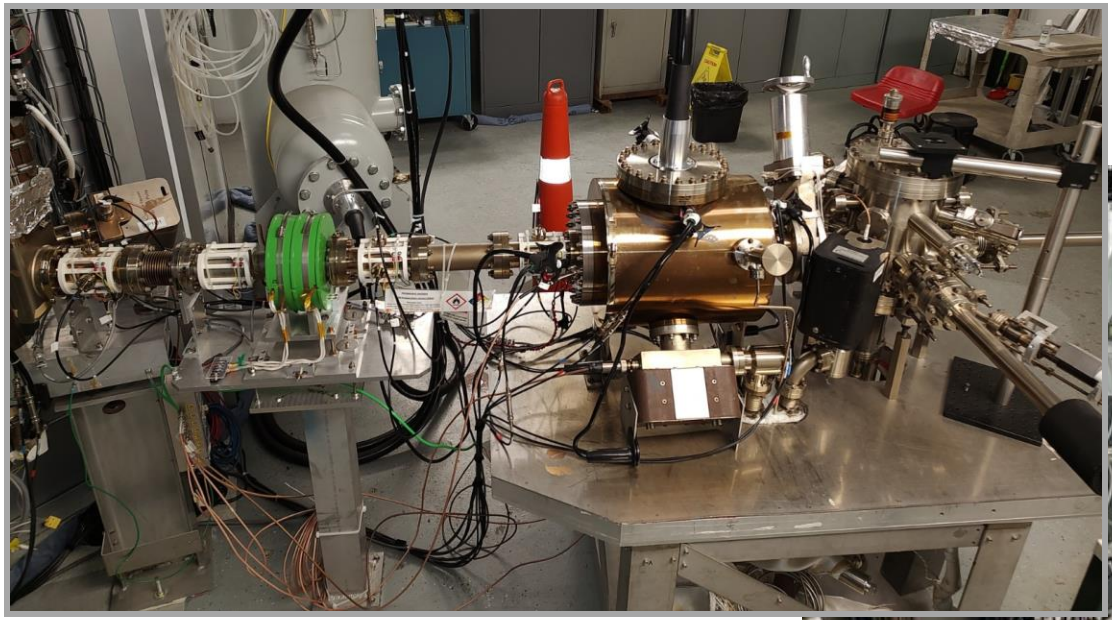


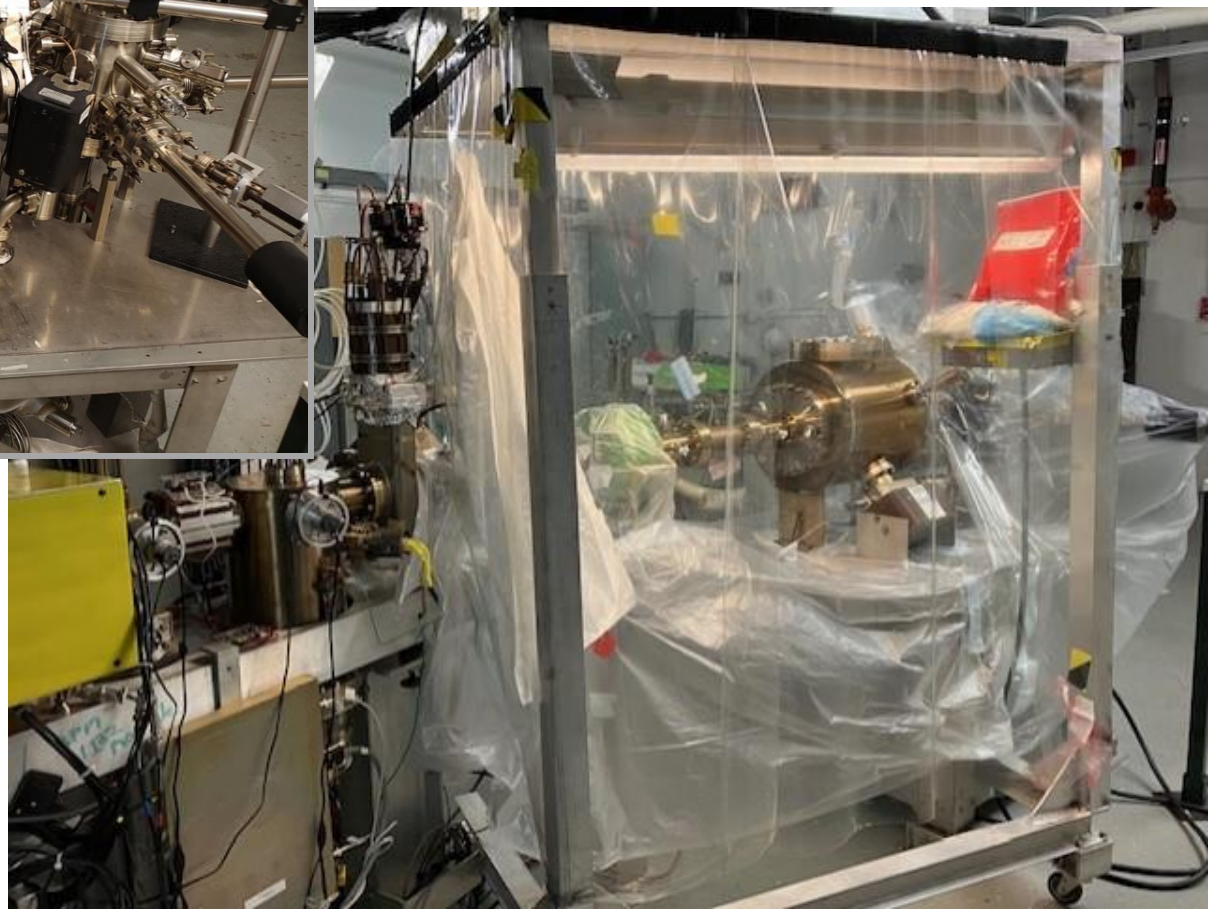


- Pumping between gun and y chamber: only NEG coating
- Model suggests adding additional holes to support tube will improve vacuum in critical gun region



