MiniBooNE: Status and plans

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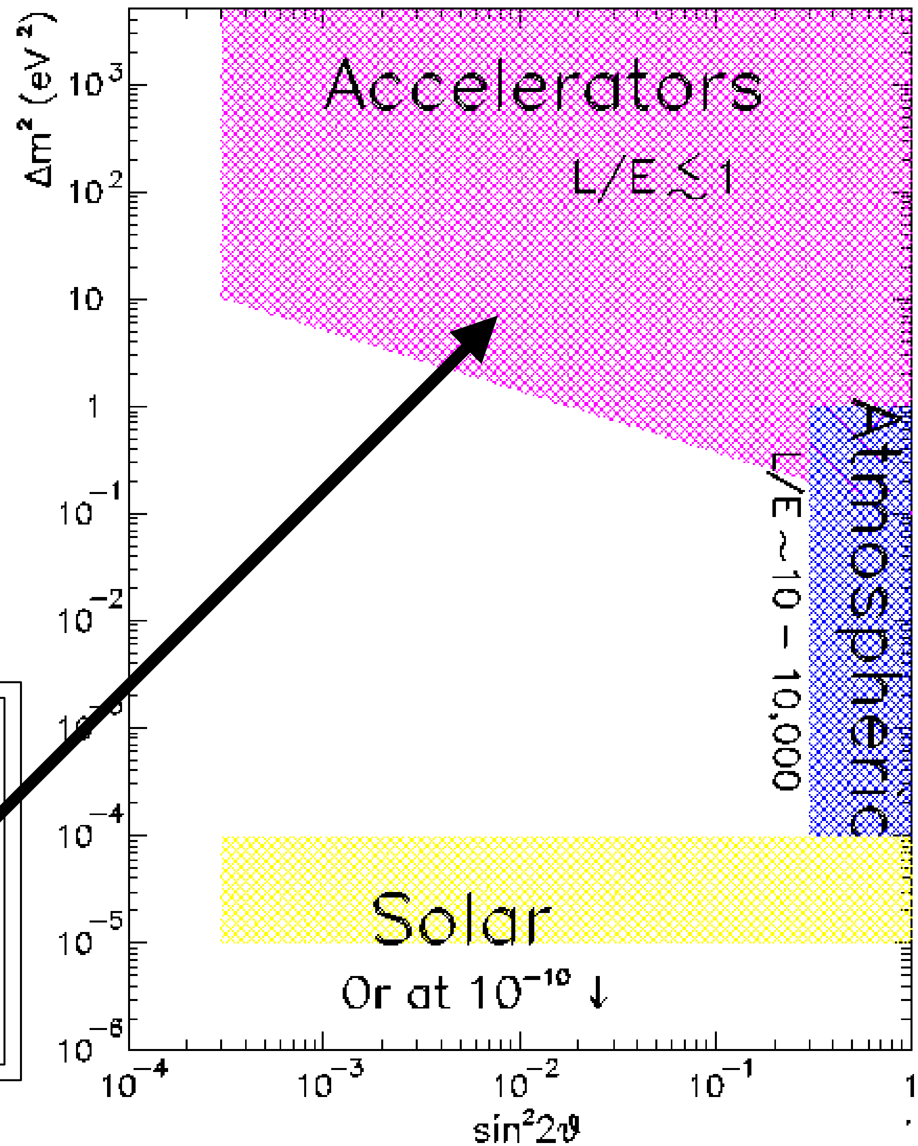
ICHEP, Amsterdam, 27 July 2002

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

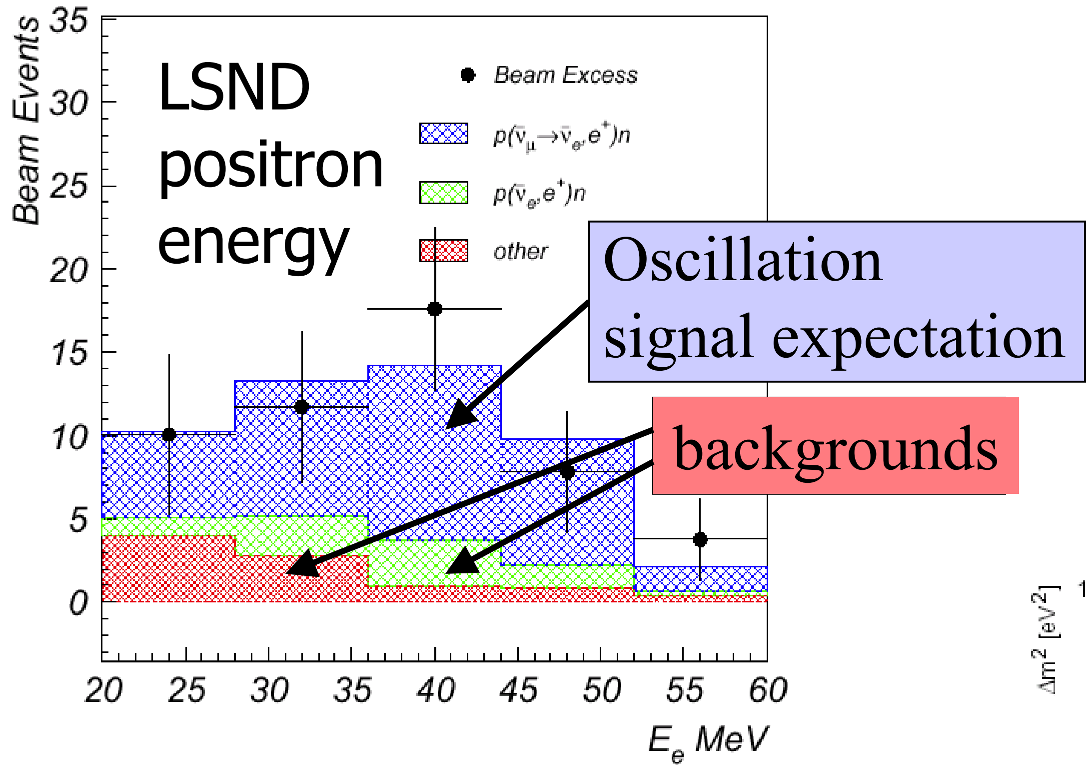
LSND and Karmen II Results

Status of MiniBooNE



LSND and KARMEN search for $\overline{\nu}_\mu \to \overline{\nu}_e$

Source is μ^+ decay at rest endpoint energy 53 MeV



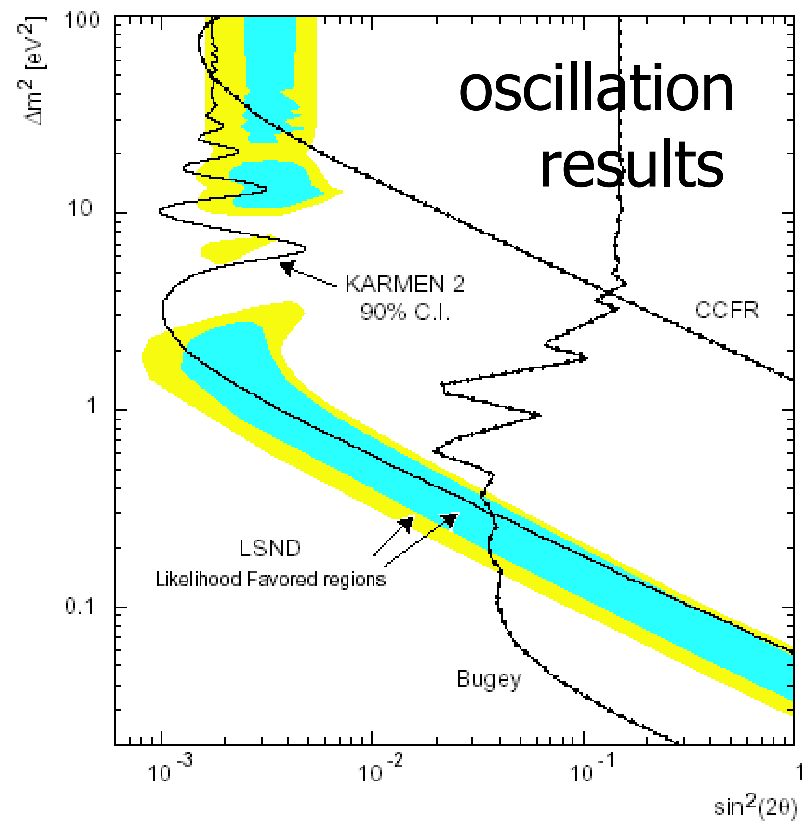
LSND

Signal above background:

