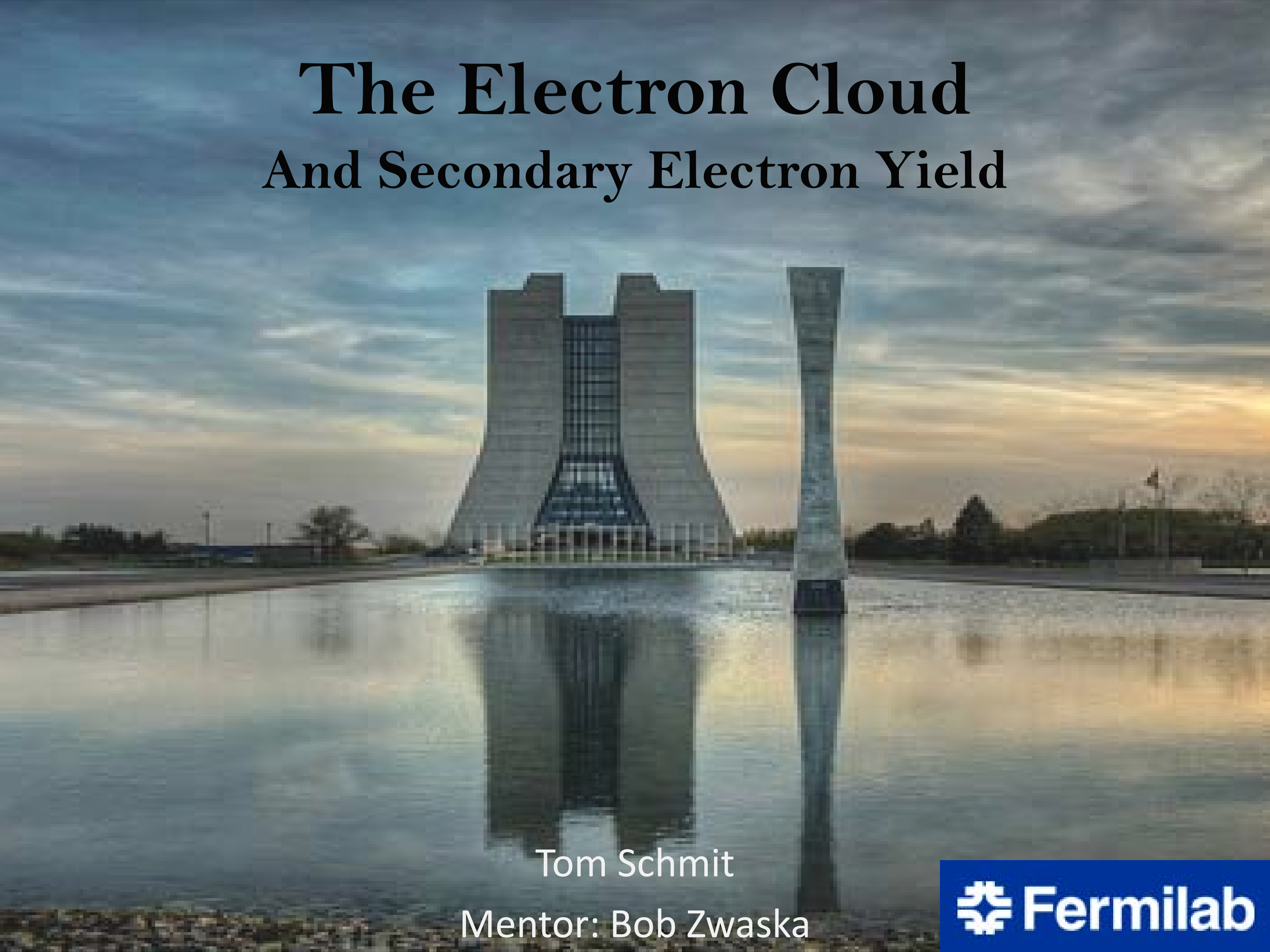


The Electron Cloud

And Secondary Electron Yield

Tom Schmit

Mentor: Bob Zwaska

Fermilab

The Electron Cloud

- Fermilab and the intensity frontier
  - Accelerators are approaching a new regime in intensity
  - Many difficulties are associated with increased intensity
- Increased intensity results in electron cloud instabilities
  - Very hard problem to solve analytically
  - Not well understood

Fermilab

The Electron Cloud

- A secondary effect of accelerating particles
  - Primary electrons collide with beam pipe and components and generate secondary electrons
    - In proton/antiproton accelerators, primary electrons are formed mostly from residual gas ionization
    - In electron/positron machines, primary electrons are generated by the photoelectric effect
  - Secondary electron yield greater than unity for most materials => AMPLIFICATION!

Fermilab

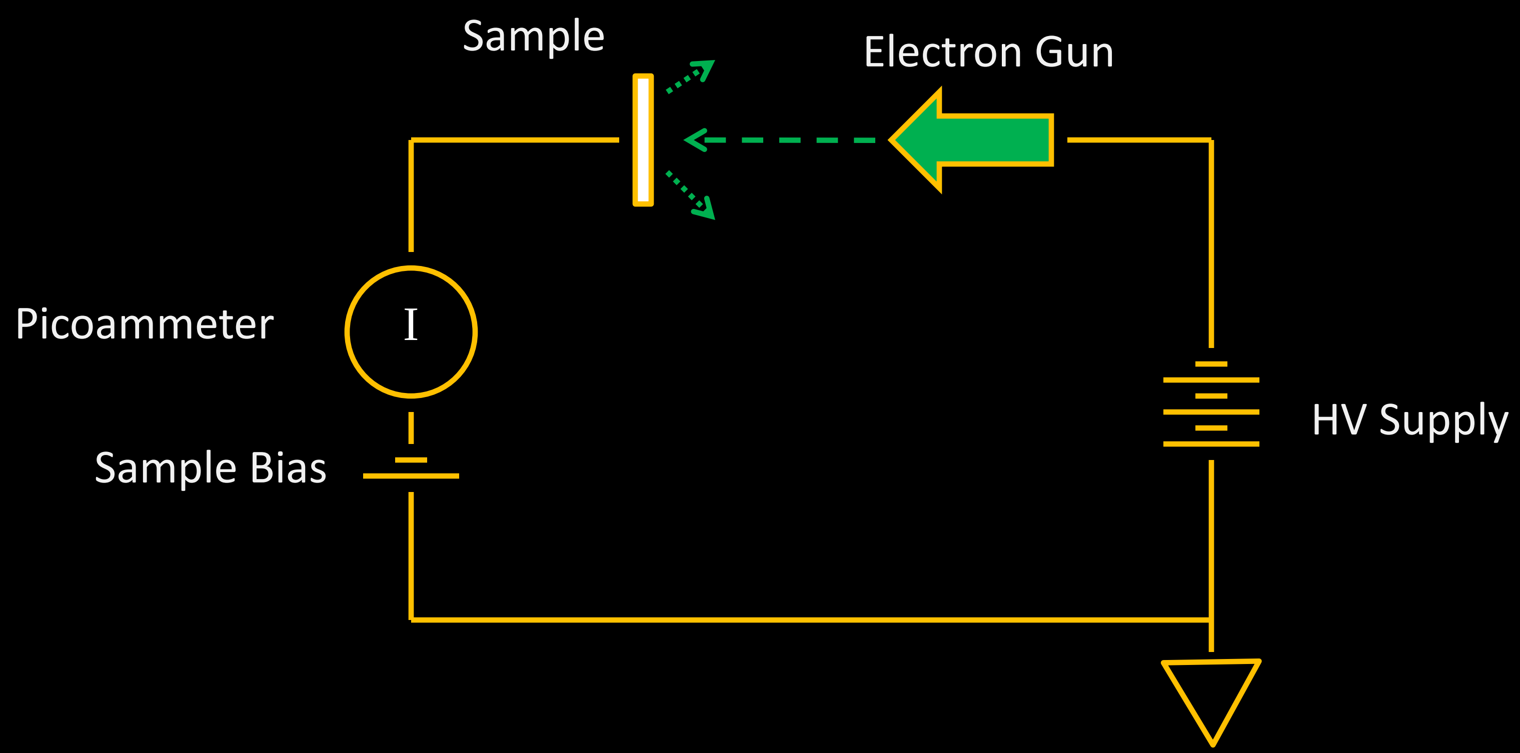
Secondary Electron Yield

- Combat electron cloud formation by reducing secondary electron yield

- Commission a test stand to examine different materials for use in a beam line
  - Must be vacuum compatible
  - Durable
  - Have a low SEY

