

Neutrons from MINERvA's Nuclear Targets

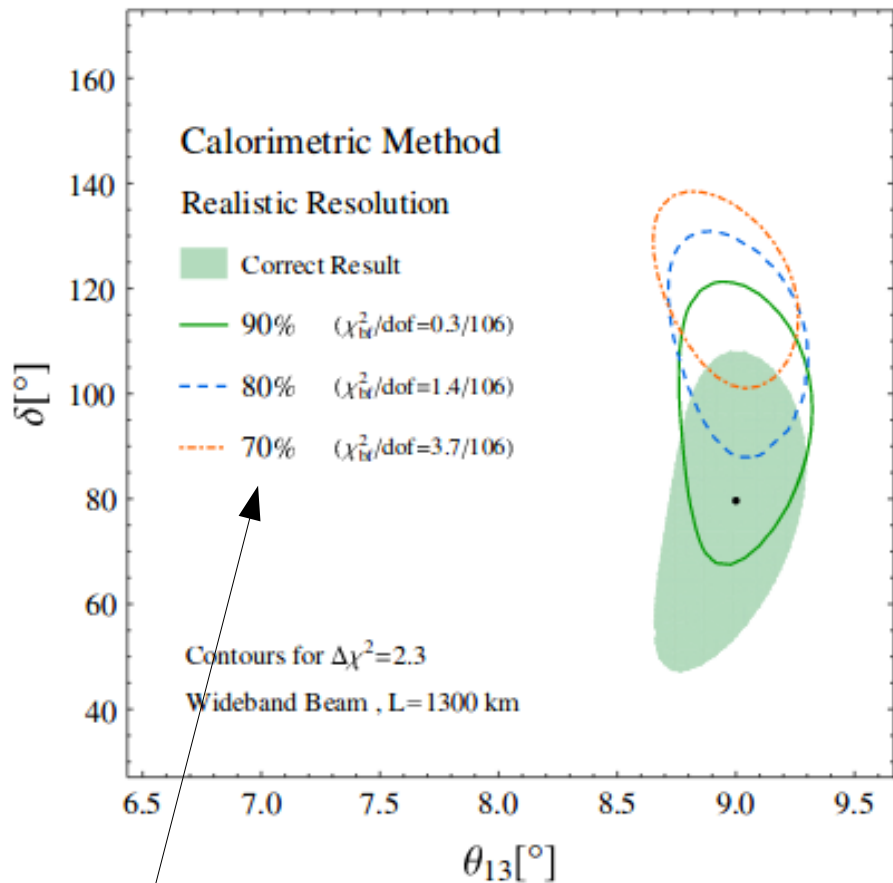
Andrew Olivier
for the MINERvA Collaboration
New Perspectives 2020

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Why Neutrons from Neutrinos?

PHYSICAL REVIEW D 92, 091301(R) (2015)

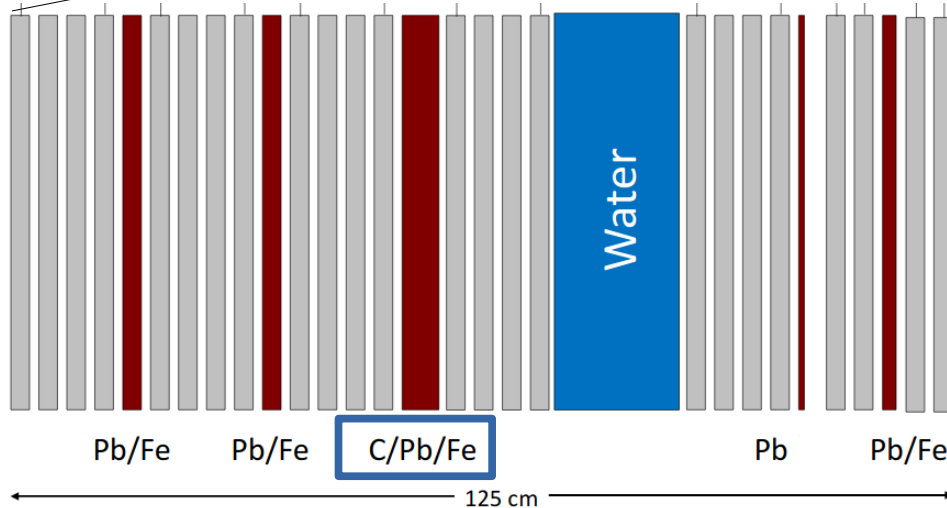
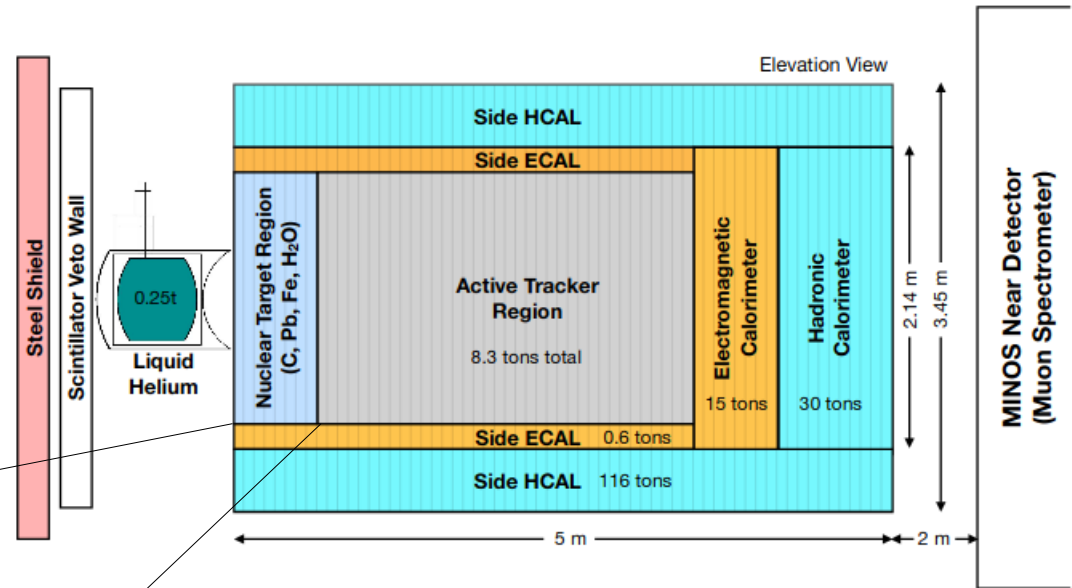


