NEW PERSPECTIVES 2019

MINERvA IN 10 MINUTES!

Main Injector Experiment for ν-A

Barbara Yaeggy
(On behalf of the MINERvA Collaboration)

UNIVERSIDAD TECNICA
FEDERICO SANTA MARIA

Fermilab

Outline

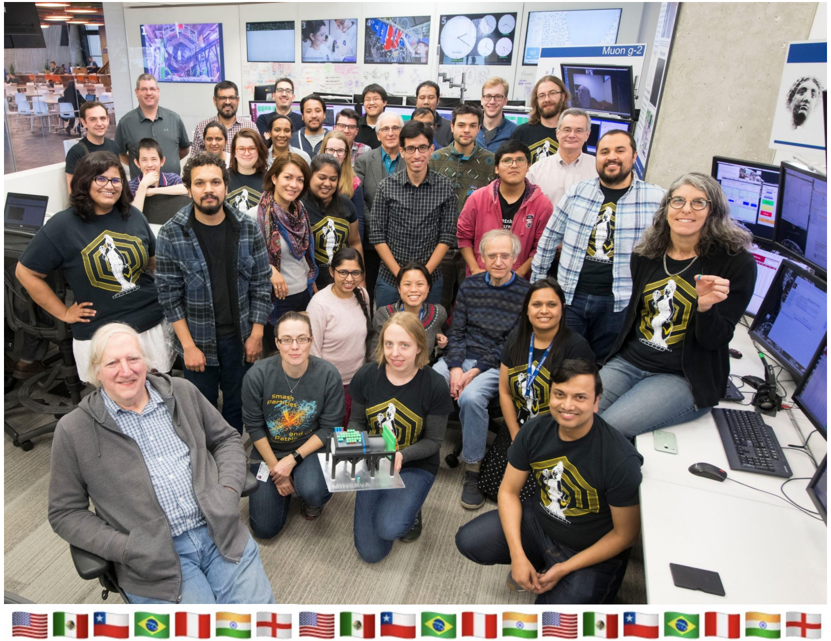
- Minerva Experiment
- Motivations
- Detector
- Low and Medium Energy era
- Comments

MINERvA's Physics

MINERvA is studying neutrino interactions in unprecedented detail on nuclei – He, C, CH, H_2O, Fe, Pb.

- Unique information about nuclear effects.
- Measured in exclusive final states:
  → As function of a measured neutrino energy
  → Study differences between ν and anti-ν.

02/26/2019: end of data taking



Low Energy (LE) Beam Goals:

- Exclusive and Inclusive signal and background reactions relevant to oscillation experiments.

Medium Energy (ME) Beam Goals:

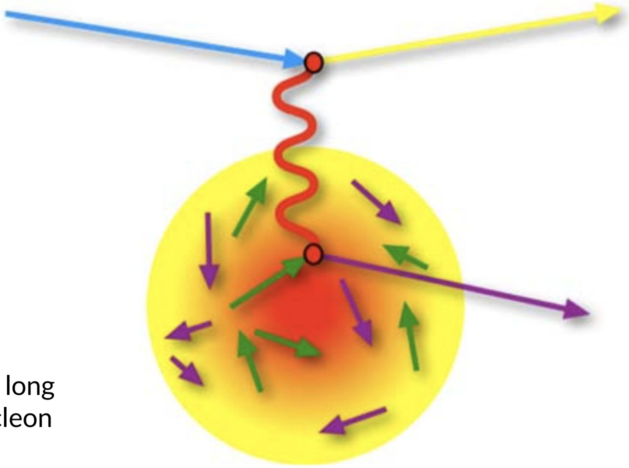
→ Structure functions on nuclei (quark structure, PDF's).
→ Higher statistics.
→ Delta resonances studies and beyond.

Collaboration with generator, flux and oscillation communities.

