First Anti-Neutrino oscillation results from MiniBooNE

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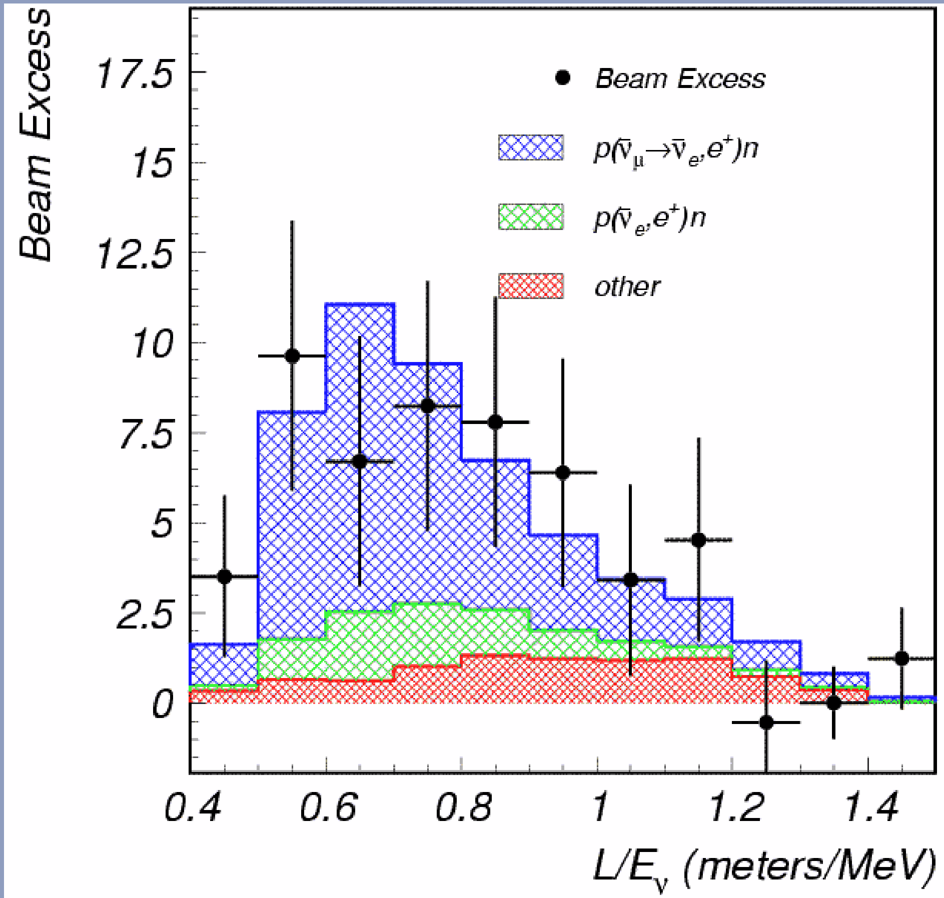
LSND signal

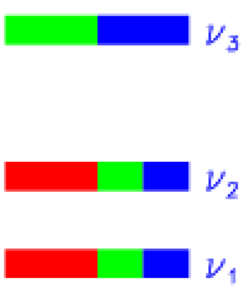
- MiniBooNE designed to test LSND
- LSND observed excess of $\overline{\nu}_e$ in $\overline{\nu}_\mu$ beam
  87.9 ± 22.4 ± 6.0 (3.8σ)
- Assuming two neutrino oscillation:

$$P(\overline{\nu}_\mu \to \overline{\nu}_e) = \sin^2(2\theta)\sin^2\left(\frac{1.27\ L\ \Delta m^2}{E}\right)$$
$$= 0.245 \pm 0.067 \pm 0.045\ \%$$



