Cosmic Muon Scattering in MicroBooNE

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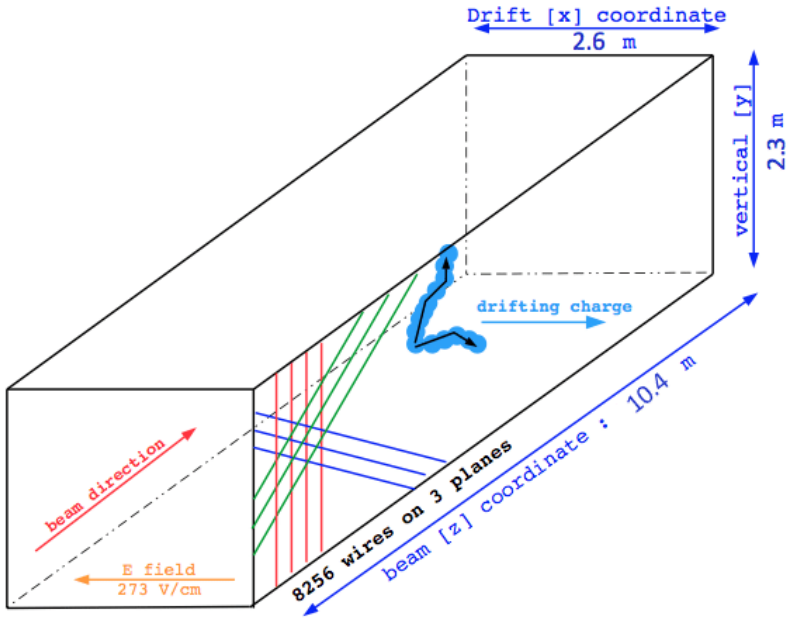
Introduction

- MicroBooNE is a neutrino experiment at Fermilab with a Liquid Argon Time Projection Chamber
- Cosmic muons are a background to these neutrino interactions

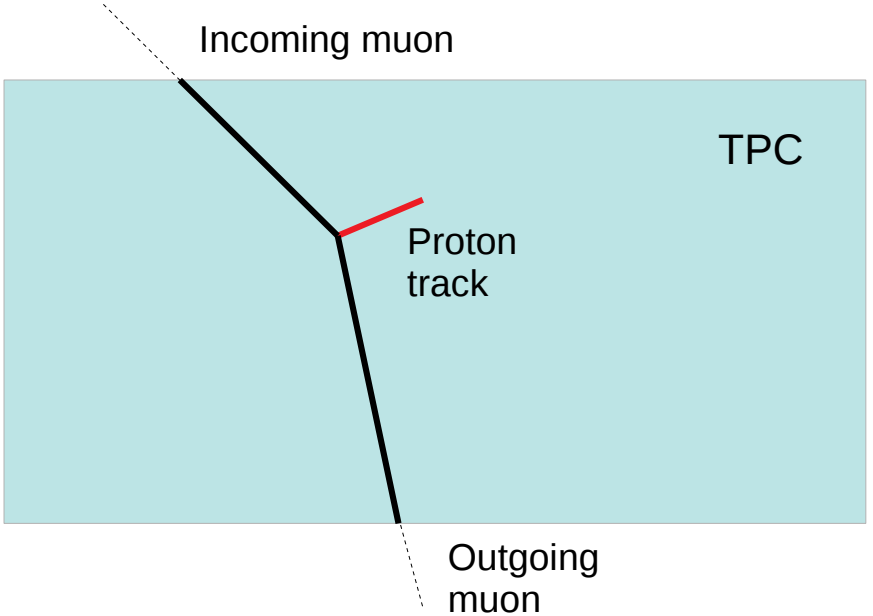


- Cosmic muons scattering off argon nuclei can knock out protons
- This produces a completely separate sample of proton tracks with different topology and angle
- Useful for checking and calibrating particle identification and reconstruction

Diagram: Rafique, A., *Measurement of Reconstructed Charged Particle Multiplicities of Neutrino Interactions in MicroBooNE*, 2017

