Mu2e at Fermilab

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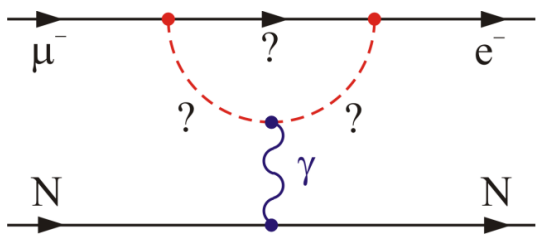
Overview

Introduction to CLFV

- Charged Lepton Flavor Violation (CLFV) is the coherent transition of a lepton flavor to another flavor
- Standard Model does not have measurable description of CLFV, so detection indicates physics beyond the Standard Model

  $\mu^- \rightarrow e^- + \bar{\nu_e} + \nu_\mu$
- Sensitivity of experiment gives best chance to see this phenomenon



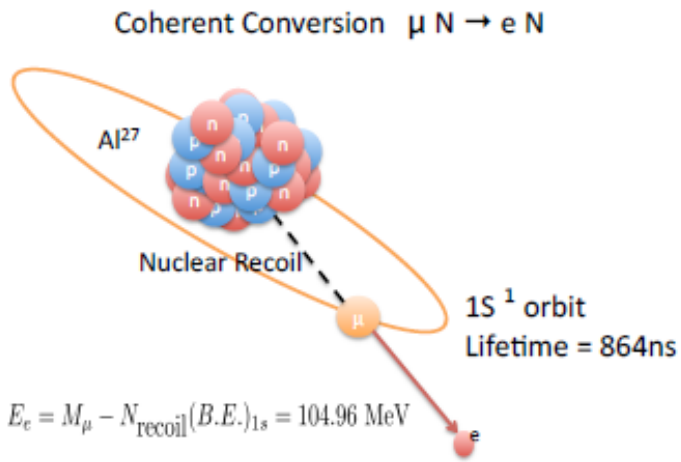
Measuring Mu2e

- Experiment seeks CLFV with muons in the field of Al nuclei

$$\mu^- + Al \rightarrow e^- + Al$$

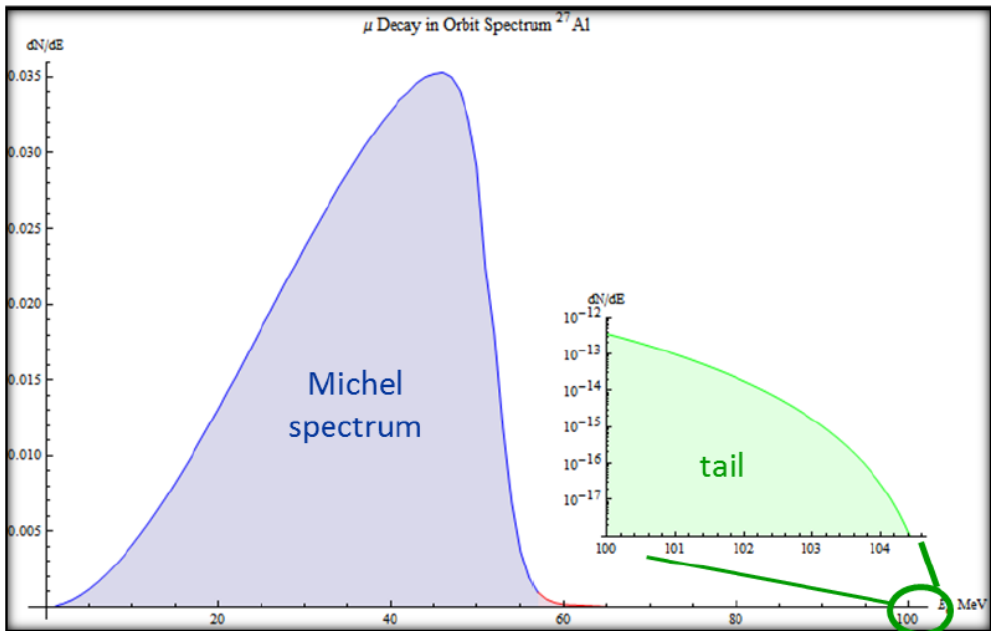
- Stopped muons occupies 1s state in nucleus forming muonic atoms where it decays
- Signal electron emitted with energy 105 MeV (rest mass of μ)
- Experiment will measure ratio of $\mu \rightarrow e$ conversions to number of μ captures

$$R_{\mu e} = \frac{\Gamma[\mu^- + A(Z,N) \rightarrow e^- + A(Z,N)]}{\Gamma[\mu^- + A(Z,N) \rightarrow \nu_\mu + A(Z-1,N+1)]}$$