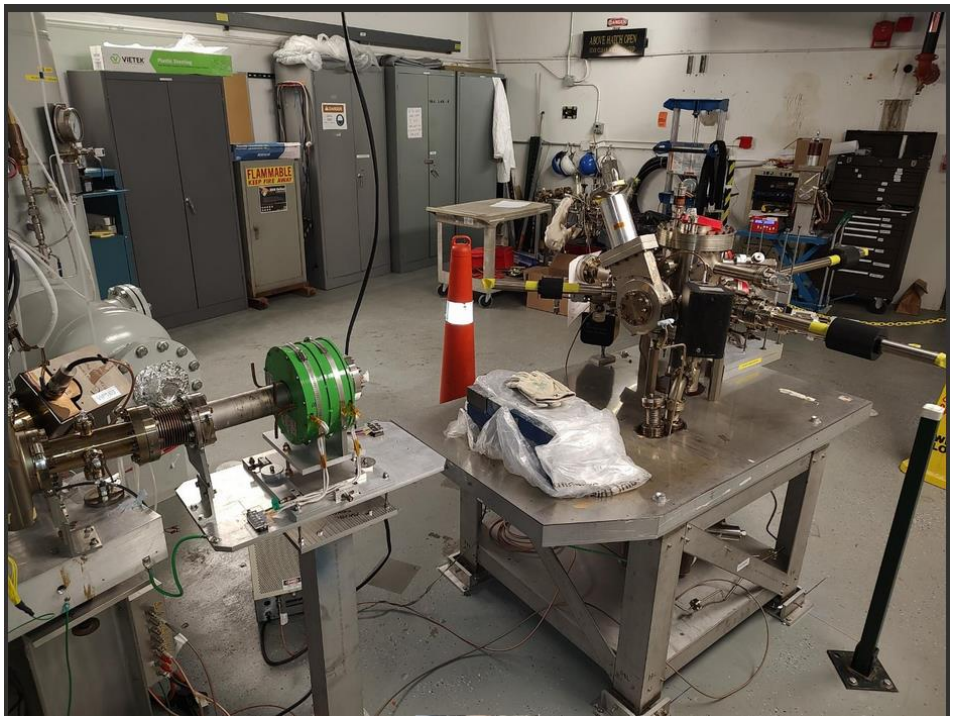
Uninstall tee-electrode gun

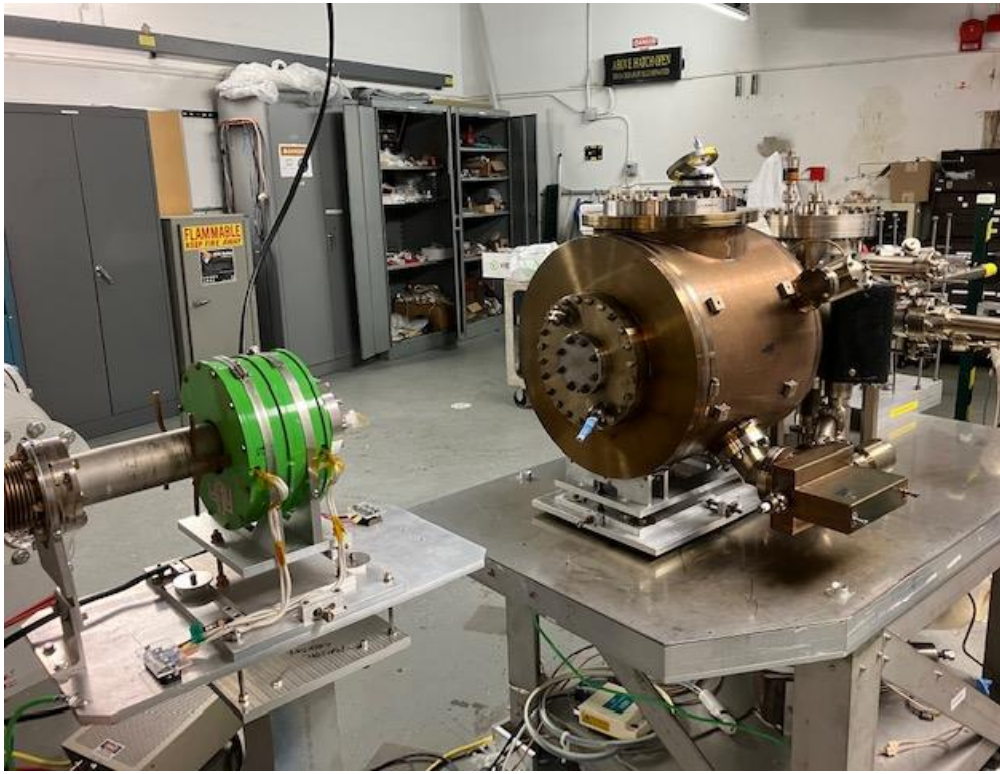




Uninstall 14” (36 cm) gun

Install spherical electrode gun

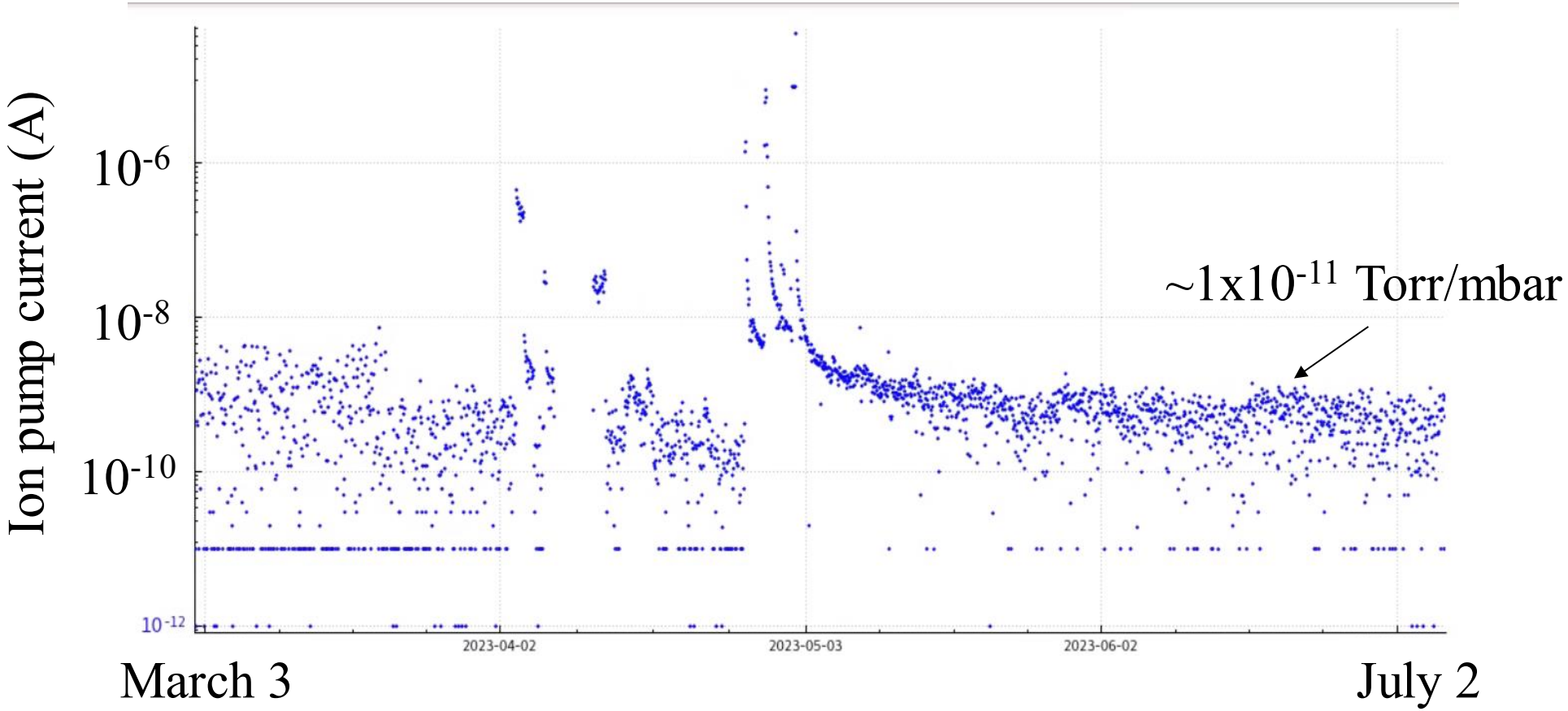




- ✓ Install
- ✓ Align
- ✓ Bake
- ✓ High voltage process

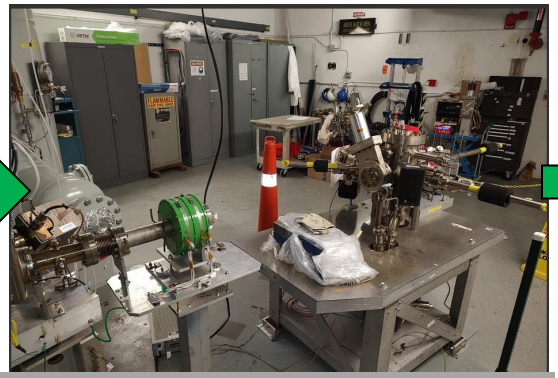
Wait: PSS certifications, safety stand-down

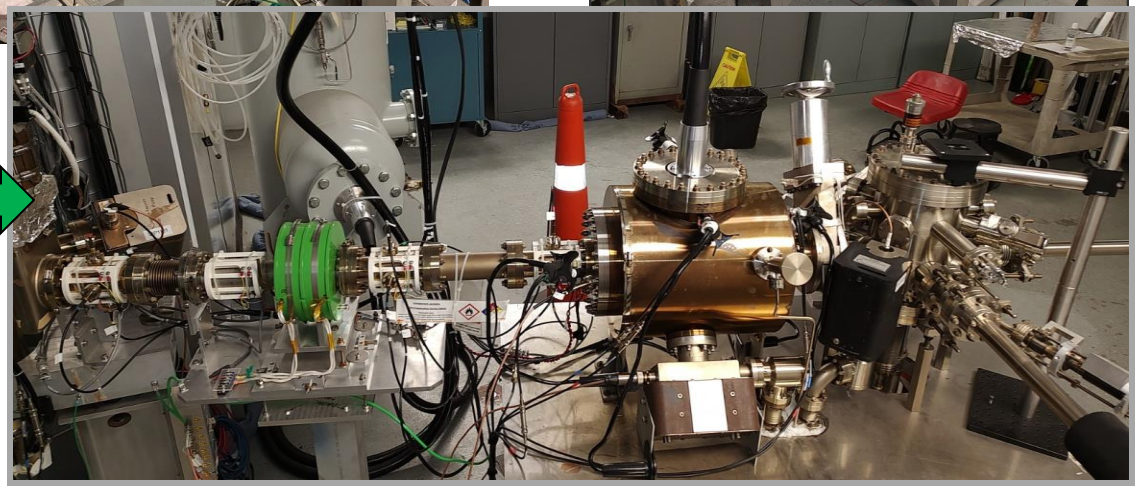
Gun vacuum recovering well from bake



Then undo it all

- Start injector commissioning after safety shutdown
- Find electrostatic optics very sensitive with spherical electrode, CEBAF beamline

