Neutrino Oscillations And MiniBooNE

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Outline

- Physics of Neutrino Oscillations
- LSND Oscillation Result
- MiniBooNE Overview
- Current Status of MiniBooNE
- Detector Calibration

I. Neutrino Oscillations

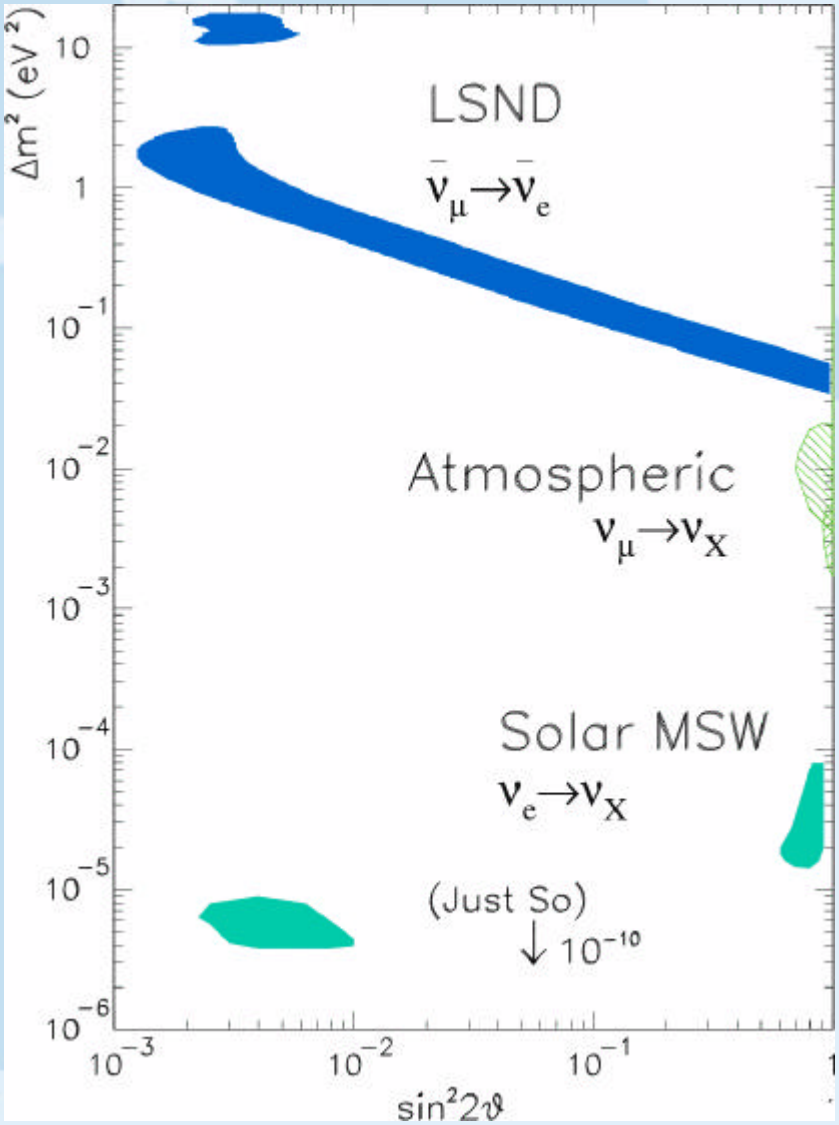
- If νs have mass, they may oscillate between flavor states. For 3 ν Generations:

$$\begin{pmatrix} \Uparrow_e \\ \Uparrow_{\Leftarrow} \\ \Uparrow_{©} \end{pmatrix} = \begin{pmatrix} U_{e1} & U_{e2} & U_{e3} \\ U_{\Leftarrow 1} & U_{\Leftarrow 2} & U_{\Leftarrow 3} \\ U_{©1} & U_{©2} & U_{©3} \end{pmatrix} \begin{pmatrix} \Uparrow_1 \\ \Uparrow_2 \\ \Uparrow_3 \end{pmatrix}$$

- 3 Generation Oscillation Probability:
  - $\mathbf{P}(\nu_\alpha \} \nu_\beta) \sim \mathbf{S}_{j<i} U_{\alpha,i} U_{\beta,i} U^*_{\alpha,j} U^*_{\beta,j} \sin^2(71.277 \Delta m^2_{i,j} L / E_\nu)$
  - ***E***xperimental Parameters: L in km, E_ν in GeV
  - ***Nature:*** $\Delta m^2_{i,j} = \frac{1}{2} | m_i^2 - m_j^2 |$ and $U_{\alpha i}$, $(\alpha = e, \mu, \tau; i = 1,2,3)$

Neutrino Oscillations

- *Solar $Dm^2 \sim 10^{-(4\sim5)}$*
- Atmospheric $\Delta m^2 \sim 3 \times 10^{-3}$
  - disappearance expts.
  - not controversial
- LSND $\Delta m^2 \sim 10^{-(0 \sim 1)}$
  - Appearance!
  - Three Δm^2 scales!
  - Unconfirmed result...



