

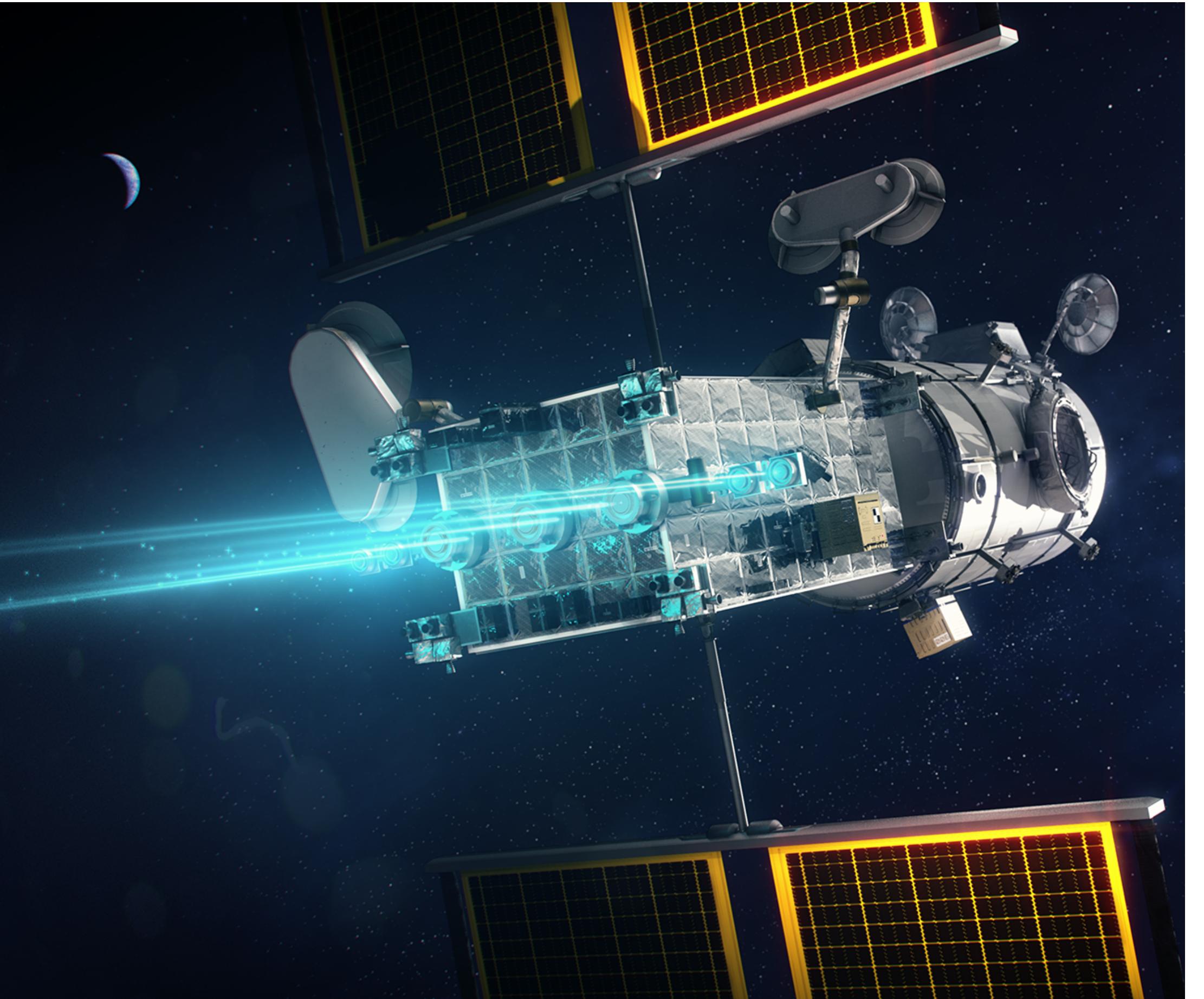
Carbon Backsputter Mitigation with a Retarding Beam Dump

Braden Oh, William Hurley, Grace Zoppi, Christopher May, Collin Whittaker, Benjamin Jorns

University of Michigan
IEPC 2024

To get to Mars...

- **Power level:** 50-300 kW ⁽¹⁾
- **Specific Impulse:** 2000-5000 s ^(1,2)
- **Lifetime:** > 5 years ⁽²⁾
- **Thrust:** >1 N

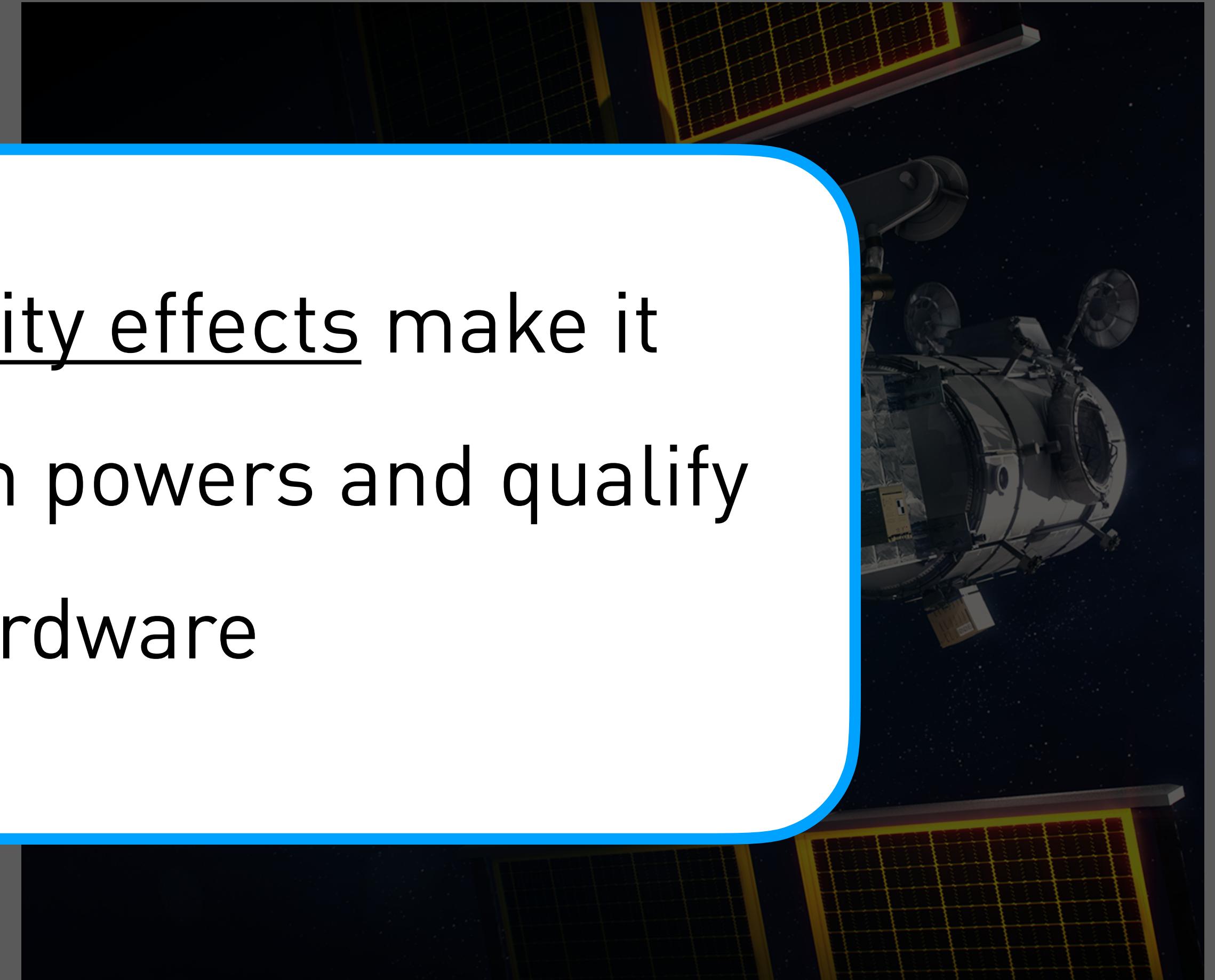


[1] NASA [BAA](#), 2015. [2] NASA [SBIR](#), 2012.

To get to Mars...

- Power
- Specific
- Lifetime
- Thrust:

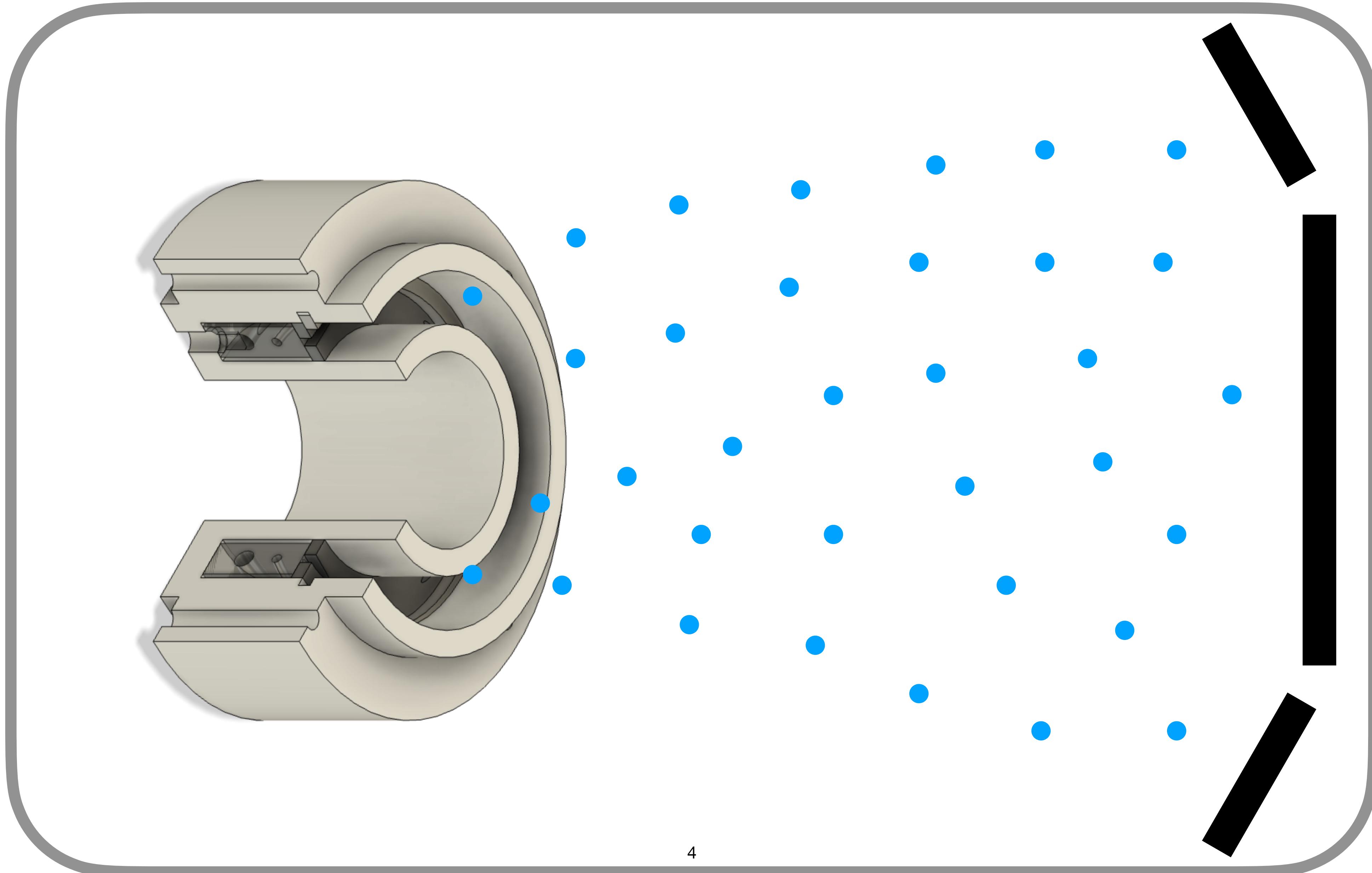
Unfortunately, facility effects make it difficult to test at high powers and qualify flight hardware



[1] NASA BAA, 2015. [2] NASA SBIR, 2012.

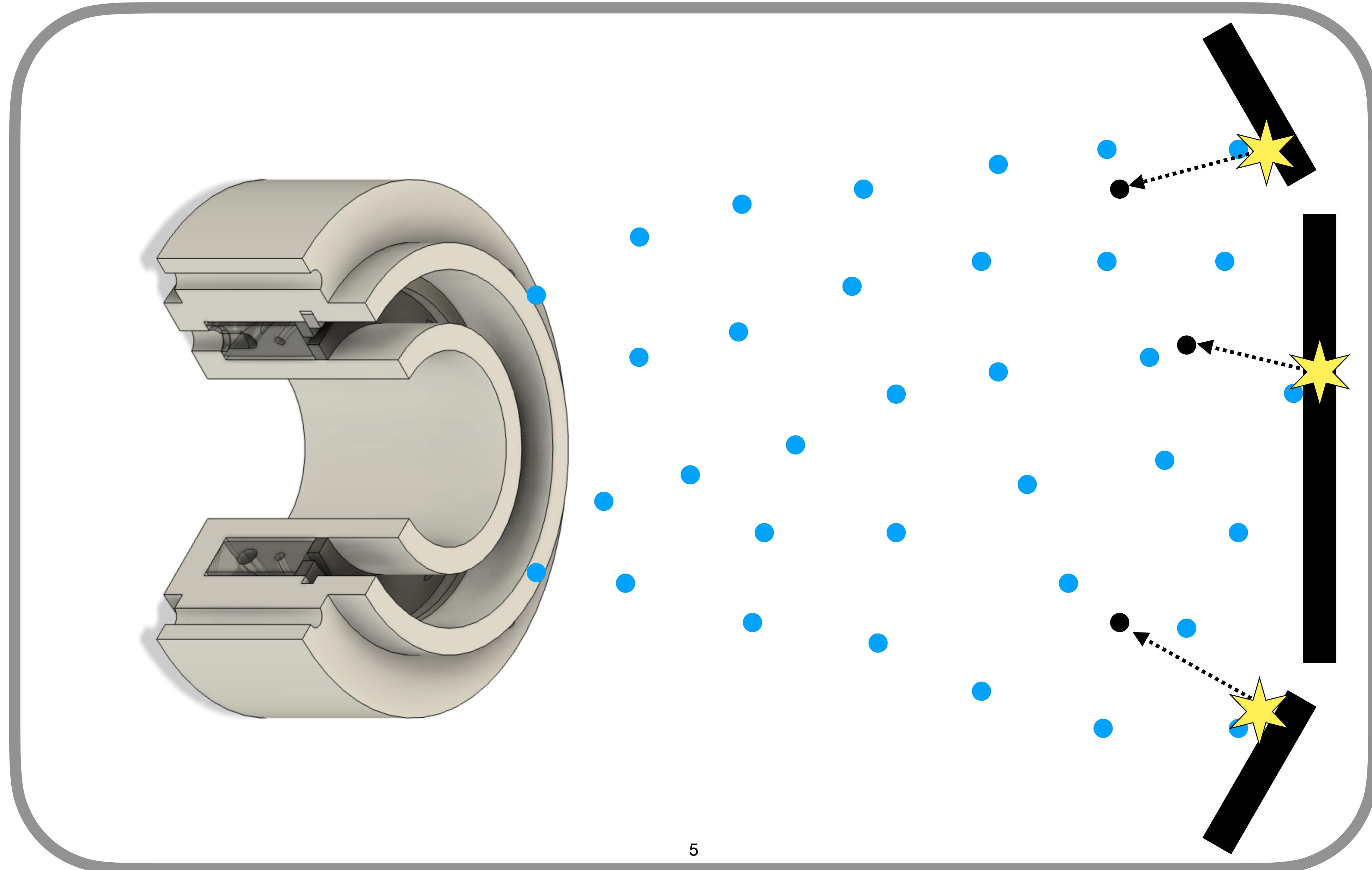
The Problem of Backsputter

M | PEPL



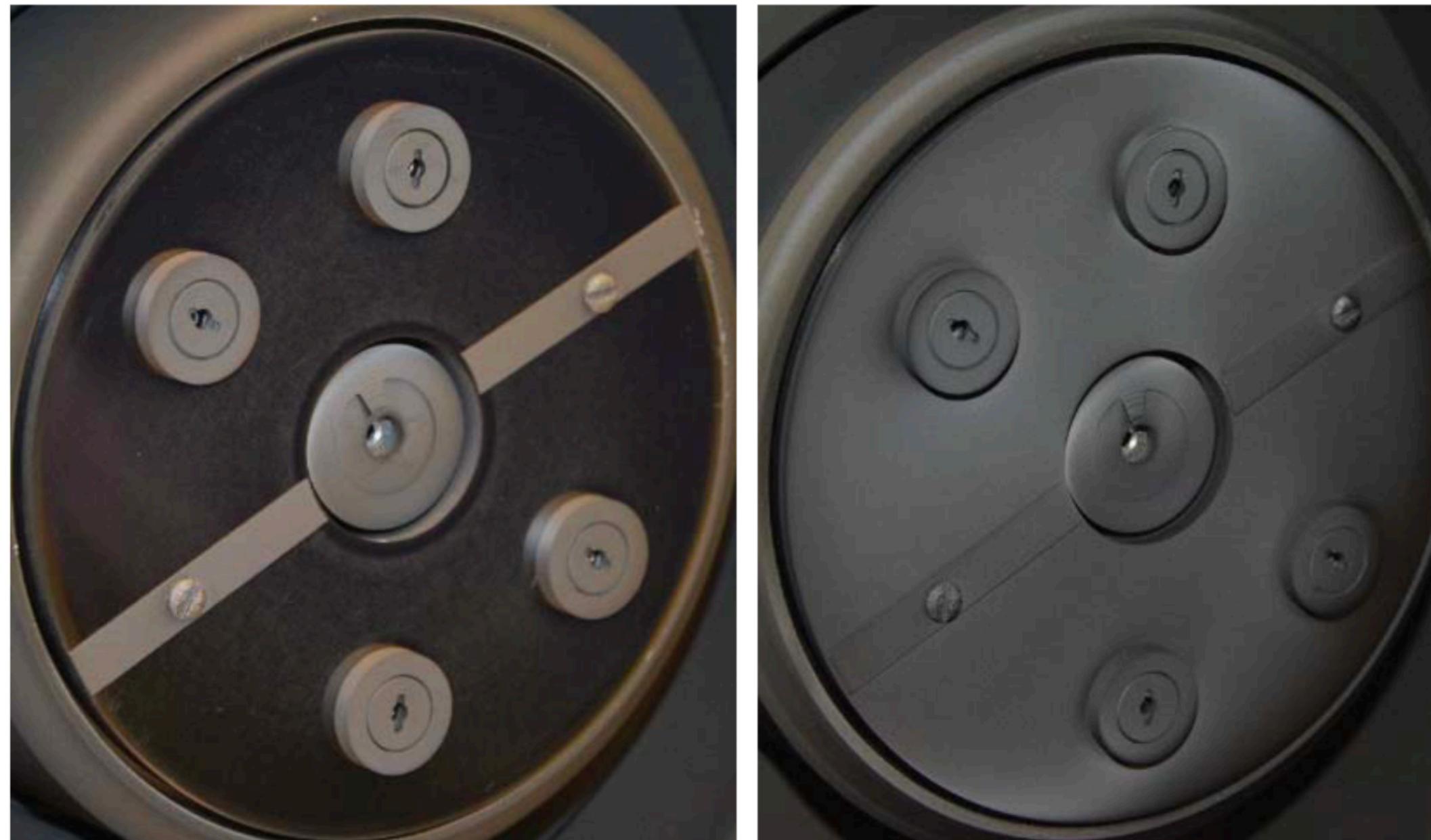
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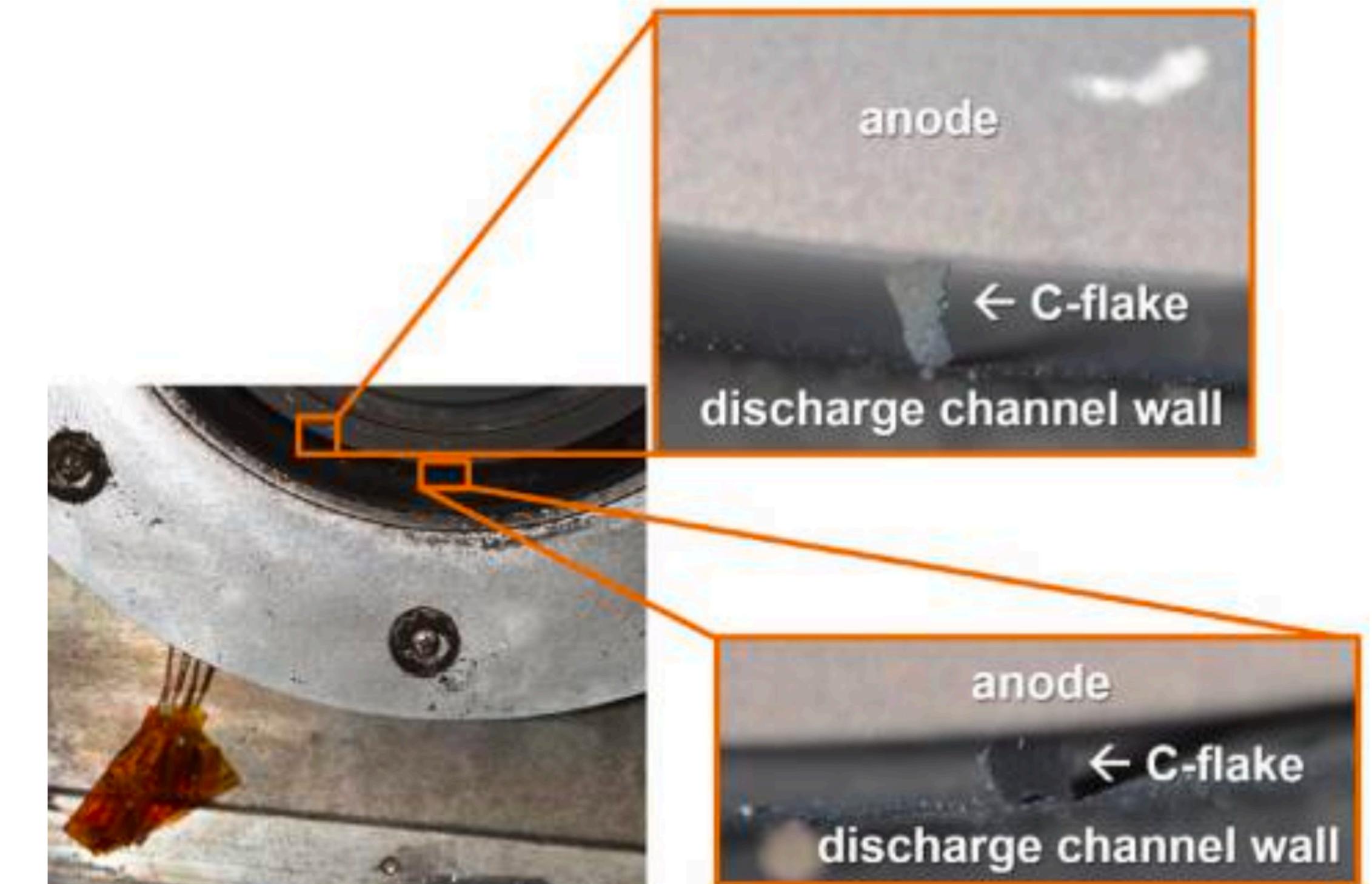


The Problem of Backsputter

**Obscures erosion
Changes emissivity**



Causes shorting

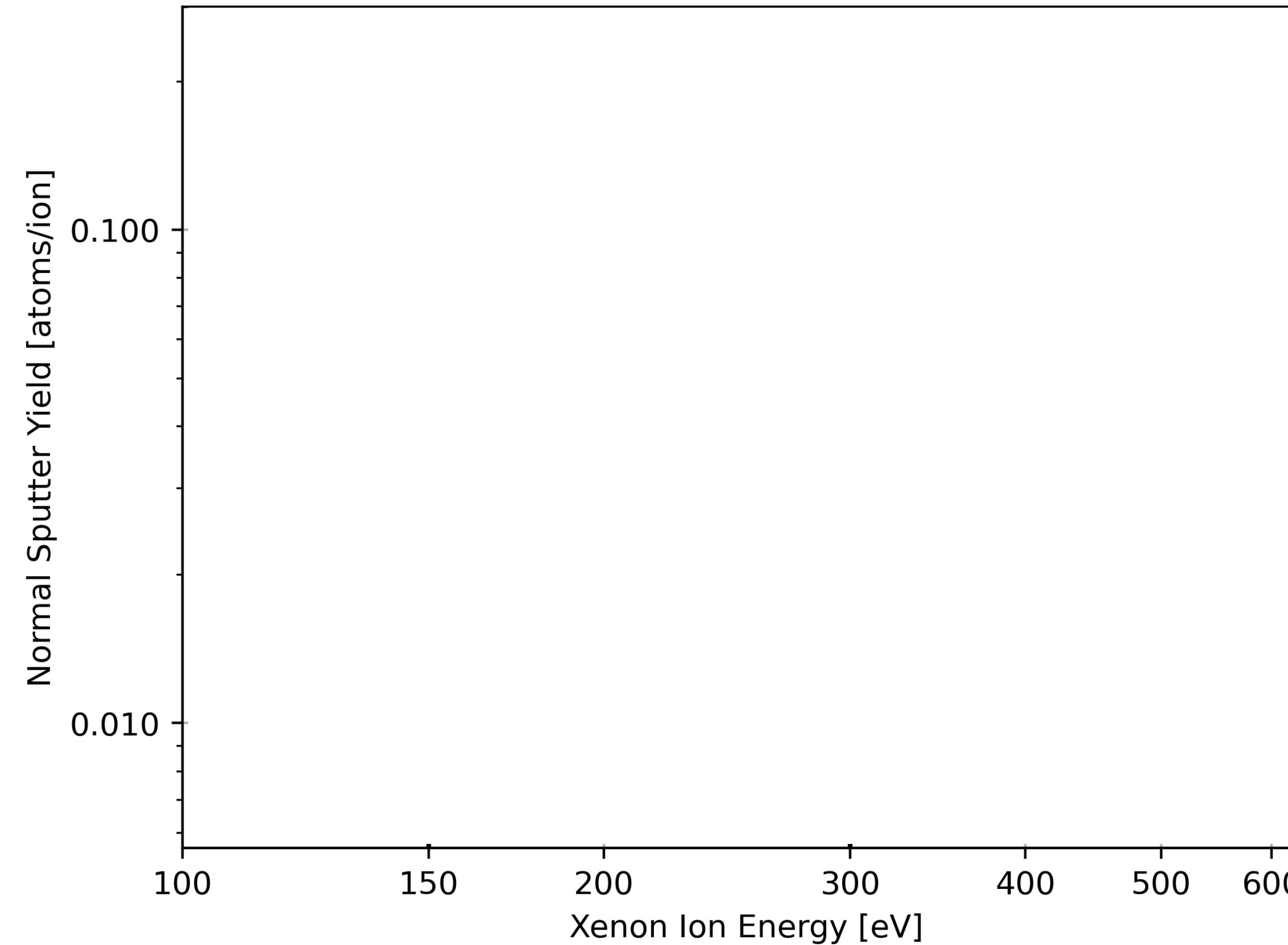


"Wear Test of the 12.5-kW AEPS Engineering Test Unit Hall Thruster" (2020)

"Accelerating 23,000 hours of Ground Test Backsputtered Carbon on a Magnetically Shielded Hall Thruster" (2019)

The Problem of Backsputter

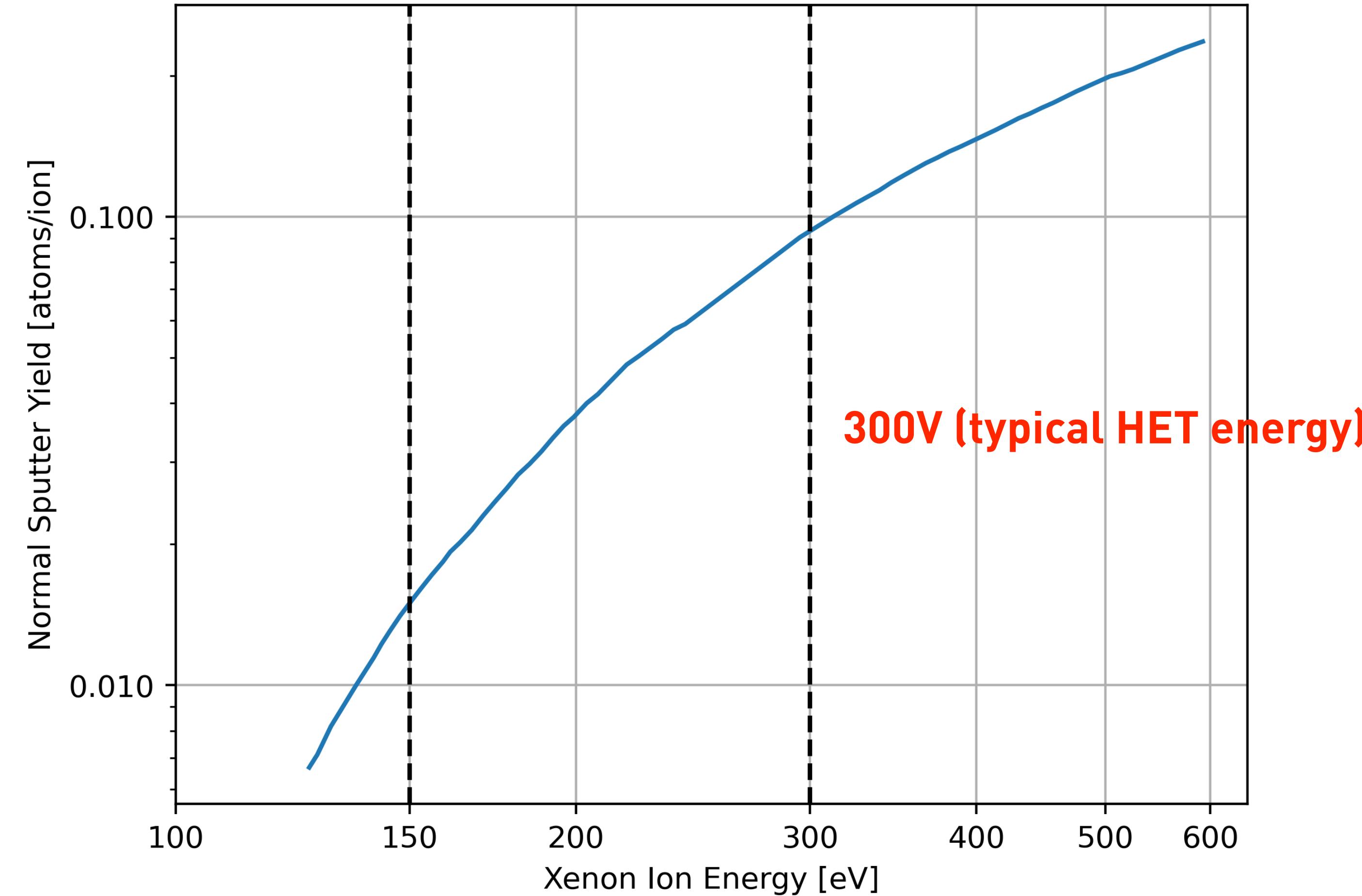
Graphite-Xenon Sputter Yield Curve



"Differential sputtering behavior of pyrolytic graphite and carbon-carbon composite under xenon bombardment" (2004)

