MiniBooNE: latest results and future plans

Outline:
- Motivation
- MB experiment
- Latest MB ν / $\bar{\nu}$ oscillation results
- MB+
- summary

INDIANA UNIVERSITY

R. Tayloe, Indiana U.
IPA Symposium
Madison, WI, 5/13

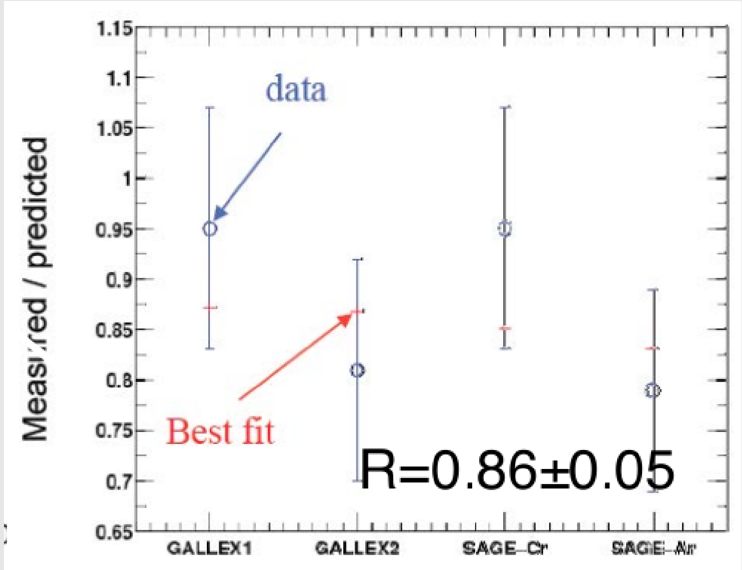
Motivation

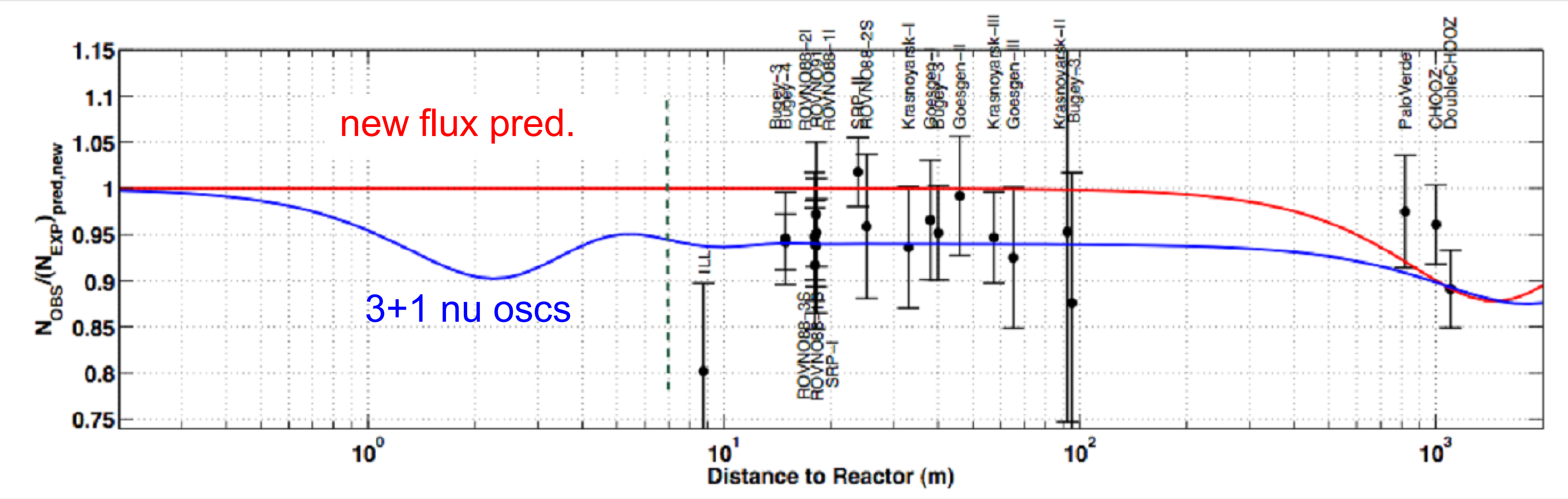
Sterile neutrinos at $\Delta m^2 \sim 1\ eV^2$?

Possible hints:

– Radioactive source ν_e disappearance (SAGE/Gallex)

– Reactor ν_e disappearance ("Reactor Anomaly")

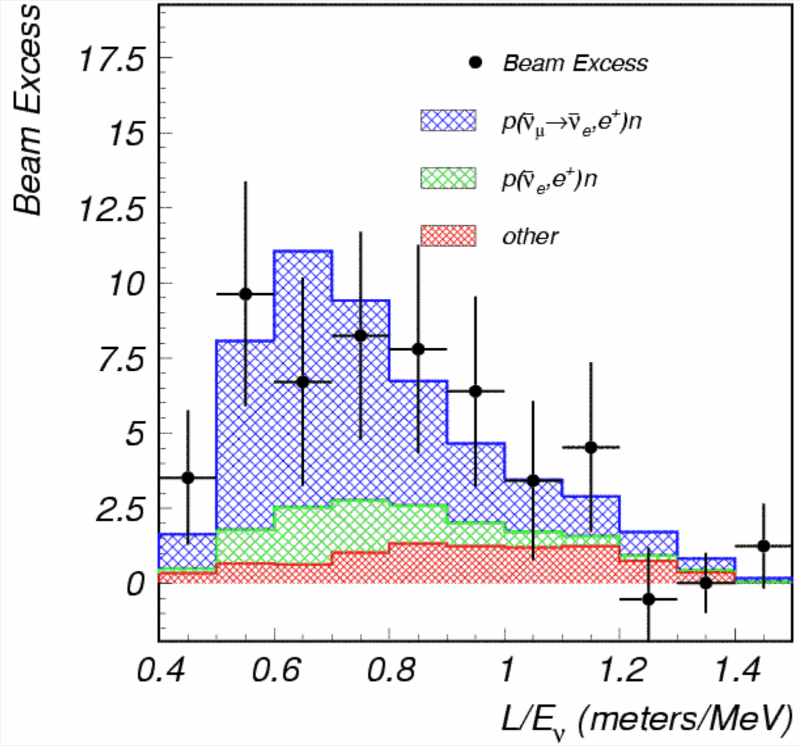


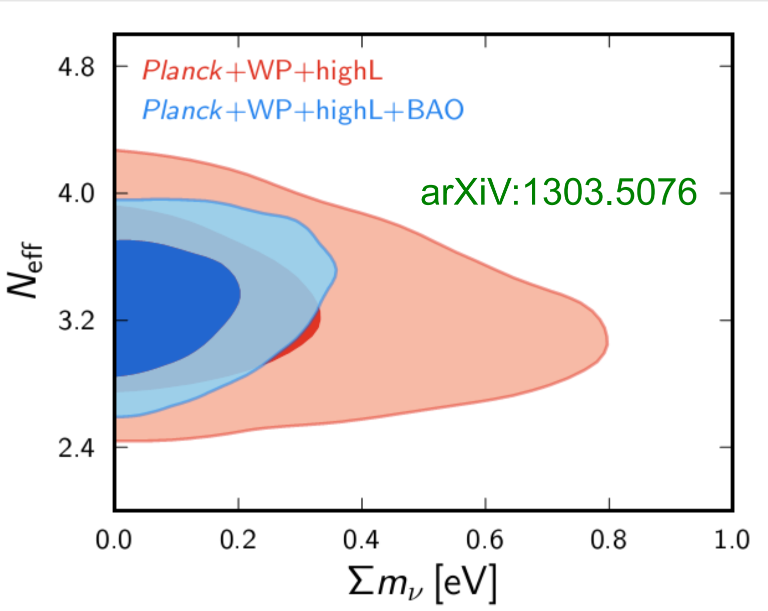


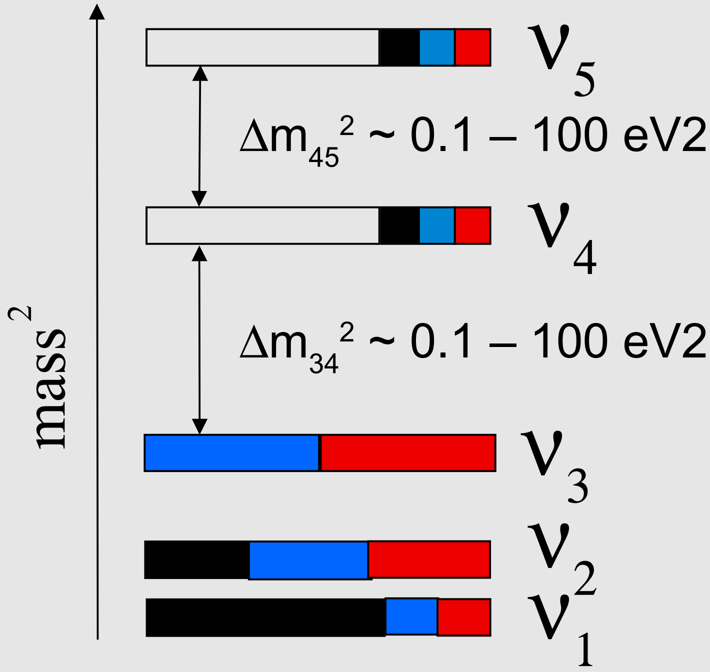
Motivation

Sterile neutrinos at $\Delta m^2 \sim 1\ eV^2$?

Possible hints:
- CMB measurements (however new results from Planck arent as favorable)
- Short-baseline LSND $\bar{\nu}_e$ appearance (from pion DAR source)



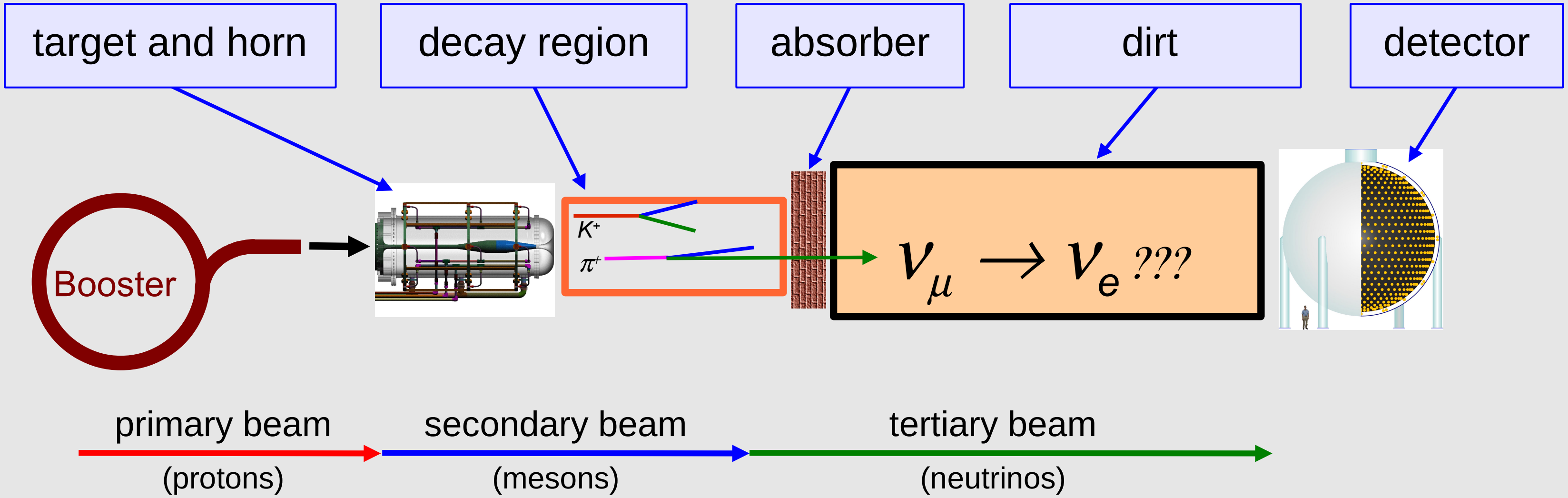




MiniBooNE experiment, overview:

- Designed and built (at FNAL) to test the LSND observation of $\bar{\nu}_\mu$ oscillations via $\nu_\mu \rightarrow \nu_e$ (and $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$) appearance.
- Compared to LSND... keep L/E same, change beam, energy, and, therefore, systematic errors
- "decay-in-flight" π^{+-} (ν_μ / $\bar{\nu}_\mu$) source, E_ν ~ 500 MeV, detector at 500m, L/E_ν ~ 1 (as LSND)
  - 2002-2005, 2007 in ν_μ mode,
  - 2005-2006, 2008-2012 $\bar{\nu}_\mu$ mode.

- See http://www-boone.fnal.gov/publications/ for publications (including theses)



Booster neutrino beam, ν flux

-Predicted $\nu/\bar{\nu}$ fluxes:

- Determined from π production measurements from HARP (CERN experiment) at MB beam momentum on 5% int. length Be target.. (Eur.Phys.J.C52(2007)29)
- .. and detailed MC (GEANT4) simulations of target+horn (PRD79(2009)072002)

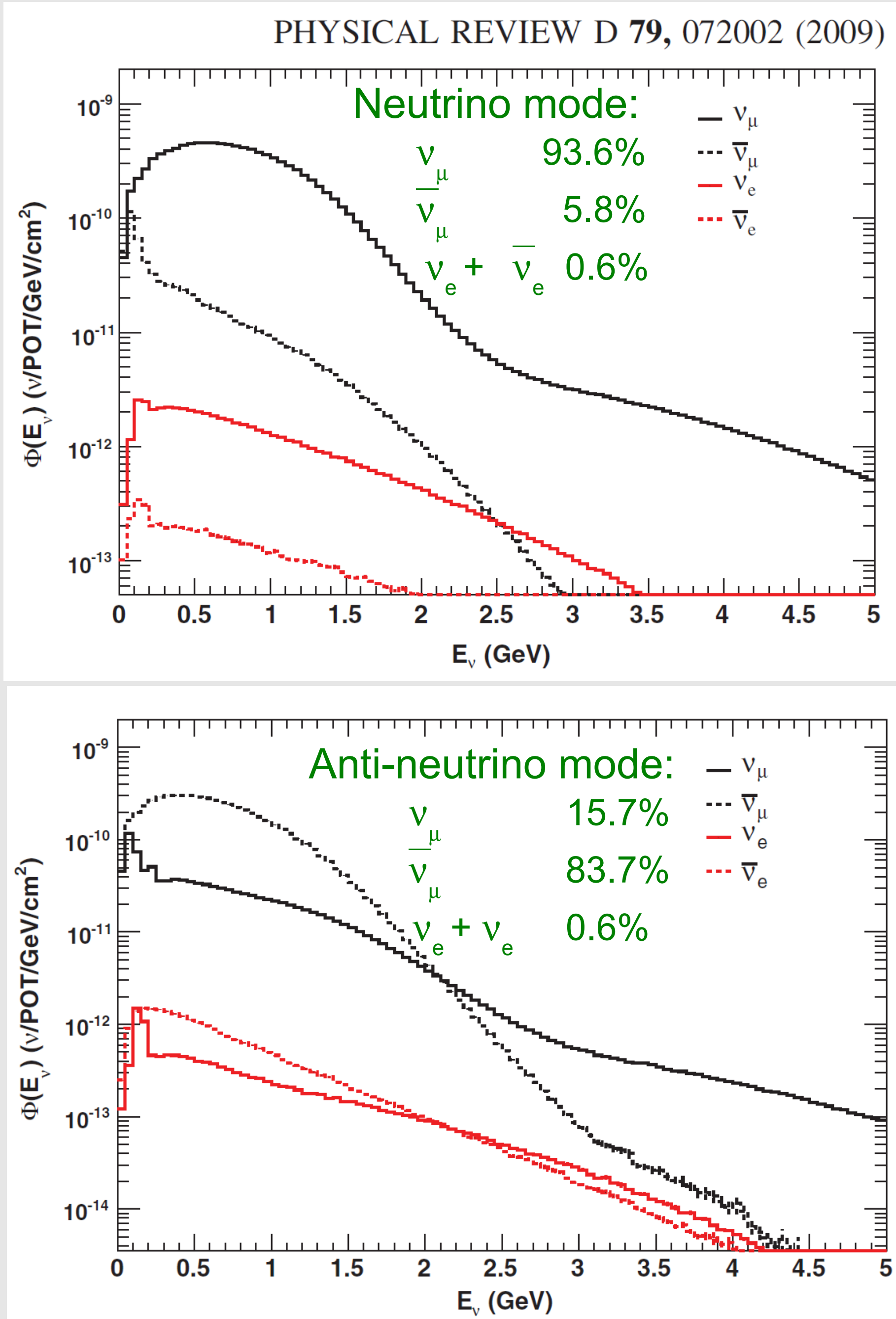
– <E> ~ 800 (650) MeV for ν ($\bar{\nu}$)

