ExB trap emptying design and simulations for the ^{6}He CRES experiment

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Outline

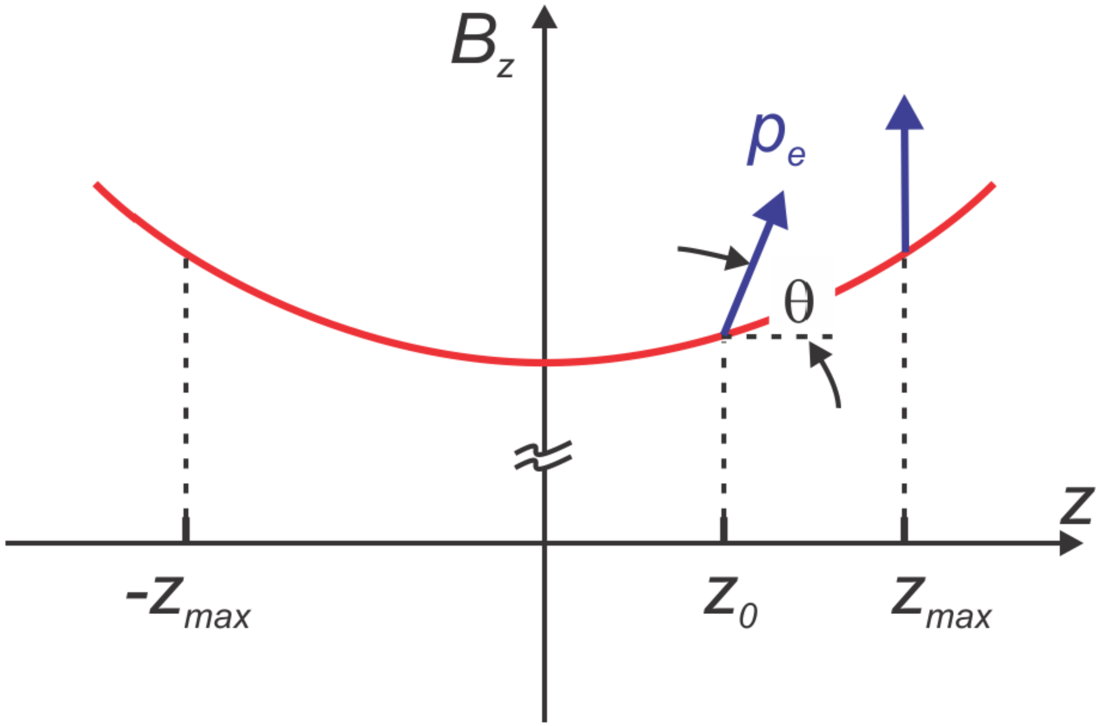
- CRES review
- Trapping field mapping
- ExB trap emptying mechanism
- Constant field proof of concept
- Single electrode tests
- Double electrode tests

Cyclotron Radiation Emission Spectroscopy (CRES)

$$\omega_c = \frac{eB}{m\gamma} = \frac{eB}{m(1 + K/mc\text{^}2)}$$

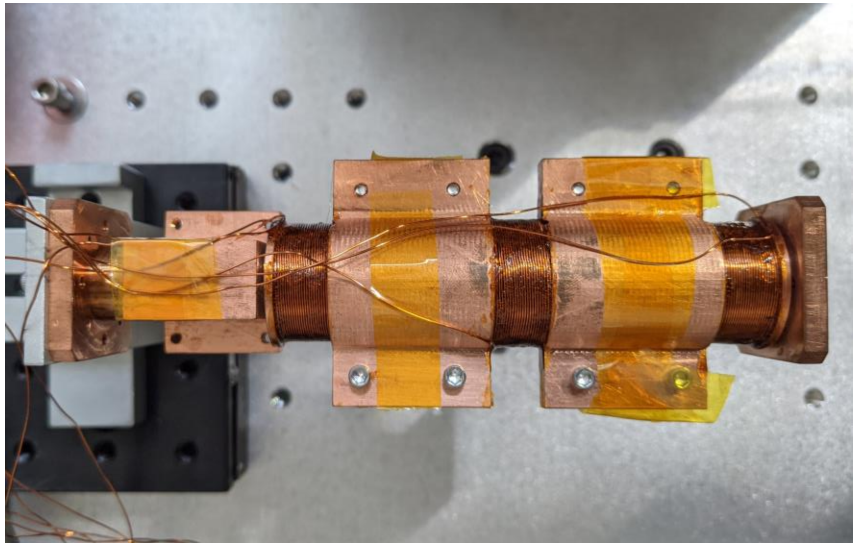
$$r^2 B(z) = \text{constant} = \left(\frac{p\sin\theta(t)}{eB(z)}\right)^2 B(z)$$

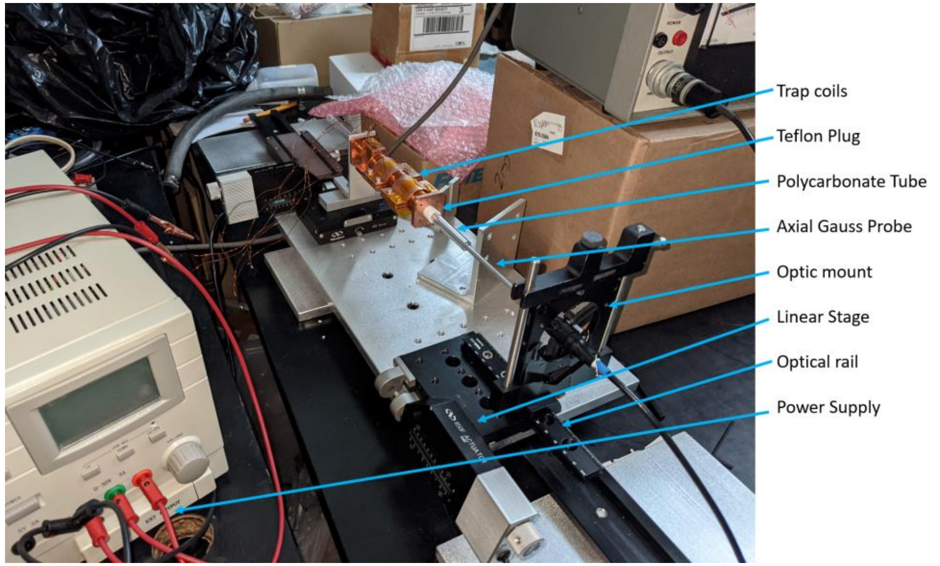
$$\frac{\sin^2\theta(t)}{B(z)} = \text{constant}$$

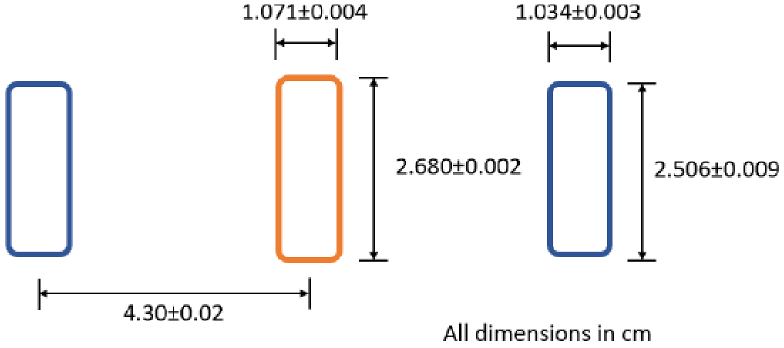


Trapping field mapping

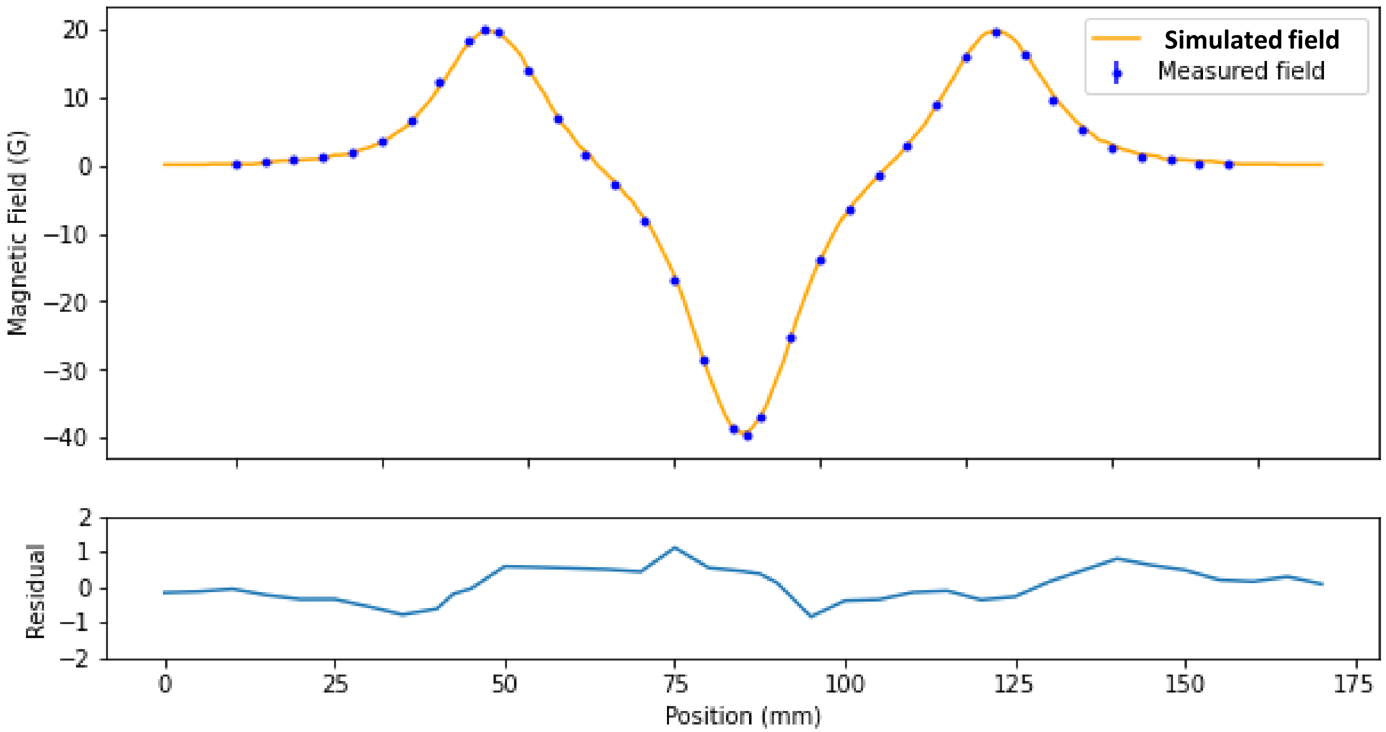
Accurate field shape is needed to simulate trajectories







