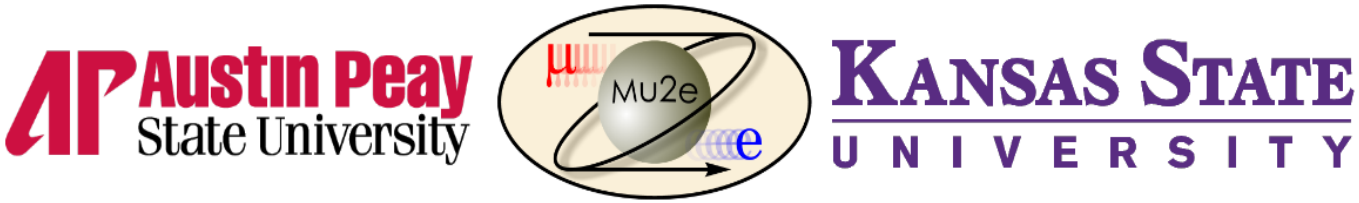
Effects of Single Counter Efficiencies on Mu2e Sensitivity and Mitigation Strategy for Individual Counter Efficiency Deficits

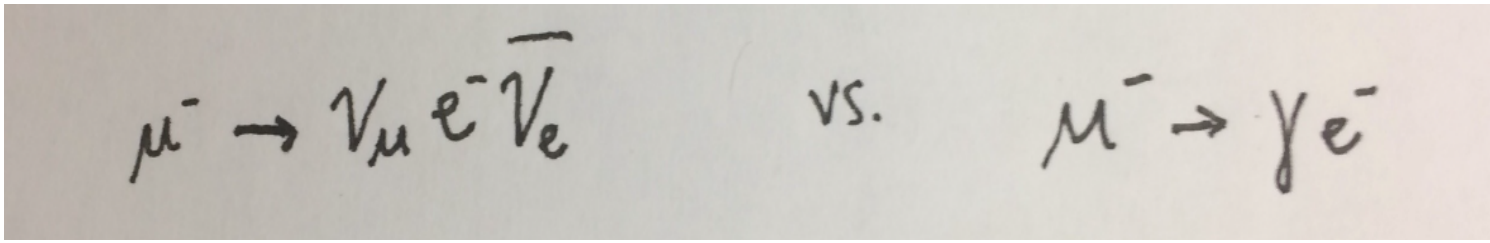


Jo Lynn Tyner,
Tim Bolton, Glenn Horton-Smith

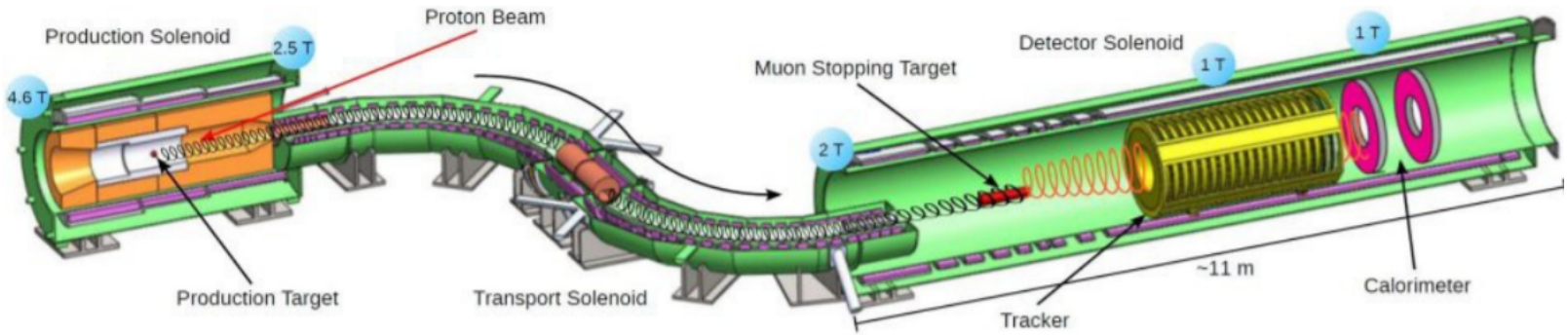
August 4, 2017

Background

- The mission of the Mu2e (Muon to Electron Conversion) experiment is to observe a muon to electron conversion. This observation would be evidence of a charged lepton flavor violation process, thereby putting into question some parts of the Standard Model.

