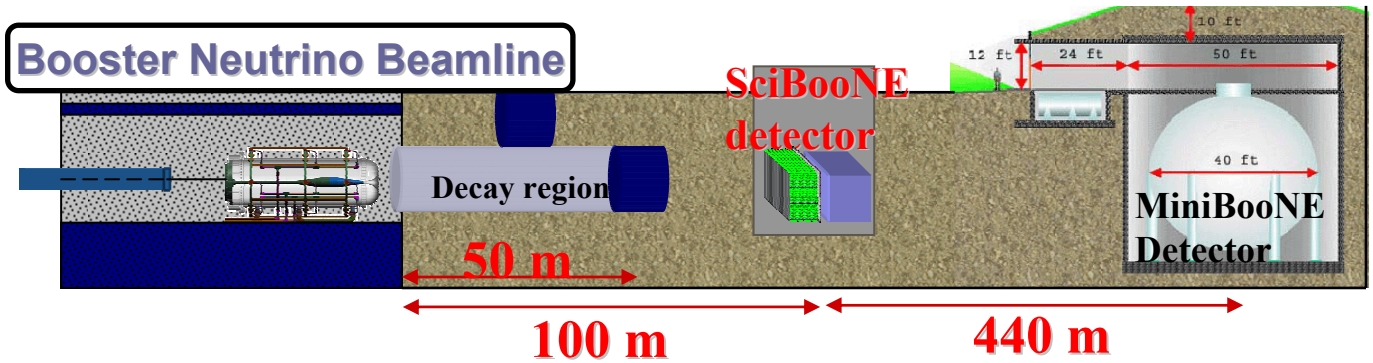
Charged current single charged pion production (CC-1π^+) in SciBooNE



Contents

- Introduction
- Event selection
- CC-1π^+ event sample
- Summary

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APS April meeting

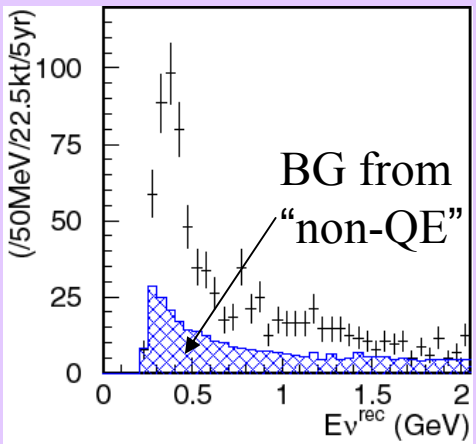
April 12th, 2008

Introduction

Charged current single charged pion production (CC-1π^+)

Motivation

- Main background for ν_μ disappearance measurements
- Need more precise knowledge



Expected ν_μ events in T2K

- **Resonant π^+**
  - $\nu + p \rightarrow \mu^- + p + \pi^+$
  - $\nu + n \rightarrow \mu^- + n + \pi^+$
- **Coherent π^+**
  - $\nu + C \rightarrow \mu^- + C + \pi^+$

Signature

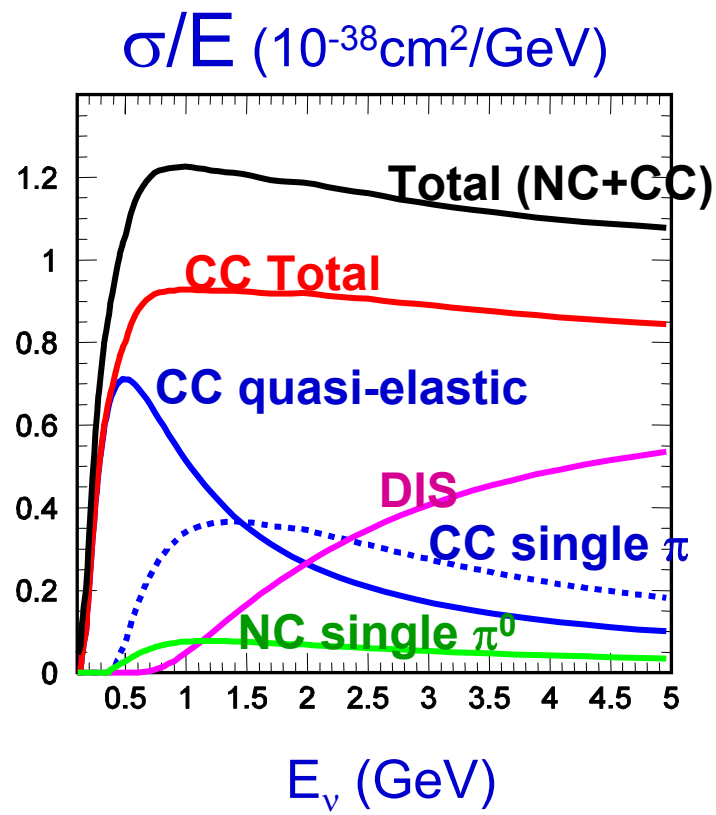
2 MIP tracks (muon and pion)

Sometimes, too short to be reconstructed

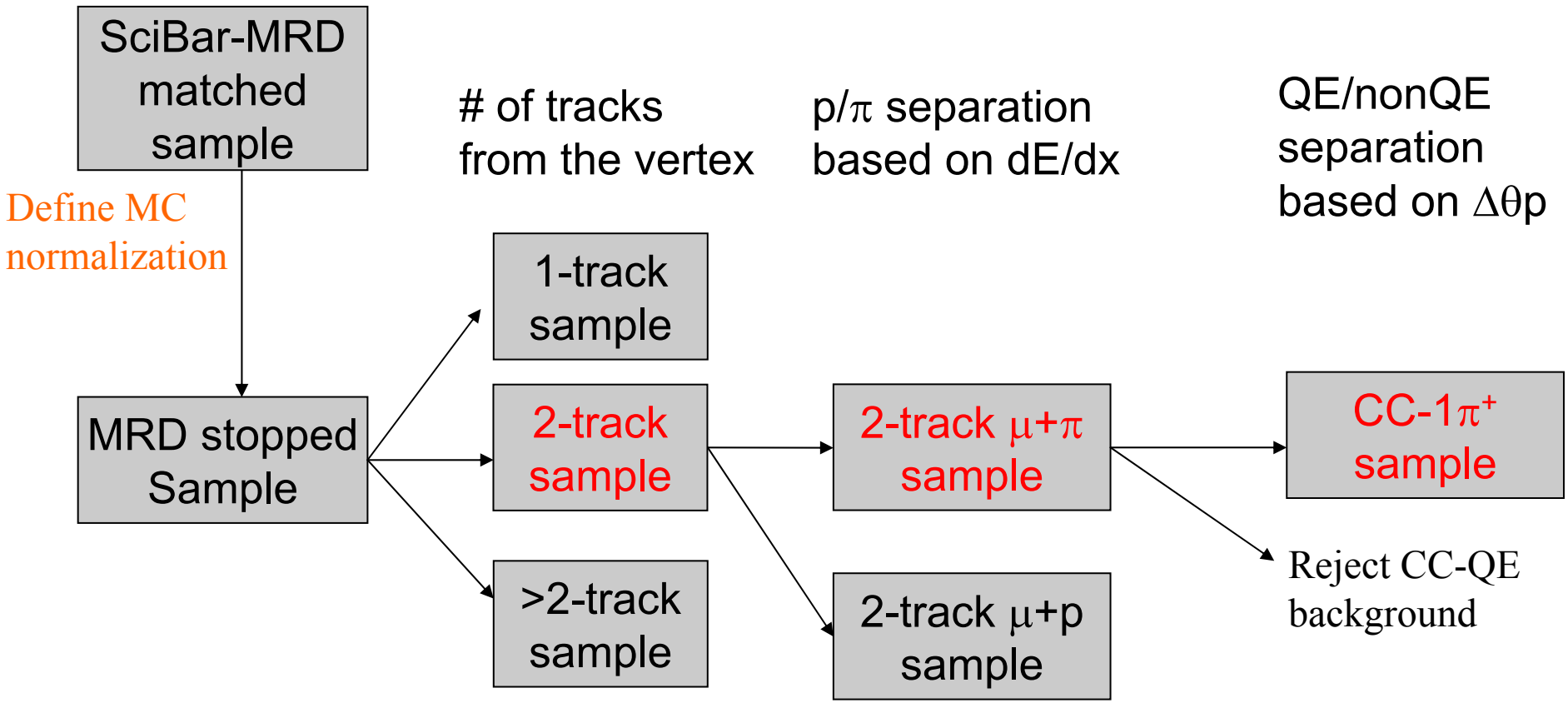
(+ proton)

Neutrino interaction simulation (NEUT)

- Target material: CH
- QE
  - Llewellyn-Smith, Smith & Moniz
  - M_A=1.1 GeV/c^2
  - P_F=217MeV/c, E_B=27MeV
- Resonant π
  - Rein & Sehgal
  - M_A=1.1 GeV/c^2
- Coherent π
  - Rein & Sehgal w/ lepton mass correction
- DIS
  - GRV98 w/ Bodek & Yang correction
- Nuclear effect
  - Formation zone and nucleon final state interaction

