MINERνA in 10 Minutes: Main Injector Experiment for ν-A

New Perspectives 08/17/2021
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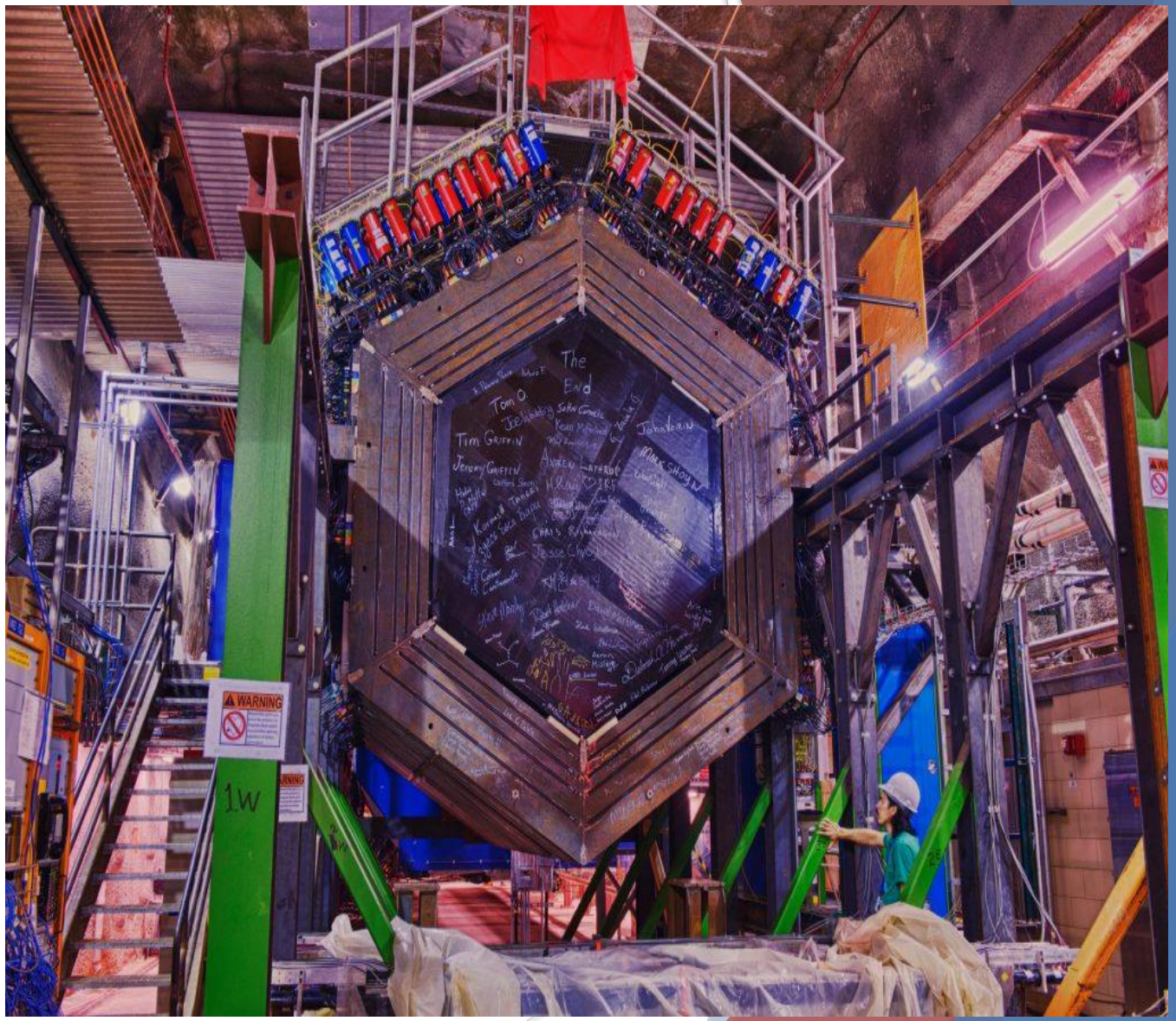
On behalf of the MINERνA Collaboration

