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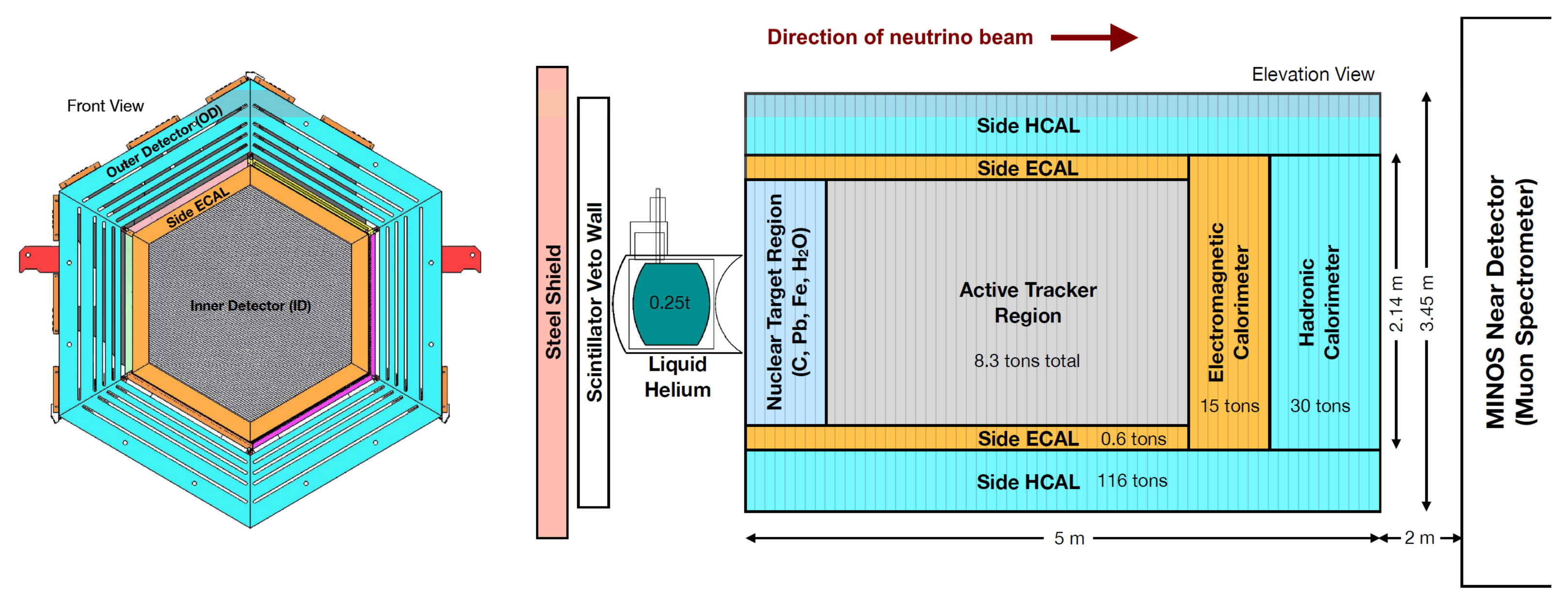
MINERvA Data Preservation: Enabling Muon Fuzz Analysis

Akeem Leonardo Hart (On behalf of the MINERvA collaboration), Queen Mary University of London