- Purity: ~94%/84% ν_μ ($\bar{\nu}_\mu$)

– Absolute flux is predicted, no tuning on MB data. Important for cross section measurements, less so for oscillations

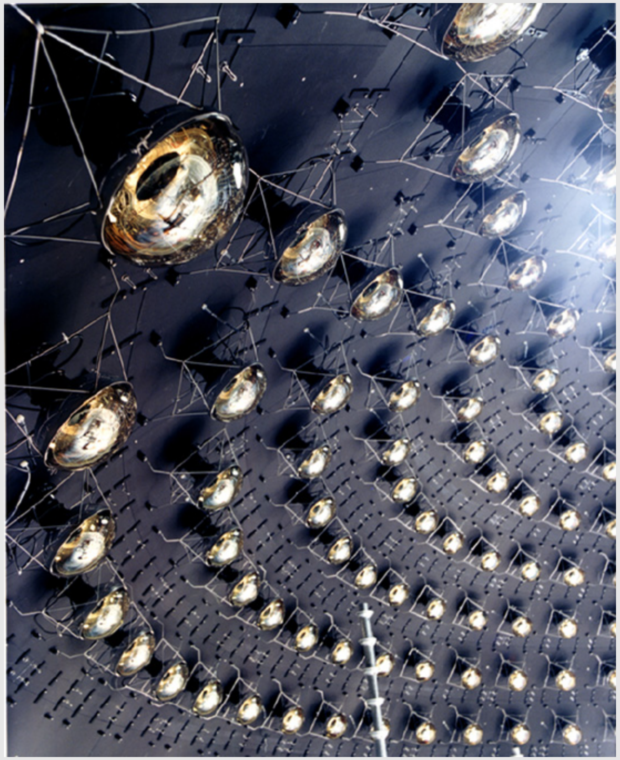
- Overall 9% flux uncertainty, with largest error (7%) from meson production.

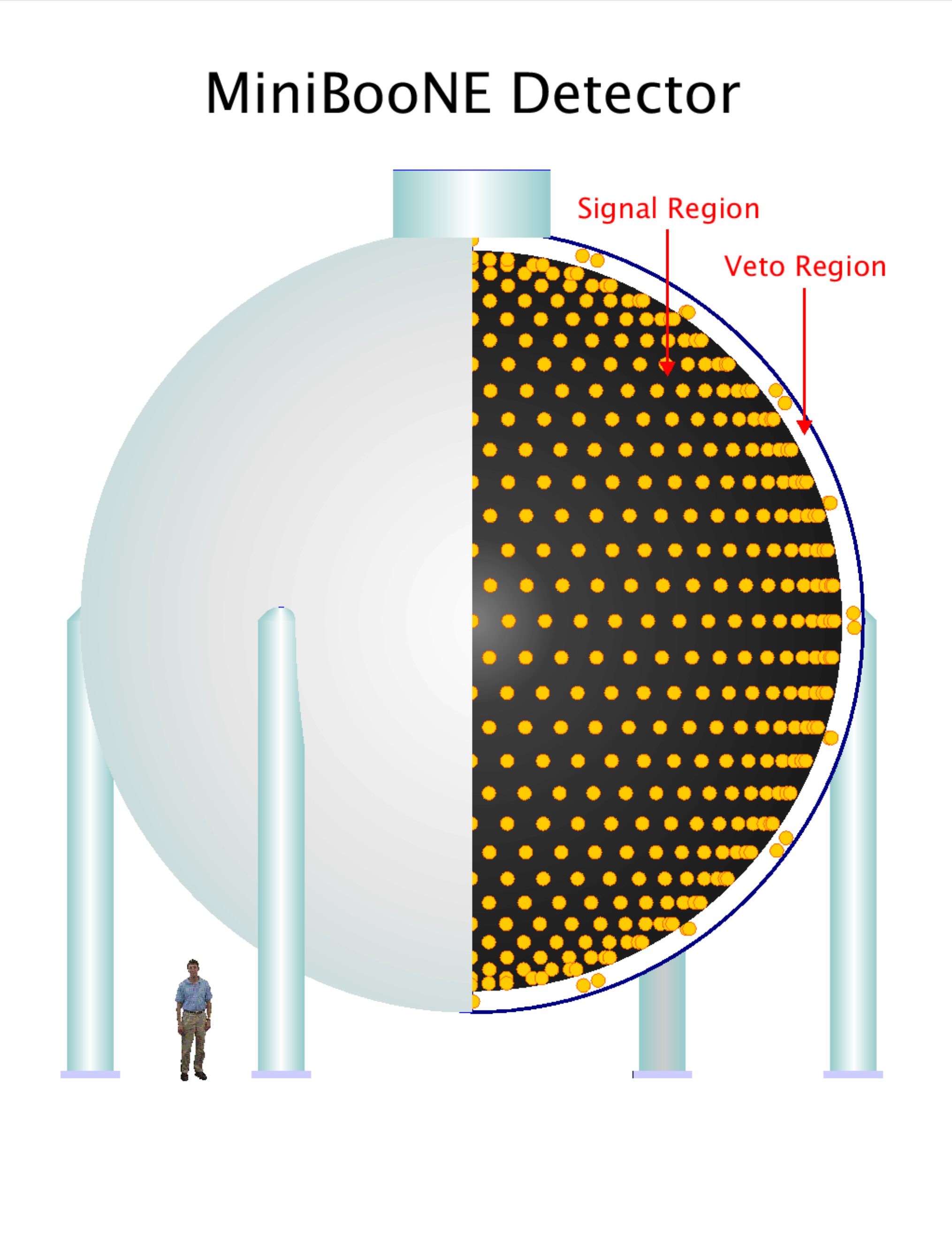
- Uncertainties on energy shape also estimated.



MiniBooNE, ν detector

- 541 meters from target
- 12 meter diameter sphere
- 800 tons mineral oil (CH_2)
- 3 m overburden
- includes 35 cm veto region
- viewed by 1280 8” PMTs (10% coverage) + 240 veto
- Simulated with GEANT3
- Nucl. Instr. Meth. A599 (2009).





MiniBooNE: event reconstruction:

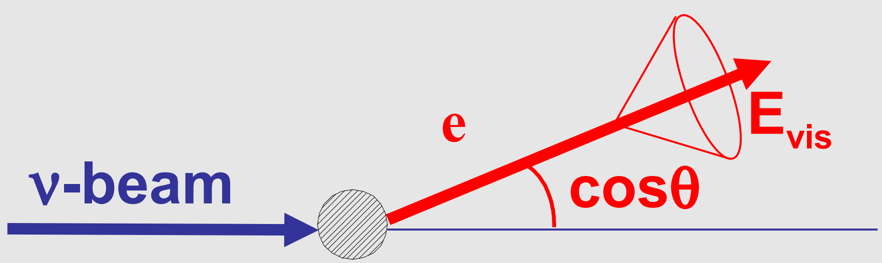
- Charged particles in mineral oil create cherenkov light and small amount of scintillation light.

- Tracks reconstructed (energy, direction, position, type) with likelihood method utilizing time, charge of PMT hits (NIM, A 608 (2009), pp. 206-224)

- in addition, muon, charged pion decays are seen by recording PMT info for 20μs around 2μs beam spill

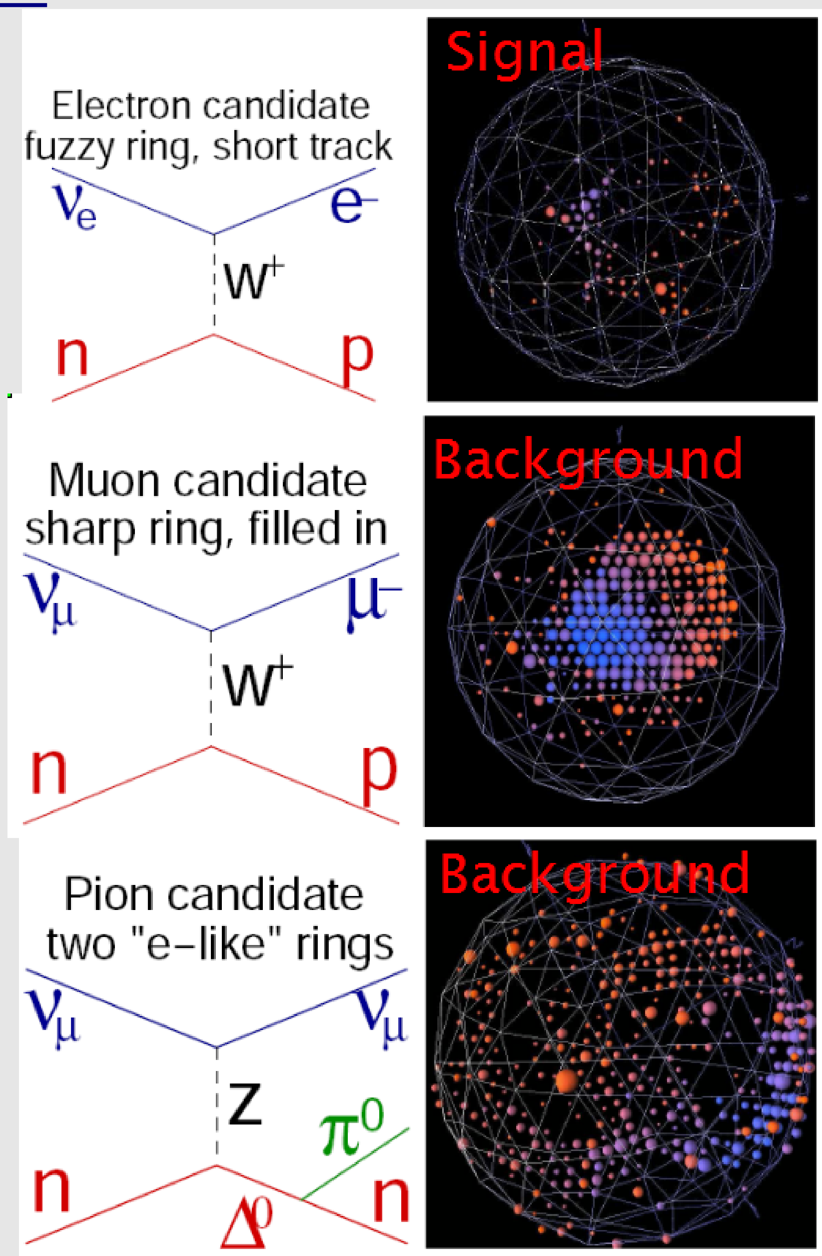
- ID ν_e and separate from backgrounds

- Measure neutrino energy E_ν^{QE} via lepton energy, angle

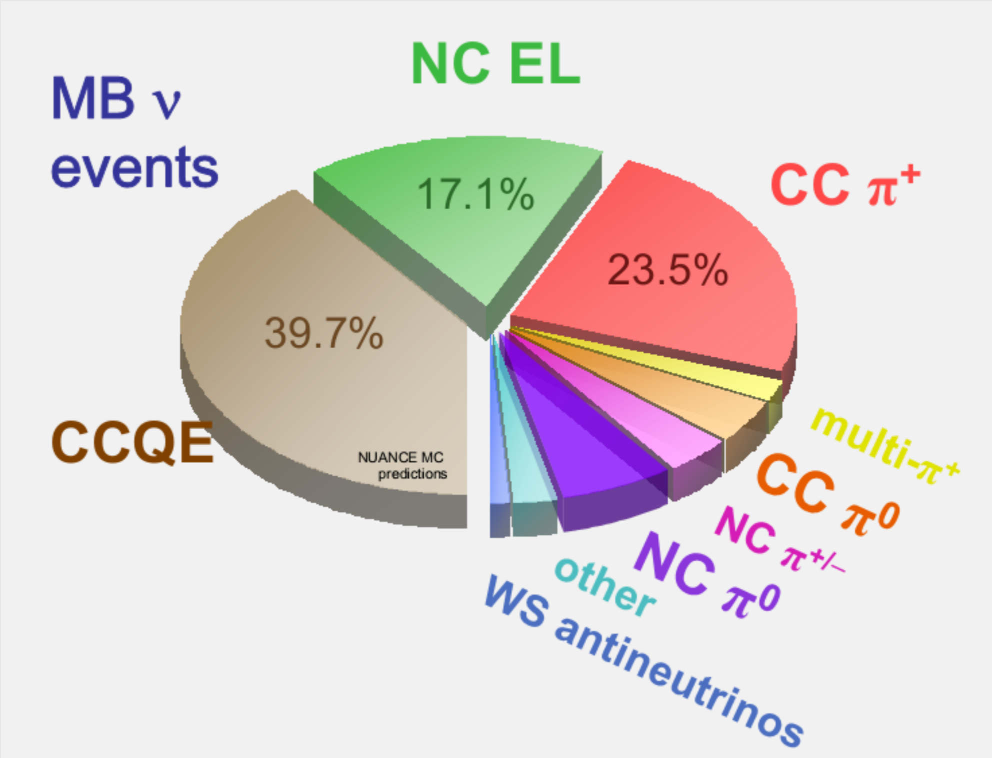


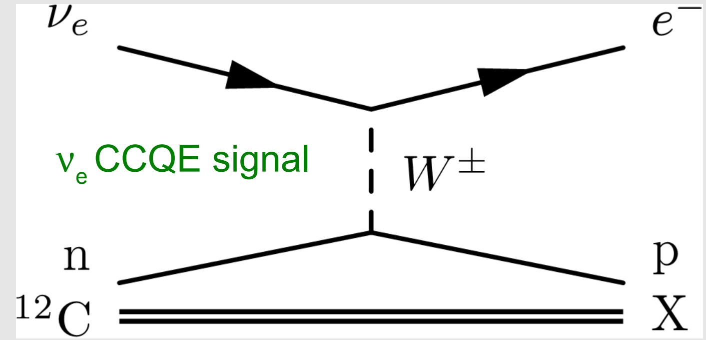
$$E_\nu^{QE} = \frac{2(M_n')E_\mu - ((M_n')^2 + m_\mu^2 - M_p^2)}{2\cdot[(M_n') - E_\mu + \sqrt{E_\mu^2 - m_\mu^2}\cos\theta_\mu]}, \quad (1)$$

