Tau Neutrino Observations
Neutral Current Event Reconstruction
Neutrons

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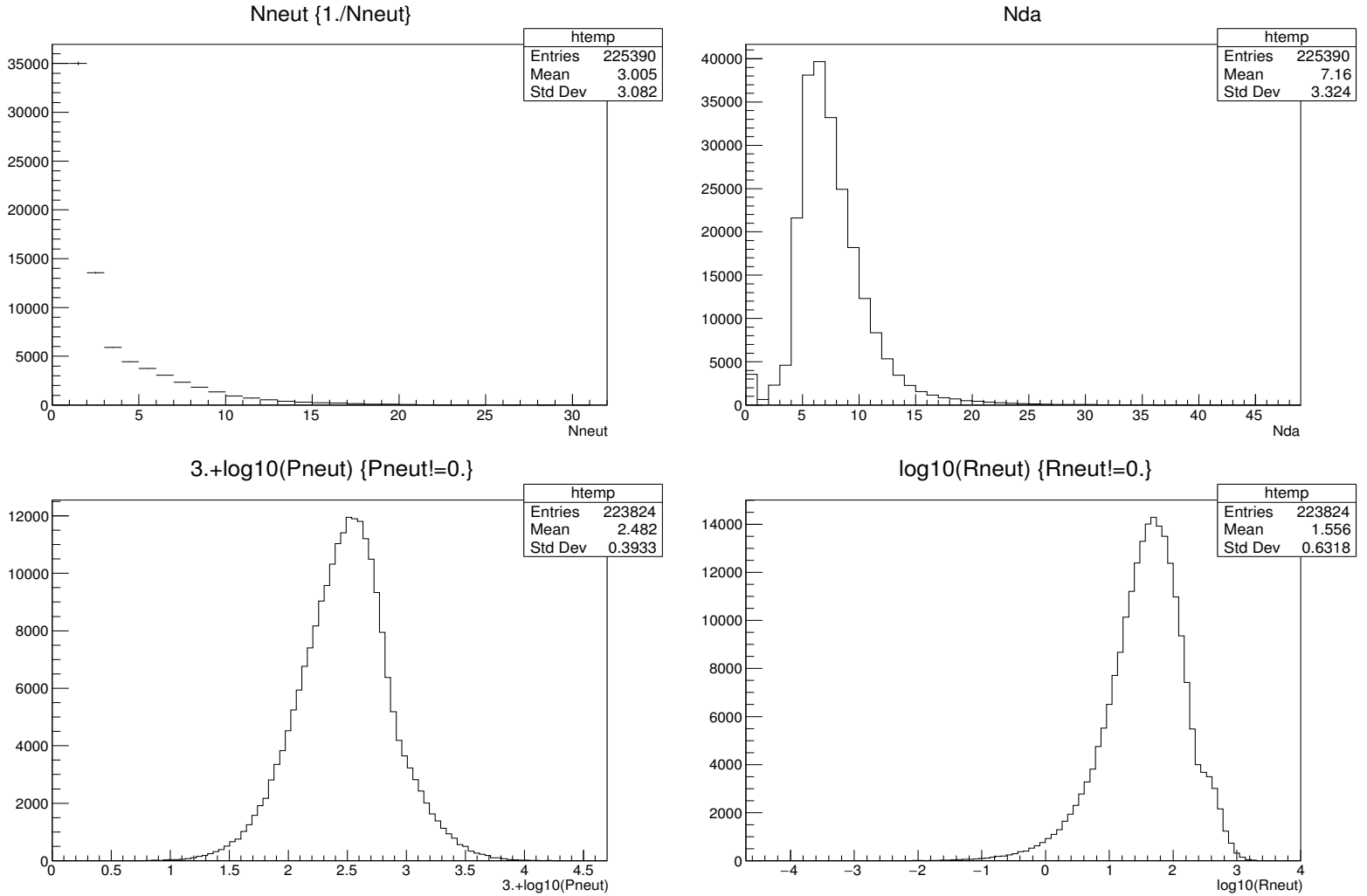
Introduction

- Interest in reconstruction of Neutral Current events
- kinematics ... conservation laws
- MCC 7 simu/reco samples – September 6, 2016
- Used results of the NueAna module
- NueAna basically converts the contents of several classes to an ntuple
  - Reconstructed Events
  - Truth values
  - Geant track list
- Problems
  - Lots of truncated reconstructed tracks
  - So use MC truth information for now.
  - Explore limitations

This talk is about measuring neutrons in these events. Measuring neutrons is an issue for all energy reconstruction for both charged and neutral current events.