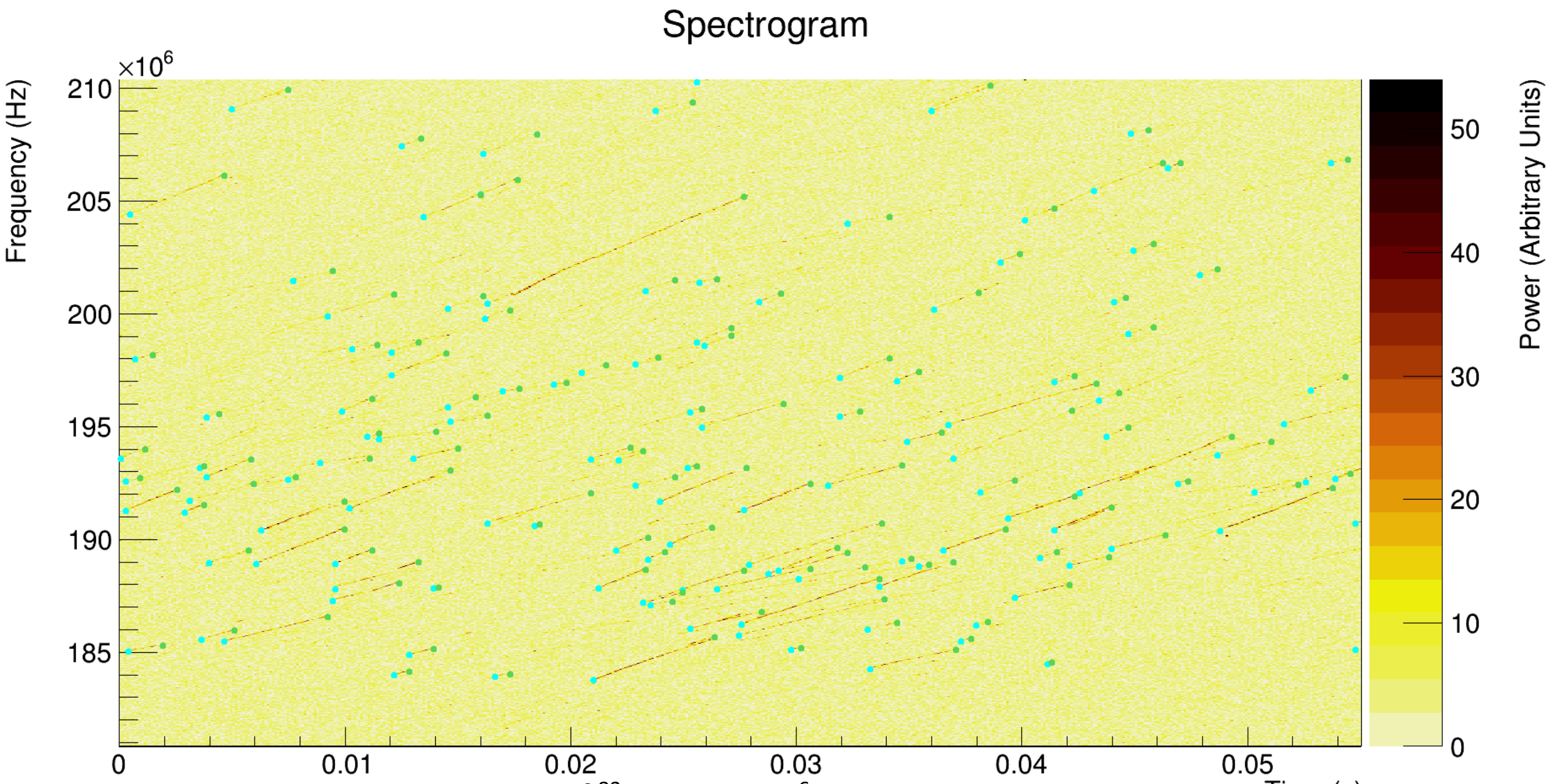
Trap coil dimensions



Average rms residual / 20G: 1.95%

ExB trap emptying

Many simultaneous events makes event reconstruction difficult



Spectrogram of ^{83}Kr events at ^{6}He CRES experiment

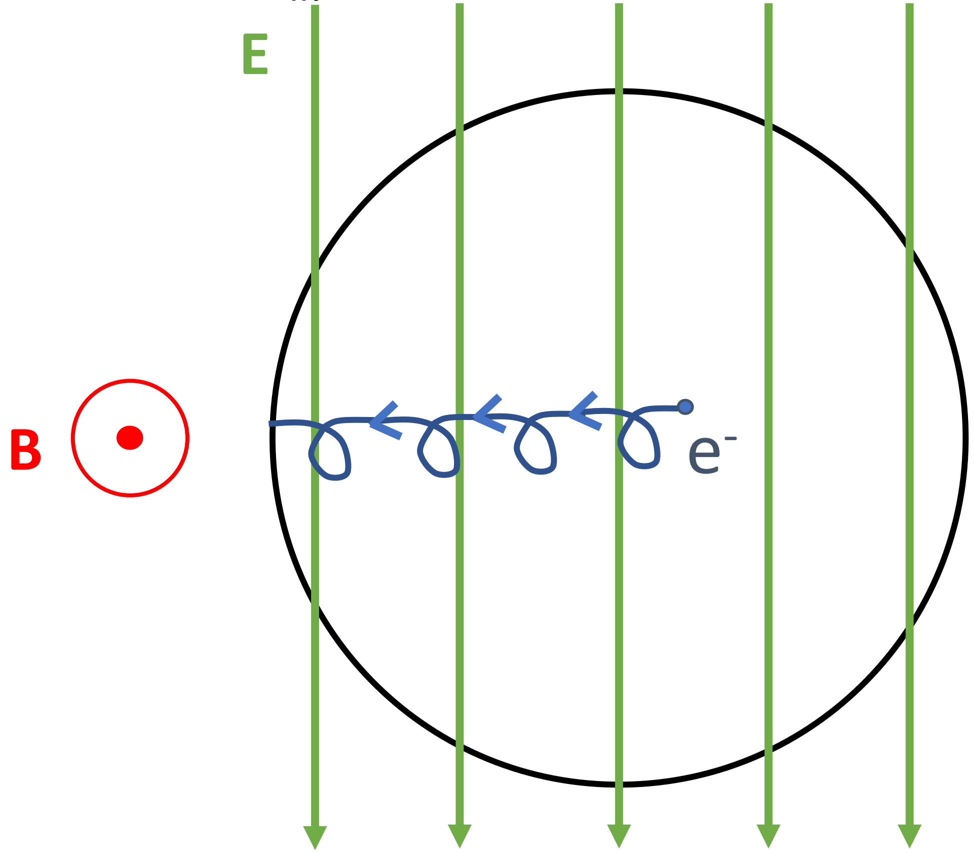
Trap emptying mechanism requirements

- Emptying less than 0.1ms
- Minimal signal loss less than -1dB
  - Signal to Noise ratio decrease from 7->6
- No disturbance of ambient magnetic field
- Compatible with cryogenic and vacuum environment

ExB trap emptying

Uniform fields: $\overrightarrow{v_D} = \frac{\vec{E}\times\vec{B}}{B^2}$ (SI units, B>=1Tesla)

$E \approx 2 \times \frac{10^{-2}V}{m}$ -> $1\ V$ to meet 0.1ms



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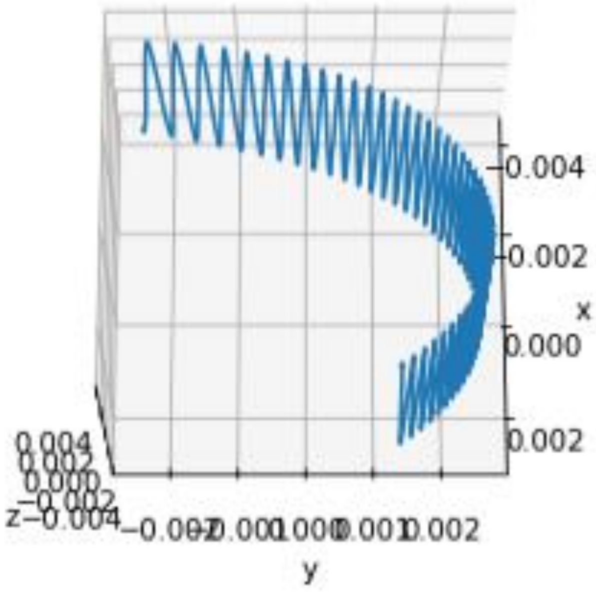
Linear E field simulation

