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Detector-Related Uncertainties in ICARUS (cont.)

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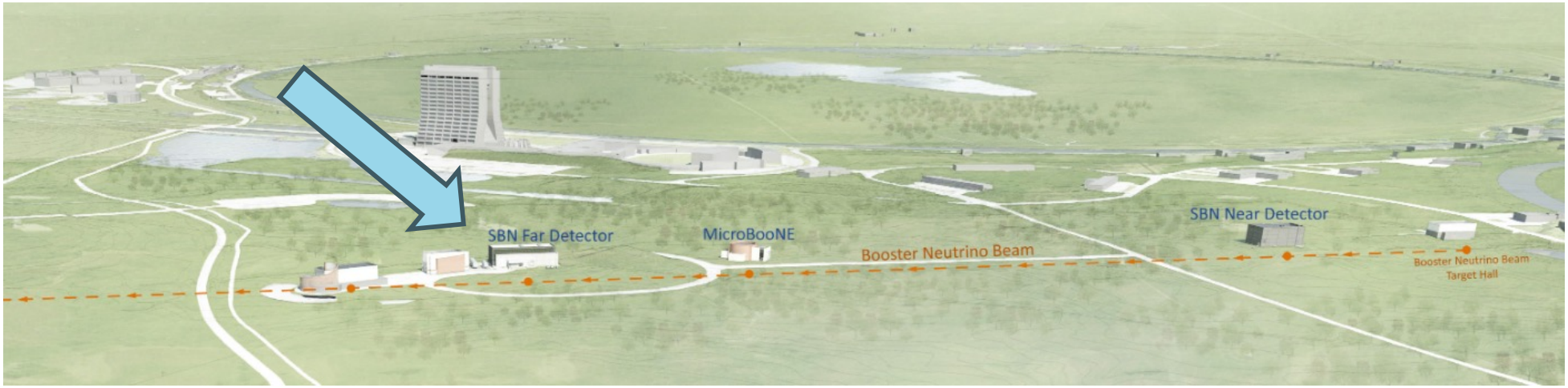
Background

What is ICARUS

- ICARUS stands for. “Imaging Cosmic And Rare Underground Signals”
- It is a Time Projection Chamber (TPC) detector, which means that it uses a uniform electric field to drift charged particles through liquid argon to create a 3D image of particle tracks
- It is designed to study neutrinos and their interactions with matter

Far Detector of Short-Baseline Neutrino Program

- Icarus has served as the far detector in the Short-Baseline Neutrino Program (SBN)
- It sits 600 meters from the Booster Neutrino Beam Target Hall



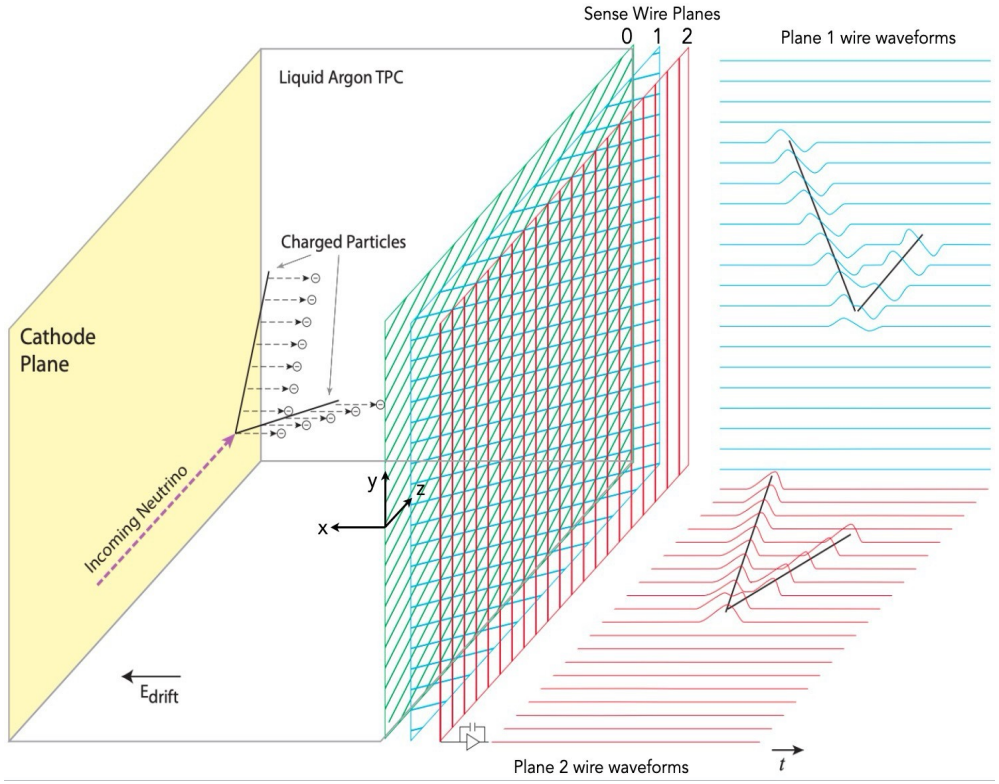
Motivation and Purpose

Purpose

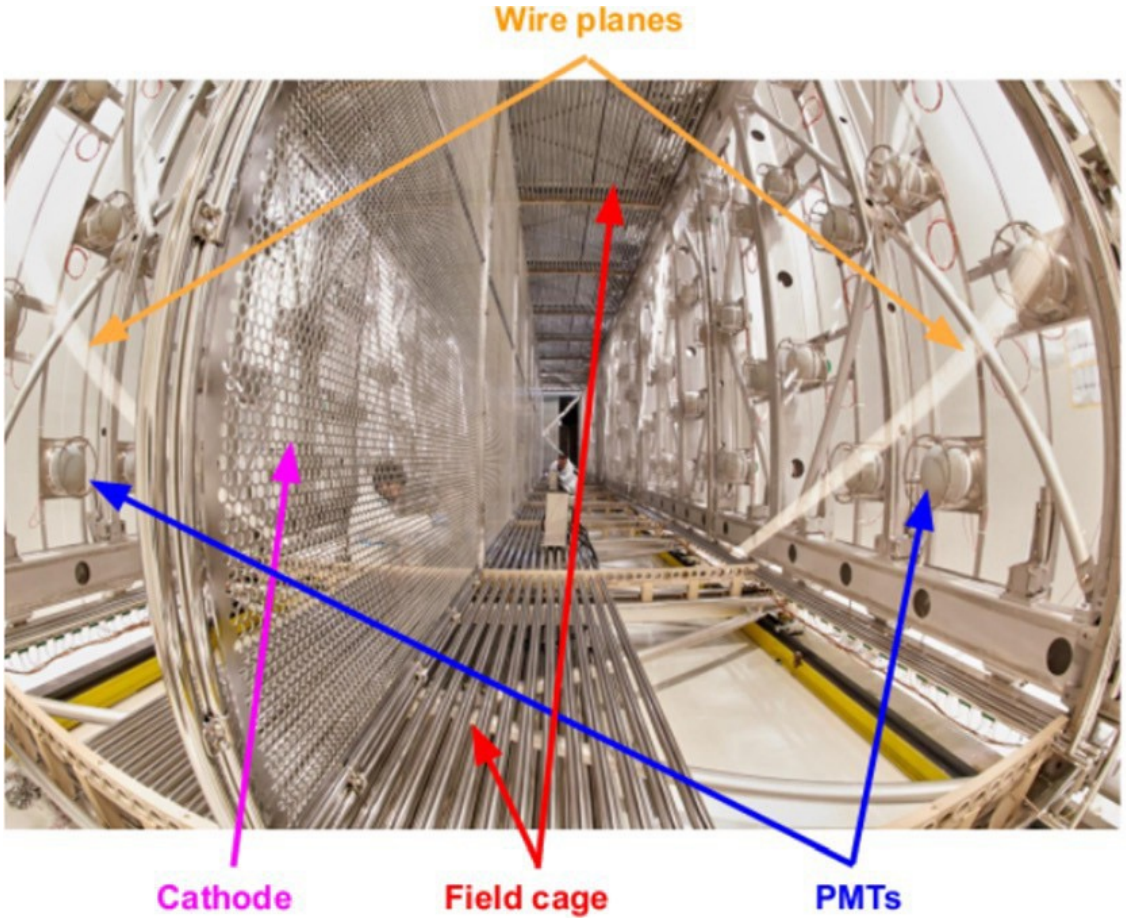
- No detector is perfect, so it is important to quantify this
- Neutrinos are so difficult to detect that this is especially true for ICARUS
- There are simulation data and experimental data
- The ratio of these data sets quantifies the differences between the Monte Carlo simulation and the experiment
- This information can be used to gain insight into detector-related uncertainties