The Problem of Backsputter

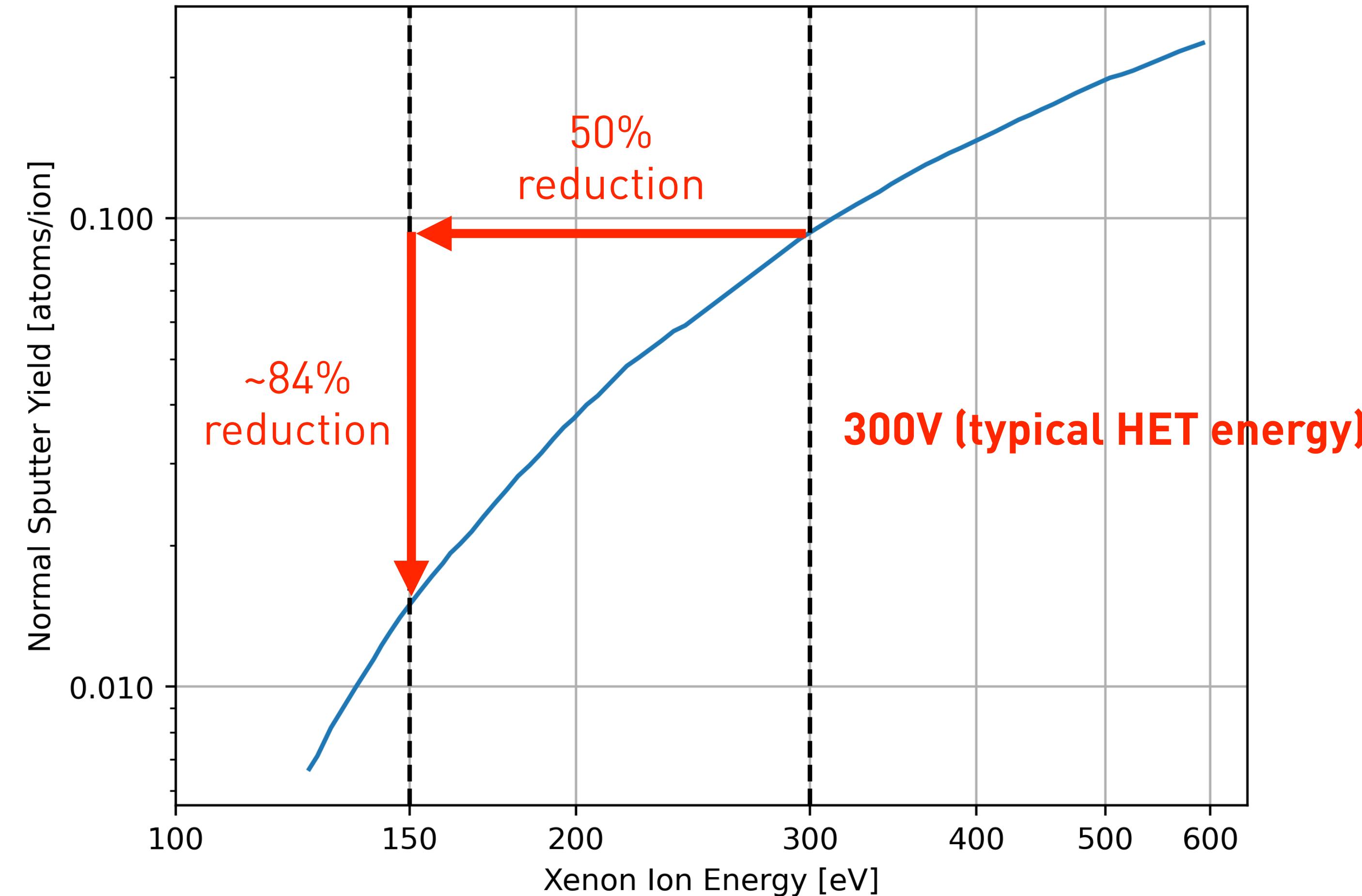
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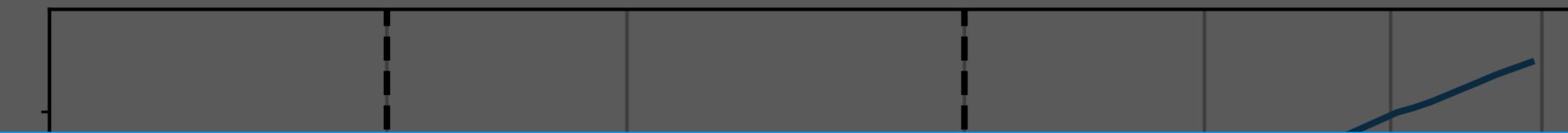
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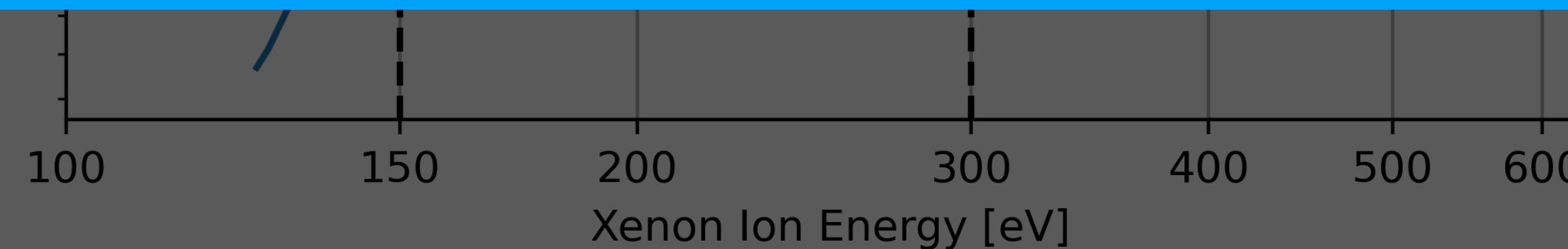
The Problem of Backsputter

Graphite-Xenon Sputter Yield Curve

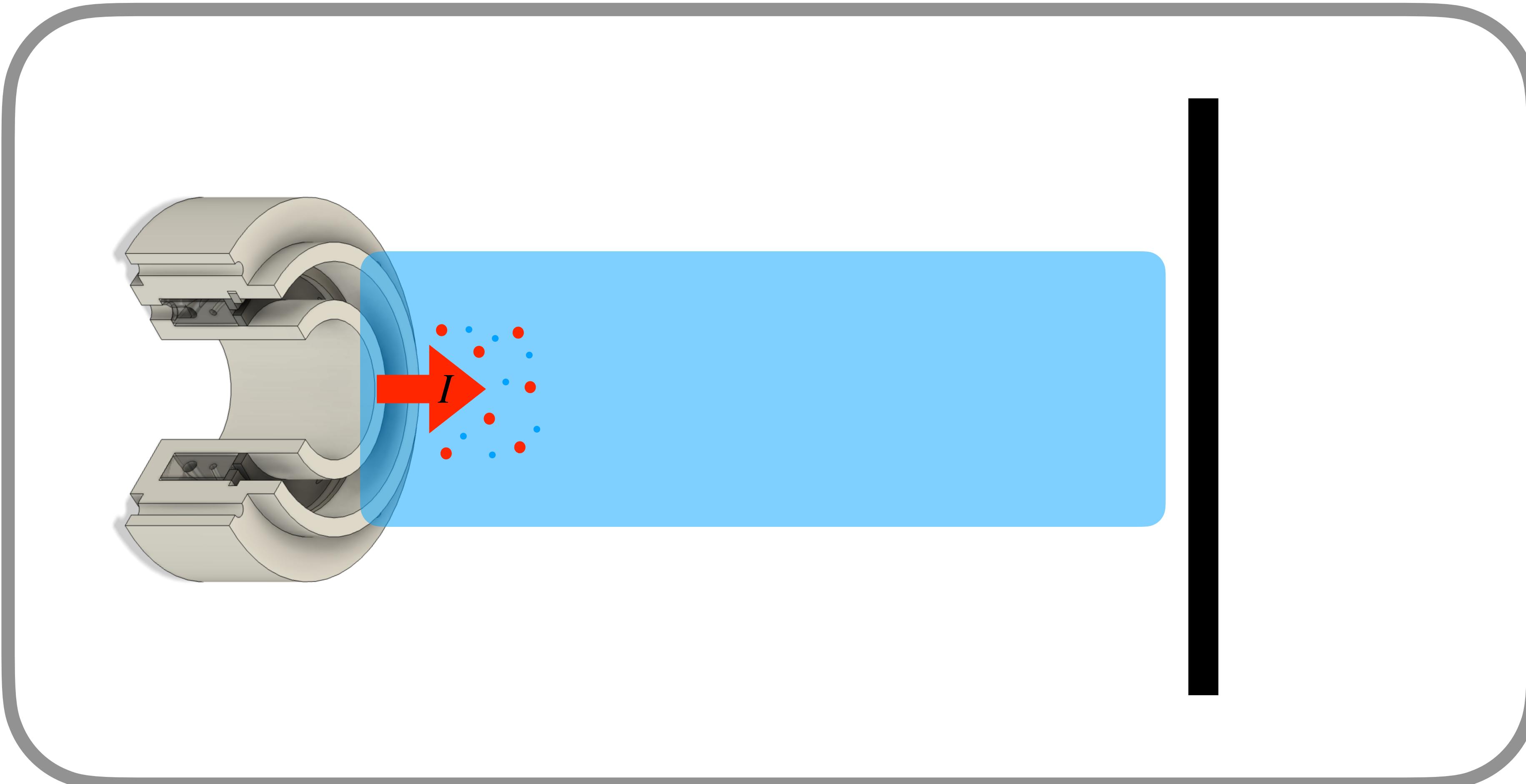


Mitigation Strategy:

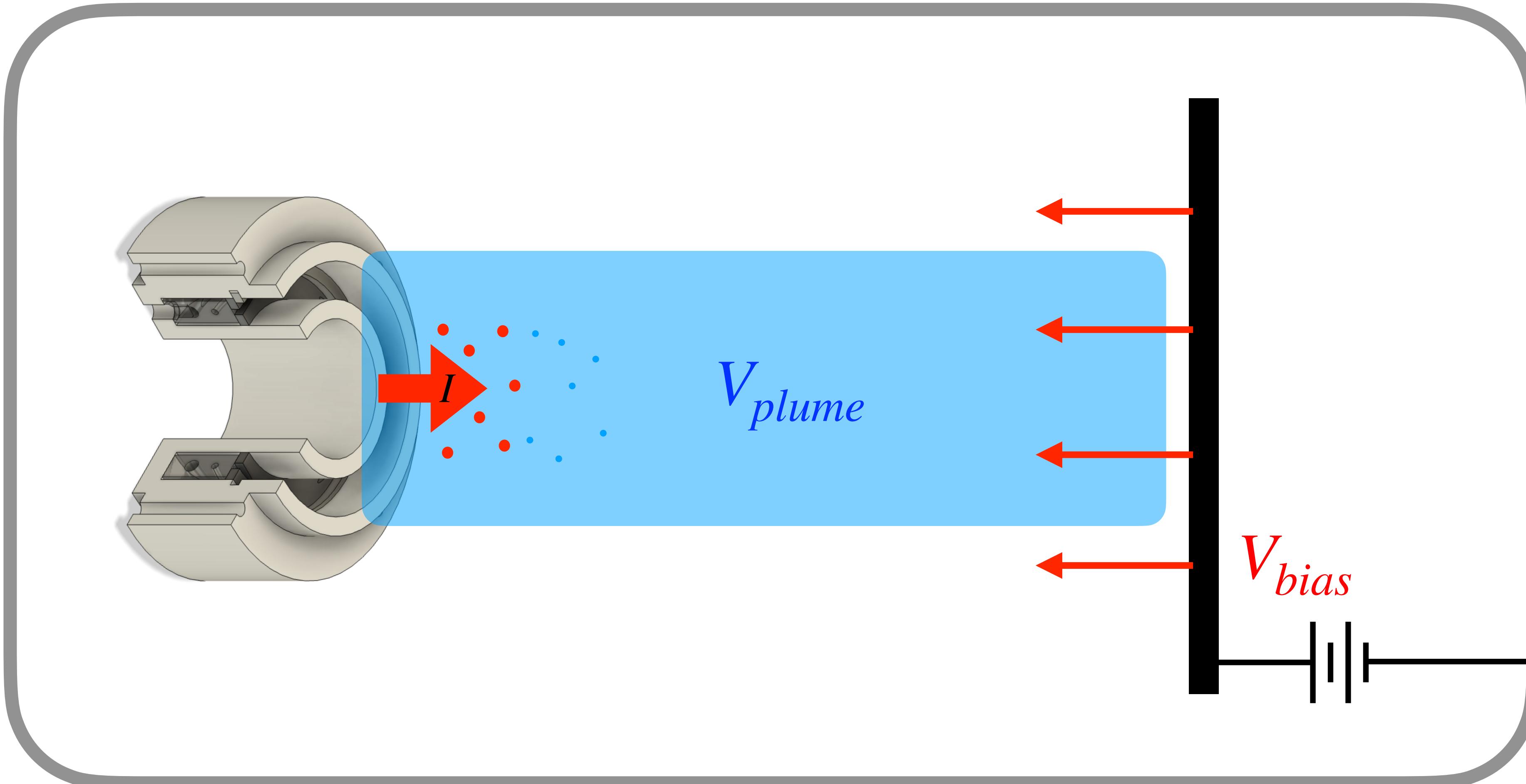
Use electrostatics to slow incoming ions
before they strike the beam dump



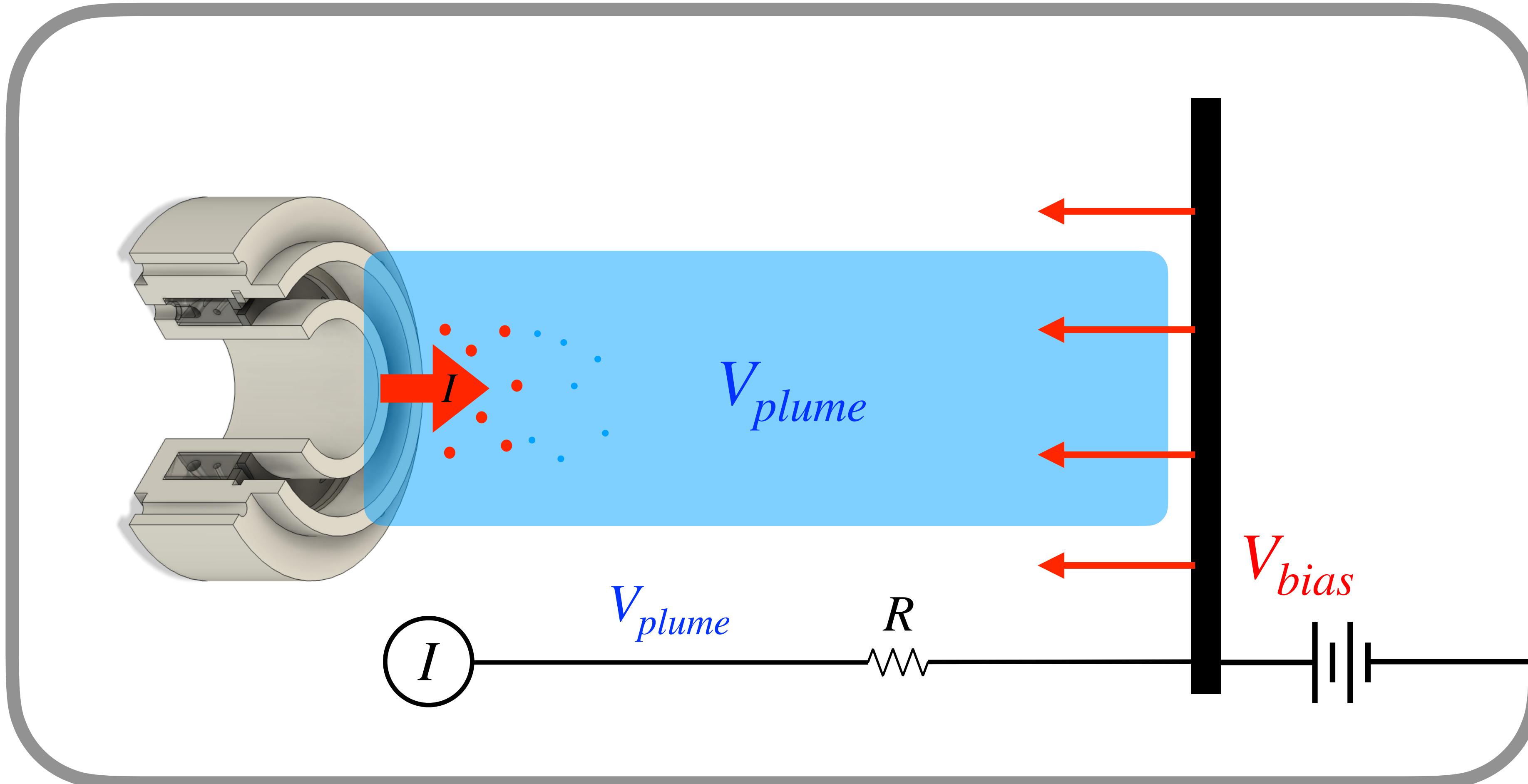
Beam Catcher Theory



Beam Catcher Theory

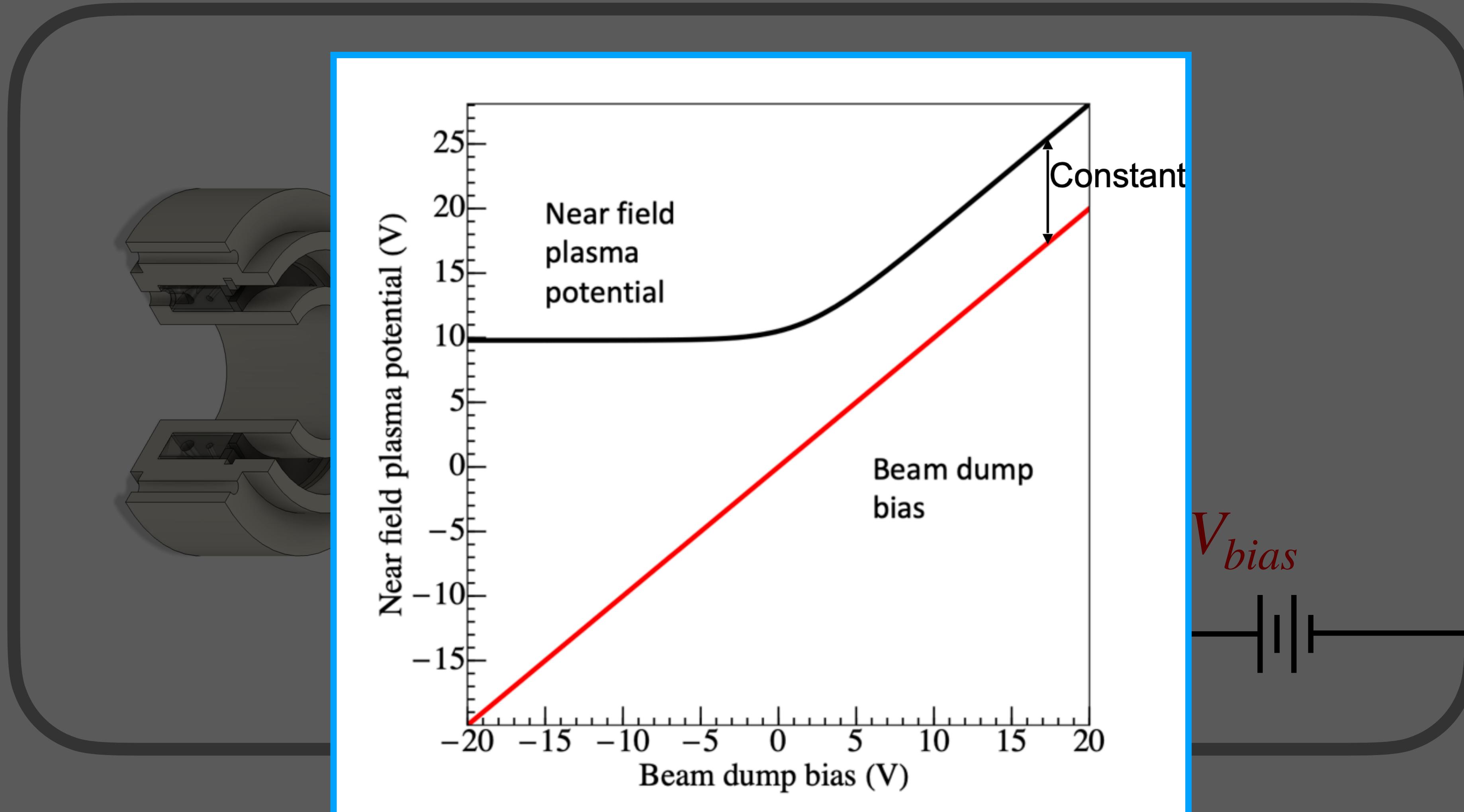


Beam Catcher Theory



$$V_{bias} - V_{plume} = IR$$

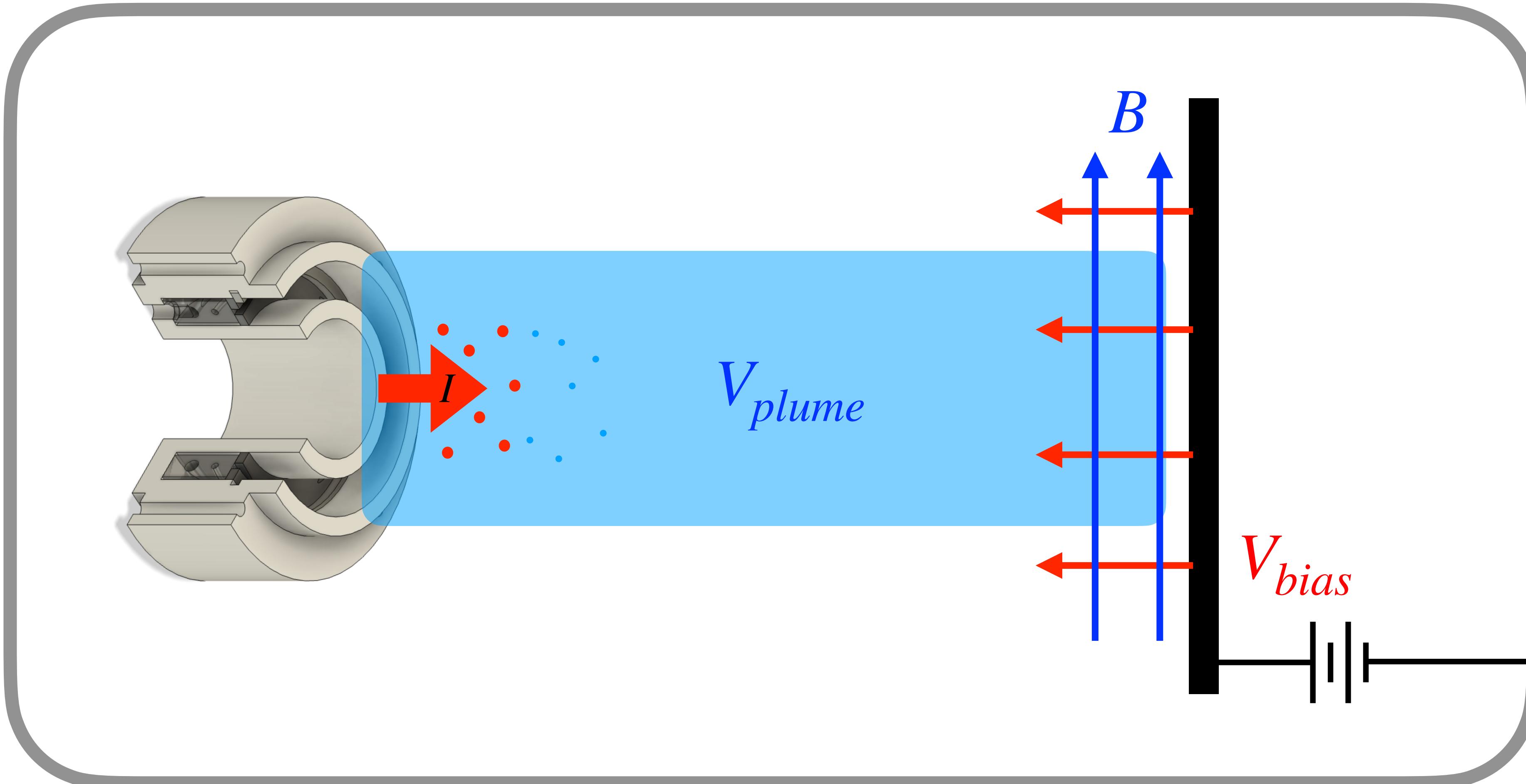
Beam Catcher Theory



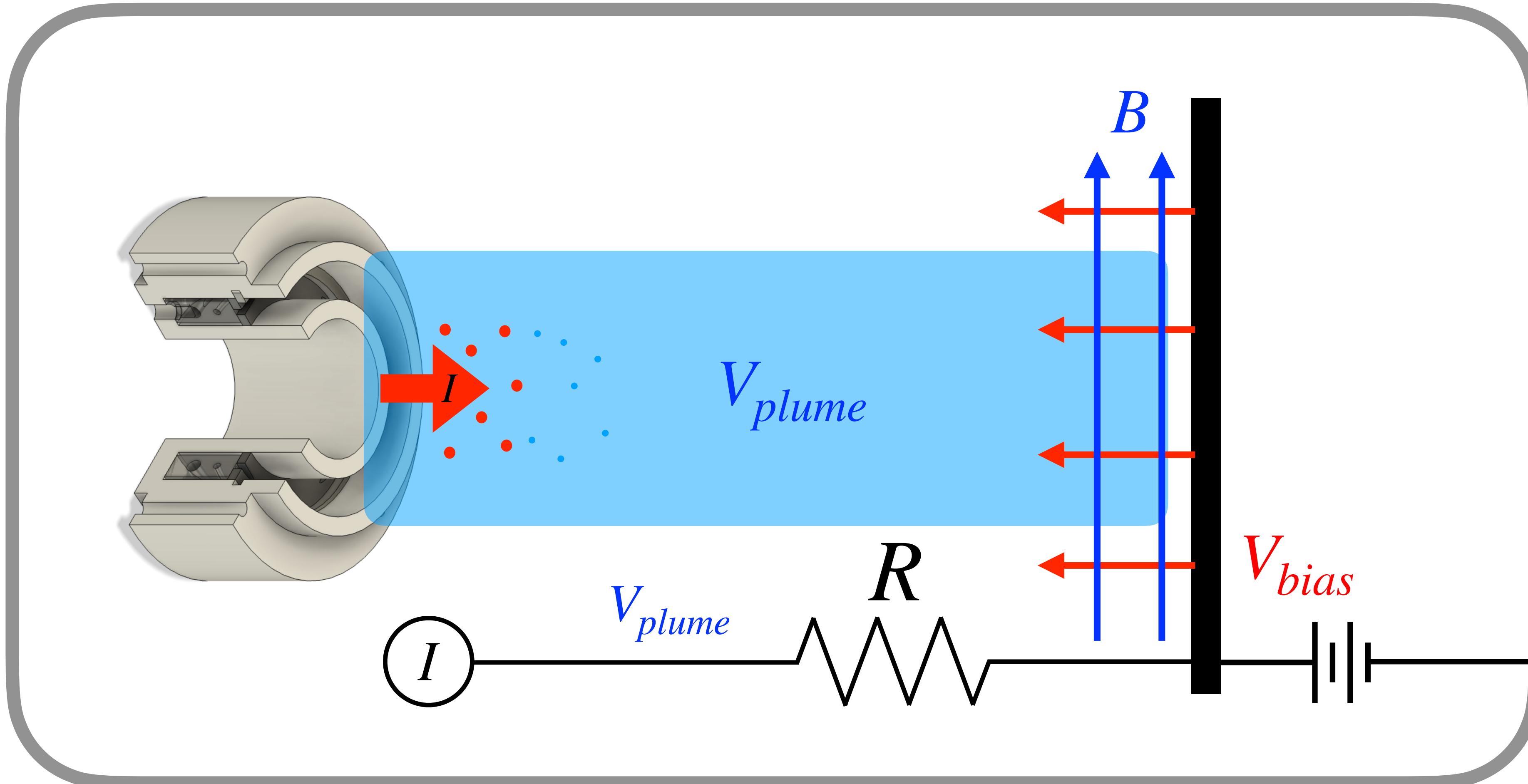
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Beam Catcher Theory

