SciBooNE/MiniBooNE

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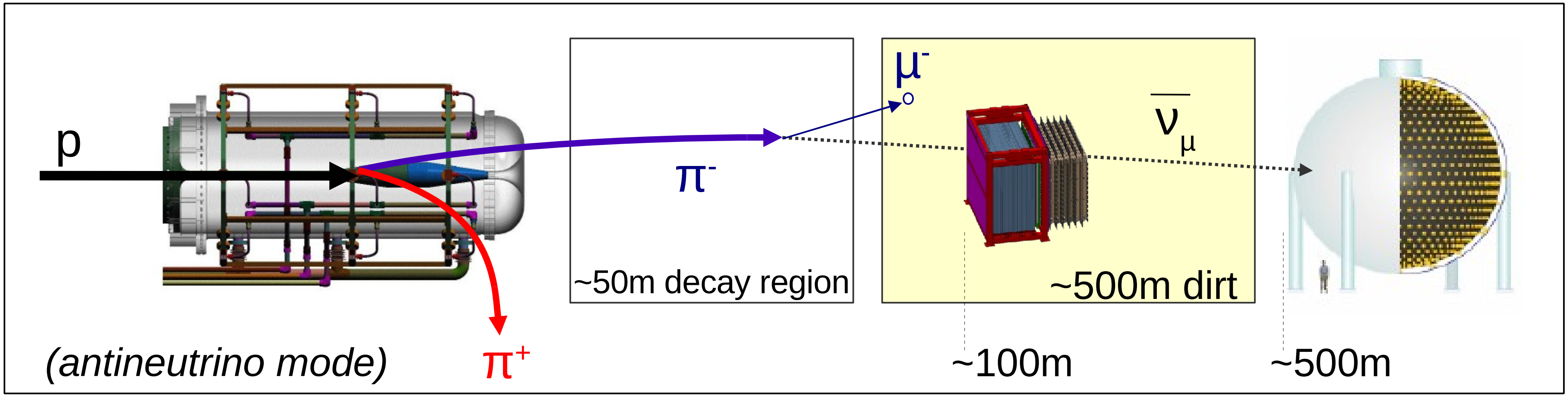
Los Alamos National Laboratory

Fermilab Users' Meeting, 2012

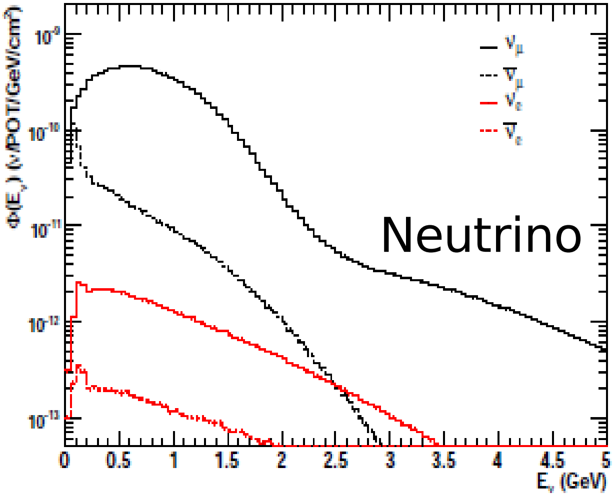
Outline

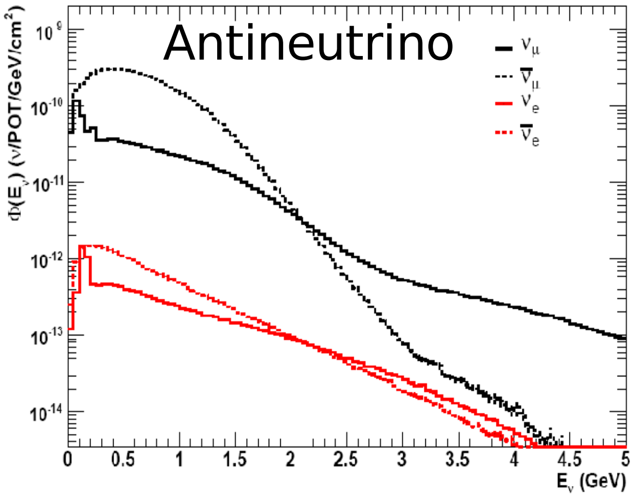
- Booster Neutrino Beamline
- SciBooNE & MiniBooNE experiments
- New results
  - MB Updated neutrino appearance analysis
  - MB Antineutrino appearance analysis
  - MB Joint Neutrino & Antineutrino appearance analysis
  - Joint SciBooNE/MiniBooNE numubar disappearance analysis
- Future prospects

Booster Neutrino Beam

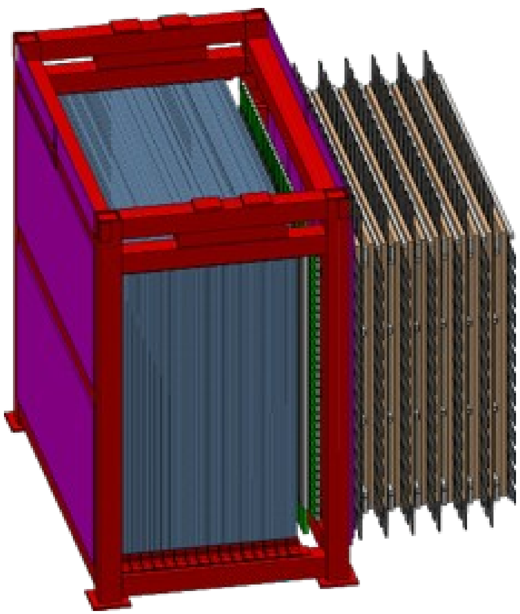


- Horn focused beam/8GeV protons from Booster
- Horn polarity → neutrino or antineutrino mode

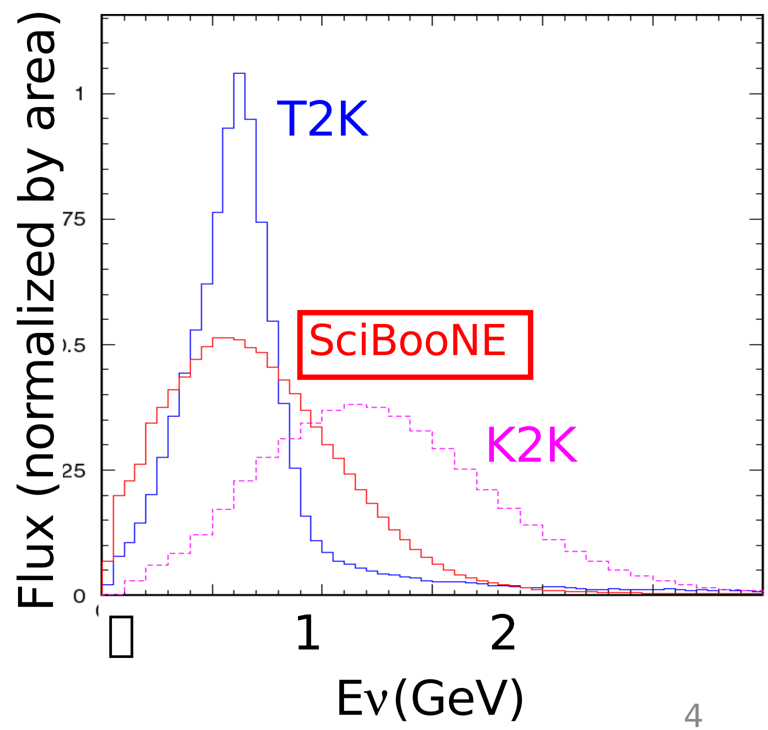




SciBooNE



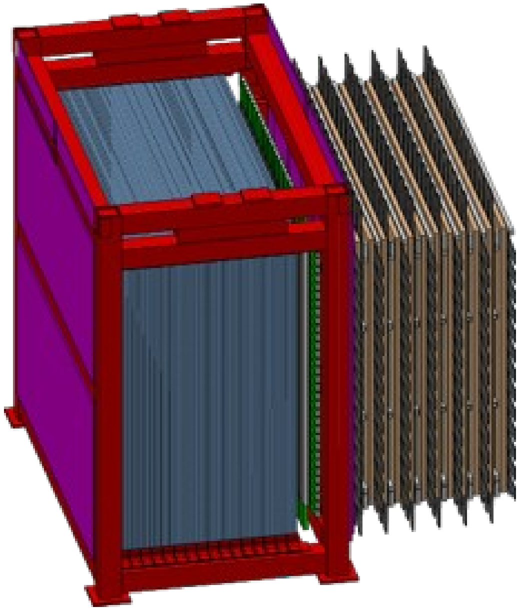
- SciBar
  - Scintillator tracking detector (15 tons)
  - Neutrino target
- Electron Catcher (EC)
- Muon Range Detector (MRD)



Physics goals:

- Precise measurements of ν and $\bar{\nu}$ cross sections
  - Non quasi-elastic interactions
- Near detector for MiniBooNE oscillation analysis

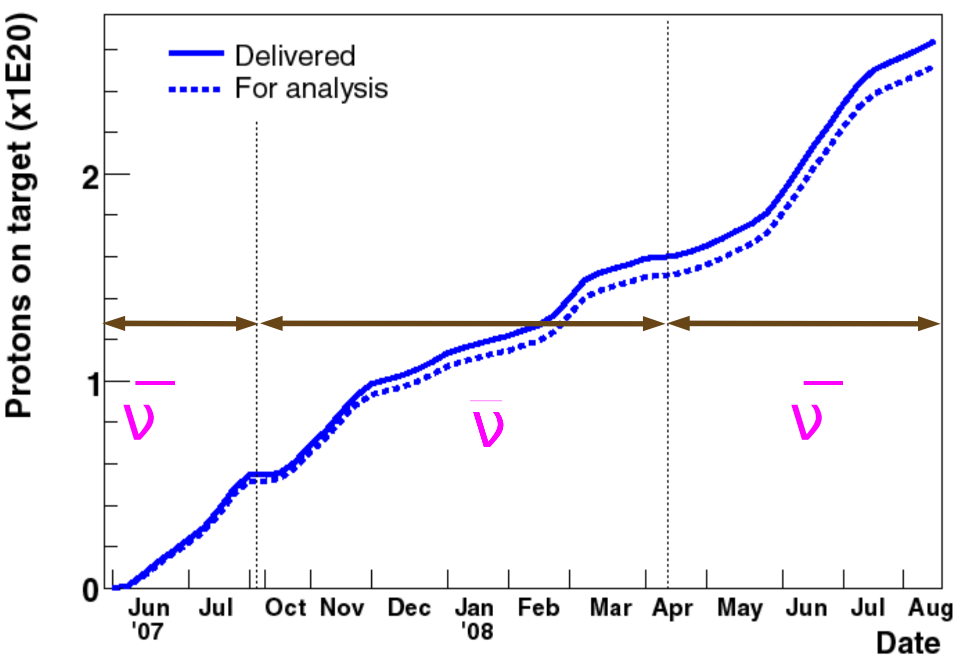
SciBooNE



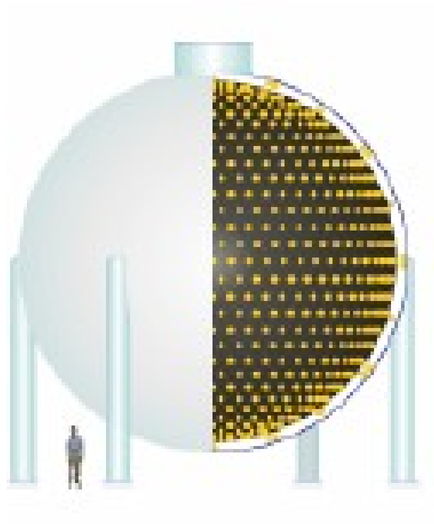
- SciBar
  - Scintillator tracking detector (15 tons)
  - Neutrino target
- Electron Catcher (EC)
- Muon Range Detector (MRD)

