The SciBooNE Experiment at FNAL

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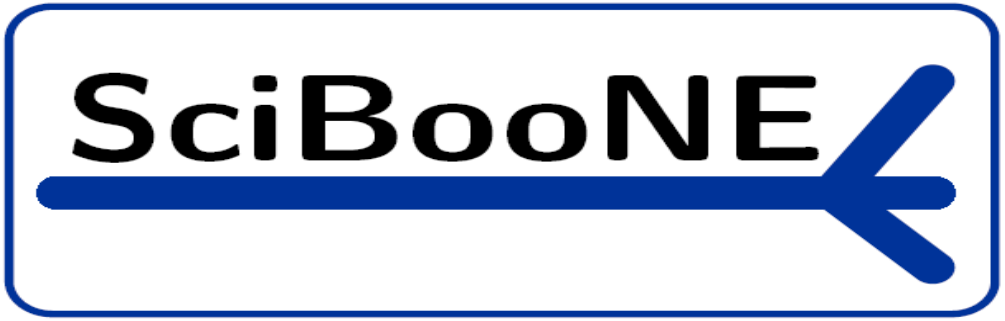

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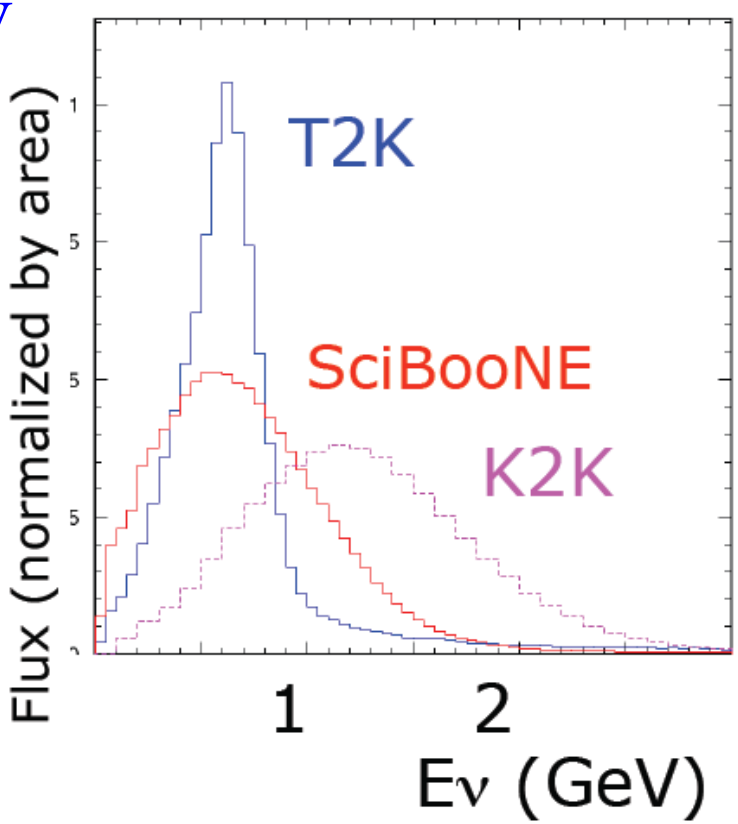
- Summary

SciBooNE (FNAL E954) Motivation

- Precise measurements of neutrino- and antineutrino-nucleus cross sections near 1 GeV
  - Essential for future neutrino oscillation experiments (T2K)
  - Few measurement in region, all low statistics

- Neutrino energy spectrum measurements and flavor measurement
  - MiniBooNE/SciBooNE joint ν_μ disappearance
  - ν_e constraint for MiniBooNE