M | PEPL

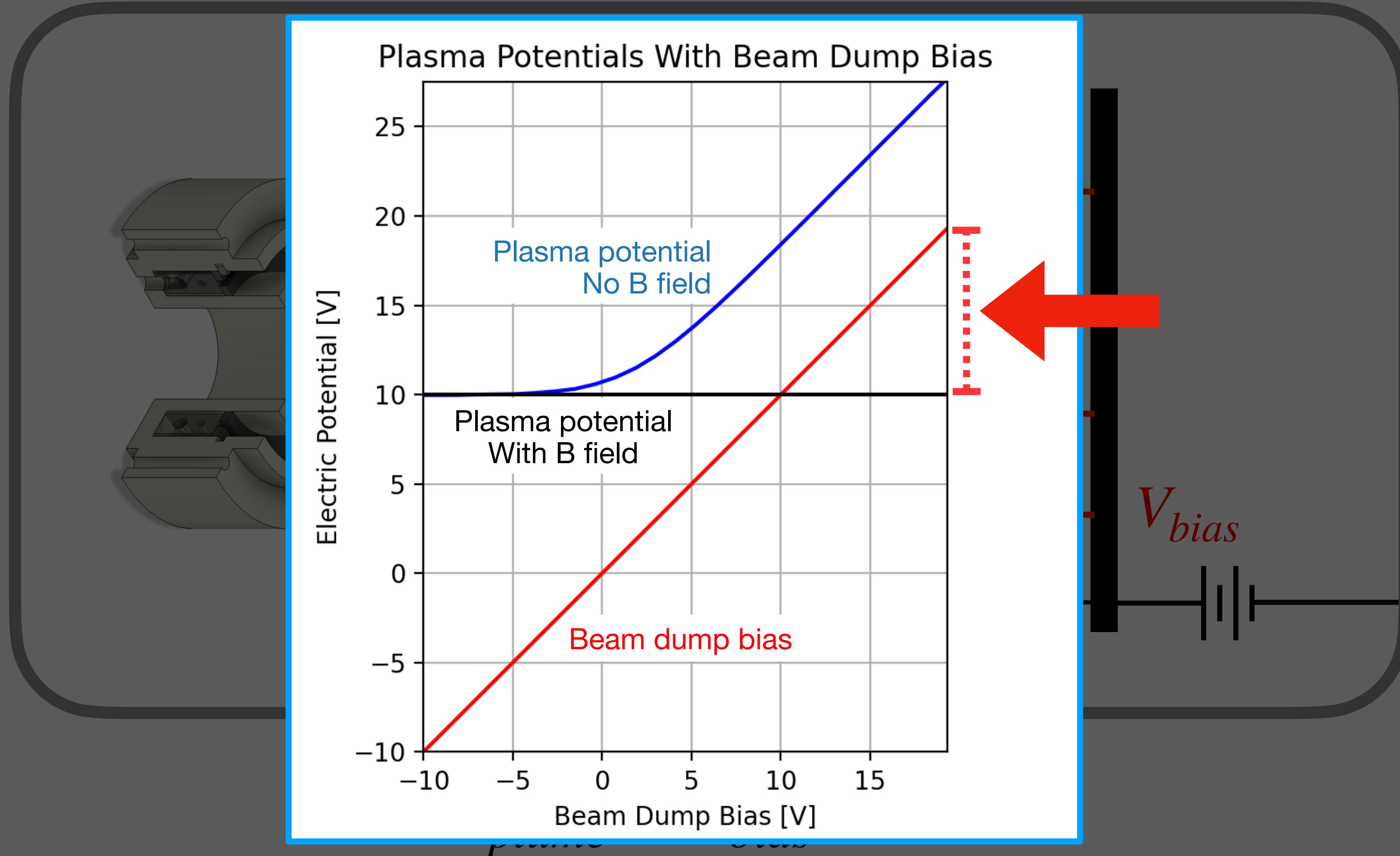


Beam Catcher Theory



$$V_{bias} - V_{plume} = IR$$

Beam Catcher Theory



R ■

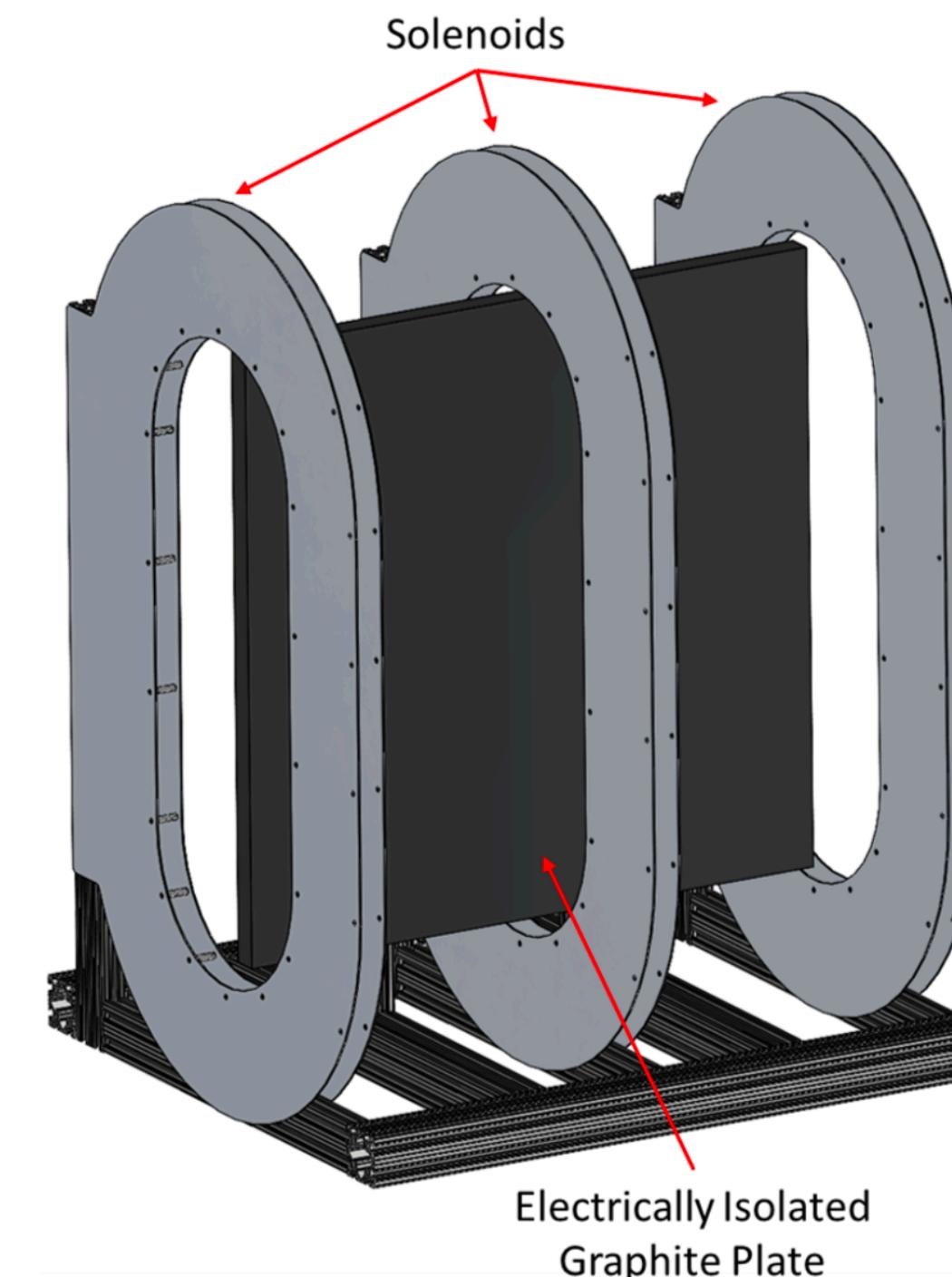
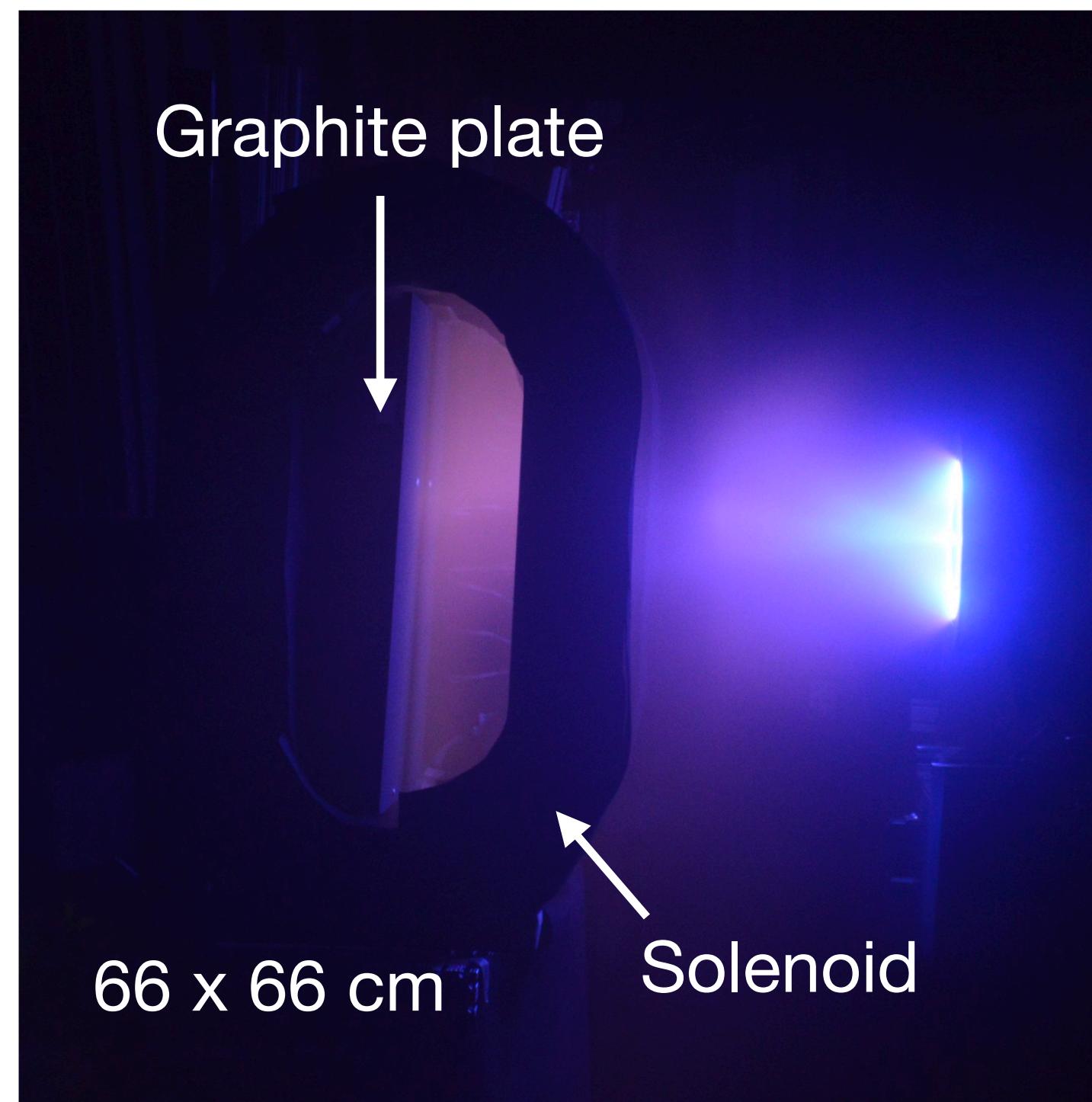
Key Questions:

1. Can we hold off a large potential?
2. Can we reduce backscatter?
3. Will our catcher affect thruster operation?

$$V_{plume} = V_{bias} - IR$$

Prior Beam Catcher Studies

Hurley et al. 2023 (U-M)



- 4.5 kW Hall thruster
- Reduced backscatter by 38%
- Unable to apply active bias

Hurley et al. 2023 (LL-M)

Graph

66 x 6

Key Questions:

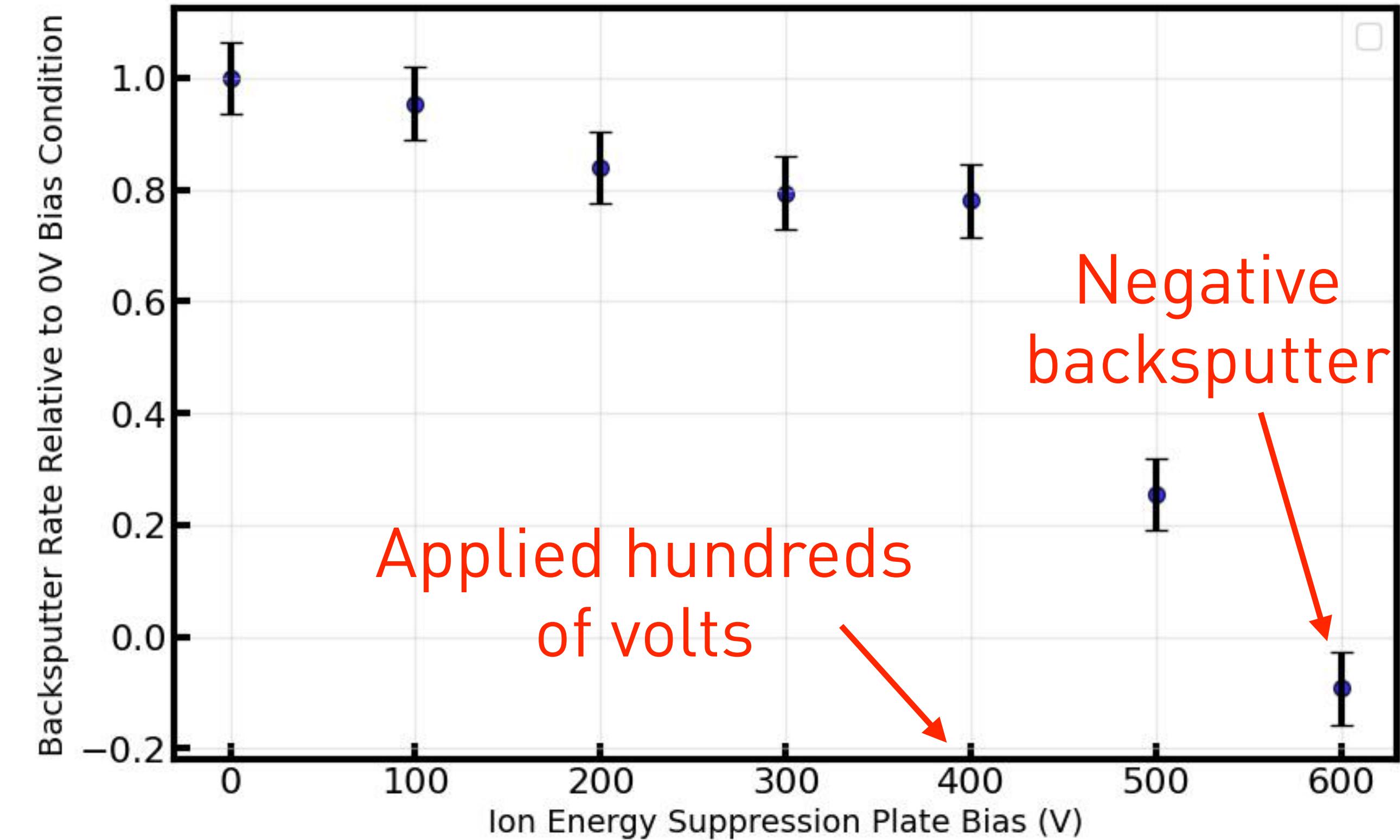
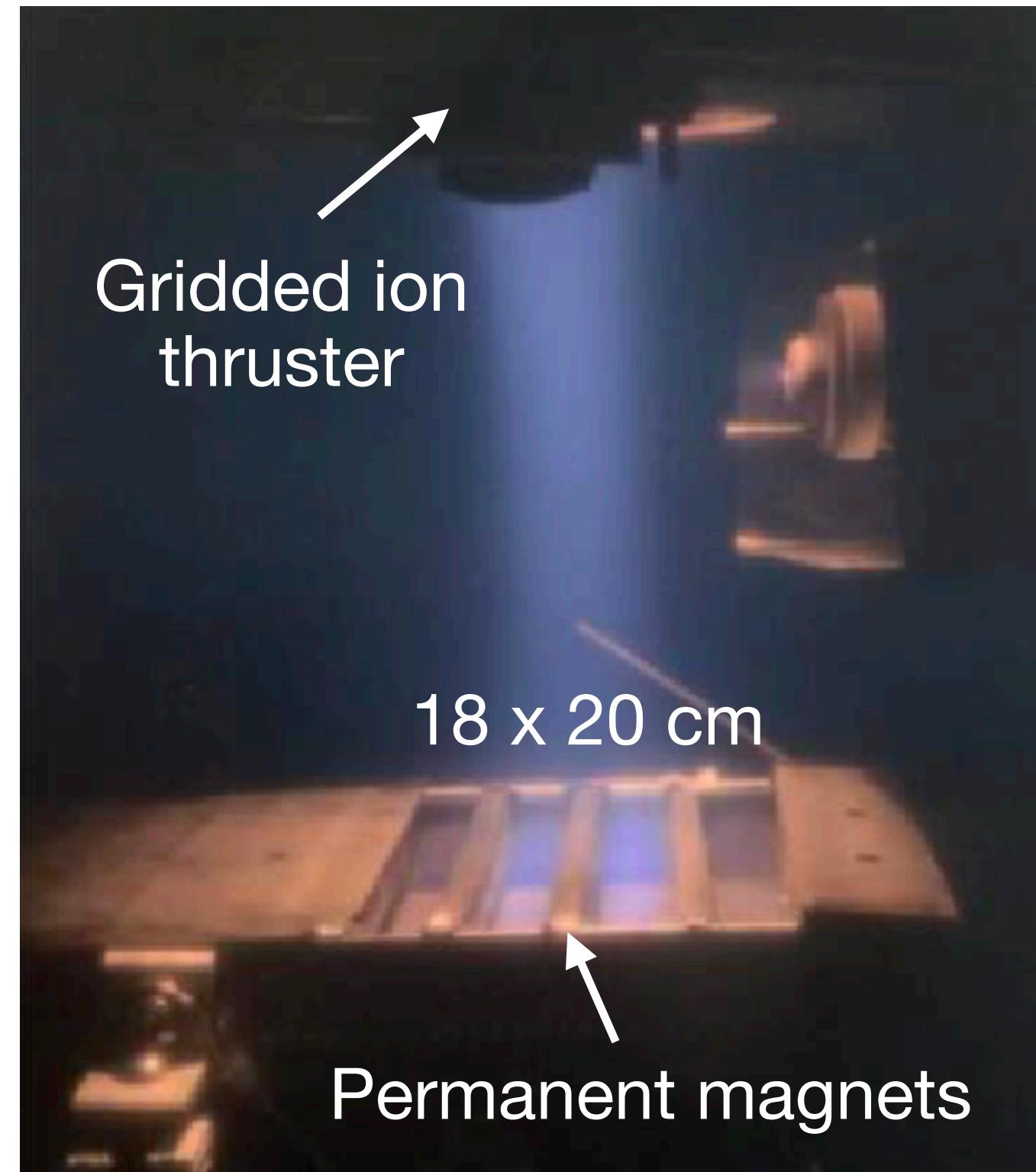
1. Can we hold off a large potential? — **No**
2. Can we reduce backscatter? — **Yes**

by 38%

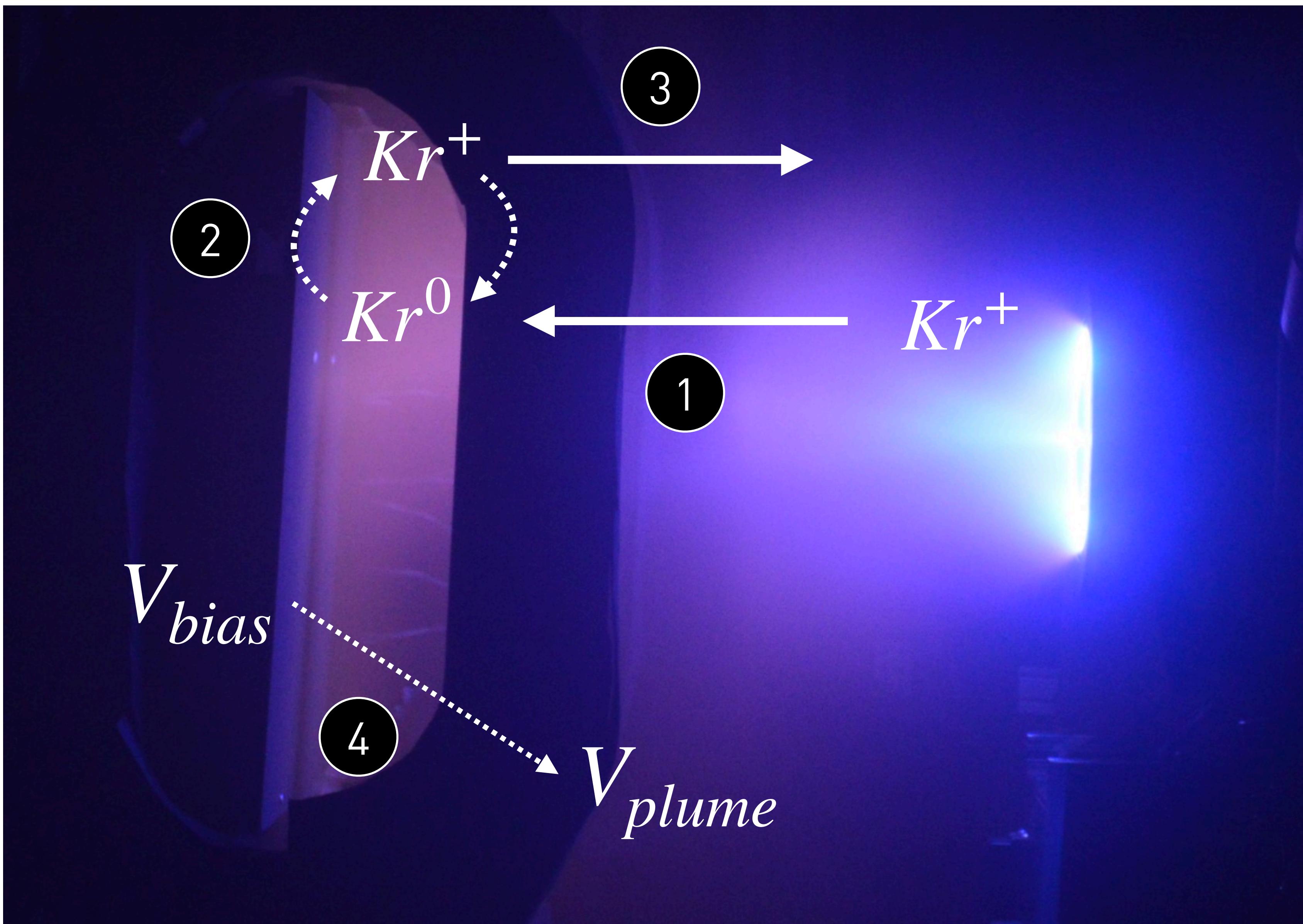
e bias

Prior Beam Catcher Studies

Thompson et al. 2023 (CSU)



Erosion Driven by Charge Exchange



3

Key Questions:

1. Can we hold off a large potential? — **Yes**
2. Can we reduce backsputter? — **Yes**

V_{plume}

3

Open Questions:

1. Can we apply large biases for a floating thruster?
2. Are biases large enough to mitigate backscatter?
3. Do we affect thruster performance?

