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Neutrons from MINERvA's Nuclear Targets

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New Perspectives 2020

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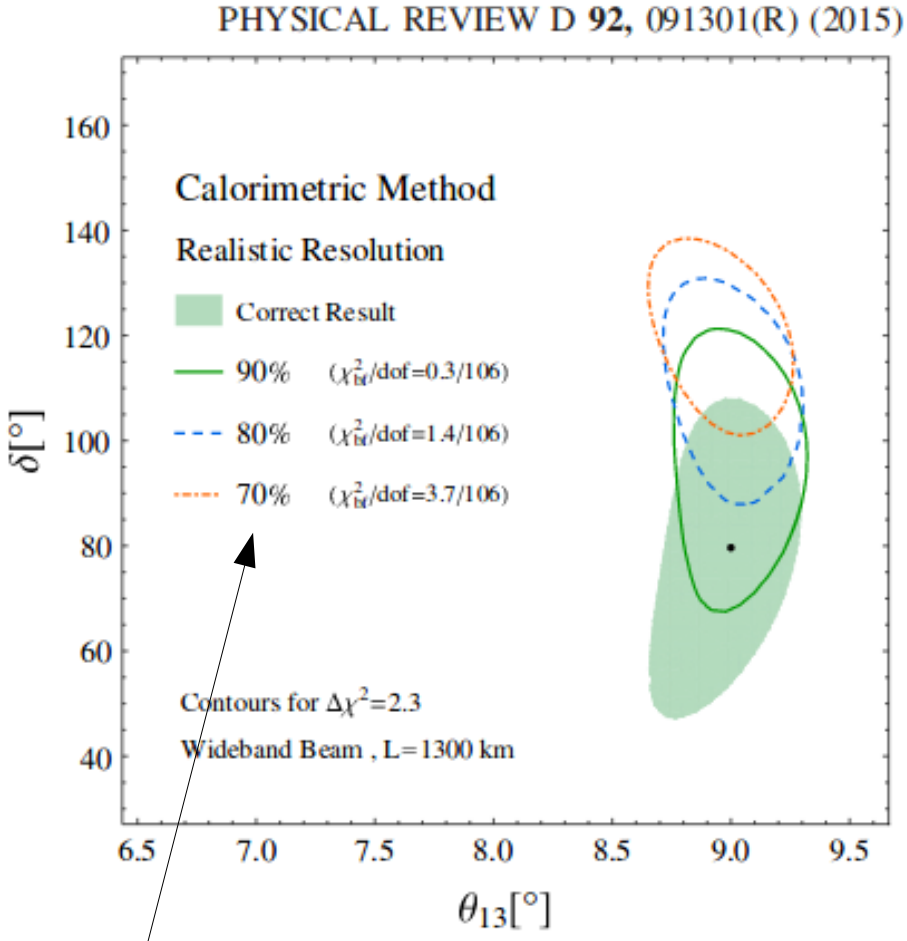
Why Neutrons from Neutrinos?

