

CC $\nu_\mu \rightarrow 1 \pi^+ + X$ production at MINERvA Experiment

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MINERvA Experiment

The MINERvA experiment (Main Injector Experiment v-A) has as main goal measure the neutrino cross section on 6 different materials, such as H₂O, Fe, Pb, He, C and CH. It was located in the MINOS detector building on axis of the neutrino NuMI beam.

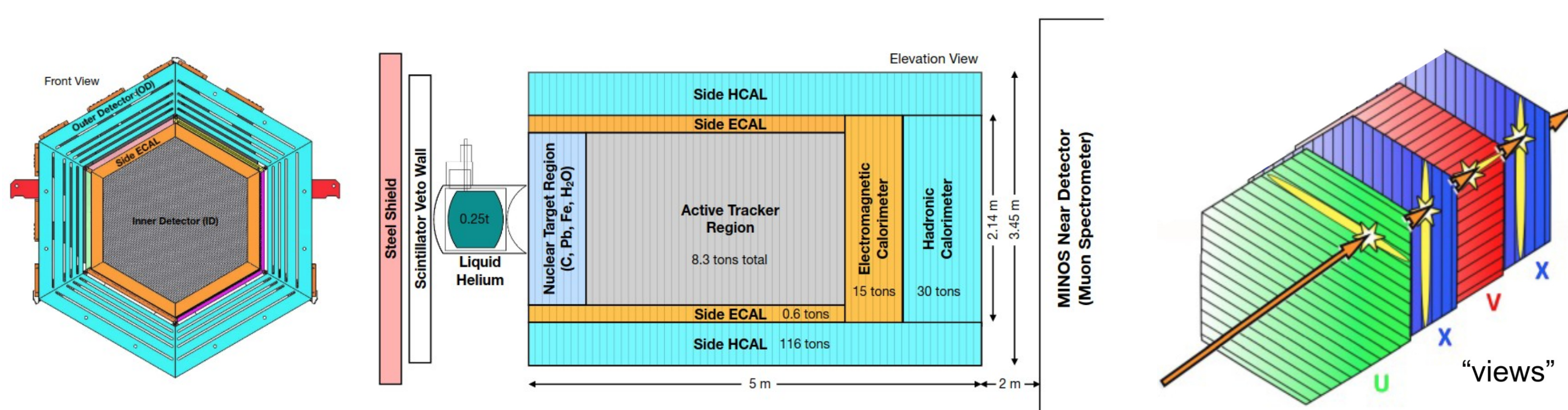


Figure 1. Left, MINERvA detector sketch. Right, Orientation of the plastic scintillator strips in a detection module.

NuMI Beam

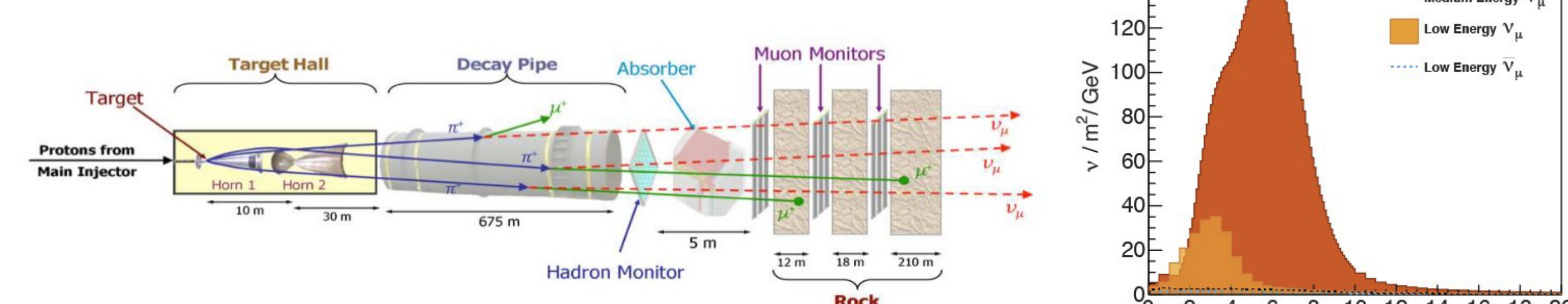


Figure 2. NuMI beam sketch.

