Recent results from MINERvA

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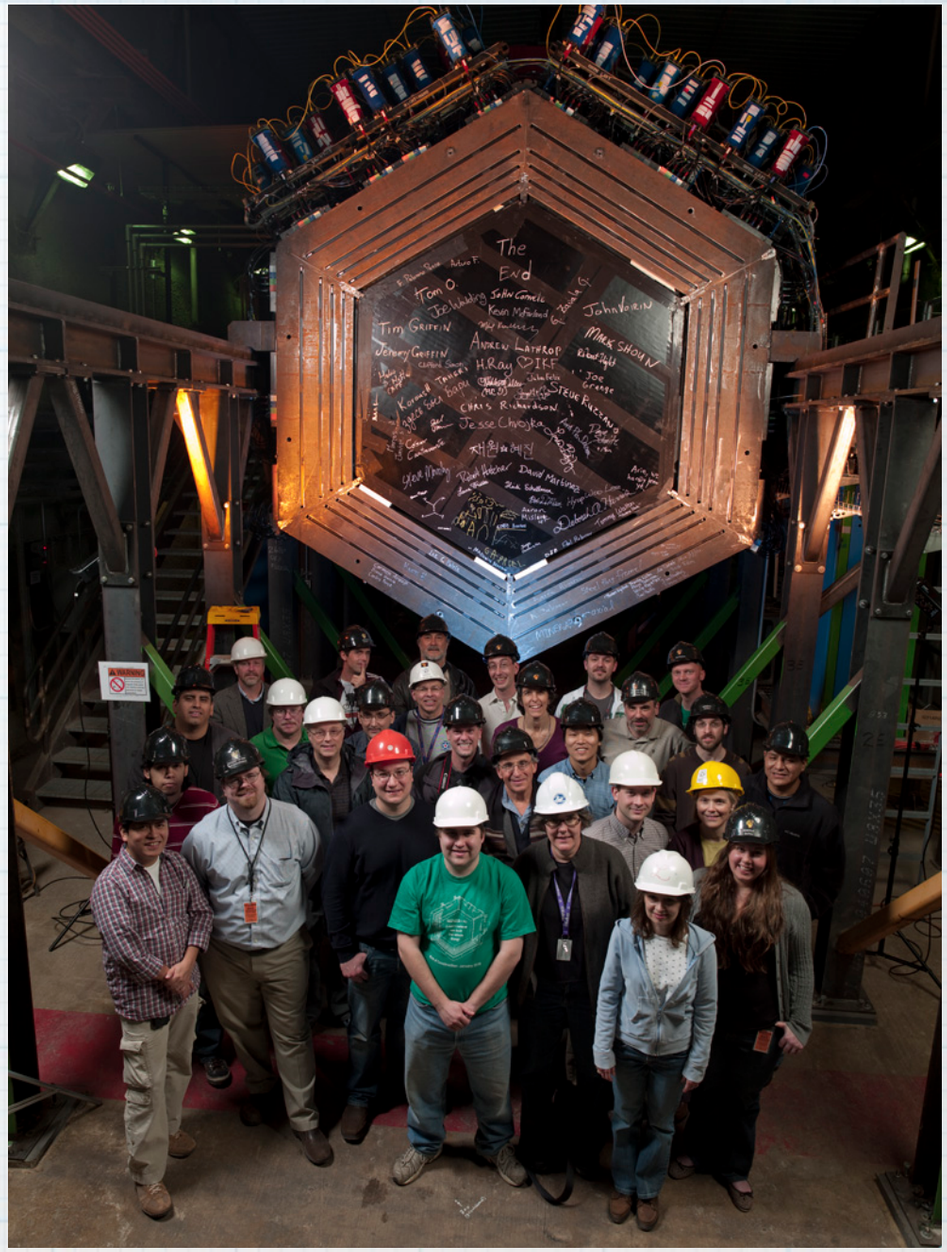
PANIC NOW

Outline

- Introduction to MINERvA
- Recent important results:
  - charged pion production
  - coherent pion production
  - inclusive charged current scattering
  - ~~quasi-elastic scattering~~ arXiv:1305.2243 and arXiv: 1305.2234
- Conclusions and Future

MINERvA Collaboration

- Located underground at Fermilab, near Chicago USA.
- Institutions from over 9 countries with over 60 collaborators.



University of Athens
University of Texas at Austin
Centro Brasileiro de Pesquisas Físicas
Fermilab
University of Florida
Université de Genève
Universidad de Guanajuato
Hampton University
Inst. Nucl. Reas. Moscow
Mass. Col. Lib. Arts
Northwestern University
University of Chicago
Otterbein University
Pontificia Universidad Catolica del Peru
University of Pittsburgh
University of Rochester
Rutgers University
Tufts University
University of California at Irvine
University of Minnesota at Duluth
Universidad Nacional de Ingeniería
Universidad Técnica Federico Santa María
William and Mary

NuMI Beam

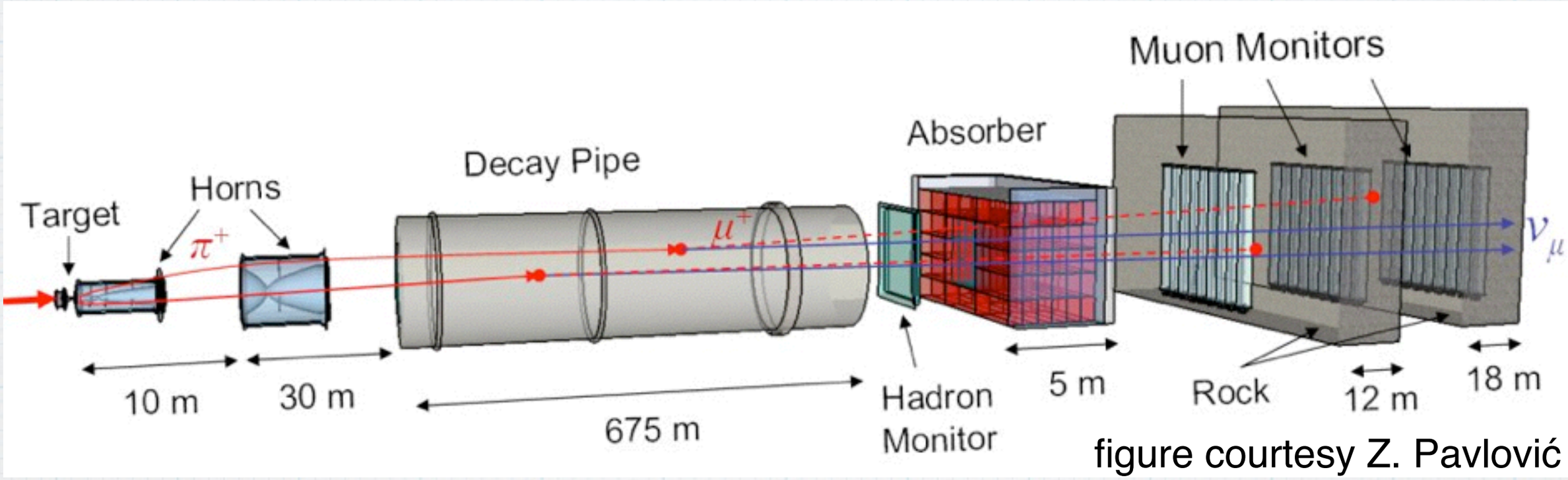
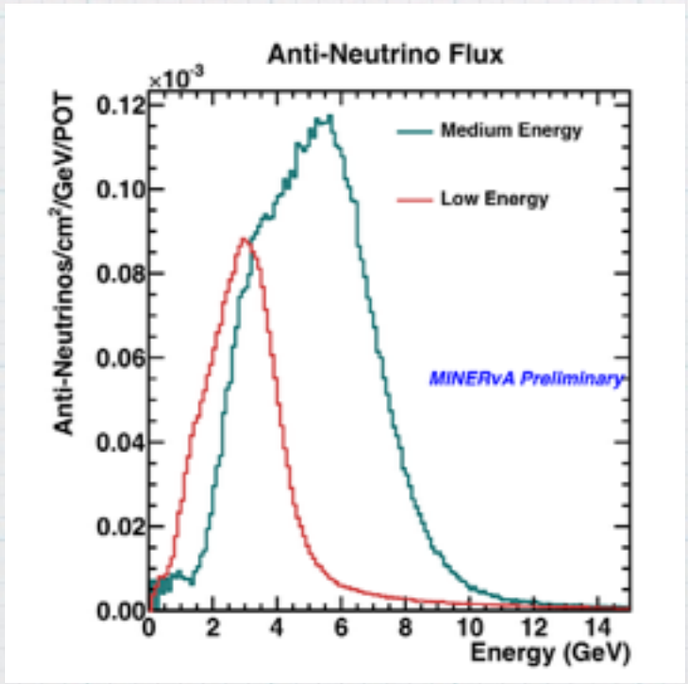
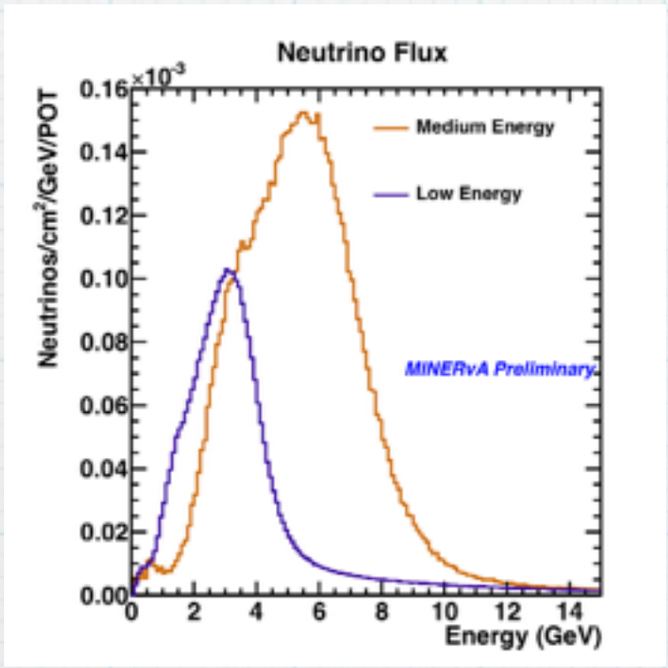


