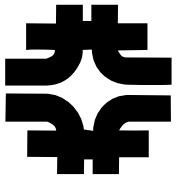
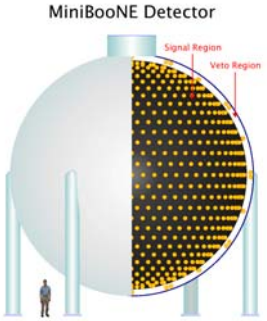


MiniBooNE at Fermilab



Light Transmission Properties of a Pure Mineral Oil Neutrino Detector

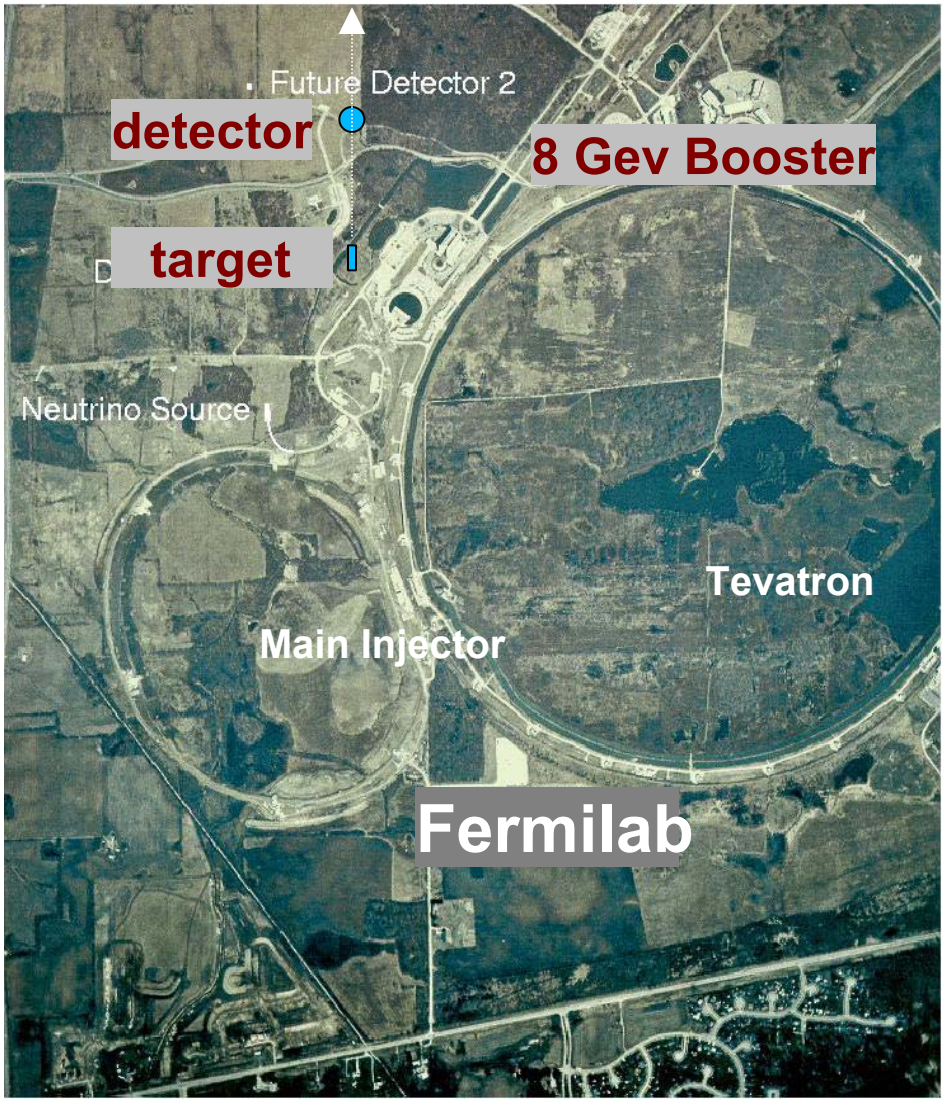
Bruce C. Brown, Fermilab
For the MiniBooNE Collaboration
(Fermilab E898)

BooNE -- Booster Neutrino Experiment

Search for
Appearance of
Electron Neutrinos
in a Muon Neutrino Beam
produced by 8 GeV Protons
On a Be Target

MiniBooNE

Phase I of
BooNE with
One Detector



BooNE: Fermilab Booster Neutrino Experiment

Y. Liu, I. Stancu *Alabama*
S. Koutsoliotas *Bucknell*
E. Hawker, R.A. Johnson, J.L. Raaf *Cincinnati*
T. Hart, E.D. Zimmerman *Colorado*
A. Aguilar-Arevalo, L.Bugel, J.M. Conrad,
J. Formaggio, J. Link, J. Monroe, D. Schmitz,
M.H. Shaevitz, M. Sorel, G.P. Zeller *Columbia*
D. Smith *Embry Riddle*
L.Bartoszek, C. Bhat, S J. Brice, B.C. Brown,
D.A. Finley, 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. Nienaber, E. Prebys,
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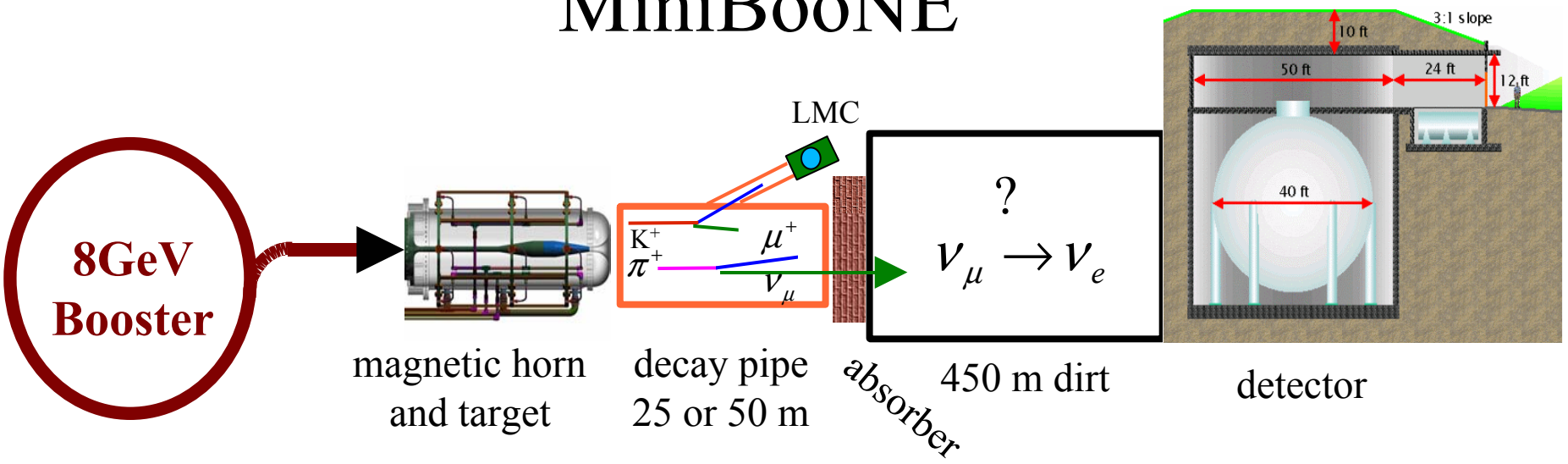
G.T. Garvey, C. Green, W.C. Louis, G.McGregor,
S.McKenney, G.B. Mills, V. Sandberg,
B. Sapp, R. Schirato, R. Van de Water,
D.H. White *Los Alamos*
R. Imlay, W. Metcalf, M. Sung, M.O. Wascko
Louisiana State
J. Cao, Y. Liu, B.P. Roe *Michigan*
A.O. Bazarko, P.D. Meyers, R.B. Patterson,
F.C. Shoemaker, H.A.Tanaka *Princeton*

MiniBooNE



8-GeV protons on Be target →

π^+, K^+,…, focused by horn

decay in 50-m pipe, mostly to ν_μ

all but ν absorbed in steel and dirt

ν's interact in 40-ft tank of mineral oil

charged particles produce light

detected by phototube array

Look for electrons produced by mostly-ν_μ beam

The MiniBooNE detector

MiniBooNE detector

pure mineral oil (Cherenkov:scint ~ 3:1)

