Status Report

Sungbin Oh

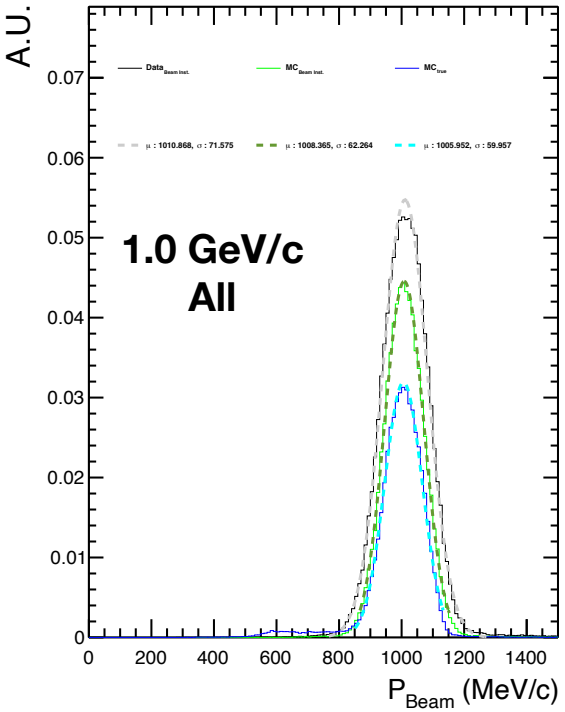
FNAL DUNE Sim-Reco Group Meeting

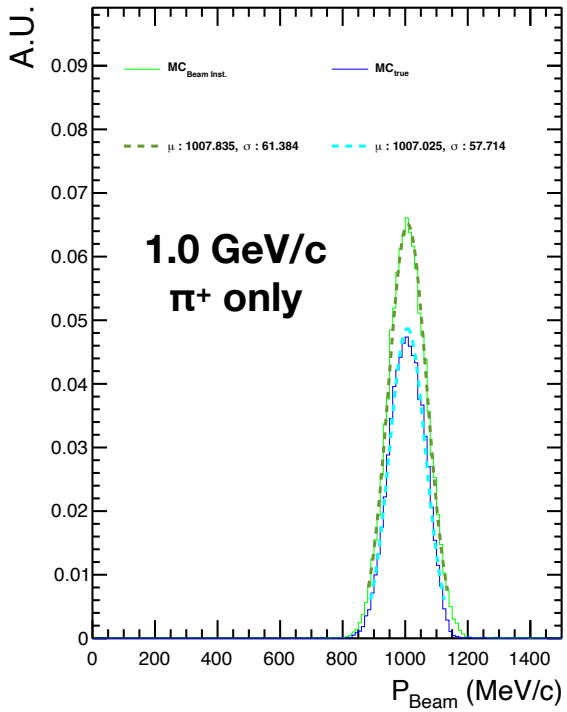
17 August 2022

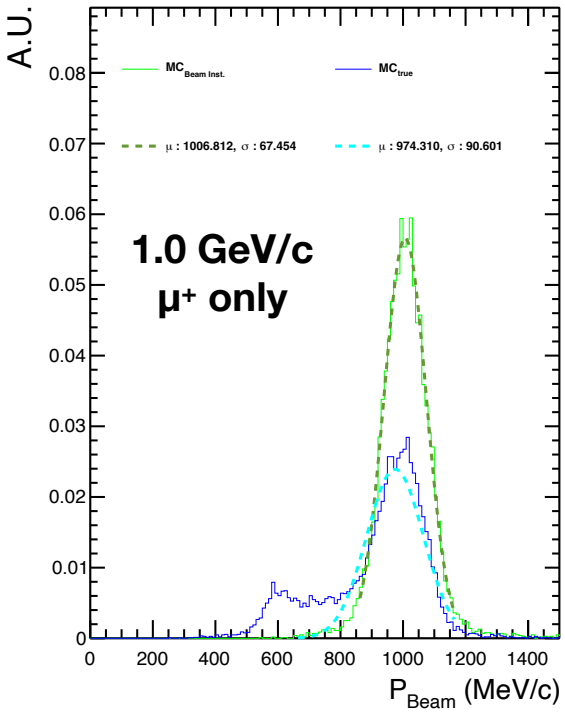
Study for ProtoDUNE-SP Beam

Purpose of the study

- I want to understand muon contribution better
- Black : data, green : MC, blue : MC truth
- To solve the well known mismodeling problem for muon beam contribution







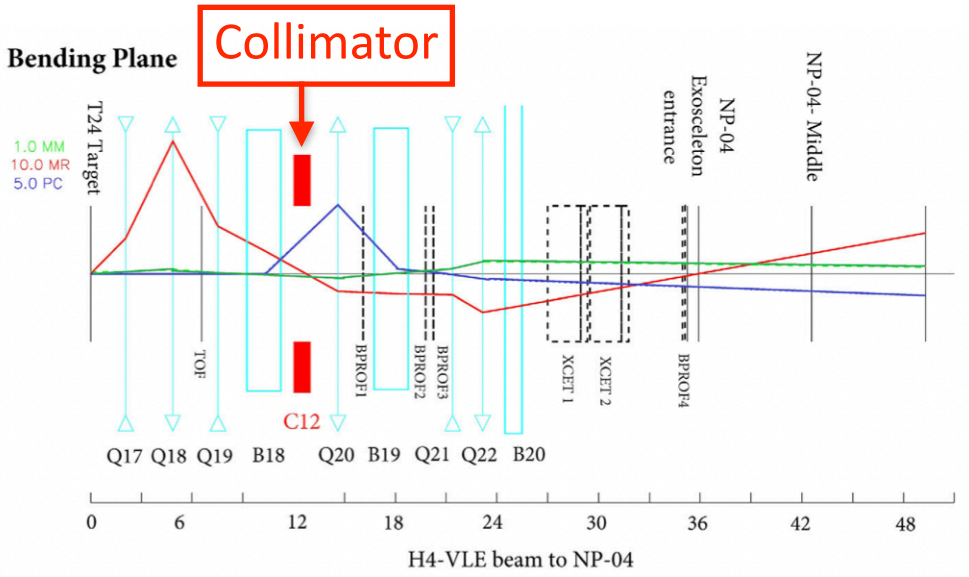
Study for ProtoDUNE-SP Beam

H4-VLE Beam line

- Secondary target to collimator : 12 m
- To BPROF1 (~ 15.4 m), BPROF2 (~ 19.1 m), and BPROF3 (~ 19.5 m)
- To cryostat : 36 m

Let's assume that muon contribution is negligible right after the secondary target

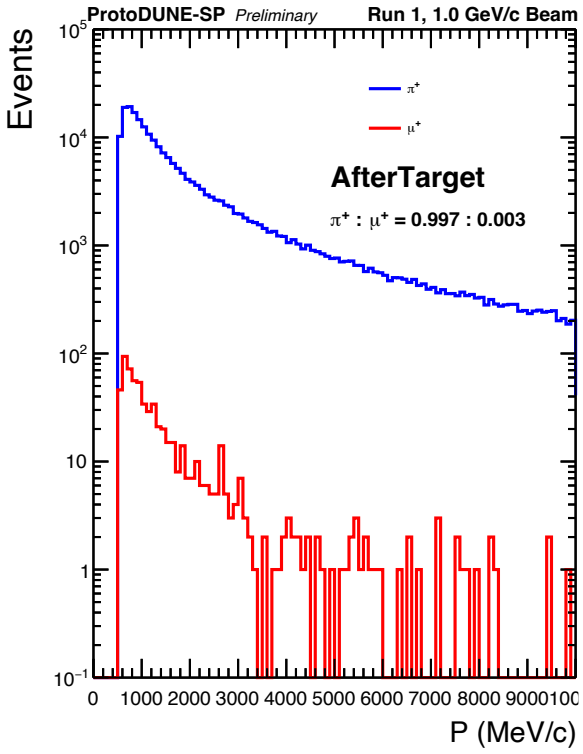
- γcτ of 1 GeV/c π^+ is 56.4 m
- At collimator
  - Exp[-12 / 56.4] = 0.808
- BPROF1
  - Exp[-15.4 / 56.4] = 0.761
- BPROF2, 3
  - 0.7127, 0.7077
- Cryostat
  - Exp[-36/56.4] = 0.5282

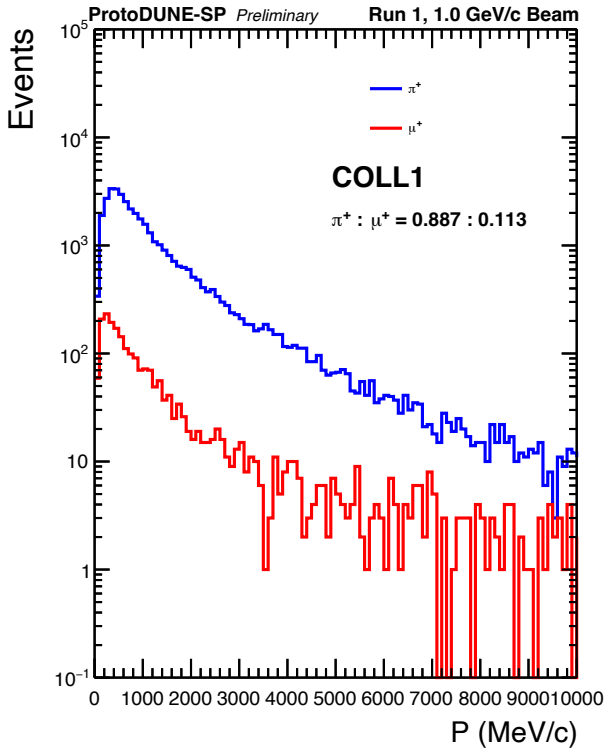


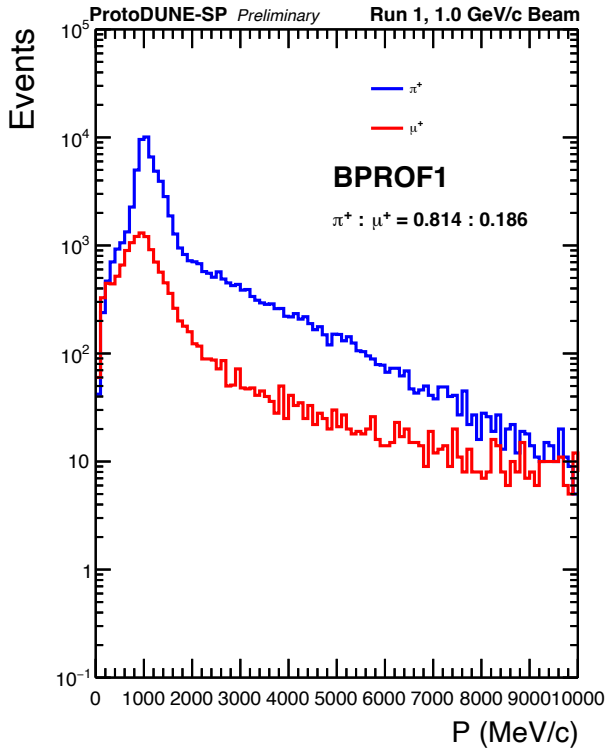
Study for ProtoDUNE-SP Beam

Using the 1 GeV/c G4beamlineVersion3.06 sample

- 0.5M events for each stage
- After collimator, a peak at 1 GeV/c is observed
- Muon contribution is increasing due to decay-in-flight of charged pions



