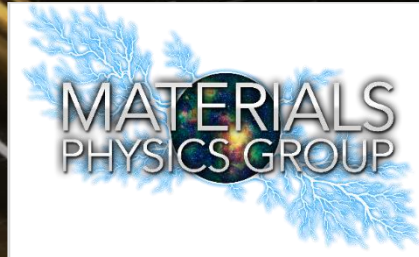


# Plasma Deflection Test Setup for E-Sail Propulsion Concept

Allen Andersen  
Jason Vaughn  
Todd Schneider  
Ken Wright



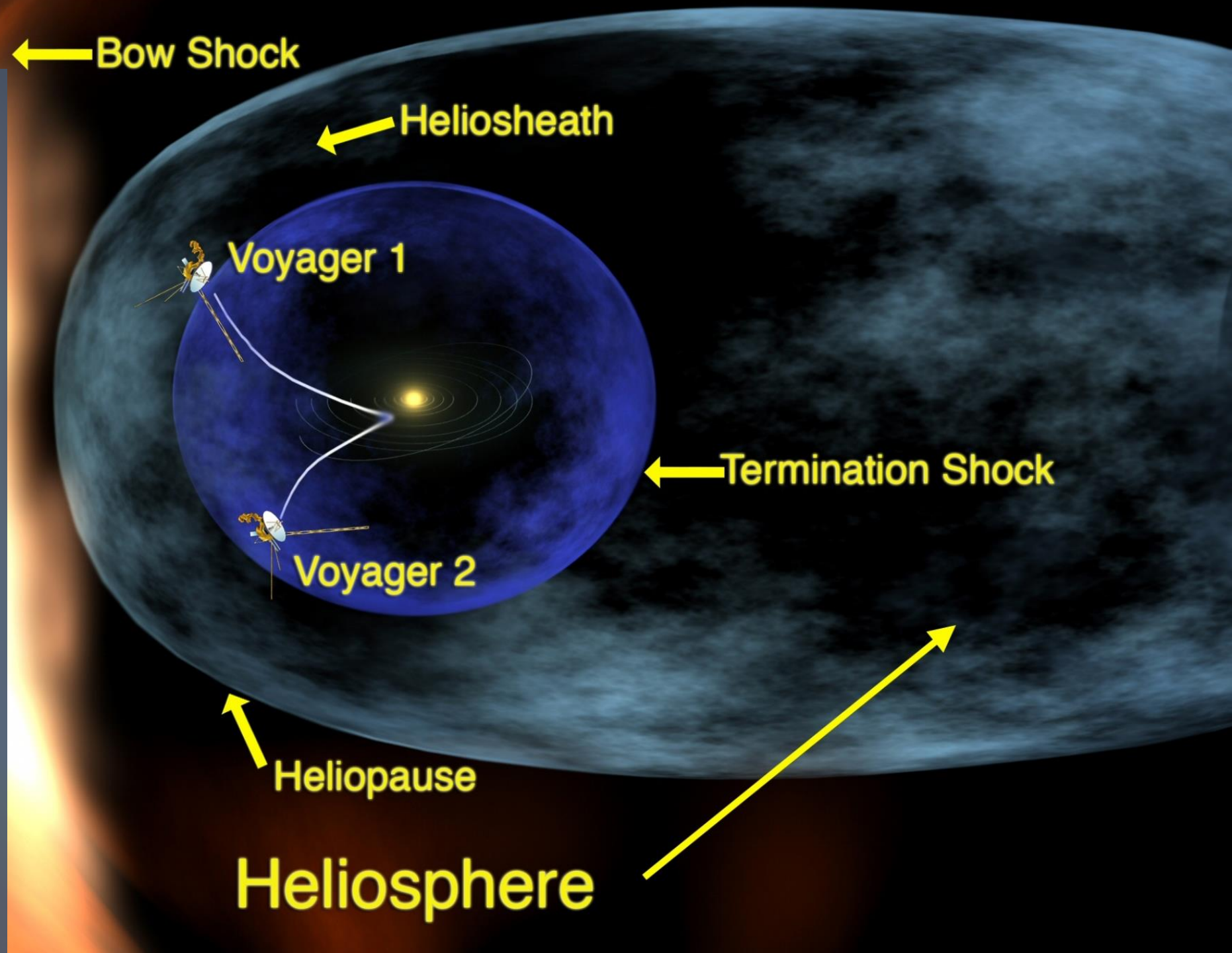
# Many Thanks!



# HERTS

The Heliopause Electrostatic Rapid Transit System (HERTS) mission will use E-Sail propulsion to reach the Heliopause in ~10 years.

An E-Sail achieves thrust with many positively charged conductors, each 10-30 km in length, exchanging momentum with fast solar protons. The spacecraft potential will be maintained via an onboard electron gun.



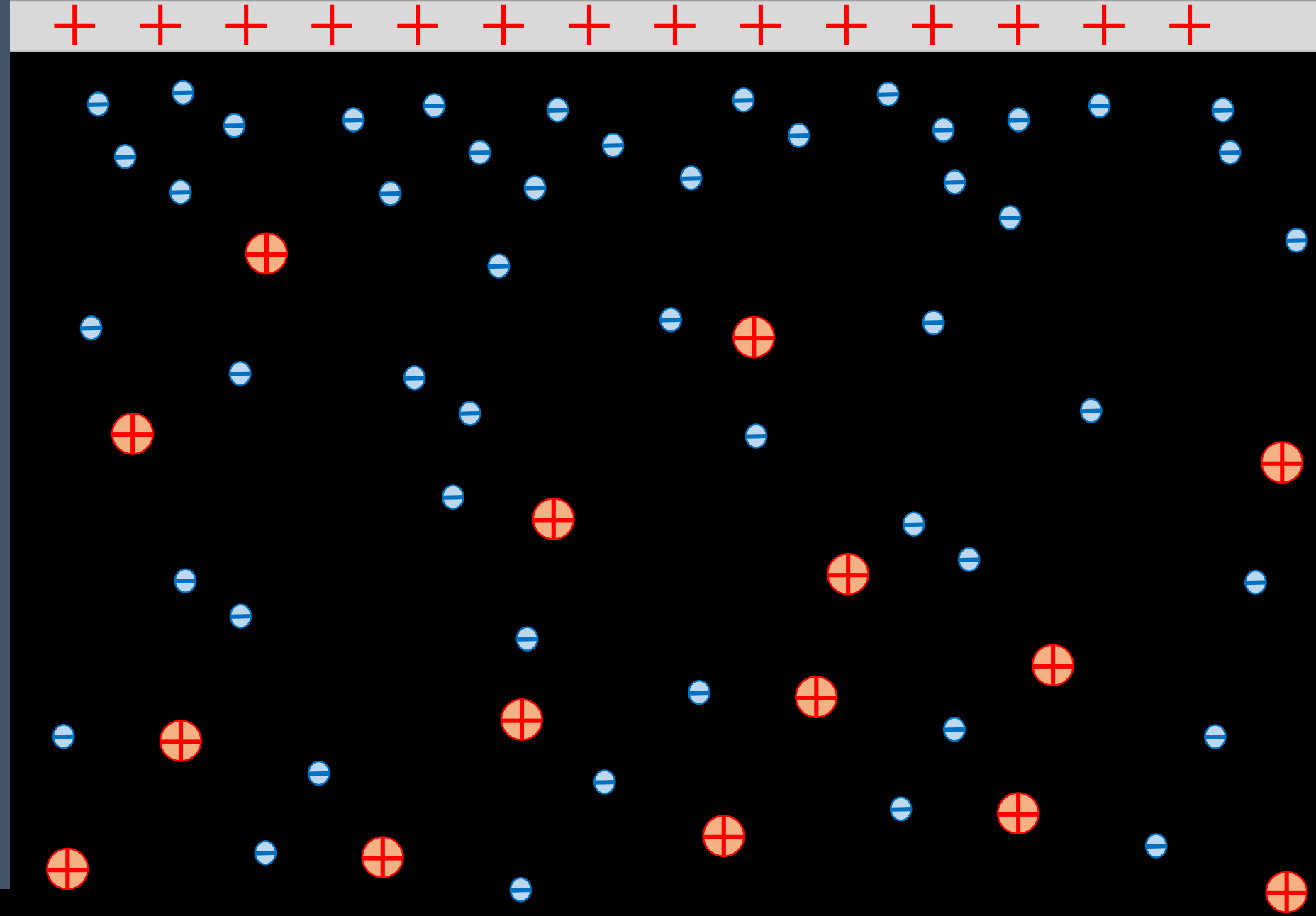
# Debye

## Shielding

Consider a charged conductor in a plasma.

Boundary conditions:

- High potential at the conductor.
- Zero potential at infinity.