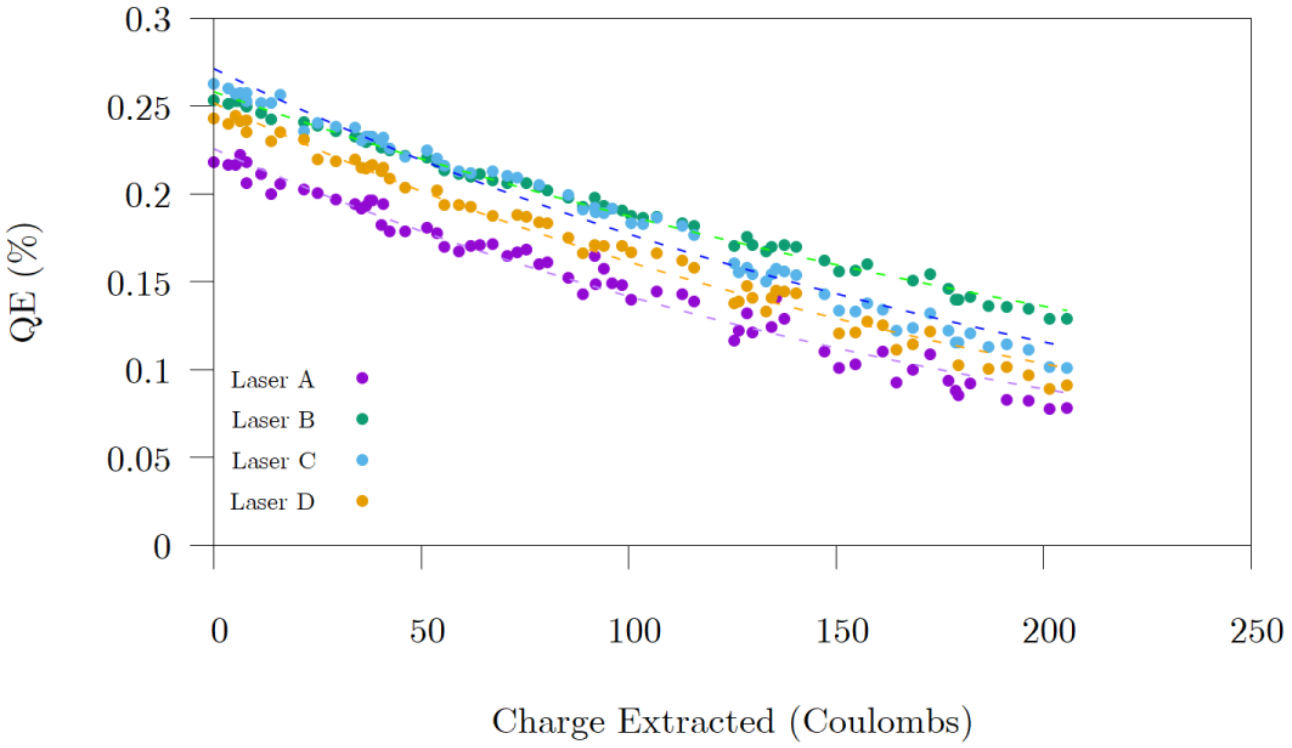




Back to original setup

- No operational lifetime for new system
- Original working well

Charge lifetime measurement



9/9/2021-12/01/2021, compiled Josh Yoskowitz

Daily measurement of

- Quantum Efficiency (QE) = electrons out/photons in
- Charge delivered

Charge lifetime

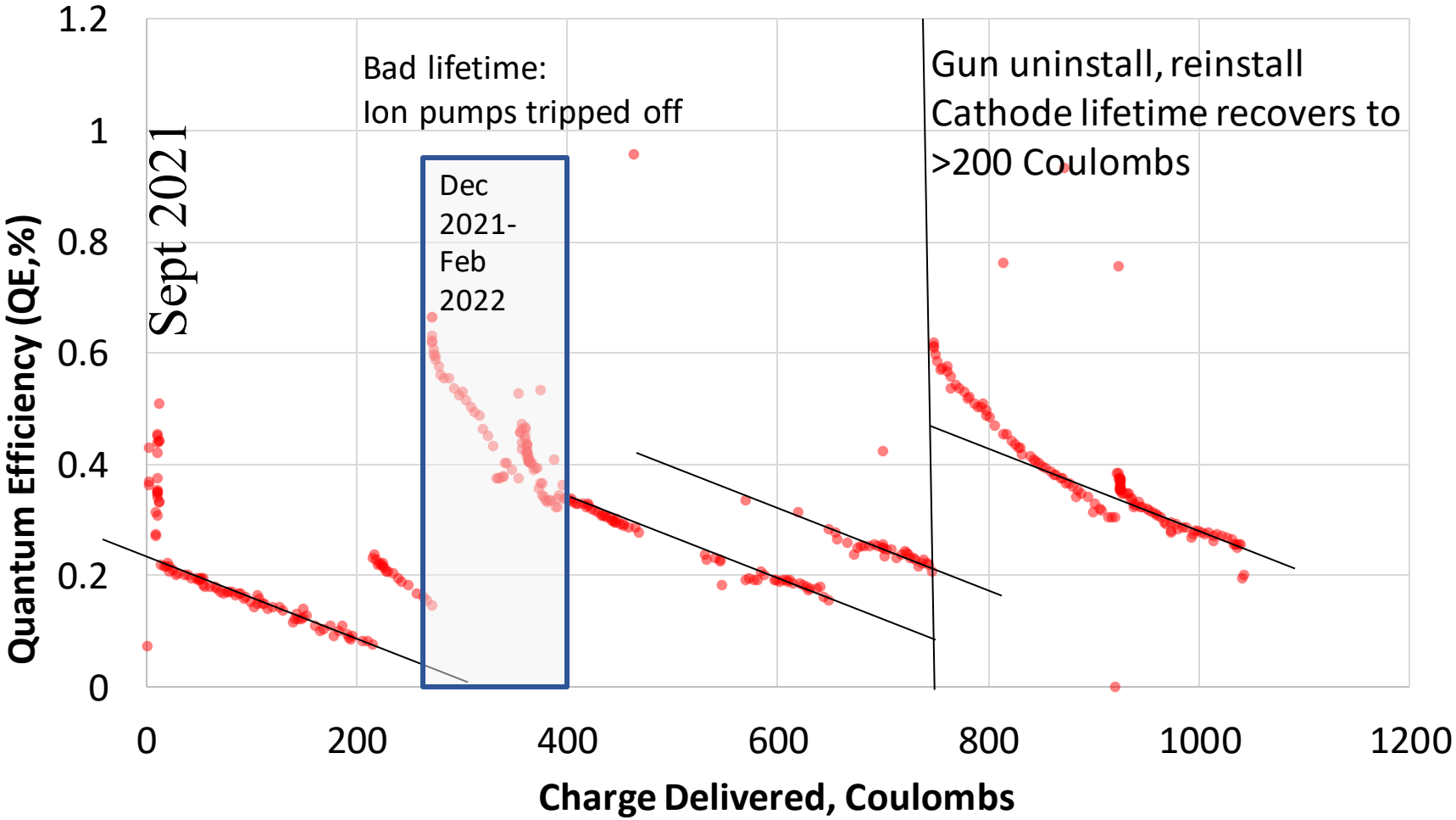
$$Q = Q_O e^{t/\tau}$$

Quantifies gun performance

- Cathode quality
- Vacuum
- HV field emission
- Biased anode efficacy

Hopeful for improved lifetime with new gun.

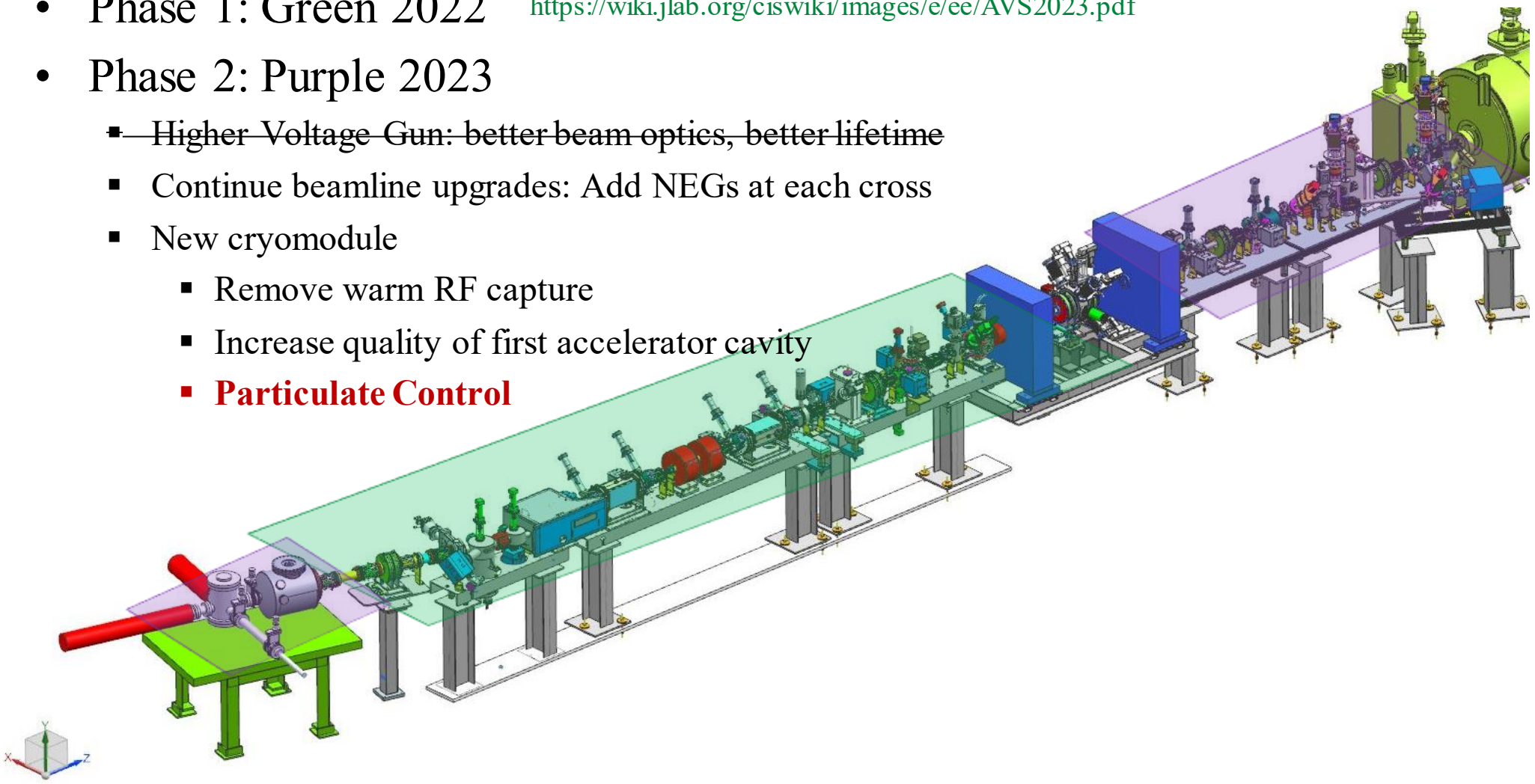
14” Gun Lifetime recovery



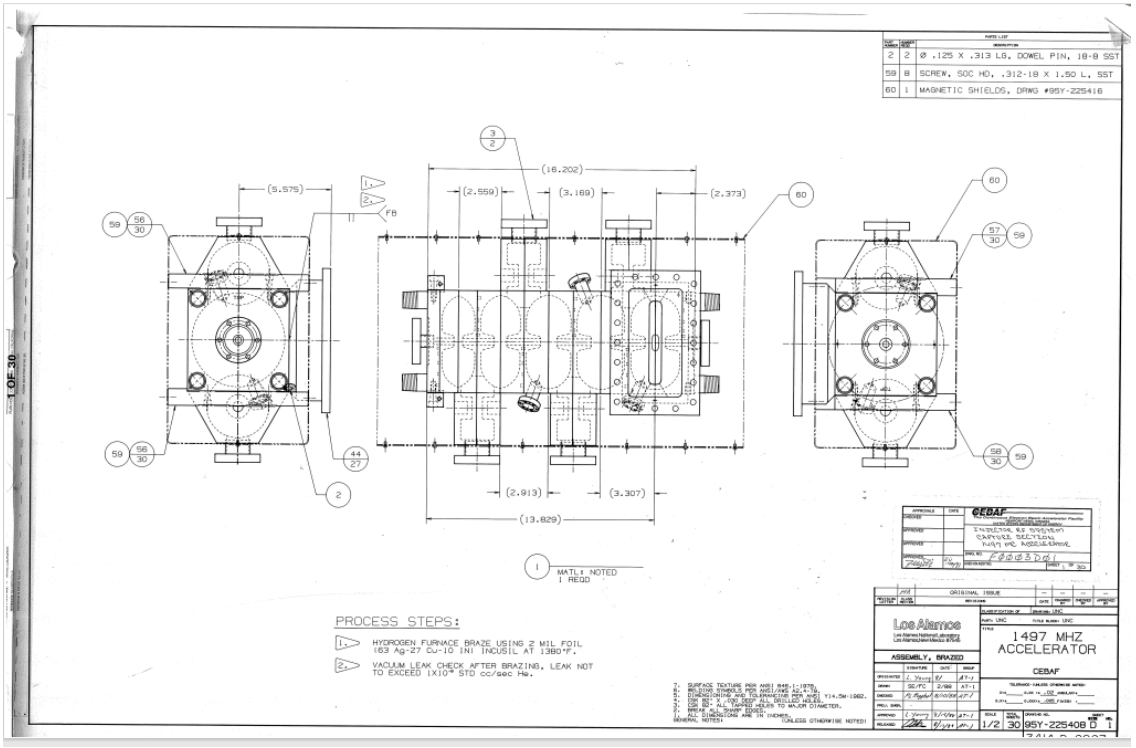
Rapid recovery of good photocathode lifetime after bake

Injector Upgrade: Phases 1 & 2

- Phase 1: Green 2022 https://wiki.jlab.org/ciswiki/images/e/ee/AVS2023.pdf
- Phase 2: Purple 2023
  - ~~Higher Voltage Gun: better beam optics, better lifetime~~
  - Continue beamline upgrades: Add NEGs at each cross
  - New cryomodule
    - Remove warm RF capture
    - Increase quality of first accelerator cavity
    - **Particulate Control**