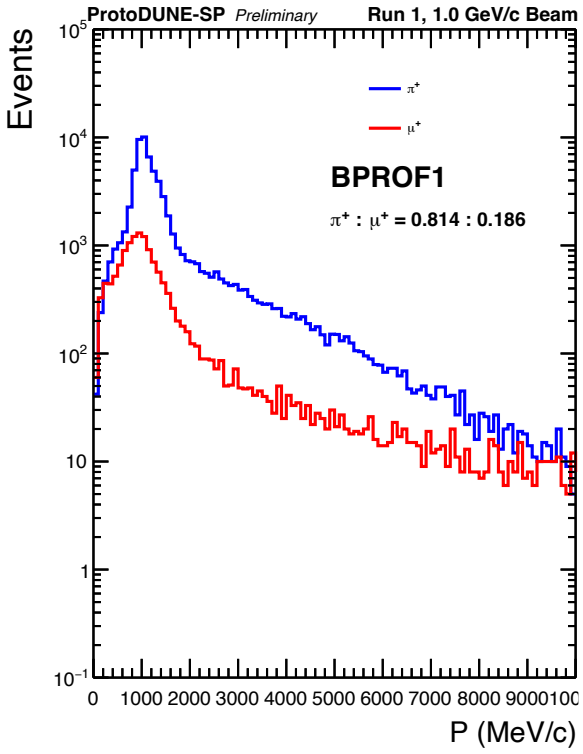


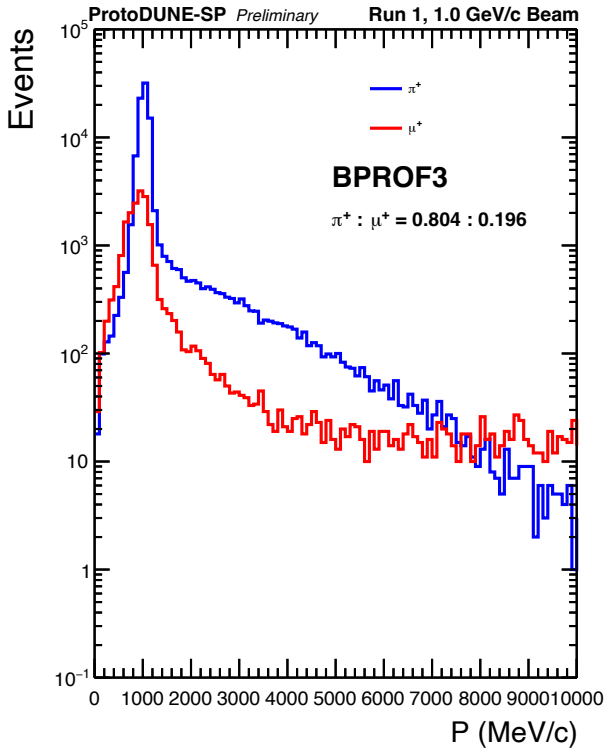


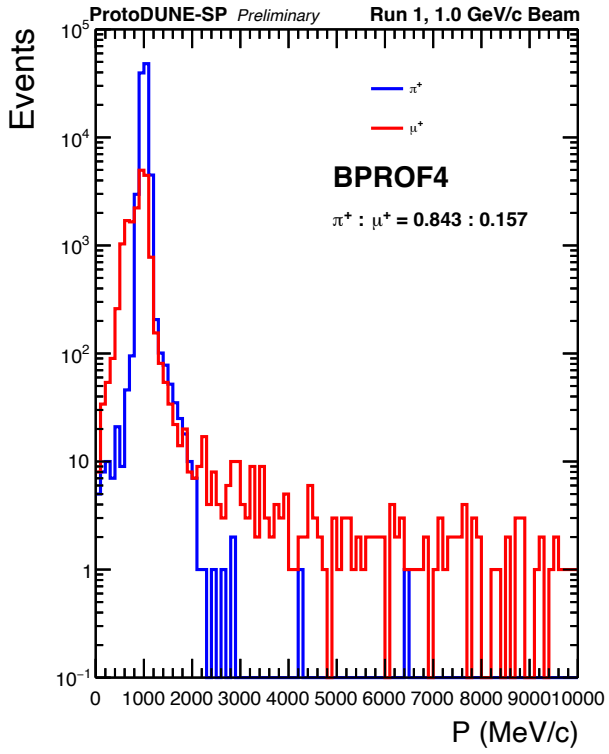
Study for ProtoDUNE-SP Beam

Using the 1 GeV/c G4beamlineVersion3.06 sample

- The 1 GeV/c peak becomes more clear due to B-field at momentum spectrometer
- We also see decay-in-flight muon shoulder at BPROF4 (close to the cryostat)
- Muon contribution decreases at BPROF4







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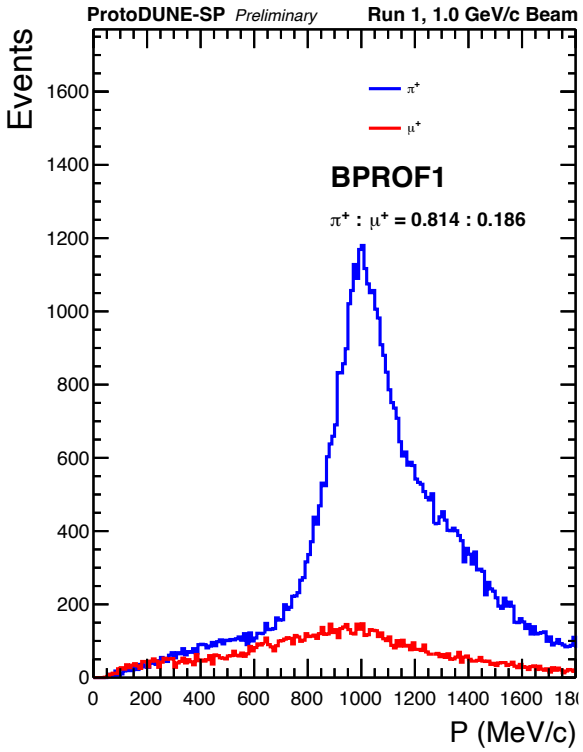

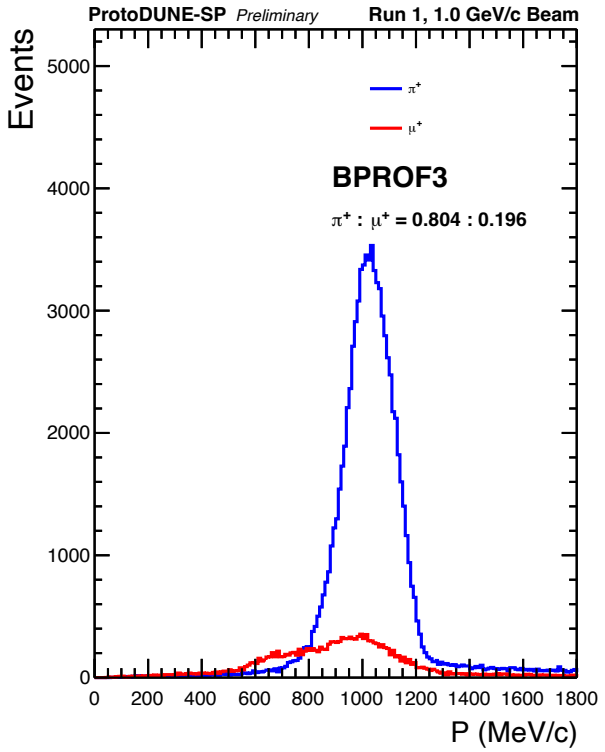

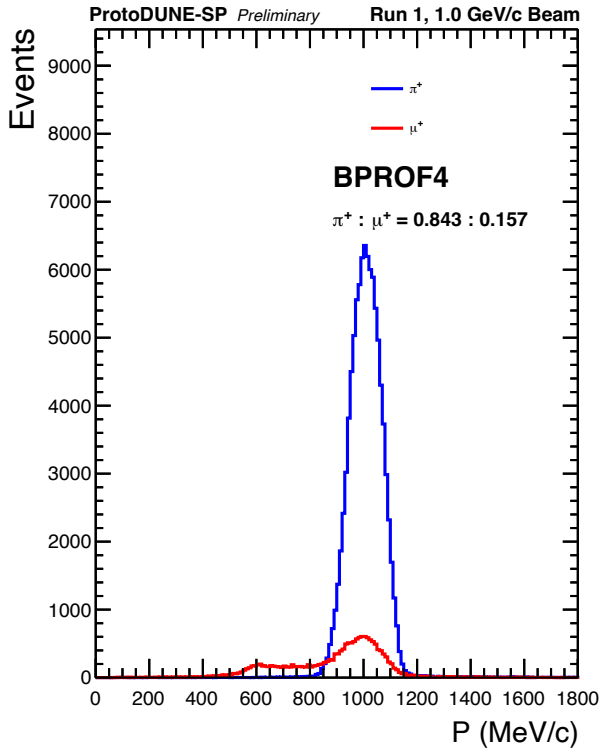

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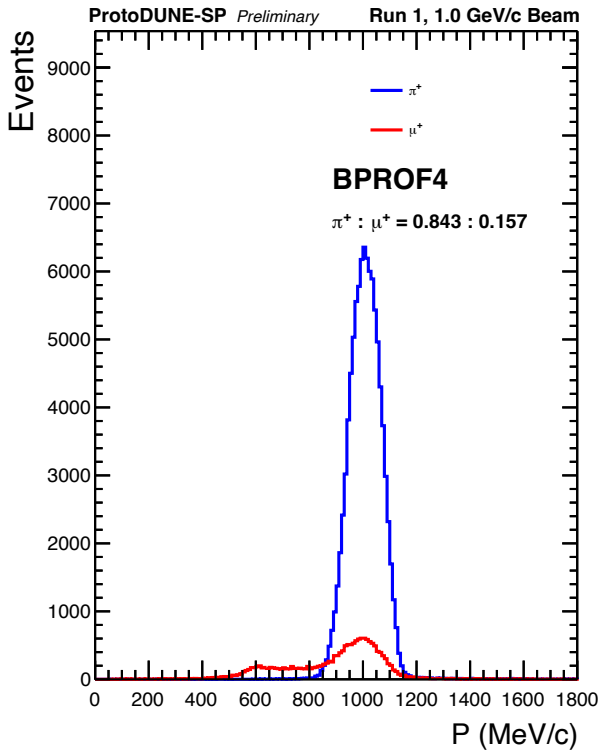

