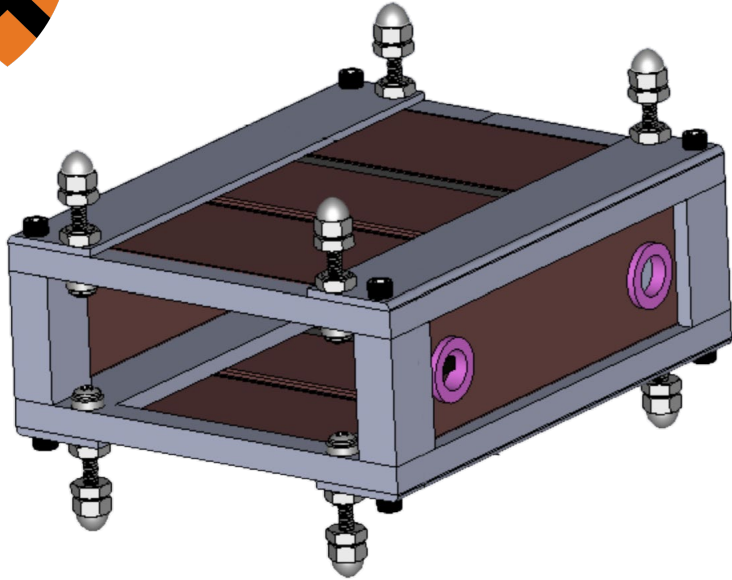
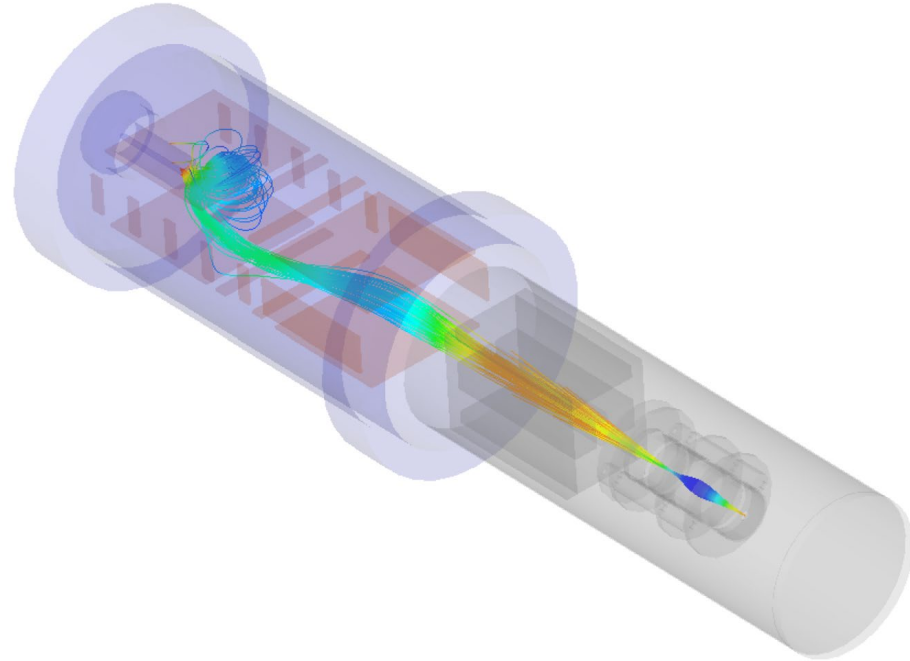


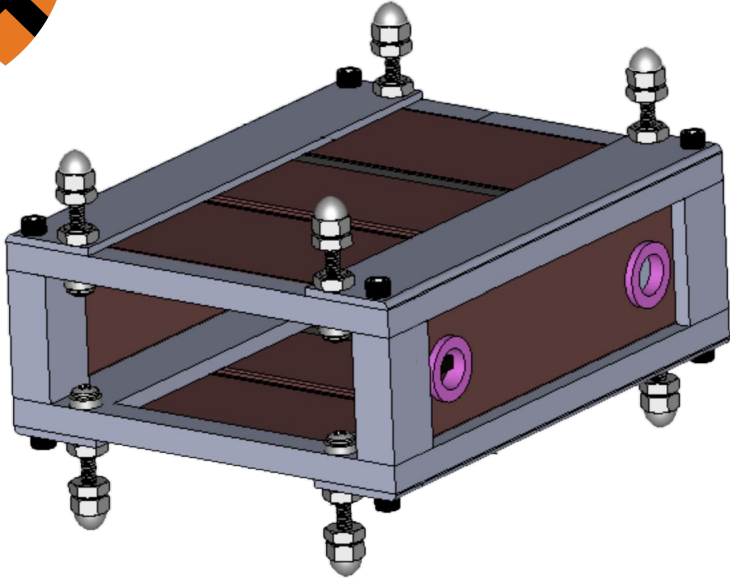
Demonstrating Electron ExB Slow Drift and Steps Toward Injection



[arXiv:2503.10025](https://arxiv.org/abs/2503.10025)

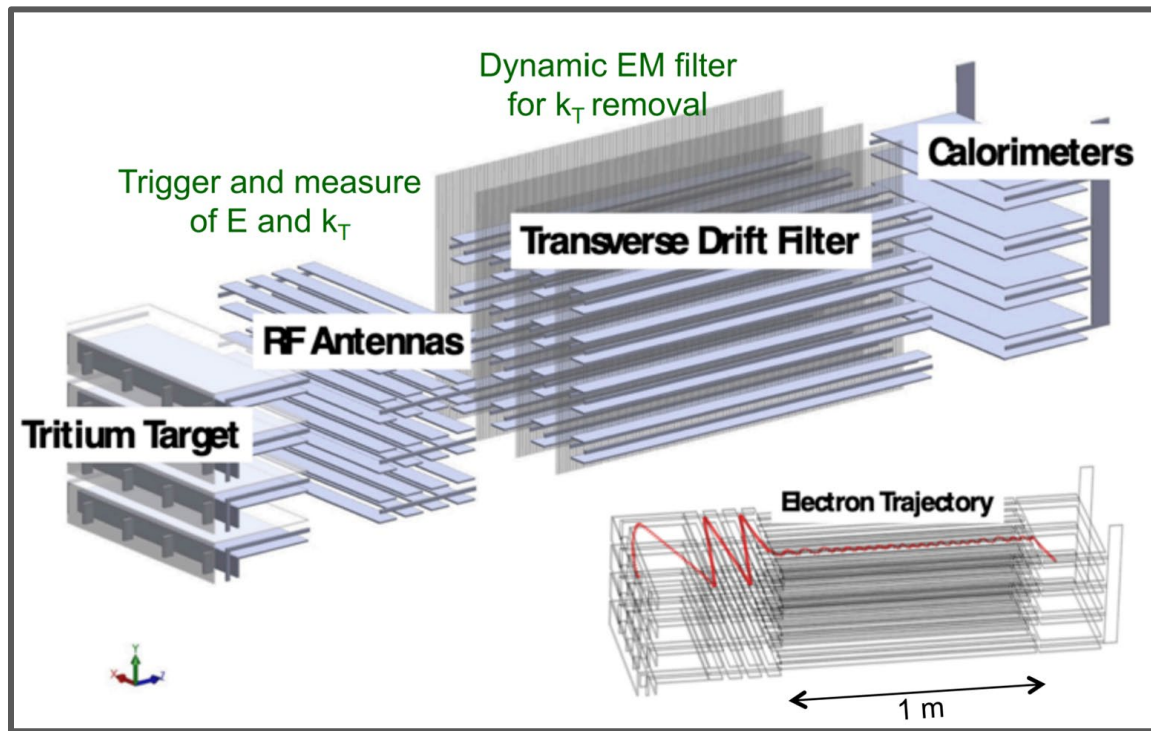


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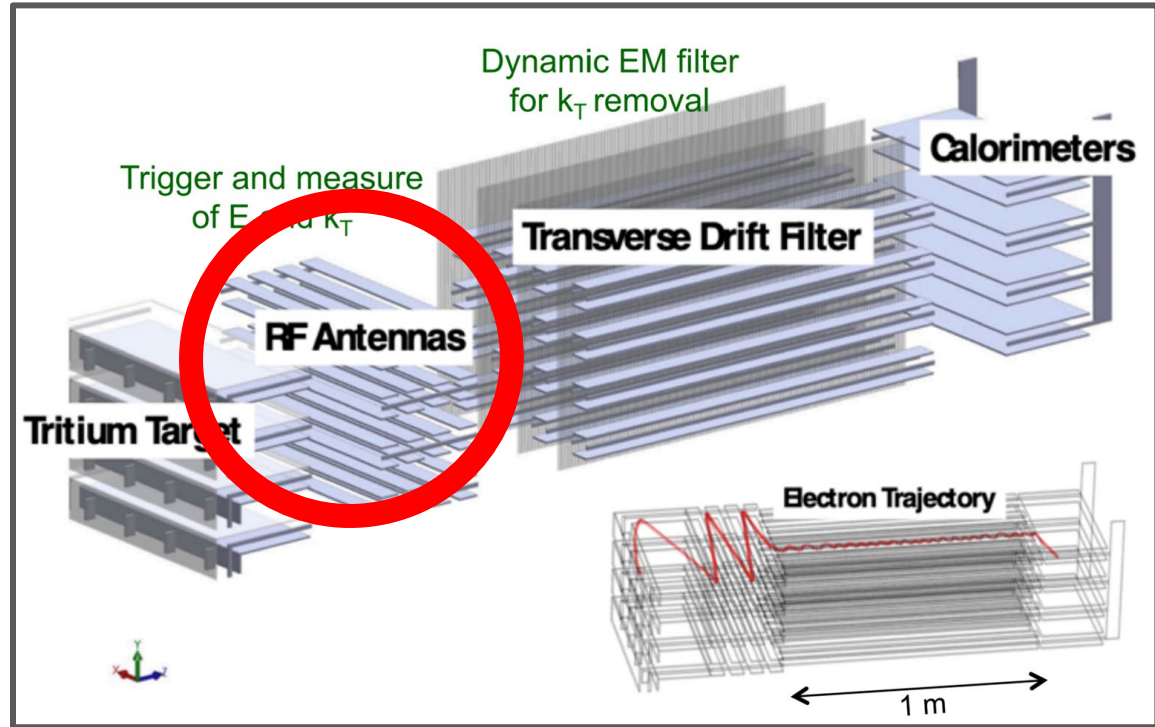
Detector Schematic



Detector Schematic

Requires slowing of $\mathbf{E} \times \mathbf{B}^*$ drift to tag electrons and suppress background (cyclotron radiation emission spectroscopy)

$$*\mathbf{V}_E = \frac{\mathbf{E} \times \mathbf{B}}{B^2}$$



B. Monreal and J.A. Formaggio, *Relativistic cyclotron radiation detection of tritium decay electrons as a new technique for measuring the neutrino mass*, *Phys. Rev. D* **80** (2009) 051301.

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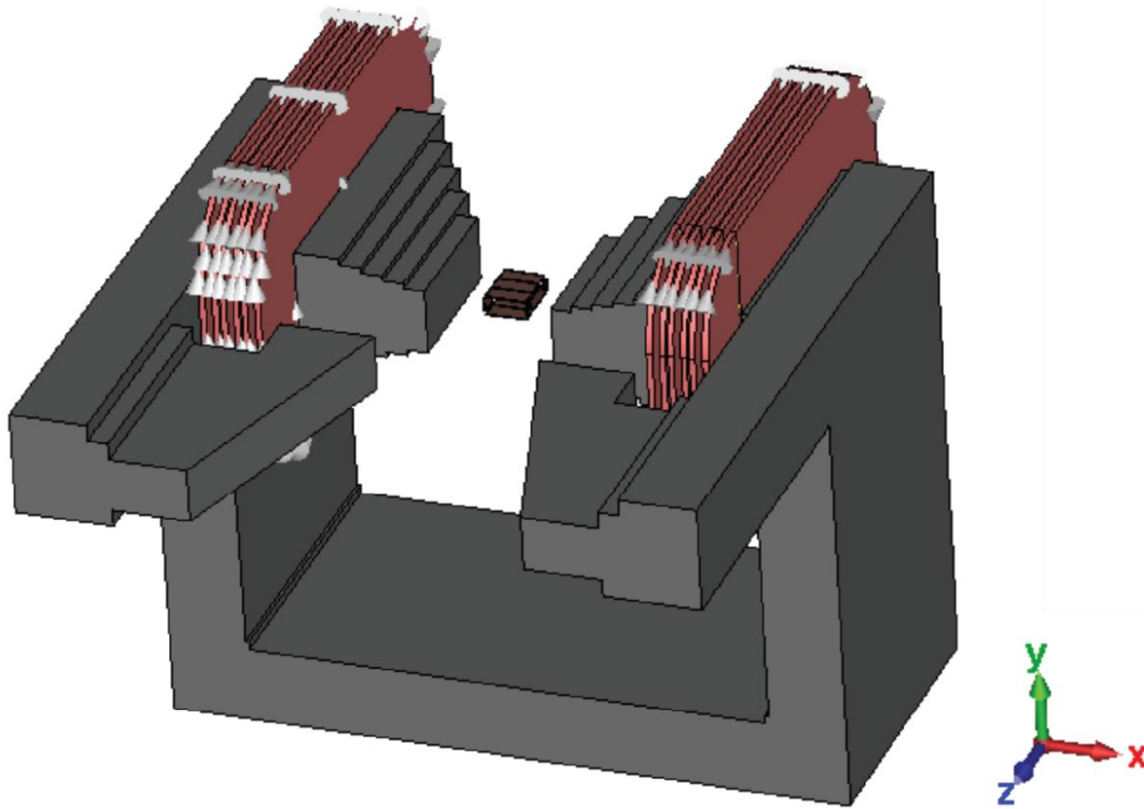
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3. Compare results with simulated model using 3D EM analysis software (CST Studio Suite) => demonstrate validity of simulated model

