MiniBooNE Quasi-Elastic Events

DNP '04
Friday 29th October, 2004

- Motivation and detector overview
- Flux and cross sections
- Reconstruction and results
- Summary and outlook

Chris Green
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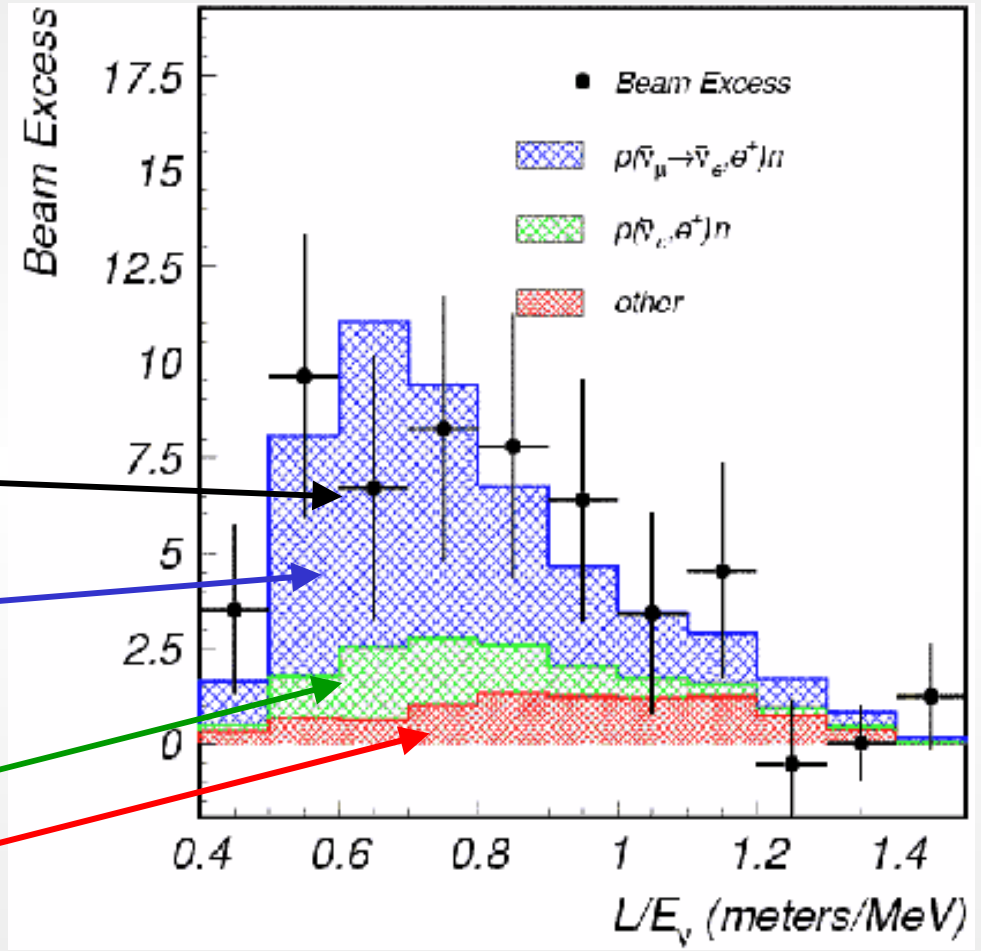
Oscillations and LSND

- Signal over background: 87.9 ± 22.4 ± 6.0 events
- Oscillation probability: (0.264 ± 0.067 ± 0.045) %

➔ 3.8σ result!



Data points after beam-off subtraction

Expectation for oscillation

Beam related backgrounds

The MiniBooNE collaboration

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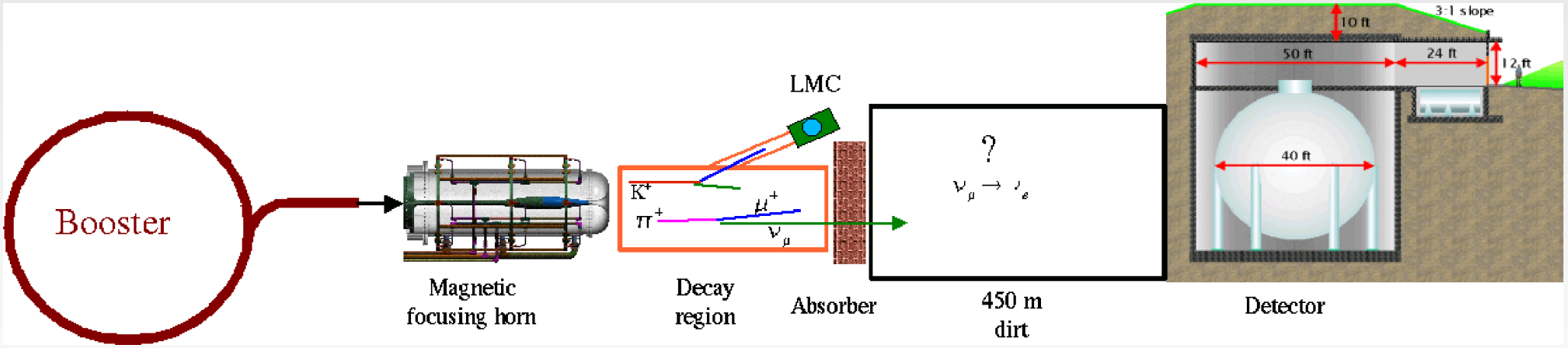
BooNE

