Status of MiniBooNE Experiment

idm2002

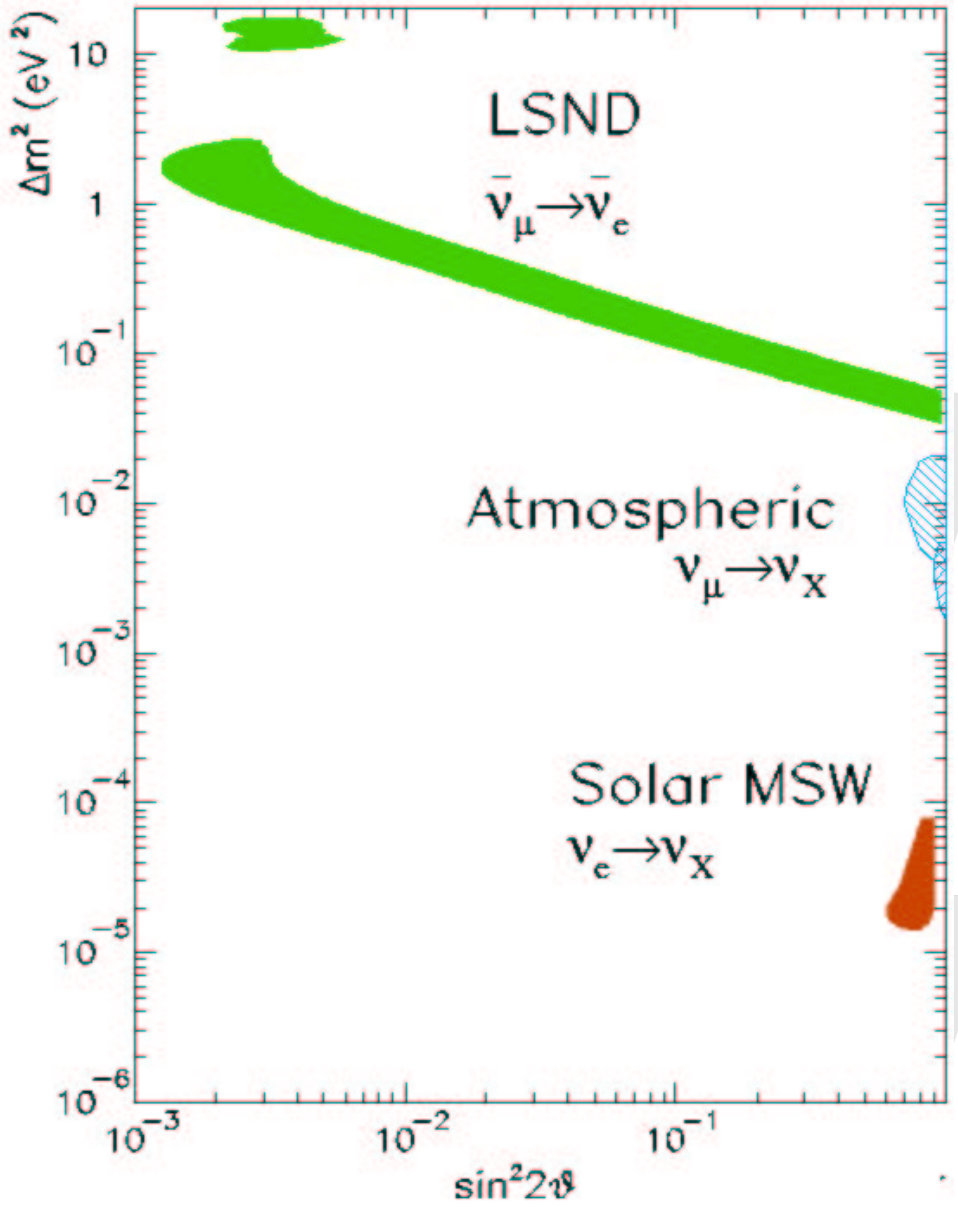
4th International Workshop on the Identification of Dark Matter

September, 2002

Myungkee Sung (LSU/MiniBooNE)

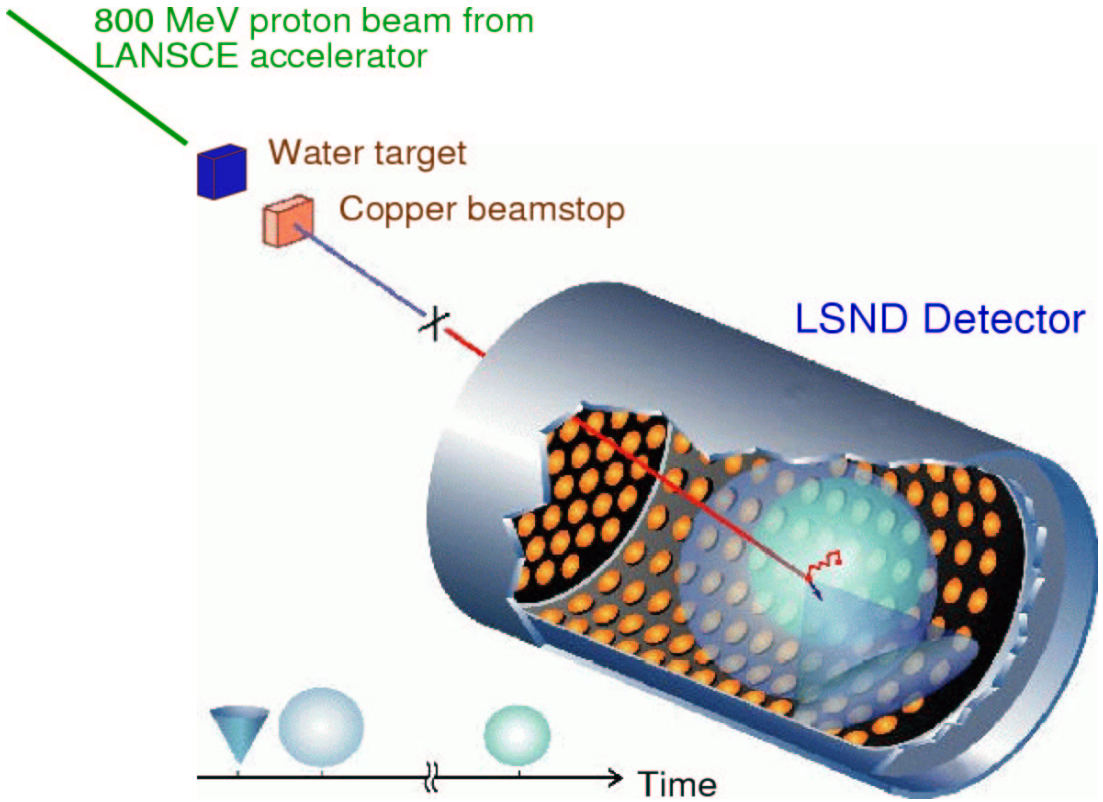
Neutrino Osillation at High Δm^2

- Cosmologically Interesting Region; Hot Dark Matter?
- LSND Signal at High Δm^2
- KARMEN II narrowed the signal region
- MiniBooNE will fully address this signal.

