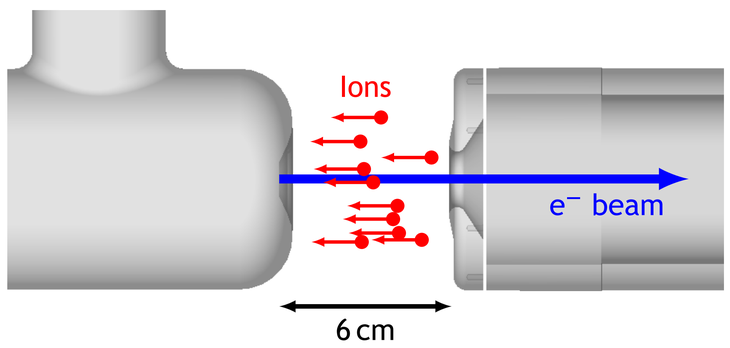
New Results at JLab Describing Operating Lifetime of GaAs Photo-guns

M. Bruker[1], J. Grames[1], C. Hernández-García[1], V. Lizárraga-Rubio[2], M. Poelker[1], C. Valerio-Lizárraga[2], J. T. Yoskowitz[3], S. Zhang[1]

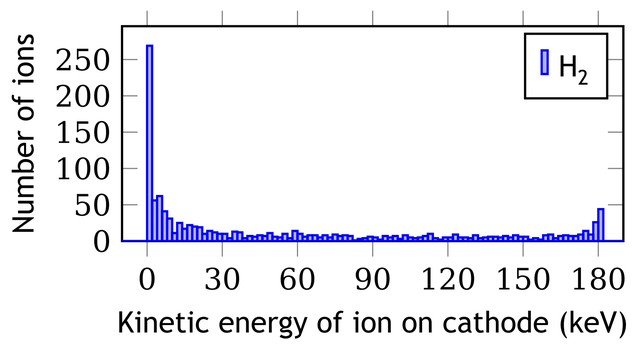
[1] Thomas Jefferson National Accelerator Facility, Newport News, VA, USA
[2] FCFM-UAS, Culiacan, Sinaloa, Mexico
[3] Old Dominion University, Norfolk, VA, USA

Center for Injectors and Sources

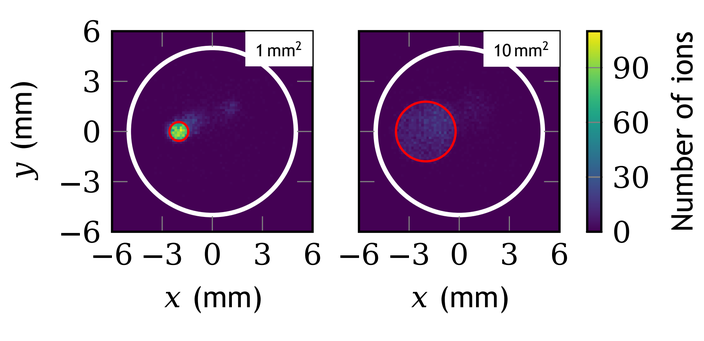
Objective



- Dominant limitation of photocathode lifetime in DC photoguns: beam ionizes residual gas; ions are accelerated back and hit cathode surface (*ion back-bombardment*)
- Study damage as function of parameters



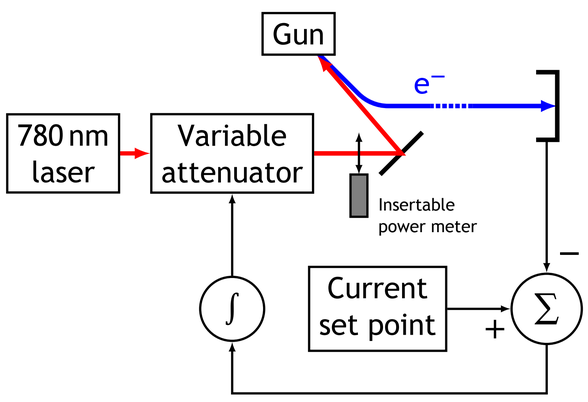
- General assumption: total ion production rate decreases at higher voltage (ionization cross section)
- Ion spectrum at cathode has significant high-energy content; number of ions alone may not tell the full story



- GPT model for ion generation and tracking
- Precursory study: position & size of damage area as function of laser spot position & size
- Shape of ion distribution dominated by area emitting electrons, but electrostatic field also focuses high-energy ions

Experimental setup and data

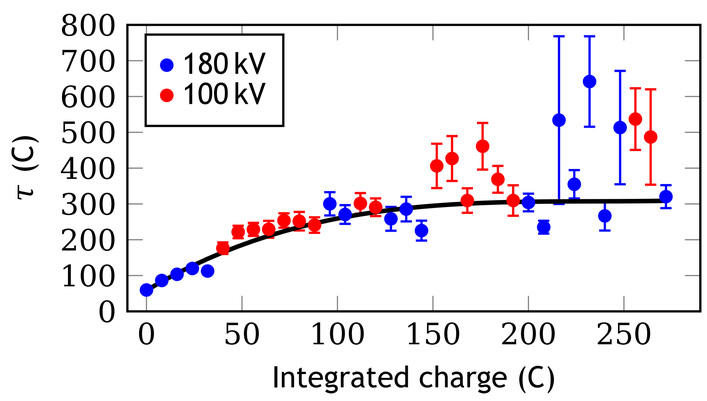
Beam test at Upgraded Injector Test Facility (UITF):



- Beam current 300–500 µA throughout the study; constant for each data point
- Periodically insert power meter ⇒ QE(t)
- Alternate between gun voltages
- Measure QE distribution between runs; novel method at high voltage, but still slow

