CDR

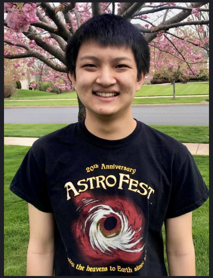
Absolute Beam Monitor

AST 250/251
Spring 2023

AST 250/251 Introductions

Mila Bileska

Wolf Cukier



Jupiter Ding

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Xander Jenkin

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Joe Radel

Kate Sheldon

Table of Contents

Science Background

Interstellar Mapping and Acceleration Probe (IMAP)

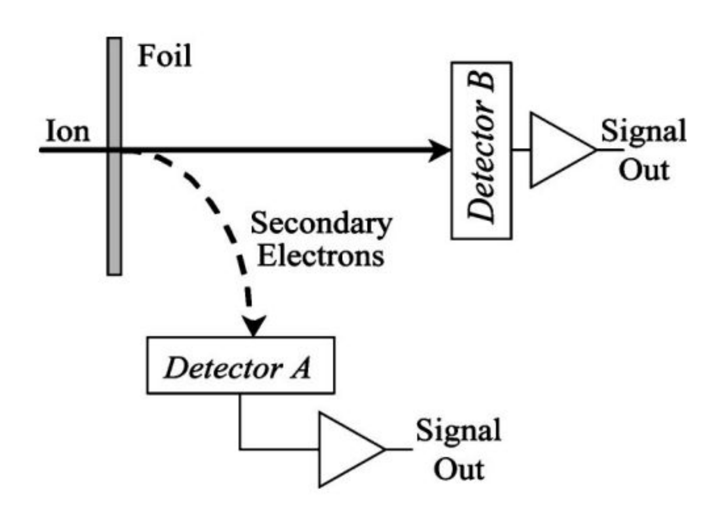
- Composition of Interstellar Medium (ISM)
- Magnetic + Solar Wind Interactions with ISM
- High Energy Particles in the Solar System

Solar Wind and Pickup Ions (SWAPI)

- ~10 Different Labs
- Different Beam Line Conditions
- Need to cross-calibrate

Relatively cheap, portable, and easy to construct instrument – the ABM

What is an Absolute Beam Monitor?



Funsten+ 2005

An Absolute Beam Monitor is a detector that can accurately determine the ENA flux of a Neutral Atom Beam Source.

The instrument would intercept an ion beam source, separate and detect the resulting neutral atoms

Detected Counts and the Absolute Efficiency

$$C = A \int\int\int j \varepsilon_D G \mathrm{d}E \mathrm{d}\Omega \mathrm{d}t,$$

The above equation calculates coincidence counts. It is dependent on

j, differential particle flux

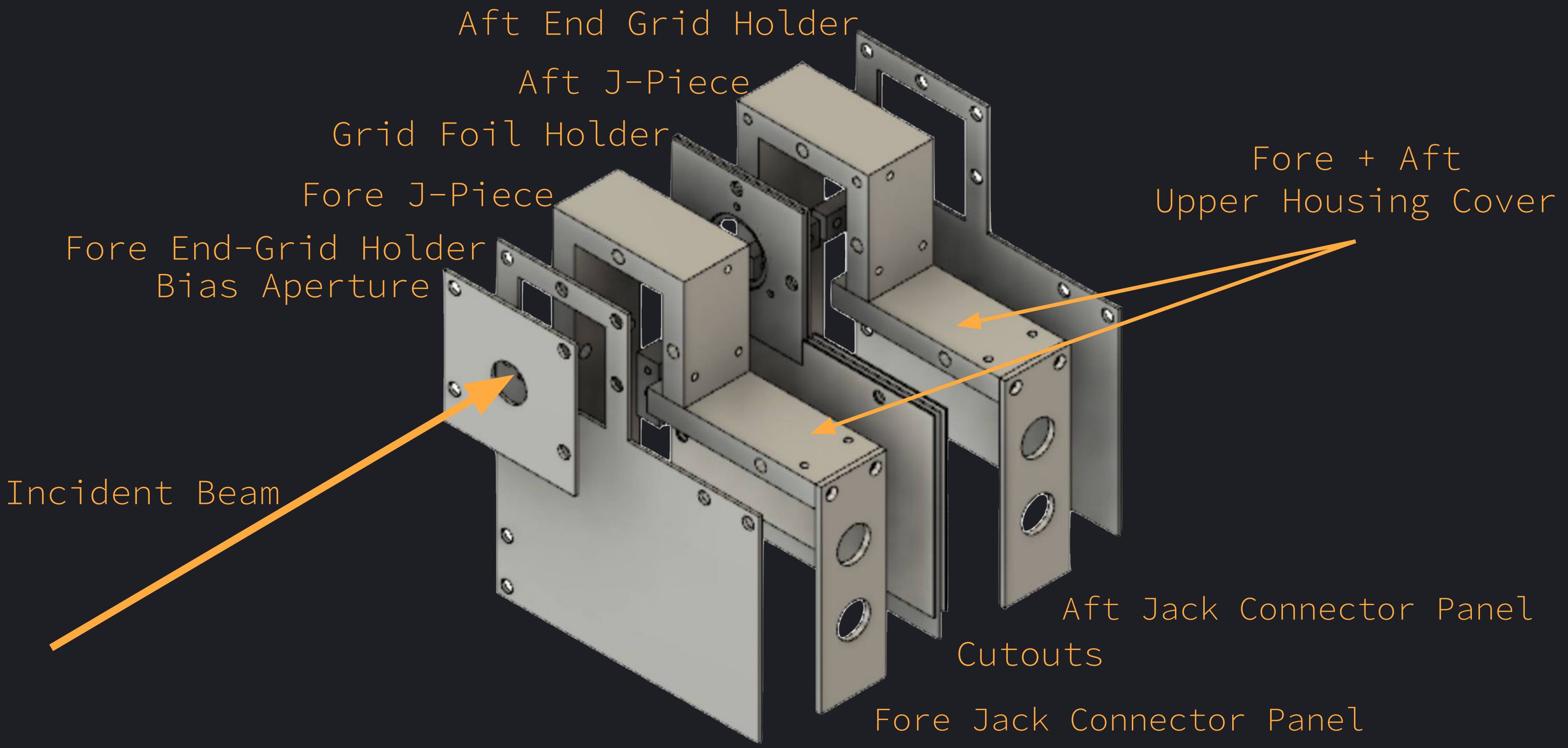
E**D**, the absolute efficiency of the detector system

G, the instrument geometric factor

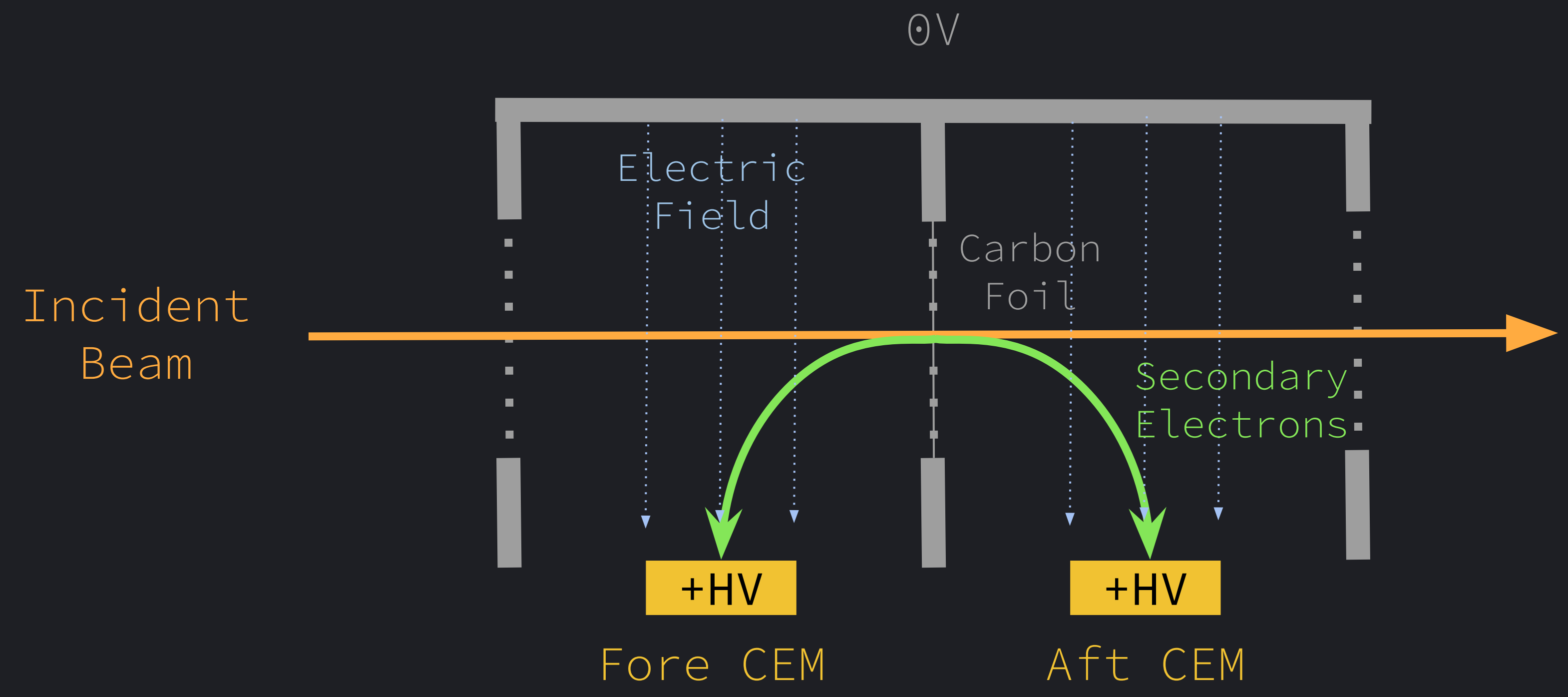
The absolute efficiency of the detector system depends on the Probability for registering a coincidence event, along with probability of transmission through the foil

$$\varepsilon_D = T_G T_F P_A P_B.$$

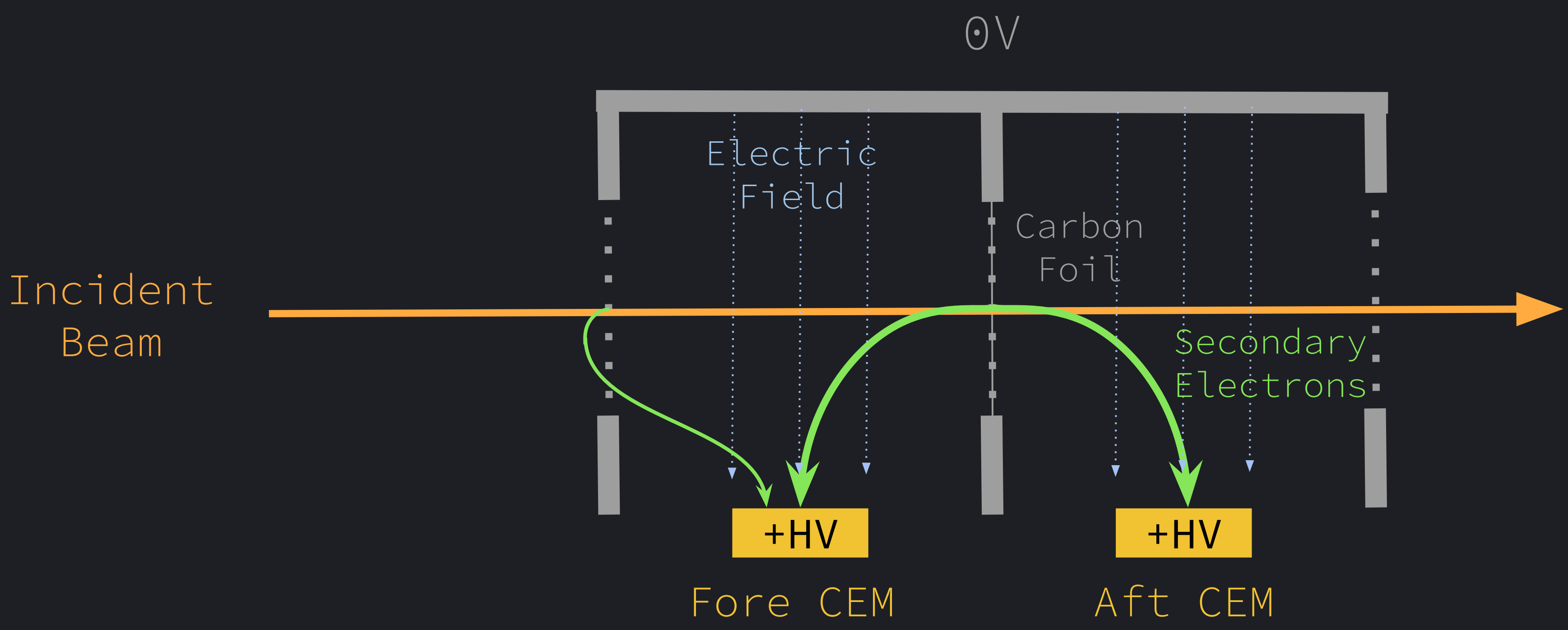
ABM-1 Design and Instrument


Aft End Grid Holder
Aft J-Piece
Grid Foil Holder
Fore J-Piece
Fore End-Grid Holder
Bias Aperture
Fore + Aft
Upper Housing Cover
Incident Beam
Aft Jack Connector Panel
Cutouts
Fore Jack Connector Panel

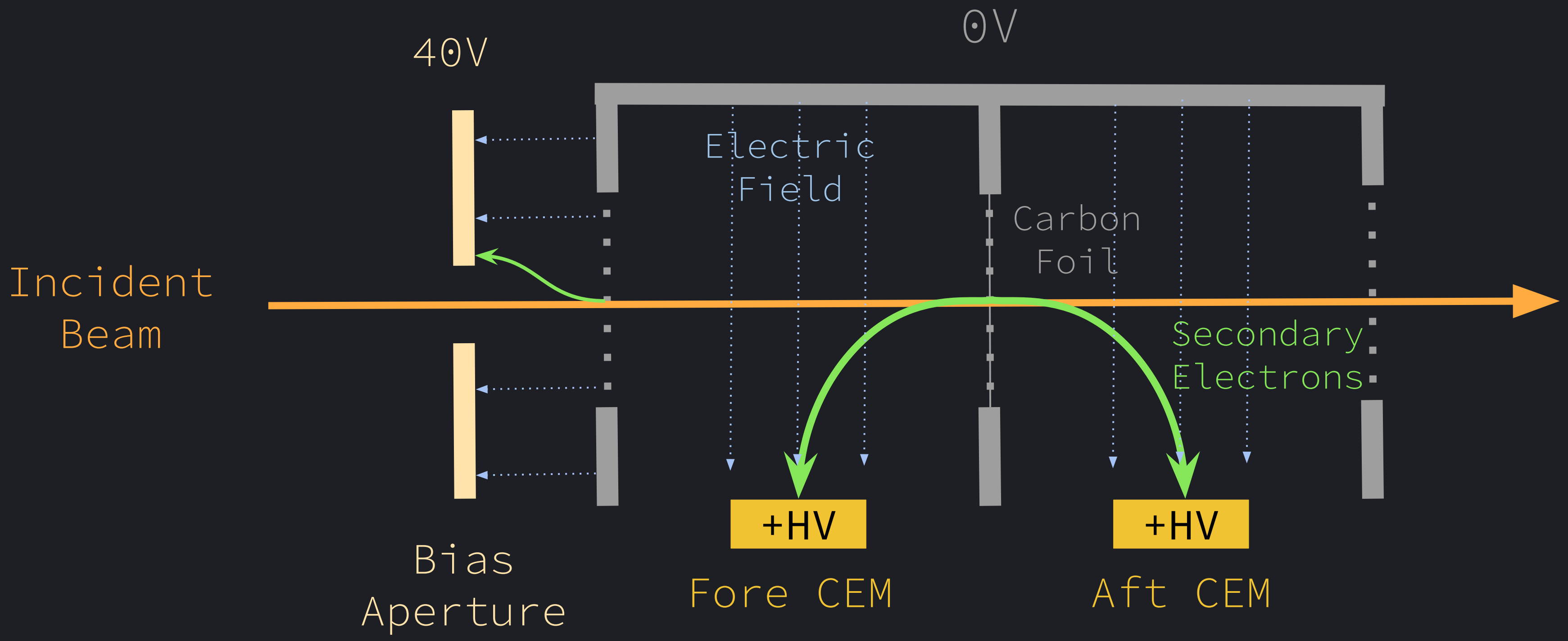
ABM-1 Design



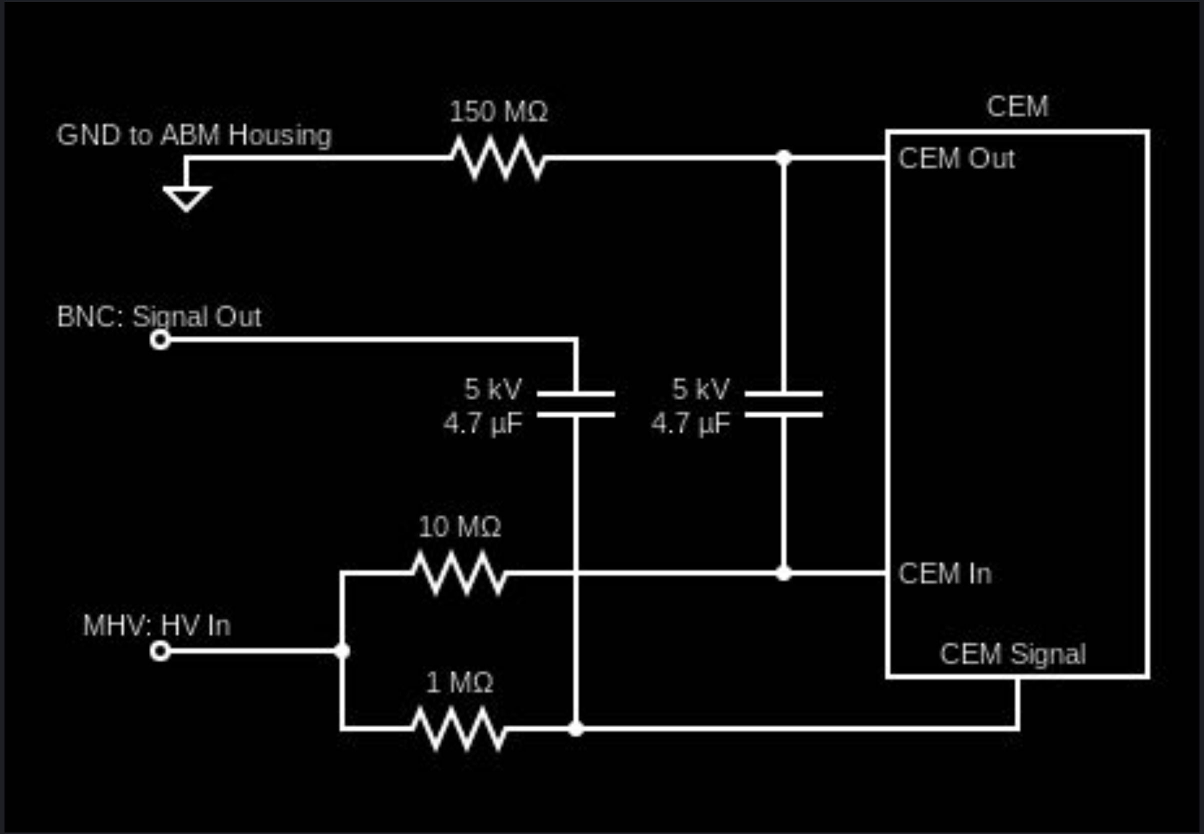
ABM Electro-Optics



ABM Electro-Optics

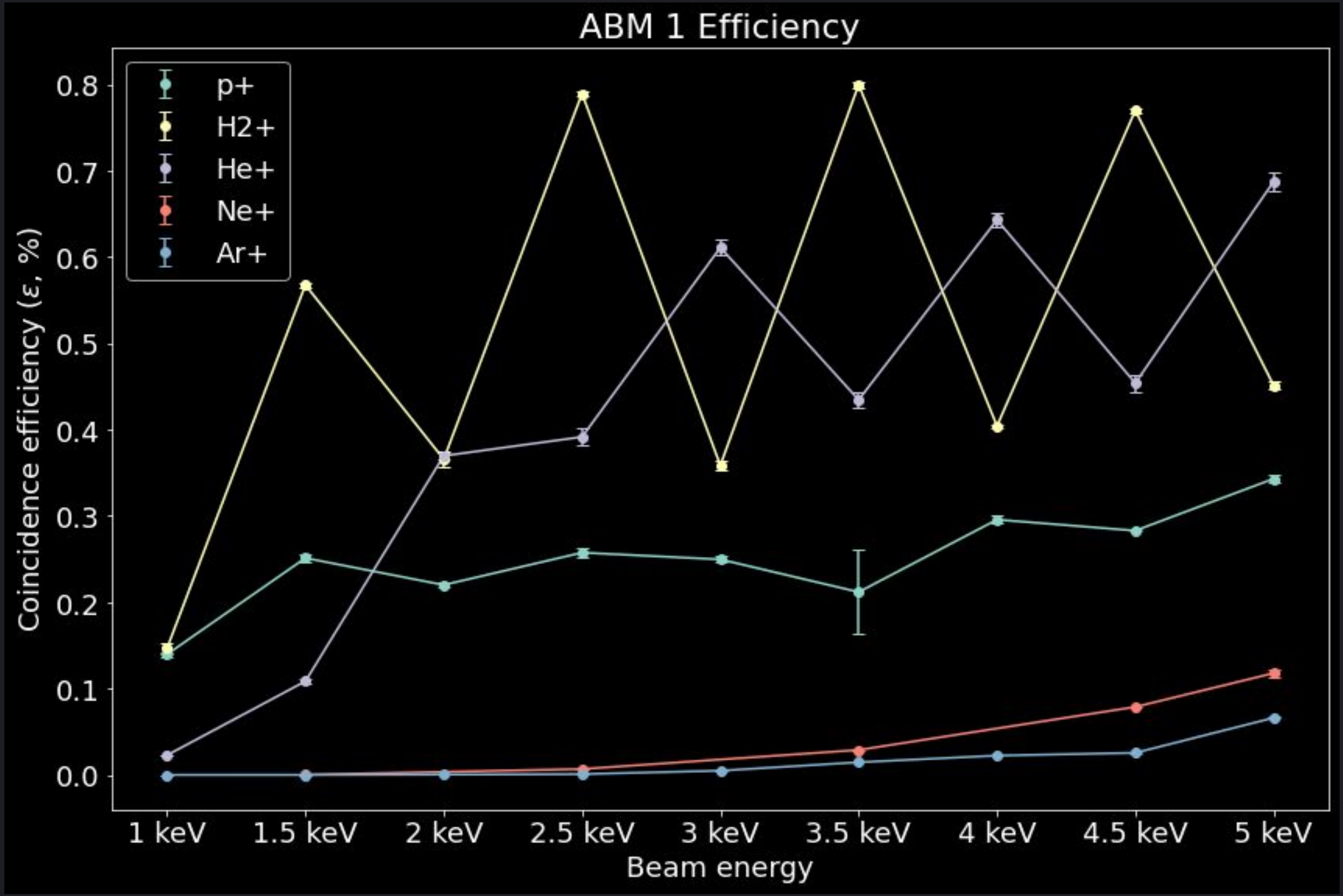


ABM Electro-Optics



ABM-1 Internal Electronics

ABM-1 Problems


ABM 1 Efficiency
Coincidence efficiency (ε, %)
Beam energy
p+
H2+
He+
Ne+
Ar+
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
1 keV
1.5 keV
2 keV
2.5 keV
3 keV
3.5 keV
4 keV
4.5 keV
5 keV

