MINERvA in 10 Minutes

Maria Mehmood on behalf of the **MINERvA Collaboration**

New Perspectives 2024

ON AXIS in the NuMI beamline, we placed the MINERvA detector

SIMPLE, WELL UNDERSTOOD

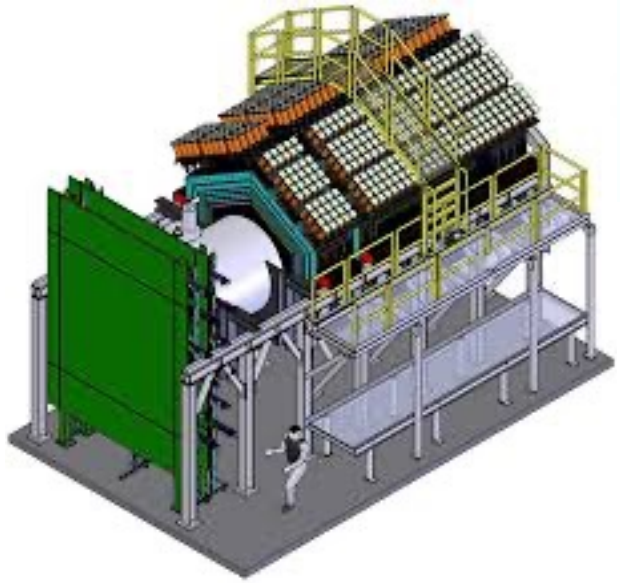
Detector Technology

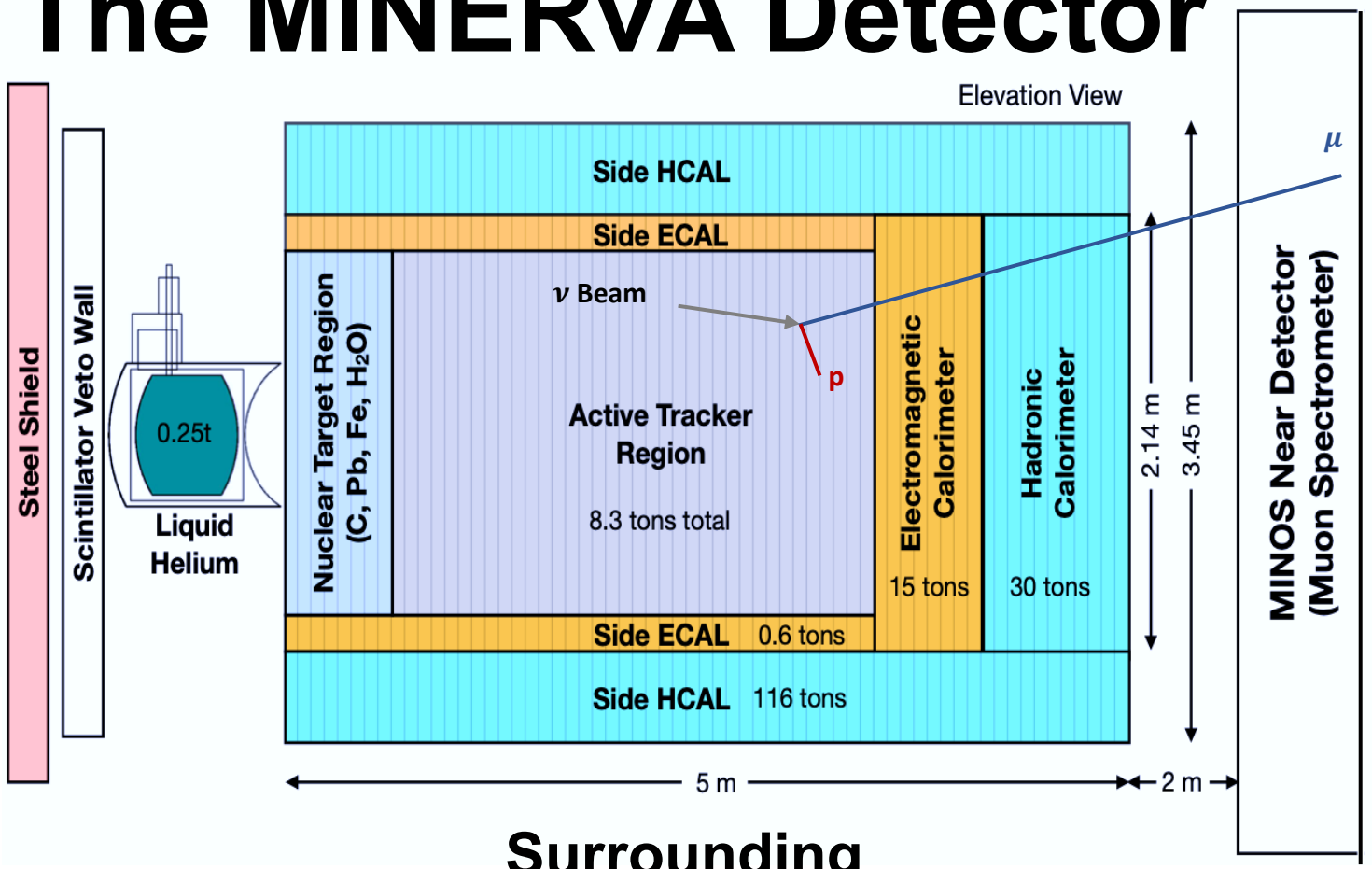
The MINERvA Detector

ACTIVE CORE

Segmented Solid Scintillator

- Used for tracking particles and identifying them





Surrounding ACTIVE CORE:

Electromagnetic and Hadronic Calorimeters

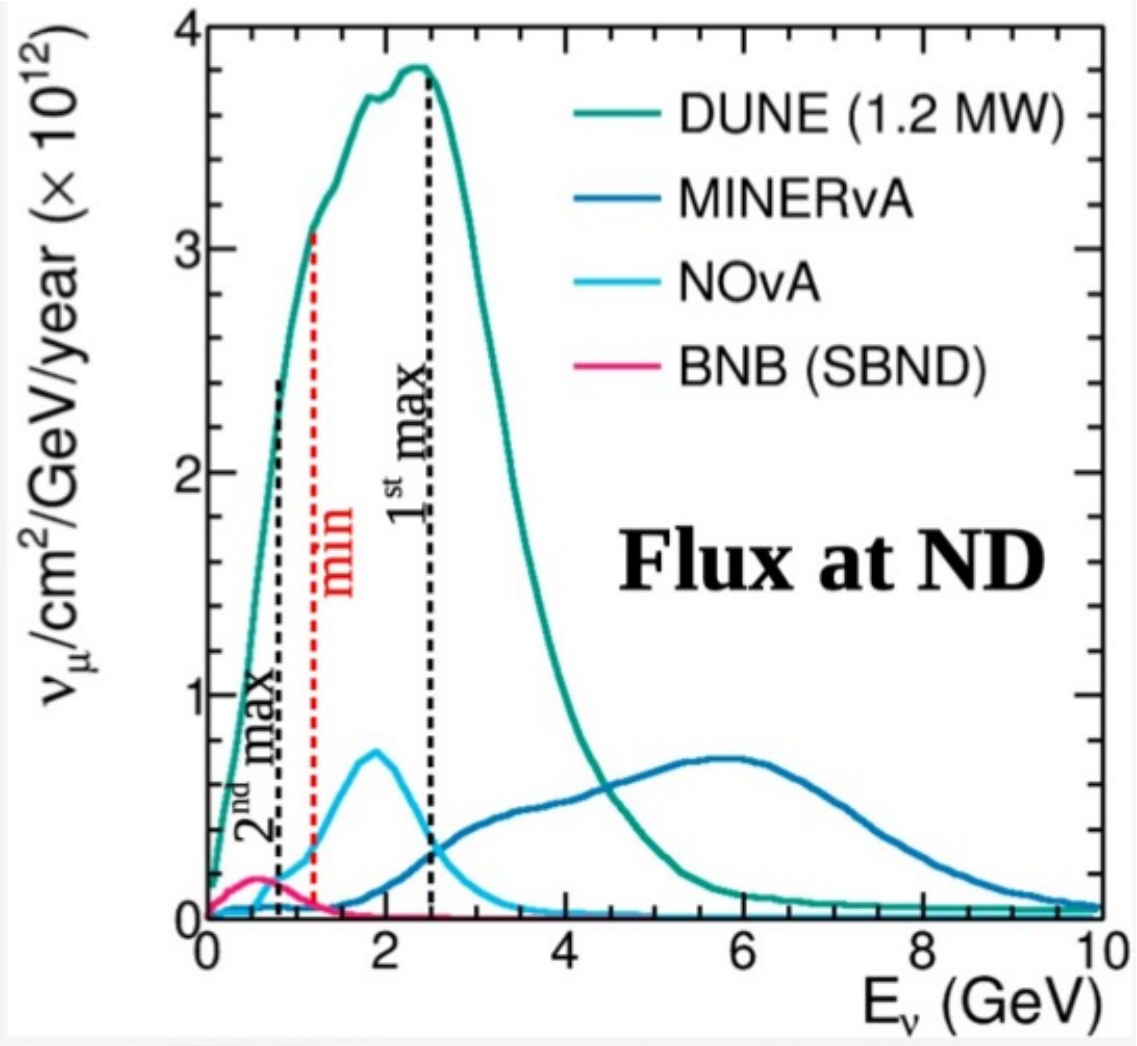
- Energy measurement for photons and hadrons

