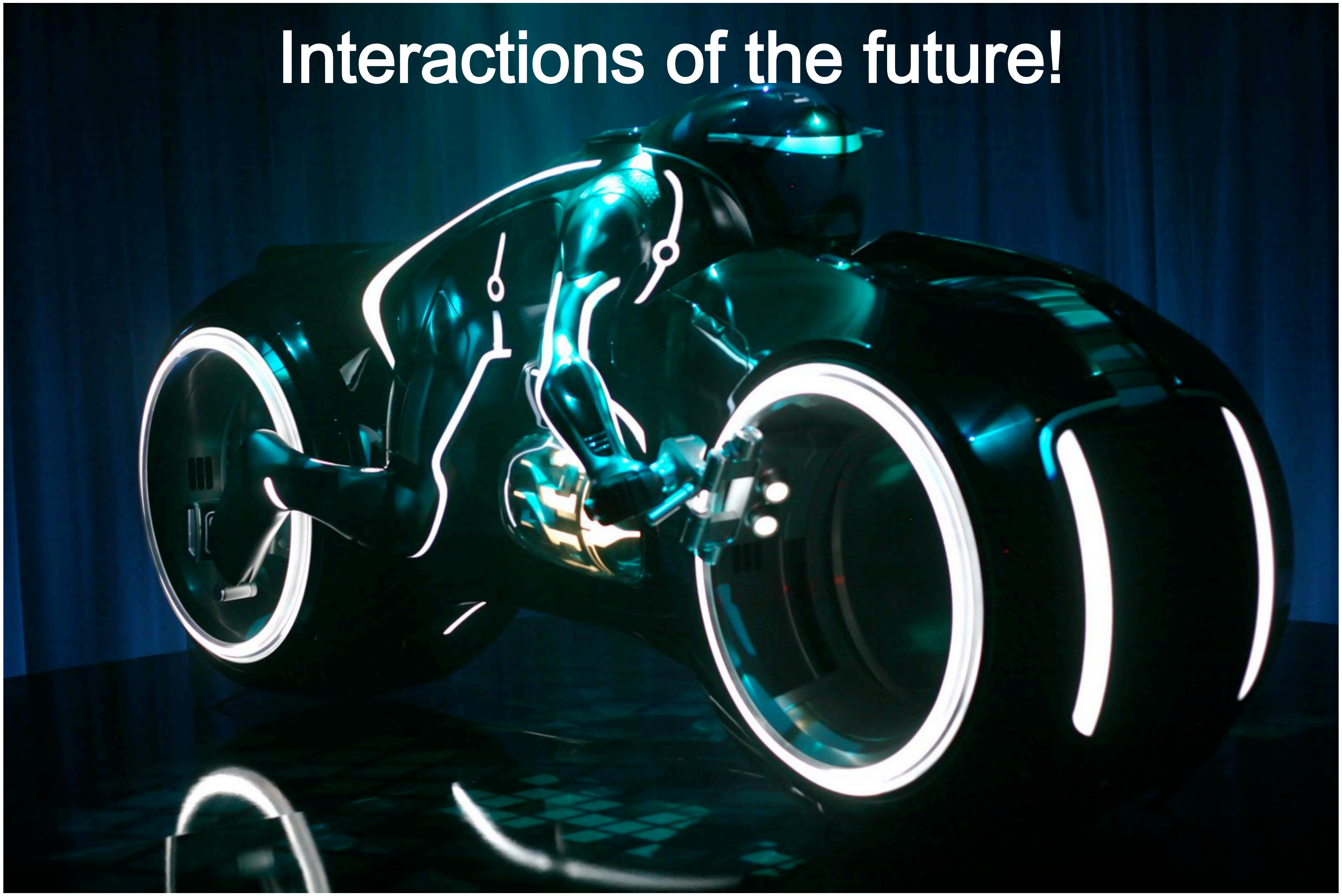
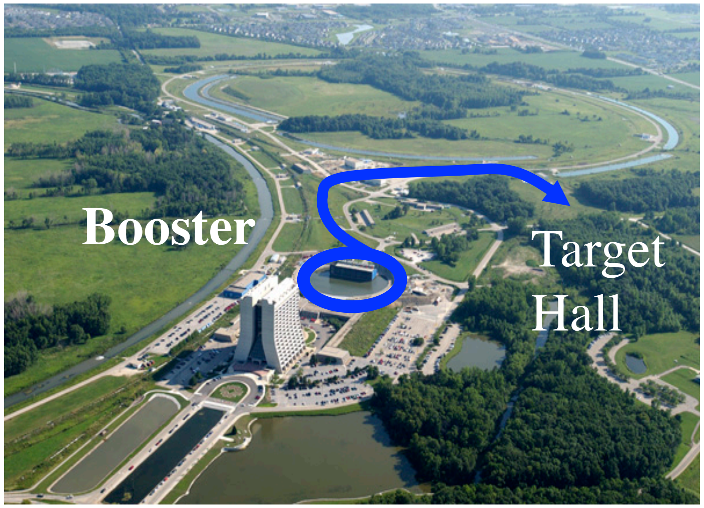
MiniBooNE Cross Section Results



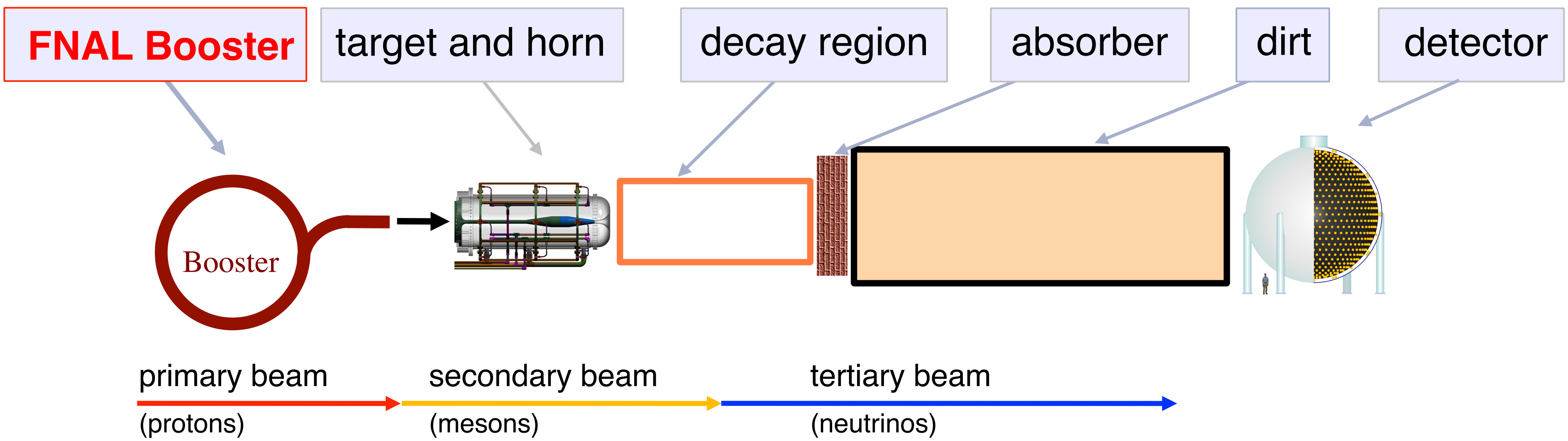
MiniBooNE Neutrino Beam



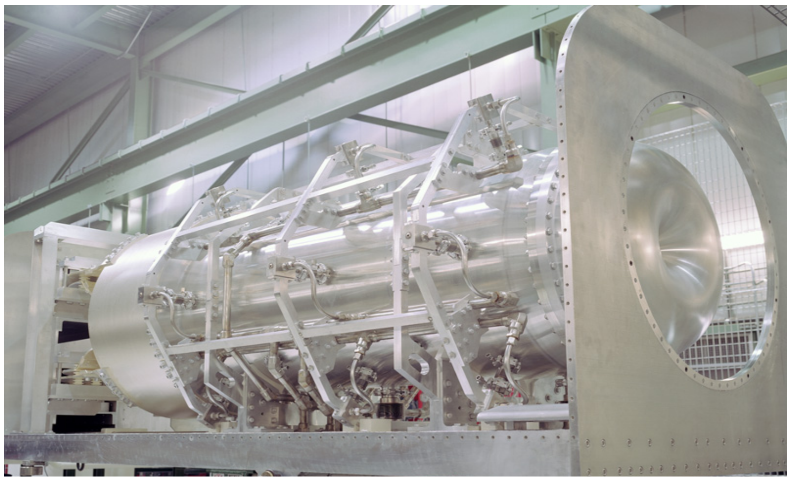
8.9 GeV/c momentum protons extracted from Booster