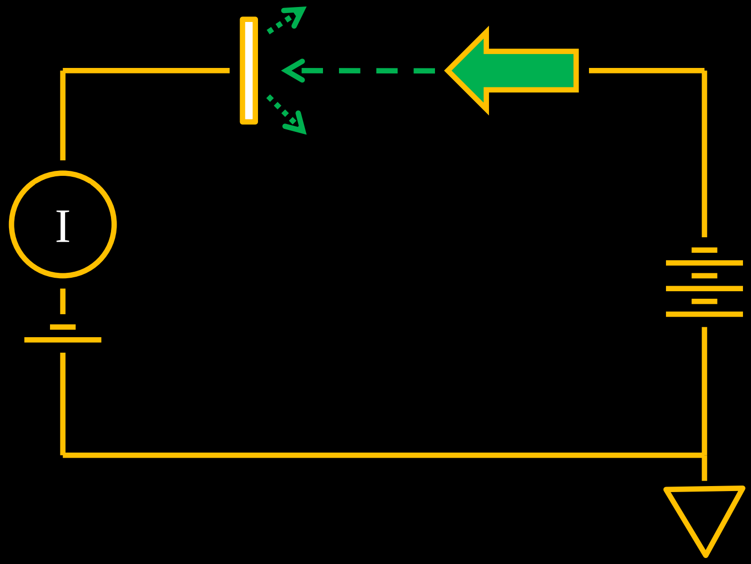
Fermilab

The Setup



SEY Measurement Technique

- Bias the sample to +500 volts and measure beam current
- Bias sample to -50 volts and measure current
- SEY current is the difference between the -50 V bias reading and the +500 V bias reading
- SEY is then given as the ratio of SEY current to beam current



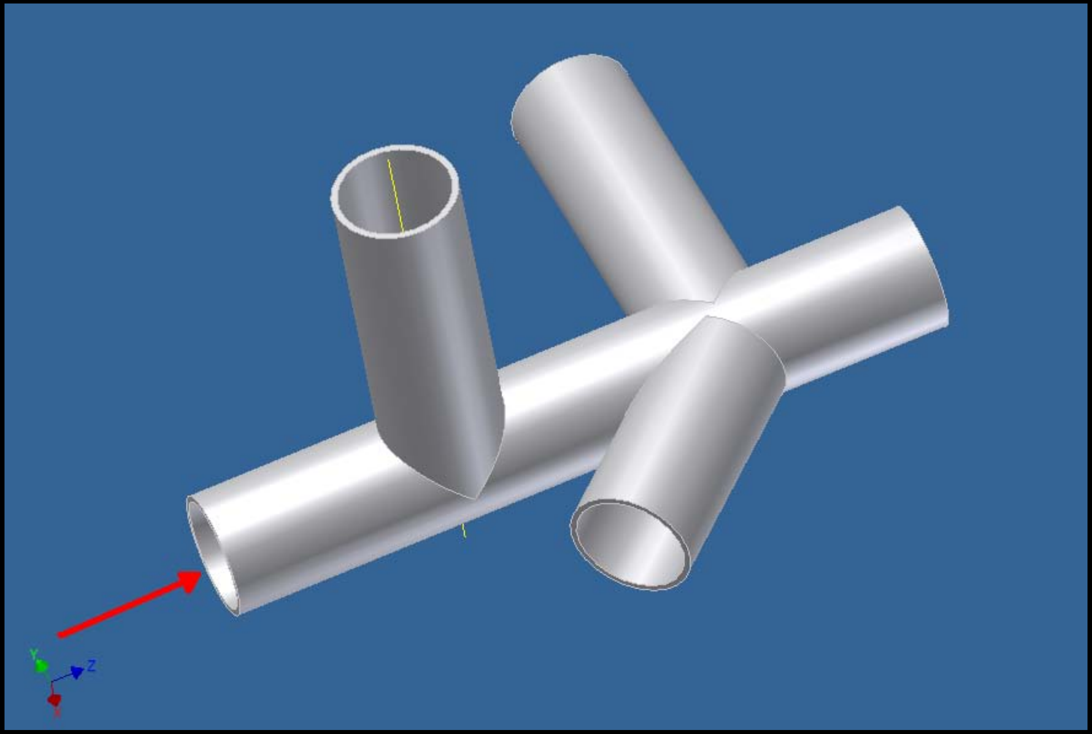
Fermilab

In Practice

- Sample is stationary and electrically isolated (mounted to SHV feedthrough)

- Pumped with Varian TPS-Compact pumping station (turbo pump backed with oil-less scroll pump)