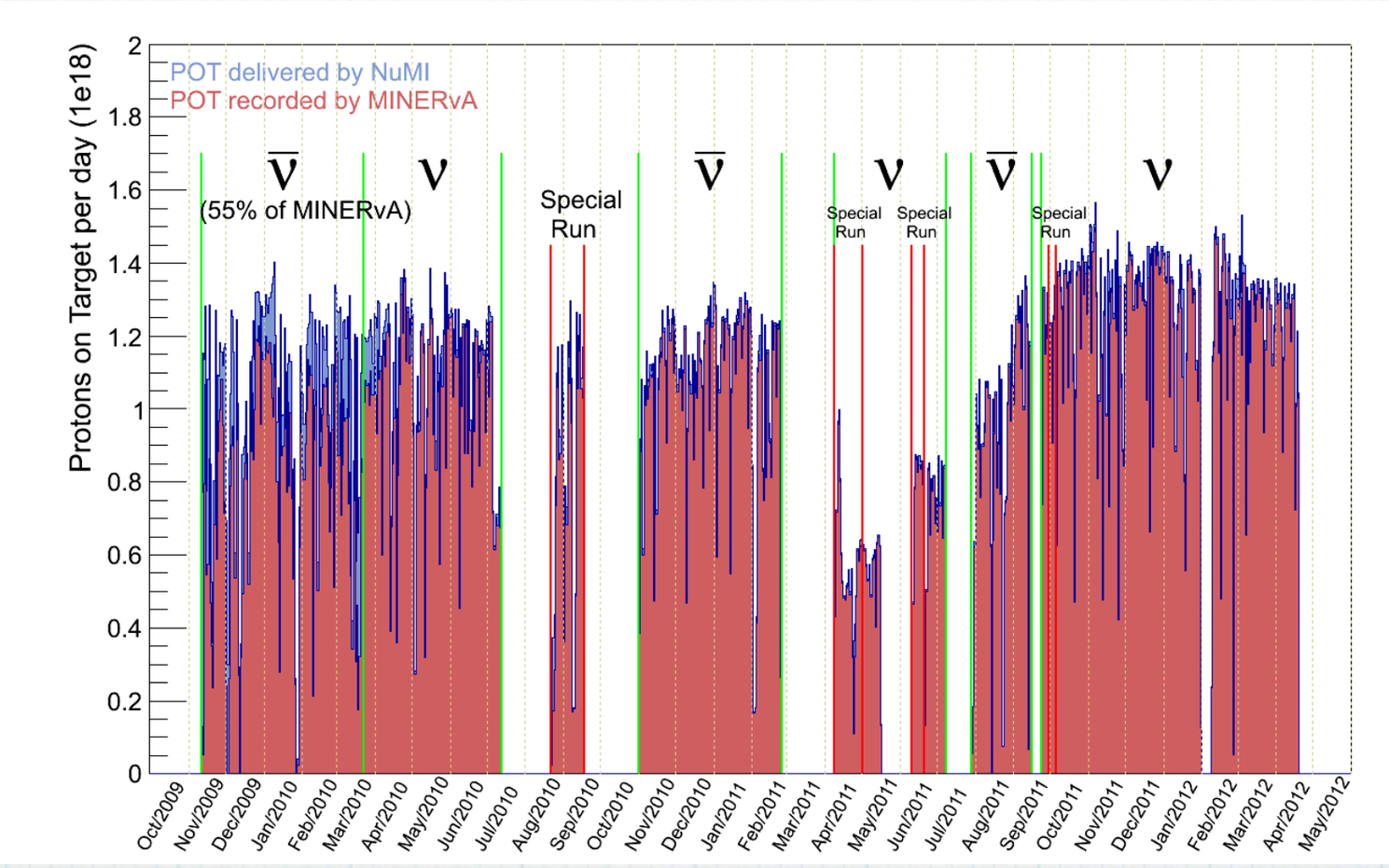
figure courtesy Z. Pavlović



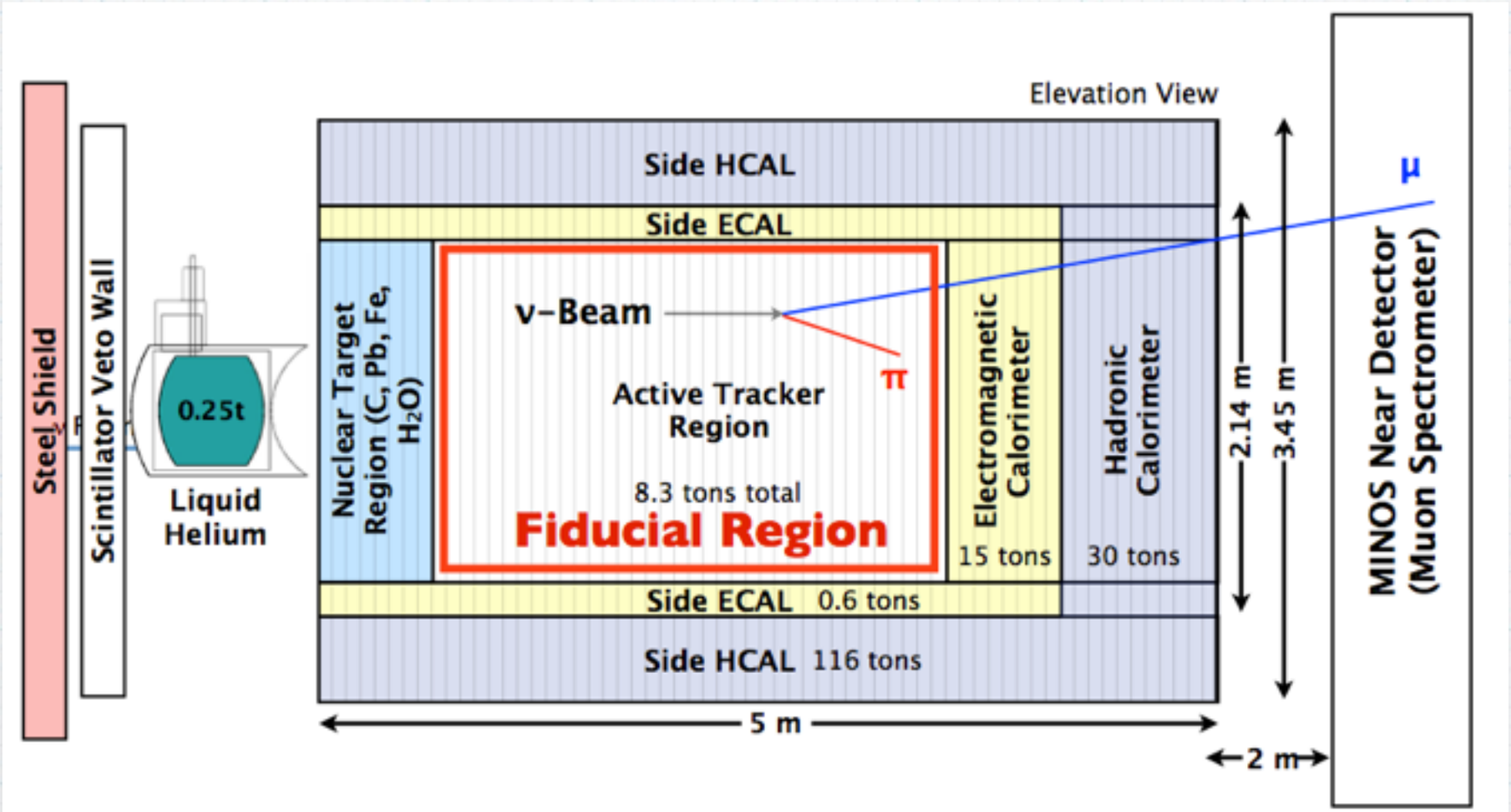


- 120 GeV/c protons from Main Injector.
- Graphite target
- ME run started September 2013.

Backup


POT delivered by NuMI
POT recorded by MINERvA
ν̄
ν
(55% of MINERvA)
Special Run
Special Run
Special Run
Special Run
Protons on Target per day (1e18)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Oct/2009
Nov/2009
Dec/2009
Jan/2010
Feb/2010
Mar/2010
Apr/2010
May/2010
Jun/2010
Jul/2010
Aug/2010
Sep/2010
Oct/2010
Nov/2010
Dec/2010
Jan/2011
Feb/2011
Mar/2011
Apr/2011
May/2011
Jun/2011
Jul/2011
Aug/2011
Sep/2011
Oct/2011
Nov/2011
Dec/2011
Jan/2012
Feb/2012
Mar/2012
Apr/2012
May/2012

