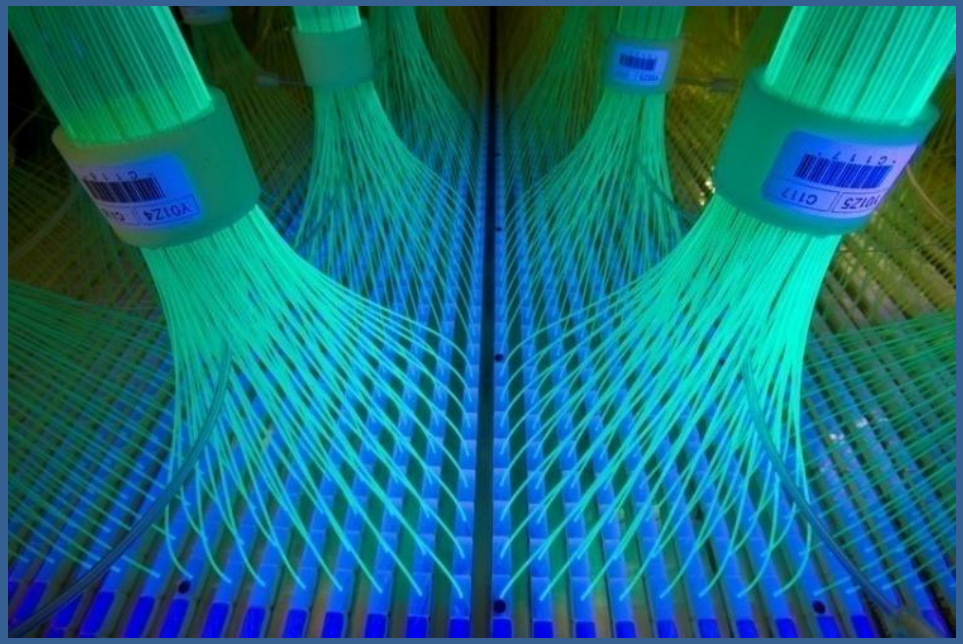
An Update on the Progress of the SciBooNE Experiment



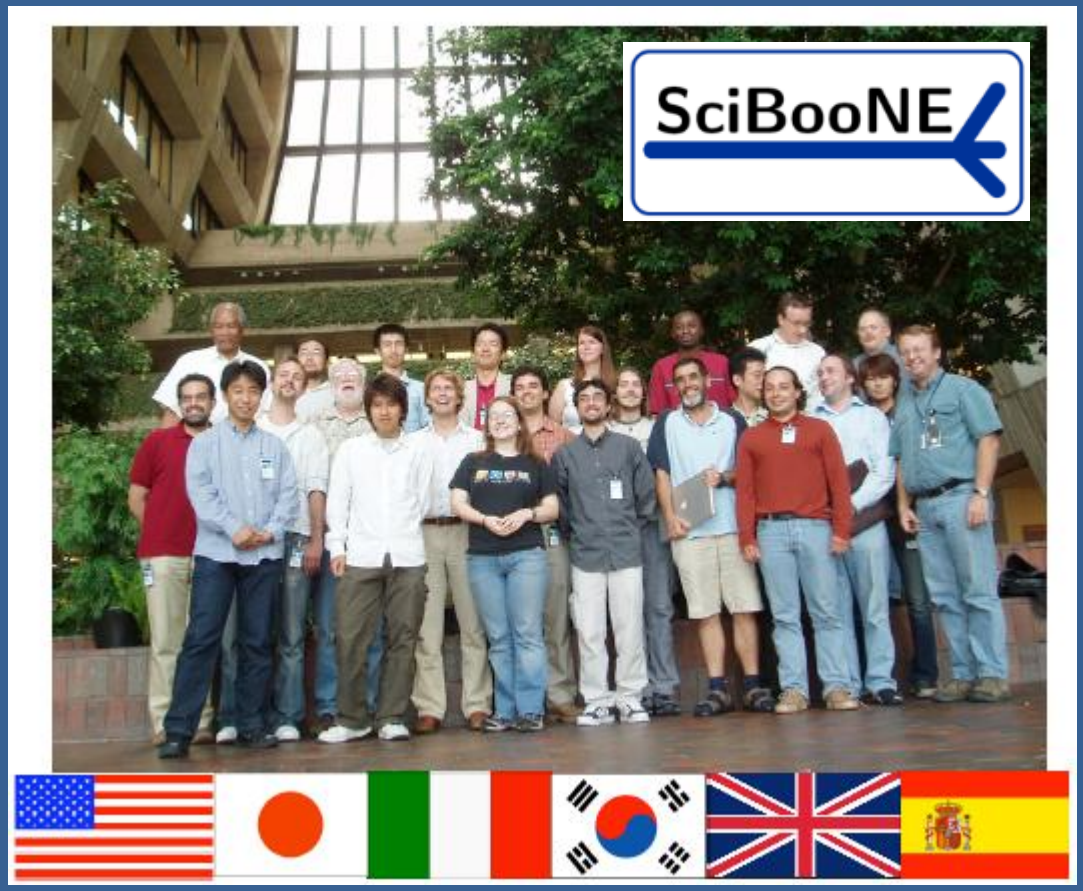
Robert Napora
Purdue University Calumet
May 30th 2007

Outline

- Introduction to SciBooNE
- SciBooNE Detector
- SciBooNE Physics
- SciBooNE Status/Timeline
- Summary

The SciBooNE Collaboration

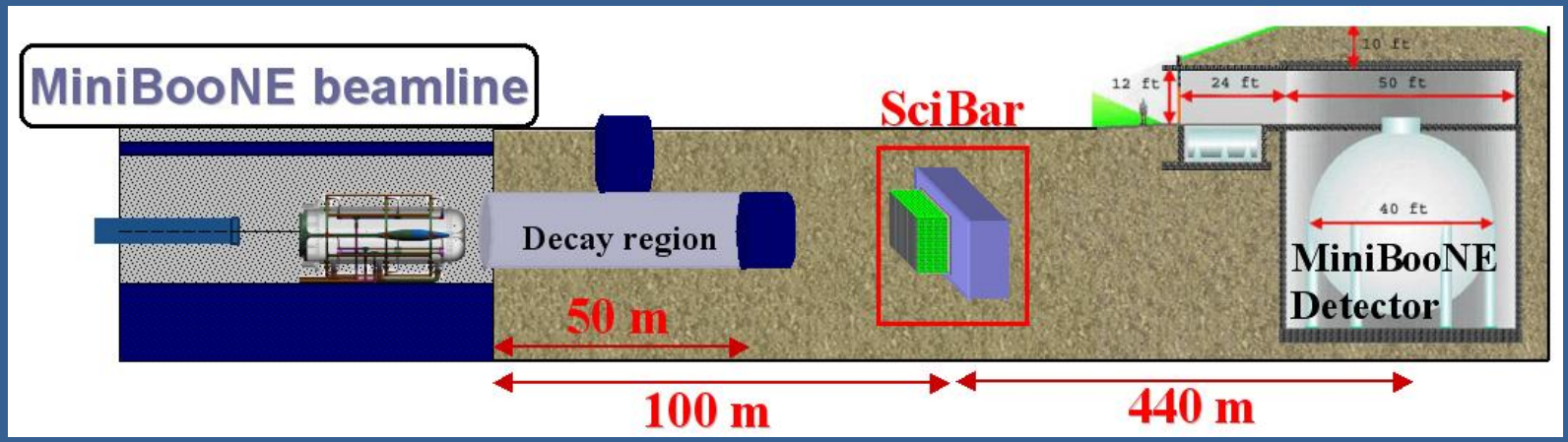
- Universitat Autonoma de Barcelona
- Chonnam National University
- University of Cincinnati
- University of Colorado
- Columbia University
- Dongshin University
- Fermi National Accelerator Laboratory
- High Energy Accelerator Research Organization (KEK)
- Imperial College London*
- Indiana University
- 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
- Seoul National University
- Tokyo Institute of Technology
- Universidad de Valencia



About 70 collaborators from 19 institutions and 6 countries.

SciBooNE

Placed the preexisting SciBar/EC detectors along with a locally constructed MRD in the Booster Neutrino Beam.



using (mostly) pre-existing detectors + piggy-backing on an existing beam = good physics at low cost

The Booster Neutrino Beam

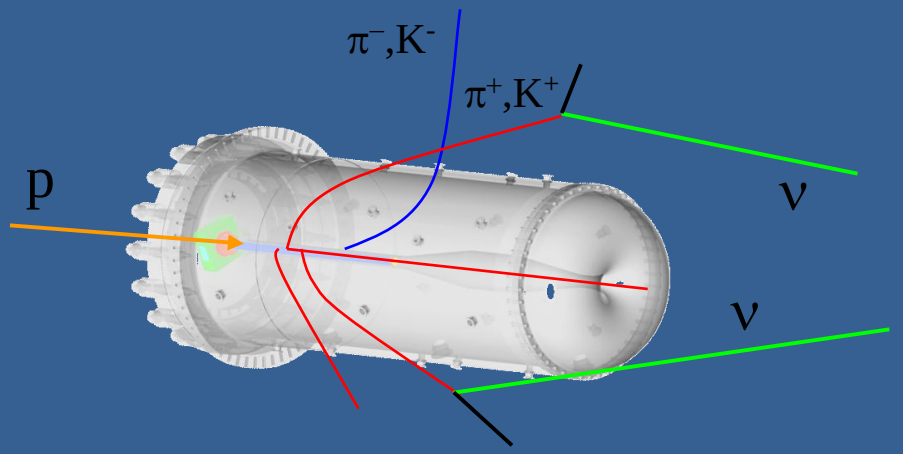
- 8 GeV protons incident on beryllium target . Magnetic horn focuses appropriately signed π/K