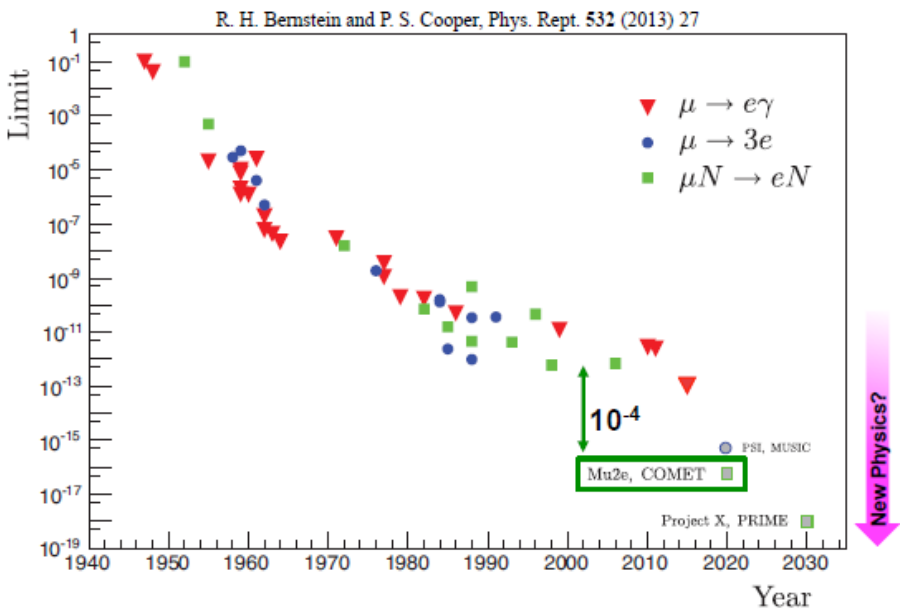
Sources of Background

- 0.41 total background events in 3 year running at design intensity
- Muon Decay in Orbit DIO: 53%
- Anti-Protons: 24%
- Cosmic Rays: 12%
- Other Background: 11%



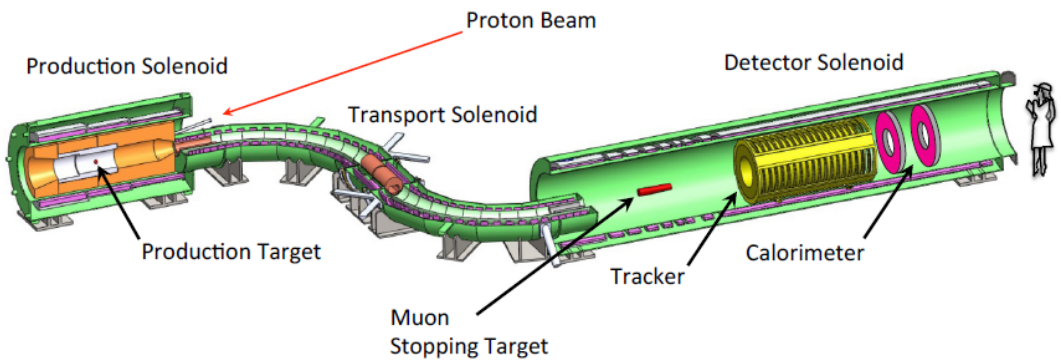
Achieving Mu2e Sensitivity

- Single event sensitivity of 2.87×10^{-17} (10^4 improvement in sensitivity)
- Mass reach on the order of 1000 TeV (far heavier than direct reach of LHC)
- Far more muons on target
- Apparatus strategically designed to remove significant amount of background
- More time between proton pulses allows significant dissipation of background before signal window



