Neutron Counting: recent MINERvA results and implications for DUNE ND

S. Manly (showing results from
MINERvA Collaboration)
DUNE ND workshop
CERN
Nov. 6, 2017

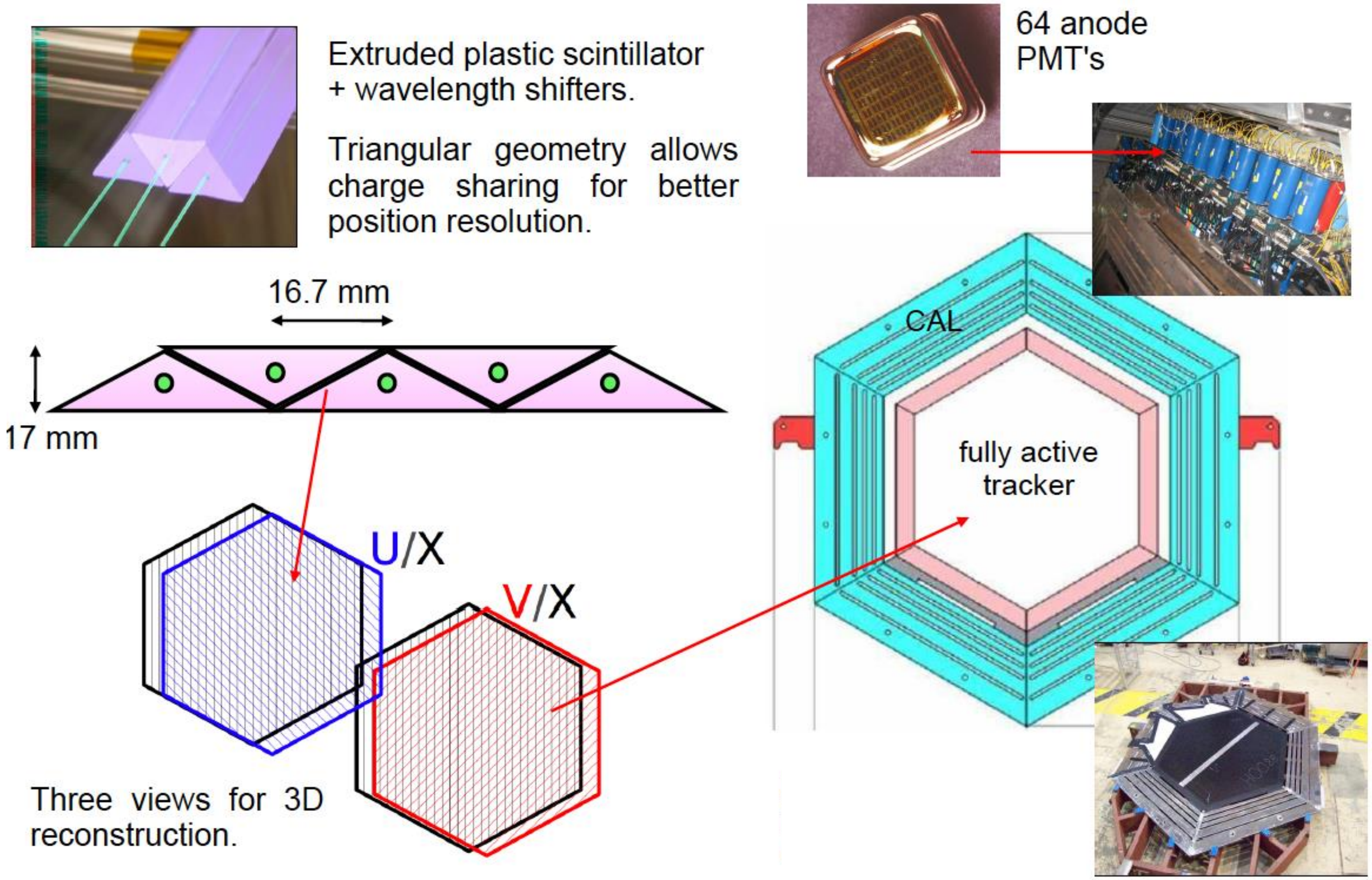
Summary of a fraction of MINERvA results presented at Fermilab Wine and Cheese talk last Friday by Rik Gran

Neutrons, why do we care?