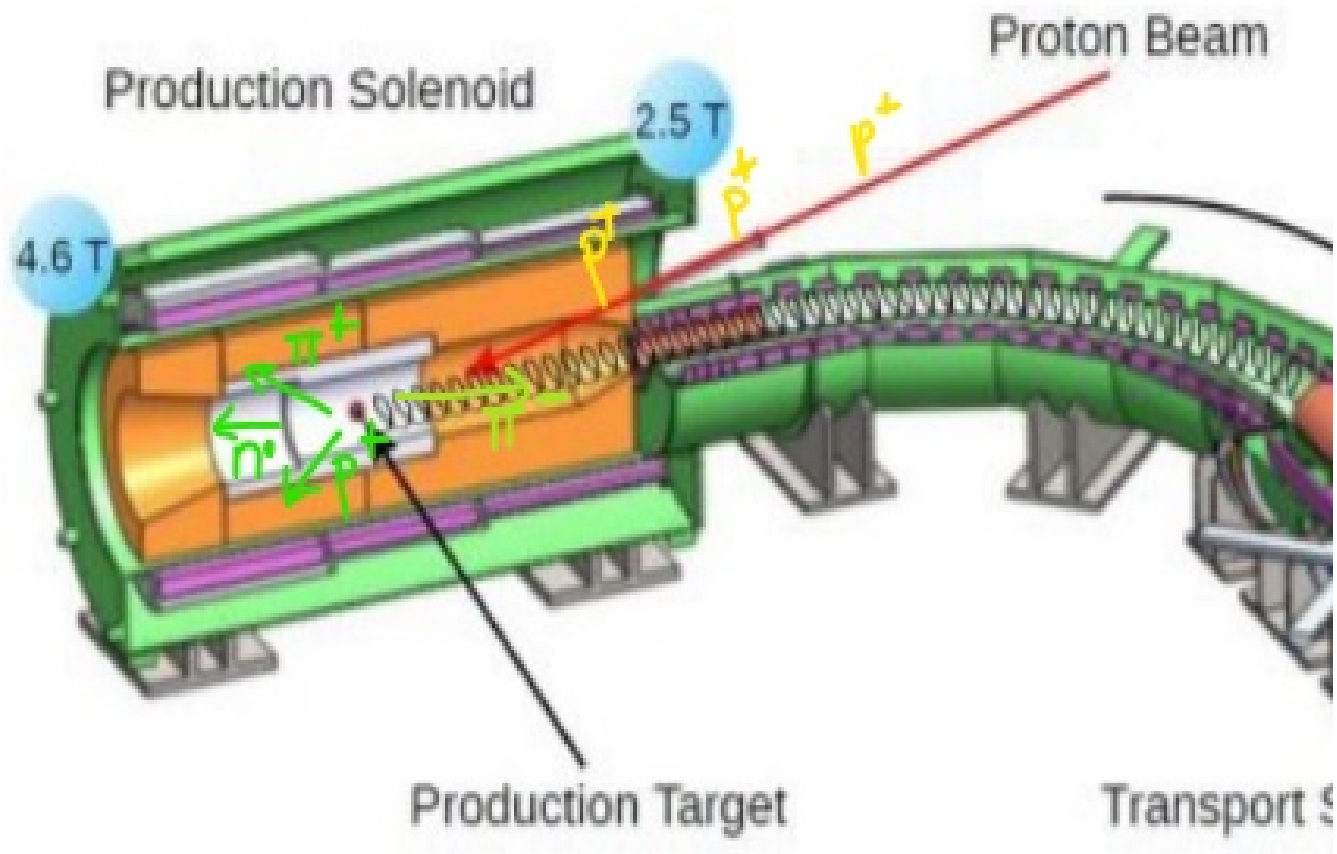


Mu2e Layout