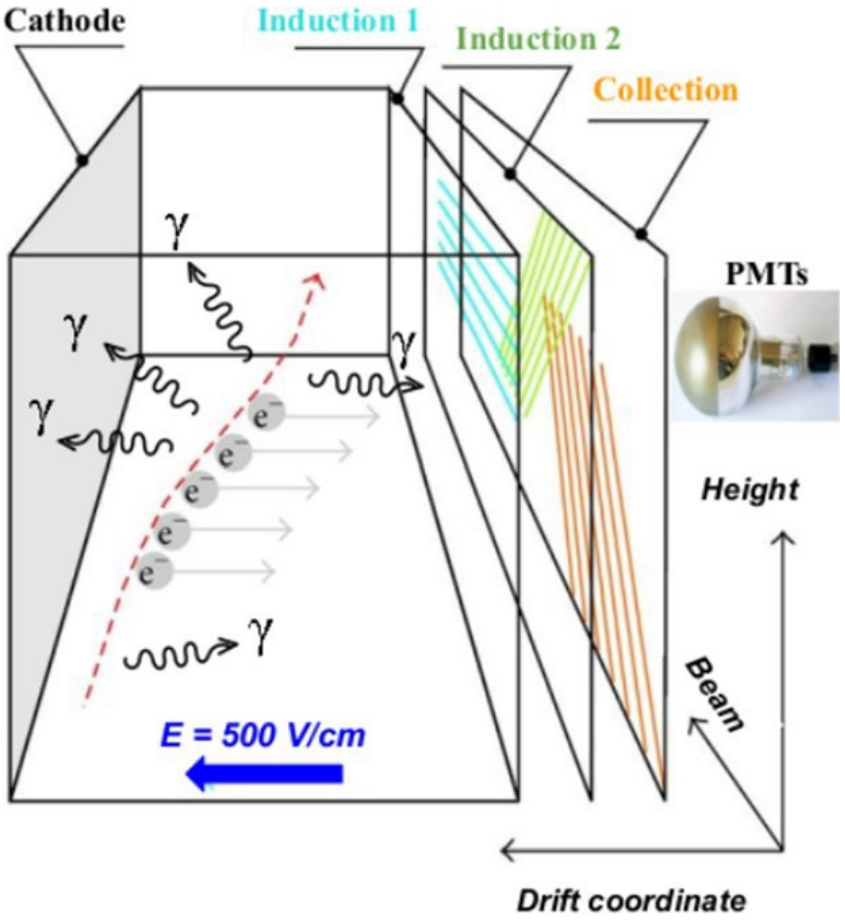
Wire Planes in MicroBooNE

- Ionization electrons drift in the applied electric field until they reach the three sense wire planes located at the anode
- The drifting charged particles induce signals on induction planes (0 and 1)
- The particles directly contribute to collection wire plane (2)
- The collection plane wires are aligned vertically, and the induction plane wires are oriented at ±60 degrees from the vertical of the collection plane



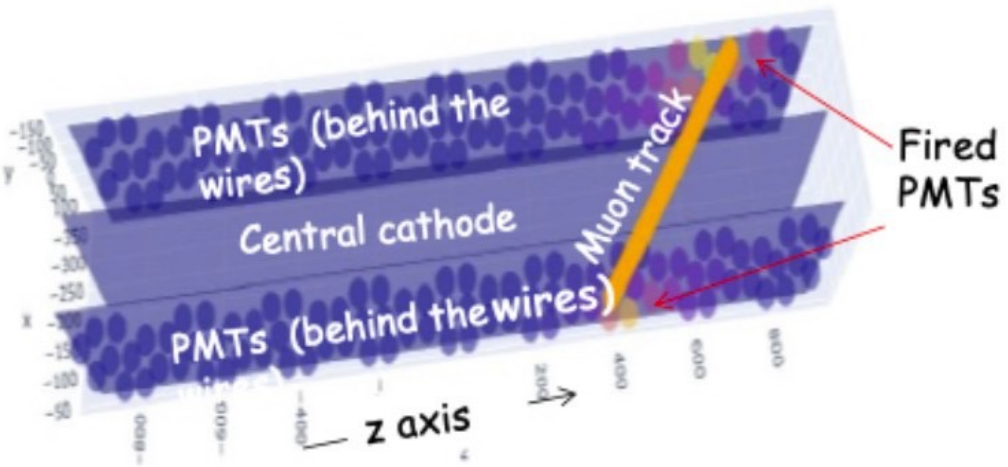
ICARUS Detector Layout





[1] Icarus layout

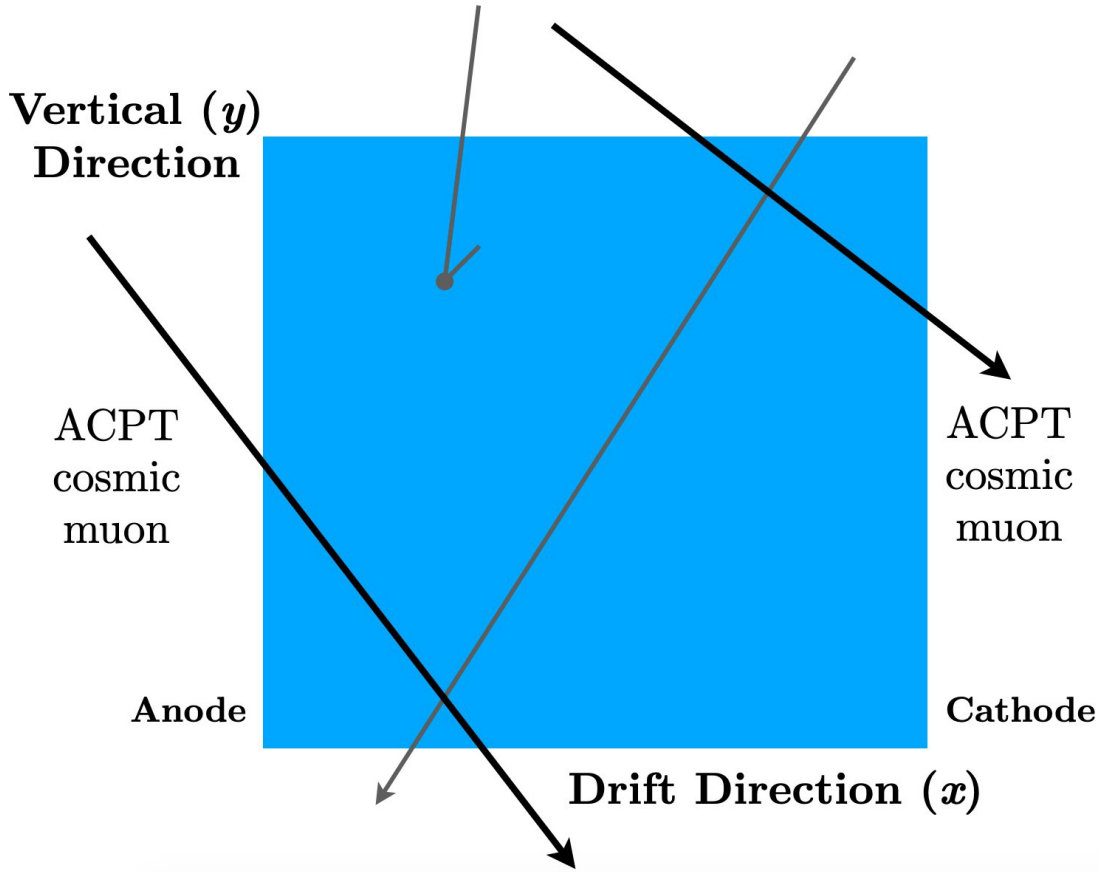
ICARUS Geometry



- The variables used to analyze the geometry are X, Y, Z, Θ, and φ
- Θ is the hit's angle of the drift direction, X, relative to the wire plane's relative Z direction
- φ is the hit's angle of the plane's relative Y and Z directions
- To understand detector related uncertainties, it is helpful to look at the different wire planes throughout the geometry of the detector as they each receive signals differently

Use of Cosmic Rays

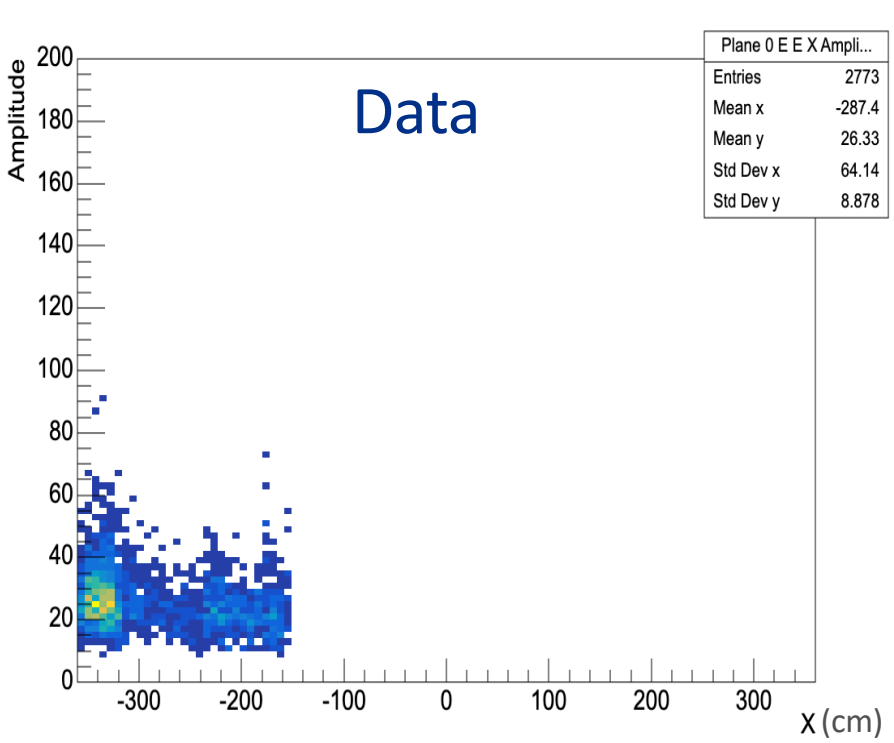
- Neutrinos are the goal; however, cosmic rays help analyze the detector itself
- Cosmic rays are far easier to detect and provide a source of unbiased data