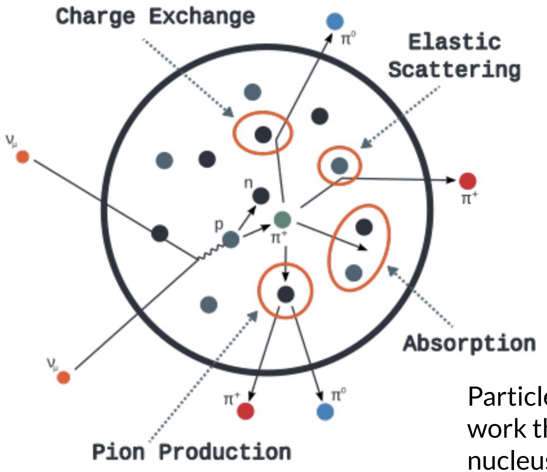
Study Nuclear Effects

Does particles behave the same in different materials?

Is possible to get a description of the correlation between neutral and charged particles?

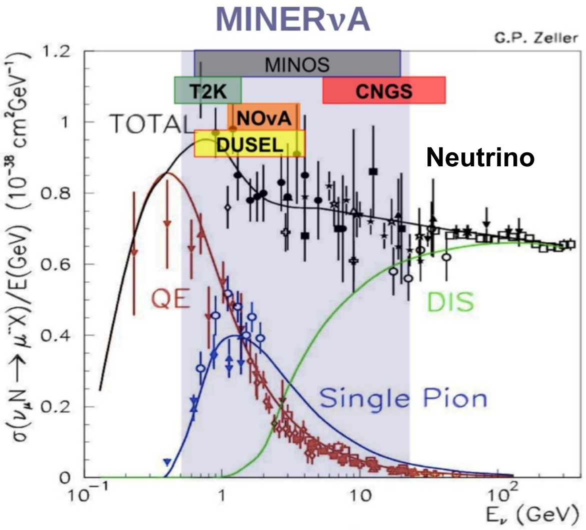


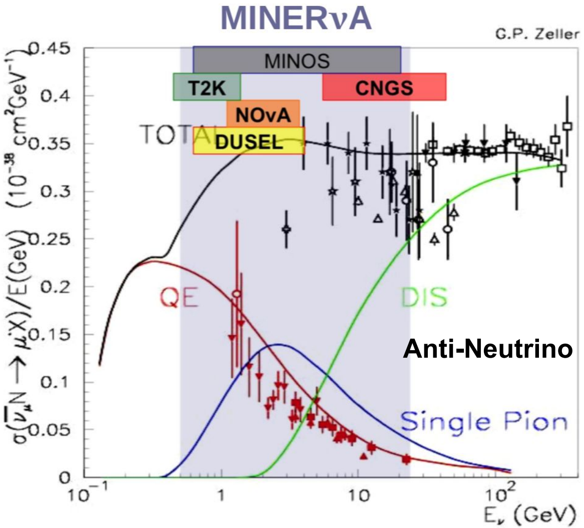
Short, medium and long range nucleon- nucleon correlations



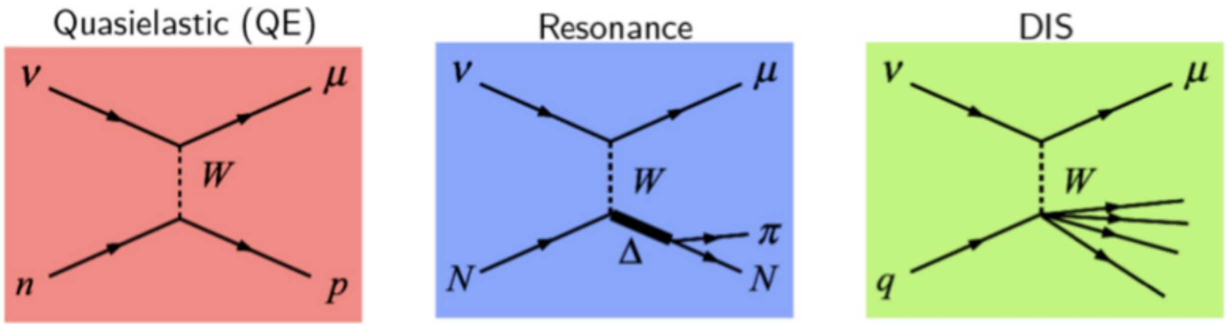
Particles created have to work their way out of the nucleus - final state interactions (FSI)

These effects smear out the detected neutrino energy!