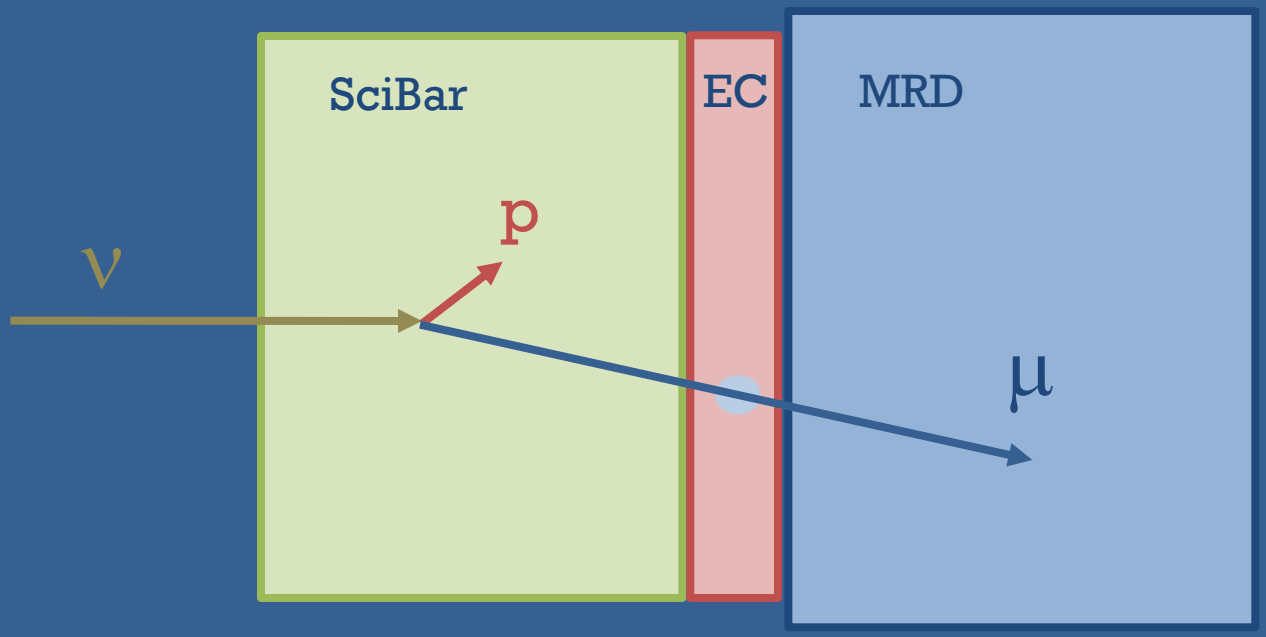
- BNL E-910 and CERN HARP data for secondary production predictions

- Mean ν energy 0.8 GeV
  Peak ν energy 0.65 GeV
  →similar to T2K spectrum

- ν_e contamination <0.6%

- SciBooNE anticipates
  - ~1e20 POT ν
  - ~1e20 POT anti-ν





SciBooNE

Schematic of CCQE event:

$\nu_\mu + n \rightarrow p + \mu$

$(\nu_e + n \rightarrow p + e)$

Scintillating Bar Detector (SciBar)

- Extruded scintillator with WLS fiber readout
- 224 MA-PMTs x 64 ch/pmt = 14,336 channels
- Scintillator is neutrino target (~15 tons)
- 2.5 x 1.3 x 300 cm^3 cells
- Can use de/dx to distinguish π from p
- Previously used in K2K experiment

Electron Catcher (EC)

- "Spaghetti" calorimeter
- 1mm fibers in grooves between lead foils
- 1 vertical and 1 horizontal layer
- 4 x 4 cm^3 readout from both ends
- 256 channels
- Previously used in K2K, CHORUS

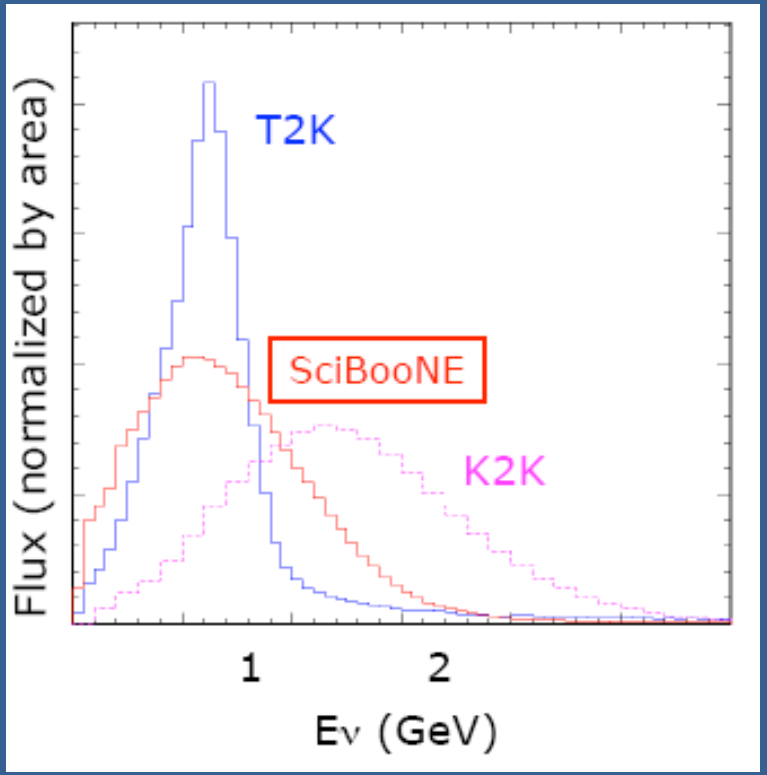
Muon Range Detector (MRD)

- Steel and scintillator sandwich calorimeter
- Twelve 9' x 10' x 2" steel sheets, 48 tons of absorber material
- Can stop virtually all muons of momentum ~0.9 GeV/c or lower (within acceptance)
- 362 channels
- Constructed here at Fermilab, mostly out of recycled parts

SciBooNE Physics

SciBooNE will measure neutrino and anti-neutrino cross-sections in the Booster Neutrino Beam.

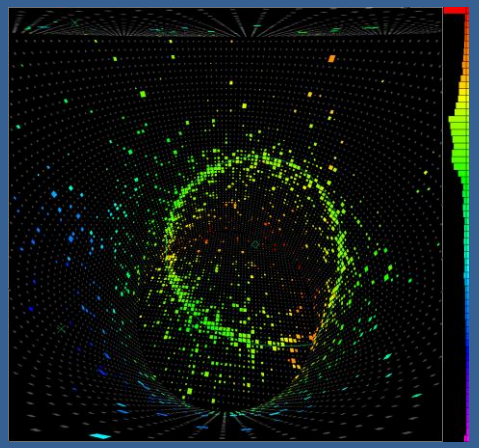
- Precise knowledge of cross sections necessary to T2K and other experiments
- MiniBooNE near detector; cross-check for BNB
- Anti-neutrino cross section measurements would complement MiniBooNE values. Useful for T2K phase-II.



SciBooNE's fine grained resolution affords certain advantages. For example…

You are searching for $\nu_\mu \rightarrow \nu_e$ oscillations (measuring θ_{13})

Signal: CC-QE interaction $\nu_e + n \rightarrow e^- + p^+$

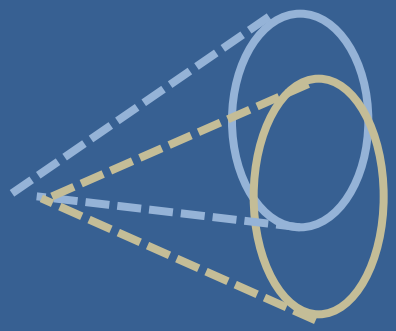


Signature: Cherenkov ring made by the electron

The dominant background is the NC-π^0 interaction

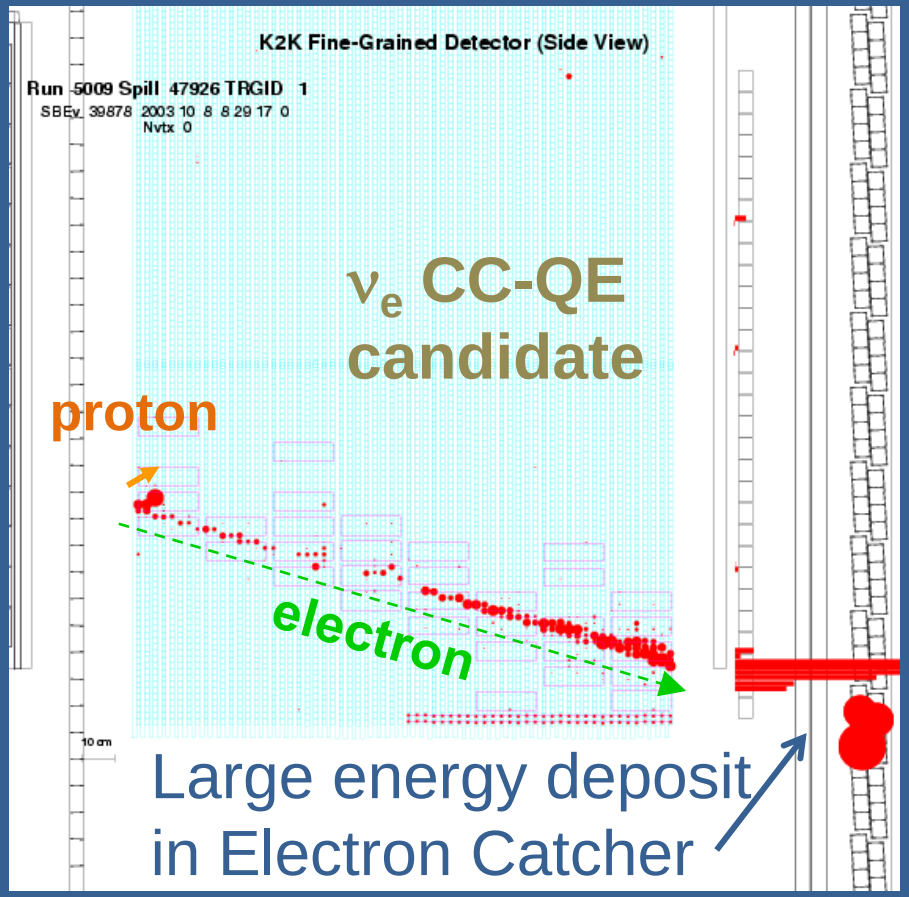
$$\nu_\mu + N \rightarrow \nu_\mu + N + \pi^0$$