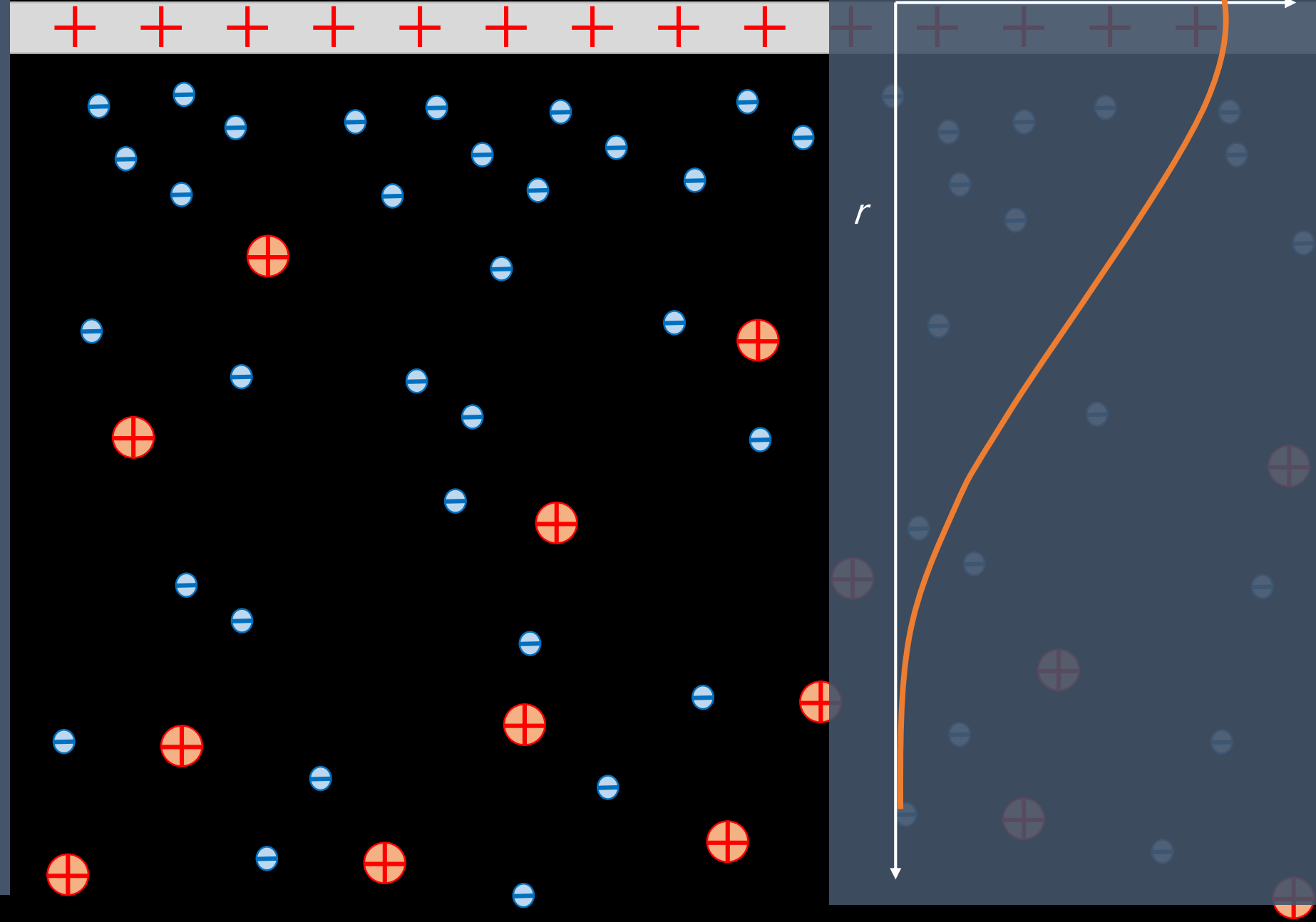
# Debye

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# Debye

## Shielding

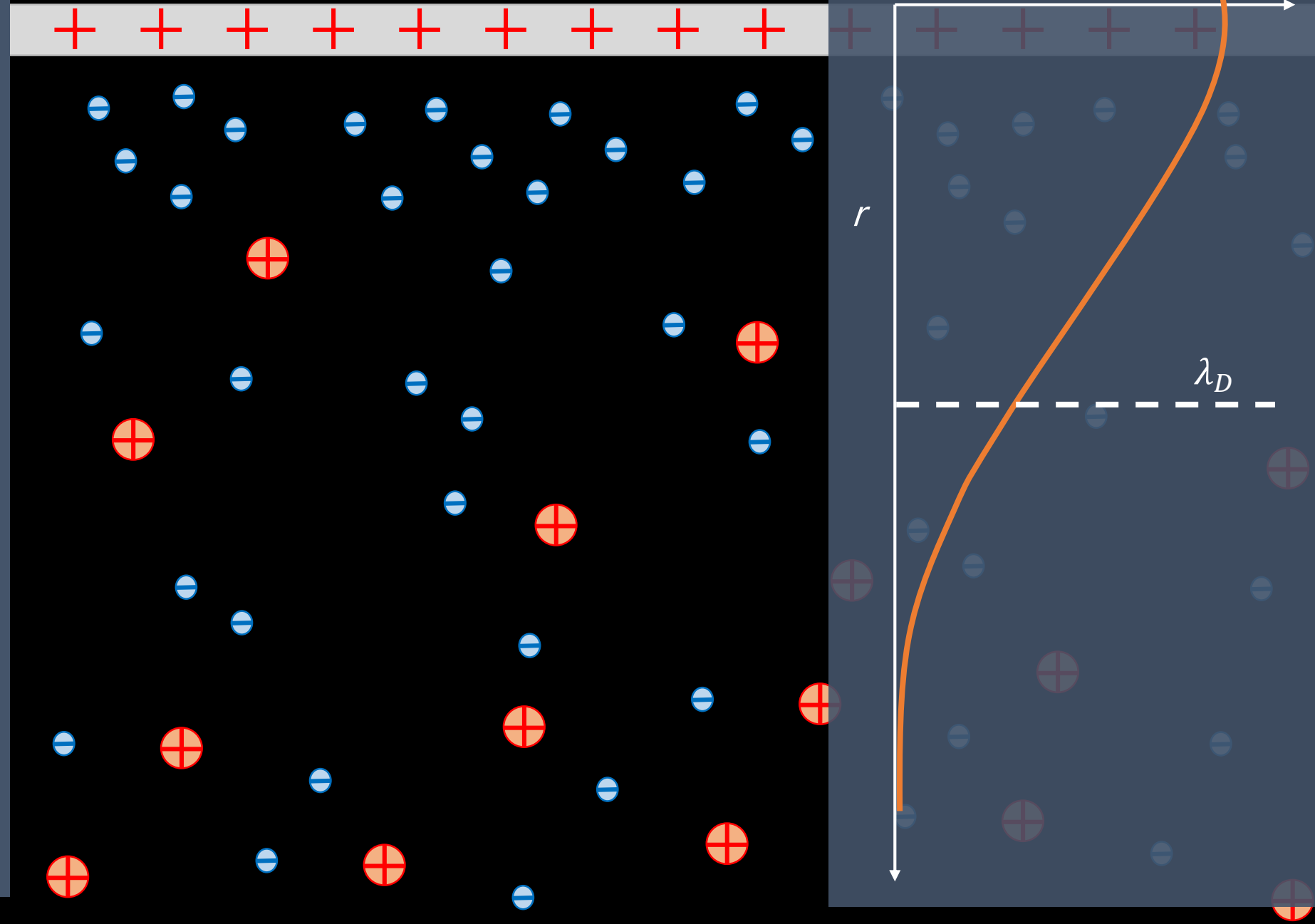
Consider a charged conductor in a plasma.

Boundary conditions:

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Solving Poisson's Equation for cold ions gives the characteristic length

$$\lambda_D = \left( \frac{\epsilon_0 k T_e}{n_0 q_e^2} \right)^{\frac{1}{2}}$$



# Debye

## Shielding

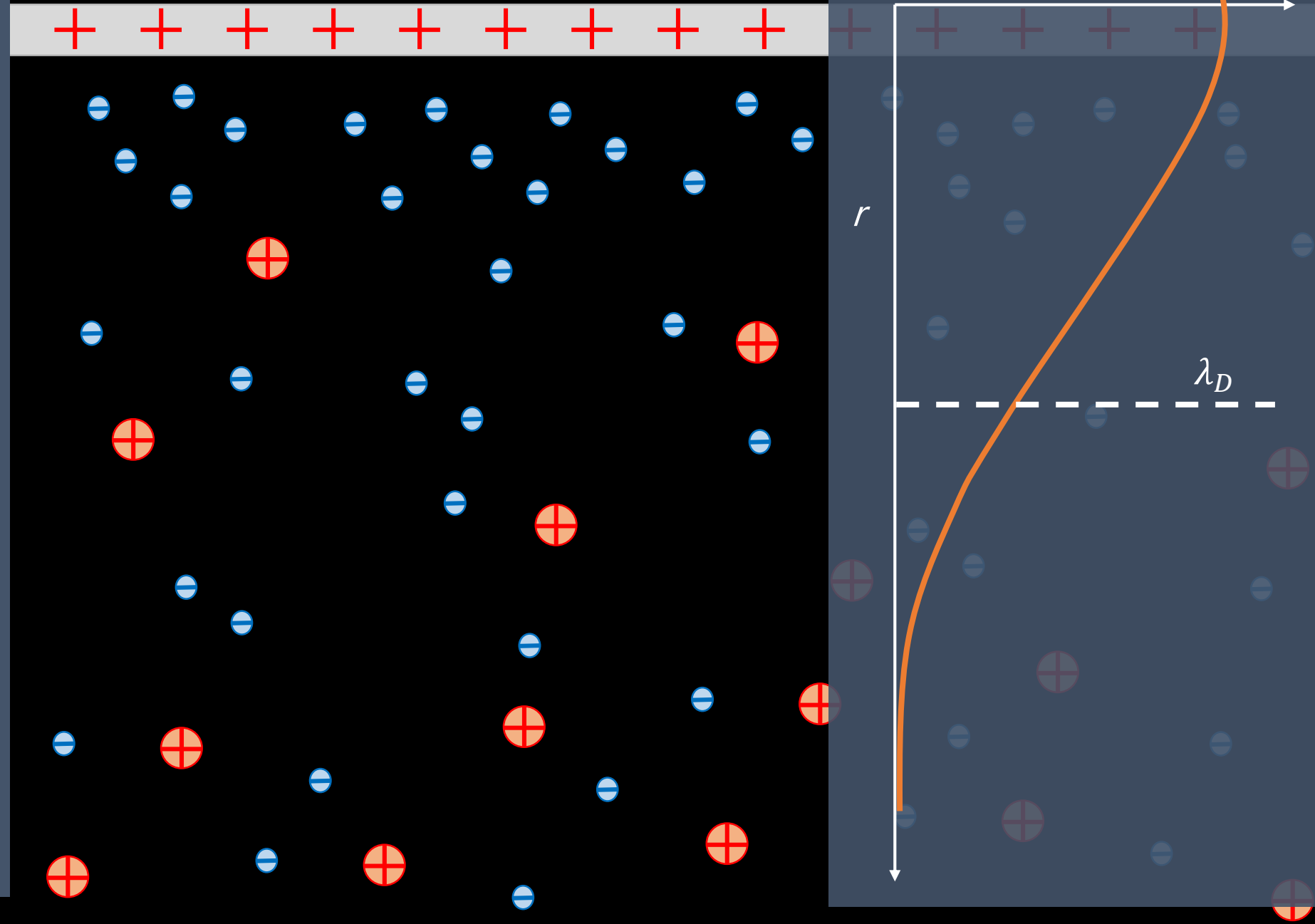
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# E-Sail

Negatively biased wires in plasmas have been extensively studied and flown, however, positively biased wires in a plasma are not as well understood.

Advanced Particle In Cell (PIC) computational plasma models are used to estimate thrust per unit length of E-sail conductor.

Key assumptions of the PIC model calculations for plasma deflection by a positive conductor need to be tested by laboratory experiments.



# Test Plan

- Set up Differential Ion Flux Probe (DIFP) in plasma chamber.
- Verify the function and angular response of the DIFP.
- Map the free stream plasma.
- Test with test body in place (positively charged conductor).

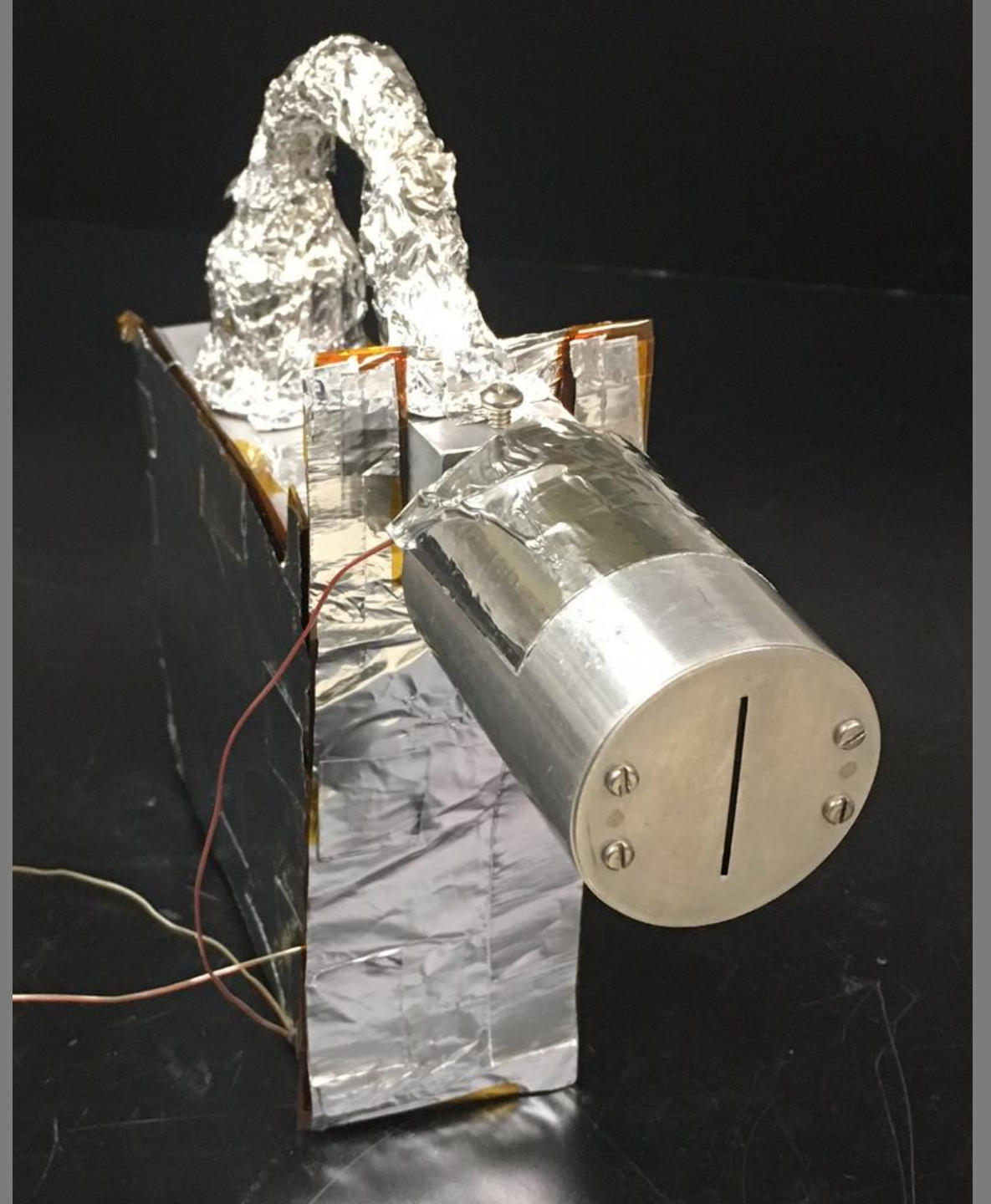
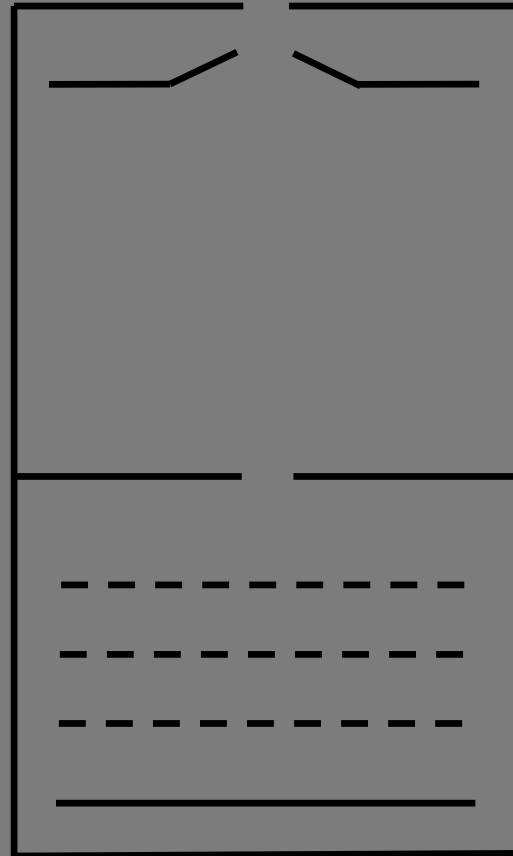