II. LSND

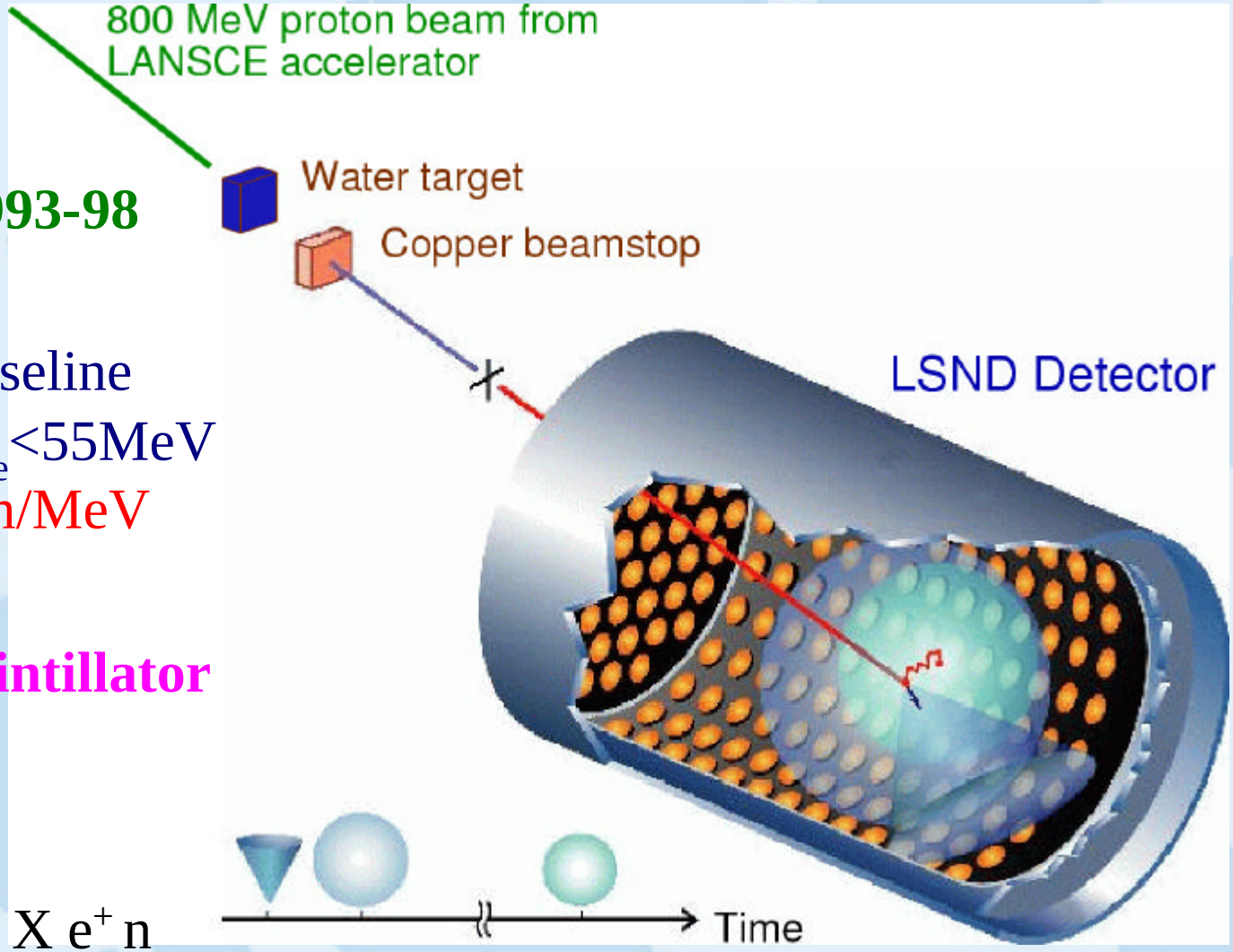
Data Collected 1993-98

30 m baseline

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

L/E ~ 1m/MeV

167 tons liquid scintillator



Signal Reaction:

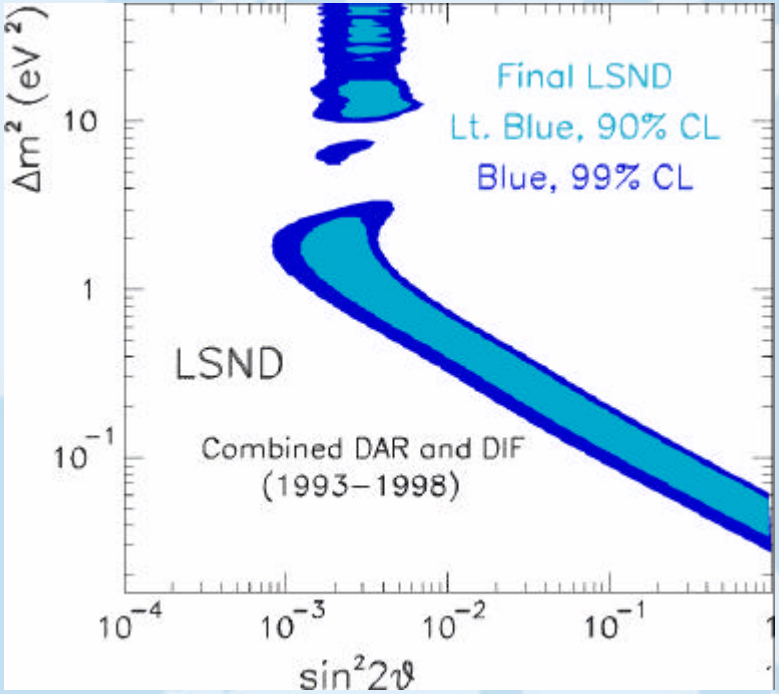
$$\bar{\nu}_e p \rightarrow X e^+ n$$

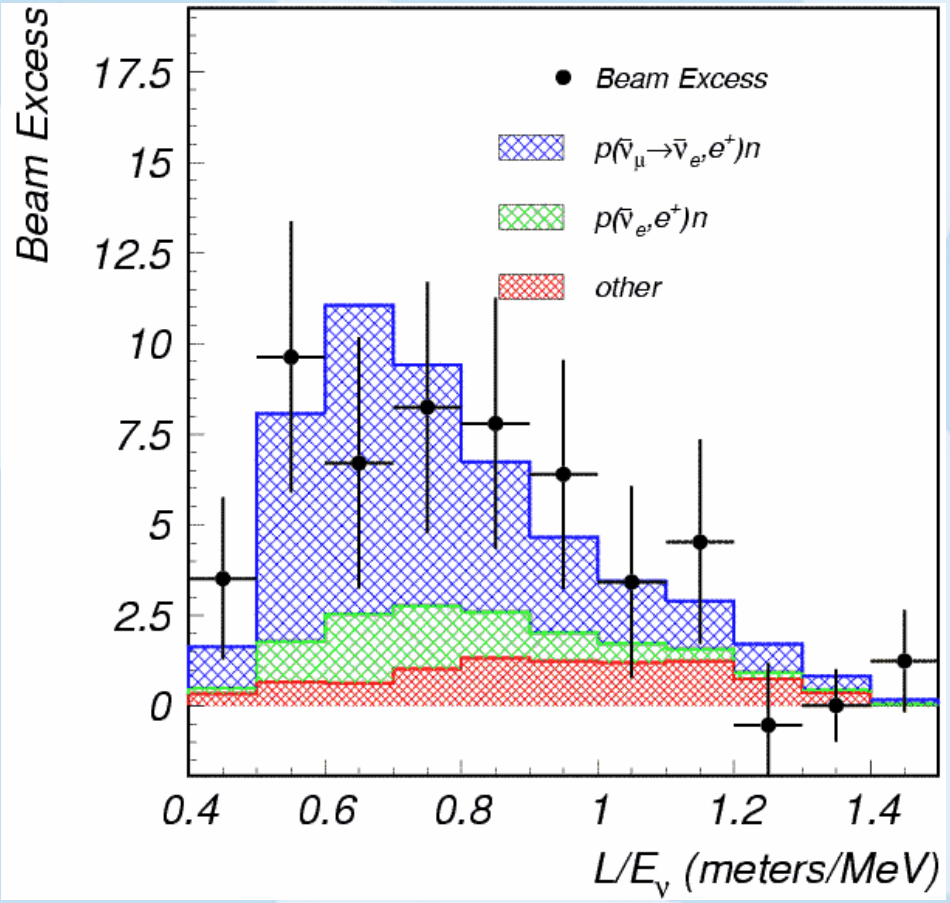
$$n p \rightarrow d \gamma(2.2\text{MeV})$$

LSND Oscillation Signal

Excess: 87.9 ± 22.4 ± 6.0 evts.

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





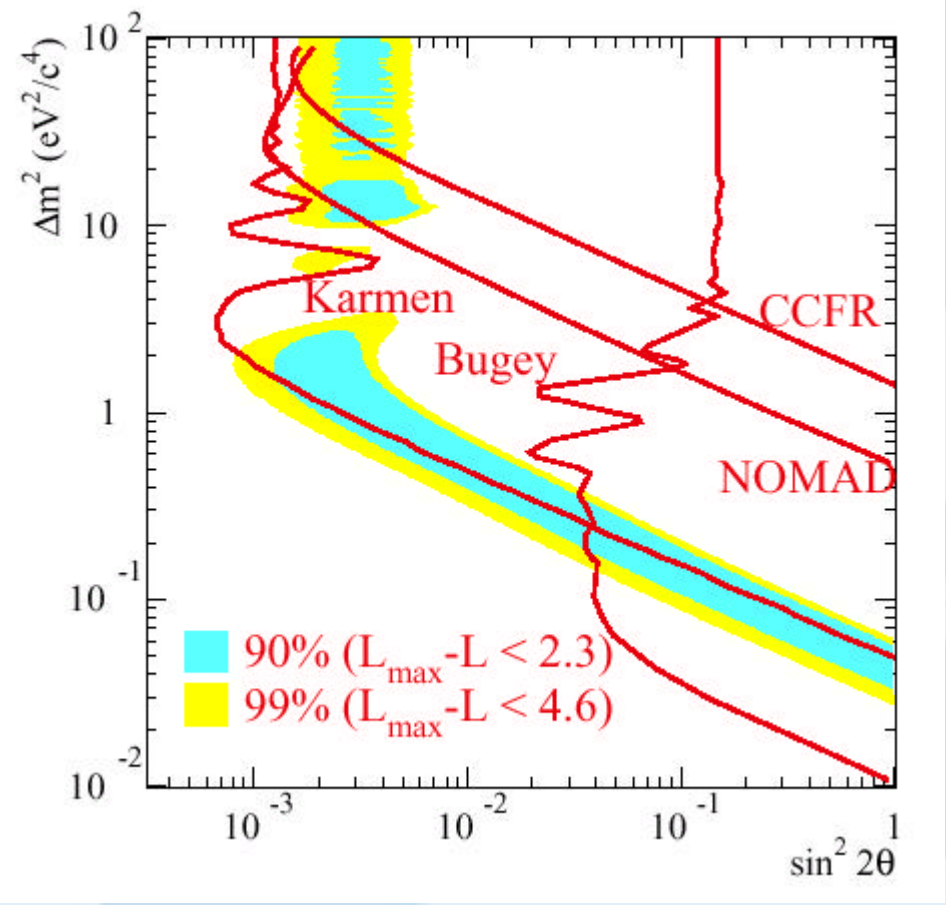
3.6 σ statistical significance of excess.

