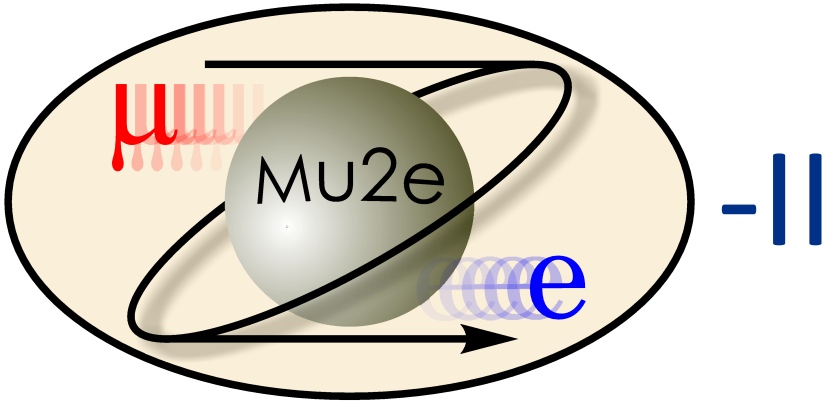
Mu2e-II Tracker Workgroup: Snowmass Paper Status

Dan Ambrose

Mu2e-II Feb 2022 Workshop

22 Feb 2022



Tracker (mu2eii-tracker@fnal.gov)

Convenors:

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Giovanni Tassielli (INFN Lecce)

Members:

David Brown (LBNL)
Brendan Casey (FNAL)
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Stefano Roberto Soleti (LBNL)

Join the list-serve : MU2EII-TRACKER@fnal.gov

Meeting Schedule : Bi-weekly Tuesdays 12:00 PM CST. Next one is Mar 8th.
Zoom link sent through list-serv

Snowmass : Mu2e-II White Paper

Additional Tracker related sections

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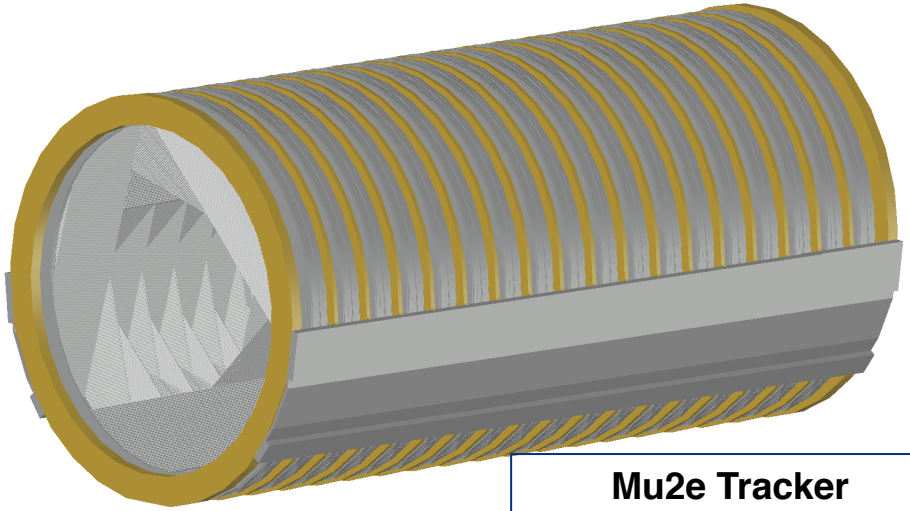
Tracker Description

Mu2e-II tracker faces all the same challenges of Mu2e with additional requirements due to :

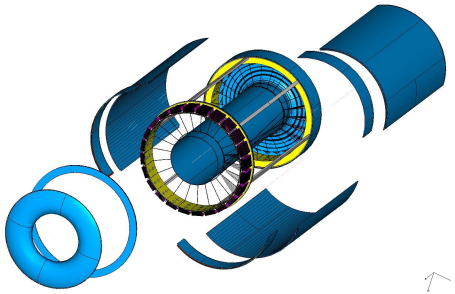
- Increased beam intensity
- Better sensitivity requirements
- Higher radiation rates

Baseline Mu2e-II tracker used in simulations is the same geometry as Mu2e tracker with thinner walled straws and no gold plating on inside of straws.

Besides the a similar Mu2e design, geometries have been proposed which have longitudinal sense wires and some with a single enclosed gas volume with field wires instead of a segmenting each channel by straws. Studies on different tracker geometries is underway. We hope to have some simulation results for the paper in the next week.



