BooNE is BEGINNING

E.D. Zimmerman
Univ. of Colorado

SLAC Experimental Seminar
March 26, 2002
E898 is beginning

- Physics motivation: neutrino oscillations and LSND
- Boone overview
- The v beam
- The Oil Čerenkov detector / reconstruction
- First event displays
- Schedule and physics prospects
Neutrino Mass

- No good theoretical understanding of whether neutrinos should have mass or not.

- Cosmology: Neutrino masses $\geq 1 \text{eV}/c^2$ contribute significantly to mass of universe.

- Direct searches: Kinematic measurements show no evidence for nonzero neutrino mass, but limits are fairly high ($\approx 3 \text{eV}/c^2$ for $\nu_e$, $<0.2 \text{MeV}/c^2$ for $\nu_\mu$, $<18 \text{MeV}/c^2$ for $\nu_\tau$).

- Neutrino oscillations: Sensitive to much smaller masses; experiments show evidence for too many nonzero neutrino masses!
NEUTRINO OSCILLATIONS

- Expected if neutrinos have mass and masses not degenerate and weak flavor eigenstates not same as mass eigenstates.

- Evidence for oscillations:
  "\(\nu_e\) from sun observed on earth in insufficient numbers. (Do they oscillate into a different flavor?)

  "Excessive \(\bar{\nu}_e\) observed in beam stop experiment LSND. (Do they come from oscillating \(\bar{\nu}_\mu\)?)

  "\(\nu_\mu\) from atmospheric \(\tau_e/\mu\) decays show angle-dependent deficit. (Do they oscillate into a different flavor traversing the earth?)

- Formalism in a two-flavor system: flavor states \(\nu_e, \nu_\mu\); mass \(\nu_1, \nu_2\).
  \[
  |\nu_e\rangle = \cos \theta |\nu_1\rangle + \sin \theta |\nu_2\rangle \\
  |\nu_\mu\rangle = -\sin \theta |\nu_1\rangle + \cos \theta |\nu_2\rangle
  \]

So... Given a pure \(\nu_e\) state at position (time) \(L = 0\),

\[
\text{Prob. (observe } \nu_\mu\text{)} = \sin^2 2\theta \sin^2 (1.27 \Delta m^2 \frac{L}{E})
\]

\text{Mixing angle } \theta

\[
(m_2^2 - m_1^2) \text{ (eV/c)}^2
\]

\(L = \text{flight path (km)}\)

\(E = \text{neutrino energy (GeV)}\)
OR:

Oscillations is not sensitive to one set of experiments.

Either:

$\frac{\Delta m_{L-S}^2}{\Delta m_{A}^2} \approx 10^{-2,4}$

$\Delta m_{\text{Atmos}} \approx 10^{-3,7} \text{eV}^2$

$\Delta m_{\text{Solar}} \approx 10^{-3,2} \text{eV}^2$

$\Delta m_{\text{L-S}} \approx 0.17 \text{eV}^2$

To this one, cannot add up these two.

There are too many non-oscillation signals to be explained easily with only 3 mass states.
An Experimentally Allowed Model

- Bimaximal mixing in 3+1 models
  - W. Krolikowski HEP-PH/0106350

\[ \Delta m^2_{\text{LSND}} \]
\[ \Delta m^2_{\text{Atm.}} \]
\[ \Delta m^2_{\text{Solar}} \]

- \[ \nu_e \]
- \[ \nu_\mu \]
- \[ \nu_\tau \]
- \[ \nu_S \] New "sterile" neutrino - has no normal weak interactions
An Alternative Model

- Maximal CPT violation in Dirac mass terms
  - Barenboim, Borissov, Lykken & Smirnov HEP-PH/0108199
  - Generates independent masses for $\nu$'s and $\bar{\nu}$'s
  - Motivated by branes with extra dimensions

\[ \nu_e \quad \nu_\mu \quad \nu_\tau \quad \nu_3 \]

\[ \Delta m^2 \text{ LSND} \]

\[ \nu_3 \quad \bar{\nu}_2 \quad \nu_2 \quad \bar{\nu}_1 \quad \nu_1 \]

\[ \Delta m^2 \text{ Atm.} \quad \Delta m^2 \text{ Solar} \]

New idea last summer: solve "too many $\Delta m^2$" problem by giving distinct masses to $\nu, \bar{\nu} \Rightarrow 6$ masses vs. 3.

