Energy Loss in the lH2 Absorber and Wedge

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Aims

- Look at energy loss in the wedge
- Determine Alignment of wedge
- Investigate energy loss for lH2 absorber at various densities

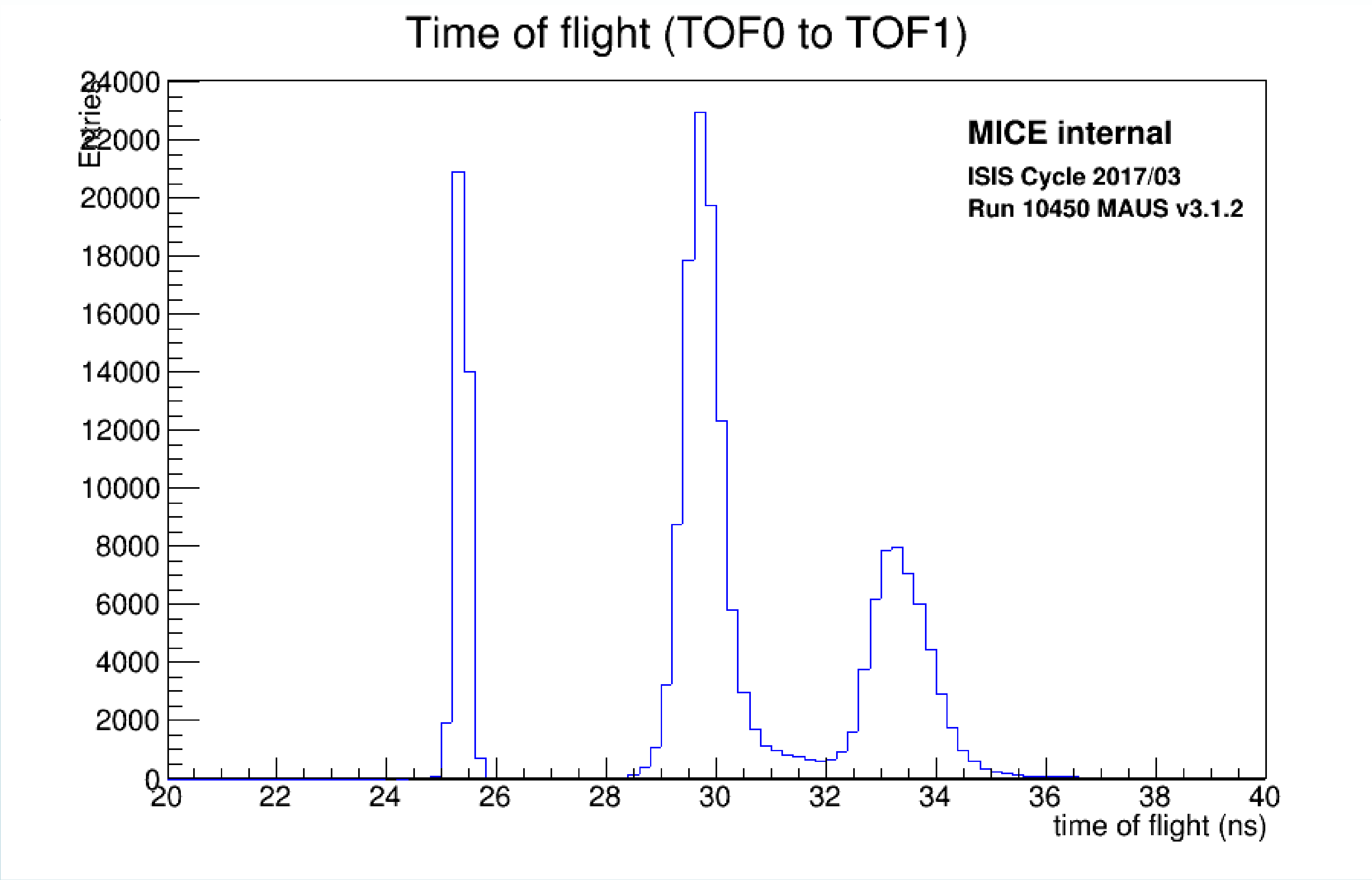
Data Sets

- Looking at three data sets
- Data sets with cooling channel 2017-02-7
- Data sets with Optics 6-140+M3-Test2

- Data Set 10450 has no absorber
- Data Set 09949 has liquid Hydrogen absorber
- Data Set 10537 has wedge

- Make Momentum Cut 135 to 145 MeV/c
- As well as a TOF Cut 28 to 32 ns
- 2 Tracks, one upstream and one downstream
- Using Station 1 and plane 0 of Sci Fi Trackers

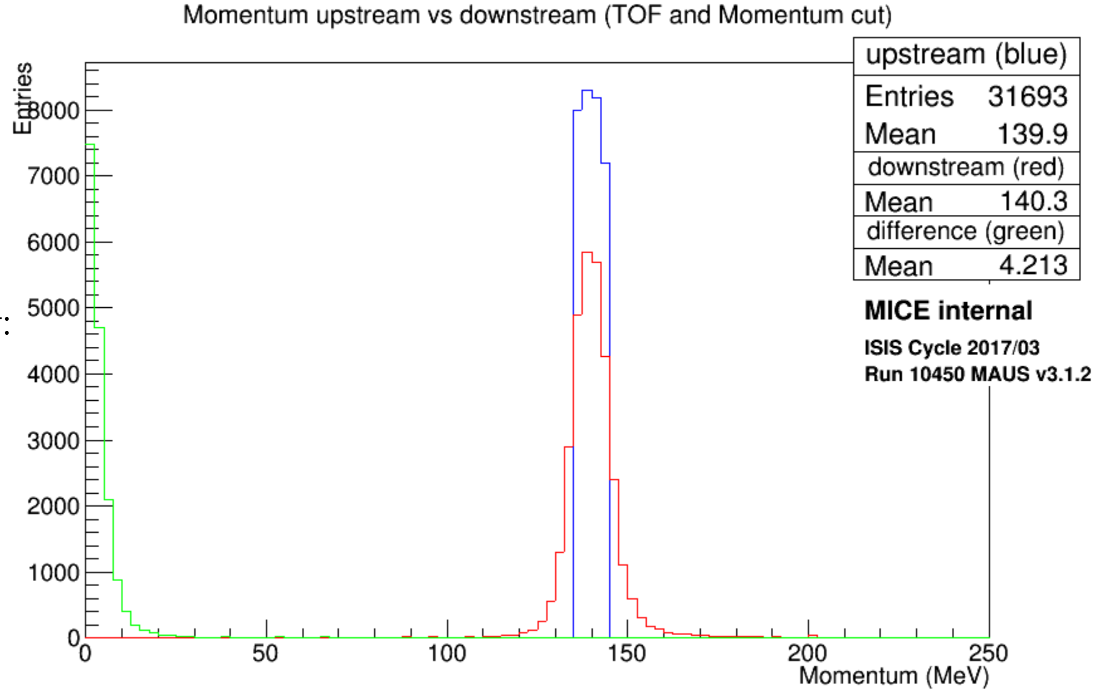
No Absorber

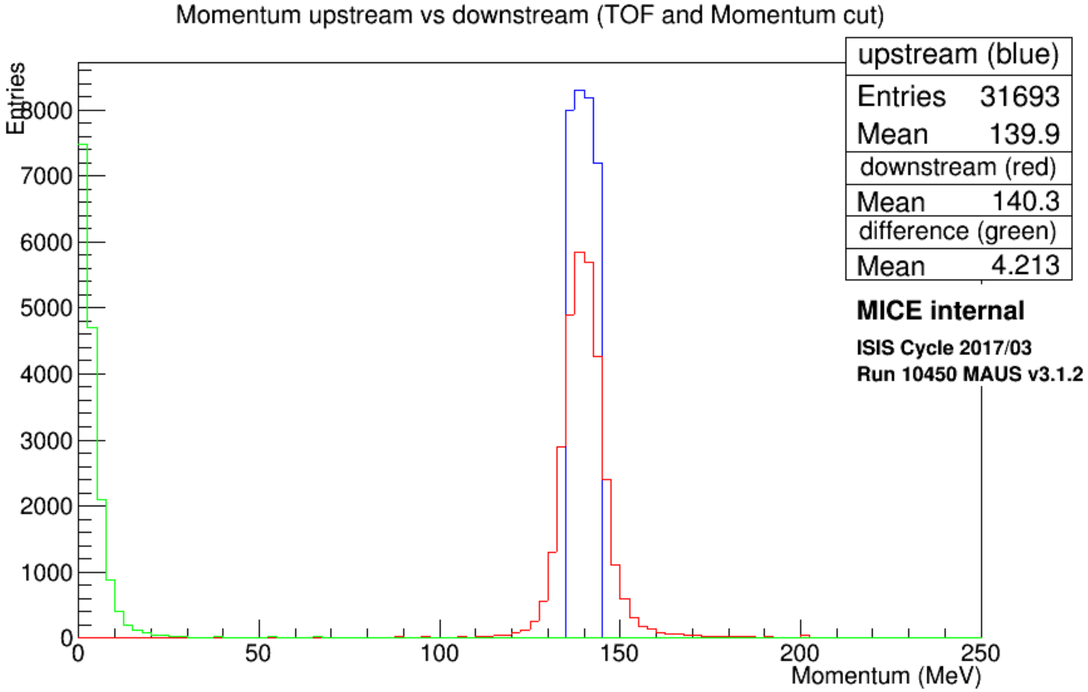

Time of flight (TOF0 to TOF1)
Entries
MICE internal
ISIS Cycle 2017/03
Run 10450 MAUS v3.1.2
24000
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
20
22
24
26
28
30
32
34
36
38
40
time of flight (ns)

