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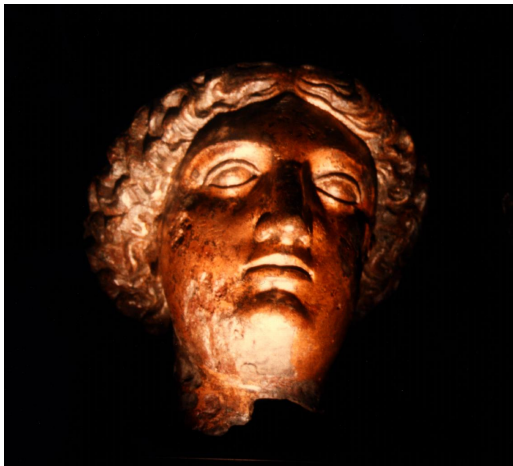
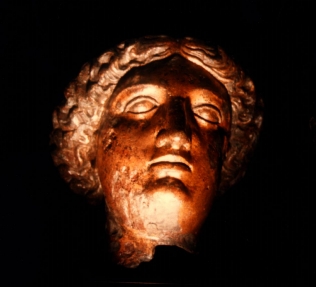
New Perspectives 2018

DEEPIKA JENA
Fermilab
(on behalf of MINERvA Collaboration)
18 June 2018



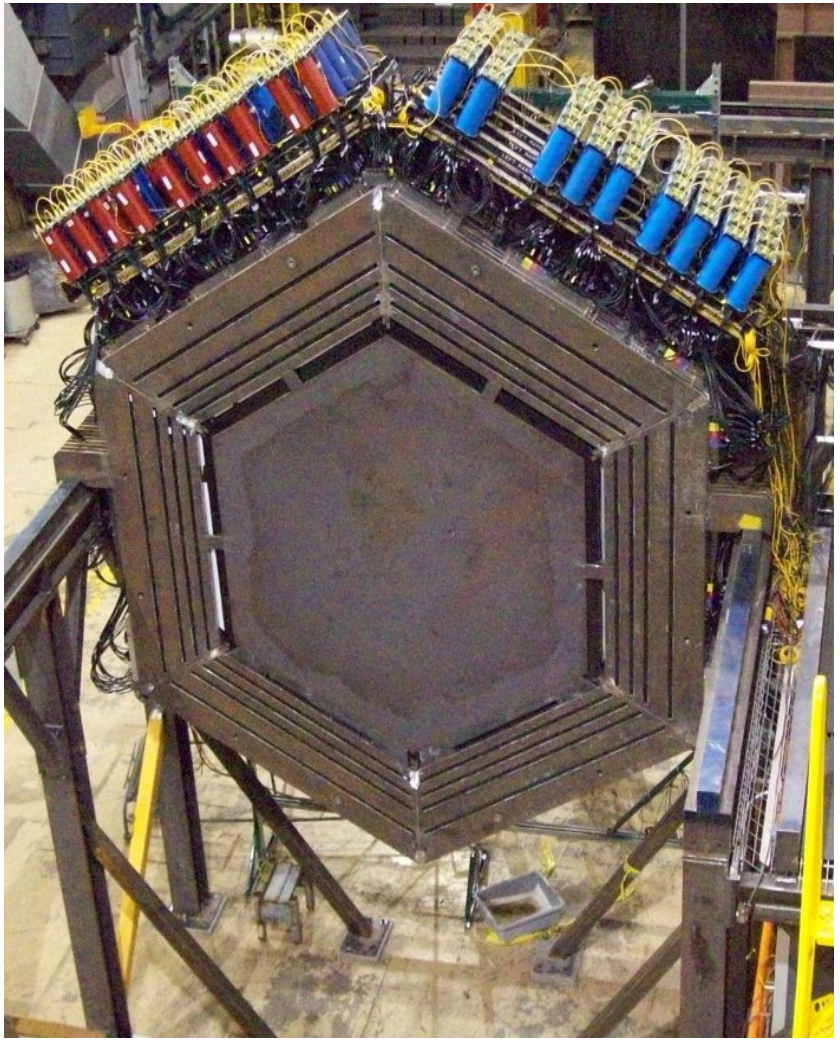
Outline

- What is MINERvA ?
- Why Measure Neutrino Cross Section ?
- Recent Analysis Results
- Summary