Side benefit: heavier $\nu$ hierarchy allows lepton asymmetry in early universe in thermal equilibrium $\Rightarrow$ enables baryogenesis.
$\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ \textbf{APPEARANCE OSCILLATION RESULT}

800 MeV P from LAMPE

$^{76}$Se\textsuperscript{+} STOP; $^{76}$Te\textsuperscript{-} \textbf{CAPTURED}

\textbf{NOTE: NO} $\bar{\nu}_e$ \textbf{PRODUCED IN THE TARGET!}

Stopping Target (Cu or H\textsubscript{2}O)

\textbf{LSND DETECTOR}

$\nu_\mu, \bar{\nu}_\mu, \nu_e$

$\sim 30m$

\textbf{DECAY-AT-REST} $\bar{\nu}_\mu$ \textbf{HAS} $E < 0.053$ GeV.

\textbf{BASELINE} $L = 30m$ \textbf{\begin{align*} \sum \frac{L/E}{(\text{km/GeV})} &\sim 1 - 1.5 \\textbf{ENERGY}\ E \approx 50\text{ MeV} \end{align*}}
LSND DETECTOR:
167 TONS CH₂ (mineral oil, doped)
1220 PMT's (8° Hamamatsu)
ACTIVE VETO SHIELD
PASSIVE SHIELDING TOO

LAMPF beam:
800 MeV/c protons
6% duty factor
28,998 Coulombs on target
1993-98
Neutrino Fluxes

DAR Flux (96) at the Center of LSND

DECAYS
AT REST

DIF Flux (96) at the Center of LSND

DECAYS
IN FLIGHT

LSND Neutrino Physics
LSND OSCILLATION SIGNATURE

From $\mu^+$ decay at rest:

$$\overline{\nu}_\mu \rightarrow \overline{\nu}_e$$

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

ČERENKOV + SCINTILLATION SIGNAL

$T = 186 \mu s$

$$n + p \rightarrow d + \gamma$$

2.2MeV SIGNAL

RECONSTRUCT $e^+$ AND $\gamma$

WITH APPROPRIATE DELAYED COINCIDENCE.
EVENT SELECTION
TARGETED BACKGROUND
NON-ELECTRON
COSMIC RAY MUON
COSMIC RAY NEUTRON
POSITRON FROM $\mu$ DECAy
ACCIDENTAL $\gamma$ COINCIDENCE
REMAINING BEAM-UNRELATED BACKGROUND

CRITERIA AT LSND
CUTS

PARTICLE ID USING ČERENOV CONE SHAPE AND TIMING DISTRIBUTION
VETO SHIELD
ONLY ONE $\phi$ RECONSTRUCTS
NO MUON-LIKE ACTIVITY IN 15ms BEFORE EVENT
CUT ON LIKELIHOOD RATIO $R$
(INTEGRATES SPATIAL, TEMPORAL PROXIMITY)
MEASURE USING BEAM-OFF DATA (94% OF LIVE TIME) AND SUBTRACT.

