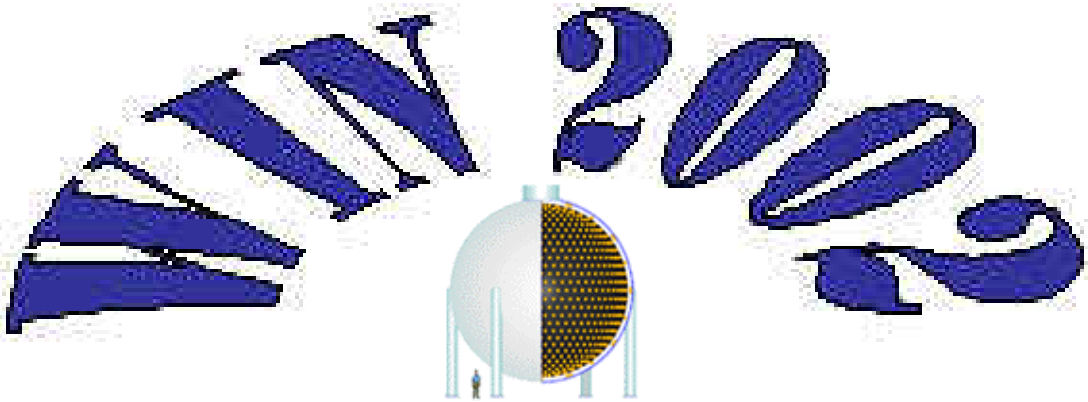
LSND, Karmen &MiniBooNE



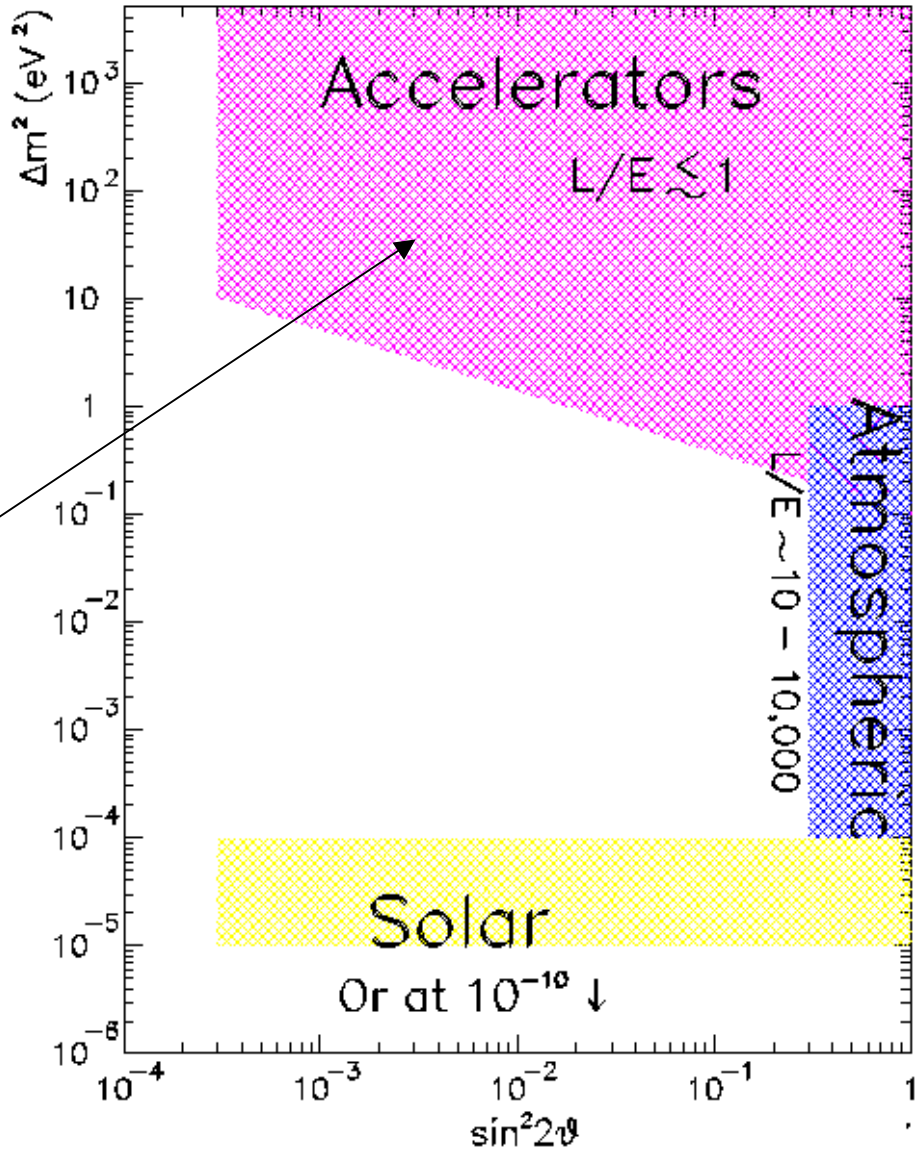
A status report on
Investigations of

$\nu_\mu \rightarrow \nu_e$ at high Δm^2

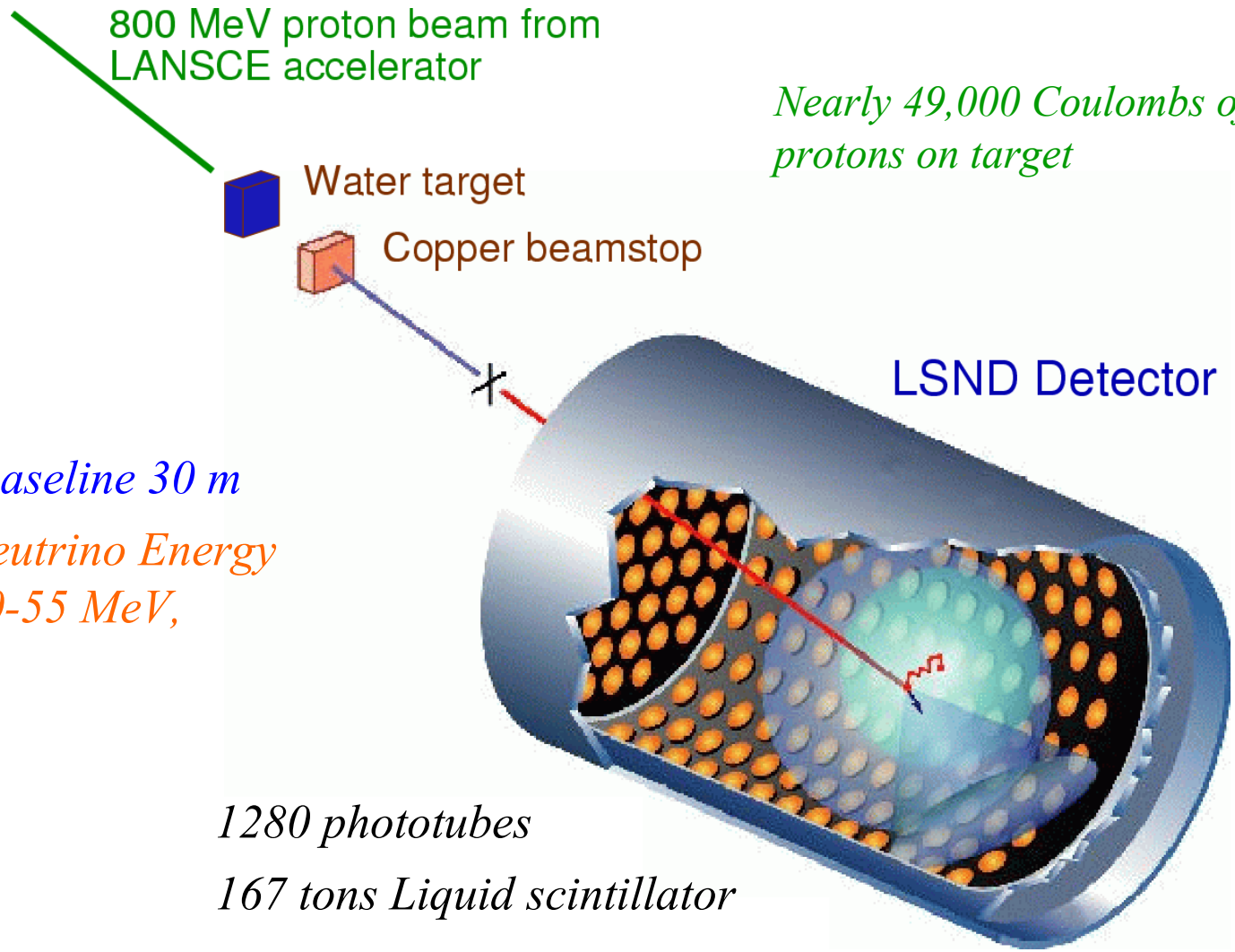
I. LSND Final Results

II. Karmen II Results

III. Progress on MiniBooNE



The LSND Experiment (1993-98)



Nearly 49,000 Coulombs of protons on target

Baseline 30 m

Neutrino Energy 20-55 MeV,

1280 phototubes

167 tons Liquid scintillator

Main Analysis: Decay at Rest (DAR)

