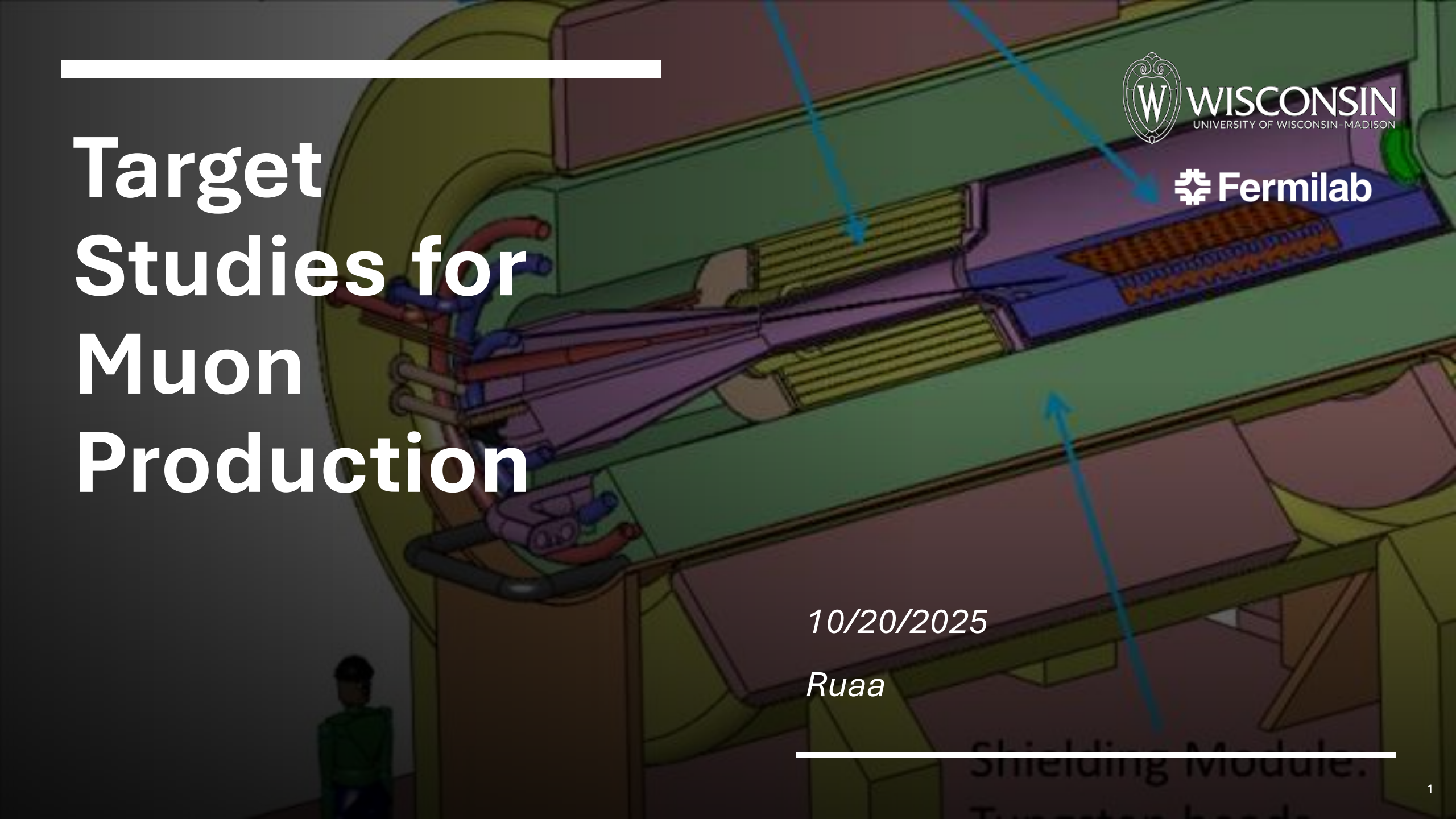
Target Studies for Muon Production



WISCONSIN
UNIVERSITY OF WISCONSIN-MADISON

Fermilab

10/20/2025

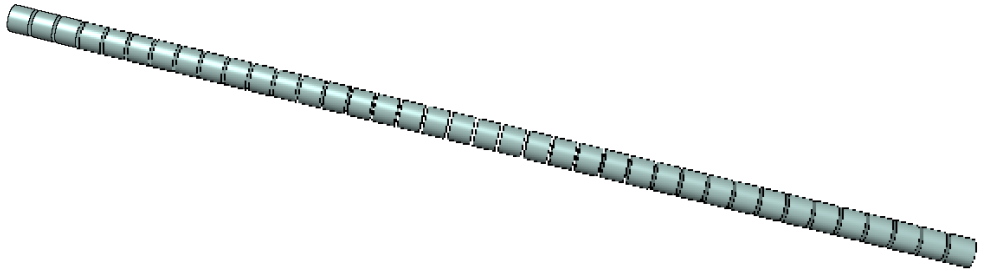
Ruaa

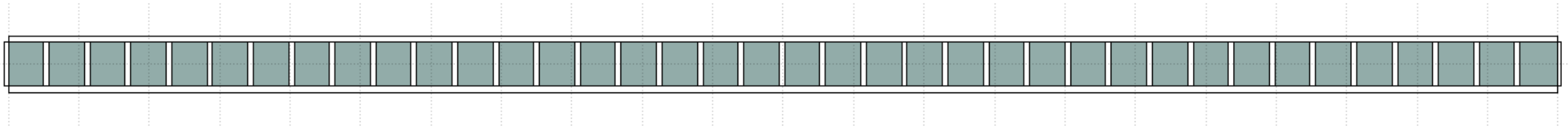
Mu2e target design

→Material: Tungsten

→The target is **20** cm in length and has radius of 0.315 cm.

→The target is divided into **34** sections, each 0.5 cm wide, separated by 0.08 cm gap.





MiniBooNE target design

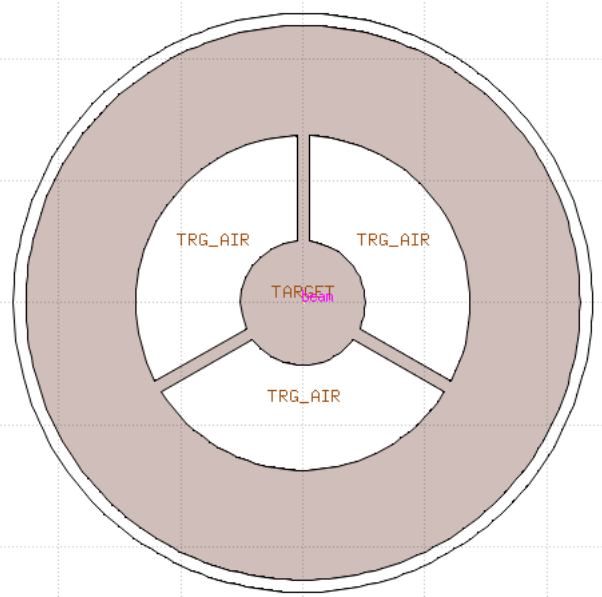
→ Material: Beryllium

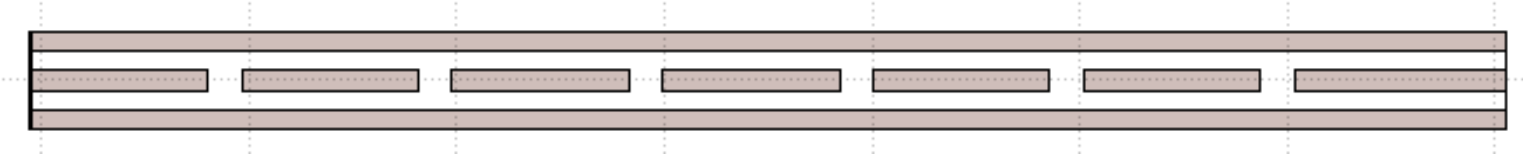
→ The target is **84** cm in length and has radius of 0.51 cm.

→ The target is divided into 7 slugs, each **10.7** cm wide, separated by **1.5** cm gap.