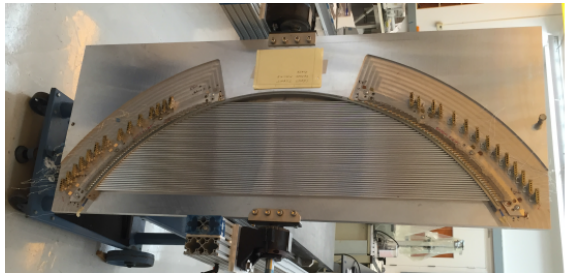
Experimental Apparatus

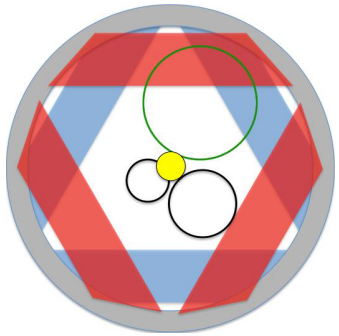
- Pulsed 8 GeV proton beam sent to W production target
- S shaped solenoid selects negative particles and allows remaining pions to decay to muons
- Muons stop at Al stopping target where electron is emitted isotropically
- Annular design of tracker detects fine range of electron energy
- Apparatus will be located at Fermilab

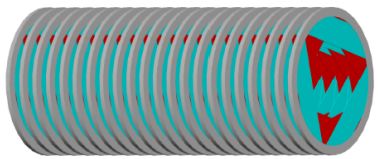


Tracker Design

- Tracker composed of stacked planes, each containing 6 panels
- Each panel contains 96 straws filled with 80:20 Ar CO_2 mixture
- Magnetic field applied along the axis at 1 T to create helical path of charged particles
- Tracker evacuated to maintain predictable electron trajectory
- Geometry of tracker designed to see only high energy electrons

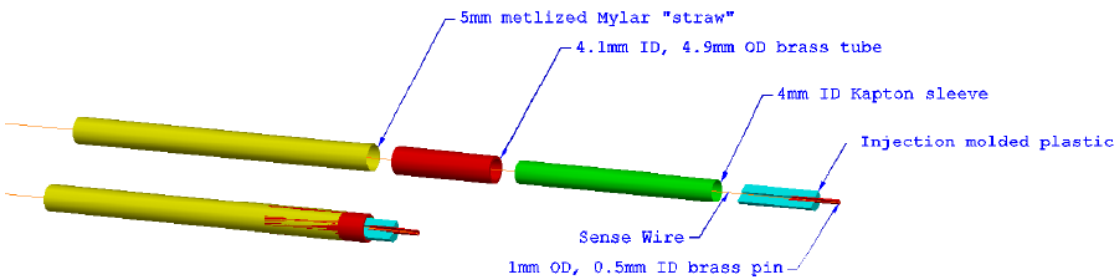






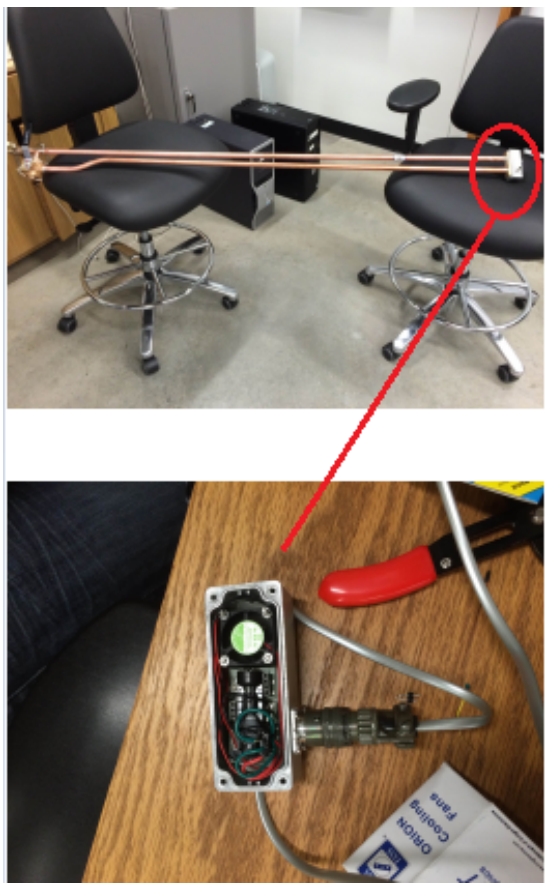
Seeing Signal with Straws

- Straws have 15 μm thick mylar walls which surround 25 μm diameter, Gold plated, Tungsten sense wires
- Interior and exterior coated with Aluminum
- Inner Aluminum coated with Gold, which makes outer wall cathode
- Ar is ionized by charged particle and signal is collected by the sense wire
- CO_2 easily permeates through mylar