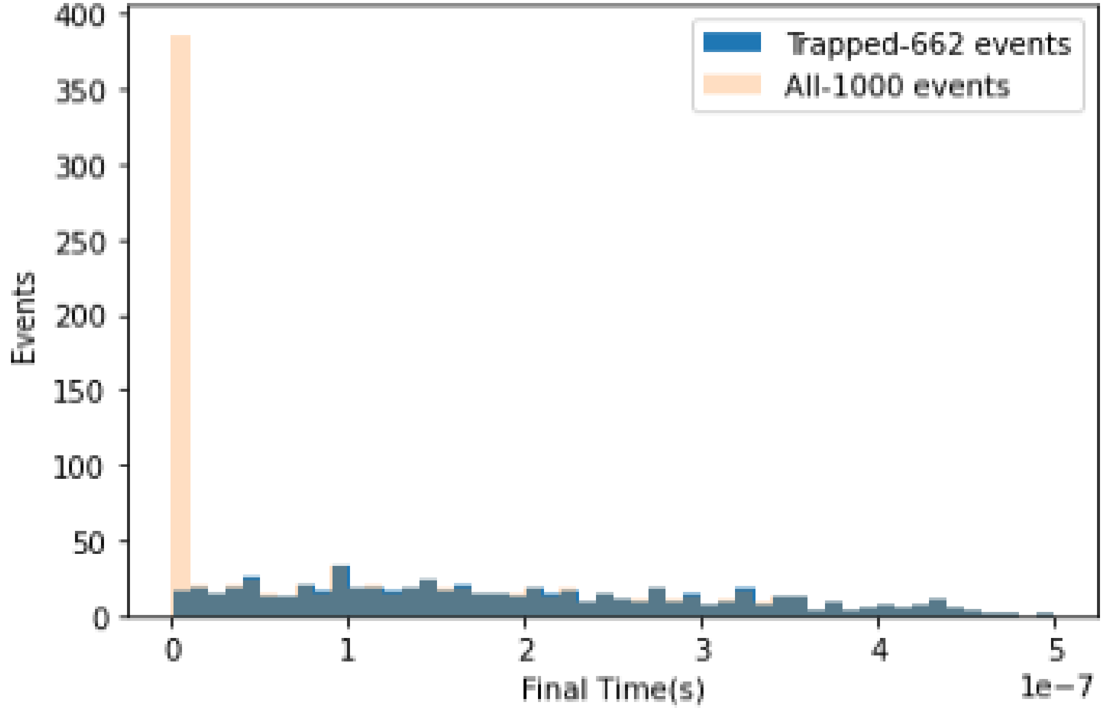
Trap coil field calculation

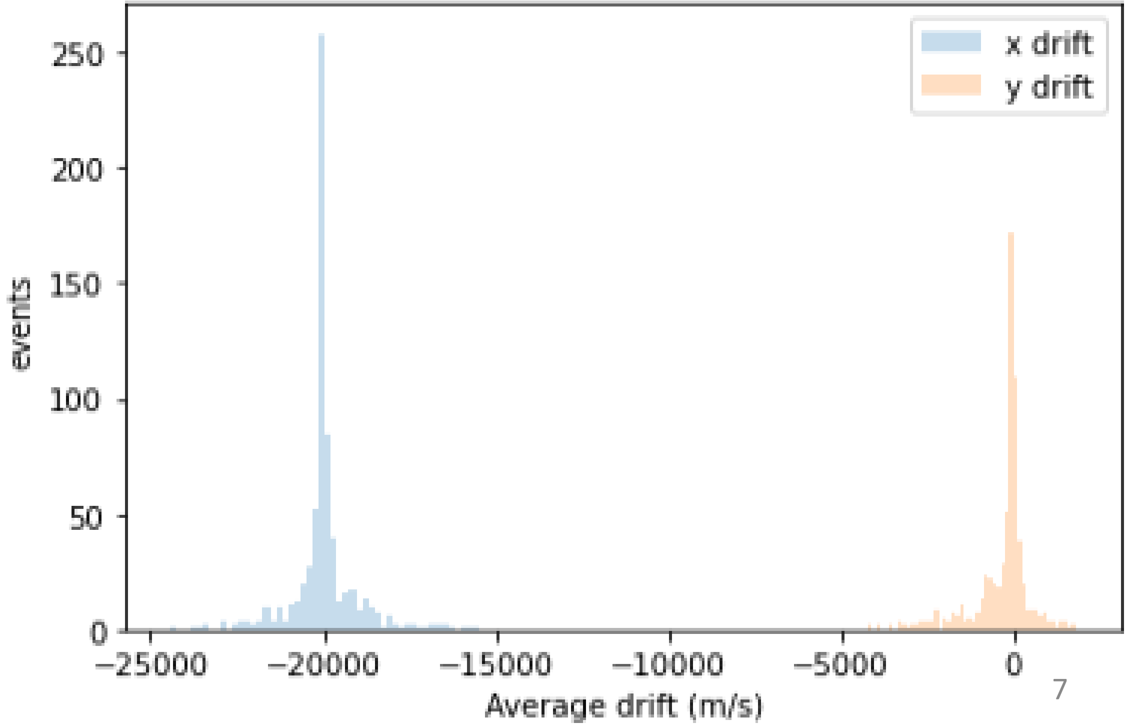
linear axial B field (1 Tesla)

linear electric field (-200 V/cm $\hat{y}$)

