PROCEEDINGS OF SCIENCE

Mu2e Straw Tube Tracker

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The Mu2e experiment will search for neutrinoless conversion of muons into electrons in the field of an aluminum nucleus. The signature of this process is an electron with energy nearly equal to the muon mass. Precise and robust measurement of the outgoing electron momentum, combined with other background rejection methods, are essential to the experiment. We rely on a low-mass straw tube tracker to achieve these goals. The tracking system must operate in a vacuum and a 1 Tesla magnetic field. We have chosen to use about 20,000 thin-wall Mylar straws held under tension to avoid the need for supports within the active volume. In addition to measuring distance from the wire by drift time, subnanosecond measurement of signal propagation time will be used to measure the position along the wire. The collected charge will be measured using ADCs to provide particle identification capability. In this talk we will describe details of the Mu2e tracker.

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1. Mu2e Experiment

The Mu2e experiment will search for neutrinoless conversion of muons into electrons in the field of an aluminum nucleus. The signature of this process is a monoenergetic electron with energy nearly 105 MeV, slightly less than the muon mass. Mu2e's measurement will improve the existing sensitivity by four orders of magnitude over previous experiments, achieving a single event sensitivity corresponding to $R_{\mu e}$ of 2.4×10^{-17}, which is more sensitive than the level predicted by many new physics models[2]. Precise and robust measurement of the outgoing electron momentum, combined with other background rejection methods, is essential to the experiment. The Monte Carlo estimation of expected sensitivity and background can be seen in Figure 1.

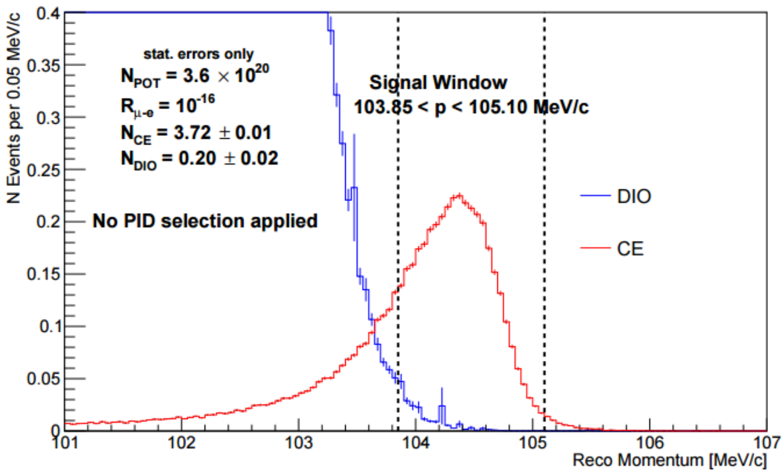

Figure 1: Monte Carlo simulation of estimated signal and background levels from the Mu2e experiment after 3 years assuming a signal rate of 10^{-16}.

2. Tracker design

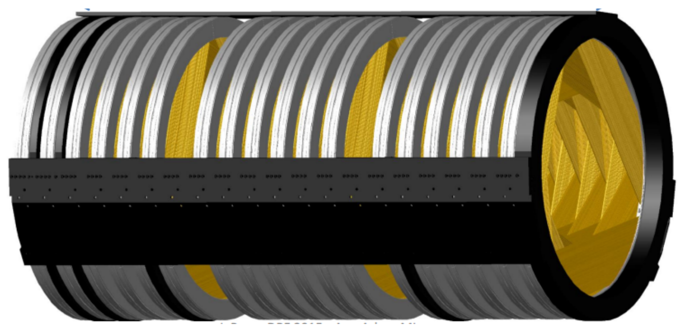

Figure 2: 3D rendering of the full tracker design.

To achieve these goals, we have designed a low-mass straw tube tracker, seen in Figure 2. The tracking system must operate in a vacuum(10^{-4} Torr) and a 1 Tesla magnetic field. We have chosen

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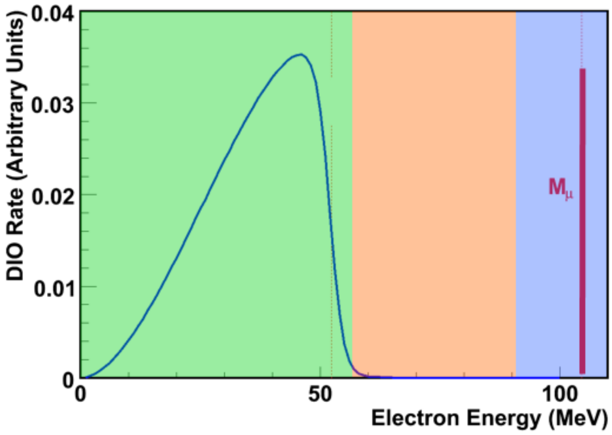
to use 20,736 thin-wall Mylar straws held under tension to avoid the need for supports within the active volume. In addition to measuring the distance from the wire by drift time, a subnanosecond measurement of signal propagation time will be used to measure position along the wire. Charge will be measured using ADCs to provide particle identification capability.