87.9±22.4±6.0 events

Oscillation Probability:

(0.264±0.067±0.045)%



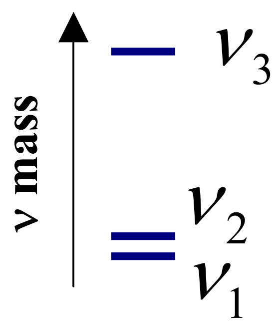
KARMEN 2

Excludes part of LSND region

ν Oscillation Scenarios:

With current results from solar, atmospheric, and LSND ν–oscillation searches (3 Δm^2s), we have an interesting situation:

Only 3 active ν:

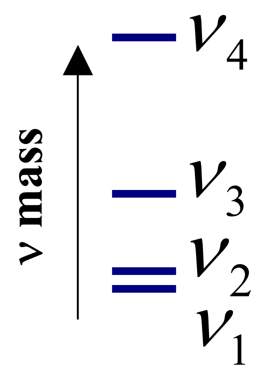


OR...

$$\text{solar}: \nu_e \to \nu_\mu$$
$$\text{atmos}: \nu_\mu \to \nu_e, \nu_\tau$$
$$\text{LSND}: \bar{\nu}_\mu \to \bar{\nu}_\tau \to \bar{\nu}_e$$

- not a good fit to data

3 active+1 sterile ν:

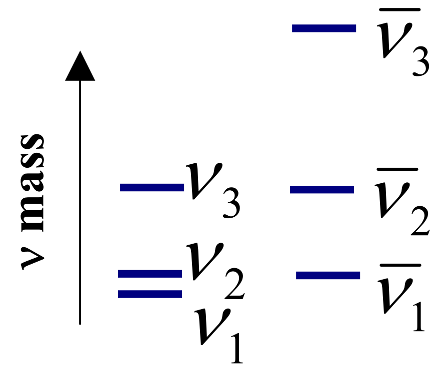


OR...

$$\text{solar}: \nu_e \to \nu_\mu, \nu_\tau$$
$$\text{atmos}: \nu_\mu \to \nu_\tau$$
$$\text{LSND}: \bar{\nu}_\mu \to \bar{\nu}_s \to \bar{\nu}_e$$

- possible(?)

CPT violation:



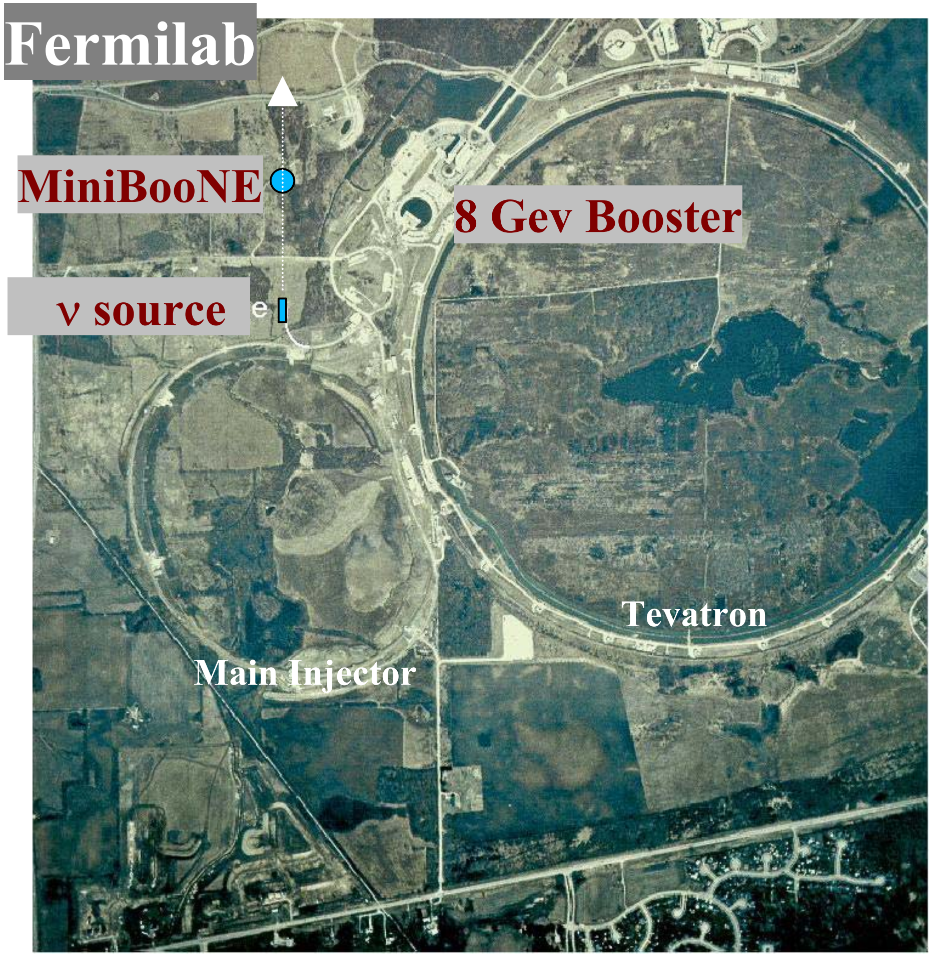
OR...

$$\text{solar}: \nu_e \to \nu_\mu$$
$$\text{atmos}: \nu_\mu \to \nu_\tau$$
$$\text{LSND}: \bar{\nu}_\mu \to \bar{\nu}_e$$

- possible(?)

Need to definitively check the LSND result.

Enter: MiniBooNE



High statistics

×10 more events than LSND (~2 calendar years)

Different systematics

× 10 higher beam energy
different event signatures and backgrounds

High significance

5σ over entire LSND region as a "counting experiment" (more significant when energy dependence is included)

Start to run in summer 2002

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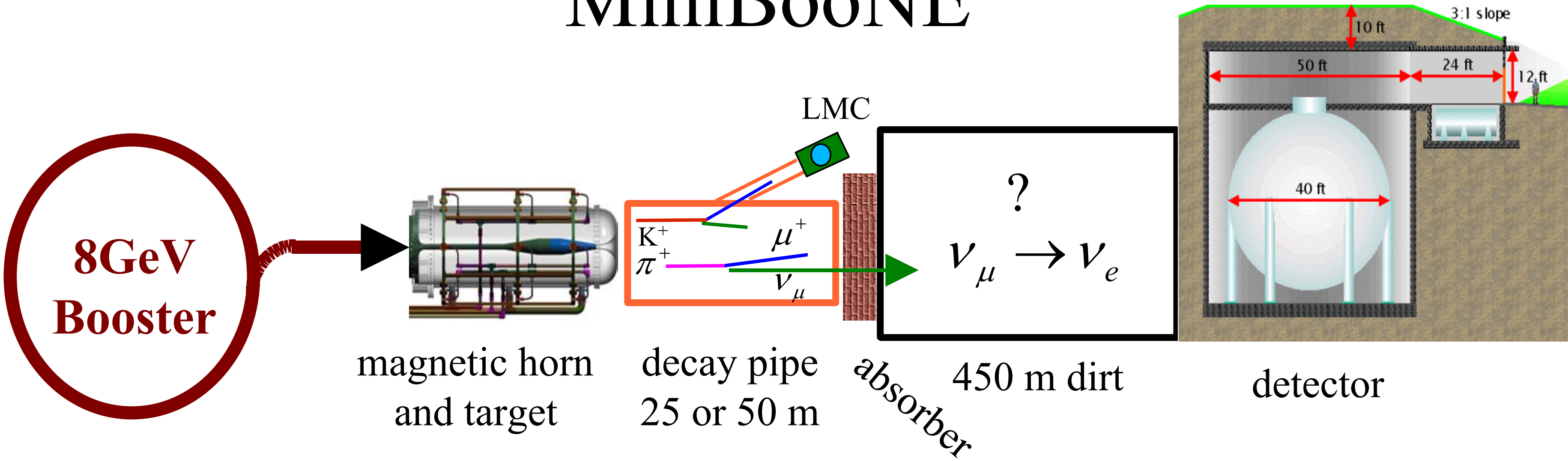
MiniBooNE