- Inverted Magnetron Pirani vacuum gauge

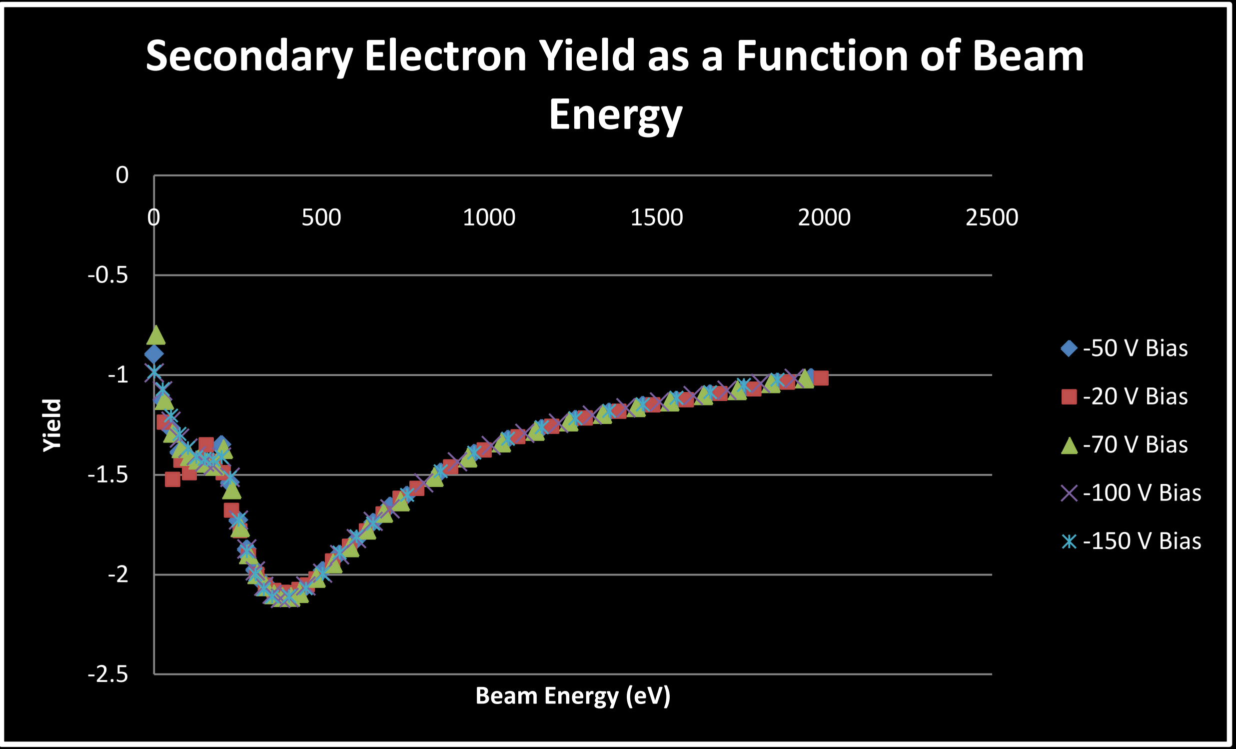


-> Electron beam indicated by red arrow

Fermilab

SEY Measurement Technique

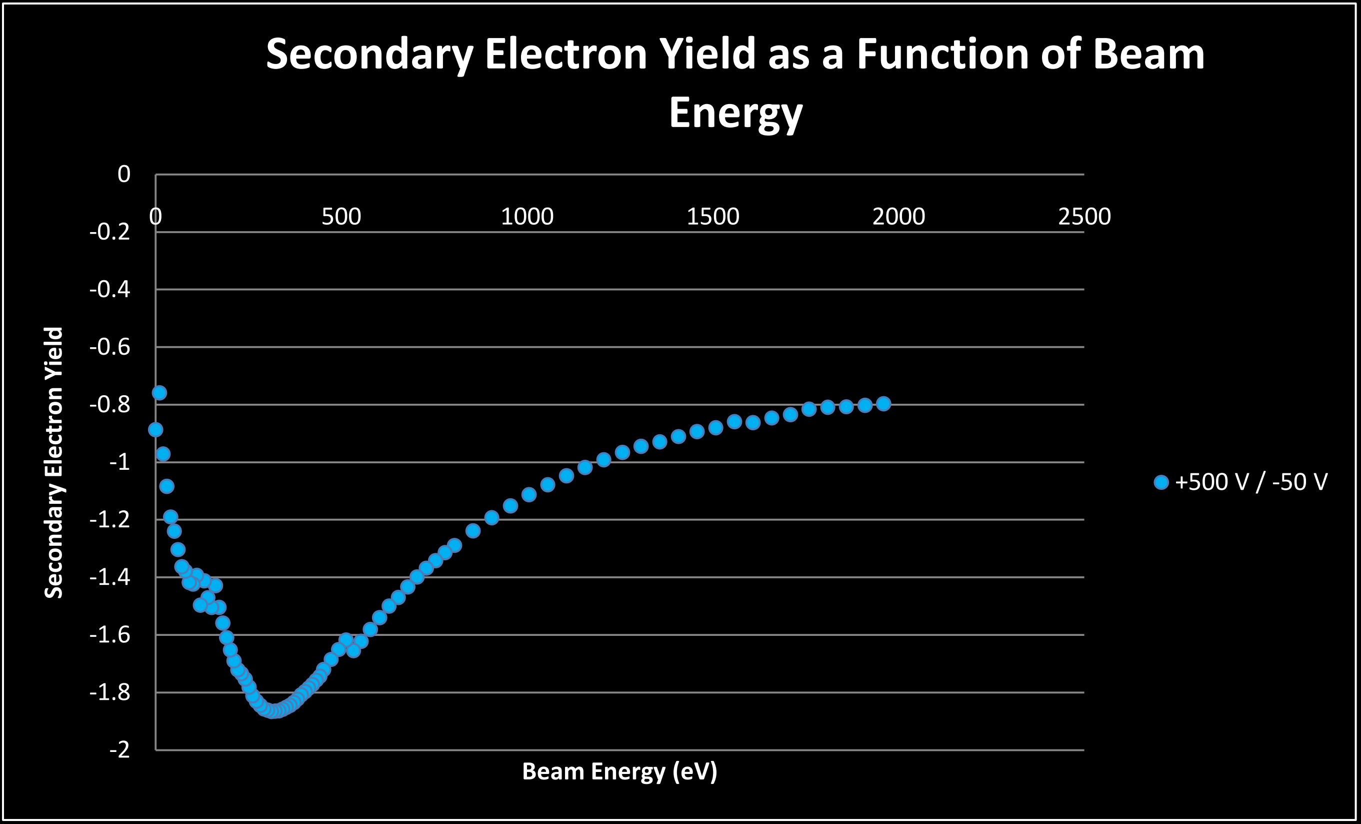
- Why -50 volts?
  - Convention suggests -20 volts



Fermilab

Initial Results

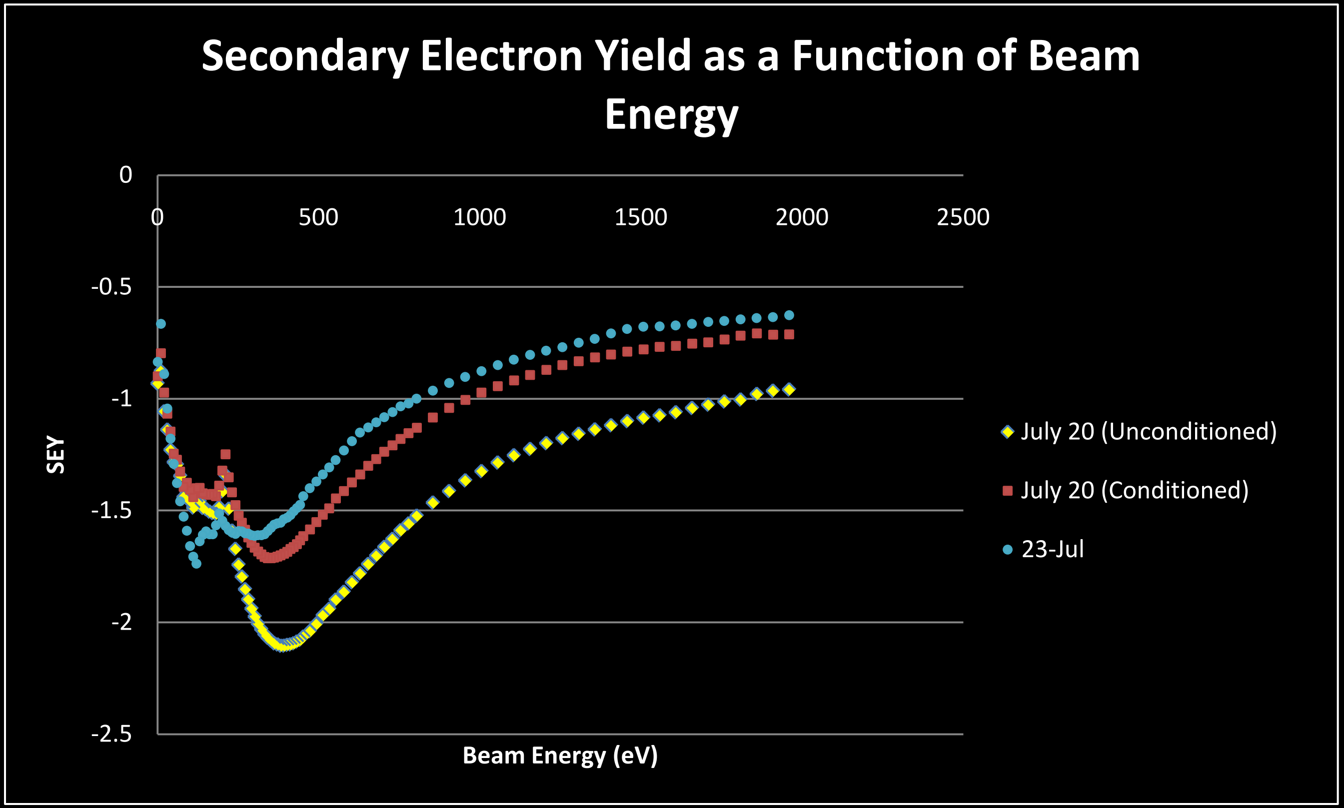
- Copper sample
- Qualitatively good data



Fermilab

Initial Results

- Copper sample
- Proof of conditioning



Refining the Technique

- Stray magnetic fields from gauge and ion pump had an unknown effect on low energy beams
    - *Mu-metal shielding*
- SEY measurements appeared to be sensitive to gun parameters
    - Spot size changes as parameters change
    - Measurement drift due to self-conditioning
        - *Perform beam studies*
        - *Speed up measurements by automating process with LabView*
- SEY current from residual gas ionization (i.e. not all of the measured current was necessarily from sample)
    - *Improve vacuum*

Fermilab

Refinements

- Shielded gauge using AD-MU-80; a high nickel alloy with a very large μ
  - Magnetic field reduced to a maximum of 3 gauss outside the chamber and ~ 1 gauss in the chamber
- Installed an ion pump
  - Vacuum improved to 4.1 E -7

    -> Dirty sample (typical monolayer formation time ~ 25 seconds according to *Building Scientific Apparatus* by Moore, Davis and Coplan)
- Performed basic beam study; spot size measured through beam extinction technique

Fermilab

MYSTERY MAGNETICS

- Vacuum gauge produces a field of roughly 30 gauss at the KF flange
- After removal, 8-9 gauss still measured inside the chamber!
- Supports for the test stand were magnetic; fields on the order of 42 gauss!

- SOLUTION: Build degausser using a half torroid ferrite and a variac.