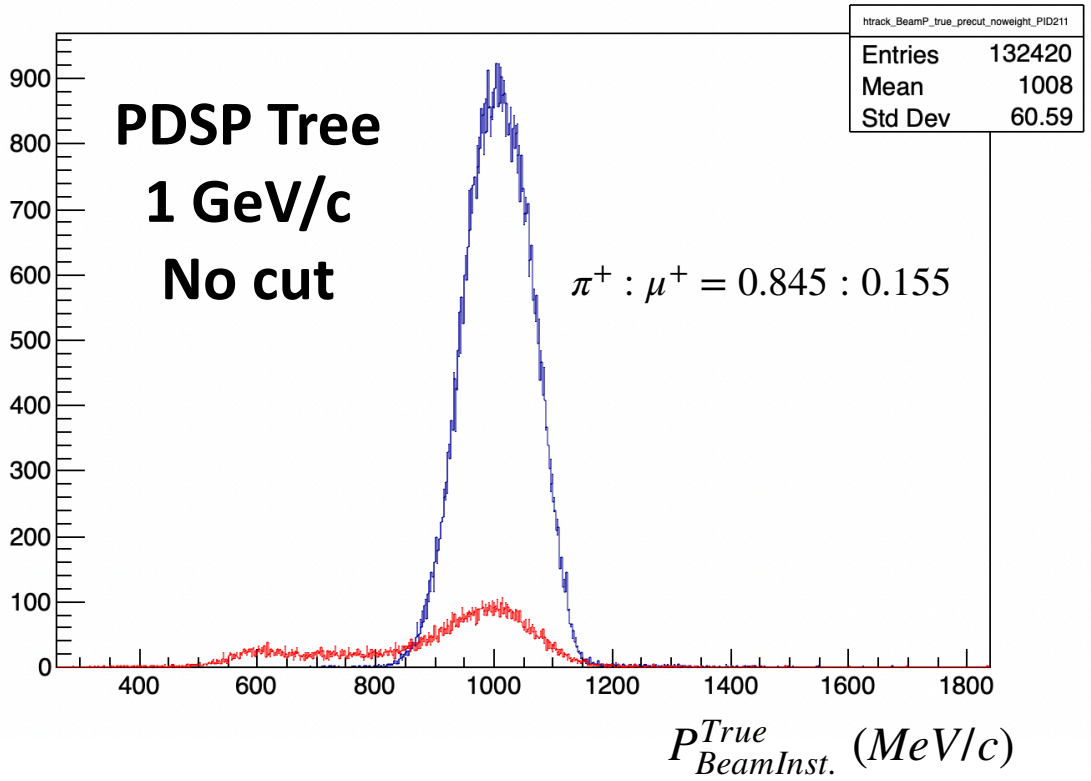

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Study for ProtoDUNE-SP Beam

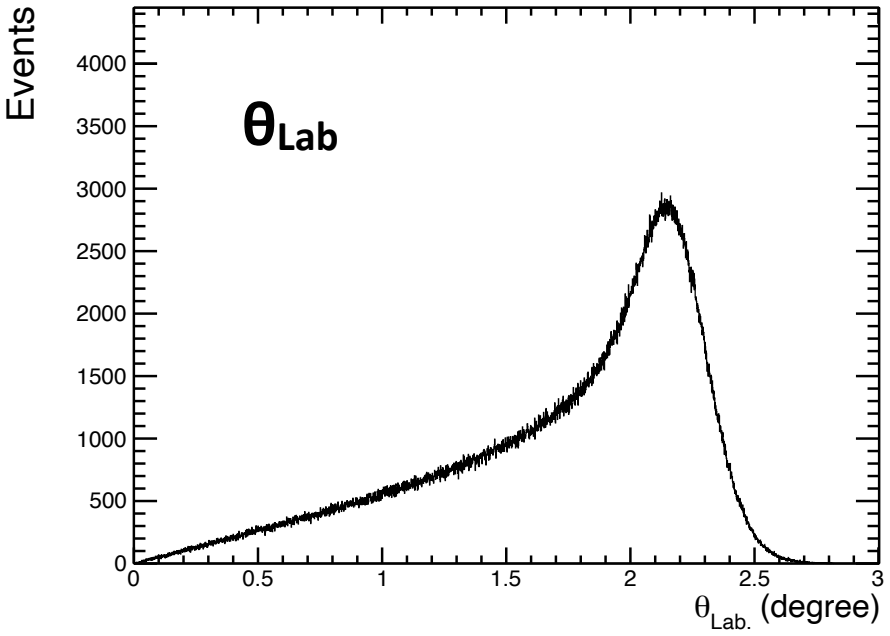
Considered an additional effect - γ factor and decay probability

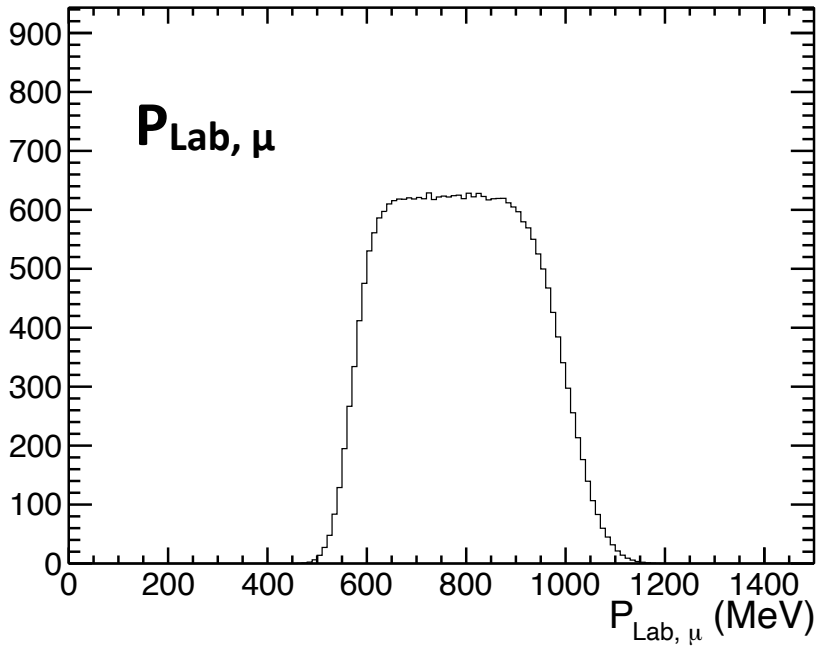
- P_{Decay} = 1 - exp(-L/γcτ)
  - P_{Decay} of 1 GeV/c π+ between BPROF3 and 4 (= 14.5 m) is 22.7%
  - Bigger than 15.7%
- Using the Gaussian fitted truth P(π^+), randomly select momentum value - γ and β
- Using a random number in [0, 1], decay π+ if the number is smaller than P_{Decay}
- 10^7 trials
  - Scale using a weight : $\int_{800}^{1200} Gaus(\pi^+, P_{true}) dP_{true} \; / \; N_{\pi^+ \; Not \; decayed}$
  - Number of pions which are not decayed to be same with the area of the Gaussian fitted truth P(π^+)

Study for ProtoDUNE-SP Beam

Considered an additional effect - γ factor and decay probability

- The opening angle (θ) of muon at the lab frame

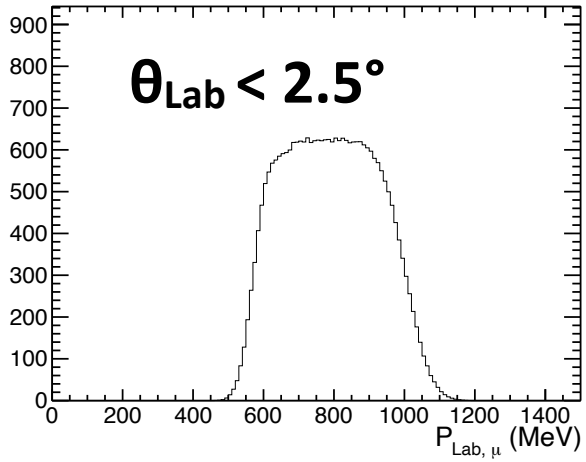


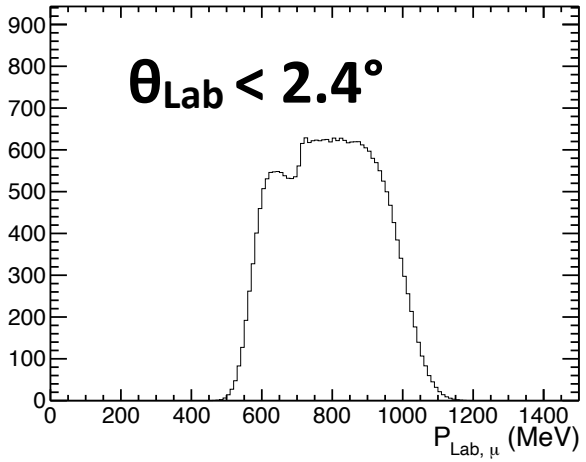


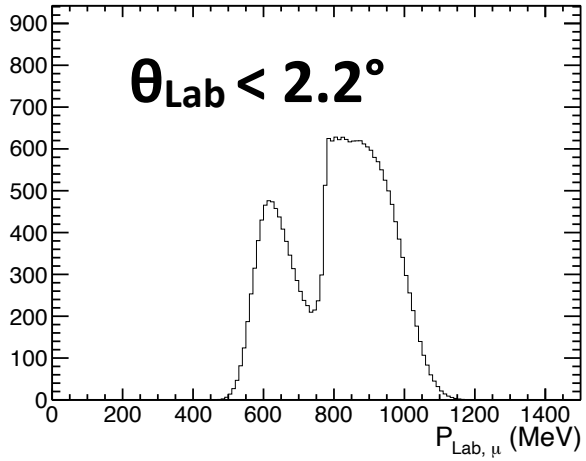
Study for ProtoDUNE-SP Beam

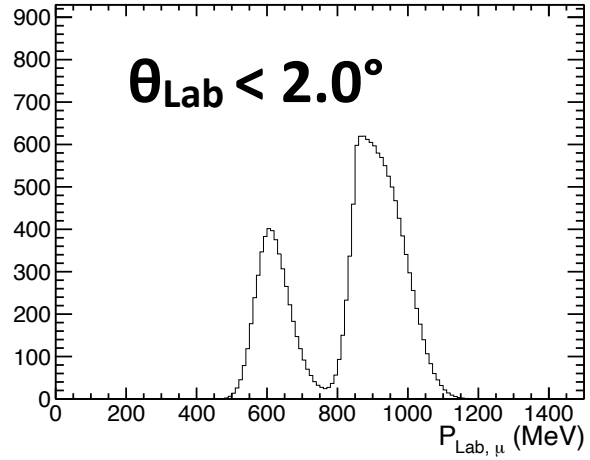
Cut on θ_{Lab} can affect the shape much