The straw tracker is designed with a central hole that deliberately blinds the detector to low momentum electrons and ensures no material is available to deflect beam particles into the detector as background. This can be seen in Figure 3 by comparing how different momentum tracks will interact with the detector. The colored circles show an expected path for electrons with momentum in certain regions marked by the colors on the left plot. The green region contains almost the entire spectrum of electrons from muons that decay while in orbit around the Al nucleus (DIO) and they pass undetected through the center hole of the detector. Only our signal region, in blue, will leave enough hits in the detector for a reconstructable track.



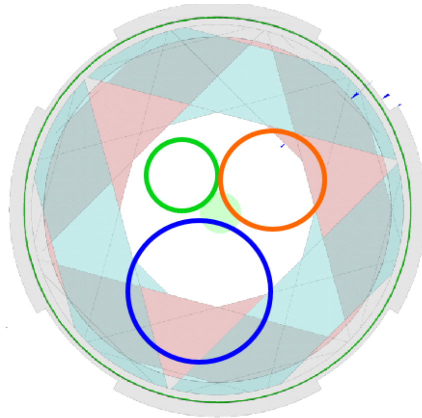


Figure 3: Left plot shows electron momentum for both the decay in orbit electrons and the conversion electrons. The momentum range has been split into three regions marked by color. The right picture shows an expected path of an electron from each region compared to the active detector area.

Mu2e's tracker uses 20,736 double helically wrapped metallized mylar straw tubes. These tubes have a 5 mm diameter and a 15 micron thick wall, which are the thinnest straws used in a straw tube tracker to date. The straw's metallization consists of 500 Å of Aluminum on both the inside and outside, with an additional 200 Å of Gold on the inside. The inside metallization serves as the cathode in the straw tube, while the outside metallization is used to reduce the leak rate of the gas. Though thin, the straws measured have been quite robust, able to withstand 8 ATM pressure difference between the inside and out, and 2.5 kg tension without breaking. Each straw has its leak rate, conductivity (both the inside and out), and length measured before being placed into a panel.

A panel consists of an 120° aluminum manifold constraining the ends of two layers of 48 straws each. The manifold houses the electronics and is separated into two sections in order to flow the $ArCO_2$ gas through the straws. Each panel will have its leak rate tested in vacuum and have the location of all straw tubes and sense wires determined by an X-ray scanner[3].

The panel is the building block of the detector. Three panels connected form a 360° ring and 6 panels connect to form a plane. Two planes combine to form a station; the tracker consists of 18

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stations. The tracker has a outer radius of 700 mm and a length of 3 meters. The length ensures signal electrons will make multiple loops through the straws, increasing resolution and background discrimination. 105 MeV/c electrons will have a momentum resolution less than 180 keV/c.

3. Electronics

Each panel will have a DRAC (Digitizer Readout Assembler and Controller) and a preamp on each end of the straw. The preamp signals are compared separately for timing information and summed together for the total energy deposited into the straw and particle ID. Less than 100 ps time resolution will give us a longitudinal location of the particle to within 3 cm by comparing time from either side of the straw. Using the timing of multiple straw hits the ionized particles drift distance can be determined. Stereo pairs of straw hits can be identified which leads to significant improvement to the track location. An Artificial Neural Network(ANN) will identify stereo pairs of hits and sort out signal from background.

Signal tracks should leave hits in roughly 40 straws as they travel through the detector, which will allow us to precisely calculate the track's path and momentum. Studies have been done to ensure the electronics are radiation hard. High voltage can be shut off to each pair of straws without physical access to the detector to allow the detector to operate with broken wires.

More details on both the tracker and the Mu2e experiment can be found in the technical design report [4].

4. Acknowledgements

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References

[1] Mu2e Collaboration, http://mu2e.fnal.gov/collaboration.shtml

[2] R. H. Bernstein and P. S. Cooper, 10.1016/j.physrep.2013.07.002 https://arxiv.org/abs/1307.5787

[3] S.H. Oh and C. Wang, "An X-ray mapper for the Mu2e experiment" http://dx.doi.org/10.1016/j.nima.2015.09.083

[4] Mu2e Collaboration, Mu2e Technical Design Report, http://arxiv.org/abs/1501.05241, 2015

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