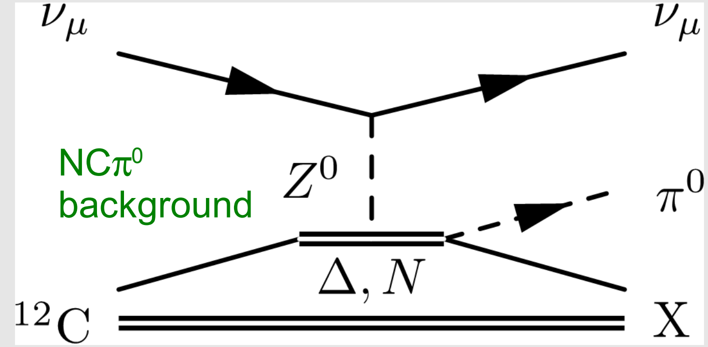
$$Q^2_{QE} = -m_\mu^2 + 2E_\nu^{QE}(E_\mu - \sqrt{E_\mu^2 - m_\mu^2}\cos\theta_\mu), \quad (2)$$

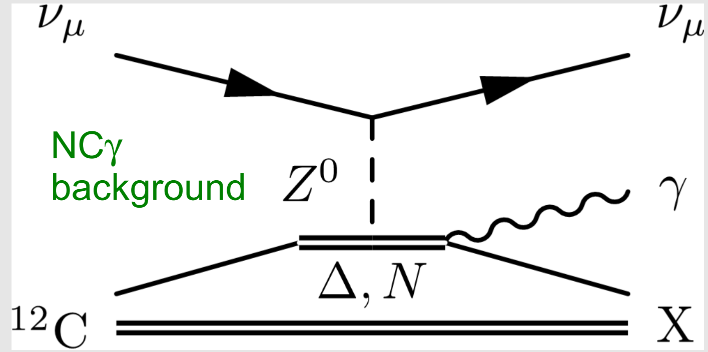


ν scattering channels for oscillation search









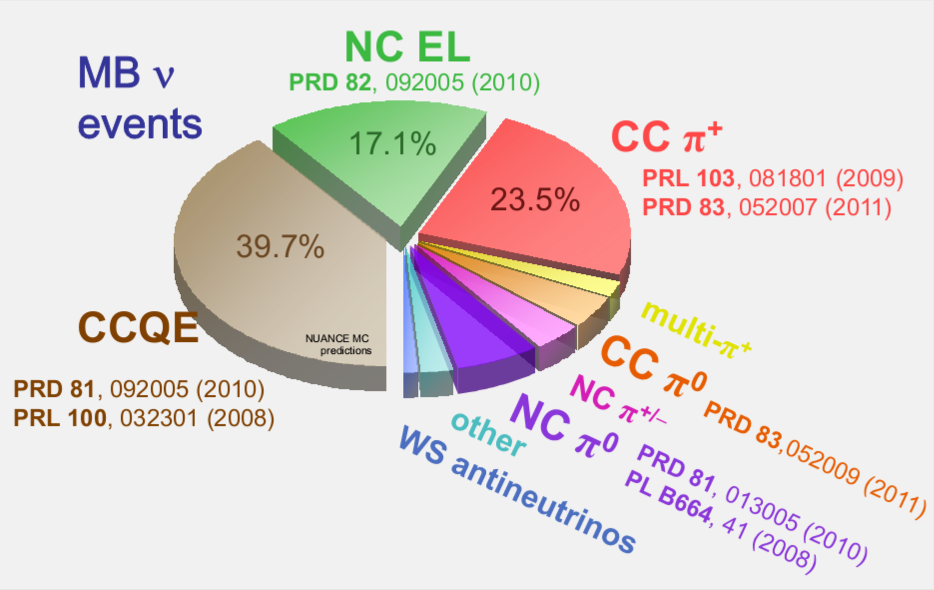
Most important channels for oscillations:

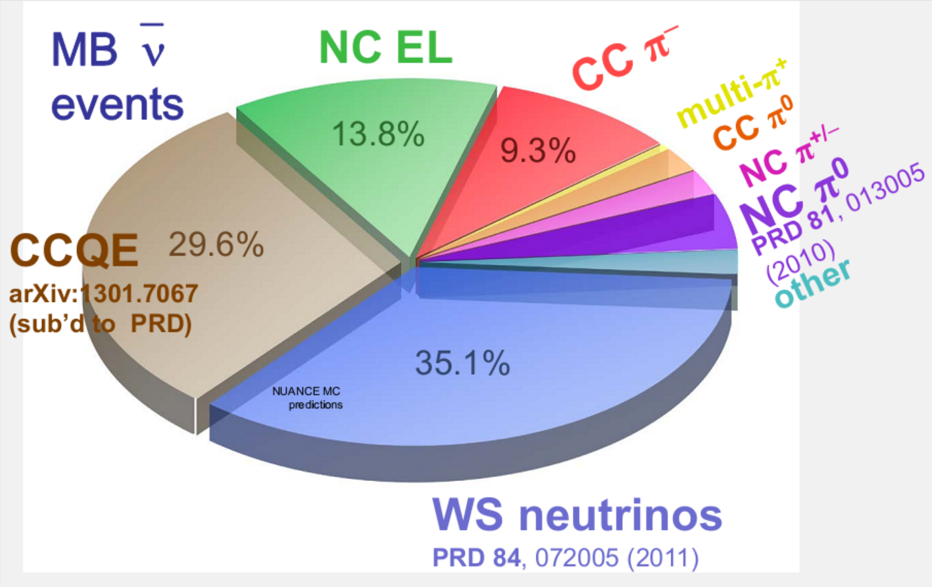
- ν CC quasielastic (CCQE)
  - detection and normalization signal for oscillations
- ν NC production of neutral pions (NCπ^0)
  - very important oscillation background
- ν NC production of photons (NCγ)
  - a possible oscillation background

ν cross sections measured with MiniBooNE

These ν, $\bar{\nu}$ reactions have all been studied, pub'd, and incorporated into model used for oscillation search.

- ν CC quasielastic (CCQE)
  - detection and normalization signal for oscillations
  - charged-current axial formfactor
- ν NC elastic (NCel)
  - predicted from CCQE excepting NC contributions to form factors (possibly strange quarks)
- ν CC production of π^+, π^0 (CCπ)
  - background (and perhaps signal) for oscillations
  - insight into models of neutrino pion production via nucleon resonances and via coherent production
- ν CC inclusive scattering (CCinclusive)
  - should be understood together with exclusive channe
  - ~independent of final state details
- ν NC production of neutral pions (NCπ^0)
  - very important oscillation background
  - complementary to CC pion production
- ν NC production of photons (NCγ)
  - a possible oscillation background
  - complementary to NC pion production





ν cross sections measured with MiniBooNE

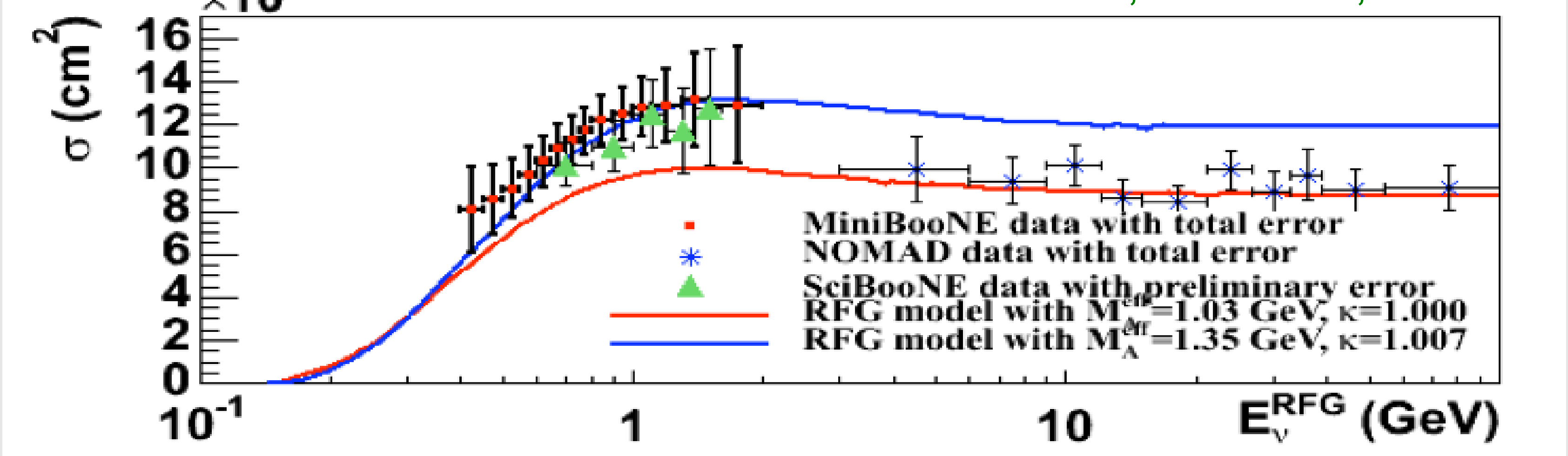
These ν, $\bar{\nu}$ reactions have all been studied, pub'd, and incorporated into model used for oscillation search.

Have observed 20-40% larger rates for these neutrino- (and antineutrino-) nucleus than initially predicted assuming nucleon form factors and independent nucleons in carbon.

Perhaps nucleon correlations?

New results from MINERvA, T2K, Argoneut, microBooNE, may tell..

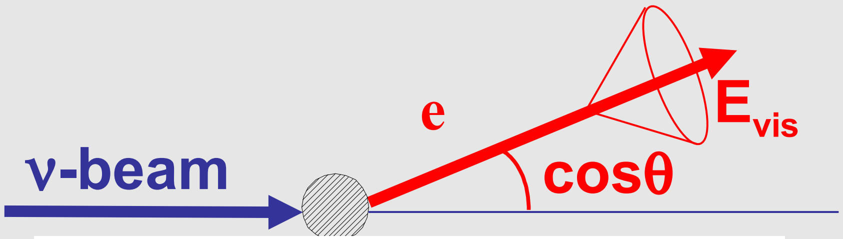
ν CCQE total cross section measurement from MiniBooNE, SciBooNE, NOMAD



MiniBooNE $\nu_\mu \rightarrow \nu_e$ search:

Method:

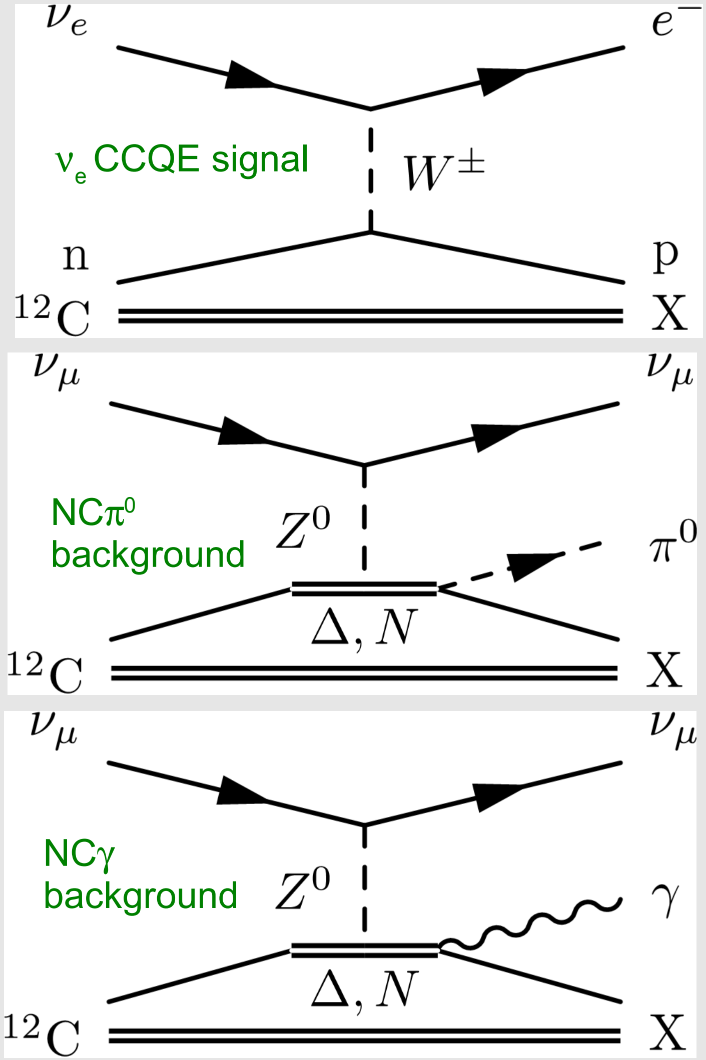
- ID $\nu_\mu \rightarrow \nu_e$ (ν_e CCQE) candidates
- normalize flux and cross section to ν_μ CCQE events
- determine and constrain backgrounds from in-situ MB data, eg:
  - intrinisic ν_e tied to high-E ν_μ events and SciBooNE ν_e CCQE
  - NCπ^0 well-measured by MB
  - NCγ constrained by NCπ^0
  - ”dirt” neutrino events measured
- Measure neutrino energy E_ν^{QE} via lepton- energy, angle:



$$E_\nu^{QE} = \frac{2(M_n')E_\mu - ((M_n')^2 + m_\mu^2 - M_p^2)}{2\cdot[(M_n') - E_\mu + \sqrt{E_\mu^2 - m_\mu^2}\cos\theta_\mu]}, \quad (1)$$

$$Q^2_{QE} = -m_\mu^2 + 2E_\nu^{QE}(E_\mu - \sqrt{E_\mu^2 - m_\mu^2}\cos\theta_\mu), \quad (2)$$

...then connect to true E_ν with interaction physics model



- … and collect data for 10 years...