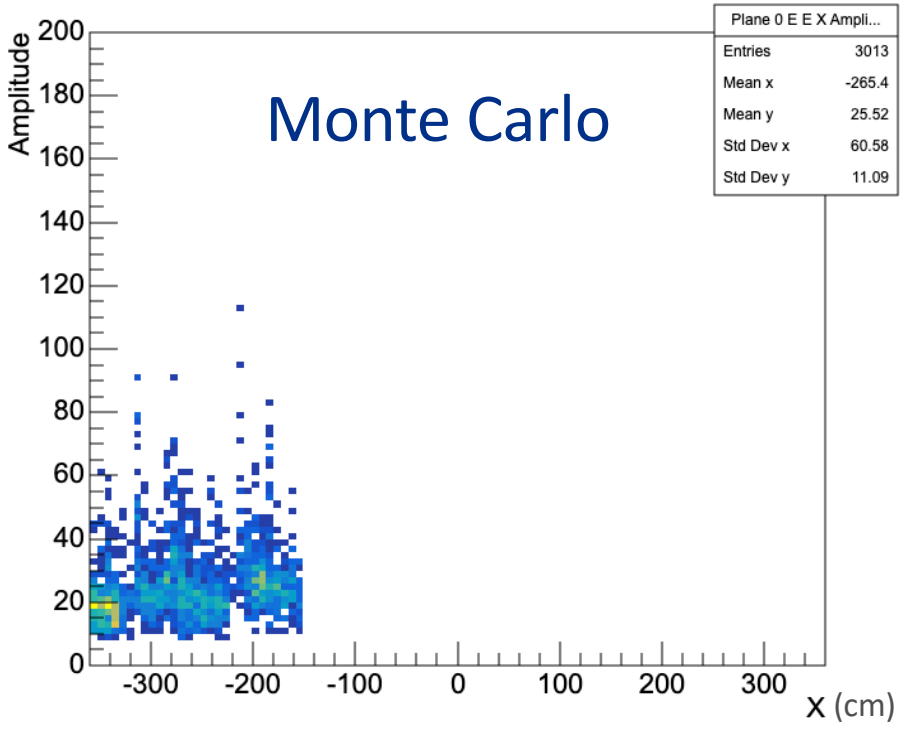


Results

Histograms of Data and Simulations

- Various histograms were made of the data for the positional variables for each of the TPCS, cryostats, and planes
- Below is data histogram (left) and MC histogram (right) for plane 0, east tpc, and east cryostat

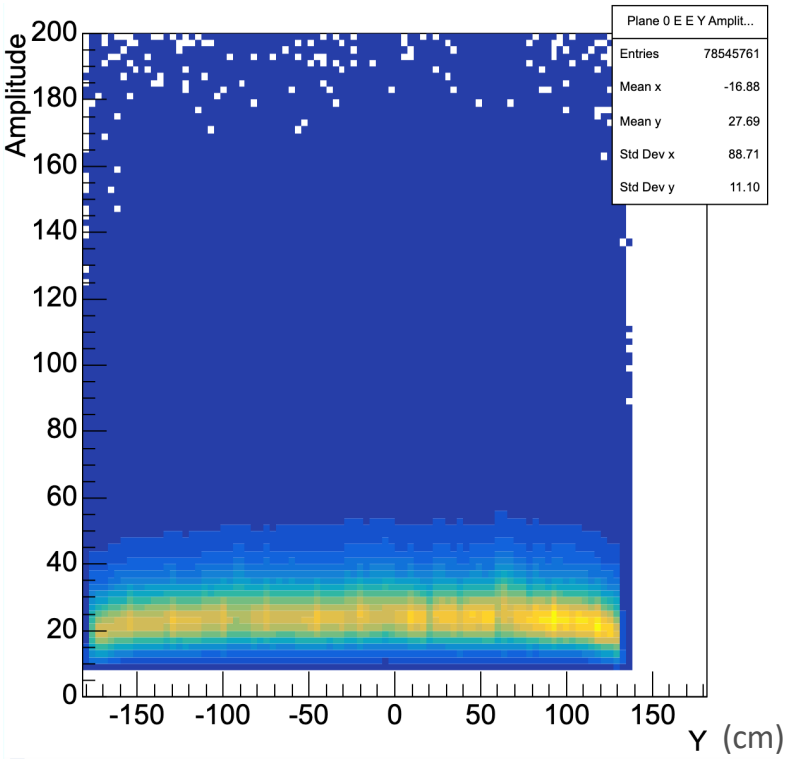




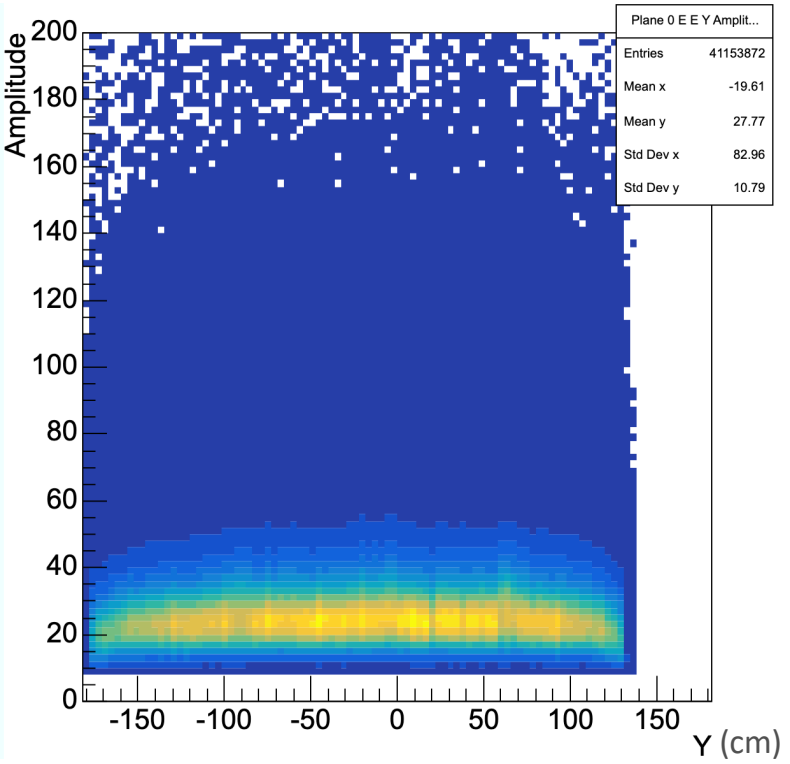
Hit Selection

- Additionally, plots were filtered by whether or not the hits crossed an anode or cathode, as those hits have more accurate timing information