- Jun. 2007 -Aug. 2008
- 95% data efficiency
- 2.52×10^{20} POT in total
- neutrino : 0.99×10^{20} POT
- antineutrino: 1.53×10^{20} POT

Number of Protons on target (POT)



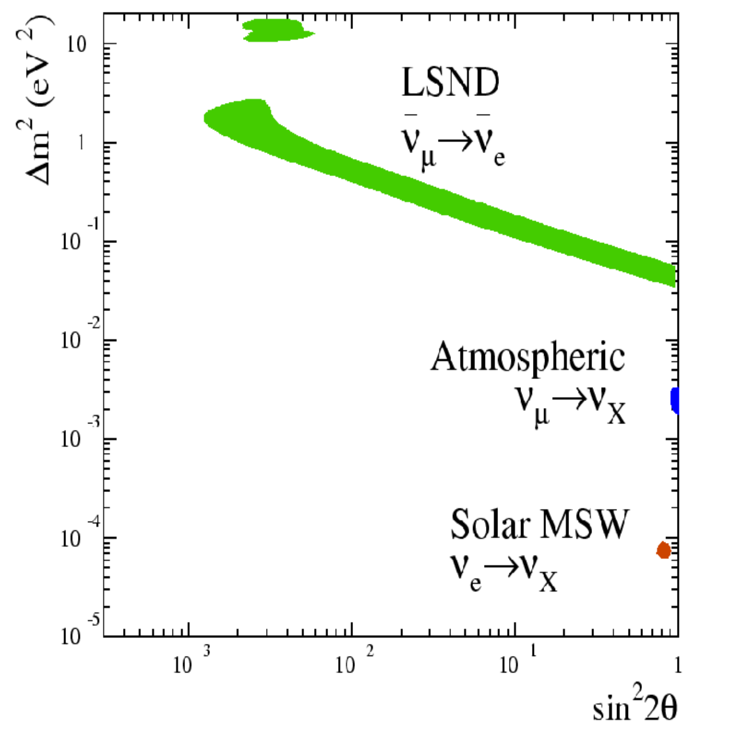
MiniBooNE



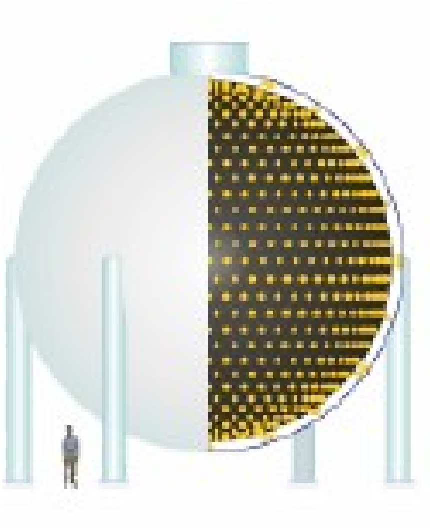
- 800t mineral oil Cherenkov detector
- 1520 PMTs in inner/outer region

Physics goals:

- Neutrino and antineutrino oscillations at $\Delta m^2 \sim 1 eV^2$ (motivated by LSND experiment)
- Cross sections

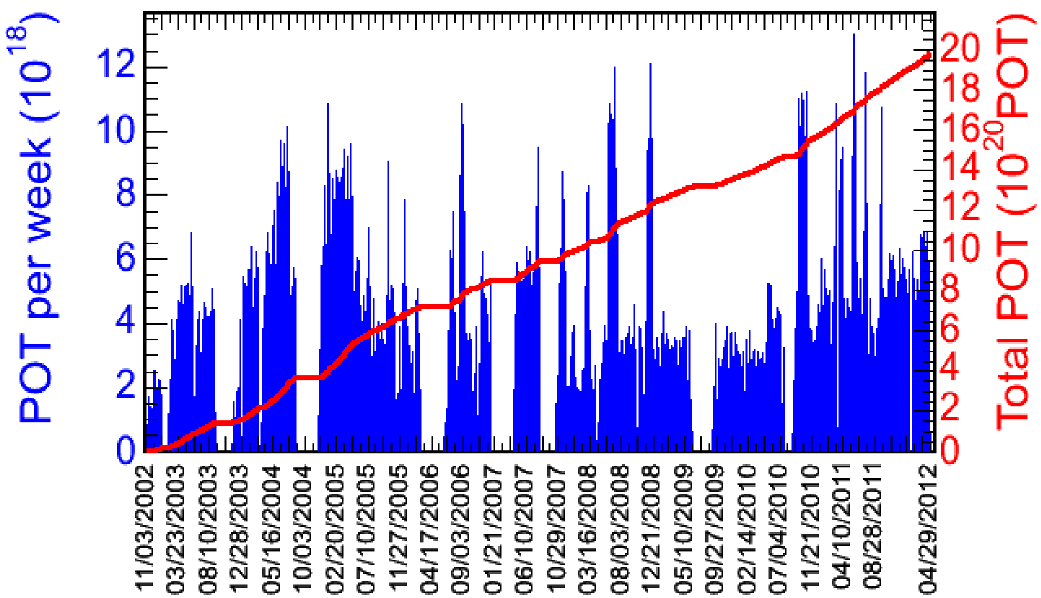


MiniBooNE



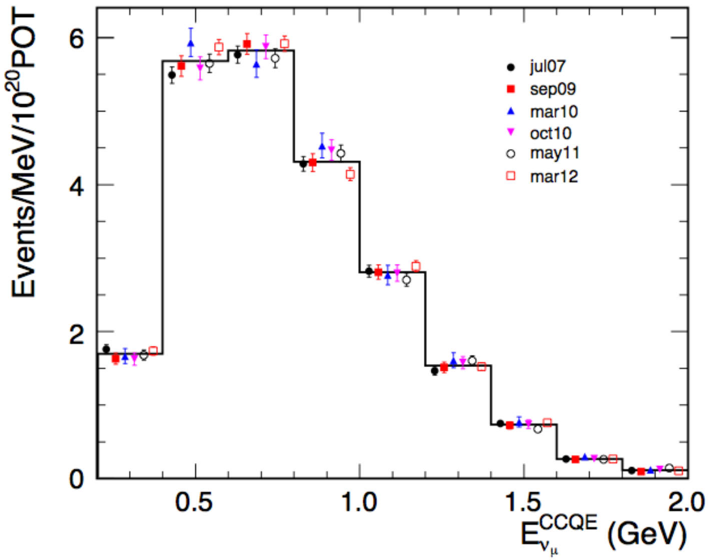
- 800t mineral oil Cherenkov detector
- 1520 PMTs in inner/outer region

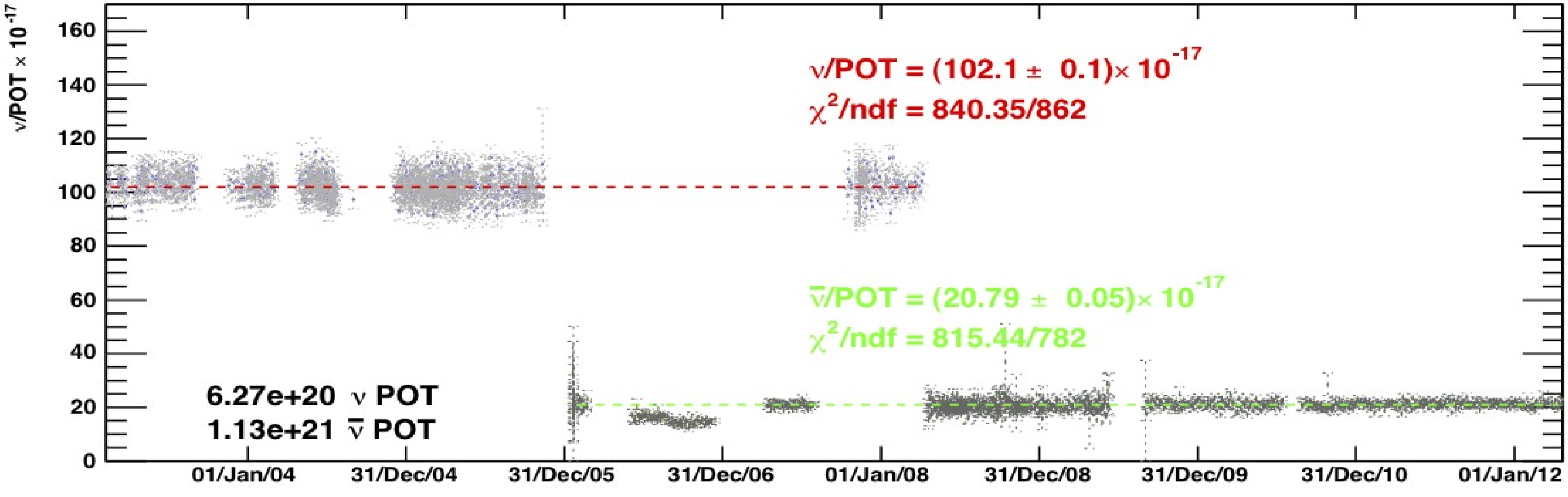
- Data taking: 2002-2012
- Total POT 19.8×10^{20}
- Neutrino: 6.5×10^{20}
- Antineutrino: 11.3×10^{20}



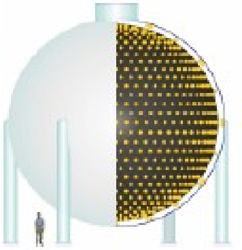
10 years of running

- Detector and beam extremely stable
- Neutrino/POT within 2%
- Detector calibration stable at 1% level

