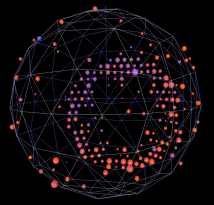
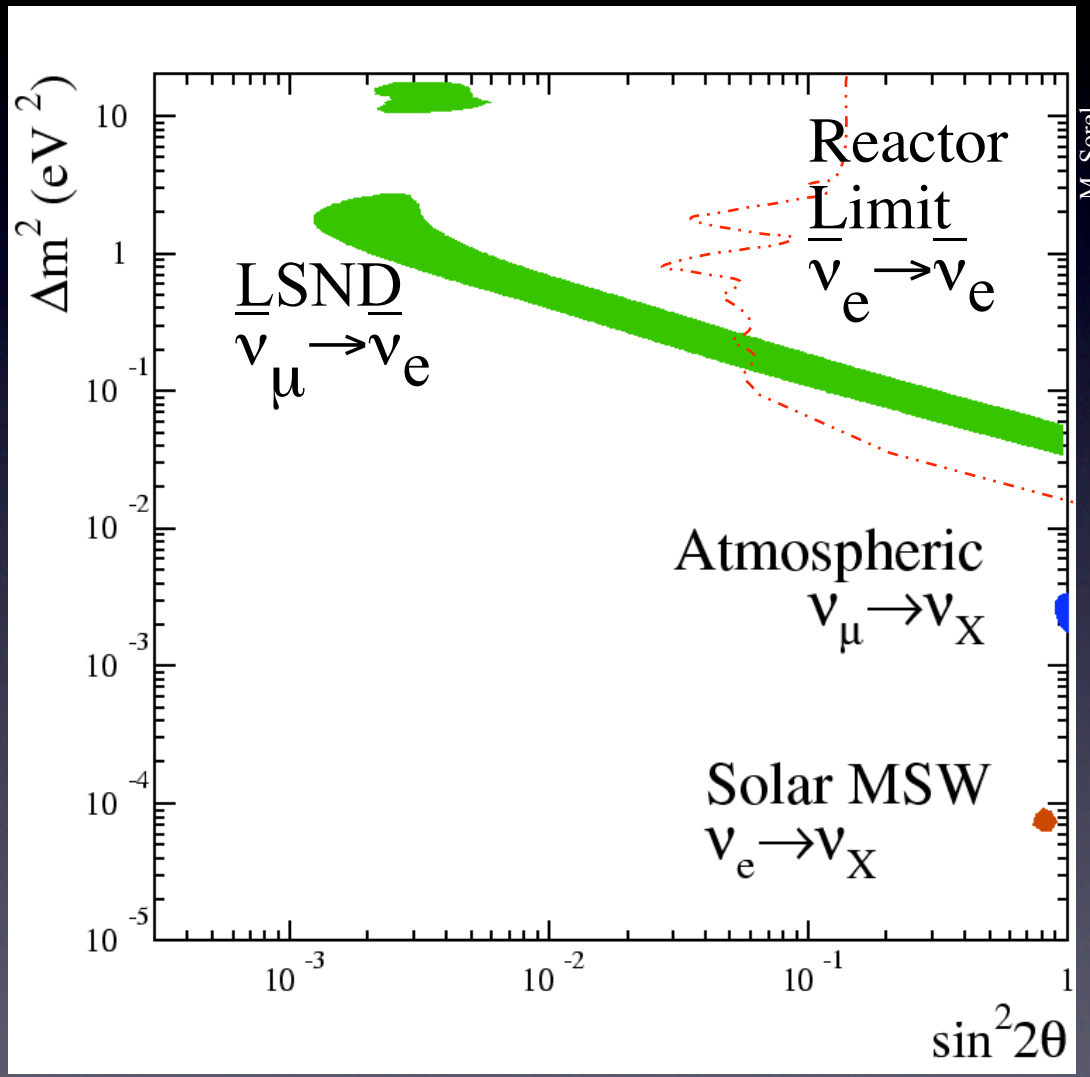
MiniBooNE's First Oscillation Result

Morgan Wascko
Imperial College London

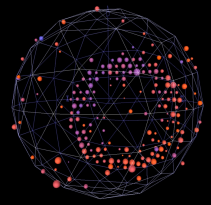
Motivation



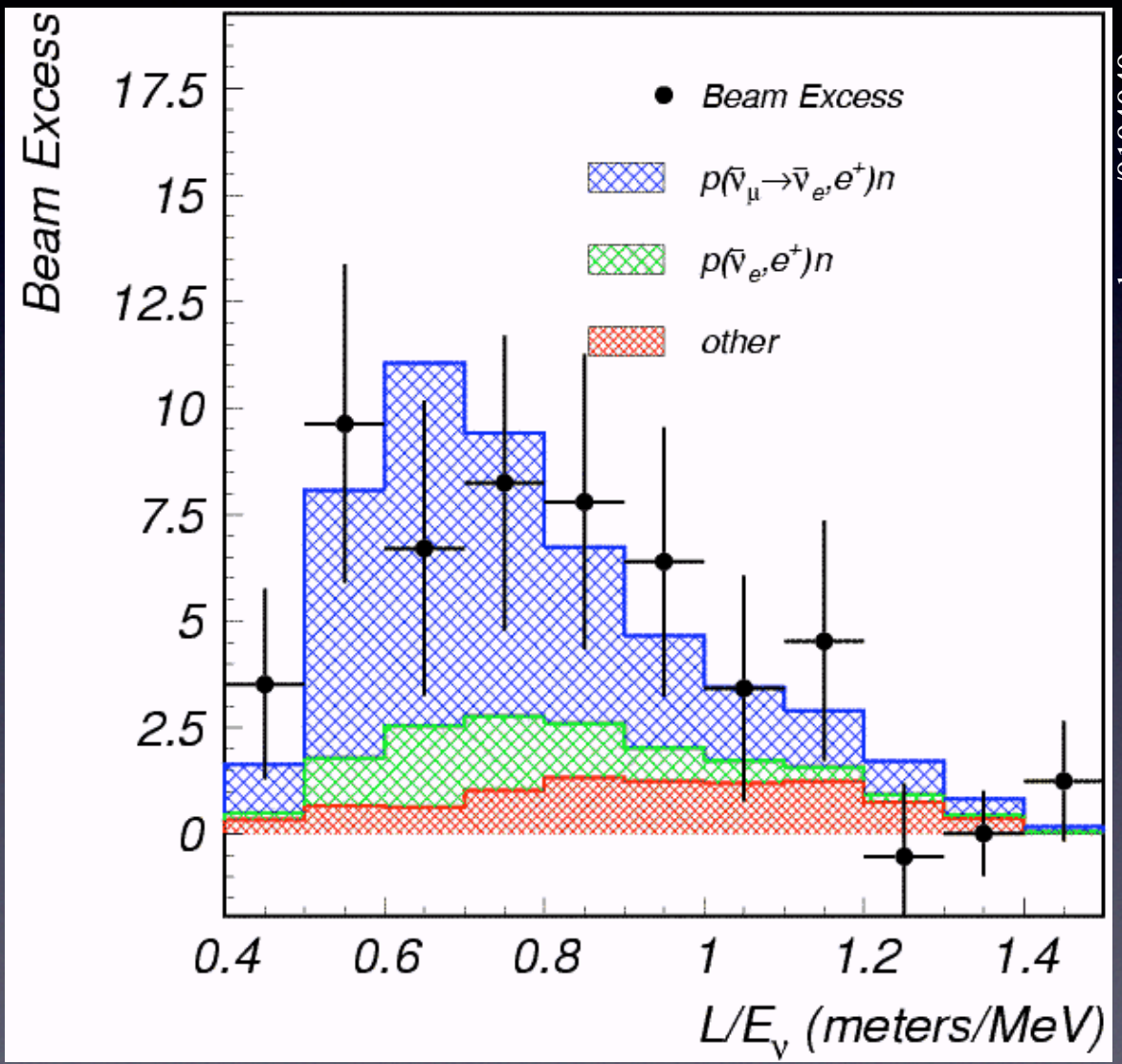
- Three different neutrino oscillation signals
- Three independent Δm^2
- Problem:
  We only need two!
- Explanation requires physics well beyond the standard model
- *Is it true?*



LSND Signal



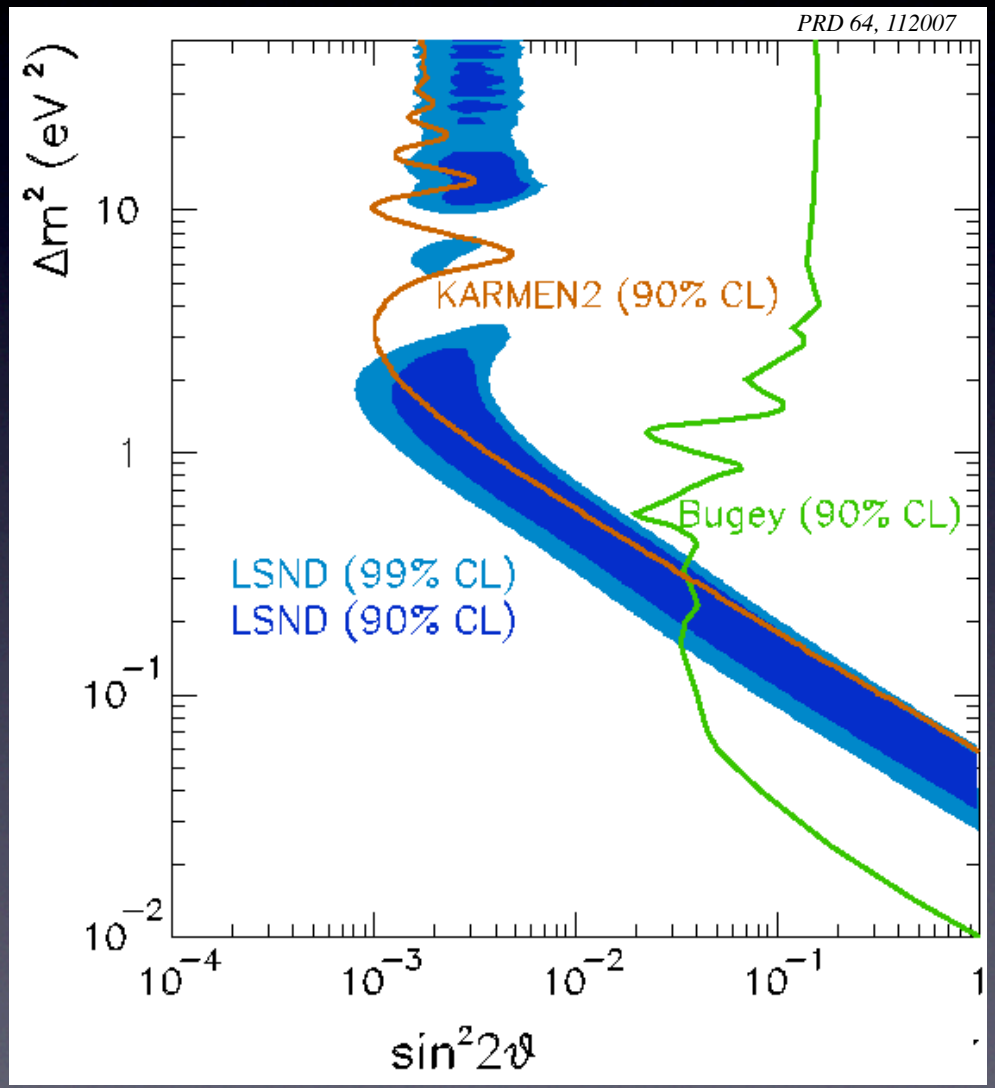
- Clean experimental signature
  - Stopped pion neutrino source
  - Delayed coincidence detection signal
- excess: 87.9 ± 22.4 ± 6.0
- Interpreted as 2 ν oscillation
- $P(\bar{\nu}_\mu \rightarrow \bar{\nu}_e) = 0.26\%$