DIFP

Differential

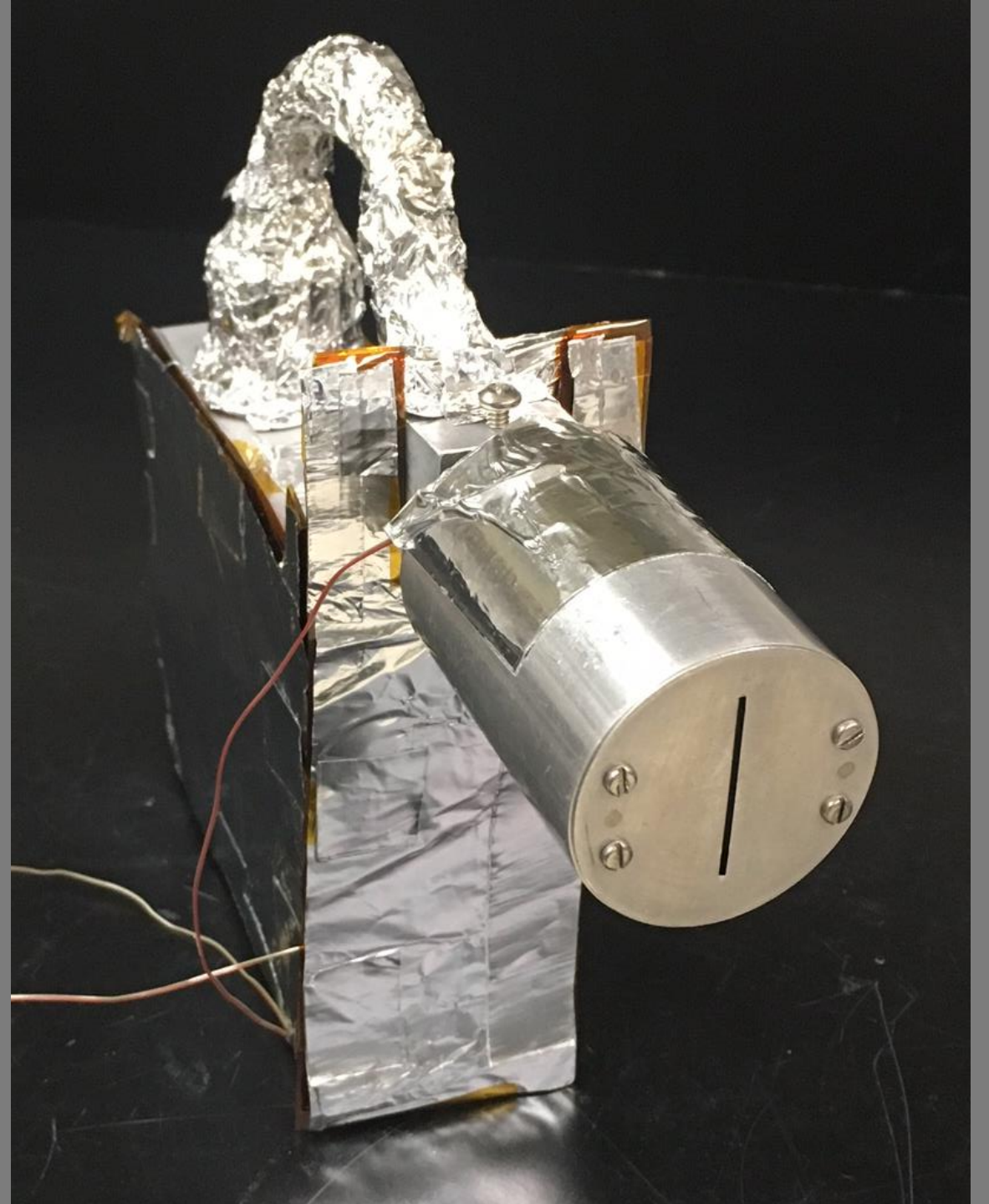
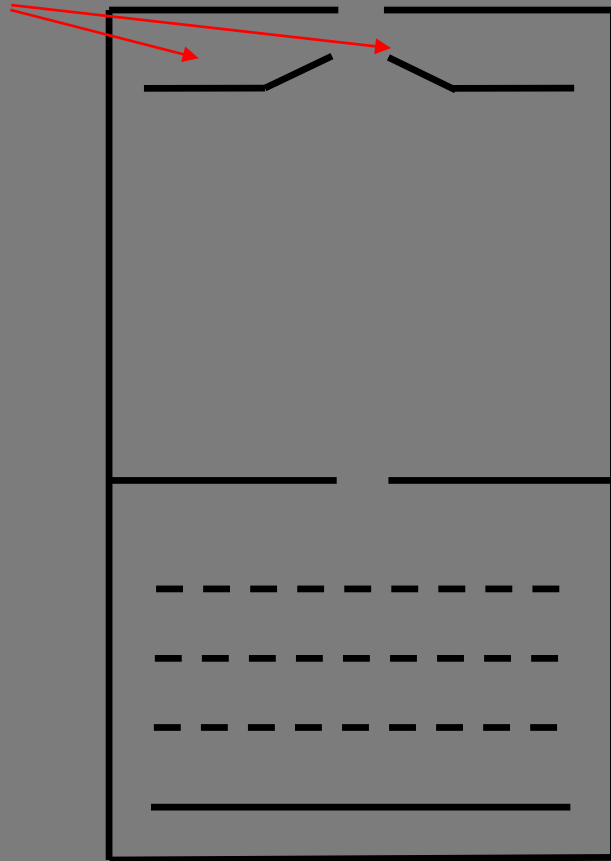
Ion Flux