MiniBooNE $\nu_\mu \rightarrow \nu_e$ results:

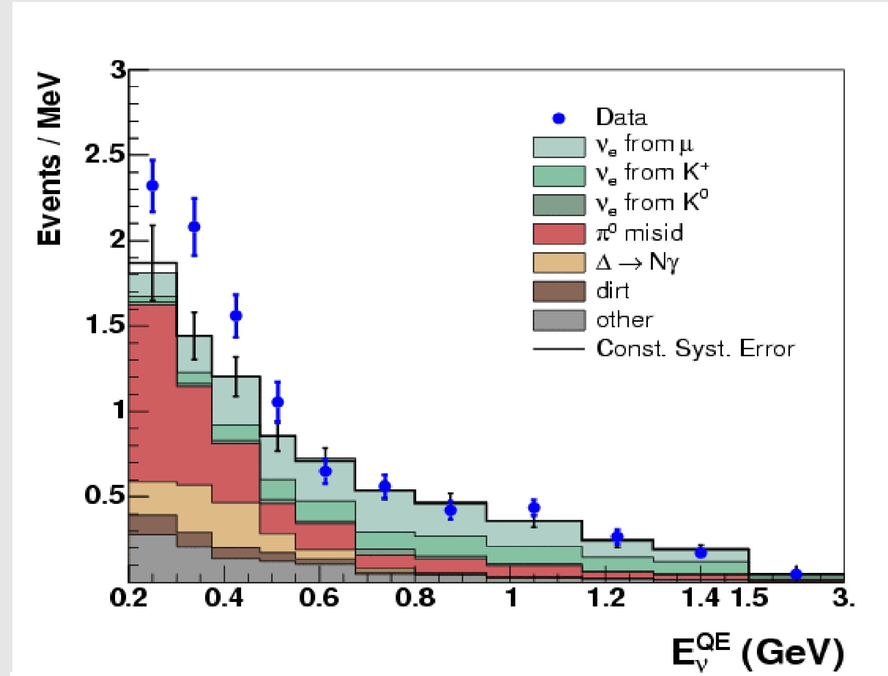
Neutrino mode search:

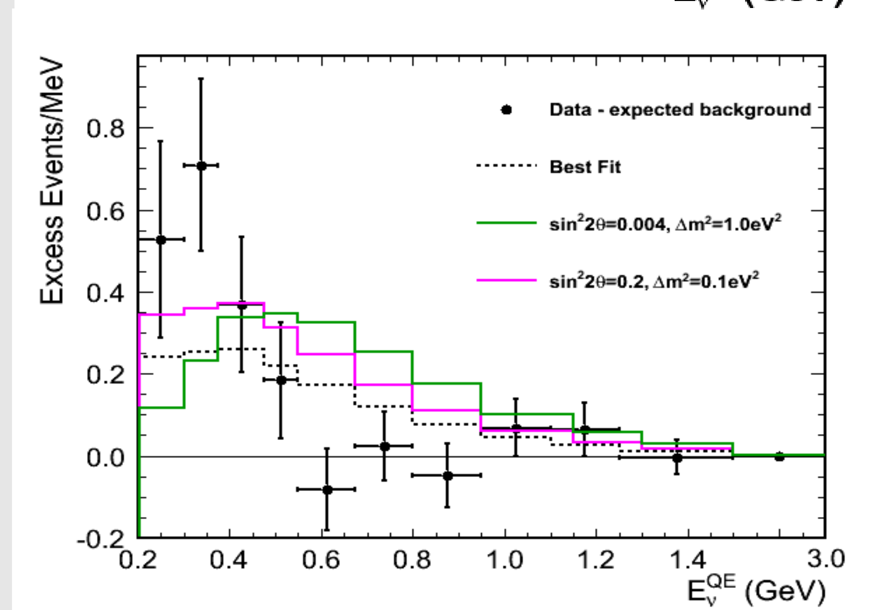
- conducted 2002-2007, 6.7E20 POT

- Excess(E > 200 MeV): 146.3 ± 28.4 ± 40.2

χ^2 probabilities, for null,
best-fit (bf) 2ν-osc hypotheses

ν mode	E > 200 MeV	E > 475 MeV
Prob(null)	0.5%	36.6%
Prob(bf)	6.12%	42.0%





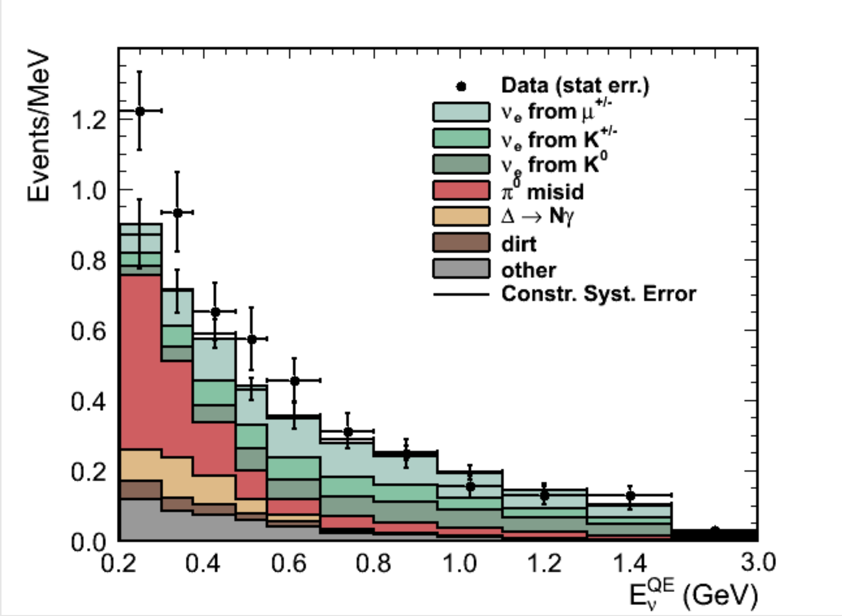
MiniBooNE $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ results:

Antineutrino mode search:

- conducted 2005-2012, finished 4/12

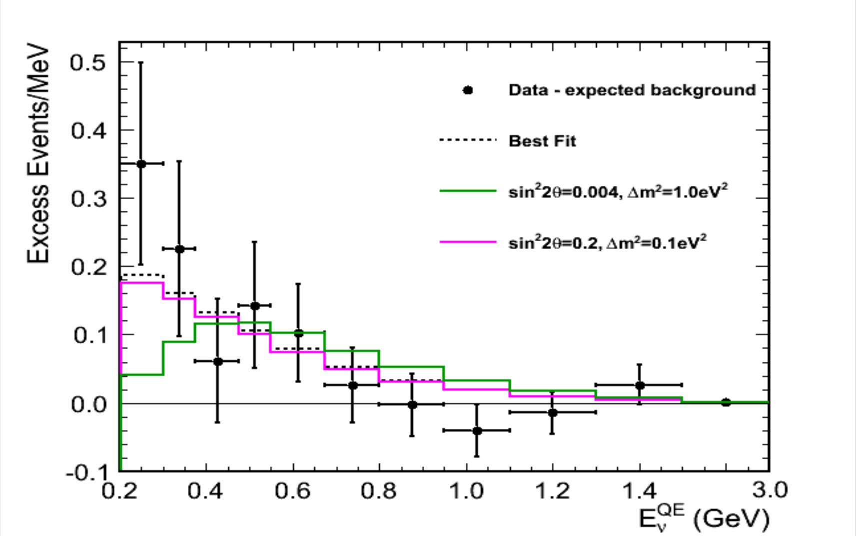
- 11.3E20 POT

- Excess(E>200 MeV): 77.8 ± 20.0 ± 23.4



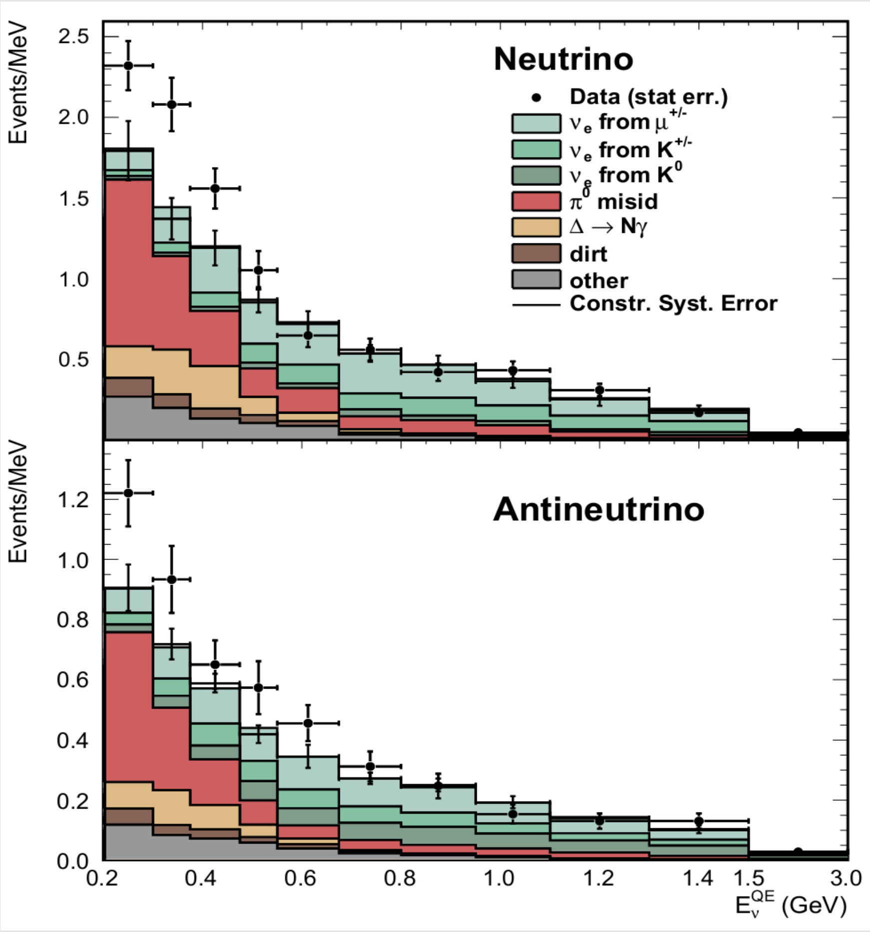
χ^2 probabilities, for null, best-fit (bf) 2ν-osc hypotheses

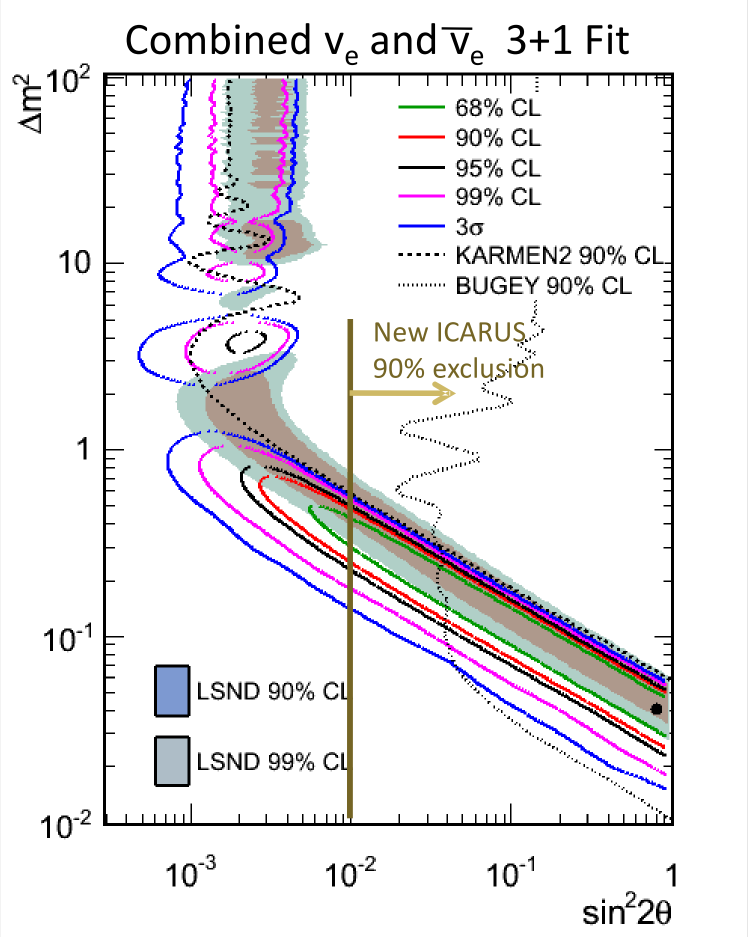
$\bar{\nu}$ mode	E > 200 MeV	E > 475 MeV
Prob(null)	5.8%	26.4%
Prob(bf)	67.5%	50.2%



MiniBooNE oscillation excess:

- The combined $\nu / \bar{\nu}$ data set (including all $\bar{\nu}$ data to date) yields a combined excess of 240.3±62.9 events (3.8σ) and is consistent with LSND.

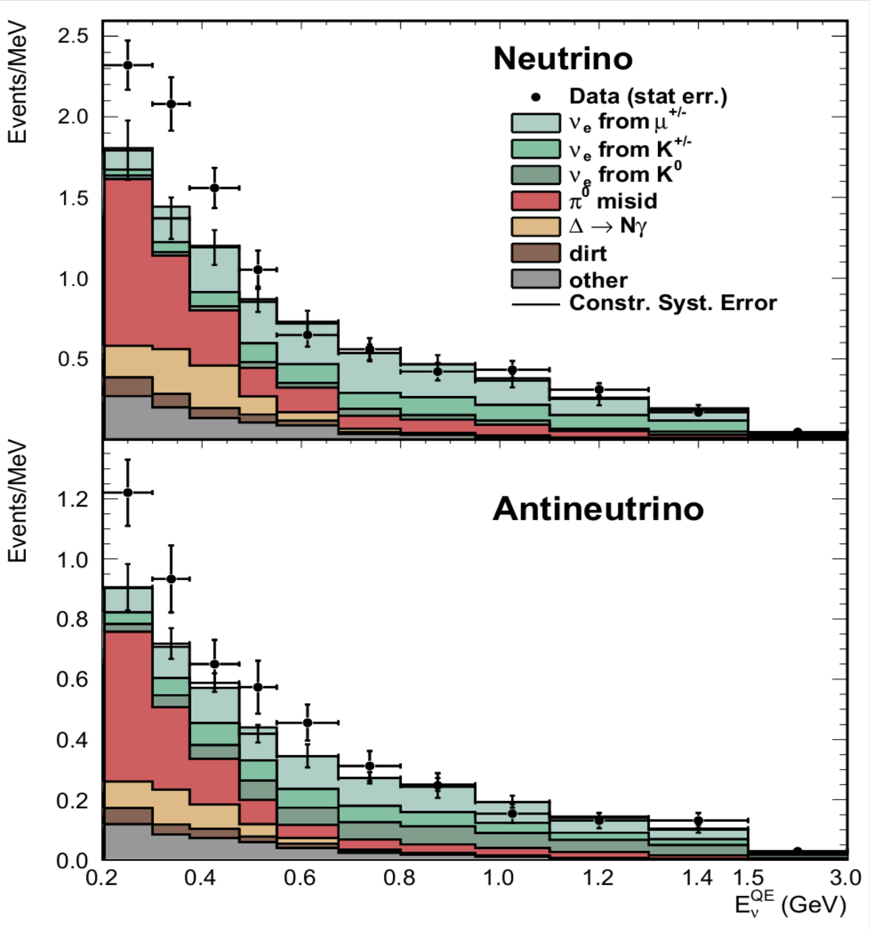




MiniBooNE oscillation excess:

- The combined $\nu/\bar{\nu}$ data set (including all $\bar{\nu}$ data to date) yields a combined excess of 240.3±62.9 events (3.8σ).