Mu2e Tracker
Mu2e Docdb 11567-v3



Possible Mu2e-II Alternative I-Tracker Design

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Simulation Description :

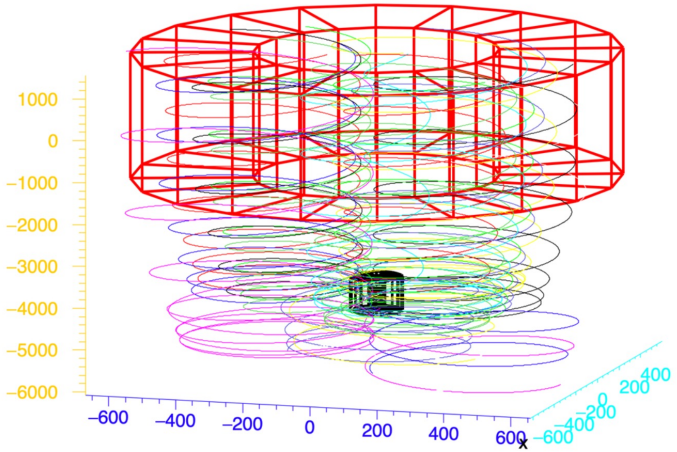
There are two models being used for simulation studies of the tracker :

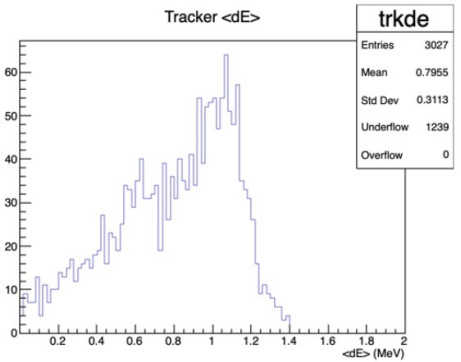
1. Geant4 model, in which we can look at comparisons of the base Mu2e, Mu2e-II environments and make comparisons.
2. The TrackToy hybrid Monte Carlo is used to quickly estimate the relative importance of different tracker and tracker-region parameters on the Mu2e-II signal sensitivity.

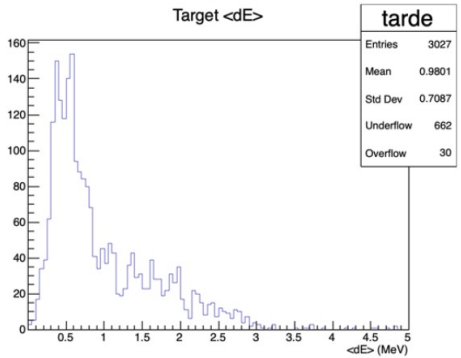
In TrackToy, muon particle 4-vectors from the Geant4 simulation are propagated through a simplified Detector Solenoid (DS) magnetic field to the stopping target, using the KinKal package.

The stopping target, IPA and Tracker are modeled as a hollow cylinders with an adjustable but uniform mass density.

Dave Brown, Docdb 39519







The TrackToy stopping rate, times, and positions were found to be in good agreement with predictions from the Geant4 simulation.

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Critical Issues

- **Momentum resolution**
  - Simulations on expected momentum resolution with base setup
  - Resolution is considered in relation to stopping target, IPA and Tracker
  - R&D suggested :
    - Thinner straws material studies
    - Lower mass gas
    - Alternative technologies and geometries
- **Increased hit occupancy and timing window**
  - Faster gas
  - Improved pattern recognition : Machine Learning studies
- **Survive the increased charge deposition and beam flash radiation :**
  - Develop radiation-resistant front-end electronics
    - ASICS
    - DC-DC converter
    - Optical components

Momentum Resolution :

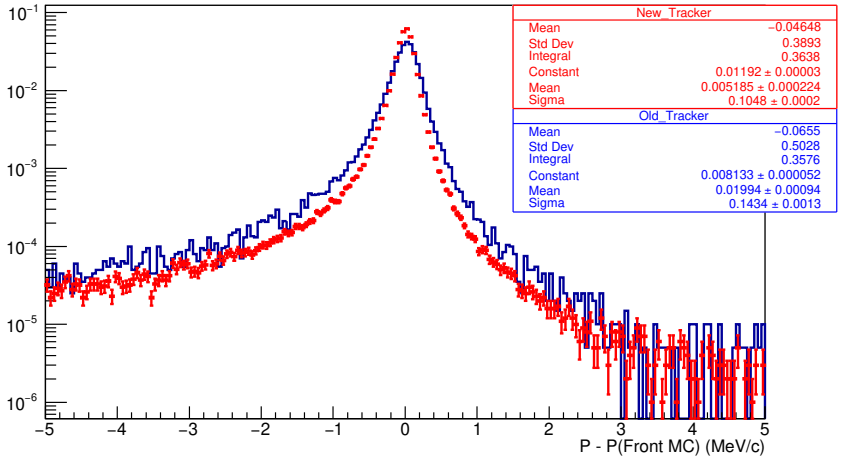
Initial simulations suggested the need to improve momentum resolution by half to maintain DIO/CE discrimination.