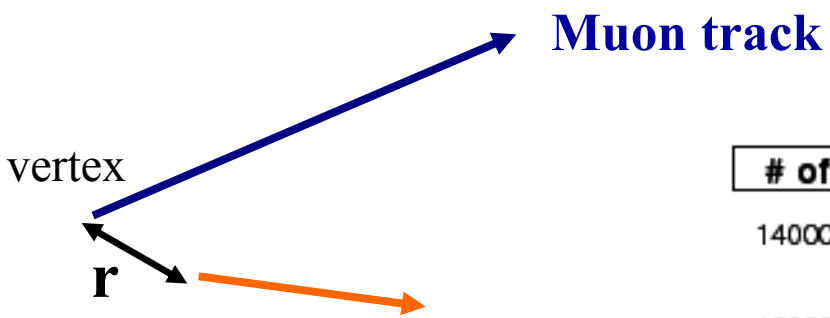


Event selection

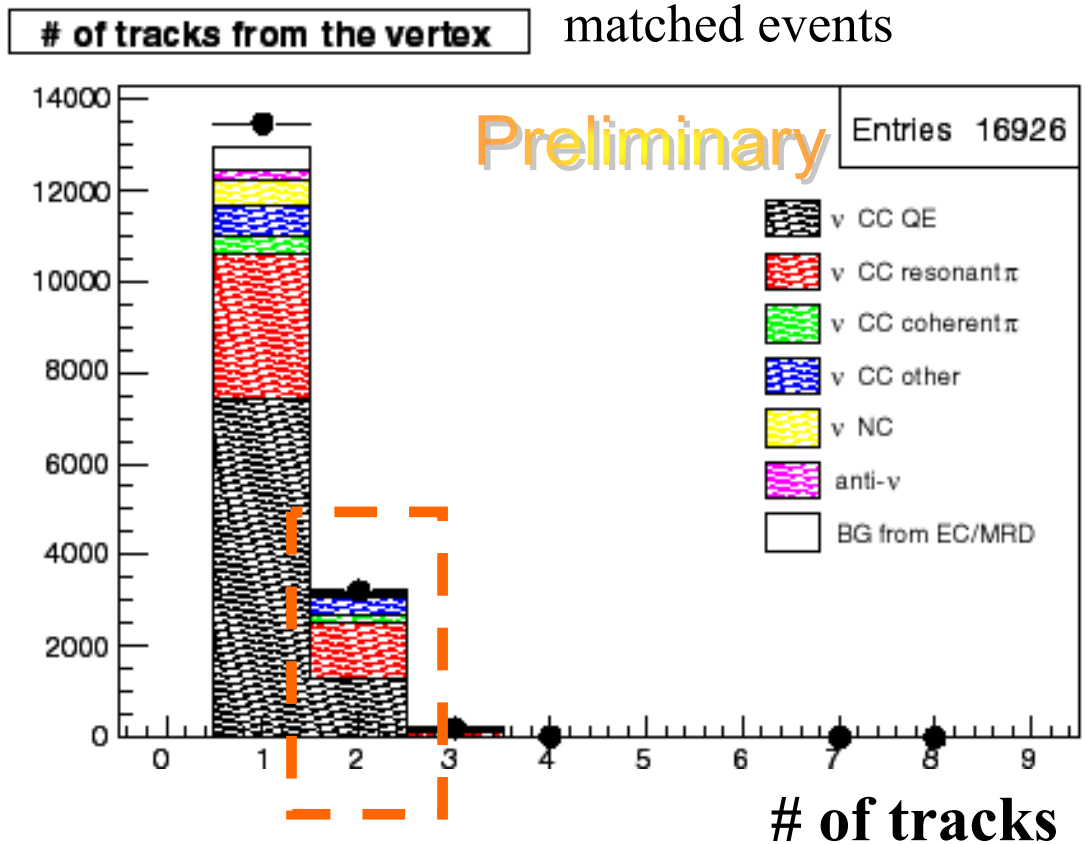


7.7x10^{19} POT neutrino data (77% of collected)

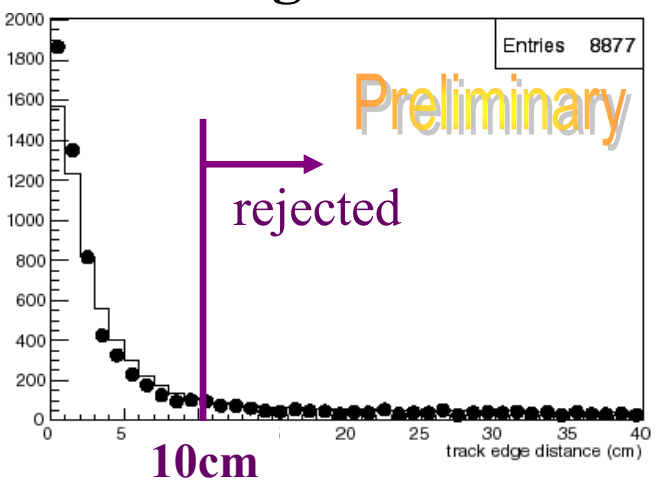
Number of tracks from the vertex



MC is normalized by the number of SciBar-MRD matched events



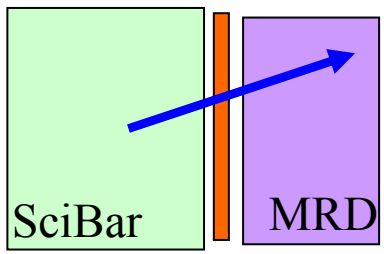
Track edge distance: r

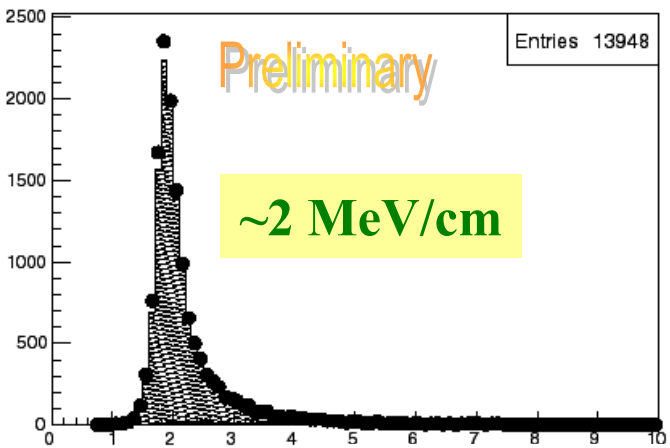


p/π separation using dE/dx

Muon track sample

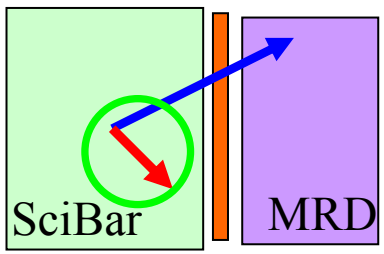
SciBar-MRD matched track



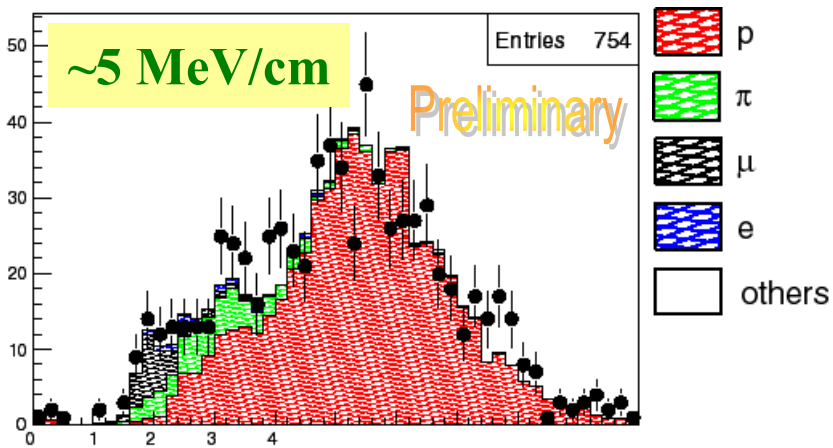


dE/dx (MeV/cm)