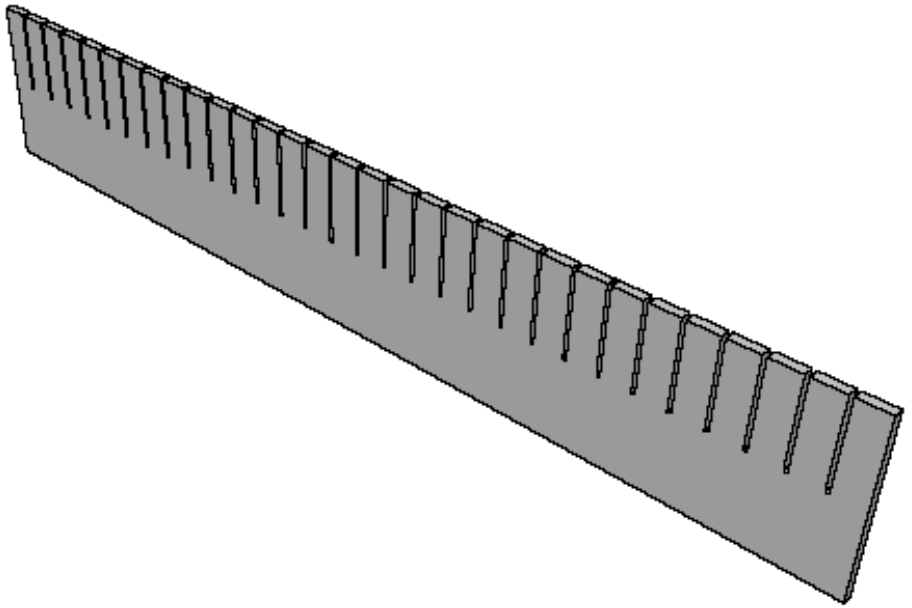
→ The slugs are housed within a beryllium sleeve that is 0.9 cm thick with an inner radius of 1.37 cm.

→ Each slug is supported inside the sleeve by three beryllium fins





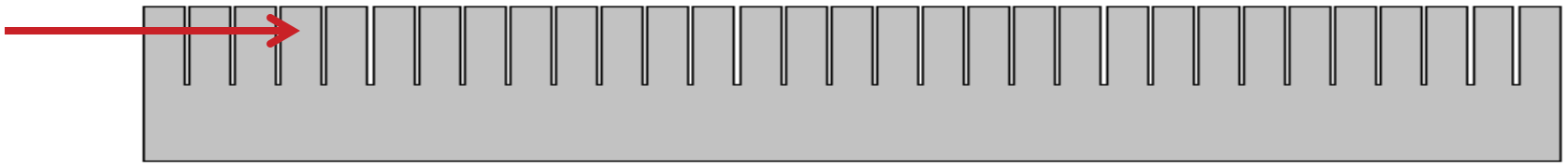
NOvA target design



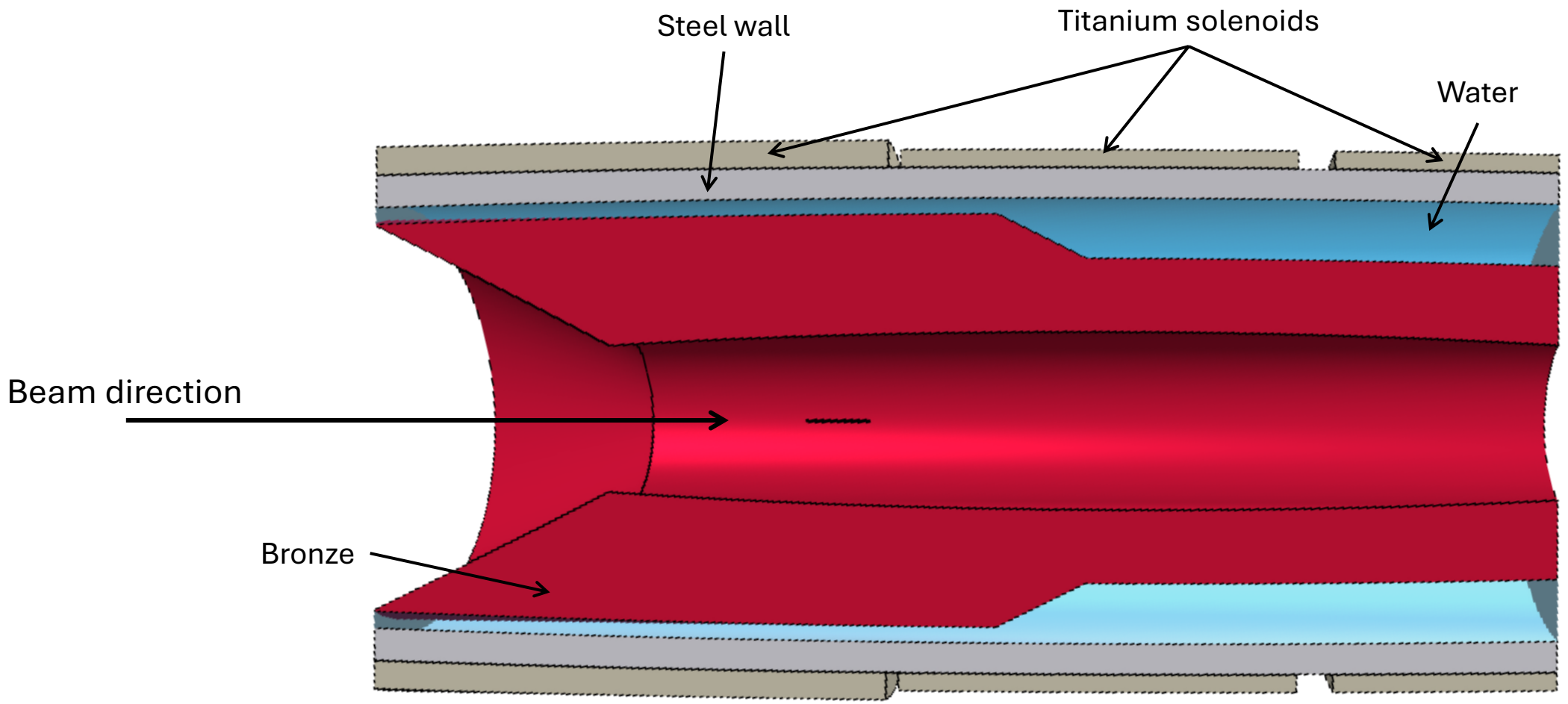
→ Material: Graphite

→ The target is **78** cm in length and 0.74 cm wide.

→ The target has 31 fins, each measuring 2.4 cm in length along the beam direction, and 6.3 cm in height, spaced by 0.05 cm gaps.