- is consistent with LSND.
  Sterile ν ? Perhaps, but:
  - 3ν + 1 sterile ν fits to global data not good
  - 3ν + 2 sterile ν fits, better but still in tension with ν_μ disappearance
  - see, eg: Conrad etal, Adv.High Energy Phys. 2013 (2013) 163897



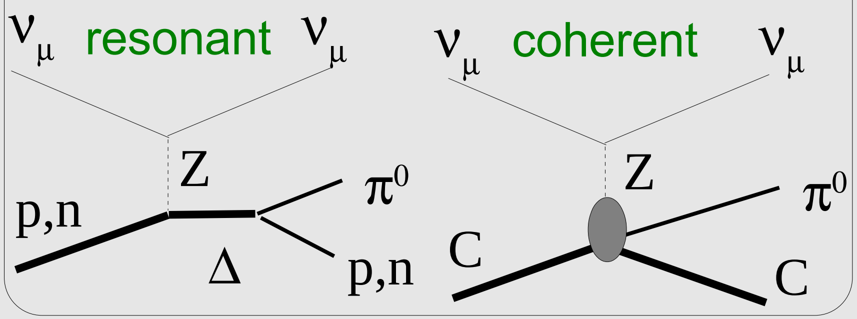
What else?
- Not a stat fluctuation, statistically 6σ
- Unlikely to be intrinsic ν_e, a small bkg at low-E

- Excess occurs mostly at low-energy where NCγ and NCπ^0 are dominant.
  Natural to examine these backgrounds further.

MiniBooNE oscillation NC backgrounds:

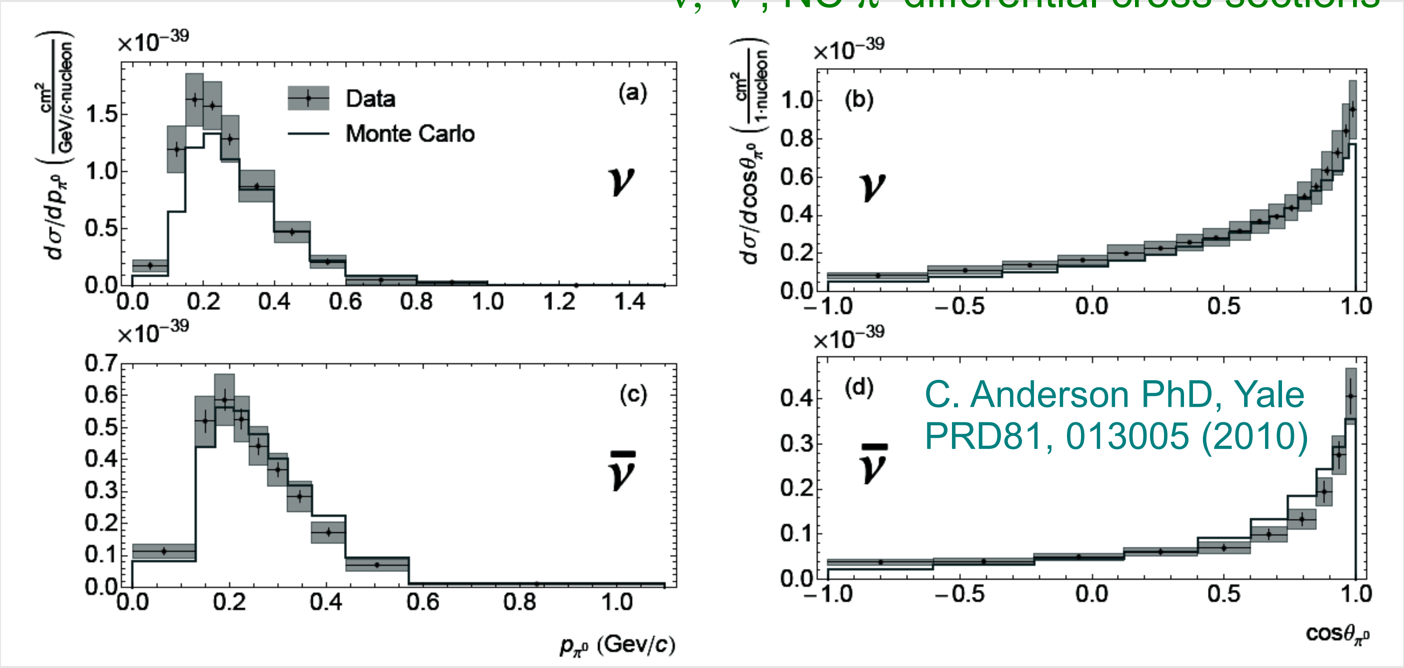
- Both NCγ and NCπ^0 are constrained with additional MB measurements.
  - NCπ^0 directly measured in MB
  - NCγ constrained to NCπ^0 (due to dominance of Δ, $\Delta \rightarrow N\gamma$)

$$\nu_\mu(p,n) \rightarrow \nu_\mu(p,n)\pi^0,\ \pi^0 \rightarrow \gamma\gamma$$



NCπ^0 production

ν, $\bar{\nu}$, NC π^0 differential cross sections



MiniBooNE oscillation NC backgrounds:

NCγ production cross section

- Also.... recent theoretical calculations agree with MB calculations

B. D. Serot and X. Zhang, arXiv:1110.2760 [nucl-th].

B. D. Serot and X. Zhang, Phys. Rev. C **86**, 015501 (2012) [arXiv:1206.3812 [nucl-th]].

X. Zhang and B. D. Serot, arXiv:1208.1553 [nucl-th].

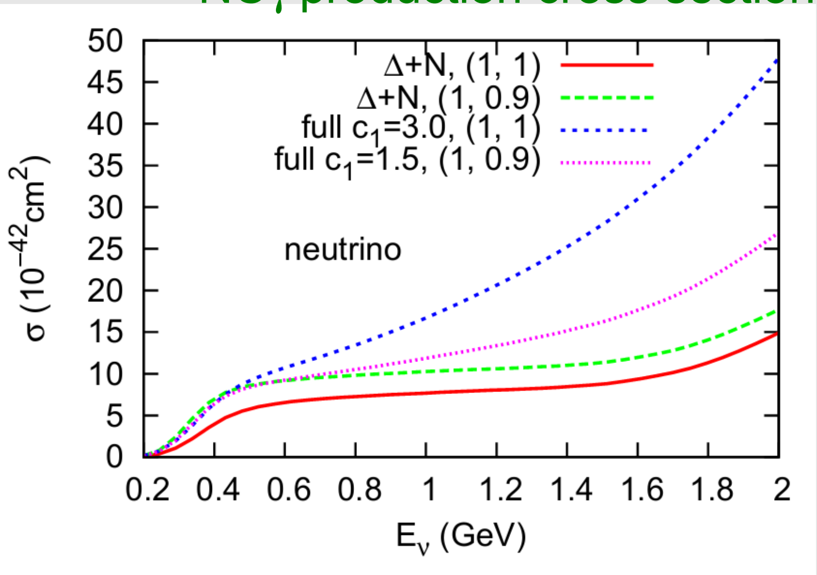
X. Zhang and B. D. Serot, arXiv:1206.6324 [nucl-th], accepted to Physical Review C.

J. A. Harvey, C. T. Hill and R. J. Hill, Phys. Rev. Lett. **99**, 261601 (2007) [arXiv:0708.1281 [hep-ph]].

R. J. Hill, Phys. Rev. D **81**, 013008 (2010) [arXiv:0905.0291 [hep-ph]].

X. Zhang and B. D. Serot, in Press.

R. J. Hill, Phys. Rev. D **84**, 017501 (2011) [arXiv:1002.4215 [hep-ph]].



Zhang, Serot, Phys.Lett. B719 (2013) 409.

- However, additional experimental tests called for...
  - important to resolve source for MB low-energy excess, sterile ν?
  - may be important for other future experiments in this energy range (eg: T2K)

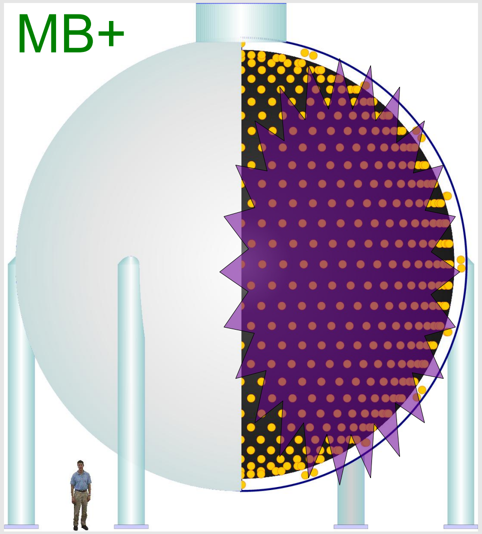
E_{QE}(GeV)	[0.2 , 0.3]	[0.3 , 0.475]	[0.475 , 1.25]
coh	1.3 (2.4)	6.4 (9.9)	2.4 (9.3)
inc	9.5 (10.5)	27.6 (31.3)	16.7 (27.1)
H	3.0 (3.3)	10.6 (11.7)	5.4 (7.4)
Total	13.8 (16.2)	44.6 (52.9)	24.5 (43.8)
MiniBN	19.5	47.3	19.4
Excess	42.6 ± 25.3	82.2 ± 23.3	21.5 ± 34.9

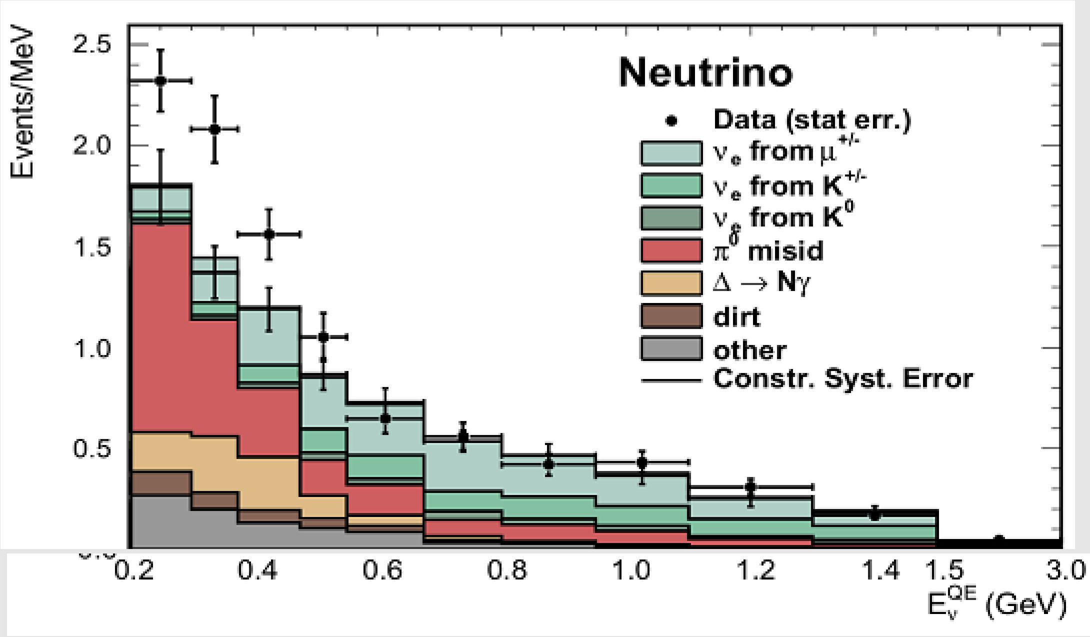
TABLE II: E_{QE} distribution of the NC photon events in the MiniBooNE neutrino run, comparing our estimate to the MiniBooNE estimate [1].

MiniBooNE+ (scintillator)

- Add scintillator to MB to enable reconstruction of 2.2 MeV n-capture photons
- rerun MB $\nu_\mu \rightarrow \nu_e$ search

The n-capture ($np \rightarrow d\gamma$) signal will enable separation of CC oscillation signal events from NC backgrounds for an improved test of the low-energy MiniBooNE oscillation excess.



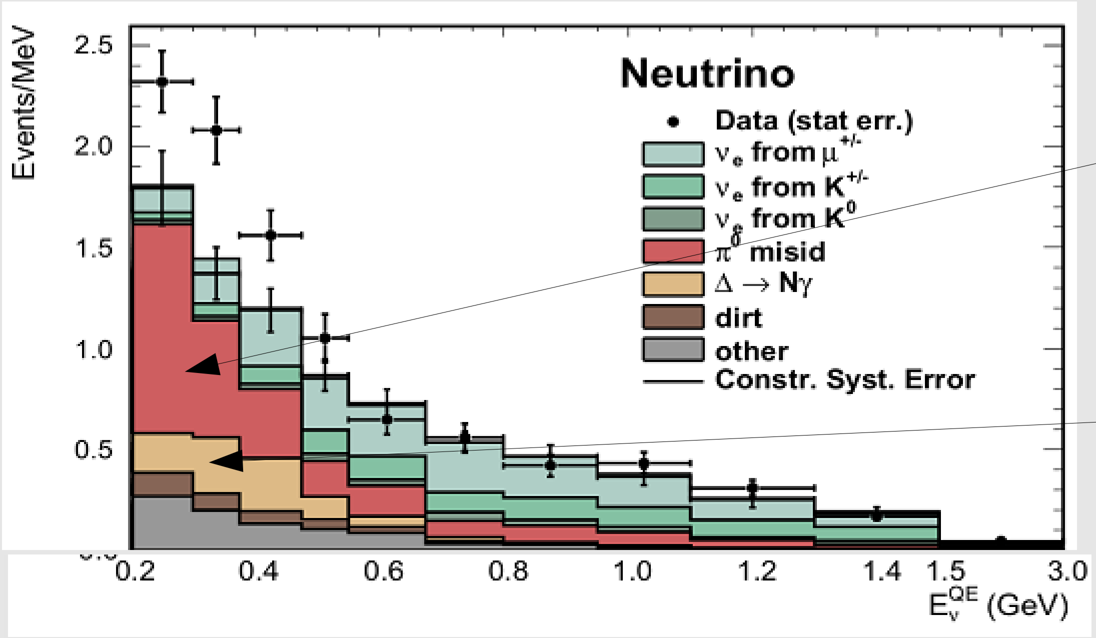


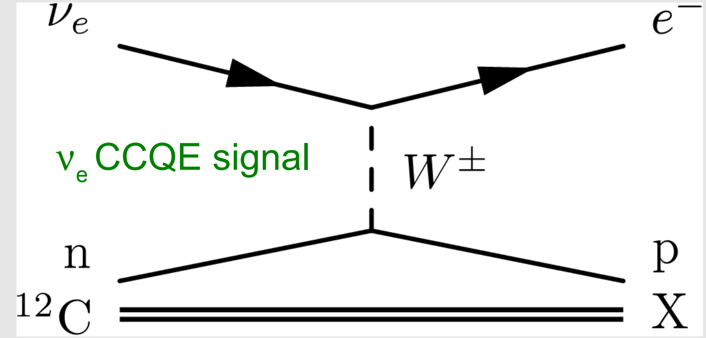
Physics: $\nu_\mu \rightarrow \nu_e$ search with NC tag

