

ProtoDUNE-SP 1GeV Beam Stopping Muons KE

Sim/Reco Meeting - 08/01/2020
Owen Goodwin

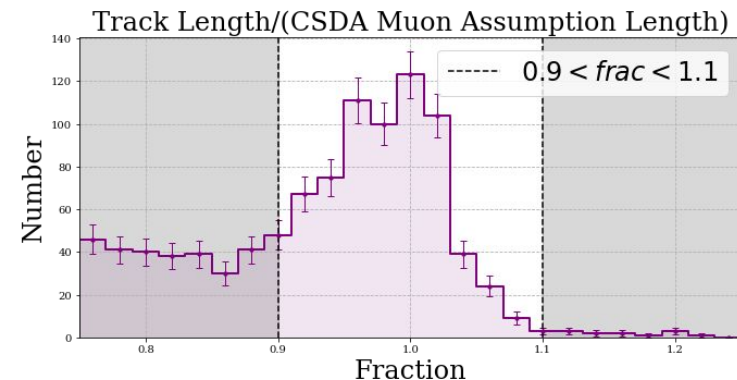
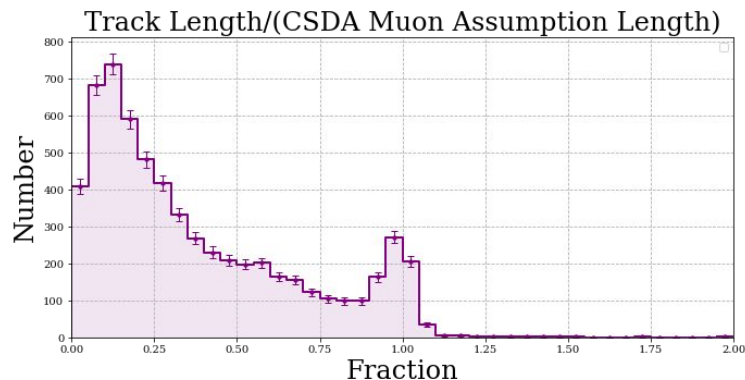
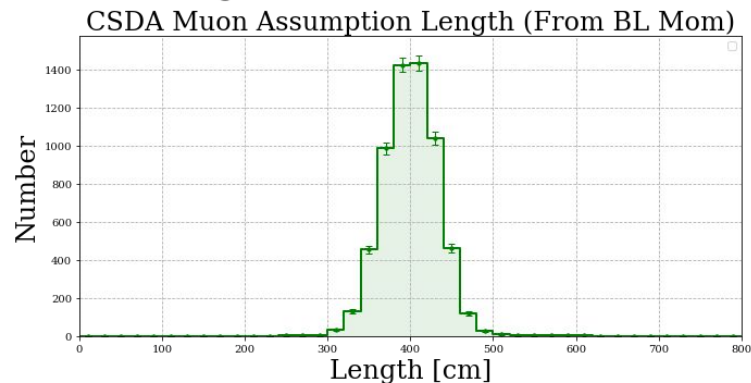
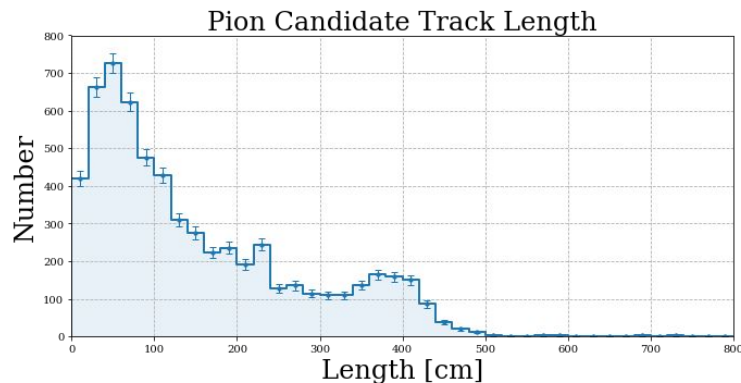


- 1 GeV beam stopping muon selection in both MC and data.
- Stopping muon kinetic energy reconstruction
- Effect of APA gap on KE reco

Selection/Samples - PDSPProd2

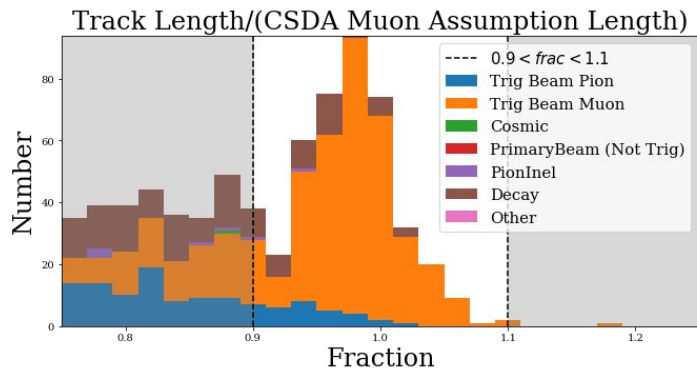
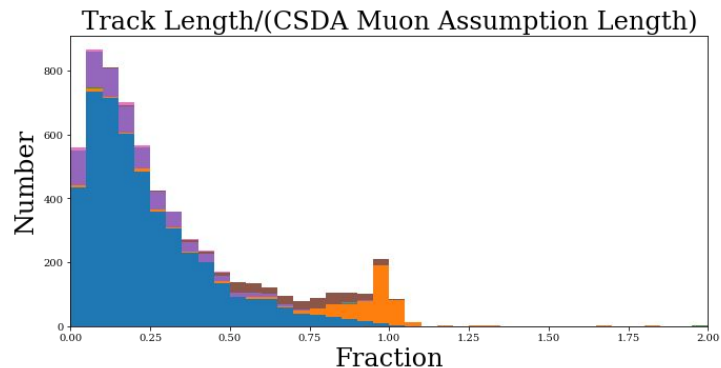
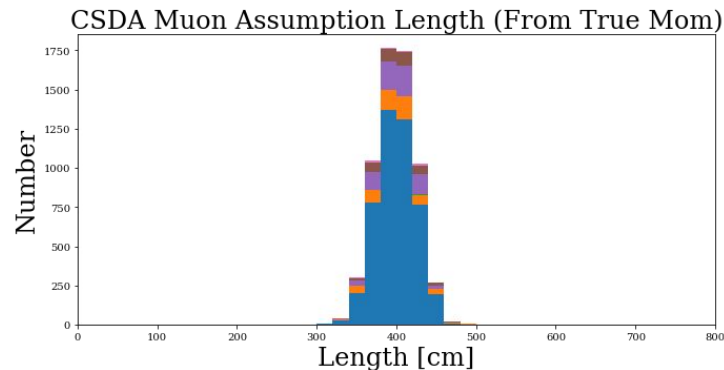
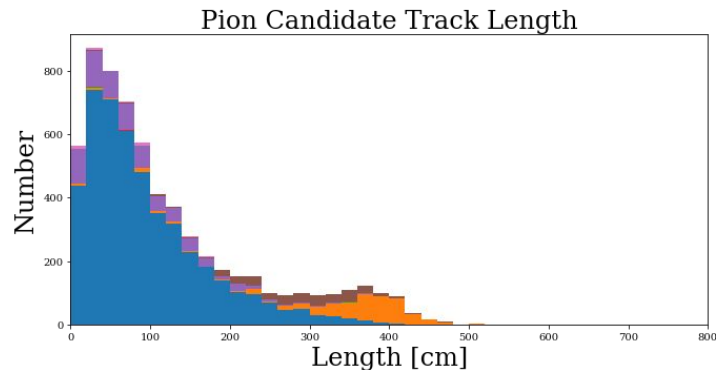
- *Run 5387 (1 GeV Hadron trigger).*
 - Unstable HV filter
 - Inactive FEMB filter (Beamside APAs)
 - Beamline 1 GeV Pion/Muon selection (ToF <110 ns and no hits in the low pressure Cherenkov counter)
- *1 GeV high stats MC (SCE- Prod 2);*
 - events where the true beam particle is pion or muon.
- Beam quality cuts
- Range/Expected range stopping muon cut.

