# The Mu2e Experiment

Andrew Vold

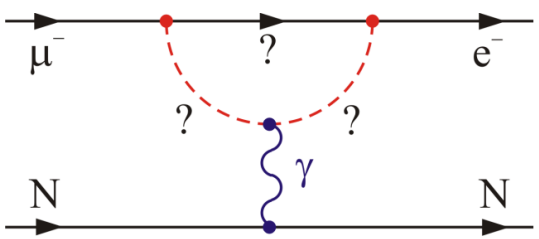
University of Minnesota

April 11, 2015

# Overview

# Introduction to CLFV

- Charged Lepton Flavor Violation (CLFV) is when the total lepton flavor is not conserved in an interaction
- Standard Model process is $\mu^- \rightarrow e^- + \bar{\nu}_e + \nu_\mu$
- Transition rate $< 10^{-50}$, so observation indicates physics beyond the Standard Model
- Sensitivity of experiment gives best chance to see this phenomenon



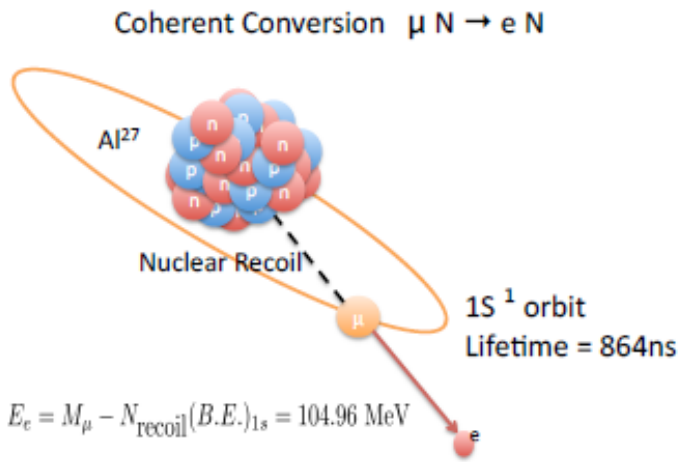
# Measuring Mu2e

- 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 $\mu$)
- Experiment will measure ratio of $\mu \rightarrow e$ conversions to number of $\mu$ captures

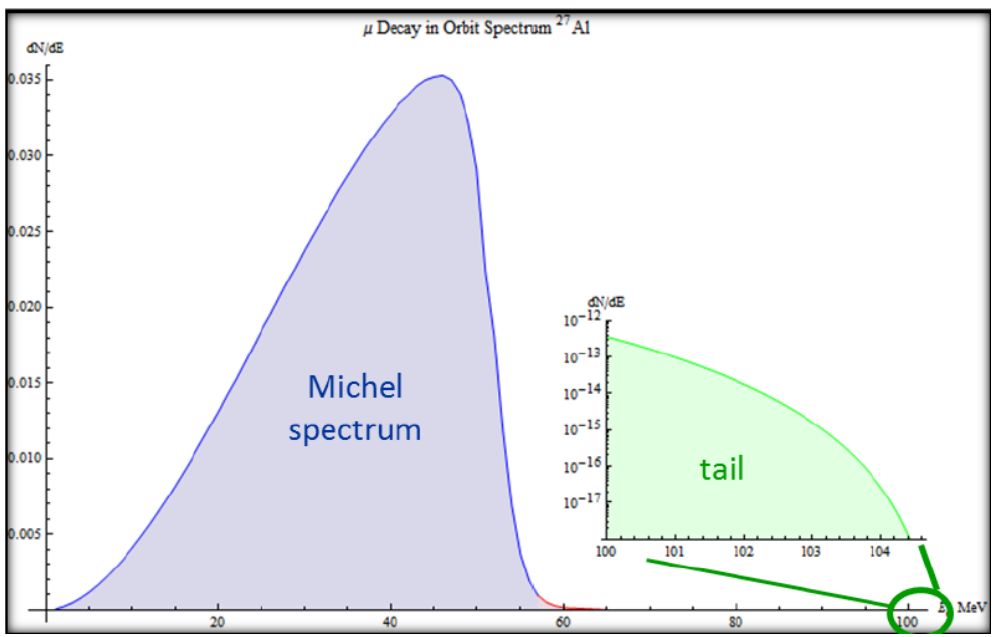
$$R_{\mu e} = \frac{\Gamma[\mu^- + A(Z,N) \rightarrow e^- + A(Z,N)]}{\Gamma[\mu^- + A(Z,N) \rightarrow \nu_\mu + A(Z-1,N+1)]}$$