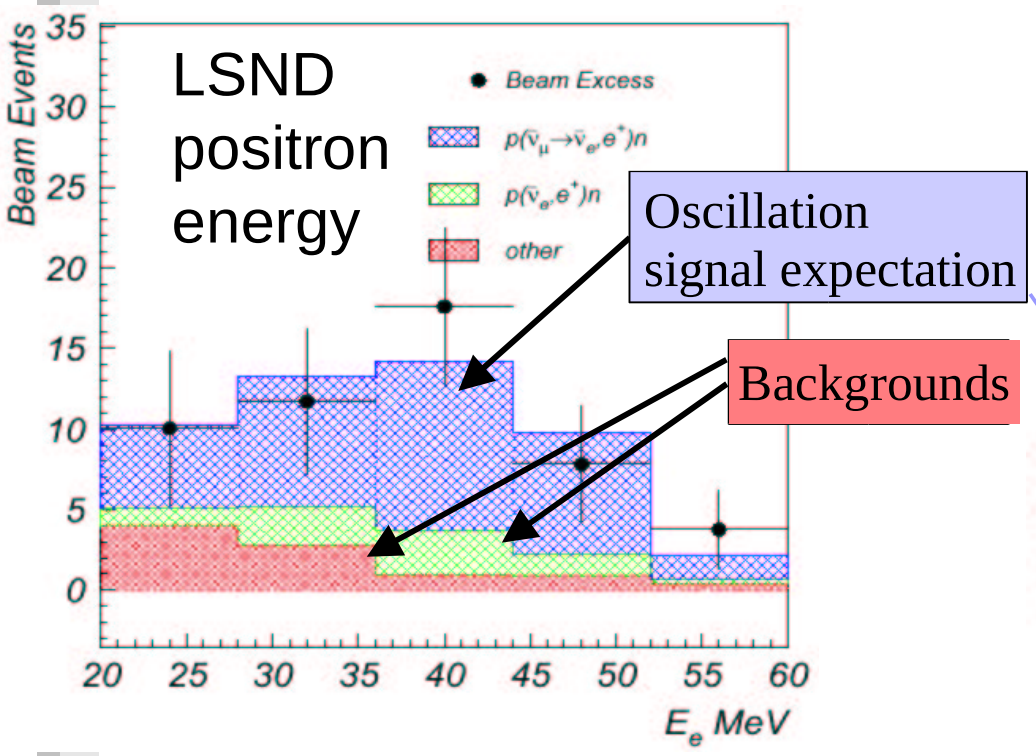


LSND: Searching for $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$

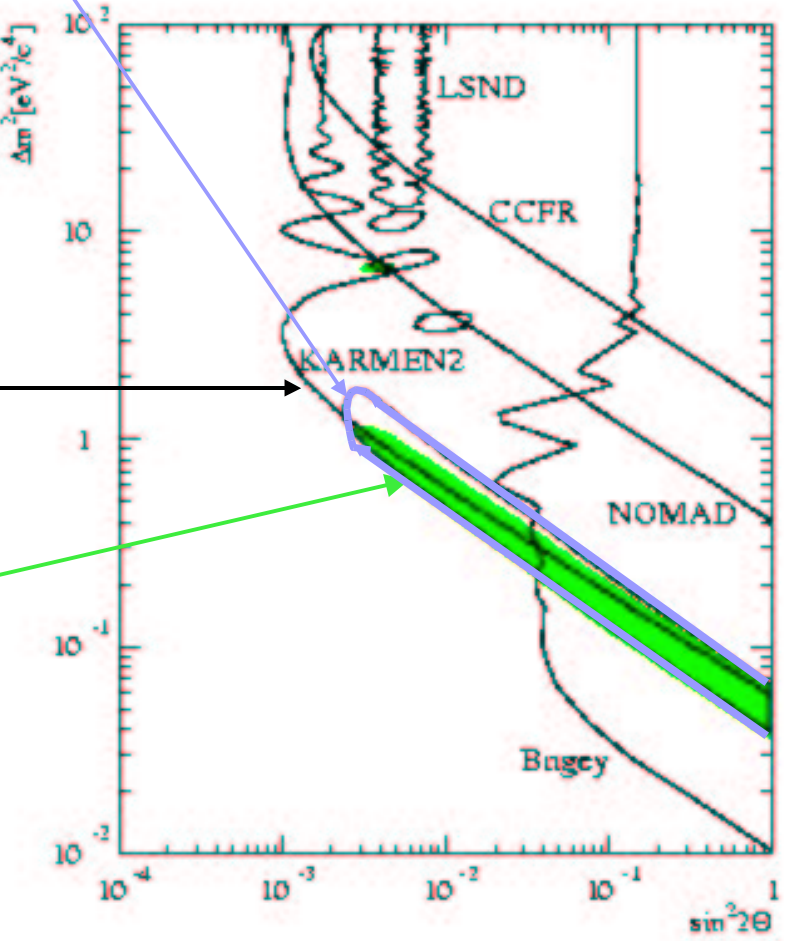
- $\bar{\nu}_\mu$ – From μ^+ decay at rest with endpoint energy 53 MeV
- L = 30m, L/E ~ 1m/MeV, 167 tons of Mineral Oil
- Look for $\bar{\nu}_e$ Appearance: $\bar{\nu}_e\, p \rightarrow e^+ n$, $n\, p \rightarrow d\, \gamma$ (2.2MeV)



LSND Oscillation Signal



- Signal above background:
  87.9±22.4±6.0 events
- Oscillation Probability:
  (0.264±0.067±0.045)%

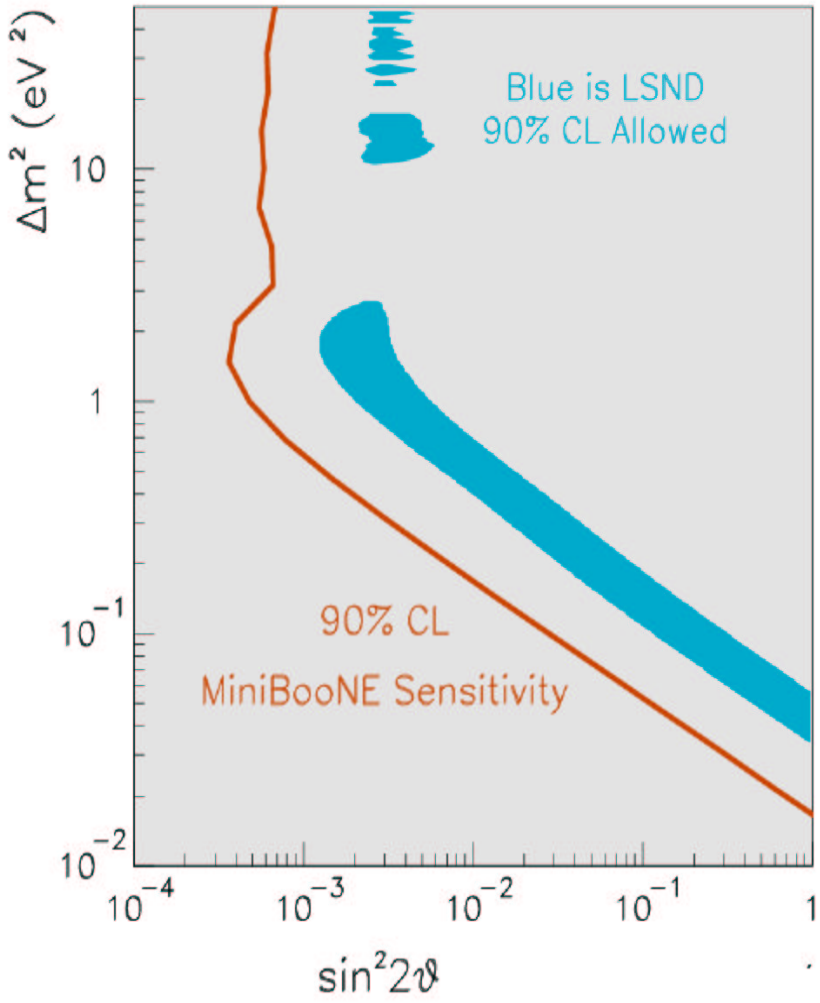


- KARMEN II Narrowed the Signal Region
- Joint Analysis of Karmen and LSND
- Needs Confirmation

  $\Rightarrow$ **MiniBooNE**

MiniBooNE Experiment

- To Confirm or Rule Out LSND Signal Region
- Same L/E (~ 1 m/MeV)
- Higher Statistics − 10 times more in 2 calendar years
- Different Systematics −10 times higher energy: Different events signature and background
- Higher Significance −5σ over entire LSND region as a "counting experiment" (more significant when energy dependence is included)



The BooNE Collaboration

62 Scientists from 13 institutions

3 Undergraduate Universities
9 Graduate Universities
2 National Laboratories

Y. Liu, I Stancu
University of Alabama, Tuscaloosa, AL 35487

S. Koutsoliotas
Bucknell University, Lewisburg, PA 17837

E. Church, C. Green, G. J. VanDalen
University of California, Riverside, CA 92521

E. Hawker, R. A. Johnson, J. L. Raaf
University of Cincinnati, Cincinnati, OH 45221

T. Hart, E. D. Zimmerman
University of Colorado, Boulder, CO 80309

J. M. Conrad, J. Link, J. Monroe, M. H. Shaevitz, M. Sorel, G. P. Zeller
Columbia University, Nevis Labs, Irvington, NY 10533