Data (After Stitching)



- Track Length is CaloRange (SCE corrected)
- Used Jake's APA track stitcher function

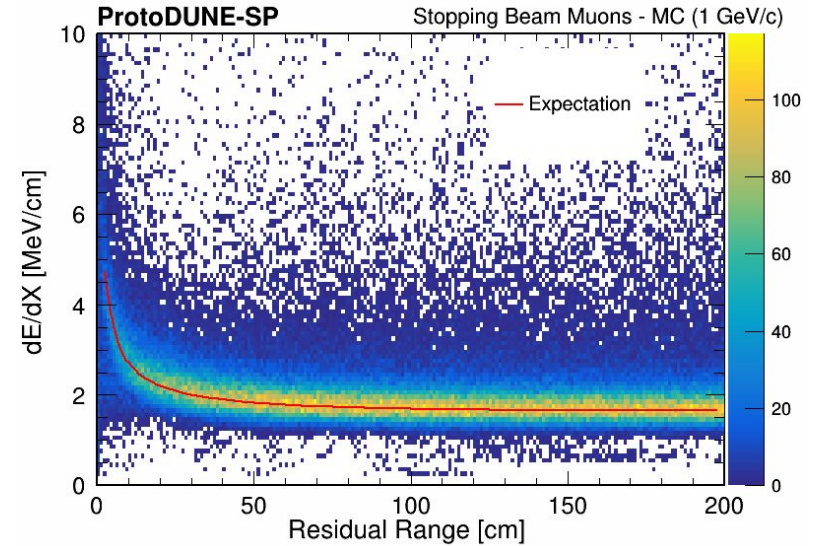
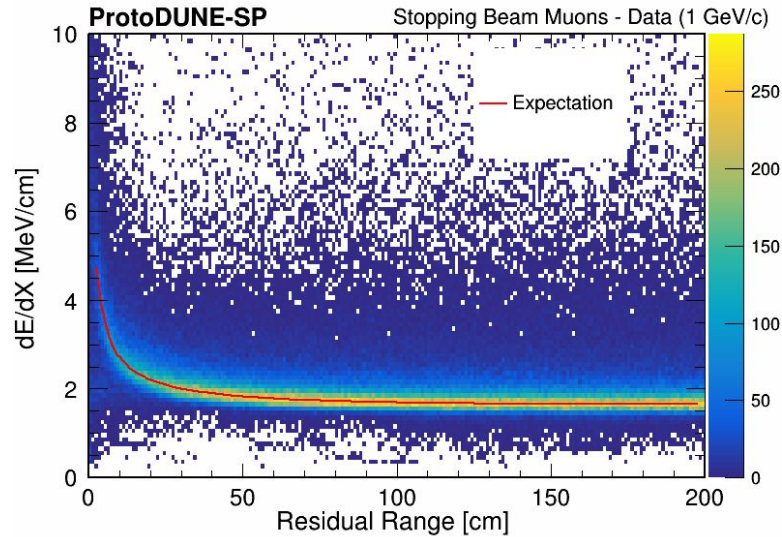
MC (SCE)



- Track Length is CaloRange (SCE corrected)

Stopping muons

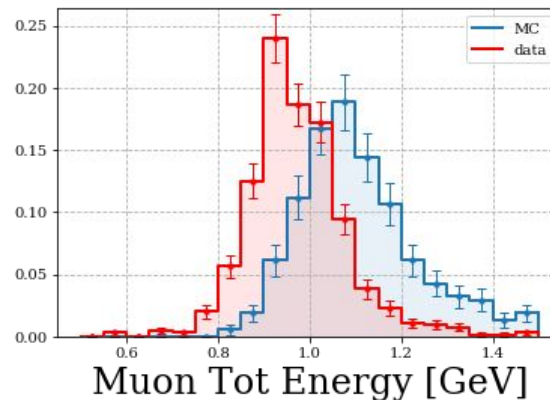
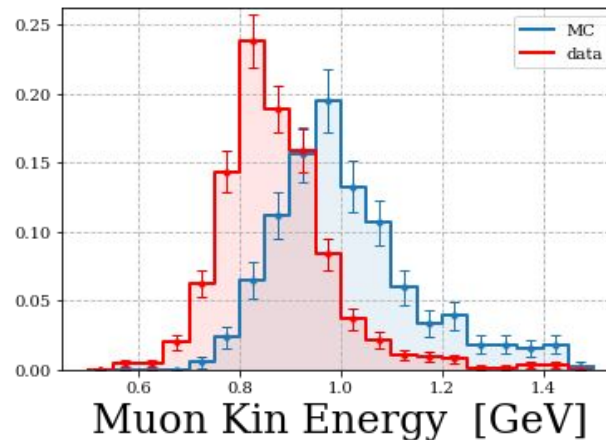
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Selecting tracks with track length compatible with Stopping Muon
($0.9 < \text{CSDA frac} < 1.1$)

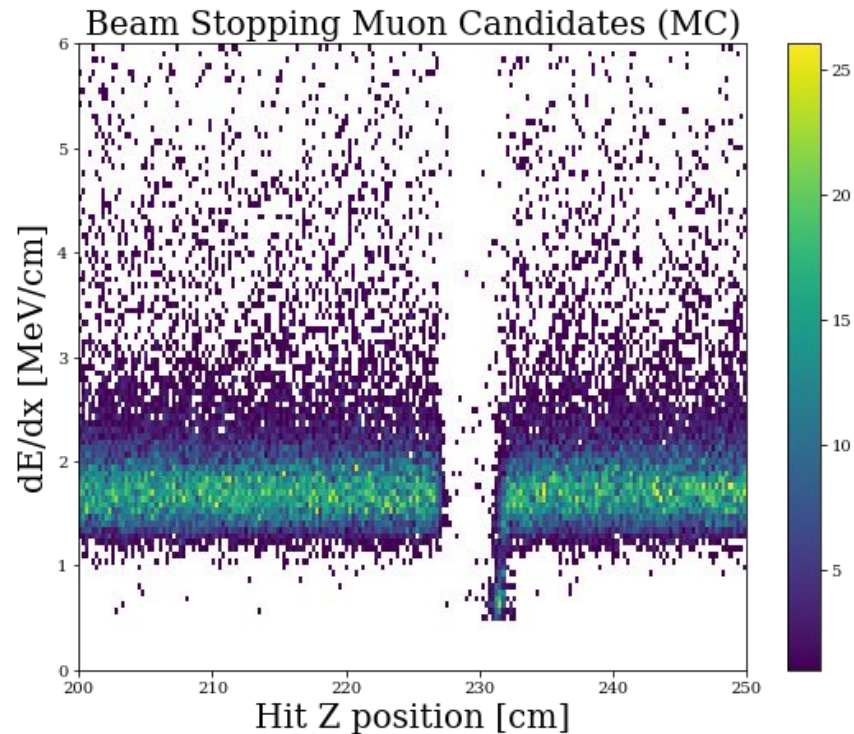
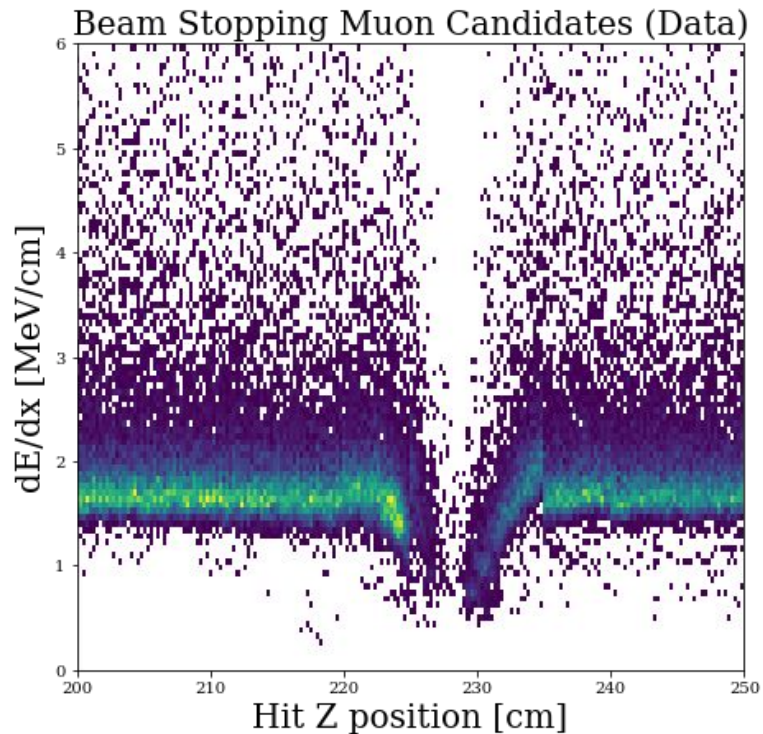
$$\sum_j \left(\frac{dE}{dX} \right)_j * (ResRange_j - ResRange_{j-1})$$