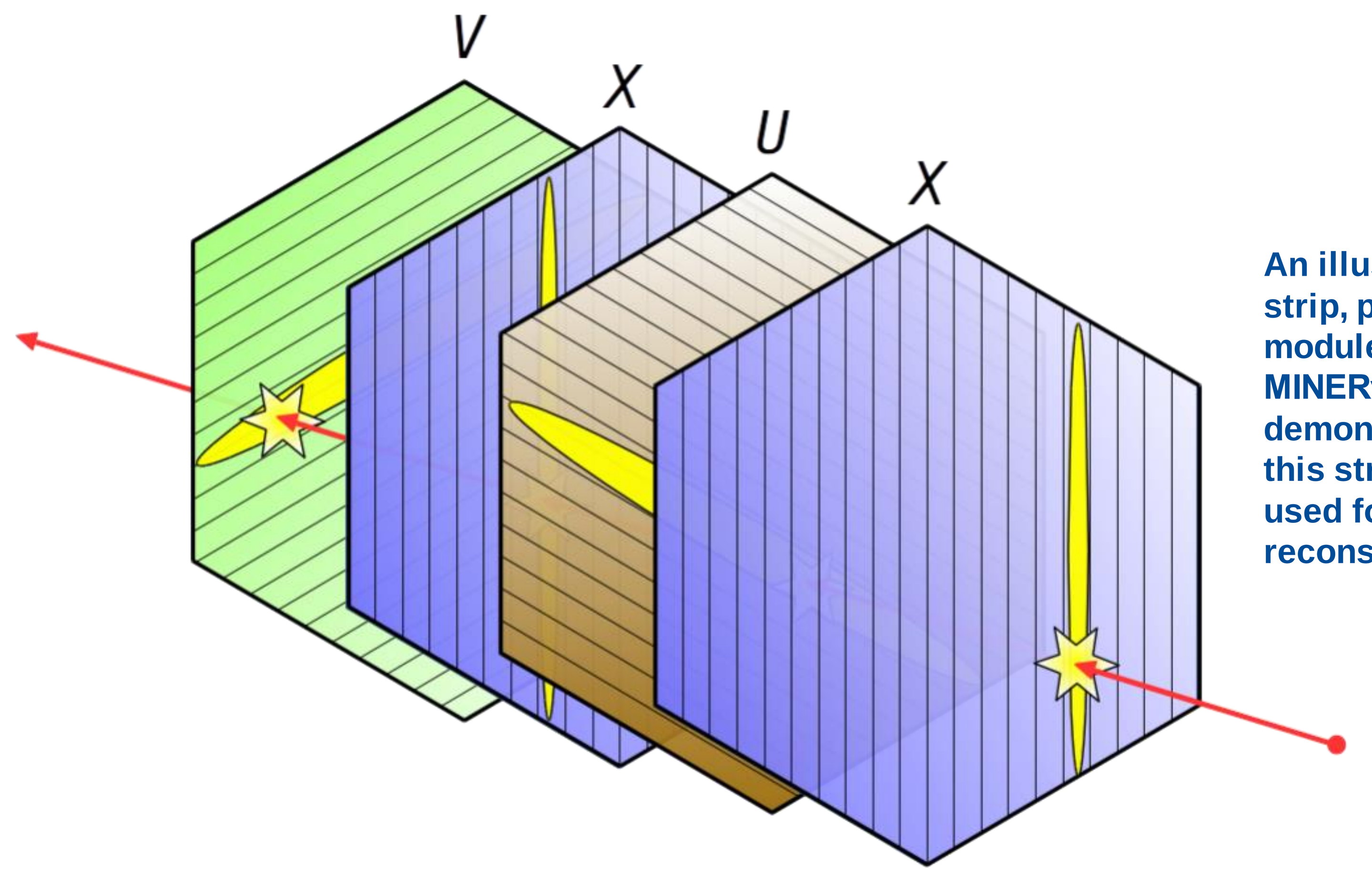
What is MINERvA?

- A neutrino detector at Fermilab designed to explore neutrino-nucleus interactions along the NuMI neutrino beam.
- Captured interactions on different materials (Fe, Pb, C, He, Water, Plastic) with ≈ 30 × 10^{20} POT from 2010-19 for LE & ME neutrinos and antineutrinos [1][2].
- Focus is now on data preservation and analysis.



Schematic of the MINERvA detector. Left: The view from the front, looking along the NuMI beam. Right: The view from the side, looking perpendicularly at the NuMI beam [1]