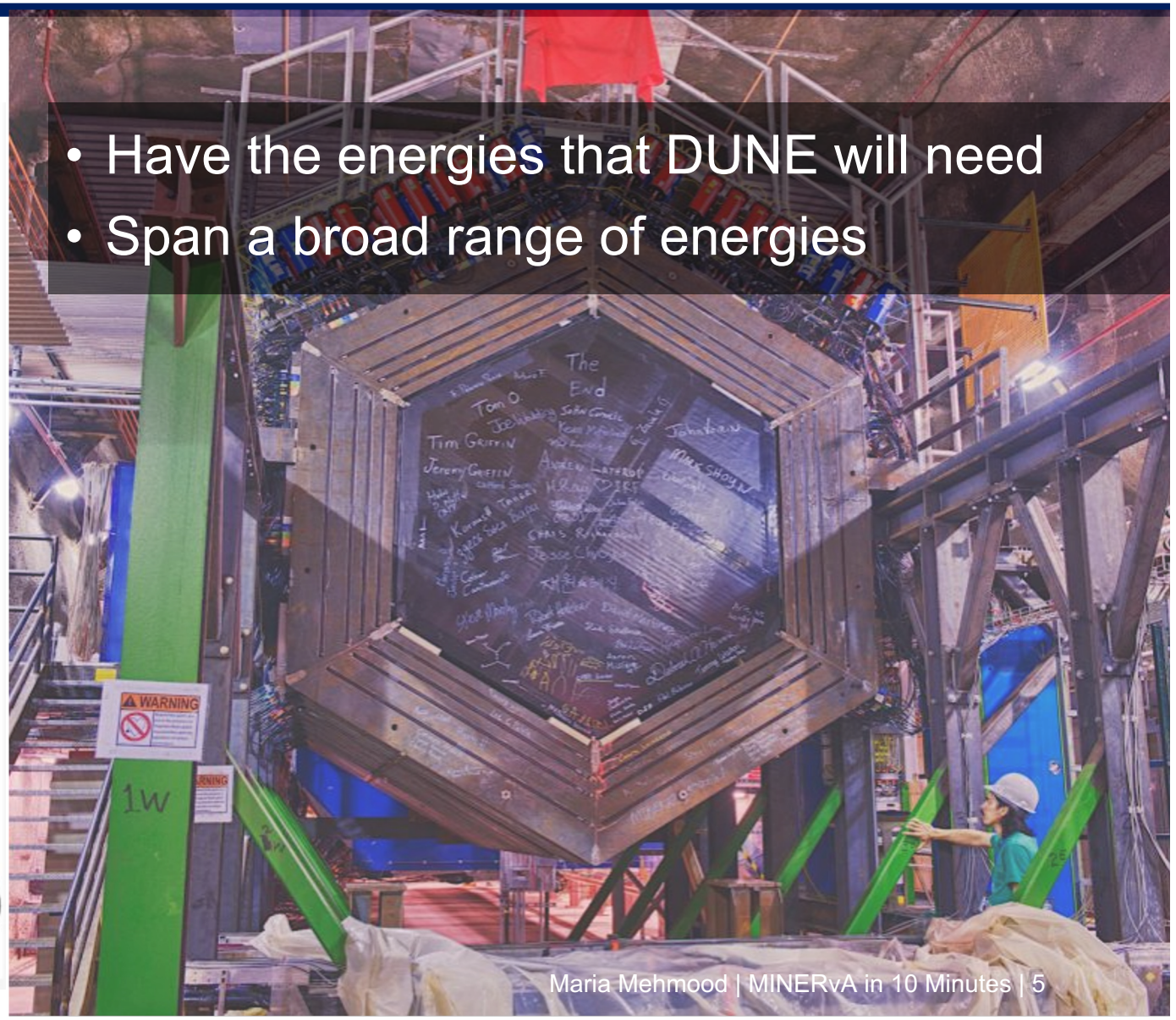
Downstream of Detector:

MINOS muon catcher

- Determines muon momentum and charge

The FLUX that MINERvA Used





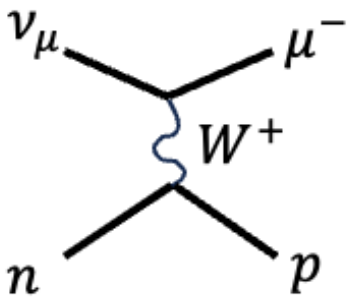
MINERvA extracts **cross section measurements** of **different neutrino processes** on **different nuclei**

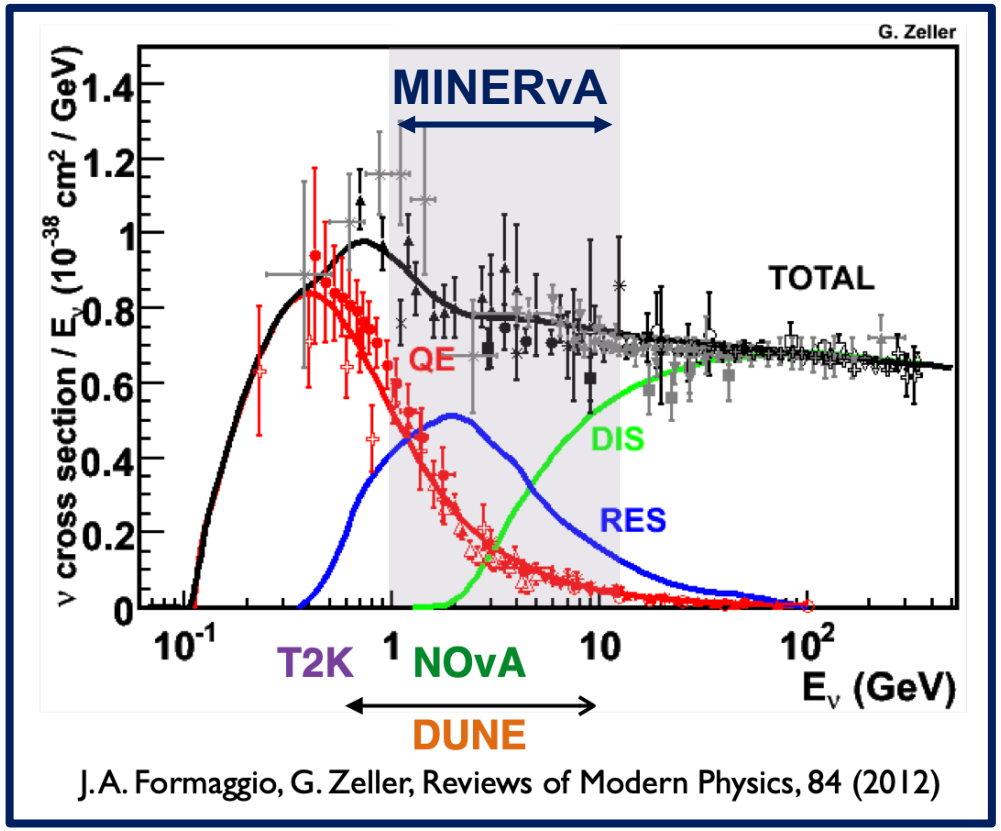
- Cutting edge neutrino oscillation experiments on the horizon!
- Cross section measurements describe the probability of neutrino interactions occurring at a given neutrino energy
- Two parts of a cross section: Base interaction and the effect of the nucleus, need measurements on a variety of nuclei to improve our models

MINERvA extracts **cross section measurements** of **different neutrino processes** on **different nuclei**

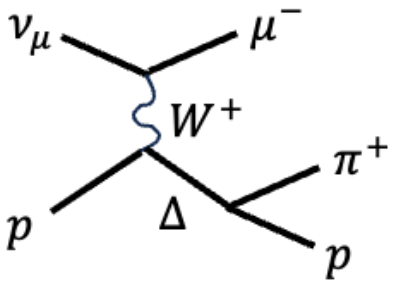
- When a few GeV neutrinos interact with a particle detector we get a range of different neutrino interactions:

Quasi-elastic scattering: Neutrino scatters elastically off the nucleon and ejects a nucleon from the target

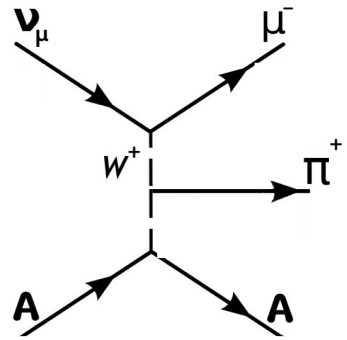




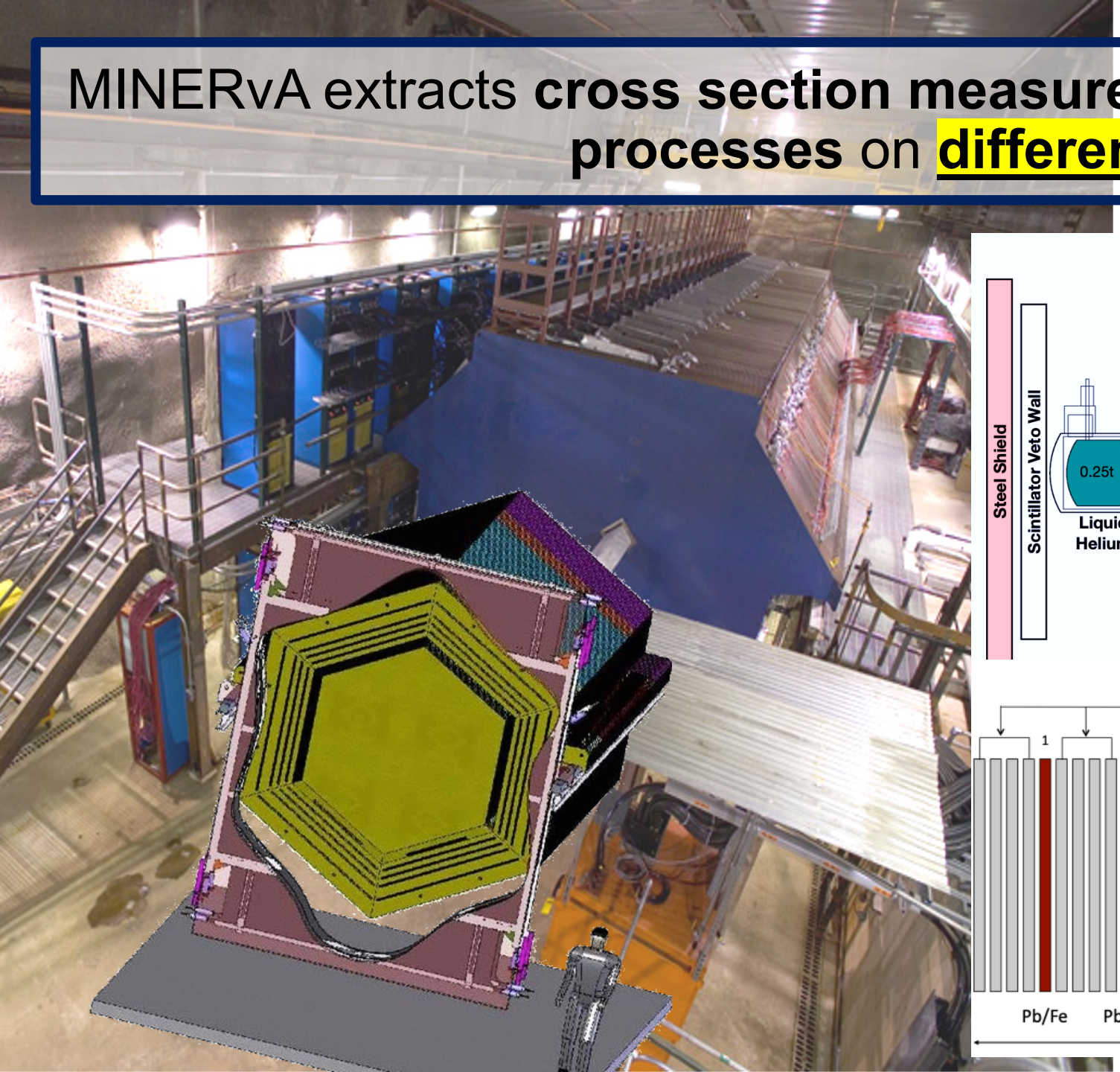
Resonant production: Neutrino excites target nucleon to an excited state

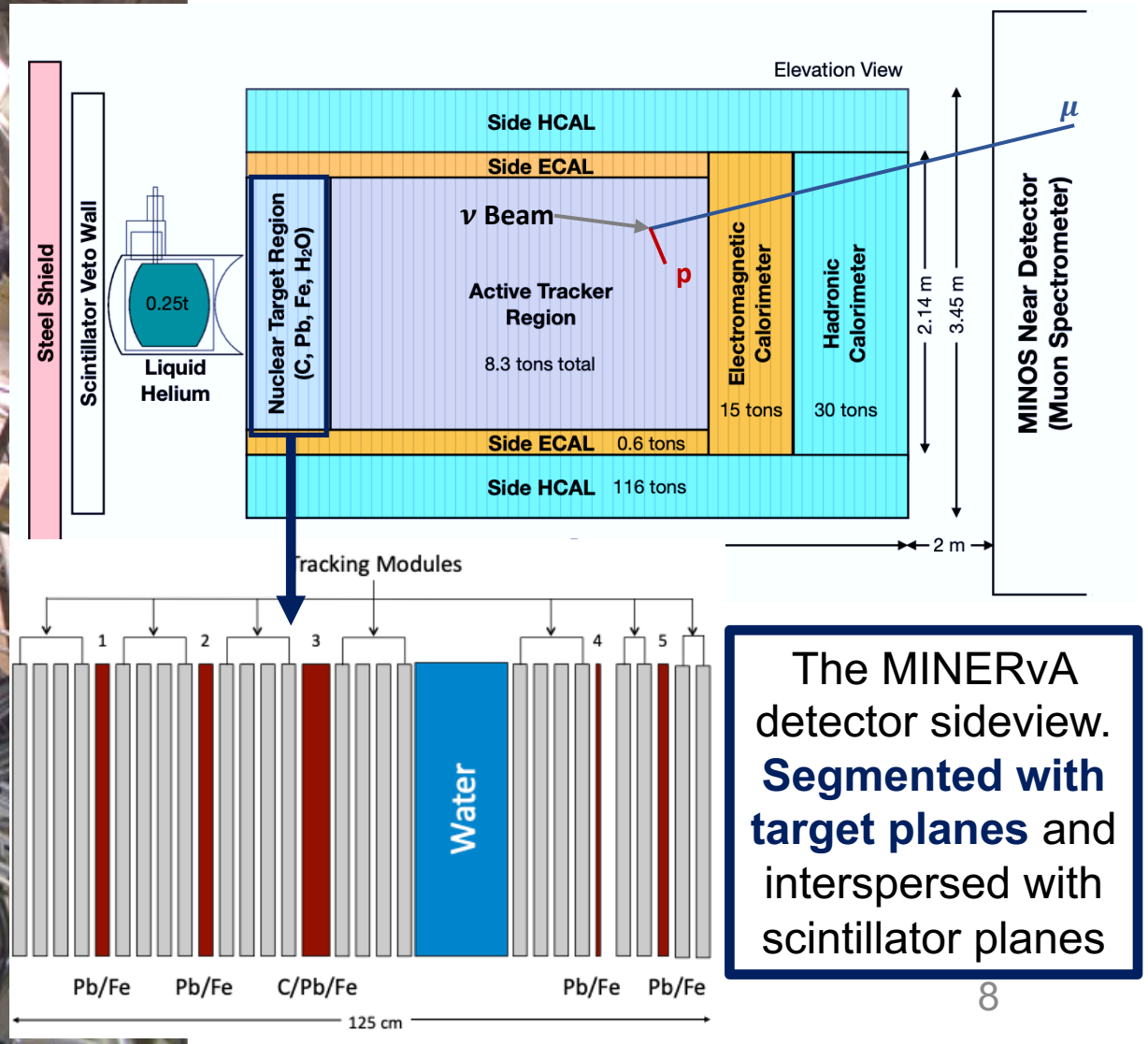


Coherent pion production: Nucleons in nucleus recoil in phase and the nucleus remains in its initial quantum state



