Electron Neutrino Cross-sections

"How Important are they Really?"

Ian Taylor, University of Warwick

nuSTORM Phone Meeting - 01/18/13

Short Answer

- Really quite important!
  - They have had a major effect on past/present osc. experiments (T2K, MINOS, NOVA).
  - They will probably have the same effect on future experiments (LBNE, LBNO, T2HK).
    - Dark matter too (understanding the neutrino background will soon become very important).
  - They really aren't very well understood.
  - Offer the potential for a lot of thesis topics.
- Some people find them to be quite fun too...

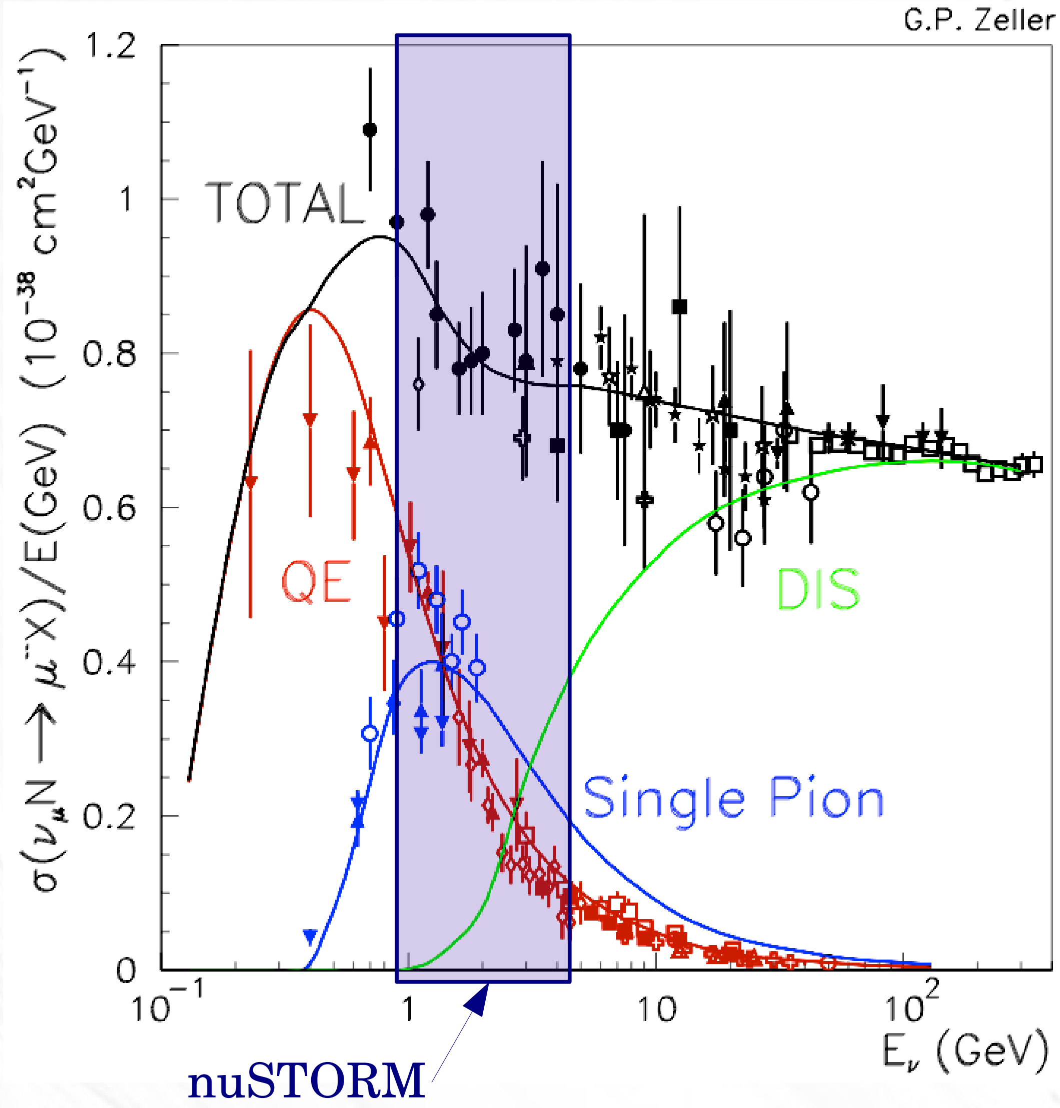
State of the Art - ν_μ

CCQE
$\nu_\mu + n \rightarrow \mu^- + p$

Single Pion
$\nu_\mu + N \rightarrow \mu^- + N' + \pi$

Inclusive
$\nu_\mu + N \rightarrow \mu^- + N' + \ldots$

Doesn't look too bad, but...



