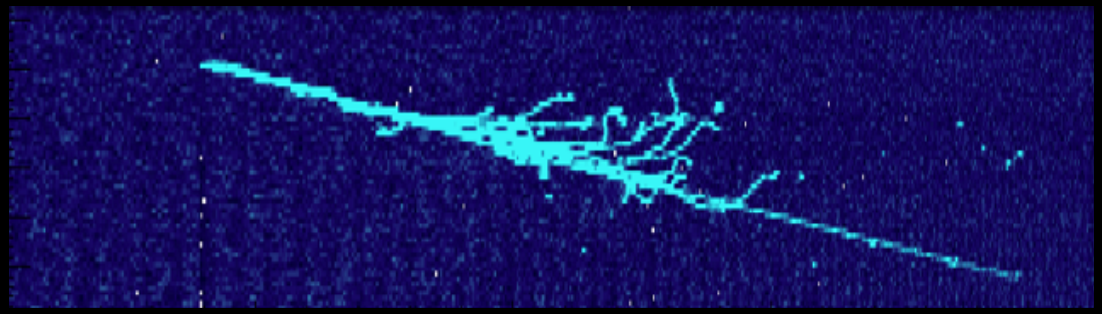
Recent results from the ArgoNeuT liquid argon TPC



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The ArgoNeuT Collaboration

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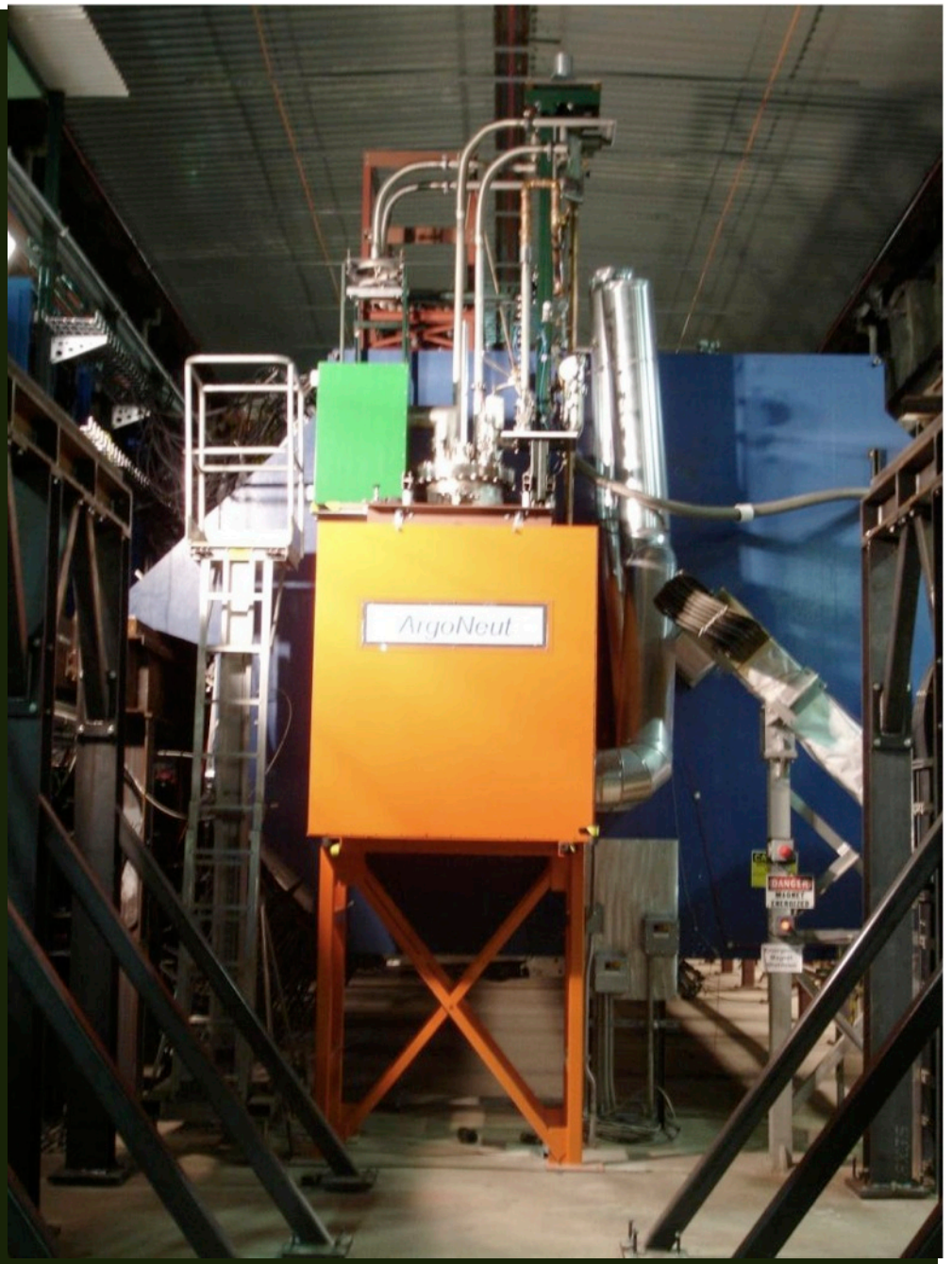
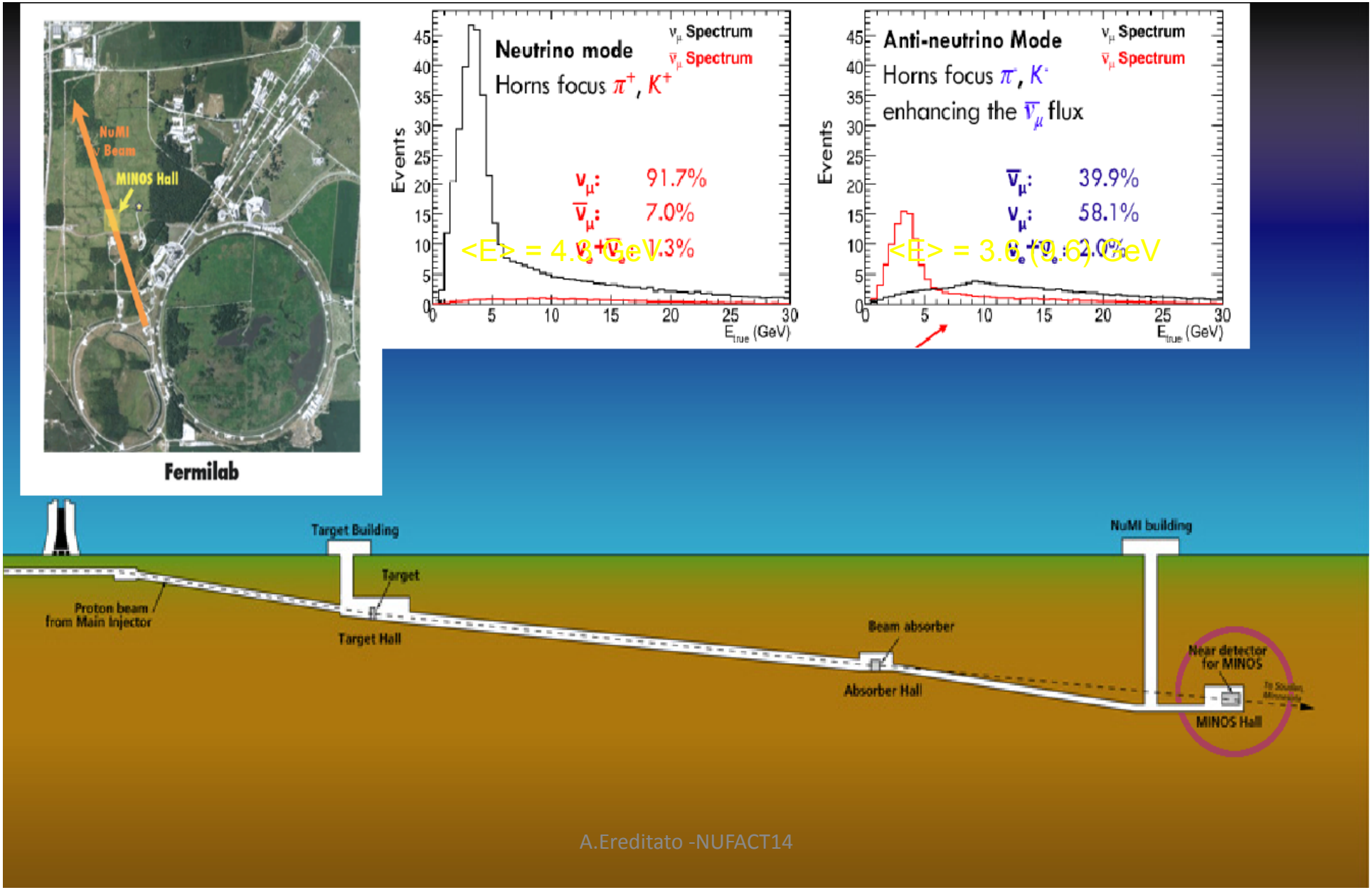
- ArgoNeuT: a 175 l liquid argon TPC
- Placed in the NUMI neutrino beam at Fermilab in front of the MINOS near detector (acting as a muon identifier)
- 3 wire planes oriented at 60° relative to each other
- Each plane: 240 wires with 4 mm pitch
- Electric field of 500 V/cm
- 2048 samples in 400 μs
- More details on the detector:

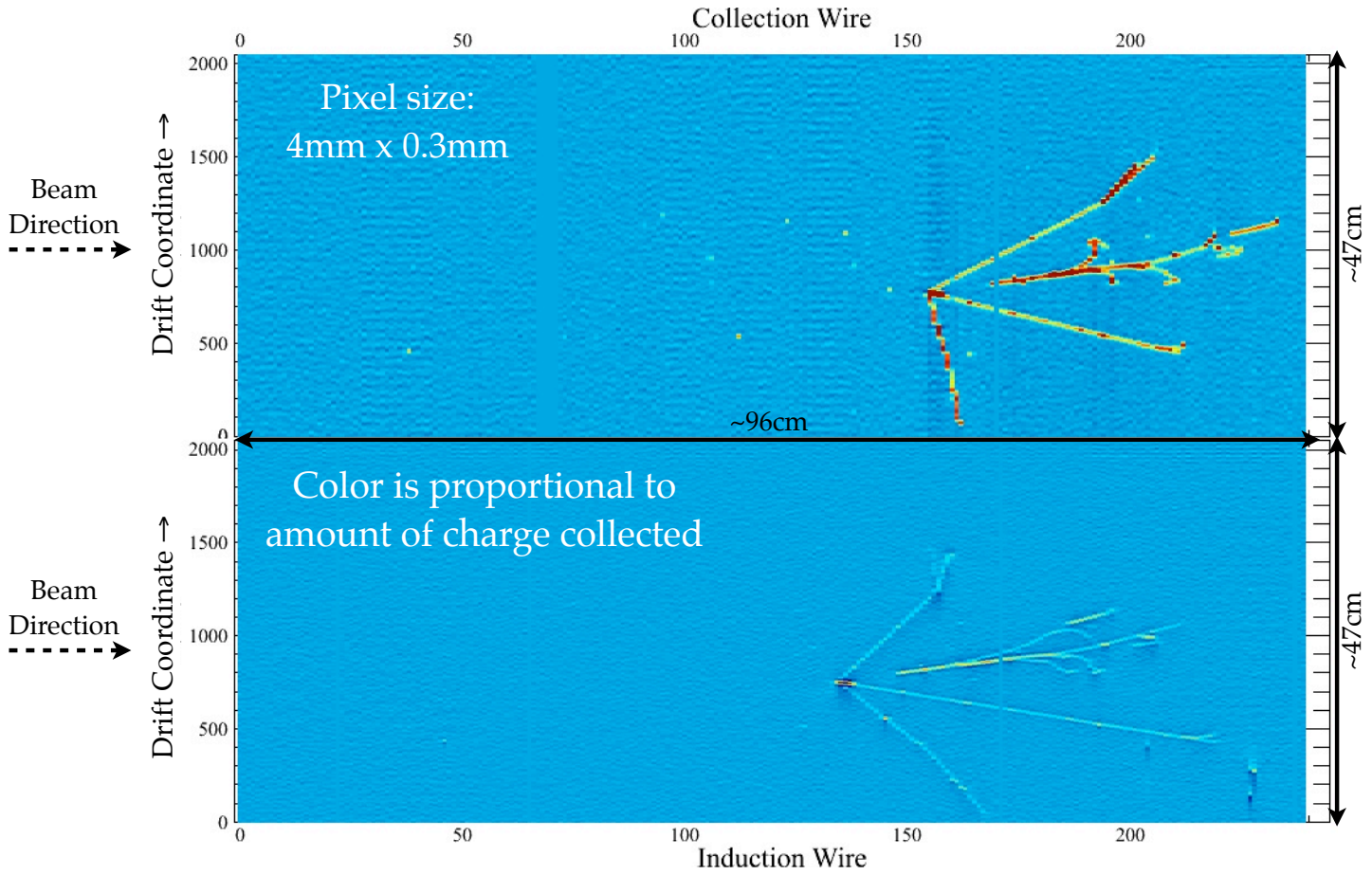
  JINST 7 (2012) P10019
  JINST 7 (2012) P10020
  JINST 8 (2013) P08005



The neutrino beam (Fermilab to Soudan Mine)



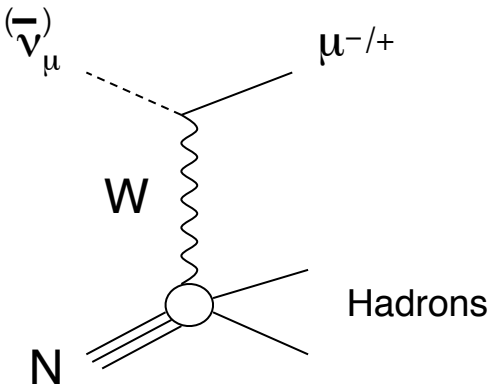
ArgoNeuT detector at Fermilab (first LAr TPC in USA)

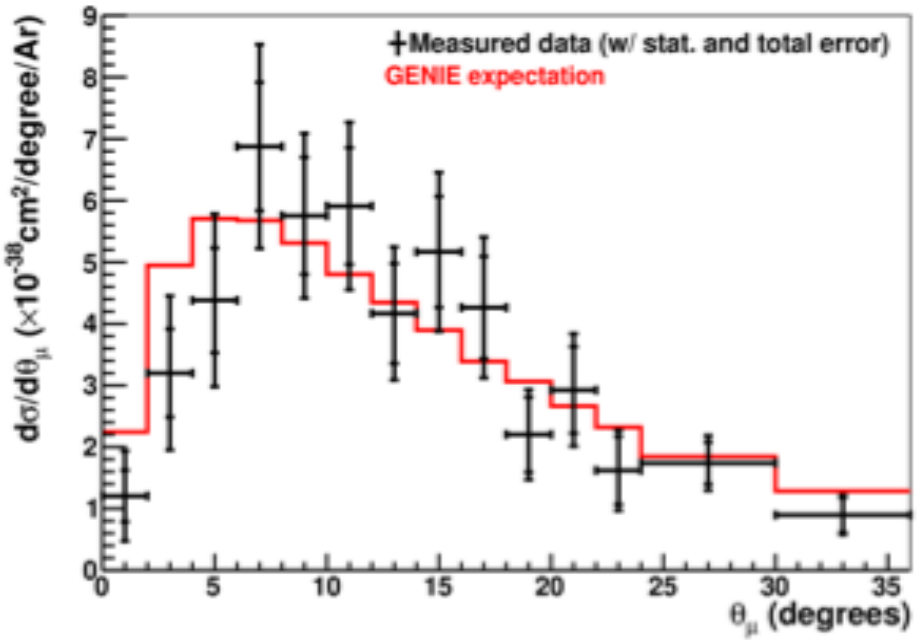


The largest set of low-energy neutrino interactions (0.1-10 GeV) collected and analyzed in a LAr TPC: 1.35×10^{20} pot, 7000 CC events

Collection of physics results

ν_μ CC inclusive cross section



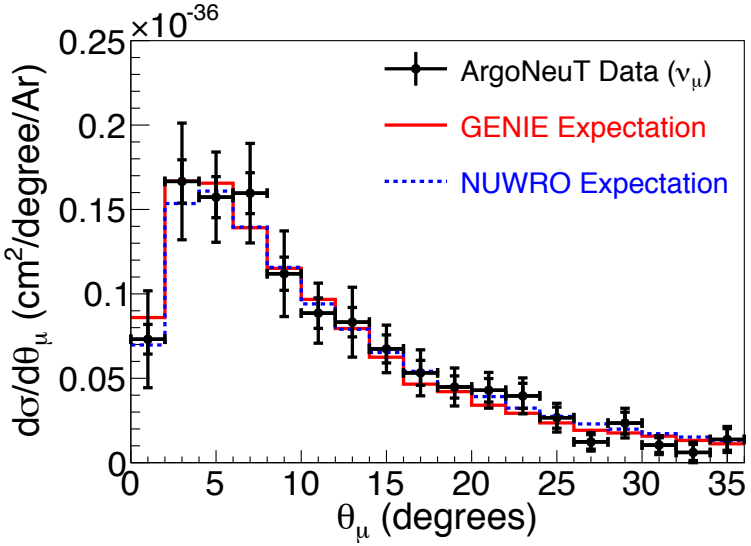


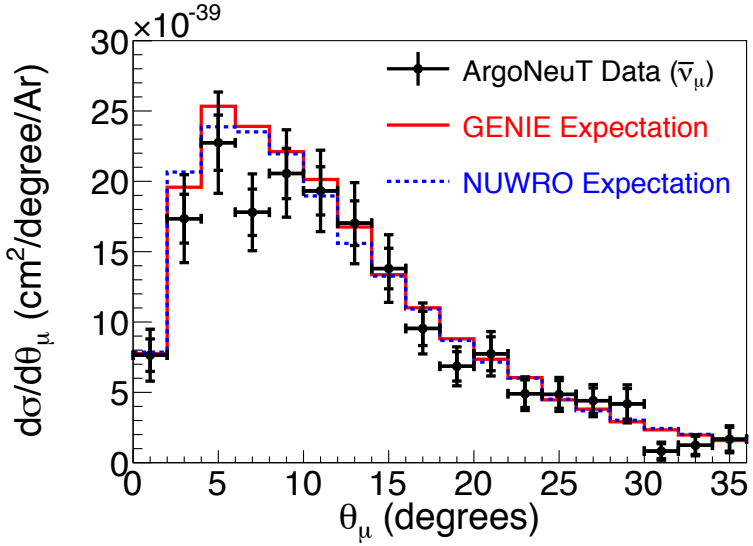
Neutrino mode running:

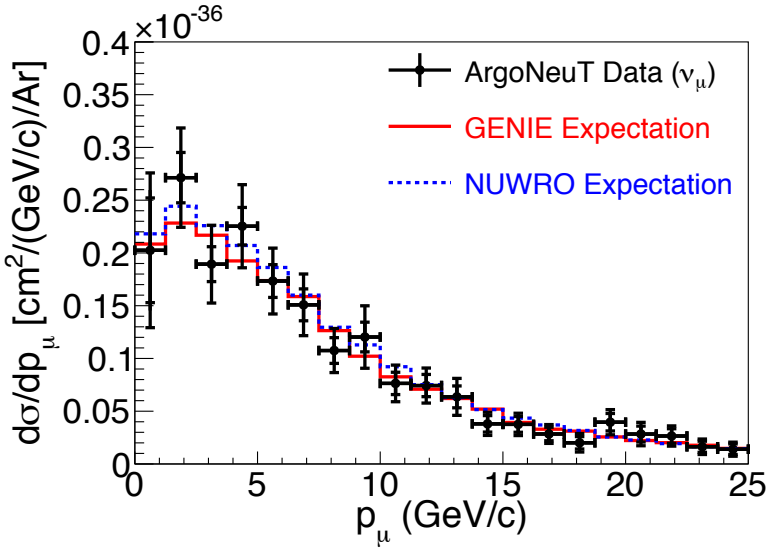
- 2 weeks of data taking
- Fully automated reconstruction

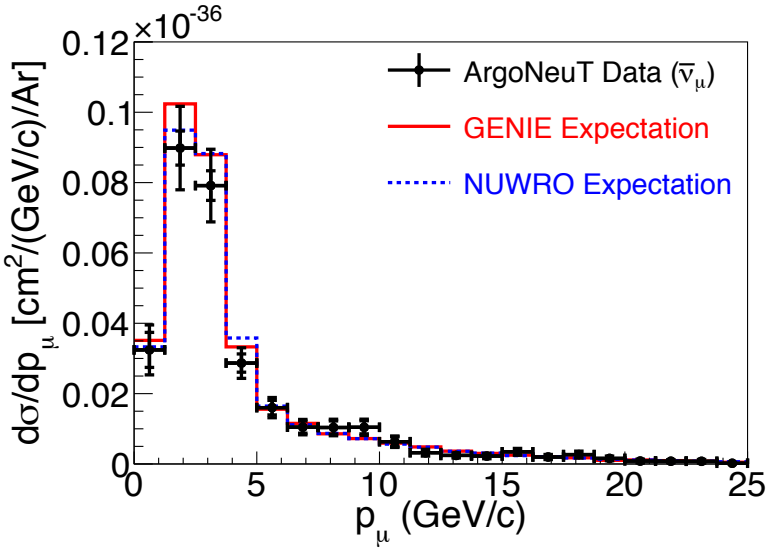
C. Anderson et al., PRL 108, 161802 (2012)

$\overline{\nu}_\mu$ vs ν_μ CC inclusive cross section





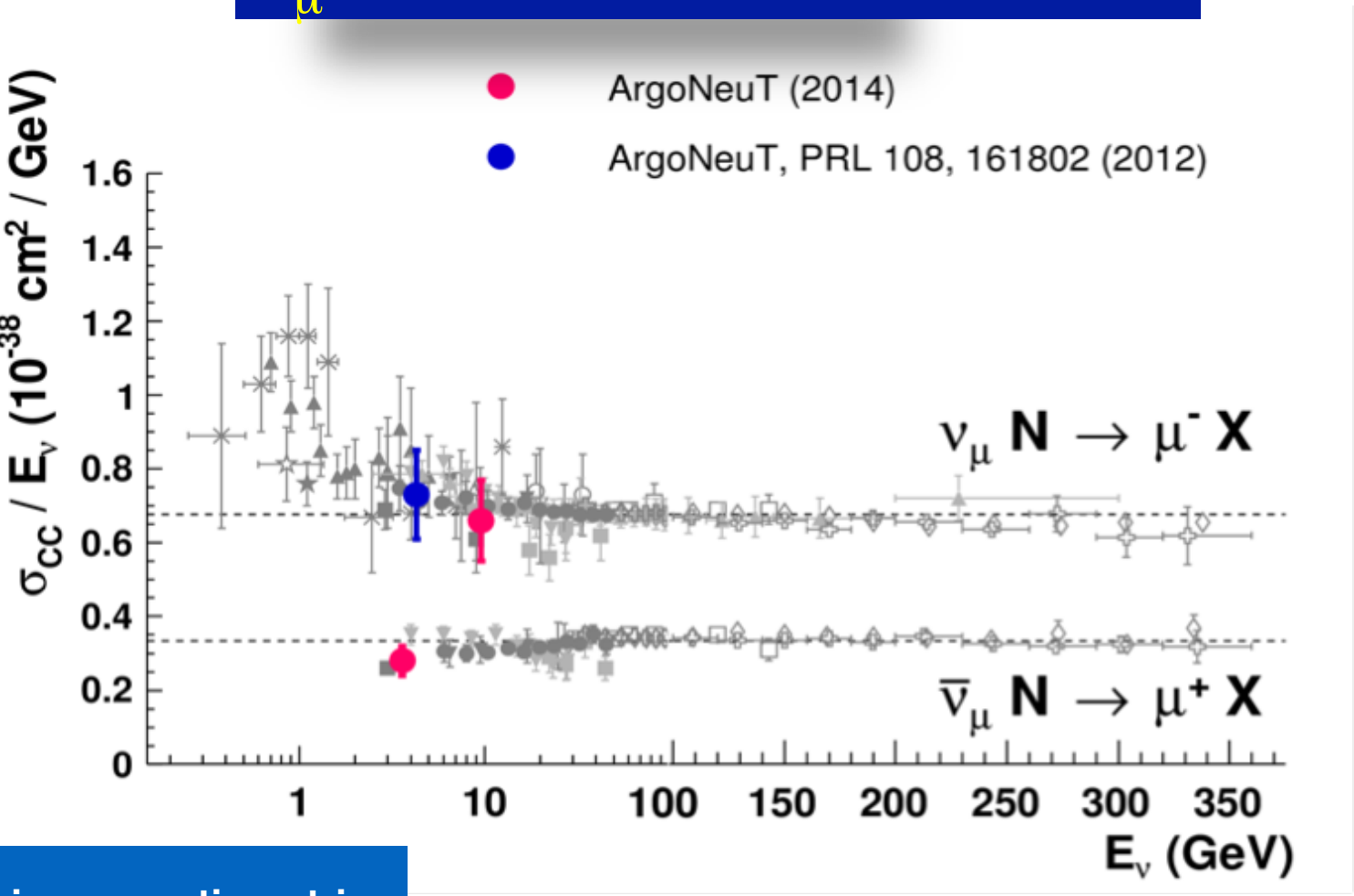




R. Acciarri et al., Phys. Rev. D 89, 112003 (2014)

Antineutrino mode running:
5 months of data taking

ν_μ CC inclusive cross section



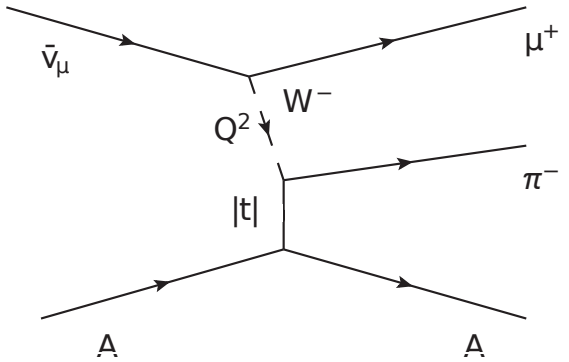
neutrino	anti-neutrino	
0.66+/-0.03+/-0.08	0.28+/-0.01+/-0.03	σ
9.6+/-6.5	3.6+/-1.5	E