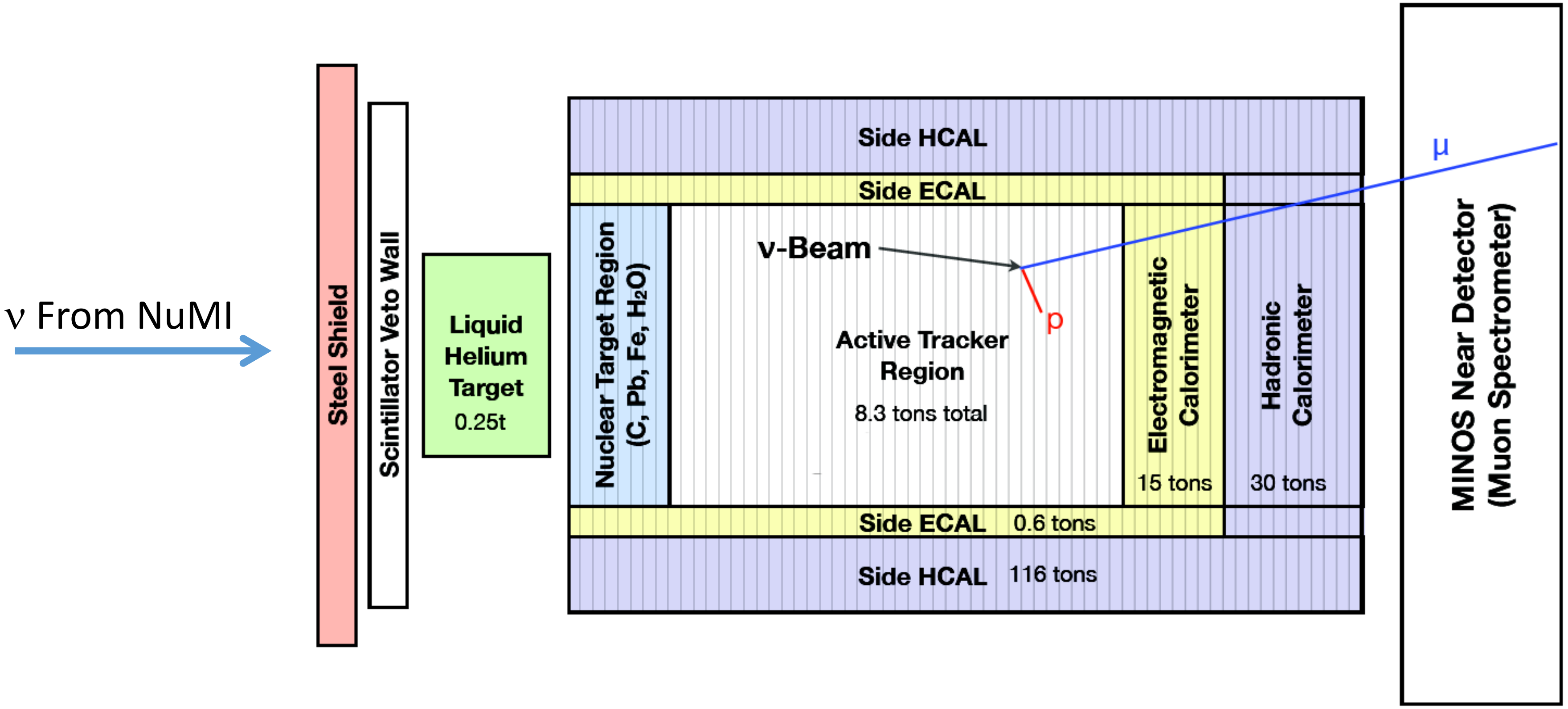
- CCQE – simple lepton-based energy reconstruction has low-side bias in reconstruction with multi-nucleon processes (2p2h), presence of neutrons might tag issues
- Other topologies, helpful to know if neutrons
- DUNE FD not sensitive to neutrons (or not very)
  - How does that hurt us?
  - How well can we model the effect, i.e., (what size of systematic bites us)?
- Presence of unreconstructed neutrons can hurt ability to use pT to separate CC from NC (See C.Marshall talk at March 2017 DUNE ND meeting, a couple of slides in backup)
- Recent MINERvA tune to data set wants RPA and 2p2h (see Rik's talk)
- For DUNE ND
  - STT and GArTPC not sensitive to neutrons
  - May be able to tag neutrons with info from ECAL. Can this be done with slow detector?
  - Can 3DST give us some sensitivity to neutrons?

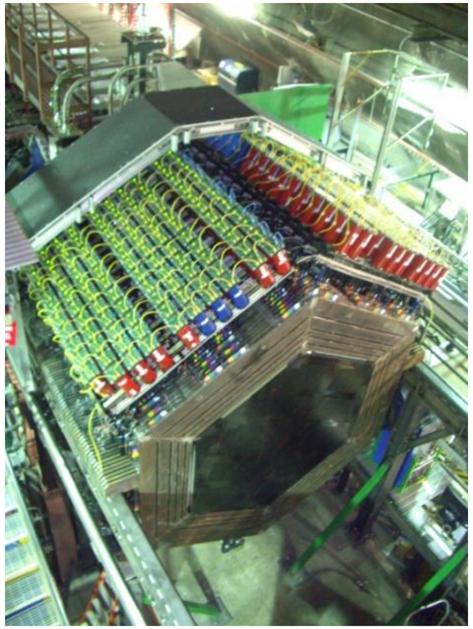
The detector

MINERνA "modules"