Percent missing energy
Accounted for

- Neutrino oscillation experiments need to measure E_ν
 - 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

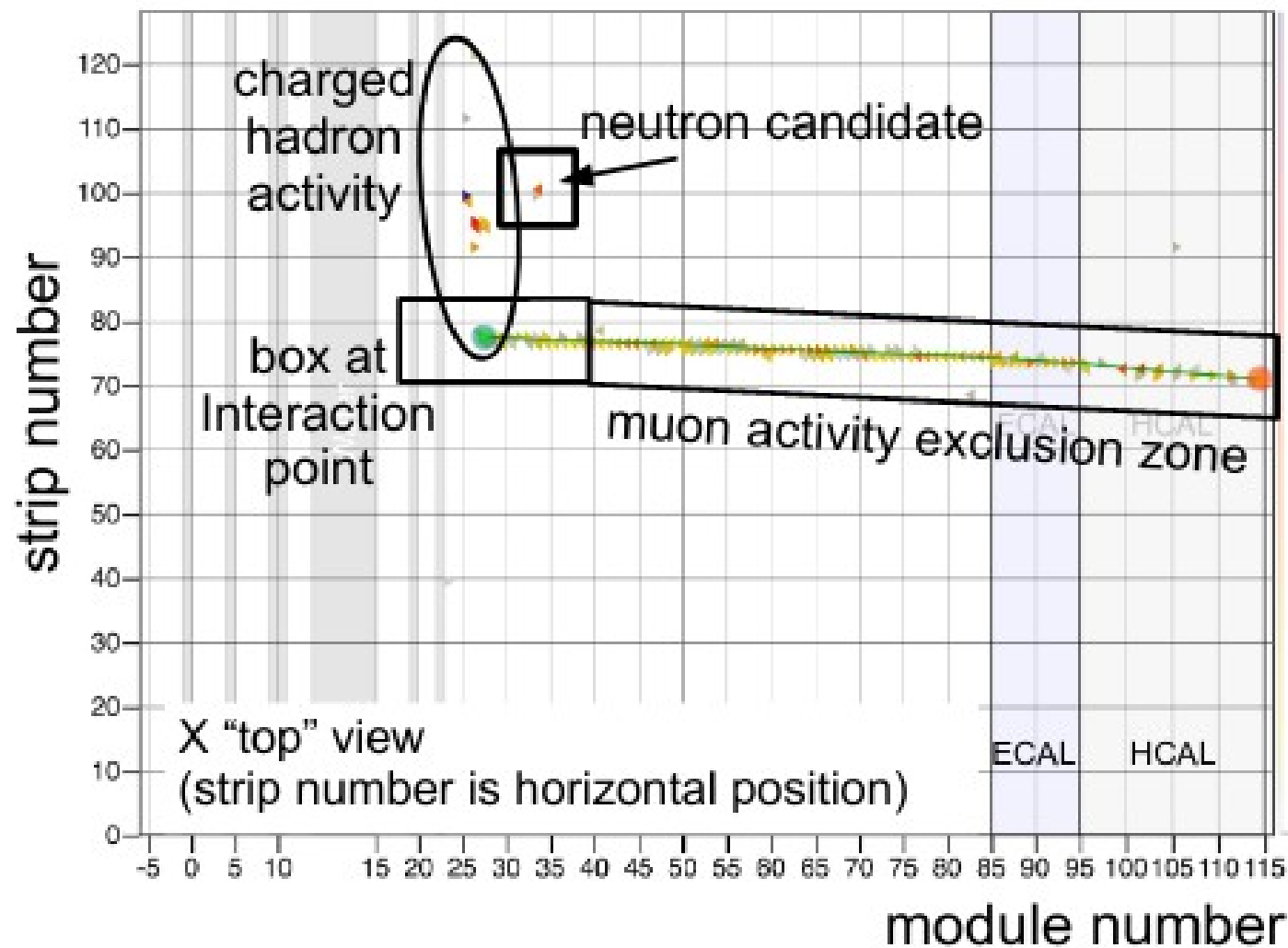
The MINERvA Detector

- 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?