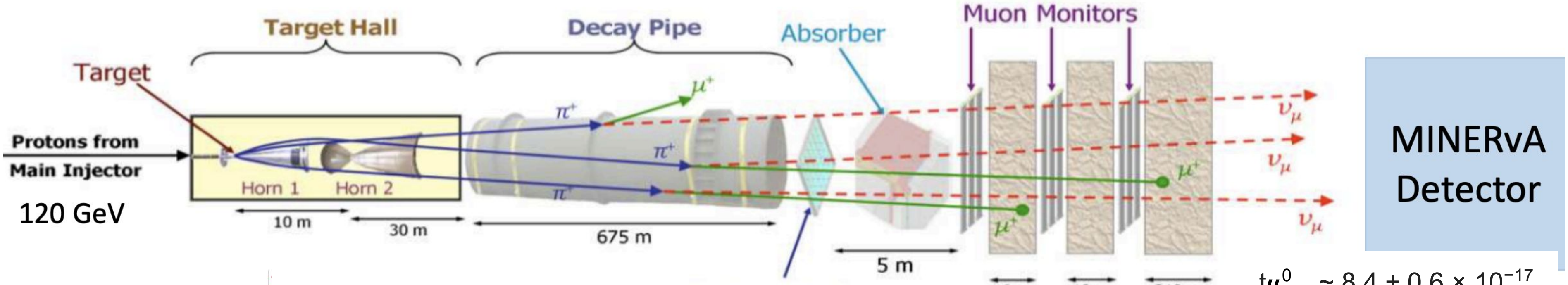


- Oscillation experiments (DUNE, NOvA) measure neutrino energy in the 1-20 GeV region, where many interactions channels are active.
- These interactions channels are signal and the majority of backgrounds in oscillation experiments.



Interactions within the nucleus can fool reconstruction – making it hard to determine both Ev and the interaction channel.

Neutrino At Main Injector (NuMI) Beam line



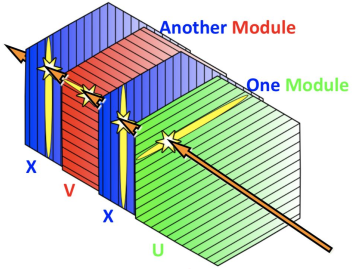
$t_{\mu^0_{1/2}} \sim 8.4 \pm 0.6 \times 10^{-17}$

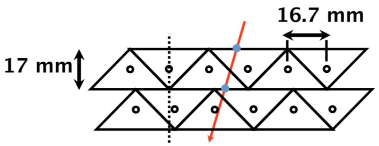
$\pi^+ \rightarrow \mu^+ + \nu_\mu$ $\quad t_{\pi^+_{1/2}} \sim 2.6033 \times 10^{-8}$s

$K^+ \rightarrow \mu^+ + \nu_\mu$ $\quad t_{K^{+/-}_{1/2}} \sim 1.2380 \times 10^{-8}$ s $\quad t_{\mu^{+/-}_{1/2}} \sim 2.1969811 \times 10^{-6}$ s

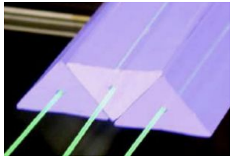
- Colliding protons with a graphite target and focusing the resulting pions and kaons before they decay to produce neutrinos.

This allows us to **distinguish events in the Helium Target from events upstream.**