- Use calibrated dE/dx to calculate Stopping muons kinetic energy
 - Only using complete (non stitched tracks) from here on
- Kinetic energy from calorimetry systematically higher in MC than data
- Disagreement is from the APA gap



dE/dx vs Z position

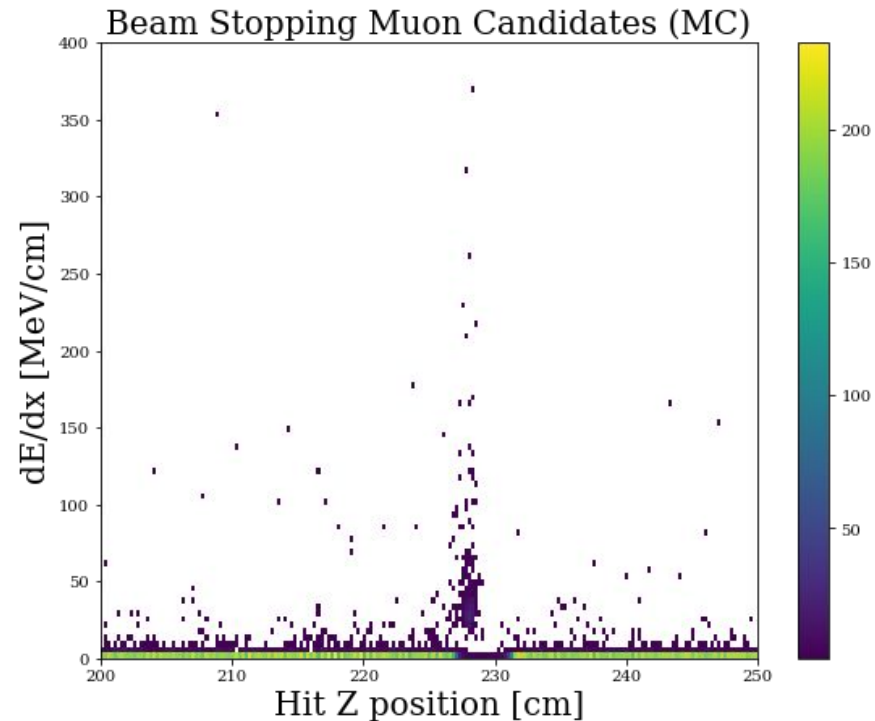
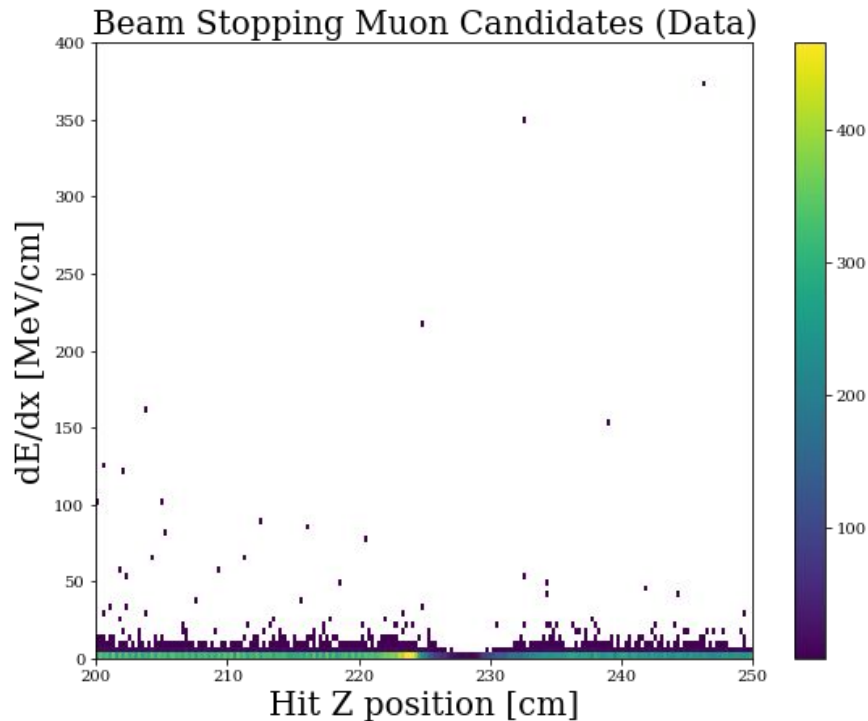
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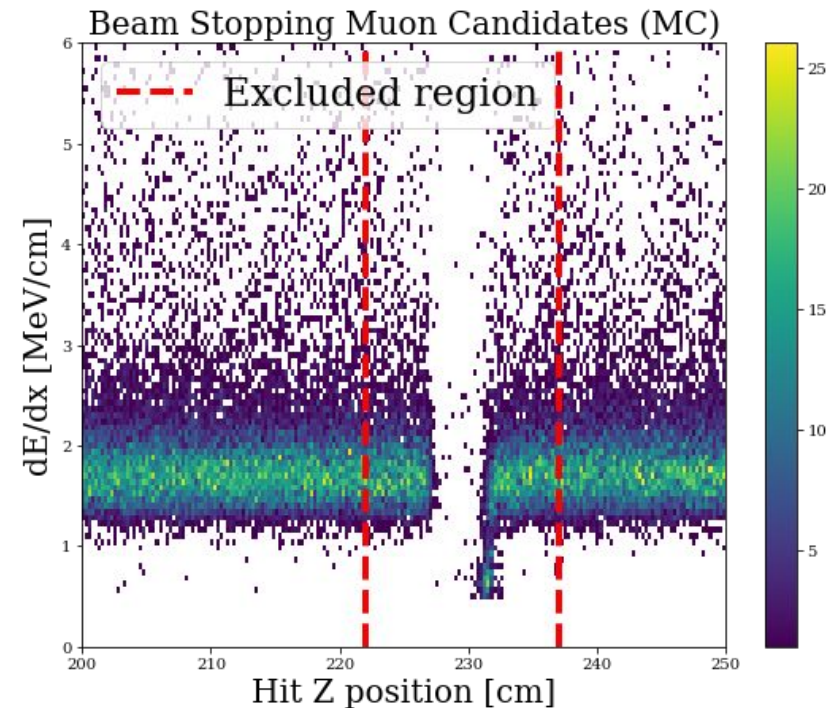
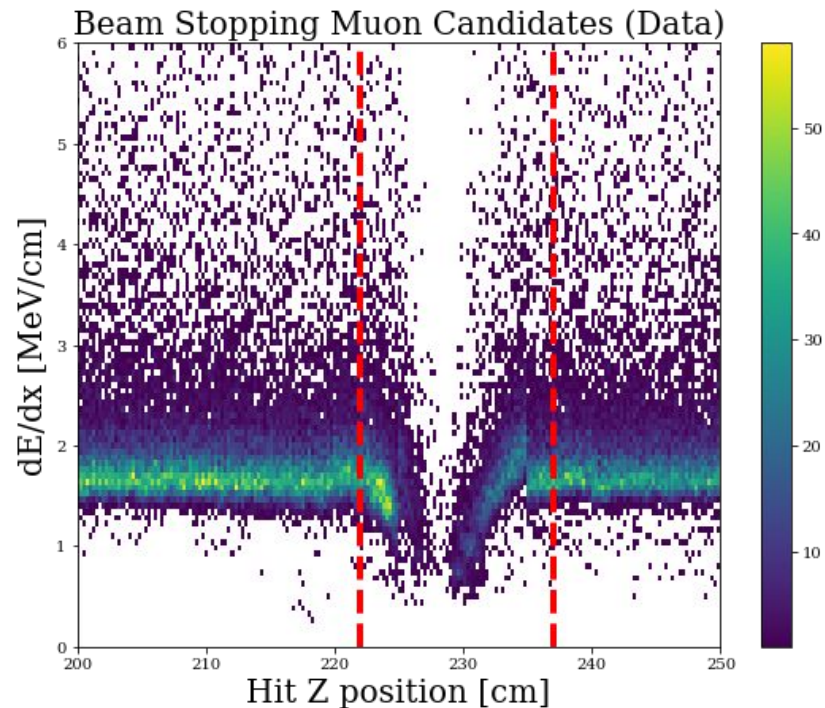
Different behaviour around APA gap between data and MC

