A high-intensity, polarized-beam prototype photogun for the Ce^{+}BAF positron source

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LDRD review
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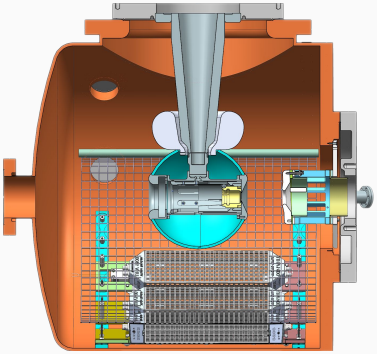
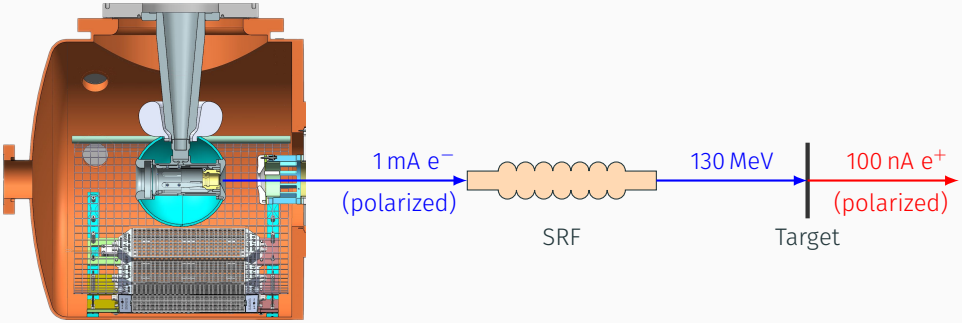


Example of a state-of-the-art polarized photogun:
the 200 kV CEBAF gun (“R30-3”)

Impact and strategic value: Ce^+BAF positron injector

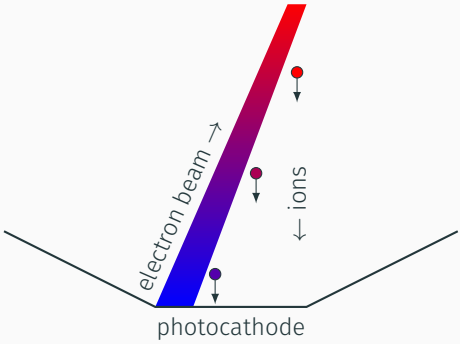


- Current CEBAF gun: lifetime 300 C ≈ 3 days at 1 mA
- Requirement for unprecedented lifetime of high-polarization photocathodes (> 1000 C ≈ 11 days at 1 mA) poses major technical risk for Ce^+BAF program
- Developing a strategy to enhance lifetime raises technical readiness

Dominant limitation of photocathode lifetime: ion back-bombardment

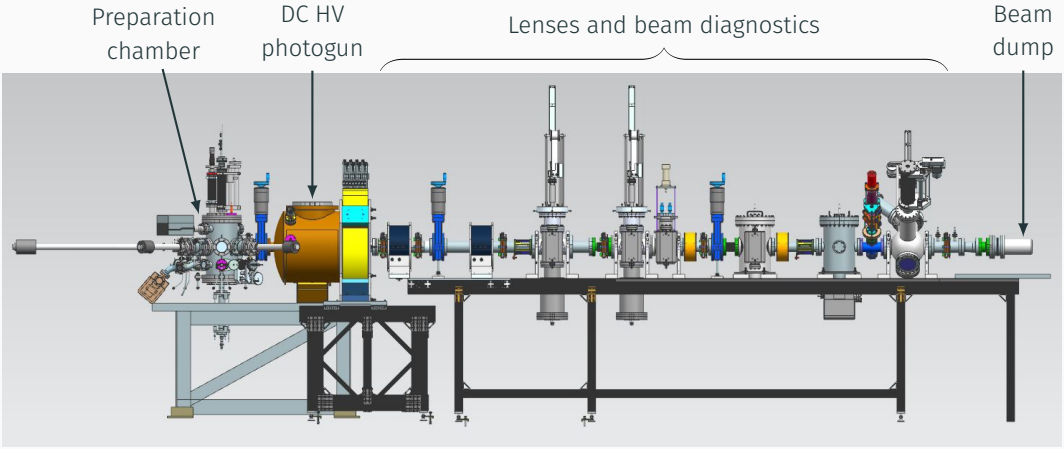
- Electron beam ionizes residual gas within accelerating gap
- Ions are accelerated toward the photocathode
- Ions striking photocathode surface locally degrade its quantum efficiency (QE)
- Dynamics can be simulated, but degradation depends on ion energy in an unknown way