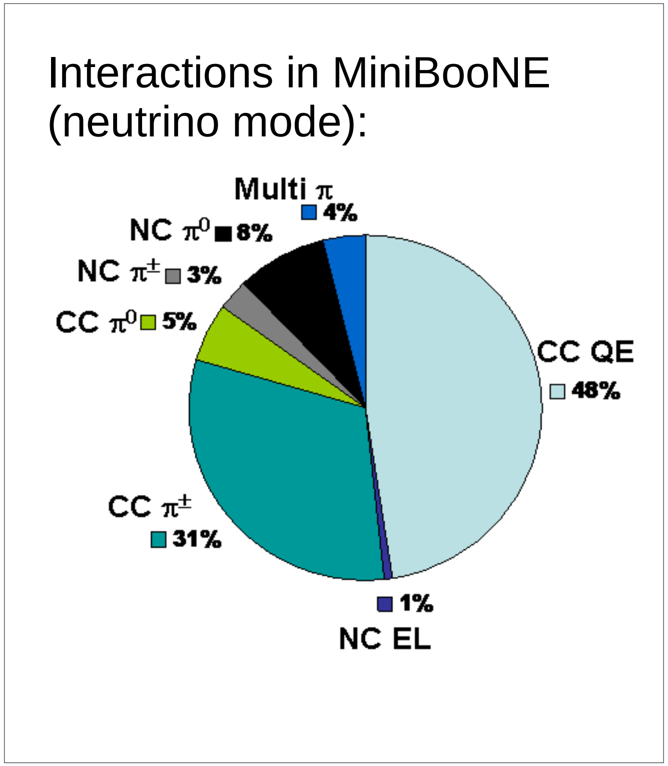


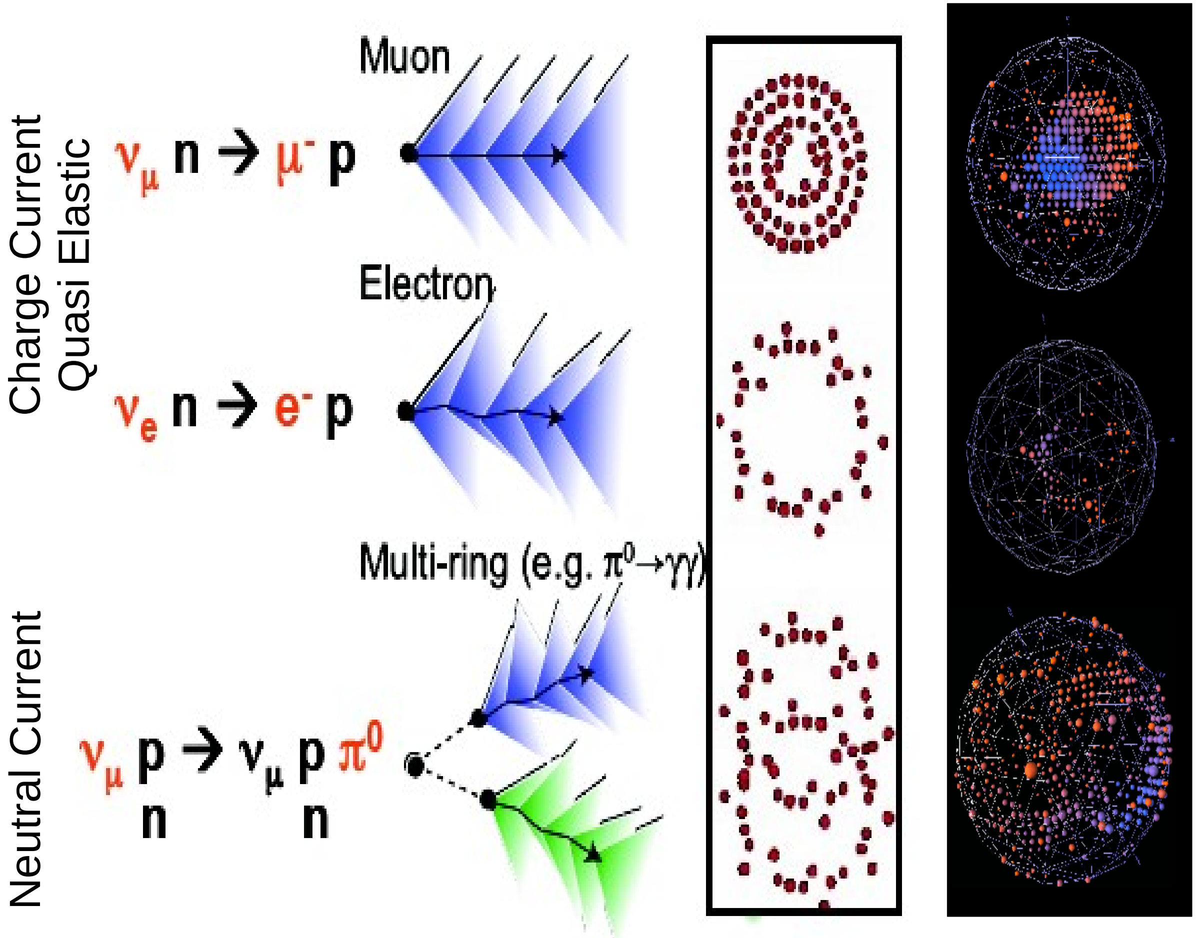


Events in MB



- Identify events using timing and hit topology
- Use primarily Cherenkov light



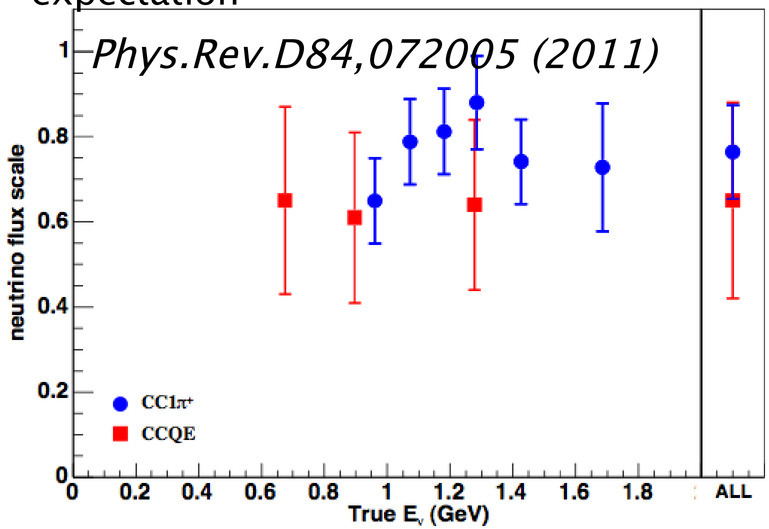


MiniBooNE appearance analysis:

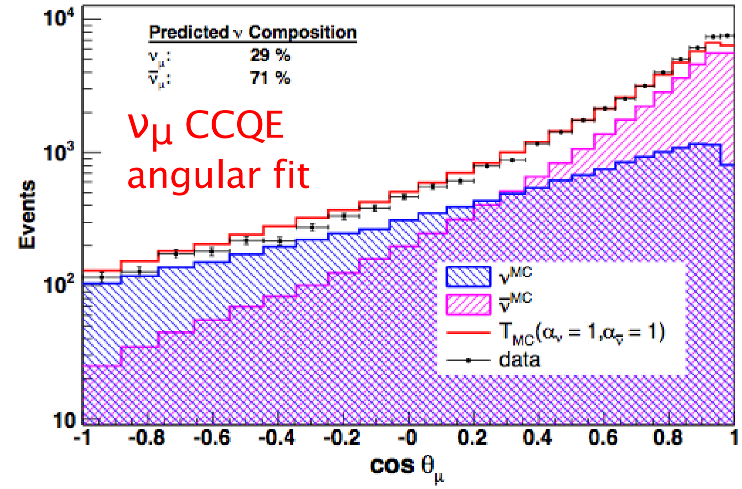
1) Neutrino mode update
2) New Antineutrino results
3) Combined neutrino and antineutrino mode

What's new since last oscillation publication?

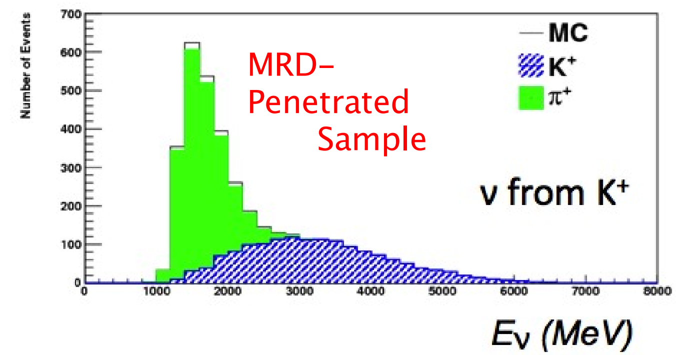
- *In situ* measurement of WS contamination in anti-ν beam
  - ν_μ CCQE angular fit, and new constrain from CCπ+ rate...good agreement with expectation

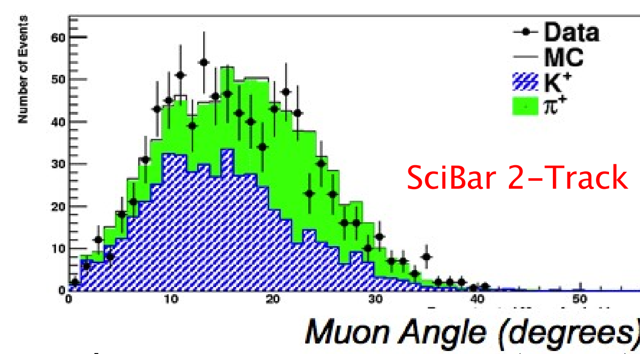


Phys.Rev.D84,072005 (2011)



- New SciBooNE constraint on intrinsic ν_e from K+
  - Found K+ production to be 0.85 ± 0.12 relative to prediction, consistent with prior MiniBooNE assessment of 1.00 ± 0.30
  - Combined with world K+ production data, reduces error on K+ flux to 9% in MB En range
  - Leading error on K+ bkgs becomes ~20% error from cross-section

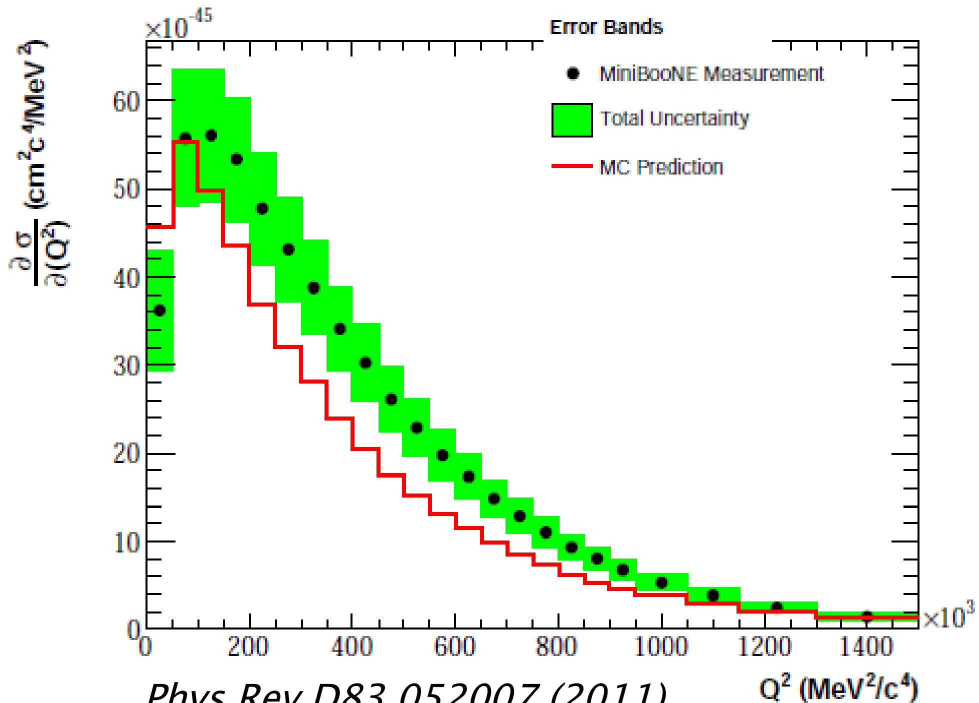




Phys.Rev.D84,012009 (2011)

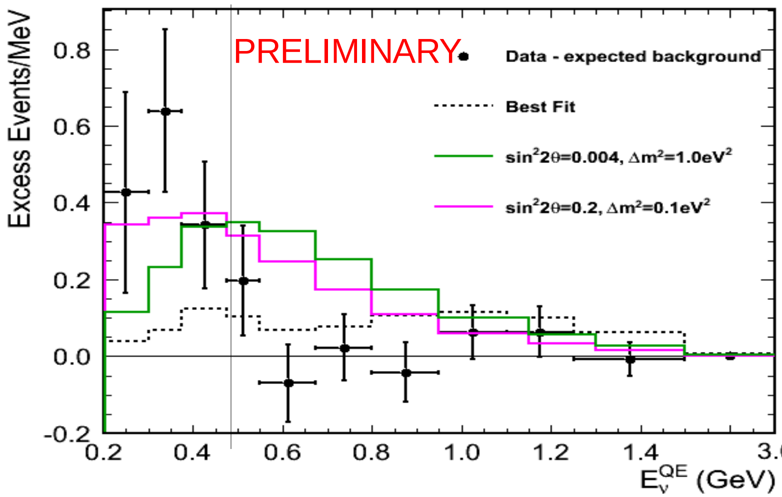
What's new since last oscillation publication?