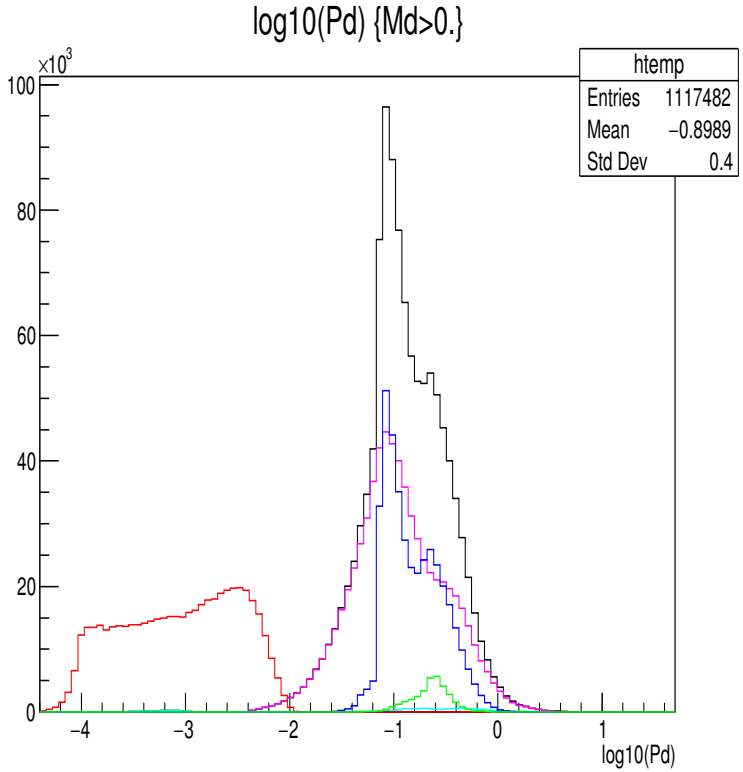
What does the MC "Say"

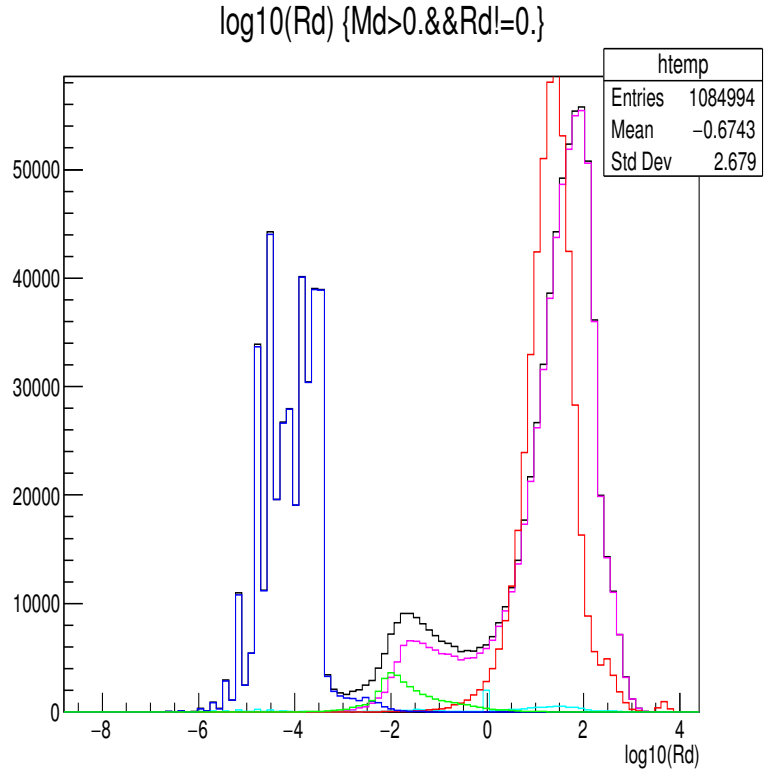


Left to right: Number of neutrons per event (3.05), the number of daughters of each neutron (7.2), the log of the neutron momentum (in MeV) (303 MeV) and the log of the neutron range in the detector (36 cm)