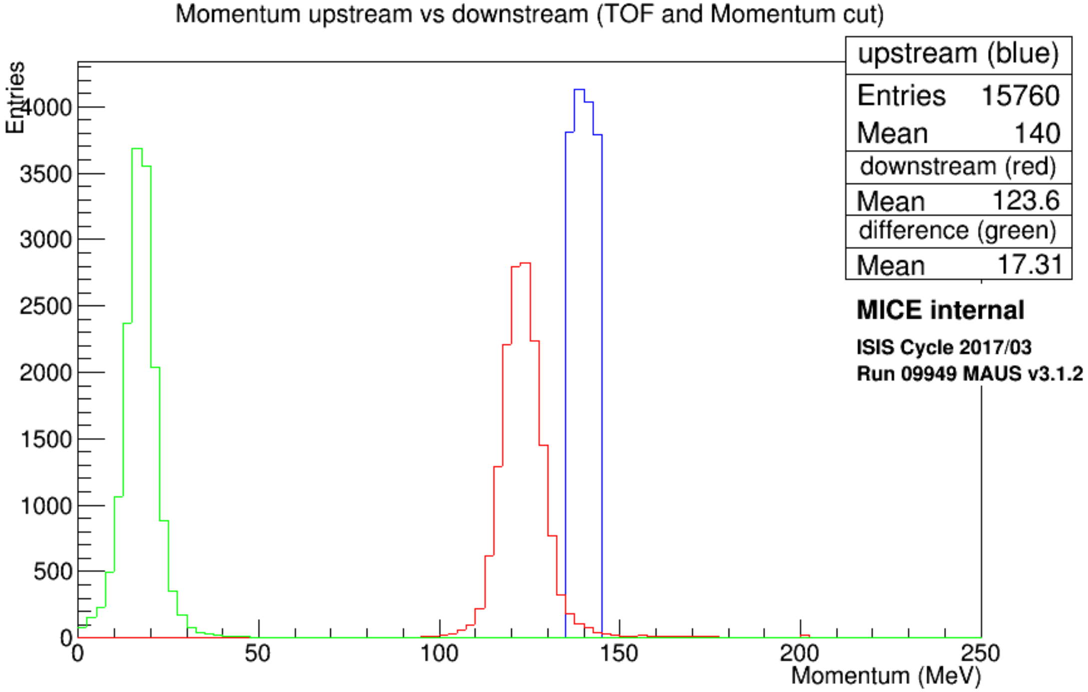
Top Left and Right:
No Absorber

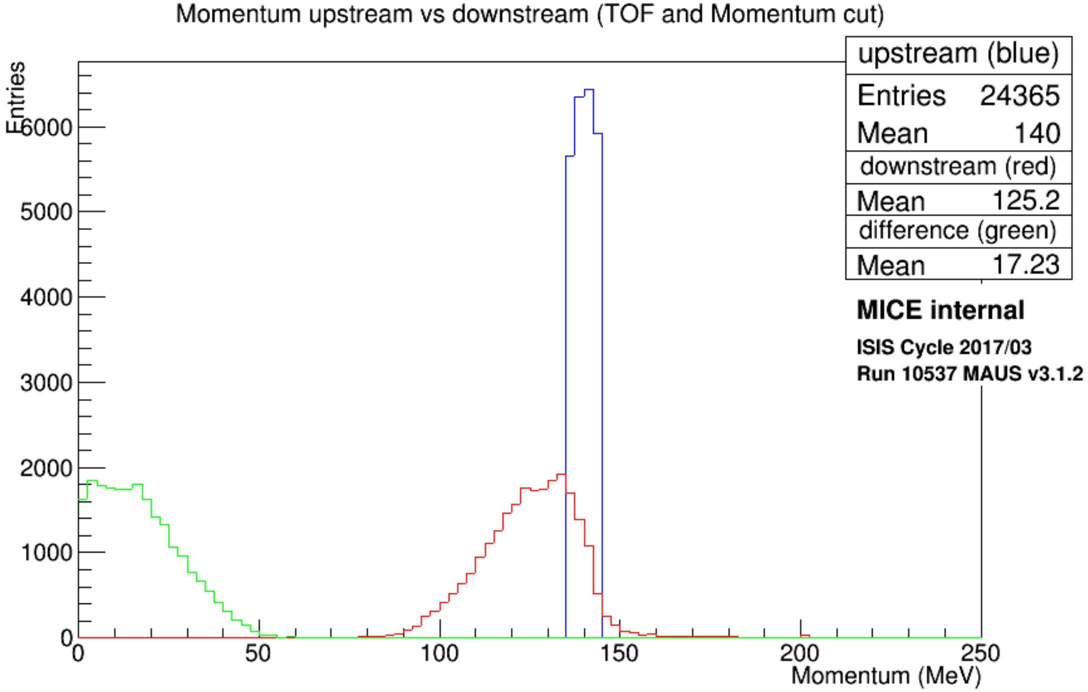
Bottom Left:
Liquid Hydrogen

Bottom Right:
Wedge





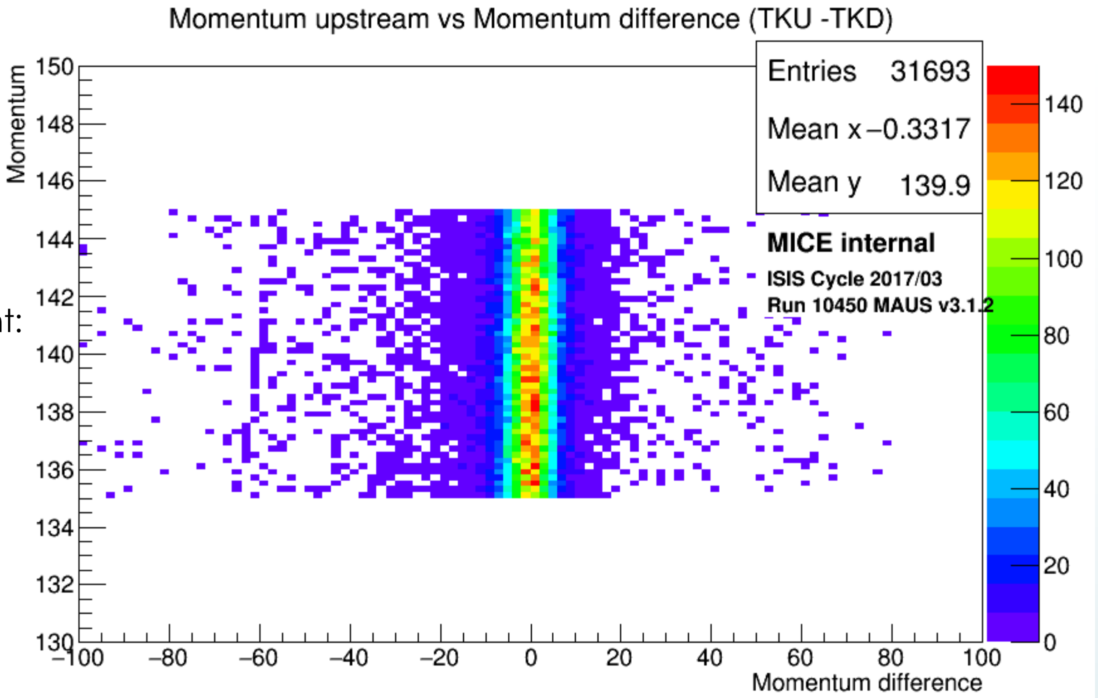


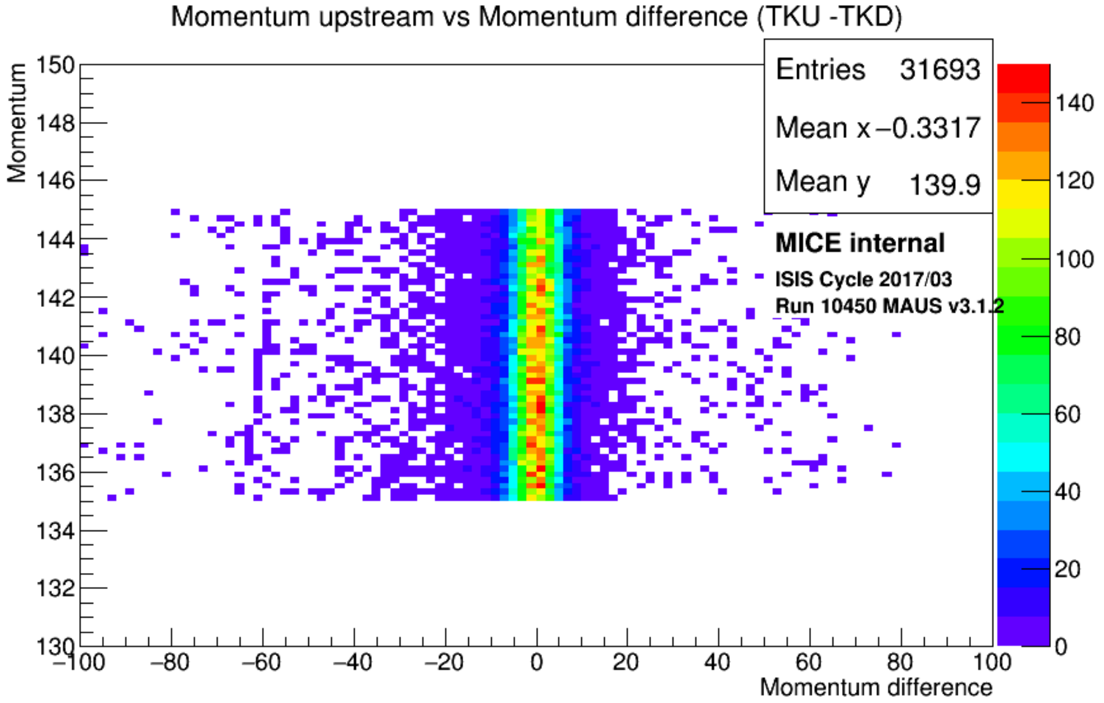


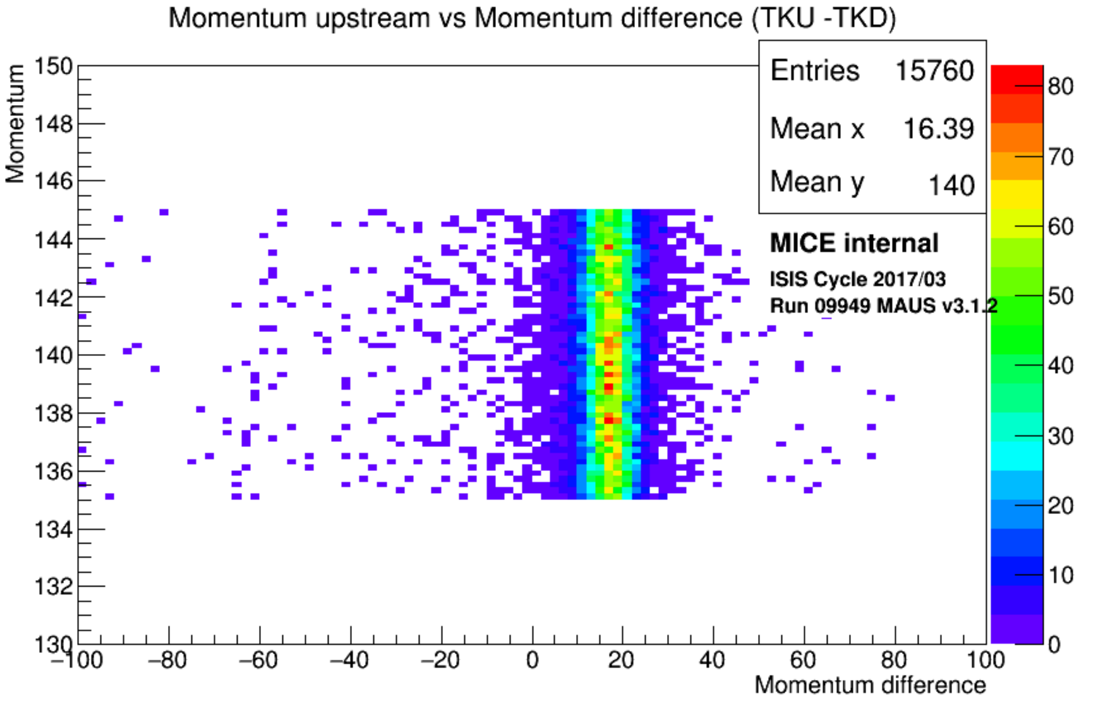
Top Left and Right: No Absorber

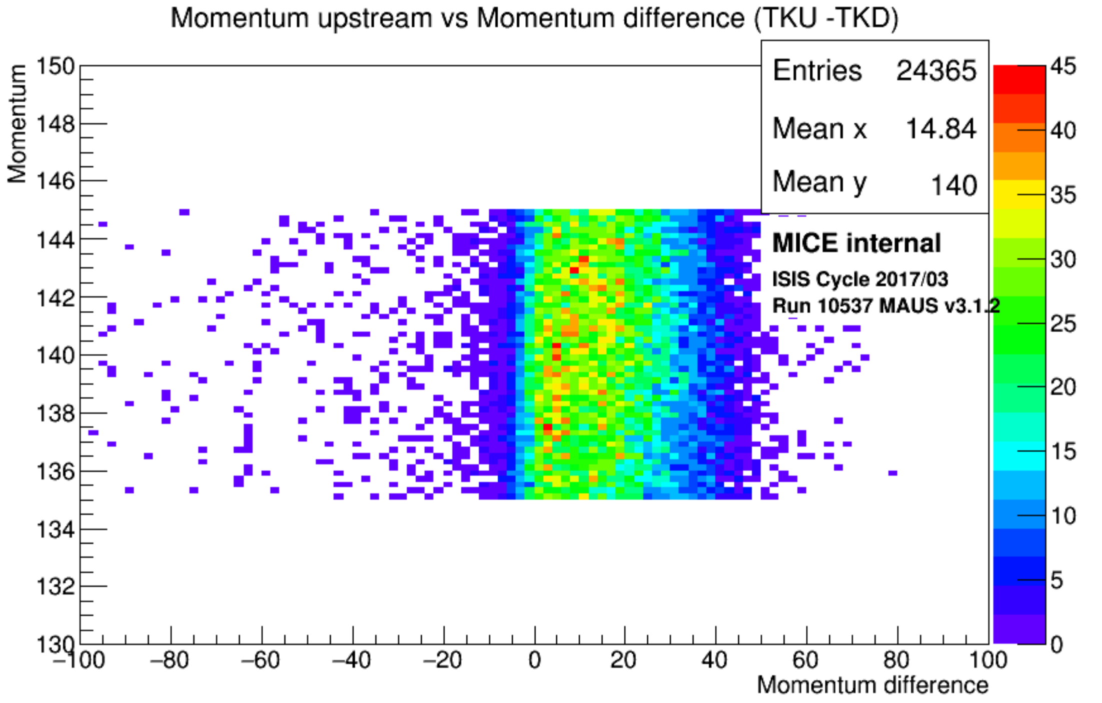
Bottom Left: Liquid Hydrogen

Bottom Right: Wedge







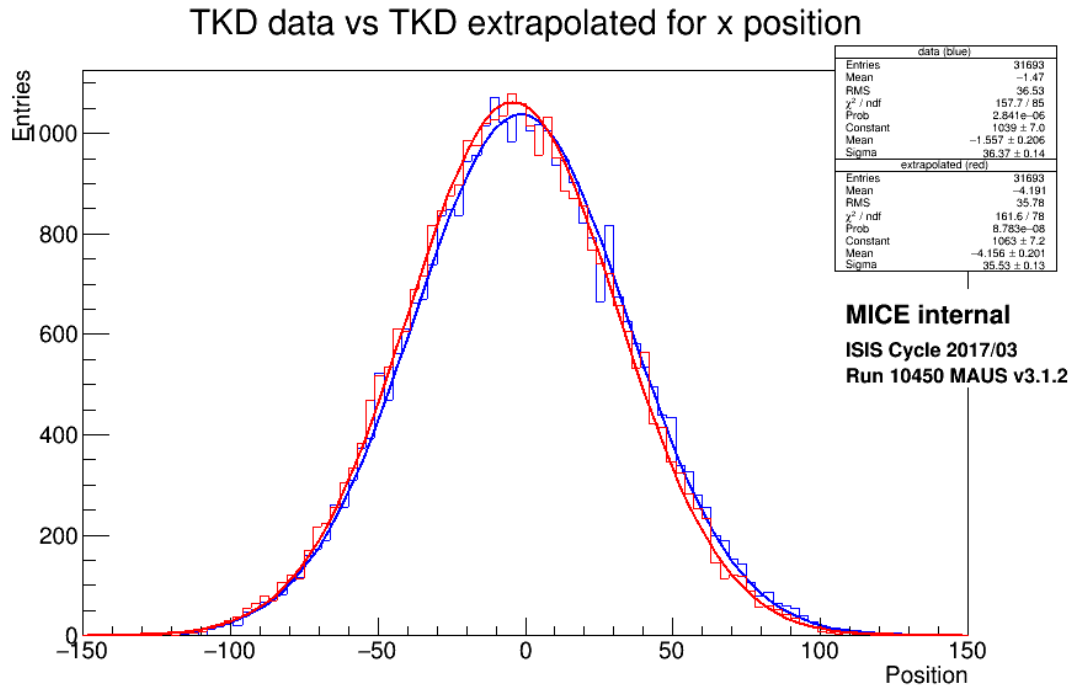


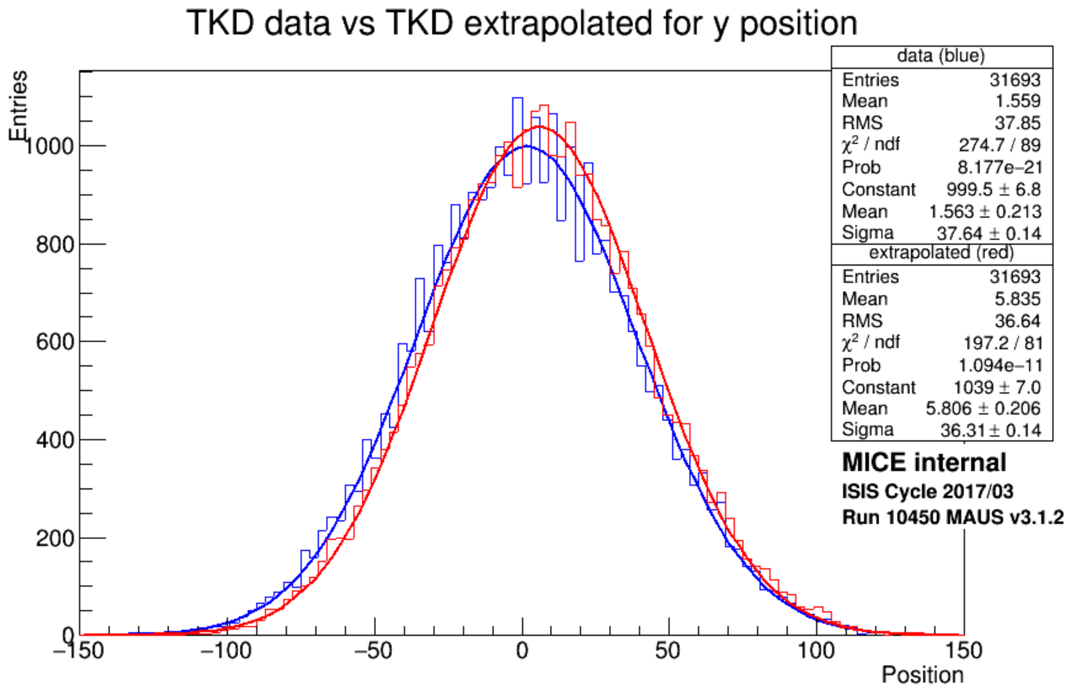
Momentum difference at the absorber/wedge

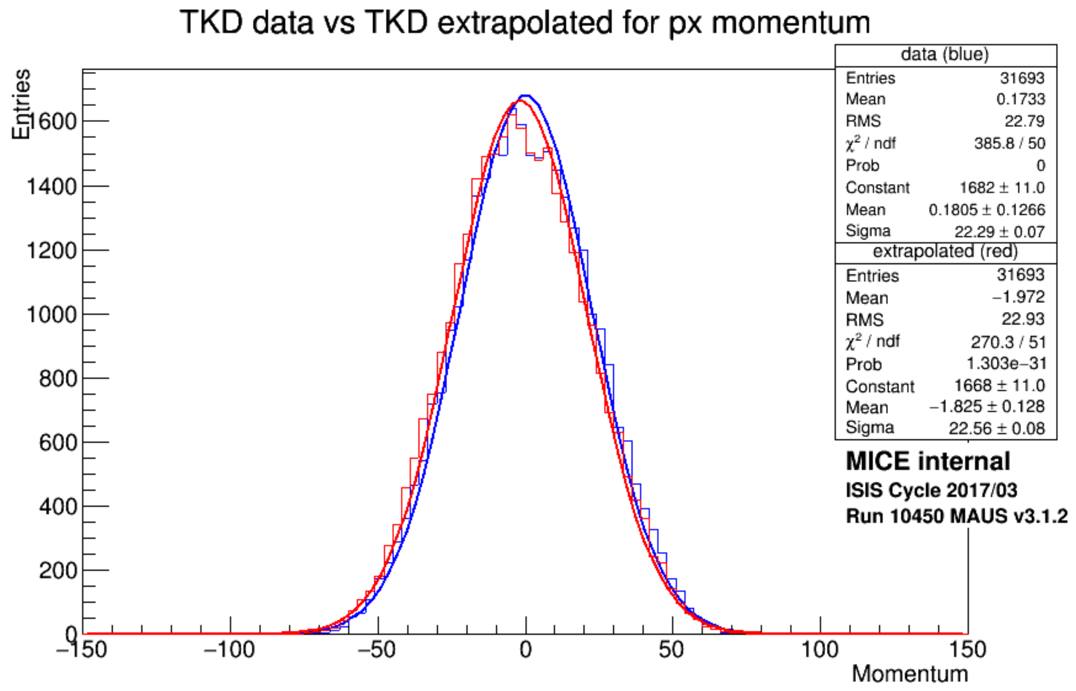
- Extrapolate data from TKU to wedge
- Showing Momentum difference for various radii, x and y position