The FNAL Booster

injects beam to the Be target

resulting mesons decay

neutrinos traverse 450 m of dirt

to the oil-based Cherenkov detector

source:

$\pi^+ \to \mu^+ \nu_\mu$ search for $\nu_\mu \to \nu_e$, which leads to e^- in detector

backgrounds are: ν_μ interactions with mis-id μ^- or π^0 as e^-

intrinsic ν_e in the beam from μ^+ or K-meson decay

The 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 + MiniBooNE
5×10^{12} protons per pulse, machine running at a rate of 7 Hz
(5 Hz for MiniBooNE)

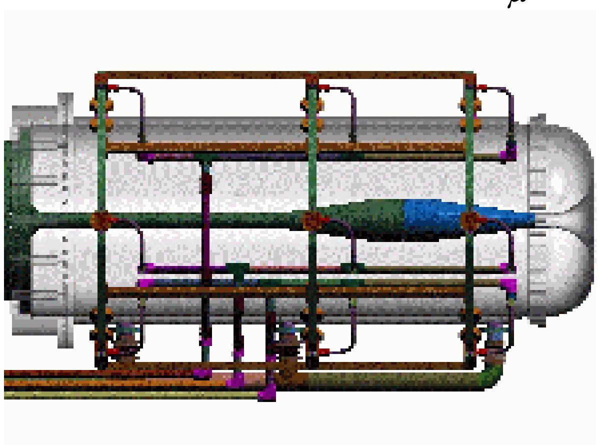
MiniBooNE: 5×10^{20} protons on target in one year

Due to radiation issues it will be a challenge to reach these goals.

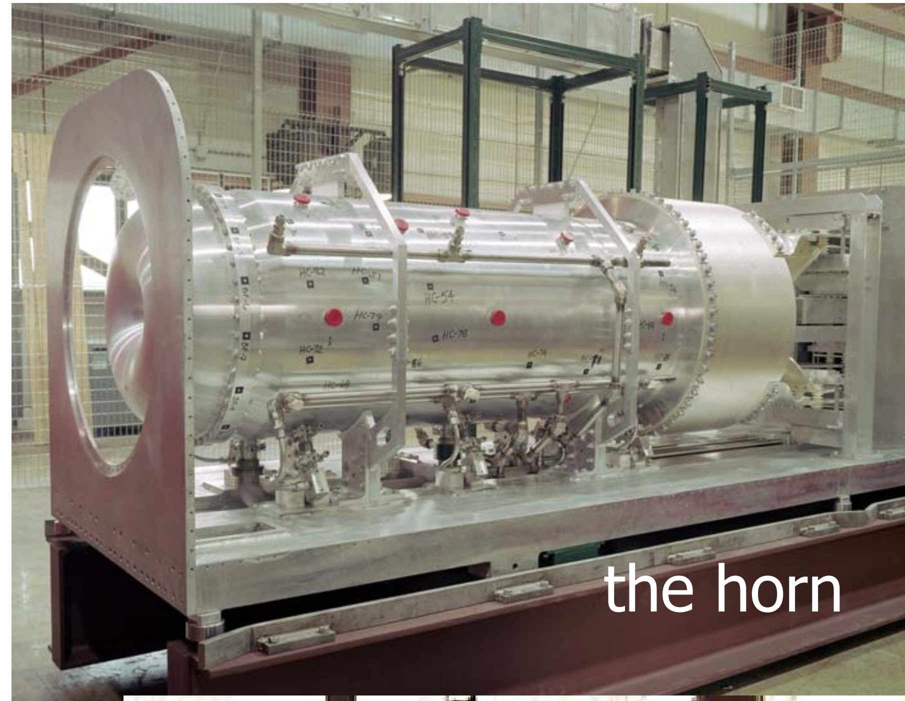
A magnetic horn focuses the charged particles to the detector.

Initially positive particles will be focused (neutrinos) $\pi^+ \rightarrow \mu^+ \nu_\mu$

then the horn current can be reversed (antineutrinos) $\pi^- \rightarrow \mu^- \bar{\nu}_\mu$



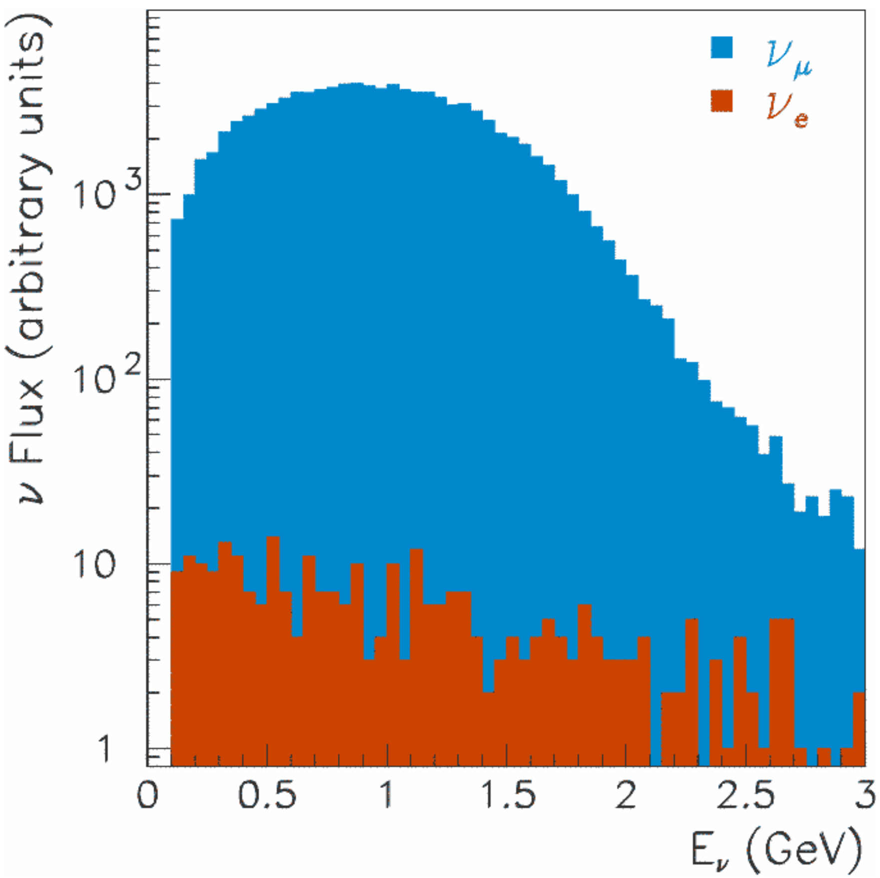
170 kA in 140 μsec pulses @ 5 Hz



Tested to 10 million pulses behaves as expected (vibration, temperature, etc.)

Neutrino Flux at the Detector

The L/E ~1 m/MeV is similar to that at LSND.



-8 GeV protons on Be:

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

-yield a high flux of ν_μ :

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

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

-with a low background of ν_e :

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

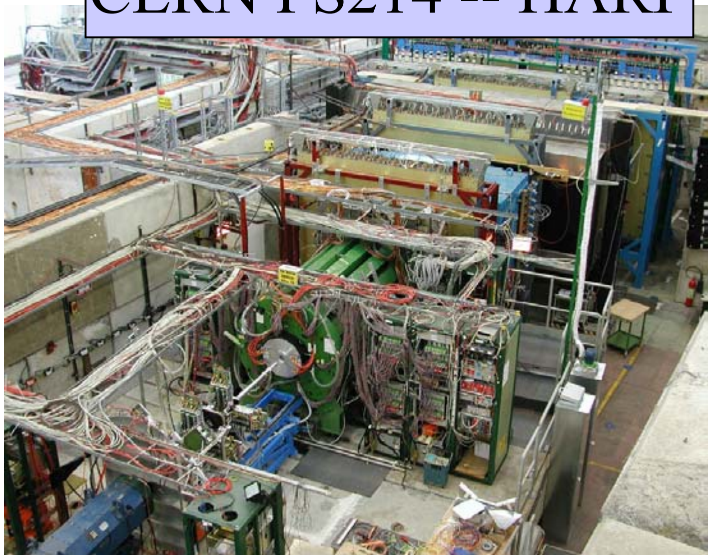
$\mathbf{K^+} \rightarrow \pi^0 e^+ \nu_e$, $K^0_L \rightarrow \pi^- e^+ \nu_e$

Flux estimate is important!

