CCQE at MINERvA in the ME Era

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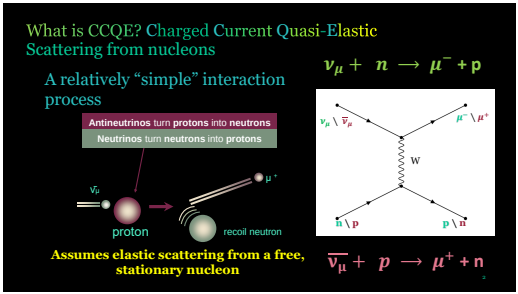
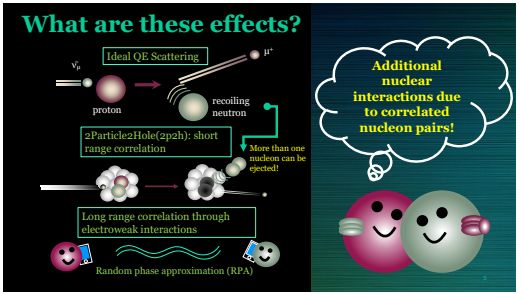
CCQE at MINERvA in the ME Era

- Mehreen did a great job introducing this process
- An important interaction channel for Monte Carlo validation

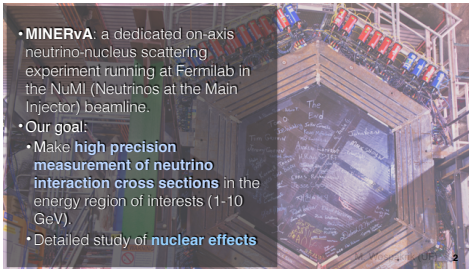




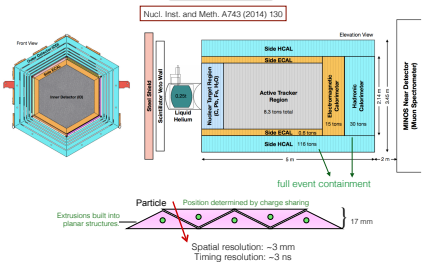
CCQE at MINERvA in the ME Era

- Maya did a great job introducing our detector and physics program
- Designed for *precision measurements* of cross sections

What is MINERvA?

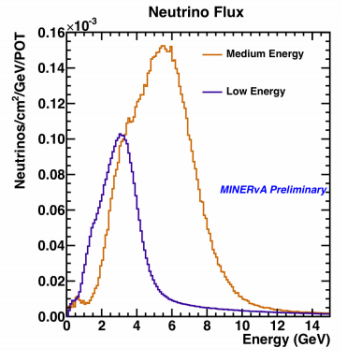


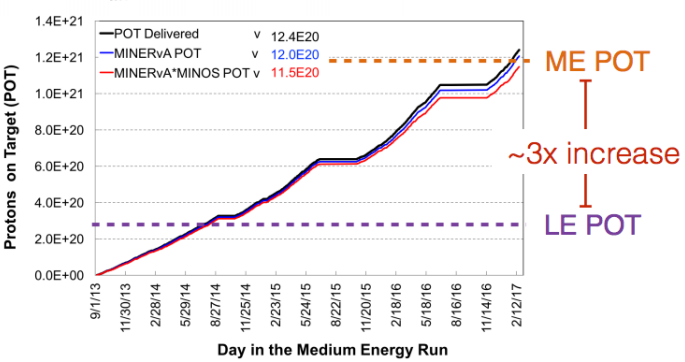
MINERvA Detector



CCQE at MINERvA in the ME Era

- 'Low Energy' (LE): $\sim 4 \times 10^{20}$ protons-on-target, peaked at 3 GeV
- 'Medium Energy' (ME): $\sim 12 \times 10^{20}$ protons-on-target, peaked at 6 GeV





