Targeting Studies for Mu2e-II
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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.

Abstract

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.

Muon to Electron Conversion

- Mu2e measures $R_{\mu e} = \frac{\mu^+ + A(Z,N) \rightarrow e^- + A(Z,N)}{\mu^+ + A(Z,N) \rightarrow v_\mu + A(Z - 1,N)}$.
- Current limit: $R_{\mu e} < 7 \times 10^{-13}$ (90% C.L.)
- Target: $R_{\mu e} < 2.87 \times 10^{-17}$

Mu2e-II

- A second-generation Mu2e experiment
- Target: $R_{\mu e} < 2.87 \times 10^{-18}$
- Mu2e-II uses a high-intensity proton beam available after Proton Improvement Plan-II.

<table>
<thead>
<tr>
<th>Mu2e</th>
<th>Mu2e-II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam Kinetic Energy</td>
<td>8 GeV</td>
</tr>
<tr>
<td>Beam Power</td>
<td>8 kW</td>
</tr>
<tr>
<td>Protons-On-Target (POT)</td>
<td>$3.6 \times 10^{20}$</td>
</tr>
<tr>
<td>Run Duration</td>
<td>3 years</td>
</tr>
<tr>
<td>Run Time</td>
<td>2 $\times 10^7$ sec/year</td>
</tr>
<tr>
<td>Duty Factor</td>
<td>0.32</td>
</tr>
<tr>
<td>POT Pulse Full Width</td>
<td>200 ns</td>
</tr>
<tr>
<td>POT Pulse Spacing</td>
<td>1695 ns</td>
</tr>
<tr>
<td>POT Extinction</td>
<td>$&lt;1 \times 10^{-10}$</td>
</tr>
</tbody>
</table>

*expected

Rate of Stopped Muons

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

<table>
<thead>
<tr>
<th>Kinetic Energy</th>
<th>Stops / POT</th>
<th>Stops / kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 GeV</td>
<td>$1.69 \times 10^{-3}$</td>
<td>$7.607 \times 10^{16}$</td>
</tr>
<tr>
<td>800 MeV</td>
<td>$1.035 \times 10^{-4}$</td>
<td>$4.657 \times 10^{16}$</td>
</tr>
</tbody>
</table>

- 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) produces $4.657 \times 10^{16}$ muons will be stopped during 3 years. This is 7.65 times more muons than Mu2e (8 GeV, 8 kW).

Arrival Time of Muons

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

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.

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 stopping 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

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Reference