dE/dx vs Z position

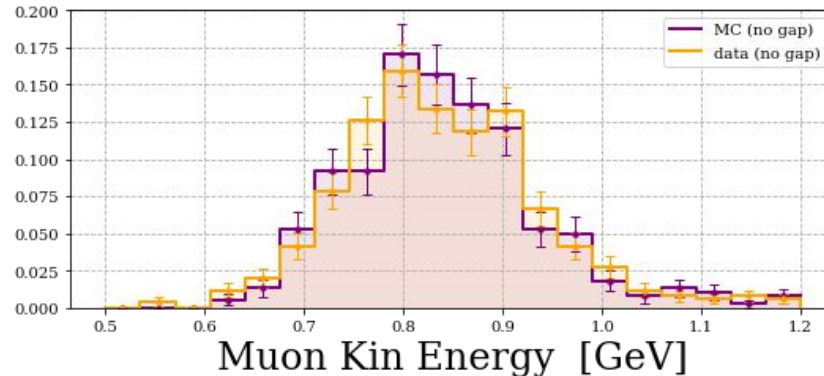
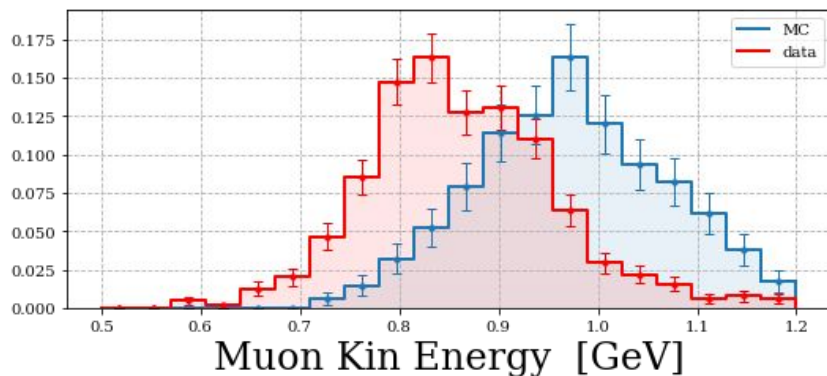
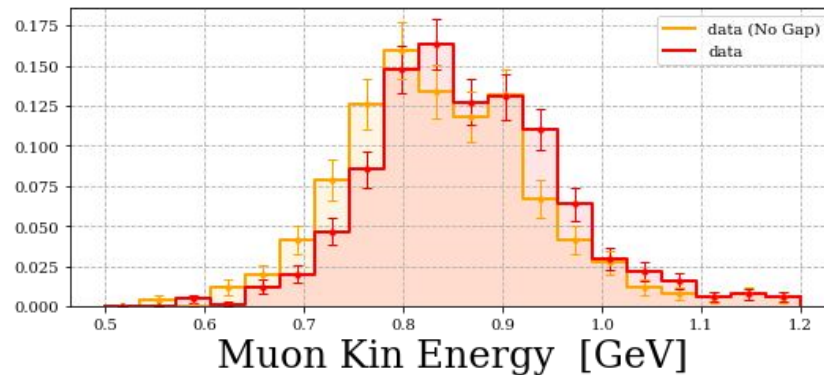
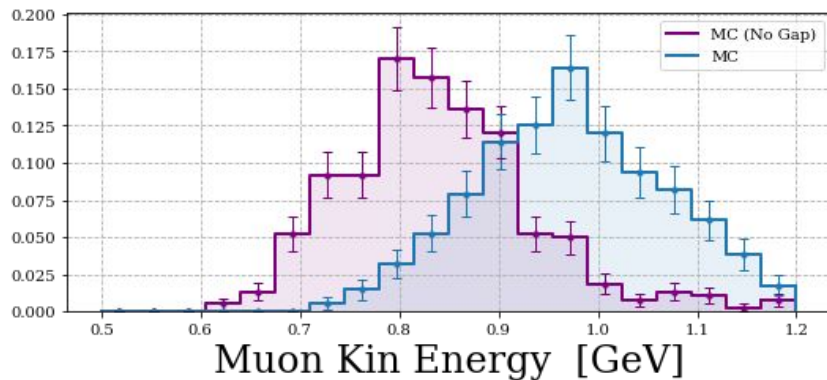
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In particular many very large de/dx values in gap for MC



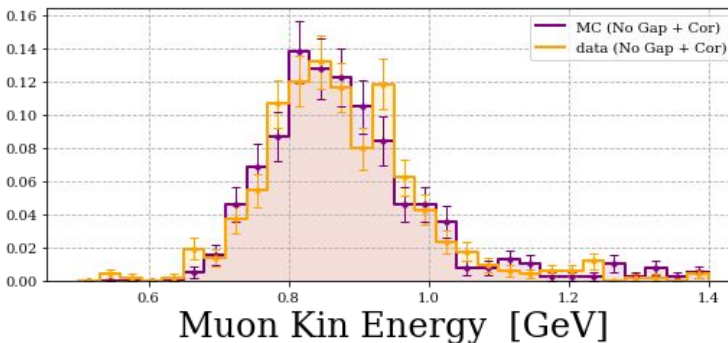
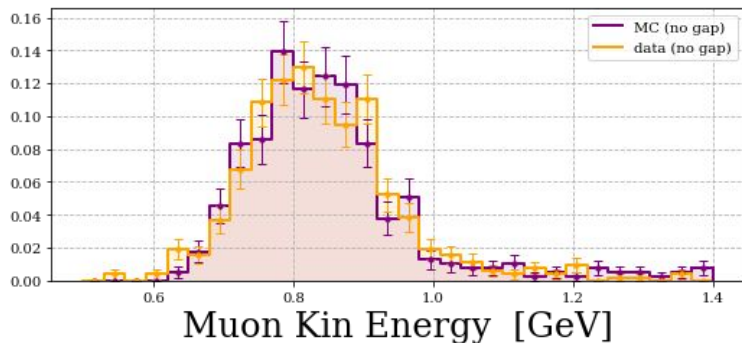
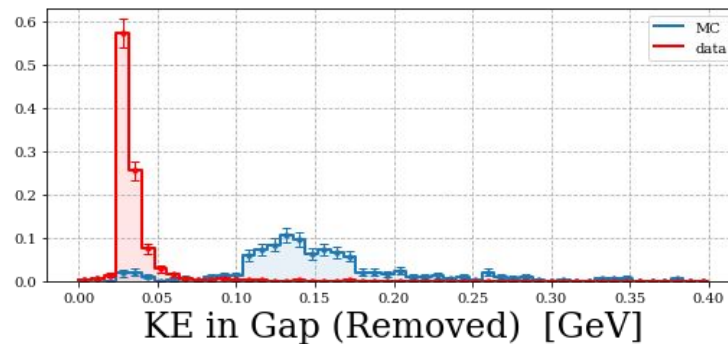
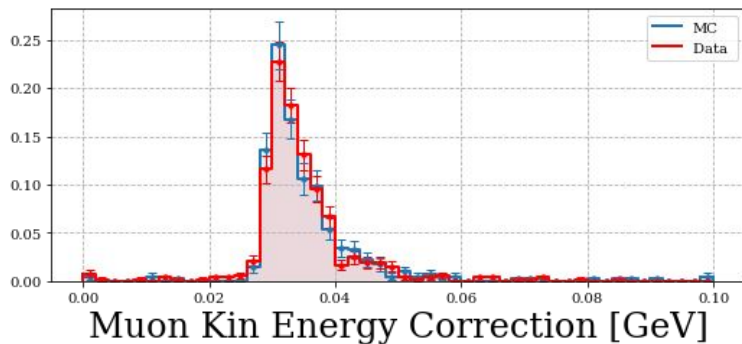
Choose to exclude hits in or near the APA gap from KE calc ($222\text{cm} < Z < 237\text{cm}$)