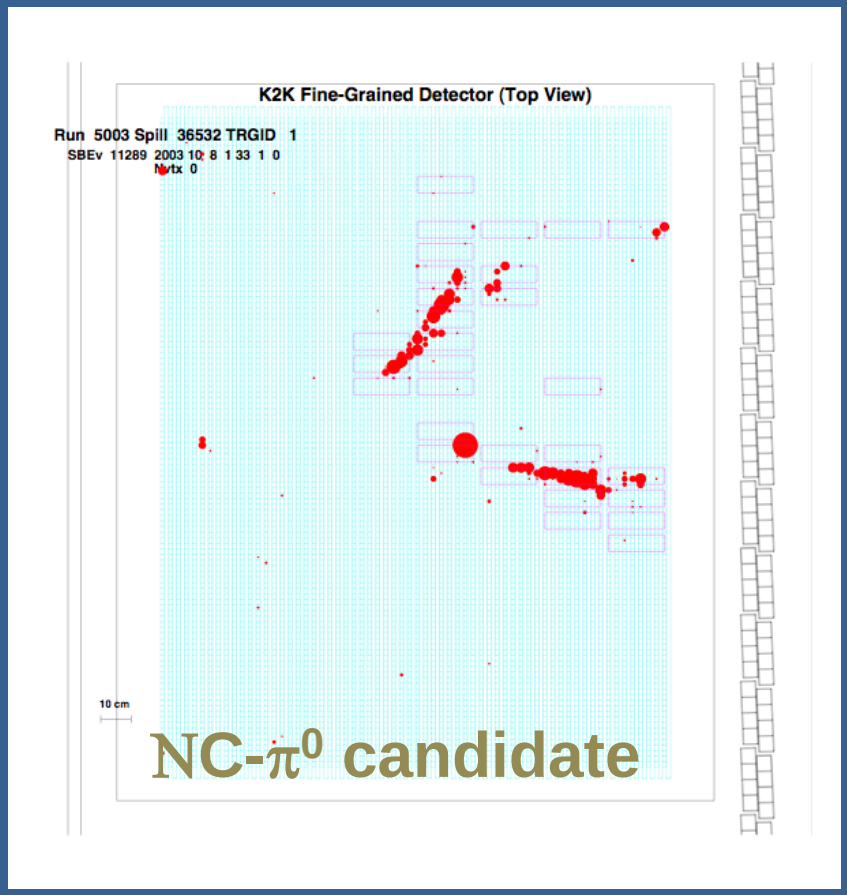
where the pion decays to two photons



The two photons can make a "fuzzy ring" that looks like an electron to your Cherenkov detector.

SciBooNE will be able to discriminate between these two channels.

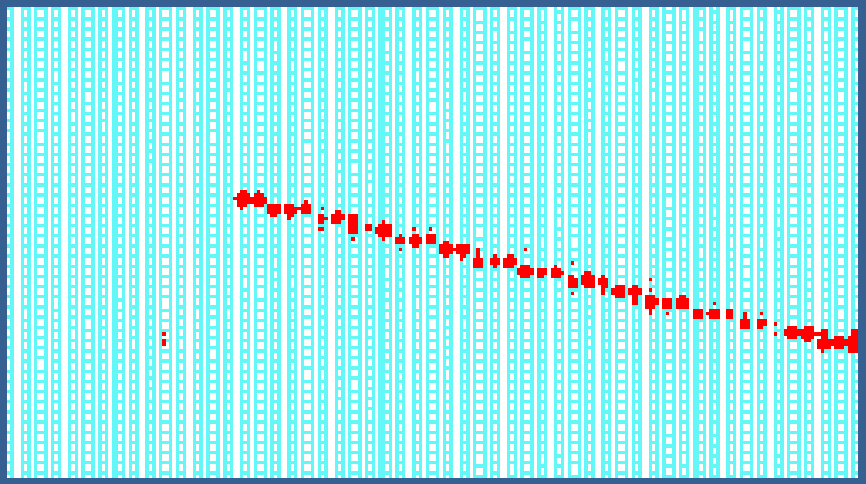




These are event displays of SciBar data from K2K.

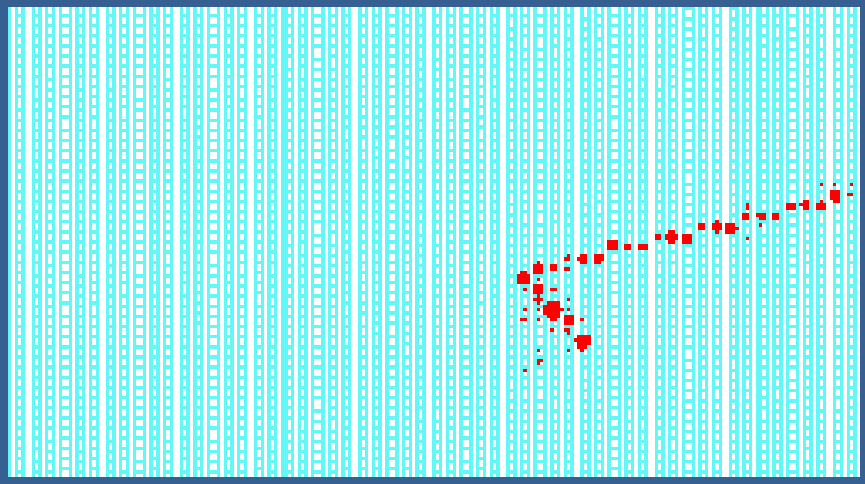
Another example: BNB wrong sign background

CC ν/anti-ν events typically distinguished by identifying charge of outgoing lepton. MB cannot distinguish ν/anti-ν on an event by event basis.*



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

Right Sign



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

Wrong Sign

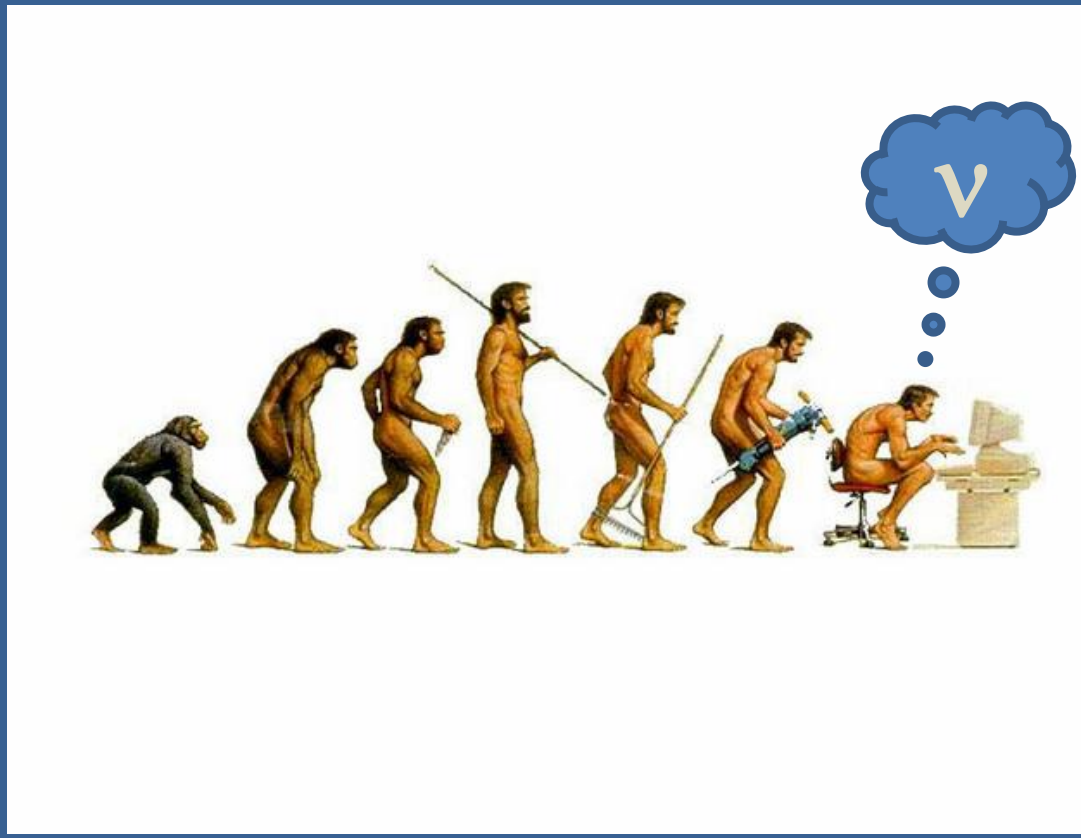
(in anti-ν mode)