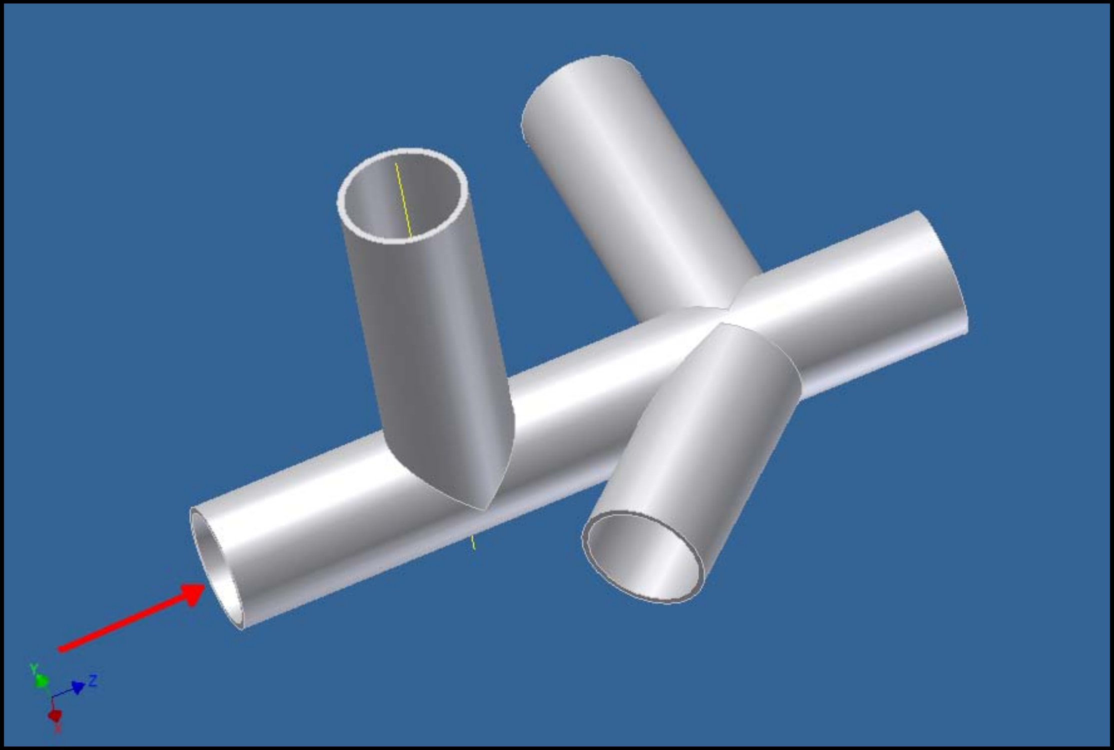
Fermilab

Degaussing a Wrench

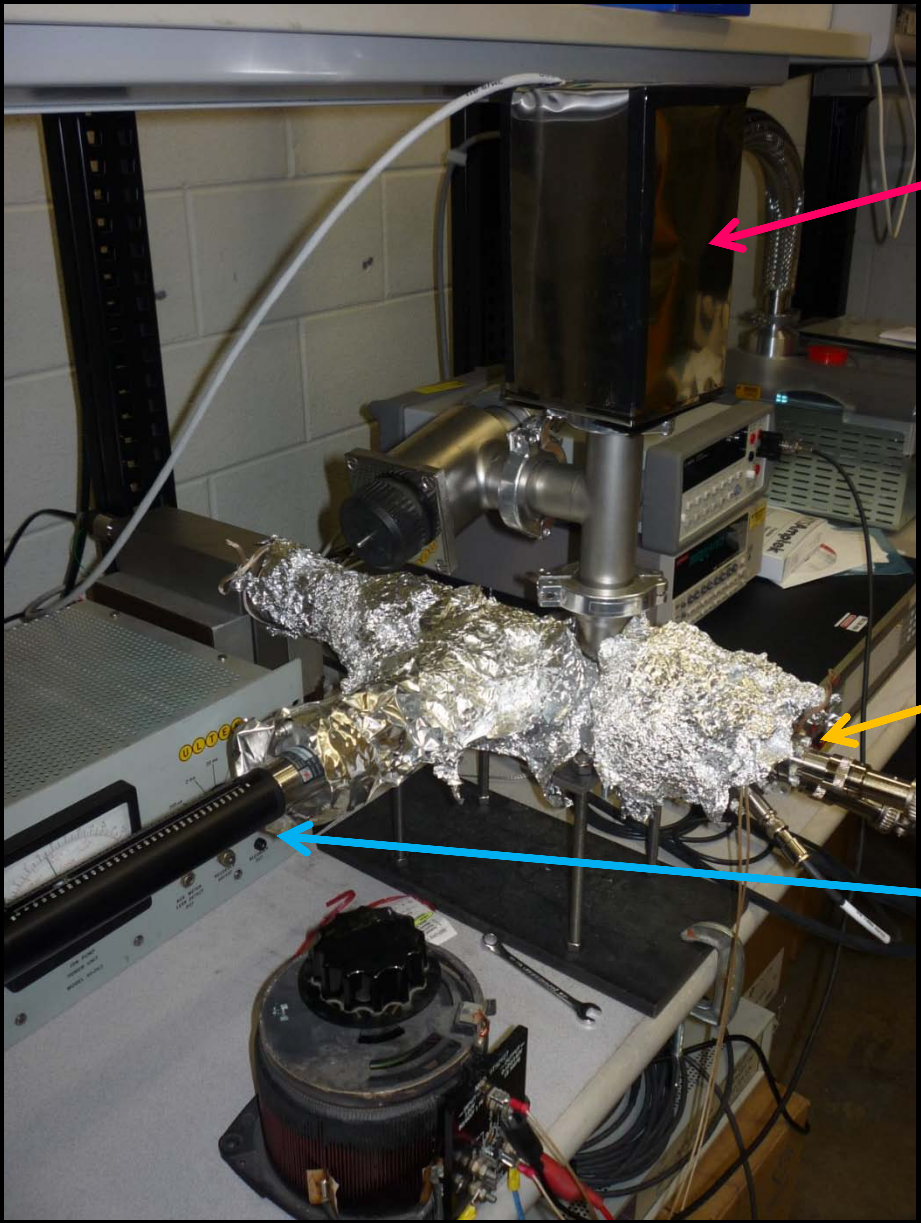
Fermilab

Improved Test Stand

- Sample electrically isolated and stationary
- Aperture mounted on mechanical feedthrough for extinction measurements
- Ion pump installed



