

# The Mu2e Experiment



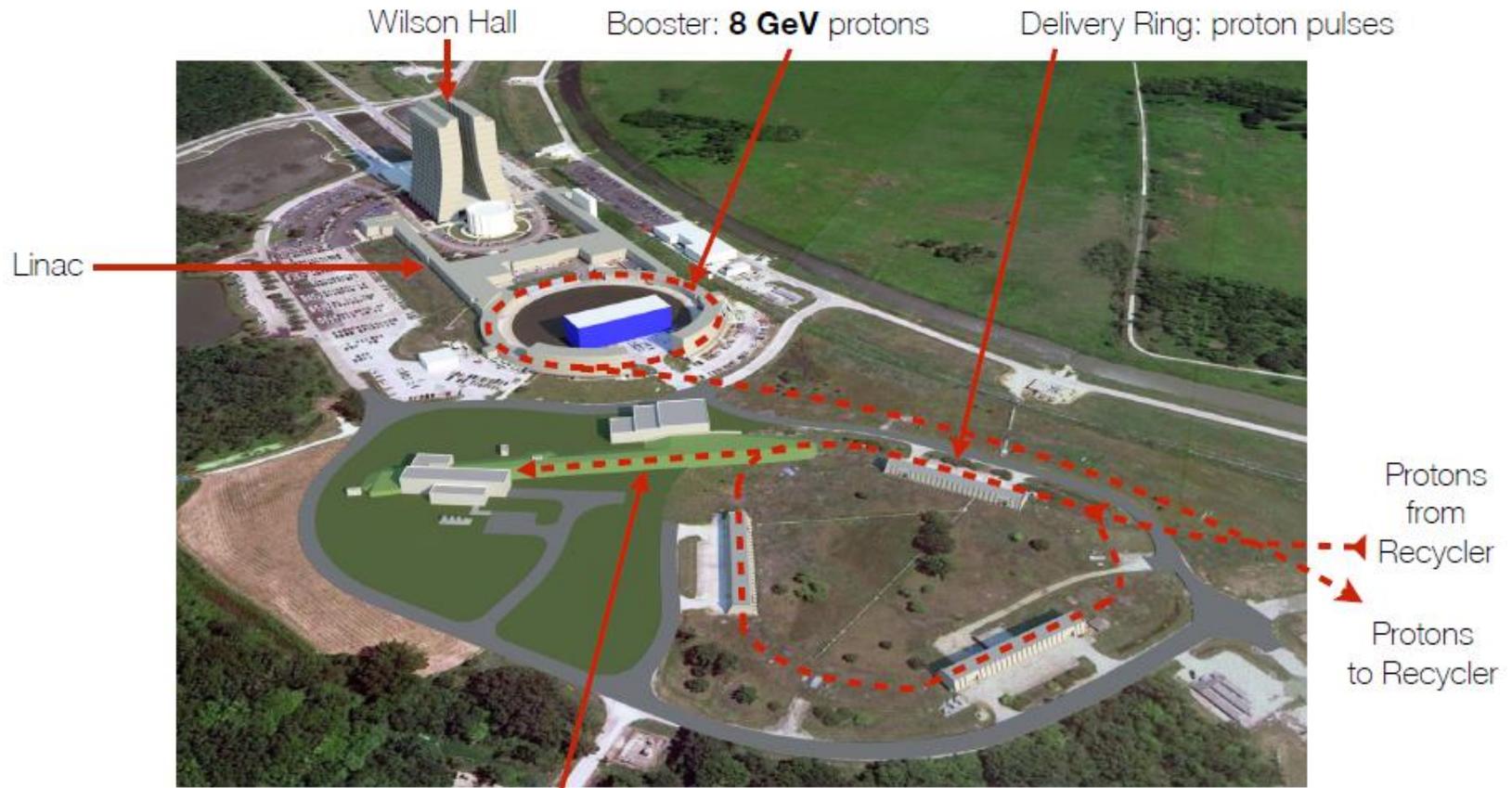
Dan Ambrose  
 University of Minnesota  
 May 31, 2016

# How do we measure $2.5 \times 10^{-17}$ ?

- Stop  $10^{18}$  Muons in Aluminum stopping target
- Momentum resolution  $\sigma < 180 \text{ keV}/c$
- Reduce expected background to less than 1 event over full run period.

Tall tasks, but the accelerator and Mu2e have been designed to accomplish this.

