Status of SciBooNE

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NuFact 07 @ Okayama Univ., Japan

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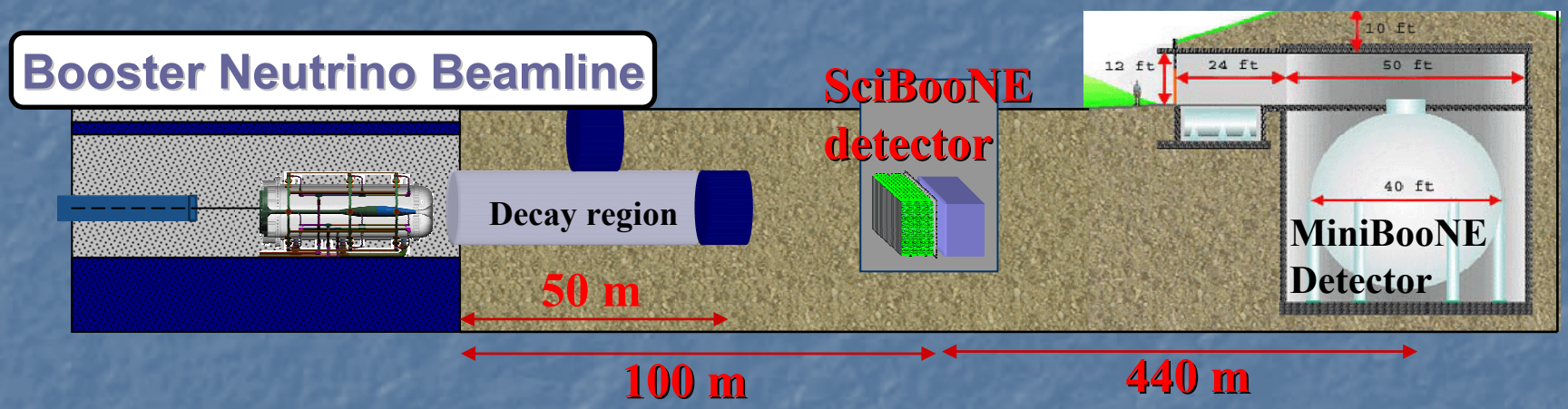
Introduction



- SciBooNE (FNAL E954)
  - Precise study of neutrino-nucleus cross section around 1GeV
  - Combination of Booster Neutrino Beam at FNAL and SciBar Detector used in K2K

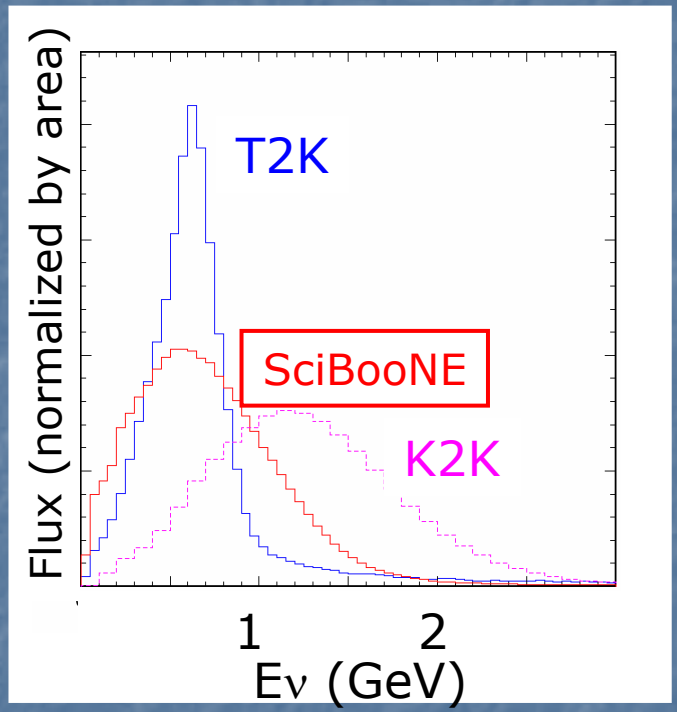
SciBooNE collaboration

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

Spokespeople:
T. Nakaya, Kyoto University
M.O. Wascko, Imperial College

Physics Motivation

- Precision study of neutrino cross sections for T2K
- Anti-neutrinos
  - Unexplored physics territory and important for CP study in T2K-II
- MiniBooNE near detector



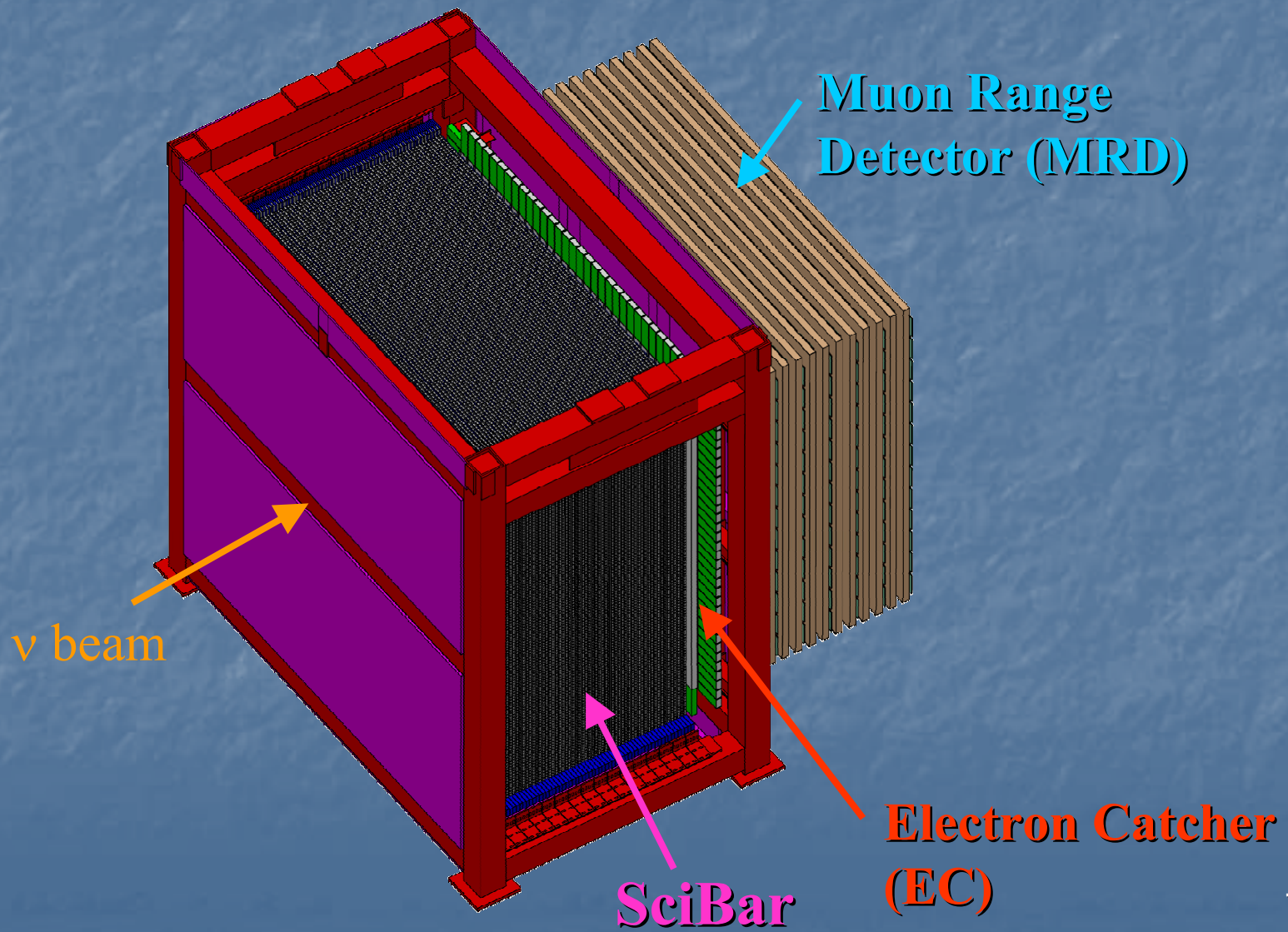
Projected
$1x10^{20}$ POT for neutrinos
$1x10^{20}$ POT for anti-neutrinos

SciBooNE timeline

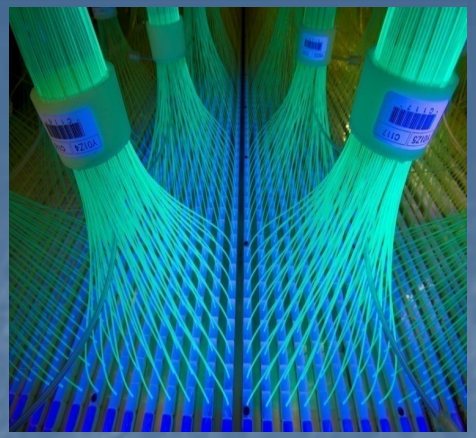
- 2005, Summer - Collaboration formed
- **2005, Dec - Proposal**
- 2006, Jul - Detectors move to FNAL
- 2006, Sep - Groundbreaking
- 2006, Nov - EC Assembly
- 2007, Feb - SciBar Assembly
- 2007, Mar - MRD Assembly
- 2007, Mar - Cosmic Ray Data
- 2007, Apr - Detector Installation
- 2007, May - Commissioning
- **2007, Jun – Anti-neutrino Data Run**

Two years from formation to first data!

SciBooNE Detectors

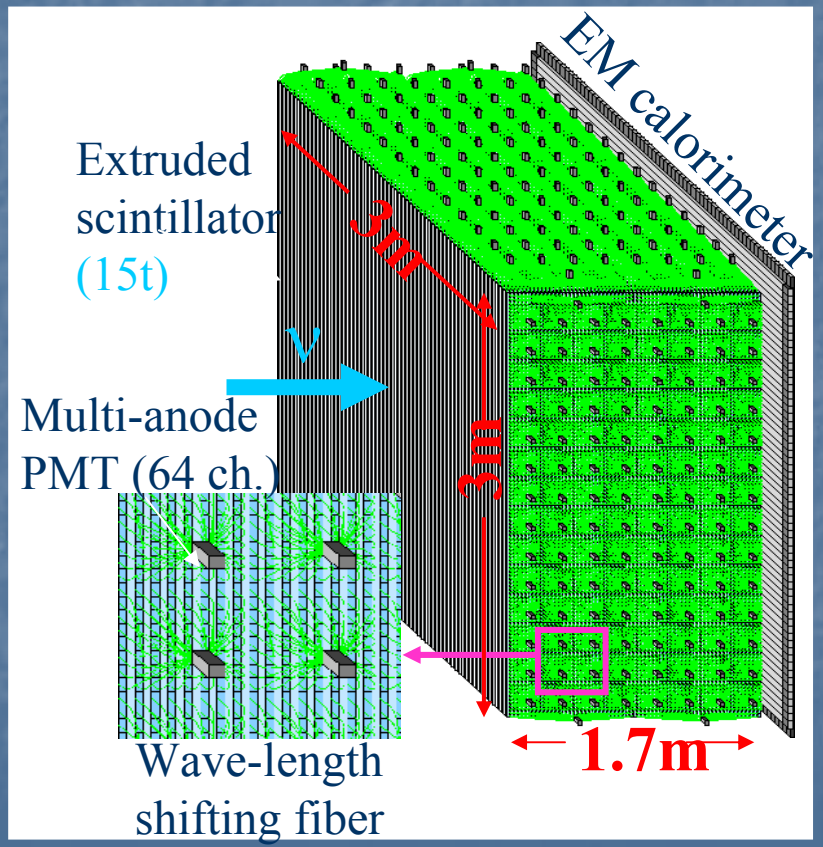


SciBar Detector



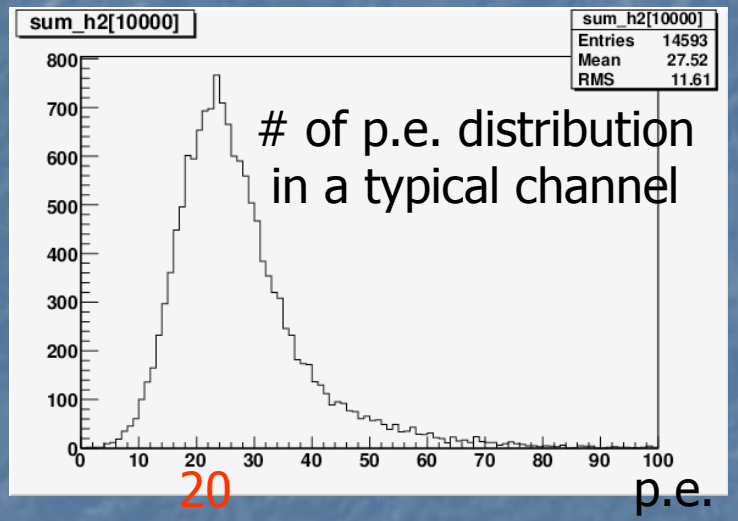
- Extruded scintillators with WLS fiber readout
- Scintillators are the neutrino target
- 2.5 x 1.3 x 300 cm^3 cell
- 14,336 channels
- Detect short tracks (>8cm)
- Distinguish a proton from a pion by dE/dx
- Total 15 tons

