MiniBooNE: Up and Running

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MiniBooNE detector
at Fermi National Accelerator Lab

Outline

- Motivation
- MiniBooNE Overview
- Physics at MiniBooNE
- Current Status
- First Data!

Neutrino Oscillations
The Evidence So Far ...

Solar $\Delta m^2 \sim 10^{-(4\sim5)}$

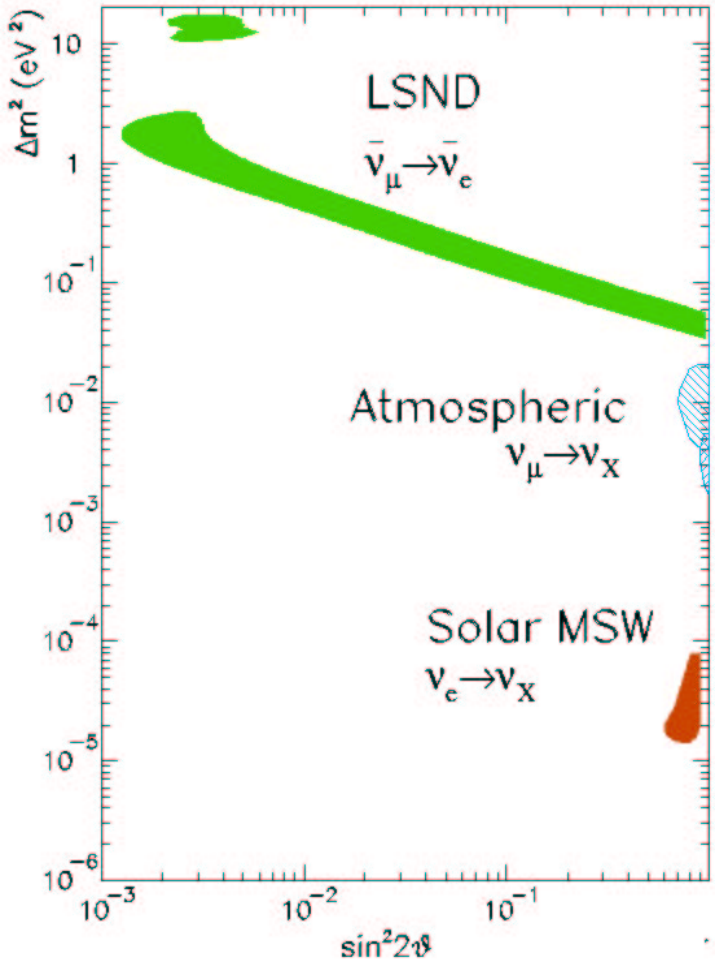
Atmospheric $\Delta m^2 \sim 3 \times 10^{-3}$

both are well established

LSND $\Delta m^2 \sim 10^{-(0 \sim 1)}$

Three Δm^2 scales!

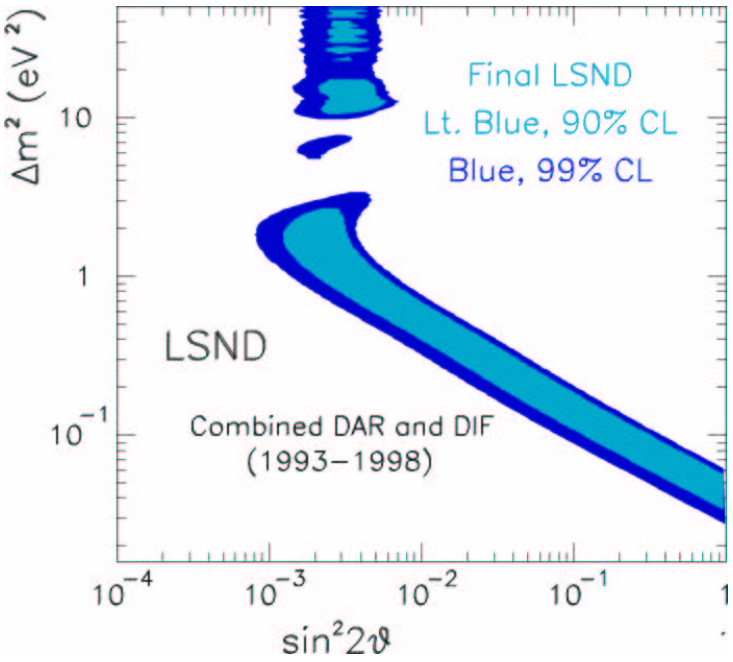
Unconfirmed result...

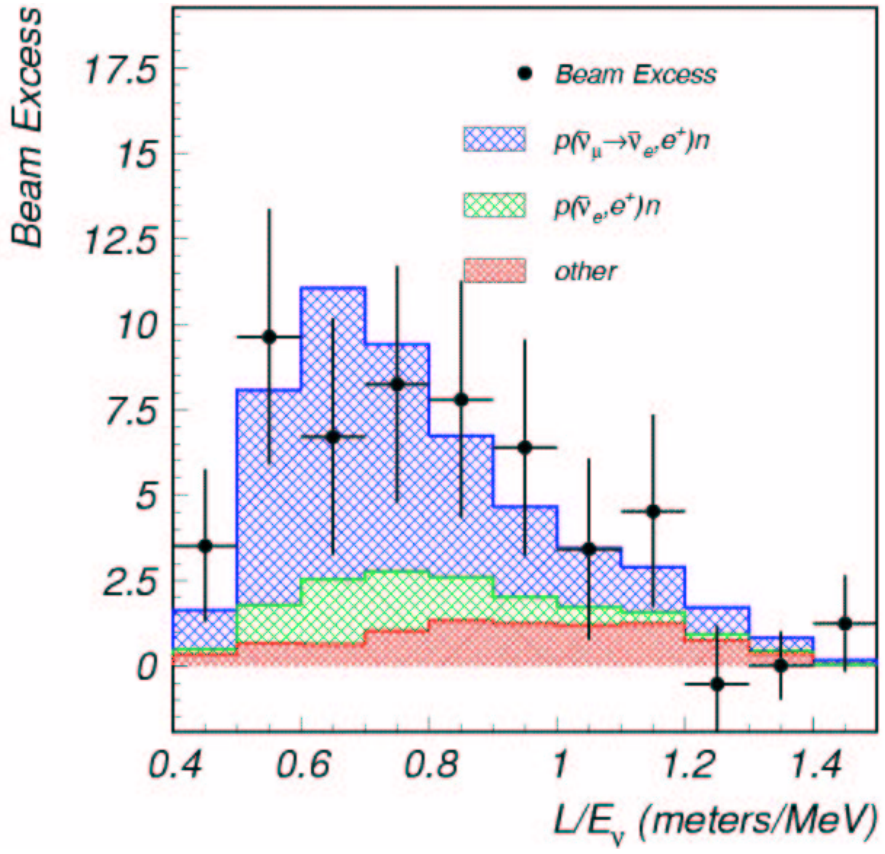


Motivation for MiniBooNE
The LSND Oscillation Signal

Excess: 87.9 ± 22.4 ± 6.0 evts.

Oscillation probability: (0.264 ± 0.067 ± 0.045)%.





3.8 σ statistical significance of excess.