Daughter Tracks

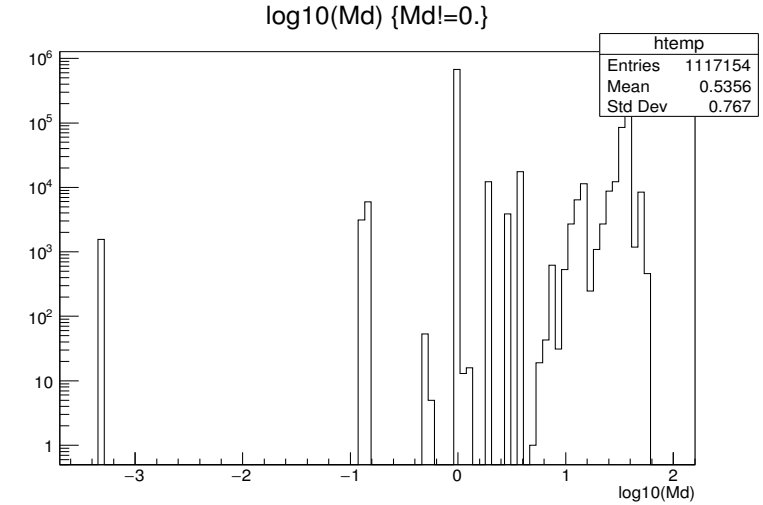
Mostly nucleons, photons and nuclear fragments