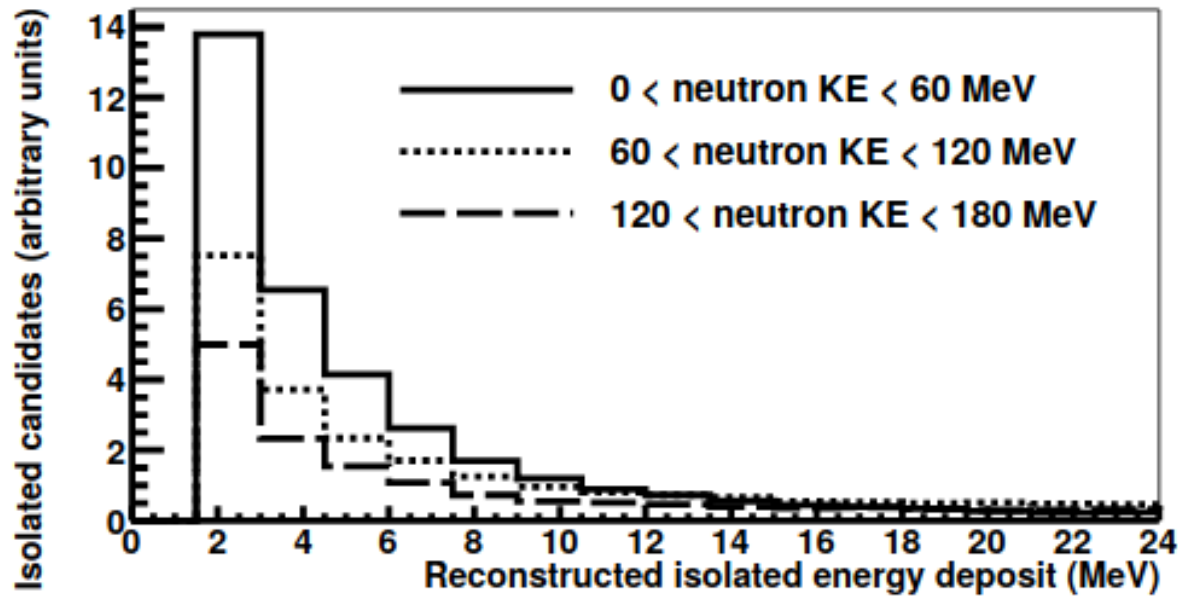
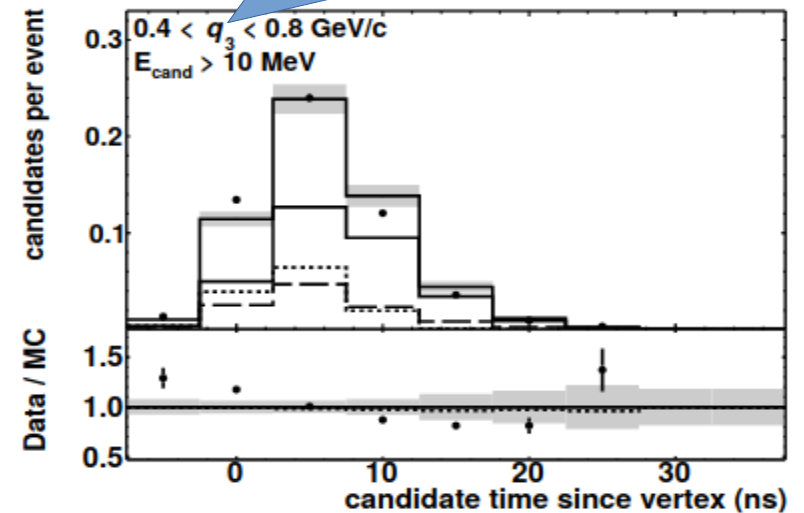
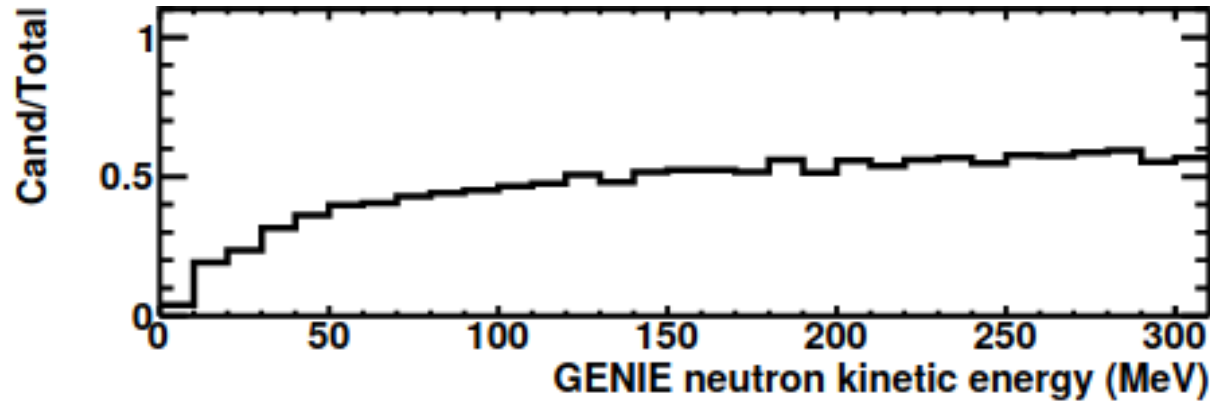
<https://arxiv.org/pdf/1901.04892.pdf>