Confirmation is Crucial!

LSND Oscillation Signal

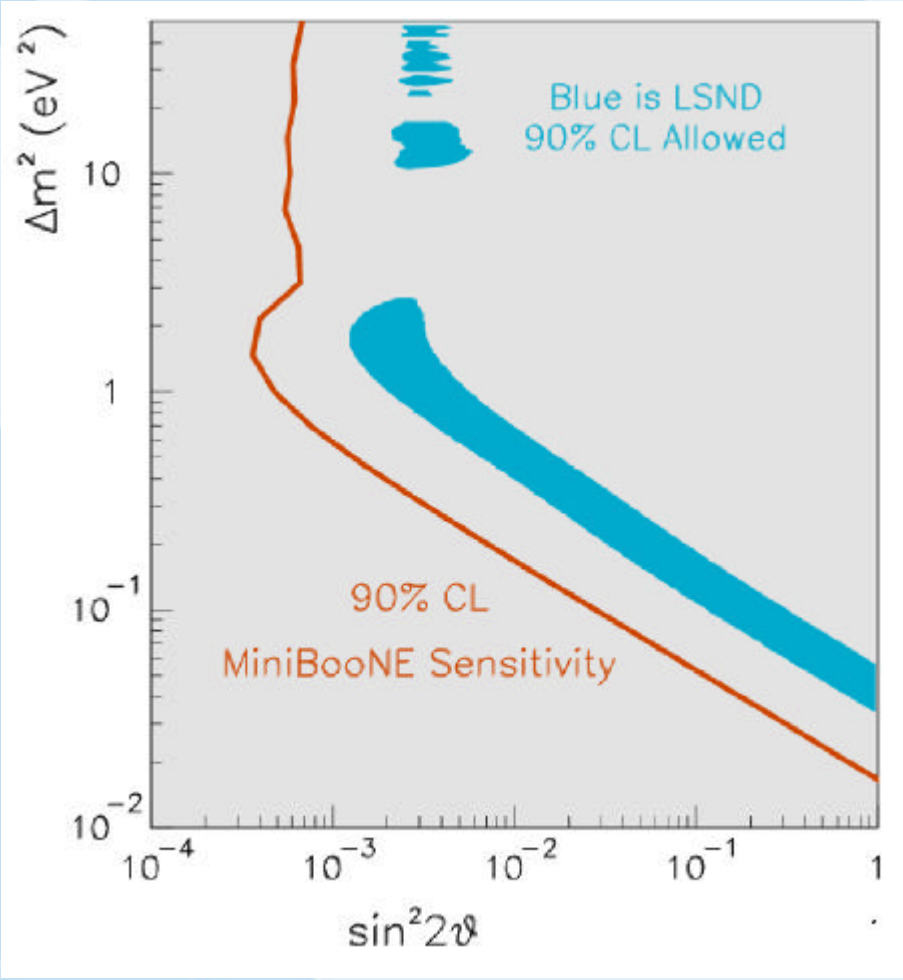
Karmen result excludes part of LSND allowed region

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



Enter MiniBooNE

- 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 is:

The BooNE Collaboration

February 22, 2002

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60 scientists

from 14 institutions

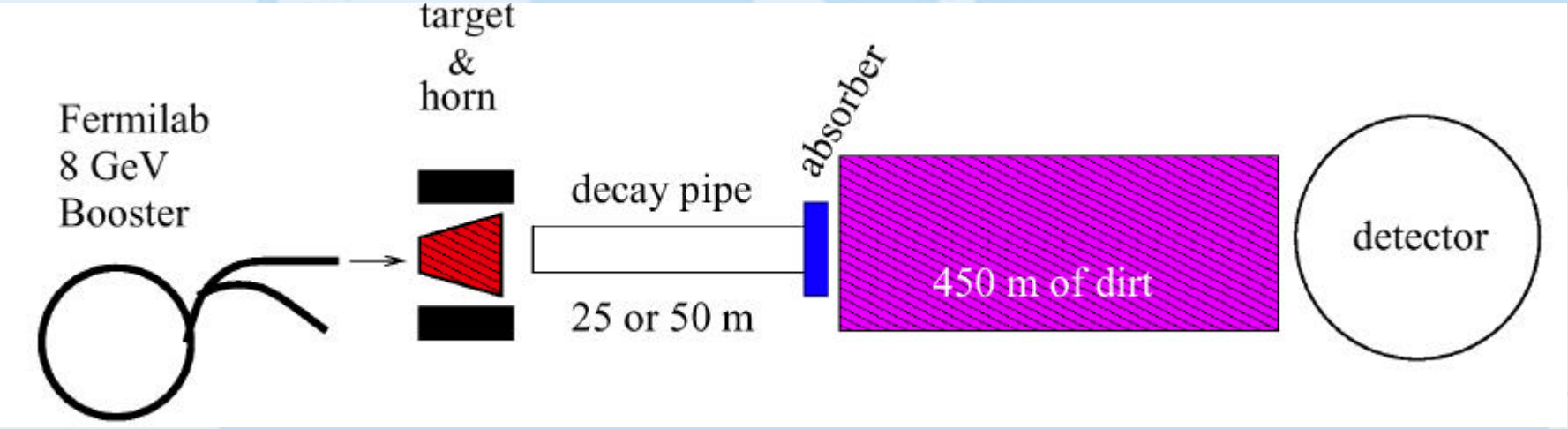
with one goal

III. MiniBooNE Overview

+8GeV protons from Fermilab Booster

+Incident on Be target

+Magnetic horn focuses interaction products



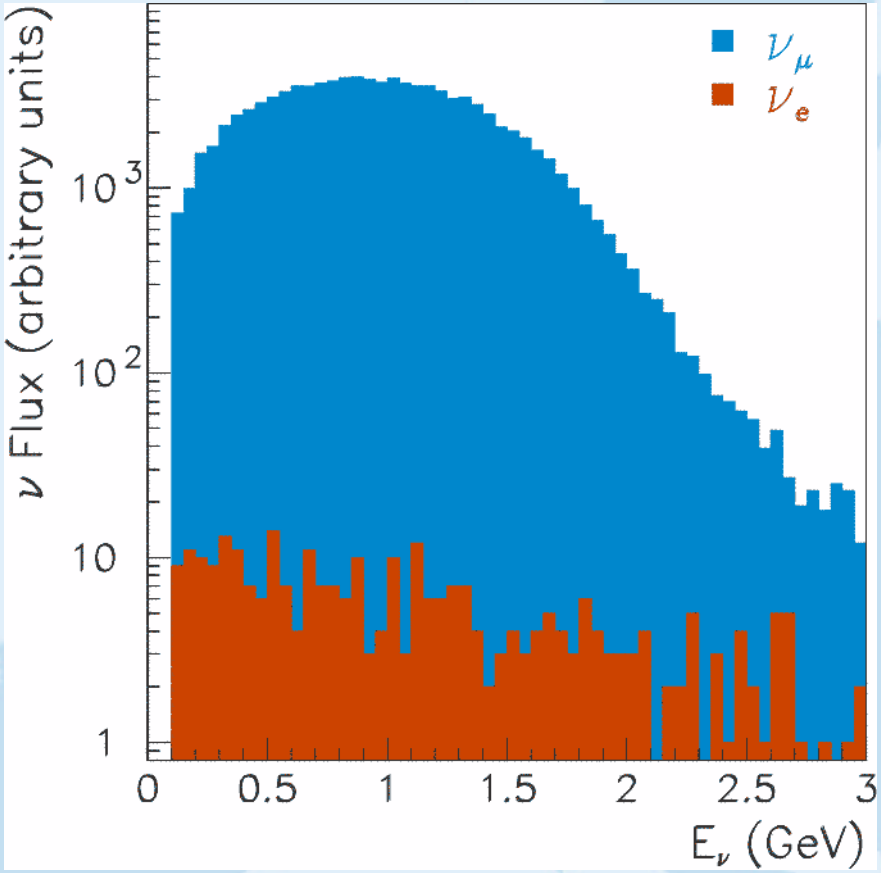
+ πand K secondaries traverse decay pipe

+Traverse beam absorber + berm

+νs proceed through detector ha

MiniBooNE Neutrino Fluxes

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



The beam is comprised almost entirely of ν_μ

$p^+ \rightarrow \mu^+ \nu_\mu$ 99.9%

$K^+ \rightarrow \mu^+ \nu_\mu$ 63.5%

$\rightarrow \pi^+ \pi^0$ 21.2%

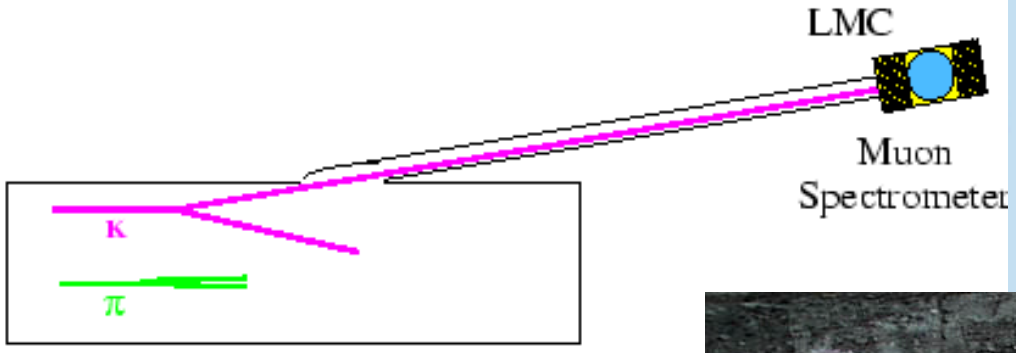
Intrinsic ν_e flux is small compared to ν_μ flux

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

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

Little Muon Counters

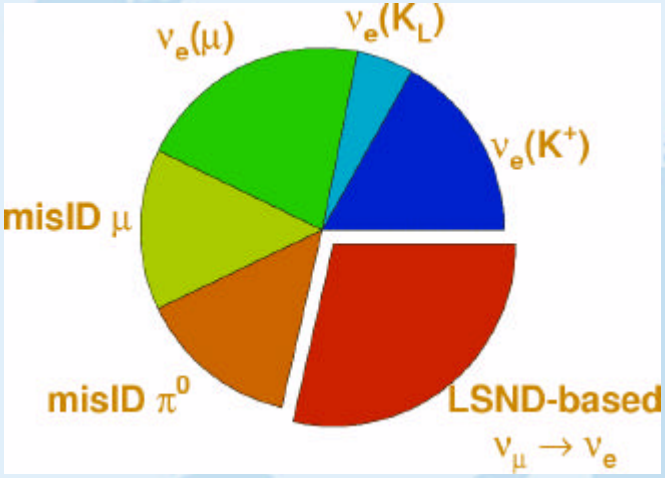
Beam flux cross check



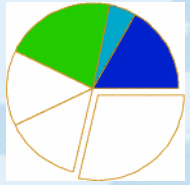
Exploits wide angle decay of Ks

Enclosure complete, installation progressing

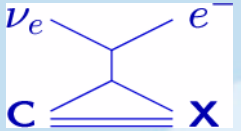
MiniBooNE Signal



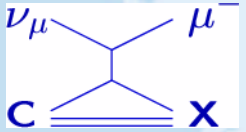
Approximately 500,000 ν_μC events expected in MiniBooNE with two years of running.