LSND anomaly

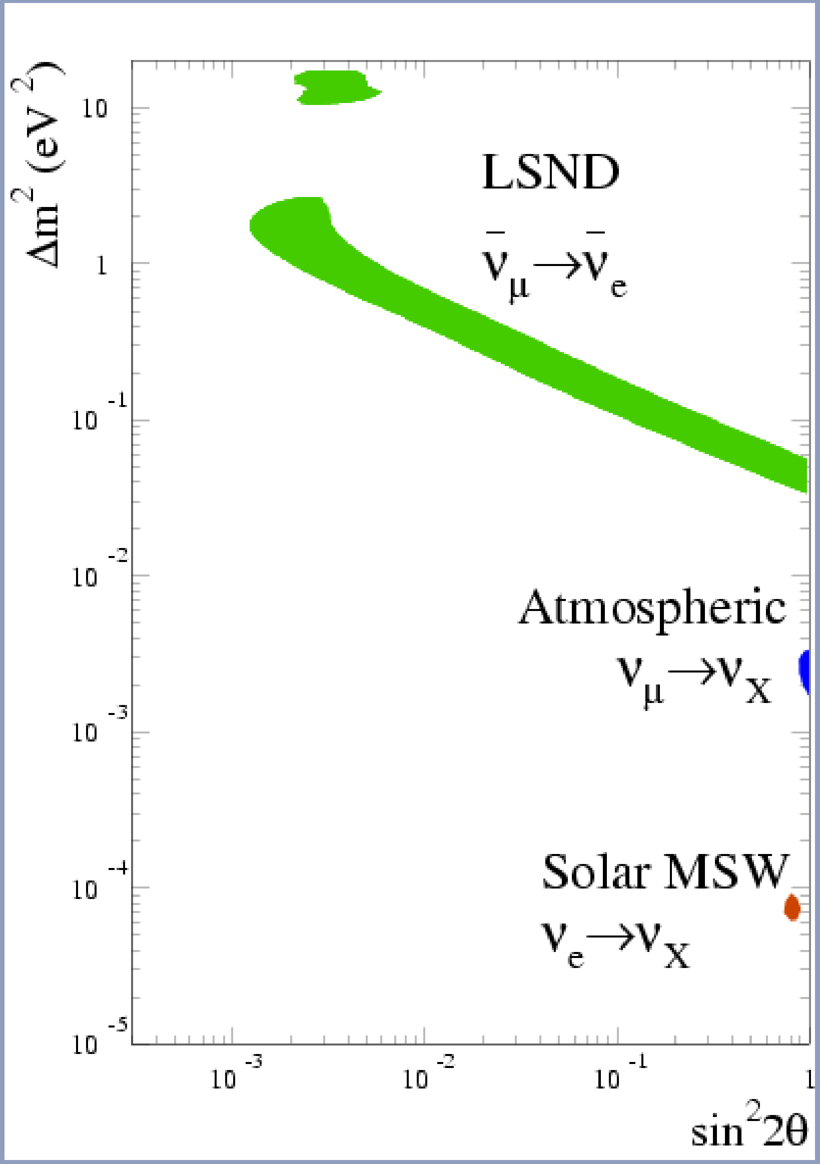
- Within Standard Model 3 neutrino framework LSND signal is not compatible with atmospheric and solar neutrino data