First measurement in argon

CC coherent pion production (1)

$$\nu_\mu + A \rightarrow \mu^- + \pi^+ + A$$

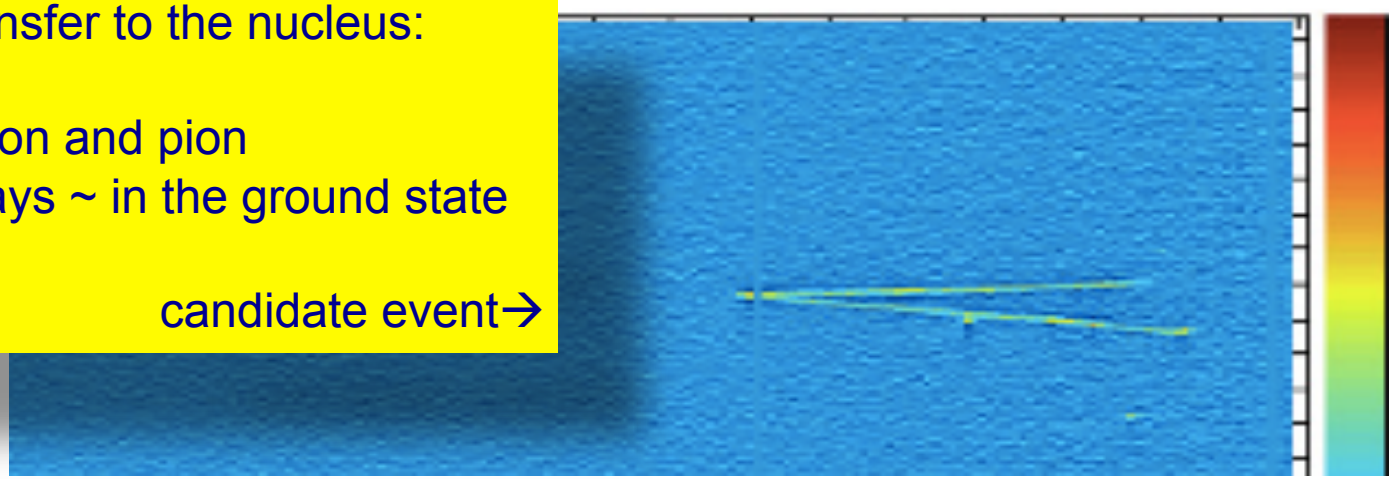
$$\bar{\nu}_\mu + A \rightarrow \mu^+ + \pi^- + A$$



Small momentum transfer to the nucleus:

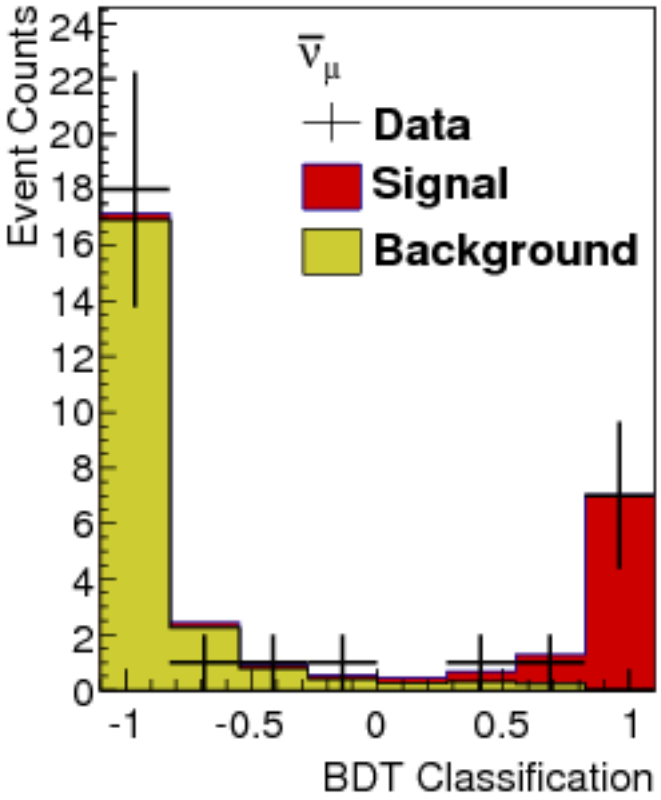
→ Forward going muon and pion
→ The Ar nucleus stays ~ in the ground state

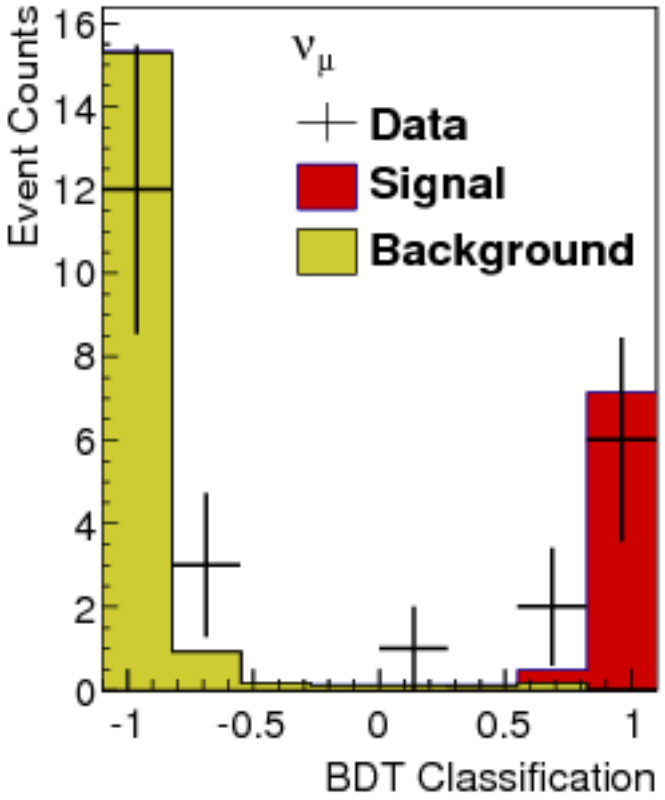
candidate event→



	$\langle E \rangle$, GeV	Integrated Flux, cm^{-2}
$\bar{\nu}_\mu$	3.6 ± 1.5	2.94×10^{12}
ν_μ	9.3 ± 6.5	6.56×10^{11}

CC coherent pion production (2)