hep-ex/0104049

Verifying LSND

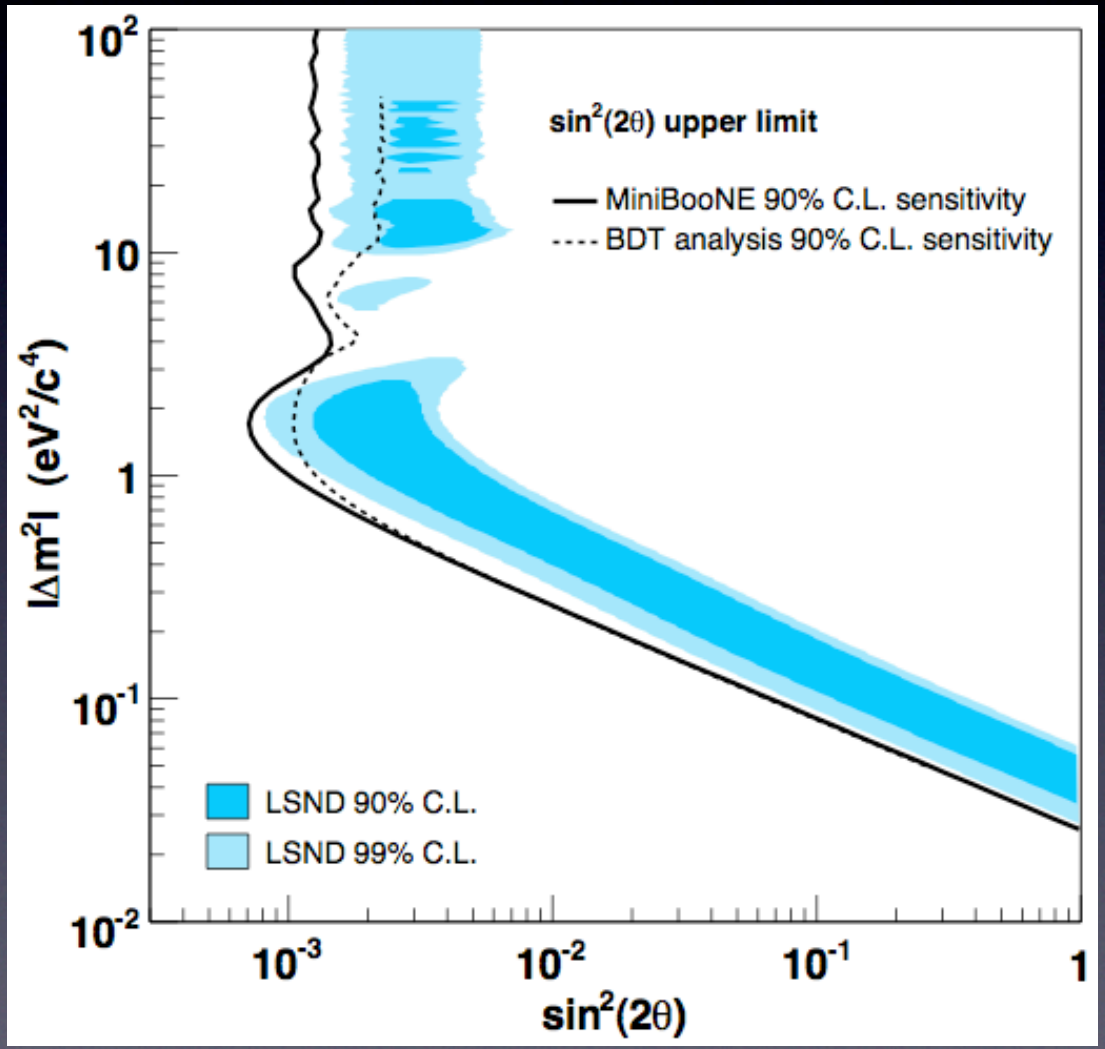
$$P(\nu_\mu \to \nu_e) = \sin^2 2\theta_{12} \sin^2(1.27\Delta m^2_{12}\frac{L}{E})$$



- Verification requires same (L/E) and high statistics
  - Different systematics
- MiniBooNE chose higher L and E
- Strategy: search for ν_e excess in ν_μ beam

Verifying LSND

$$P(\nu_\mu \to \nu_e) = \sin^2 2\theta_{12} \sin^2(1.27\Delta m^2_{12}\frac{L}{E})$$



MiniBooNE Sensitivity

- Verification requires same (L/E) and high statistics
  - Different systematics
- MiniBooNE chose higher L and E
- Strategy: search for ν_e excess in ν_μ beam

MiniBooNE Collaboration

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Fermilab Visual Media Services

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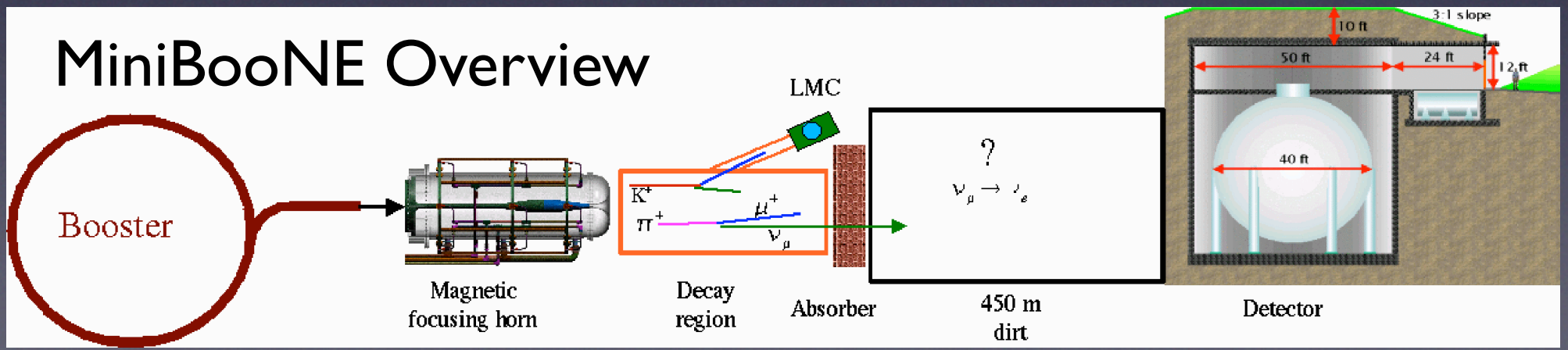
[16] *Yale University, New Haven, CT 06520*

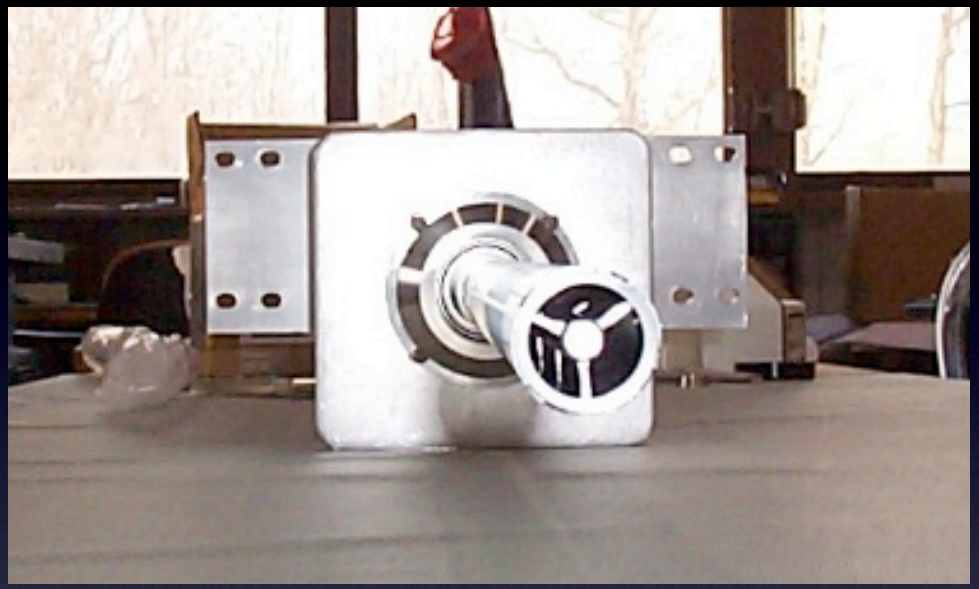
Our task: Dead reckon the background estimates and uncertainties with just one detector.