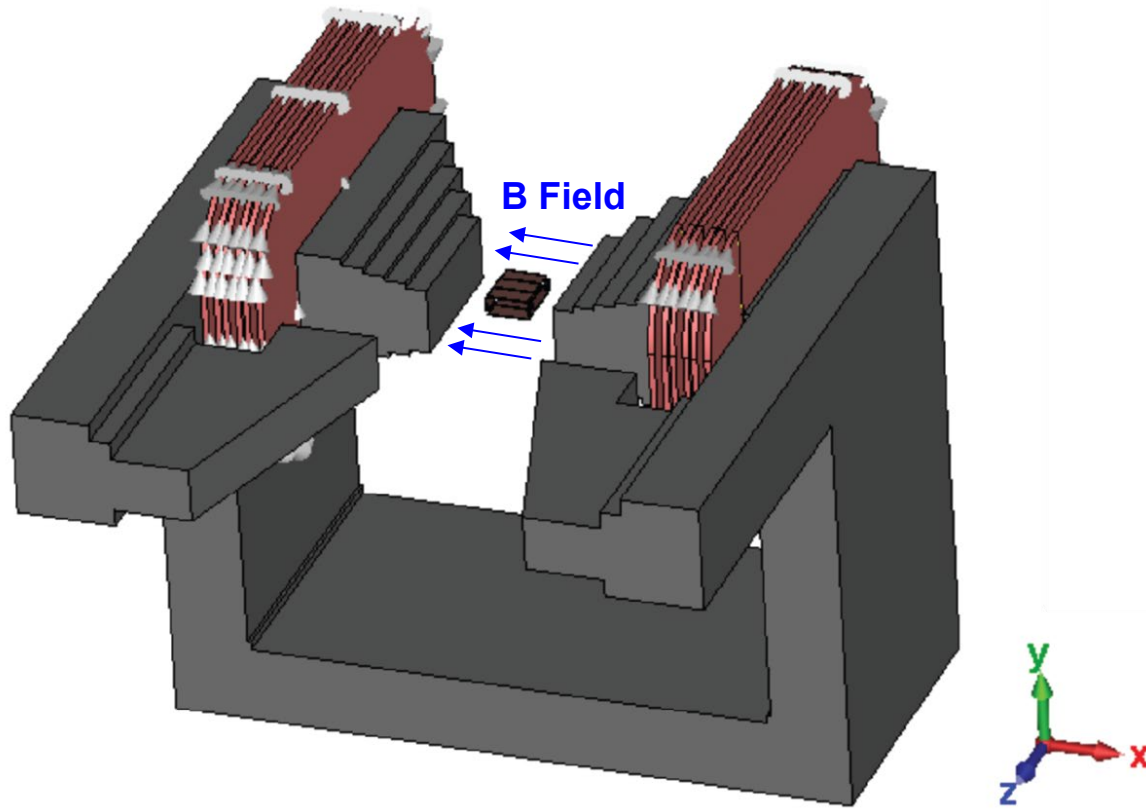
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4. Use simulation to extract electron time of flight information

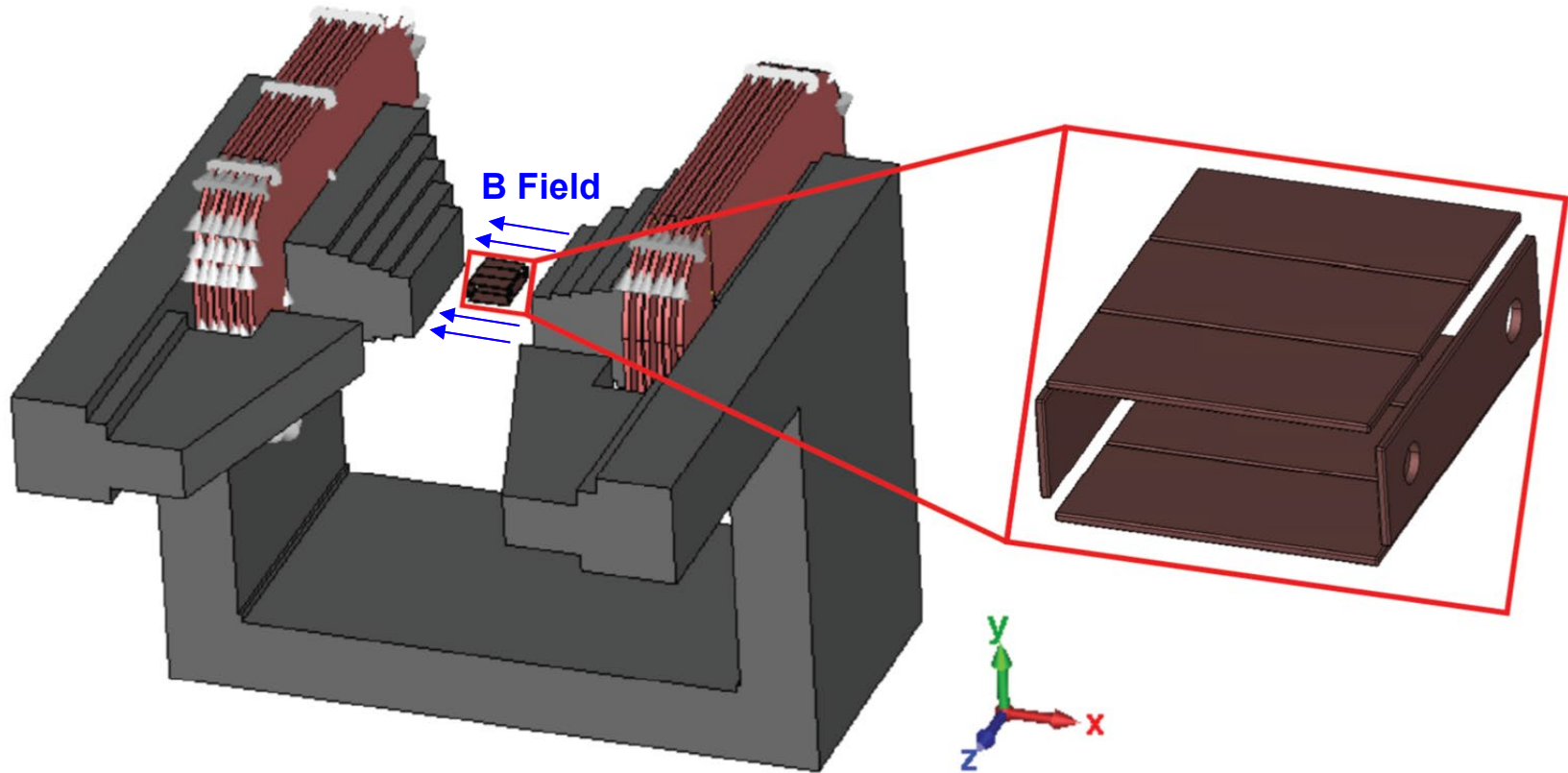
ExB Slow Drift Demonstrator Concept



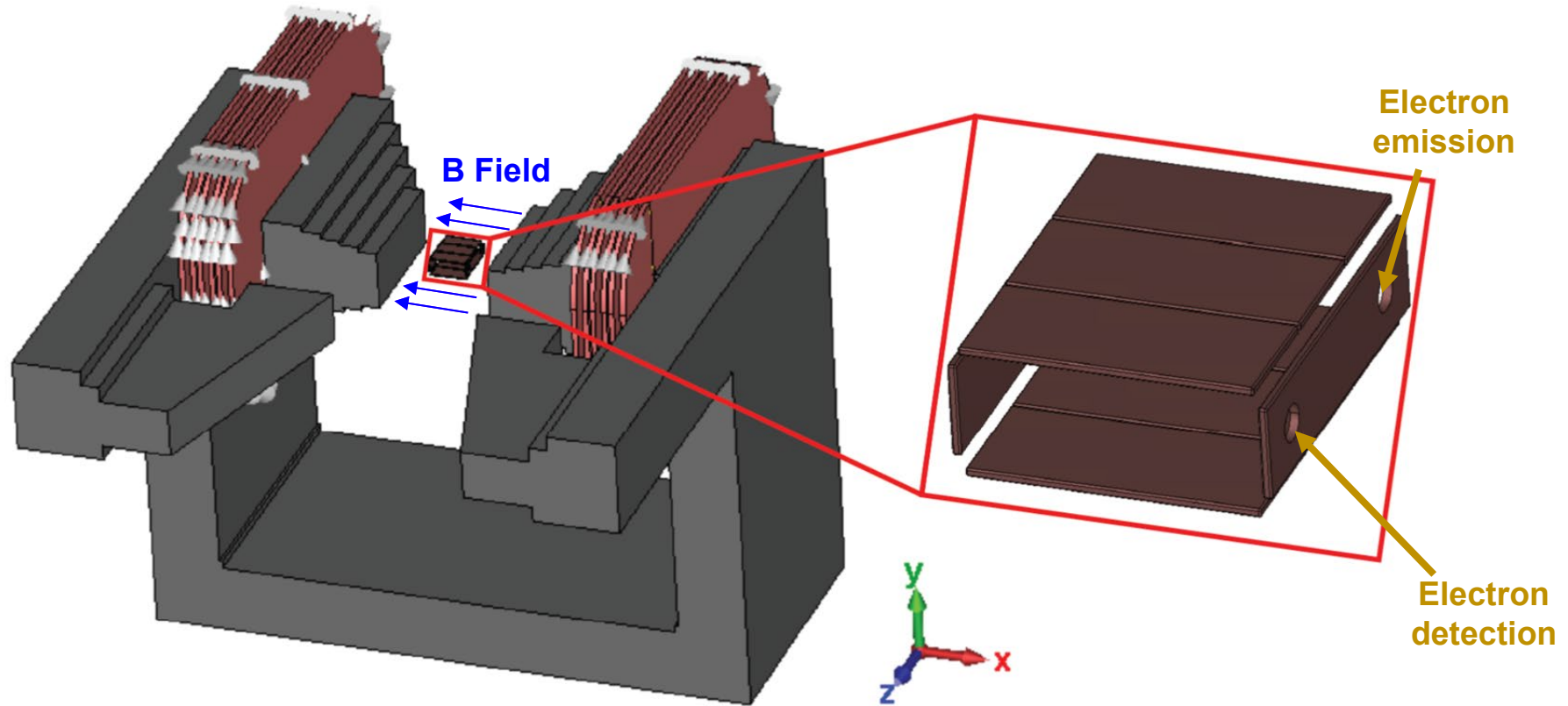
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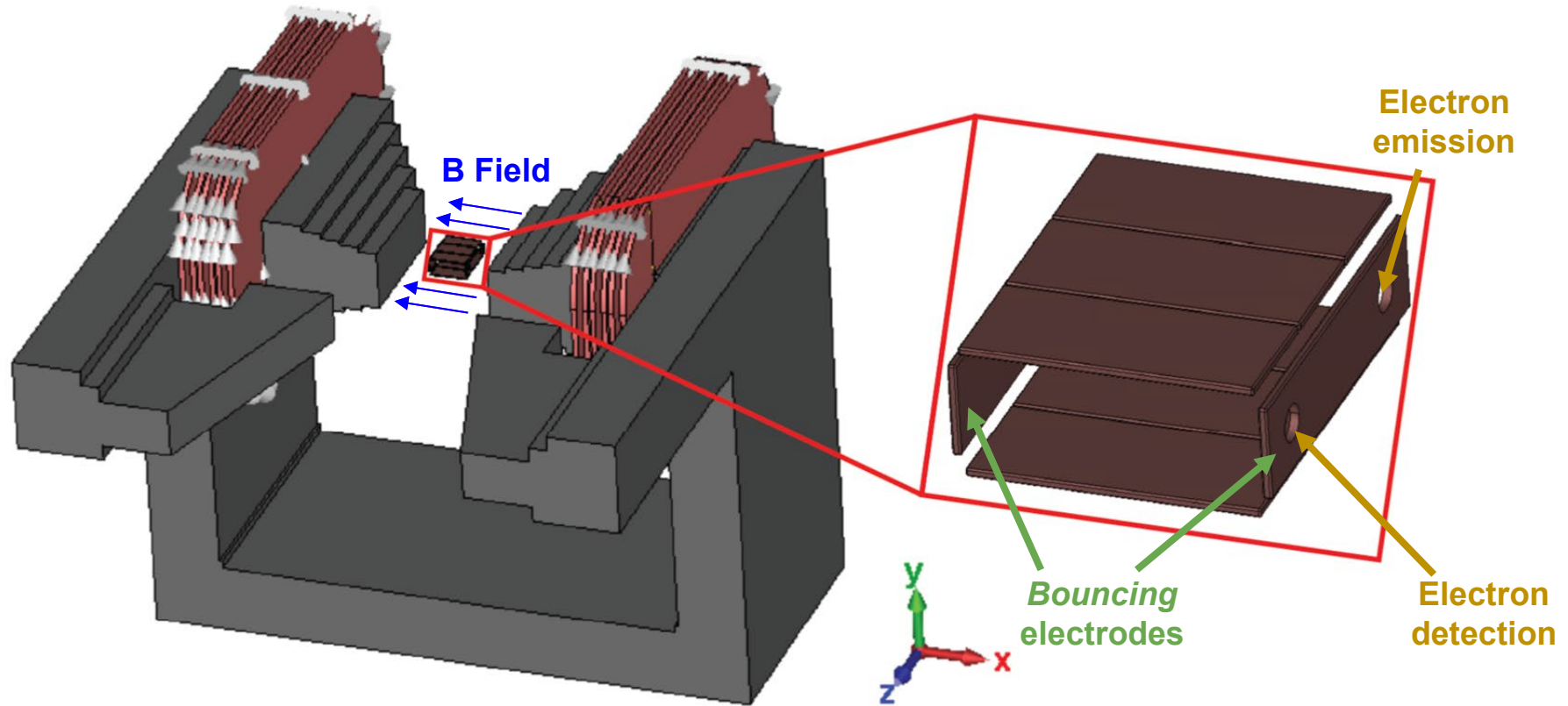
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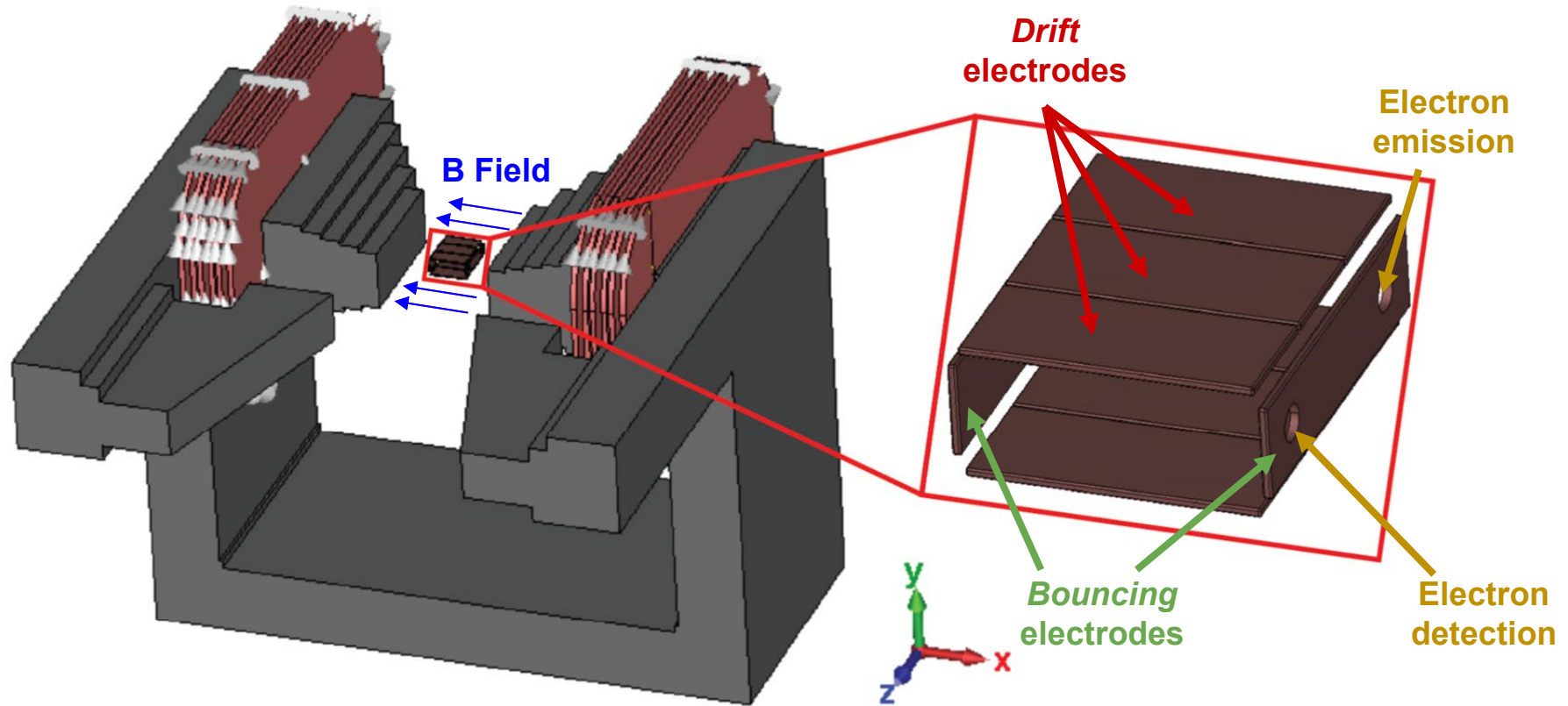
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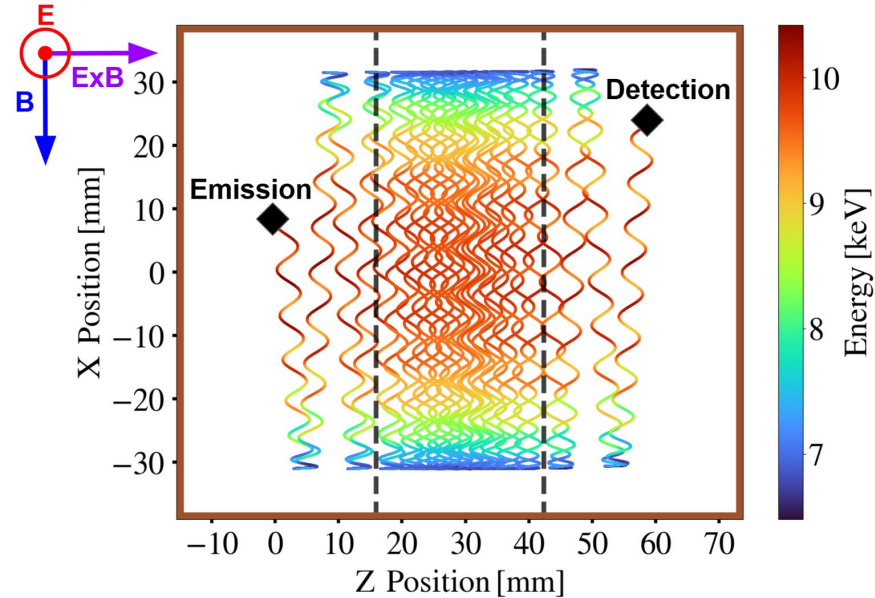
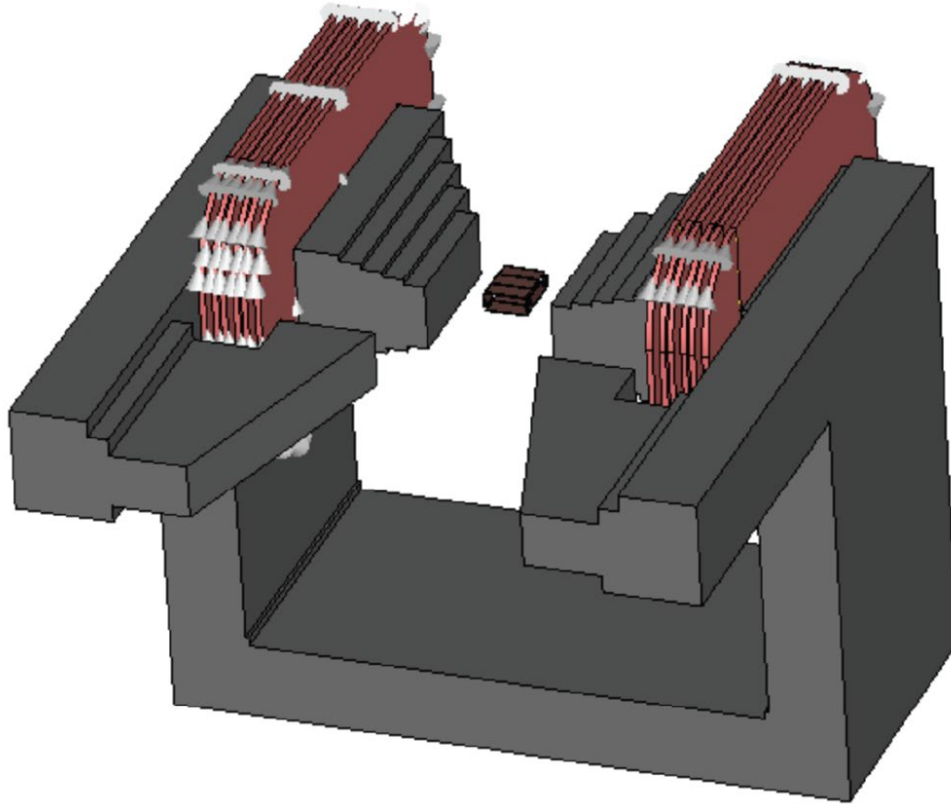
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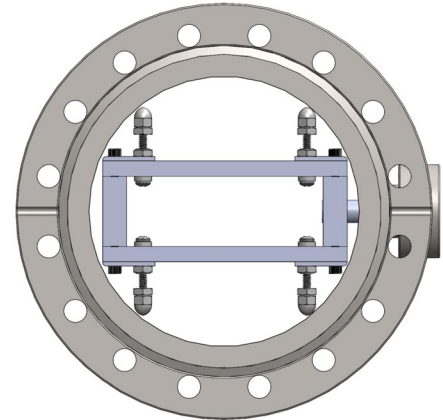
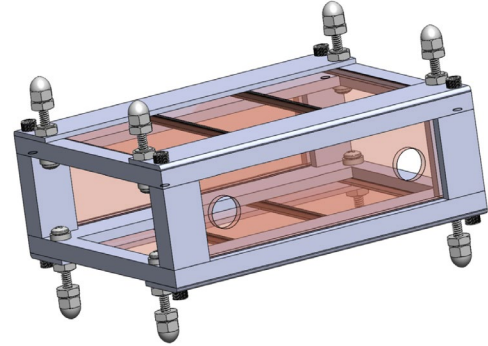
ExB Slow Drift Demonstrator Concept