Proton track sample



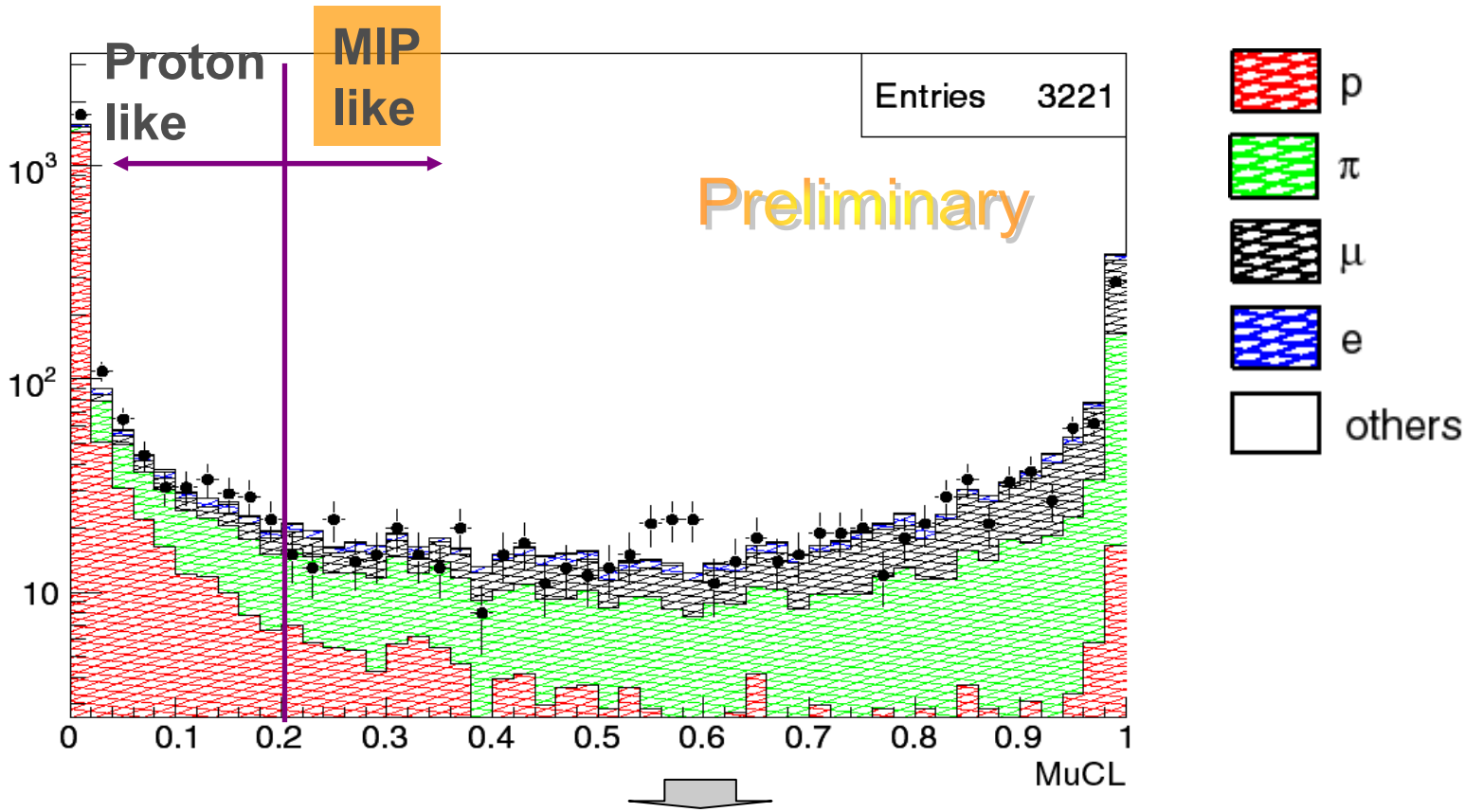
2nd track in QE-like events (based on Δθp)



dE/dx (MeV/cm)

Make Muon Confidence Level (MuCL) to separate MIP (muon and pion) from proton

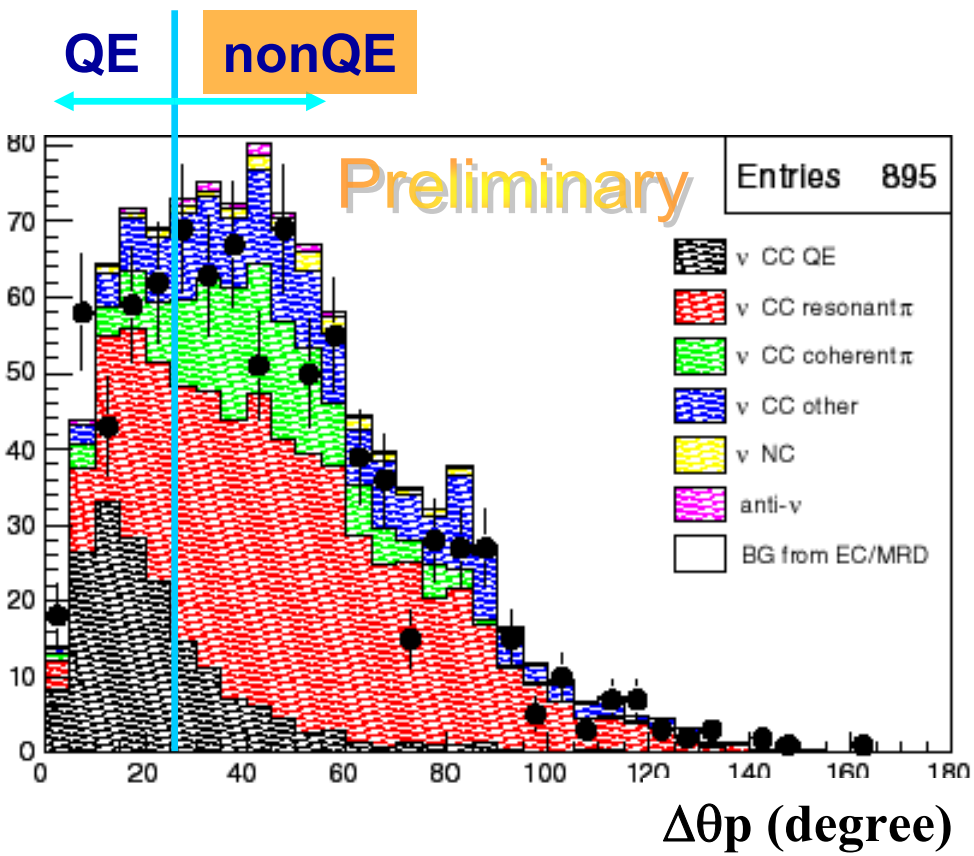
MuCL distributions (2nd track in 2 track sample)

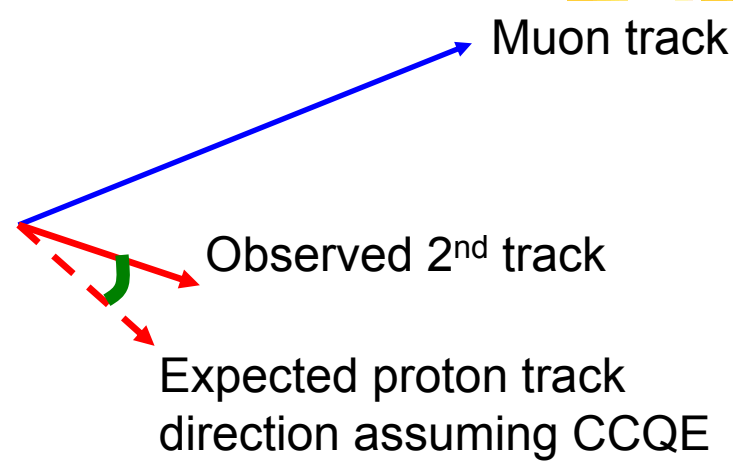


Muon efficiency = 98%
Pion efficiency = 74%
Proton mis-ID as MIP = 7.2%

QE/nonQE separation

$\Delta\theta p$ … **opening angle between the 2nd track and the expected proton track assuming CCQE**