$R > 10 \iff \text{"golden mode"}$
LSND

20 MeV < E\text{visible} < 60 MeV DATA

• FROM \( R > 10 \) SAMPLE (LOWEST BACKGROUND)

<table>
<thead>
<tr>
<th>OBSERVED EVENTS</th>
<th>83</th>
</tr>
</thead>
<tbody>
<tr>
<td>BEAM-UNRELATED BACKGROUND</td>
<td>33.7</td>
</tr>
<tr>
<td>( \bar{\nu}_e ) BACKGROUND (mostly from ( \mu^- ) in beam dump)</td>
<td>8.5</td>
</tr>
<tr>
<td>( \bar{\nu}_\mu ) BACKGROUND (( \mu^+ ) decay in detector)</td>
<td>3.5</td>
</tr>
<tr>
<td>OTHER ( \nu ) BACKGROUNDS (WITH NO NEUTRON)</td>
<td>4.6</td>
</tr>
</tbody>
</table>

UNEXPLAINED EXCESS 32.7 ± 9.2

• FROM FIT TO \( R \) DISTRIBUTION

OSCI LLATION EXCESS \( 83.3 ± 21.2 \)

\( \bar{\nu}_\mu \rightarrow \bar{\nu}_e \) OSCILLATION PROBABILITY \( (2.5 ± 0.6 ± 0.4) \times 10^{-3} \)
$R > 10 \ e^+ + \gamma \ \text{EVENTS}$
FIG. 14: Comparison of oscillation searches performed by different short baseline experiments.

both experimental results. At high $\Delta m^2$ values, the LSND solutions are in clear contradiction with the KARMEN upper limit.

VIII. CONCLUSION

Results based on the entire KARMEN2 data set collected from 1997 through to 2001 have been presented. The extracted candidate events for $\bar{\nu}_e$ are in excellent agreement with background expectations showing no signal for $\bar{\nu}_\mu \rightarrow \nu_e$ oscillations. A detailed likelihood analysis of the data leads to upper limits on the oscillation parameters $\sin^2(2\Theta)$ and $\Delta m^2$ excluding parameter regions not explored analyzed by other experiments.
A JOINT KARMEN-LSND Likelihood Analysis
Joint KARMEN-LSND allowed region
BooNE

Booster 8 GeV protons Neutrino Source (horn-focused mesons)

"Booster Neutrino Experiment"

• Purpose is to test the LSND signal:
  - x10 statistics
  - Different beam
  - Different energy
  - Different systematic errors
  - Different oscillation signature

• Primary beam: 8 GeV protons from FNAL Booster

• Horn-focused secondary π, K beam decays in flight to neutrinos

• 500 meter oscillation baseline ("L")

• 800-ton mineral oil target / Čerenkov detector
The BooNE Collaboration

I.Stancu  
University of Alabama, Tuscaloosa

S.Koutsoliotas  
Bucknell University, Lewisburg

E.Church, G.J.VanDalen  
University of California, Riverside

E.Hawker, R.A.Johnson, J.L.Raaf, N.Suwonjandee  
University of Cincinnati, Cincinnati

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

Columbia University, Nevis Labs, Irvington

D.Smith  
Embry Riddle Aeronautical University


Fermi National Accelerator Laboratory

D.C.Cox, J.A.Green, H.Meyer, R.Tayloe  
Indiana University, Bloomington

Los Alamos National Laboratory

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

J.Cao, B.P.Roe  
University of Michigan, Ann Arbor

A.O.Bazarko, M.Leung, P.D.Meyers, R.B.Patterson, F.C.Shoemaker  
Princeton University, Princeton
Oscillation signature at Boone:

\[ \nu_e N \rightarrow e^- N' \] quasielastic scattering

Neutrino energy: 0.5 - 1 GeV

Normalize to \[ \nu_m N \rightarrow \mu^- N' \] (several \( \times 10^5 \) interactions)

Particle ID by Čerenkov ring shape.

Backgrounds to oscillation:

Intrinsic \( \nu_e \) in beam:
- From \( \pi \rightarrow \mu \rightarrow \nu \) decay in secondary beam
- From \( K_{e3} \) decays (\( K^+ \rightarrow \pi^+ e^+ \bar{\nu}_e \), \( K^0 \rightarrow \pi^0 e^+ e^- \bar{\nu}_e \))

Particle mis-id in detector:
- \( \mu \) decays to \( e \), \( \mu \) not observed
- \( \mu \) mis-id as \( e \), decay not seen
- \( \pi^0 \) produced in neutral currents, mis-id as \( e \)
WHAT IS "MINI-BOONE?"