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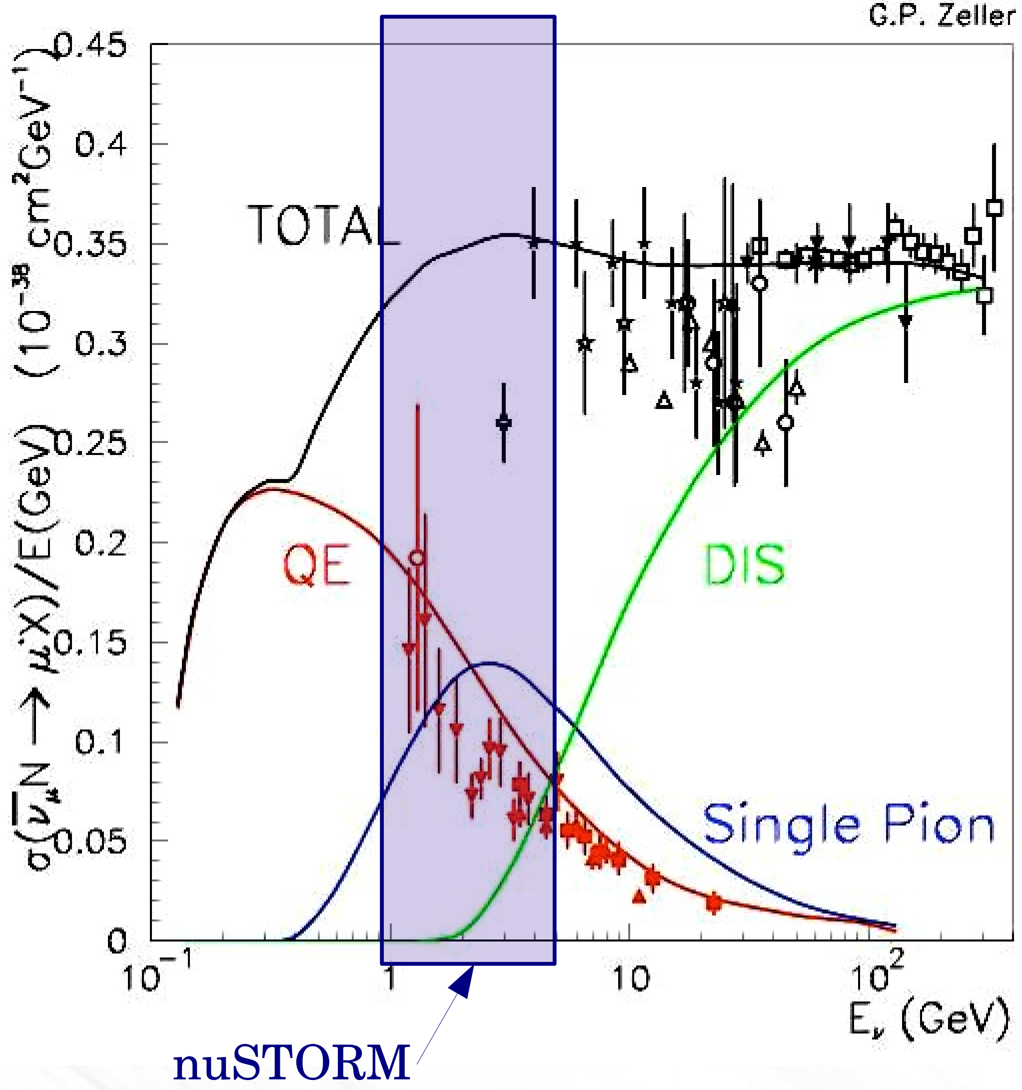
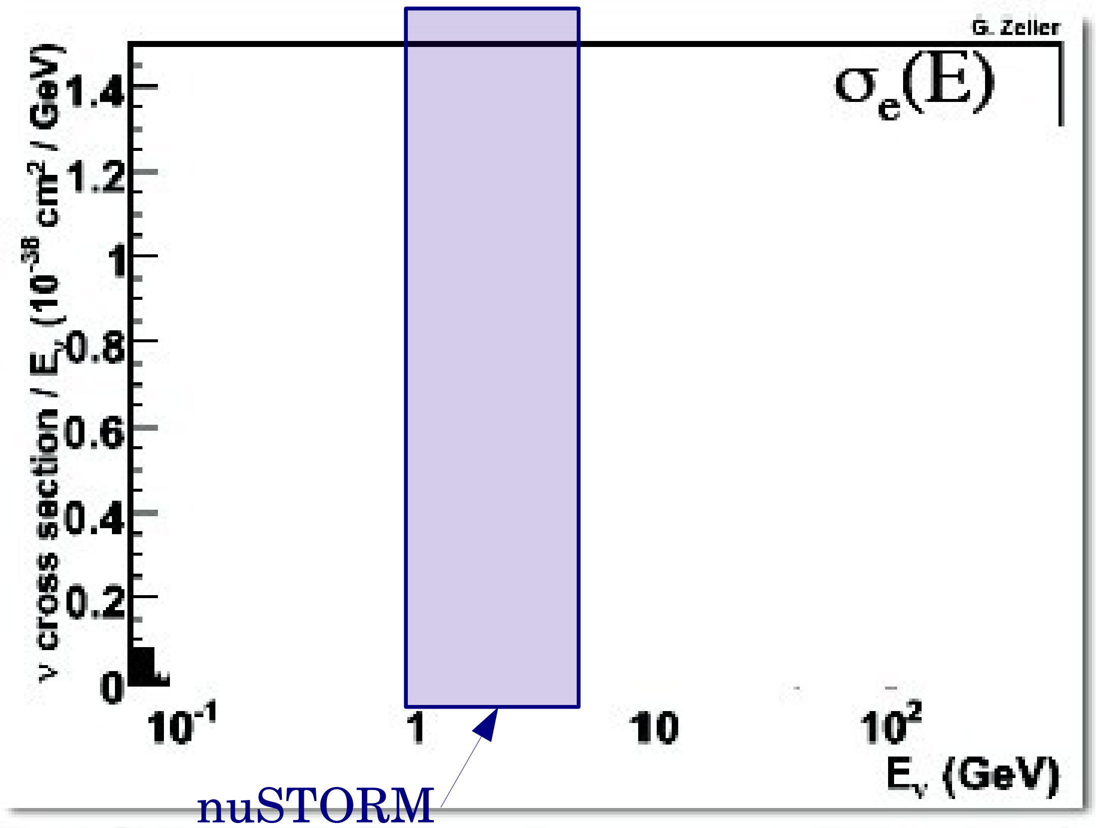
Anti-ν_μ is much sparser, and …