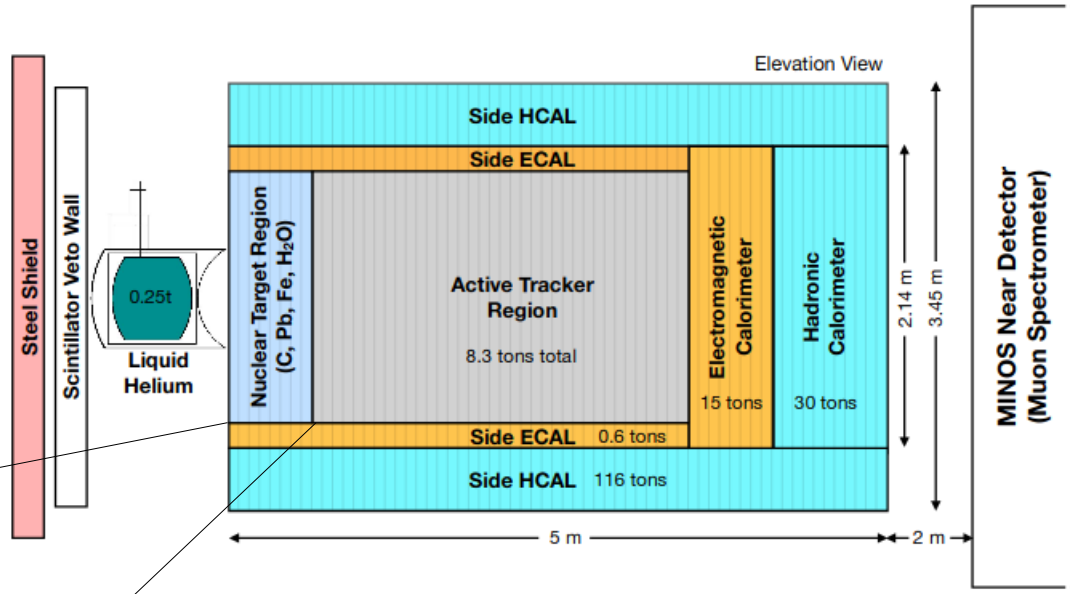


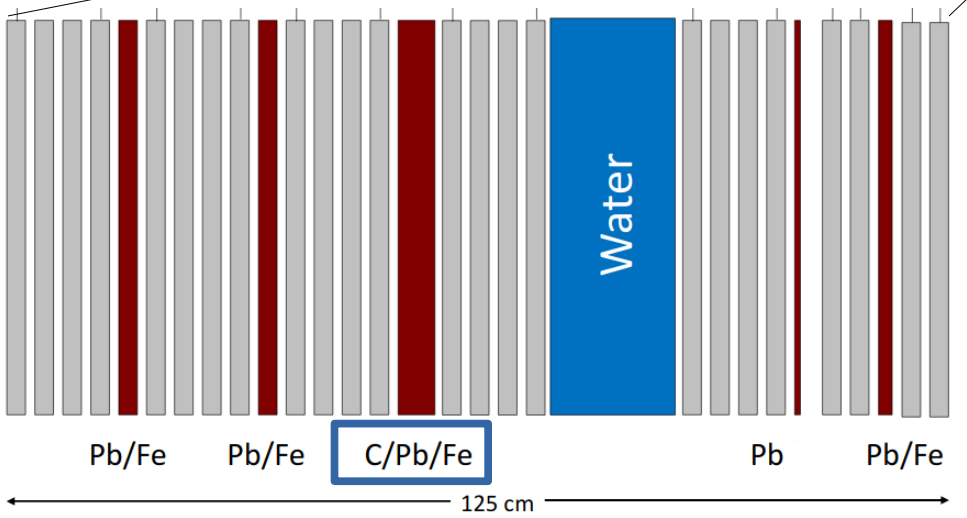
Percent missing energy Accounted for

- Neutrino oscillation experiments need to measure $\mathbf{E_\nu}$
  - Charged Current Quasi-Elastic: Just need muon
  - Calorimetric: Need all particles
- Neutrons disrupt both
  - Signal interaction on multiple nucleons
  - Missing energy
- Neutron production measurements from neutrinos rare

The MINERvA Detector

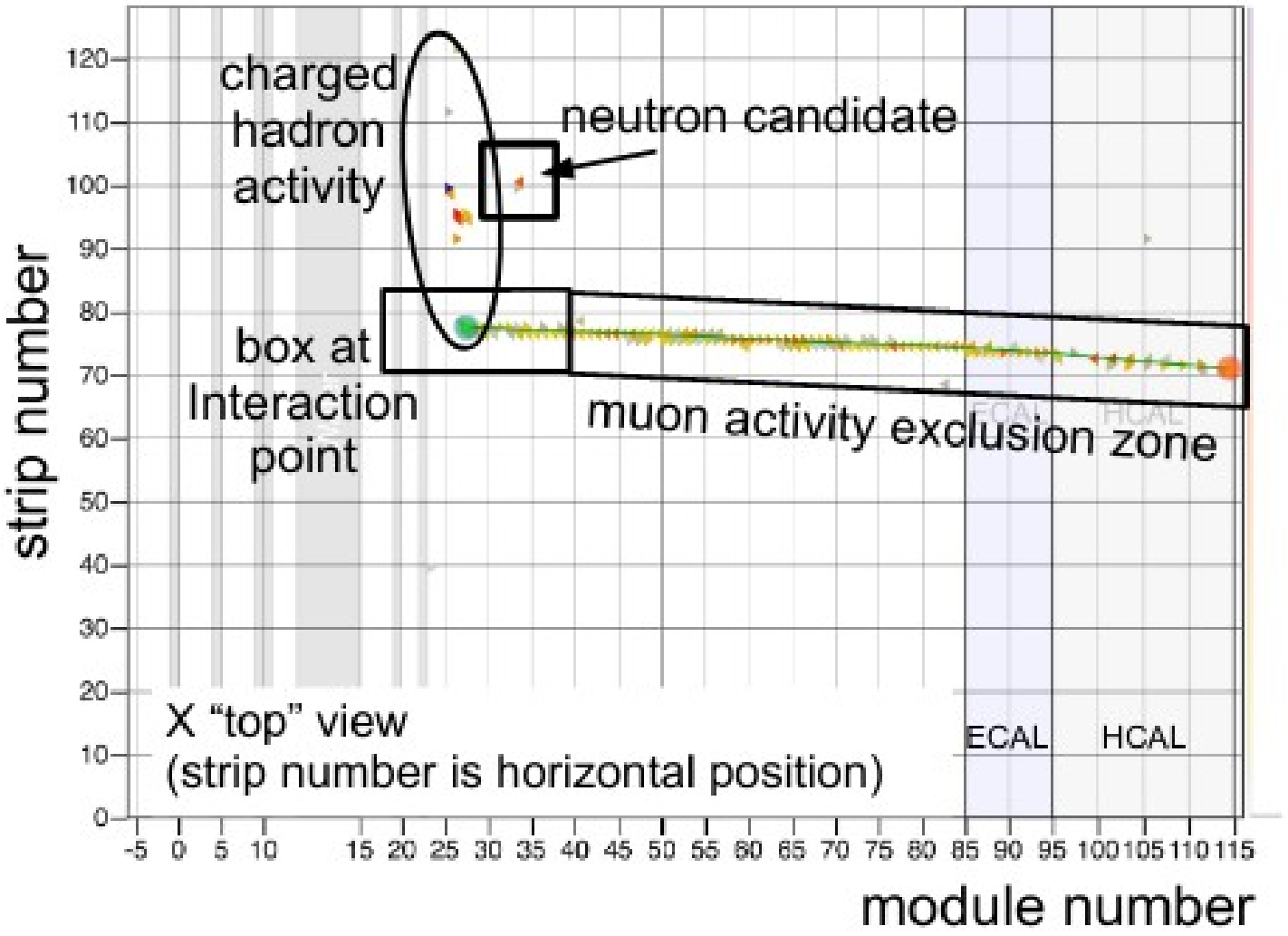
- Plastic scintillator (CH) → tracking, calorimetry
- Magnetized MINOS near detector → muons
- Sampling ECAL and HCAL





- **17mm** strips → resolution for neutrons
- 3 views → need >= 2 for 3D reconstruction