Penn
PHYSICS & ASTRONOMY

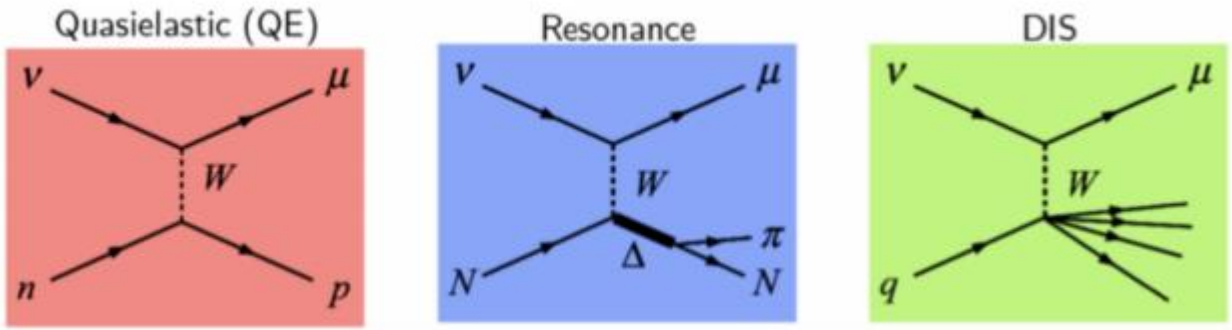
MINERνA in 1 Slide

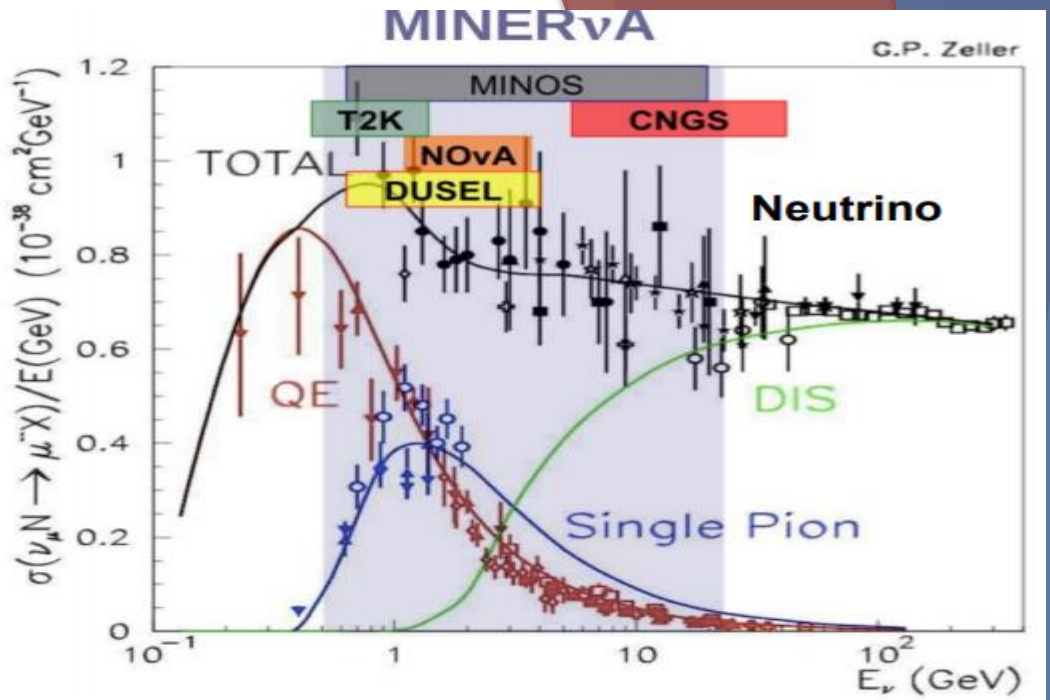
- MINERνA is an experiment dedicated to studying neutrino-nucleus interactions in the NuMI (Neutrinos at the Main Injector) beamline:
  - High Statistics Neutrino and Antineutrino data
  - Neutrino energy range of ~1-50 GeV
  - Array of Nuclear targets (CH, Fe, Pb, C, H2O, He) allow for study of nuclear effects
  - Viability for various inclusive and exclusive final state measurements

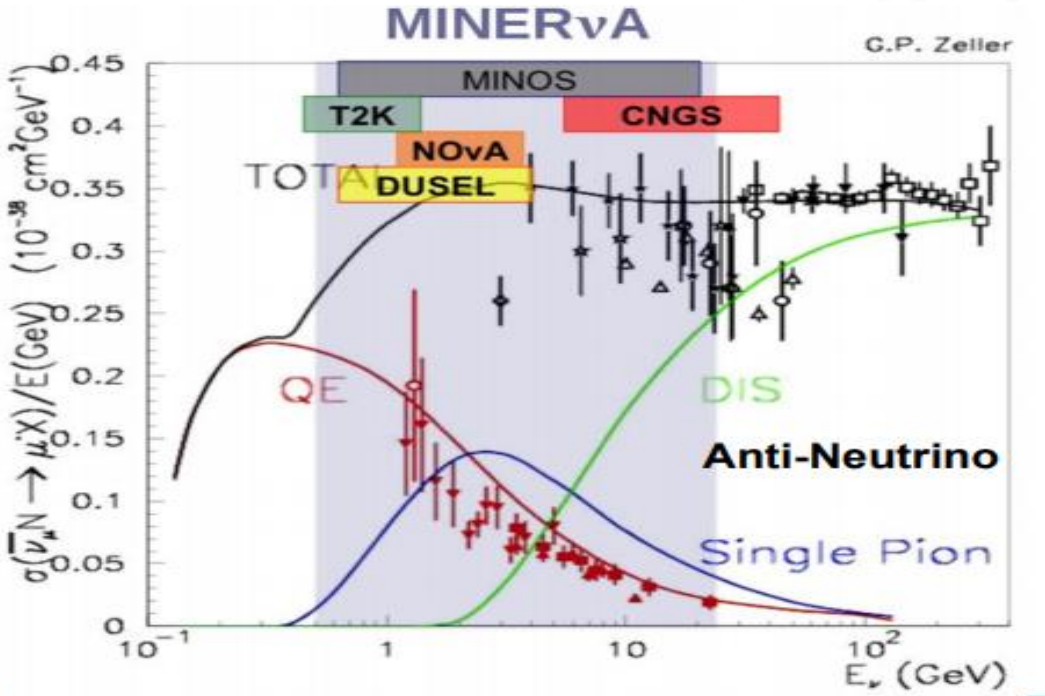


Relation to Oscillation Experiments

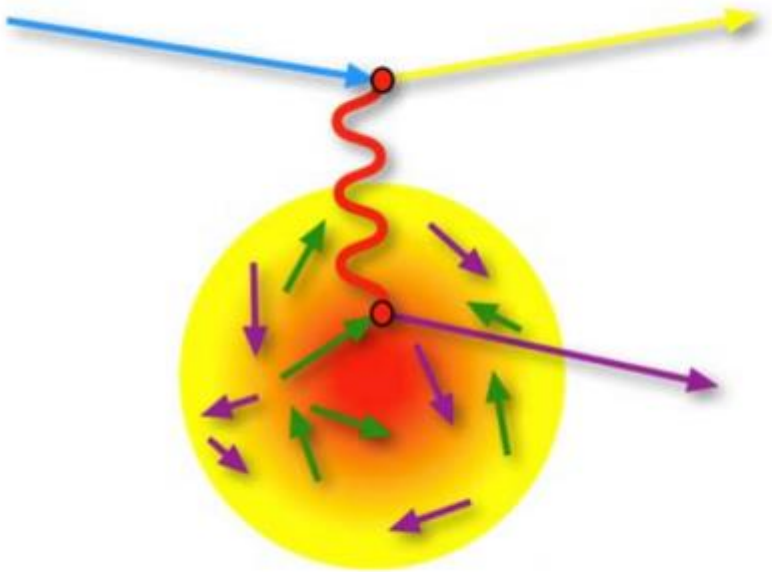
- Neutrino energy reconstruction is a central component of oscillation measurements
- Neutrino event generators rely on neutrino-nucleus interaction models: improved by high precision measurements
- Improvements to model also reduce systematic uncertainties: critical for goals of future oscillation experiments such as DUNE

