Status of MiniBooNE Experiment

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Neutrino Oscillation at High $\Delta m^2$

- Cosmologically Interesting Region; Hot Dark Matter?
- LSND Signal at High $\Delta m^2$
- KARMEN II narrowed the signal region
- MiniBooNE will fully address this signal.
LSND: Searching for $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$

- $\bar{\nu}_\mu$ – From $\mu^+$ decay at rest with endpoint energy 53 MeV
- $L = 30\text{m}, L/E \sim 1\text{m/MeV}, 167\text{ tons of Mineral Oil}$
- Look for $\bar{\nu}_e$ Appearance: $\bar{\nu}_e p \rightarrow e^+ n, n p \rightarrow d \gamma (2.2\text{MeV})$
LSND Oscillation Signal

- Signal above background: 87.9±22.4±6.0 events
- Oscillation Probability: (0.264±0.067±0.045)%

- KARMEN II Narrowed the Signal Region
- Joint Analysis of Karmen and LSND
- Needs Confirmation ⇒ MiniBooNE
MiniBooNE Experiment

- To Confirm or Rule Out LSND Signal Region
- Same L/E (~ 1 m/MeV)
- Higher Statistics – 10 times more in 2 calendar years
- Different Systematics – 10 times higher energy: Different events signature and background
- Higher Significance – 5σ over entire LSND region as a “counting experiment” (more significant when energy dependence is included)
The BooNE Collaboration

62 Scientists from 13 institutions

3 Undergraduate Universities
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MiniBooNE Overview

- Primary beam of 8 GeV protons from FNAL Booster Ring
- Be target produces secondary beam of π’s and K’s
- Horn focuses particles toward detector
- Mesons decays in decay region $\Rightarrow$ Intense $\nu$ beam with $E_\nu \sim 1$ GeV
- Neutrinos traverse 450 m of dirt: Oscillation?
- Mineral oil Cerenkov detector
Supply 8 GeV proton beam to Tevatron and Main Injector.

Must now run at record intensity.

MiniBooNE will run simultaneously with other programs. (e.g. Run II + BooNE)

BooNE: 5Hz, $5 \times 10^{12}$ protons/pulse, $5 \times 10^{20}$ p.o.t/year

Challenges are radiation issues, losses.
Target and Horn

- 71 cm long Be target.
- \( p + Be \rightarrow \pi^\pm, K^\pm, K^0_L \)
- Horn applies Toroidal Field;
  - Focuses the charged particles on the detector.
  - Initially positive particles will be focused selecting \( \nu \),
    but the horn current can be reversed to select \( \bar{\nu} \).
- Increases neutrino intensity by an order of magnitude.
- Successfully Tested.
\textbf{Decay Region}

- $$\nu\mu$$ Beam from meson decay:
  \[
  \pi^+ \rightarrow \mu^+ \nu\mu \quad \text{K}^+ \rightarrow \mu^+ \nu\mu \quad \text{K}^0_L \rightarrow \pi^- \mu^+ \nu\mu
  \]

- Switching between 25 and 50 m decay length helps us to understand the $$\nu_e$$ background from $$\mu$$ decay.

- The Little Muon Counter (LMC) cross-checks the beam flux and $$\nu_e$$ background from K decays
Neutrino Flux at the Detector

- High Flux of $\nu_\mu$
- Small $\nu_e$ Background from
  
  \[ \mu^+ \rightarrow e^+ \nu_e \nu_\mu \]
  
  \[ K^+ \rightarrow \pi^0 e^- \nu_e \]
  
  \[ K^0_L \rightarrow \pi^+ e^- \nu_e \]

Flux Estimate:

- Detailed simulations
- HARP measurements
- $\nu_\mu$–Carbon charged current $\sigma$
- 50m & 25m decay region (µ background)
- Off–axis muon counter, LMC (K background)
Background Measurement in Beamline

- Varying the **length of the decay region** from 50m to 25m:
  - An oscillation signal would go down by a factor of 2.
  - Background $\nu_e$ rate ($\mu$ decay) would go down by a factor of 4.
  - $\nu_e$'s from decay of short-lived sources not affected.

- **Little Muon Counter:**
  A spectrometer which exploits the wide-angle decays of the Kaons, and will get the $E_\mu$ distribution to constrain the $\nu_e$ production rate from Kaons.
MiniBooNE Detector

- 12 m (40’) diameter sphere
- 807 ton (445 ton in fiducial volume) of mineral oil
- Optically isolated inner region lined with 1280 PMTs (10% coverage)
- Veto region with 240 PMTs
- Extensive calibration system – laser flasks, muon tracker, stopping muon cubes
- $\nu$ interactions in oil produce:
  - Prompt Cerenkov light (mostly)
  - Delayed scintillation light
PMTs and Electronics

- 8 inch Photomultiplier tubes:
  - 1197 tubes from LSND (R1408)
  - 324 New Hamamatsu tubes (R5912)
  - 240 tubes from LSND in the veto region (R1408)
- Operated at 1700 to 2200 V, with $16 \times 10^6$ electrons/pe
- Custom front-end electronics
  (some new, some recycled from LSND)
- All new DAQ software
Laser Calibration System

- Designed to calibrate PMTs individually by generating known light pulses
- 400 nm Laser
- 4 Ludox-filled flasks
- Calibrate PMT gain, timing, time slewing
- Oil attenuation length monitoring
Muon Tracker System + Scintillator Cubes

- Scintillator tracker above the tank
- 7 Optically isolated scintillator cubes in tank
- $\mu$’s with known trajectory through the oil
- Provides:
  - Range for energy calibration
  - Cross checks on reconstruction algorithms
Inside the MiniBooNE Detector
Calibration Events

Laser Events, ½ full of Oil

Cosmic Ray Muon
Cosmis Ray Muons – Lifetime

- Muon stops and decay (Michel) electron observed.

hit times for 3 "Michel" events

PMT hit time (µs)

Fit Lifetime = 2.12±0.05 µs
Expected in oil: 2.12 µs
with 8% µ⁻—capture
Particle Identification: $\mu$, $e$ and $\pi^0$

- PID based on ring id, track extent, ratio of prompt/late light signatures

- Short track, no multiple scattering
- $e$’s: short track, multiple scattering, brems.
- $\mu$’s: long track, slow down sharp outer ring with fuzzy inner
- $\pi^0$: 2 e–like tracks 2 fuzzy rings
Expected Events from MiniBooNE

- With $10^{21}$ protons on target (2 years)
- ~500k $\nu_\mu C$ charged current events
- Approximate number of $\nu_e$–like events

- Intrinsic $\nu_e$ background: 1,000 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 Expected Sensitivity

With 2 years of running
The MiniBooNE experiment is ready.
First Beam on Target in August 24.
Low Intensity Run
Horn turned on August 29th
High Intensity Runs start this week
Conclusion

The MiniBooNE experiment has started to take data.