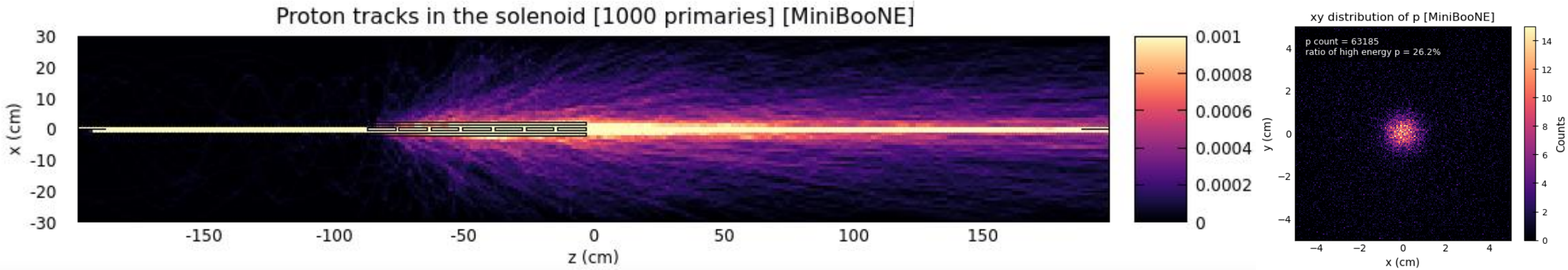


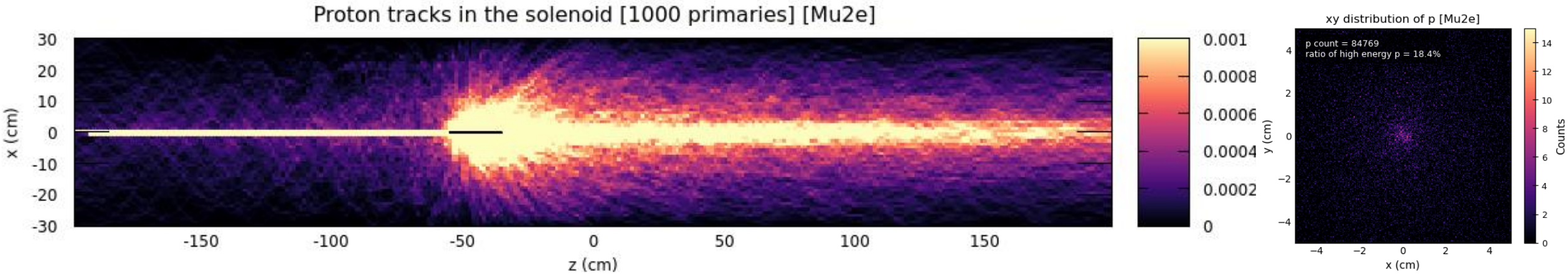
Mu2e Solenoid

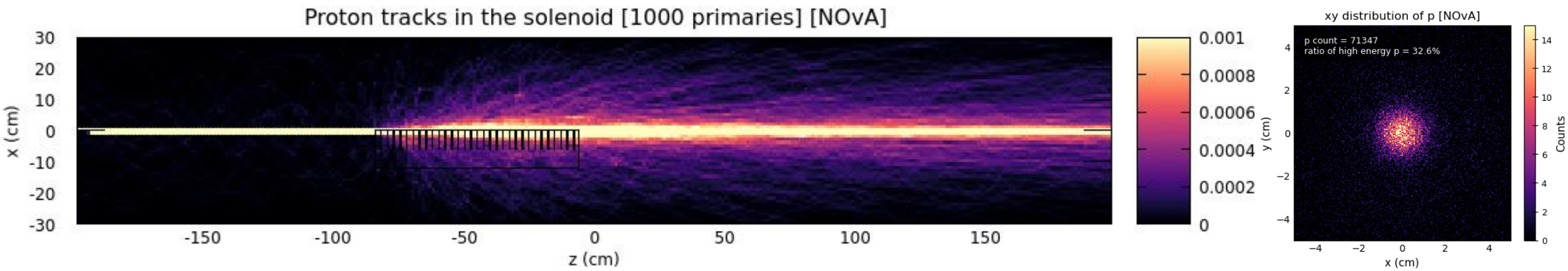


Analysis of the proton beam

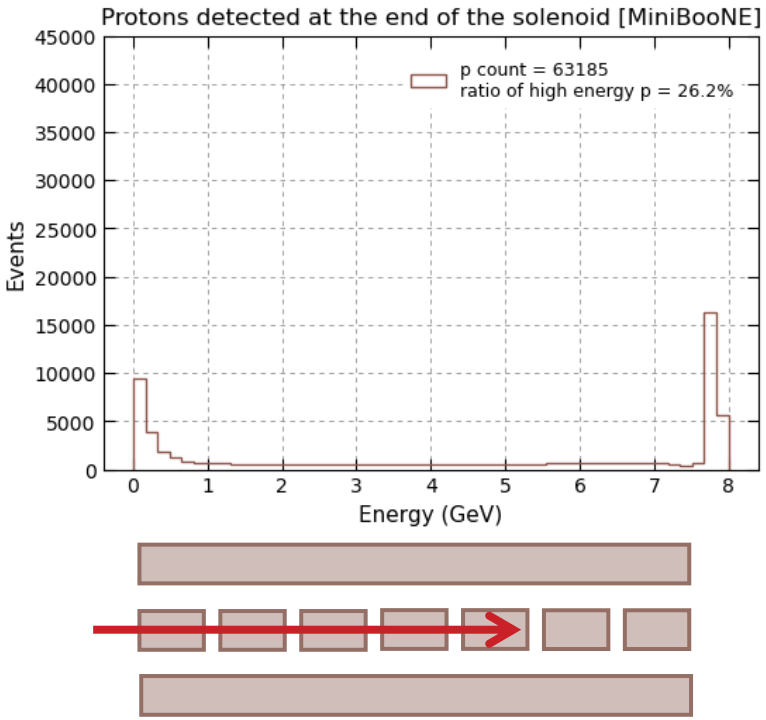
pions

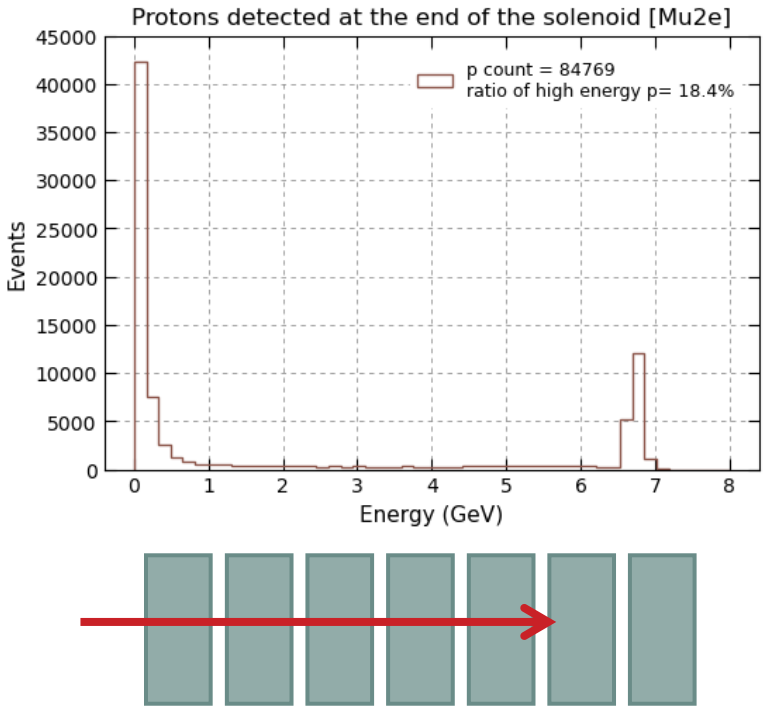

Proton tracks in the solenoid [1000 primaries] [MiniBooNE]
x (cm)
z (cm)
xy distribution of p [MiniBooNE]
p count = 63185
ratio of high energy p = 26.2%
y (cm)
x (cm)
Counts

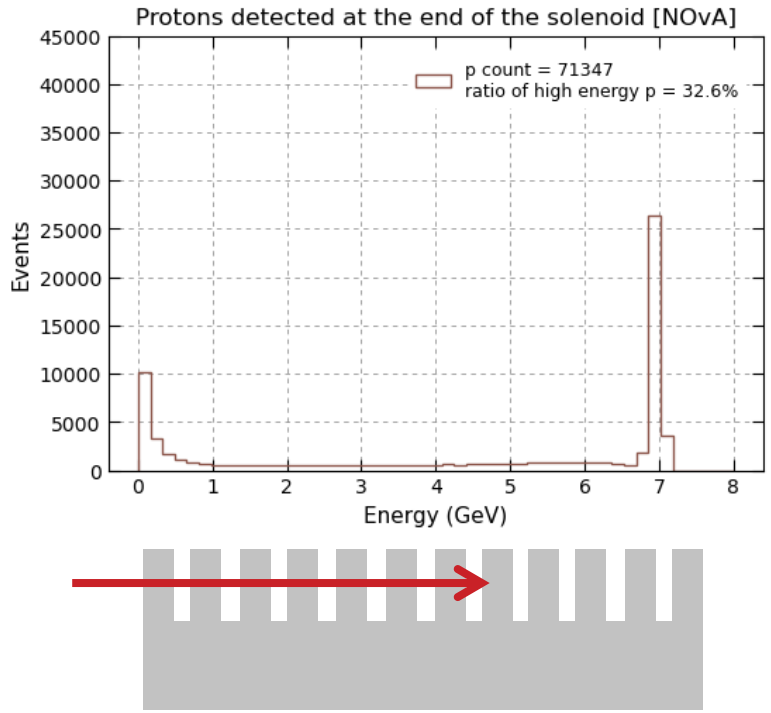

Proton tracks in the solenoid [1000 primaries] [Mu2e]
x (cm)
z (cm)
xy distribution of p [Mu2e]
p count = 84769
ratio of high energy p = 18.4%
y (cm)
x (cm)
Counts

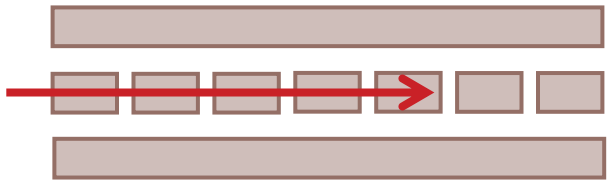

Proton tracks in the solenoid [1000 primaries] [NOvA]
x (cm)
z (cm)
xy distribution of p [NOvA]
p count = 71347
ratio of high energy p = 32.6%
y (cm)
x (cm)
Counts

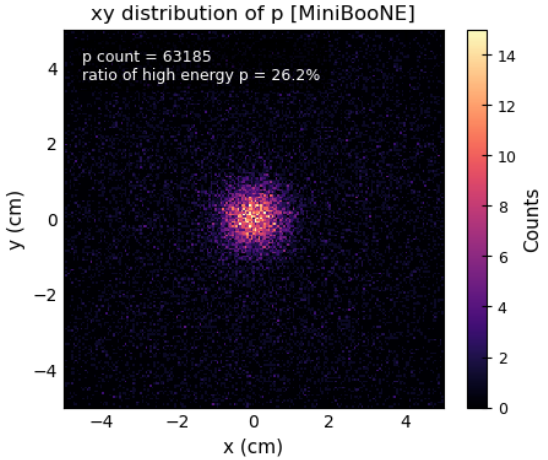
Protons energy distributions at the end of the solenoid