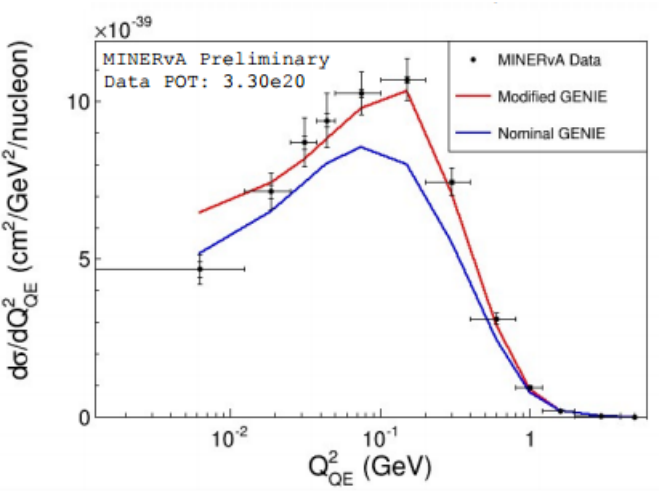
I'm *not* going to tell you about:

- Improvements to our reconstruction, cross section extraction, etc.
- Progress towards publishing this analysis

I *am* going to tell you:

- How we use our measurements to validate and improve theoretically-motivated modifications that we make to our Monte Carlo
- A specific example of this
- Prospects of these efforts using our ME data set

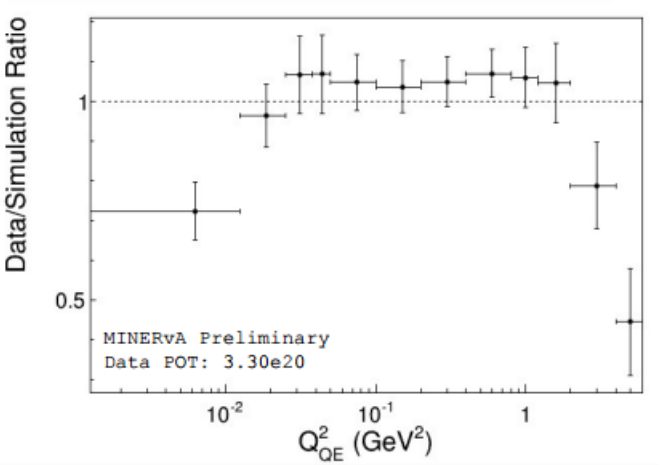
On the LE CCQE Results



- Data clearly prefer 'Modified GENIE':
  - reduce non-resonant π-production
  - Add Nieves 2p2h and RPA
  - Incorporate fit to inclusive low-recoil sample
- But, agreement is still poor in some regions

On the LE CCQE Results

- Simulation over-predicts cross section at low- and high-Q^2_{QE}
- Can we simulate this using updated models?



Example: Quasi-Elastic Cross Section Formalism

- Theoretical calculations of ν-scattering cross sections can be parameterized by "form factors"

$$\frac{d\sigma}{dq^2} \propto (F_1, F_2, F_A)$$

- The so-called "axial form factor", F_A, is a particular example, and isn't well-constrained by existing measurements

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$$\frac{\mathrm{d}\sigma}{\mathrm{d}Q^2}_{QE}\begin{pmatrix}\nu_l n \to l^- p\\ \bar{\nu}_l p \to l^+ n\end{pmatrix} = \frac{M^2 G_F^2 \cos^2\theta_C}{8\pi E_\nu^2}\left\{A(Q^2) \mp B(Q^2)\frac{s-u}{M^2} + C(Q^2)\frac{(s-u)^2}{M^4}\right\}$$

$$A(Q^2) = \frac{m_l^2+Q^2}{M^2}\left\{\left(1+\frac{Q^2}{4M^2}\right)|F_A|^2 - (1-\frac{Q^2}{4M^2})F_1^2 + \frac{Q^2}{4M^2}(1-\frac{Q^2}{4M^2})(\xi F_2)^2 + \frac{Q^2}{M^2}Re(F_1^*\xi F_2) - \frac{Q^2}{M^2}(1+\frac{Q^2}{4M^2})(F_A^3)^2 - \frac{m_\mu^2}{4M^2}\left[|F_1+\xi F_2|^2 + |F_A+2F_P|^2 - 4(1+\frac{Q^2}{4M^2})((F_V^3)^2+F_P^2)\right]\right\}$$

$$B(Q^2) = \frac{Q^2}{M^2}Re\left[F_A^*(F_1+\xi F_2)\right] - \frac{m_l^2}{M^2}Re\left[(F_1-\tau\xi F_2)F_V^{3*} - F_A^*\left(1+\frac{Q^2}{2M^2}F_P\right)F_A^3\right]$$

$$C(Q^2) = \frac{1}{4}\left\{F_A^2 + F_1^2 + \tau(\xi F_2)^2 + \frac{Q^2}{M^2}(F_A^3)^2\right\}$$