- Momentum selection using B-field affect shape of decay-in-flight muon P distribution much









- Tight θ cut means we select forward (1002 MeV) and backward (571 MeV) decays
- Difficult to distinguish forward decay-in-flight muons and 1 GeV/c collimated muons

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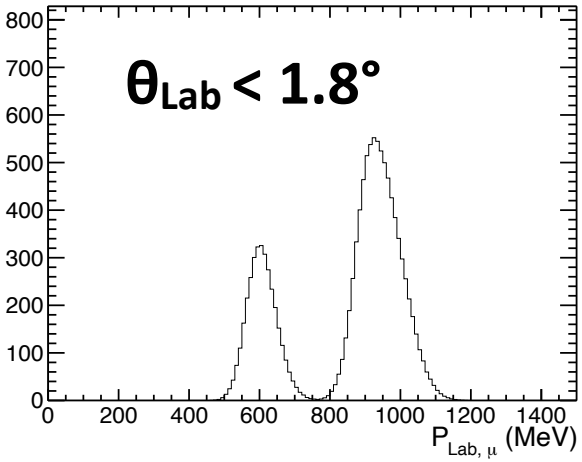

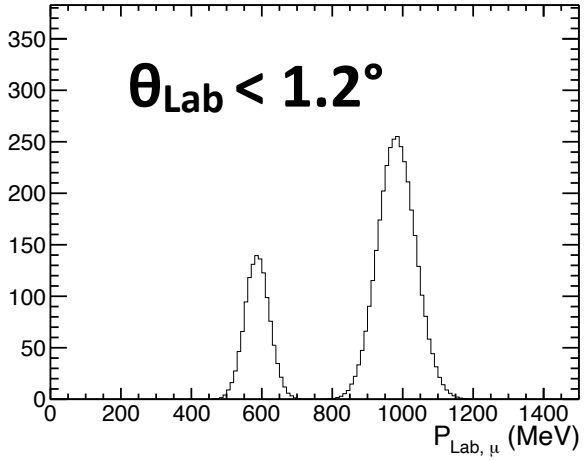

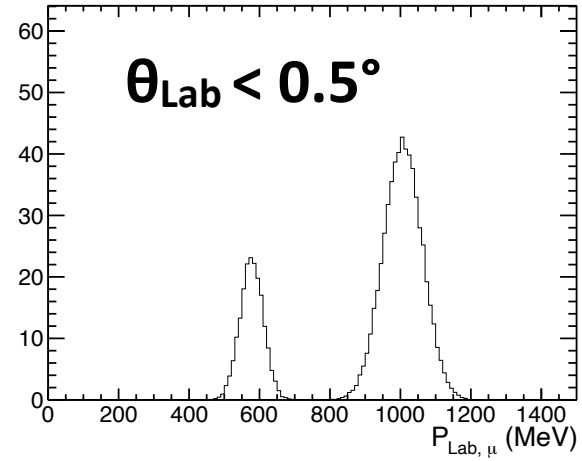

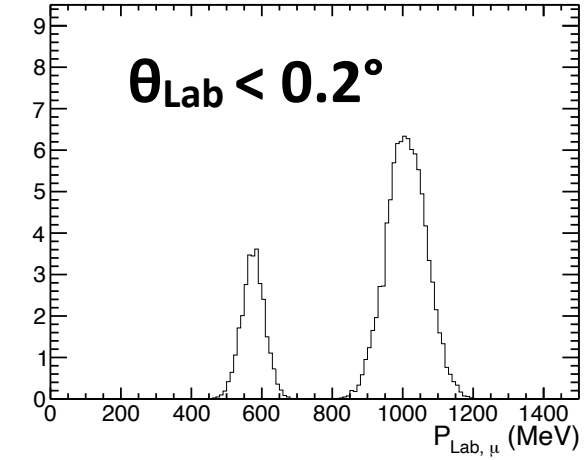

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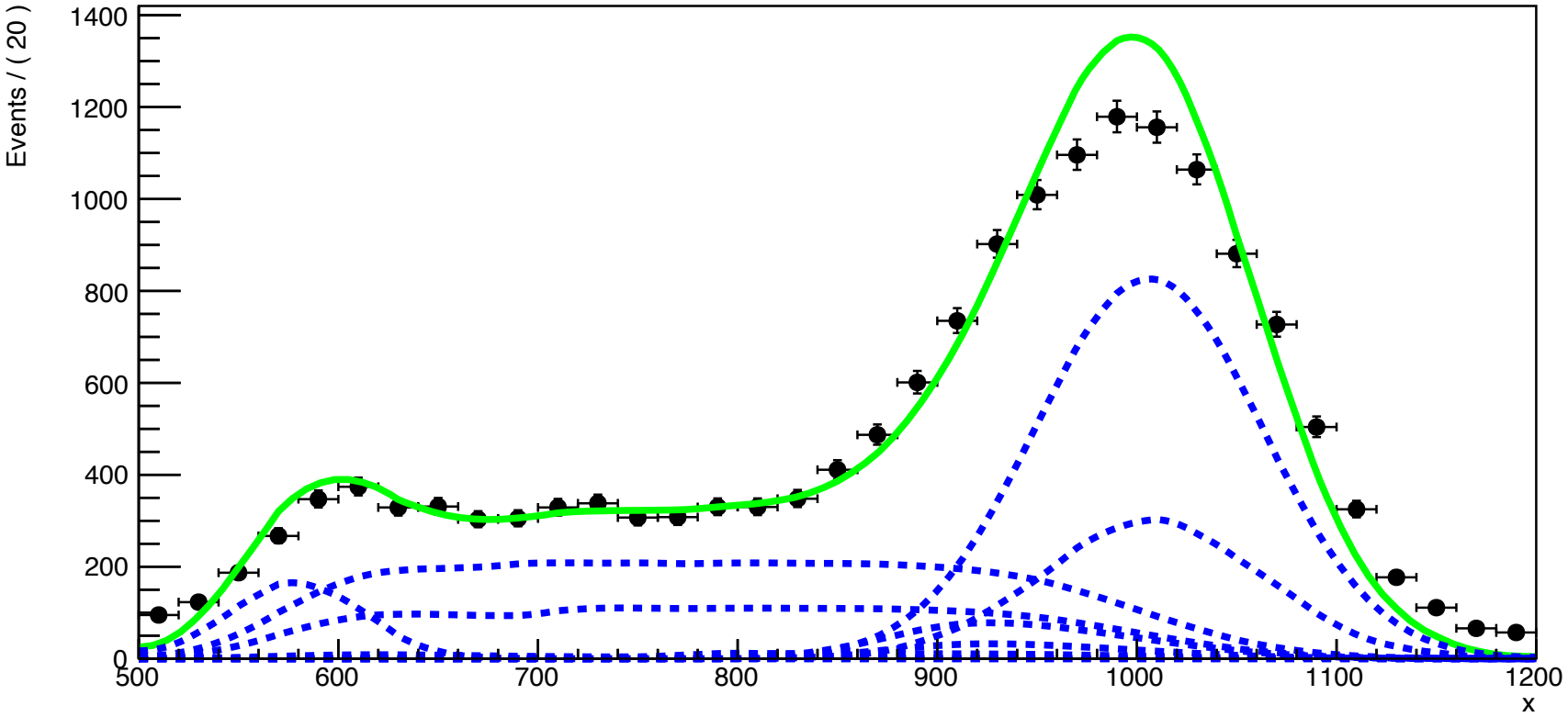
Study for ProtoDUNE-SP Beam

Can we reproduce muon momentum spectrum through template fitting using previous shapes?