MINERvA Detector



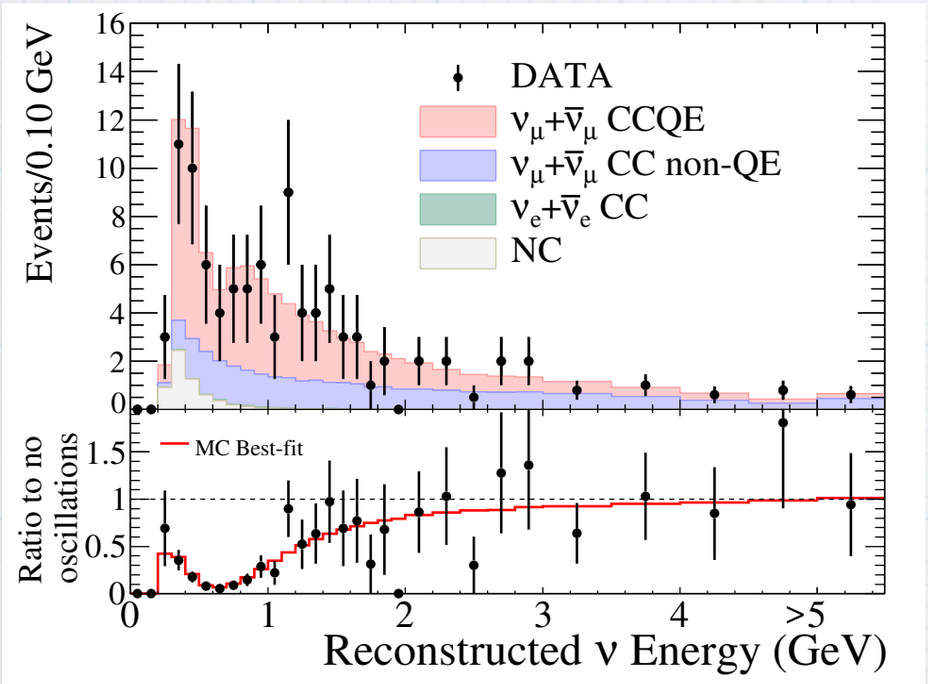
- 120 modules for tracking and colorimetry (32k readout channels)
- Completion in Spring 2010,.
- The MINOS near detector serves as a muon spectrometer.

Nucl. Inst. and Meth. A743 (2014) 130

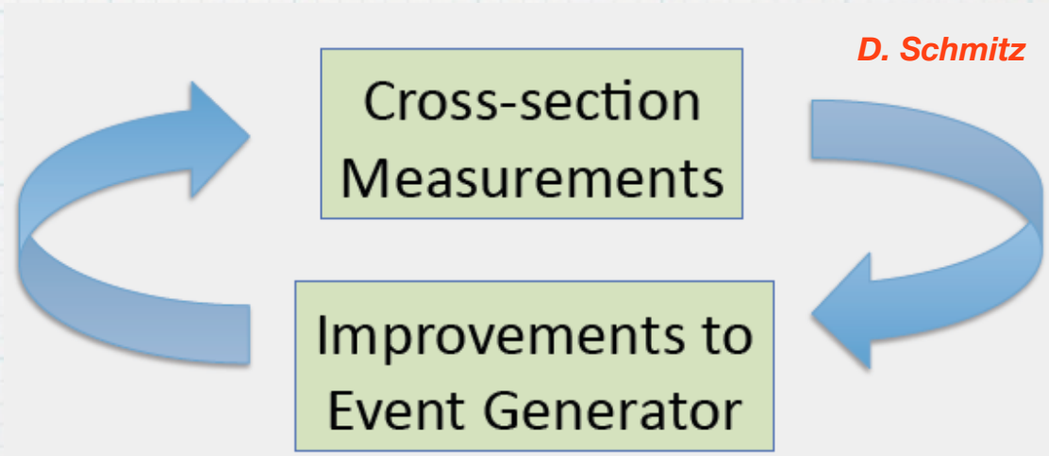
Neutrino Event Generator (GENIE)

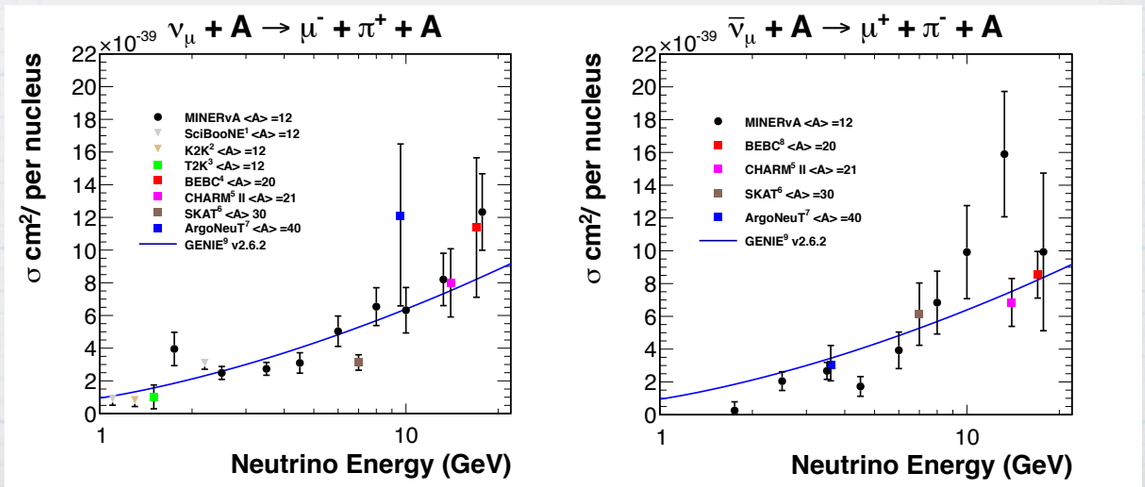
* Includes a lot of physics: electron scattering, final state interaction (FSI) models, and nuclear physics models
* Provides framework for realising physics analysis for neutrino (especially oscillation) experiments
* NOvA, IceCube, MINERvA

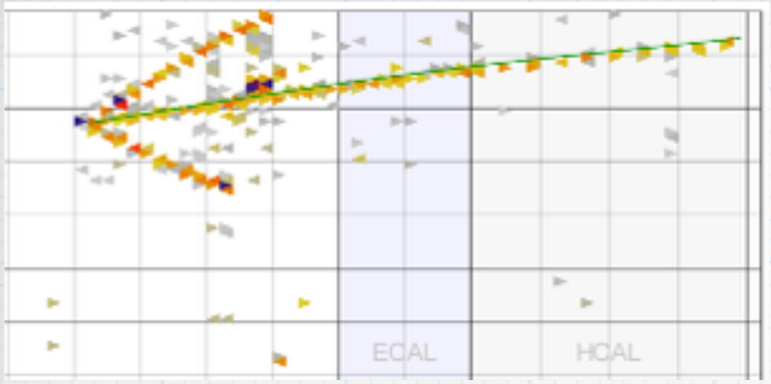
T2K



Phys. Rev. Lett. 112, 181801, 2014

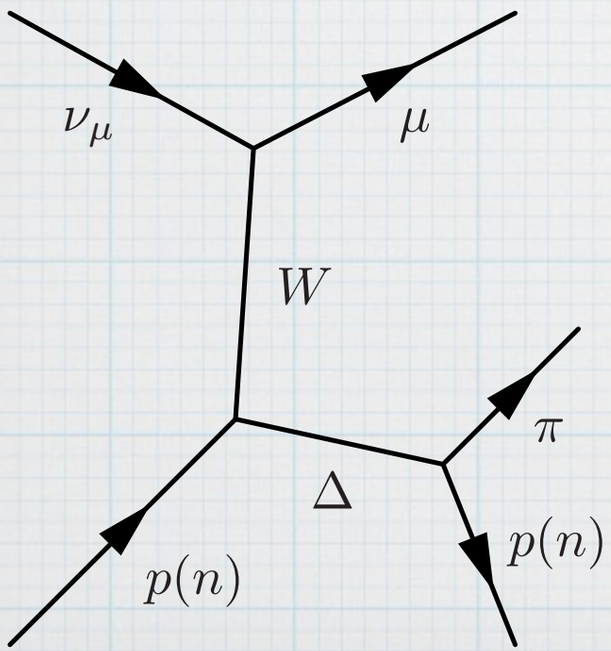






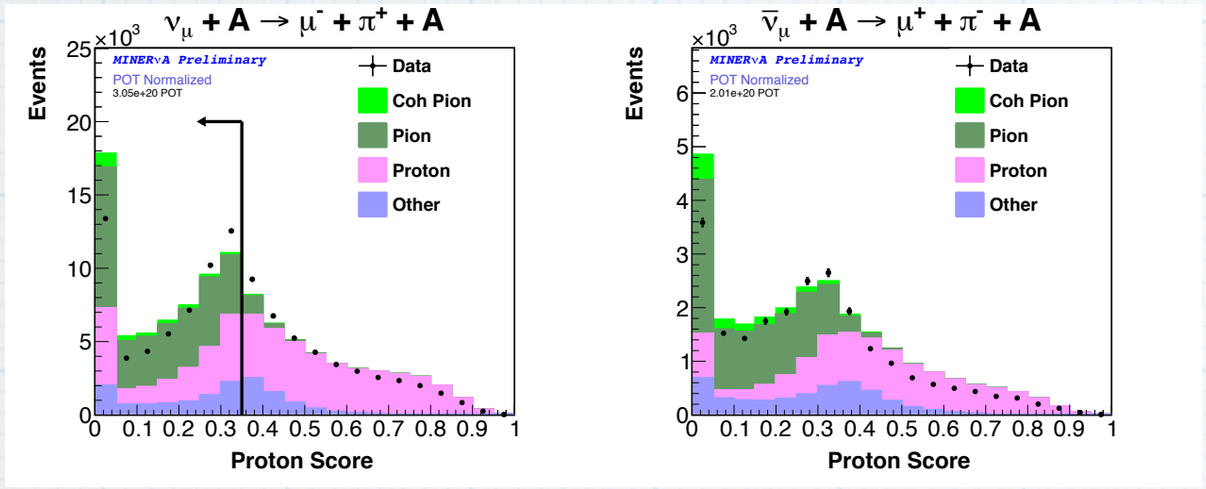
Publication forthcoming
on arXiv:1406.6415