CC-QE contamination:
17% → 7%

CC-1π+ purity:
59% → 66%

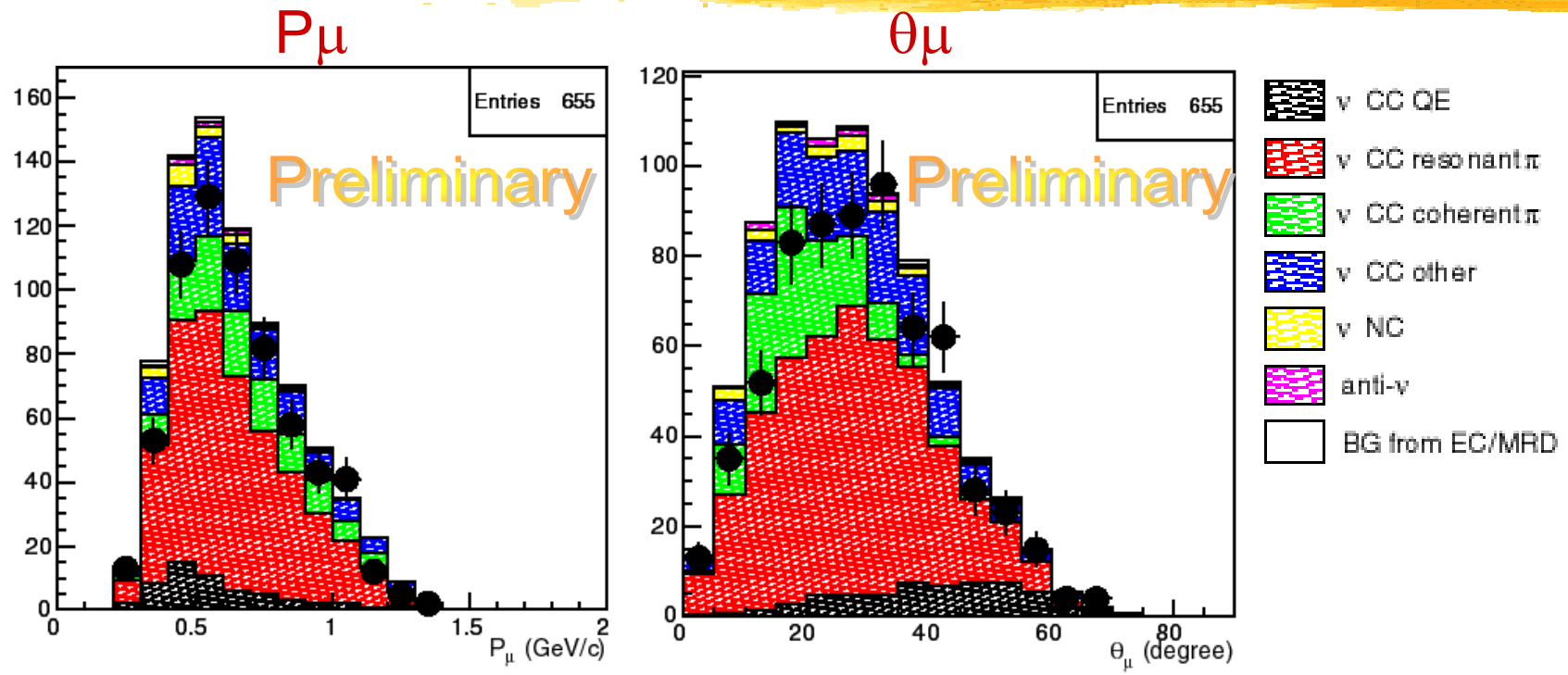
Summary of event selection

Preliminary

	DATA	MC normalized	CC-π^+ purity
MRD matched	23,737	23,737	25.6%
MRD stopped	16,926	16,248	27.1%
2 track	3,221	3,294	39.0%
$\mu+\pi$ (MuCL cut)	895	1,077	58.8%
non-QE ($\Delta\theta p$>25 degree)	655	795	65.5%

- ~700 events selected
- ~20% DATA deficit!

CC-1π^+ event sample



- ~700 events selected
- ~20% DATA deficit!

- $\mu+\pi^+$ final state purity : ~80%
- CC-1π^+ purity: 66%
  - $\nu p \rightarrow \mu p \pi$: 36%
  - $\nu n \rightarrow \mu n \pi$: 14%
  - coherent π : 16%

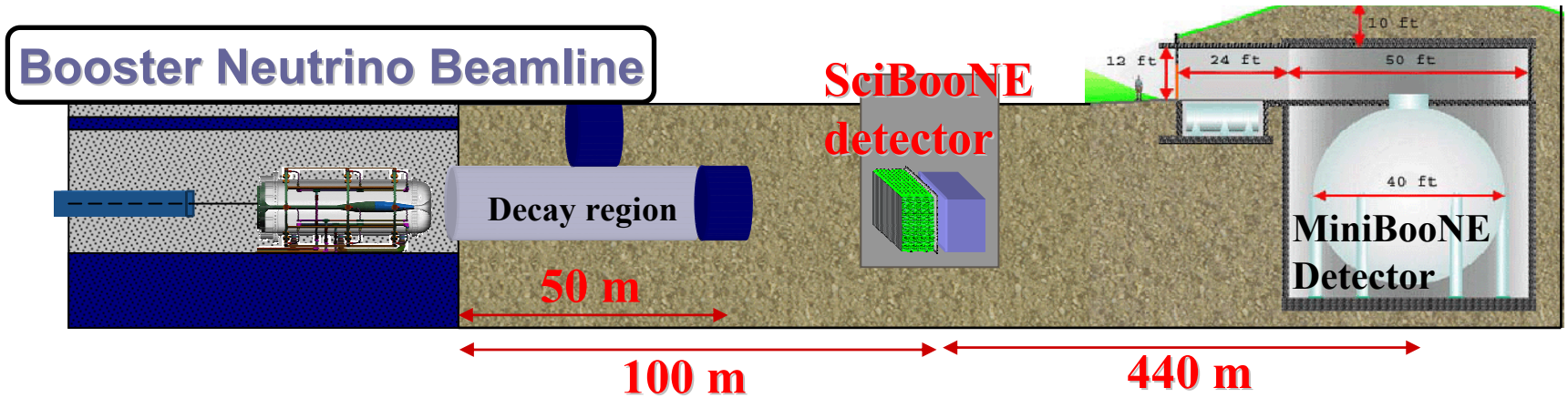
Summary

- CC-1π^+ cross section measurement is important for future neutrino oscillation experiments
- First look at CC-1π^+ events in the SciBooNE neutrino data
  - ~20% DATA deficit (no systematic uncertainty yet)

- Further study is on-going
  - Improvement of 2nd track reconstruction
  - Search for additional proton track (or activity)

Backup slides

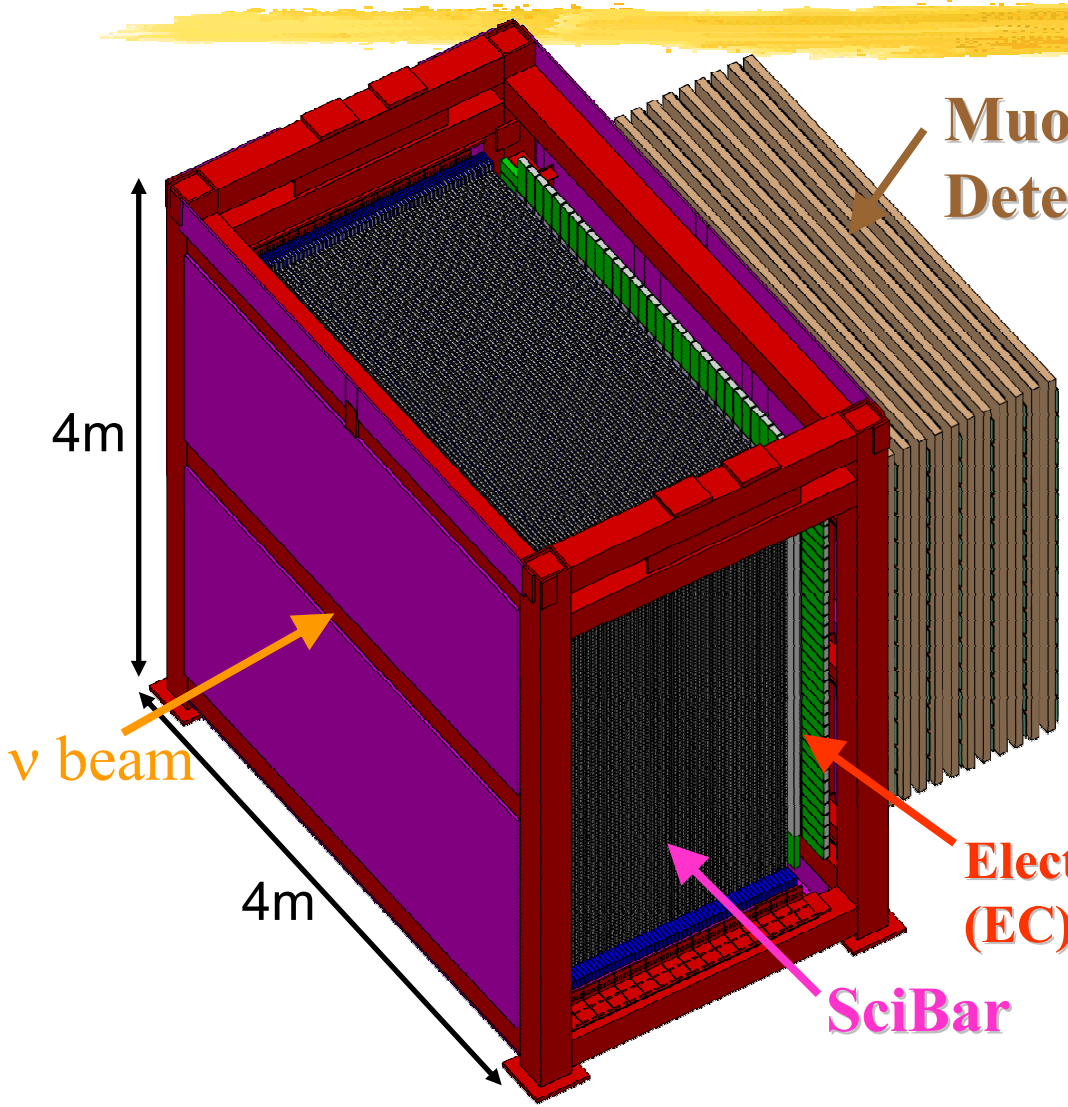
SciBooNE Experiment



- SciBooNE (FNAL E954)
  - Intense ~1 GeV neutrino beam at Fermilab
  - Fully active scintillator tracking detector (SciBar)