A. Norman

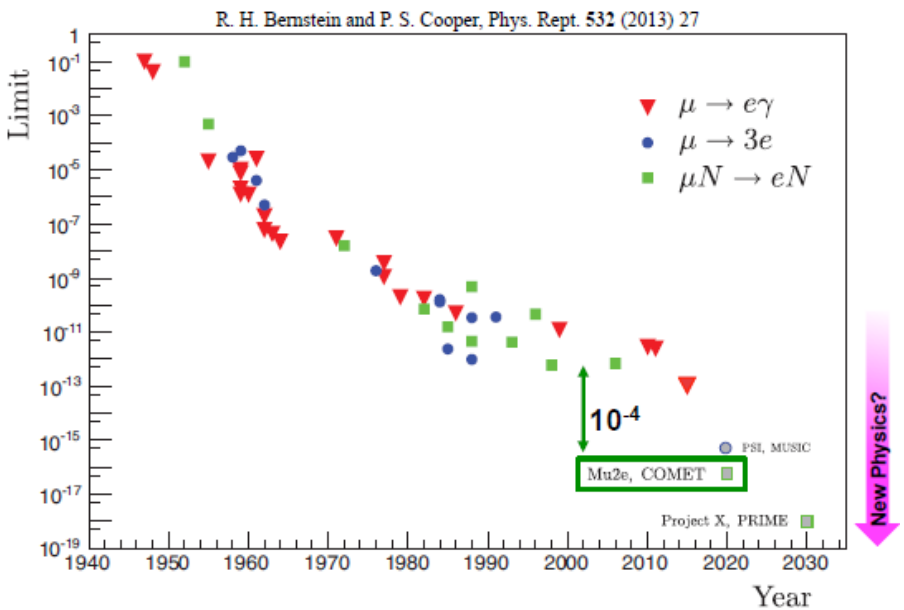
# Sources of Background

- 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%



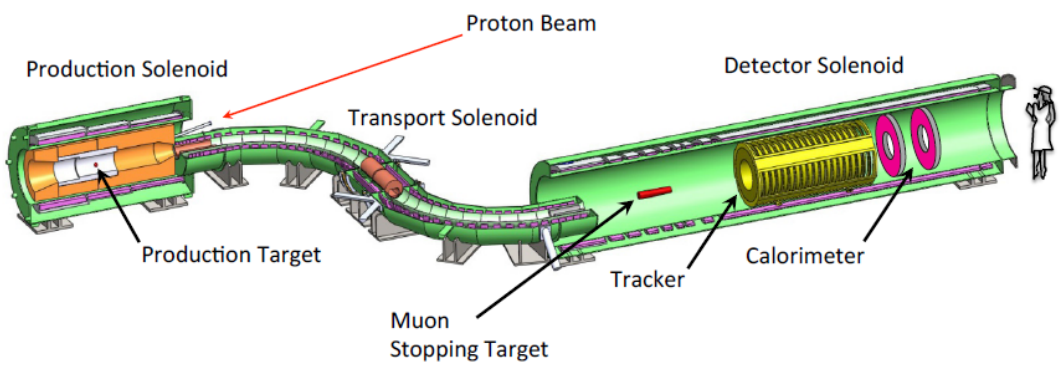
# Achieving Mu2e Sensitivity

- Single event sensitivity of $2.87 \times 10^{-17}$ ($10^4$ 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



