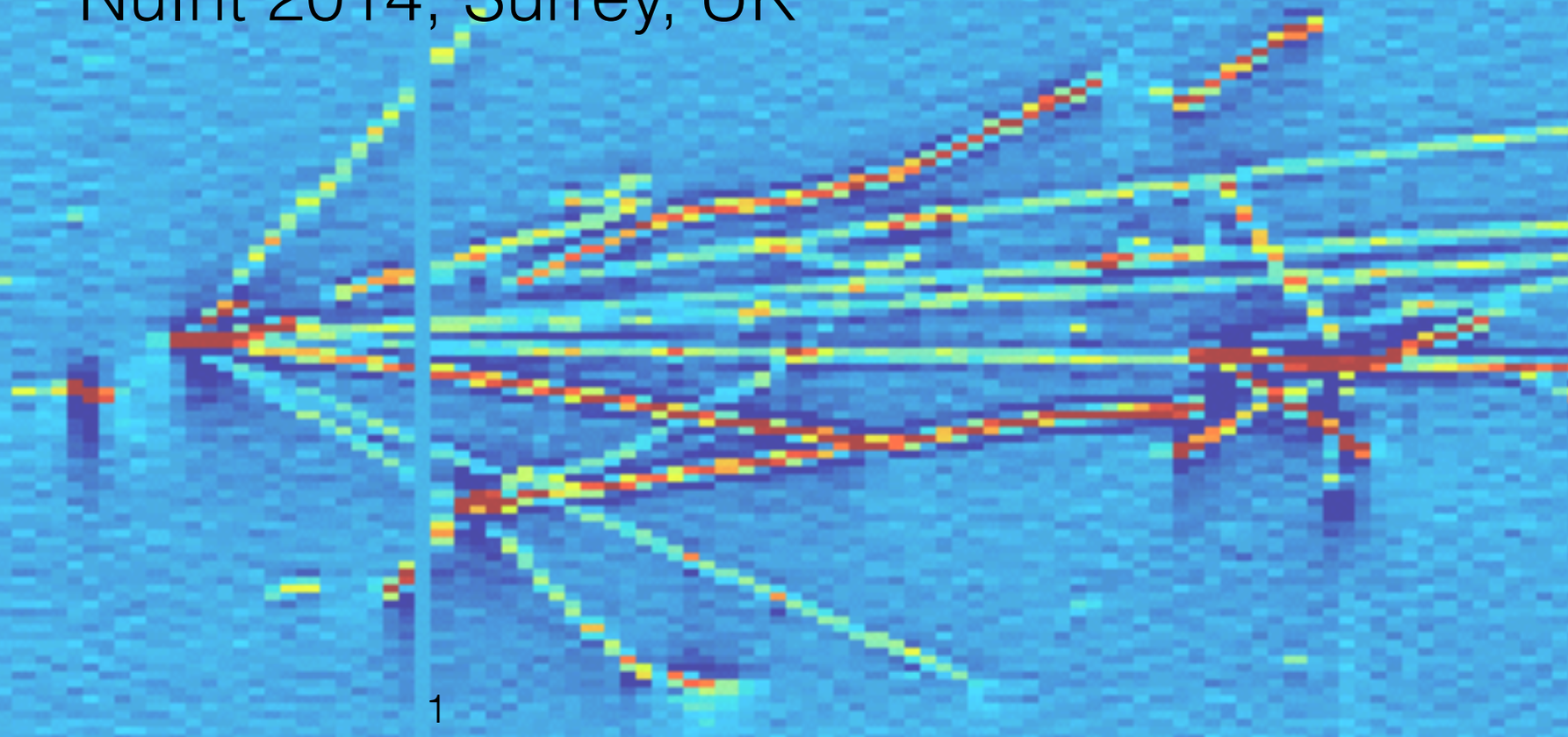
ArgoNeuT's Measurement of the Charged Current Inclusive Cross Section in the Low Energy NuMI Anti-neutrino mode Beam

Eric Church, Yale University

NuInt 2014, Surrey, UK



Liquid Argon Time Projection Chambers in the US

A LArTPC program following up on the work pioneered by ICARUS.

Yale TPC

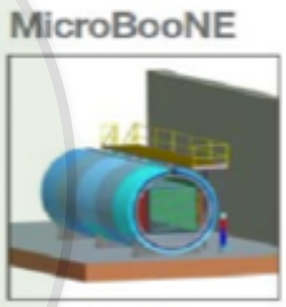
Location: Yale University
Active volume: 0.002 ton
operational: 2007

Bo

Location: Fermilab
Active volume: 0.02 ton
operational 2008

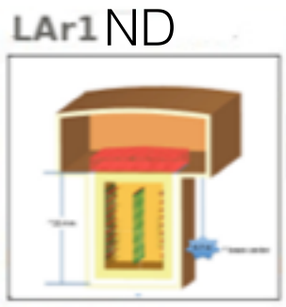
ArgoNeuT

Location: Fermilab
Active volume: 0.3 ton
operational: 2008
First neutrinos: June 2009



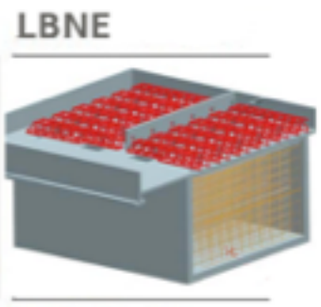
MicroBooNE

Location Fermilab
Active volume: 0.1 kton
Construction start: 2011



LAr1 ND

Location: Fermilab
Active volume: 1 kton
Construction start: 2016?



LBNE

Location: Homestake
Active volume: 10 kton
Construction start 2020

Luke

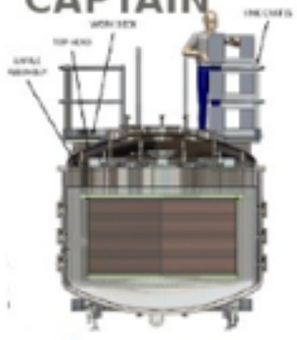
Location: Fermilab
Purpose: materials test st
Operational: since 2008

LAPD

Location: Fermilab
Purpose: LAr purity demo
Operational: 2011

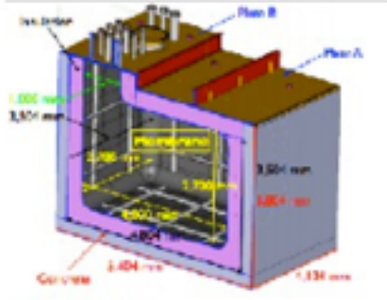
LArIAT

Location: Fermilab
Purpose: LArTPC calibration
Operational: 2014 (phase 1)



CAPTAIN

Location: LANL
Purpose: LArTPC calibration
Operational: 2014



LBNE 35 Ton

Location: Fermilab
Purpose: purity demo
Operational: 2013

This result

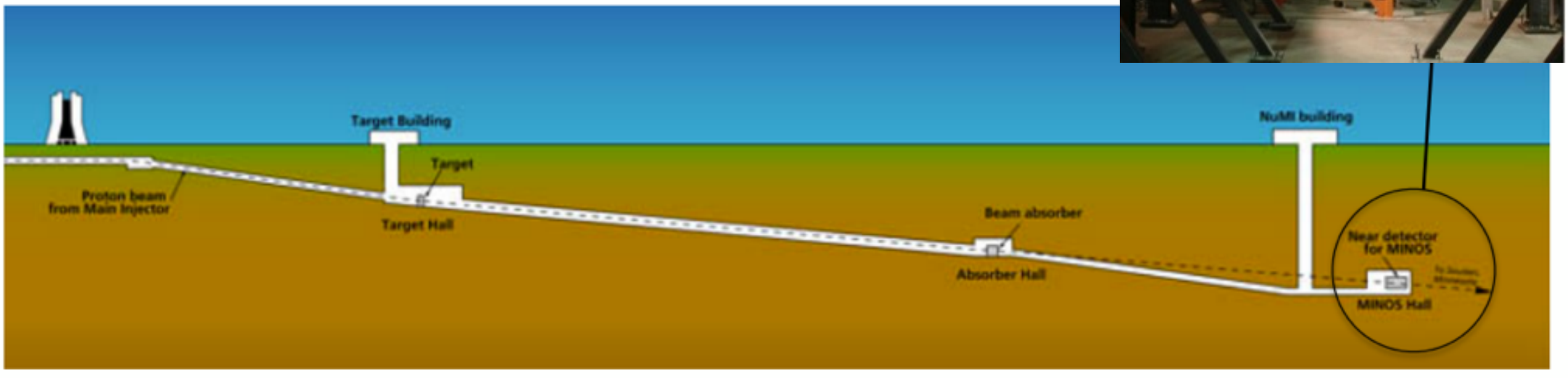
- This is the first cross-section measurement in Argon of anti-neutrinos. We also give a neutrino cross-section result at a new energy with respect to the previous ArgoNeuT result.

- These results are at an energy that bears directly on the future US neutrino detection program

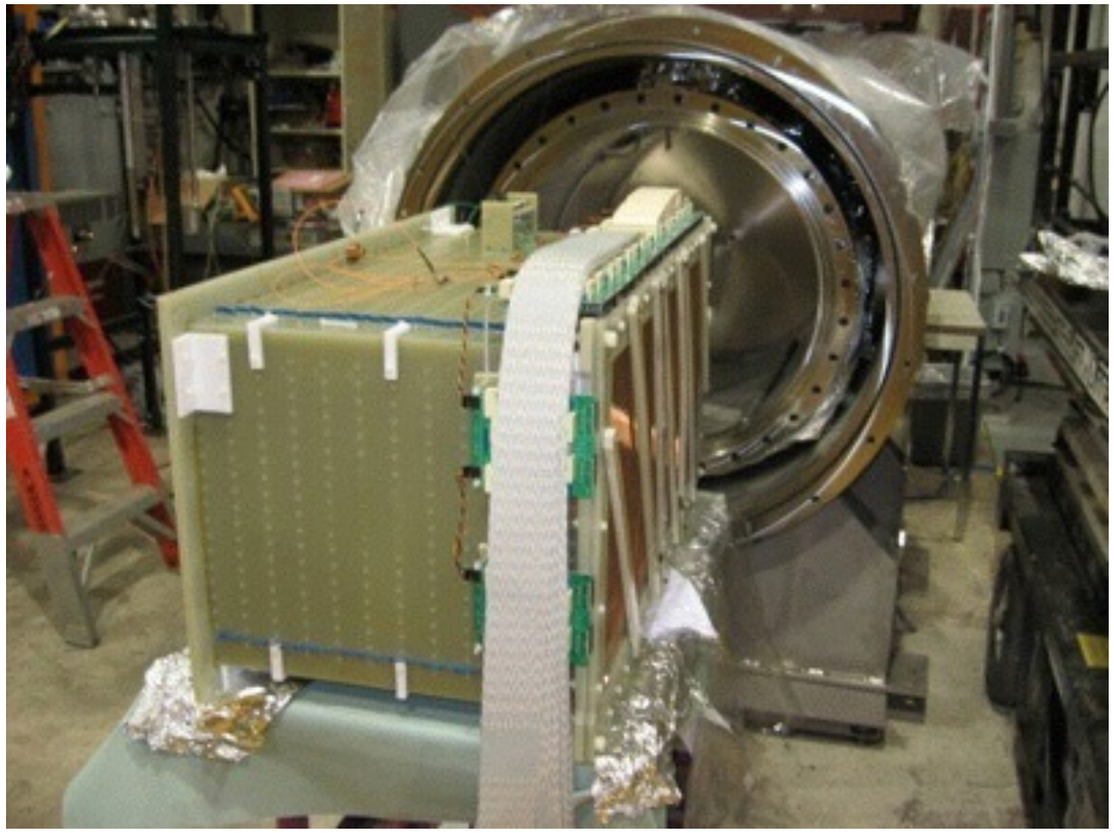
- We show differential cross-sections in the kinematic variables characterizing the muon: its outgoing momentum and angle. **arXiv:1404.4809**

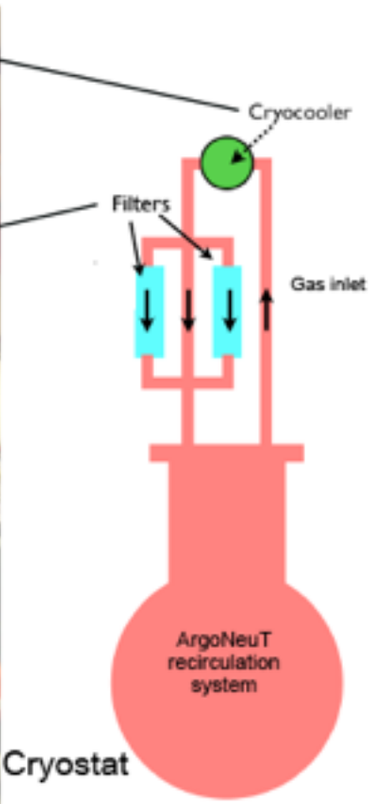
ArgoNeuT at Fermilab

- First TPC in a low energy (1-10 GeV) US neutrino beam …
  - the Neutrinos-from-Main-Injector (NuMI) beam at Fermilab
- Uses the Minos Near Detector as a spectrometer



the ArgoNeuT detector





JINST 7 (2012) P10019

Cryostat Volume	500 Liters
TPC Volume	170 Liters
# Electronic Channels	480
Wire Pitch	4 mm
Electronics Style (Temperature)	JFET (293 K)
Max. Drift Length	47 cm
Light Collection	None