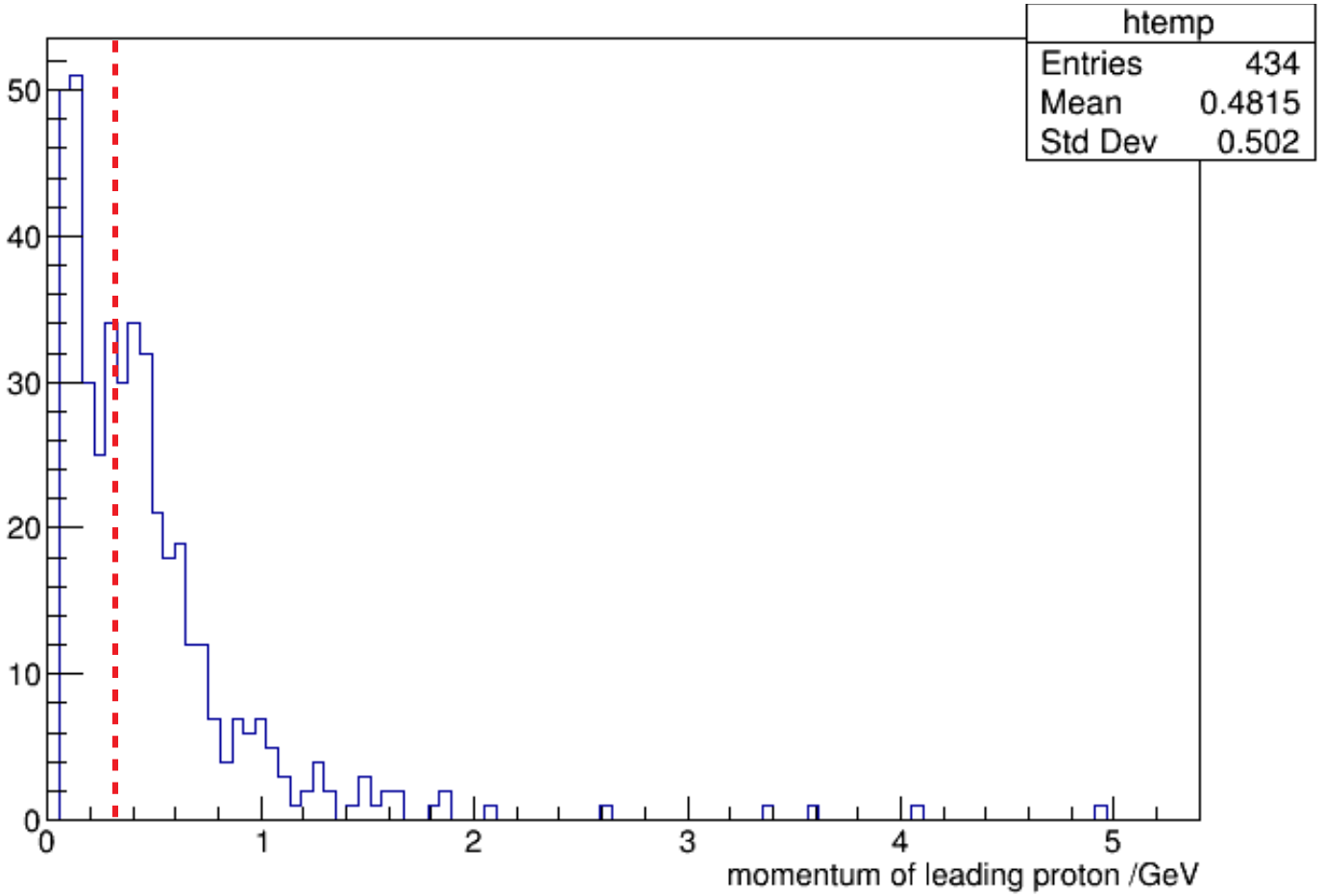
What We Looked For

- Used Corsika Monte Carlo sample to look for these scatters in cosmic ray simulated events
- Ran over 64850 events
- Events where a cosmic muon scatters off an argon nuclei in the MicroBooNE TPC and produces one or more protons
- Selected events where a proton had the process ‘muonNuclear’ and used track ID to find parent muon
- Applied containment cut to leading proton, including an x dependent time cut