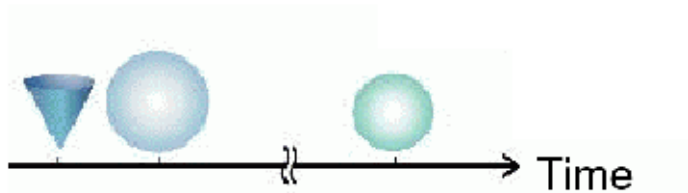
$$\pi^+ \rightarrow \mu^+ \nu_\mu$$
$$\hookrightarrow e^+ \nu_e \bar{\nu}_\mu$$

Oscillations?

$$\hookrightarrow \boxed{\bar{\nu}_e}$$

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

detect prompt *e* track,
$20 < E_e < 60$ MeV



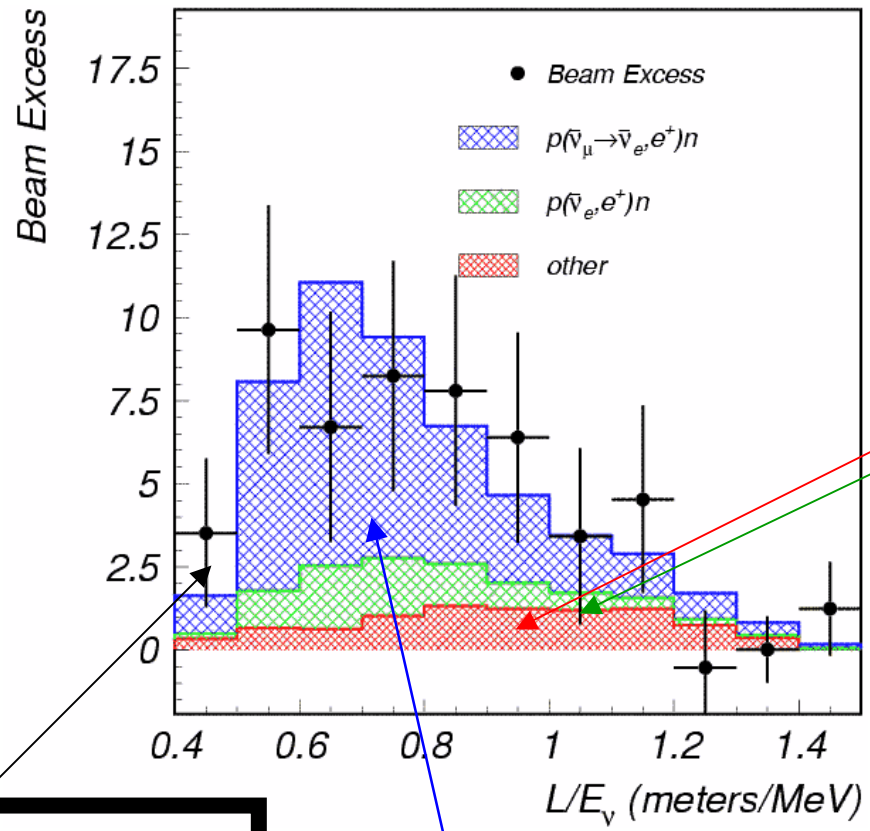
neutron capture:

$$\boxed{np \rightarrow d\gamma}$$

2.2 MeV

Secondary Decay-in-Flight (DIF) analysis included in final result, but not statistically significant

The LSND DAR Signal



Size of the Beam-related backgrounds

Data points: Excess after Beam-off subtraction

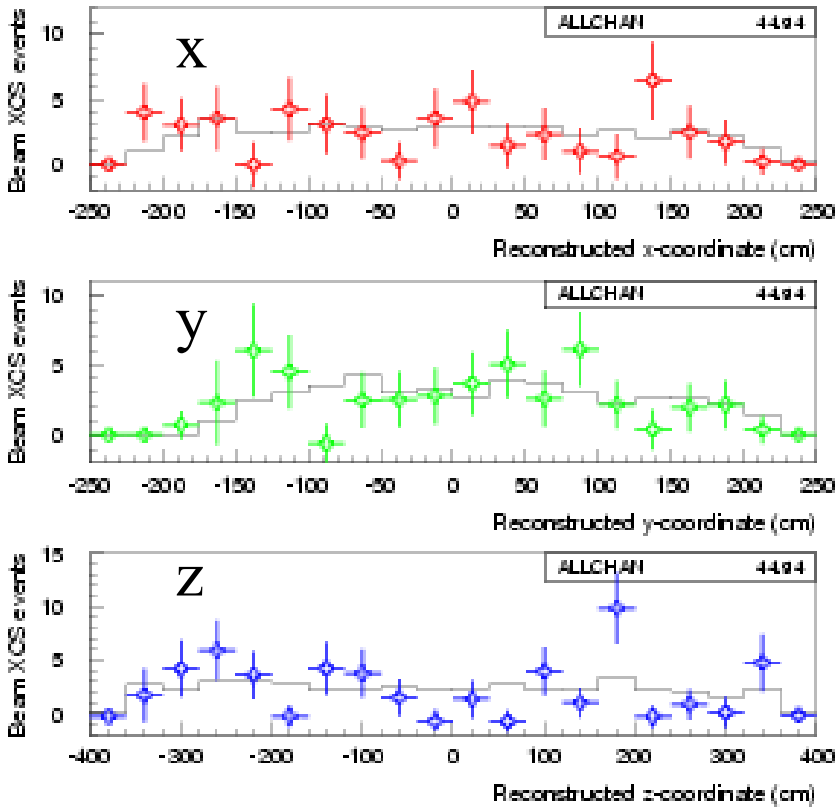
Expectation for oscillations (at high Δm^2)

Spatial Distribution
Of the excess events

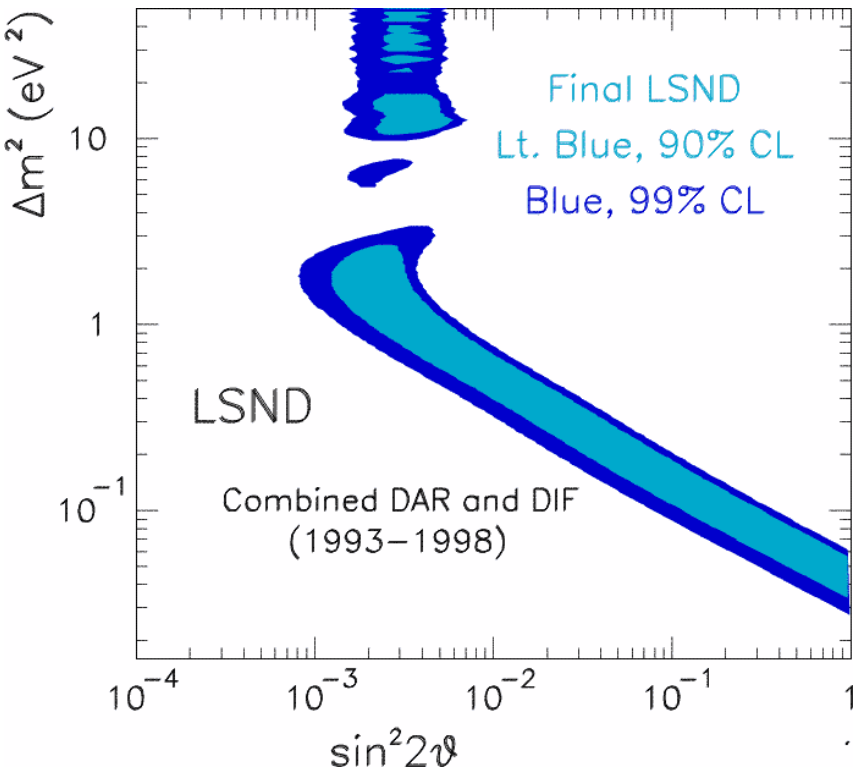
Points: $\bar{\nu}_e$ events
Hists: ν_e events

An oscillation signal should agree in shape with the histogram because it is ν-beam related