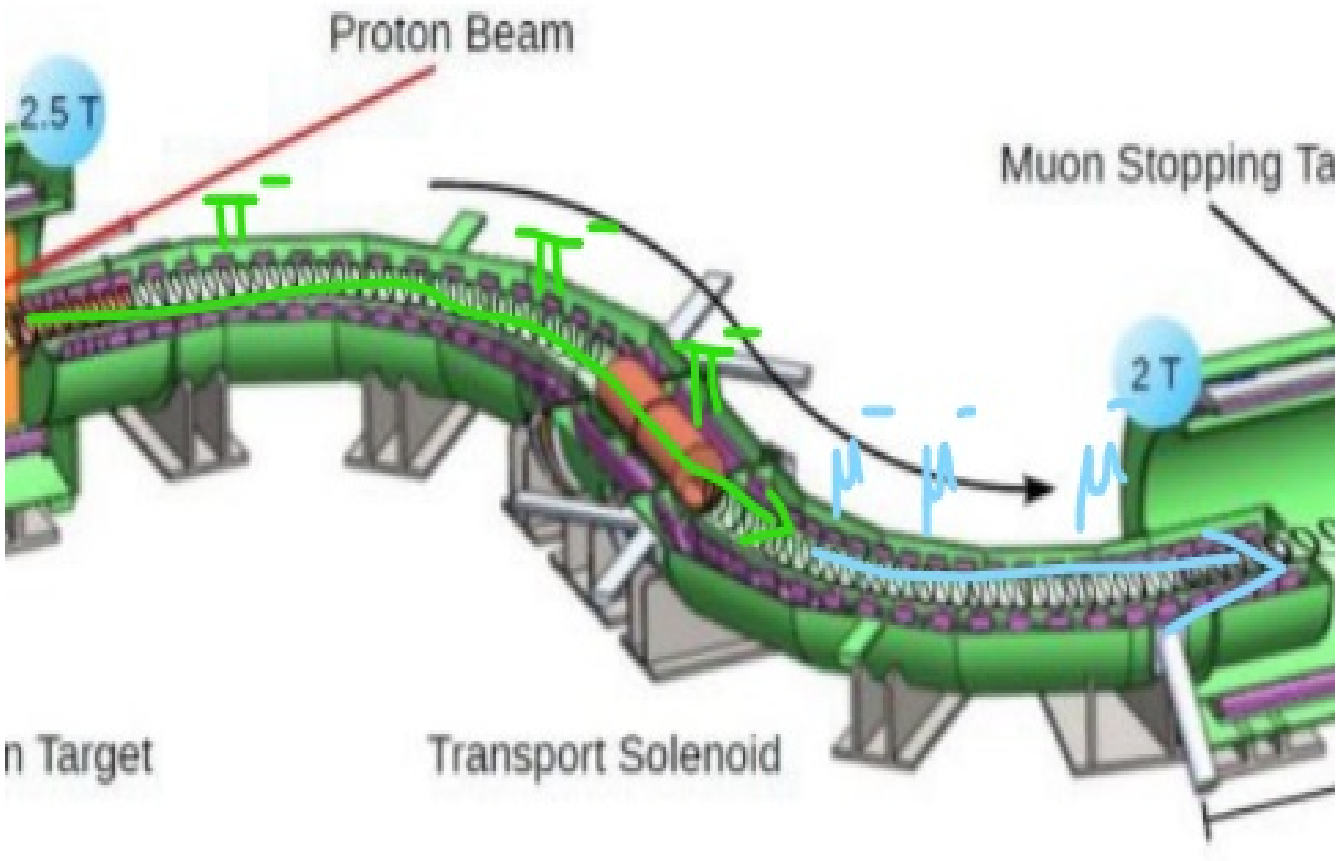


[1]

