LAr hadronic containment Event rates vs. kinematics vs. detector size

Chris Marshall
Lawrence Berkeley National Laboratory
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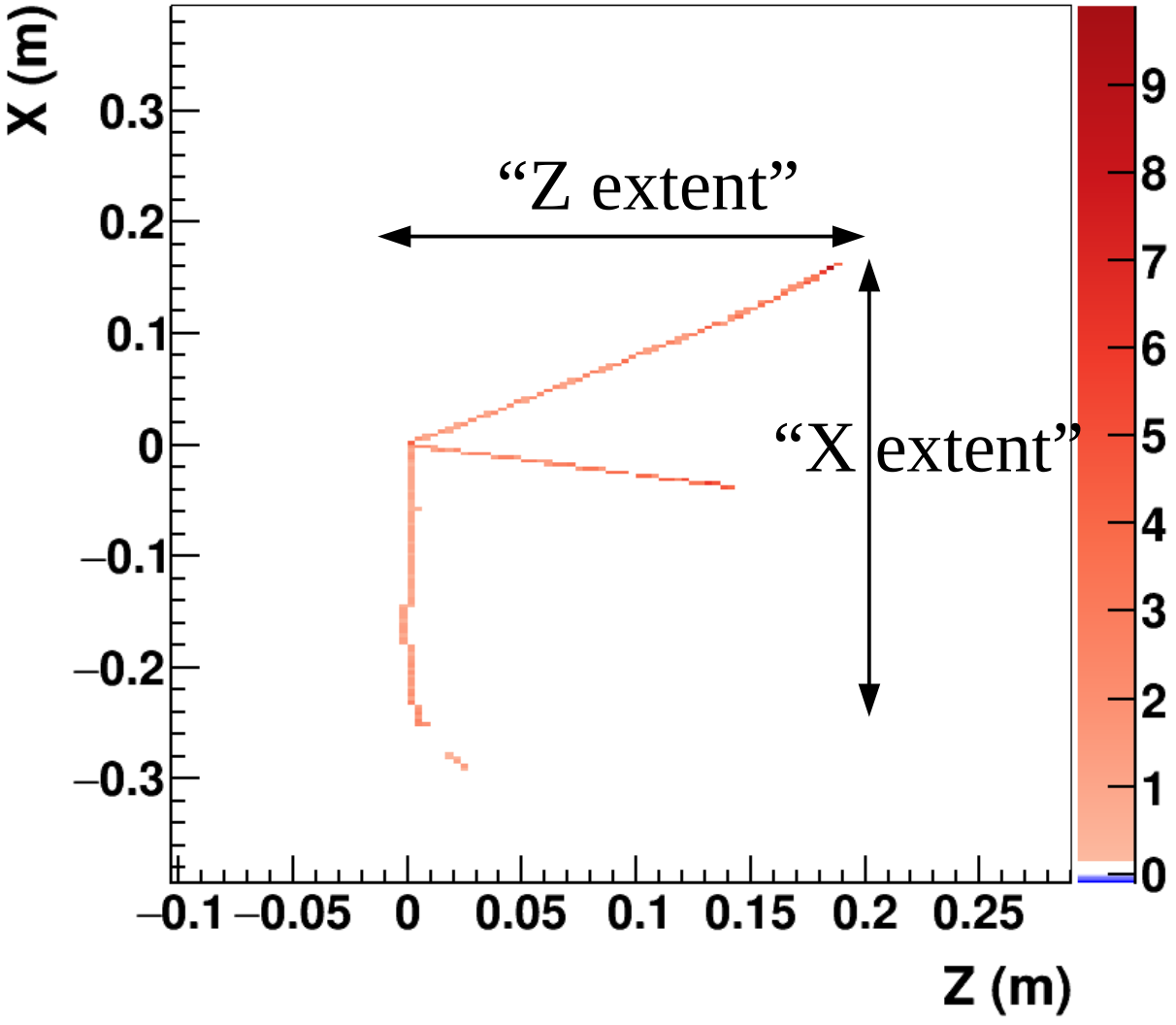
Containment, efficiency, event rates

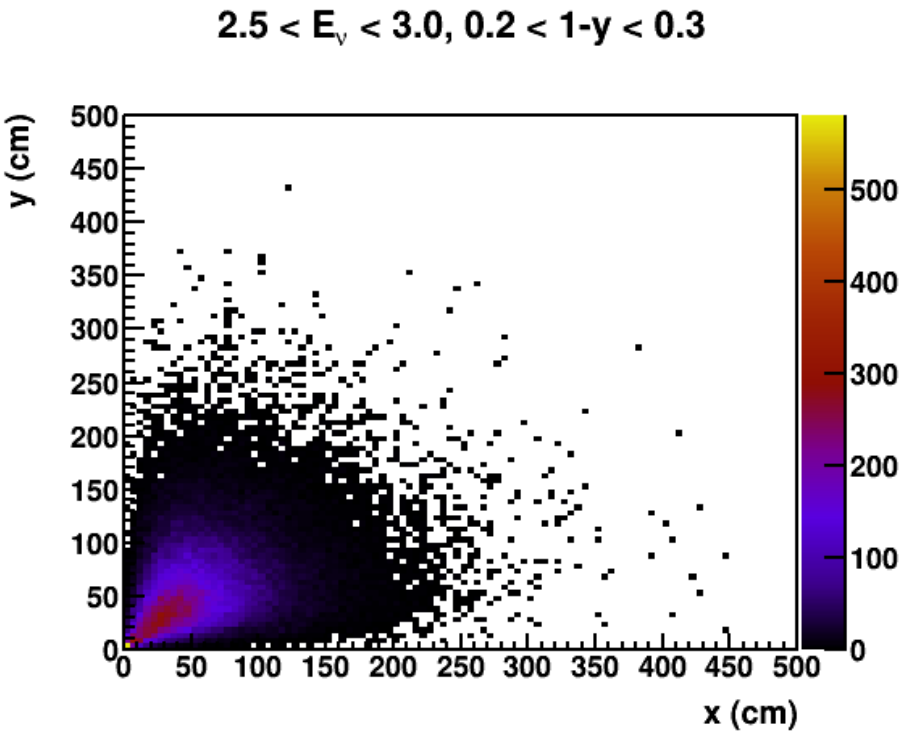
- Simulate GENIE events in LAr with Geant4
- Separate large (~7M event) sample into bins of E_ν and elasticity $1\text{-}y = E_\mu/E_\nu$
- For each event, ask: what is the extent of the hadronic shower in each direction?
- Or, for a given detector size (i.e. 3x3x4m): what is the fiducial volume for this event to be fully contained?
- From that, determine:
  - Efficiency for full containment in each bin
  - Expected event rates

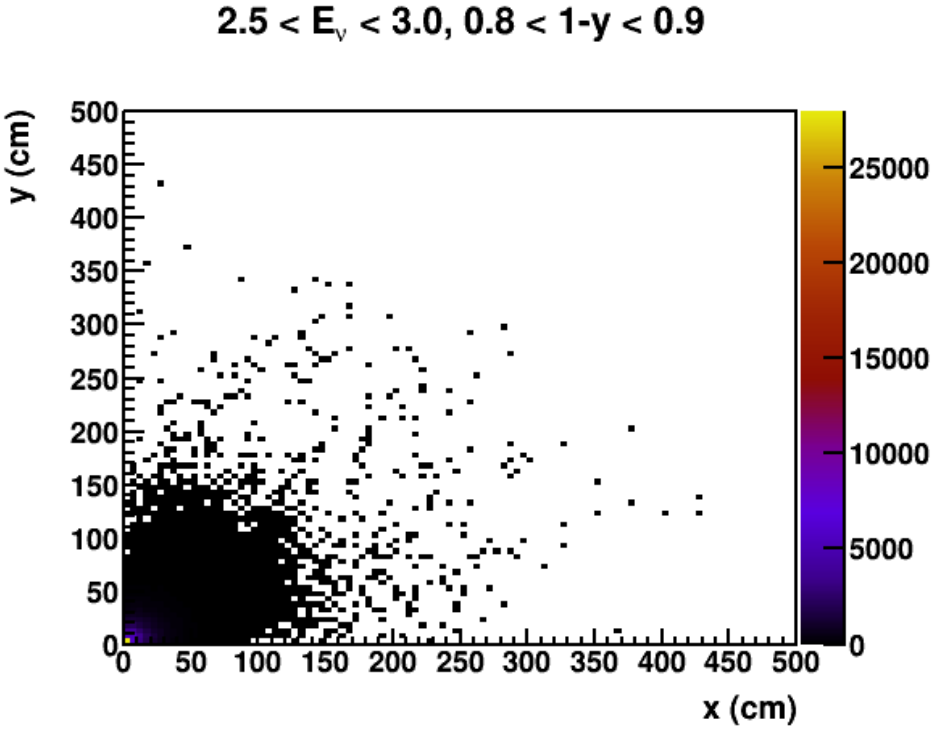
Event “extent” in each direction



- Event display in XZ plane, where color is hit energy in MeV (in 3x3mm voxyls)
- “Extent” is the minimum region that contains 95% of the visible (non-neutron) energy
- 20cm in Z and 40cm in X for this event
- Also a Y dimension which is used, but is not shown here