A non-neutrino related background most likely would not agree



LSND's Final Result

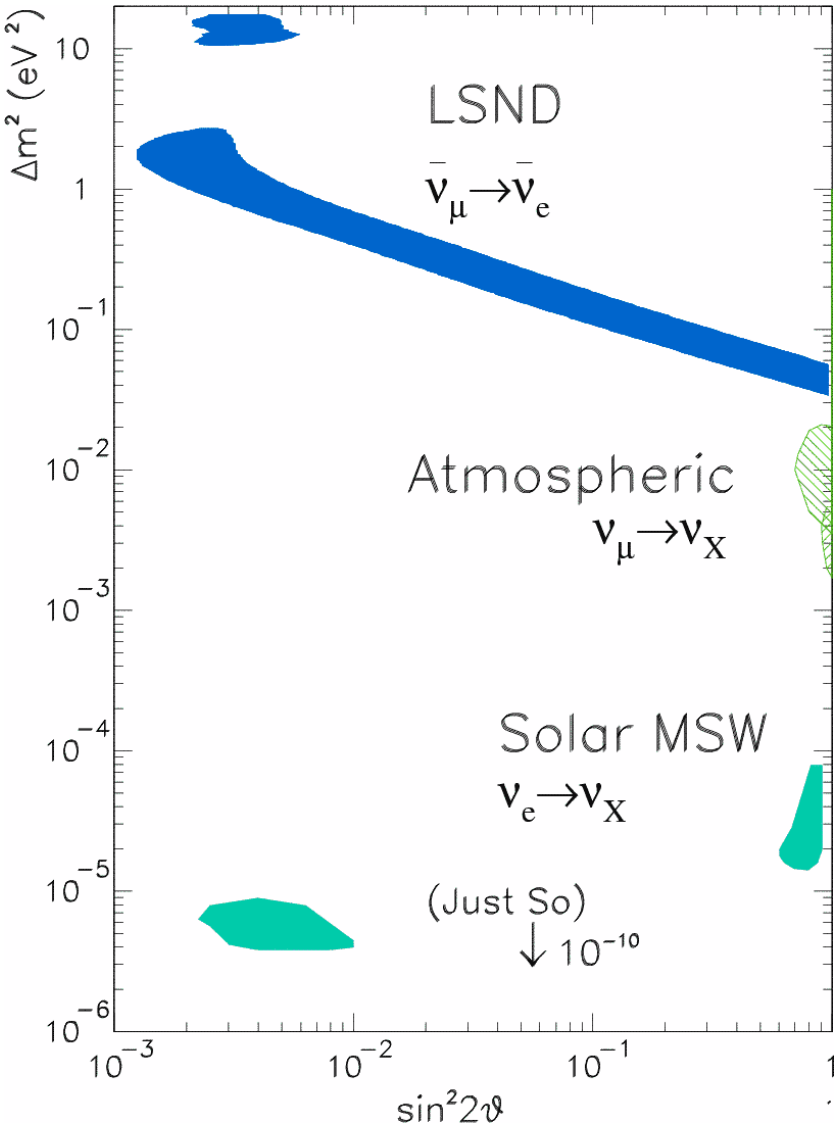


DAR excess: $87.9 \pm 22.4 \pm 6.0$ evts.

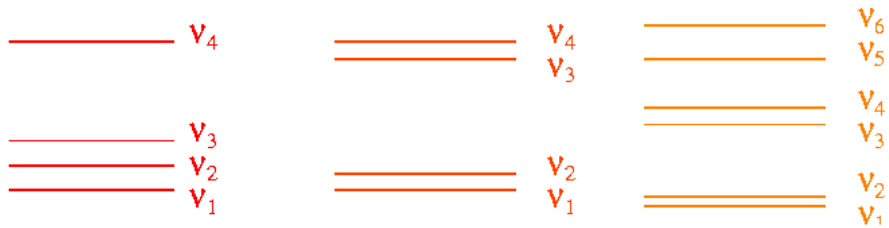
Corresponding osc. probability: $(0.264 \pm 0.067 \pm 0.045)\%$.

$3.3\ \sigma$ evidence for oscillation.

What are the implications?



❖3 Δm^2 imply at least 4 neutrinos



Or maybe something more exotic! ?!
CPT violation?(Barenboim, Borissov, Lykken & Smirnov)

❖High Δm^2 oscillations may affect models for…

- ➢The supernova R-process
- ➢Big Bang Nucleosynthesis
- ➢Power spectrum of galaxies

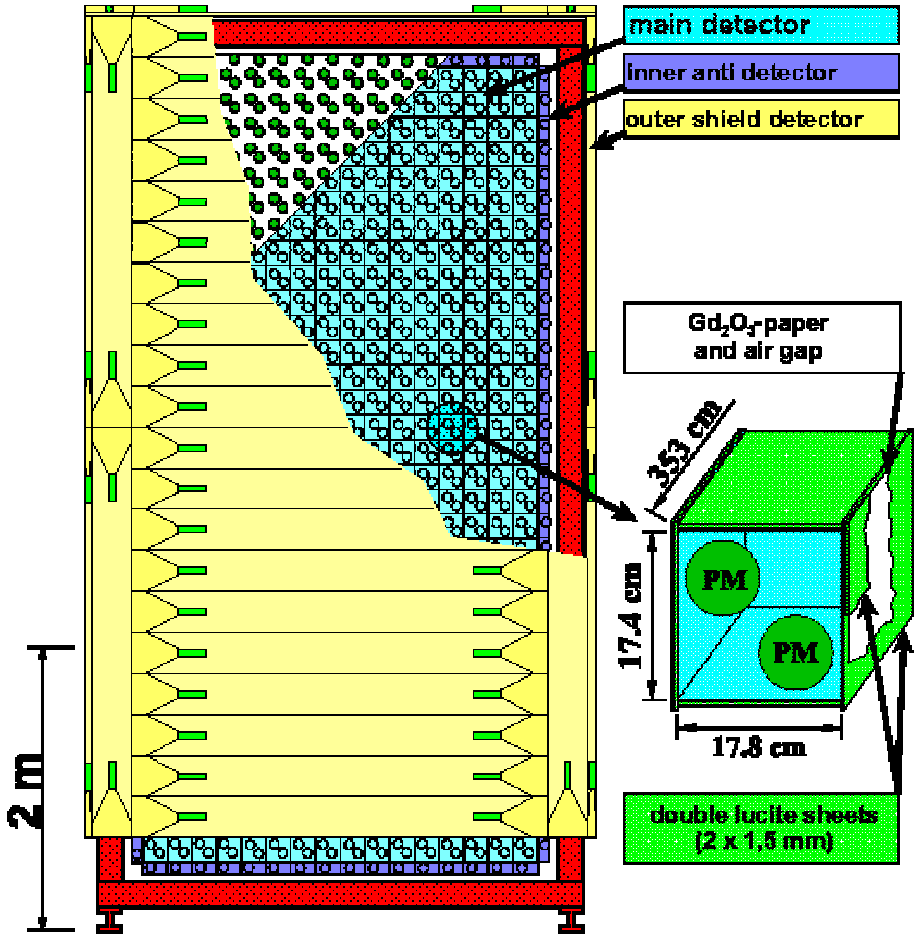
Karmen II *1997-2001*

- Pulsed 800 MeV pot (ISIS)
- DAR beam (90º to target)

- 17.6 m baseline

- 56 tons of liquid scintillator
- 512 modules
- Gd-doped (8 MeV γ)

- ×10 less statistics (due to integrated intensity & detector size)



We are within a few weeks of seeing Karmen II final results

But not yet…
Preliminary results, March, '00

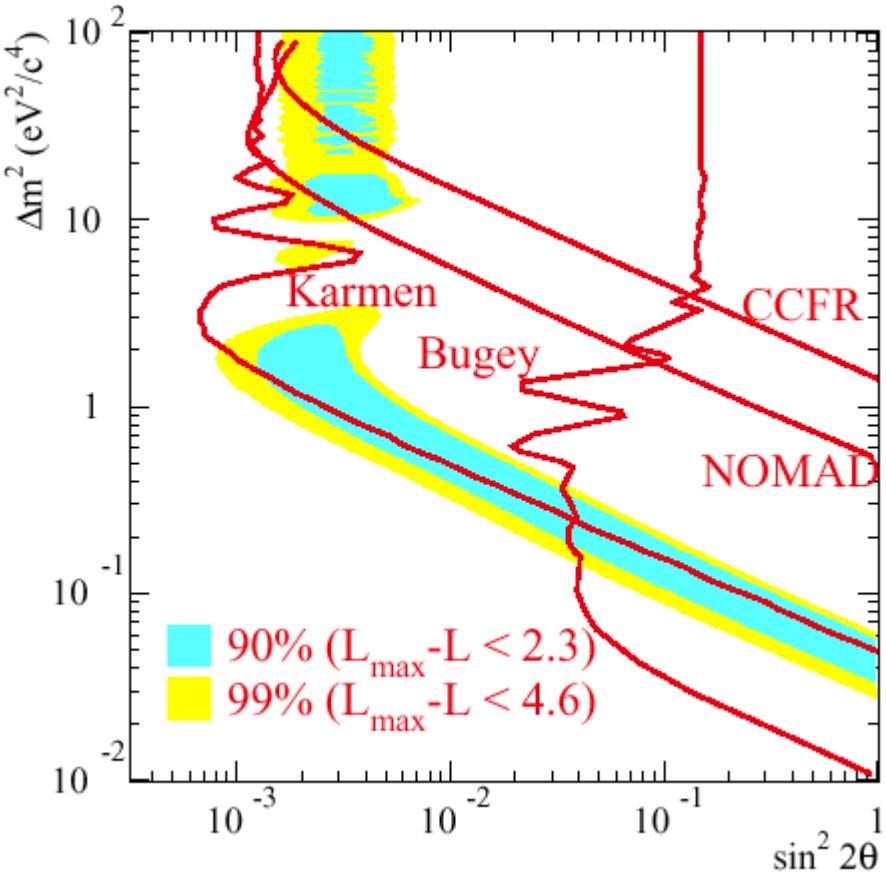
11 events observed

12.3 ± 0.6 events expected

Allows a limit of

<3.1 oscillation events

In the Karmen II data @ 90% CL



(Announced at Karmenfest:
Results through Nov '00:
14 observed, 14.3 expected)

Also coming soon: A new joint analysis by Klaus Eitel!