Coincidence efficiency

Very low coincidence efficiency

Highest was around .8% for 2-4.5 keV H2 (H2 was highest for SWAPI too), p+ generally got around .2-.3%

Don't know why H2 and He jump, possibly due to testing on different days

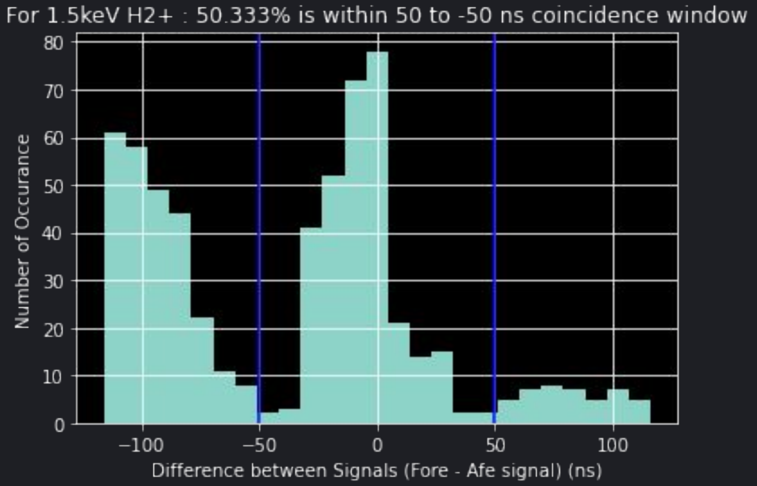
No coincidence/very low counts for heavy elements (Ne+ and Ar+)

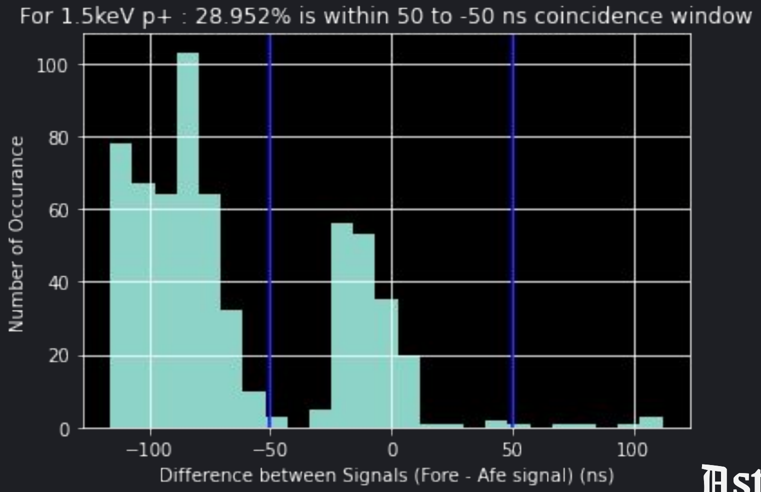
Generally increases with beam energy

Our goal is around 10%, so these values need to be improved

Bimodal Coincidence Window Distribution

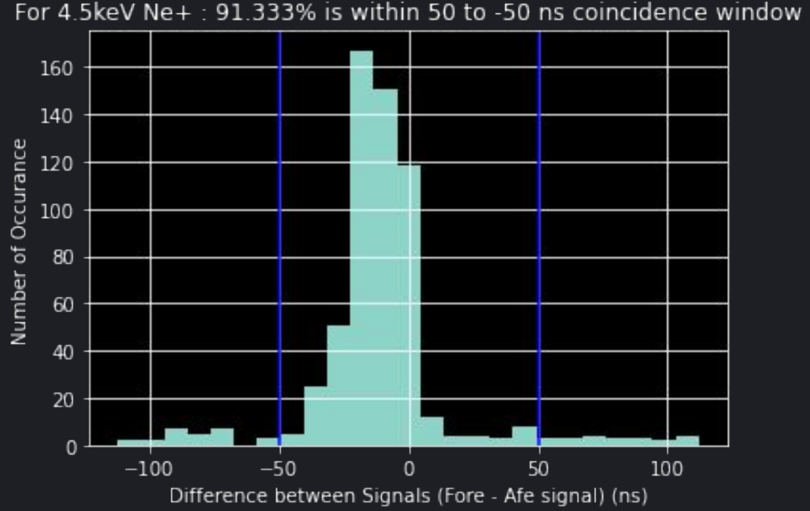
- Bimodal distribution for majority of beams
- We wanted an almost gaussian distribution with majority falling with a specific window

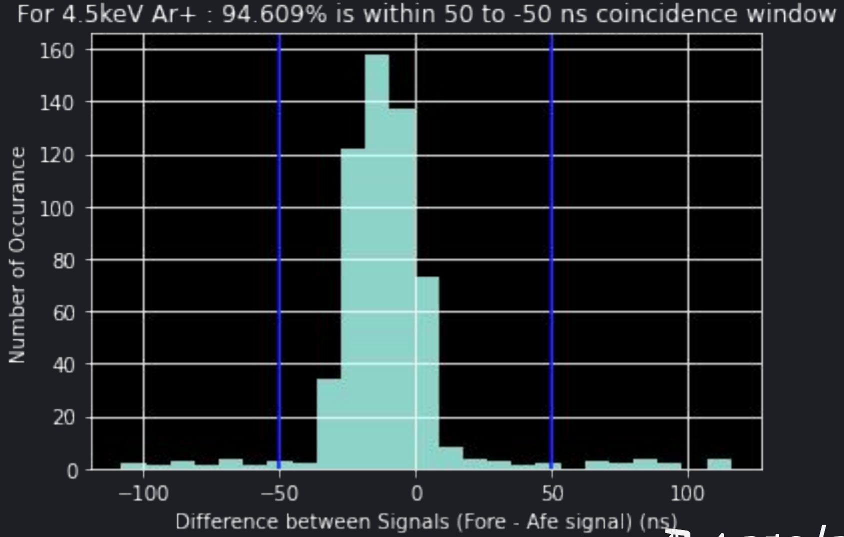




Bimodal Coincidence Window Distribution

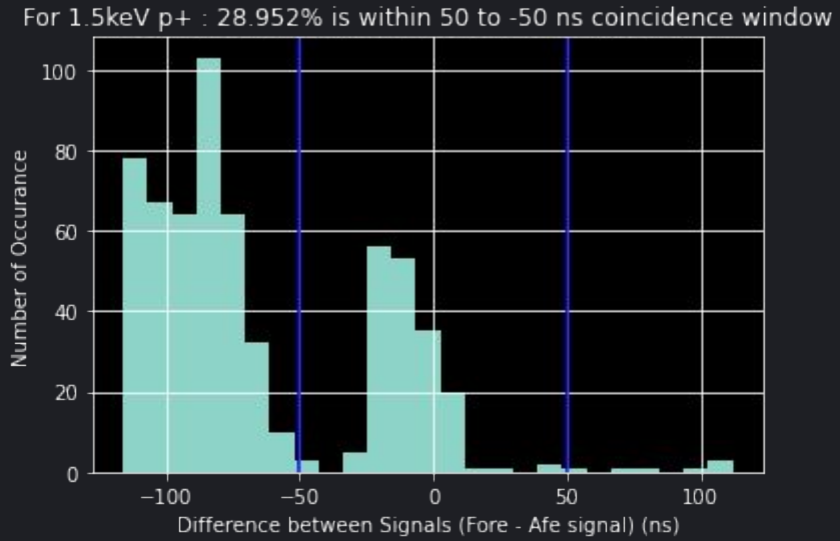
- Less likely in larger species, like Ne or Ar
- Lower energies were worth though:
- 1.5keV Ne+ : 76.5%, 1.5keV Ar+ : 81.667%

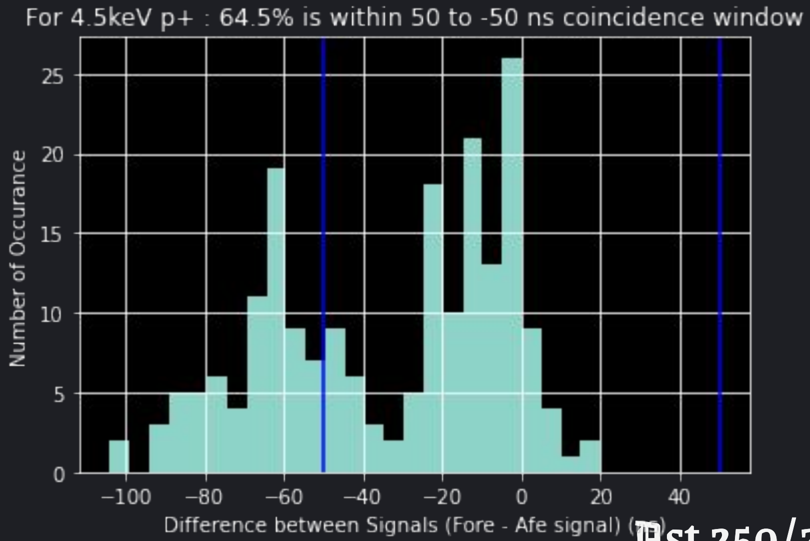




Bimodal Coincidence Window Distribution

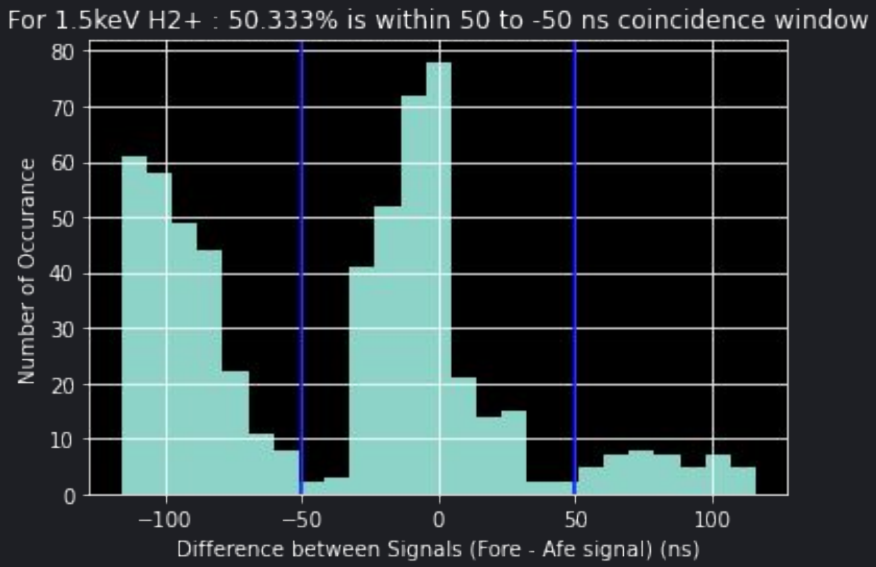
- Bimodality changed with energy. Lower energies was worse

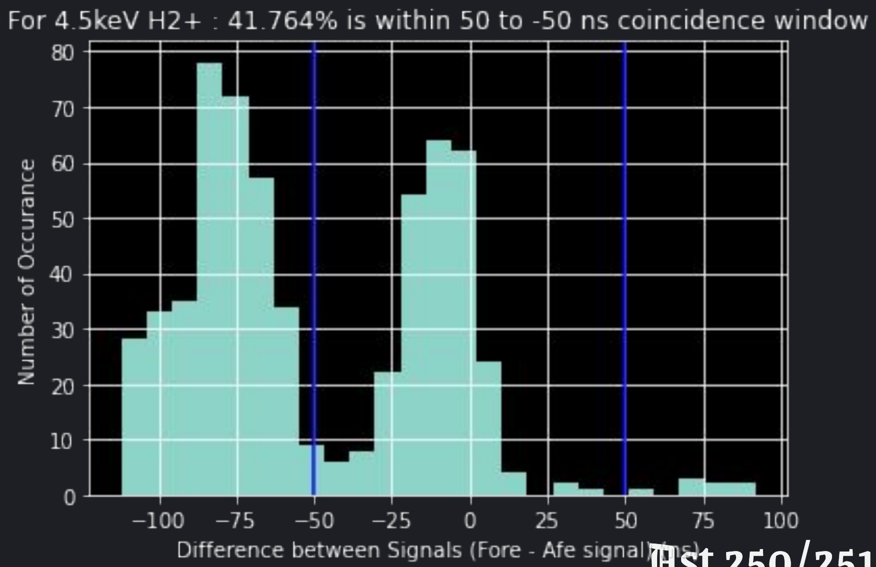




Bimodal Coincidence Window Distribution

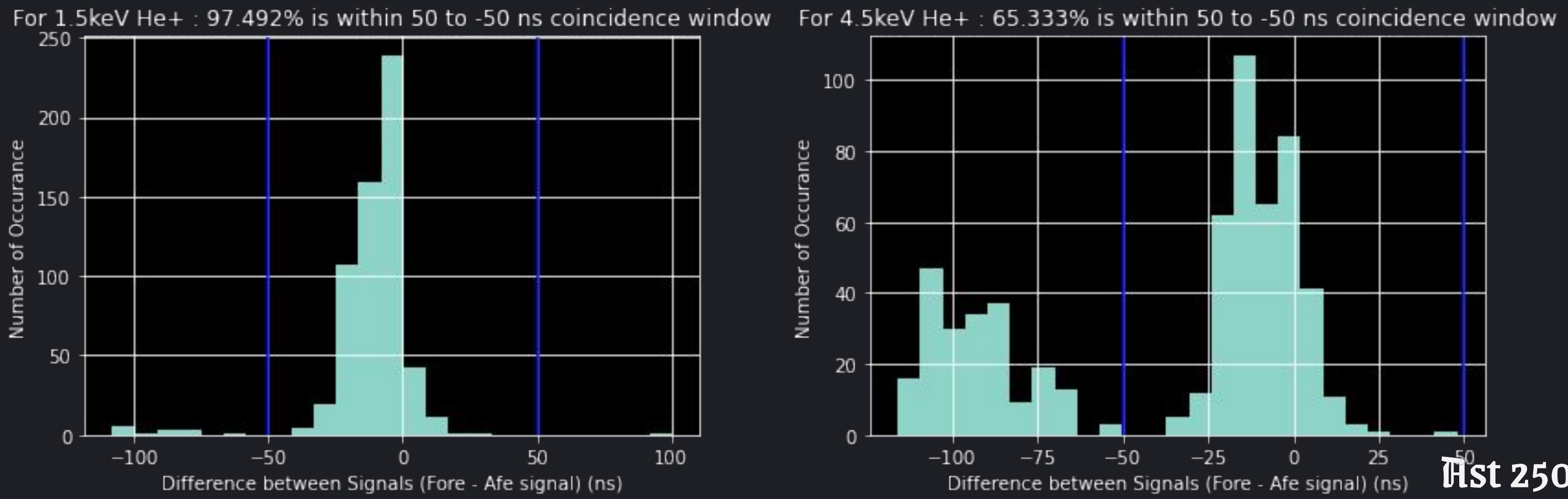
- Bimodality changed with energy. Higher energy worse





Bimodal Coincidence Window Distribution

- Bimodality changed with energy. Higher energy worse



Bimodal Coincidence Window Distribution

- Why it's bimodal?
  - Backscattering?
  - Neutral Particles
  - Bias voltage

High Operating Voltage

ABM-1 FORE/AFT Voltages: 4000V

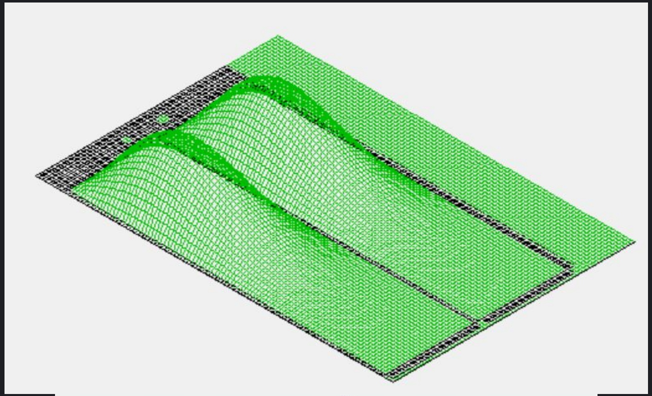
(gain curve tests up to 4500V)

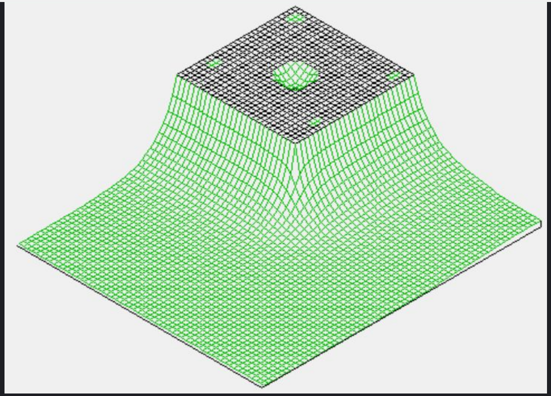
HVPS limit: 5000V

*Still safe to apply, we only see ~2000V on the CEMs, but we *shouldn't* be so close to our power limit

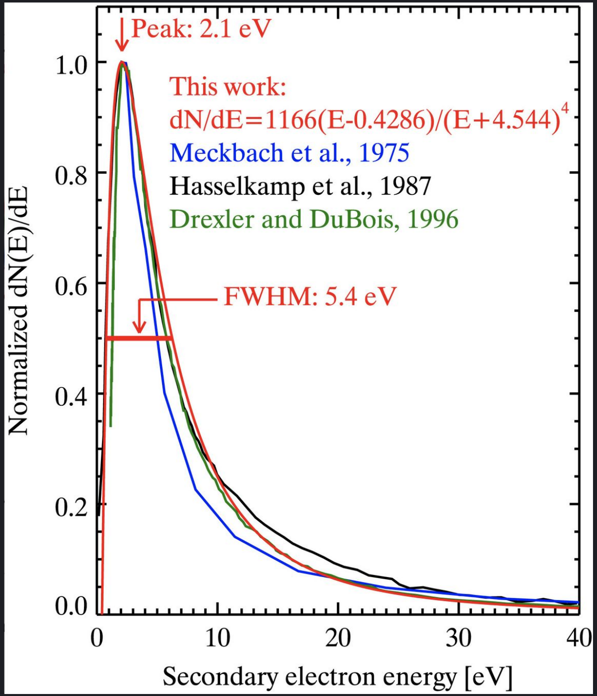
SIMION

- Cannot simulate secondary electrons (SE) from the incident beam directly
- *Considerations:*
  - SE distribution ≤ 15 eV located at center
  - CEM Range: 500 – 2000 V
  - ABM-1: 2062 V FCEM, 2090 V ACEM
  - 1 keV – 5 keV H^+
  - Aperture Bias: 40 V