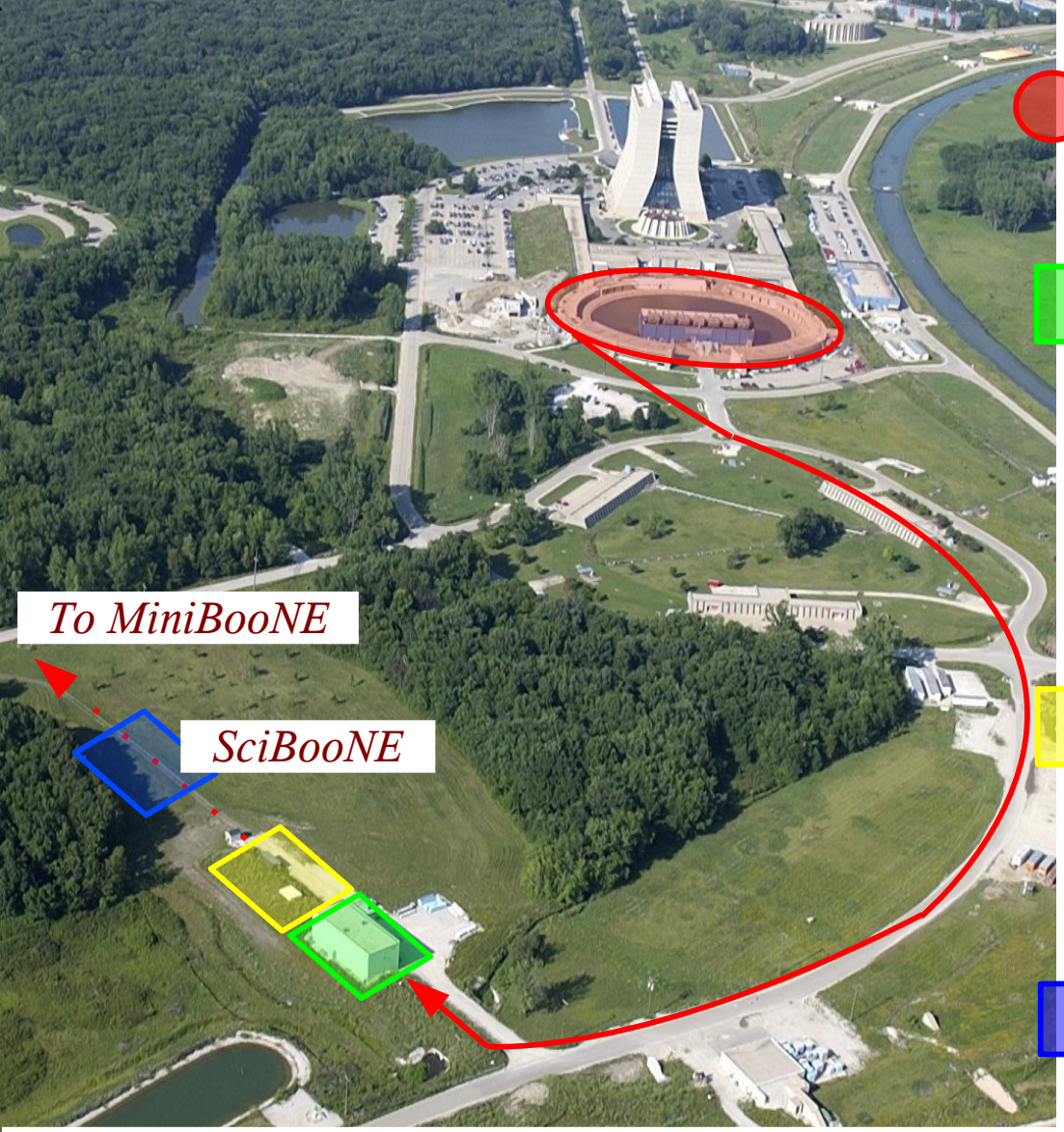


SciBooNE Collaboration

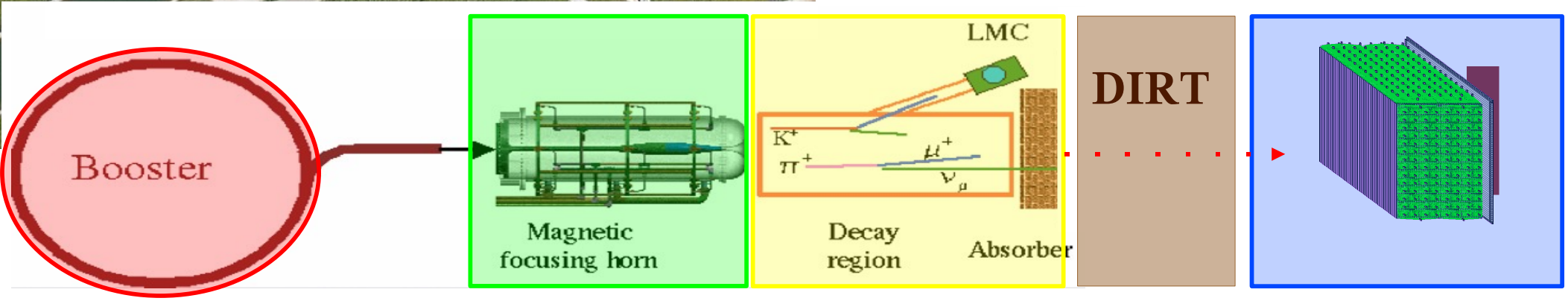
A selection of SciBooNE collaborators at the last collaboration meeting. March 2008