Simulate fields and electron trajectories using Kassiopeia



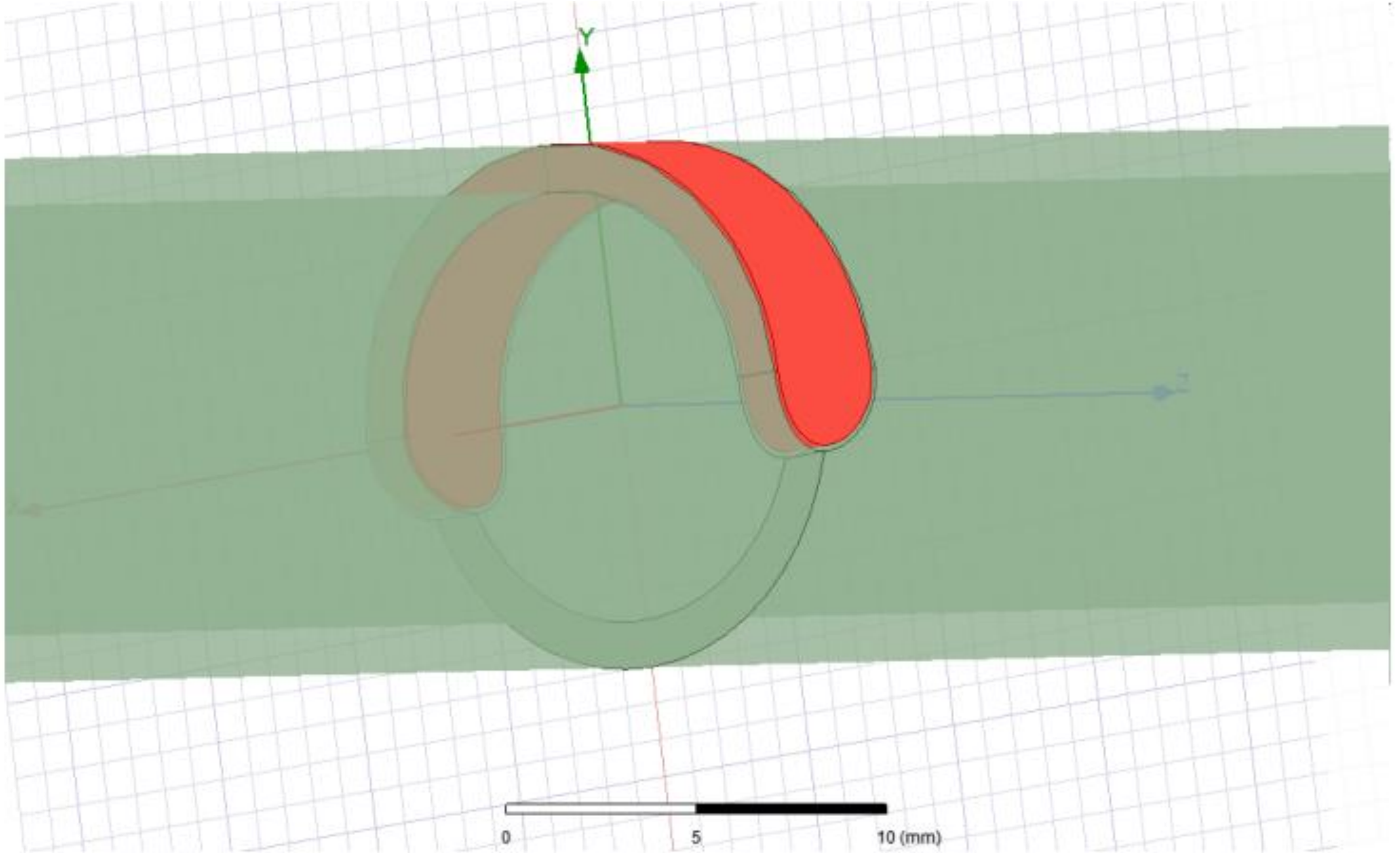




Single electrode ExB sweeper

Trap emptying mechanism requirements

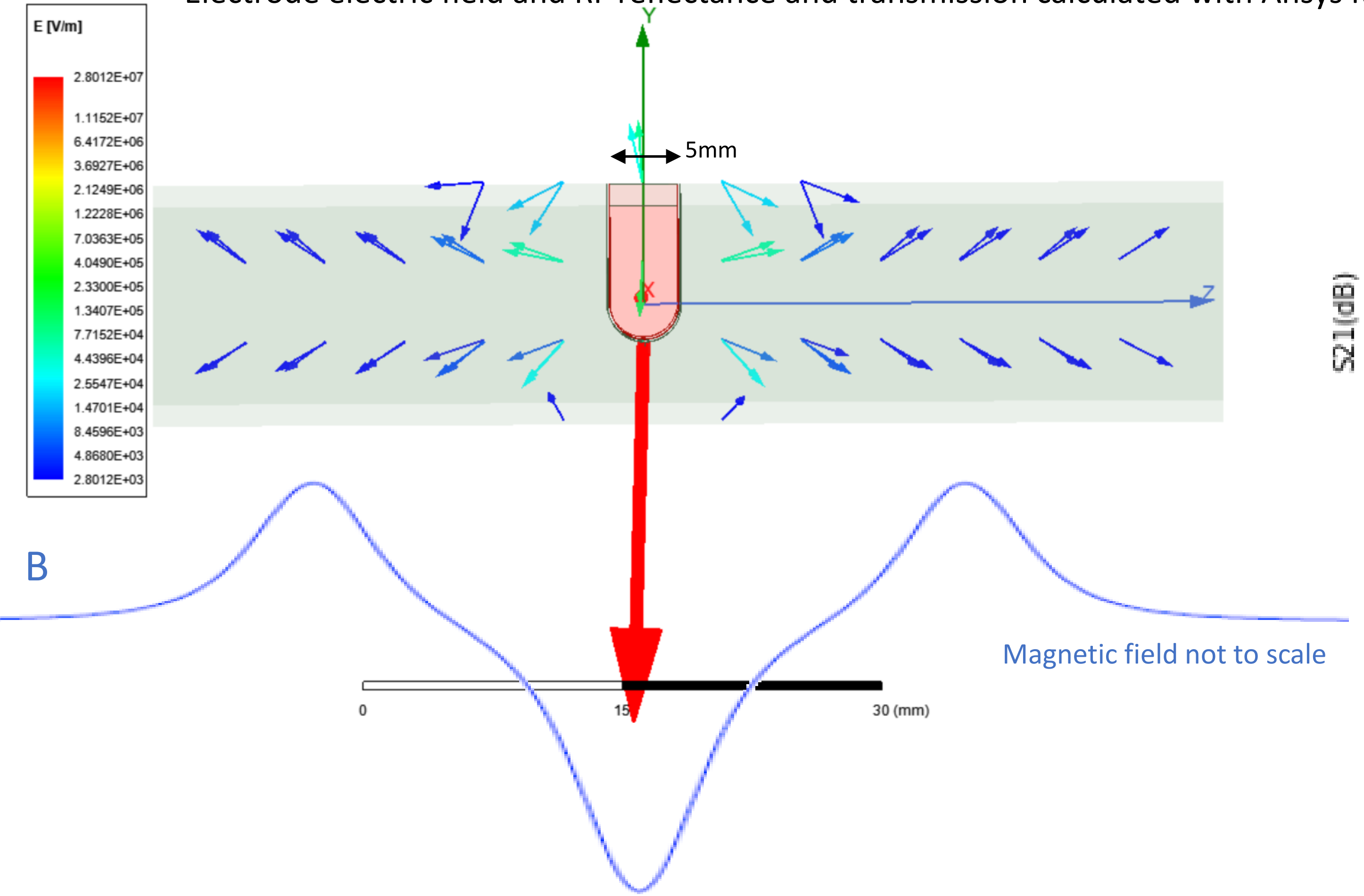
- Emptying less than 0.1ms
- Minimal signal loss >-1dB
  - Signal to Noise ratio decrease of 1
- No disturbance of ambient field
  -> Electrode can be turned on and off, and acts as waveguide when not emptying trap (creates detector noise)
- Compatible with cryogenic and vacuum environment
  -> Electrode is same material as waveguide, and gap is filled with dielectric adhesive with excellent adhesive and low temperature properties (Stycast 2850FT)