Directed on to a Beryllium

Maximum rate of 5 Hz



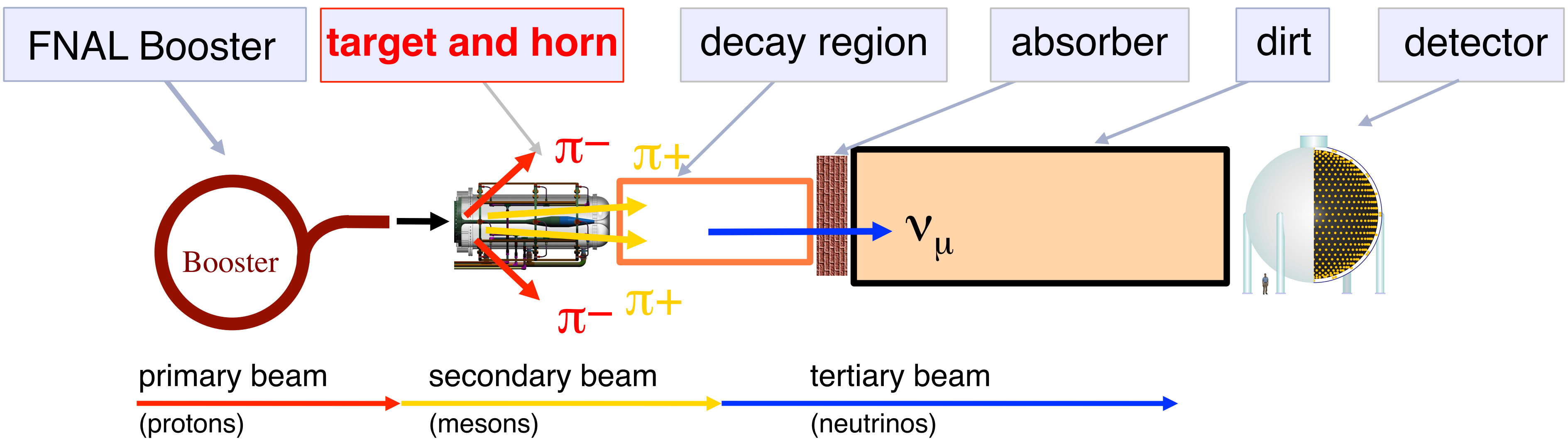
MiniBooNE Neutrino Beam



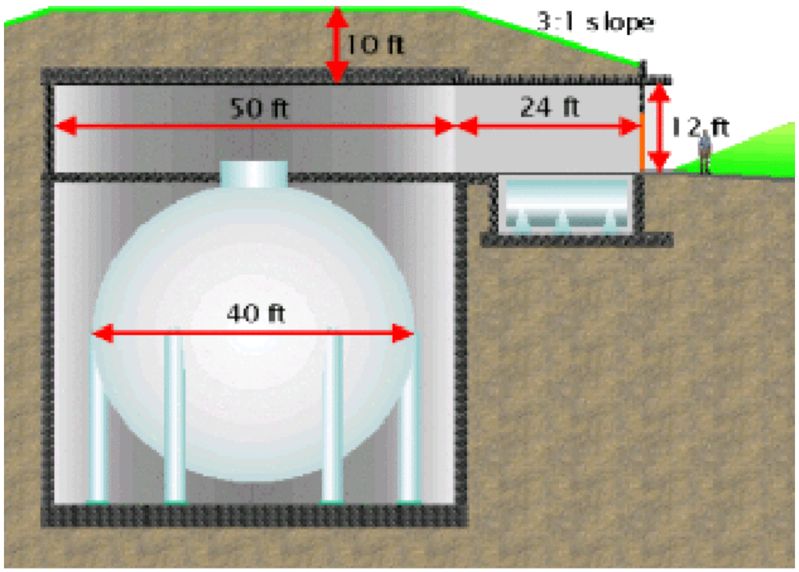
Magnetic horn with reversible polarity

Focuses either neutrino or anti-neutrino parent mesons

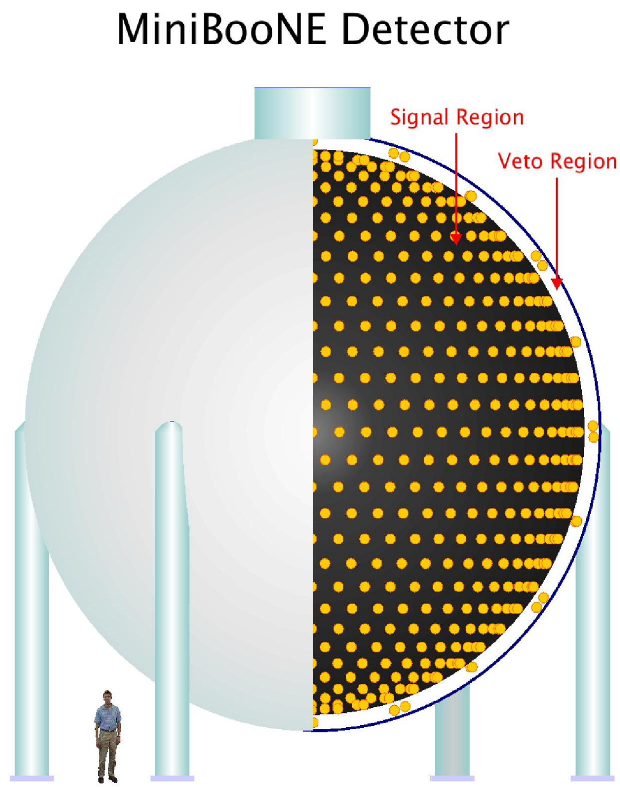
Collect data in neutrino, anti-neutrino mode, <E_ν> ~700 MeV