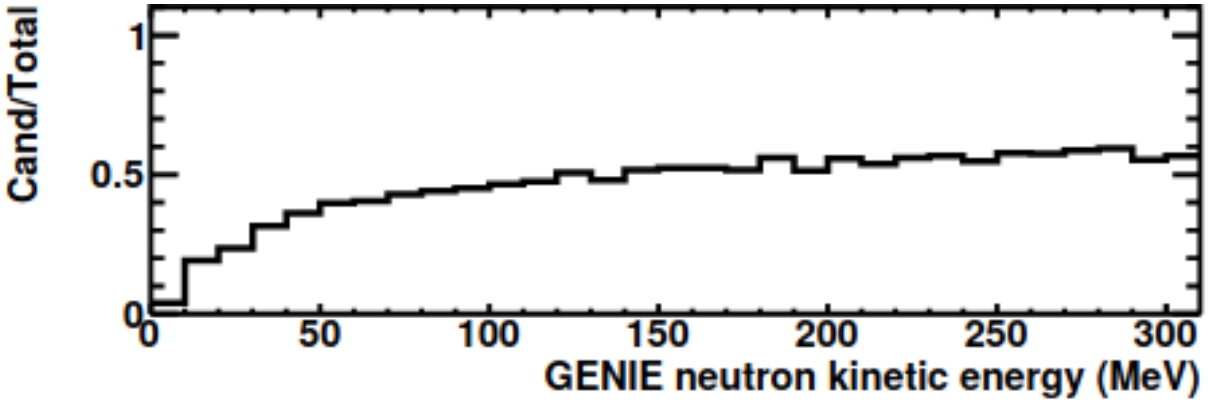
What do Neutrons Look Like?

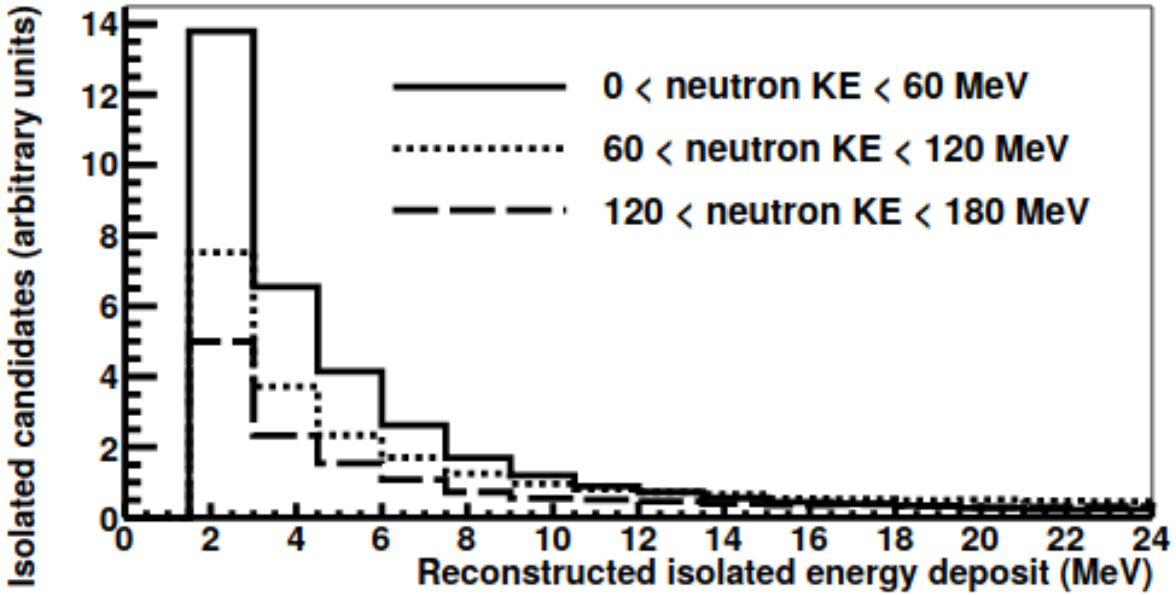


https://arxiv.org/pdf/1901.04892.pdf

- Isolated energy deposits
- Not too close to charged particle activity
- Theshold: > 1.5 MeV deposited