Enter: MiniBooNE

- Quick to stage
  - *Proposed in summer 1998,*
  - *Running in spring, 2002*
- High statistics
  - *×10 more events than LSND*
  - *(~2 calendar years)*
- Different systematics
  - *× 10 high beam energy*
  - *Results in different beam backgrounds and event signatures*
- High significance
  - *5σ over entire LSND region as a "counting experiment"*
  - *(more significant when energy dependence is included)*

The BooNE Collaboration

October 16, 2001

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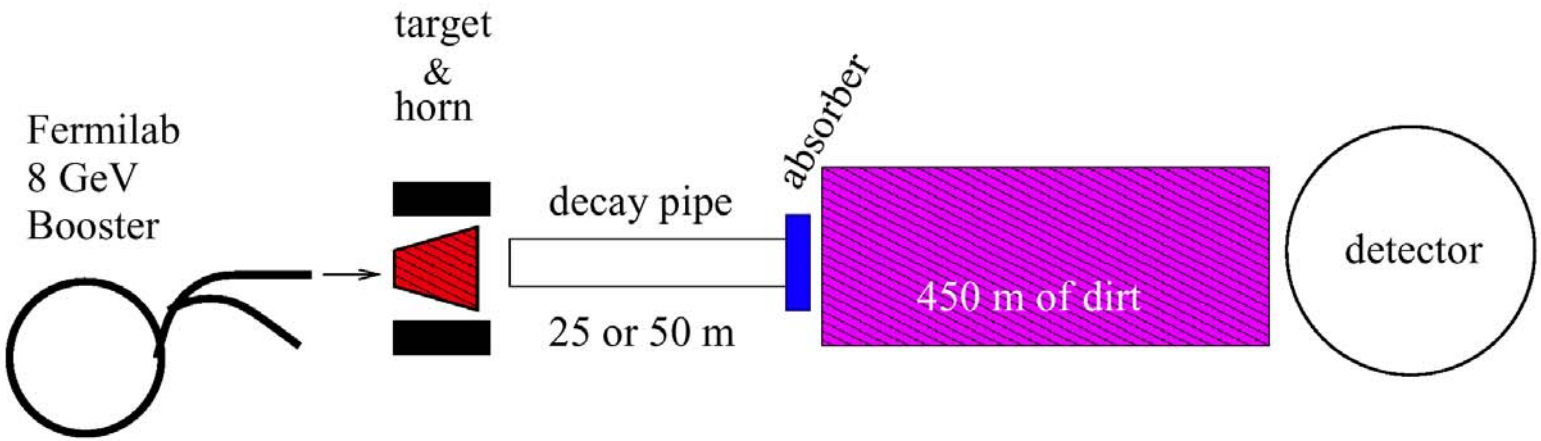
We are…

55 scientists

from

14 institutions.

MiniBooNE



The FNAL Booster

injects beam to the target

resulting mesons decay and

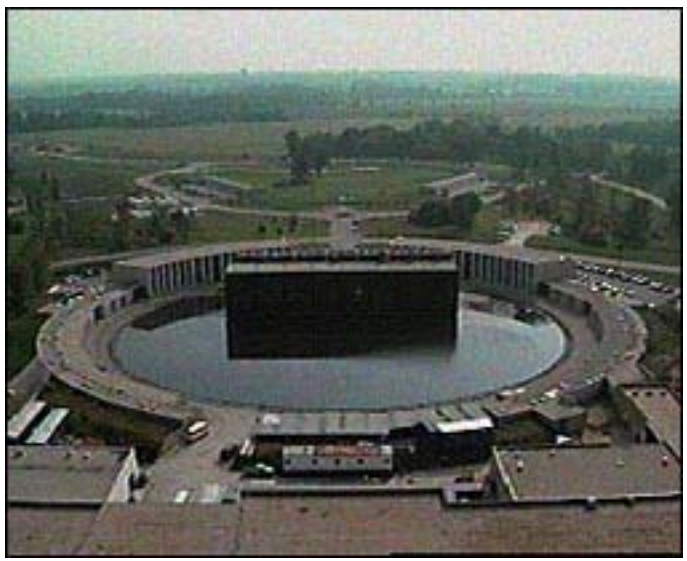
neutrinos traverse 450 m of dirt

to the oil-based Cerenkov detector

The FNAL Booster

8 GeV proton accelerator built to supply beam to the Main Ring, it now supplies the Main Injector

Booster must now run at record intensity



MiniBooNE will run simultaneously with the other programs:
e.g. Run II + BooNE; 5×10^{12} protons per pulse at a rate of 7.5 Hz; (5 Hz for BooNE)

5×10^{20} p.o.t in one year
Challenges are radiation issues, losses

The MiniBooNE Secondary Beam

The beam is delivered to a 71 cm long Be target.
Most ν_μ are from π decays.
ν_e backgrounds are from μ and K decays

Understanding secondary production from the target is very important

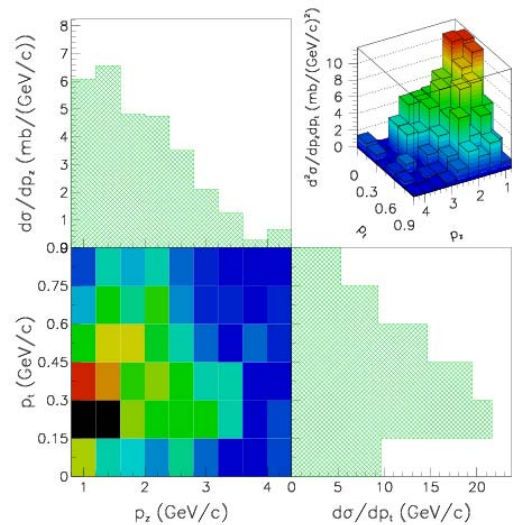
We are collaborating with…

BNL E910

Preliminary results

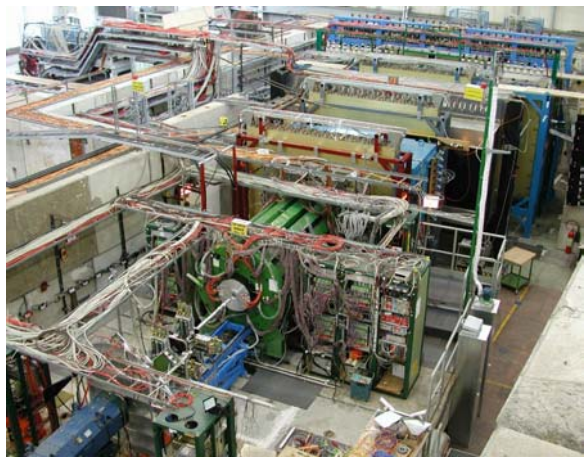
Inclusive K^+ cross-section:

$p + Be \rightarrow K^+ + X$ for 12.5 GeV/c protons



Analysis by
Michel Sorel

CERN PS214 -- Harp

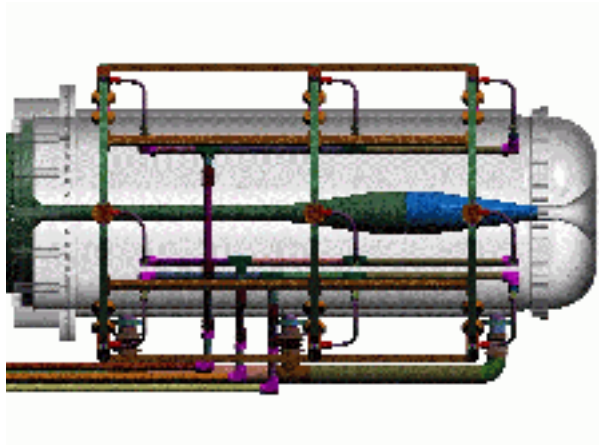


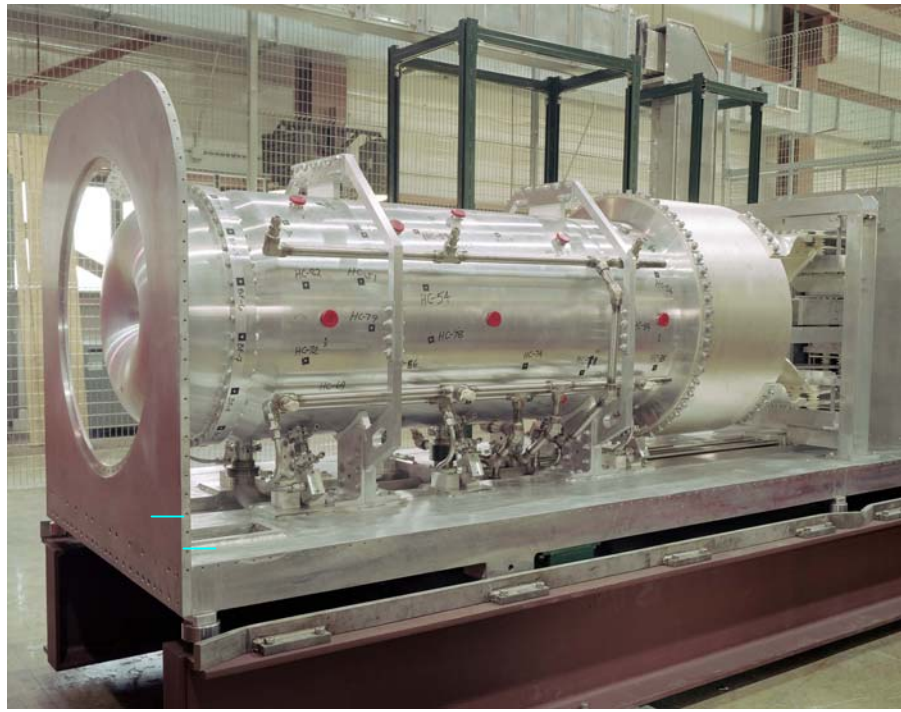
8 GeV protons on our actual target!

A magnetic horn focuses the charged particles to the detector.