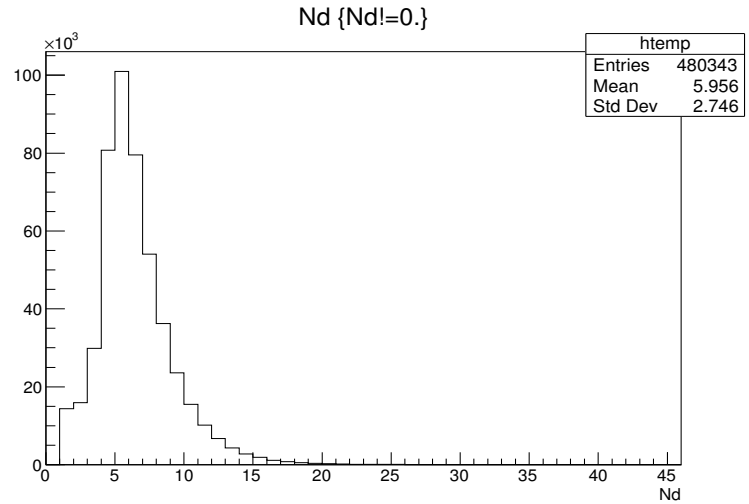


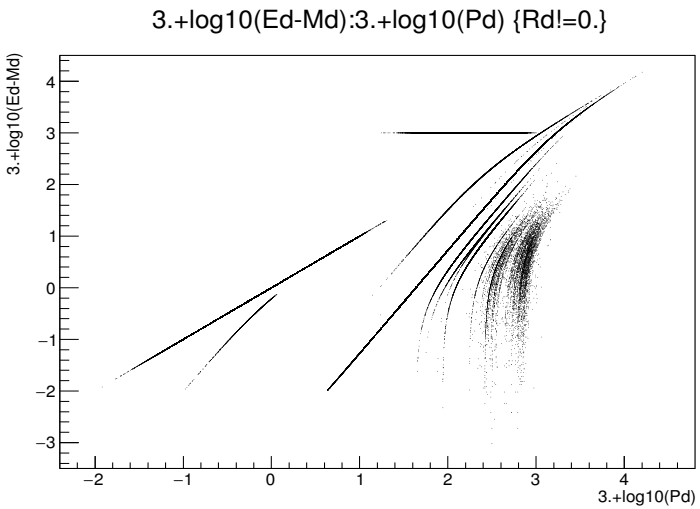


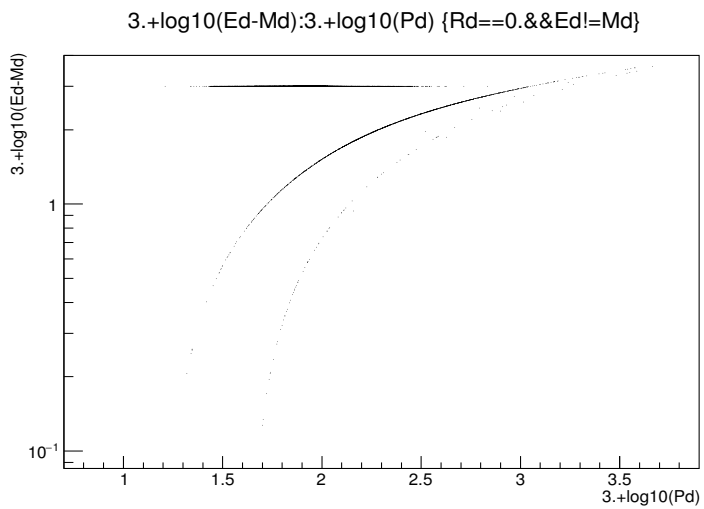
Log of the daughter momentum (left) and range (right): Black is all but photons. Magenta are nucleons. Cyan are mesons and leptons 0<M<0.5. Red are photons. Blue are nuclear fragments M>5. Green are light nuclear fragments 0.94<M<5