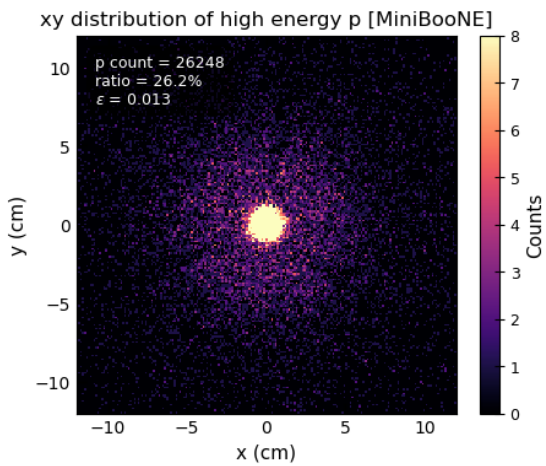


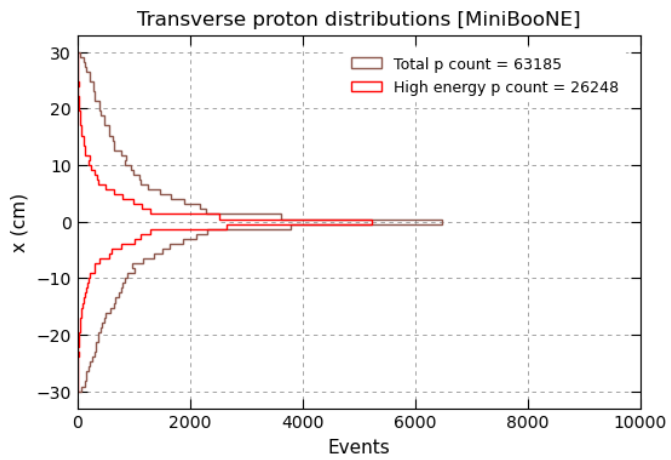


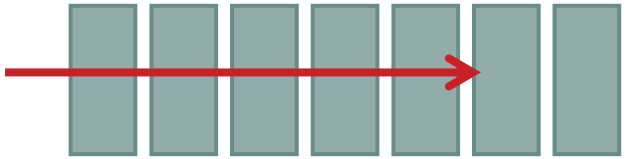


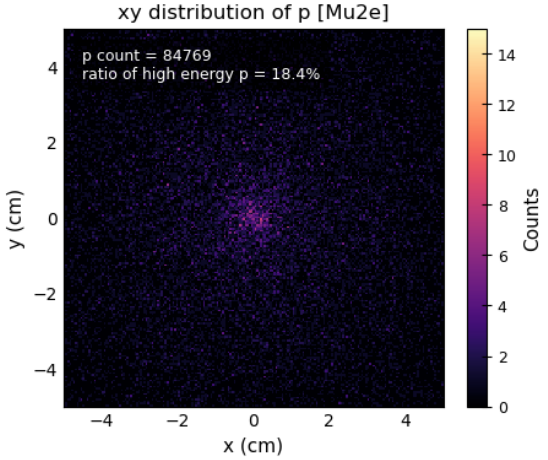


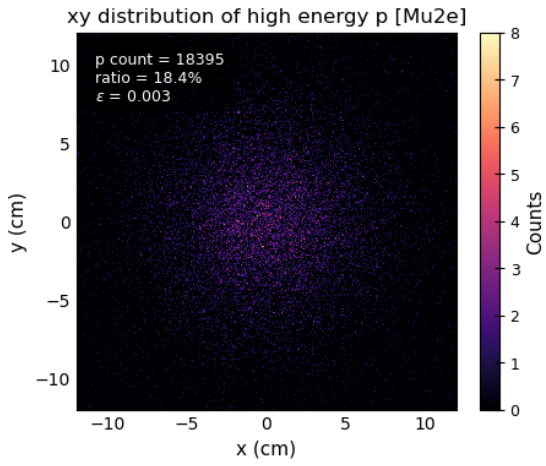

xy distribution of p [MiniBooNE]
p count = 63185
ratio of high energy p = 26.2%
y (cm)
x (cm)
Counts

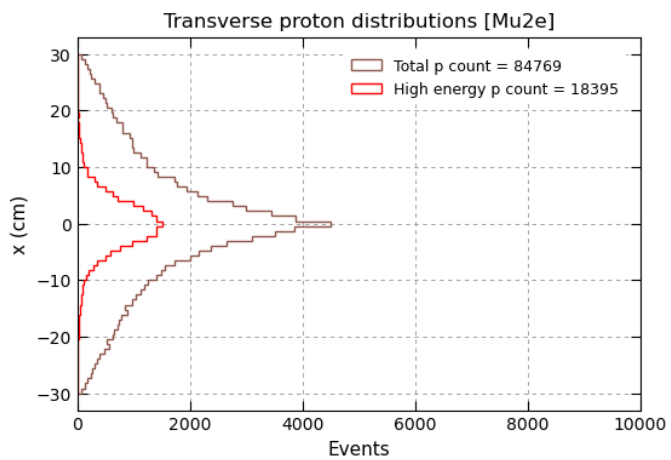

xy distribution of high energy p [MiniBooNE]
p count = 26248
ratio = 26.2%
ε = 0.013
y (cm)
x (cm)
Counts

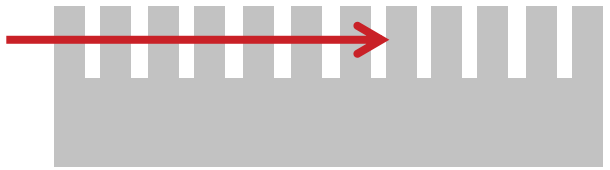

Transverse proton distributions [MiniBooNE]
Total p count = 63185
High energy p count = 26248
x (cm)
Events

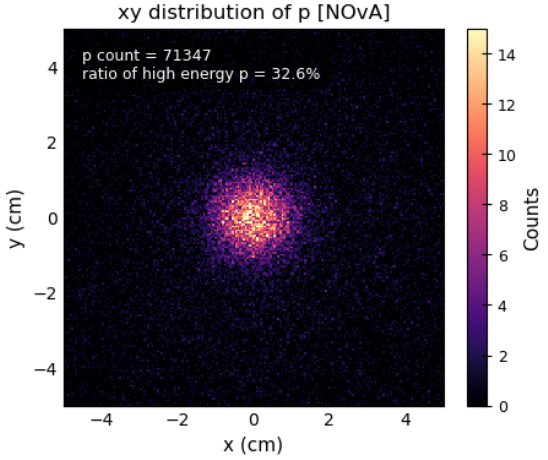


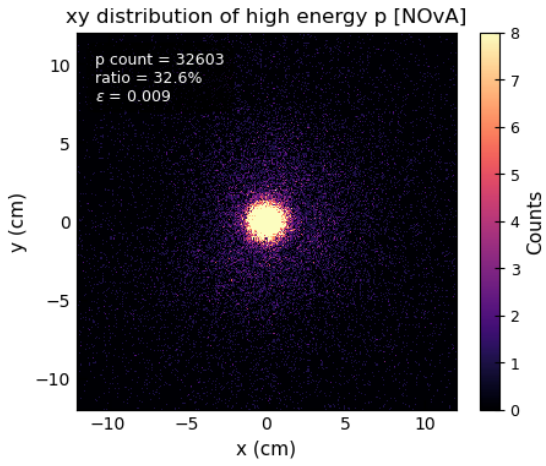

xy distribution of p [Mu2e]
p count = 84769
ratio of high energy p = 18.4%
y (cm)
x (cm)
Counts

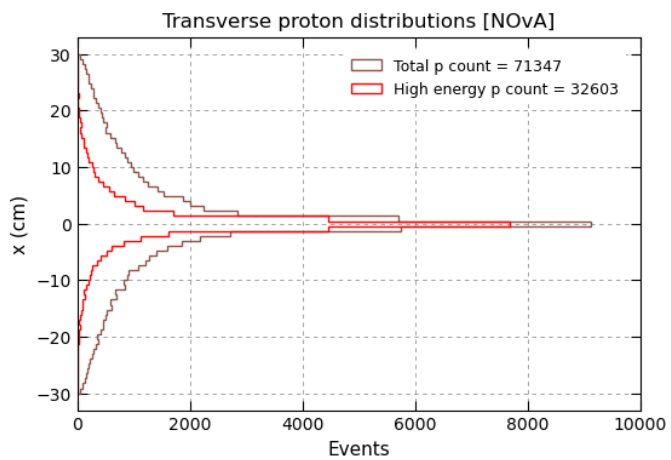

xy distribution of high energy p [Mu2e]
p count = 18395
ratio = 18.4%
ε = 0.003
y (cm)
x (cm)
Counts