The MiniBooNE beamline

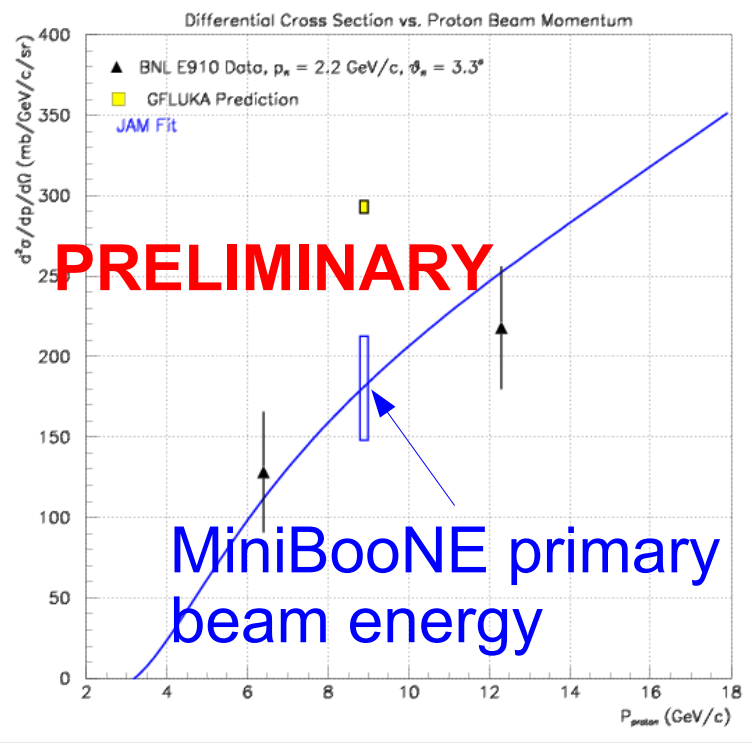


- 8 GeV protons from FNAL Booster strike beryllium target in 1.6μs spills of ~4.5×10^{12};
- Magnetic horn to focus decay products, pulse 170kA at ~5Hz average rate;
- Monitoring systems for primary & secondary beams;
- Little Muon Counter helps measure ν_e background from kaons (7° to beam direction).

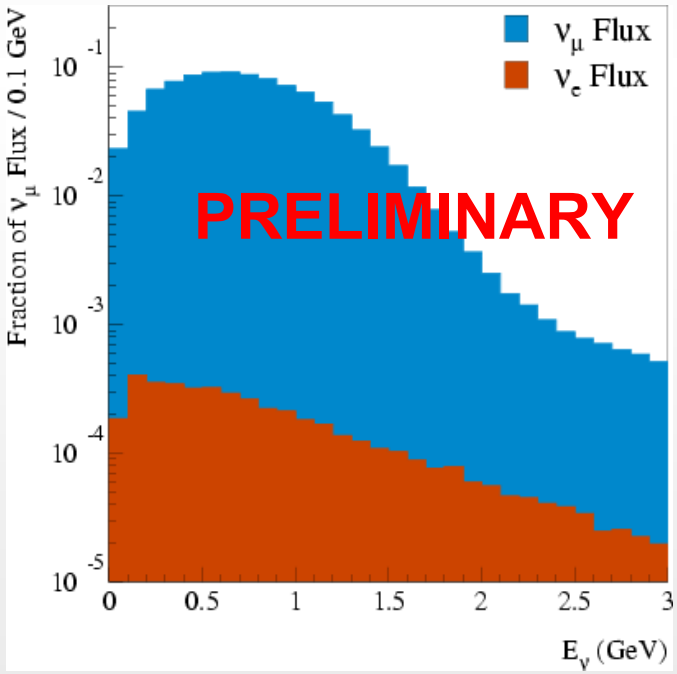
Modelling the flux

$$\frac{d^2\sigma}{dp\,d\Omega} = W_1 p_\pi^{W_2}\left(1-\frac{p_\pi}{p_{proton}}\right) \times \exp\left(\frac{-W_3 p_\pi^{W_4}}{p_{proton}^{W_5}} - W_6\theta_\pi\left(p_\pi - W_7 p_{proton}\cos^{W_8}\theta_\pi\right)\right)$$

- Need "modern" Sanford Wang fit to relevant low-energy data
- Use Be target data from E910 (BNL) & HARP (CERN)



- Beam simulated using Geant 4, with meson production models from MARS (kaons) & Sanford-Wang fits (pions)



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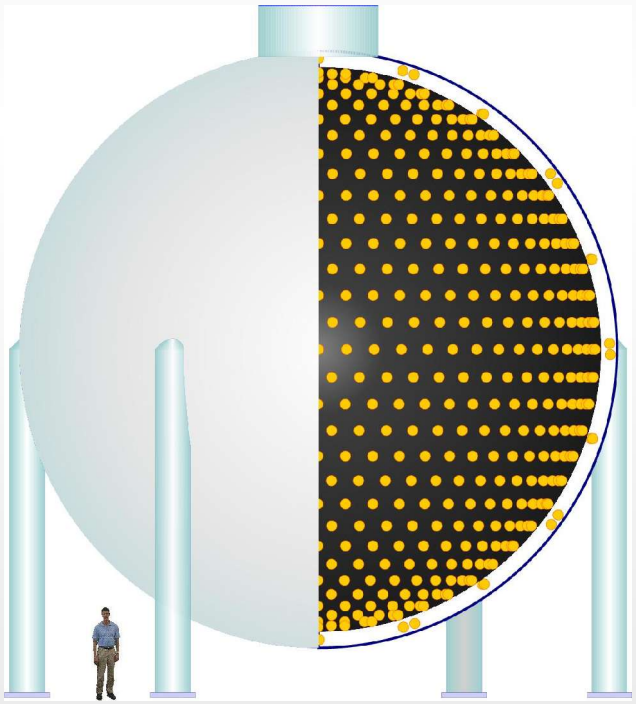
BooNE