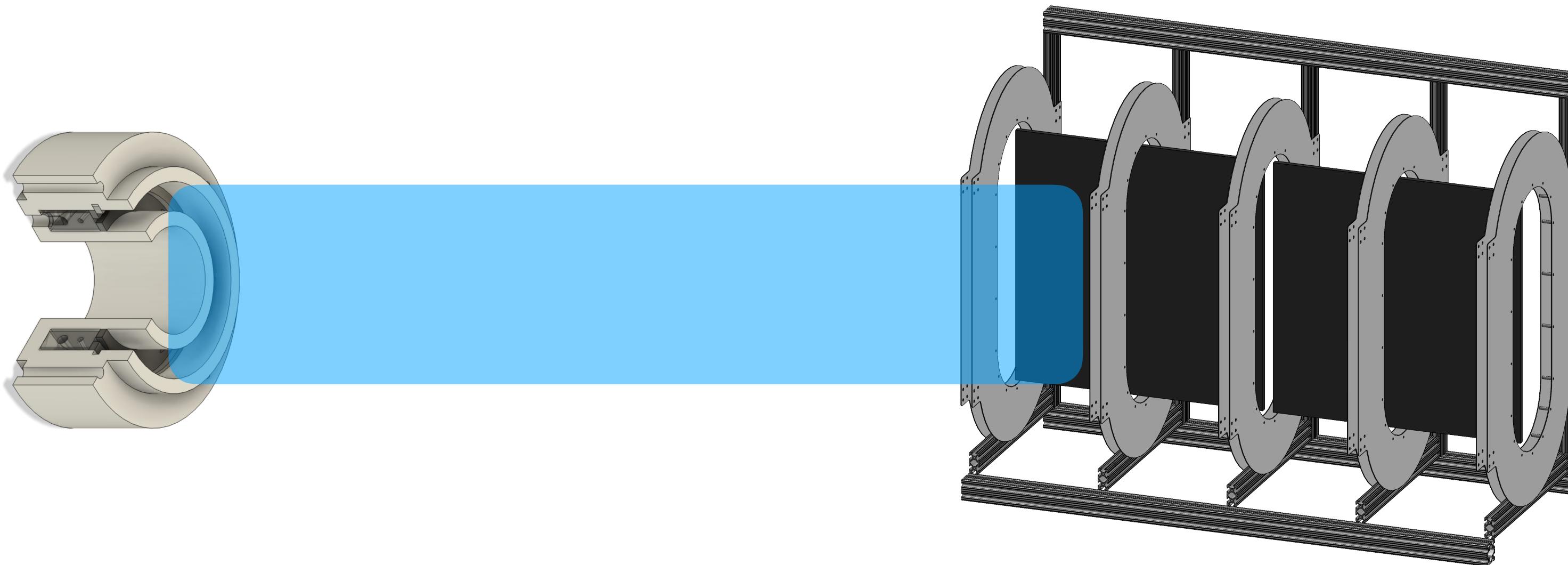
V_{plume}

Experimental Concept

- To apply large biases —>

Lower plasma density = higher resistivity for a given B field

- To evaluate operation

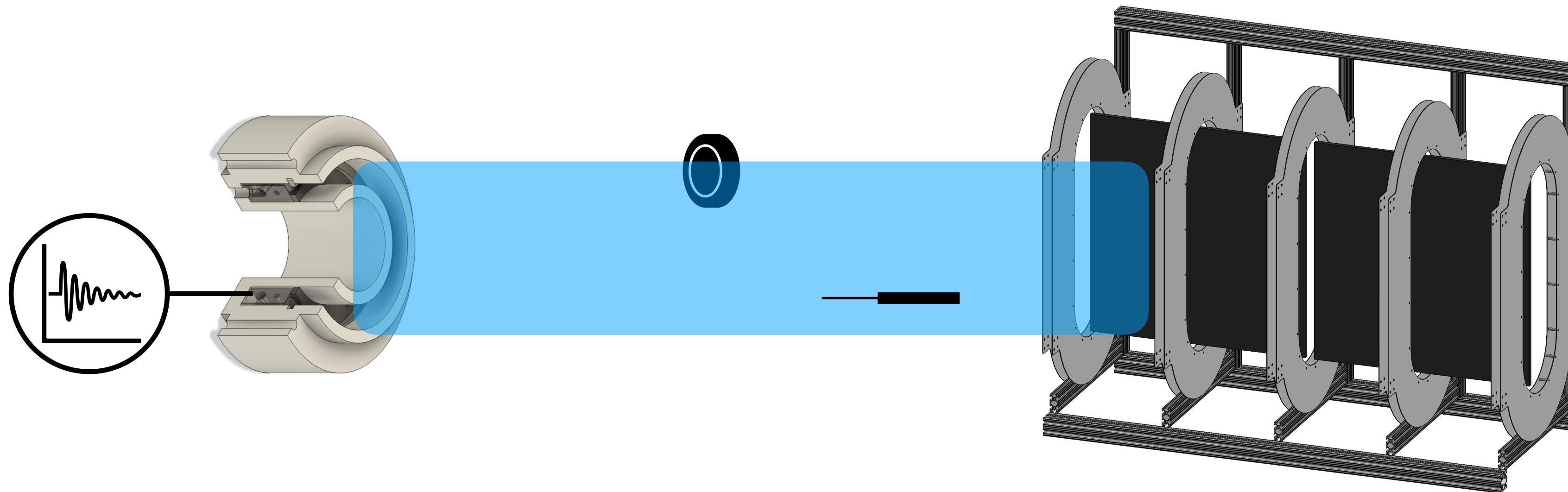


Experimental Concept

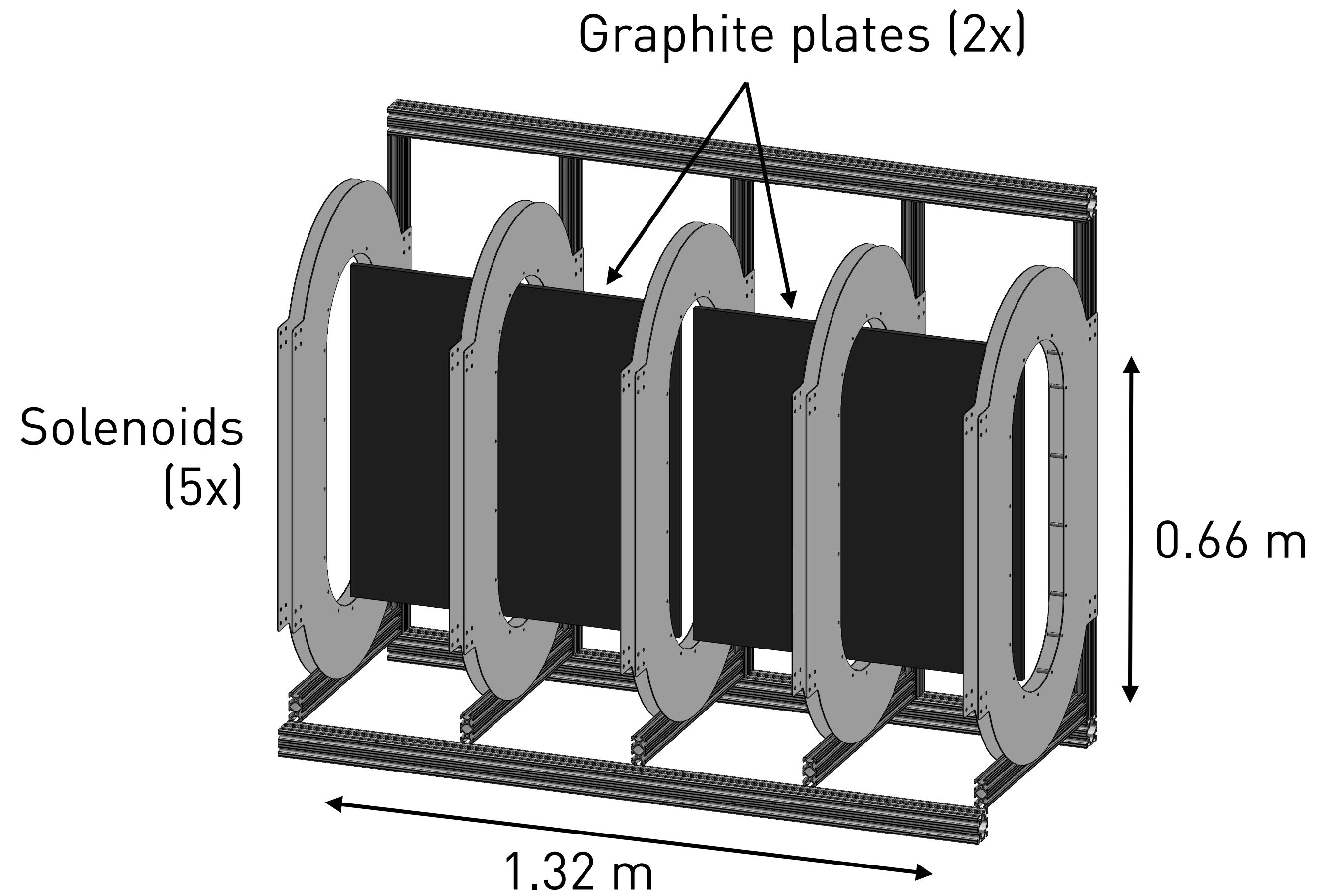
- **To apply large biases —>**

Lower plasma density = higher resistivity for a given B field

- **To evaluate operation —> measure operating metrics**

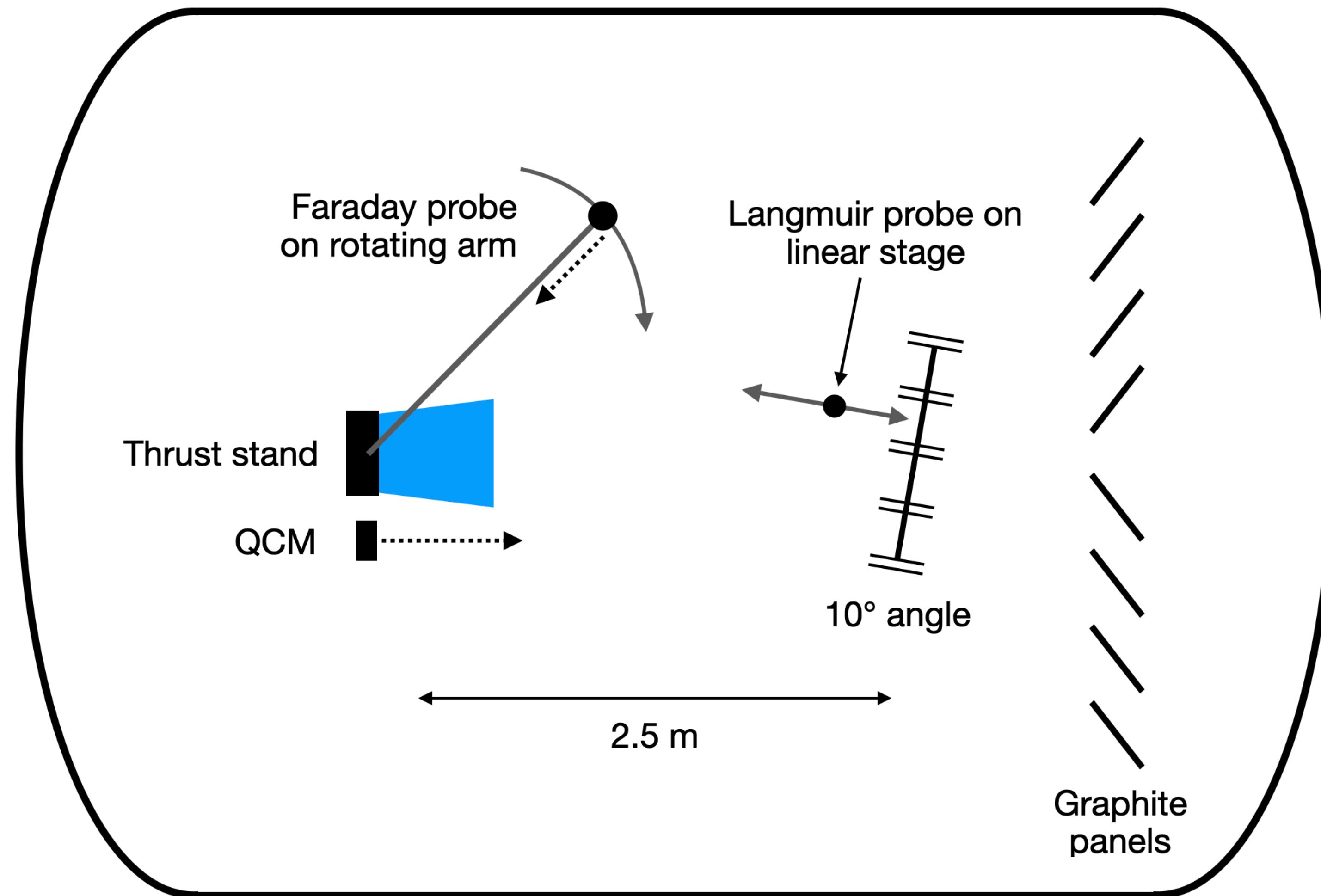


Large Scale Experimental Design



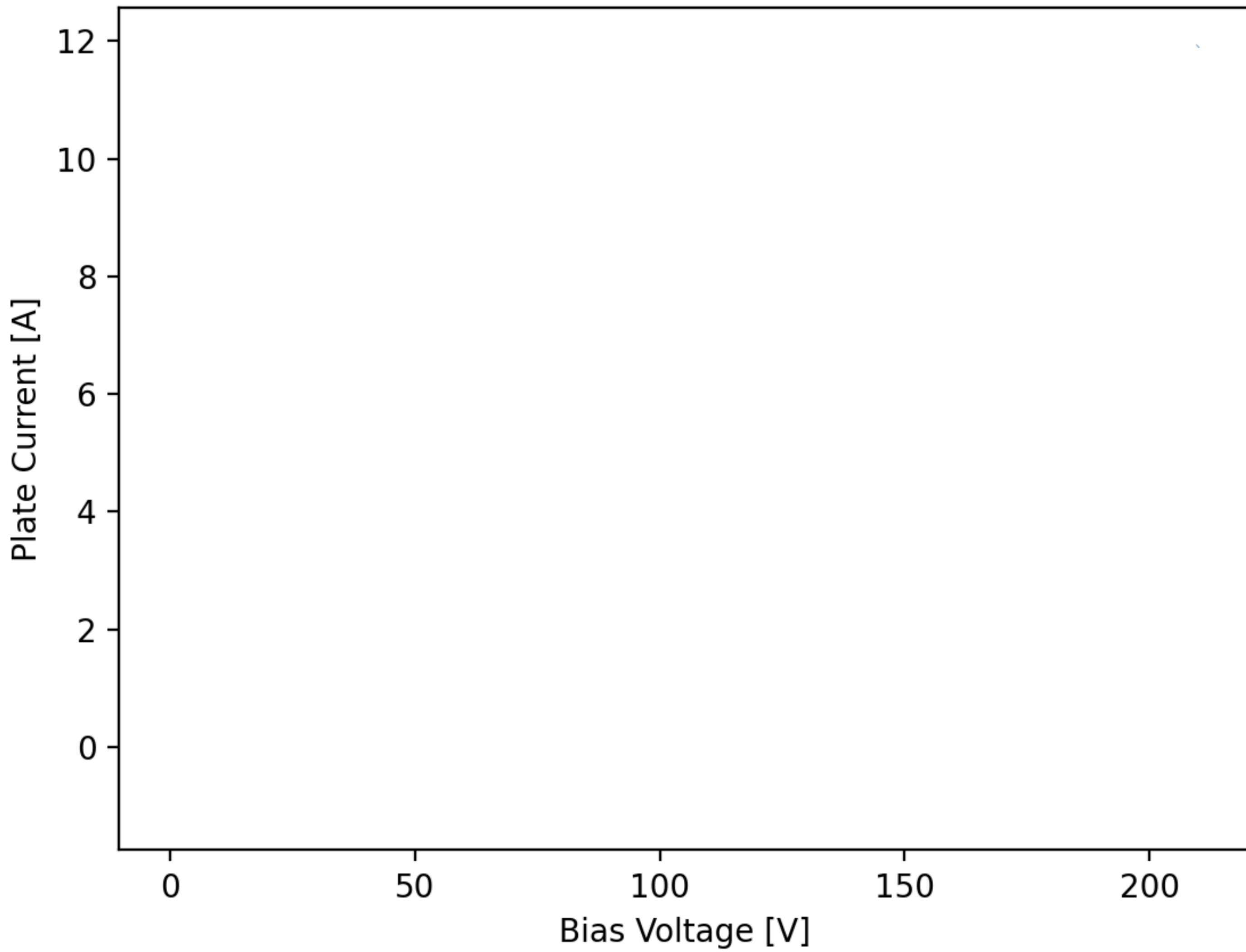
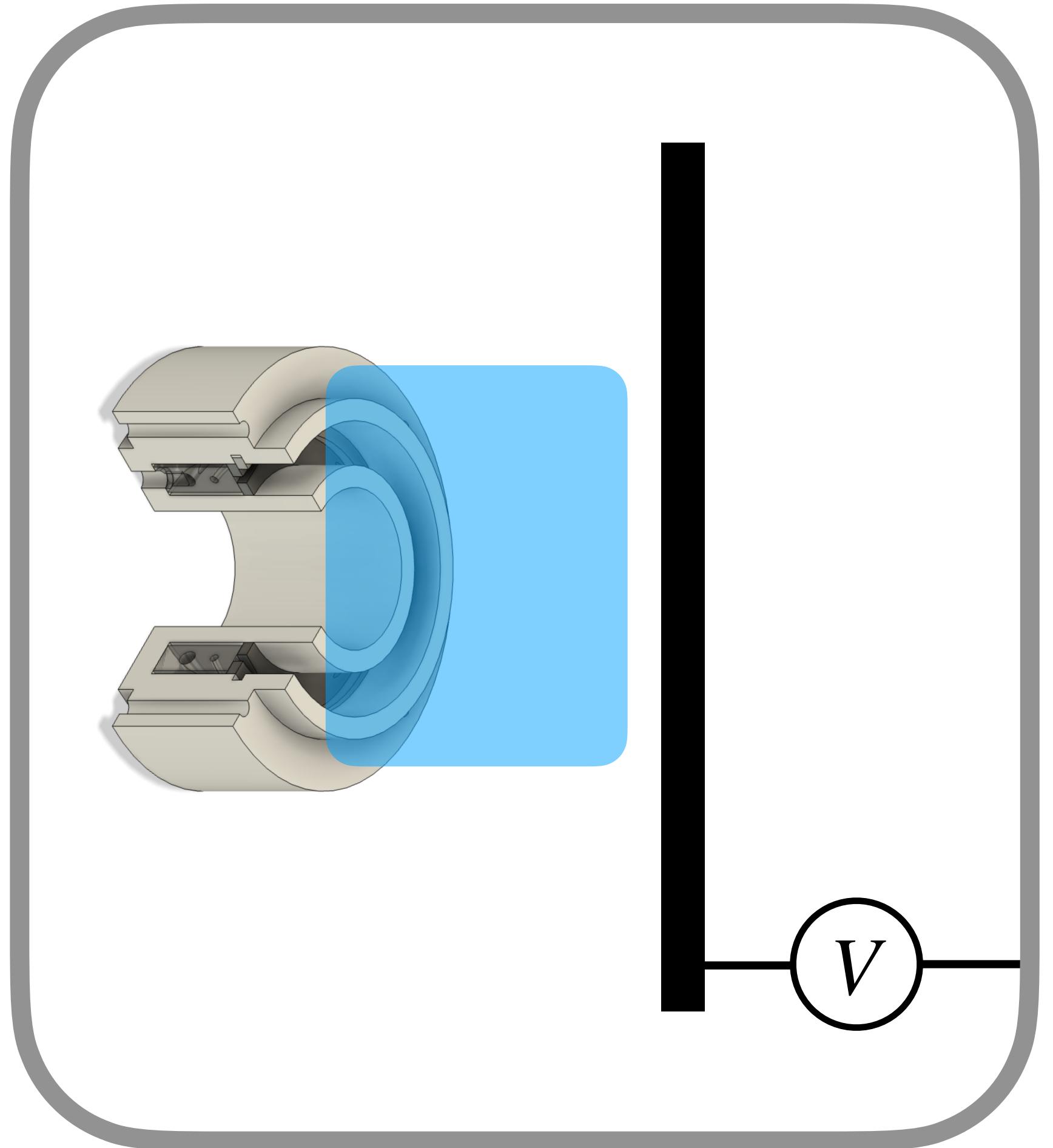
(Probe tower)

Large Scale Experimental Design

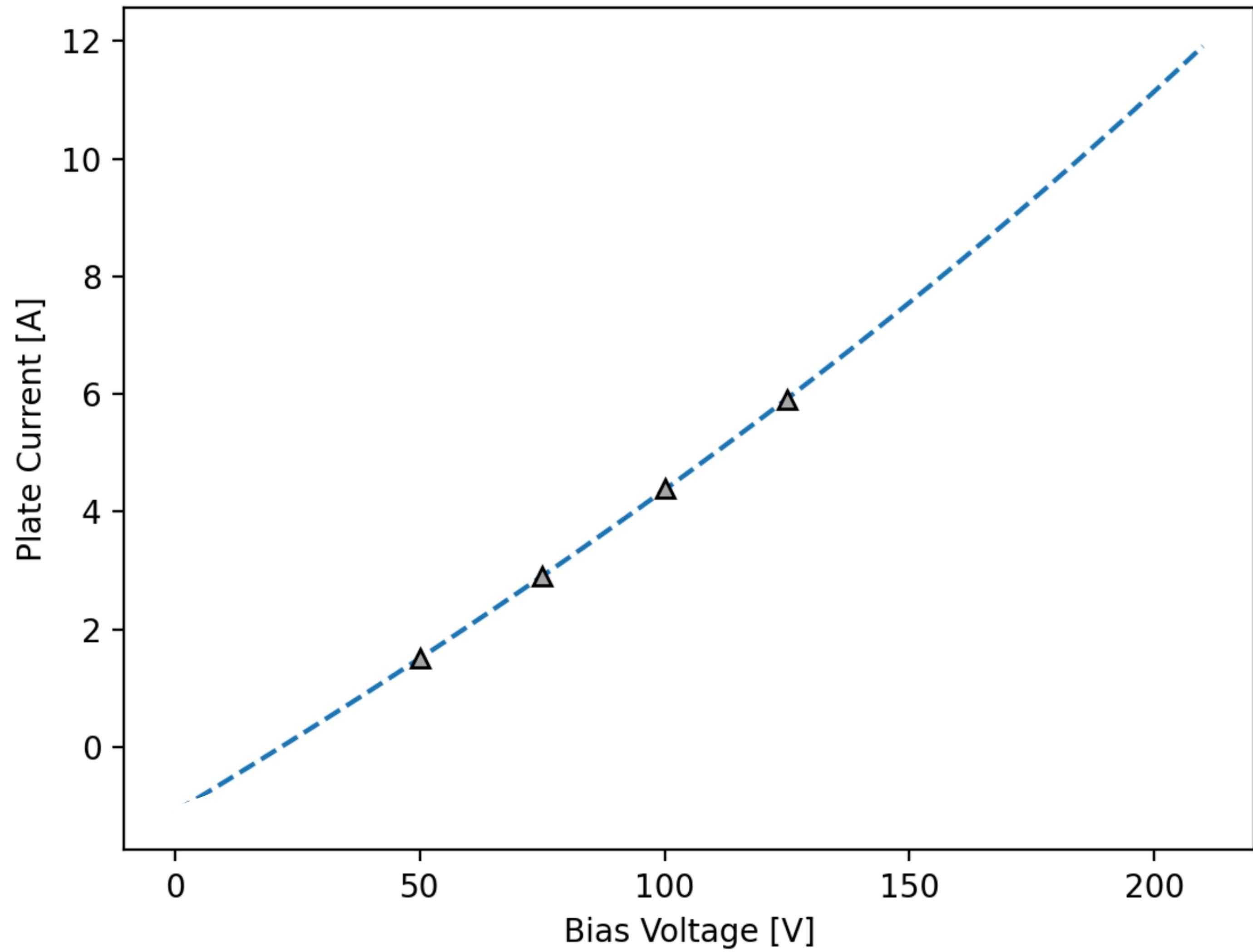
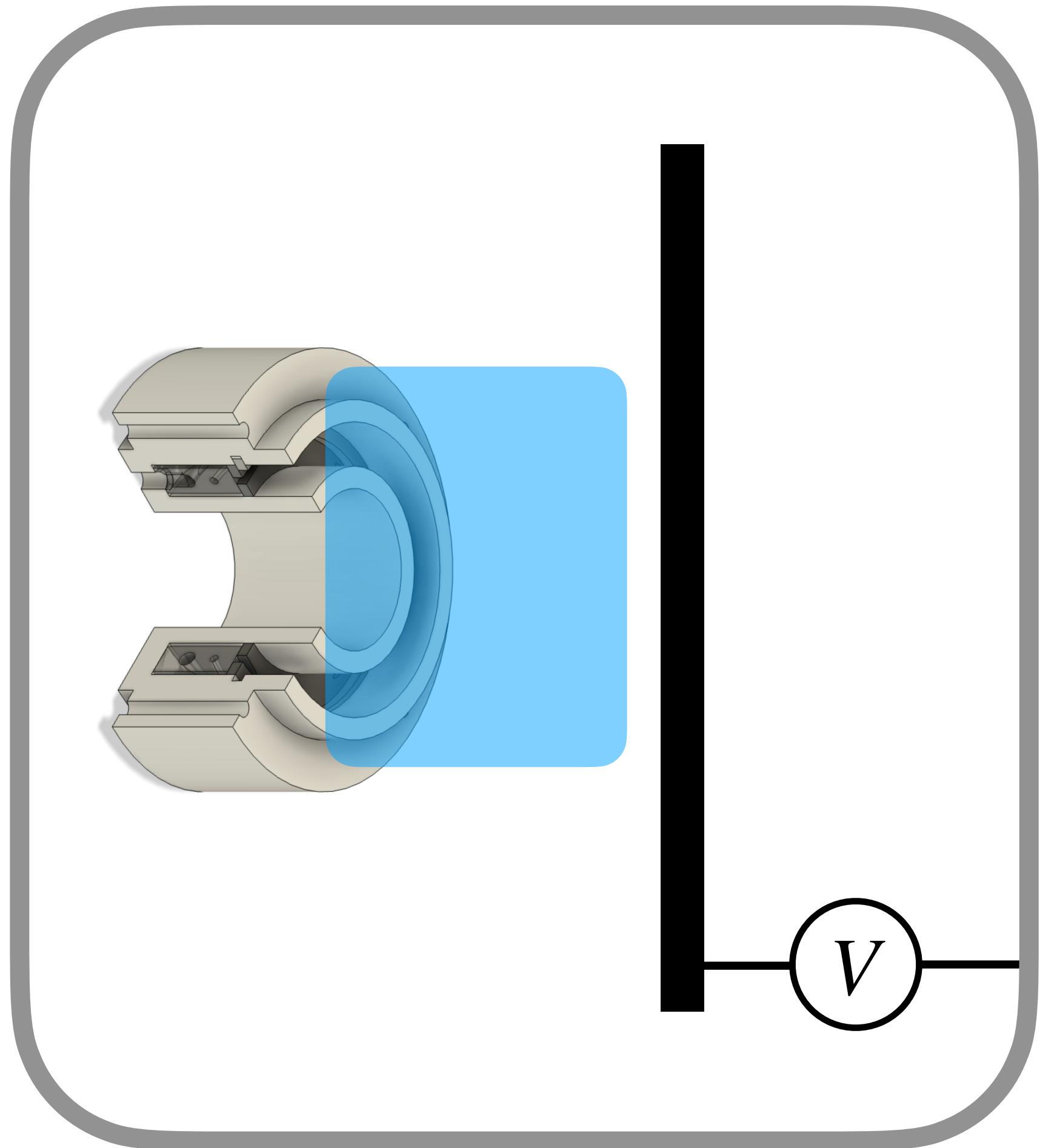