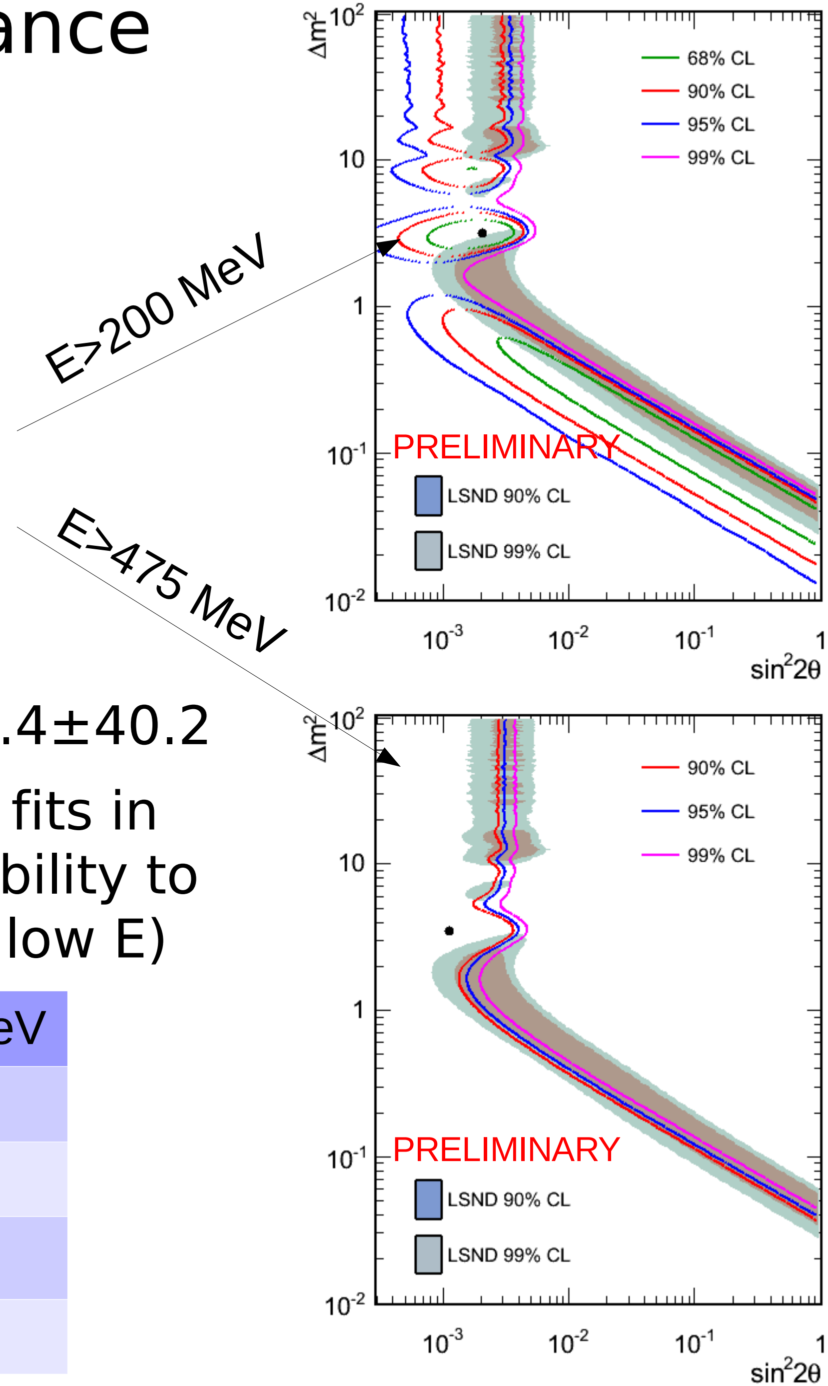
- Few other minor updates...
  - Higher stats for all MC samples, reduces fluctuations in error matrices
  - Added error matrix for intrinsic ν_e from K–
  - Improved smoothing algorithm that was being used to assess systematics due to discriminator thresholds and PMT response
  - CCπ+ events (bkg for ν_μ CCQE when π+ is absorbed) Q^2 reweighting applied based on internal MB measurement



Phys.Rev.D83,052007 (2011)

Updated Neutrino Appearance results

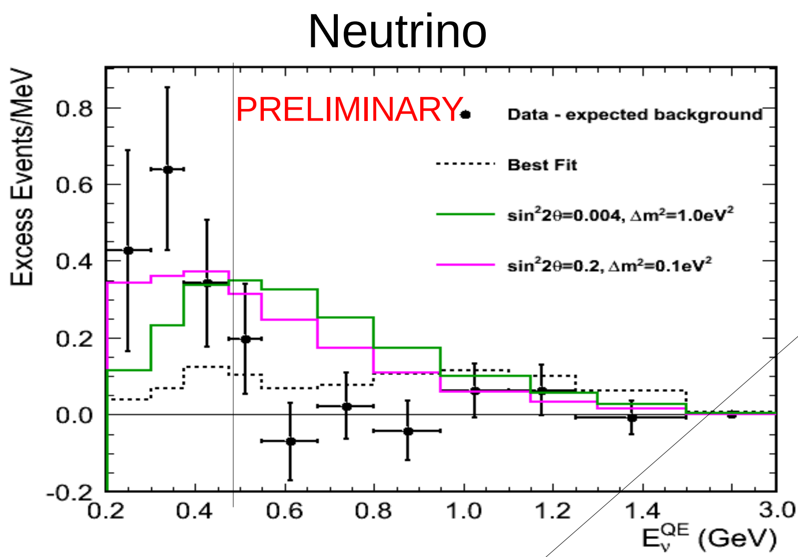


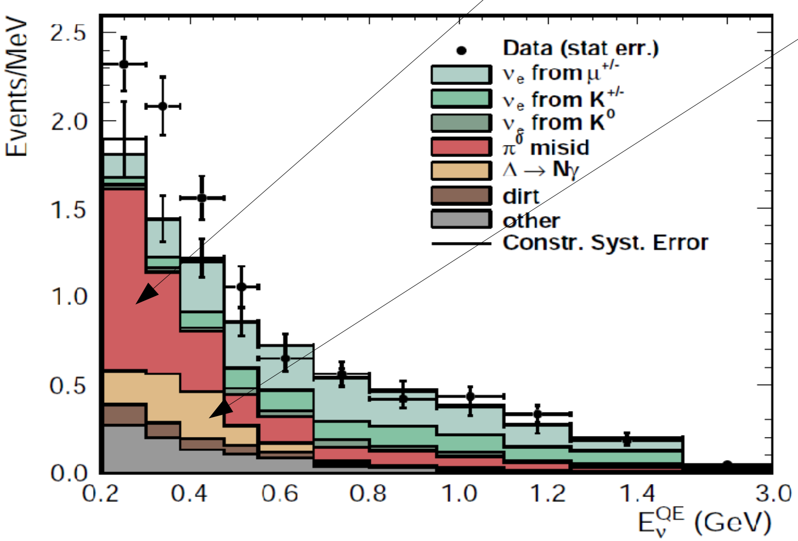


- Excess (200-1250 MeV): 146.3±28.4±40.2
- Some tension between 3+1 model fits in two energy regions (1.4% probability to see 3.73→13.24 when including low E)

ν mode	E > 200 MeV	E > 475 MeV
χ^2(null)	22.81	6.35
Prob(null)	0.5%	36.6%
χ^2(bf)	13.24	3.73
Prob(bf)	6.12%	42.0%

What can we say about low-E excess

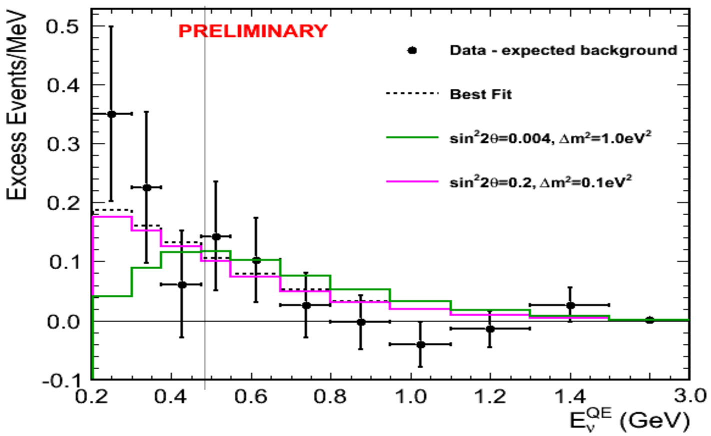




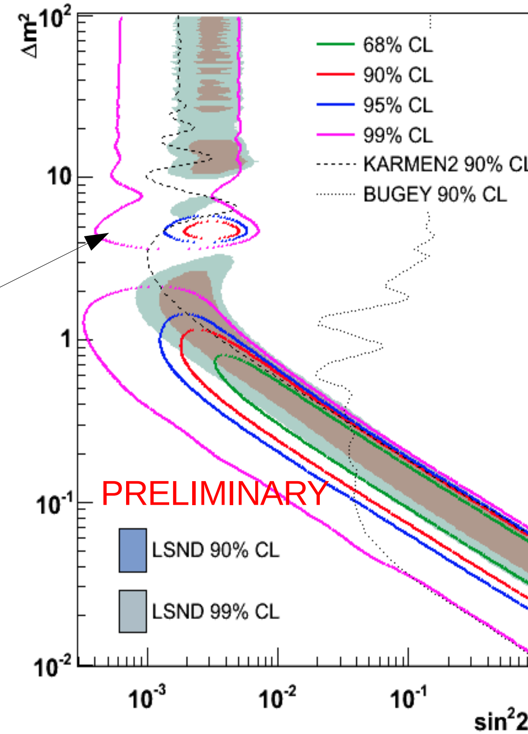
- Not a stat fluctuation, statistically 6σ
- Unlikely to be intrinsic ν_e, small bkg at low E
- NC π^0 background dominates
  - Reduces significance to 3σ
  - Heavily constrained by NC π^0 *in situ* measurement
- Region where single γ can contribute
- MB ties $\Delta \rightarrow N\gamma$ expected rate to be 1% of measured NC π^0 rate
  - Number of theory calculations for various single γ processes
  - All find total cross section within 20% of MB ~5×10^{-42} cm^2/N
  - Would need nearly 300% change

R. Hill, arxiv:0905.0291
Jenkins & Goldman, arxiv:0906.0984
Serot & Zhang, arxiv:1011.5913

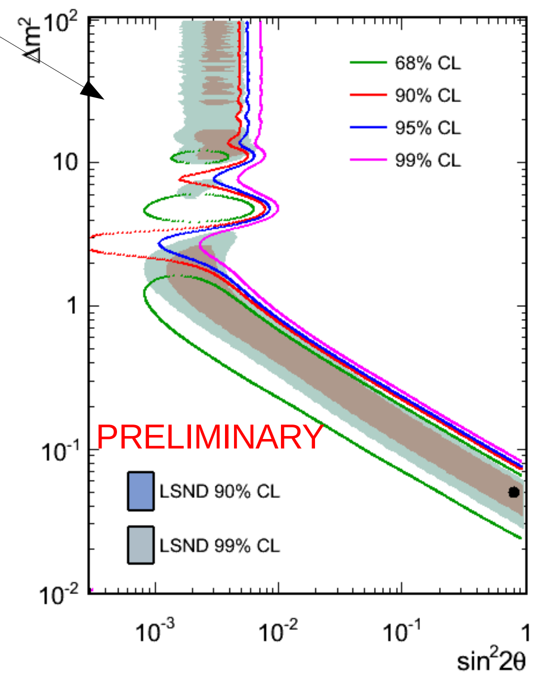
Antineutrino Appearance results 11.3x10^{20} POT