A reduction of the tracker straw mass by 50% sees resolution improvements of ~6%.

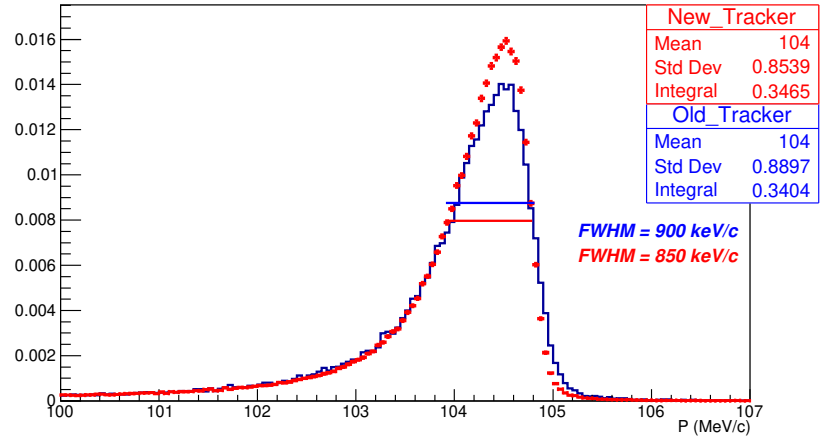
More than half of the CE energy loss is in the stopping target and the IPA.

- Resolution improvement relies on the whole stopping target, IPA, and tracker system
- Simulation studies on Stopping target and IPA mass
- Alternative IPA geometries could be explored

Mu2e-II CE momentum resolution at the Tracker front



Mu2e-II CE reconstructed momentum



Occupancy

Increased muon rate, reduced IPA shielding, and increased timing windows could all lead to more hits, cross-talk, and dead-time in channels.

A key component to issues of caused by occupancy in the detector is the pattern reconstruction algorithm for reconstructing the tracks. R&D into ML algorithms can improve on classic cuts.

There is room to improve timing resolution in electronics.

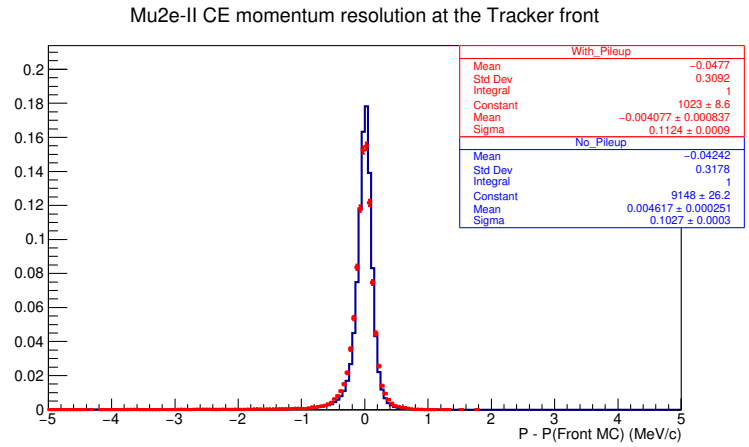
There is the possibility of using a faster gas to improve timing resolution and reduce channel dead time.

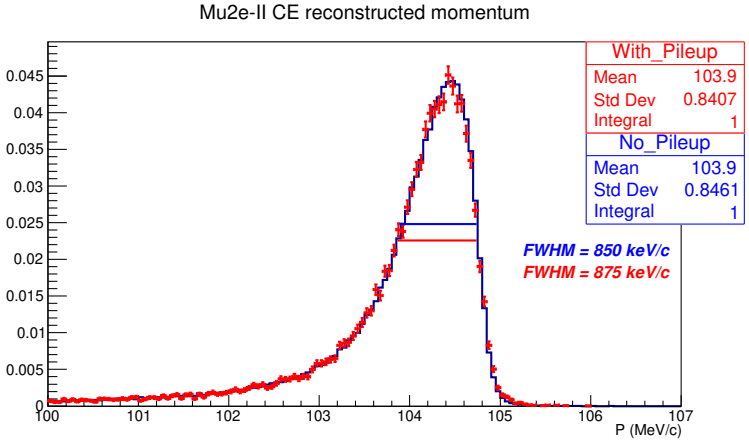
Radiation and Rates

We are working on simulation studies, scaling Mu2e beam rates to Mu2e-II levels.