Results: Charged Pion Production

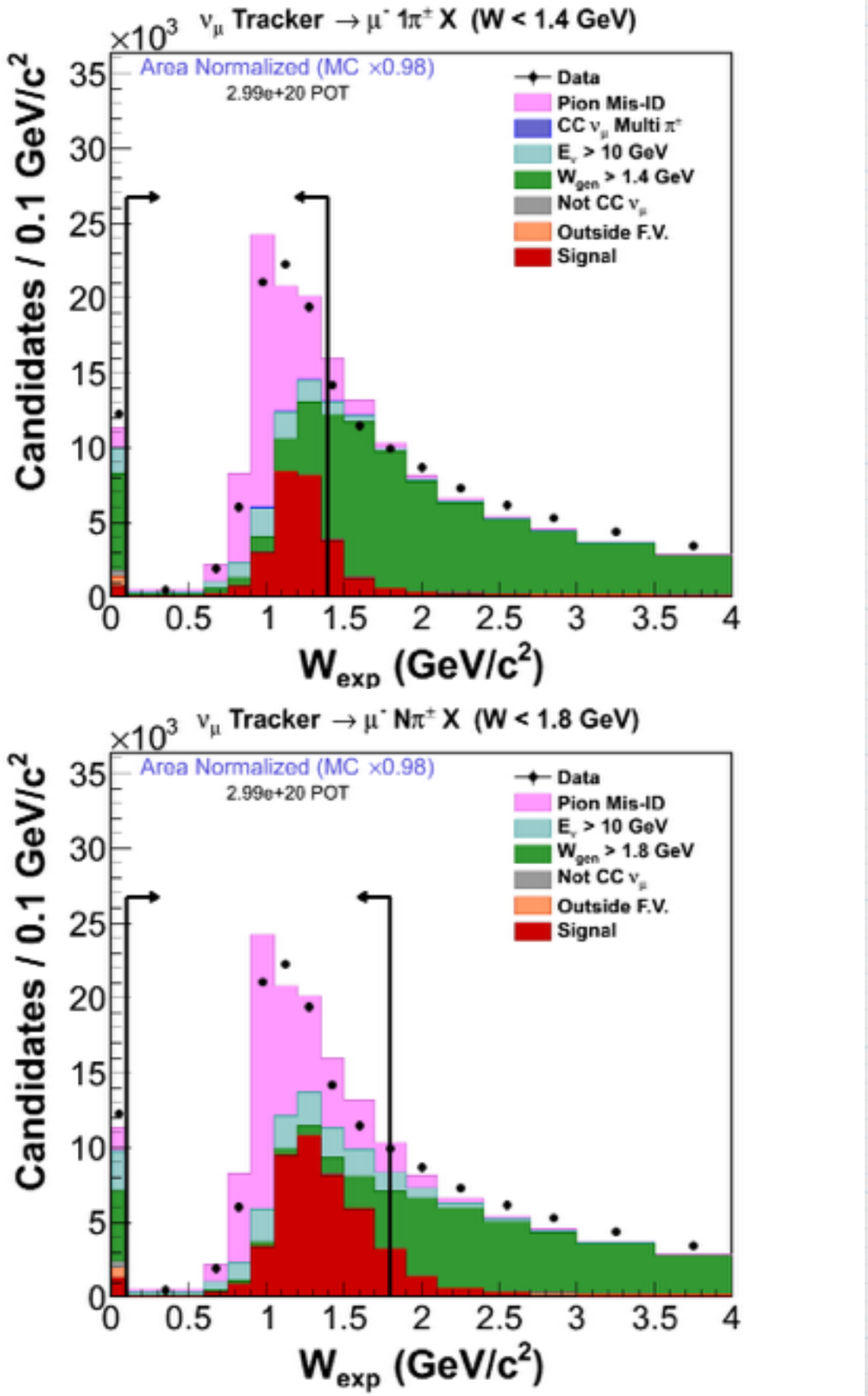


3.04e20 POT neutrinos

Event selection



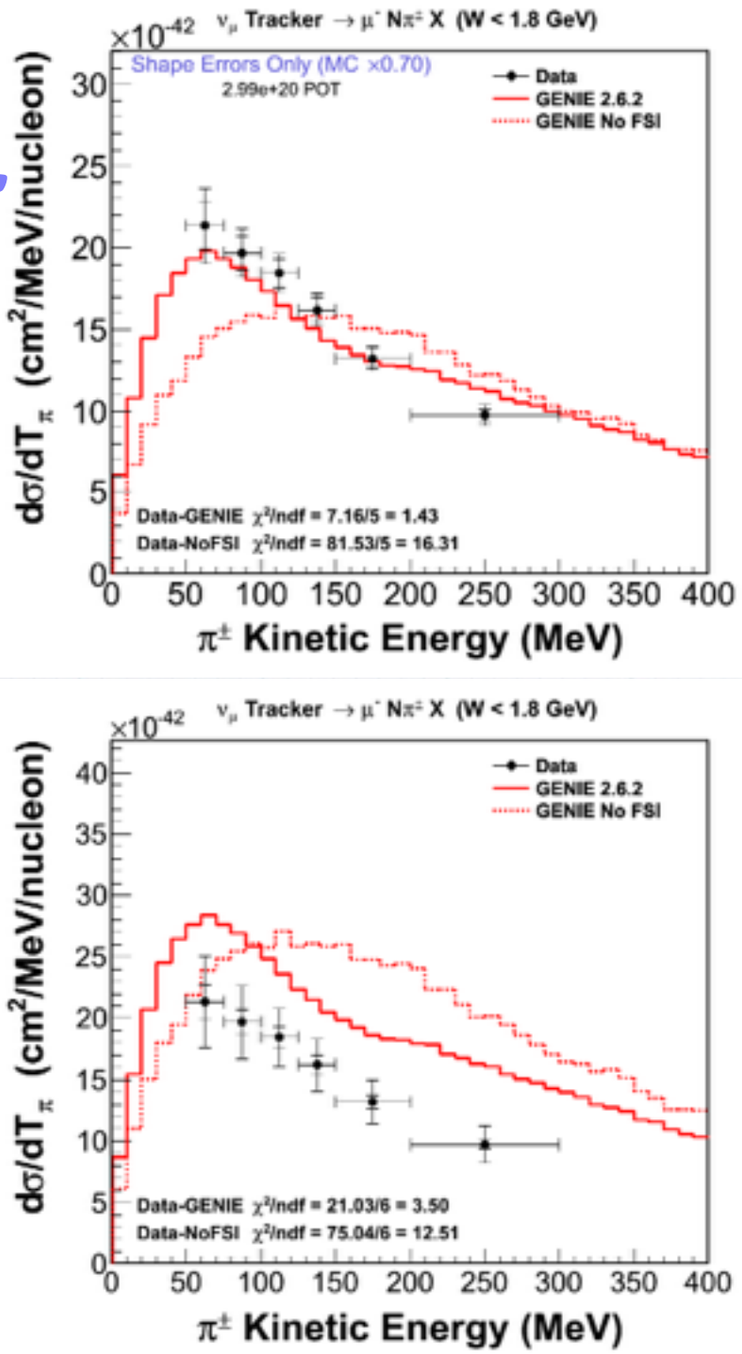
* Events contain one muon matched in MINOS.
* Events contain at least one hadron track.
* Only tracks which stop in the Ecal or tracker region are accepted.
* Pions are identified by dE/dx, and the existence of a Michel electron at the end of the pion track.



