# Propagating FSI Model Differences to Reconstructed ν–Pb/C Observables in MINERvA

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## 1 The MINERvA experiment

- MINERvA records High-statistics $\nu_\mu$–A interactions[1].
- ECAL consists of thin Pb absorber sheets (2 mm) interleaved with CH scintillator (17 mm).
- ECAL Pb fiducial mass is ≈4× larger than the dedicated Pb target.

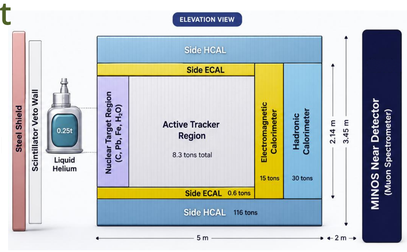


*Figure 1. The MINERvA detector.*

## 2 Final State Interactions (FSI)

- FSI dominate nuclear-model uncertainties in heavy targets.
- We aim to reweight to map between FSI predictions.
- Comparing:
  - GENIE 2 hA
    - GENIE 3 hA [2]
    - INCL [3]
- Results shown as a function of fate and pre-FSI kinetic energy.

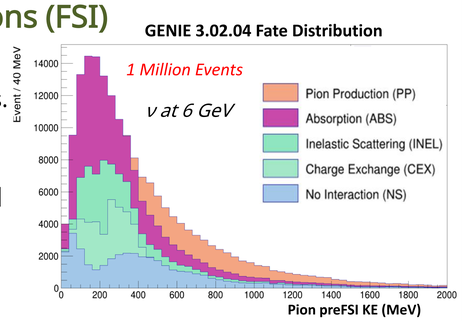


*Figure 2. **π energy distribution** for FSI fates in a ν–Pb sample from only resonant interactions.*

Workflow


## 3 Pre-FSI Distributions

Pre-FSI QE protons and RES pions are classified by FSI fate versus kinetic energy, enabling direct comparisons across models and nuclei.

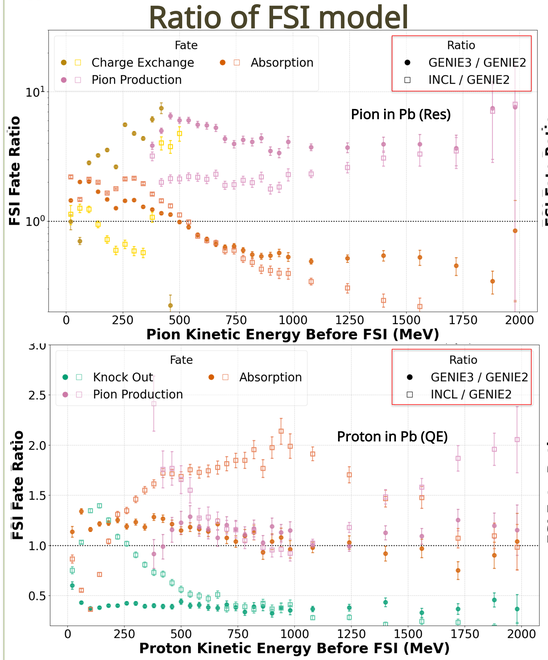


*Figure 3. Model fate ratios. The huge deviations from 1 highlight differences in FSI modeling.*

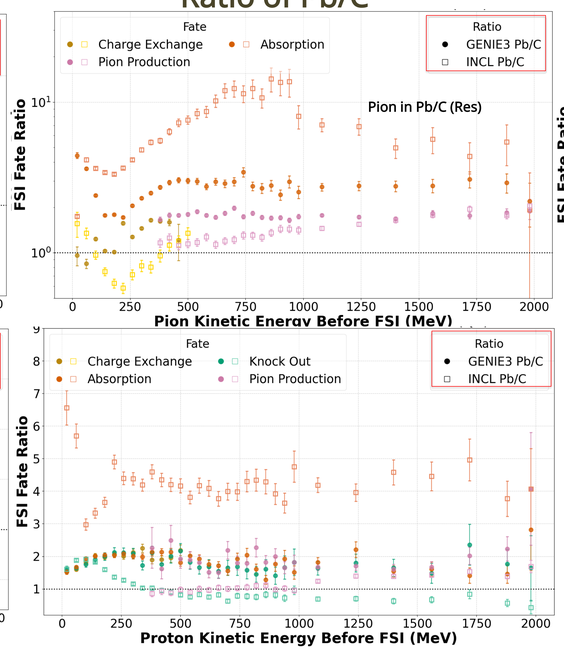


*Figure 4. Pb/C fate ratios. Larger nuclei amplify FSI interactions and enhance differences in predictions.*

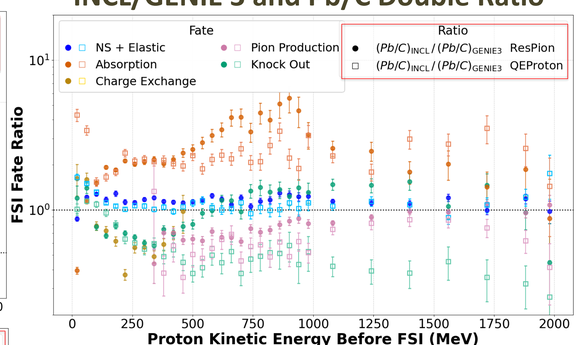


*Figure 5. Deviations from 1 indicate that the fractional fate rates scale with nuclear size differently between INCL and GENIE 3.*


### Acknowledgments

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### References


[1] MINERvA Collaboration, Nucl. Instrum. Methods A 743 (2014) 130.
[2] C. Andreopoulos et al. (GENIE Collaboration), Phys. Rev. D 103 (2021) 113008.
[3 ] Liang Lu, et al arXiv:2605.14196 [hep-ex] (2026).


