Towards GENIE v4: a theoretical (and personal) perspective

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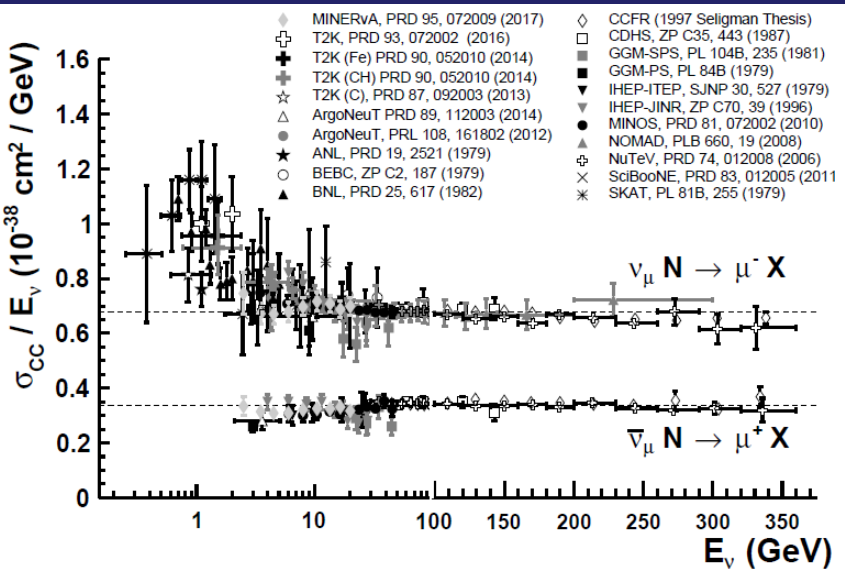
Consistency

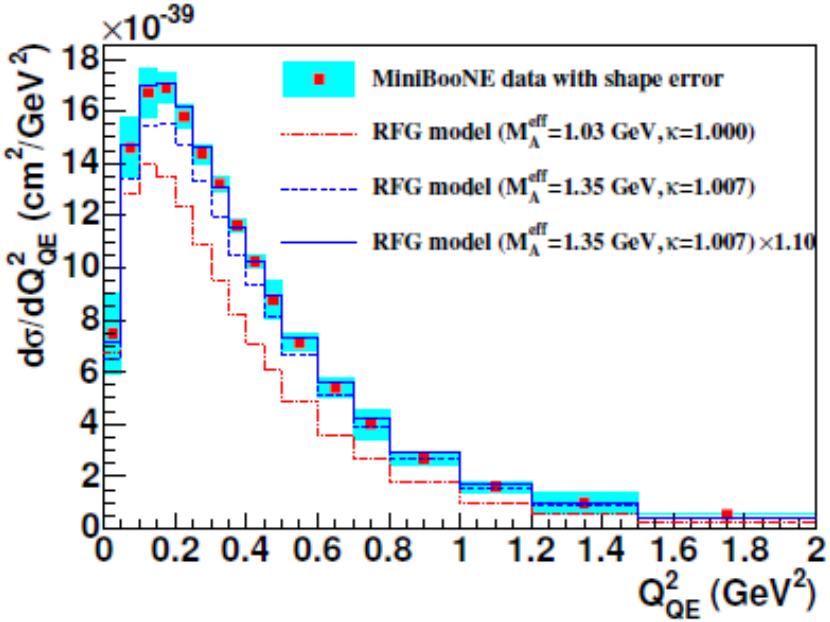


G. P. Zeller for PDG

- ν–nucleus event generation for oscillation experiments involves the simulation of a large variety of processes over a broad kinematic range:
  - NC and CC (with l= e, μ, τ)
  - (Quasi)elastic, inelastic, deeply inelastic
    $\nu_l\, N \to l\, X\,, \qquad X = N\,, N\pi\,, N\pi\pi\,, N\eta\,, \Lambda\bar{K}\,, \Sigma\bar{K}\,, \ldots$
  - on nucleons and nuclei
  - incoherent and coherent
  - various theoretical models implemented but how consistently?

Consistency is important

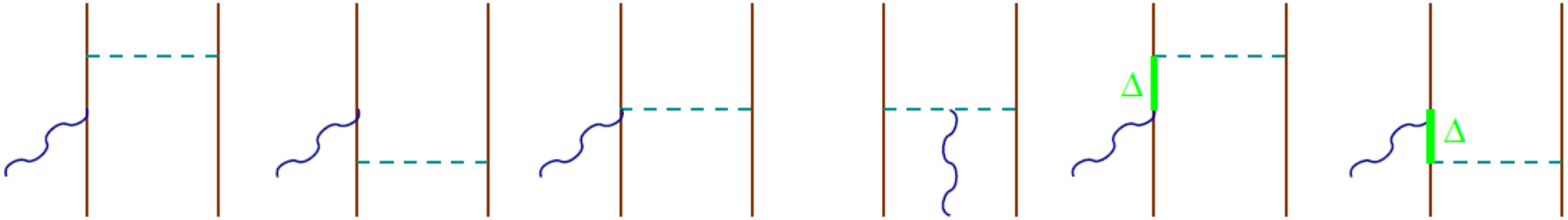
- Inconsistencies expose theoretical mismodeling and/or experimental problems
  - Classic example: CCQE @ MiniBooNE:



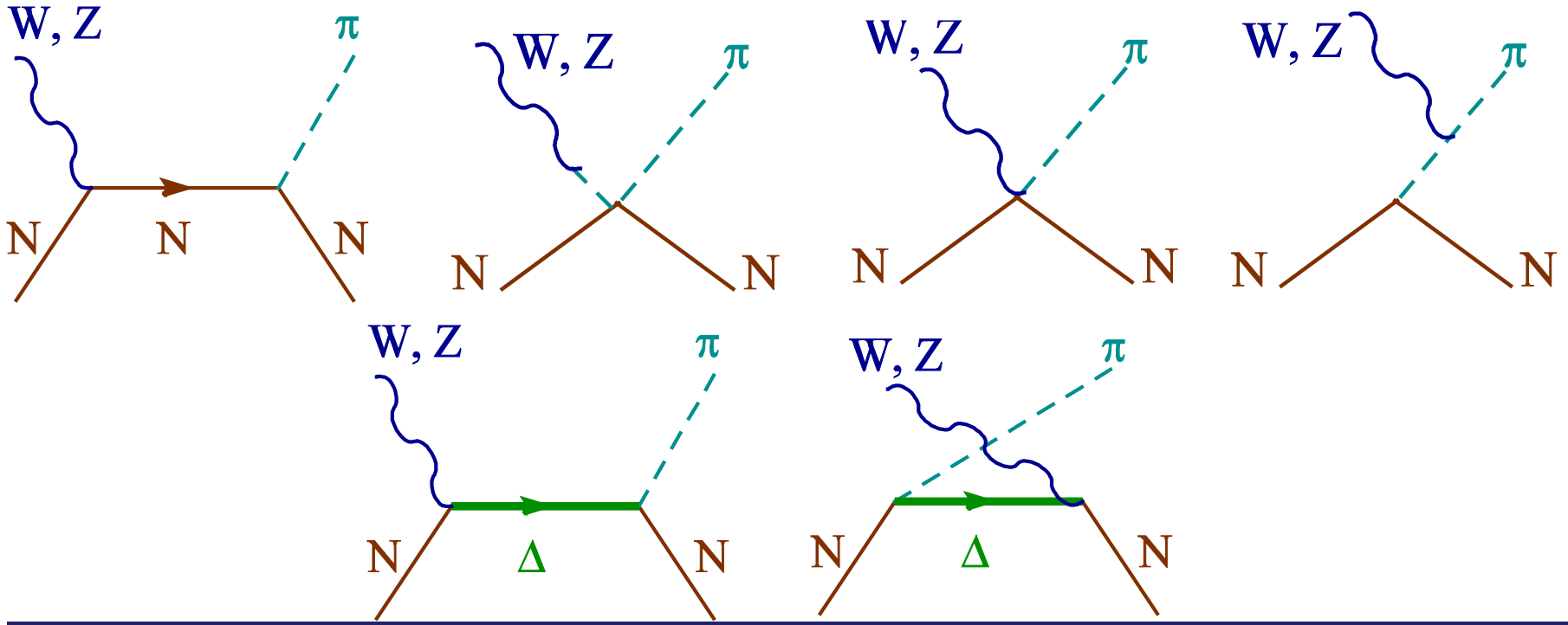
  - M_A =1.35 ± 0.17 GeV in tension with $M_A \approx$ 1 GeV from bubble chamber data
  - Two-nucleon contribution to the 0π cross section
- Consistency should lead to a more universal error budget