- Theoretically captures ~47% of beam current

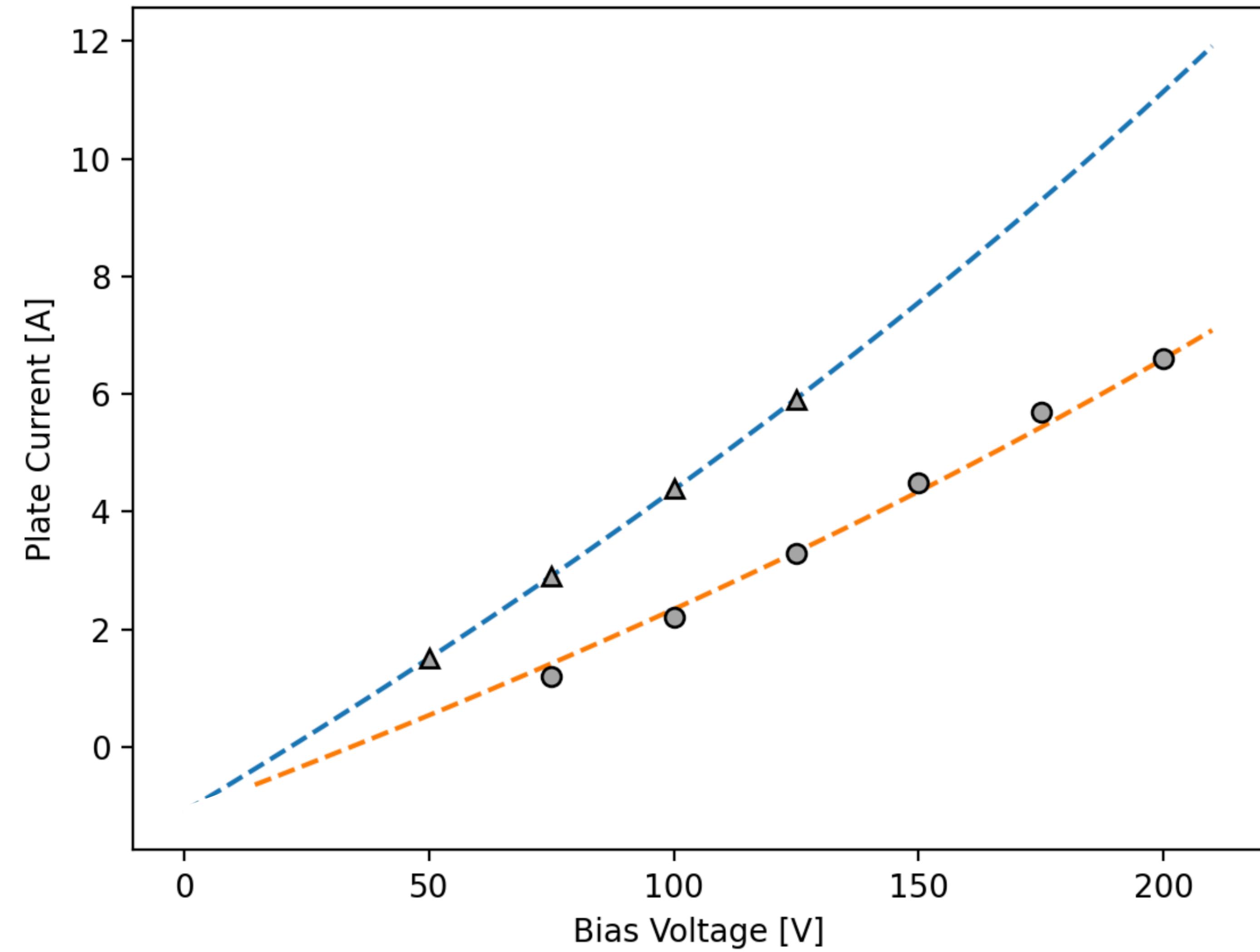
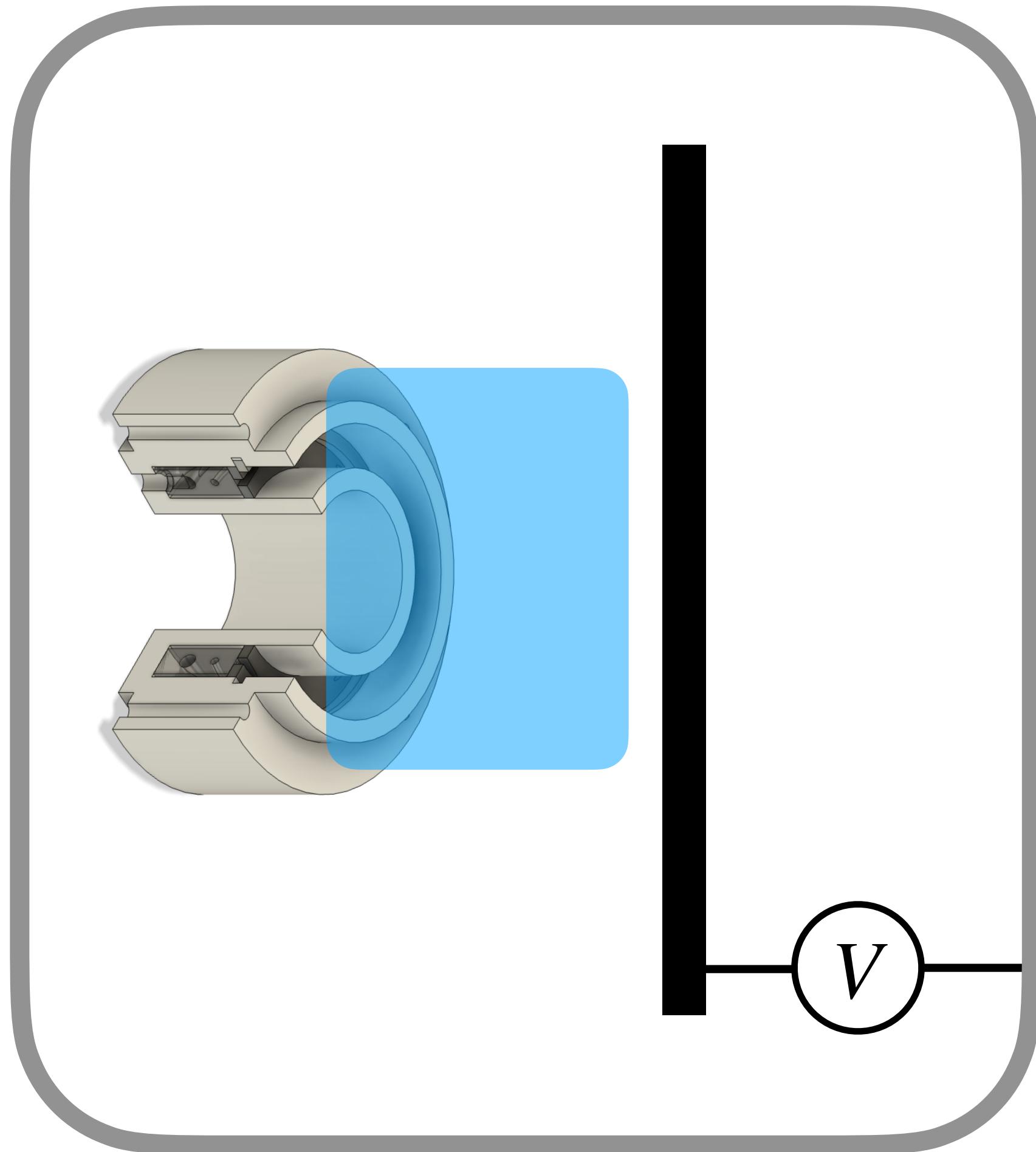
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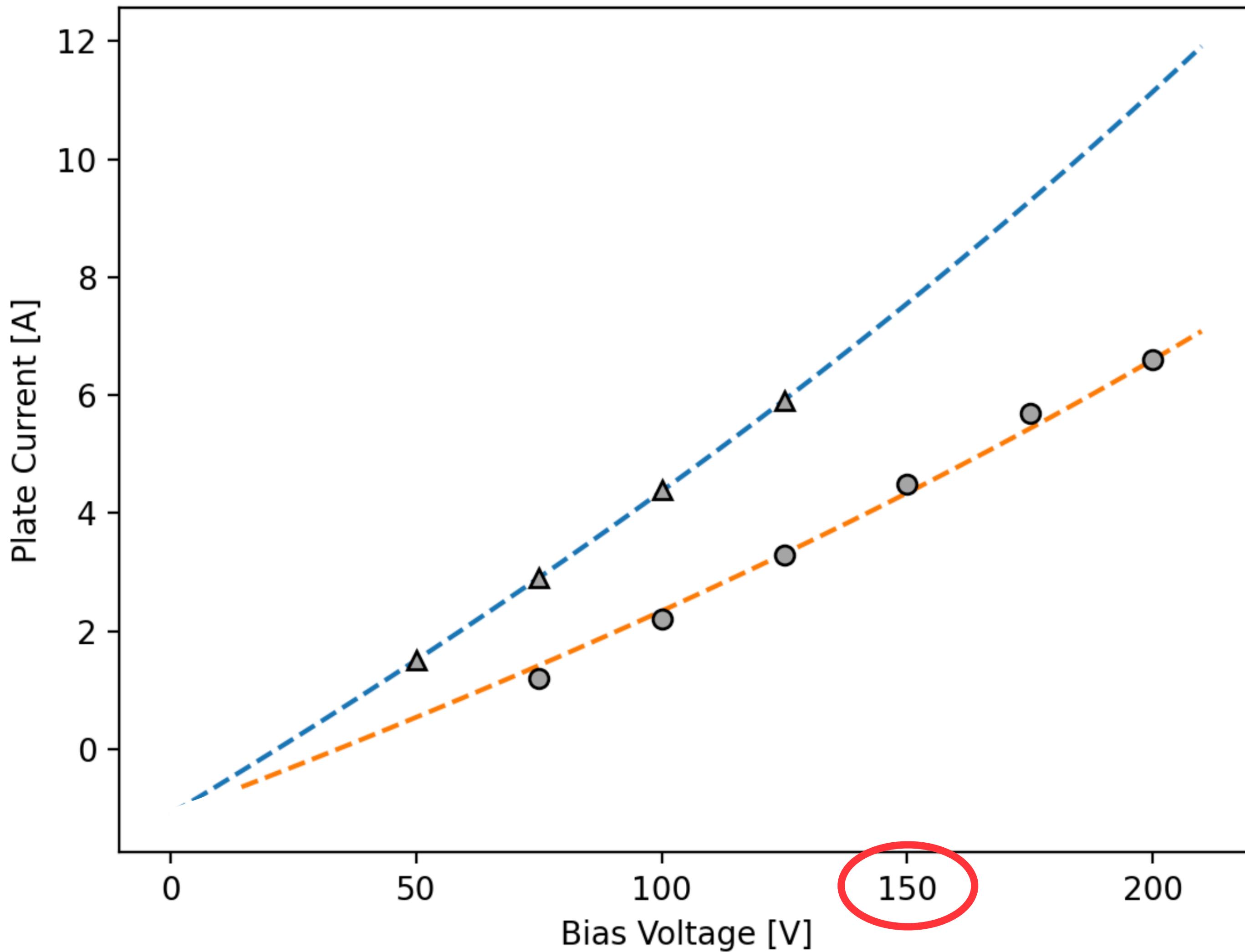
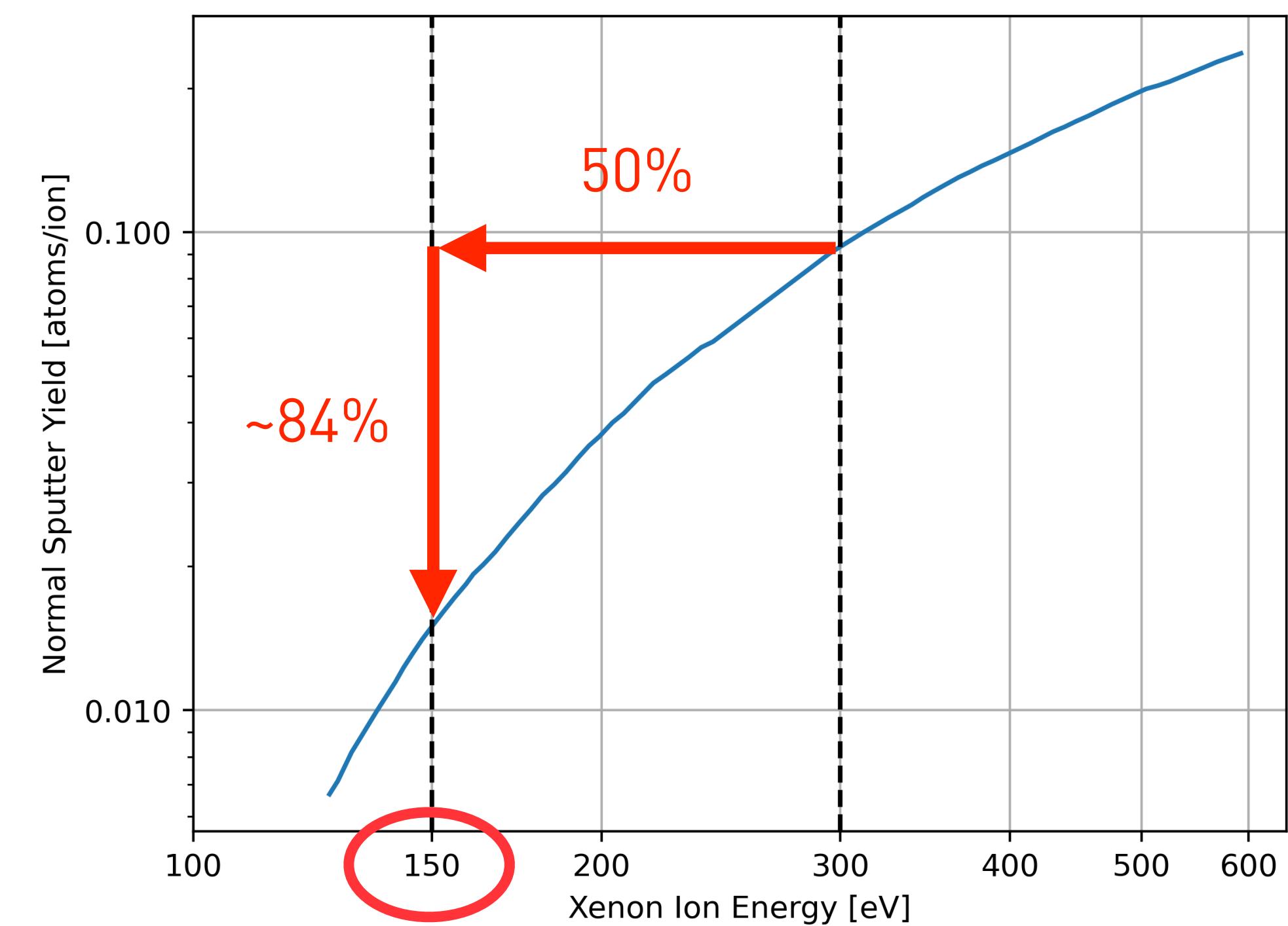
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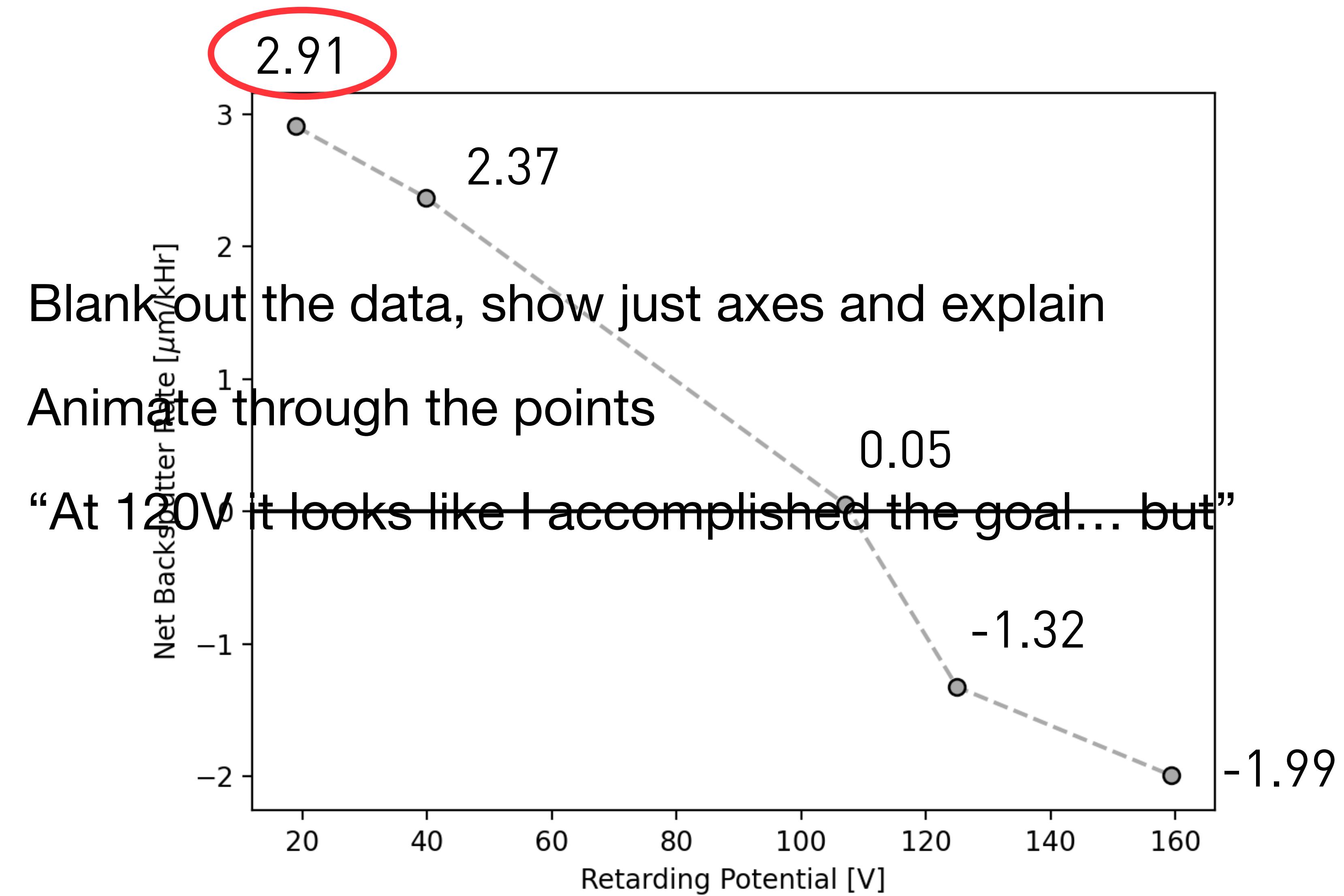
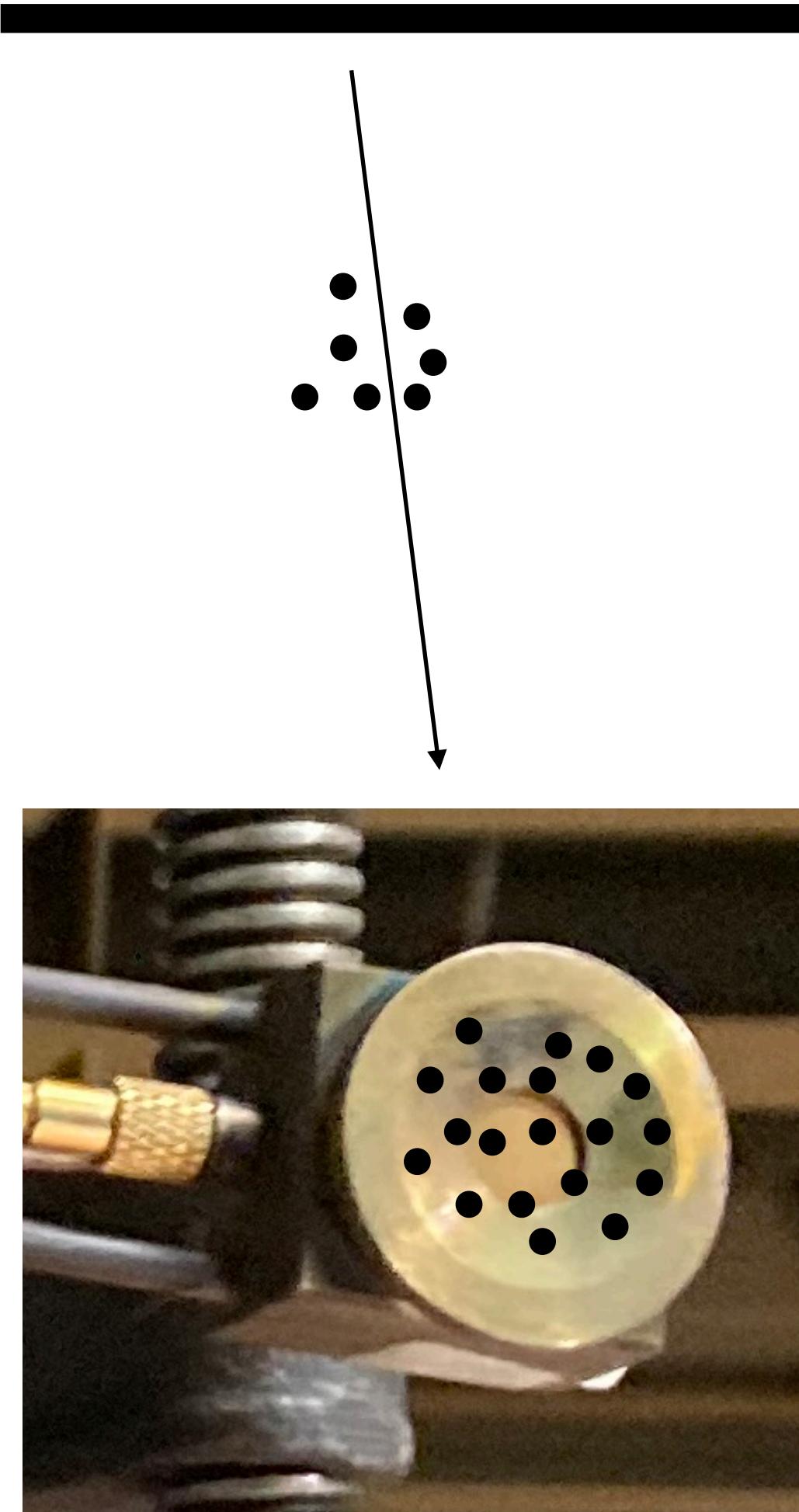
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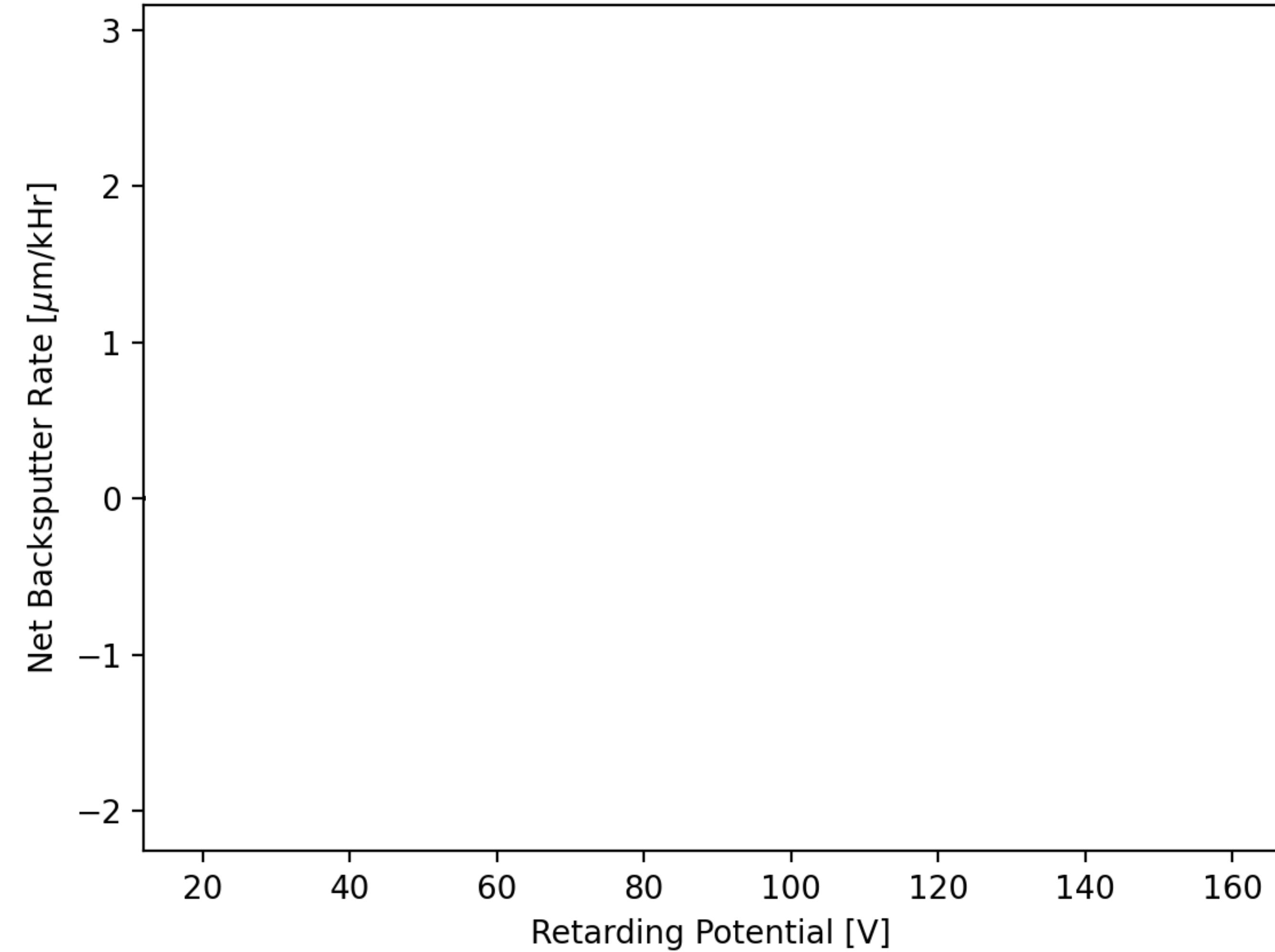
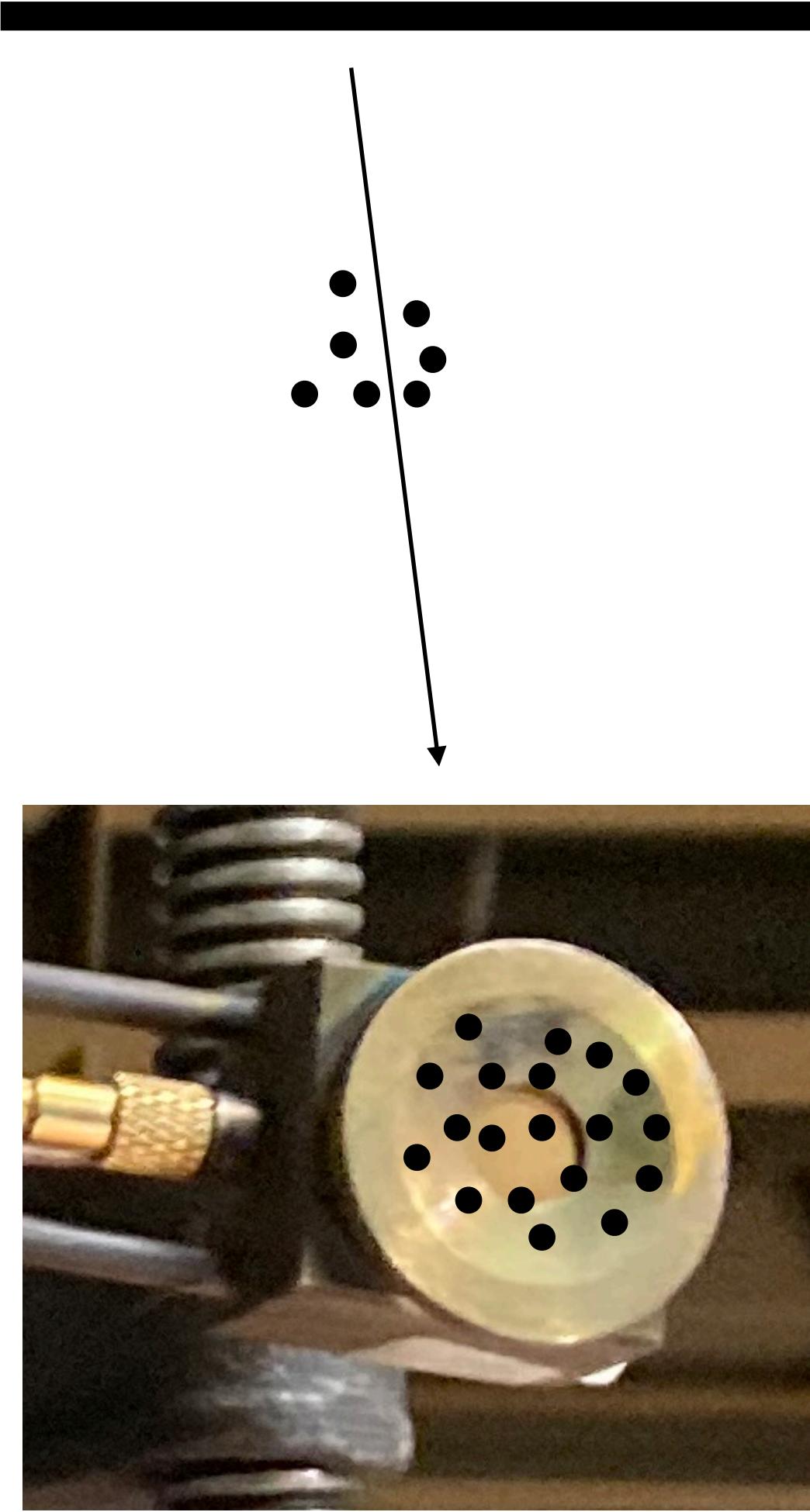
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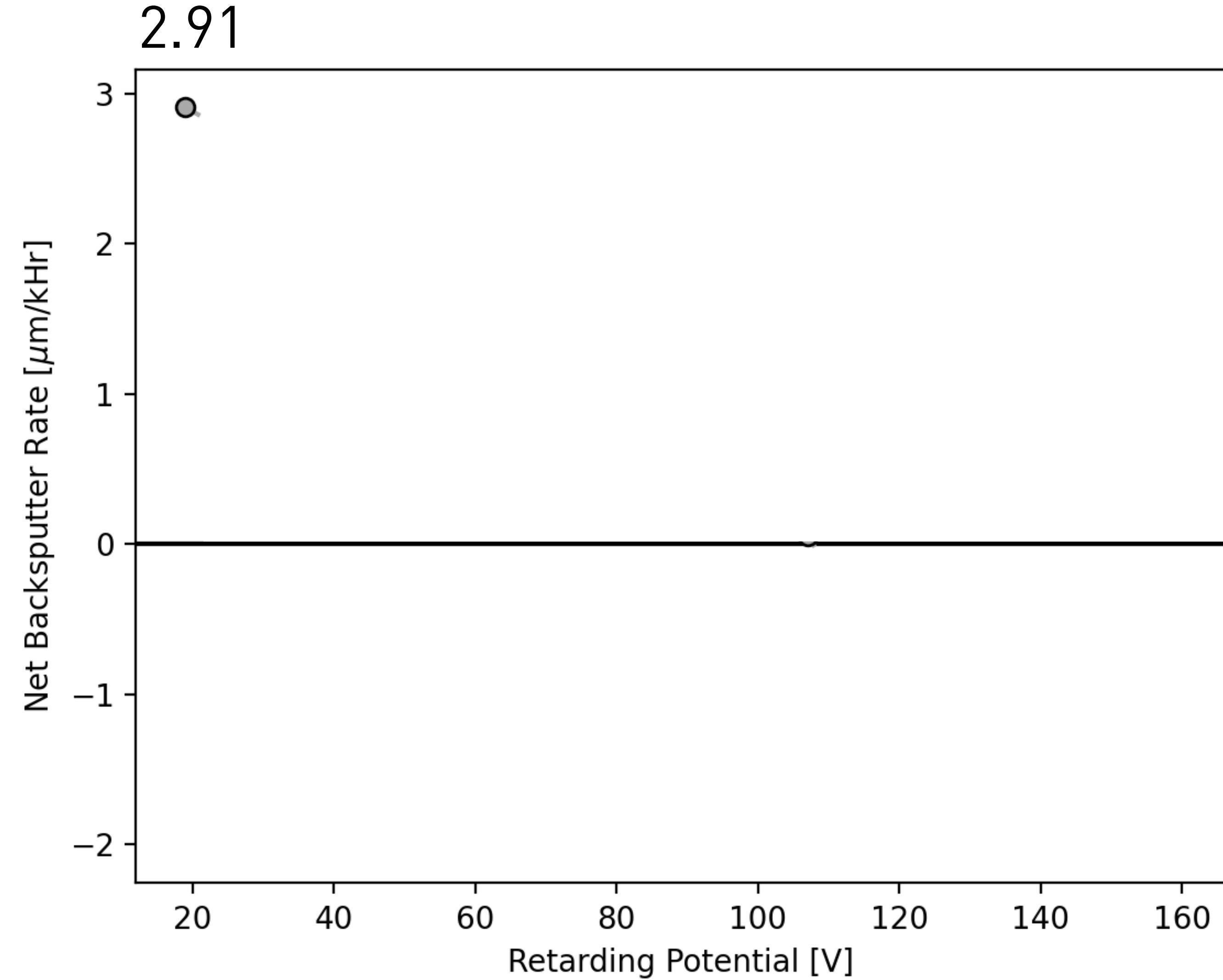
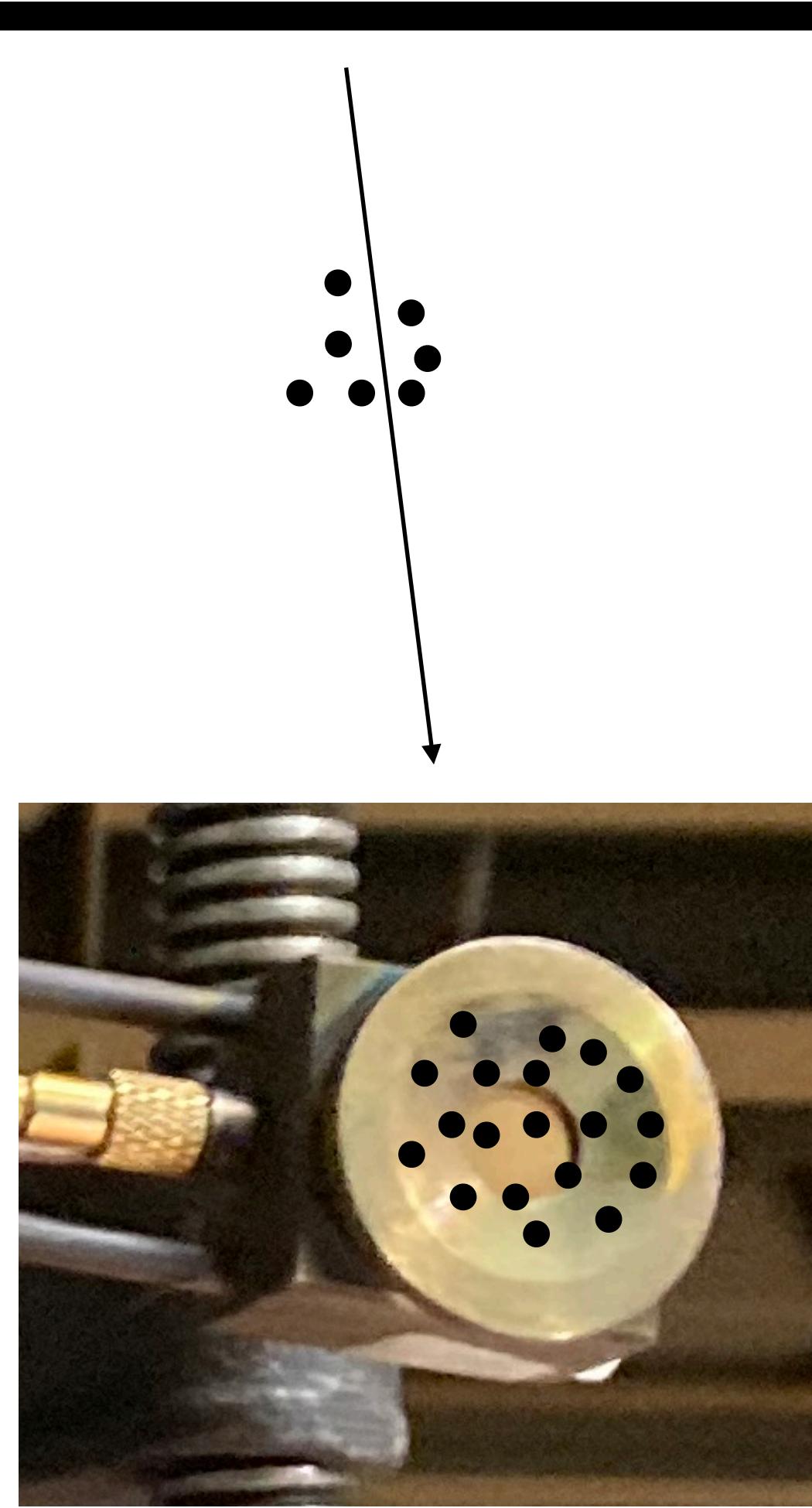
2. Are biases large enough to mitigate backsputter?