- Included Gaussian(π+, momentum) as a basis
- It seems that a Gaussian component with wider σ compared to P(π^+) is required…

Example of composite pdf=(sig1+sig2)+bkg



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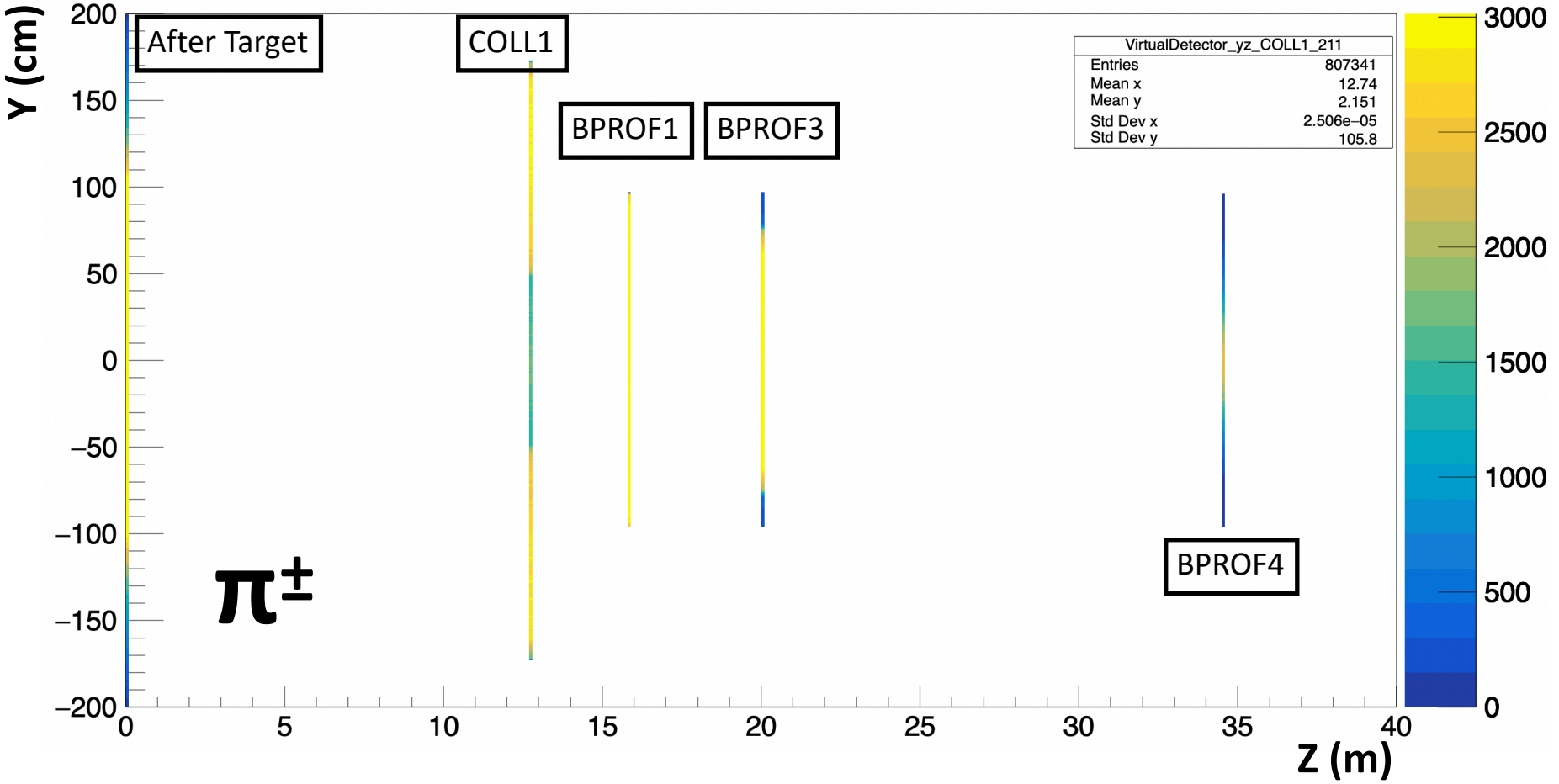

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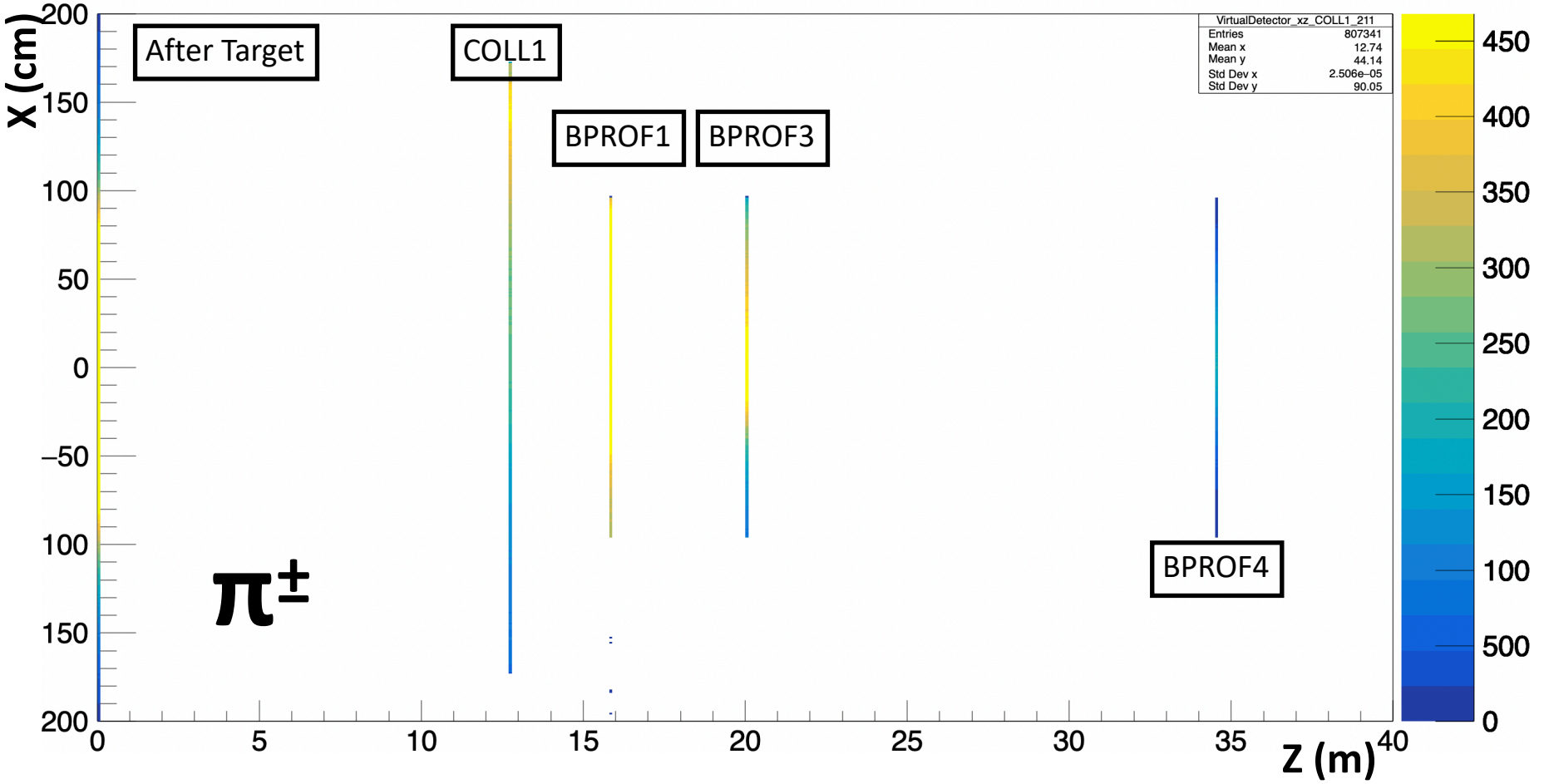

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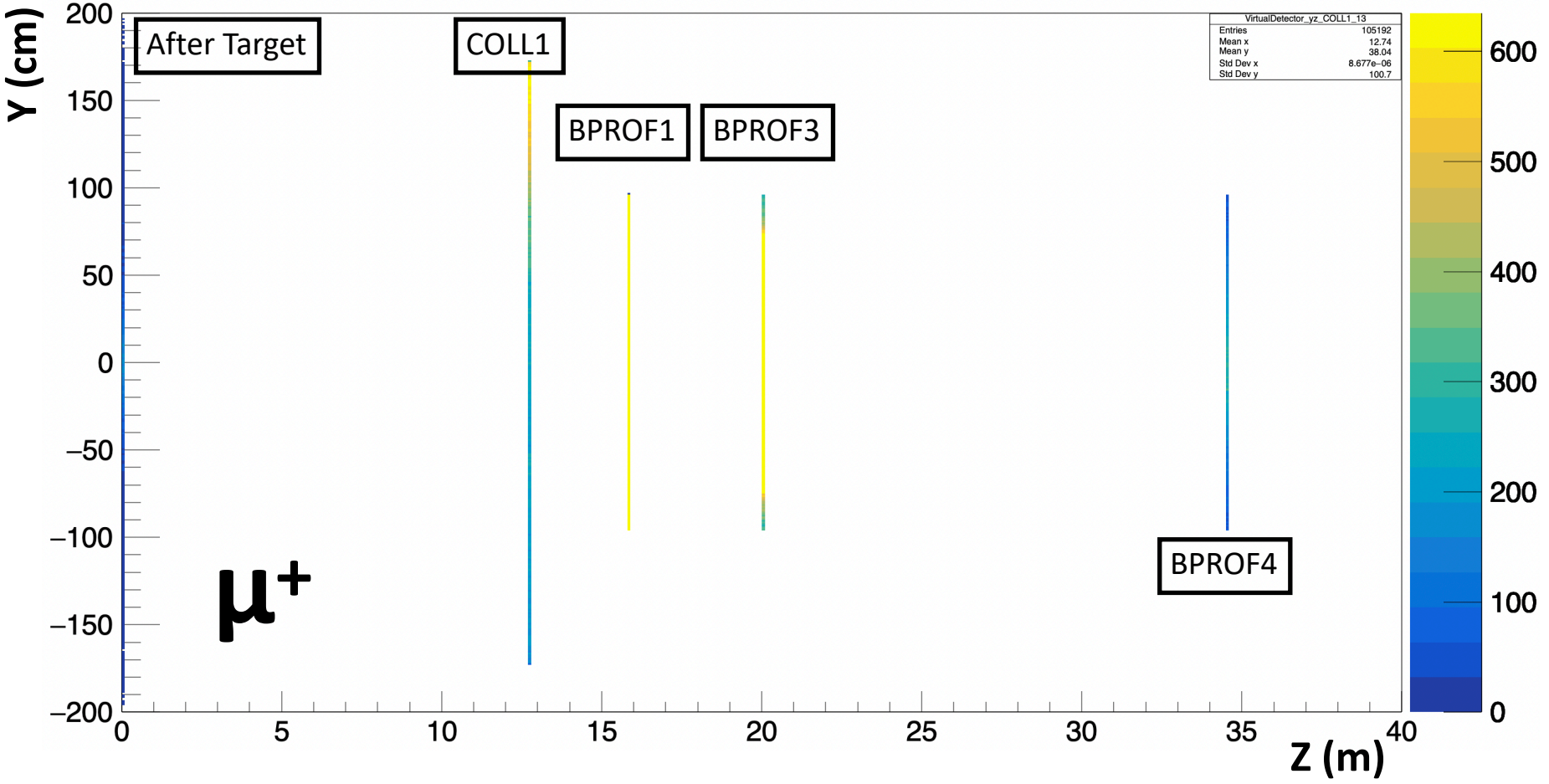