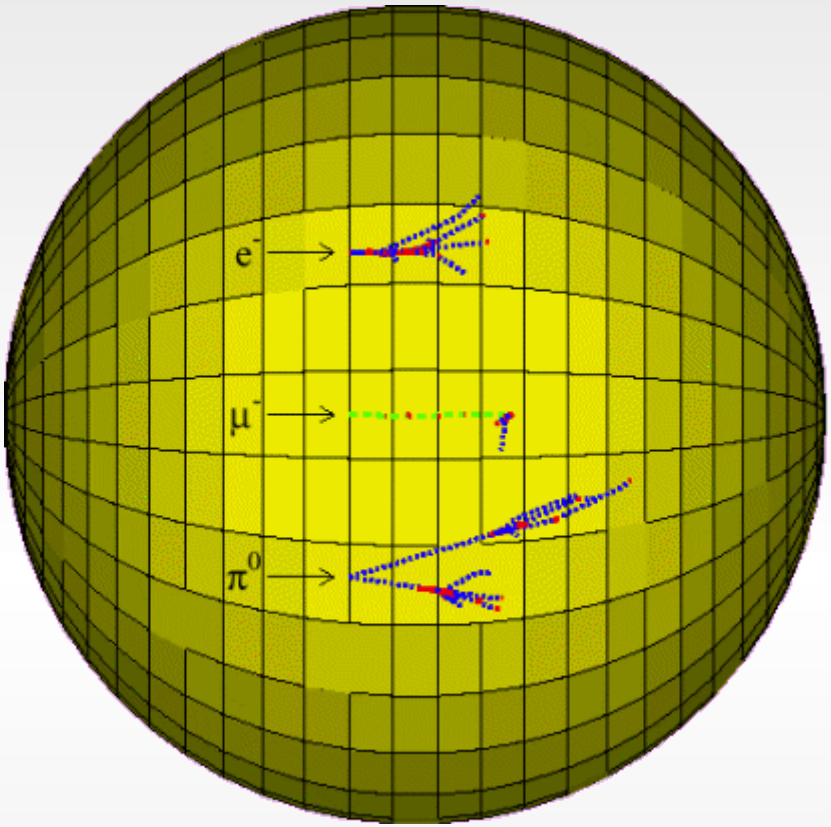
The MiniBooNE detector

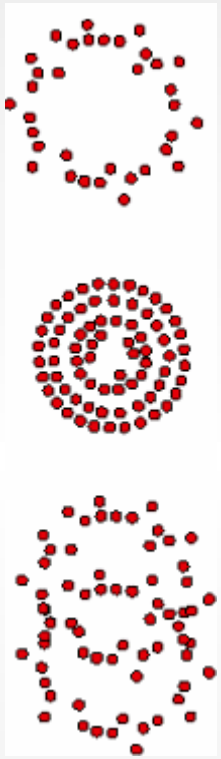
- 12m diameter sphere
- 250,000 gallons of white mineral oil
- Optically isolated inner region with 1280 PMTs (10% coverage)



- Veto region (240 PMTs)
- Primary DAQ electronics: some new, most recycled from LSND
- All new DAQ and analysis software
- In-situ calibration systems: cosmic ray muon tracker, laser, etc