Excluding hits in or near the APA gap ($222\text{cm} < Z < 237\text{cm}$) brings KE for data and MC in to much better agreement (bottom right)

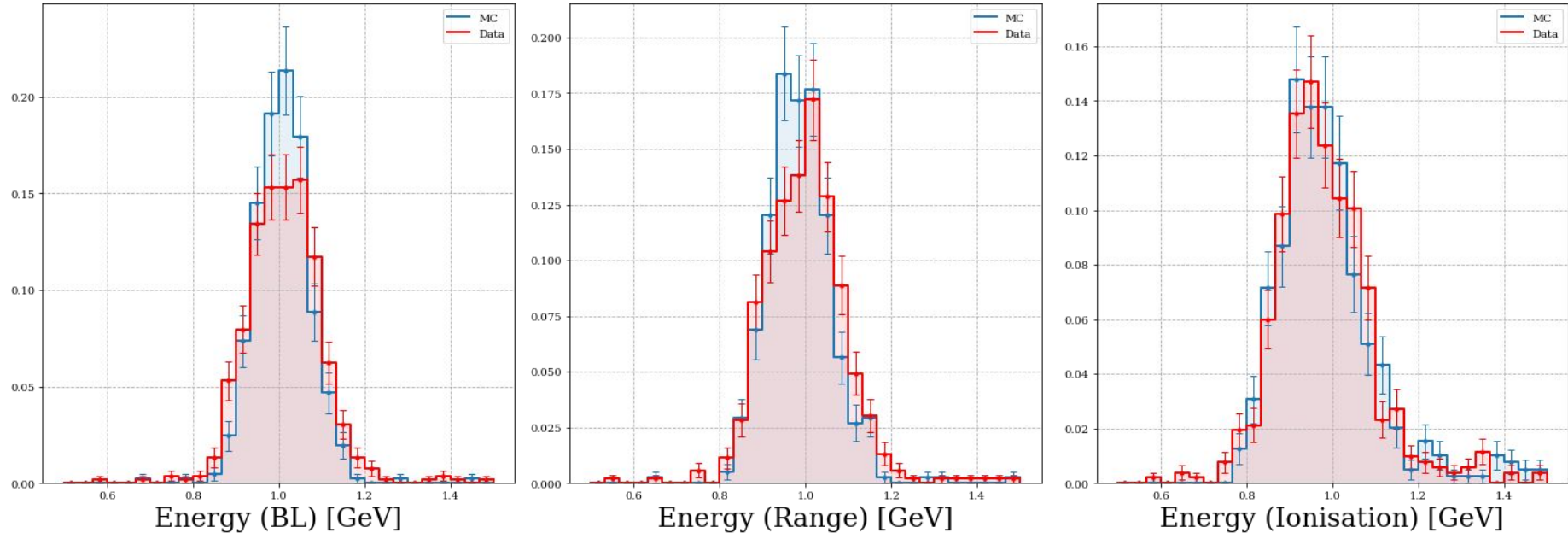
- Correction for removed hits

- $E_{cor} = (\text{Mean of 10 hits before and 10 hits after gap}) * (\text{dist between last hit before and first after gap})$

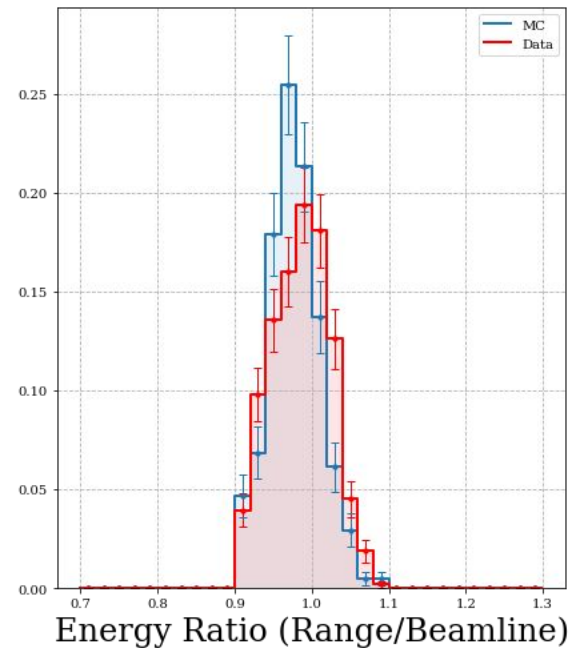
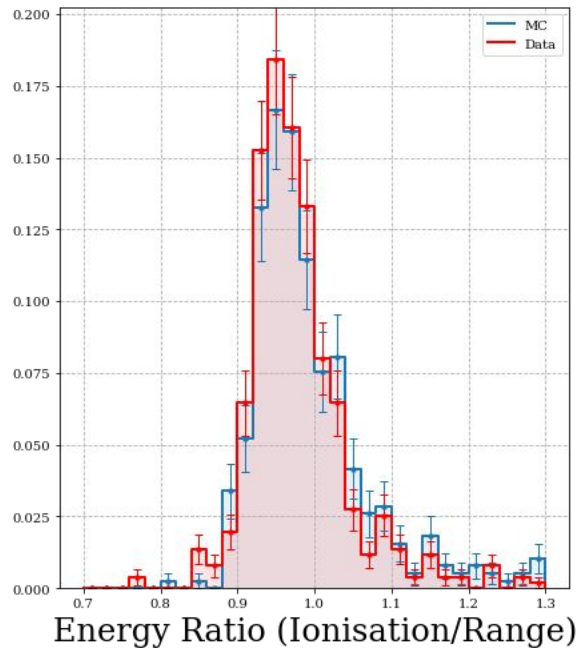
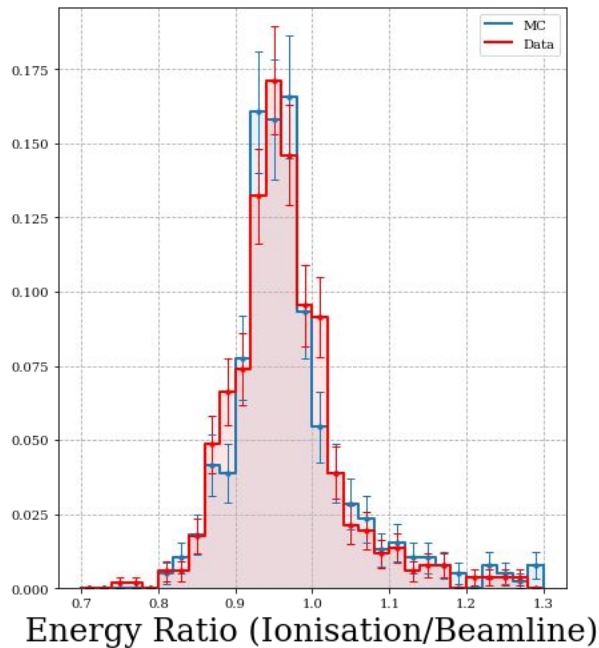


Stopping Muon Total Energy

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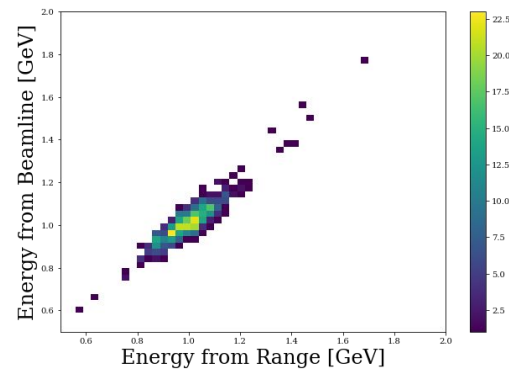
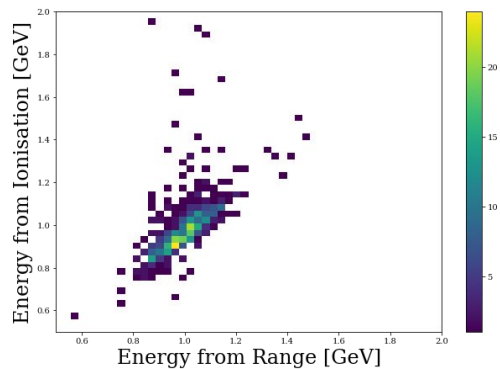
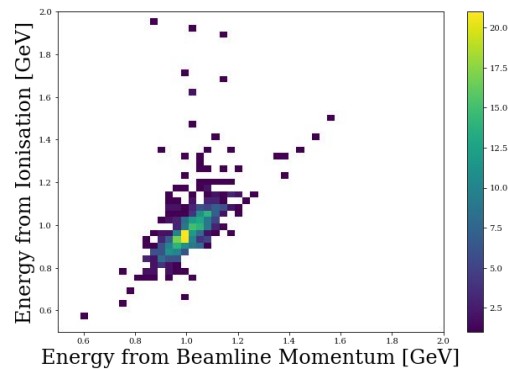


- Total energy including muon mass
- Ionisation from KE after removing APA gap hits and applying correction
- Ionisation method appears to slightly underestimate.