- Isolated energy deposits
- Not too close to charged particle activity
- Threshold: $> 1.5 \text{ MeV}$ deposited



Neutron Reconstruction in MINERvA

phase space constraint

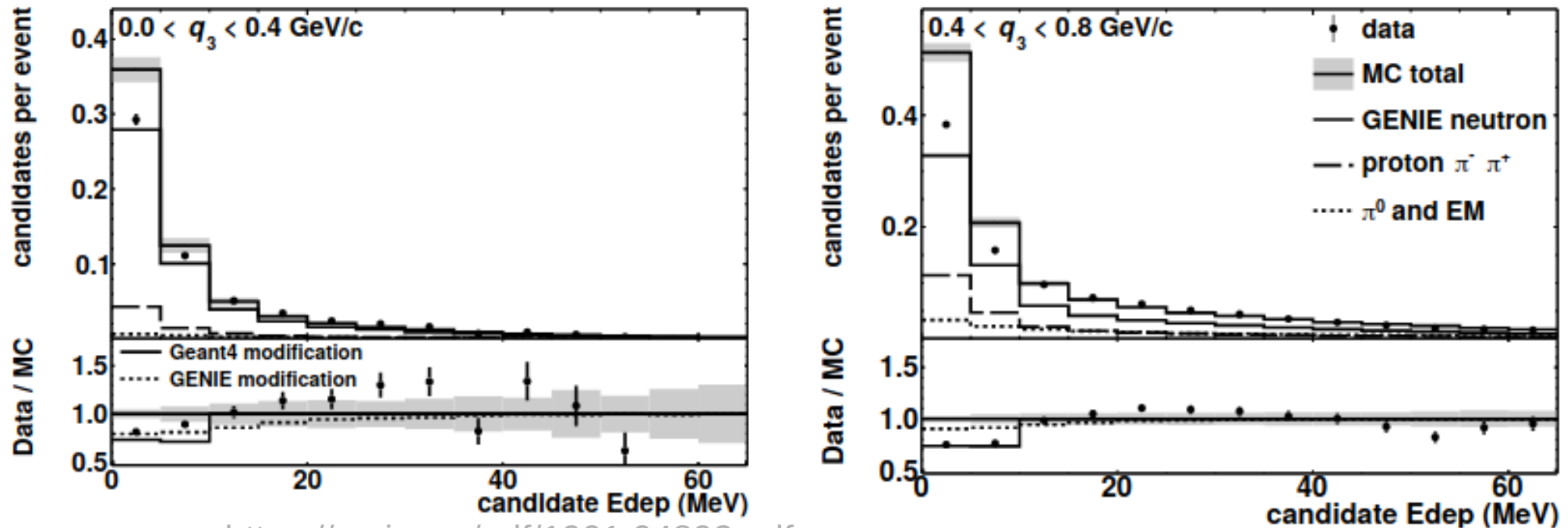


- **Prompt** neutron energy deposits
- Less scattering
 - Timing
 - Direction?
- Can't get KE from edep