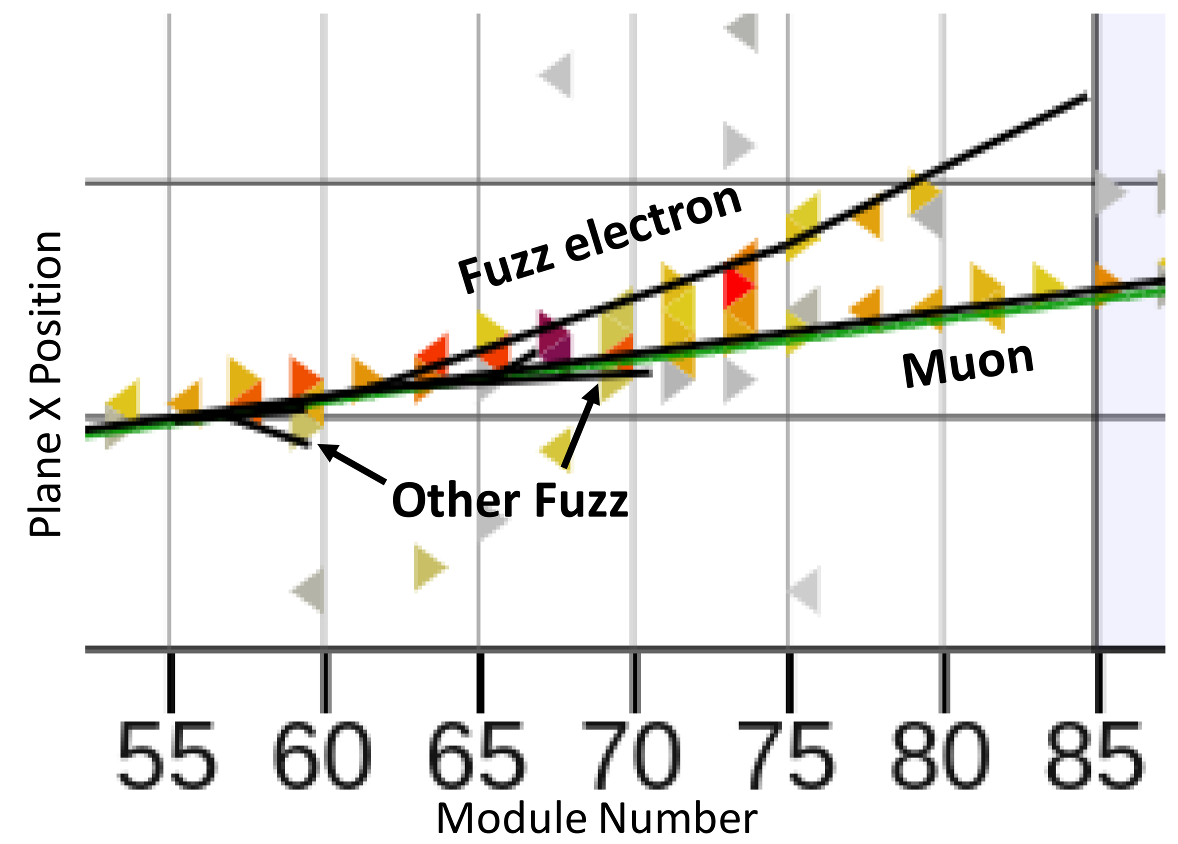
- MINERvA is composed of planes made of scintillating strips, containing wavelength shifting fibres connected to PMTs.
- The planes have 3 orientations, offset by 60°, allowing for 3D track reconstruction. Planes of different orientations are grouped together into modules.
- MINOS near detector is downstream and is utilized for tagging and calorimetry of muons exiting MINERvA.

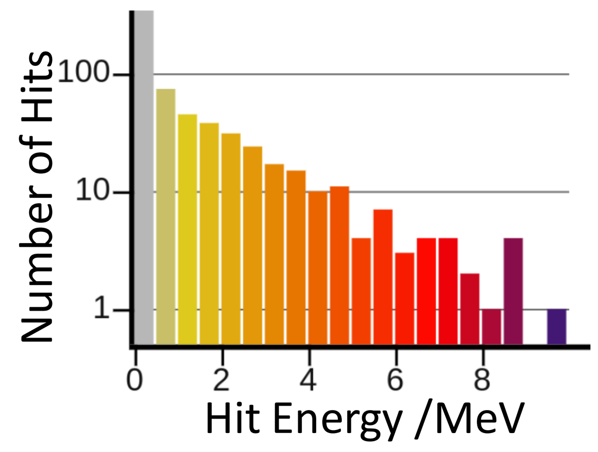


An illustration of the strip, plane and module structure of MINERvA, demonstrating how this structure is used for 3D reconstruction [4]

What is muon fuzz?

- Muon fuzz is bremsstrahlung photons or scattered electrons produced as muons transit the detector [3].
- This is called the muon fuzz because it comes off the muon track like strands of fuzz.
- Identifying the fuzz is important for neutrino energy reconstruction to prevent fuzz energy deposition being misattributed.