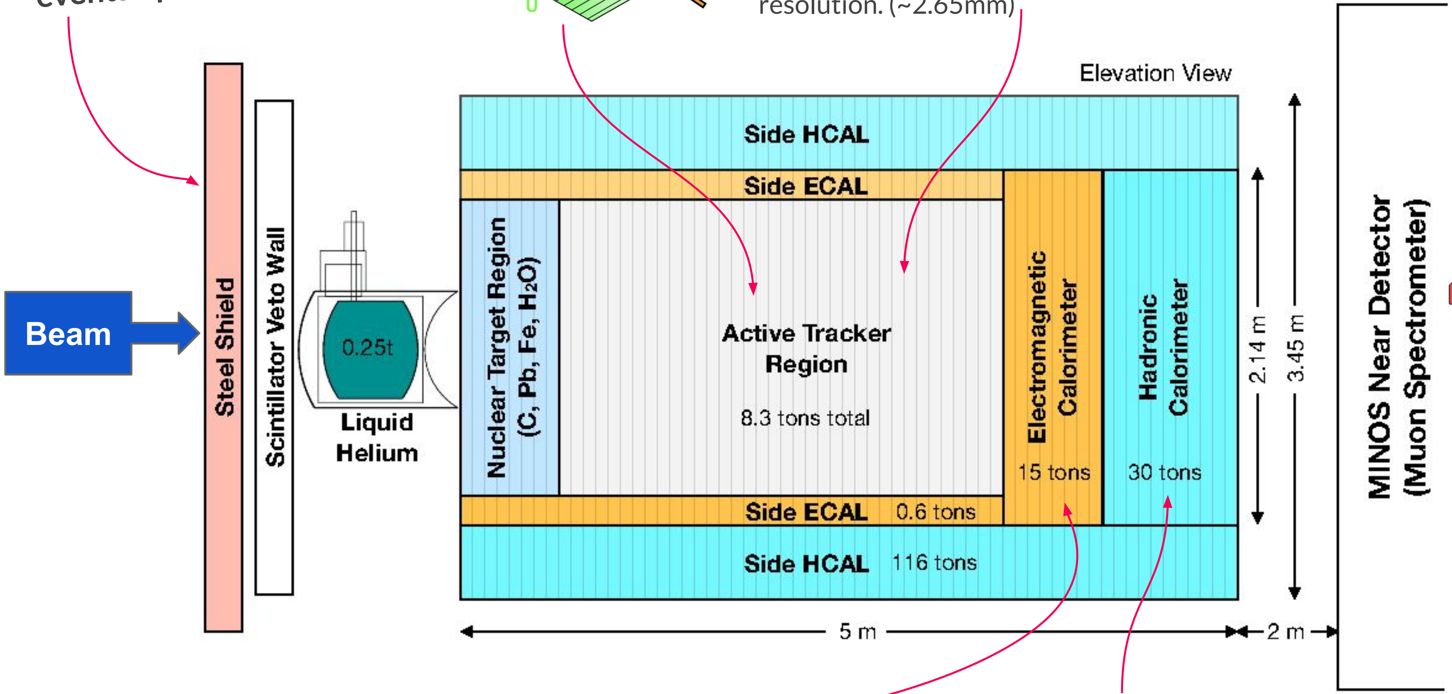


Charged particles hit more than one strip, giving better position resolution. (~2.65mm)

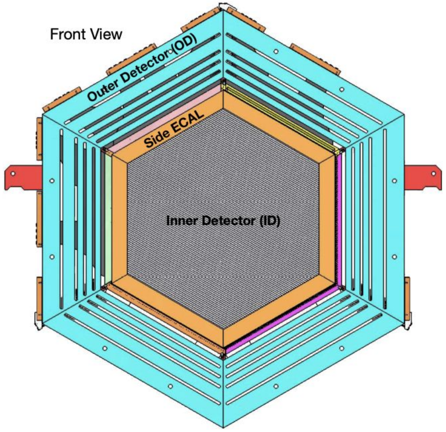


Scintillator:charged particle can ionize the atoms it passes, pulling electrons free.

When those electrons recombine with an atom, photons are released.