Transverse proton distributions [Mu2e]
Total p count = 84769
High energy p count = 18395
x (cm)
Events



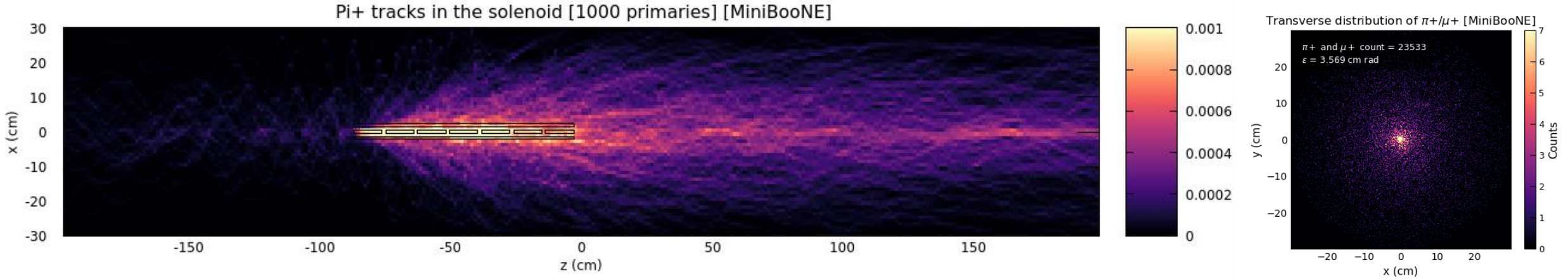

xy distribution of p [NOvA]
p count = 71347
ratio of high energy p = 32.6%
y (cm)
x (cm)
Counts

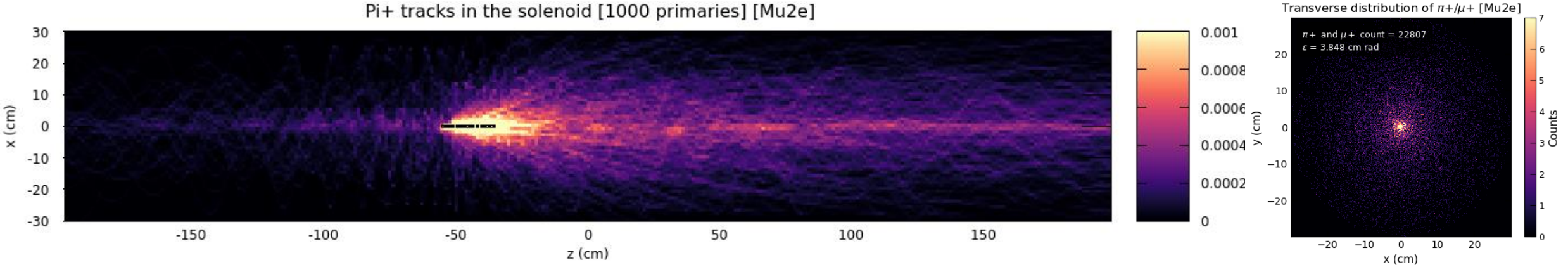

xy distribution of high energy p [NOvA]
p count = 32603
ratio = 32.6%
ε = 0.009
y (cm)
x (cm)
Counts

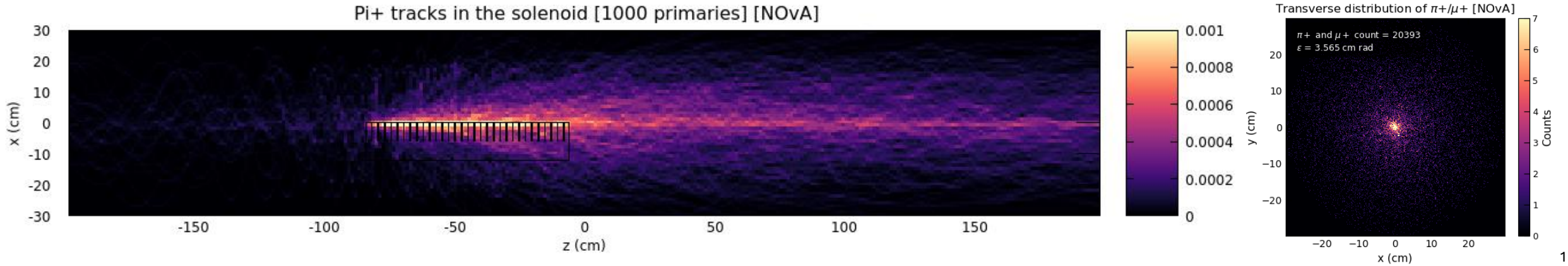

Transverse proton distributions [NOvA]
Total p count = 71347
High energy p count = 32603
x (cm)
Events

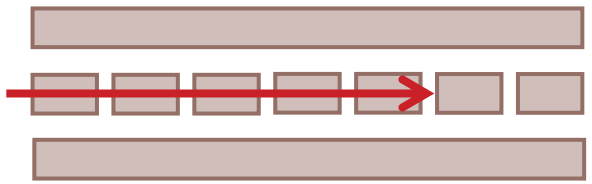
Analysis of the π/μ beam

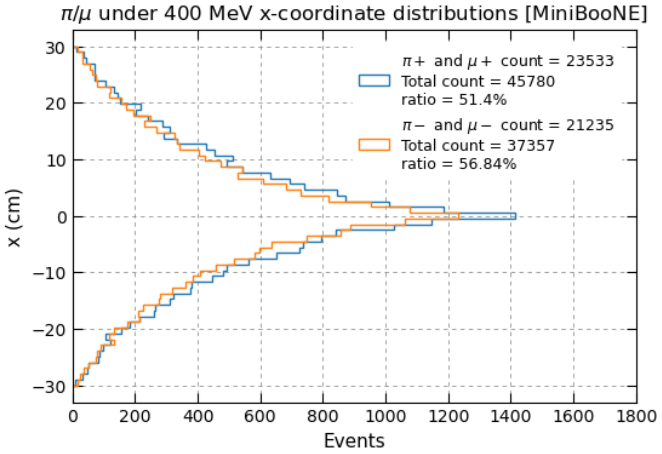
protons

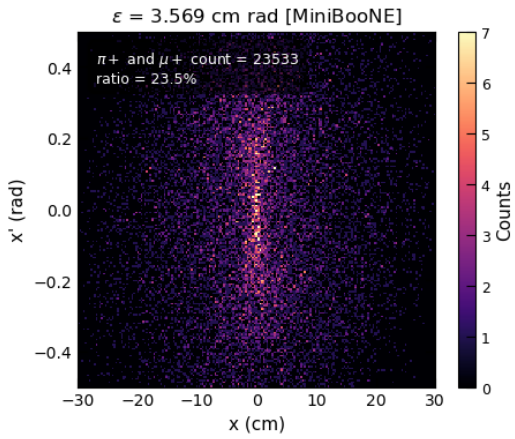

Pi+ tracks in the solenoid [1000 primaries] [MiniBooNE]
x (cm)
z (cm)
Transverse distribution of π+/μ+ [MiniBooNE]
π+ and μ+ count = 23533
ε = 3.569 cm rad
y (cm)
x (cm)
Counts

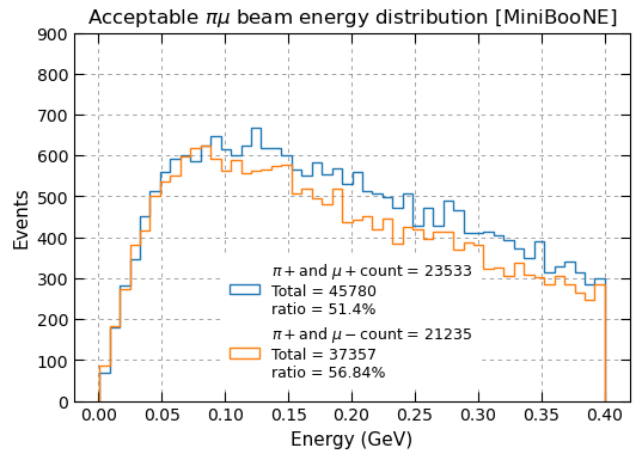

Pi+ tracks in the solenoid [1000 primaries] [Mu2e]
x (cm)
z (cm)
Transverse distribution of π+/μ+ [Mu2e]
π+ and μ+ count = 22807
ε = 3.848 cm rad
y (cm)
x (cm)
Counts