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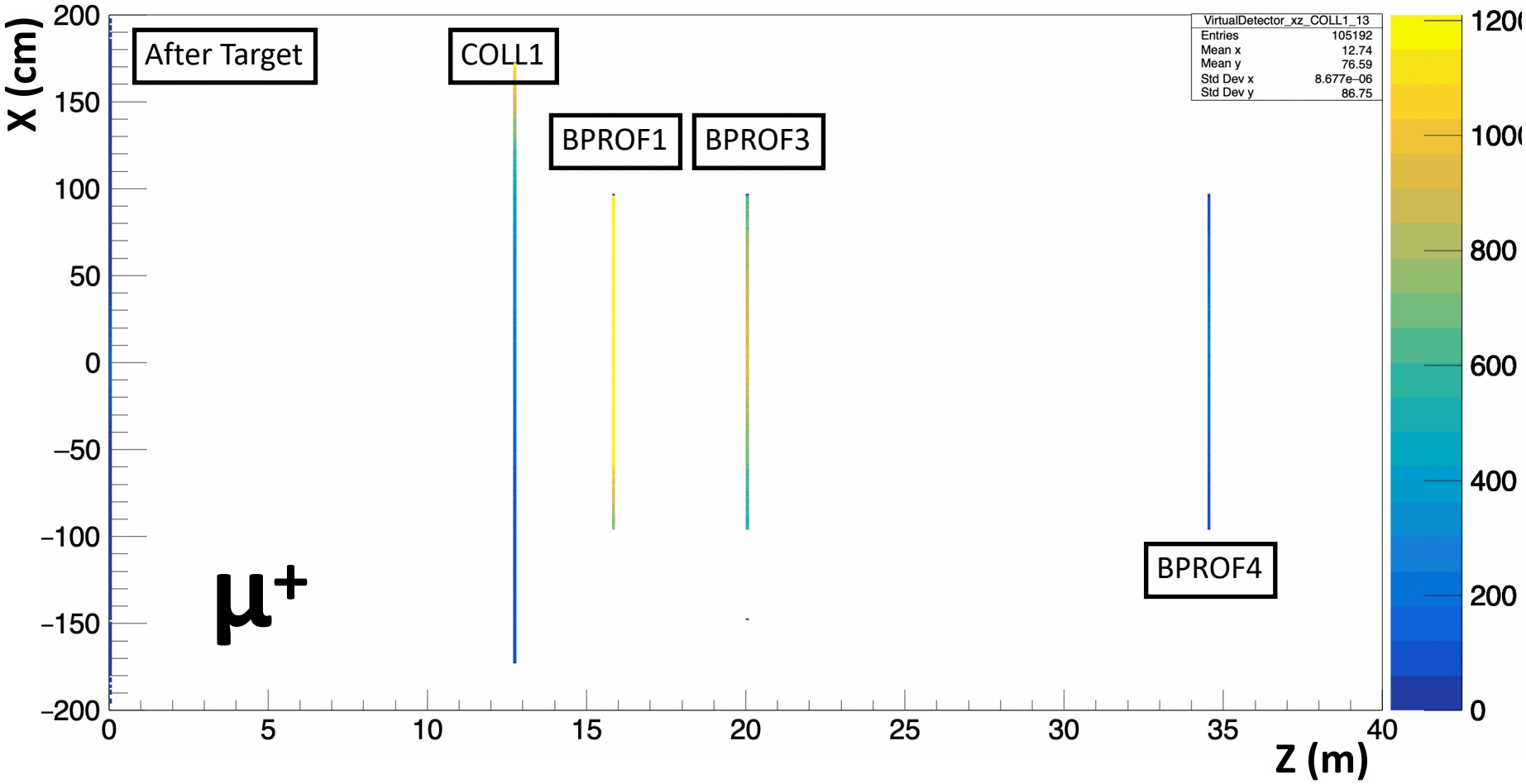

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Seems we need more information in G4Beamline simulation

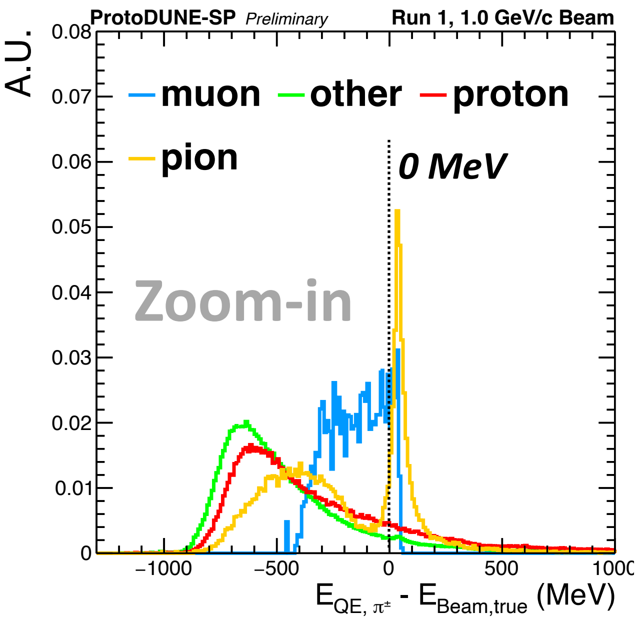
Sent a mail to the person who performed the simulation : Nikolaos

Study for Quasi-elastic Scattering of Charged Pions - ProtoDUNE-SP

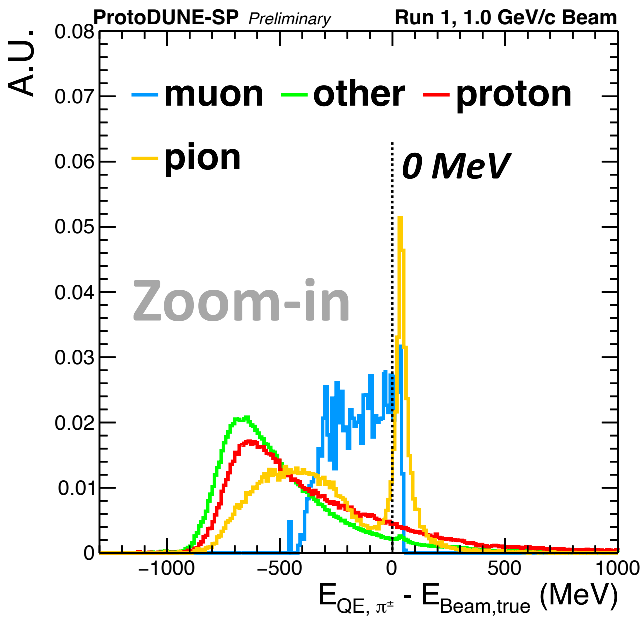
Using ProtoDUNE MC samples at generator level

- Difference between truth level beam particle energy at interaction point and E_{QE}
- The QE peak is observed
- E_b = 4 MeV gives the peak near 0 MeV

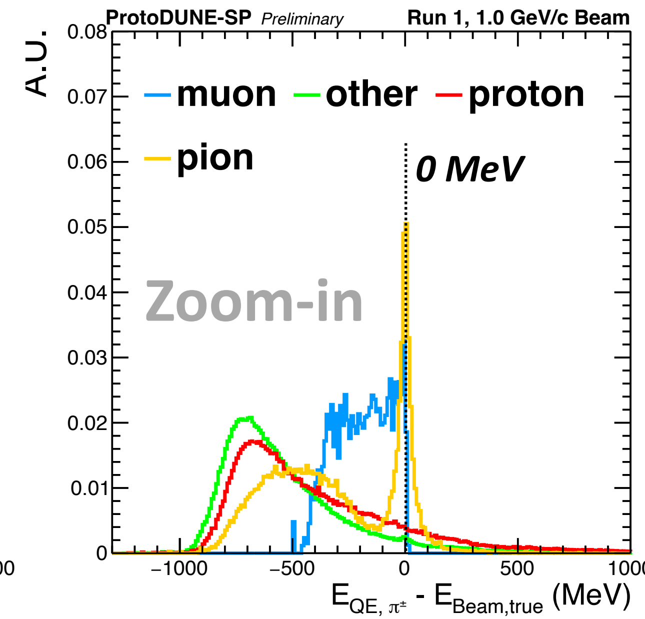
$E_{QE}^{Arrpox.}(E_b = 40\ MeV)$



$E_{QE}^{-}(E_b = 40\ MeV)$



$E_{QE}^{-}(E_b = 4\ MeV)$

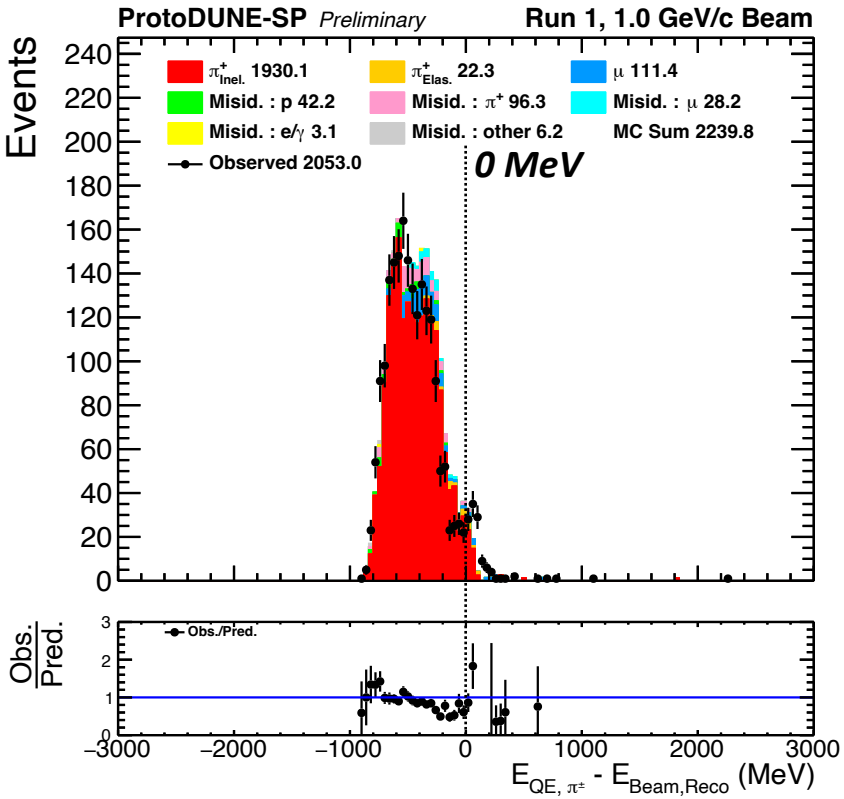


Study for Quasi-elastic Scattering of Charged Pions - ProtoDUNE-SP

Data vs MC distributions

- Charged pions with Michel score > 0.5, energy using the CSDA
- StartZ of daughter < 220 cm