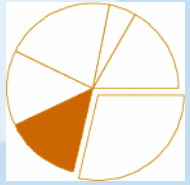


Intrinsic ν_e background: 1,500 events

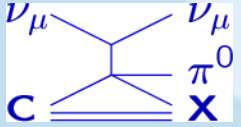


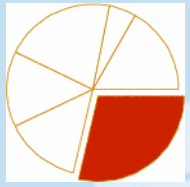
μ mis-ID background: 500 events



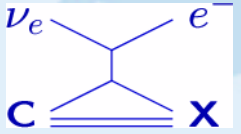


π^0 mis-ID background: 500 events



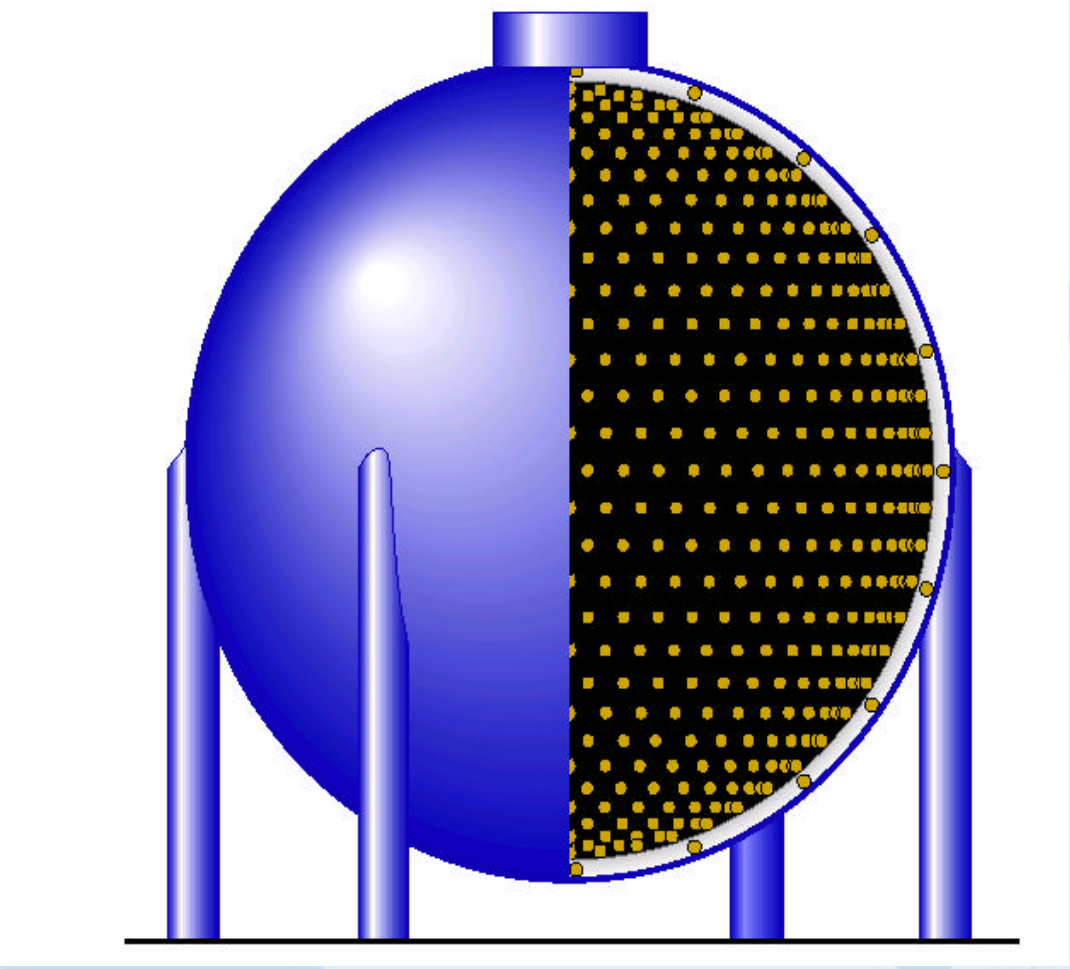


LSND-based $\nu_\mu \rightarrow \nu_e$: 1,000 events

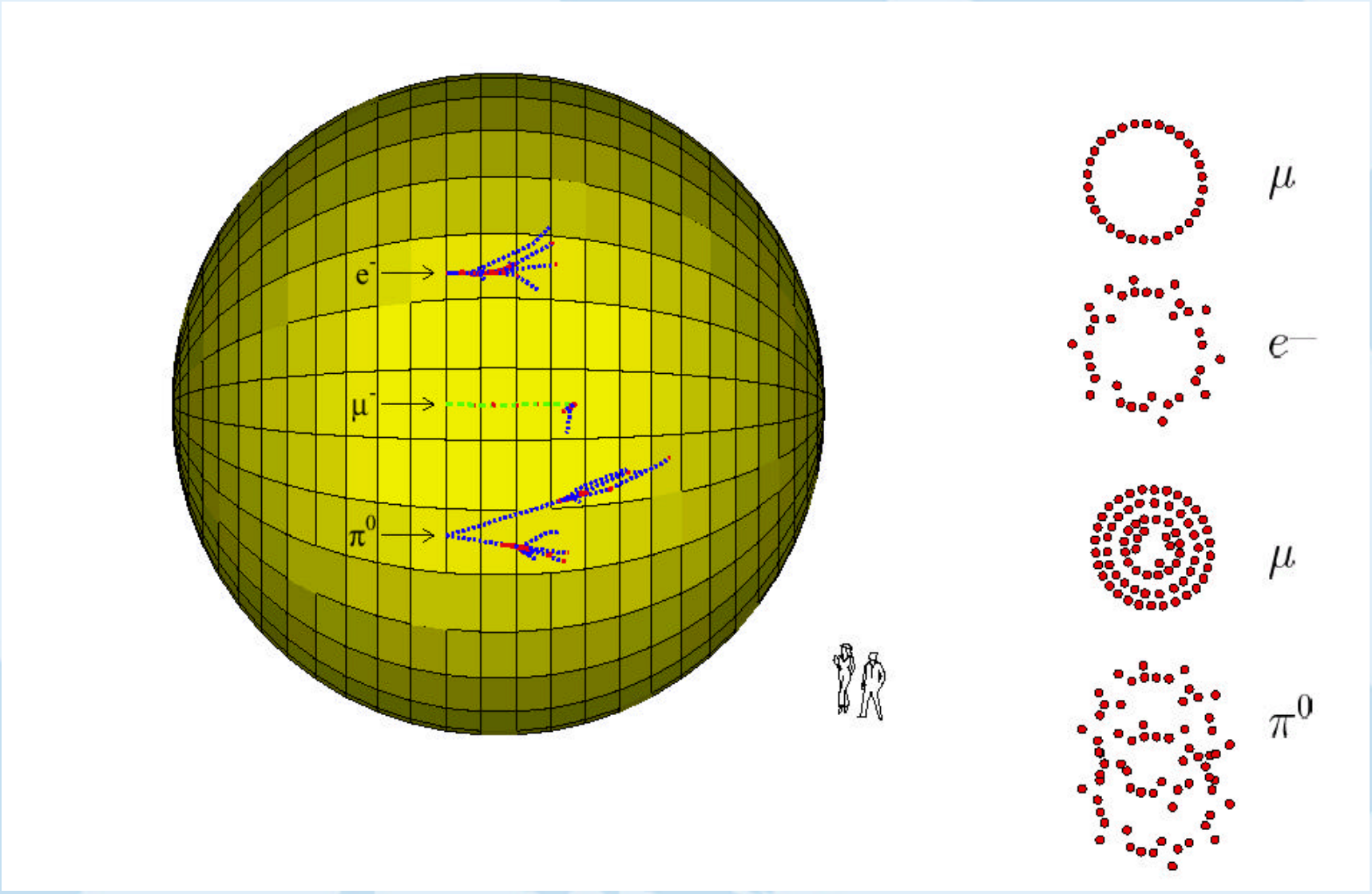


MiniBooNE Detector

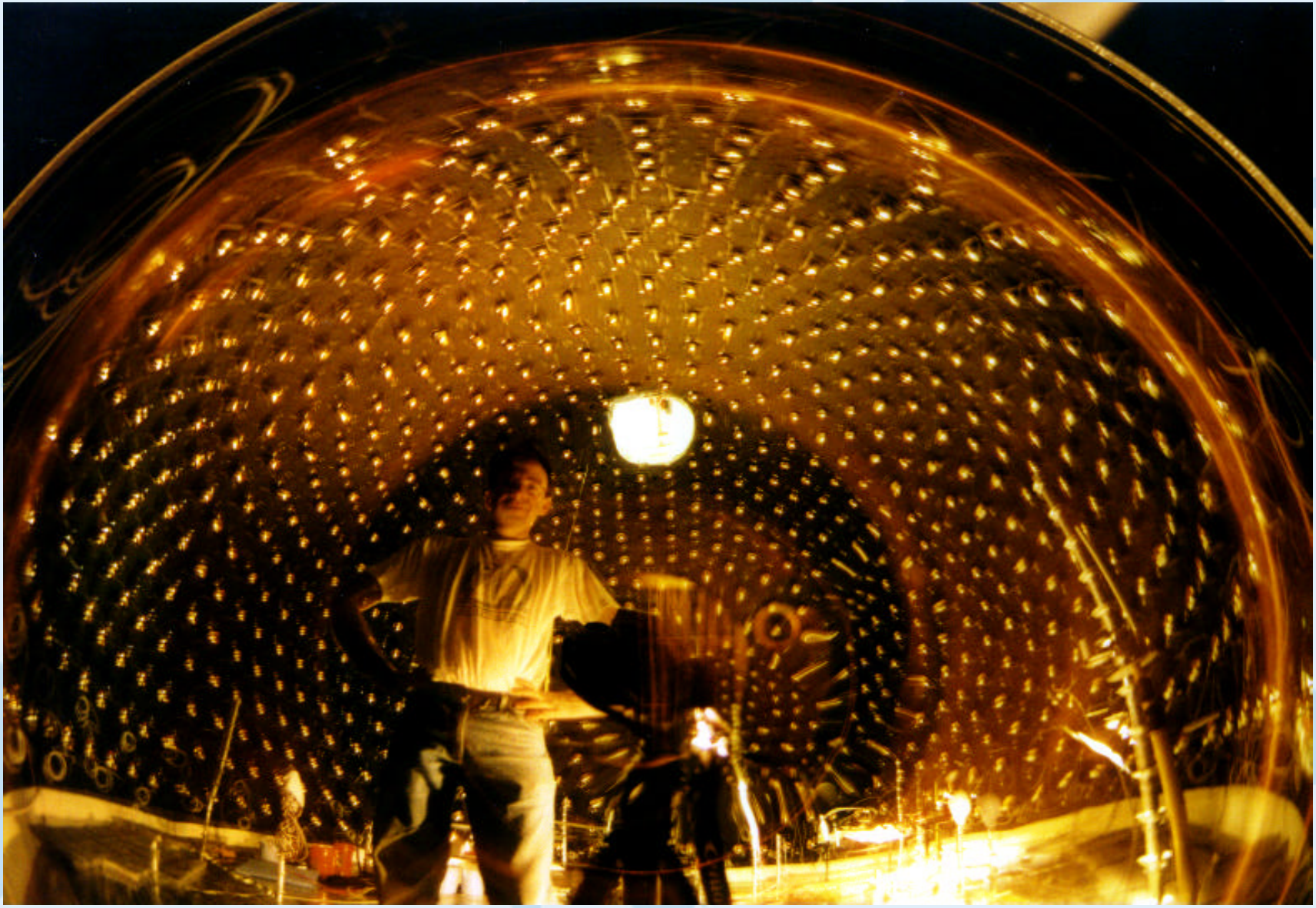
- 12m diam. sphere
- lined with 8" PMTs
  - 1280 main region
  - 240 veto region
- 800 tons of mineral oil
- Custom electronics from LSND
- All new DAQ