- We recirculate argon through a copper filter.
- A cryocooler is used to re-condense boil-off gas.
- U and V wire planes

other ArgoNeuT talks at NuInt2014

Ornella Palamara

0-pion reactions and nuclear effects

Ed Santos

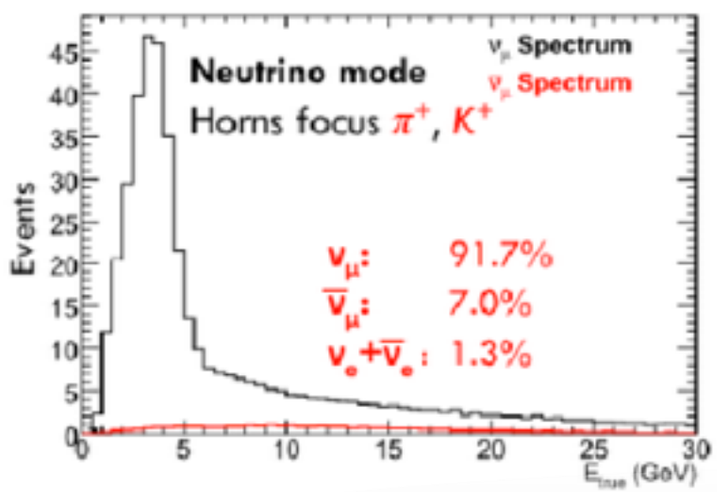
Coherent Charged Current measurement

Jonathan Asaadi

showers in LArTPCs

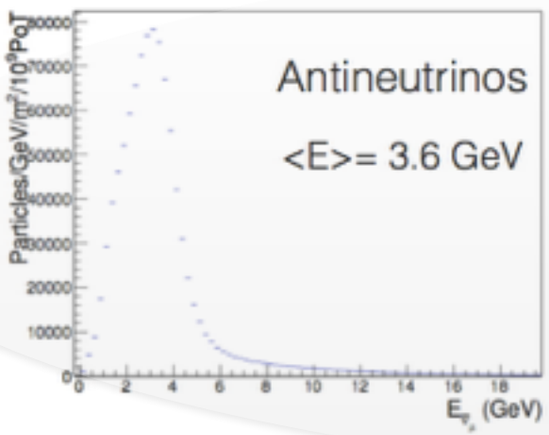
Fluxes

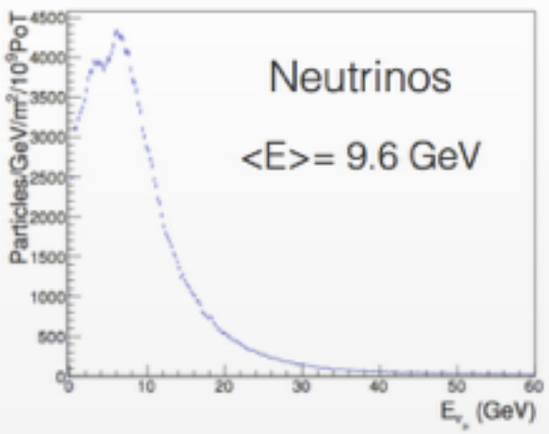
0.085e20 POT



- ArgoNeuT took data over 5 months during 2009-2010.
- **Previous** Inclusive Charged-Current (CC) cross section results based on ν_μ's in the **neutrino beam**: PRL 108 (2012) 161802.

1.2e20 POT



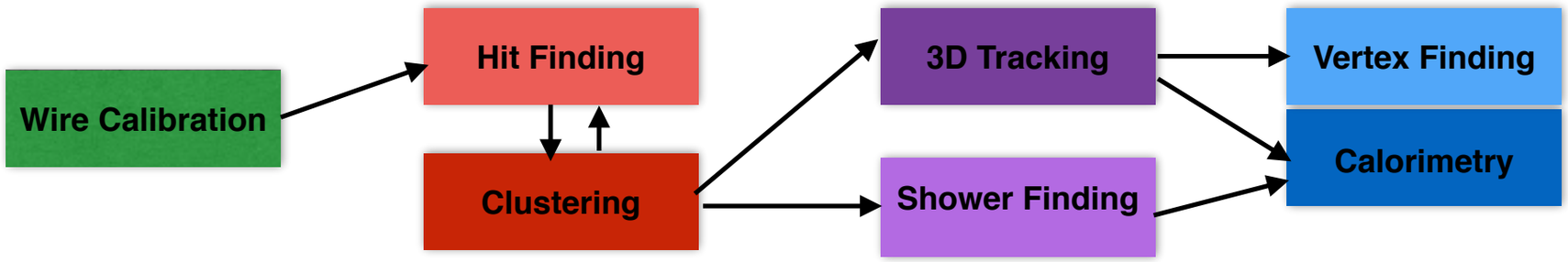


- **New** results are based on ν_μ's **and** $\bar{\nu}_\mu$'s in the **anti-neutrino** beam

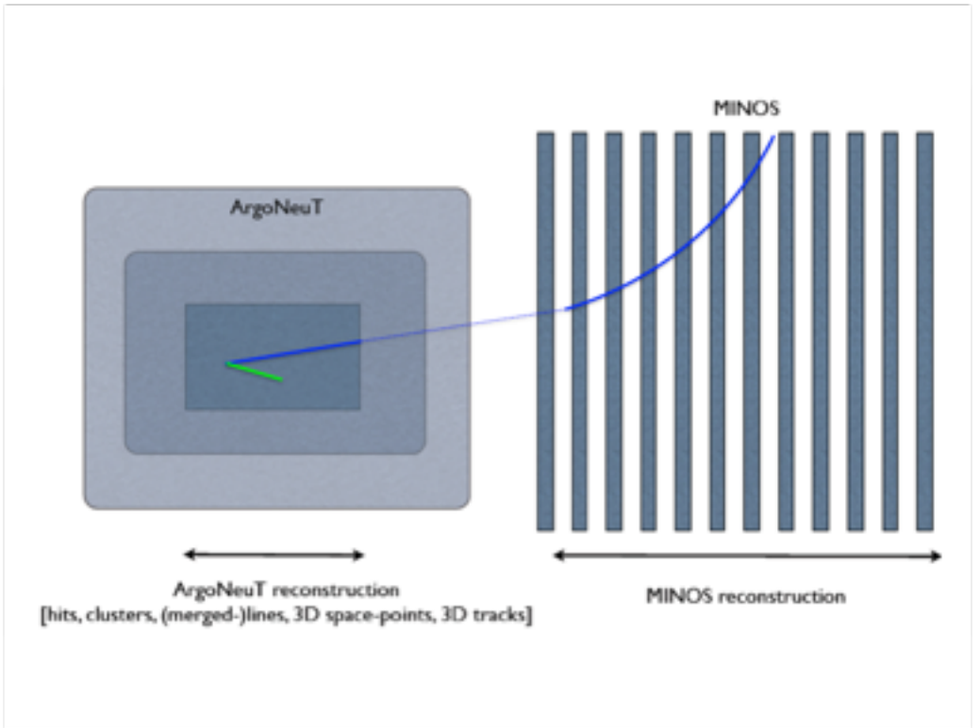
We use so-called SKZP MINOS flux: NuMI flux simulation plus FLUKA, tuned from NA49 data and Minos ND data and a +/- 11% flat systematic error.

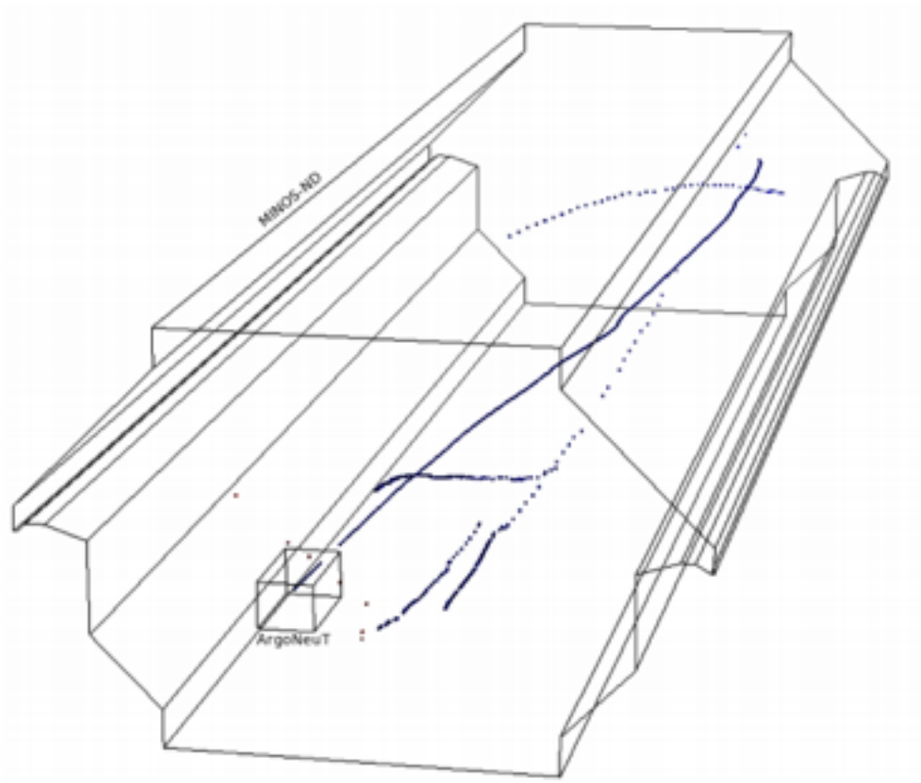
Reconstruction

ArgoNeuT uses the LArSoft package: A FNAL-supported C++ framework, which is utilized by O(5) other LArTPC collaborations.



Track Matching with the MINOS ND



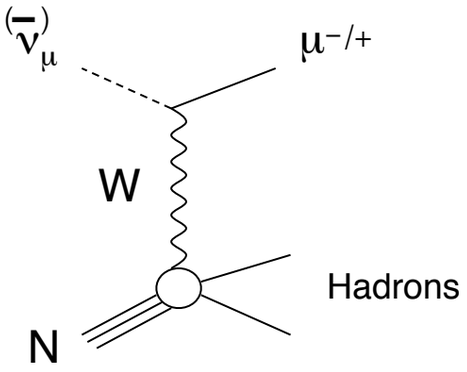


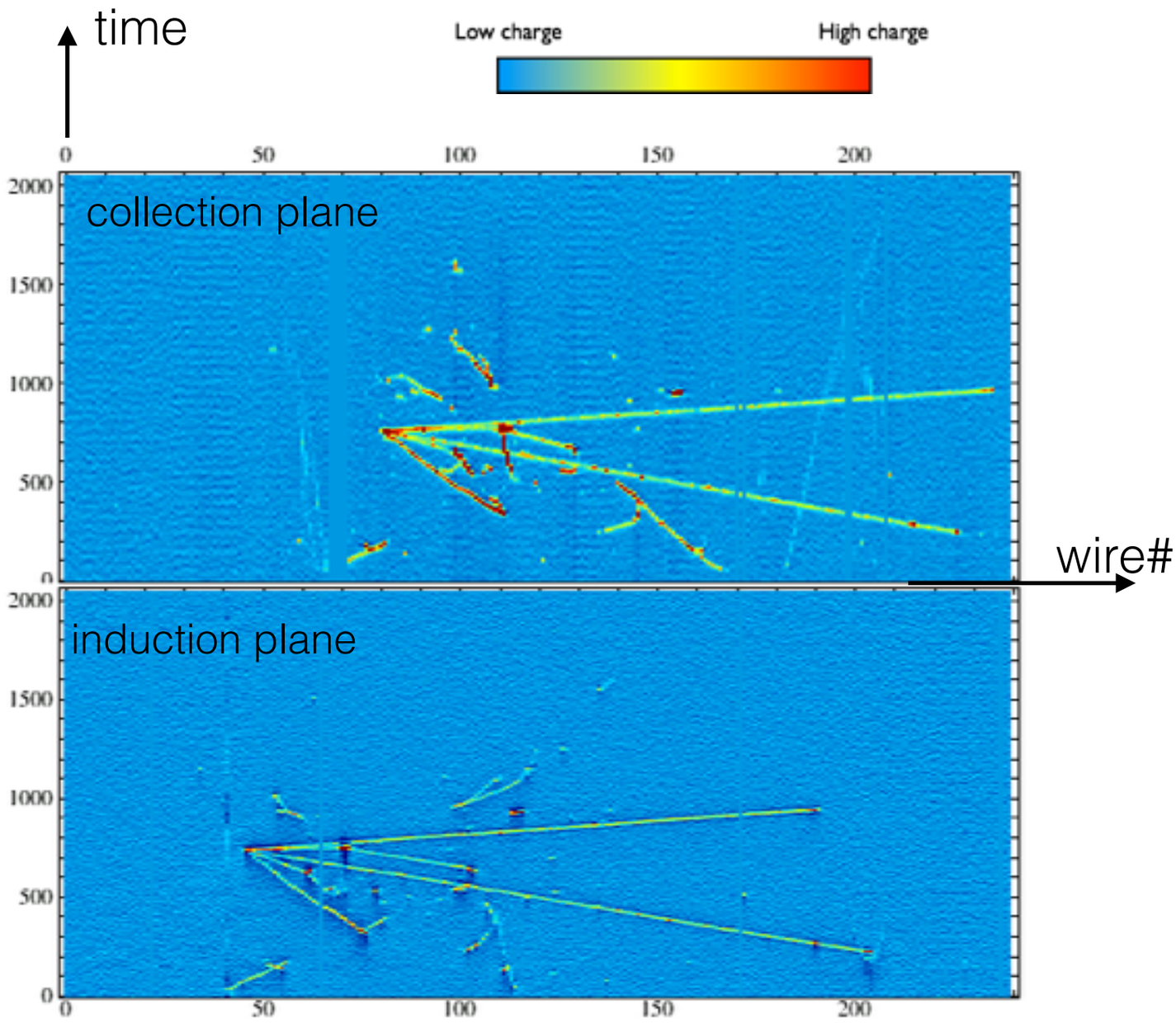
The MINOS collaboration graciously provides simulation and reconstruction of tracks in their Near Detector.