Initially positive particles will be focused (neutrinos)

but the horn current can be reversed (antineutrinos)





170 kA in 140 μsec pulses @ 5 Hz

Tested to 10 million pulses & about to be installed!

Cross-checks in the beamline

- Varying the length of the decay region from 50 m to 25 m:

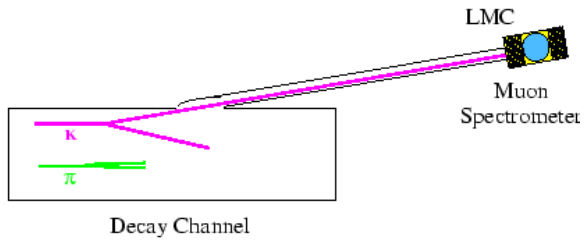
  If an excess is the signal, the rate will change by × 2

  Excess from unmodeled ν_e from μ decay will change by ×4

  Excess from short-lived sources will see little change

- The Little Muon Counters

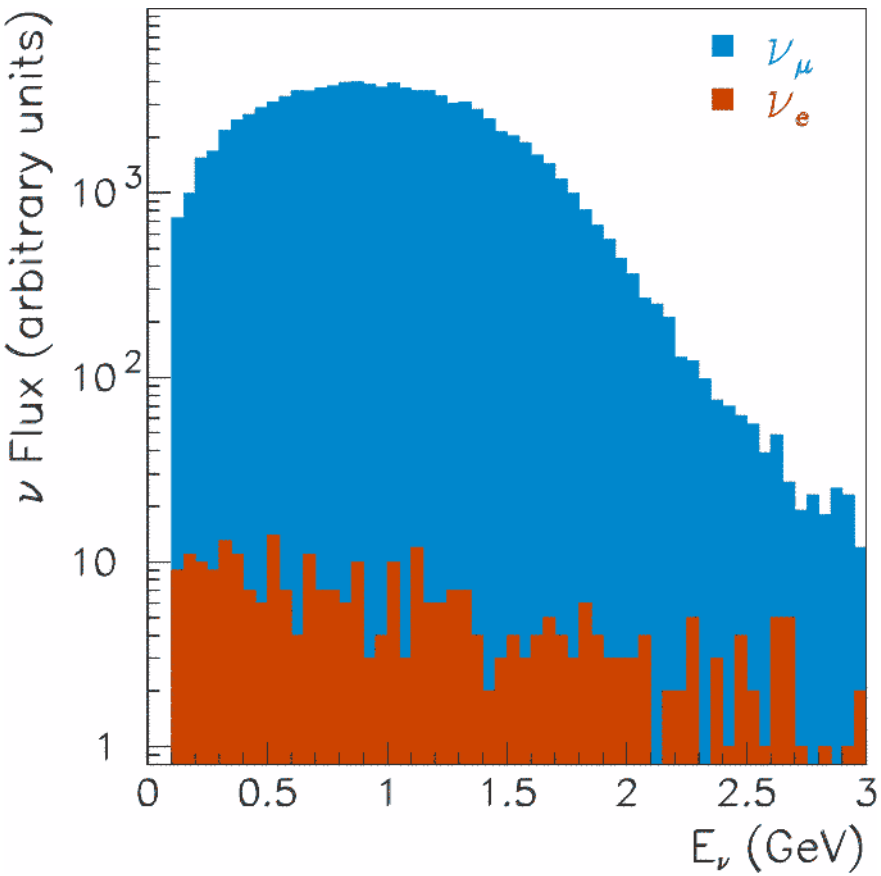
  Exploits wide-angle decays of K's to measure production rate



- Varying the horn current & sign of focusing

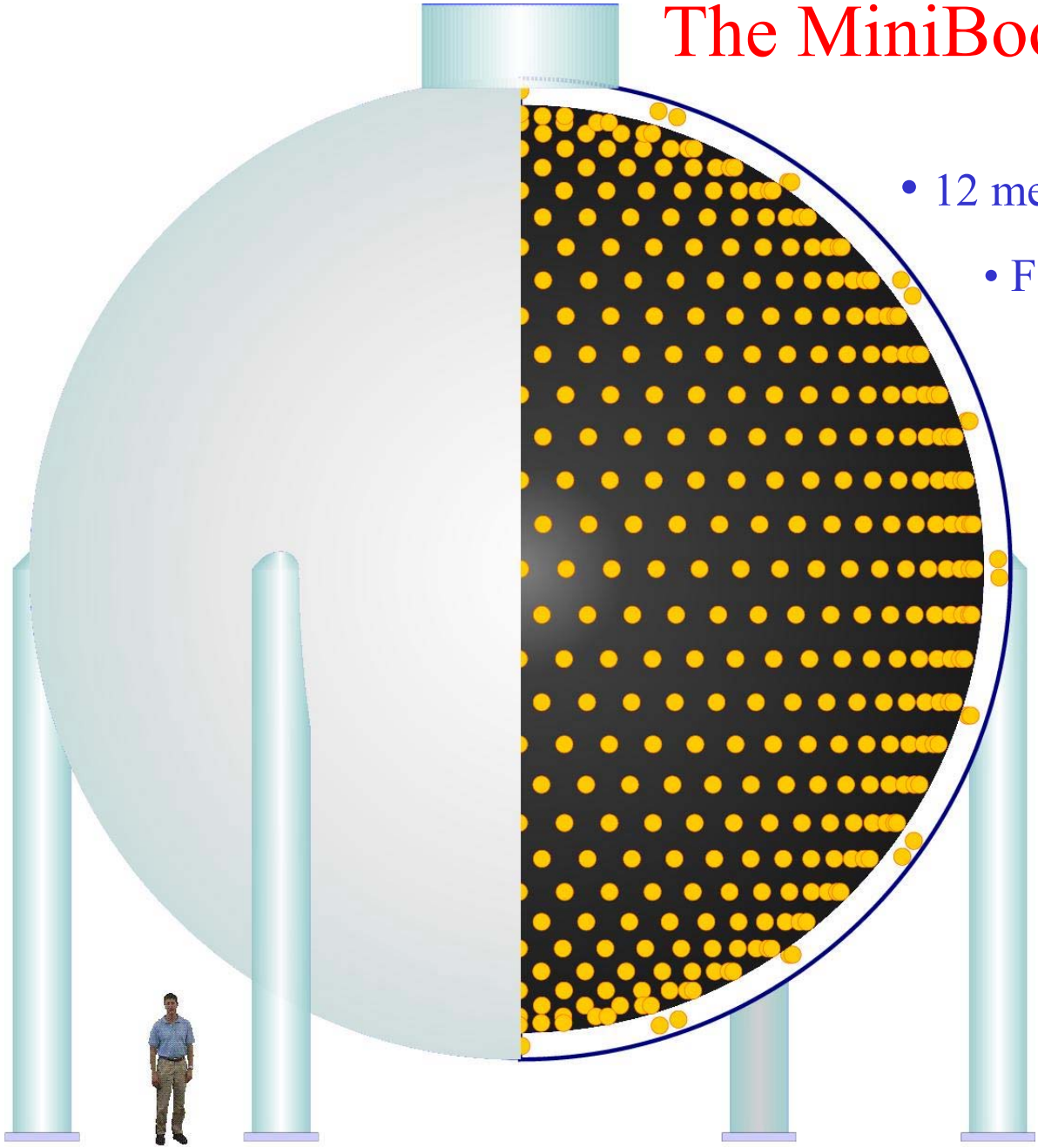
Neutrino Flux at the Detector

The L/E is designed to be a good match to LSND at ~1 m/MeV.



Expected intrinsic ν_e flux is small compared to the ν_μ flux.

The MiniBooNE Detector



- 12 meter diameter sphere
- Filled with 950,000 liters of undoped mineral oil
- Light tight inner region with 1280 photomultiplier tubes
- Outer veto region with 241 PMTs.

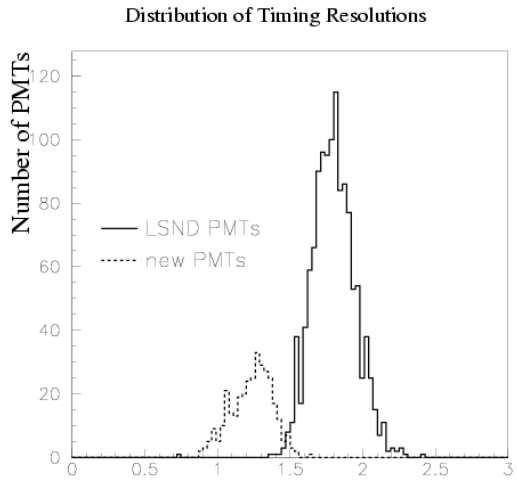
Neutrino interactions in oil produce:

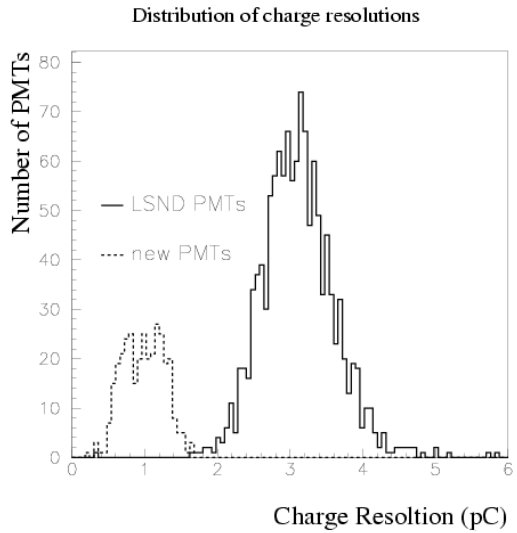
- Prompt Čerenkov light
- Delayed scintillation light

