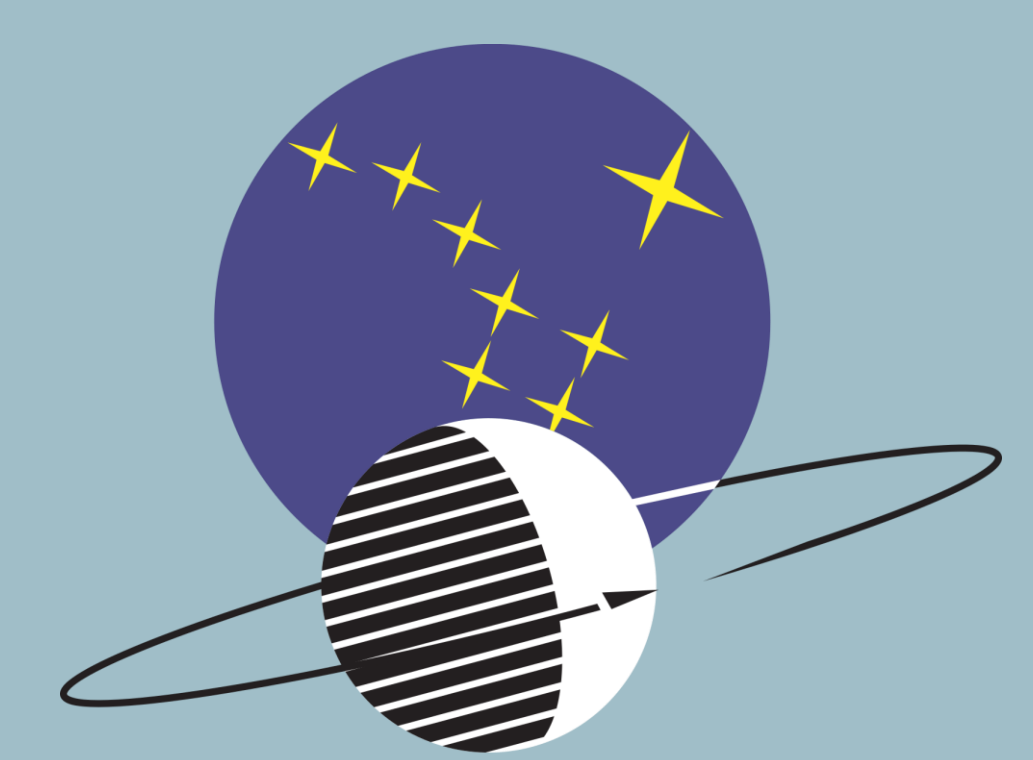


Plastic Printed Electron Gun and Faraday Cup Testbed

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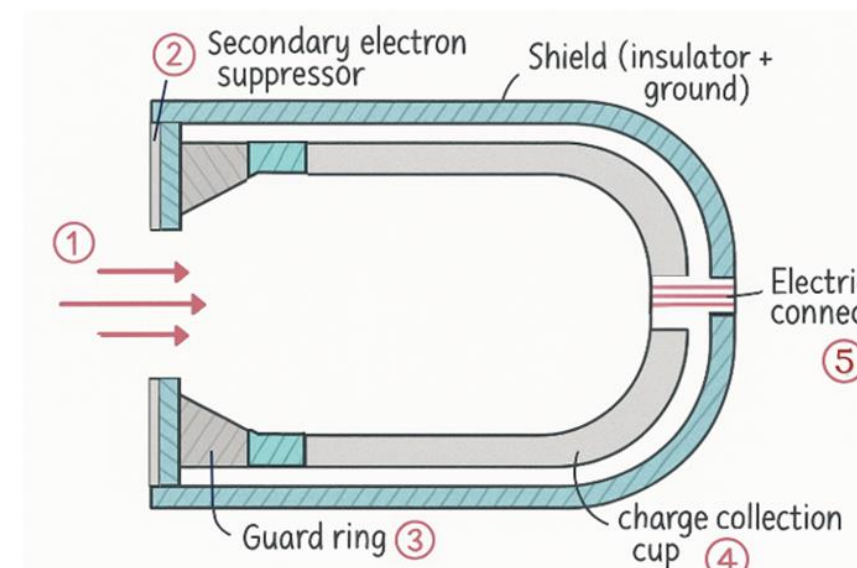


Introduction

- Faraday cup: a conductive metal cup that catches charged particles in a vacuum and measures beam current or charge of the ions