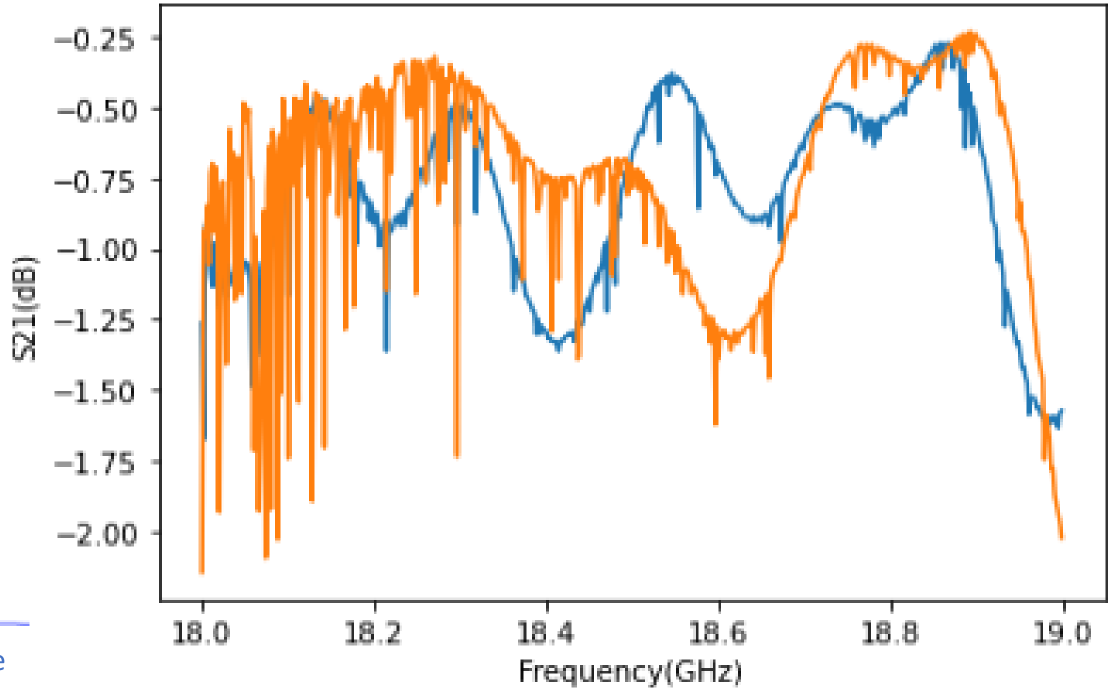


Single electrode ExB sweeper

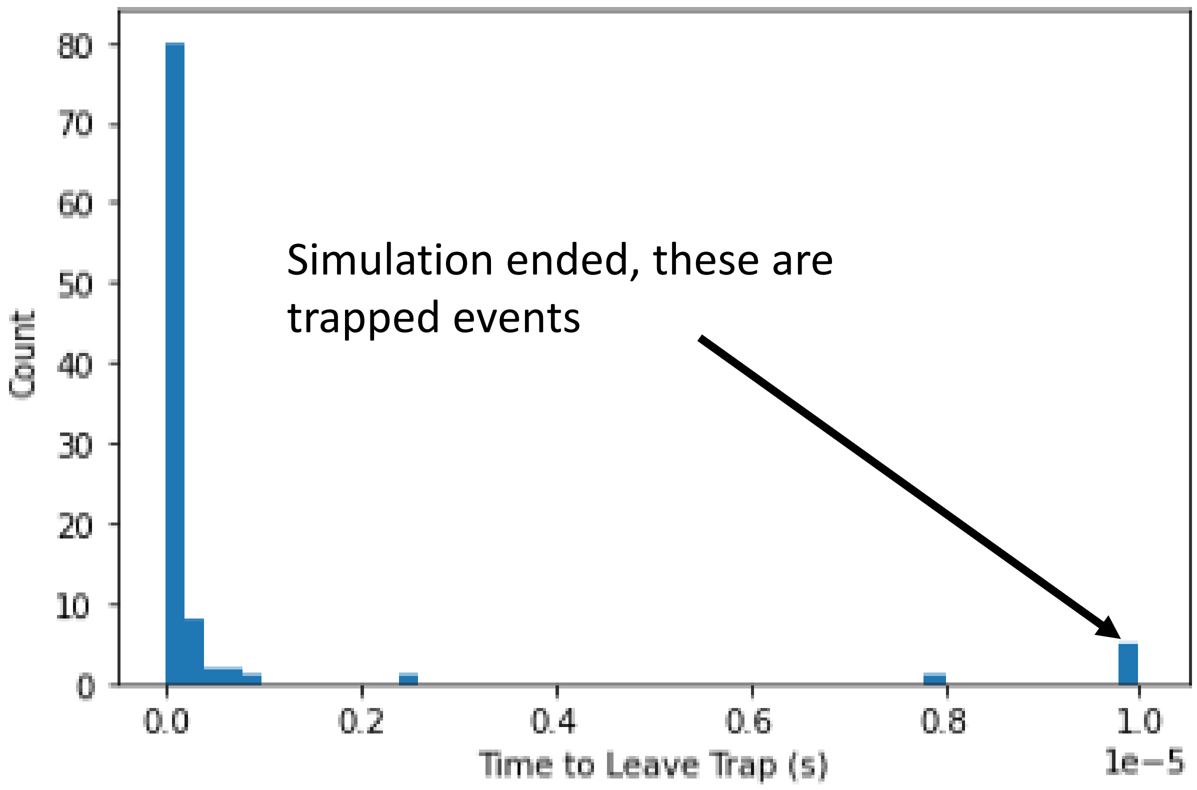
Non-optimized electrode

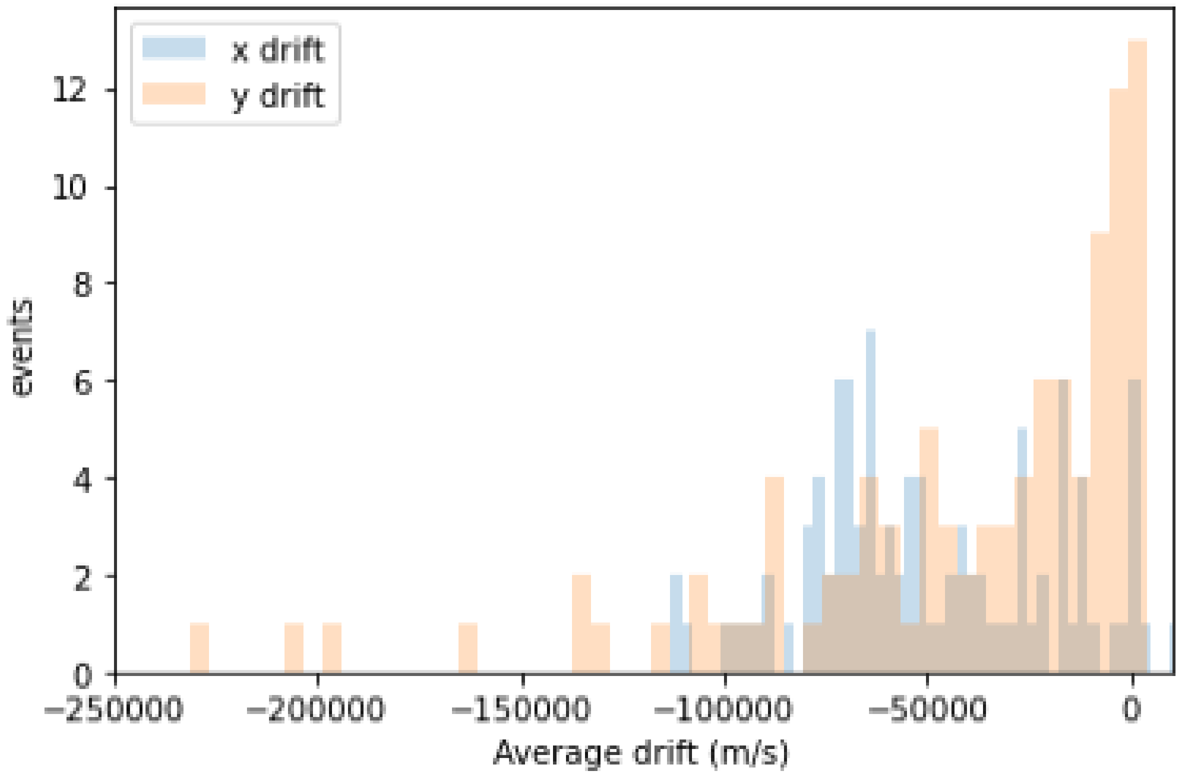
Electrode electric field and RF reflectance and transmission calculated with Ansys Maxwell and HFSS respectively.





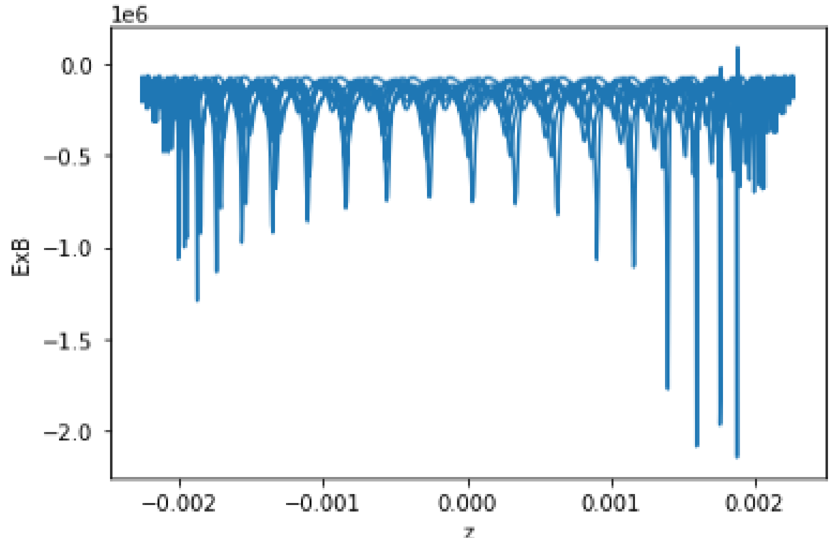
9mm electrode sweep tests



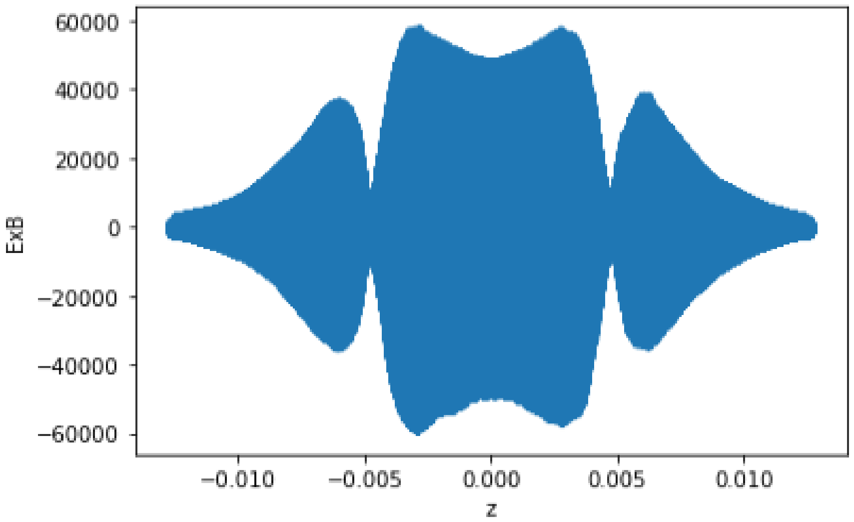


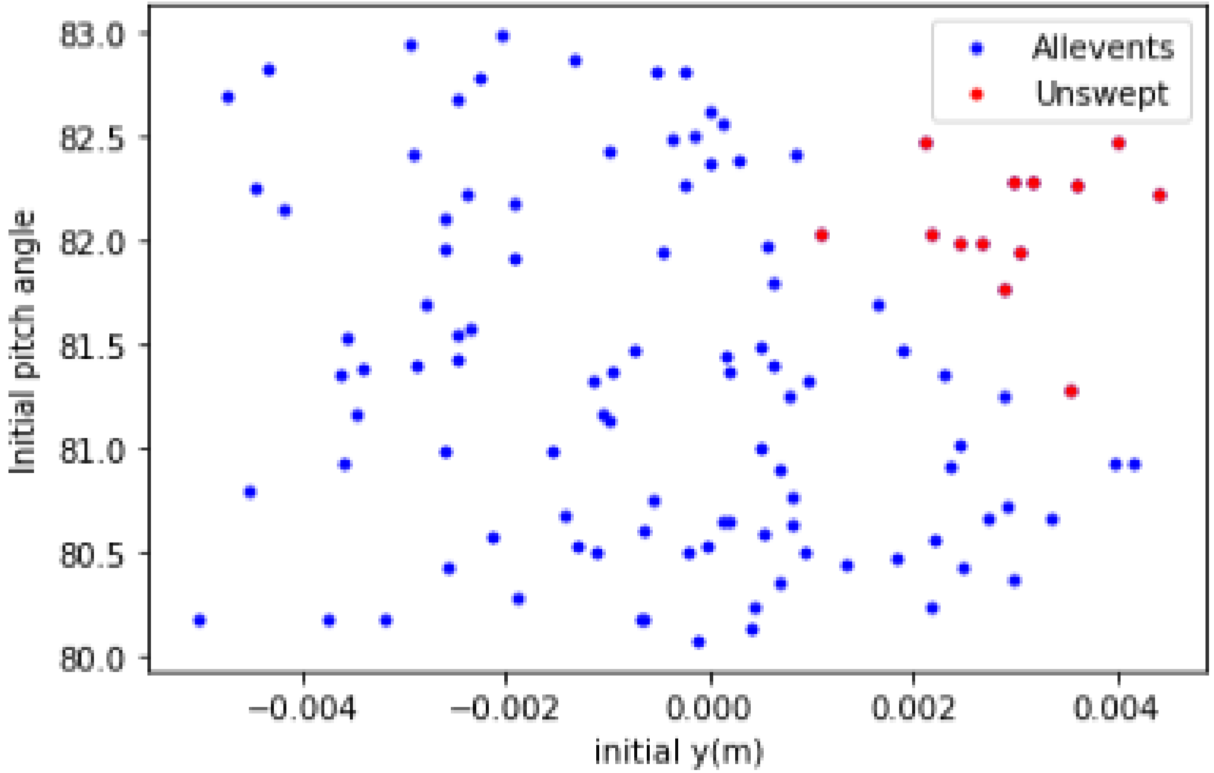
9mm electrode swept vs trapped trajectories