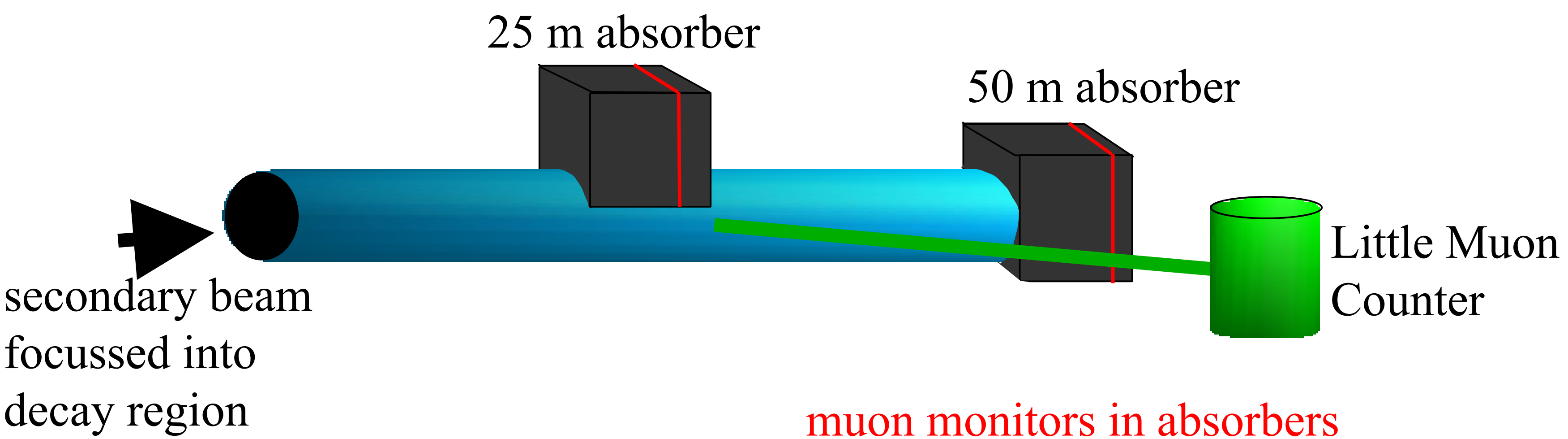
Secondary particle production

Meson production
by 8 GeV protons
on MiniBooNE target slug
will be measured by
the HARP experiment at CERN
in August.

CERN PS214 -- HARP



MiniBooNE secondary beam cross-checks



MiniBooNE secondary beam cross-checks

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

checks μ background

Rate of ν_μ from π depends on L, whereas rate of ν_e from μ depends on L^2.

Therefore, if an excess is the signal, the rate will change by $\times 2$

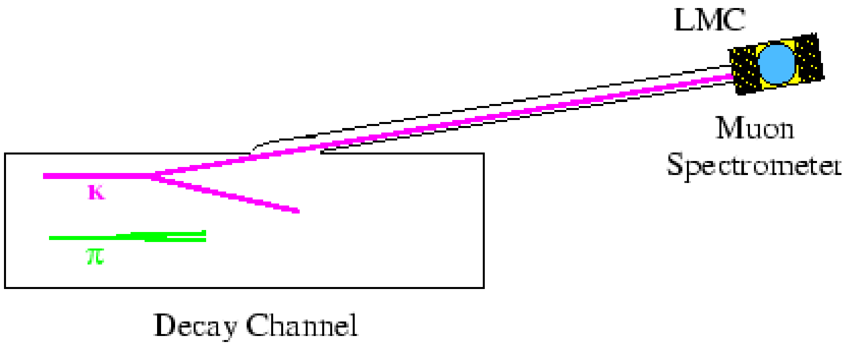
Excess from unmodeled ν_e from μ decay will change by $\times 4$

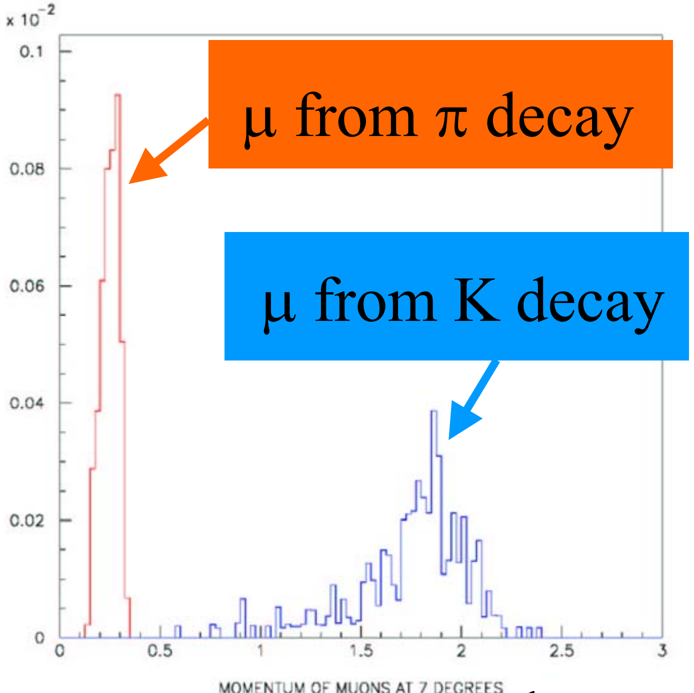
-Little Muon Counter (LMC)

