Fluka-Based Optimization of Target Design of Muon Production for Muon Collider Demonstrator

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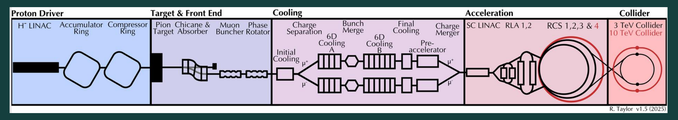
Introduction

- Efficient muon production is crucial for future muon collider facilities.
- Muons are created from pions produced by proton-target interactions.

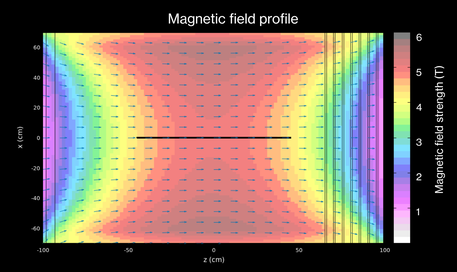
$$p + p \rightarrow p + p + \pi^0$$
$$p + p \rightarrow p + n + \pi^{\pm}$$
$$\pi^+ \rightarrow \mu^+ + \nu_\mu$$
$$\pi^- \rightarrow \mu^- + \bar{\nu}_\mu$$

- This study explores different target materials and geometries to maximize pion yield for an 8 GeV proton beam.
- The current setup includes a 2 m long, 0.7 m radius, solenoid with 5 T peak magnetic field, where the target is positioned in the middle of the solenoid.



First challenge: Magnetic field

- There is no direct way to define solenoidal magnetic field in flair.
- Field map was generated using G4beamline.
- A custom Python script was developed to reformat this data for compatibility with flair's MGNDATA card, which manually reads in field points.
- Challenges around fortran syntax → minor spacing errors in the input file could lead to reading failures.

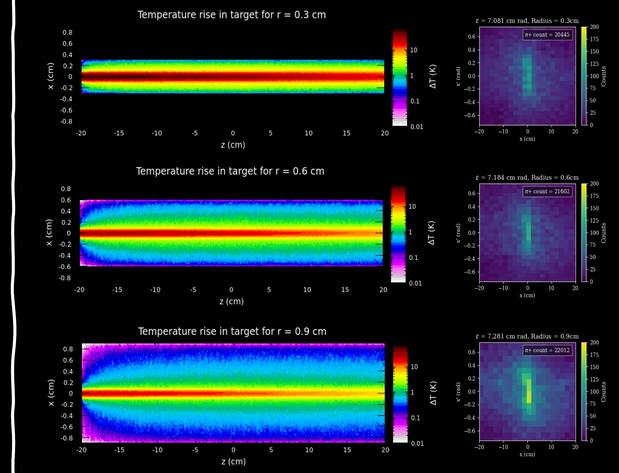


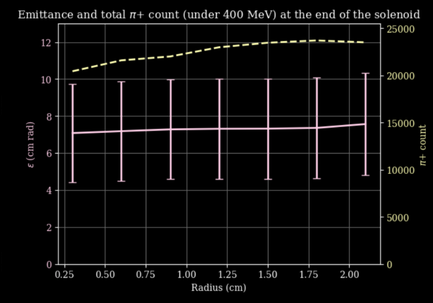
Second challenge: User Routines

- Standard flair scoring cards could not provide the detailed pion distribution and momentum data needed for this study.
- Used custom user routines that extract detailed particle information in selected regions.
- Familiarized myself with Fluka pre-defined variables and logic.

Target Design

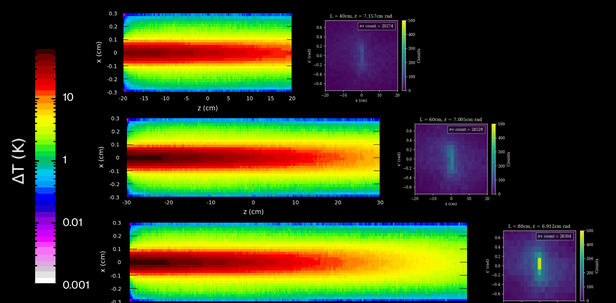
- We have so many parameters to play with:
  - Length
  - *Radius*
  - *Shape: cylindrical, conical… or maybe hybrid?*
  - Material: graphite, tungsten, Inconel…
  - Angle of tilt with respect to the beam axis (z-axis)
  - Location in the z-axis
- Here, I am going to present the changes that we see when we change radius and shape.

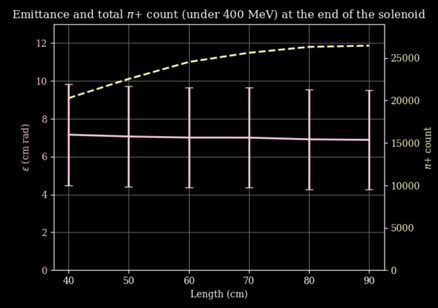




Radius…

The emittance seems to slightly worsen as the radius of the target is increasing. However, there is an obvious increase in the number of pions detected at the end of the solenoid



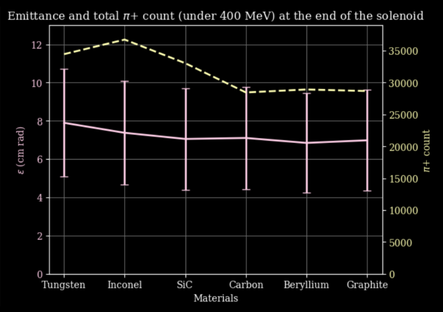


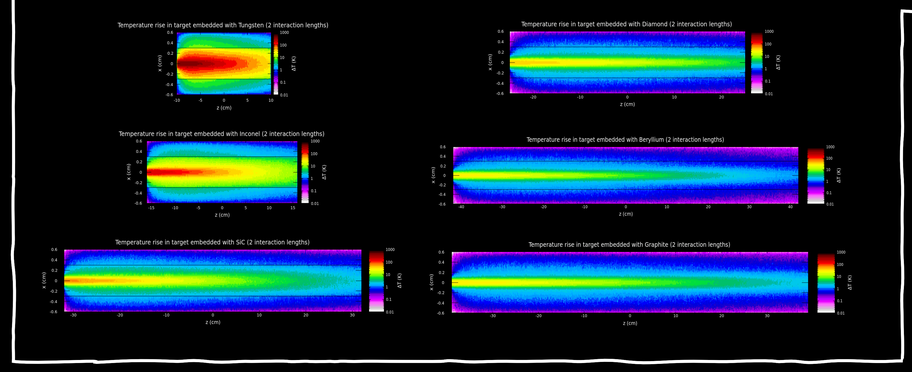
Length…

Both; the emittance and the number of pions detected at the end of the solenoid improve as the length increases.

Materials…

The target design that I attempted to explore consists of graphite cylindrical shell embedded with different materials.
Motivation: Since graphite tends to withstand higher temperatures better that other materials, I thought of embedding the denser materials inside graphite. This way, even if the inner material breaks the target would remain intact.





Conclusion

- The aim of this study was to build an intuition for the effect of target geometry and material on pion/muon production, specifically pions and muons with energies under 400 MeV.
- **Future work:** Look into a way to get rid of energetic protons before the cooling stage. One way to do this is to tilt the target with respect to the beam axis.
- I would also like to look into the synergies between the demonstrator and the Mu2e experiment solenoid.

[1] Ambrosio, G., et al. "Reference design of the Mu2e Production solenoid." Ref: Mu2e-doc-3647.