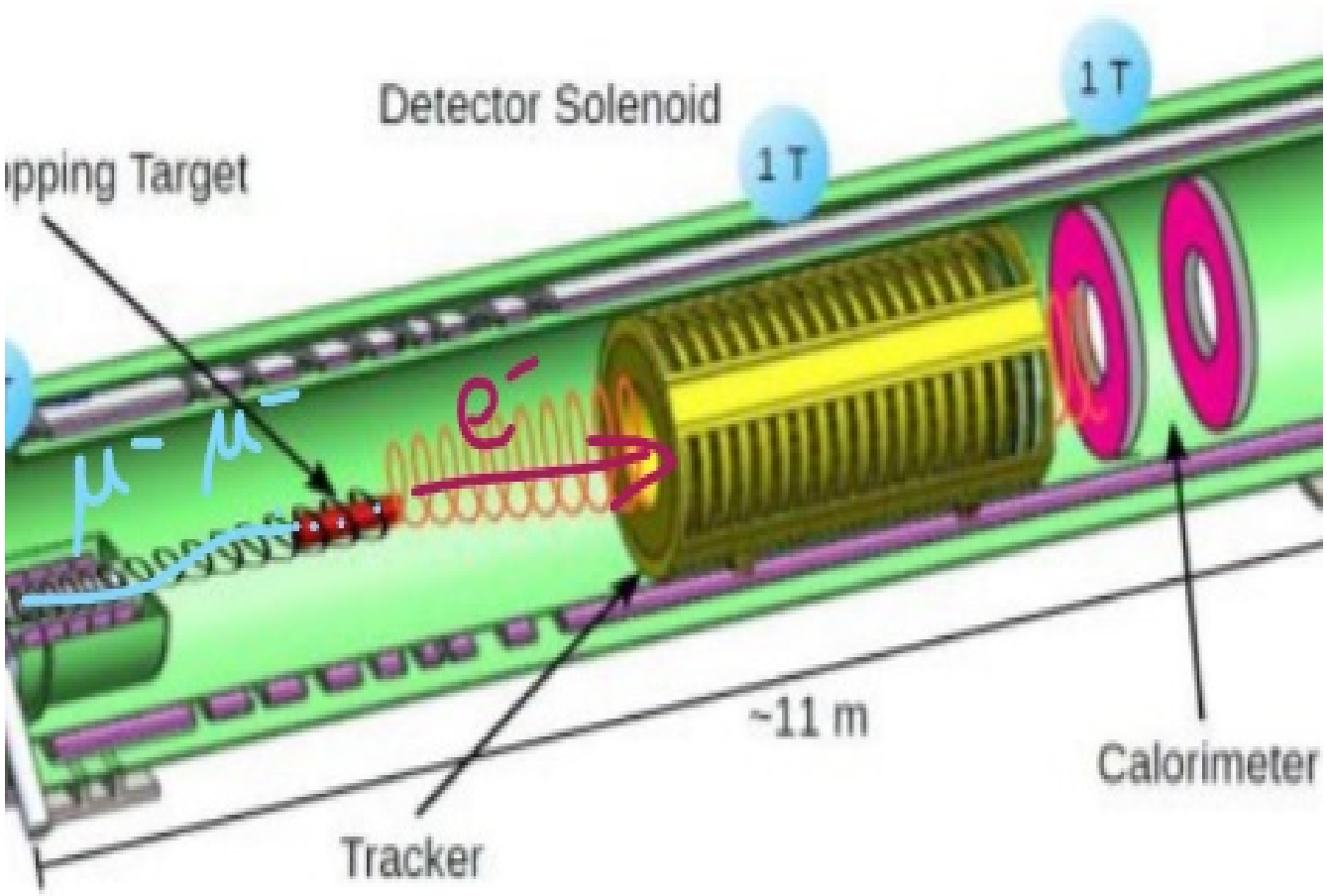
Mu2e Layout


Proton Beam
Production Solenoid
2.5 T
4.6 T
Production Target

Mu2e Layout


Proton Beam
2.5 T
Muon Stopping Ta
2 T
n Target
Transport Solenoid

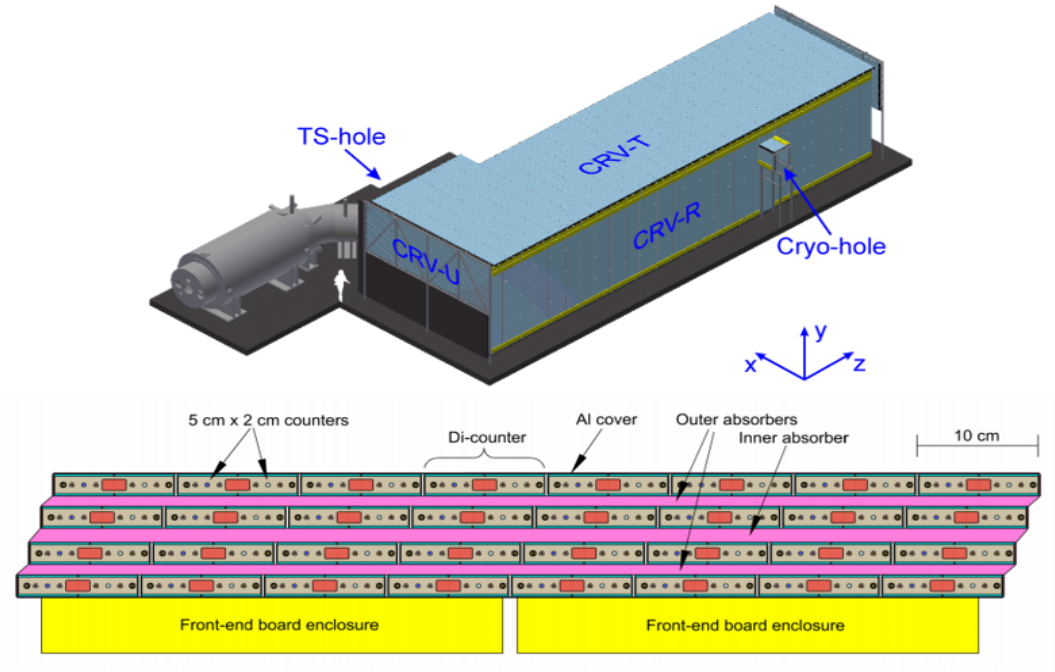
Mu2e Layout


Detector Solenoid
1 T
1 T
pping Target
μ⁻ μ⁻
e⁻
~11 m
Calorimeter
Tracker

Cosmic Ray Veto

Importance

- Cosmic Rays interfering with the detection devices in Mu2e create background that can hide electron conversion events in noise.
- The Cosmic Ray Veto will measure cosmic ray strikes and veto the events from the final data.



[2]

Efficiency

- To be considered a veto event, a signal must be detected in at least three out of four counters.
- The counters must have a combined overall efficiency of 99.99%.
- Individual counter efficiencies affect overall efficiency.

Simulation

- I have developed a simulation in which I generate an event which consists of:
  - four random integer generations representing possible hits
  - if this number is the individual counter efficiency, a hit count is iterated by one integer
  - This hit count value is recorded (0-4)
- There are 1,000,000 events per simulation. After all of these have run, passing events and failing events are printed out.
- Passing evens have four or three hits, failing events have zero, one, or two hits.

Gap Hits

- To get an accurate overall efficiency, the gaps in the detector need to be accounted for.
- Based on the design of the CRV-T, I calculated there is about a 0.37% chance that a cosmic ray will hit a gap.
- If the gap random number generation meets the 0.37% chance criteria, the number of random number generations representing possible hits drops to three.

Gap Hits


```
Passing Events
4 / 4 hits: 982286
3 / 4 hits: 17607
Failing Events
2 / 4 hits: 107