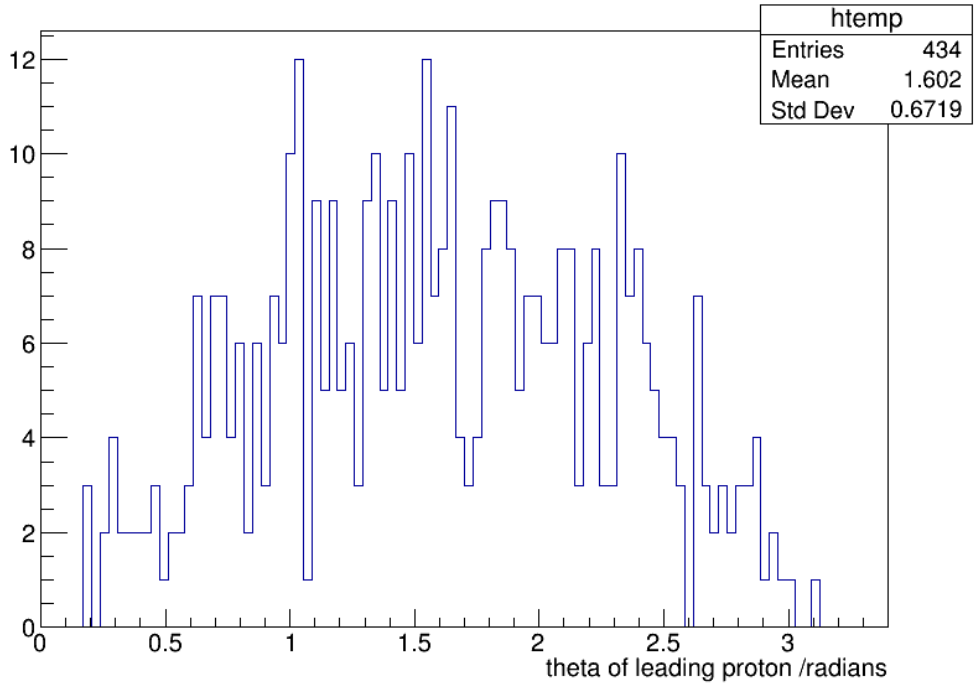
Momentum of the Leading Proton

0.3GeV/c threshold

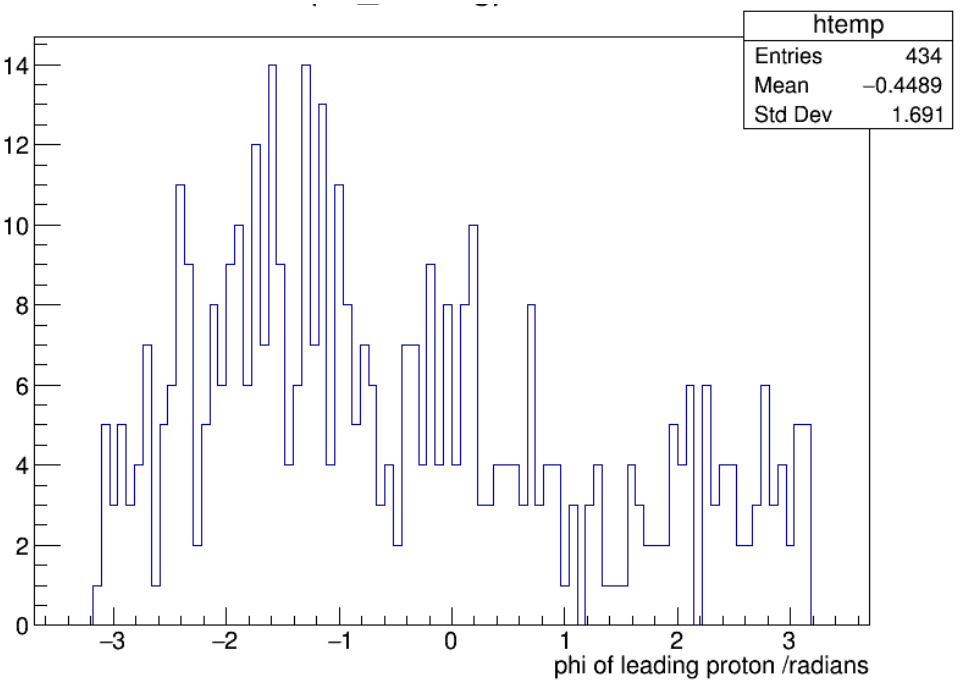


In 64850 events, 434 cosmic muon scatters were identified within the FV.