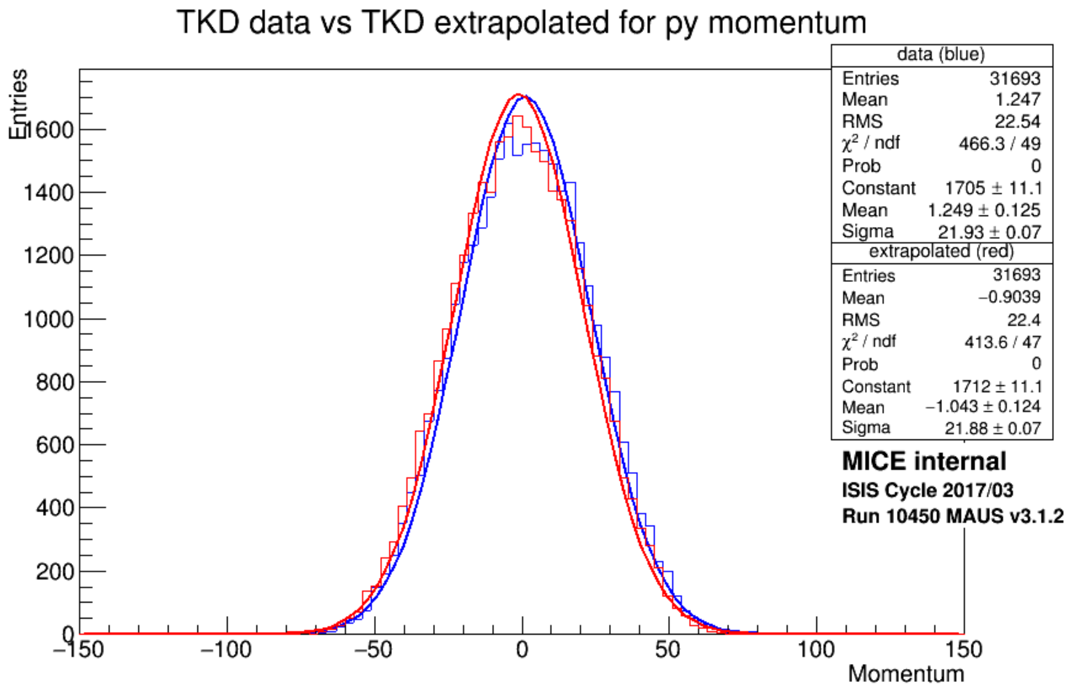
- Uses maus_cpp.global_error_tracking for particle propagation
- Inherent differences between model and extrapolation
- E.g. due to detector resolution, energy straggling etc.
- Will use full MAUS routine in future

No Absorber

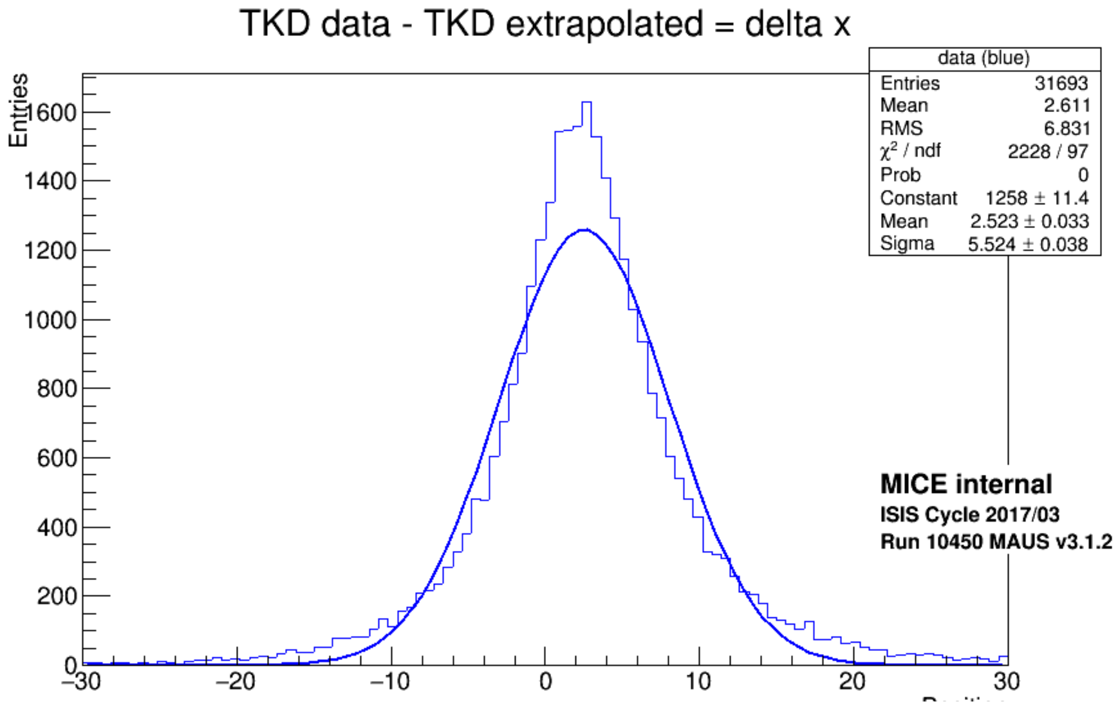

TKD data vs TKD extrapolated for x position
Entries
Position
data (blue)
Entries 31693
Mean −1.47
RMS 36.53
χ² / ndf 157.7 / 85
Prob 2.841e−06
Constant 1039 ± 7.0
Mean −1.557 ± 0.206
Sigma 36.37 ± 0.14
extrapolated (red)
Entries 31693
Mean −4.191
RMS 35.78
χ² / ndf 161.6 / 78
Prob 8.783e−08
Constant 1063 ± 7.2
Mean −4.156 ± 0.201
Sigma 35.53 ± 0.13
MICE internal
ISIS Cycle 2017/03
Run 10450 MAUS v3.1.2

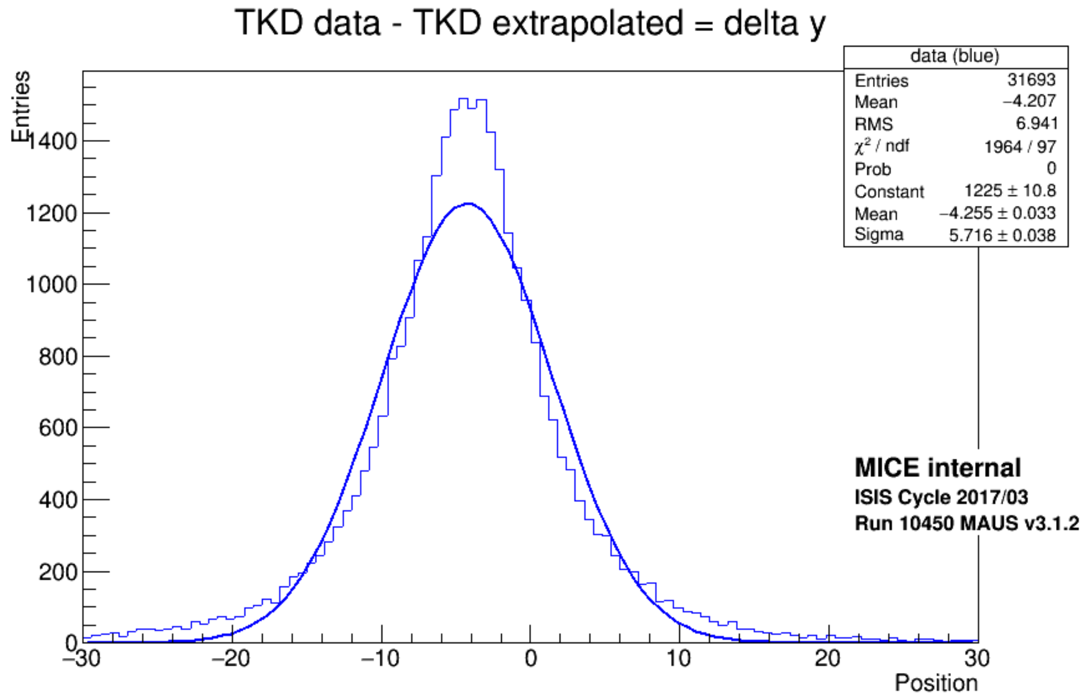

TKD data vs TKD extrapolated for y position
Entries
Position
data (blue)
Entries 31693
Mean 1.559
RMS 37.85
χ² / ndf 274.7 / 89
Prob 8.177e−21
Constant 999.5 ± 6.8
Mean 1.563 ± 0.213
Sigma 37.64 ± 0.14
extrapolated (red)
Entries 31693
Mean 5.835
RMS 36.64
χ² / ndf 197.2 / 81
Prob 1.094e−11
Constant 1039 ± 7.0
Mean 5.806 ± 0.206
Sigma 36.31 ± 0.14
MICE internal
ISIS Cycle 2017/03
Run 10450 MAUS v3.1.2

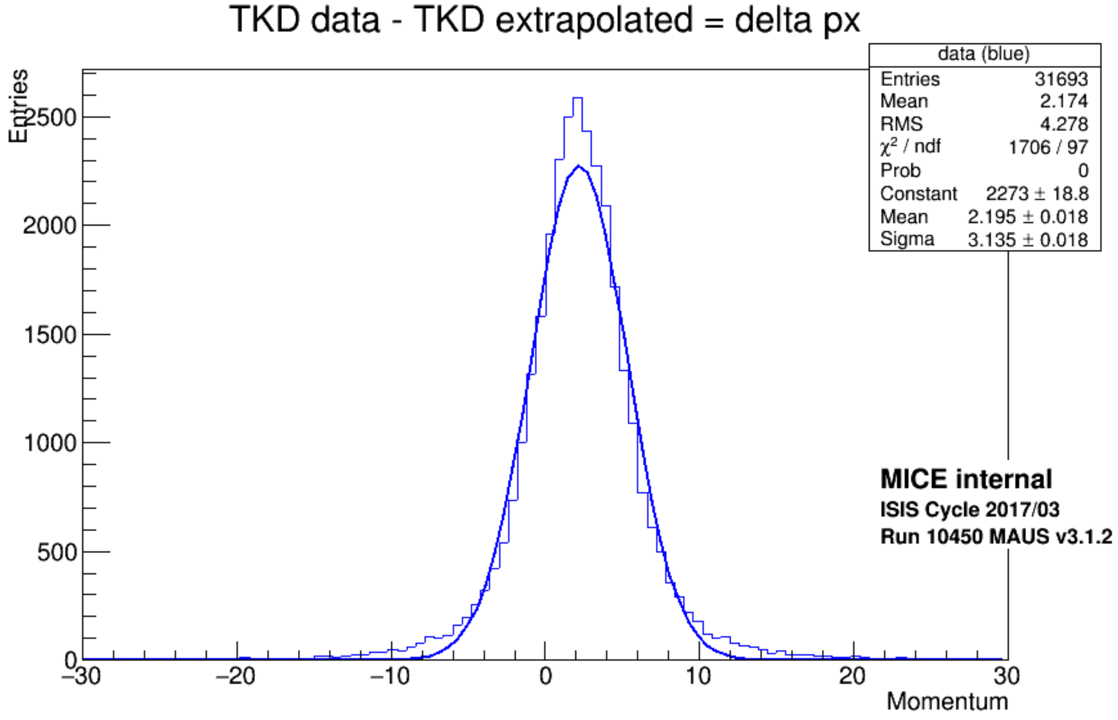

TKD data vs TKD extrapolated for px momentum
Entries
Momentum
data (blue)
Entries 31693
Mean 0.1733
RMS 22.79
χ² / ndf 385.8 / 50
Prob 0
Constant 1682 ± 11.0
Mean 0.1805 ± 0.1266
Sigma 22.29 ± 0.07
extrapolated (red)
Entries 31693
Mean −1.972
RMS 22.93
χ² / ndf 270.3 / 51
Prob 1.303e−31
Constant 1668 ± 11.0
Mean −1.825 ± 0.128
Sigma 22.56 ± 0.08
MICE internal
ISIS Cycle 2017/03
Run 10450 MAUS v3.1.2

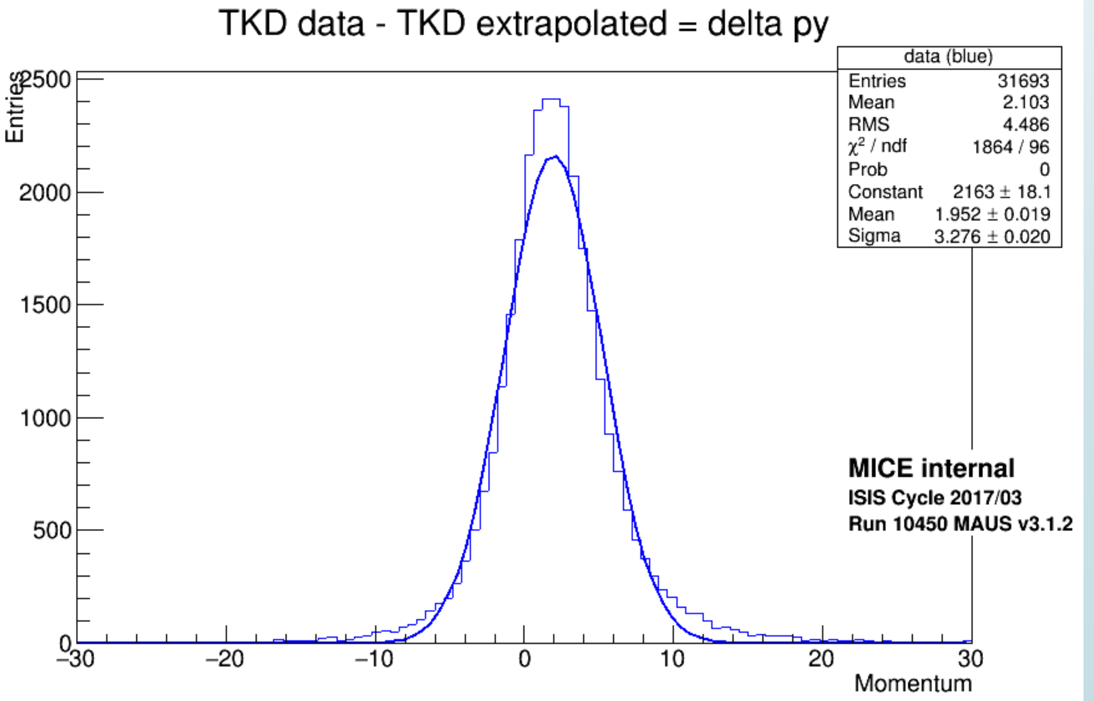

TKD data vs TKD extrapolated for py momentum
Entries
Momentum
data (blue)
Entries 31693
Mean 1.247
RMS 22.54
χ² / ndf 466.3 / 49
Prob 0
Constant 1705 ± 11.1
Mean 1.249 ± 0.125
Sigma 21.93 ± 0.07
extrapolated (red)
Entries 31693
Mean −0.9039
RMS 22.4
χ² / ndf 413.6 / 47
Prob 0
Constant 1712 ± 11.1
Mean −1.043 ± 0.124
Sigma 21.88 ± 0.07
MICE internal
ISIS Cycle 2017/03
Run 10450 MAUS v3.1.2