Overview

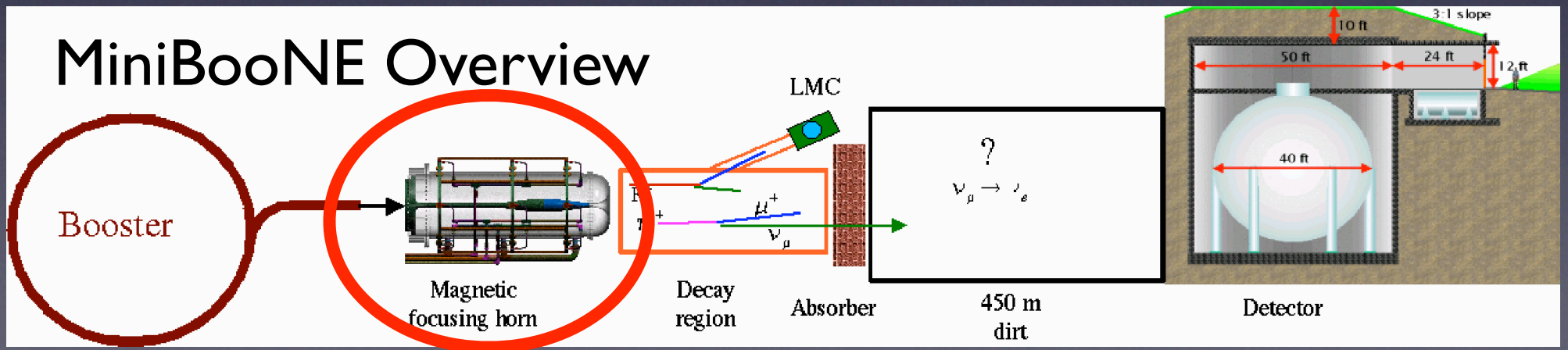
MiniBooNE Overview



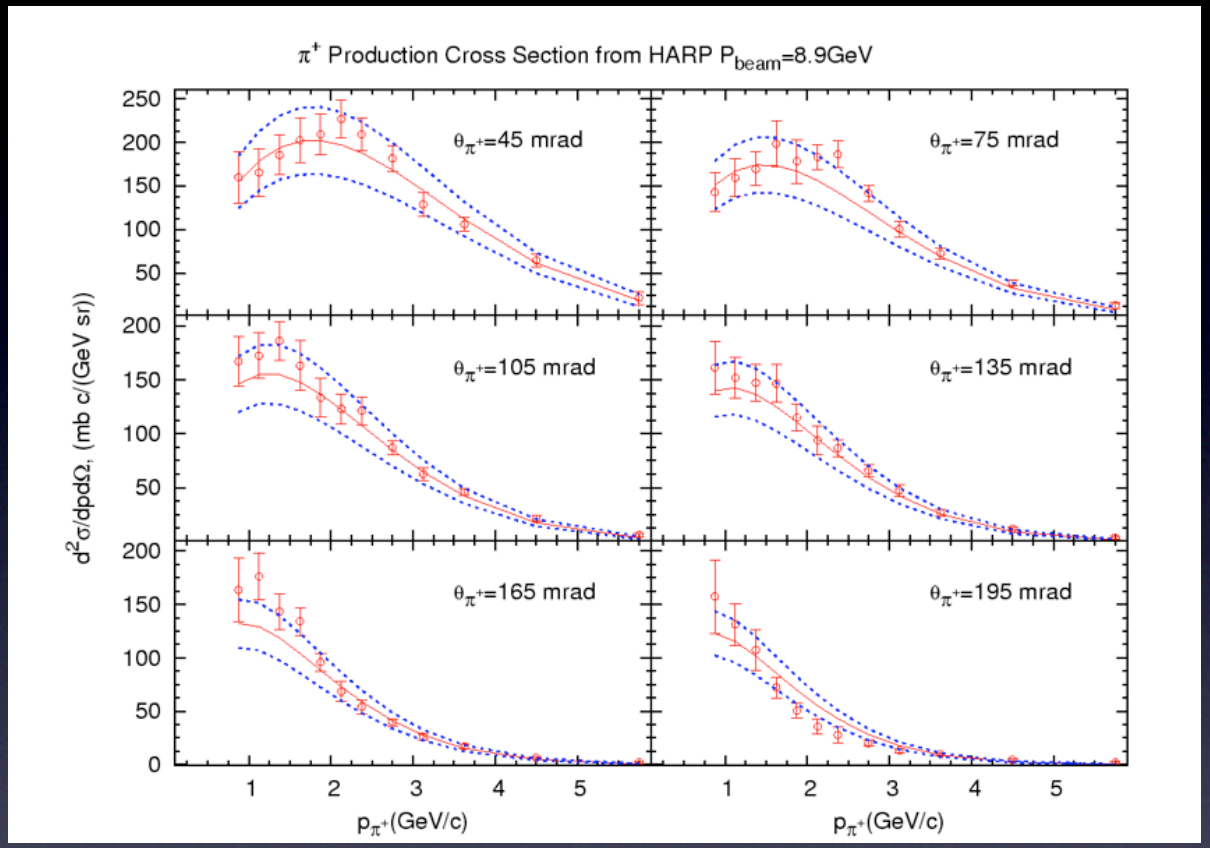
Target & Horn



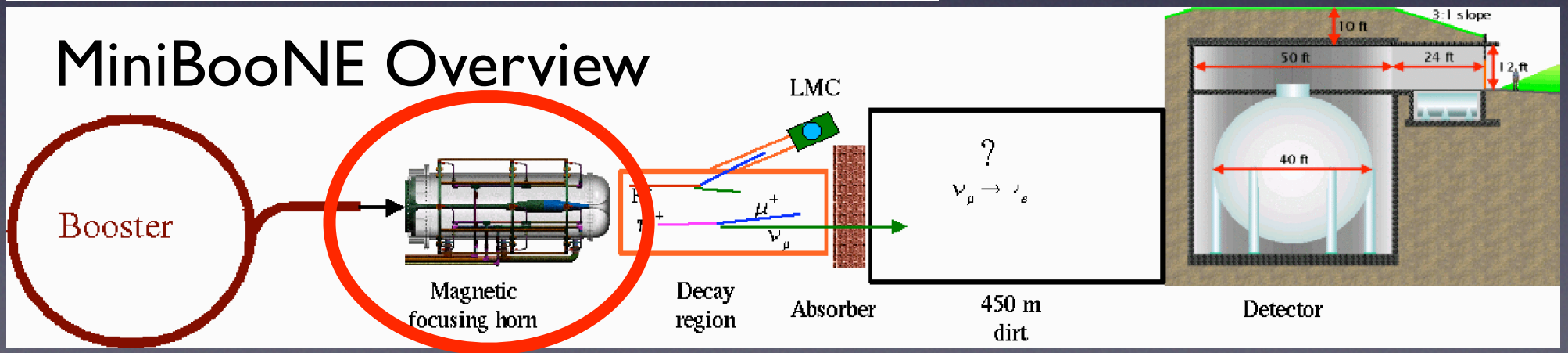
Main components of Booster Neutrino Beam (BNB)



Meson Production

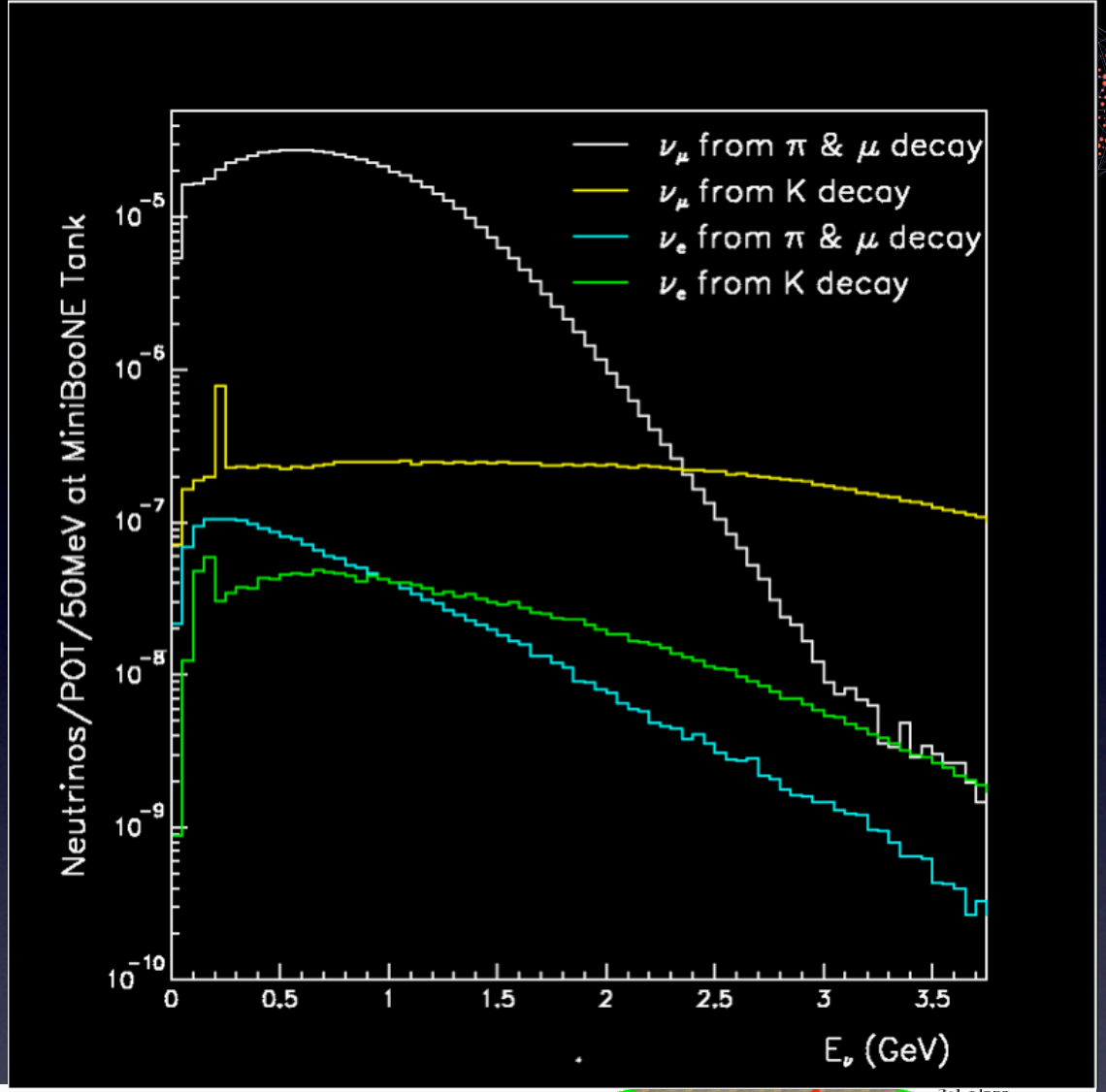


- External meson production data
  - HARP data (CERN)
- Parametrisation of cross-sections
  - Sanford-Wang for pions
  - Feynman scaling for kaons

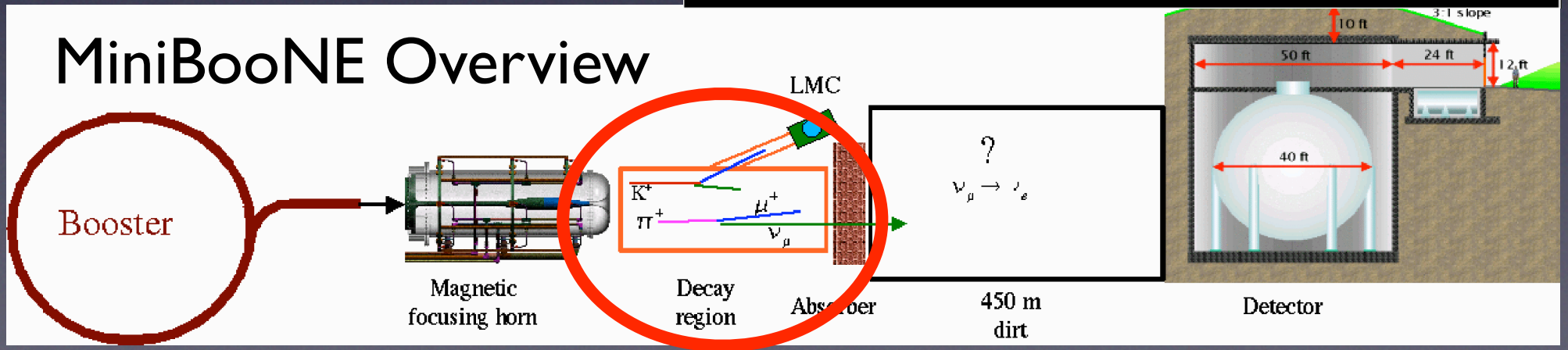


ν Flux

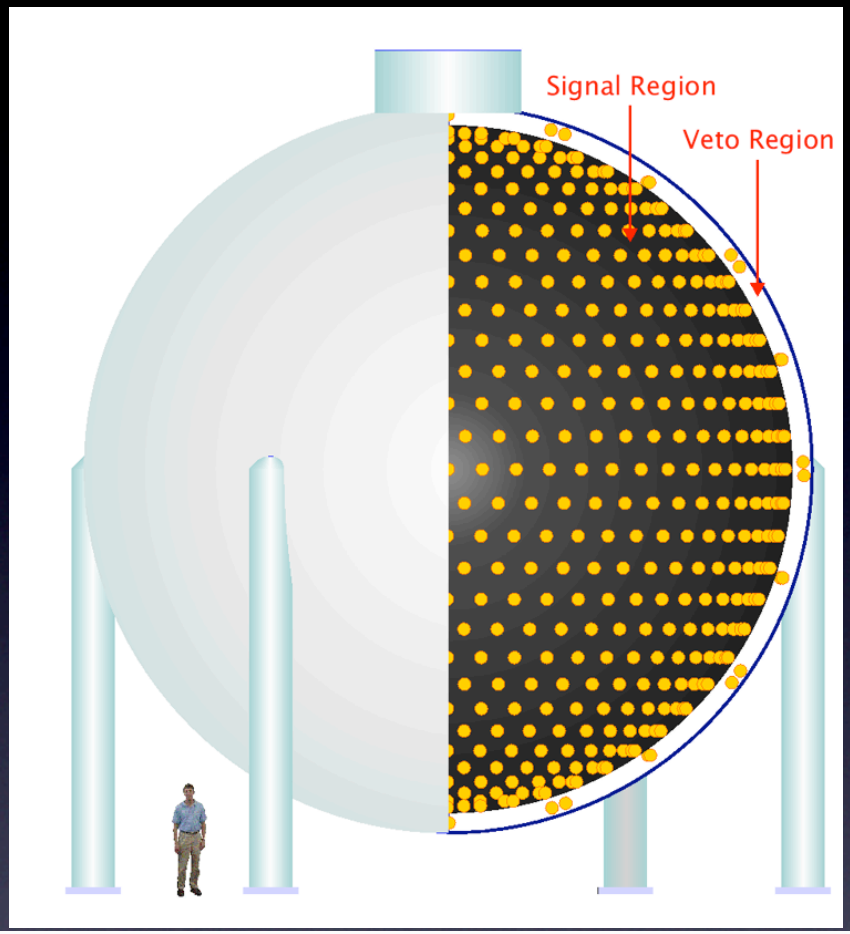
- 99.5% pure muon flavour
- 0.5% intrinsic ν_e
- Constrain ν_e content with ν_μ measurements