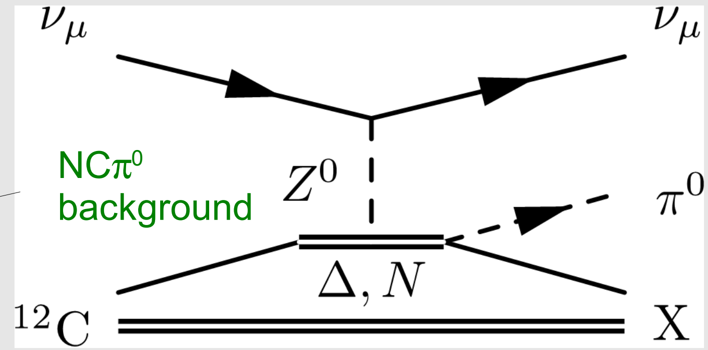
Select oscillation candidates with an associated n-capture "tag".
If event excess (at low energy) is:

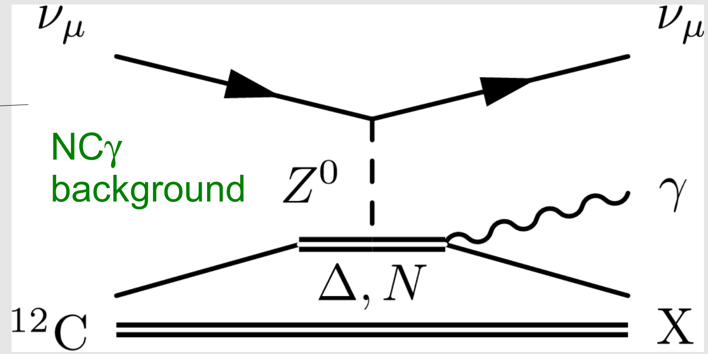
- CC oscs: excess will disappear since it is mostly CCQE (with only 1-10% neutrons)

- NC bckgd: excess will not disappear since it will contain 50% neutrons. This is because of dominance of NC Δ with equal branch to p/n decay

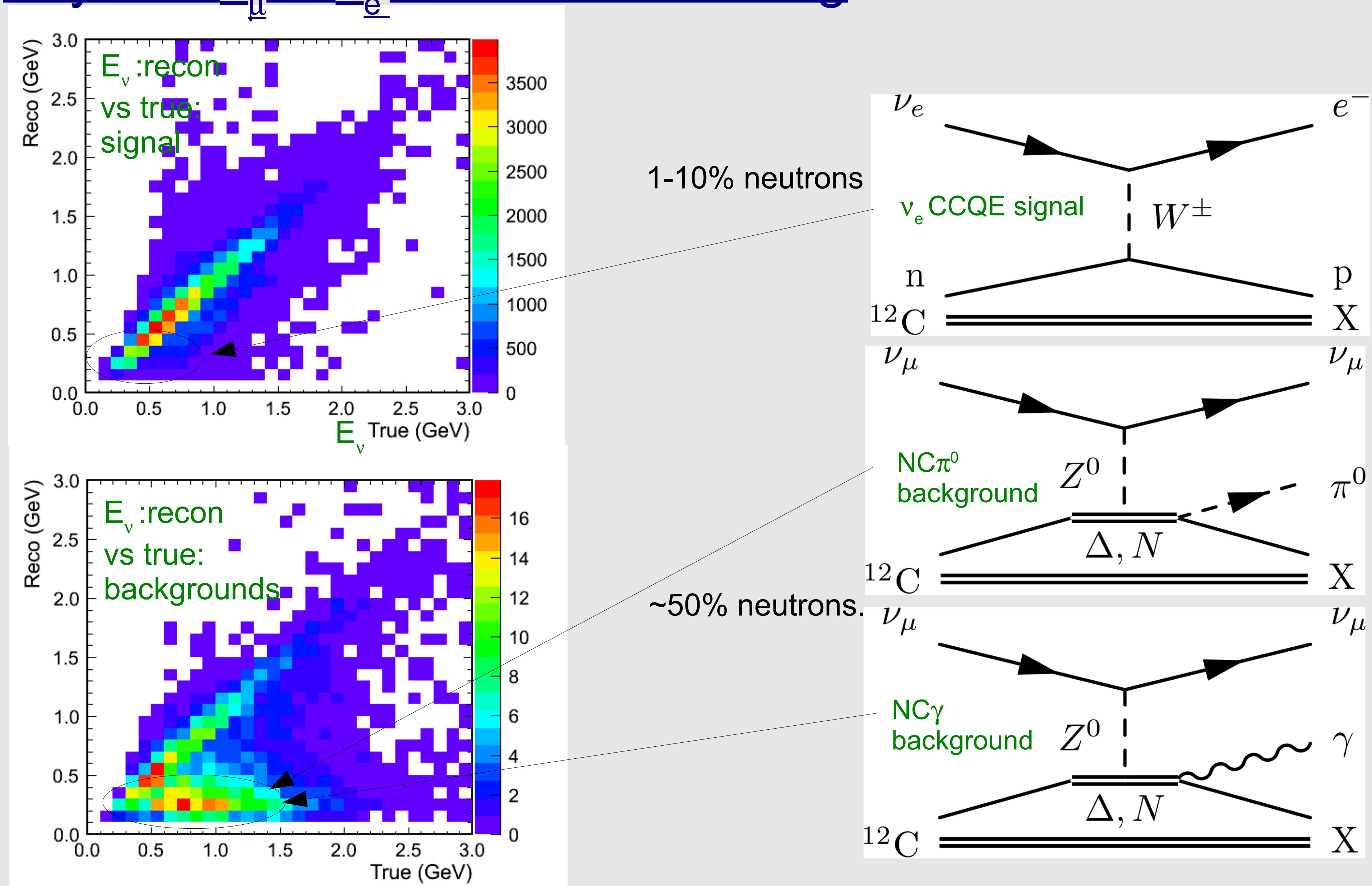








Physics: $\nu_\mu \rightarrow \nu_e$ search with NC tag



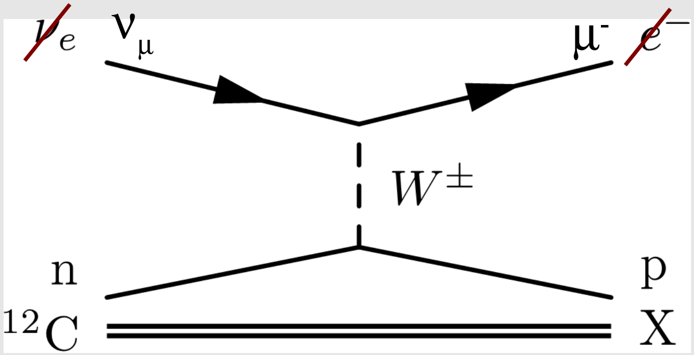
Calibration of signal/background n-fraction

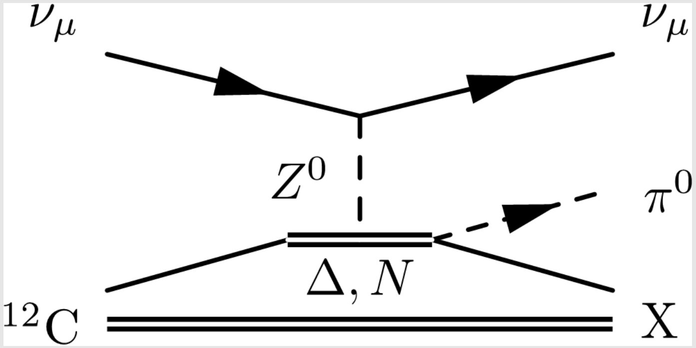
Assumed n-fraction in CC/NC is very important component of this analysis.
Numbers here have been estimated from previous data and model guidance.

In actual experiment they will be *measured.*

- For ν_e CCQE interactions, can measure n-fraction in ν_μ CCQE events

- For ν_μ NC backgrounds, ν_μ NCπ^0 events (with well-identified) π^0 will be used





Results in measured n-fraction for both CC signal and NC background, bin-bin in reconstructed ν energy.
These measurements include final state effects.

Simulated Analysis

A new oscillation analysis of MB + scintillator has been simulated:

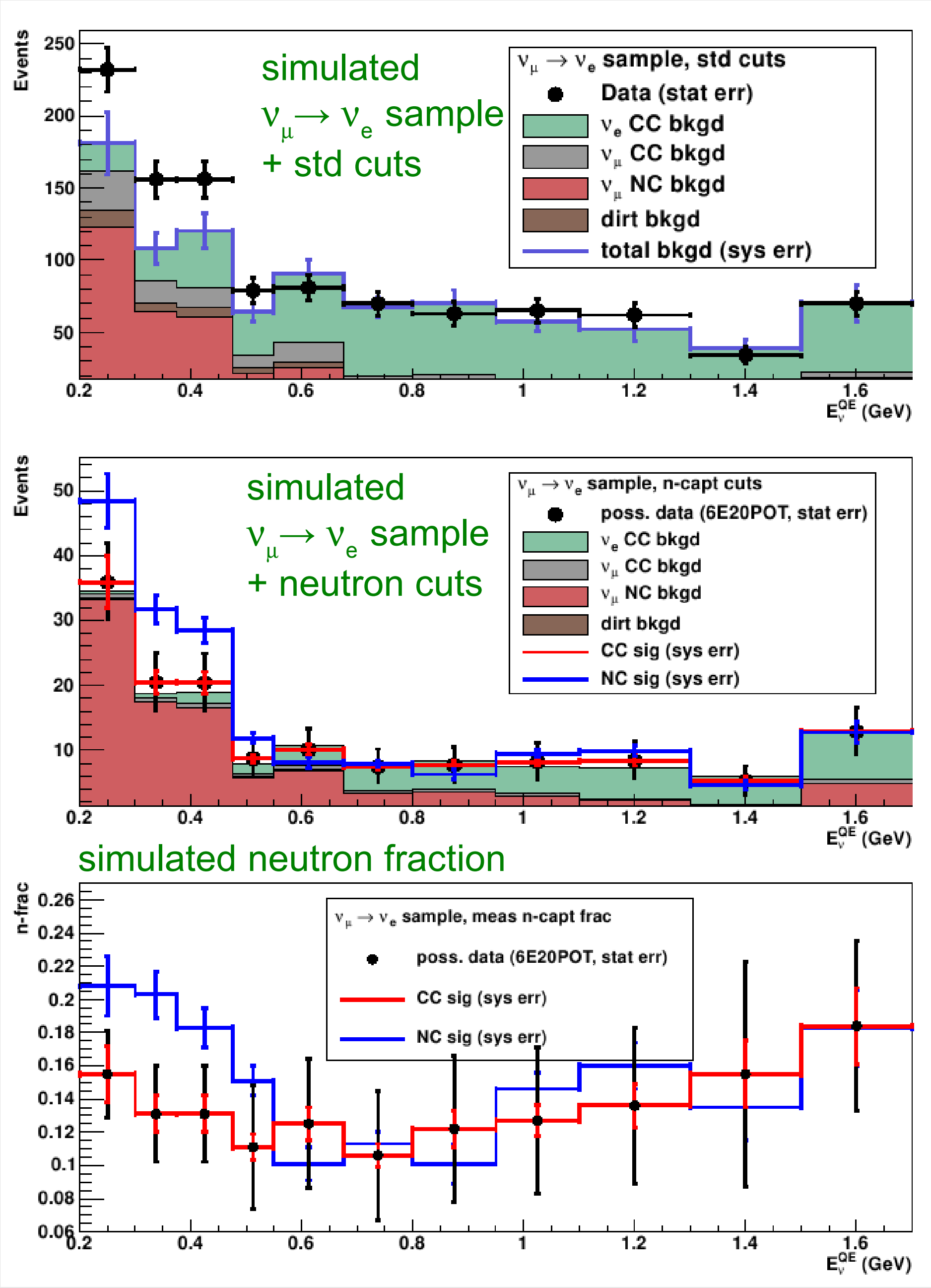
Assumptions:
- Previous ν oscillation experiment performed with same cuts and same statistics (6.5E20POT)
  - reconstruction performance same as previous
  - same excess is seen in this analysis (top plot)

- Then n-capture events are required and a reduced data set is obtained (middle plot)

Note that data excess disappears in middle plot and is same as CC prediction (red lines). If excess due to NC background (blue lines), then excess remains.

If excess is CC oscillation signal, then NC/CC separation is 3.5σ for this test. Combined with independent neutrino-mode excess in 1st stage analysis (of 3.4σ)

Yields a ~5σ test of MB excess.



MiniBooNE+ and MicroBooNE

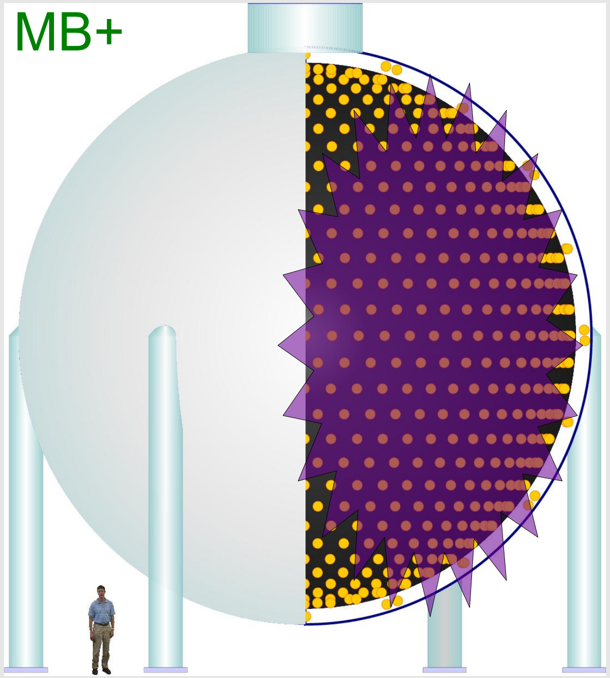
This would be a complementary effort to that of MicroBooNE which also has a goal of understanding MB excess...

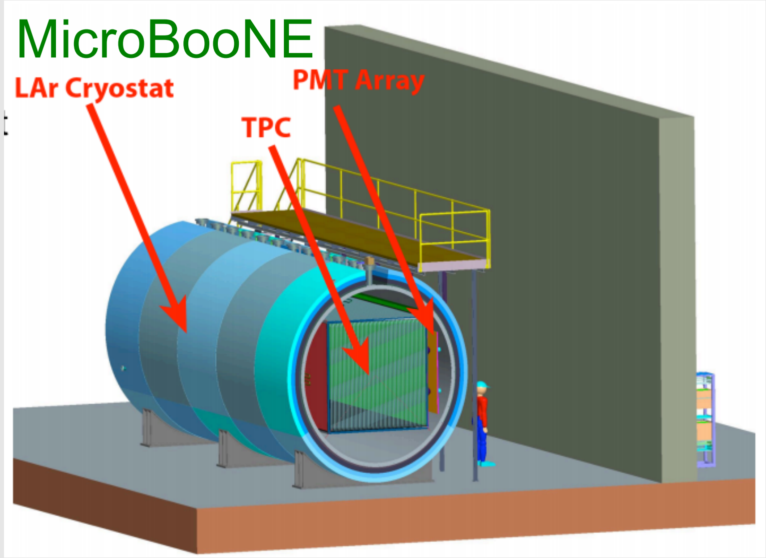
- Different nuclei: Carbon vs Argon

- MicroBooNE goal is to differentiate CC/NC via γ/e separation.
  MB+ will focus on nucleons, in particular neutrons with no energy threshold

- MicroBooNE will have precision tracking, but low event counts.
  MB+ cerenkov/calormetric reconstruction, higher event rates.