  ➔ Precise study of neutrino-nucleus cross section in the 1 GeV region

SciBooNE Detectors



Muon Range Detector (MRD)

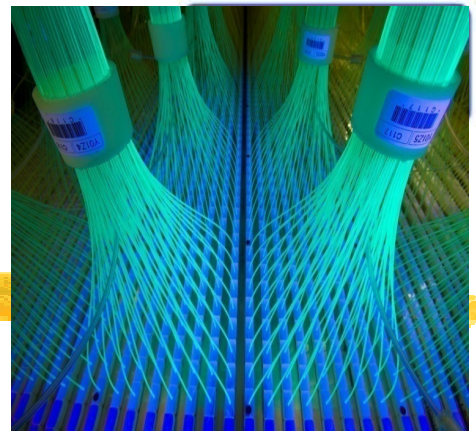
Reuse materials from past experiments at FNAL

Electron Catcher (EC)

SciBar

Used in K2K

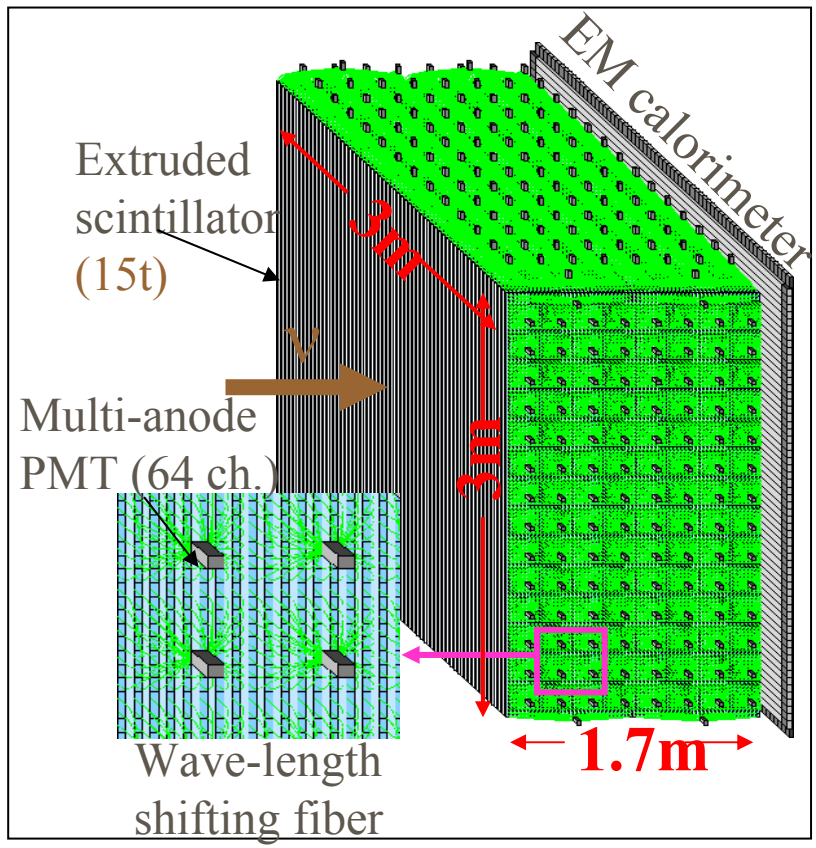
SciBar/EC Detector



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

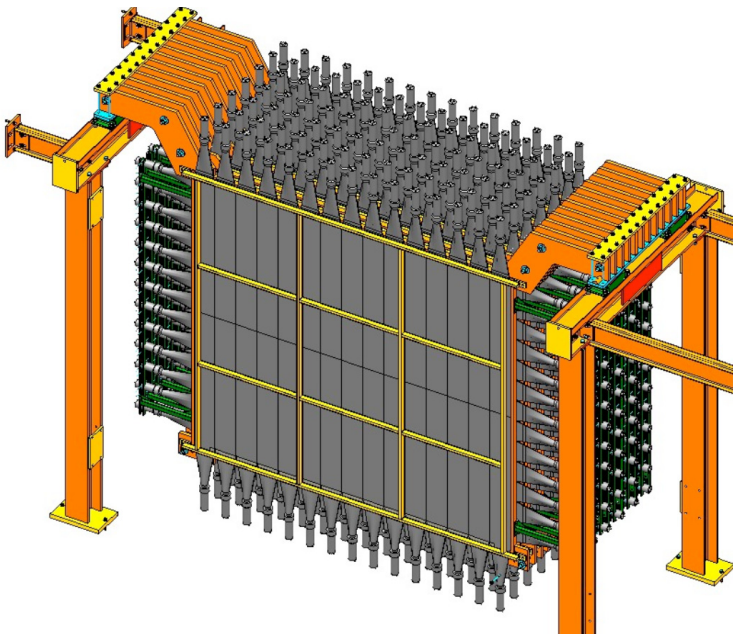
➔Clear identification of ν interaction process

- EM calorimeter to identify π^0 / ν_e



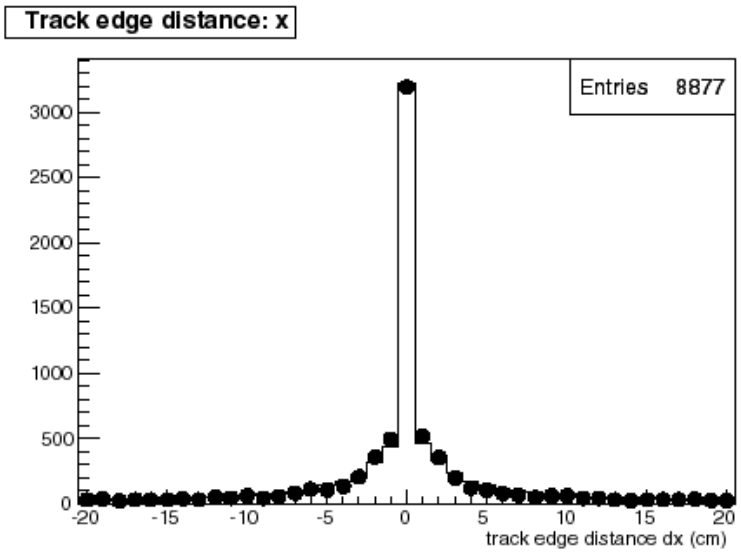
MRD

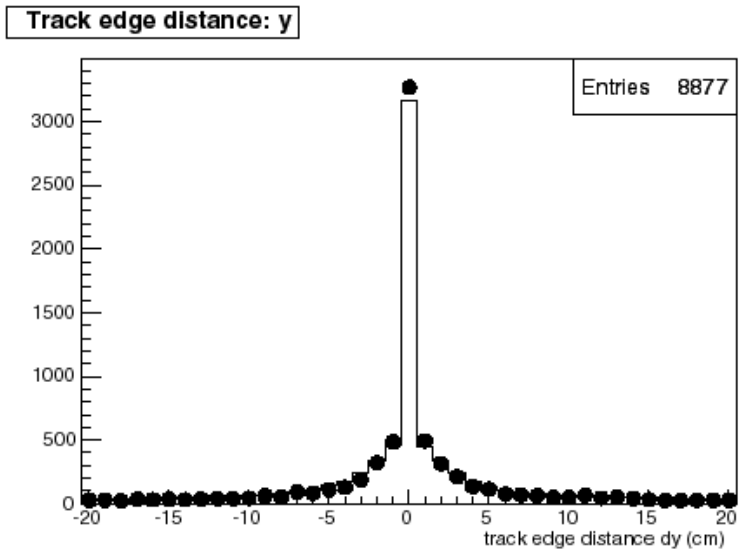
A new detector built with the used scintillators, iron plates and PMTs to measure the muon momentum up to 1.2 GeV/c.

