Simulating target tests at AP0 facility for Mu2e

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Background

The **Muon to Electron Conversion Experiment** (**Mu2e**) has the goal of detecting the conversion of muons to electrons in the field of a nucleus without the emission of neutrinos, a charged lepton flavor violating process with an unmeasurably small cross section in the Standard Model [1]. Incoming protons hit the 3.15 x 160 mm production tungsten target, generating pions that decay into muons. A magnetic field then transports the muons to a detector that can track if any conversion event occurs. A goal of the experiment is to reach a single event sensitivity of $3x10^{-17}$.

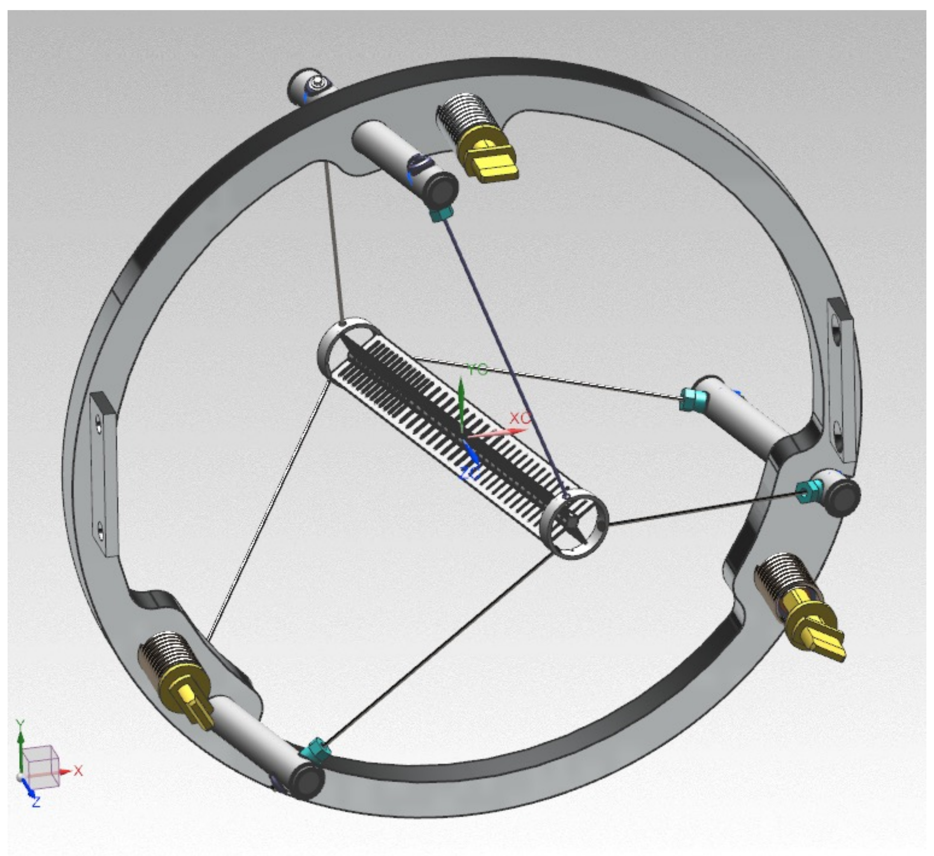

Fig 1. Current design of the Mu2e production target mounted on bicycle wheel support.
Image: Dave Pushka

Purpose

The predicted production of muons and energy deposition for the production target are dependent on the documentation of cross-sections values, the properties of the target material, etc. Hence, making real tests on similar targets before its use on Mu2e will be a good indicator of the accuracy of the simulations done for the experiment. The main goal of the project is to simulate a target test at the **AP0 Target Facility,** previously used to create the muon beam for the **Muon g-2 experiment,** using different target sizes.

Simulation in G4beamline

The **Neutrinos at the Main Injector (NuMI)** steel vessel will be used as a holder for the tested target. We then simulate the AP0 facility in G4Beamline, with the various targets placed inside the 3D model of the NuMI vessel for each run. An 8 GeV proton beam of 1 million particles was used for each simulation. Different tested targets were cylinders of radius from 1 to 5 mm and lengths from 70 to 150 mm.

Fig 2. G4beamline simulation model of the AP0 facility (calorimeter and pulsed magnet) with the NuMI vessel and target placed inside.

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The target was divided into small volumes using a grid of cylindrical shells and circular cross-sections to calculate the energy deposition across the target. Each volume was set to have a **radius of 0.2 mm** and **length of 2 mm,** with the number of volumes varying on each target size.

Results

Energy across target radius and length was normalized using the volume of each geometrical segment. **Statistical errors** were based on multiple runs of each target size, each run with 1 million events. Some statistical error bars, specifically through target radius, turned out to be very small, approximately the size of line on graph. **Systematic uncertainties** from volume sectioning and model dependencias were not considered, as the goal of the test program will be to validate cross section models in the simulation framework.