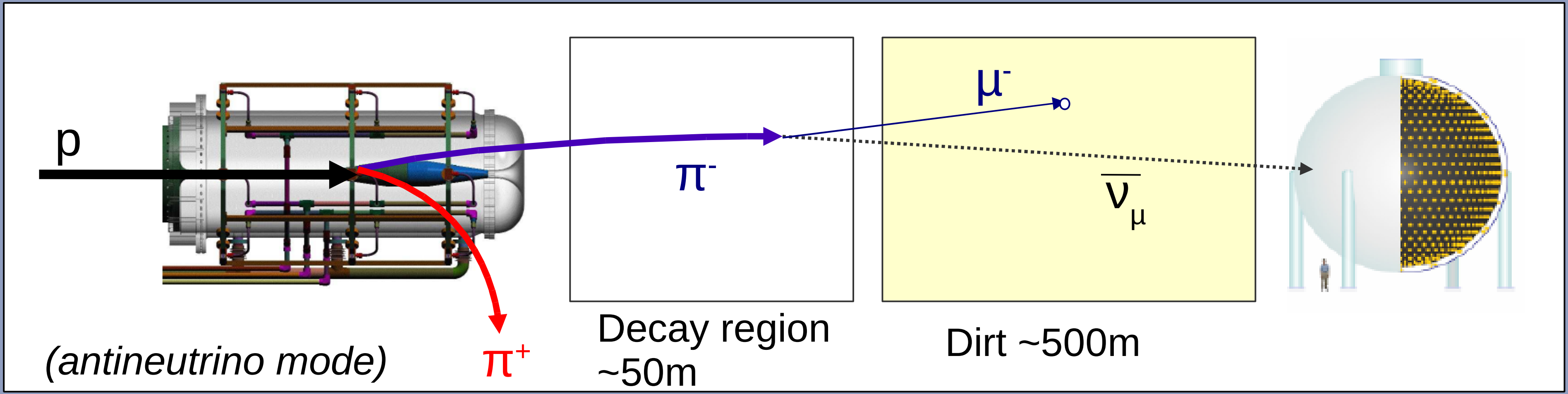
$$\Delta m_{23}^2 = m_2^2 - m_3^2$$

$$\Delta m_{12}^2 = m_1^2 - m_2^2$$

$$\Delta m_{13}^2 = \Delta m_{12}^2 + \Delta m_{23}^2$$



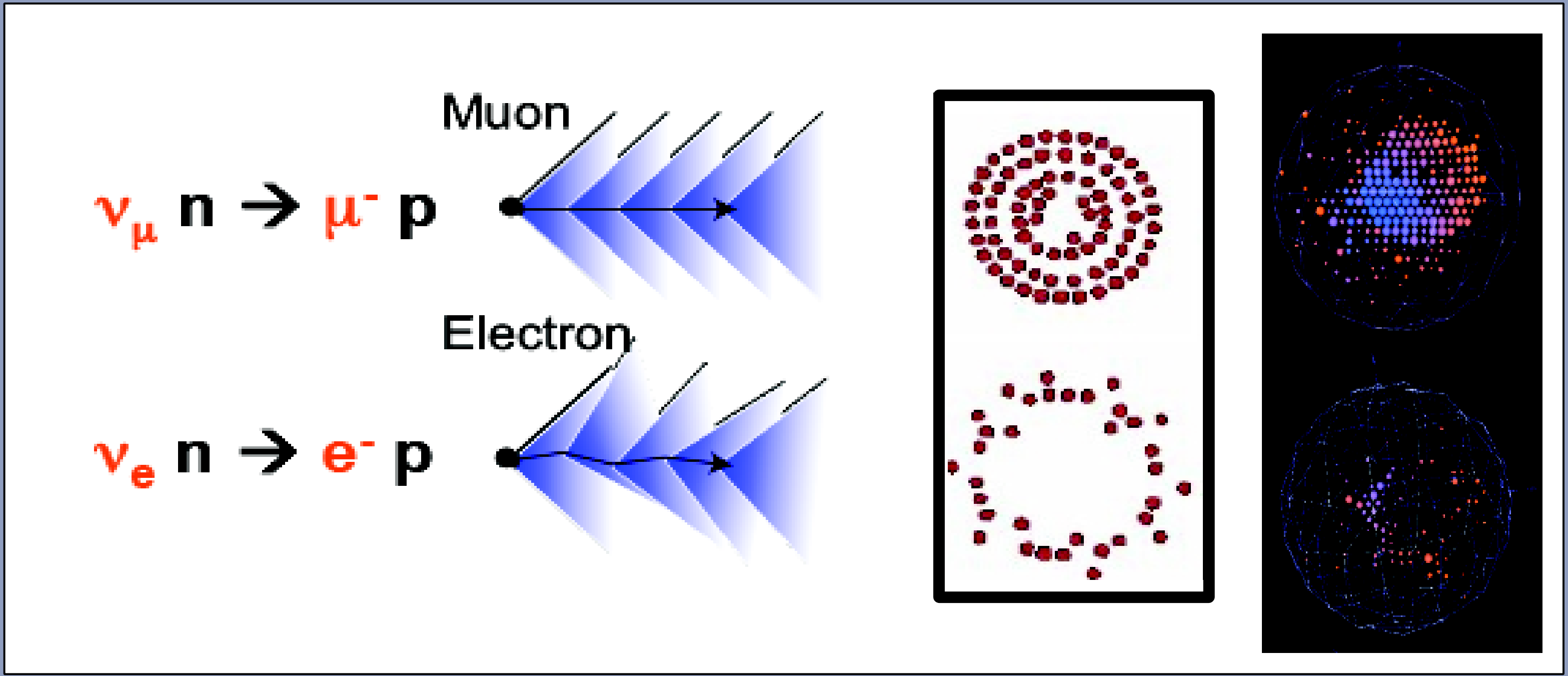
MiniBooNE



- Similar L/E as LSND
- MB detector:
  - 800 ton mineral oil Čerenkov detector
  - 12m diameter
  - 1280 inner PMT’s, and 240 outer veto PMT’s
- Focus either positive or negative mesons
- Collected & analysed:
  - 6.5e20 POT in neutrino mode
  - 3.4e20 POT in anti-neutrino mode