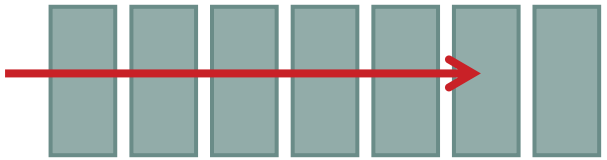

Pi+ tracks in the solenoid [1000 primaries] [NOvA]
x (cm)
z (cm)
Transverse distribution of π+/μ+ [NOvA]
π+ and μ+ count = 20393
ε = 3.565 cm rad
y (cm)
x (cm)
Counts

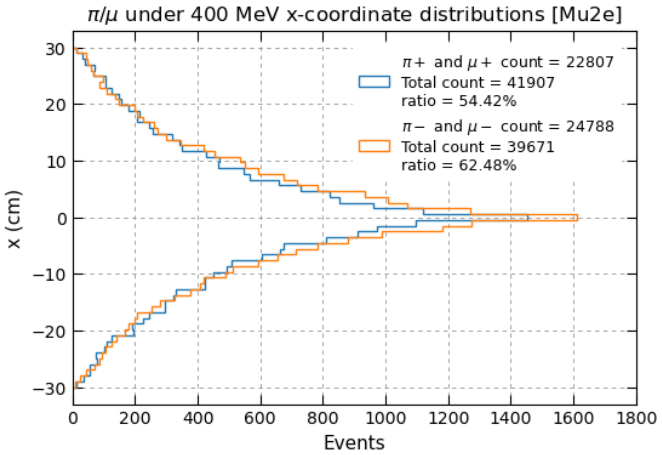


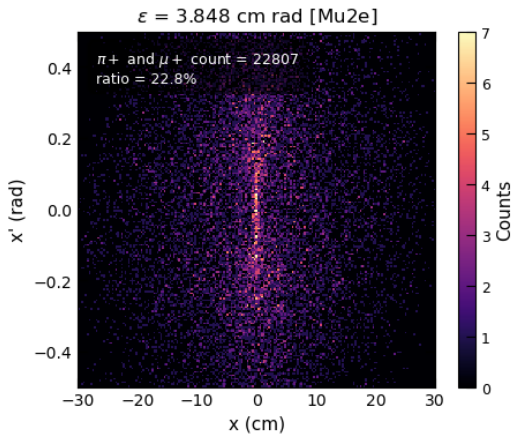

π/μ under 400 MeV x-coordinate distributions [MiniBooNE]
π+ and μ+ count = 23533
Total count = 45780
ratio = 51.4%
π− and μ− count = 21235
Total count = 37357
ratio = 56.84%
x (cm)
Events

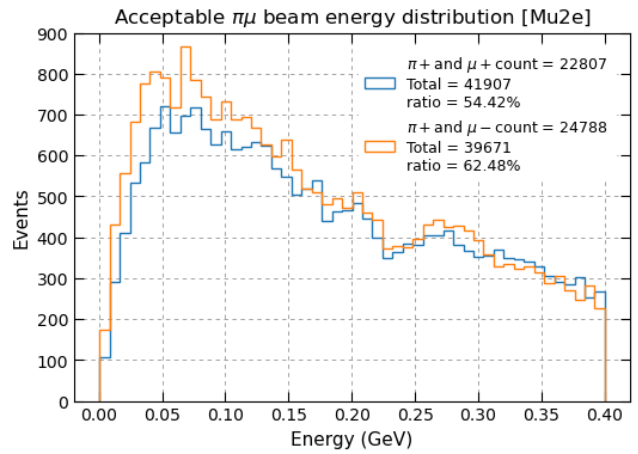

ε = 3.569 cm rad [MiniBooNE]
π+ and μ+ count = 23533
ratio = 23.5%
x' (rad)
x (cm)
Counts

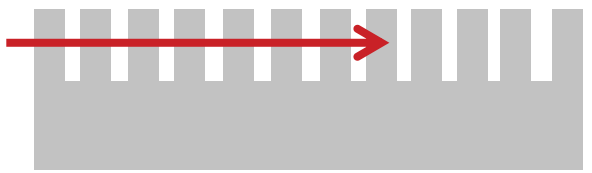

Acceptable πμ beam energy distribution [MiniBooNE]
π+ and μ+ count = 23533
Total = 45780
ratio = 51.4%
π+ and μ− count = 21235
Total = 37357
ratio = 56.84%
Events
Energy (GeV)

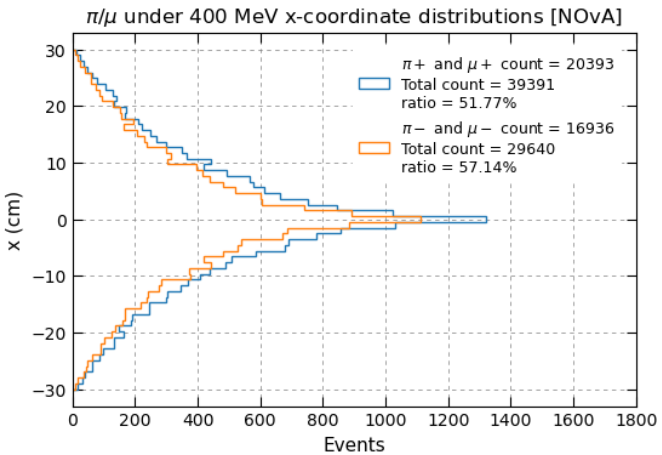


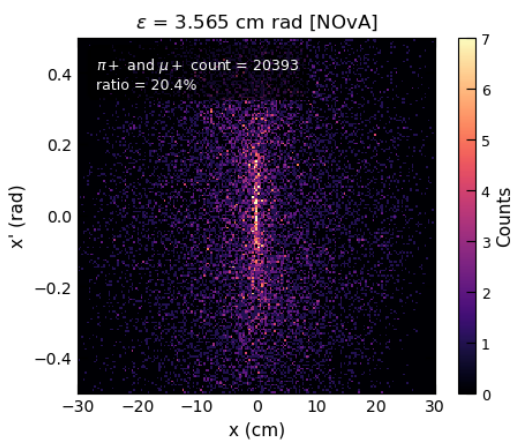

π/μ under 400 MeV x-coordinate distributions [Mu2e]
π+ and μ+ count = 22807
Total count = 41907
ratio = 54.42%
π− and μ− count = 24788
Total count = 39671
ratio = 62.48%
x (cm)
Events

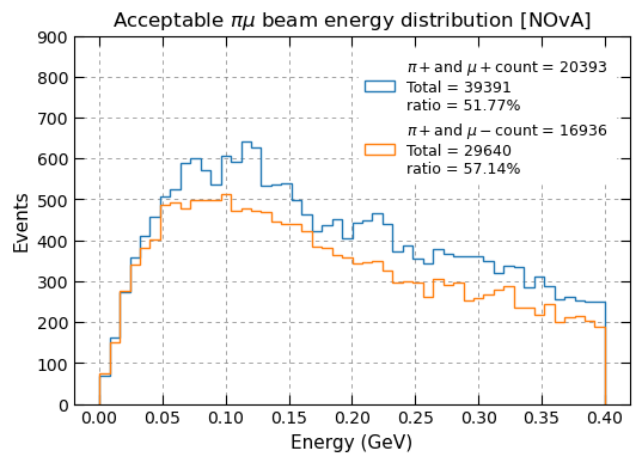

ε = 3.848 cm rad [Mu2e]
π+ and μ+ count = 22807
ratio = 22.8%
x' (rad)
x (cm)
Counts


Acceptable πμ beam energy distribution [Mu2e]
π+ and μ+ count = 22807
Total = 41907
ratio = 54.42%
π+ and μ− count = 24788
Total = 39671
ratio = 62.48%
Events
Energy (GeV)