$E^{-}_{QE}(E_b = 4\ MeV)$



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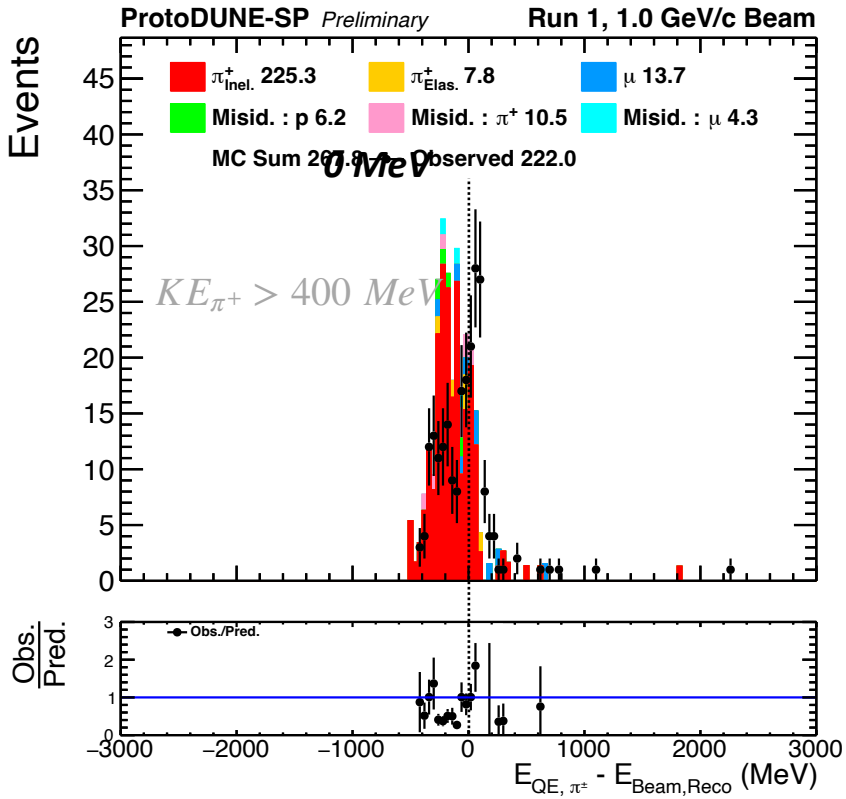

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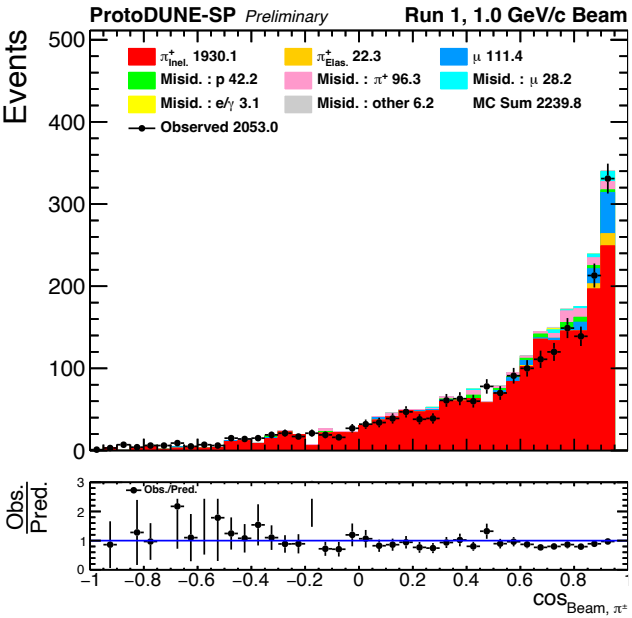
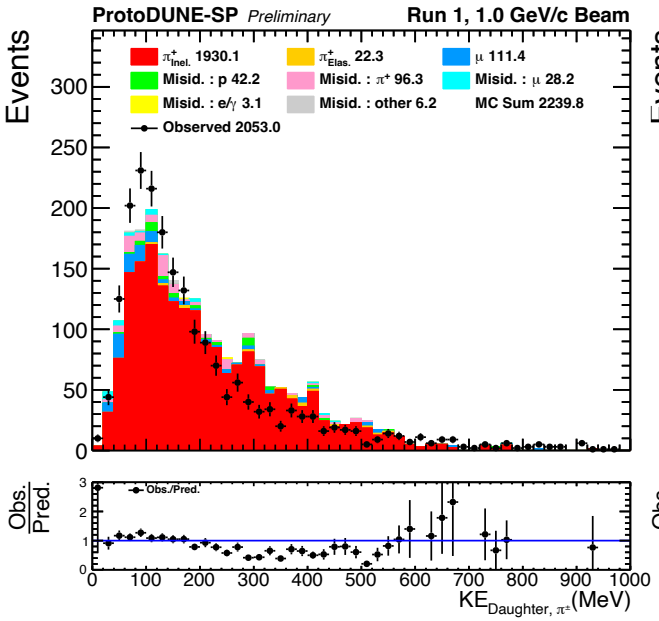
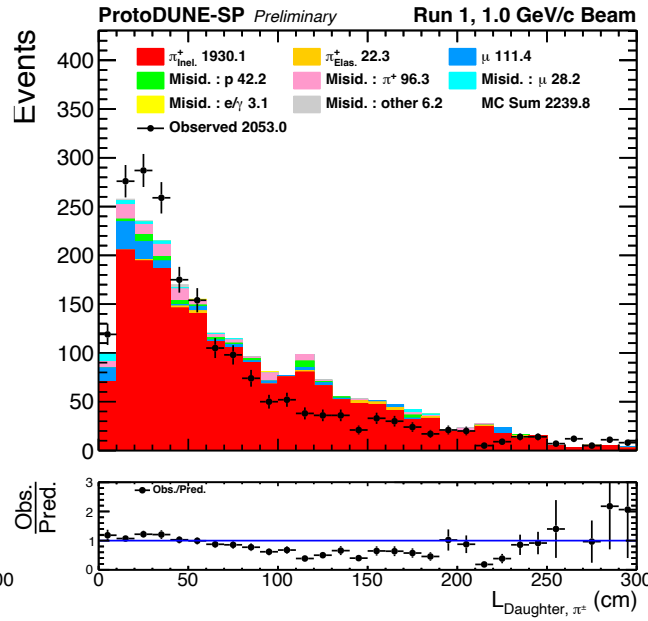
Study for Quasi-elastic Scattering of Charged Pions - ProtoDUNE-SP

Other variables for reconstructed charged pion

- Angle between beam and charged pion is well described
- But, track length of charged pions is not described well
  - Charged pions in data is generally shorter than the MC
  - I will check if daughter tracks are also cut off due to diverter





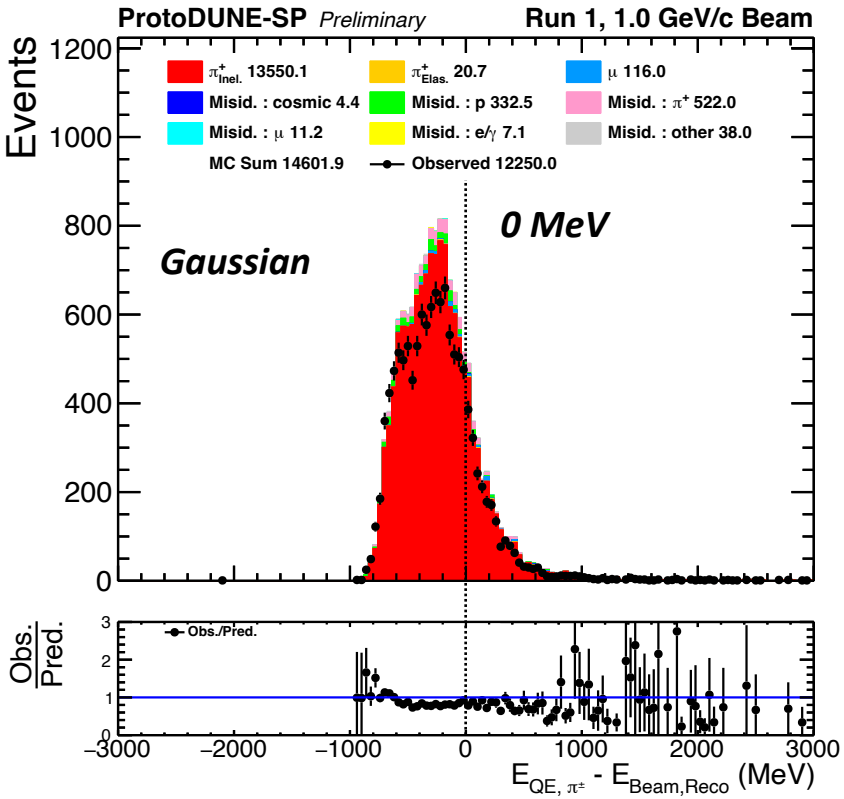


Study for Quasi-elastic Scattering of Charged Pions - ProtoDUNE-SP

Data vs MC distributions

- Charged pions with Michel score < 0.5, energy using hypothetical track length
- StartZ of daughter < 220 cm