No Absorber

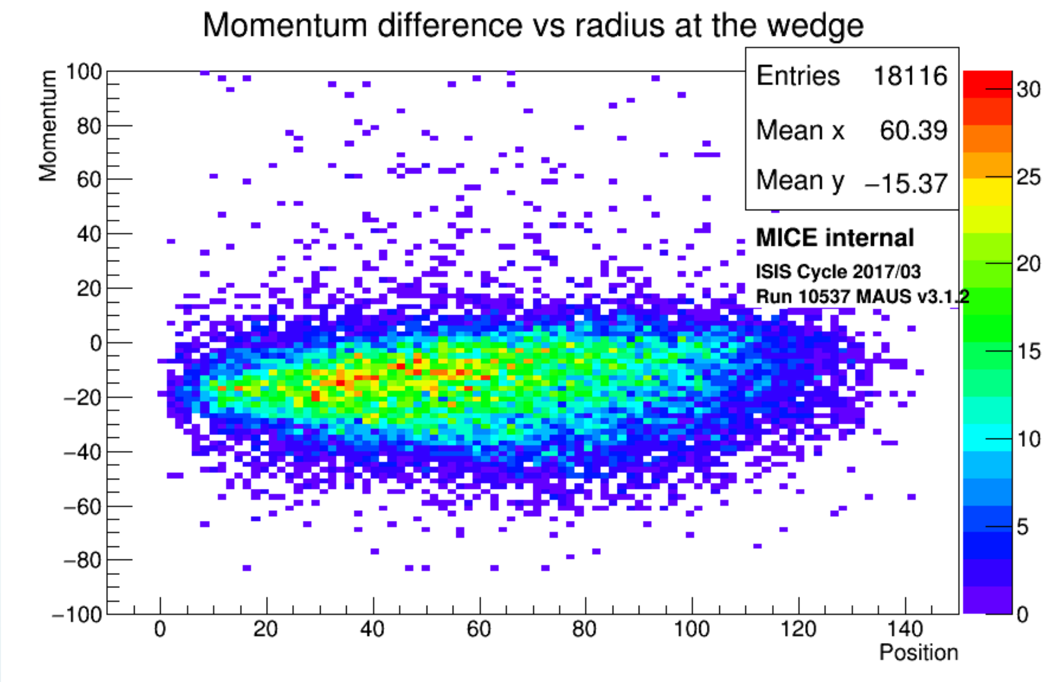

TKD data - TKD extrapolated = delta x
data (blue)
Entries 31693
Mean 2.611
RMS 6.831
χ² / ndf 2228 / 97
Prob 0
Constant 1258 ± 11.4
Mean 2.523 ± 0.033
Sigma 5.524 ± 0.038
Entries
MICE internal
ISIS Cycle 2017/03
Run 10450 MAUS v3.1.2

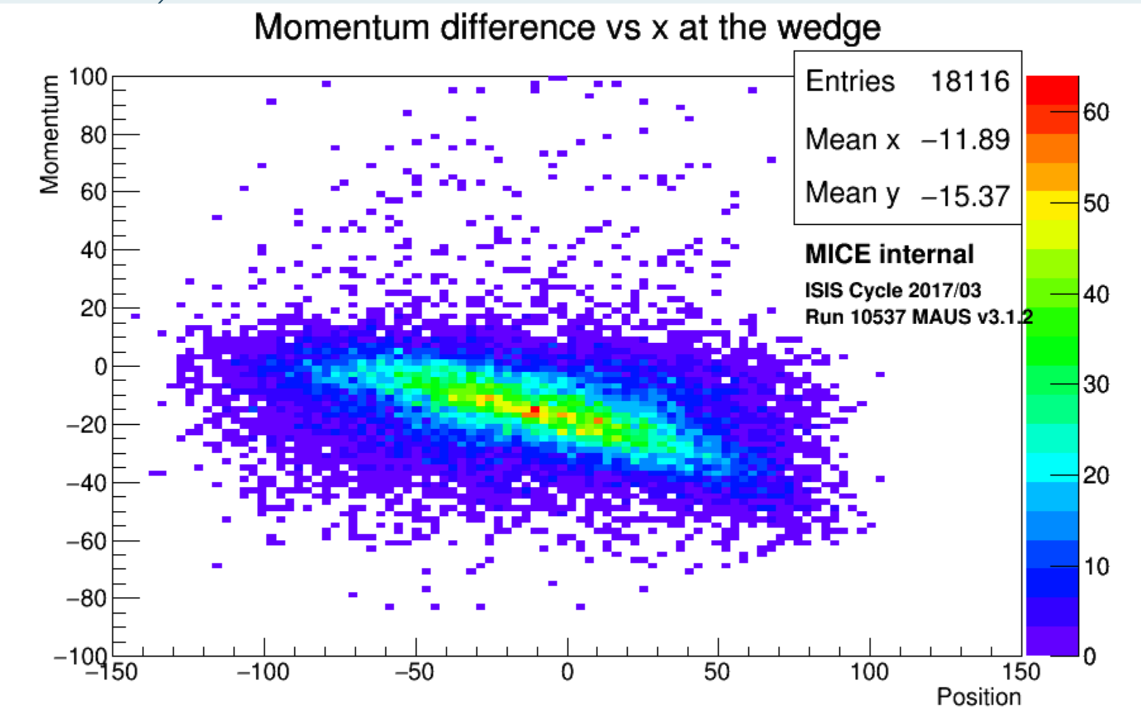

TKD data - TKD extrapolated = delta y
data (blue)
Entries 31693
Mean −4.207
RMS 6.941
χ² / ndf 1964 / 97
Prob 0
Constant 1225 ± 10.8
Mean −4.255 ± 0.033
Sigma 5.716 ± 0.038
Entries
Position
MICE internal
ISIS Cycle 2017/03
Run 10450 MAUS v3.1.2

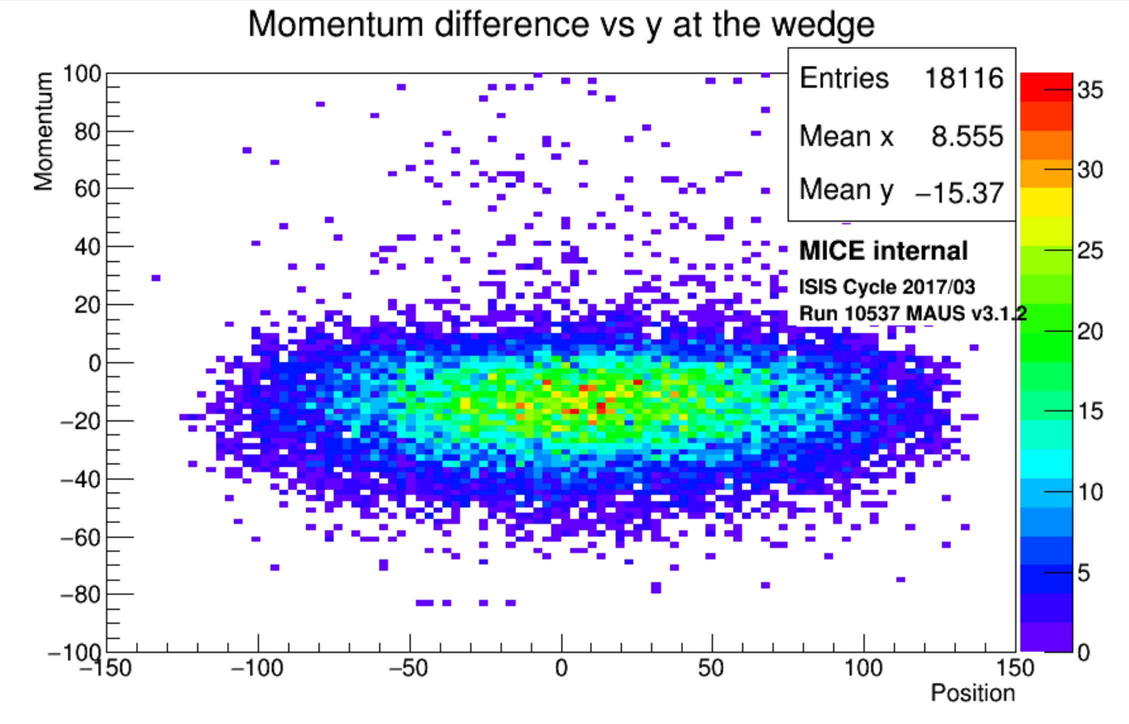

TKD data - TKD extrapolated = delta px
data (blue)
Entries 31693
Mean 2.174
RMS 4.278
χ² / ndf 1706 / 97
Prob 0
Constant 2273 ± 18.8
Mean 2.195 ± 0.018
Sigma 3.135 ± 0.018
Entries
Momentum
MICE internal
ISIS Cycle 2017/03
Run 10450 MAUS v3.1.2


TKD data - TKD extrapolated = delta py
data (blue)
Entries 31693
Mean 2.103
RMS 4.486
χ² / ndf 1864 / 96
Prob 0
Constant 2163 ± 18.1
Mean 1.952 ± 0.019
Sigma 3.276 ± 0.020
Entries
Momentum
MICE internal
ISIS Cycle 2017/03
Run 10450 MAUS v3.1.2