**FIRST PHASE OF THE BOONE PROGRAM:**

- A SINGLE NEUTRINO DETECTOR, BASELINE 500 m
- GOAL IS DEFINITIVE TEST OF LSND SIGNAL
- SOME SENSITIVITY TO $\nu_e$ DISAPPEARANCE

This is experiment 898, or "Mini-Boone."
It is approved, funded, and under construction.

**FUTURE PHASE OF THE PROGRAM:**
Assuming LSND confirmed,

- BUILD A SECOND DETECTOR OF SIMILAR DESIGN
- NEW DETECTOR BASELINE OF 1000 m (if low $\Delta m^2$)
  250 m (if high $\Delta m^2$)
- PRECISE MEASUREMENT OF OSCILLATION PARAMETERS
- MUCH BETTER SENSITIVITY TO $\nu_e$ DISAPPEARANCE.
GENERATING THE BOONE NEUTRINO BEAM

- The Booster
- Horn and Target
- Decay Pipe
- Beam Absorbers
- Kaon Decay Monitor (LMC)
THE BOOSTER

8 GeV proton accelerator:

- Built to inject protons to main ring.
- Now injects main injector—but has extra capacity.
- Magnets cycle at 15 Hz.

EXTRACTION:

- All beam extracted in single turn.
- Pulse is 1.6 ms long, consists of 84 bunches ("RF buckets") 19 ms apart. $10^{-5}$ duty factor eliminates non-beam bux!
- New 8 GeV fixed-target facility being built for Boone; can accommodate other users too.

DEMANDS ON MACHINE:

- Tevatron run 2 + Boone + Numi will require record booster current ($5 \times 10^{12}$ ppp) and repetition rate (~10 Hz).

- Beam loss at injection, extraction, and around ring currently limit throughput. Accelerator group is implementing solutions.
HORN AND TARGET - PRODUCTION + FOCUSING OF SECONDARY BEAM

A GENERIC HORN/TARGET COMBINATION:

- INCOMING PROTONS
- NEGATIVE PARTICLES
- OUTER CONDUCTOR
- TARGET
- CURRENT FLOW
- INNER CONDUCTOR
- FORWARD PARTICLES UNAFFECTED
- POSITIVE PARTICLES FOCUSED

SECONDARY BEAMING

$\pi \rightarrow \mu \nu$
THE HORN

- OPERATES AT 170 kA; CURRENT PULSE 150 μS
- POTENTIAL ~4 kV

1 foot

BEAM DIRECTION

OUTER CONDUCTOR (CUT AWAY)

COOLING WATER DRAIN

65 cm Be target INSIDE INNER CONDUCTOR

INNER CONDUCTOR: 3 mm THICK ALUMINUM
OUTER CONDUCTOR: 25 mm THICK ALUMINUM

POWER FEED ("STRIP LINES")
Horn Challenges:

- Current (170 kA) is "modest"

- Voltage (4 kV) is high but not unprecedented
  (need to keep corona, etc under control)

- Beam on target is intense — horn will activate to several curves.
  → Horn replacement system provides complete shielding at all times: horn is removed in a 20-ton steel coffin.

- Pulse repetition rate is unprecedented — 5 Hz.
  Previous "high-rate" BNL horn operated at 0.8 Hz.
  → High-flow water cooling of inner conductor
  → Design to minimize aluminum fatigue
  (must survive $10^8$ pulses — no other horn has gone beyond $2 \times 10^7$)

- Be target has separate air-cooling system.
TARGET PILE

CONSTRUCTED OF "BLUE BLOCKS"
(MODULAR STEEL SHIELING BLOCKS)

COLLIMATOR
(Exit 35 in. dia, 5 m from target)
CONSTRUCTED OF LAB E STEEL PLATES
THE DECAY PIPE