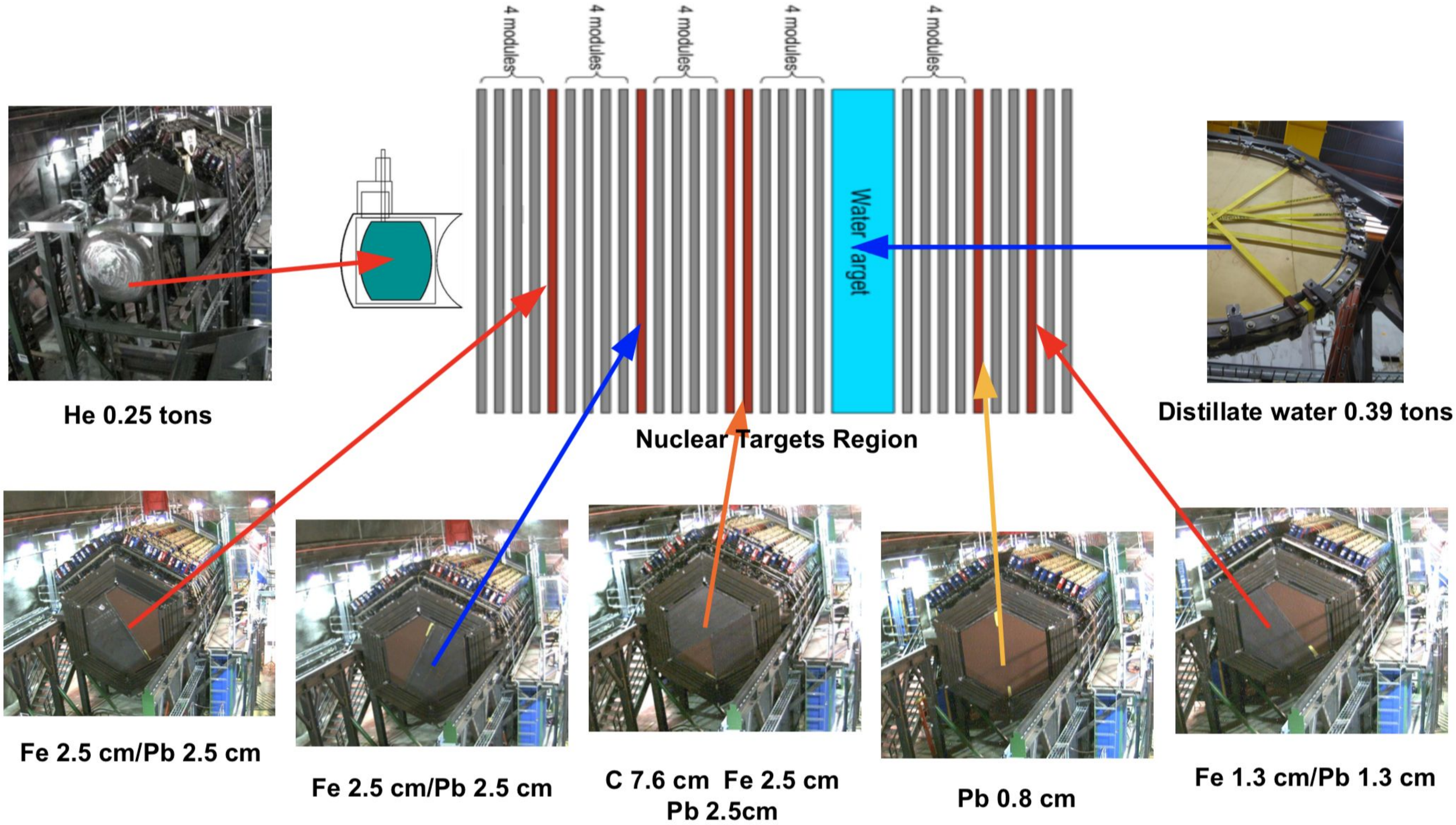
Front View
Single Module



Scintillator - Tracking
Lead - EM calorimetry
Steel - Hadronic calorimetry

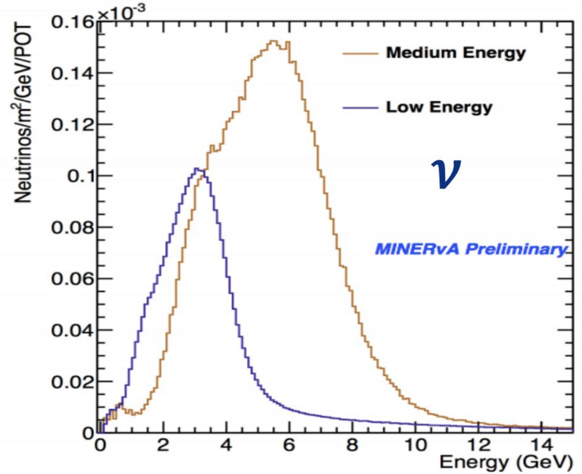
Lead, stop electromagnetic particles.

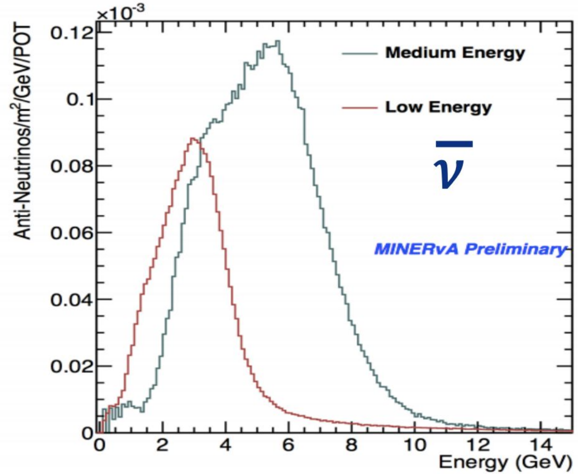
Steel, stop hadronic particles.