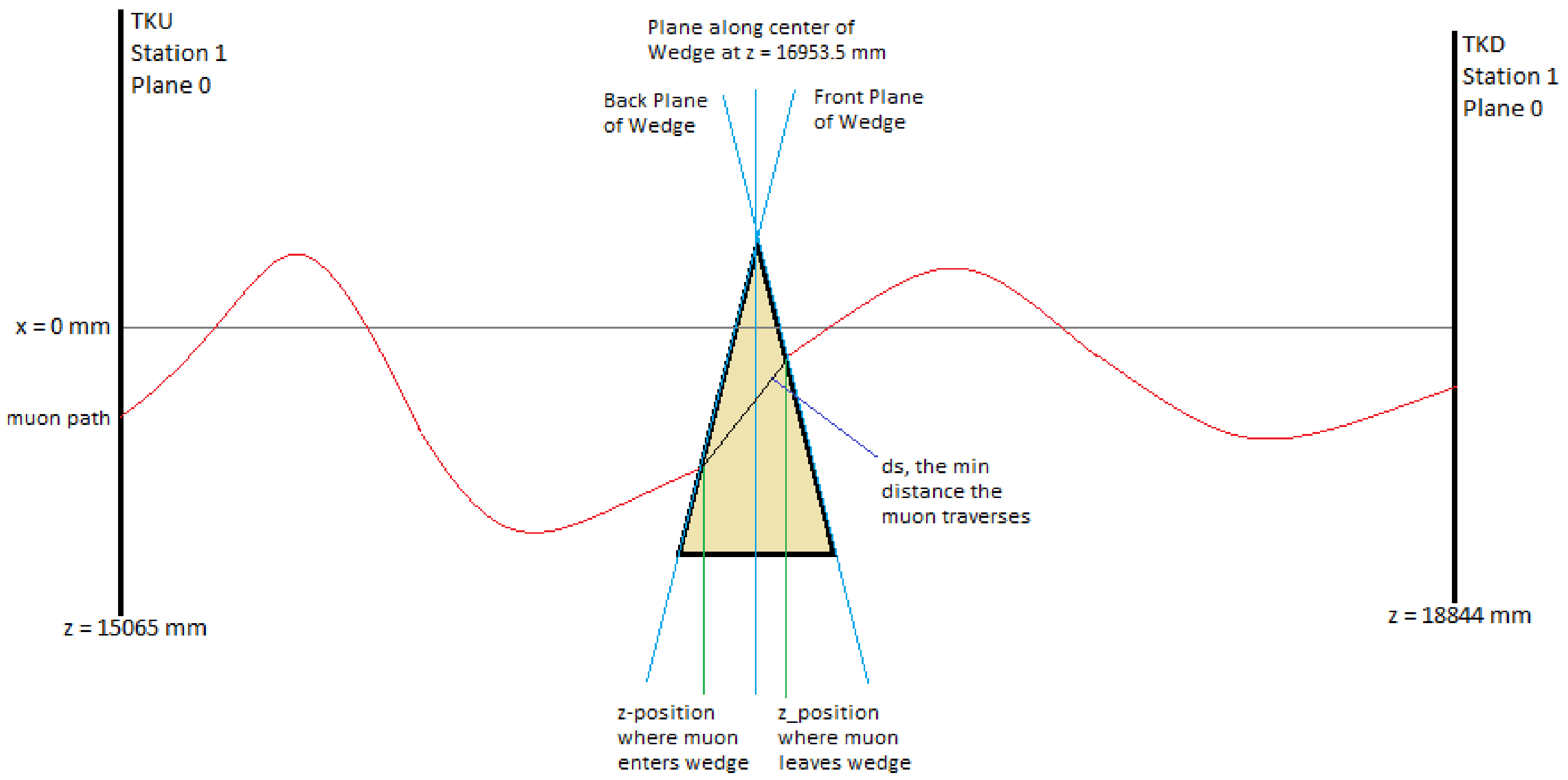
Sample of Wedge Data







Mock Diagram of muon path



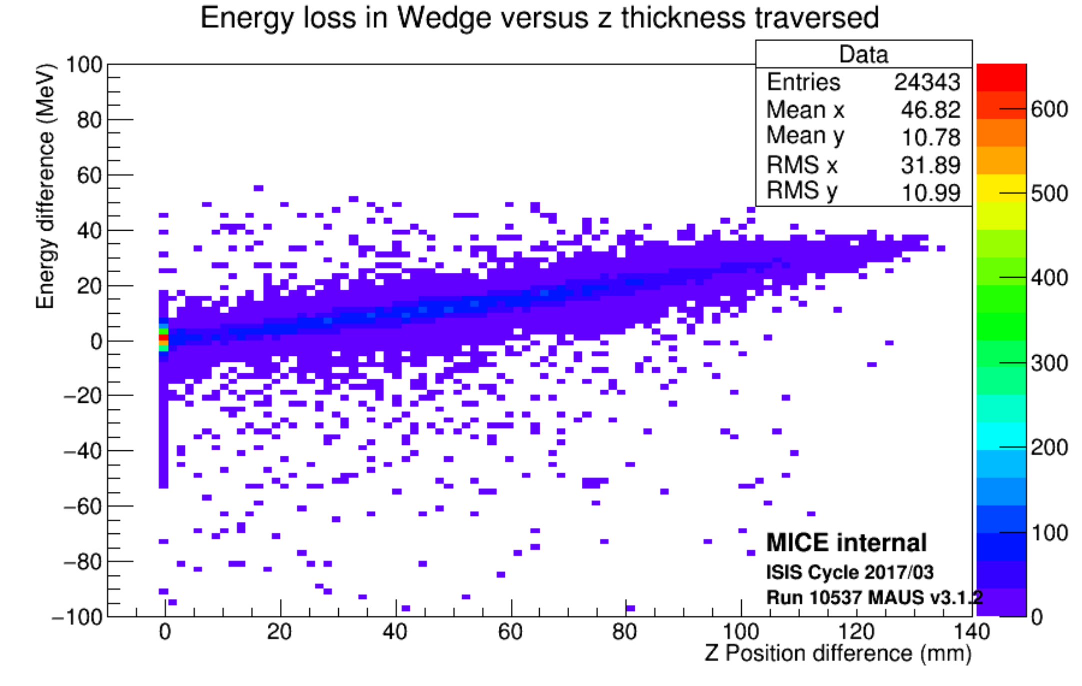
Energy Loss in Wedge

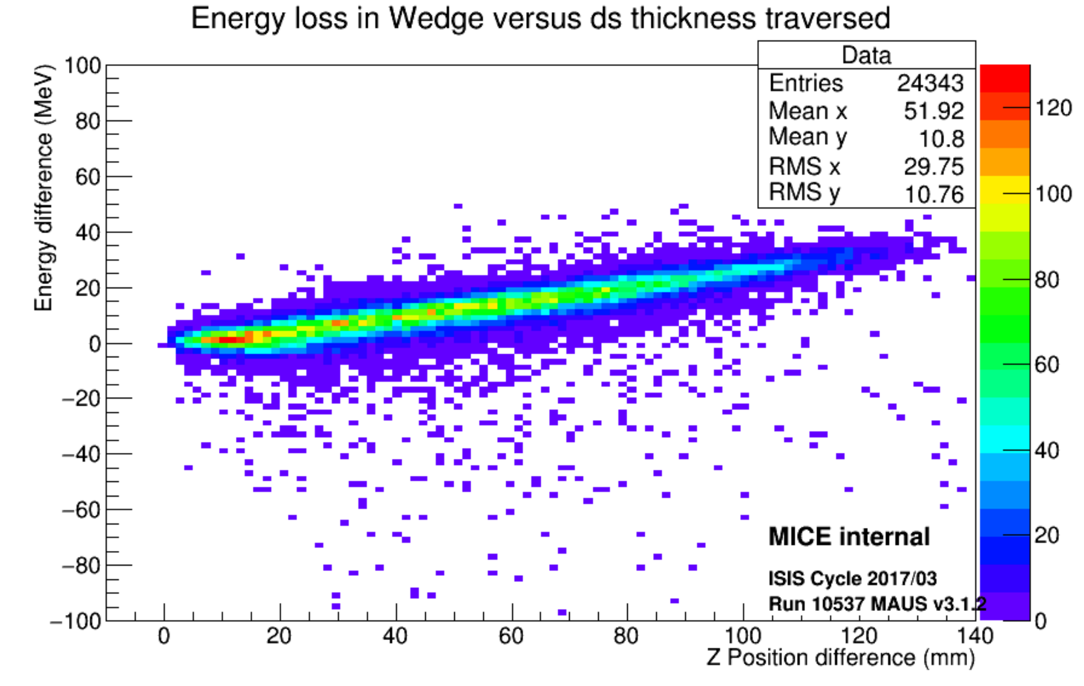
- Extrapolate from TKU to Wedge
- Extrapolate back from TKD to Wedge
- Energy difference is Energy Loss as it passes through Wedge
- Look at Energy difference for dz and ds
- Cut data to the left of the wedge where there is no energy loss

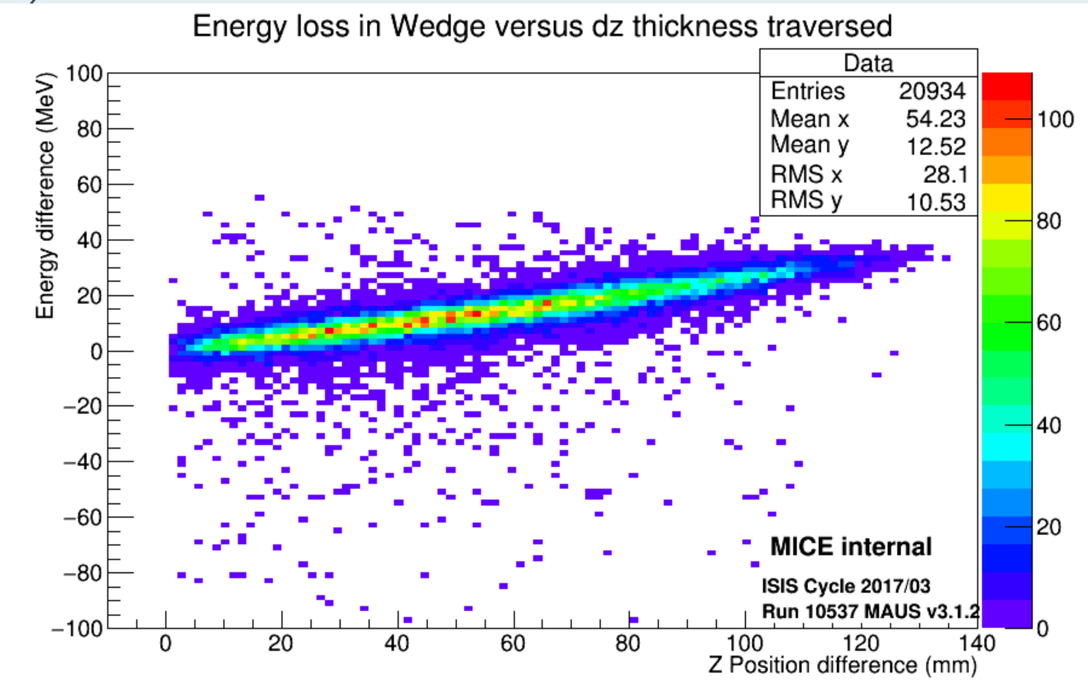
Energy Loss in Wedge versus dz and ds

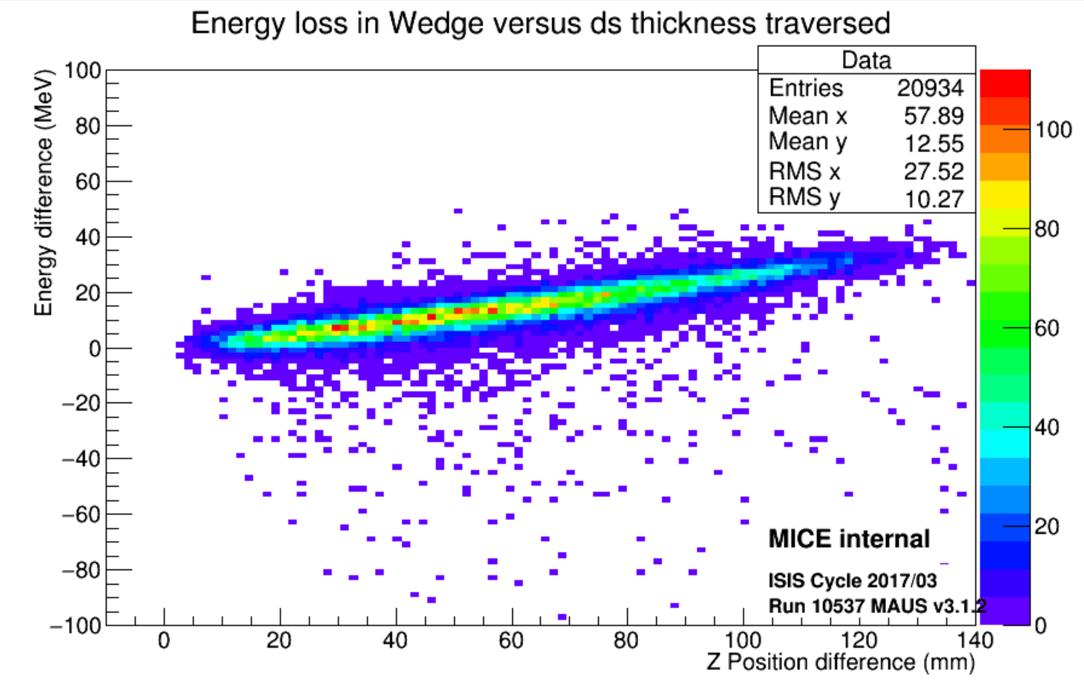
Top:
Full x range

Bottom:
Wedge x range







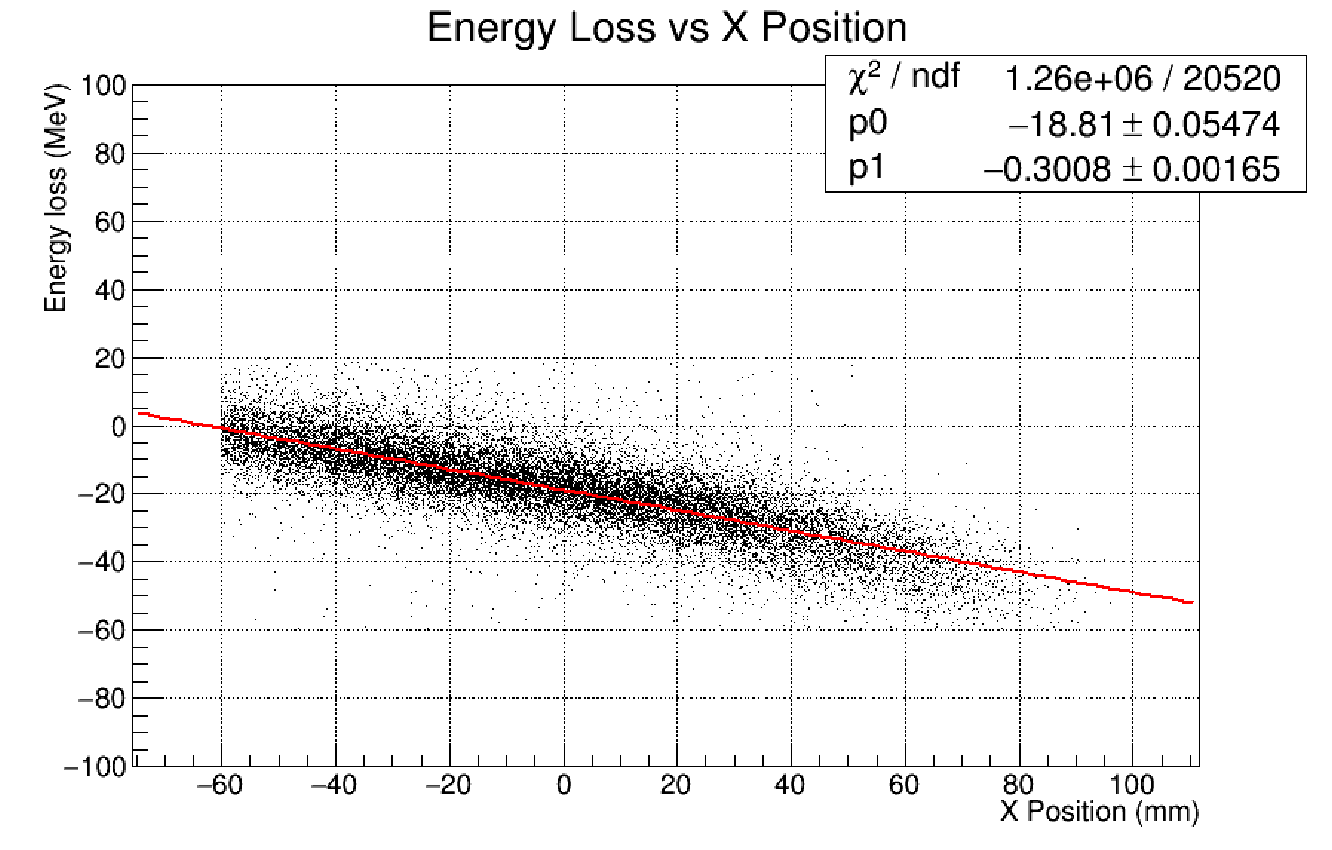


Alignment of Wedge

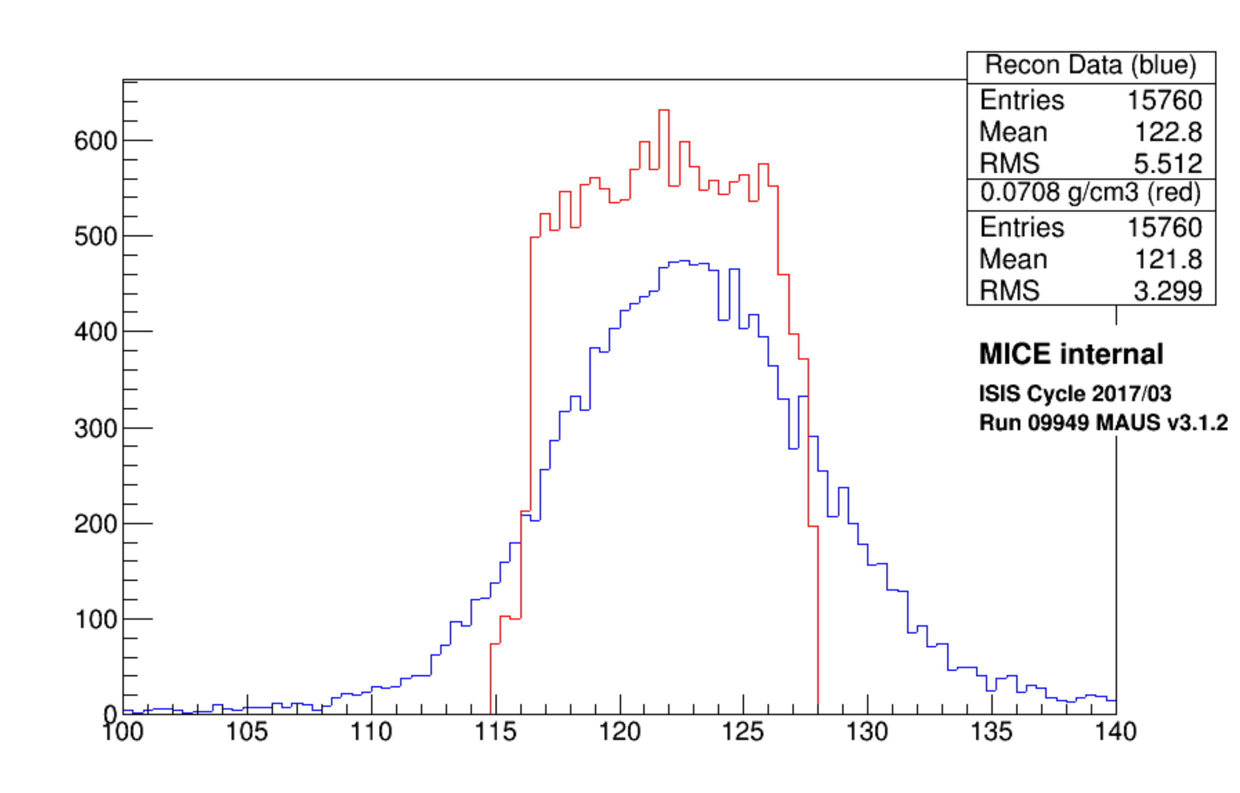
- Check if there is any rotation in the wedge
- Rotate extrapolated x and y coordinates an angle theta at wedge until greatest gradient for Energy Loss versus X Position
- $X(new) = x.\cos(\theta) - y.\sin(\theta)$
- $Y(new) = x.\sin(\theta) + y.\cos(\theta)$
- For the range of the wedge greatest gradient at a rotation of 0.306 degrees
- For symmetric range of 60mm either side of the central axis, the greatest gradient is at a rotation of 0.419 degrees
- Current extrapolation is only accurate to within a few mm
- => Wedge is aligned straight
- Need to use full MAUS routine for greater accuracy