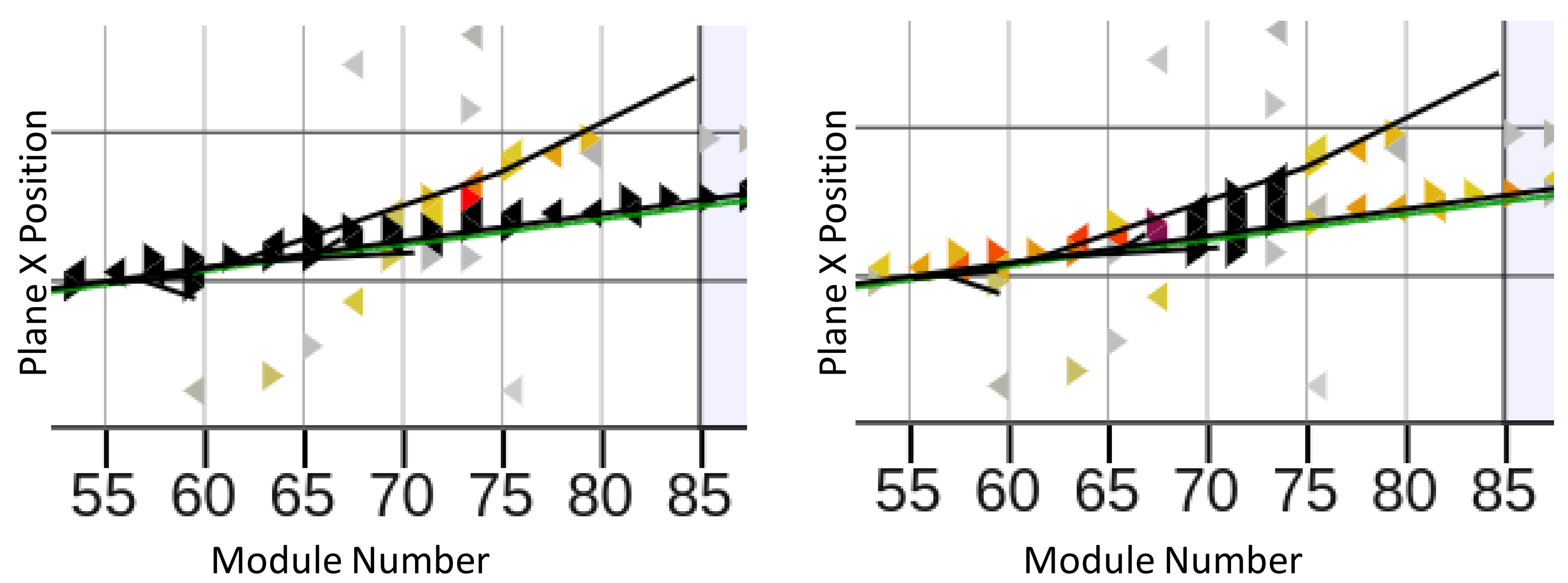


Left: A labelled view of the MINERvA event display illustrating an event with a muon track and muon fuzz.

Below: The energy distribution and colour scheme for the illustrated events

Motivations & Implementation

- Previous investigations show that current Monte Carlo simulated fuzz poorly for MINERvA [3].
- These investigations didn't include the fuzz that lies along the track. One analysis has been proposed to do this.
- To do this, we need to be able to extract the fuzz component of on track clusters.
- I modified the existing MINERvA software framework to output cluster information for clusters on and around the track, then we can estimate the muon fuzz component.
- For simulated events, I also save key properties of the true fuzz particles.



Two views of the MINERvA event display, Left – the hits identified as along the muon track highlighted in black, Right – the hits identified as muon fubzz highlighted in black. Detailed information about the clusters containing the illustrated hits is now outputted, from this outputted information we can assess how well our MC models simulate muon fuzz.

References

[1] Aliaga, L et al. (MINERvA Collaboration), Design, calibration, and performance of the MINERvA detector, Nucl. Instrum. Methods Phys. Res., Sect. A 743, 130 (2014).

[2] Lu, XG et al. (MINERvA Collaboration), Exploring neutrino–nucleus interactions in the GeV regime using MINERvA. Eur. Phys. J. Spec. Top. 230, 4243–4257 (2021). https://doi.org/10.1140/epjs/s11734-021-00296-6

[3] Ren, L. Measurement of Neutrino and Antineutrino Total Charged-current Cross Sections on Carbon with MINERvA. Doctoral Dissertation, University of Pittsburgh. (2017)

[4] Roy, N. Measurement of antineutrino elastic scattering on free protons in the MINERvA experiment. Presentation. Canadaian Assosciation of Physicists. (2023)

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