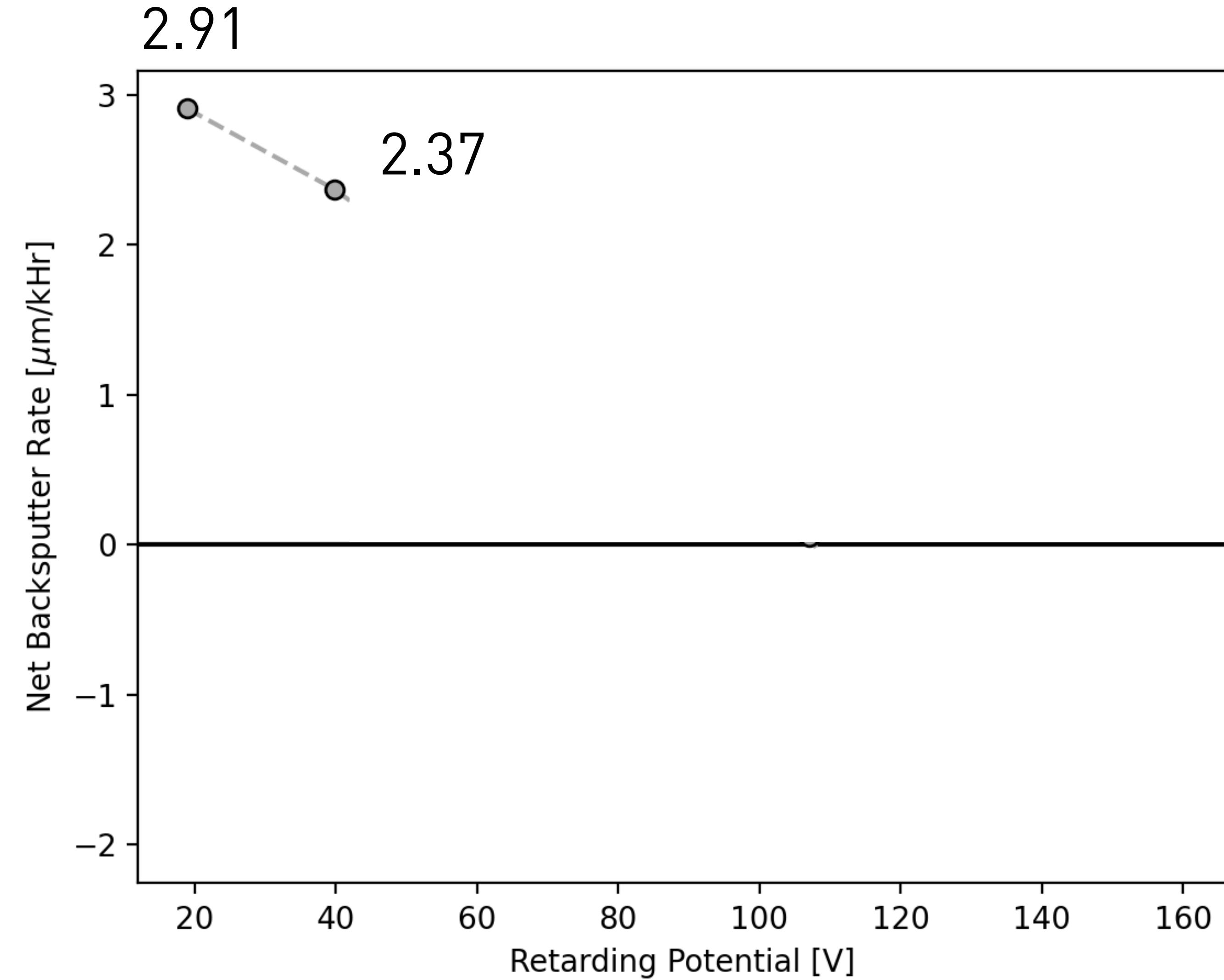
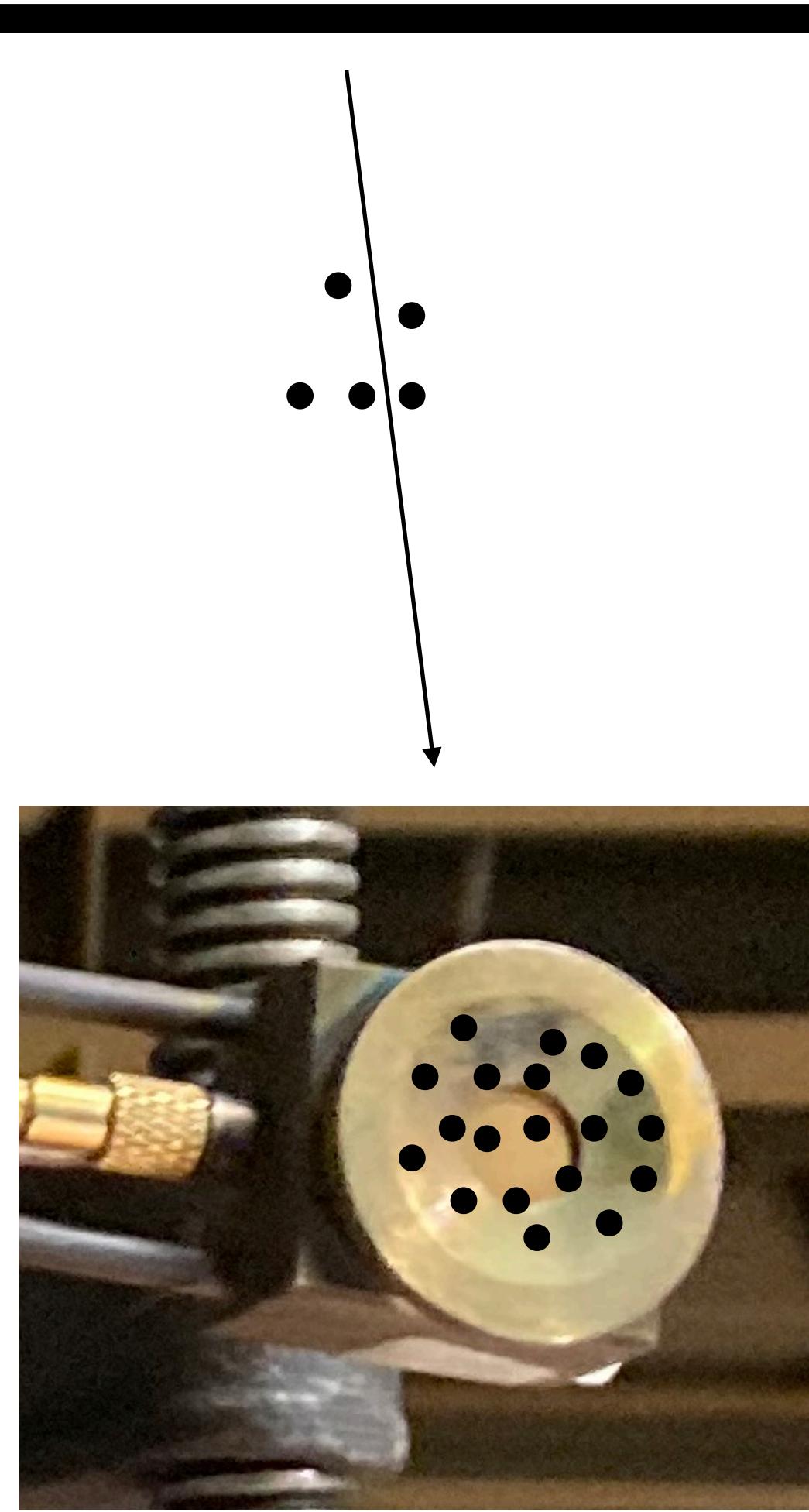
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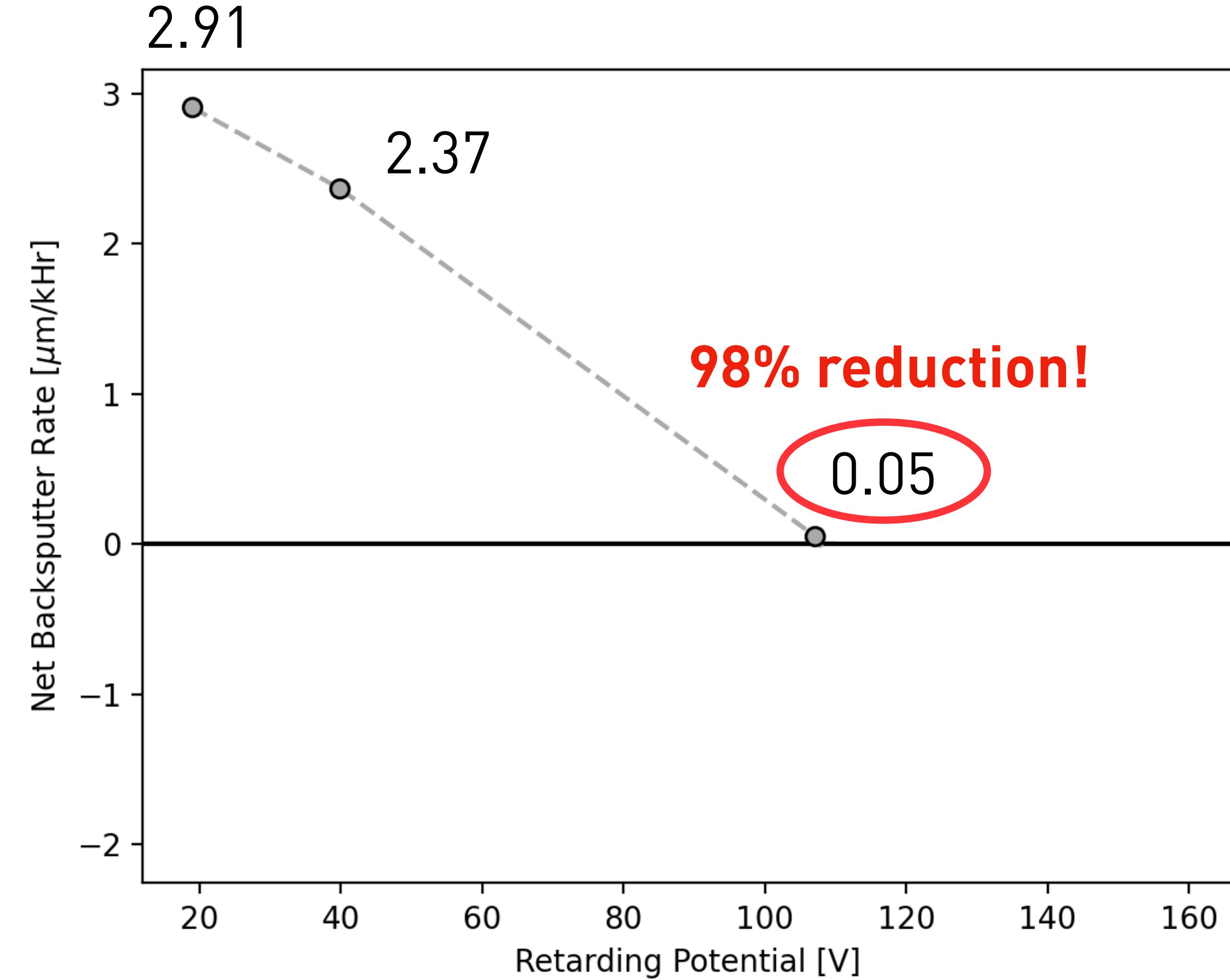
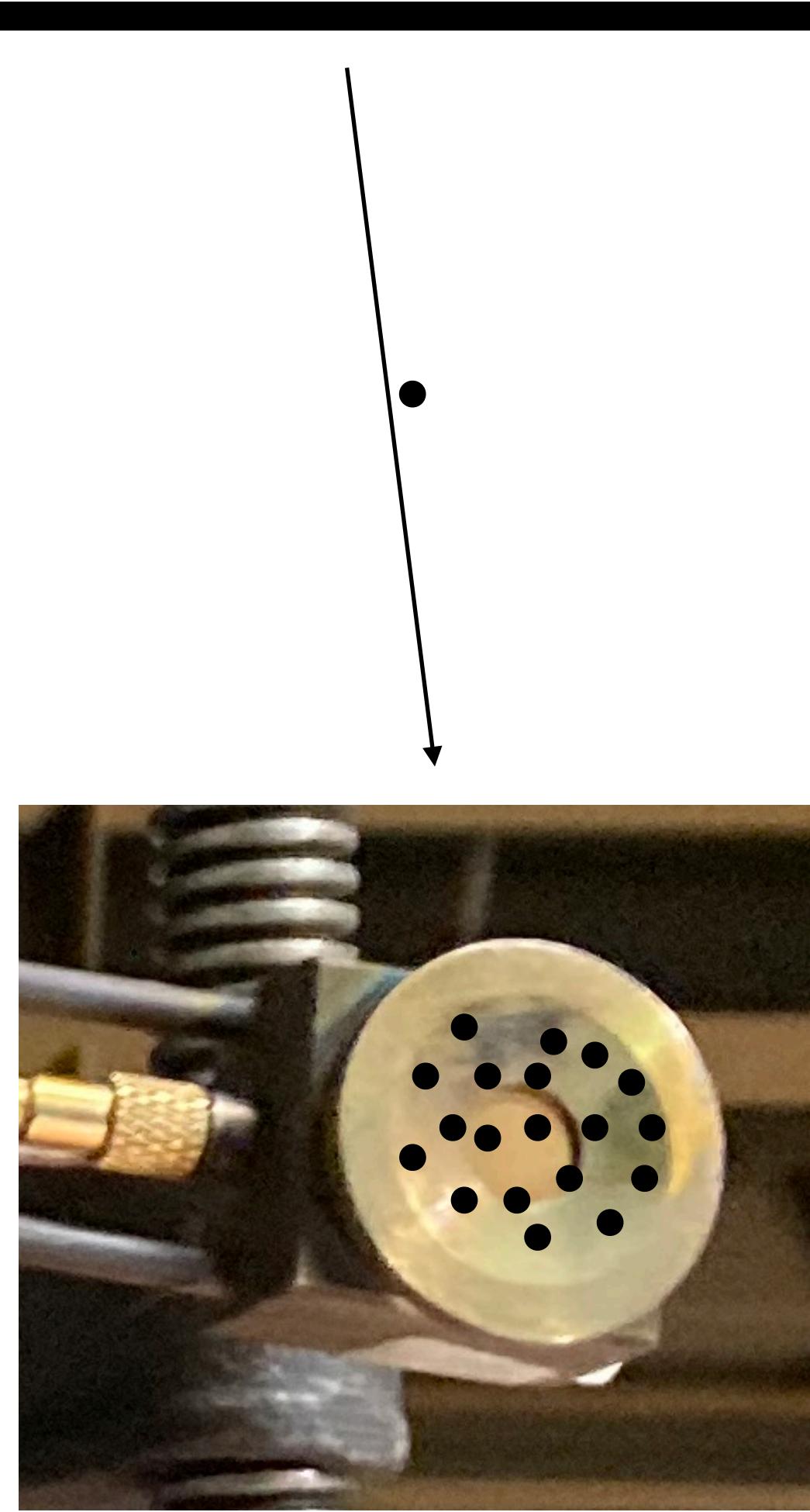
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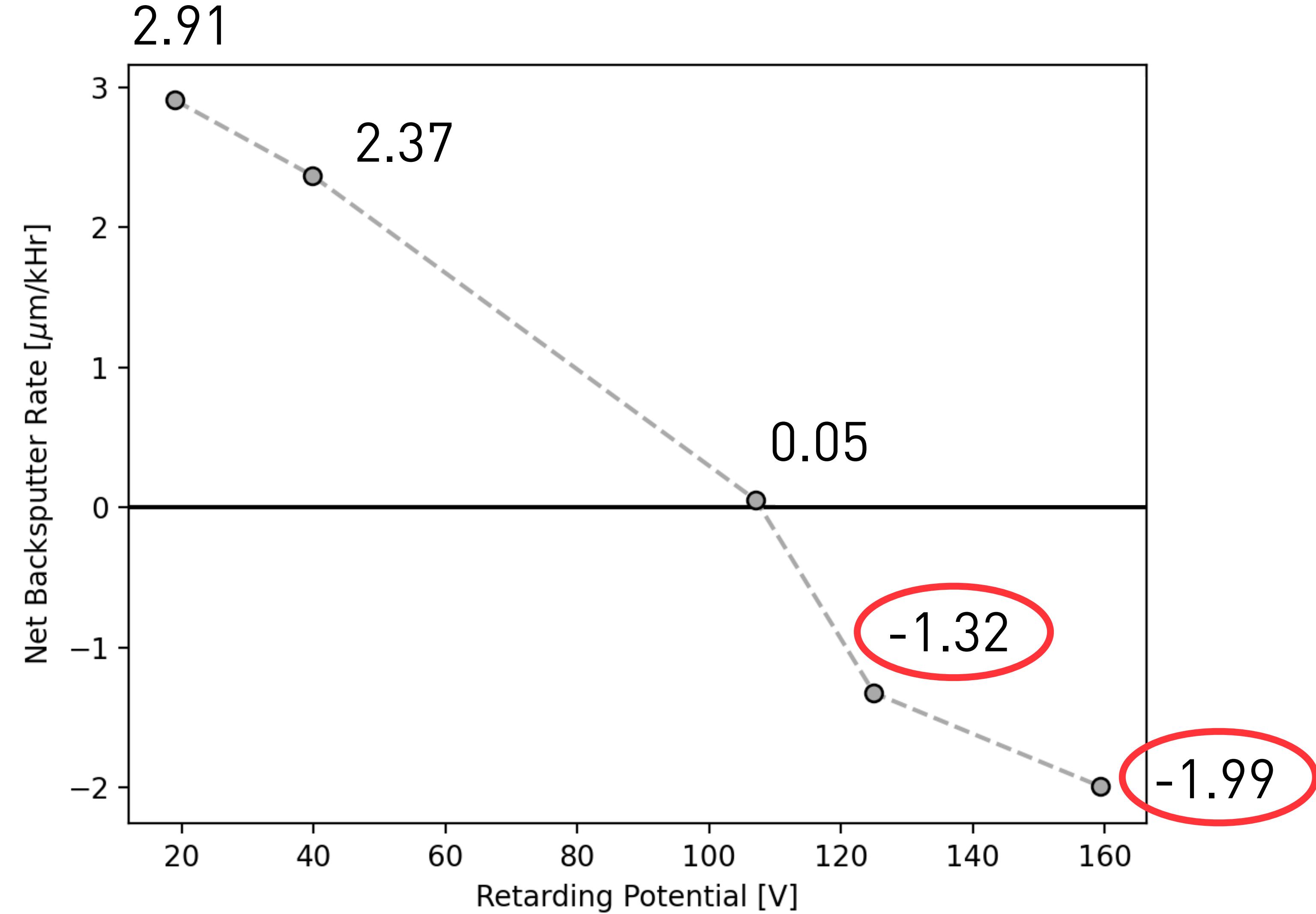
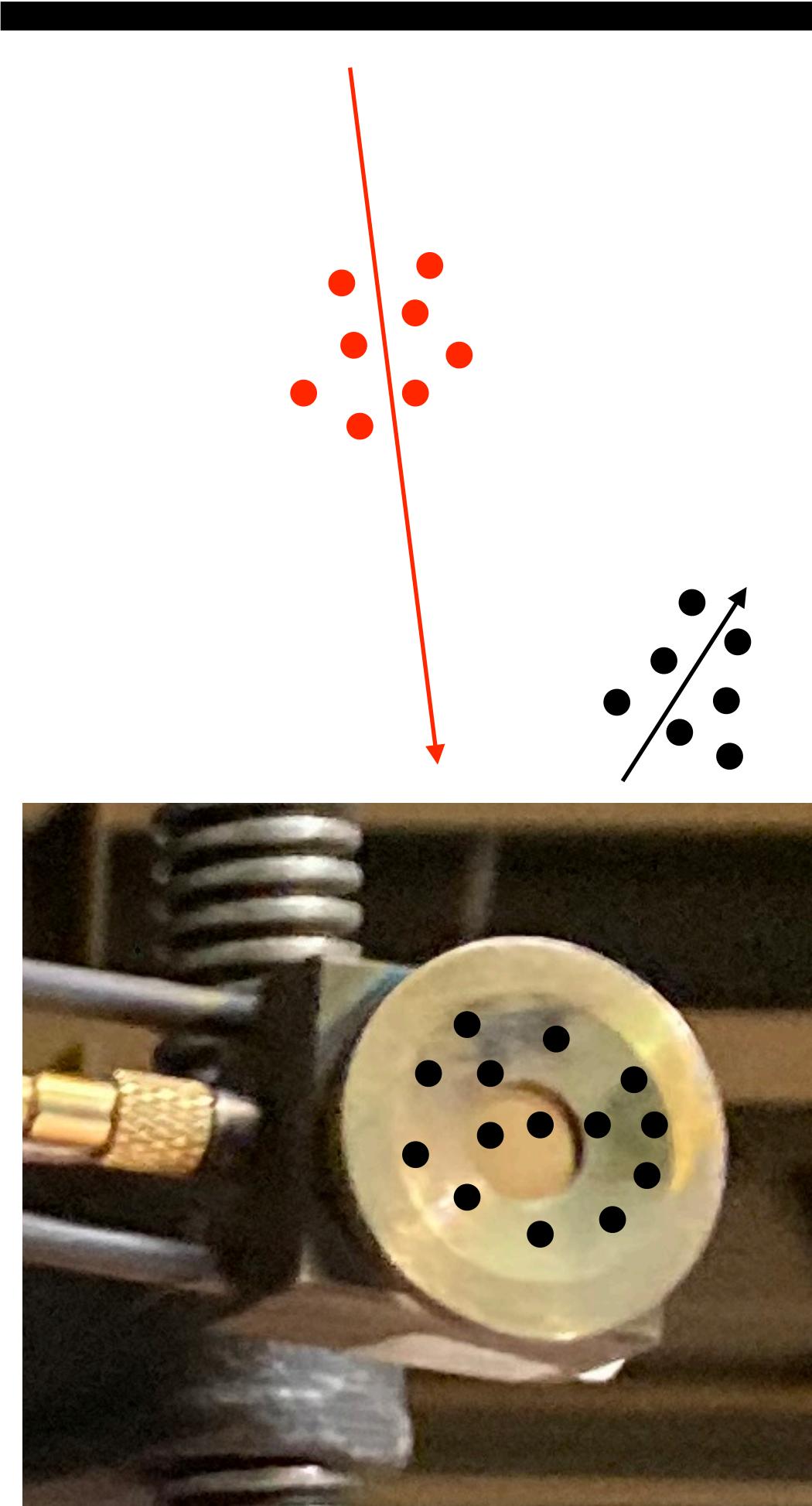
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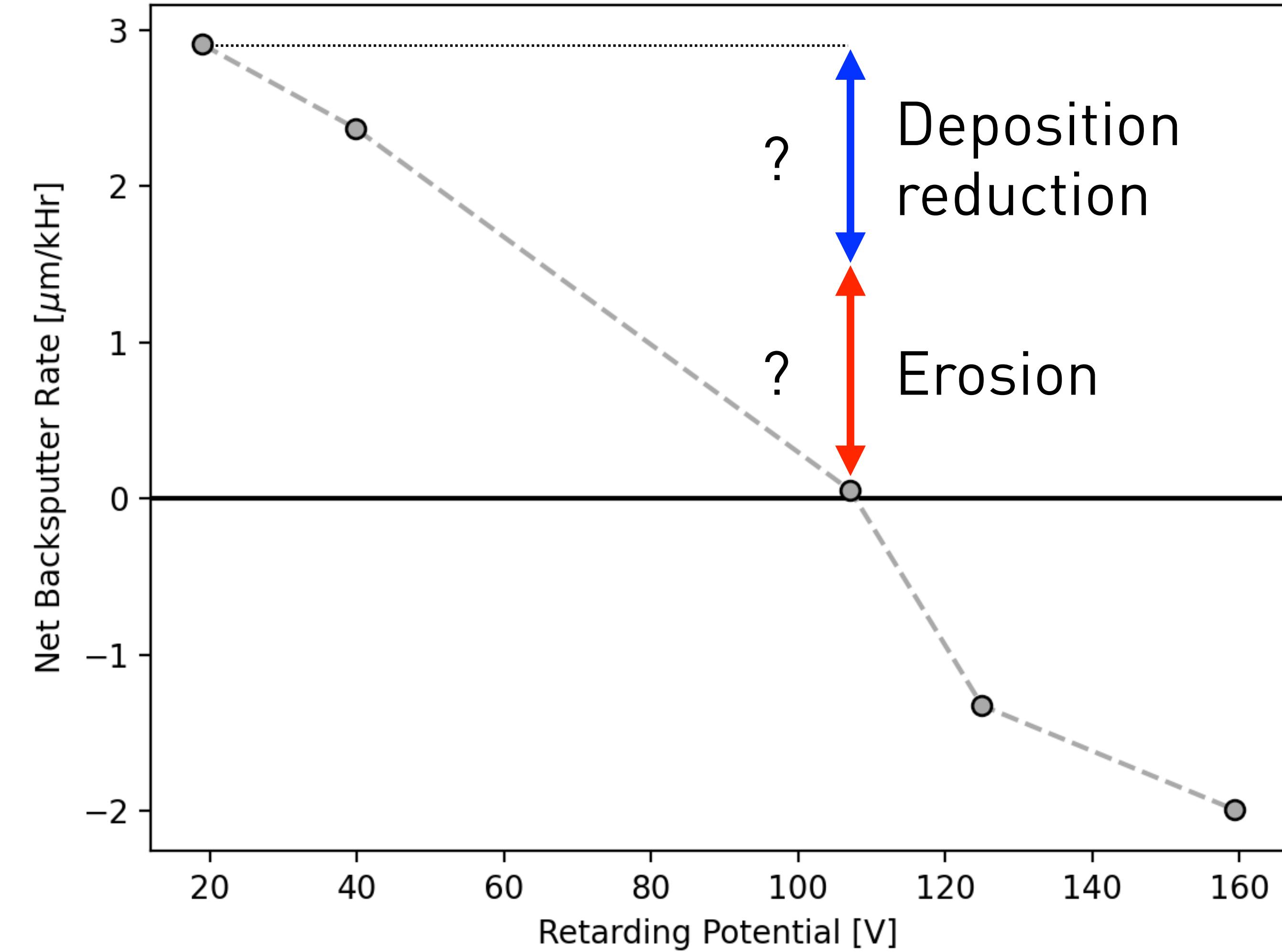
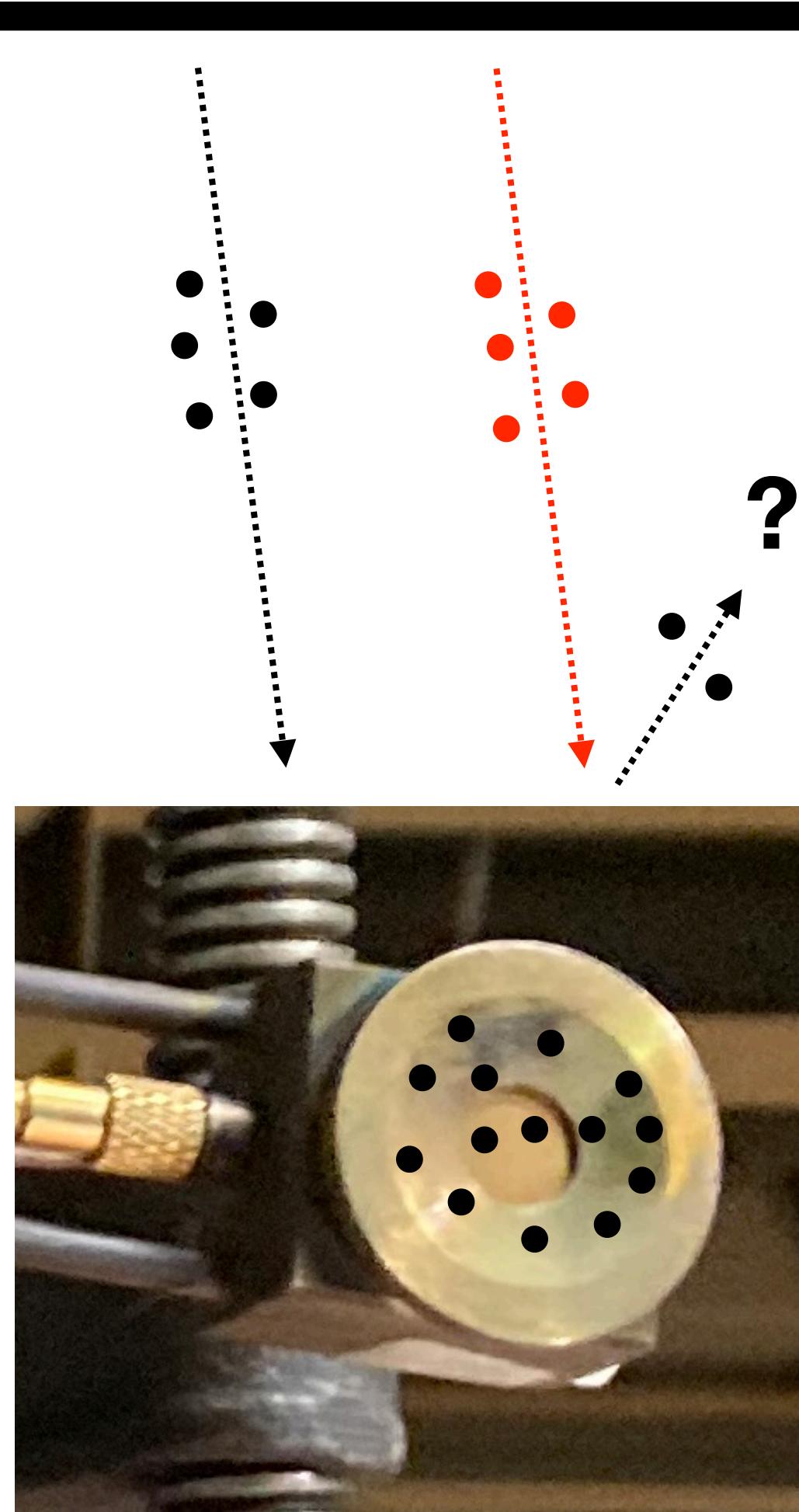
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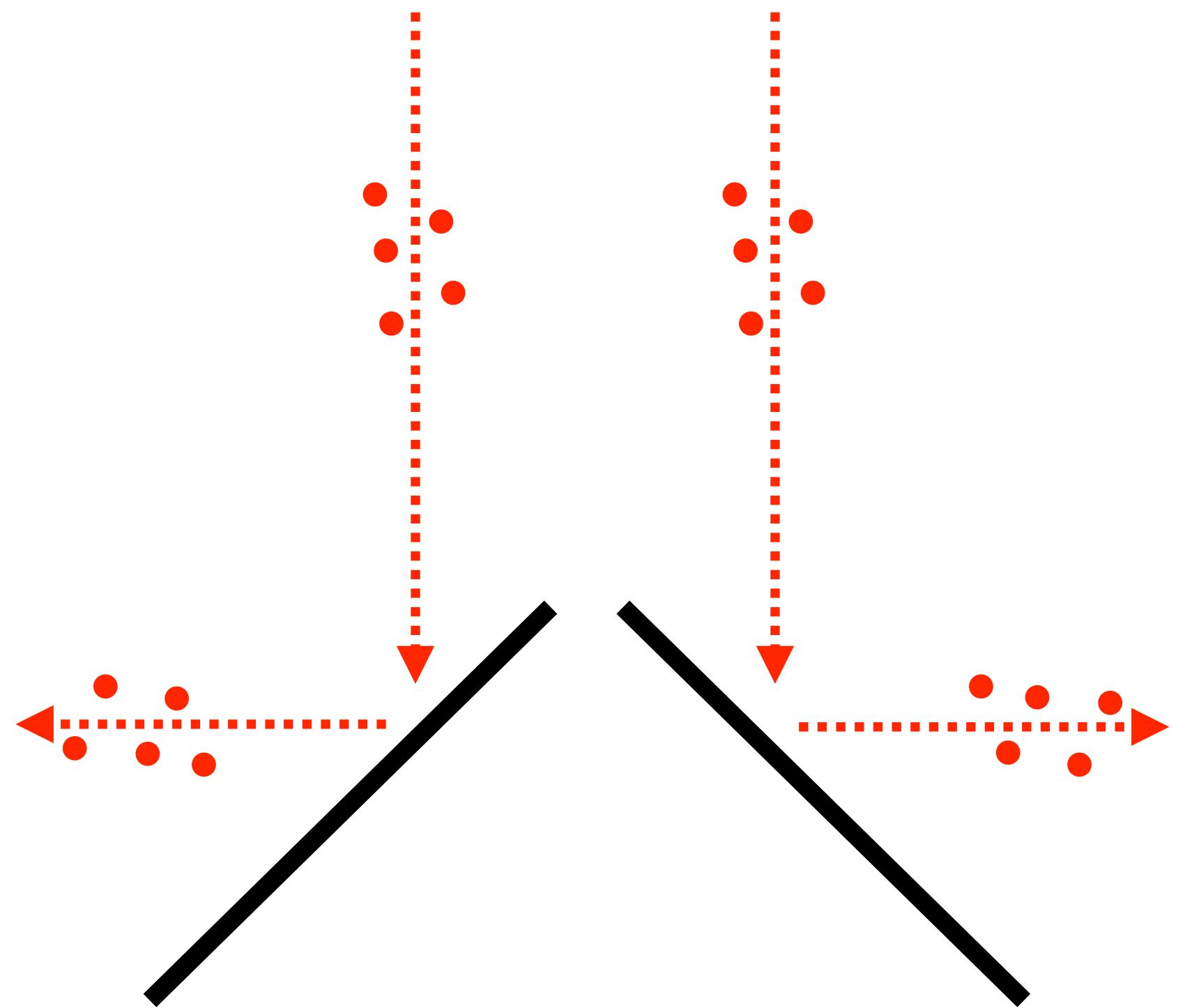
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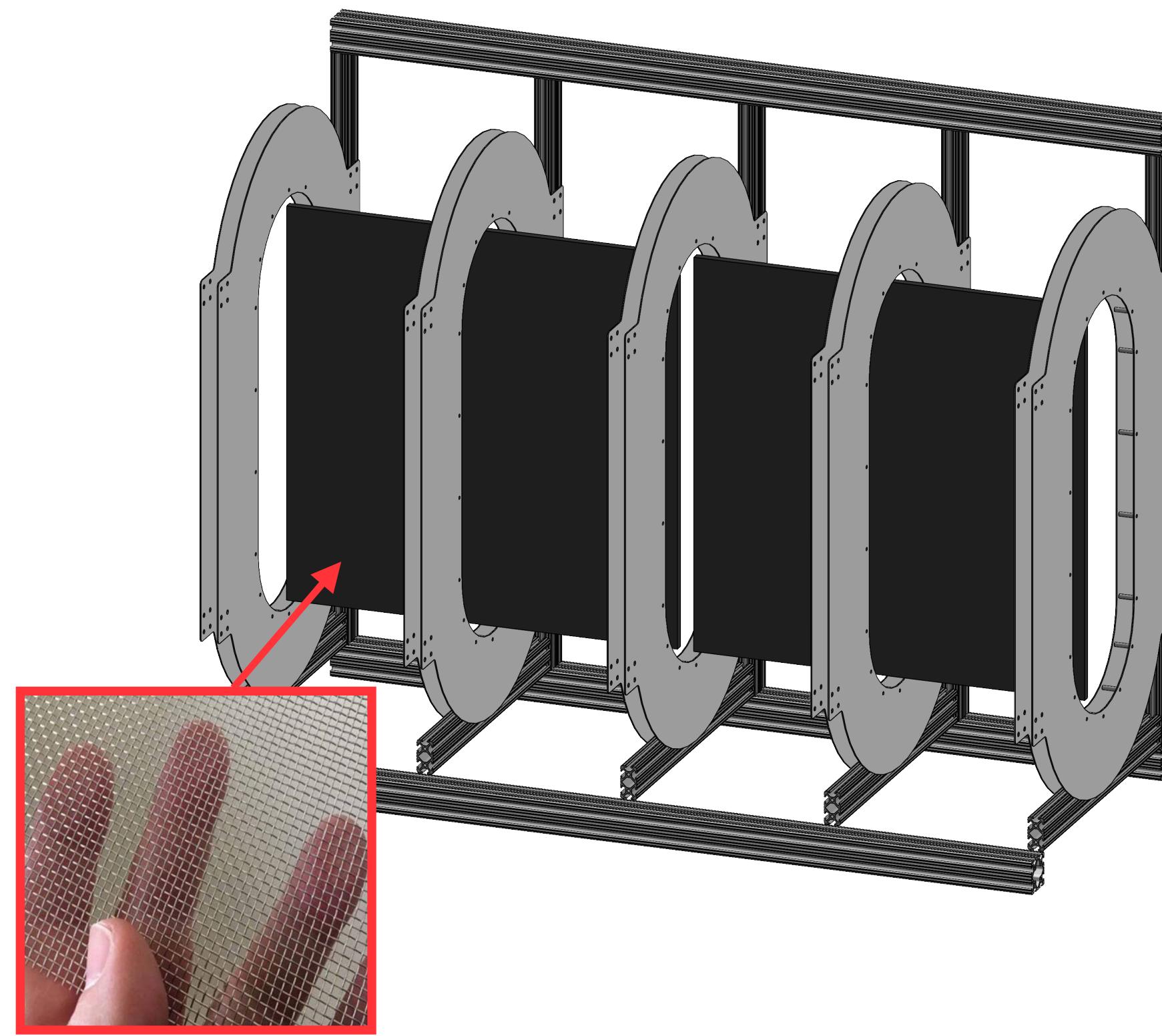
2. Are biases large enough to mitigate backsputter?



2. How can we mitigate CEX?



Angle beam catcher plates
(deflect ions)



Use mesh for bias plate
(reduce neutral density)

2. How can we mitigate CEX?

Are biases large enough to mitigate backsputter?

Yes, we can achieve net zero rates

Unable to separate erosion and deposition processes

Possible mitigations available for CEX launch-back

Angle beam catcher plates
(deflect ions)

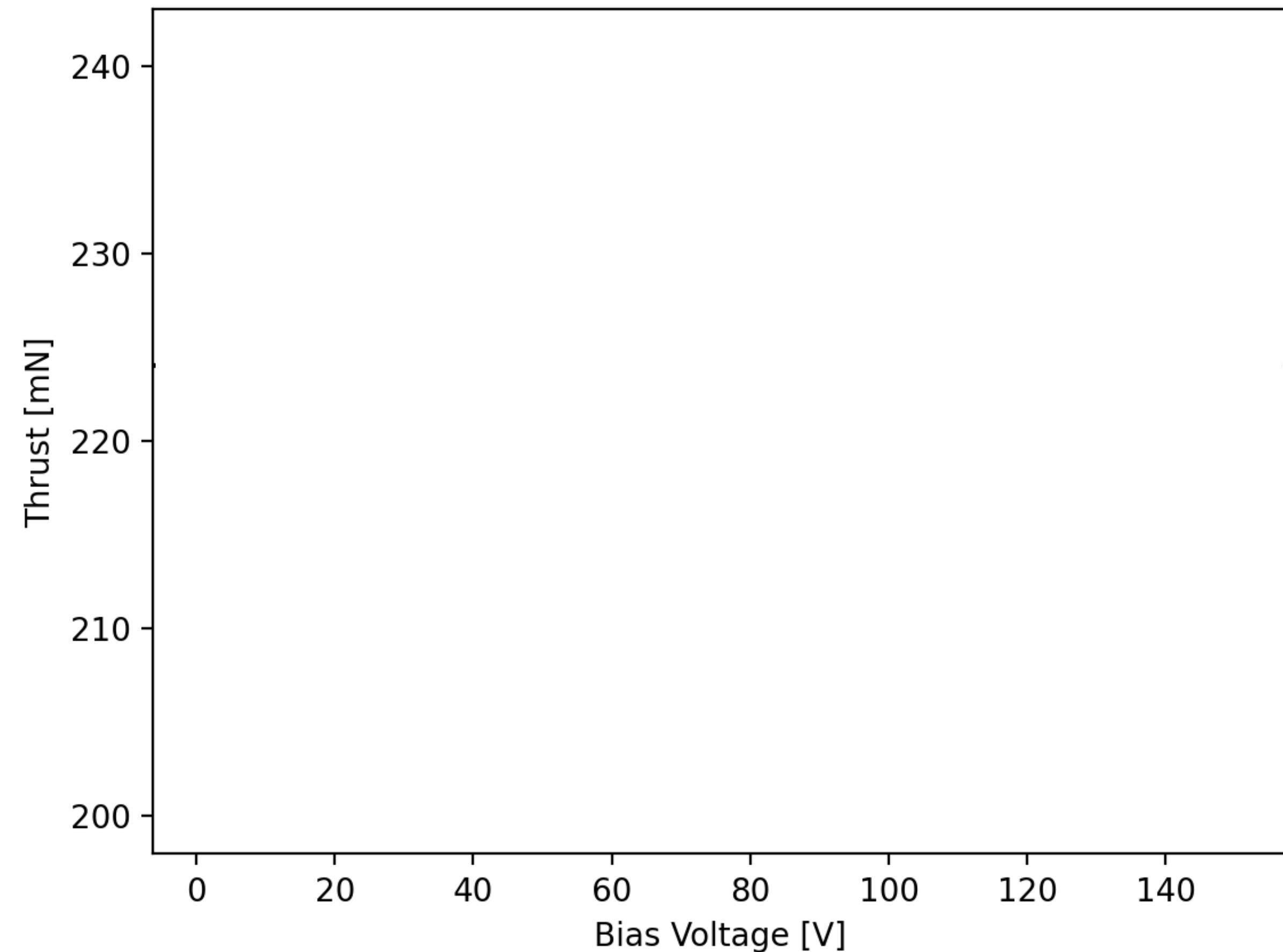
Use mesh for bias plate
(reduce neutral density)

2. Do we affect thruster performance?

Property	Answer
Thrust Levels	Does the thrust change?
Thruster Oscillations	Do the instabilities change?
Far Field Plasma Potential	Does the magnetic field decouple the plasma and bias voltages?
Plume Distribution	Does the plume change shape?

