Cyclotron Radiation Emission Spectroscopy
in a Penning Trap

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Motivation
- Use Cyclotron Radiation Emission Spectroscopy (CRES) to reconstruct the beta decay spectrum of $^6$He to measure the Fierz parameter.
- Check the validity of this experiment in a Penning trap and the accommodations that must be made to incorporate the Penning trap into the experiment.

Fierz Parameter
- In Standard Model Physics the Fierz term, $b = 0$.
- A non-zero $b$ would lead to non-zero contributions of scalar or tensor couplings which is beyond the Standard Model.

\[ WdE \propto \frac{E(\gamma \pm E)}{2\pi^3} pE(\gamma - E)^2 \text{d}E \xi \left(1 + b \frac{m}{E}\right) \]

Cyclotron Radiation Emission Spectroscopy
- Measure the emitted cyclotron radiation from a beta particle as it travels through a constant magnetic field.
- Reconstructs the starting kinetic energy from the cyclotron frequency.

\[ f = \frac{qB}{2\pi(m + E)} \]

Kassiopeia
- Simulated Penning trap with a single electron track showing the loss of energy due to cyclotron radiation.

Optimization of Kassiopeia
- Kassiopeia had extremely long computation times which had to be lowered.
- Compared to Project8 experiment to ensure the simulation remained physical.

Beta Decay Spectrum
- Fig. 4 Beta decay spectrum created from an initial cyclotron frequency.

Conclusions and Future Work
- Successfully implemented a Penning trap into Kassiopeia and drastically reduced computation time per event.
- Was able to use the CRES technique to reconstruct the beta decay spectrum of $^6$He.
- Showed in HFSS that the loss from the mesh and trap is acceptable for the experiment.
- Begin development of Penning Trap.

HFSS
- High Frequency Structure Simulator is used to measure the power loss over the waveguide.
- Applied a mesh to the bend in the guide to allow a beam to enter the trap.
- Loss needs to be below 1 dB.

HFSS Loss
- Fig 1 Loss of current guide compared to updated guide.

This work is supported by U.S. Department of Energy and National Nuclear Security Administration Grant No. DEFG02-93ER40773 and DE-NA0003841