Angle of the Leading Proton



Theta Angle



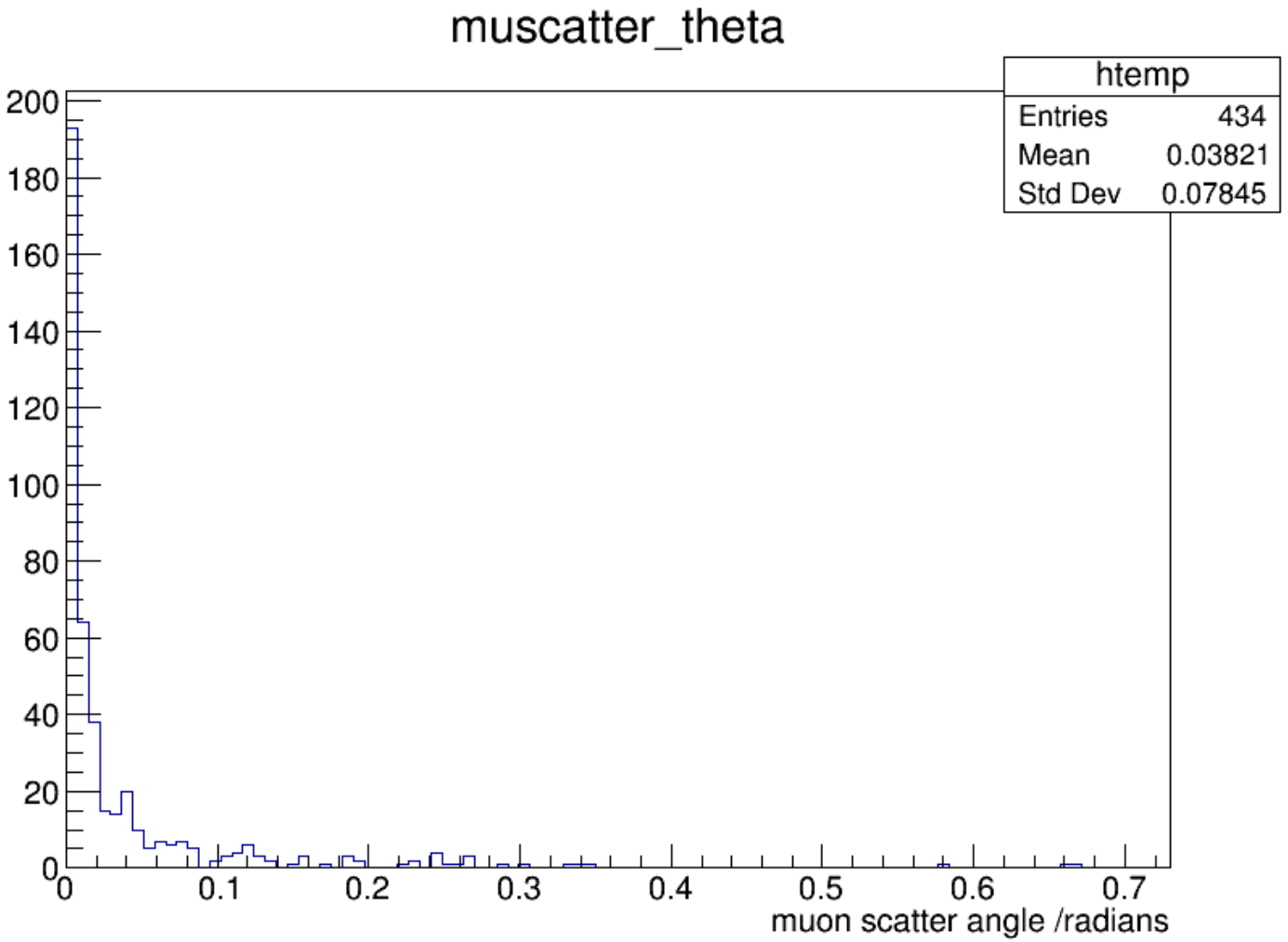
Phi Angle

Scattering Angle of the Muon

0.1 rad = 6 deg

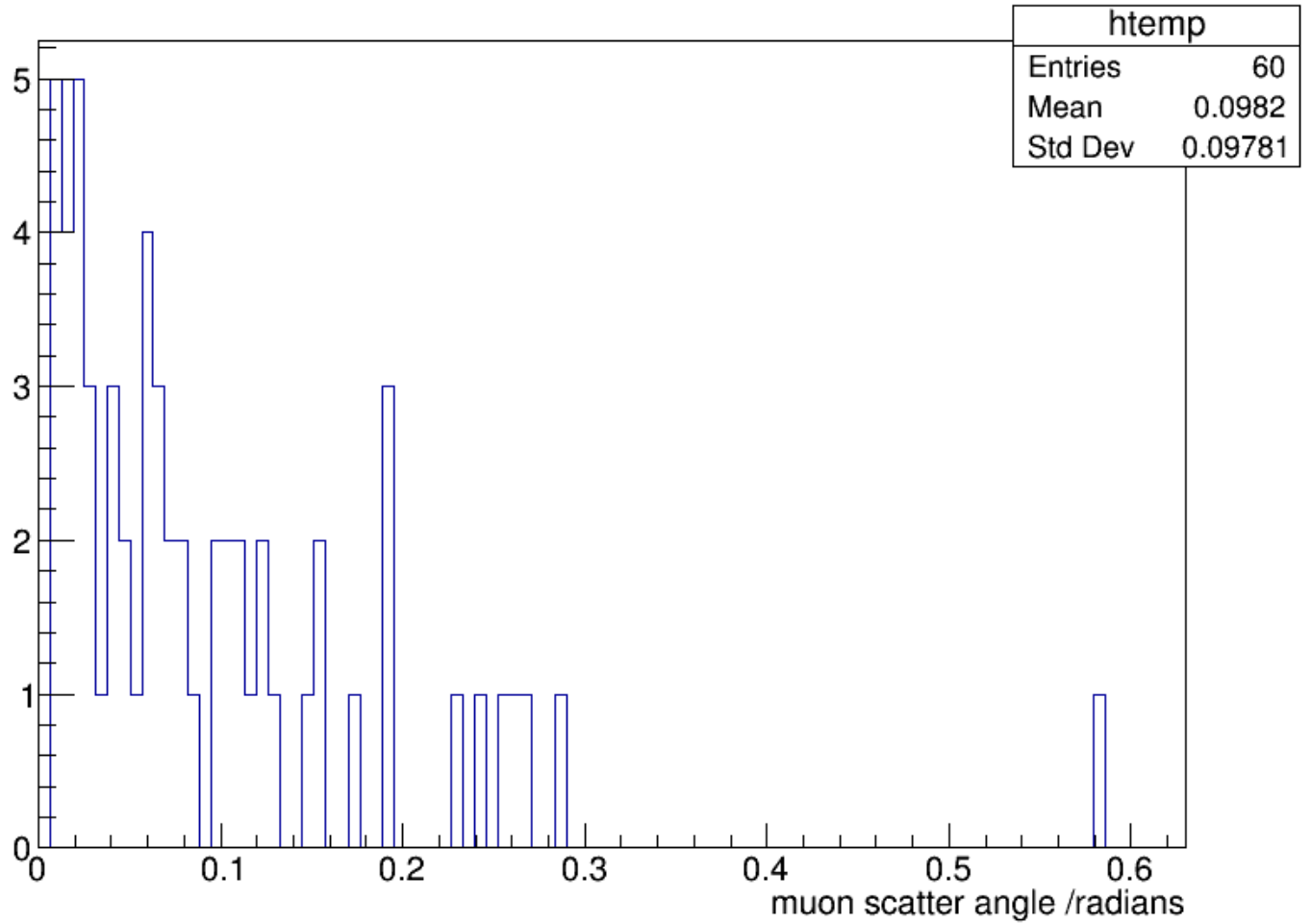
0.3 rad = 17 deg

0.6 rad = 34 deg



Scattering Angle of the Muon

Events with leading proton momentum > 0.3 GeV/c and muon momentum < 5GeV/c.