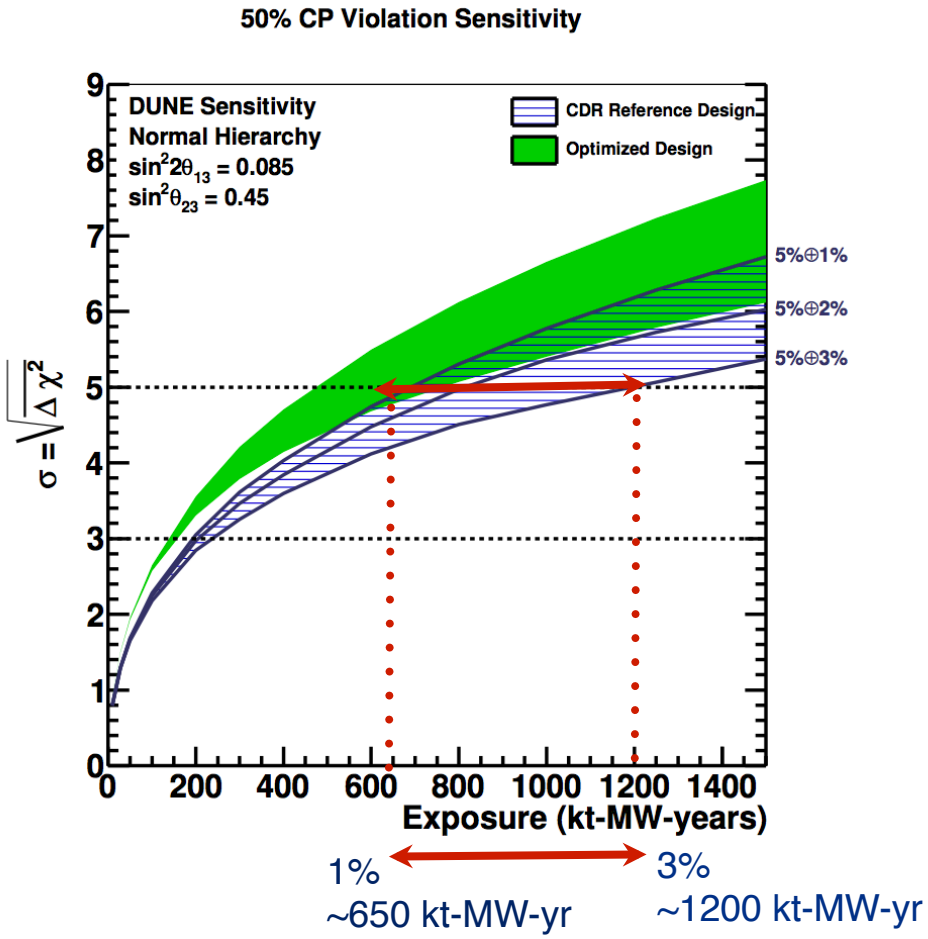


What is MINERvA?

- MINERvA: a dedicated on-axis neutrino-nucleus scattering experiment running at Fermilab in the NuMI (Neutrinos at the Main Injector) beamline.
- Our goal:
  - Make high precision measurement of neutrino interaction cross sections in the energy region of interests (1-50 GeV).
  - Study nuclear effects



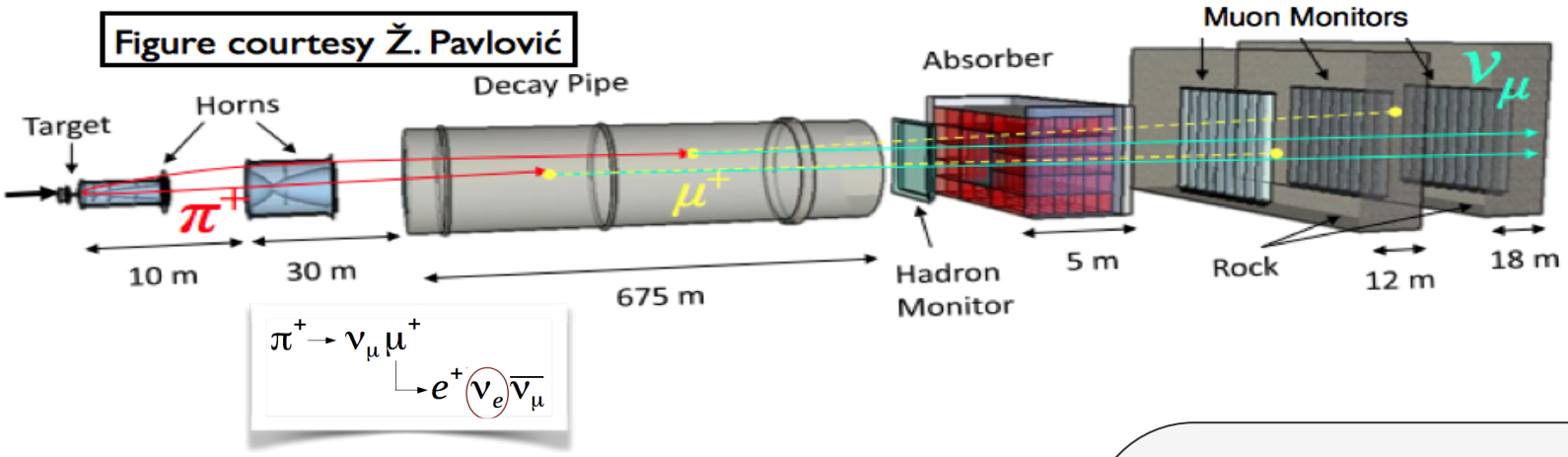
Why care about cross section?



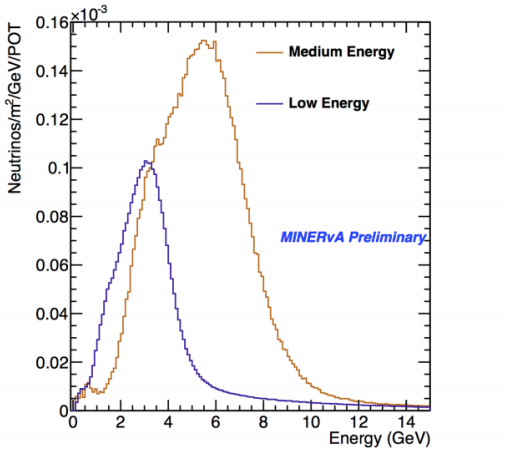
- In a period of precision neutrino oscillation measurements
  - Reducing systematics uncertainties is critical
- Reaching low systematics goals requires control of all systematics, including those from neutrino interaction cross sections.
- Acceleration based Oscillation experiments rely on neutrino-nucleus interaction models in neutrino event generators.
  - Need better model and high precision data -> goals of MINERvA

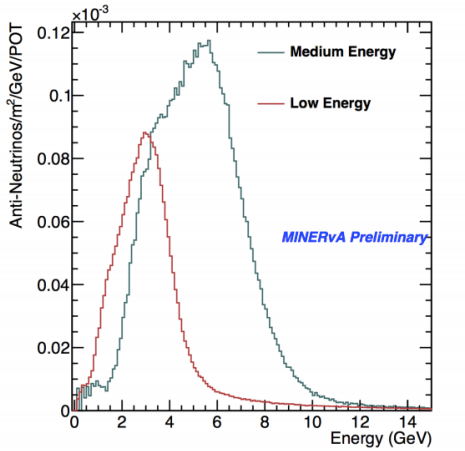
*** 300 kt-MW-years** corresponds to **7 years** data-taking