- 6' DIA. CORRUGATED METAL PIPE, AIR-FILLED
- SURROUNDED BY GRAVEL SHIELDING.
- 50 m LONG, FIXED DUMP AT END
- INTERRUPTED AT 25 m FOR MOVABLE BEAM DUMP

WHY A MOVABLE DUMP? CROSS-CHECK ON BACKGROUND:

INTRINSIC $\nu_e$ COMES PRIMARILY FROM:
- MUONS: $\pi^+ \rightarrow \mu^+ \rightarrow e^+\nu_e\bar{\nu}_\mu$ → DOUBLE DECAY $\propto L^2$: MOSTLY DOWNSTREAM
- KAONS: $K^+ \rightarrow \pi^+ e^+\nu_e$ → SHORT LIFETIME: MOSTLY UPSTREAM

SAV WE HAVE A 300 EVENT $\nu_e$ EXCESS: CHANGE DECAY LENGTH TO 25 m:

<table>
<thead>
<tr>
<th>DECAY LENGTH</th>
<th>$\nu_e$ EVENTS</th>
<th>$\nu_e$ EXCESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 m</td>
<td>~400,000</td>
<td>300</td>
</tr>
<tr>
<td>25 m</td>
<td>~220,000</td>
<td>~250 (if K mis-estimate), ~80 (if $\mu$)</td>
</tr>
</tbody>
</table>
$\nu_\mu$ FLUX AT BOONE

(FROM GEANT MC)
K-INDUCED $\nu_e$ AT BOONE

BoONE will see $\sim$200-400 $\nu_e$ from $K^+$ and $K^0_L$ decays per year — comparable to our expected yield of oscillated $\nu_e$ if LSND is correct. $K^+ \to \pi^+ e^- \nu_e$ (BR=5%) and $K^0_L \to \pi^0 e^+ e^- \bar{\nu}_e$ (BR=39%)

Goal is a systematic error <10% on the K-decay $\nu_e$.

Information on the $\nu_e$ will come from:

- **MONTE CARLO:** GEANT, MARS, DPMJET, … (50% disagreements)

- **PRODUCTION MEASUREMENTS:**
  - BNL E910 (12 GeV p on THIN Be)
  - HARP at CERN PS (8 GeV p on THIN Be (2001), THICK (2002))

- **IN-SITU MEASUREMENTS:**
  - LITTLE MUON COUNTER (LMC)
**Decay Kinematics**

- In the downstream part of the secondary beam, high-transverse-momentum mesons have generally been removed by collimation.

\[ \Rightarrow \text{High}-p_T \text{ particles here come primarily from decays:} \]

- Muons specifically:
  \[ \pi^+ \rightarrow \mu^+ \nu \quad p_T(\text{max}) = 30 \text{ MeV}/c \]
  \[ K^+ \rightarrow \mu^+ \nu \quad 236 \text{ MeV}/c \]
  \[ K_L^0 \rightarrow \pi^+ \mu^+ \nu \quad 216 \text{ MeV}/c \]

High-\(p_T\) muons come almost exclusively from \(K\) decays.

\(p_T\) separation becomes energy separation when specific decay angle selected.

\[ \Rightarrow \text{Exploit by measuring } \mu \text{ momentum distribution at a particular angle; infer parent particle.} \]
Setting $K^+ p_T = 0$:

Muons leaving beam btw. 6° and 8° from $K^+$ decay

$E_K (GeV)$

$E_\mu (GeV)$
Adding the $\pi$ decays with proper relative normalization.

\[ x \times 10^{-2} \]

\[ \begin{align*}
0 & \quad 0.25 & \quad 0.5 & \quad 0.75 & \quad 1 & \quad 1.25 & \quad 1.5 & \quad 1.75 & \quad 2 & \quad 2.25 & \quad 2.5 \\
& \quad \mu \text{ from } K & \quad \mu \text{ from } \pi \\
\end{align*} \]

