SciBooNE (E954) update

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Outline

• SciBooNE experiment
  – Data taking status
  – Detectors

• Status of physics analyses

• Run plan

• Summary
SciBooNE Collaboration

• Universitat Autonoma de Barcelona
• University of Cincinnati
• University of Colorado, Boulder
• Columbia University
• Fermi National Accelerator Laboratory
• High Energy Accelerator Research Organization (KEK)
• Imperial College London
• Indiana University
• Institute for Cosmic Ray Research (ICRR)
• Kyoto University
• Los Alamos National Laboratory
• Louisiana State University
• Purdue University Calumet
• Universita degli Studi di Roma "La Sapienza and INFN"
• Saint Mary's University of Minnesota
• Tokyo Institute of Technology
• Universidad de Valencia

5 countries 17 institutions

Spokespeople:
M.O. Wascko (Imperial), T. Nakaya (Kyoto)

Mar 18, 2008 @London
SciBooNE Experiment
SciBooNE Experiment
(K2K-SciBar detector at FNAL Booster Neutrino Beam line)

- Precision measurement of $\nu$ & $\bar{\nu}$-bar cross sections at ~1GeV — Important for T2K and other oscillation experiments

- **SciBar:**
  - Originally K2K-near detector
  - Shipped to FNAL

- **BNB:** Intense & low energy $\nu$ beam
  - $E_\nu$ good match to T2K
  - $\nu$ and $\bar{\nu}$ beam

- **MiniBooNE** near detector
Data taking status

- Projected Protons On Target (POT): 2E20
  - ~1 year run
- Total collected POT so far: 1.48E20
  - $\nu$: 9.4E19 (goal: 1E20)
  - $\bar{\nu}$: 5.4E19 (goal: 1E20)
- Averaged detector live time fraction: 94%

Data taking is ongoing.

![Graph showing data taking status with POT values and months](data.png)
SciBooNE Detectors
SciBooNE Detectors

SciBar

ν beam

Muon Range Detector (MRD)

Electron Catcher (EC)
SciBar Detector

- Fully active target & tracking detector
  - Extruded scintillators with WLS fiber readout
  - 2.5 x 1.3 x 300 cm$^3$ cell
  - ~15,000 channels
- Total 15 tons, Fiducial volume: ~10 tons
- Distinguish a proton from a pion by $dE/dx$

Detector performance (SciBooNE cosmic ray data)

- Light yield for MIP:
  ~20 p.e./ 1.3cm
- Hit finding efficiency; ~99.9%
Electron Catcher (EC)

- EM calorimeter
- Electron, gamma ID
- 1mm scintillation fibers in the grooves of lead foils
- 2 planes (total 11X₀)
- Expected resolution 14%/√E

![dE/dx distribution for cosmic ray muons](image)

SciBooNE cosmic data

E dep. of MIP in EC ~100MeV

Muon Range Detector (MRD)

- Measure μ momentum with range
  - momentum up to 1.2GeV/c
- Iron Plate
  - 2” thick x 12 planes
- Scintillator Plane
  - 13 planes alternating horizontal and vertical planes

![Hit finding efficiency~99%](image)

SciBooNE cosmic data

Mean efficiency: mean of |y| < 100 cm
Status of Analyses

- Neutrino data (no $\bar{\nu}$ data in this talk)
- $7.7 \times 10^{19}$ POT is used
- Preliminary results
  - No systematic uncertainties yet
- MC sample: NEUT event generator
- All MC sample normalized by # of MRD match events (see later slides)
Physics Topics

Several analyses are in progress

• Charged Current
  – CC inclusive: Y. Nakajima (Japan)
  – CC-QE: J. Alcaraz (Spain), J. Walding (UK)
  – CC-$1\pi^+$: K. Hiraide (Japan)
  – CC-$\pi^0$: J. Catala (Spain)

• Neutral Current
  – NC-$\pi^0$: Y. Kurimoto (Japan)
  – NC-elastic: H. Takei (Japan)

• $\nu_\mu$ disappearance: K. Mahn (US)

8 PhD students are working on analyses
(+ 2 already graduated; C. Mariani (PhD) and C. Giganti (graduate), (Italy))
Physics Topics

Several analyses are in progress

- **Charged Current**
  - CC inclusive: Important for $\nu_\mu$ disappearance
  - CC-QE: Important for $\nu_\mu$ disappearance
  - CC-$1\pi^+$:
  - CC-$\pi^0$: J. Catala (Spain)

- **Neutral Current**
  - NC-$\pi^0$: Important for $\nu_e$ appearance
  - NC-elastic: H. Takei (Japan)

- $\nu_\mu$ disappearance: K. Mahn (US)

8 PhD students are working on analyses
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Charged Current analyses

• CC-inclusive, CC-QE, CC-1π⁺
Signature of **CC** event at SciBooNE

- **Muon = SciBar-MRD matched track**

**CC-QE**

**CC-1π (resonance)**

SciBar-MRD match sample:
- CC purity: 96%
- Cosmic ray background: <0.5%
Muon distributions

Sample: events $\mu$ stopped inside the MRD
(MC samples: normalized by # of MRD match events)

Reconstructed $\theta_\mu$

Reconstructed $P_\mu$

DATA/MC

Larger angle in data

Slightly higher $P_\mu$
Event kinematics

Reconstructed $E_\nu$ (assume CCQE)

Reconstructed $Q^2$ (assume CCQE)

$E_{\nu}^{\text{rec}} = \frac{m_n E_\mu - m_n^2 / 2}{m_n - E_\mu + P_\mu \cos \theta_\mu}$

Assume CC-QE

$\mu$ angle is important for $\nu$ energy reconstruction at SciBooNE (and T2K as well)
Independent Check on $\mu$ angle

- $\nu$ events inside MRD
- (SciBar not used for this sample)

Data/MC disagreement is not caused by detector effect.