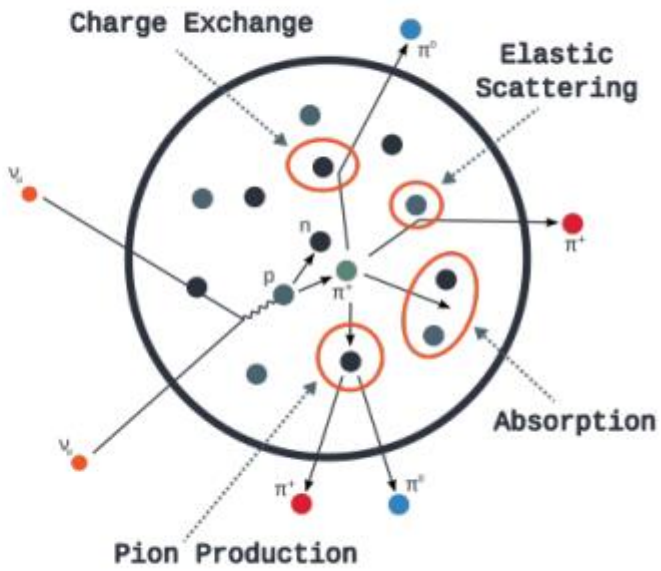






Probing Nuclear Structure and Effects



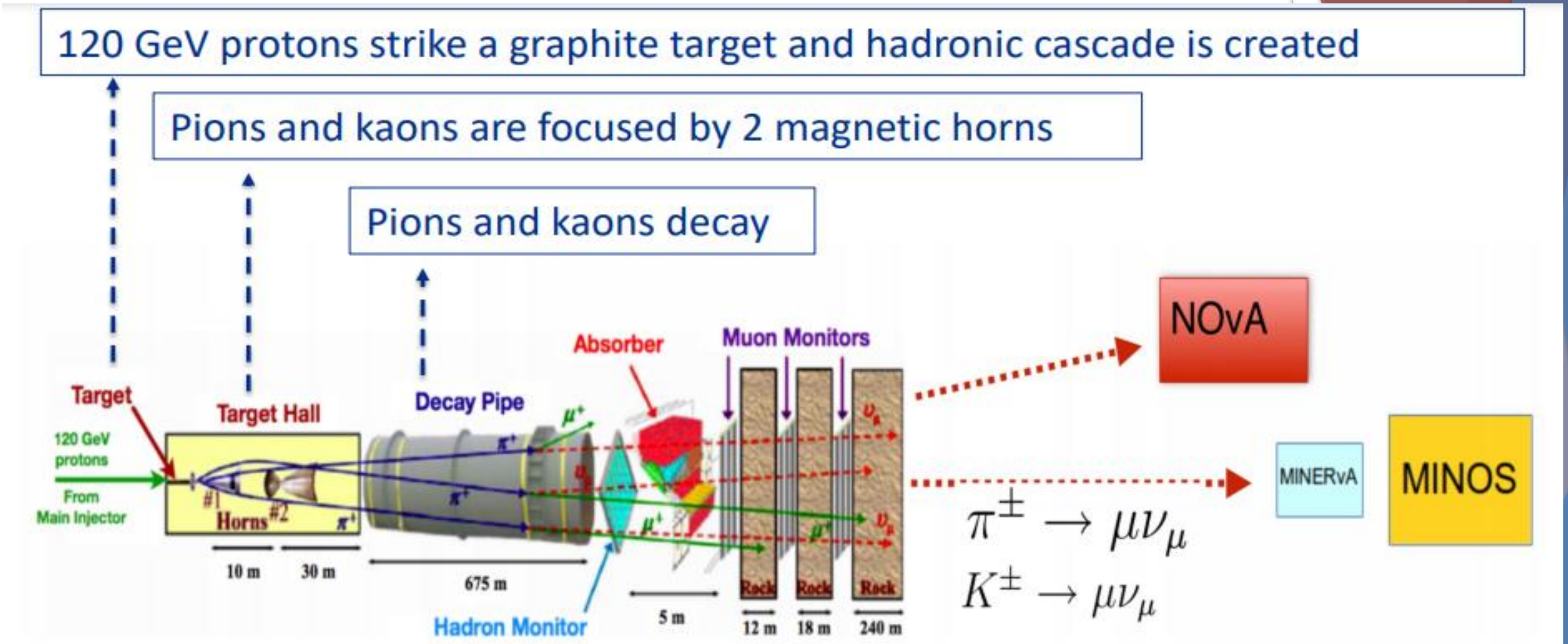


Probe the behavior of nucleons in nuclei: correlations of nuclei, distribution of nuclear momentum

Final State Interactions “FSI”: Interactions of neutrino final state particles exiting the nucleus.

Both categories affect neutrino energy reconstruction through modified final states in both particle content and kinematics