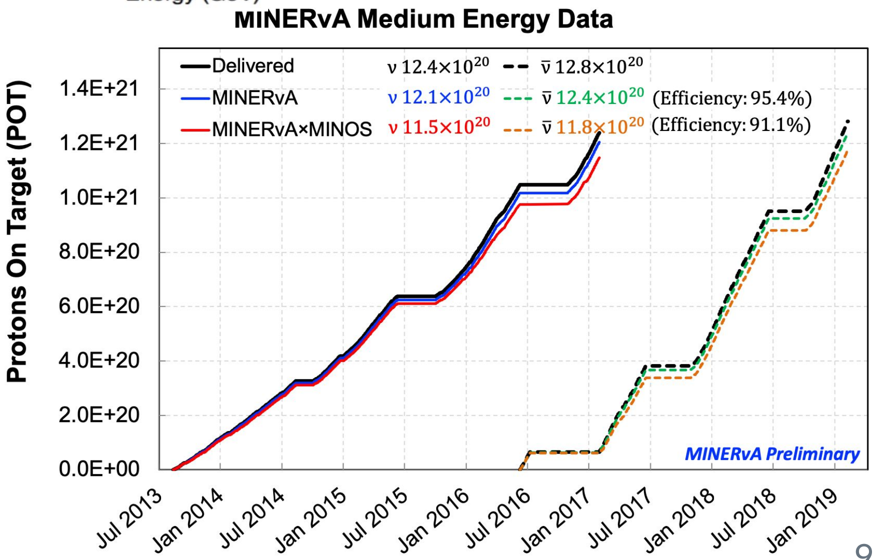
Hexagonal planes in three orientations (0˚, ±60˚) provide 3D track reconstruction.