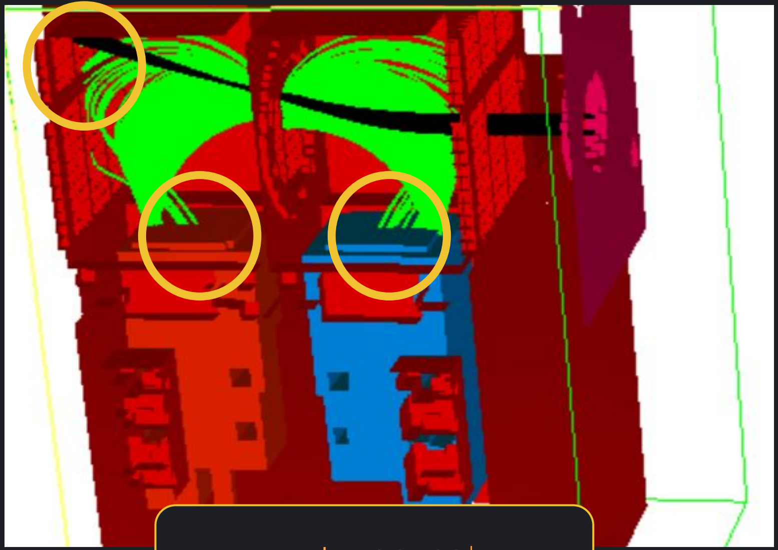




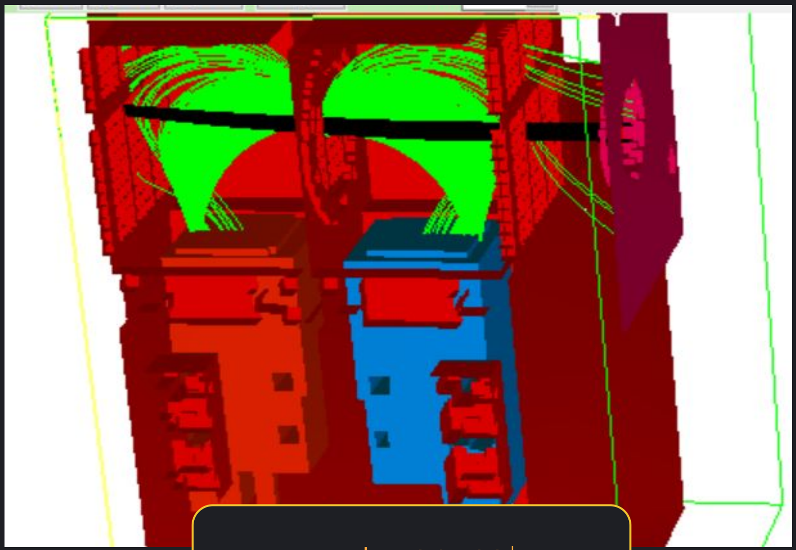
Secondary Electron Distribution



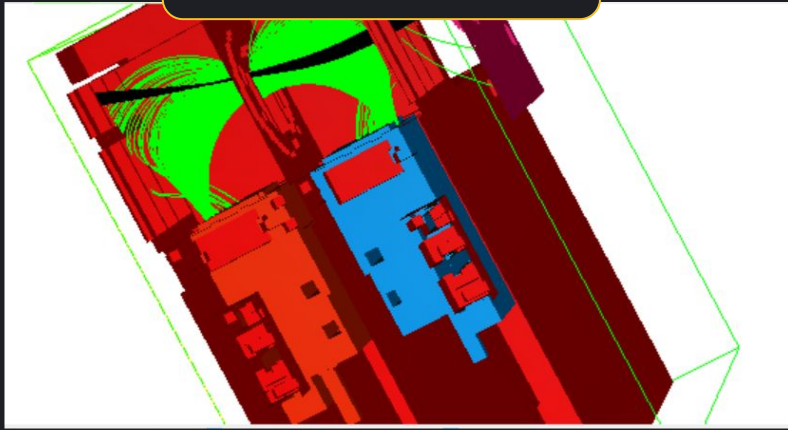
Allegrini+ 2016



1 keV H^+



5 keV H^+

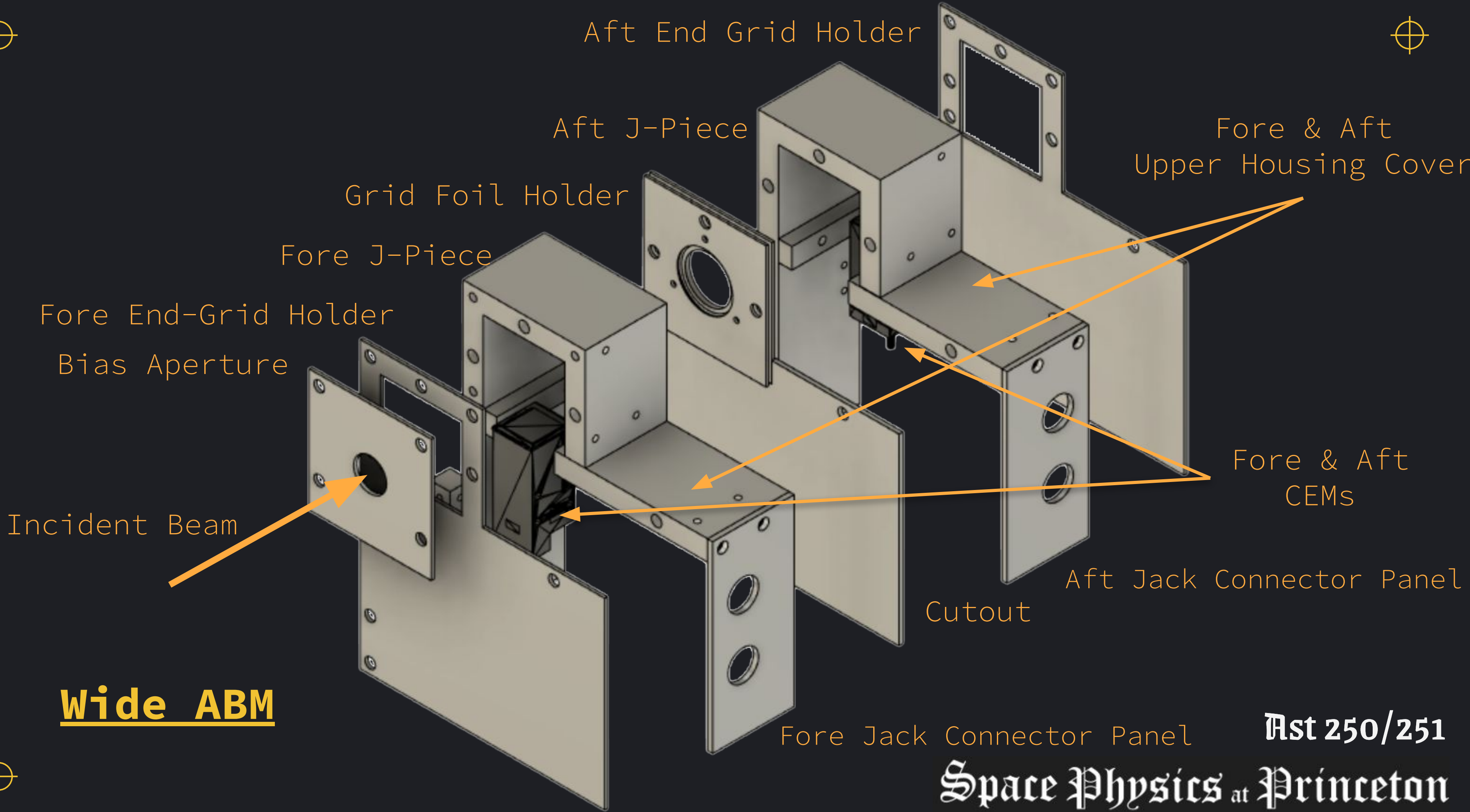


Beam bending, scattering range of electrons explain low coincidence efficiency and bimodality.

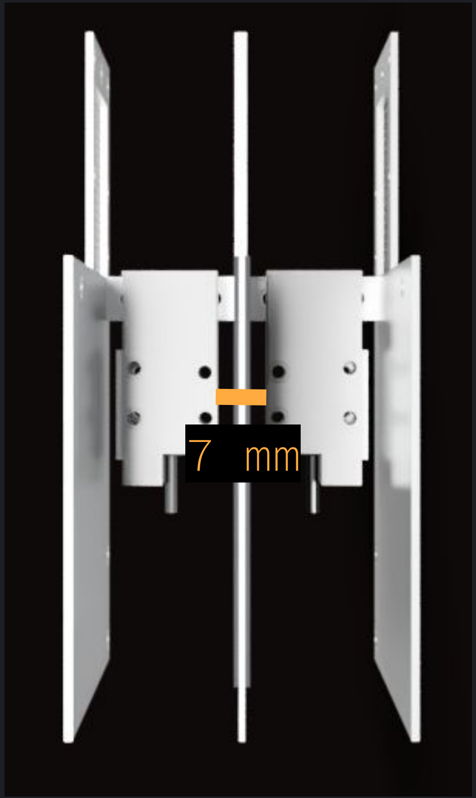
Mechanical Corrections with ABM-1

- CEM Anode Disconnection
- Remove Teflon sheet and screws
- Center CEMs
- Add insulation plating
- Electrical connection to bias plate

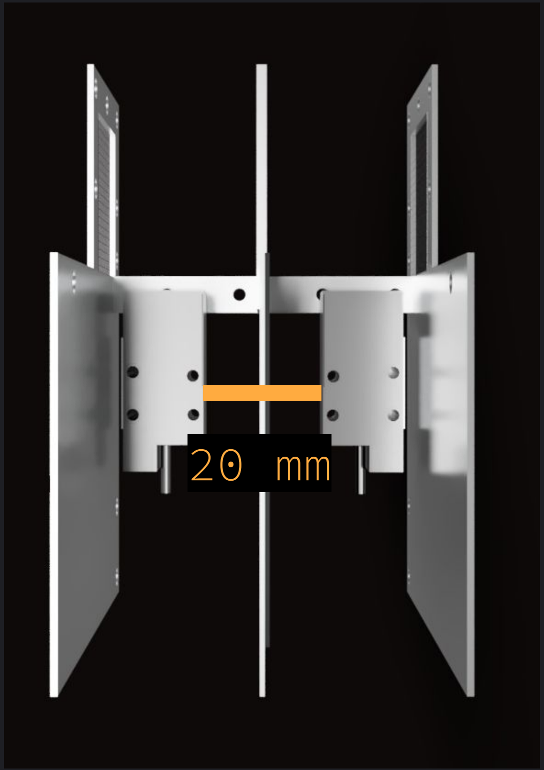
Wide ABM Design


Aft End Grid Holder
Aft J-Piece
Fore & Aft
Upper Housing Cover
Grid Foil Holder
Fore J-Piece
Fore End-Grid Holder
Bias Aperture
Incident Beam
Fore & Aft
CEMs
Aft Jack Connector Panel
Cutout
Fore Jack Connector Panel