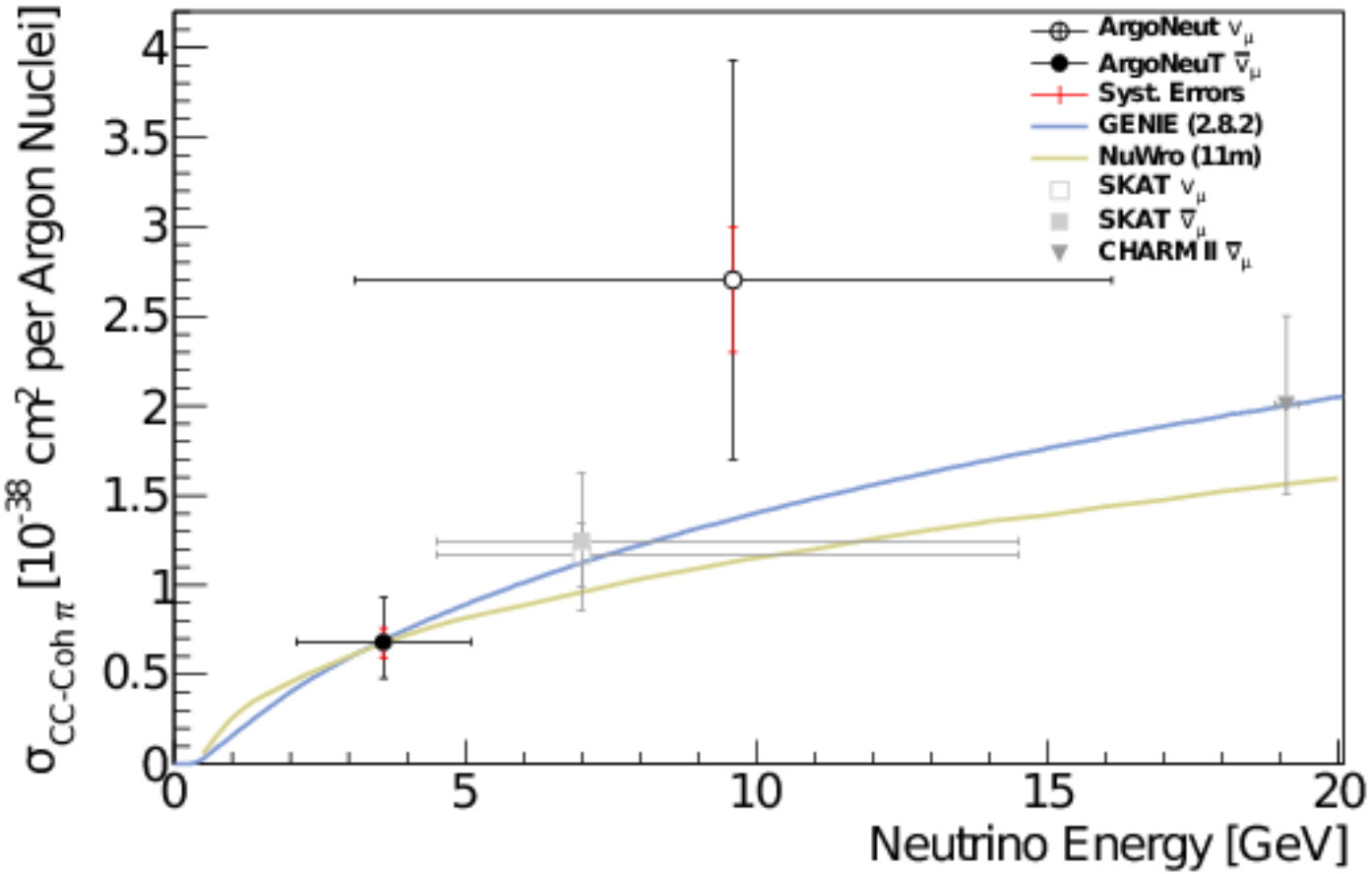


Boosted Decision Tree (BST) method→

antineutrino $10.8^{+3.9}_{-3.1}$ neutrino: $7.6^{+3.2}_{-2.5}$

CC coherent pion production (3)

R. Acciarri et al., ArXiv:1408.0598
Submitted to PRL

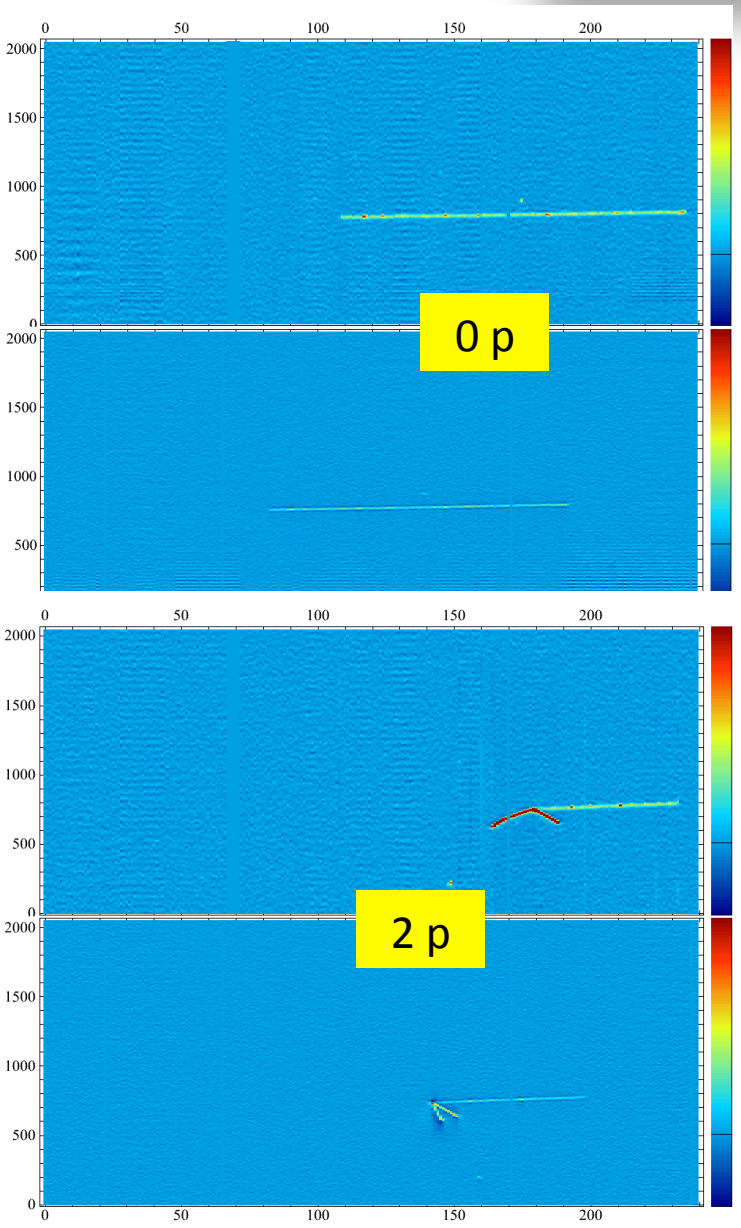


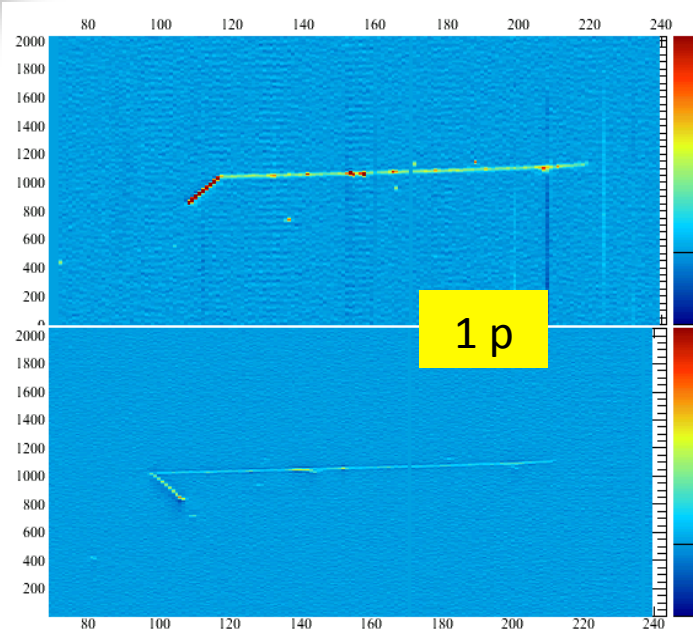
$$\langle \sigma_{\bar{\nu}_\mu} \rangle = 6.8^{+2.5}_{-2.0}(stat)^{+0.8}_{-0.9}(syst) \times 10^{-39}\mathrm{cm}^2$$

$$\langle \sigma_{\nu_\mu} \rangle = 2.7^{+1.2}_{-0.9}(stat)^{+0.3}_{-0.4}(syst) \times 10^{-38}\mathrm{cm}^2$$

Other measurements scaled to argon assuming the $A^{1/3}$ dependence from Rein-Seghal model (GENIE and NuWro)