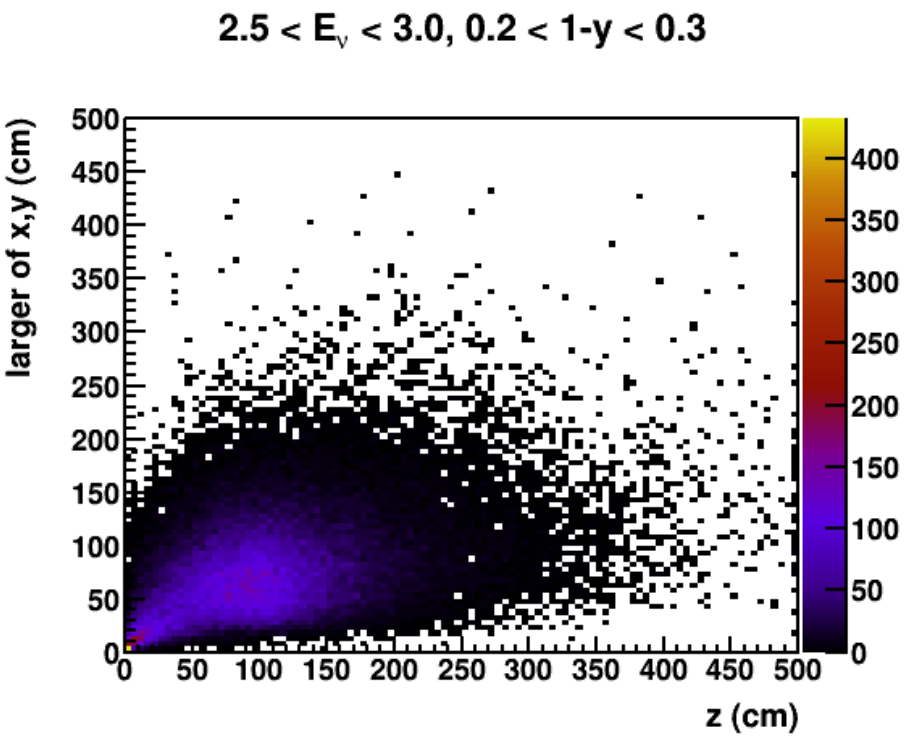
Transverse extent in example bins

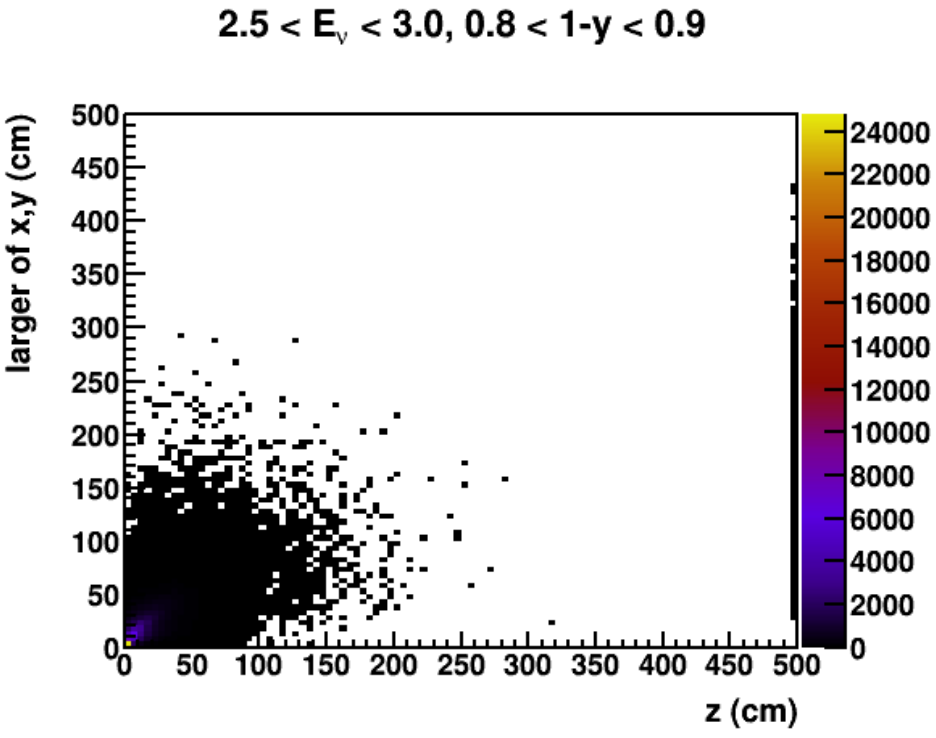




- Hadronic energy only
- Falling edge of flux peak, 2.5-3.0 GeV
- Left is very inelastic bin, right is very elastic