E>200 MeV



E>475 MeV

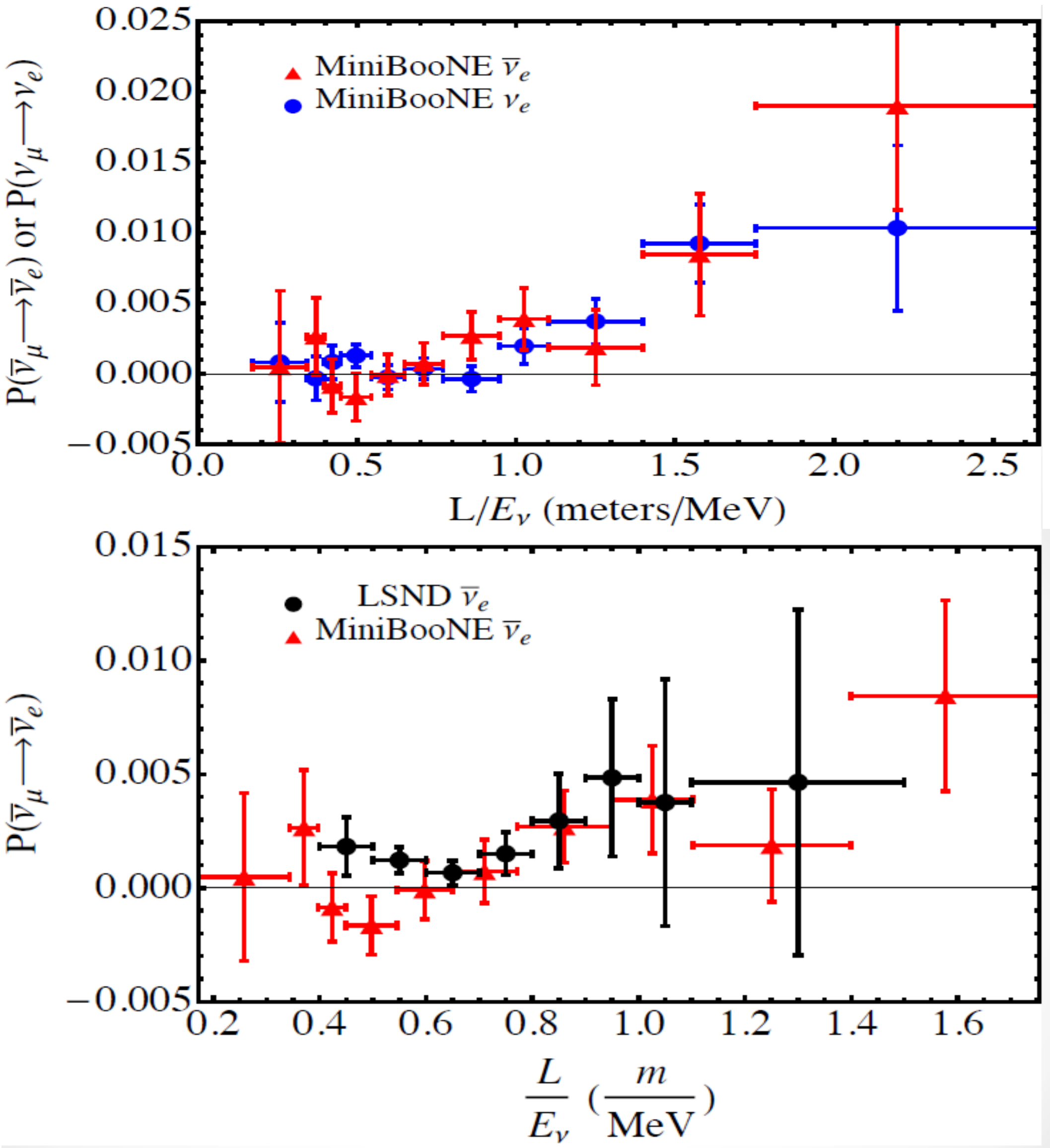


- Excess (200-1250 MeV):77.8±20.0±23.4
- No tension between fits in two energy regions
- Caveat: WS ν_μ assumed not to oscillate

anti-ν mode	E > 200 MeV	E > 475 MeV
χ^2(null)	16.3	7.59
Prob(null)	5.8%	26.4%
χ^2(bf)	4.76	3.23
Prob(bf)	67.5%	50.2%

L/E dependence

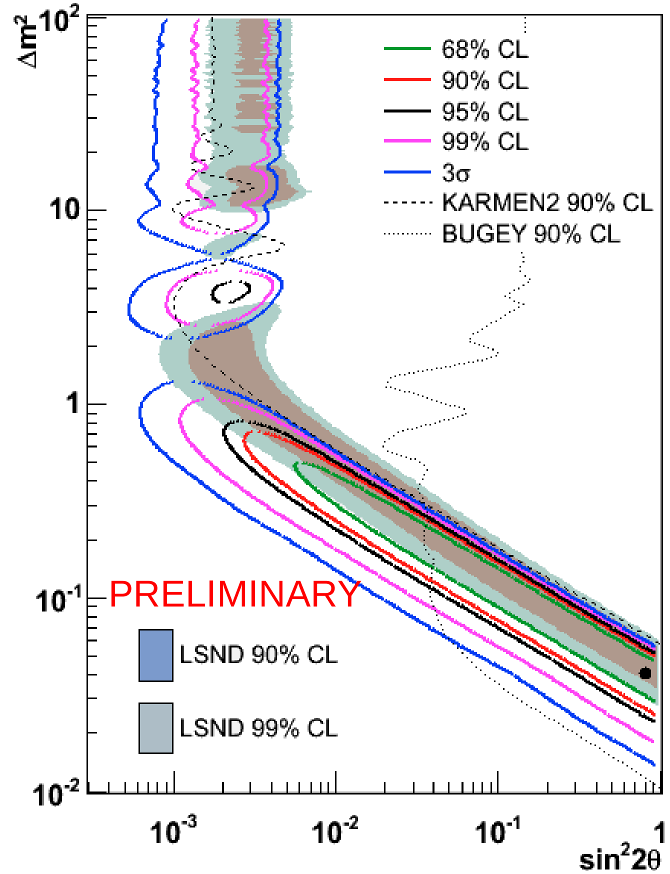
- Model independent look at the data
- The excess as a function of L/E in MiniBooNE neutrino, antineutrino and LSND data consistent

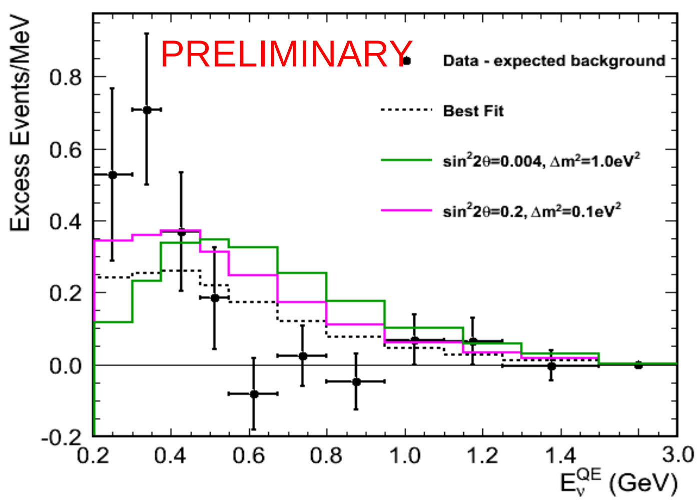


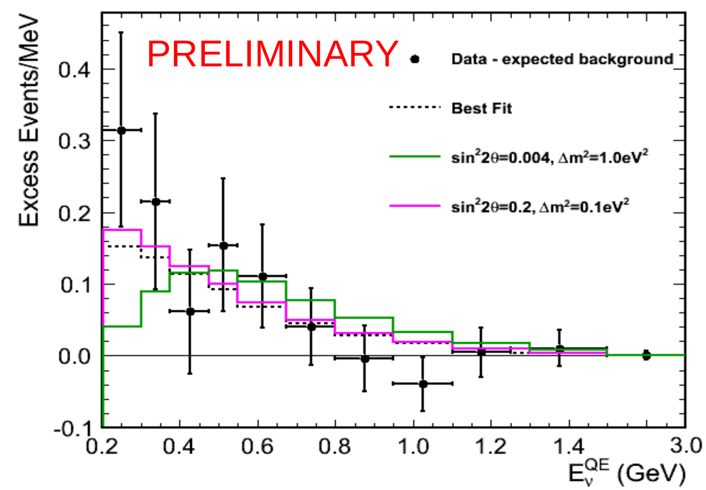
Combined ν and $\bar{\nu}$ analysis

- Consistent treatment of WS
- Full correlated systematic error matrix
- Excess (200-1250): 240±34.5±52.6 (3.8σ)
- Best Fit preferred over null at 3.6σ

combined	E > 200 MeV	E > 475 MeV
χ^2(null)	42.53	12.87
Prob(null)	0.1%	35.8%
χ^2(bf)	24.72	10.67
Prob(bf)	6.7%	35.8%





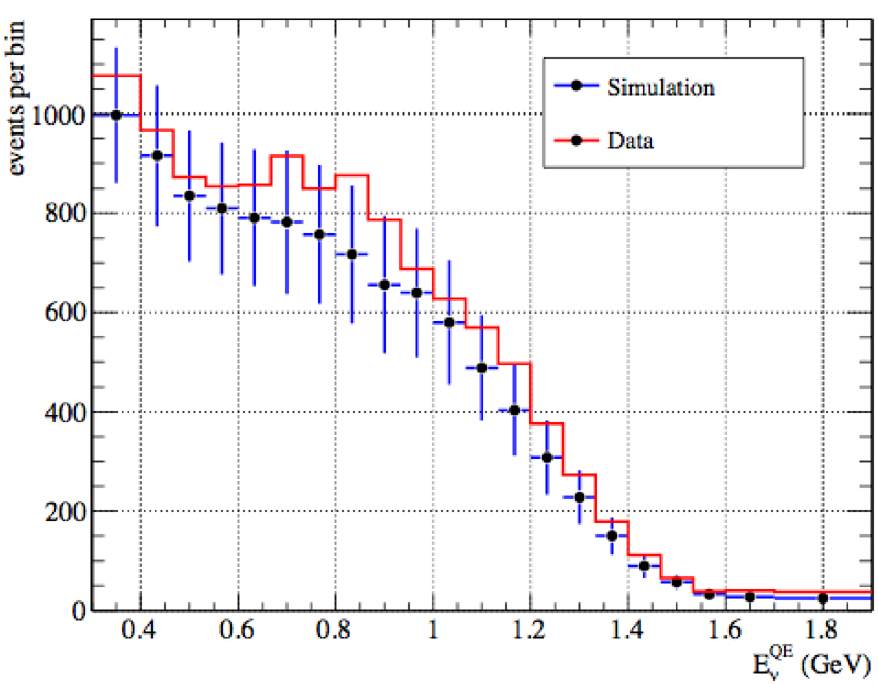


Joint SciBooNE & MiniBooNE disappearance analysis

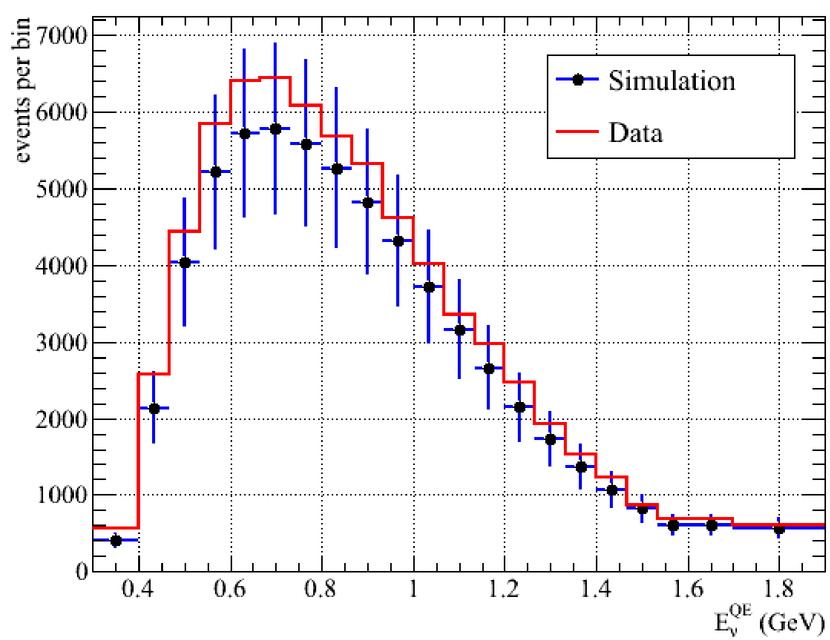
$\bar{\nu}_\mu$ disappearance

- 3+N sterile neutrino models require some disappearance of ν_es and/or ν_μs
- Data:
  - POT for MiniBooNE: 10.1 x 10^{20}
  - POT for SciBooNE: 1.53 x 10^{20}