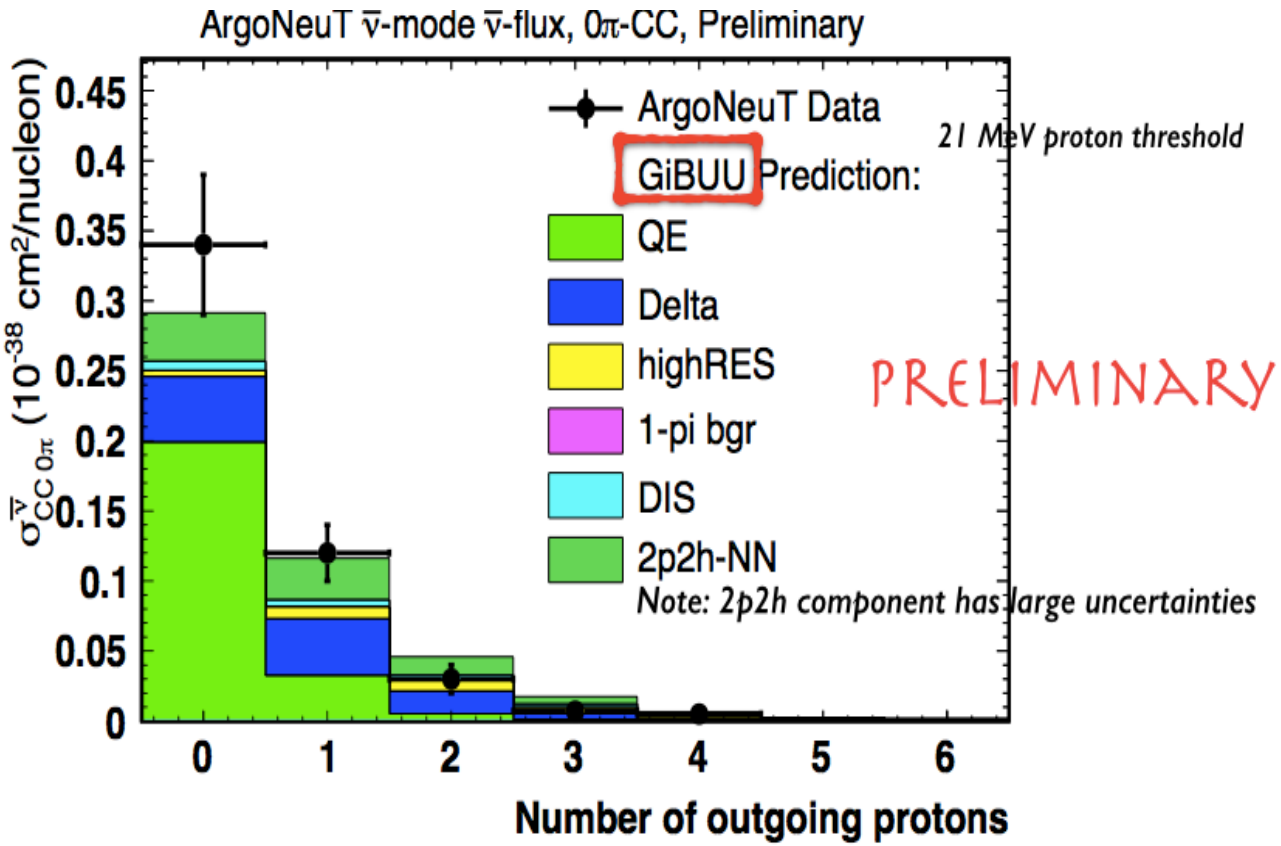
ν_μ CC 0-pion proton multiplicity



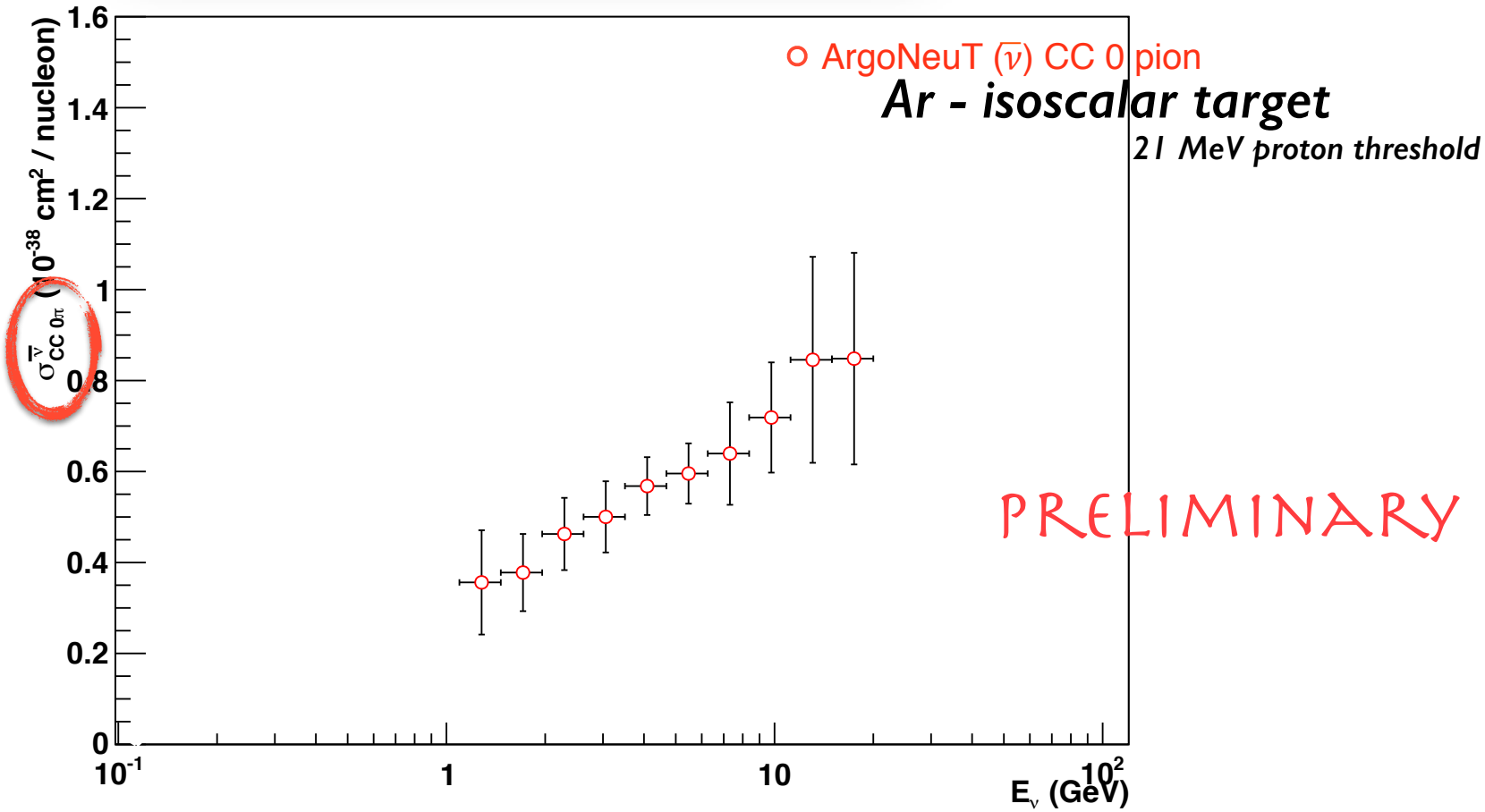


Low-kinetic energy proton threshold: 21 MeV

$\overline{\nu}_\mu$ CC 0-pion cross section vs proton multiplicity



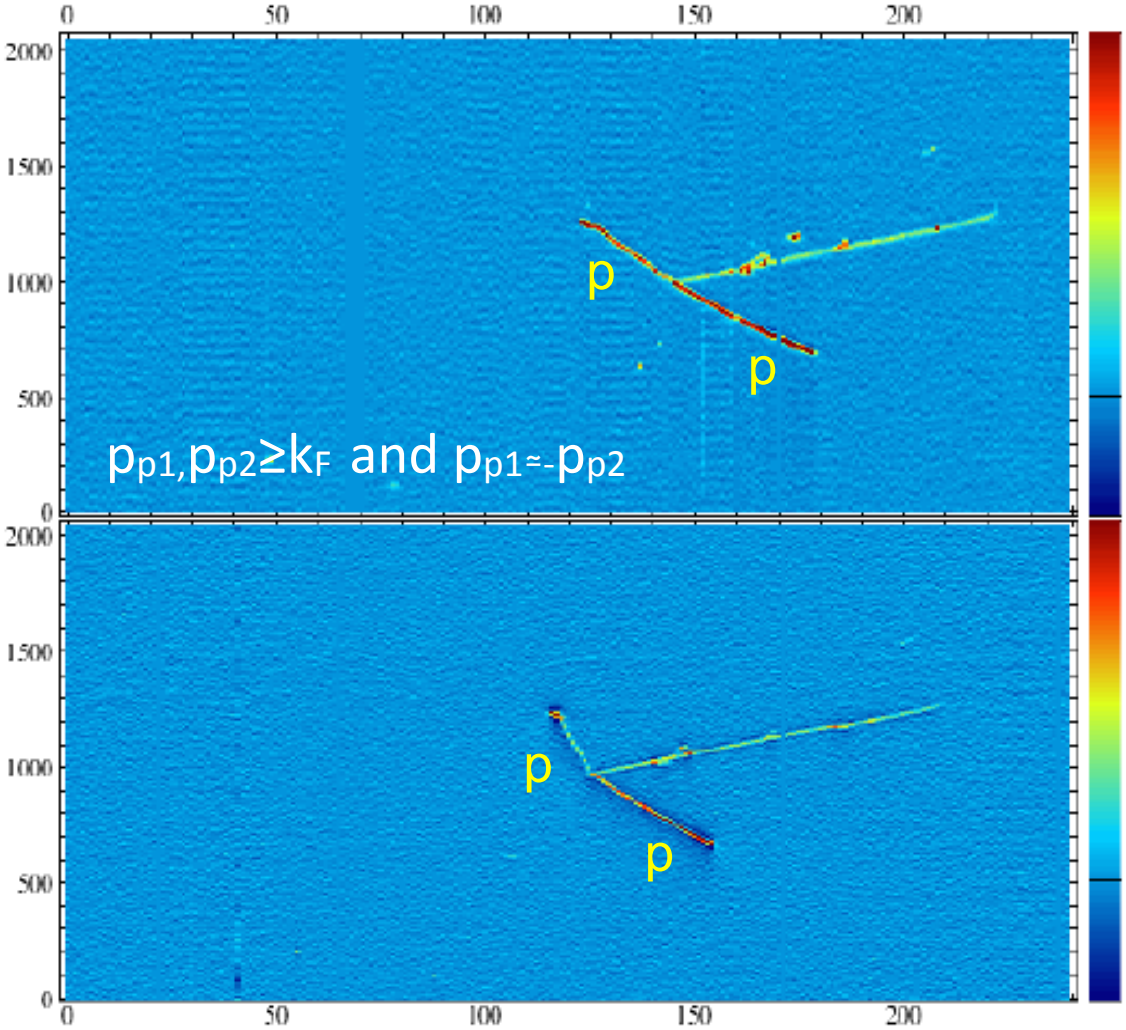
$\overline{\nu}_\mu$ CC 0-pion cross section vs reconstructed E_ν