In SciBooNE these appear as 1-track vs. 2-track events

SciBooNE Timeline

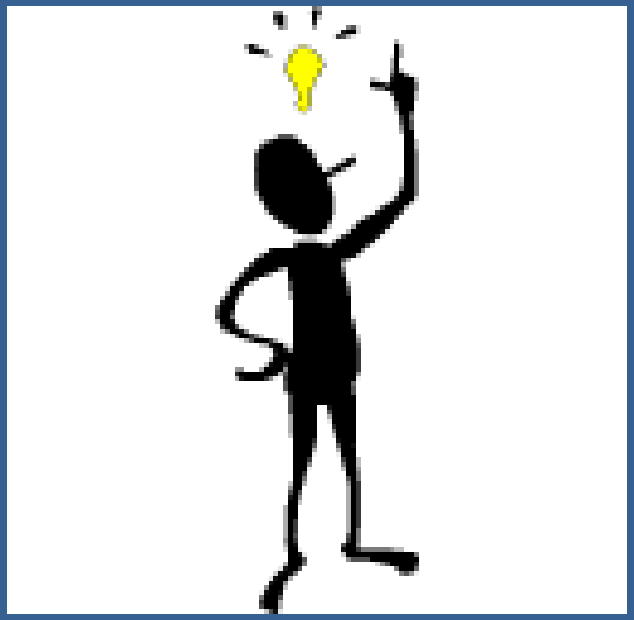
- Mar. 2005: K2K ends
- Summer 2005: Collaboration formed
- Nov. 2005: Proposed
- Dec. 2005: Approved
- Mar 2006: First collaboration meeting
- May. 2006: Set baseline cost and schedule
- Jun 2006: MRD prototype counters
- Jul. 2006: SciBar/EC arrive
- Aug. 2006: Civil construction contract
- Sep. 2006: Groundbreaking
- Sep. 2006: Begin MRD counter construction
- Nov 2006: Install EC horizontal layer
- Dec. 2006: SciBar Plane Installation
- Dec. 2006: Install EC vertical layer, first cosmics seen in EC
- Jan 2007: Begin MRD counter installation
- Jan. 2007: Beneficial occupancy
- Feb 2007: SciBar fibers & FEBs installed
- Mar 2007: First cosmics in SciBar
- Mar. 2007: First cosmics in MRD
- Apr. 2007: Pre-install hall work complete
- Apr. 2007: Move detectors to enclosure
- May 2007: Cabling and commissioning
- May 2007: First events seen in detector

SciBooNE has evolved a lot over the last two years.



SciBooNE Timeline

- Mar. 2005: K2K ends
- Summer 2005: Collaboration formed
- Nov. 2005: Proposed
- Dec. 2005: Approved
- Mar 2006: First collaboration meeting
- May. 2006: Set baseline cost and schedule
- Jun 2006: MRD prototype counters
- Jul. 2006: SciBar/EC arrive
- Jul. 2006: Begin MRD counter construction
- Aug. 2006: Civil construction contract
- Sep. 2006: Groundbreaking
- Nov 2006: Install EC horizontal layer
- Dec. 2006: SciBar Plane Installation
- Dec. 2006: Install EC vertical layer, first cosmics seen in EC
- Jan 2007: Begin MRD counter installation
- Jan. 2007: Beneficial occupancy
- Feb 2007: SciBar fibers & FEBs installed
- Mar 2007: First cosmics in SciBar
- Mar. 2007: First cosmics in MRD
- Apr. 2007: Pre-install hall work complete
- Apr. 2007: Move detectors to enclosure
- May 2007: Cabling and commissioning
- May 2007: First events seen in detector

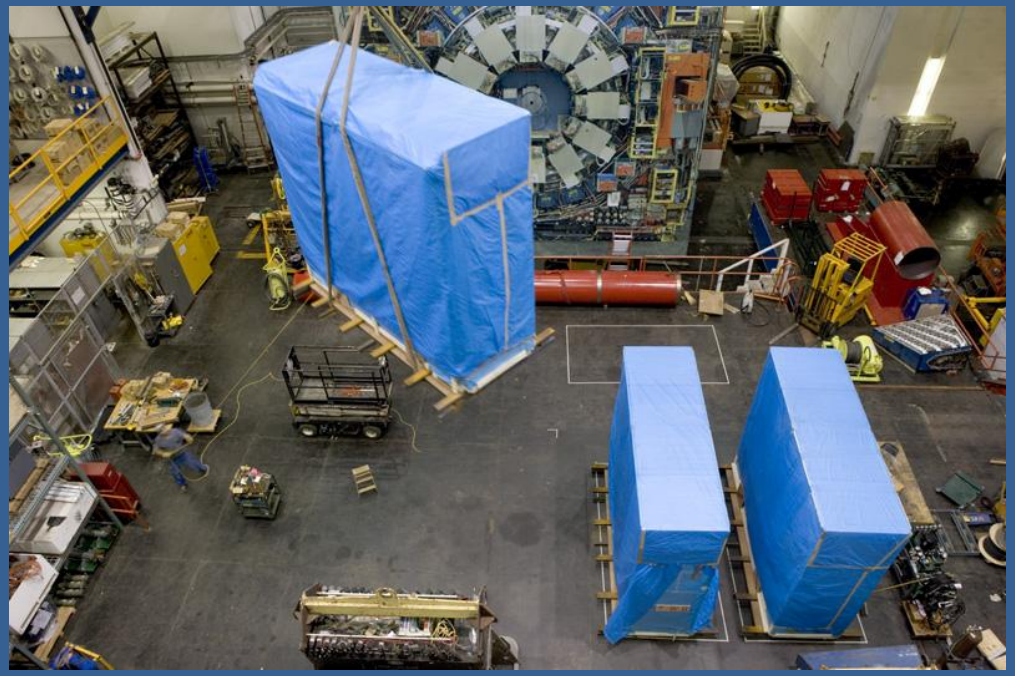


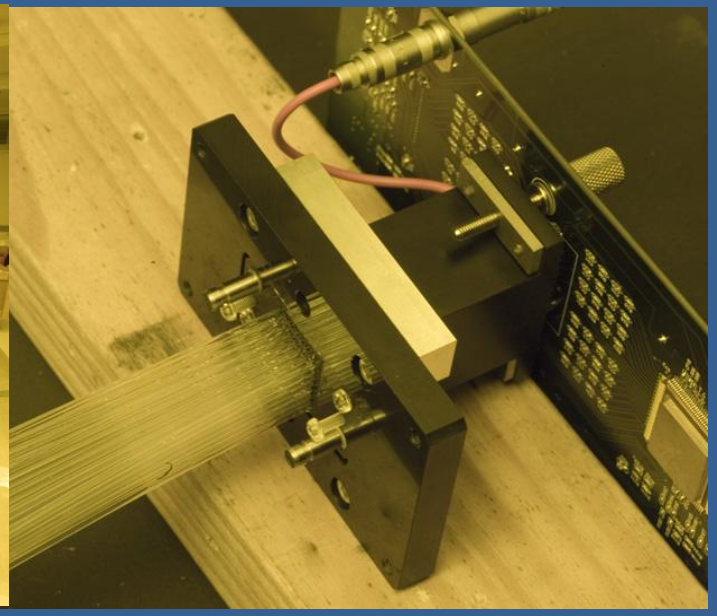
In 2005 an idea was born…

SciBooNE

SciBooNE Timeline

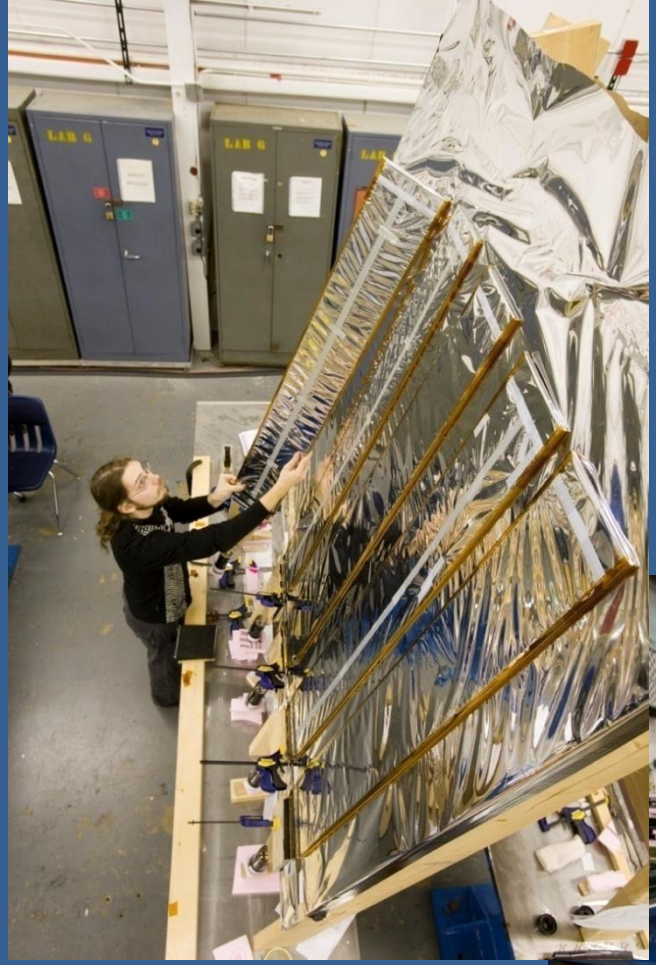
- Mar. 2005: K2K ends
- Summer 2005: Collaboration formed
- Nov. 2005: Proposed
- Dec. 2005: Approved
- Mar 2006: First collaboration meeting
- May. 2006: Set baseline cost and schedule
- Jun 2006: MRD prototype counters
- **Jul. 2006: SciBar/EC arrive**
- Jul. 2006: Begin MRD counter construction
- Aug. 2006: Civil construction contract
- Sep. 2006: Groundbreaking
- Nov 2006: Install EC horizontal layer
- Dec. 2006: SciBar Plane Installation
- Dec. 2006: Install EC vertical layer, first cosmics seen in EC
- Jan 2007: Begin MRD counter installation
- Jan. 2007: Beneficial occupancy
- Feb 2007: SciBar fibers & FEBs installed
- Mar 2007: First cosmics in SciBar
- Mar. 2007: First cosmics in MRD
- Apr. 2007: Pre-install hall work complete
- Apr. 2007: Move detectors to enclosure
- May 2007: Cabling and commissioning
- May 2007: First events seen in detector