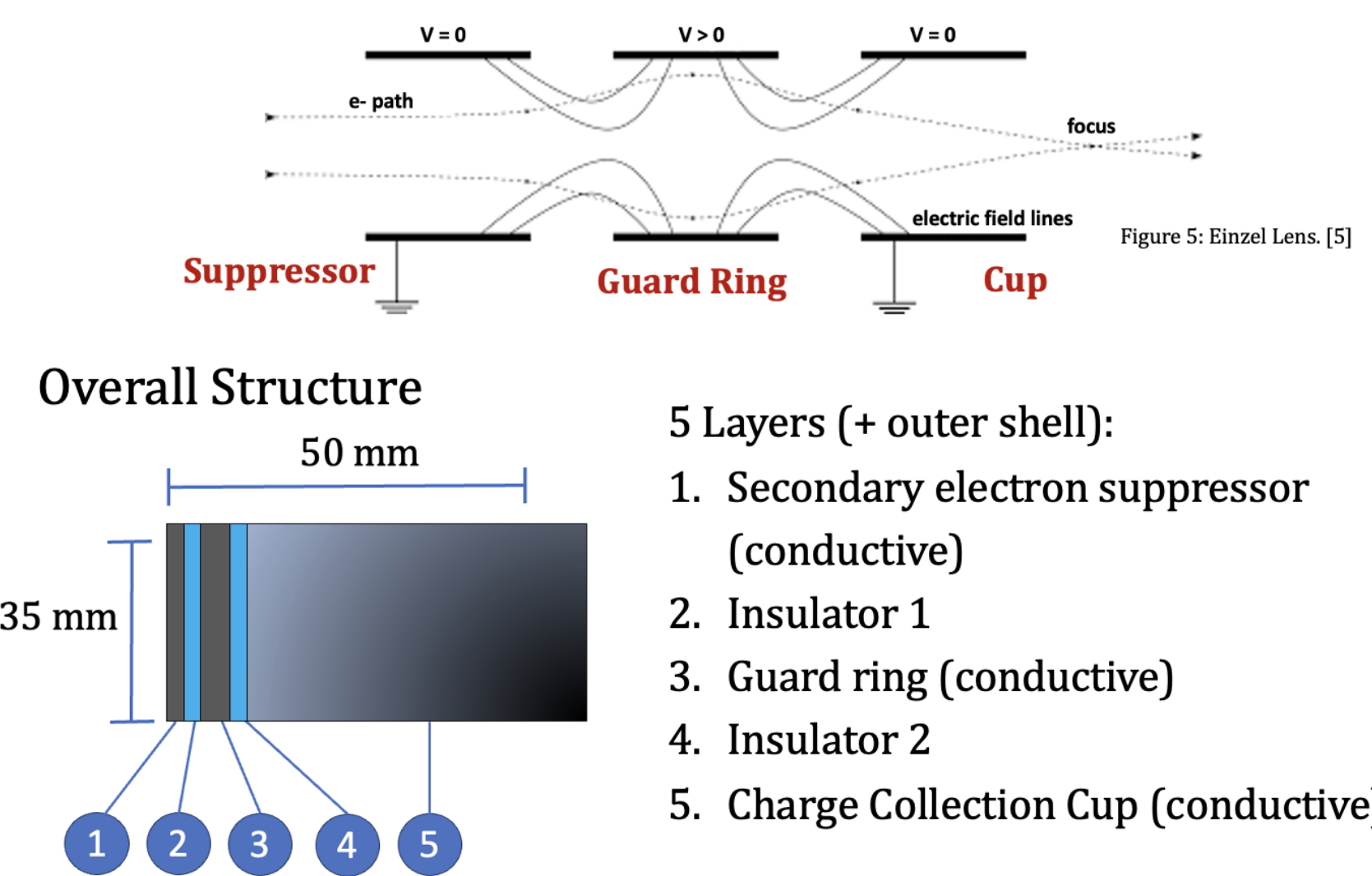
How It Works

- Ions enter the cup.
- A suppressor keeps the secondary electrons from reflecting out.
- The current of ions can be controlled by inserting a guard ring.
- Ions hit the inner surface and are collected.
- The small current is measured by an ammeter.



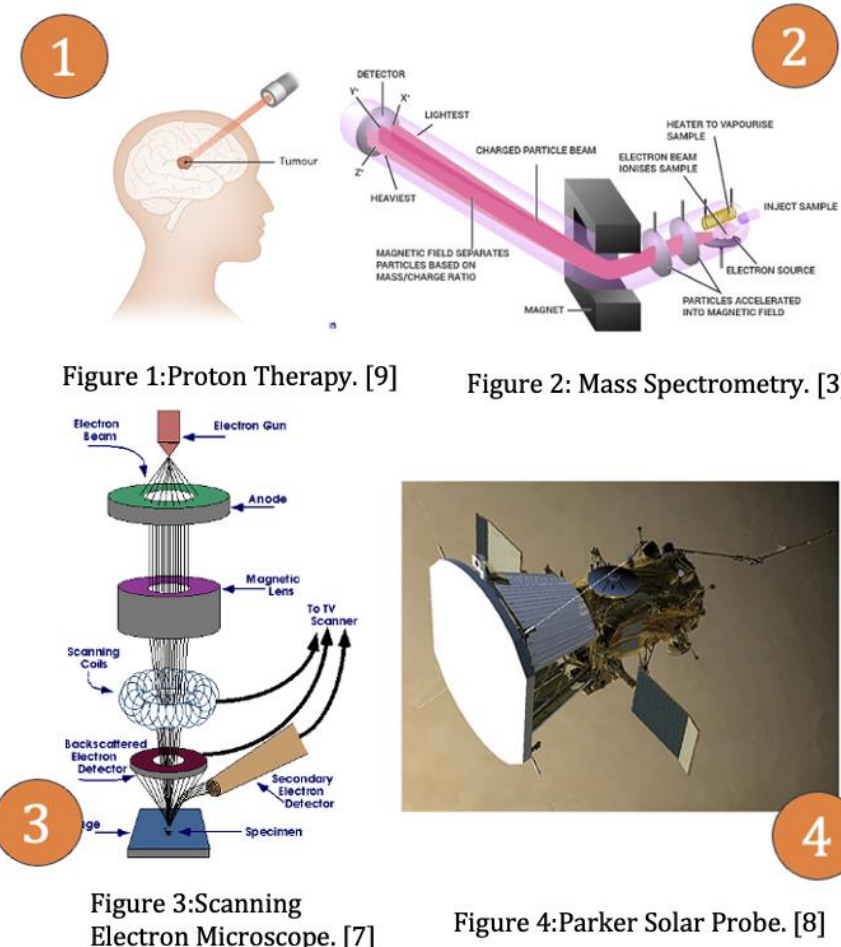
Structuring the Faraday Cup

Inserting a Guard Ring to form an Einzel Lens



Applications

- Precisely measures the amount of proton radiation
- Determines isotope charge in mass spectrometry
- Measures electron current in SEMs
- Determines space weather by measuring ion flow in space
 - Voyager 1 & 2 (4 cups each)
 - Parker Solar Probe (1 cup)
 - Europa Clipper Mission (4 cups)