NuMI



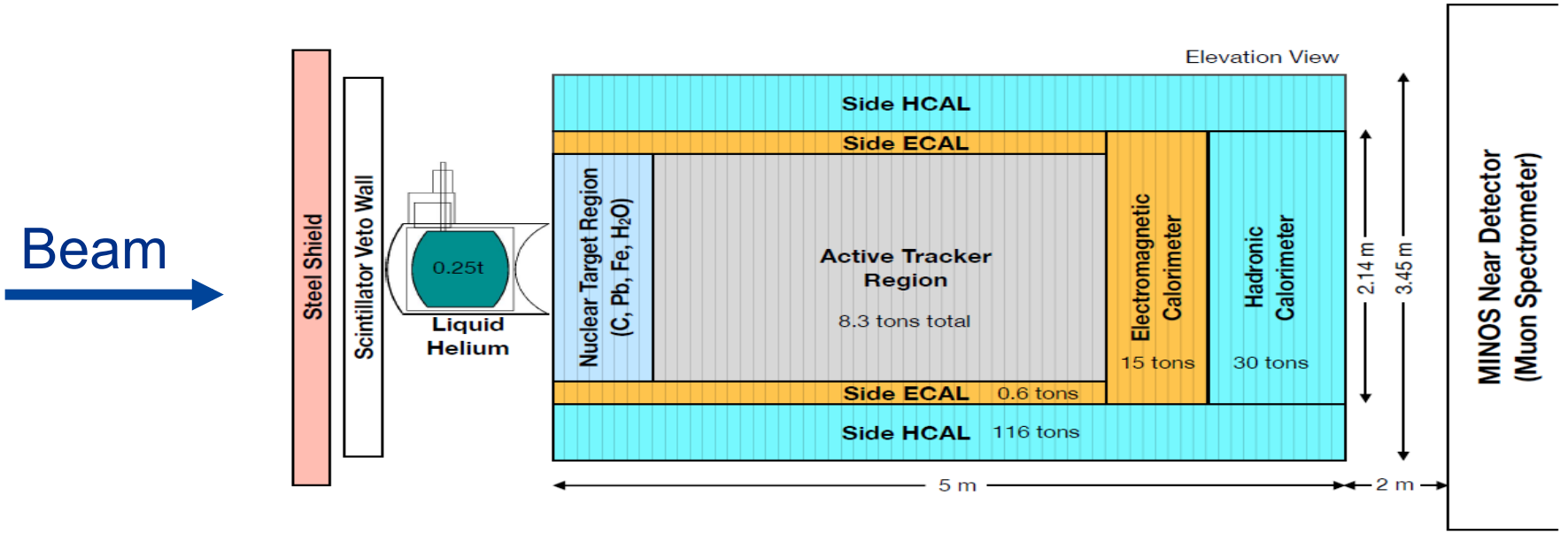
MINERvA





- MINERvA sits on-axis in the NuMI Beam at Fermilab
- Completed low-energy run which peaks at 3.5 GeV.
- Currently accumulating data in medium-energy run which peaks at 6 GeV.

The MINERvA Detector

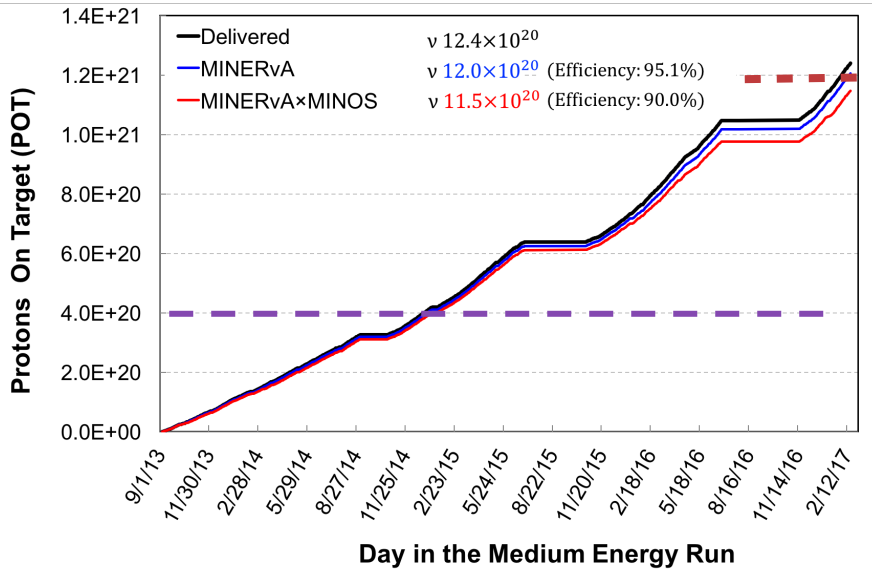


MINERvA takes data on Many Different Targets, Simultaneously !

- Highly granular, fully active detector designed to make high precision of neutrino-nucleus interactions.
- Composed of finely segmented scintillator based inner tracking region surrounded by electromagnetic and hadronic sampling calorimetry.
- Three Plane orientations (0 (X) , ±60 (U & V) rotations around the z-axis -> 3D reconstruction

Low Energy Era → Medium Energy Era

- "Protons on target" is a proxy for number of neutrinos.
- Higher energy -> More events
- Compare with T2K (2010-2013): 6.6e20