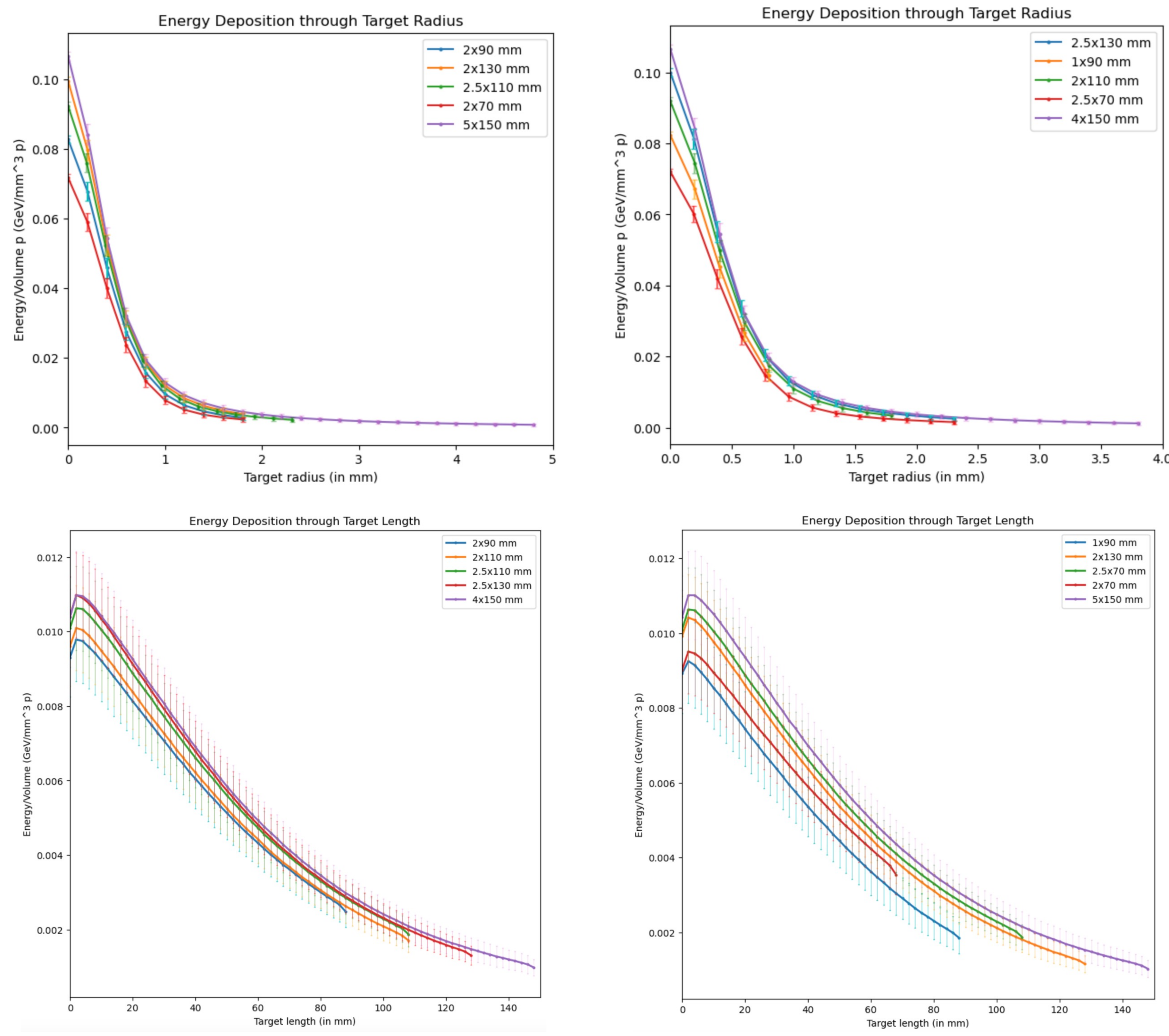

Fig 3. Up: Energy Density (in GeV/mm^3) across various target radii (statistical error bars are the size of line). Down: Energy Density (in GeV/mm^3) across various target lengths (statistical error bars are the size of the line). A decrease in energy density is shown for targets with radius > 2 mm and across length at around 150 mm.

Conclusions

Results from these simulations will be used as input for engineering models of the target to produce predicted stress and surface temperature distributions, parameters that will later be measured in future beam runs to validate underlying cross section models. Future G4beamline simulations will consider muon yield distributions to determine the optimal location to place particle detectors within AP0 to allow us to further refine the cross section models.

References

[1] Bernstein, R. H. (2019). The Mu2e Experiment. *Frontiers in Physics, 7.* https://doi.org/10.3389/fphy.2019.00001