$E_\mu$ (GeV)

\[ \begin{align*}
0 & \quad 0.05 & \quad 0.1 & \quad 0.15 & \quad 0.2 & \quad 0.25 & \quad 0.3 \\
& \quad \mu \text{ from } K & \quad \mu \text{ from } \pi \\
\end{align*} \]

clear separation between $K$ and $\pi$ decays.

\[ \Rightarrow \text{High } K/\pi \text{ parentage ratio because} \]

\[ \begin{align*}
a) & \text{ Most } \pi \text{ in beam too high energy to produce a } 7^\circ \text{ muon} \\
& \text{Low-energy } \pi \text{ more likely to decay upstream} \\
\end{align*} \]
THE LMC
"LITTLE MUON COUNTER" PROJECT

Concept is to draw a beam of muons into an evacuated drift pipe pointed 7° from the decay pipe (beam axis), then use a magnetic spectrometer to measure the momentum distribution.

41 m from target
The spectrometer concept:

SCINTILLATING FIBER HODOSCOPE TRACK \( \mu \)
MAGNET BEND MEASURES CHARGE & MOMENTUM

Permanent 3kG dipole magnet
BASED ON FNAL RECYCLER RING DIPOLE DESIGN
THE COLLIMATOR

Steel bricks (not shown) stacked around outside to produce 16" x 16" outer dimensions. (40 cm x 40 cm)

Aperture cone: radius 0.3 cm upstream
0.5 cm downstream

Selects $\mu$ coming along central axis of drift pipe
$\Rightarrow$ Rejects dirt muons
FROM GEANT MC:

SCINT. FIBER SPECTROMETER PROVIDES
≥5% MUON MOMENTUM RESOLUTION
Boone Beam Timing

2 sec. "supercycle"

67 ms

1.6 \mu s

Booster Spill

5 \times 10^{12} protons

19 ns

2.5 ns

RF

Bucket

6 \times 10^{10} protons
$\mu$ SPECTRUM OUT OF COLLIMATOR:

NOMINAL POSITION OF LMC ENCLOSURE

<table>
<thead>
<tr>
<th>ID</th>
<th>55</th>
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</thead>
<tbody>
<tr>
<td>Entries</td>
<td>15657</td>
</tr>
<tr>
<td>Mean</td>
<td>0.6063</td>
</tr>
<tr>
<td>RMS</td>
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<tr>
<td>UDFLW</td>
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<tr>
<td>OVFLW</td>
<td>0.9970E-05</td>
</tr>
<tr>
<td>ALLCHAN</td>
<td>0.7093E-01</td>
</tr>
</tbody>
</table>

BLUE—CLEAN MUONS
RED—DIRT MUONS
BLACK—SUM

ENERGY OF DIRT $\mu$ THROUGH HOLE

TOTAL RATE 0.07 $\mu$ PER RF BUCKET
**LMC Rates:**

**Total Muon Rate:**

0.07 per RF Bucket  
= 6 per 1.5 μs spill (5x10^12 protons on target)  
= 30 per second (running beam at 5 Hz)  
= 2.5x10^6 per day

→ Measurements with LMC are not statistics limited!

**Other Particles:**

0.011 photons/ bucket (most from π^0 decays)  
1.5x10^-3 e^±/ bucket  
5x10^-3 π^±/ bucket

→ All well below muon rate  
   Most from K decays too
- Outer (veto) volume has 240 PMTs
- Inner volume has 1280 8" phototubes (mostly from LUNA)
- Fiducial mass 445 tons (5 m radius)
- Pure mineral oil - total mass 800 tons (20 m radius)
PHOTOTUBE SUPPORT STRUCTURE (PARTIALLY ASSEMBLED VIEW)

- LAT SUPPORT STRUTS
- LATS
- PANEL MOUNTING
- VETO TUBES
- BARRIER PANEL

Support structure panels form opaque barrier between main volume (black) and veto volume (white)
OIL

- Selected Exxon's MARCOL 7 oil from about a dozen candidates.
- Attenuation length 20-25 m (spec was 20)
- Density 0.836 g/cc

Delivery by railcar from Houston began in December.