Swept

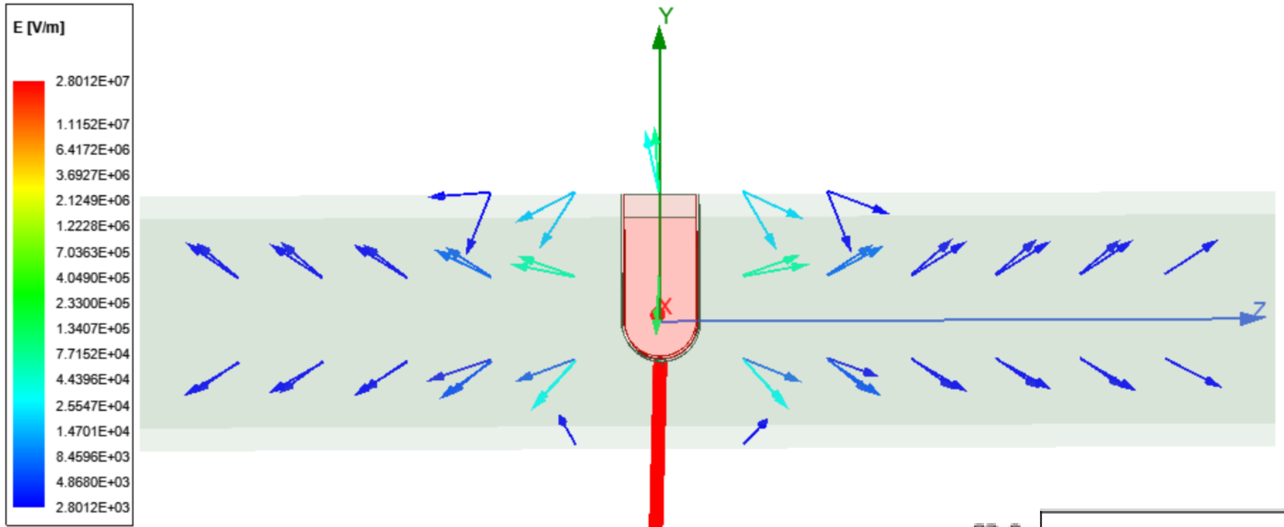


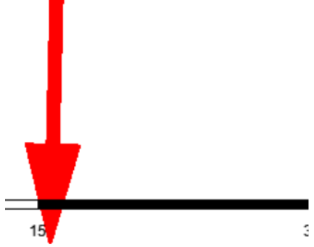
Trapped



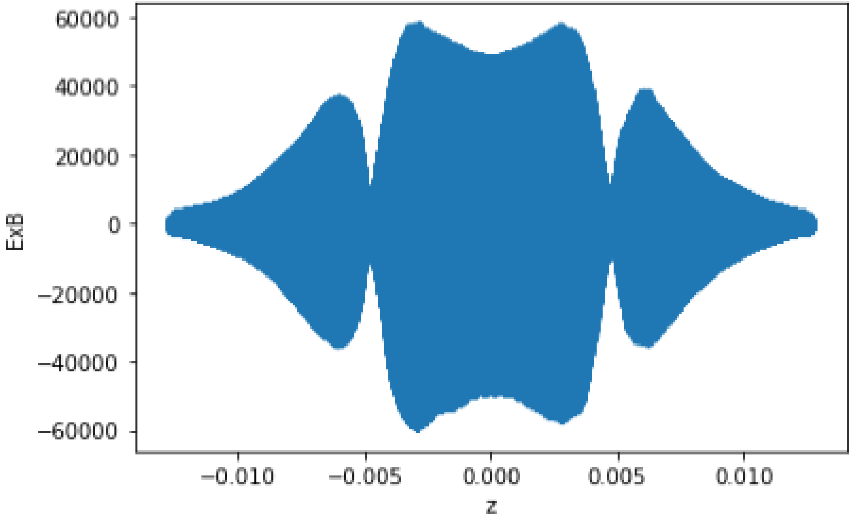


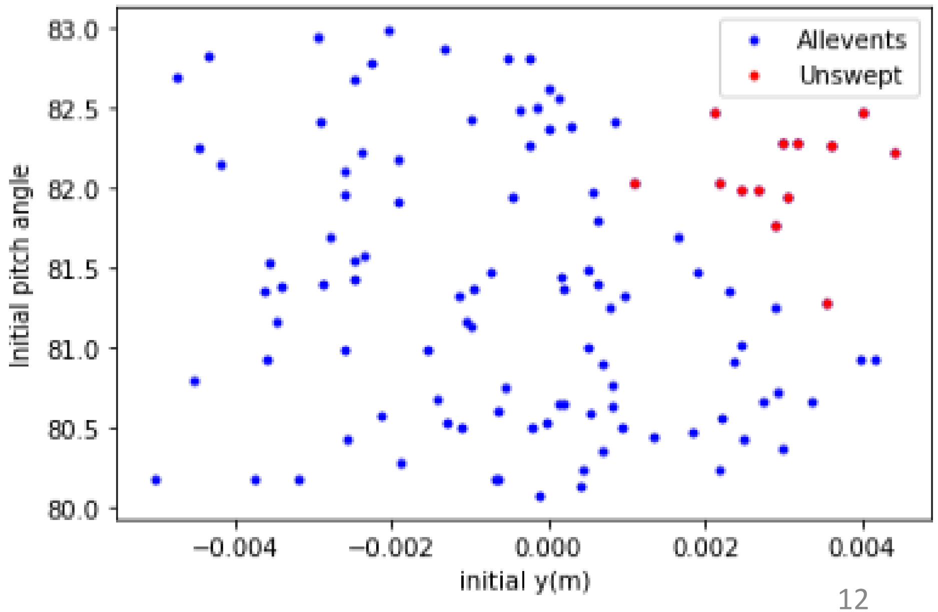
9mm electrode swept vs trapped trajectories