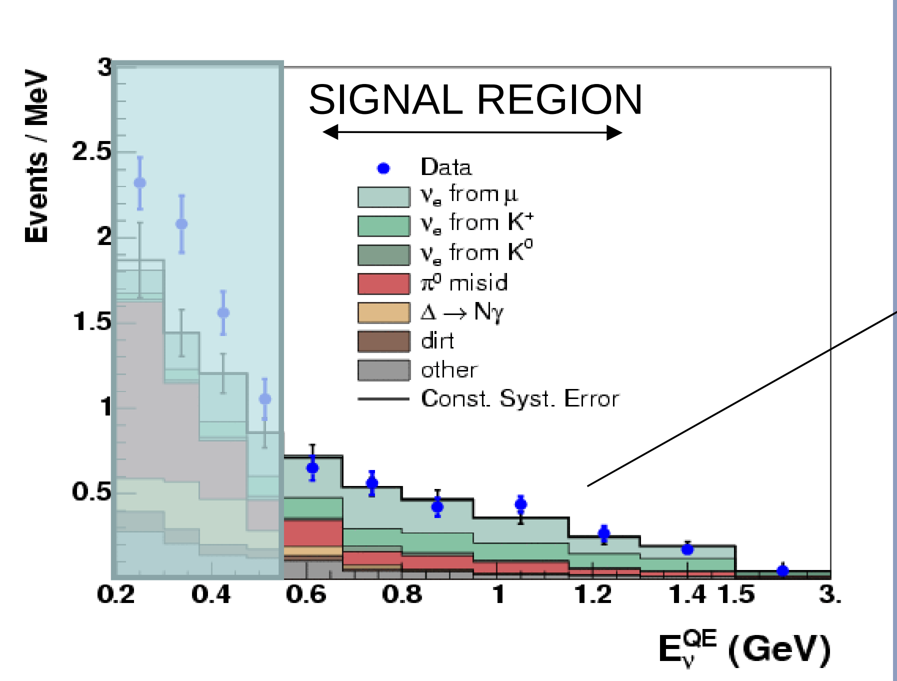
Neutrino events

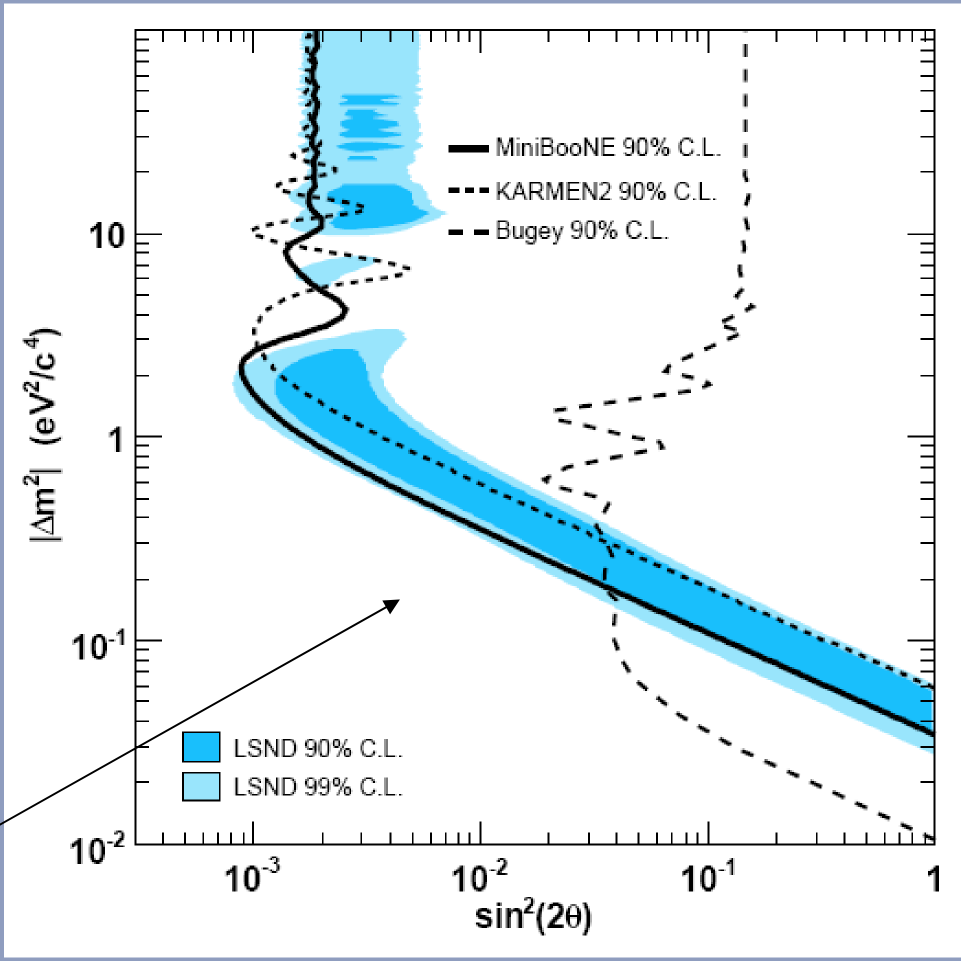
- Čerenkov rings used to identify the products of ν interactions
- Looking for ν_e CCQE signal events
- Backgrounds:
  - Intrinsic ν_e
  - Mis-identified events
- Use ν_μ CCQE to constrain intrinsic nues



Neutrino run results

- No excess of events in signal region
- Ruled out 2 ν oscillations as source of LSND signal (assuming no CP or CPT violation)