Probe



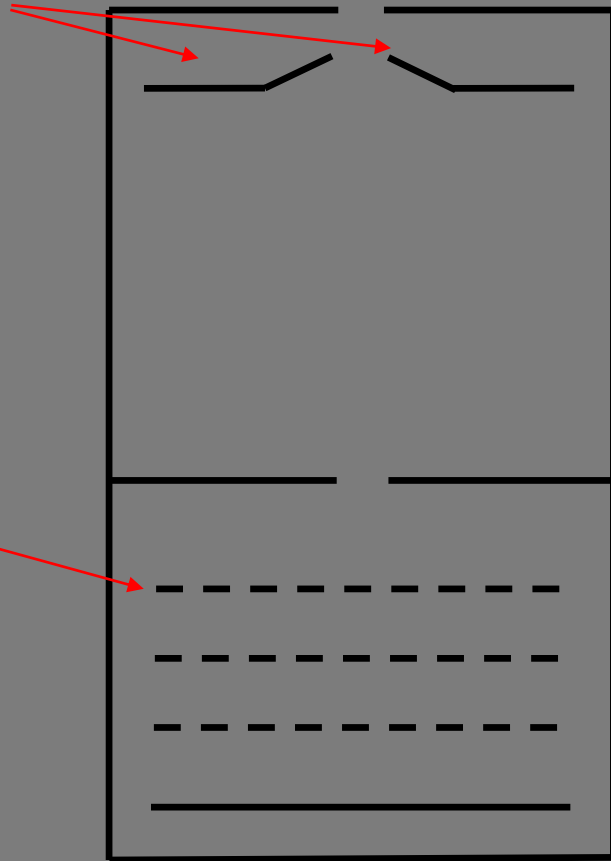
# DIFP

Deflection Plates

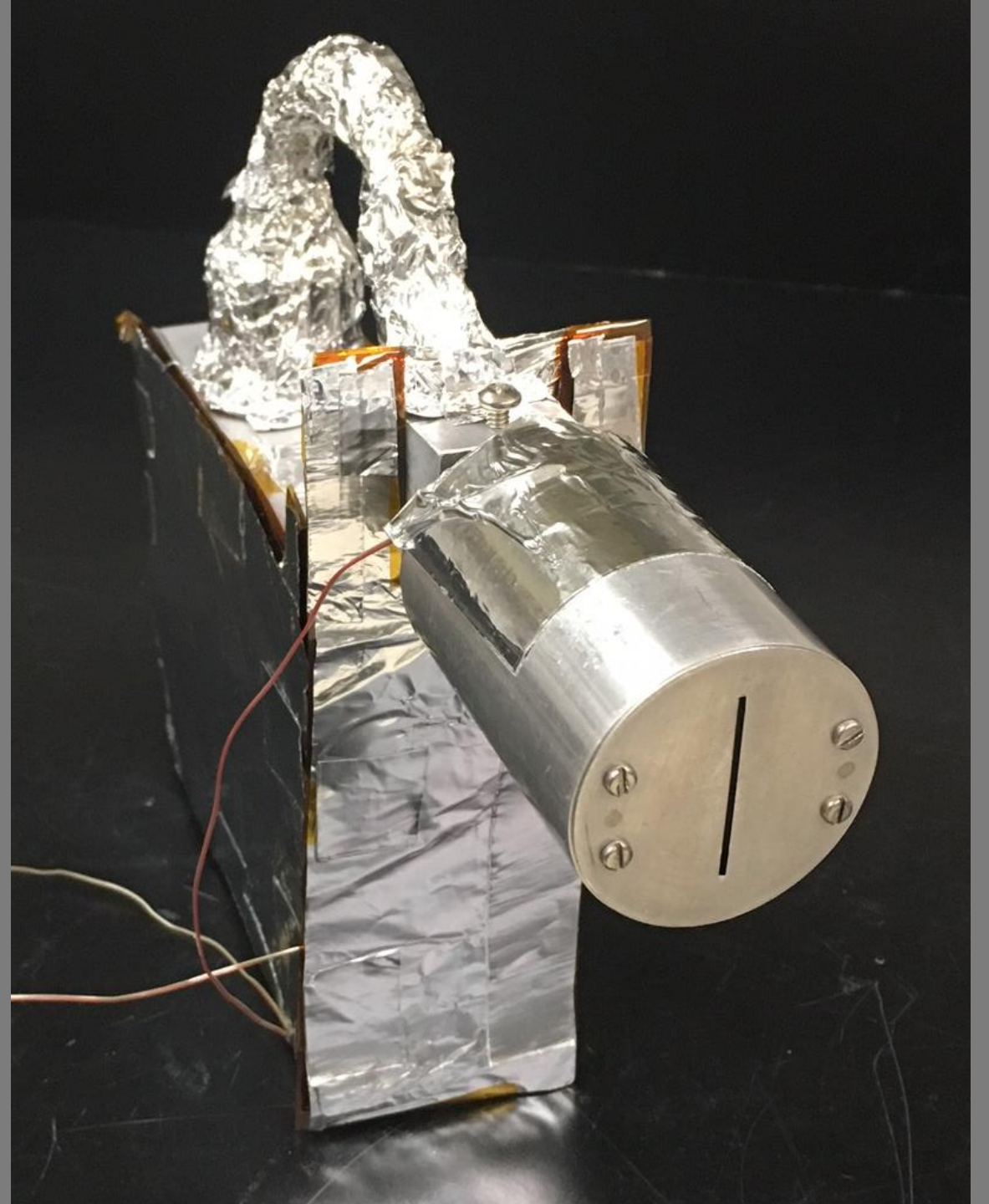


# DIFP

Deflection Plates

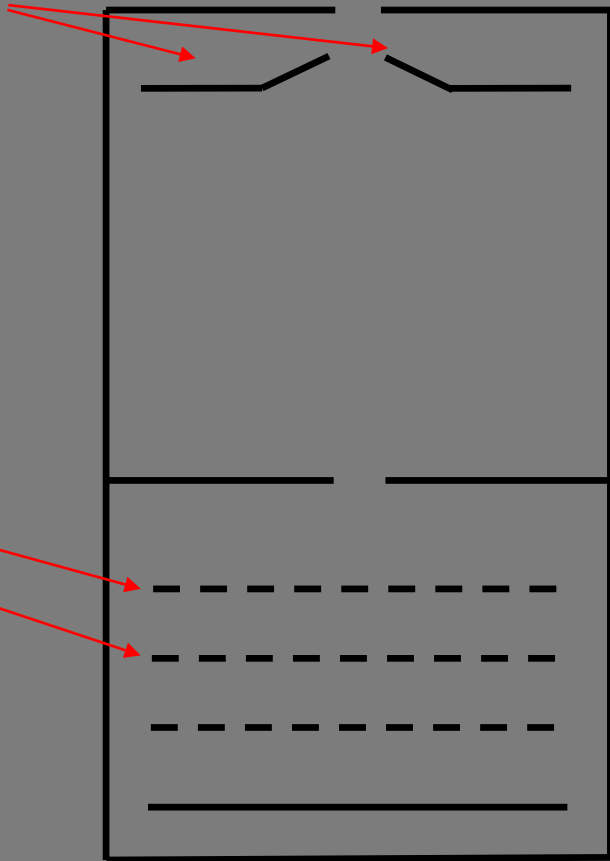


Repeller Grid

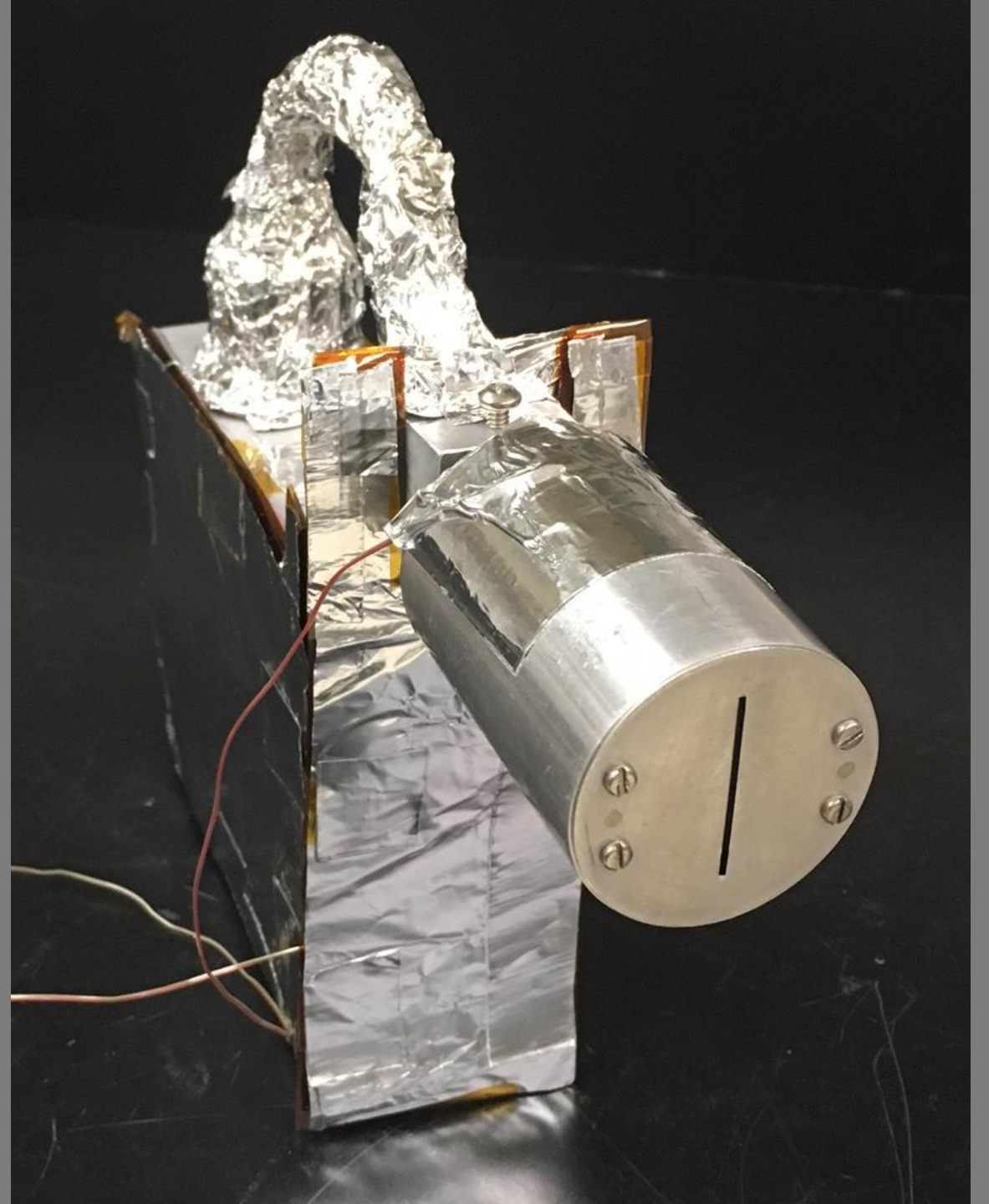


# DIFP

Deflection Plates

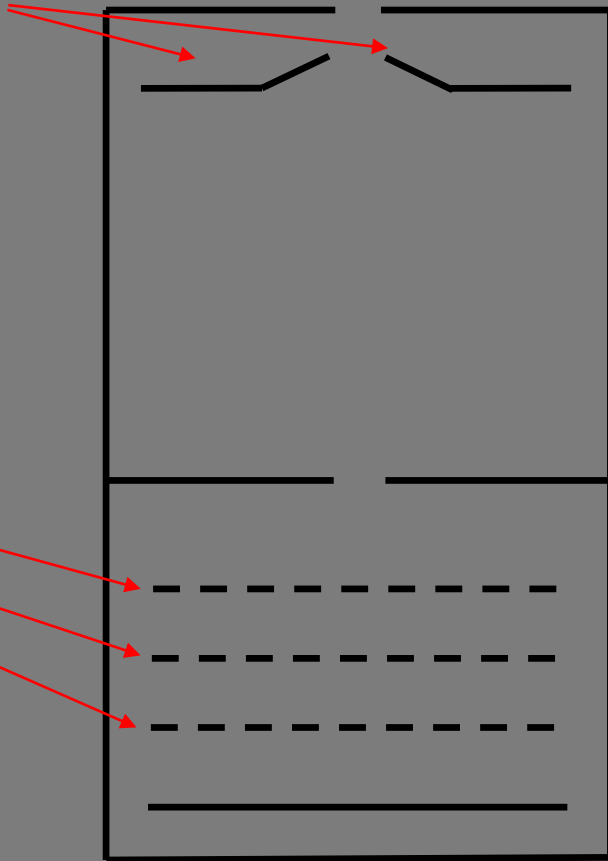


Repeller Grid  
Retarding Grid



# DIFP

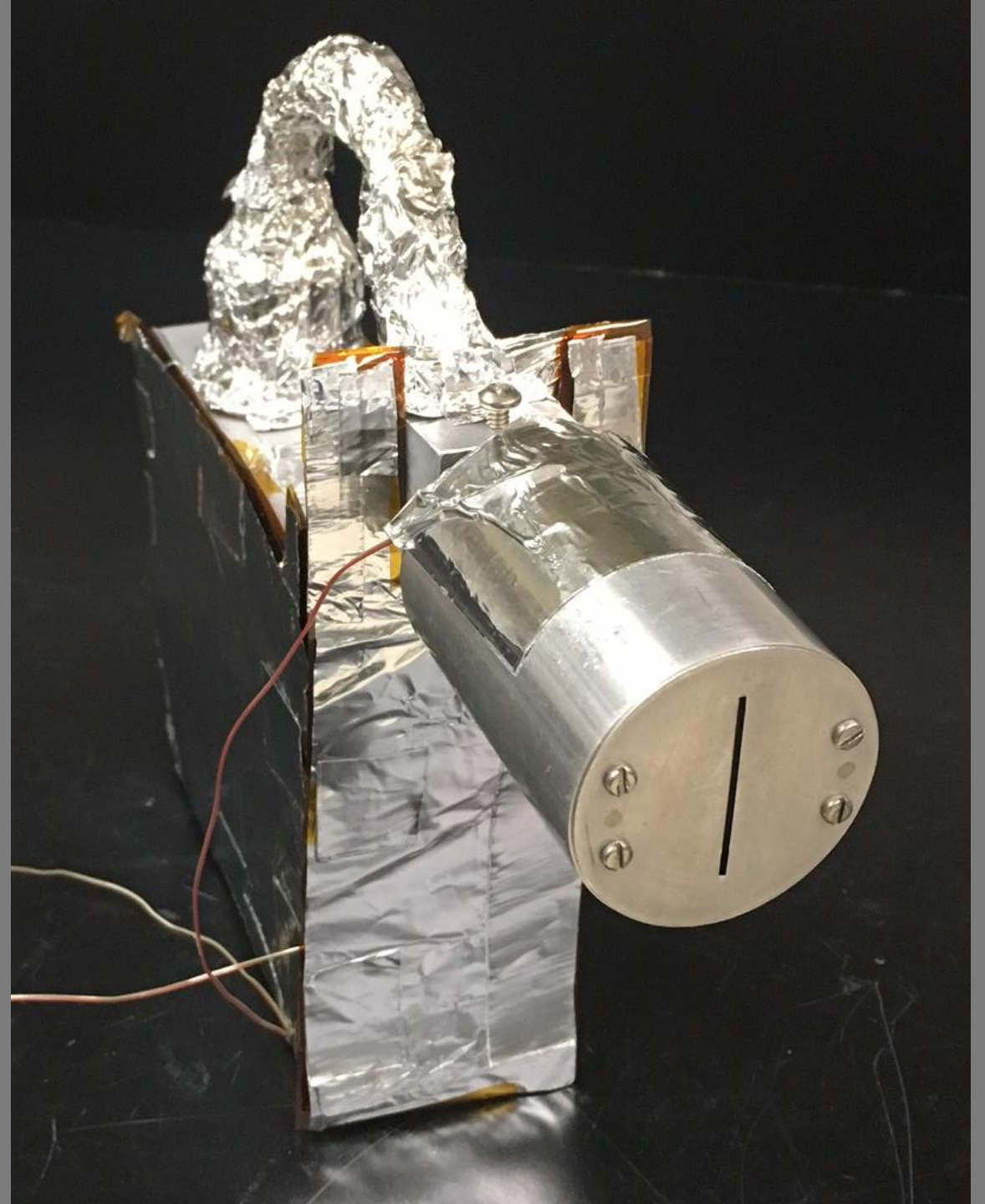
Deflection Plates



Repeller Grid

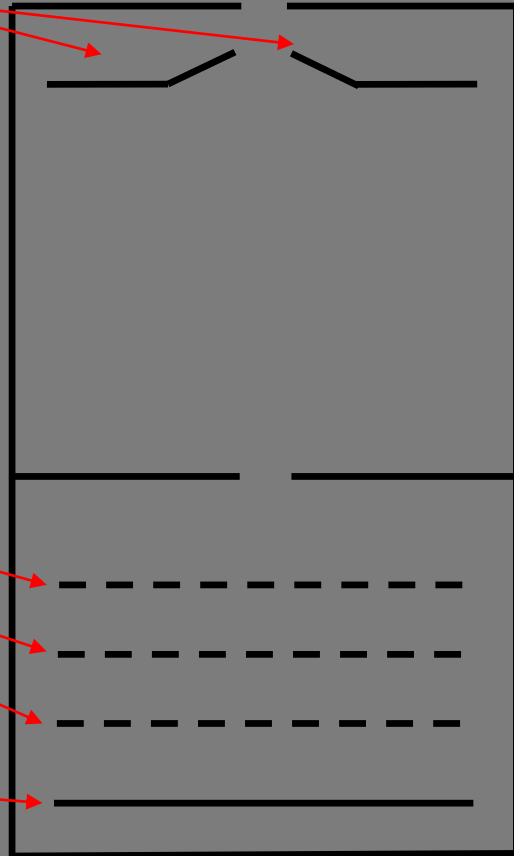
Retarding Grid

Suppressor Grid



# DIFP

Deflection Plates