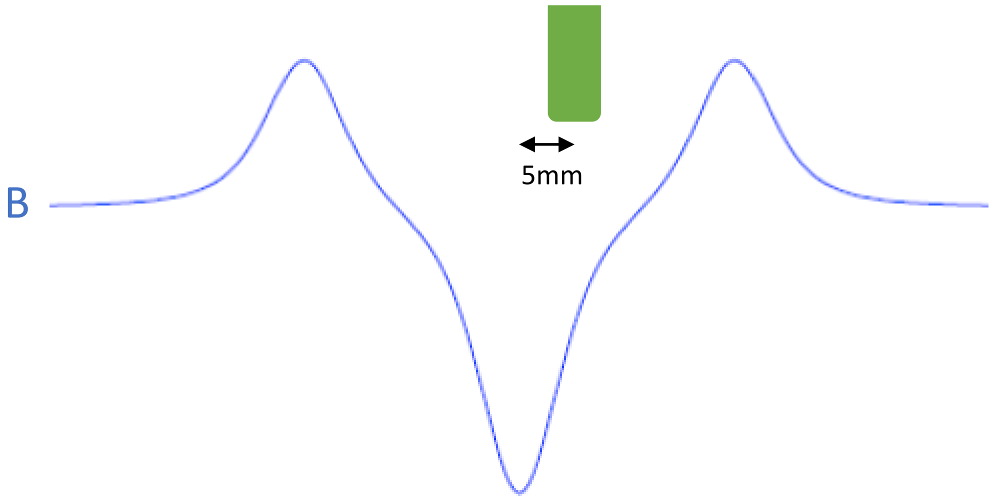


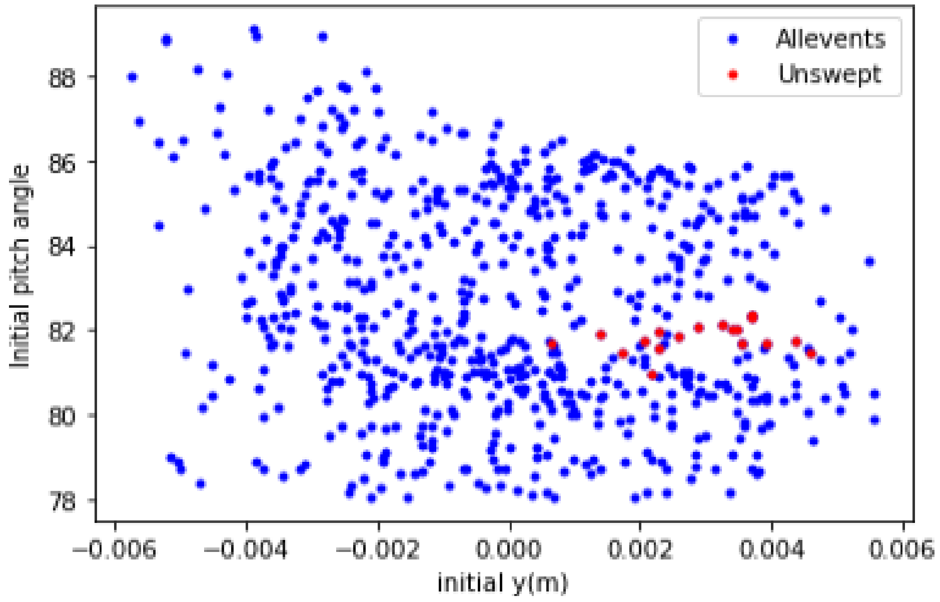
Trapped





Shifted electrode



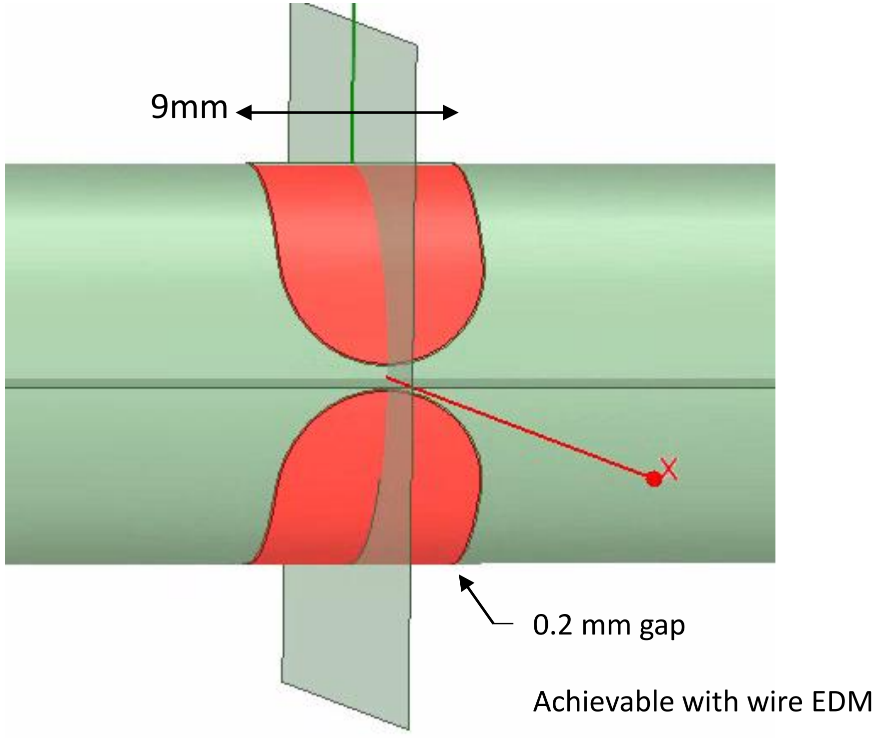


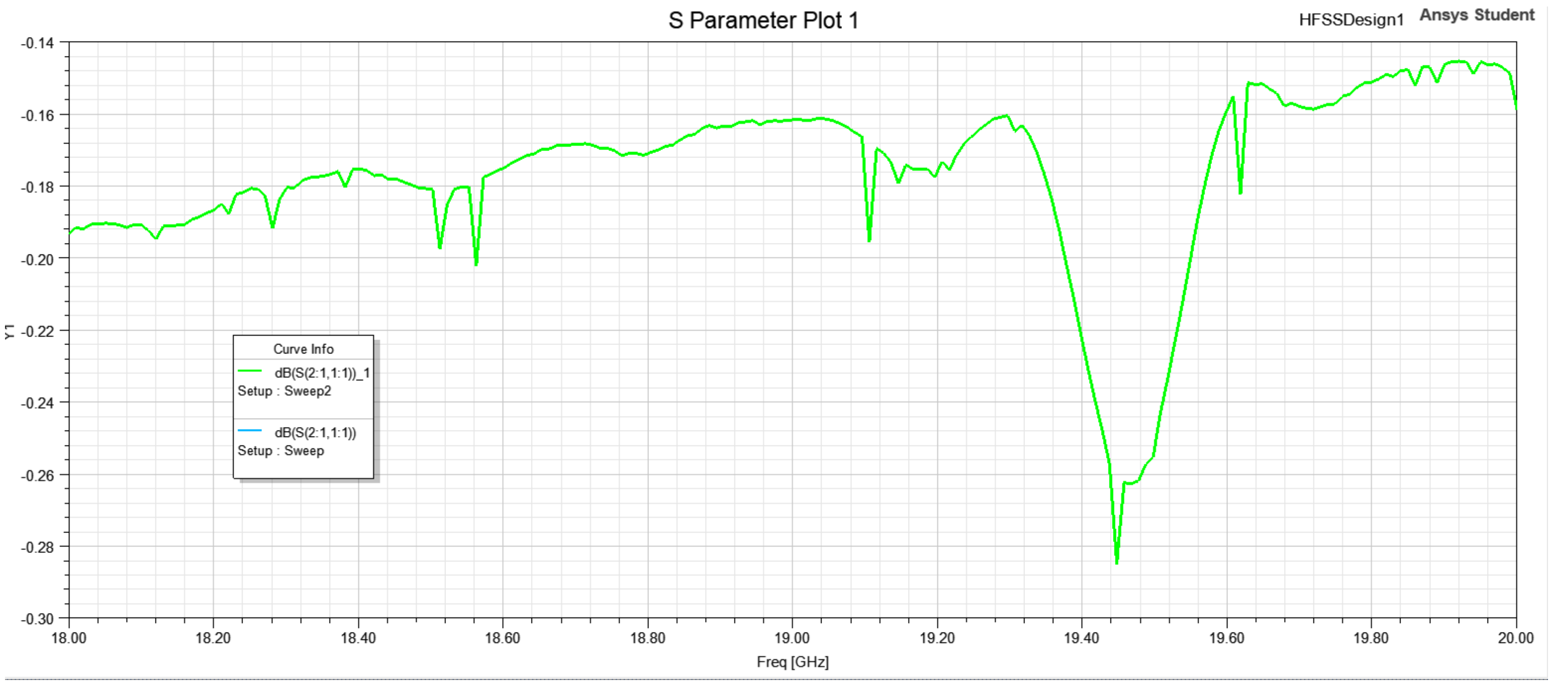
Shifting electrode can improve sweeping from 6% ->1.5%

Electrons experience unequal fringe fields

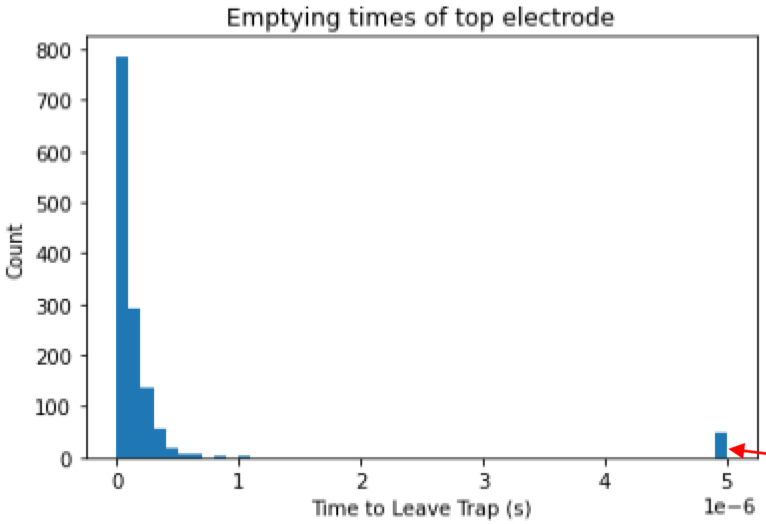
2 electrode design – mirrored electrodes

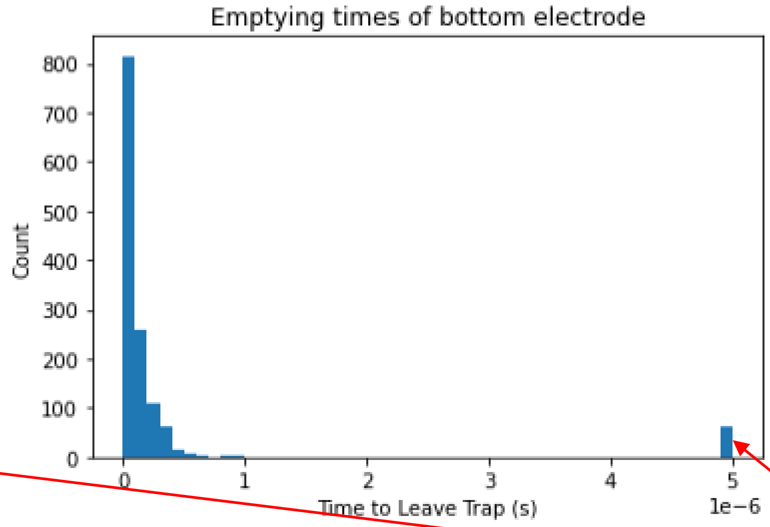
Inefficient sweeping near electrode, so we can apply voltage to each electrode separately to sweep complete volume