Longitudinal extent examples

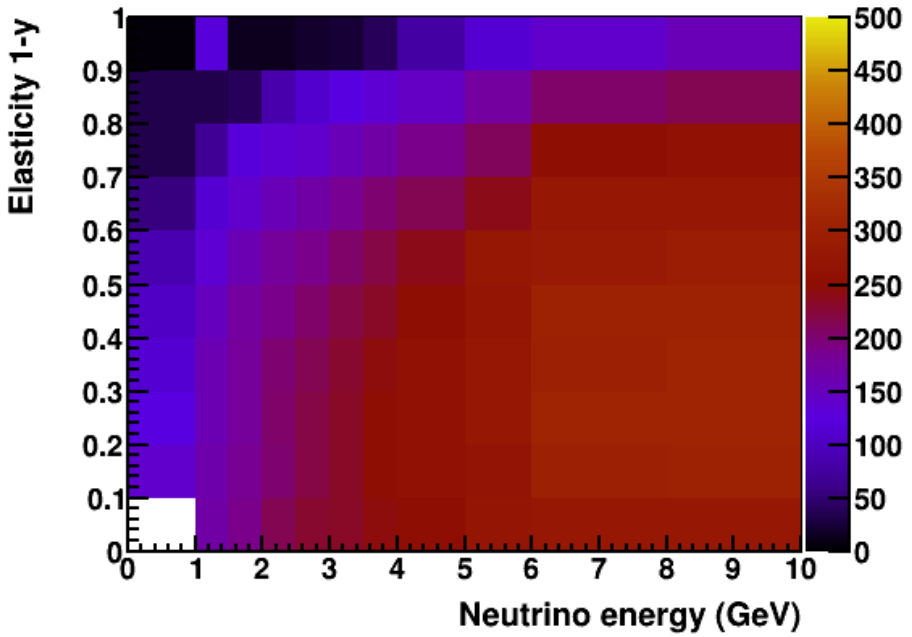




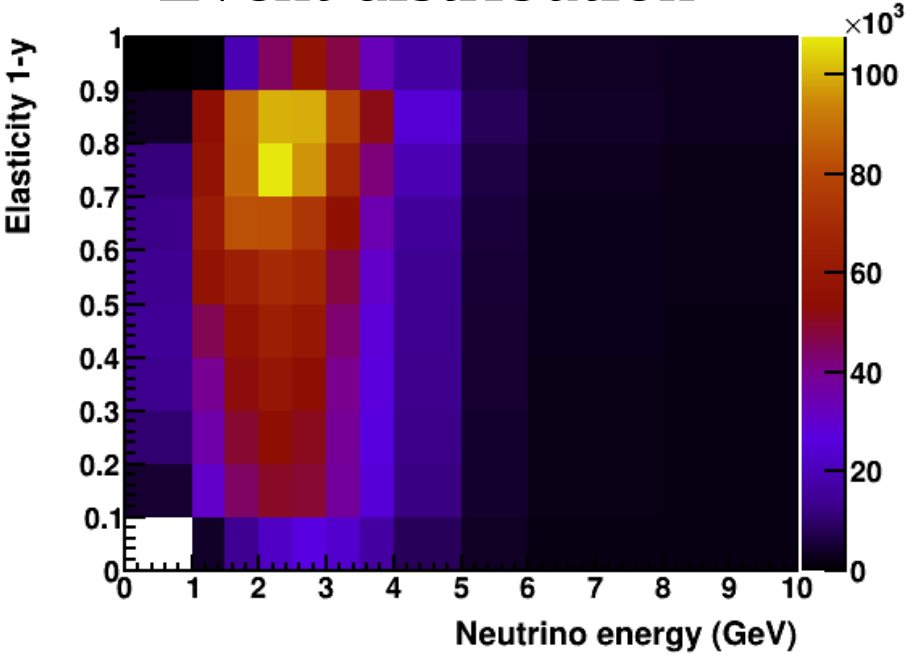
- Same bins as previous slide: left is very inelastic, right is mostly muon energy

Transverse 99% containment

Transverse direction



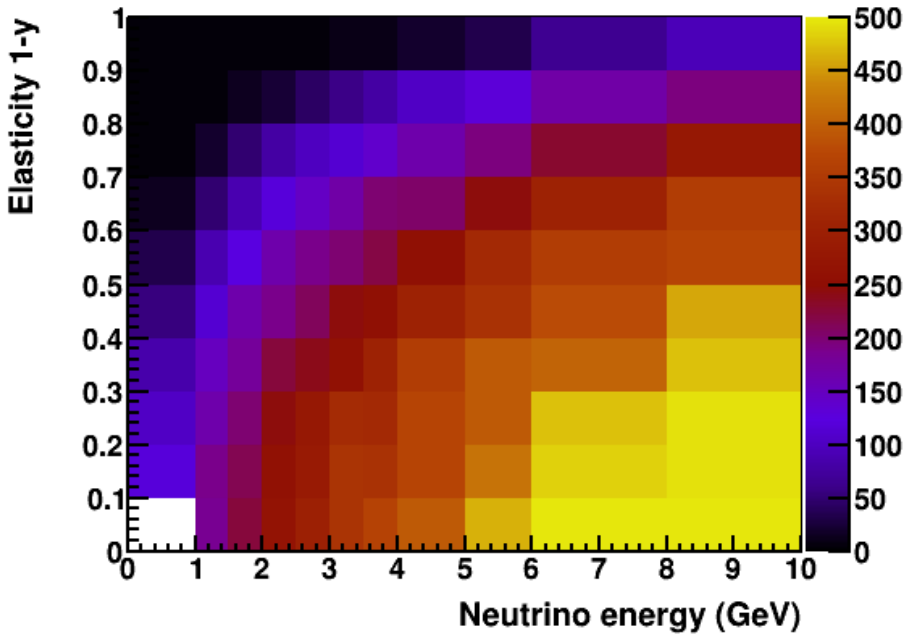
Event distribution



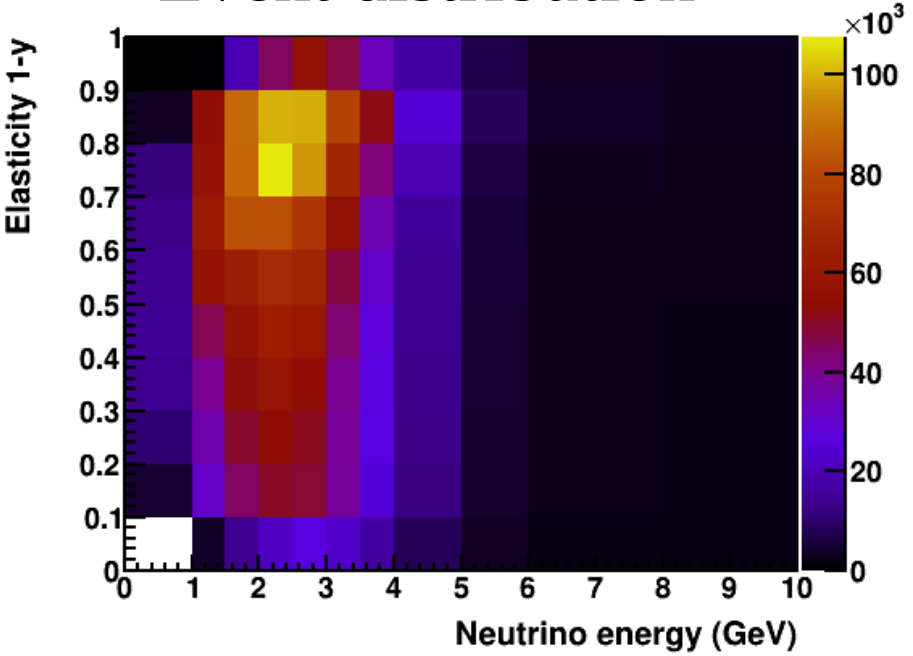
- Left: color of each bin is the minimum transverse size to contain 95% of hadronic energy in 99% of events in that bin
- Right: distribution of events