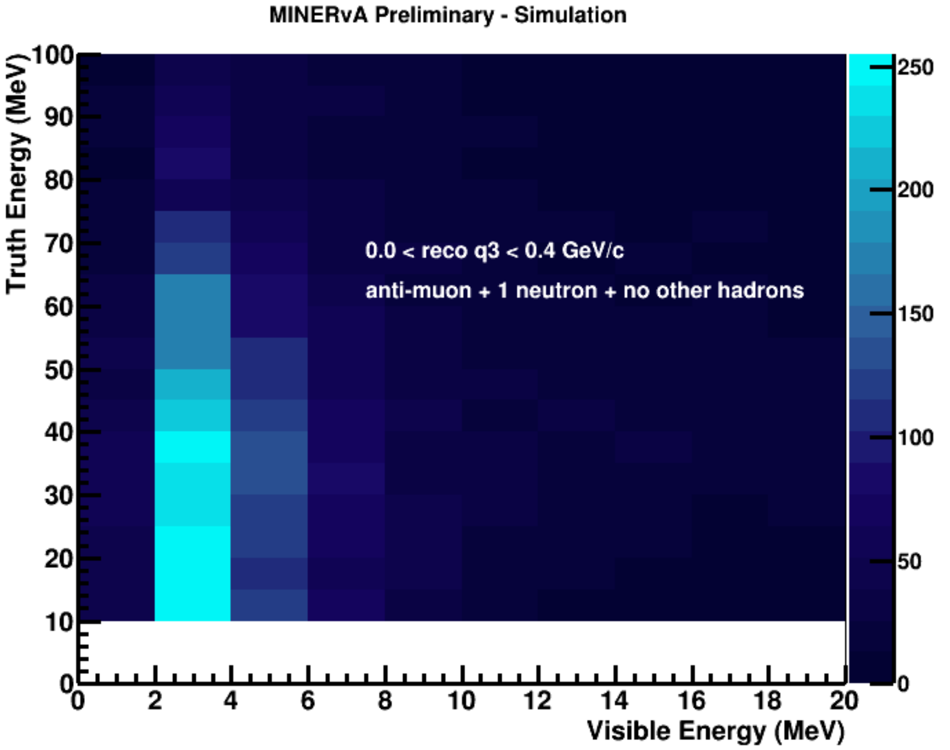
The detector

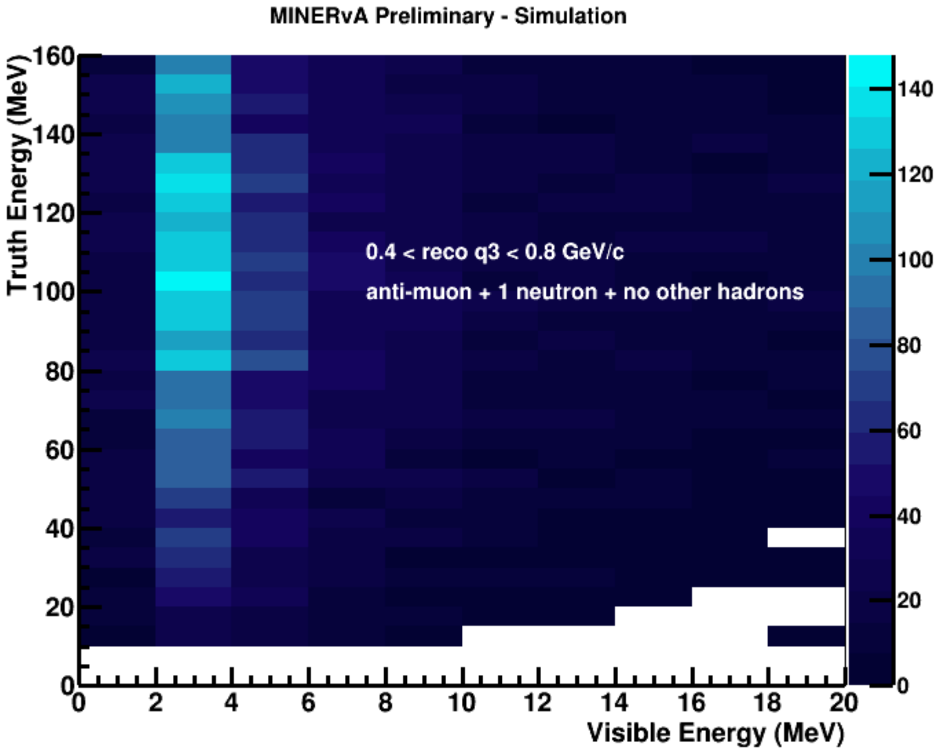




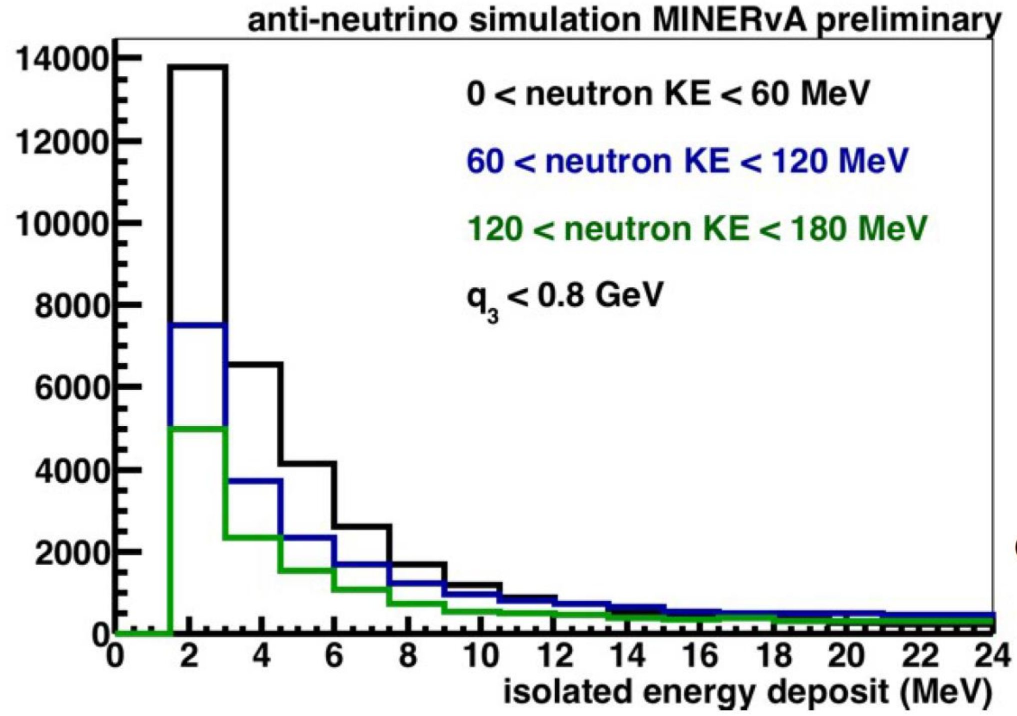
What does MINERvA see according to GEANT4?

