Targeting Studies for Mu2e-II

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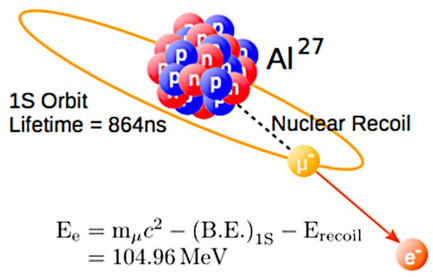
Abstract

The target of a next-generation Mu2e experiment (Mu2e-II) is to achieve a sensitivity approximately by a factor ten better than the currently planned Mu2e facility. An 800 MeV proton beam with high intensity will be available after the completion of the Proton Improvement Plan-II. We investigated the potential of using the beam for Mu2e-II using G4beamline. The number of stopped muons per kilowatt dropped by a factor of 1.63, indicating Mu2e-II will produce 7.65 times more stopped muons than Mu2e during 3 years.

Muon to Electron Conversion

- Mu2e searches for a neutrino-less $\mu^- \rightarrow e^-$ conversion in an atomic nucleus.
- Observation of charged-lepton-flavor-violation is a direct evidence of *new physics*.



- Mu2e measures

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

- Current limit: $R_{\mu e} < 7\times10^{-13}$ (90% C.L.)
- Target: $R_{\mu e} < 2.87\times10^{-17}$

Mu2e-II

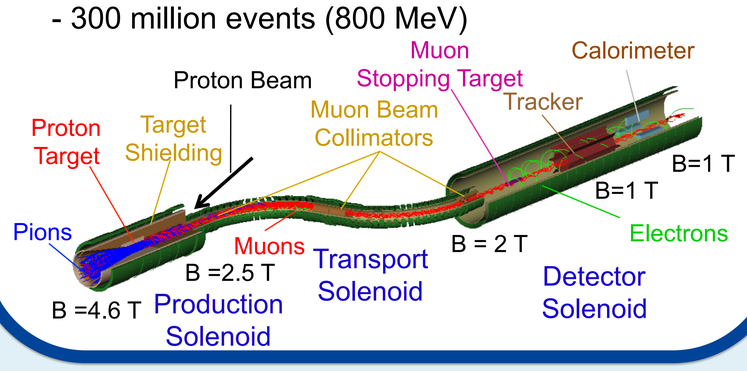
- A second-generation Mu2e experiment
- Target: $R_{\mu e} < 2.87\times10^{-18}$
- Mu2e-II uses a high-intensity proton beam available after Proton Improvement Plan-II.

	Mu2e	Mu2e-II
Beam Kinetic Energy	8 GeV	800 MeV
Beam Power	8 kW	8-100 kW
Protons-On-Target (POT)	3.6×10^{20}	3.6×10^{21} - 4.5×10^{22}
Run Duration	3 years	3 years
Run Time	2×10^{7} sec/year	2×10^{7} sec/year
Duty Factor	0.32	0.90
POT Pulse Full Width	200 ns	-
POT Pulse Spacing	1695 ns	-
POT Extinction	$<1\times10^{-10}$	$<1\times10^{-12}$*

*expected

Simulations

- Software: G4beamline v2_16
- Starting point of a beam: ~2mm in front of the production target
- Kinetic energy of a beam: 8 GeV & 800 MeV
  - 40 million events (8 GeV)
  - 300 million events (800 MeV)



Rate of Stopped Muons

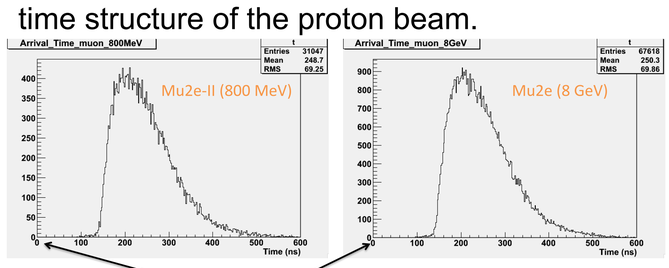
- A comparison of the number of stopped muons at the stopping target between the scenarios of Mu2e and Mu2e-II

Kinetic Energy	Stops / POT	Stops / kW
8 GeV	1.690×10^{-3}	7.607×10^{16}
800 MeV	1.035×10^{-4}	4.657×10^{16}

- Stops / kW: The rate of stopped muons for Mu2e-II dropped by 38.7% compared to the rate of Mu2e
- Mu2e-II (800 MeV, 100 kW)
  → 4.657×10^{18} muons will be stopped during 3 years. This is 7.65 times more muons than Mu2e (8GeV, 8 kW).