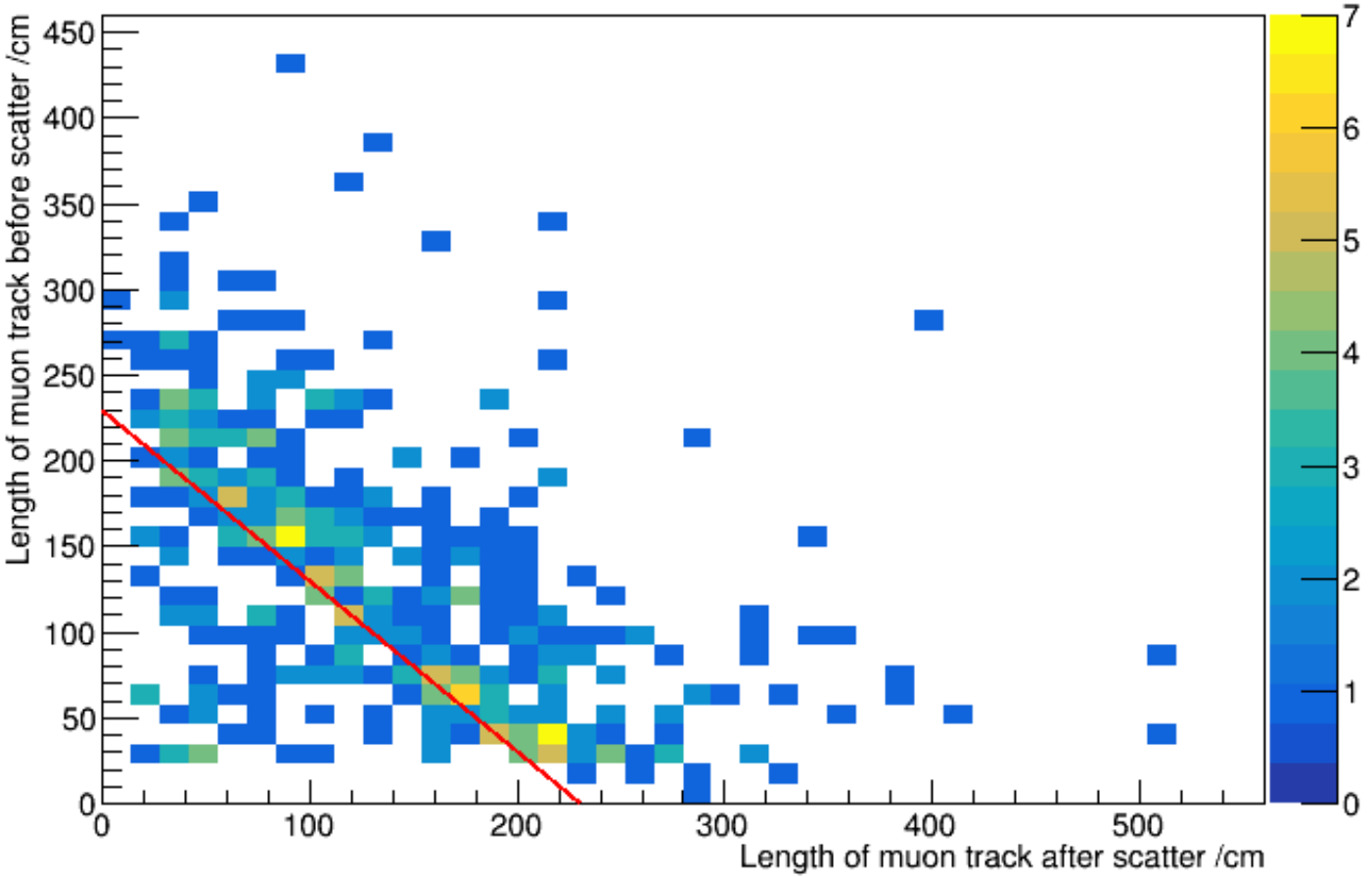


Angles should be large enough to measure for these events of interest.

Track Length of Muon

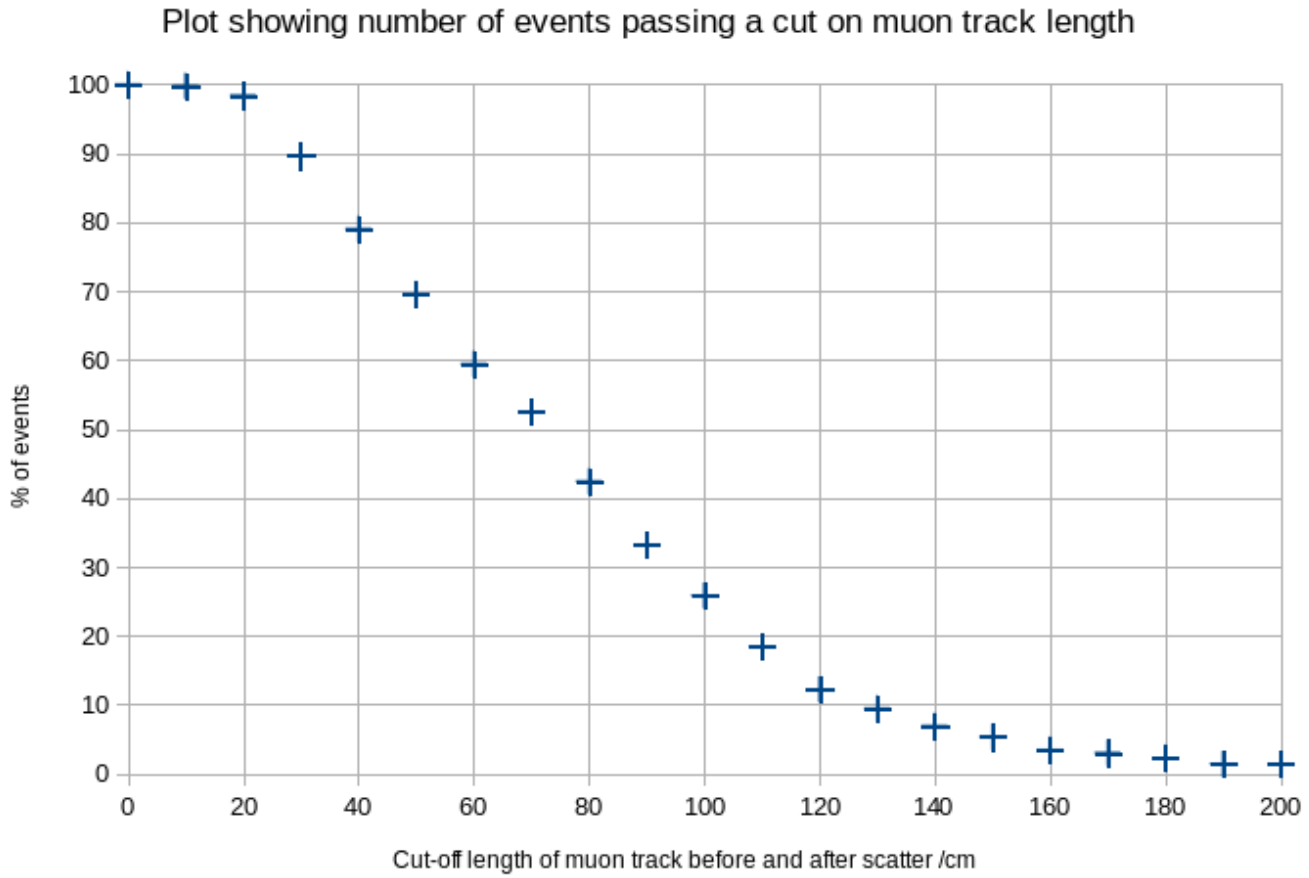
- For reconstruction, it is usually required that a track should be greater than 1m in order to estimate the momentum using multiple coulomb scattering (MCS)
- Want to estimate both the initial and final momentum of the muon – have to use MCS due to it being through going
- This means that we require a minimum length of track on **both** sides of the scatter

Length of Muon Track Before Against Length of Muon Track After Scatter



Red line shows where track before + track after is equal to the height of the TPC.