MINERvA extracts **cross section measurements** of **different neutrino processes** on **different nuclei**



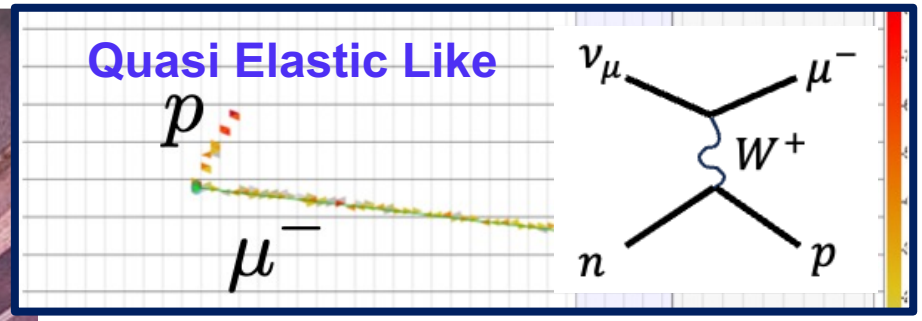


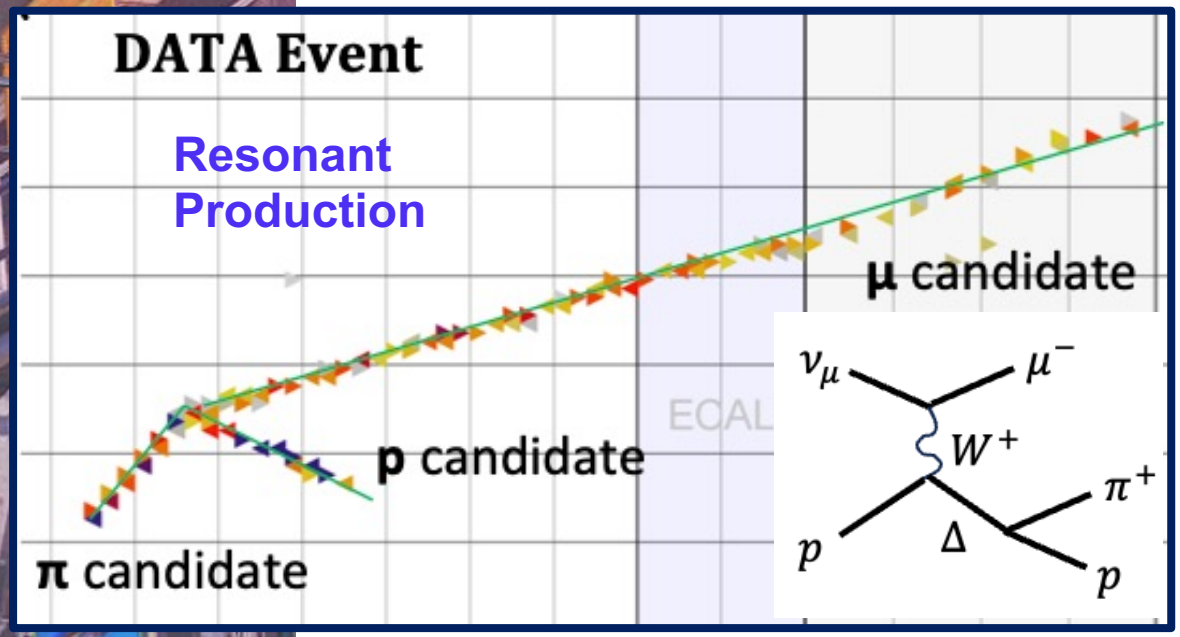
The MINERvA detector sideview. **Segmented with target planes** and interspersed with scintillator planes

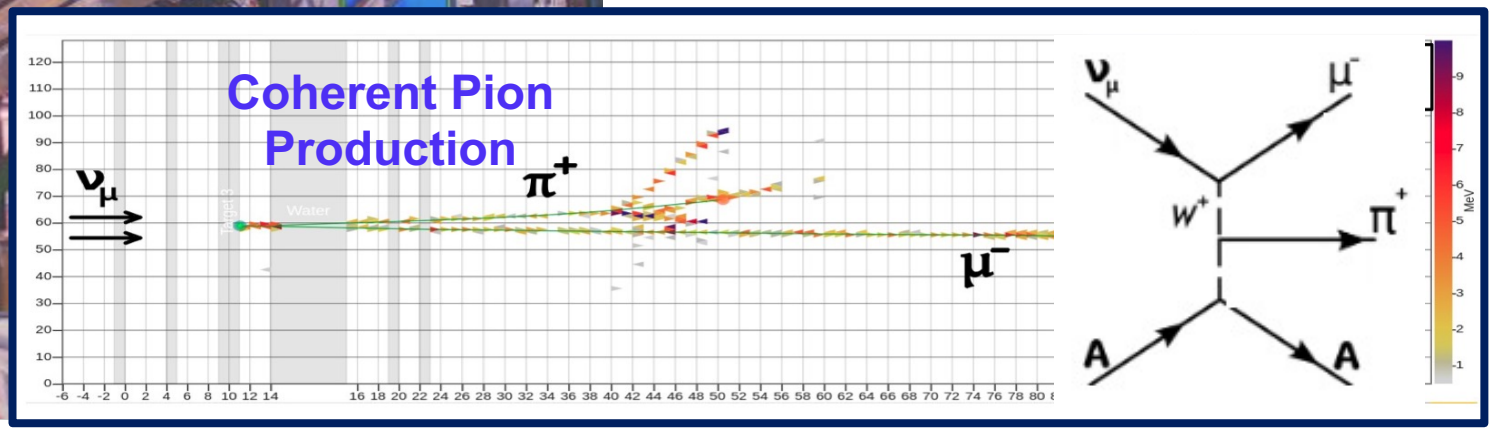
Event Displays for Different Neutrino Interactions

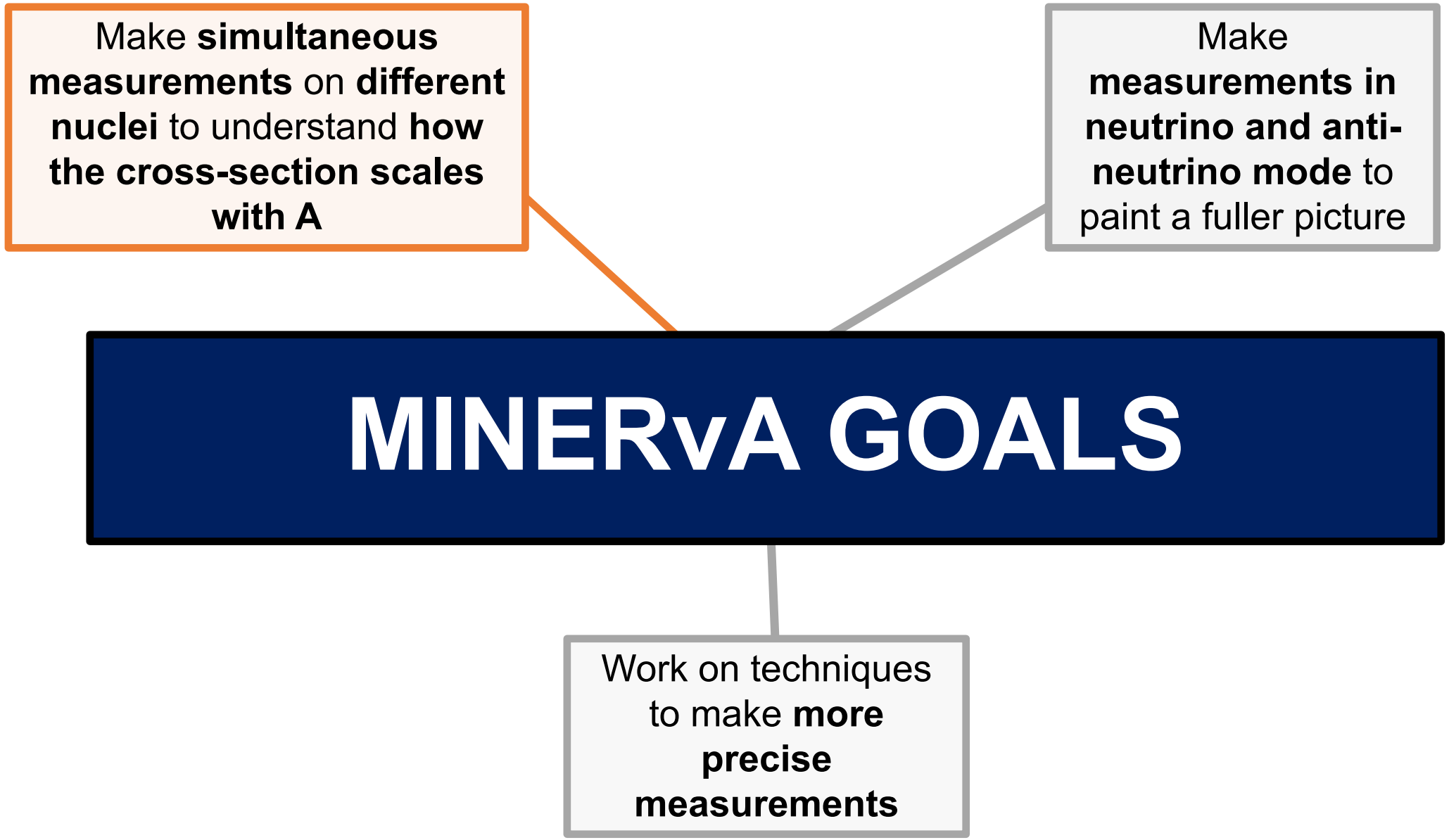
- [LEFT]: **One of three views**
- We see several hits per particle to make tracks
- We use final state particles to reconstruct neutrino energy