data

JINST 7 (2012) P10020

CC Inclusive event

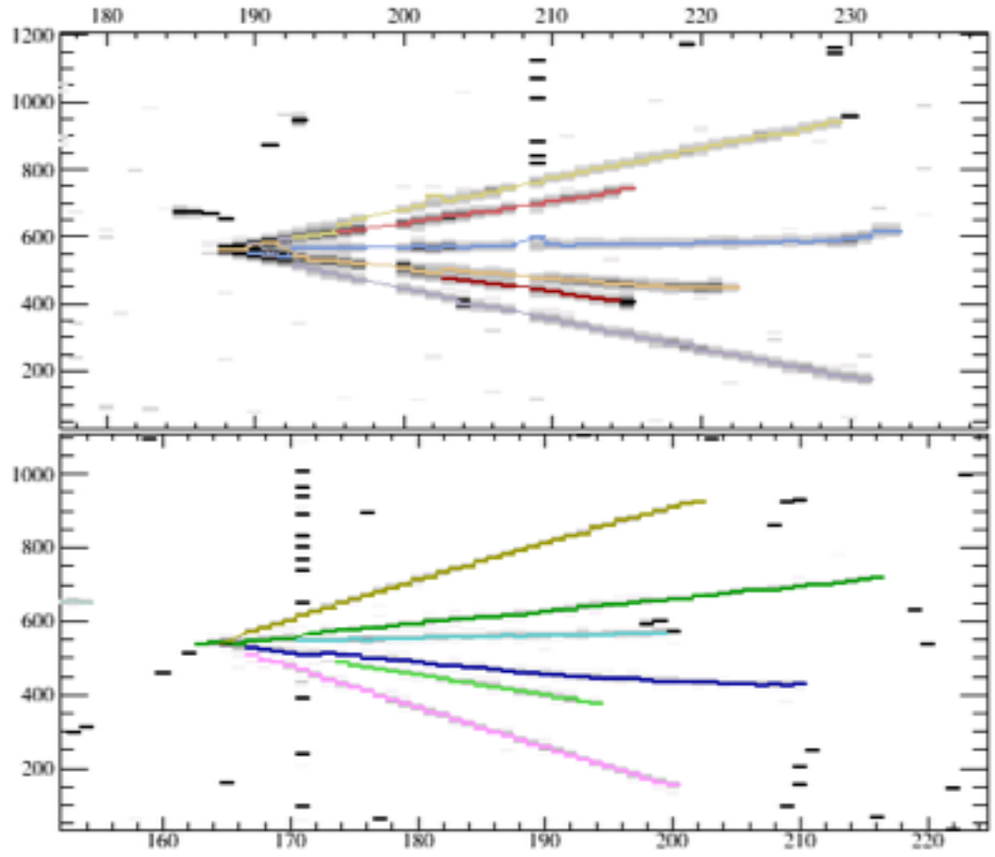




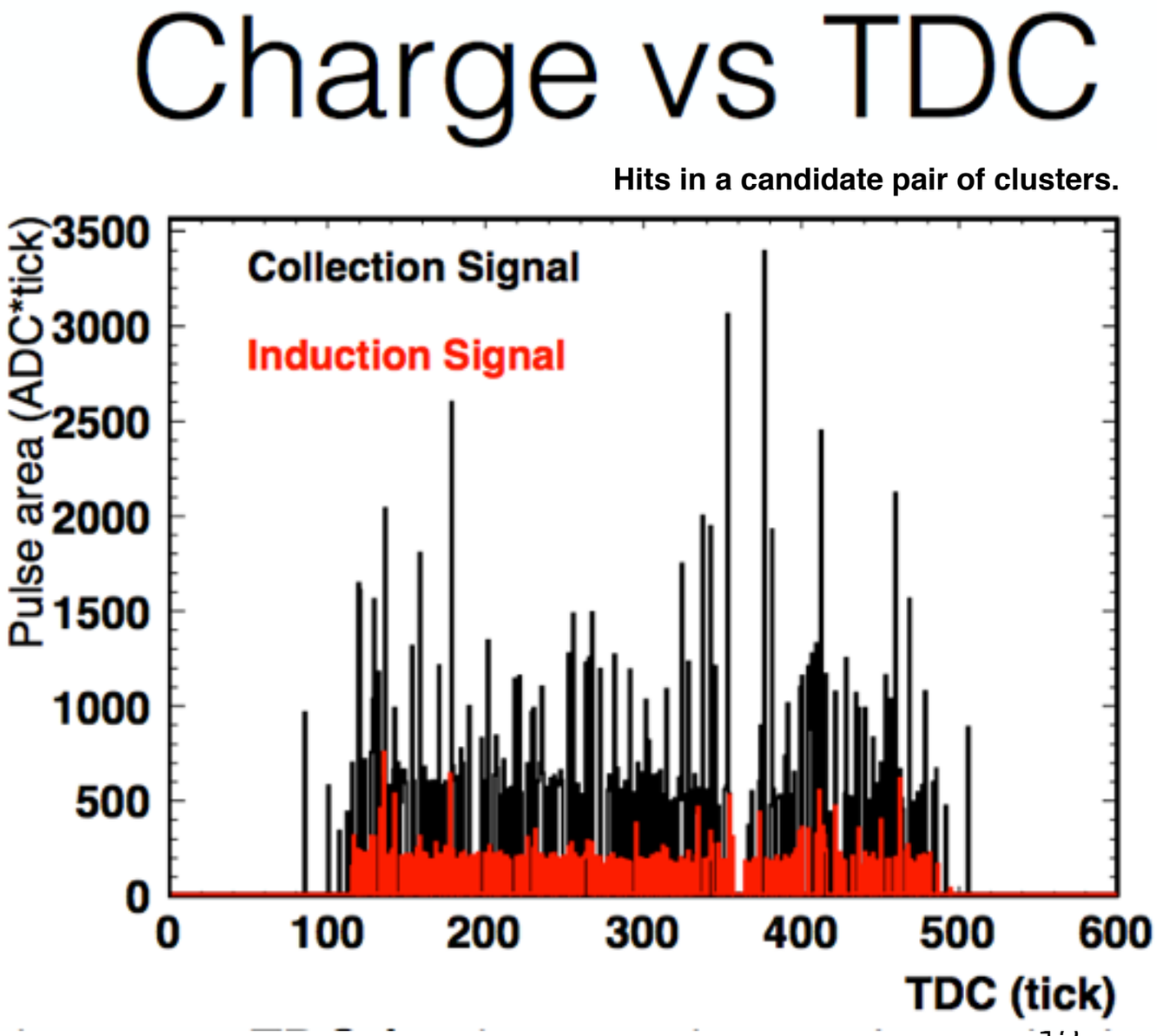
data

Reconstruction: Hits, Clusters

- Hit and Cluster finding in this analysis uses one module that finds self-consistent hits in track-like clusters



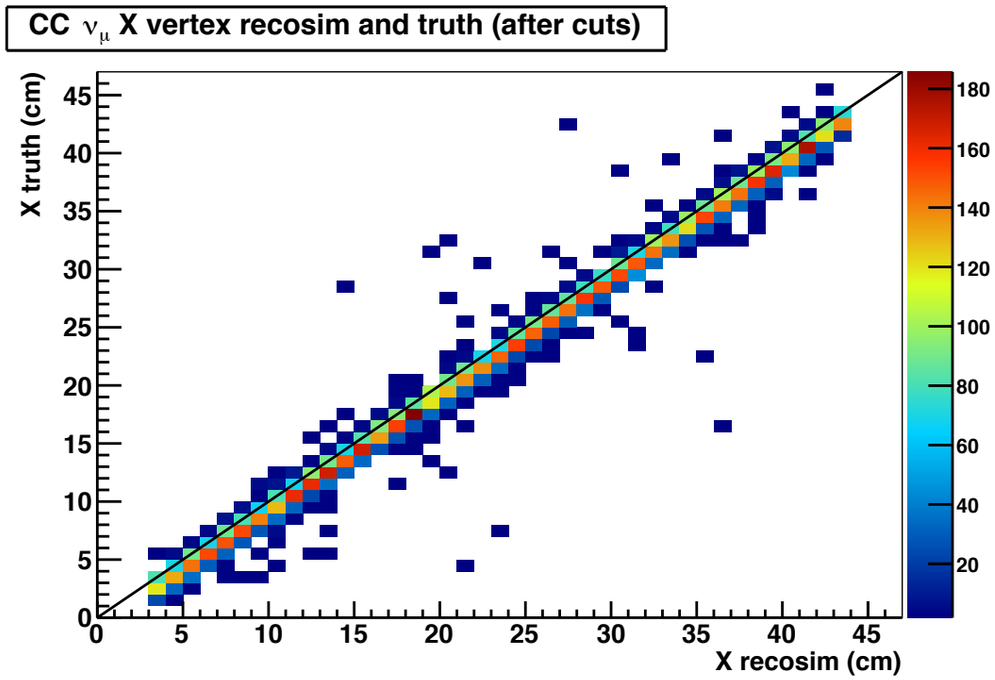
Reconstruction 3: cluster pairing

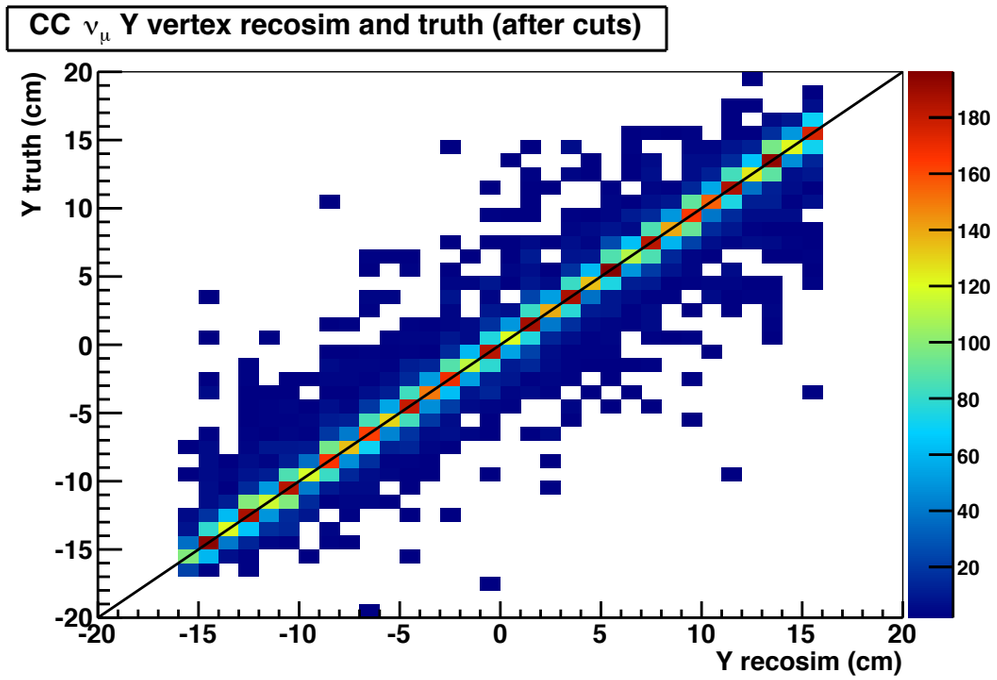


It is necessary to pair clusters across the two planes, from which coincident hits form 3D spacepoints.
A 3D track runs through the spacepoints.

