R&D toward design for a pion-production target for Mu2e-II

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APS April Meeting 2021

Abstract

The Mu2e experiment at Fermilab will search for evidence of charged lepton flavor violation by observing the conversion of a negative muon into an electron in the Coulomb field of a nucleus without emission of neutrinos and will probe effective new-physics mass scales in the 10^3-10^4 TeV range. One of the main parts of the Mu2e experimental setup is its target station in which negative pions are generated in interactions of the 8 GeV primary proton beam with a tungsten target, which will be capable of producing ~$2\cdot10^{17}$ negative muons per year. Mu2e can be extended by a next generation experiment, Mu2e-II, with a sensitivity improved by another factor of 10 or more. The improved sensitivity would be enabled by the PIP-II accelerator upgrade project, which is a 250-meter-long linac capable of accelerating a 2 mA proton beam to a kinetic energy of 800 MeV corresponding to 1.6 MW of power. To achieve another factor of ten improvement in sensitivity, Mu2e-II will require about 100 kW of proton beam on target, and the added power requires a new target design. We will present our progress in R&D of a target station conceptual design for Mu2e-II, using the MARS15 and G4beamline Monte-Carlo codes toward a selection between granular, "conveyor", and rotating cylindrical target options.

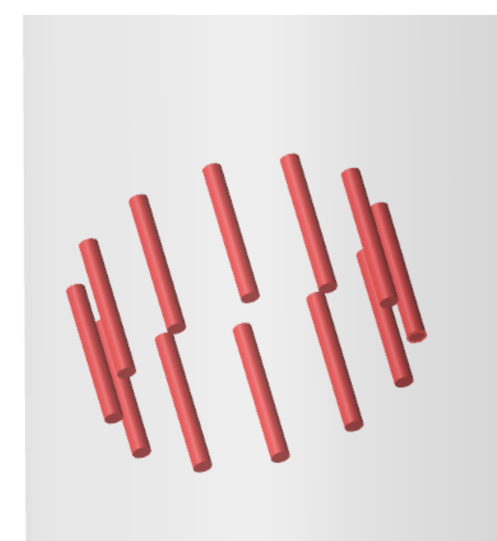
The Mu2e experiment and its upgrade

The Mu2e-II improved sensitivity would be enabled by the PIP-II accelerator upgrade project, which is a 250-meter-long linac capable of accelerating a 2 mA proton beam to a kinetic energy of 800 MeV corresponding to 1.6 MW of power (Mu2e-II is planning to use 100 kW).

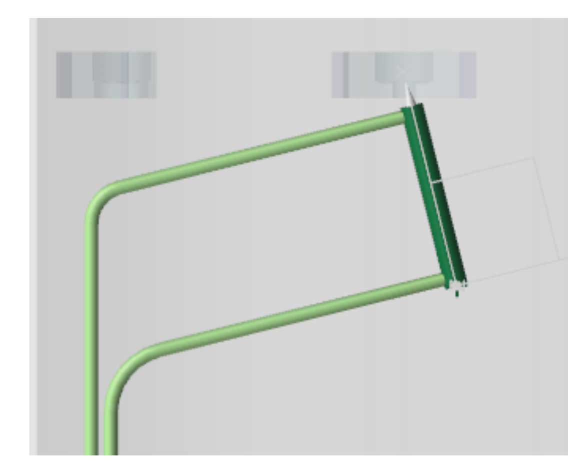
Keeping the HRS design for Mu2e-II is technically challenging, as will be a redesign of the PS magnetic field.

Mu2e Heat and Radiation Shield (HRS)
Compatibility with HRS dimensions – a requirement for the Mu2e-II production target

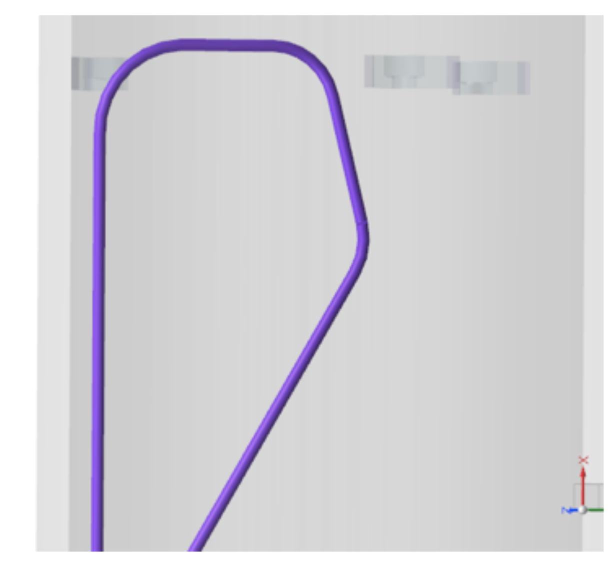
Prioritizing target designs



"Rotating rods"
Pros: Radiation damage can be distributed over many rods
Cons: Its hardware would require a significant space inside the bore (complicates cooling and muon flow)