- 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

~70 physicists from 5 countries



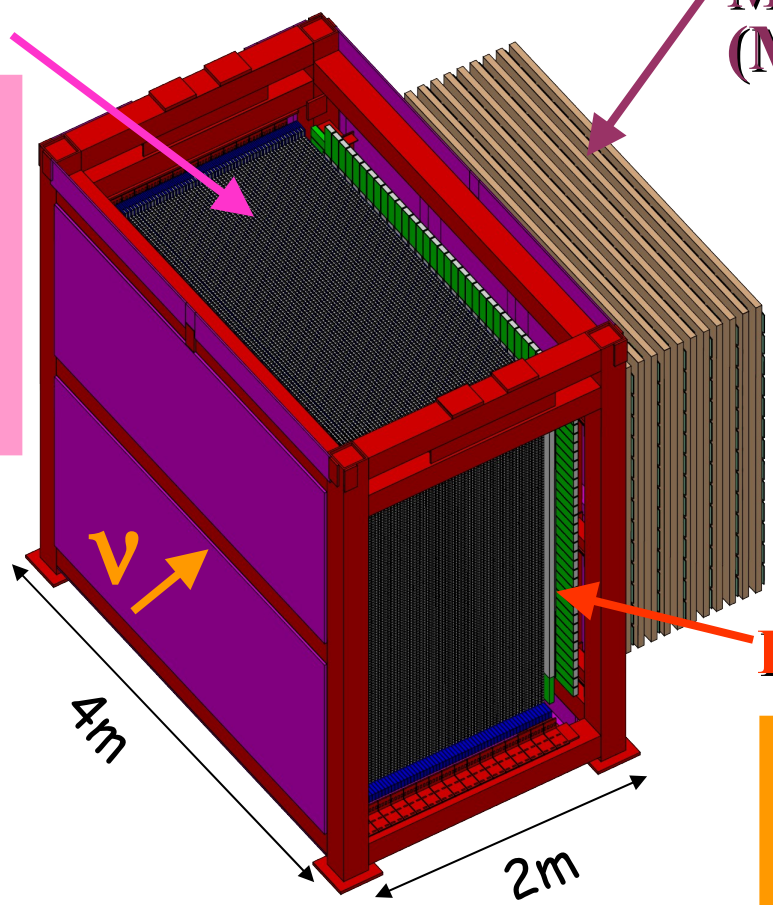
- Booster Proton accelerator
  - 8 GeV protons sent to target
- Target Hall
  - Beryllium target: 71cm long 1cm diameter
  - Resultant mesons focused with magnetic horn
  - Reversible horn polarity
- 50m decay volume
  - Mesons decay to μ & ν_μ
  - Short decay pipe minimises $\mu \rightarrow \nu_e$ decay
- SciBooNE located 50m from Absorber



SciBooNE detector

SciBar

- 14,336 scintillator bars (15 tons)
- detect all charged particles
- p/πseparation using dE/dx



Muon Range Detector (MRD)

- 12 2”-thick steel + scintillator planes
- measure muon momentum with range up to 1.2 GeV/c

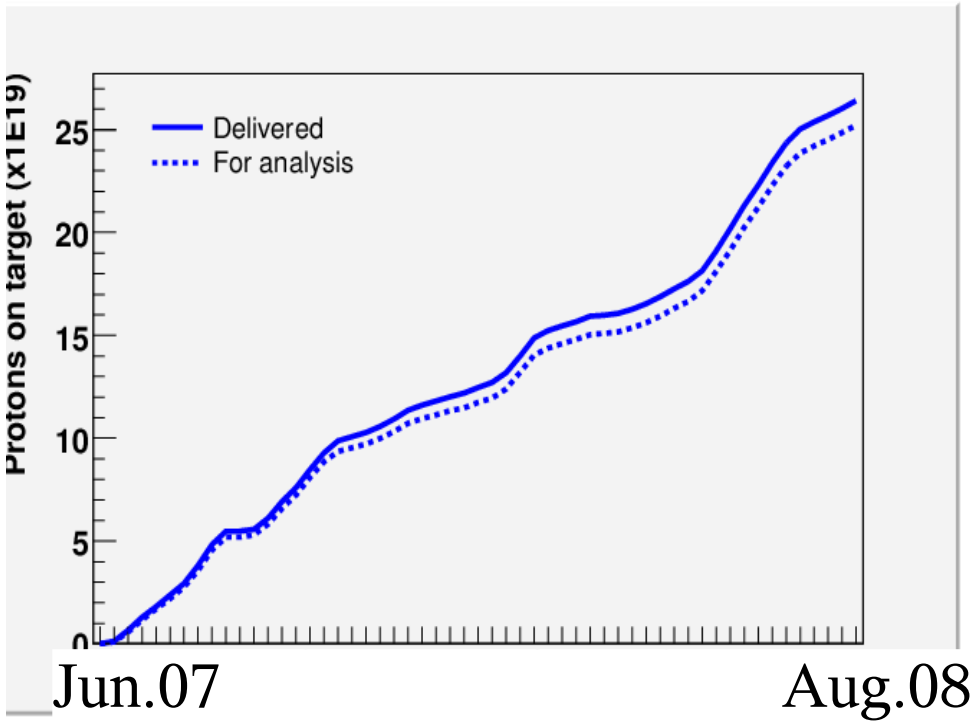
Electron Catcher (EC)

- spaghetti calorimeter
- 2 planes (11 X_0)
- identify π^0 and ν_e

Data taking

We completed data taking at Aug. 18th 2008 !!!!!!