SciBooNE Timeline

- Mar. 2005: K2K ends
- Summer 2005: Collaboration formed
- Nov. 2005: Proposed
- Dec. 2005: Approved
- Mar 2006: First collaboration meeting
- May. 2006: Set baseline cost and schedule
- Jun 2006: MRD prototype counters
- Jul. 2006: SciBar/EC arrive
- Jul. 2006: Begin MRD counter construction
- Aug. 2006: Civil construction contract
- Sep. 2006: Groundbreaking
- Nov 2006: Install EC horizontal layer
- Dec. 2006: SciBar Plane Installation
- Dec. 2006: Install EC vertical layer, seen in EC
- Jan 2007: Begin MRD counter installation
- Jan. 2007: Beneficial occupancy
- Feb 2007: SciBar fibers & FEBs installed
- Mar 2007: First cosmics in SciBar
- Mar. 2007: First cosmics in MRD
- Apr. 2007: Pre-install hall work complete
- Apr. 2007: Move detectors to enclosure
- May 2007: Cabling and commissioning
- May 2007: First events seen in detector



SciBooNE Timeline

- Mar. 2005: K2K ends
- Summer 2005: Collaboration formed
- Nov. 2005: Proposed
- Dec. 2005: Approved
- Mar 2006: First collaboration meeting
- May. 2006: Set baseline cost and schedule
- Jun. 2006: MRD prototype counters
- Jul. 2006: SciBar/EC arrive
- Jul. 2006: Begin MRD counter construction
- Aug. 2006: Civil construction contract
- Sep. 2006: Groundbreaking
- Nov 2006: Install EC horizontal layer
- Dec. 2006: SciBar Plane Installation
- Dec. 2006: Install EC vertical layer, first cosmics seen in EC
- Jan 2007: Begin MRD counter installation
- Jan. 2007: Beneficial occupancy
- Feb 2007: SciBar fibers & FEBs installed
- Mar 2007: First cosmics in SciBar
- Mar. 2007: First cosmics in MRD
- Apr. 2007: Pre-install hall work complete
- Apr. 2007: Move detectors to enclosure
- May 2007: Cabling and commissioning
- May 2007: First events seen in detector

20 September 2006

SciBooNE Timeline

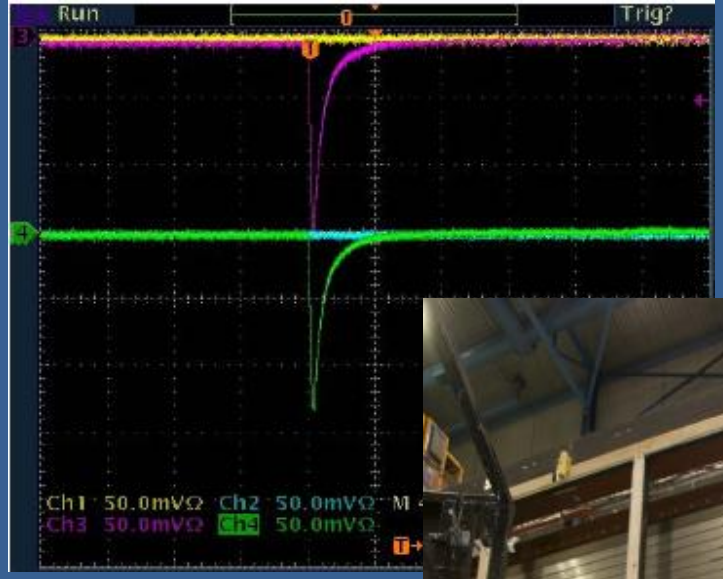
- Mar. 2005: K2K ends
- Summer 2005: Collaboration formed
- Nov. 2005: Proposed
- Dec. 2005: Approved
- Mar 2006: First collaboration meeting
- May. 2006: Set baseline cost and schedule
- Jun 2006: MRD prototype counters
- Jul. 2006: SciBar/EC arrive
- Jul. 2006: Begin MRD counter construction
- Aug. 2006: Civil construction contract
- Sep. 2006: Groundbreaking
- Nov 2006: Install EC horizontal layer
- Dec. 2006: SciBar plane installation
- Dec. 2006: Install EC vertical layer, first cosmics seen in EC
- Jan 2007: Begin MRD counter installation
- Jan. 2007: Beneficial occupancy
- Feb 2007: SciBar fibers & FEBs installed
- Mar 2007: First cosmics in SciBar
- Mar. 2007: First cosmics in MRD
- Apr. 2007: Pre-install hall work complete
- Apr. 2007: Move detectors to enclosure
- May 2007: Cabling and commissioning
- May 2007: First events seen in detector

SciBooNE Timeline

- Mar. 2005: K2K ends
- Summer 2005: Collaboration formed
- Nov. 2005: Proposed
- Dec. 2005: Approved
- Mar 2006: First collaboration meeting
- May. 2006: Set baseline cost and schedule
- Jun 2006: MRD prototype counters
- Jul. 2006: SciBar/EC arrive
- Jul. 2006: Begin MRD counter construction
- Aug. 2006: Civil construction contract
- Sep. 2006: Groundbreaking
- Nov 2006: Install EC horizontal layer
- Dec. 2006: SciBar plane installation
- Dec. 2006: Install EC vertical layer, first cosmics seen in EC
- Jan 2007: Begin MRD counter installation
- Jan. 2007: Beneficial occupancy
- Feb 2007: SciBar fibers & FEBs installed
- Mar 2007: First cosmics in SciBar
- Mar. 2007: First cosmics in MRD
- Apr. 2007: Pre-install hall work complete
- Apr. 2007: Move detectors to enclosure
- May 2007: Cabling and commissioning
- May 2007: First events seen in detector

SciBooNE Timeline

- Mar. 2005: K2K ends
- Summer 2005: Collaboration formed
- Nov. 2005: Proposed
- Dec. 2005: Approved
- Mar 2006: First collaboration meeting
- May. 2006: Set baseline cost and schedule
- Jun 2006: MRD prototype counters
- Jul. 2006: SciBar/EC arrive
- Jul. 2006: Begin MRD counter construction
- Aug. 2006: Civil construction contract
- Sep. 2006: Groundbreaking
- Nov 2006: Install EC horizontal layer
- Dec. 2006: SciBar plane installation
- Dec. 2006: Install EC vertical layer, First cosmics seen in EC
- Jan 2007: Begin MRD counter installation
- Jan. 2007: Beneficial occupancy
- Feb 2007: SciBar fibers & FEBs installed
- Mar 2007: First cosmics in SciBar
- Mar. 2007: First cosmics in MRD
- Apr. 2007: Pre-install hall work complete
- Apr. 2007: Move detectors to enclosure
- May 2007: Cabling and commissioning
- May 2007: First events seen in detector



SciBooNE Timeline

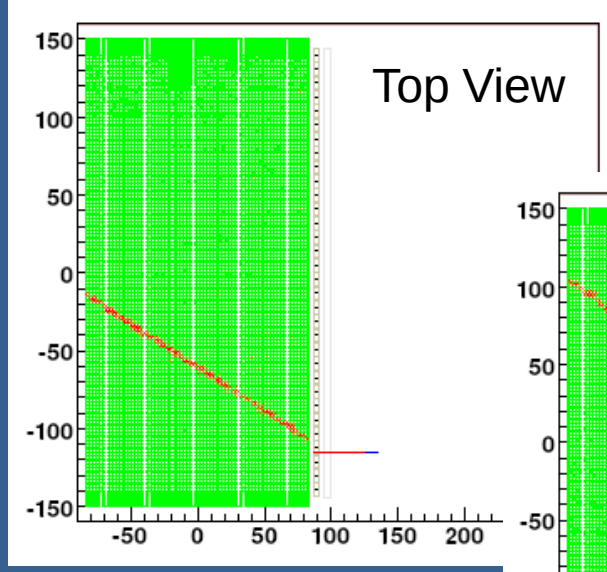
- Mar. 2005: K2K ends
- Summer 2005: Collaboration formed
- Nov. 2005: Proposed
- Dec. 2005: Approved
- Mar 2006: First collaboration meeting
- May. 2006: Set baseline cost and schedule
- Jun 2006: MRD prototype counters
- Jul. 2006: SciBar/EC arrive
- Jul. 2006: Begin MRD counter construction
- Aug. 2006: Civil construction contract
- Sep. 2006: Groundbreaking
- Nov 2006: Install EC horizontal layer
- Dec. 2006: SciBar plane installation
- Dec. 2006: Install EC vertical layer,
  First cosmics seen in EC
- Jan 2007: Begin MRD counter installation
- Jan. 2007: Beneficial occupancy
- Feb 2007: SciBar fibers & FEBs installed
- Mar 2007: First cosmics in SciBar
- Mar. 2007: First cosmics in MRD
- Apr. 2007: Pre-install hall work complete
- Apr. 2007: Move detectors to enclosure
- May 2007: Cabling and commissioning
- May 2007: First events seen in detector