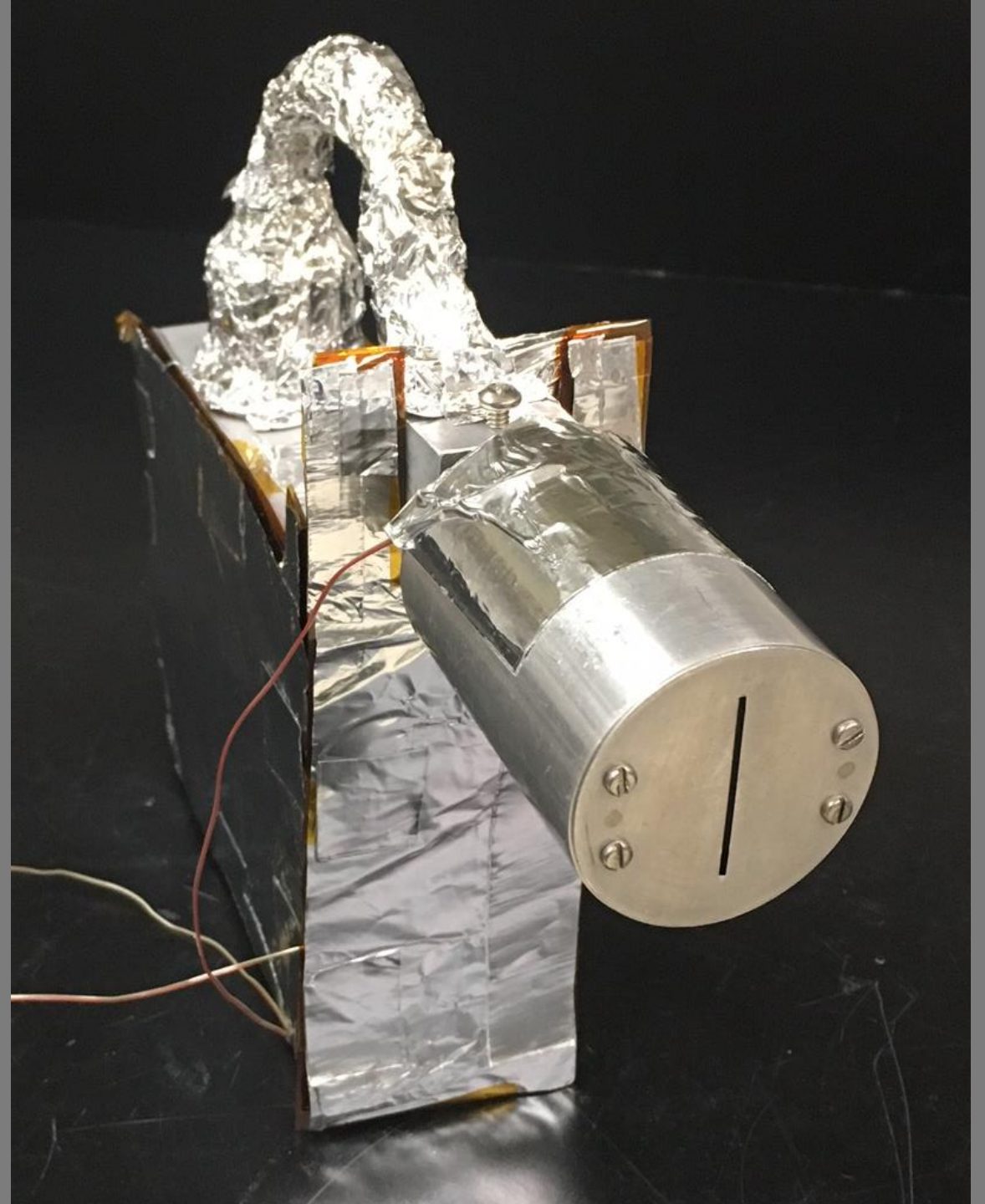


Repeller Grid

Retarding Grid

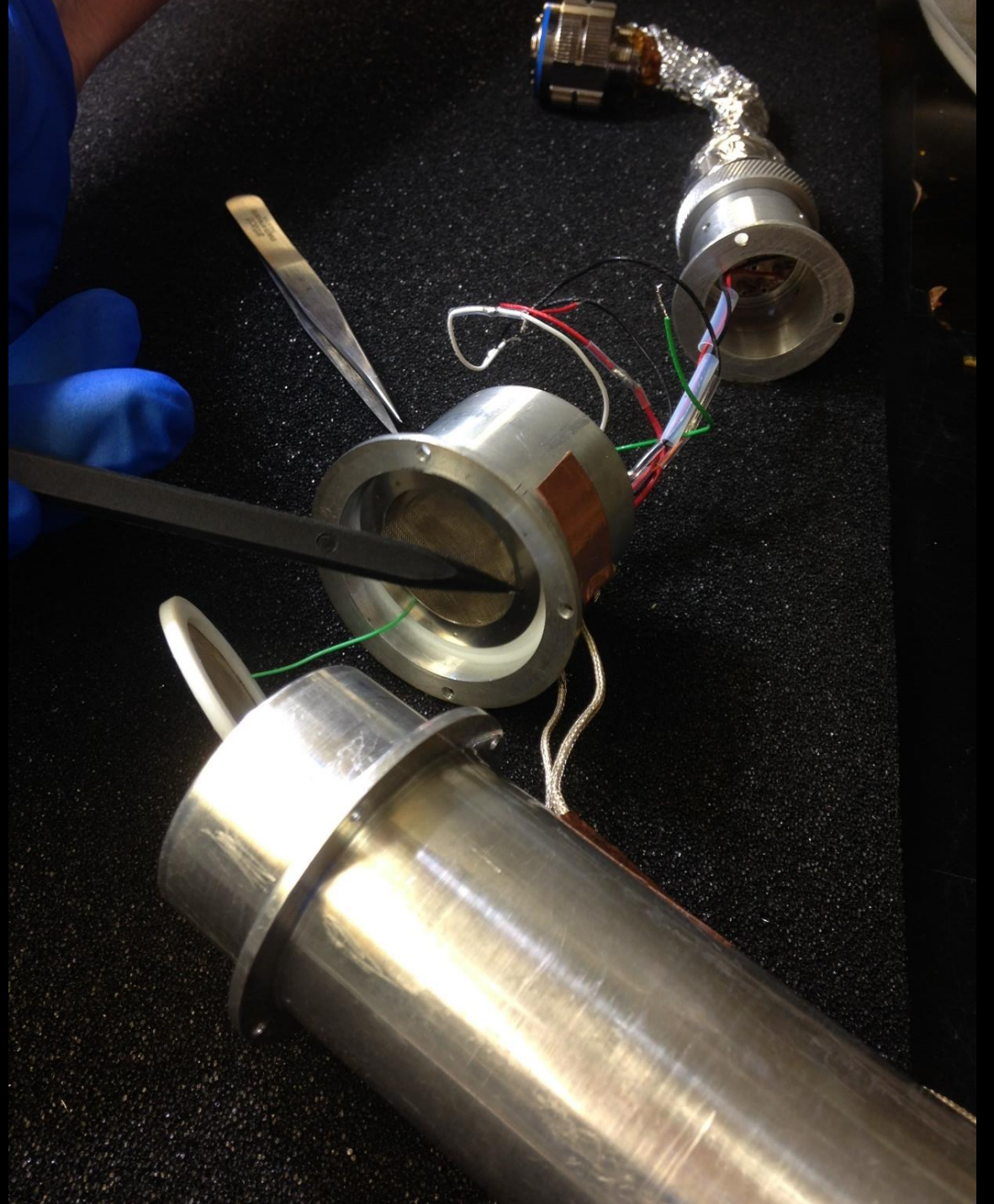
Suppressor Grid

Collector



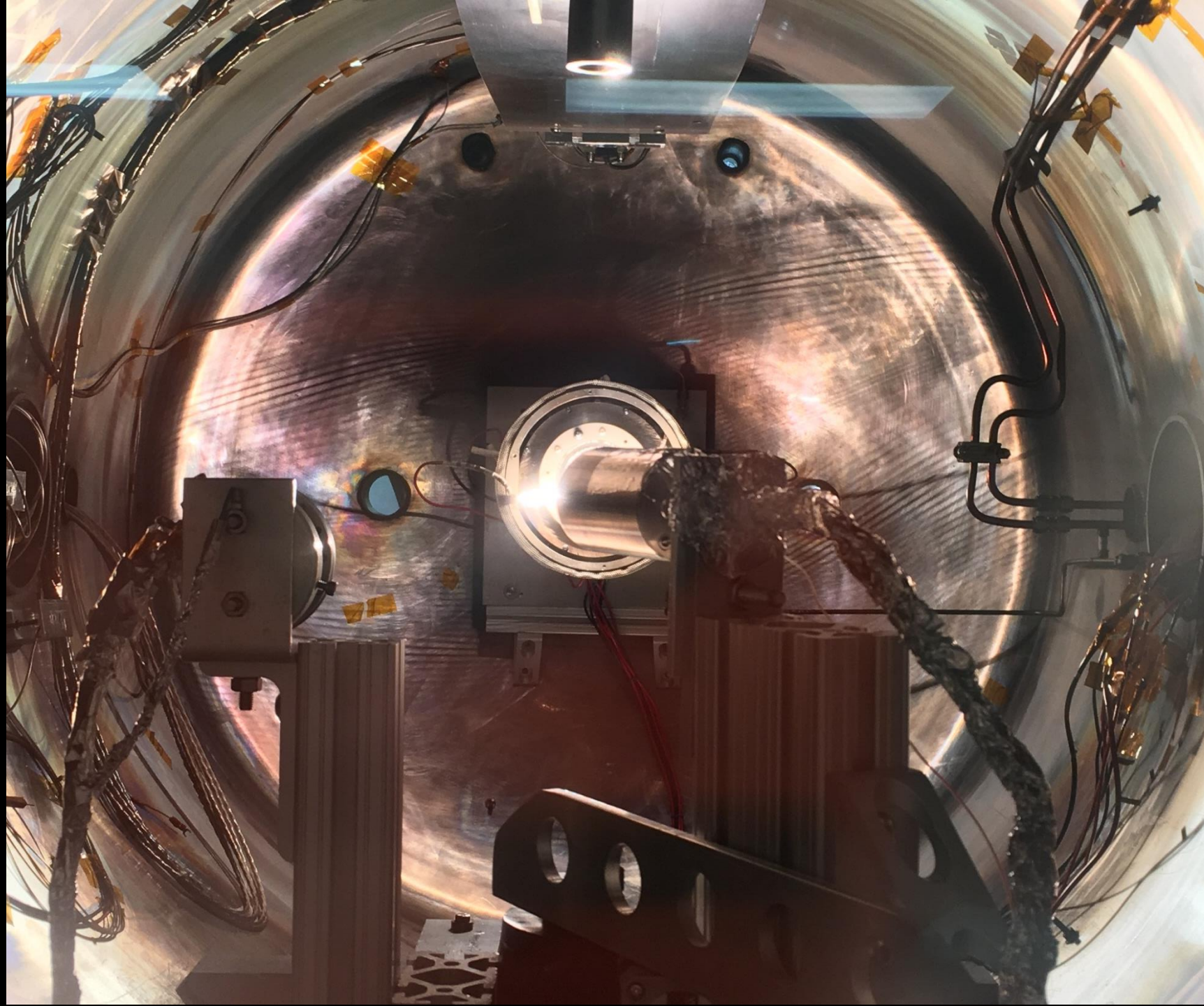
# DIFP Challenges

- Alignment and mounting
- Electronics issues
- New LabVIEW control and data acquisition
- Thermal Issues



# Solutions

- Significant Electronics Troubleshooting
- Rudimentary MLI thermal shielding was added.
- Temperature sensitive electronics box moved to the chamber floor.
- Additional thermal shielding.