**Increased density of
trajectory lines
indicates slowed drift**

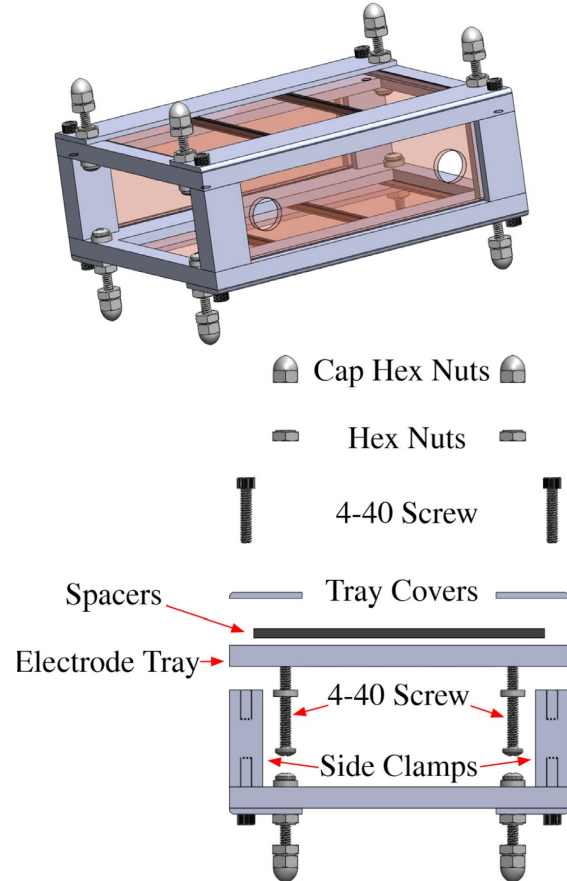
Field Cage Design

- Built to fix relative positions of copper electrode plates and position within 10.2 cm outer diameter vacuum chamber



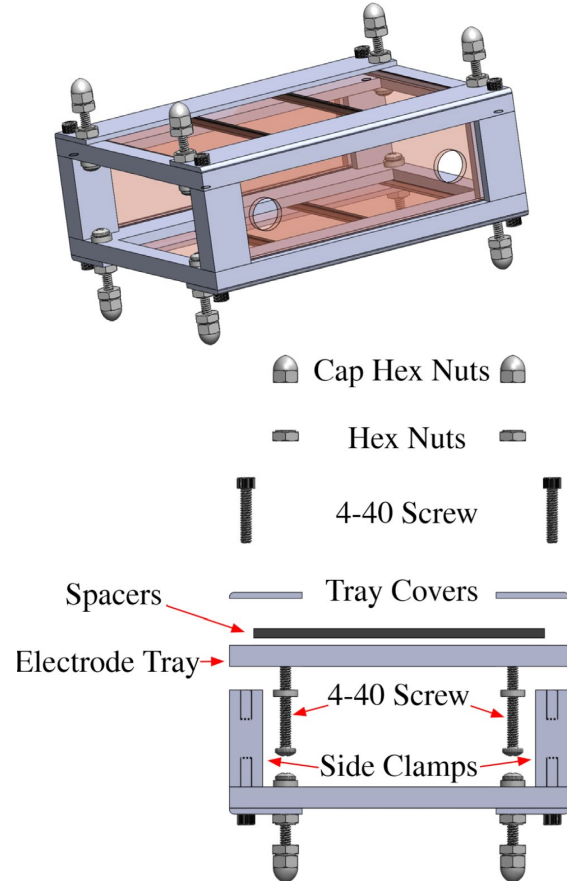
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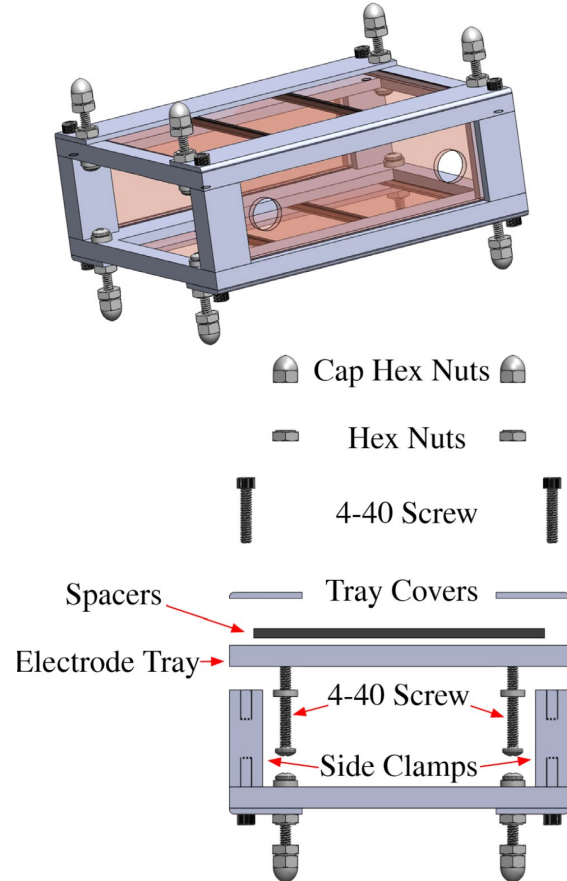
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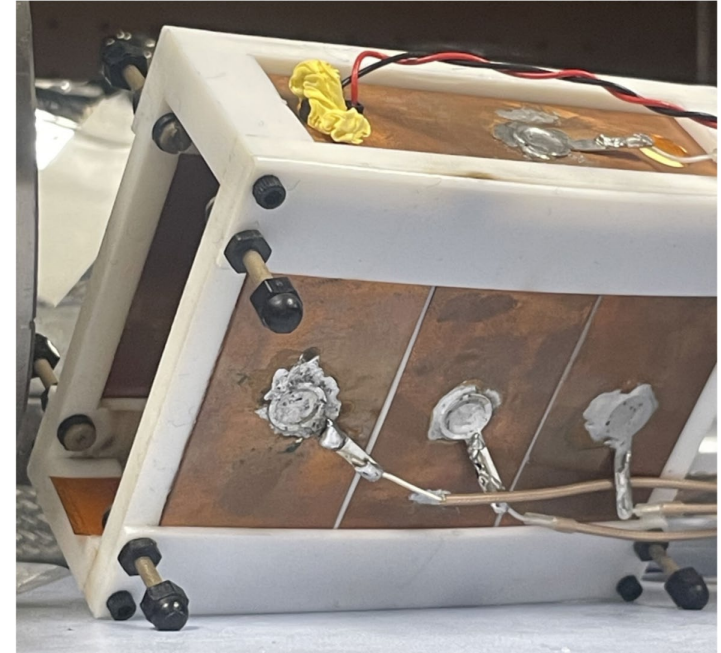
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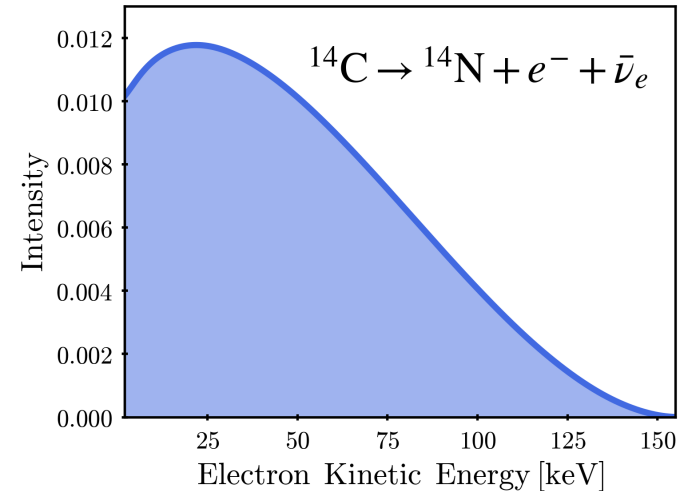
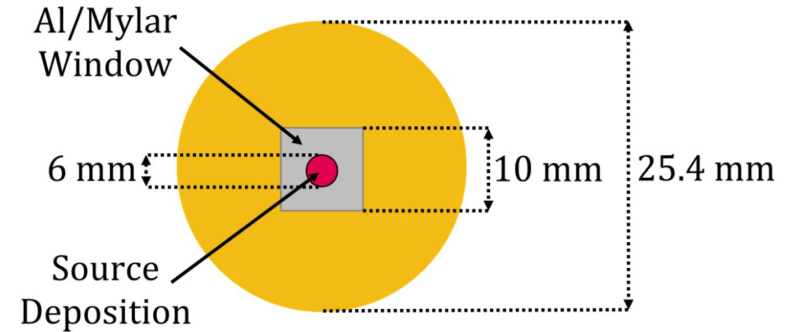
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- Brackets soldered directly to each electrode to connect to power supply



