Single Pion Measurement Capabilities at SciBooNE

Yasuhiro Nakajima, Kyoto University
NuInt07
June 1, 2007
Outline

- SciBooNE experiment
- Motivations to \( CC\pi^{+} \) measurement
- \( CC\pi^{+} \) measurement capability at SciBooNE
- Summary
SciBooNE overview

- Well developed fine-grained fully active detector: SciBar, used in K2K
- On the well-understood neutrino beam-line: Fermilab Booster Neutrino Beamline
- Aiming for precise cross-section measurements below ~1 GeV region.
  - Helps MiniBooNE (near detector) and T2K (same energy region).
- Single pion production is one of very important topics.

Y. Nakajima

June 1st, 2007  NuInt07
Motivations for single pion measurement (1)

- $\nu_\mu$ disappearance ($\nu_\mu \rightarrow \nu_x$) experiment: T2K, MiniBooNE (Cherenkov detectors)
  - Signal: CCQE (~40% of total int.). Neutrino energy can be reconstructed by muon kinematics.
  - Background: CC-$\Pi^+$ (~20% of total int.). Since pions and protons are low momentum, they are below Cherenkov threshold.

Precise knowledge of cross-section is required to understand the backgrounds.
Motivations for single pion measurement (2)

T2K case:
- Cross section errors have very large effect on the sensitivity.

Expected $\nu_\mu$ event at SK

- Disappearance (1ring $\mu$-like)
  - $\sin^2 2\theta_{23} = 1.0$
  - $\Delta m^2 = 2.7 \times 10^{-3}$ eV$^2$

5% measurement is ideal

Non-QE (Mostly CC$\pi^+$) backgrounds

Y. Nakajima

June 1st, 2007  NuInt07
Previous cross-section measurement

- Most of data comes from old bubble-chamber experiments.
  - poor statistics
- K2K and MiniBooNE are making great measurements.
- SciBooNE will follow with:
  - higher statistics than K2K
  - higher resolution than MiniBooNE.

\[ \sigma_\nu \text{ in this } E \text{ range of interest:} \]

\[ \sigma_{cc}/L_\nu \ (10^{-34} \text{ cm}^2/\text{GeV}) \]

\[ \nu, \pi^\pm, \text{QE, DIS} \]

\[ \text{CCFRR, BNL 7-feet, ANL 12-feet, ANL 12-feet} \]

\[ \text{Total CC, } \sigma(\text{DIS}), \sigma(\text{qel}), \sigma(1\pi) \]

MINOS, MINERvA, NOvA
K2K
MiniBooNE, T2K, SciBooNE
Super-K atmospheric \( \nu \)

Y. Nakajima June 1st, 2007 NuInt07
Single Pion Measurement at SciBooNE
CC- $\pi^+$ final state tagging

- Clear event-by-event final state tagging!
- Able to separate $\nu_\mu p \rightarrow \mu^- p \pi^+$ from $\nu_\mu n \rightarrow \mu^- n \pi^+$
Sensitivity to Pion absorption in nuclei

- We can distinguish Pion absorption events from CCQE by checking p-\(\mu\) kinematics.
- Capability of measuring effect of pion absorption in nuclei.

MC: \(\nu_\mu p \rightarrow \mu^- p \pi^+\)

Absorbed in nuclei

>20% of CC-1\(\pi^+\)
Sensitivity

- Expect \(~28000\) resonant CC-1\(\pi^+\) interactions in SciBar fiducial volume (10t) (for \(1.0 \times 10^{20}\) P.O.T.)

- We will have sufficient statistics/systematics to measure CC-1\(\pi^+\)/CCQE cross-section ratio with 5 % precision

\[\frac{n_{\text{QE}}}{n_{\text{QE}}} = 5\%\]

\[\frac{n_{\text{QE}}}{n_{\text{QE}}} = 20\%\]

Non-QE events: dominant background for "disappearance"

At BNB energies, non-QE B originate by CC events

\((90\% \text{CL})\) stat. only

\[\frac{n_{\text{QE}}}{n_{\text{QE}}} = 5\%\]

\[\frac{n_{\text{QE}}}{n_{\text{QE}}} = 20\%\]

\(p\pi\) separation with \(dE/dx\)
Summary

- SciBooNE is aiming to make precision cross-section measurements below ~1 GeV region.
  - Helps MiniBooNE, T2K
- For $CC \pi^+$ measurement, all muons, pions, and protons can be reconstructed as tracks.
  - Clear separation of interaction type.
  - Sensitivity to pion absorption in nuclei.
We’ve just started!

- We’ve just finished detector installation, and started commissioning!
- Exciting new data is coming soon!

\[ \nu p \rightarrow \mu^+ - p \pi^- + \]

candidate

Real data!
Backup slides
Geometrical acceptance for CC events

- Require μ stopped inside the detectors.
- ~60% total geometrical acceptance for CC interaction.

\[
\begin{align*}
\text{Entries} & : 121961 \\
\text{Mean} & : 0.5595 \\
\text{RMS} & : 0.3507 \\
\text{Underflow} & : 0 \\
\text{Overflow} & : 3263 \\
\text{Integral} & : 1.187 \times 10^5
\end{align*}
\]
### Event selection criteria for CC-1π⁺ (ν+N→μ⁻+N+π⁺)

- 2 tracks from the common vertex
- Both tracks are MIP-like (μ & π)

#### Neutrino run (0.5x10²⁰ POT)

| Selection criteria | # of events | # of CC-1π⁺ events | Purity  | Efficiency |
|--------------------|-------------|---------------------|---------|------------|
| Generated in FV    | 73,219      | 13,892              | --------| 100%       |
| CC inclusive sample (SciBar+EC+MRD) | 37,174 | 8,977 | 24.1% | 64.6% |
| # of tracks =2     | 8,291       | 2,705               | 32.6%   | 19.5%      |
| 1st track PID =μ-like | 7,845 | 2,580 | 32.9% | 18.6% |
| 2nd track PID =μ-like | 2,898 | 1,355 | 46.8% | 9.8%     |