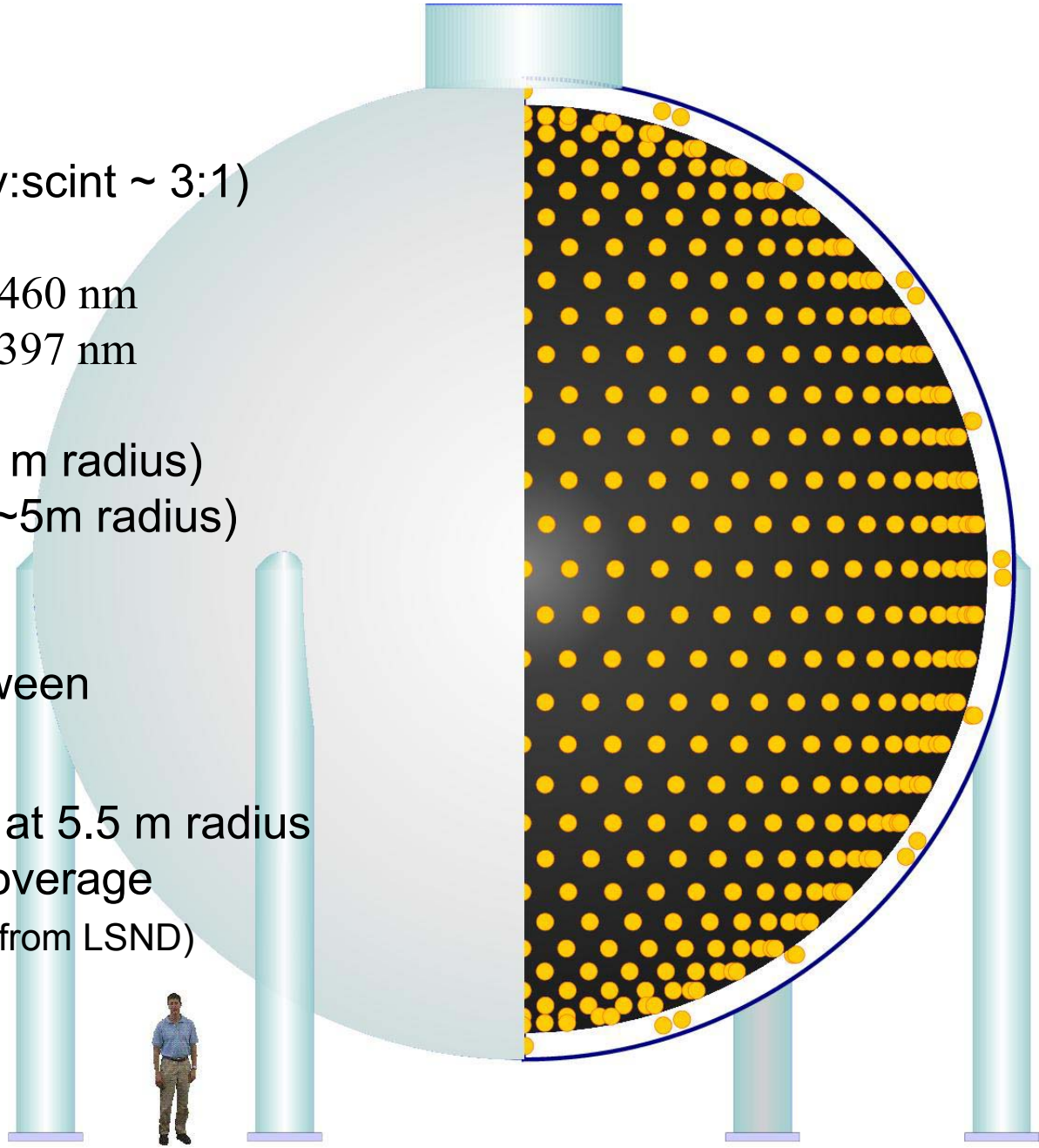
- no scintillator added
- Attenuation Length >20 m at 460 nm
- Attenuation Length ~10 m at 397 nm

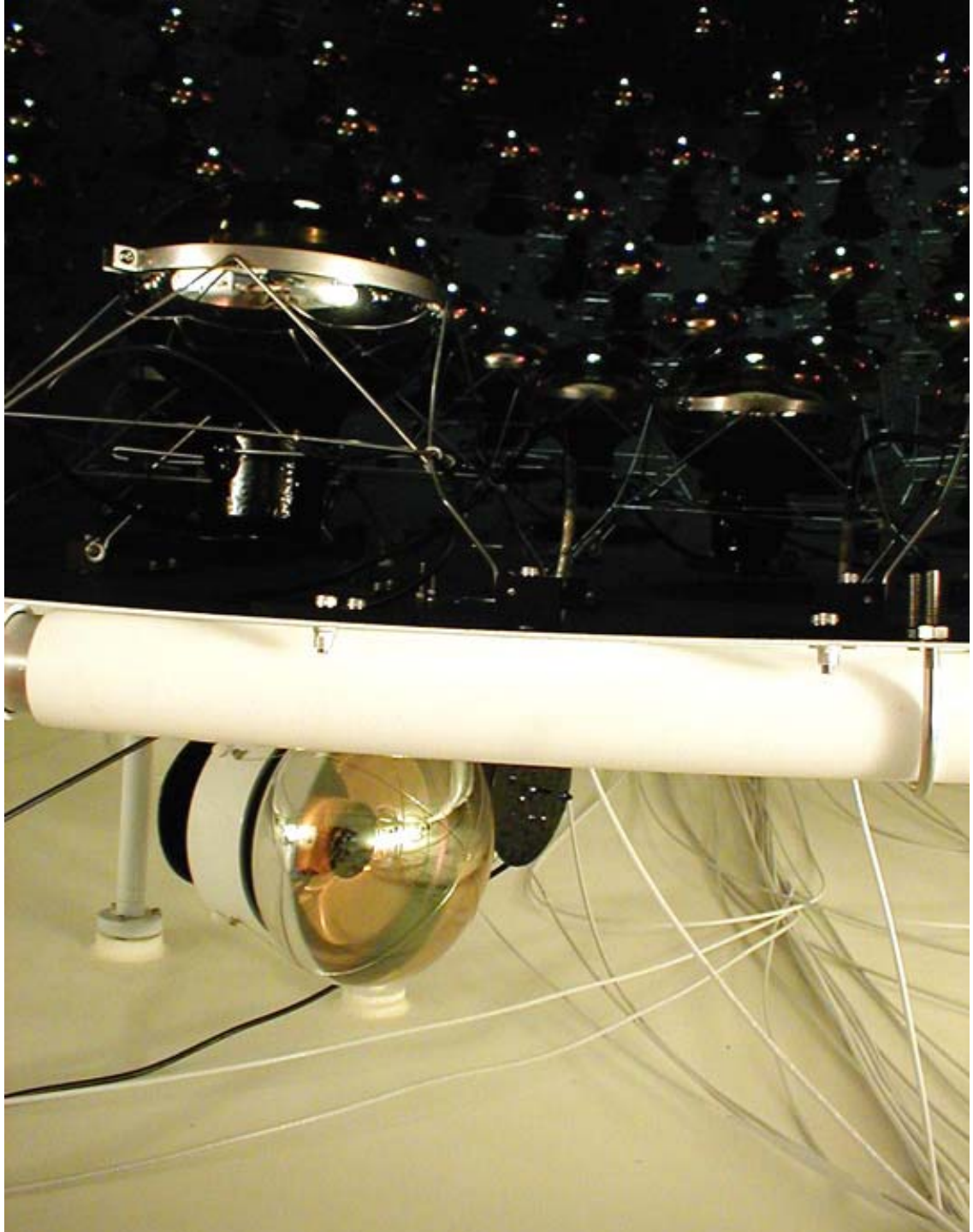
total volume: 800 tons (6 m radius)
fiducial volume: ~445 tons (~5m radius)