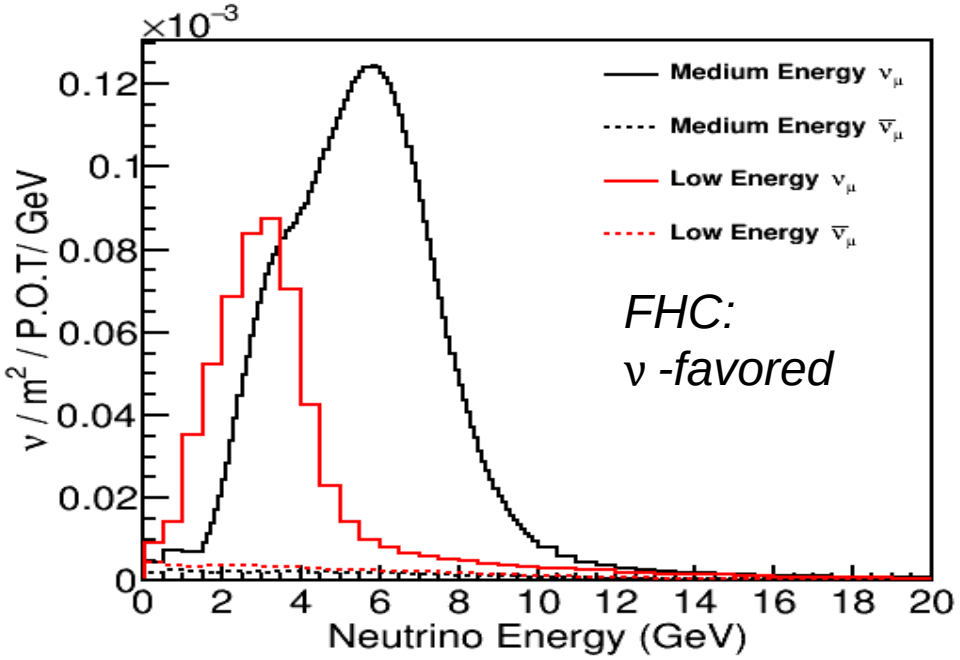
NuMI Beamline

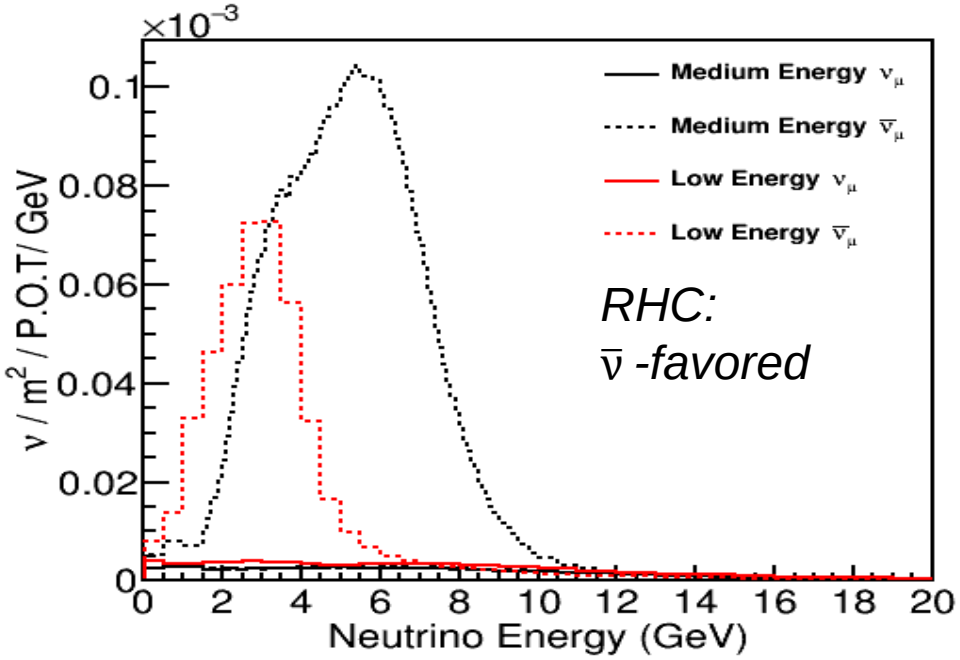


2 Focusing States:
"FHC": Forward Horn Current, focuses positive particles to give primarily neutrinos
"RHC": Reverse Horn Current, focuses negative particles to give primarily antineutrinos

MINERνA Datasets Some History

- EOI: 2002, Construction Start: 2007, First Full Detector Data: 2009
- Data-taking has been completed for both energy configurations → **MINERvA has been decommissioned**



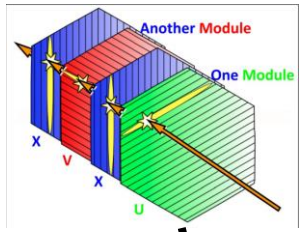


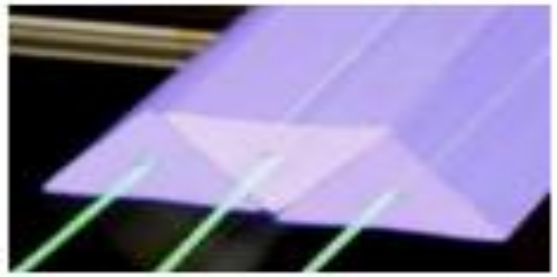
Energy	ν- P.O.T.	ν̄ - P.O.T.
Low Energy: ~3.5 GeV peak (2010-2012)	4.0 E 20	1.7 E 20
Medium Energy: ~6 GeV peak (2013-2019)	12.1 E 20	12.4 E 20