- The MiniBooNE excess is important to resolve, best to have two detectors looking at it, esp since nucleus changes in MicroBooNE





More physics w/MB+

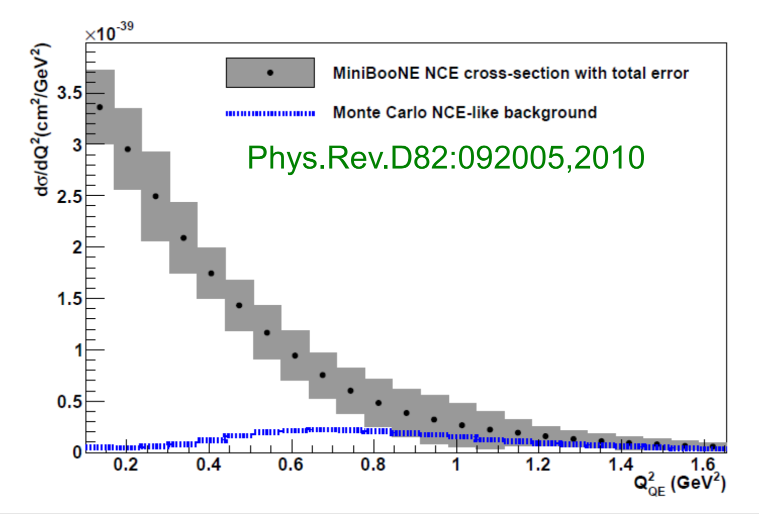
NC elastic scattering and Δs :

- MiniBooNE has measured ν – nucleon NC elastic scattering in both ν and $\bar{\nu}$ channels.
- Addition of scintillator allows for n/p separation and measurement of Δs (s-quark contribution to nucleon spin) via:

$$R(NCp/NCn) = \frac{\sigma(\nu_\mu p \rightarrow \nu_\mu p)}{\sigma(\nu_\mu n \rightarrow \nu_\mu n)}$$

for more input to ongoing proton spin puzzle.

MiniBooNE NC elastic differential cross section



$$\frac{d\sigma}{dQ^2}(\nu N \rightarrow \nu N) \propto (-\tau_z G_A + G_A^s)^2$$

$$G_A^s(Q^2=0) = \Delta s$$

$$\Delta\Sigma = \Delta u + \Delta d + \Delta s$$

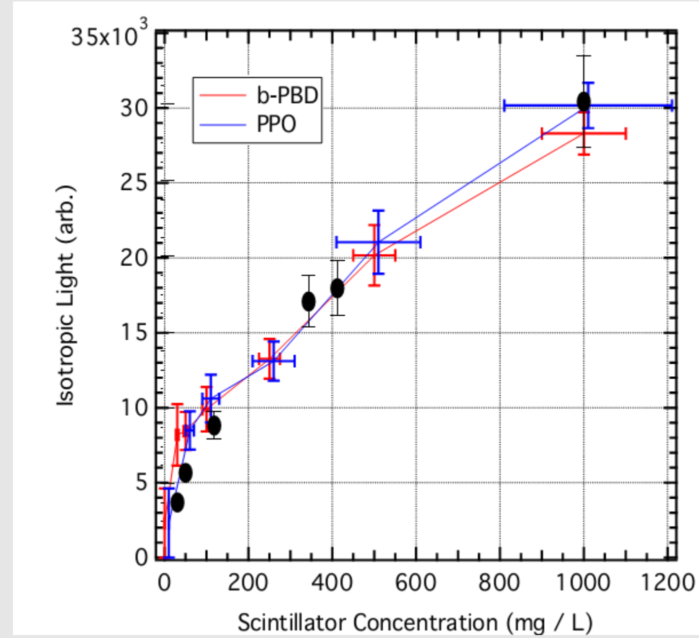
$$\Delta q = q\uparrow - q\downarrow + \bar{q}\uparrow - \bar{q}\downarrow$$

- Measurement of $\nu_\mu C \rightarrow \mu^- N_{g.s.}$
  - tagged with $N_{g.s.}$ β decay (~15MeV endpoint, enabled with scintillator)
  - cross section known to ~2% near threshold allows a low-E flux test

- Test of E_ν^{QE} in ν energy reconstruction
  - addition of scintillator will allow total energy of event to be measured and compared with E_ν^{QE}, the current method of reconstruction that assumes quasielastic ν–nucleon scattering.

MB+scintillator: some details

scintillation light vs scintillant concentration



From MC studies combined with lab tests:

- 300kg of PPO (~$75k) added to the 800 tons of MiniBooNE mineral oil (0.3g/l) will increase light to enable reconstruction of 2.2 MeV γ

Full measurement (repeat of ν oscillation search) requires 6.5E20POT. Assuming that 2E20POT/year available on Booster neutrino beamline.

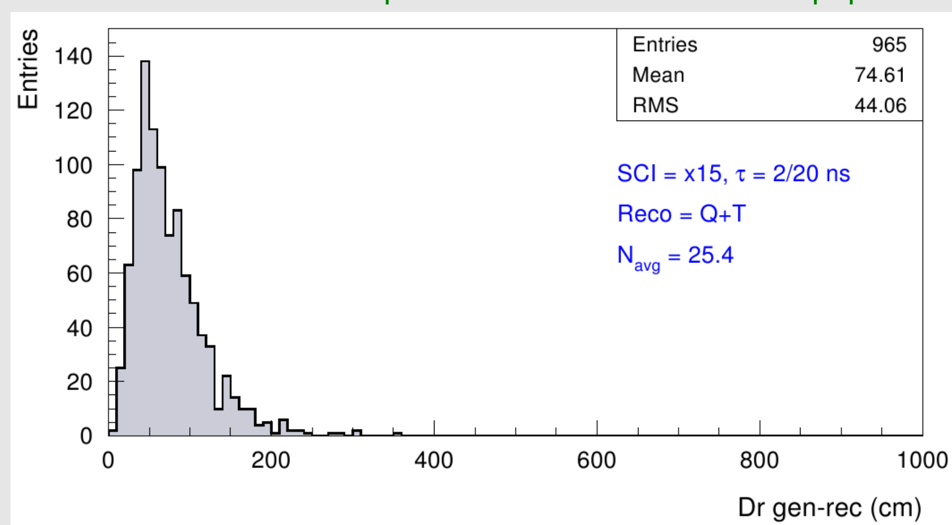
Then:
- add scintillator in soon
- run 2E20POT/yr 2014-2016 concurrently with MicroBooNE.

- LOI to FNAL in Fall'12. Proposal soon...

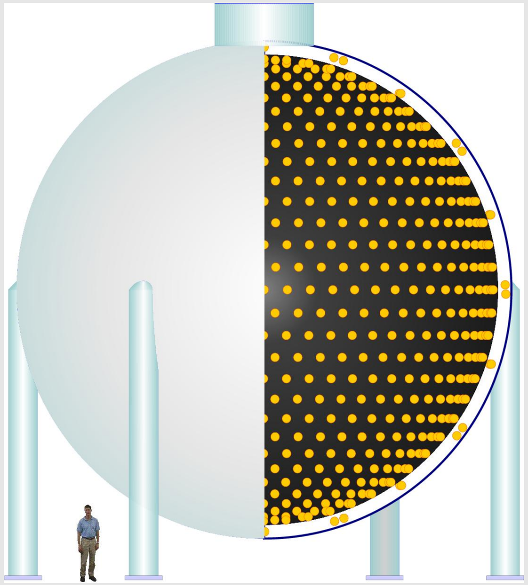
Letter of Intent: A new investigation of $\nu_\mu \rightarrow \nu_e$ oscillations with improved sensitivity in an enhanced MiniBooNE experiment

arXiv:1210.2296

position reconstruction of n-capt phtons



Summary



- MiniBooNE observes, in a combined $\nu / \bar{\nu}$ data set (including all $\bar{\nu}$ data to date) an excess of 240.3±62.9 events (3.8σ), consistent with LSND.

- Perhaps evidence for sterile neutrino

- The excess is at low-energy where NC backgrounds dominate.

- (others) calculations of those backgrounds agree with those from MB which are constrained with in-situ data.

- MB+ can check the MB NC backgrounds with the addition of PPO (~$100k) and redo the oscillation search for a 5σ test of MB excess.

- MB+: Exciting new physics, results in timely manner.

Backup slides

MiniBooNE, ν interactions results

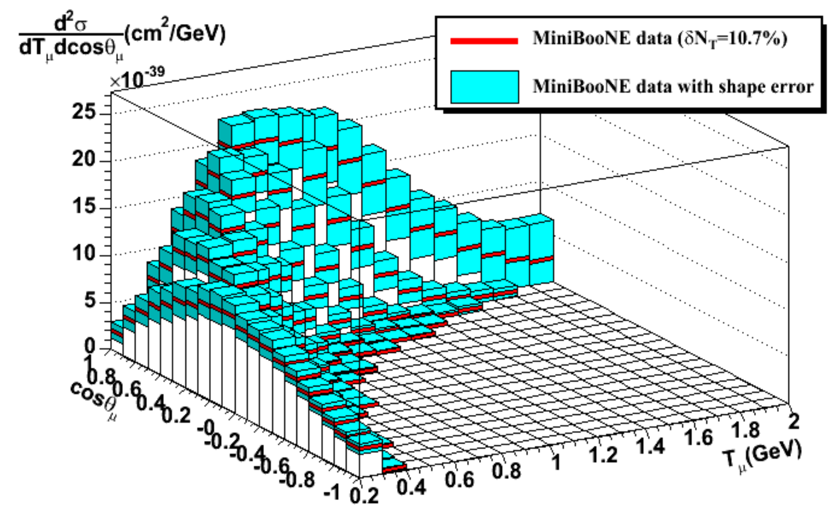
Published results from these channels:

- ν CC quasielastic (CCQE)
  - detection and normalization signal for oscillations
- ν NC elastic (NCel)
- ν CC production of π^+, π^0
- ν CC inclusive scattering
- ν NC production of neutral pions
  - very important oscillation background

Have learned:

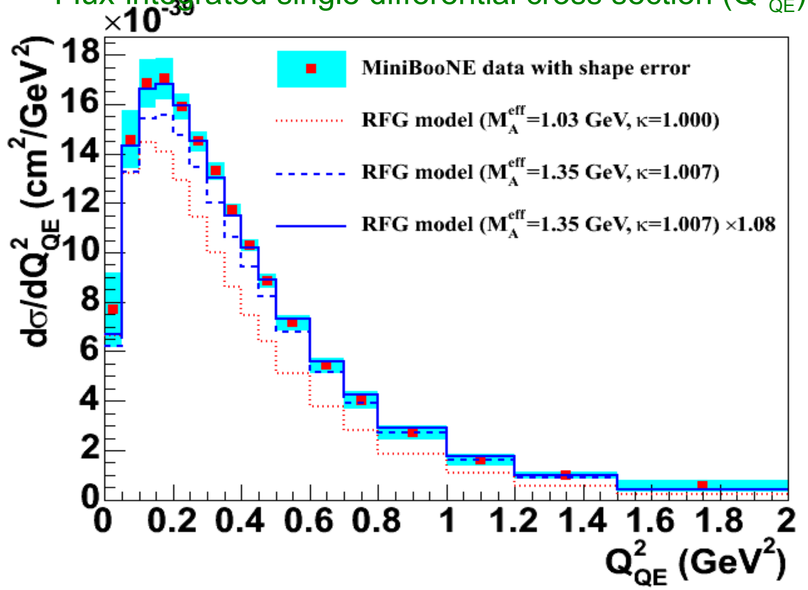
- ν measured cross sections ~20-40% higher than expected. Perhaps multi-N effects.
- Impulse Approx + Fermi Gas mode, adequate to explain muon kinematics, albeit with $M_A \sim 1.35$
- measured ν_μ rates to predict/constrain ν_e oscillation search signal/background

Flux-integrated double differential cross section (T_μ-cosθ):



PRD 81, 092005 (2010)

Flux-integrated single differential cross section (Q^2_{QE}):



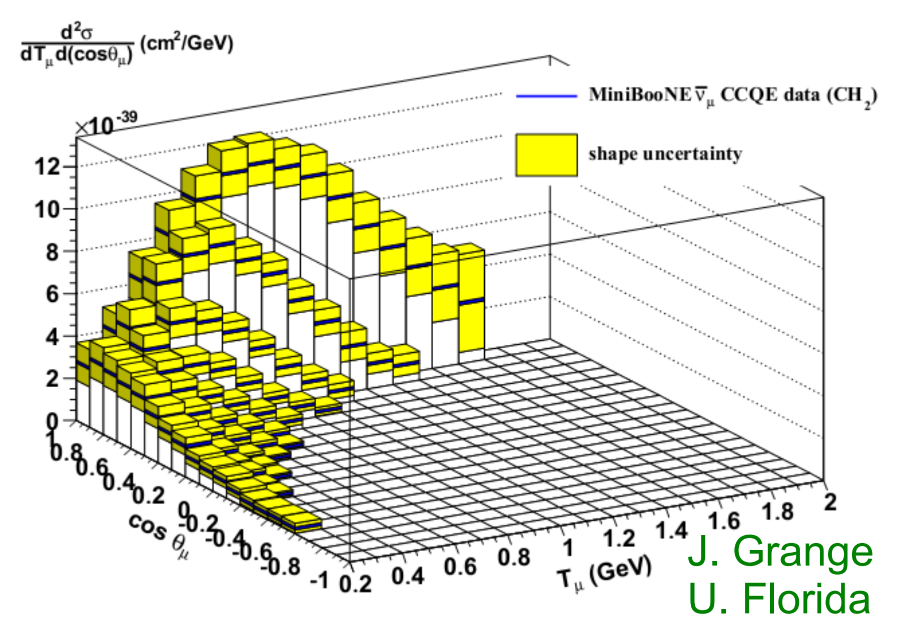
MiniBooNE, $\bar{\nu}$ interactions results

New results from these antineutrino channels:

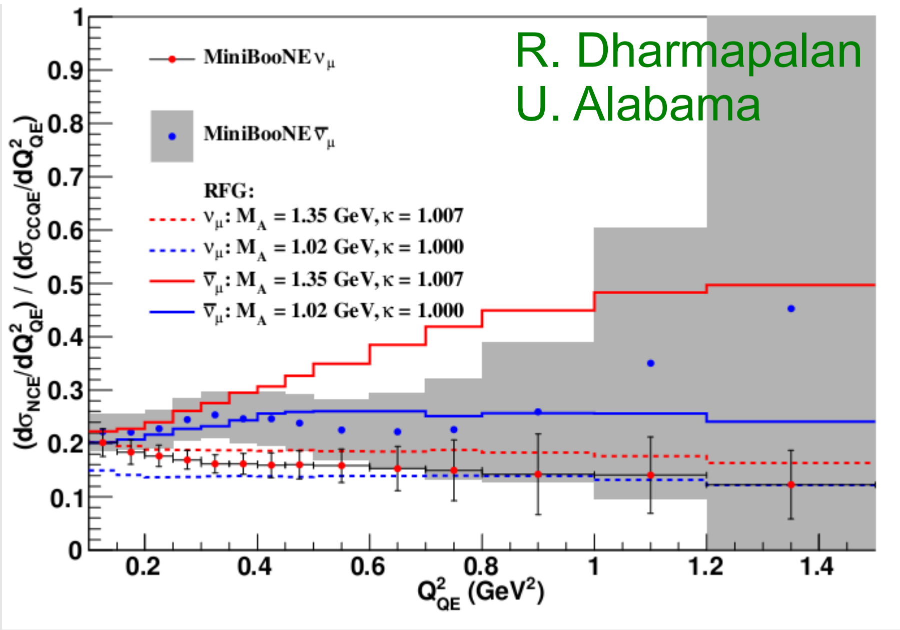
- $\bar{\nu}$ CC quasielastic (CCQE)
  - arXiv:1301.7067
- $\bar{\nu}$ NC elastic (NCel)
  - publication imminent

Should provide additional information on scattering mechanism.