LDRD scope: model calibration and lifetime scaling experiment at GTS

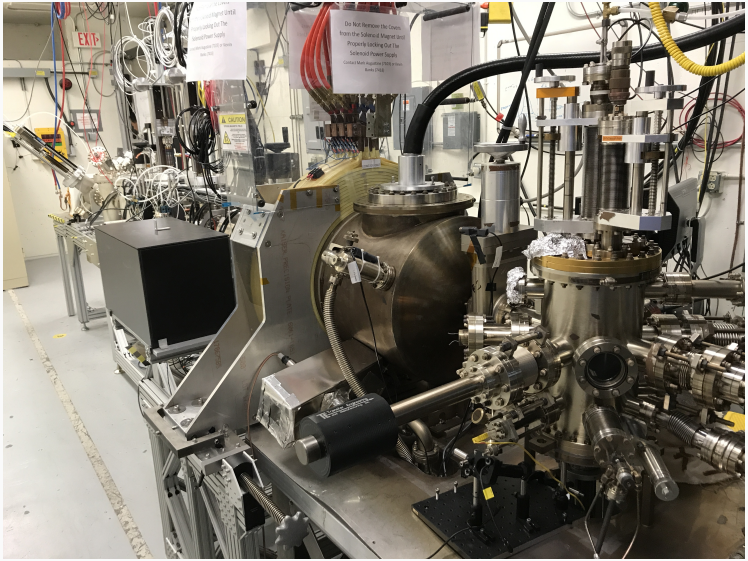


Beam trajectory in gap determines energy distribution of ions incident on emission area

Lifetime measurements at the Gun Test Stand (GTS) in the LERF building

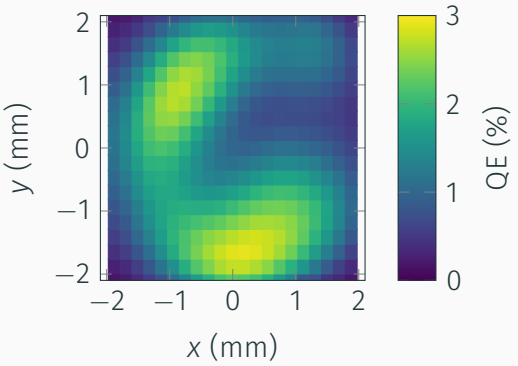


GTS photo


EXIT
Do Not Remove the Cover
from the Solenoid Magnet and
Properly Locking Out The
Solenoid Power Supply
CAUTION

Objective 1: QE damage measurements in existing GTS gun, model calibration

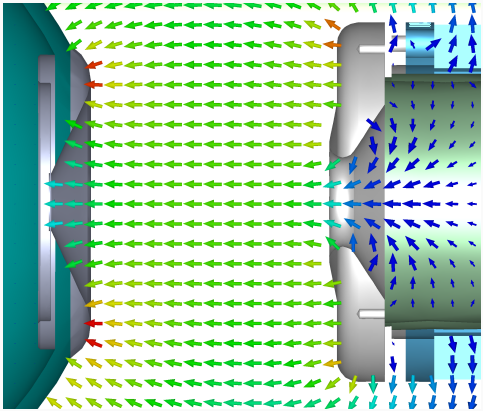
- Add Cs and NF_3 to prep chamber (GaAs activation), install 780 nm laser system, commission with beam (Q1–Q2 FY2025)
- Set up GPT/IONATOR simulation model for GTS, predict lifetime vs. spot size, shape, and position (Q1 FY2025)
- Measure lifetime and map QE damage vs. spot size, compare with simulation (Q3–Q4 FY2025)