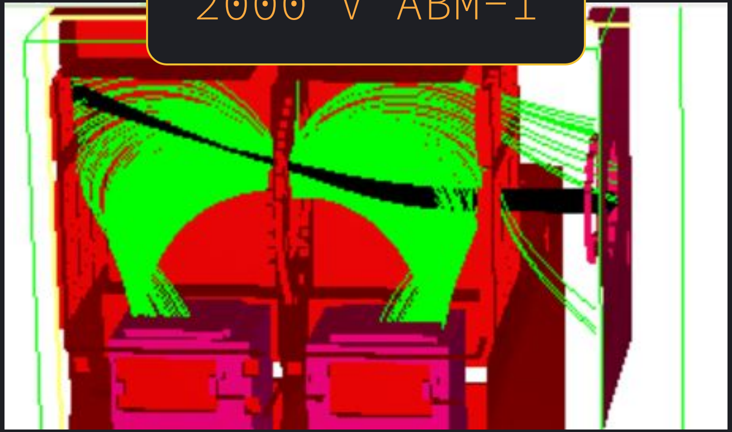
<u>Wide ABM</u>



ABM-1



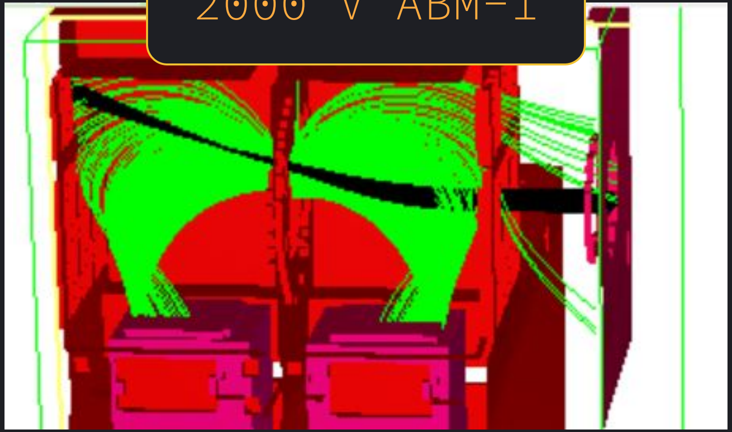
Wide ABM



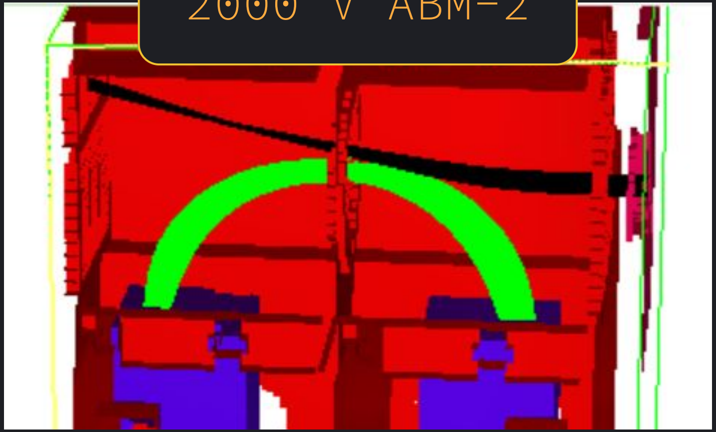
2000 V ABM-1

1
keV
H^+

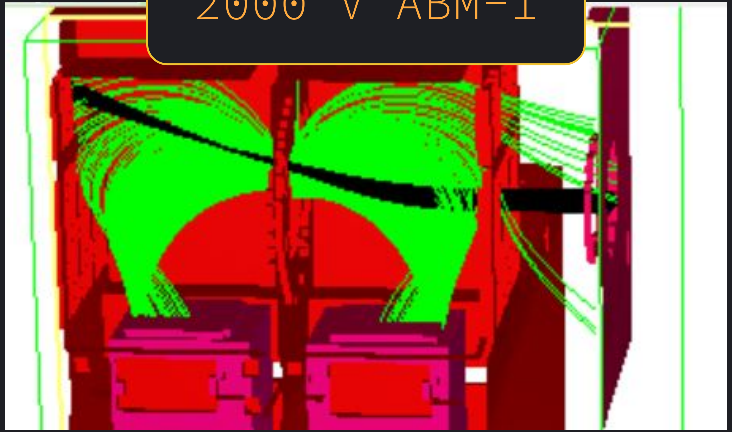
2000 V ABM-1



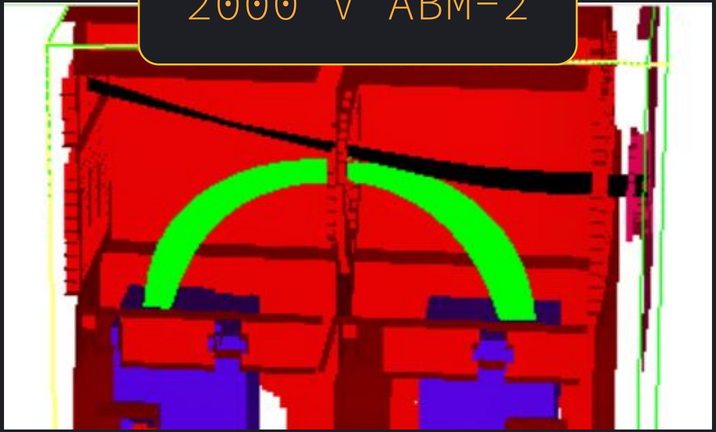
2000 V ABM-2



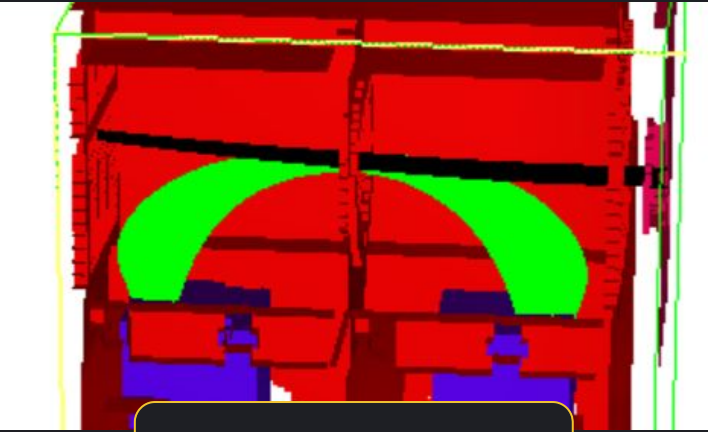
1 keV H^+



2000 V ABM-1

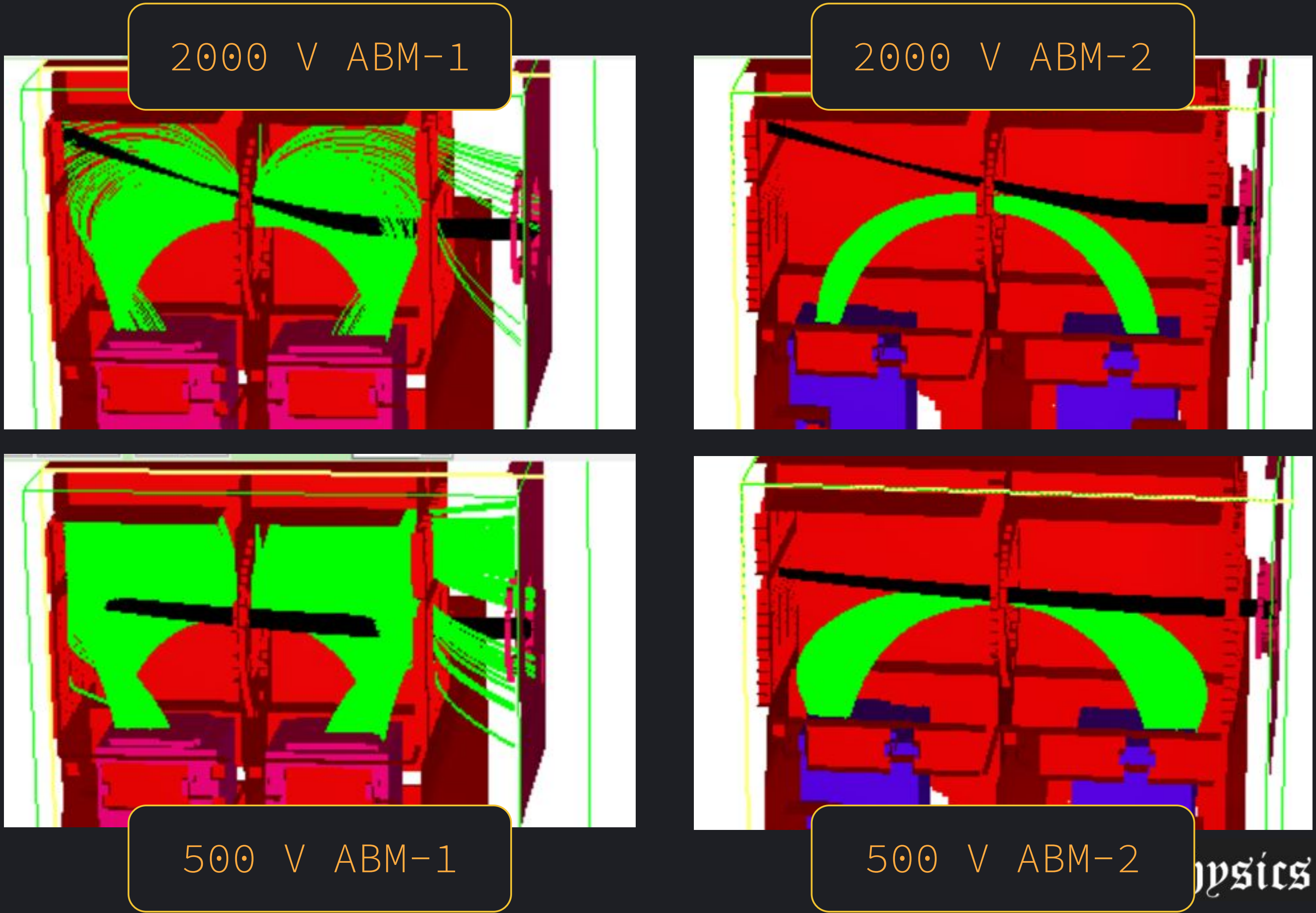


2000 V ABM-2

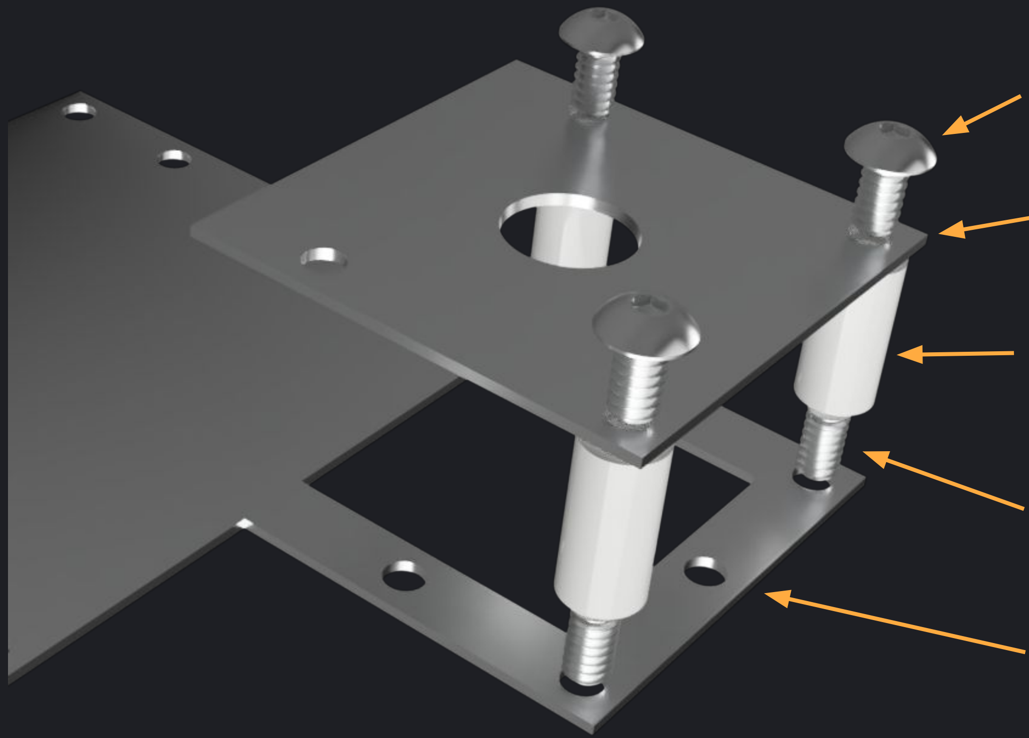


500 V ABM-2

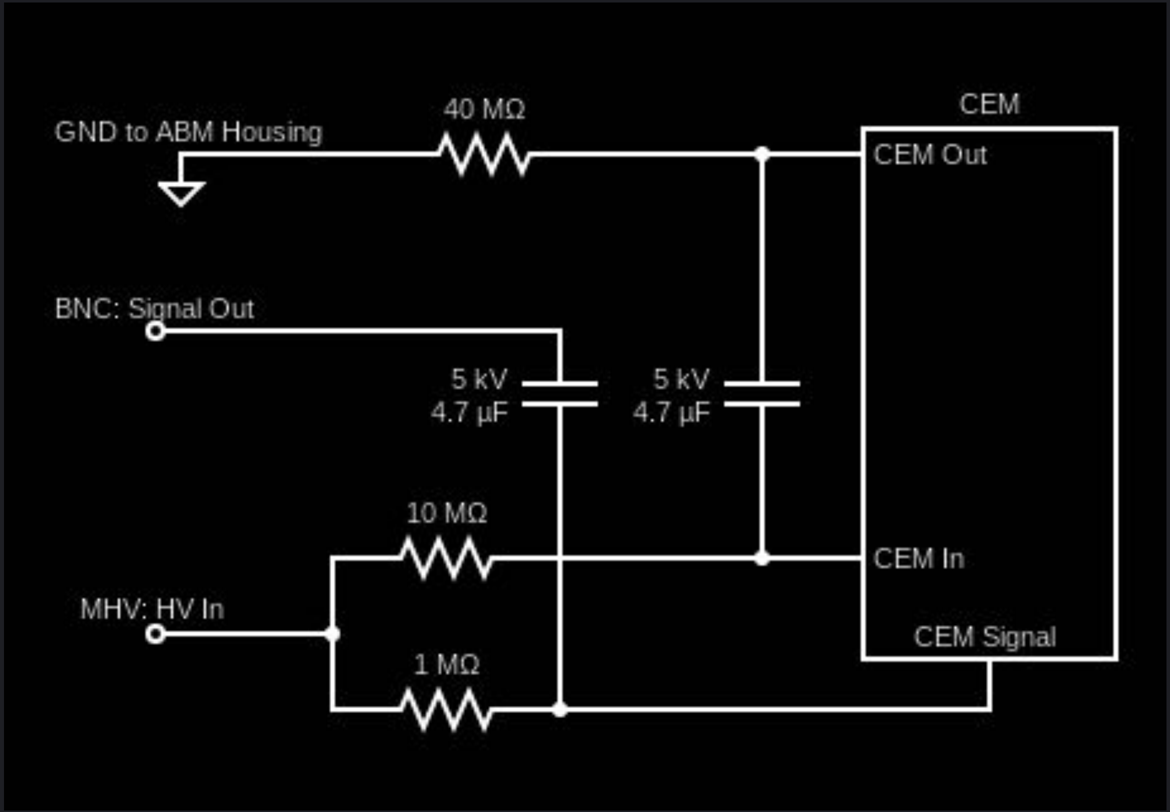
1 keV H^+



1 keV H^+



Wide ABM Bias Aperture Mount



Wide ABM Internal Electronics

Lower Operating Voltage

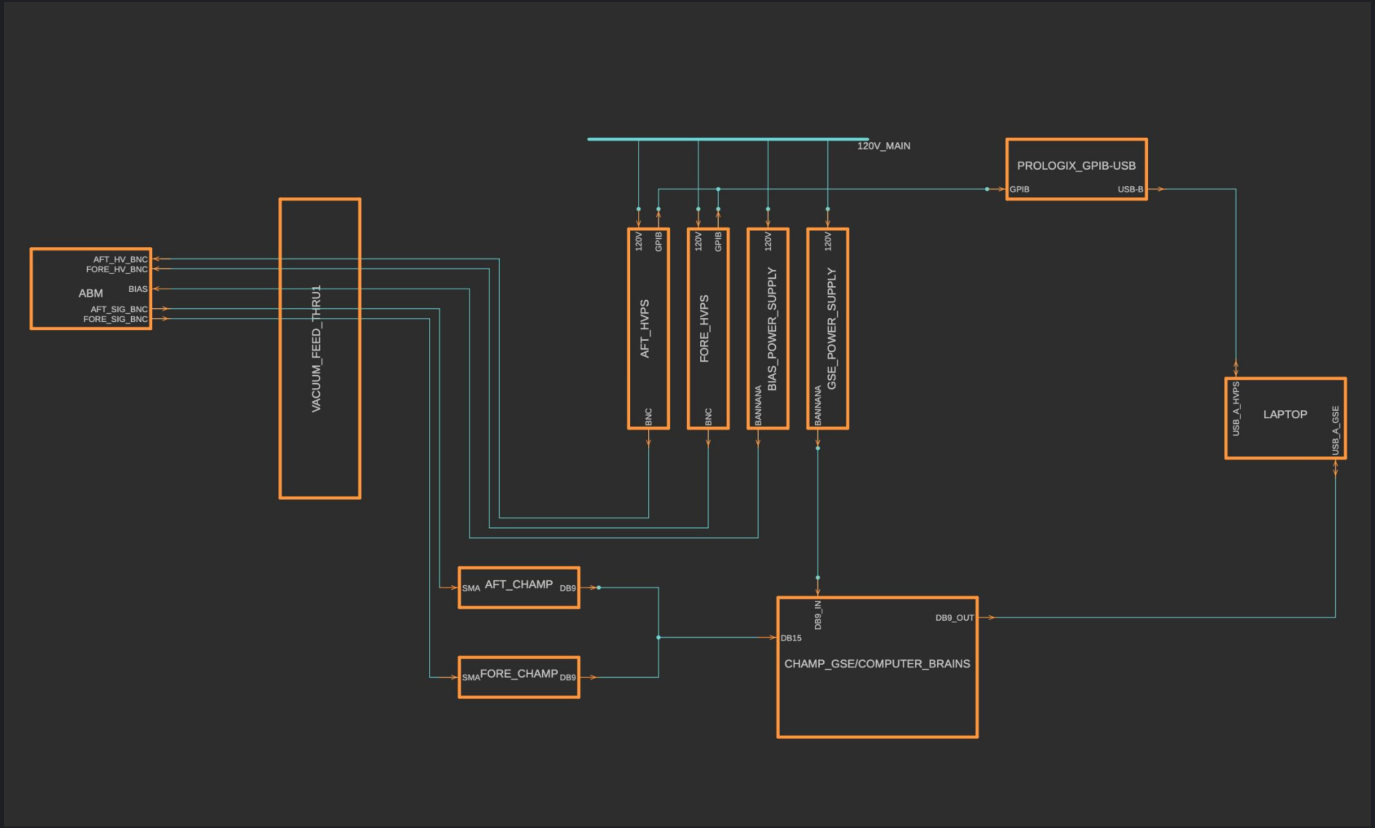
ABM-1 FORE/AFT Voltages: 4000V

HVPS limit: 5000V

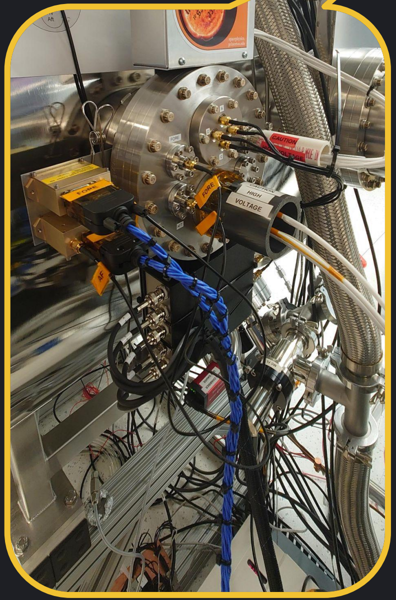
WIDE ABM FORE/AFT Voltage Range: 2000-2500V

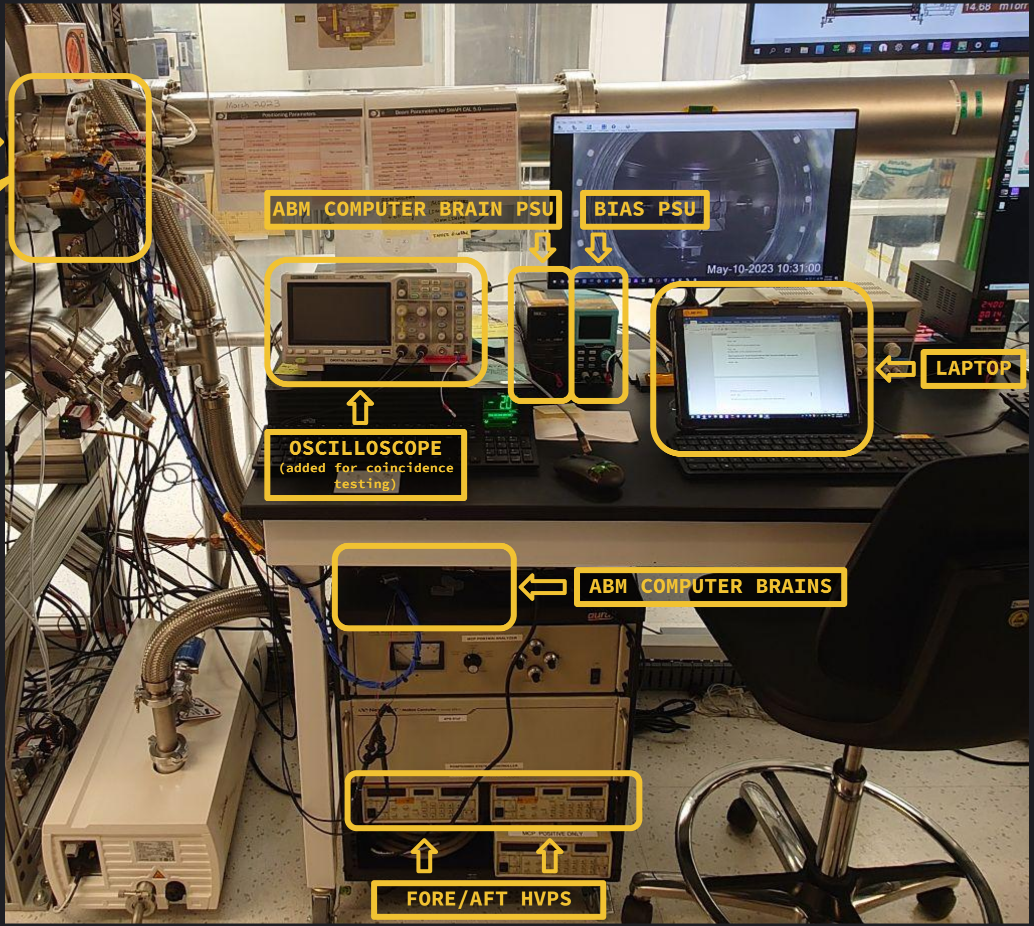
*We still will only see ~2000V on the CEMs

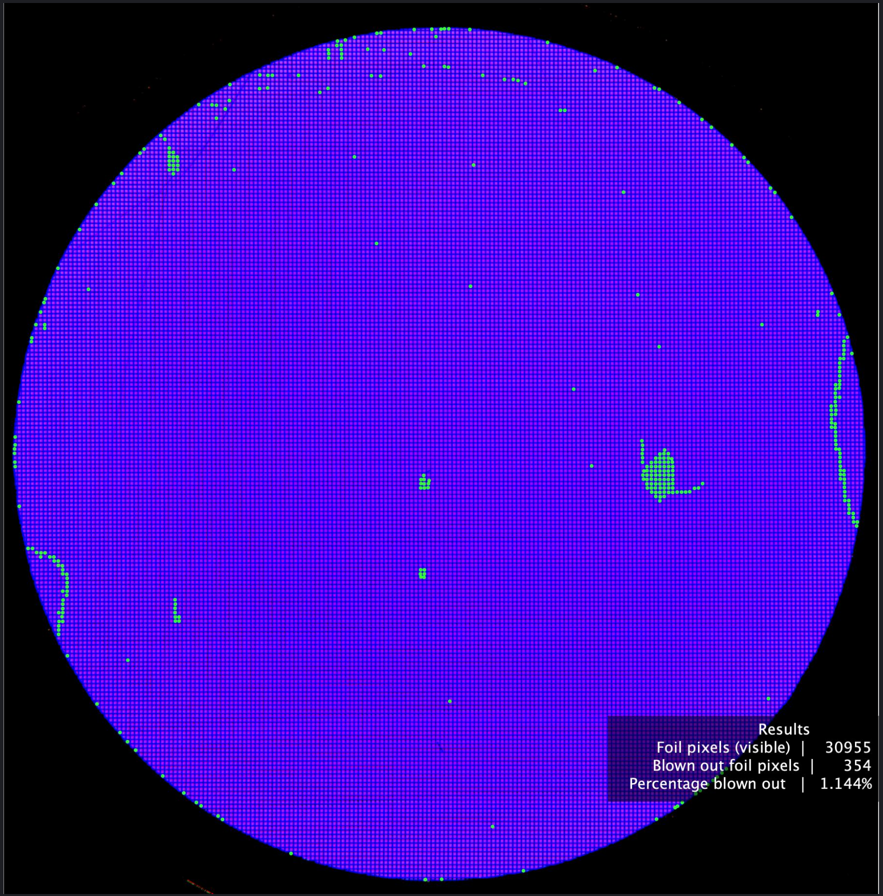
ABM-2 Instrument



ABM System Wiring



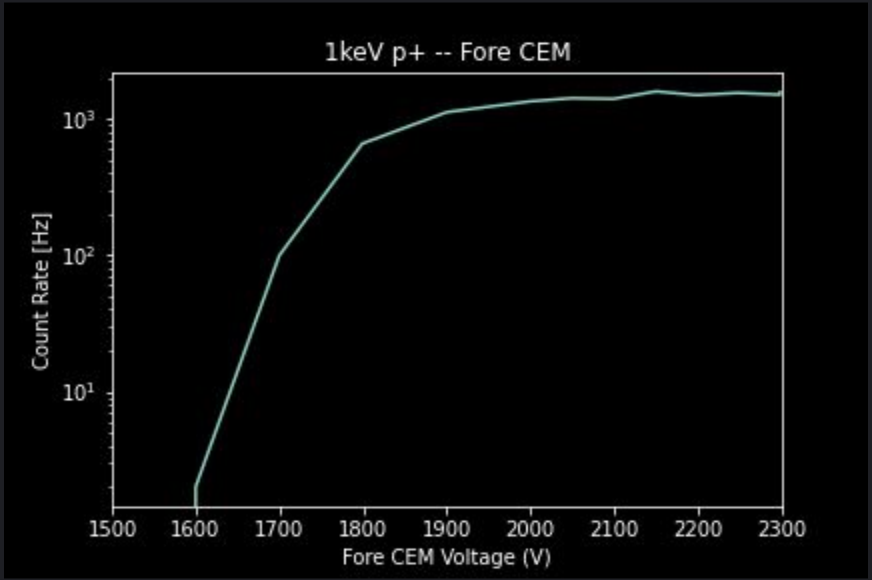

VACUUM FEED-THRU
ABM COMPUTER BRAIN PSU
BIAS PSU
OSCILLOSCOPE
(added for coincidence testing)
LAPTOP
ABM COMPUTER BRAINS
FORE/AFT HVPS
May-10-2023 10:31:00

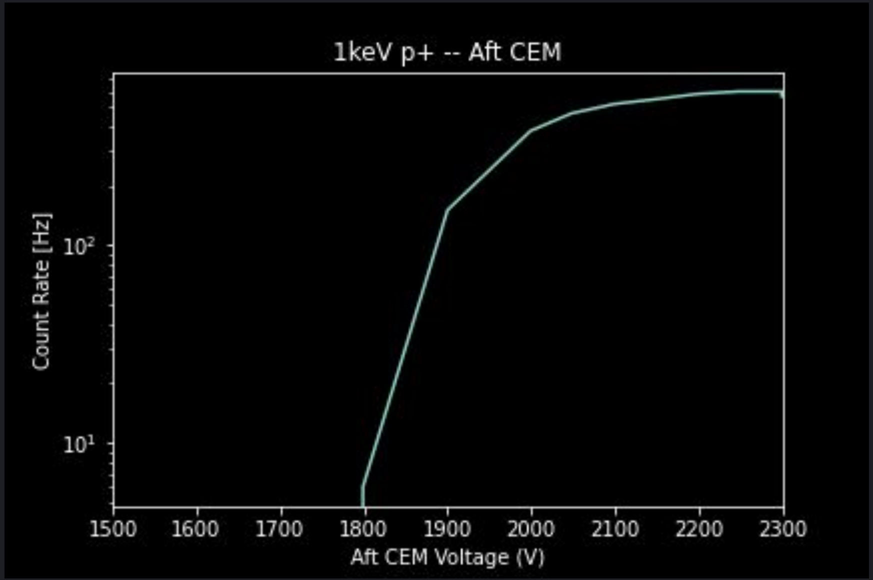


Carbon Foil

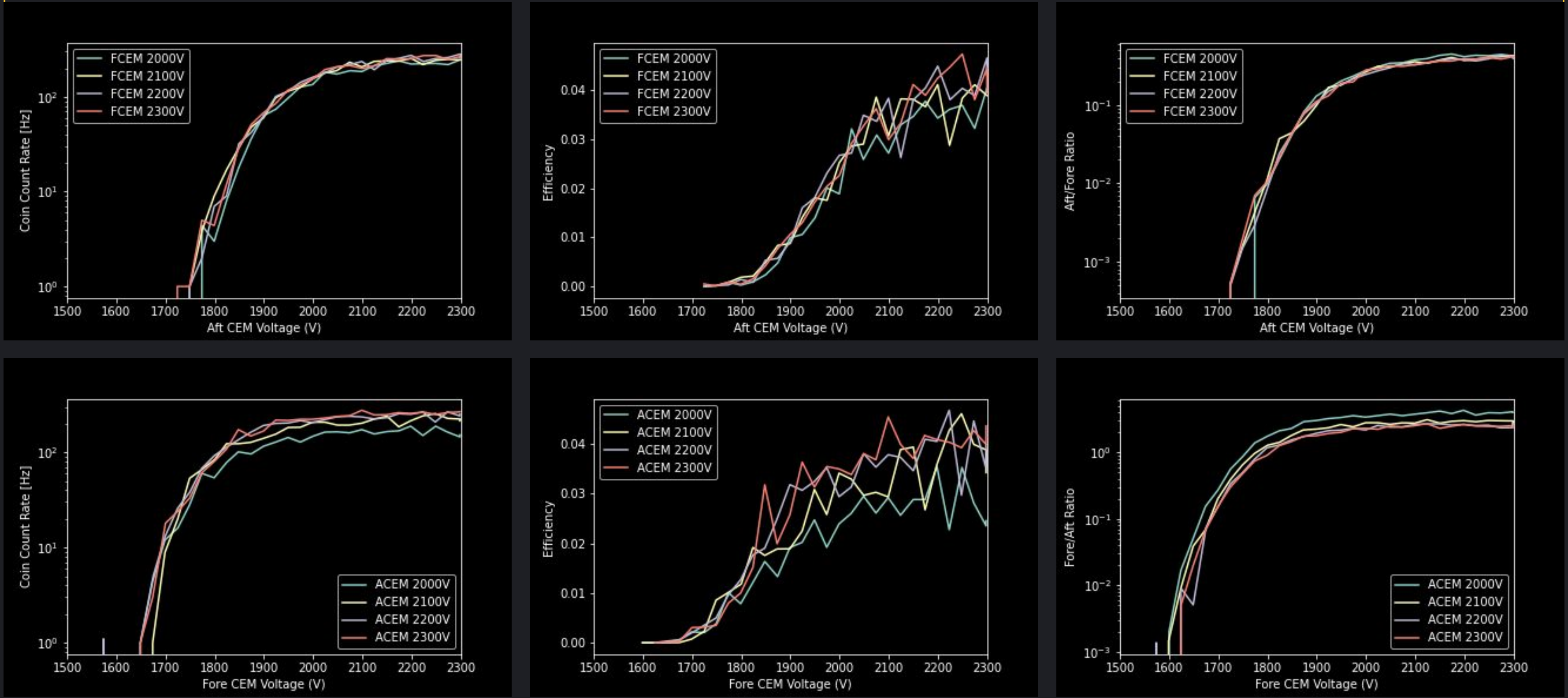
- 0.5 ug/cm^2 thickness
- Floating: 40°C DW
- Inspection: VHX6000 and MATLAB Code
- No problems with drying or edge tears