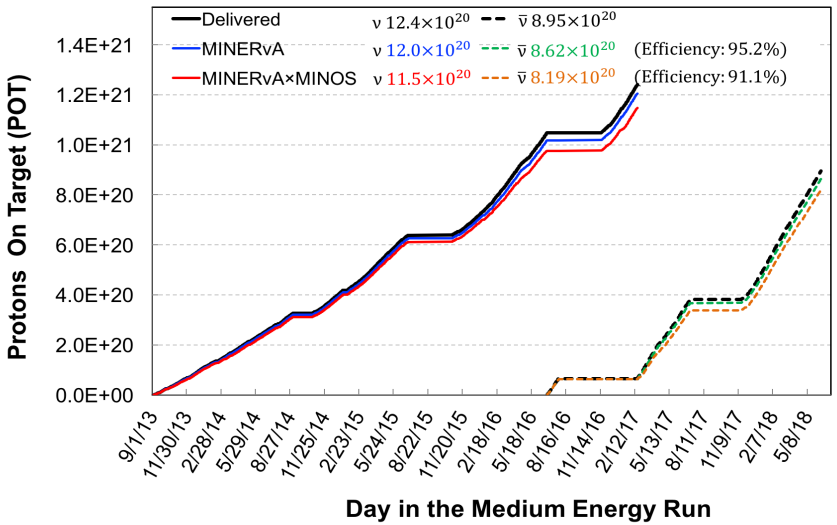


ME POT

~ 3x increase

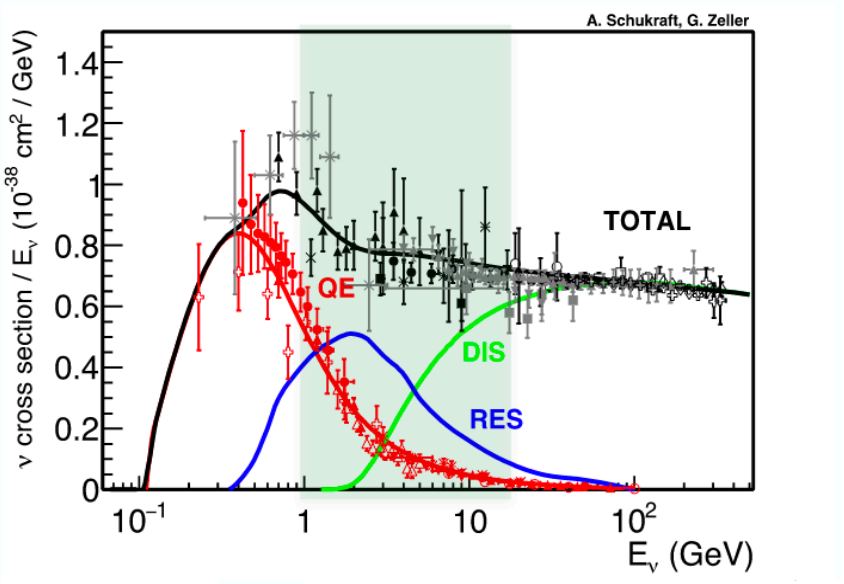
LE POT

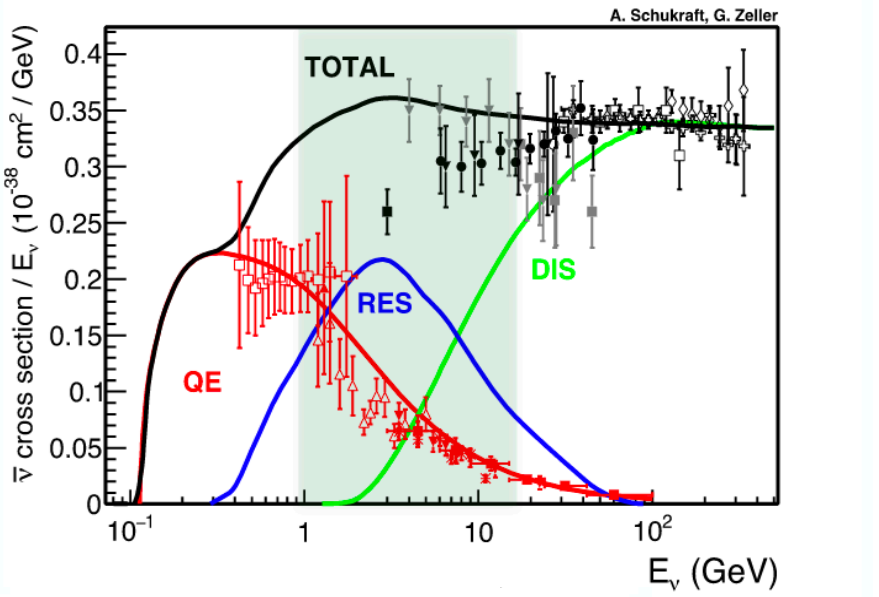
Mode	LE (~ POT)	ME (~ POT)
Neutrino	4 e^{20}	1.2 e^{21}
Anti-Neutrino	1 e^{20}	8 e^{20}

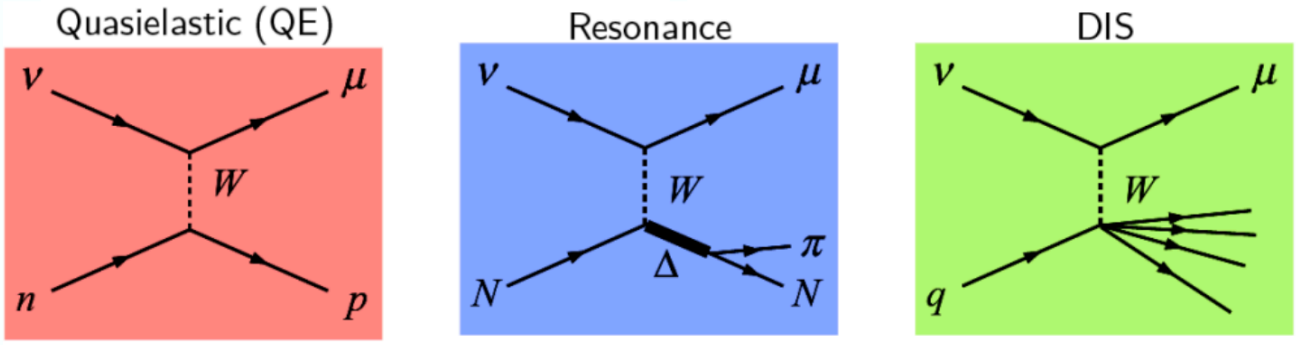


Charged Current Interaction

- Oscillation experiments (DUNE, NOvA) measure neutrino energy E_ν in the 1-50 GeV region, where many interactions channels are active.
  - These interactions channels are signal and the majority of backgrounds in the oscillation experiment