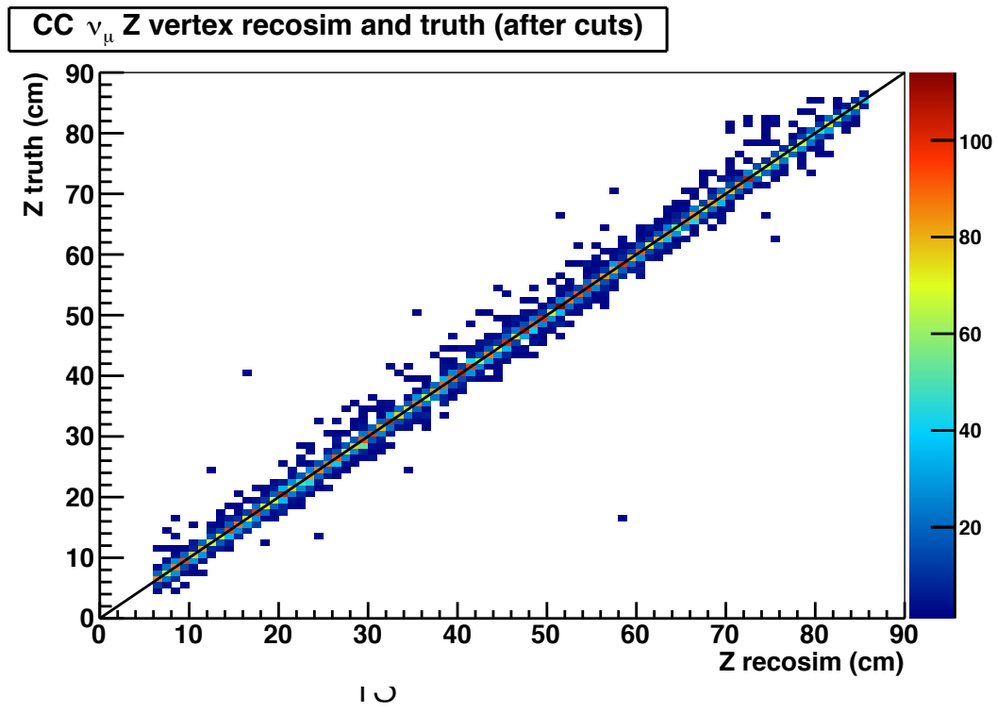
One forms a Kolmogorov statistic on the timing of hits in candidate cluster pairs and keeps those with a high likelihood of being proper pairs.