Quantitative analysis





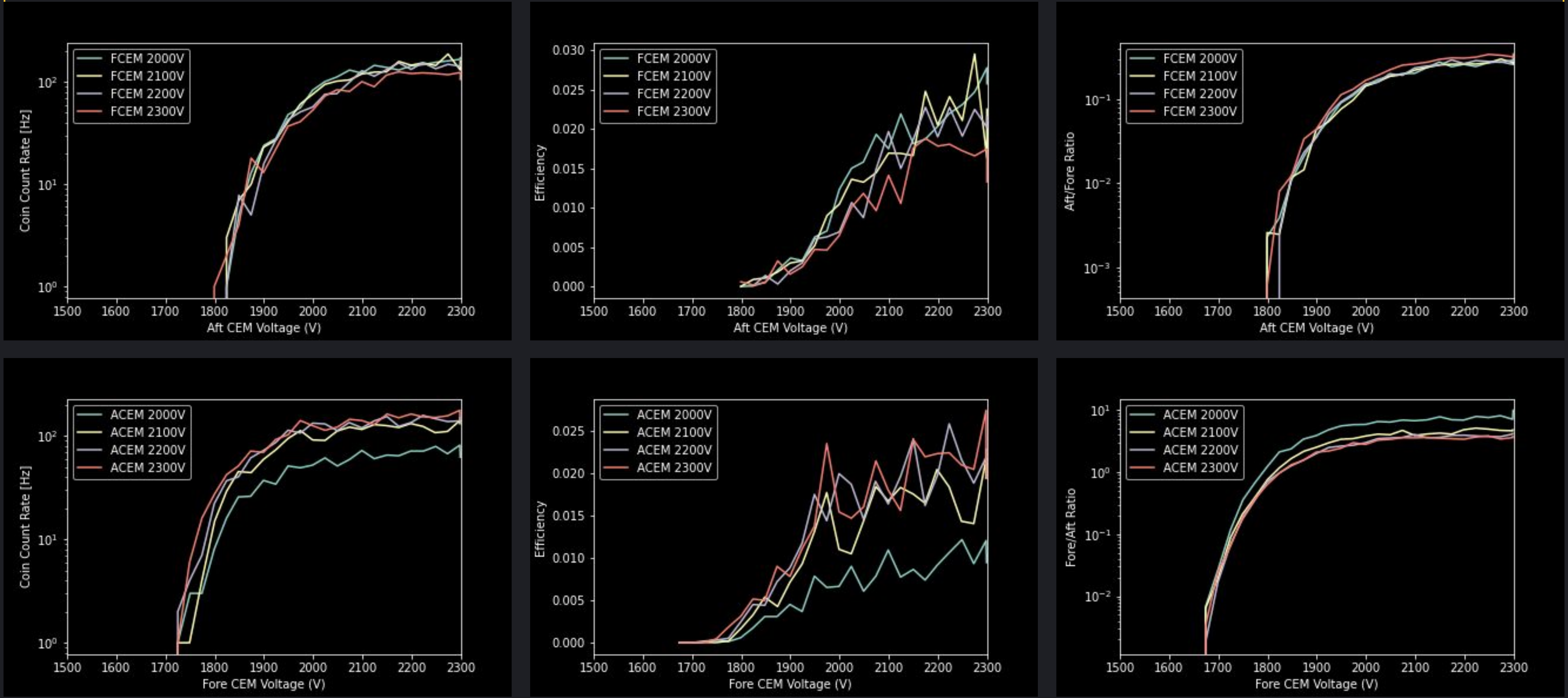
ABM-2: p+ Gain Curve



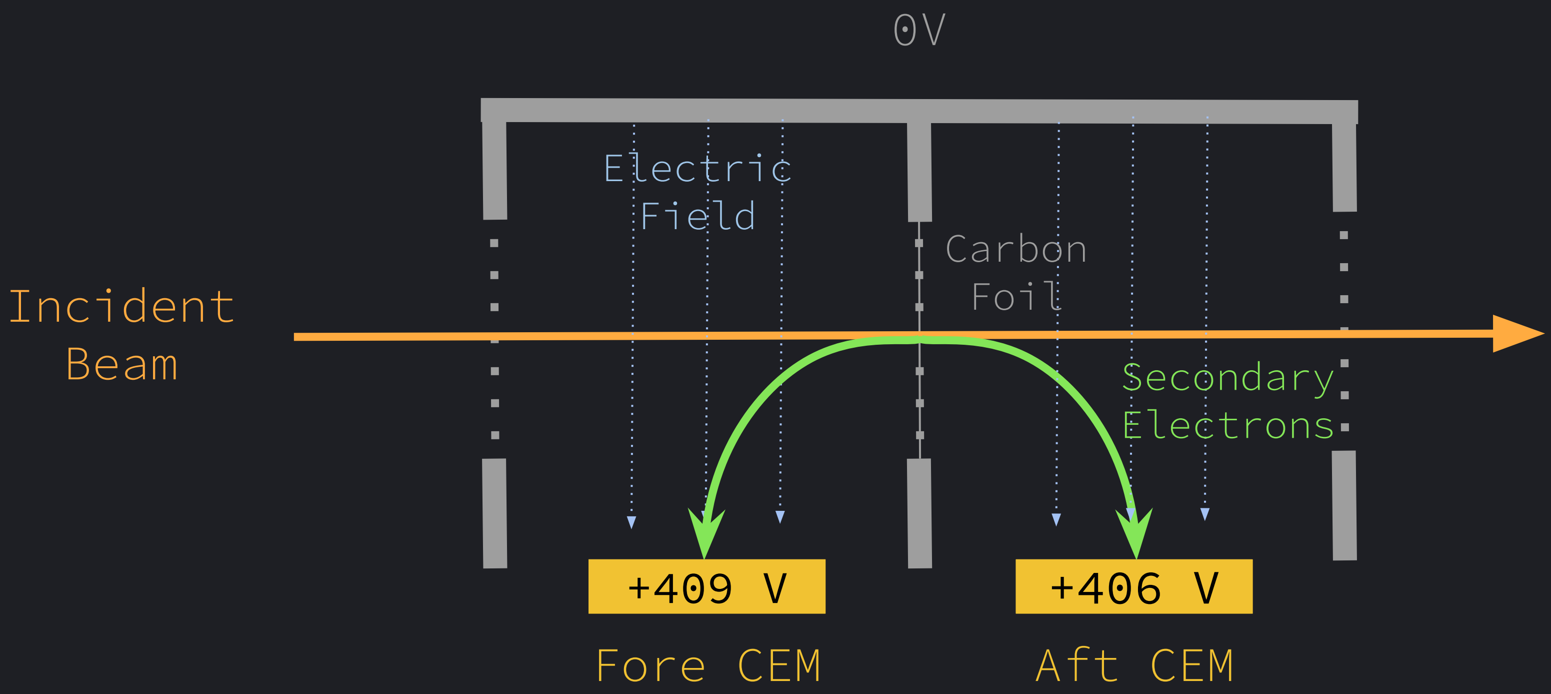
ABM-2: p+ Gain Matrix

Ast 250/251

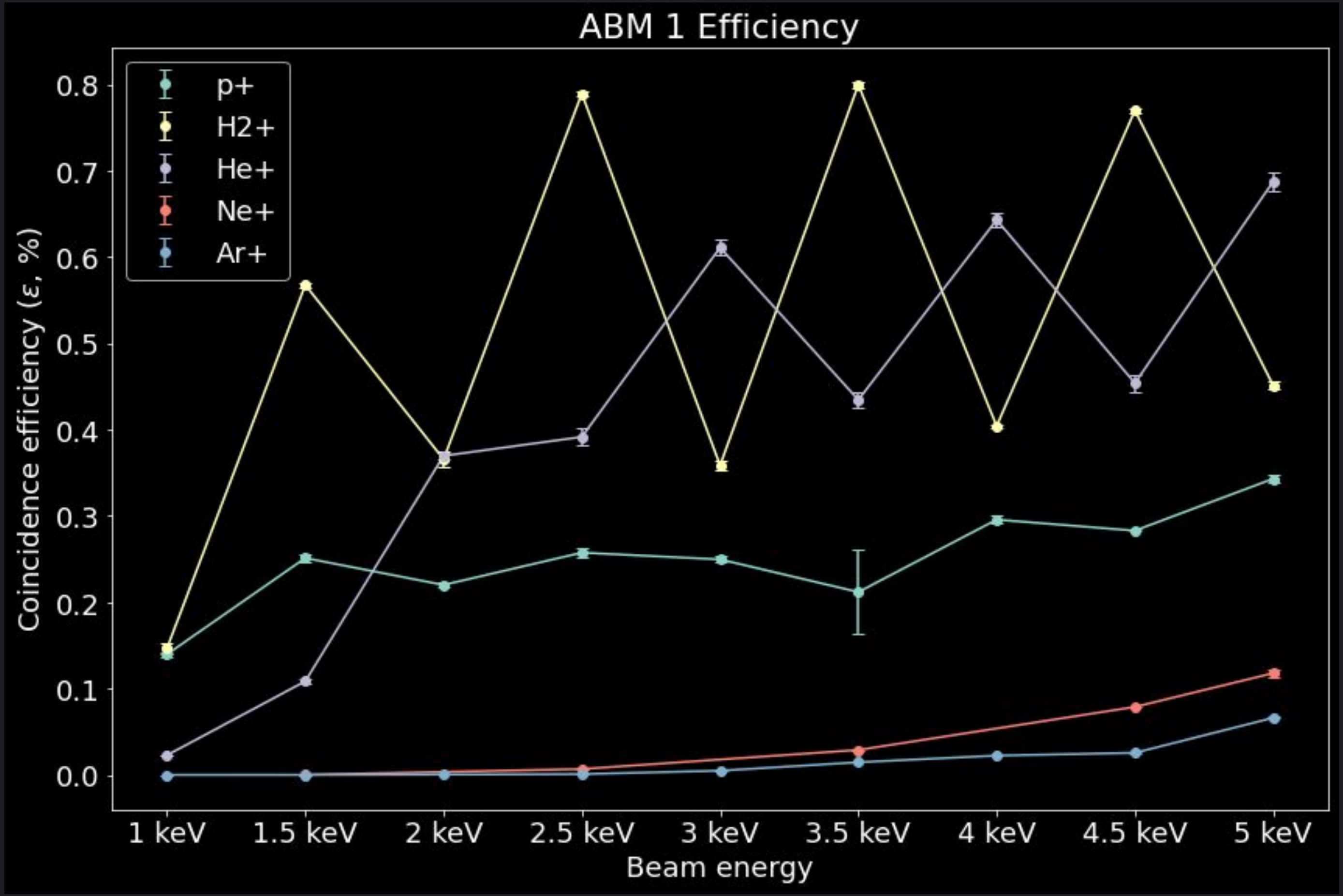
Space Physics at Princeton

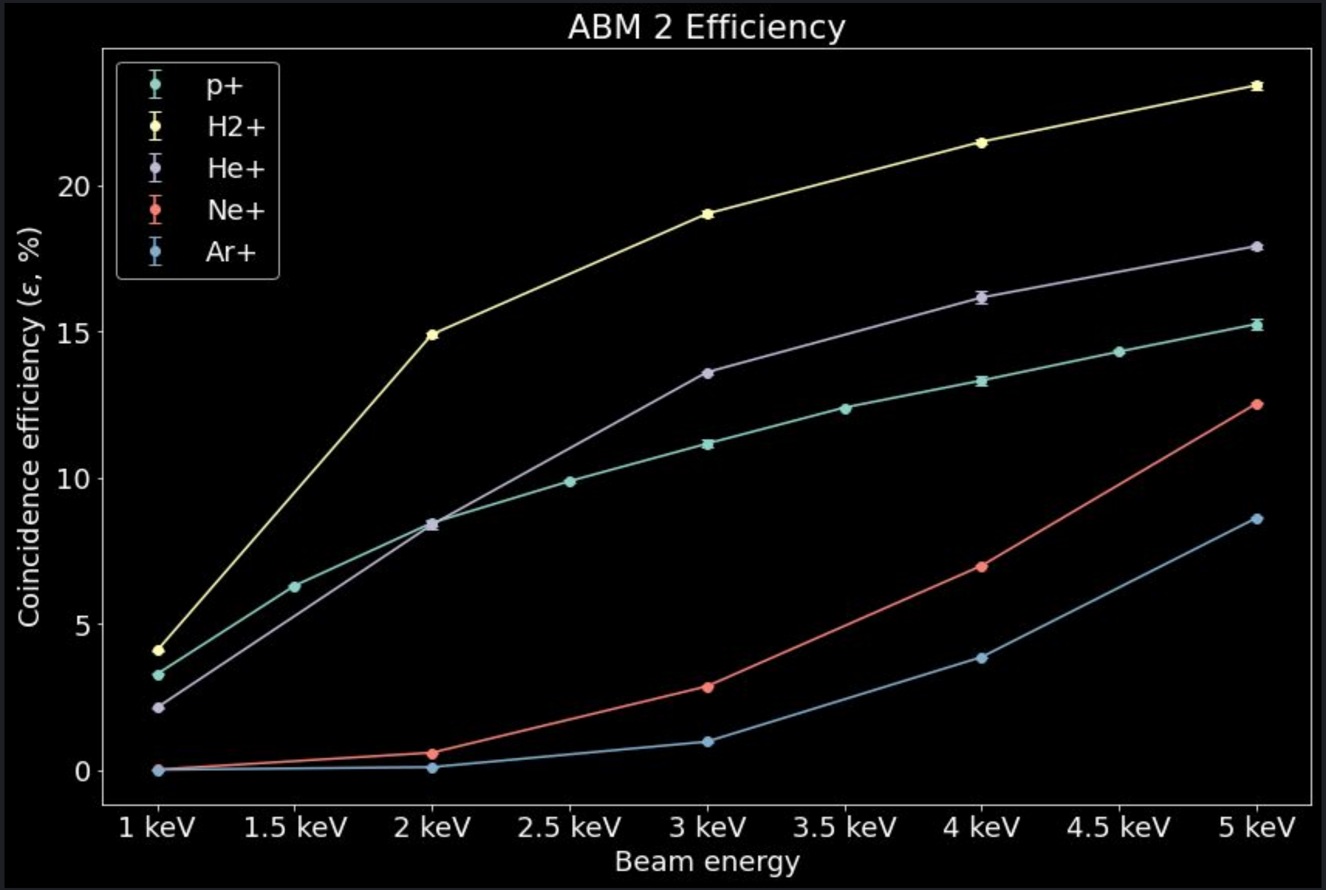


ABM-2: He+ Gain Matrix

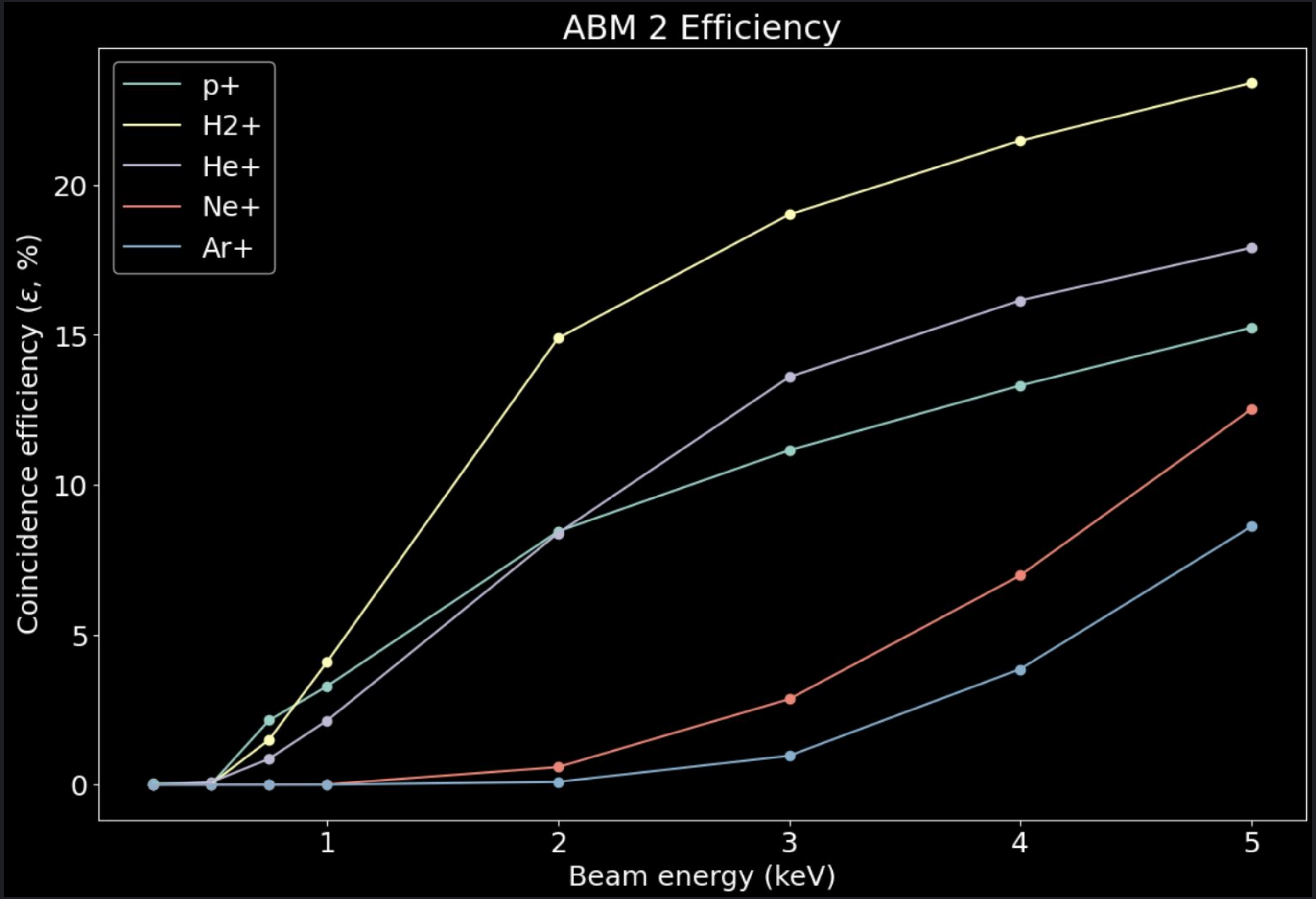


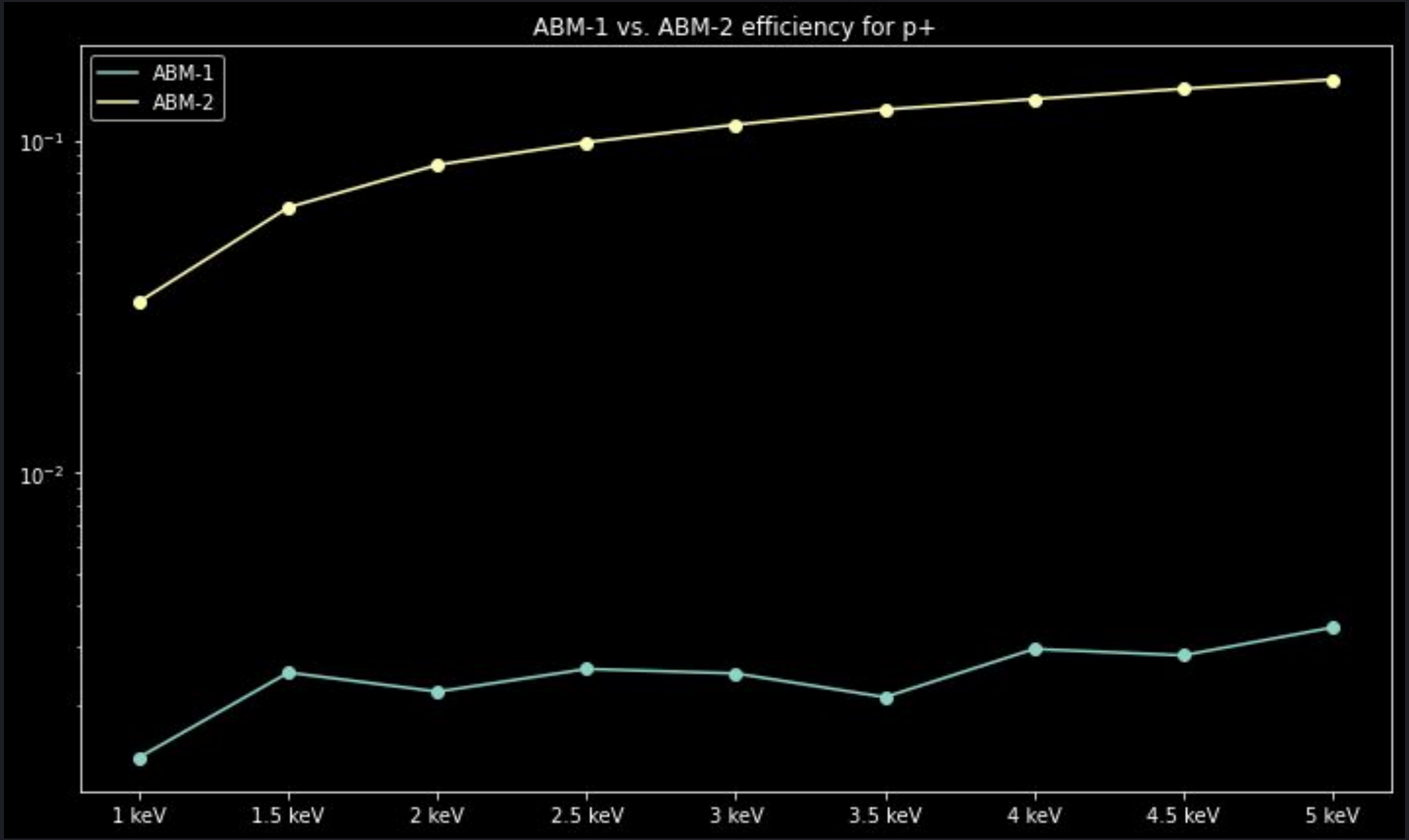
ABM-2 Electro-Optics

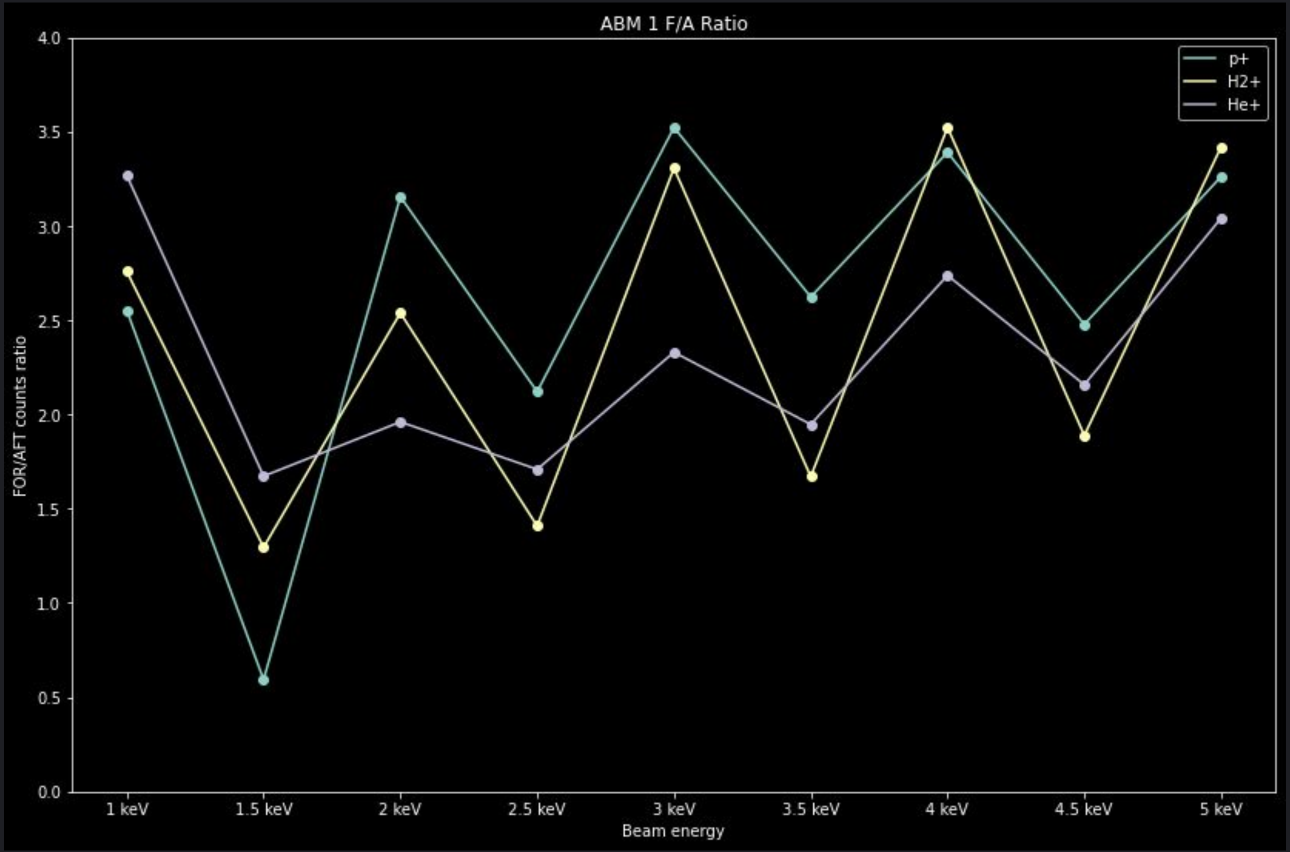

ABM 1 Efficiency
p+
H2+
He+
Ne+
Ar+
Coincidence efficiency (ε, %)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
1 keV
1.5 keV
2 keV
2.5 keV
3 keV
3.5 keV
4 keV
4.5 keV
5 keV
Beam energy