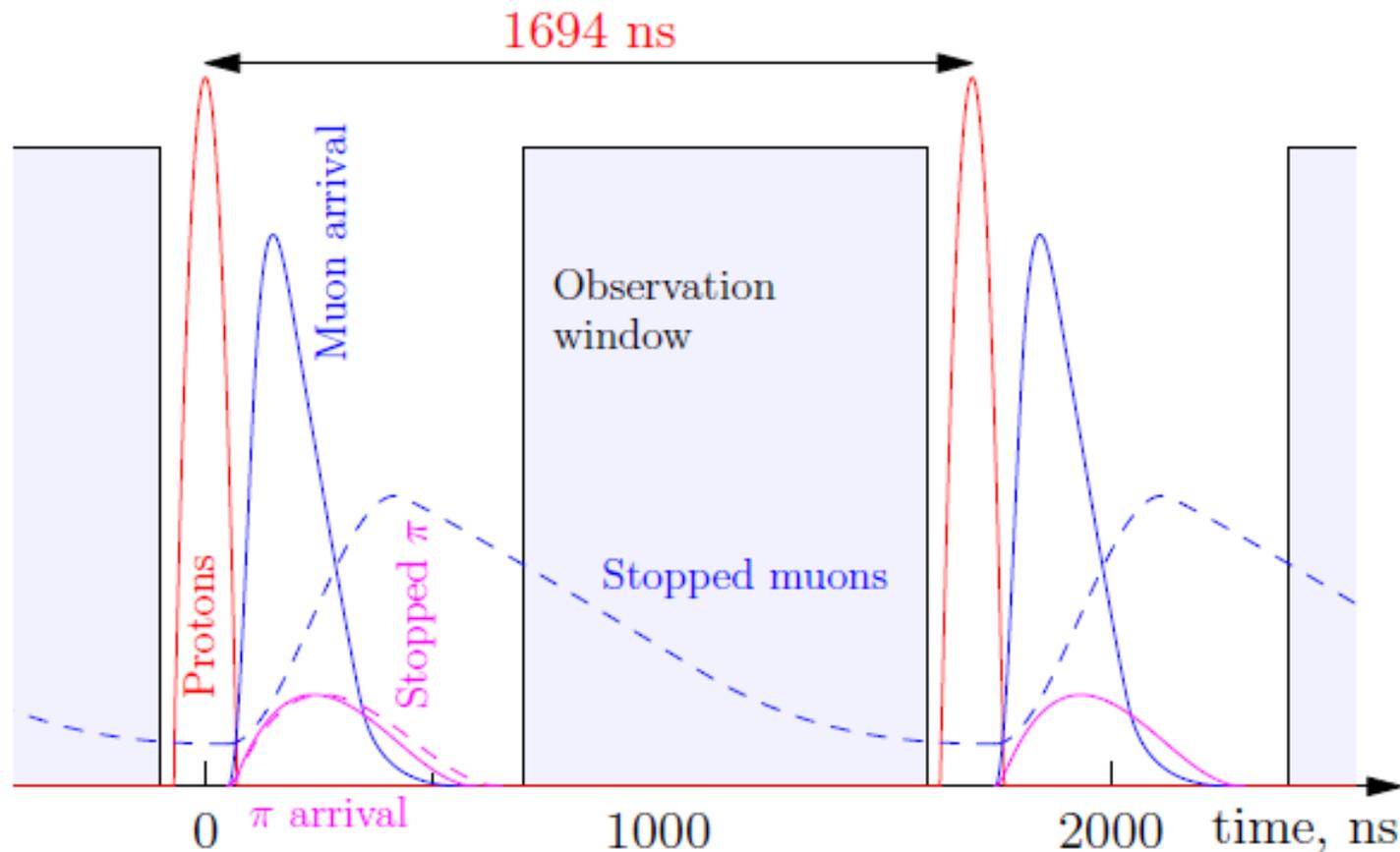
# Proton Path



Protons to  
mu2e every  
1694 ns  
(~600 kHz)

$3.6 \times 10^{20}$  total protons on target  
 $3.1 \times 10^7$  protons per bunch  
Share the beam with NOvA and g-2