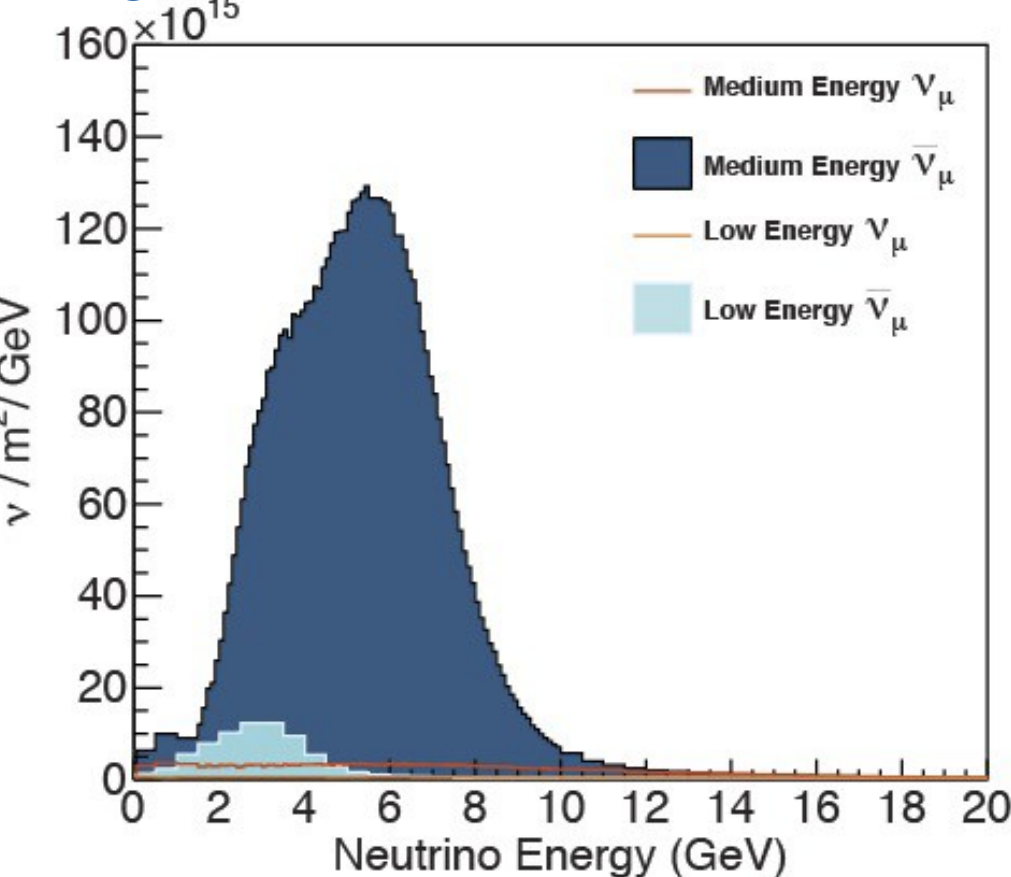


Figure 4. Antineutrino flux during LE and ME.

The data taken by the detector is divided in two eras, Low Energy era (LE) with $\langle E_\nu \rangle = 3$ GeV during 2009-2012 and Medium Energy era (ME) with $\langle E_\nu \rangle = 6$ GeV during 2013-2019, for neutrino and antineutrino modes.

Why MINERvA matters to oscillation experiments?

$$R(\vec{x}) = \phi(E_\nu) \times \sigma(e_\nu, \vec{x}) \times \epsilon(\vec{x}) \times P(\nu_A \rightarrow \nu_B)$$

Where:

- $R(\vec{x})$: event rate of oscillated neutrinos.
- ϕ : neutrino flux.
- σ : neutrino cross section.
- ϵ : detector efficiency.
- $P(\nu_A \rightarrow \nu_B)$: oscillation probability.
- \vec{x} : distance measured from the neutrino source.