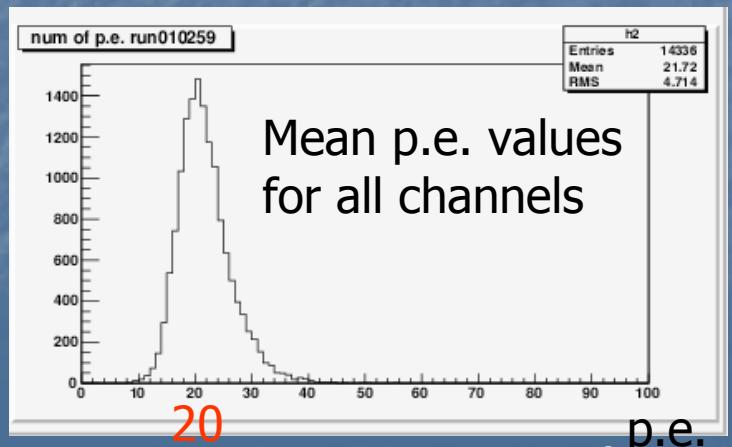
➔Clear identification of ν interaction process



Basic Performance of SciBar Detector

- Light yield for minimum ionizing particle
  - **~20 p.e./ 1.3cm** @30cm from PMT (average over all channels)
- Hit finding efficiency
  - Horizontal plane: **99.9%**
  - Vertical plane : **99.8%**
- # of dead channels is only **4/14,336 channels (0.03%)**

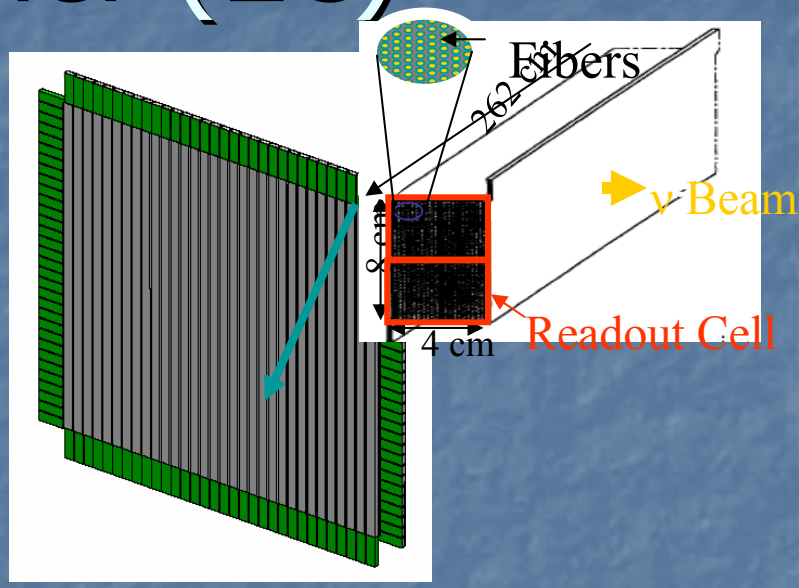


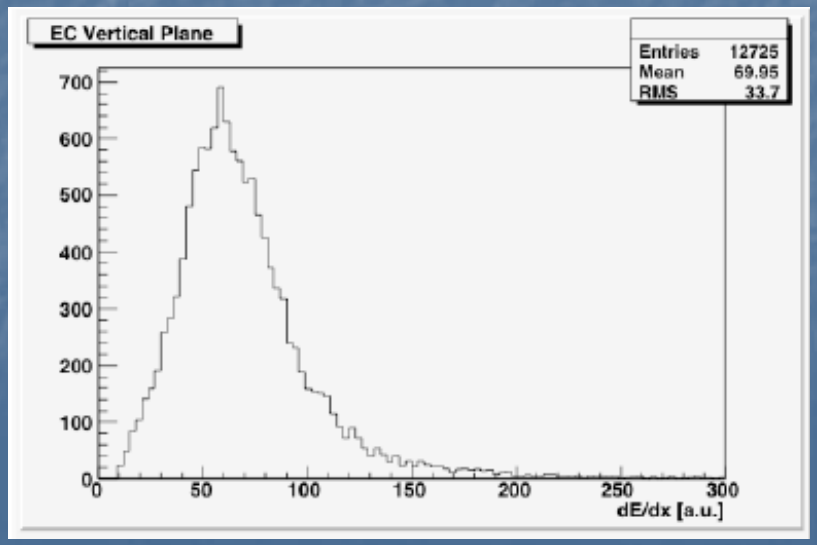


Electron Catcher (EC)

- "spaghetti" calorimeter re-used from CHORUS
- 1mm diameter fibers in the grooves of lead foils
- 4x4cm^2 cell read out from both ends
- 2 planes ($11X_0$)

  Horizontal: 32 modules
  Vertical : 32 modules
- Total 256 readout channels
- Expected resolution $14\%/\sqrt{E}$
- Linearity: better than 10%

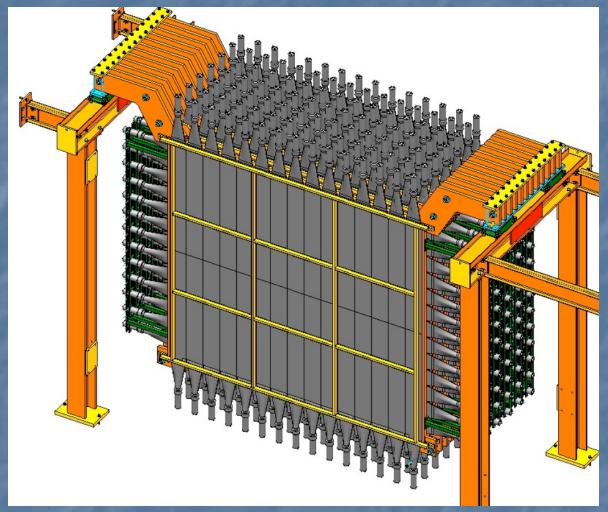




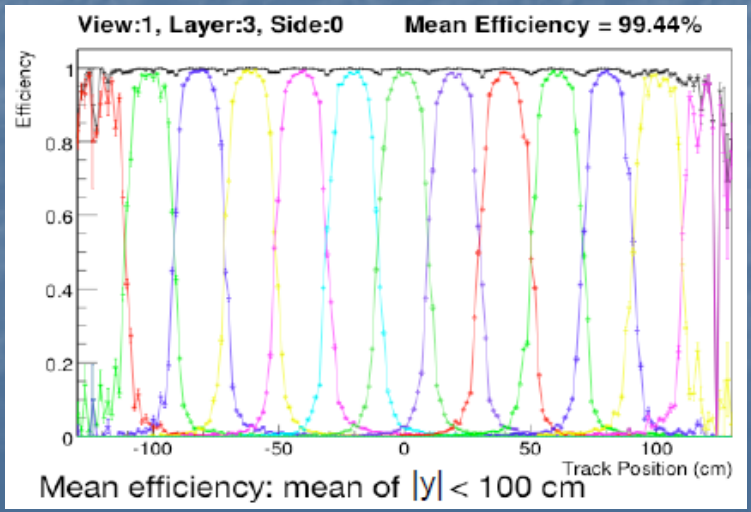
dE/dx distribution of vertical plane for cosmic ray muons

Muon Range Detector (MRD)

A new detector built with the used scintillators, iron plates and PMTs to measure the muon momentum up to 1.2 GeV/c.

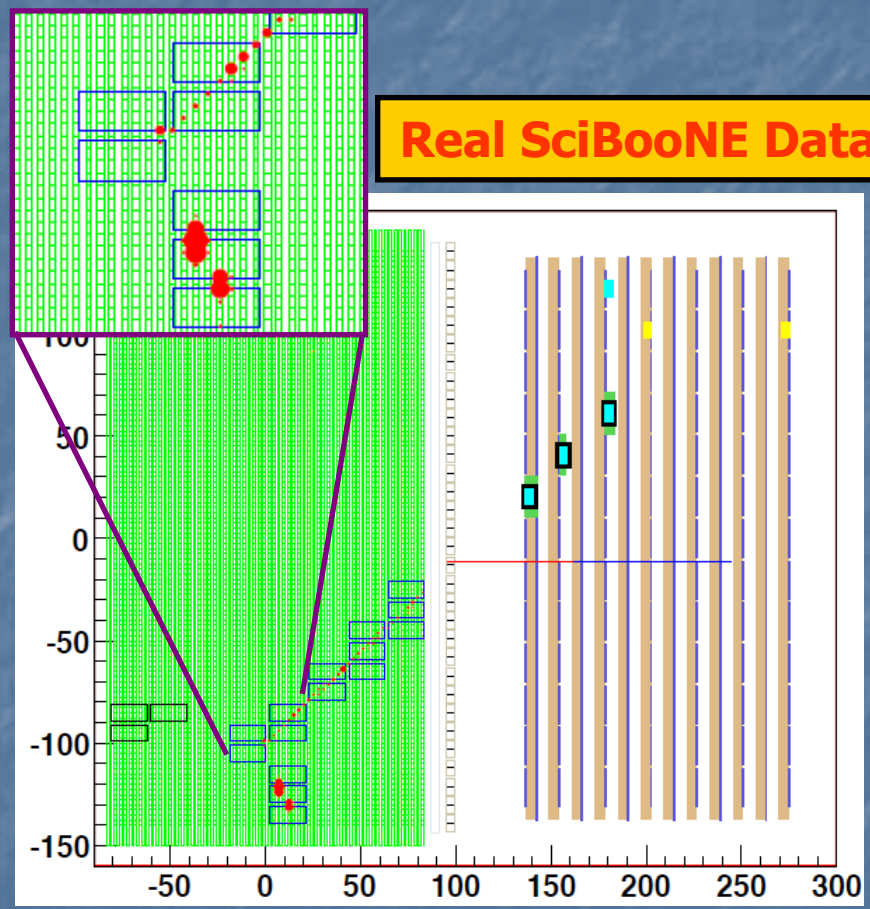


- Iron Plate
  - 305x274x5cm^3
  - Total 12 layers
- Scintillator Plane
  - Alternating horizontal and vertical planes
  - Total 362 channels