Different bins of momentum transfer





Neutron of all energies leave small energy deposits

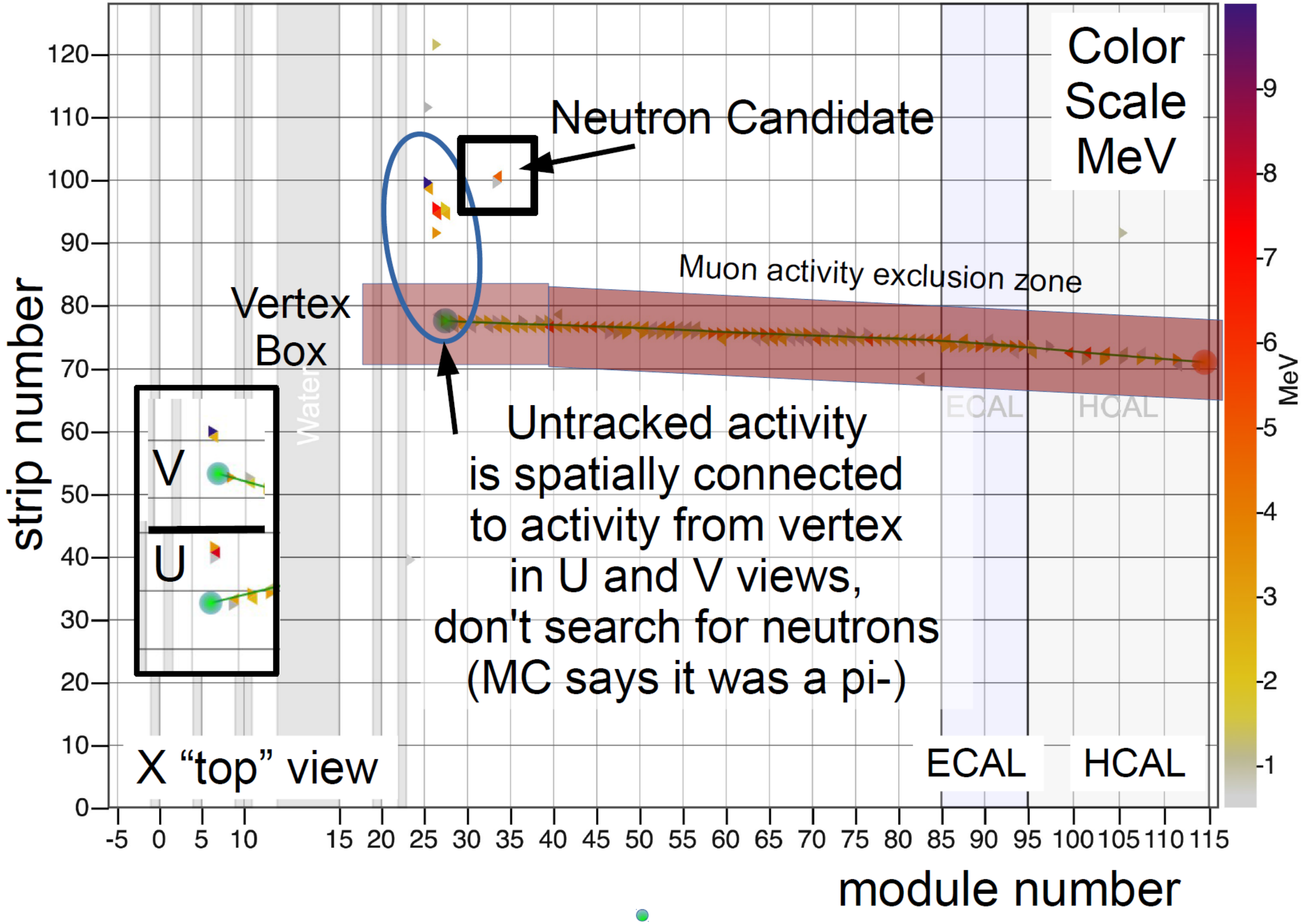


Selection keeps only E > 1.5 MeV

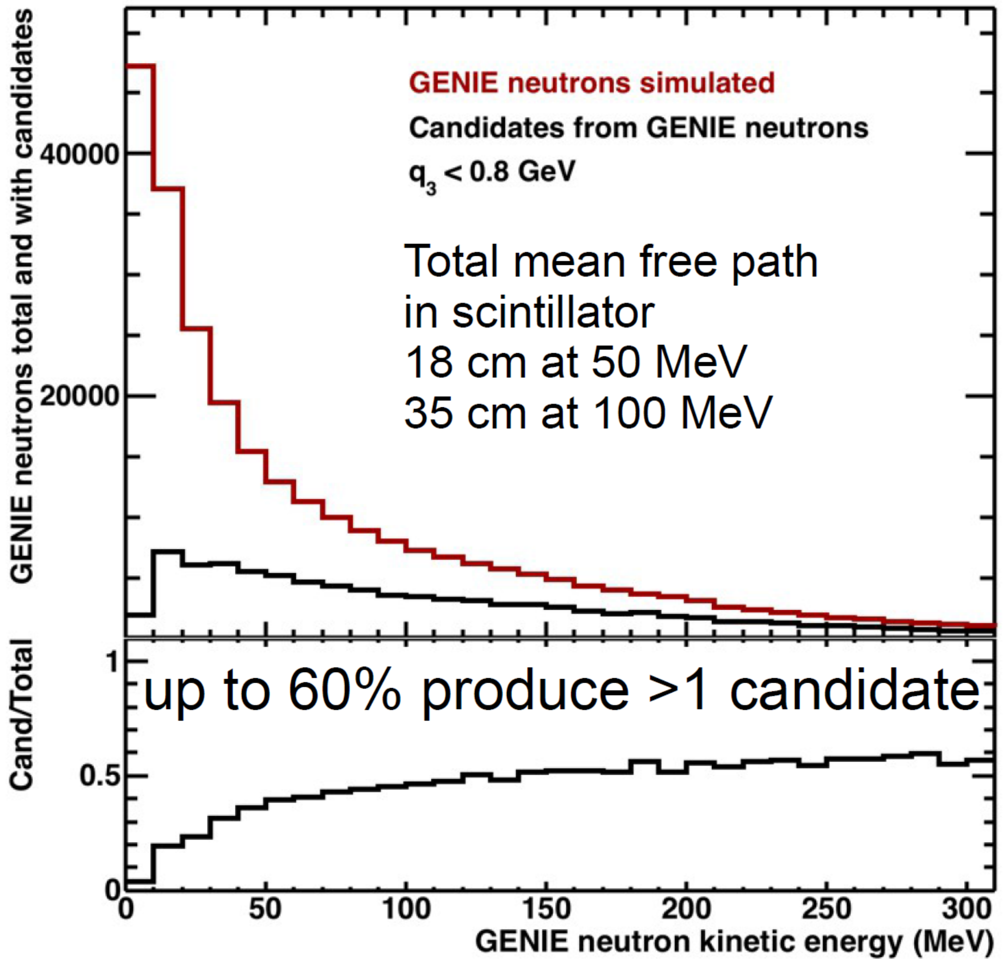
Geant4 says they prefer to leave < 10 MeV scattered protons.
with rare cases up to the total neutron energy.
Some neutrons will multiple scatter, leaving more energy.