Protons on target



- started in June 2007
- 95.5% data efficiency

- Neutrino data : 0.99 x10^{20} POT completed!

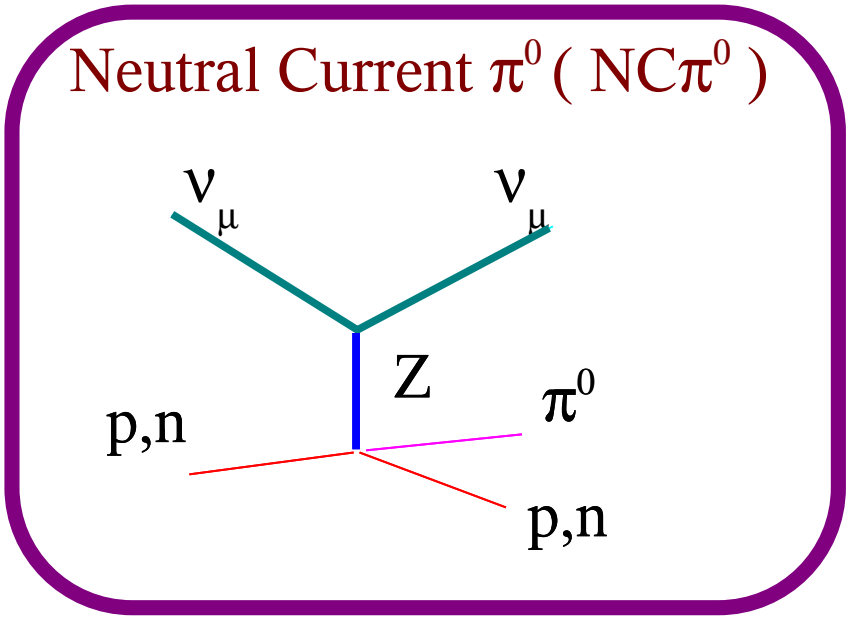
- Antineutrino data: 1.53 x10^{20} POT completed!

Total : 2.52x10^{20}

Proposal : 2.00x10^{20}

Preliminary result from full neutrino data set are presented

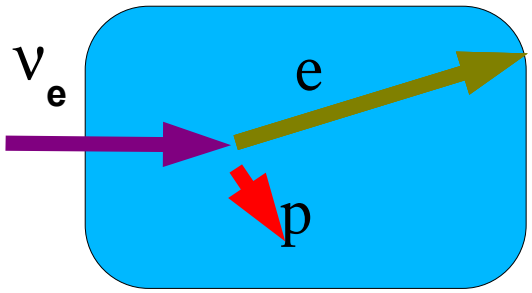
Neutral Current π^0 Production



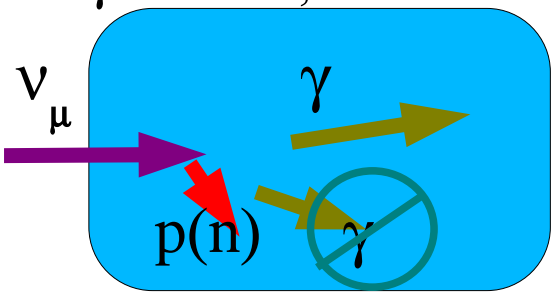
NCπ^0 is the main background of the search for ν_μ to ν_e oscillation