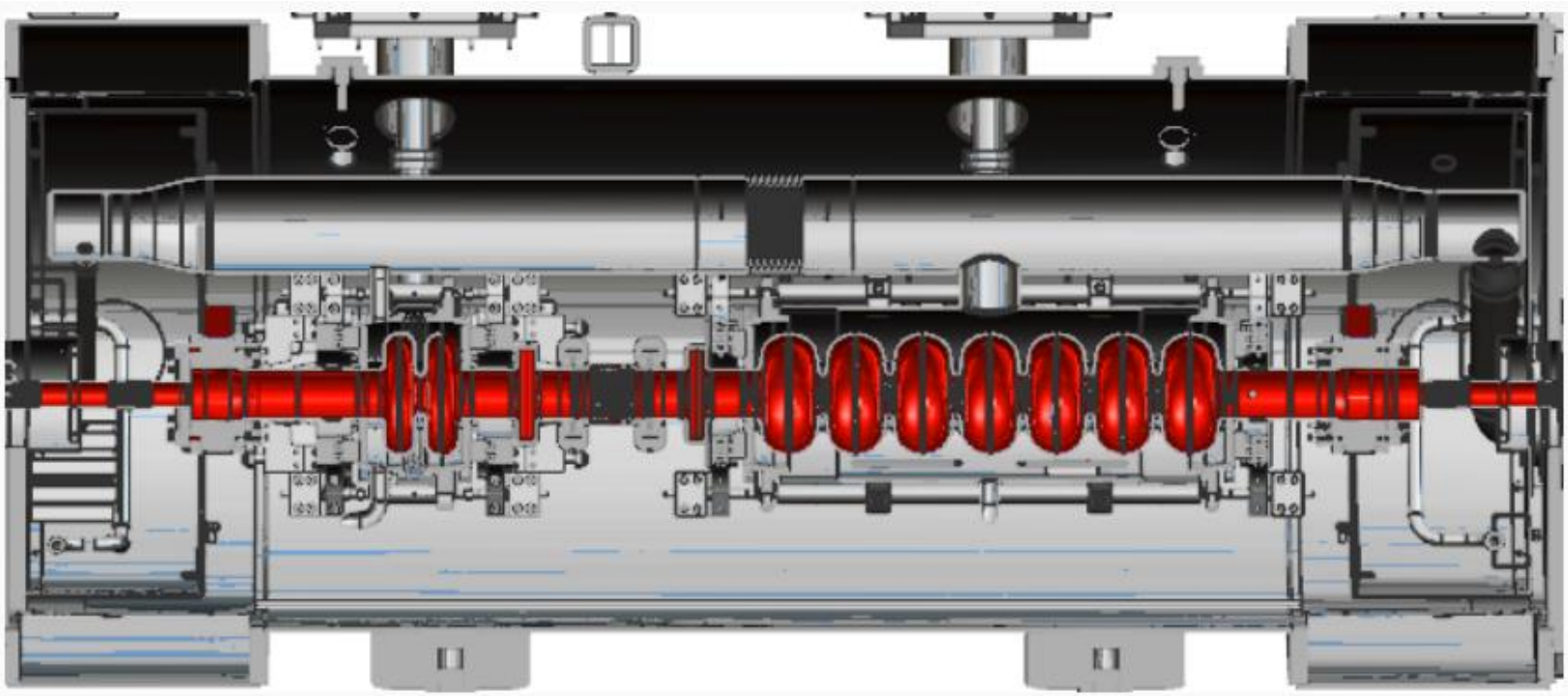
JLab capture and quarter cryomodule



JLab capture
Only warm RF accelerator cavity
Non-uniform with current

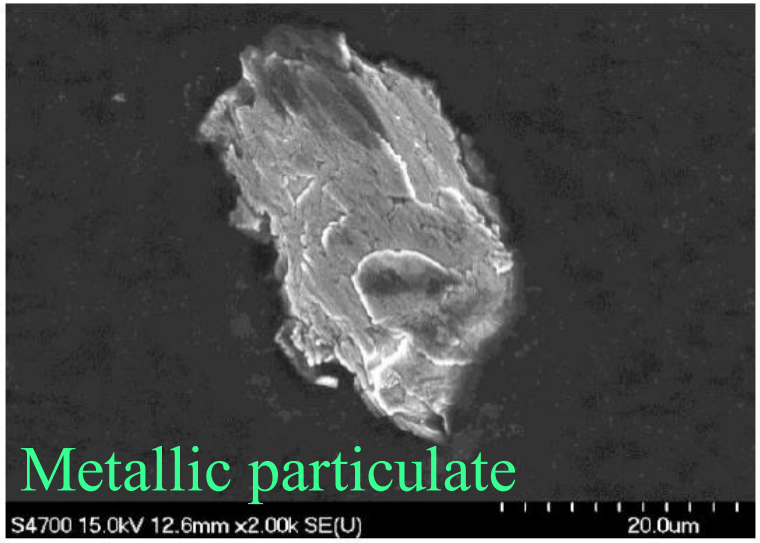
Quarter cryomodule:
early JLab SRF module
Poor beam optics, lower energy

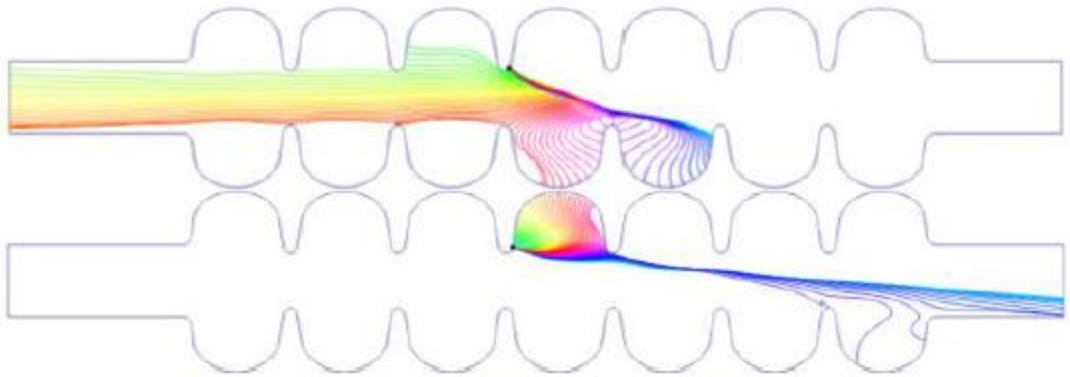
Replacement: Booster



Eliminates warm RF capture
Higher energy capability
Better beam optics
Essential for future parity violation experiments

Particulates and SRF

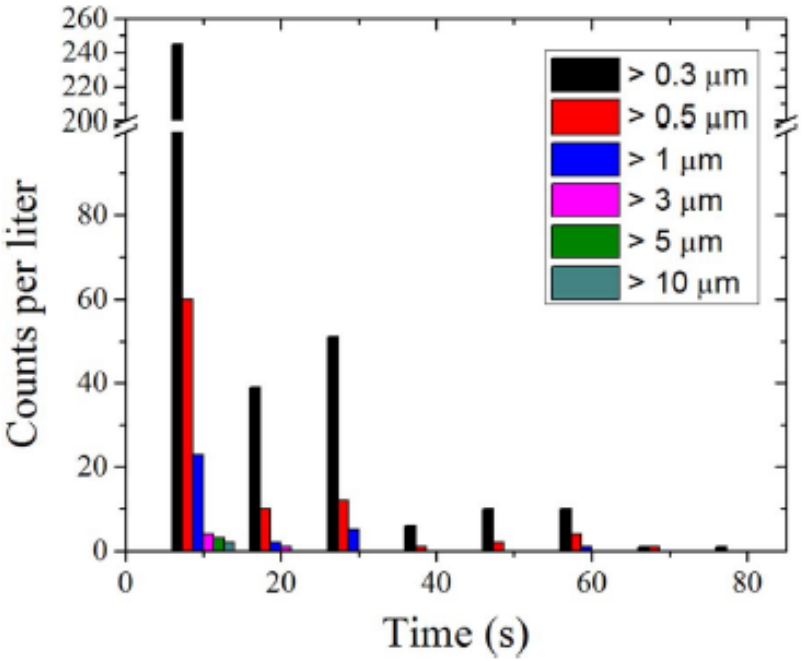


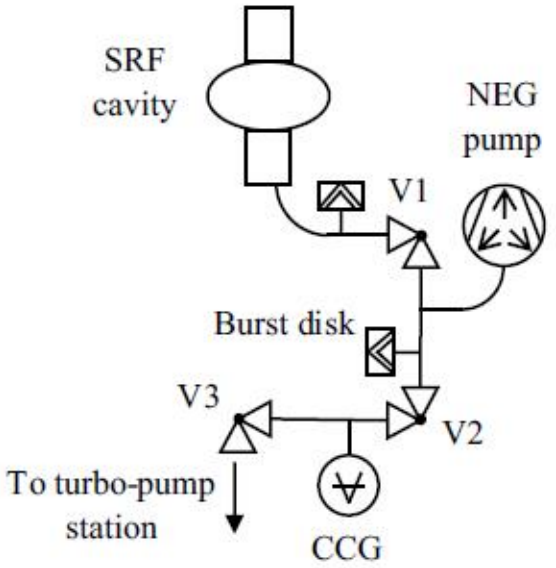


JLab SRF: ISO 9001:2015 certification

Field emission fan simulation: Limits gradient, damages equipment

Working adjacent to SRF





(a)

(b)

ZAO HV NEG: Measurement of particulate generation vs. cleaning time

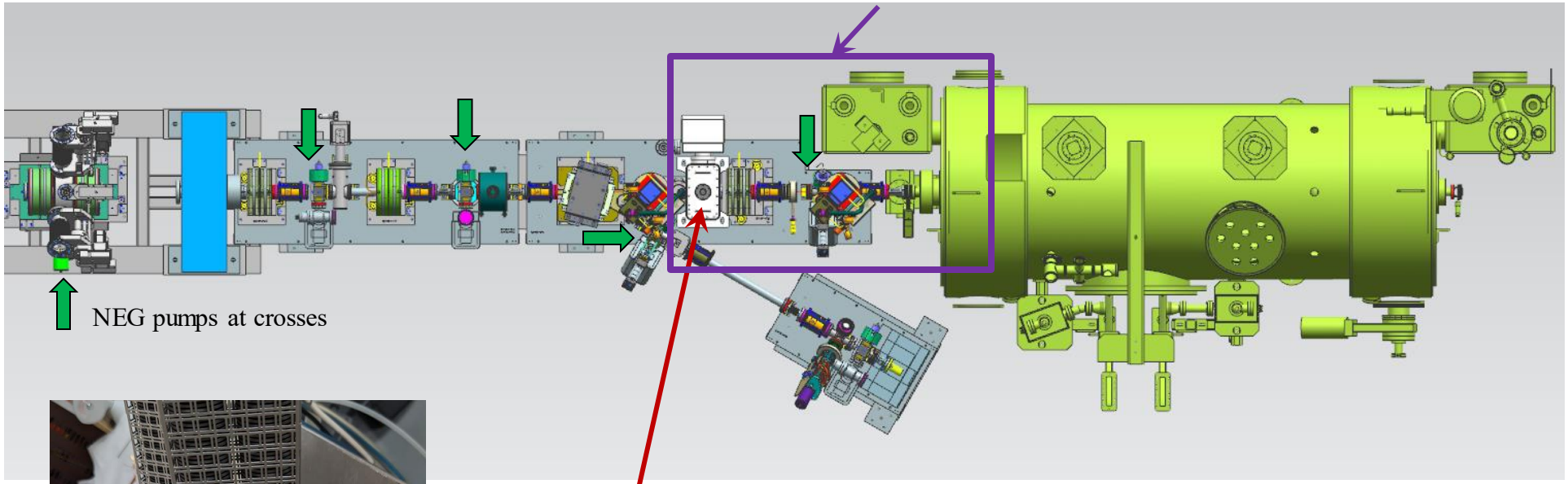
Experimental operation of SRF with NEG ZAO