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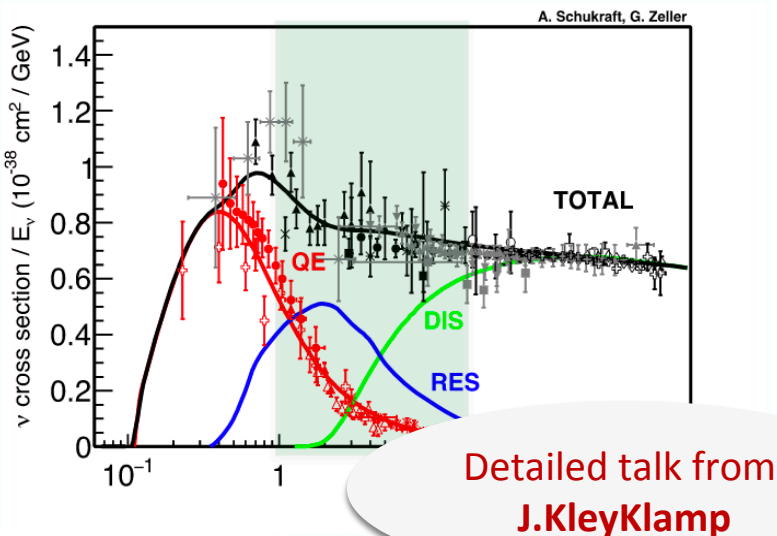
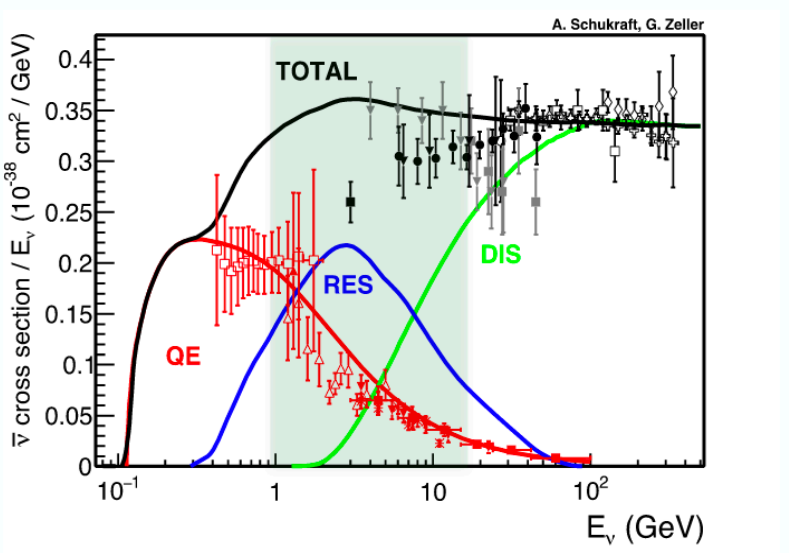
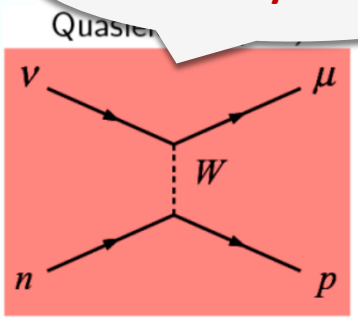
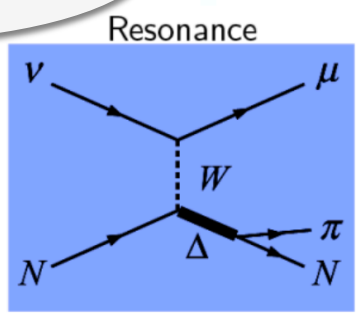
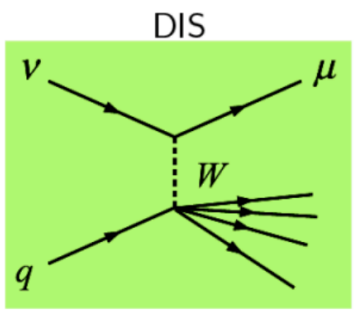