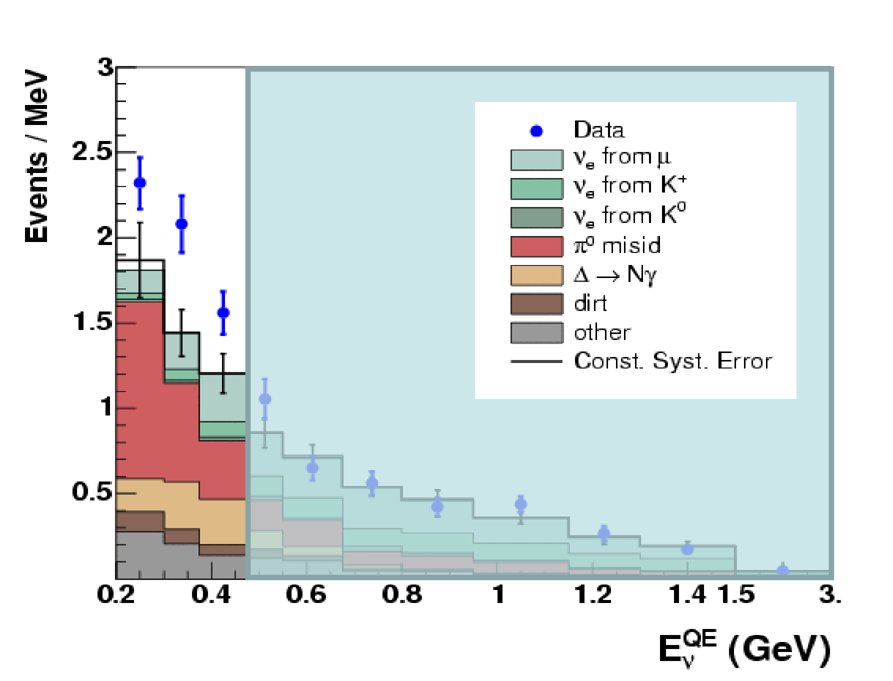




A. A. Aguilar-Arevalo et al., Phys.Rev.Lett. 98: 231801,2007;
A. A. Aguilar-Arevalo et al., Phys.Rev.Lett.102:101802,2009

Neutrino run results

- Excess of events observed at low energy:
  128.8 ± 20.4 ± 38.3 (3.0σ)
- Shape not consistent with 2 ν oscillations
- Magnitude consistent with LSND



- Anomaly Mediated Neutrino-Photon Interactions at Finite Baryon Density: Jeffrey A. Harvey, Christopher T. Hill, & Richard J. Hill, arXiv:0708.1281
- CP-Violation 3+2 Model: Maltoni & Schwetz, arXiv:0705.0107; T. Goldman, G. J. Stephenson Jr., B. H. J. McKellar, Phys. Rev. D75 (2007) 091301.
- Extra Dimensions 3+1 Model: Pas, Pakvasa, & Weiler, Phys. Rev. D72 (2005) 095017
- Lorentz Violation: Katori, Kostelecky, & Tayloe, Phys. Rev. D74 (2006) 105009
- CPT Violation 3+1 Model: Barger, Marfatia, & Whisnant, Phys. Lett. B576 (2003) 303
- New Gauge Boson with Sterile Neutrinos: Ann E. Nelson & Jonathan Walsh, arXiv: 0711.1363