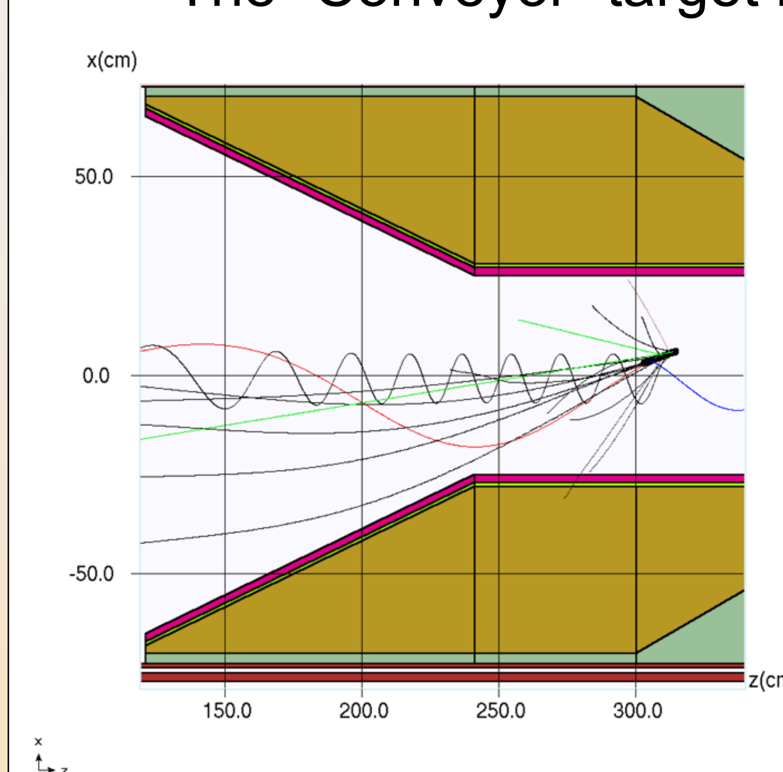


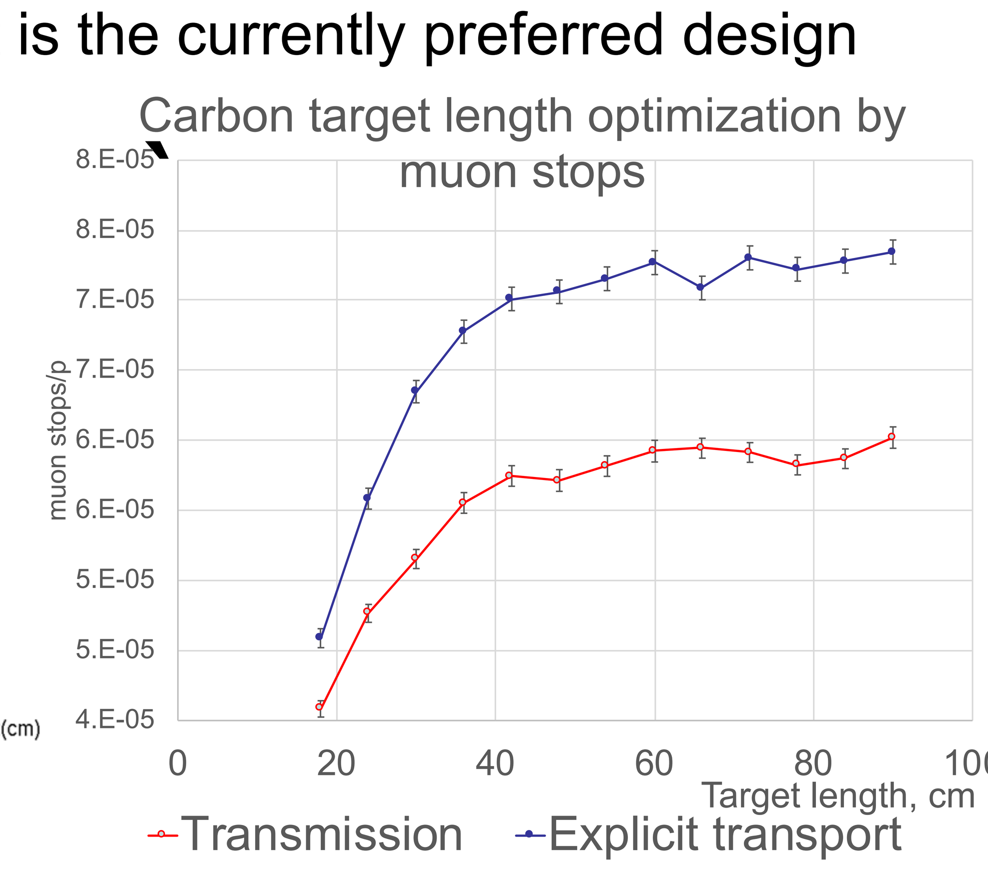
"Fixed granular"
Pros: Small space required
Cons: Peak DPA (MARS15) >300/yr; gas cooling cannot be performed effectively



"conveyor"
Pros: Small space required; He gas could be used for both cooling and moving elements inside conveyor; radiation damage can be distributed;
Cons: Technical complexity (prototyping needed)

The "Conveyor" target is the currently preferred design





Based on muon stopping rate studies with MARS15 and G4beamline optimal target lengths were determined to be: 28 balls (C target), 9 balls (W and WC targets), 19 balls (SiC); MoGRCF was studied. A good agreement between transmission and explicit allows saving the computational time.

Type\material	Tungsten/WC	Lower-density bent (Carbon)
Rotating rods	Requires a large amount of hardware in HRS	Too large to fit HRS
Fixed granular	DPA is too high	DPA is high; lower pion production
Conveyor	Thermal analysis is ongoing	Lower pion production; thermal analysis is ongoing

Fermi National Accelerator Laboratory is operated by the Fermi Research Alliance, LLC under Contract No. DE-AC02-07CH11359 with the U.S. Department of Energy, Office of Science, Office of High Energy Physics.