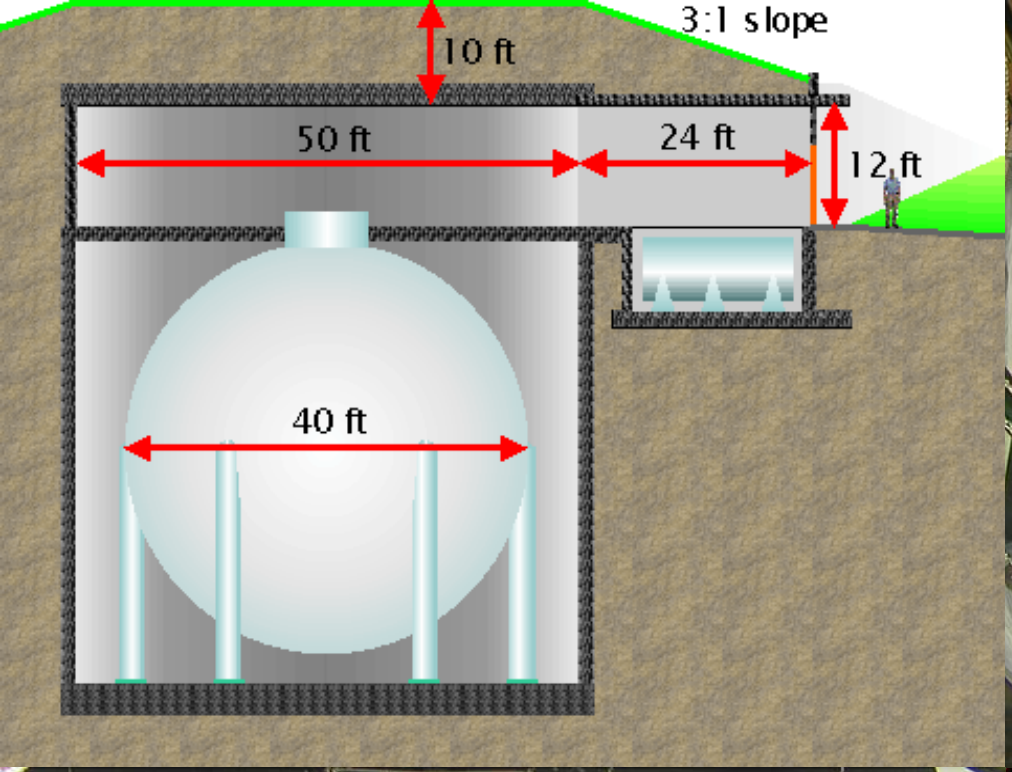
Phototube support structure provides opaque barrier between veto and main volumes

1280 20-cm PMTs in detector at 5.5 m radius
→ 10% photocathode coverage
(330 new tubes, the rest from LSND)

240 PMTs in veto



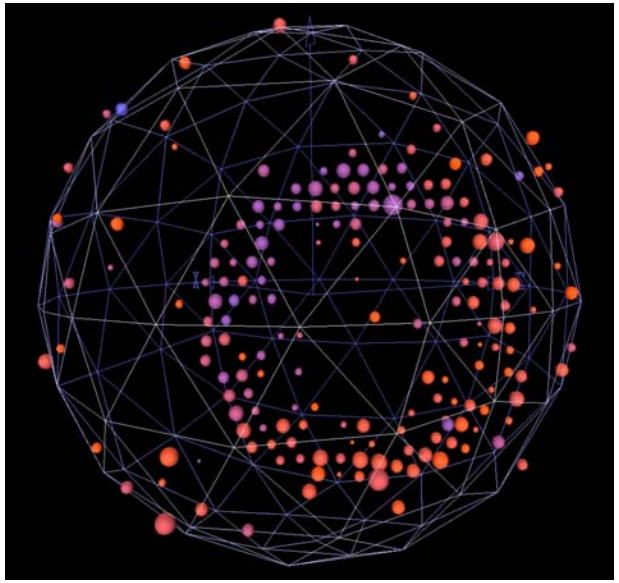



3:1 slope
10 ft
50 ft
24 ft
12 ft
40 ft

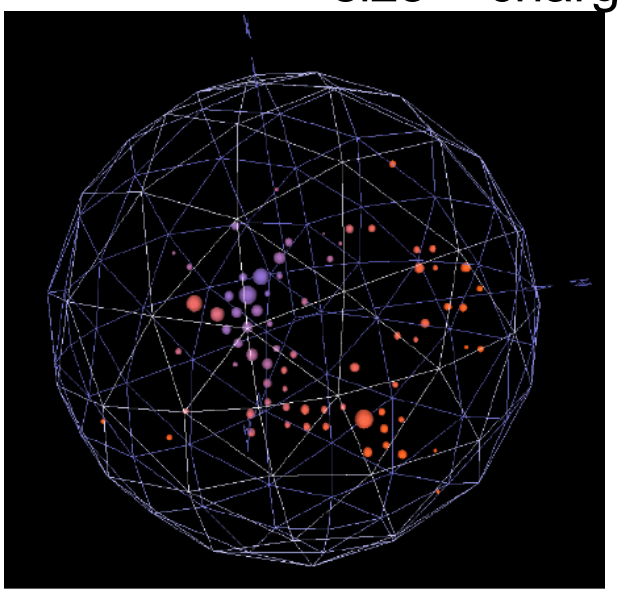
Pattern of hit tubes (with charge and time information)
allows reconstruction of track location and direction
and separation of different event types.

e.g. candidate events:

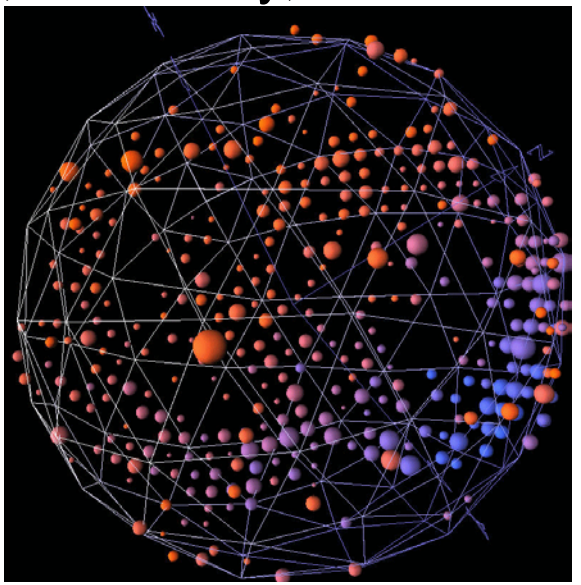
size = charge; red = early, blue = late



muon
from ν_μ interaction



Michel electron
from stopped μ decay
after ν_μ interaction



$\pi^0 \rightarrow$ two photons
from ν_μ interaction

Features of Detected Light

- **Ring of Cherenkov Light -- Prompt**
  [Signal for Electrons and Muons]

- **Isotropic Scintillation Light – Delayed**
  [Added information on Leptons,
  Potential signal of Hadronic Interactions]

- **Scattered Light**
  Correlated to Source – Delayed
  [Background]

For Study of Oil Properties

Previously reported:

Mineral Oil Tests for the MiniBooNE Detector

J. L. Raaf *et. al., NSS2001*

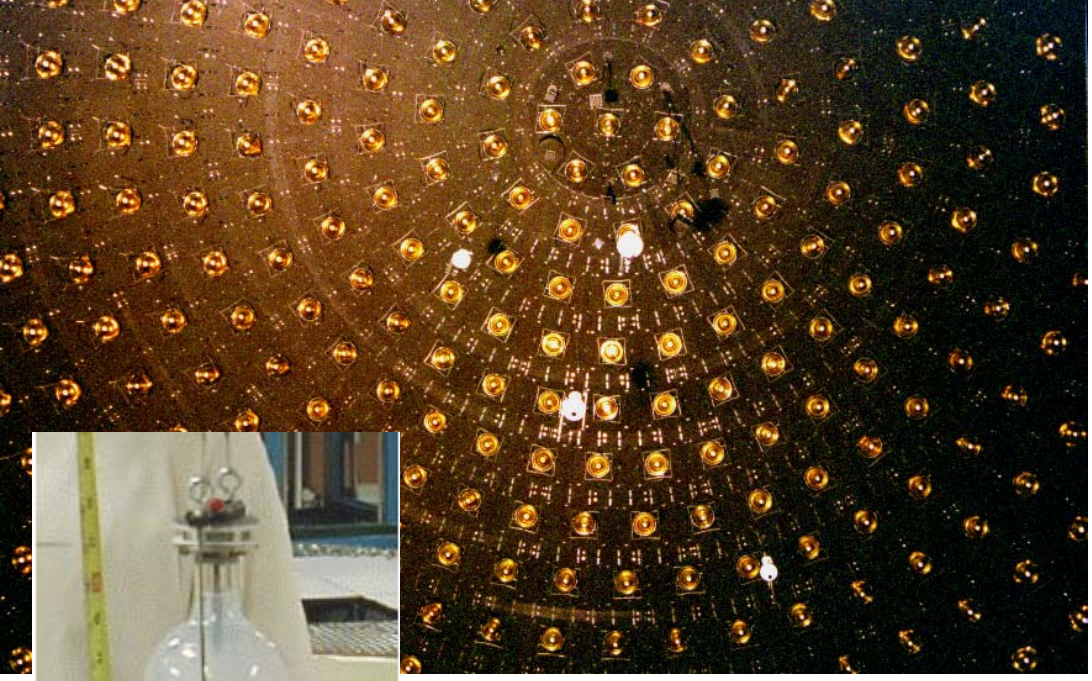
Ex Situ Light Production/Transmission Tests for Oil:

- *Variable Pathlength Attenuation Test (460 nm)*
- *Variable Wavelength Attenuation Test (300-500 nm)*
- *Scintillation Test (180 MeV protons)*

In Situ Light Transmission Tests:

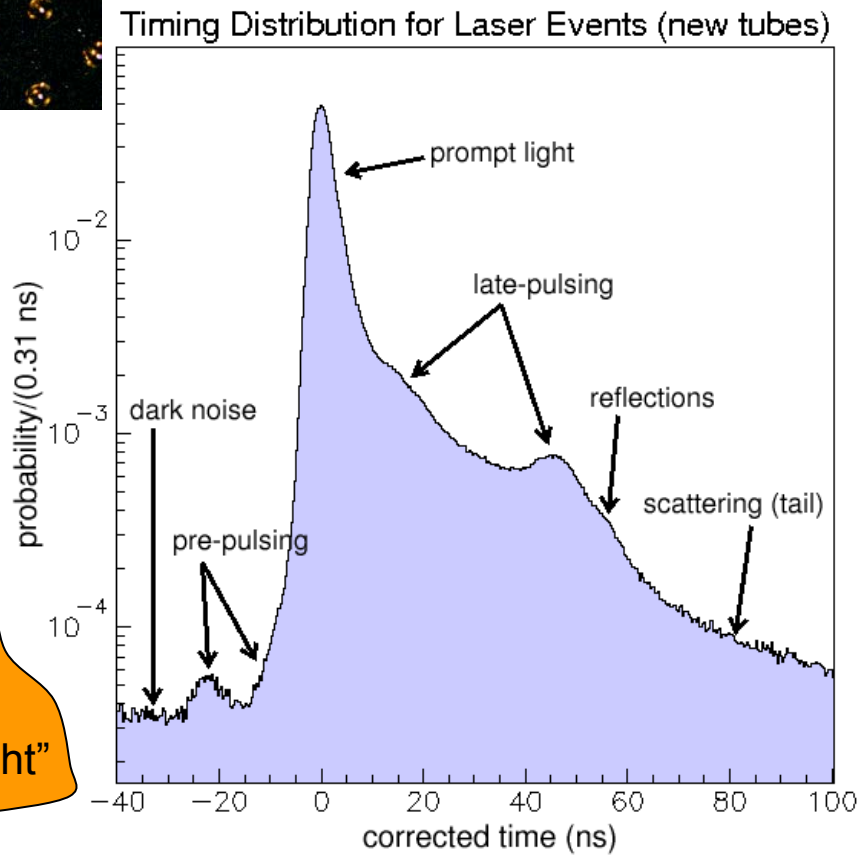
- **Laser pulses (via dispersion flasks or via bare fiber)**
- *Cosmic muons (including those stopped in scint. Cubes)*
- *Michel electrons from muon decay*

Understanding the detector



Laser flasks

four Ludox-filled flasks
fed by optical fiber from laser



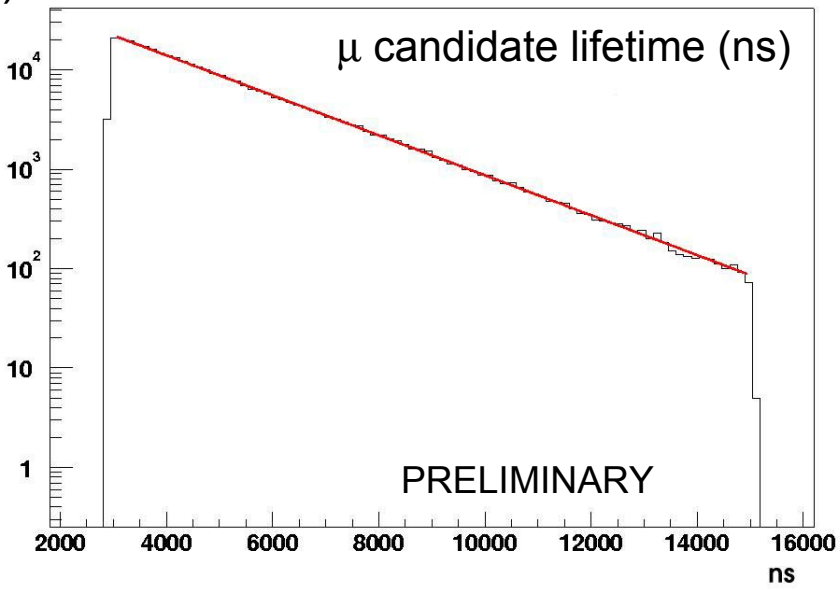
measure:
PMT charge and time response
and
oil attenuation length

397 nm laser
(no scintillation!)
modeling other sources of “late light”

Michel electrons

(electrons from the decay of stopped muons)

plentiful source from cosmics
and beam-induced muons



cosmic muon lifetime in oil

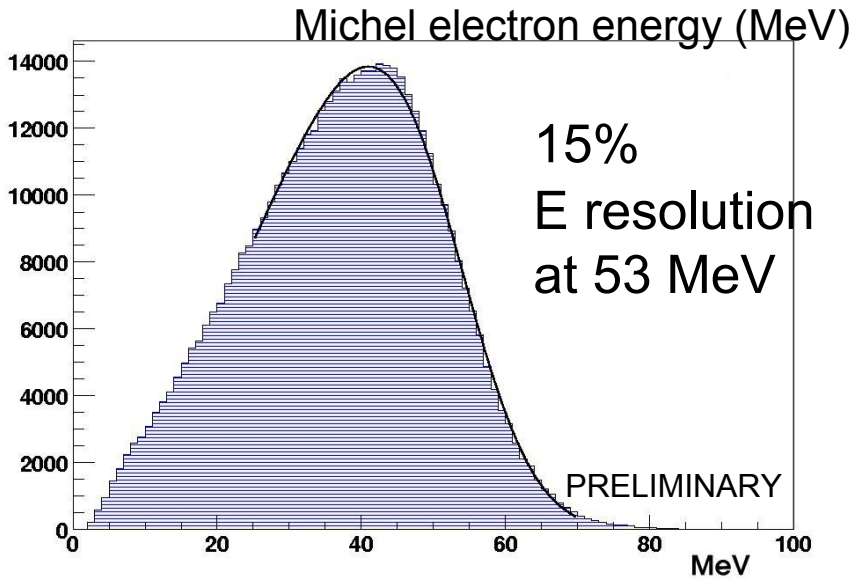
measured: $\tau = 2.15 \pm 0.02\ \mu s$

expected: $\tau = 2.13\ \mu s$

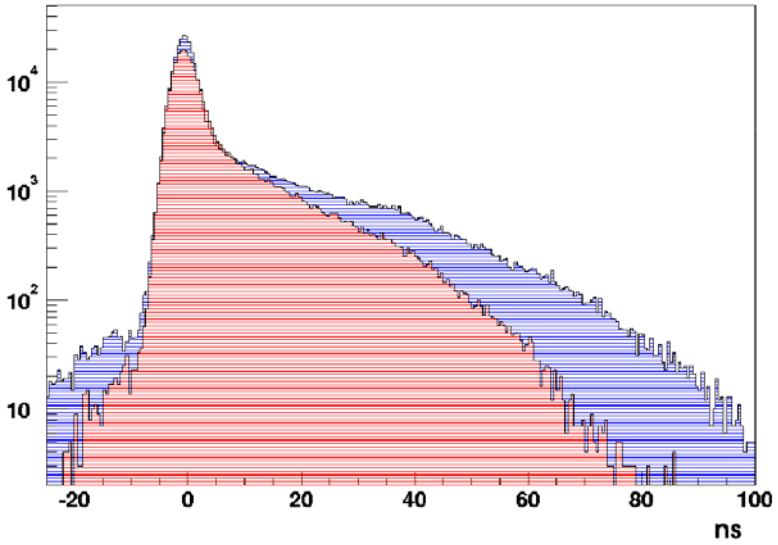
(8% μ^- capture)

Energy scale and resolution
at Michel endpoint (53 MeV)