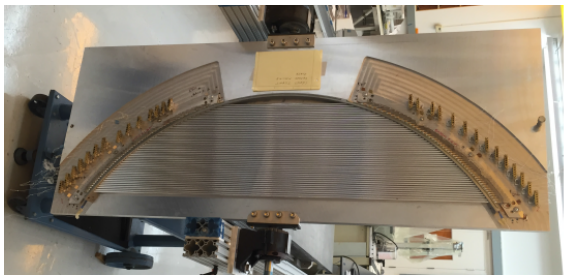
# Experimental Apparatus

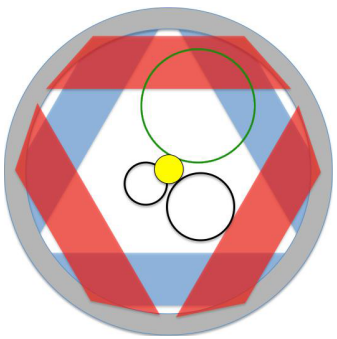
- Pulsed 8 GeV proton beam sent to W production target
- S shaped solenoid selects negative particles and allows remaining pions to decay to muons
- Muons stop at Al stopping target where electron is emitted isotropically
- Annular design of tracker detects fine range of electron energy
- Experiment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

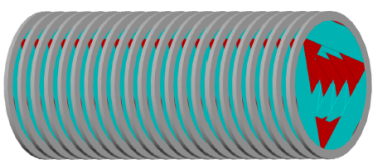


# Tracker Design

- 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 signal energy electrons

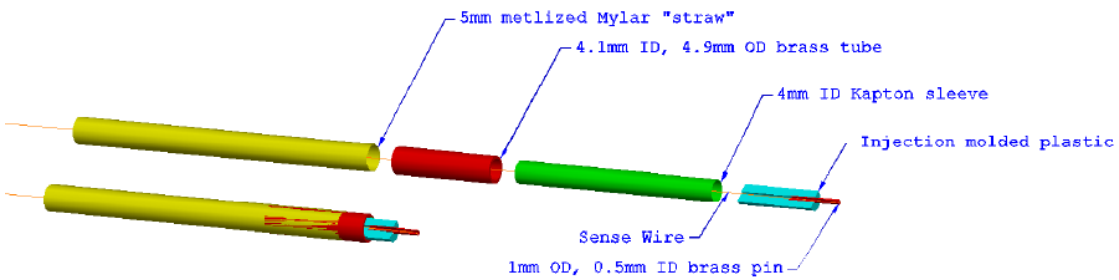






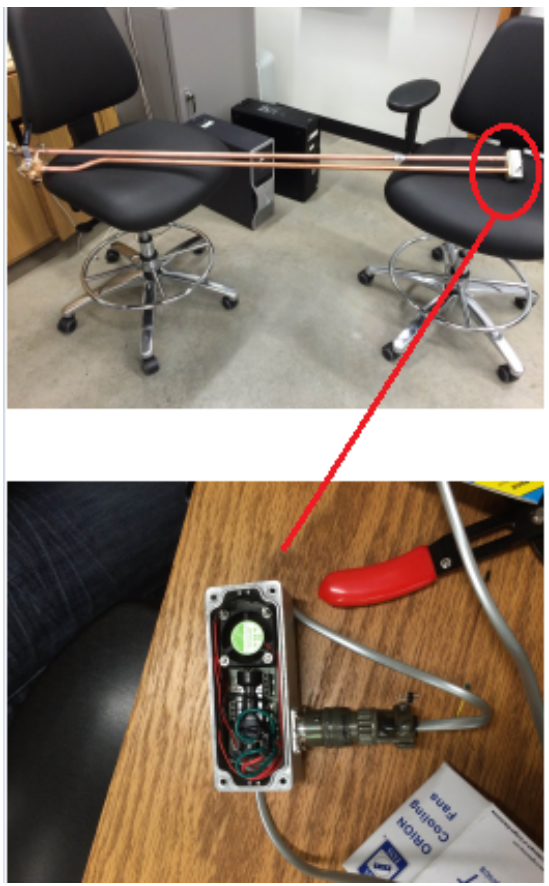
# Seeing Signal with Straws

- Straws have 15 $\mu m$ thick mylar walls which surround 25 $\mu m$ 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