Beam direction 99% containment

Transverse direction



Event distribution

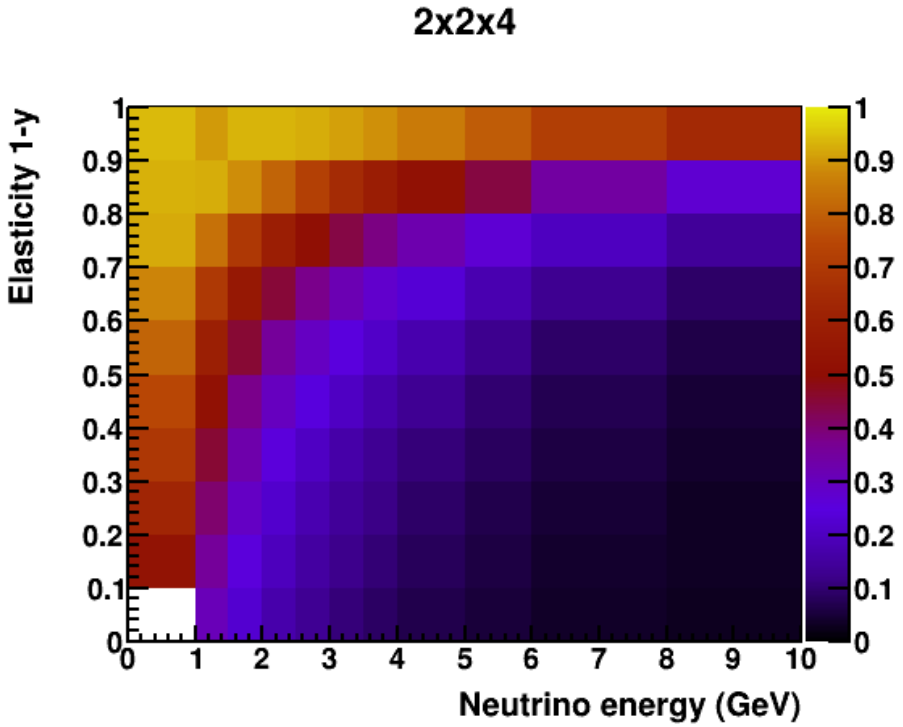


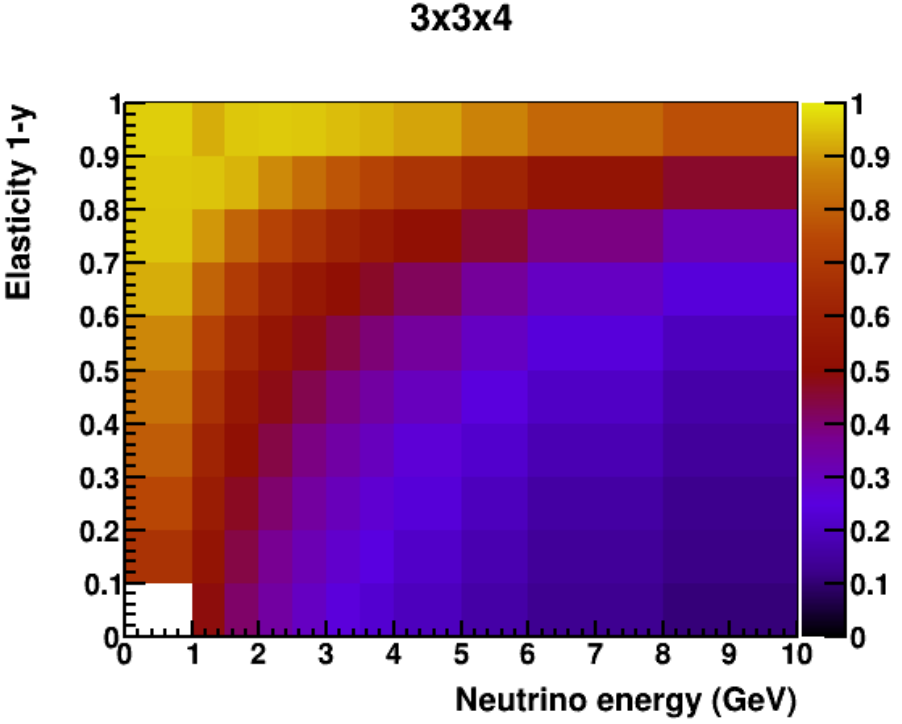
- Left: color of each bin is the minimum longitudinal size to contain 95% of hadronic energy in 99% of events in that bin
- Right: distribution of events

Efficiencies

- Start with a fixed detector size, i.e. 3x3x4m
- Assume you need 50cm “empty” around an event to know that it is contained, so an event is “contained” if 95% of its hadronic energy is within the region with 50cm buffer around it, i.e. 2x2x3m FV
- Assume uniform distribution of vertices
- Determine efficiency in each kinematic bin
- Note: We don't expect this efficiency to be high for all kinematics. If a vertex is 50cm from the downstream edge of the detector and there is 2 GeV of hadronic energy, it's not likely to be contained

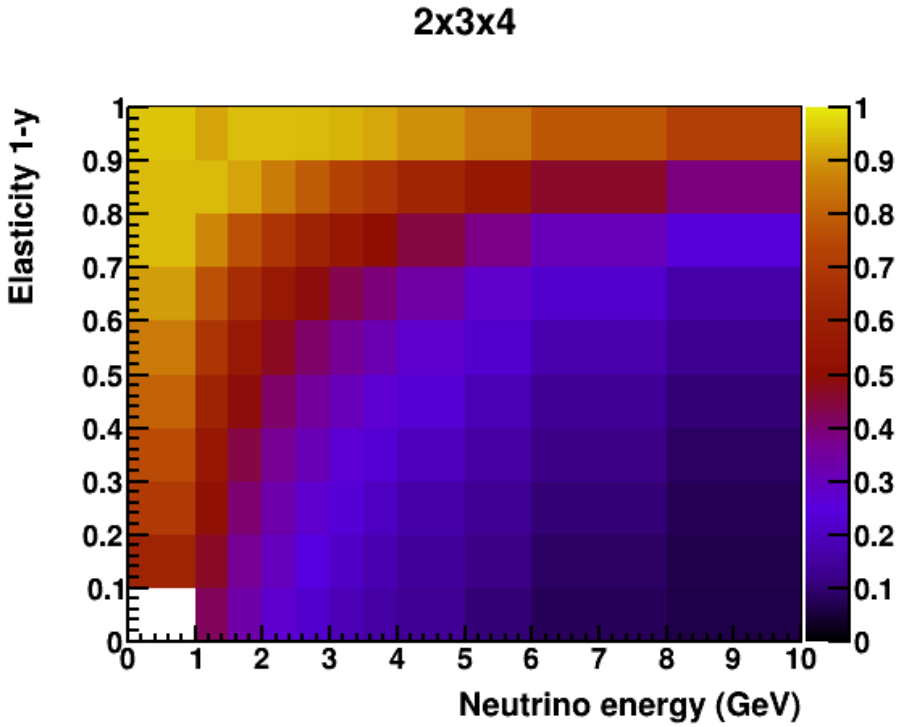
Efficiencies for 95% hadronic containment with 50cm buffer

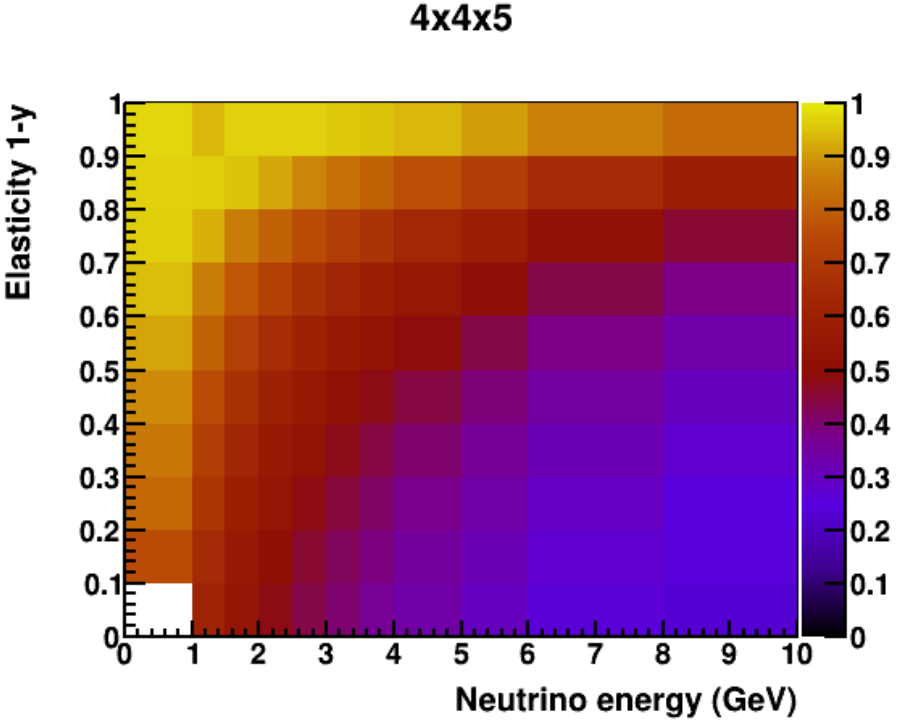




- 2x2x4m detector (left)
- 3x3x4m detector (right)

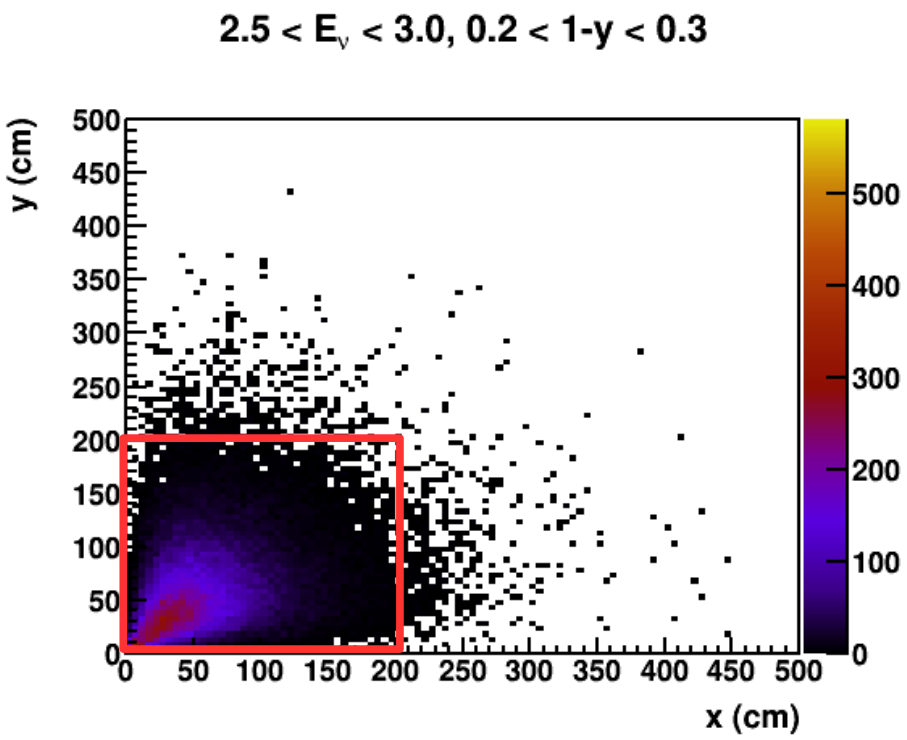
Efficiencies for 95% hadronic containment with 50cm buffer





- 2x3x4m detector (left)
- 4x4x5m detector (right)

Is 99% of a given bin enough?