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



First Neutron Result from MINERvA



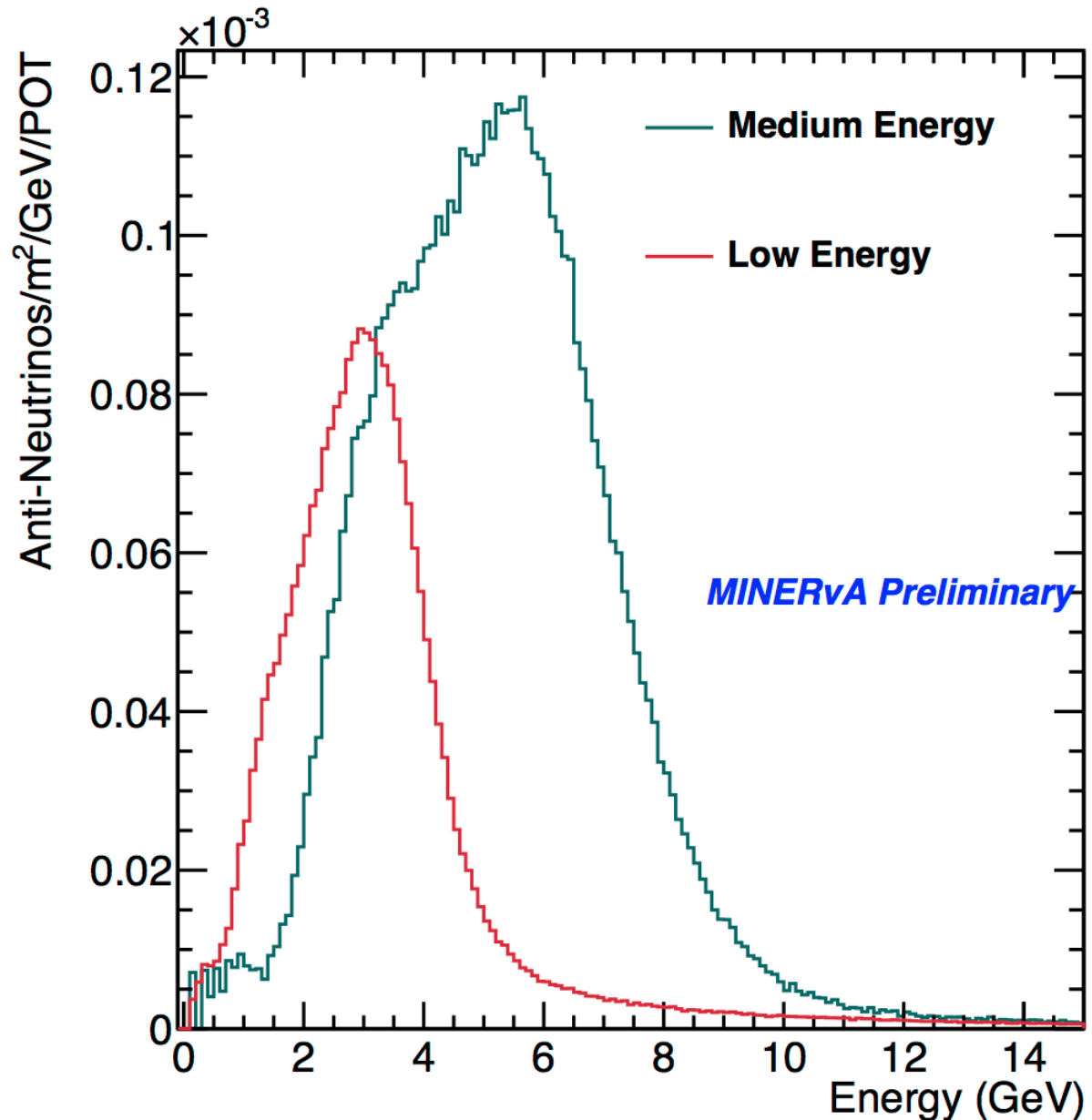
<https://arxiv.org/pdf/1901.04892.pdf>

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

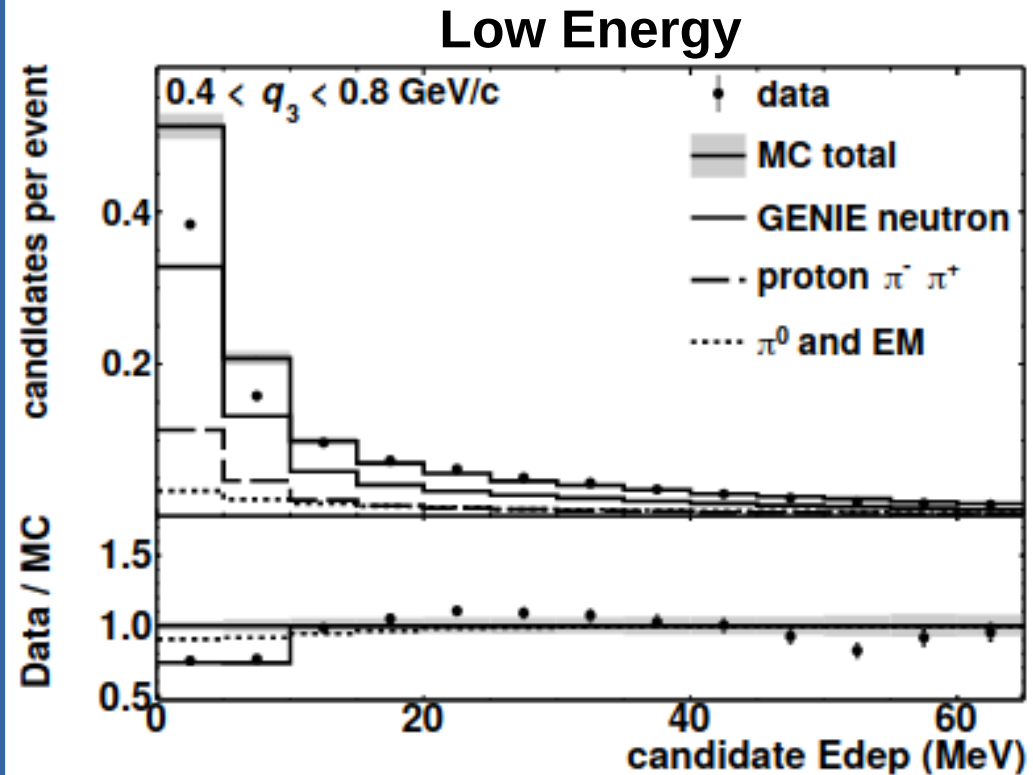
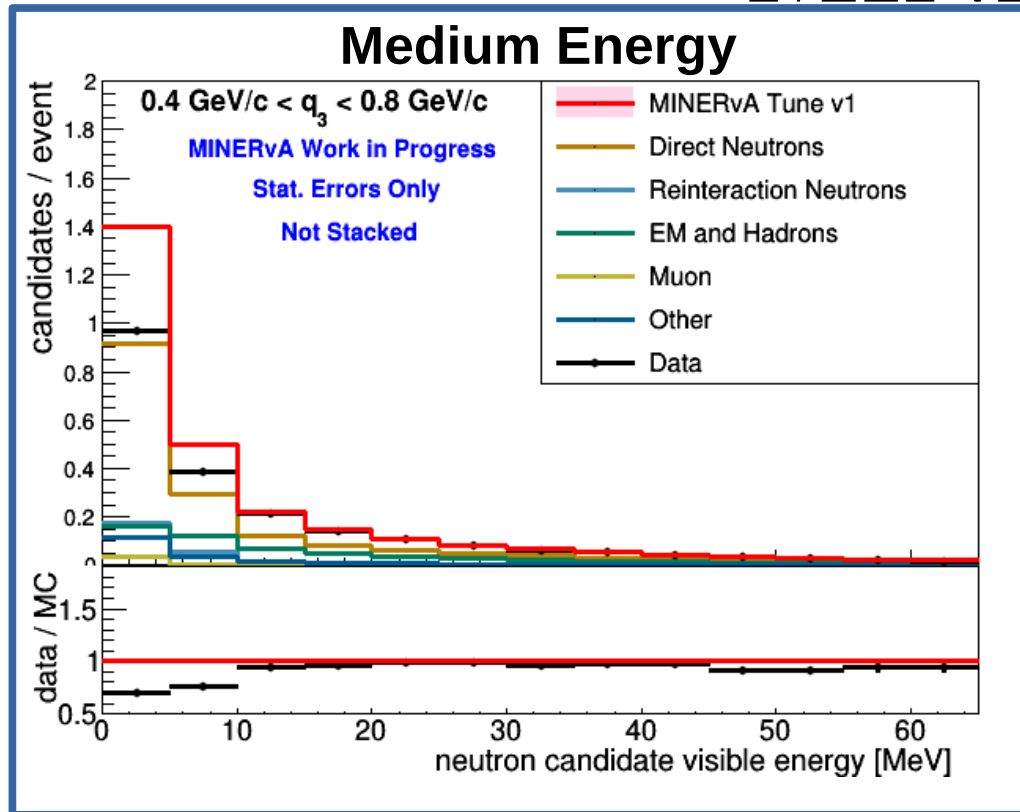