D. Smith
Embry Riddle Aeronautical University, Prescott, AZ 86301

C. Bhat, S. J. Brice, B. C. Brown, L. Bugel, B. T. Fleming, R. Ford, F. G. Garcia, P. Kasper, T. Kobilarcik, I. Kourbanis, A. Malensek, W. Marsh, P. Martin, F. Mills, C. Moore, P. J. Nienaber, E. Prebys, A. Russell, P. Spentzouris, R. Stefanski, T. Williams
Fermi National Accelerator Laboratory, Batavia, IL 60510

C. Cox, A Green, H. −O. Meyer, R. Tayloe
Indiana University, Bloomington, IN 47405

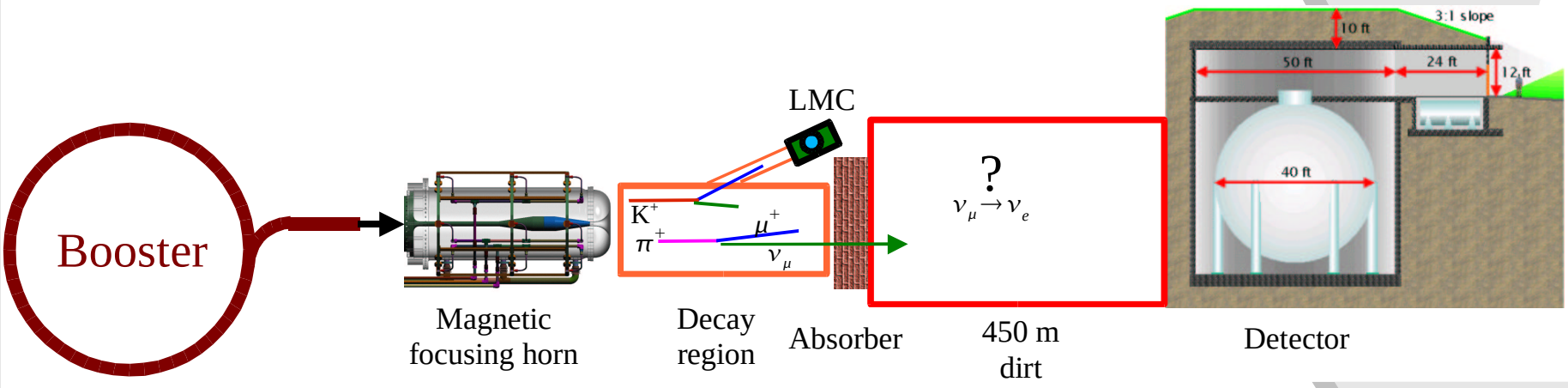
G. T. Garvey, W. C. Louis, G. B. Mills, V. Sandberg, B. Sapp, R. Schirato, R. Van de Water, D. H. White
Los Alamos National Laboratory, Los Alamos, NM 87545

R. Imlay, W. Metcalf, M. Sung, M. O. Wascko
Louisiana State University, Baton Rouge, LA 70803

J. Cao, Y. Liu, B. P. Roe
University of Michigan, Ann Arbor, MI 48109

A. O. Bazarko, P. D. Meyers, R. B. Patterson, F. C. Shoemaker
Princeton University, Princeton, NJ 08544

MiniBooNE Overview

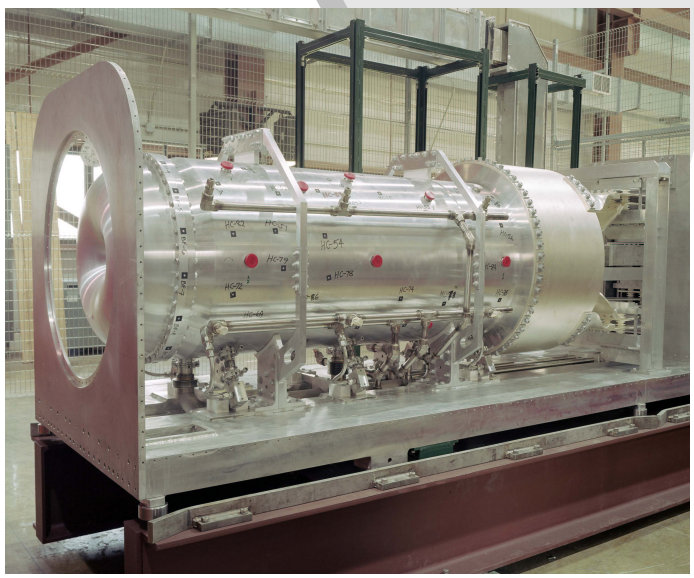


- Primary beam of 8 GeV protons from FNAL Booster Ring
- Be target produces secondary beam of π's and K's
- Horn focuses particles toward detector
- Mesons decays in decay region ⇒ Intense ν beam with E_ν ~1 GeV
- Neutrinos traverse 450 m of dirt: Oscillation?
- Mineral oil Cerenkov detector

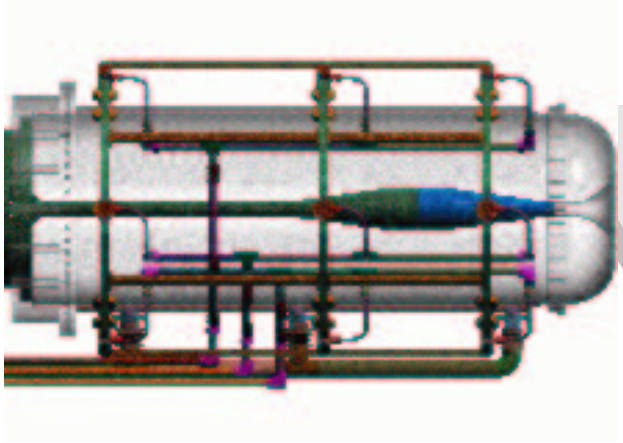
FNAL Booster

- Supply 8 GeV proton beam to Tevatron and Main Injector.
- Must now run at record intensity.
- MiniBooNE will run simultaneously with other programs. (e.g. Run II + BooNE)
- BooNE: 5Hz, 5×10^{12} protons/pulse, 5×10^{20} p.o.t/year
- Challenges are radiation issues, losses.

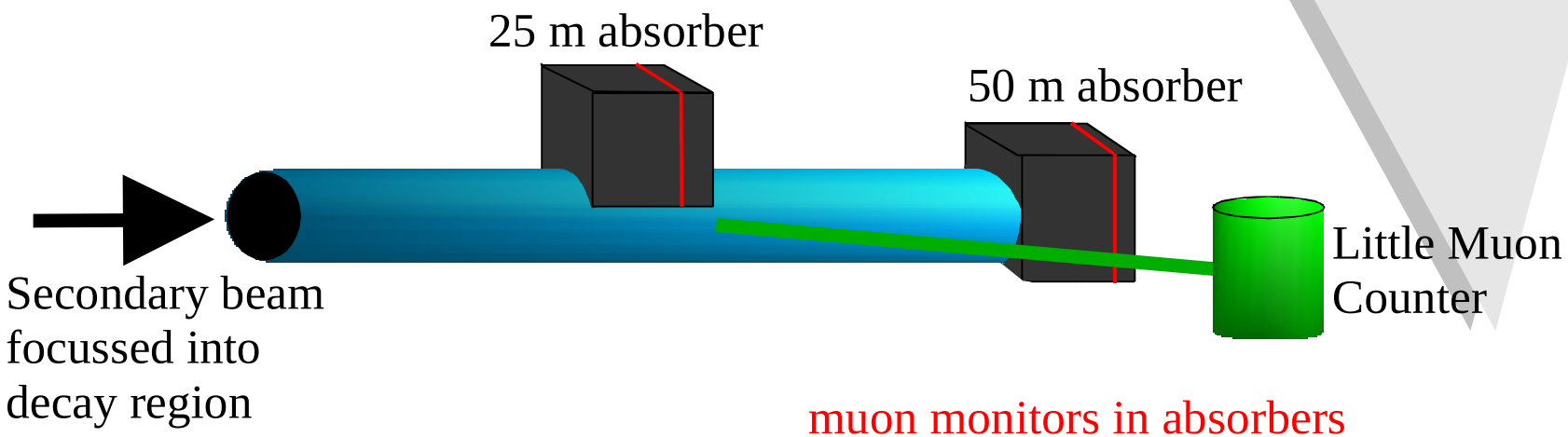
Target and Horn



- 71 cm long Be target.
- $p + Be \rightarrow \pi^{\pm}, K^{\pm}, K^{0}_{L}$
- Horn applies Toroidal Field;
  - Focuses the charged particles on the detector.
  - Initially positive particles will be focused selecting ν, but the horn current can be reversed to select $\bar{\nu}$.
  - Increases neutrino intensity by an order of magnitude.
  - Successfully Tested.