The MINERvA Detector, front face view of module








Make **simultaneous measurements** on **different nuclei** to understand **how the cross-section scales with A**
Make **measurements in neutrino and anti-neutrino mode** to paint a fuller picture
MINERvA GOALS
Work on techniques to make **more precise measurements**

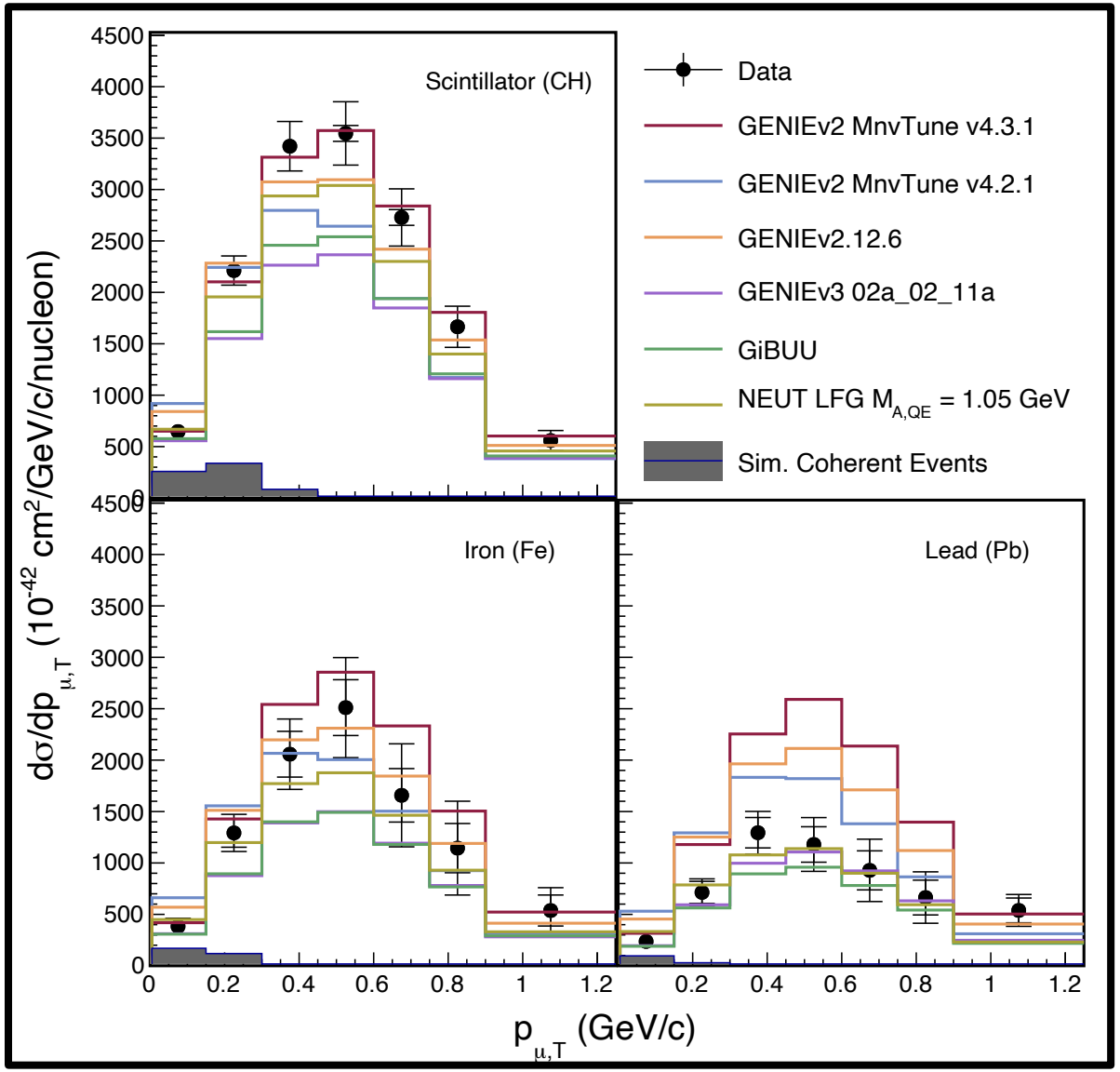
MINERvA extracts **cross section measurements** of **different neutrino processes** on **different nuclei**

*Revisiting this slide again

- Cutting edge neutrino oscillation experiments on the horizon!
- Cross section measurements describe the probability of neutrino interactions occurring at a given neutrino energy
- Two parts of a cross section: **Base interaction** and the **effect of the nucleus**, need measurements on a variety of nuclei to improve our models

Cross Sections on A

CC Single π^+ production



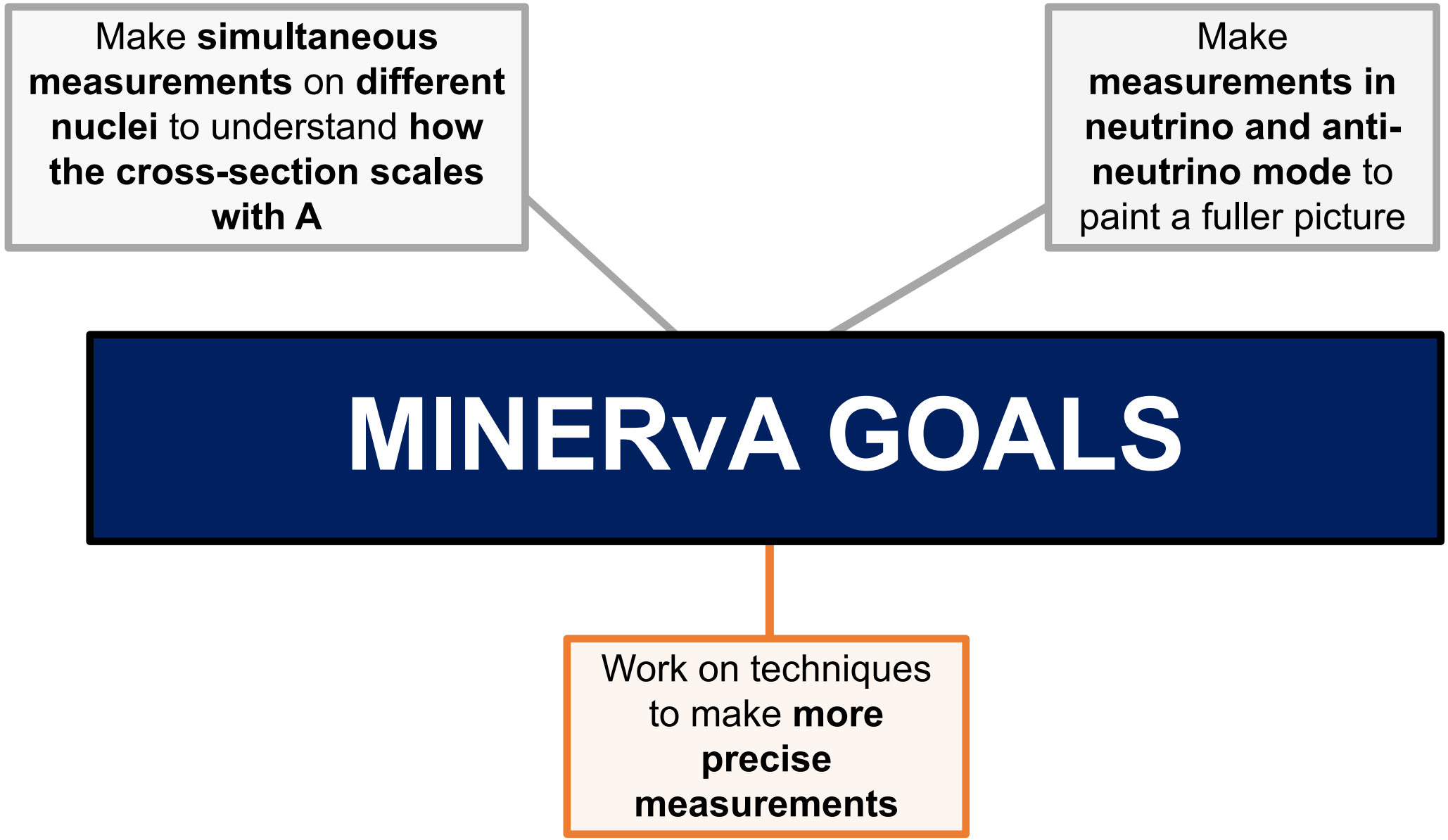
A. Bercellie *et al.* (The MINERvA Collaboration)