Particle ID

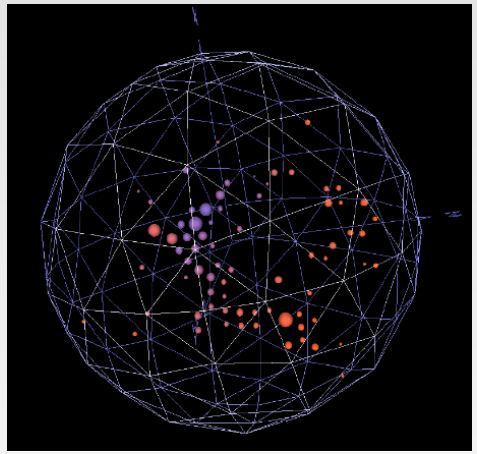


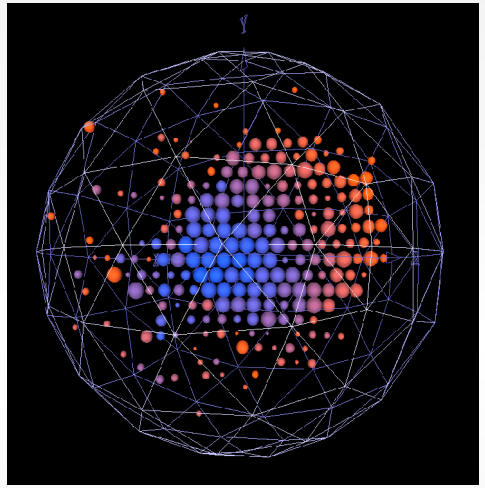


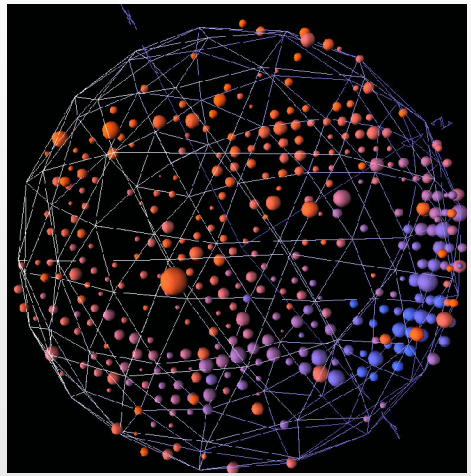
Michel e candidate

Beam μ candidate

Beam π^0 candidate



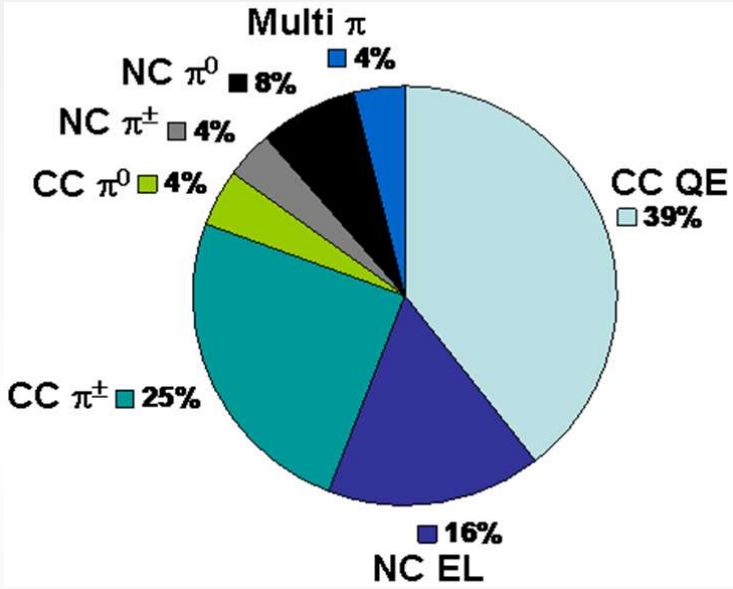


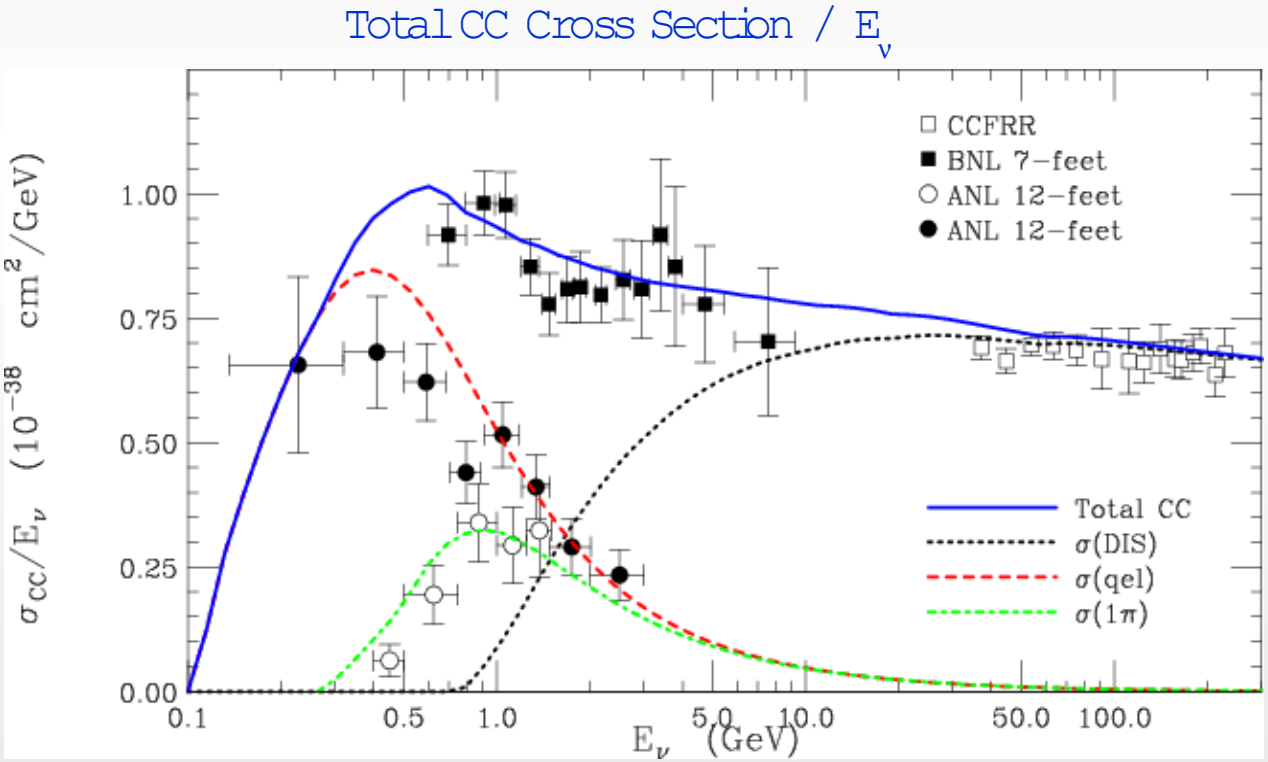


- Identify electrons (and thus candidate ν_e events) from characteristic hit topology

ν cross sections at MiniBooNE

- Cross sections and events modelled using Nuance v3 (IMB, SuperK / K2K, D. Casper)