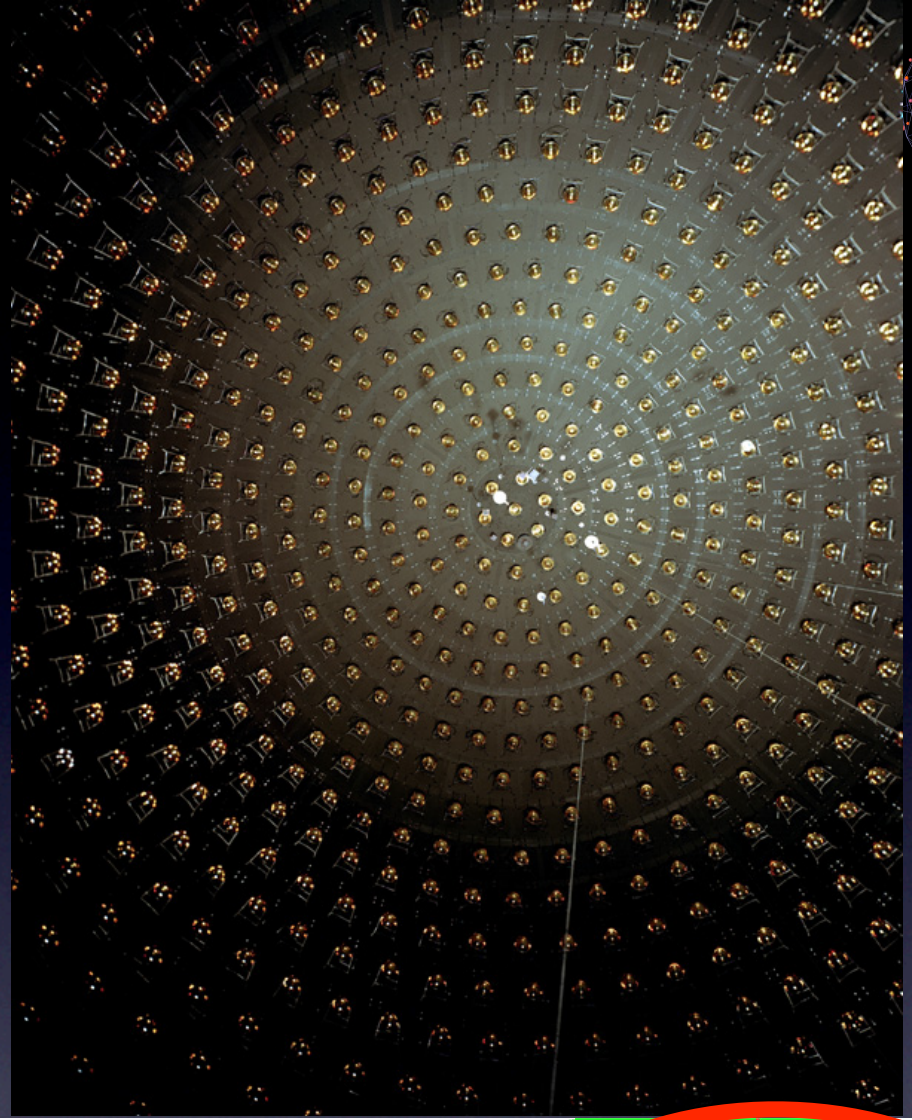


MiniBooNE Overview

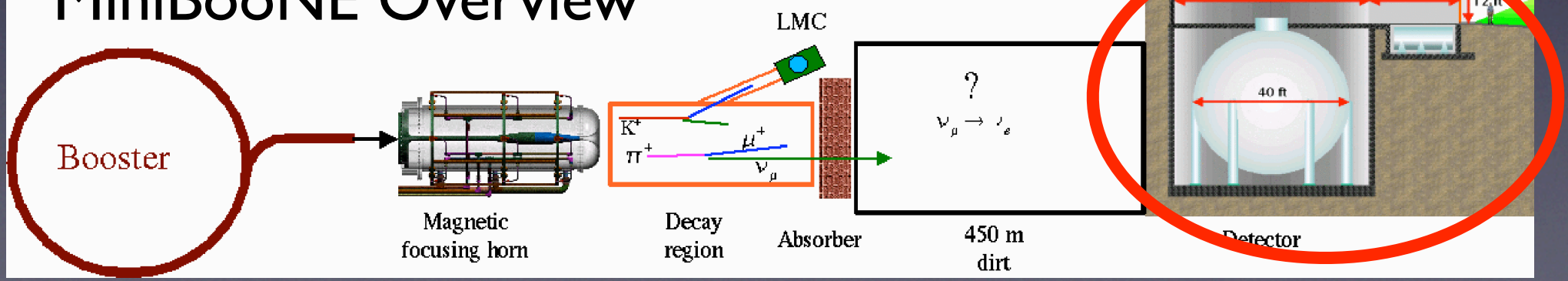


100 Detector

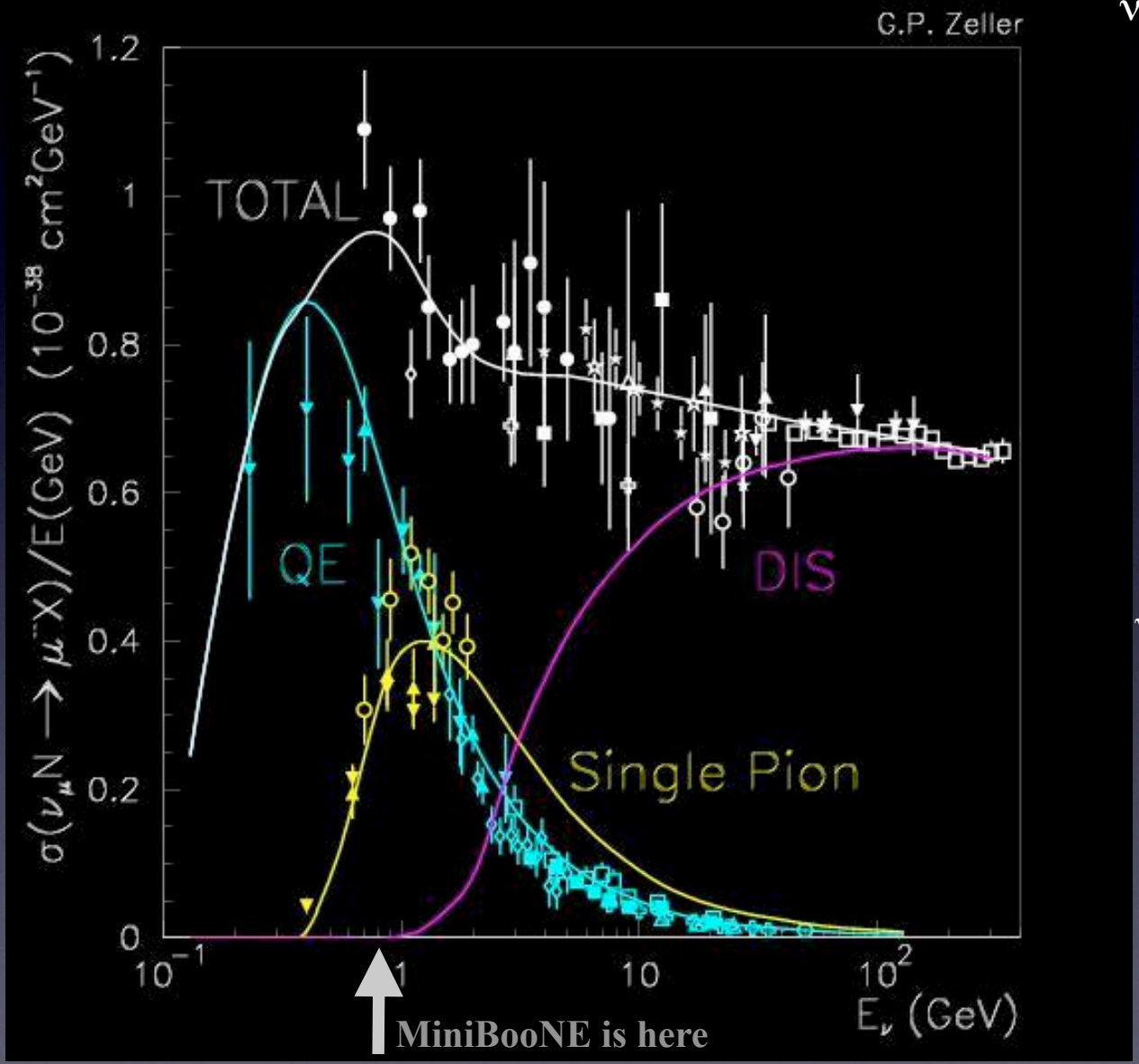


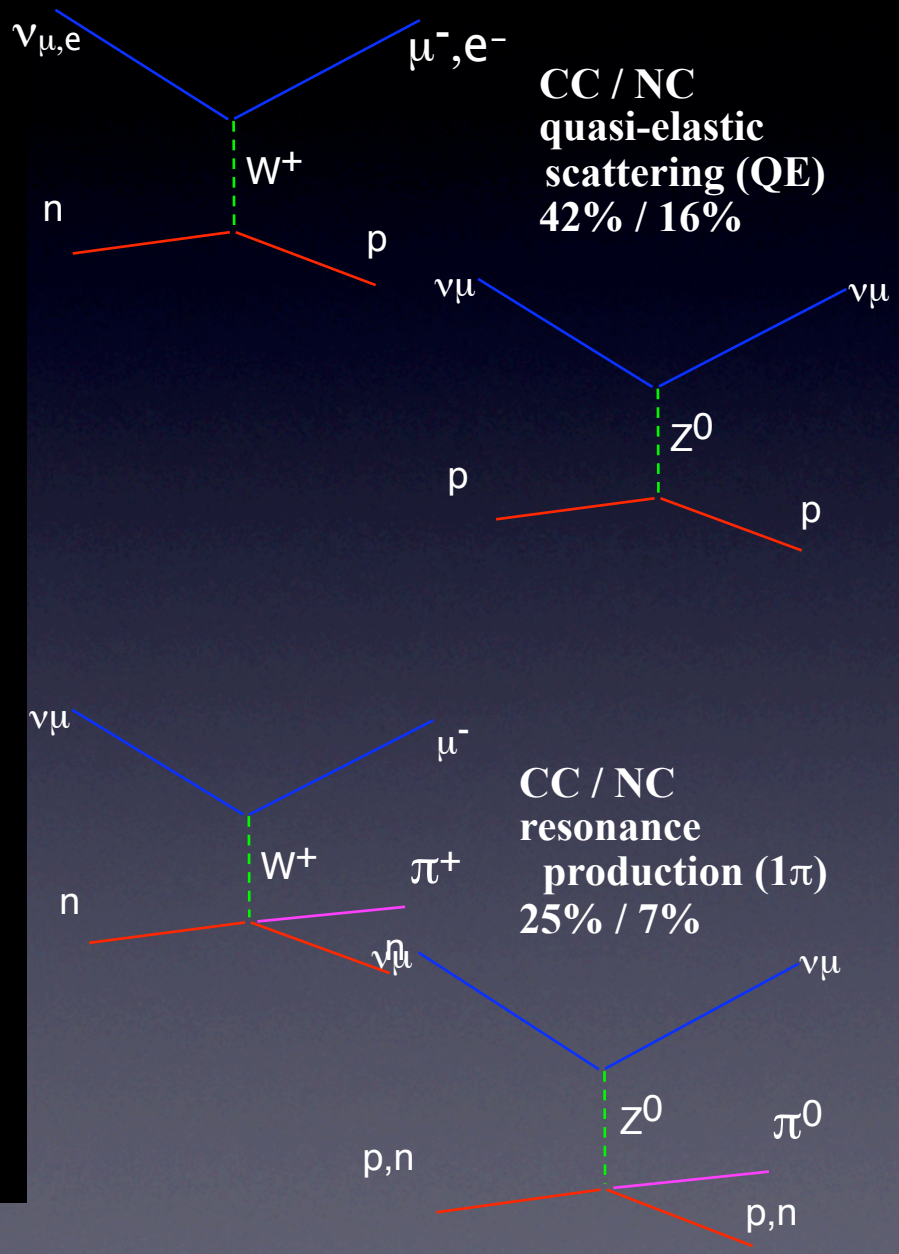


MiniBooNE Overview

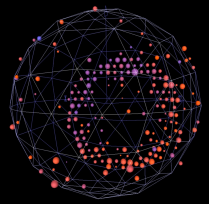


Neutrino Interactions





Track Reconstruction

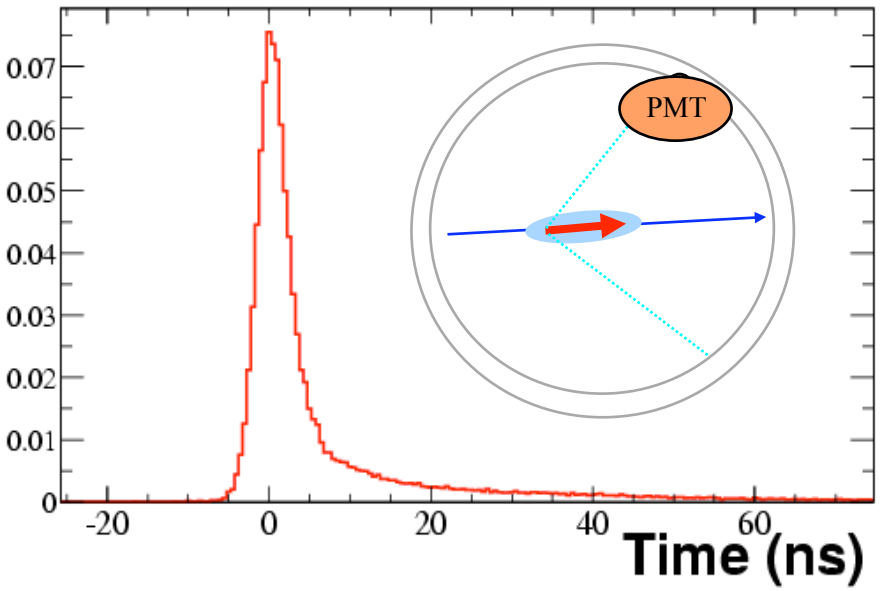


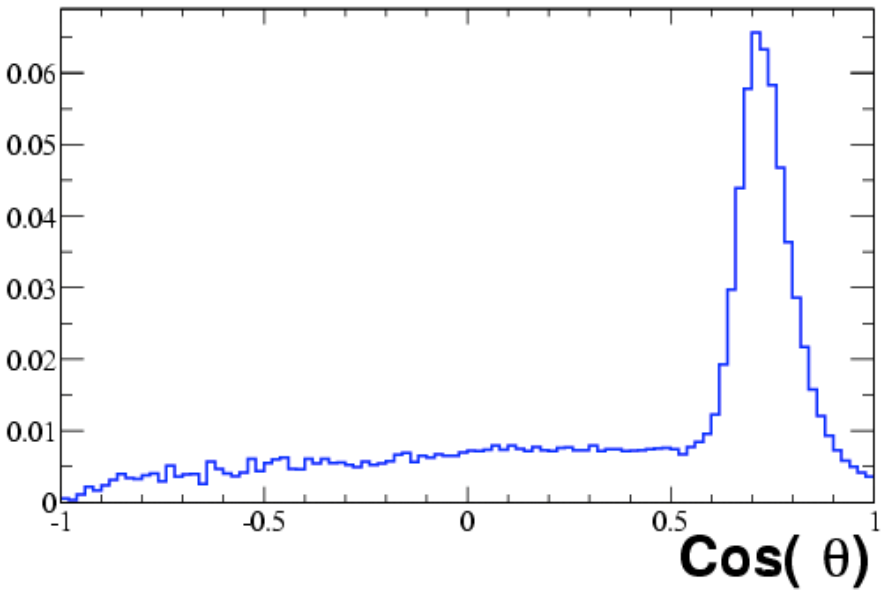
Charged particles produce Cherenkov and scintillation light in oil

PMTs collect photons, record t,Q

Reconstruct tracks by fitting time and angular distributions