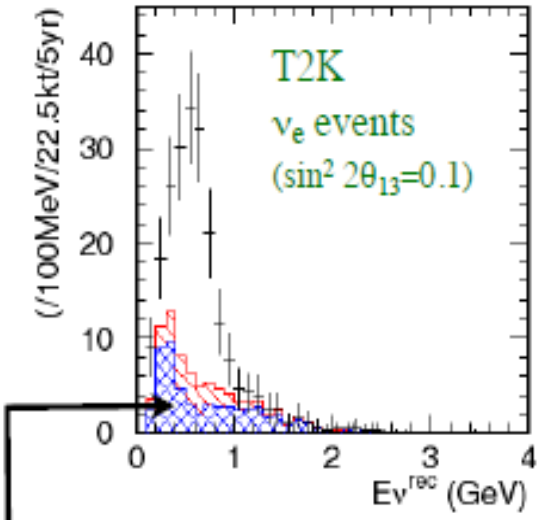
- gamma mimics electron from ν_e

The ν_e signal : electron



The background from NCπ^0 :
One γ from π^0 , miss another γ

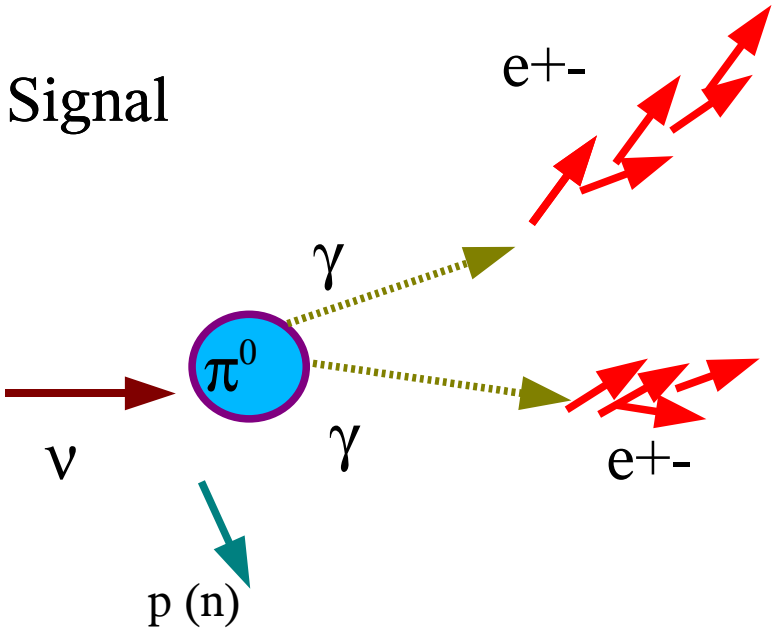




– Signal: CC-QE (ν+n→e+p)
– Background
- Beam ν_e
- NC-1π^0

NCπ^0 signal and background

Signal



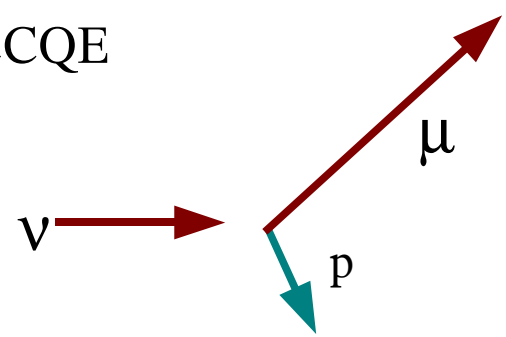
2γ from π^0

- 2 tracks in Fiducial Volume
- Disconnected
- Both tracks are not μ,p

Background μ, p common vertex or outside from detector(external)