1 / 4 hits: 0
0 / 4 hits: 0
```

A printout from a gap corrected simulation.

- To meet the overall efficiency requirement, the individual counter efficiency needs to be 99.65%.
- Note: The probability of hitting all four counters is calculated by

$$(.9965)^4 + 4 * (1 - 0.9965) * (.9965)^3 = 0.9999$$

Dead Counter

- Manufacturing and electronic malfunctions could cause some counters to be dead.
- In all counters being simulated, there is a dead counter condition.
- If the condition is met, there will not be a hit incrementation.
- A 99.8% individual counter efficiency with 0.2% dead counters will result in the target overall efficiency.

Dropping the Local Pass/Fail Rate

- The individual efficiencies of the counters cannot change once they have been manufactured.
- The target overall efficiency must be met even though some counters may experience failures.
- When a dead counter is present in the track, dropping the pass qualification to two or three hits, and the fail qualification to zero or one hits will solve this problem.
- Using this local dropped pass/fail rate, the individual counter efficiency can again be 99.65%.

Future Work

- It is unknown if dropping the local pass/fail rate will increase dead time a significant amount. This must be studied before the solution is put into play.

References and Acknowledgements

[1] Corcoran, Marj. *Intro to the Mu2e tracker*. Mu2e Summer Student Lecture Series. July 20, 2015.
[2] Technical Design Report. Mu2e Document 4299-v15. March, 23, 2015. Mu2e Document Database.

We would like to thank our Mu2e collaborators both at Fermilab and Kansas State University. This project was funded by the National Science Foundation (NSF) and the Air Force Office of Scientific Research (AFOSR) through NSF grant number PHYS-1461251.