The rates are important for estimating damage on active tracker material and electronic rad-hard requirements.

Not much room for additional shielding in tracker.





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Anticipated Requirements

- Hard to make statements on the anticipated requirements of the tracker as research into critical issues will set our limits.
- Decisions on stopping target and IPA will also affect the requirements.
- For now, we will outline the expectation based on simulations of the baseline design.

R&D material studies

Studies of prototype straws have shown the constructing and using them is feasible.

Straws were able to :

- **Be produced**
- **Mounted into a mock detector end**
- **Hold pressure for days**
- **Hold tension for days**

Additional studies needed to determine :

- **Leak rate**
- **Creep rate**
- **Charge accumulation tolerance**

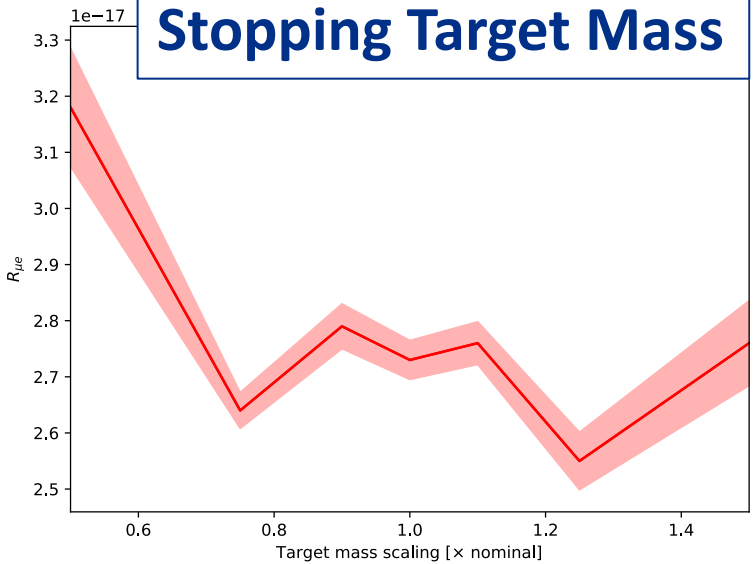
8μm wall prototype straw

	Mu2e	Mu2e-II
Wall thickness (μm)	18.1	8.2
Al thickness (μm)	0.1	0.2
Au thickness (μm)	0.02	0.0
Linear Density (g/m)	0.35	0.15
Pressure limits (atm)	0–5	0–3
Elastic Limit (gf)	1500	500

TABLE III. Comparison for the Mu2e and Mu2e-II straw tubes.

Stopping Target and IPA Mass Scaling studies

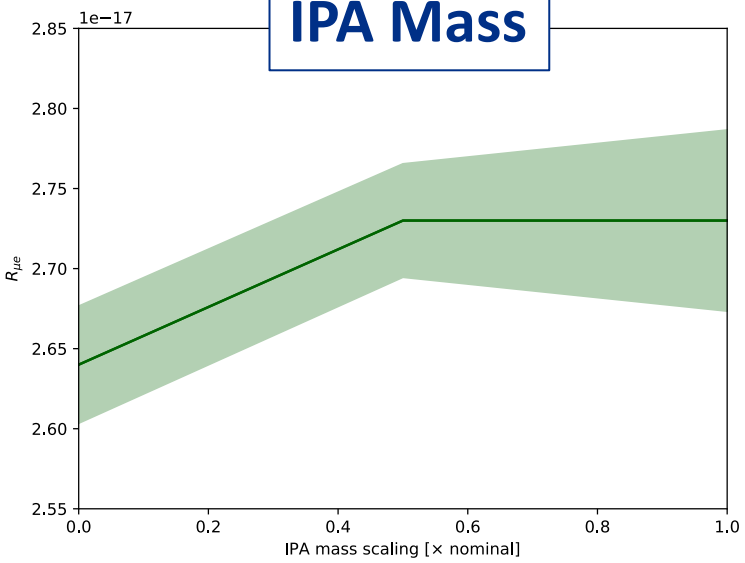
Stopping Target Mass



$R_{\mu e}$ discovery potential for a scan of the target mass values, obtained by maximizing the number of CEs while keeping the number of expected DIOs below 0.2.