CC $\nu_\mu \rightarrow 1 \pi^+ + X$ production, Signal Definition

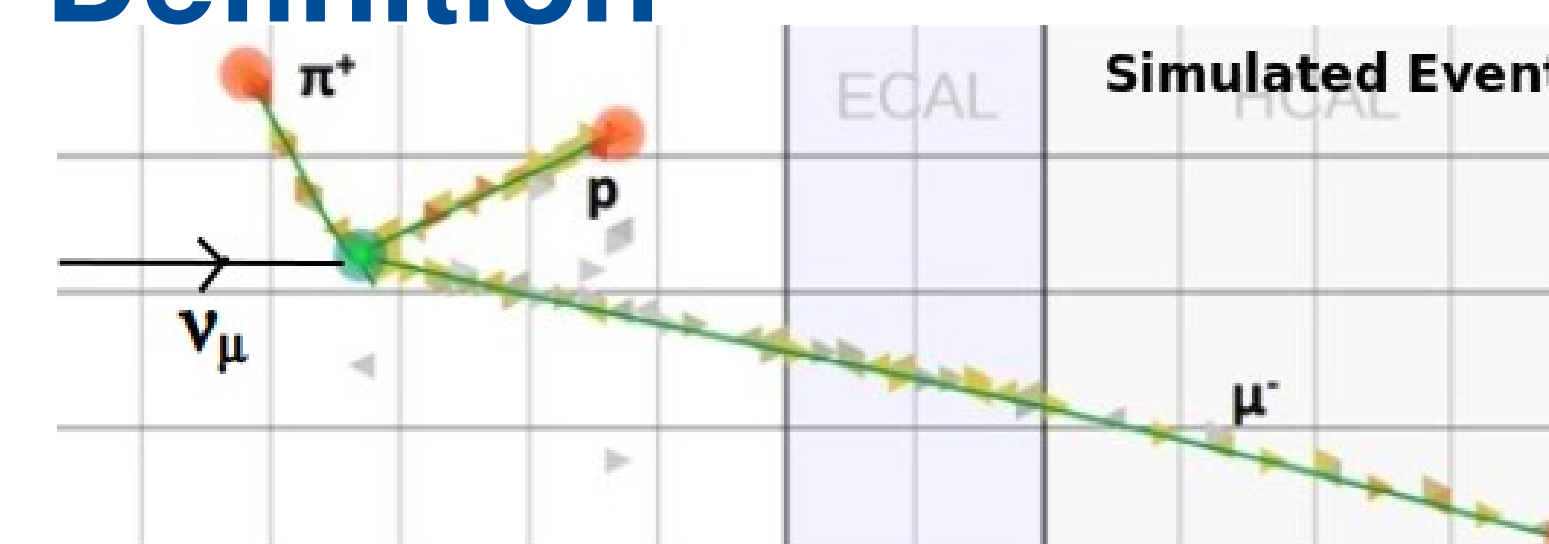


Figure 5. Event Display of a simulated event in the MINERvA tracker.

For the event selection we apply the following cuts:

- Vertex position
- Muon cuts
- At least one hadron track
- dE/dx Particle ID
- One Michel electron
- Invariant Mass < 1.4 GeV

$$\left(\frac{d\sigma}{dx}\right)_\alpha = \frac{\sum_j U_{j\alpha} (N_{data,j} - N_{data,j}^{bkgd})}{A_\alpha(\Phi T)(\Delta x)}$$

Labels: Unfolding, Events Selected, Backgrounds, Acceptance, Flux, Targets, Bin-width

Figure 6. Equation that shows how is calculated the cross section.