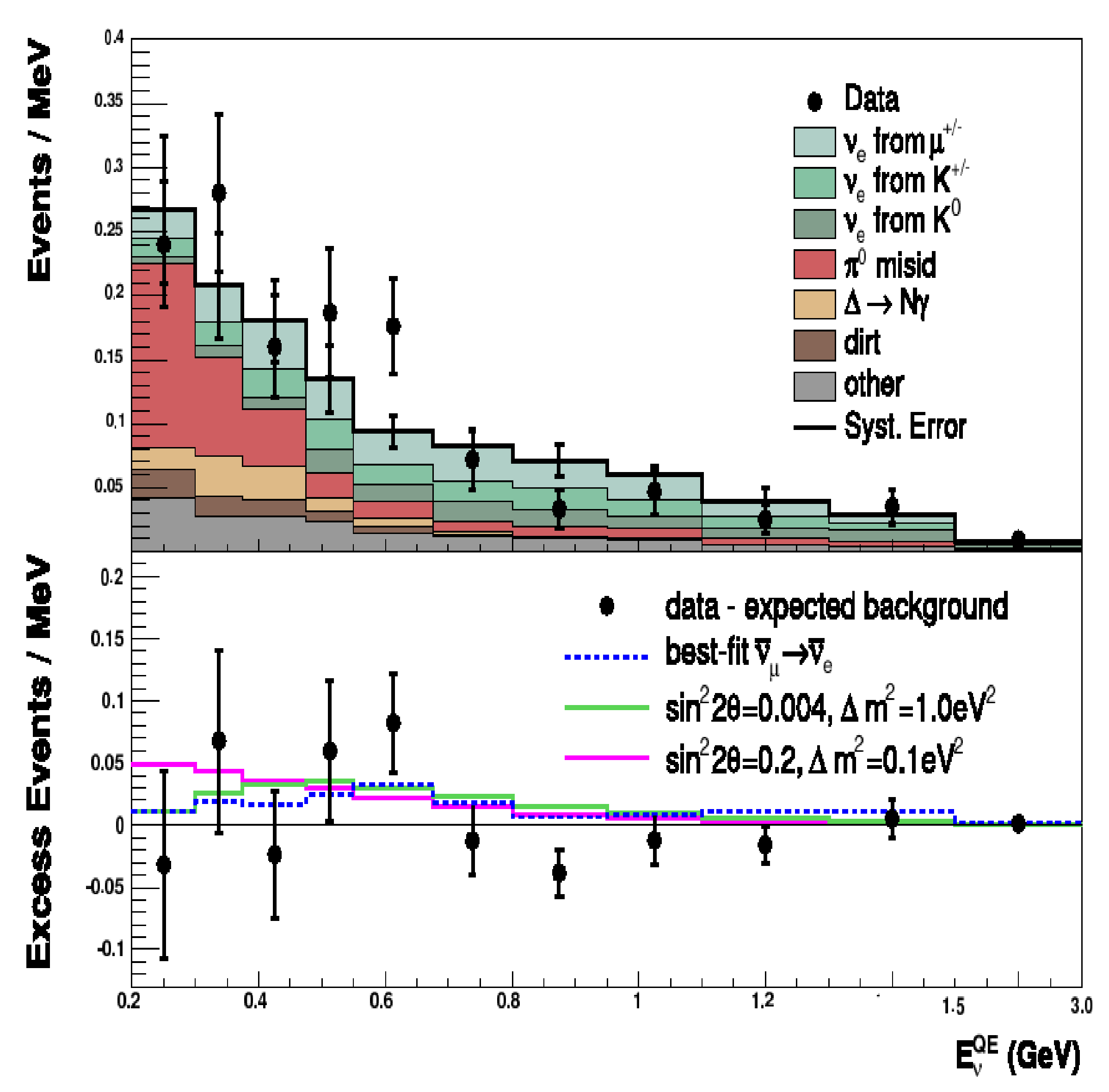
Anti-Neutrino run

- Further insight in low energy excess
- Provides direct test of LSND
- Statistics low at present
  - First result with 3.4E20 POT
  - The total number of CCQEs down by order of magnitude compared to neutrino run
- Already have data corresponding to 4.86E20 POT
  - Approved for additional 5E20 POT run