MINERvA's Datasets

- 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



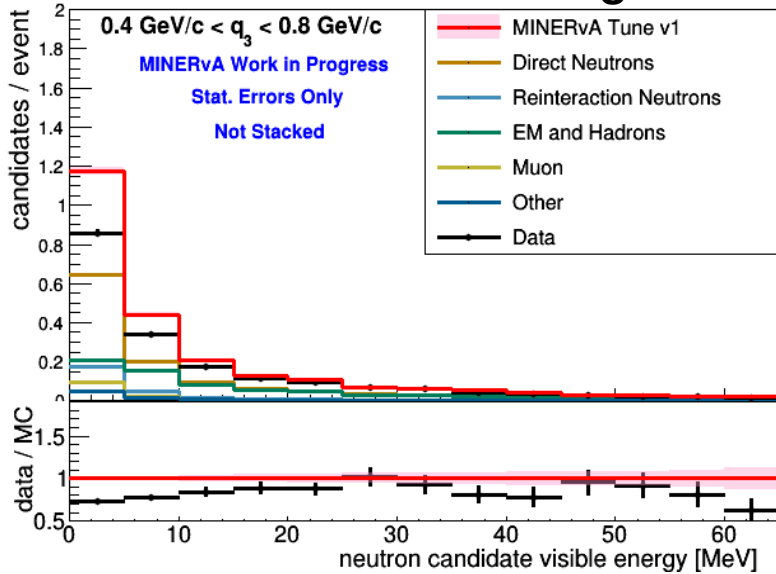
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- More efficient than LE
 - New charged hadron removal
 - No vertex box
- Same data/MC trend
- Same ratio of backgrounds to FS neutrons