## 4 Weight Application

Polynomial reweights enable rapid propagation of GENIE3 and INCL FSI predictions to MINERvA observables without new MC production.

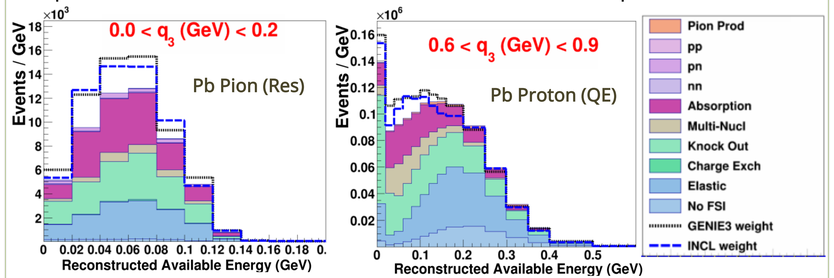


*Figure 6. Distributions in ν–Pb before/after FSI reweighting with truth-level selections.*

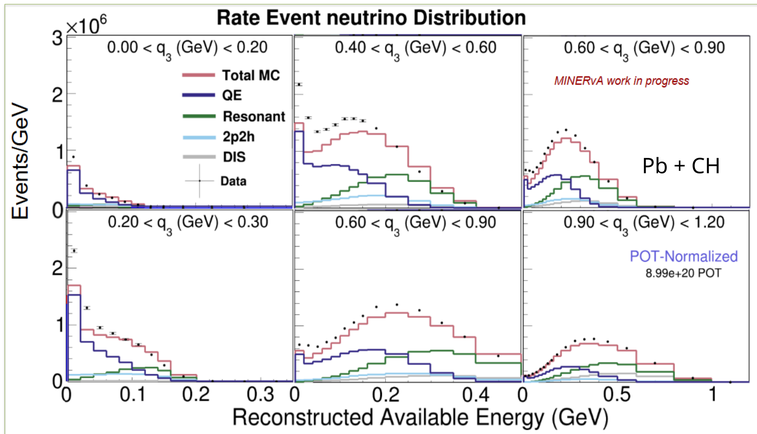


*Figure 7. Spectrum predicted using default FSI mode from GENIE 2.*

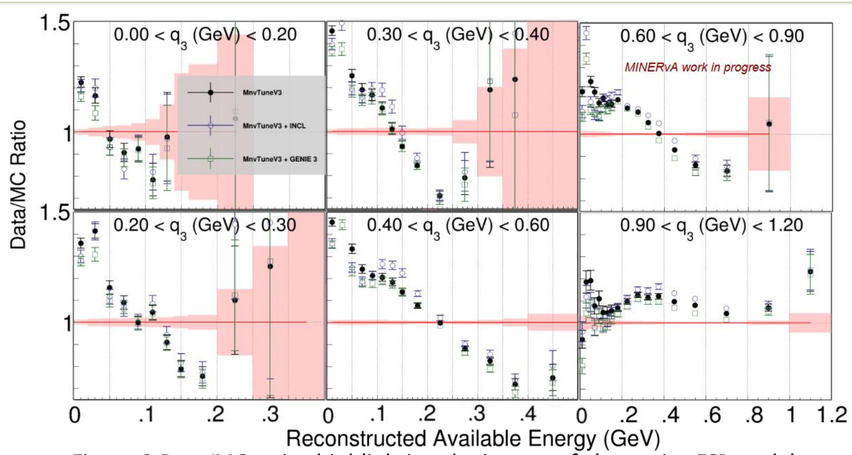


*Figure 8.* Data/MC ratios highlighting the impact of alternative FSI models.

## 5 Results

- Reweights were applied to the reconstructed sample.
- Data is compared to the nominal simulation and FSI-reweighted predictions based on GENIE 3 and INCL.

**GENIE 3 and INCL FSI models modify reconstructed Available Energy by 3–6%, with the largest effects observed in ν–ECAL interactions where nuclear-medium effects are amplified.**

| | Mean deviation shift | | Max deviation shift | |
|---|---|---|---|---|
| q3 (GeV) | INCL | GENIE 3 | INCL | GENIE 3 |
| 0.0 - 0.2 | 2.92% | 3.95% | 7.44% | 7.98% |
| 0.2 - 0.3 | 3.99% | 3.18% | 6.01% | 10.64% |
| 0.3 - 0.4 | 4.44% | 3.77% | 10.11% | 12.60% |
| 0.4 -0.6 | 5.60% | 4.50% | 15.10% | 16.28% |
| 0.6 - 0.9 | 4.17% | 4.89% | 10.22% | 17.69% |
| 0.9 - 1.2 | 3.87% | 5.31% | 9.90% | 14.08% |

*Table 1. Percentage changes relative to the nominal model.*

## 6 Conclusions

- Pb/C reveal stronger reinteraction probabilities in heavy nuclei.
- MINERvA data in the ECAL reveal **strong nuclear-medium–dependent FSI topology differences (3-6%)** not predicted by GENIE 2.
- The observed differences represent experimentally measurable consequences of alternative FSI models.
- Framework is directly applicable to **future neutrino oscillation analyses** (DUNE) that use heavy-nucleus near detectors, enabling systematic propagation of FSI uncertainties without regenerating large MC samples for nusystematics.
- MINERvA Open data is already available for public use.

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