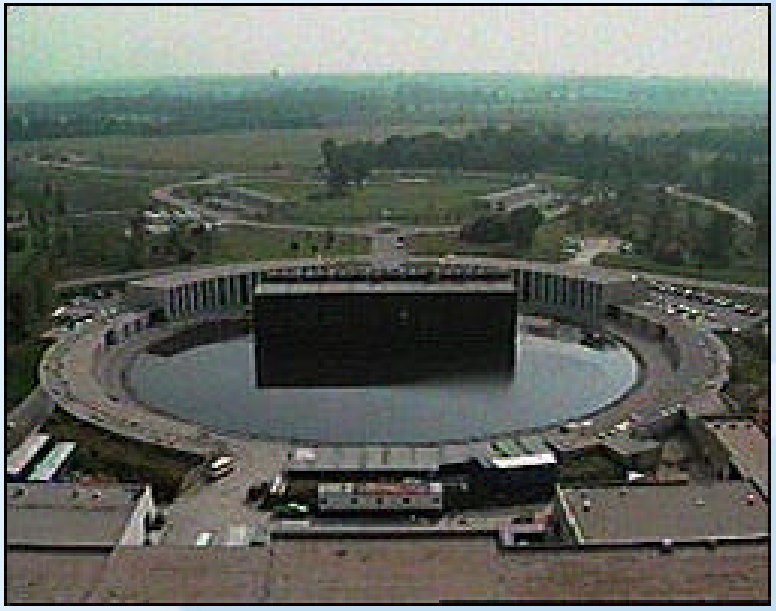
MiniBooNE Particle ID



IV. Current MiniBooNE Status



MiniBooNE Neutrino Beam Status

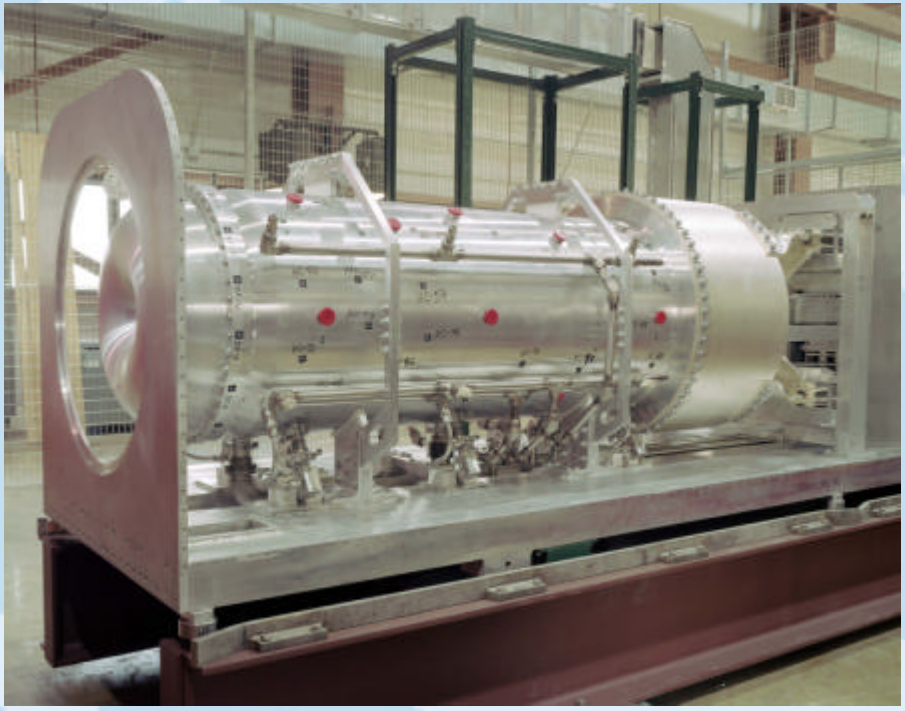


8GeV protons (will be) extracted from Fermilab Booster Accelerator

MiniBooNE proton beamline, installation complete 1 April, 02

MiniBooNE target and HorN

Beryllium target in situ, testing in progress

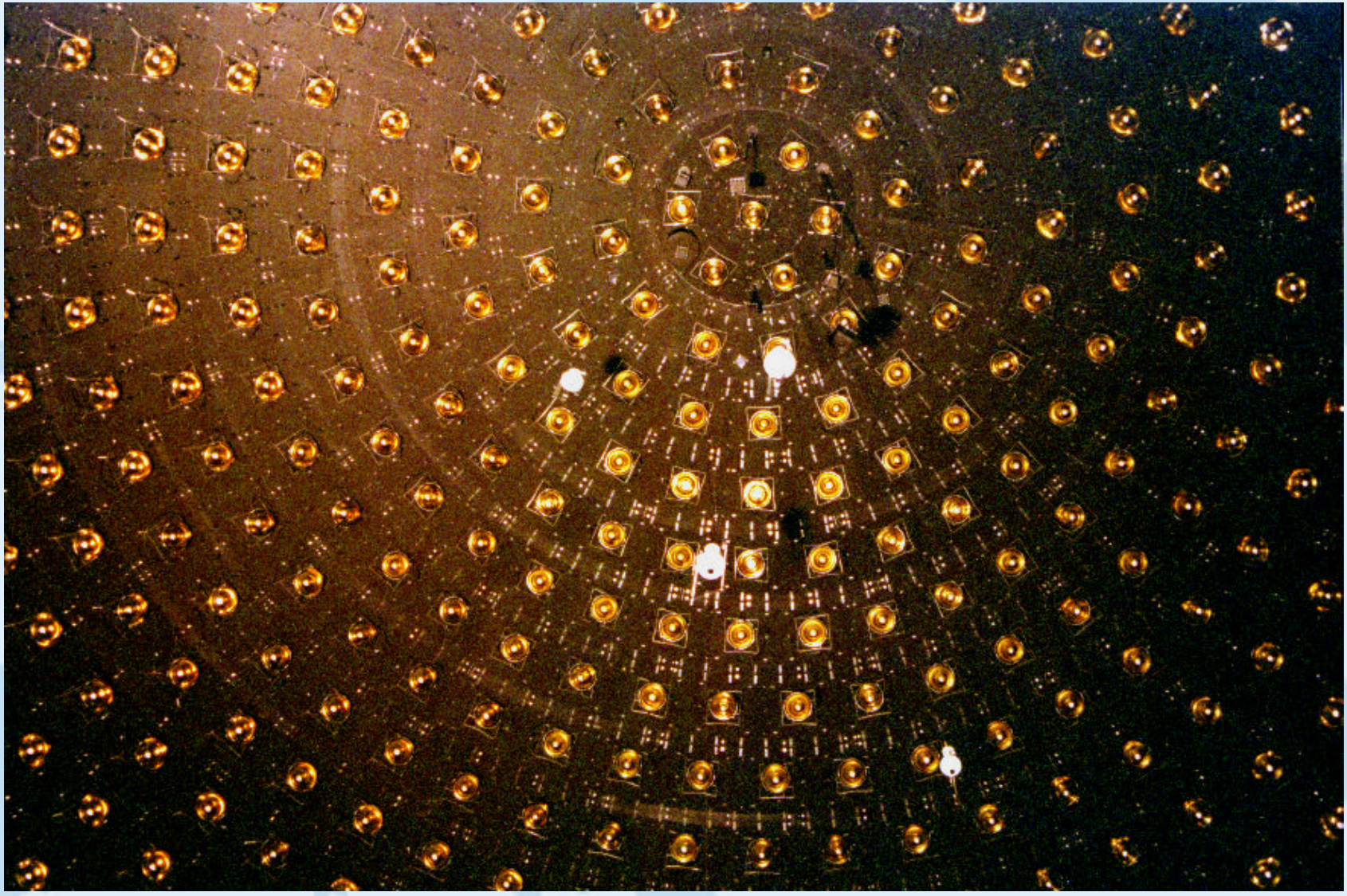


Aluminum horn testing complete

MiniBooNE Detector Status

- All PMTs installed, tested in tank
- All electronics channels installed