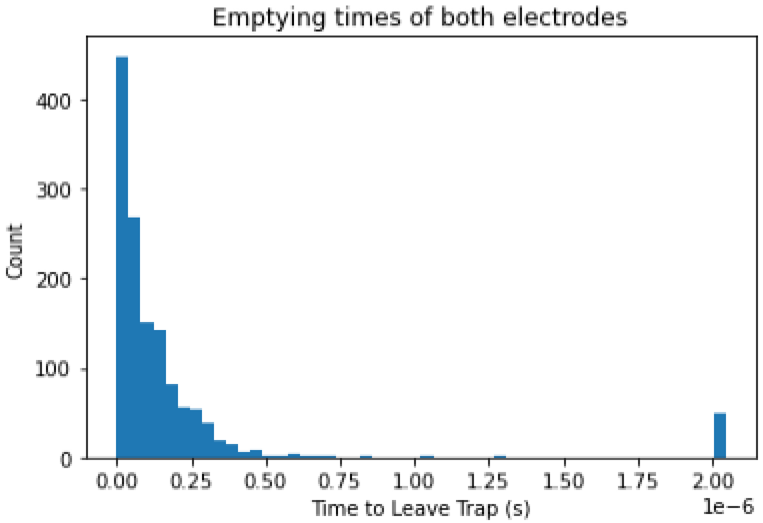


Mirrored electrodes sweeping





Events not swept by single electrode



Top electrode on from 0-2 μs

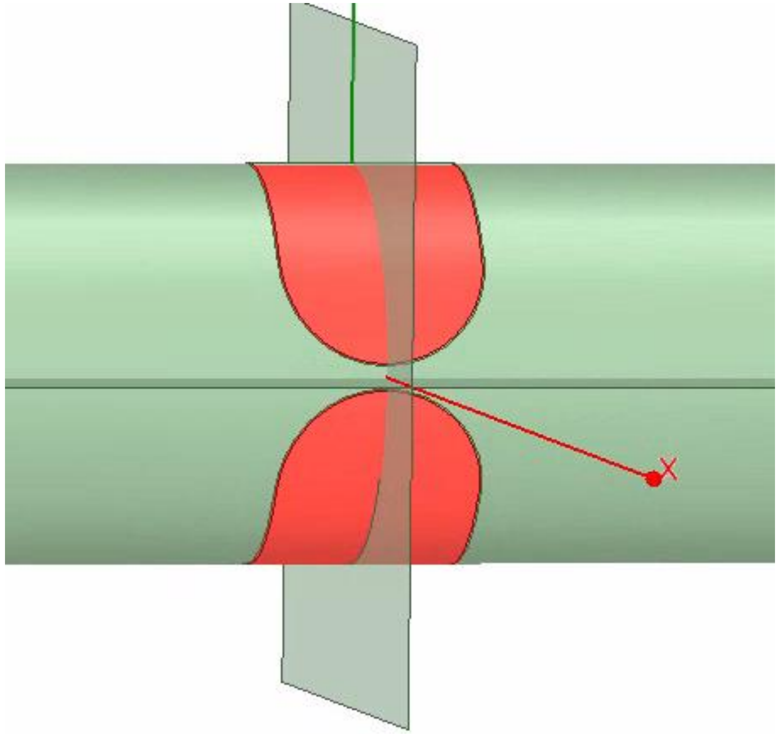
Bottom electrode on after 2 μs

All electrons swept within 2.05 μs

Mirrored electrode design

Trap emptying mechanism requirements

- Emptying less than 0.1ms
  - O(μs) trap emptying times
- Minimal signal loss >-1dB
  - -0.3 dB signal loss
- No disturbance of ambient field
  - acts as waveguide when not emptying trap, fast emptyi time allows flexibility with voltage timing
- Compatible with cryogenic and vacuum environment
  - Electrodes are same material as the waveguide, gaps are filled with dielectric adhesive with excellent adhesive and low temperature properties (Stycast 2850FT)



^{6}He-CRES collaboration

W. Byron[1], W. DeGraw[1], B. Dodson[2], M. Fertl[2], A. Garcia[1], G. Garvey[1], B. Graner[1], H. Harrington[1], L. Hayen[3], K. Knutsen[1], D. Melconian[4], D. McLain[4], P. Mueller[5], N. Oblath[6], R.G.H. Robertson[1], G. Rybka[1], G. Savard[5], E. Smith[1], D. Stancil[3], D. Storm[1], H.E. Swanson[1], R.J. Taylor[3], B.A. Vandeevender[6], F. Wietfeldt[7], A. Young[3]

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Questions?

^{6}He CRES experiment

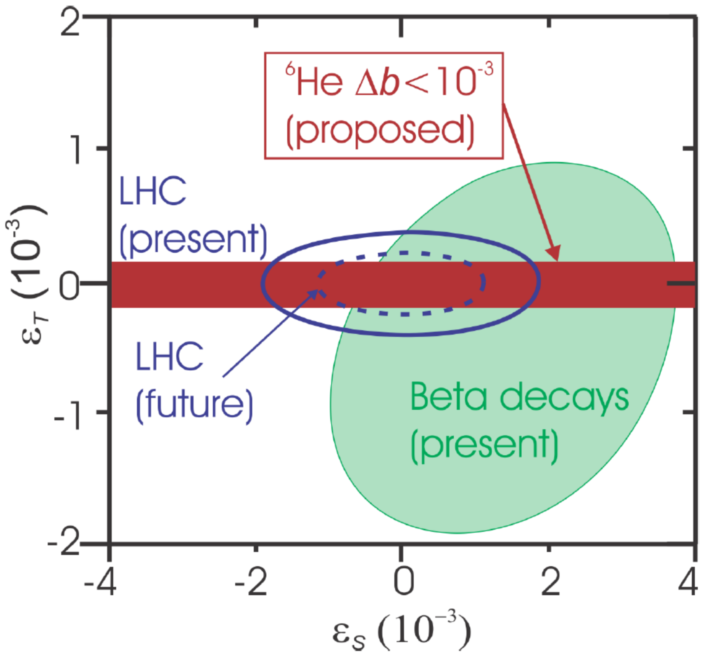
$$\frac{dW}{dE} \approx \frac{dW_0}{dE}\left(1 + \frac{m}{E} b\right)$$

$$g_V = 1 \approx g_T \approx g_S$$

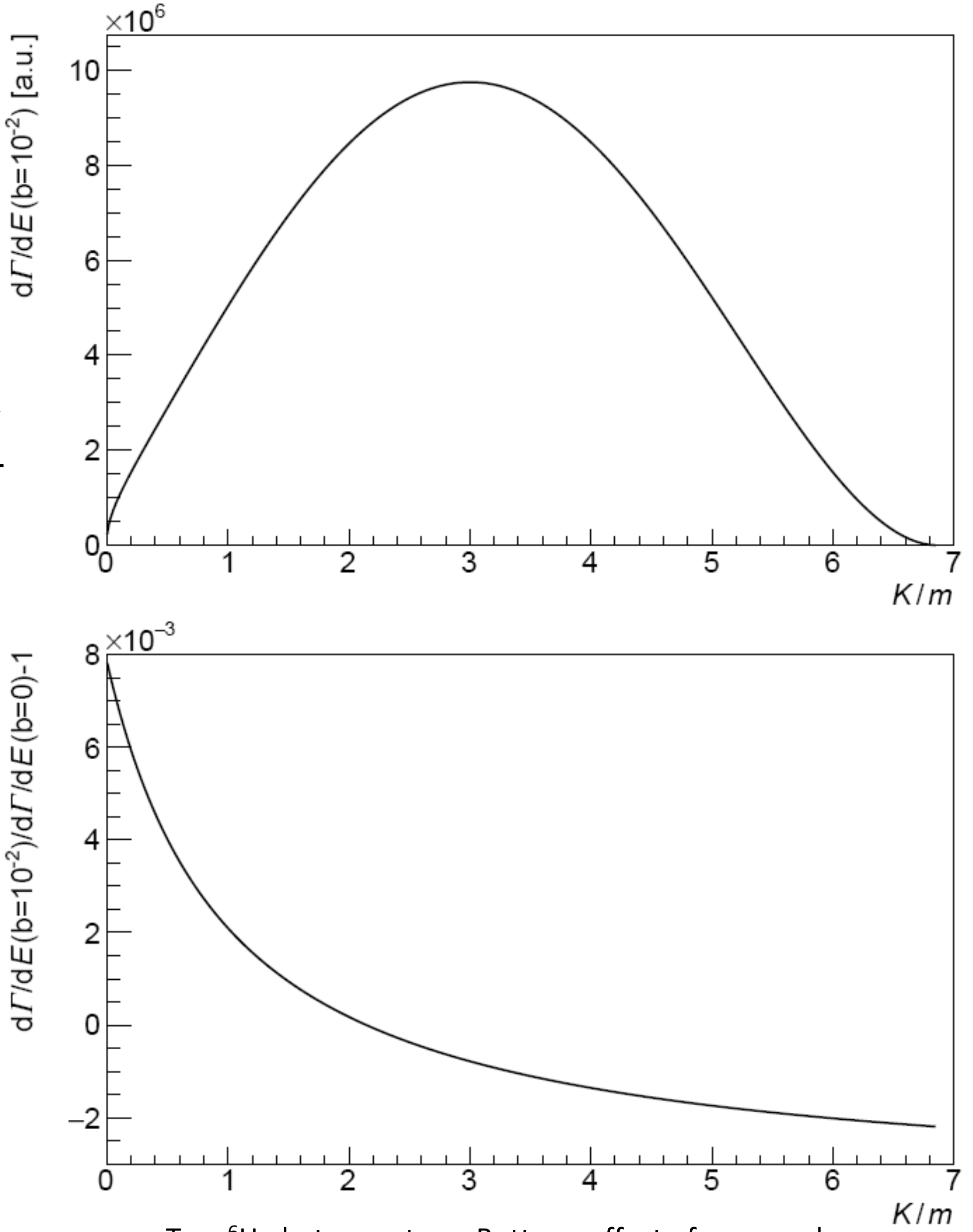
$$b = \pm 2\sqrt{1-(\alpha Z)^2}\,\frac{\epsilon_S - 4\left(\frac{\langle\sigma\tau\rangle}{\langle\tau\rangle}\right)^2 g_A \epsilon_T}{1 + \left(\frac{\langle\sigma\tau\rangle}{\langle\tau\rangle}\right)^2 g_A^2}$$

$$C_i = \left(\frac{G_F V_{ud}}{\sqrt{2}}\right)\bar{C}_i$$

$$\overline{C_T} = 8 g_T \epsilon_T$$



Experimental upper limits (90%) on left-handed tensor vs. scalar currents



Top: ^{6}He beta spectrum Bottom: effect of nonzero b