"P.O.T.": Protons on Target, a proxy for number of neutrinos produced

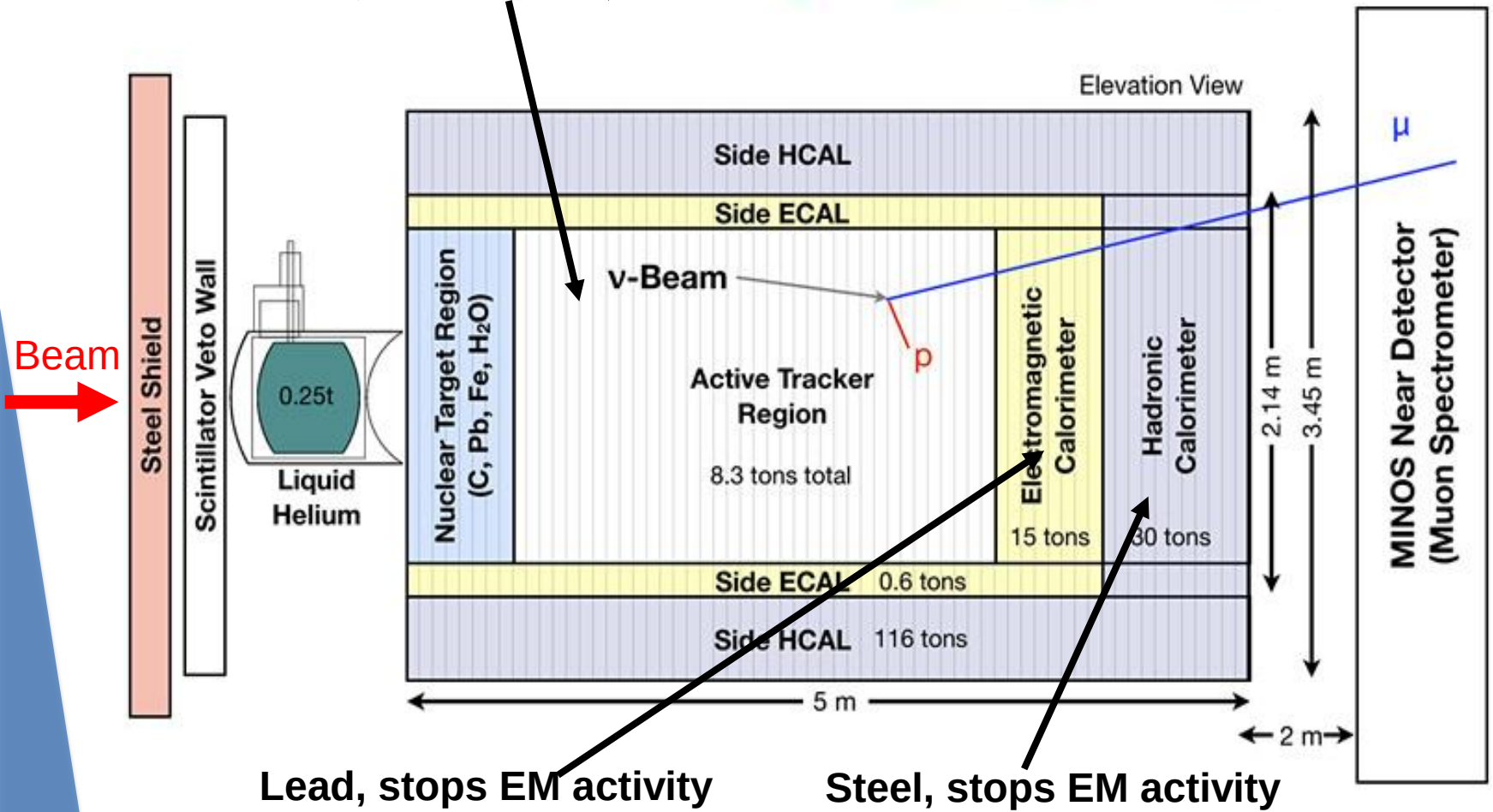
MINERνA Detector

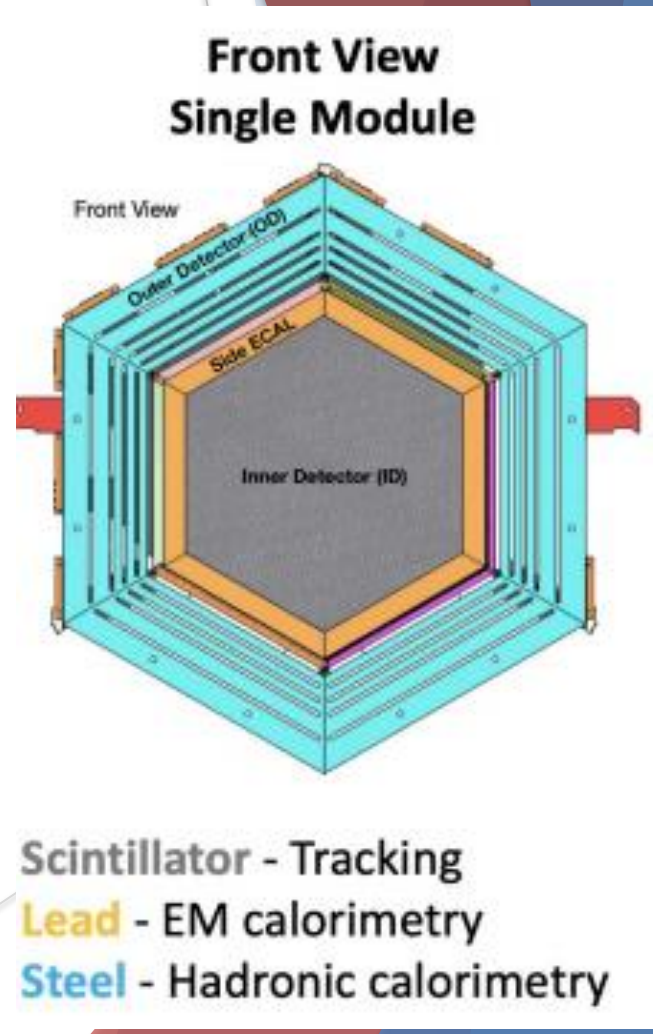
Plane rotation of scintillator allows for tracking





Charged particles pass through strips of scintillator. Light collected by fibers, measured by photomultiplier tubes.