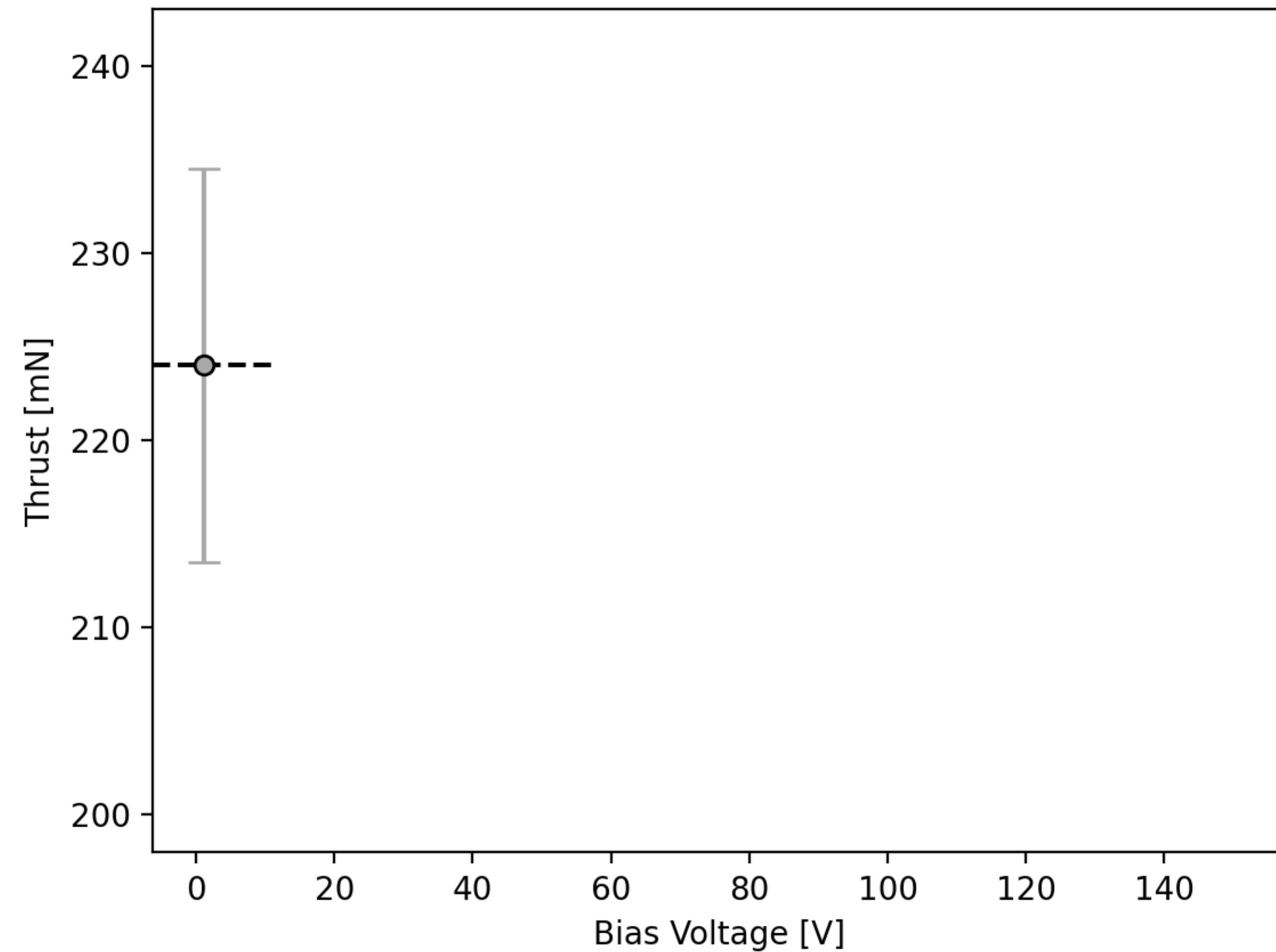
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Property	Answer
Thrust Levels	
Thruster Oscillations	
Far Field Plasma Potential	
Plume Distribution	



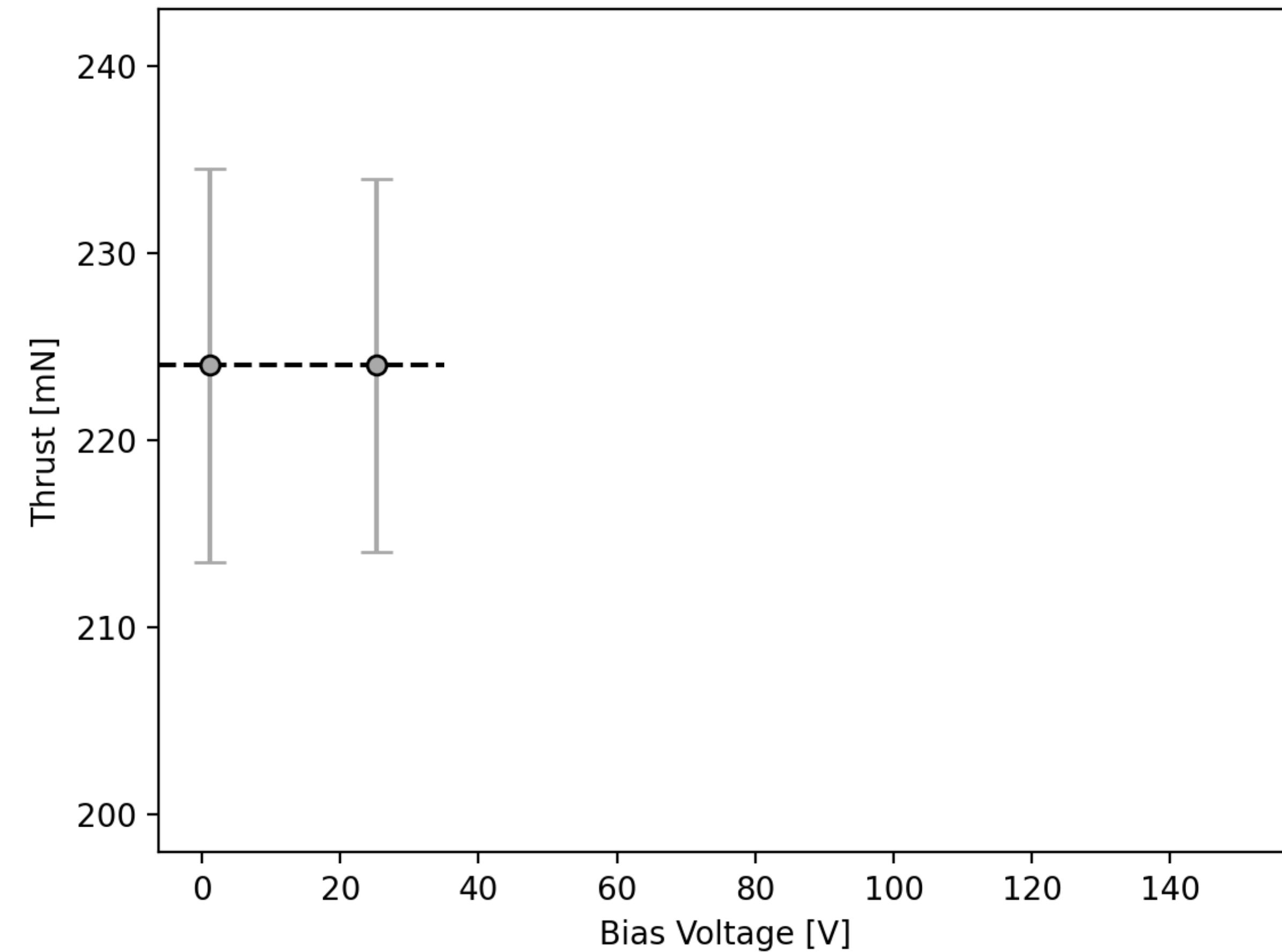
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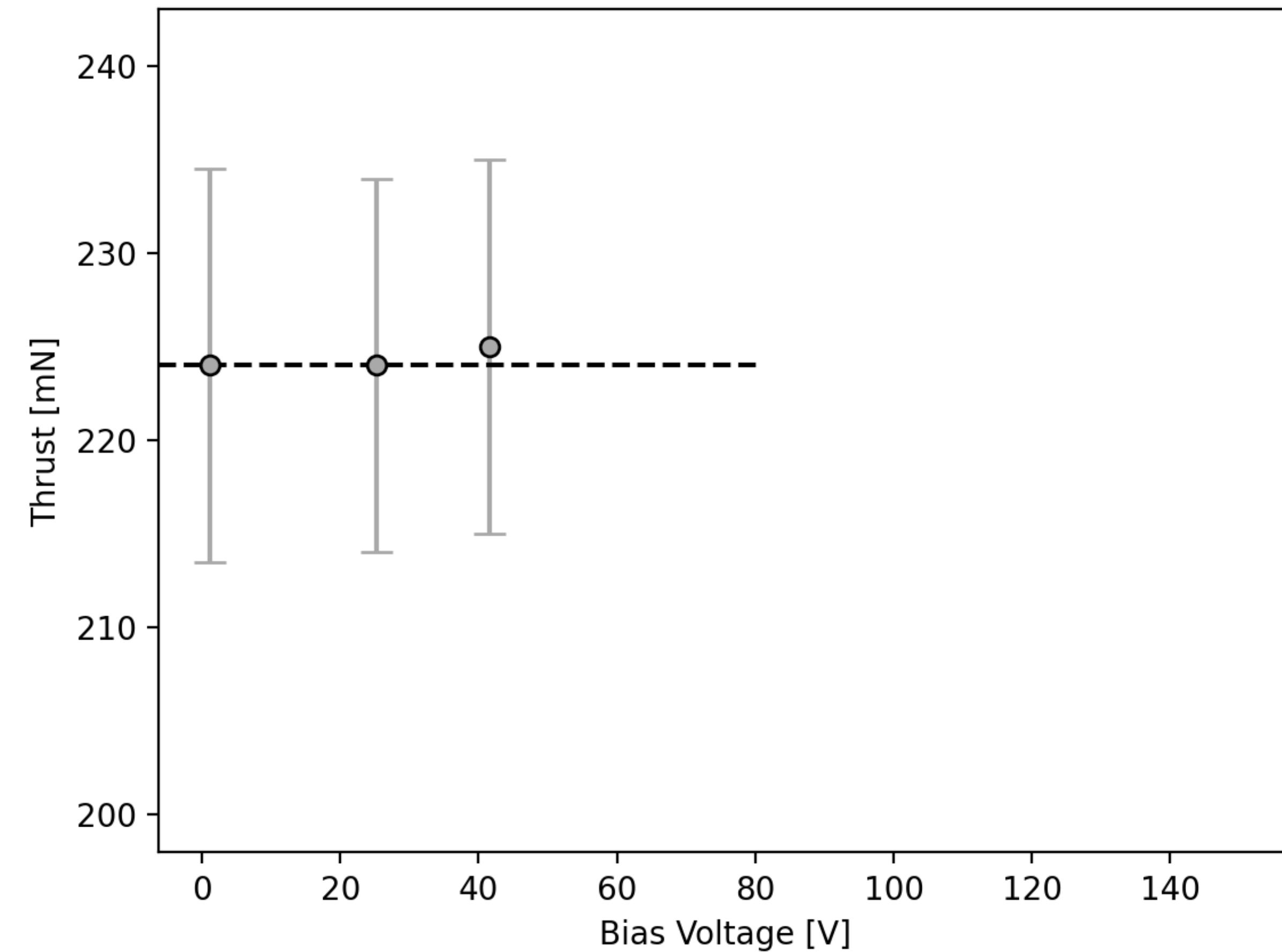
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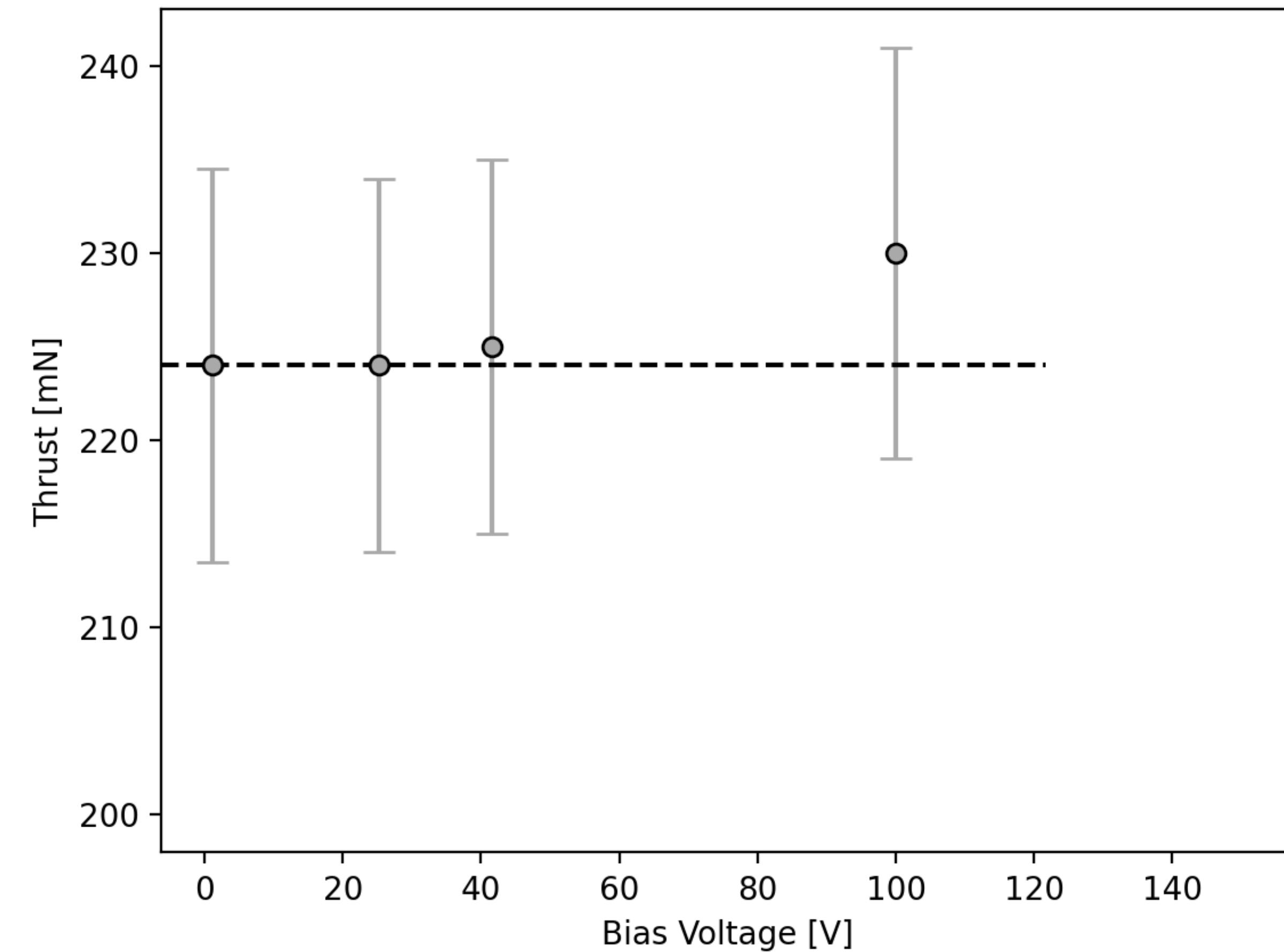
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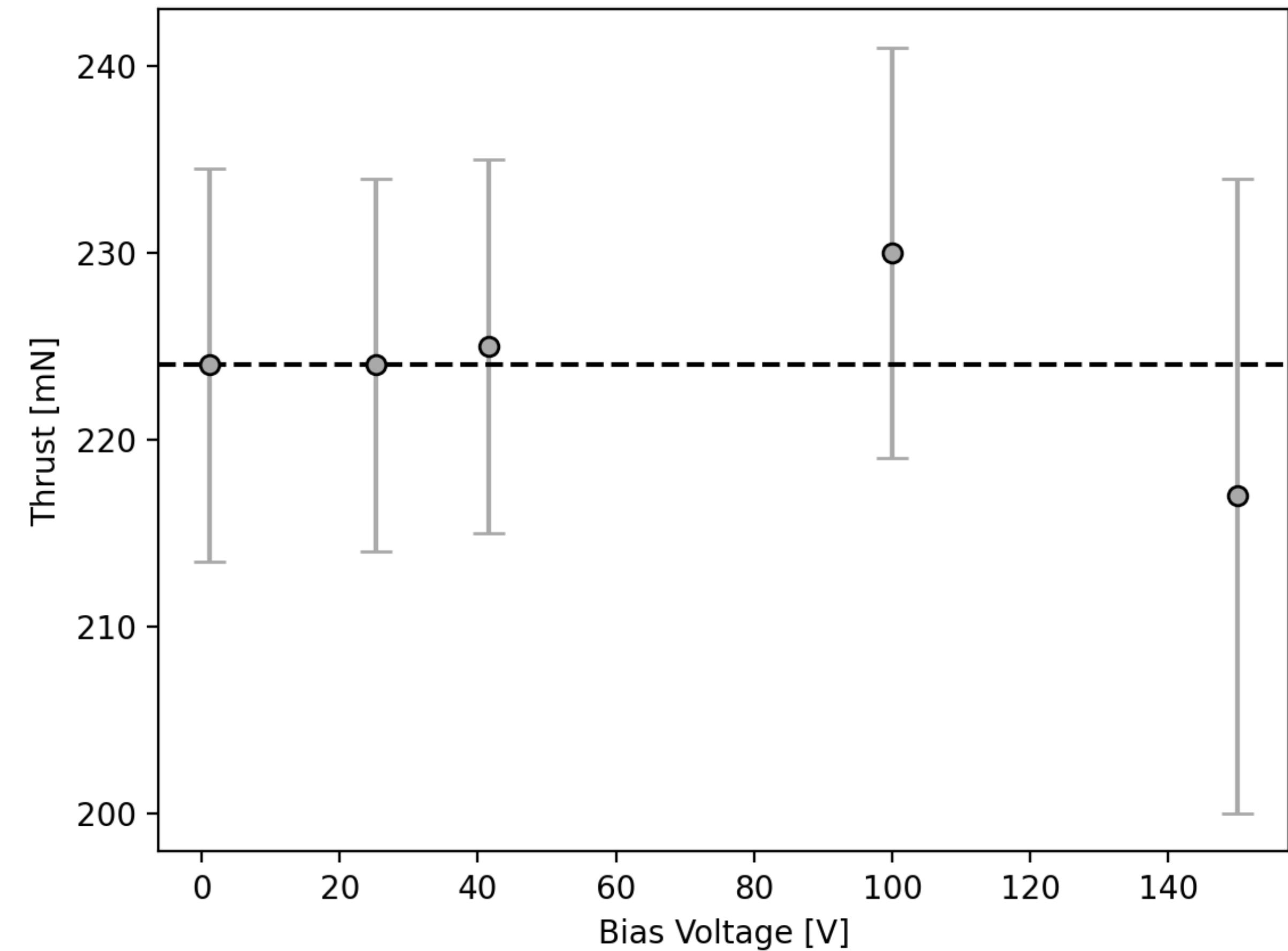
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Plume Distribution	



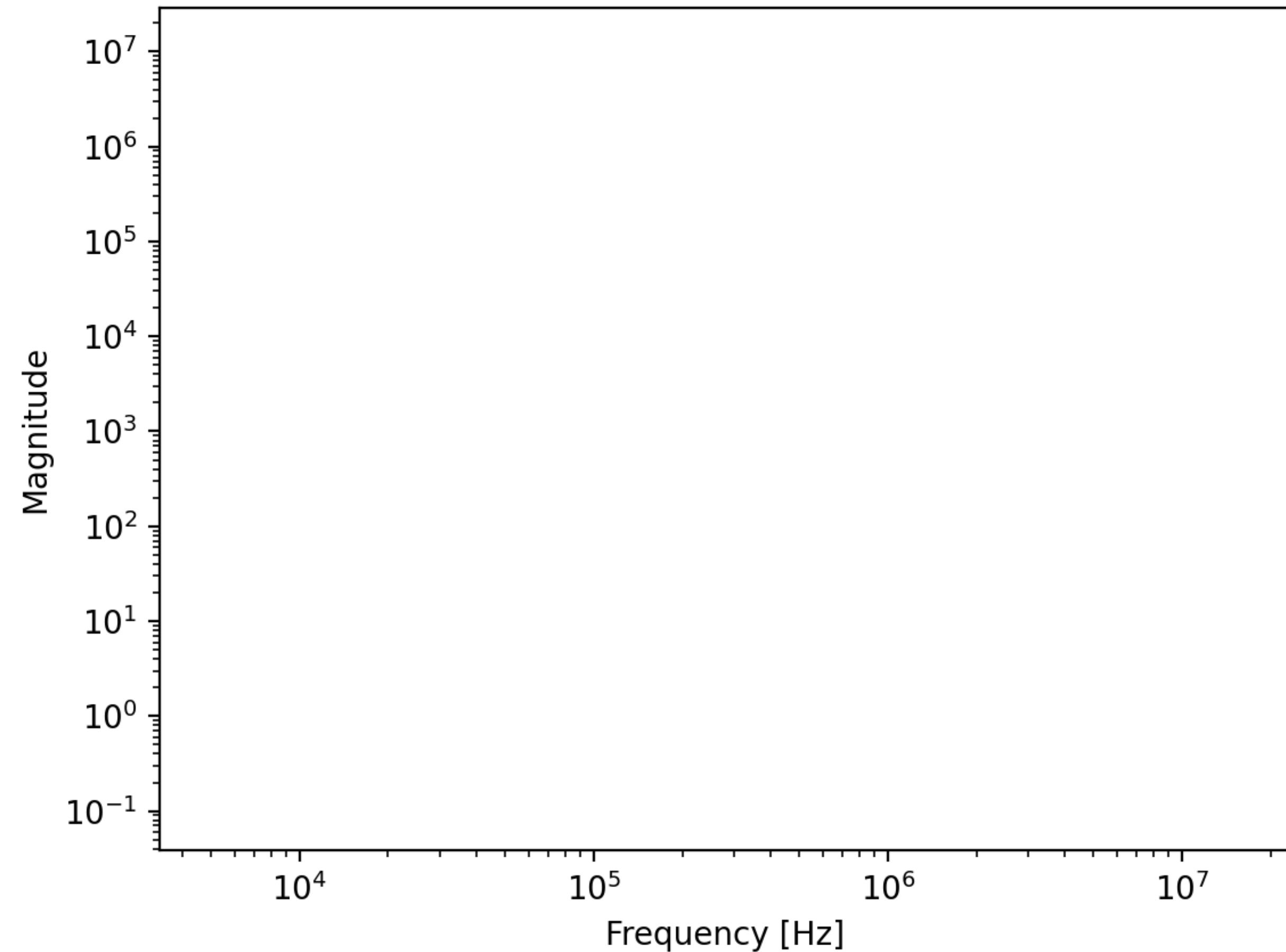
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Property	Answer
Thrust Levels	No
Thruster Oscillations	
Far Field Plasma Potential	
Plume Distribution	



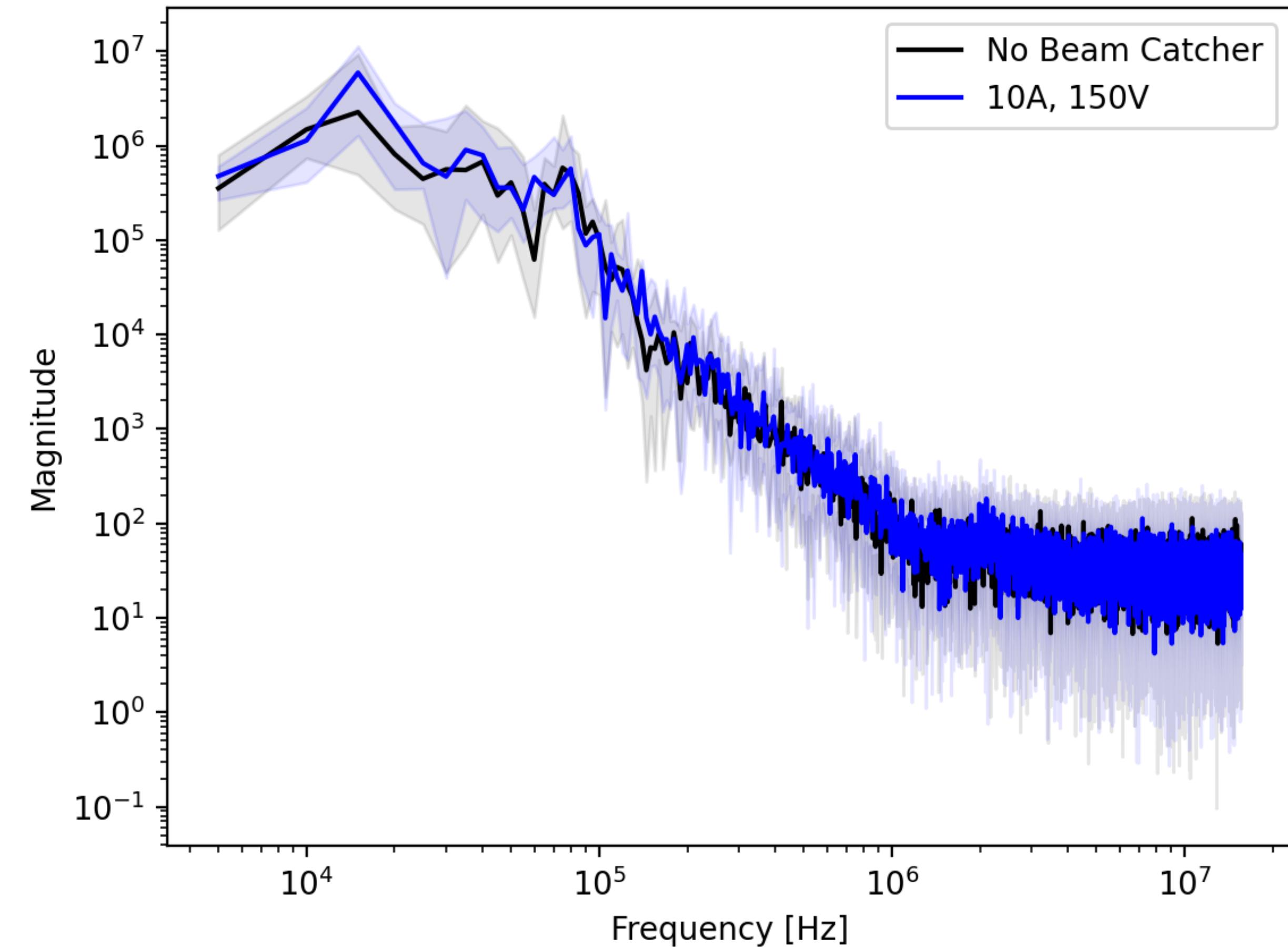
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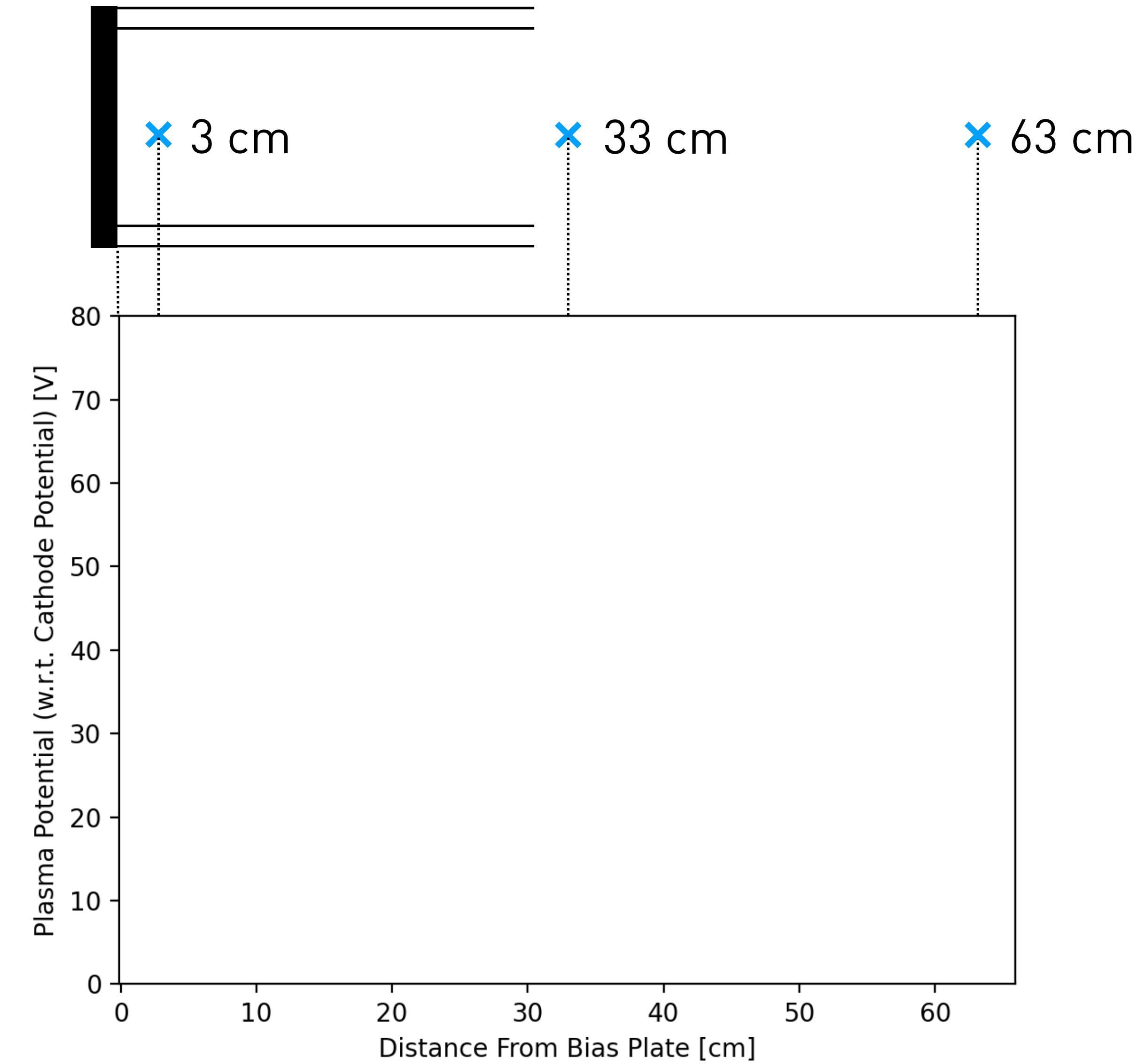
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Plume Distribution	