Low Energy and Medium Energy Range

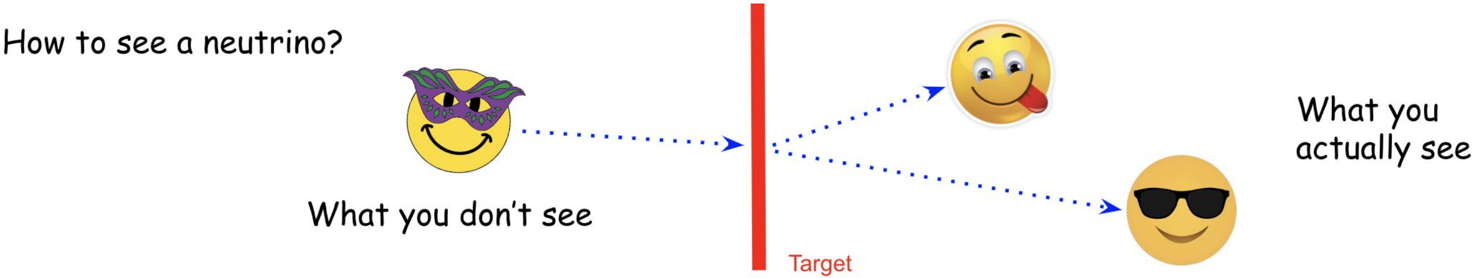




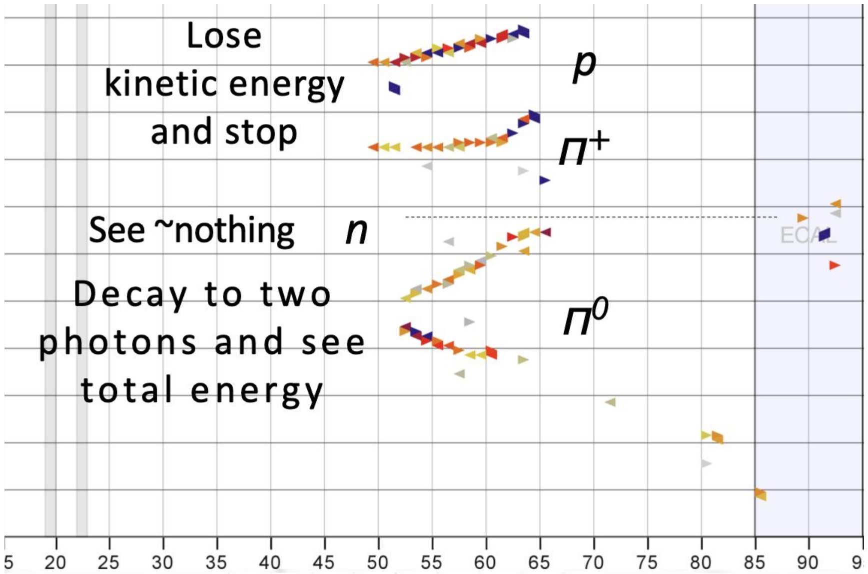
Mode	ν ~ POT	ν̄~ POT
Low Energy (2009 - 2012)	4.0 E+20	1.7E+20
Medium Energy (2013 - 2019)	12.1 E+20	12.4 E+20



- Completed low-energy run which peaks at 3.5 GeV.
- Completed medium-energy run which peaks at 6 GeV.



How particles look like in MINERvA?



Since we don't know the neutrino energy....

- Must determine neutrino energy from the final state energy.

MINERvA's Timeline

2002

MINERvA EOI
Scintillator tracker and passive targets, NUMI

2007

Construction Start
Begin fiber, scintillator production

2010

First Full Detector Data-taking
Low Energy

2013

1rst Interaction Paper
CCQE in neutrino and antineutrino beams

Switch to ME

- 26 LE publications
- Inclusion of machine learning algorithms

2019

- **Feb 2019: end of data taking.**
- **First ME paper (ν_e scattering)**

Future

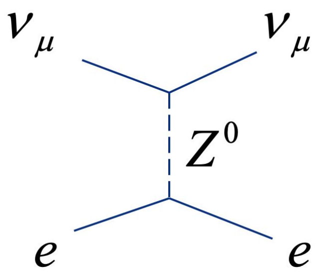
First anti-neutrino ME paper

Exploring new transverse kinematic variables.

Nu+e Elastic Scattering

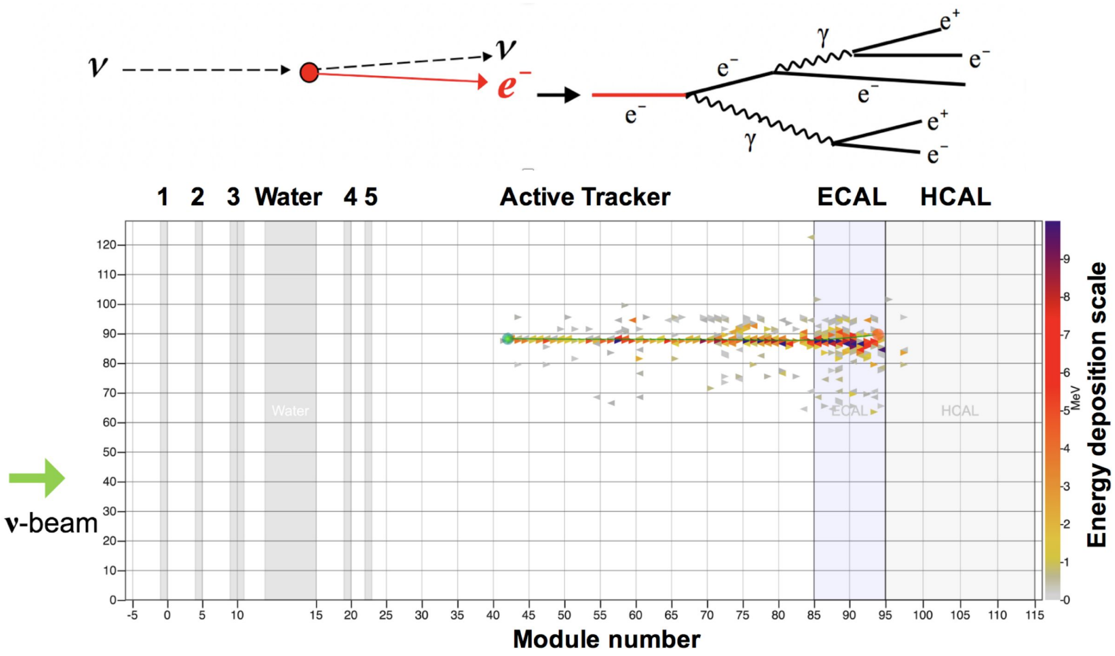
First Medium Energy result submitted to PRD
arXiv:1906.00111