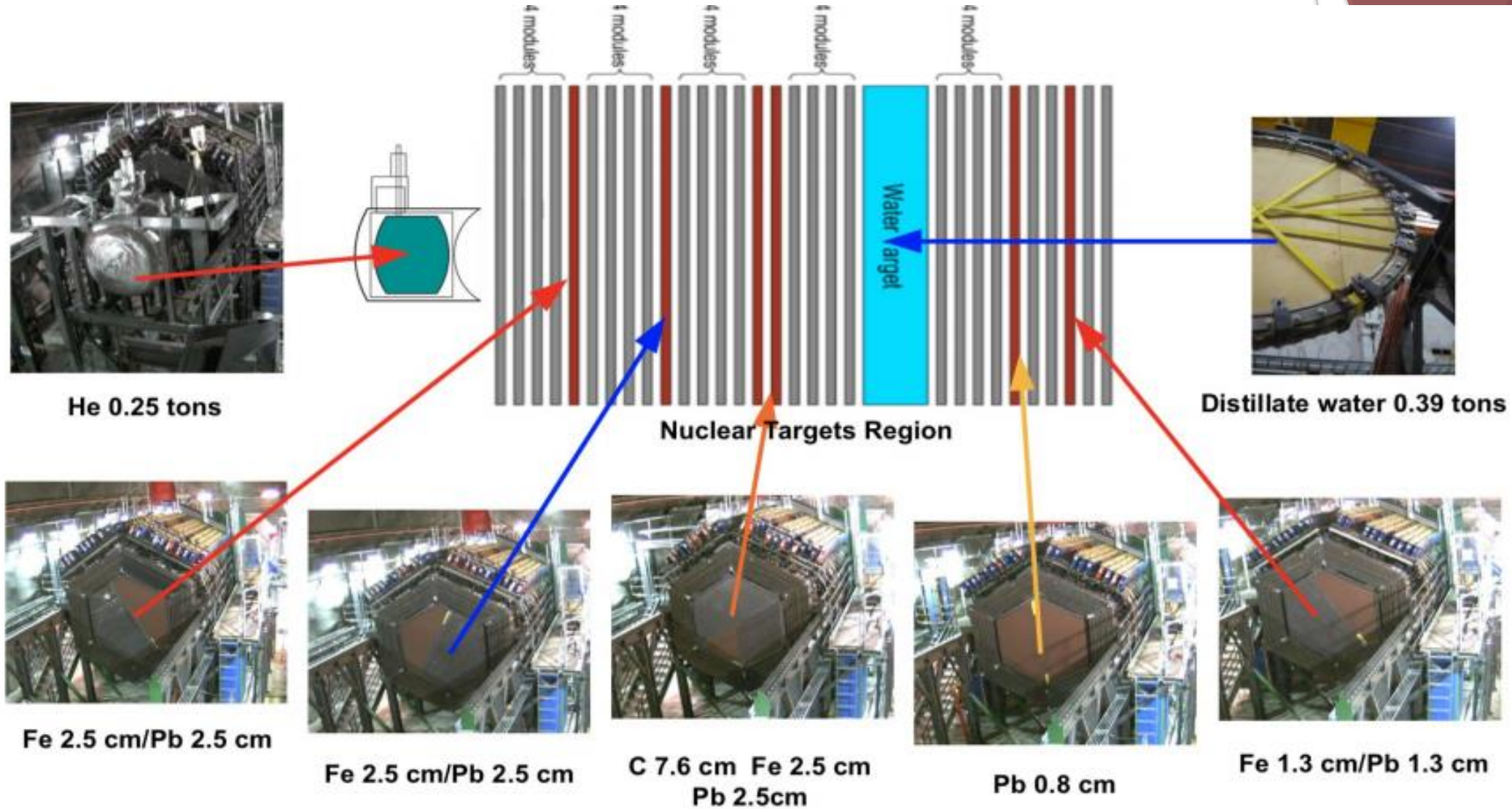




Lead, stops EM activity

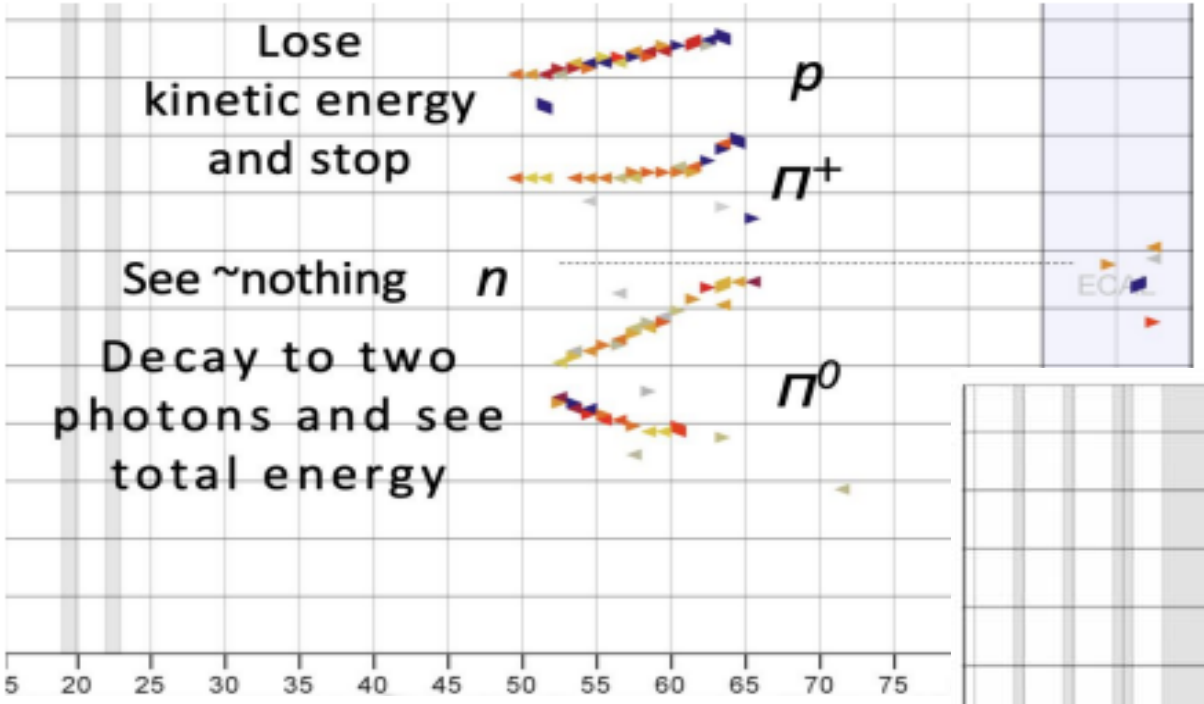
Steel, stops EM activity

MINERνA Detector: Target Region



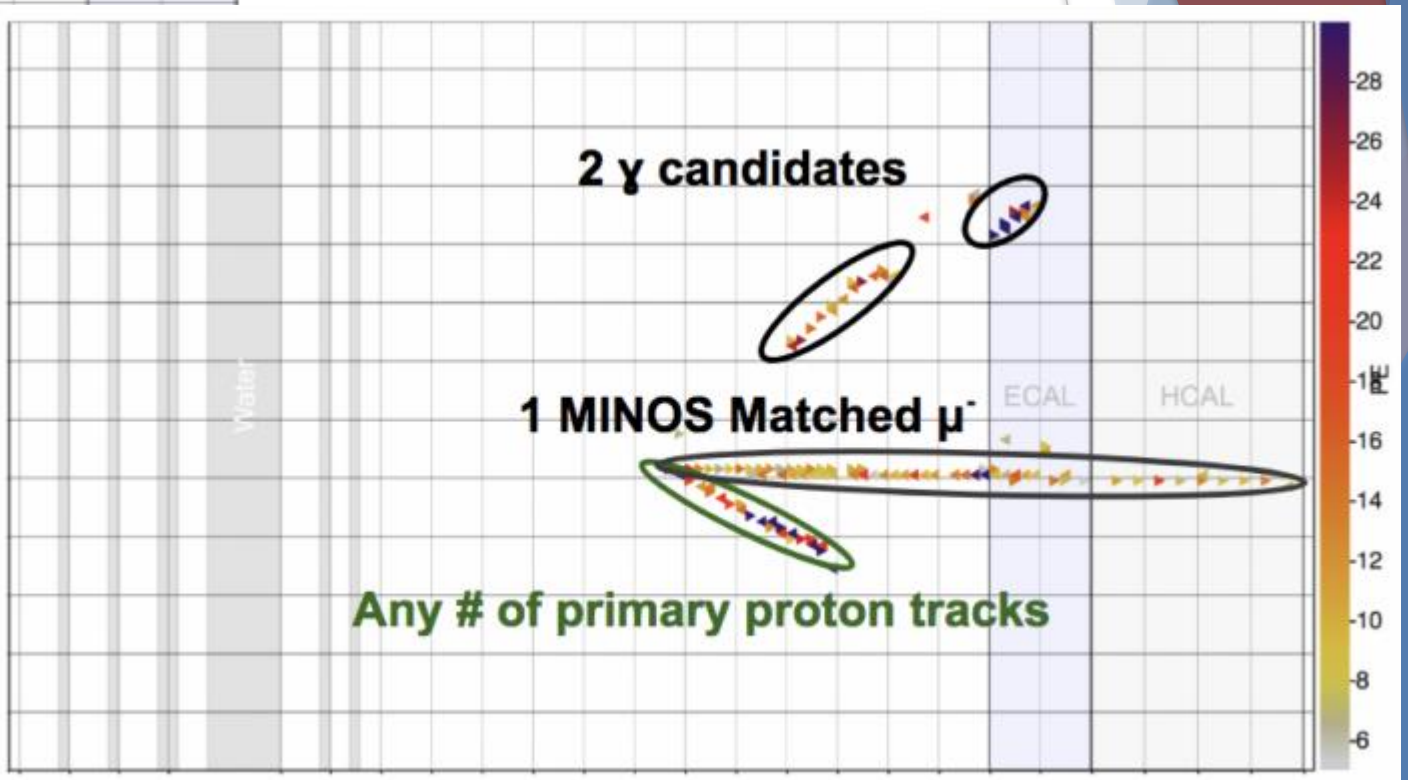
How Does MINERνA See?