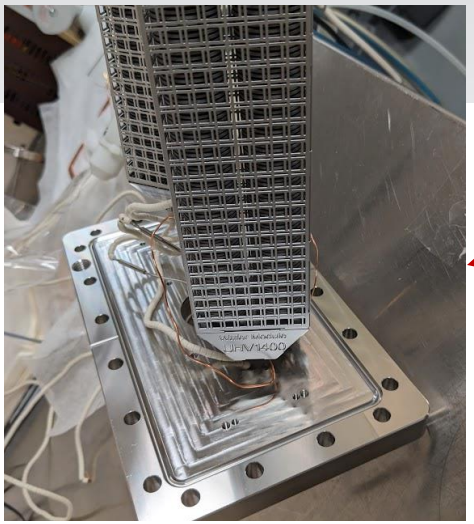
Acceptable for use near SRF

Ciovati.. Stutzman et al., NIMA 964 (2020) 163788

Particulate minimization

cleanroom assembly for adjacent beamline

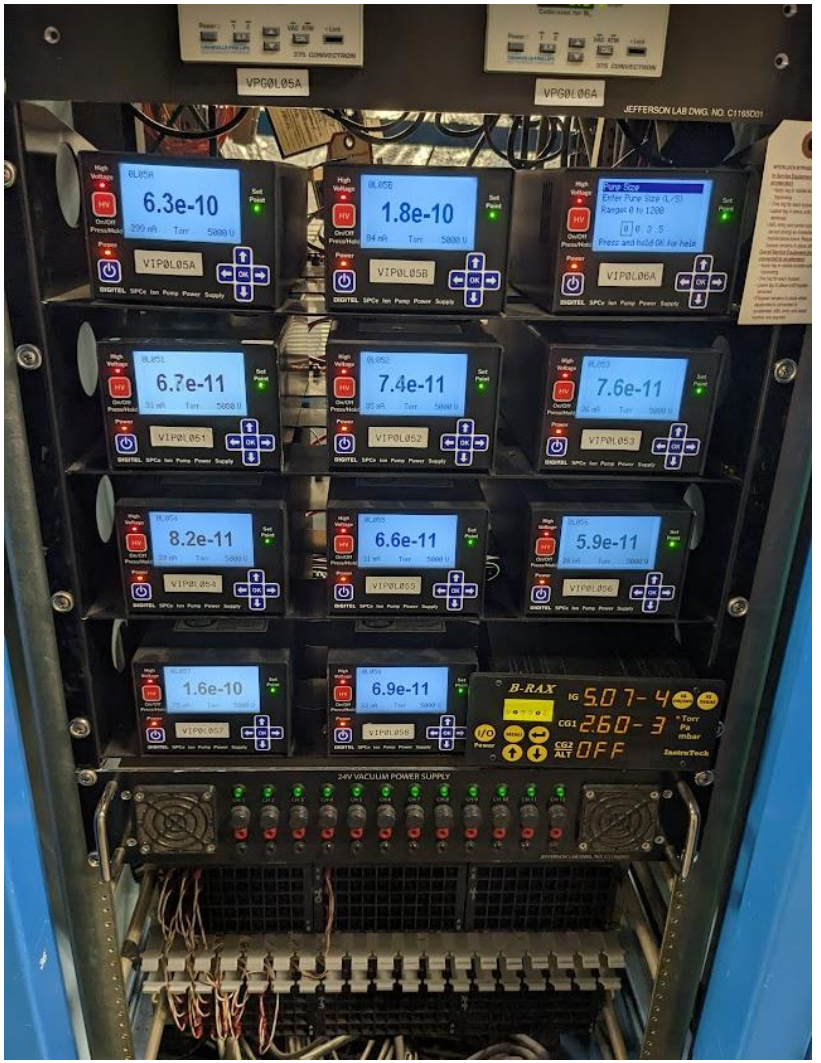




DP Can:
Replace WP1250 with ZAO

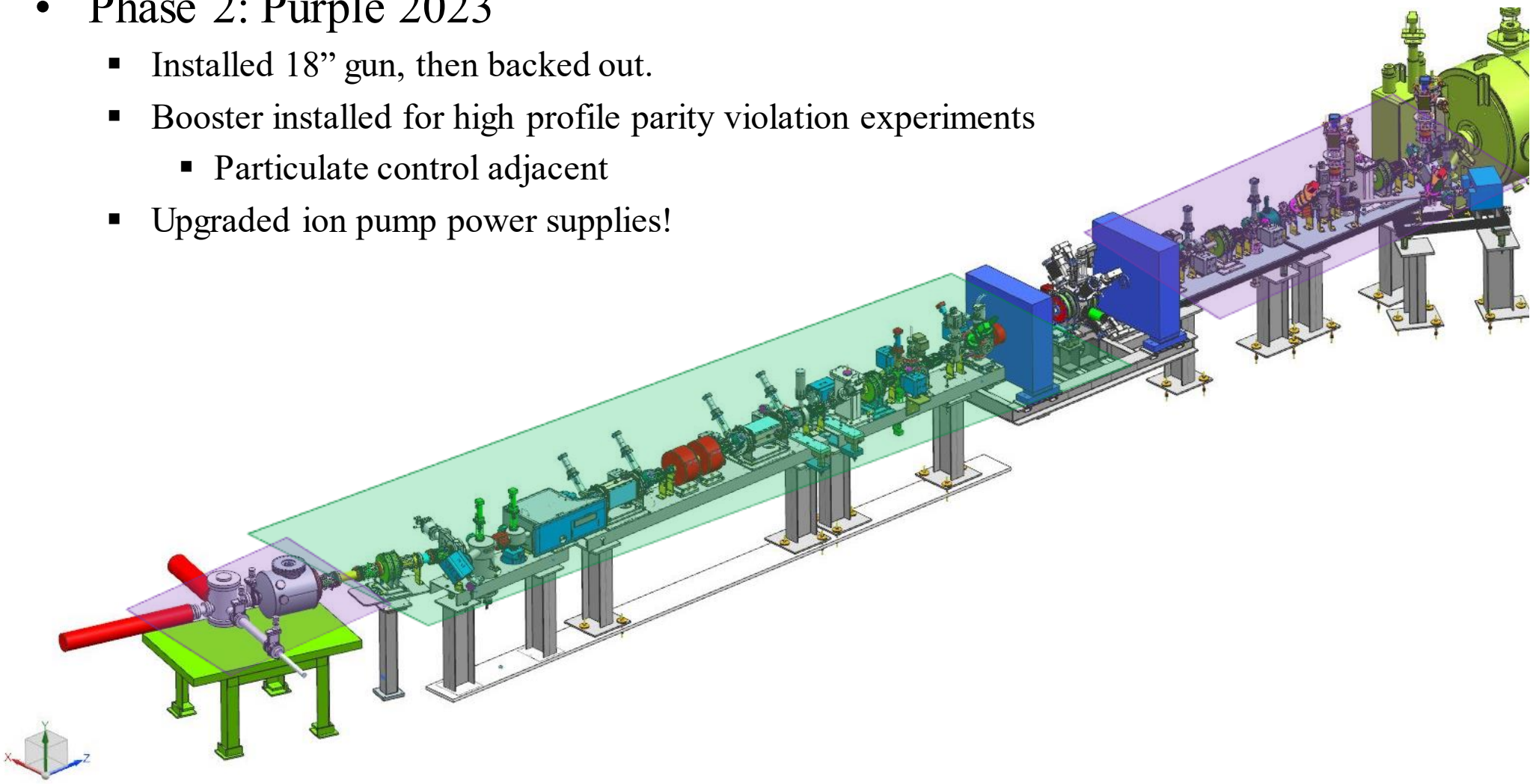
Ion pump power supply upgrades!

No longer using Digitel 500 supplies



Injector Upgrade: Phases 2

- Phase 2: Purple 2023
  - Installed 18” gun, then backed out.
  - Booster installed for high profile parity violation experiments
    - Particulate control adjacent
  - Upgraded ion pump power supplies!



Acknowledgements

U.S. DOE Contract No. DE-AC05-06OR23177 and with funding from the DOE R&D for Next Generation Nuclear Physics Accelerator Facilities Funding Opportunity Number: DE-FOA-0000339

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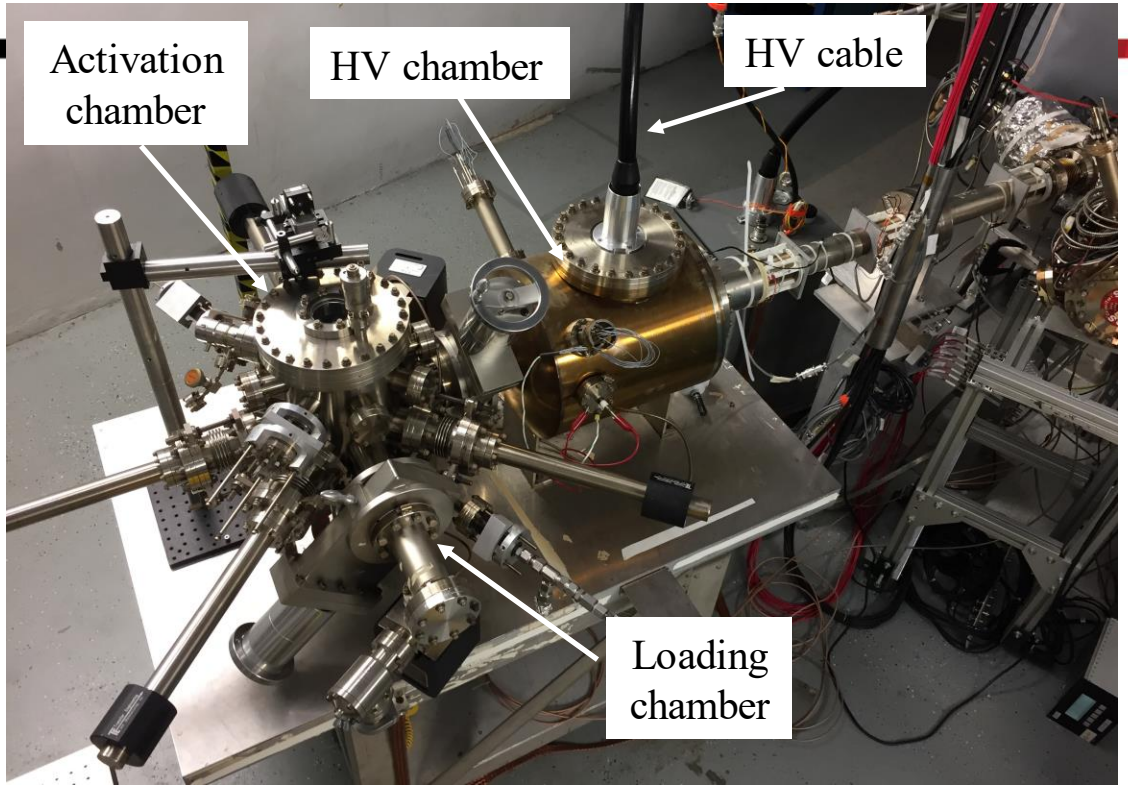
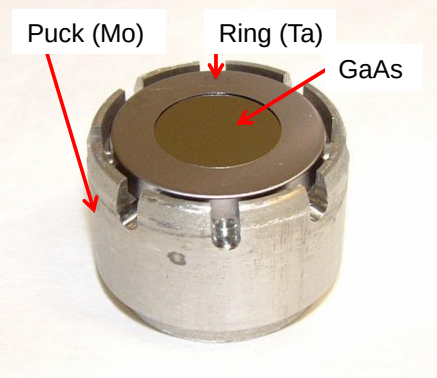
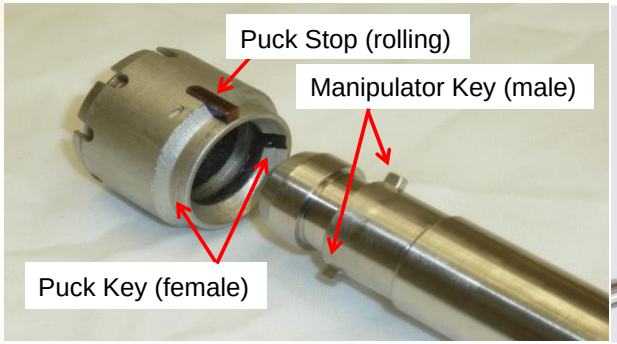
Any mention of products in this presentation is for information only and does not imply recommendation or endorsement.