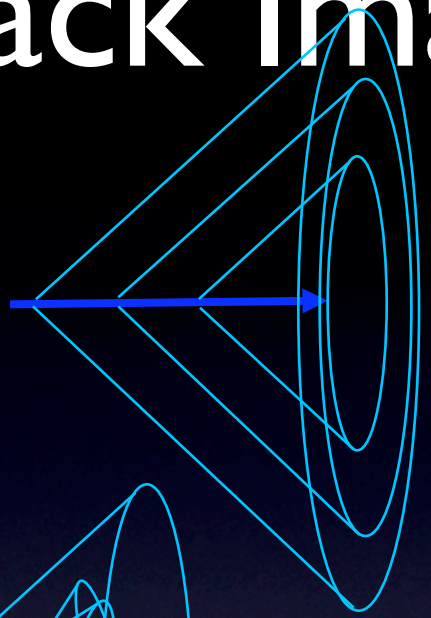
Find position, direction, energy

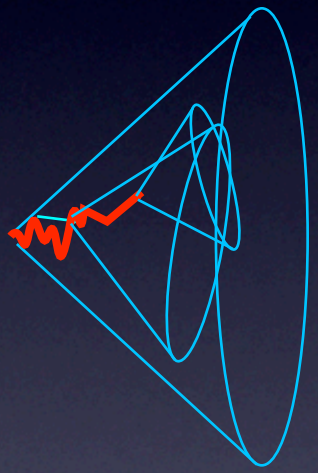


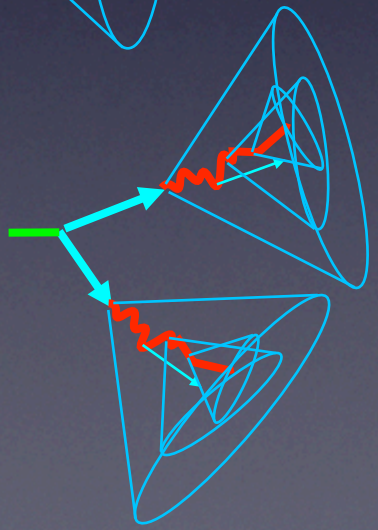
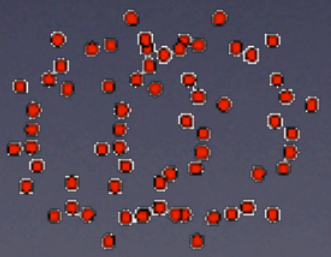
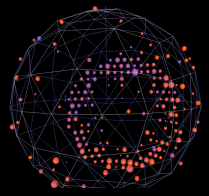
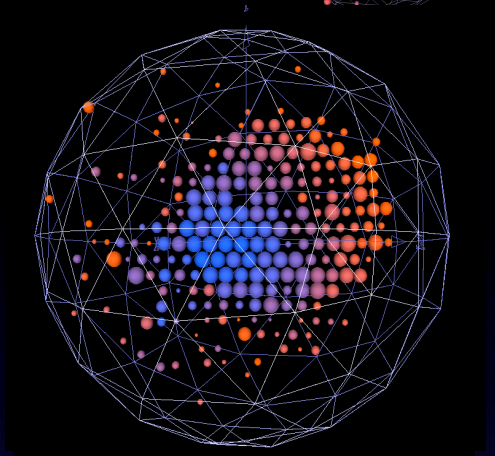
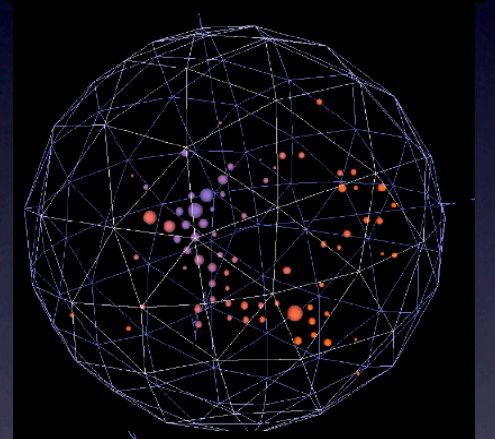
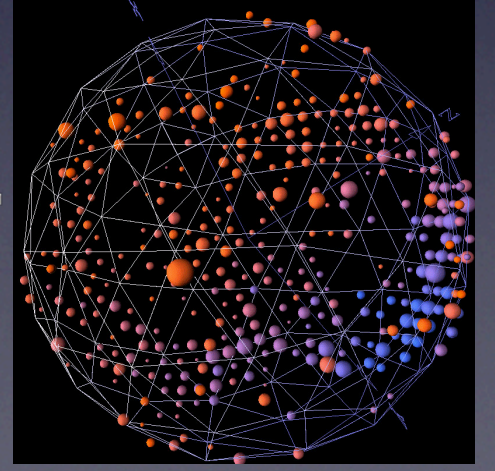


Track Images

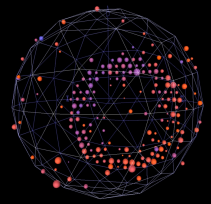
- Muons
  - full rings
- Electrons
  - fuzzy rings
- Neutral pions
  - double rings