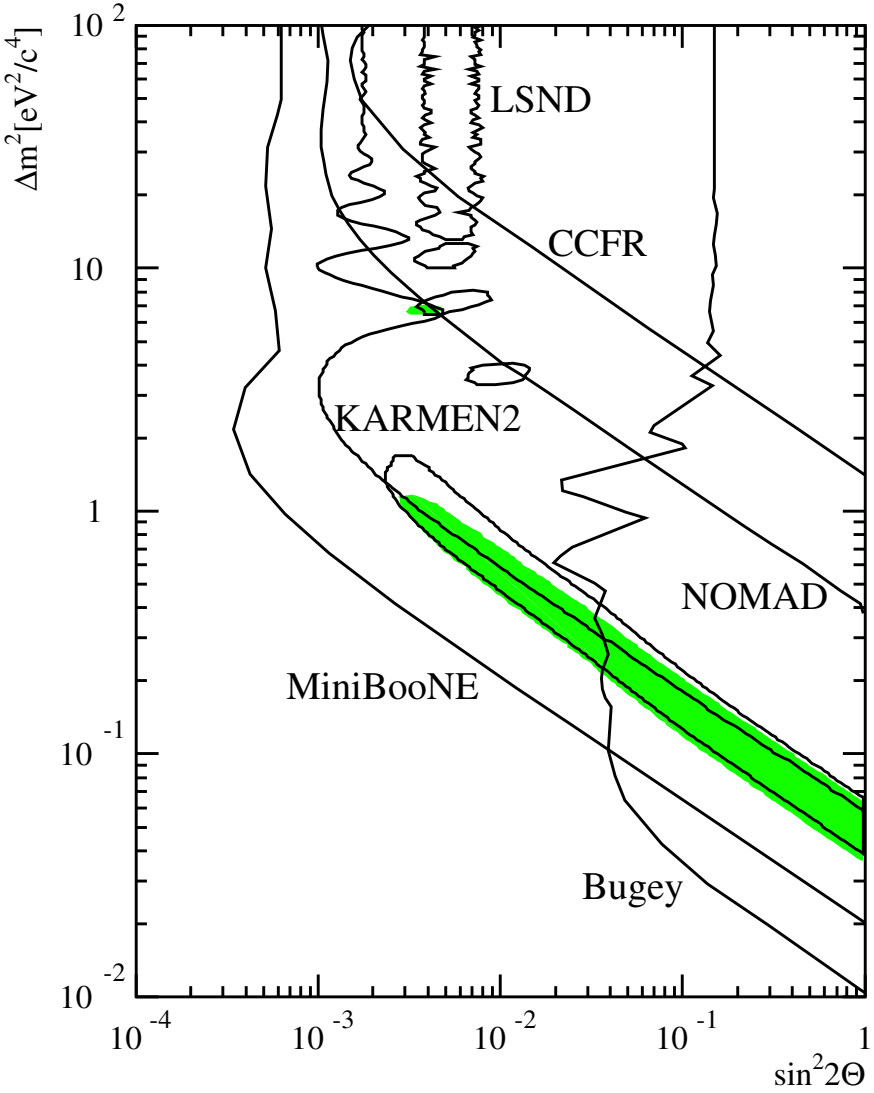
Confirmation is Crucial!

Motivation for MiniBooNE
The LSND Oscillation Signal (2)

Karmen result excludes
part of LSND allowed region

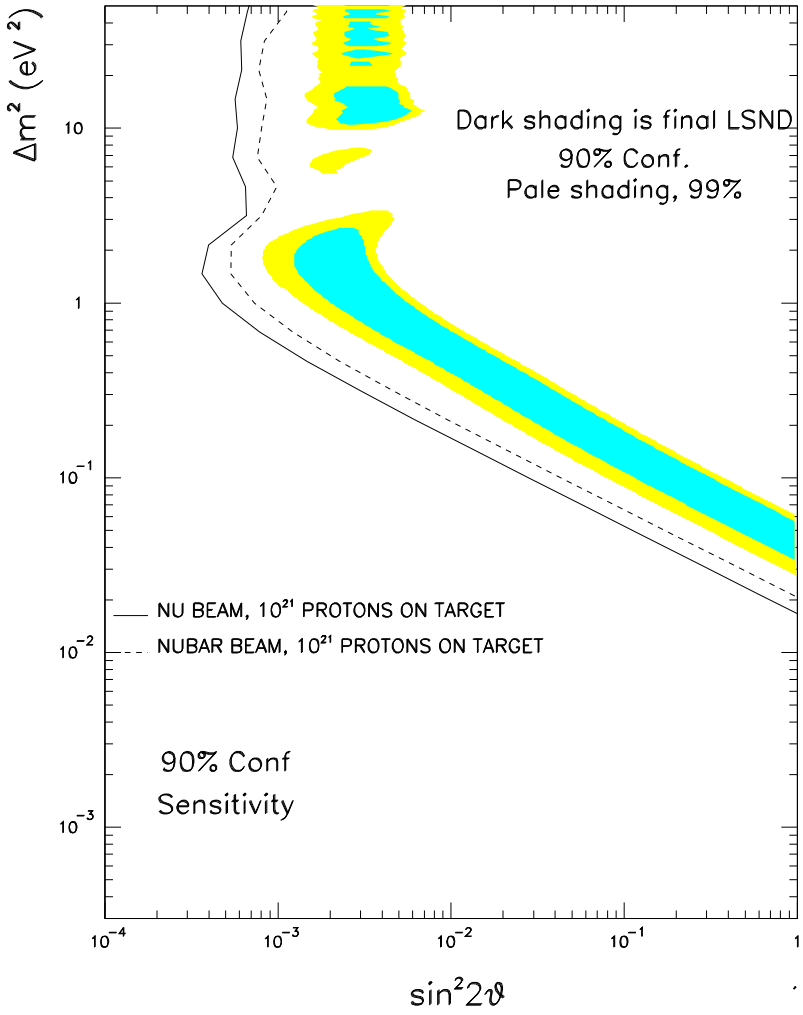
...but a lot of phase space
is left open

Plot taken from
Church, Eitel, Mills, and Steidl
hep-ex/0203023



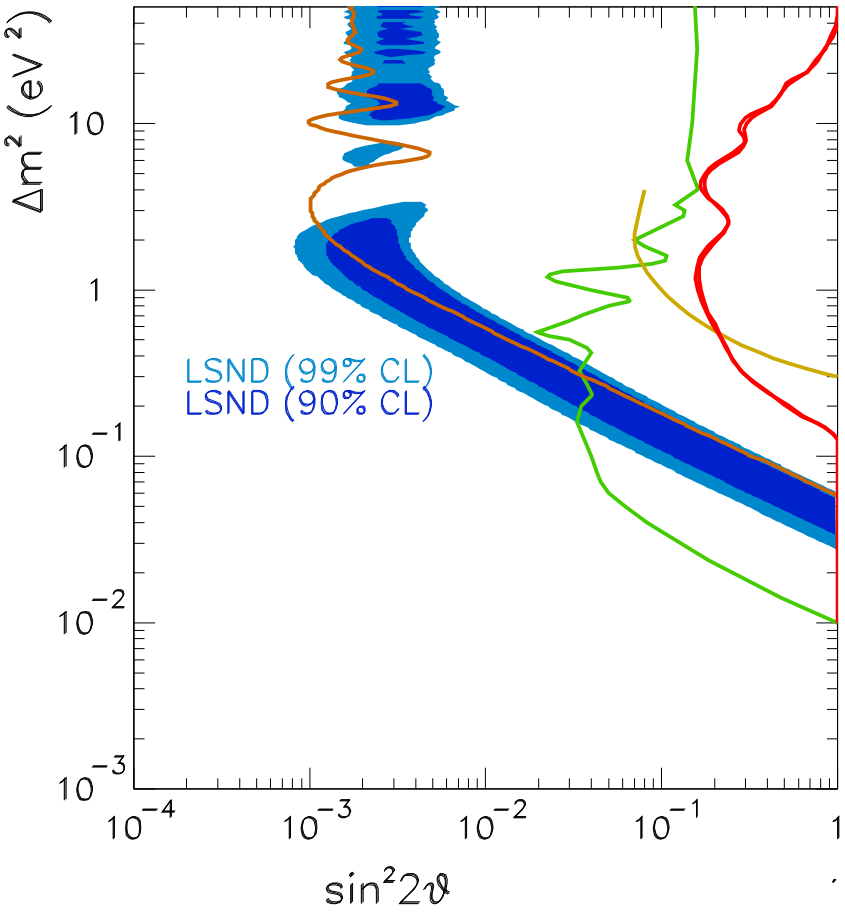
MiniBooNE Sensitivity to ν_e Appearance

- Same L/E as LSND
  - Higher statistics
  - Different systematics (different L, E)
- MiniBooNE sensitivity will cover entire LSND allowed region at 5 σ level in two years