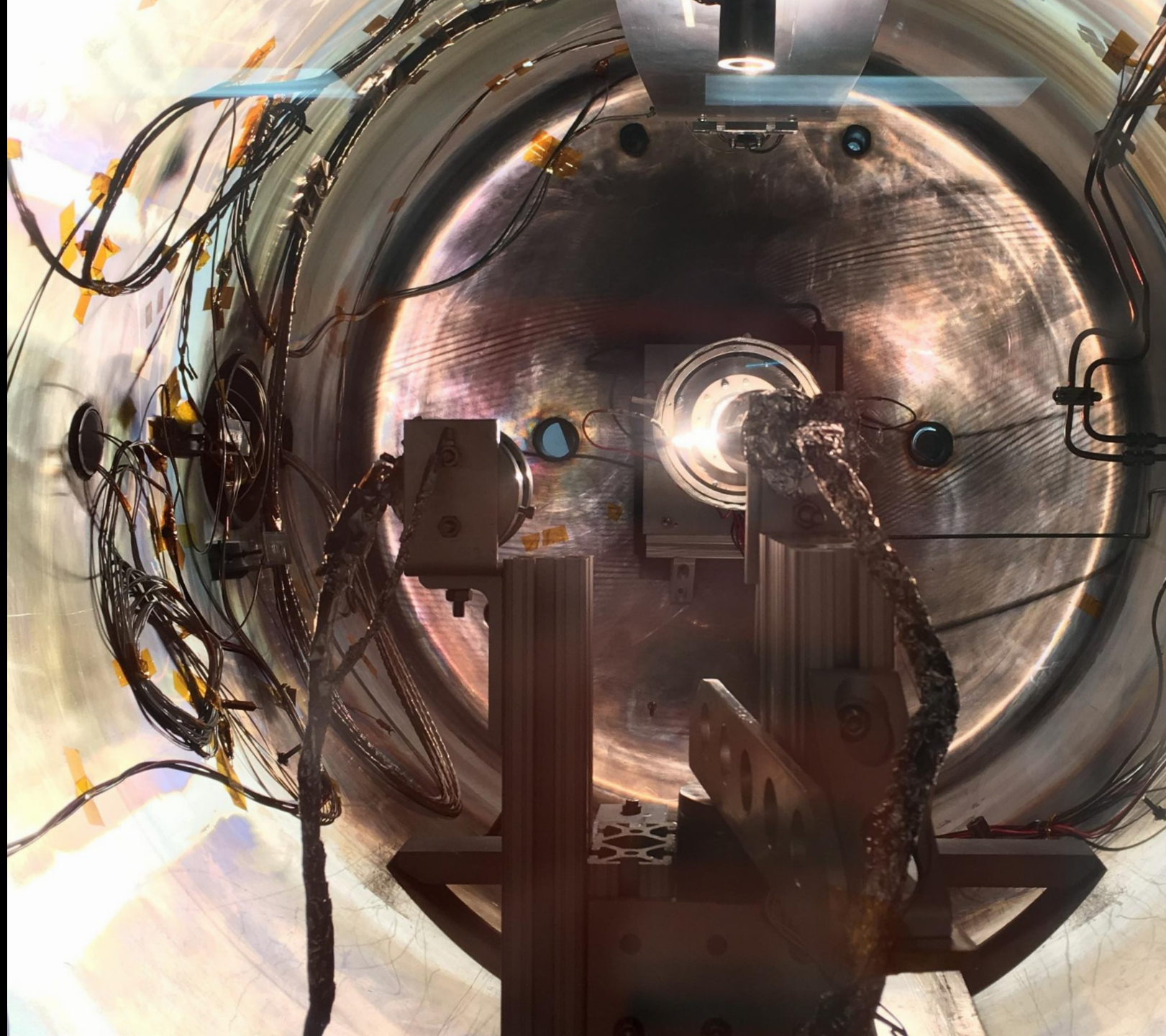


# DIFP

## Angle

## Calibration

- DIFP is rotated through a set of known angles in a free stream plasma.
- Voltage swept on deflection plates.
- The deflection plate voltage with the peak ion current corresponds to the angle of the DIFP with respect to the plasma stream.

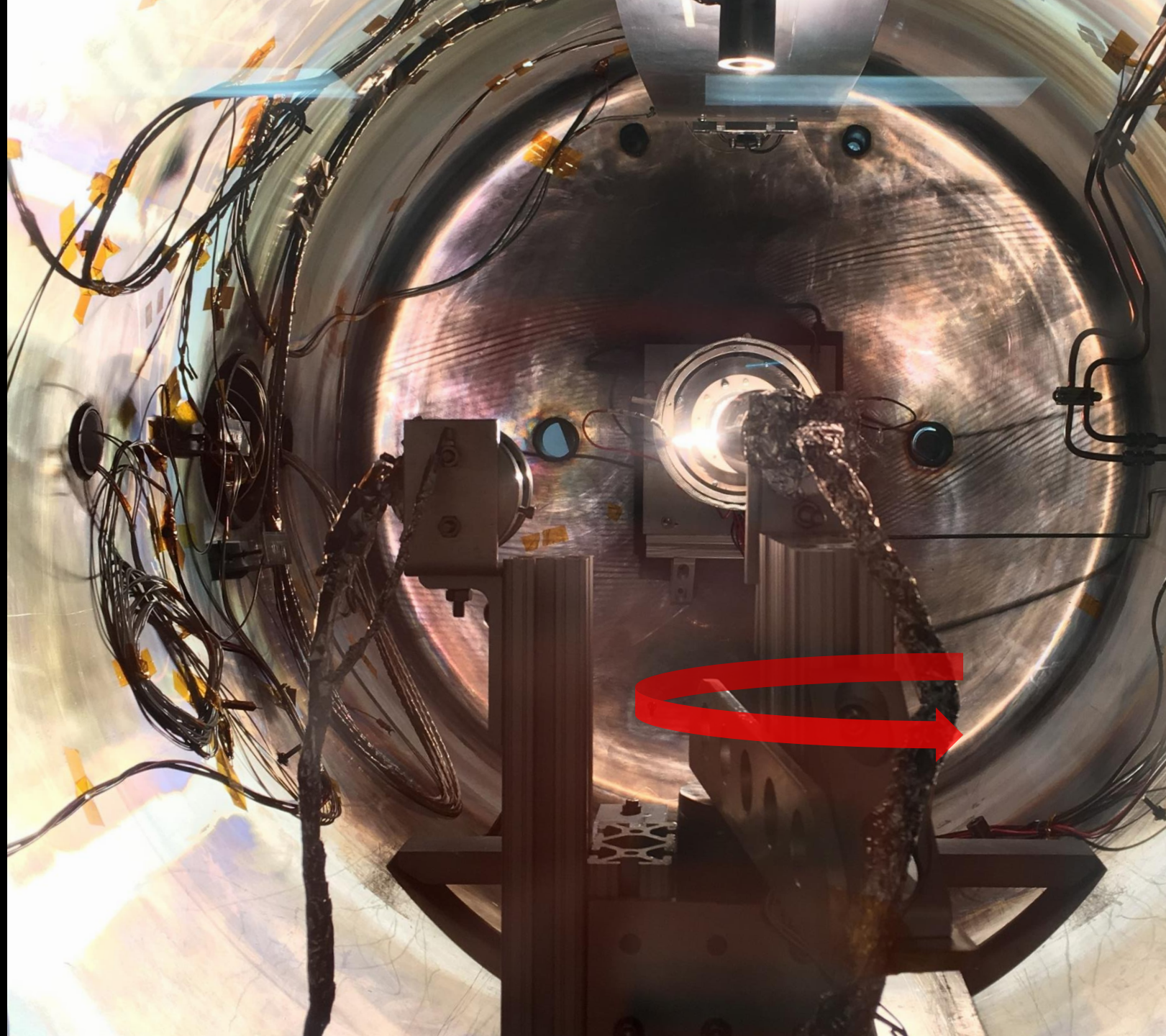


# DIFP

## Angle

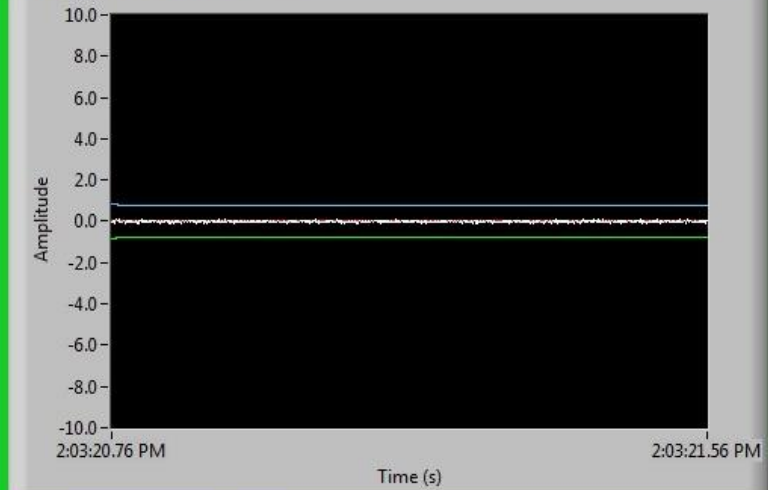
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File Settings DAQ Setup File Headers Deflection Sweep Settings Deflection Data RPA Sweep Settings RPA Data