for the whole analysis sample $0 < q_3 < 0.8$ GeV
cut on 1.5 MeV energy deposits

Map of where we do and do not look for neutrons



Efficiency for tagging "fast" neutrons



signal in plot on left:
Neutrons from GENIE

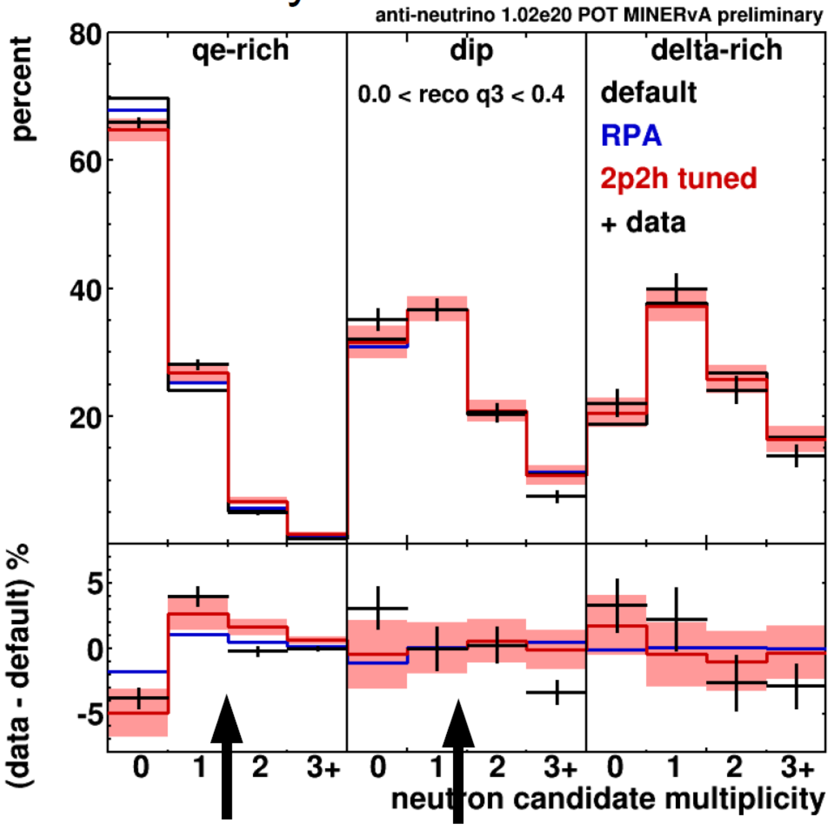
Sorta signal, not in plot
Neutrons from
pions and protons
~20% of total

background not in plot
neutral pion decays
~10% of total

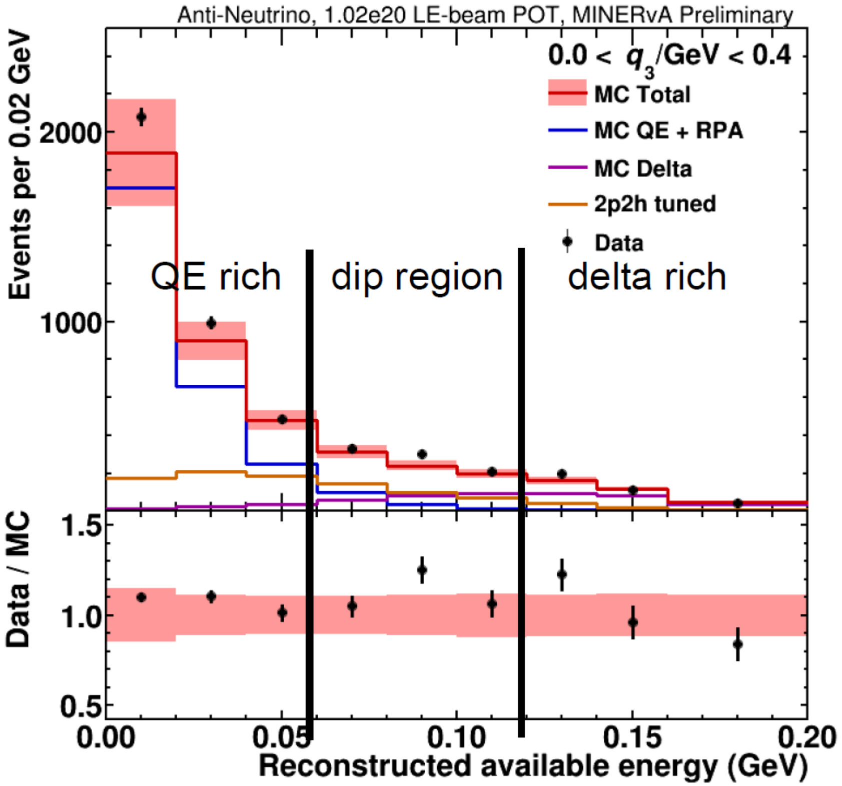
Other (beam pileup,
muon) ~5% of total

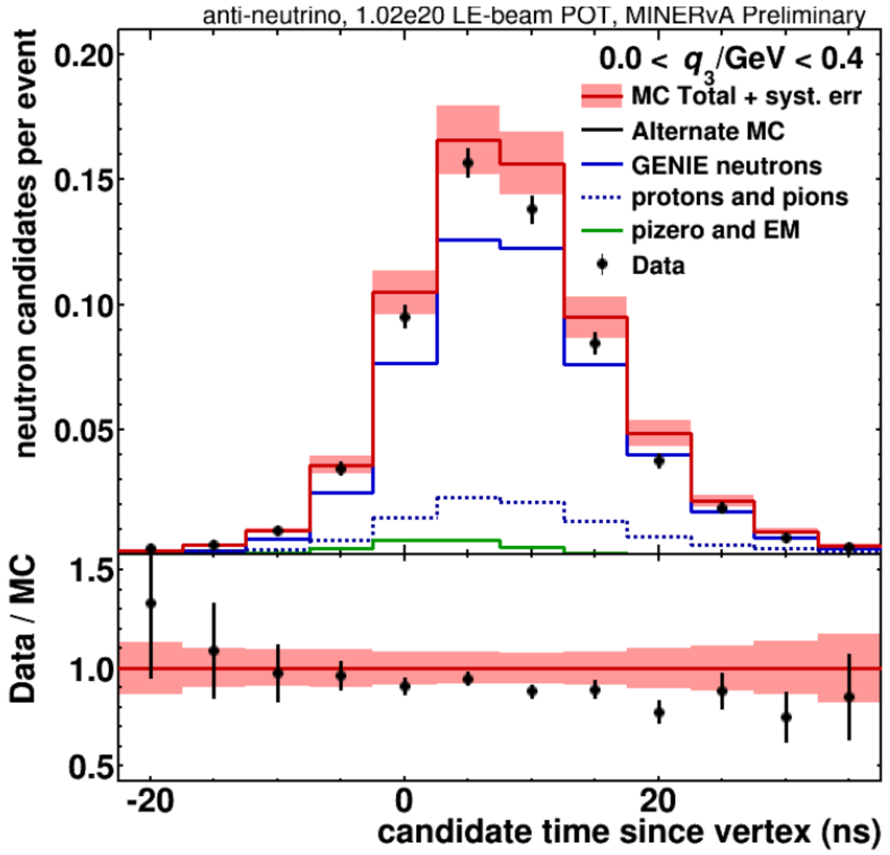
not shown in this figure, about 45% of neutrons
deposit energy (also or instead) in the vertex region