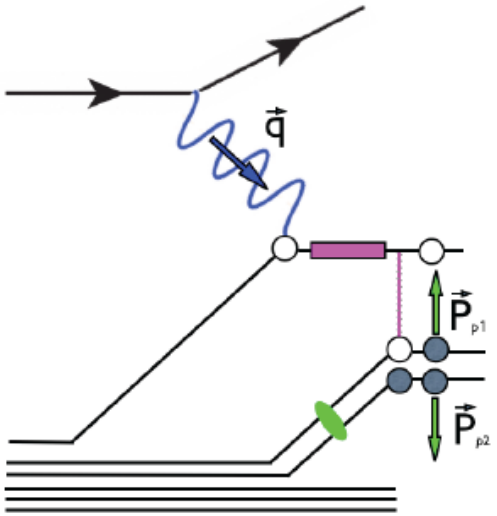
from *lepton AND proton reconstructed kinematics:* $E_\nu = (E_\mu + \sum T_{pi} + T_X + E_{miss})$

back-to-back proton pair events (hammer events)

4 events detected, back-to-back in the lab frame

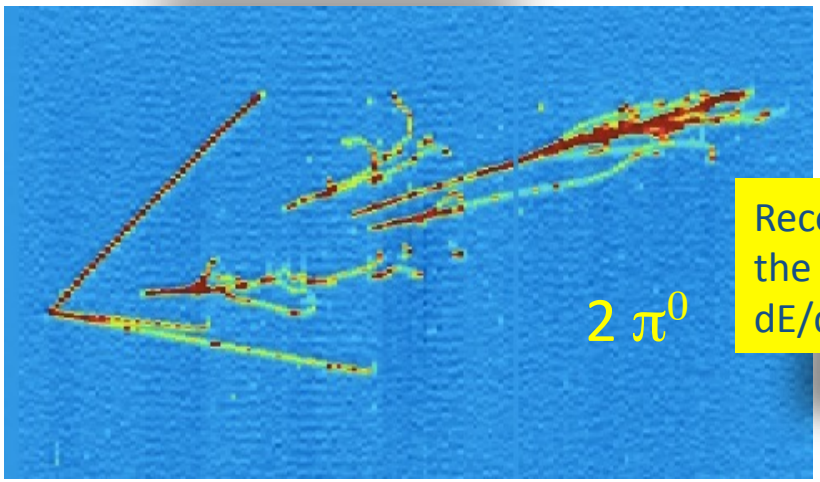


R. Acciarri et al., PRD 90, 012008 (2014)

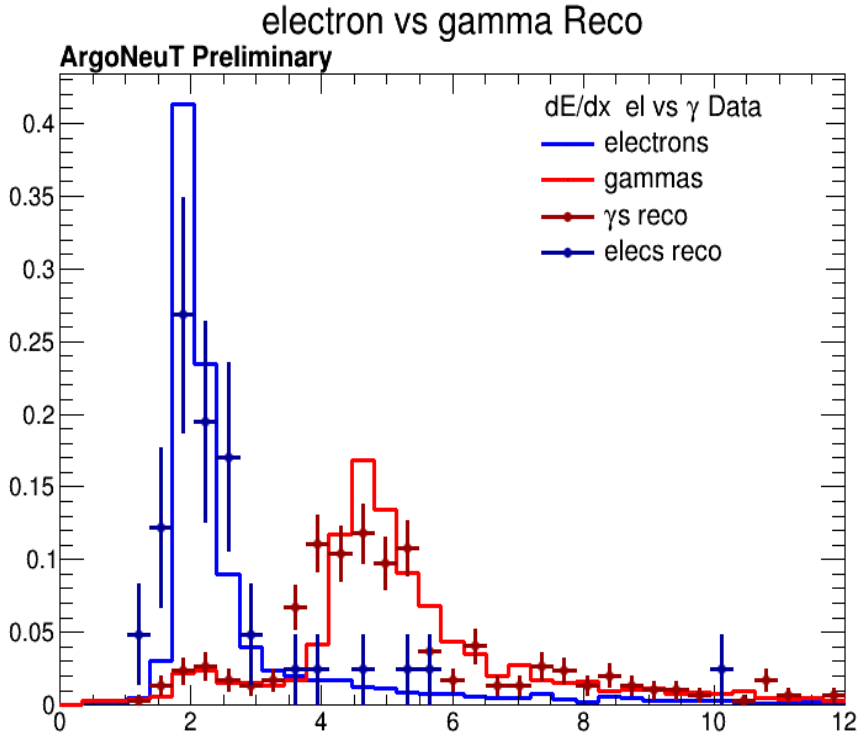


Possible mechanism:
CC RES 0-π reactions involving pre-existing Short Range Correlation (SRC) np pairs.

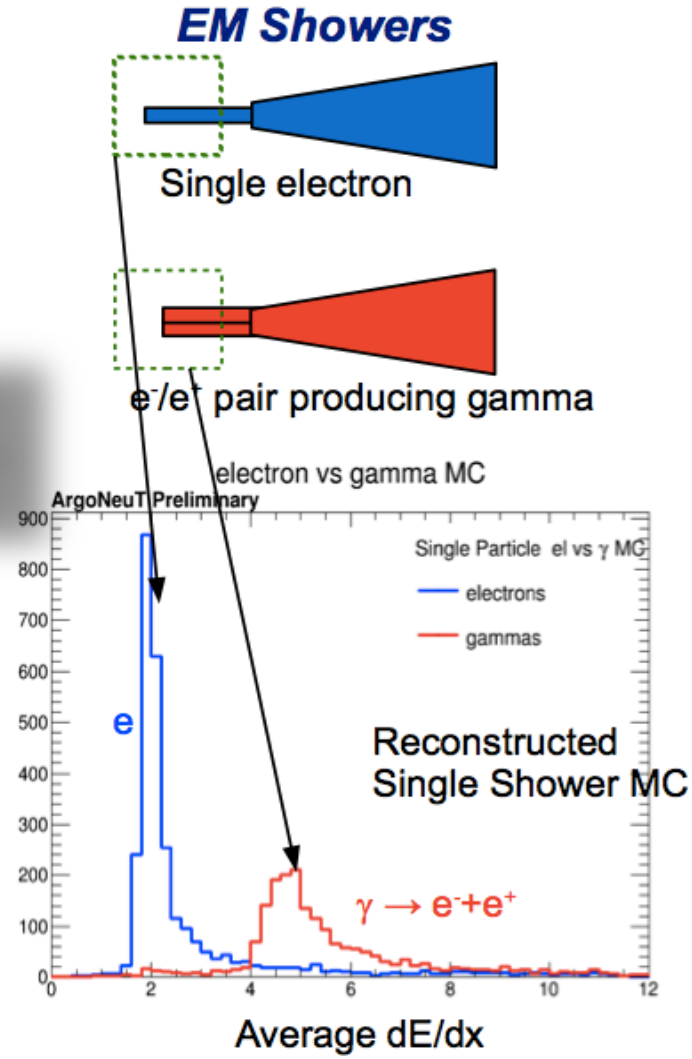
e/γ separation (1)



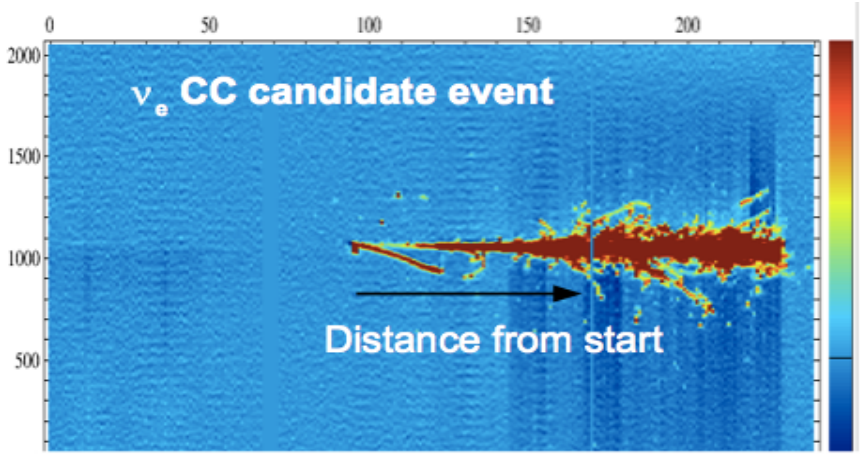
Reconstruct charge at the start of the shower: dE/dx discrimination.