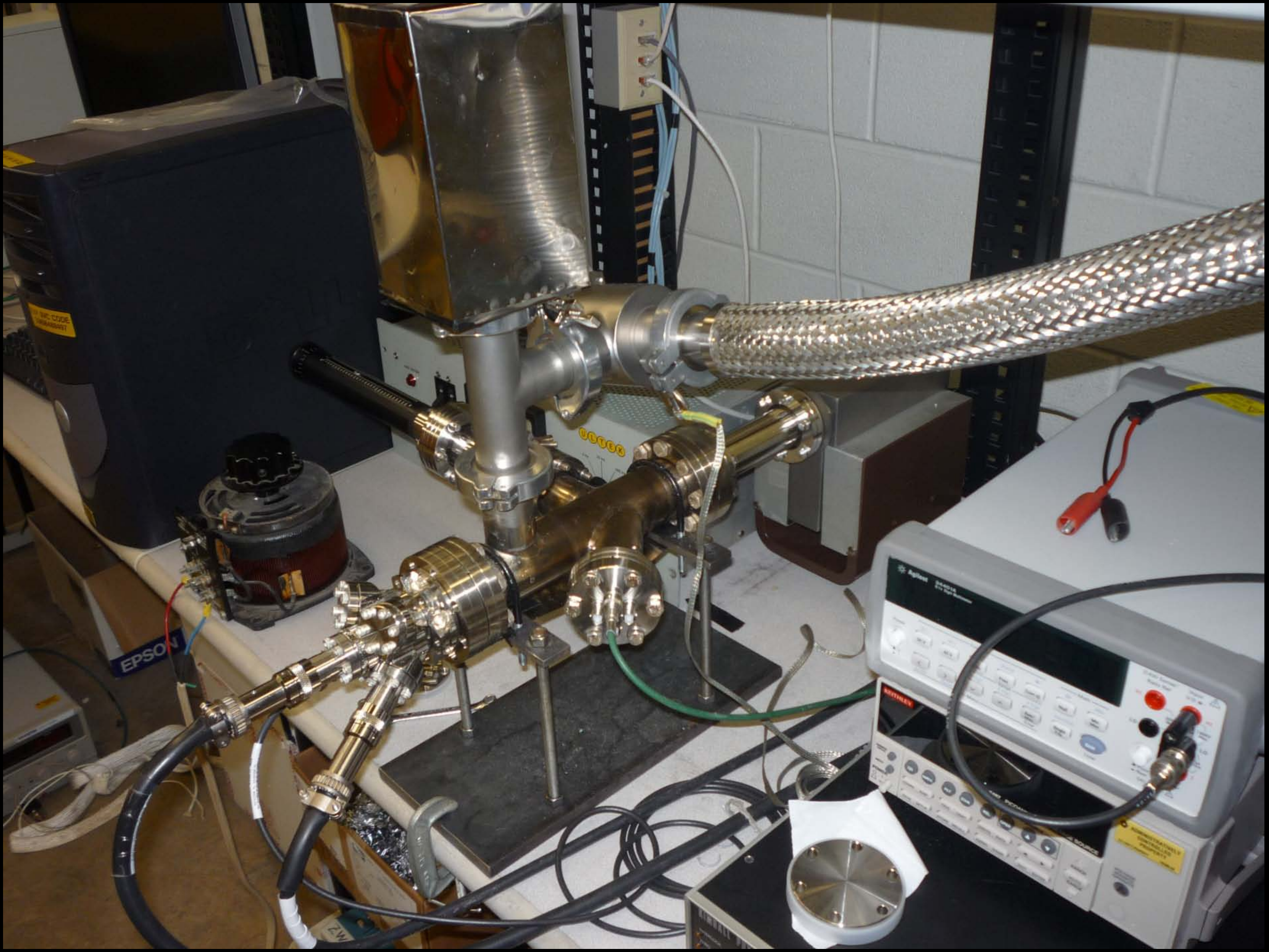
Fermilab



Mu-Metal shielding for gauge

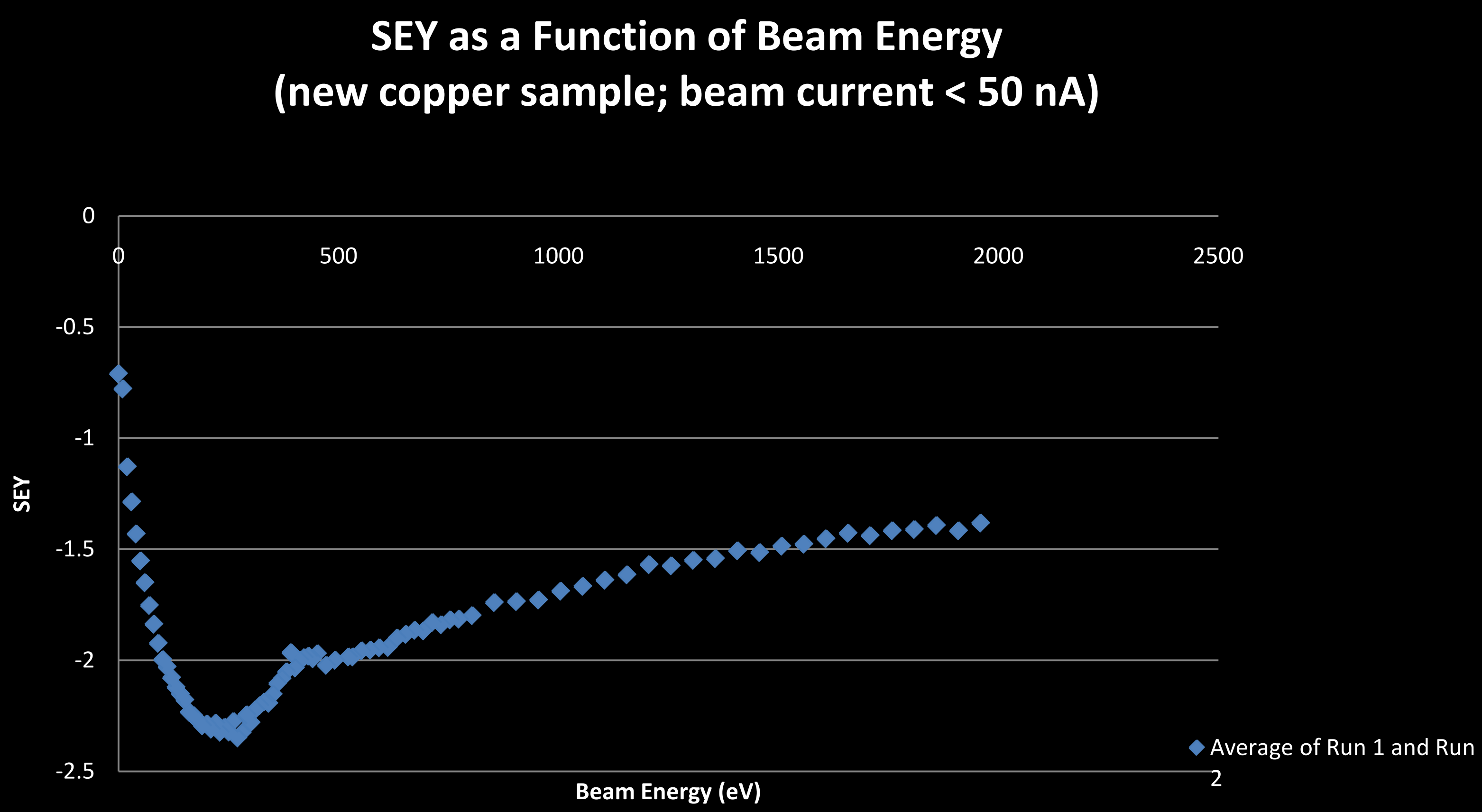
Electron Gun

Mechanical feedthrough for aperture



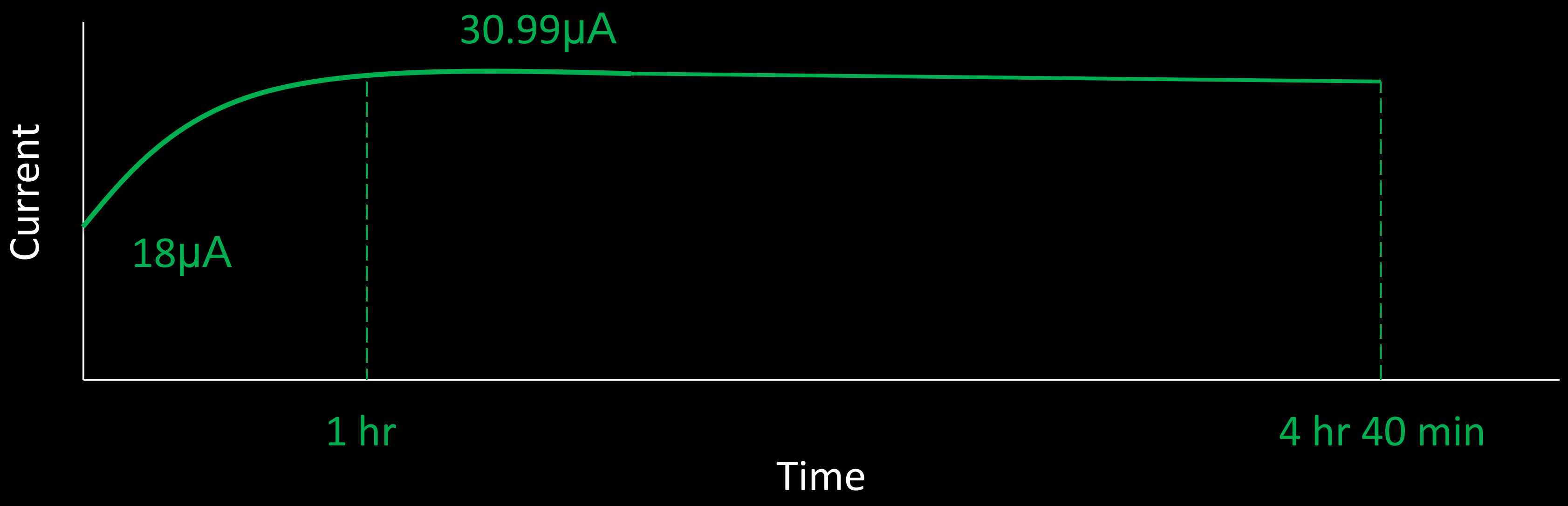
Fermilab

Initial Results



Conditioning

- Made a critical mistake; first hour of conditioning the emission current indicated on the EGPS increased



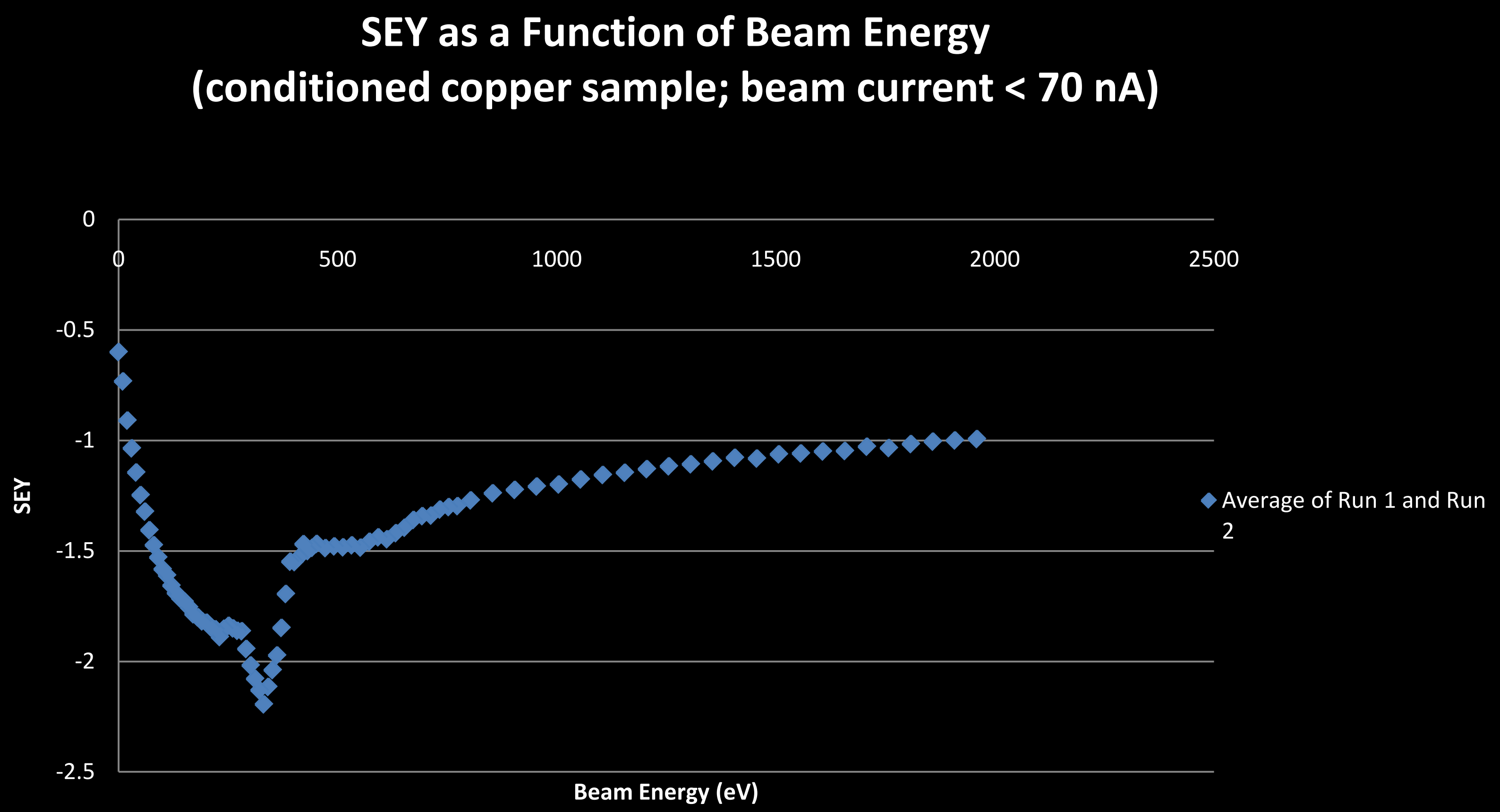
- Estimated dose: ~ 137.63 μA-hr*

Questions About Conditioning (Future Work)