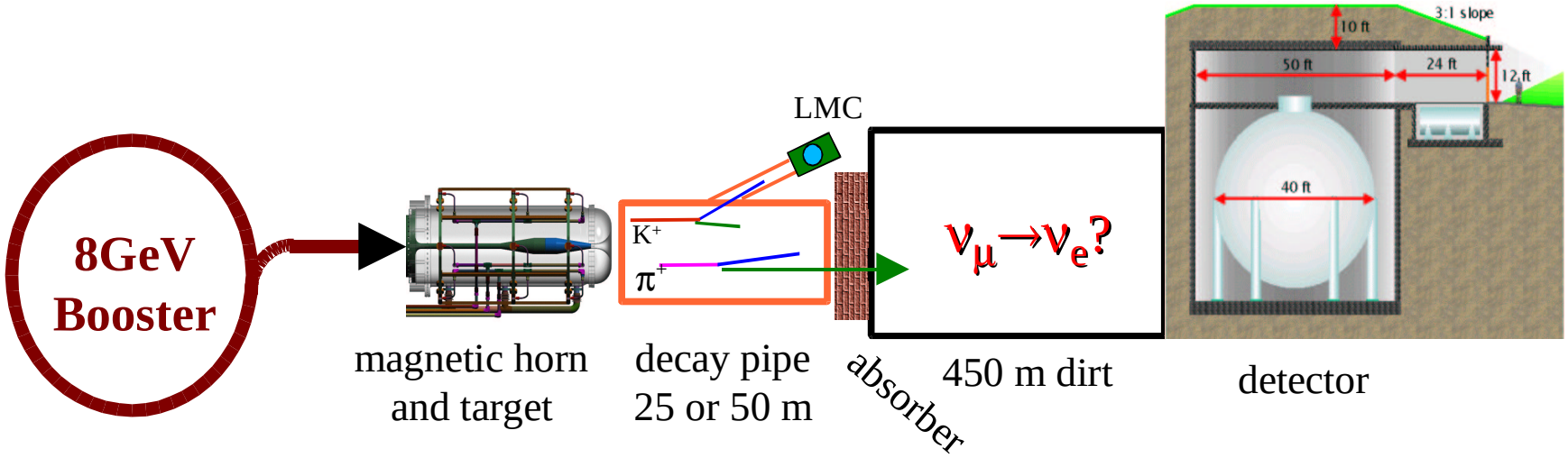
MiniBooNE Sensitivity to ν_μ Disappearance

- Can help distinguish 3+1 from 2+2 Allowed Regions
  - Complementary Analysis
  - Lower Δm^2 reach than CDHS
- MiniBooNE will have HIGH statistics for ν_μ disappearance!



MiniBooNE Experiment: Beamline Overview

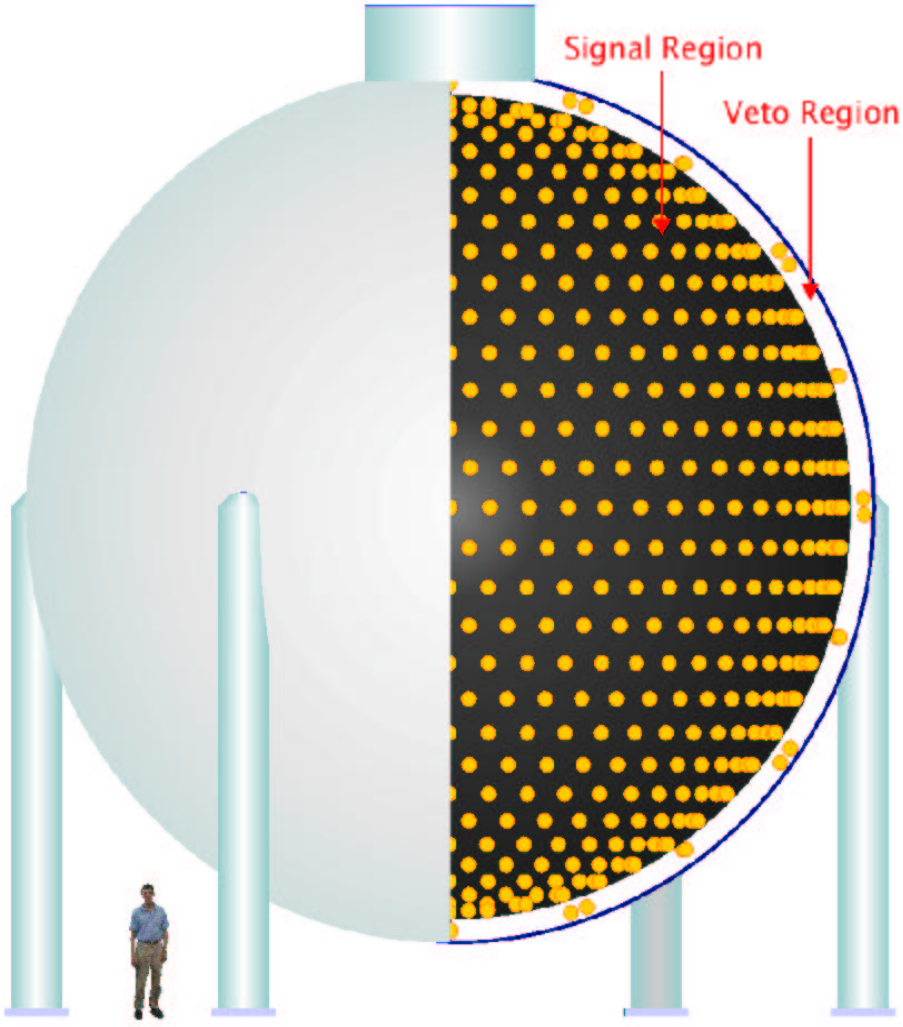
- 8GeV protons from Fermilab Booster
- Incident on Be target
- Magnetic horn focuses interaction products



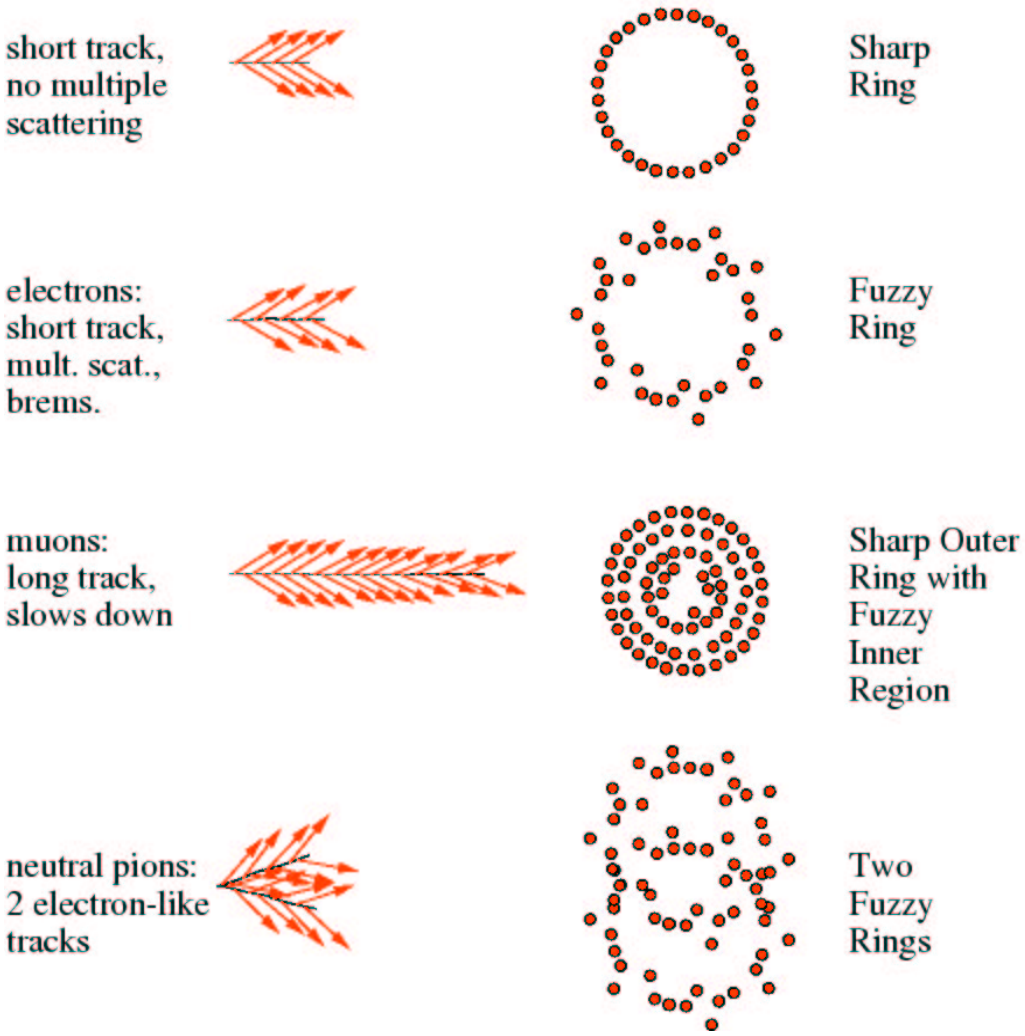
- π and K secondaries traverse decay pipe
- Traverse beam absorber + berm
- νs proceed through detector hall