Goal

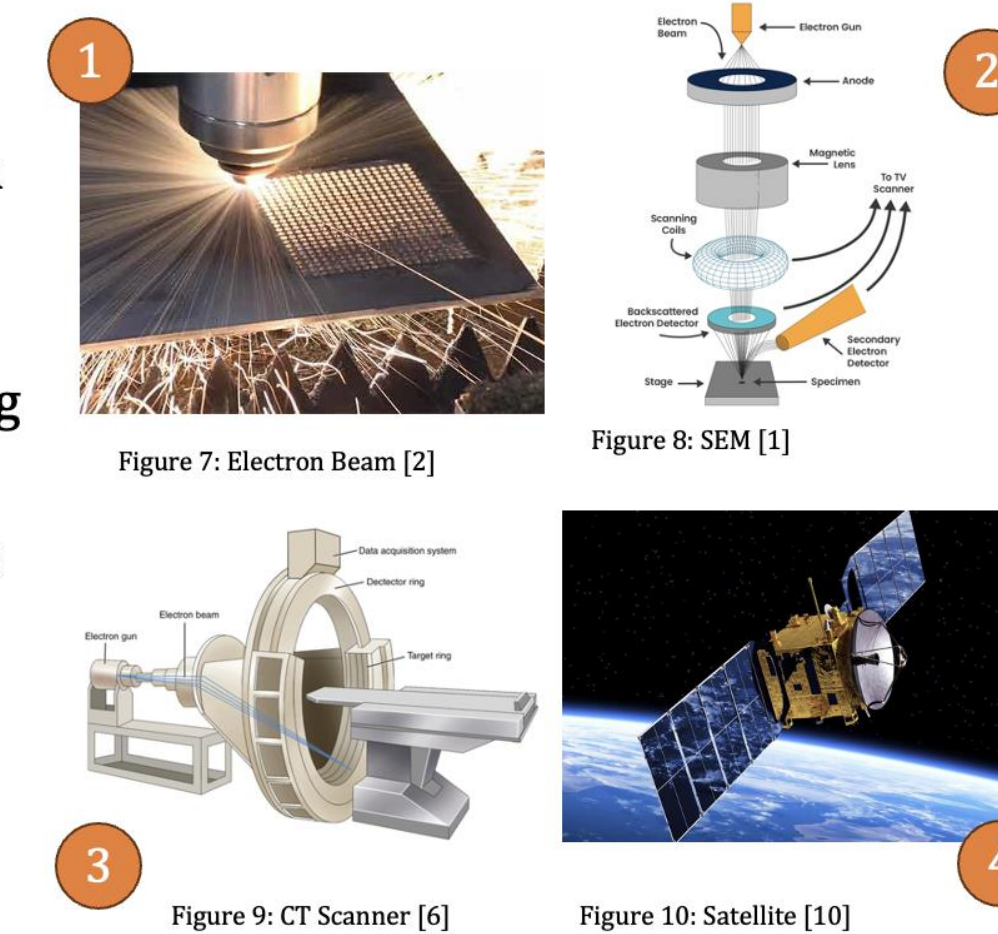
- Both electron guns and Faraday cups are proven to be simple and reliable scientific instruments and are utilized in many fields.
- Especially in outer space research, detectors such as these have limits in size, weight, and cost.
- Is there a way we can construct an electron gun-Faraday cup system that would be lightweight, cheaper, and high-performing?**

Proposal

- Both instruments are typically made of metal, because they require conductivity; however, recent studies show that plastic can reach good conductivity.
- Key advantages to a conductive plastic system are:
 - Light weight
 - Design freedom
 - Cost and size efficiency
 - Chemical resistance
- Thus, I will attempt to create a conductive plastic system.**

Applications

- Used for high resolution imaging and microscopy in SEMs
- Used for precise welding and additive manufacturing
- Generates X-rays and ionizes vaporized particles in mass spectrometry
- Used in ion thrusters and for space environment testing

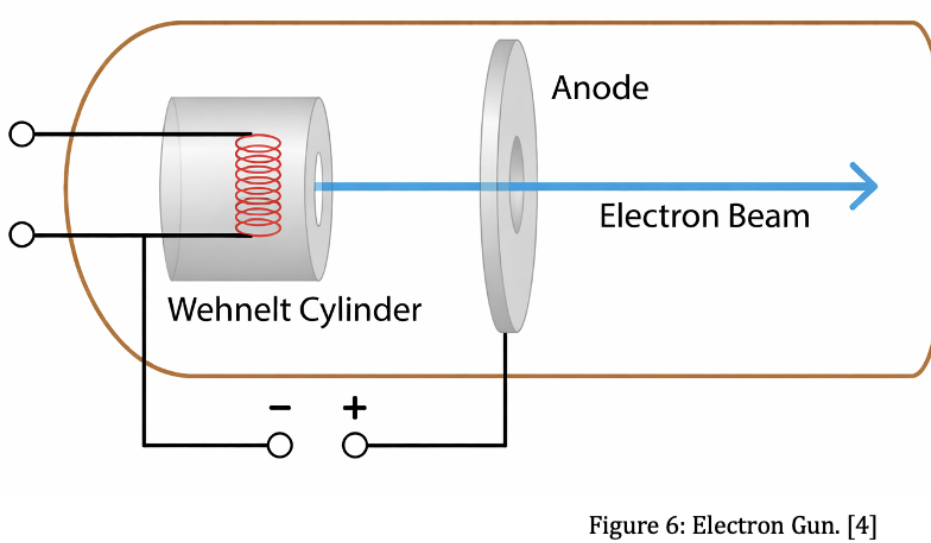


Introduction

- Electron gun: an electrical component that produces a narrow electron beam that has precise kinetic energy.