Daughters



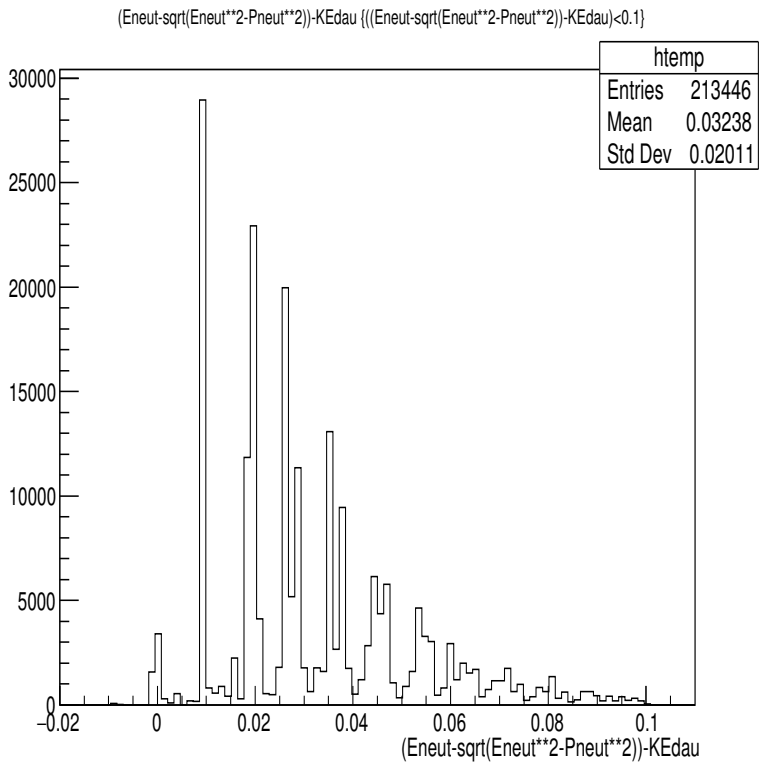


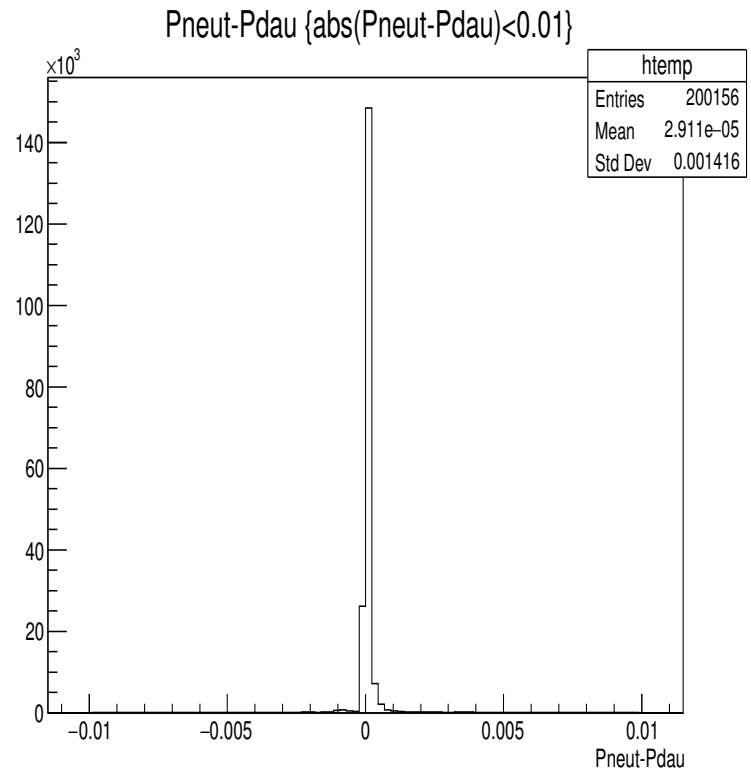




The daughter log mass, the number of daughters of the daughters, the kinetic energy of the daughters vs their momentum and the kinetic energy of the daughters vs their momentum for daughters with zero range.

Daughter Kinematic Match?