- Same analysis as for neutrino mode with few checks

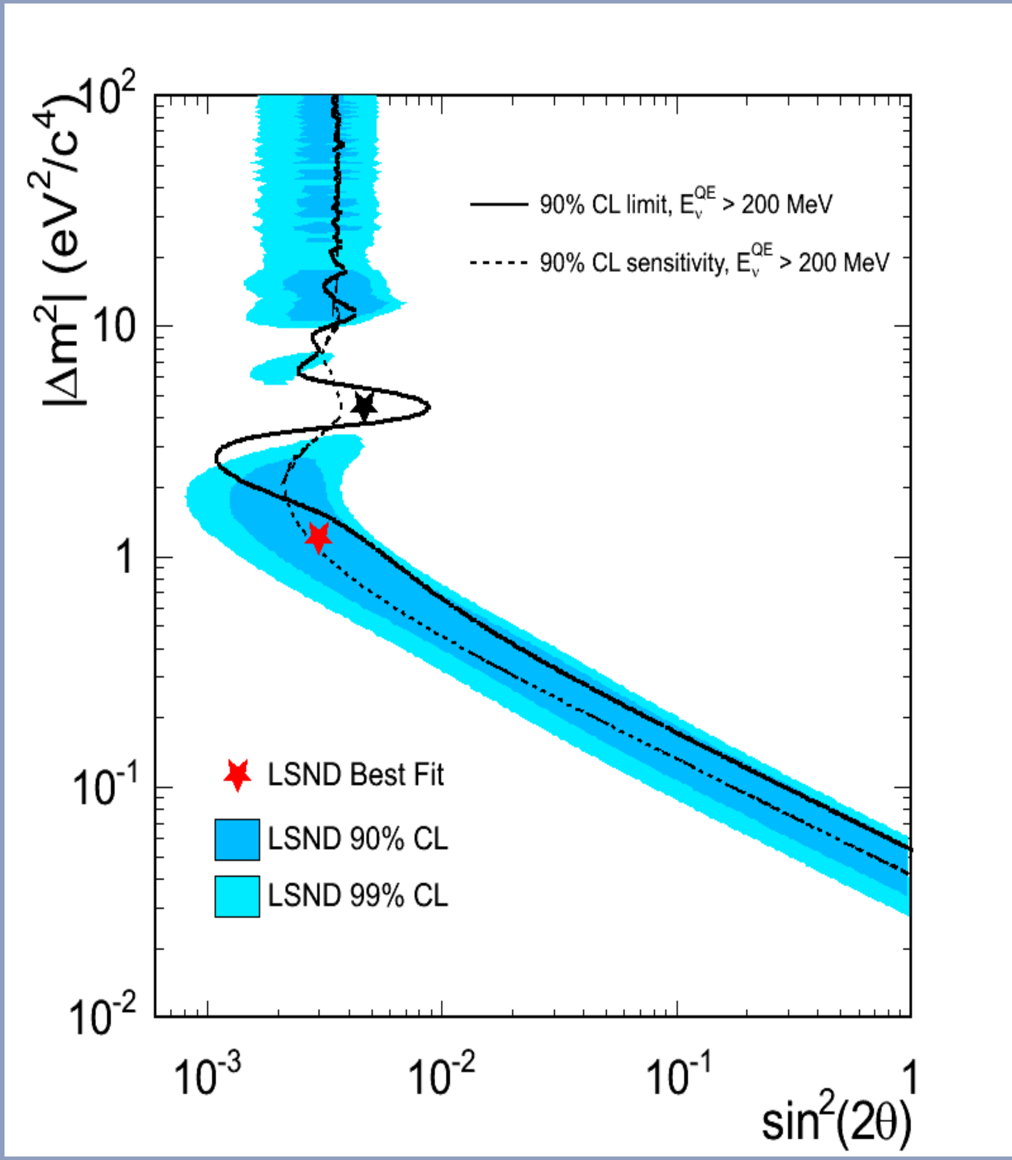
Antineutrino results

- No significant excess observed at either low or high energy



Limit from anti-neutrino run

- No significant excess observed at either low or high energy
- Assumes that neutrinos don't oscillate, only antineutrinos do
- Both LSND and null signal consistent with data at 90% CL
- Need more data



Low Energy Excess

- Preliminary results of the fits to ν and $\bar{\nu}$ data in low E region
- Ignoring what we know about various backgrounds and looking only at how compatible two datasets are
- Preferred model: excess is due to neutrinos in the beam (no contribution from antineutrinos)

	Stat. Error Only	100% Correlated Syst. Error	Uncorrelated Syst. Error
Same $\nu,\bar{\nu}$ NC	0.1%	0.1%	6.7%
NC π^0 scaled	3.6%	6.4%	21.5%
POT scaled	0.0%	0.0%	1.8%
Bkgd scaled	2.7%	4.7%	19.2%
CC scaled	2.9%	5.2%	19.9%
Low-E Kaons	0.1%	0.1%	5.9%
ν scaled	38.4%	51.4%	58.0%

Maximum χ^2 probability from fits to ν and $\bar{\nu}$ data in 200-475 MeV range

Conclusion

- MiniBooNE observes excess of low energy events in neutrino run consistent in magnitude with LSND signal, however energy shape not consistent with 2 ν oscillations
- With 3.4e20 POT MiniBooNE does not observe low energy excess in anti neutrino data
- High energy data consistent with both LSND best fit point and no oscillations
- Collecting more anti-neutrino data (approved for a new 5e20POT run)