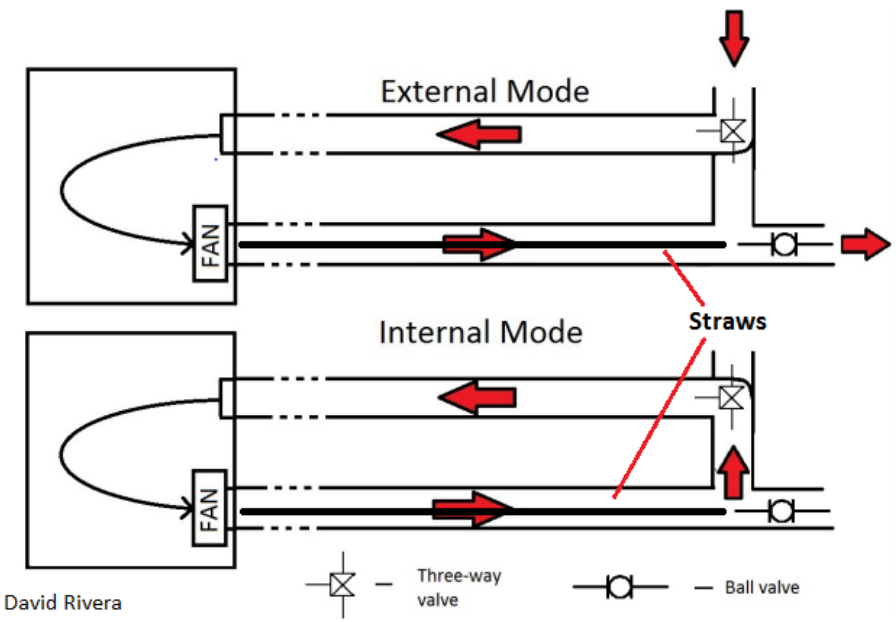
# Leak Test Apparatus

- 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



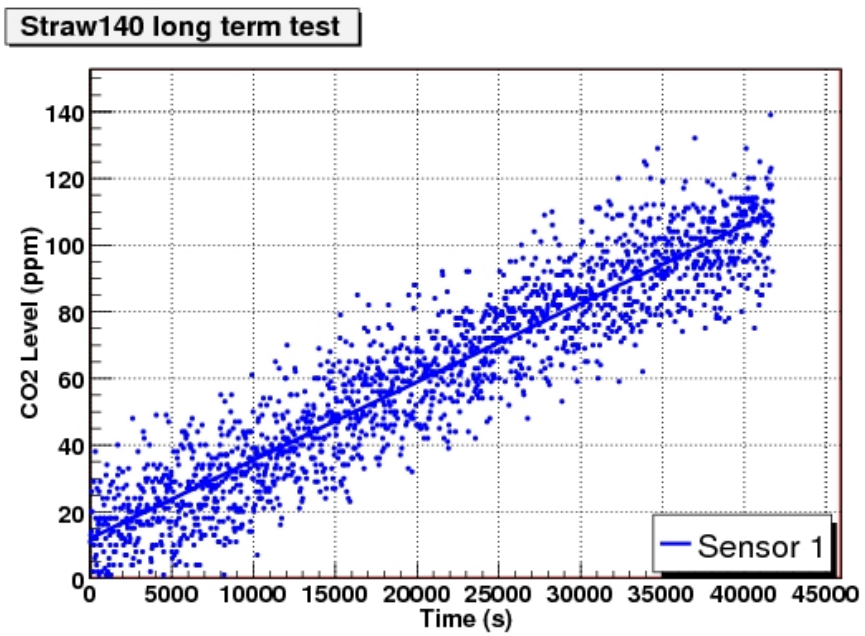
# Determining Leak Rate

- 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 from straw leakage 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 $2.87 \times 10^{-17}$
- 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