Wedge Gradient

Rotate Wedge until greatest gradient for Energy Loss vs X Position



Momenta for various densities of the Liquid Hydrogen Absorber



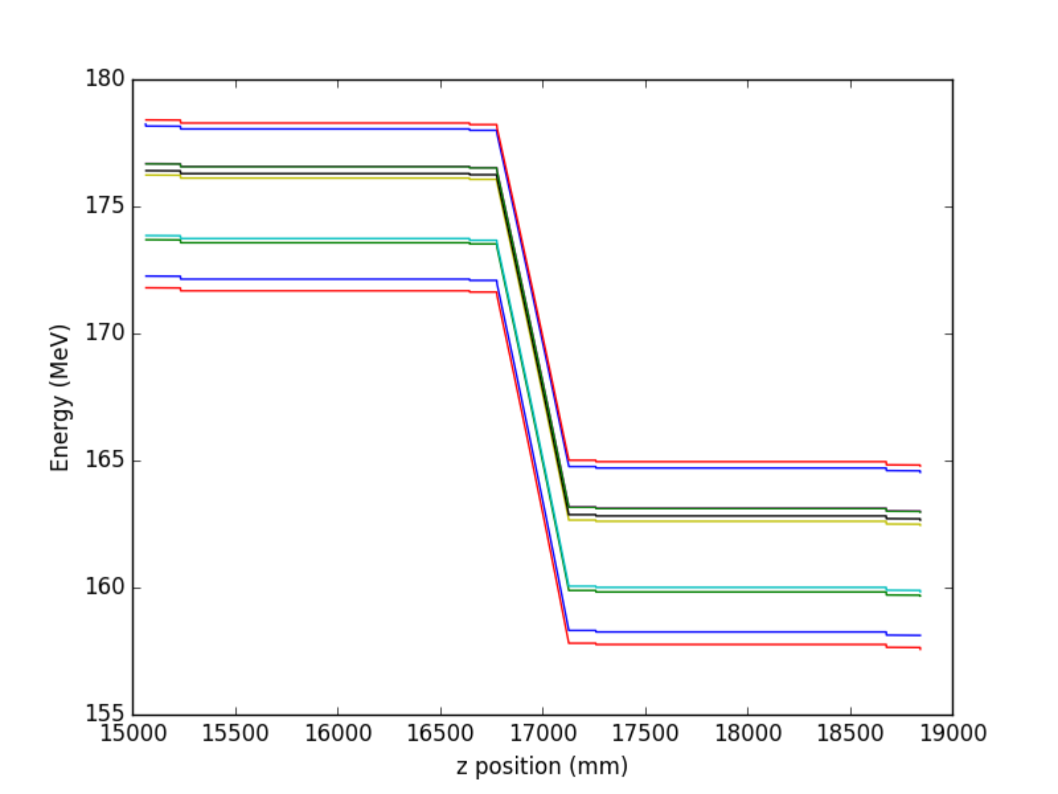
Using same extrapolation propagation as previously

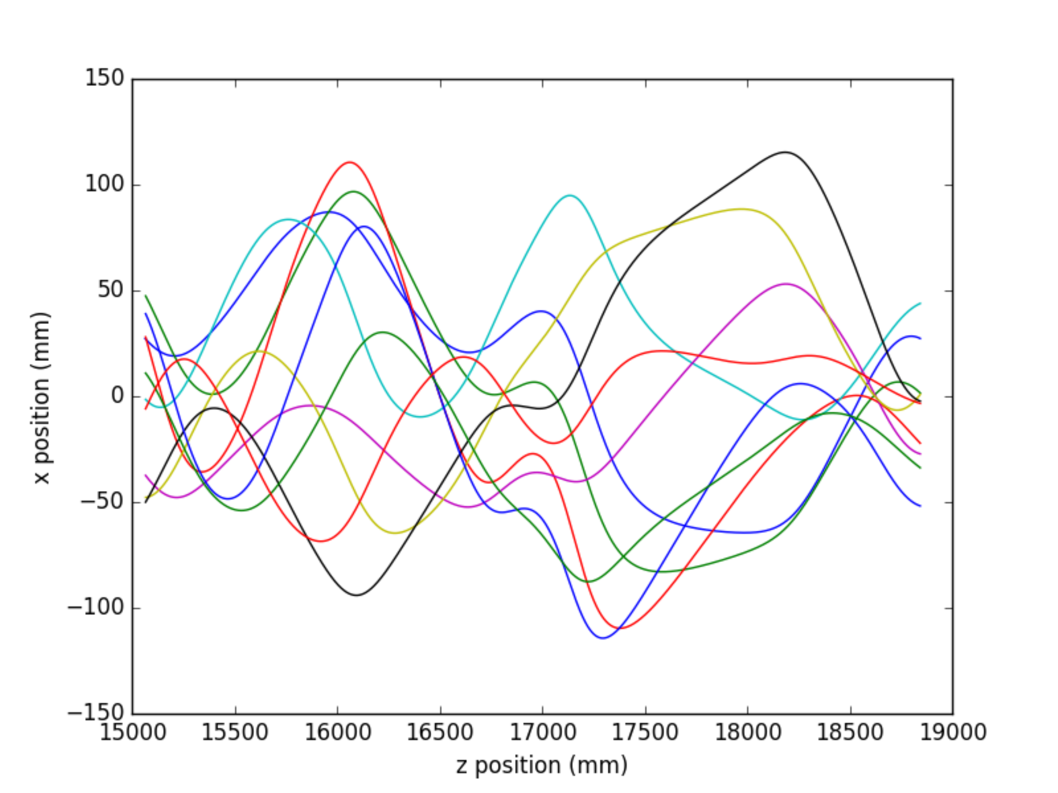
Loses a fixed amount of energy per unit length

Need to update to full MAUS routine to take better account of energy straggling

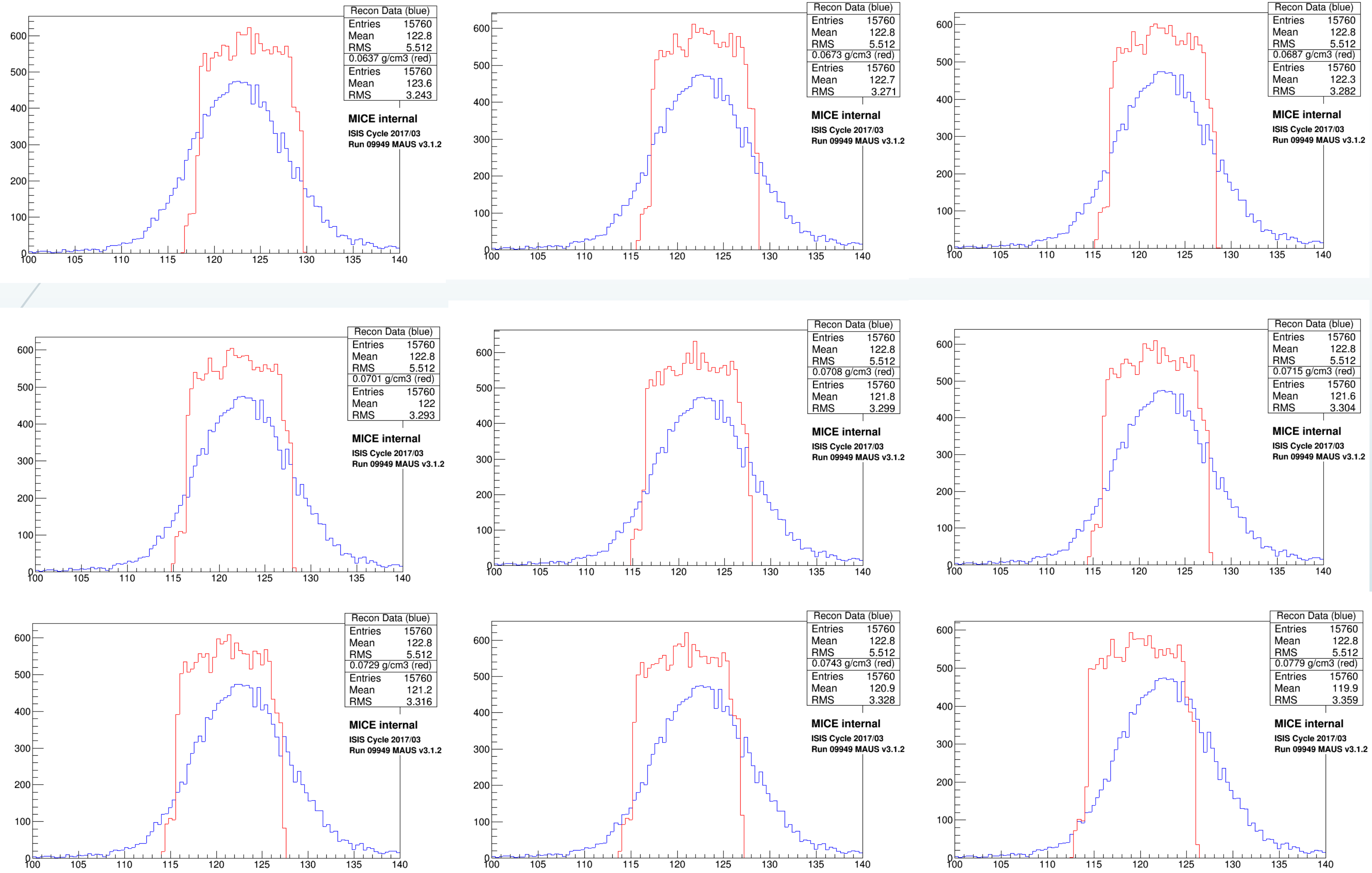
Can then better compare peaks and determine density

Sample of 10 muons





TL: -10%
TC: -5%
TR: -3%
CL: -1%
CC: 0%
CR: +1%
BL: +3%
BC: +5%
BR: +10%



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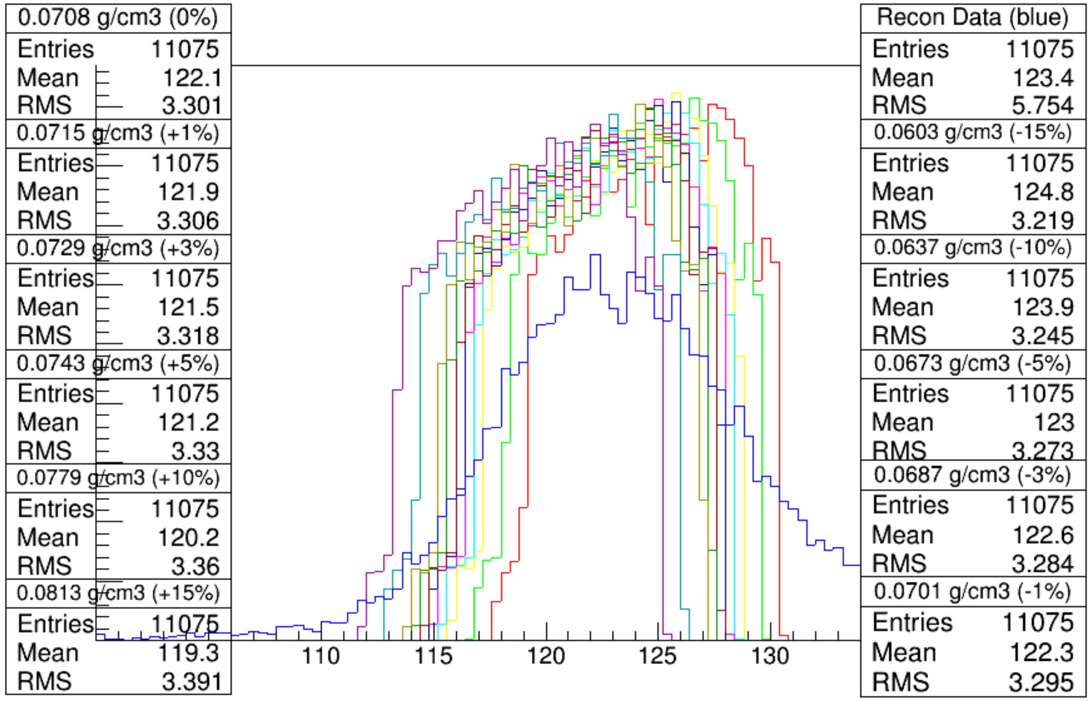
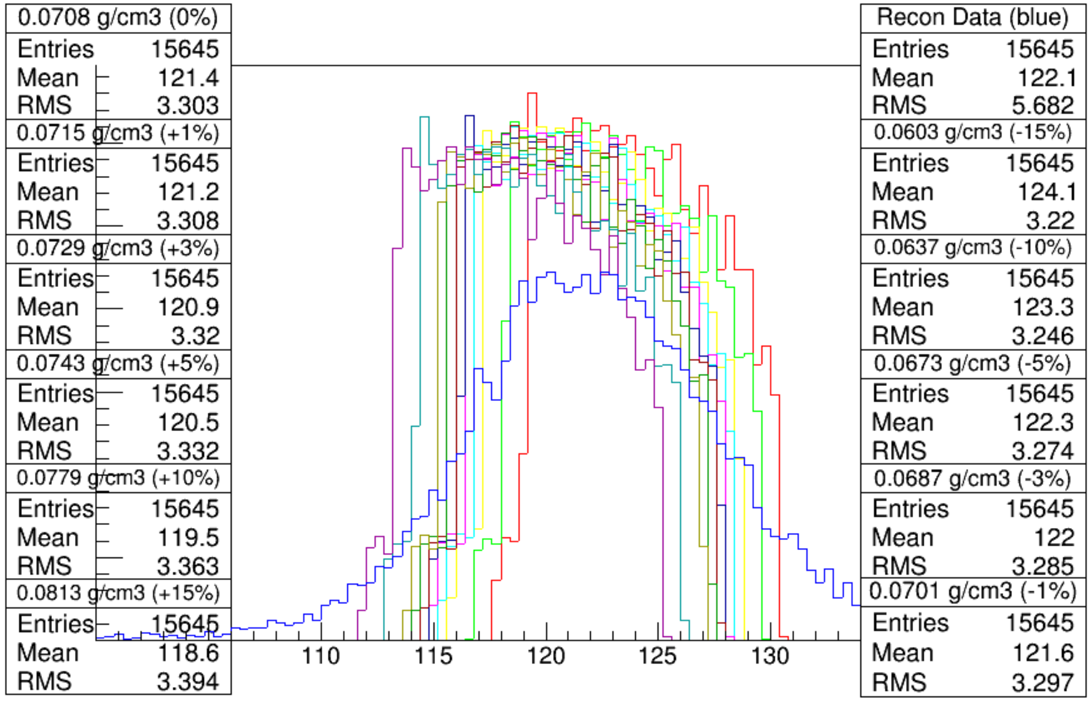
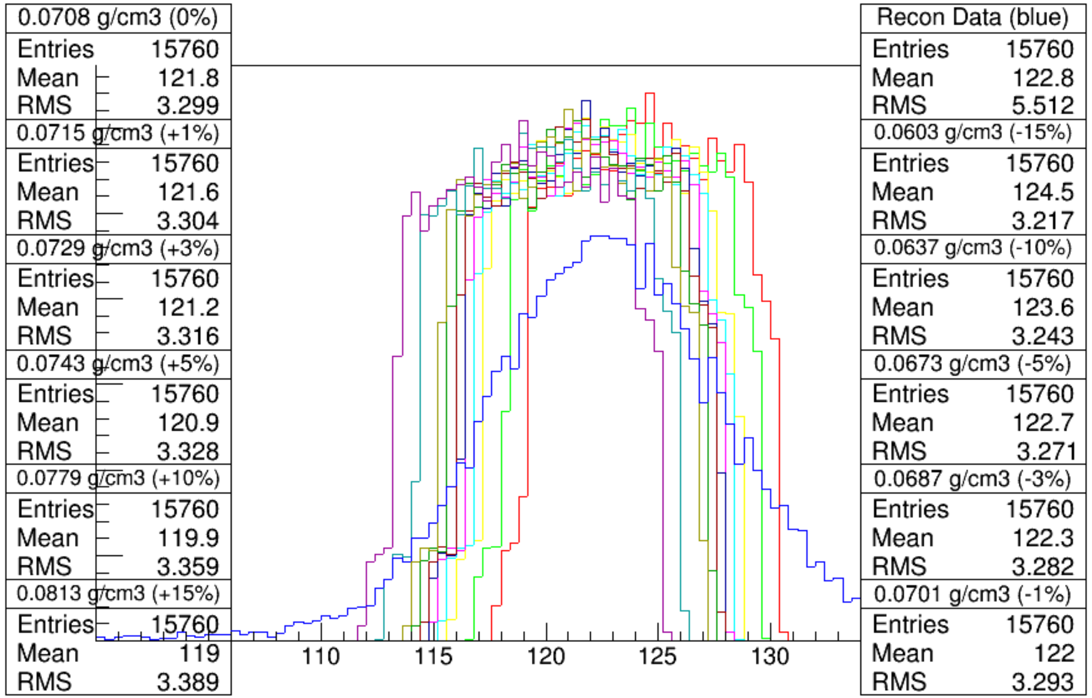
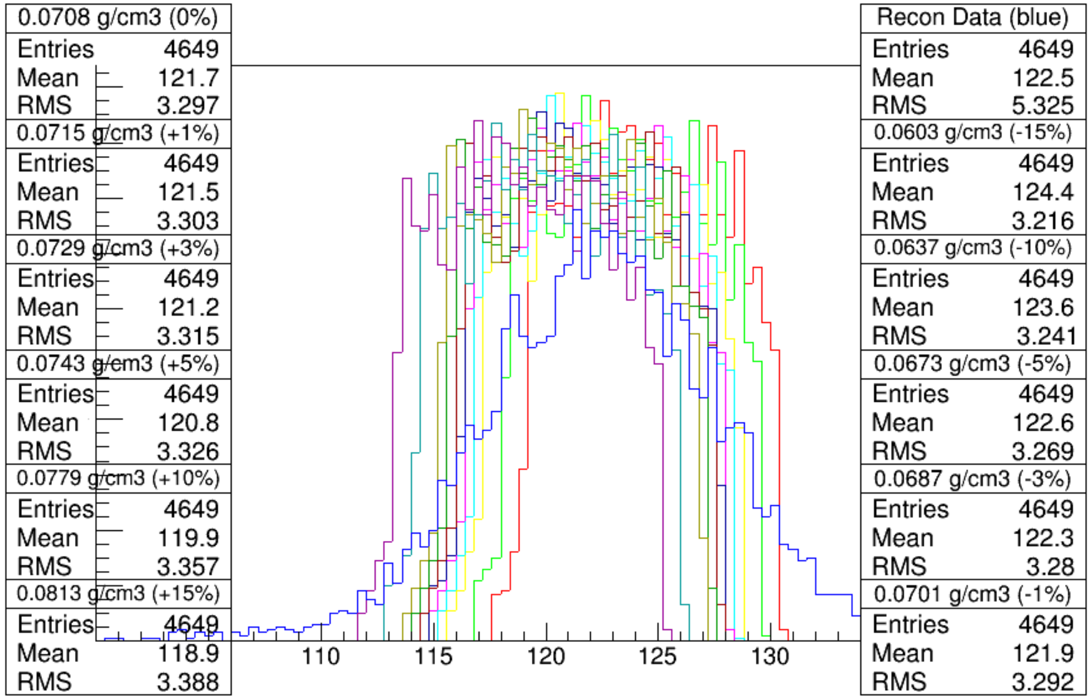
Energy Loss at Various densities Compared to Recon Data