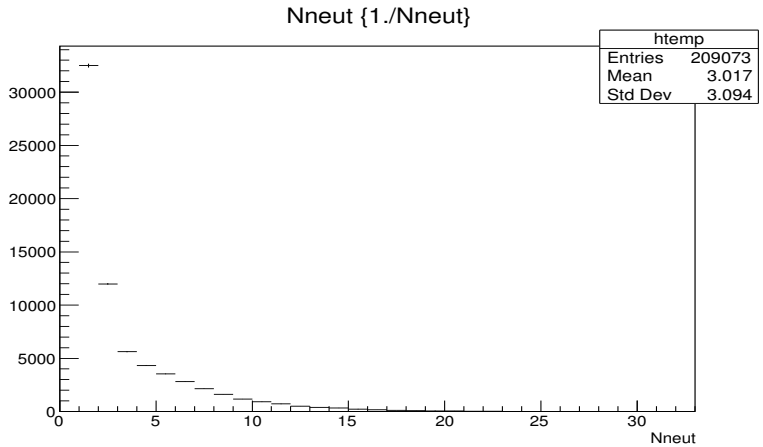


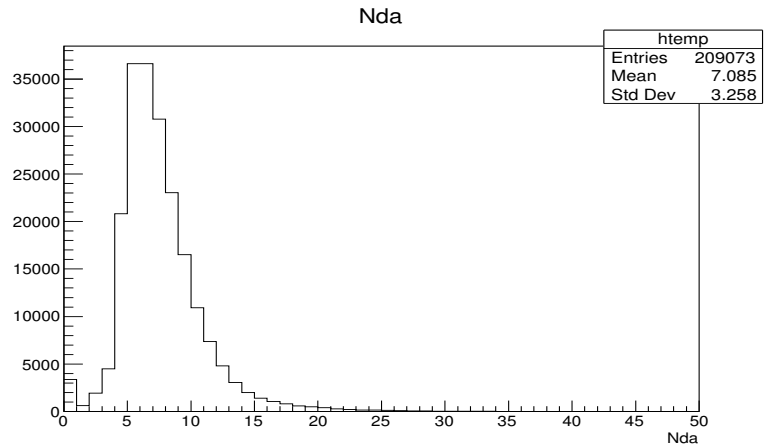


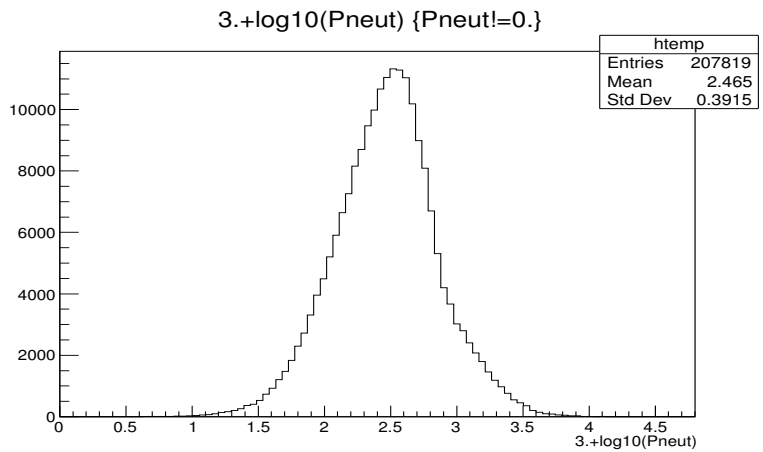
The sum of the daughters compared to the parent neutron. Left is the kinetic energy. Right is the total momentum.

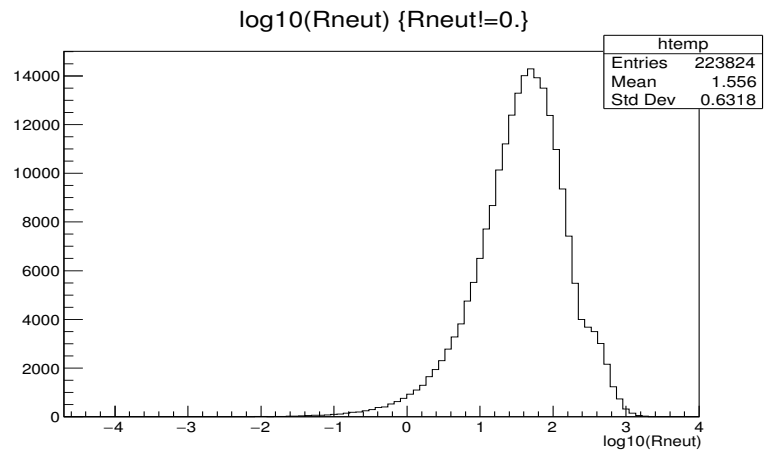
Need to subtract the mass from nuclear fragments

Neutrons in ν_μ Interactions (CC and NC)