Phys Rev Lett 131, 011801

- For events with charged pions, we need a precise model of pion production to reconstruct neutrino energy
  - Essential for neutrino oscillation experiments

(Transverse to the neutrino beam)

- On the x axis: Transverse Muon Momentum
  - Proxy for momentum transferred to nucleus
- Compared with model predictions: GENIE, GiBUU, NEUT which are all discrepant for at least one target material
  - Models are assuming some A dependence, but their A-scaling is not a great match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Flux constraint developed to **reduce flux uncertainties**

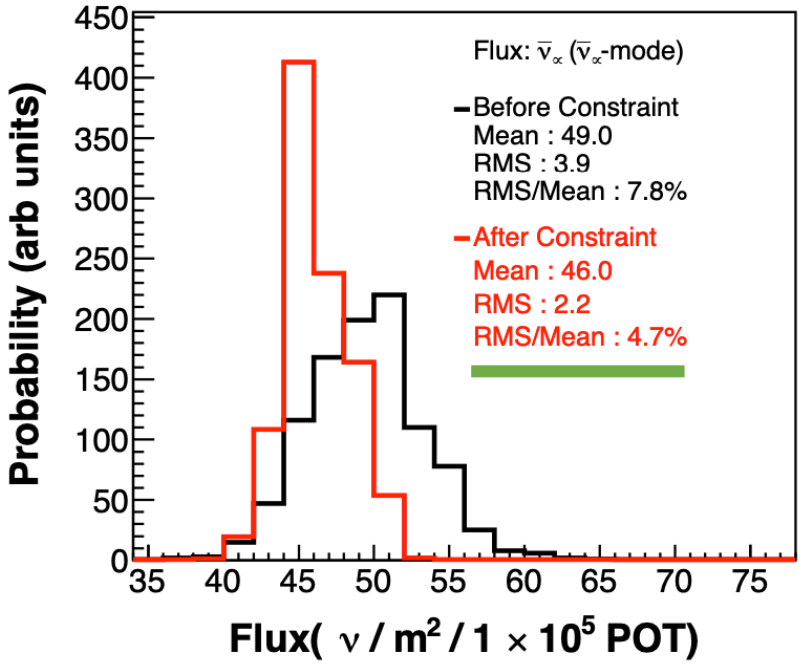
- **Precisely known cross sections** in the Standard Model:
  - Neutrino electron elastic scattering ($\nu + e^- \rightarrow \nu + e^-$)
  - Inverse Muon Decay ($\nu_\mu + e^- \rightarrow \mu^- + \nu_e$)
  - Anti neutrino electron elastic scattering ($\bar{\nu} + e^- \rightarrow \bar{\nu} + e^-$)

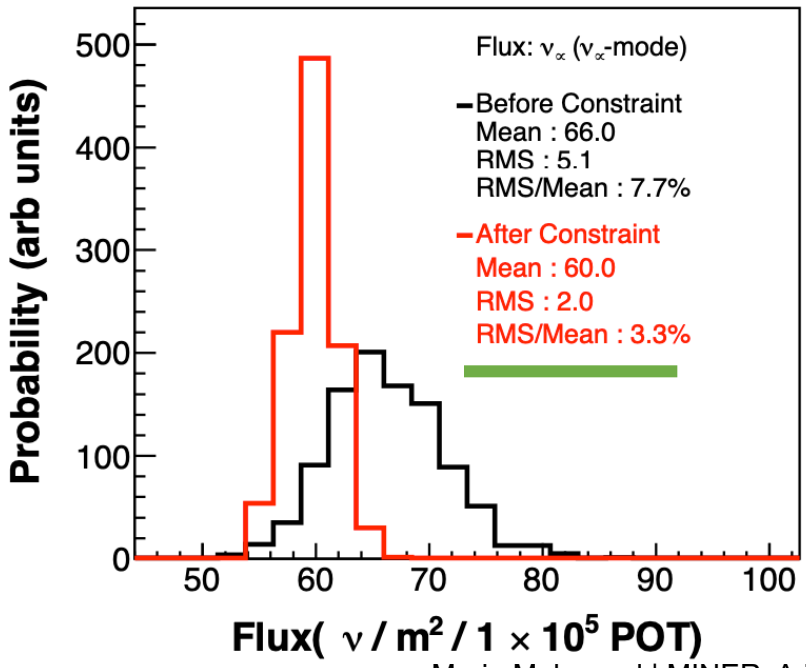
L. Zazueta *et al.* (The MINERvA Collaboration)

Phys Rev Lett 131, 011801

- Used these cross sections and the measured event rates in the detector **to constrain the flux and reduce the uncertainty drastically!**