Neutron Reconstruction in MINERvA





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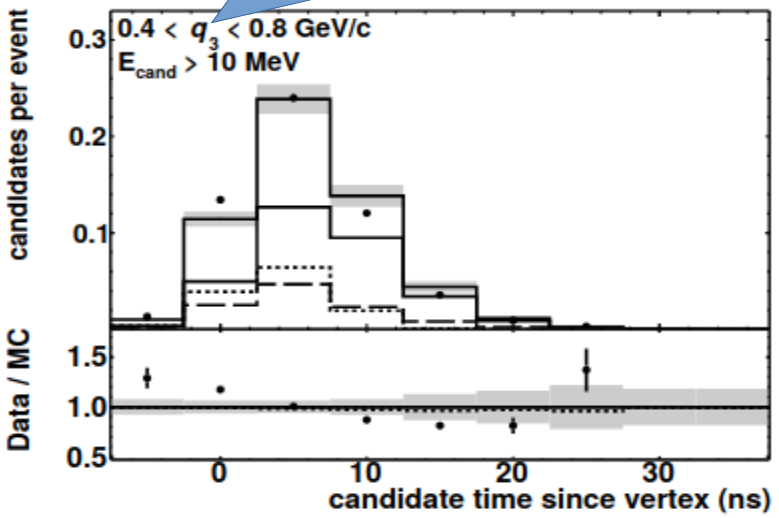
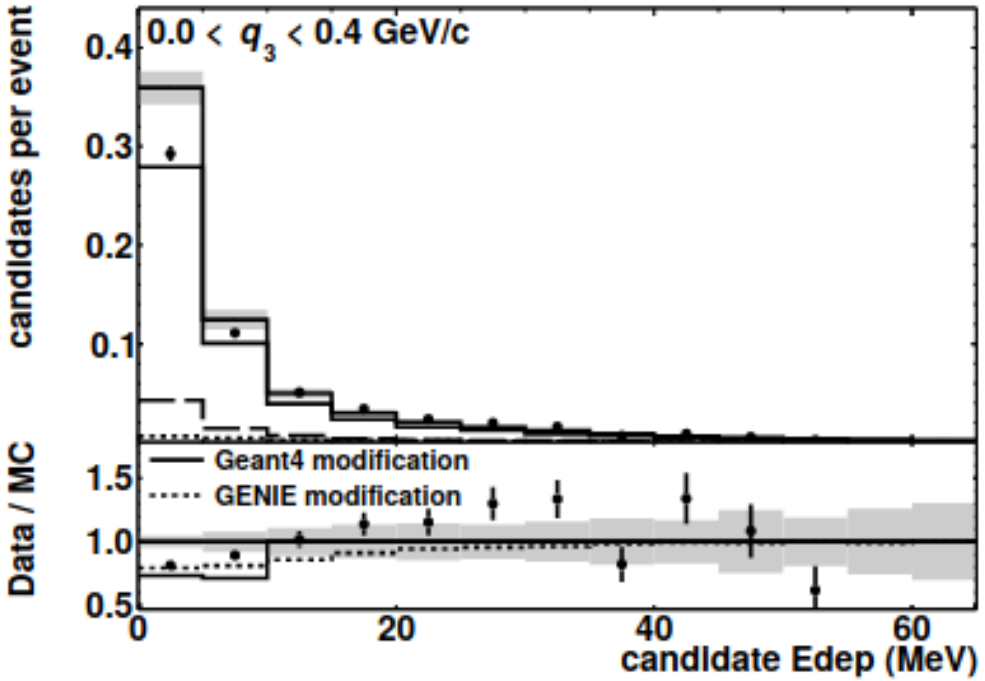
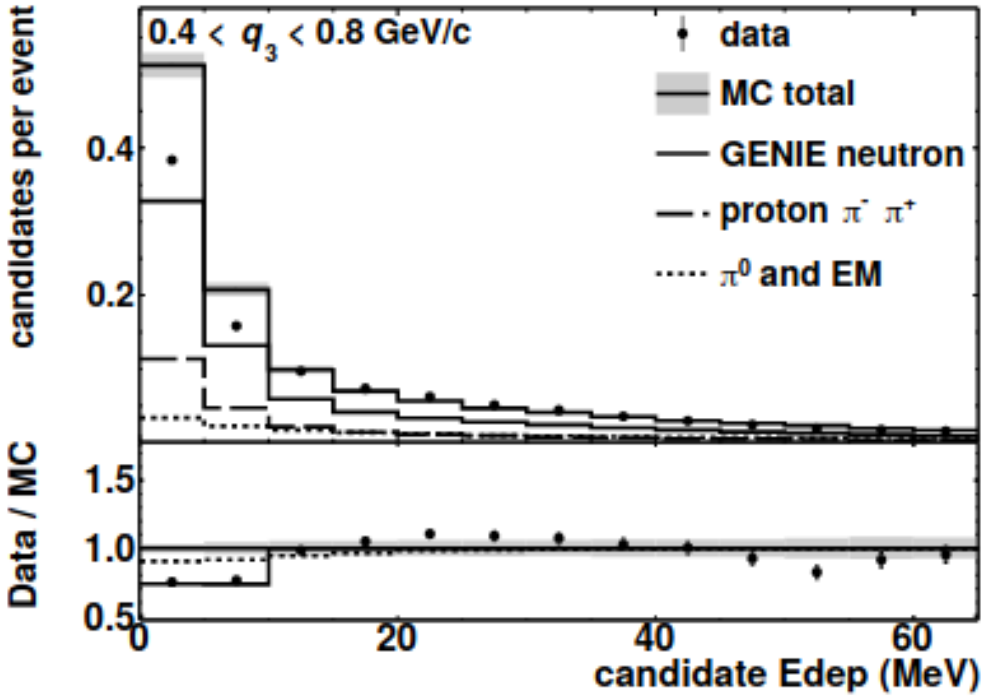
phase space constraint



- **Prompt** neutron energy deposits
- Less scattering
  - Timing
  - Direction?
- Can't get KE from edep