Decay Region

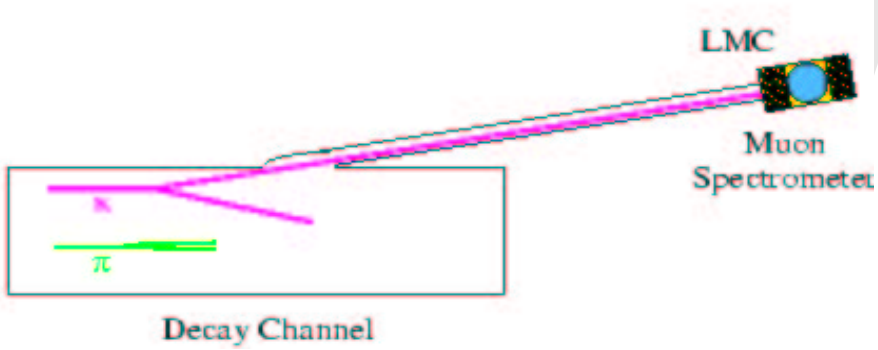


- ν_μ Beam from meson decay;

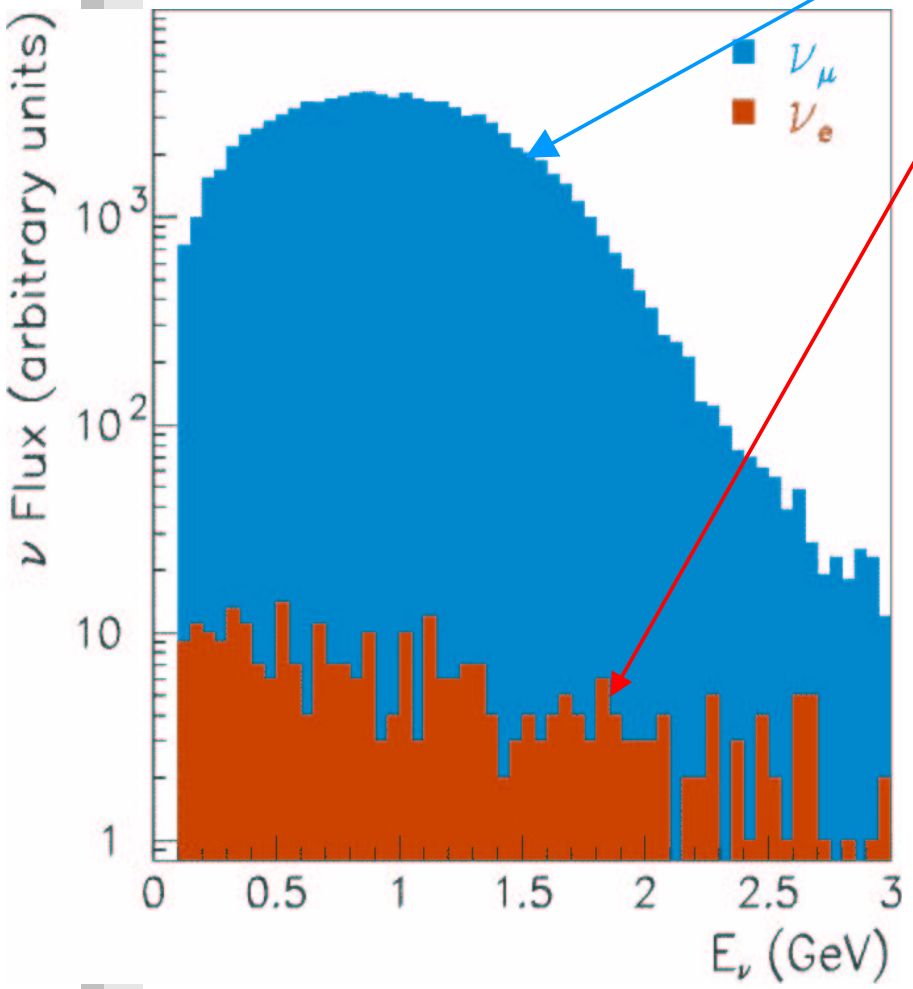
$$\pi^+ \rightarrow \mu^+ \nu_\mu \qquad \mathbf{K}^+ \rightarrow \mu^+ \nu_\mu \qquad K^0_L \rightarrow \pi^- \mu^+ \nu_\mu$$

- Switching between 25 and 50 m decay length helps us to understand the ν_e background from μ decay.

- The Little Muon Counter (LMC) cross−checks the beam flux and ν_e background from K decays



Neutrino Flux at the Detector



- High Flux of ν_μ
- Small ν_e Background from

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

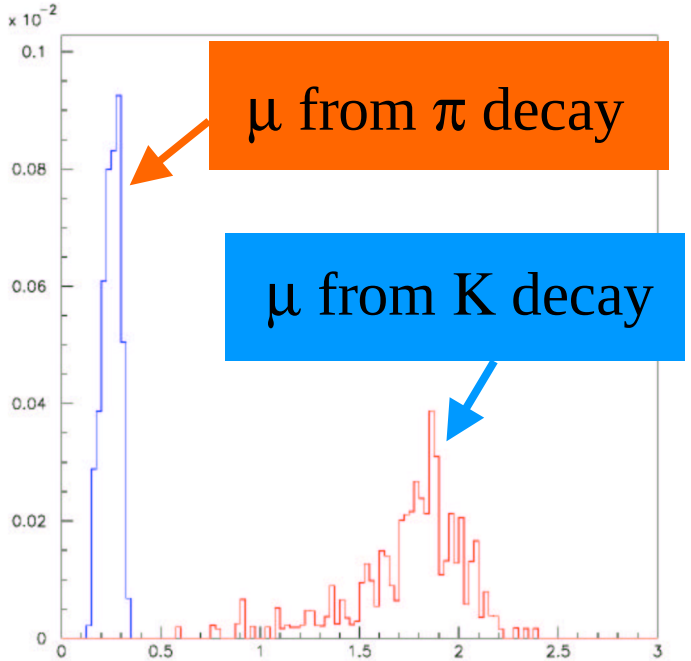
$$K^+ \rightarrow \pi^0 e^- \nu_e$$

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

- Flux Estimate:
  - Detailed simulations
  - HARP measurements
  - ν_μ–Carbon charged current σ
  - 50m & 25m decay region (μ background)
  - Off−axis muon counter, LMC (K background)