Plates Coarse Steps Measurement

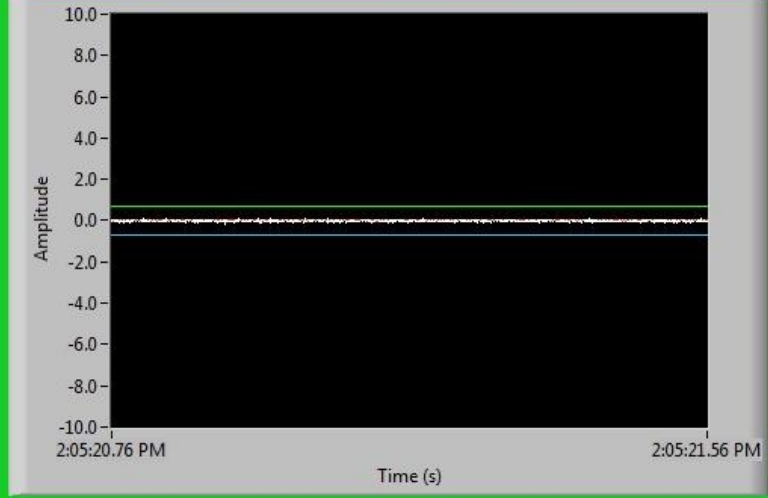


- Dev1/ai0
- Dev1/ai1
- Dev1/ai2
- Dev1/ai3

STOP



Plates Fine Steps Measurement



- Dev1/ai0
- Dev1/ai1
- Dev1/ai2
- Dev1/ai3

STOP

Power Supply Applied Voltage To Plates

15

Current Mean

-0.00835099

Grid Mean

0.144907

Plate 1 Mean

14.5677

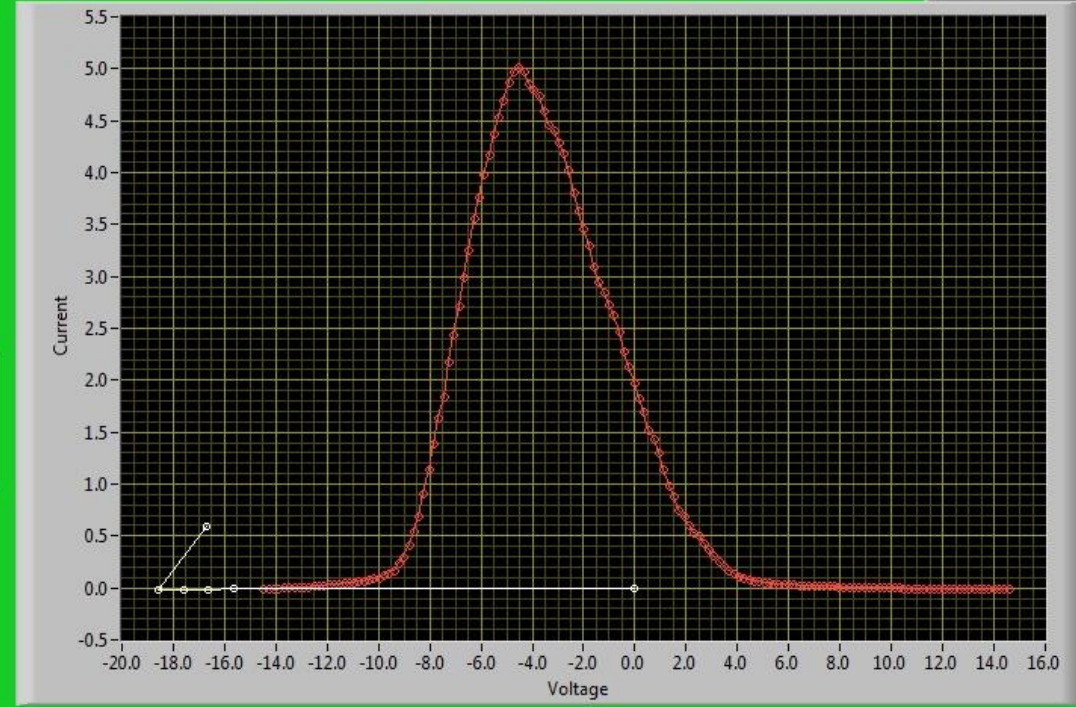
Plate 2 Mean

-14.3069

Deflector Plate +V  
XY Graph



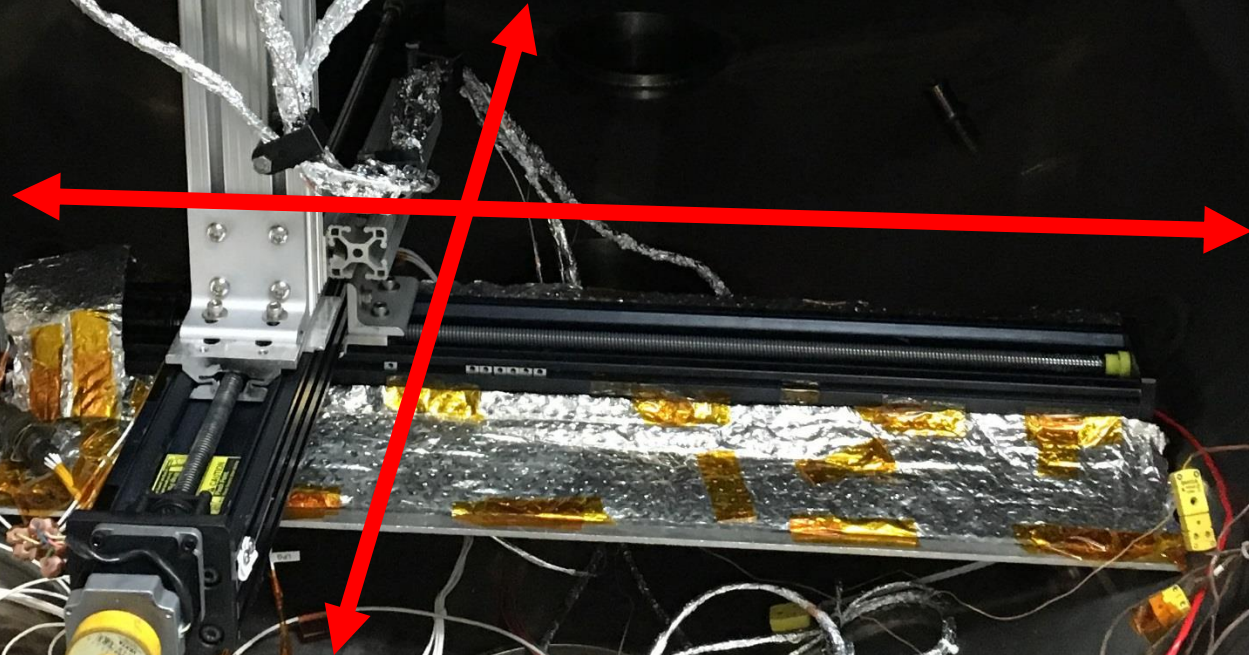
- Plot 0
- Plot 1



Free stream  
mapping



Free stream  
mapping

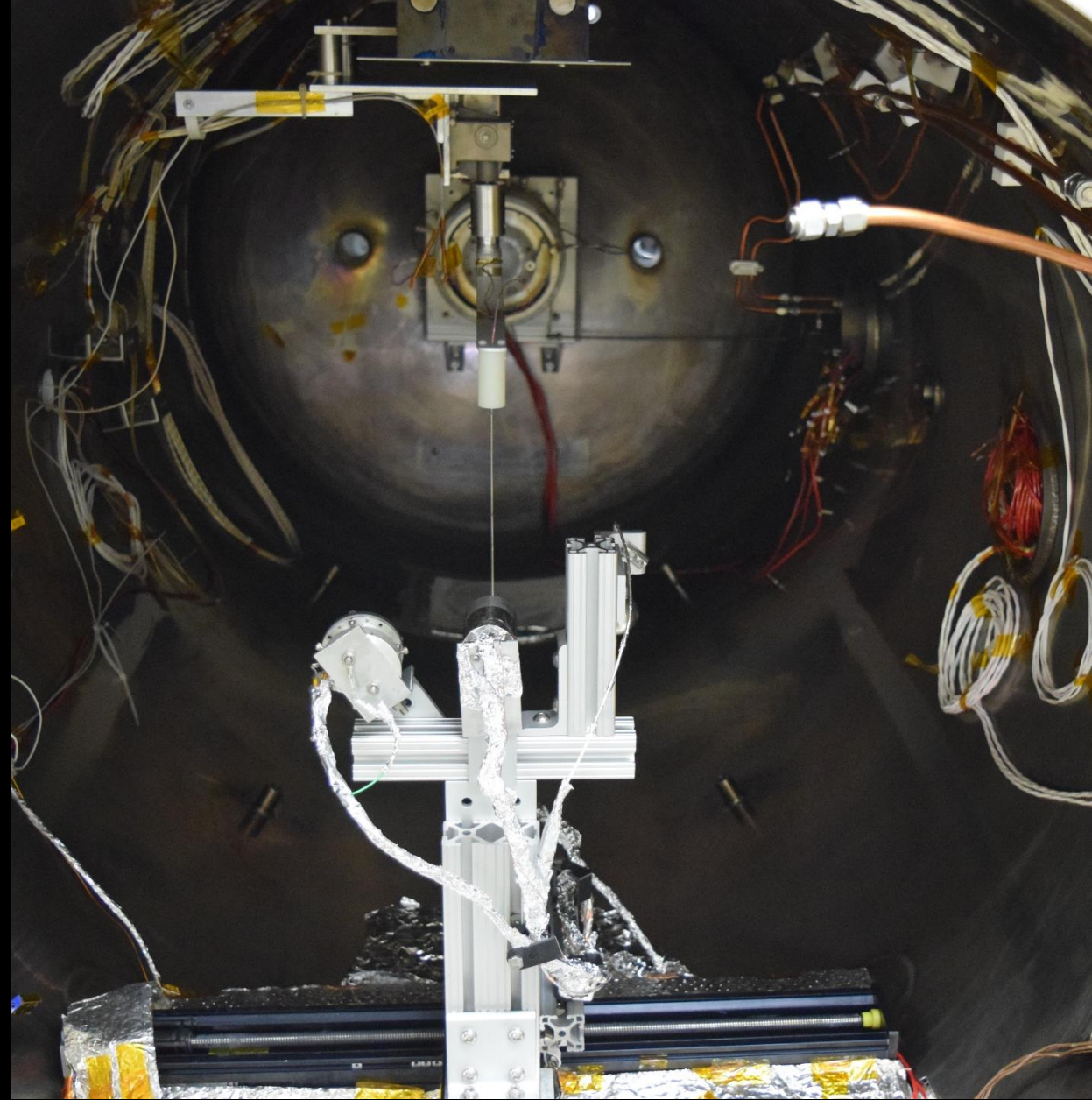


# Test Body in Place

The test body is attached to a rotating arm.

The test body is divided into three electrically isolated segments. All segments are held at the same potential, the center segment is attached to an ammeter.

Mapping the angles of the plasma with and without the test body is a measurement of the plasma sheath induced by the charged test body.

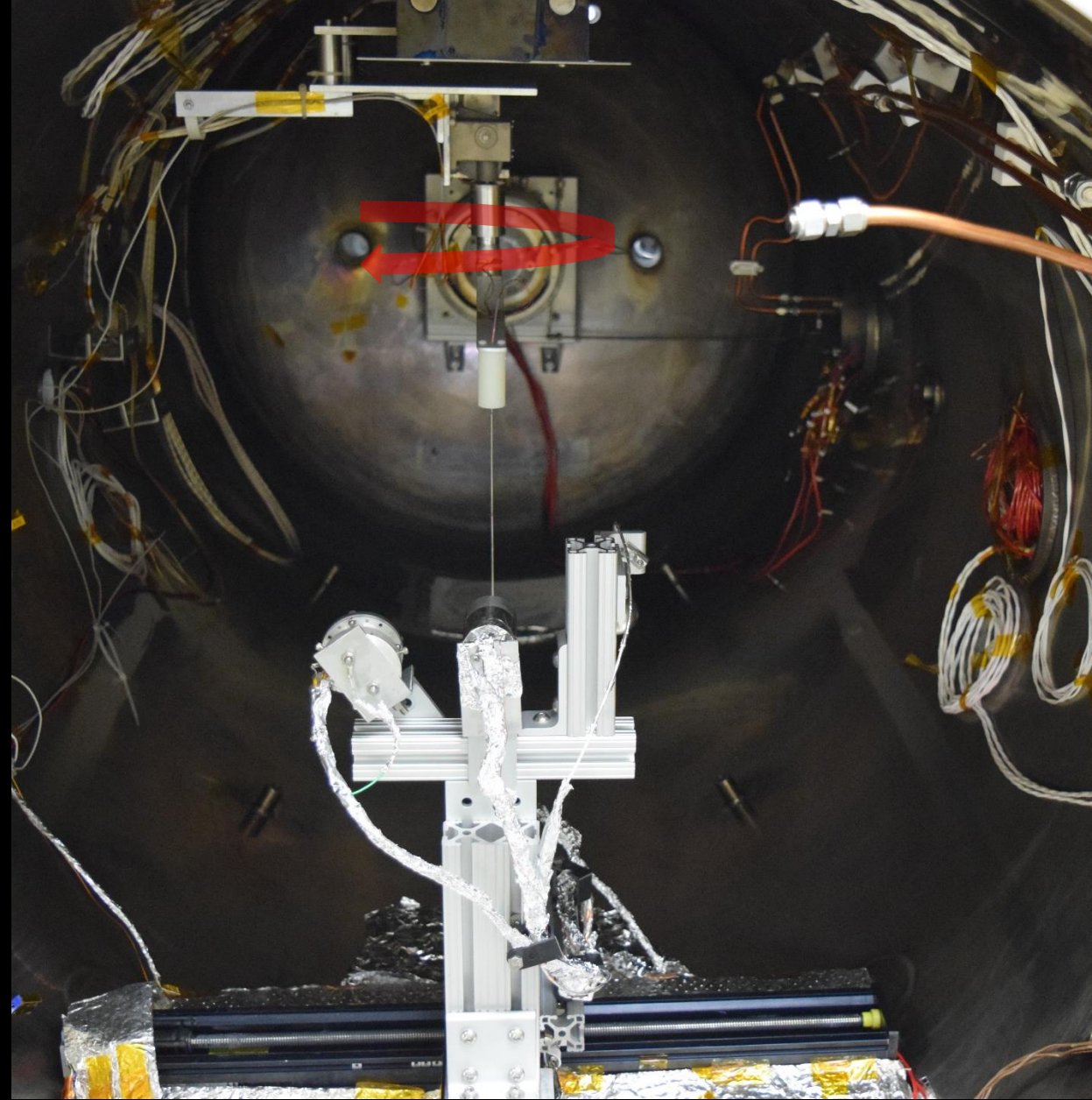
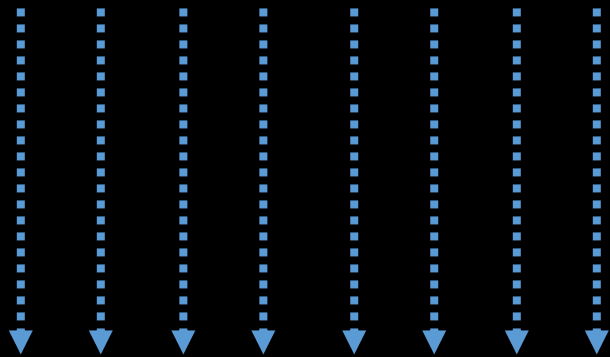