There are two competing effects at play:
A heavier target increases the stopping rate, but it distorts the momentum spectrum.

IPA Mass



$R_{\mu e}$ discovery potential for a scan of the IPA mass values (0, half, full). The shaded region corresponds to the statistical uncertainty.

Though preferred in this study, 0 IPA is not reasonable due to detector radiation exposure.

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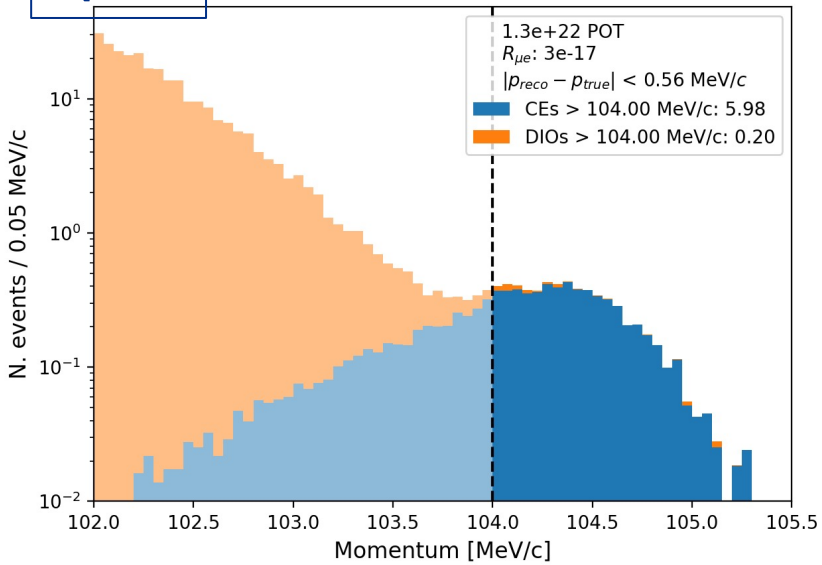
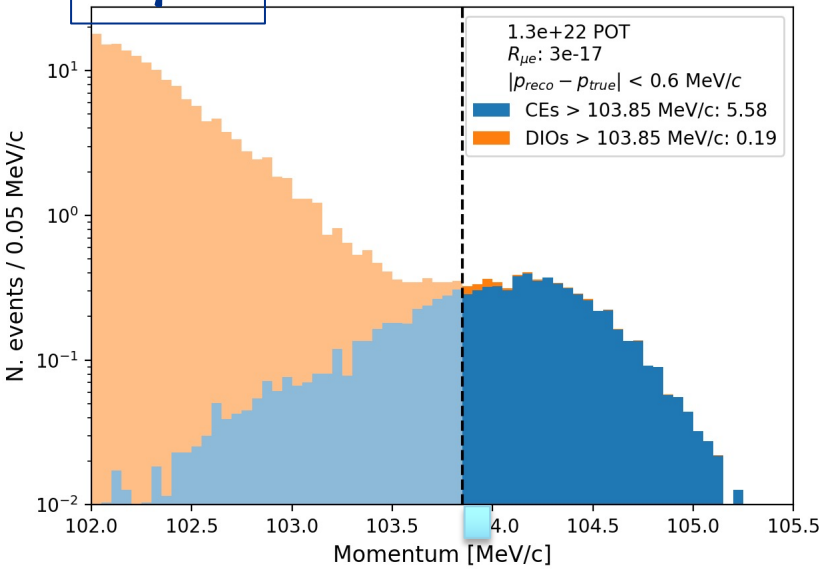
Thinner straw event discrimination

8μm



15μm



Stacked histograms of the simulated reconstructed momentum spectra for CEs (blue) and DIOs (orange), with 8μm (left) and 15 μm (right) thick straw tubes.

Less mass leads to energy smearing in CEs and DIO.
~7% increase in signal to background in CE/DIO ratio
~12% reduction in cosmic ray background from reduced acceptance window.

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Future Studies

- Continue Material studies on thinner straws
- Continue developing tracker construction techniques with limitations of thinner straws.
- Optimize stopping target, IPA and tracker for resolution
- Improve pattern recognition
- Simulate faster gas and measure leak rate in straws
- Develop rad-hard electronics (ASICs)

Summary

- There has been good work done on tracker simulation
- We are starting to narrow requirements and outline needed R&D
- There are still simulation studies we are trying to include
  - We think they will be completed in time, otherwise a conversation in future studies will outline plans
- Significant writing to be improved over the next 2 weeks