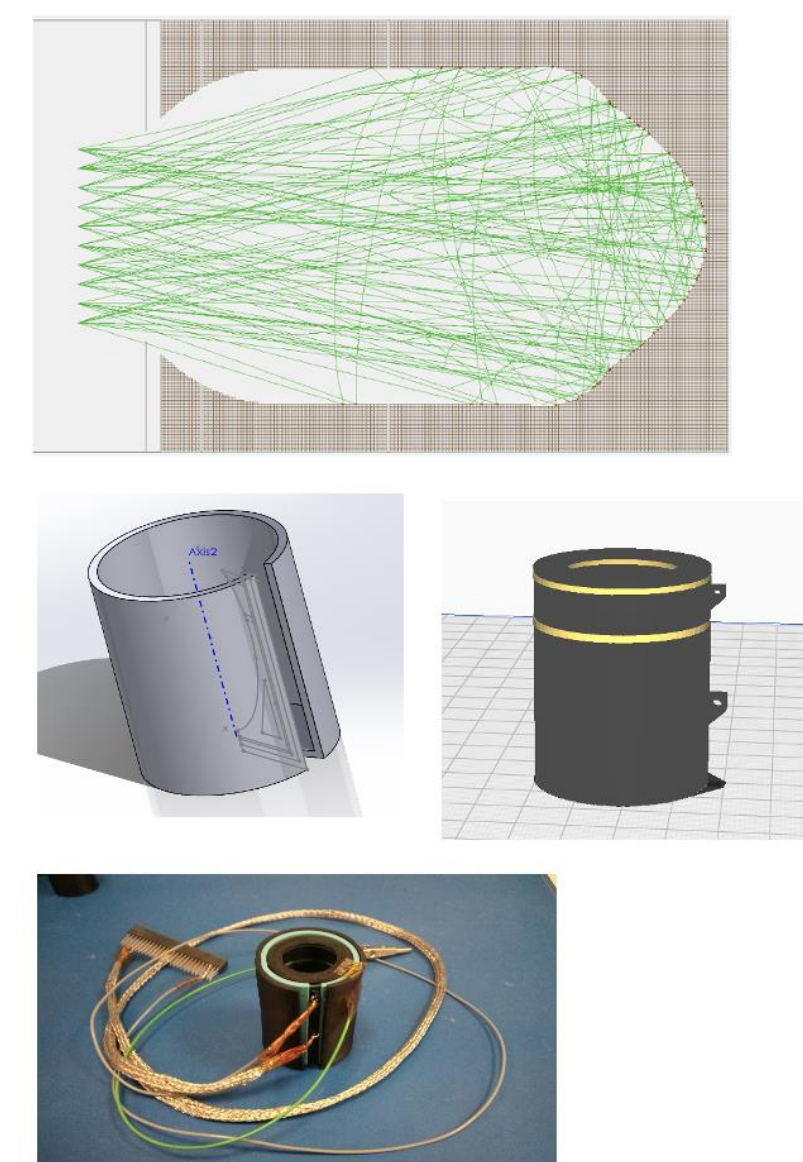
How It Works

- The heater heats the cathode and emits the electrons.
- A control grid, or Wehnelt cylinder, has negative potential relative to cathode, focusing the electrons.
- An anode is positively charged, attracting the electrons and making them accelerate.