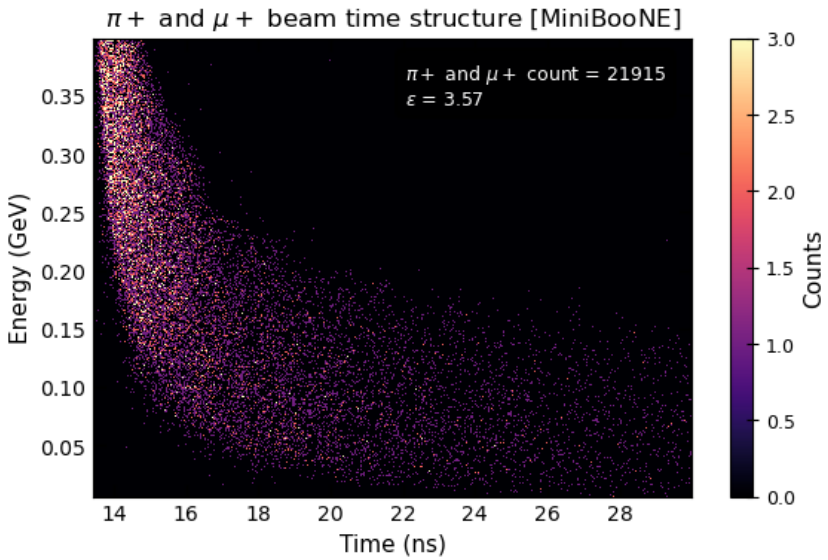


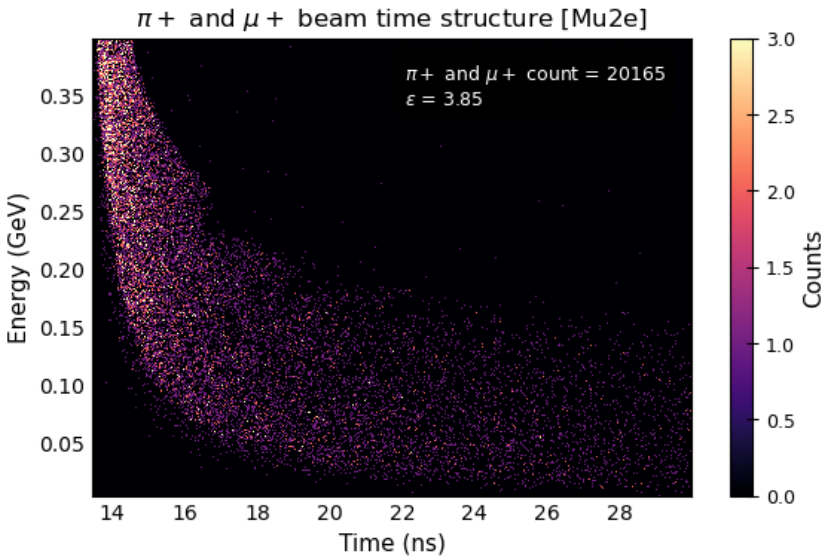

π/μ under 400 MeV x-coordinate distributions [NOvA]
π+ and μ+ count = 20393
Total count = 39391
ratio = 51.77%
π− and μ− count = 16936
Total count = 29640
ratio = 57.14%
x (cm)
Events

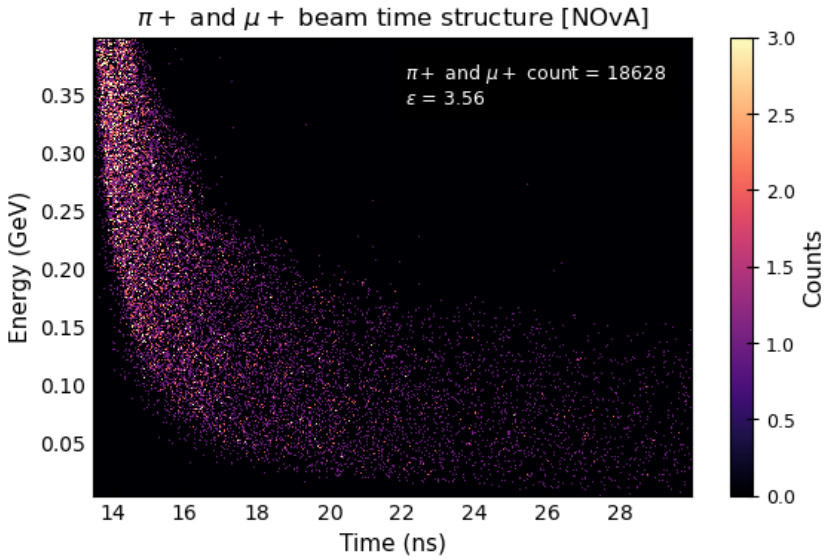

ε = 3.565 cm rad [NOvA]
π+ and μ+ count = 20393
ratio = 20.4%
x' (rad)
x (cm)
Counts

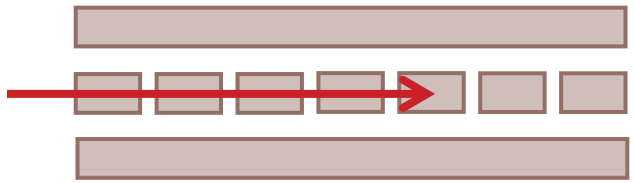

Acceptable πμ beam energy distribution [NOvA]
π+ and μ+ count = 20393
Total = 39391
ratio = 51.77%
π+ and μ− count = 16936
Total = 29640
ratio = 57.14%
Events
Energy (GeV)

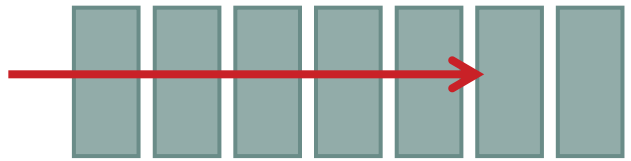
π/μ beam time structure at the end of the solenoid