- Tank is halfway filled with oil, fill complete 1 April, 02
- DAQ is running, recording data
- Calibrations systems installed and running

Calibration Hardware Status



V. MiniBooNE Calibration Systems

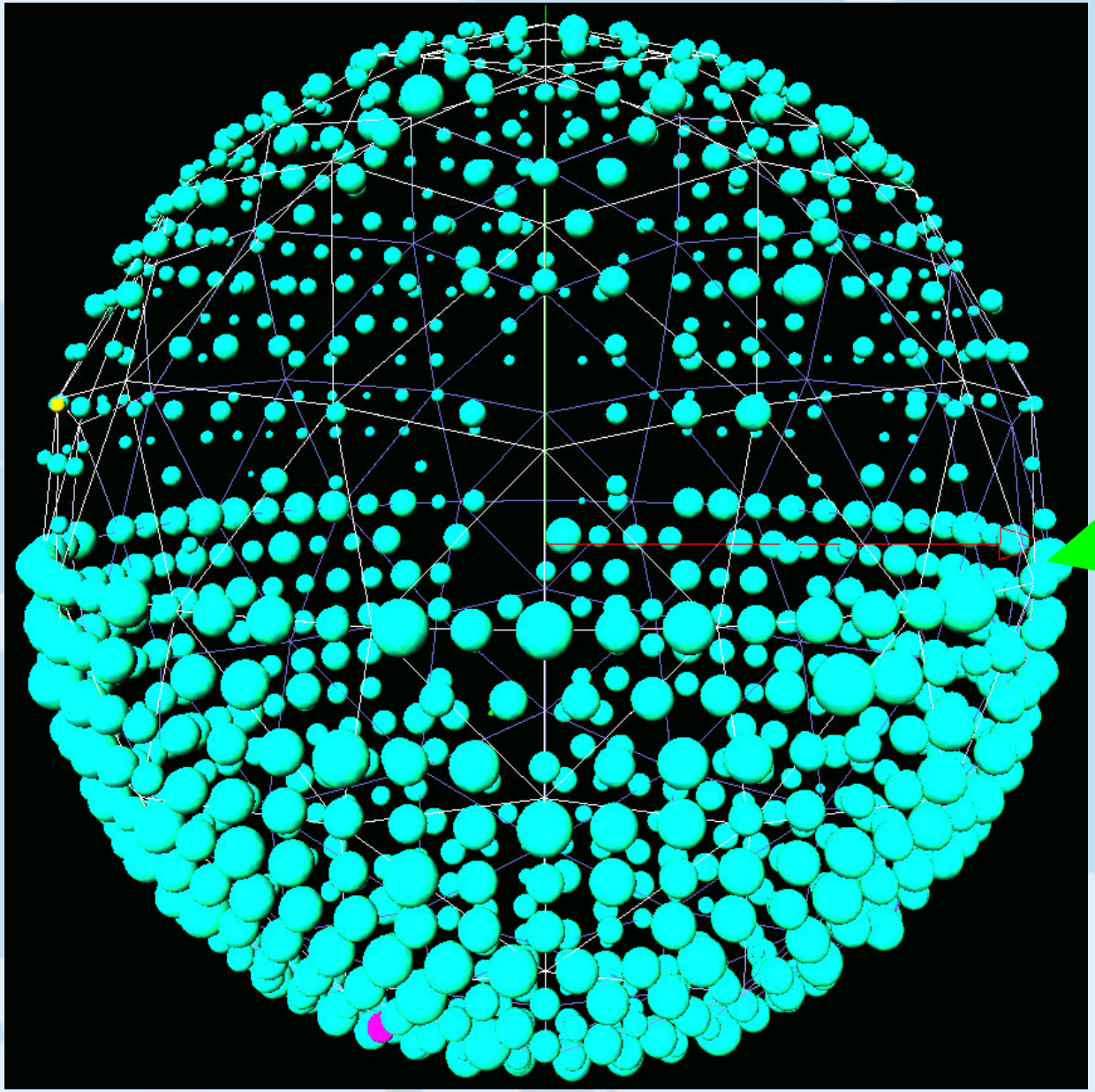
- 400 nm LASER + Ludox Flasks
  - **Laser System is designed to calibrate PMTs individually by generating known light pulses.**
- Muon Tracker System + Scintillator Cubes
  - **Muon Trackers are designed to calibrate response of entire detector by tagging particles with known trajectories.**