Testing

Faraday Cup



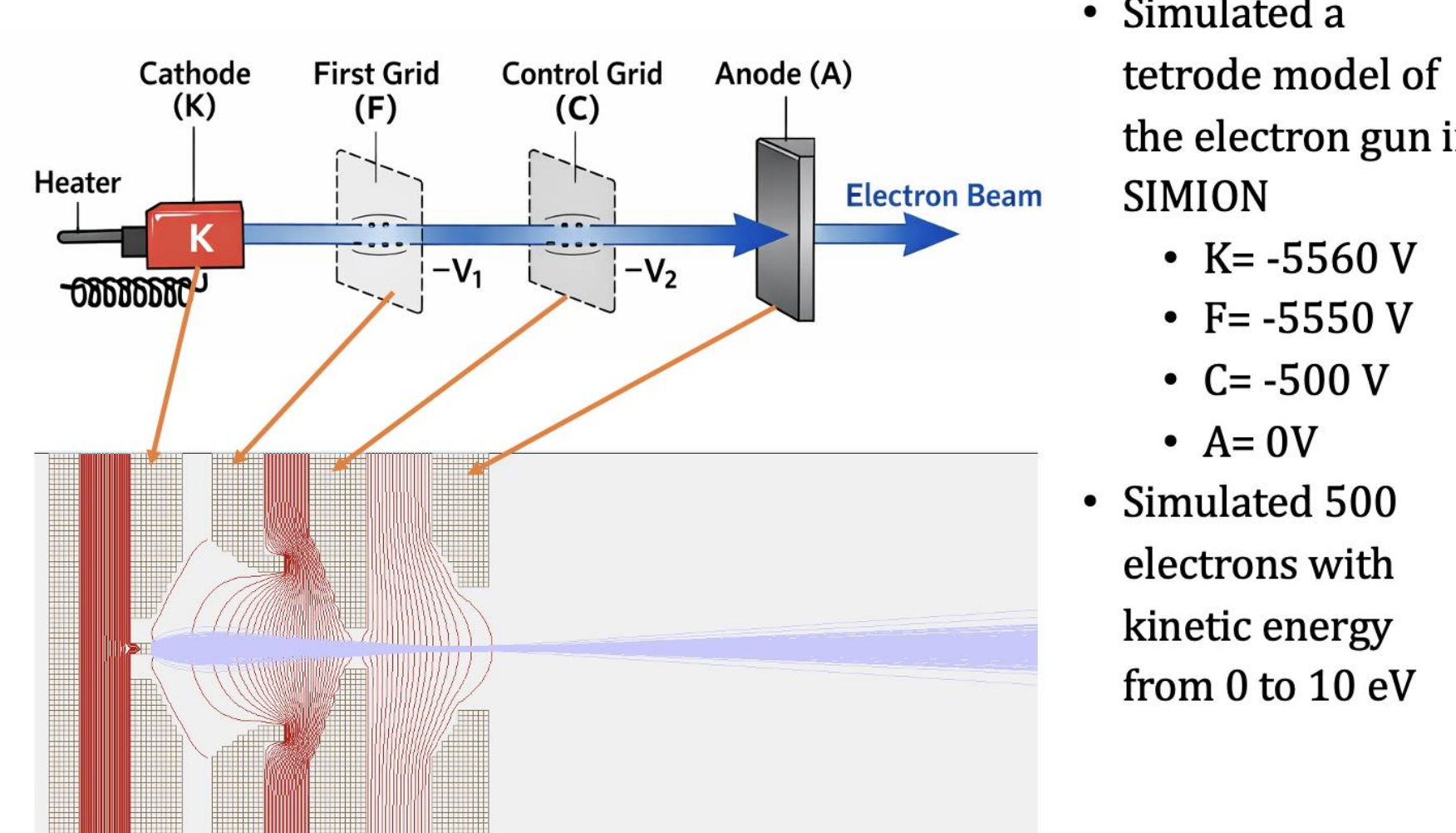
Electron Gun



This experimental system tests whether a 3D-printed conductive plastic Faraday cup and electron gun system can accurately measure and transmit ion beams.