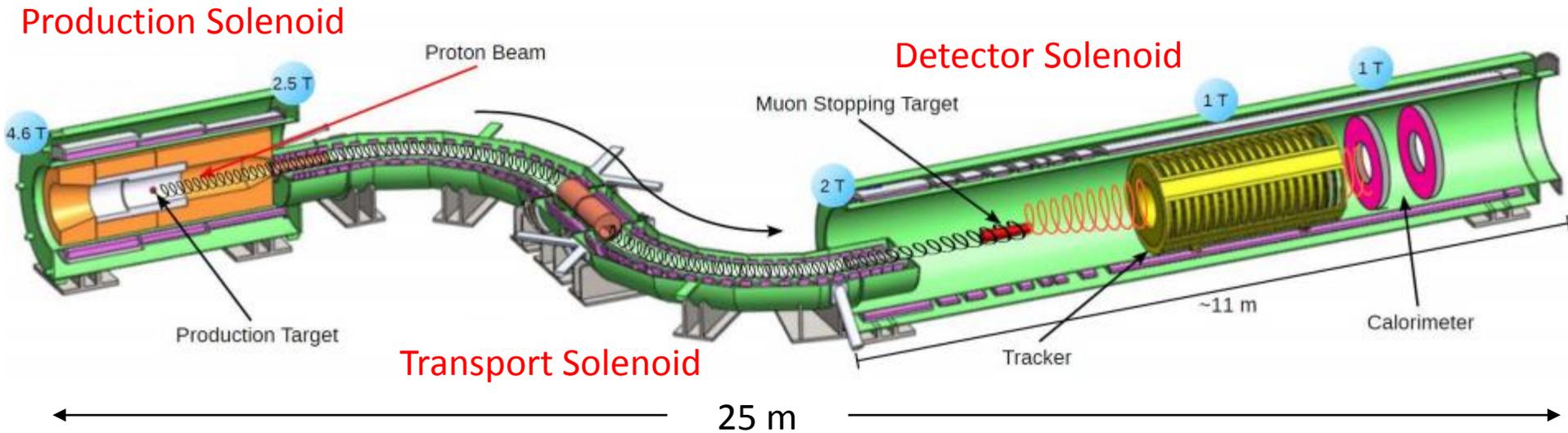
# Beam Time



- ~20,000 muons per bunch
- $10^{10}$  muons per second

Almost all protons, unstopped muons, stopped and unstopped pions will be through the detector before observation window.

# Mu2e Design



3 main components: Production Solenoid (PS), Transport Solenoid (TS), and Detector Solenoid (DS)

Experimental setup contained within vacuum space

Gradient magnetic field ( $4.6 \text{ T} \rightarrow 1 \text{ T}$ ) moves charged particles downstream

Step 1:

8 GeV proton beam hits tungsten target and produces Pions in PS

Pions decaying into muons are pushed downstream towards TS

Step 2:

TS selects particles based on charge and momentum

TS collimators eliminate backgrounds

Step 3:

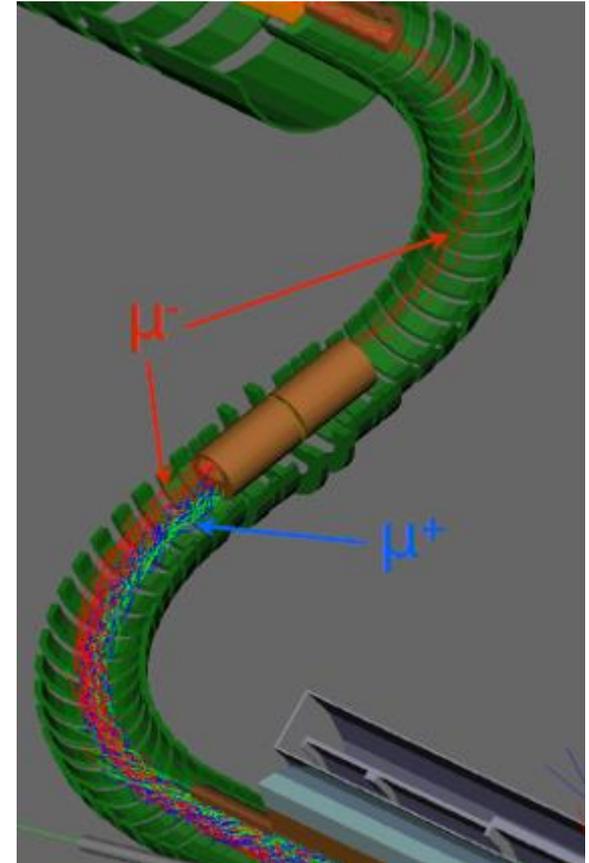
Muons are captured in Aluminum target foils

Conversion electron trajectories measured and validated in tracker and calorimeter

# Transport Solenoid

- 'S' Shape blocks line-of-sight particles
- Bend creates a charge and momentum dependent vertical shift
- Asymmetric collimator rejects positive and high momentum particles.
  - Collimator can be rotated for opposite selection to test background.