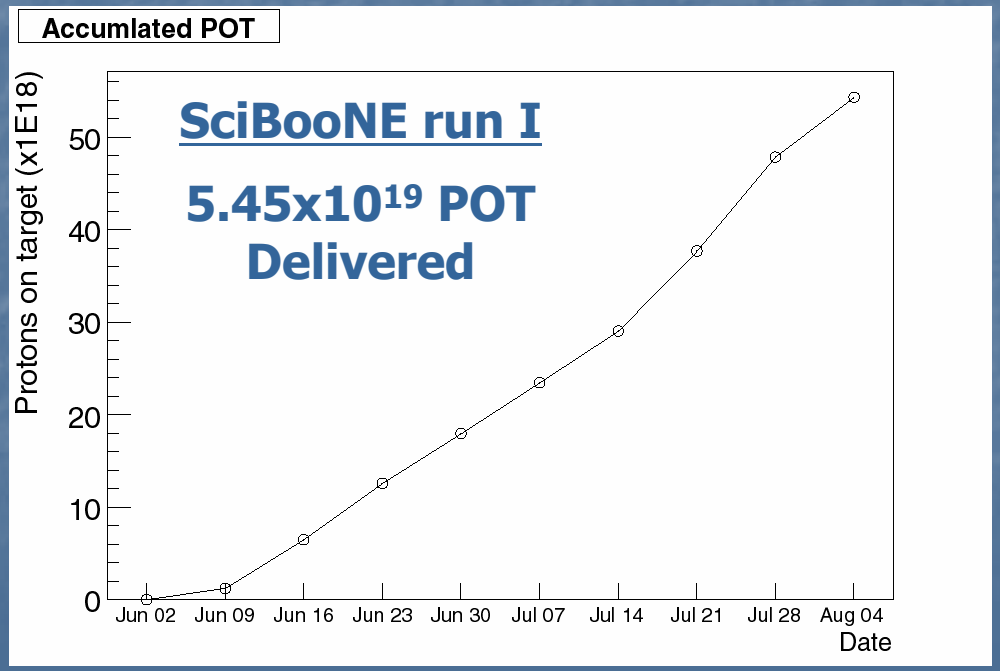
Hit efficiency of a typical horizontal plane

Anti-neutrino data run



- **Run I: Jun. 8 – Aug. 3**
- Delivered **5.45x10^{19} POT**
- Detector live time fraction ~95%

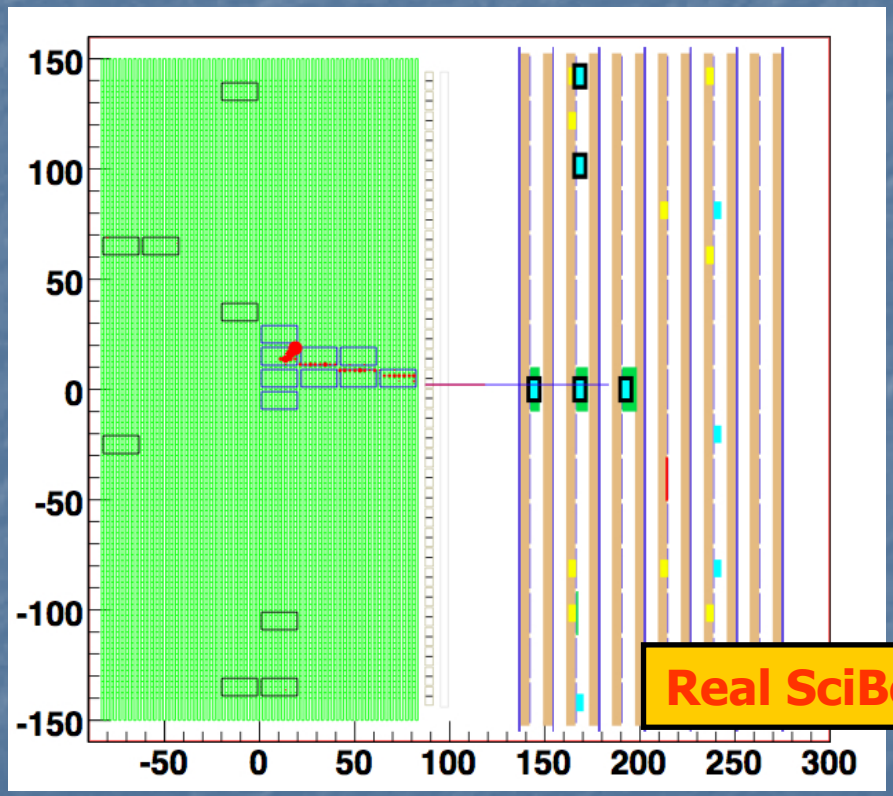
half of projected for anti-neutrinos!



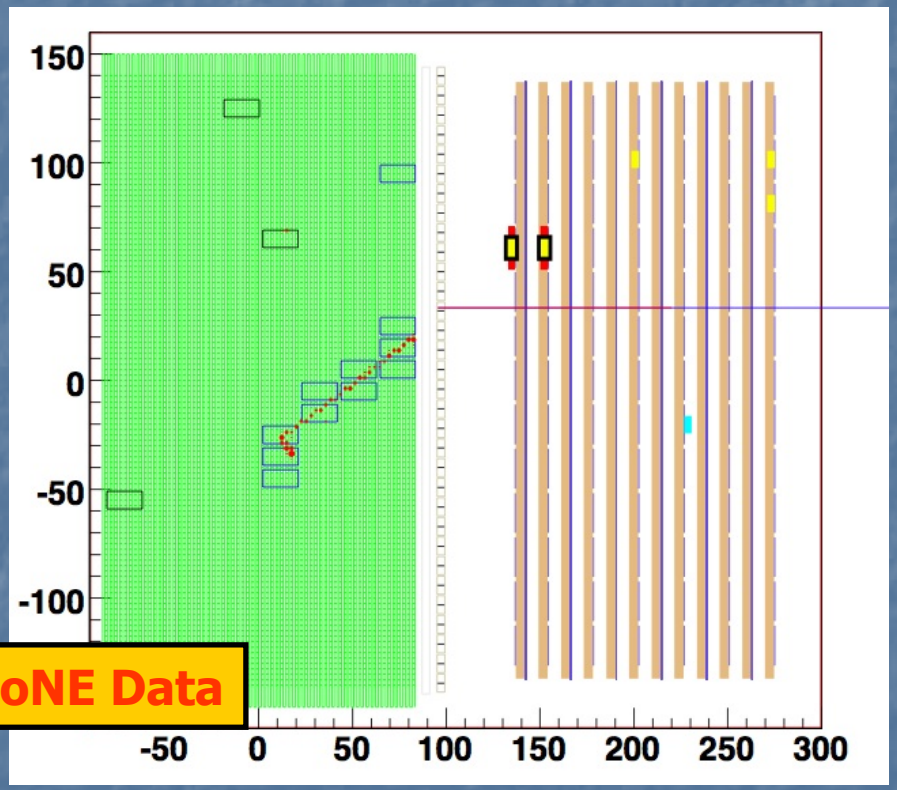
anti-$\nu\mu$ CC-QE candidate
($\overline{\nu}_\mu + p \rightarrow \mu + n$)