MiniBooNE Detector



Detector



Nucl. Instr. Meth. A599 (2009) 28-46

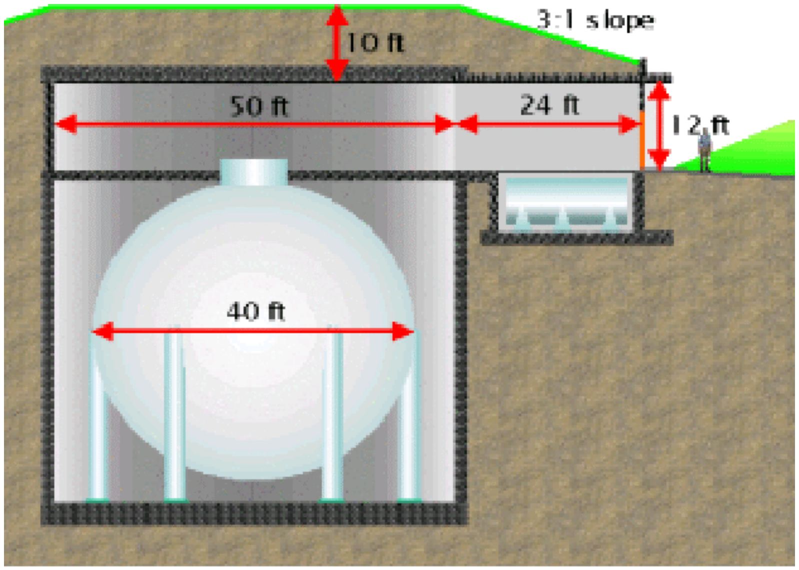
12.2 meter diameter sphere

Pure mineral oil, interactions on CH_2

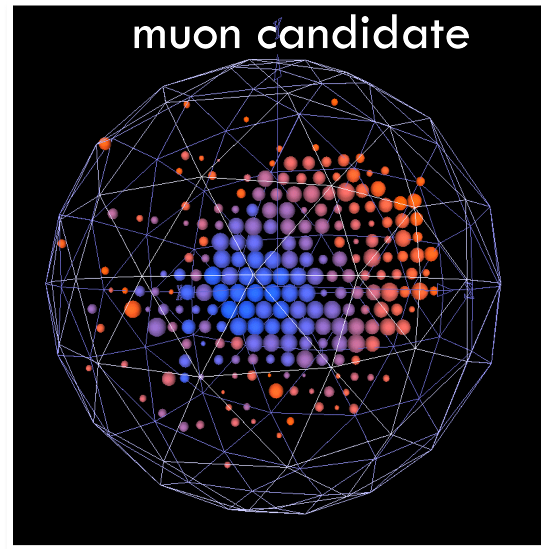
2 regions

- Inner light-tight region, 1280 PMTs (10% coverage), 4π coverage
- Optically isolated outer veto-region, 240 PMTs

MiniBooNE Detector



Detector

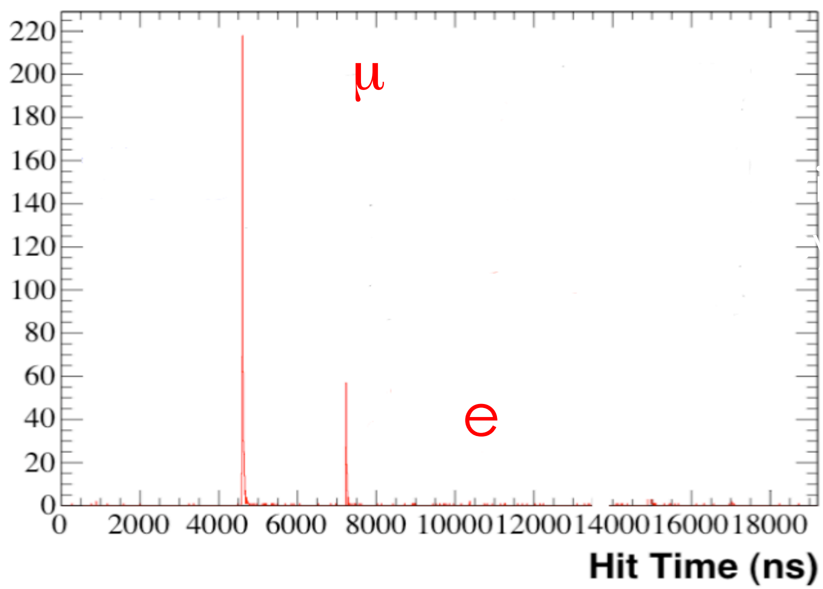


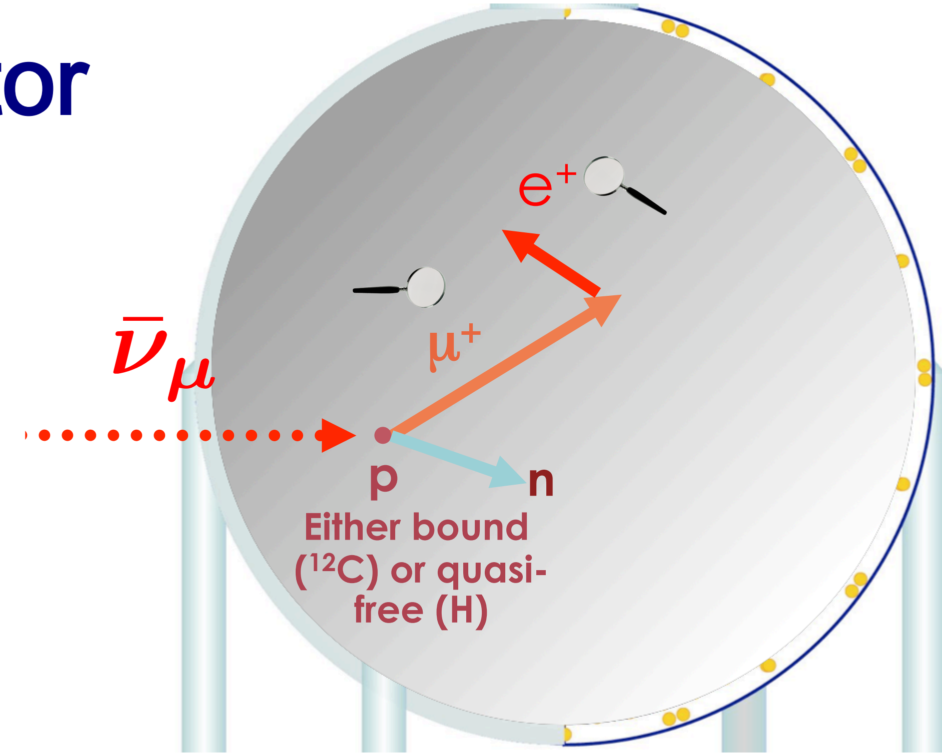
Cerenkov detector → ring imaging for event reconstruction and PID, use particle decays for event ID ($\mu \rightarrow e$, $\pi^+ \rightarrow \mu \rightarrow e$)

Separate clusters of PMT hits in time

Scintillation light enables NC EL measurement

MiniBooNE Detector





Cerenkov detector → ring imaging for event reconstruction and PID, use particle decays for event ID ($\mu \rightarrow e$, $\pi^+ \rightarrow \mu \rightarrow e$)

Separate clusters of PMT hits in time

Scintillation light enables NC EL measurement

Measuring a Cross Section

$$\sigma = \frac{N_{obs} - N_{bgd}}{\Phi * N_{targets} * \varepsilon}$$

Flux of incoming particle beam

Targets seen by beam

Efficiencies of event selection

Precision xsecs require firm knowledge of flux!

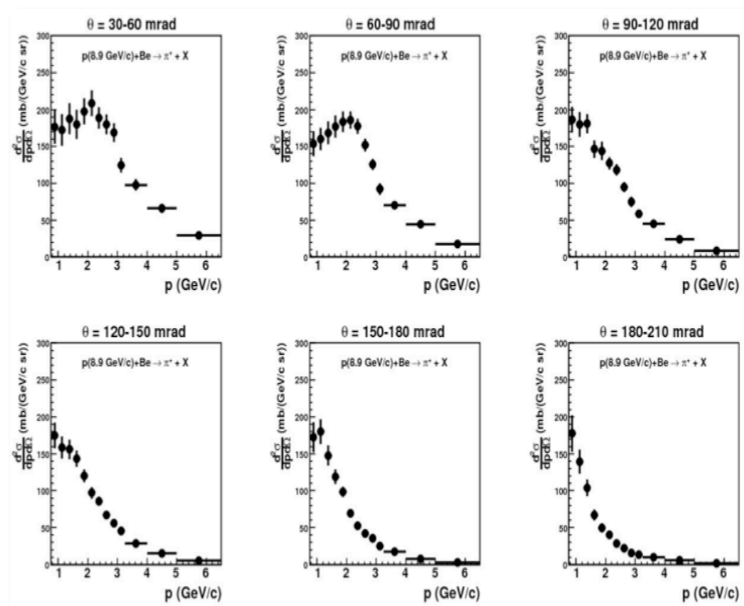
Use external data for flux prediction → no in-situ tuning!

