Pion-production target design for Mu2e-II: radiation damage and thermal analysis

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Abstract

The central aim of the Mu2e experiment being built at Fermilab is a search for the neutrinoless conversion of a negative muon into an electron in the field of a nucleus. The baseline Mu2e will be using the 8-kW 8-GeV proton beam to generate pions in a radiatively cooled, finned, segmented tungsten rod target. The future includes a proposed extension of the experiment (Mu2e-II) at the linac complex PIP-II. Mu2e-II will allow improving the sensitivity by increasing the stopped muons in the experiment by another factor of 10 or more. Mu2e-II will probe New Physics mass scales up to 10^5 TeV by utilizing a 100-kW proton beam, which requires a new target design. In this talk we discuss our recent progress in R&D for a target station conceptual design for Mu2e-II based on thermal and radiation damage analyses. We use the MARS15 and G4beamline simulation packages to estimate the feasibility of several target options. At the present stage of analysis, our simulations have allowed us to rule out some designs, and to estimate the range of required working parameters and constraints for others under consideration.

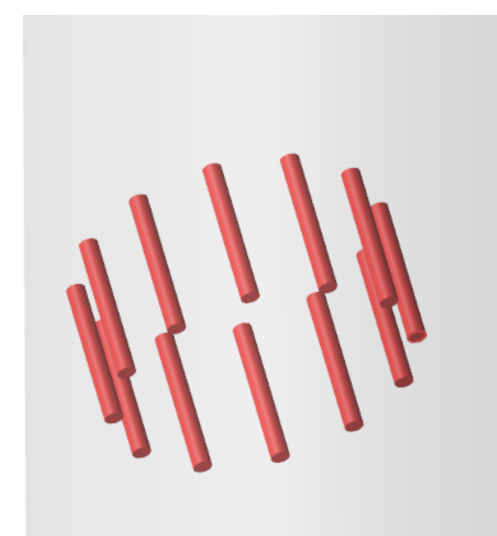
The Mu2e experiment and its upgrade

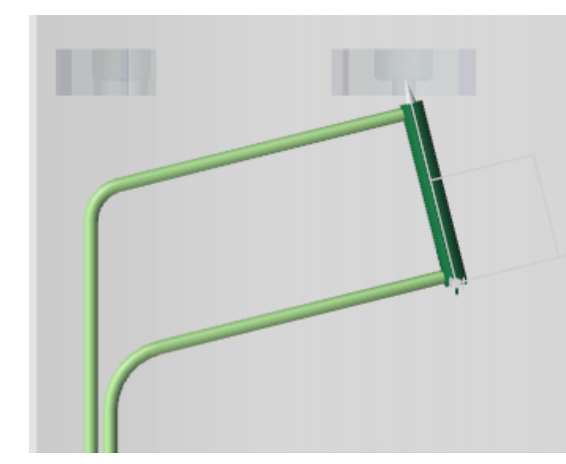
The Mu2e-II improved sensitivity would be enabled by the PIP-II accelerator upgrade project, which is a 250-meter-long linac capable of accelerating a 2 mA proton beam to a kinetic energy of 800 MeV corresponding to 1.6 MW of power (Mu2e-II is planning to use 100 kW).

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



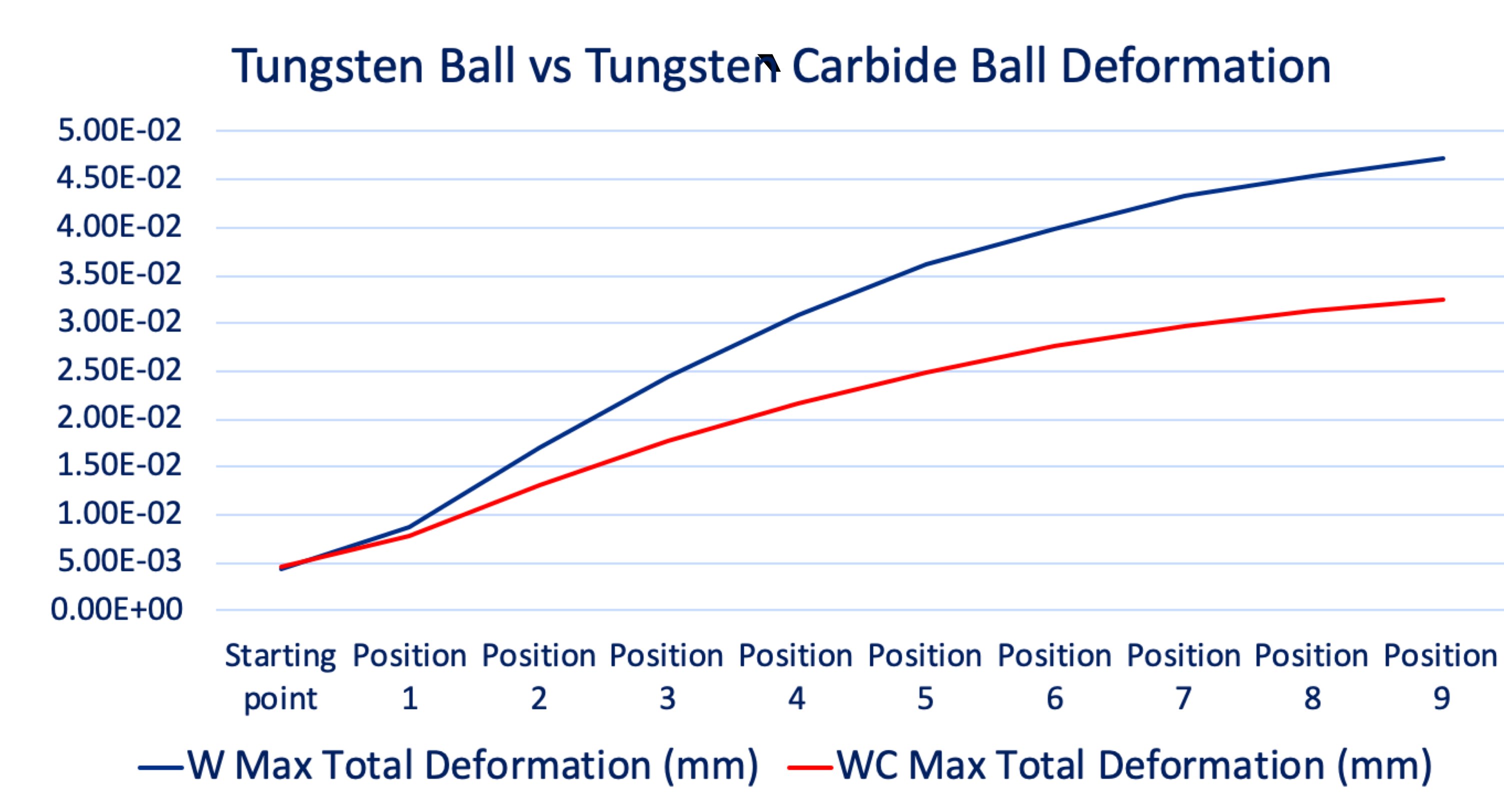


"Rotating rods"
Pros: Radiation damage can be distributed over many rods
Cons: Its hardware would require a significant space inside the bore (complicates cooling and muon flow)

"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



Mechanical and thermal analysis indicate WC performs better than W. 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.

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

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