Detailed talk from **J.KleyKlamp**







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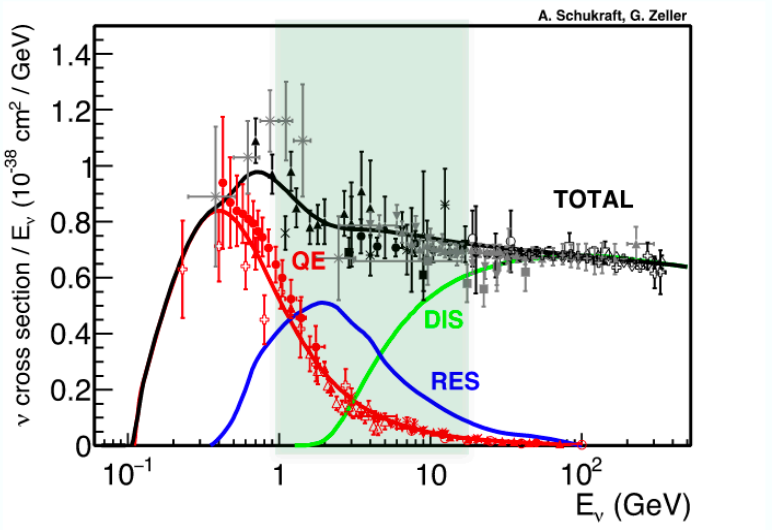
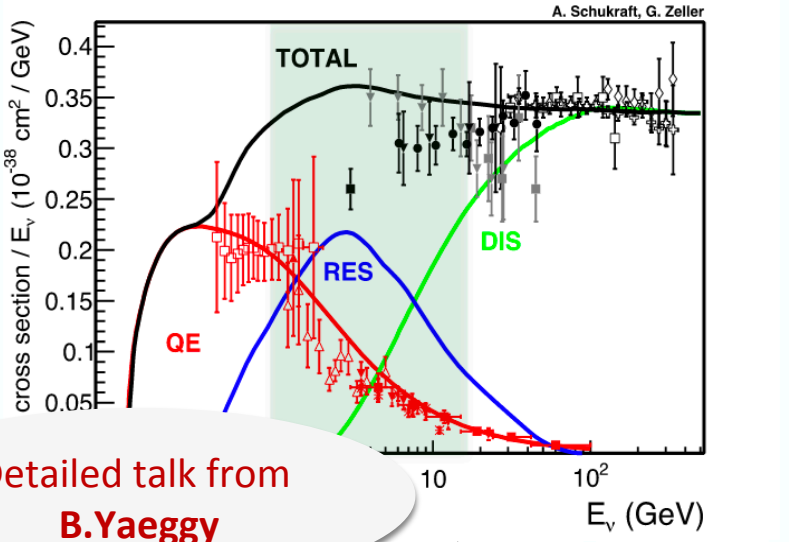
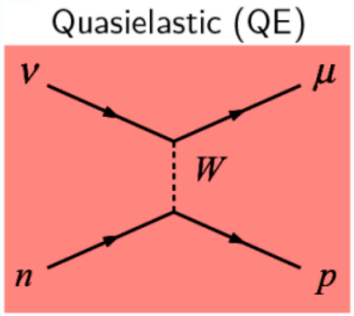
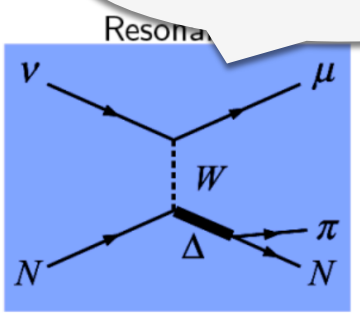
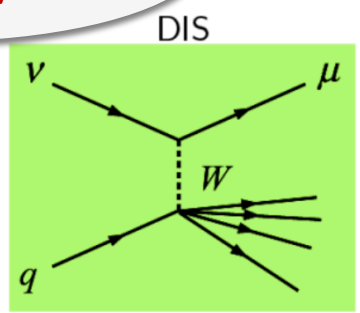




Detailed talk from **B.Yaeggy**







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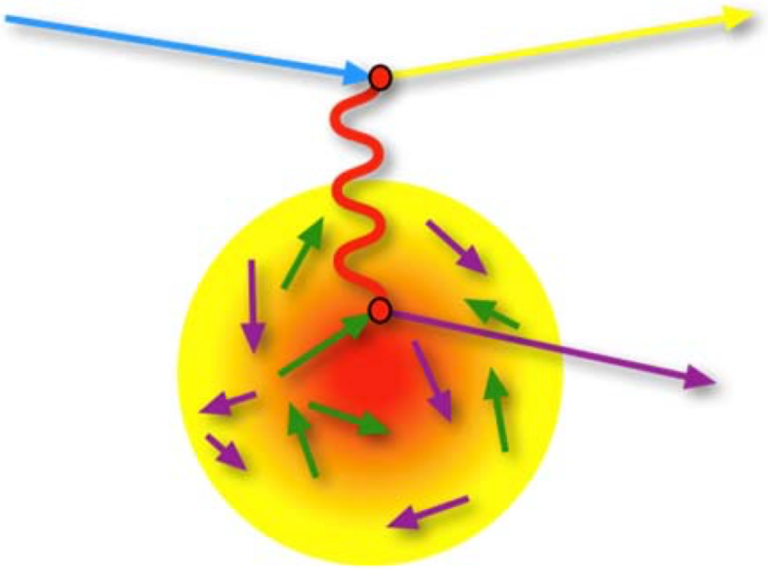
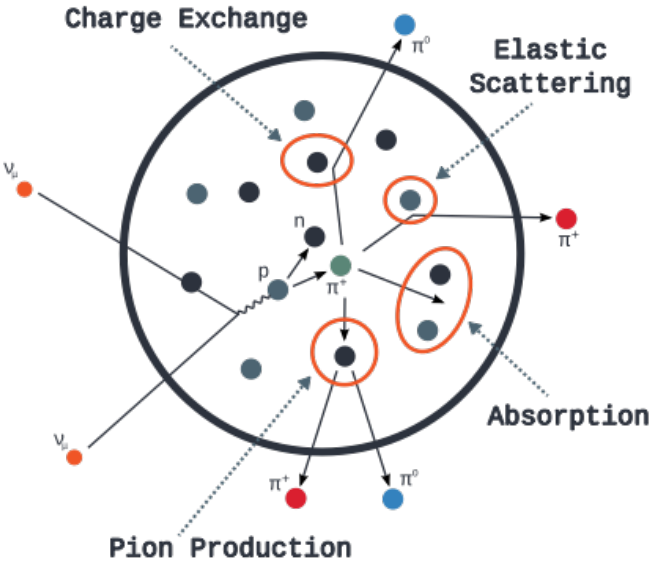
Study of Nuclear Effects





- Short, medium and long range nucleon-nucleon correlations on the initial condition
  - "RPA" effect -"2p2h" effect

Particles created have to work their way out of the nucleus -
final state interactions (FSI)

these effects smear out the detected neutrino energy!