HARP: dedicated hadro-production expt

same beam E, exact replica target

BNL E910

Overall 9% flux uncertainty, dominates error on xsec measurement

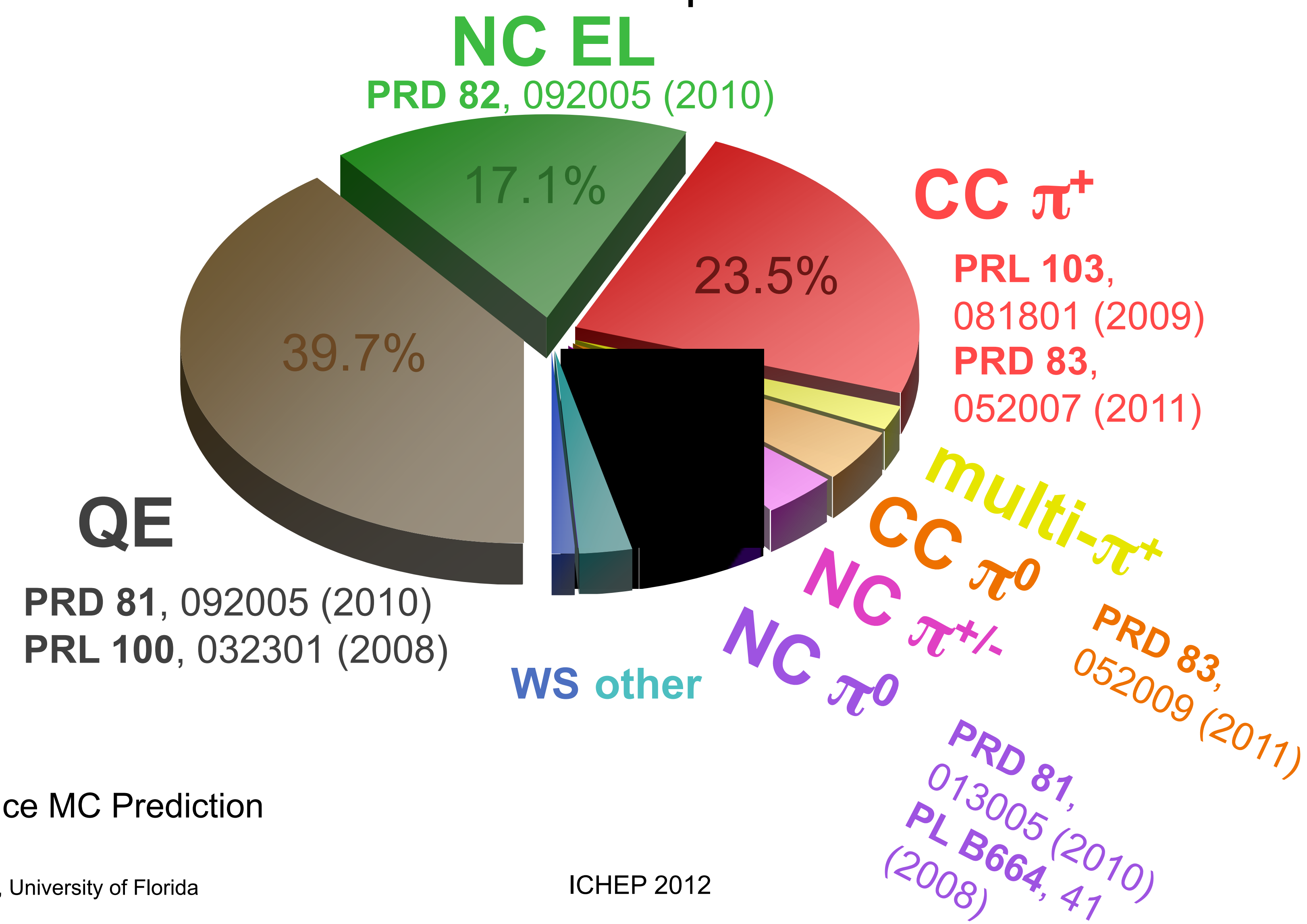


M. Catanesi *et al.*, Eur. Phys. J. **C52**, 29 (2007)

Neutrino Cross Sections

Collected ν data
2002-2005, 2007
6.46e20 POT

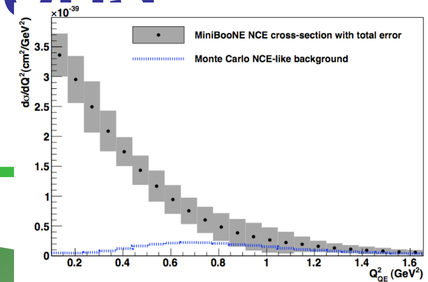
8 ν cross section publications

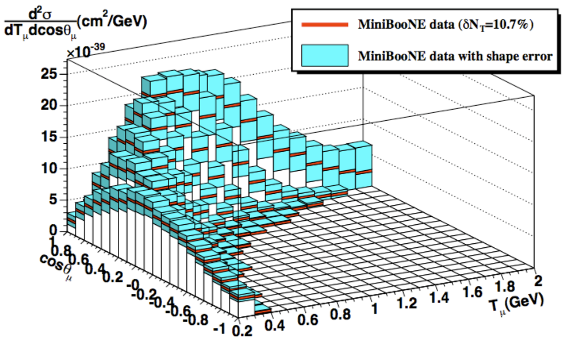


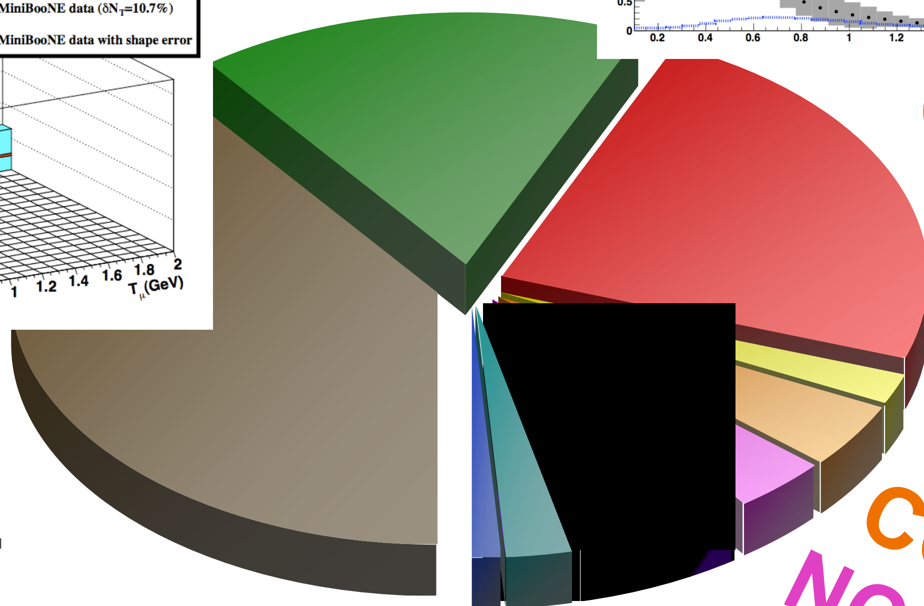
Nuance MC Prediction

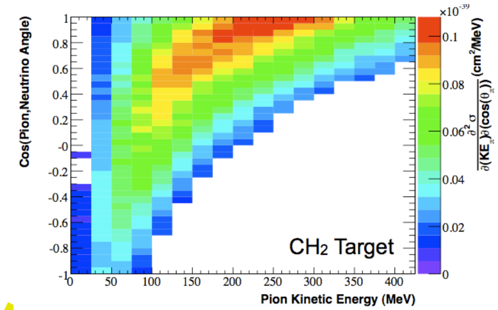
Neutrino Cross Sections

Collected ν data
2002-2005, 2007
6.46e20 POT

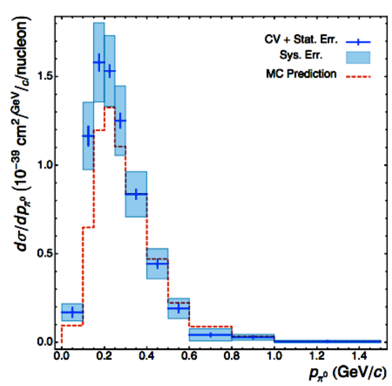