Multiplicity two models, data with systematic error band



Available energy distribution data vs. MINERvA tune v1

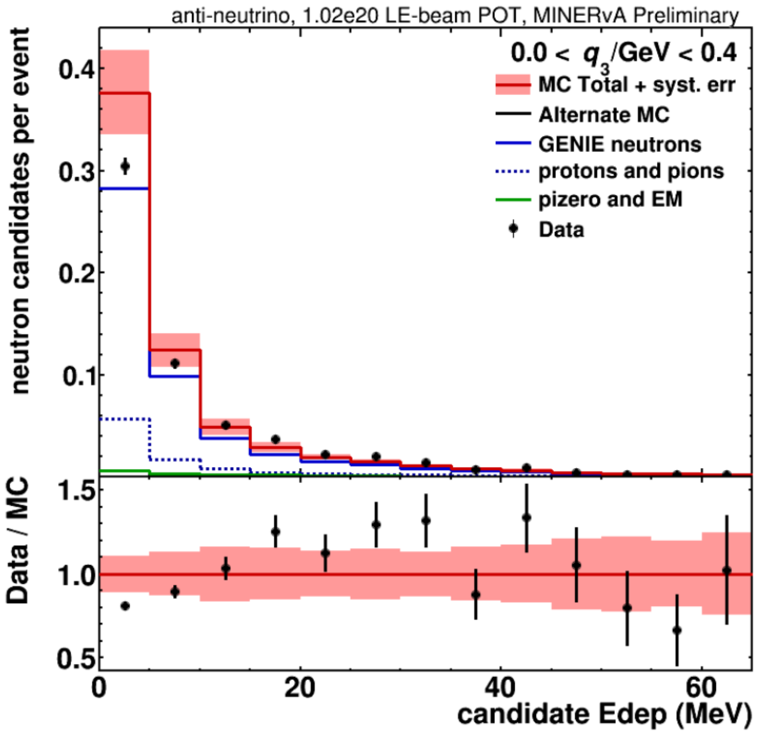




neutron candidate time since interaction

compared to MINERvA Tune v1

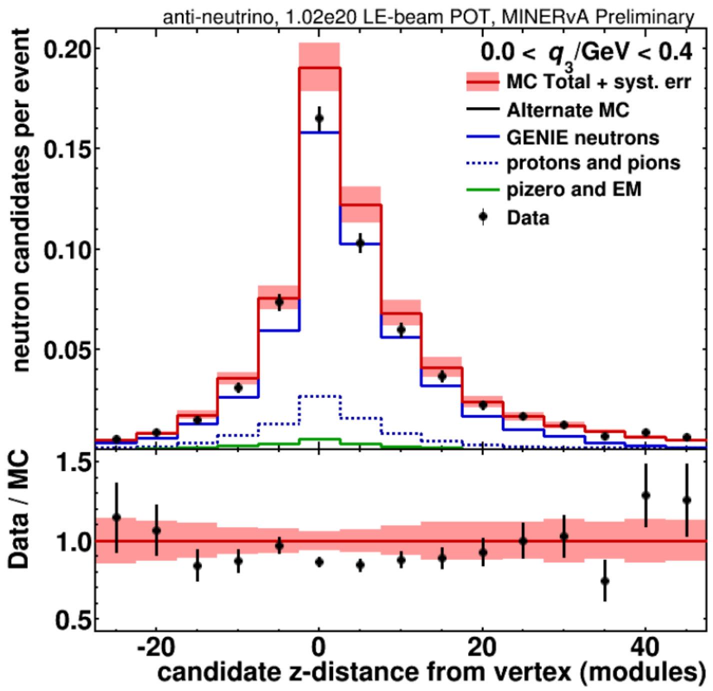
Excess in the MC late in time
slow neutrons, not EM backgrounds



neutron candidate energy deposition

compared to MINERvA tune v1

Excess in first bin
small energy deposits



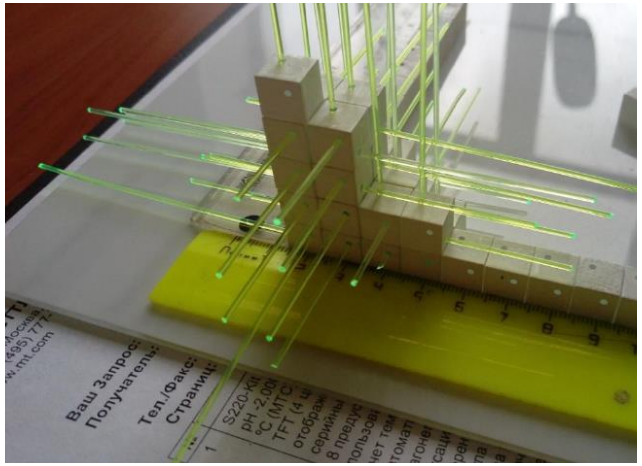
neutron candidate position up/downstream

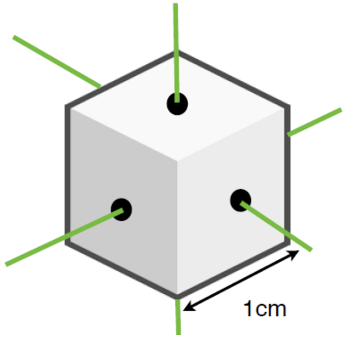
compared to MINERvA Tunve v1

Excess in the MC
close to interaction point

Conclusions

- MINERvA demonstrating ability to count neutrons in the scintillator tracker with an efficiency that is high enough to be useful.
- Planning to study neutrons in nuclear targets
- Will be interesting to see how to use the information
- Worth studying performance of possible DUNE ND 3DST (cube size, 3DST size)





Super-FGD, D. Sgalaberna, A. Longhin, Yuri Kudenko

Backups

Technical slide: steps to calorimetric reconstruction

We do not start knowing the energy of the neutrino, only the direction.

Measure the energy E_μ and angle θ_μ of the outgoing muon.
Measure the detected energy attributed to hadrons $E_{visible}$.