MiniBooNE Calibration

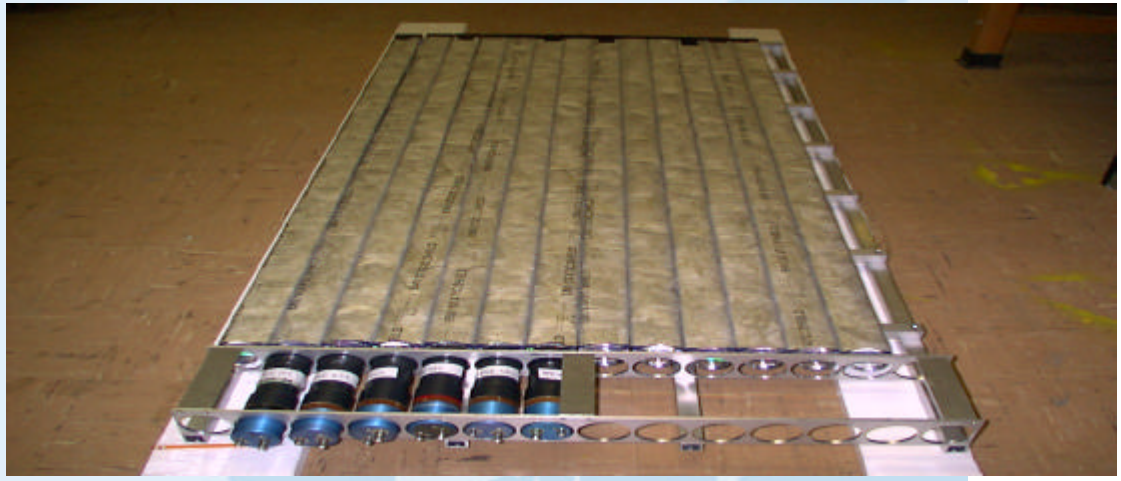
Laser flask

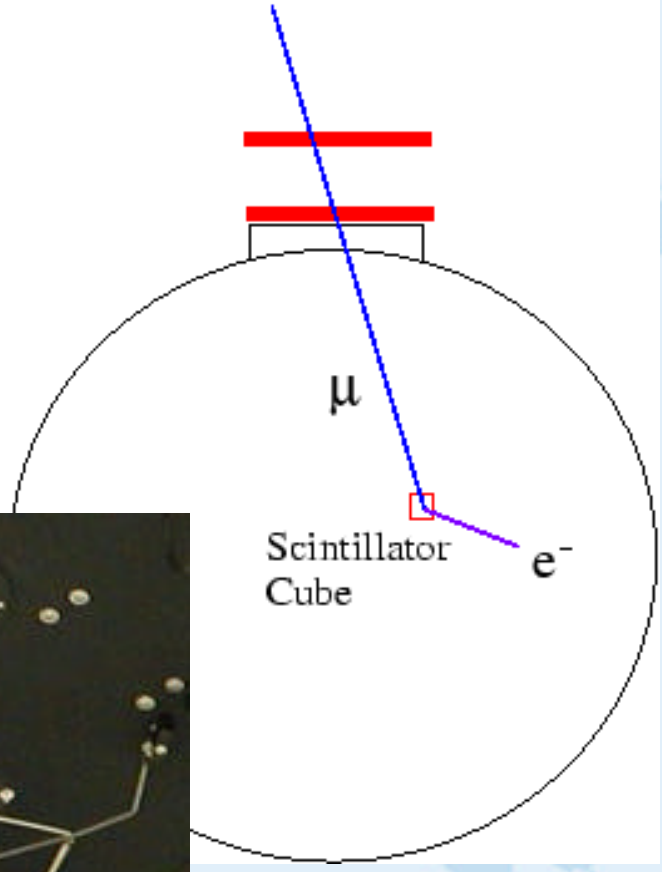
MiniBooNE Calibration
Laser Event

Laser Calibration Data

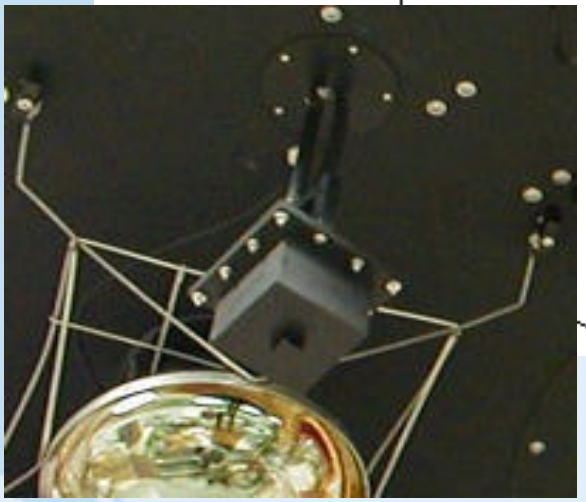


MiniBooNE Calibration
Muon Tracker System

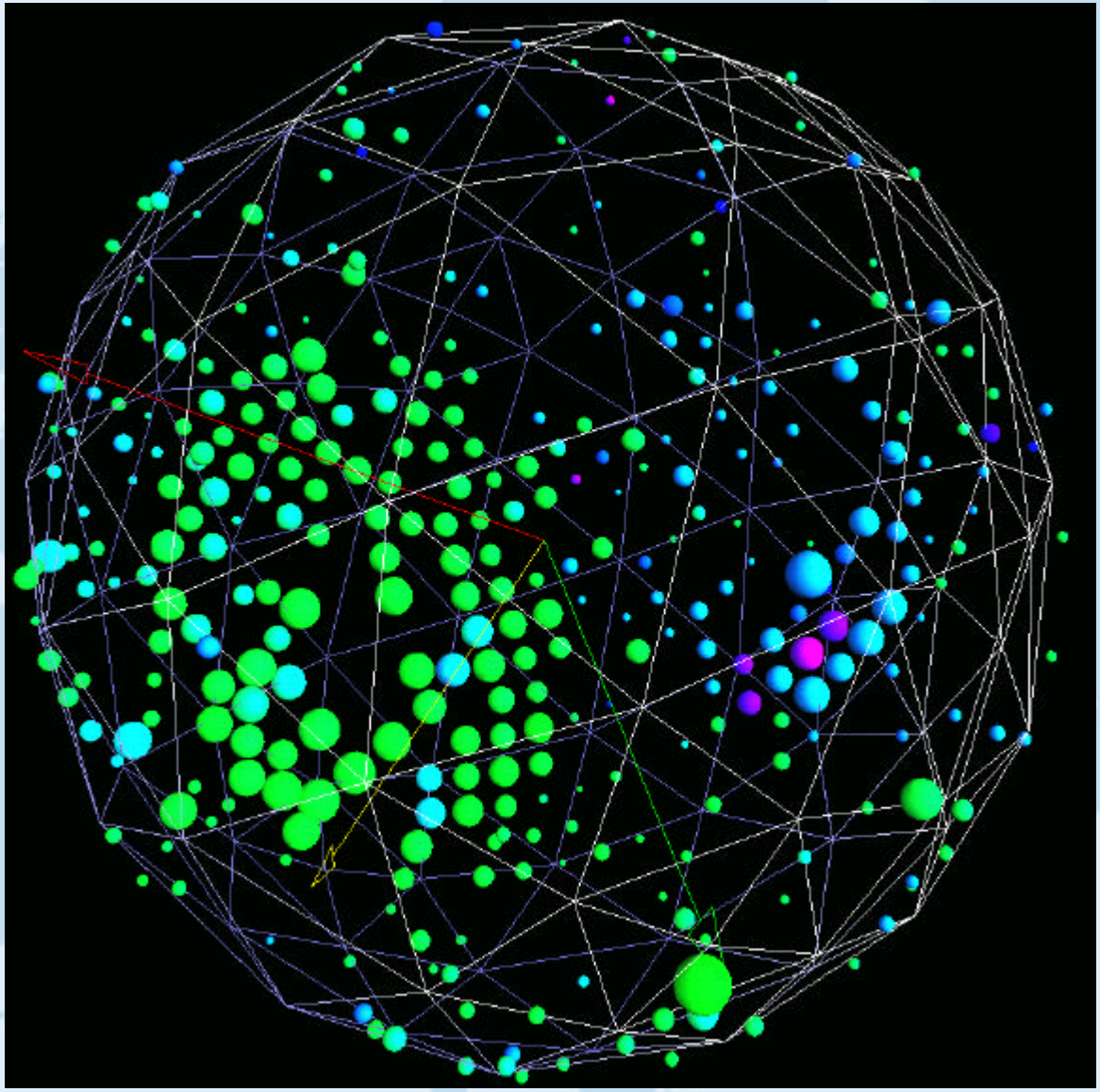




- **Scintillator strip layers tag cosmic ray m**
- **Scintillat**or cubes collect stopping μ
- **Tag decay vertex for Michel electrons**



MiniBooNE Calibration Muon Tracker Event



MiniBooNE Outlook

- **Physics data starts in June**
- In 2 years of running MiniBooNE will:
  - take 10^{21} protons on target
  - Confirm or Refute LSND at 5σ
  - ...Possible upgrade to two detector experiment to carefully measure Δm^2.
  - Will run in anti-neutrino mode