Example of a QE scan from UITF, showing ion damage on bulk GaAs

Objective 2: Design and fabrication of gun electrodes to enhance lifetime

- Using CST and GPT/IONATOR, design electrostatic optics for strongly focusing, low-aberration gun, optimizing for lifetime (Q3–Q4 FY2025)
- Mechanical design of new electrodes (Q4 FY2025–Q1 FY2026)
- Fabrication and assembly (Q1–Q2 FY2026)

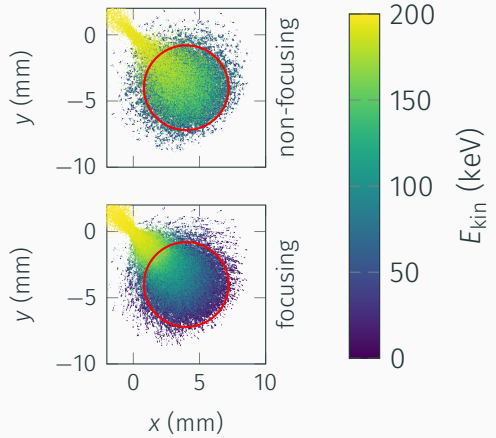


Example of a strongly focusing gun: R30-3 electrode geometry and field distribution

Examples of fabricated electrode assemblies

Objective 3: QE damage measurements with modified gun

- Bench-test gun assembly, verifying puck insertion and vacuum (Q2 FY2026)
- Install and commission modified gun in GTS: alignment, bakeout, HV conditioning, beam-line setup (Q3 FY2026)
- Measure lifetime and map QE damage vs. spot size, compare with simulation (Q4 FY2026)



Simulated ion distributions for non-focusing (top) and focusing (bottom) guns

Contributors

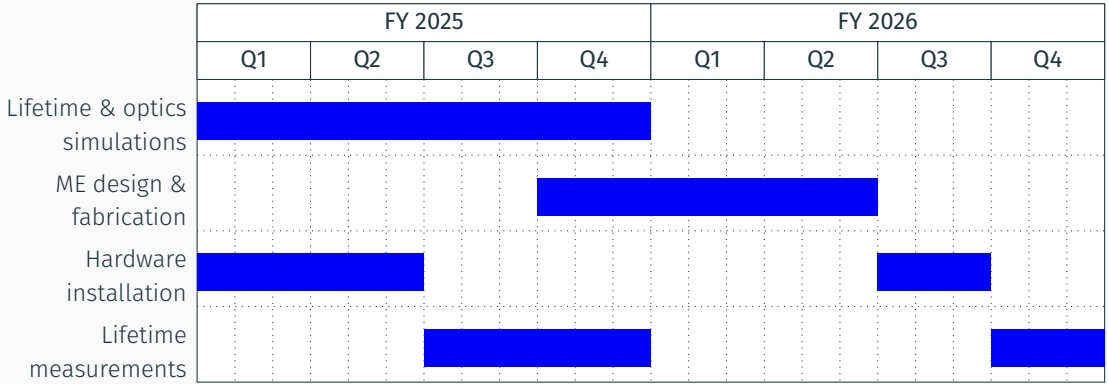
Contributor	Task	FY25 (weeks)	FY26 (weeks)
Max Bruker	PI, measurements, particle-tracking simulations	15	15
Gabriel Palacios-Serrano	electrostatic simulations, fabrication coordination, assembly, HV conditioning	11	11
Shukui Zhang	install 780 nm laser system	2	1
I&C technician	integrate controls	1	—
Mechanical designer	mechanical design of gun electrodes	5	5
CIS technician	assembly, vacuum work	1	3
S&A technician	align gun electrodes to vacuum chamber and gun to beam line	—	1

Budget

Item	Justification	FY25 ($k)	FY26 ($k)
Labor	(see Contributors slide)	144.4	147.5
Laser (total)	near-bandgap photoemission with variable profile	48.8	—
Vacuum hardware	flanges, valves, dispensers, etc.	10.7	10.6
CST partial license	electrostatic simulations	2.7	2.7
Raw materials	electrode fabrication	—	15.9
Machine shop	electrode fabrication	10.0	20.0
Travel	present results at IPAC 2026	—	7.5
Total	(loaded)	**216.5**	**204.2**
pre-proposal	(loaded)	243.8	244.7