checks K background

Exploits wide-angle decays of kaons

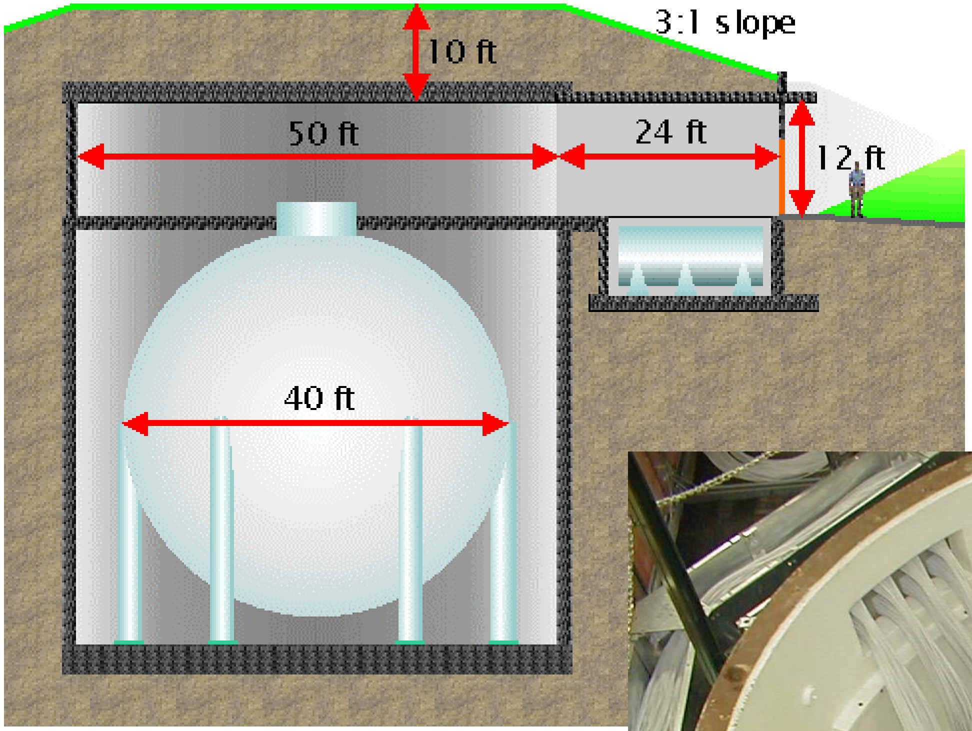
to measure their presence





muon momentum at 7 degrees

MiniBooNE detector



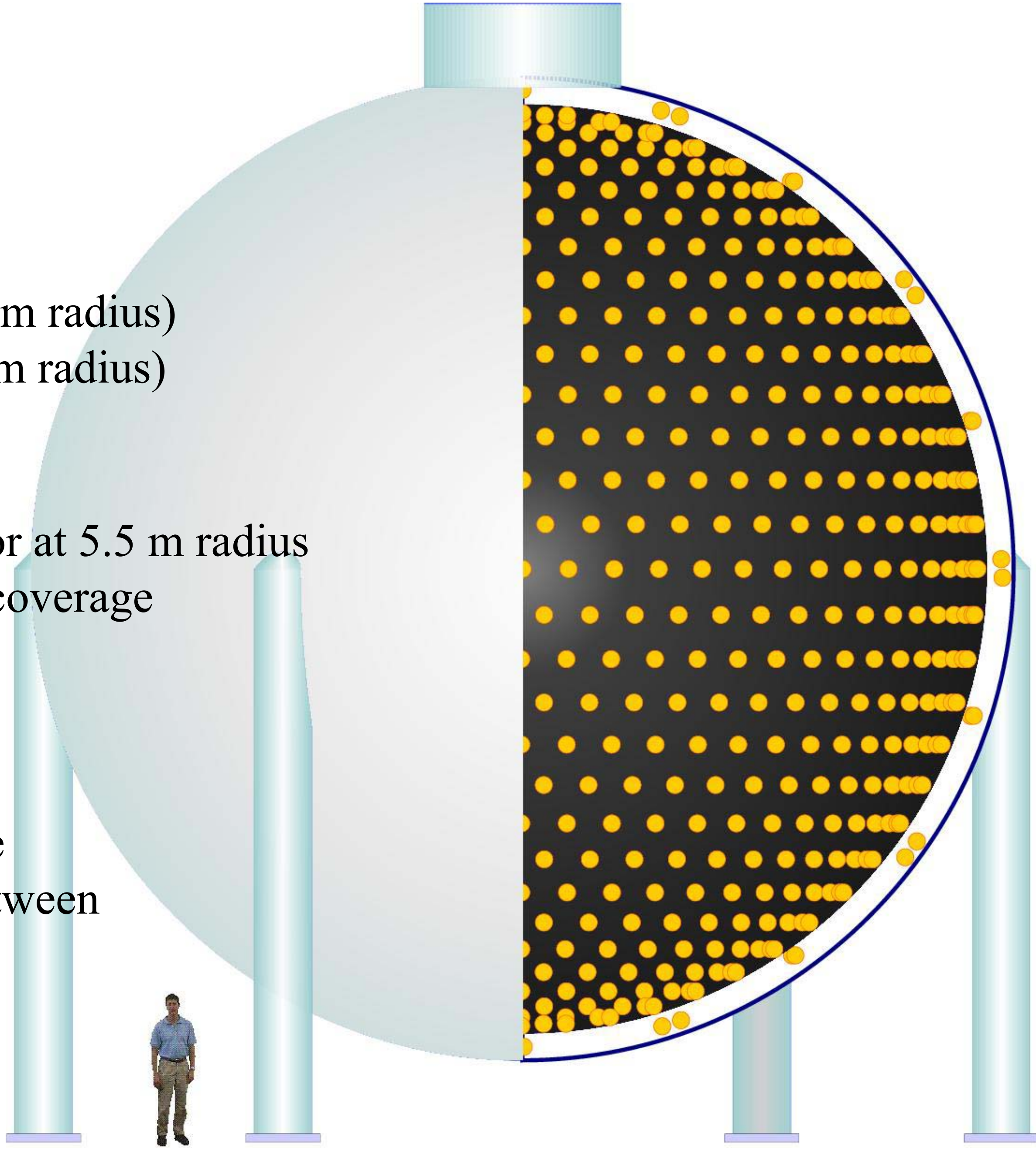
MiniBooNE detector

pure mineral oil

total volume: 800 tons (6 m radius)
fiducial volume: 445 tons (5m radius)

1280 20-cm PMTs in detector at 5.5 m radius
→ 10% photocathode coverage
240 PMTs in veto

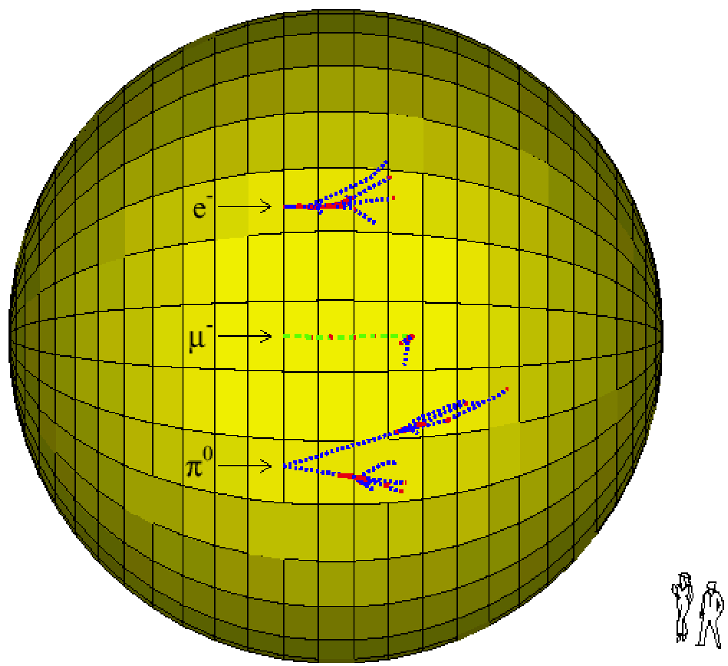
Phototube support structure provides opaque barrier between veto and main volumes

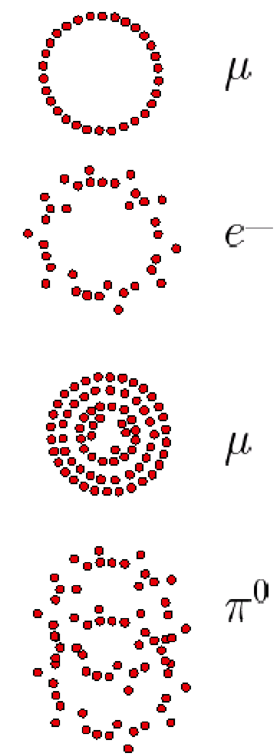


Analysis: e, μ, π^0 discrimination

Pattern of hit tubes (with energy and time information) allows for the separation of different event types.