P. Lipari, Nucl. Phys. Proc. Suppl. 112, 274 (2002) (NuInt01)

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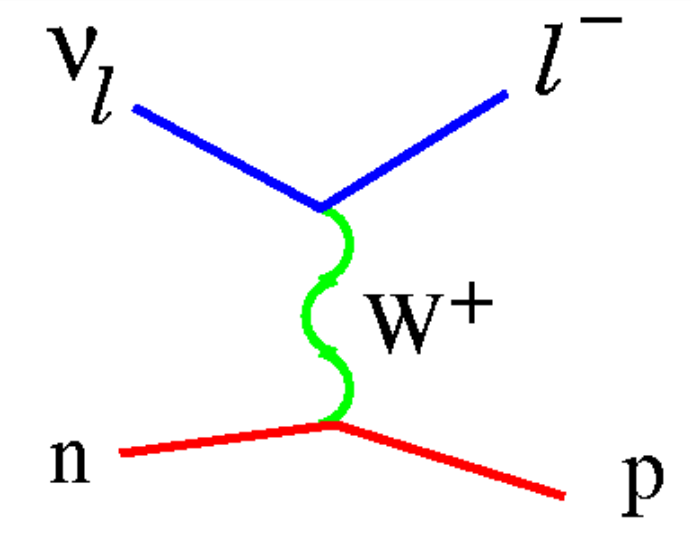
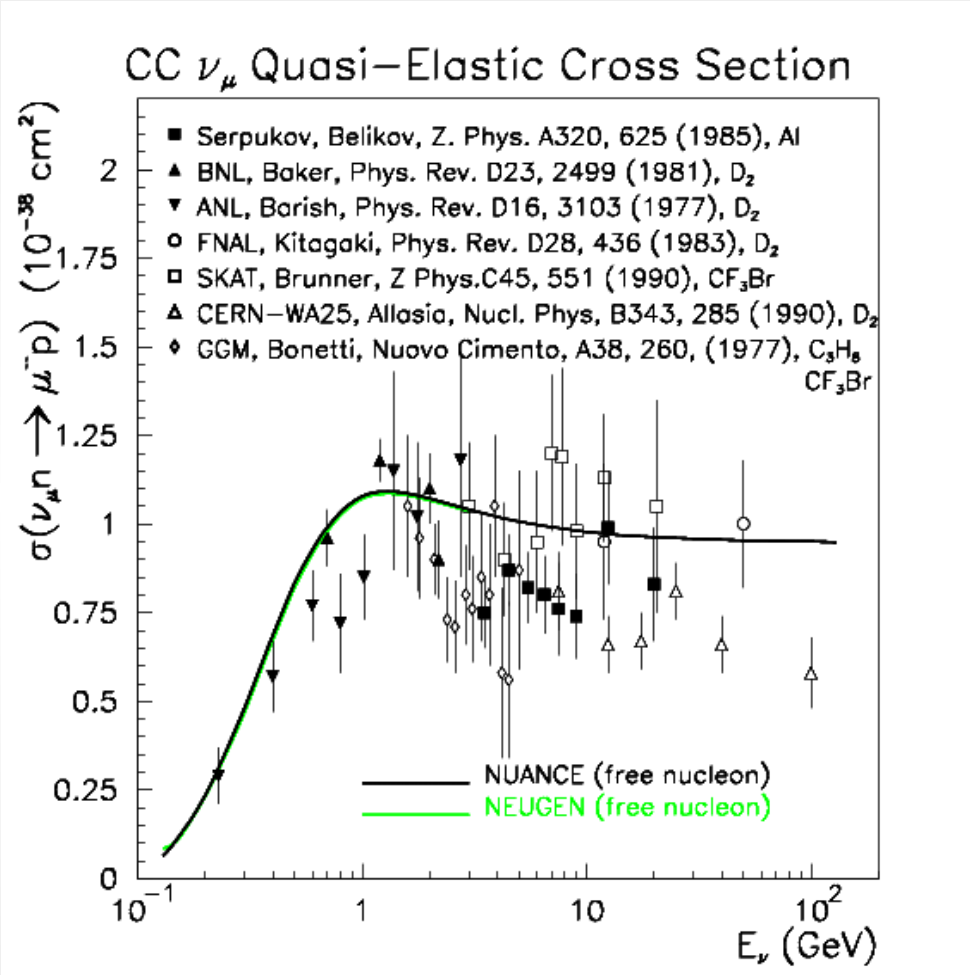
BooNE

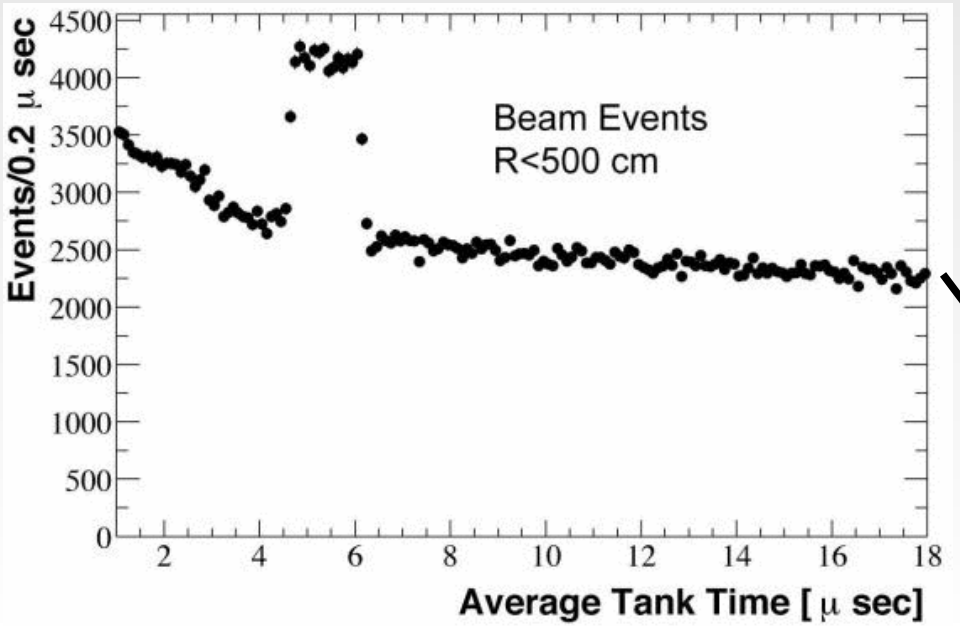
Charged current QE cross sections

- Understanding of signal and relevant backgrounds essential to understand flux and measure oscillations
- Dominant process at $E_\nu \sim 1$GeV: 40% of MiniBooNE beam