MC: truth vs reco



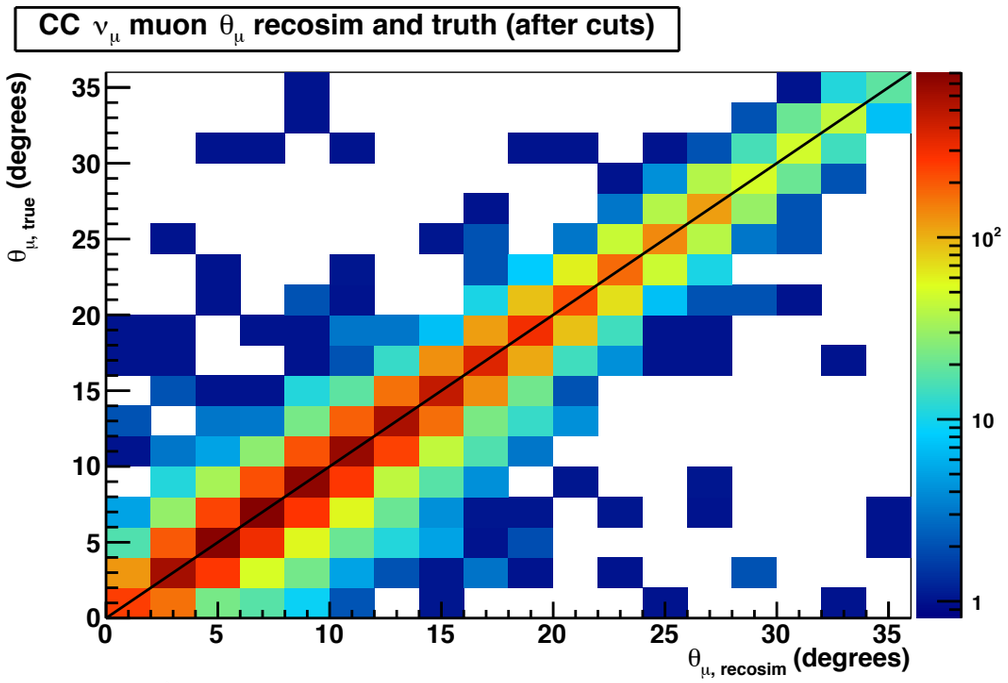


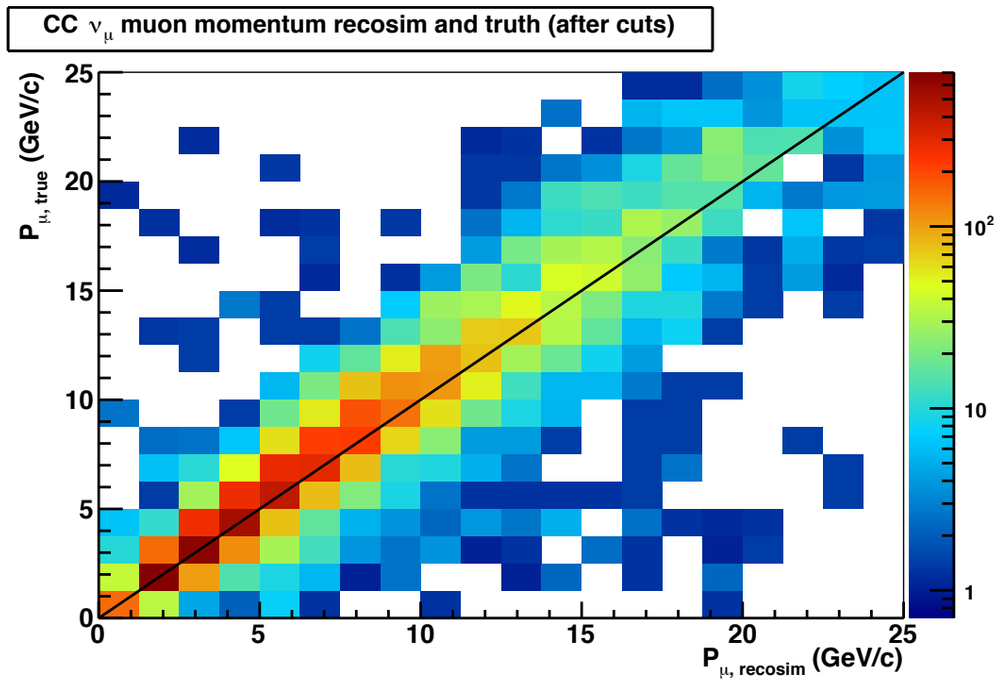
From the ν sample

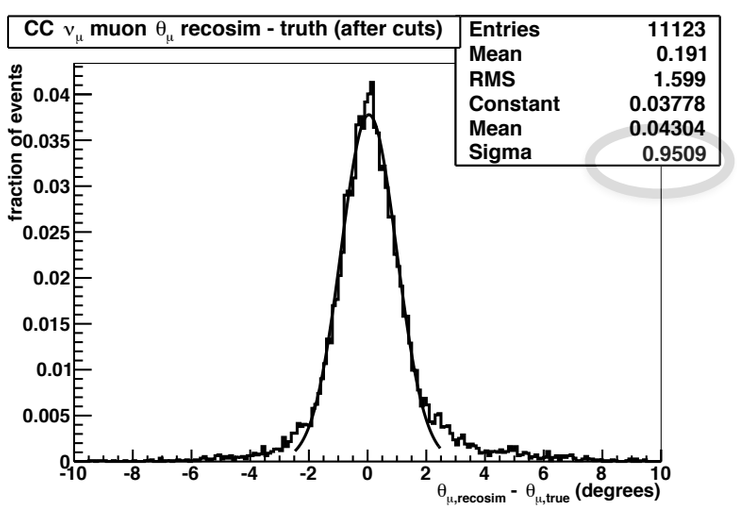


MC: angular and momentum resolution

From the $\overline{\nu}$ sample

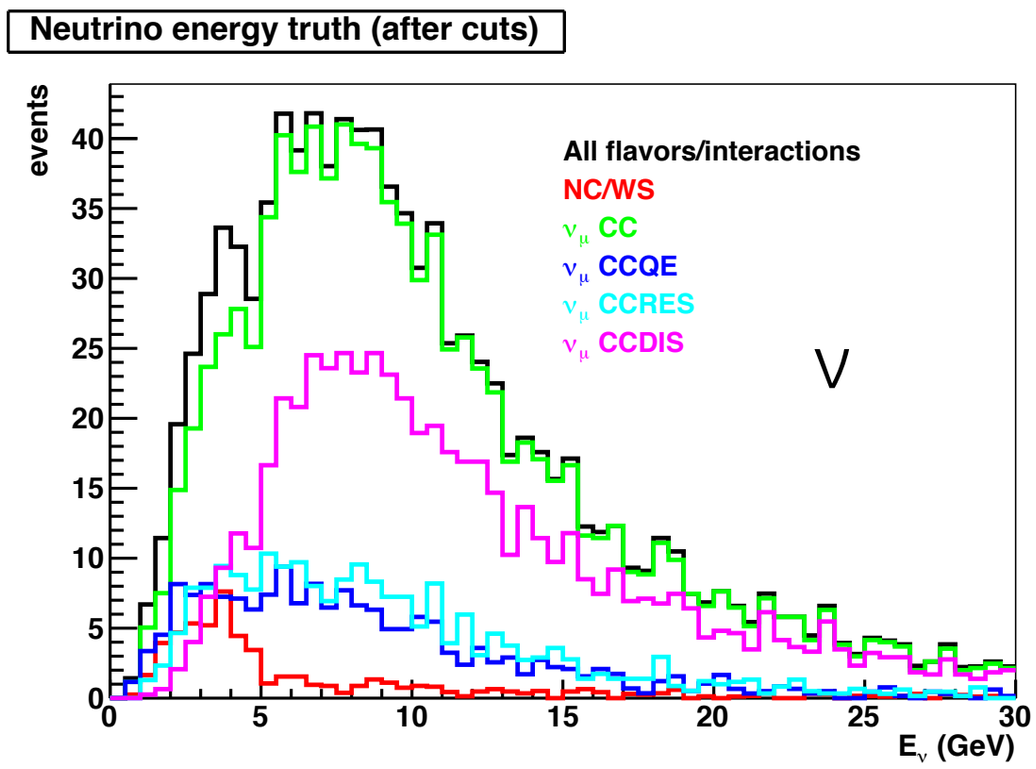


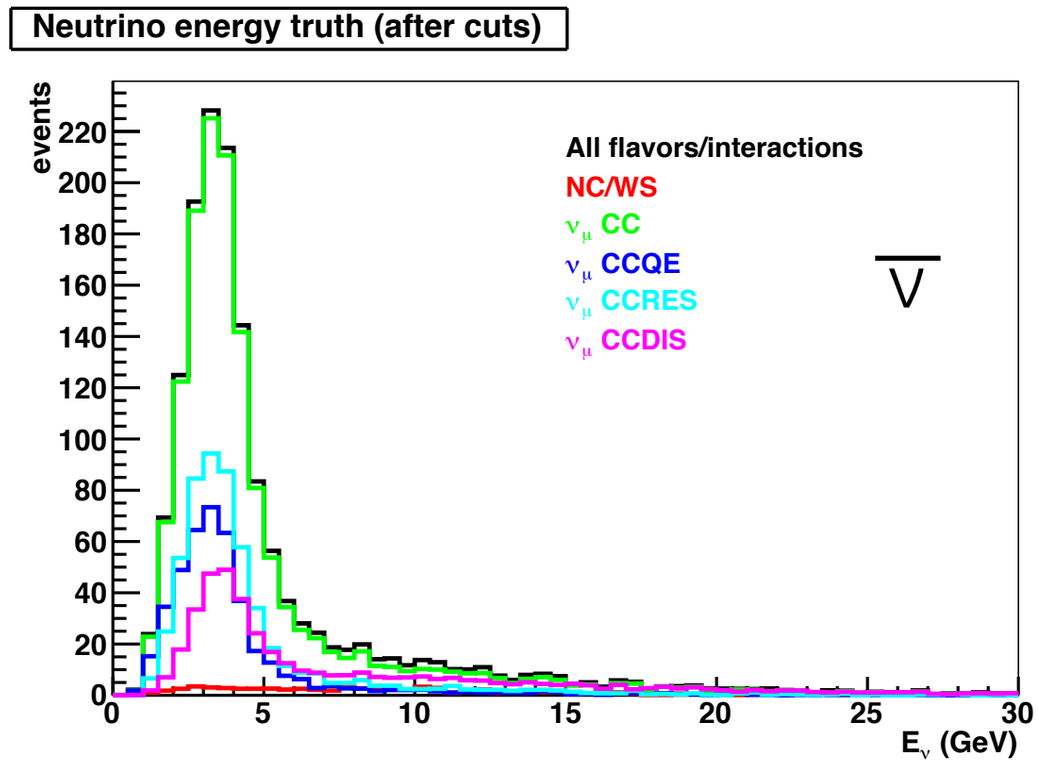




1 degree resolution

MC: post-cuts spectra

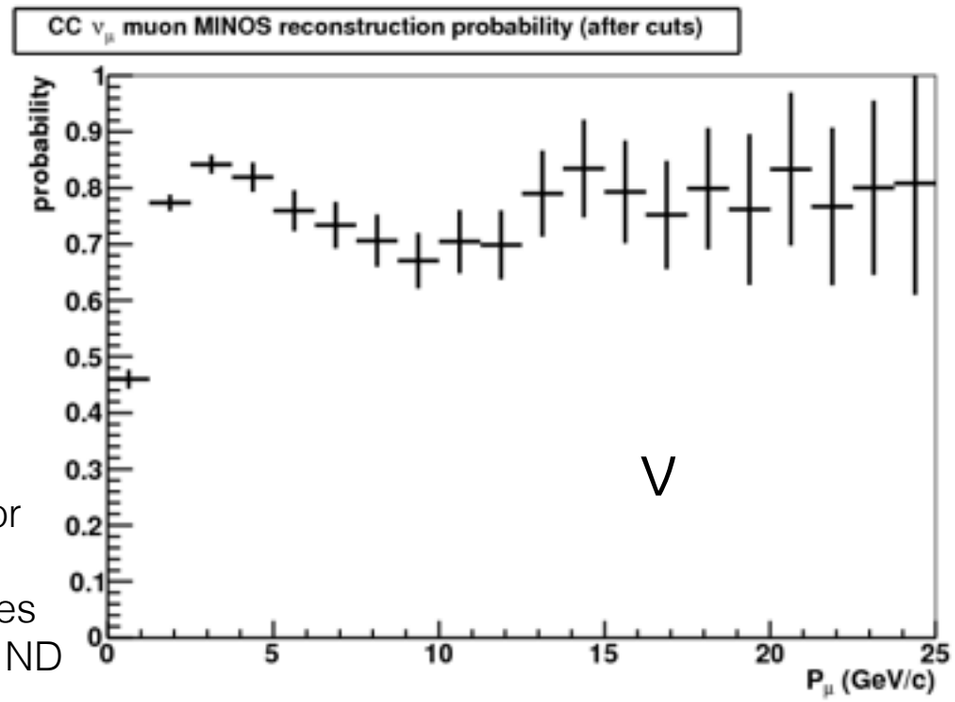


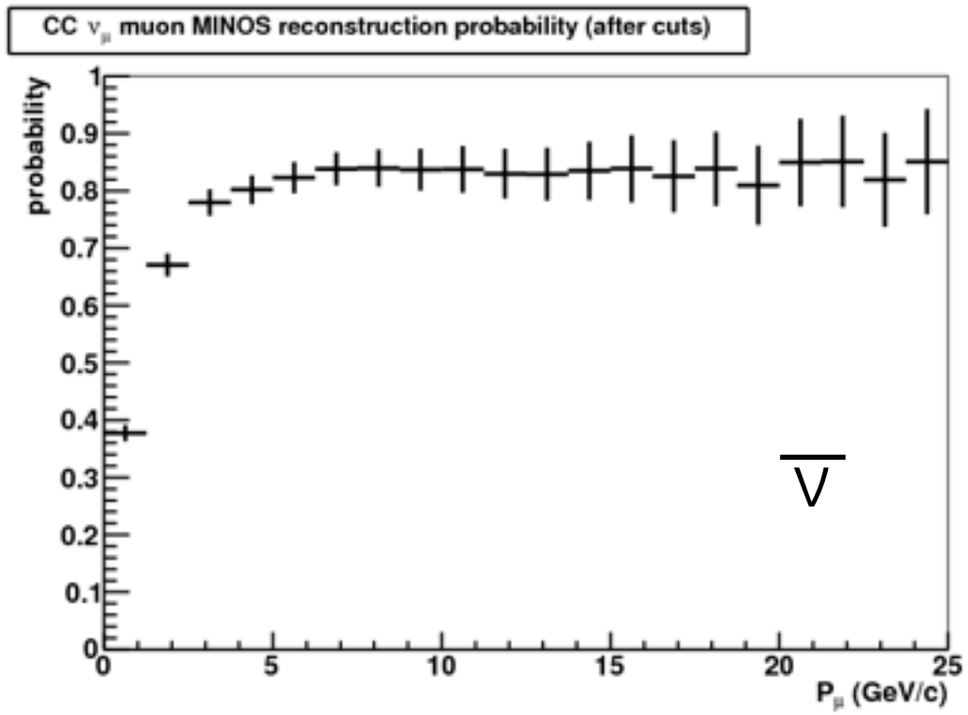


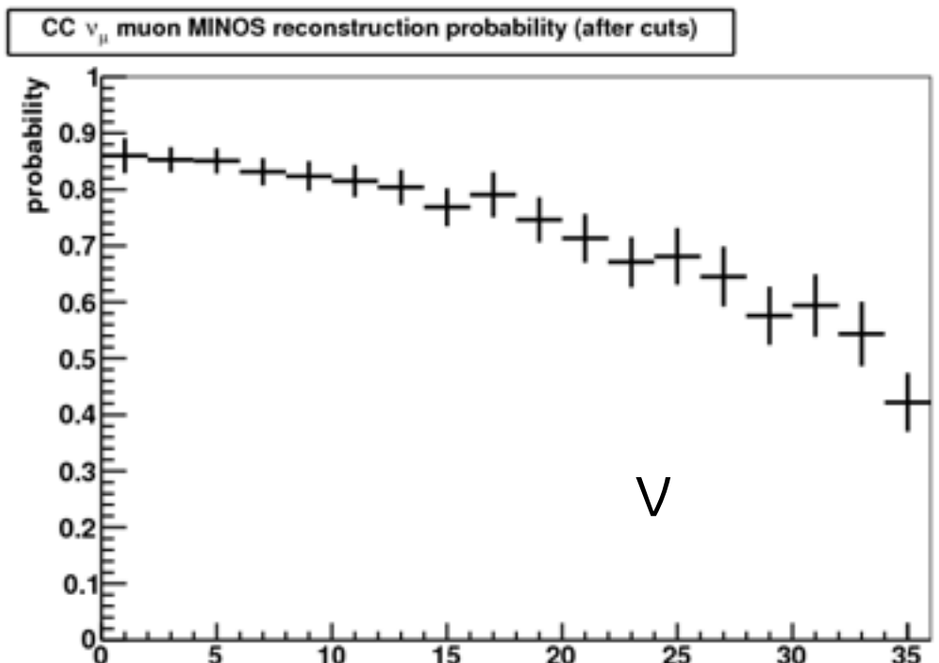
Acceptance

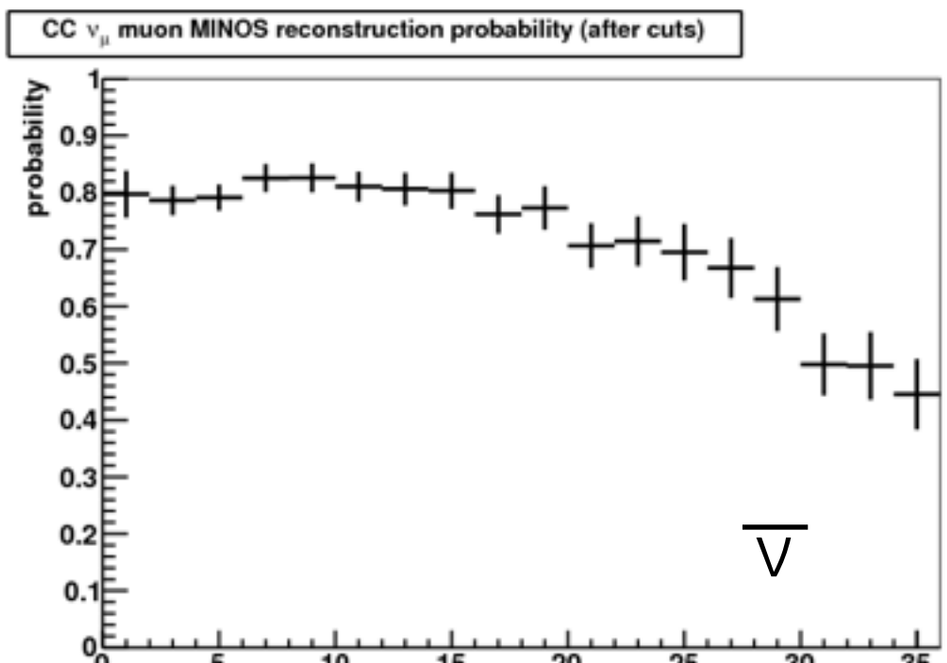
Is there a CC track in ArgoNeuT that points roughly to any track in Minos ND?

At low momentum or large angles the charged particle does not make it to MINOS ND