Backup

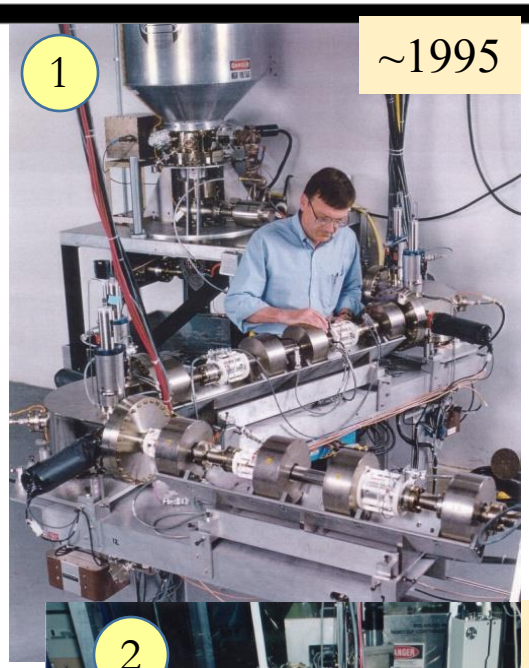
Polarized electron source



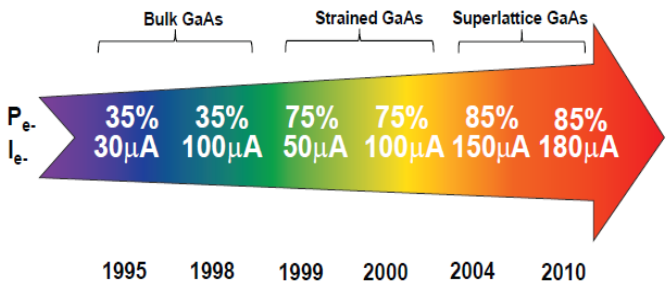




Polarized Electron Sources : *Quest for Perfection!*

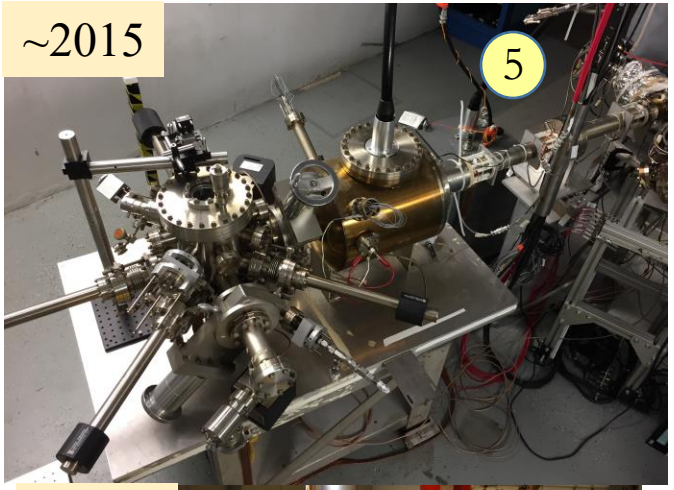


~1995

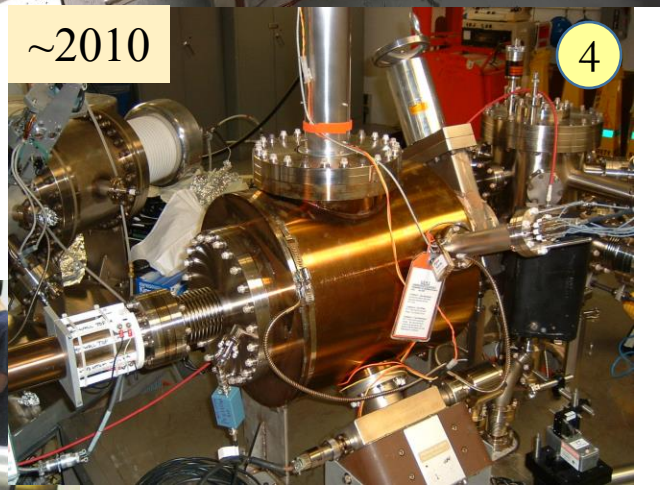


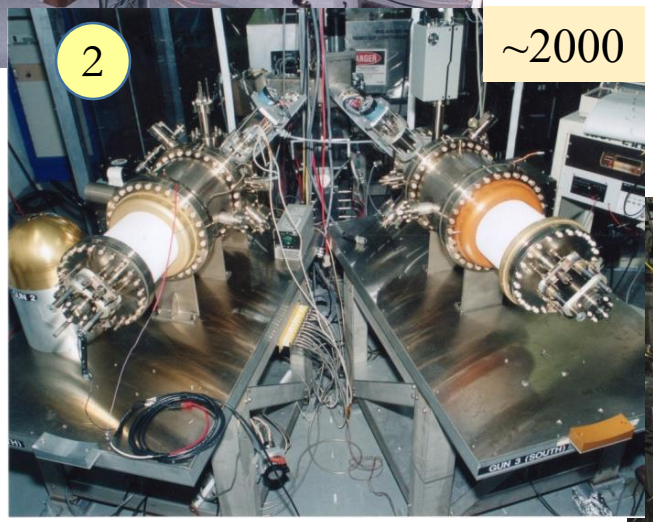
The endless quest for perfection

~2015



~2010





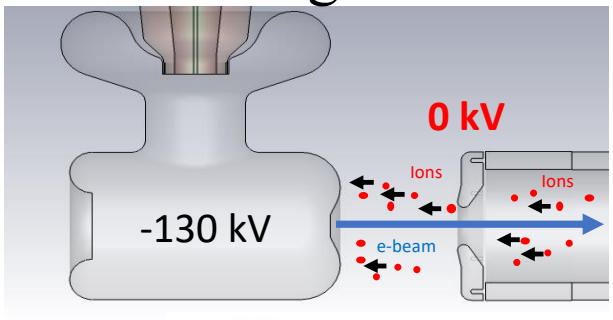
~2000

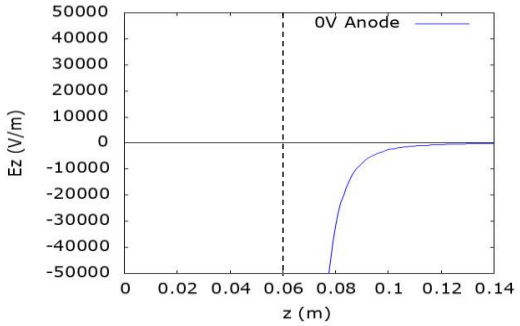
~2005

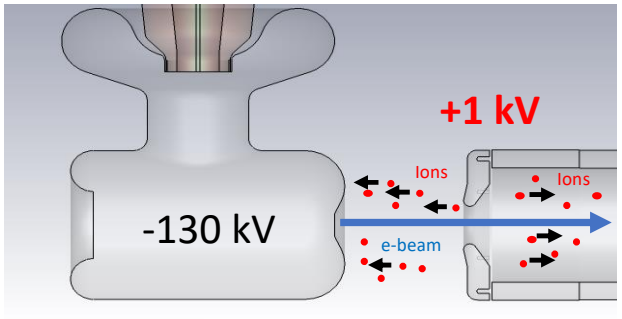
Mitigating ion back-bombardment

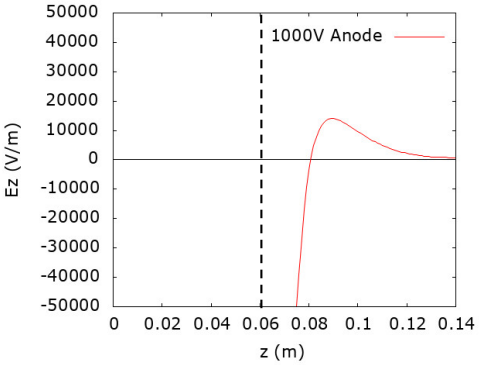
Work of J. Yoskowitz (Old Dominion University) IPAC'21