Additional Components

β Electron Source

- C-14 (156 keV Q-value)
- $10\mu\text{Ci}$ source activity
- Deposited on 25.4 mm laminate disk with aluminized Mylar



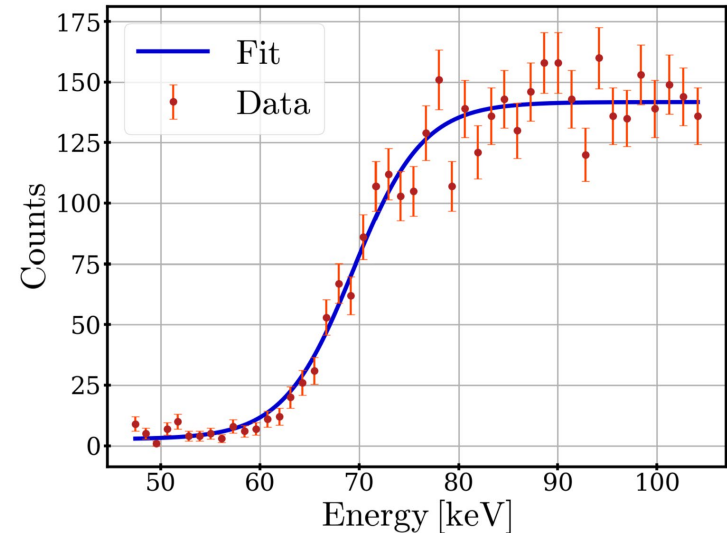
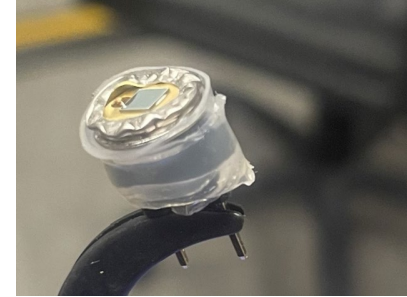
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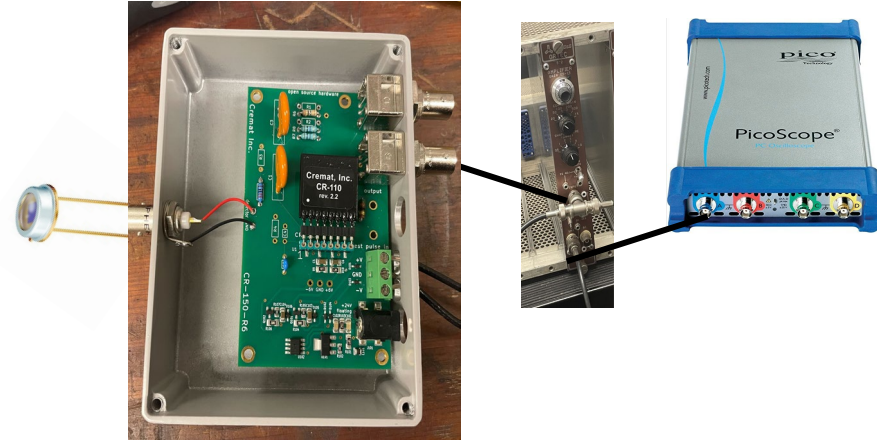
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- Diode connected to Cremat CR-150-R6 Evaluation Board
- Amplified with Ortec model 527 shaping amplifier
- Signal read out by PicoScope 6404 USB PC oscilloscope



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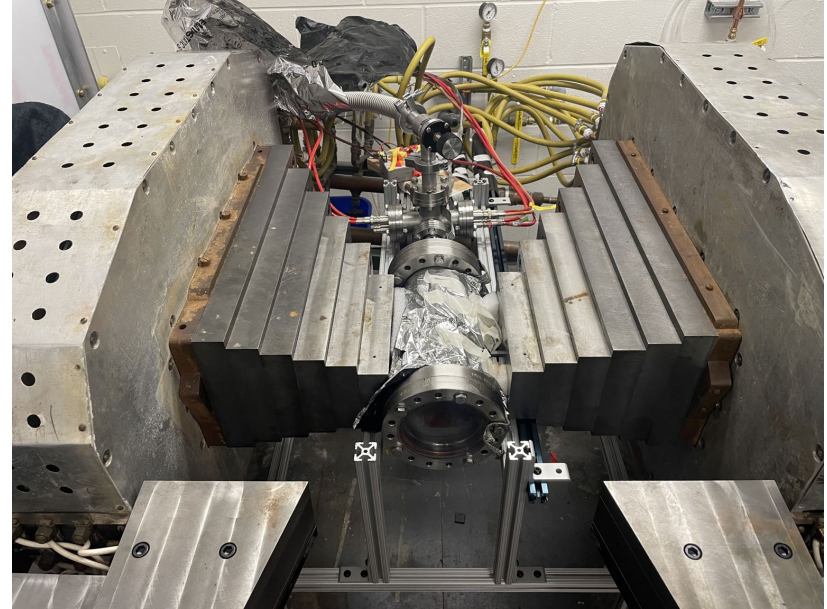
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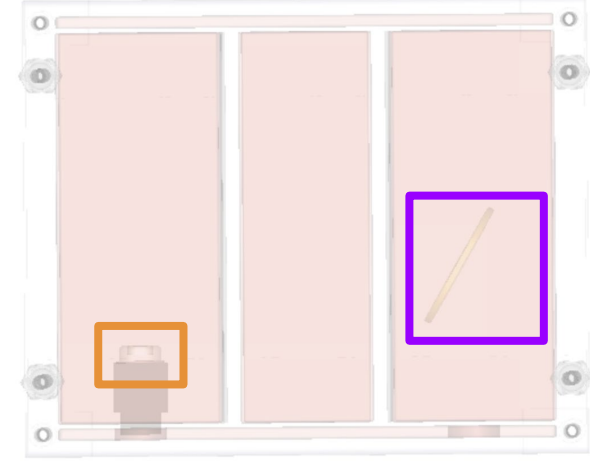
Magnet

- Powered by Walker HS-96-302 & HS-1575-4SS power supplies
- Can attain $\sim 1\text{T}$ uniform field between $\sim 15\text{ cm}$ pole face gap



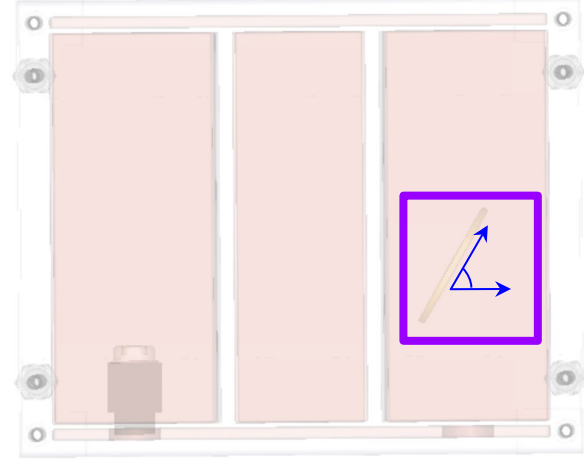
Configuration

- **C-14** source disk and **PIN Diode** placed inside chamber



Configuration

- **C-14** source disk and PIN Diode placed inside chamber
- **C-14** source disk set at **60 degree angle**

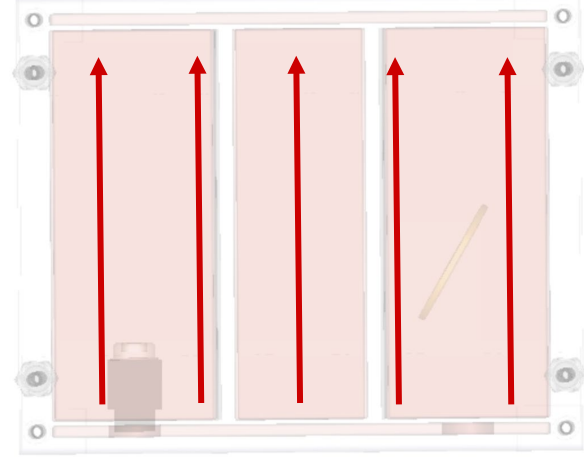


$$\mathbf{v}_E = \frac{\mathbf{E} \times \mathbf{B}}{B^2}$$



Configuration

- C-14 source disk and PIN Diode placed inside chamber
- C-14 source disk set at 60 degree angle
- **B-field** operated at 0.16 T

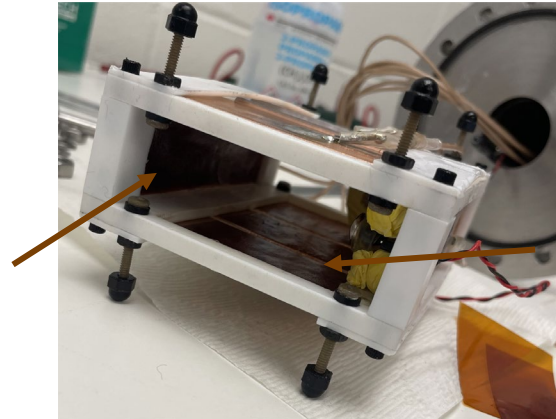
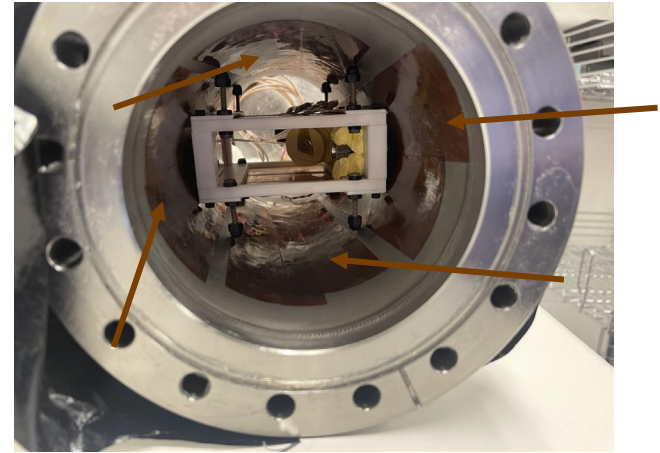


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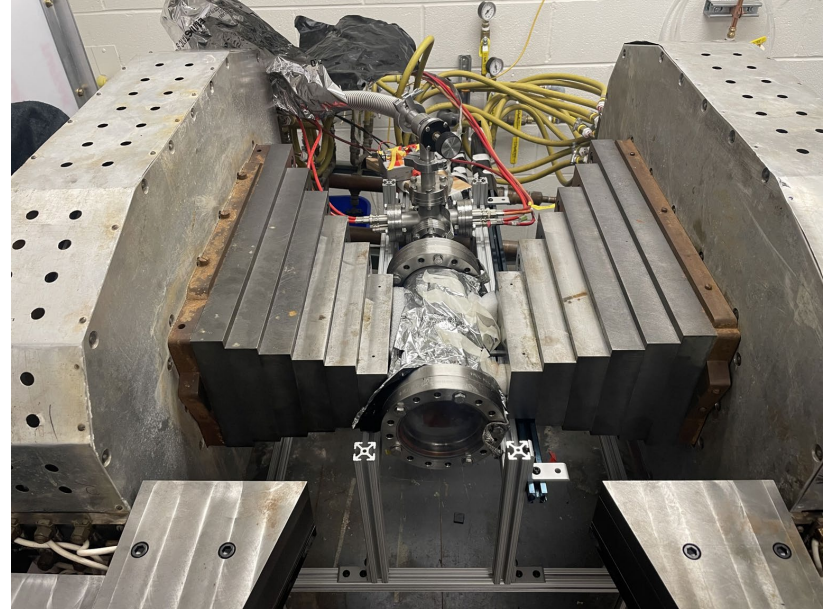
Configuration

- C-14 source disk and PIN Diode placed inside chamber
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- B-field operated at 0.16 T
- **Kapton** lined inside vacuum chamber & electrodes



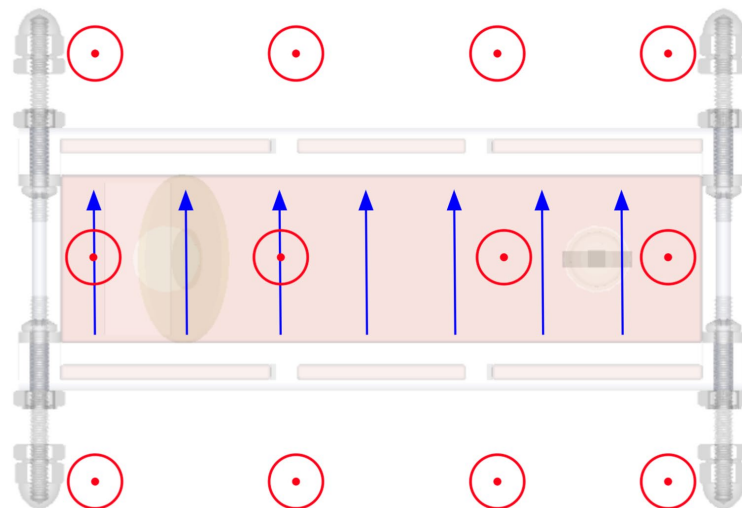
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- Bulk of chamber situated between magnet pole faces, maintained at ~ 0.1 mPa by molecular drag pump



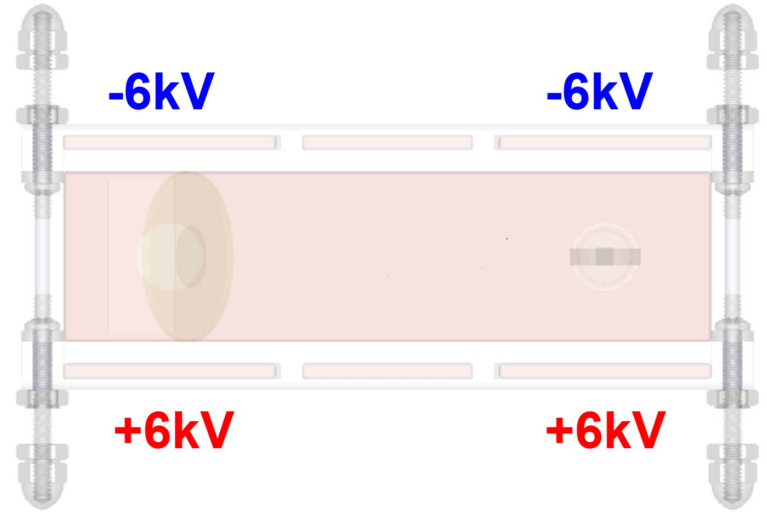
Procedure

- Operate 0.16 T **B field** and set voltages on drift electrodes to generate an upward **E field**