A. turn $E_{visible}$ into $E_{available}$ using detector MC, discounts neutrons
$E_{available}$ = Proton KE, $\pi^\pm$ KE, π^0, e, γ energy (plus heavier particles)
little neutrino model dependence (some anti-nu model dependence)

B. Use MC and correct to energy transfer q_0 (= E_{had} = ν = ω)
(unbiased, but correction has some dependence on interaction model)

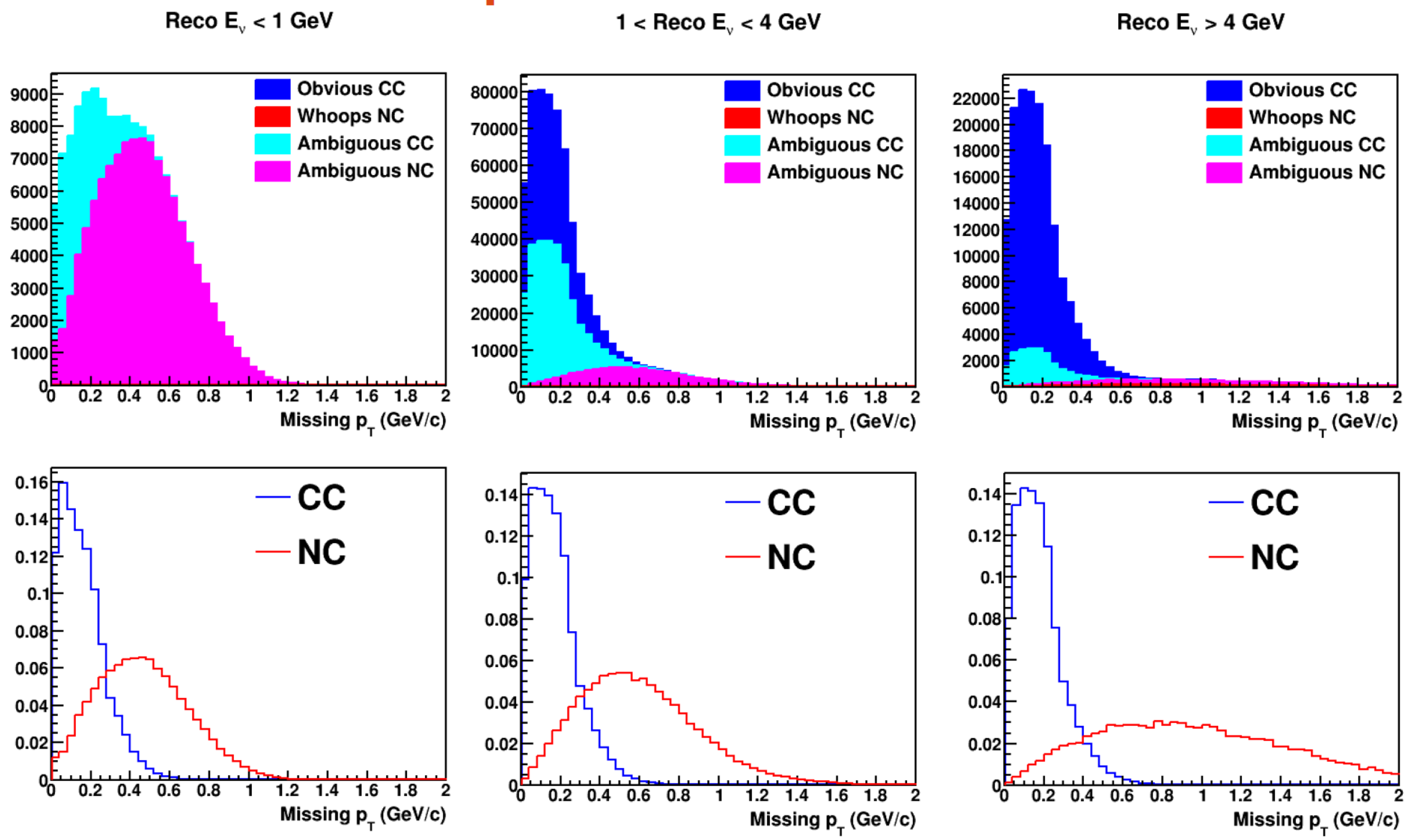
B. Estimated neutrino energy $E_\nu = E_\mu + q_0$

C. Estimated four-momentum $Q^2 = 2 E_\nu (E_\mu - p_\mu \cos\theta_\mu) - M_\mu^2$

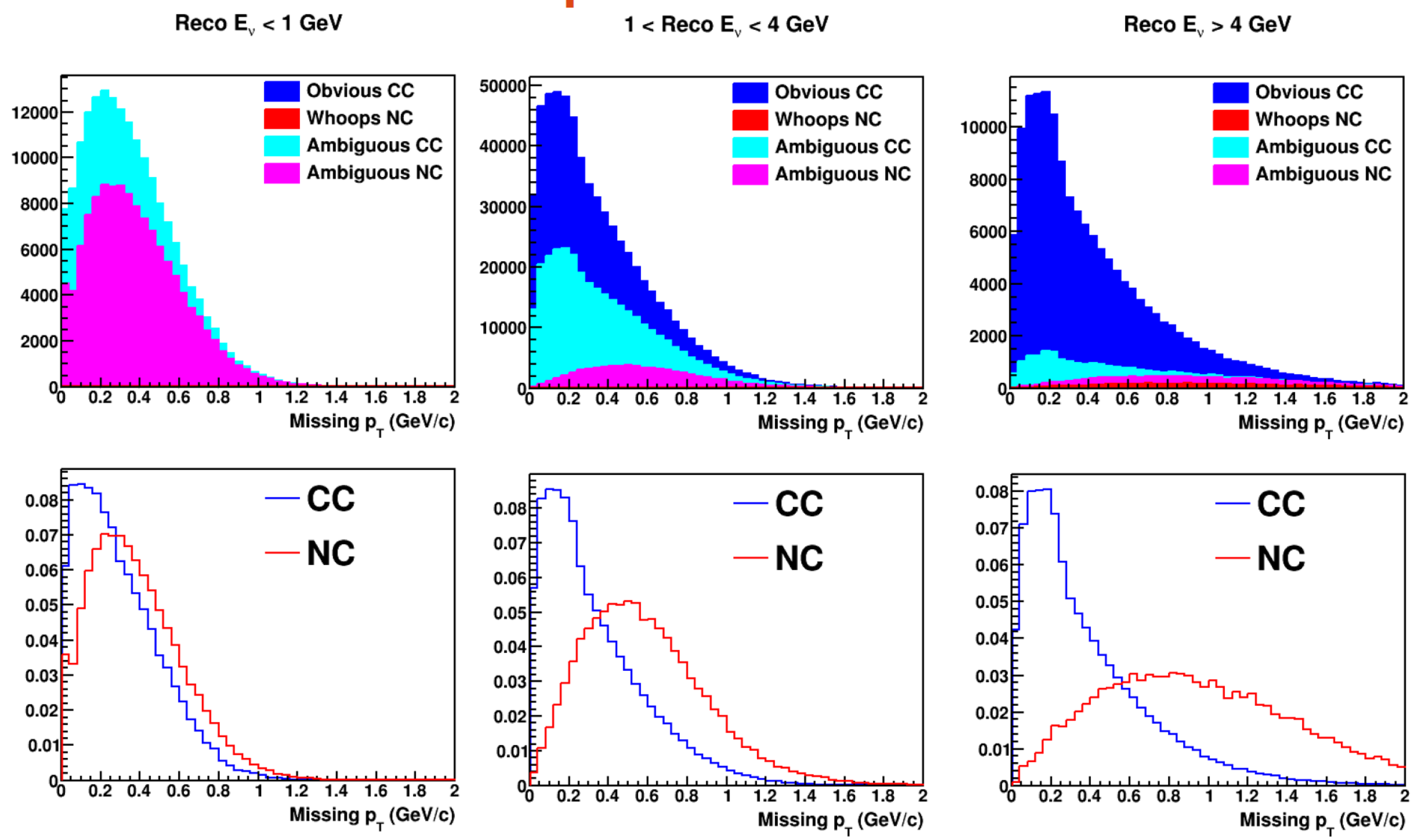
D. Estimated momentum transfer $q_3 = \mathrm{Sqrt}(Q^2 + q_0^2)$