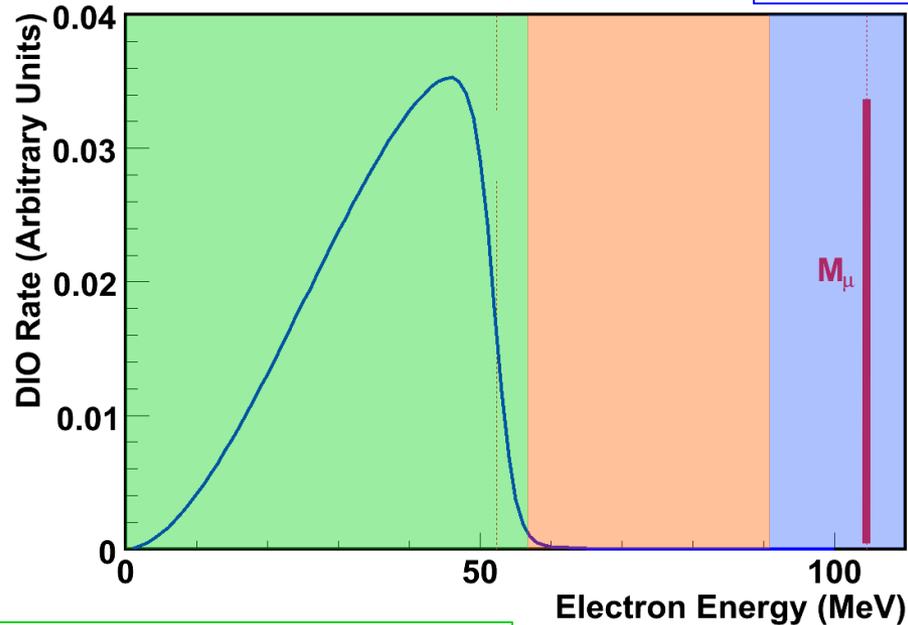
Detector Solenoid



Production Solenoid

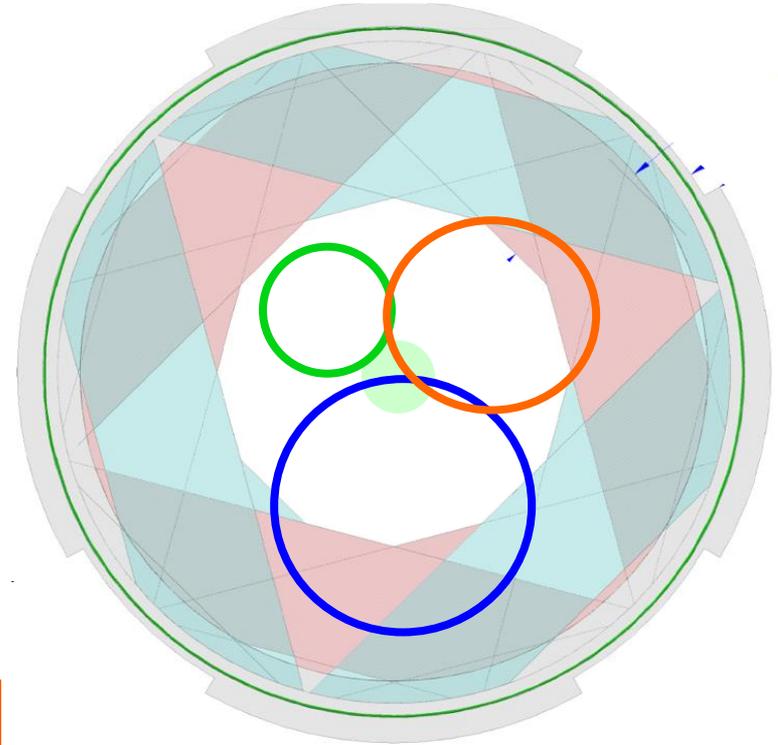
# Tracker is blind to most background

Reconstructable tracks