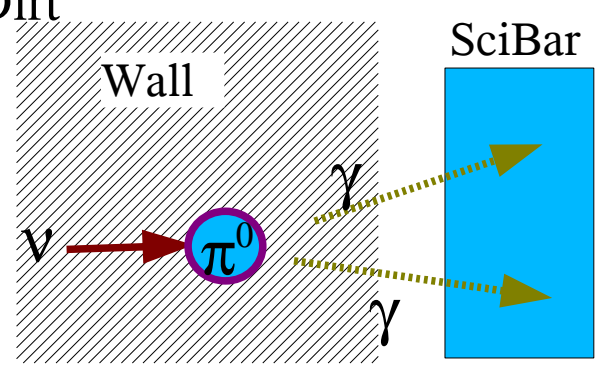
Internal B.G. : ν int. in SciBar

ex. : CCQE



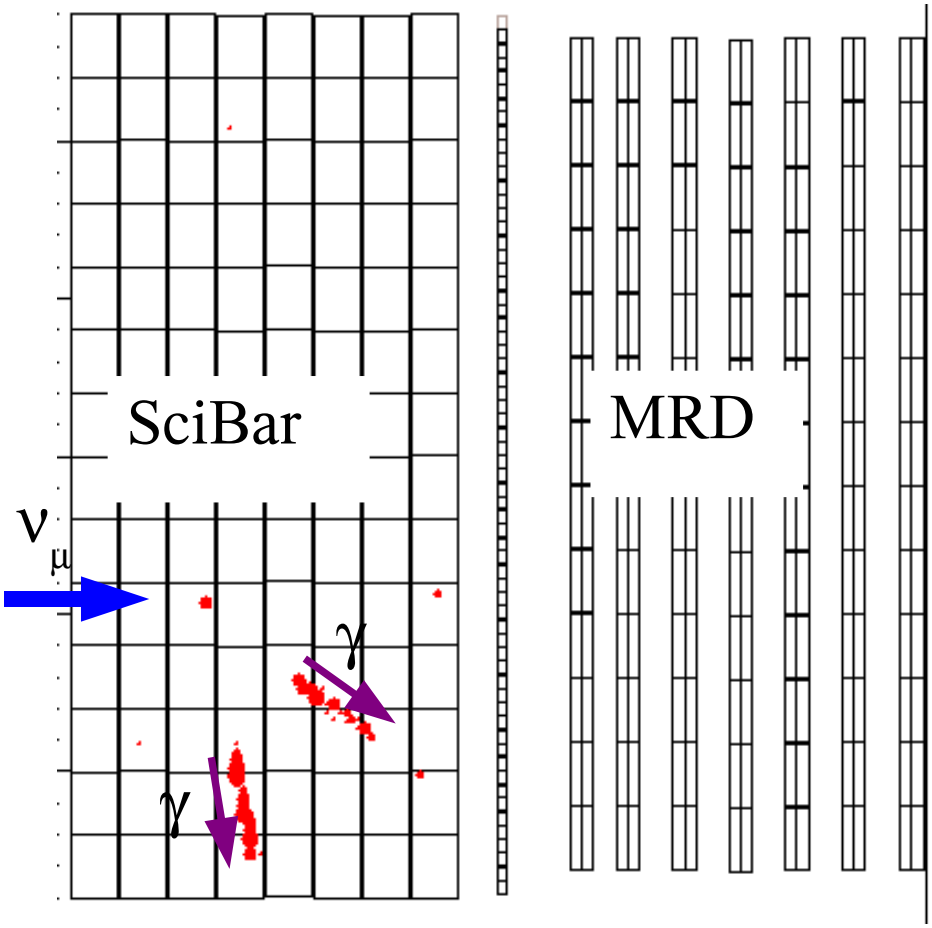
External B.G : from outside

ex : Dirt



Event Selection

NCπ^0 Candidate



Event Selection

0.Pre-Selection

- At least two tracks (2γ)
- without 1st layer hits (reject dirt)
- Tracks Stopped in SciBar (reject μ)