MiniBooNE Experiment: Detector Overview

- 12m diam. sphere
- lined with 8" PMTs
  - 1280 main region
  - 240 veto region
  - 10% coverage
- 800 tons of mineral oil
- Custom electronics from LSND
- All new Data Acquisition System

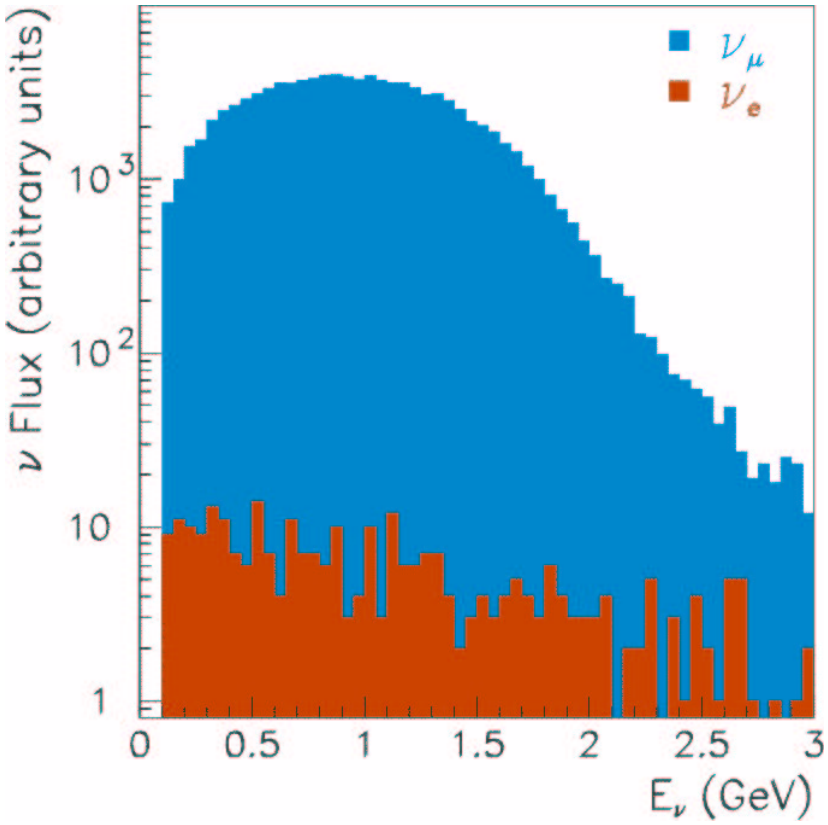


MiniBooNE Experiment: Particle Identification



MiniBooNE Experiment: Neutrino Fluxes

$$p + Be \rightarrow \pi^+, K^+, K^0_L$$



The beam is comprised almost entirely of ν_μ

$$\pi^+ \rightarrow \mu^+ \nu_\mu$$

$$K^+ \rightarrow \mu^+ \nu_\mu$$

$$\rightarrow \pi^+ \pi^0$$

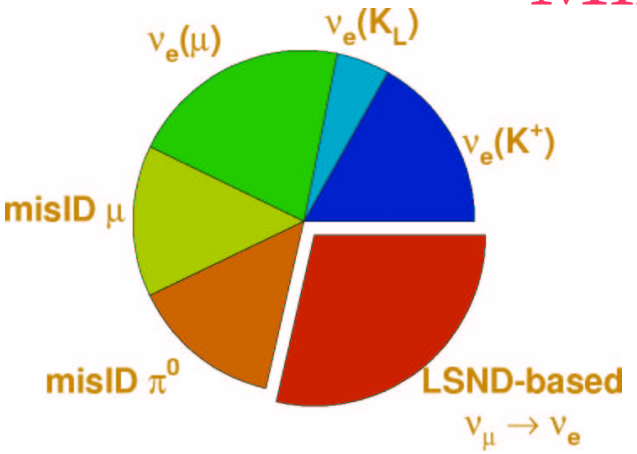
Intrinsic ν_e flux is small compared to ν_μ flux

$$K^0_L \rightarrow \pi^+ e^- \nu_e$$

$$\mu^+ \rightarrow e^+ \nu_e \nu_\mu$$

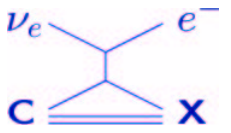
$$K^+ \rightarrow e^+ \nu_e$$

MiniBooNE Experiment: Numbers of Events

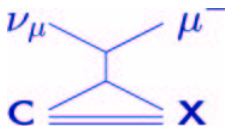


Approximately 500,000 ν_μC events expected in MiniBooNE with two years of running.

Intrinsic ν_e background: **1,500 events**



μ mis−ID background: **500 events**



π^0 mis−ID background: **500 events**

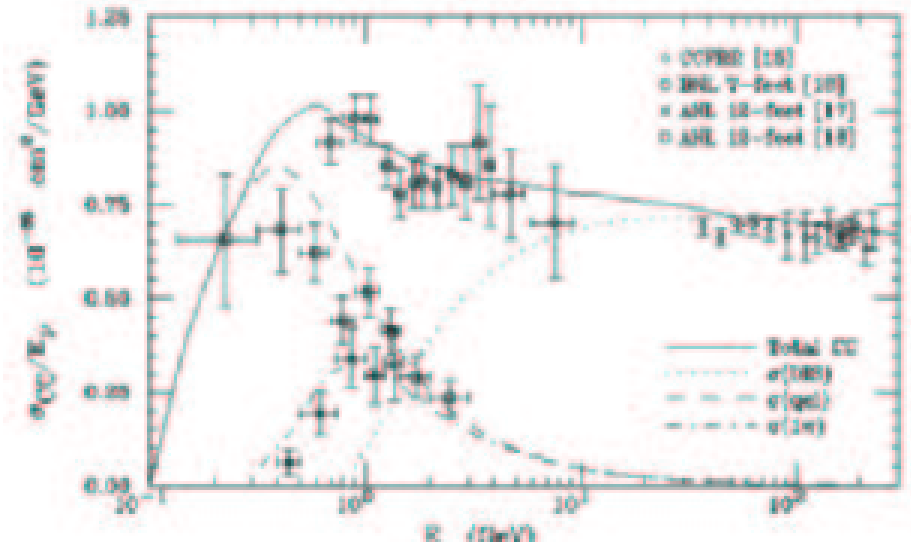
LSND−based $\nu_\mu \rightarrow \nu_e$: **1,000 events**