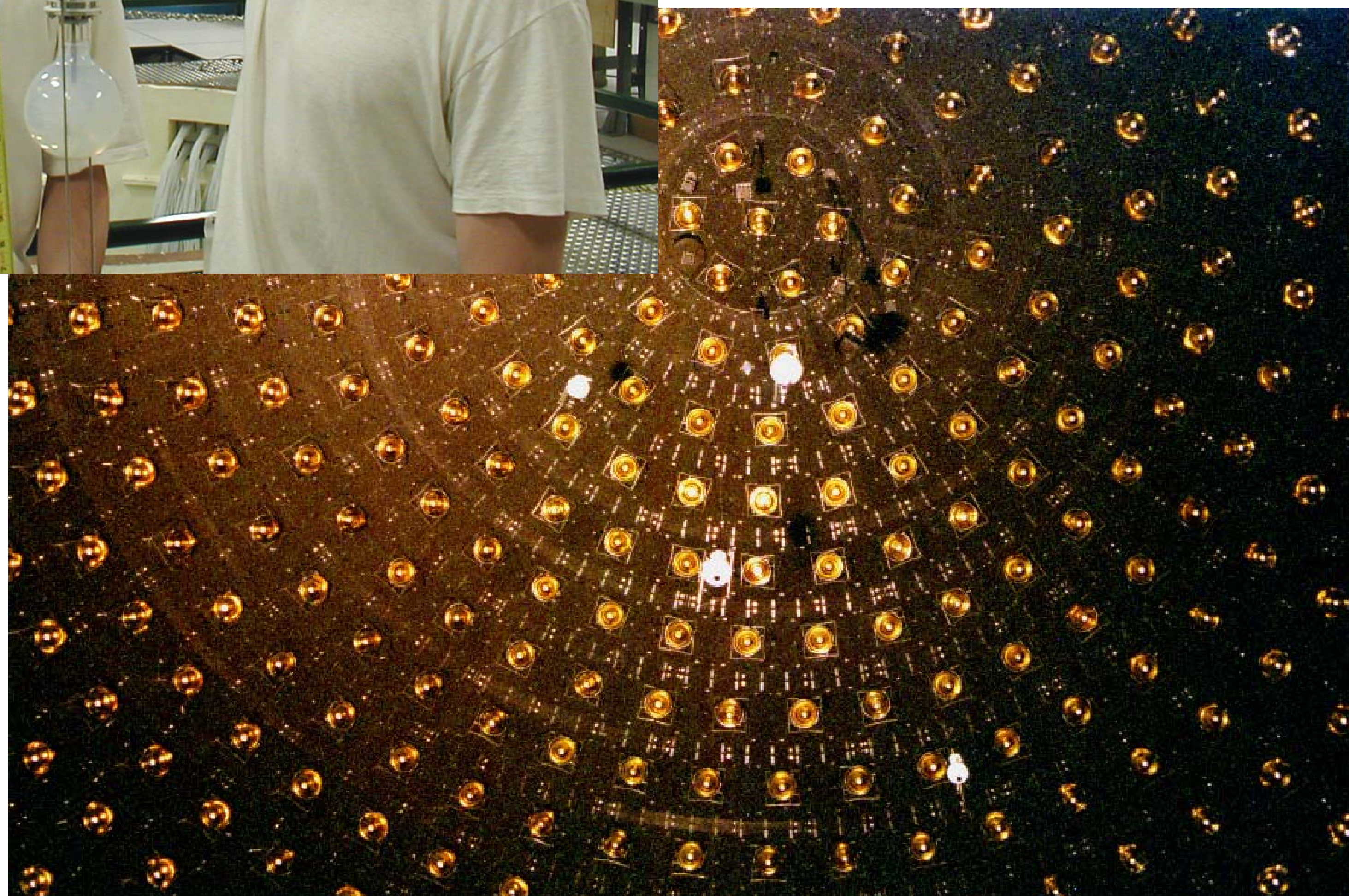
signatures substantially different from LSND
- x10 higher energy
- neutron capture does not play a role





Laser calibration system

four Ludox-filled flasks attached to fiber optic cables

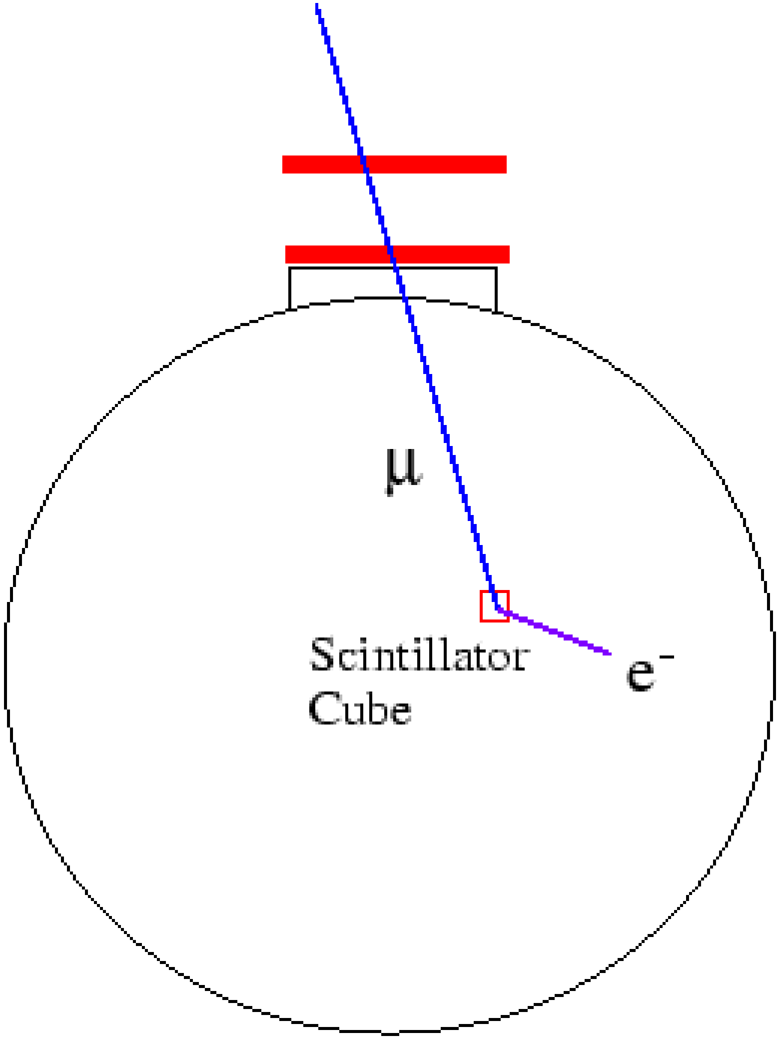


provide:
PMT gain and timing

and
oil attenuation length monitoring

Stopping muon calibration system

Scintillator tracker above the tank



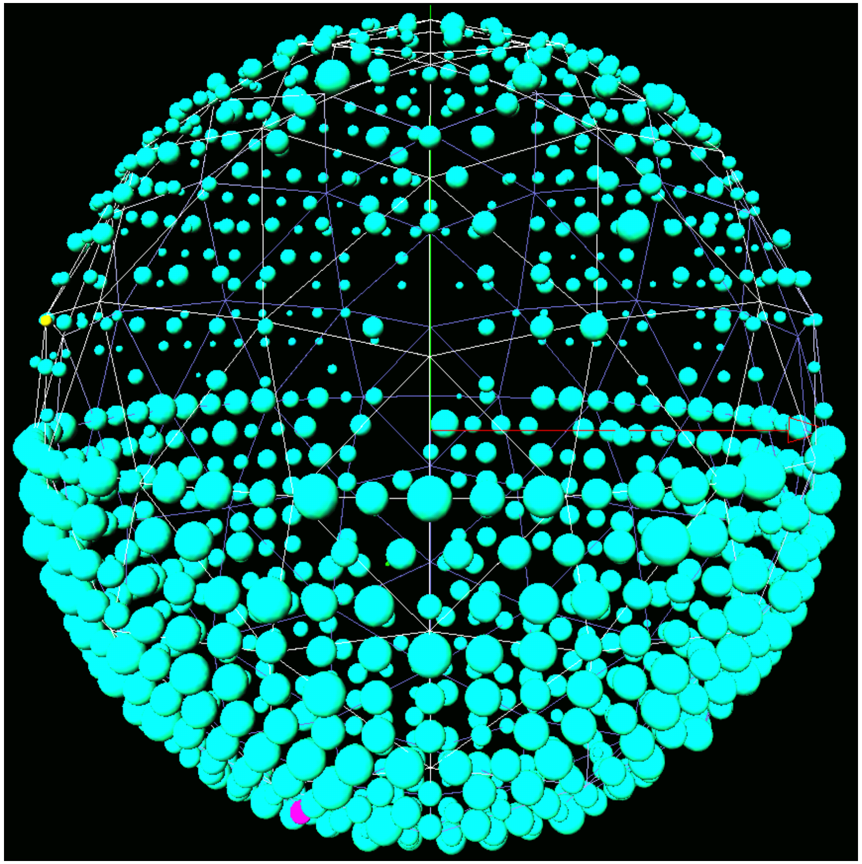
Optically isolated scintillator cubes in tank:
- six 3-inch (7.6 cm) cubes
- one 4-inch cube