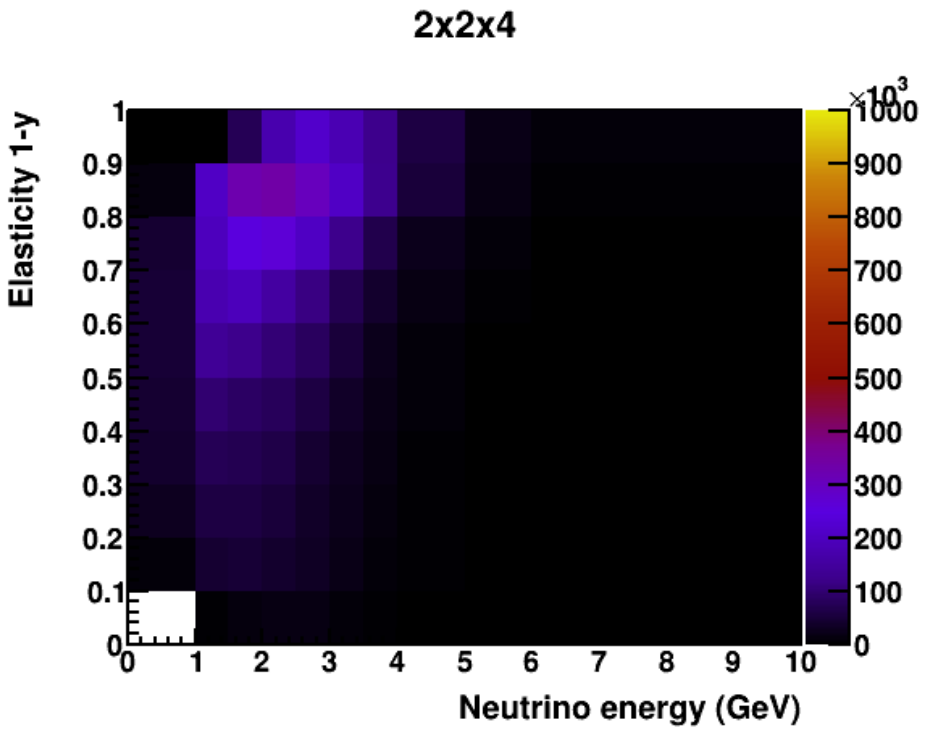


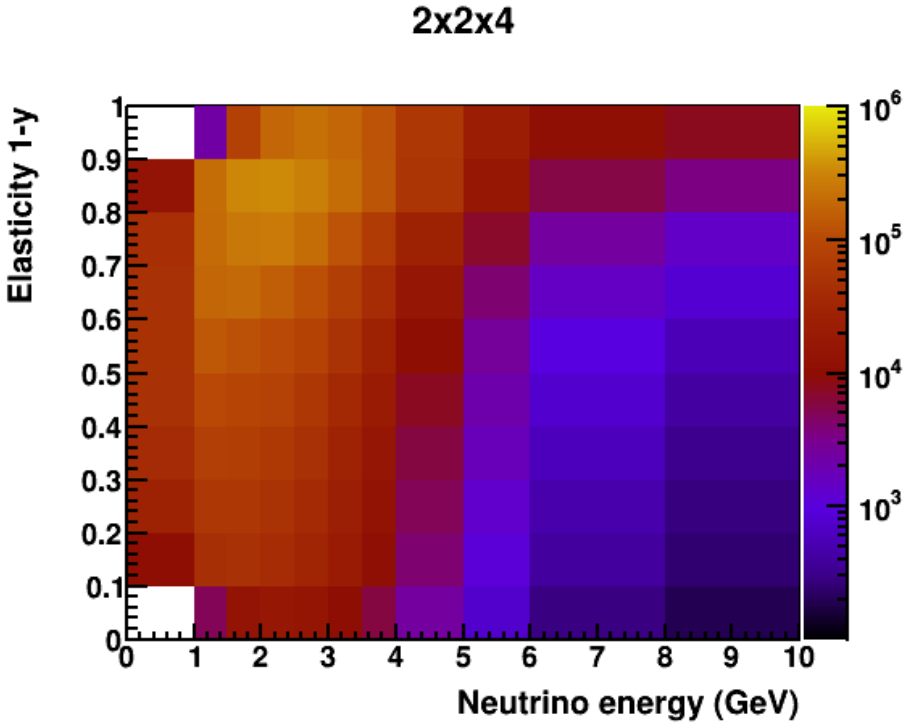
- For very inelastic interactions, even near the flux peak, 99+% of events can be fully contained in a ~2x2m transverse region
- It is worth investigating what the events with larger transverse extent are
- We may be missing some particular topology

Event rates per year

- Assuming 1MW beam, 1.47E21 POT
- Rates shown are per GeV per 0.1 bin of 1-y
  - Add up the column to get per GeV for all y
- Assumes you analyze a F.V. with 50cm buffer only, but accept only events which are fully contained inside the F.V.
- Rates are per 1 year, for whatever mass the detector has (varies due to different sizes)