Anti-neutrino flux uncertainty reduced from 7.8% to 4.7%

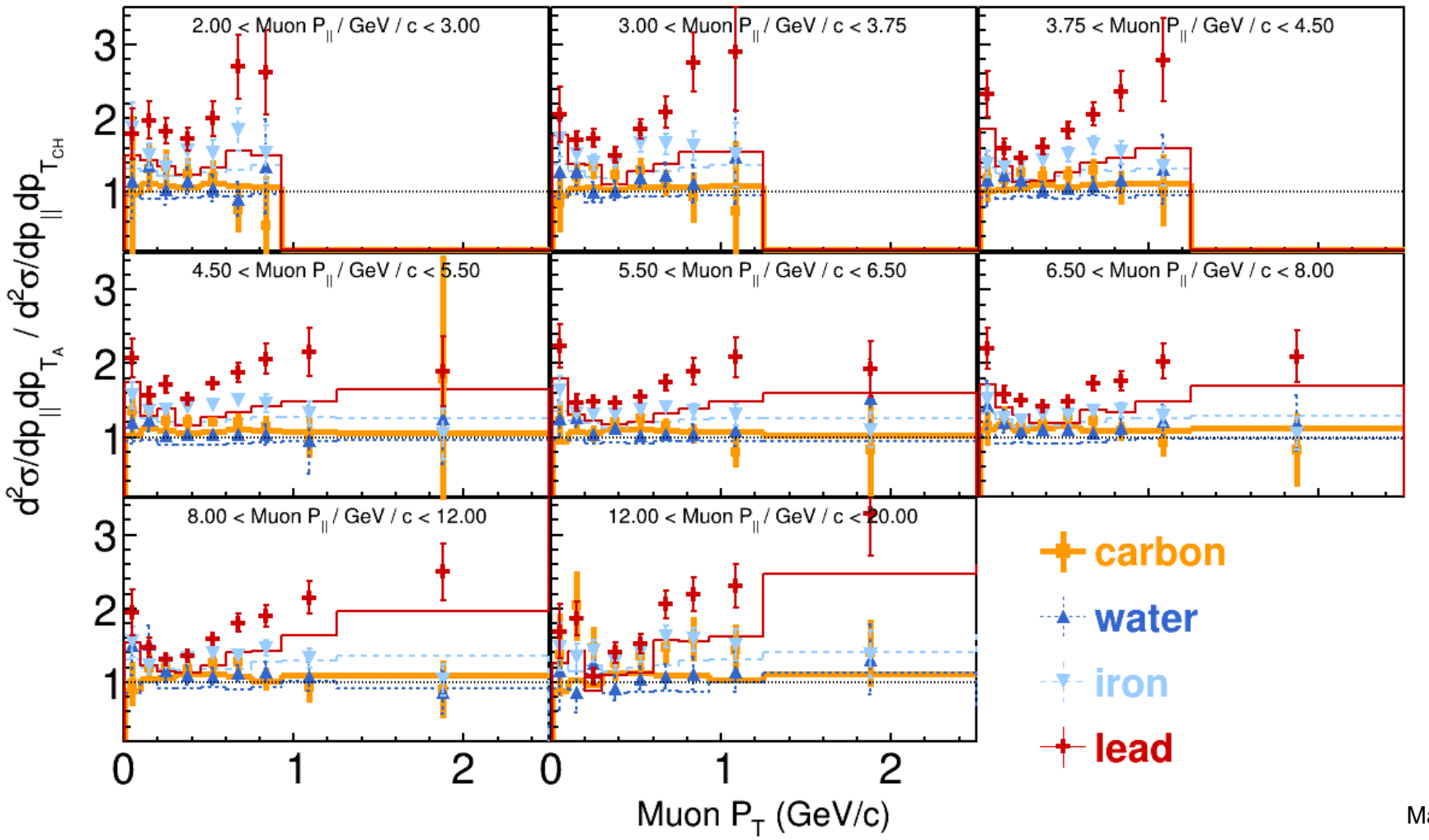




Neutrino flux uncertainty reduced from 7.7% to 3.3%

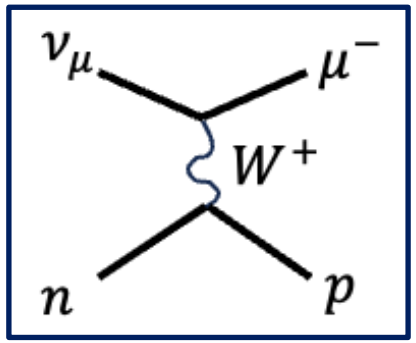
Take cross section **ratios to reduce uncertainties**

J. Kleykamp *et al.* (MINERvA Collaboration) *Phys Rev Lett 130, 161801*



Quasielastic-like

- **2-Dimensional plot** with **muon transverse momentum** on the x axis and panels of **muon longitudinal momentum**
- Double differential cross section ratio taken with scintillator for different target materials



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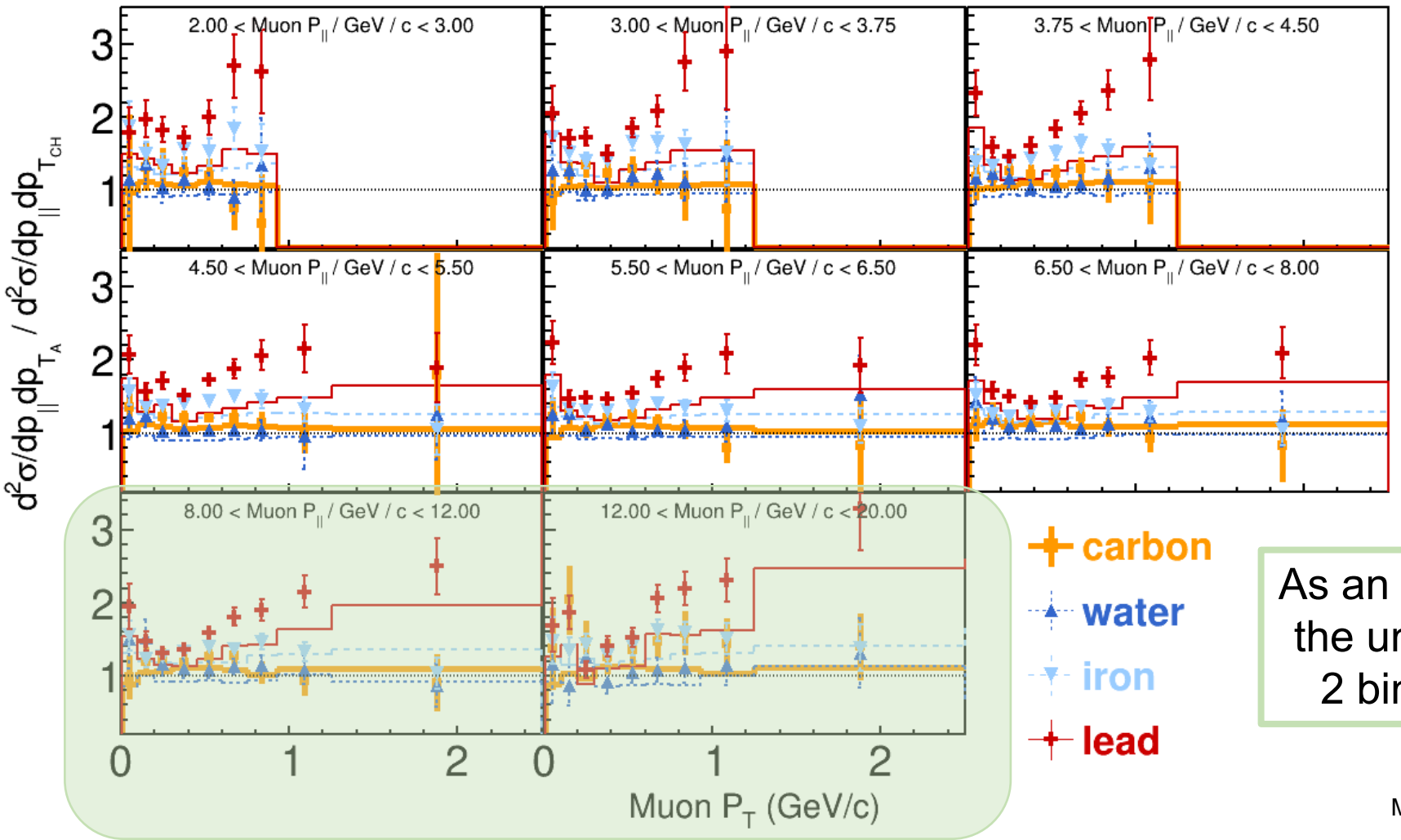