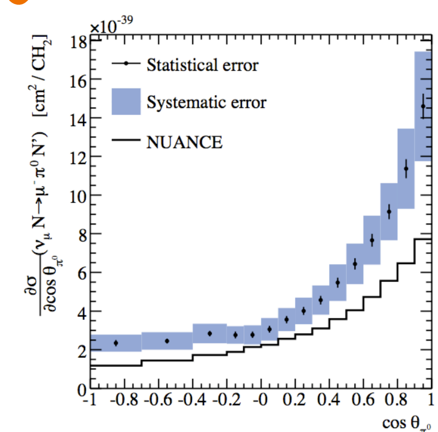




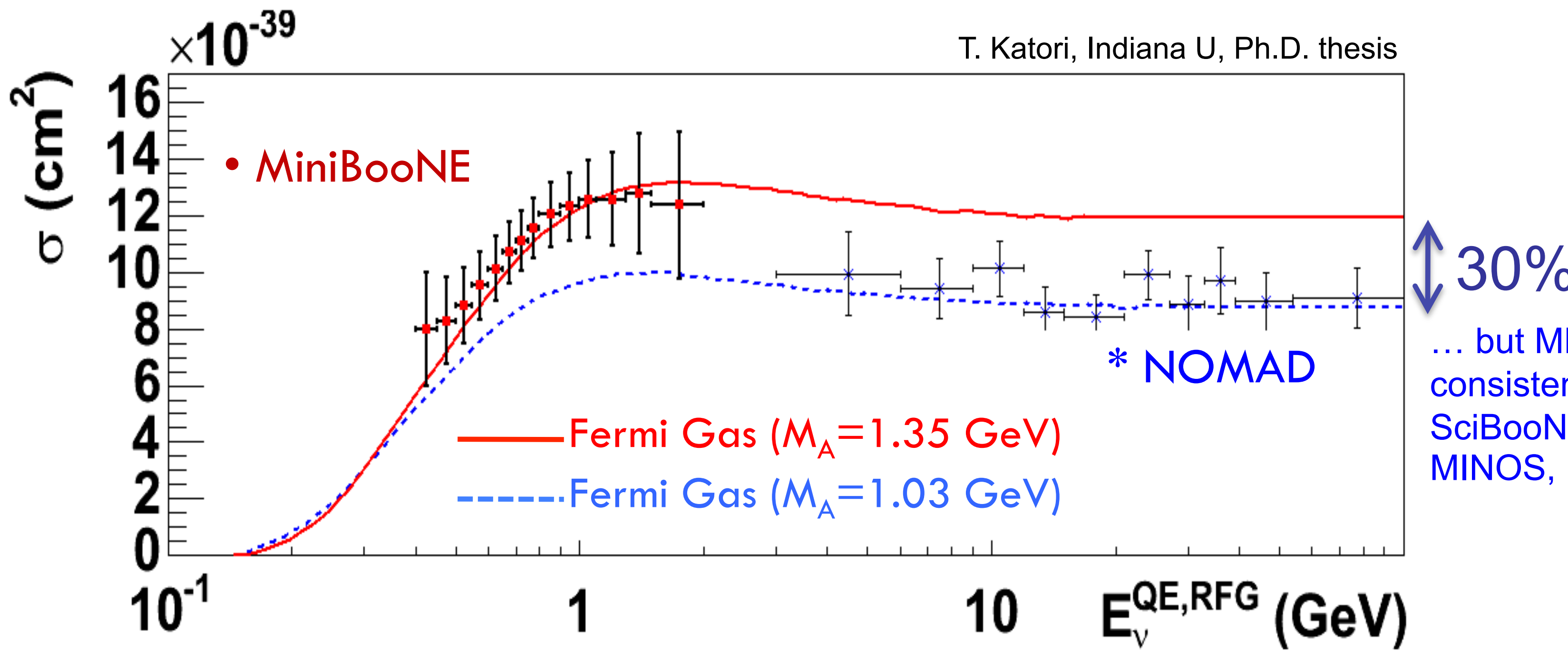


1st time full kinematics have been reported for many of these reaction channels!





Neutrino CC Exclusive Intrigue



… but MB consistent with SciBooNE, MINOS, K2K

Tension between existing CC exclusive measurements, different expts

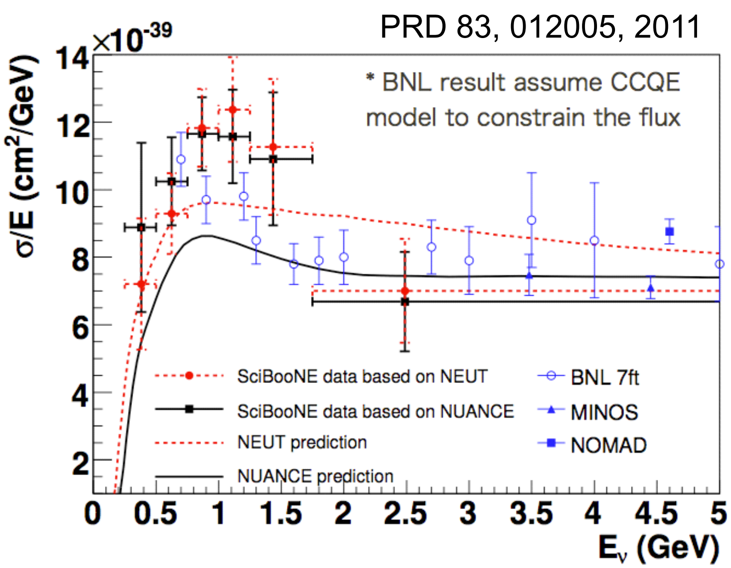
Tension between CC exclusive measurements and theory, QE, π^+, π^0
nuclear interactions may be the key

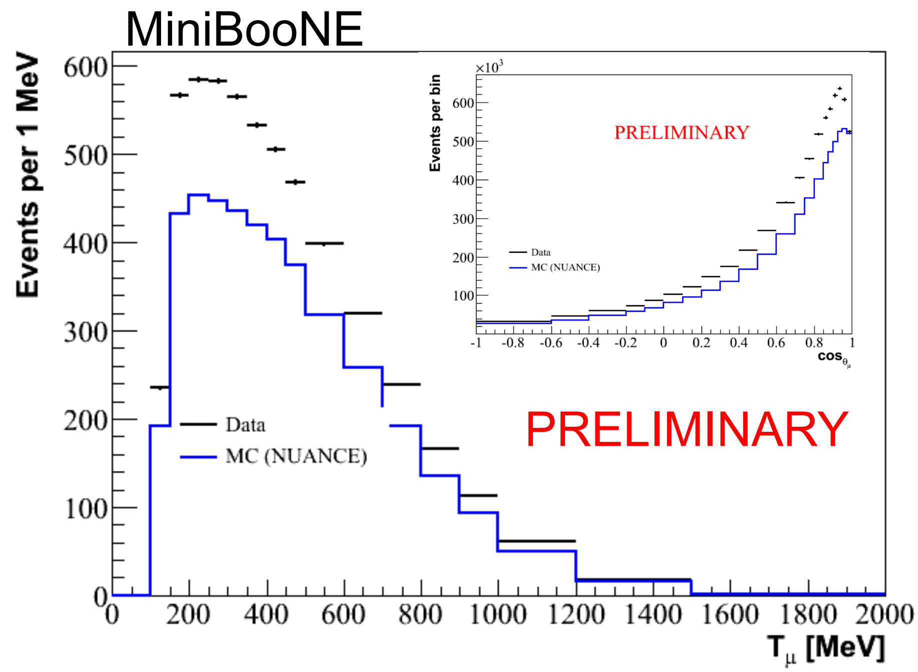
Need to understand CC scattering as a whole

Neutrino CC Inclusive

Full 6.46e20 POT

M. Tzanov, LSU





Can’t do straight sum of exclusive channels; would sum systematic errors too!