Background Measurement in Beamline

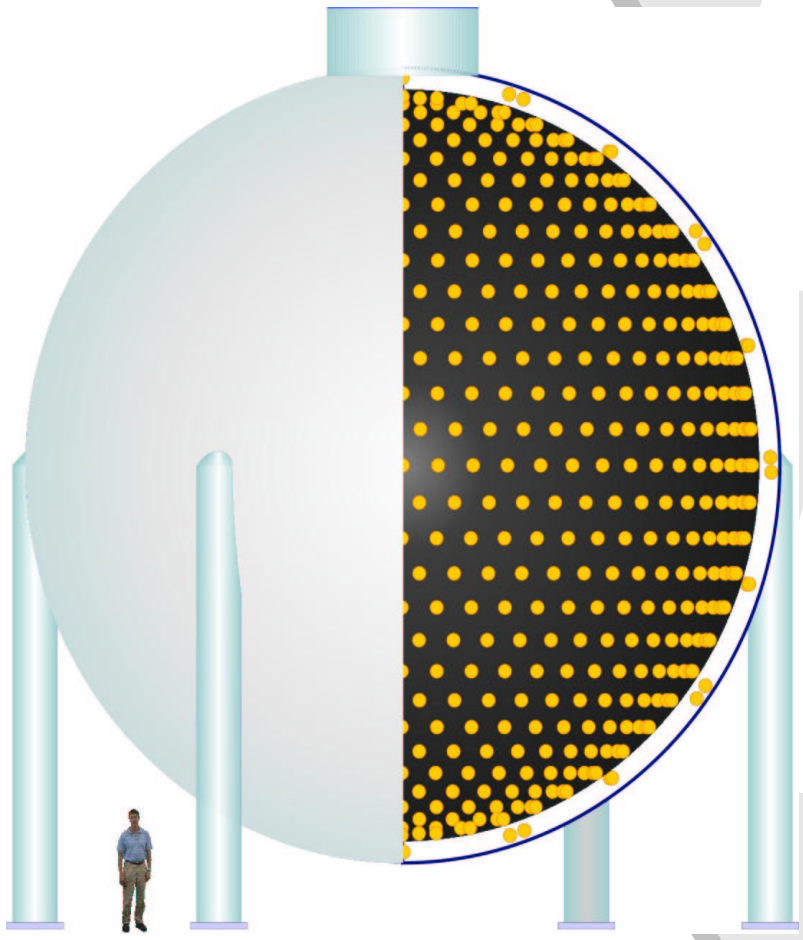
- Varying the **length of the decay region** from 50m to 25m :
  - An oscillation signal would go down by a factor of 2.
  - Background ν_e rate (μ decay) would go down by a factor of 4.
  - ν_e's from decay of short−lived sources not affected.
- **Little Muon Counter**:
  A spectrometer which exploits the wide−angle decays of the Kaons, and will get the E_μ distribution to constrain the ν_e production rate from Kaons.



P_μ at 7 degrees

MiniBooNE Detector

- 12 m (40') diameter sphere
- 807 ton (445 ton in fiducial volume) of mineral oil
- Optically isolated inner region lined with 1280 PMTs (10% coverage)
- Veto region with 240 PMTs
- Extensive calibration system − laser flasks, muon tracker, stopping muon cubes
- ν interactions in oil produce:
  - Prompt Cerenkov light (mostly)
  - Delayed scintillation light



PMTs and Electronics

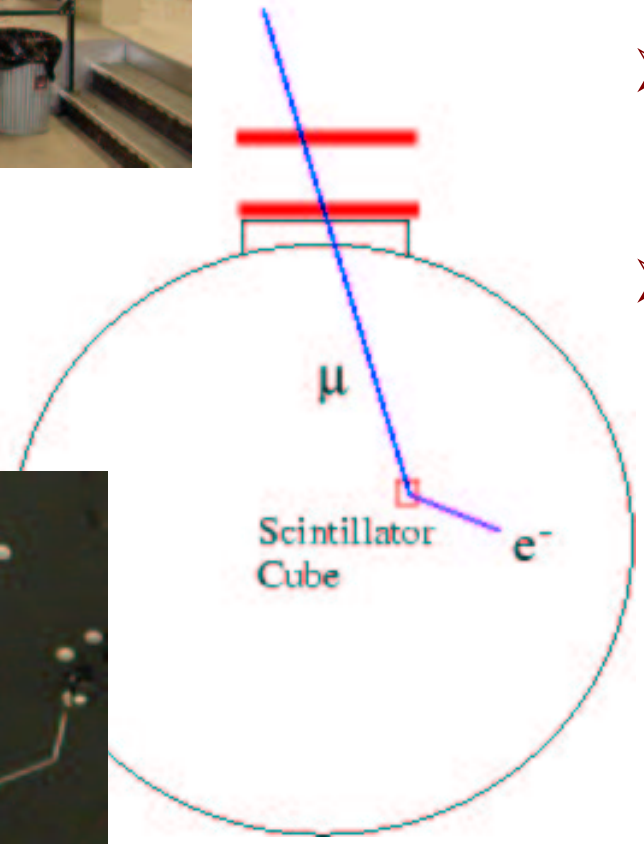
- 8 inch Photomultiplier tubes:
  - 1197 tubes from LSND (R1408)
  - 324 New Hamamatsu tubes (R5912)
  - 240 tubes from LSND in the veto region (R1408)
  - Operated at 1700 to 2200 V, with 16×10^6 electrons/pe
- Custom front−end electronics
  (some new, some recycled from LSND)
- All new DAQ software

Laser Calibration System

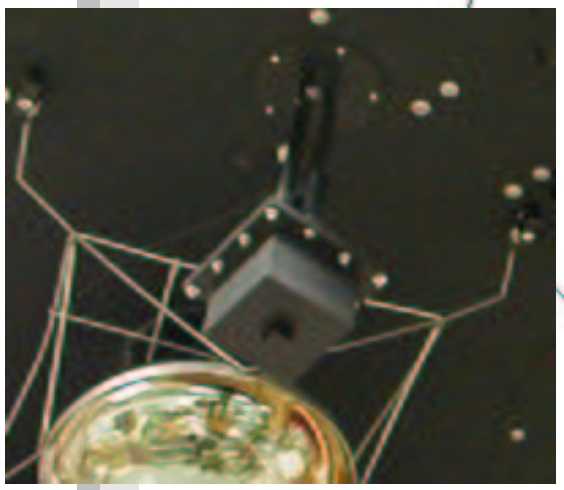
- Designed to calibrate PMTs individually by generating known light pulses
- 400 nm Laser
- 4 Ludox−filled flasks
- Calibrate PMT gain, timing, time slewing
- Oil attenuation length monitoring

Muon Tracker System + Scintillator Cubes

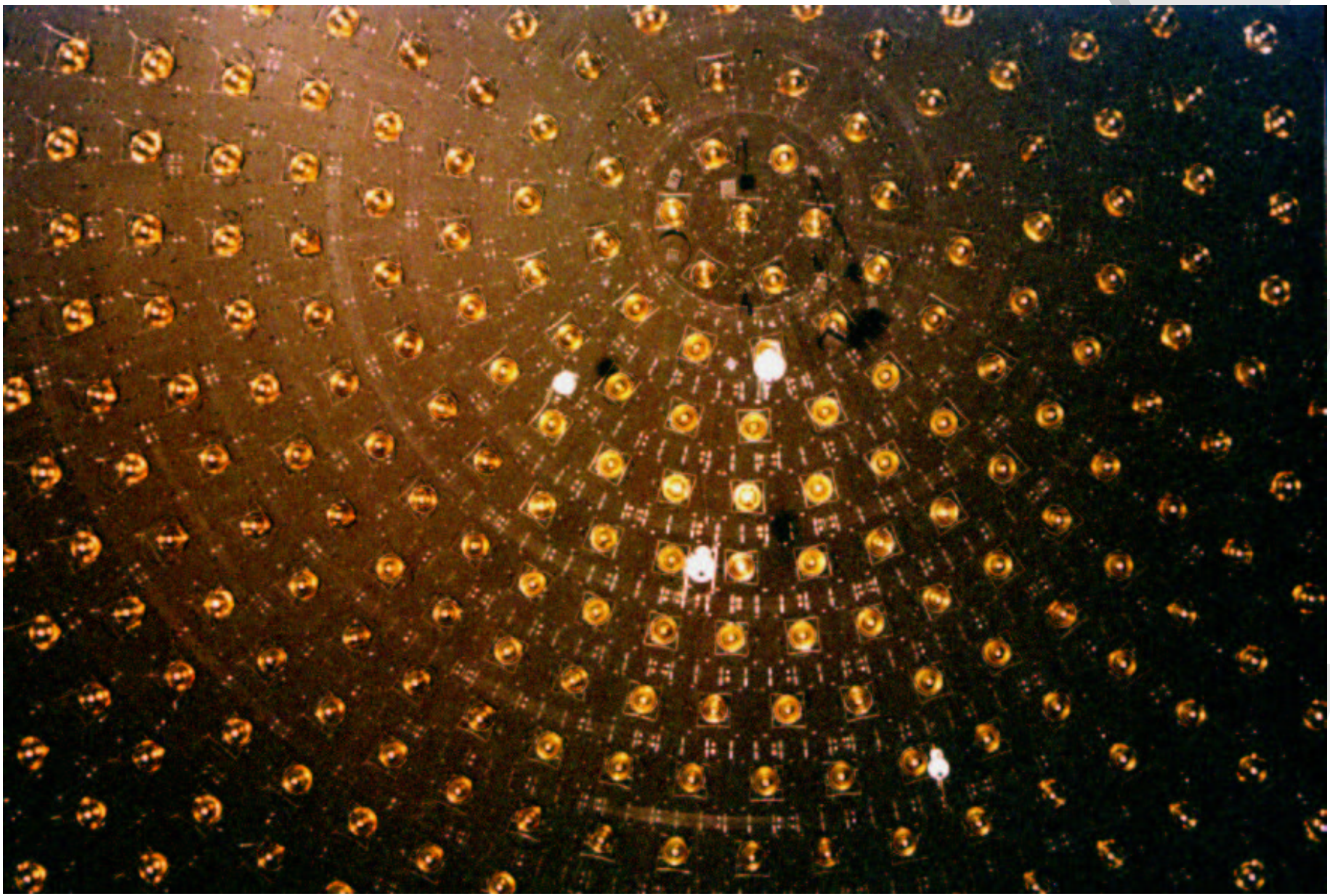
- Scintillator tracker above the tank
- 7 Optically isolated scintillator cubes in tank