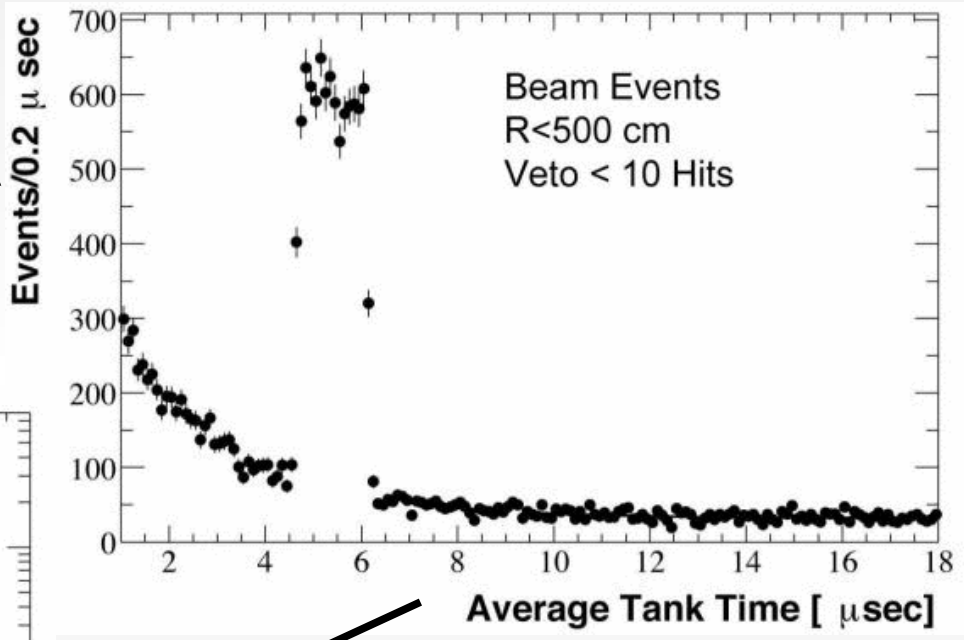


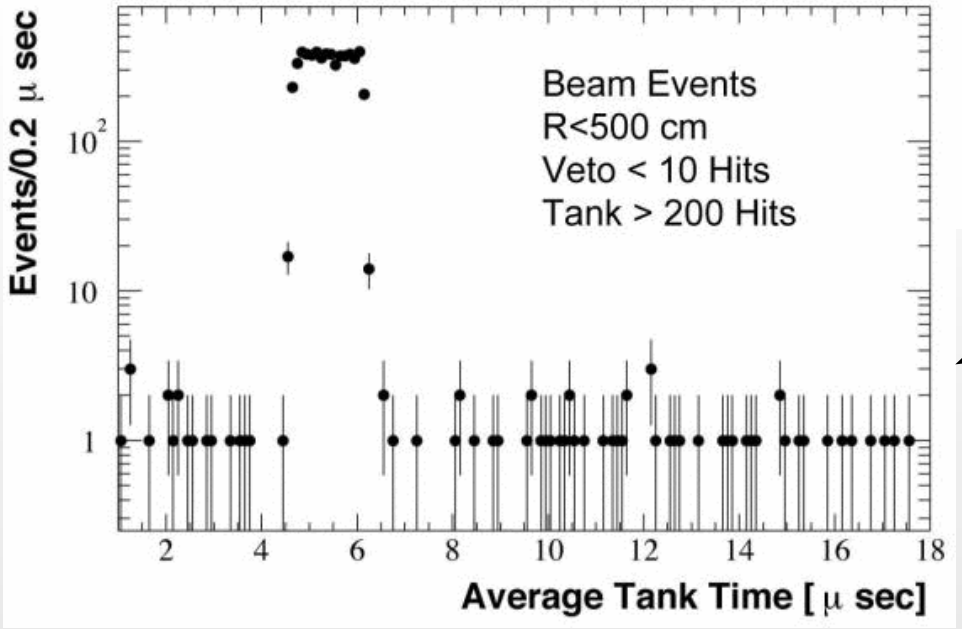


ν beam events



- Clean recognition of beam neutrino events with simple cuts





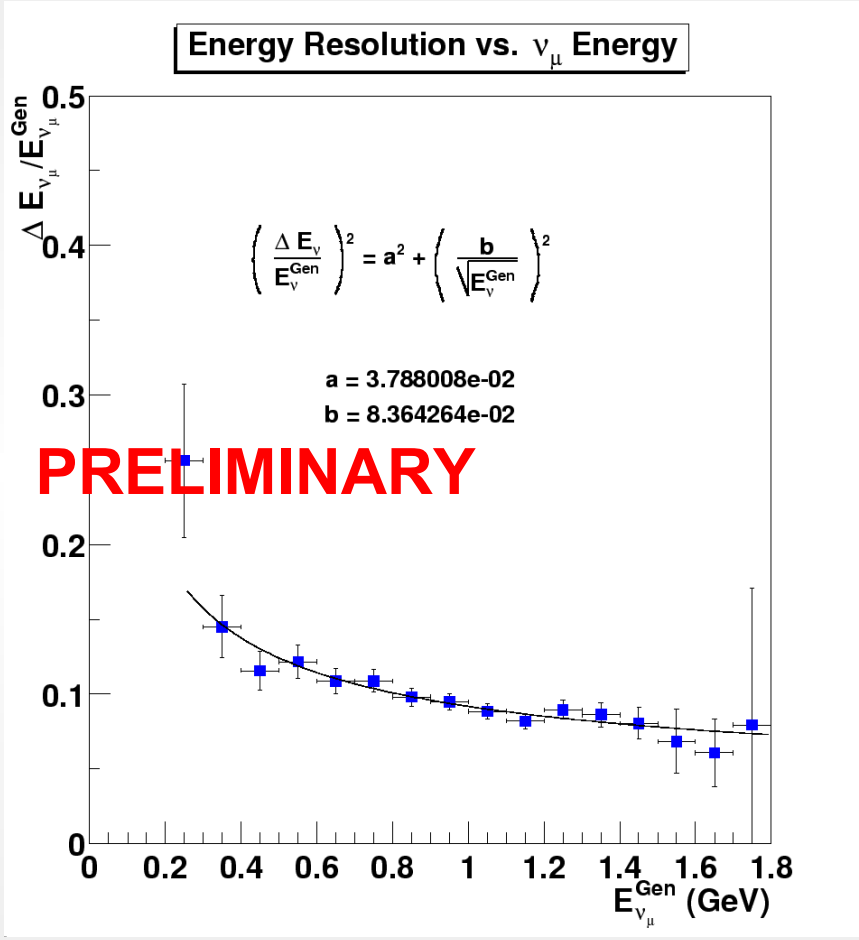
Charged current QE reconstruction

- Muon Cherenkov ring detected (measure momentum)
- Topological, timing cuts
- ~80% pure, ~50% efficient in an r = 5m fiducial volume
- Reconstruct E_ν from E_{vis}:

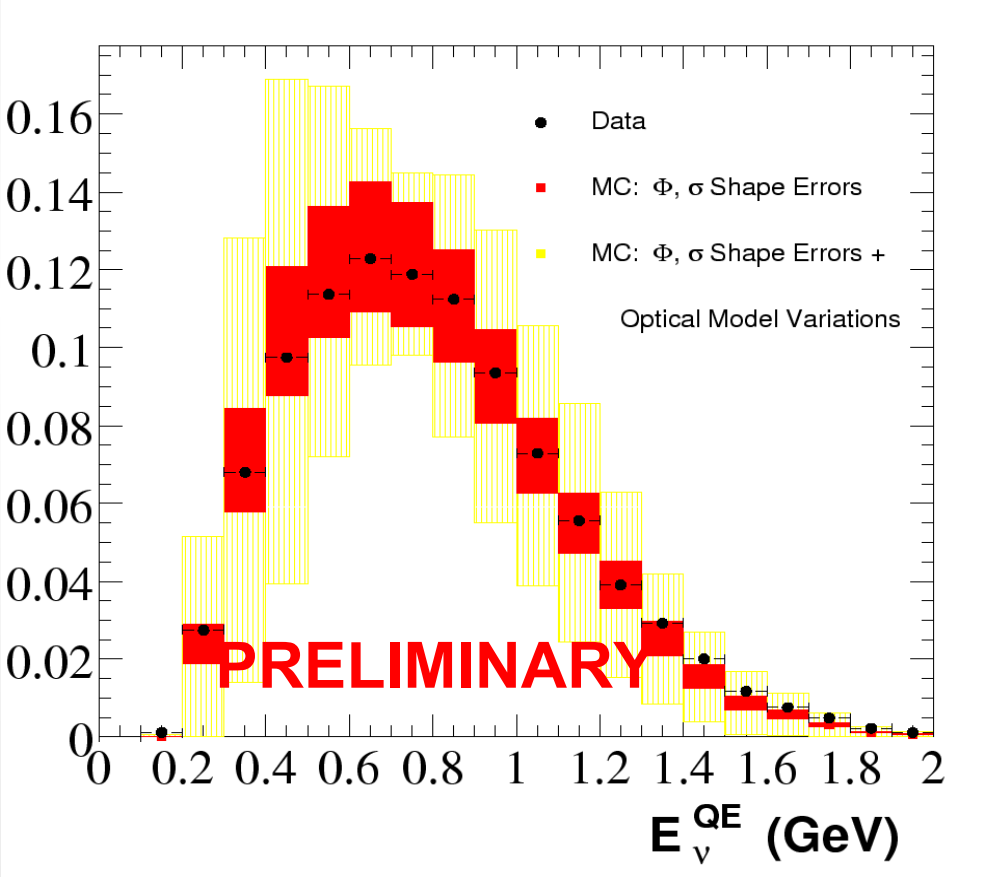
$$E_\nu^{QE} = \frac{1}{2}\frac{2M_p E_\mu - m_\mu^2}{M_p - E_\mu + \sqrt{(E_\mu^2 - m_\mu^2)}\cos\theta_\mu}$$

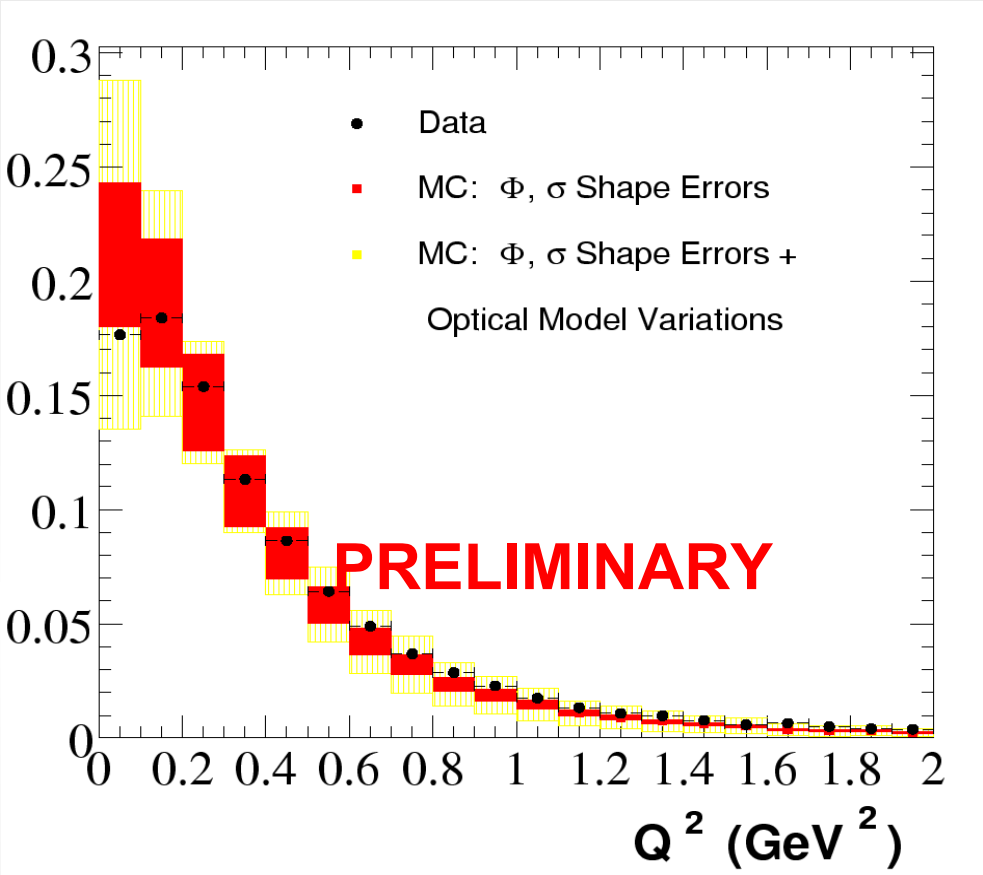
- Reconstruct Q^2:

$$Q^2 = 2E_\nu E_\mu(1 - \beta_\mu \cos\theta_\mu) - m_\mu^2$$



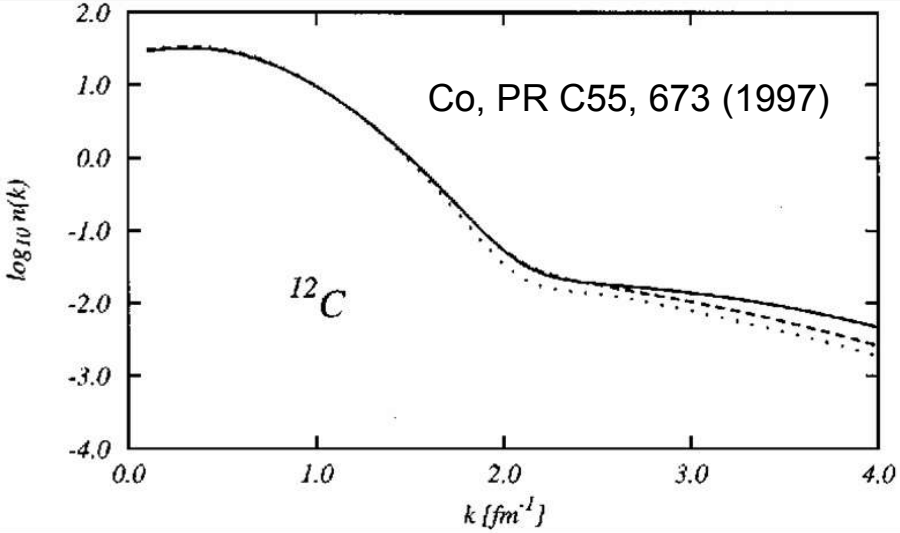
Charged current QE results

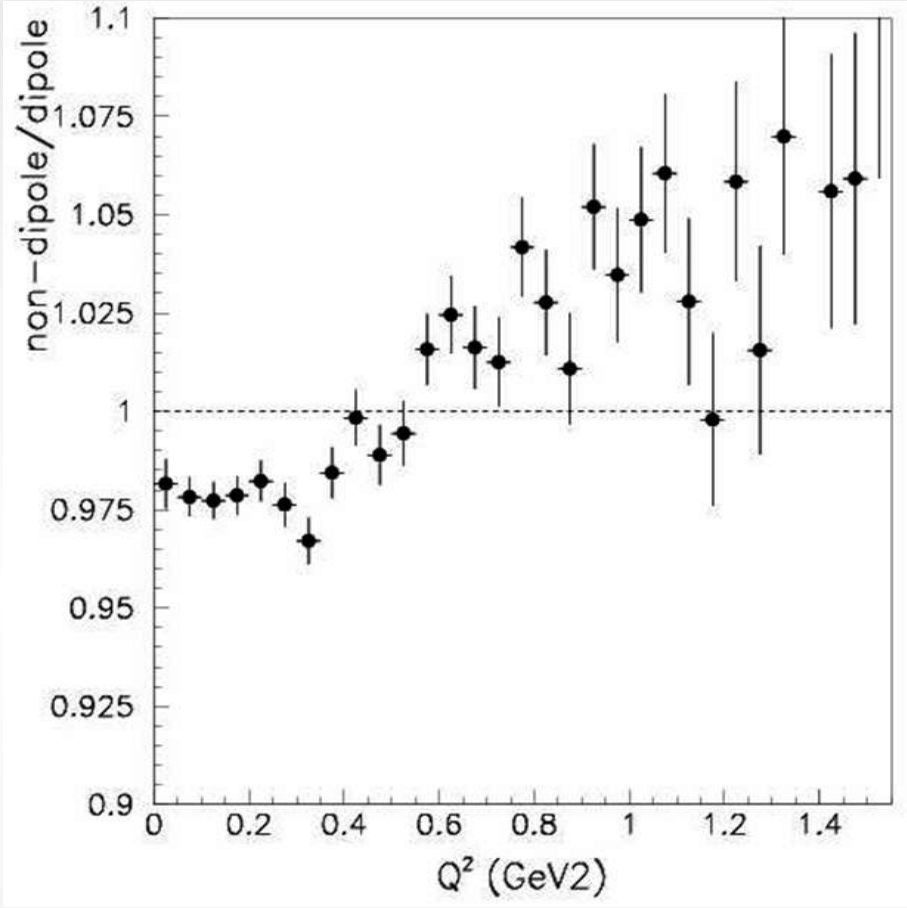




Charged current QE interactions in Nuance

- Use Smith-Moniz Fermi gas model (known problems): improve (Co)?
- Pion absorption, charge exchange from pion data





- Non-dipole vector form factors: Bosted, Phys. Rev. C51, 409 (1995)
- Other Improvements: shadowing (PL B227, 481 (1989)), effective mass corrections, e-p data (nucl-th/0409078)?

Summary and outlook

- ~148K CCQE events so far, more expected
- Good E_ν reconstruction
- Improved optical model and uncertainties coming soon
- HARP data expected to improve S-W fit
- Improved FSI / nuclear model on the way: more ideas? Code!