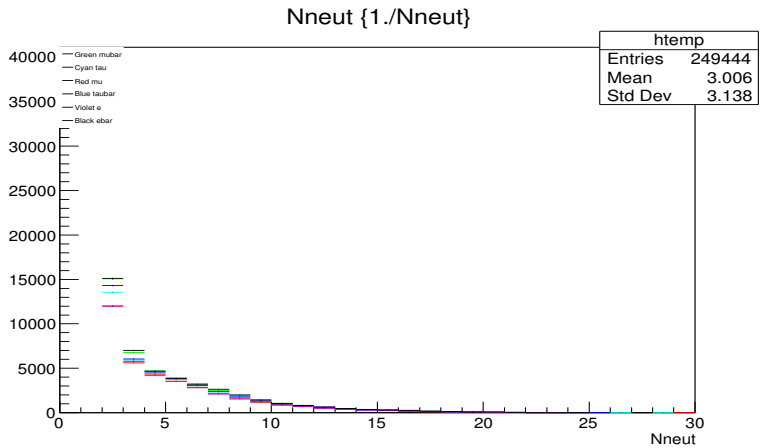


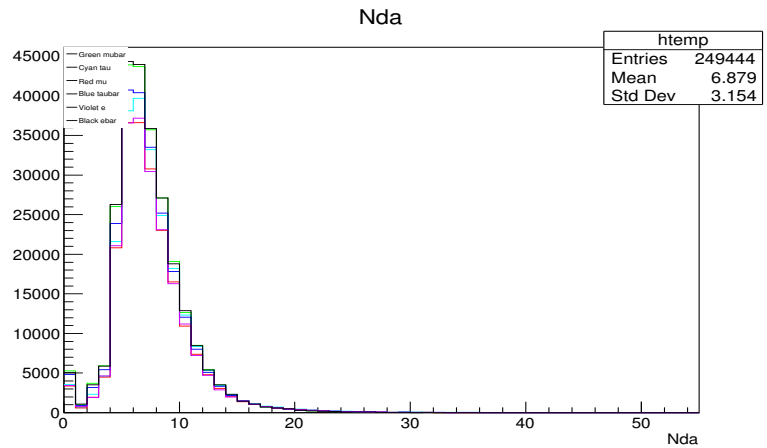


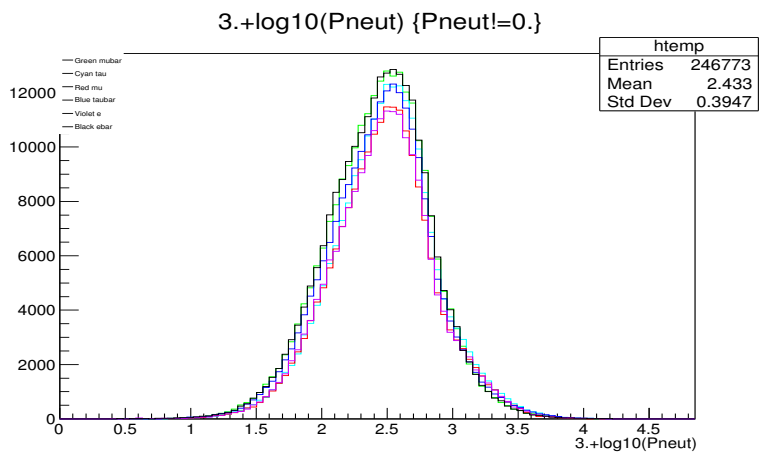


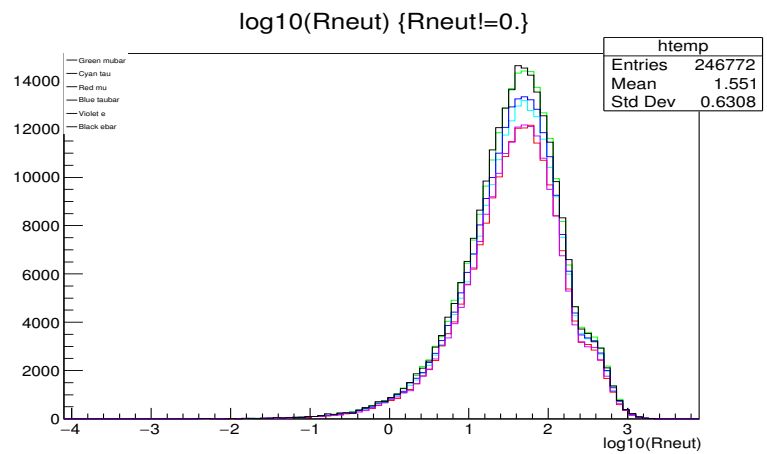
Left to right: Number of neutrons per event (3.02), the number of daughters of each neutron (7.1), the log of the neutron momentum (in MeV) (292 MeV) and the log of the neutron range in the detector (36 cm). Not much difference from the NC dominated ν_τ. Similar results for $\bar{\nu}_\tau$. Is this a model problem?