⇒ 8 of 11 cars have arrived

Detector is > 3/3 full
TRIGGER AND READOUT

- Electronics reused from LSND
- Records time of first hit per tube and charge integral over 100 ms.
- Fully pipelined readout

TRIGGER:
- Record 20 μs about every beam pulse
- Trigger on certain patterns of detector activity off-spill to calibrate with cosmic rays and grab extra physics (may be able to see neutrinos from a galactic supernova!)
- Also trigger on calibration laser pulses
Reconstructing Neutrino Events

Oscillation analysis will use:

Čerenkov cone reconstruction

Veto information

Visible energy (total PMT charge)

Prompt and delayed light distribution

Early activity

Late activity
Analysis: $e, \mu, \pi^0$ discrimination

Current reconstruction is based on shape $\chi^2$ variables adapted from LSND.

→ New reconstruction algorithms and particle ID schemes under development (including neural nets)
Consider the energy dependence:

Signal for two possible sets of oscillation parameters:

\[ \Delta m^2 = 2 \text{ eV}^2, \sin^2 2\theta = 0.002: \]

\[ \Delta m^2 = 0.3 \text{ eV}^2, \sin^2 2\theta = 0.03: \]
Neutrino Energy Spectra:

$\nu_\mu$ spectrum mostly below 1 GeV. For low-$\Delta m^2$ oscillations, $\nu_e$ will have even lower energy.

$\nu_\mu$ energy (GeV)

$\nu_e$ energy (GeV) -- from $\mu^+$ decay

$\nu_e$ energy (GeV) -- from $K^0$ decay

$\nu_e$ backgrounds tend toward higher energy — where cross-section is higher too. $\Rightarrow$ Energy cut helpful for low-$\Delta m^2$ sensitivity.
SCINTILLATION LIGHT

"Pure" mineral oil does scintillate — for a $v_e$ interaction 10-30% of light from scintillation (depends on type of oil)

Scint. light is delayed and isotropic → helps establish vertex position

Recoil proton, neutron in neutral-current $\pi^0$ event (from $\Delta$ resonance) enhances scintillation vs. $e^-$ signal event → helps particle ID.

Preliminary tests at Indiana Cyclotron show our oil has relatively low scintillation. We may decide to dope it with scintillator.
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**EARLY/LATE ACTIVITY**

The DAQ will record a 20μs window around each beam spill. This can reject two kinds of background:

- **Electrons from μ decay in detector:**
  
  → Search backward several μ lifetimes (τ ≈ 2.2μs) for μ production or cosmic ray track entrance

- **Muons mis-identified as electrons:**
  
  → Search forward several μ lifetimes for μ decay at rest.

  (Note—8% of μ⁻ capture in nuclei and cannot be detected by decay!)
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Schedule

• Oil fill should finish in the next few weeks

• 25m absorber installation next month (final component of decay region)

• Upstream primary beam tests in April

• Beam on target June

• High-intensity physics data late summer

• 2-year initial run ($10^{21}$ protons on target)
In light of new interest in CPT, we are discussing neutrino/antineutrino running plans.
IF THERE IS A SIGNAL, FROM COUNTING AND E < 1 GeV CUT ALONE WE SEE SIGNIFICANT SIGNAL:

ALL LSND 95% C.L. REGION ACCESSIBLE
AT > 5σ.
IF A SIGNAL IS OBSERVED, HOW WELL COULD BooNE (2 DETECTORS) MEASURE OSCILLATION PARAMETERS?
Conclusions:

In 3 (?) years, either:

• The LSND thorn will be removed from the sides of oscillation phenomenologists

Or:

• We shall have confirmed the LSND result, and the world of neutrino physics will be much more interesting.