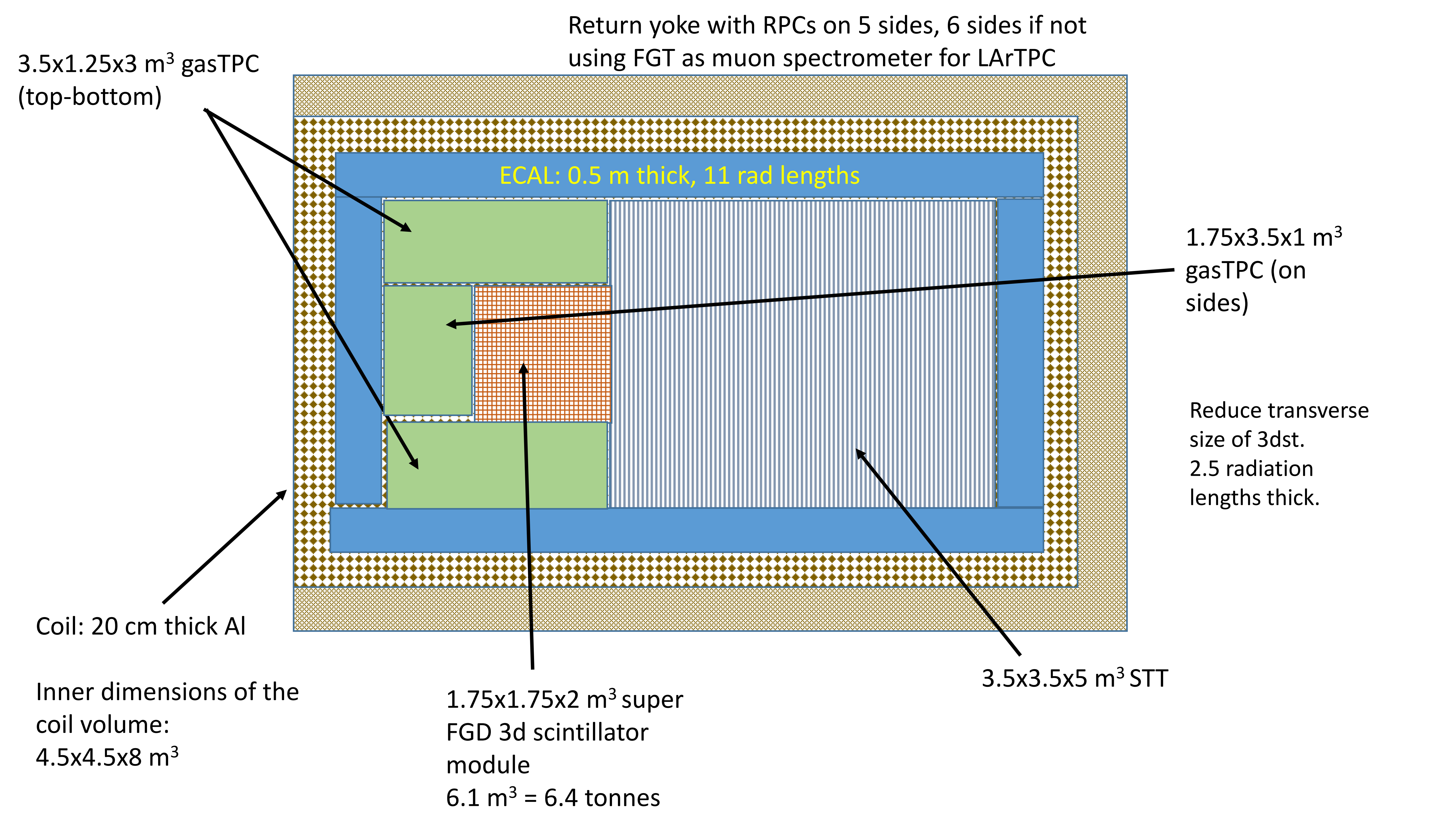
From Chris Marshall – presented at ND workshop on March 28, 2017

FHC ν_μ perfect detector



FHC ν_μ no neutrons




Return yoke with RPCs on 5 sides, 6 sides if not using FGT as muon spectrometer for LArTPC
3.5x1.25x3 m^3 gasTPC (top-bottom)
ECAL: 0.5 m thick, 11 rad lengths
1.75x3.5x1 m^3 gasTPC (on sides)
Reduce transverse size of 3dst.
2.5 radiation lengths thick.
Coil: 20 cm thick Al
Inner dimensions of the coil volume:
4.5x4.5x8 m^3
1.75x1.75x2 m^3 super FGD 3d scintillator module
6.1 m^3 = 6.4 tonnes
3.5x3.5x5 m^3 STT