First Neutron Result from MINERvA



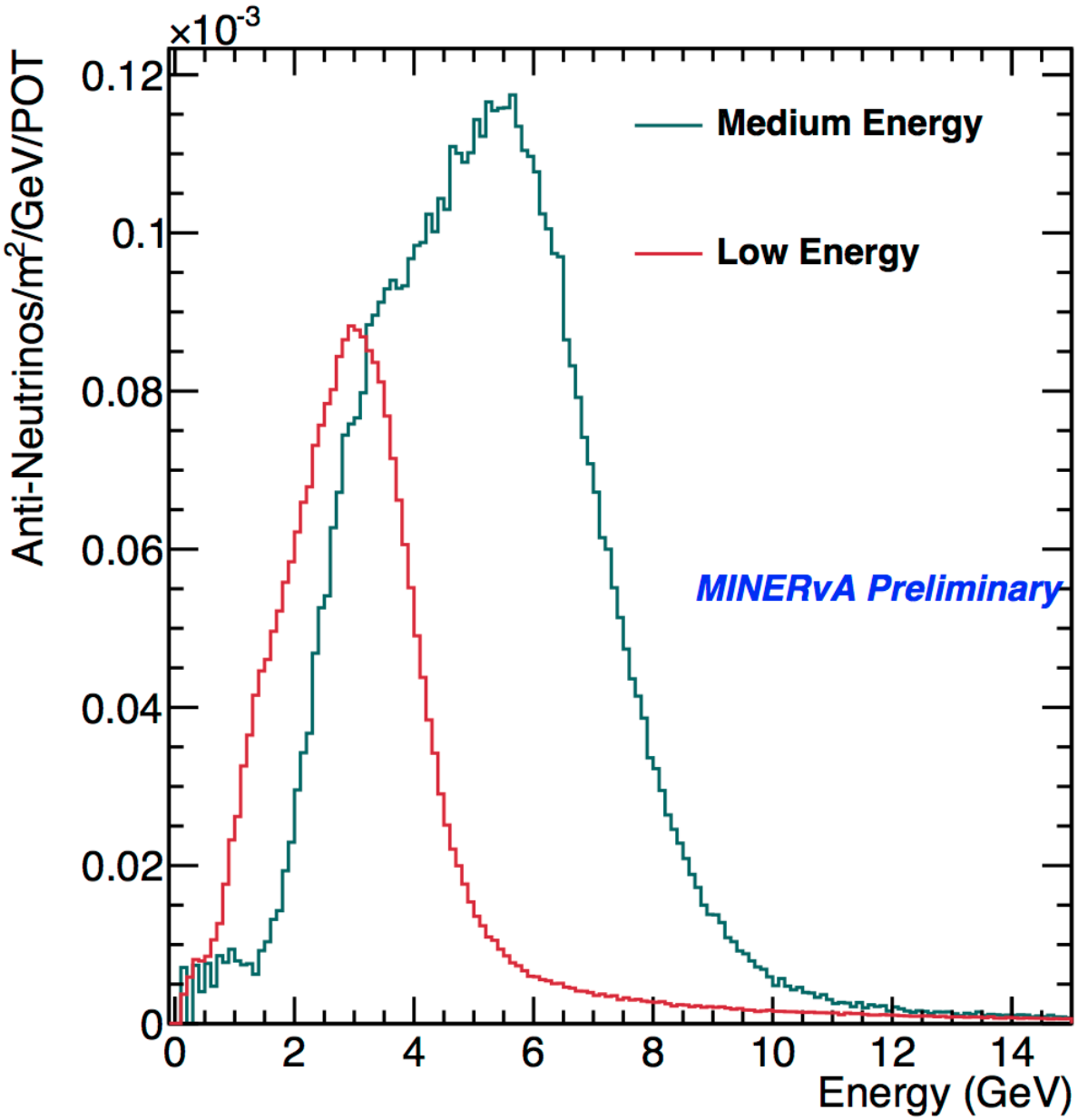


https://arxiv.org/pdf/1901.04892.pdf

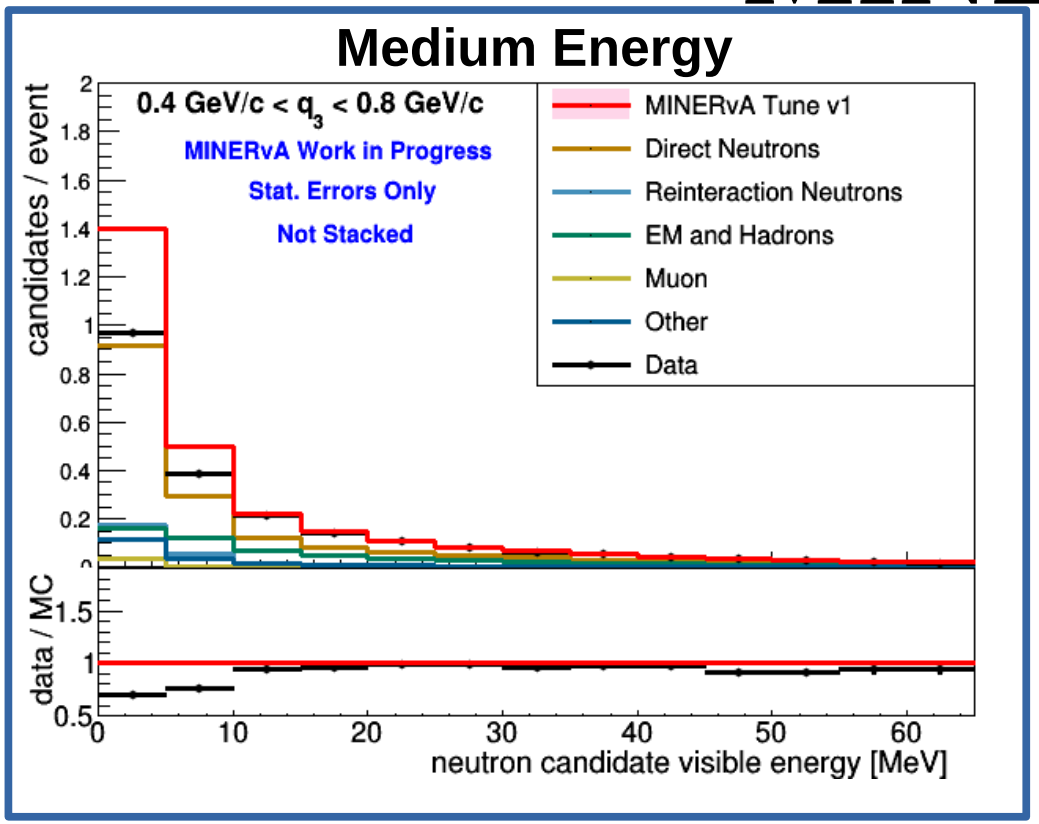
- Data/MC disagreement of undetermined origin at low edep
- Also measured relativistic β and multiplicity