Designing the Electron Gun

Tetrode Type System

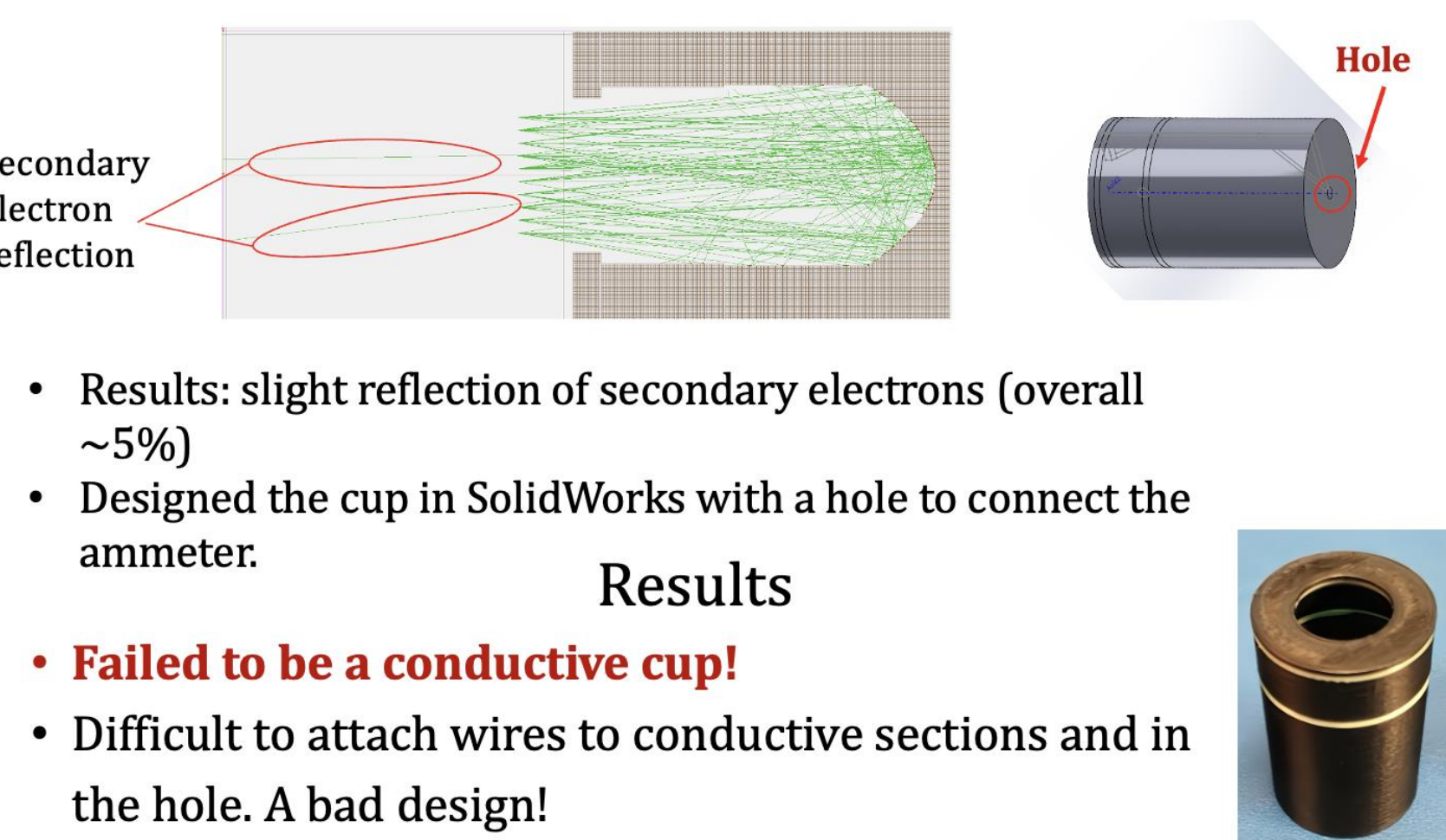


Trial 2: Improving Design

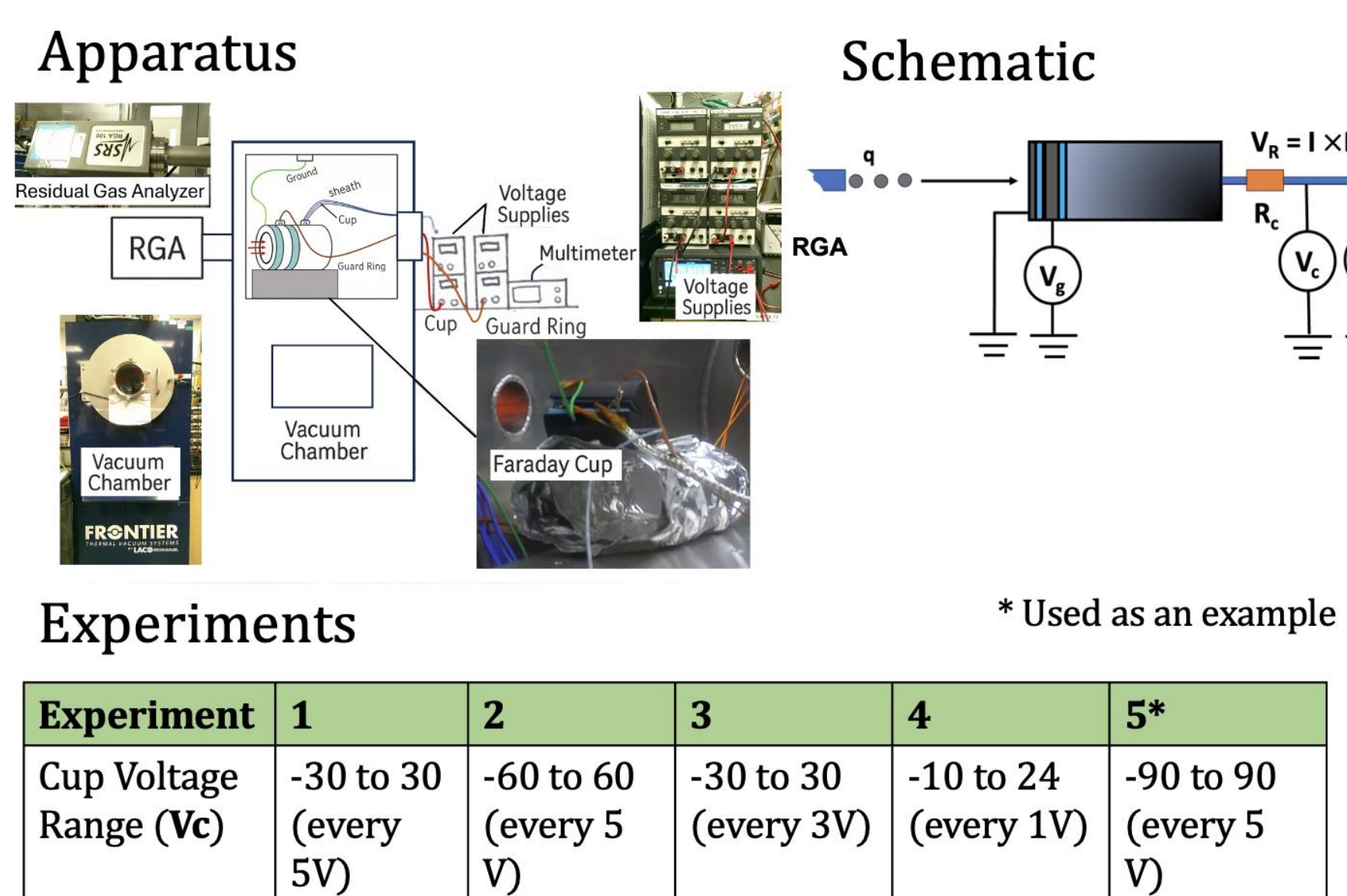
- Using SIMION, designed different shapes of the cup's interior
- The curved design produced the least reflected secondary electrons
- Added handles for the wires
- Printed out a double-layer insulator-conductive shell to ground the Faraday cup
- Soldered the wires unto their respective parts and to a connector.