??Physics??
Independent Check on $\mu$ angle

- $\nu$ events inside MRD
- (SciBar not used for this sample)

Data/MC disagreement is not caused by detector effect.

??Physics??

Continue to work to understand muon distribution

Reconstructed $\cos{\theta}$

Entries 80220

Preliminary

$\cos{\theta}_\mu$

$\theta_\mu$

SciBar
EC
MRD
Muon track
CC-QE and CC-nonQE
CC-QE and non-QE separation

Sample: SciBar-MRD match event & 2 track

QE/non-QE separation by 2nd track kinematics.

$\Delta \theta_p$: Opening angle between observed 2nd track and expected proton track assuming CCQE.

$\mu (P_\mu, \theta_\mu)$

Observed 2nd track

$\Delta \theta_p$

Preliminary sample (<25 deg)
- Purity: 74%

Non-QE sample (>25 deg)
- Purity: 84%
Muon distributions
with QE and non-QE samples

**CC-QE**
QE Purity: 74%

**CC-nonQE**
Non-QE Purity: 84%

- $\mu$ angle discrepancy is due to non-QE events??

![Data/MC](DATA/MC)

Preliminary

![BG from EC/MRD](BG from EC/MRD)
CC-$1\pi^+$ analysis
**CC-1\(\pi^+\) (\(\nu+N\rightarrow\mu+\pi+N'\))**

- **Signature:** muon + pion (2 MIP tracks)
  - Short proton track
  
- **Apply PID to 2nd track** (\(\pi\) or \(p\)) of non-QE sample to separate CC-\(\pi\) from other interactions.

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**dE/dx distributions**

- **Muons**
- **Protons**

**MIP confidence level**

- **Proton mis-ID as pion = 7.2%**
  - (Pion track efficiency = 74%)
**CC-1\(\pi^+\) \((\nu+N\rightarrow\mu+\pi+N')\)**

2-track, \(\mu+\pi\), non-QE-like

**\(P_\mu\)**

**\(\theta_\mu\)**

Reconstructed \(E_\nu\)

Reconstructed \(Q^2\)

**CC-1\(\pi\):**
- CC-resonance \(\pi\)
- CC-coherent \(\pi\)
- CC-multi \(\pi\)

655 events,
**CC-1\(\pi^+\)** Purity: 66% (MC)

(resonance)
Neutral Current Analysis

NC-$\pi^0$
NC-π0 \((\nu+N \rightarrow \nu+\pi^0+N')\)

Event signature:
- No muon = No SciBar-MRD match track
- All tracks contained in SciBar

- In order to select NC-π0
  - Chose: 2 isolated tracks
  - Reject: \(\mu, \pi^+, p\)
**NC-π0**

\[ \nu+N \rightarrow \nu+\pi^0+N' \]

846 events selected

**EMShower**

**Histo: MC**

- **NC\(\pi^0\) (19%)**, **CC\(\pi^0\) (17%)**
- Proton (19%)
- Muon (17%)

**Applying cuts:** Trk distance, Muon (by Michel e), Proton (by PID with dE/dx)

**Data**

- **EM shower**
- **Muon**
- **Proton**
- **Charged Pion**
- **Other BG**
Run Plan
Switch Horn Polarity ($\nu \rightarrow \bar{\nu}$)

- **Total POT so far ($\nu$ mode):** $9.4 \times 10^{19}$ (at Mar 22)
  
  (Projected POT for $\nu$: $1 \times 10^{20}$)
  
  - Delivered POT: $1 \times 10^{20}$! \textcopyright Thanks AD!!
  
  - For physics: ~$0.06 \times 10^{20}$ left
  
  - $\nu$ mode data taking complete before Apr 14

- **Will switch horn polarity April 14**
  
  - MiniBooNE spokespeople agreed to switch horn polarity on April 14.
  
  - BNB Machine Coordinator and Horn experts also agreed with the date.
  
  - Expected duration: ~1 week
data taking and end of run


\[ \bar{\nu} \] data taking: \(4.6 \times 10^{19}\) POT

Horn switch (Apr 14 - 21)

\(\bar{\nu}\) data taking complete:
- October (~6 months with ~1Hz)
- July (~3 months with ~2Hz)

※ AD trying to send beam to BNB with 2Hz
  (but not clear yet)
Summary

• SciBooNE Experiment
  – Precision measurement of $\nu$ and $\bar{\nu}$ cross section at $\sim 1\text{GeV}$
  – Data taking have been started June, 2007
    • Through Aug. 2007: Antineutrino mode
    • Started Oct. 2007: Neutrino mode
  – Data taking is going smoothly

• Run plan:
  – Horn polarity will be switched ($\nu \rightarrow \bar{\nu}$) on April 14.
  – Reach projected POT ($\nu + \bar{\nu}$: $2E20$) in this summer
    • Expected: in July with 2Hz or October with 1Hz

• Several physics analyses are in progress.
  – First results in this summer.
Backup
ν events timing distribution

- Beam window: 2usec (1.6us beam spill)

- Requiring SciBar-MRD match, cosmic ray background contamination <0.5%

SciBar-MRD match sample: CC purity: 96%
Vertex and # of tracks
Sample: SciBar-MRD track matched event

SciBar-MRD matched trk (Muon track)

X, Y

Z

ν beam dir.

SciBar EC MRD

Vertex

# of tracks from vtx

X-vertex

Y-vertex

Z-vertex

Preliminary

Entries 23737

ν CC QE
ν CC resonantπ
ν CC coherentπ
ν CC other
ν NC
anti-ν
BG from EC/MRD

Preliminary

Preliminary

Preliminary

Preliminary