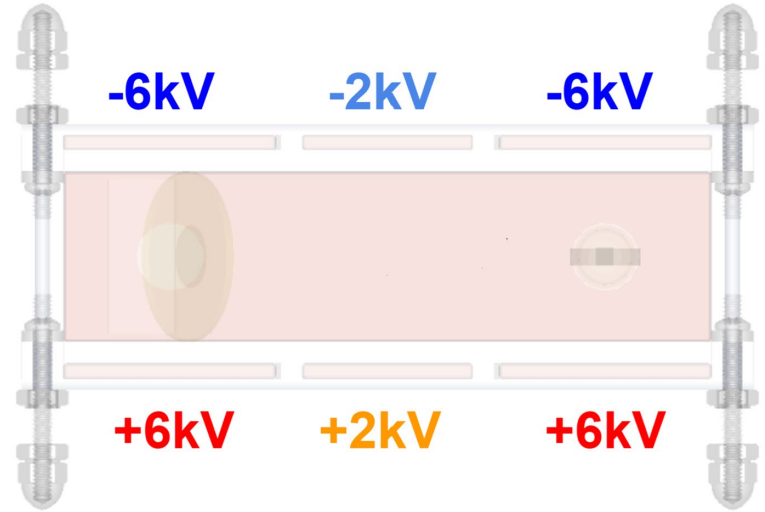
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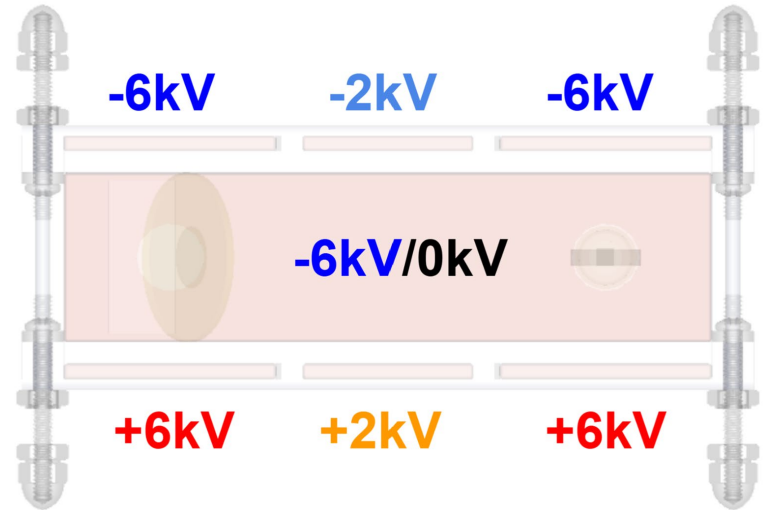
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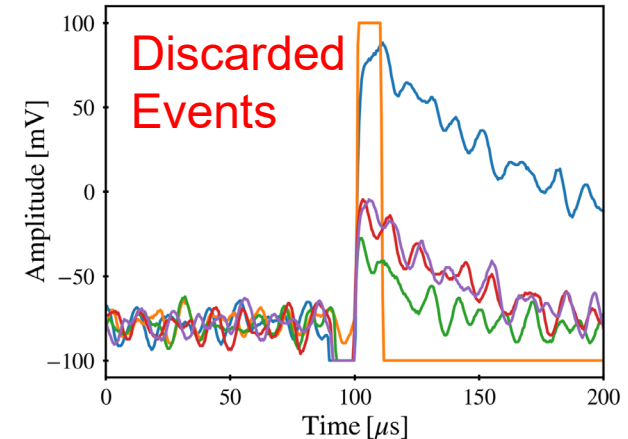
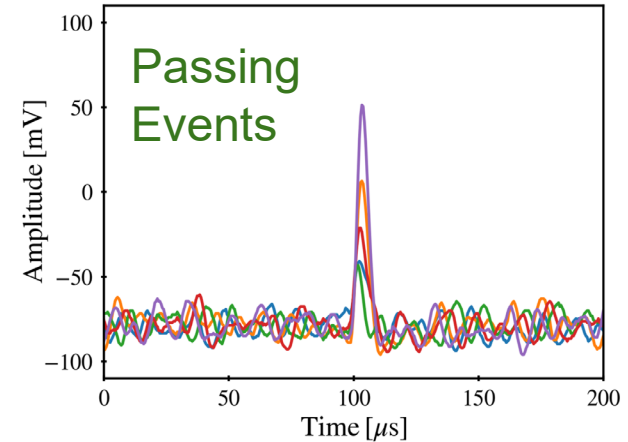
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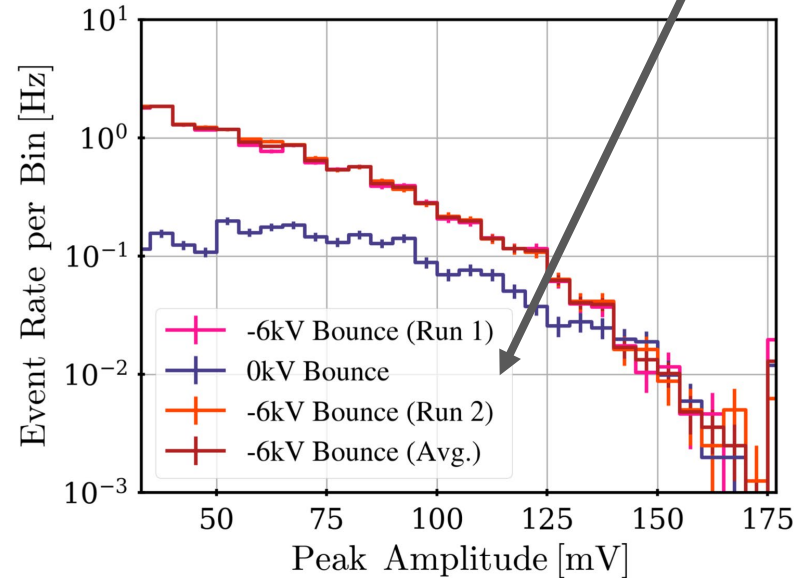
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Multiple runs taken to ensure consistent behavior

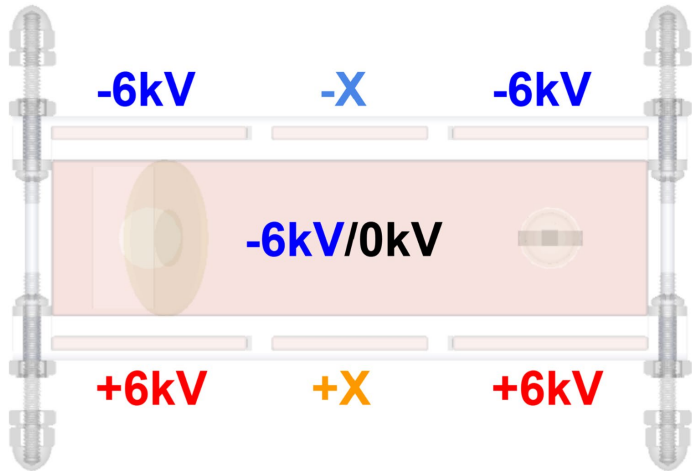


Max amplitude of waveform output

Modes of Operation

Symmetric Slow Drift

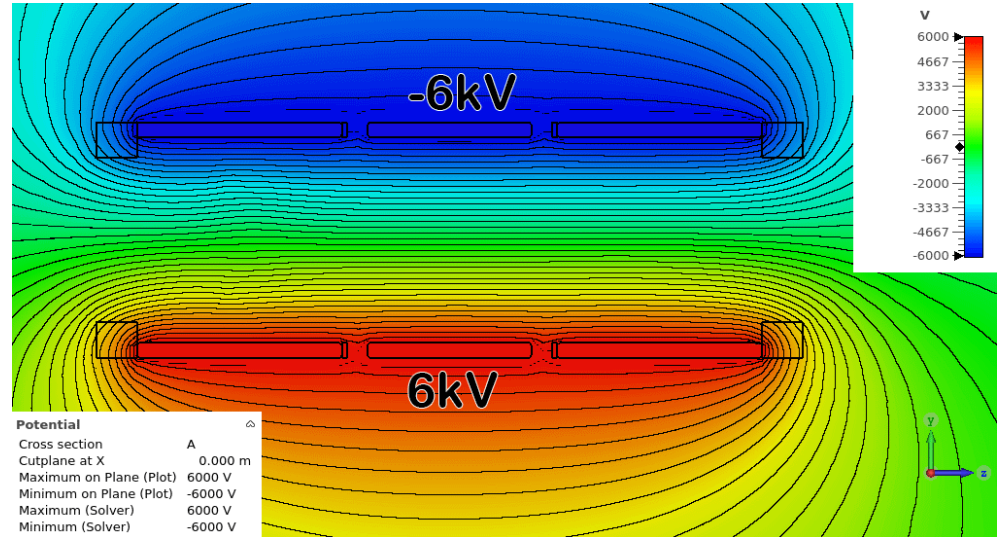
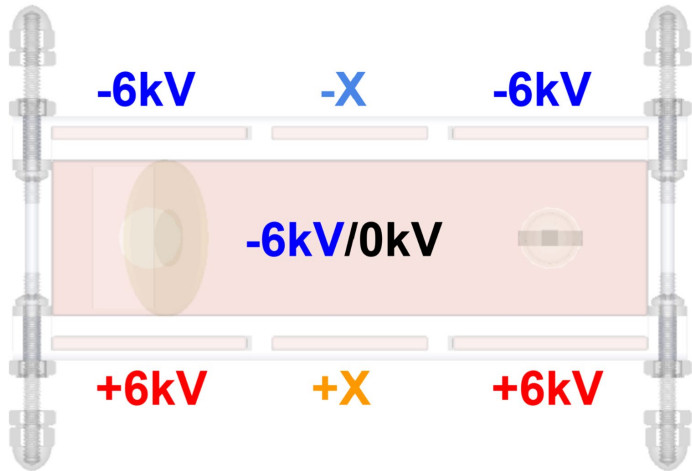
- Symmetrically lower magnitude of top and bottom electrodes



Modes of Operation

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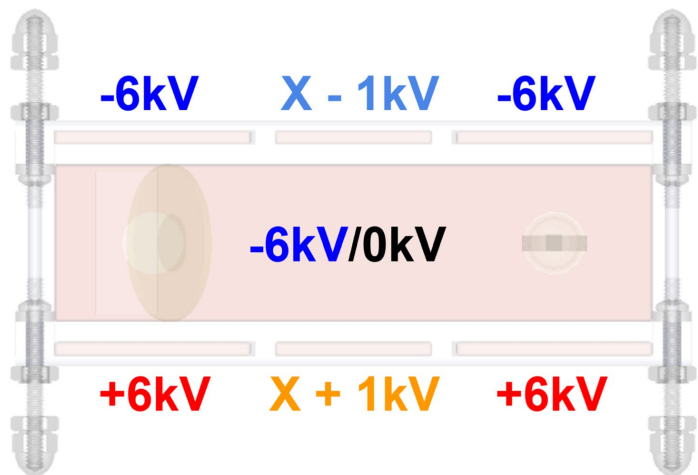
- Symmetrically lower magnitude of top and bottom electrodes
- Expectation: as X decreases, so too does event rate (electrons following potential lines $\rightarrow$ more likely to terminate on wall)



Modes of Operation

Voltage Scan (e.g., 2kV)

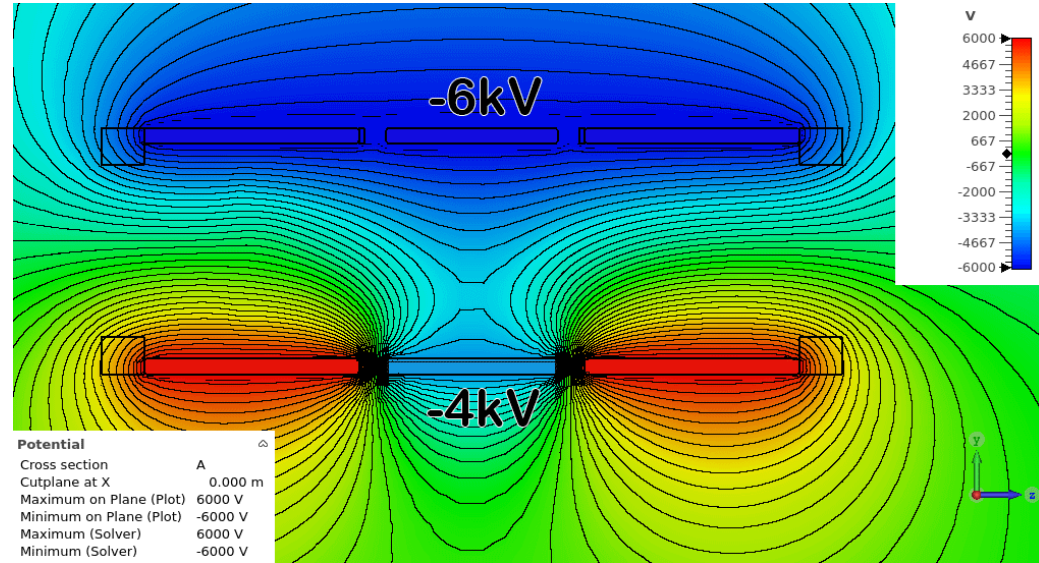
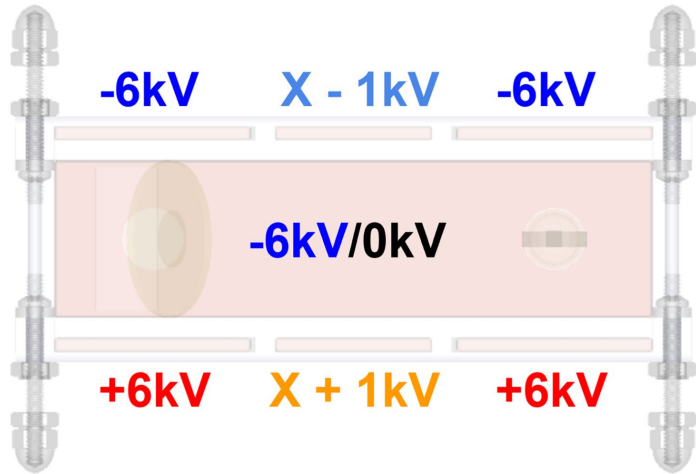
- Record event rates within 2kV window around varying center voltage **X**



Modes of Operation

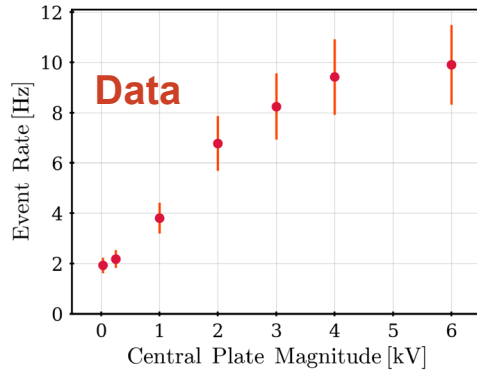
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- Record event rates within 2kV window around varying center voltage **X**
- Zooms in on a specific potential window of emission spectra