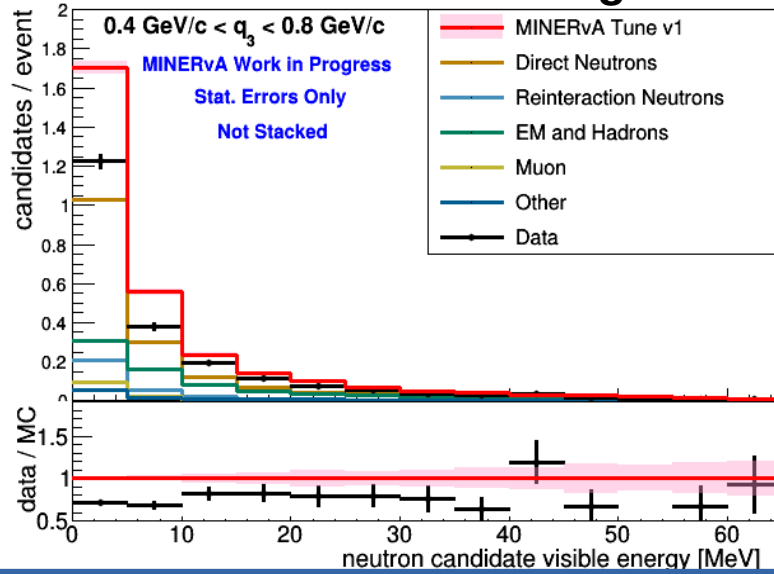


Neutrons from Different Nuclei

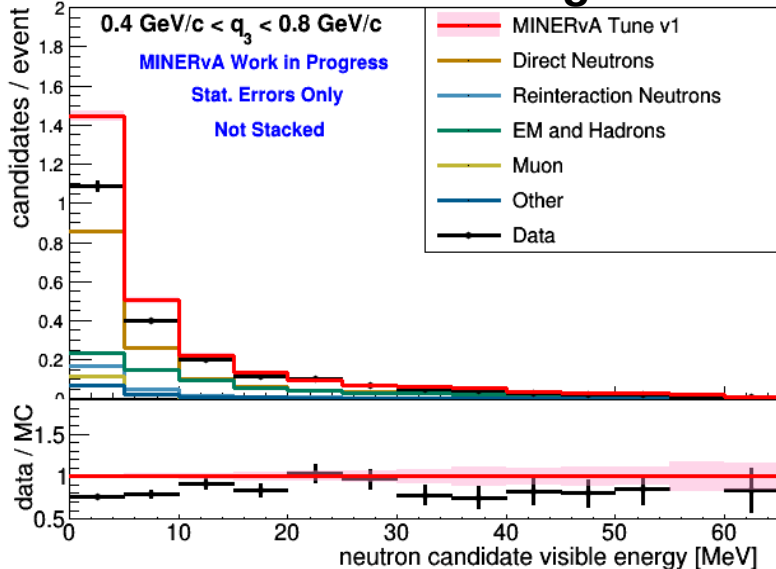
Passive Carbon Target



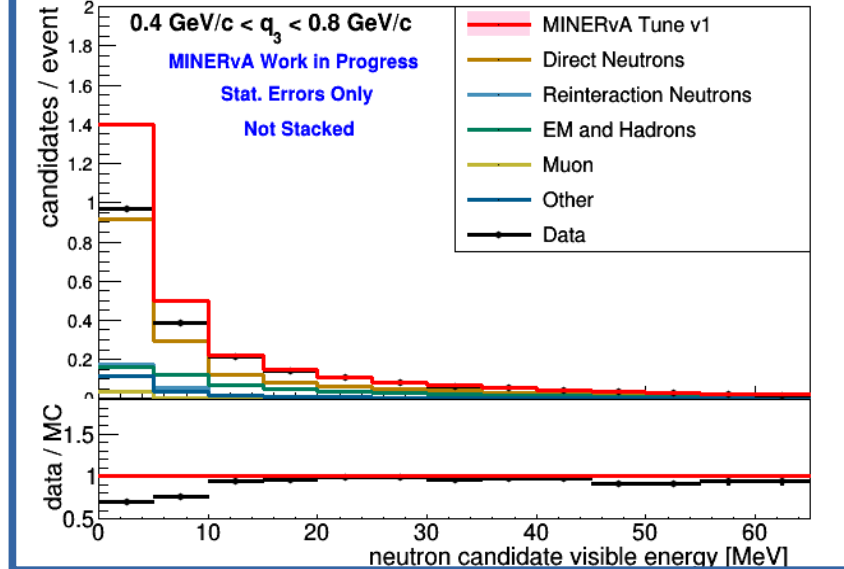
Passive Lead Target



Passive Iron Target



CH Tracker



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

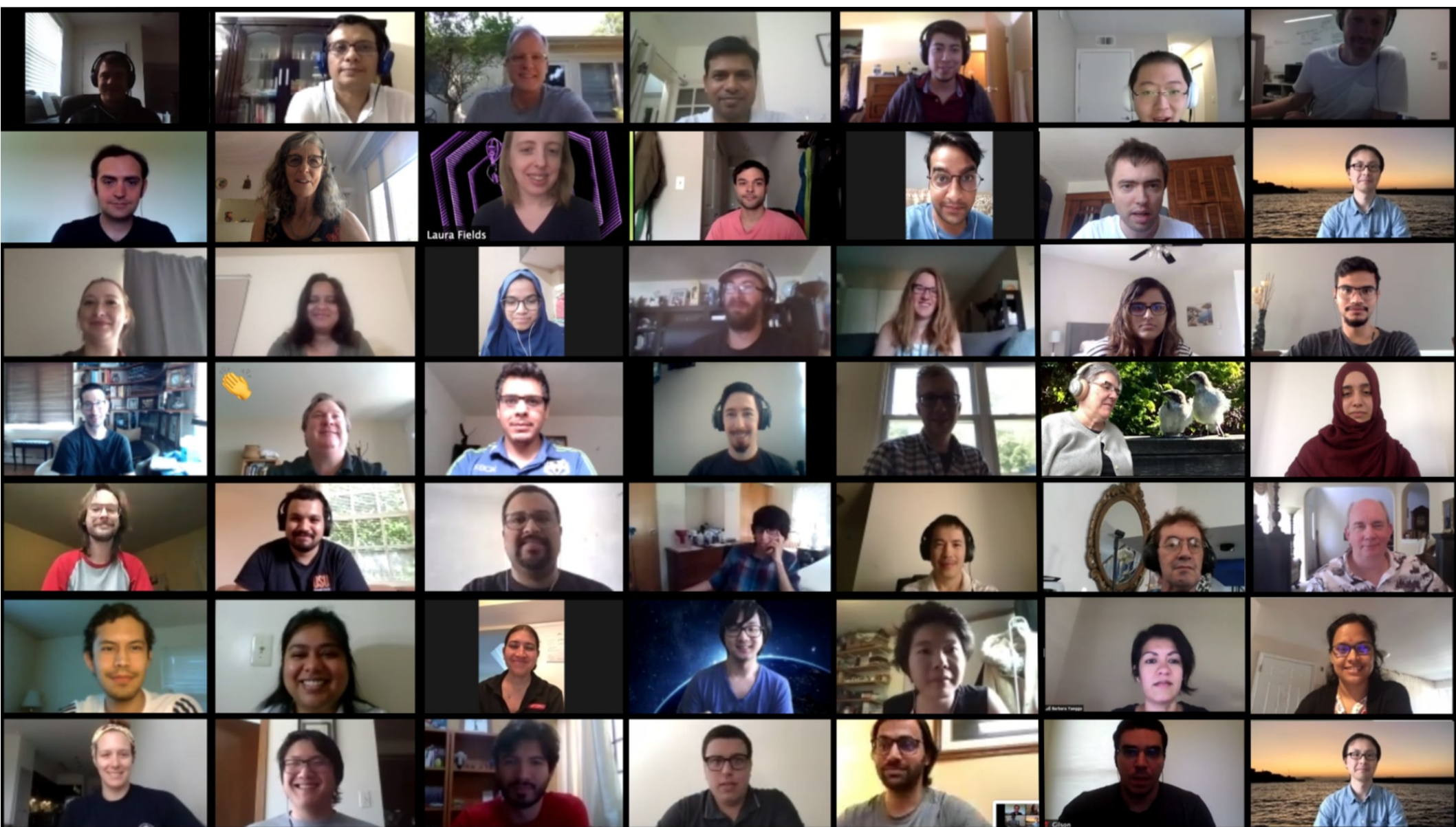