Events Passing Track Length Cut



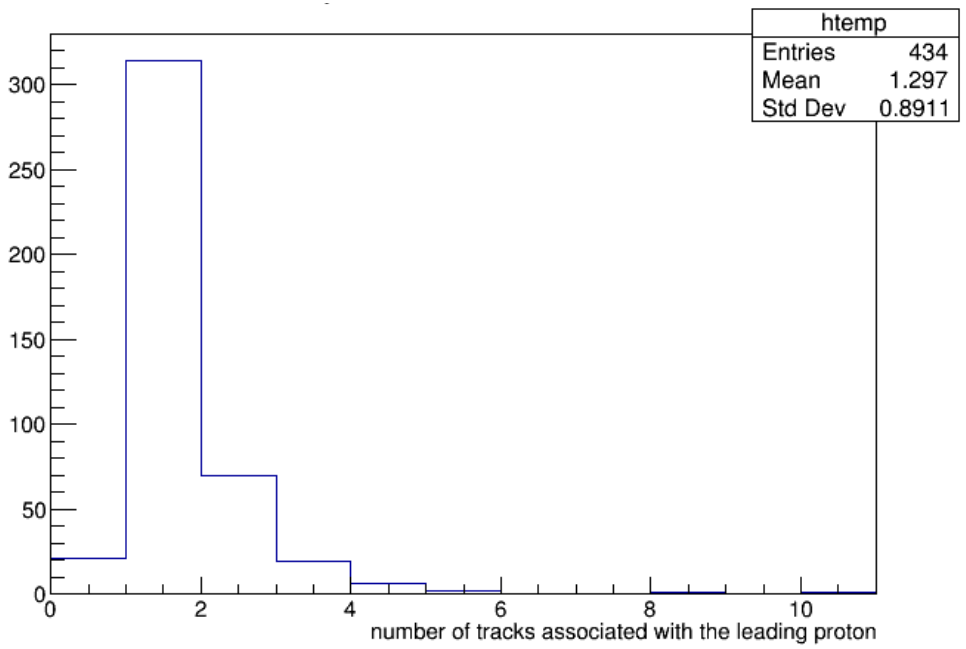
25.8% of events were found to pass a cut requiring the muon track before and after the scatter to be greater than 100cm.

Estimate of Rate of Muon Scatters

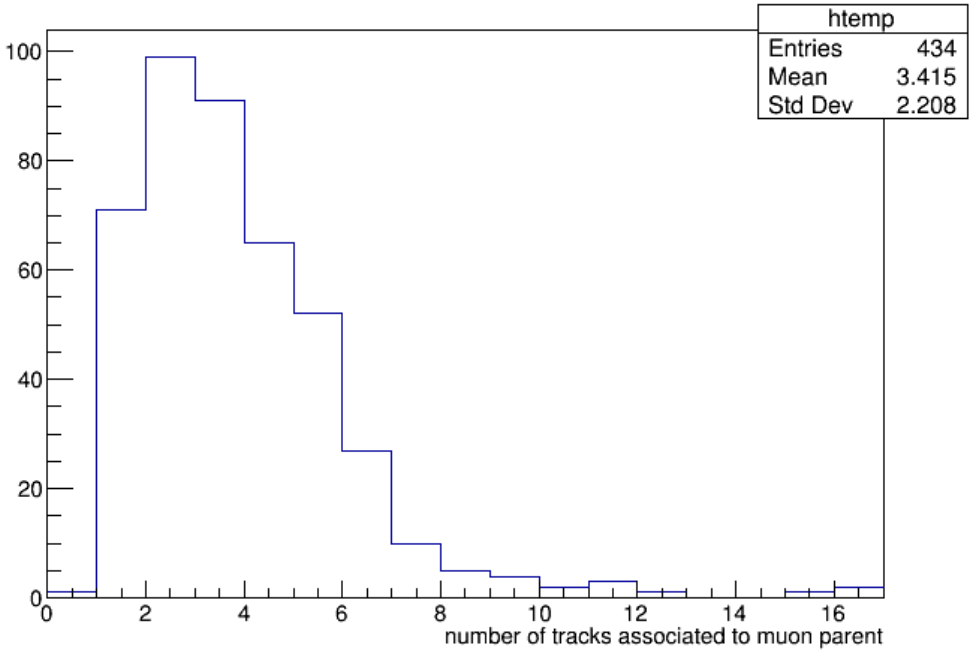
- 64850 Corsika events were analysed
- 434 cosmic muon scatters within the FV were found
- 60 of these had muon momentum < 5GeV/c and leading proton with momentum > 0.3 GeV/c
- In 900k events from the first run of MicroBooNE data we would expect to see ~830 muon nuclear scatters that passed these selection cuts
- With track length cut of 100cm this becomes ~210