Cross Section results for LE and ME eras

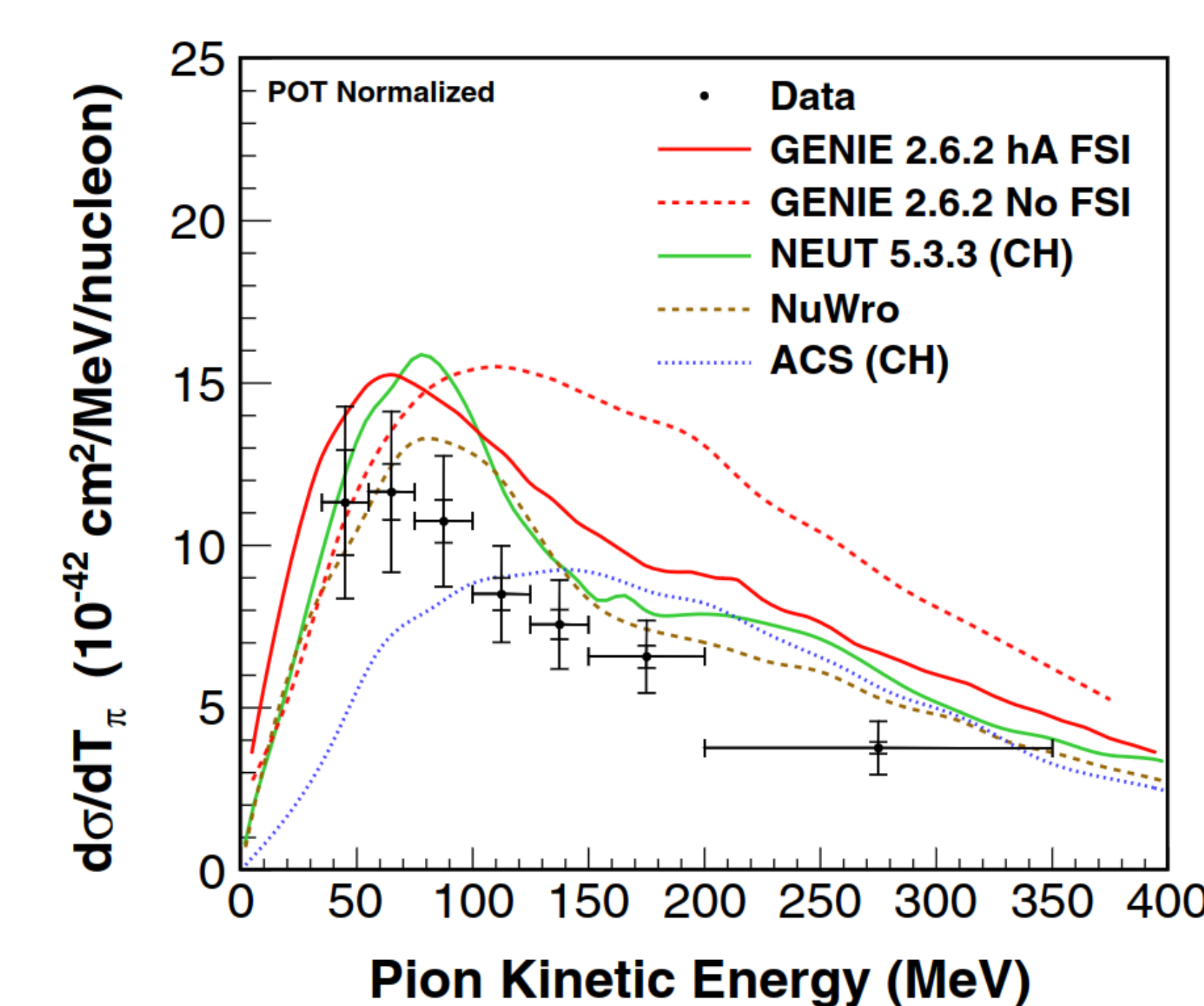


Figure 7. Differential cross section as function of the pion kinetic energy (T_π) For LE era in the tracker detector region.