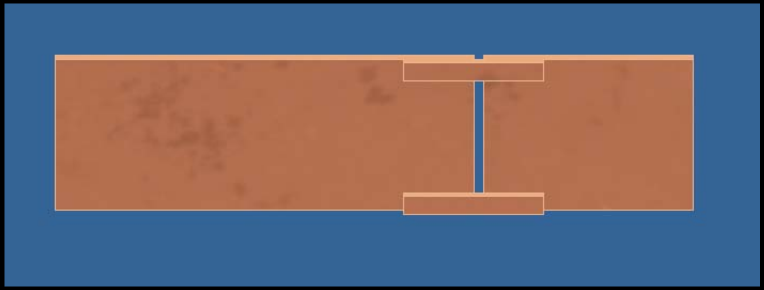
- How does the conditioning beam energy effect sample conditioning?
  - Produce SEY comparisons of conditioned and unconditioned samples for several different conditioning energies

- How does sample bias effect conditioning?
  - Conditioning current measured from EGPS “emission current”, which does not always match actual beam current
  - Can the sample be effectively conditioned with a large positive bias (allowing more accurate dose measurements)?

Results After Conditioning

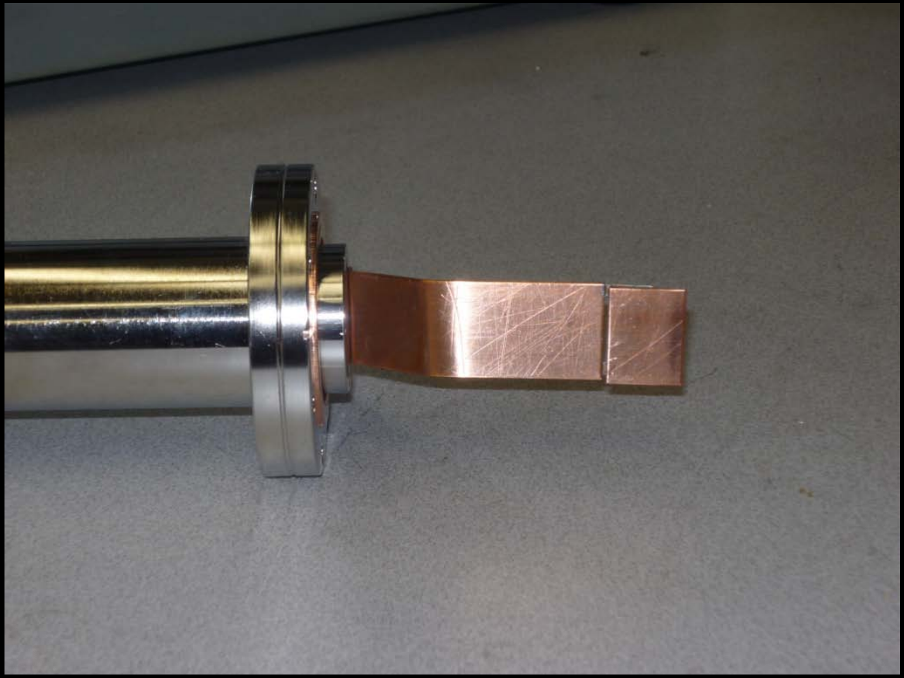


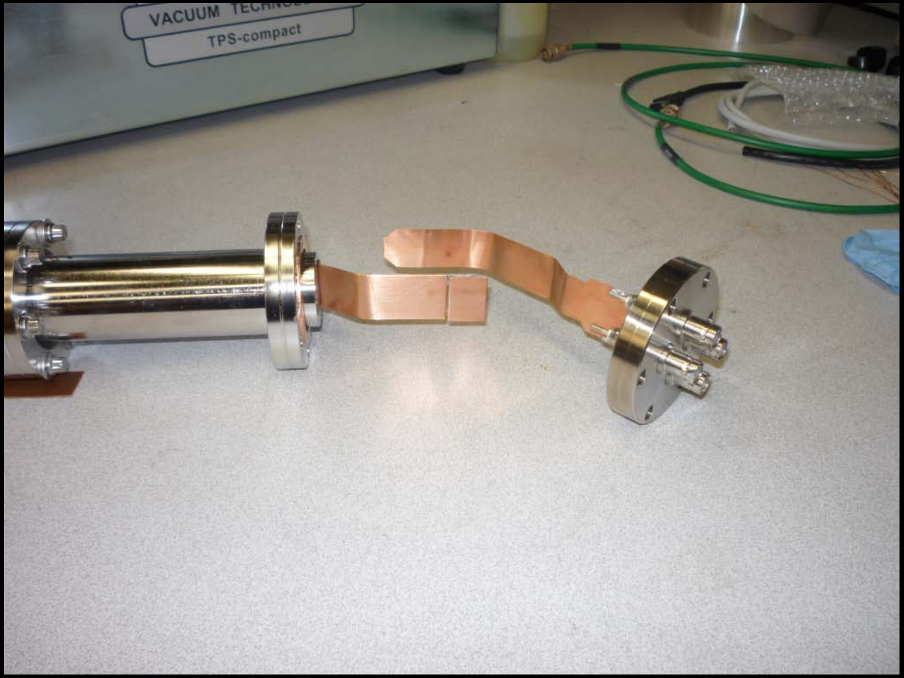
Investigate Spot Size



- Installed an aperture
- Measurement technique:
  - Feed aperture into beam; record position when beam current is reduced to 99% of the unobstructed beam current
  - Continue feeding until beam current drops to 1% of unobstructed beam current and record position
- Double edge aperture used to gain a rough beam profile
  - Raster aperture back and forth, recording the current as a function of position