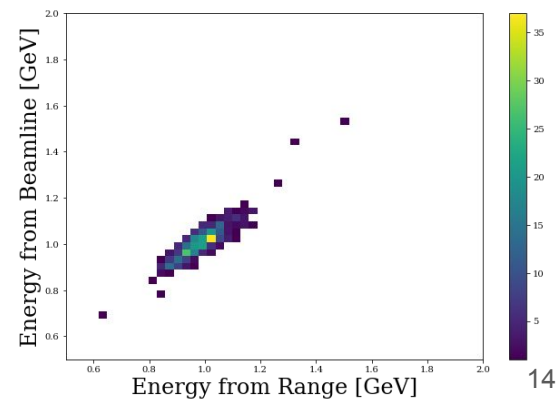
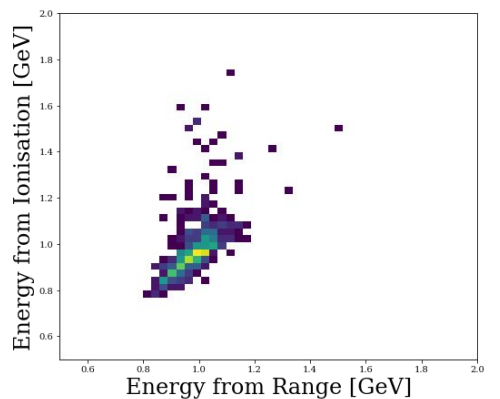
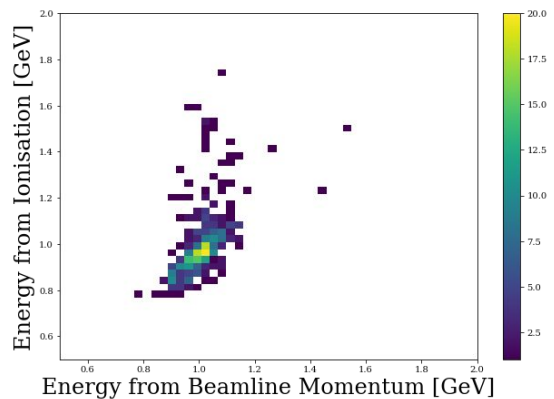


- Ionisation ratios peak slightly below one, have high tail
- Range calculation underestimates wrt BL greater in MC than data

Data

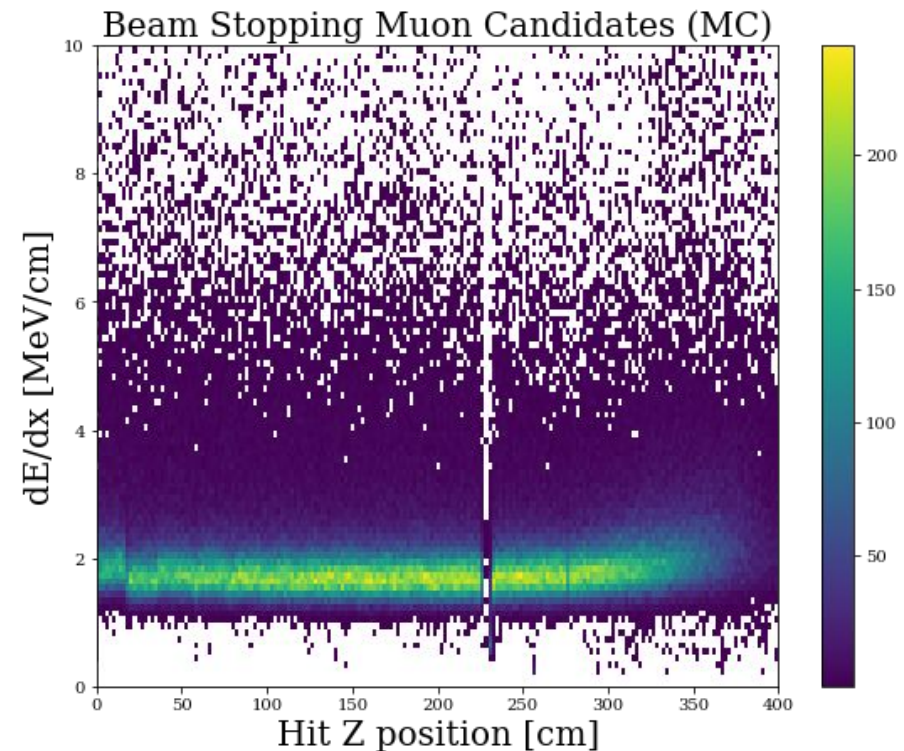
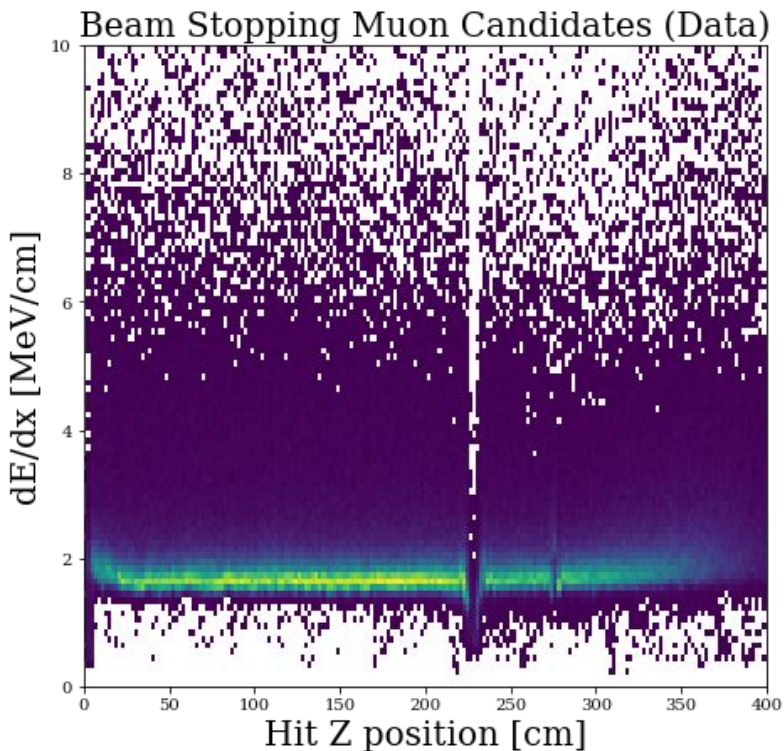


MC



- Looked at calorimetric reconstruction of beam stopping muons kinetic energy.
- Excluding hits near APA gap gives reasonable Data/MC agreement
- Would like to understand what cause high dE/dx hits near gap in MC
- Want to incorporate estimated losses before TPC

Back up



Samples - PDSPPProd2

- Data filters.
 - Unstable HV filter
 - Inactive FEMB filter (Beamside APAs)
 - Beamline 1 GeV Pion selection (ToF <110 ns and no hits in the low pressure Cherenkov counter)
- MC selection;
 - 1 GeV MC with data driven SCE
 - events where the true beam particle is pion or muon.