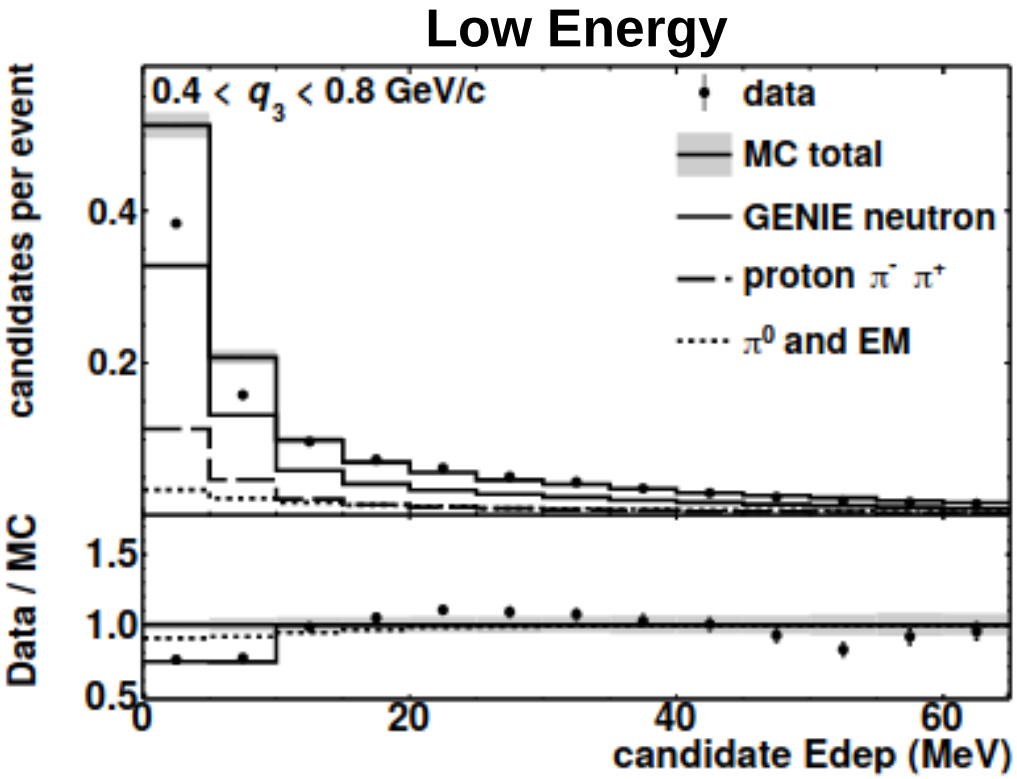
MINERvA's Datasets

- Low Energy
  - ~3 GeV beam
  - 1e20 POT
  - MINOS era
- Medium Energy
  - ~6 GeV beam
  - 12e20 POT
  - NOvA era
- More statistics in ME → more target analyses!



The Next Generation of Neutrons in MINERvA



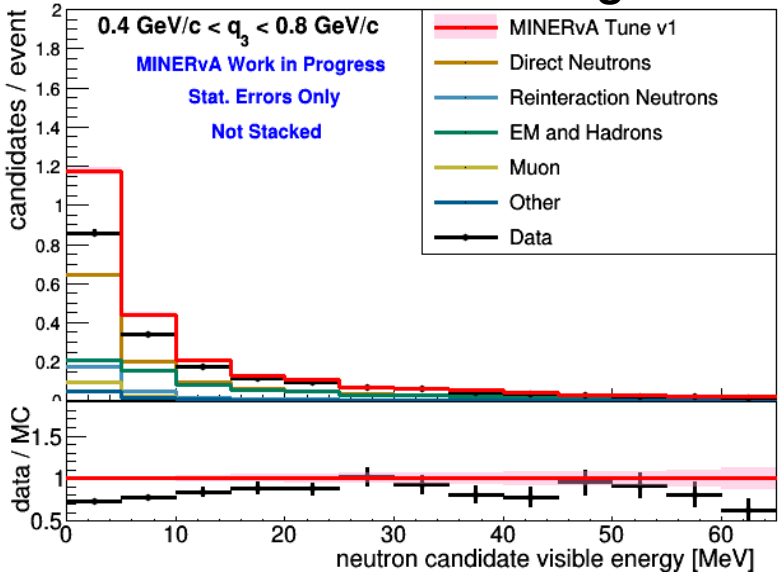


https://arxiv.org/pdf/1901.04892.pdf

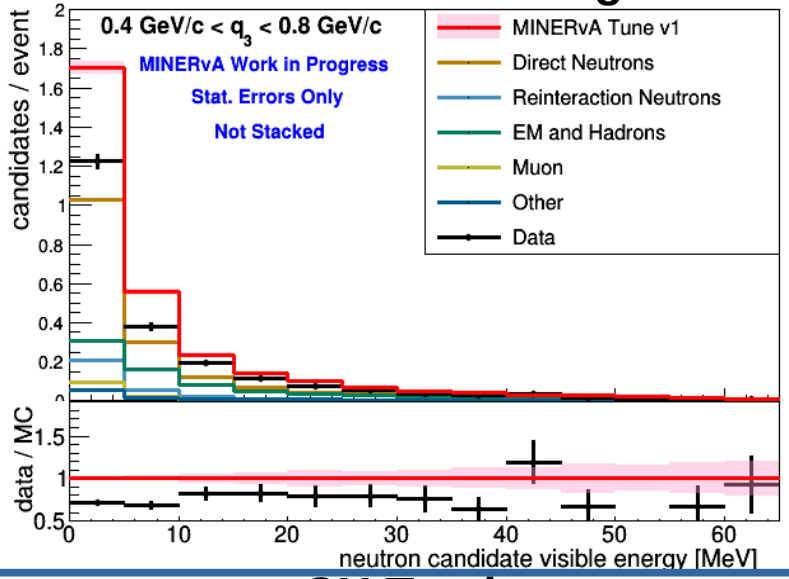
- More efficient than LE
  - New charged hadron removal
  - No vertex box
- Same data/MC trend
- Same ratio of backgrounds to FS neutrons