1. Using the track information

- Reject p using the dE/dX
- Reject μ using the decay e

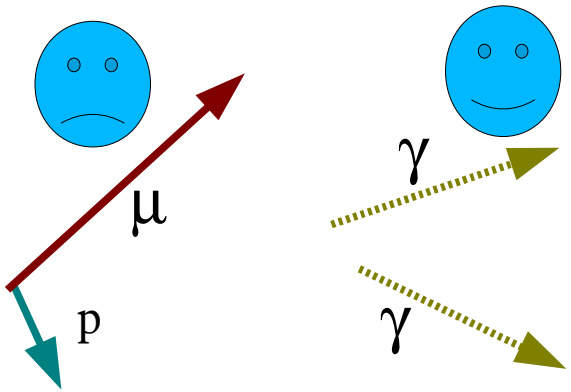
2. Using the event topology

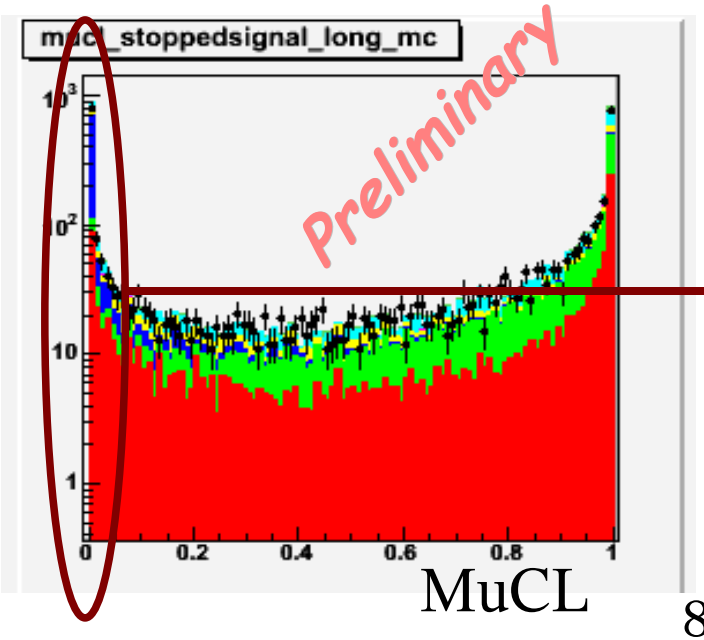
Disconnection between 2 tracks

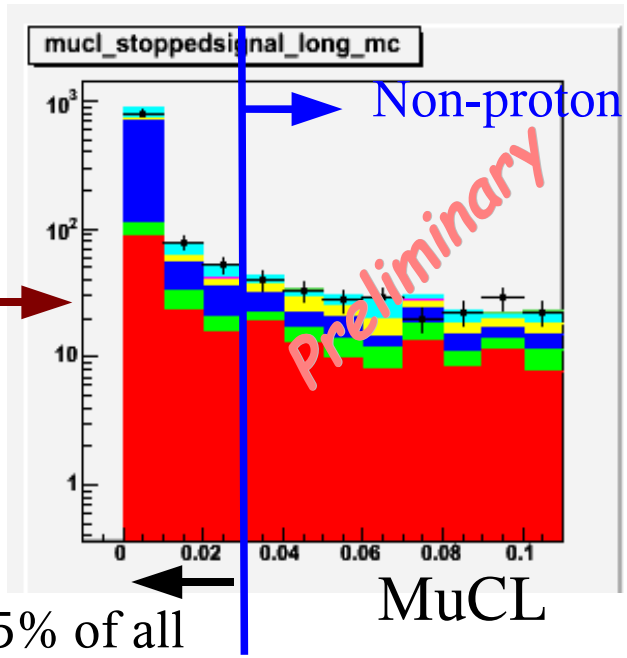
Proton rejection using dE/dx

Proton have larger energy deposit than any other particle

→ Construct "Muon Confidence Level" to separate proton from other particle







85% of all protons here

Dot : data

Cosmic
Dirt

Charge π
p
μ
EMShower

External
Internal

Non-proton-like : MuCL > 0.03

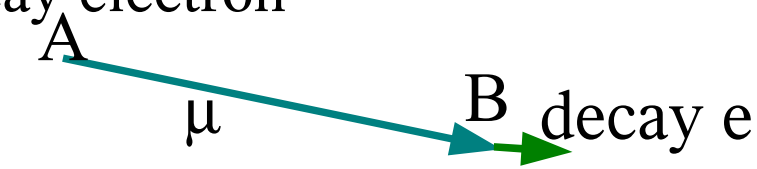
Events are required to have at least 2 non-proton-like tracks

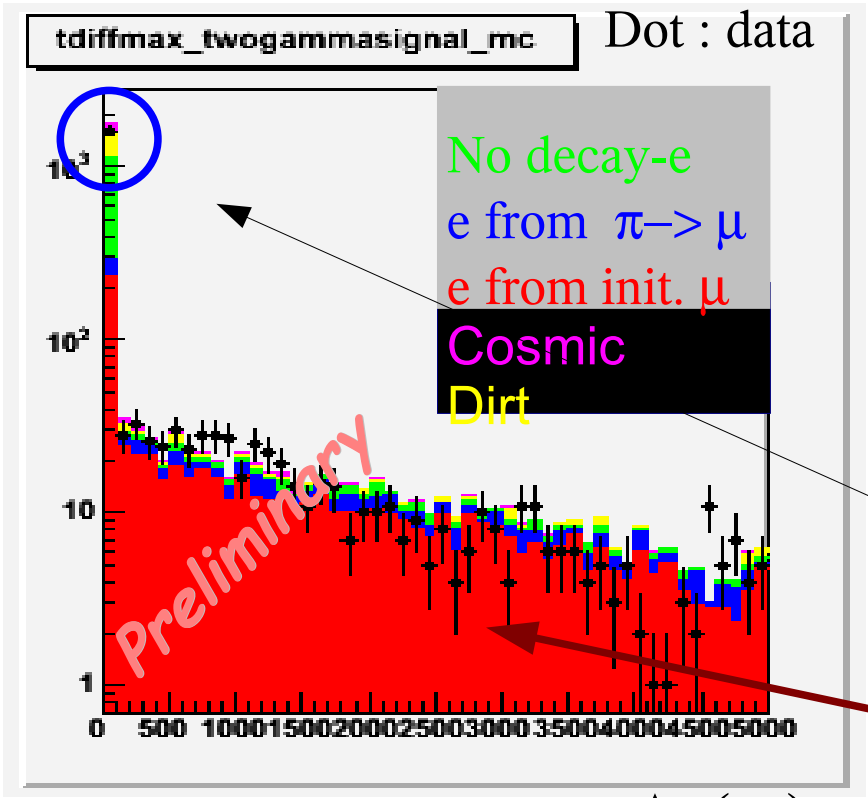
Muon rejection with the decay election

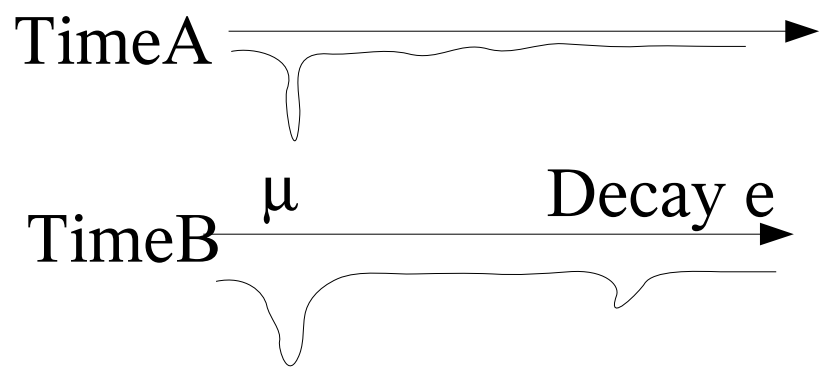
There are muons stopping in SciBar

These muons can be removed using the decay electron

Time difference btw track edges







Δt = (The latest) TimeB - TimeA

Most "no decay" events is in the region < 100 ns (first bin)

→ Reject " > 100 ns "