Compare $\bar{\nu}_\mu, \nu_\tau, \nu_\mu, \bar{\nu}_\tau, \nu_e, \bar{\nu}_e$

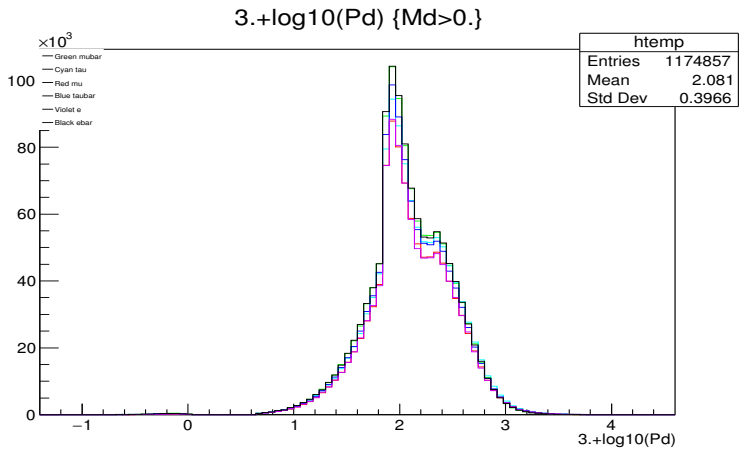


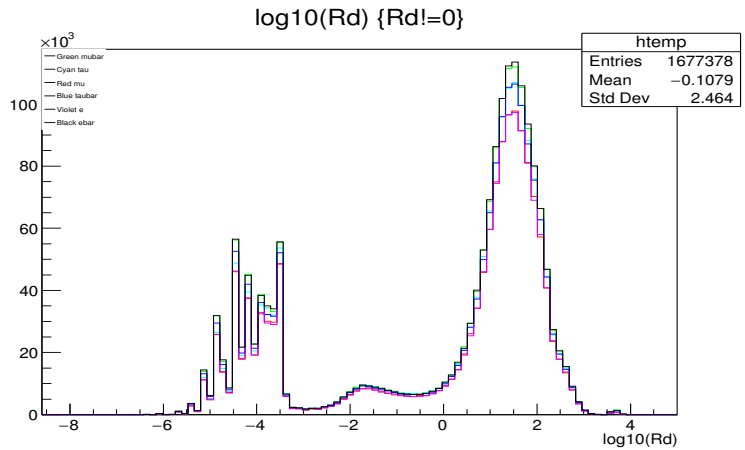


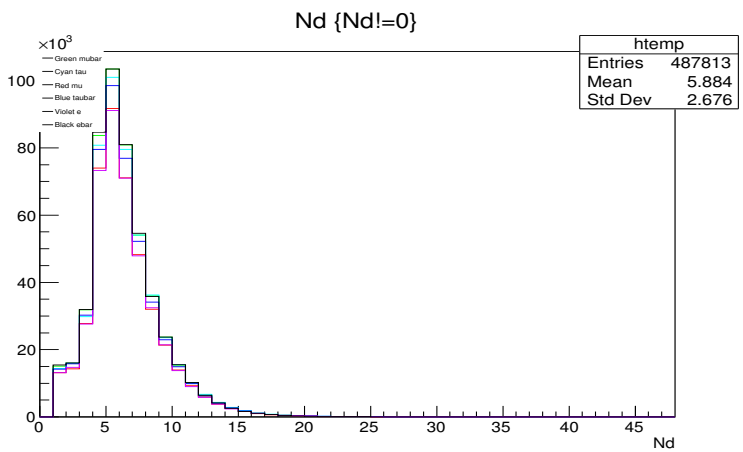




Daughters Compare $\bar{\nu}_\mu, \nu_\tau, \nu_\mu, \bar{\nu}_\tau$







Open Questions

- Can energy in low energy photons be recovered?
- How does liquid argon respond to highly ionizing nuclear fragments?
- Nonlinear detector response?
- Can track length help?
- multitrack vs time ambiguity in TPC?
- Are the nuclear fragments modeled correctly?
- Does Genie predict the correct neutron spectrum from NC interactions on argon?
- Does Geant represent low energy neutrons in argon reliably?

The answers are important for energy reconstruction in CC events too.

Conclusions

- Neutron momentum not high ... about 300 MeV
- Number of neutron daughters ... about 7
- Number of daughter daughters ... about 6
- Nuclear fragments
- Range of daughters. Short for nuclear fragments
- Good momentum match to daughters.
- Nuclear binding energy introduces 10's of MeV differences to the sum of the daughter kinetic energy.
- Nonlinear response to highly ionizing fragments?