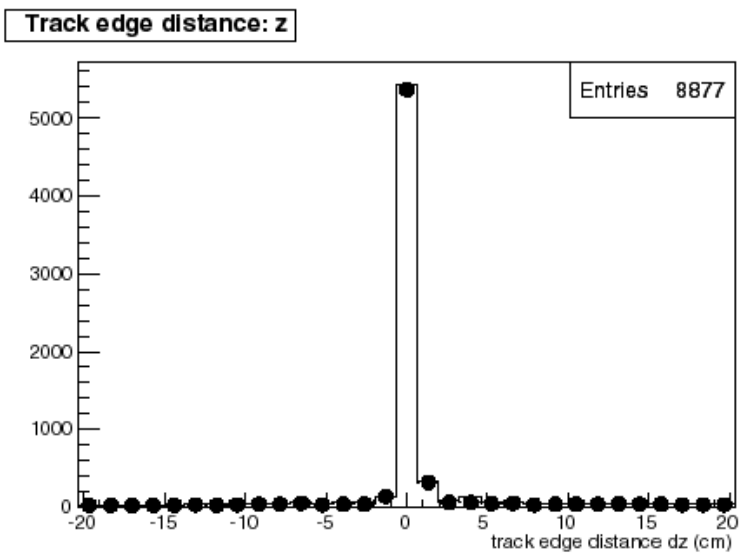


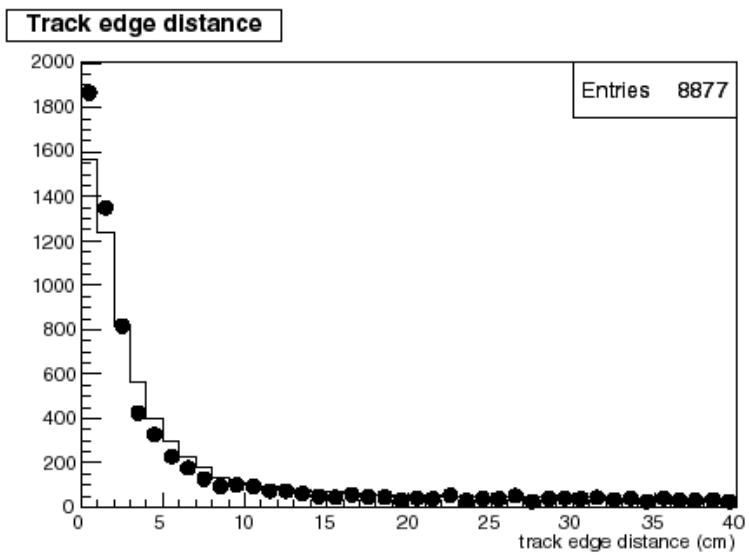
- Iron Plate
  - **305 x 274 x 5cm^3**
  - **Total 12 layers**
- Scintillator Plane
  - **Alternating horizontal and vertical planes**
  - **Total 362 channels**

Track edge distance





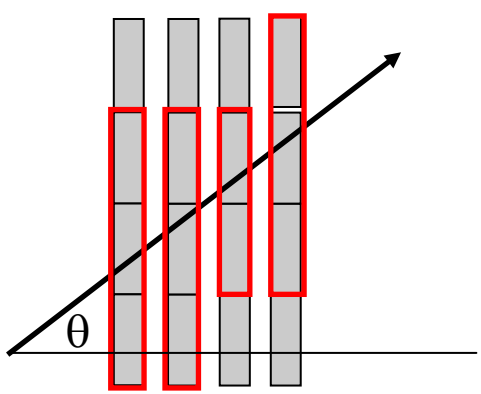




p/π^+ separation using dE/dx

dE/dx → separate pion (~MIP) from proton

dE/dx calculation



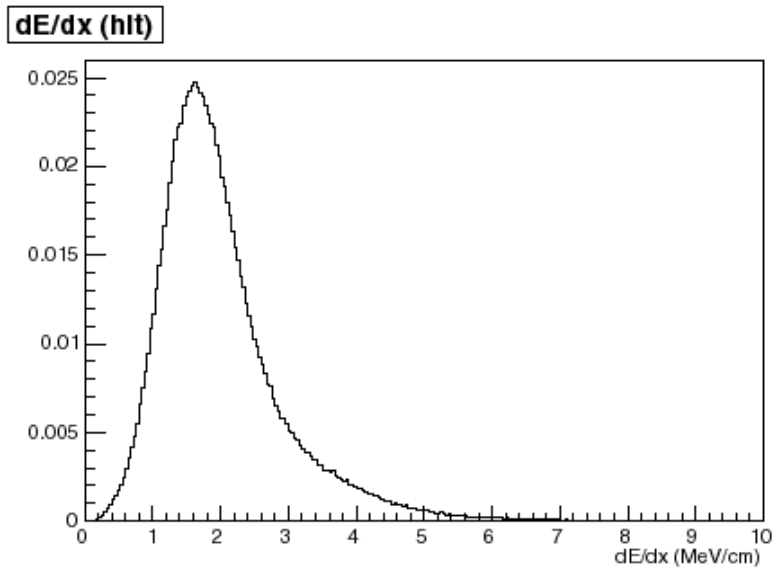
To avoid cross-talk effect, energy deposit in all the channels associated with the track are summed on a plane-by-plane basis

Then, dE/dx in each plane is calculated.

$$dE/dx = \frac{E}{1.3cm/\cos\theta}$$

(plane-based) muon confidence level

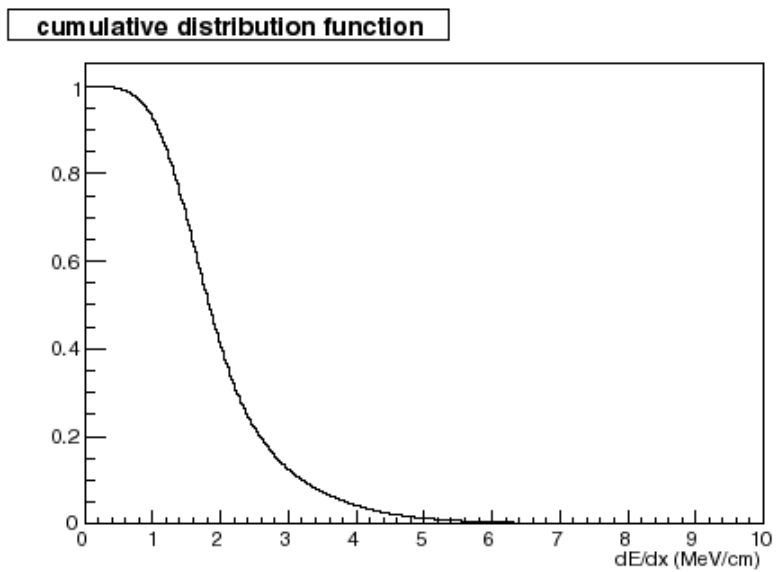
dE/dx distribution by muon (cosmic-ray MC)



Cumulative distribution function

$$F(x) = \int_x^{\infty} f(x')dx'$$

Probability that dE/dx by a muon is above the measured value
→ (plane-based) confidence level



Muon confidence level (MuCL)

dE/dx measurements in each plane
→ confidence levels (x1,x2,…,xn)

Combined probability assuming measurements are independent

$$P = x_1 \cdot x_2 \cdots x_n$$

Muon C.L. is the probability that the combined CL by muon is below the measured value P

$$MuCL = 1 - \int_P^1 \int_{\frac{P}{x_1}}^1 \cdots \int_{\frac{P}{x_1 x_2 \cdots x_{n-1}}}^1 dx'_1 dx'_2 \cdots dx'_n$$

$$= P\left(\sum_{i=0}^{n} \frac{(-\ln P)^i}{i!} \right)$$

MuCL ~1 → MIP-like
MuCL ~0 → non MIP-like

Sort & truncate confidence levels

plane-based confidence levels are sorted by ascending

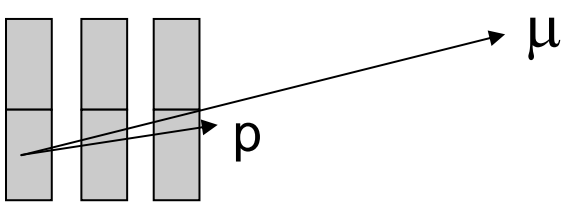
x1 < x2 < …… < …… < …… < xn

C.L. : Small → Large

dE/dx : Large → Small

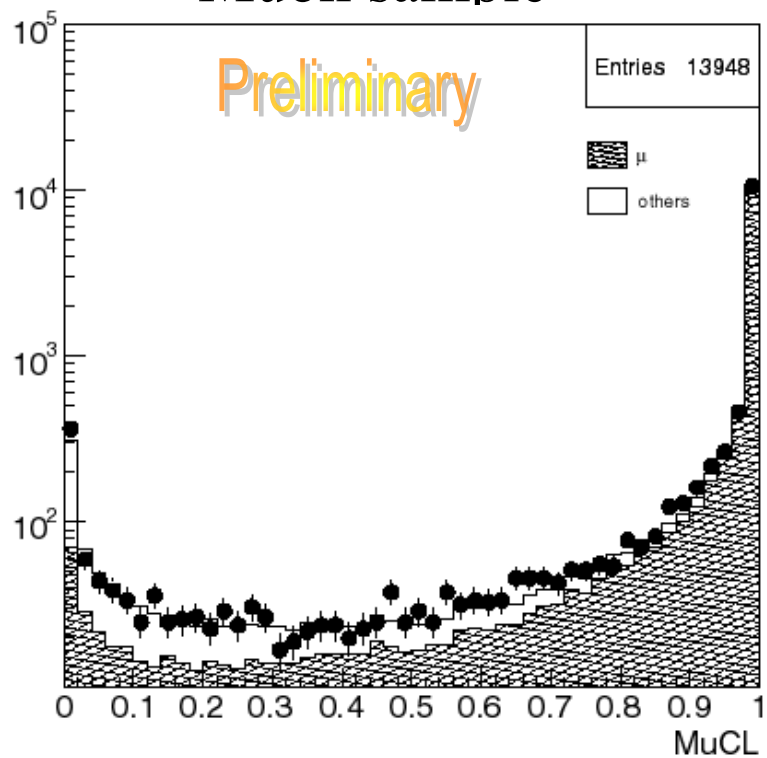
50% — Removed to avoid effect of track overlapping