Correlations exist between exclusive channels

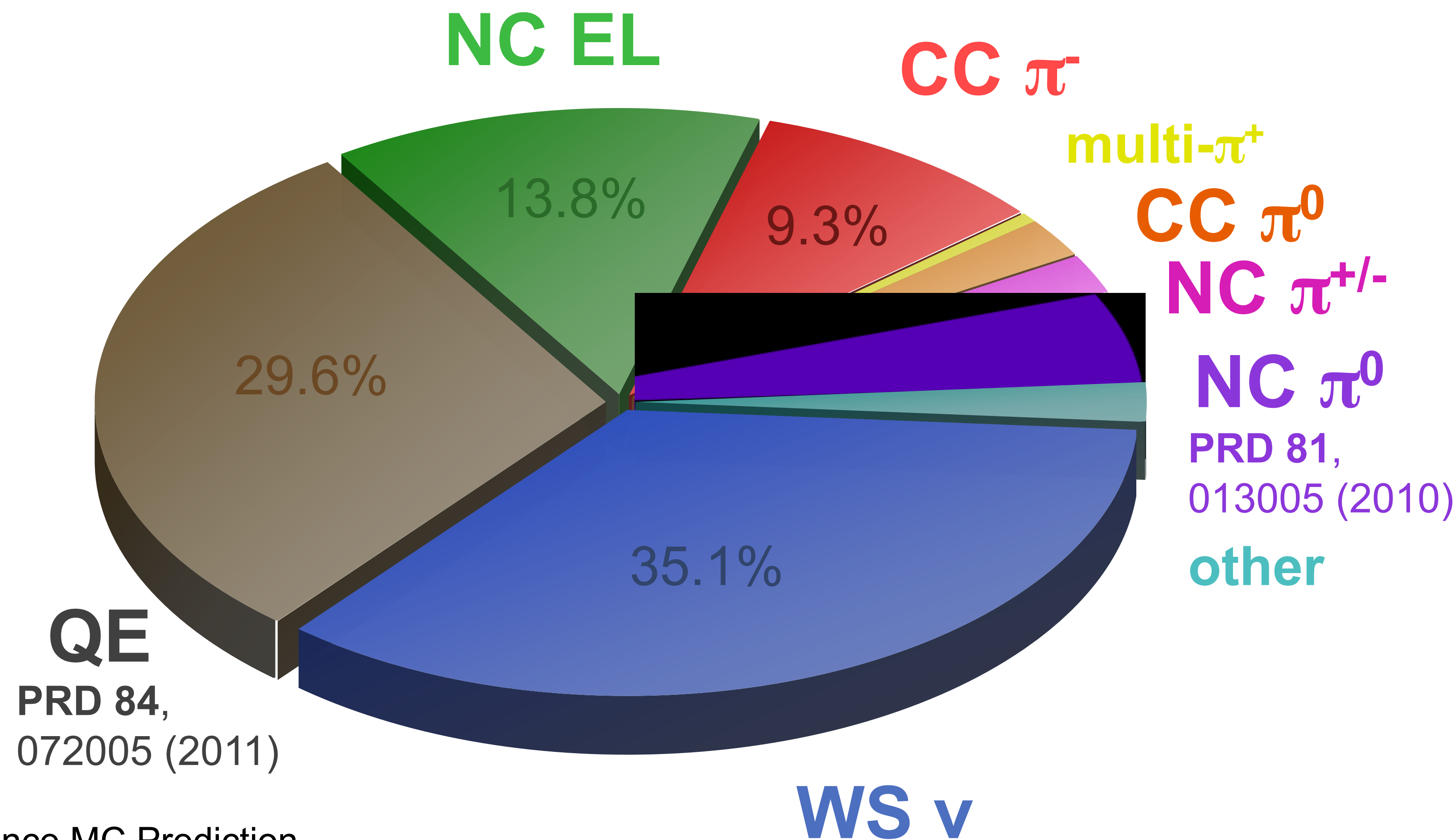
Require at least 2 clusters of hits in time (μ→e)

~344k events after cuts, purity of 96%

Cross Section Coming Soon!!

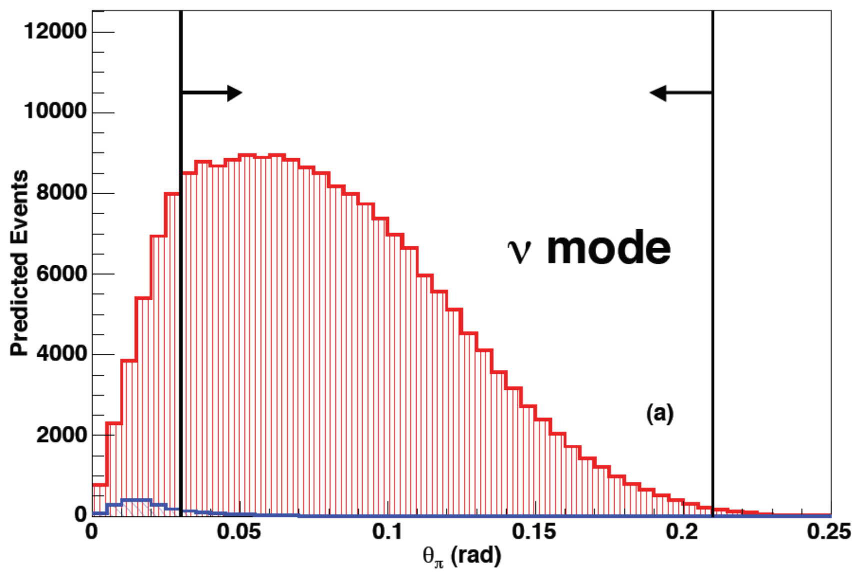
Anti-neutrino Cross Sections

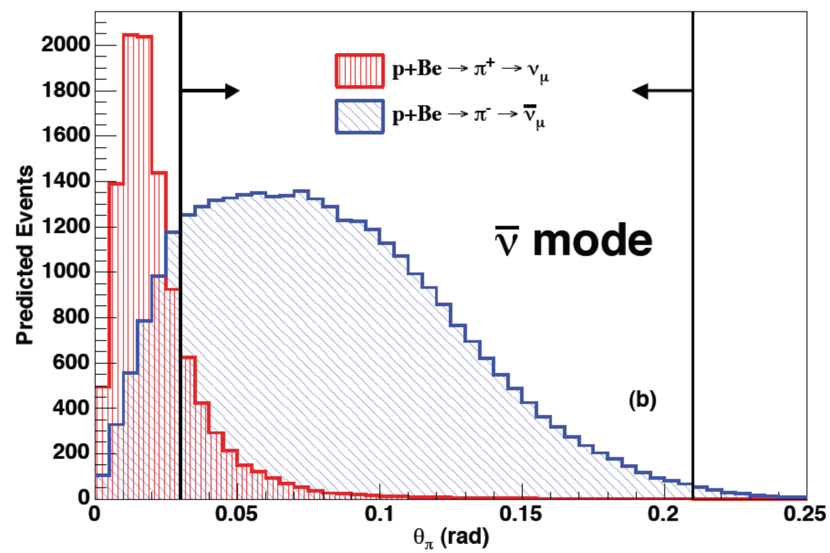
Collected anti-ν data
2005-2006, 2008-2012
10.1e20 POT