MiniBooNE Experiment: Blindness Scheme

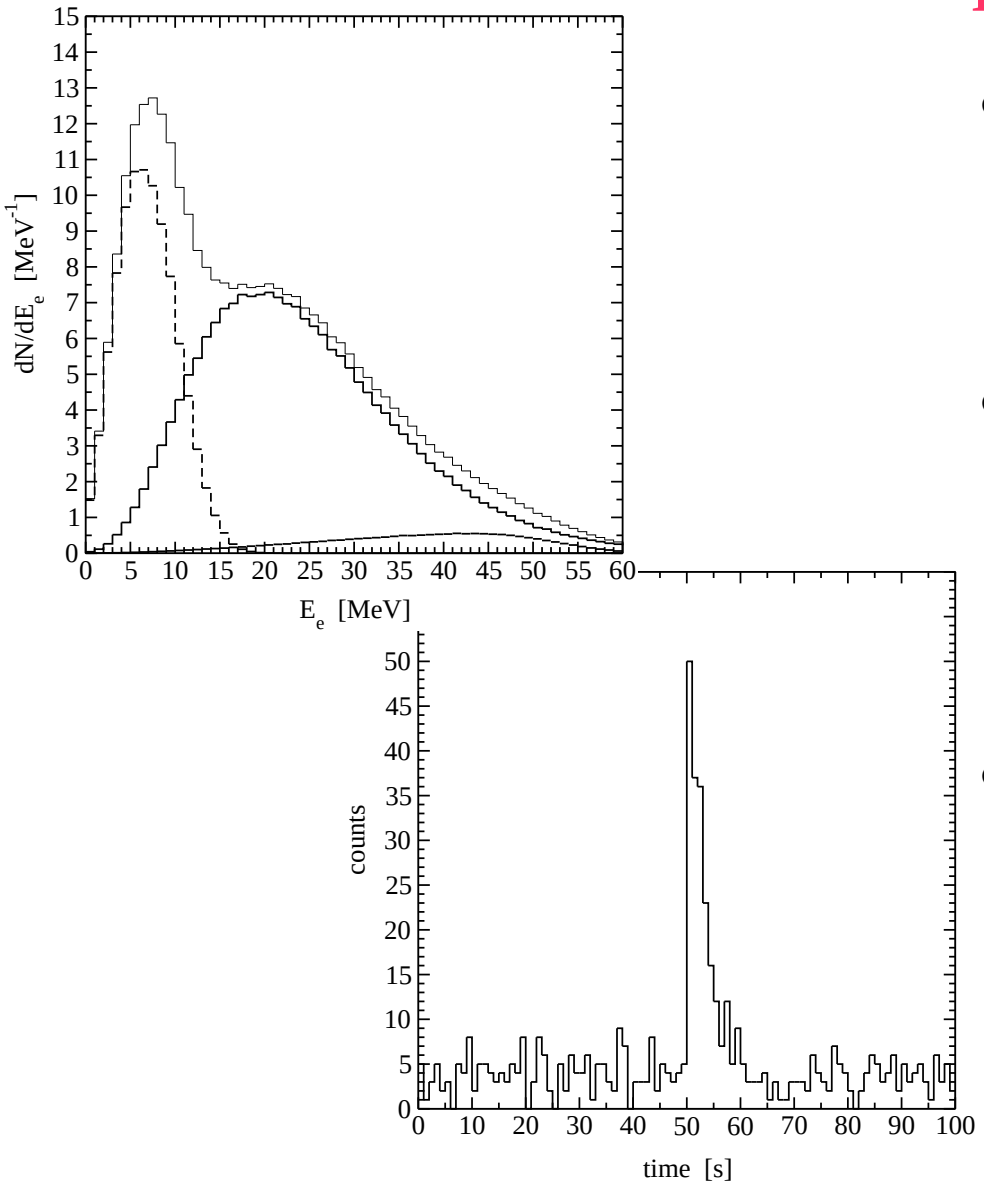
- Blind analysis is used to prevent bias
  - Encourages sound development of Monte Carlo
- In a nutshell:
  - Start by putting all but clean ν_μ CC events "in the box"
  - Take 1000 open event to use for studies
  - Open the box incrementally to extract clean μ and π^0 samples

Non−Oscillation Physics: ν–C Cross−Section Measurements

- Quasi−elastic ν−C cross−sections are key for the oscillation measurement
- We will improve on the current uncertainty in the total νcross−section around 1 GeV



Non−Oscillation Physics: MiniBooNE the Supernova Detector



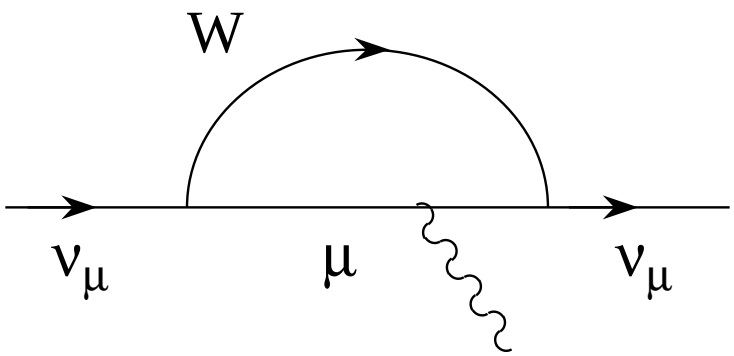
- Estimated sensitivity: 190 ν_e p $\rightarrow$ e^+ n for a galactic supernova at 10 kPc
- Supernova trigger in action! 15.2 μsec holdoff after cosmic rays + 99% veto efficiency cuts michel e^-
- ^{12}B decay background peaked at lower energy, cosmic ray background peaked at higher energy

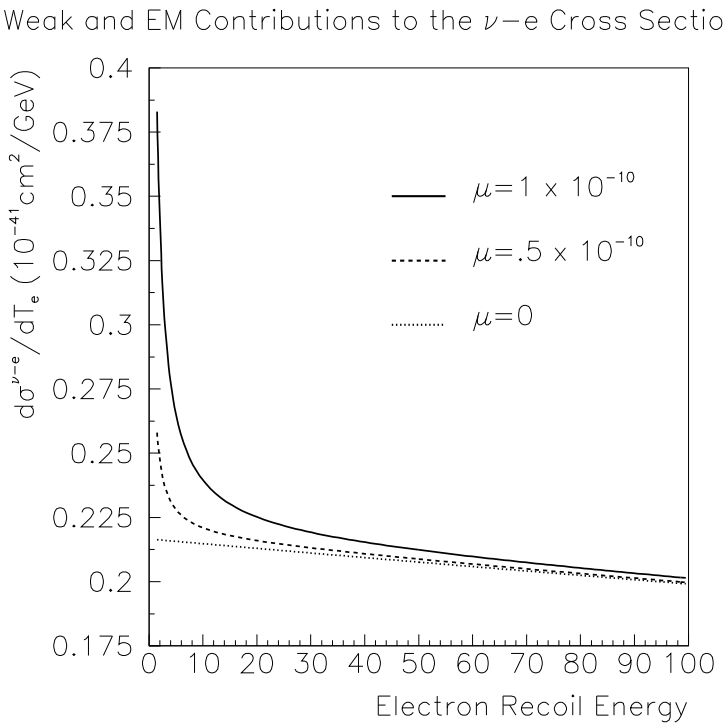
M. K. Sharp, J. F. Beacom, J. Formaggio, **hep−ph/0205035**

Non−Oscillation Physics: Anomalous Neutrino Magnetic Moment

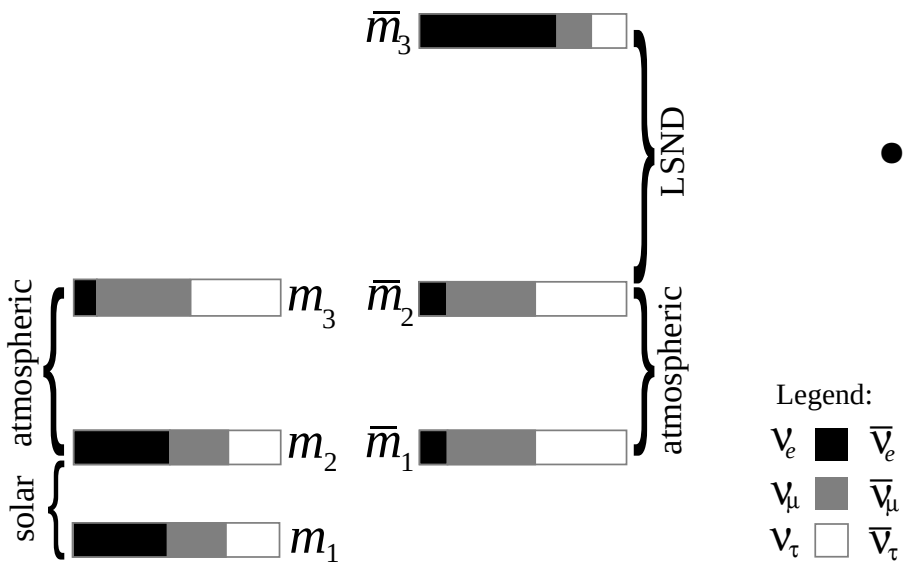
- If non−zero μ_ν, νs can have EM interactions → large contribution to ν_e scattering cross−section at low electron recoil energy
- Expected sensitivity: ~ 100 ν−e scattering events will give a factor of 2 improvement over LSND μ_ν limit