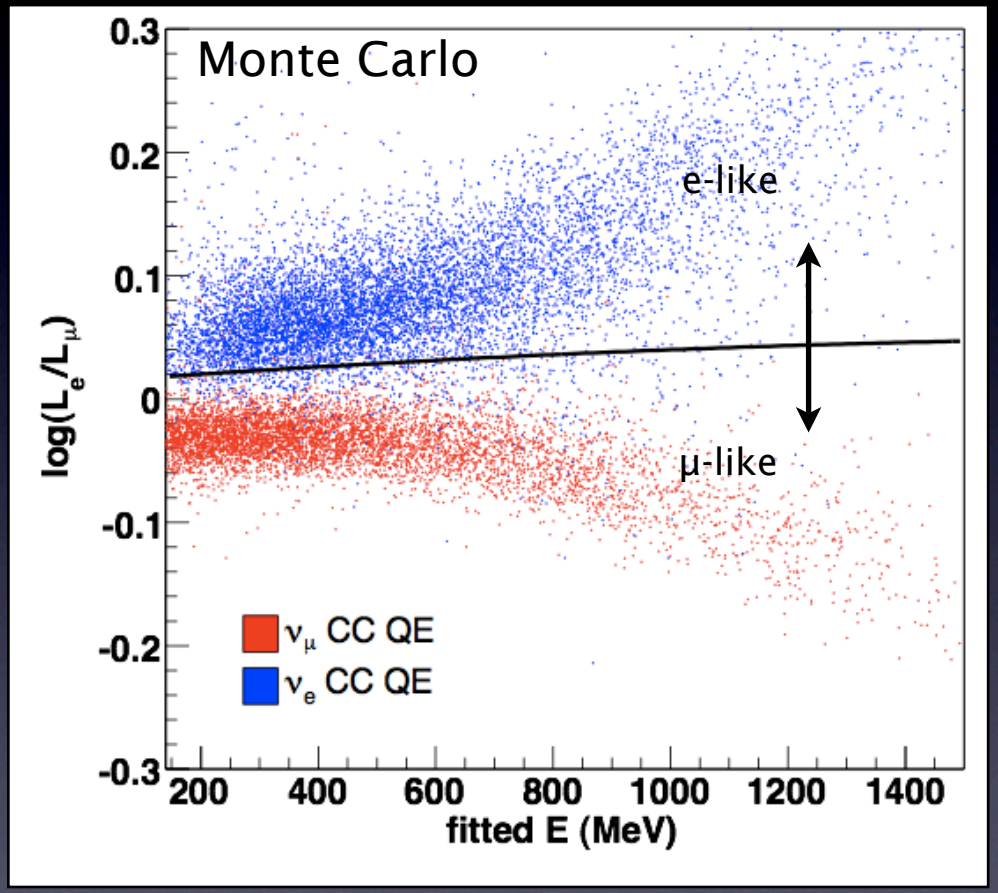


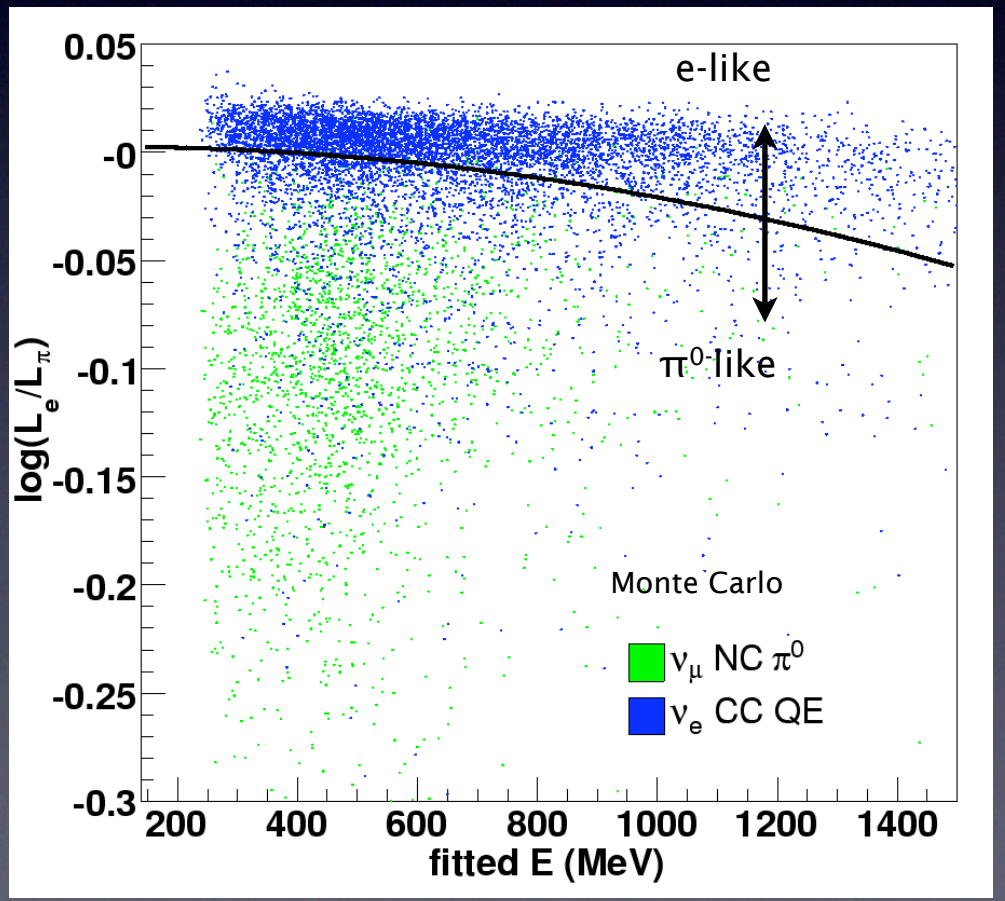
Particle Identification



Reconstruct under 3 possible hypotheses: μ-like, e-like, π^0-like



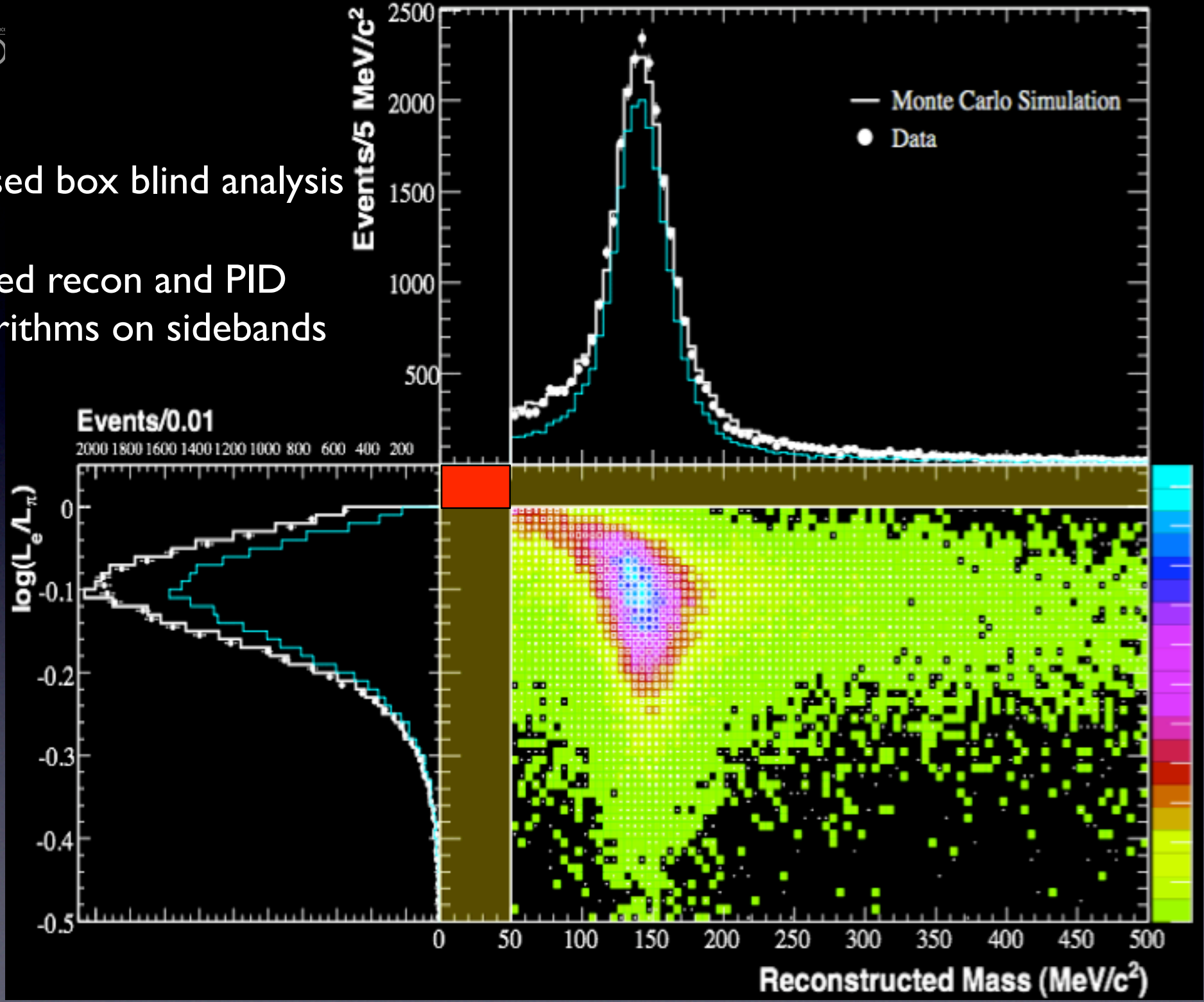
Reconstruction produces likelihoods for the three hypotheses



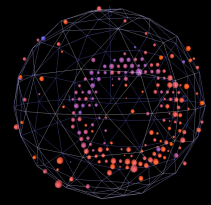
ν_e particle ID cuts on likelihood ratios

cuts chosen to maximise sensitivity to $\nu_\mu \rightarrow \nu_e$ oscillation

- Closed box blind analysis
- Tested recon and PID algorithms on sidebands

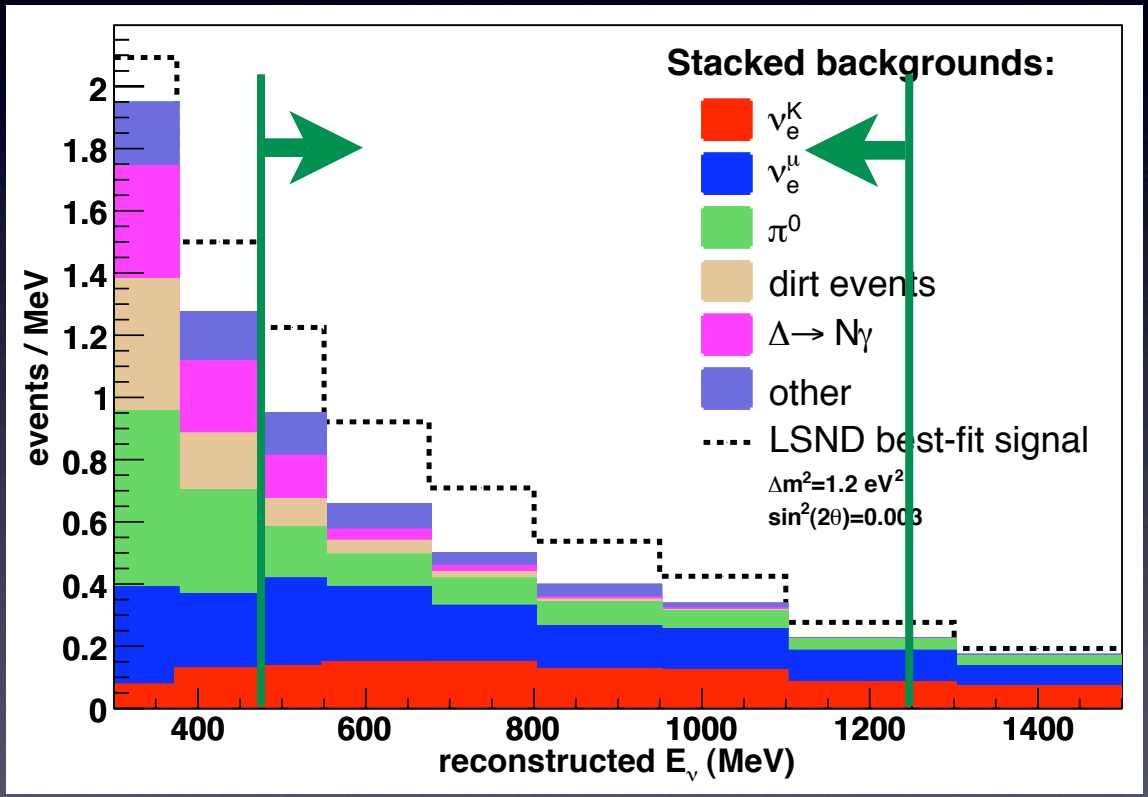


Signal & Background

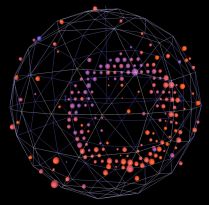


475-1250 MeV	
ν_e(μ decay)	132
ν_e(K decay)	94
Radiative Δ	20
NCπ^0	62
Dirt	17
Other	33
Total	*358*
Signal	*163*

Predicted ν_e energy distribution



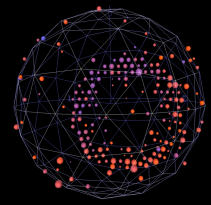
Uncertainties

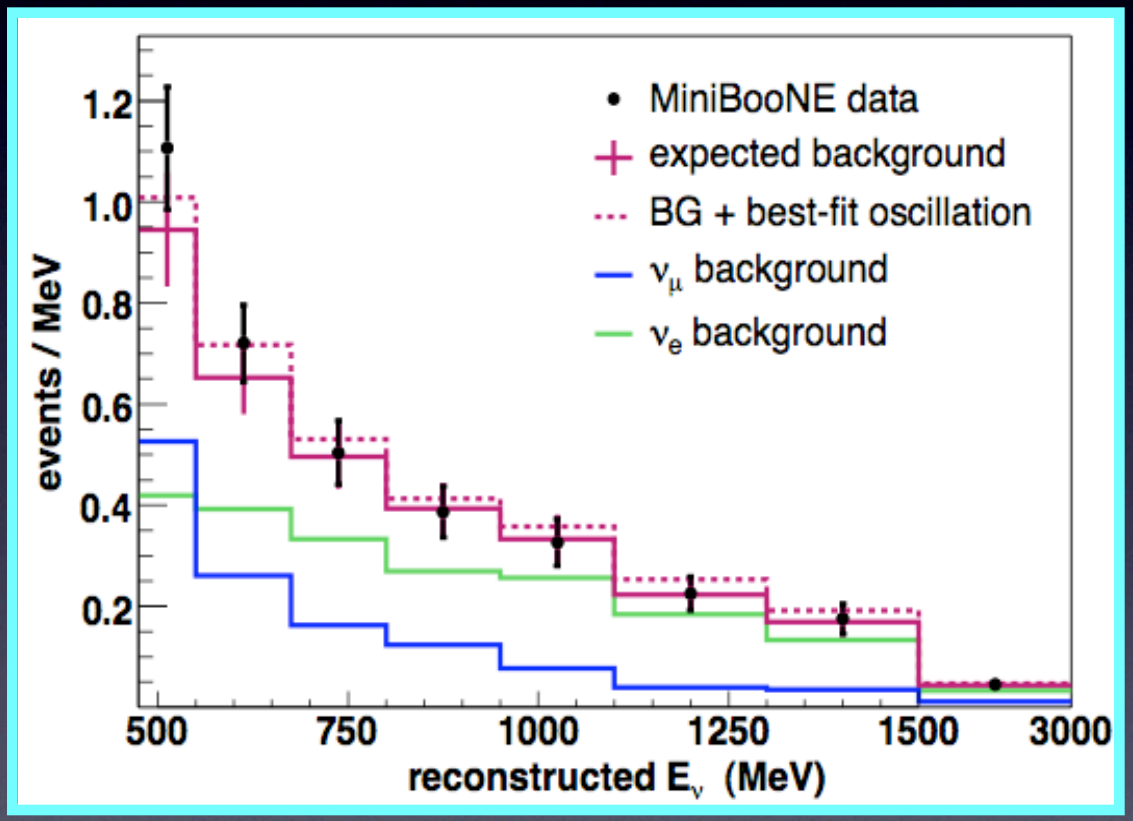


	source	*uncertainty (%)*
√	Flux from π^+/μ^+ decay	6.2
√	Flux from K^+ decay	3.3
√	Flux from K^0 decay	1.5
	Target and beam models	2.8
√	ν-cross section	12.3
	NC π^0 yield	1.8
	External interactions	0.8
√	Optical model	6.1
	Electronics & DAQ model	7.5
	constrained total	9.6

Note:
"total" is **not** the quadrature sum-- errors are further reduced by constraints from ν_μ data

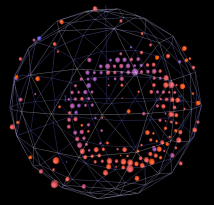
Opened box!