Reconstruction

- Attempted to reconstruct these cosmic muon scatters using PandoraCosmic package
- Plots show number of reconstructed tracks assocaiated to each true particle

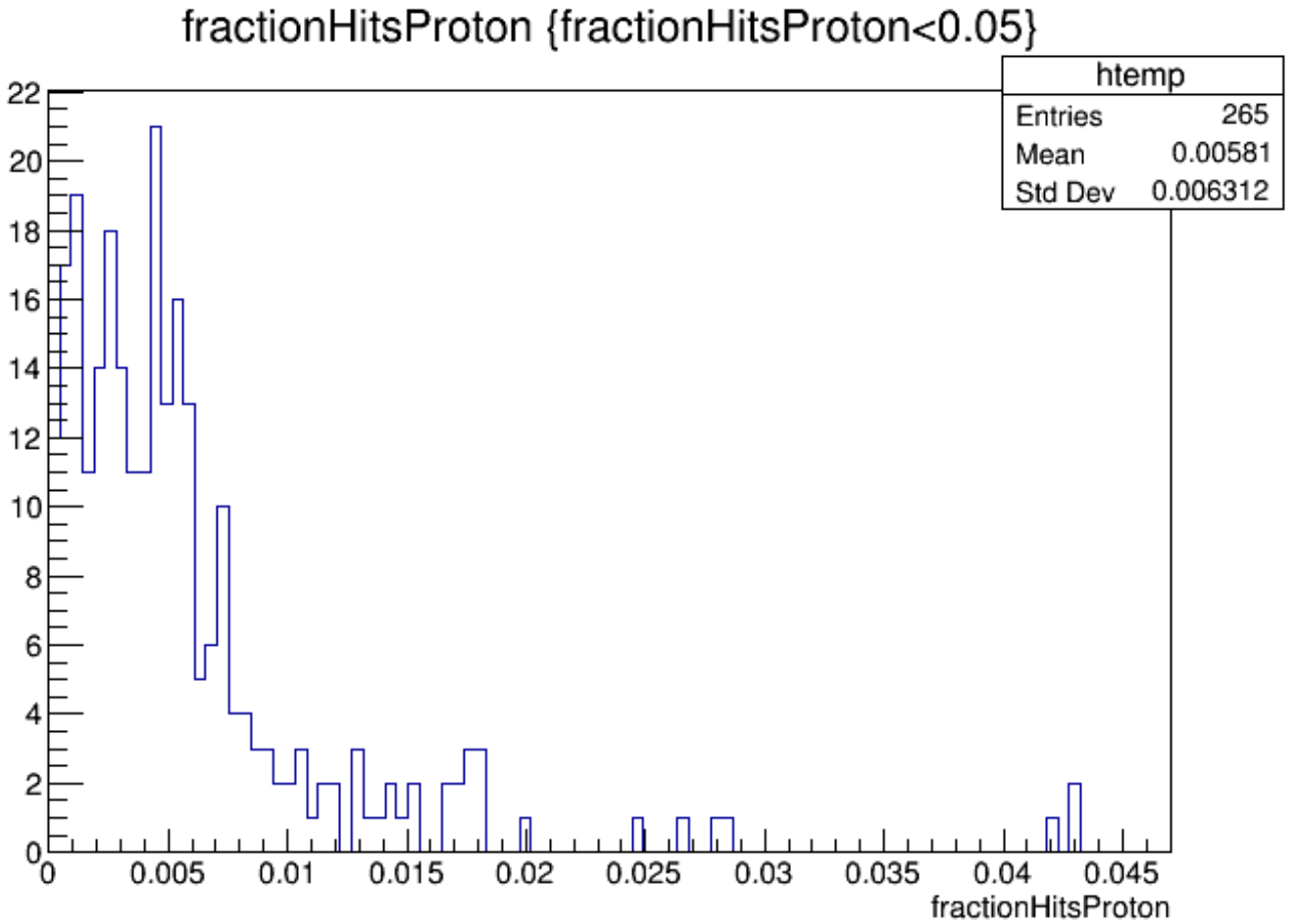


Leading Protons



Parent Muons

Reco Track Hits



In most events, less than 2% of hits in a reconstructed proton track actually come from the true proton, suggesting the proton track is not being properly reconstructed

Conclusions and Future Work

- Initially concluded that PandoraCosmic was not suitable for this analysis, however a bug was later found in the associations between reco and true objects
- Need to verify whether we have an appropriate reconstruction package
- Develop a reco-level event selection to look for muon scatters and assess backgrounds
- Assuming a reasonable efficiency event selection, expect to be able to see 10s-100s of these events per year in MicroBooNE

Any Questions?