Nuance MC Prediction

Anti-neutrino Wrong Sign Contamination





Large wrong-sign contribution to data sample

Largest in region not covered by HARP

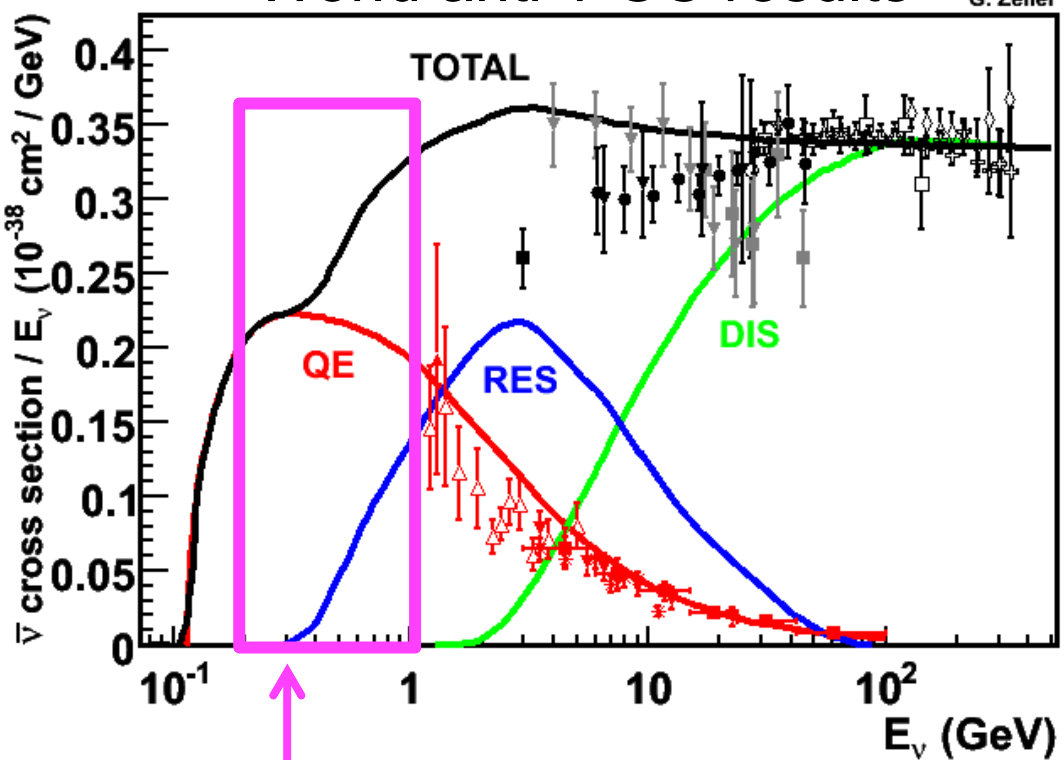
Measure WS in-situ, using complementary methods

1st measurement of WS in a non-magnetized detector!

Phys. Rev. D84, 072005 (2011)

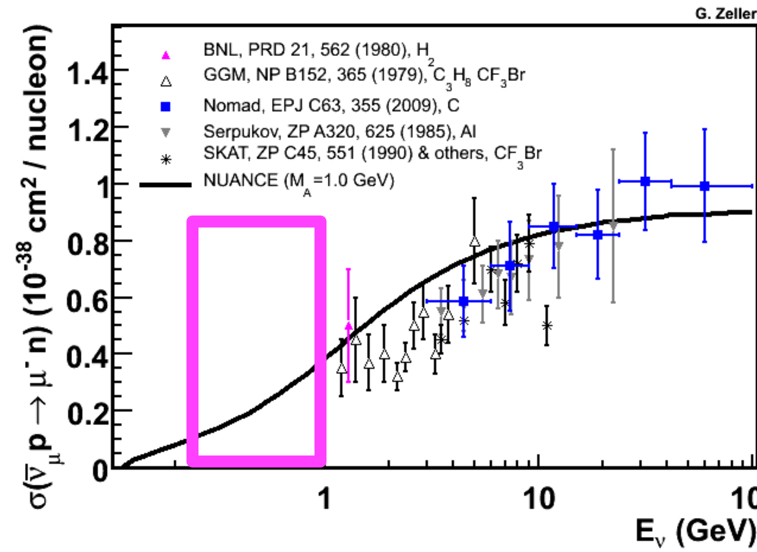
Anti-Neutrino CC Cross Sections

World anti-ν CC results



MiniBooNE <E_ν> = 700 MeV

World anti-ν CCQE results

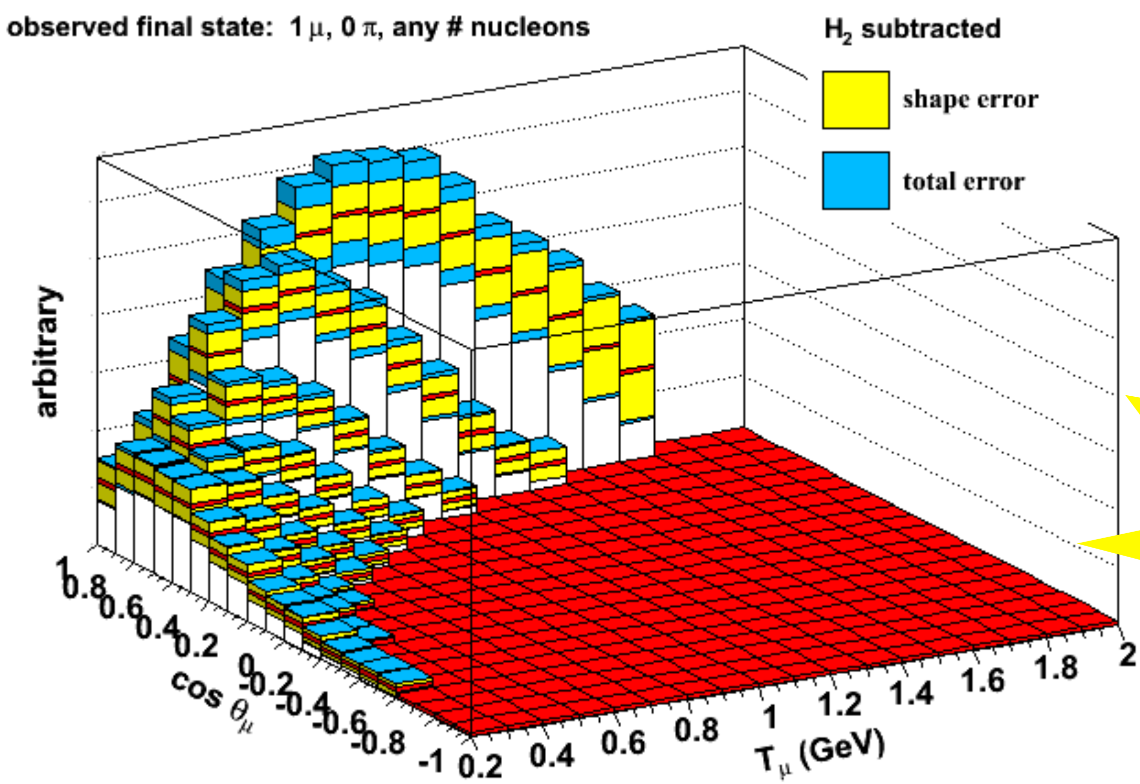


J. Formaggio and G. Zeller, RMP, to be published (2012)

Anti-neutrino CCQE Cross Section

Full 10.1e20 POT

J. Grange, University of Florida



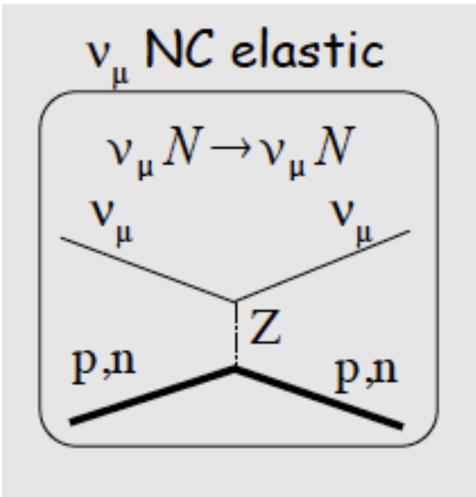
Applying identical cuts as neutrino-mode CCQE PRD analysis