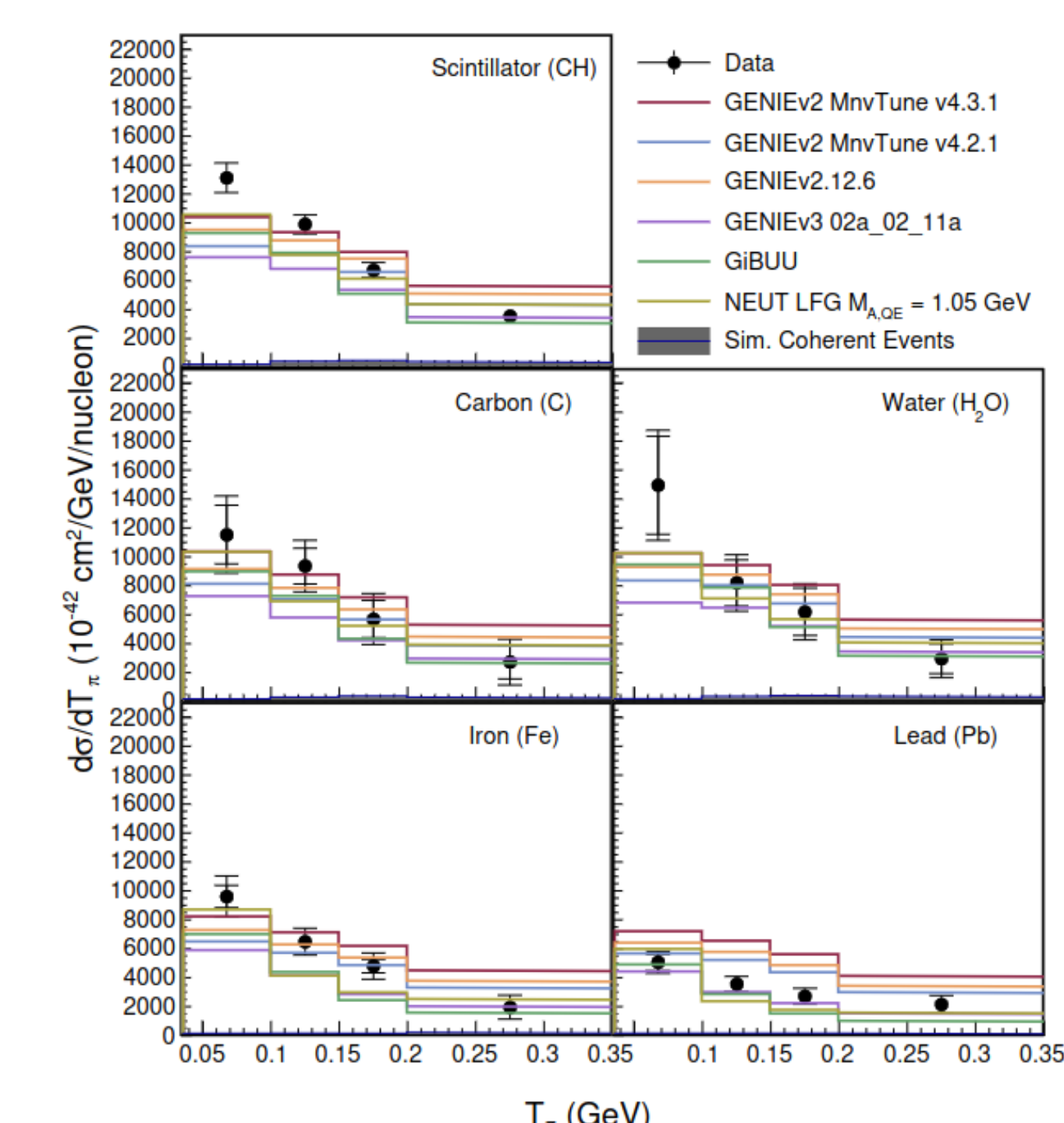


Figure 8. Differential cross section as function of the pion kinetic energy (T_π) For ME era in the targets and tracker regions.

- More statistics for ME era.
- The results are compared with different neutrino interaction generators.