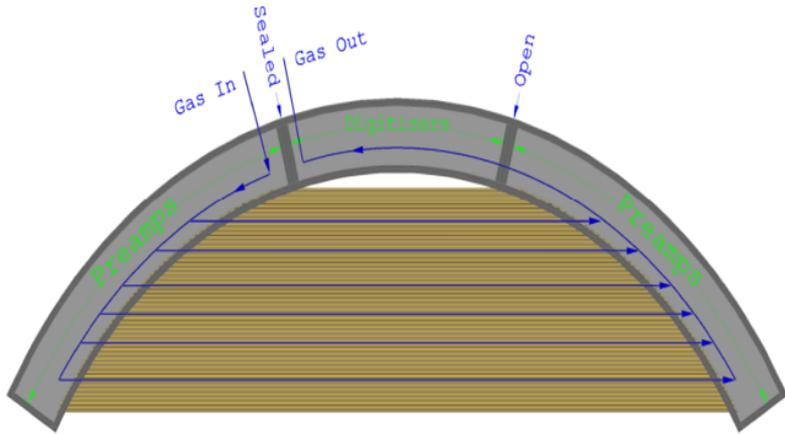
No hits in detector

Some hits in detector.  
Tracks not reconstructable.

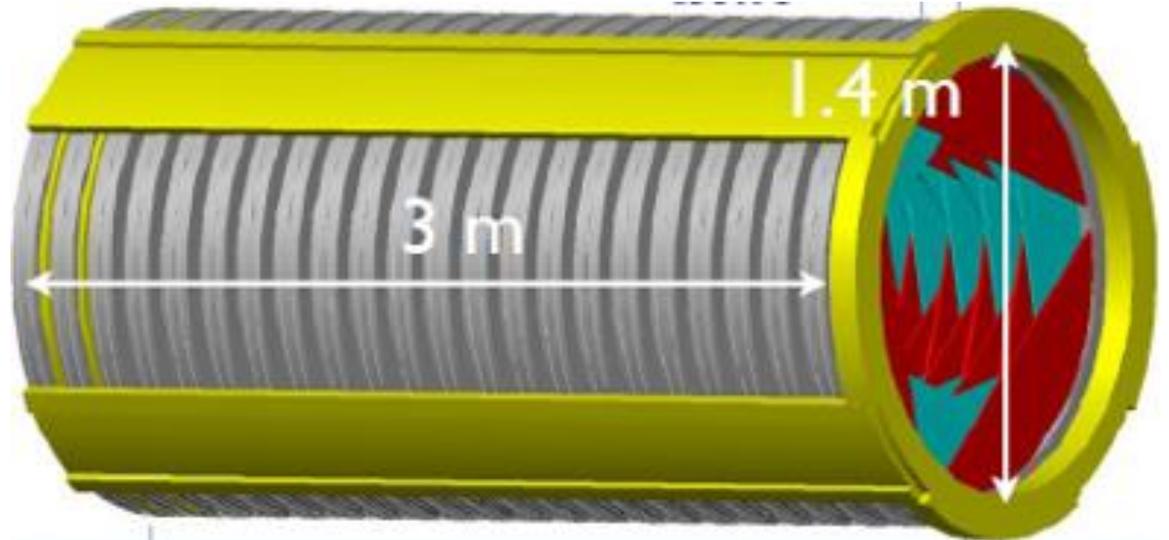
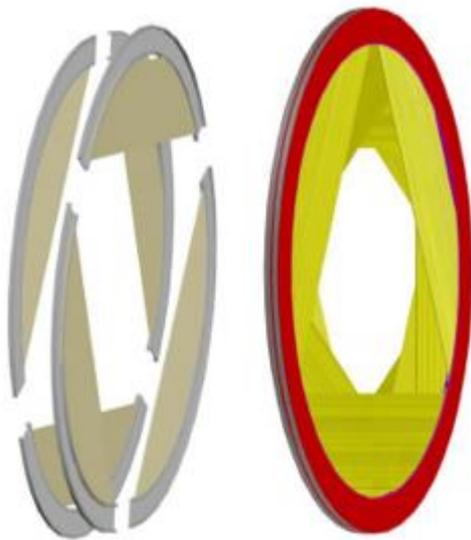