8 inch Photomultiplier tubes:

- 1197 tubes from LSND in detector (R1408)
- 324 new Hamamatsu tubes in detector (R5912)
- 241 tubes from LSND in the veto region (R1408)

Operated at 1700 to 2200 V, with 16×10^6 electrons/pe

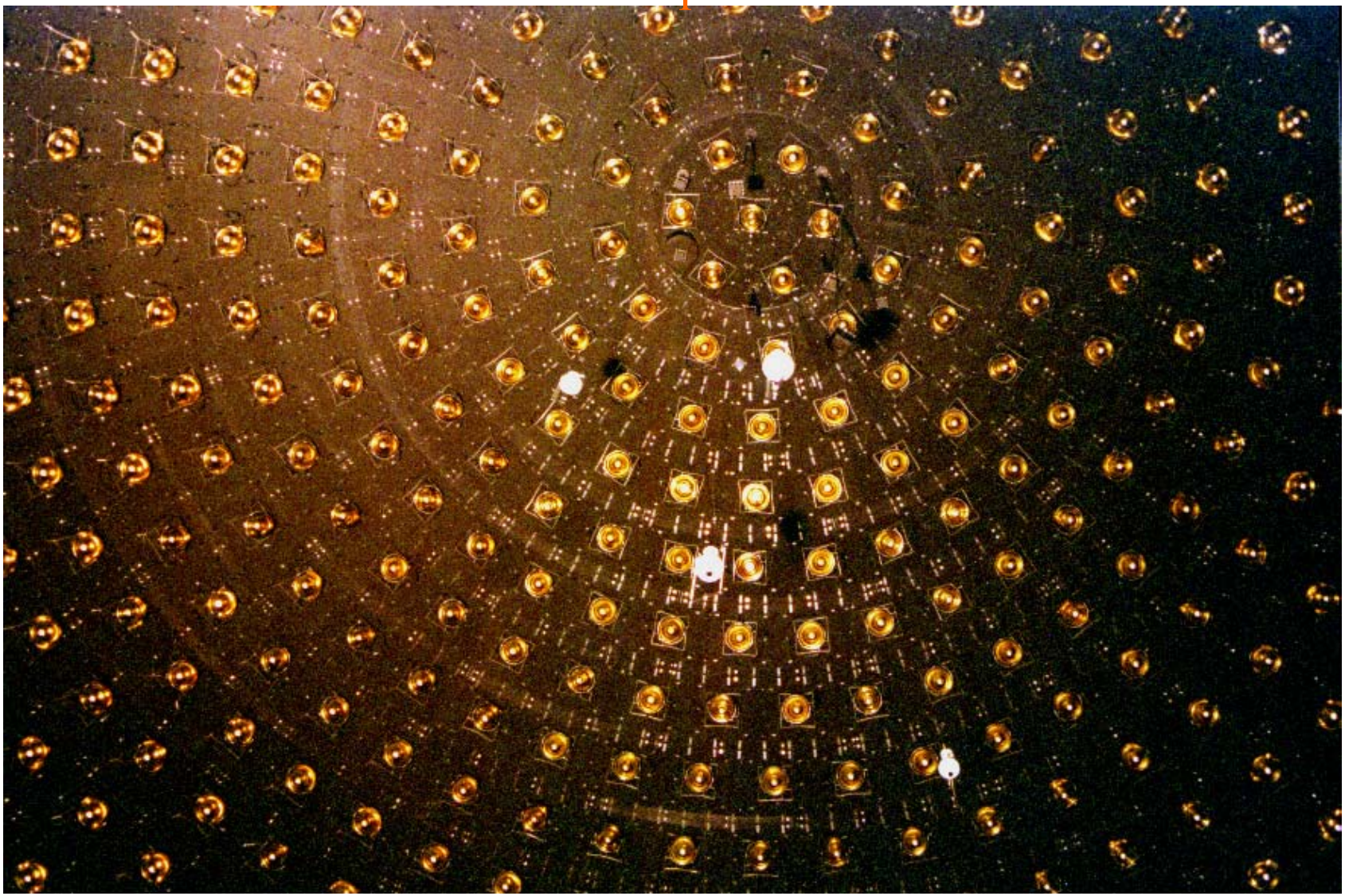




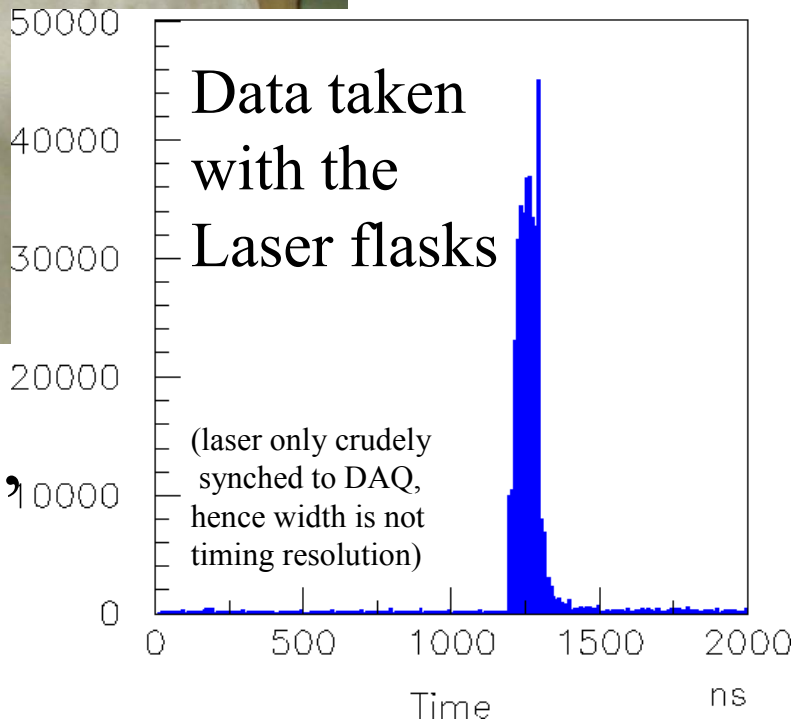
Paper submitted to
IEEE TNS

Inside the MiniBooNE Detector

PMT installation completed in October.



Five ludox-filled laser flasks provide tube calibration



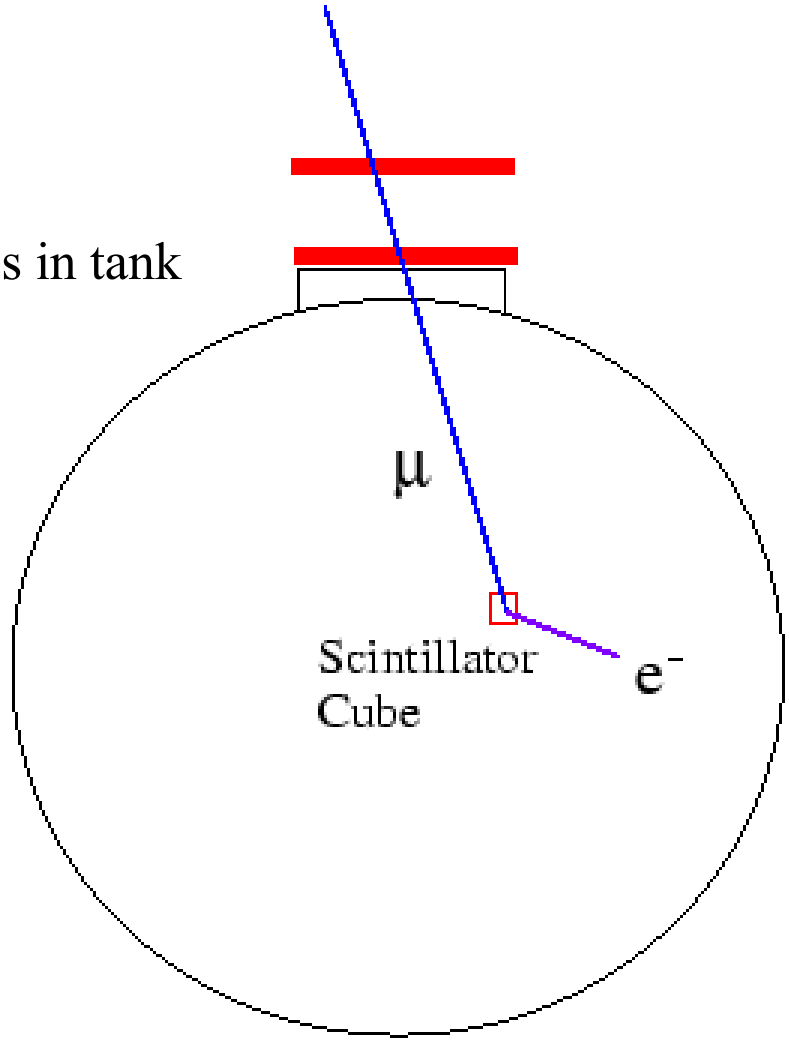
The MiniBooNE "Air Run"

The Muon Tracking System:

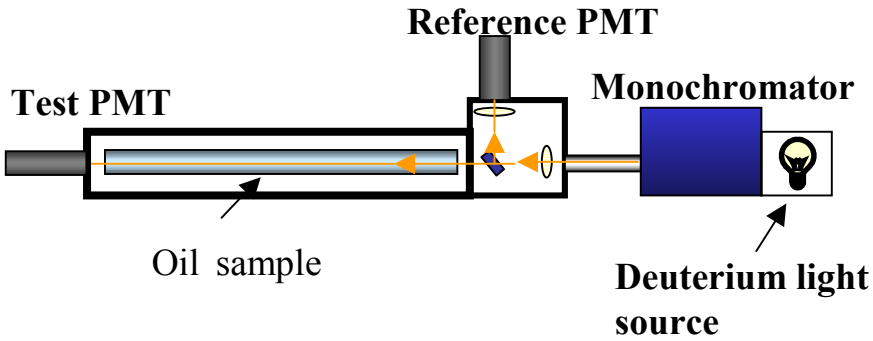
- ❖Scintillator trackers at top of tank
- ❖Optically isolated scintillator cubes in tank

Cross-checking Reconstruction Algorithms:

- ❖Track direction
- ❖Energy
- ❖Vertex position



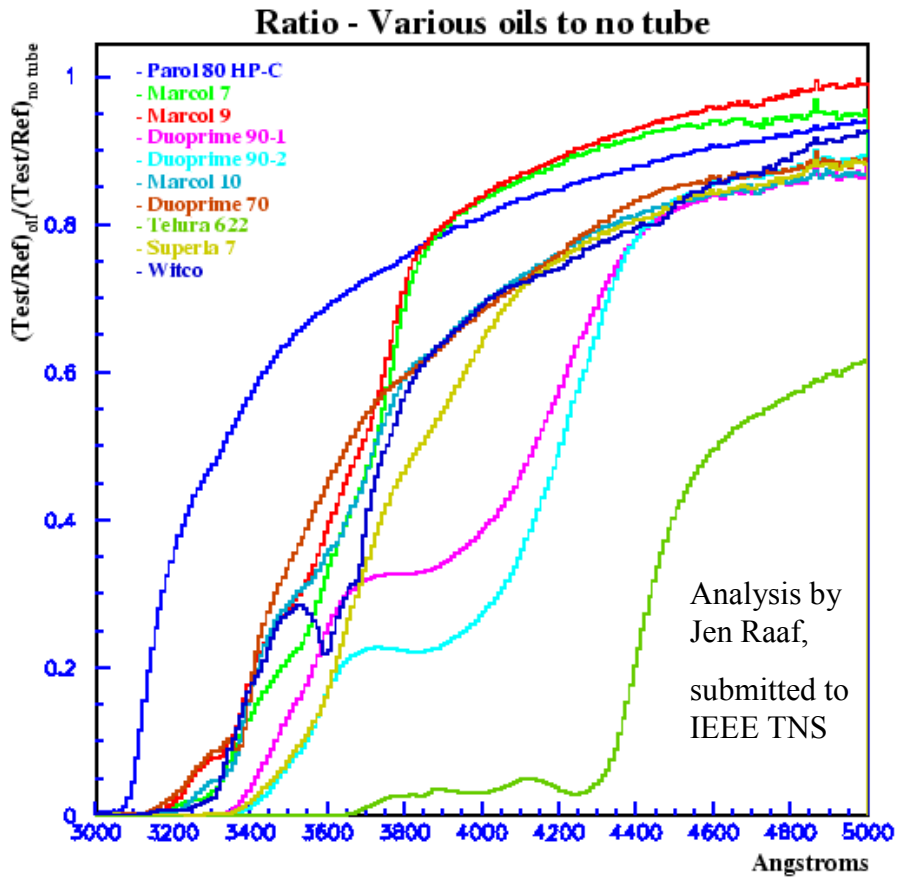
Test 1: Light Transmission *vs* Wavelength



$$\frac{\text{Test PMT}}{\text{Reference PMT}} = \frac{\text{Light transmitted through oil}}{\text{Reference light at that wavelength}}$$

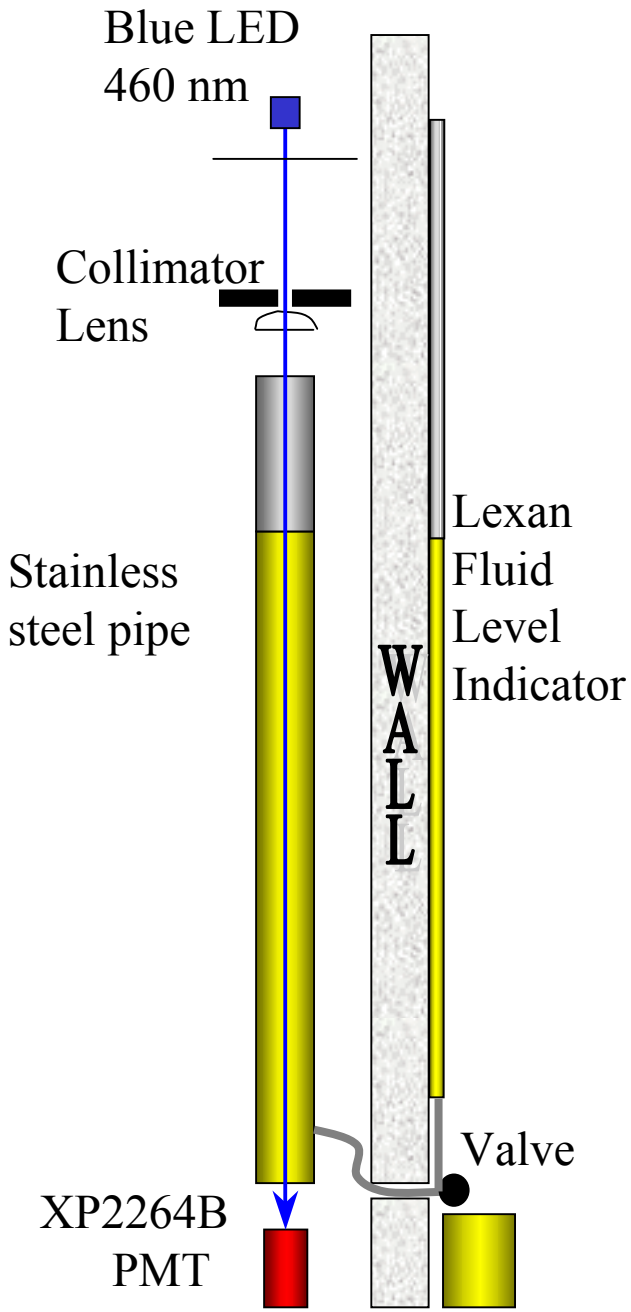
- Test range is 3000-5000 Å
  in steps of 10 Å
- ~ 90% of the light through oil sample
- ~ 10% light to reference PMT

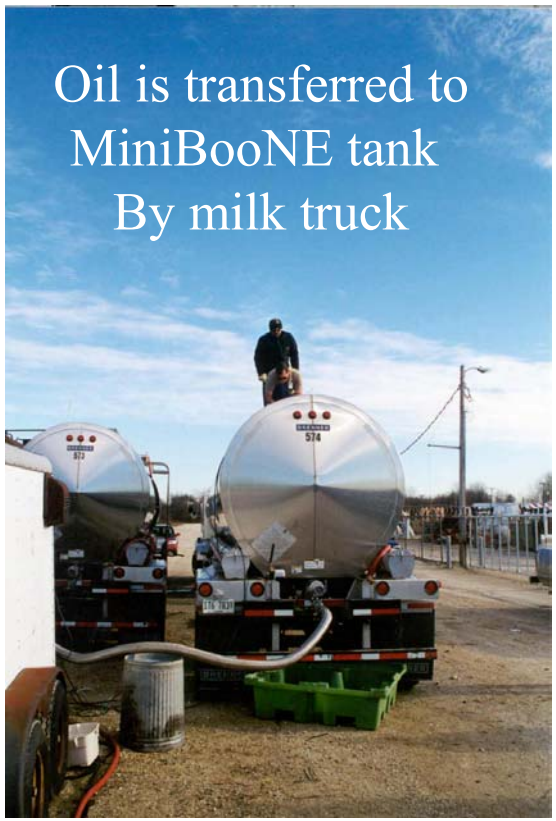
Setup provides ***relative*** attenuation length of different oils and ***shape*** of transmission curve