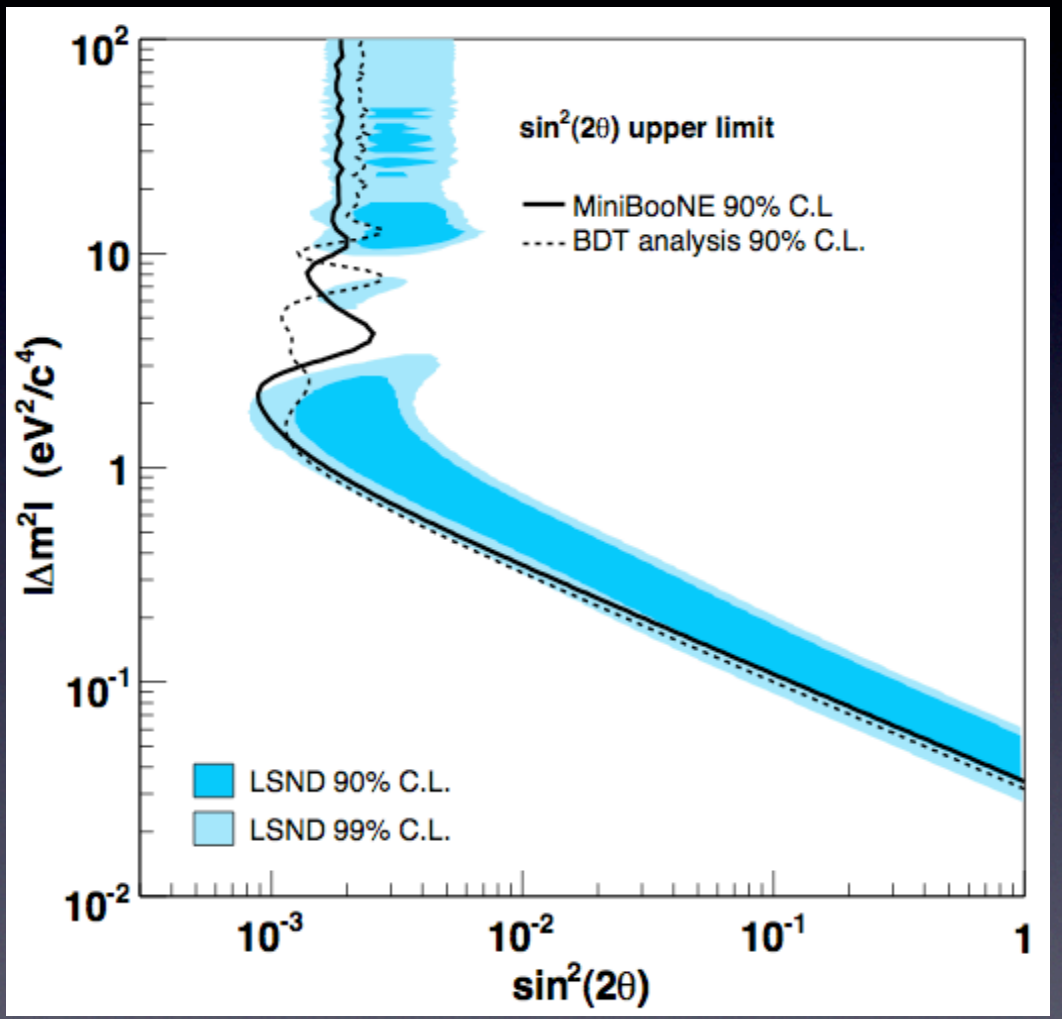
- Counting Experiment (475-1250 MeV)
- Expect 358 ± 19(stat) ± 35(sys)
- Observe 380
- Significance 0.55 σ

Exclusion Curve

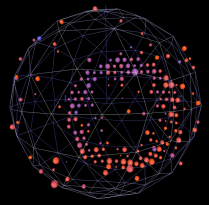


- No evidence for $\nu_\mu \rightarrow \nu_e$ 2ν appearance only oscillations
- Independent second analysis finds similar result
- Incompatible with LSND at 98% CL

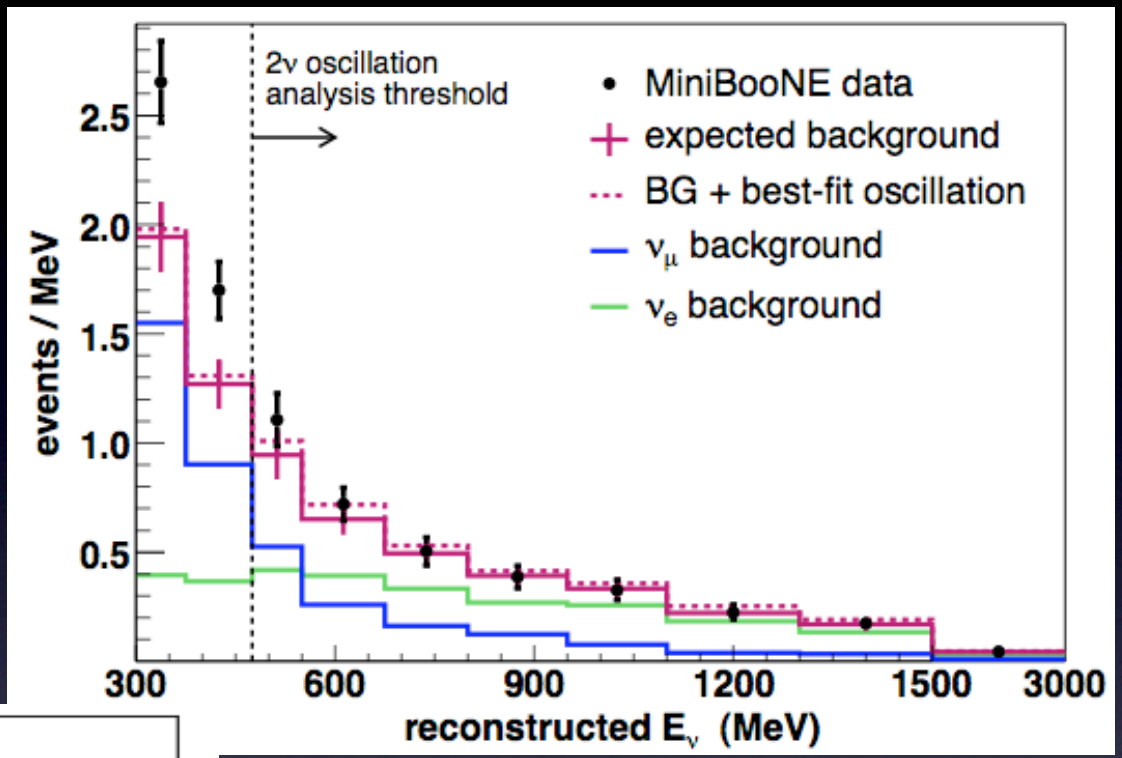
MiniBooNE First Result

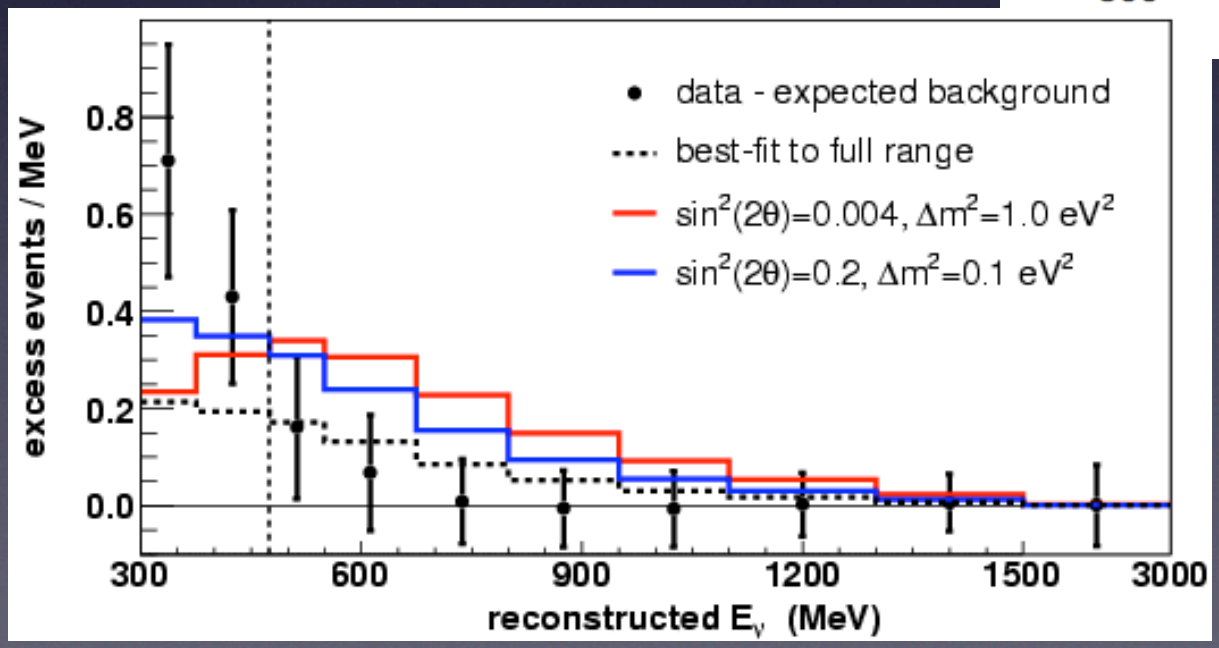


At lower energy...



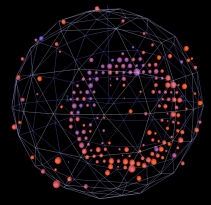
- Lowering the energy threshold reveals ν_e excess
- Currently under investigation





- Excess not consistent with LSND signal

What Does It Mean?



- With the blind analysis, we have asked the question:

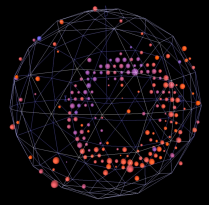
Do ν_μs oscillate directly to ν_es with $\Delta m^2 \sim 1 eV^2$, ala LSND?

- We have a clear answer:

NO

More work yet to do...

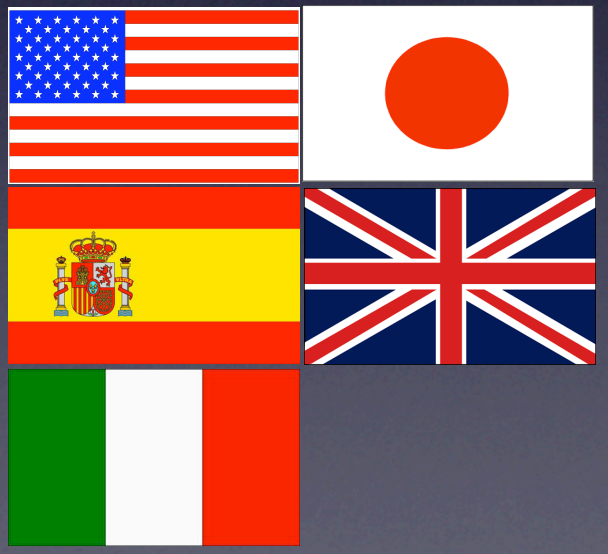
What's Next?