Neutrons from Different Nuclei

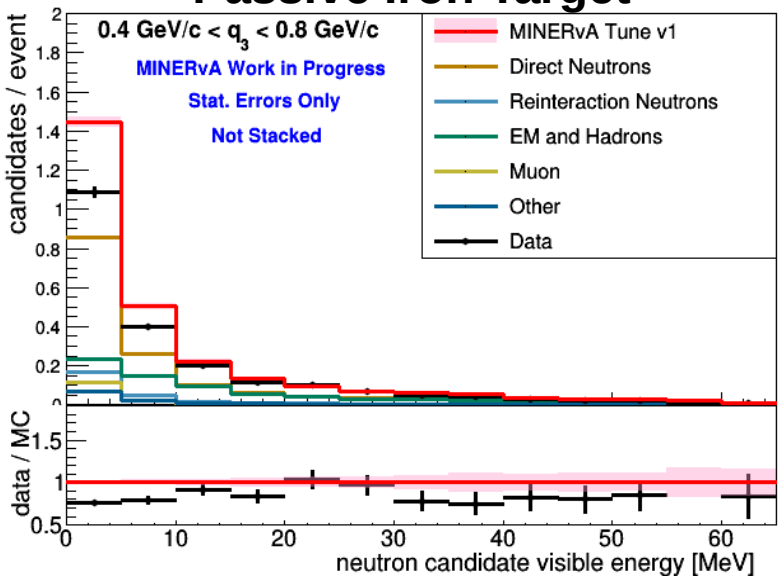
Passive Carbon Target



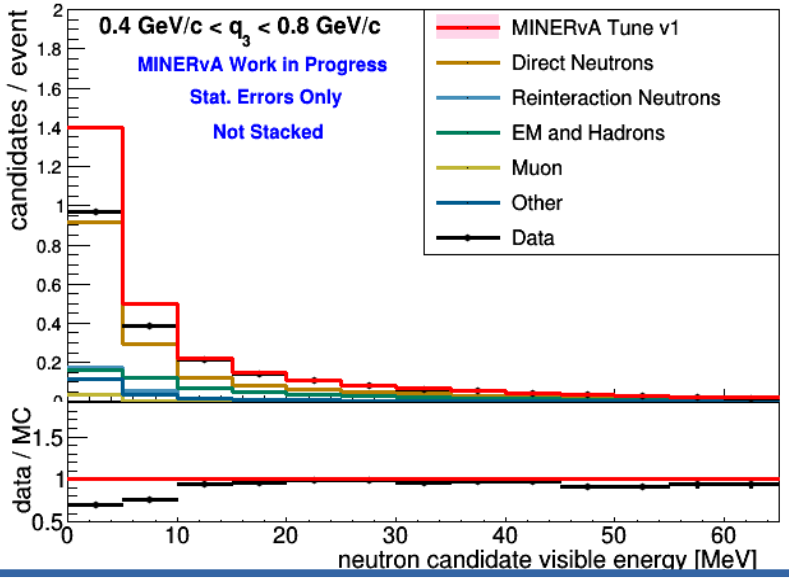
Passive Lead Target



Passive Iron Target



CH Tracker

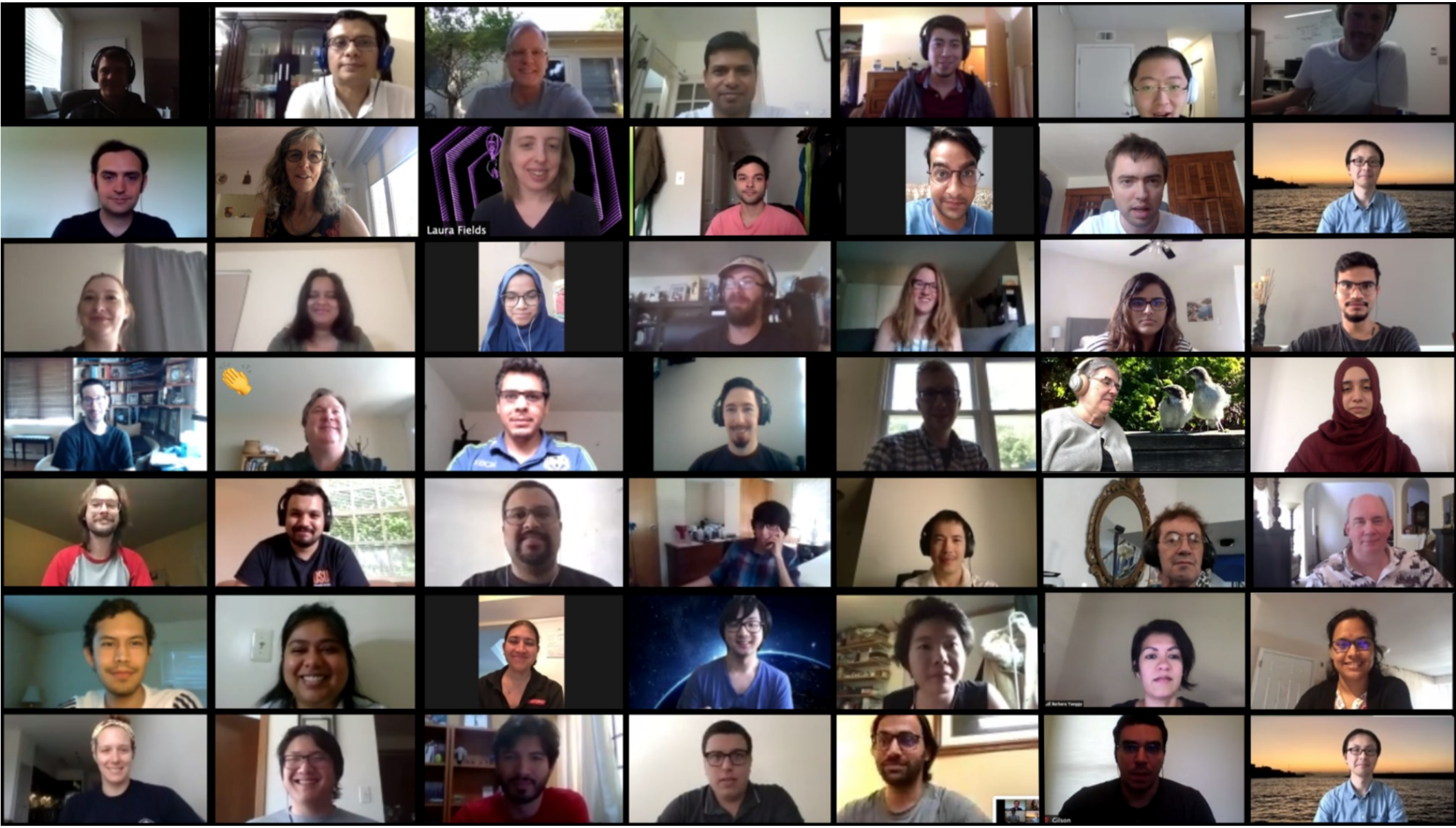


- Backgrounds bigger but still manageable
- C similar to CH
- Lead ratio different
- 7.5x data in ME!