Event displays

TOP view



SIDE view

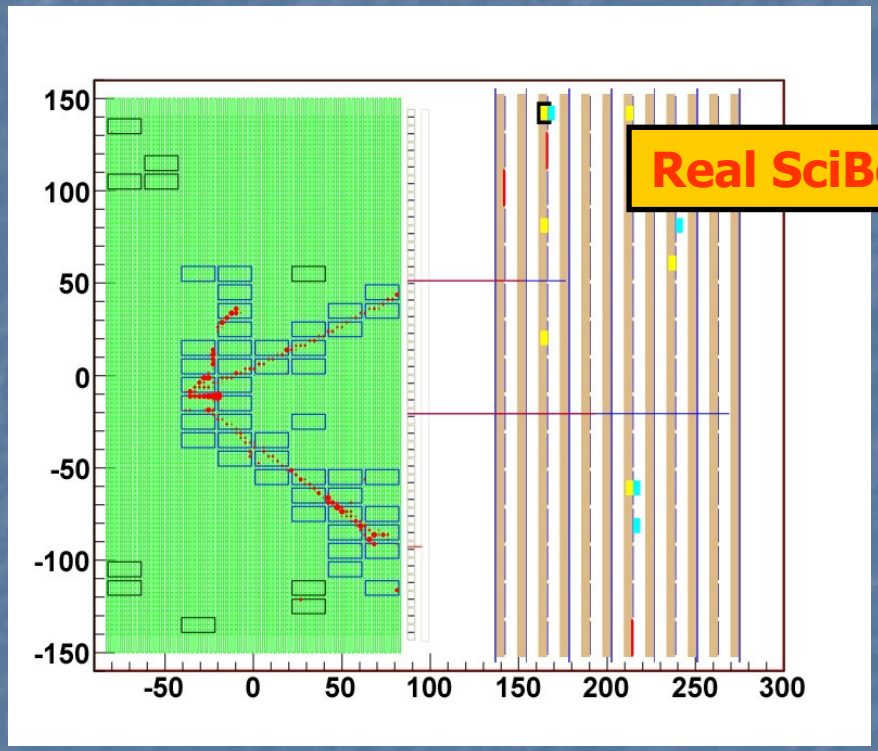


Real SciBooNE Data

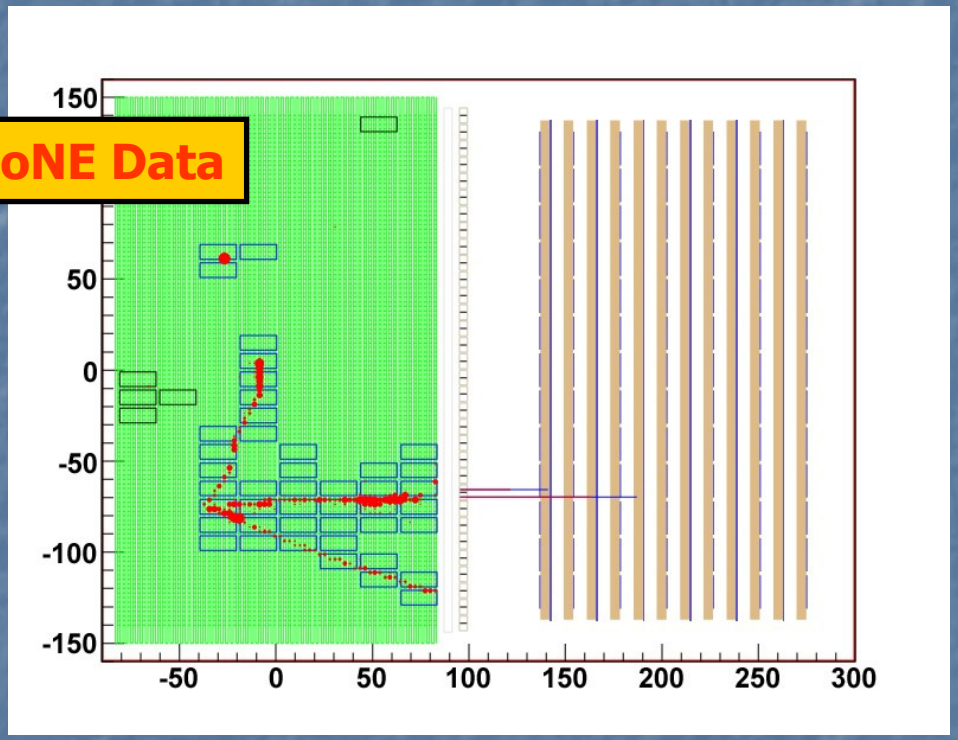
ν_μ CC-QE (ν_μ + n → μ + p) candidate

Event displays

TOP view



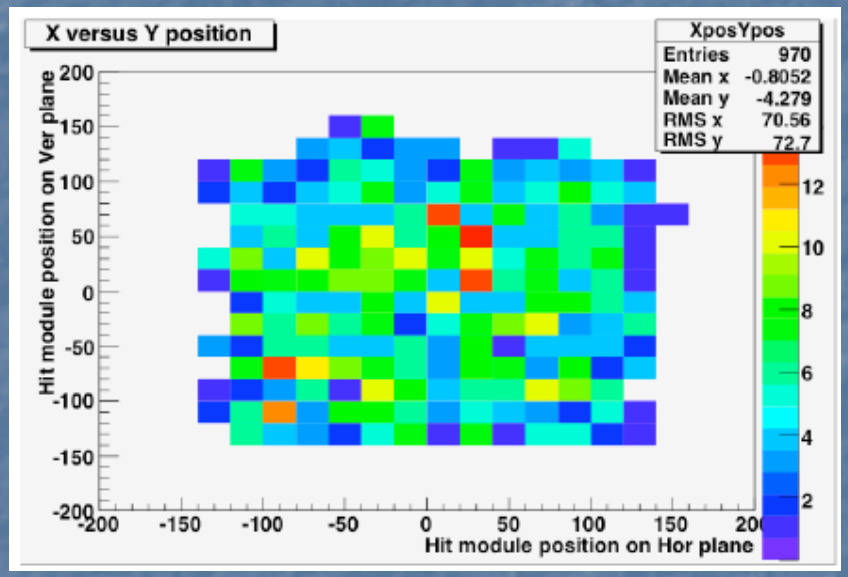
SIDE view



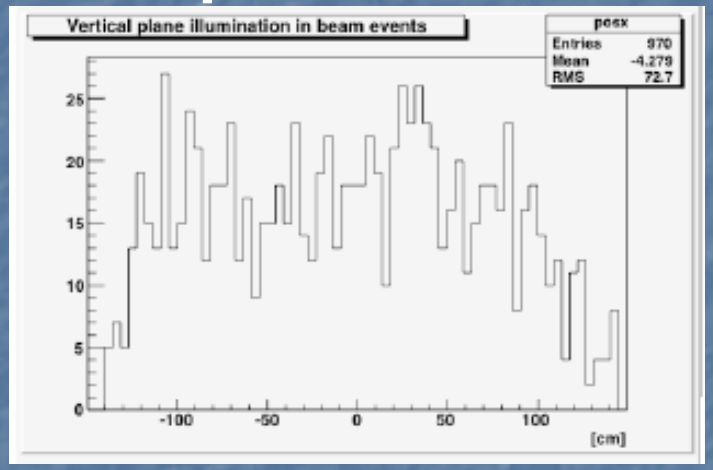
Real SciBooNE Data

3-track event

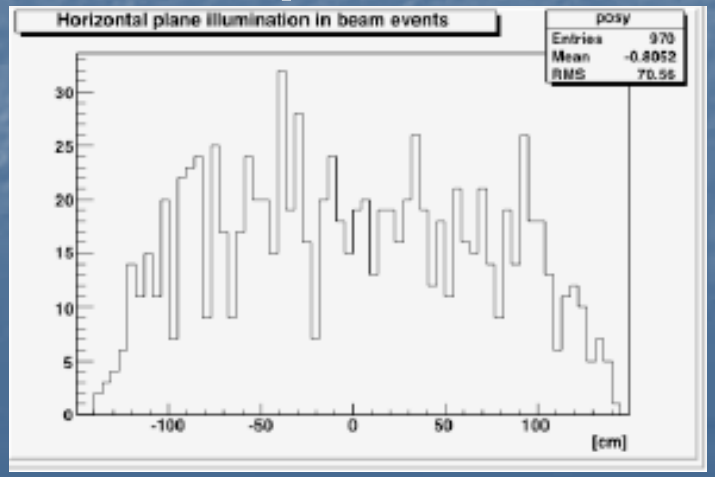
EC illumination with beam



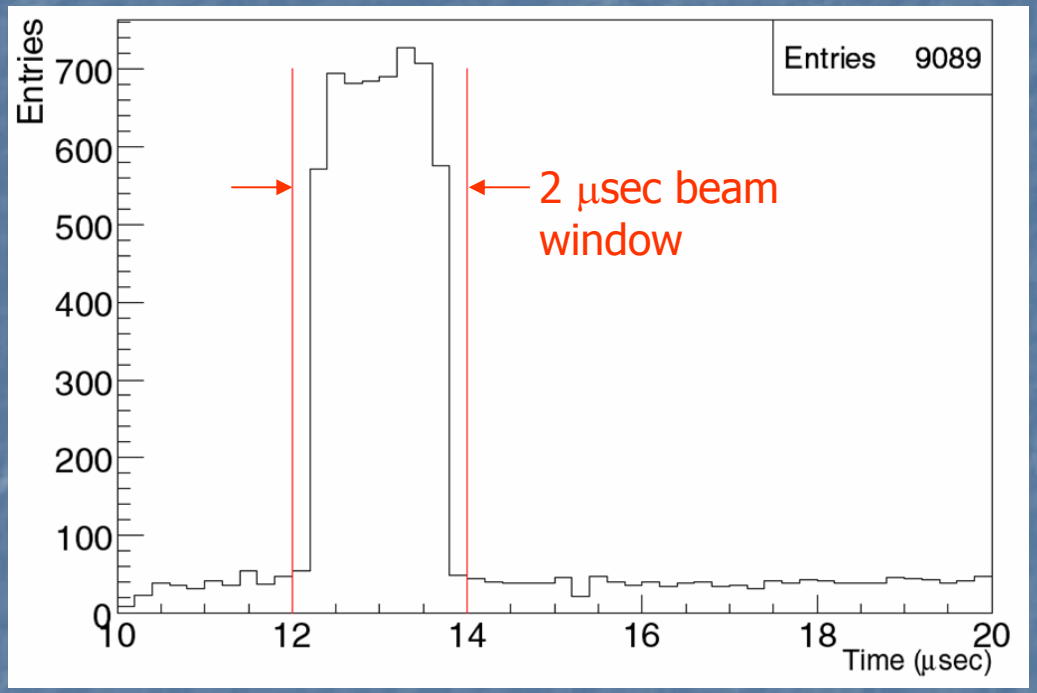
Vertical plane



Horizontal plane



CC candidates vertex inside SciBar ~event timing distribution~



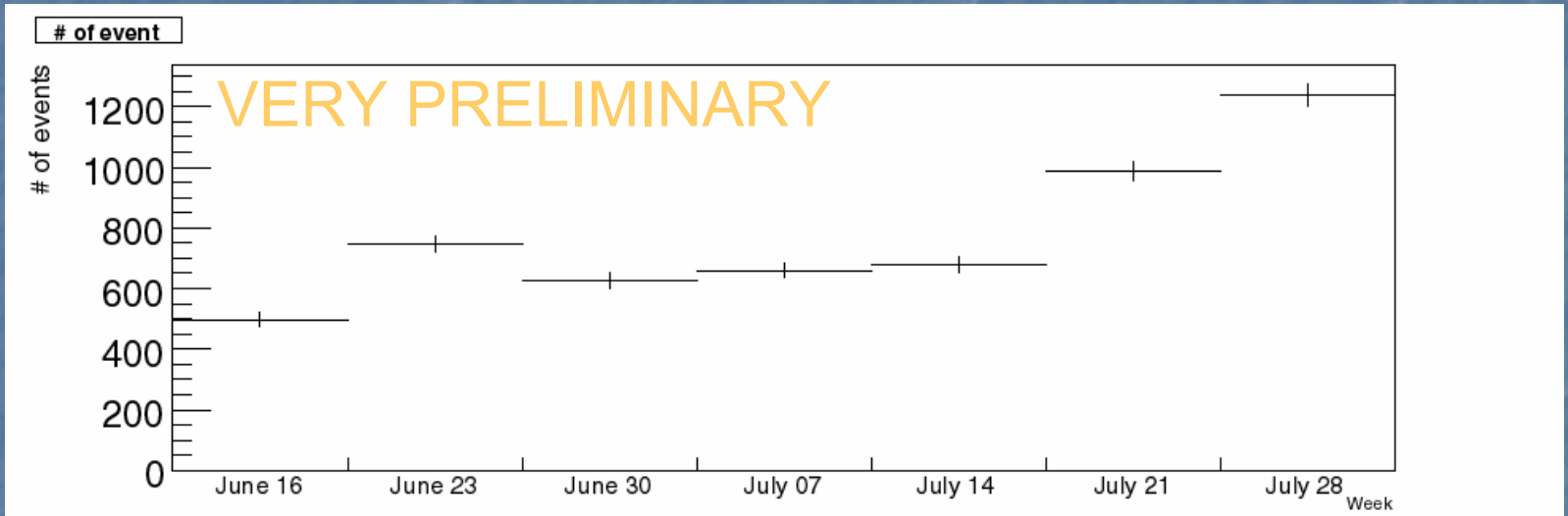
Event timing of CC candidates vertex inside SciBar

- Simple selection
  - Require a hit in the most downstream layer
  - Track penetrating more than 4layers
  - Vertex inside FV of SciBar (FV mass: 10.6 tons)
  - Within 2 usec beam window

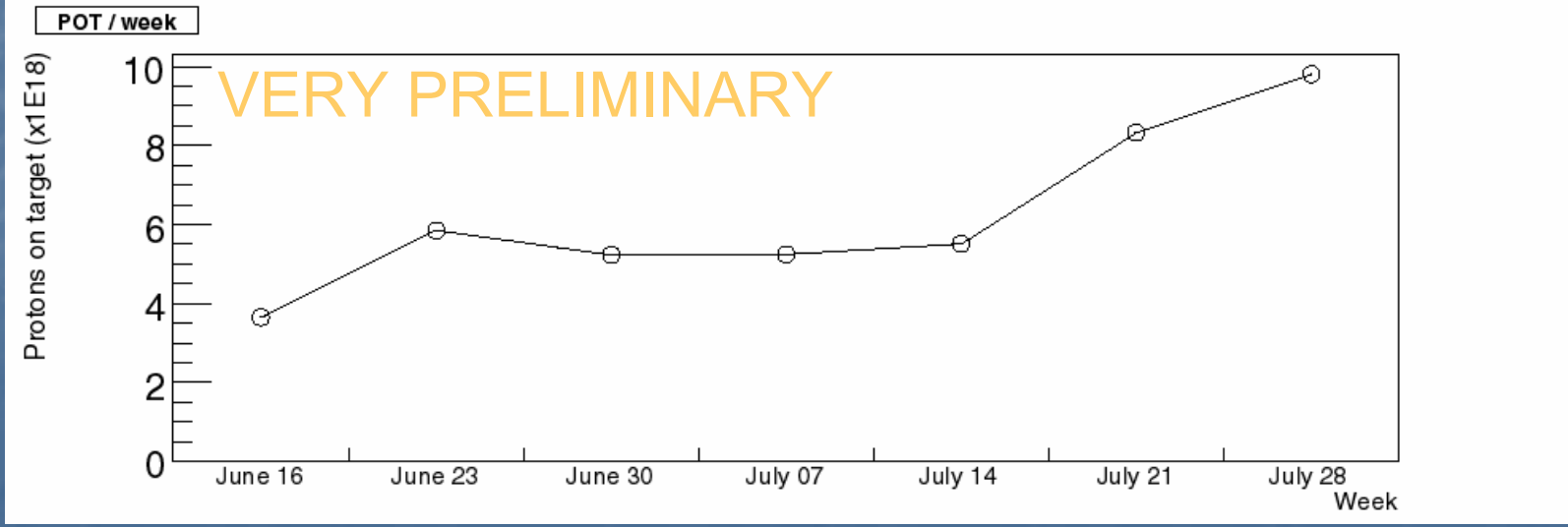
- NOTE: This selection is just only for stability check (not for physics)