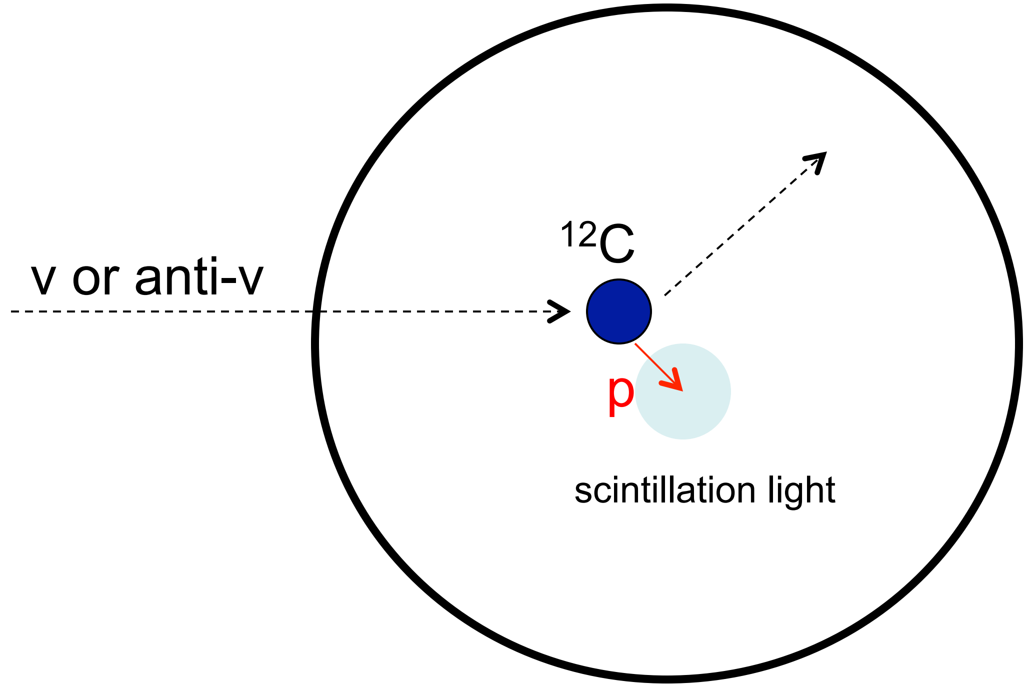
~77,000 events pass CCQE cuts (not bkg subtracted or efficiency corrected)

More than 10x the statistics of all other previously published anti-neutrino CCQE samples!

Next step: neutrino/anti-neutrino, exploit error correlations, narrow down correct model(s)

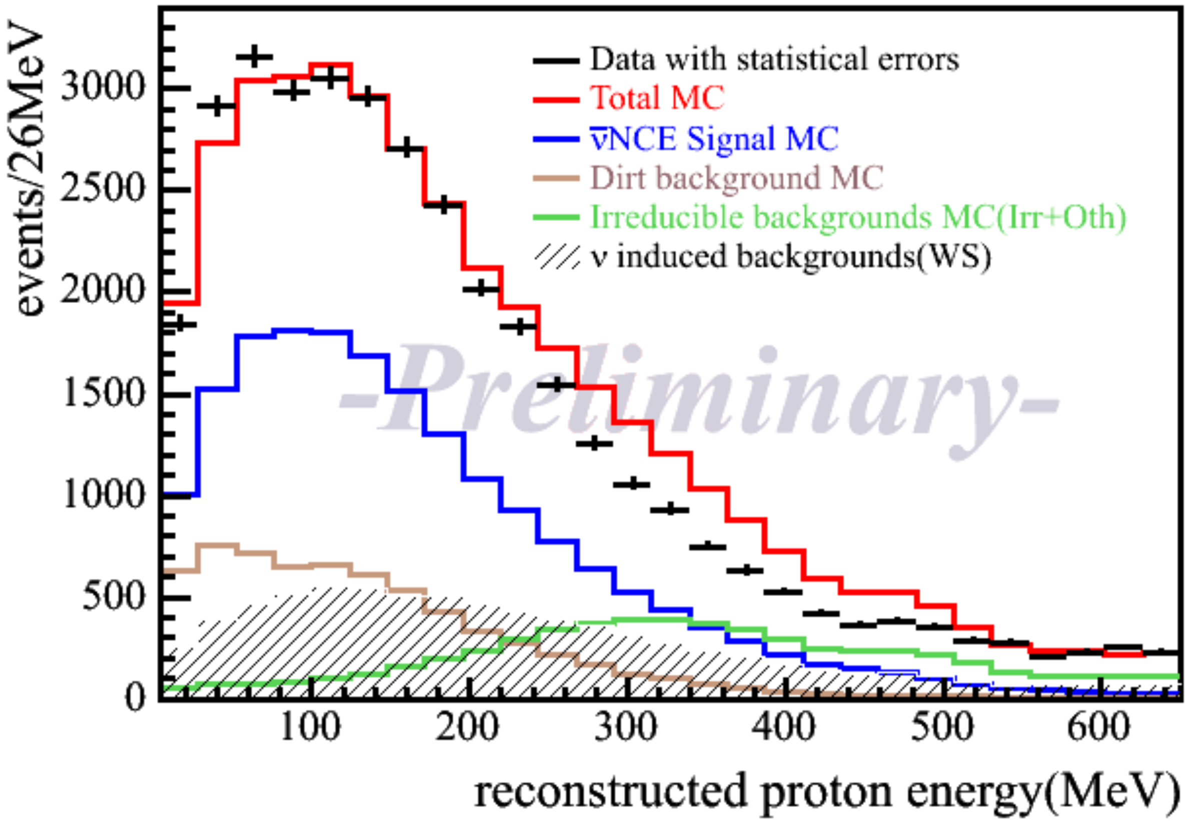
Anti-neutrino NC Elastic Cross Section





- Only 1 nucleon in final state
- Below Cerenkov threshold
- Reconstruct recoiling nucleon via a small amount of scintillation light
- Uses Likelihood ratio to distinguish protons from low energy electrons
- Largest bgd from NC $\pi^\pm$ where π is missed due to absorption in oil

Anti-neutrino NC Elastic Cross Section



7.4e20 POT

R. Dharmaplalan,
University of Alabama

~44,000 NCE events, 40% purity

World record anti-ν NCE sample!

Next step: neutrino/anti-neutrino ratio

Future Plans!

- Neutrino CC inclusive (Martin Tzanov, LSU)
- Antineutrino CCQE (Joe Grange, U Florida)
- Antineutrino NC elastic (Ranjan Dharmapalan, U Alabama)
- Neutrino CCQE with proton reconstruction (Athula Wickremasinghe, U Cincinnati)

MiniBooNE has performed ν-nucleon scattering measurements in a variety of interaction channels!

8 publications so far!

These analyses will complete the highly successful MiniBooNE cross section program