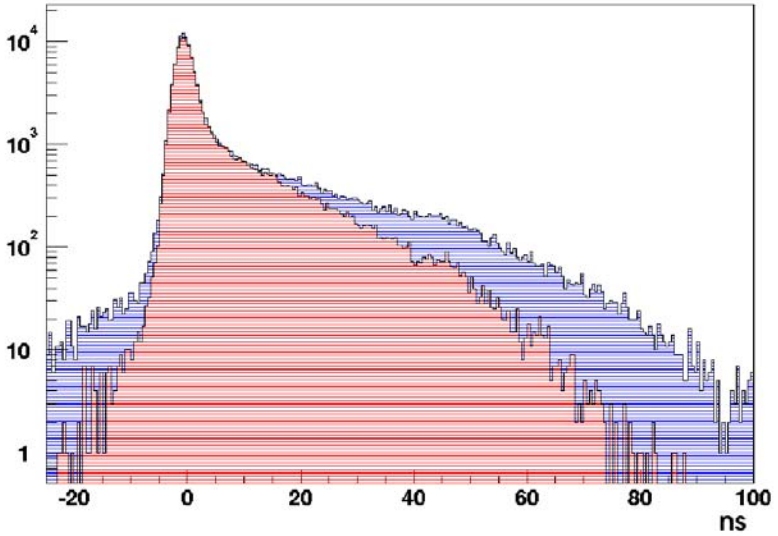
Michel electrons throughout
detector (r<500 cm)



Old Tubes

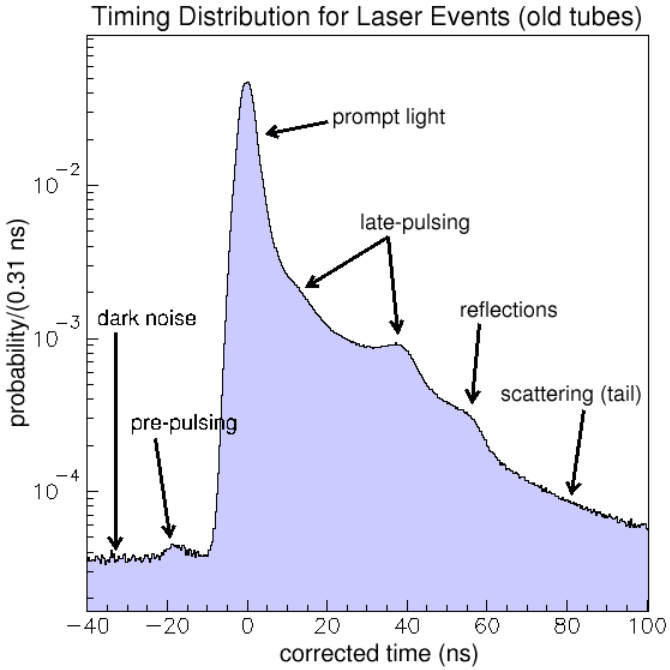


New Tubes



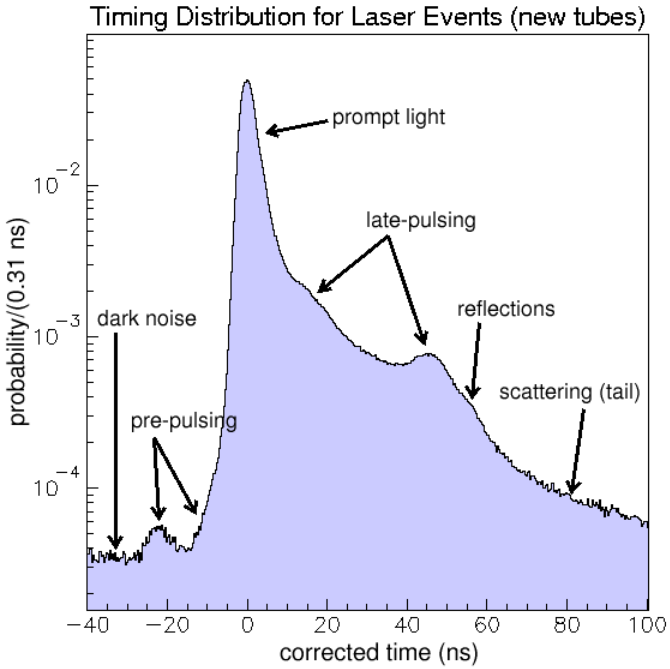
Time Spectra of Phototube Signals From Michel (decay) Electrons Corrected for Flight time from Decay vertex to Phototube.

[Blue is Data]
[Red is Monte Carlo]



Time Spectra from Laser

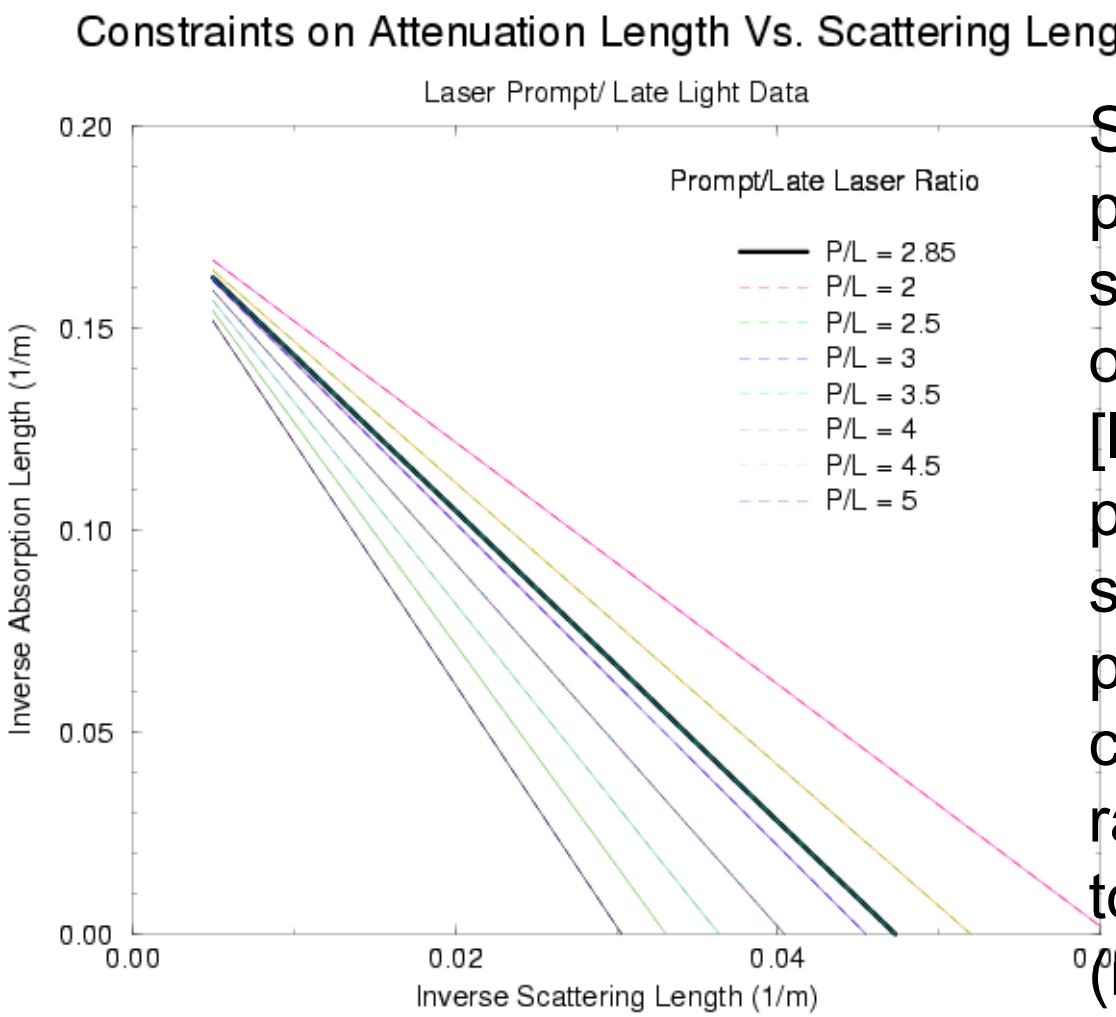
Central Dispersion Flask
397 nm Laser
Single P.E. Light Levels



Features Observed:

Prompt Peak
(time calibration)
Phototube Features
Scattered Light

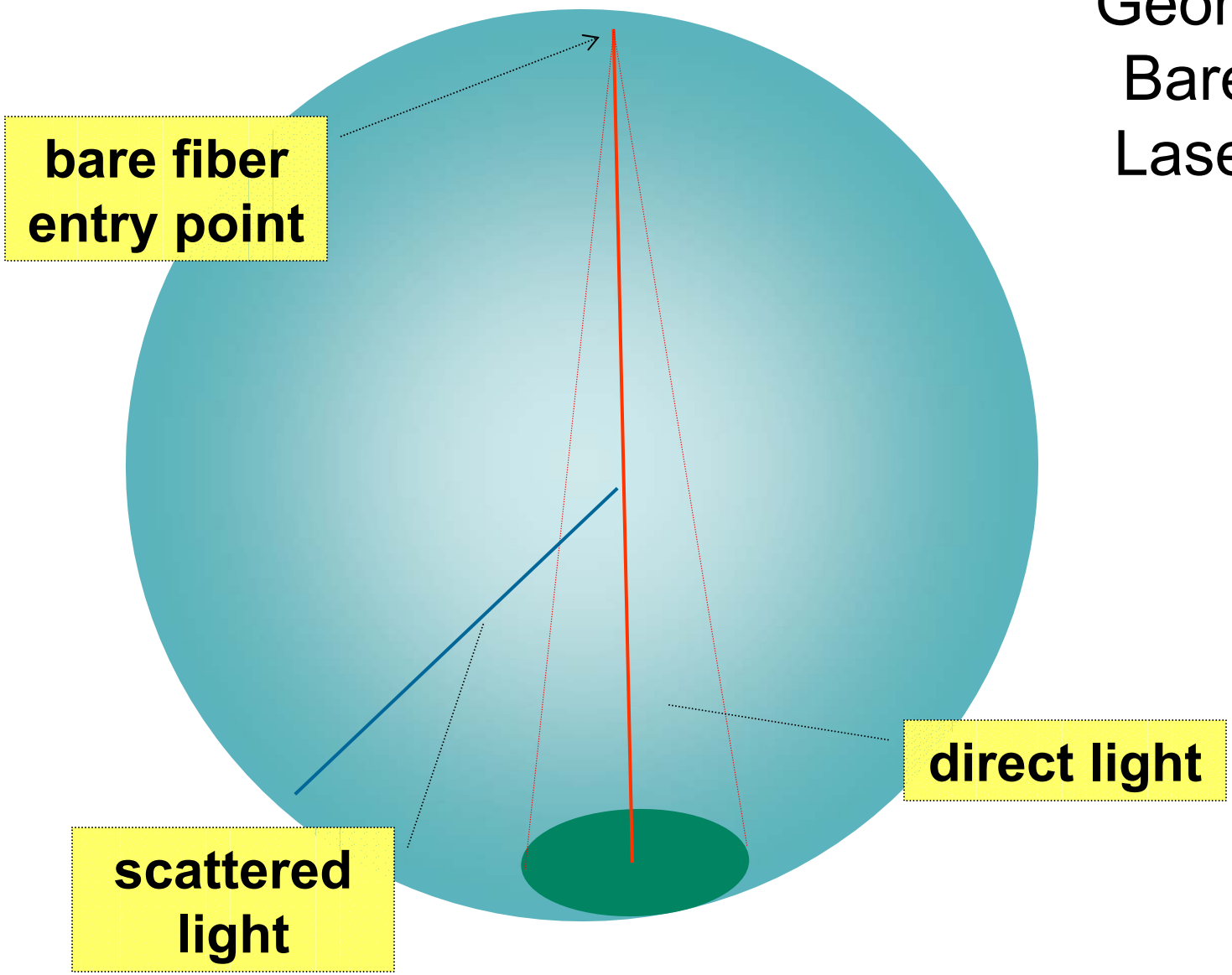
Late Light Constraints on Scattering

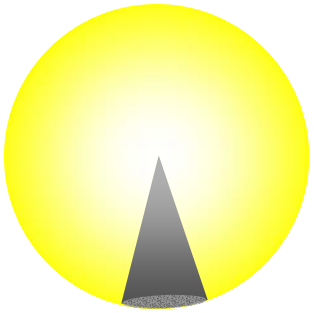


$1/L_A = 1/ s – 1/L_s$ **[Prompt/Late + 1]**

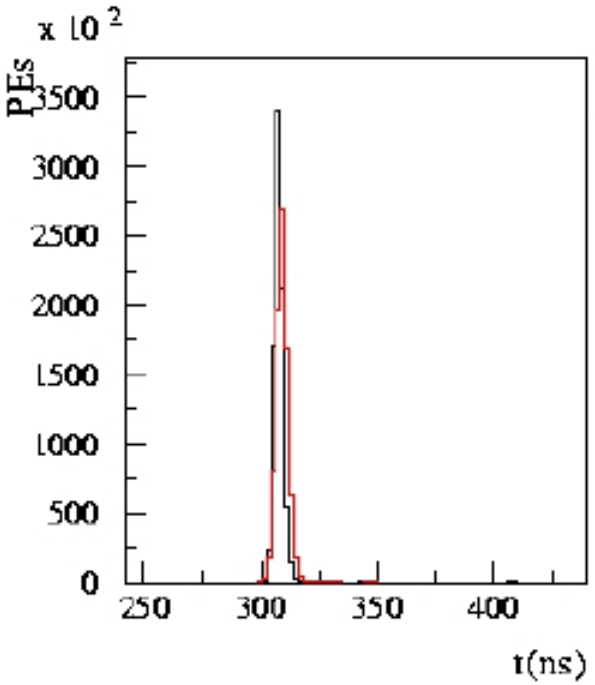
Scattered light produces late signals. The ratio of prompt/late light [late signal with phototube features subtracted] provides a constraint on the ratio of scattering to absorption (normalization to total light not available).