CC candidates vertex inside SciBar ~number of ν events and POT~

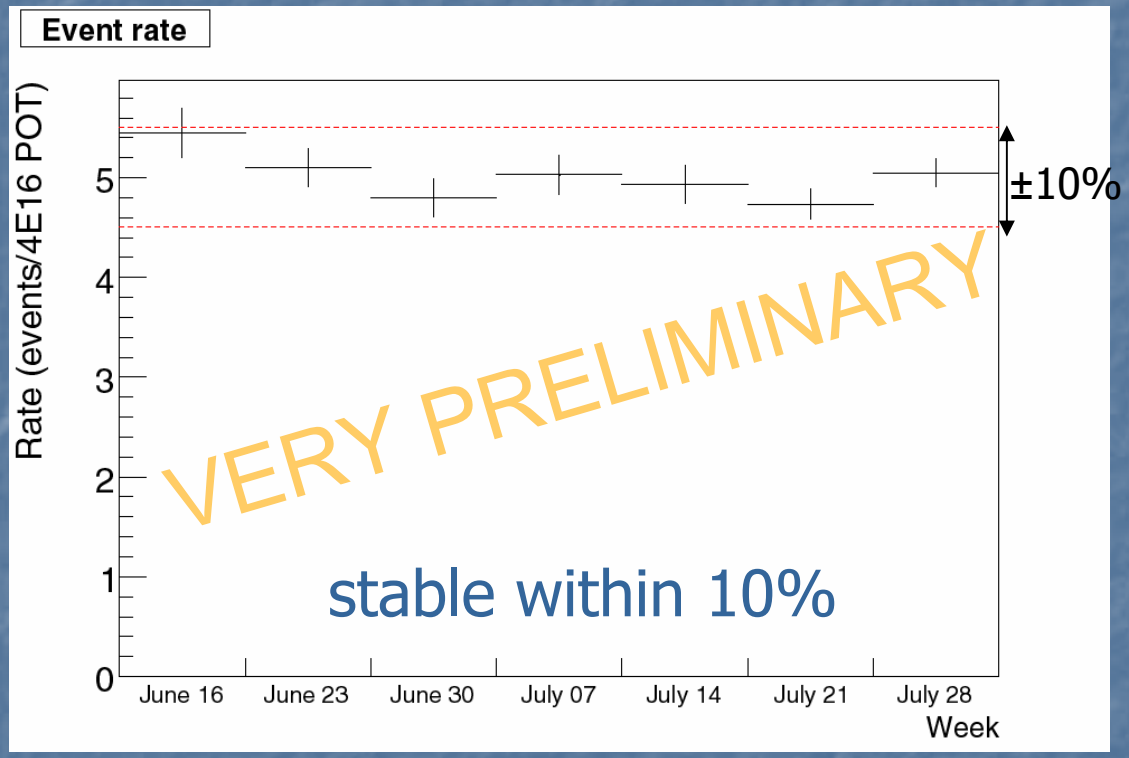
of events / week



POT / week (x1E18)



CC candidates vertex inside SciBar ~event rate normalized with POT~



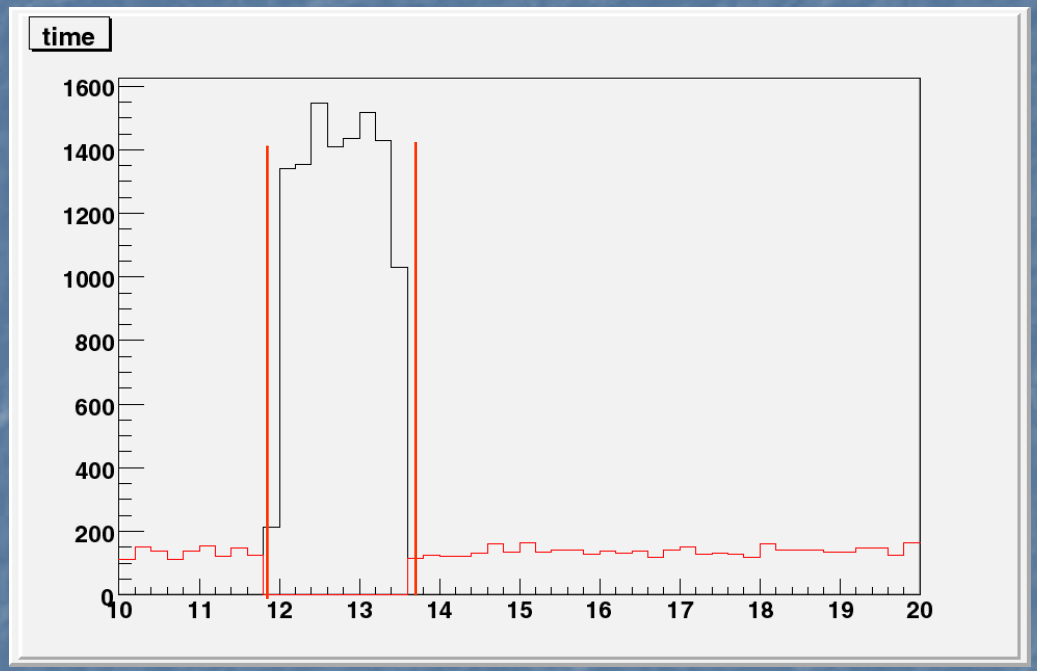
CC event candidates vertex inside SciBar ~5,000 events

FV mass: ~10.6 tons
Period : Jun. 12-Jul. 28 (~4x10^{19} POT)

NOTE:
- CC event efficiency: ~45%
- CC event purity: ~94%
- $\bar{\nu}$, ν fraction:
  - $\bar{\nu}_\mu$~63%, ν_μ~36%

(estimated from MC)

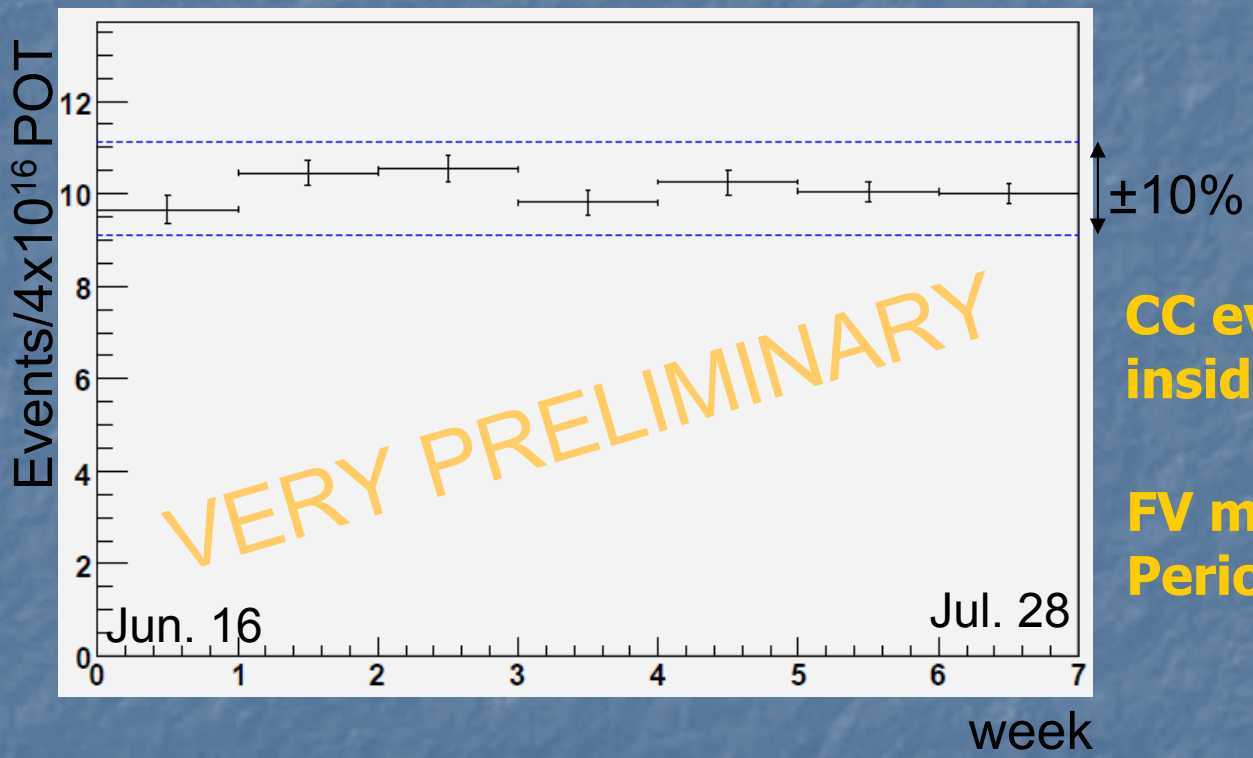
CC candidates vertex inside MRD ~event timing distribution~



Event timing of CC candidates vertex inside MRD

- Event rate study independent from SciBar
- Simple selection
  - Most outer counter used as veto for cosmic ray muons
  - Track penetrate 4 layers
  - TDC-hit clusters inside beam window
- NOTE: This selection is just only for stability check (not for physics)

CC candidates vertex inside MRD
~event rate normalized with POT~



CC event candidates vertex inside MRD ~10,000 events

FV mass: ~19 tons
Period : Jun. 12-Jul. 28
(~4x10^{19} POT)

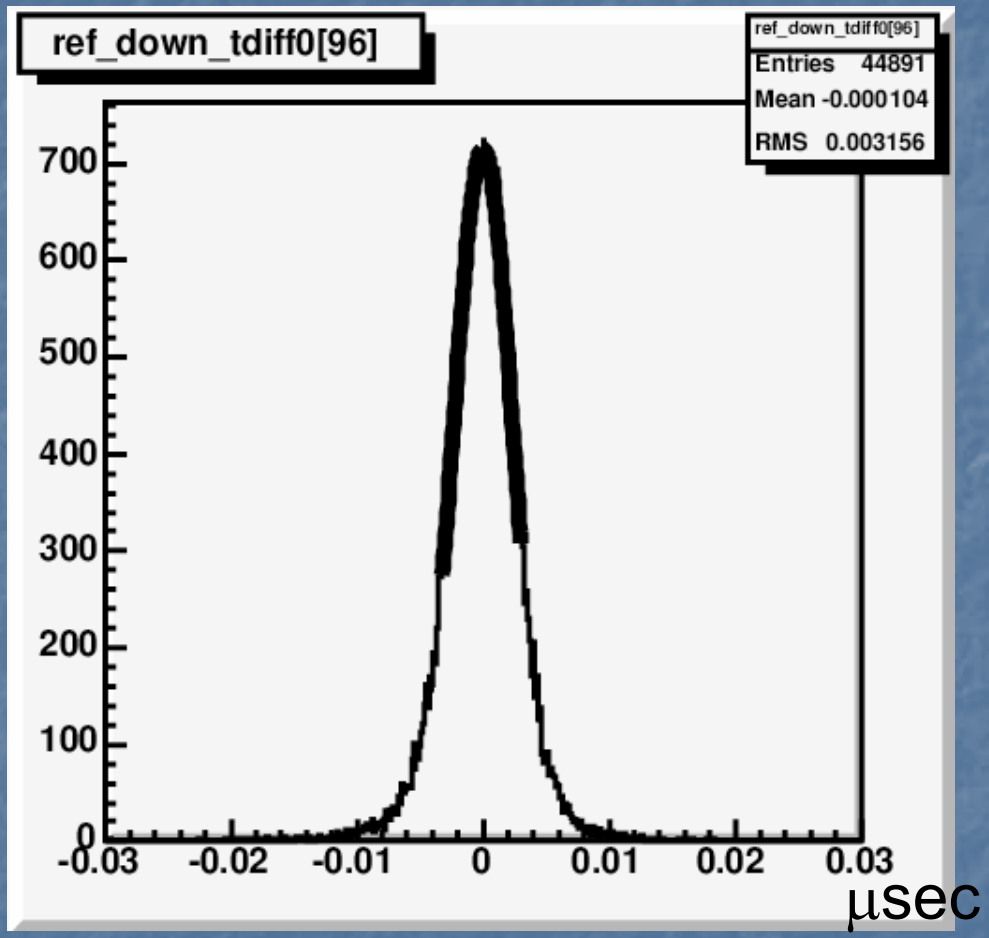
Stable within ±10%

Summary

- Precise study of neutrino and anti-neutrino cross section near 1GeV
- Project $2x10^{20}$ POT
- SciBooNE detectors are working well
- SciBooNE has been collected anti-neutrino data
  - Switch to neutrino mode running from October
  - run one more year