B. Fleming and J. Beacom, in preparation





More Oscillation Related Physics: Test of CP and CPT

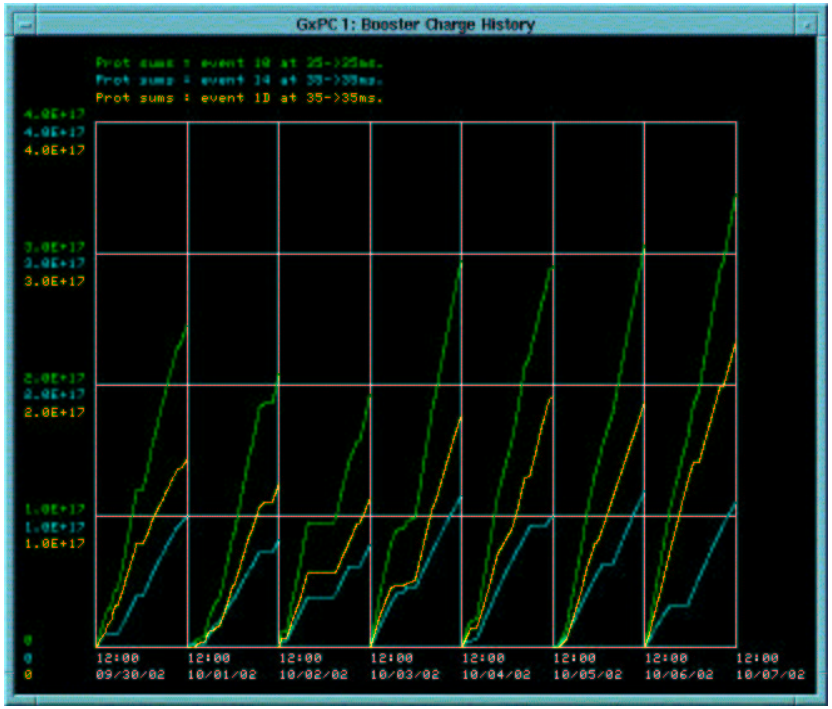


- MiniBooNE can run in ν or anti−ν mode
- Recent CPT violating models account for all current experimental oscillation results with only 3 νs

G. Barenboim, L. Borissov, J. Lykken, A. Yu. Smirnov, **hep−ph/0108199**

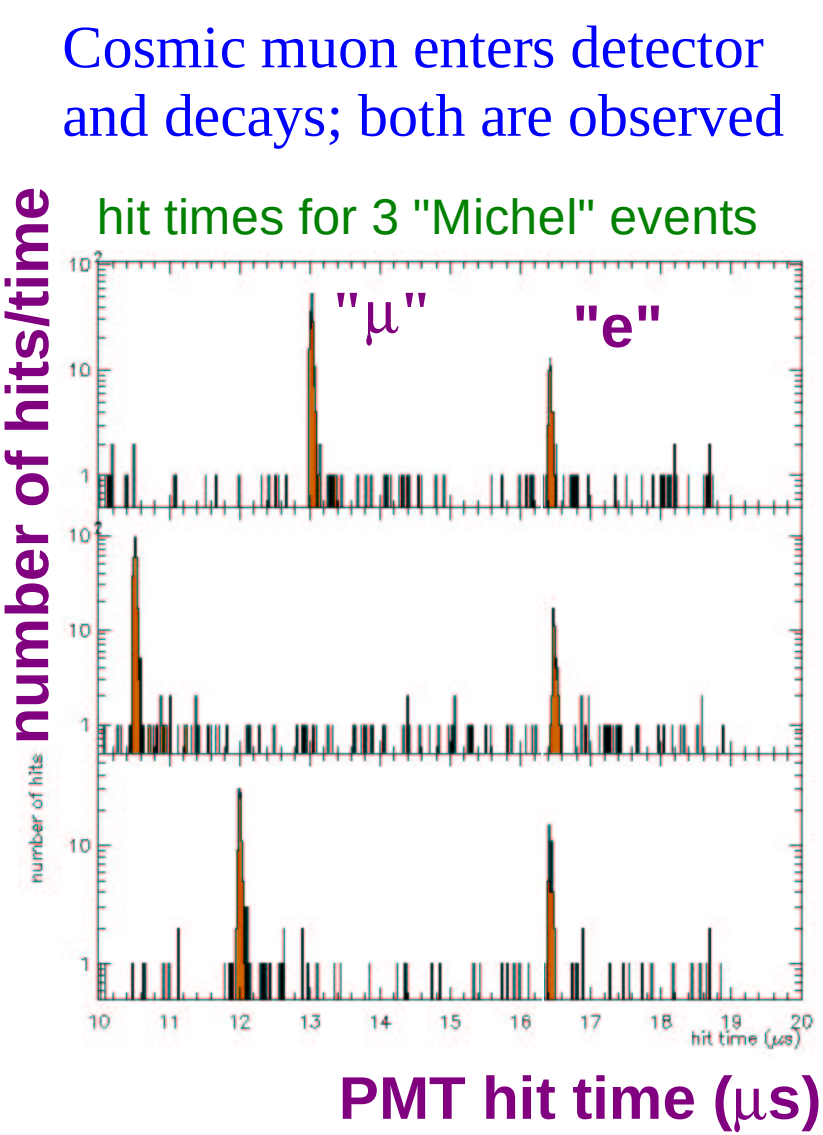
Current Status of MiniBooNE: Protons on target!

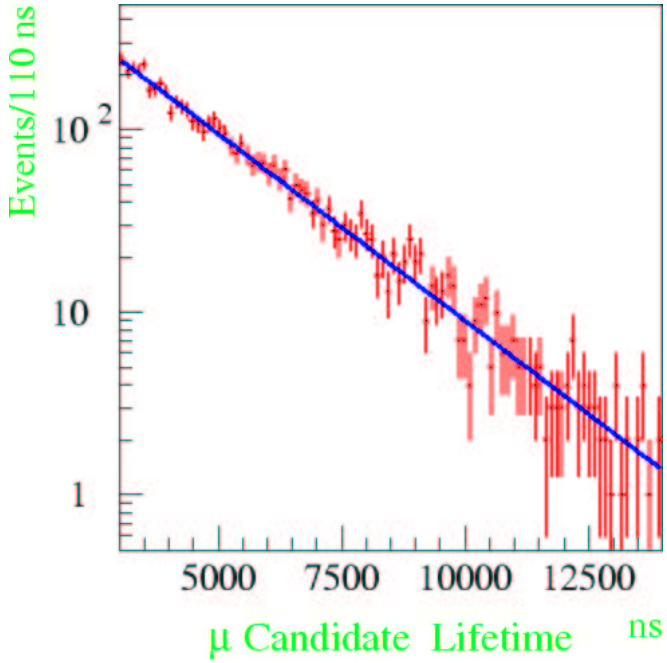
- Protons on target for physics running since August 24, 2002
- Average intensity is about 10% of desired level
- Shown in plot:
  - Total
  - MiniBooNE
  - Stacking