State of the Art - ν_e

- There are no measurements in the regions of interest.
- All experiments rely on either ν_μ/ν_e ratio, or 'extrapolating' ν_e.



Neutrino Interaction vs Final State Particles

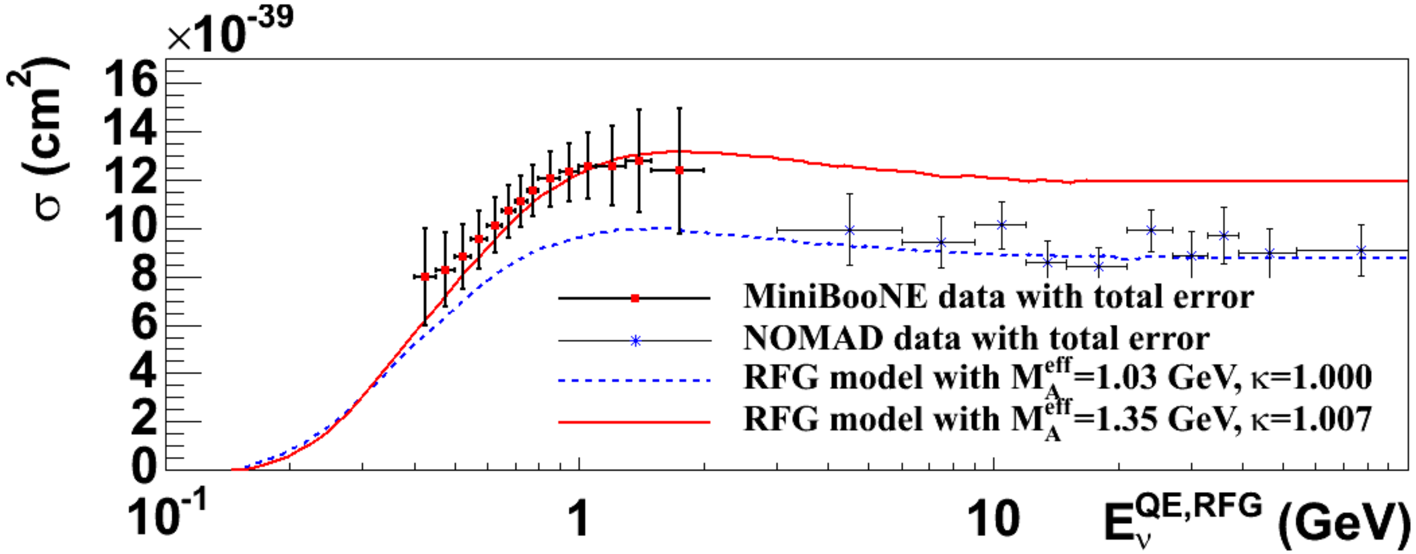
- Each experiment 'tunes M_A, and none of them agree.
- Instead of trying to force agreement, we must acknowledge that we have been measuring different things!