Arrival Time of Muons

- Arrival time of muons is critical to determine the time structure of the proton beam.

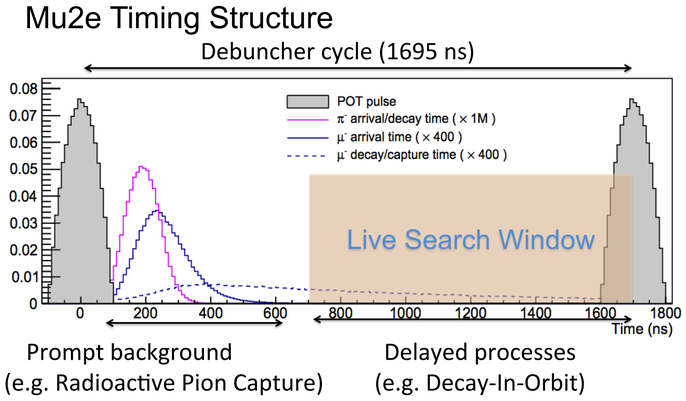


A proton beam hits the production target (t=0)

- It takes 100-600 ns for muons to arrive at the stopping target for both 8 GeV and 800 MeV scenarios.
  → The arrival time of muons is independent of the proton beam energy.

Timing Structure

- Mu2e Timing Structure

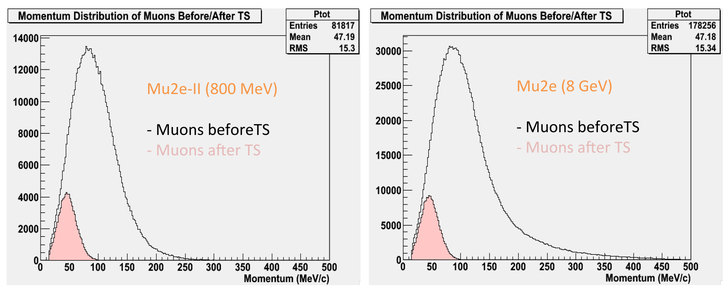


- Mu2e-II Timing Structure Considerations
  - Reduced pulse width of a proton beam
  - No constrain on a debuncher cycle of 1695 ns
  - Cosmic-ray-induced-background

Discussion

Why does the rate of the stopped muons (800 MeV) drop by only a factor of 1.63?

- Muons produced by the 800 MeV proton beam have a shorter tail on the momentum distribution.
- Only muons with low momentum (15-100 MeV) survive the Transport Solenoid.



- Momentum distributions of muons after TS for both scenarios look very alike.
- ~38% of survived muons is stopped at the stopping target for both scenarios.

How does Mu2e-II affect backgrounds?

- No antiproton production
- Less radioactive pion capture due to the narrower proton pulse

Conclusion

Rate of stopping muons

The number of stopped muons at the stopping target per kilowatt dropped by a factor of 1.63, indicating Mu2e-II will produce 7.65 times more stopped muons than Mu2e during 3 years.

Future directions

- Delivery of protons to the production target for Mu2e-II
- Background studies for Mu2e-II

Acknowledgements

I am very grateful to my mentor, Thomas J. Roberts for his valuable advice, Eric Prebys and Tanja Waltrip for organizing the Lee Teng internship. I would also like to thank the Fermi National Accelerator Laboratory, and the Illinois Accelerator Institute for funding the project.

Reference

K. Knoepfel *et al.*, "Feasibility Study for a New-Genration-Mu2e Experiment", arXiv: 1307.1168v2.

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