Multi-N effects should interfere differently (than impulse approximation model) in antineutrino scattering.



J. Grange
U. Florida



R. Dharmapalan
U. Alabama

NCγ calculations

From R. Hill, Phys.Rev. D81 (2010) 013008,
Phys.Rev. D84 (2011) 017501

- "high-energy" approach pushed to lower energies..

- Determines NCγ production dominated by incoherent Δ production

- Predicts rates that are substantial fraction of MB excess

- However, the efficiencies used were high (~x2 and no-energy dependence)

- New, corrected, energy-dep MB efficiencies available, looking forward to new background estimates

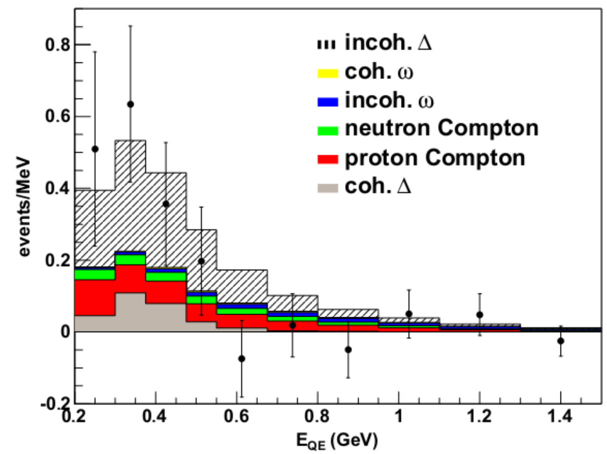


FIG. 1: Single-photon events at MiniBooNE for 6.46×10^{20} protons on target in neutrino mode. A 25% efficiency is assumed. The hatched line represents the difference between the direct calculation and MiniBooNE π^0-constrained incoherent $\Delta \to N\gamma$ background. Data points correspond to the excess events reported in [4], Fig. 2.

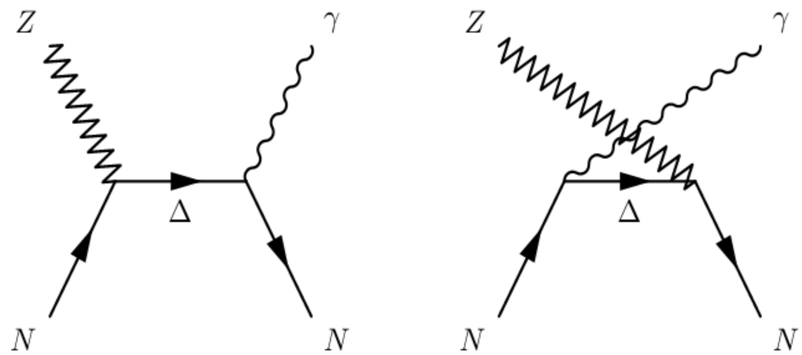


FIG. 3: Production of photons through the Δ resonance.

TABLE I: Single photon and other backgrounds for MiniBooNE ν-mode in ranges of E_{QE}. Ranges in square brackets are the result of applying a $20-30\%$ efficiency correction.

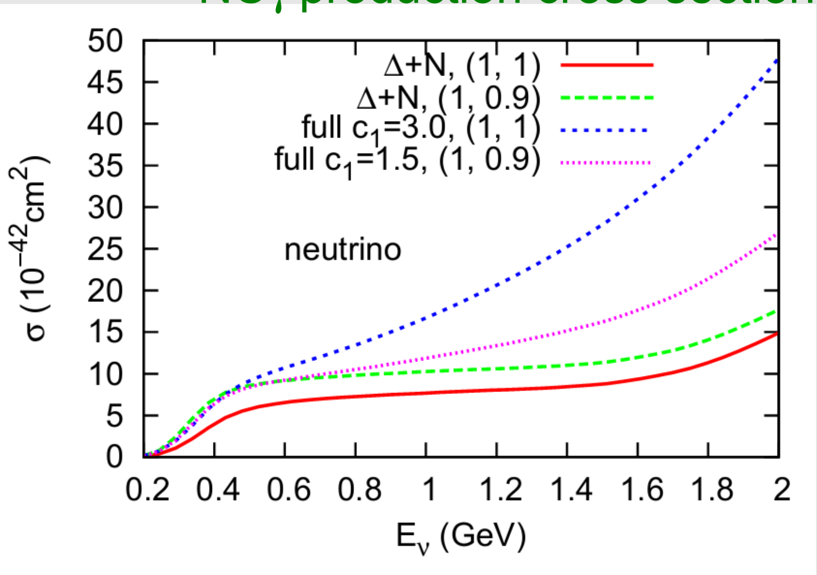
process	200-300	300-475	475-1250
1γ, non-Δ	85[17 − 26]	151[30, 45]	159[32, 48]
$\Delta \to N\gamma$	170[34 − 51]	394[79 − 118]	285[57 − 86]
$\nu_\mu e \to \nu_\mu e$	14[2.7 − 4.1]	20[4.0 − 5.9]	40[7.9 − 12]
$\nu_e n \to ep$	100[20 − 30]	303[61 − 91]	1392[278 − 418]
MB excess	45.2 ± 26.0	83.7 ± 24.5	22.1 ± 35.7
MB $\Delta \to N\gamma$	19.5	47.5	19.4
MB $\nu_\mu e \to \nu_\mu e$	6.1	4.3	6.4
MB $\nu_e n \to ep$	19	62	249

NCγ calculations

From Zhang, Serot Phys.Rev. C86 (2012) 015501, arXiv:1206.6324 (accepted), arXiv:1208.1553 (submitted)

- An effective field theory model with N, π, Δ, ω, ρ, σ fields. Benchmarked substantially with π electro production, electron scattering data.
- A "low-energy" model, not applicable above E_ν = 500MeV (but extrapolations can be made).
- Compared to latest from R. Hill:
  - also find that NCγ production dominated by incoherent Δ production,
  - but finds smaller ω contribution due to nuclear effects.
  - and, less Compton production
- Estimated NC backgrounds consistent with MB estimates

NCγ production cross section



From Zhang and Serot, arXiv:1210.3610

E_{QE}(GeV)	[0.2 , 0.3]	[0.3 , 0.475]	[0.475 , 1.25]
coh	1.3 (2.4)	6.4 (9.9)	2.4 (9.3)
inc	9.5 (10.5)	27.6 (31.3)	16.7 (27.1)
H	3.0 (3.3)	10.6 (11.7)	5.4 (7.4)
Total	13.8 (16.2)	44.6 (52.9)	24.5 (43.8)
MiniBN	19.5	47.3	19.4
Excess	42.6 ± 25.3	82.2 ± 23.3	21.5 ± 34.9

TABLE II: E_{QE} distribution of the NC photon events in the MiniBooNE neutrino run, comparing our estimate to the MiniBooNE estimate [1].

- However, additional experimental tests called for...
  - important to resolve the MB low-energy excess
  - may be important for other future experiments in this energy range (eg: T2K)

Simulated Analysis: details

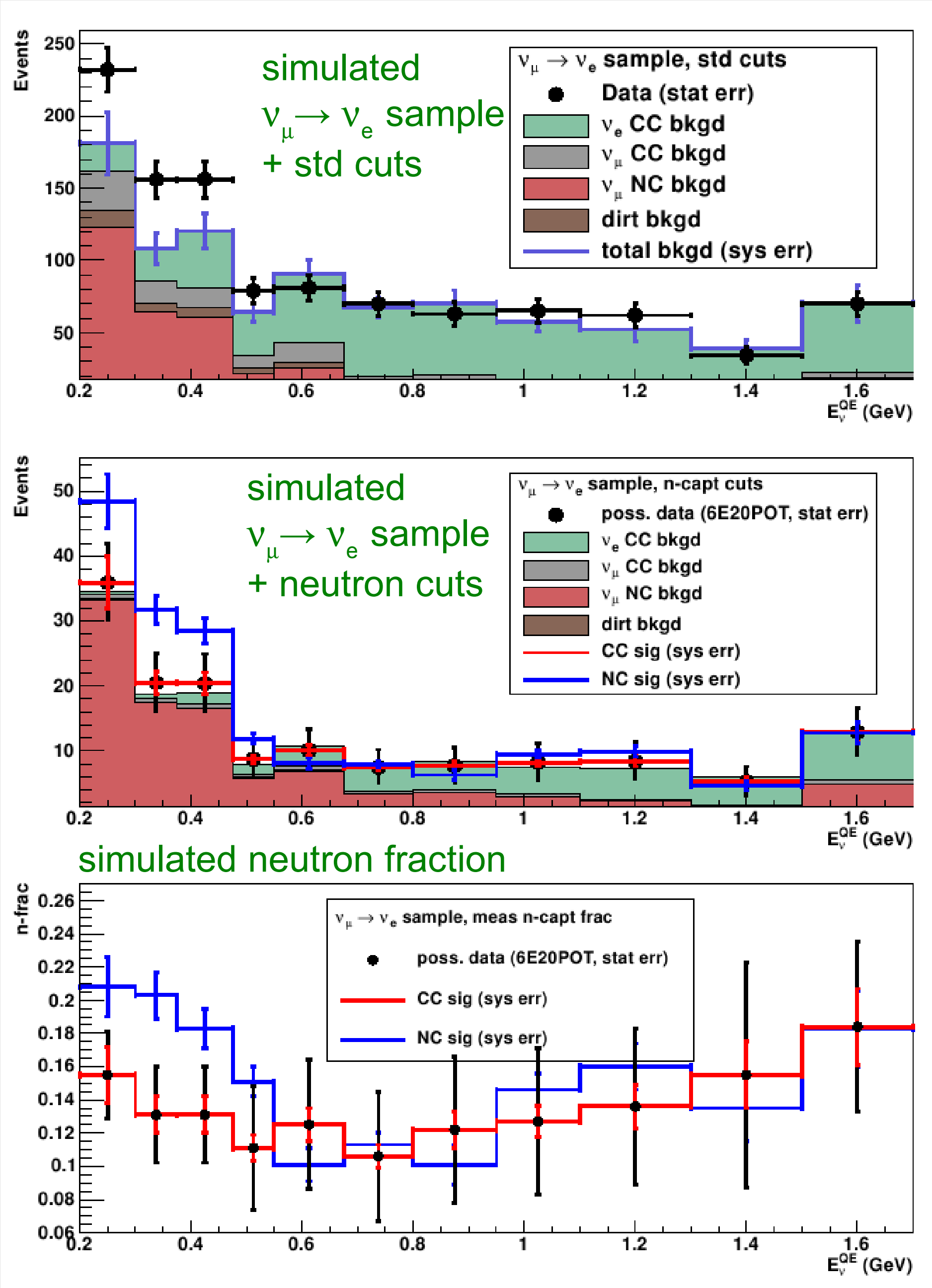
A new oscillation analysis of MB with scintillator has been simulated:

Assumptions:
- Previous ν oscillation experiment performed with same cuts and same statistics (6.5E20POT)
  - reconstruction performance same as previous
  - same excess is seen in this analysis (top plot)

- Then n-capture events are required and a reduced data set is obtained (middle plot)

Assumptions:
  - excess is due to oscillations (CCQE events)
  - CC event n-fraction = 1%(250 MeV) - 10%(1GeV), includes final state effects and has been measured.
  - NC event n-fraction = 50%. From Δ dominance in both NCγ and NCπ^0
  - 50% n-capture efficiency
  - 2% accidental n-capture probability
  - systematic errors assigned to all these and variational studies performed.

Note that data excess disappears in middle plot and is same as CC prediction (red lines). If excess due to NC background (blue lines), then excess remains.



Simulated Analysis

If excess is CC oscillation signal, then separation from NC hypothesis is 3.5σ for this NC/CC test. Combined with expected neutrino-mode excess in 1st stage analysis (of 3.4σ) yields ~5σ

Variations of study assumptions performed.

- POT, statistics limited study, need 6.5E20POT
- background rejection important to achieve sensitivity.

	neutron fraction									
configuration	NC prediction			fake data			difference			$n\sigma$
standard	0.191	±	0.008	0.134	±	0.015	0.057	±	0.016	**3.48**
4E20POT	0.191	±	0.008	0.134	±	0.018	0.057	±	0.019	2.95
2E20POT	0.191	±	0.008	0.134	±	0.026	0.057	±	0.027	2.16
(bckgnd error)×0.5	0.191	±	0.005	0.134	±	0.015	0.057	±	0.015	3.73
(n-capture efficiency)=0.75	0.277	±	0.012	0.191	±	0.018	0.086	±	0.021	4.13
(accidental efficiency)×2	0.211	±	0.008	0.154	±	0.016	0.057	±	0.017	3.29
(CC n-fraction)×2	0.191	±	0.008	0.137	±	0.015	0.054	±	0.017	3.26
(low-E CC n-fraction)=0.06	0.199	±	0.008	0.147	±	0.015	0.051	±	0.017	3.00
(NC n-fraction error)×2	0.191	±	0.010	0.134	±	0.015	0.057	±	0.017	3.31
dirt n-fraction=0.5	0.203	±	0.008	0.145	±	0.015	0.057	±	0.017	3.32
(NC bckgnd)×2	0.215	±	0.011	0.175	±	0.014	0.040	±	0.017	2.29
(NC bckgnd)×2 + ∞ POT	0.215	±	0.011	0.175	±	0.000	0.040	±	0.010	3.81
(NC n-fraction)= 0.42	0.165	±	0.006	0.117	±	0.014	0.048	±	0.015	3.17
∞ POT	0.191	±	0.008	0.134	±	0.000	0.057	±	0.008	7.63