TL: 3-140
TR: 4-140
BL: 6-140
BR: 10-140

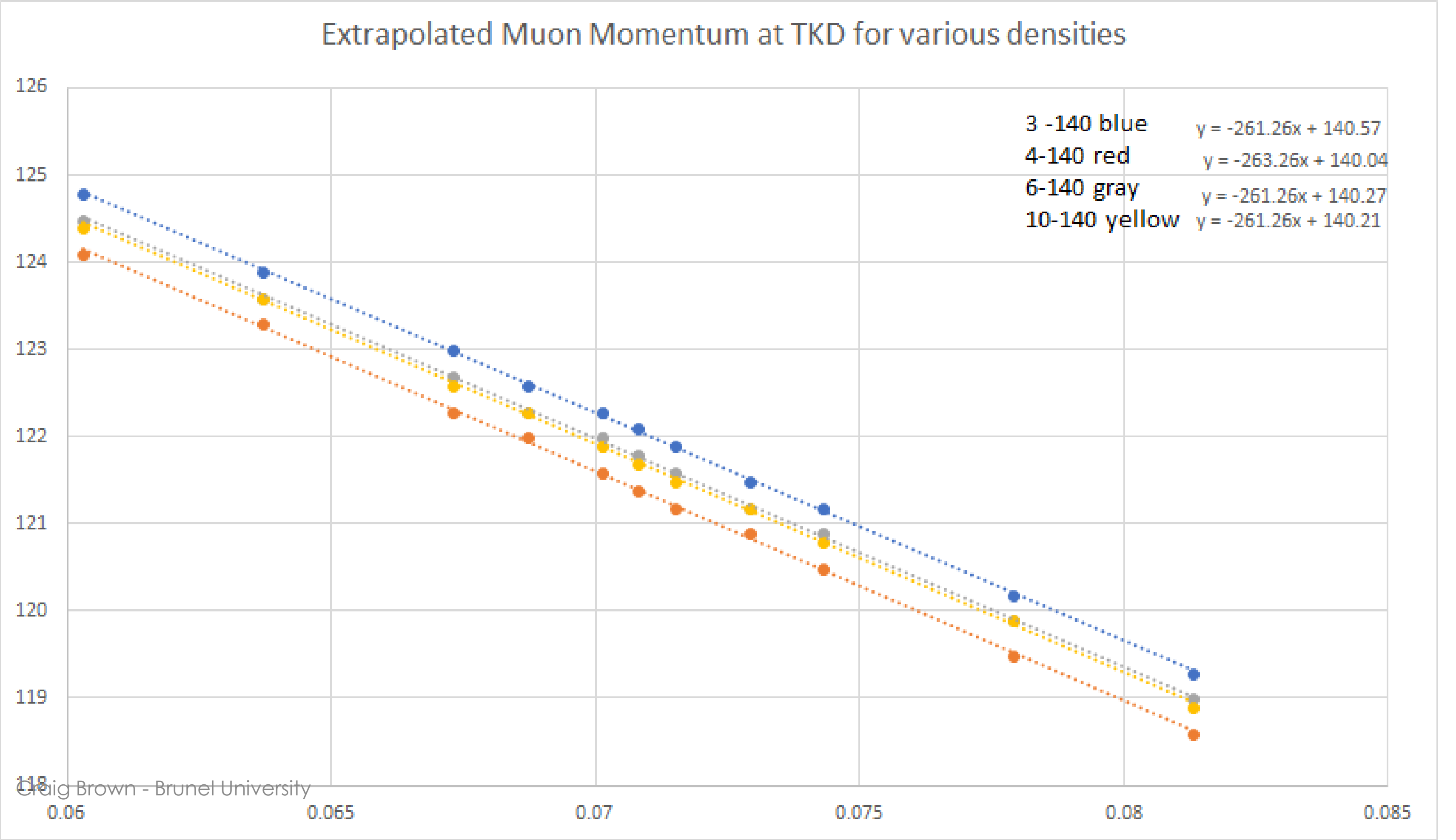








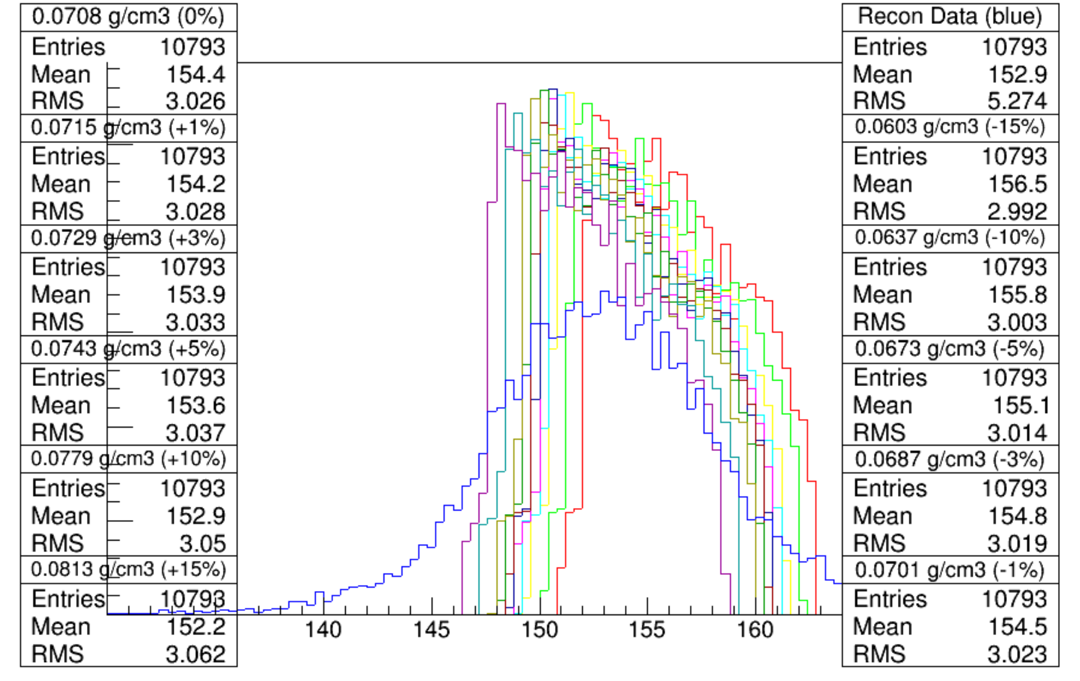
Energy loss for various densities of 3-140, 4-140, 6-140 and 10-140 data

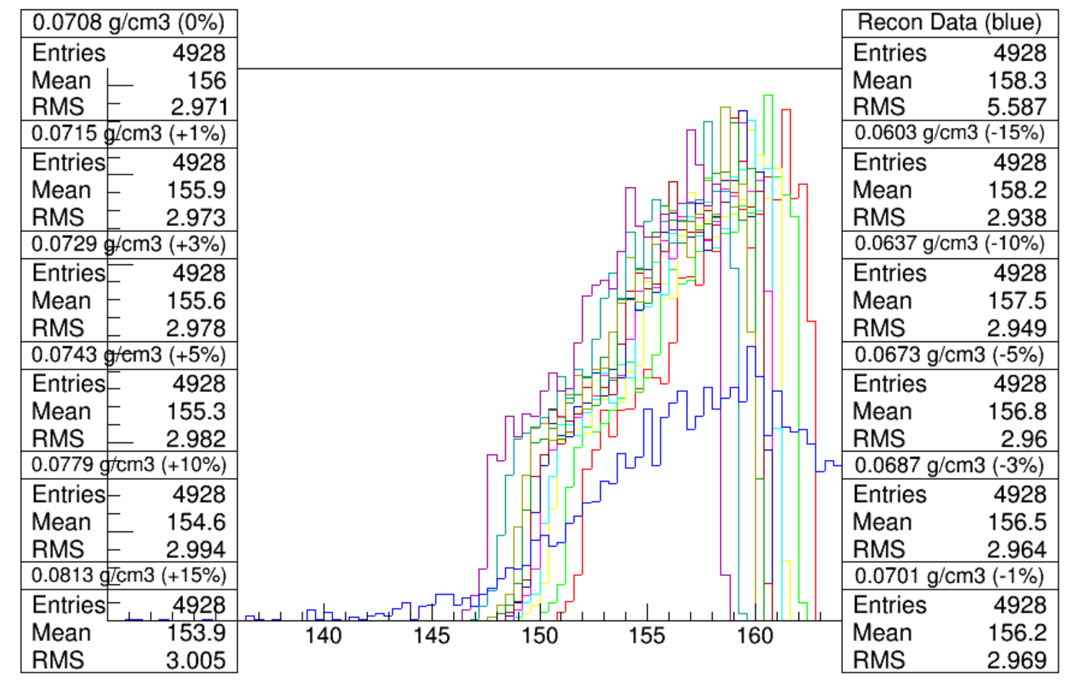


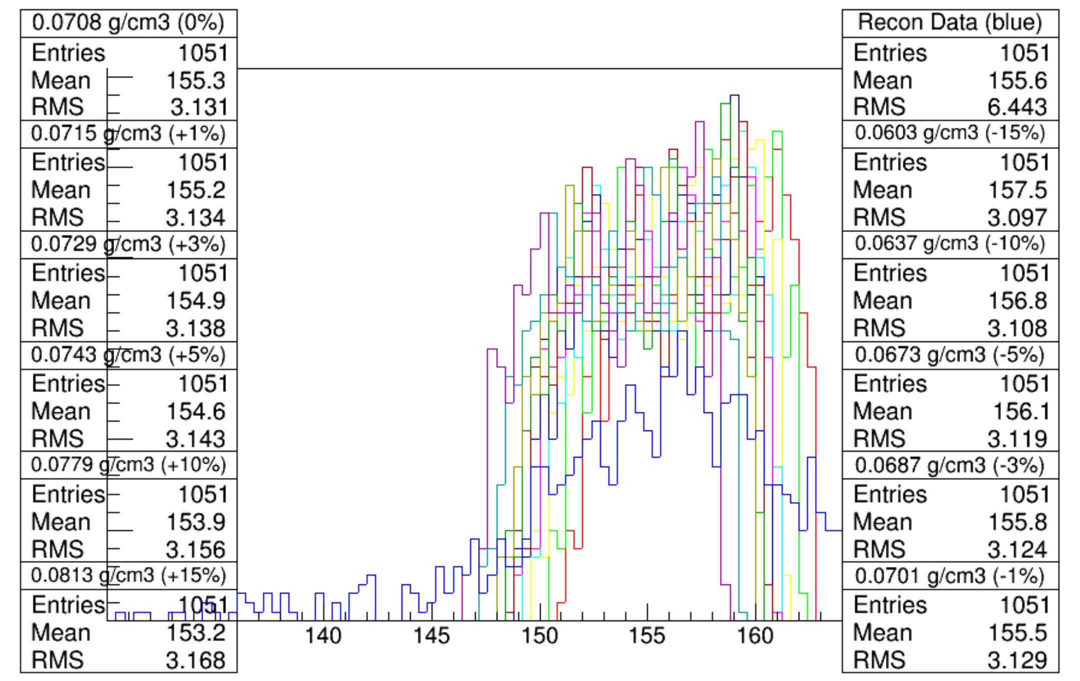
The End

- Wedge follows linear energy loss model, investigate actual muon path through wedge
- Wedge aligned to within 0.4 degrees, although can improve accuracy , use full MAUS routine in future to determine accuracy
- Update to full MAUS routine for lH2 absorber to take into account energy straggling and determine uncertainties
- Thank you