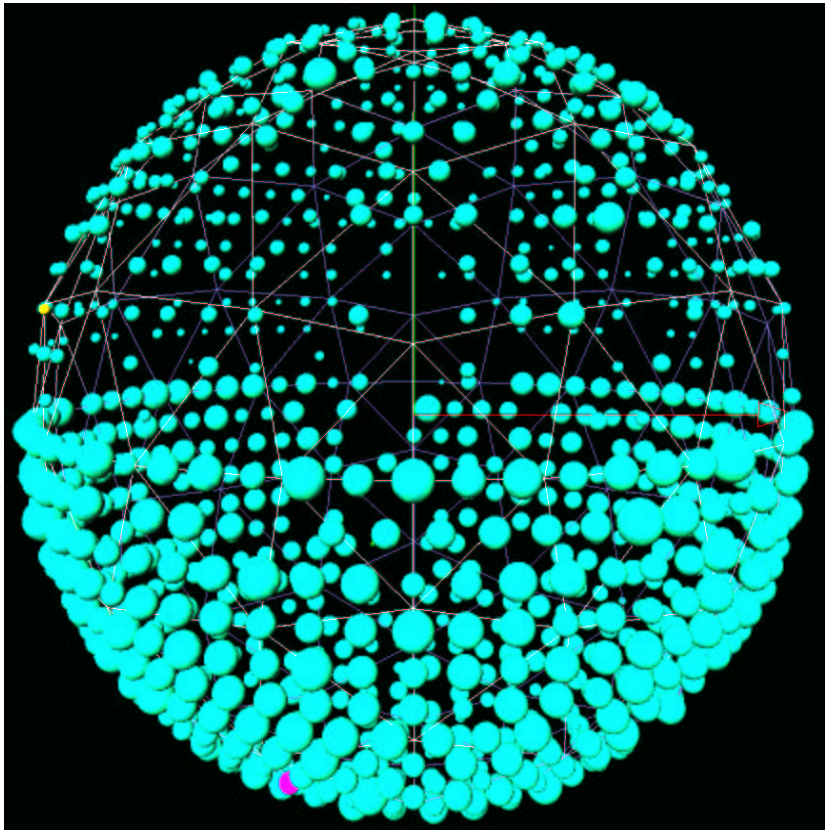
- μ's with known trajectory through the oil
- Provides:
  - Range for energy calibration
  - Cross checks on reconstruction algorithms