All Hits



Selected Hits



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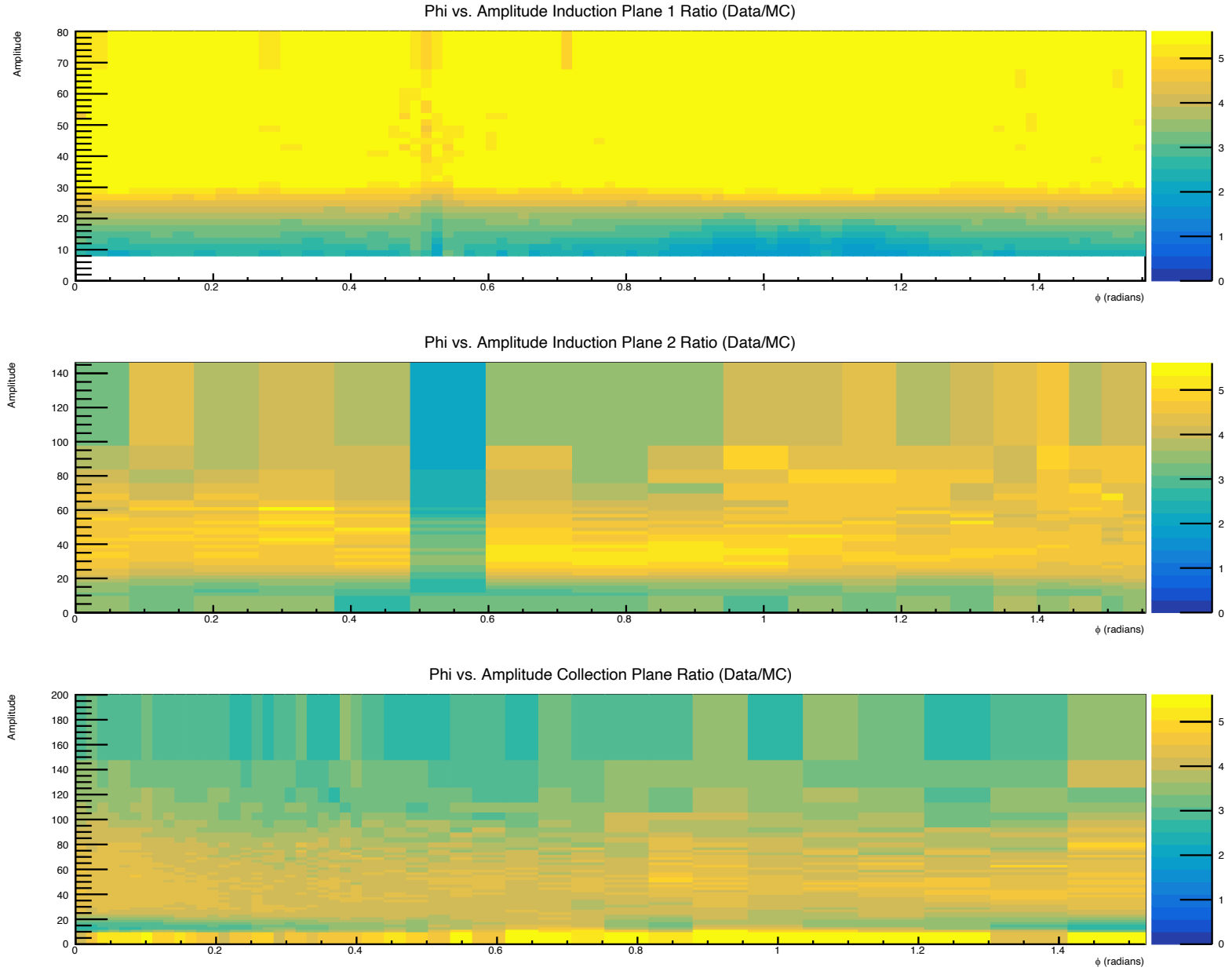
2D Histogram Ratios

- The data/mc histograms were summed by plane and processed to combine bins such that there are enough data points in each bin and so there are no empty points (leads to divide by zero in ratio)
- Then the ratio is taken (Data/MC)

Phi (wire plane angle) vs Amplitude Ratios



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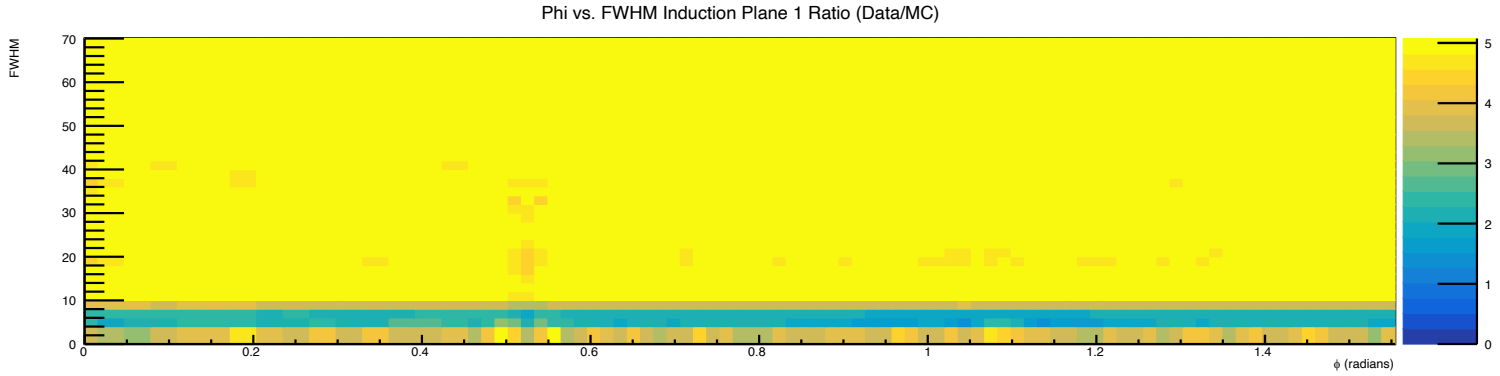
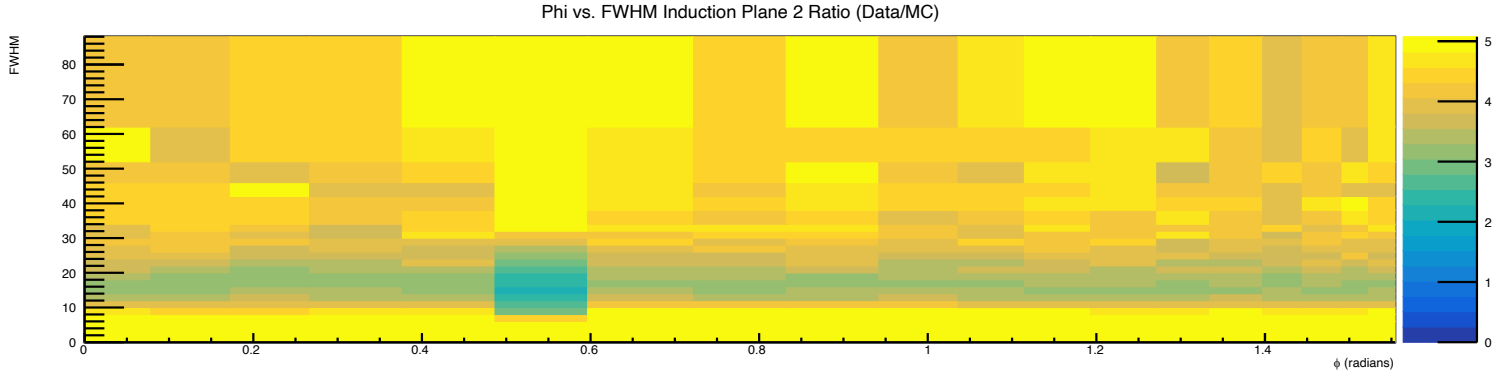
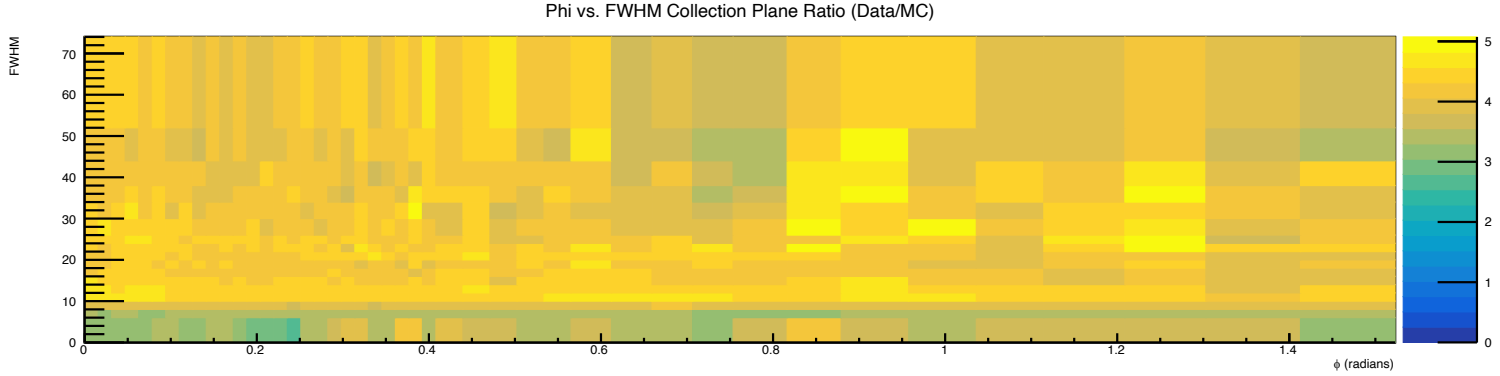
Phi vs Full Width at Half Max (FWHM) Ratios