SciBooNE Timeline

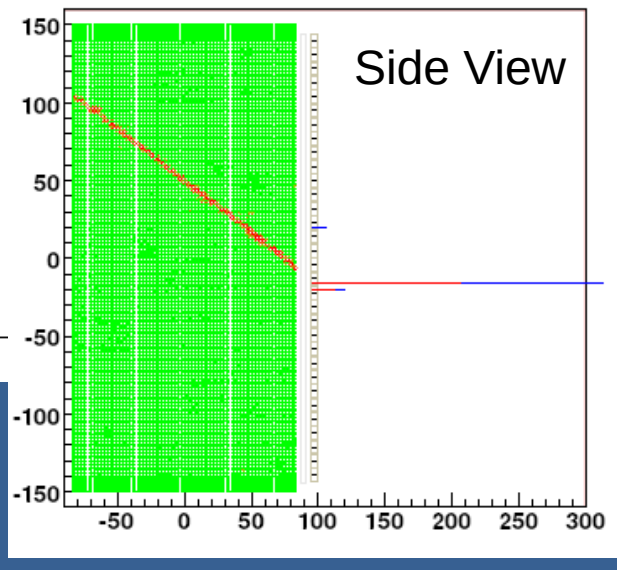
- Mar. 2005: K2K ends
- Summer 2005: Collaboration formed
- Nov. 2005: Proposed
- Dec. 2005: Approved
- Mar 2006: First collaboration meeting
- May. 2006: Set baseline cost and schedule
- Jun 2006: MRD prototype counters
- Jul. 2006: SciBar/EC arrive
- Jul. 2006: Begin MRD counter construction
- Aug. 2006: Civil construction contract
- Sep. 2006: Groundbreaking
- Nov 2006: Install EC horizontal layer
- Dec. 2006: SciBar plane installation
- Dec. 2006: Install EC vertical layer,
  First cosmics seen in EC
- Jan 2007: Begin MRD counter installation
- Jan. 2007: Beneficial occupancy
- Feb 2007: SciBar fibers & FEBs installed
- Mar 2007: First cosmics in SciBar
- Mar. 2007: First cosmics in MRD
- Apr. 2007: Pre-install hall work complete
- Apr. 2007: Move detectors to enclosure
- May 2007: Cabling and commissioning
- May 2007: First events seen in detector

SciBooNE Timeline

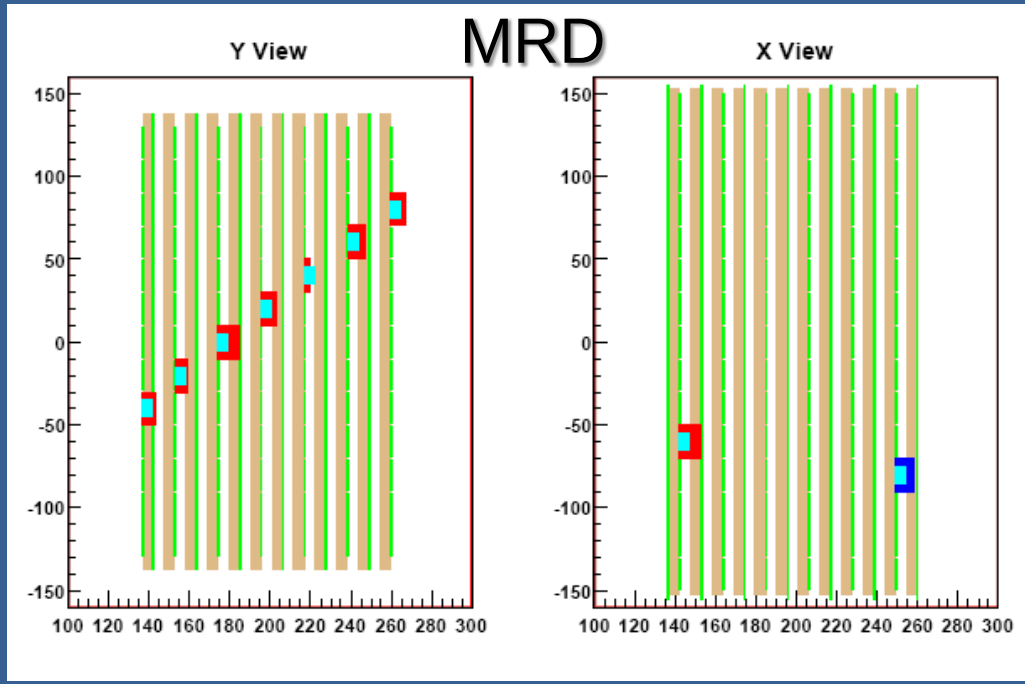
- Mar. 2005: K2K ends
- Summer 2005: Collaboration formed
- Nov. 2005: Proposed
- Dec. 2005: Approved
- Mar 2006: First collaboration meeting
- May. 2006: Set baseline cost and schedule
- Jun 2006: MRD prototype counters
- Jul. 2006: SciBar/EC arrive
- Jul. 2006: Begin MRD counter construction
- Aug. 2006: Civil construction contract
- Sep. 2006: Groundbreaking
- Nov 2006: Install EC horizontal layer
- Dec. 2006: SciBar plane installation
- Dec. 2006: Install EC vertical layer,
  First cosmics seen in EC
- Jan 2007: Begin MRD counter installation
- Jan. 2007: Beneficial occupancy
- Feb 2007: SciBar fibers & FEBs installed
- Mar 2007: First cosmics in SciBar
- Mar. 2007: First cosmics in MRD
- Apr. 2007: Pre-install hall work complete
- Apr. 2007: Move detectors to enclosure
- May 2007: Cabling and commissioning
- May 2007: First events seen in detector