Electron bunch generated every 0.66 ns

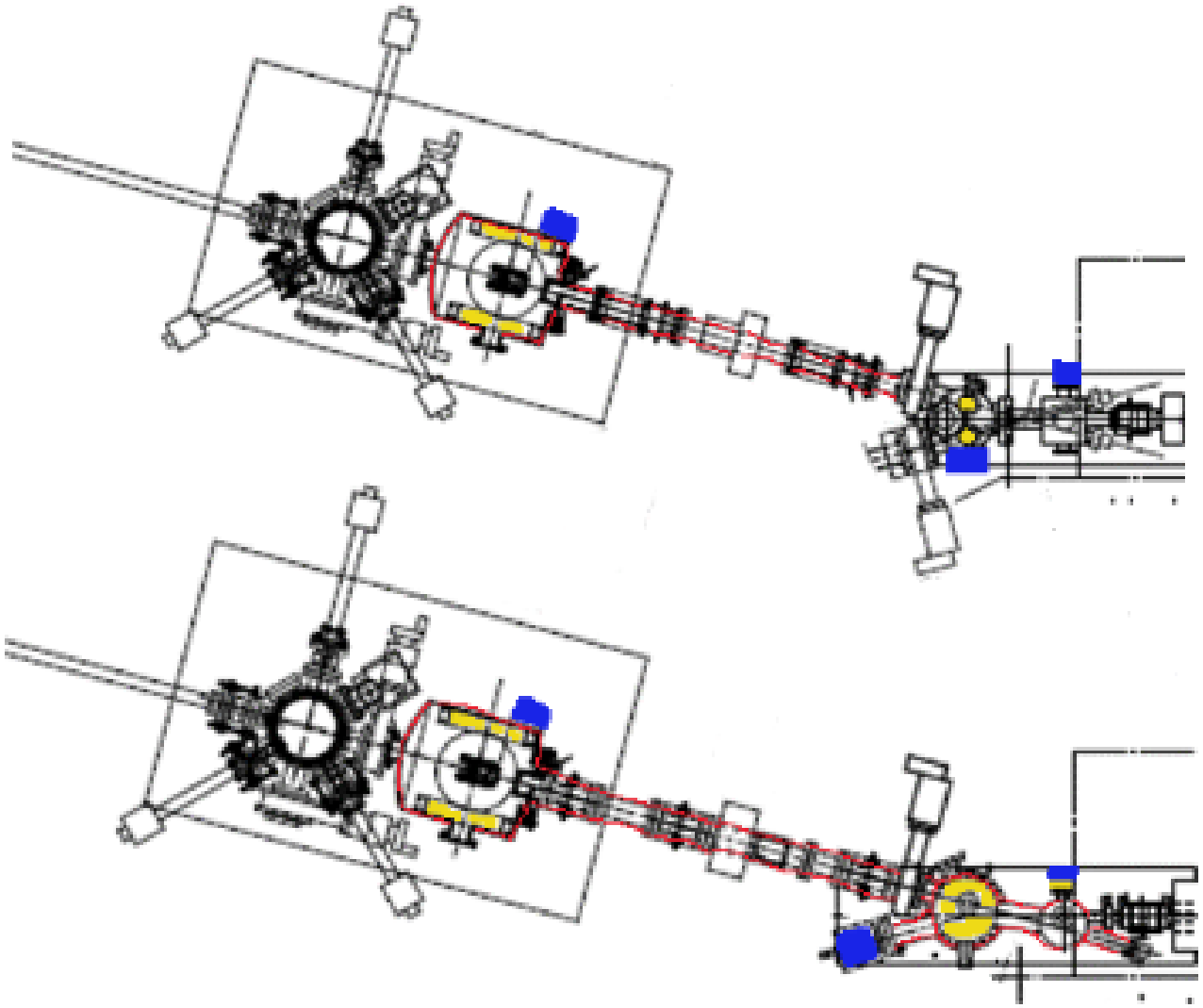






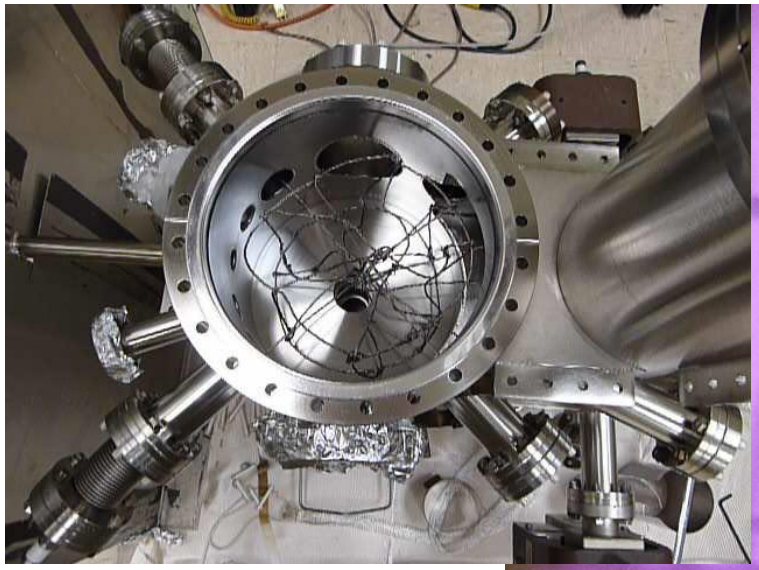


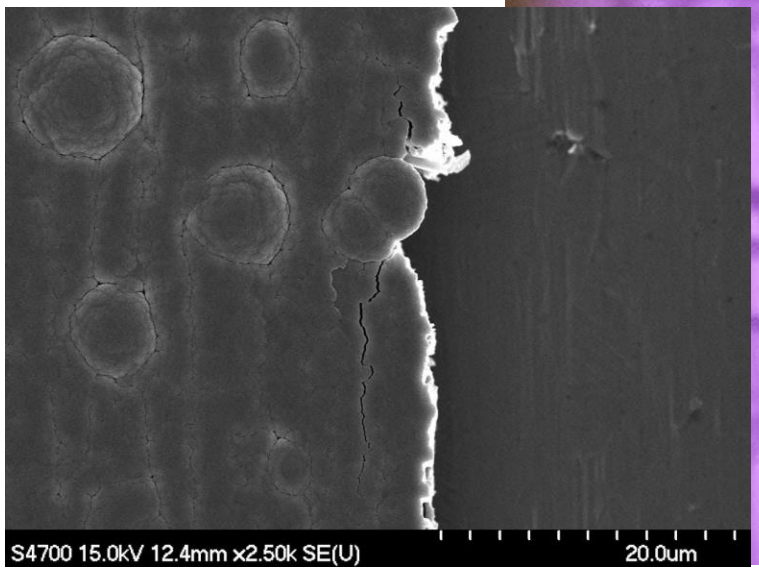
Vacuum Improvements: AIPINJ phase1



- Gun Chamber not changed
- NEG tube: One BPM added, new NEG coating
- Y and Laser Chambers:
  NEG coated
- Y chamber:
  4x UHV 1400 ZAO pumps installed
  (Replacing 2x Capacitorr 100)

NEG coatings

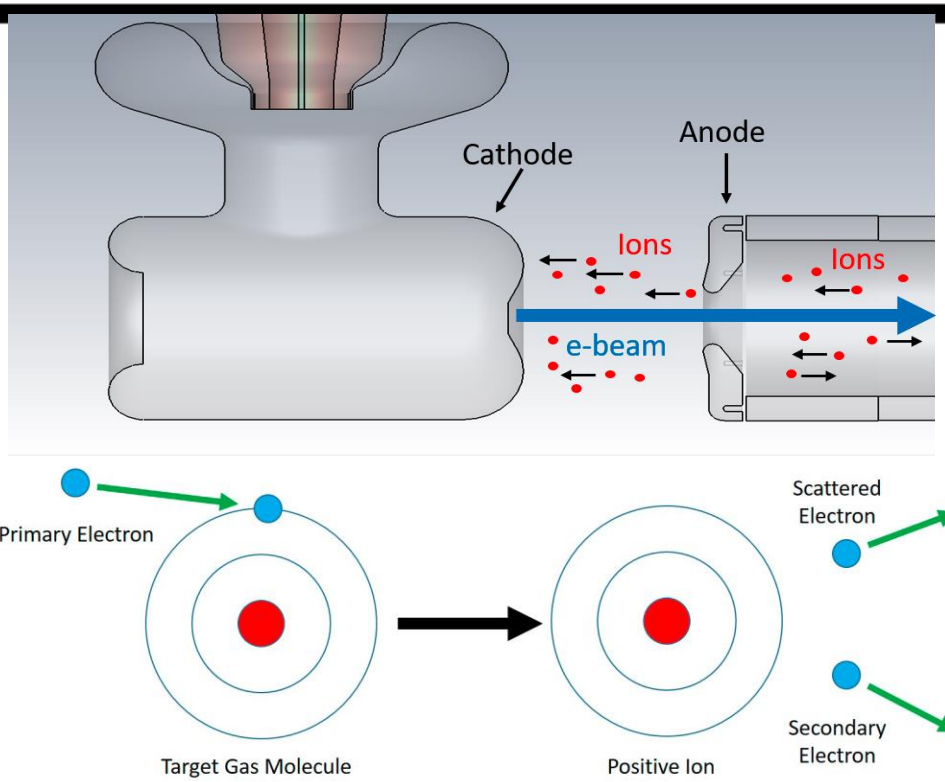


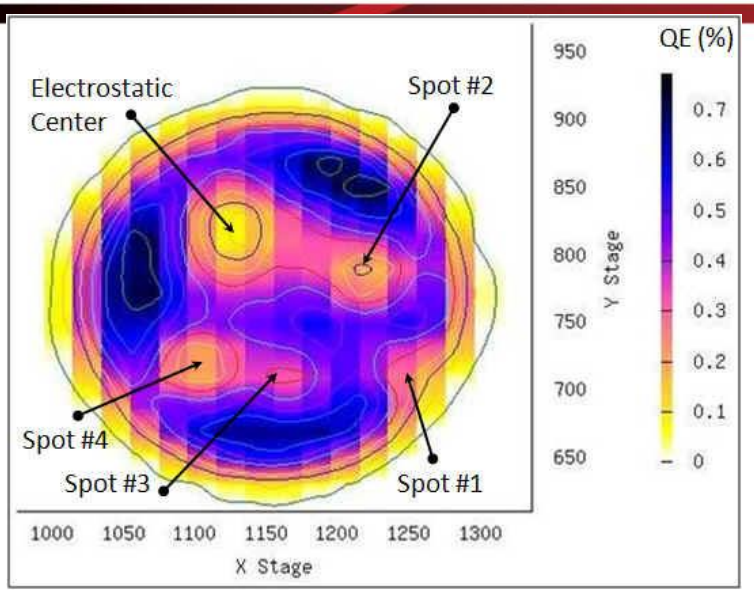


- In house Ti-Zr-V NEG coating
- Sputter deposition, Kr, without magnetron
- Freestanding, isolated "basket" of twisted NEG wires
- Dense, Columnar structure
- Up to 5 μm thick
- Small pump speed (0.05 L/s/cm^2)
- Barrier to outgassing

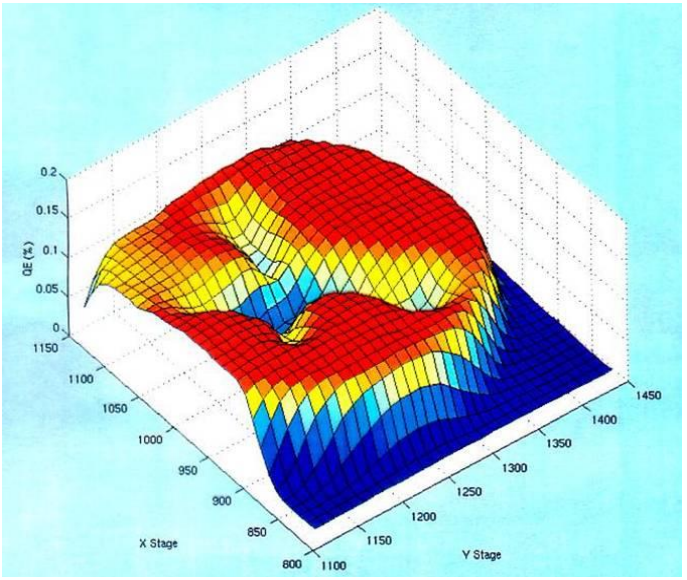
J. Vac. Sci. Technol. A **36**, 031603 (2018)

Ion back-bombardment leads to QE reduction

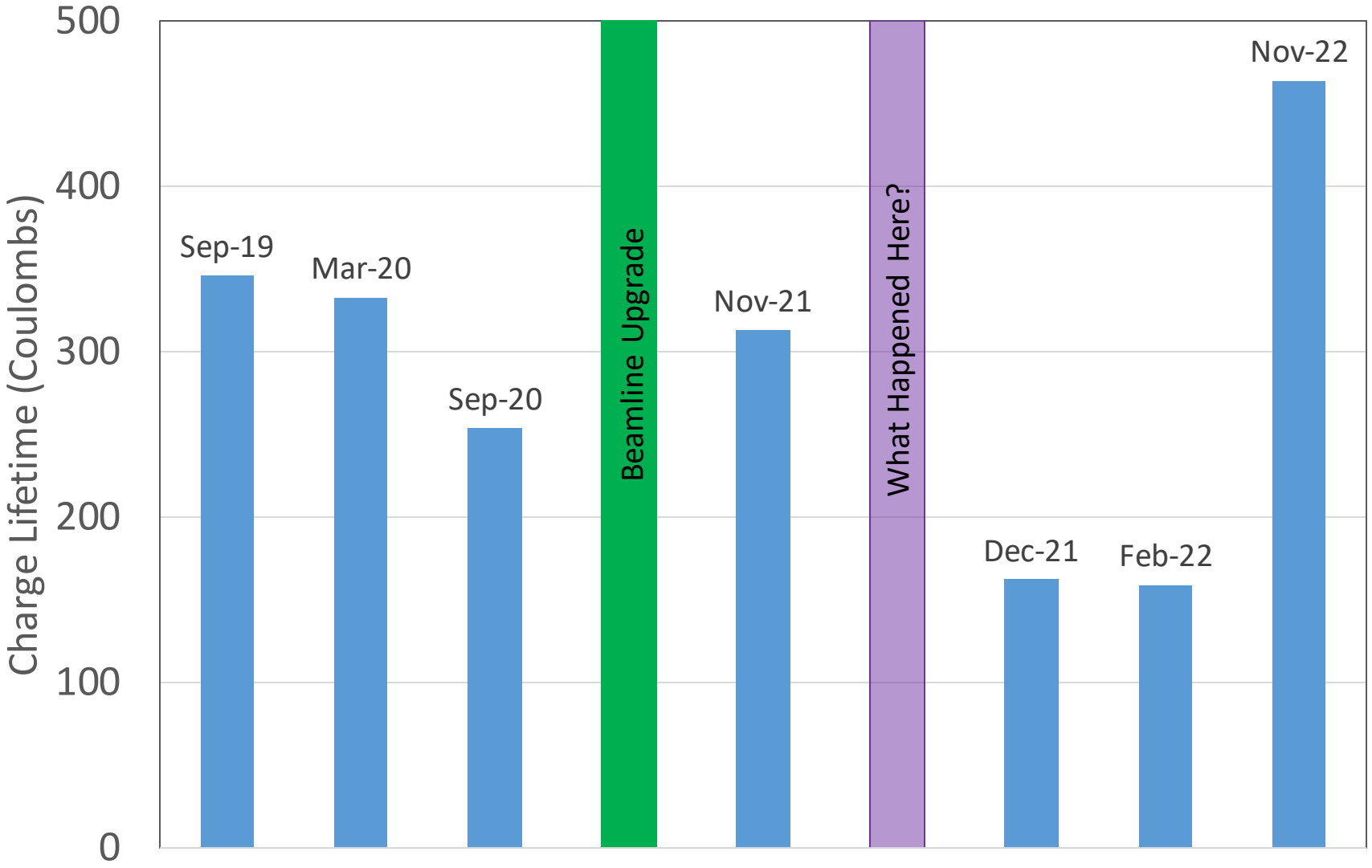




These ions may strike the photocathode, generate secondary electrons or x-rays, and desorb gas from surfaces; all leading to a reduction of the photocathode quantum efficiency (QE).