Trial 1: Designing through SIMION

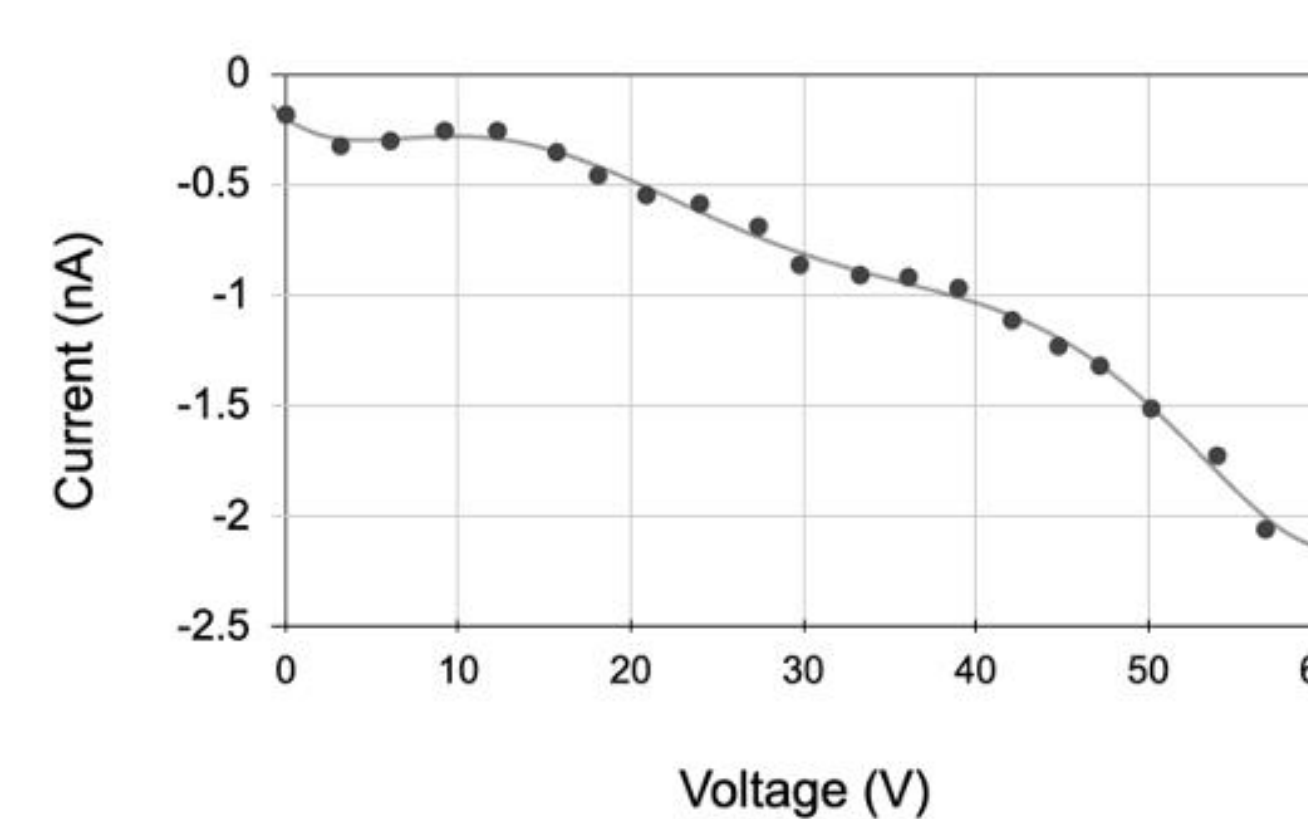
- Simulated 100 electrons with primary & secondary tracks with kinetic energy from 20 V to 3000 V



Testing the Faraday Cup



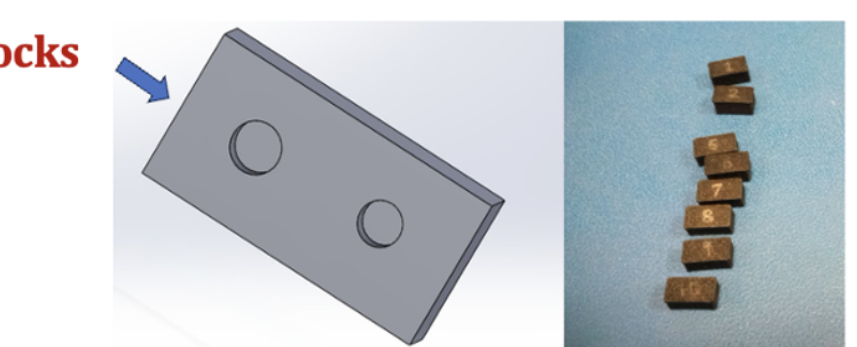
Preliminary Results



- Scanned cup voltage from 0 to 60 V, and ran the electron gun current at 0.4 A, 25 V difference
- Higher positive voltages of the Faraday cup attracted more electrons from the electron gun
- The electron gun is emitting current, but there seems to be background noise -> More testing needed!