Conclusions

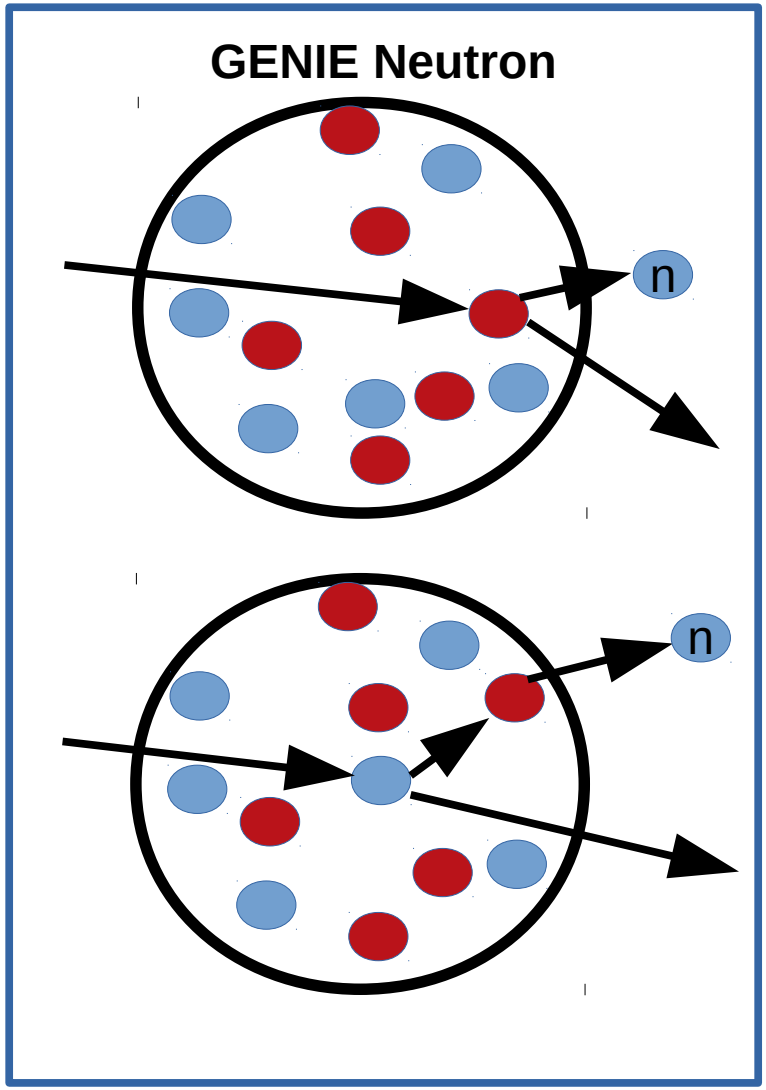
- MINERvA can count neutrons
- Low Energy data suggests need for neutron production tuning
- Can we pinpoint problematic model with Medium Energy statistics?
- Capable of studying neutron production in **carbon**, **iron**, and **lead** with same detector

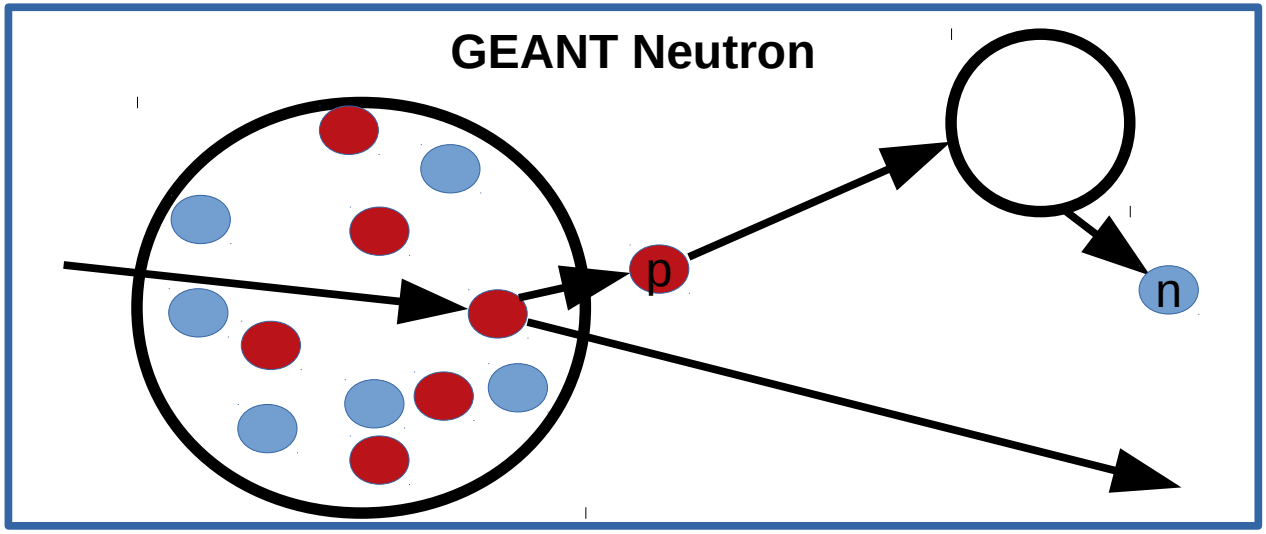
Thank You



Backup Slides Follow

What are GEANT Neutrons?





- GENIE neutrons probe neutrino kinematics
- GEANT neutrons irreducible background
- Other particles can be mis-reconstructed as neutrons
  - π^0s
  - Brehmstrahlung from muon
  - Low momentum charged pions
  - NC interactions