Historical Lifetimes

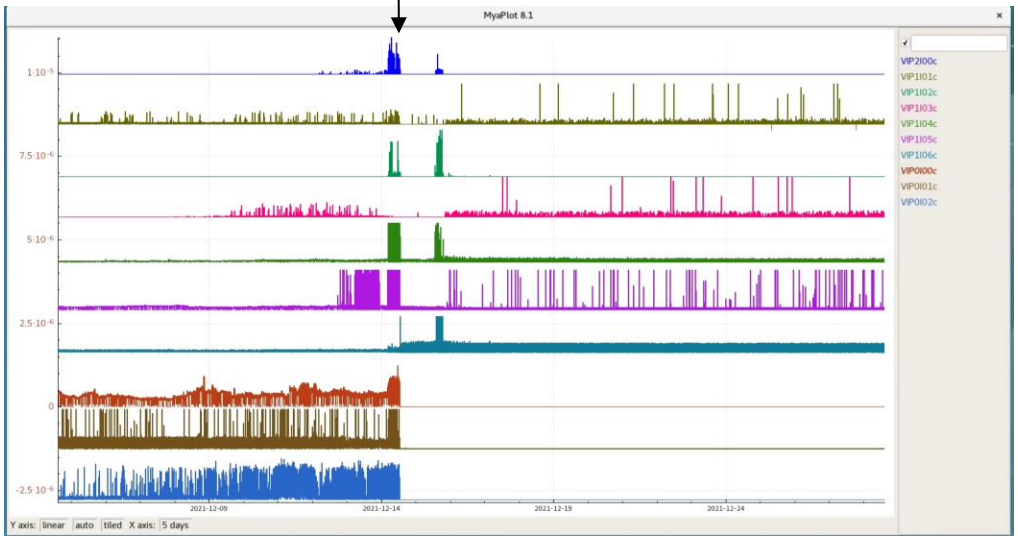


Ion pump power supply power supply failure

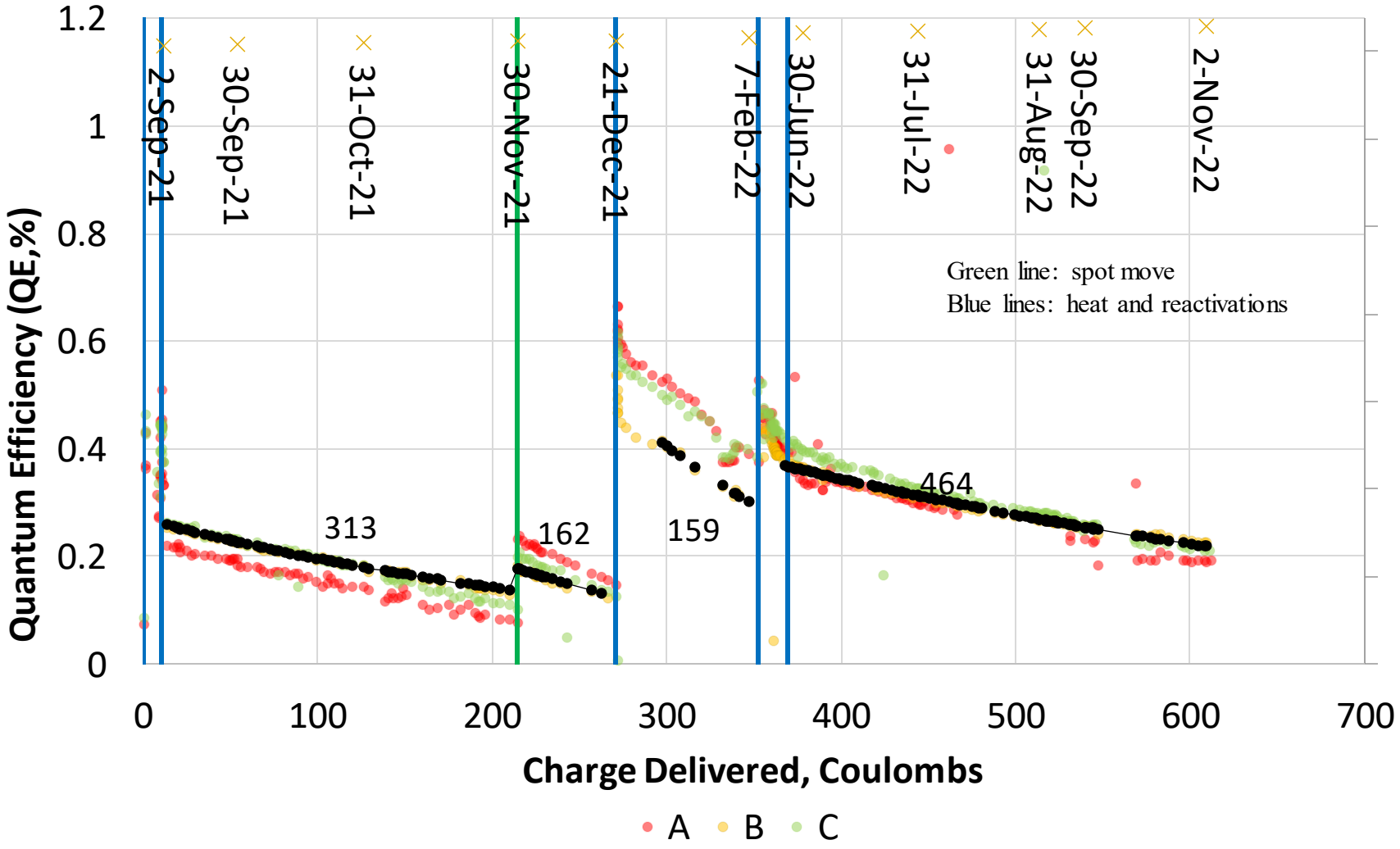
JLab-made UHV ion pump power supplies
https://doi.org/10.1063/1.3215609

Common 12V power source

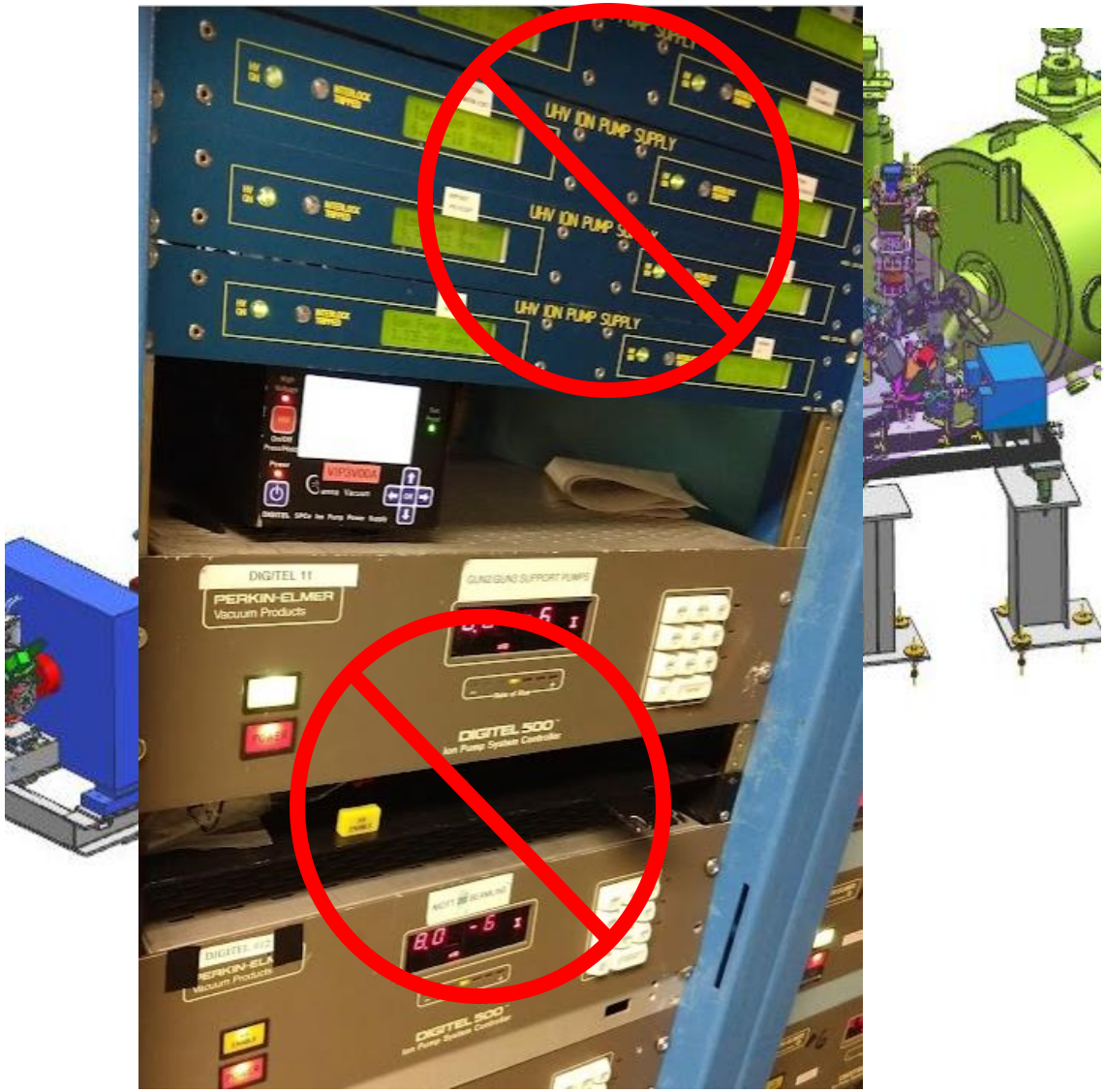
- stopped working correctly Dec 14
- Values did not trip alarms



Gun Lifetime



Phase 2 improvements



- Adding NEG pumps at each cross
- Upgrading DP can NEG pumps to ZAO
- Upgrading to modern commercial controllers
- Particulate control during installation near cryomodule