New analyses coming

- Trackless pion analysis and 2D Analysis.
- And more ...

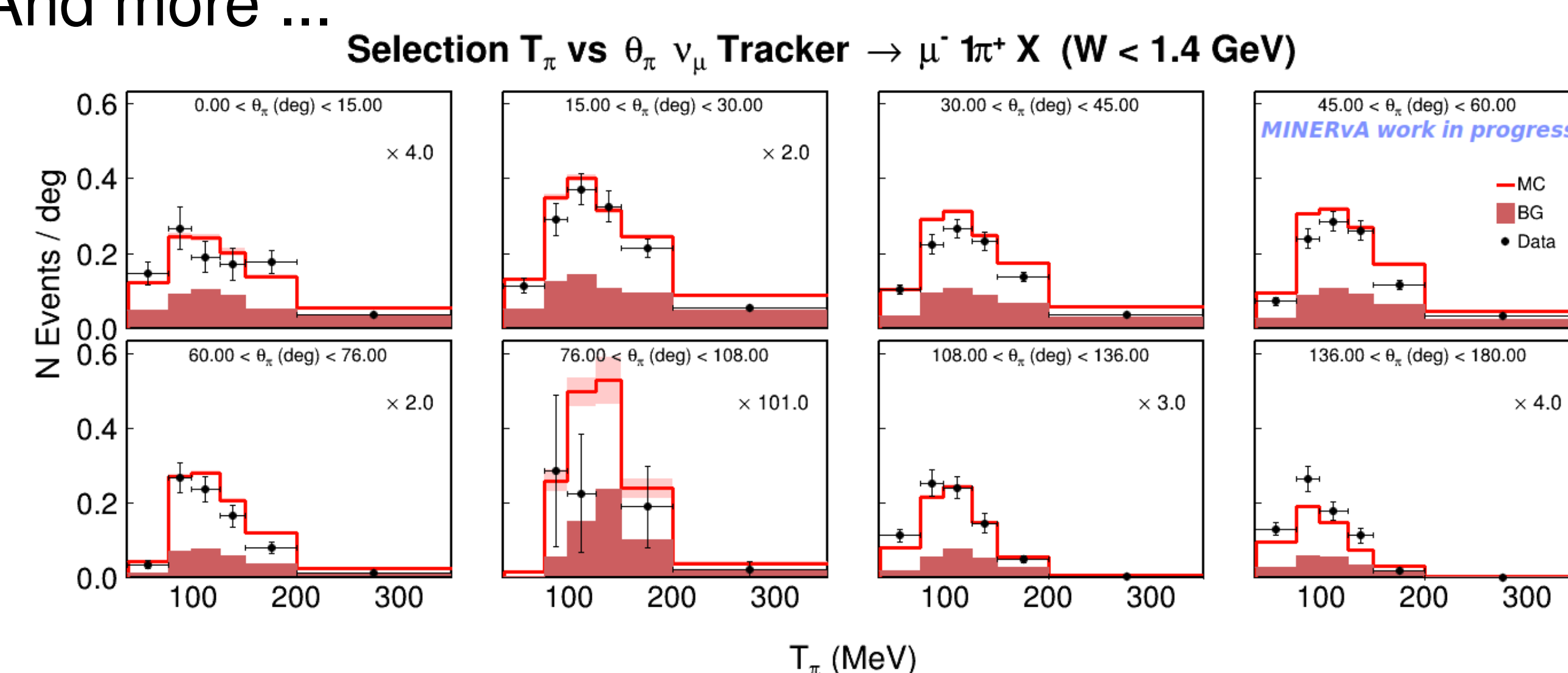


Figure 9. 2D data selection for CC $\nu_\mu \rightarrow 1 \pi^+ + X$ production.

Conclusions

- More MINERvA analysis are coming!!
- CC $1 \pi^+$ are very important to improve nuclear models and reduce uncertainties.
- The MINERvA experiment has a large data set to be analyzed
- A lot things to be discovered ...