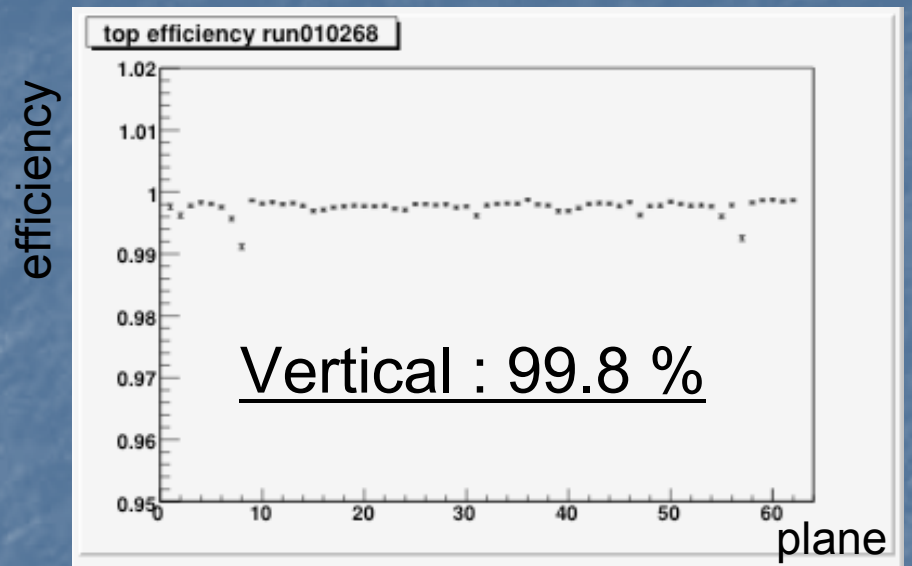
Backup slides

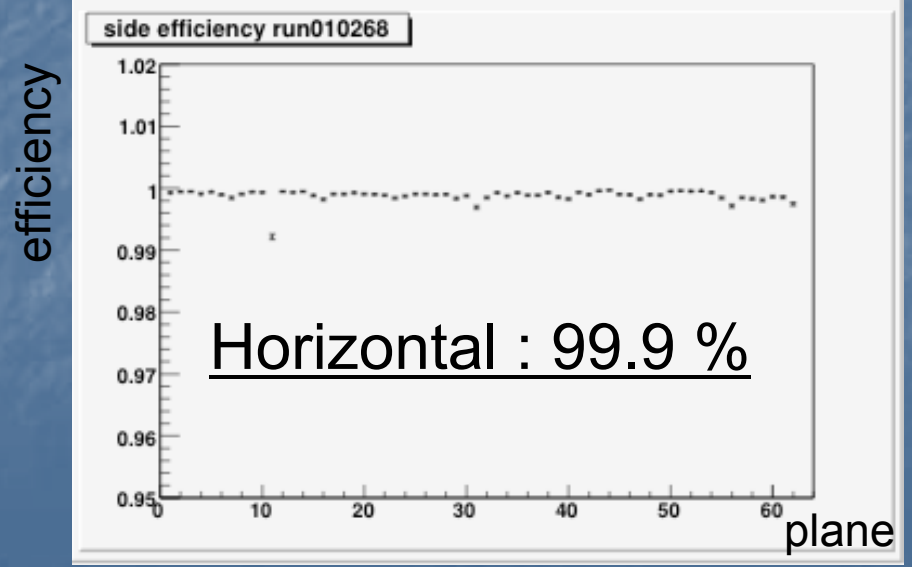
SciBar Timing resolution



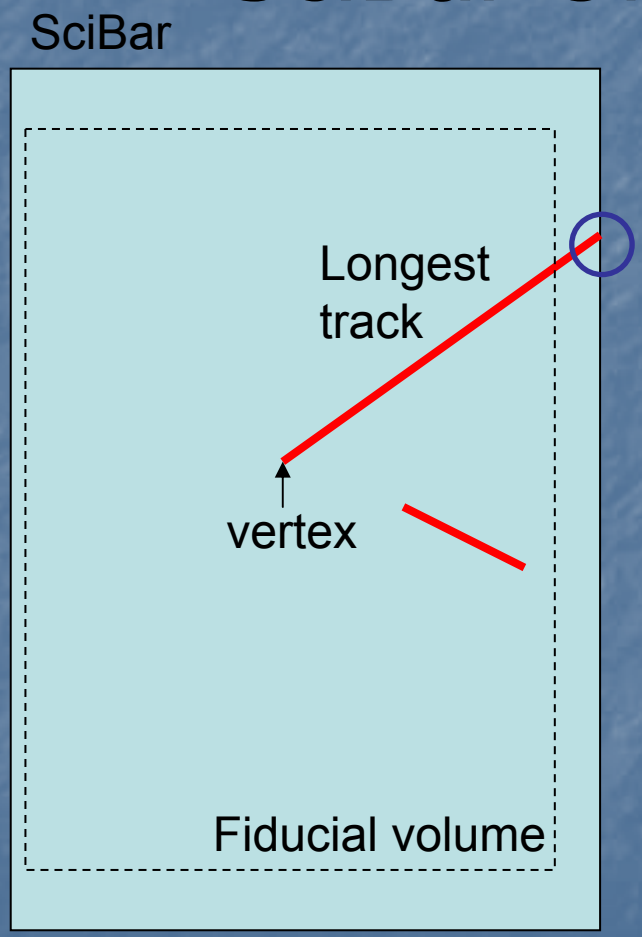
Timing resolution: 1.6 ns (averaged over all channel)

SciBar hit efficiency





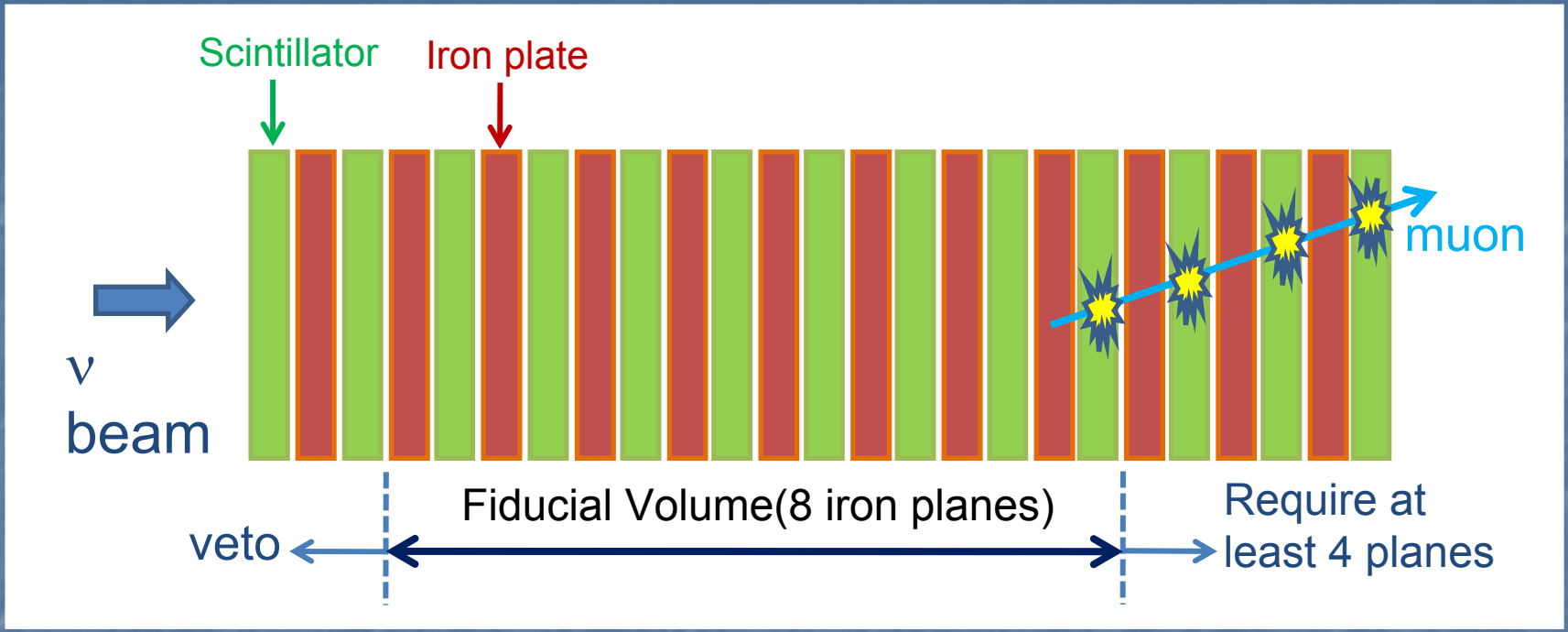
Event selection for SciBar event rate study



- More than 3 hits in each view
  - Threshold: 5 sigma (~2 p.e)
- Require hit in most downstream layer
- Track length > 4 layers
- Vertex in fiducial volume
  - -130cm<x<130cm
  - -130cm<y<130cm
  - 2.62cm<z<157.2cm (2nd~60th layer)
- Within 2usec on-timing window (12<t<14 usec)

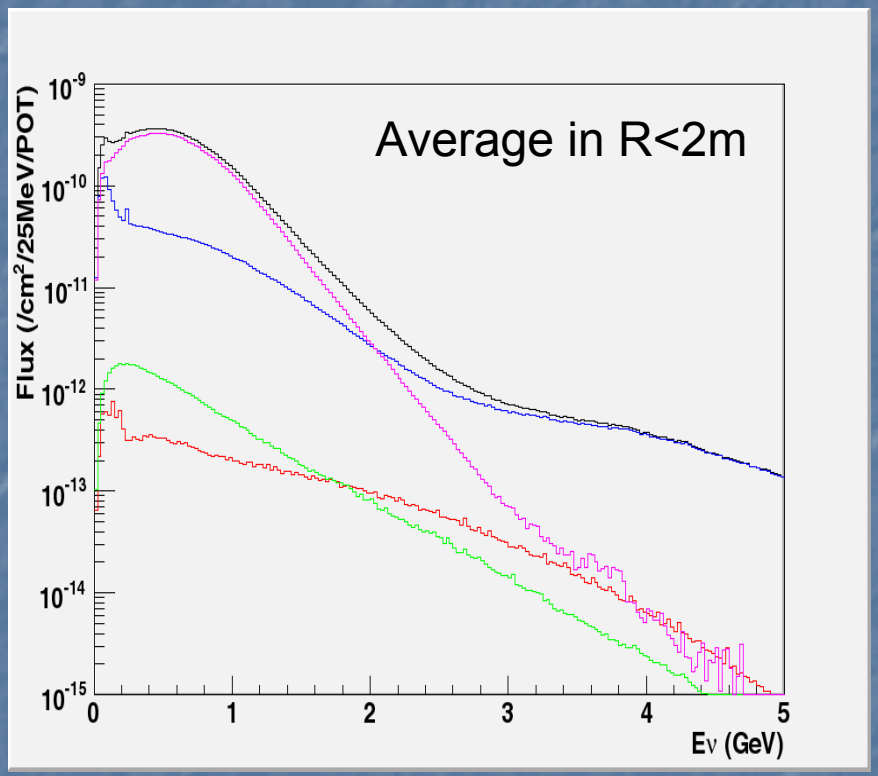
NOTE: This selection is just only for event rate stability check (Not for physics analysis)

Event selection for MRD event rate study



- Reconstruction
  - **Hits on 4 scintillator planes are required (→ 2vertical, 2horizontal)**
- Fiducial volume
  - **-132cm < X < 132cm**
  - **-111cm < Y < 111cm**
  - **8 iron planes (thickness of 1plane ~2inch)**
- Timing
  - **Cluster within 2μsec time window is selected**