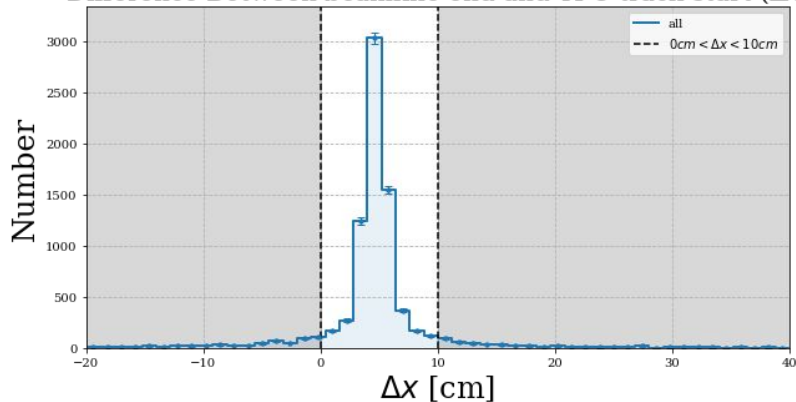
Data Run 5387	# Events after filters with Pion trig	# events with Pandora reco beam track
Pions/Muons	21969	14447

Monte Carlo	# true beam events	# events with Pandora reco beam track
Muons	627	564
Pions	9839	7223

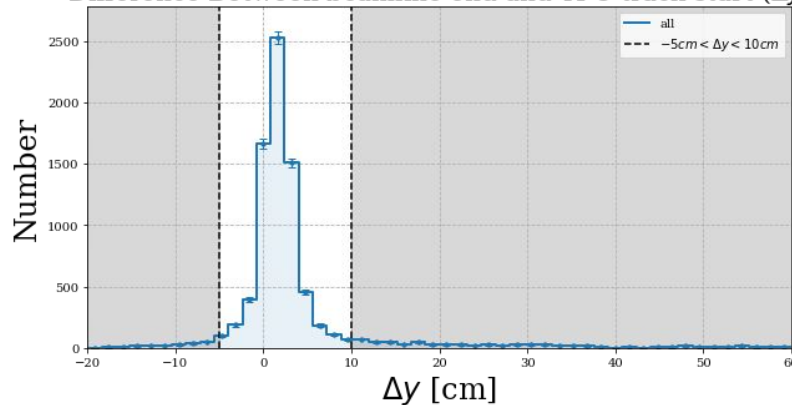
Data Quality Cuts

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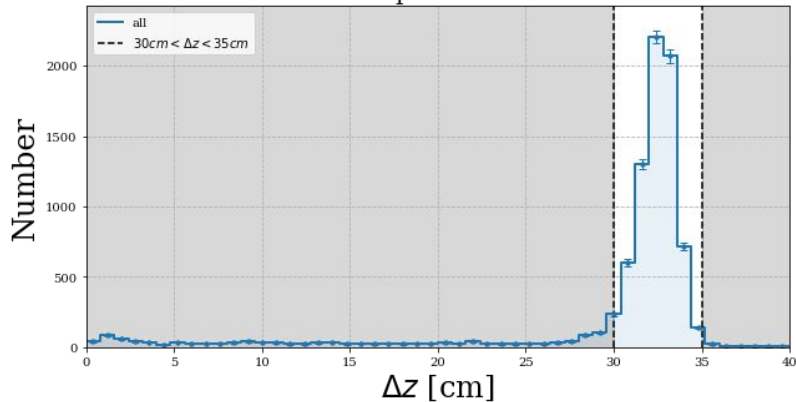
Difference Between beamline end and TPC track start (Δx)



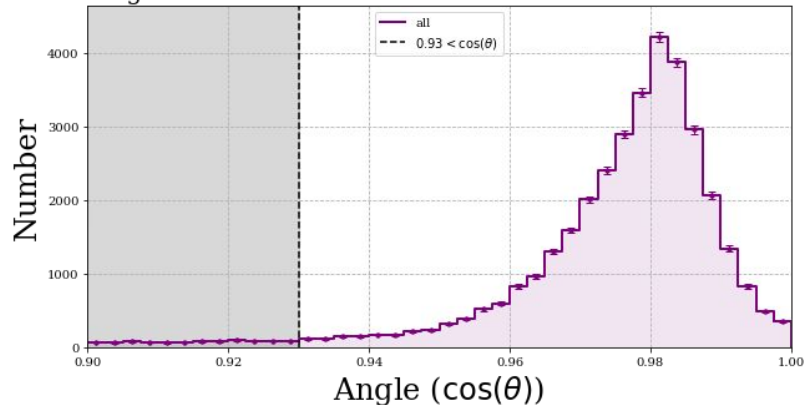
Difference Between beamline end and TPC track start (Δy)



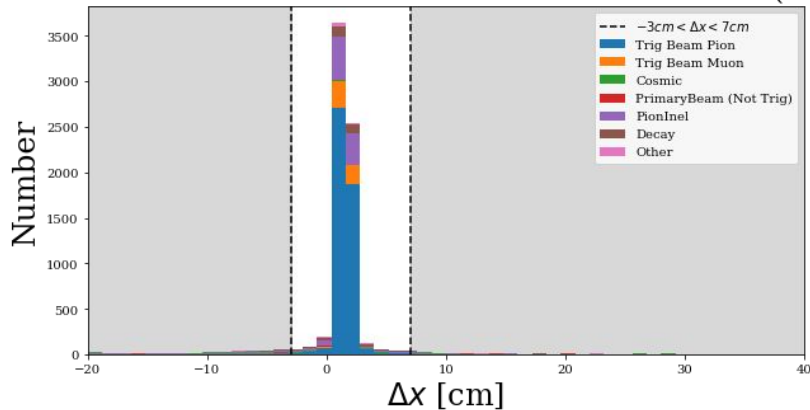
Difference Between beamline particle end and TPC track start (Δz)



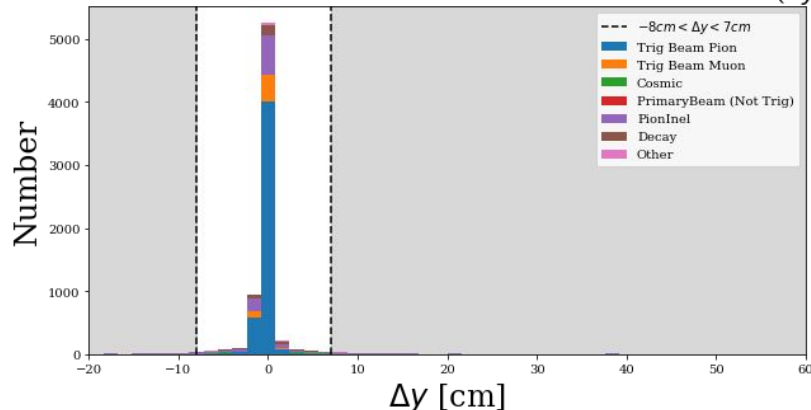
Angle between Beamline and TPC track start direction



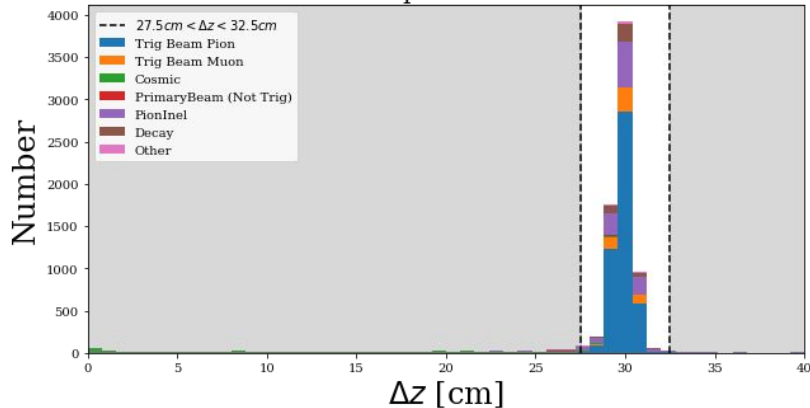
Difference Between beamline end and TPC track start (Δx)



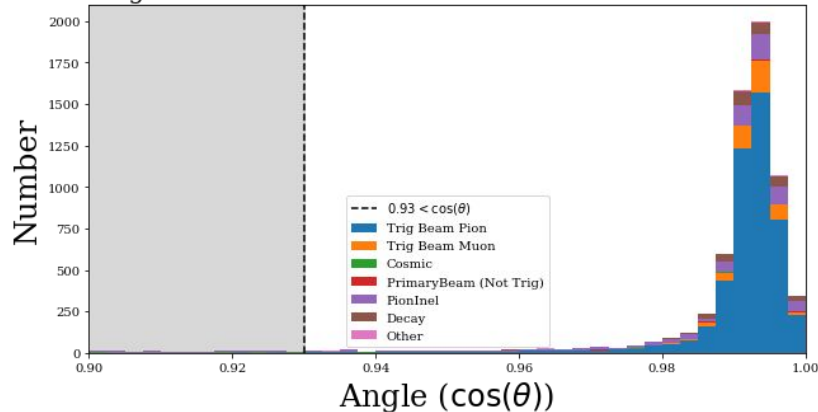
Difference Between beamline end and TPC track start (Δy)