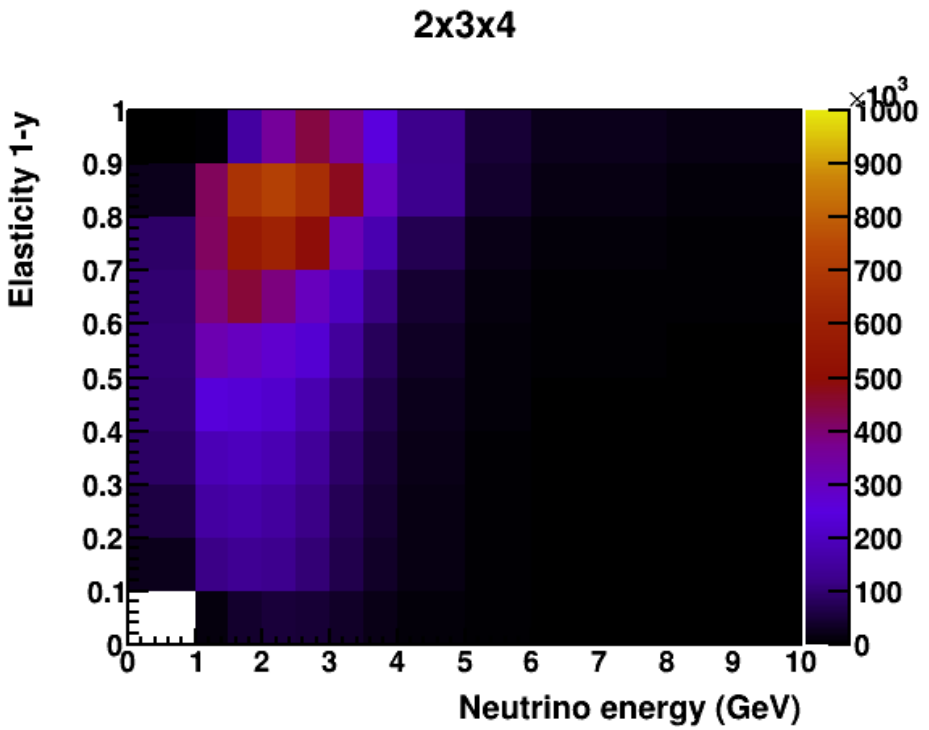
2x2x4 detector

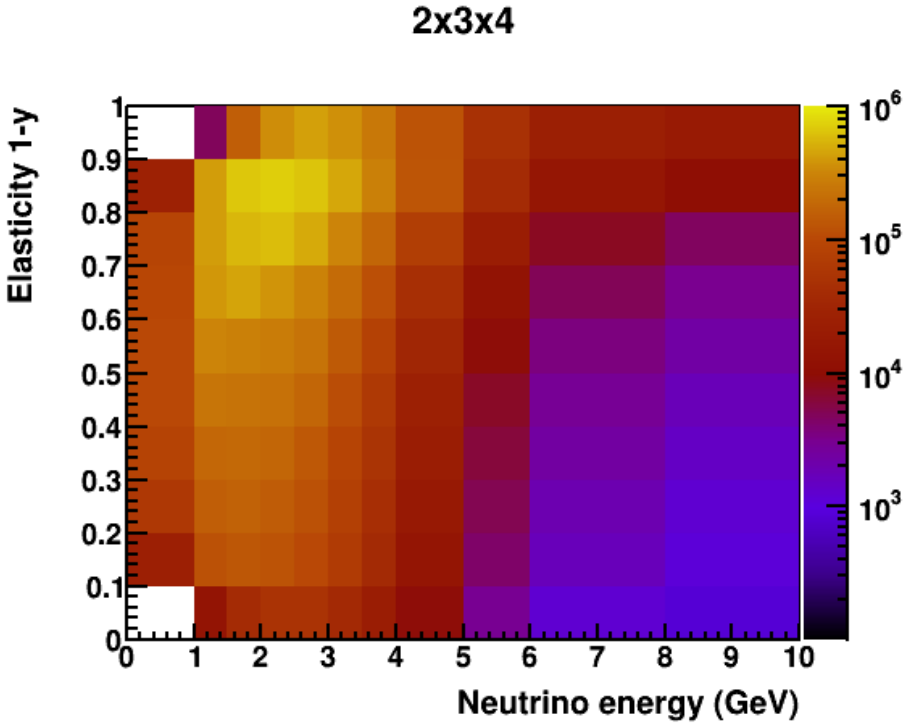




- ~10^4-10^5 per bin in the peak
- 1000s events per bin at 5-8 GeV

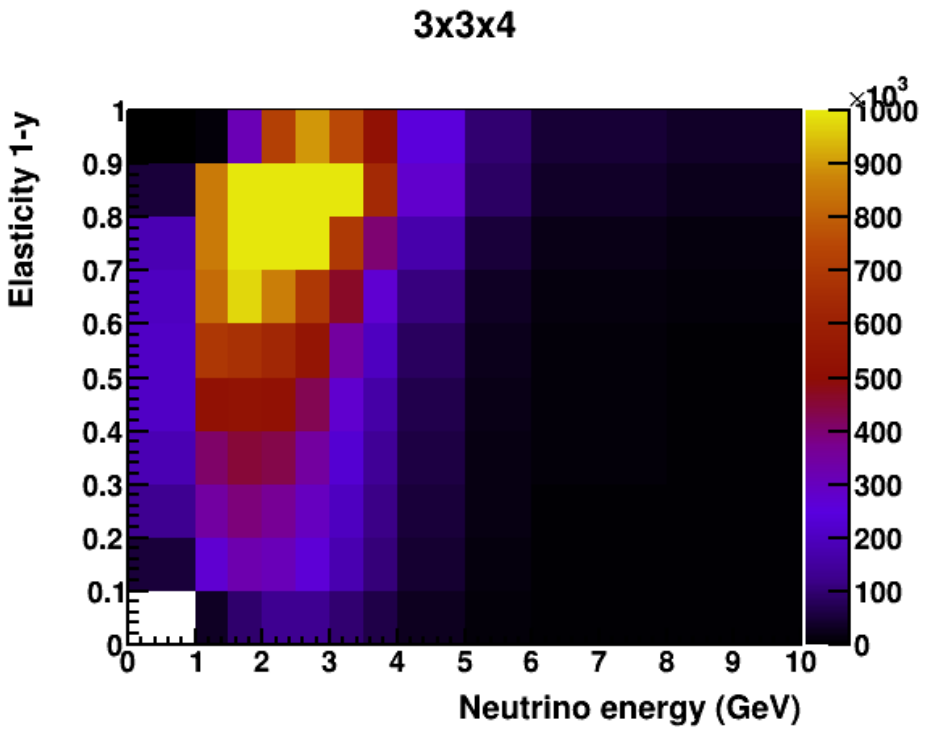
2x3x4 detector

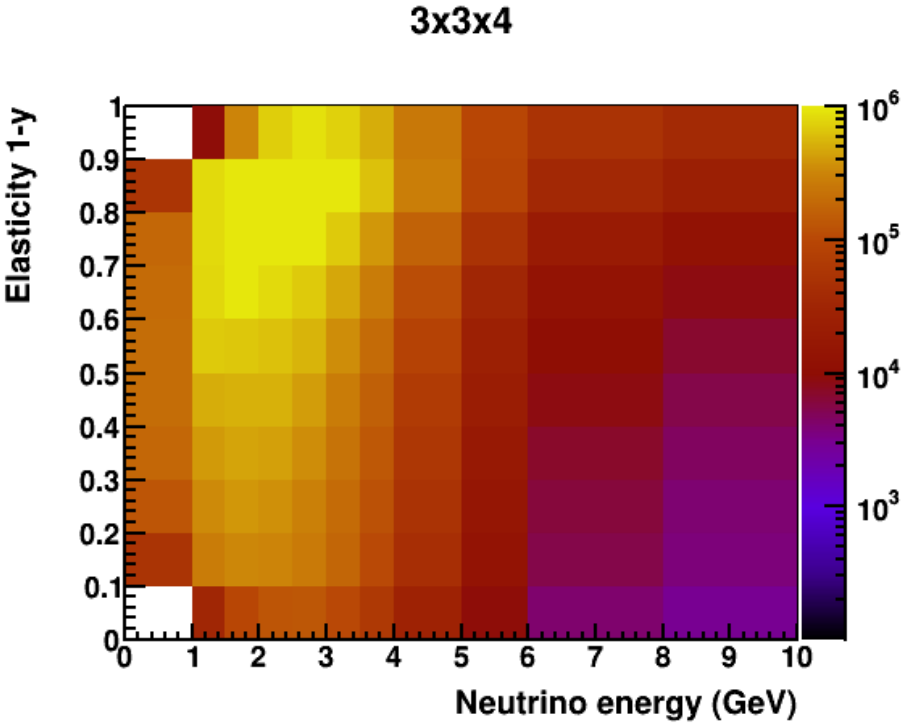




- ~few*10^5 per bin in the peak
- 1000s events per bin at 5-8 GeV