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- **2-Dimensional plot** with **muon transverse momentum** on the x axis and panels of **muon longitudinal momentum**
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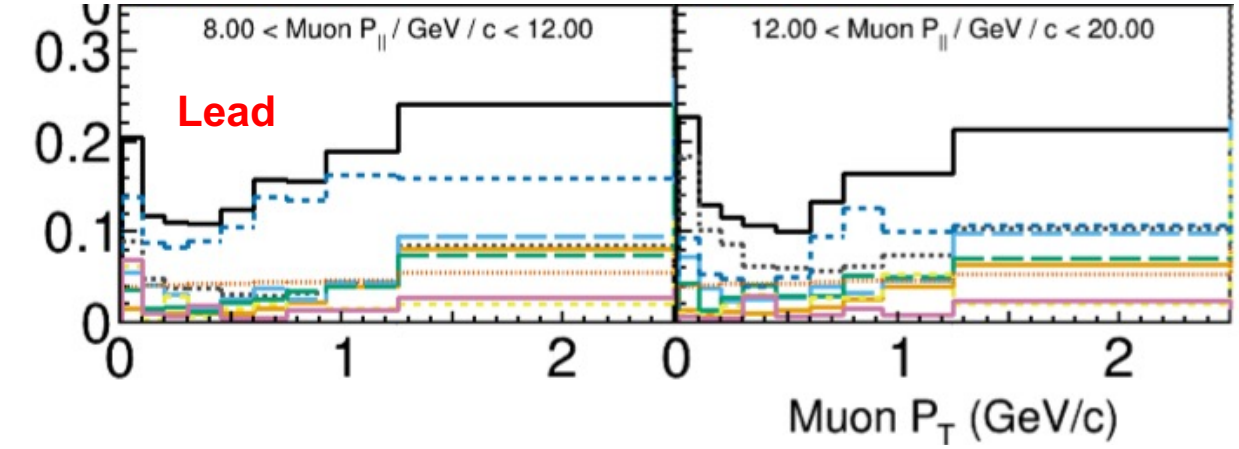
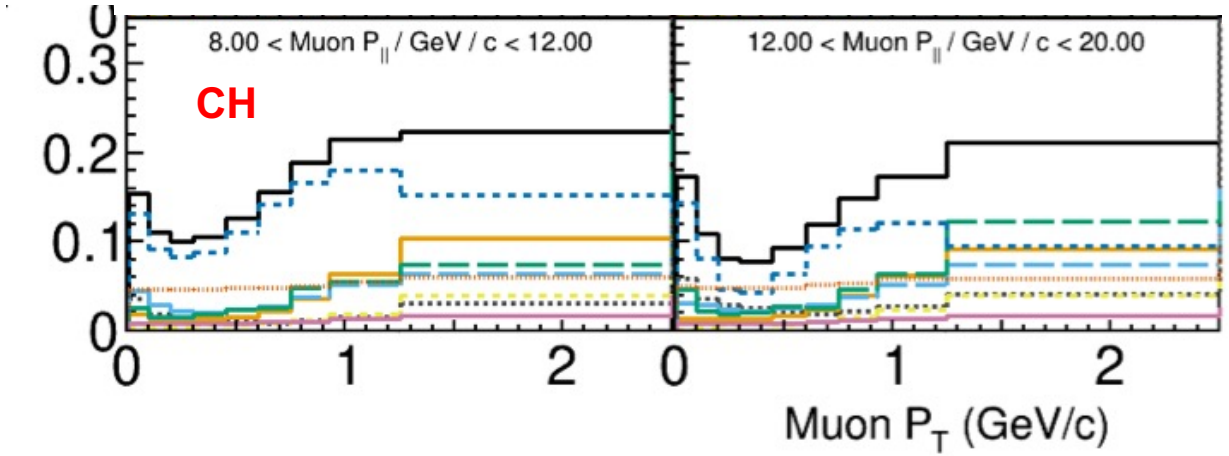
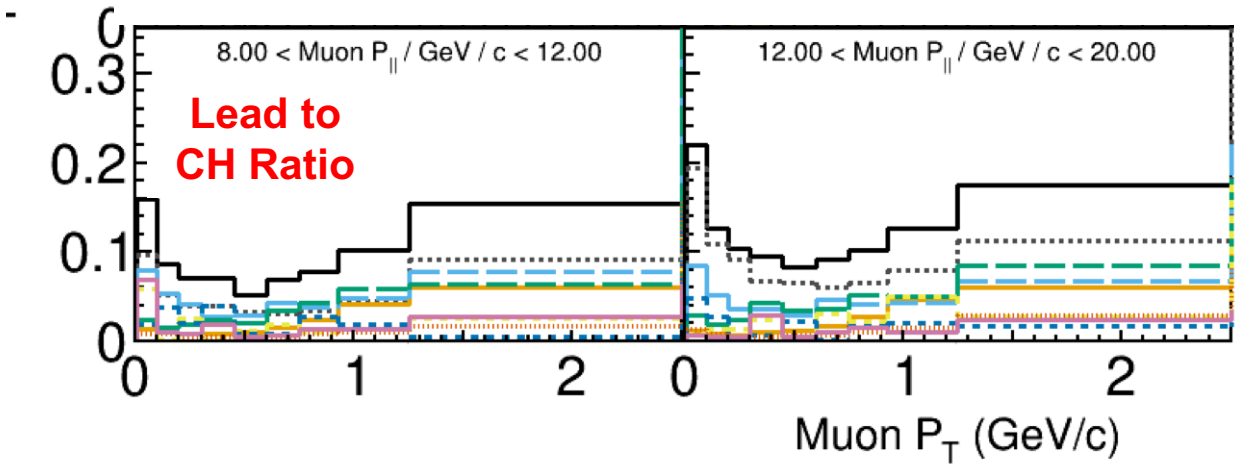
As an example, let's look at the uncertainties on these 2 bins on the next slide







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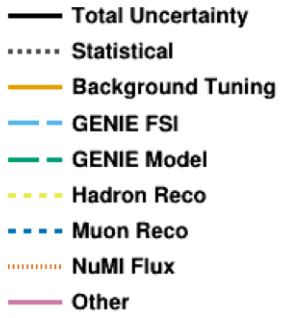
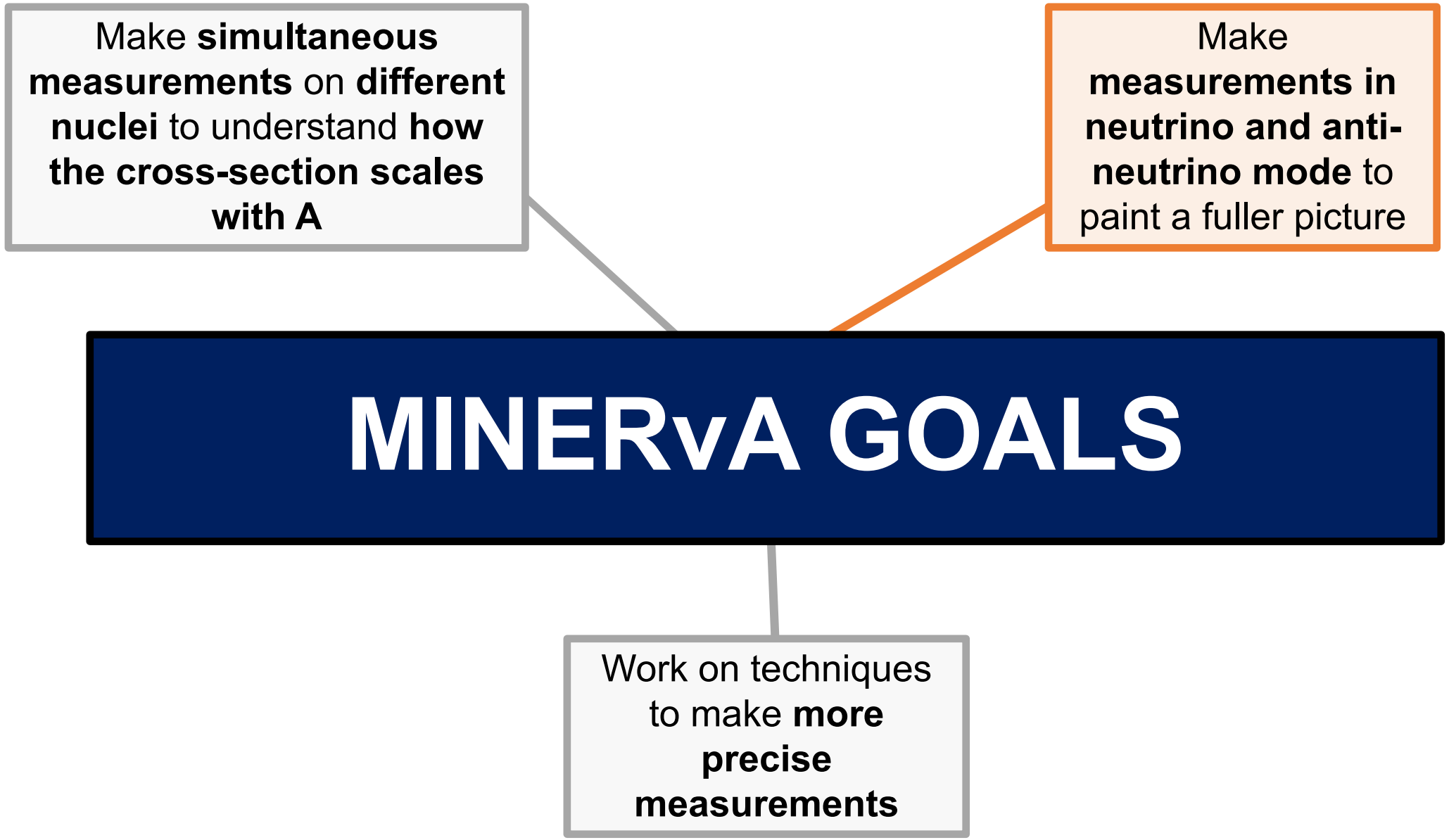


Cancellation of some systematics on the **cross-section ratio**

- Uncertainty on the cross-section ratio is lower than either the numerator or denominator or both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Making measurements in neutrino and anti neutrino mode

- MINERvA has made measurements in **anti-neutrino mode** as well as its important to understand both neutrino and anti-neutrino modes for painting a fuller picture of neutrino nucleus interactions

Some recent measurements:

- High-Statistics Measurement of **Antineutrino Quasielastic-like** scattering at Ev ~ 6 GeV on a Hydrocarbon Target
  - A. Bashyal *et al.* (MINERνA Collaboration), Phys. Rev. D **108**, 032018

- Measurement of the **Multi-Neutron Antineutrino Charged Current** Differential Cross Section at Low Available Energy on Hydrocarbon
  - A. Olivier *et al.* (MINERνA Collaboration), Phys. Rev. D **108**, 112010

- Measurement of **Electron Neutrino and Antineutrino** Cross Sections at Low Momentum Transfer
  - S. Henry *et al.* (The MINERvA Collaboration), Phys. Rev. D **109**, 092008

Conclusion

- Models for cross sections aid in neutrino oscillation experiments by enabling them to translate the number of events that they see at a far detector to some incoming neutrino flux
- More simultaneous measurements of neutrino interactions on different nuclei in the pipeline, please stay tuned!
- Also, a data preservation product will be available!

THANK YOU!