SciBooNE Reconstructed Energy Distribution



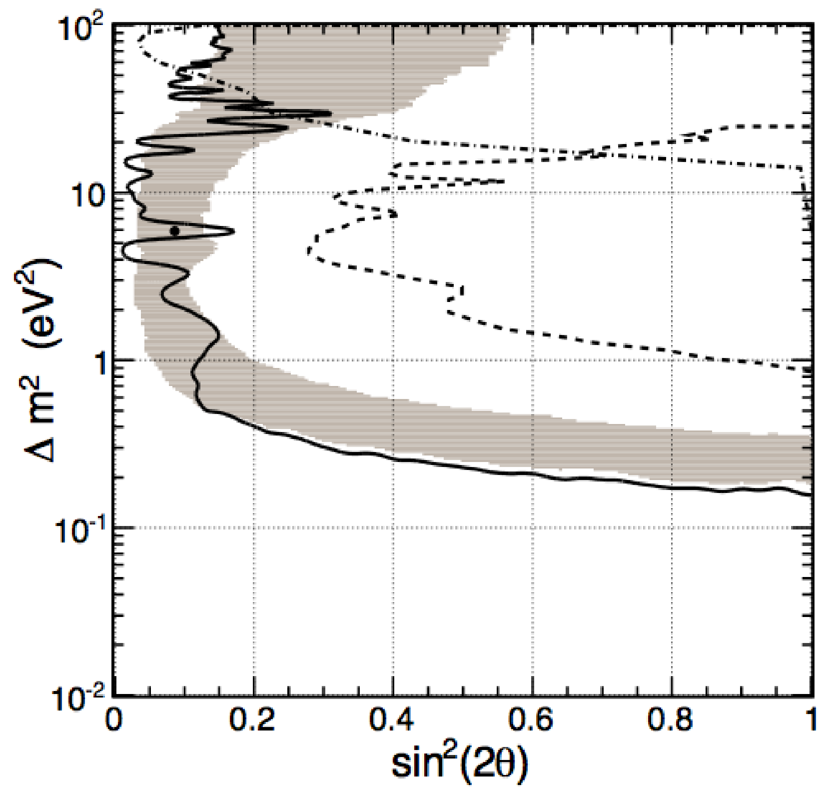
Reconstructed Energy Distribution



Combined disappearance result

- Joint analysis:
- Compatible with no oscillations
- BF point $\Delta m^2 = 5.9\ eV^2$, $\sin^2 2\theta = 0.086$
- $\chi^2 = 40.0$ (probability 47.1%) at the best fit point
- $\chi^2 = 43.5$ (probability 41.2%) for the null hypothesis

- Probabilities are based on fake data studies



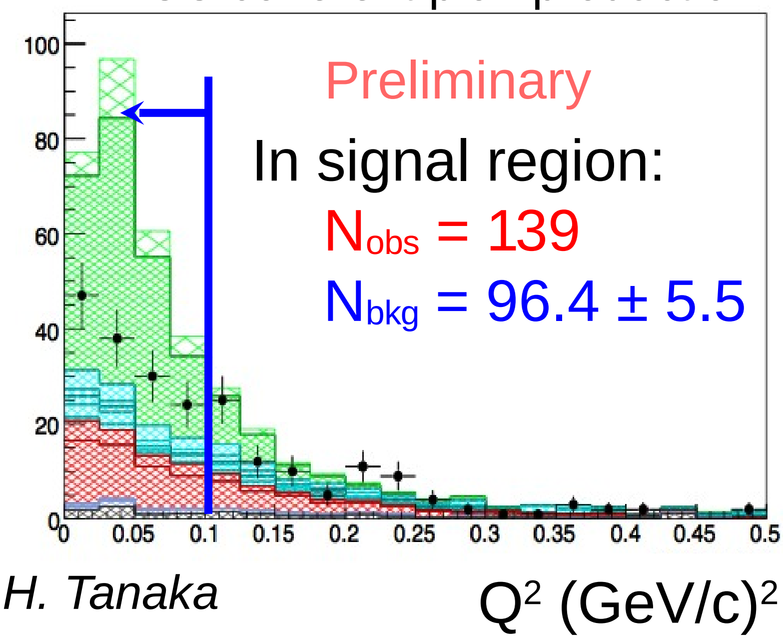
G. Cheng, W. Huelsnitz

Future Prospects

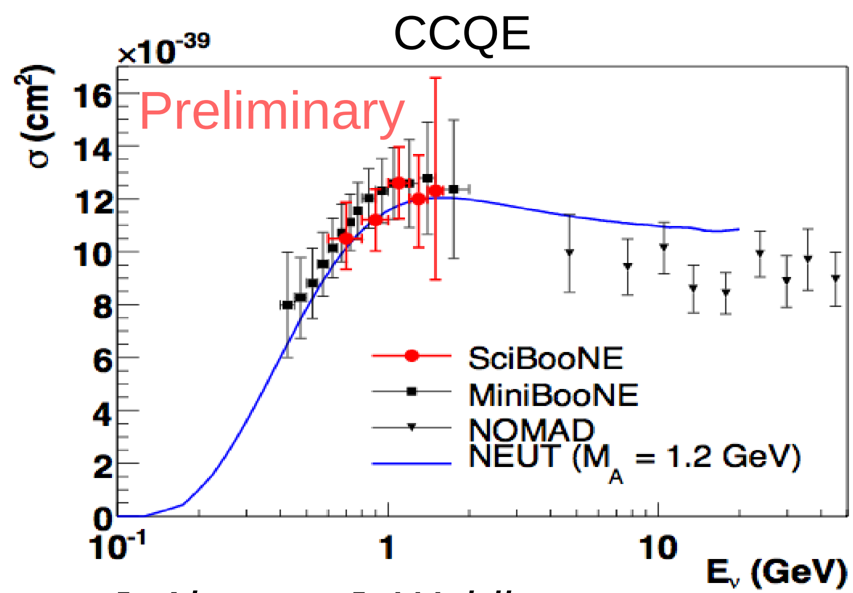
Upcoming results - SciBooNE

- CCQE cross section
- $\nu/\bar{\nu}$ CC coherent pion production
- Neutral current elastic scattering
- CC1pi0

$\bar{\nu}$ CC coherent pion production



H. Tanaka

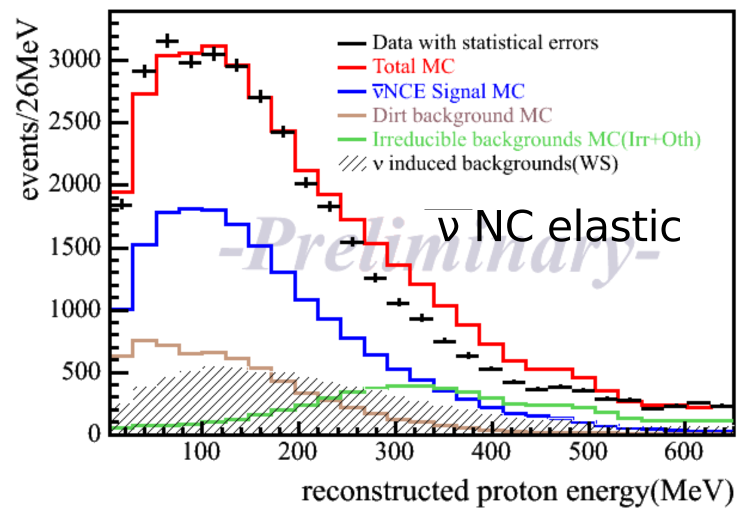


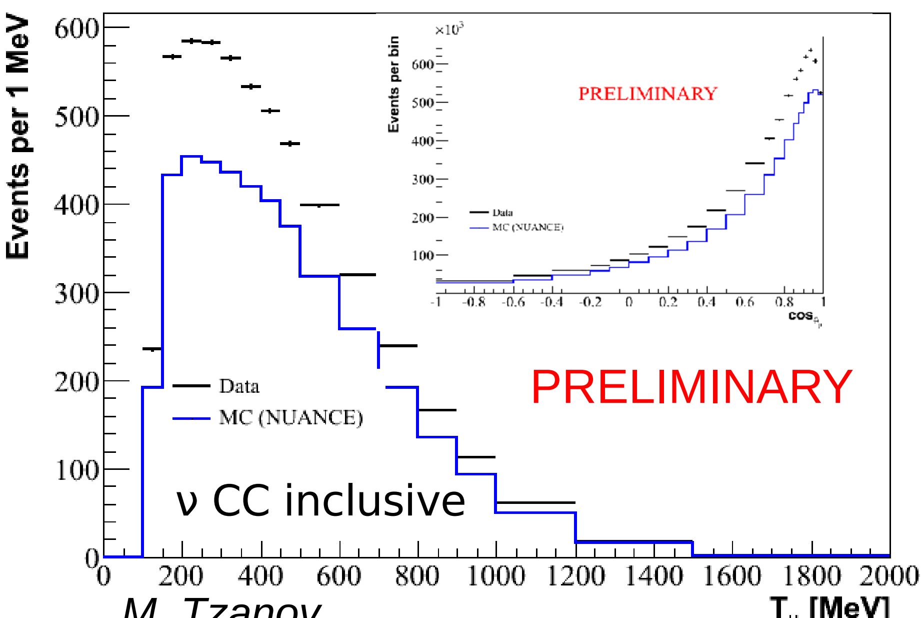
J. Alcaraz, J. Walding

Upcoming results - MiniBooNE

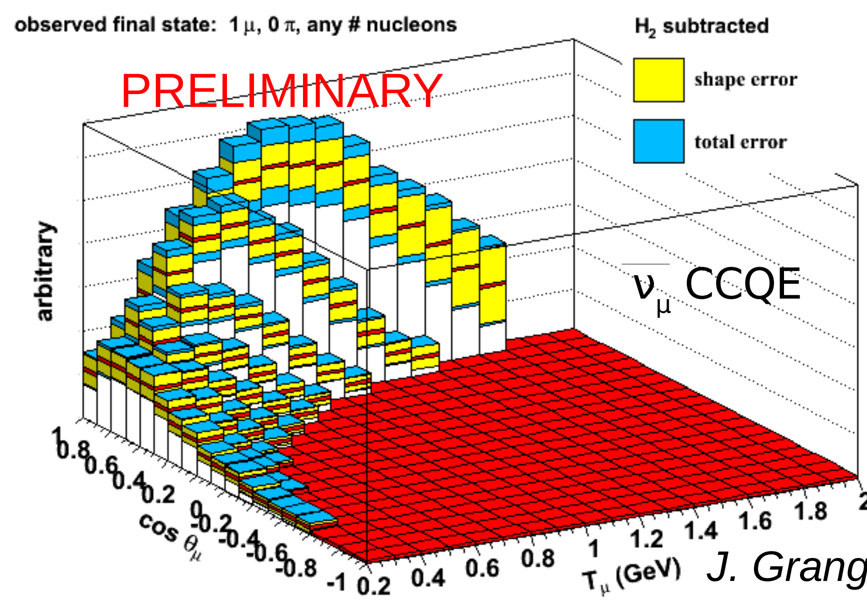
- $\bar{\nu}$ NC elastic
  - 44k events (40 % purity)
  - world record $\bar{\nu}$ NC elastic sample
- ν CC inclusive
  - 344k events (96% purity)
- $\bar{\nu}_\mu$ CCQE
  - 77k events
  - 10x more stats then all older samples combined

