Background Estimates of Radiative Pion and Muon Capture for Mu2e Experiment

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The Mu2e experiment seeks to observe muon-electron conversion.

\[ \mu^- + ^{27}\text{Al} \rightarrow e^- + ^{27}\text{Al} \]

A muon interacts with an aluminum nucleus and is converted into an electron, which emerges with momentum and energy on the magnitude of the muon's mass (~106 MeV).

This conversion process is an example of lepton flavor violation which is when lepton family number is not conserved. This has never been observed experimentally, and according to the standard model of particle physics it has essentially a zero chance of happening. If the experiment succeeds, then it will serve as evidence that there is new physics beyond the standard model.

Production Solenoid

Here the production target is hit with an & GeV/(10^5 eV) proton beam which produces many particles, the most important being pions.

Graded magnetic fields cause many particles to flow into the transport solenoid.

Radiative Pion Capture (RPC)

Because the decay of particles is a probabilistic process, there will be a number of pions that don't decay. Therefore, if any surviving pions make it to the muon stopping target they can interact in the following way:

\[ \pi^- + ^{27}\text{Al} \rightarrow \gamma + X \]

The X represents that there will be more than one nuclear state which suggests the energy of the photon will not be monochromatic but rather follow a spectrum structure. This makes the background harder to estimate.

Radiative Muon Capture (RMC)

RMC is similar to RPC. In this process, a muon converts into a photon and a neutrino, described by the following equation:

\[ \mu^- + ^{27}\text{Al} \rightarrow \gamma + \nu_{\mu} + \text{Mg} \]

In both RPC and RMC, the pion or muon gives some of its energy to the photon which can produce an electron-positron pair. If the photon is energetic enough, there is a chance that the electron produced has a similar momentum and energy to an electron produced from muon-electron conversion (~105 MeV). This means that this electron could be confused with a Mu2e electron which poses a problem.

Approach to the Problems of RMC and RPC

One way to estimate the amount of background from RPC and RMC is to directly measure it. To do this, the number of conversion photons which produce electron-positron pairs must be known. Simulation software provides an estimate of the number and energies of conversion photons and electron-positron pairs. The following histograms were made using one million photons and describe some of the physics of RPC and RMC. (RPC histograms took into account a larger geometry and therefore have a larger conversion rate and amount of events).

Conclusion

The results of simulation show that 0.4% - 1.5% of RPC and RMC photons convert into an electron-positron pair. Taking into consideration experimental conditions the Mu2e experiment can expect to see around 150 billion pairs produced in the experiment. If Mu2e chooses to take the approach of direct measurement of RMC and RPC, it will not only account for the background, but also provide valuable data on those processes for potential other use.