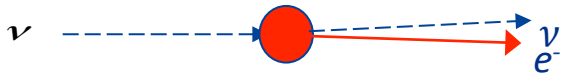
Few MINERvA Publications:

- "Antineutrino charged Current charged-current reactions on scintillator with low momentum transfer" 10.1103/PhysRevLett.120.221805
- ***"Measurement of the muon anti-neutrino double-differential cross section for quasi-elastic scattering on hydrocarbon at~Ev~3.5GeV" Phys. Rev. D 97, 052002 (2018)***
- "Measurement of Total and Differential Cross Sections of Neutrino and Antineutrino Coherent $\pi^{\pm}$ Production on Carbon" Phys. Rev. D 97, 032014, (2018)
- "Measurement of $\nu\mu$ charged-current single π^0 production on hydrocarbon in the few-GeV region using MINERvA" Phys. Rev. D 96, 072003 (2017)
- "Direct Measurement of Nuclear Dependence of Charged Current Quasielastic-like Neutrino Interactions using MINERvA" Phys. Rev. Lett. 119, 082001 (2017)
- "Measurement of the antineutrino to neutrino charged-current interaction cross section ratio on carbon" Phys. Rev. D 95, 072009 (2017)
- "Measurement of neutral-current K+ production by neutrinos using MINERvA" Phys. Rev. Lett. 199, 011802 (2017)
- "Measurements of the Inclusive Neutrino and Antineutrino Charged Current Cross Sections in MINERvA Using the Low-ν Flux Method" Phys. Rev. D 94, 112007 (2016)
- "Neutrino Flux Predictions for the NuMI Beam" Phys. Rev. D 94, 092005 (2016)
- "First evidence of coherent K+ meson production in neutrino-nucleus scattering" Phys. Rev. Lett. 117, 061802 (2016)
- "Measurement of K+ production in charged-current $\nu\mu$ interactions" Phys. Rev. D 94, 012002 (2016)
- "Cross sections for neutrino and antineutrino induced pion production on hydrocarbon in the few-GeV region using MINERvA"Phys. Rev. D 94, 052005 (2016).
- "Evidence for neutral-current diffractive neutral pion production from hydrogen in neutrino interactions on hydrocarbon" Phys. Rev. Lett. 117, 111801 (2016)
- ***"Measurement of Neutrino Flux using Neutrino-Electron Elastic Scattering", Phys. Rev. D 93, 112007 (2016)***
- "Measurement of Partonic Nuclear Effects in Deep-Inelastic Neutrino Scattering using MINERvA", Phys. Rev. D 93, 071101 (2016).
- "Identification of nuclear effects in neutrino-carbon interactions at low three-momentum transfer", Phys. Rev. Lett. 116, 071802 (2016).
- "Measurement of electron neutrino quasielastic and quasielastic-like scattering on hydrocarbon at average E_ν of 3.6 GeV", Phys. Rev. Lett 116, 081802 (2016).
- "Single neutral pion production by charged-current anti-ν_μ interactions on hydrocarbon at average E_ν of 3.6 GeV", Phys. Lett. B749 130-136 (2015).
- "Measurement of muon plus proton final states in ν_μ Interactions on Hydrocarbon at average E_ν of 4.2 GeV" Phys. Rev. D91, 071301 (2015).
- "MINERvA neutrino detector response measured with test beam data", Nucl. Inst. Meth. A789, pp 28-42 (2015).
- "Measurement of Coherent Production of $\pi^{\pm}$ in Neutrino and Anti-Neutrino Beams on Carbon from E_ν of 1.5 to 20 GeV", Phys. Rev. Lett. 113, 261802 (2014).
- "Charged Pion Production in ν_μ Interactions on Hydrocarbon at average E_ν of 4.0 GeV" , Phys. Rev. D92, 092008 (2015).

Many more to come from Medium energy data set

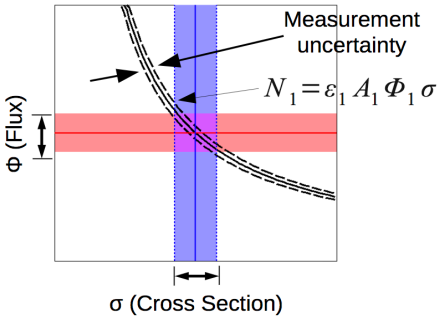
Few Results from MINERvA

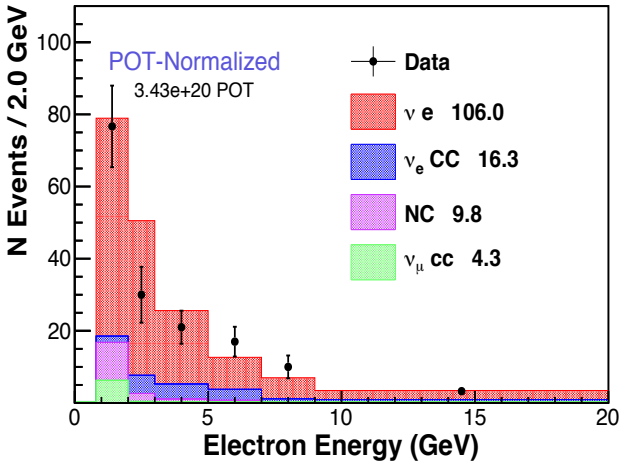
Measurement of Neutrino Flux from Neutrino-Electron Elastic Scattering