Difference Between beamline particle end and TPC track start (Δz)



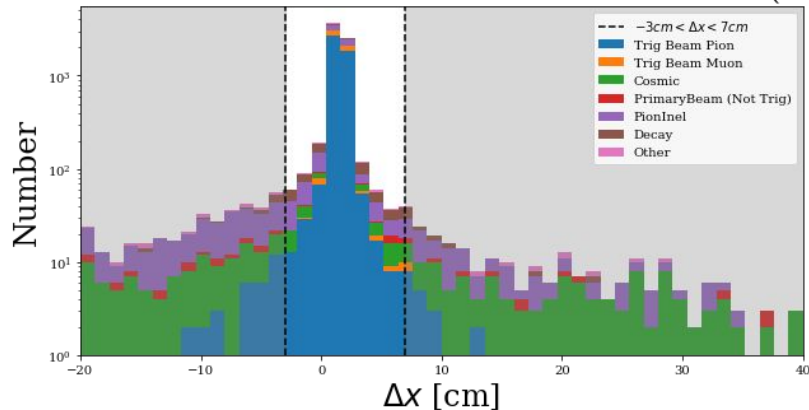
Angle between Beamline and TPC track start direction



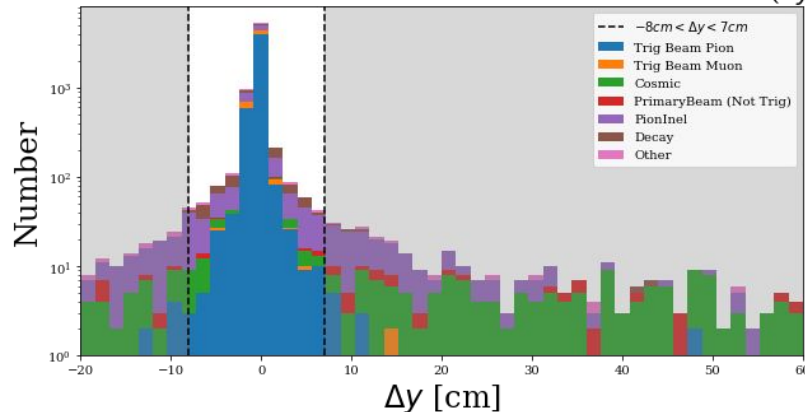
MC Quality cuts (log)

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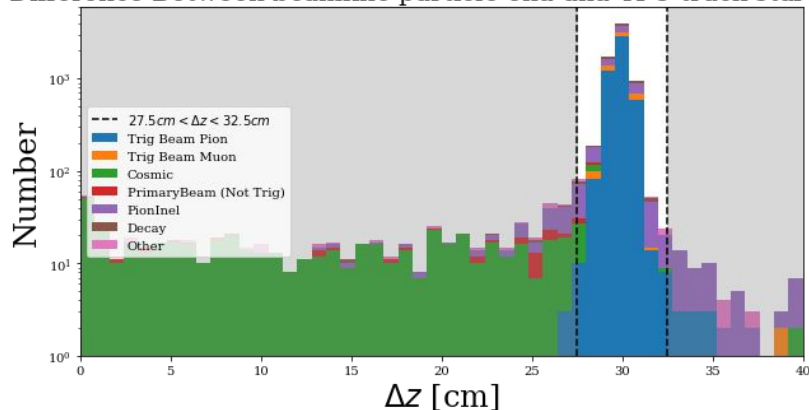
Difference Between beamline end and TPC track start (Δx)



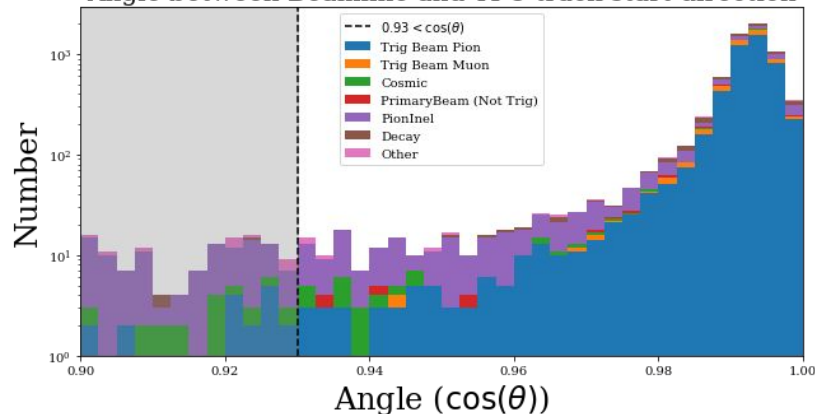
Difference Between beamline end and TPC track start (Δy)



Difference Between beamline particle end and TPC track start (Δz)



Angle between Beamline and TPC track start direction



Number of Events with No BL track

174

Number of Events with > 1 BL track

4508

Number of Events with Exactly 1 BL track

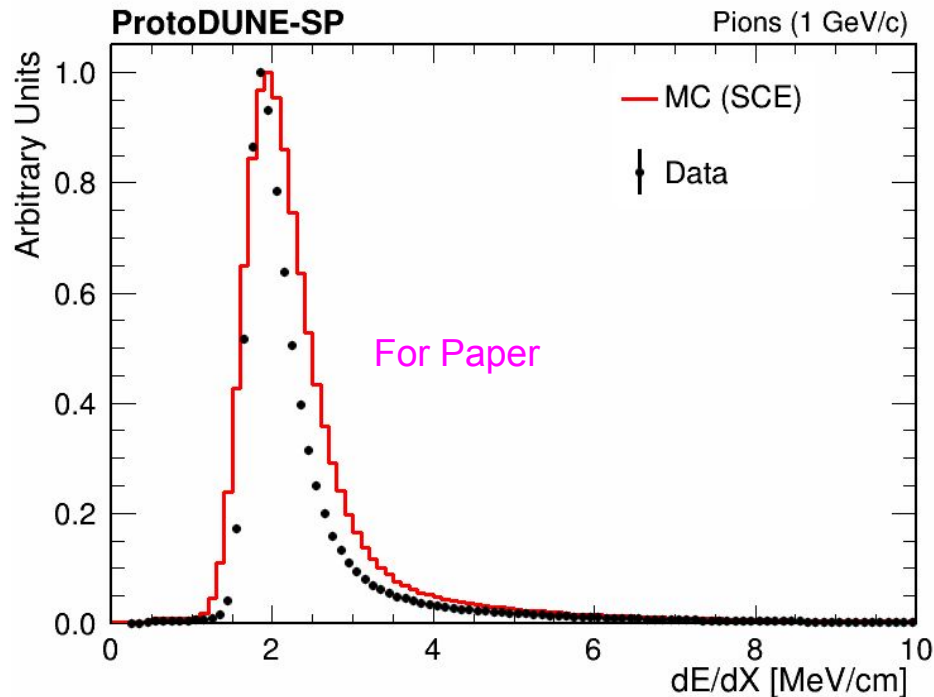
9765

Number of those with only 1 Mom value

8755

	# events before beam qual cuts	# events after cuts
MC	7787	6254
Data	8755	6199

- Use Ajib Paudel's calorimetry correction to calibrate data, described here.
https://docs.dunescience.org/cgi-bin/private/RetrieveFile?docid=15974&filename=prod2_calibration_constants_for_selected_runs.pdf&version=2
- Uses cathode crossing T0 tagged cosmic stopping muons. Calibration is for collection plane.
- Was done with cosmic data from this run 5387



Parameters used in broken track stitching

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BrokenTrackParameters: {  
  BrokenTrackZ_low: 220  
  BrokenTrackZ_high: 230
```

```
  StitchTrackZ_low: 232  
  StitchTrackZ_high: 240
```

```
  StitchXTol:    10  
  StitchYTol:    10  
}
```