SciBar/EC



MRD



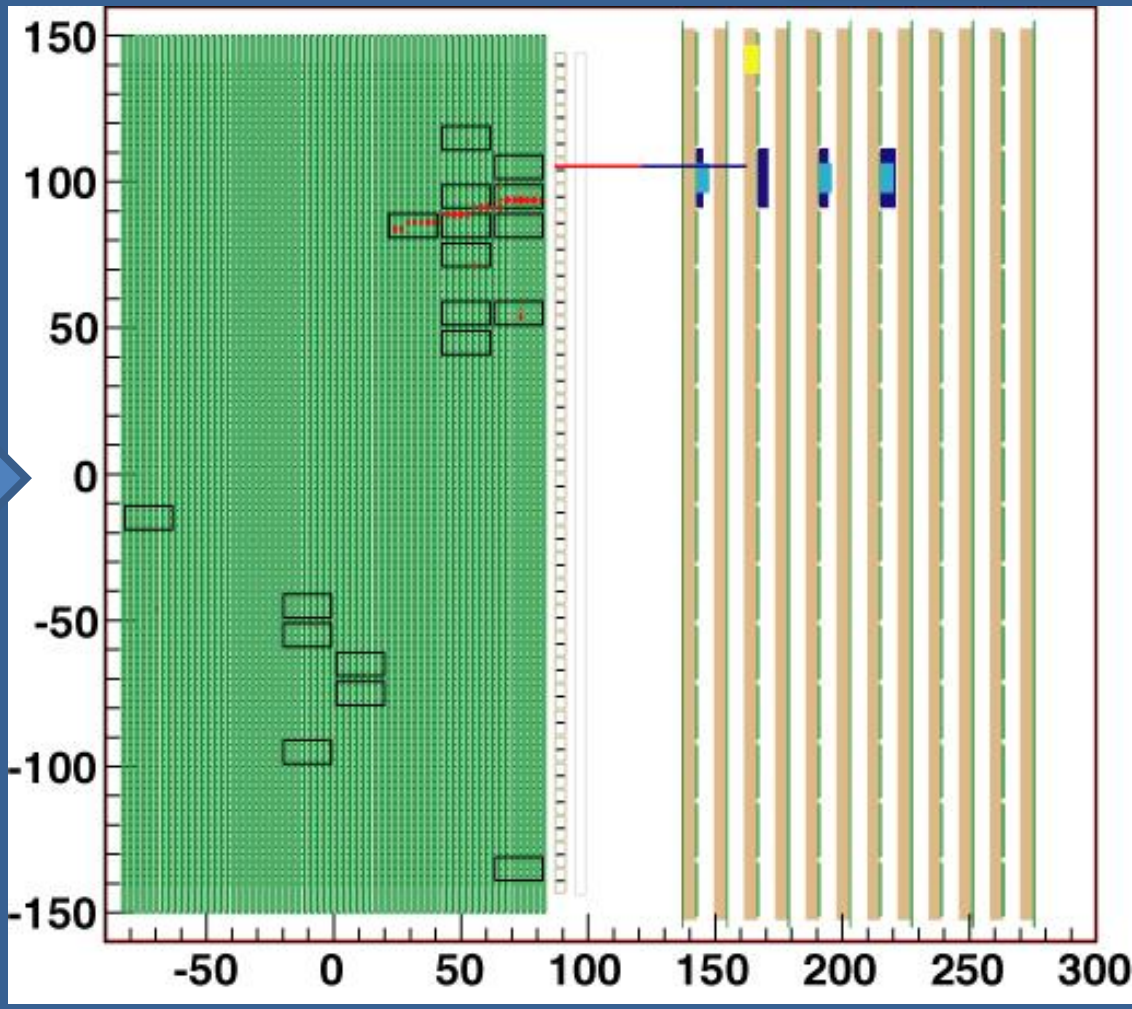
SciBooNE Timeline

- Mar. 2005: K2K ends
- Summer 2005: Collaboration formed
- Nov. 2005: Proposed
- Dec. 2005: Approved
- Mar 2006: First collaboration meeting
- May. 2006: Set baseline cost and schedule
- Jun 2006: MRD prototype counters
- Jul. 2006: SciBar/EC arrive
- Jul. 2006: Begin MRD counter construction
- Aug. 2006: Civil construction contract
- Sep. 2006: Groundbreaking
- Nov 2006: Install EC horizontal layer
- Dec. 2006: SciBar plane installation
- Dec. 2006: Install EC vertical layer,
  First cosmics seen in EC
- Jan 2007: Begin MRD counter installation
- Jan. 2007: Beneficial occupancy
- Feb 2007: SciBar fibers & FEBs installed
- Mar 2007: First cosmics in SciBar
- Mar. 2007: First cosmics in MRD
- Apr. 2007: Pre-install hall work complete
- Apr. 2007: Detectors move to enclosure
- May 2007: Cabling and commissioning
- May 2007: First events seen in detector

SciBooNE Timeline

- Mar. 2005: K2K ends
- Summer 2005: Collaboration formed
- Nov. 2005: Proposed
- Dec. 2005: Approved
- Mar 2006: First collaboration meeting
- May. 2006: Set baseline cost and schedule
- Jun 2006: MRD prototype counters
- Jul. 2006: SciBar/EC arrive
- Jul. 2006: Begin MRD counter construction
- Aug. 2006: Civil construction contract
- Sep. 2006: Groundbreaking
- Nov 2006: Install EC horizontal layer
- Dec. 2006: SciBar plane installation
- Dec. 2006: Install EC vertical layer, First cosmics seen in EC
- Jan 2007: Begin MRD counter installation
- Jan. 2007: Beneficial occupancy
- Feb 2007: SciBar fibers & FEBs installed
- Mar 2007: First cosmics in SciBar
- Mar. 2007: First cosmics in MRD
- Apr. 2007: Pre-install hall work complete
- Apr. 2007: Detectors move to enclosure
- May 2007: Cabling and commissioning
- May 2007: First events seen in detector !!!

Top View

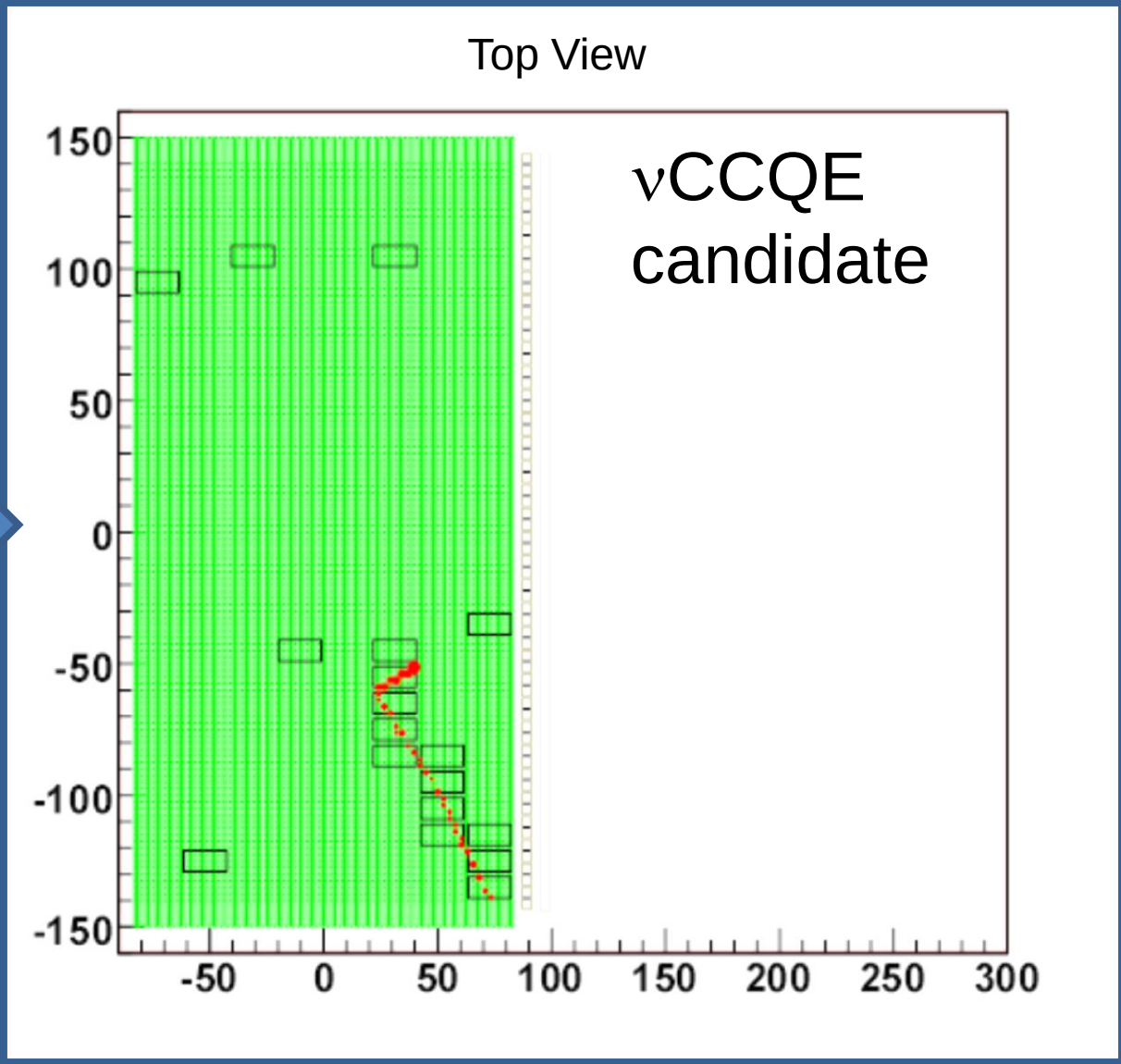


First ν event including all three subdetectors!

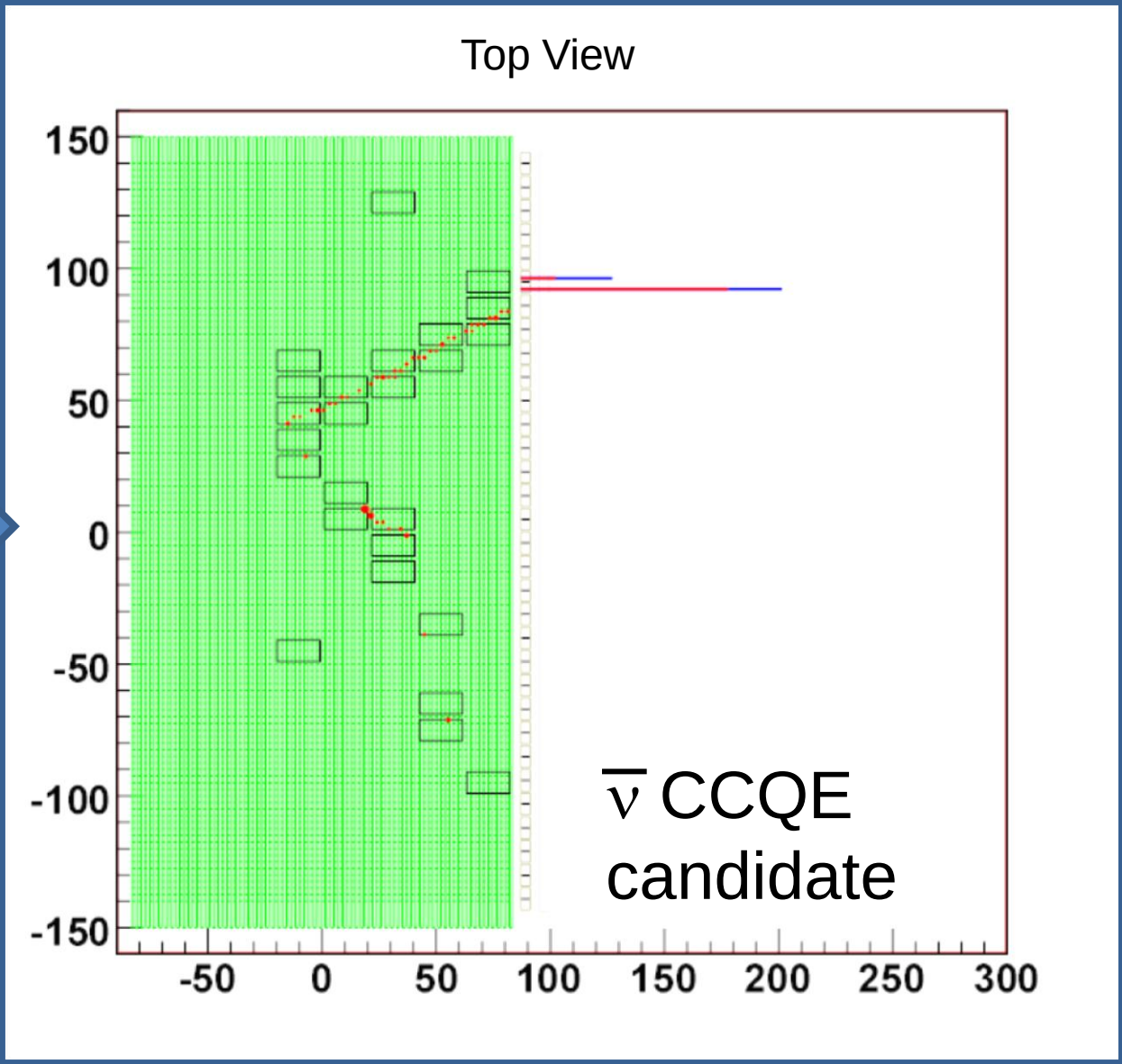
May 30, 2007 (today)

We are commissioning our detectors now, and have already begun seeing beam data!