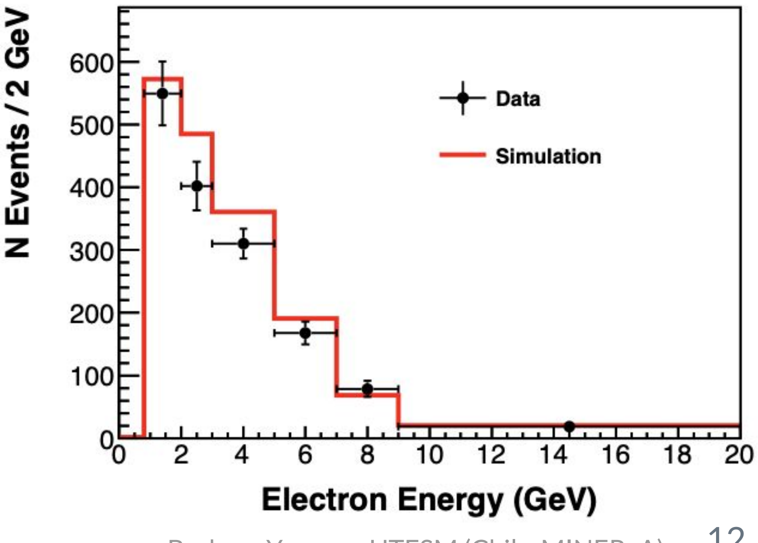
Reduction of the normalization uncertainty on the muon neutrino NuMI flux between 2 and 20 GeV from **7.5% to 3.9%**



This is the most precise measurement of neutrino-electron scattering to date.

→ Will reduce uncertainties on MINERvA's absolute cross section measurements.
→ Can be used in future neutrino beams such as LBNF





MINERvA Publications since 2018

- "Constraint of the MINERvA Medium Energy Neutrino Flux using Neutrino-Electron Elastic Scattering" arXiV:1906.00111, submitted for publication
- "Tuning the GENIE Pion Production Model with MINERvA Data" arXiV:1903.01558, submitted for publication
- "Neutron measurements from anti-neutrino hydrocarbon reactions" arXiV:1901.04892, submitted for publication
- "Measurement of Quasielastic-Like Neutrino Scattering at ⟨Eν⟩~3.5 GeV on a Hydrocarbon Target" Phys. Rev. D 99, 012004 (2019)
- "Reducing model bias in a deep learning classifier using domain adversarial neural networks in the MINERvA experiment" Journal of Instrumentation, Vol. 13 (2018)
- "Measurement of final-state correlations in neutrino muon-proton mesonless production on hydrocarbon at ⟨Eν⟩ = 3 GeV" Phys. Rev. Lett. 121, 022504 (2018)
- "Antineutrino charged Current charged-current reactions on scintillator with low momentum transfer" Phys. Rev. Lett. 120, 221805 (2018)
- "Measurement of the muon anti-neutrino double-differential cross section for quasi-elastic scattering on hydrocarbon at~Eν~3.5GeV" Phys. Rev. D 97, 052002 (2018)
- "Measurement of Total and Differential Cross Sections of Neutrino and Antineutrino Coherent π± Production on Carbon" Phys. Rev. D 97, 032014, (2018)

Summary

- Twenty-six publications from low energy range.
- By combining many analyses with different focuses, MINERvA is creating a vision of what neutrino interactions in nuclei looks like.
- Medium energy analysis for neutrino and antineutrino are going on.
- Higher Statistics.
- Results should continue to improve model descriptions used by both theory and oscillation experiments.

Active Guatemala Volcanoes: Agua, Fuego, Acatenango and Pacaya. (Foto: NASA, April 2018)

Thank you!

Barbara Yaeggy - UTFSM (Chile-MINERvA)