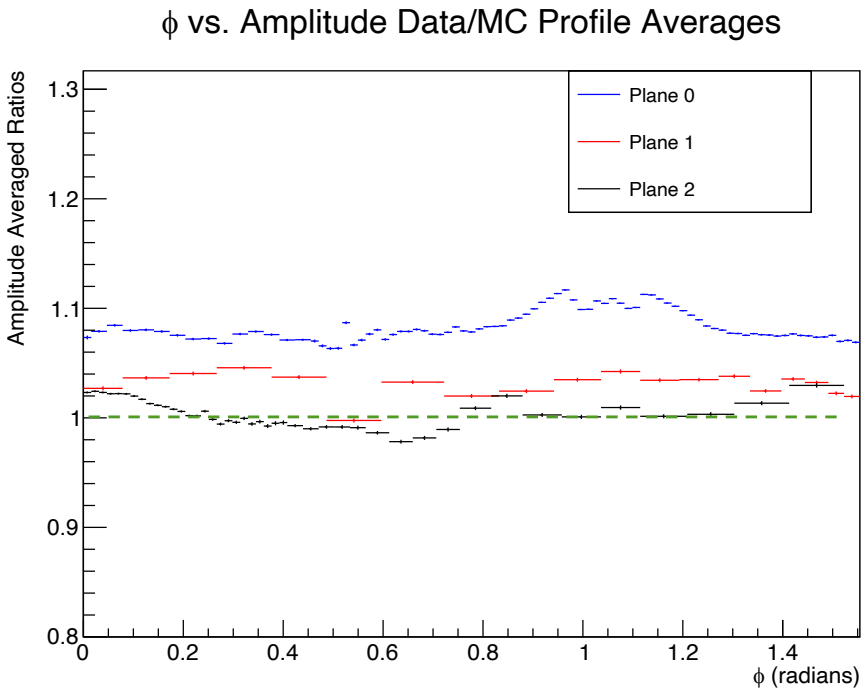


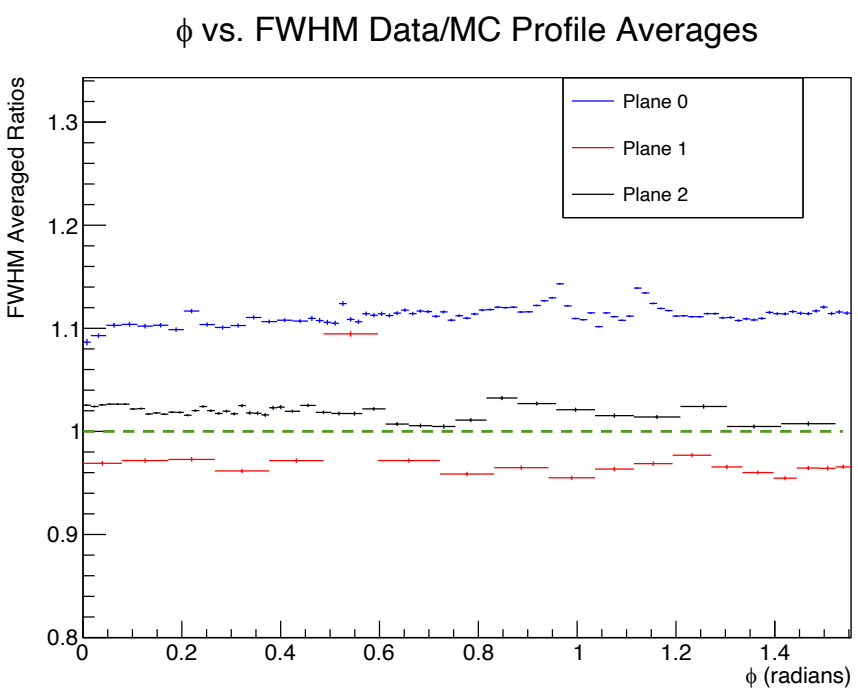




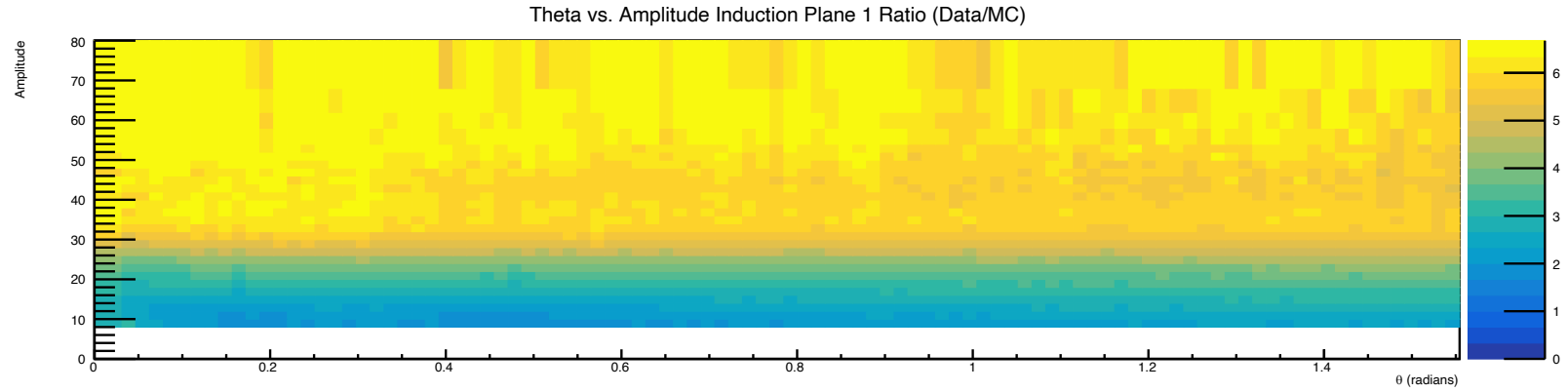
Phi Profiles

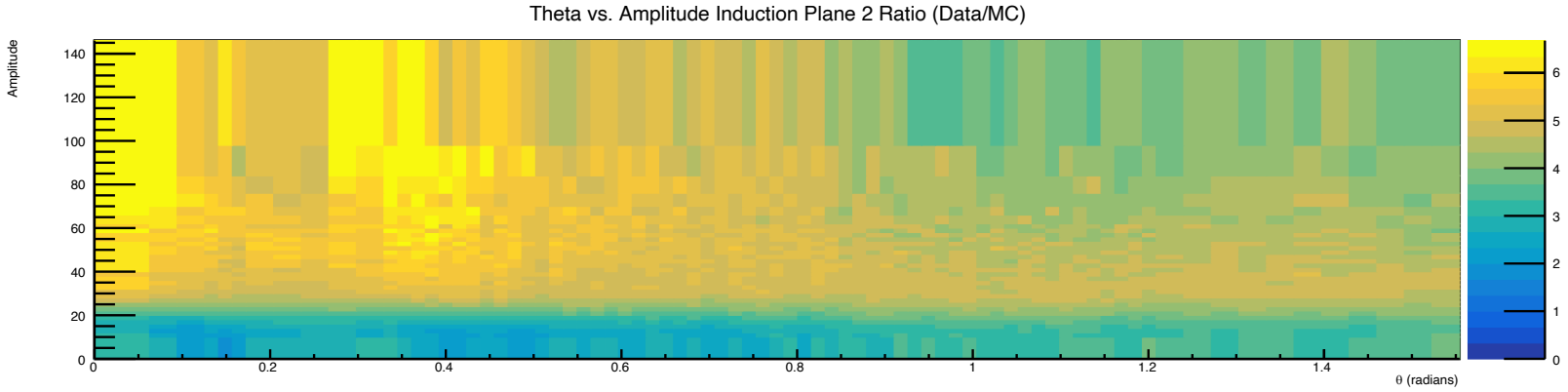
- The average of the ratios and the errors were found using ROOT's TProfile with error propagation