MiniBooNE's First Data

Cosmic muon enters detector and decays; both are observed





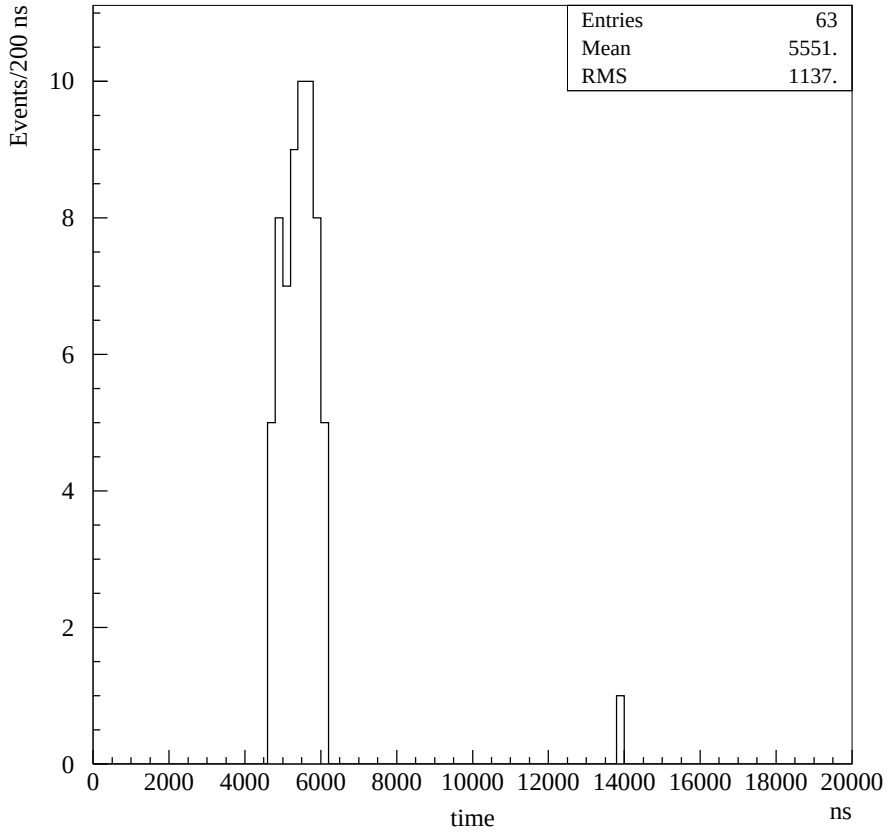
Fit Lifetime:

$\tau = 2.12 \pm 0.05\ \mu s$

Expected μ lifetime in oil
2.13 μs
with 8% μ^- capture on carbon.

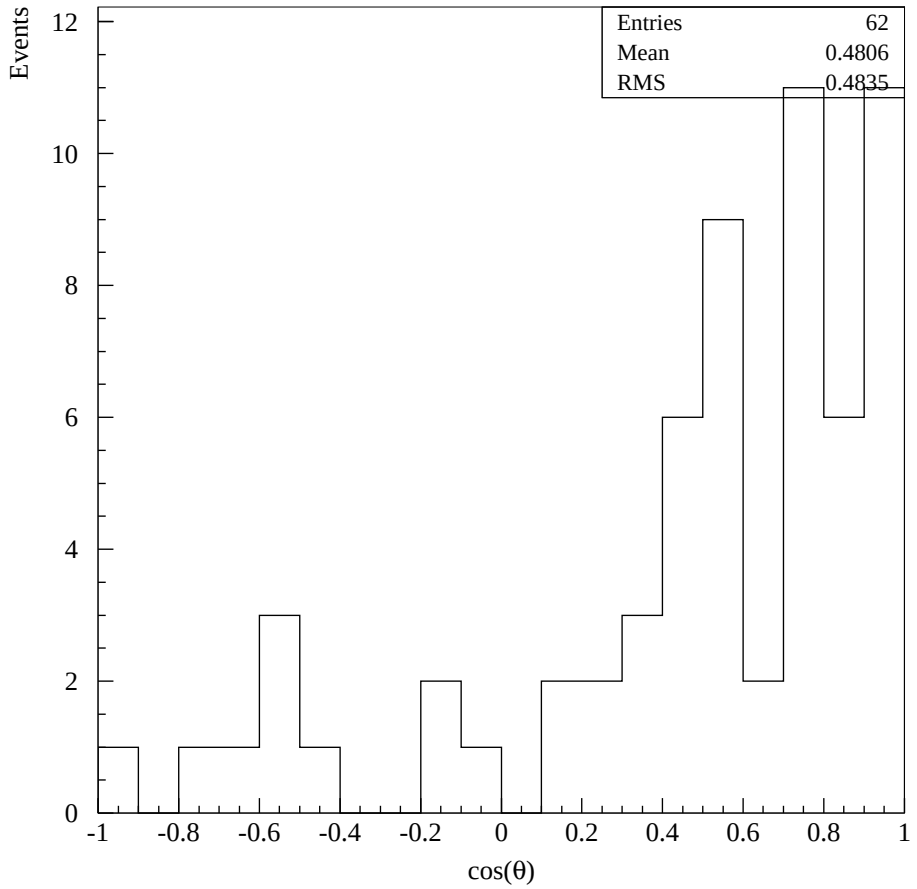
Current Status of MiniBooNE: Neutrino Events in the Detector!

- Cuts:
  - >200 hits in tank
  - <6 hits in veto region
- Average rate >1 Hz
- Typical pulse has 3.5×10^{12} protons
- 2.3×10^{-15} int/proton OR 1 ν in detector every 120 pulses