10% — Removed to avoid effect of inefficiency / cross-talk

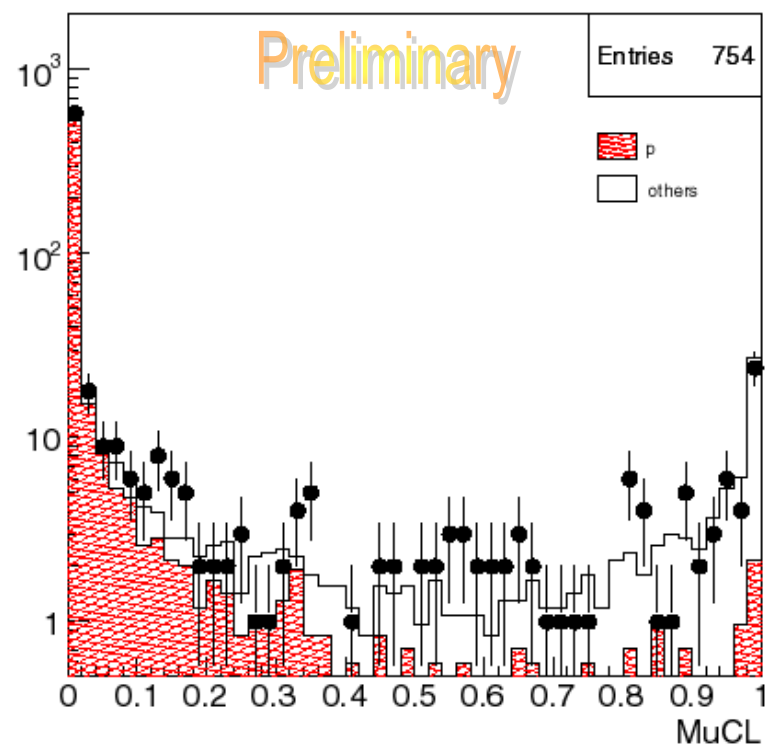


p/π separation using dE/dx

Muon sample



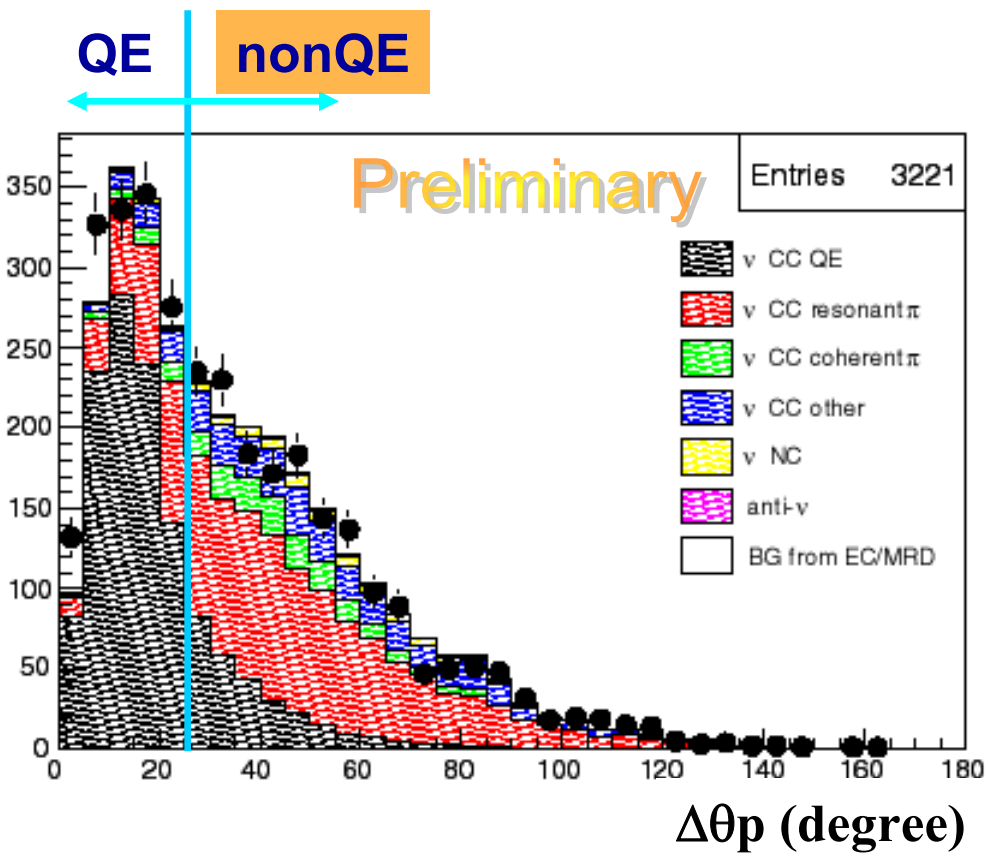
Proton sample

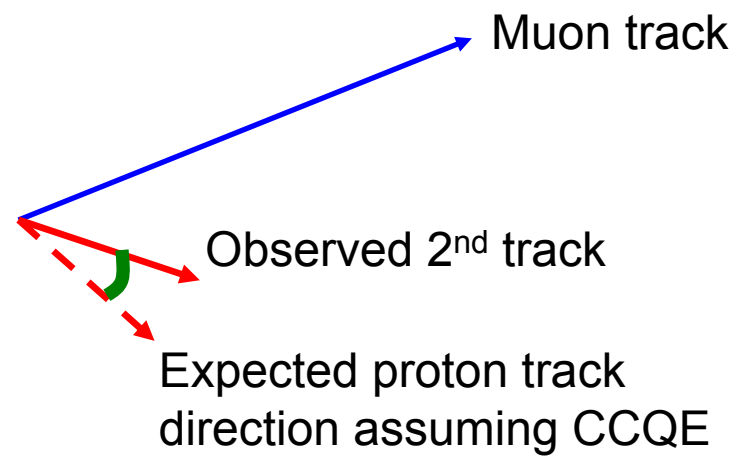


MuCL ~1 ➔ Muon-like
MuCL ~0 ➔ Proton-like

QE/nonQE separation (No MuCL cut)

$\Delta\theta p$ … **opening angle between the 2nd track and the expected proton track assuming CCQE**