$E^{-}_{QE}(E_b = 4\ MeV)$



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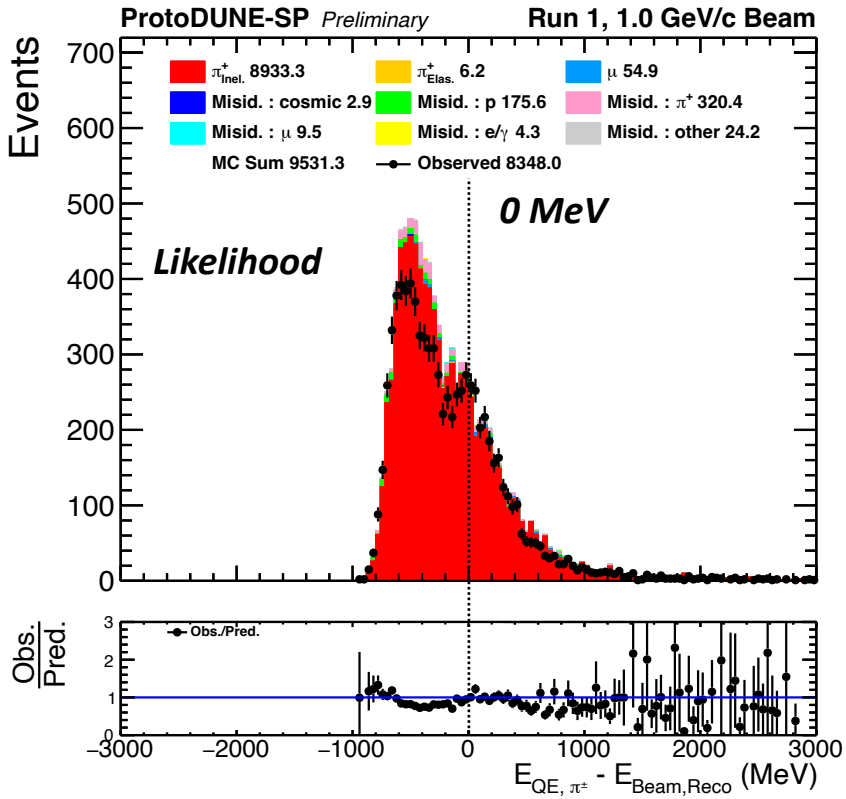
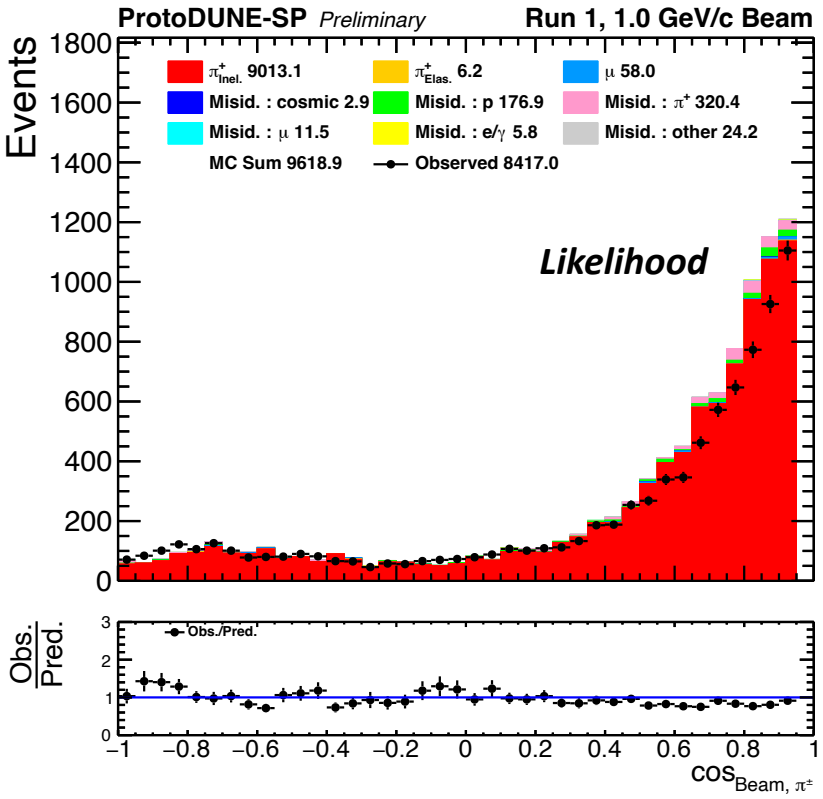
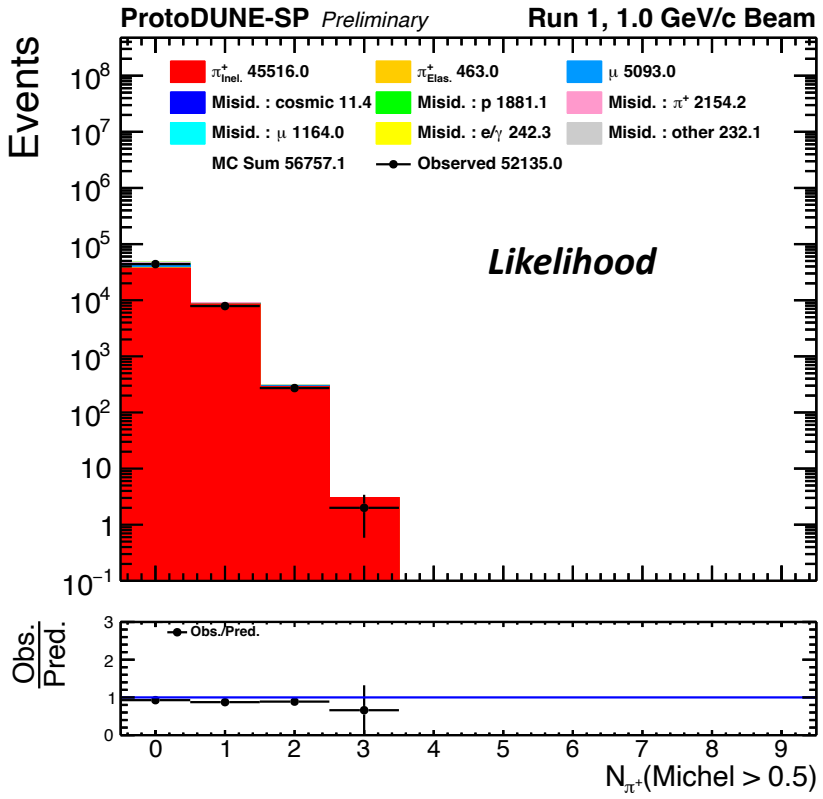


Study for Quasi-elastic Scattering of Charged Pions - ProtoDUNE-SP

Data vs MC distributions

- Angle between beam and charged pion is well described





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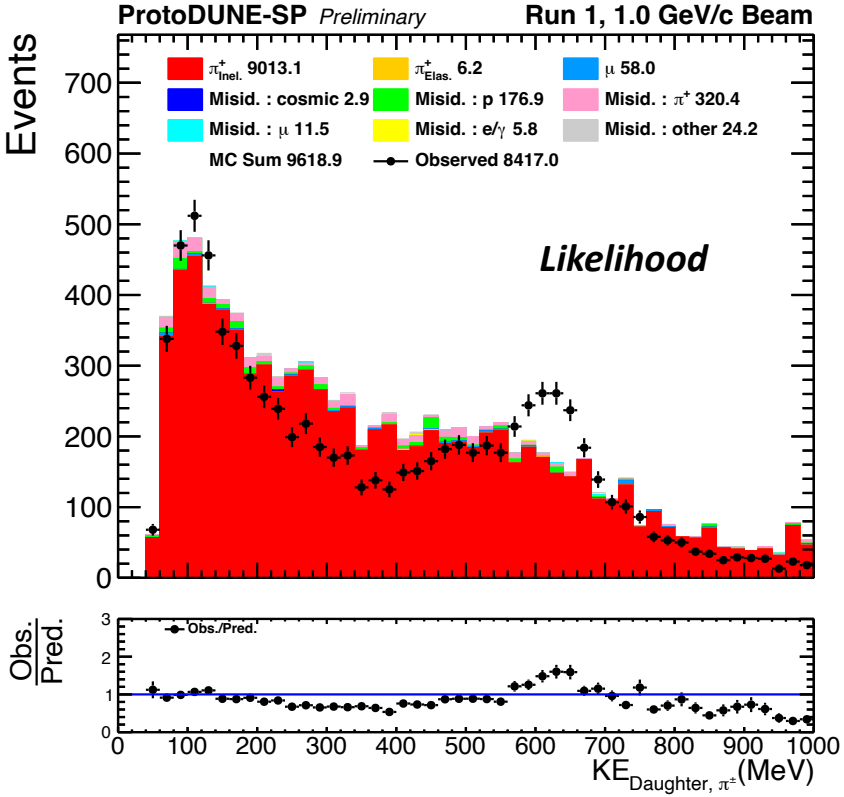
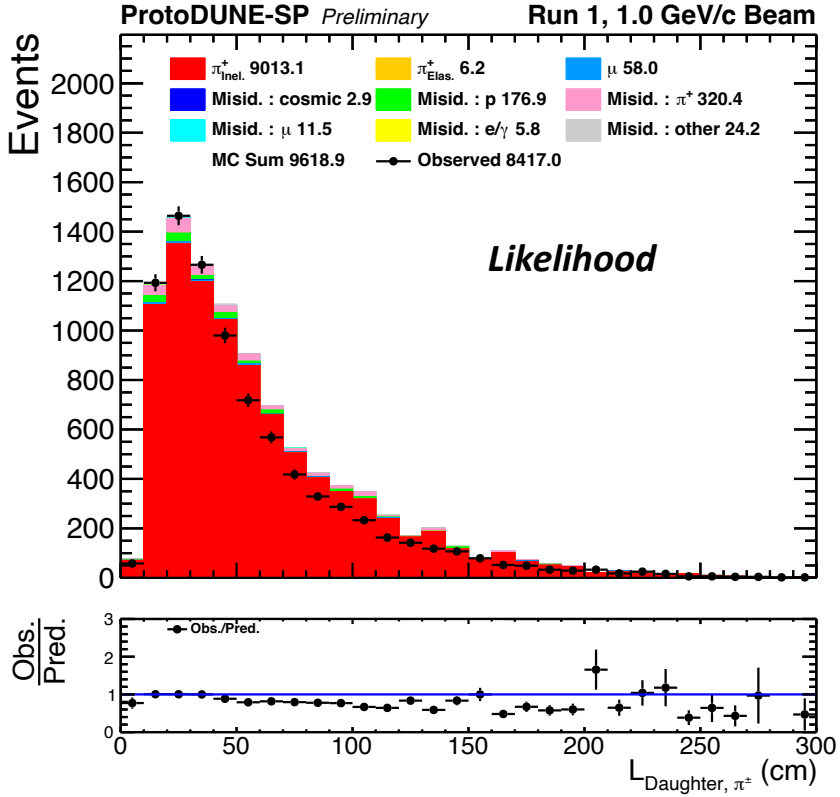
Study for Quasi-elastic Scattering of Charged Pions - ProtoDUNE-SP

Data vs MC distributions

- A bump around KE = 600 - 650 MeV
  - Tendency is similar with the ΔEQE distribution
- Again, data shows shorter daughter track length in general





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