Spot Size Measurements

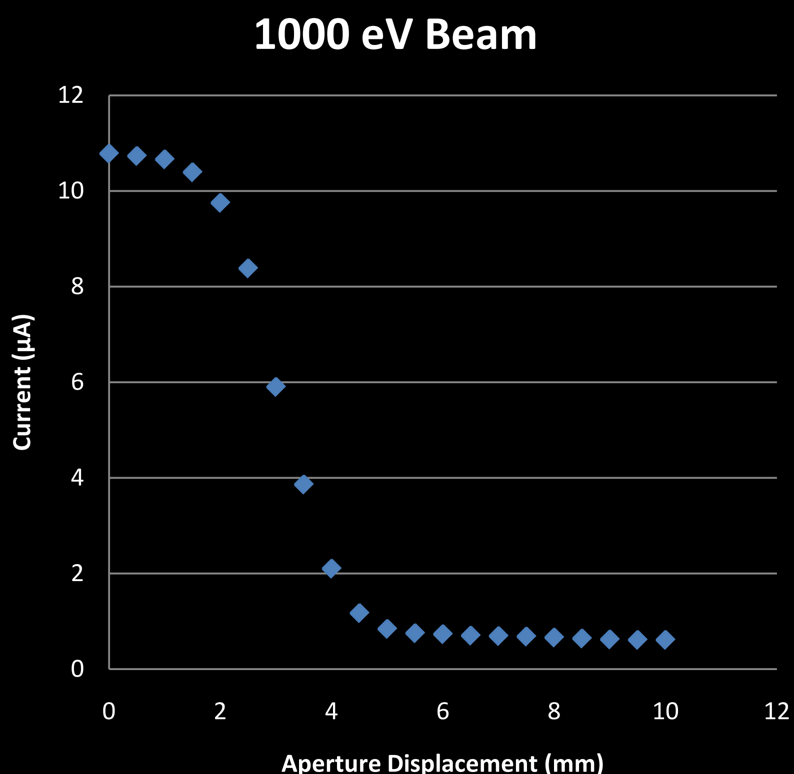




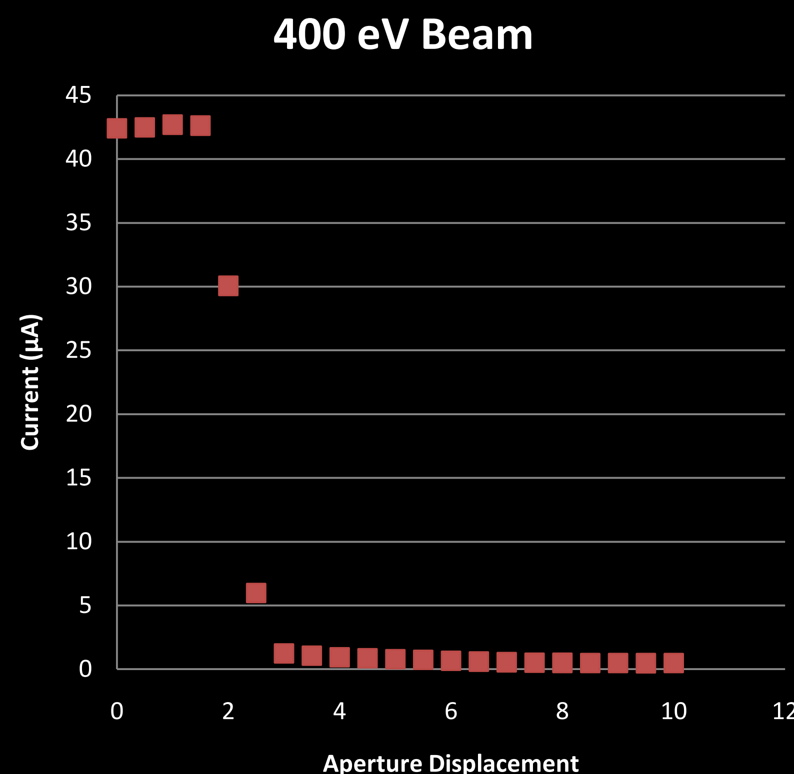
Fermilab

Spot Size

Good Measurements

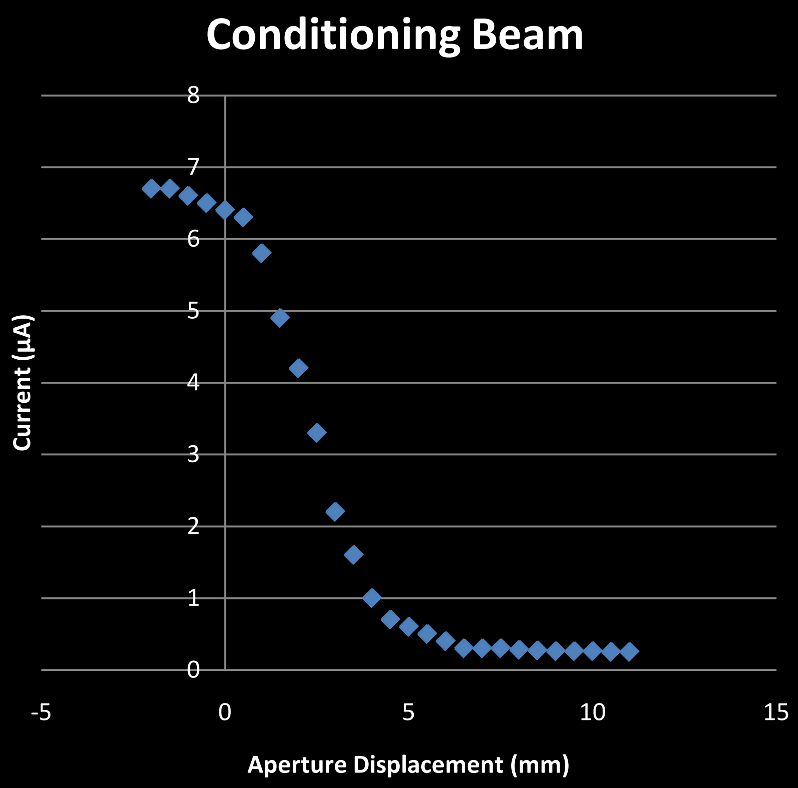


Bad Measurements

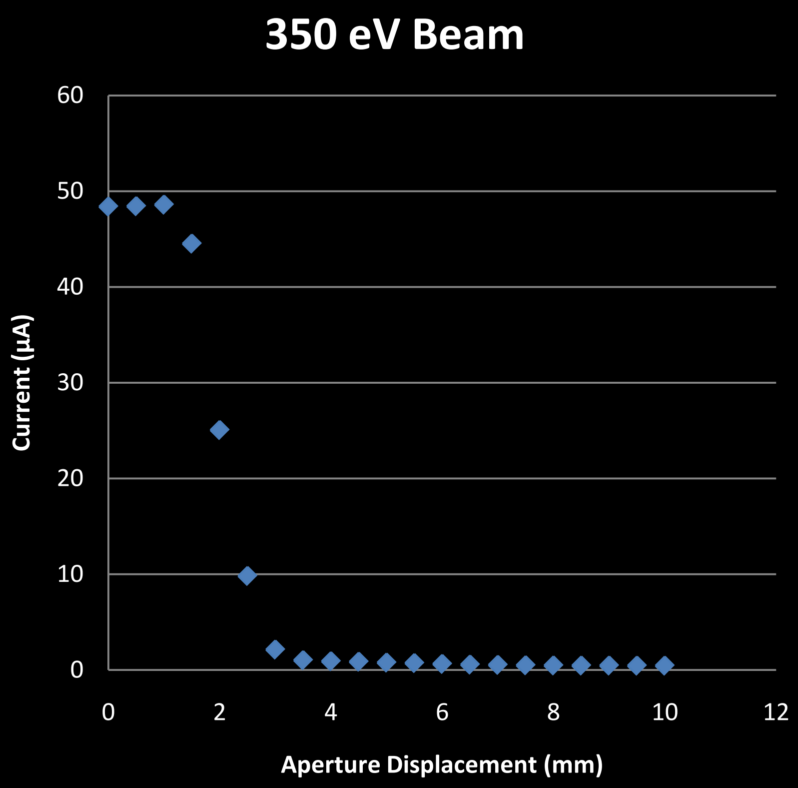


Spot Size

Conditioning Beam



Bad Measurements

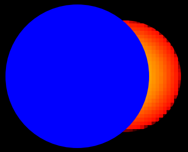


Fermilab

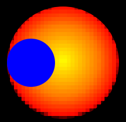
What's Going On?

Three Cases

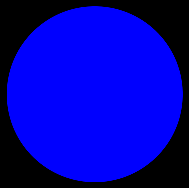
- ~ 400 eV to 200 eV range => artificially high SEY from overlap condition



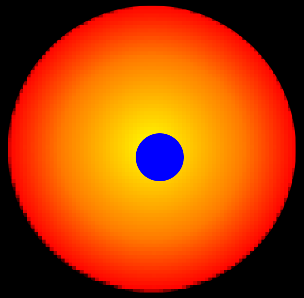
- ~600 eV to 400 eV range => appears as a plateau



- ~2000 eV to 600 eV range => qualitatively looks fine but still suffering from slight overlap



Ideal Case



New Parameters

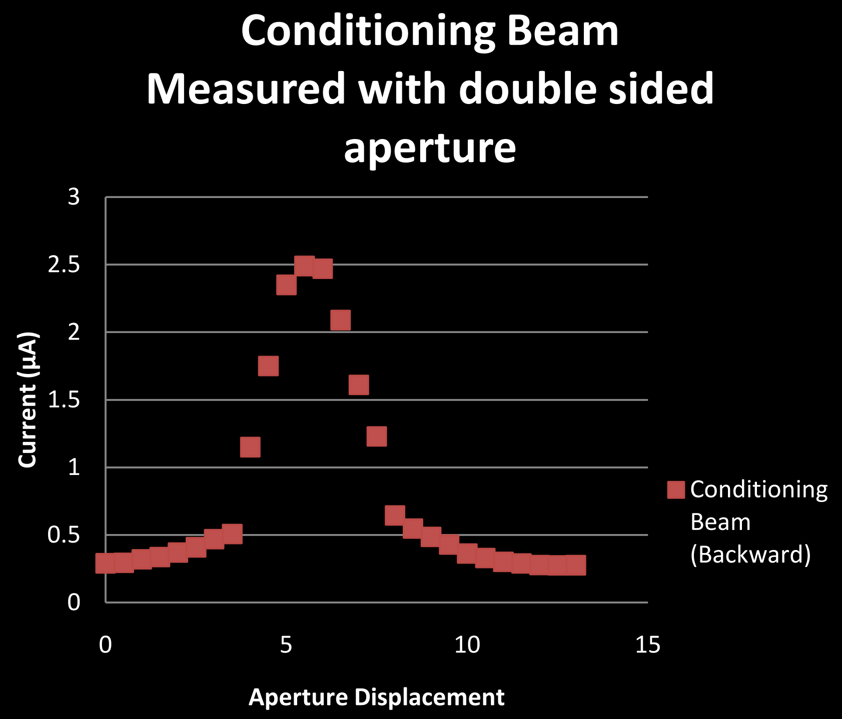
Conditioning Beam:

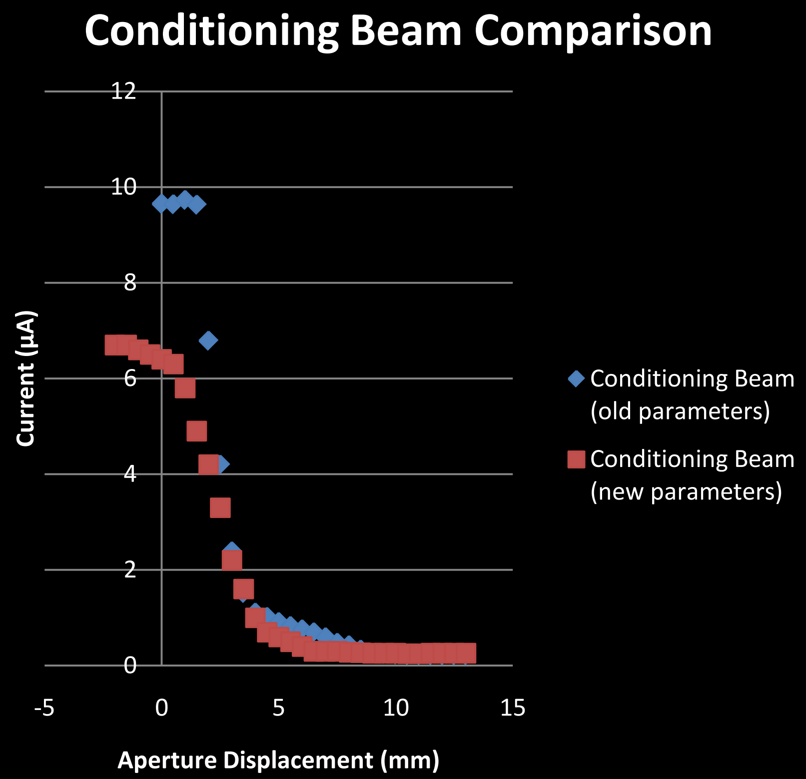
Energy	500 eV
Focus	100 V
Grid	1 V
1^{st} Anode	100.1 V
SOURCE	
Voltage	1.6 V
Current	1.622 A
Emission	30.99μA

Fermilab

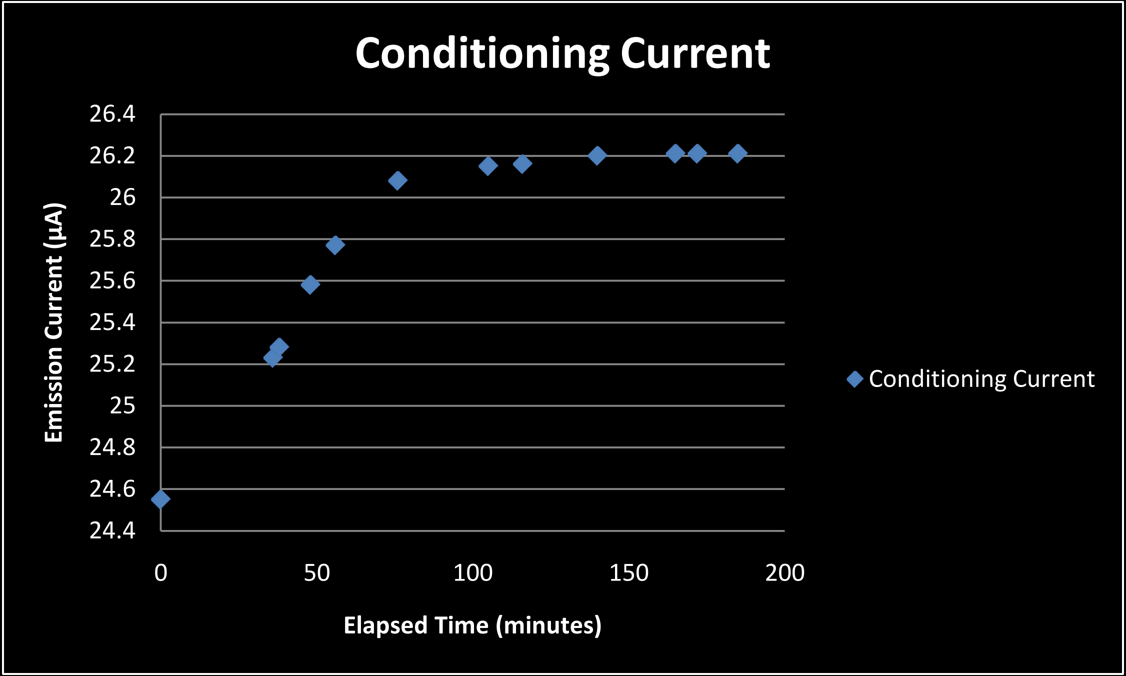
Double Sided Aperture Measurement

Single Sided Aperture Comparison



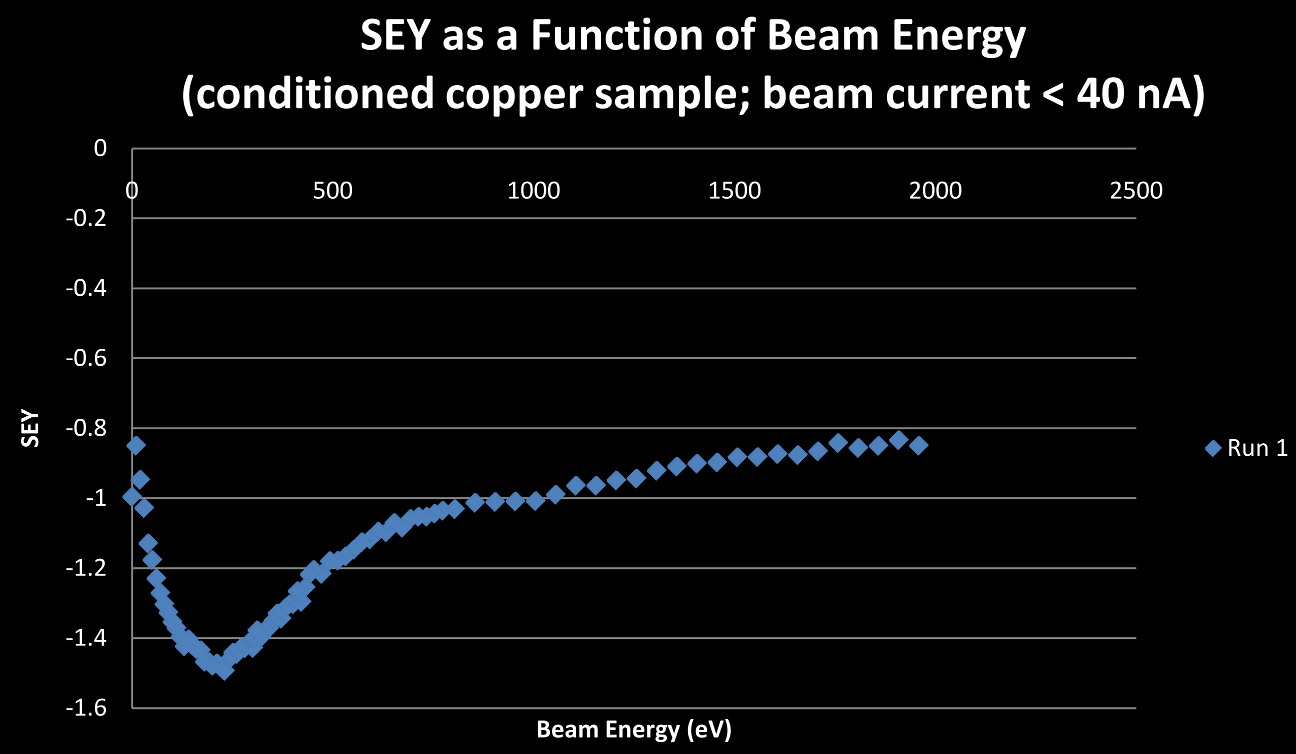


Conditioning Current



Dose approximately 0.041 C/cm^2

Initial Results with new Parameters



Useful Comparison

- **New conditioning beam and new measurement beam (E=150 eV and F = 310 V in this example)**

New conditioning beam and old measurement beam (E=150 eV and F = 150 V in this example)

CONCLUSION

- Successful proof of technique
  - Setup for biasing the sample is robust and easily controlled, either manually or via computer
  - Low noise
  - Reasonable results
- Need to develop a solid set of gun parameters for future measurements
  - Raster the beam for a larger, more uniform conditioning?
- Future work should also include a formal study of conditioning

Fermilab

Acknowledgements

- Many thanks to Bob Zwaska for his continued encouragement and support

- Thanks also to Eric Prebys and Carol Angarola along with the entire Lee Teng selection committee for this opportunity

Fermilab