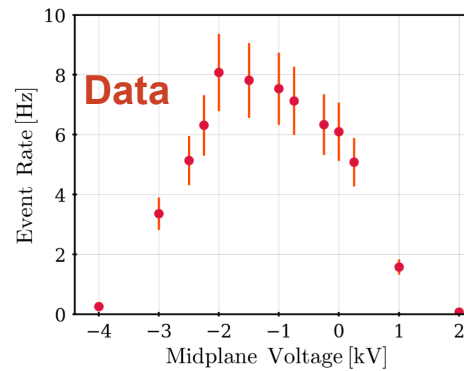


Results

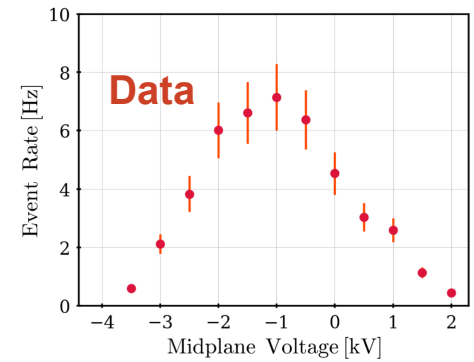
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2 kV Voltage Scan

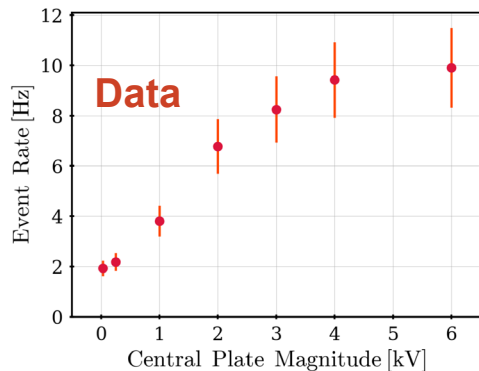


1 kV Voltage Scan

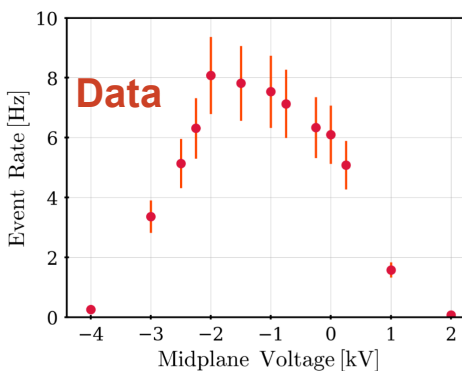


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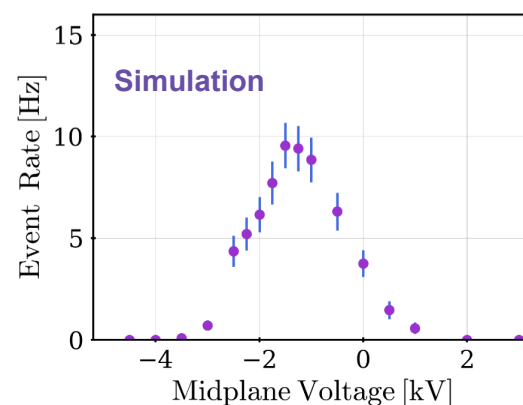
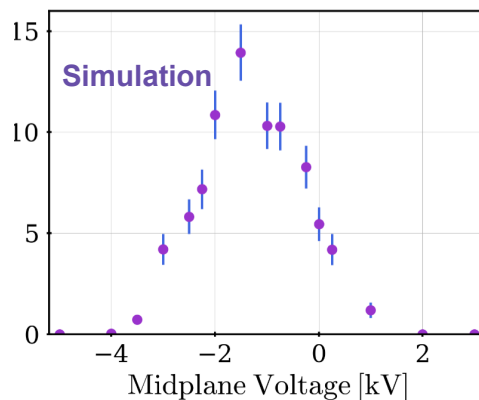
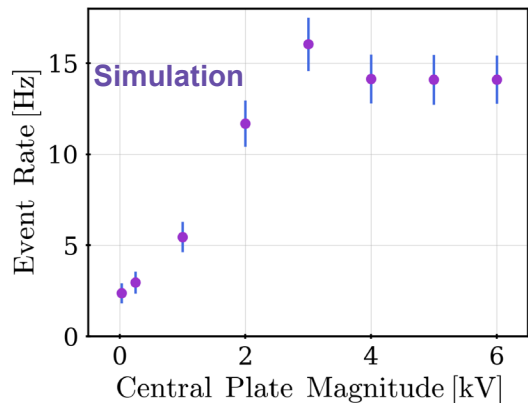
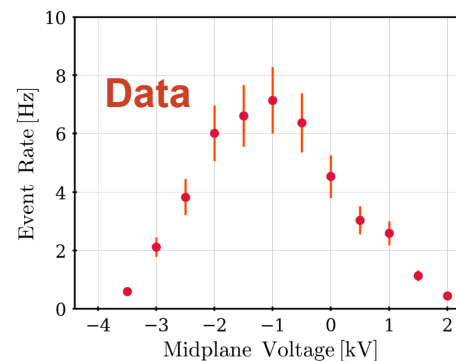
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2 kV Voltage Scan



1 kV Voltage Scan



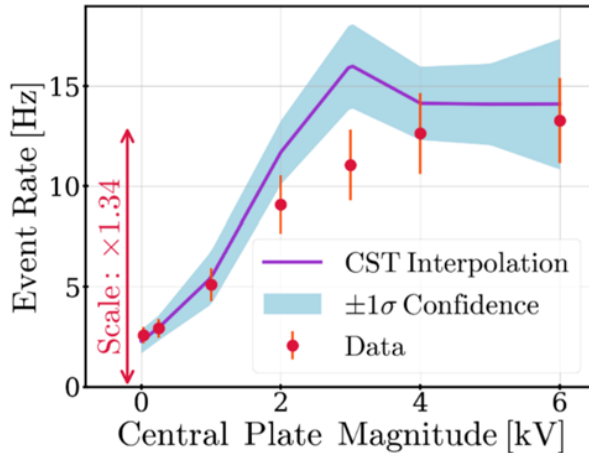
Comparison

- Perform combined least-squares regression fit to data (for scaling factor and horizontal offset) using interpolation of CST simulation results

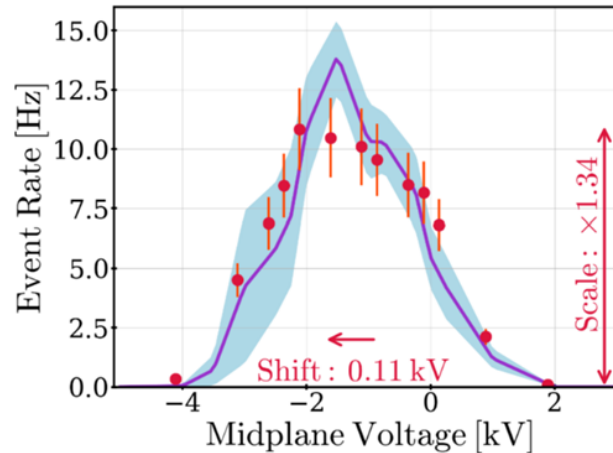
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- Scaling factor of 1.34 on the detected event rate serves as a general approximation to demonstrate the validity of the simulated model

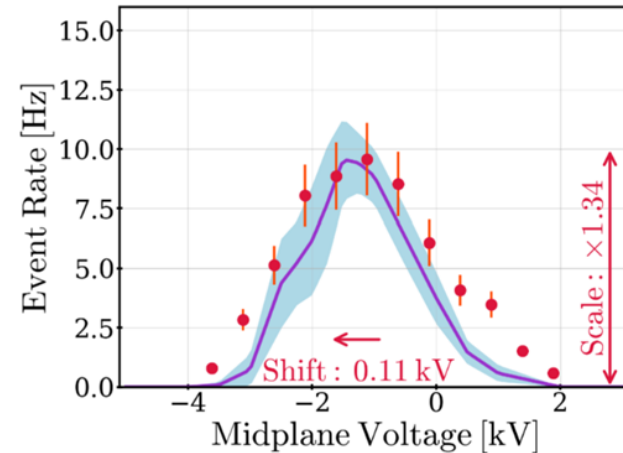
Symmetric Slow Drift



2 kV Voltage Scan



1 kV Voltage Scan



Time of Flight Extraction

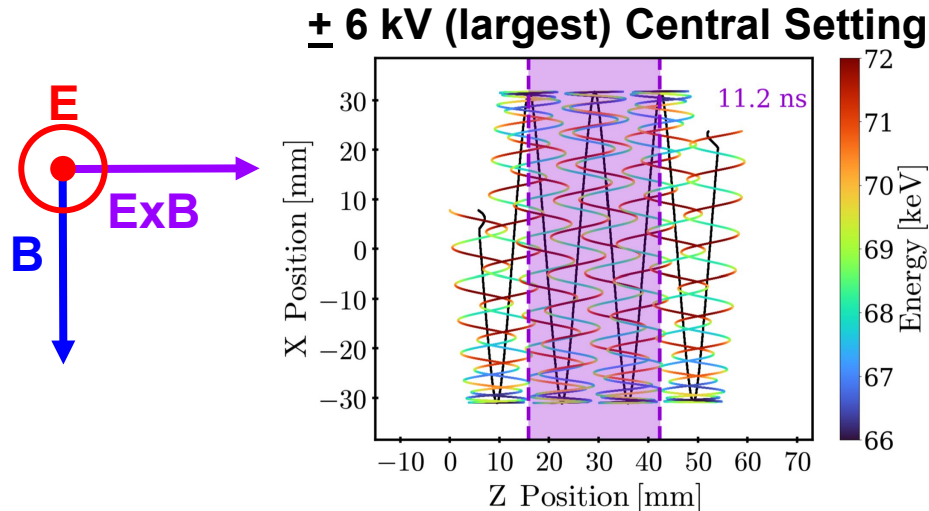
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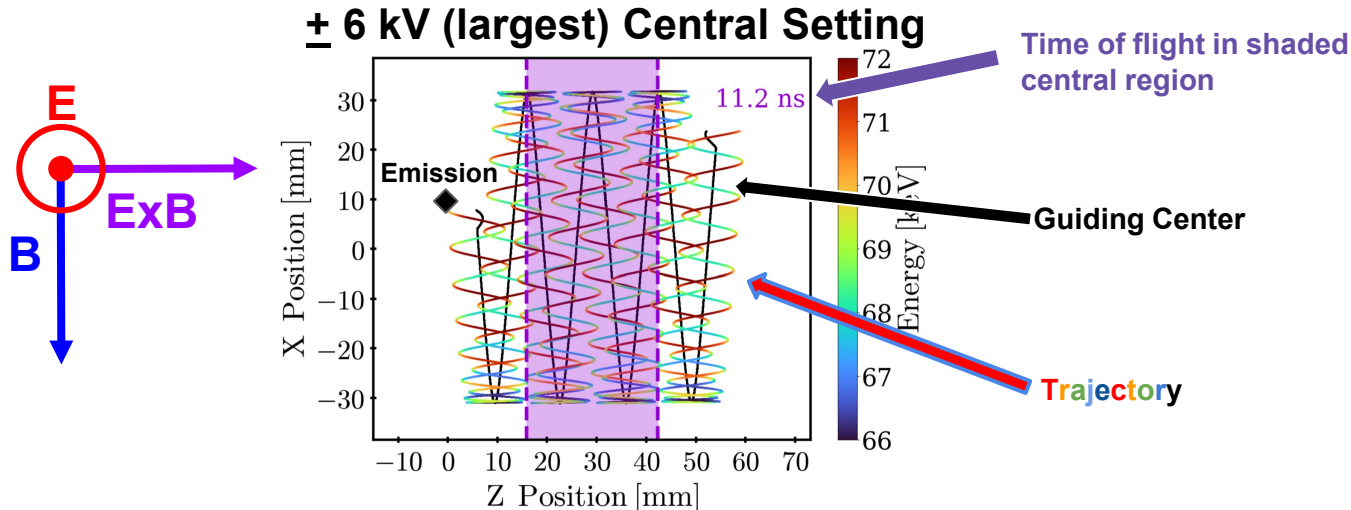
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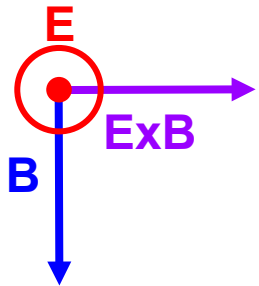
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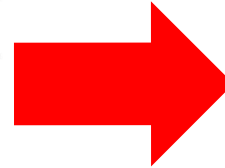
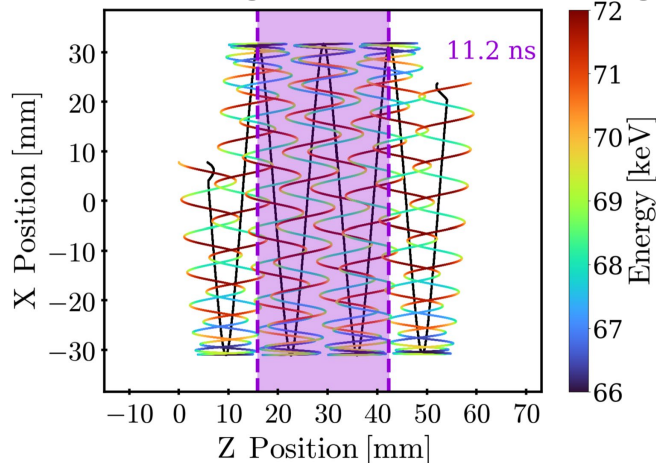


Time of Flight Extraction

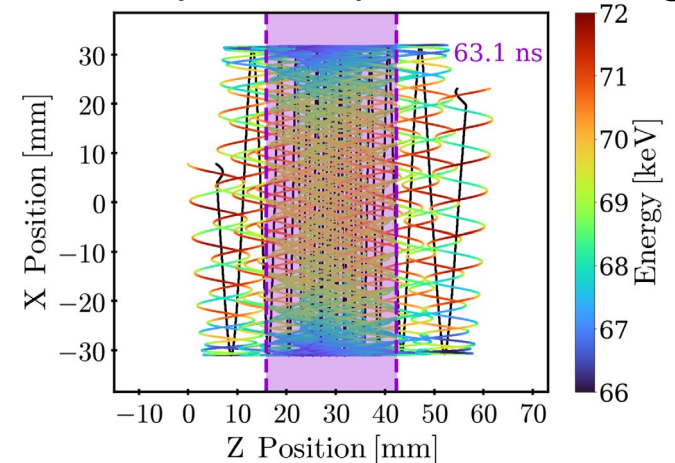
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± 6 kV (largest) Central Setting

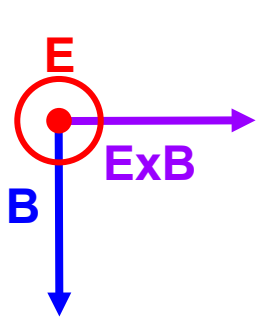


± 31.25 V (smallest) Central Setting

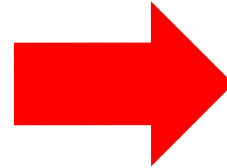
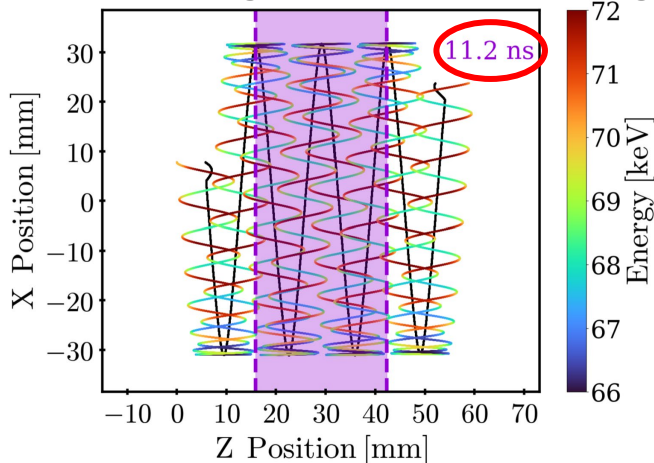