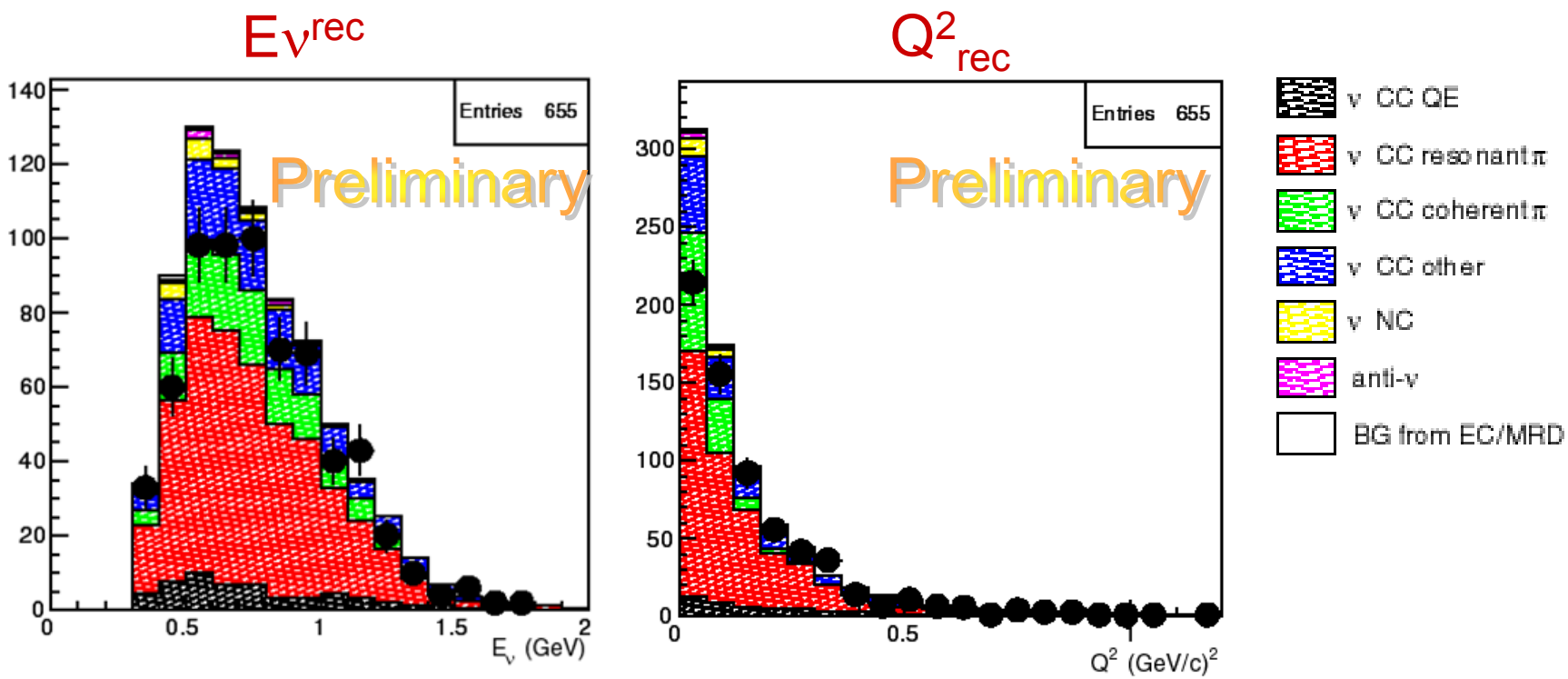




QE sample (<25degree)
Purity : 74%

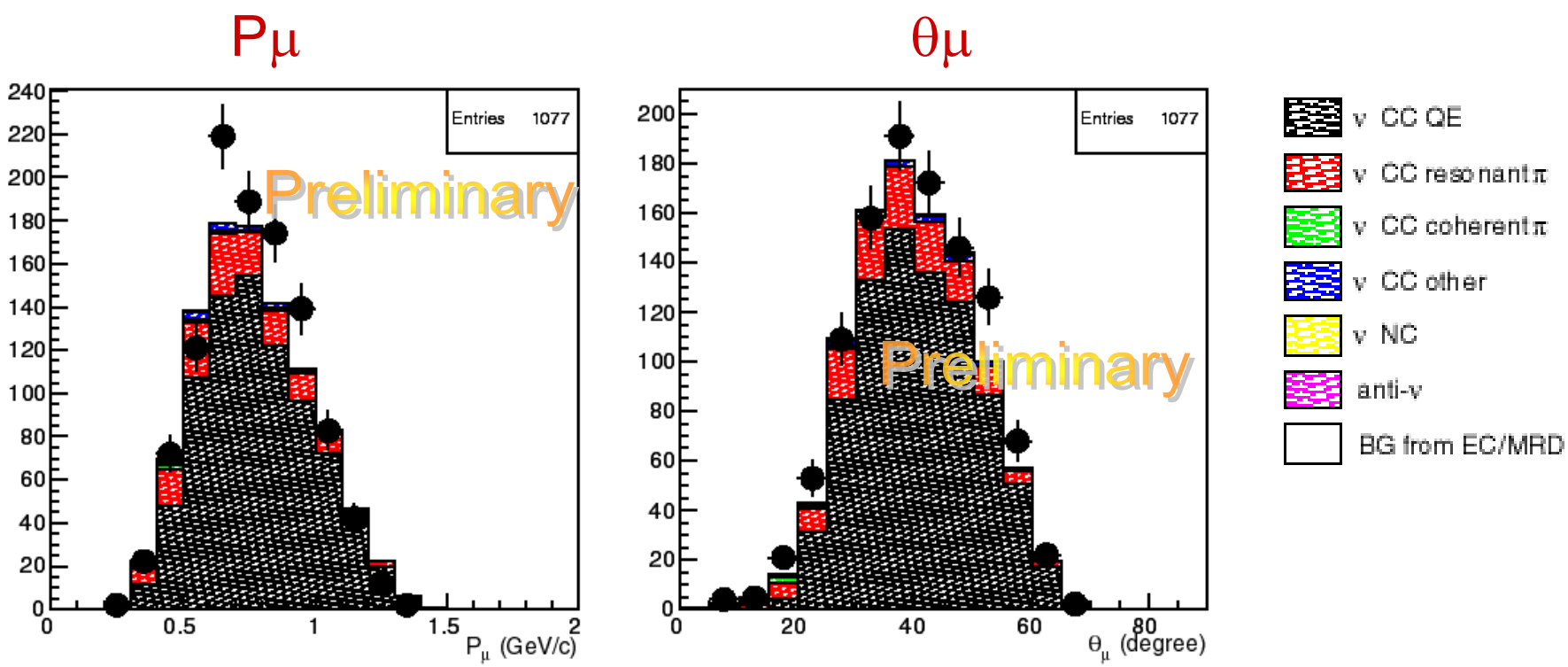
nonQE sample (>25degree)
Purity : 84%

CC-1π^+ event sample

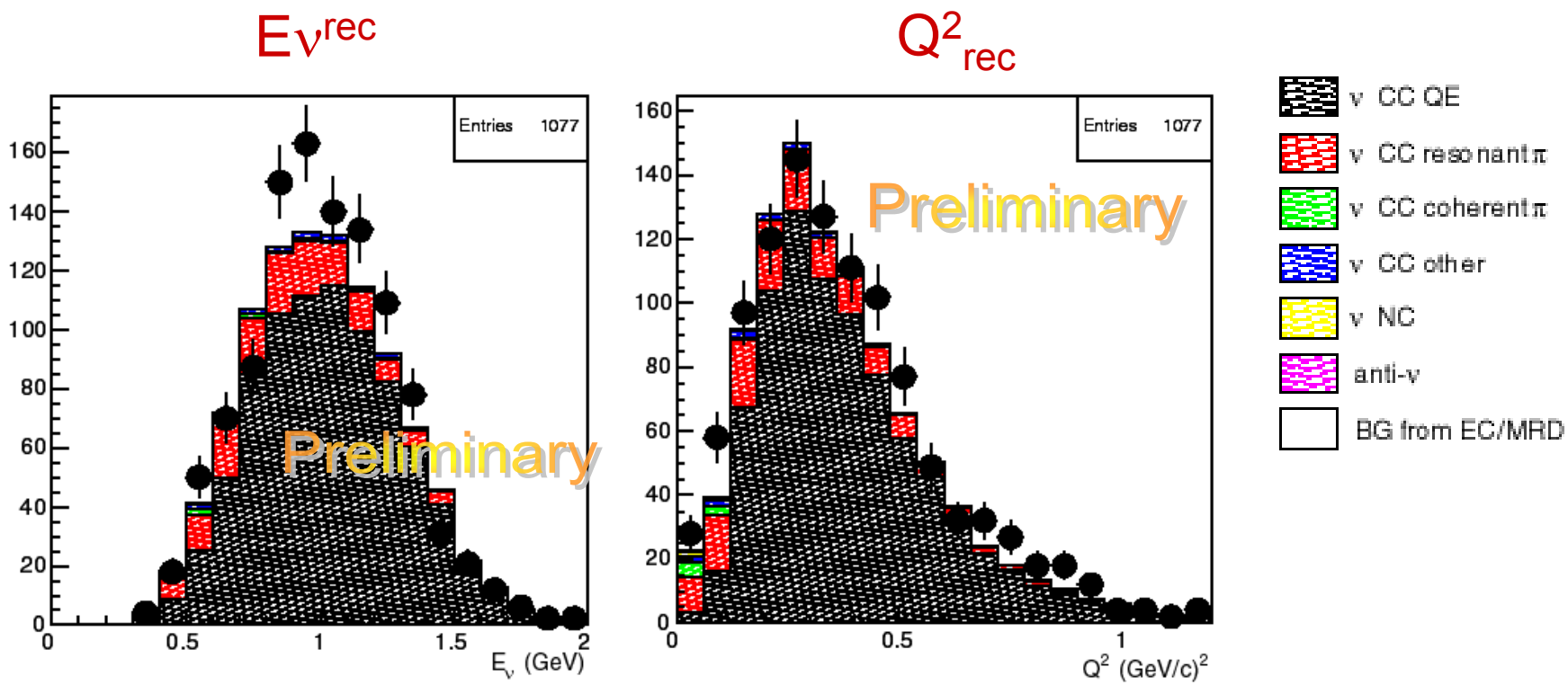


Reconstructed Eν and Q^2
assuming CC-QE kinematics

CC-QE event sample



CC-QE event sample



CC-1π^+ sample

CC-1π^+ = MRD stopped, 2 track, μ+π, $\Delta\theta$p>25degree

Preliminary	DATA	$\nu p \rightarrow \mu p \pi$ Efficiency	$\nu n \rightarrow \mu n \pi$ Efficiency	coherentπ Efficiency	CC-π^+ purity
MRD matched	23,737	24.3%	23.7%	50.4%	25.6%
MRD stopped	16,926	17.7%	16.4%	36.6%	27.1%
2 track	3,221	5.2%	3.9%	12.6%	39.0%
μ+π (MuCL cut)	895	2.0%	3.0%	9.1%	58.8%
$\Delta\theta$p>25 degree	655	1.6%	2.5%	7.6%	65.5%

2nd track reconstruction should be improved

CC-QE event sample

CC-QE sample = MRD stopped, 2 track, μ+p, $\Delta\theta p<25$ degree

Preliminary	# of events	QE efficiency	QE purity
MRD matched	23,737	29.9%	57.8%
MRD stopped	16,926	19.6%	55.5%
2 track	3,221	2.9%	40.7%
μ+p (MuCL cut)	1,983	2.4%	57.0%
$\Delta\theta p<25$ degree	1,077	1.9%	82.3%

2nd track reconstruction should be improved