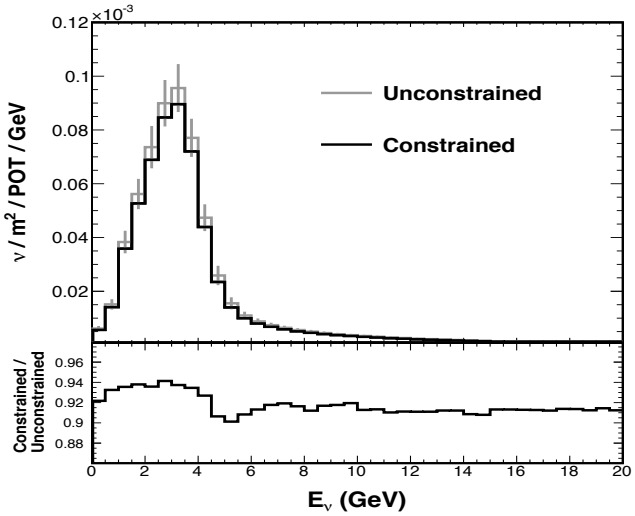
MINERvA
$\sigma = N/\varepsilon A \Phi$

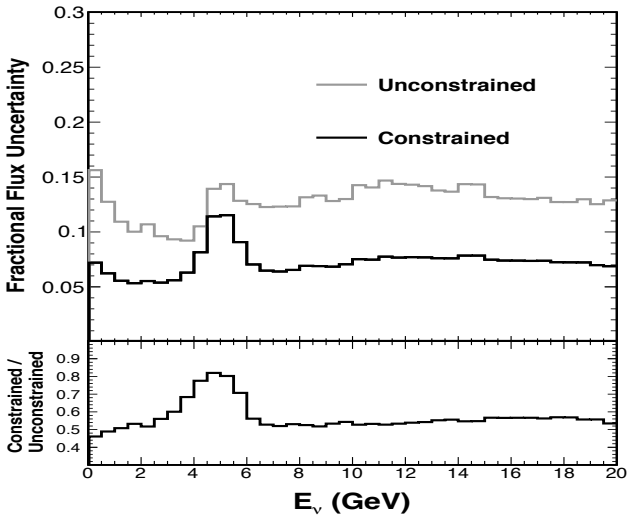
Flux uncertainty goes into the cross-section uncertainty





- Well known process : Cross section
- Use nu-e scattering measurement to constrain flux





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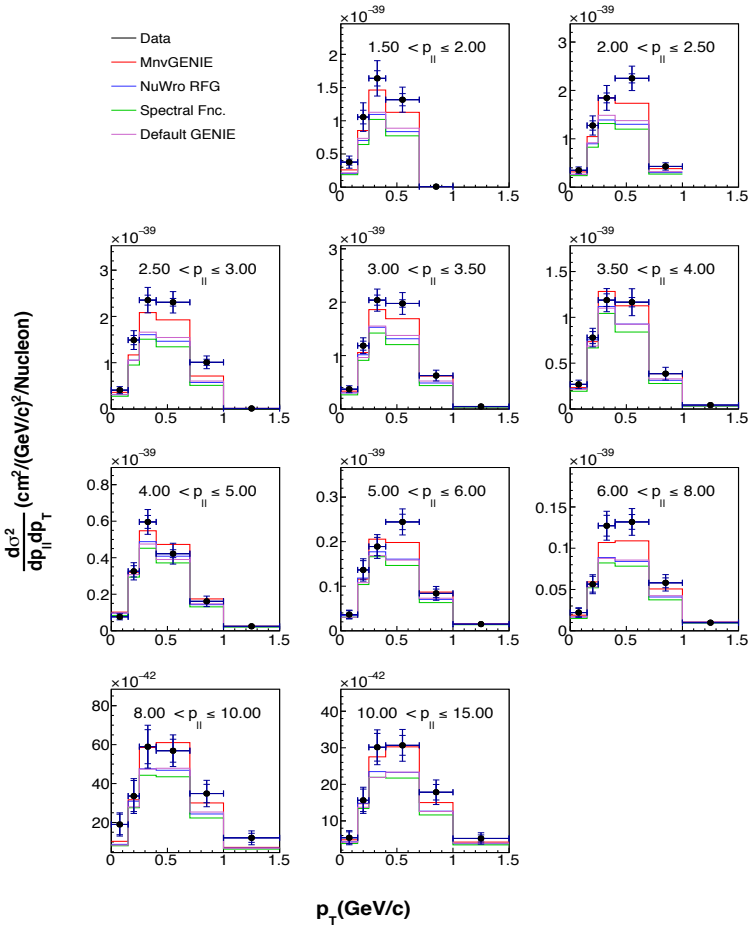
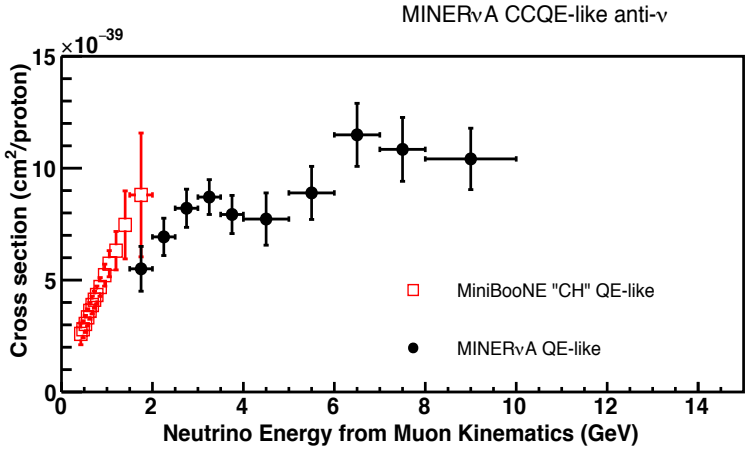
Measurement of the muon anti-neutrino double-differential cross section for quasi-elastic-like scattering on hydrocarbon at Ev ~ 3.5 GeV



Double-differential QE-like cross section vs. muon transverse momentum compared to different models.



MINERvA QE-like cross section as a function of E_ν^{QE} compared to data from the MiniBooNE experiment.

- This study improves on a previous single differential measurement by using updated reconstruction algorithms and interaction models, and provides a complete description of observed muon kinematics in the form of a double-differential cross section with respect to muon transverse and longitudinal momentum.
- The model agreement is considerably improved by a model tuned to MINERvA inclusive neutrino scattering data that incorporates nuclear effects such as weak nuclear screening and two-particle, two-hole enhancements.

Summary and Outlook

- By combining many analyses with different focuses MINERvA is creating a vision of what neutrino interactions in nuclei look like at a few GeV
- Medium Energy data taking is on going(anti-neutrino mode).
- Higher Statistics
- Results should continue to improve model descriptions used by both theory and oscillation experiments
- The next dataset of MINERvA is starting to produce results.

STAY TUNED !


ZONA
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