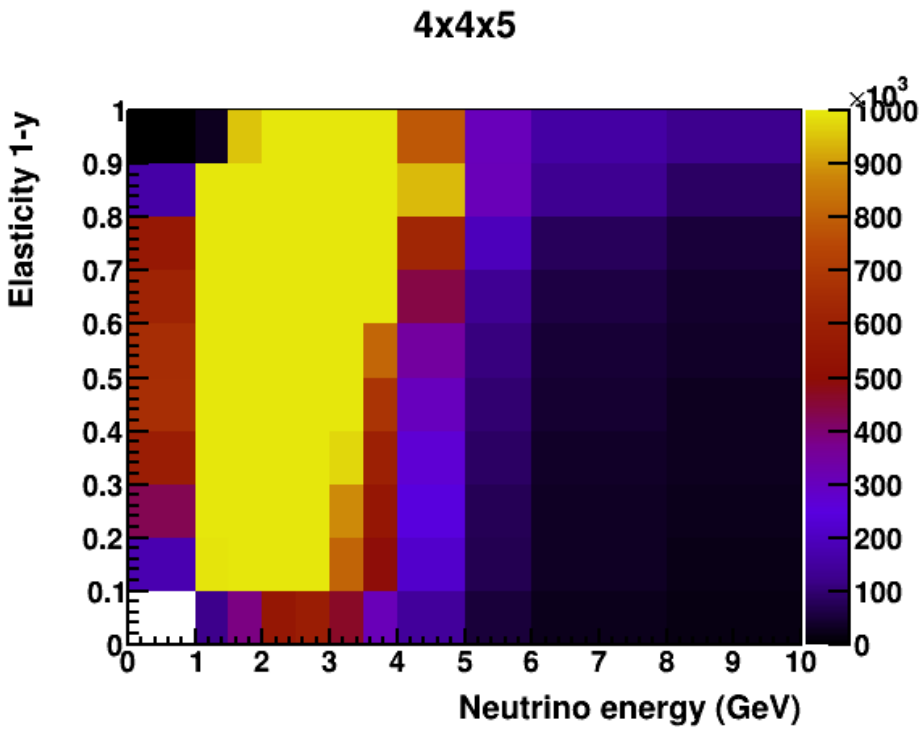
3x3x4 detector

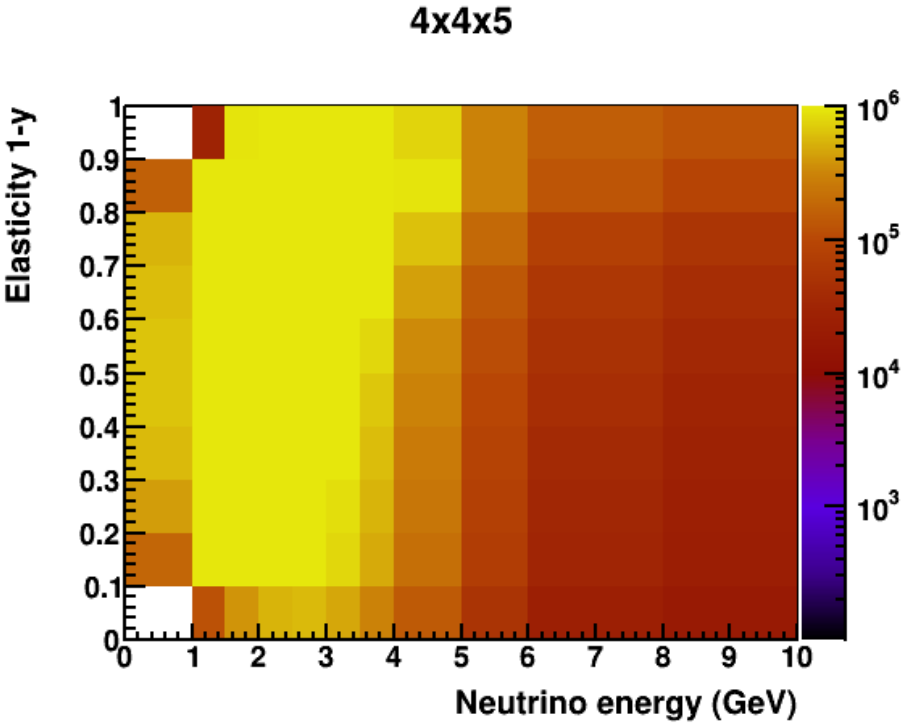




- Millions of events per bin in the peak, with ~10^5 for very inelastic events
- ~10^3-10^4 per bin at 5-8 GeV

4x4x5 detector



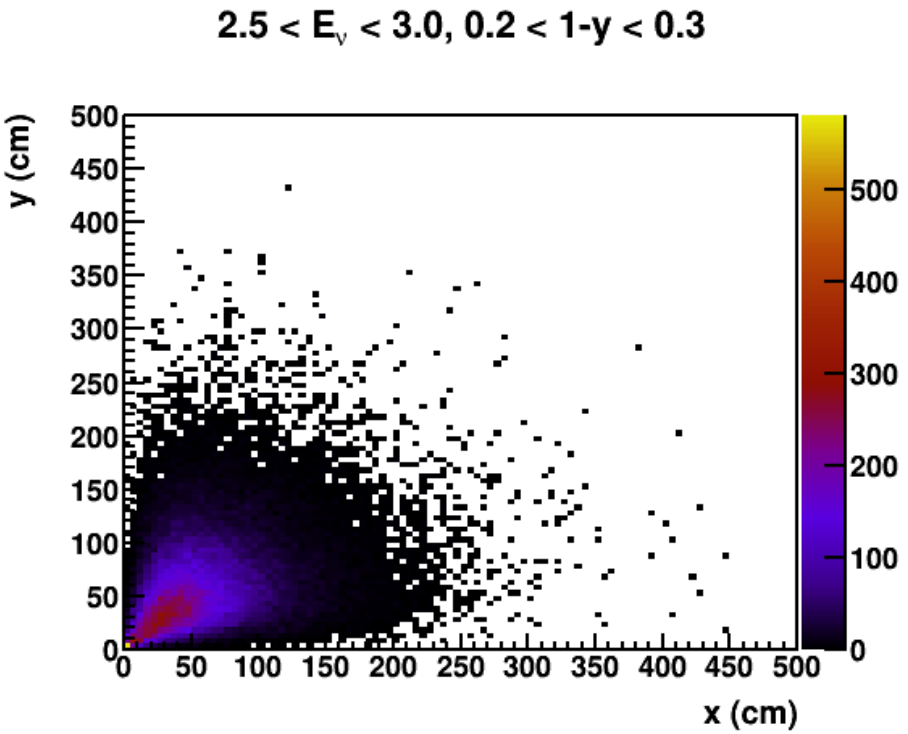


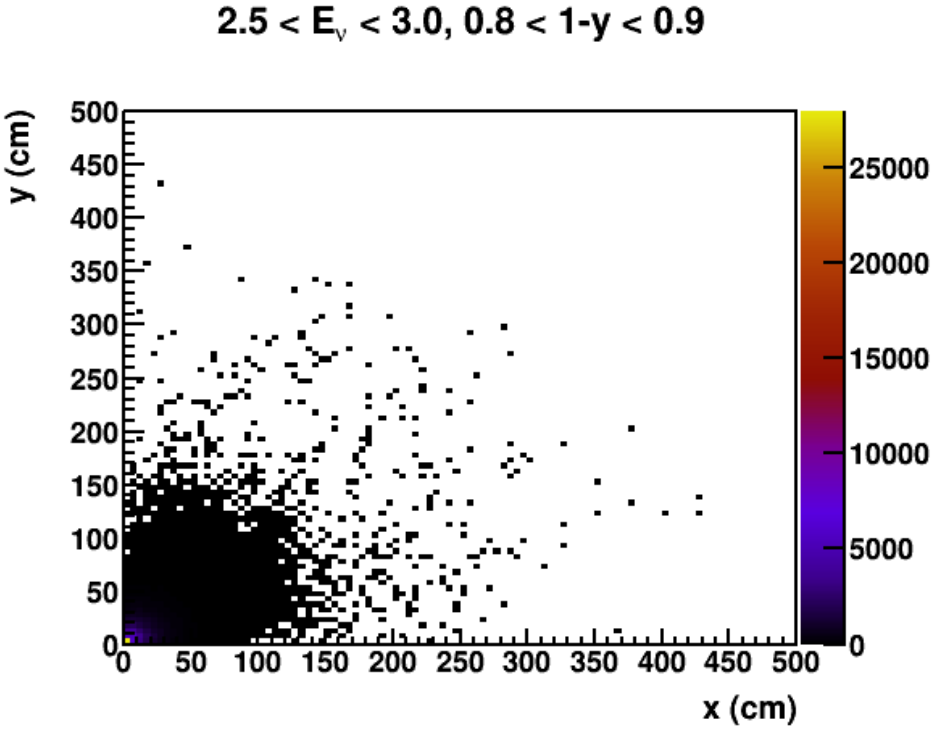
- Quite a few events

What about the muon?