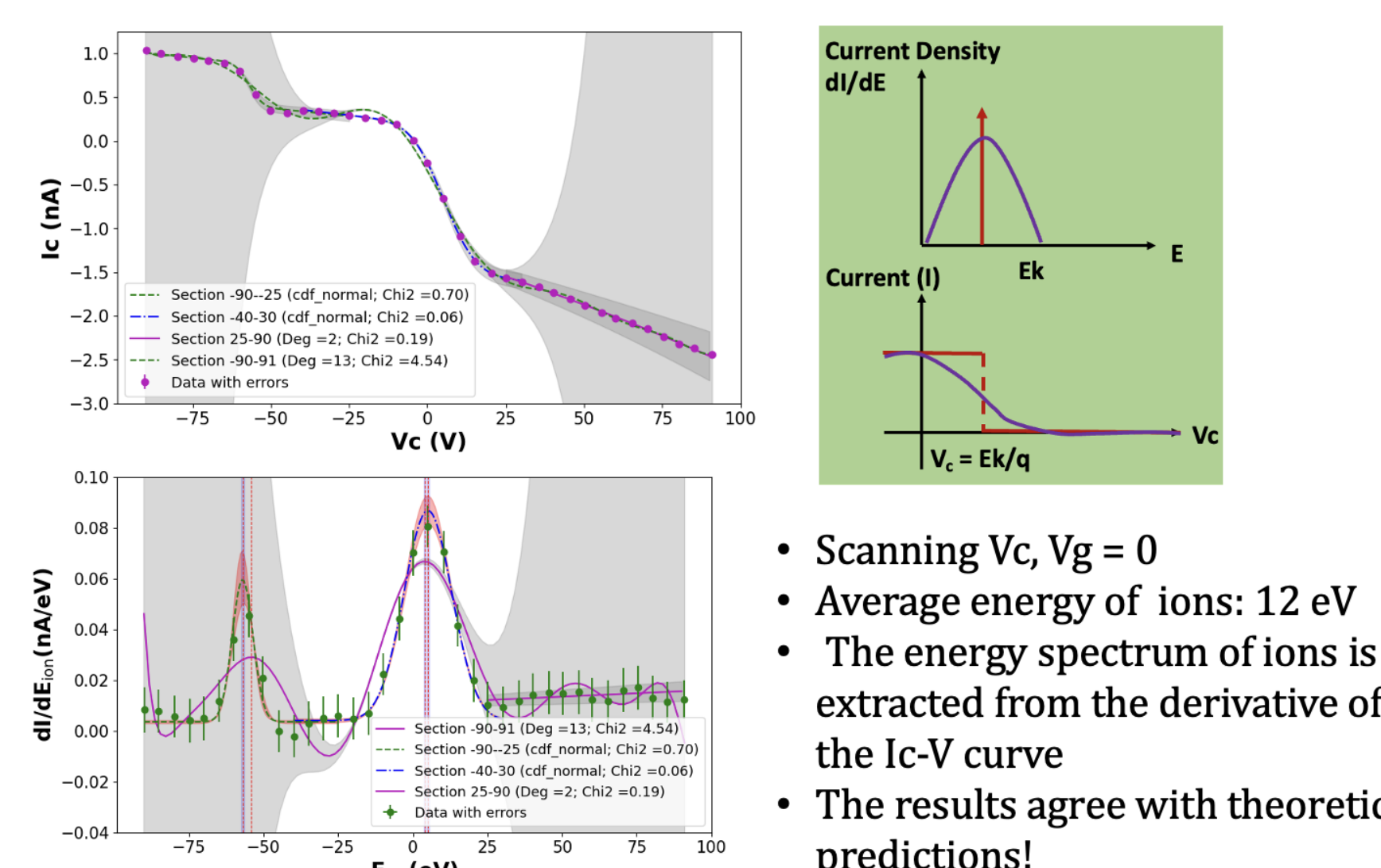
Trial 2: Improving Conductivity

- Conductive plastic filament: standard ESD-PLA with multiwall carbon nanotubes
- Printed out blocks (0.5x1x0.5 cm³) with different printer settings:
 - Speed of the nozzle
 - Height extrusion
 - Bed Temperature
 - Nozzle Temperature
- Tested the resistivity of the blocks and calculated volume resistivity
- Optimized the settings to reach the lowest resistivity, for example, nozzle temperature at 260 °C.



Final Results: Volume resistivity decreased from ~10¹³ to 2.73x10⁵ ohm-cm. Now it can be considered conductive!

Results



- Scanning Vc, Vg = 0
- Average energy of ions: 12 eV
- The energy spectrum of ions is extracted from the derivative of the Ic-V curve
- The results agree with theoretical predictions!

Conclusions and Future Plans

- The 2nd Faraday cup has the capability to detect energy spectrums and was successful during testing
- Both the second models of the Faraday cup and electron gun have good potential!
- Future Plans:**
 - Simulate the electron gun-Faraday cup system
 - Continue testing the electron gun-Faraday cup system with different filament currents, voltage ranges, angles, and an analyzer

Acknowledgements

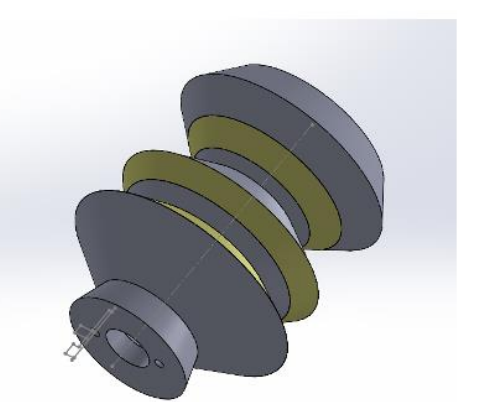
- Quetzal Larrick (University of Alaska Fairbanks Space Grant Lab Manager) – for being my mentor and guiding my project
- Dr. Denise Thorsen (Director of Alaska Space Grant) – for giving me the opportunity to work in the lab
- My parents – for supporting and encouraging me in this project

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Trial 2: Improving Design

- Modeled thicker insulator layers and used a stronger insulator: PVDF
- Tried thinner tungsten filament (0.002")
- Added smaller screws within the cathode
- Created a case for backscattering



Thermal Calculations

Calculated the radiation heat emitting from the filament

- Used Stefan Boltzmann's Law, Ohm's Law, and flux equations, and COMSOL
- Assumed surrounding temp is 293 K, and filament temp is 2000K.
- Result:** The radiation of the filament at the surrounding plastic was around 45 Celsius (acceptable range)

