Cyclotron Radiation Emission Spectroscopy

Simulations with Kassiopeia

D. McClain, V. Iacob, V. S. Kolhininen, D. Melconian, M. Nasser, A. Ozmetin, B. Schroeder, P. D. Shidling

Motivation

• Use Cyclotron Radiation Emission Spectroscopy (CRES) to reconstruct the beta decay spectrum of $^6$He.
• Check the validity of this experiment in a Penning trap.
• Fit the spectrum and measure the Fierz parameter.

Fierz Parameter

• In Standard Model Physics the Fierz term, $b = 0$.
• A deviation in $b$ may lead to possible contributions of scalar or tensor couplings.

Kassiopeia

• Particle tracking simulation for navigating through complex electromagnetic fields [2].
• Allows us to track physical quantities through user-defined spaces.
• Spaces, fields and particle generators are defined in an XML file used to run the simulation.

Optimization of Kassiopeia

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

References


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

Beta Decay Spectrum

• Successfully implemented a Penning trap into Kassiopeia and drastically reduced computation time per event.
• Was able to use the CRES technique to reconstruct the top third of the beta decay spectrum of $^6$He.
• Will be constructing a waveguide in HFSS to test the ability to read the initial radiated frequency from within the Penning trap.

Conclusions and Future Work

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.

$$f = \frac{qB}{2\pi (m + E/C^2)}$$

Fig. 1 Ratio of energy spectrum with maximum allowed Fierz value with respect to the Standard Model.

Fig. 2 Simulated Penning trap, modeled after SHIPTRAP[3], with a single electron track showing the loss of energy due to cyclotron radiation.

Fig. 3 Spectrogram of a CRES event shown by Project8 [1]

Fig. 4 Beta decay spectrum created from initial cyclotron frequency observed from a Kassiopeia simulation.

Fig. 5 Simulated Penning trap, modeled after SHIPTRAP[3], with a single electron track showing the loss of energy due to cyclotron radiation.

Fig. 6 Spectrogram of a CRES event shown by Project8 [1]

Fig. 7 Beta decay spectrum created from initial cyclotron frequency observed from a Kassiopeia simulation.