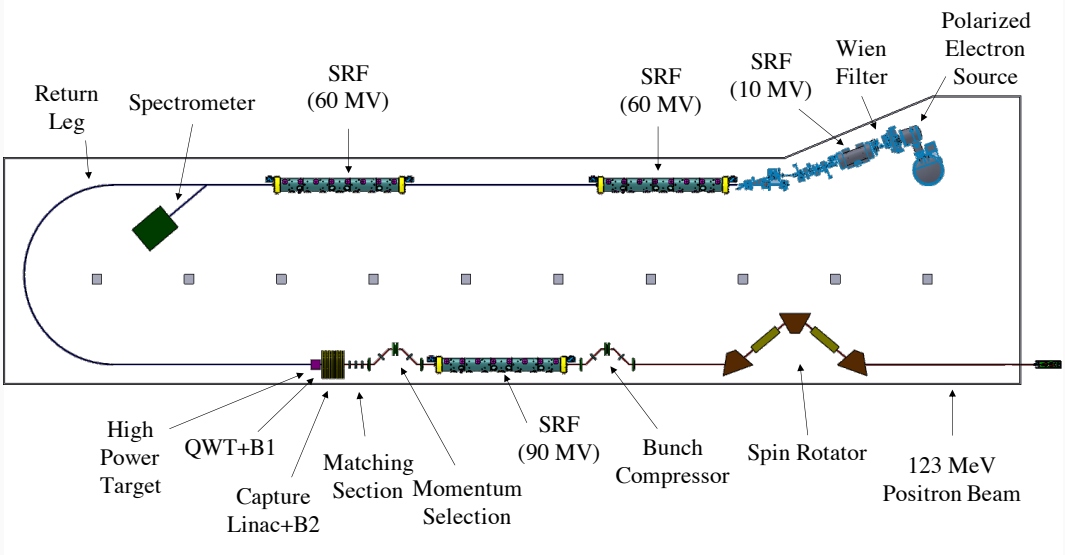
Optimized for value. Future funding opportunities: DOE-NP; DOE-HEP; ECA

Time line and expected mission significance

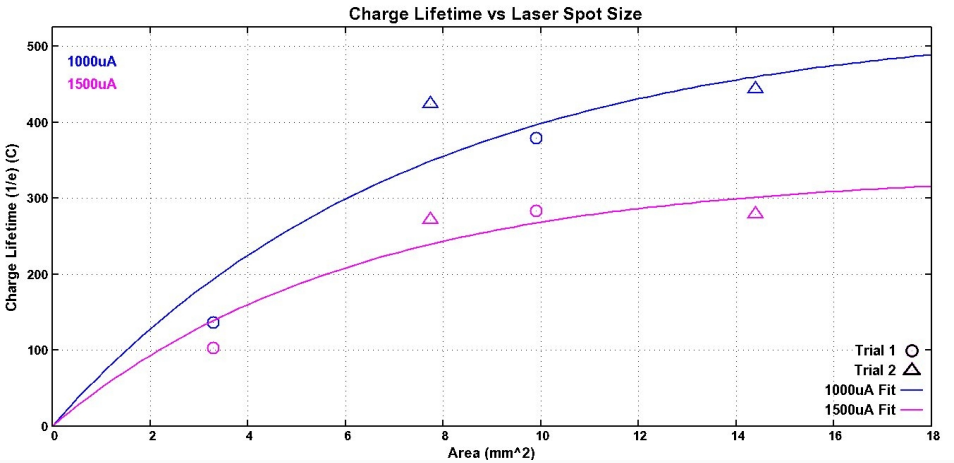


- Design future high-current guns with predictable, enhanced lifetime
- Contribution to global field of polarized c.w. guns; reinforces JLab leadership

Backup: Ce^{+}BAF positron injector layout



Backup: CEBAF measurement of lifetime vs. laser-spot size (2017)



J. Grames et al., "Milliampere Beam Studies using High Polarization Photocathodes at the CEBAF Photoinjector," Proceedings of XVII International Workshop on Polarized Sources, Targets & Polarimetry — PoS(PSTP2017), vol. 324, 2018, p. 014