SciBooNE anti-neutrino flux

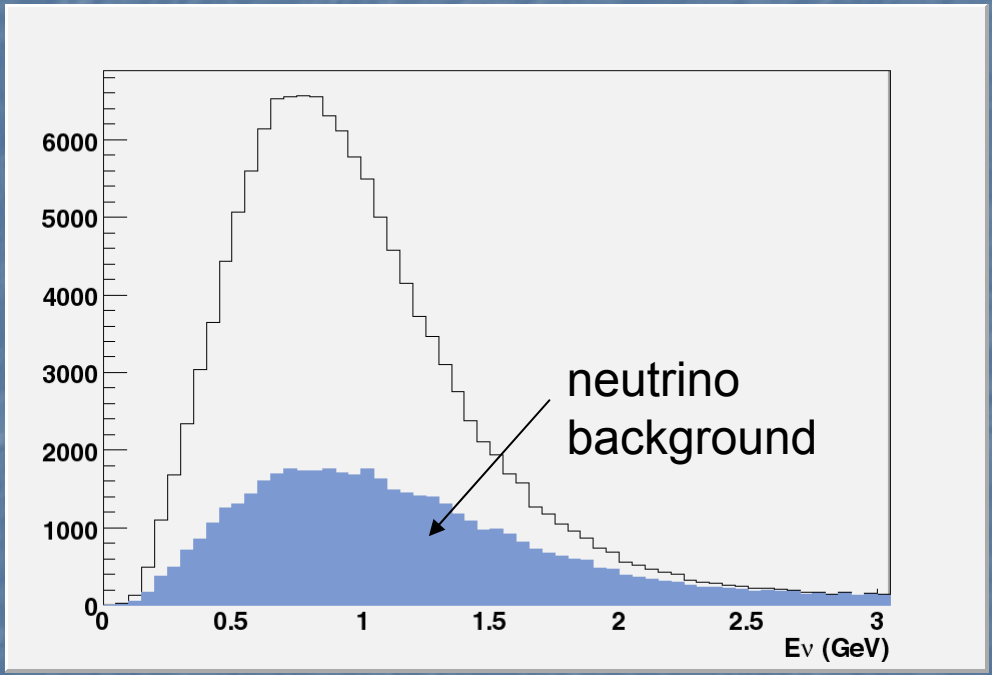


- HARP pi- preliminary result
- 100m downstream from the Be target
- radius : 25cm-bining
- energy: 25MeV binning, up to 5GeV

Average energy : 0.6GeV
Peak energy : 0.45GeV

$\bar{\nu}\mu$ ~83%
$\nu\mu$ ~16%
$\bar{\nu}e$ ~0.2%
νe ~0.4%

SciBooNE anti-neutrino interaction



NEUT simulator

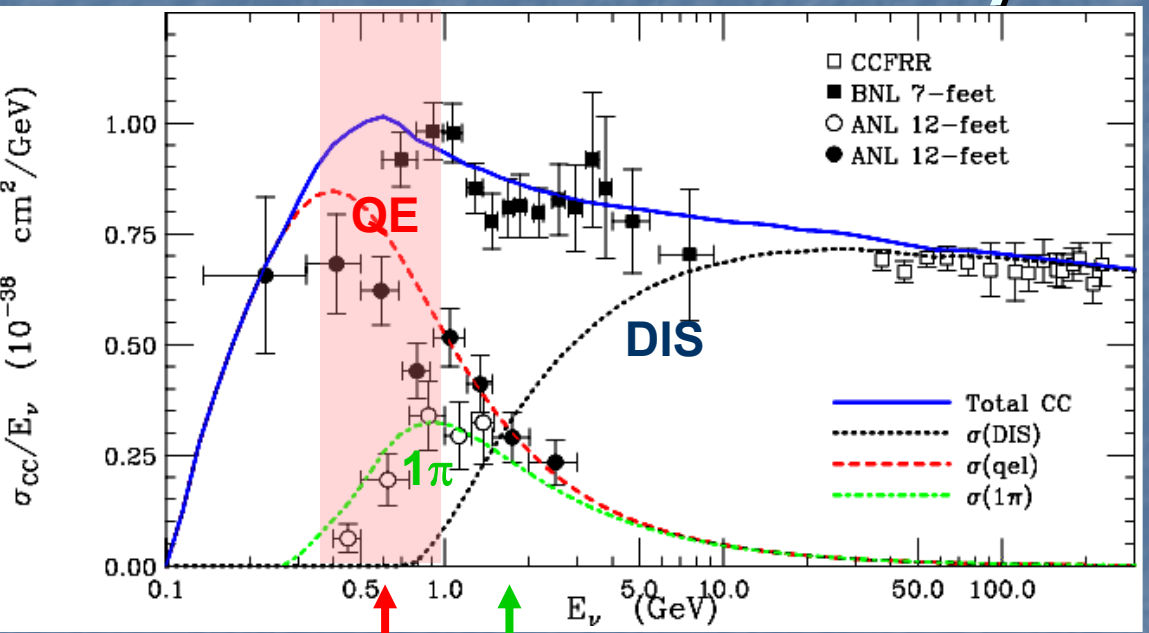
- **MA = 1.1 GeV (QE, 1π)**
- **Coherent pi production**
  Rein & Sehgal w/ lepton mass correction
- **DIS**
  GRV94 PDF
  w/ Bodek & Yang correction
- **Nuclear effect**

$\bar{\nu}\mu$ ~63%
$\nu\mu$ ~36%
$\bar{\nu}e$ ~0.4%
νe ~0.6%

Average energy :
1.0GeV ($\bar{\nu}\mu$ + $\nu\mu$)
0.9GeV ($\bar{\nu}\mu$ only)

Unexplored Areas of Neutrino Physics

σ_ν in this E range of interest:



MINOS

K2K, NOvA

MiniBooNE, T2K, SciBooNE

Super-K atmospheric ν

- **Data from old experiments** (1970~1980)
  - Low statistics
  - Systematic Uncertainties
- **Nuclear effects** (π/p/n absorption/scattering, shadowing, low Q^2 region)
  - Not well-modeled
- **New data** from MiniBooNE & K2K revealing surprises
- **More data at 1GeV with fine grained resolution will advance Neutrino Physics.**

Anti-ν cross section is in a poor situation.

NOTE: Numbers in proposal

SciBooNE Events

- Neutrino run (~1×10^{20} POT)

# of interactions
in 10 ton Fiducial Volume
ν_μ **~156,000**
ν_e~ **1400**

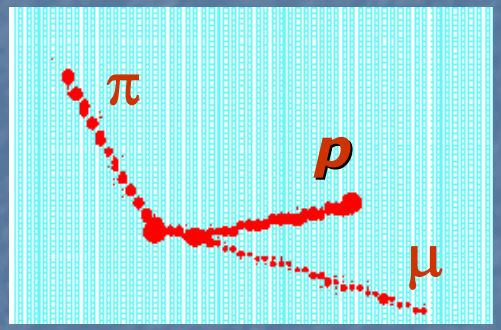
cf. K2K-SciBar (0.2×10^{20} POT) :
~25,000 ν_μ

- Anti-neutrino run (~1×10^{20} POT)

# of interactions in FV
$\bar{\nu}_\mu$ **~26,000**
ν_μ **~14,000**

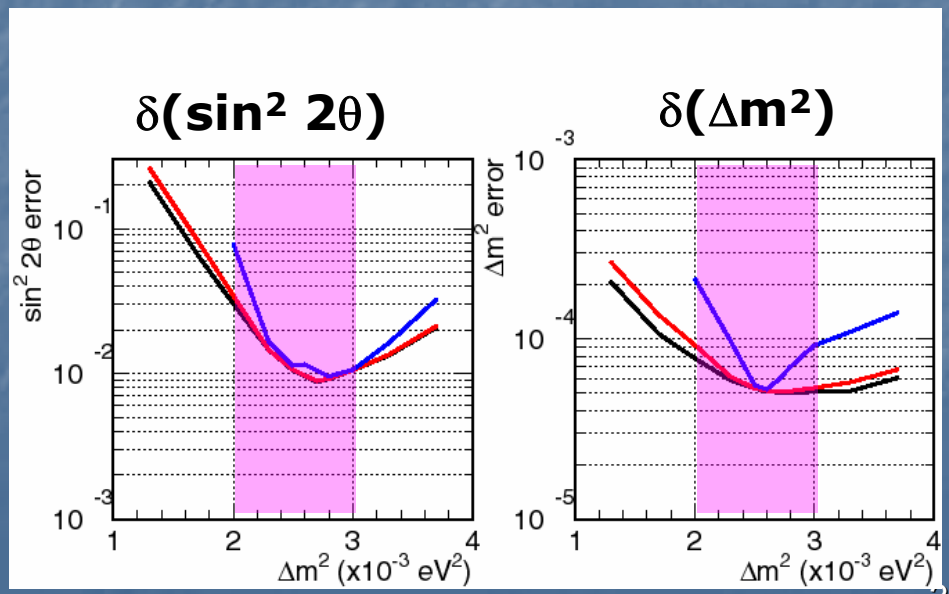
CC-1π^+ measurement

- Non-QE events: dominant background for ν_μ disappearance
  - At BNB energies, non-QE BG dominated by CC1π^+
  - T2K needs to reduce uncertainty of nonQE/QE to ~5%



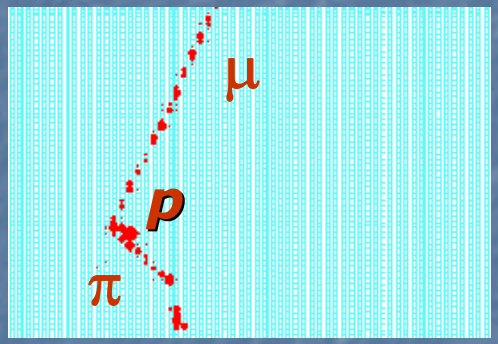
ν_μ disappearance measurement error (90%CL)

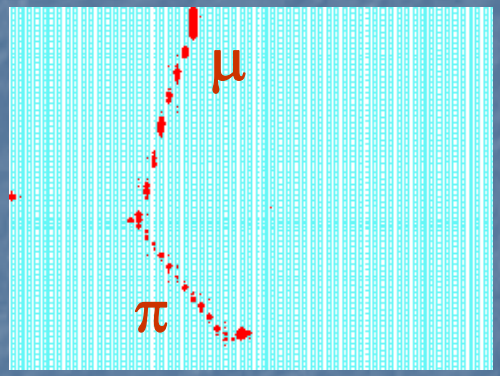
— stat. only
— δ(nQE/QE)= 5%
— δ(nQE/QE)=20%

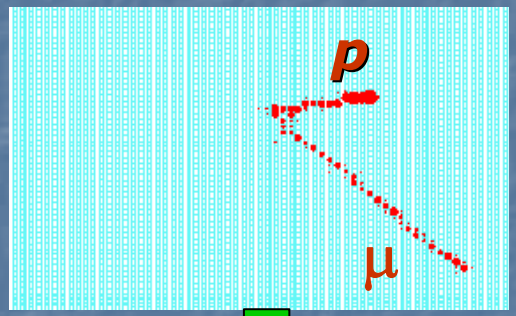


NOTE: Numbers in proposal

CC-1π^+ measurement (cont.)







Clear event-by-event final-state tagging!