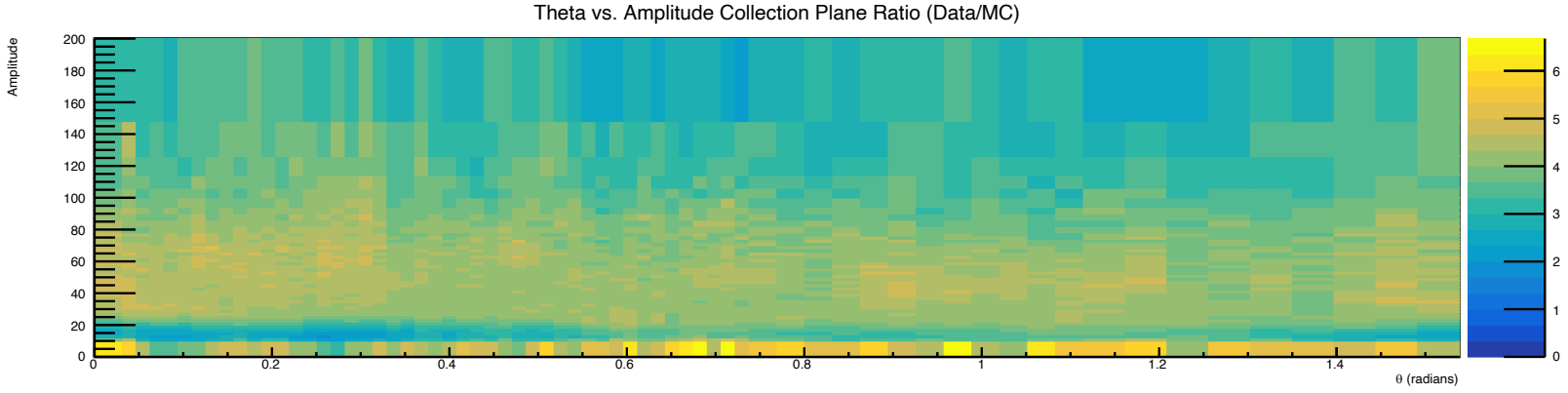




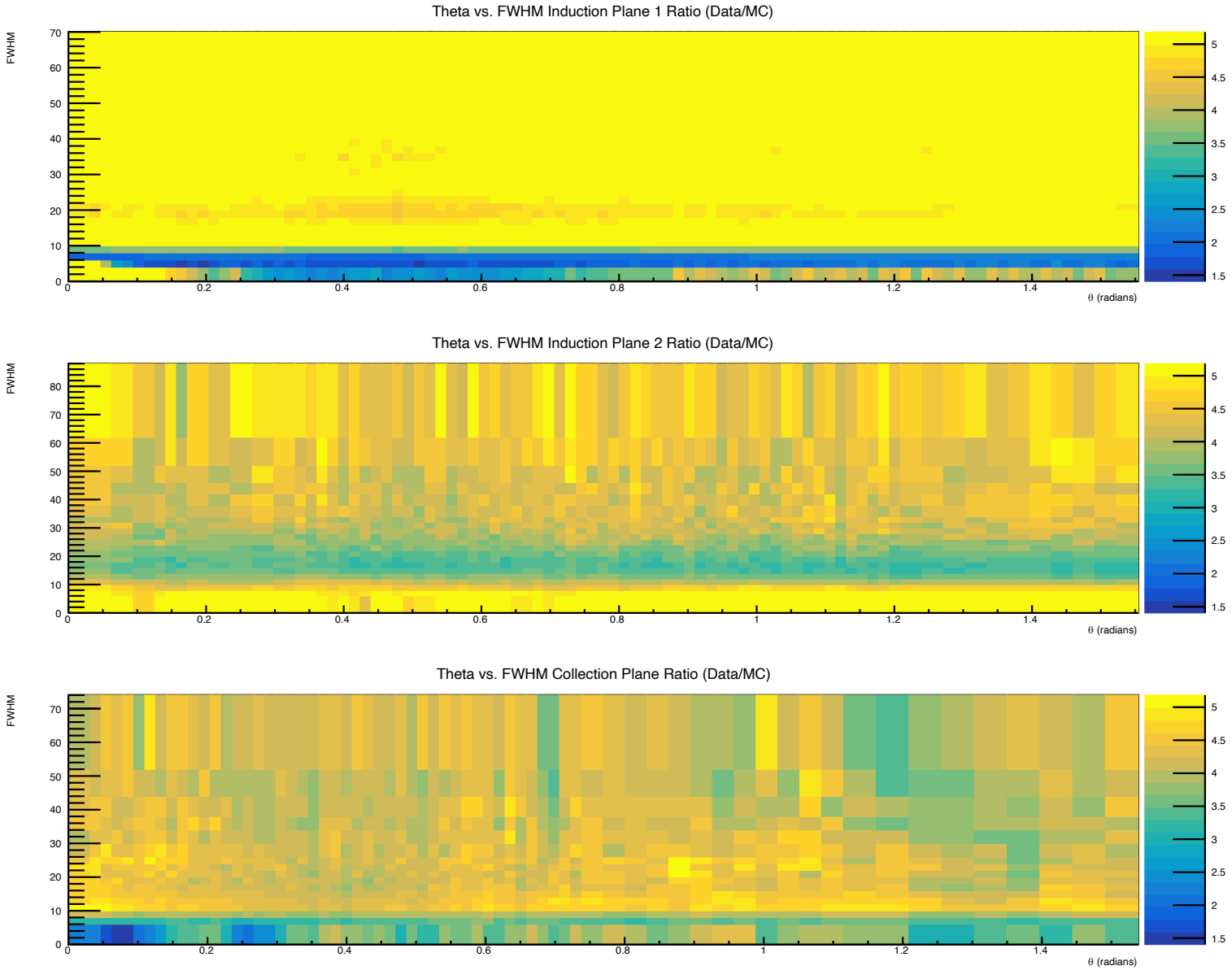
Theta (drift direction angle) vs Amplitude







Theta vs. FWHM



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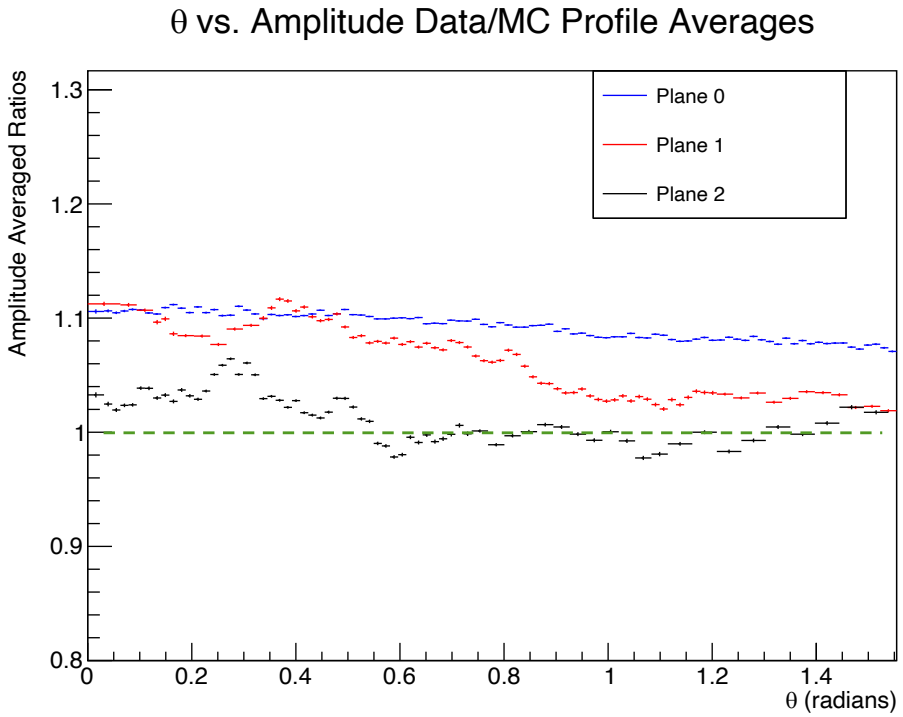
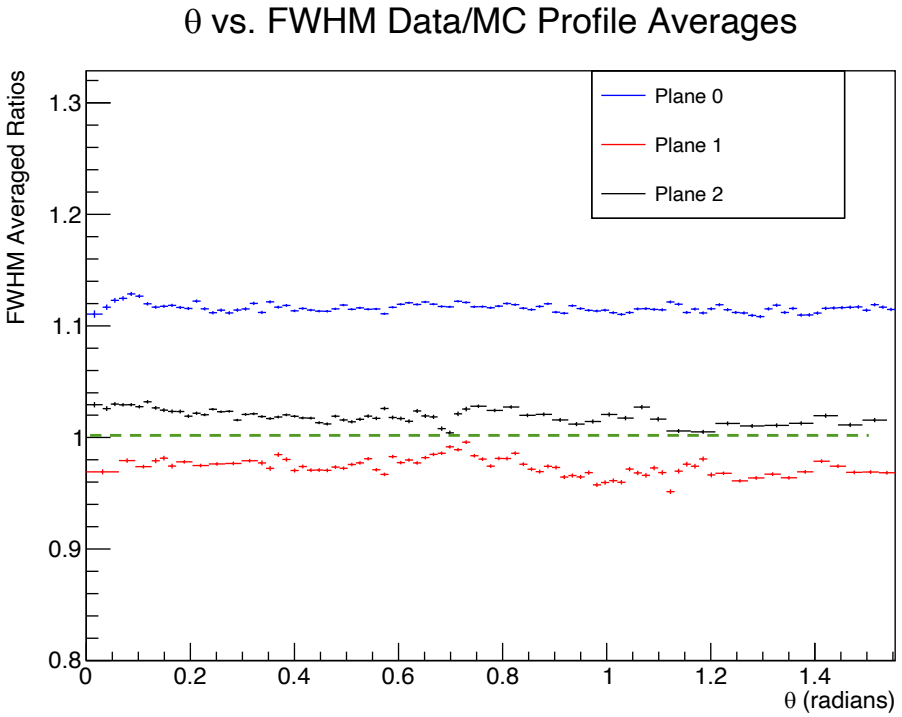
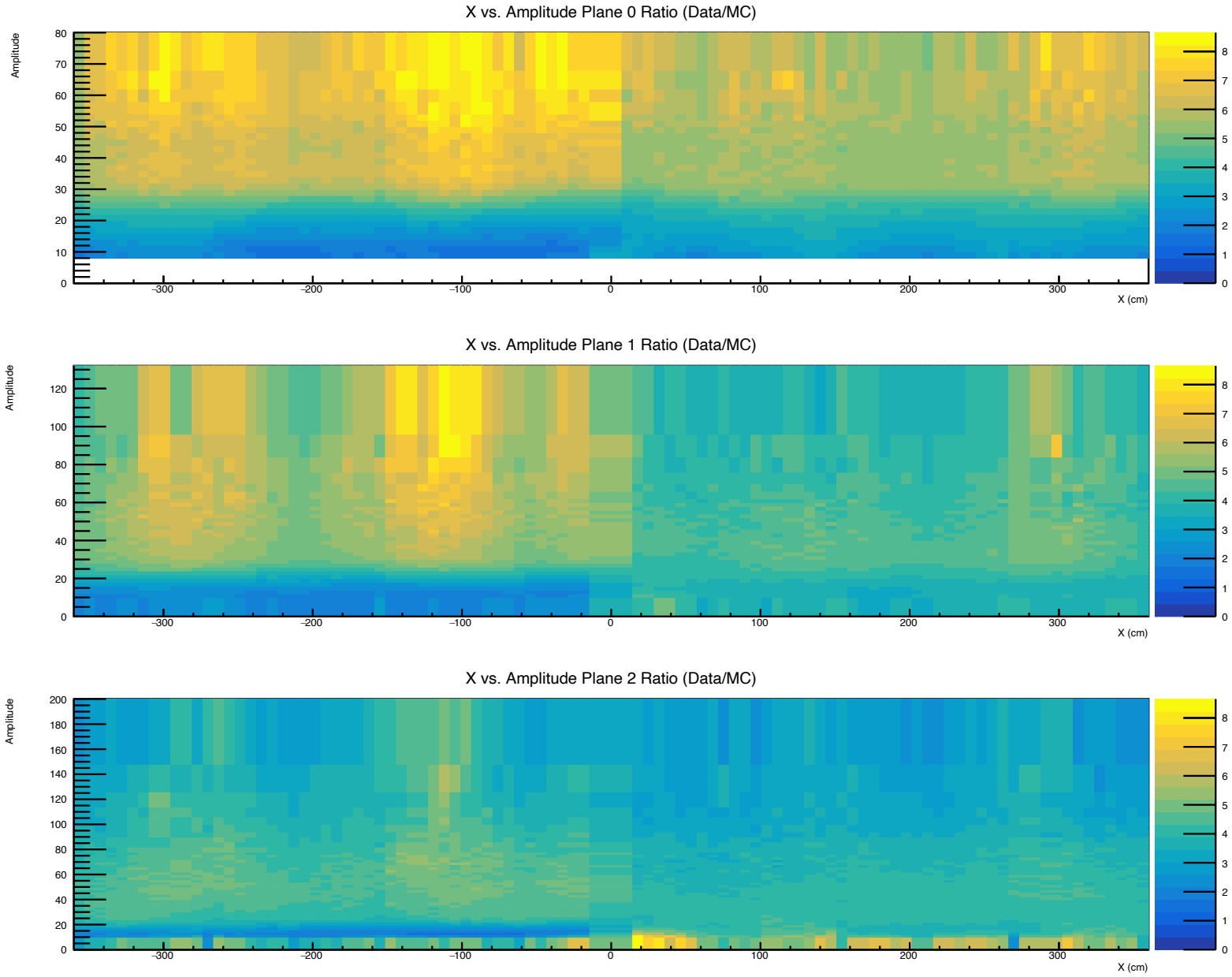
Theta Profiles