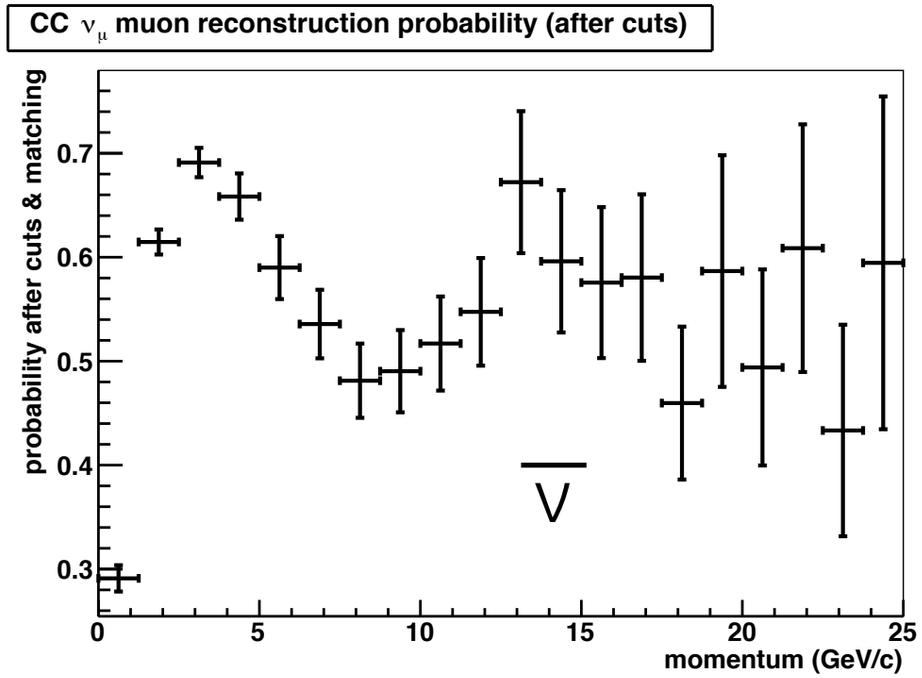


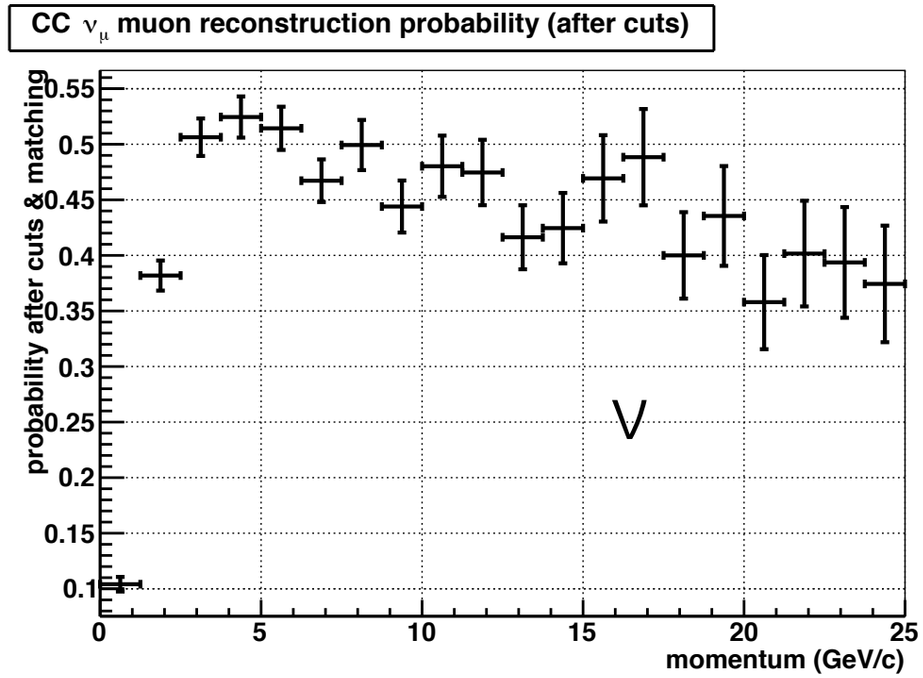


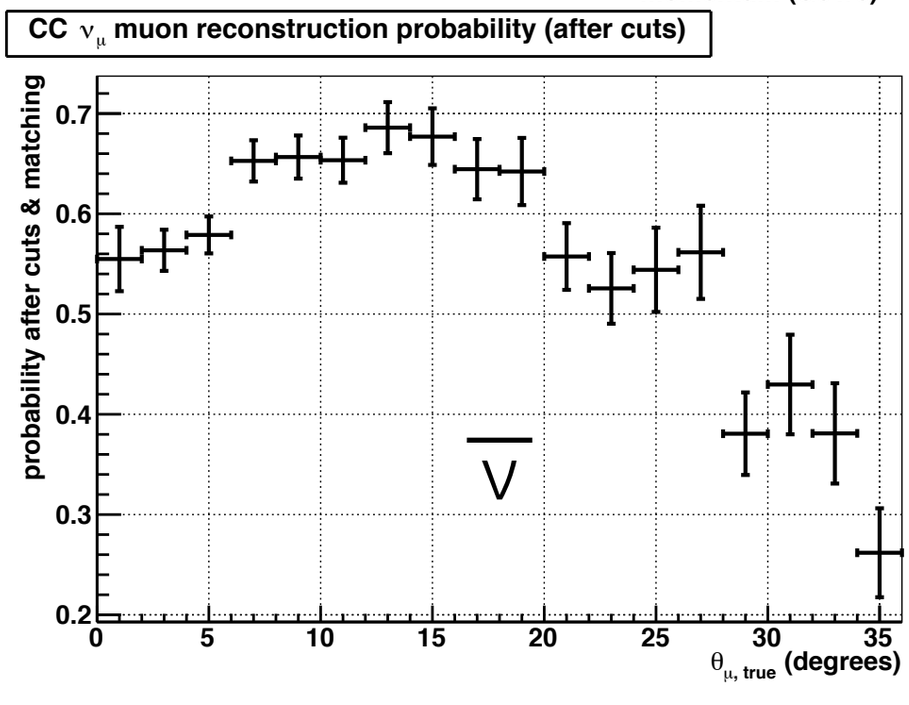


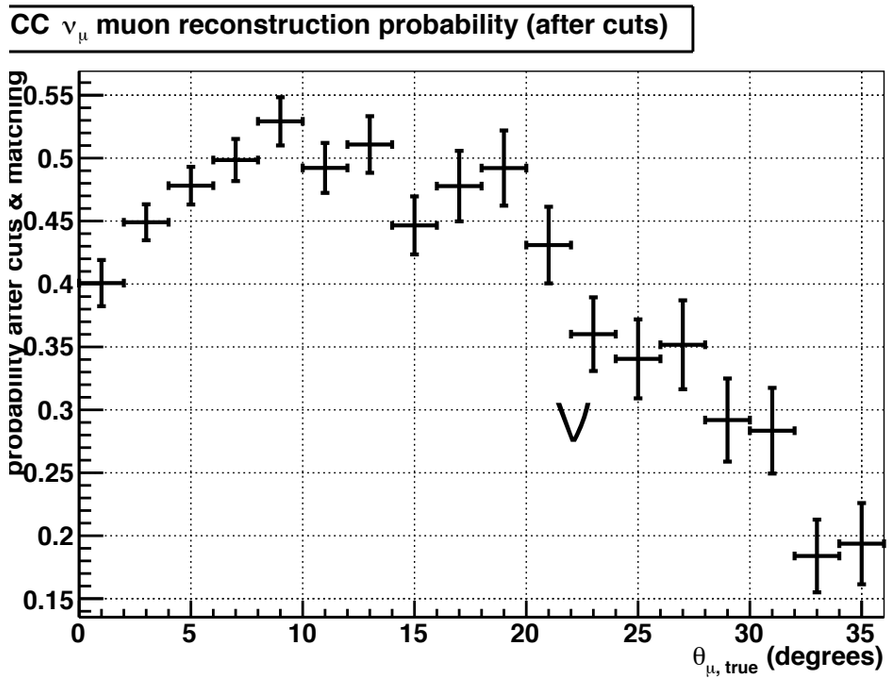
Efficiency

Is there a CC track in ArgoNeuT that points accurately at a track in Minos ND with the desired sign?









Signal size

- Track vertex required to be reconstructed in the fiducial volume — 3-4 cm boundaries within the LAr TPC.

- Best matched track to MINOS ND, reconstructed, of proper sign.

- 1676 (1605) (anti-) neutrino events remain

Backgrounds

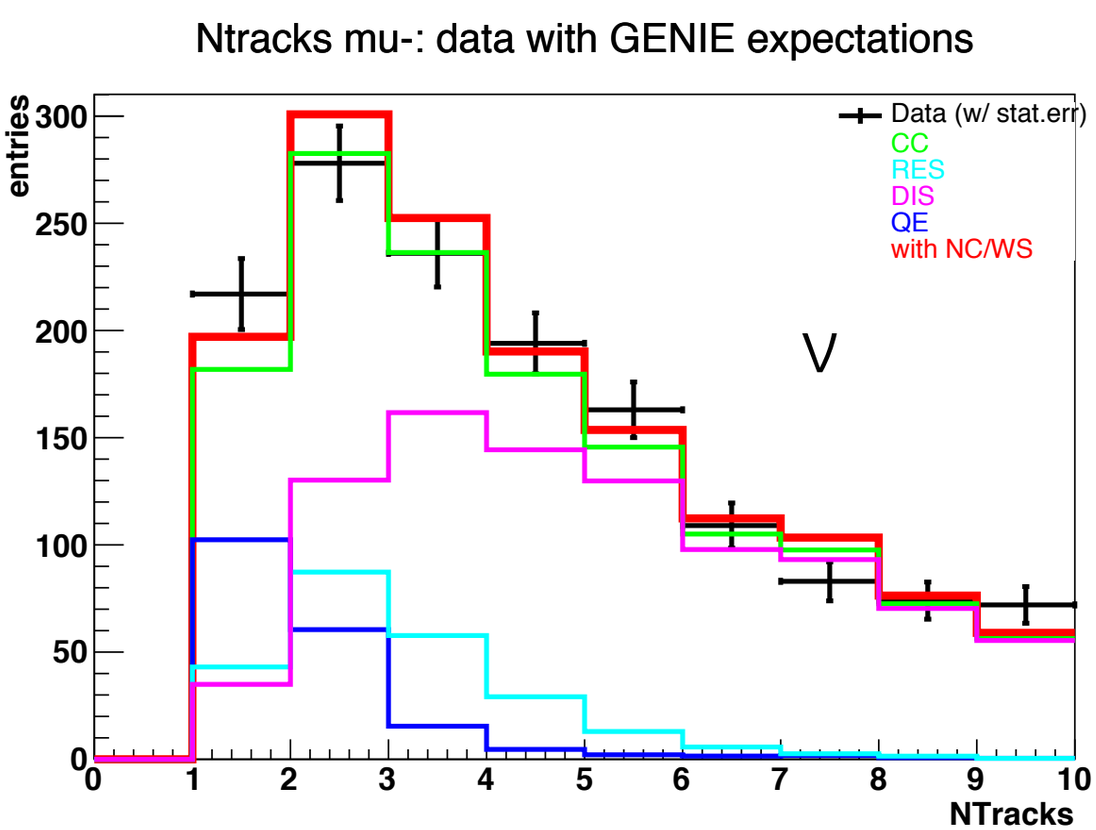
- Through-going, or “rock” muon events are removed from initial sample by a fiducial cut on the event’s most upstream vertex (and a 5% further removal by a hand-scan).

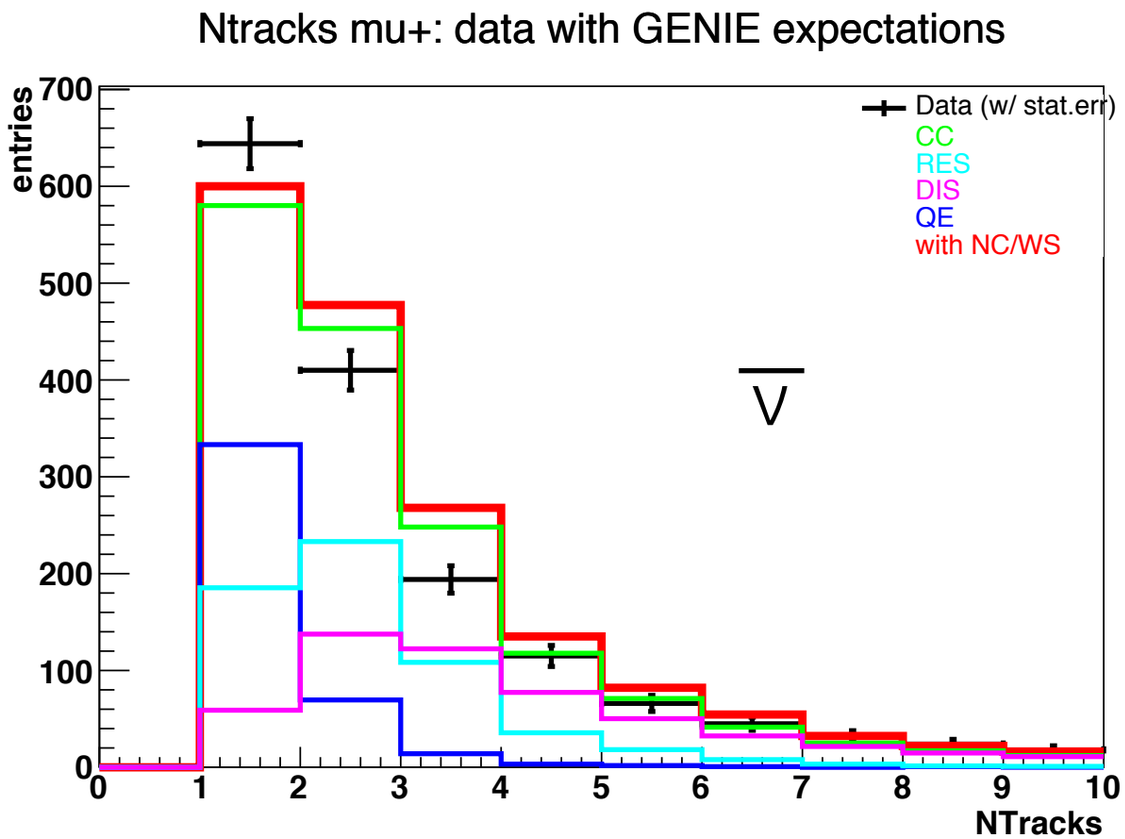
- Neutral Current “punch-through” background is small due to MINOS ND matching requirement

- Wrong-sign CC background is small due to matching and correct-sign requirement.

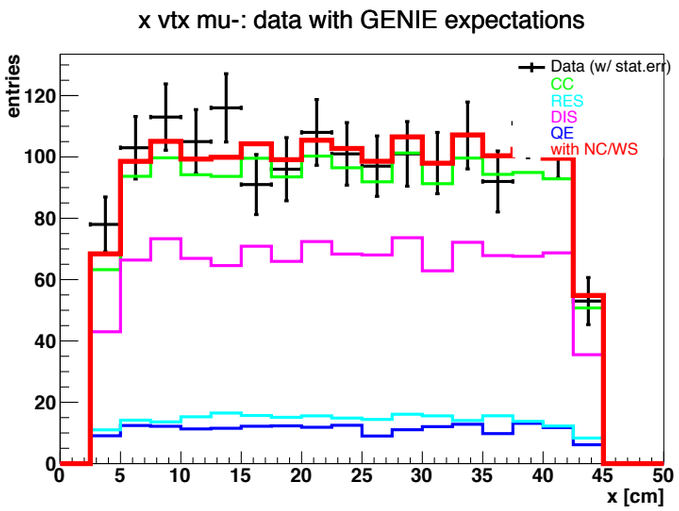
- From MC: NC+WS bkgd is 97 (141) events for (anti-)neutrino sample.