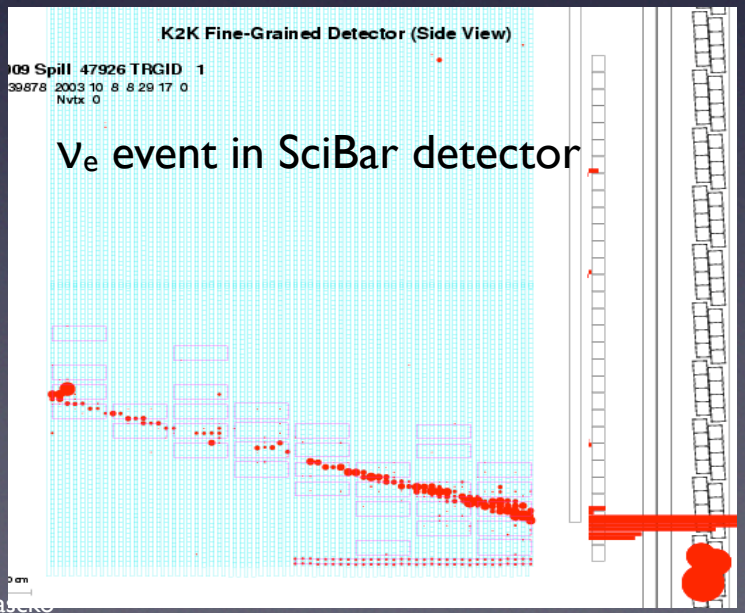
- MiniBooNE will publish several more papers soon:
  - Neutrino cross section measurements
    - CCQE paper accepted by PRL (arXiv:0706.0926 [hep-ex])
  - Joint analysis of MiniBooNE, LSND and KARMEN data
  - More exotic oscillation analyses
    - Combining the two independent analyses into one, etc.
    - 2 or 3 sterile neutrinos with CP violation
      - Maltoni & Schwetz (hep-ph/07050107)
      - MiniBooNE analysis coming soon
- MiniBooNE is running in antineutrino mode now

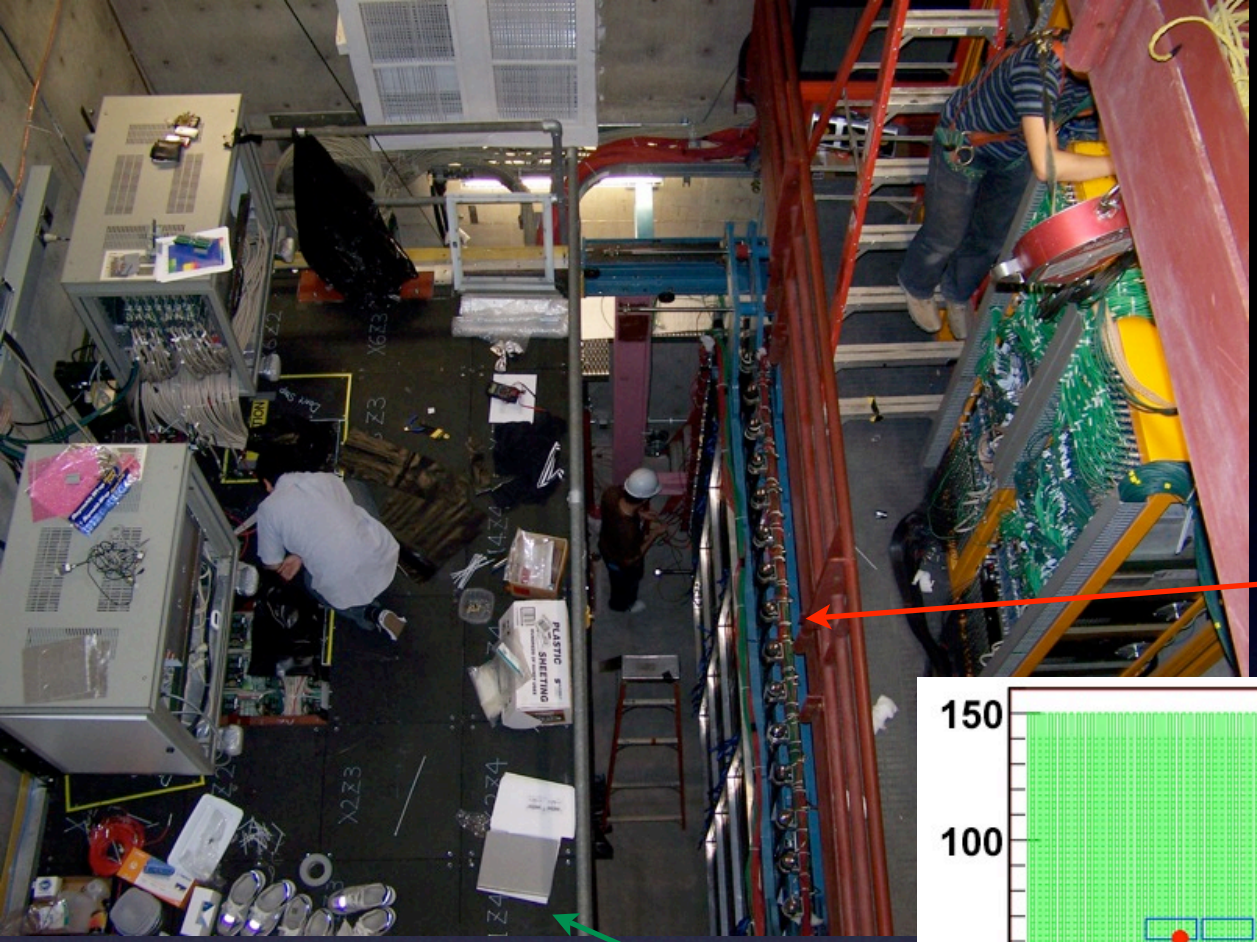
SciBooNE

- New experiment at Fermilab
- Near Detector in BNB
- We can precisely measure the intrinsic ν_e content of BNB
  - Check MiniBooNE's background estimate



Spokespeople:
T. Nakaya, Kyoto University
M.O. Wascko, Imperial College

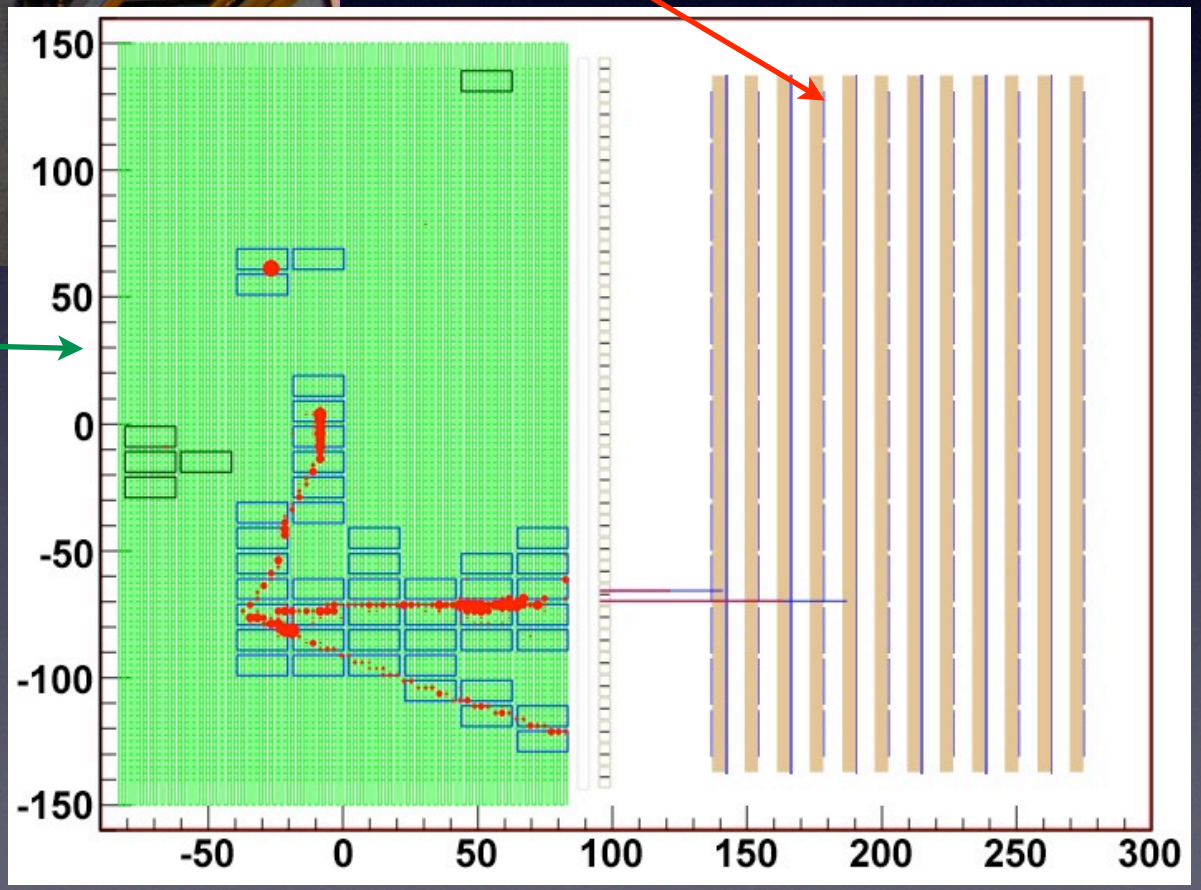




- *Data run started 25 June*

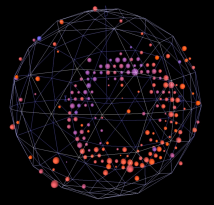
Muon Range Detector

SciBar/EC Detectors



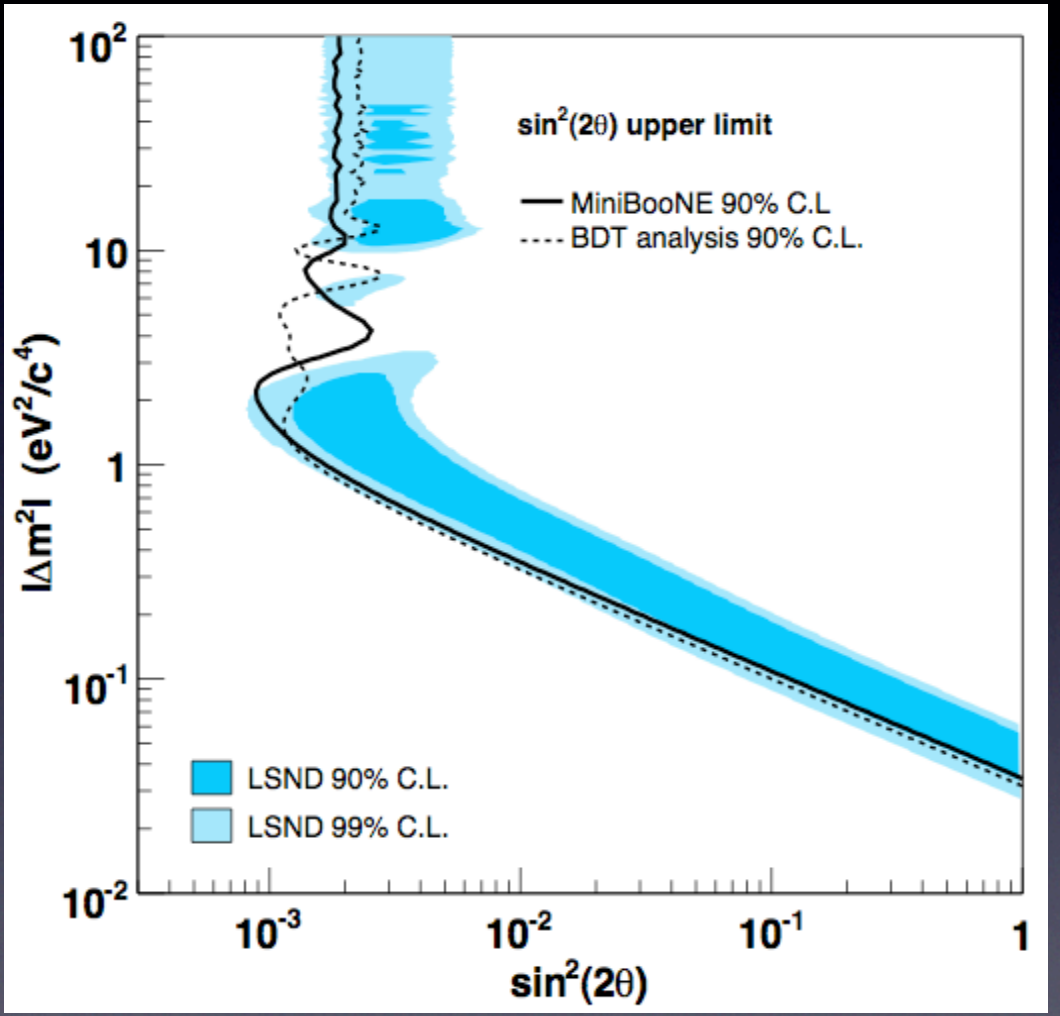
- *Now taking data (as I speak!)*

Summary



- MiniBooNE observes no evidence for $\nu_\mu \rightarrow \nu_e$ 2ν oscillations
- Incompatible with LSND $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ oscillation signal at 98% CL
- Low energy excess under investigation
- SciBooNE data coming soon

MiniBooNE First Result



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arXiv:0704.1500 [hep-ex]