R. Dharmapalan





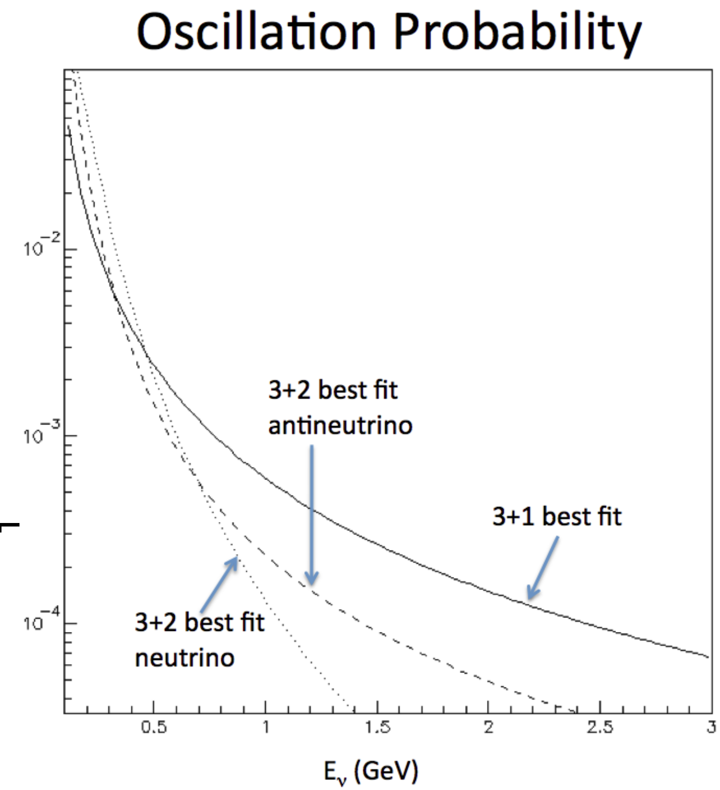
M. Tzanov

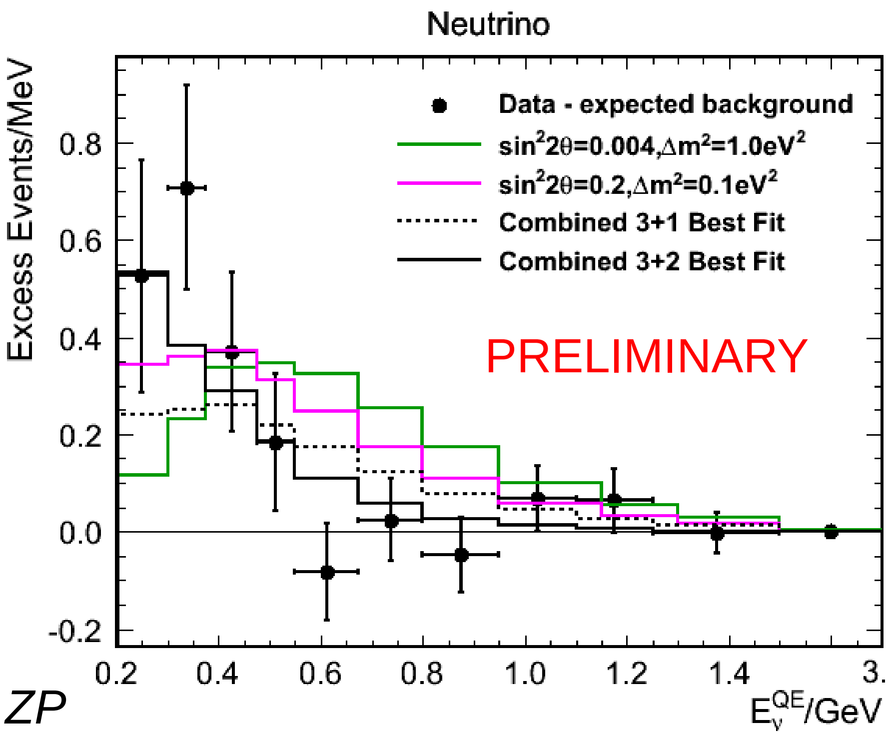


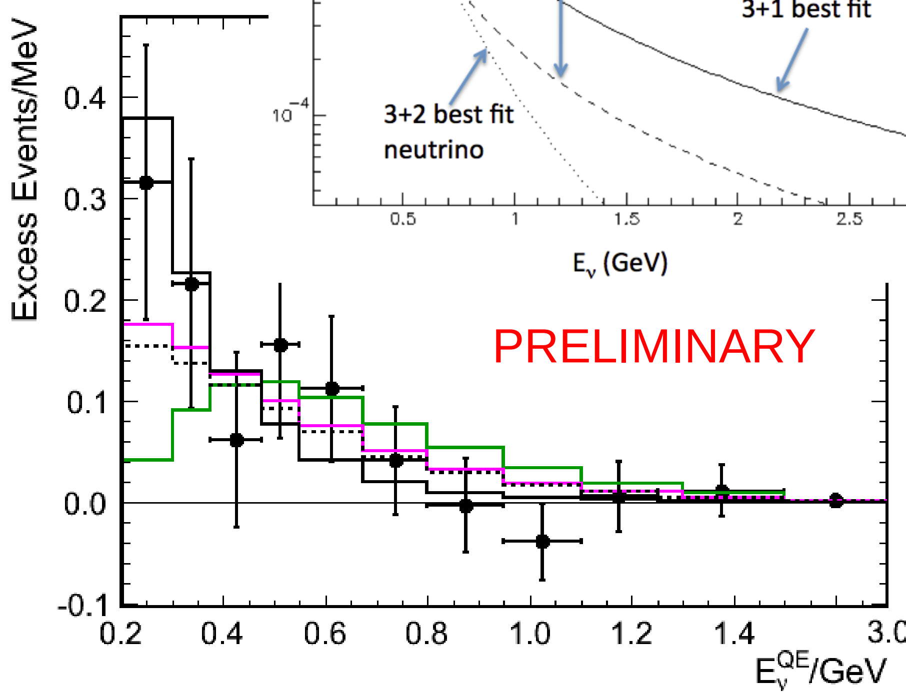
J. Grange

Upcoming results - MiniBooNE

- Fits to more complicated oscillations models (3+2 model)
  - CP violation
  - Better fit to world data





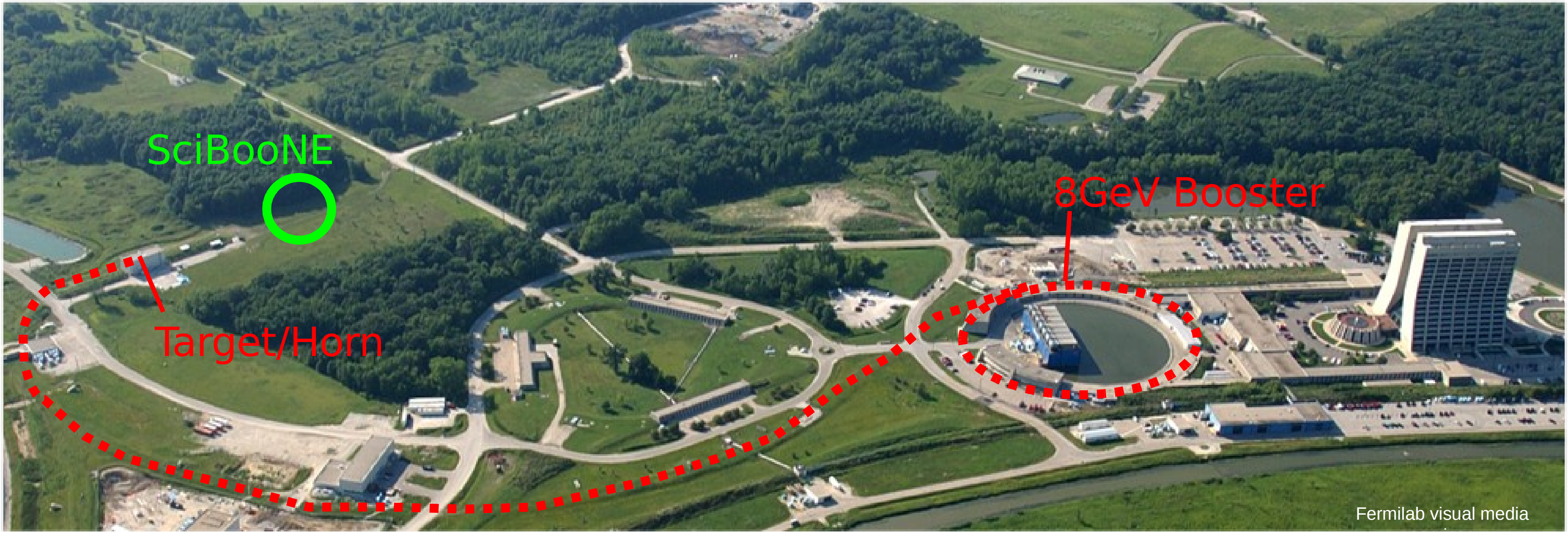


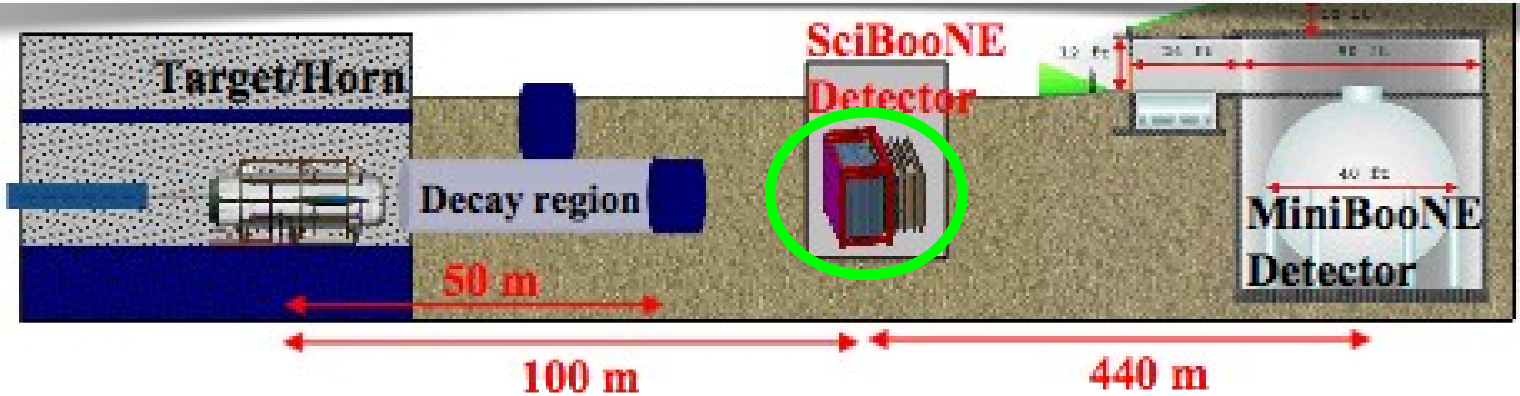
Conclusion

- SB & MB continue producing important neutrino cross section and oscillation results – more results later this year
- MiniBooNE observes an excess of 240±34.5±52.6 (3.8σ) events in electron neutrino sample with combined neutrino and antineutrino data
- No $\bar{\nu}_{\mu}$ disappearance observed in joint SciBooNE/MiniBooNE disappearance analysis
- MiniBooNE considering merits of future running
  - Running under various configurations
  - Double neutrino mode POT running along MicroBooNE