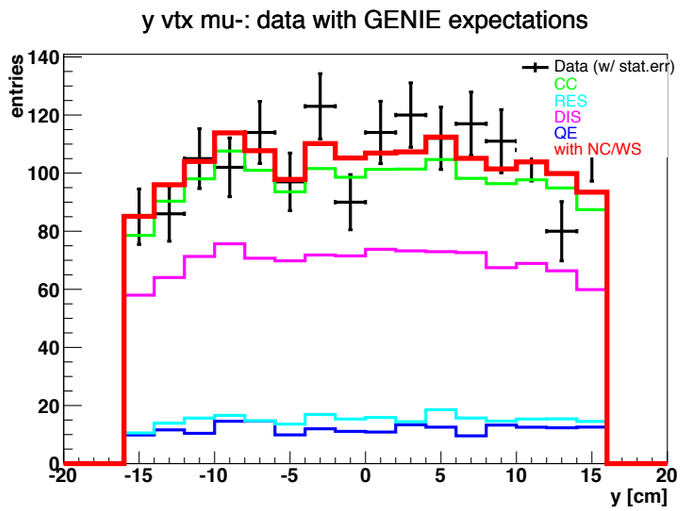
Simulation: Ntracks

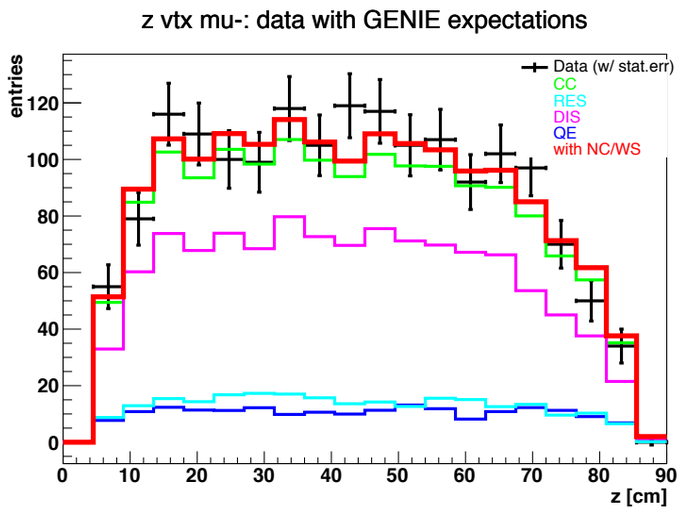




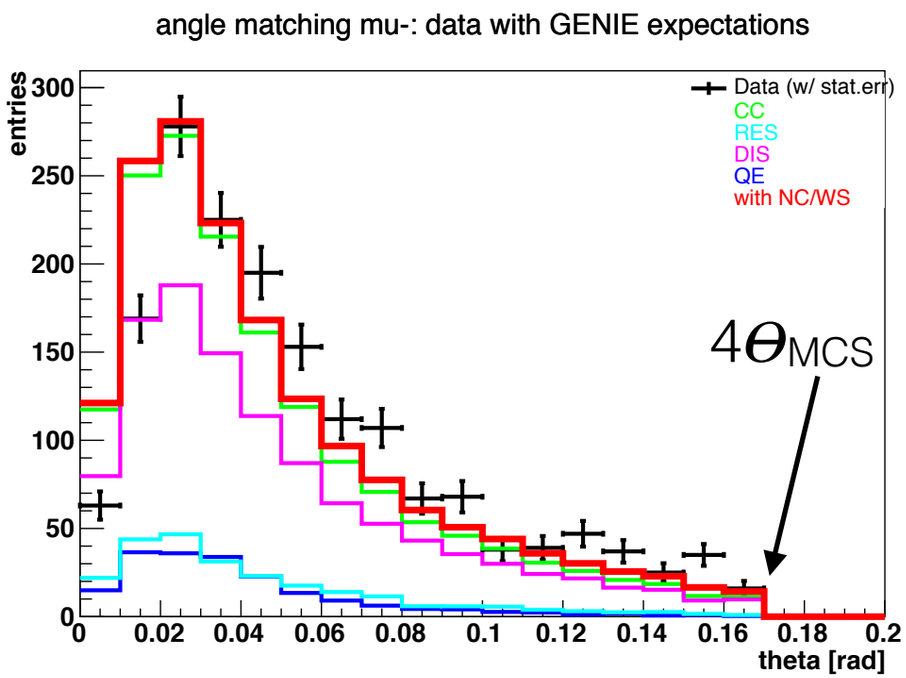
MC-data histos: ν

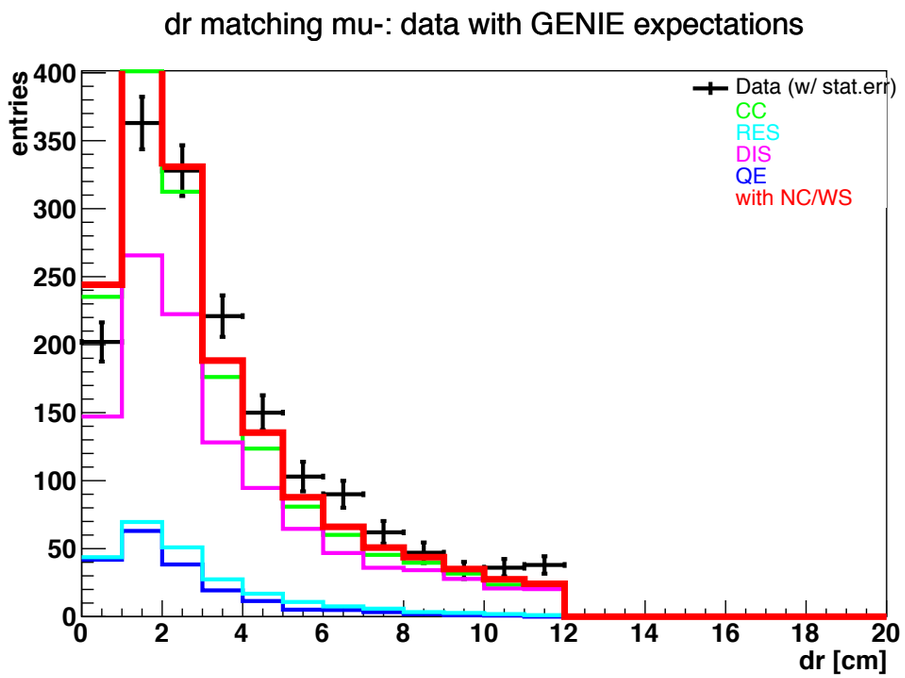






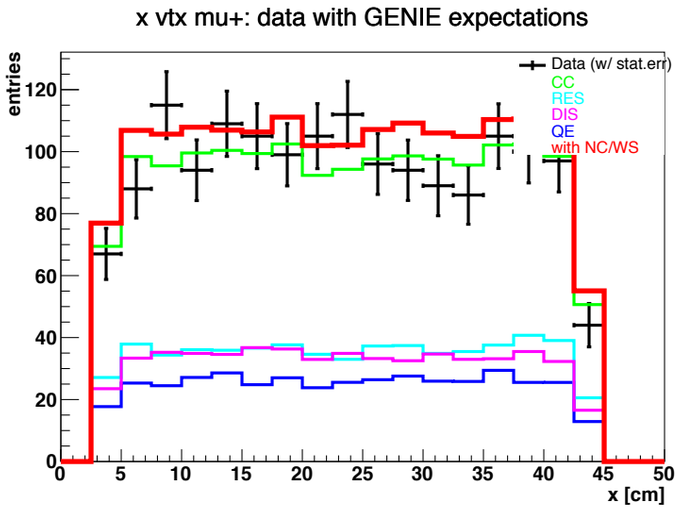
Pointing to a (-) trk in MINOS ND

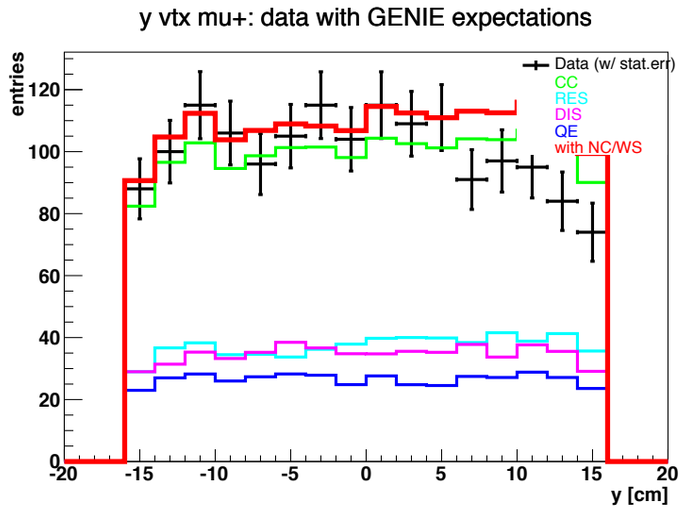


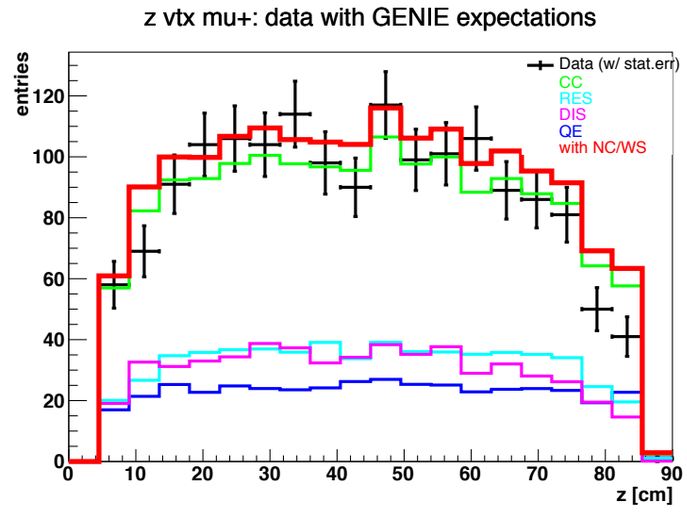


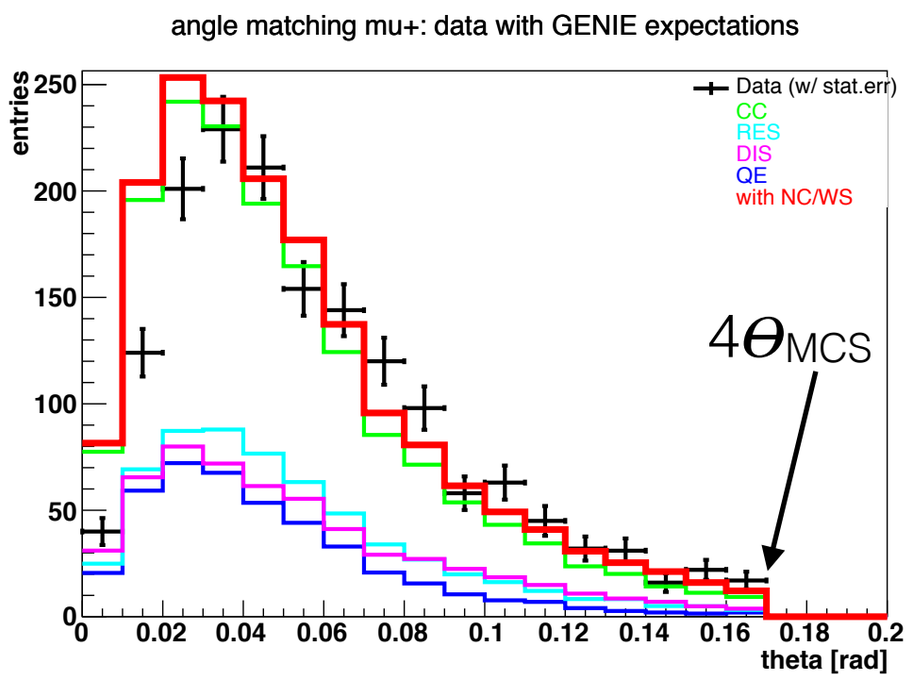
MC-data histos: $\bar{\nu}$

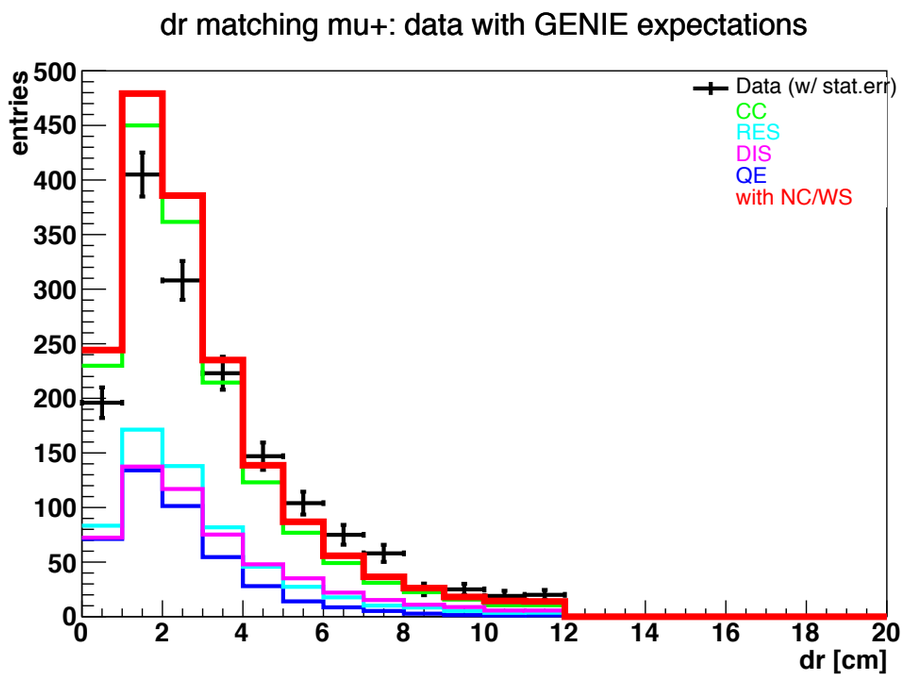
Pointing to a (+) trk in MINOS ND



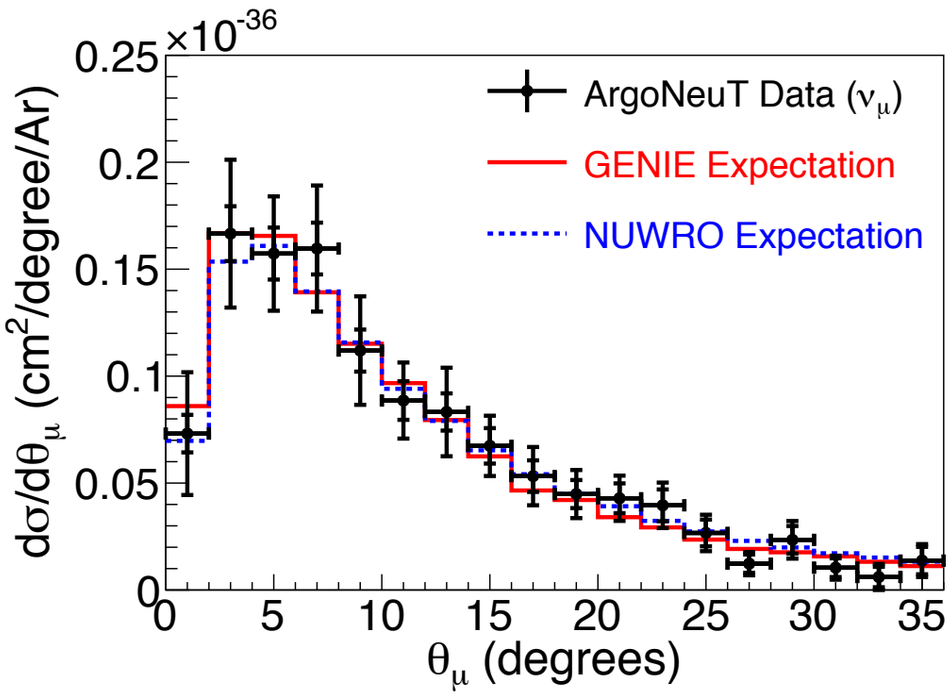


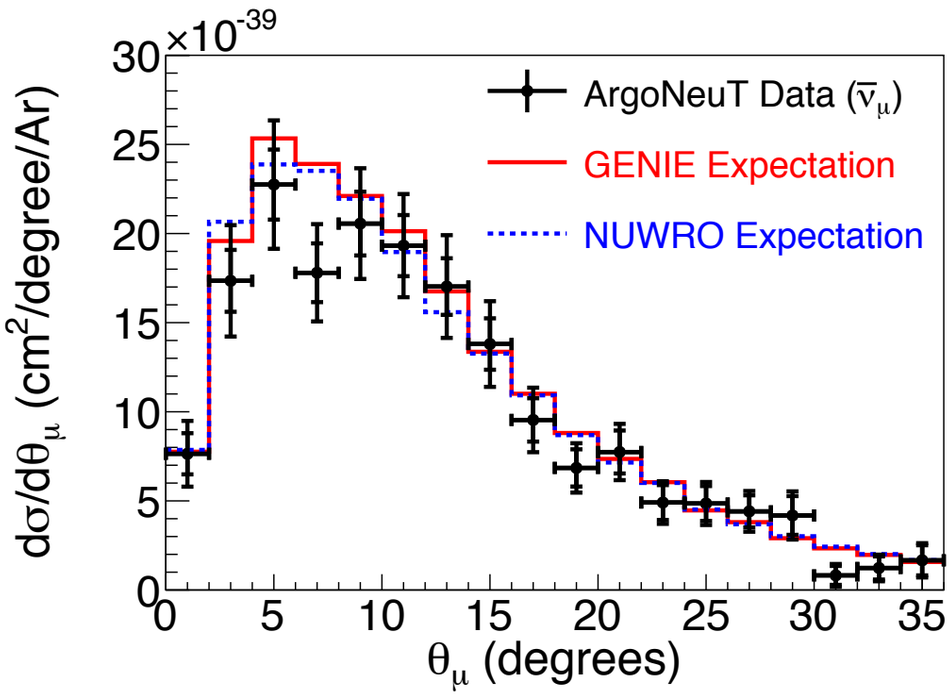


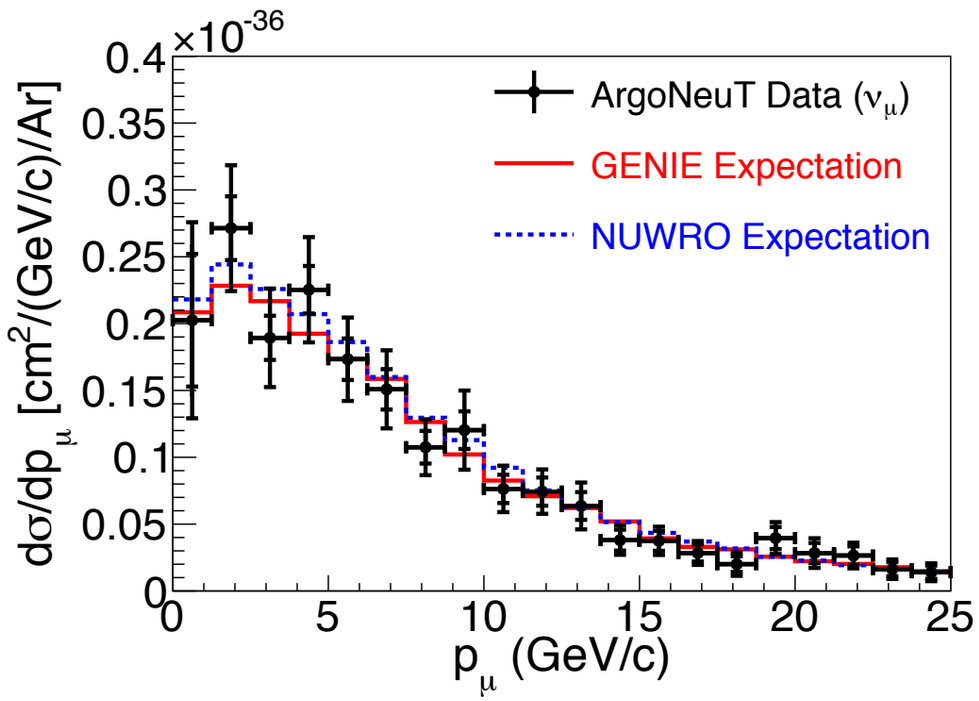


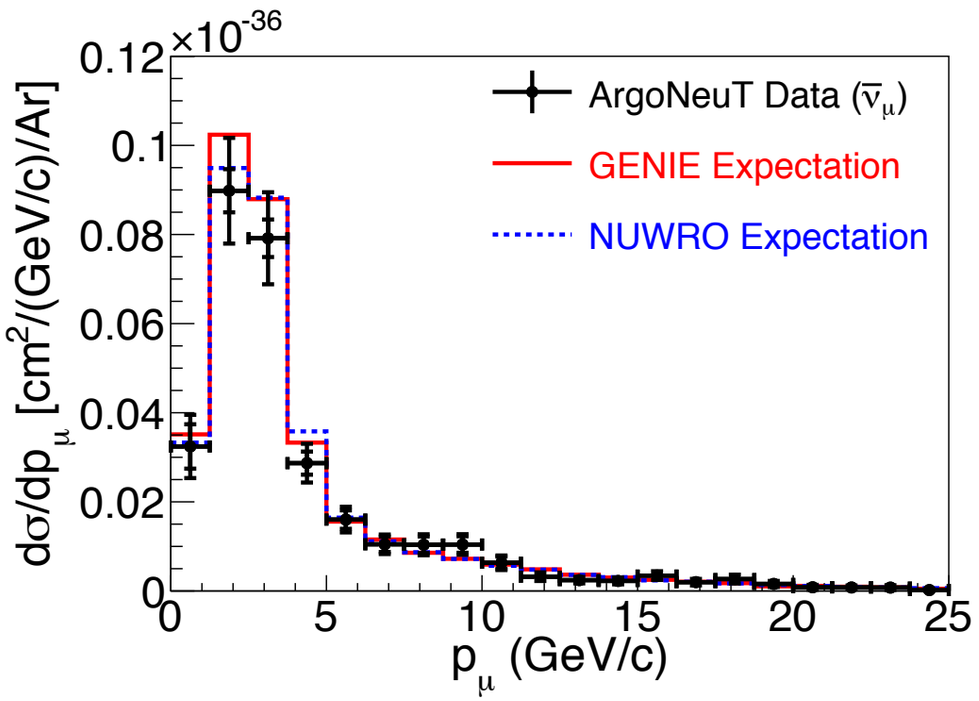


differential cross-sections on Argon









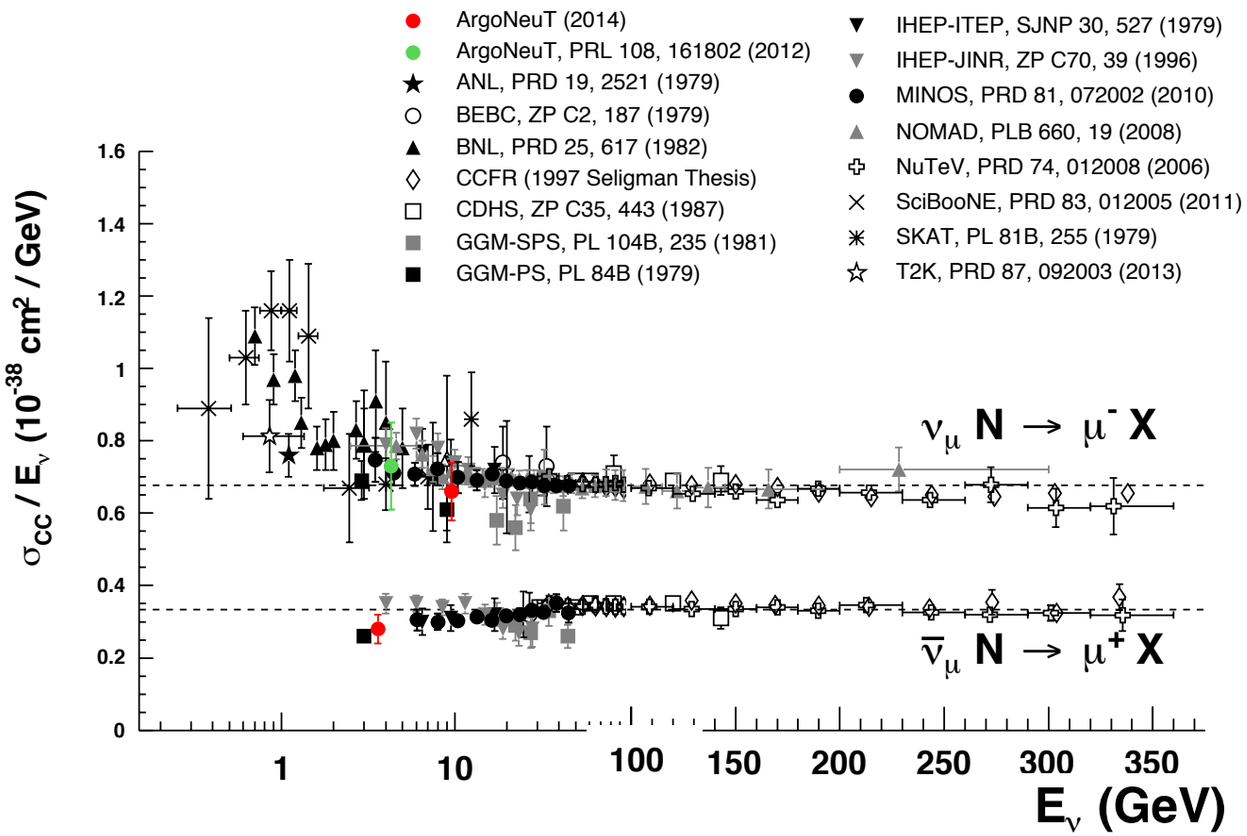
Systematics

- Uncertainties on the neutrino and antineutrino **total** cross sections get contributions from
  - flux (11%)
  - N_{Ar}, fiducial volume variations, POT (3%)

- The **differential** cross-sections receive further ~few-10 percent corrections in most bins from mis-measurement.
  - resulting mostly from incorrect match from
    - crowded environment
    - multiple coulomb scattering

Total Cross-Sections

	neutrino	anti-neutrino
cross section x10 cm	0.66+/-0.03+/-0.08	0.28+/-0.01+/-0.03
energy (GeV)	9.6+/-6.5	3.6+/-1.5



-3 (+3) % correction for iso-scalar nucleus

Conclusions

- The first anti-neutrino cross-section measurement in Argon is presented. It is in a neutrino energy region where there aren't many other measurements on any nuclei.
- The results are important to the future US LArTPC program.
- Watch for more papers from ArgoNeuT!