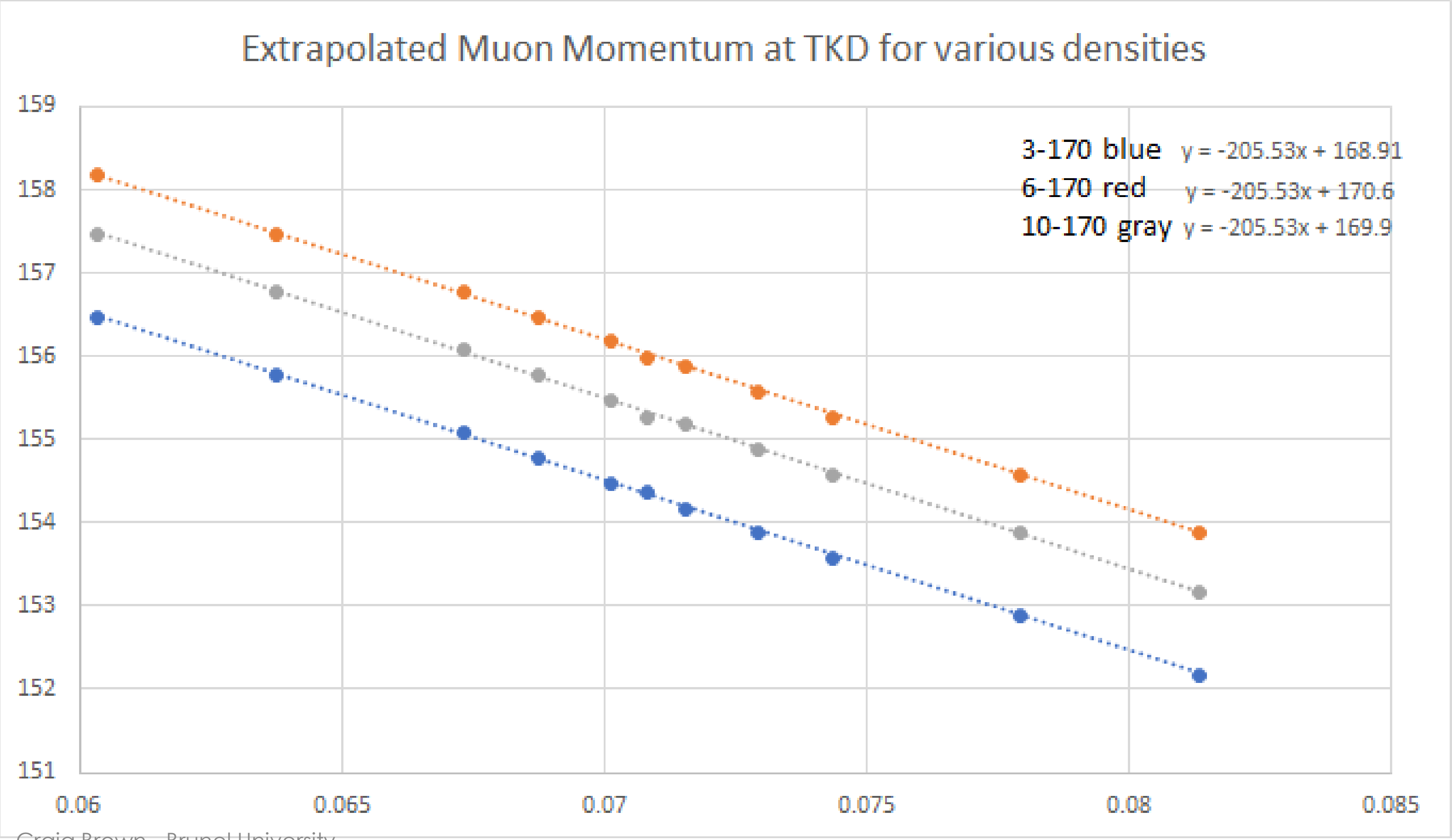
Extra Slide: 3-170, 6-170, 10-170



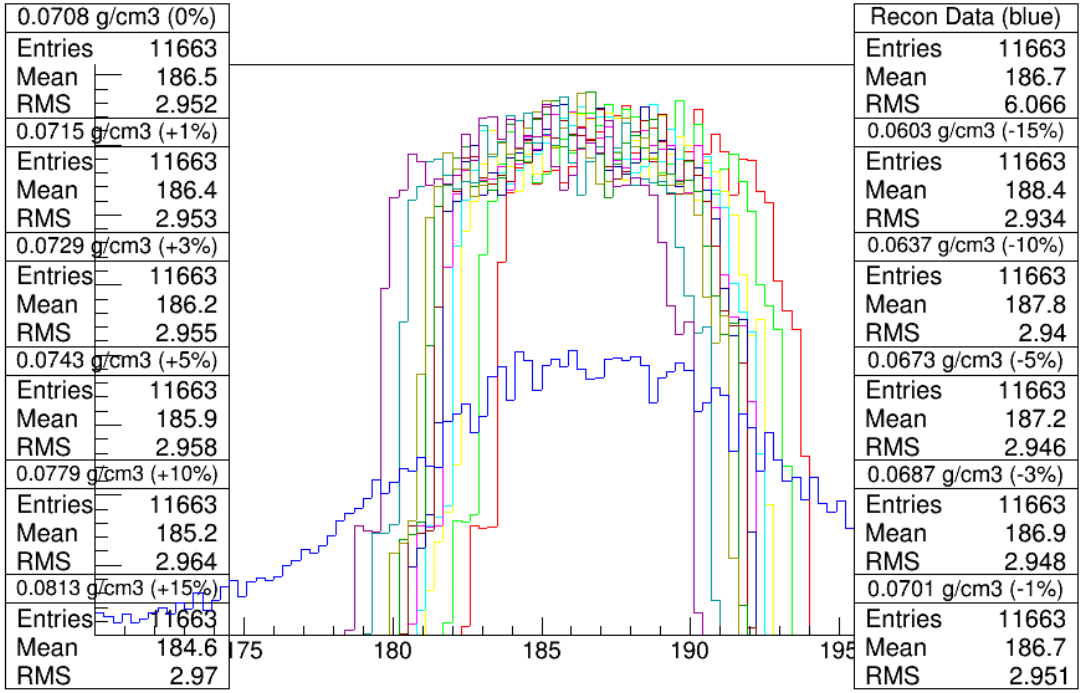


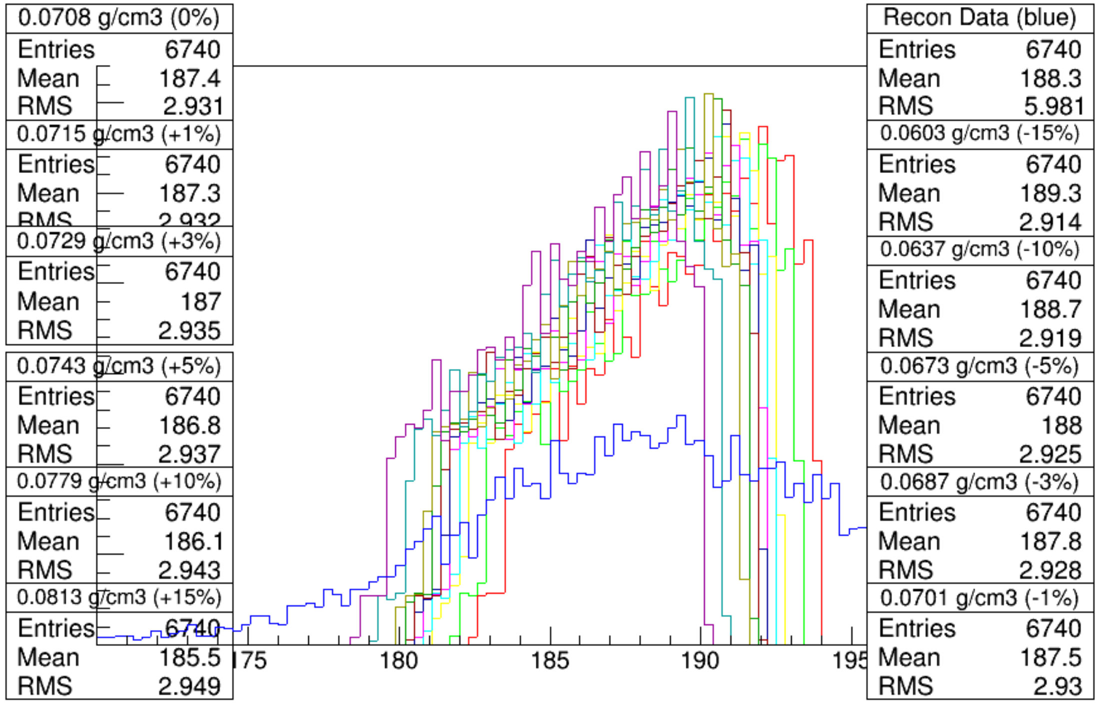


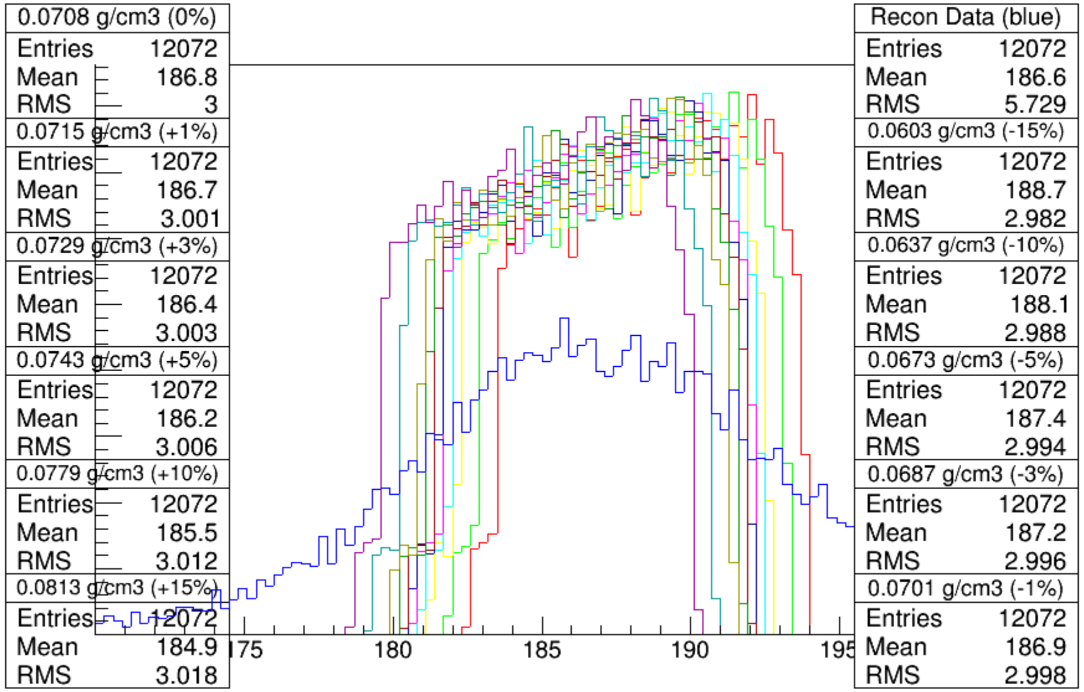
Extra Slide:
3-200, 6-200, 10-200



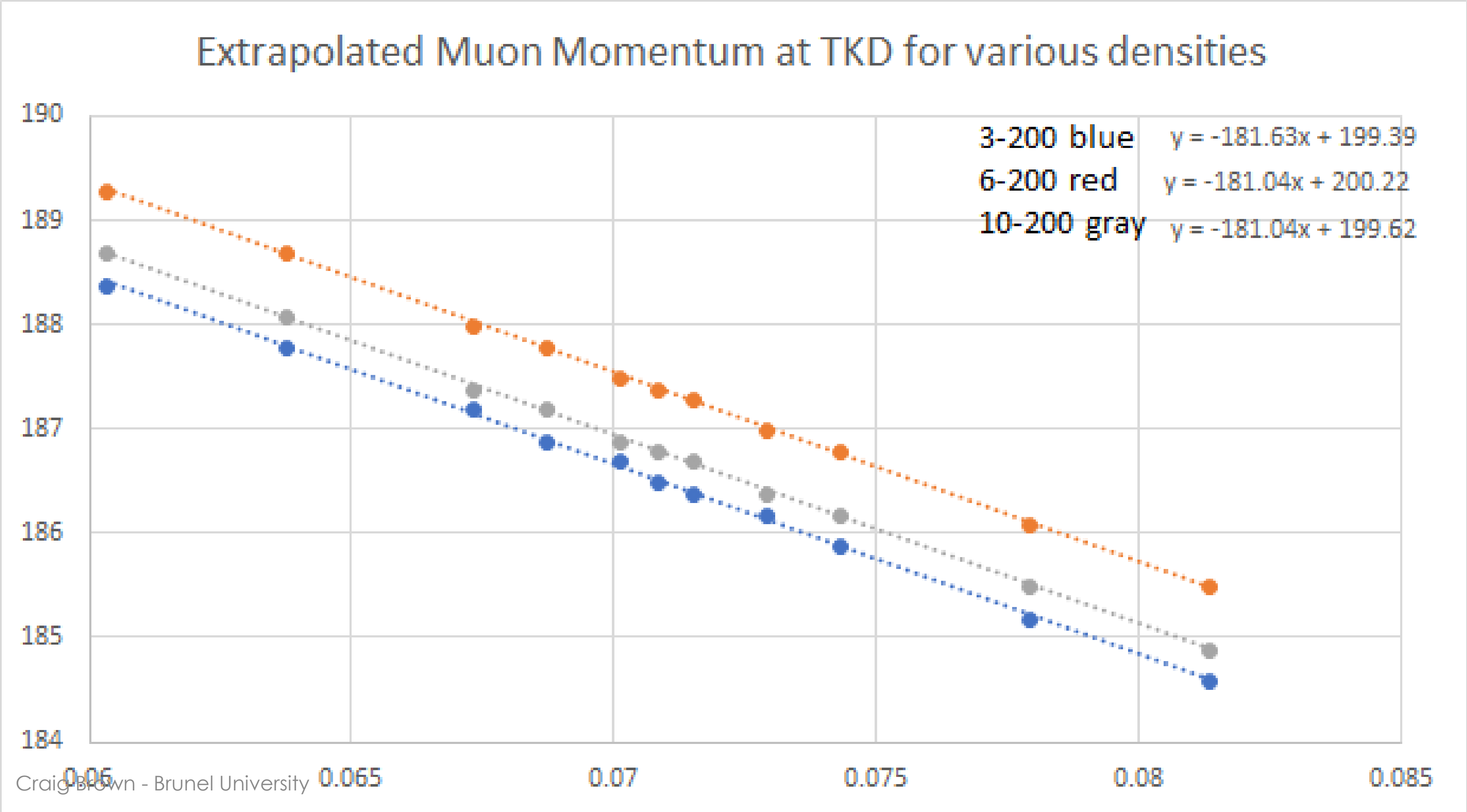
Extra Slide: 3-200, 6-200, 10-200







Extra Slide:
3-200, 6-200, 10-200



Extra Slide: 140 MeV with data