Muons with known trajectory through the oil

Provides: range for energy calibration
cross checks on reconstruction algorithms

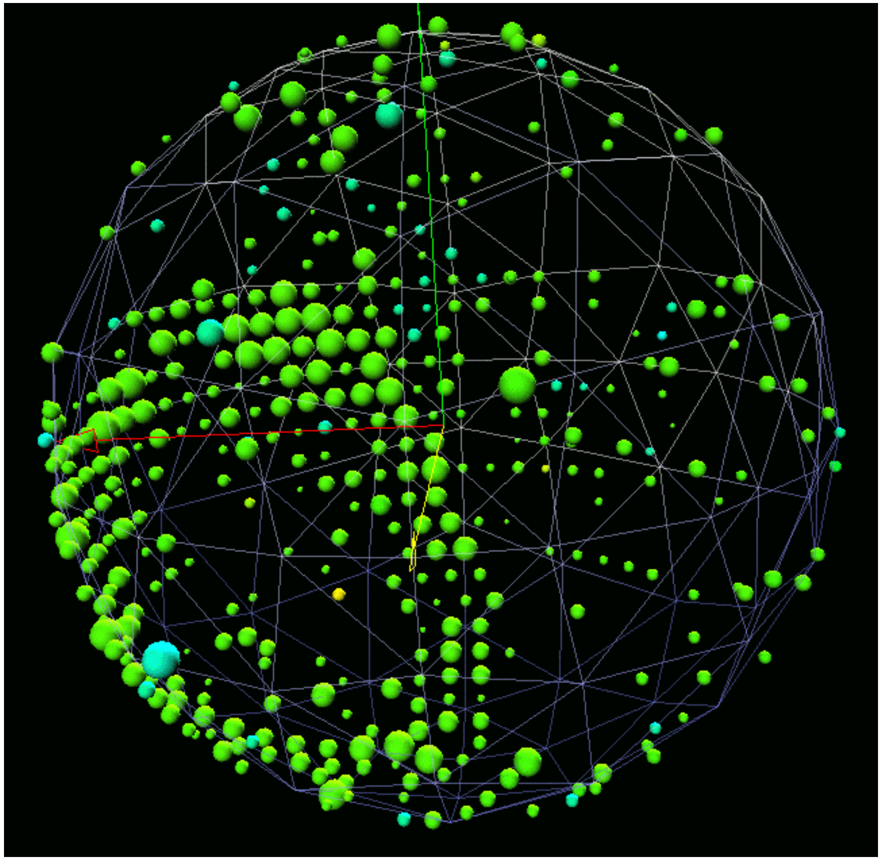
Calibration events are being collected

(size of each hit is proportional to charge)



laser event, tank ~1/2 full of oil

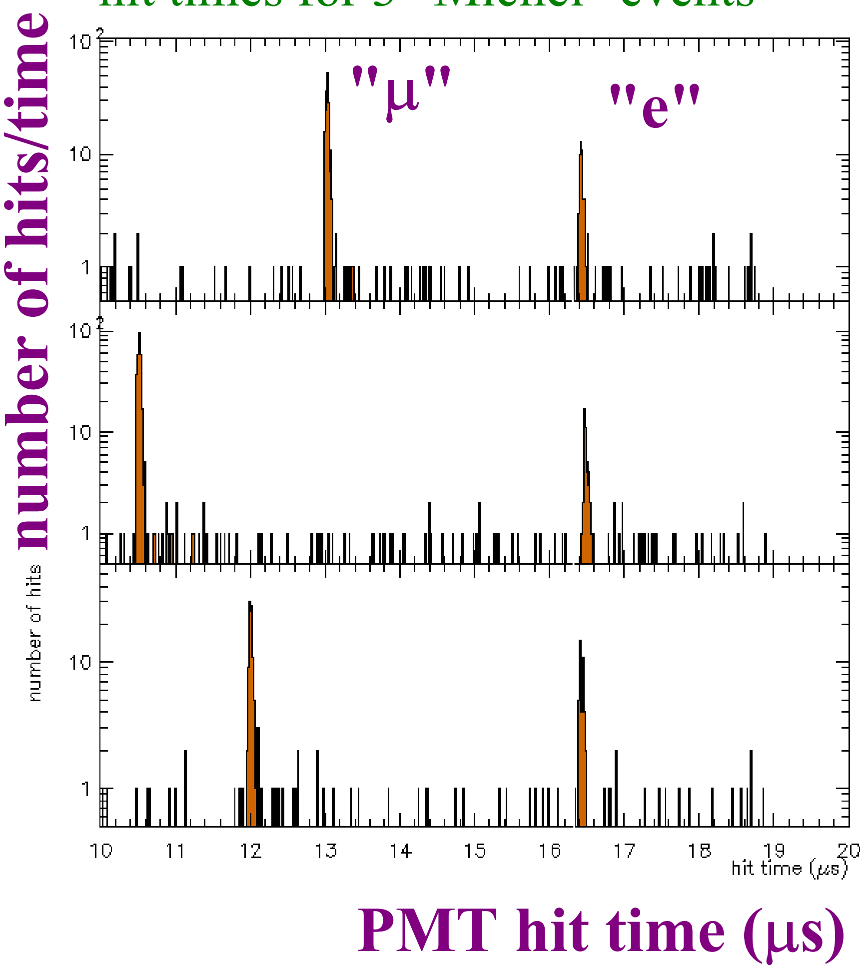
cosmic muon

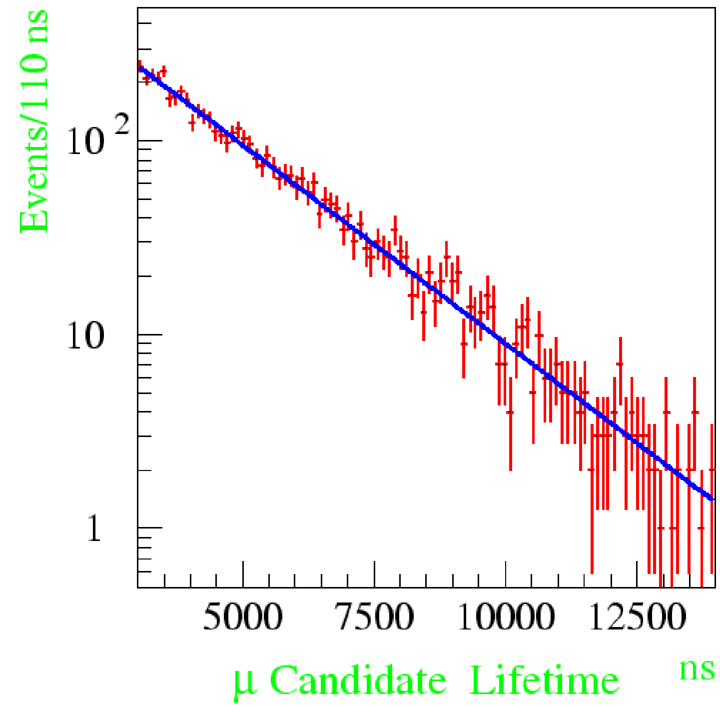


Cosmic Muon Decays

muon stops and the
decay (Michel) electron is observed

hit times for 3 "Michel" events





Fit Lifetime:

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

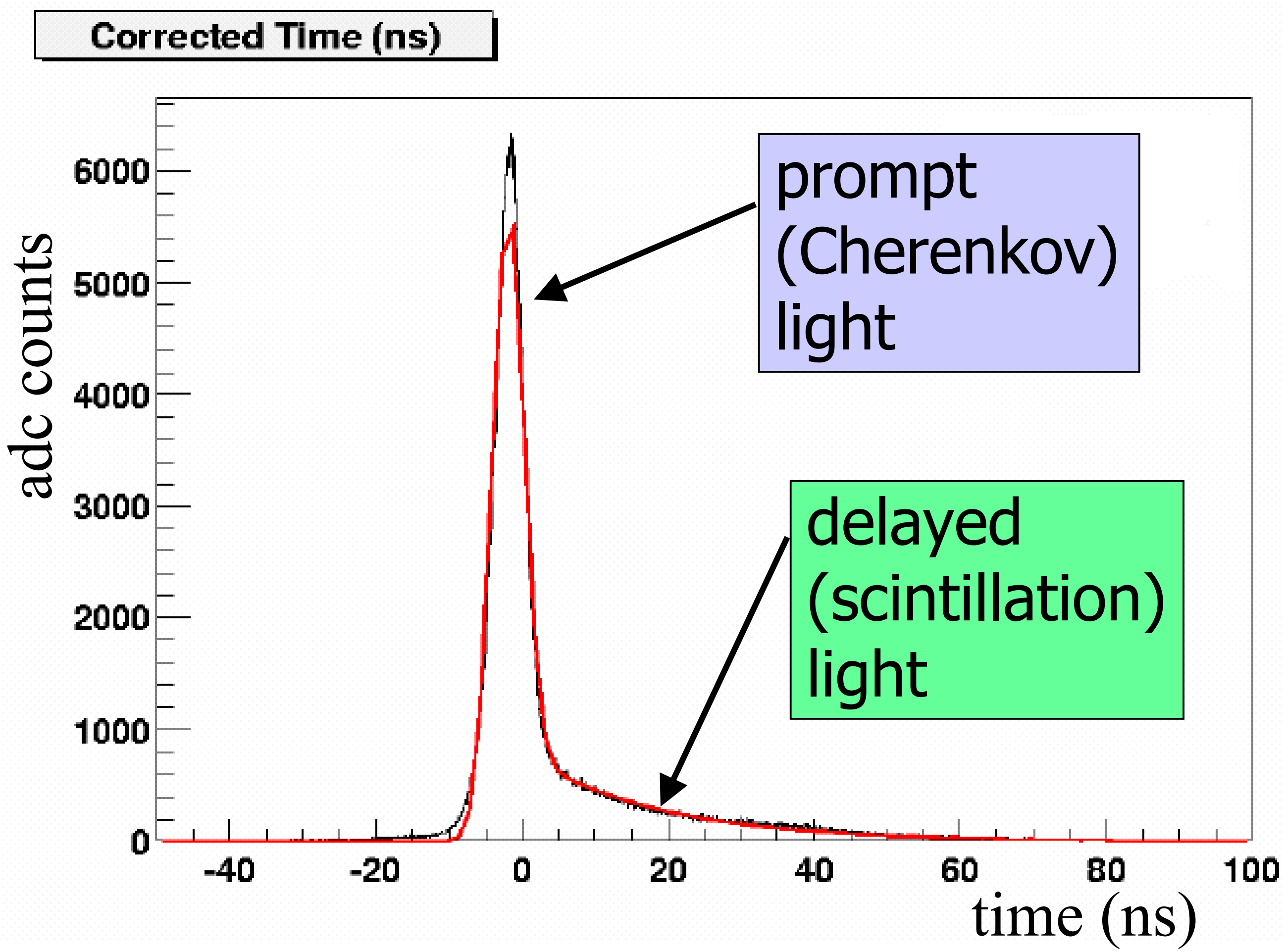
Expected µ lifetime in oil

$2.13\ \mu s$

with 8% μ^- capture on carbon.

Time spectrum of Michel electrons

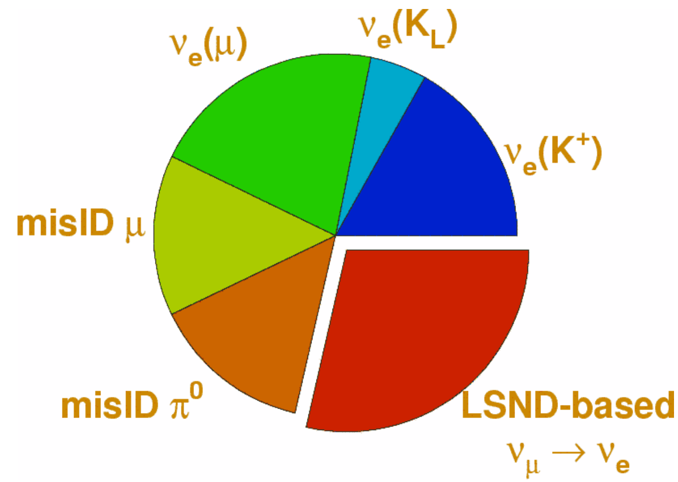
Measure, e.g., time resolution
scintillation time constant



MiniBooNE expected signal

with 10^{21} protons on target (2 years)

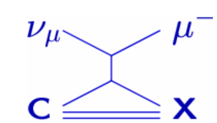
~500k ν_μC charged current events

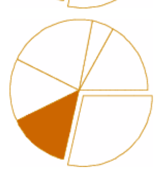


Approximate number of electron neutrino-like events

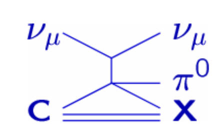
Intrinsic ν_e background: 1,000 events

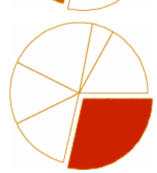
μ mis-ID background: 500 events





π^0 mis-ID background: 500 events

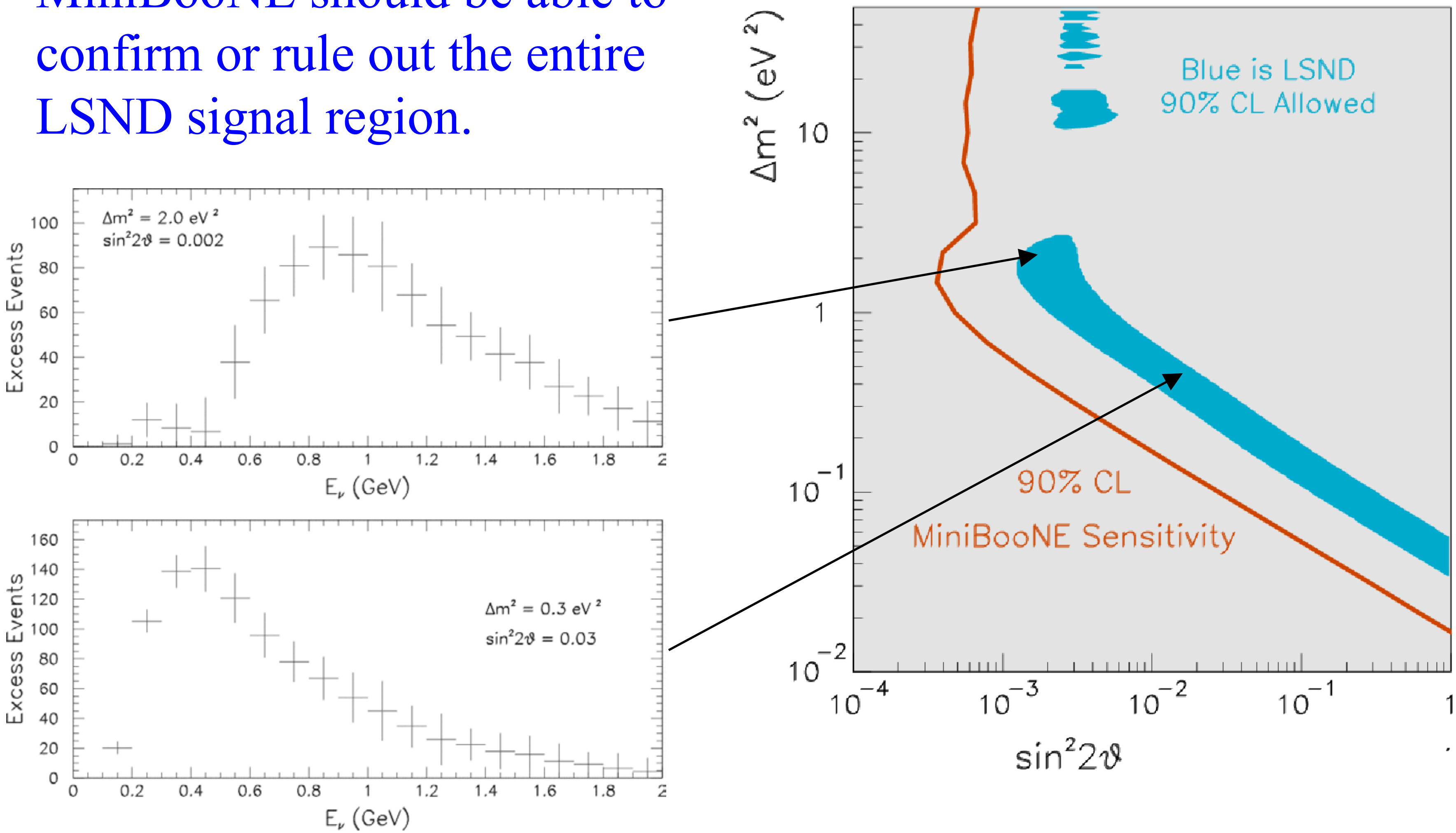




LSND-based $\nu_\mu \to \nu_e$: 1,000 events

MiniBooNE expected sensitivity

With two years of running MiniBooNE should be able to confirm or rule out the entire LSND signal region.



MiniBooNE status

Neutrino beam to be delivered in August.

summer 2002:

May: detector full of mineral oil

June: detector calibration
proton line commissioning
horn installed,
hot horn handling demonstrated

July: horn removed and protons delivered through target pile, study spot size, beam monitors

August: final beam/horn/target configuration and start of high intensity running