Conclusions

- 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

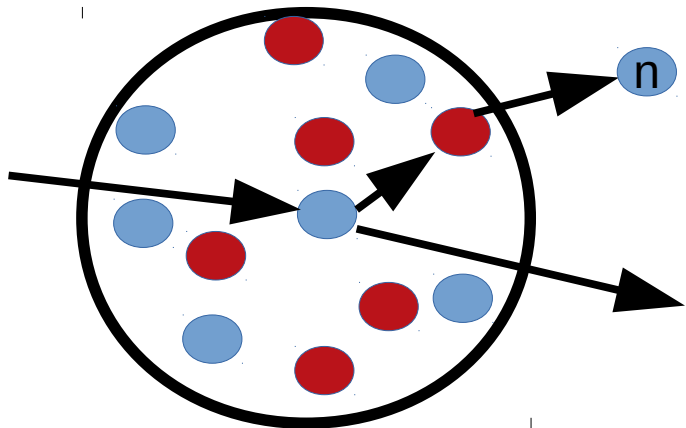
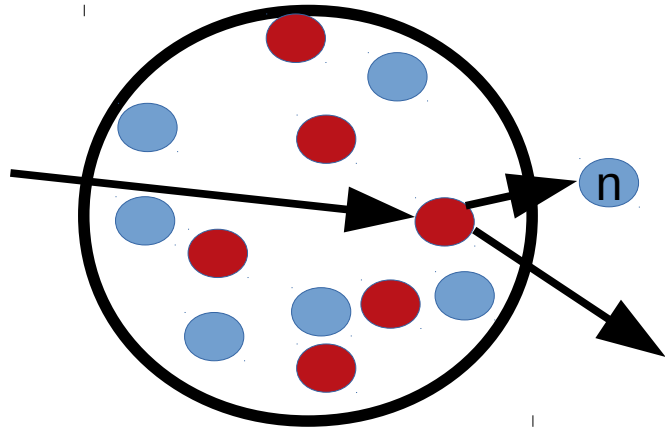


Backup Slides Follow

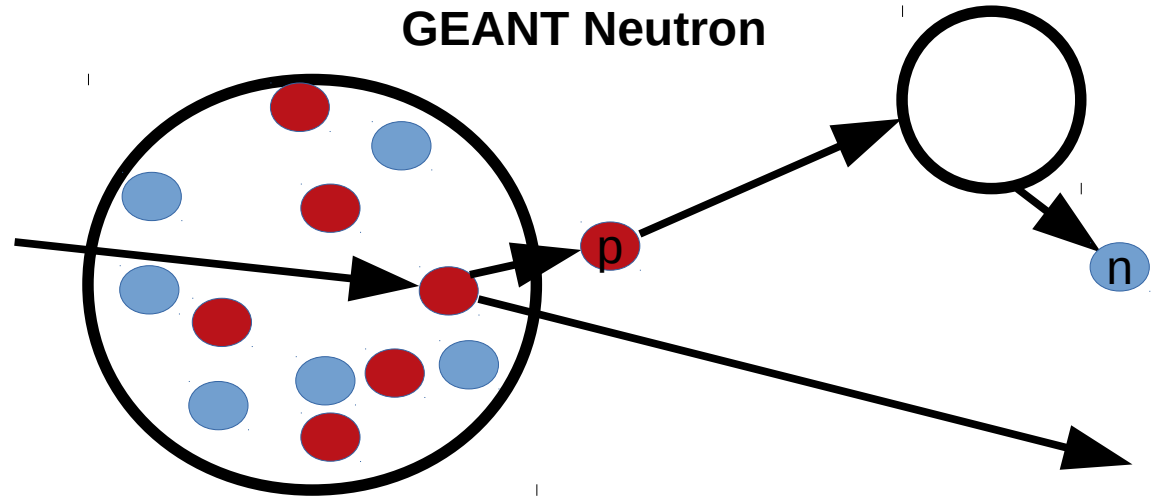


What are GEANT Neutrons?

GENIE Neutron



GEANT Neutron



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