Backup

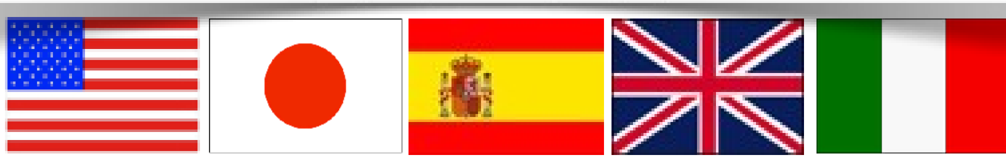
BNB


SciBooNE
8GeV Booster
Target/Horn
Fermilab visual media


Target/Horn
SciBooNE
Detector
Decay region
50 m
MiniBooNE
Detector
100 m
440 m

SciBooNE Collaboration

~65 physicists, 5 countries, 18 institutions



Universitat Autonoma de Barcelona
University of Colorado, Boulder
Columbia University
Fermi National Accelerator Laboratory
High Energy Accelerator Research Organization (KEK)
Imperial College London
Indiana University
Institute for Cosmic Ray Research (ICRR)
Kyoto University
Los Alamos National Laboratory
Louisiana State University
Massachusetts Institute of Technology
Purdue University Calumet
Università di Roma "La Sapienza“ and INFN
Saint Mary's University of Minnesota
Tokyo Institute of Technology
Universidad de Valencia

<u>Spokespersons</u>:
M.O. Wascko (Imperial), T. Nakaya (Kyoto)

Students

- Graduated
  - 8 PhD (Barcelona, Columbia, Rome, 3 Kyoto, Tokyo Tech, Imperial)
  - 3 Masters (Rome, Imperial College, Valencia)
- Active
  - 3 PhD

SciBooNE PhD students

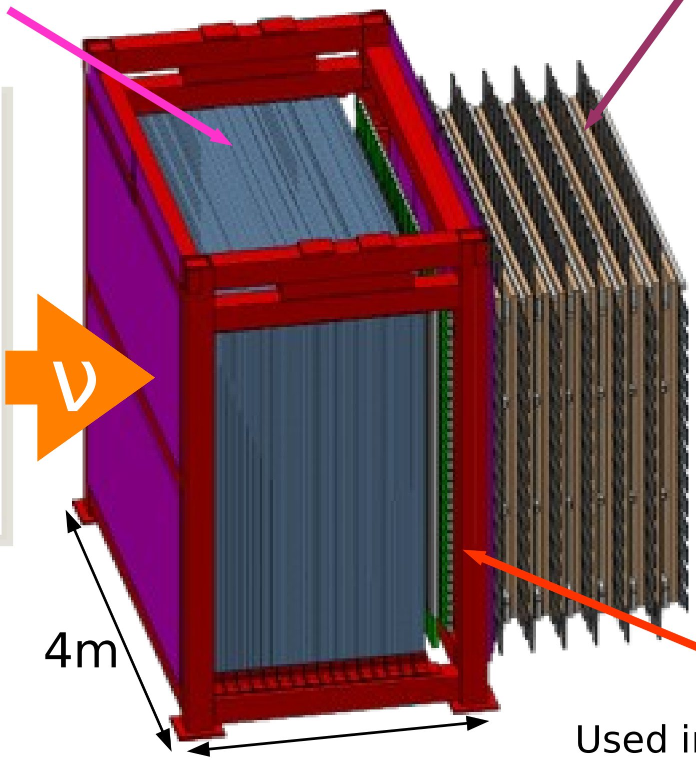
SciBooNE Masters & other students

SciBooNE detector

SciBar

- scintillator tracking detector
- 14,336 scintillator bars (15 tons)
- Neutrino target
- detect all charged particles
- p/π separation using dE/dx

Used in K2K experiment



Muon Range Detector (MRD)

- 12 2"-thick steel + scintillator planes
- measure muon momentum with range up to 1.2 GeV/c

Parts recycled from past experiments

Electron Catcher (EC)

Used in CHORUS, HARP and K2K

- spaghetti calorimeter
- 2 planes (11 X_0)
- identify π^0 and ν_e

SciBooNE publications

- NuMu disappearance
  Phys. Rev. D 85, 032007 (2012)
- Measurement of K+ production cross section
  Phys.Rev.D 84 012009 (2011)
- CC inclusive cross section
  Phys.Rev.D 83 012005 (2011)
- Coherent NCpi0 production
  Phys.Rev.D 81 111102(R) (2010)
- Inclusive NCpi0 production
  Phys.Rev.D 81 03304 (2010)
- Coherent CCpi+ production
  Phys.Rev.D 78 112004 (2008)
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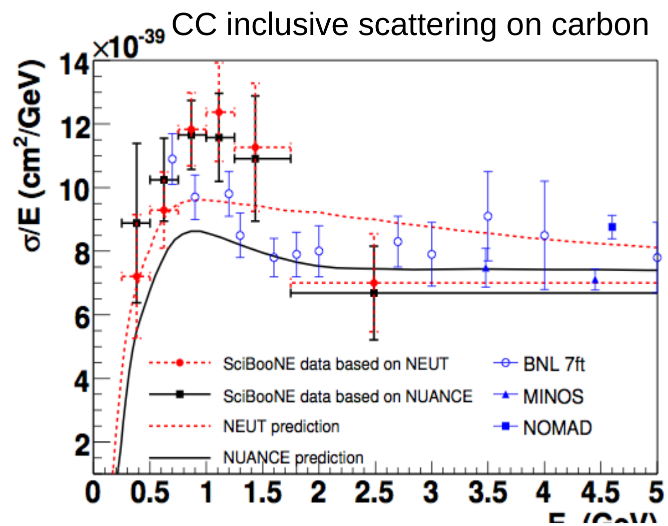

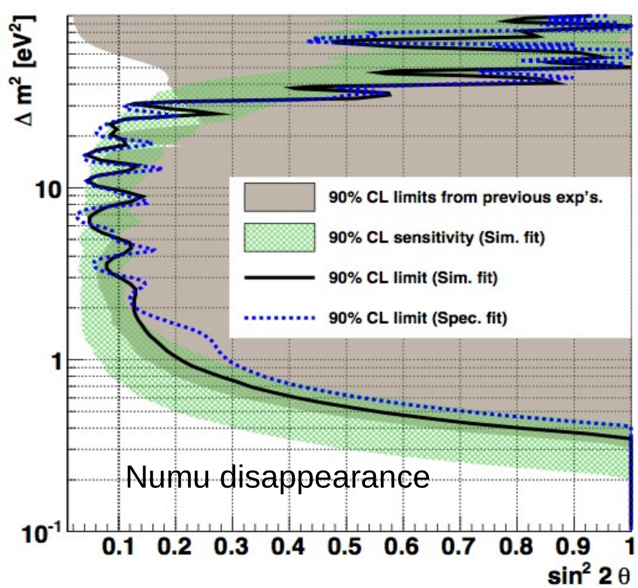

MiniBooNE Collaboration

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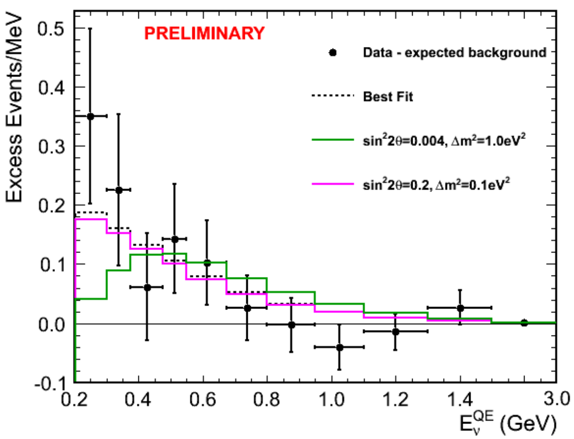
(The MiniBooNE Collaboration)

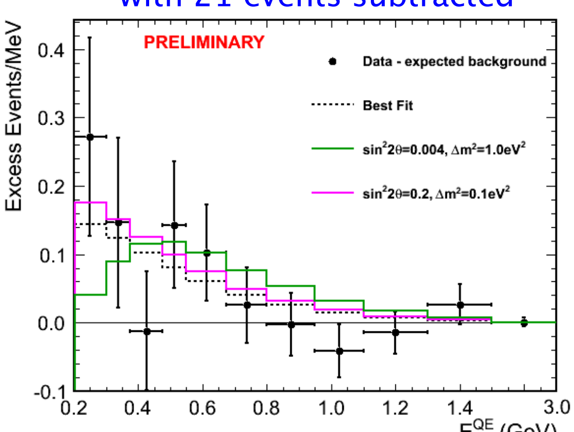
Account for neutrino low-E events

- Fits on prior page assume only anti-neutrinos are oscillating, but we know there is a low E excess in nu mode data
- Simplest scaling is to assume that there should be an excess in the low energy region proportional to the WS content (21 events)

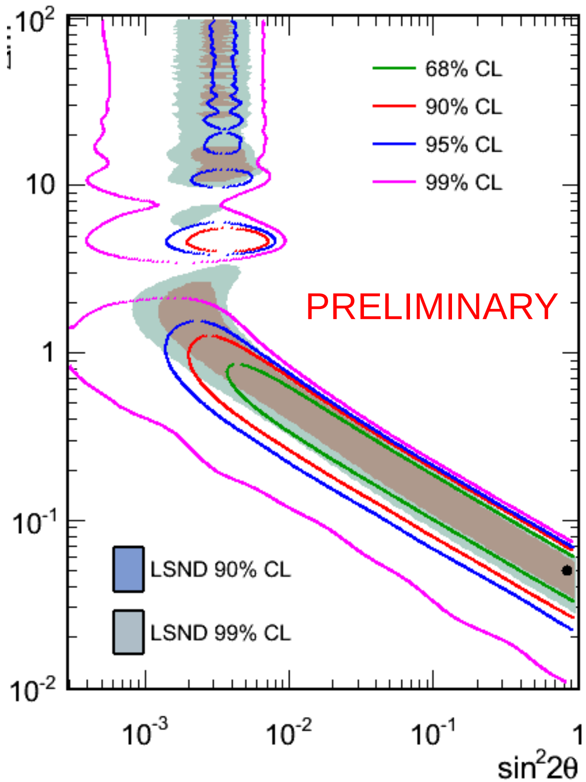
without 21 events subtracted



with 21 events subtracted



without 21 events subtracted



with 21 events subtracted