- Previous slides all assumed the LAr was to contain hadrons only
  - Muon is reconstructed by downstream tracker or side detectors
- Briefly, let's look at what is required of the LAr TPC to contain high-angle muons

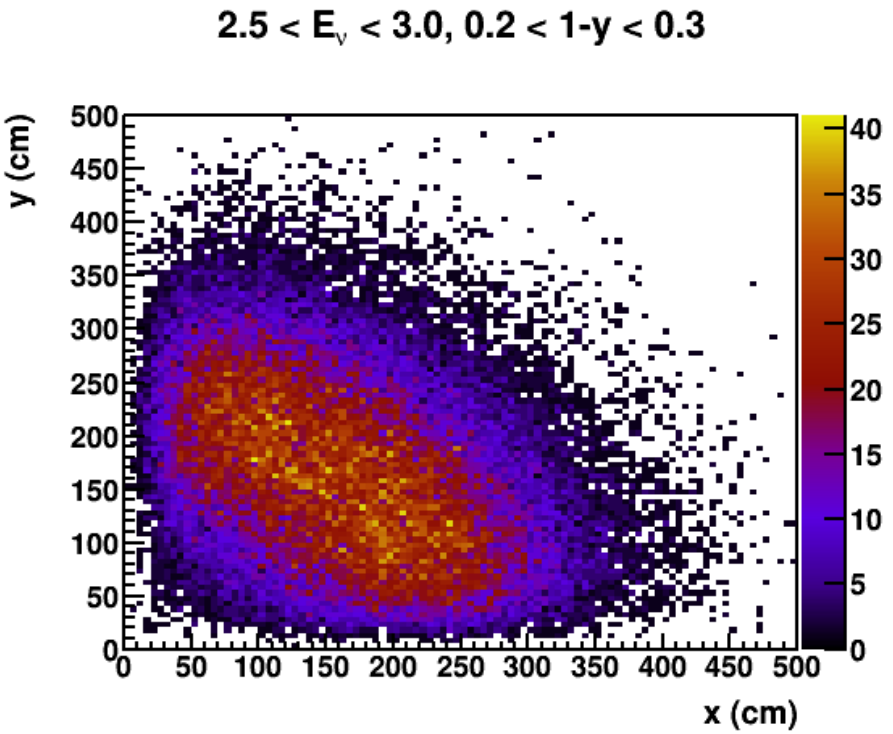
Reminder: hadrons only

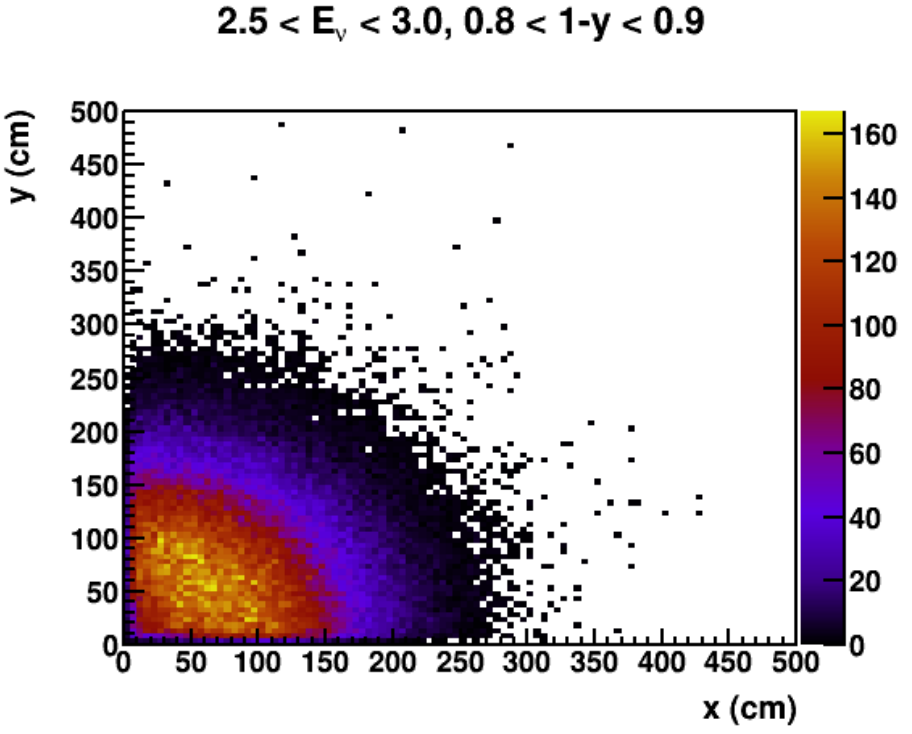




- Hadronic energy only
- Falling edge of flux peak, 2.5-3.0 GeV
- Left is very inelastic bin, right is very elastic

Same bins, hadrons + muon

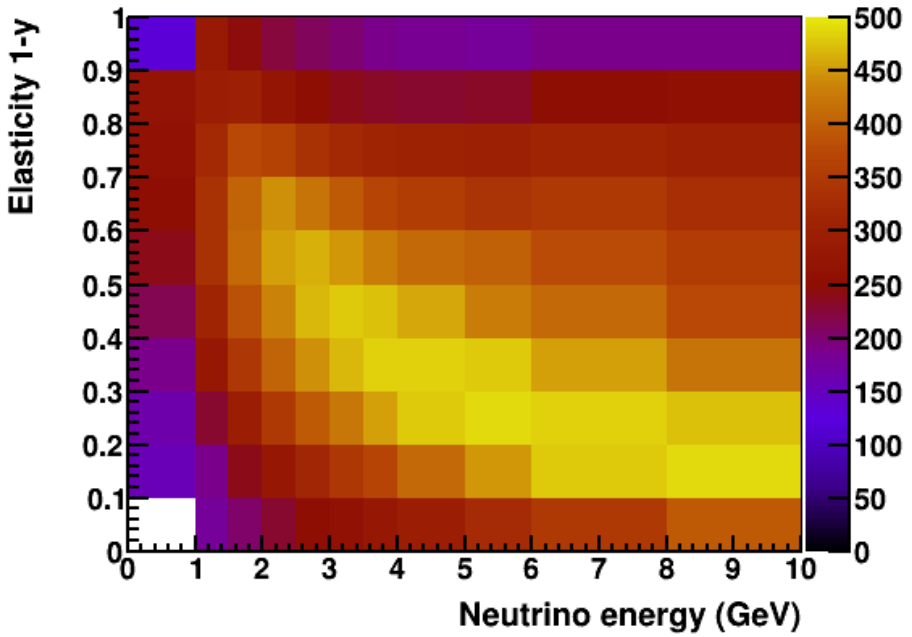




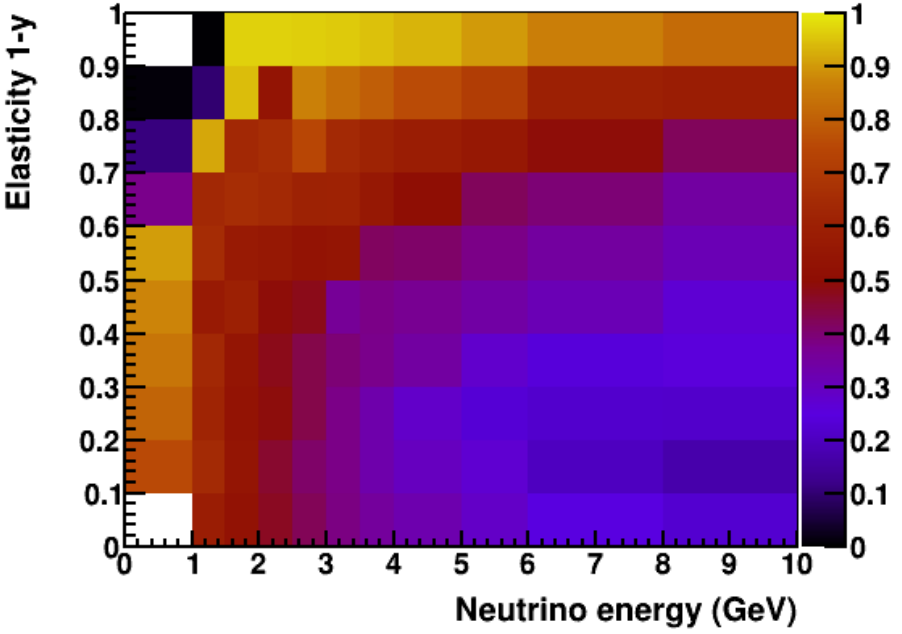
- 95% hadronic energy + 100% muon energy
- Falling edge of flux peak, 2.5-3.0 GeV
- Elastic events have forward muons (right), but inelastic events have big hadronic showers and high-angle muons (left)

Including the muon

Minimum transverse for 99%



4x4x5



- Transverse dimension needs to be >5m if we need to reconstruct muons with only the LAr

Conclusions

- Previous slides all assumed the LAr was to contain hadrons only
  - Muon is reconstructed by downstream tracker or side detectors
- Briefly, let's look at what is required of the LAr TPC to contain high-angle muons