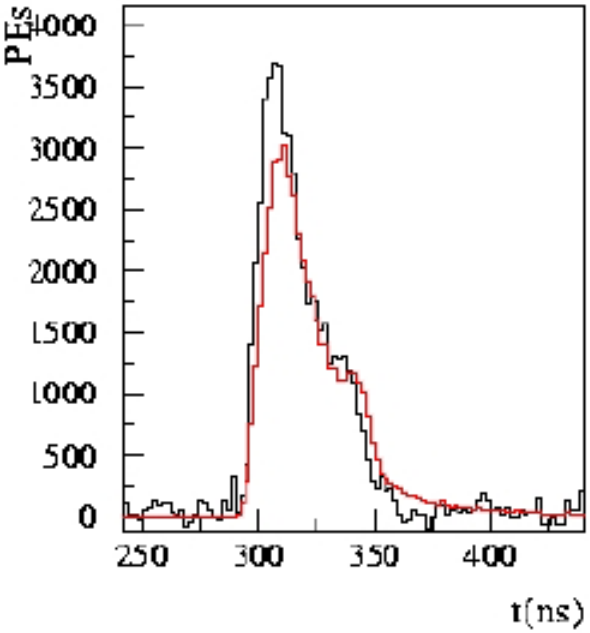
Geometry for Bare Fiber Laser Tests

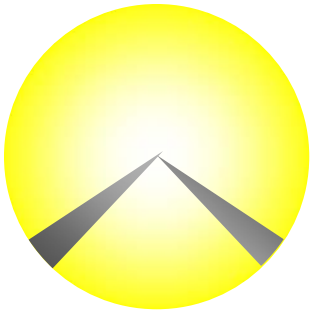




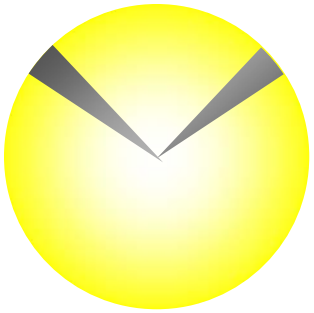
0 – 10°



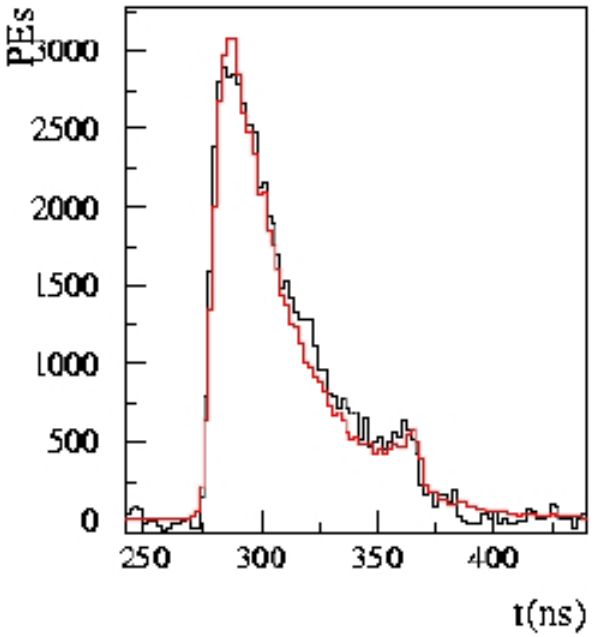


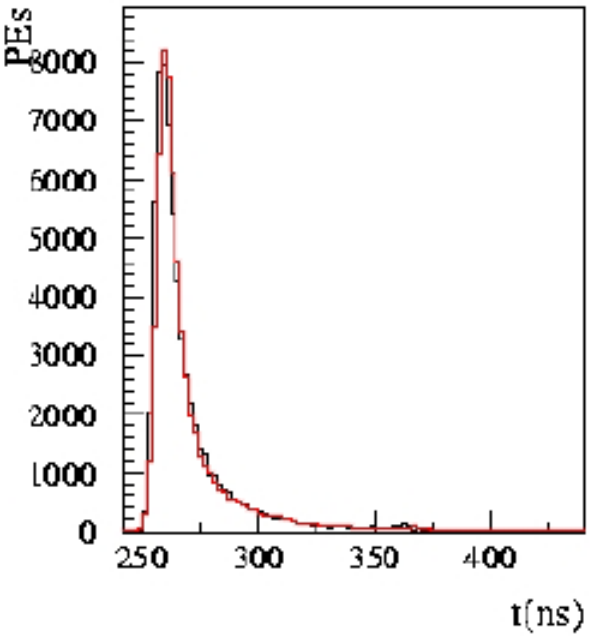


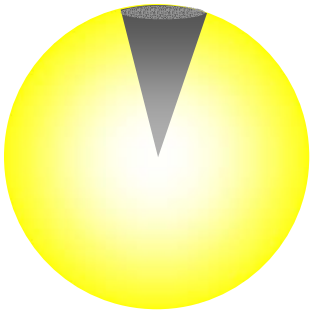
60 – 70°



120 – 130°

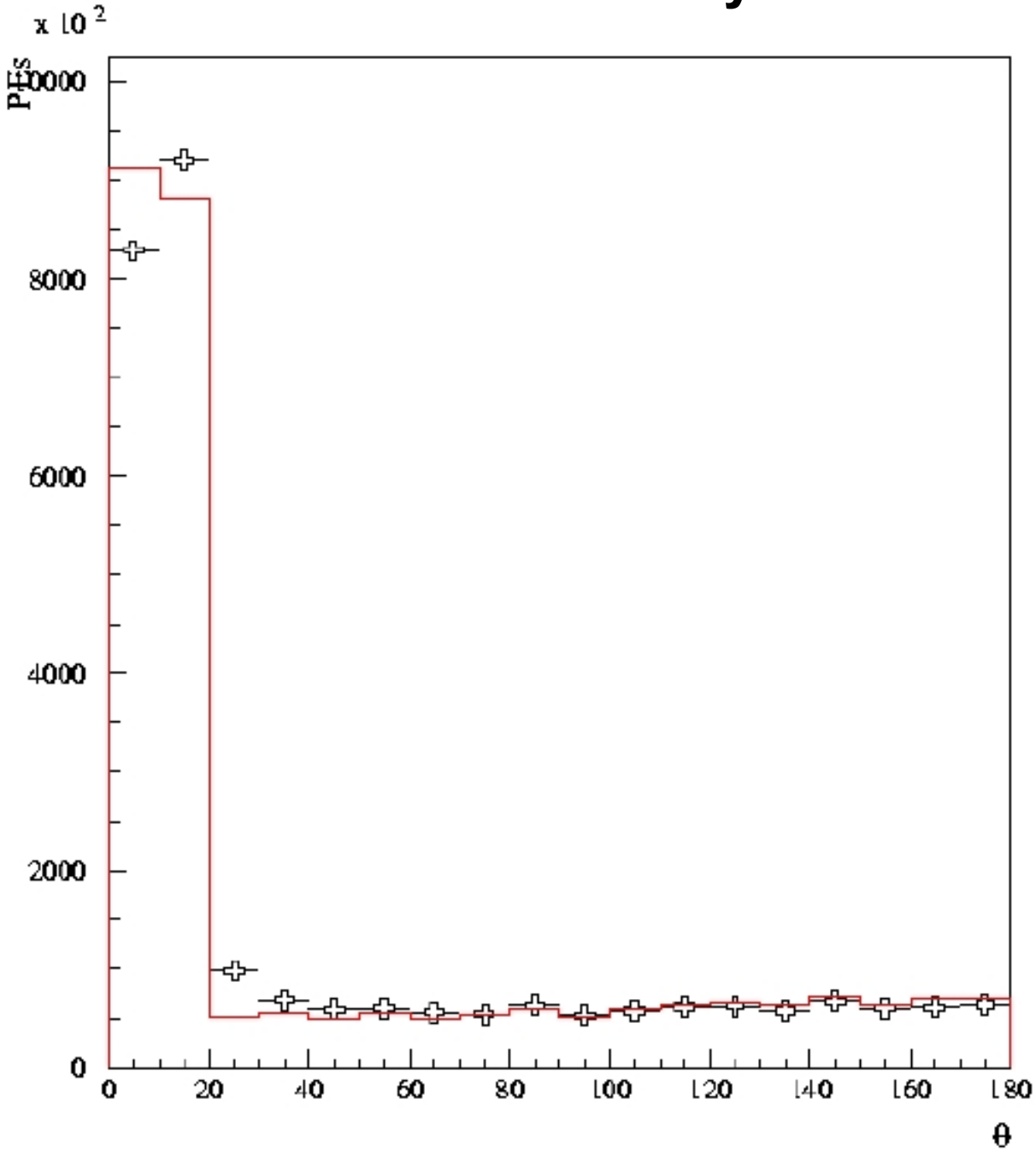






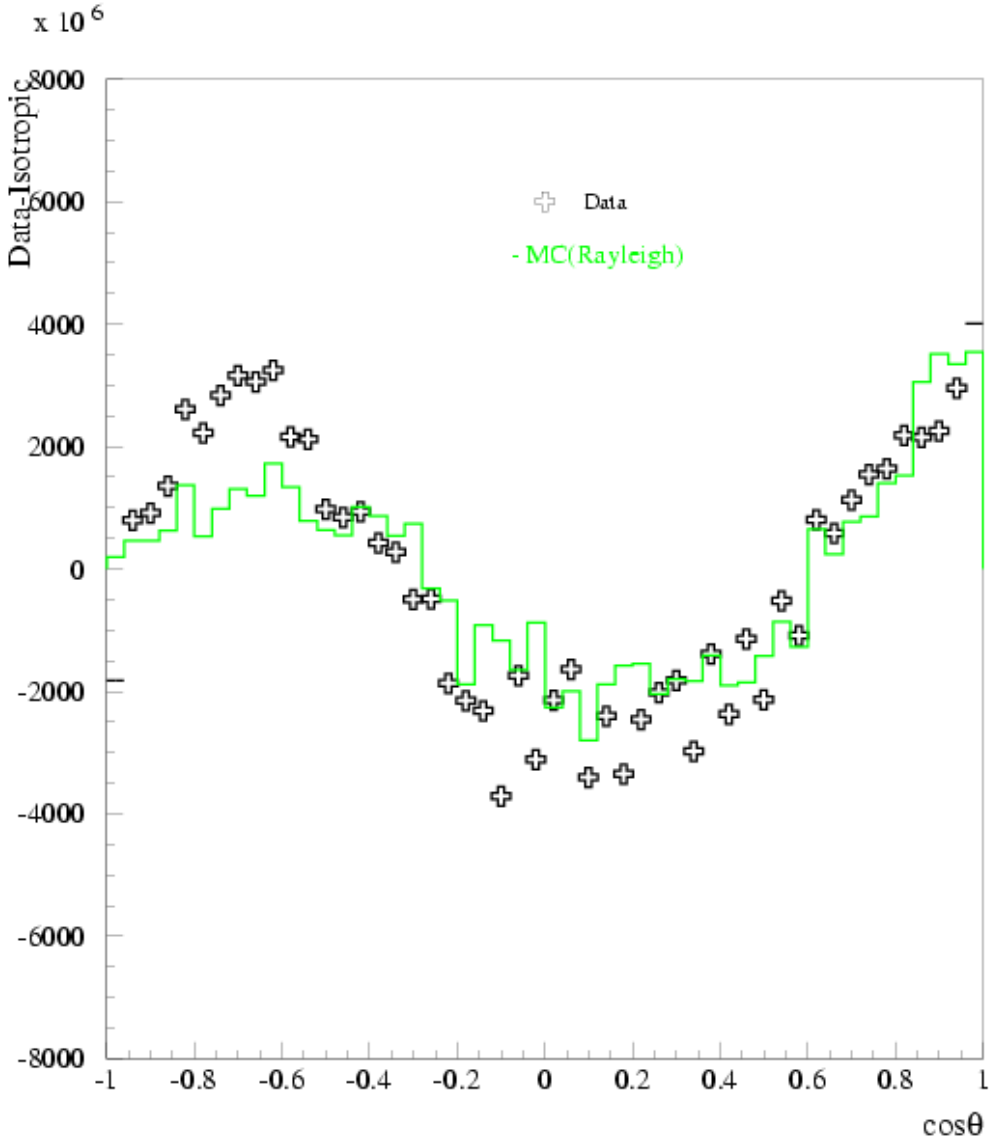
170 – 180°

Bare Fiber Laser Study



Detected Light as Function of Scattering Angle from Fiber Direction

Bare Fiber Laser Study – 397 nm Wavelength

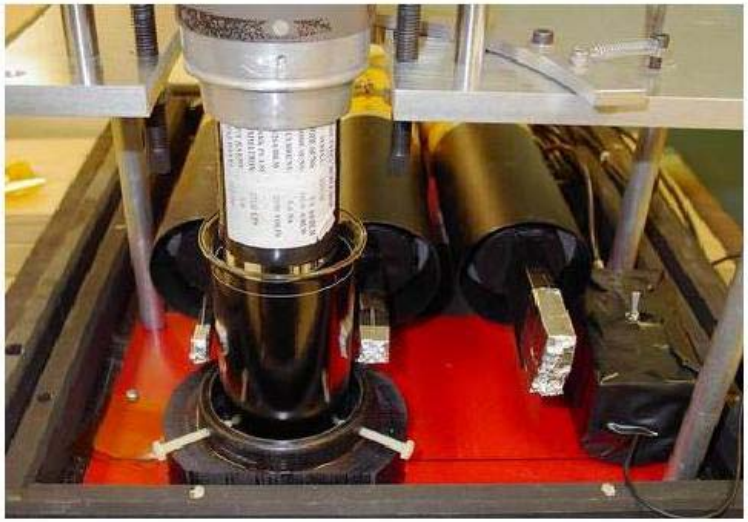


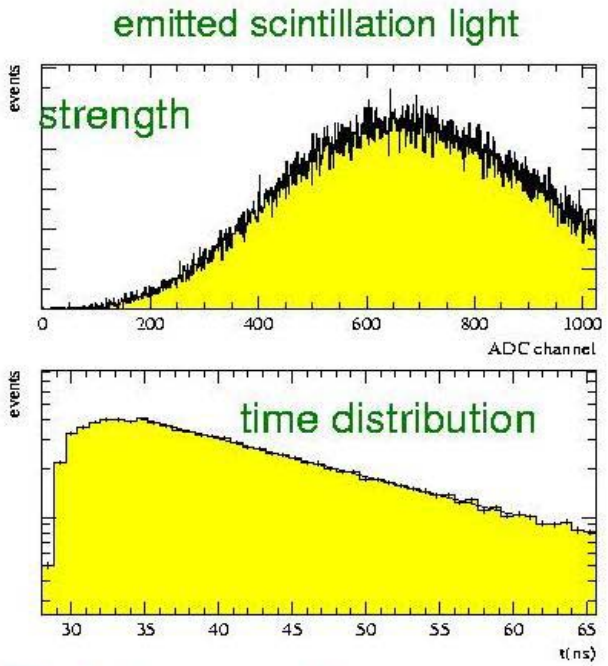
Data Event Rate Minus Monte Carlo Simulation Isotropic Scattering.

Green shows Monte Carlo of Rayleigh Scattering minus Monte Carlo Simulation Isotropic Scattering.

MiniBooNE Oil Tests

Scintillation light from MiniBooNE Marcol 7 mineral oil has been measured using the Indiana University Cyclotron Facility 200 MeV proton test beam.

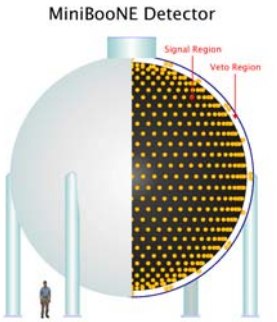




Preliminary results:

- ~5.0 PEs/MeV deposited for 100% solid angle