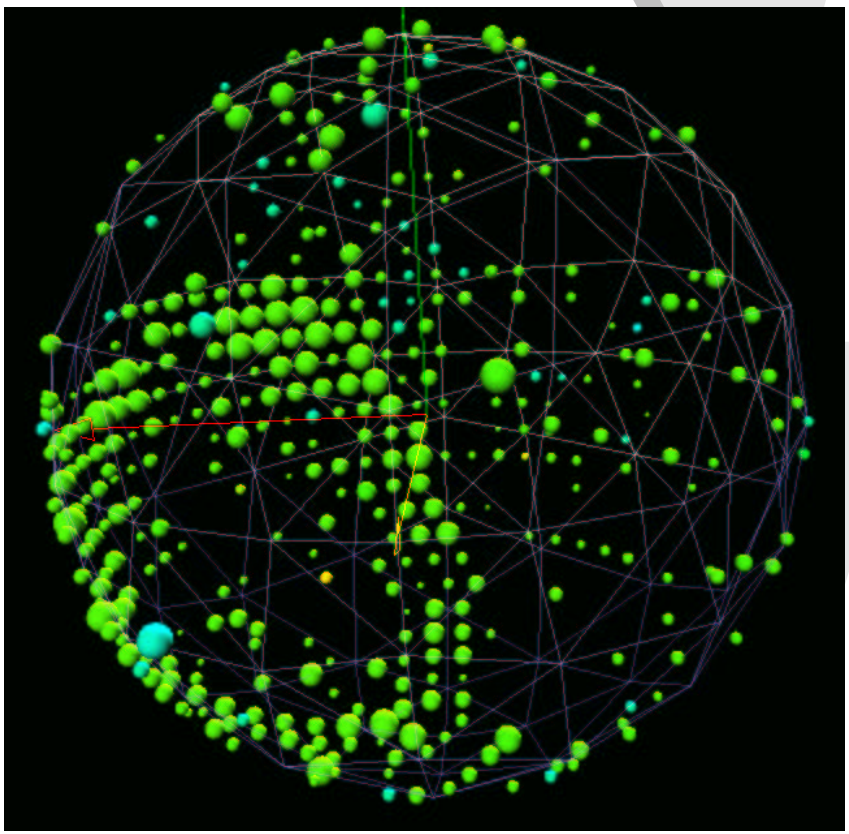
Inside the MiniBooNE Detector



Calibration Events



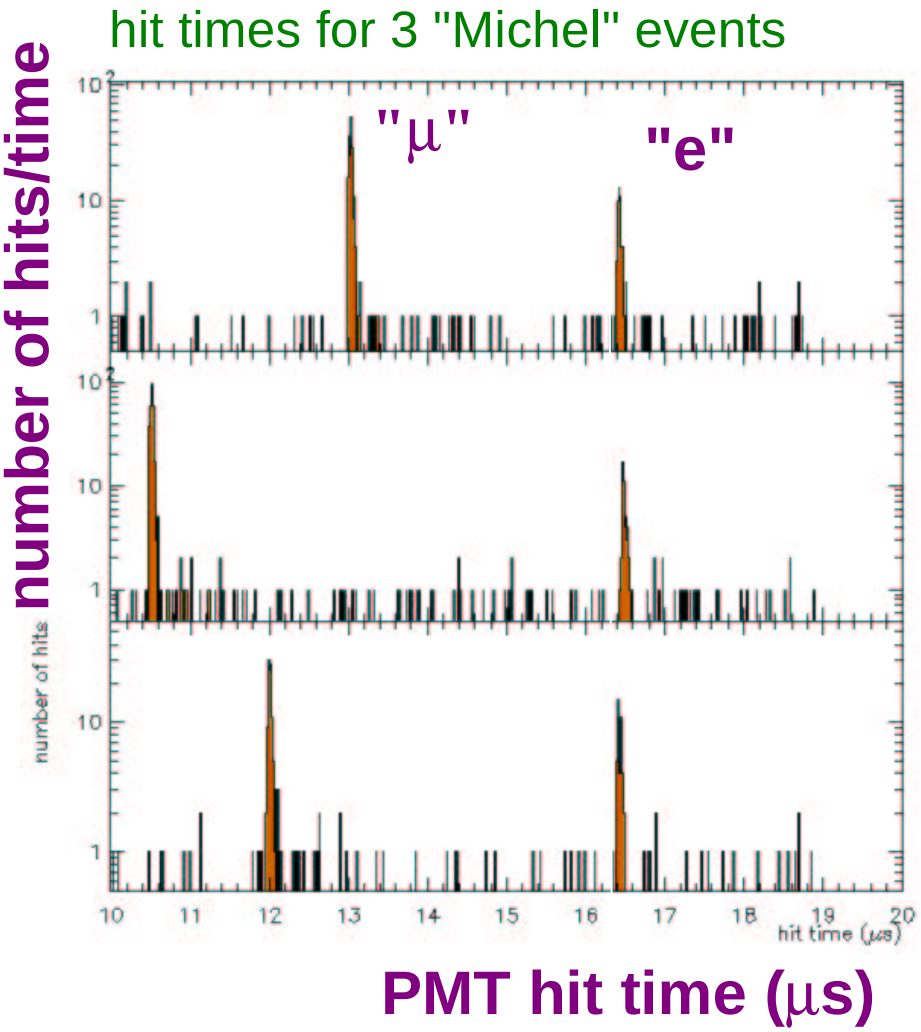
Laser Events, ½ full of Oil

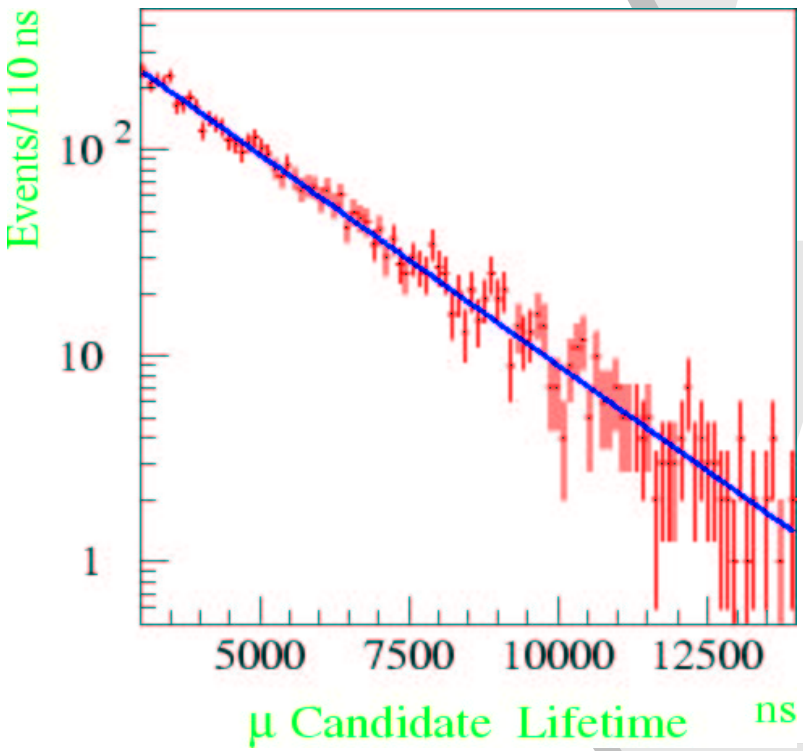


Cosmic Ray Muon

Cosmis Ray Muons –Lifetime

- Muon stops and decay (Michel) electron observed.





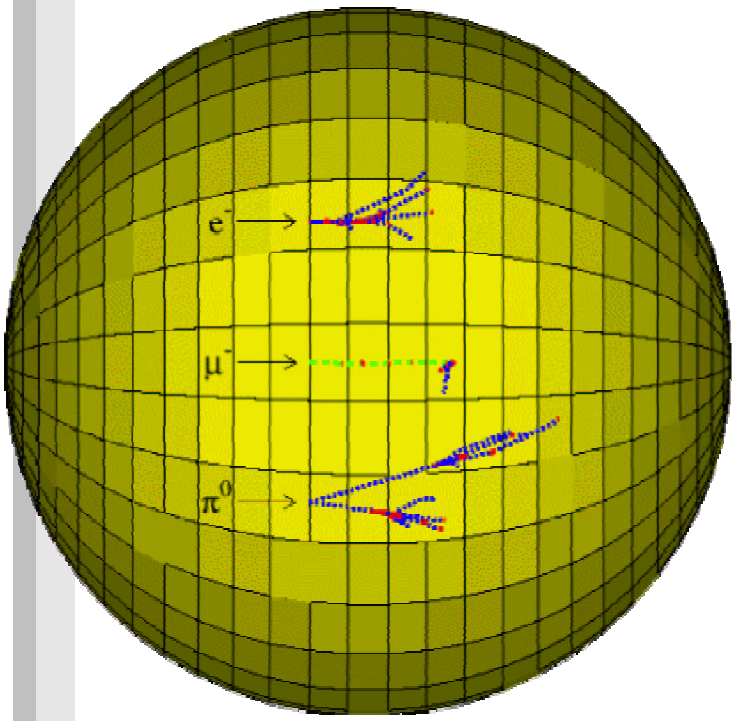
Fit Lifetime = 2.12±0.05 μs

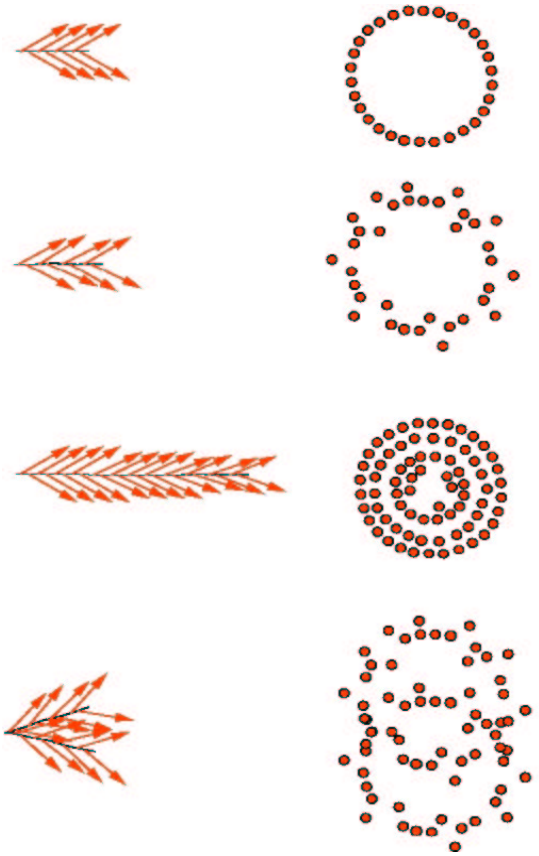
Expected in oil: 2.12 μs

with 8% μ^-−capture

Particle Identification: μ, *e* and π^0

- PID based on ring id, track extent, ratio of prompt/late light signatures





Short track, no multiple scattering

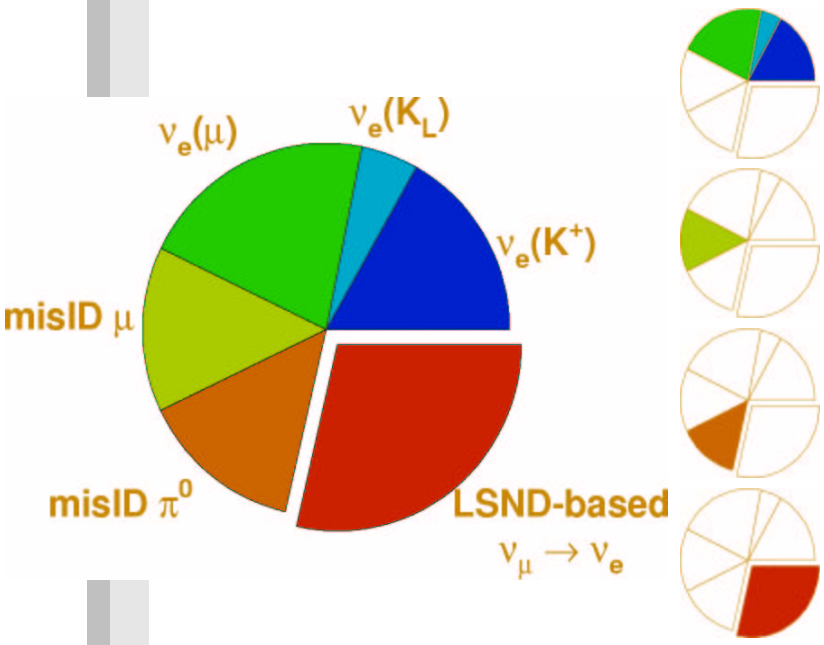
e's: short track, multiple scattering, brems.