Various Particles and how they present in MINERνA



Crucial that the tracker region is all active, so that the particle deposits can be well-separated/identified

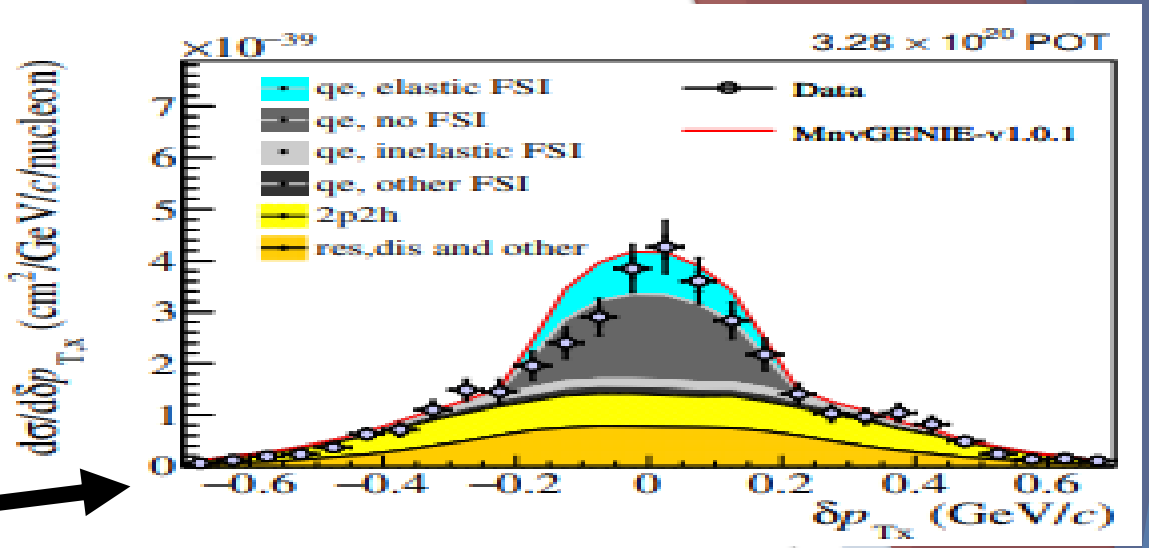
Candidate Pi0 Event in the tracker

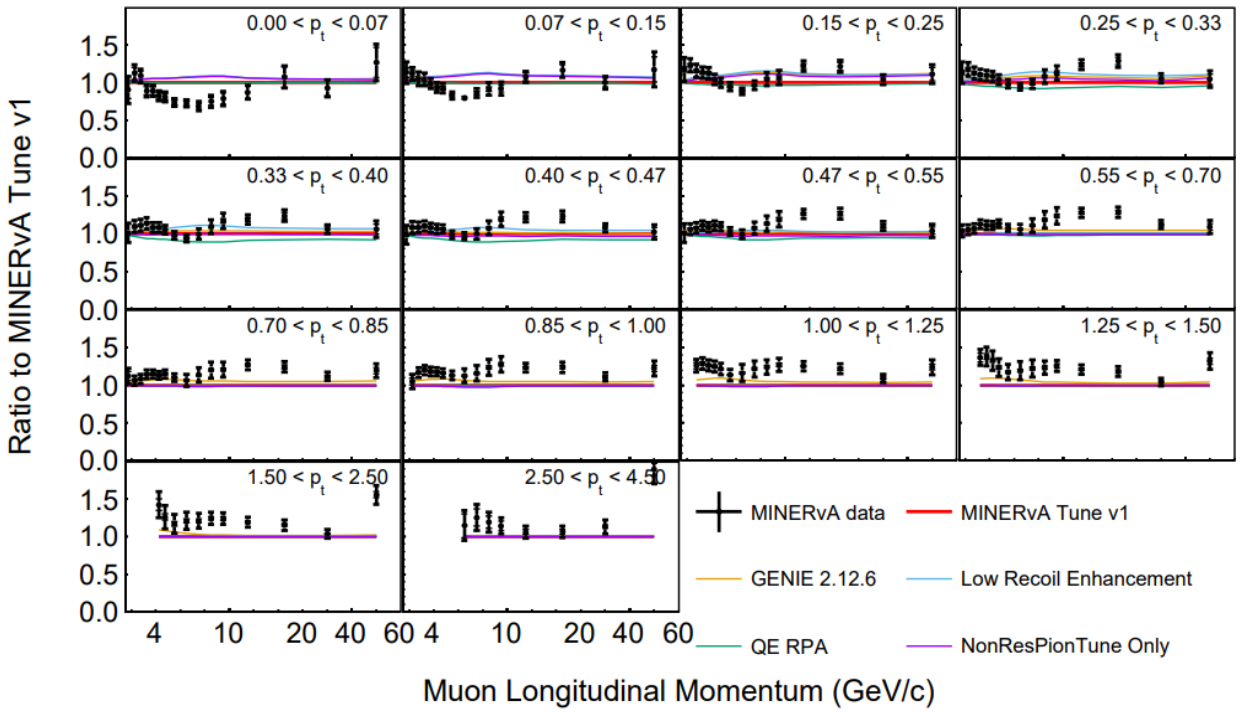


Particles traversing the detector's active elements present differently enough to allow for the selection of exclusive final states of neutrino interactions