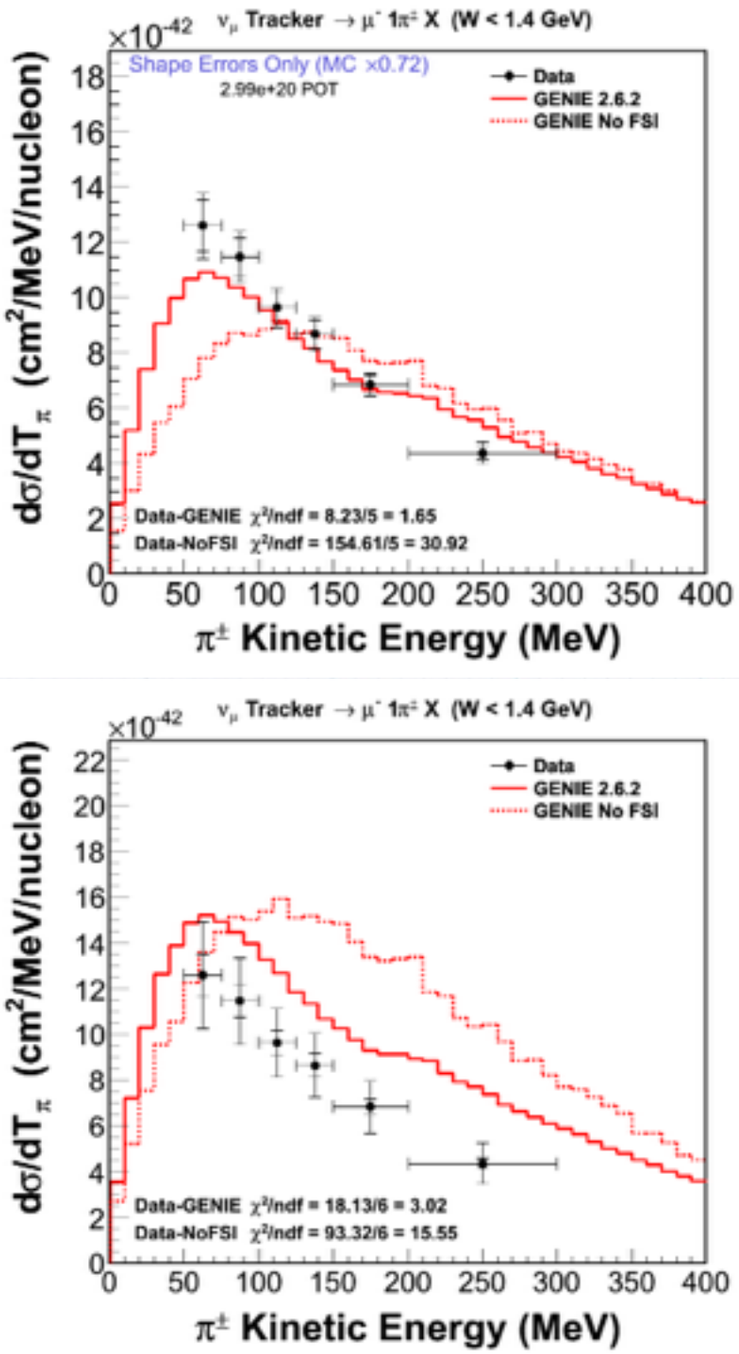
Results

MC scaled by 0.70

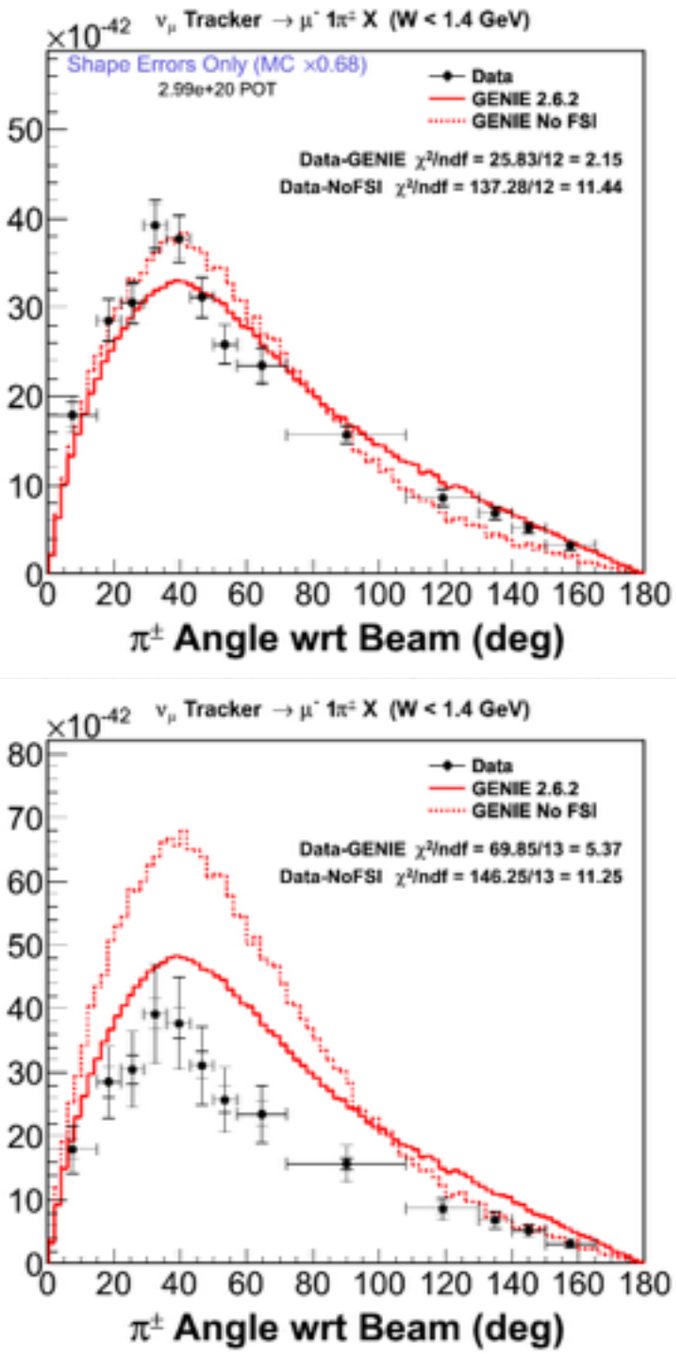
n pions



1 pion

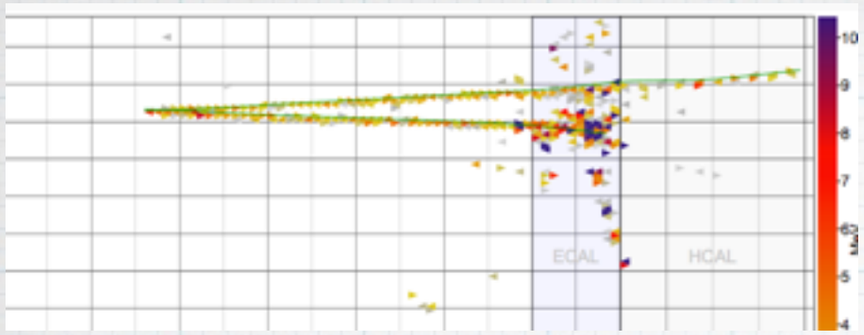


1 pion



Take away

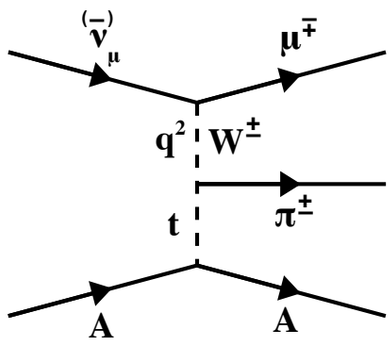
* Measurements constrains interaction rate and final state interactions in pion production.
* The contribution from Final State Interaction (FSI) is significant.
* Needed to improve signal and background predictions for oscillation experiments.
* Agreement with GENIE.



Publication forthcoming

Results: Coherent Pion Production

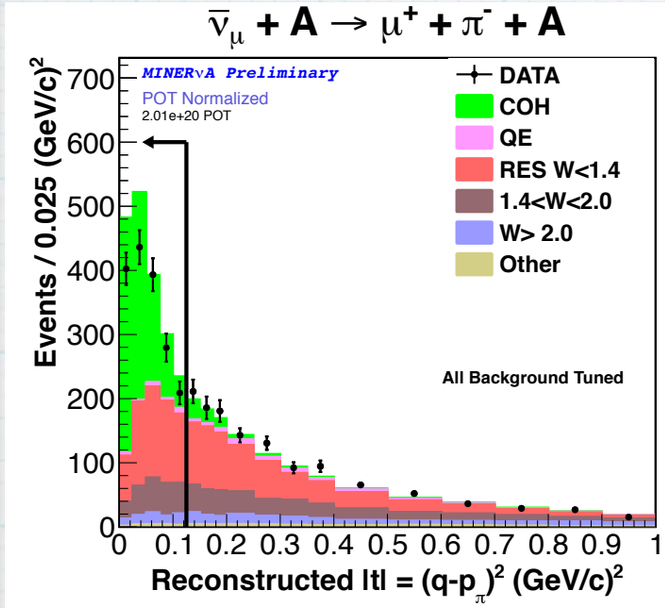
3.04e20 POT neutrinos
2.01e20 POT antineutrinos



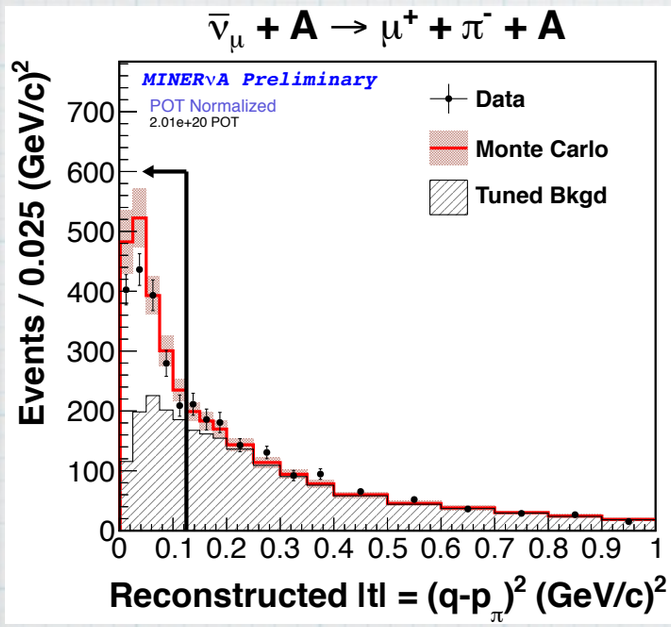
Existence of pion and muon with no nucleon breakup (quiet vertex) and low momentum transferred between nucleus and pion.

Event selection

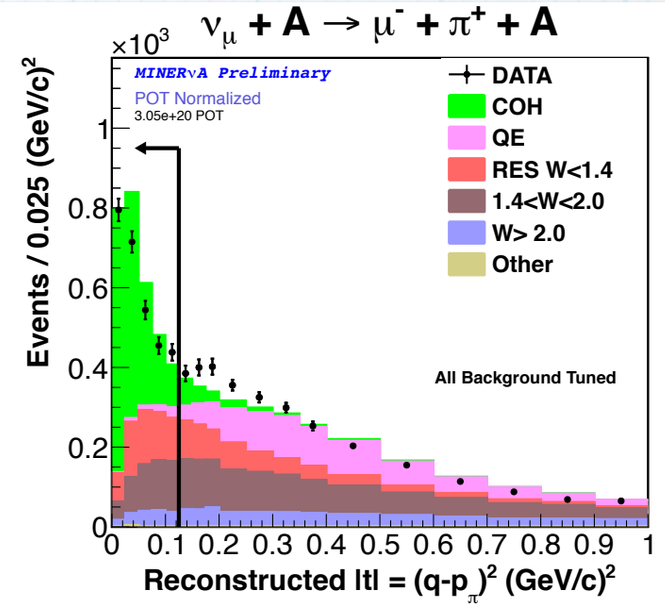
antineutrino

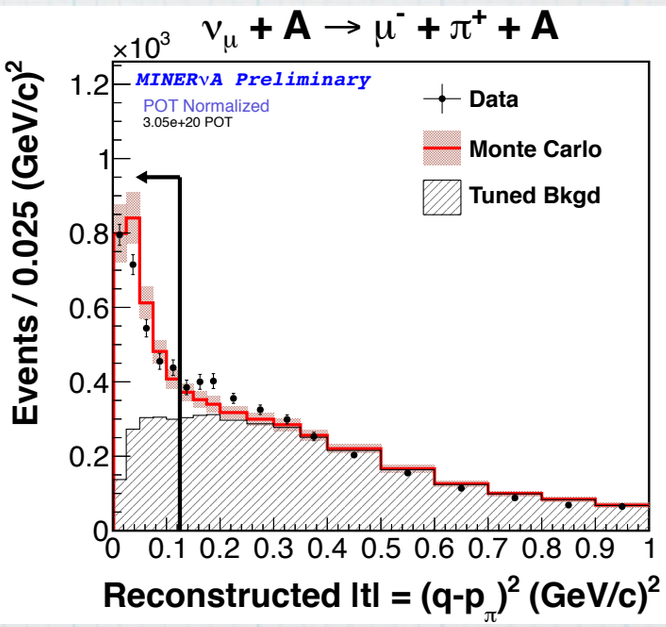


- Events have almost no vertex energy.
- Separation of coherent scattering from incoherent background by slope of |t| due to the slope being different for diffractive and resonant processes.
- Sideband is selected as the incoherent background, is tuned to MC to minimize χ^2