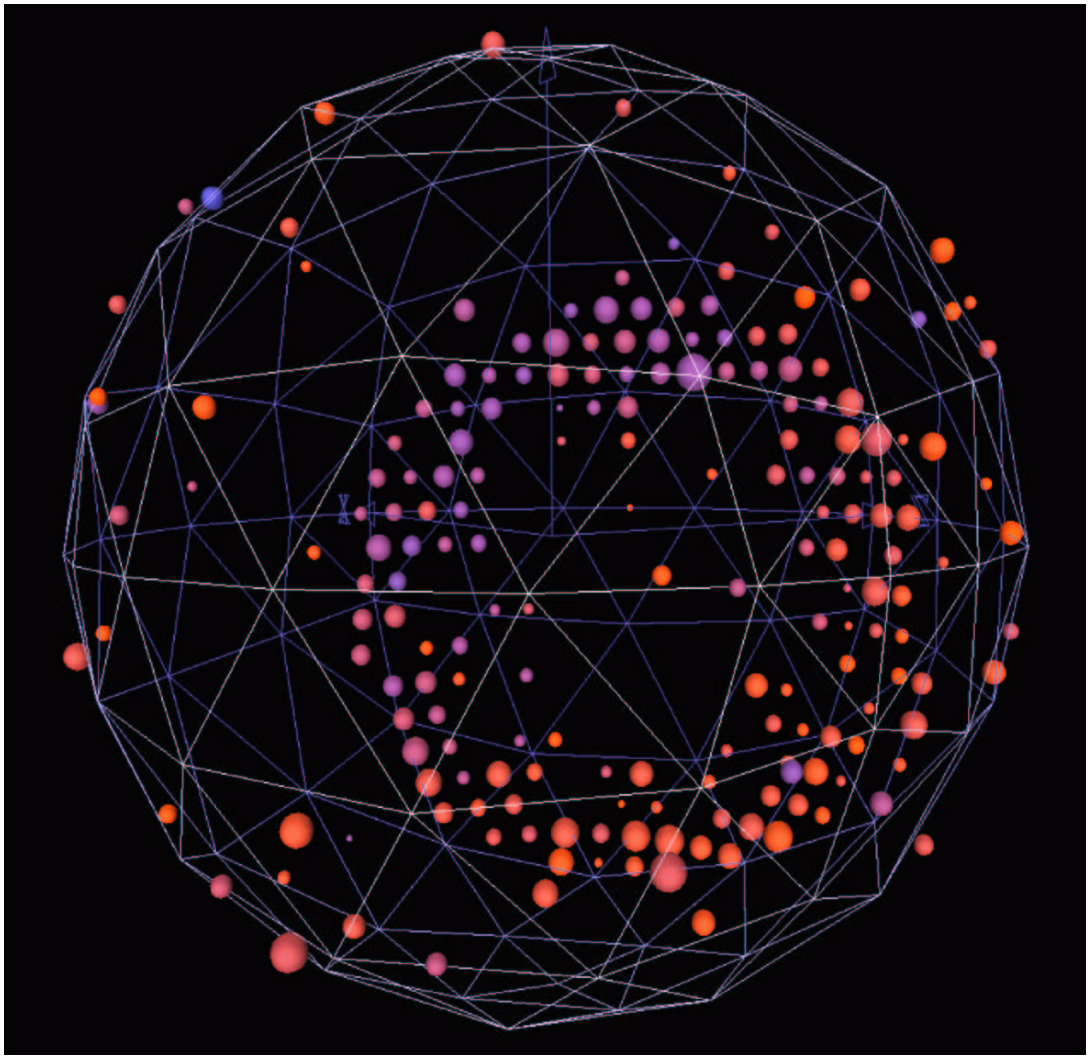
MiniBooNE Beam Data: Looking closer

Angular distribution is peaked forward − quasi−elastic scattering



MiniBooNE Beam Data: Analyzing Events in the Detector

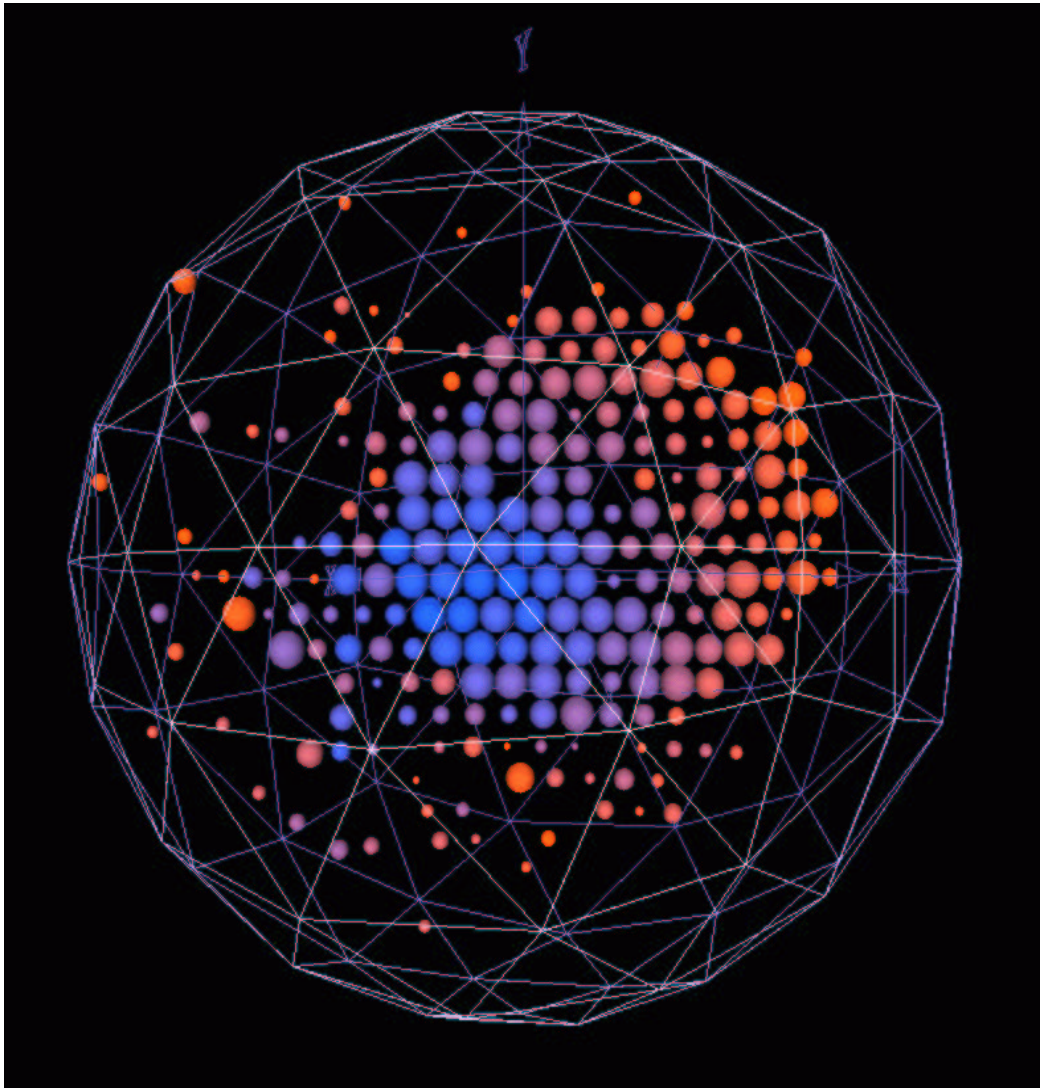
Stopping muon



Nice, clean ring

MiniBooNE Beam Data: Events in the Detector

Through–going muon



Filled circle

Current Status of MiniBooNE: Summary

- **MiniBooNE is running and taking physics data.**
- Detector is working well.
- The beam is steadily improving.
- Two years of running in ν mode
  - Two years of anti-ν mode to follow
- Will cover entire LSND region at 5σ level

Motivation for MiniBooNE
The LSND Experiment

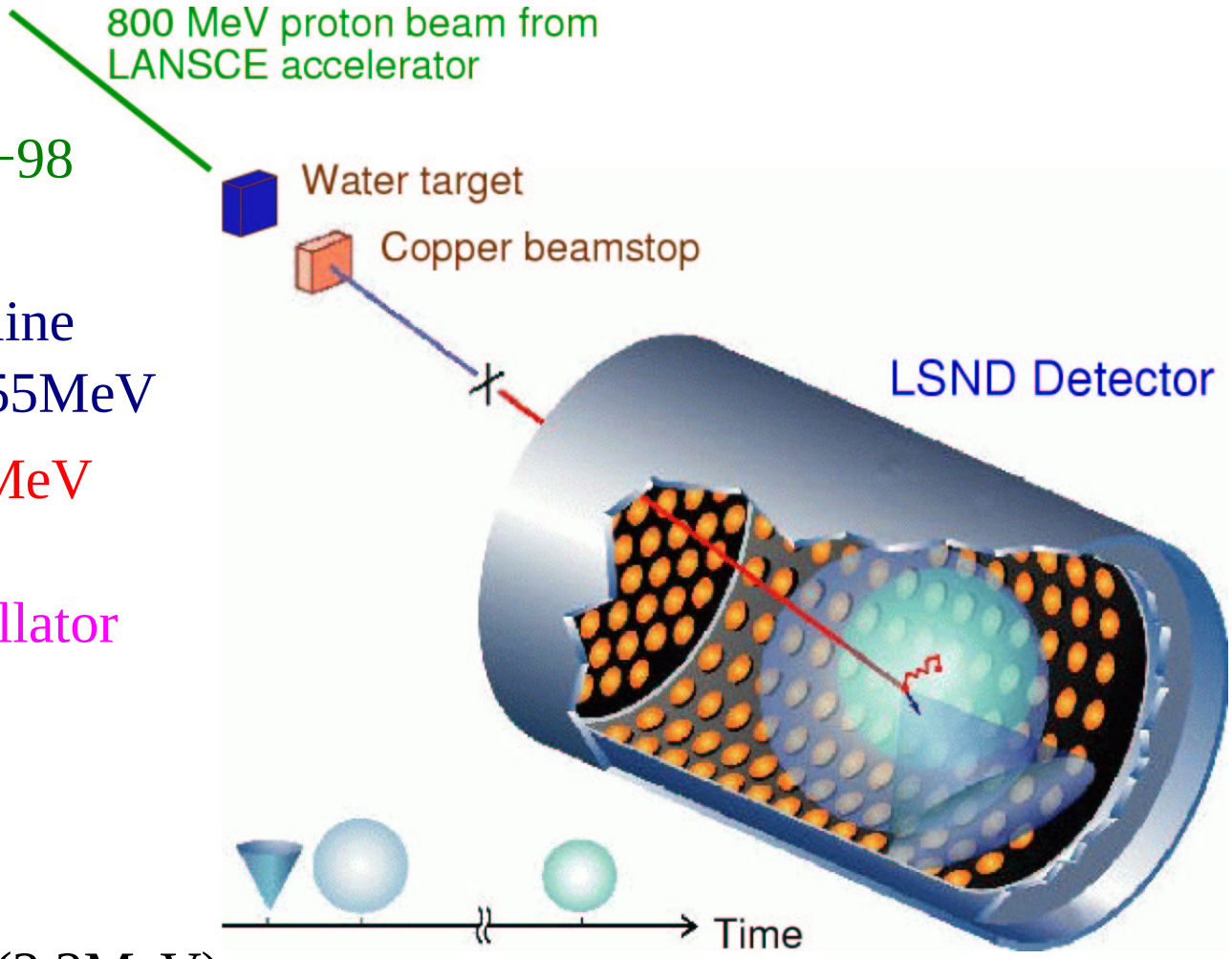
Data Collected 1993−98

30 m baseline

$20\text{MeV} < E_{\nu e} < 55\text{MeV}$

L/E ~ 1m/MeV

167 tons liquid scintillator



Signal Reaction:

$$\bar{\nu}_e\, p \rightarrow X\, e^+\, n$$

$$n\, p \rightarrow d\, \gamma(2.2\text{MeV})$$