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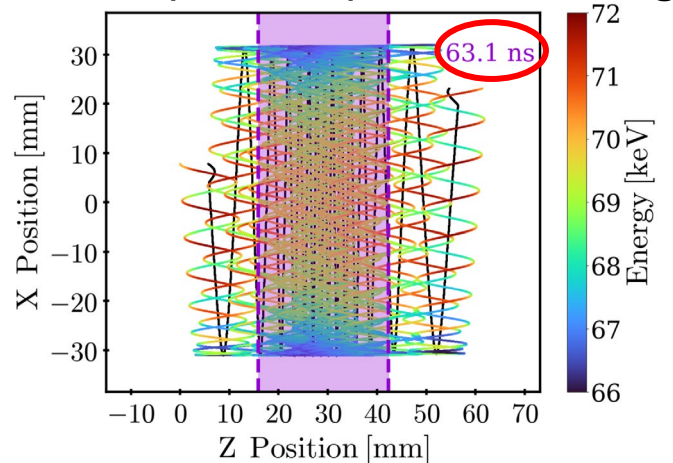
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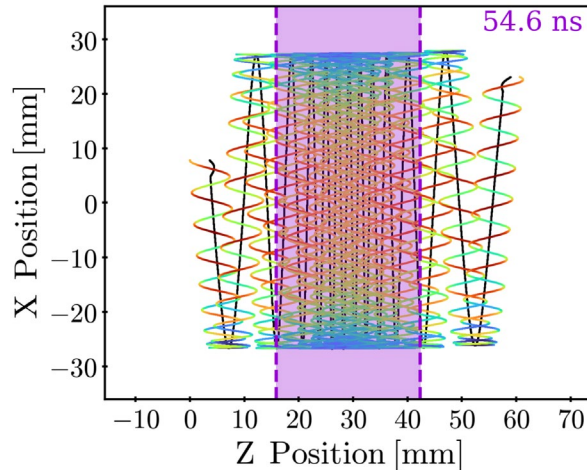
Time of Flight Characteristics

- Time of flight for smallest central plate setting largely falls within 54 - 66 ns (deviations due to proximity with bouncing plate) for most of spectra
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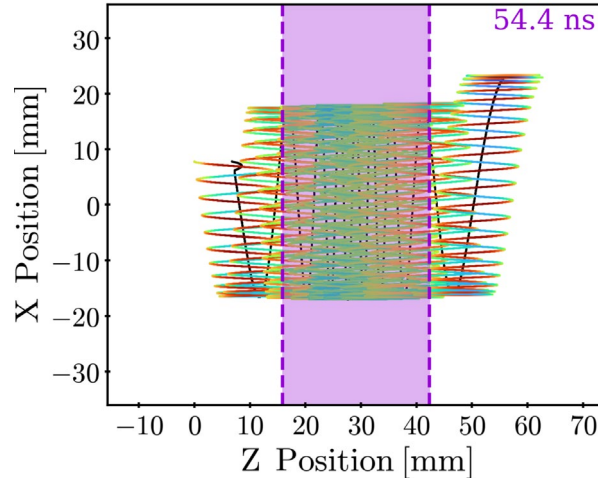
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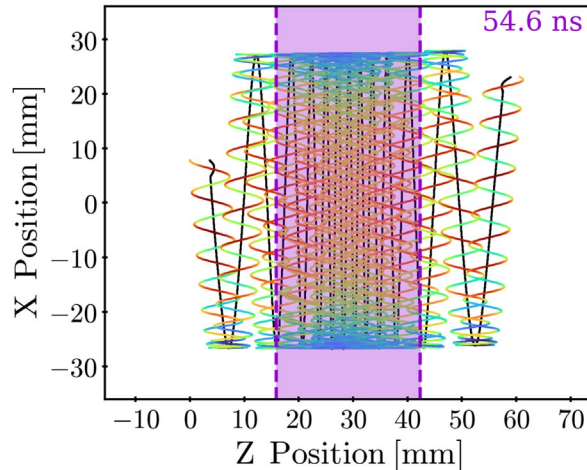
100 keV



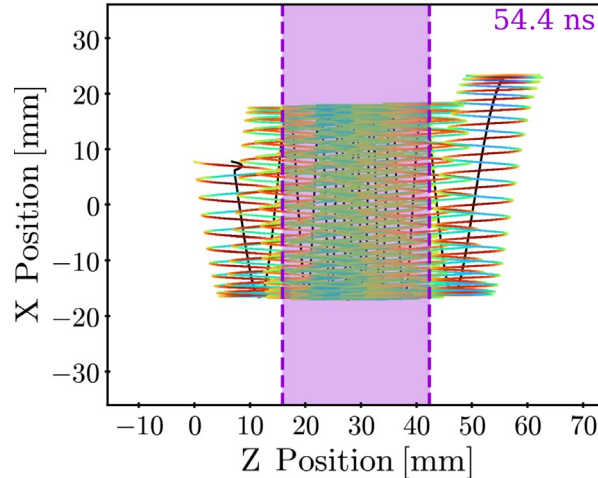
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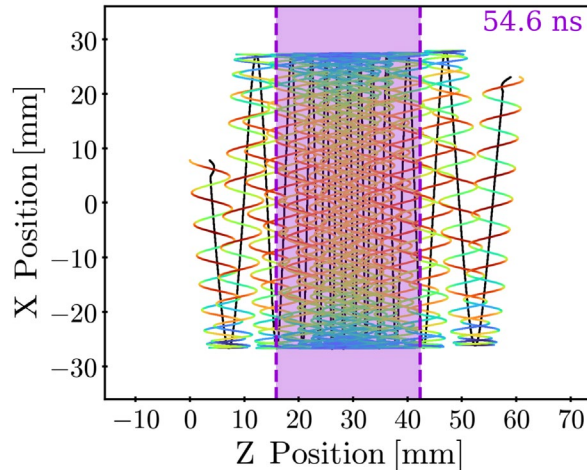
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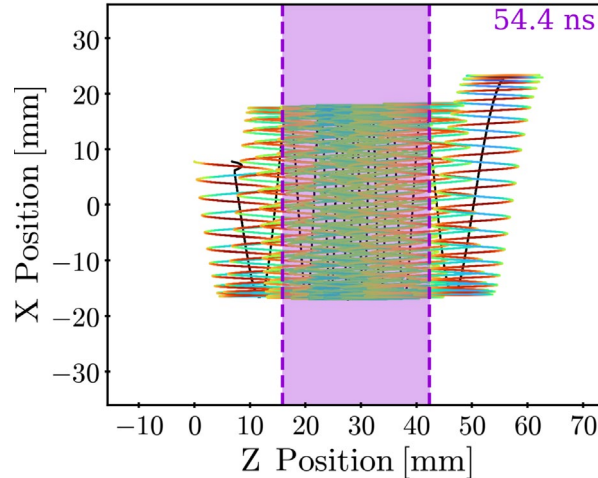
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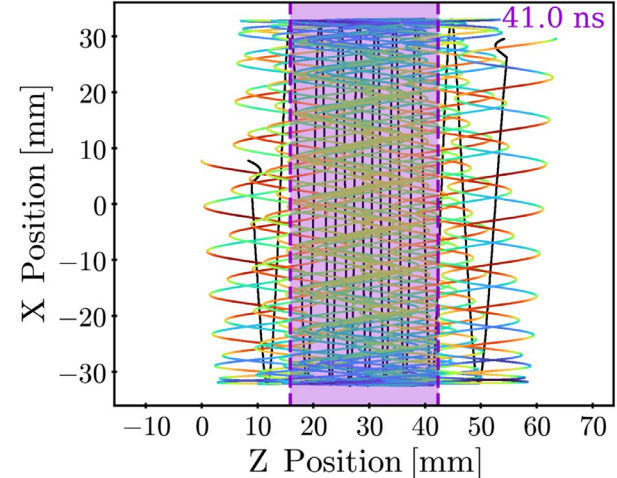
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100 keV



150 keV



ExB Demonstrator Conclusion

- Confirming validity of simulated model, our demonstrator can slow β -decay electrons by a factor of ~ 4 -5 (~ 50 -60 ns contained in slow drift region)
- Limited only by system dimension, we assert drift speed can be arbitrarily slowed to meet the needs of PTOLEMY
 - Details of study documented at [arXiv:2503.10025](https://arxiv.org/abs/2503.10025)
- Manuscript has been submitted to JINST, recently requested to make minor revisions before resubmission

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Will look to actualize other features of PTOLEMY detector...

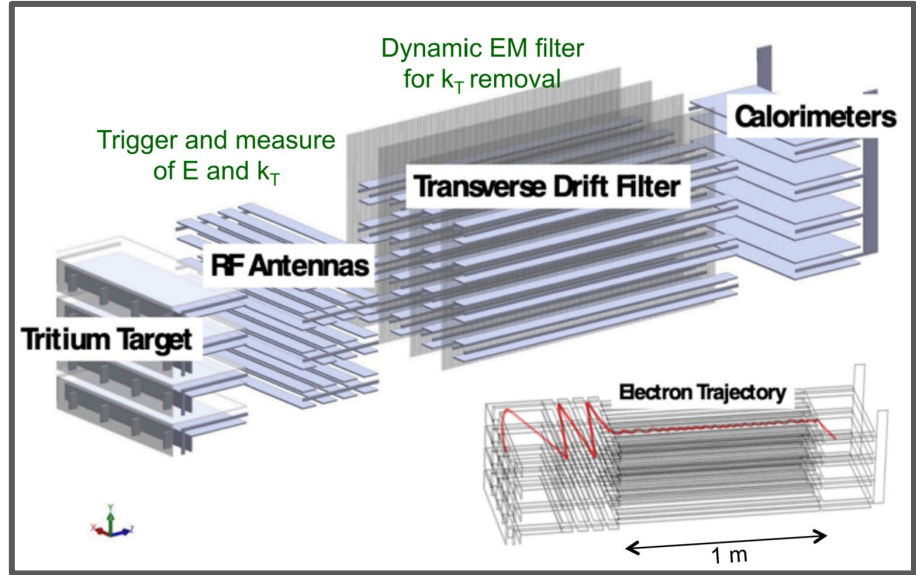
Proton Injection Project Description

ARPA-E project to accelerate protons from
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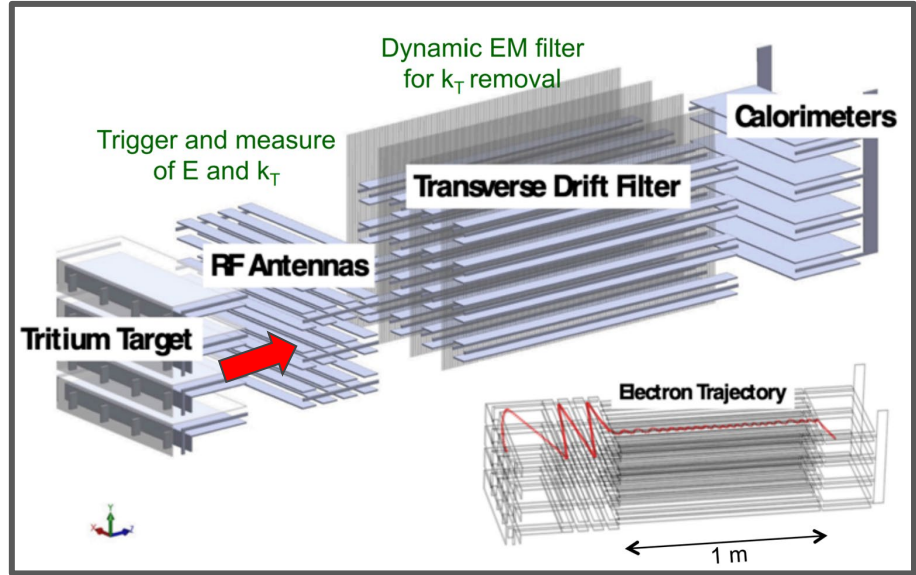


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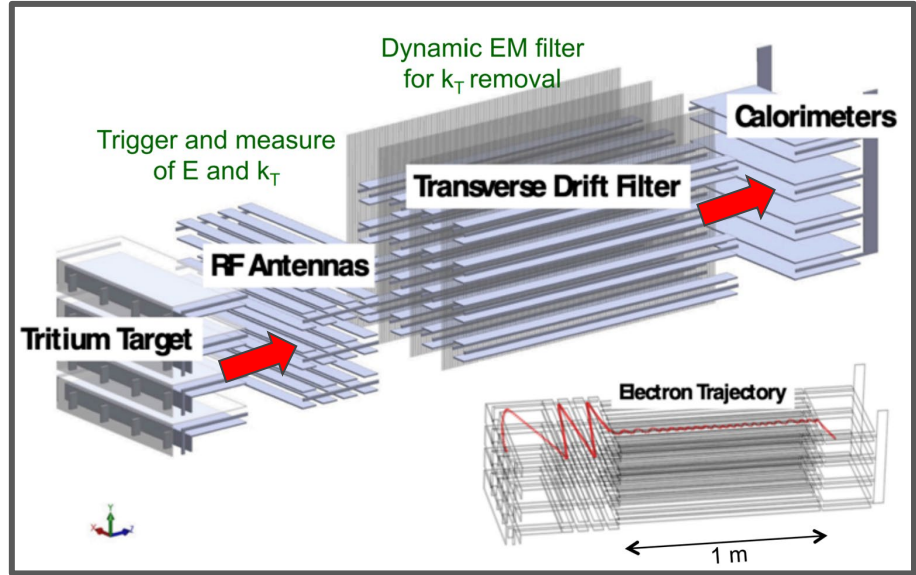


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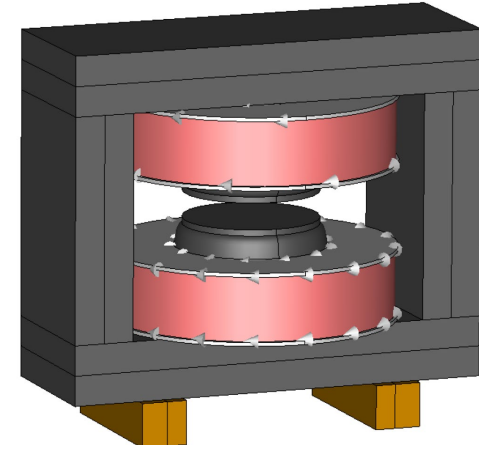
1. Transition from Target to RF Region
2. (in reverse) transition from filter to TES calorimeter