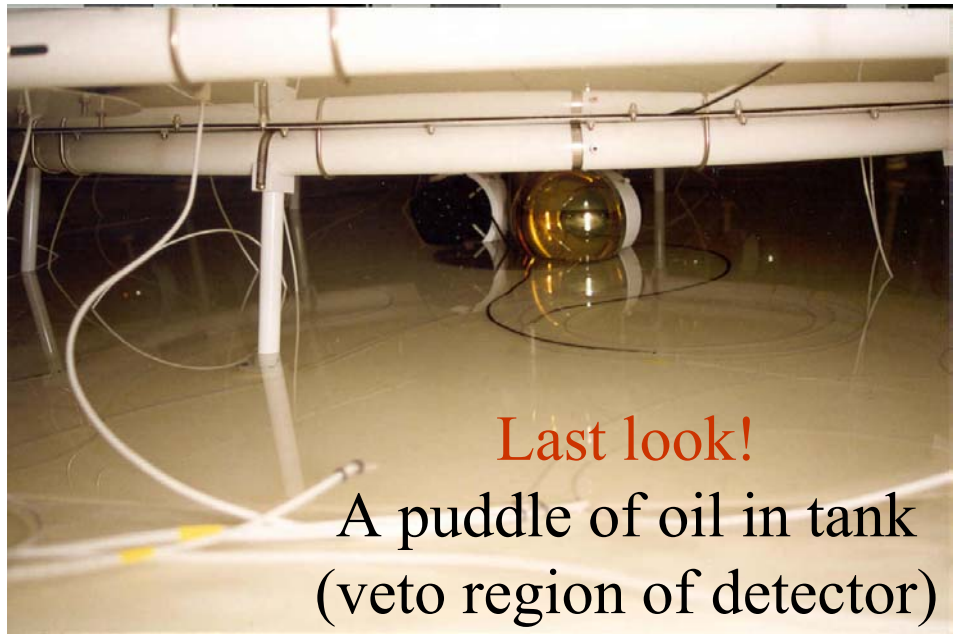


Test 2: Attenuation Length at 460 nm

Oil Sample	Atten. Length (m)
Telura 622	2.21 ± 0.01
Superla 7	9.84 ± 0.09
Witco	10.79 ± 0.11
Duoprime 90-2	12.76 ± 0.14
Duoprime 70	13.96 ± 0.16
Duoprime 90-1	14.33 ± 0.19
Marcol 10	14.52 ± 0.18
Parol 80 HP-C	15.41 ± 0.21
Marcol 9	23.65 ± 0.46
Marcol 7	**26.45 ± 0.59**





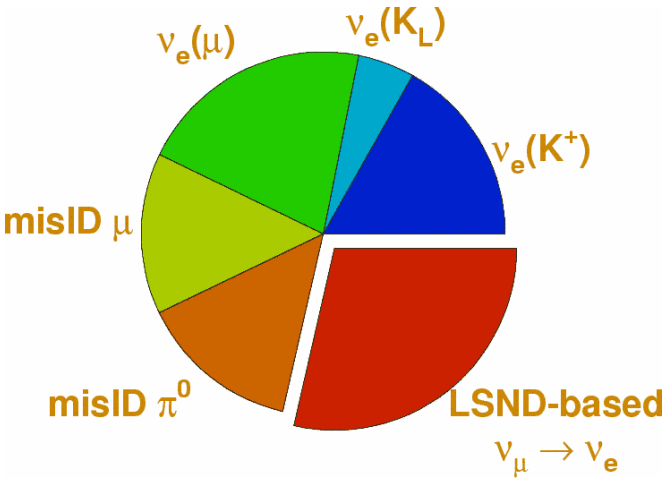


We are filling the tank now!

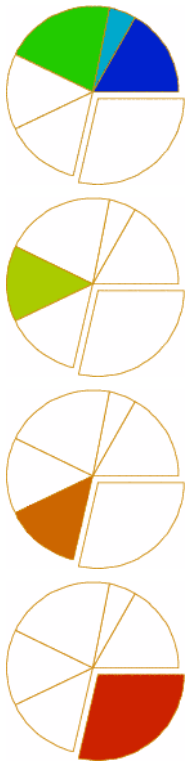
Throughout run we will test:

- Attenuation length
- Scintillation light output

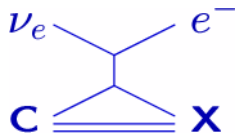
(at Indiana University Cyclotron Facility)



Approximate number of electron neutrino-like events expected in MiniBooNE with two years of running before cuts

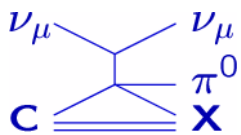


Intrinsic ν_e background: 1,000 events

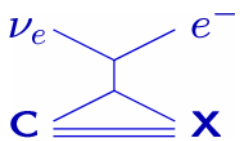


μ mis-ID background: 500 events

π^0 mis-ID background: 500 events

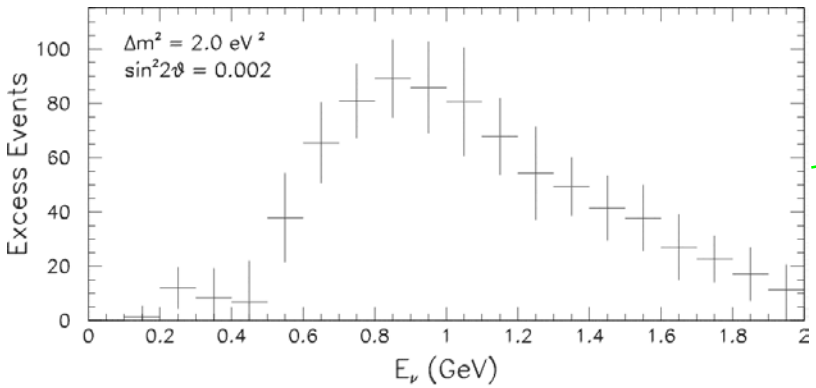


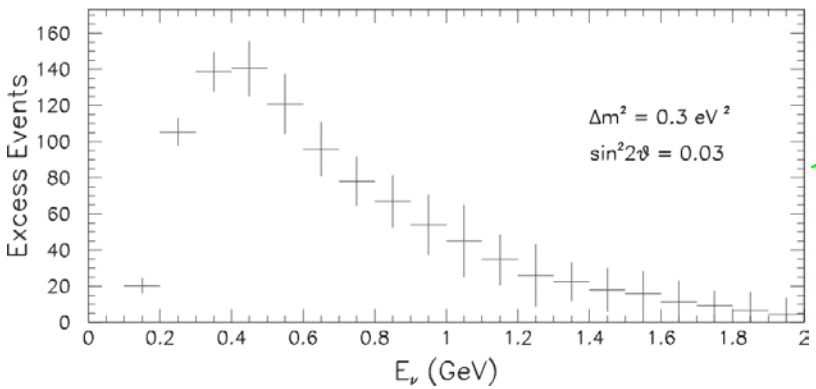
LSND-based $\nu_\mu \rightarrow \nu_e$: 1,000 events

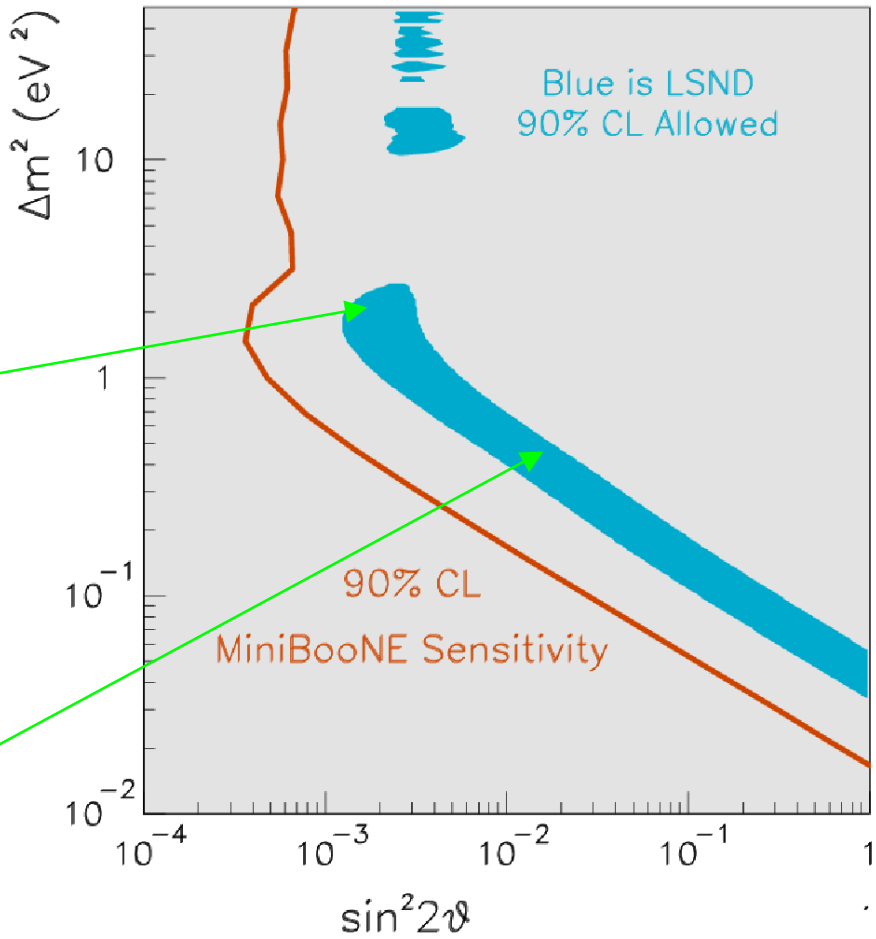


MiniBooNE Sensitivity to LSND

With two years of running MiniBooNE should be able to completely include or exclude the entire LSND signal region.







Conclusions

- Karmen has partially addressed the LSND Question
- MiniBooNE will complete the job
- We are on target to start taking data in late spring 2002.
- We will run for two years in ν mode with a total of 10^{21} pot.
- With this data we should be able to confirm or rule out the full high Δm^2 oscillation range of LSND.
- We are studying several other possible ν physics topics
- We may also run for two years in $\bar{\nu}$ mode.
- Possible upgrade to BooNE in event of a signal:

  a two detector experiment to carefully measure Δm^2.