Experiment	Target	Cut in Q^2 [GeV^2]	$M_A[GeV]$
K2K[4]	oxygen	$Q^2 > 0.2$	1.2 ± 0.12
K2K[5]	carbon	$Q^2 > 0.2$	1.14 ± 0.11
MINOS[6]	iron	no cut	1.19 ± 0.17
MINOS[6]	iron	$Q^2 > 0.2$	1.26 ± 0.17
MiniBooNE[7]	carbon	no cut	1.35 ± 0.17
MiniBooNE[7]	carbon	$Q^2 > 0.25$	1.27 ± 0.14
NOMAD[8]	carbon	no cut	1.07 ± 0.07

Juszczak et al., PR **C82**, 045502 (2010)

Contention between MiniBooNE & NOMAD

- The models we use for x-secs are increasingly obviously wrong:



- Each experiment 'tunes' M_A, and none of them agree!

Nuclear Effects to the Rescue?

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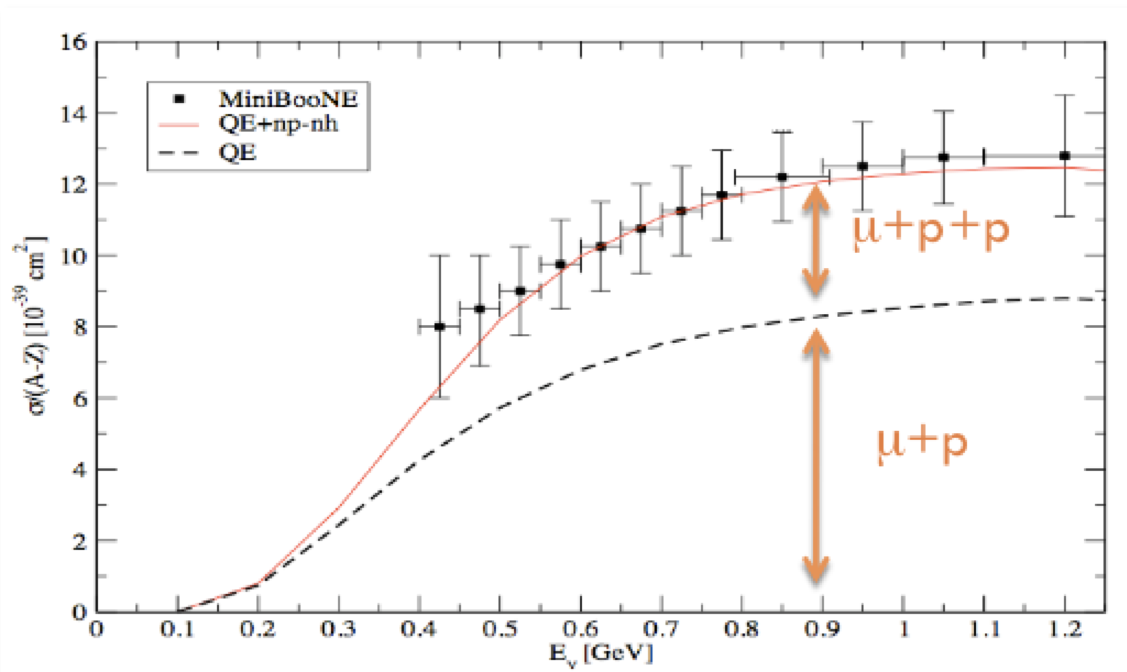
- *possible explanation*: extra contributions from multi-nucleon correlations in the nucleus (all prior calcs assume indep particles)



Martini *et al.*, PRC **80**, 065001 (2009)

- could this explain the difference between MiniBooNE & NOMAD?