Consistency is good for health

- Two-nucleon currents at the microscopic level

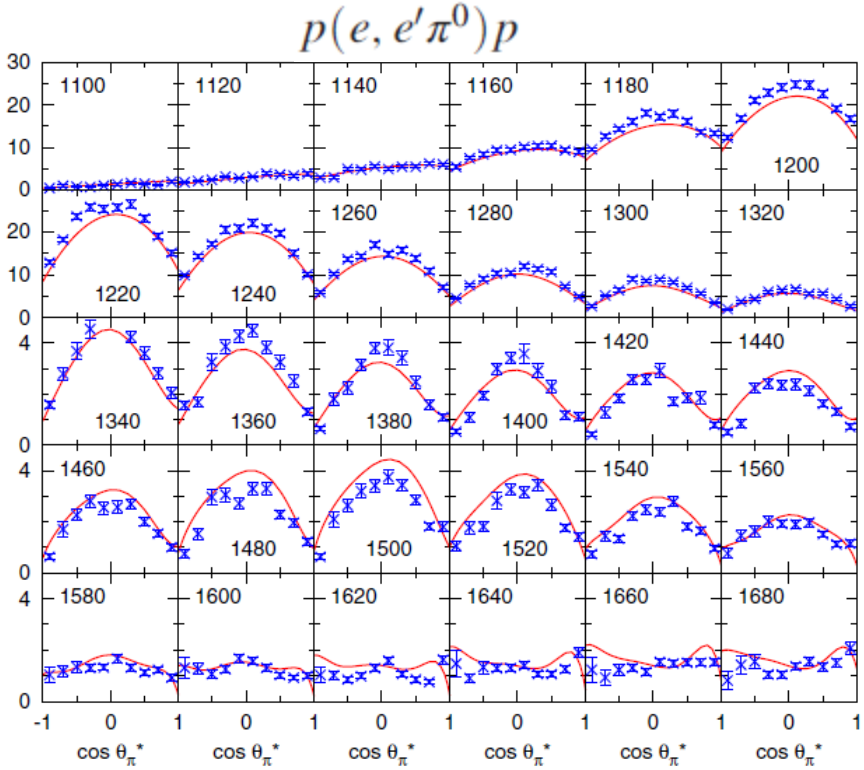


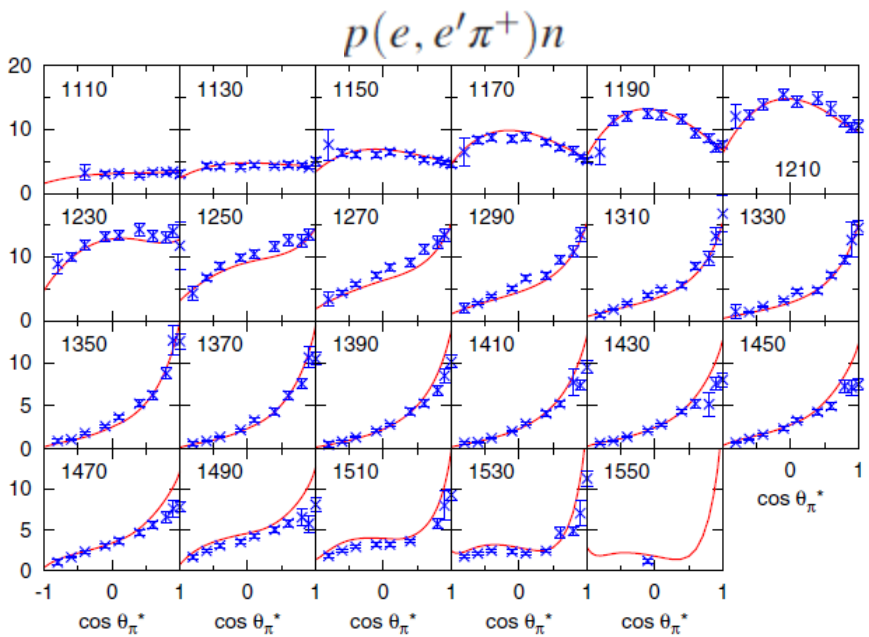
shares many ingredients with other processes, in particular pion production:



Consistency with non-ν data

- Single pion production
  - Vector current can be constrained with $\gamma N \to N \pi$, $e N \to e' N \pi$





- e.g. Dynamical Coupled Channel (DCC) Model Nakamura et al., PRD92 (2015)
- GENIE should have its own tune to $e N \to e' N \pi$, at least in the Δ region

Consistency with non-ν data

- Single pion production
  - Vector current can be constrained with $\gamma N \to N\pi$, $e N \to e' N \pi$
  - Axial current at $q^2 \to 0$ can be constrained with $\pi N \to N\pi$ (PCAC)

$$\left.\frac{d\sigma_{CC\pi}}{dE_l\, d\Omega_l}\right|_{q^2=0} = \frac{G_F^2 V_{ud}^2}{2\pi^2}\,\frac{2 f_\pi^2}{\pi}\,\frac{E_l^2}{E_\nu - E_l}\,\sigma_{\pi N}$$

- e.g. Dynamical Coupled Channel (DCC) Model Nakamura et al., PRD92 (2015)
- GENIE should have its own tune to $e N \to e' N \pi$ and $\pi N \to N\pi$, at least in the Δ region

Possible improvements

- More realistic baryon-resonance production model
- Non-resonant contribution to single pion production
- Tune/validation with $e\,N \to e'\,N\,\pi$ and $\pi\,N \to N\,\pi$ data
- Microscopic (and fully exclusive) implementation of two-nucleon mechanisms

Training

- (Young) experimentalists are usually familiar with event generators but not with the underlying physics
- (Young) theorists are usually familiar with some aspects of the underlying physics but not with event generators

- Next NuSTEC school @ CERN in 2019 or 2020:
  1. Conventional theory oriented school
  2. Theory introduction + generator training: an evolution of the 2014 Neutrino Generator School @ Liverpool
     http://school.genie-mc.org/