MiniBooNE: Up and Running

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MiniBooNE detector at Fermi National Accelerator Lab
Outline

• Motivation
• MiniBooNE Overview
• Physics at MiniBooNE
• Current Status
• First Data!
Neutrino Oscillations
The Evidence So Far ...

**Solar** $\Delta m^2 \sim 10^{-(4-5)}$

**Atmospheric** $\Delta m^2 \sim 3 \times 10^{-3}$

Both are well established

**LSND** $\Delta m^2 \sim 10^{-(0-1)}$

Three $\Delta m^2$ scales!

Unconfirmed result...

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Motivation for MiniBooNE
The LSND Oscillation Signal

Excess: $87.9 \pm 22.4 \pm 6.0$ evts.

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

3.8 $\sigma$ statistical significance of excess.

Confirmation is Crucial!

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Motivation for MiniBooNE
The LSND Oscillation Signal (2)

Karmen result excludes part of LSND allowed region
...but a lot of phase space is left open

Plot taken from Church, Eitel, Mills, and Steidl
hep-ex/0203023
MiniBooNE Sensitivity to $\nu_e$ Appearance

- Same L/E as LSND
  - Higher statistics
  - Different systematics (different L, E)

- MiniBooNE sensitivity will cover entire LSND allowed region at 5 $\sigma$ level in two years
MiniBooNE Sensitivity to $\nu_\mu$ Disappearance

- Can help distinguish $3+1$ from $2+2$
- Complementary Analysis
- Lower $\Delta m^2$ reach than CDHS
- MiniBooNE will have HIGH statistics for $\nu_\mu$ disappearance!
MiniBooNE Experiment: Beamline Overview

- **8GeV protons from Fermilab Booster**
- **Incident on Be target**
- **Magnetic horn focuses interaction products**

- $\pi$ and K secondaries traverse decay pipe
- Traverse beam absorber + berm
- $\nu_\mu \rightarrow \nu_e$?

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MiniBooNE Experiment: Detector Overview

- 12m diam. sphere
- lined with 8" PMTs
  - 1280 main region
  - 240 veto region
  - 10% coverage
- 800 tons of mineral oil
- Custom electronics from LSND
- All new Data Acquisition System
MiniBooNE Experiment:
Particle Identification

- Short track, no multiple scattering: Sharp Ring
- Electrons: short track, mult. scat., brems.: Fuzzy Ring
- Muons: long track, slows down: Sharp Outer Ring with Fuzzy Inner Region
- Neutral pions: 2 electron-like tracks: Two Fuzzy Rings
MiniBooNE Experiment: Neutrino Fluxes

\[ \text{p} + \text{Be} \rightarrow \pi^+, K^+, K^0_L \]

The beam is comprised almost entirely of \( \nu_\mu \)

\[ \pi^+ \rightarrow \mu^+ \nu_\mu \]
\[ K^+ \rightarrow \mu^+ \nu_\mu \]
\[ \rightarrow \pi^+ \pi^0 \]

Intrinsic \( \nu_e \) flux is small compared to \( \nu_\mu \) flux

\[ K^0_L \rightarrow \pi^+ e^- \nu_e \]
\[ \mu^+ \rightarrow e^+ \nu_e \nu_\mu \]
\[ K^+ \rightarrow e^+ \nu_e \]

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MiniBooNE Experiment: Numbers of Events

Approximately 500,000 $\nu_\mu C$ events expected in MiniBooNE with two years of running.

- Intrinsic $\nu_e$ background: 1,500 events
- $\mu$ mis-ID background: 500 events
- $\pi^0$ mis-ID background: 500 events
- LSND-based $\nu_\mu \rightarrow \nu_e$: 1,000 events
MiniBooNE Experiment: Blindness Scheme

- Blind analysis is used to prevent bias
  - Encourages sound development of Monte Carlo
- In a nutshell:
  - Start by putting all but clean $\nu_\mu$ CC events "in the box"
  - Take 1000 open event to use for studies
  - Open the box incrementally to extract clean $\mu$ and $\pi^0$ samples
Non–Oscillation Physics:
ν–C Cross–Section Measurements

• Quasi–elastic ν–C cross–sections are key for the oscillation measurement
• We will improve on the current uncertainty in the total ν cross–section around 1 GeV
Non−Oscillation Physics: MiniBooNE the Supernova Detector

- Estimated sensitivity: $190 \nu_e p \rightarrow e^+ n$ for a galactic supernova at 10 kPc
- Supernova trigger in action! 15.2 µsec holdoff after cosmic rays + 99% veto efficiency cuts michel $e^-$
- $^{12}$B decay background peaked at lower energy, cosmic ray background peaked at higher energy

Non–Oscillation Physics: Anomalous Neutrino Magnetic Moment

- If non–zero $\mu_\nu$, $\nu_\mu$ can have EM interactions → large contribution to $\nu_e$ scattering cross–section at low electron recoil energy
- Expected sensitivity: ~ 100 $\nu$–e scattering events will give a factor of 2 improvement over LSND $\mu_\nu$ limit

B. Fleming and J. Beacom, in preparation
More Oscillation Related Physics: Test of CP and CPT

- MiniBooNE can run in \( \nu \) or anti-\( \nu \) mode
- Recent CPT violating models account for all current experimental oscillation results with only 3 \( \nu \)s


Legend:
- \( \nu_e \) □
- \( \bar{\nu}_e \) □
- \( \nu_\mu \) □
- \( \bar{\nu}_\mu \) □
- \( \nu_\tau \) □
- \( \bar{\nu}_\tau \) □

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Current Status of MiniBooNE: Protons on target!

- Protons on target for physics running since August 24, 2002
- Average intensity is about 10% of desired level
- Shown in plot:
  - Total
  - MiniBooNE
  - Stacking
MiniBooNE’s First Data

Cosmic muon enters detector and decays; both are observed

hit times for 3 "Michel" events

Fit Lifetime:

\[ \tau = 2.12 \pm 0.05 \, \mu s \]

Expected \( \mu \) lifetime in oil

2.13 \( \mu s \)

with 8\% \( \mu^- \) capture on carbon.

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Current Status of MiniBooNE: Neutrino Events in the Detector!

- **Cuts:**
  - >200 hits in tank
  - <6 hits in veto region
- **Average rate** >1 Hz
- **Typical pulse has** $3.5 \times 10^{12}$ protons
- **$2.3 \times 10^{-15}$ int/proton** OR 1 ν in detector every 120 pulses
MiniBooNE Beam Data:
Looking closer

Angular distribution is peaked forward – quasi–elastic scattering
MiniBooNE Beam Data: Analyzing Events in the Detector

Stopping muon

Nice, clean ring
MiniBooNE Beam Data: Events in the Detector

Through-going muon

Filled circle
Current Status of MiniBooNE: Summary

• **MiniBooNE is running and taking physics data.**
• Detector is working well.
• The beam is steadily improving.
• **Two years of running in ν mode**
  • Two years of anti-ν mode to follow
• **Will cover entire LSND region at 5σ level**
Motivation for MiniBooNE
The LSND Experiment

Data Collected 1993–98
30 m baseline
$20\text{MeV} < E_{\nu_e} < 55\text{MeV}$
$L/E \sim 1\text{m/MeV}$

167 tons liquid scintillator

Signal Reaction:
$\bar{\nu}_e \, p \rightarrow X \, e^+ \, n$
$n \, p \rightarrow d \, \gamma(2.2\text{MeV})$

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