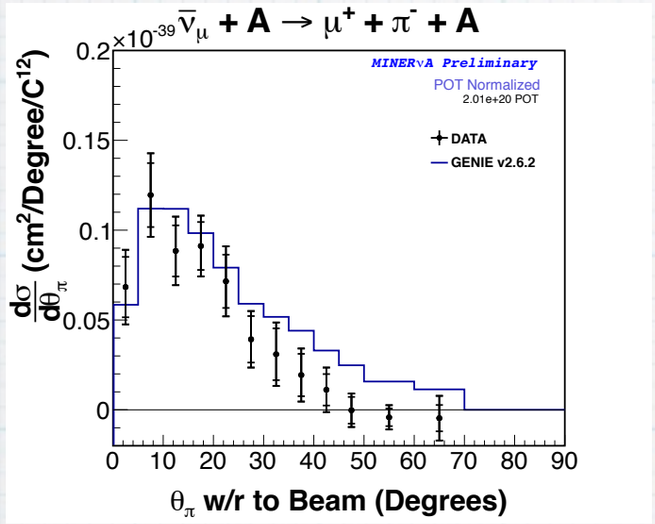
neutrino

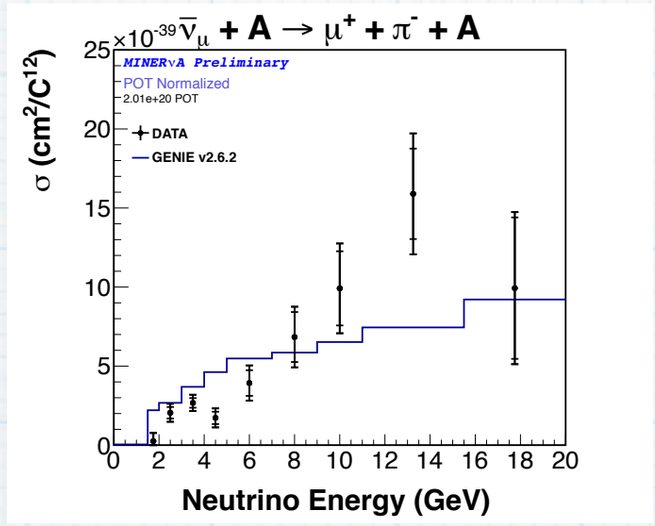


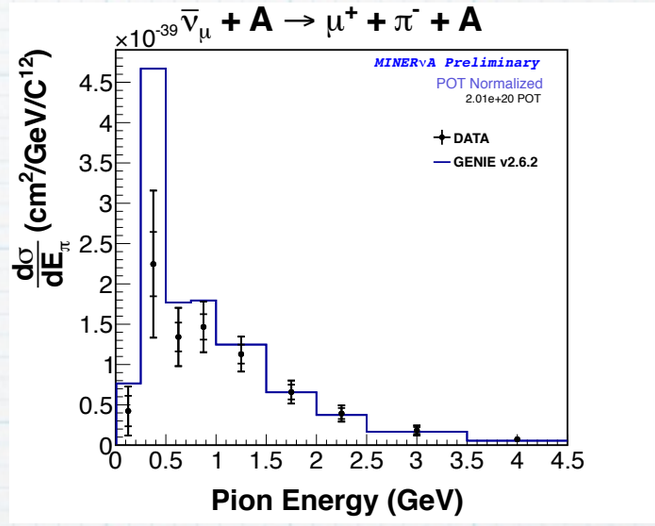


Results: Cross section

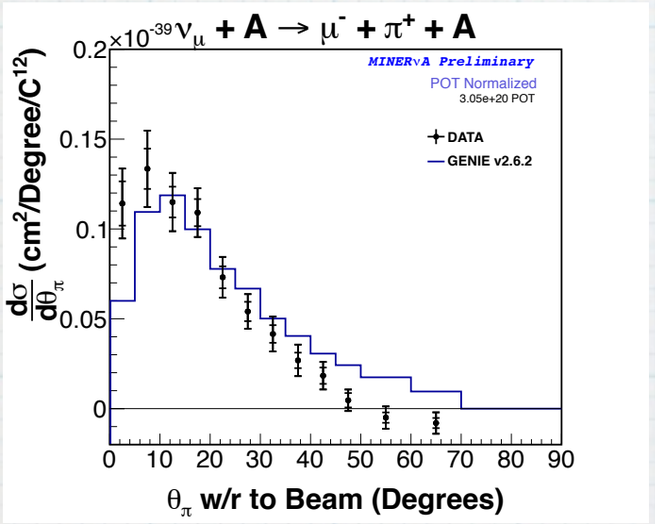
antineutrino

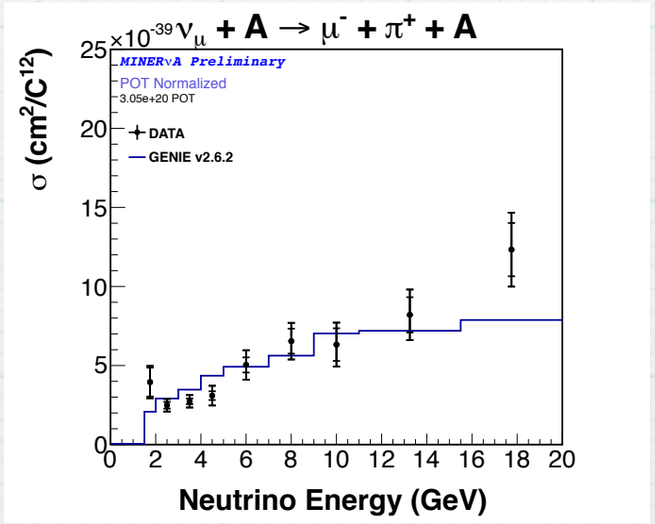


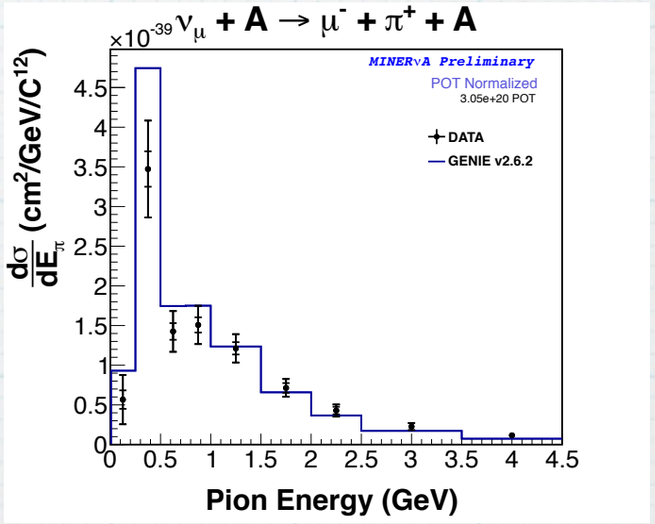




neutrino

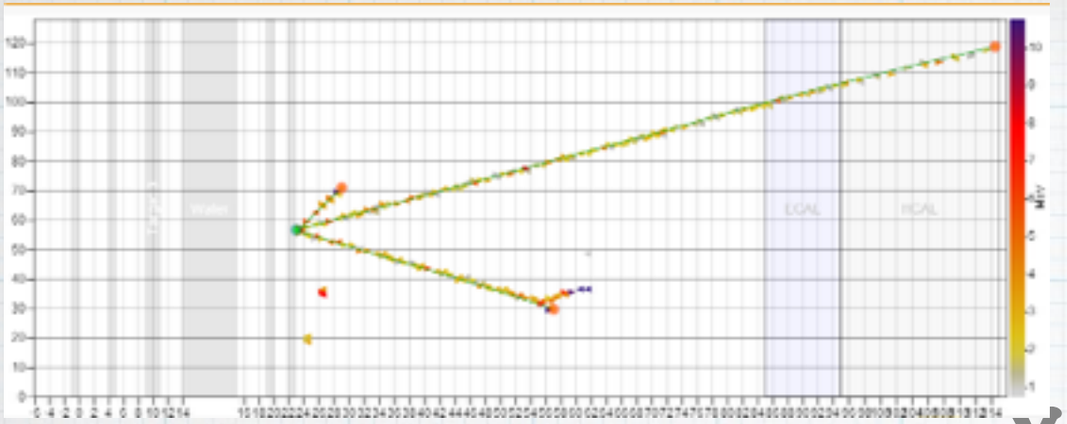






Take away

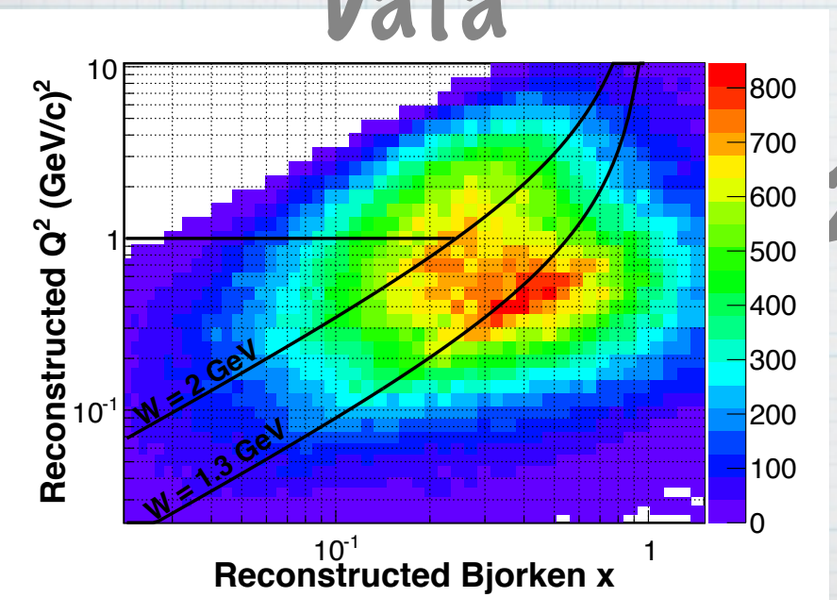
* Data shows a harder and more forward pion distribution than GENIE.
* The selection of low ltl events allows a model independent measurement of coherent pion production.
* Can be used to set systematic for oscillation experiments.
* In the NuMI ME configuration, multiple passive targets (Pb, Fe, C) will allow a measurement of A dependence.



Published
arXiv:1403.2103

Results: Inclusive Charged Current Scattering

Data

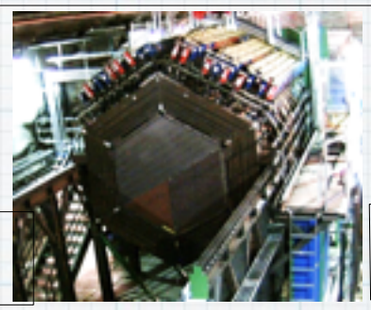


2.94e20 POT neutrinos

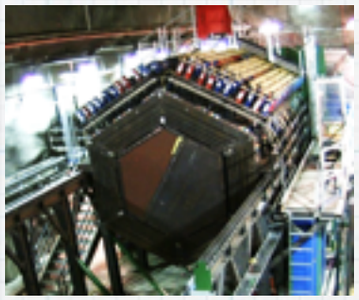
Event Selection

* Events must have a muon in MINOS.
* Target vertex must be in passive target or neighbouring scintillator.
* Neutrino energy between 2 and 20 GeV.
* Muon angle < 17 deg.