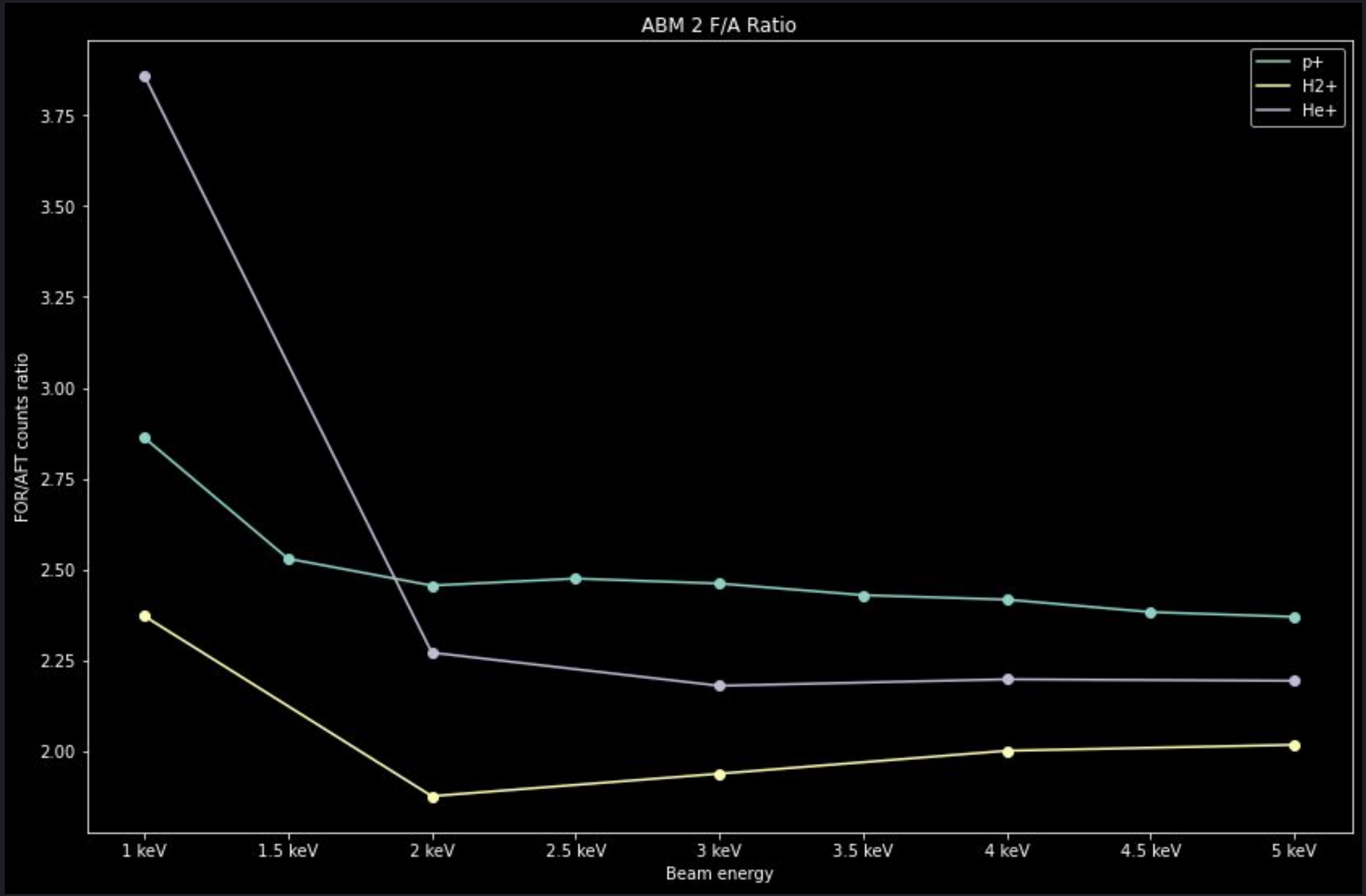


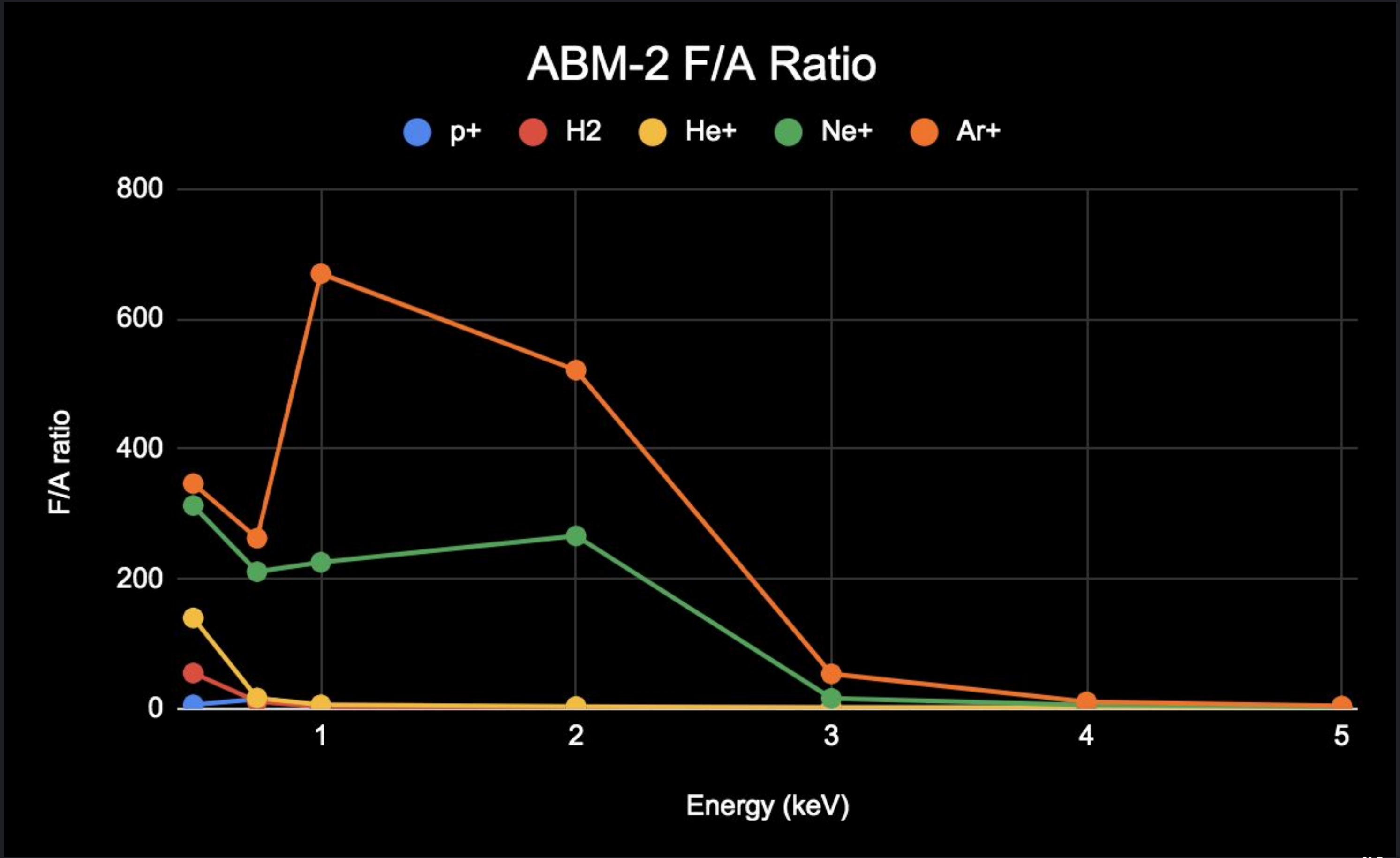
ABM 2 Efficiency
p+
H2+
He+
Ne+
Ar+
Coincidence efficiency (ε, %)
0
5
10
15
20
1 keV
1.5 keV
2 keV
2.5 keV
3 keV
3.5 keV
4 keV
4.5 keV
5 keV
Beam energy

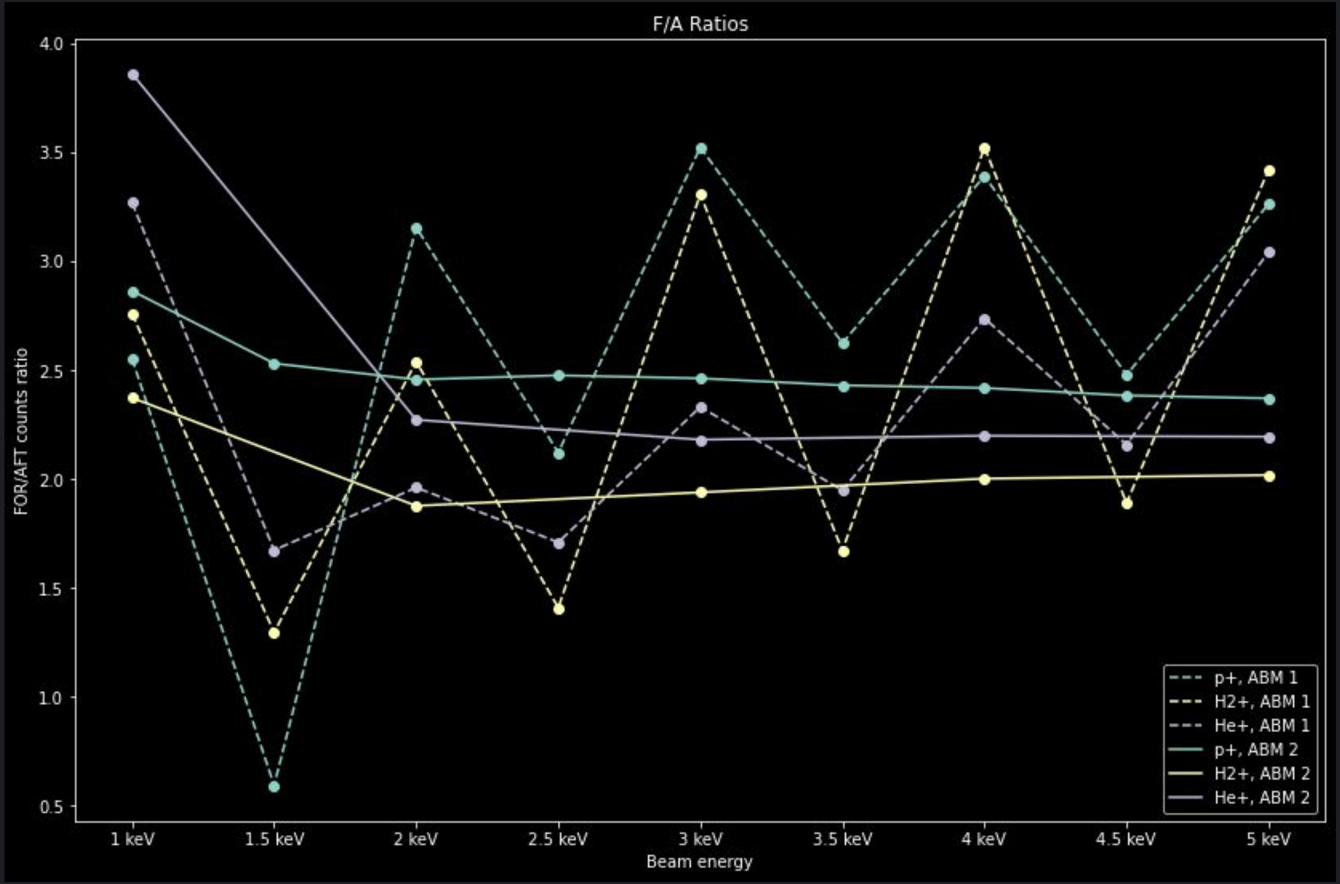

ABM 2 Efficiency
p+
H2+
He+
Ne+
Ar+
Coincidence efficiency (ε, %)
0
5
10
15
20
1
2
3
4
5
Beam energy (keV)


ABM-1 vs. ABM-2 efficiency for p+
ABM-1
ABM-2
10^{-1}
10^{-2}
1 keV
1.5 keV
2 keV
2.5 keV
3 keV
3.5 keV
4 keV
4.5 keV
5 keV

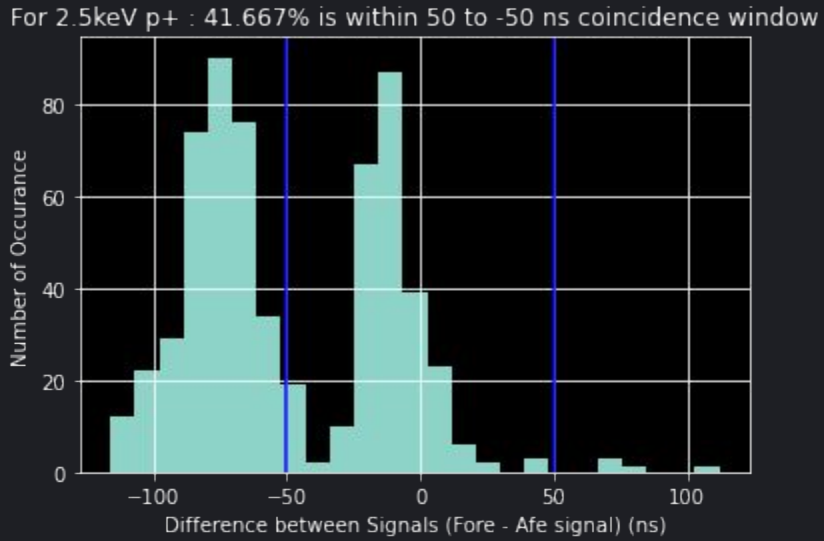

ABM 1 F/A Ratio
p+
H2+
He+
FOR/AFT counts ratio
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1 keV
1.5 keV
2 keV
2.5 keV
3 keV
3.5 keV
4 keV
4.5 keV
5 keV
Beam energy

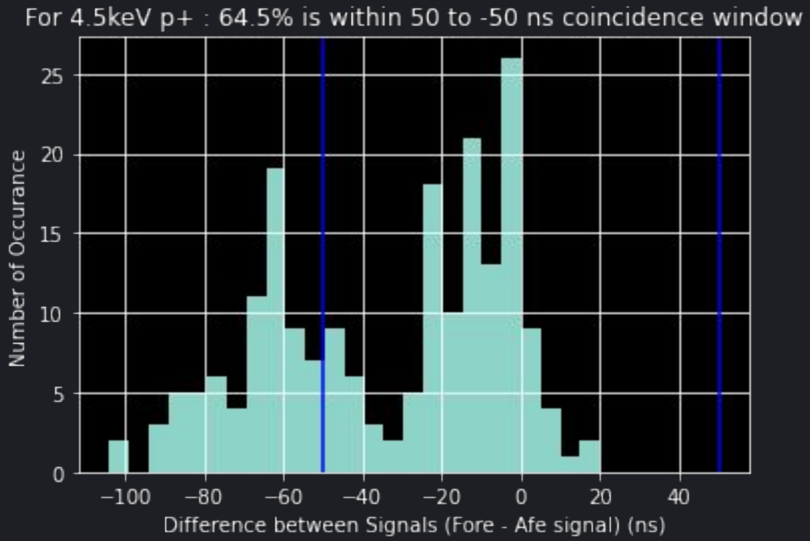

ABM 2 F/A Ratio
p+
H2+
He+
3.75
3.50
3.25
3.00
2.75
2.50
2.25
2.00
FOR/AFT counts ratio
1 keV
1.5 keV
2 keV
2.5 keV
3 keV
3.5 keV
4 keV
4.5 keV
5 keV
Beam energy

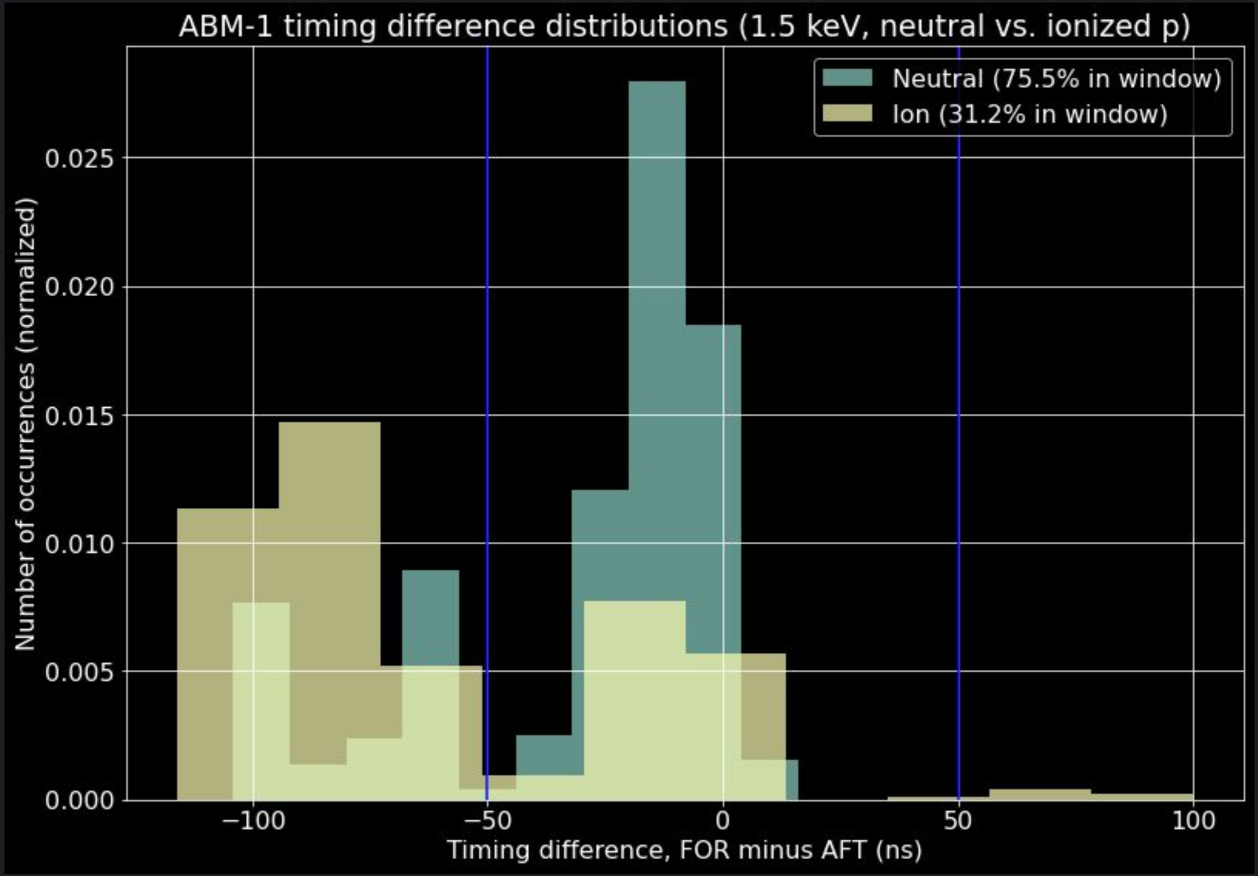

ABM-2 F/A Ratio
p+
H2
He+
Ne+
Ar+
800
600
400
200
0
F/A ratio
1
2
3
4
5
Energy (keV)


F/A Ratios
FOR/AFT counts ratio
Beam energy
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
1 keV
1.5 keV
2 keV
2.5 keV
3 keV
3.5 keV
4 keV
4.5 keV
5 keV
p+, ABM 1
H2+, ABM 1
He+, ABM 1
p+, ABM 2
H2+, ABM 2
He+, ABM 2

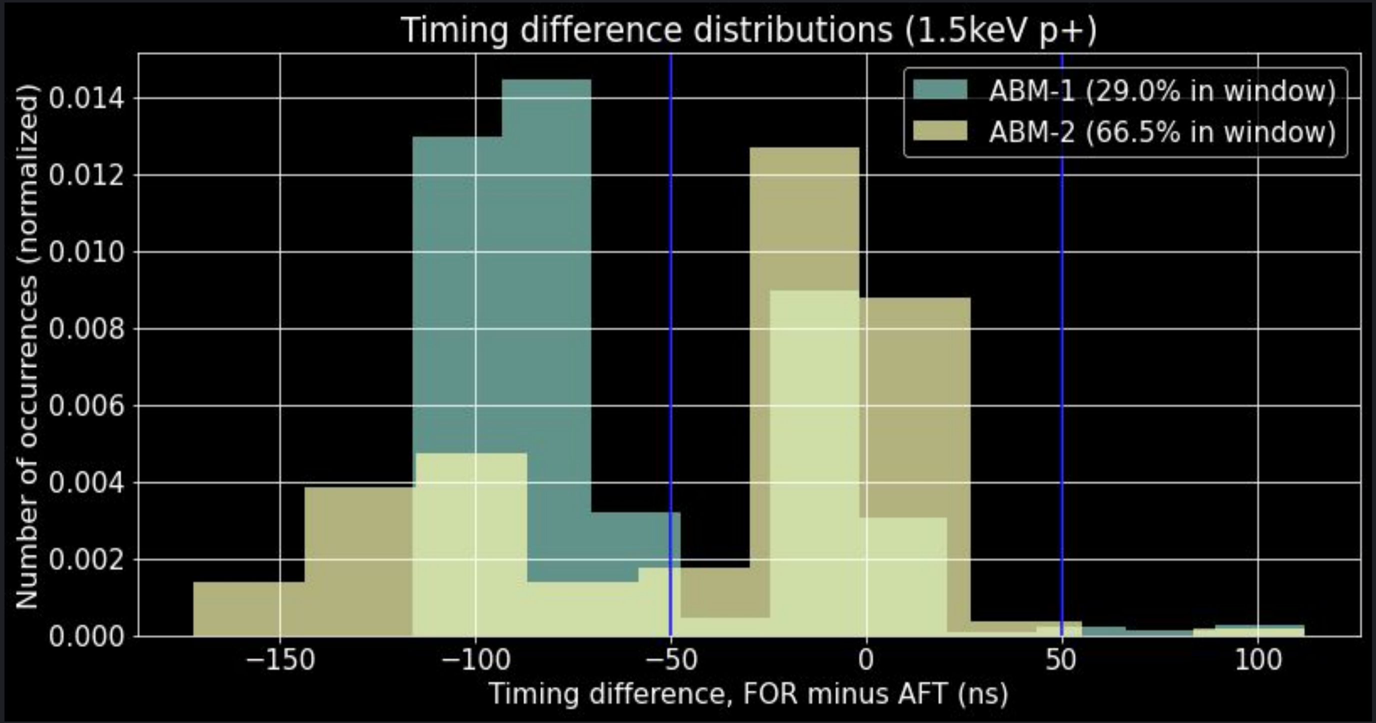
ABM-1 Timing Difference Distributions



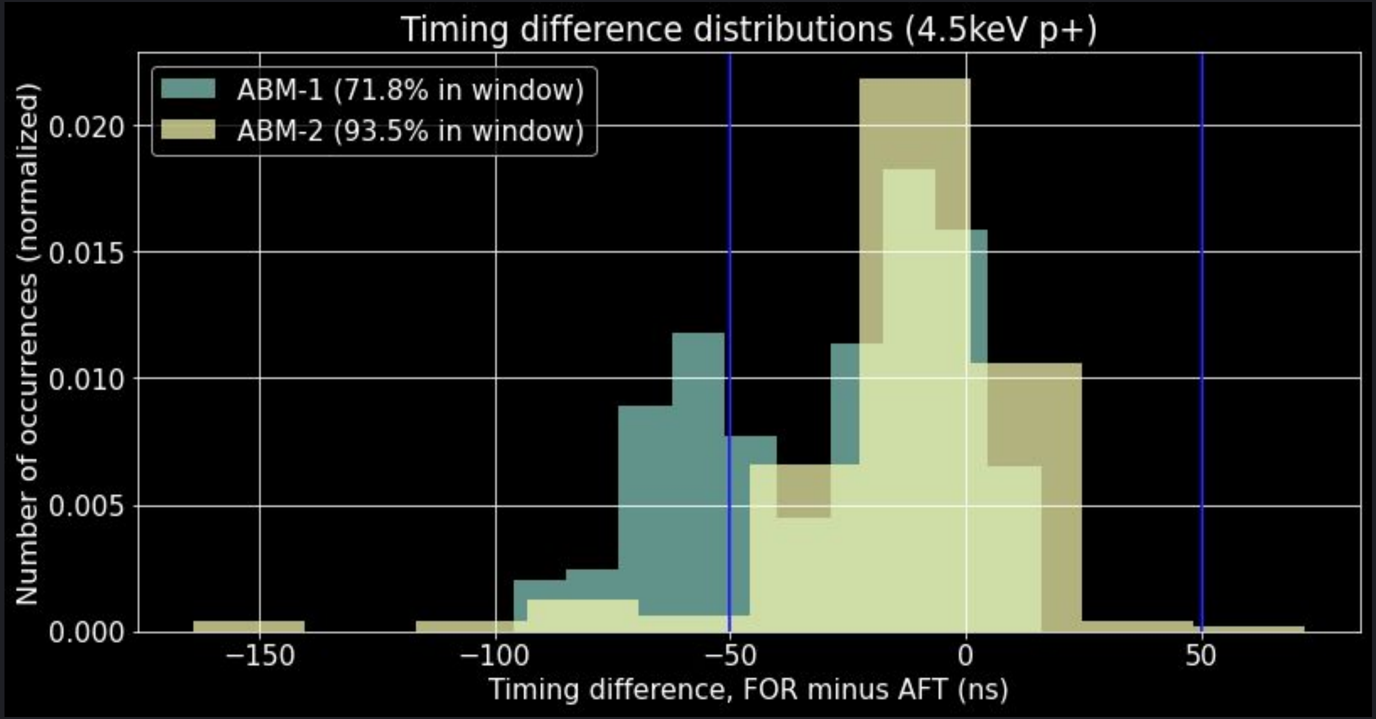



ABM-1 timing difference distributions (1.5 keV, neutral vs. ionized p)
Neutral (75.5% in window)
Ion (31.2% in window)
Number of occurrences (normalized)
0.025
0.020
0.015
0.010
0.005
0.000
−100
−50
0
50
100
Timing difference, FOR minus AFT (ns)