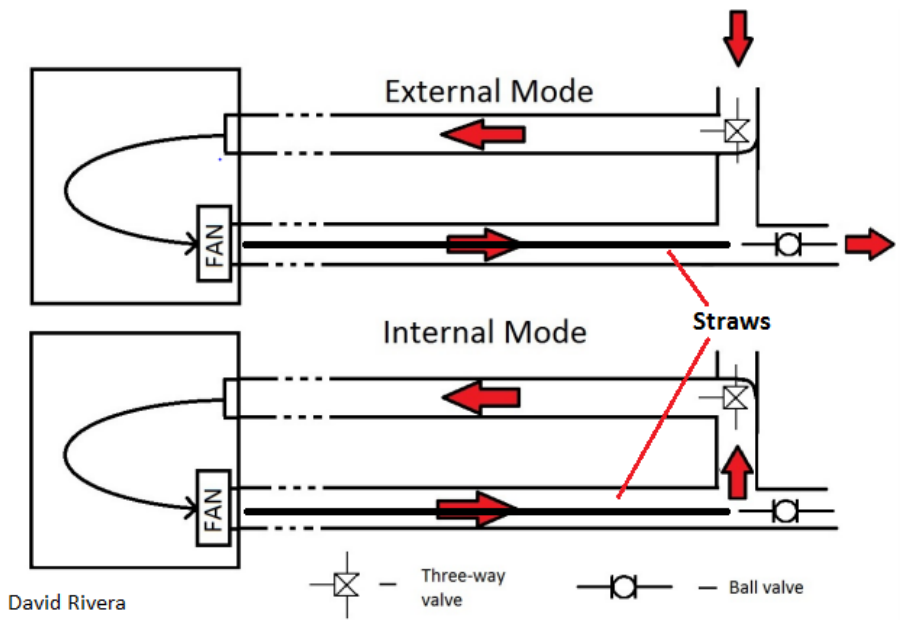
Leak Test Apparatus

- The leak rate of each straw will be measured in the apparatus
- Straw pressurized 1 atm higher than ambient pressure with 50:50 Ar CO_2 mixture
- CO_2 detector inside of detector box along with fan to circulate gas



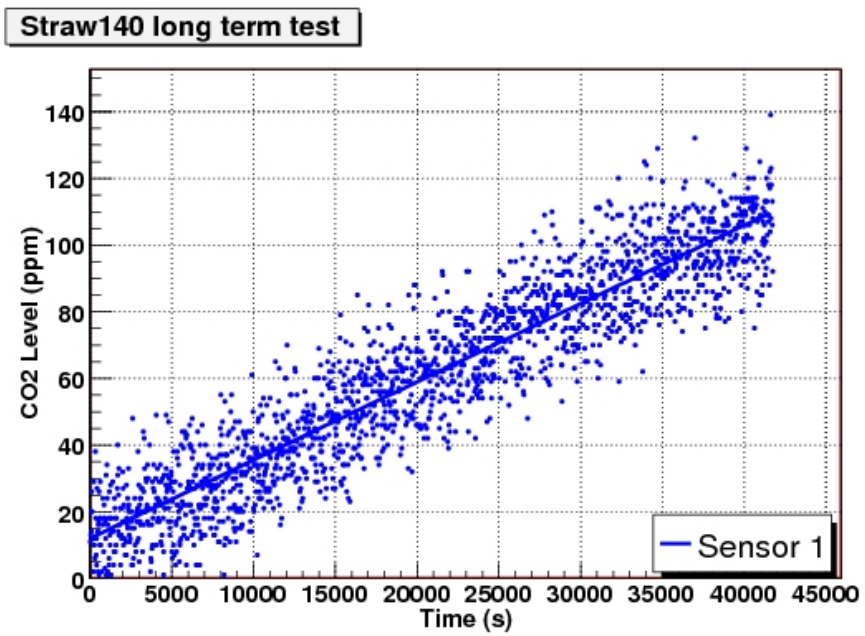
Determining Leak Rate

- Controlled insertion of CO_2 into internal mode used as calibration
- Gives us the volume of the chamber
- N_2 flushed through chamber in external mode
- CO_2 detector measures the change in CO_2 concentration as a function of time



Results

- Leak rate determined to be $1.8 \times 10^{-}5$ ccm
- Leak rate ceiling is $30 \times 10^{-}5$ ccm
- Straw leak rate lower than maximum allowed leak rate



Summary

- Measuring CLFV transition of $\mu \rightarrow e$ indicates physics beyond the Standard Model
- Mu2e has single event sensitivity of 2.87×10^{-17}
- Tracker design crucial for finding signal electrons
- All of the straws in the tracker need to be leak tested to ensure quality of the vacuum
- Lower limit of mass reach established if $\mu \rightarrow e$ not observed