Beam Direction

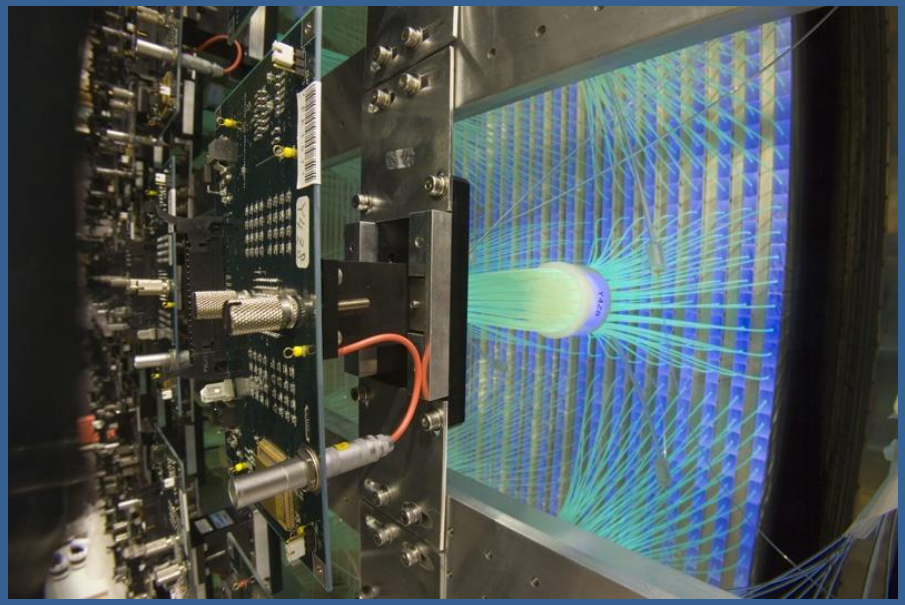


Beam Direction



SciBooNE has come a *long way* in a *short time*

The first collaboration meeting was on 17 Mar 2006, a little over a year ago.



Since then:

- New building has been constructed
- Disassembled, shipped, and reassembled two detector systems
- Designed and constructed a third detector system
- Designed and built a DAQ system
- Bulk of our analysis software already written

Started taking beam data!

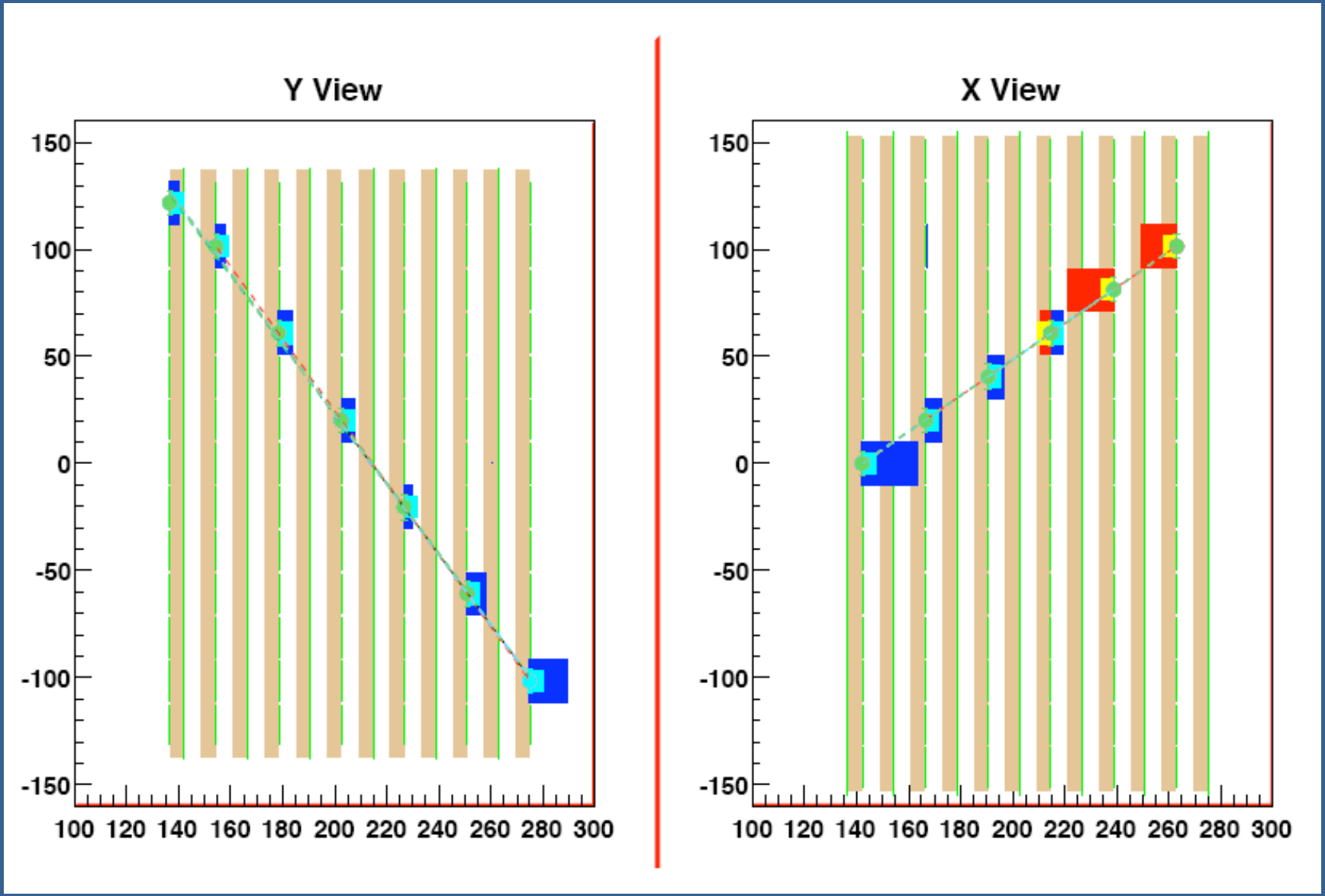
Backup Slides

Physics Motivation

- Neutrino Measurements (~5% precision)
  - CC-1π cross section
  - CCQE σ, M_A measurement
  - NCπ^0 measurement
  - Search for CC coherent π
  - Search for NC coherent π^0
  - Search for radiative Delta decay ($\nu + N \rightarrow \mu + N' + \gamma$)
  - Intrinsic ν_e flux for BNB ($\nu_\mu \rightarrow \nu_e$ appearance search)
  - Unoscillated $\Phi_\nu * \sigma$ for BNB ($\nu_\mu \rightarrow \nu_\mu$ disappearance search)

- Antineutrino Measurements (~10% precision)
  - CCQE measurement, energy dependence of σ & M_A
  - CC-1π cross section
  - NCπ^0 measurement, exclusive
  - Search for CC coherent π
  - Search for NC coherent π^0
  - Search for radiative Delta decay ($\nu + N \rightarrow \mu + N' + \gamma$)
  - Energy dependence of ν contamination for BNB anti-ν mode

Cosmic ray in MRD



The Leptonic Mixing Matrix

Flavor States

Mass States

$$\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta_{23} & \sin\theta_{23} \\ 0 & -\sin\theta_{23} & \cos\theta_{23} \end{pmatrix} \begin{pmatrix} \cos\theta_{13} & 0 & \sin\theta_{13}\, e^{-i\delta} \\ 0 & 1 & 0 \\ -\sin\theta_{13}\, e^{i\delta} & 0 & \cos\theta_{13} \end{pmatrix} \begin{pmatrix} \cos\theta_{12} & \sin\theta_{12} & 0 \\ -\sin\theta_{12} & \cos\theta_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$$

"Atmospheric Mixing"

$\theta_{23} \approx 45^0$

$\Delta m^2_{23} \sim 2.5 \times 10^{-3}$ eV^2

(SK, K2K, MINOS)

$\theta_{13} \leq 10^0$

θ_{13} constrained by reactor experiments (CHOOZ, Palo Verde), but not measured.

δ is unknown

"Solar Mixing"

$\theta_{12} \approx 32^0$

$\Delta m^2_{12} \sim 8 \times 10^{-5}$ eV^2

(SNO, KamLAND)