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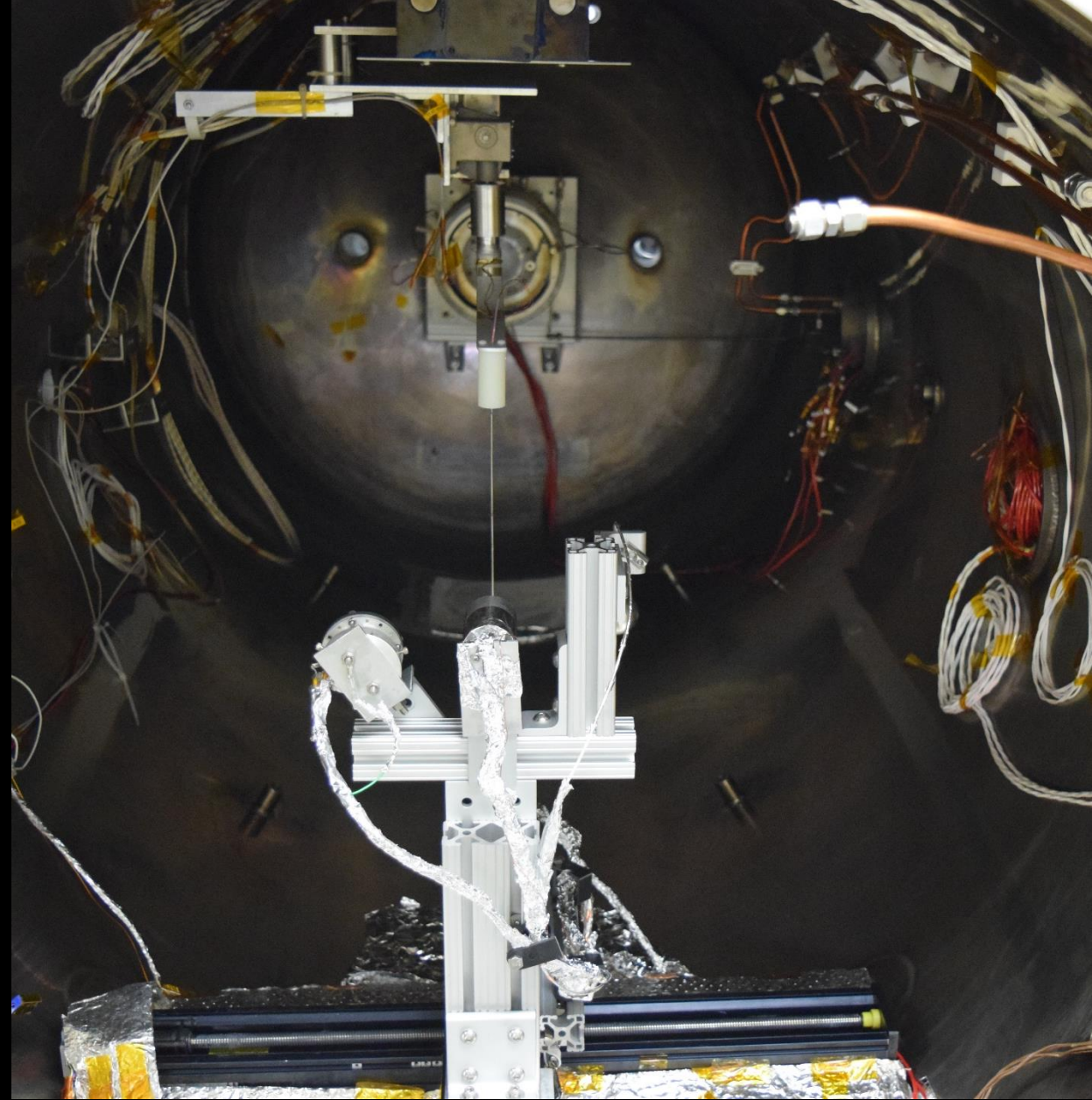
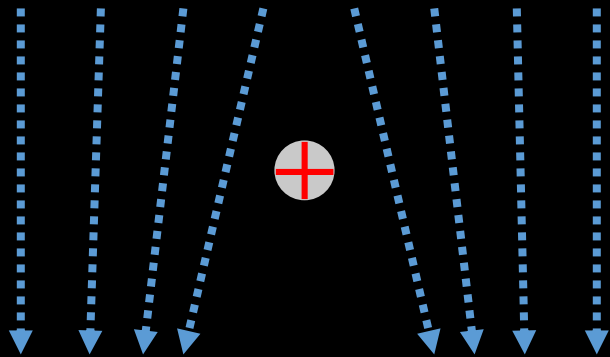


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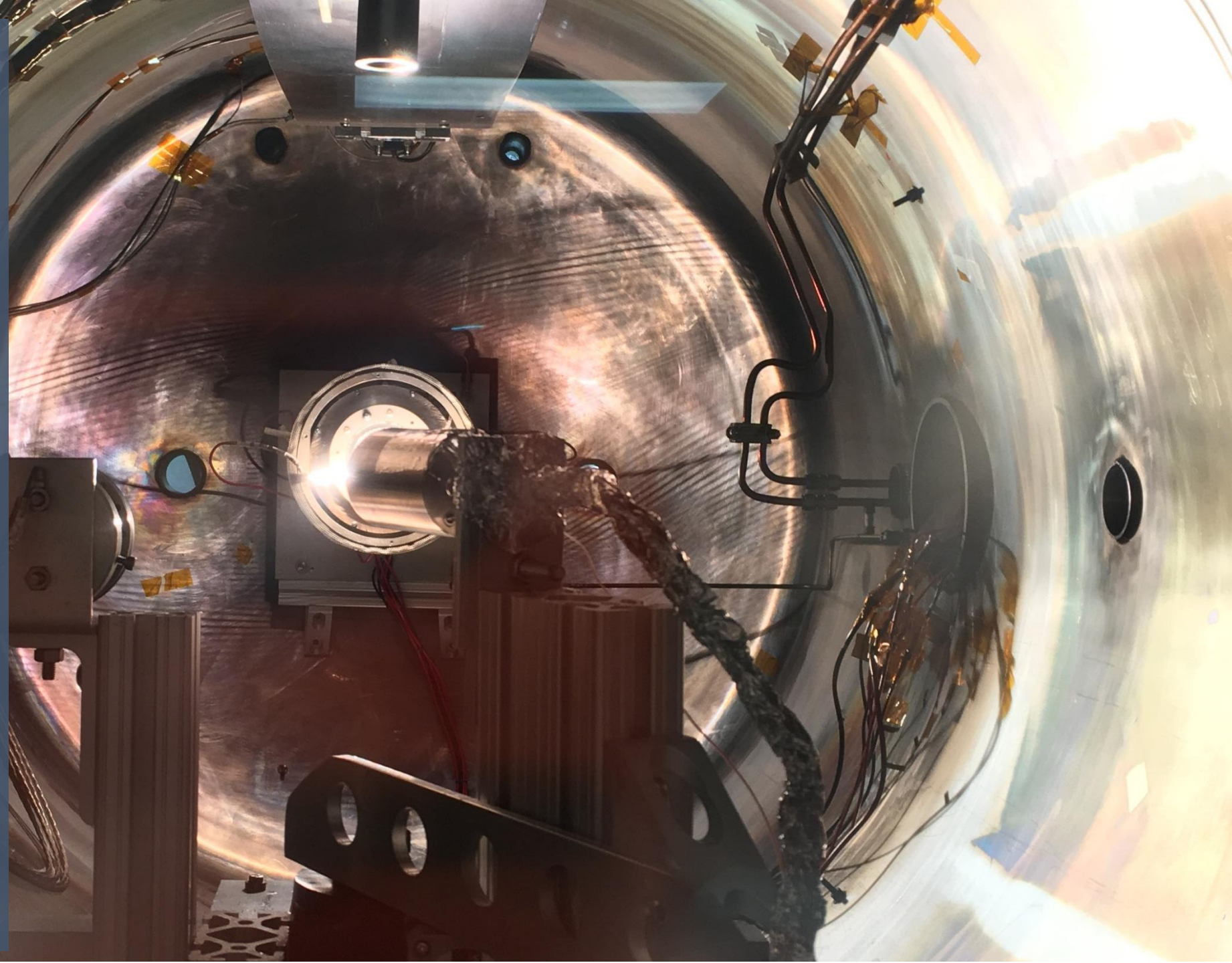
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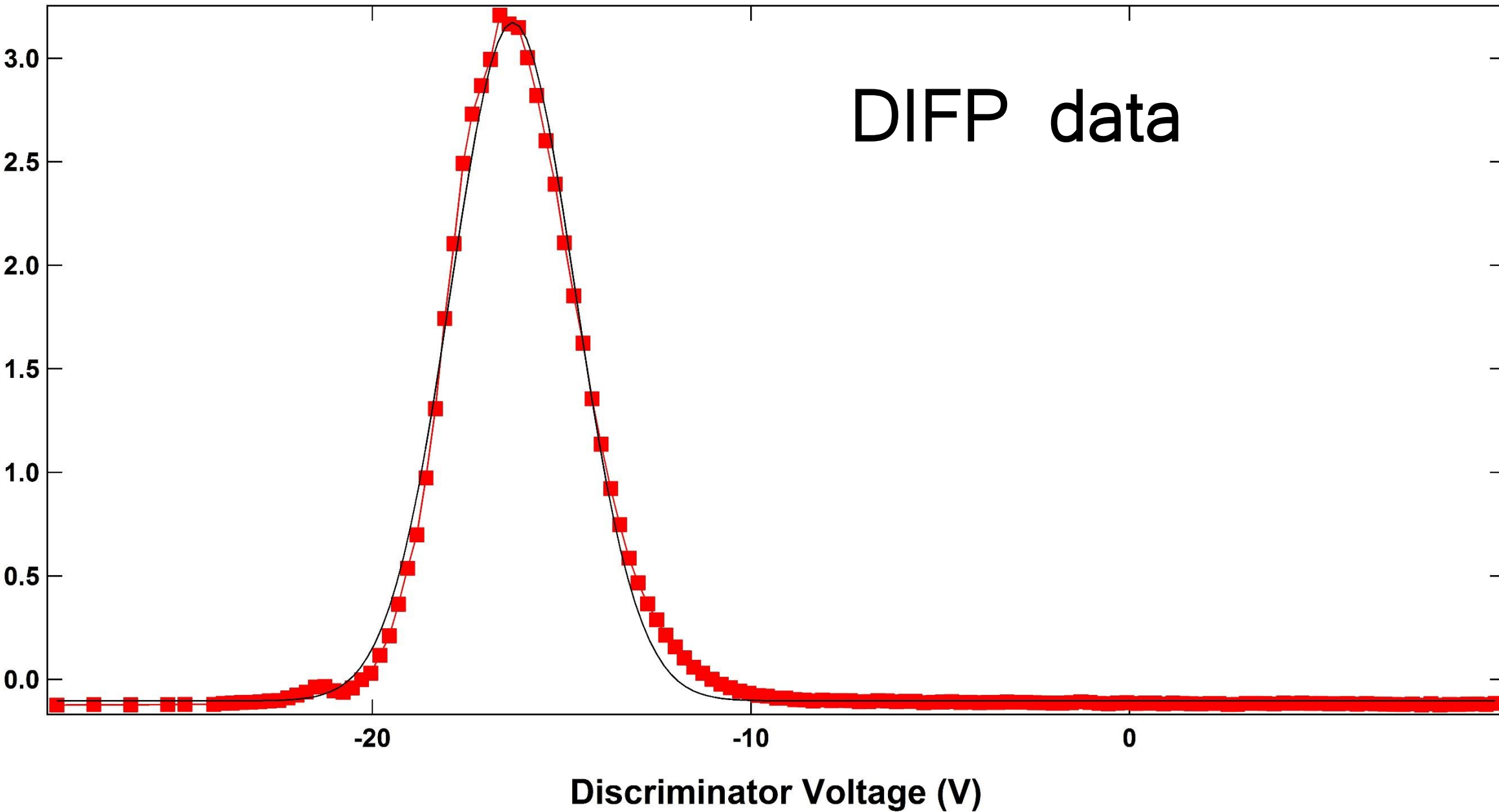


# Conclusion

- Setup is nearing readiness for tests needed to verify PIC model of E-Sail.
  - Modified RPA software for DIFP
  - Solved many hardware, electronics, and thermal issues
  - DIFP angle response calibrated
  - $x$ - $y$  testing mode in place



Collector Voltage (v)



DIFP data