Beam's-eye view of Tracker

# Low Mass Tracker Design

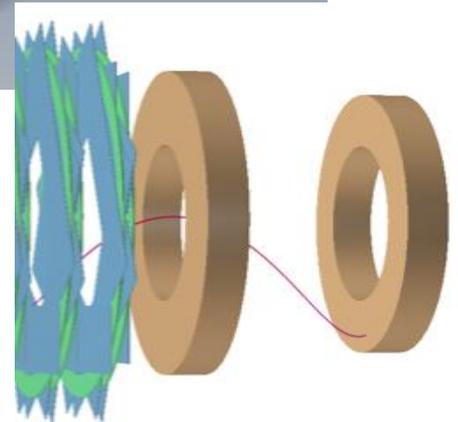
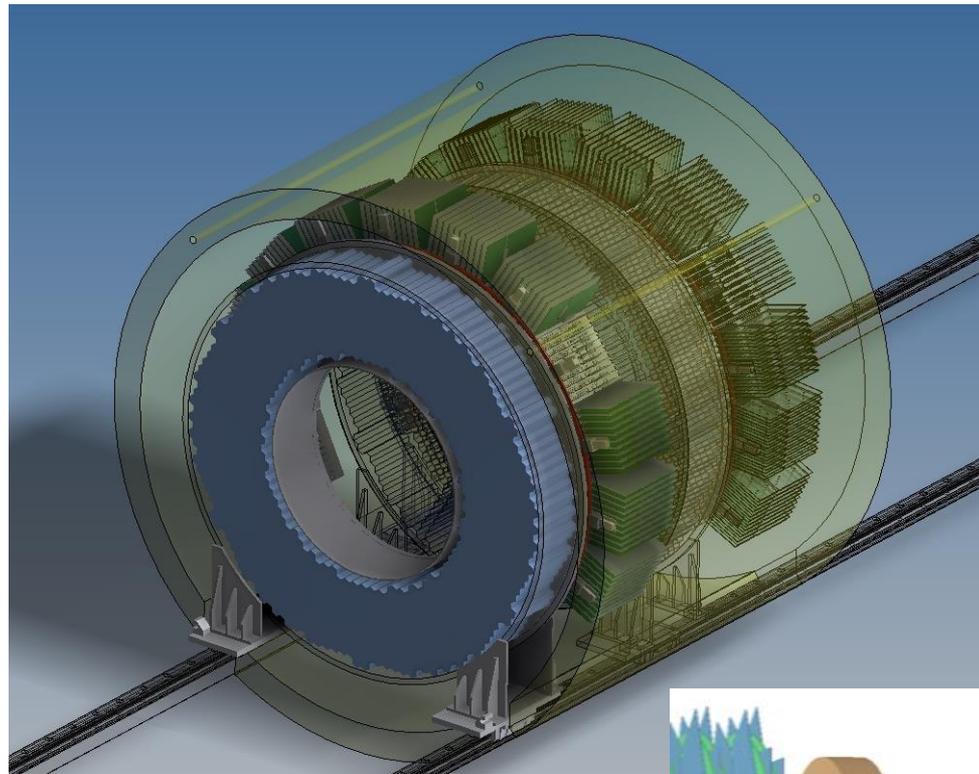


- Excellent momentum resolution better than 180 KeV/c
  - 15 micron thick Mylar straws provide for a very low mass detector
- \*More about the straws later