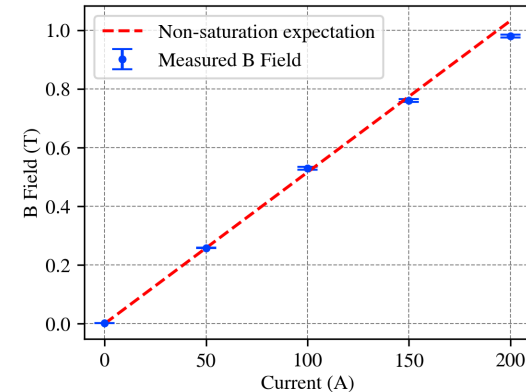
Components

Magnet

- Cyclotron magnet located in department
- Can attain 1T field (18 cm gap with 1 m diameter)
- May instead use same magnet as ExB demonstrator depending on clearance requirements



Max B Field vs. Current in Coils



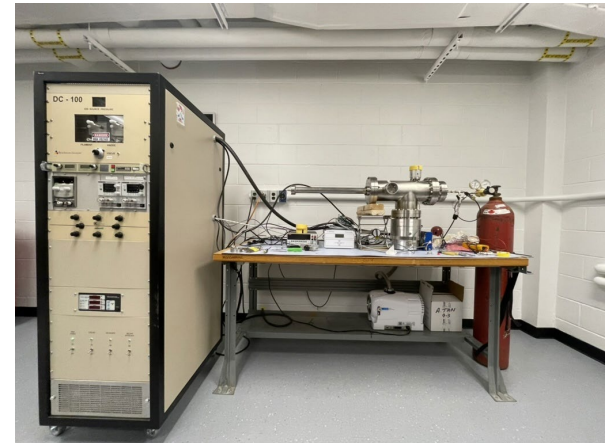
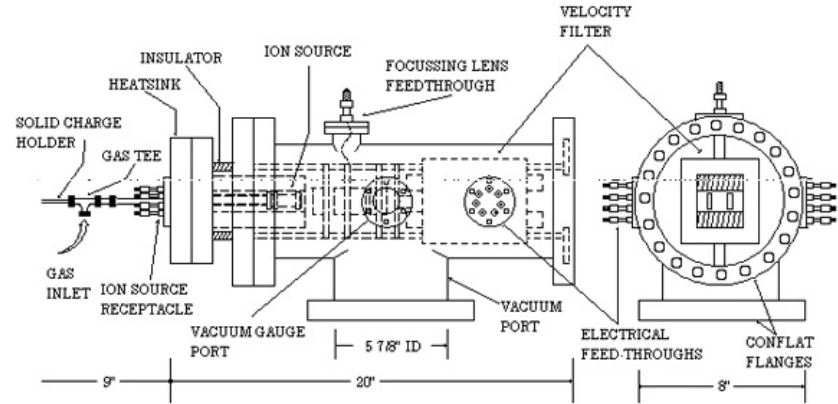
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- Model G-1 Ion Gun from Beam Imaging Solutions
- Chamber housing is ~50 cm long and ~15 cm diameter
- Velocity selector enables monoenergetic emission
- Can operate in energy range 500 eV - 10 keV



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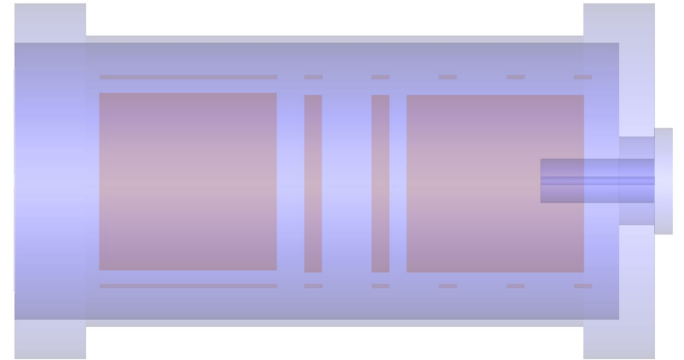
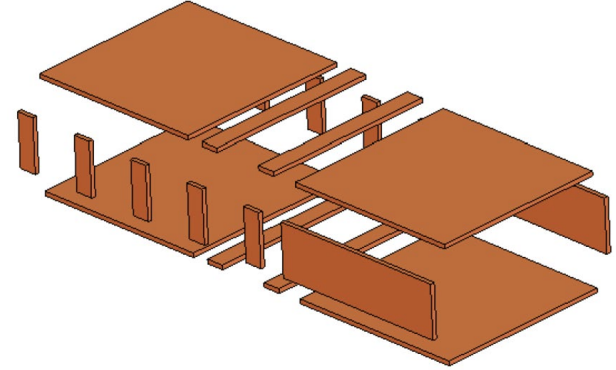
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- Situated in ~20 cm inner diameter chamber
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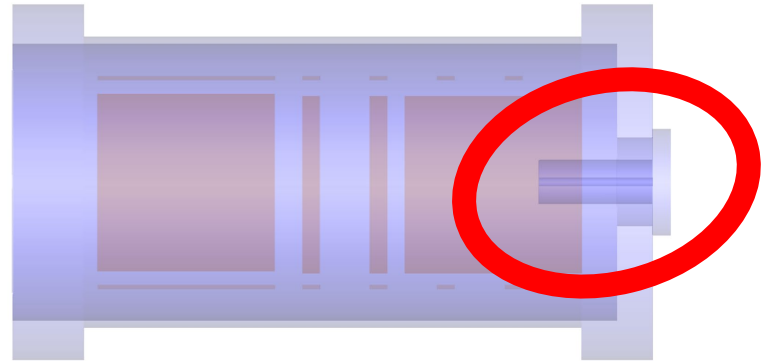
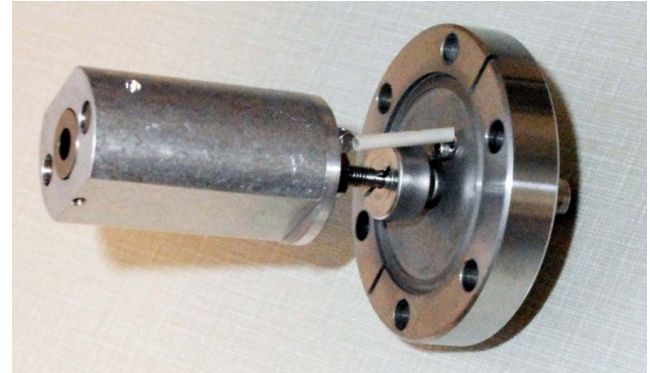
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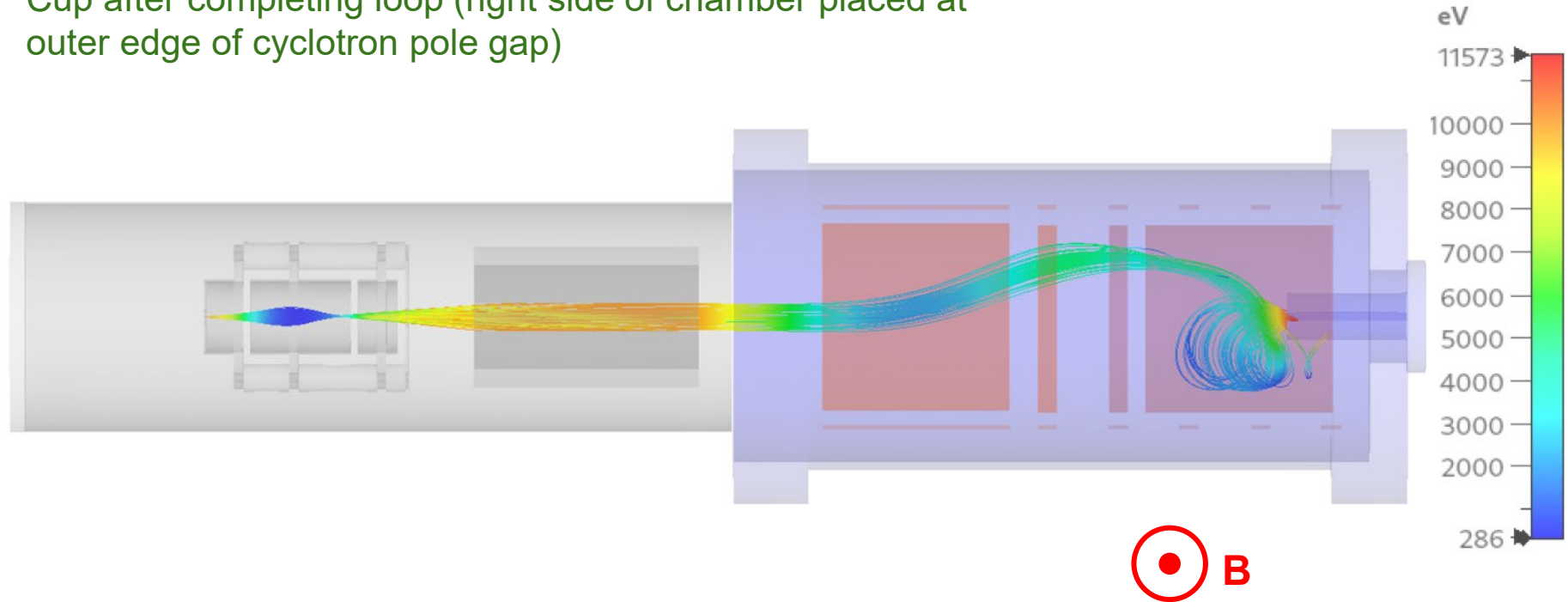
Detector

- magnetically shielded Model FC-1 Faraday Cup
- Measures ion current using an electrometer connected to a 50 ohm BNC vacuum feedthrough



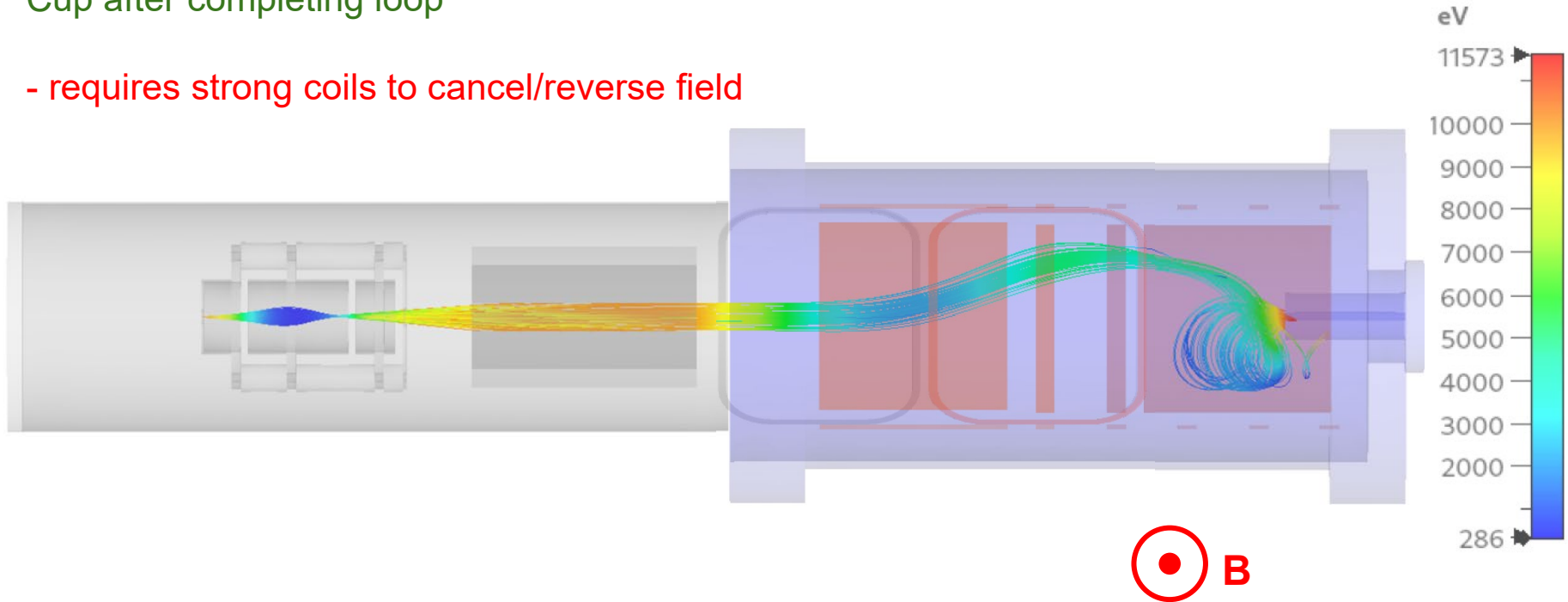
Preliminary Simulations

- 10 keV proton source successfully contacted Faraday Cup after completing loop (right side of chamber placed at outer edge of cyclotron pole gap)



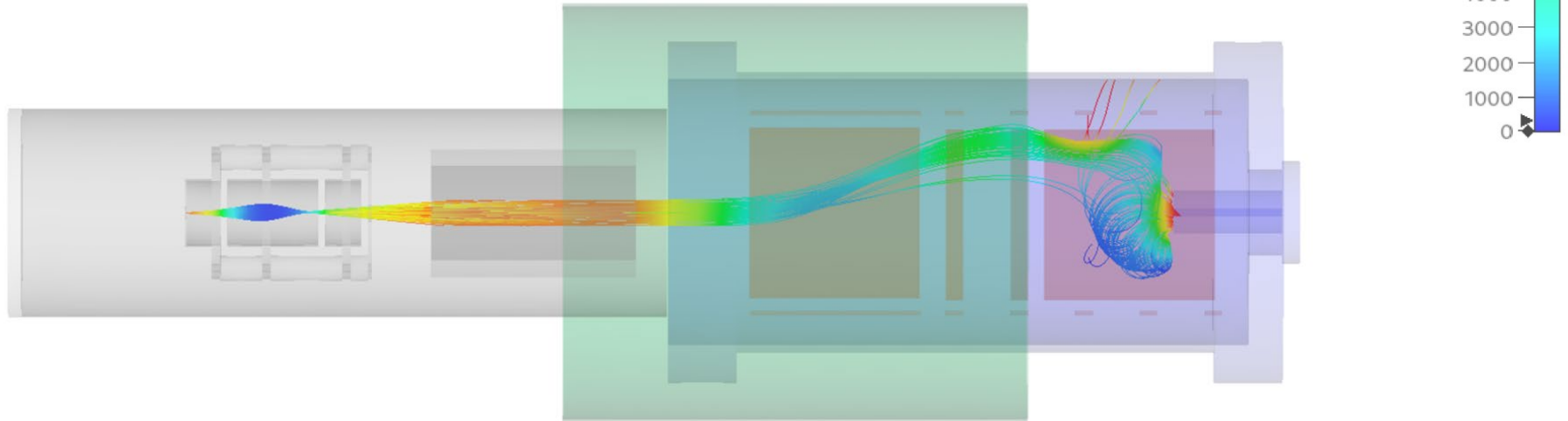
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- requires strong coils to cancel/reverse field



Preliminary Simulations

- 10 keV proton source successfully contacted Faraday Cup after completing loop
- Simulations replacing coils with magnetic shielding requires more tinkering to properly accelerate and collimate to detector



Next Steps

- Develop a working simulation accounting for available physical resources/considerations
 - Design electrode field cage and begin fabrication
- Codify method to characterize proper function of injection