3" C / 1" Fe / 1" Pb
166kg / 169kg / 121kg

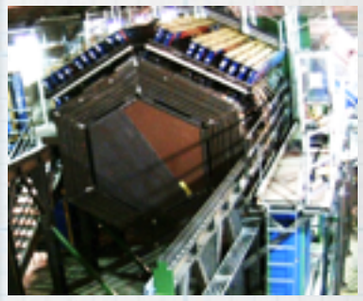


1" Pb / 1" Fe
266kg / 323kg

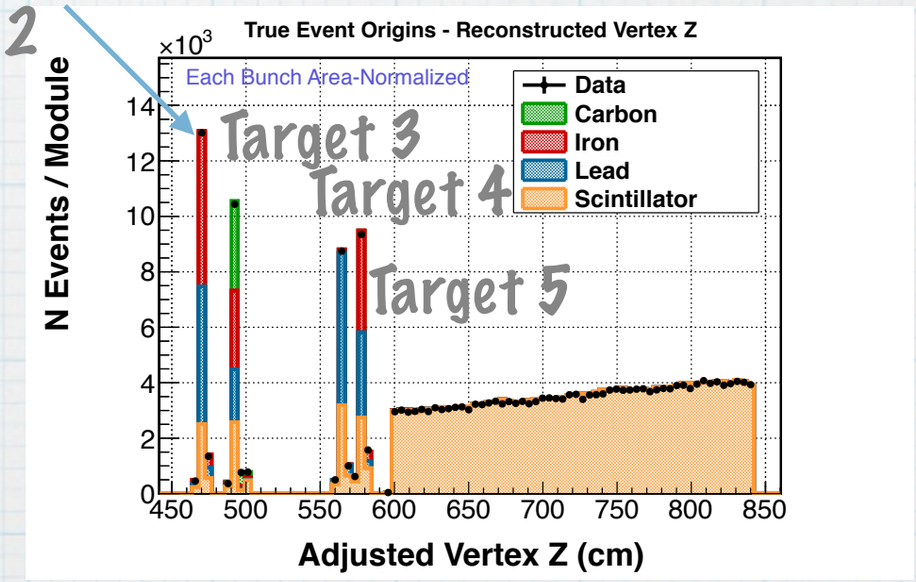


0.3" Pb
228kg

.5" Fe / .5" Pb
161kg/ 135kg

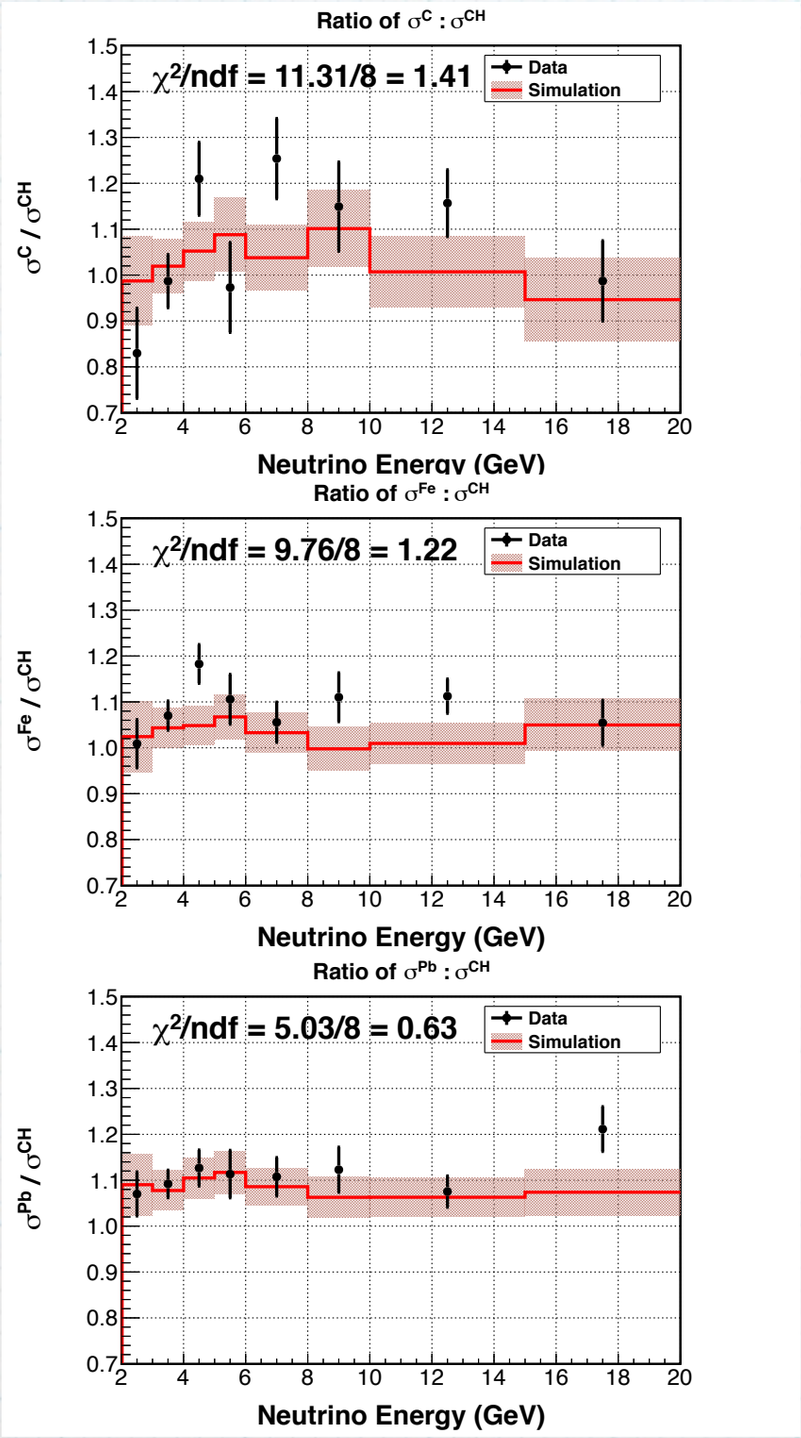


Target 2



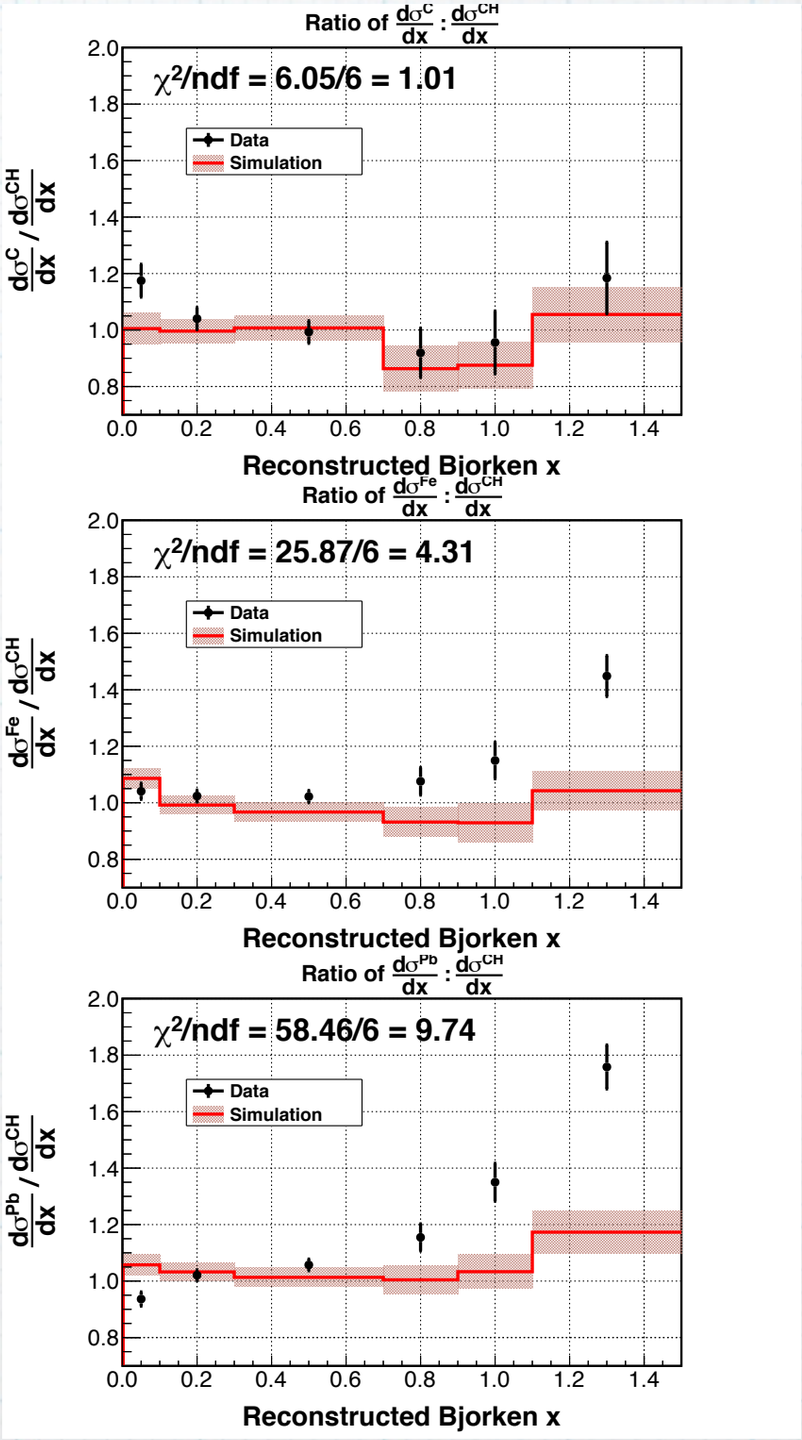
Gives MINOS acceptance (restricts kinematics).
Gives estimate of contamination from scientillator.

Ratio Results



No tension between data and MC

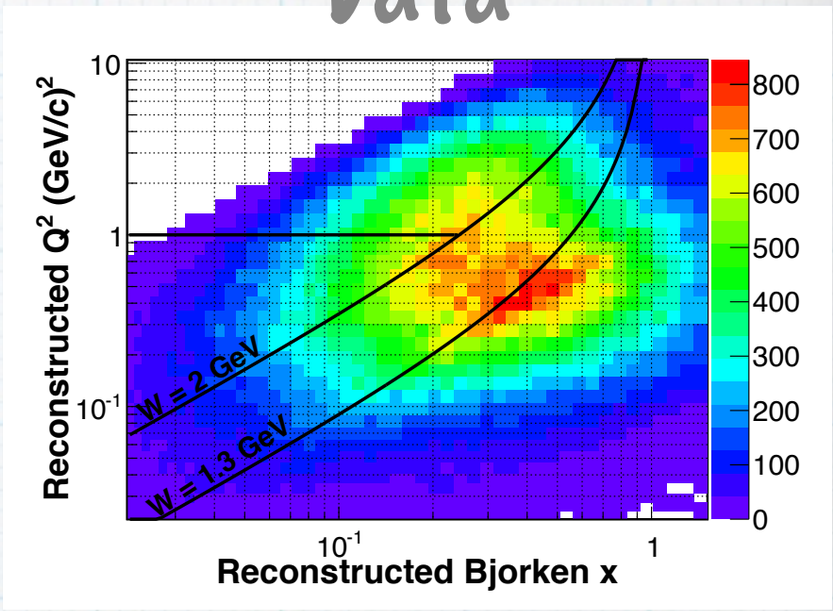
Tension between data and MC



Take away

* This is not deep inelastic scattering.
  * Theory input needed!
* Data is not reproduced by simulation.
  * Can be used to improve estimate of systematic for oscillation experiments.
  * Unexpected excess at high x and deficit at low x points to improvements needed in models (fermi motion + ? and shadowing).

Data



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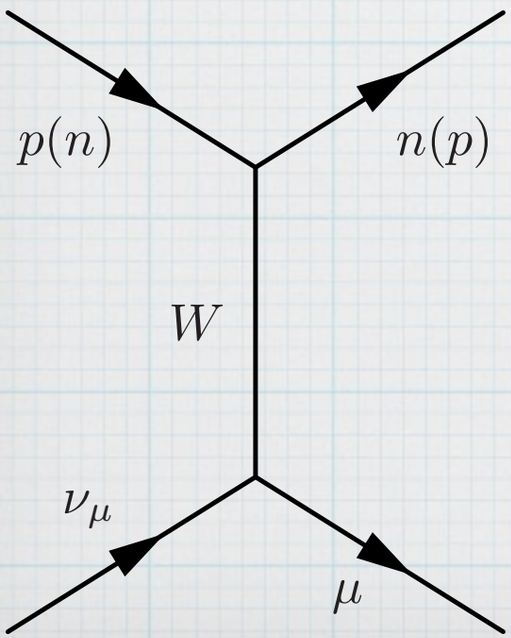
Published in PRL and arXiv:
1305.2243 and arXiv:
1305.2234

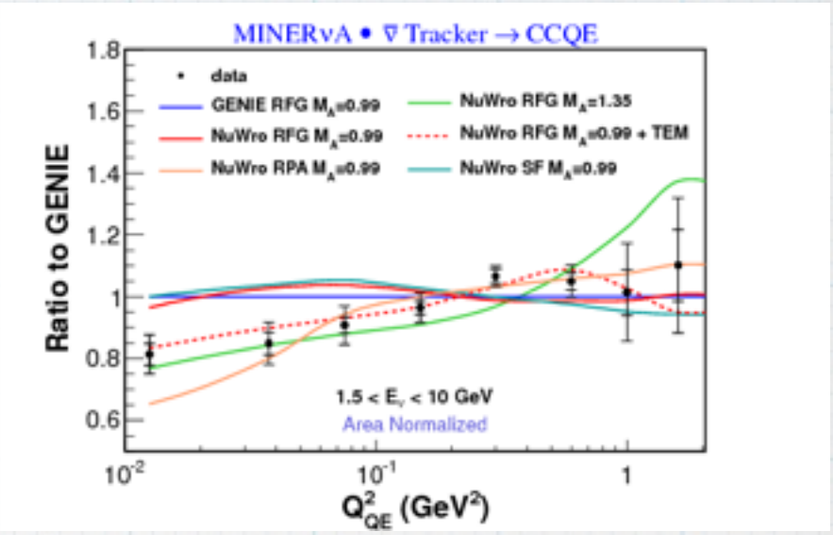
Results:Quasi-Elastic Scattering

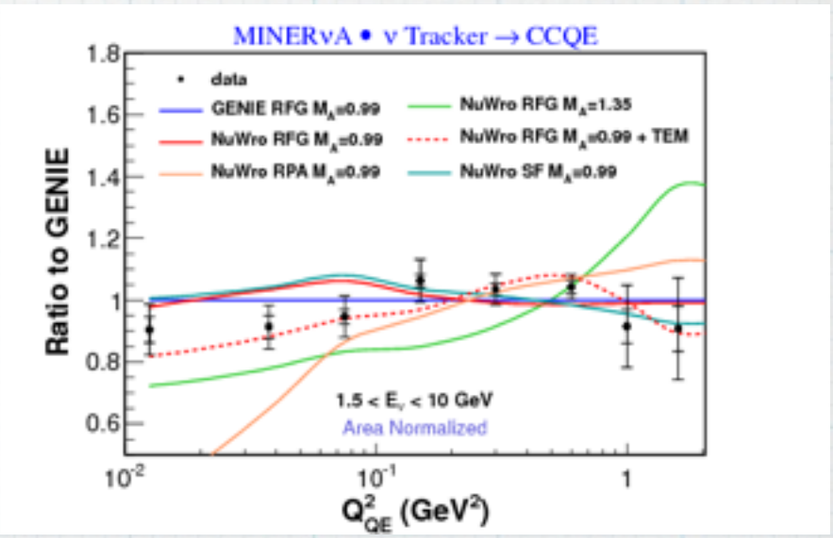


3.98e20 POT neutrinos
1.70e20 POT antineutrinos

Event Selection, Results and Take away

* Simple event selection requires single track with matching track in MINOS.
  * Requires no more than 1(2) additional blobs for anti-ν(ν)
* Basic relativistic fermi gas model disfavored.
* Increasing axial mass disfavored.





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Conclusions and Future

* MINERvA is important in developing neutrino generators (GENIE), required for oscillation experiments.
* MINERvA ME data run has begun.
* Possibilities to extend the MINERvA program.
* Many analyses in progress, expect CCPi0, K production, NuE elastic in the coming months.
* Some results show broad agreement with model predictions and others significant disagreement. No need to **PANIC**, **NOW** we have **observation**.

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