Experimental challenges:

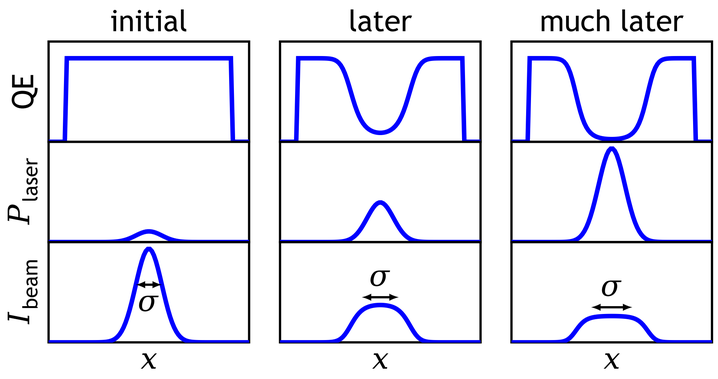
- UITF laser power limited to ≈ 50 mW
- Long run time per data point; issues with orbit stability and beam trips
- Need to avoid drifts and glitches in instrumentation



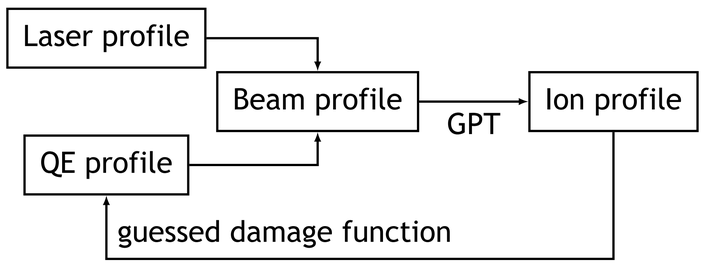
- Lifetime may be better at 100 kV than at 180 kV
- Overall increase in lifetime obfuscates dependency

Iterative model for QE degradation

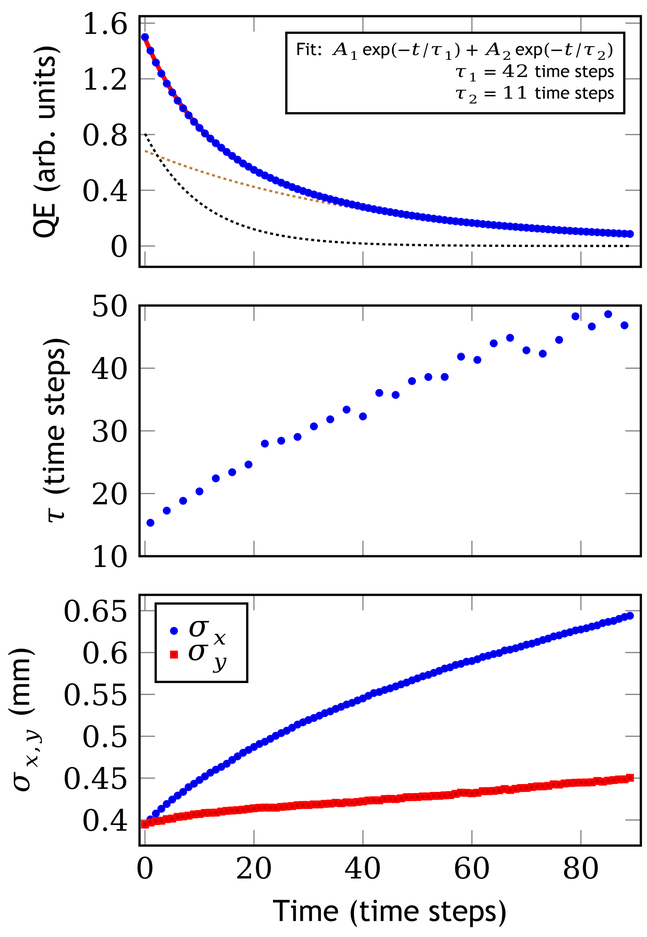
- $I_{\text{beam}}(x, y) = P_{\text{laser}}(x, y) \times \text{QE}(x, y)$
- RMS size of emitting area widens as QE is locally degraded; laser tails make most of the beam current



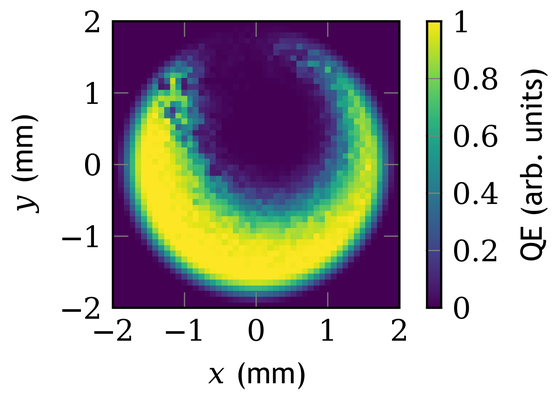
- Given an initial beam distribution, particle dynamics can be calculated from first principles (GPT)
- Degree of freedom: damage mechanism unknown, but assume each ion causes some damage



First test of model:
damage function proportional to kinetic energy



Example QE distribution after 90 time steps:



- Field causes vertical displacement of damage ⇒ $\sigma_{x,y}$ asymmetry
- QE distribution comparable to experiment (need to convolve with laser profile)
- Optimize damage function for agreement with experimental data

Areas for improvement:

- Reproducible beam conditions
- Laser spot position on cathode must be known
- Measure true initial QE distribution with smaller laser spot

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