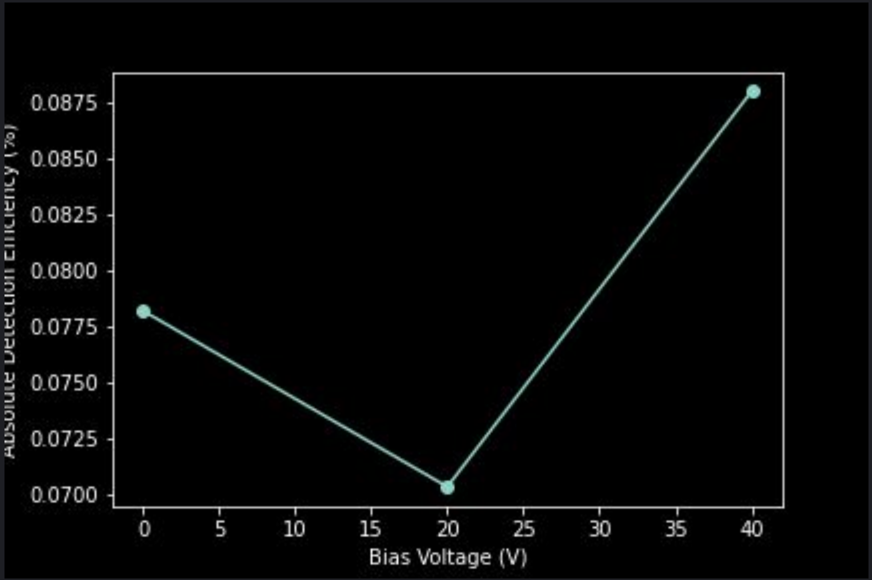
ABM-2 Timing Difference Distributions



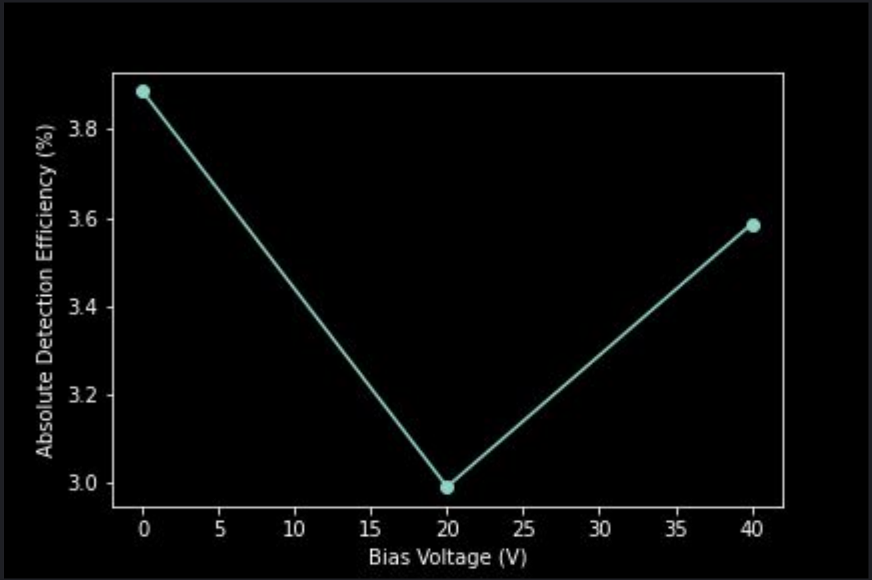
ABM-2 Timing Difference Distributions

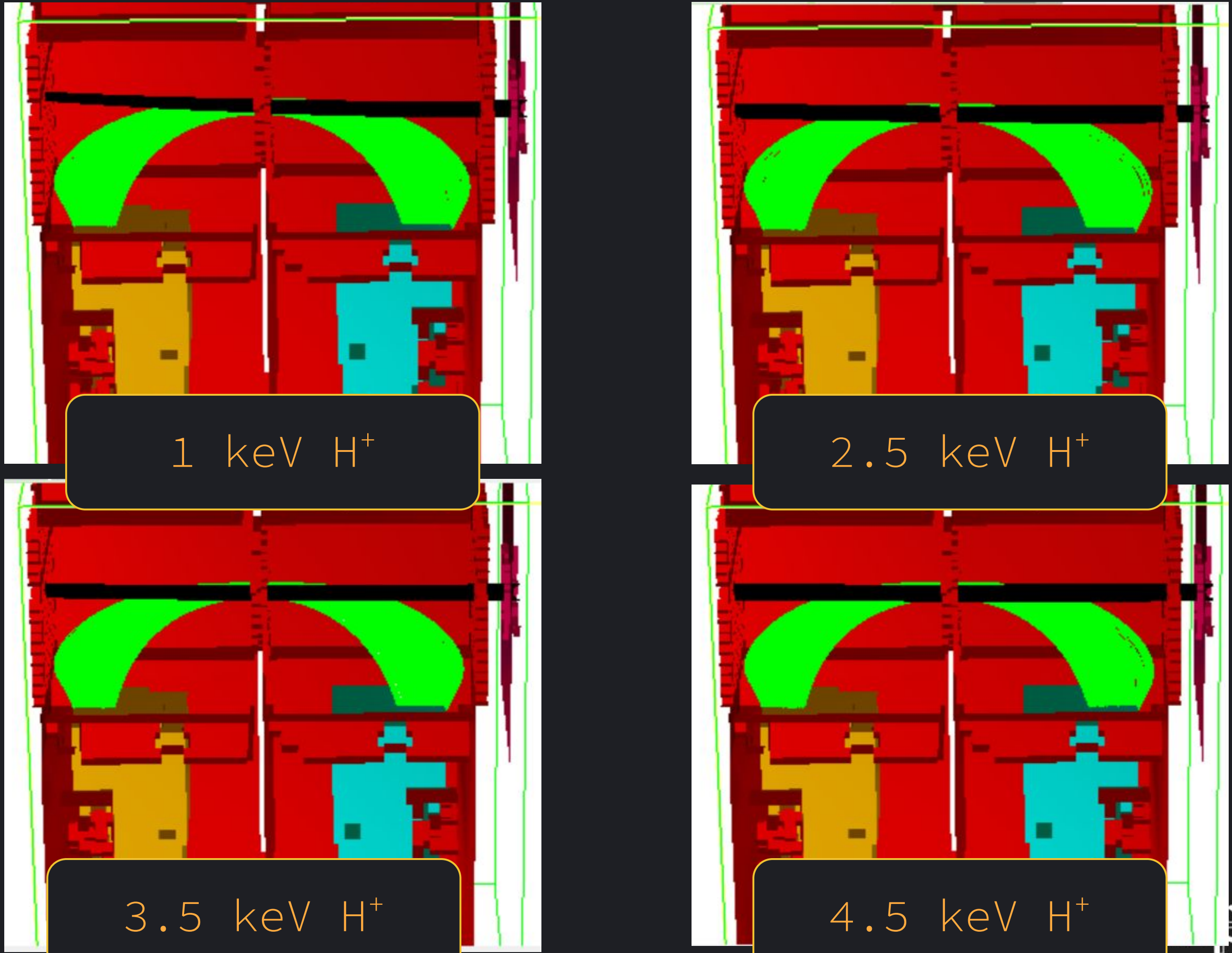


ABM-1 Bias Voltage (1 keV p+)



ABM-2 Bias Voltage (1 keV p+)





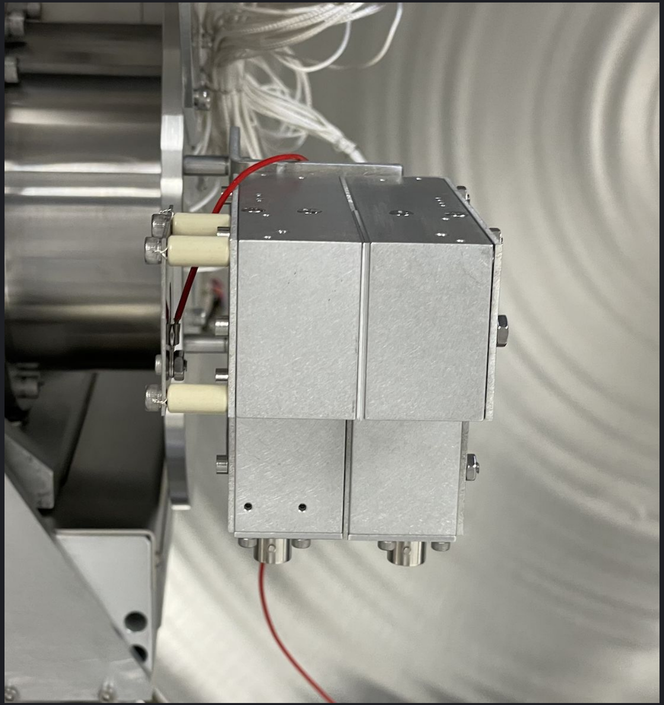
FCEM
409 V
ACEM
406 V

Time of Flight (ToF)

H+ Energy (keV)	TOF (ns)
1	95.7
2	74.6
3	65.3
4	59.7
5	55.9

- H^+ with an energy range of 1-5 keV hitting the walls + scattering secondary electron hitting the CEM → time delay
- Max distance ~3.15 cm
- Stripping efficiency: 0.88 (Chou+, 2008) for proton
- Metal secondary electron emission energy ~10 eV (Alonso+, 1980)

Safety Precautions

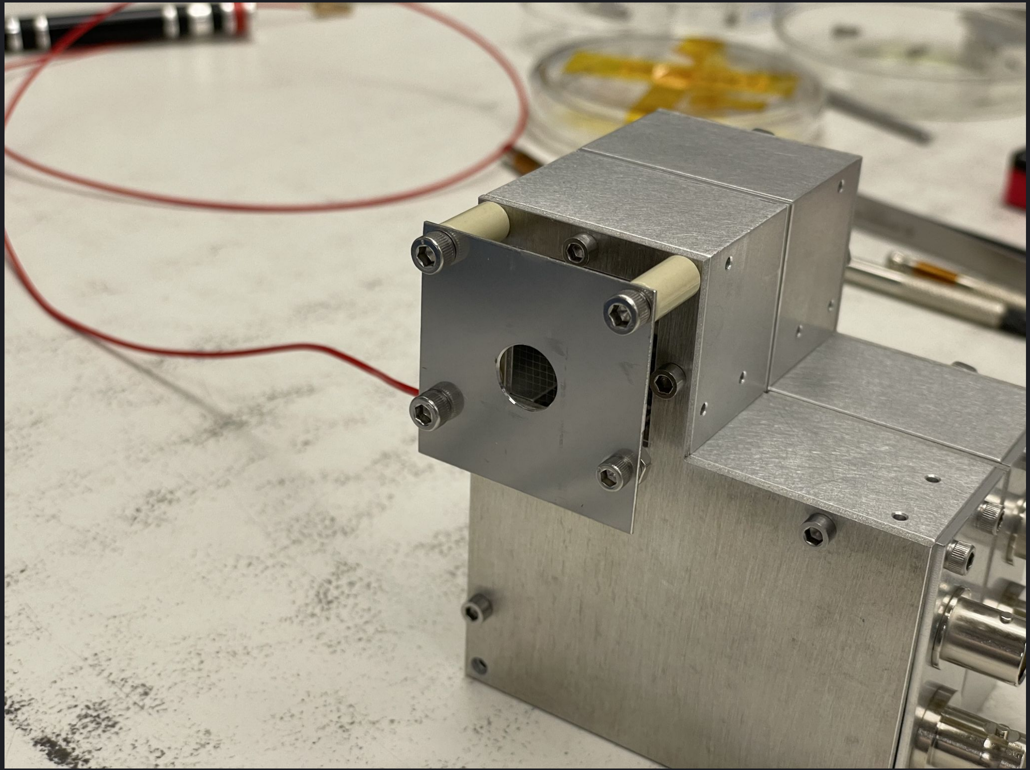


- Mounting has no clearance issues
- HV has grounded covers
- No insulators in beam line

Problems with ABM-2

Build and design issues:

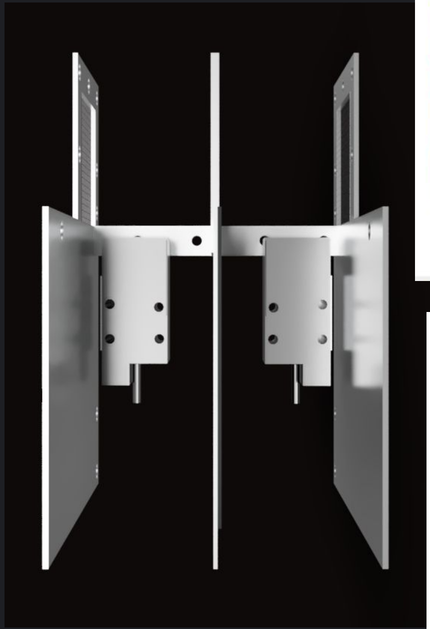
- Bias plate effectiveness and position.
- CEM location, not as intended due to misplacement of screw holes.

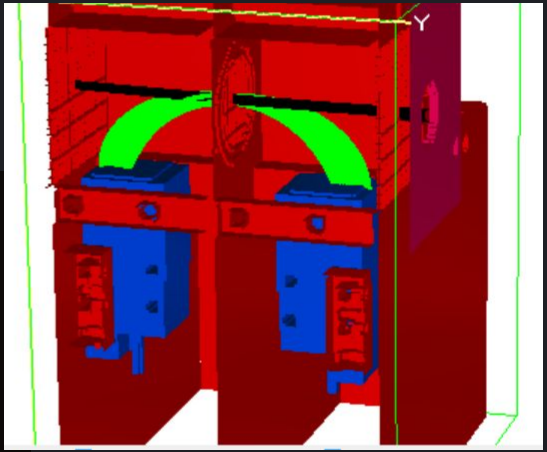


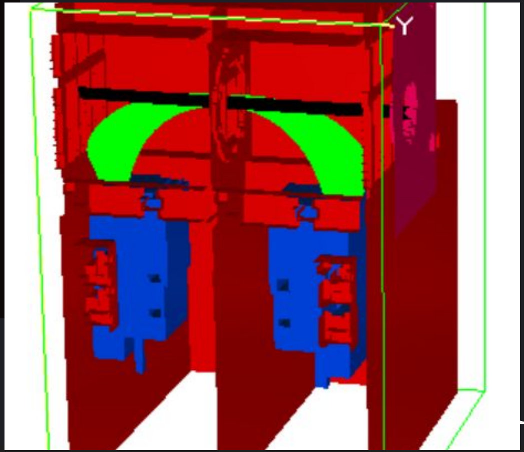
- ½ inch ceramics standoffs resulting in the 40 volt bias to have an inconclusive (not evident) impact on the ABM’s efficiency

CEM location

- The CEMs needed to be placed lower than we intended.
- Choice above proved to lower efficiency in SIMION, however, not by a considerable margin.