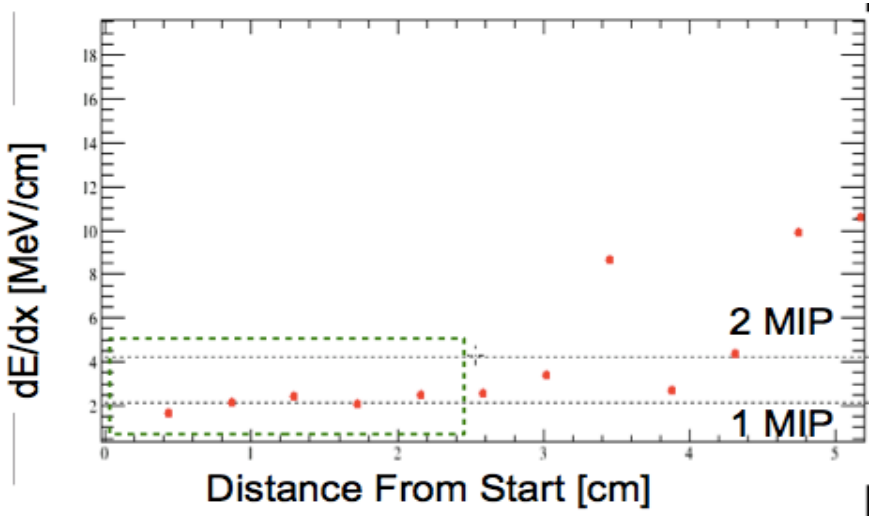


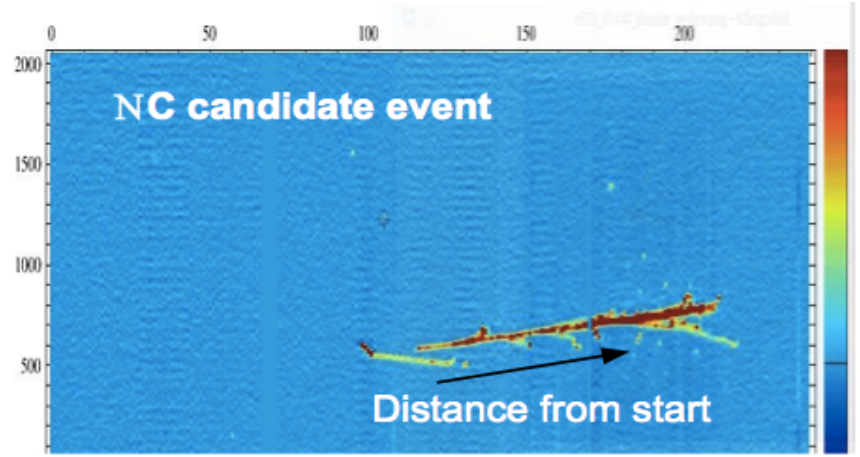
From MC to real data

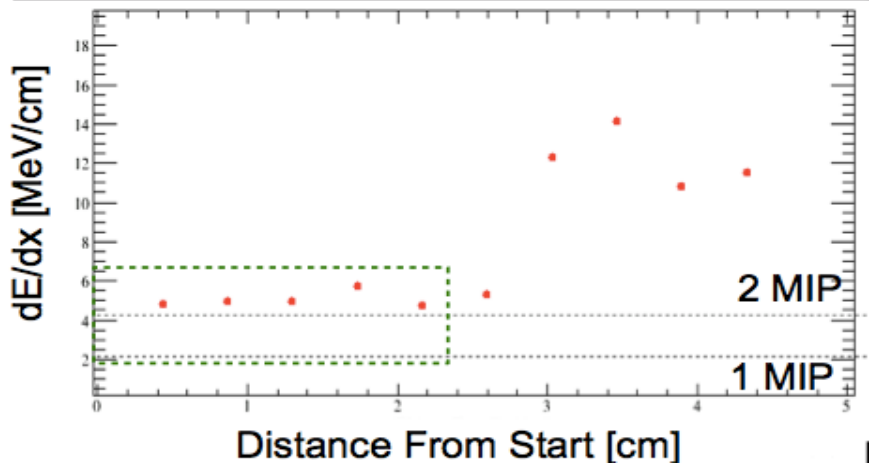


e/γ separation (2)

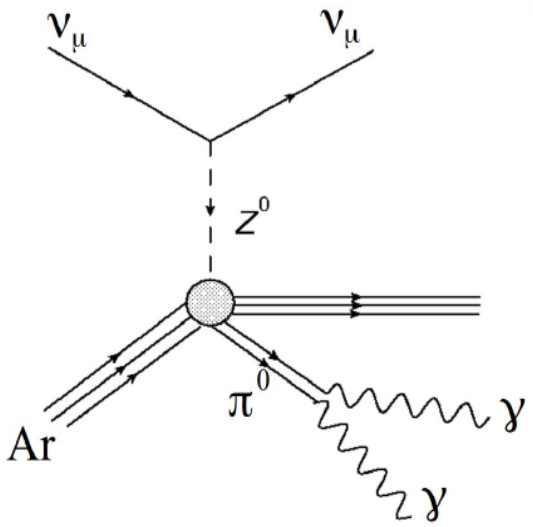


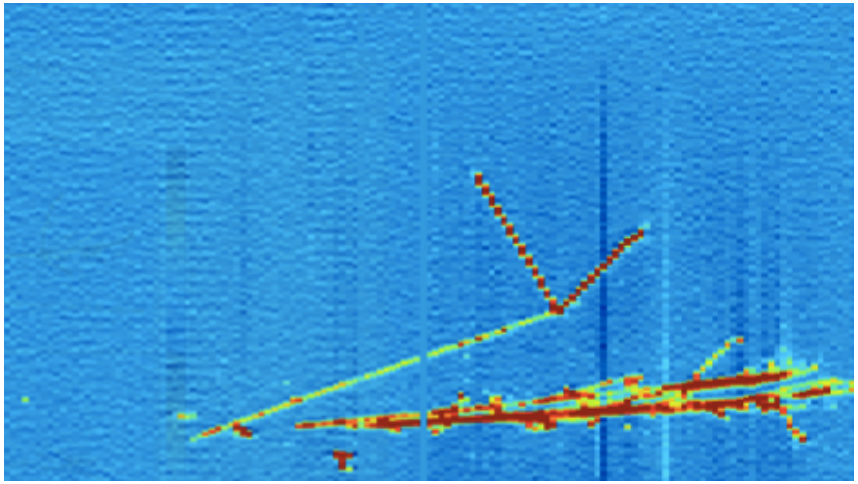


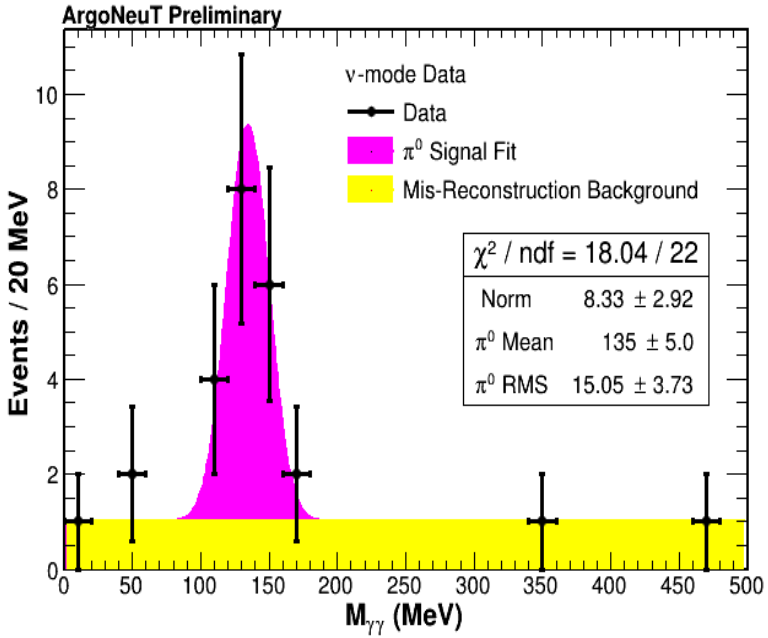




NC π^0 production in NC events







Work in progress:

Energy corrections required for the limited detector size

Conclusions

- **ArgoNeuT**: the first LAr TPC operating in a low energy neutrino and antineutrino beam and the first in the USA.

- Powerful detection technology: **ArgoNeuT** was conceived as a technology demonstrator, but despite the small LAr mass (~1/4 ton) and a short neutrino exposure (~5 months), it performed very relevant physics measurements.

- Several analyses conducted and the results published: 7 papers in the last 2 years.

- In addition, interest for current short-baseline and future long-baseline experiments employing the LAr TPC technology (MicroBooNE, LAr1-ND, LBNF).

Thank you for your attention!