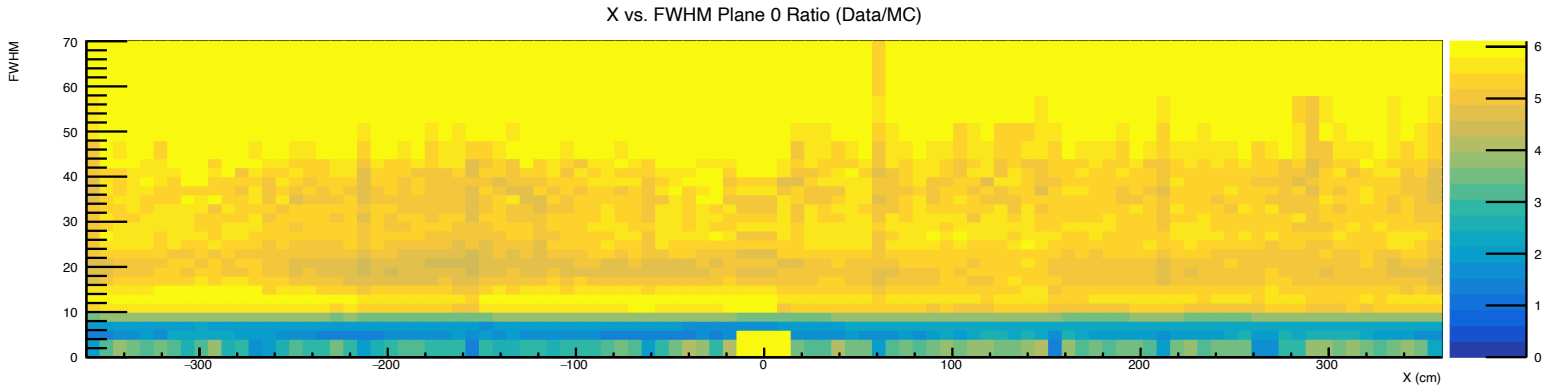


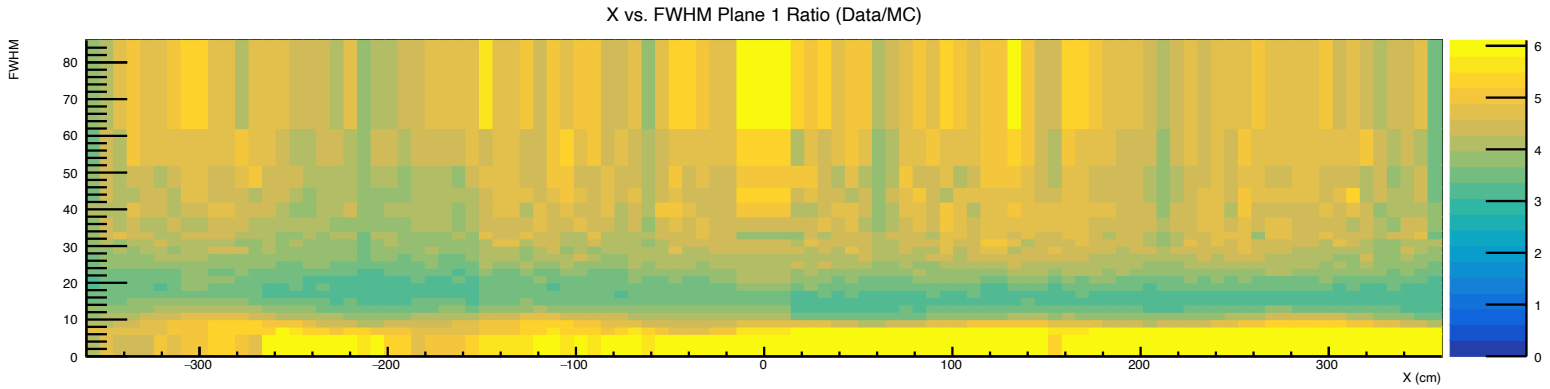


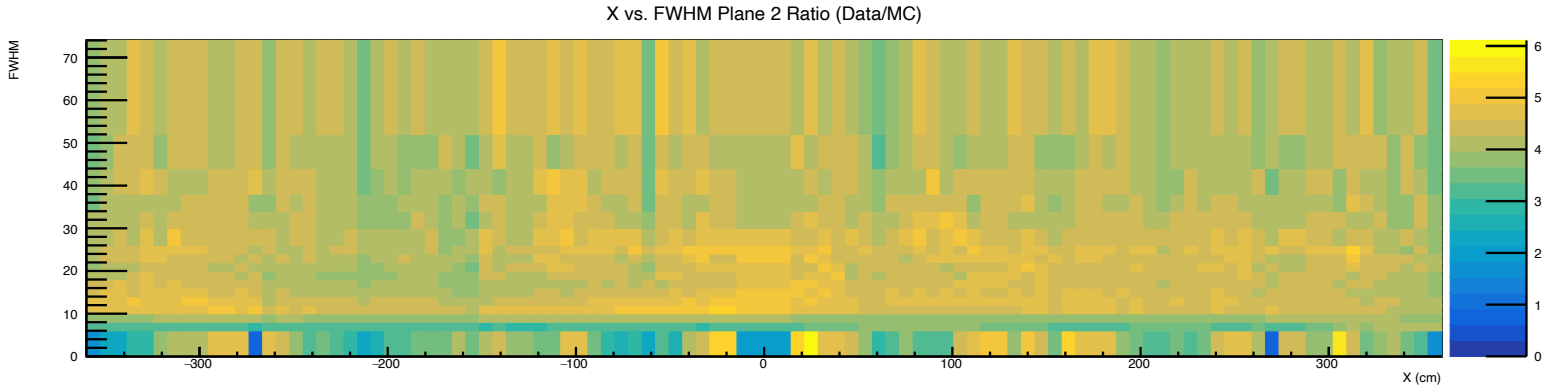
X vs Amplitude



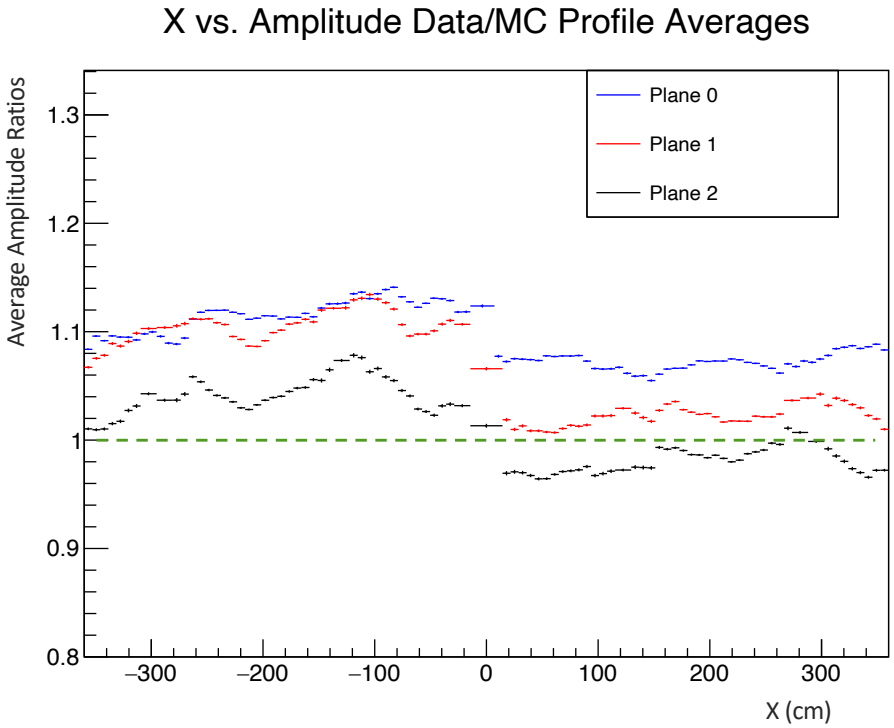
X vs. FWHM

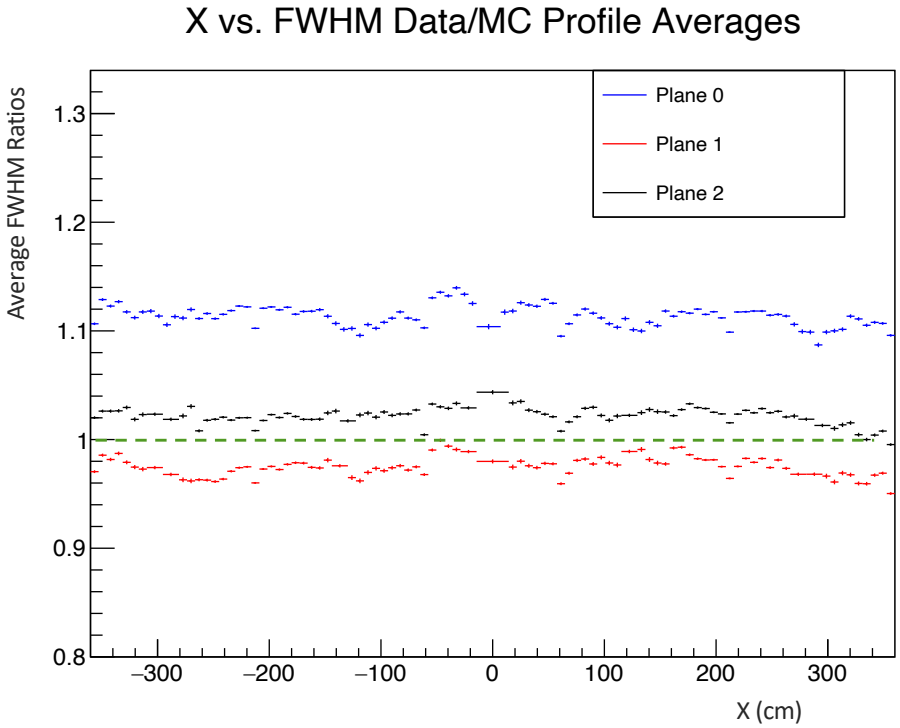

X vs. FWHM Plane 0 Ratio (Data/MC)
FWHM
X (cm)


X vs. FWHM Plane 1 Ratio (Data/MC)
FWHM
X (cm)


X vs. FWHM Plane 2 Ratio (Data/MC)
FWHM
X (cm)

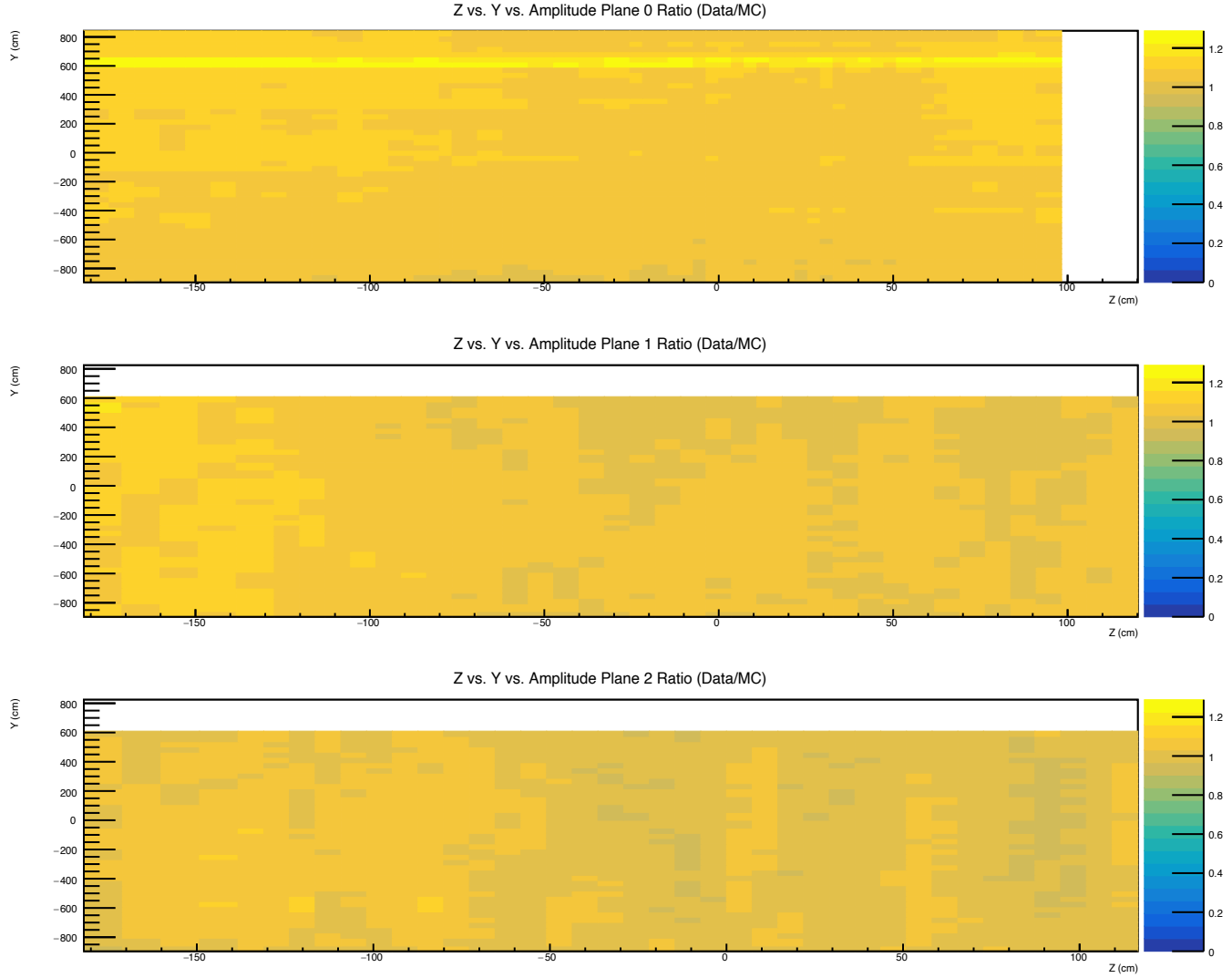
X Profiles


X vs. Amplitude Data/MC Profile Averages
Average Amplitude Ratios
Plane 0
Plane 1
Plane 2
1.3
1.2
1.1
1
0.9
0.8
−300
−200
−100
0
100
200
300
X (cm)


X vs. FWHM Data/MC Profile Averages
Average FWHM Ratios
Plane 0
Plane 1
Plane 2
1.3
1.2
1.1
1
0.9
0.8
−300
−200
−100
0
100
200
300
X (cm)

Projection of 3D Histograms

- The 3D histogram of Y vs. Z vs. Amplitude was also analyzed
- The ratio of the Amplitude projection is below due to it being 2D instead of 3D



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Conclusions

Conclusions

- Detecting Neutrinos is difficult, so it is important to understand the detector being used
- Cosmic rays provide a valuable source of data for detector analysis
- Using experimental cosmic ray and simulation data, ratio functions depending on the geometry of the detector were developed
- In the future, these ratio functions can be processed to alter the simulation waveforms to quantify detector-related uncertainties

References

1 P Abratenko, A Aduszkiewicz, F Akbar, M Artero Pons, J Asaadi, M Aslin, M Babicz, WF Badgett, LF Bagby, B Baibussinov, et al. Icarus at the fermilab short-baseline neutrino program: initial operation. The European Physical Journal C, 83(6):467, 2023.

2 MicroBooNE Collaboration et al. Novel approach for evaluating detector systematics in the microboone lartpc. Technical report, MICROBOONE- NOTE-1075-PUB. https://microboone. fnal. gov/wp-content/uploads . . . , 2020