C.H. Llewellyn Smith, Phys. Rept. 3C, 261 (1972)

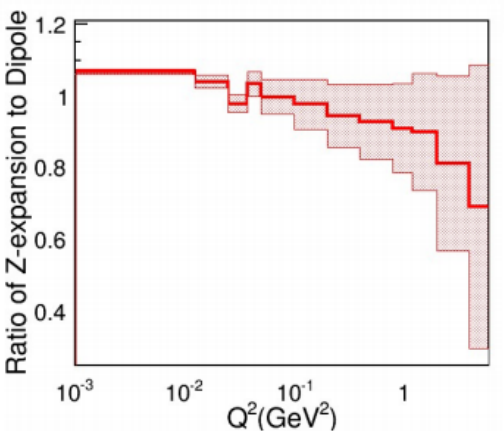
Example: Quasi-Elastic Cross Section Formalism

- F_A can be modeled as a dipole

$$F_A(Q^2) = \frac{F_A(0)}{(1 - \frac{q^2}{M_A^2})^2}$$

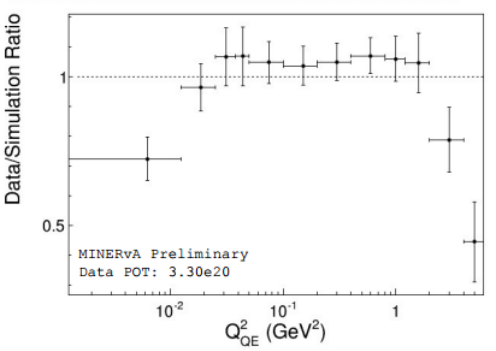
- Or, derived from QCD as an expansion:

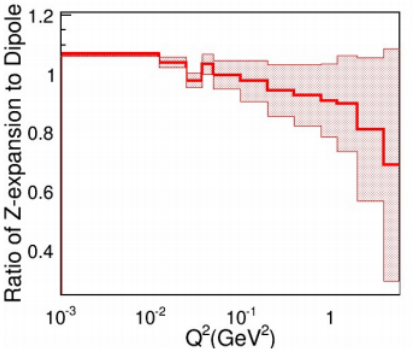
$$F_A(q^2) = \sum_{k=0}^{k_{max}} a_k z(q^2)^k$$



A. Meyer, M. Betancourt, R. Gran and R. Hill, Phys. Rev D93(2016)

Using Data to Compare Models





- Strategy: Implement z-expansion and dipole models for F_A
- Caveat: Q^2 and Q^2_{LE} aren't exactly the same

What about Medium Energy?

- I haven't actually shown you any Medium Energy CCQE distributions
- Reasons you should care about upcoming results:
  - LE double-differential CCQE cross section is statistically limited at high-Q^2
  - Access to expanded phase-space, including $Q^2 \sim 10\text{GeV}^2$

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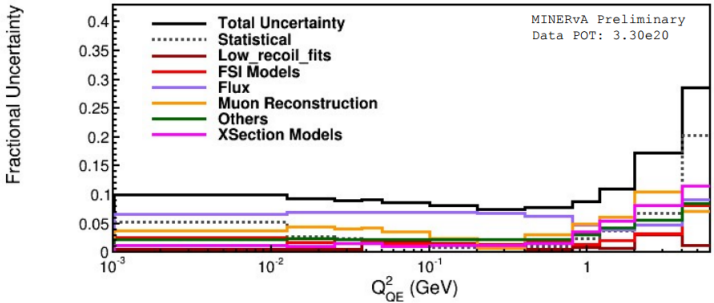

Summary

- Our QE sample in ME reaches higher Q^2 than in LE, with increased statistics
- I've given you an example of the type of model enhancement that we will be able to validate using this data set
- But this is only scratching the surface...Stay tuned

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Thank You!