Sensitive to the nuclear effect

CC-1π^+ signature:
2 MIP-like tracks

Vertex activity cuts:
separate $\nu+p\rightarrow\mu^-p\pi^+$
from $\nu+n\rightarrow\mu^+n\pi^+$

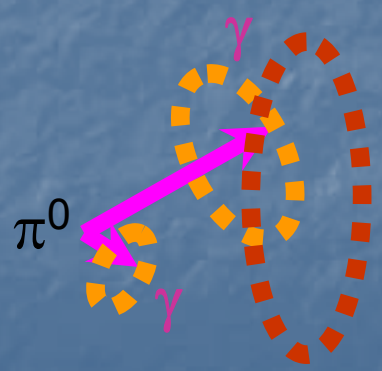
Expect ~2,800 CC-1π^+ events after cuts

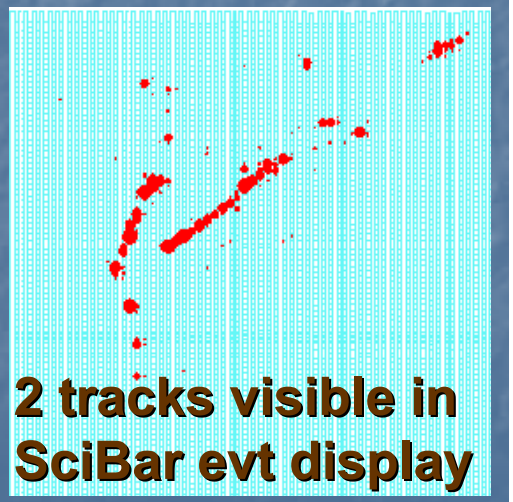
Statistics and systematics Sufficient for ~5% measurement

NC-1π^0 measurement

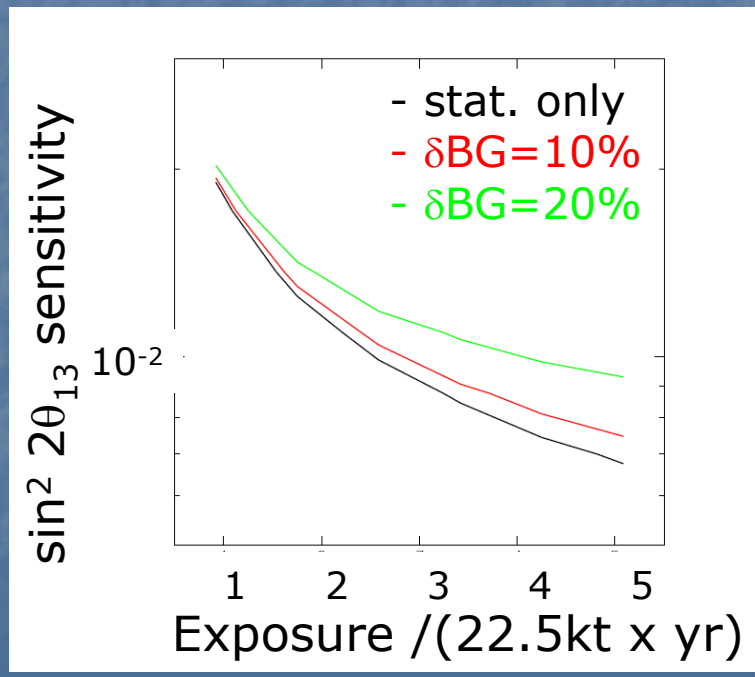
- Dominant background to ν_e appearance in any experiment
  - Overlapping rings, or back-to-back decay
  - T2K needs NC1π^0 cross section to be known at 10% level

2-ring merged to 1-ring in Cherenkov detector



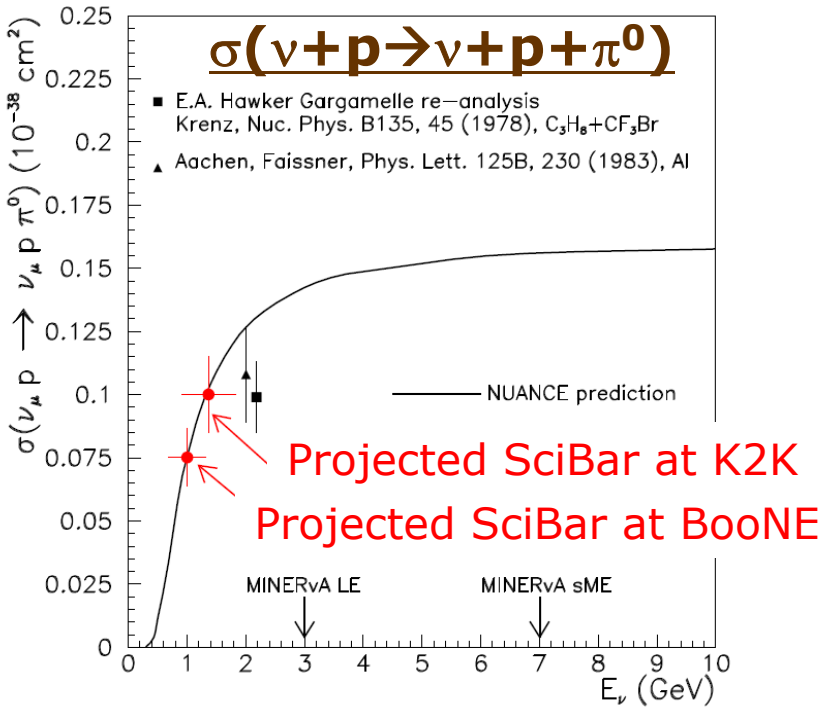


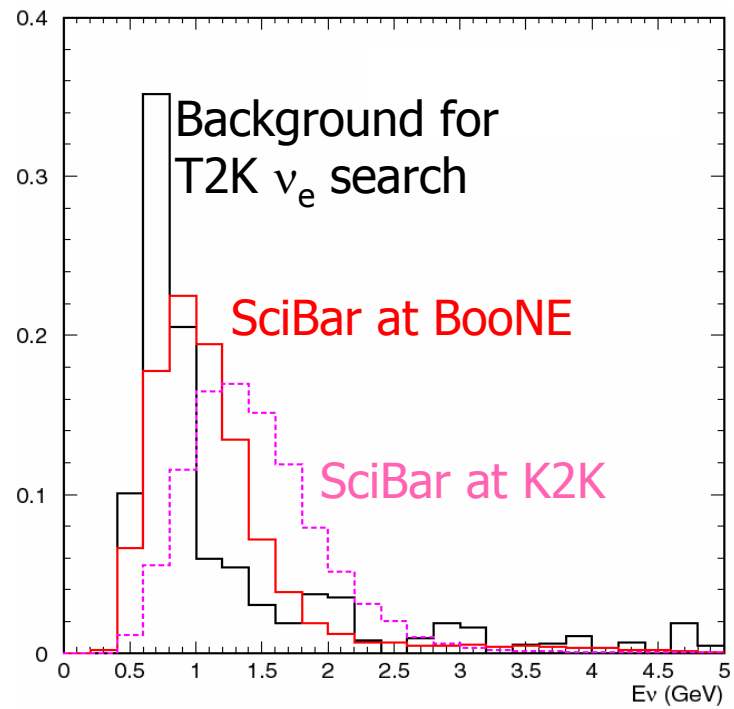
200~700MeV/c π^0s



NOTE: Numbers in proposal

NC-1π^0 measurement (cont.)





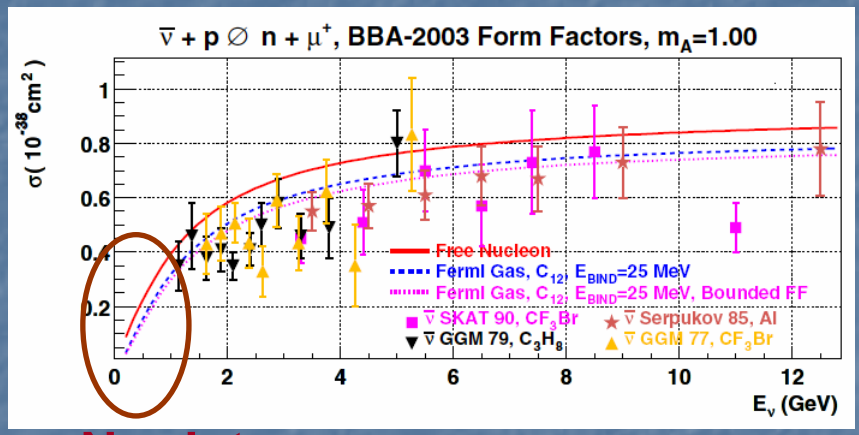
10% measurement

Map out energy dependence at point where cross section turns over, crucial for T2K NC1π^0 BGs

Anti-neutrino CC-QE measurement

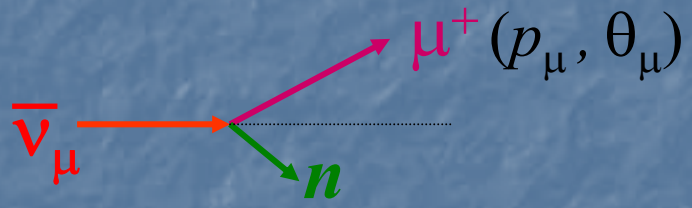
Physics motivation

- The first σ measurement with good final state separation
- It is important for T2K phase-II



No data

CC-QE: $\bar{\nu}_\mu + p \rightarrow \mu^+ + n$



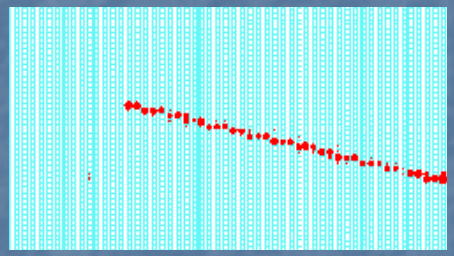
$$E_\nu^{rec} = \frac{m_N E_\mu - m_\mu^2/2}{m_N - E_\mu + p_\mu \cos\theta_\mu}$$

- **Detected as a 1-track event in SciBar**
- **Can reconstruct neutrino energy**

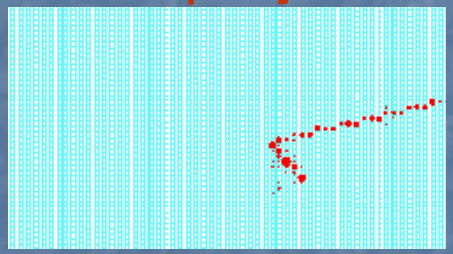
NOTE: Numbers in proposal

Anti-neutrino CC-QE and neutrino BG

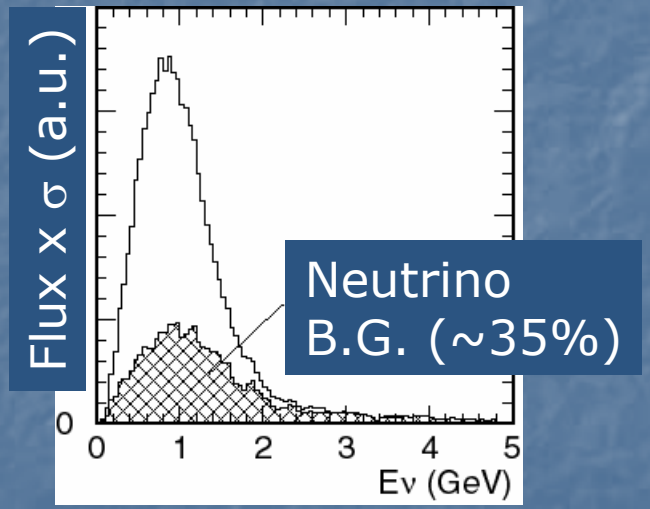
$\bar{\nu}+p \rightarrow \mu^{+}+n$

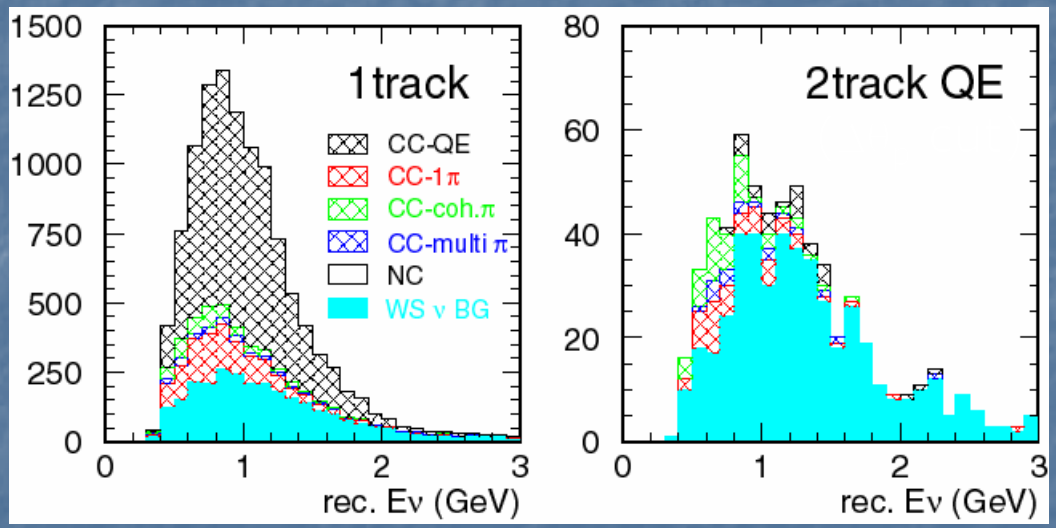


$\nu+n \rightarrow \mu^{-}+p$



Anti-neutrino beam contains neutrino backgrounds





SciBar can separate anti-ν_μ QE from ν_μ QE