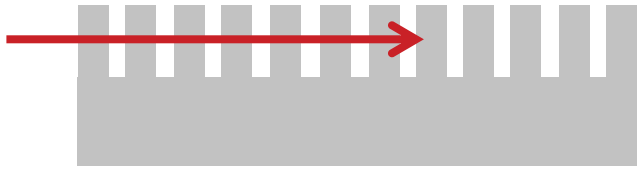




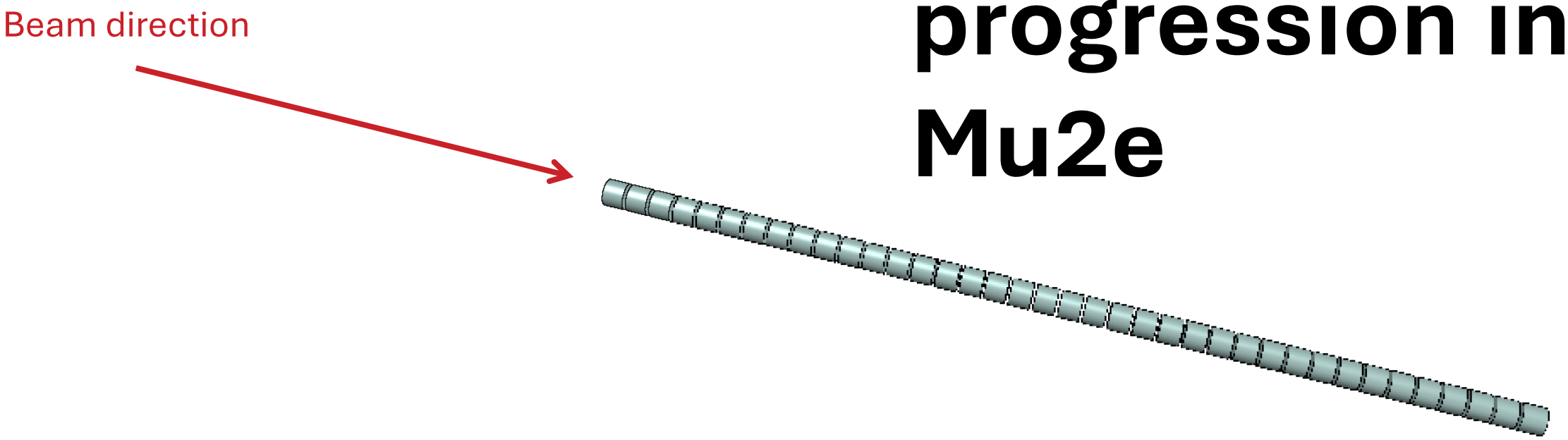


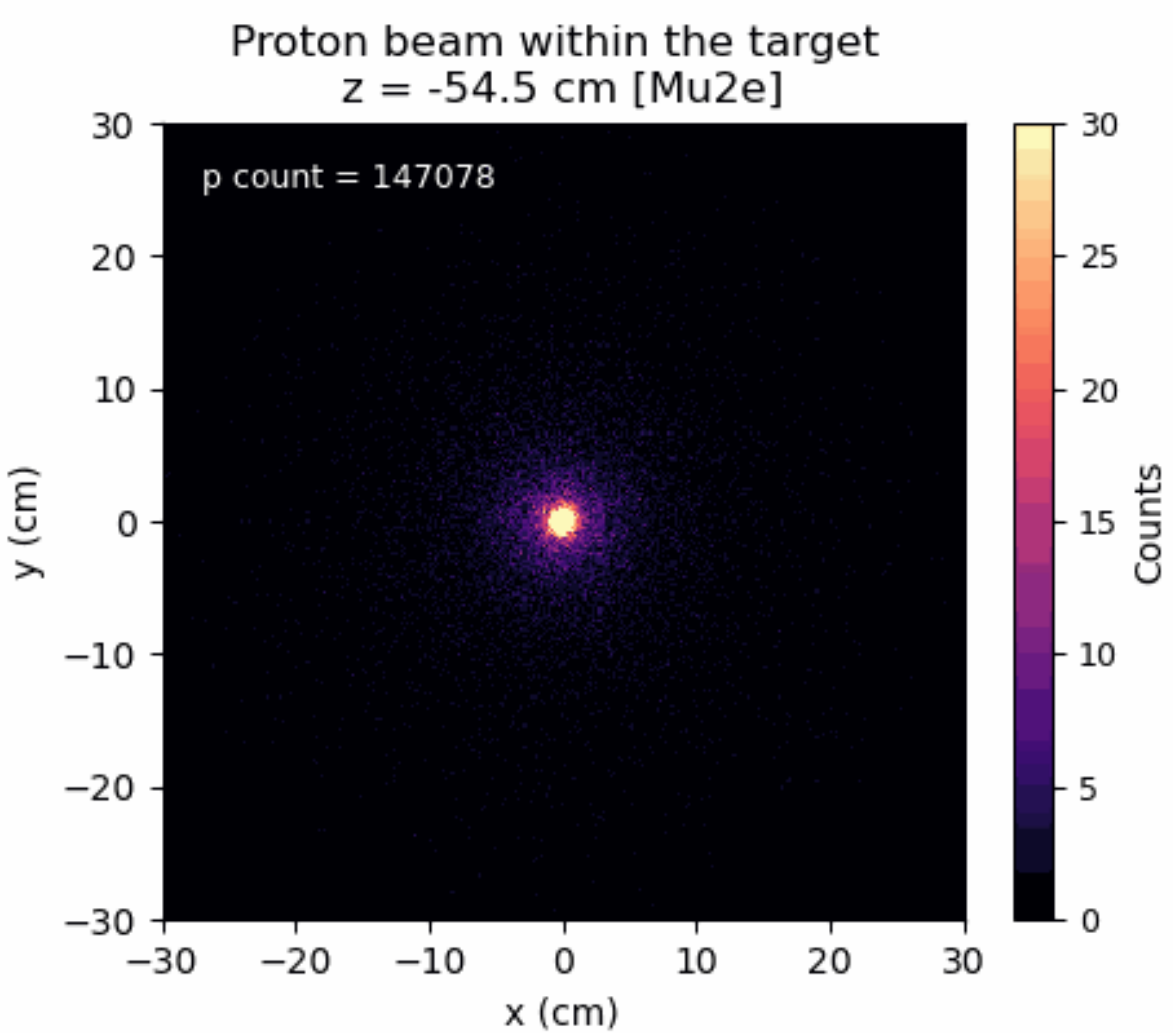


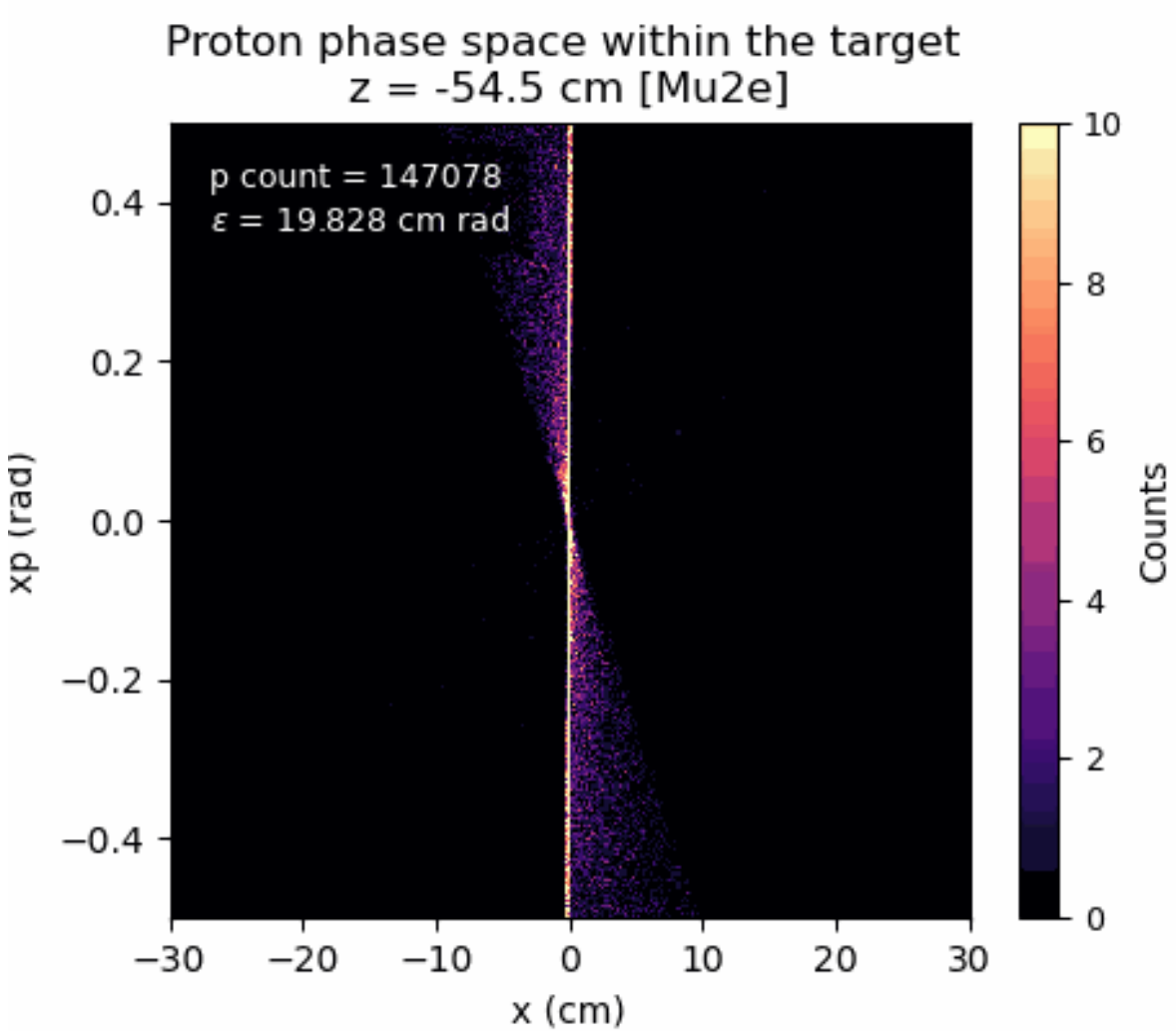


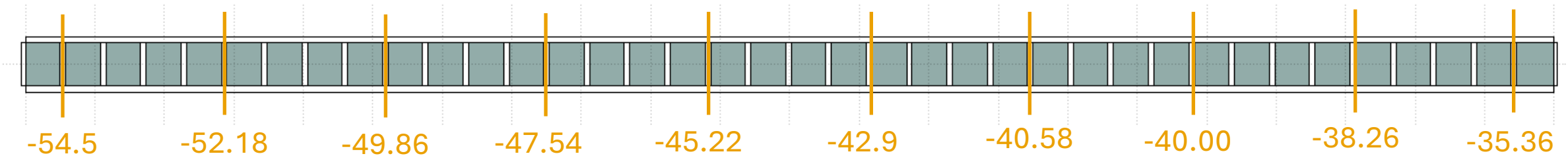


Analysis of the proton beam progression in Mu2e




Proton beam within the target
z = -54.5 cm [Mu2e]
p count = 147078
y (cm)
x (cm)
Counts


Proton phase space within the target
z = -54.5 cm [Mu2e]
p count = 147078
ε = 19.828 cm rad
xp (rad)
x (cm)
Counts


-54.5
-52.18
-49.86
-47.54
-45.22
-42.9
-40.58
-40.00
-38.26
-35.36

For next week...

→**Focus on the target damage studies.**

- → Learn more about DPA and H/He appm and how to quantify damage in different materials using these units.

→**Simulate the progression of phase space of the beam at different stages of the setup.**

- → The purpose of this analysis is to understand what part/s of the target geometry affect the produced pion beam.
- → Moreover, it will be good to know how the density of the material actually affects the pion beam (other than the fact that pion production increases).