μ's: long track, slow down sharp outer ring with fuzzy inner

π^0: 2 e−like tracks 2 fuzzy rings

Expected Events from MiniBooNE

- With 10^{21} protons on target (2 years)
- ~500k ν_μC charged current events
- Approximate number of ν_e−like events

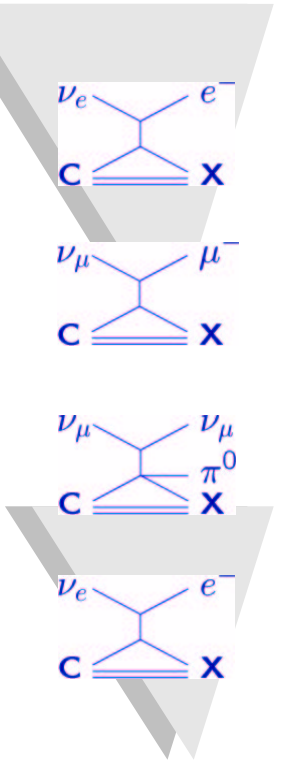


Intrinsic ν_e background: 1,000 events

μ mis−ID background: 500 events

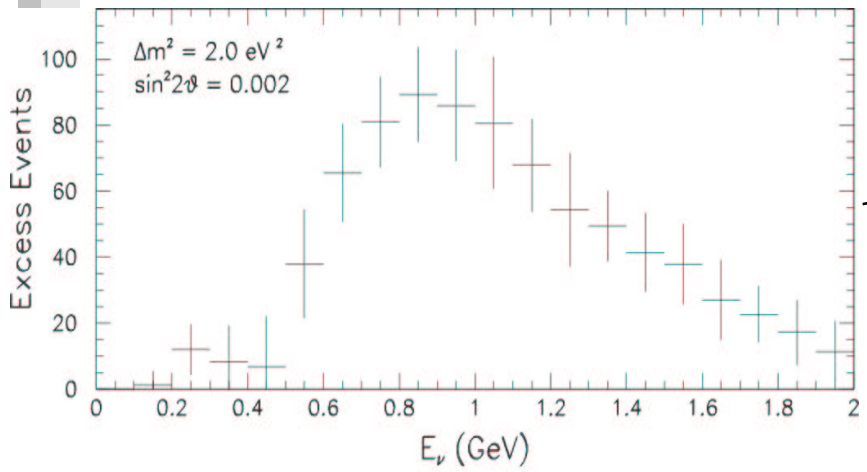
π^0 mis−ID background: 500 events

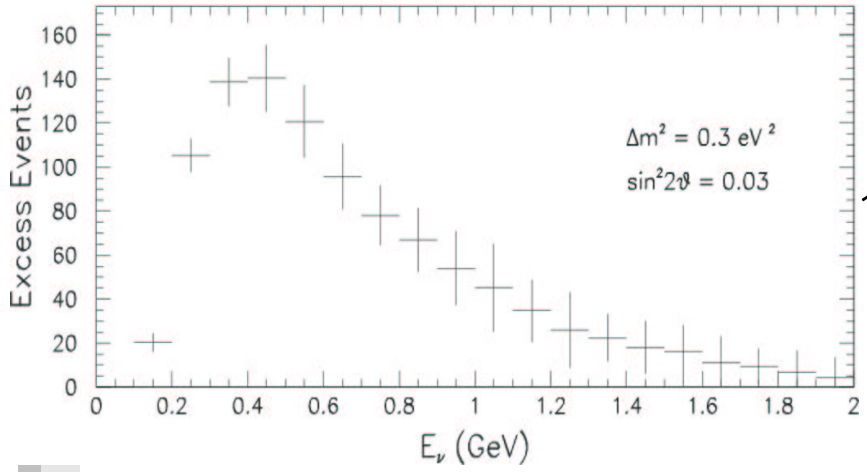
LSND−based $\nu_\mu \rightarrow \nu_e$: 1,000 events

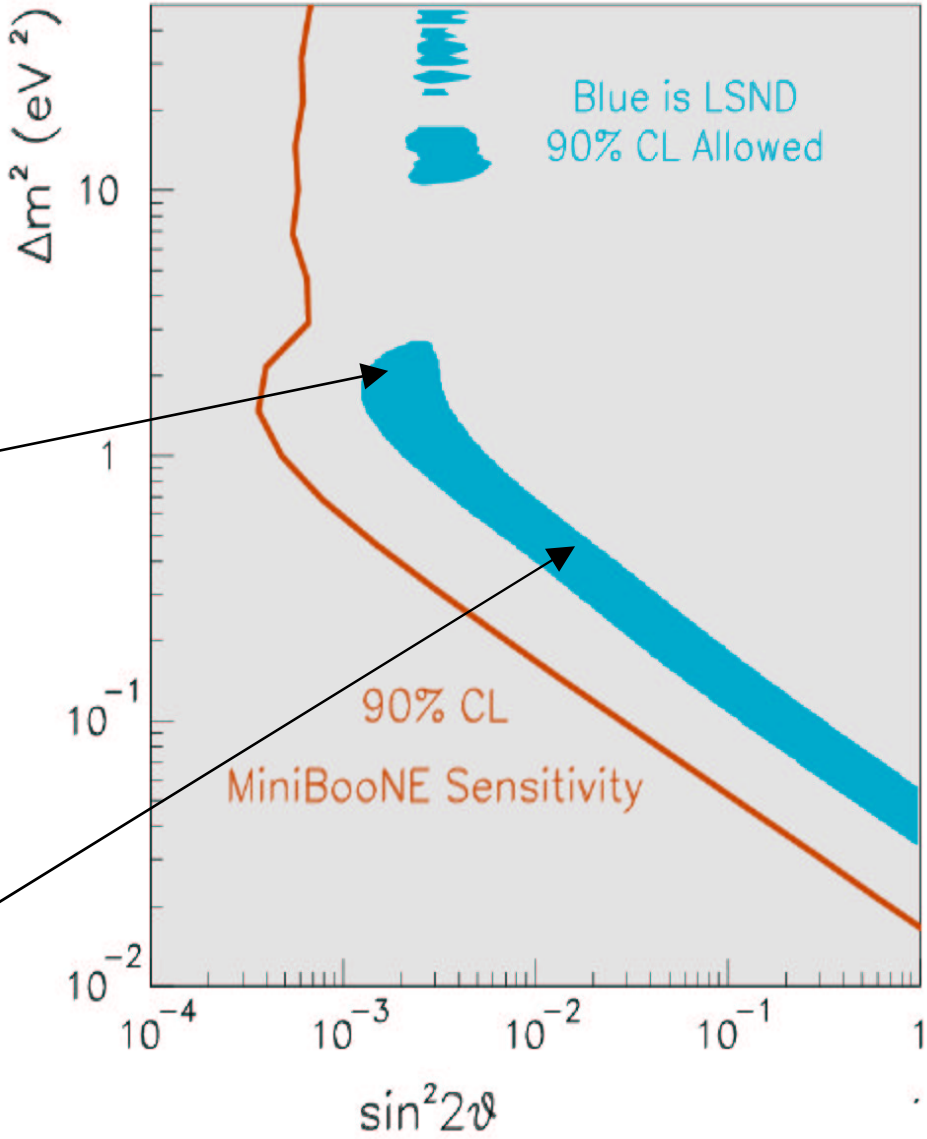


MiniBooNE Expected Sensitivity

With 2 years of running







Status of MiniBooNE

Subject: [BOONE] First Beam on Target
Date: Sun, 25 Aug 2002 01:03:10 –0500
From: Fernanda Gallinucci Garcia <fgarcia@FNAL.GOV>
Organization: Fermilab
To: BOONE@LISTSERV.FNAL.GOV

Dear Collaborators,

We had our first beam on target in August 24, 2002 at 10:34 pm.

See the MiniBooNe Beamline logbook (http://www-boone.fnal.gov/operati

The first run was 1746 (more details can be seen at the CRL).

Congratulations everybody!

Cheers,

Fernanda

- The MiniBooNE experiment is ready.
- First Beam on Target in August 24.
- Low Intensity Run
- Horn turned on August 29th
- High Intensity Runs start this week

Conclusion

The MiniBooNE experiment has started to take data.