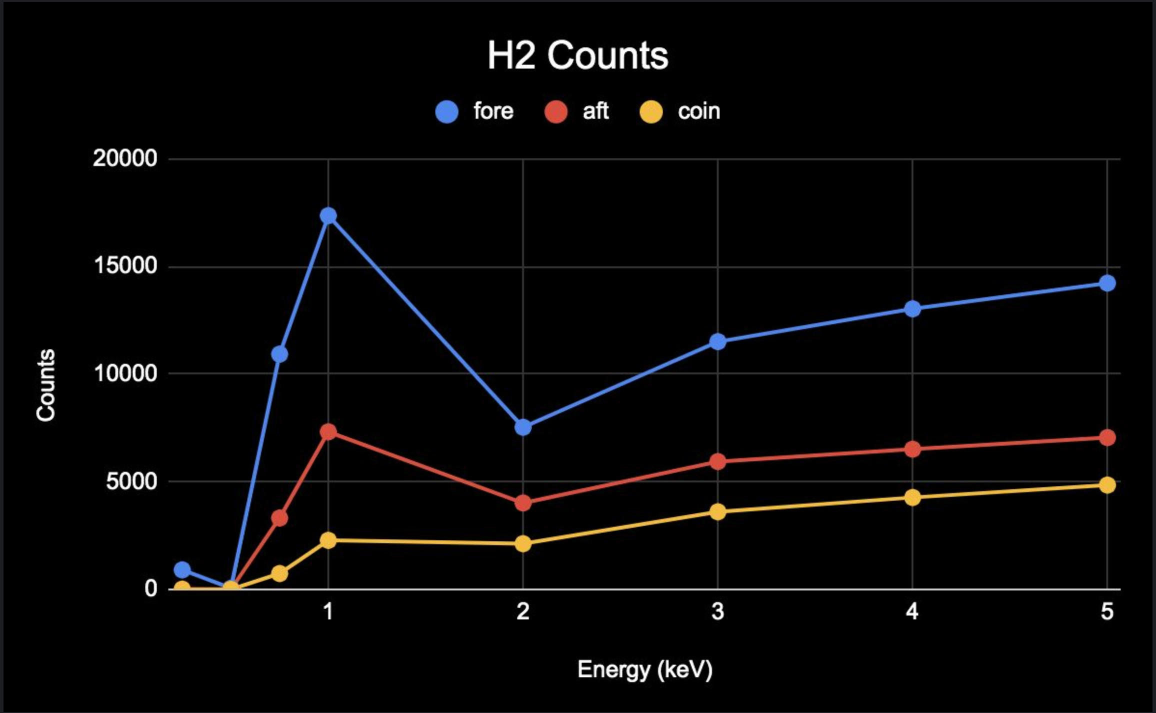
Space Physics at Princeton

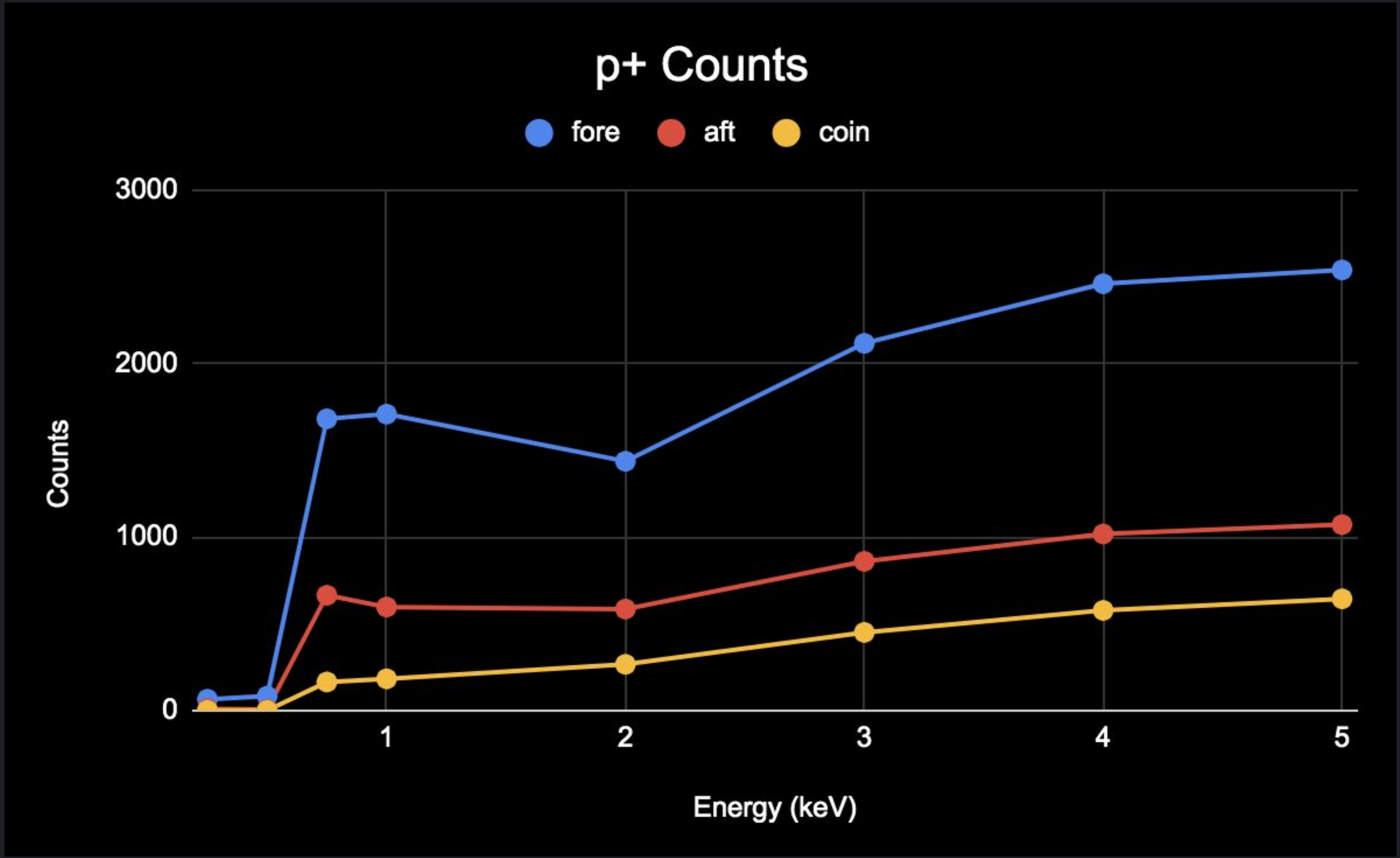
Strange Counts

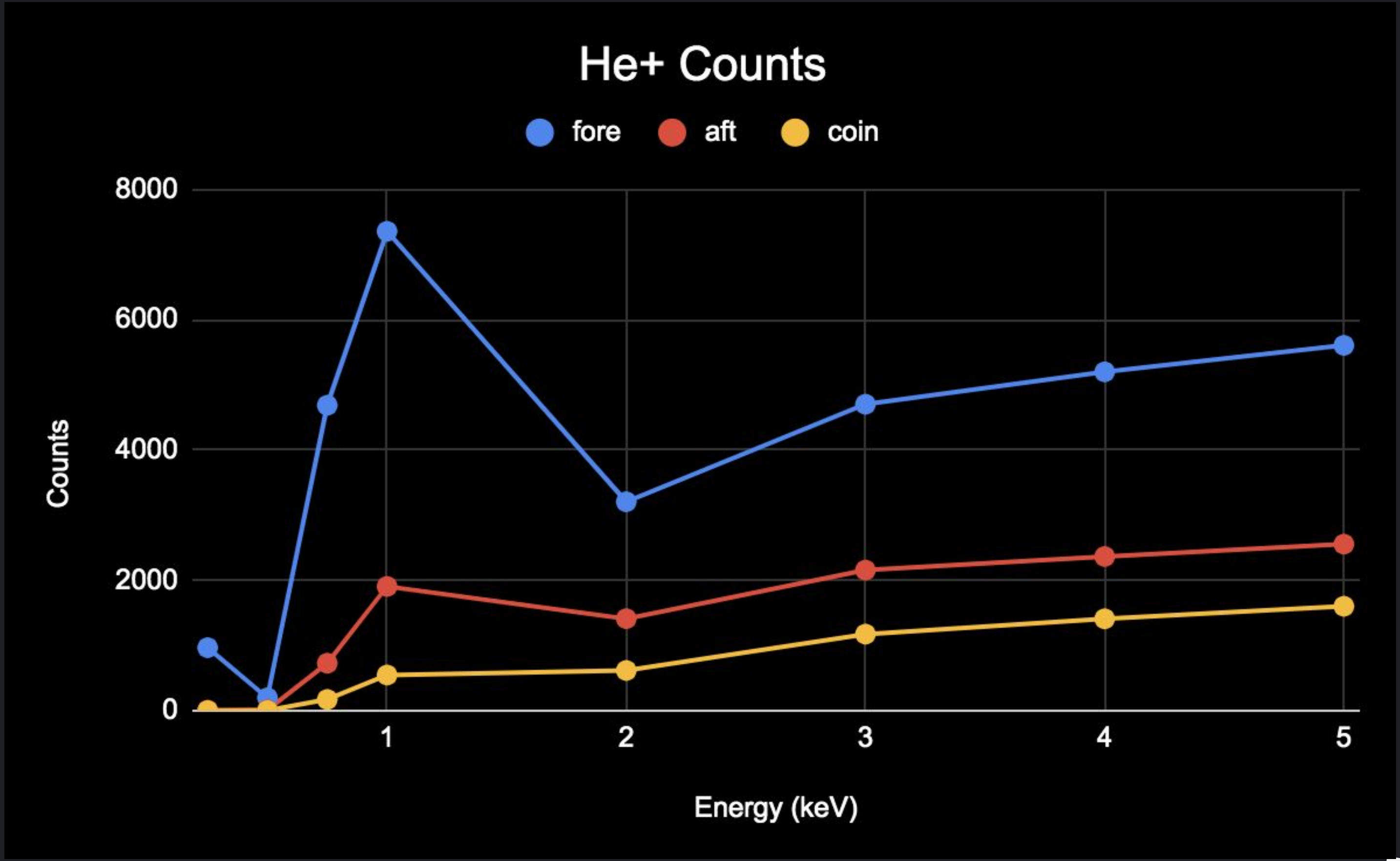
3 regions of scaling, with unique curves.

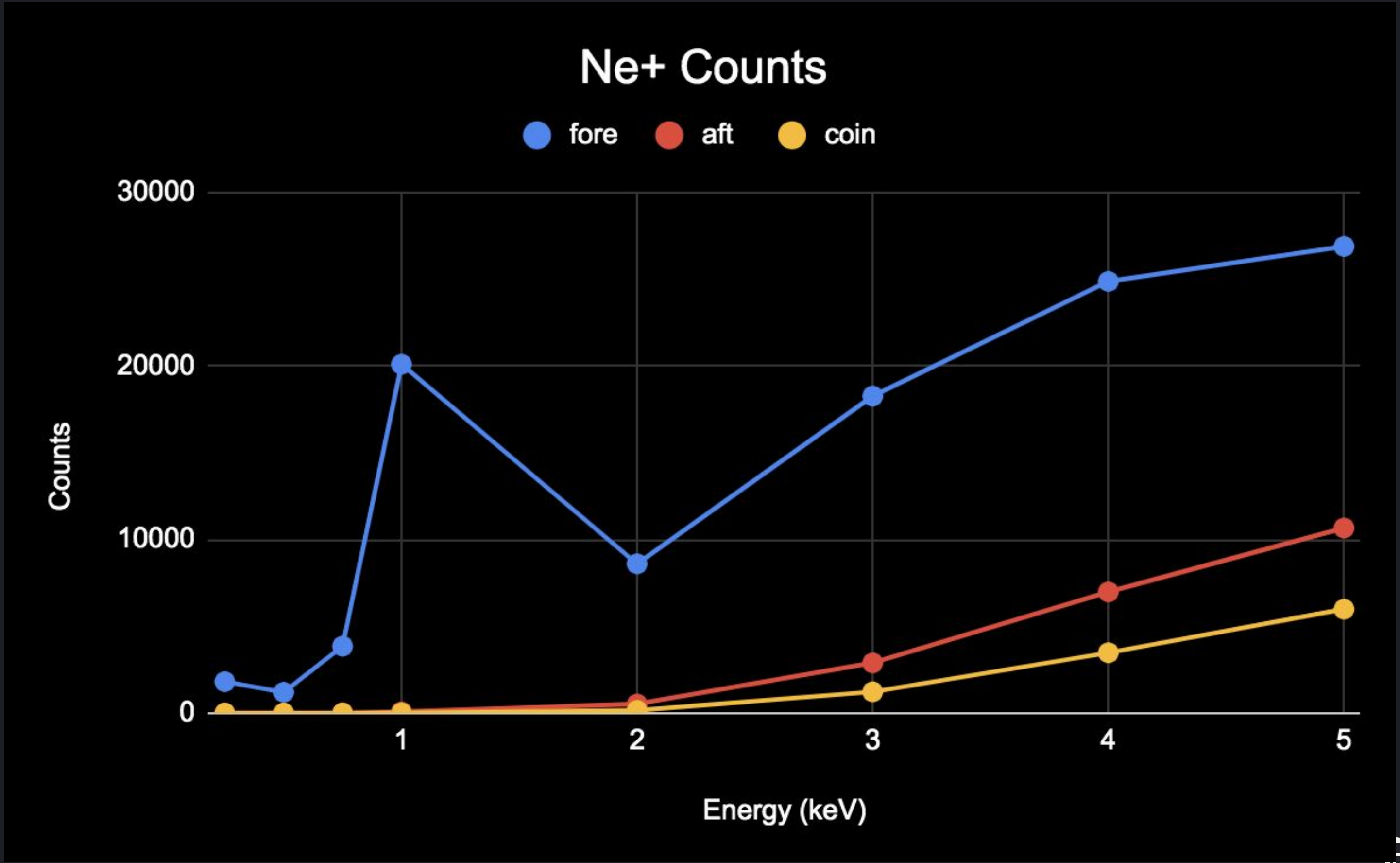
We would expect that the counts would increase as energy of beam increased.

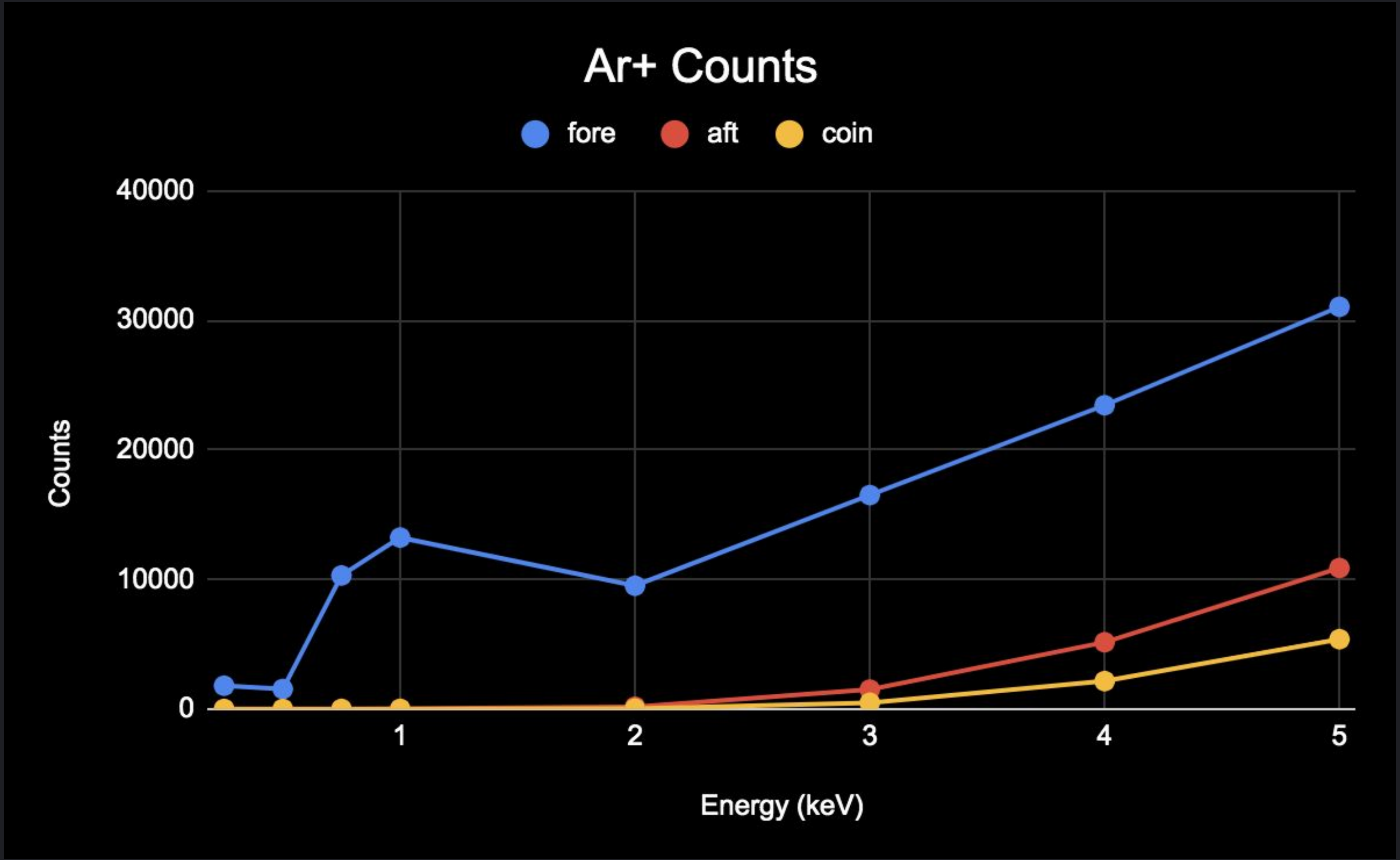
Need further testing of more energy levels to better identify the 3 regions.

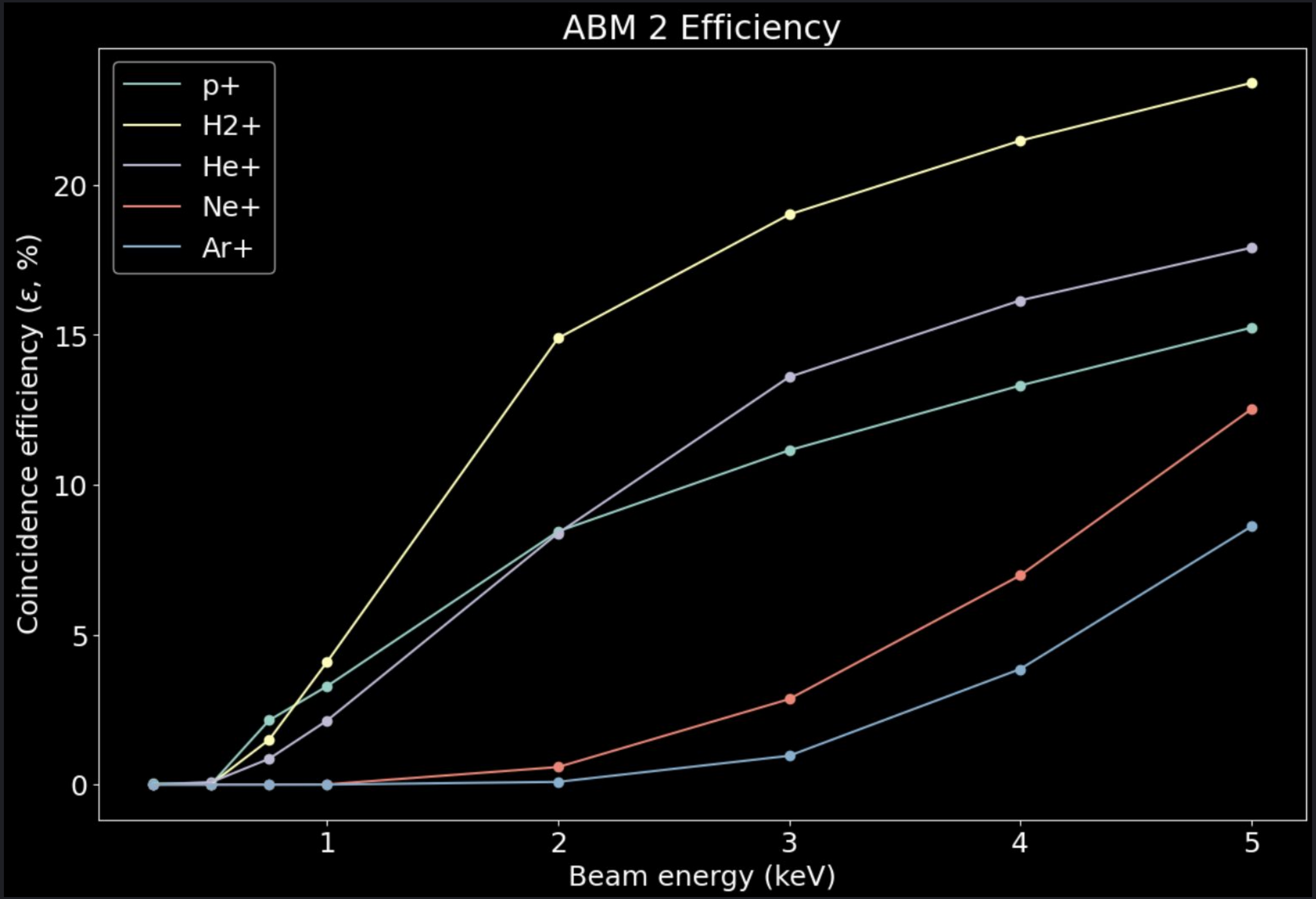



p+ Counts
fore
aft
coin
3000
2000
1000
0
Counts
1
2
3
4
5
Energy (keV)


He+ Counts
fore
aft
coin
8000
6000
4000
2000
0
Counts
1
2
3
4
5
Energy (keV)


Ne+ Counts
fore
aft
coin
30000
20000
10000
0
Counts
1
2
3
4
5
Energy (keV)


Ar+ Counts
fore
aft
coin
40000
30000
20000
10000
0
Counts
1
2
3
4
5
Energy (keV)


ABM 2 Efficiency
p+
H2+
He+
Ne+
Ar+
Coincidence efficiency (ε, %)
Beam energy (keV)
0
5
10
15
20
1
2
3
4
5

Recommendations for Improvement

Future Recommendations

- Bias Aperture Usefulness?
- Tune the ABM width
- Further tests: Neutrals, Low energy
- Build multiple and compare in beam

Summary

ABM-1 vs ABM-2

- ABM 2 is Wider
- ABM 2 CEMs requires lower power supply voltages
- (50, -50) ns Coincidence window works well with ABM 2
- ABM 2 has improved efficiencies.

Deliverables : What Are We Giving You?

Absolute Beam Monitor "Manual"

- Pdfs of Rudimentary Procedures
  - Build Assembly Procedure,
  - Power Off and On
  - Testing Procedures

- SIMION and CAD models, Code
  - Counts Analysis Code
  - Oscilloscope Testing Code
  - ABM 1 and 2 SIMION and CAD Models and Technical Drawings

Works Cited

Works Cited

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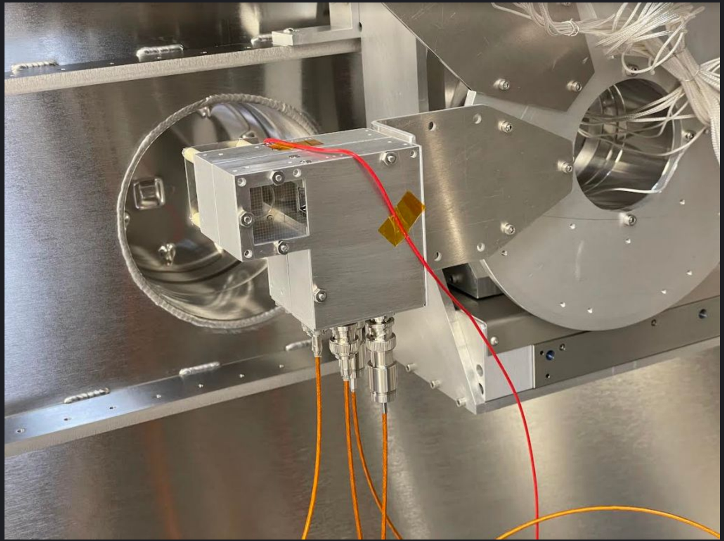
Acknowledgements

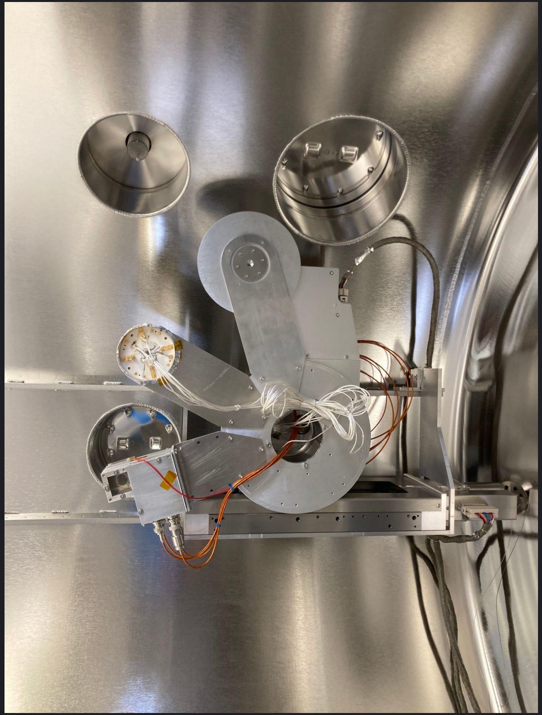
Acknowledgements

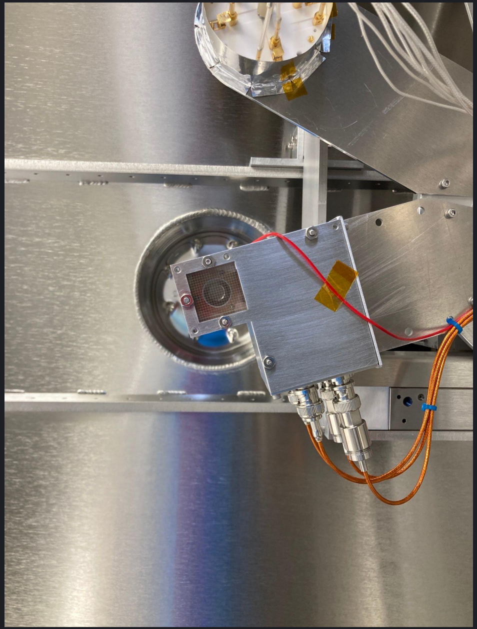
A big thank you to everybody in Space Physics, for answering our questions, demonstrating your day-to-day work, and teaching us about your research!

Thank you!

Extra slide: Installed ABM-2

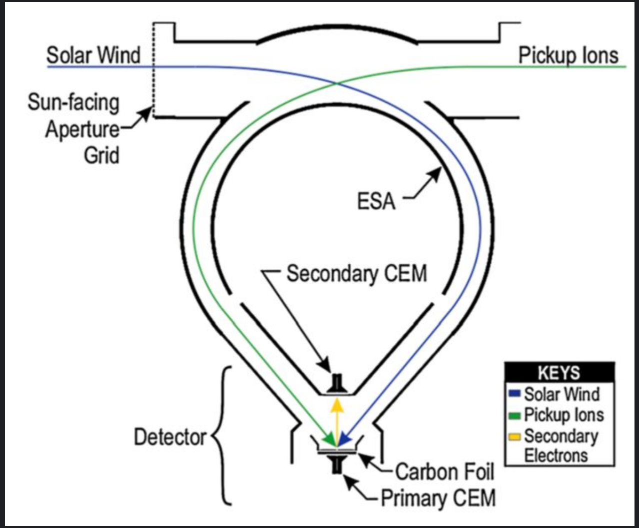






Extra slide: Solar Wind and Pickup Ions (SWAPI)

- Solar Wind + Pickup Ions
- Space Weather
- Measure Absolute Beam Flux



Princeton/IMAP