MINERvA Results' Recent Highlights

- Flux measurement techniques:
  - Inverse Muon Decay
  - Neutrino Electron Scattering
- Transverse Kinematic Imbalance "TKI" variables in single proton interactions (Phys.Rev. D 101, 092001):
  - Sensitivity to various models' handling of multiple nuclear effects (e.g. binding energy)
- ME Inclusive Final State Measurement (arXiv:2106.16210):
  - Discrepancy with various models
- All results in papers from next slide





MINERνA Recent Publications/Preprints

- "Exploring Neutrino-Nucleus Interactions in the GeV Regime using MINERvA" arXiv: 2017.02064, submitted for publication
- "Constraining the NuMI neutrino flux using inverse muon decay reactions in MINERvA" arXiv: 2107.01059, submitted for publication
- "Measurement of inclusive charged-current νμ cross sections as a function of muon kinematics at ~6 GeV on hydrocarbon" arXiv:2106.16210 , submitted for publication
- "Use of Neutrino Scattering Events with Low Hadronic Recoil to Inform Neutrino Flux and Detector Energy Scale" arXiv: 2104.05769, submitted for publication
- "Neutral pion reconstruction using machine learning in the MINERvA experiment at ⟨Eν⟩~6 GeV" arXiv: 2103.06992, accepted for publication in JINST
- "Double-Differential Inclusive Charged-Current νμ Cross Sections on Hydrocarbon in MINERvA at ⟨Eν⟩~ 3.5 GeV" Phys. Rev. D 101, 11 (2020)
- "Probing Nuclear Effects with Neutrino-induced Charged-Current Neutral Pion Production" Phys. Rev. D 102, 072007 (2020)
- "High-statistics measurement of neutrino quasielastic-like scattering at =~6 GeV on a hydrocarbon target" Phys. Rev. Lett. 124, 121801 (2020)
- "Nuclear binding energy and transverse momentum imbalance in neutrino-nucleus reaction " Phys.Rev. D 101, 092001 (2020)

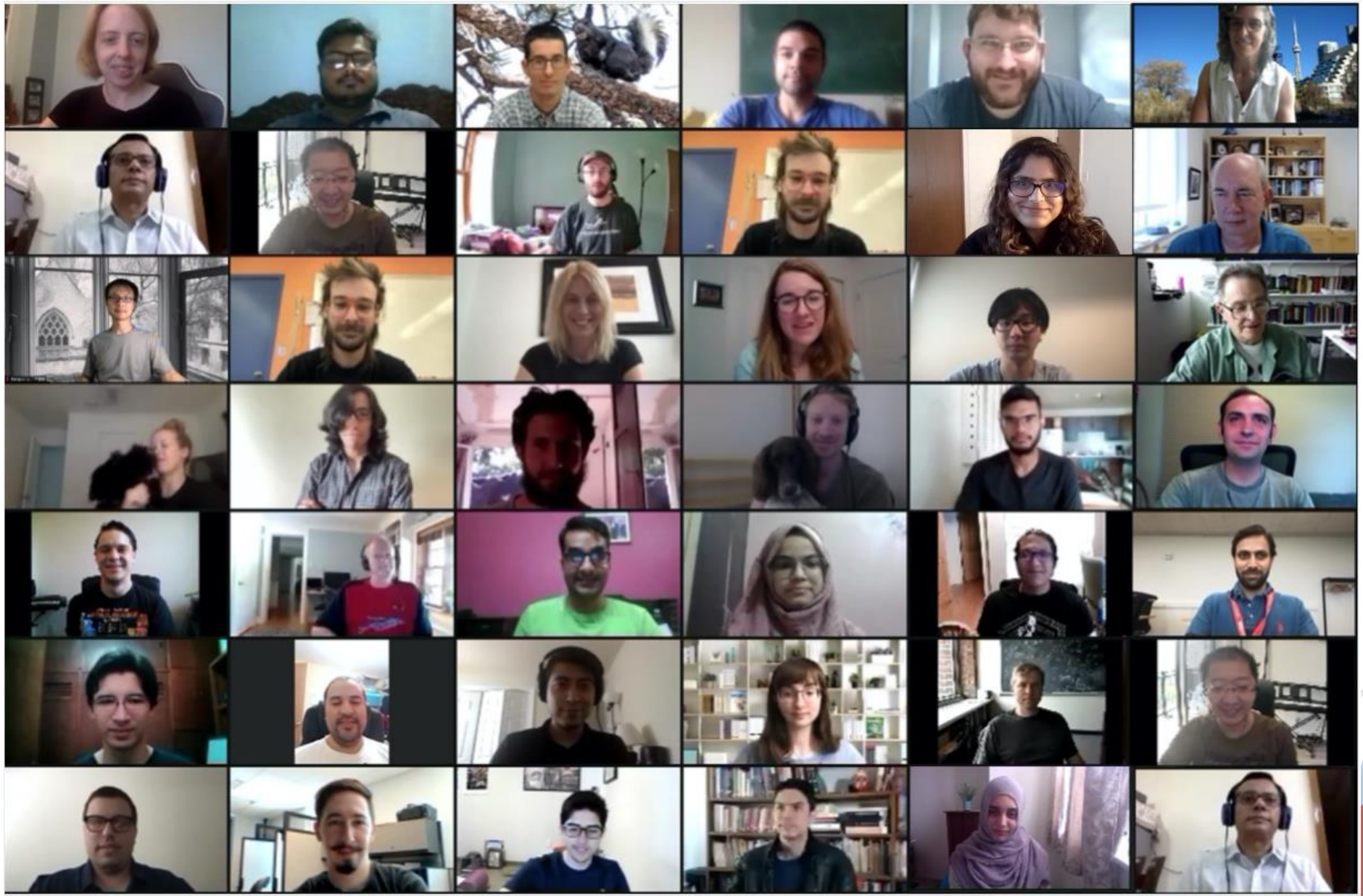
MINERνA Summary

- MINERνA has pushed, and continues to push, the boundaries of the understanding of neutrino-nucleus interactions

- MINERνA's construction and beam conditions provide ample statistics to investigate inclusive and exclusive final states of neutrino interactions across an array of nuclear targets

- The efforts made by MINERνA are in great support of the goals to model and understand nuclei as well as model and constrain uncertainties for neutrino oscillation experiments

July 2021 Zoom Collaboration Photo



Thank You!