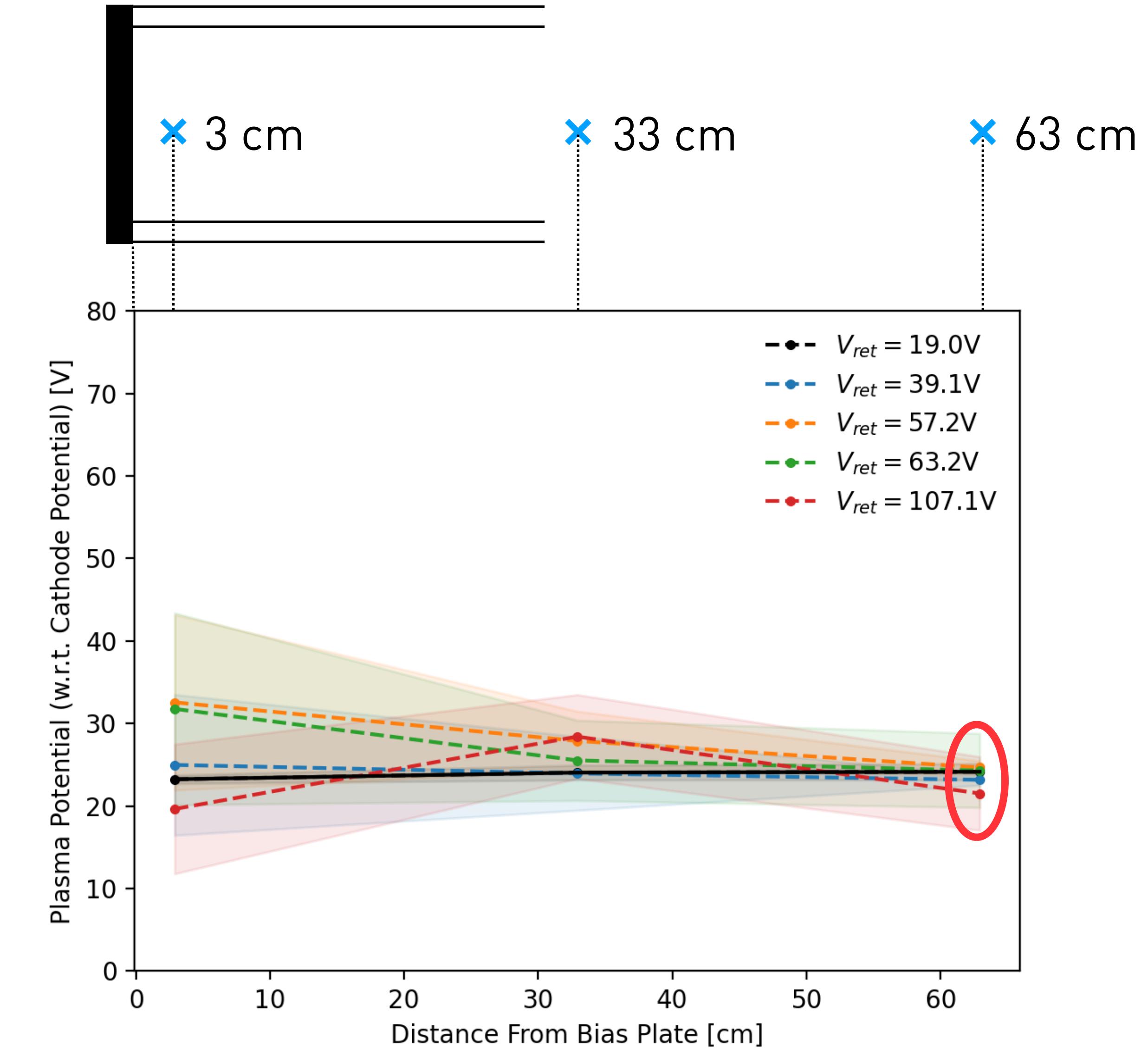
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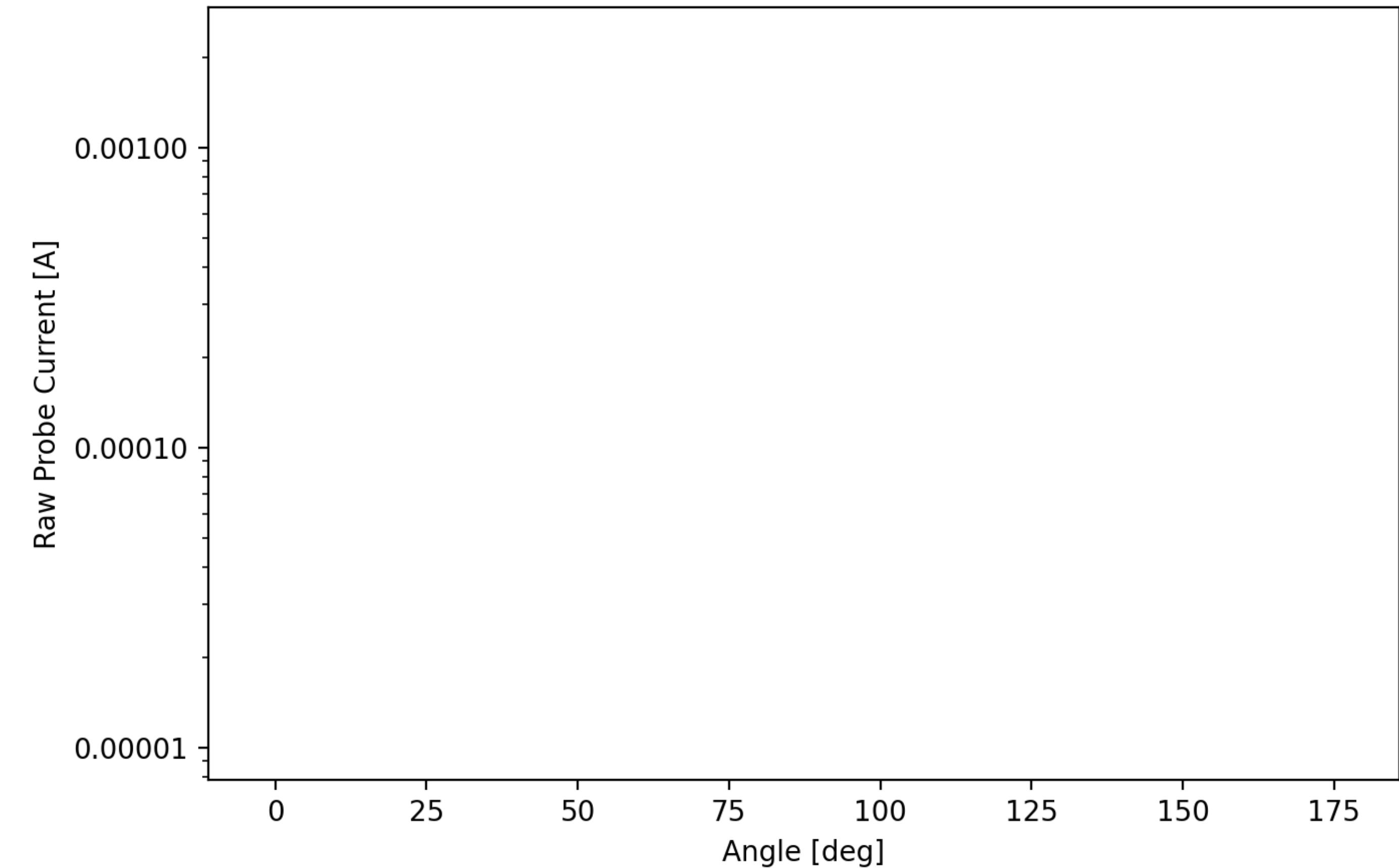
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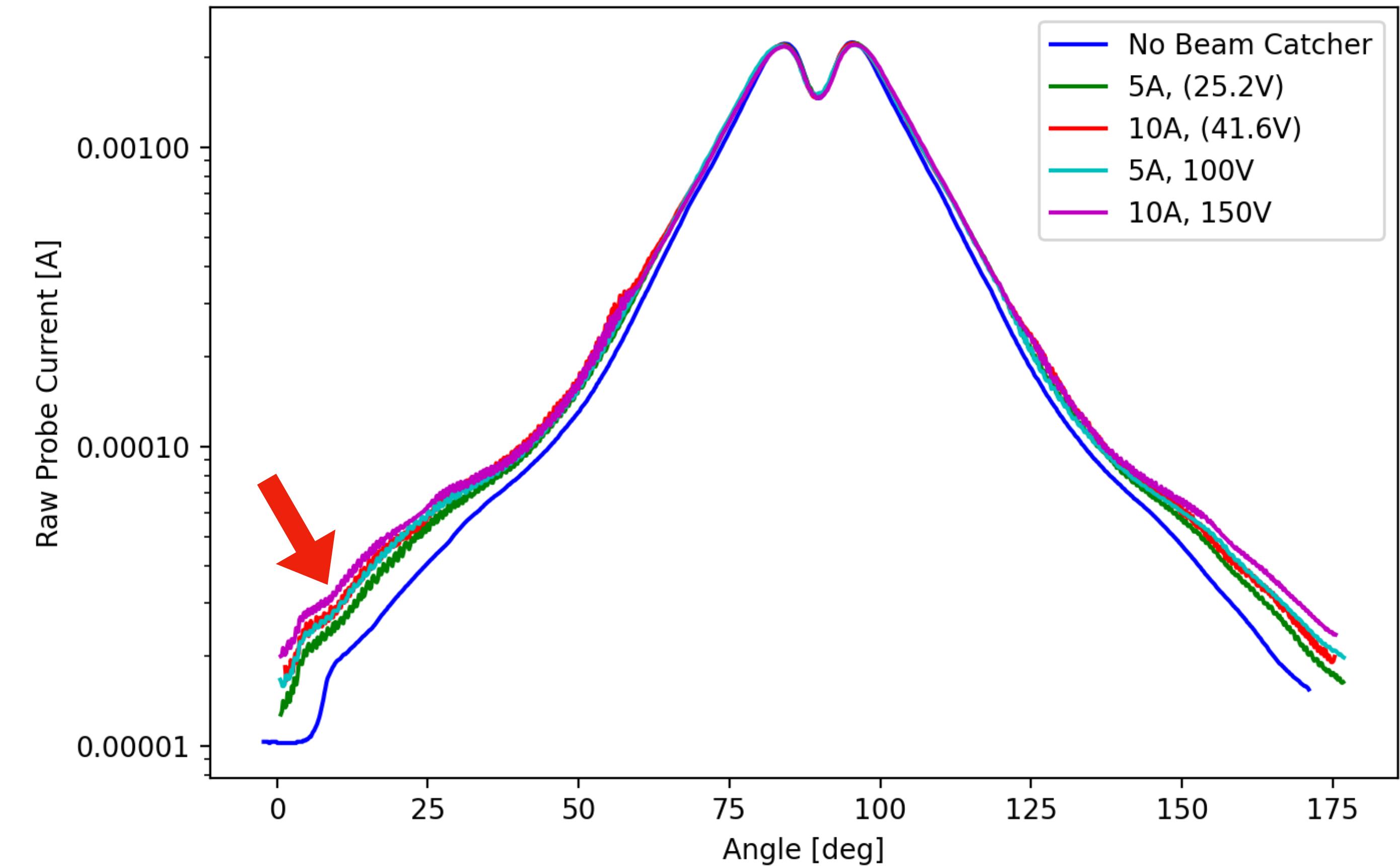
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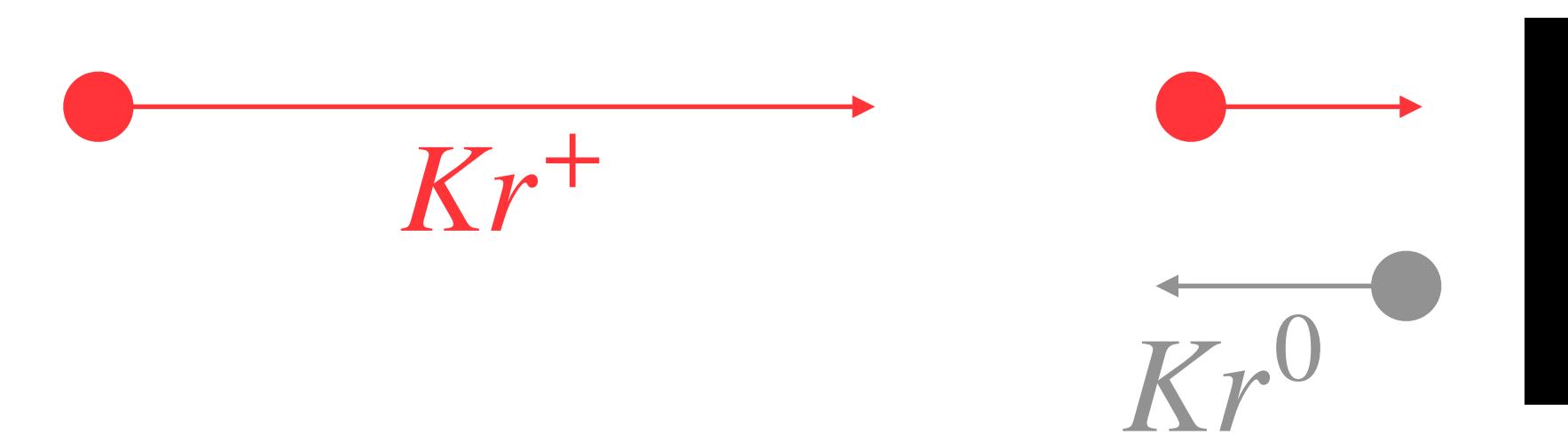
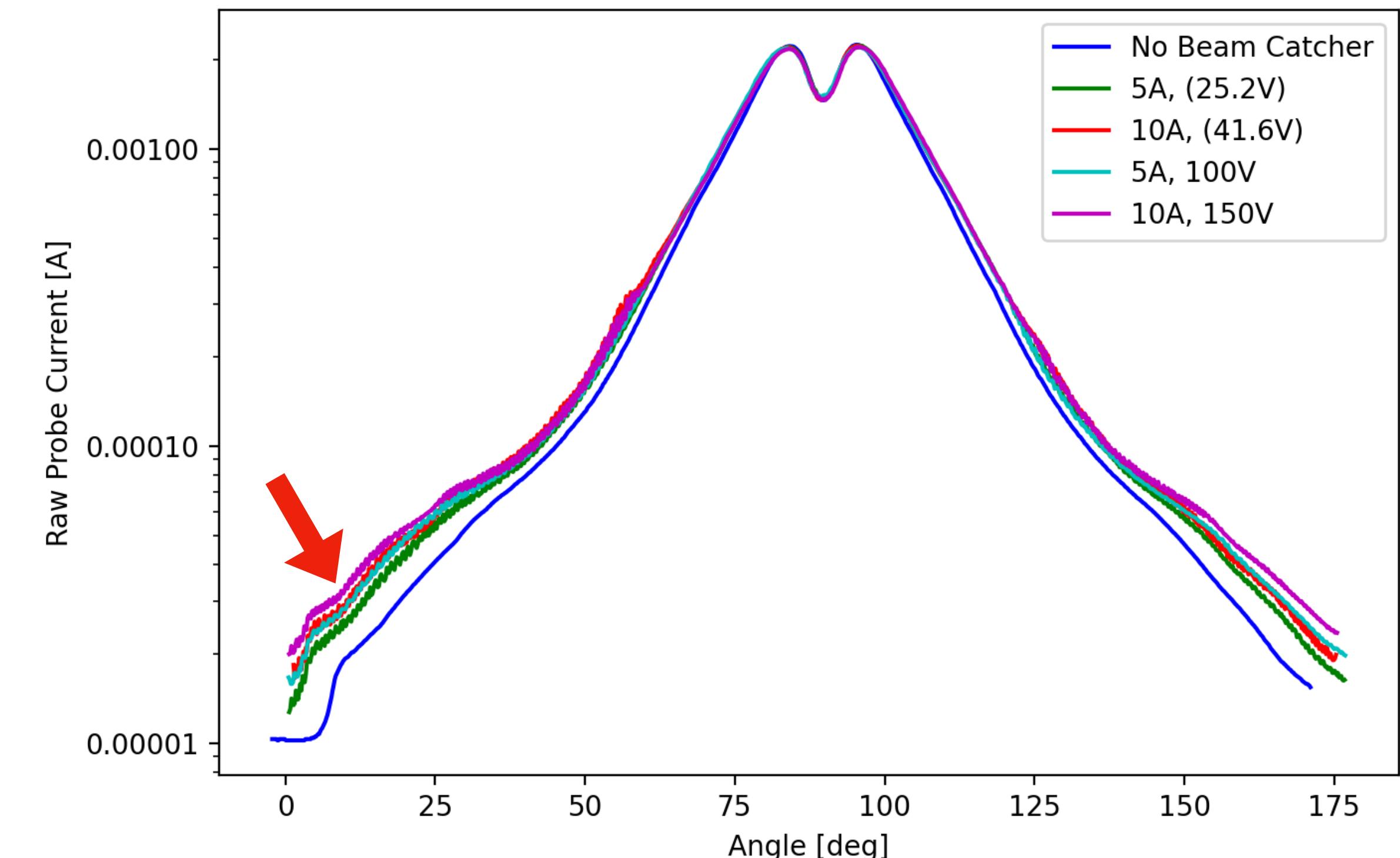


2. Do we affect thruster performance?

Property	Answer
Thrust Levels	No
Thruster Oscillations	No
Far Field Plasma Potential	No
Plume Distribution	Yes



Property	Answer
Thrust Levels	No
Thruster Oscillations	No
Far Field Plasma Potential	No
Plume Distribution	Yes

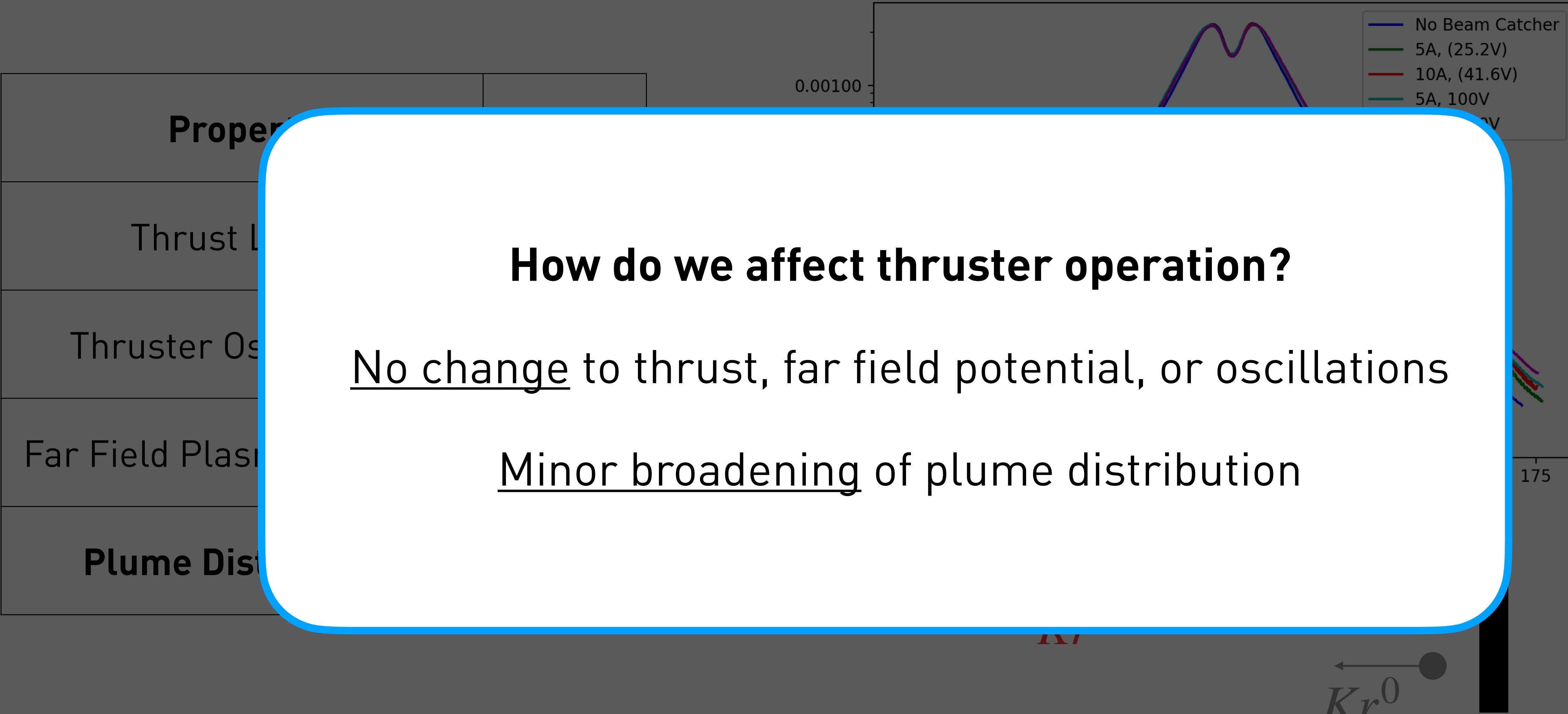


How do we affect thruster operation?

No change to thrust, far field potential, or oscillations

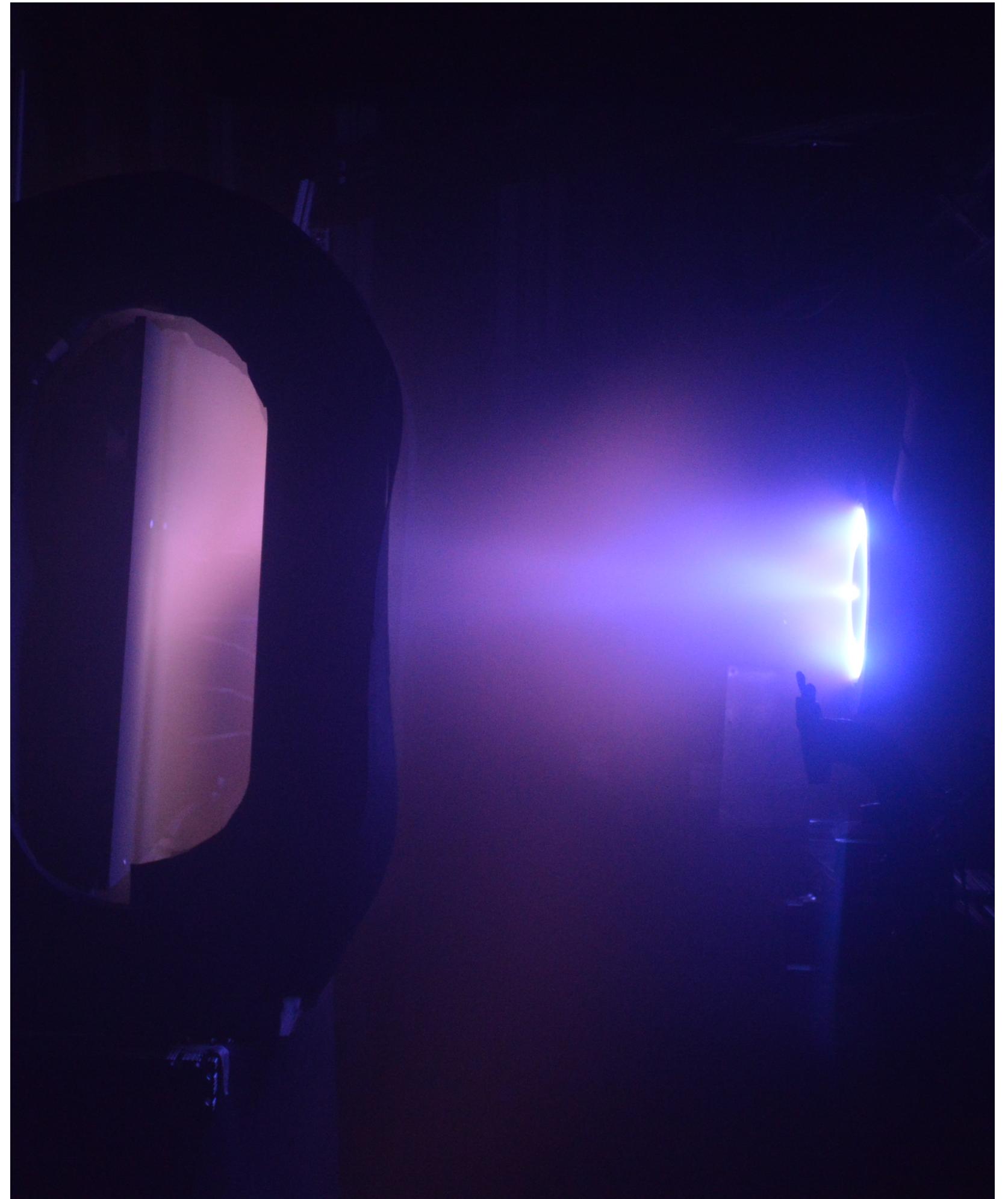
Minor broadening of plume distribution

Properties	Thrust Level	Thruster Oscillations	Far Field Plasma Potential	Plume Distribution
Properties	Thrust Level	Thruster Oscillations	Far Field Plasma Potential	Plume Distribution
Properties	Thrust Level	Thruster Oscillations	Far Field Plasma Potential	Plume Distribution
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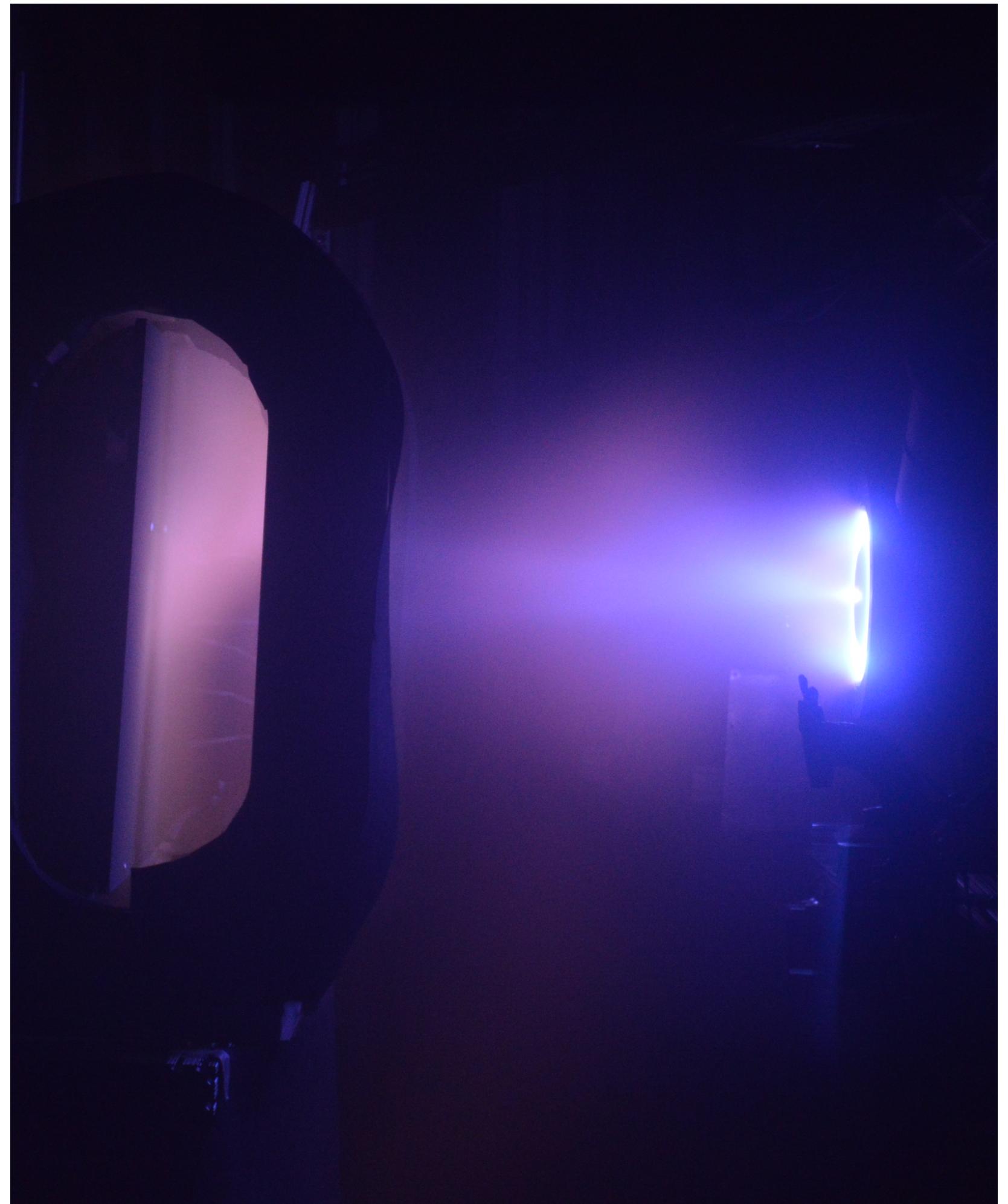
Conclusion

1. Can we apply large biases for a floating thruster?
2. Are biases large enough to mitigate backscatter?
3. Do we affect thruster performance?



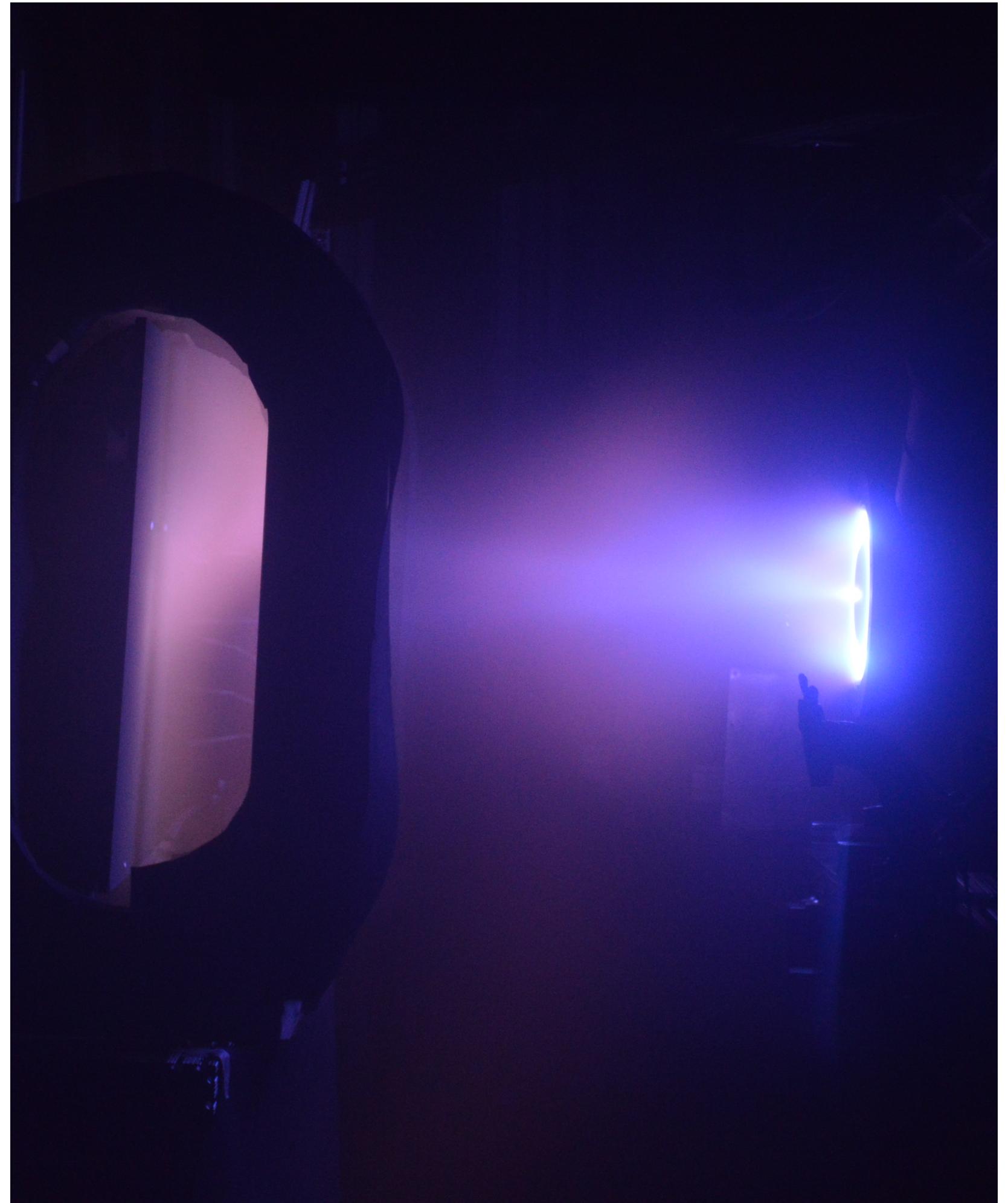
Conclusion

1. Can we apply large biases for a floating thruster?
 - Yes, we demonstrated 150-200V
2. Are biases large enough to mitigate backscatter?
3. Do we affect thruster performance?



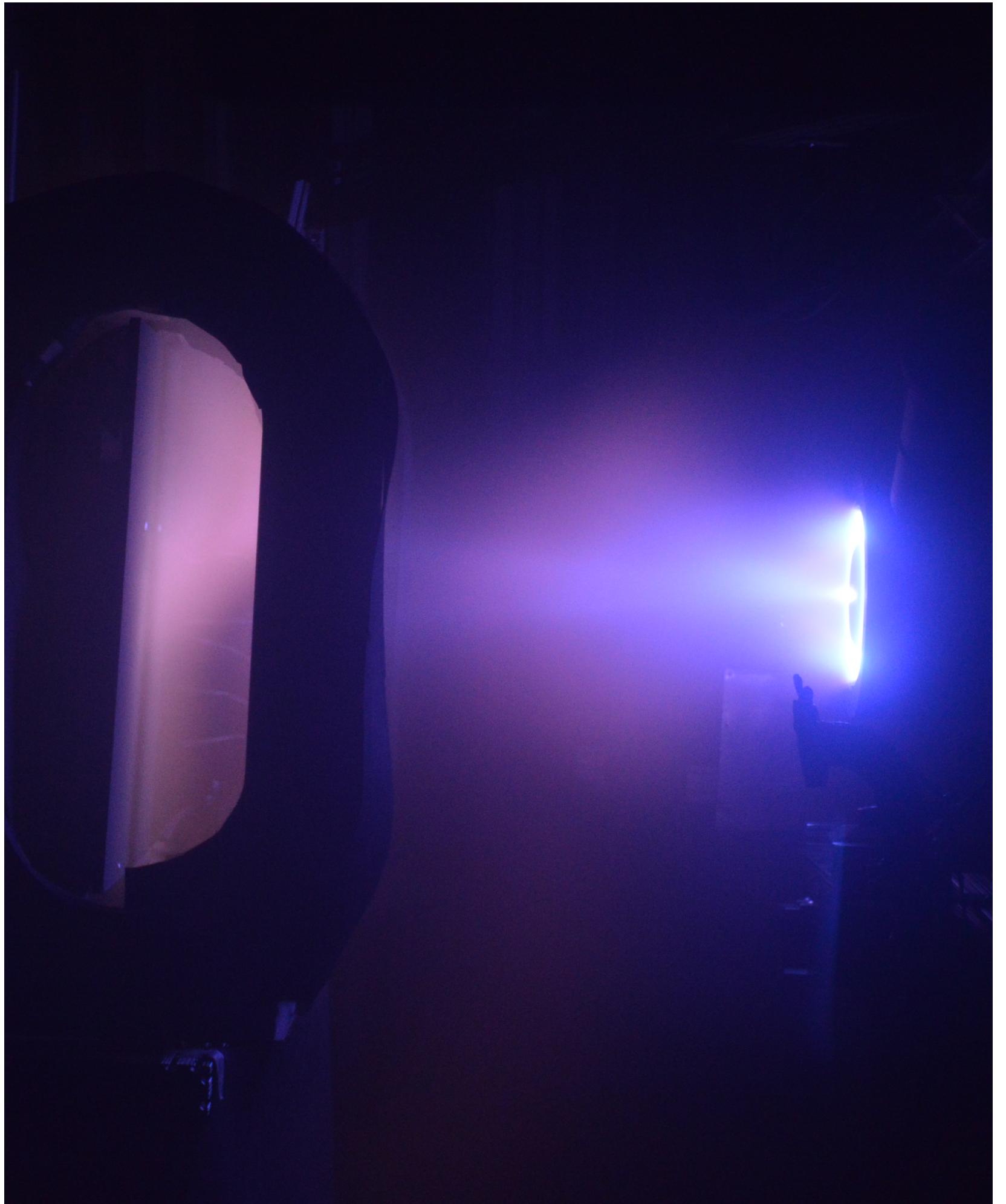
Conclusion

1. Can we apply large biases for a floating thruster?
 - **Yes,** we demonstrated 150-200V
2. Are biases large enough to mitigate backscatter?
 - **Yes,** but unknown level of CEX contribution
3. Do we affect thruster performance?



Conclusion

1. Can we apply large biases for a floating thruster?
 - Yes, we demonstrated 150-200V
2. Are biases large enough to mitigate backscatter?
 - Yes, but unknown level of CEX contribution
3. Do we affect thruster performance?
 - Minor plume widening, otherwise no



Acknowledgement



Funding

Joint Advanced Propulsion Institute, a NASA Space Technology Research Institute.

National Science Foundation Graduate Research Fellowship Program.

Thanks to

Seth Thompson, Jack Garman, Zach Robertson, Dr. John Williams (CSU).

Dr. Tate Gill and my lab mates at Michigan.

Questions