NOMAD: μ & μ + p

MiniBooNE: μ + no π's + any # p's

jury is still out on this

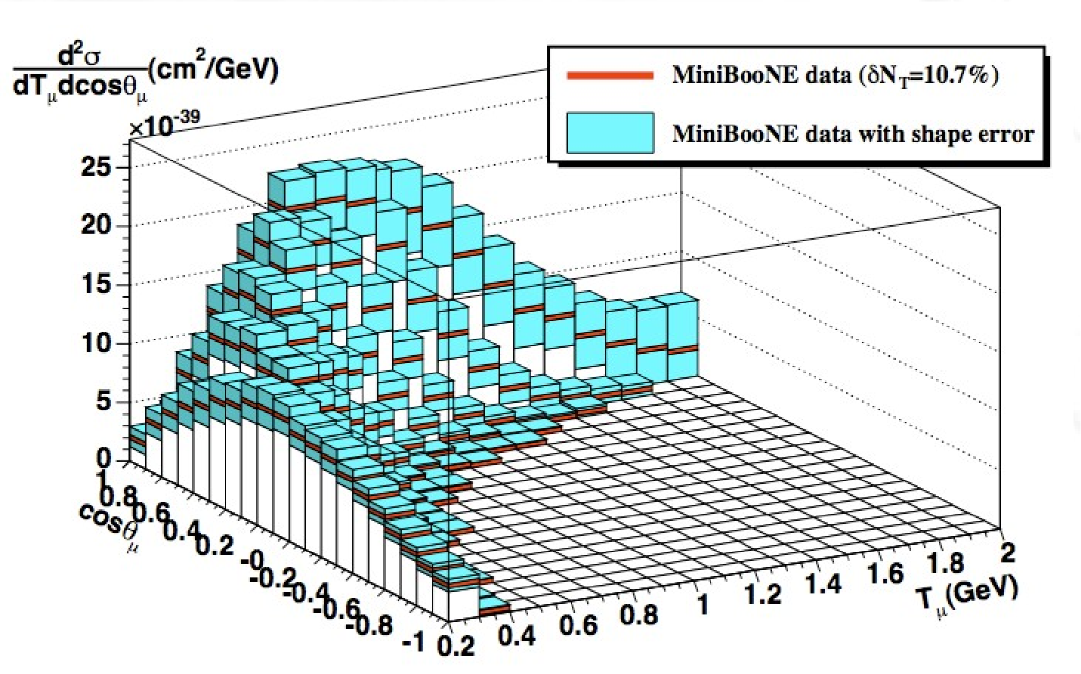
need to be clear what we mean by "QE"

S. Zeller, SBL Workshop, May 2011

additional nuclear effects contribute ~40% more x-sec & produce a multi-nucleon final state (μ+p+p)

Neutrino Interaction vs Final State Particles

- Instead, record exactly what you're measuring.
  - Report x-sec in terms of final states, not CCQE, single pion, DIS, etc.
  - Make a doubly differential measurement.



Aguilar-Arevalo et al., PRD 81, 092005 (2010)

Which Measurements to Make?

- Theorist answer:
  - 'Free Nucleon' sample, removes nuclear effects, e.g. LH2
  - Multiple target materials, with a range of Z
  - Doubly differential
- Experimentalist answer:
  - 'Final state' particles
  - Allow accurate prediction of event topology in future experiments

Difficulties of Measurements

- Even with the excellent characteristics of a stored muon beam:
  - There are many measurements to make.
  - One detector is not going to be sufficient.
- Multiple targets means multiple detectors or interchangeable target regions.
  - Target probably not instrumented, how do you decide where event came from?

Example from T2K's ND280

- Two regions: Tracker + ECal & π^0 Detector
  - ECal & P0D designs were changed to accommodate 'cross-check' measurements
  - Both were asked to reconstruct and measure 50 MeV photons and 2 GeV electrons.
    - “If you're not breeding for something, you're breeding against it”
    - Primary measurements suffered due to secondary requirements.

Proposed Software

- A framework for evaluating detector designs:
  - Simulate a rough detector geometry using GENIE and GEANT4
  - Fake a reconstruction:
    - If <experiment> can do it, so can we.
  - Evaluate the success of measuring given final state channels, e.g. e^- + p, single π^0...

Goal

- Produce a 'confusion matrix' for each detector design:
  - Estimate resolutions on: E_ν, θ_μ, etc.
  - Probability of missing extra particles: p, n, π^0
- Find a complementary set of detectors, covering 'all' measurements with reasonable efficiency
  - Cost considerations, detector technologies…

Conclusions

- Neutrino cross-sections are important.
  - They aren't well known, and the models aren't very good.
  - Especially true for electron neutrinos.
- νSTORM could be a perfect solution, but we need to build the right detectors.
- Ed Santos will now present the work to date.