- $\tau \sim 20$ns

MiniBooNE at Fermilab

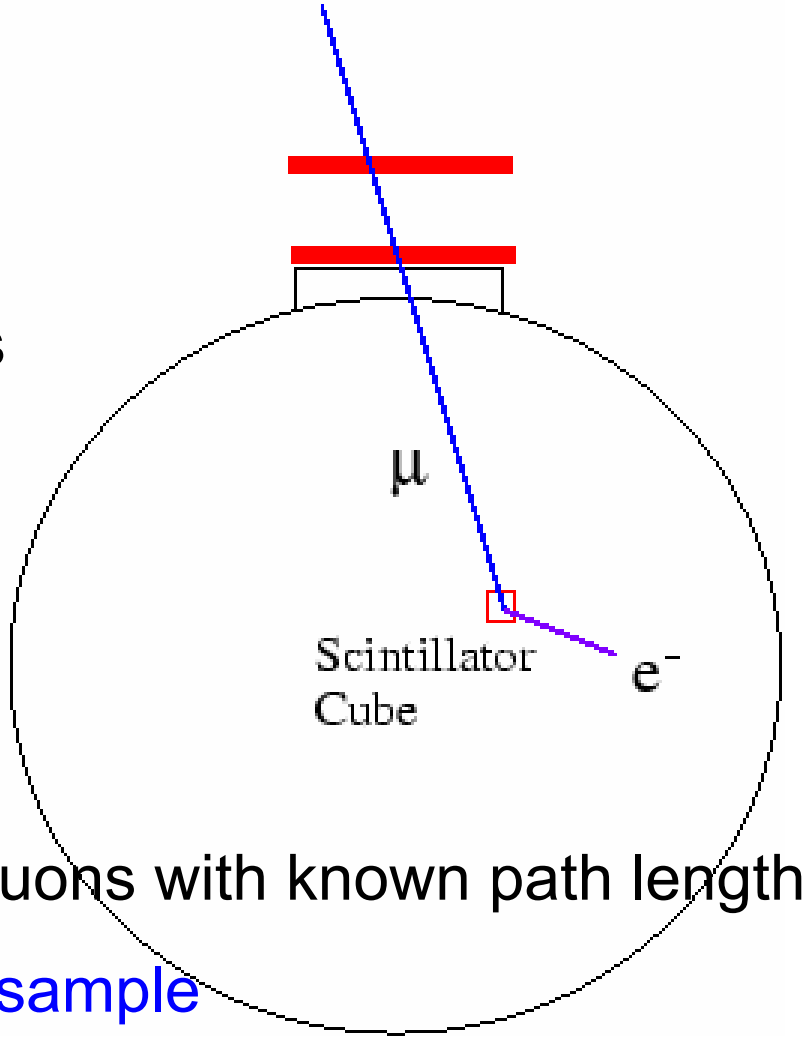


Results on Oil in MiniBooNE Detector

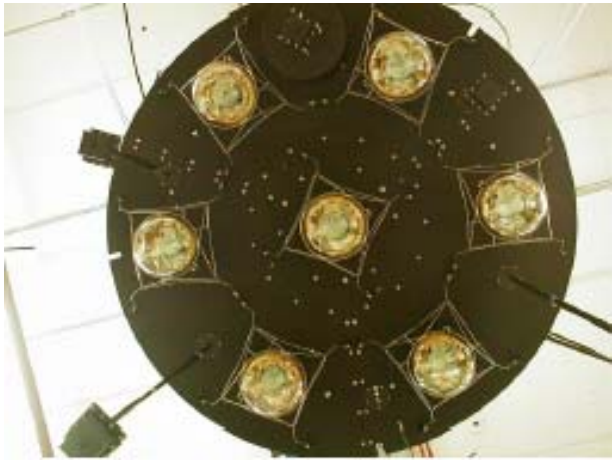
- *Cherenkov Light Yield as Expected*
- *Scintillation Light Observed*
- *Attenuation Length*
  > 20 m at 460 nm wavelength
  ~ 10 m at 397 nm wavelength
- *Absorption and Scattering are comparable at these wavelengths*
- *Calibration with Lasers, Cosmic Muons and decay electrons proceeding as planned*

Stopping muon calibration system

Scintillator tracker above the tank



Optically isolated scintillator cubes
in tank:
six 2-inch (5 cm) cubes
one 3-inch cube



stopping muons with known path length

calibration sample
of muons up to 700 MeV

Neutrino events

beam comes in spills @ up to 5 Hz
each spill lasts 1.6 μsec

trigger on signal from Booster
read out for 19.2 μsec; beam at [4.6, 6.2] μsec

no high level analysis needed to see neutrino events

backgrounds: cosmic muons
decay electrons

simple cuts reduce non-beam backgrounds to ~10^{-3}

160k neutrino candidates
in 1.5 x 10^{20} protons on target