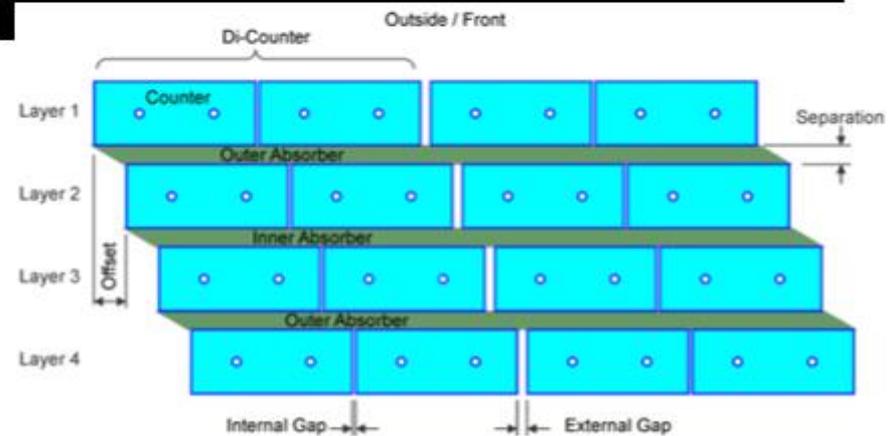
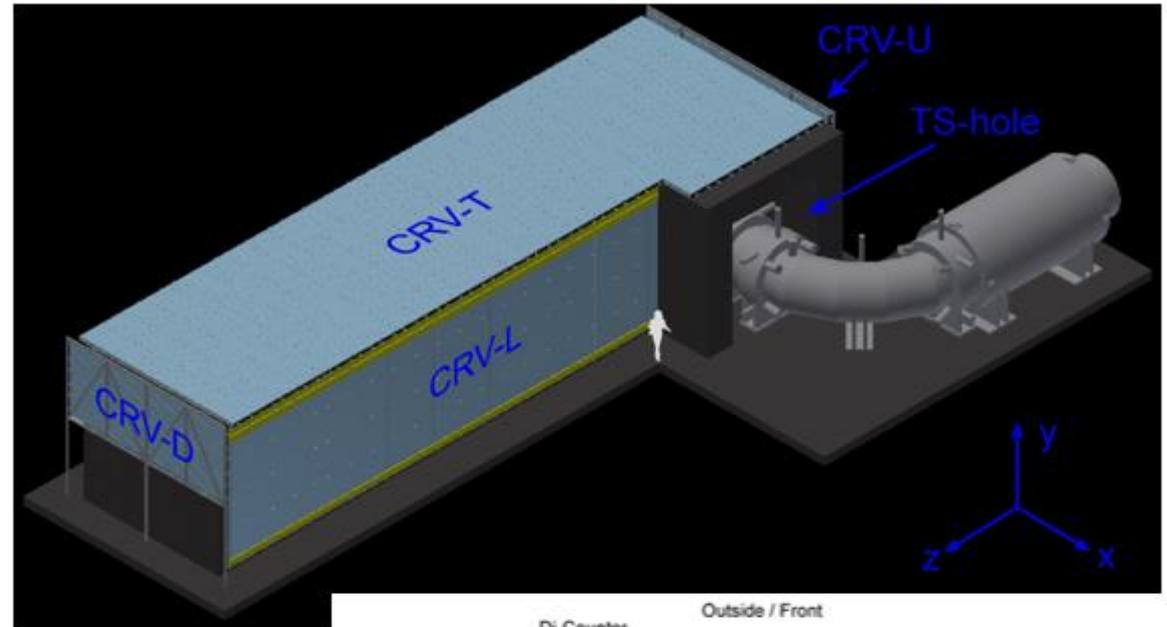
# Calorimeter

- Consists of 2 disks
- 800 BaF<sub>2</sub> crystals per disk
  - 3x3x20 cm (10 X<sub>0</sub>)
- Provides particle identification via timing and energy measurements
- Good timing (<1 ns) and energy resolution (5%)

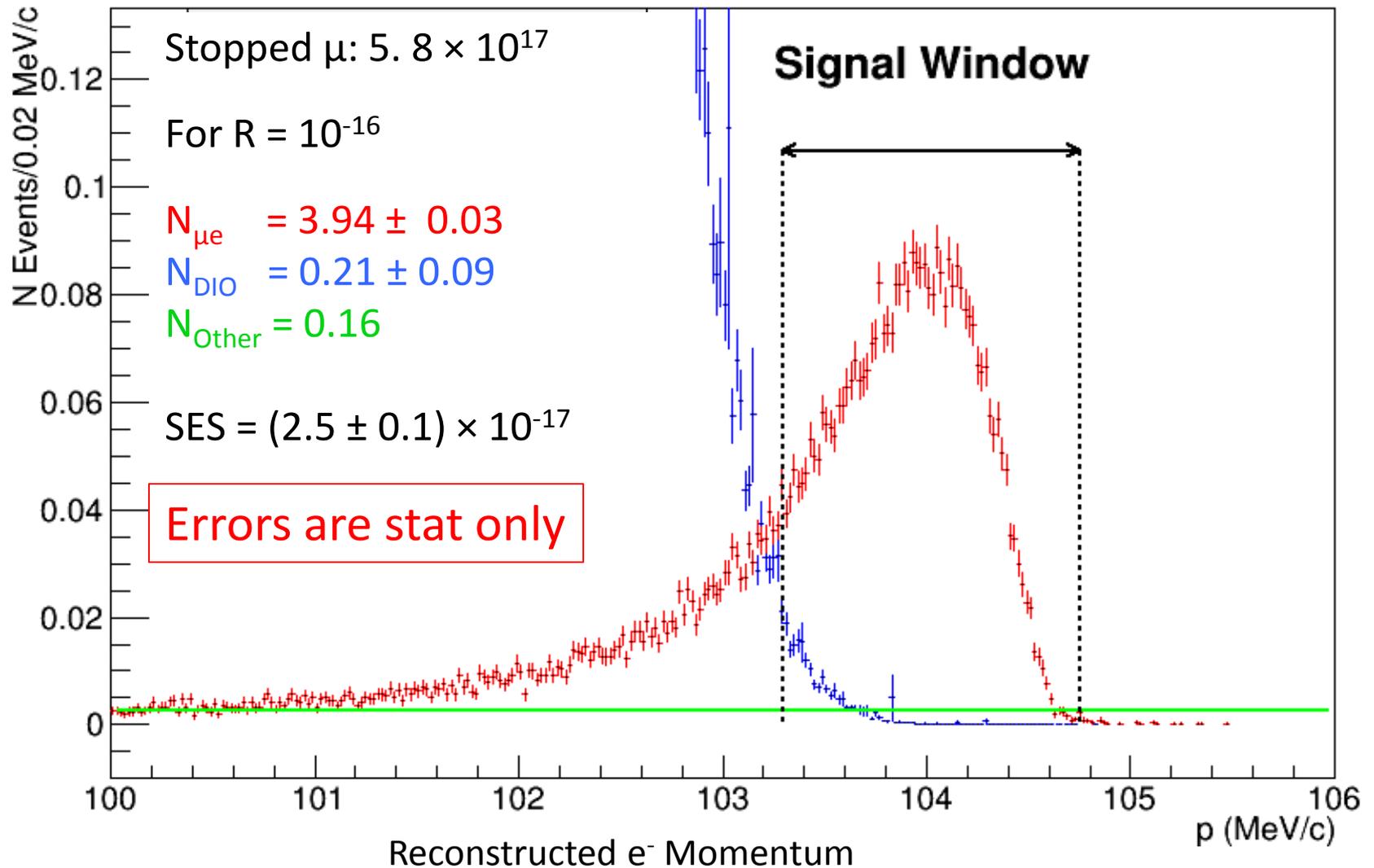


# Cosmic Ray Veto (CRV)

- The CRV covers all of DS and half of TS
- Without CRV, expect  $\sim 1$  cosmic-ray-induced background event per day (99.99% net efficiency)
- The CRV consists of 4 layers of scintillator strips with wavelength shifter and aluminum absorber



# Signal Sensitivity for 3 Year Run



# Mu2e backgrounds

Category	Source	Events
	$\mu$ Decay in Orbit	$0.21 \pm 0.09$
$\mu$ -Intrinsic	Radiative $\mu$ Capture	$<0.01$
	Radiative $\pi$ Capture	$0.023 \pm 0.006$
	Beam electrons	$0.003 \pm 0.001$
	$\mu$ Decay in Flight	$<0.003$
	$\pi$ Decay in Flight	$<0.001$
Out-of-Time	Antiproton induced	$0.047 \pm 0.024$
	Cosmic Ray induced	$0.096 \pm 0.020$
Other	Pat. Recognition Errors	$<0.01$
<b>Total Background</b>		<b><math>0.37 \pm 0.10</math></b>

\*Assuming  $6 \times 10^{17}$  stopped muons in  $6 \times 10^7$  sec of beam time

Less than 1 background event allows us to reach desired single event sensitivity

# The Mu2e Collaboration

## Member Universities:

[Boston University](#)  
[University of California, Berkeley](#)  
[University of California, Irvine](#)  
[California Institute of Technology](#)  
[City University of New York](#)  
[Duke University](#)  
[University of Houston](#)  
[University of Illinois, Urbana-Champaign](#)  
[Kansas State University](#)  
[Lewis University](#)  
[University of Louisville](#)  
[University of Minnesota, Twin Cities](#)  
[Northern Illinois University](#)  
[Northwestern University](#)  
[Novosibirsk State University, Russia](#)  
[Universita di Pisa, Pisa, Italy](#)  
[Purdue University](#)  
[University of Southern Alabama](#)  
[Rice University](#)  
[Universita del Salento, Lecce, Italy](#)  
[University of Virginia](#)  
[University of Washington](#)  
[Yale University](#)



- ~200 members
- 33 institutions
- 4 countries

# The Mu2e Tracker Group

The tracker is the key detector in the Mu2e experiment and we have a top-notch group building and developing it.

**Fermilab** : Aseet Mukherjee, Bob Wagner, Vadim Rusu and others

**Rice** : Marj Corcoran

**Berkley** : Dave Brown

**Duke** : Seog Oh

**Houston** : Ed Hungerford

**York** : Jim Popp, Kevin Lynch

**Minnesota** : Dan Hennessy

# Summary

- The Mu2e project has a design which will allow for a single event sensitivity of  $2.5 \times 10^{-17}$ .