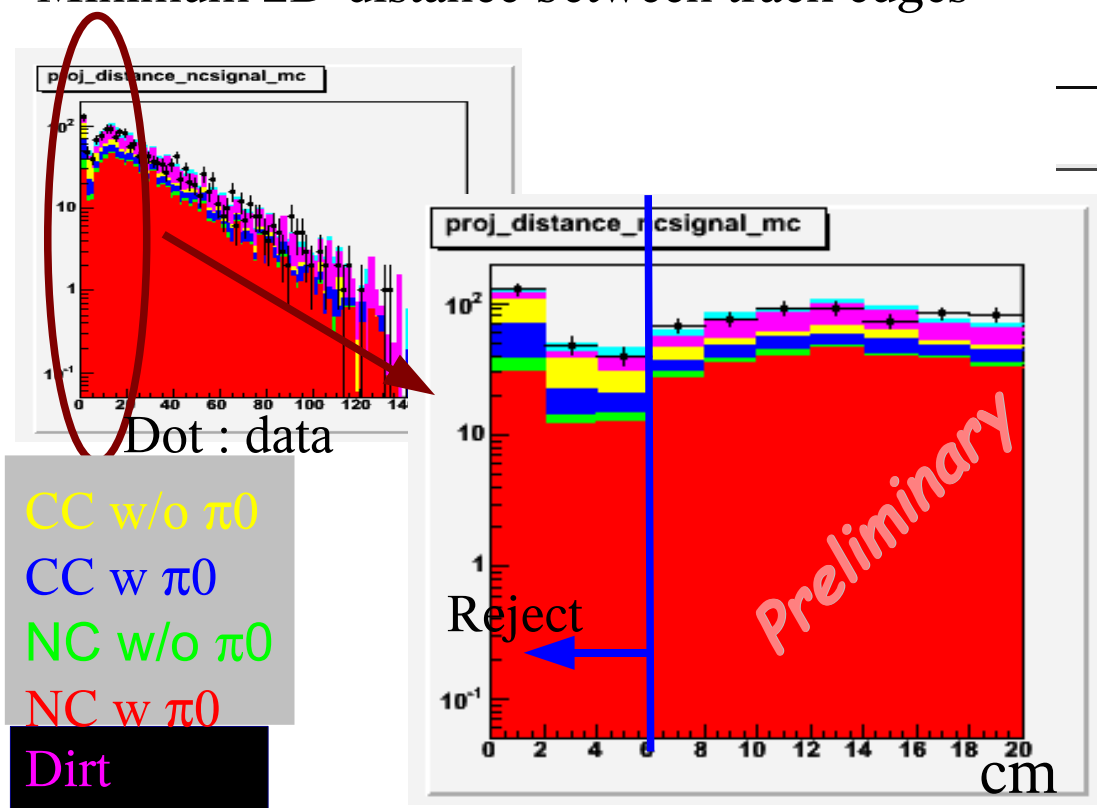
Reject 66 % of decay-e events

Keep 95 % of no decay-e events

The disconnection between tracks

The distance between tracks (after all events selection)

Minimum 2D-distance between track edges

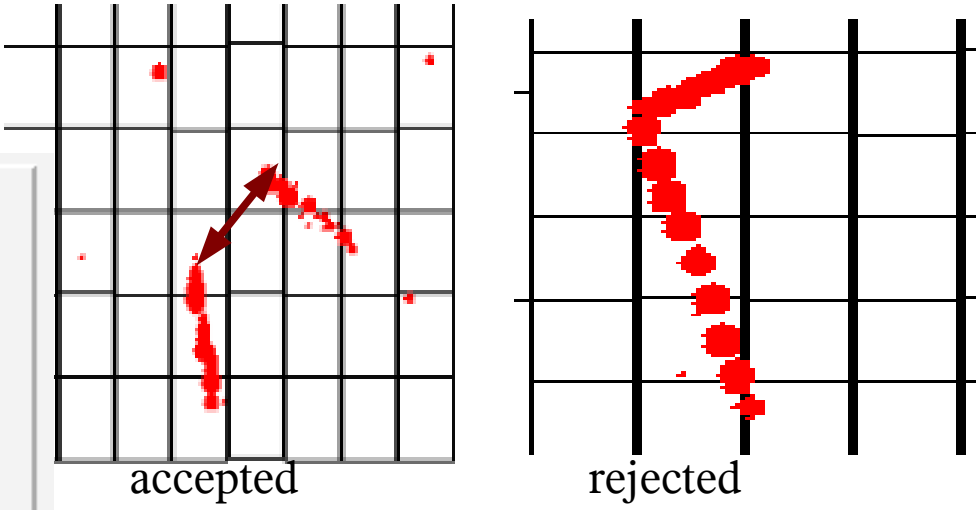


CC w/o π0
CC w π0
NC w/o π0
NC w π0
Dirt
Cosmic

Internal
External

To get 2γ from π^0 and remove CC events

Threshold = 6cm



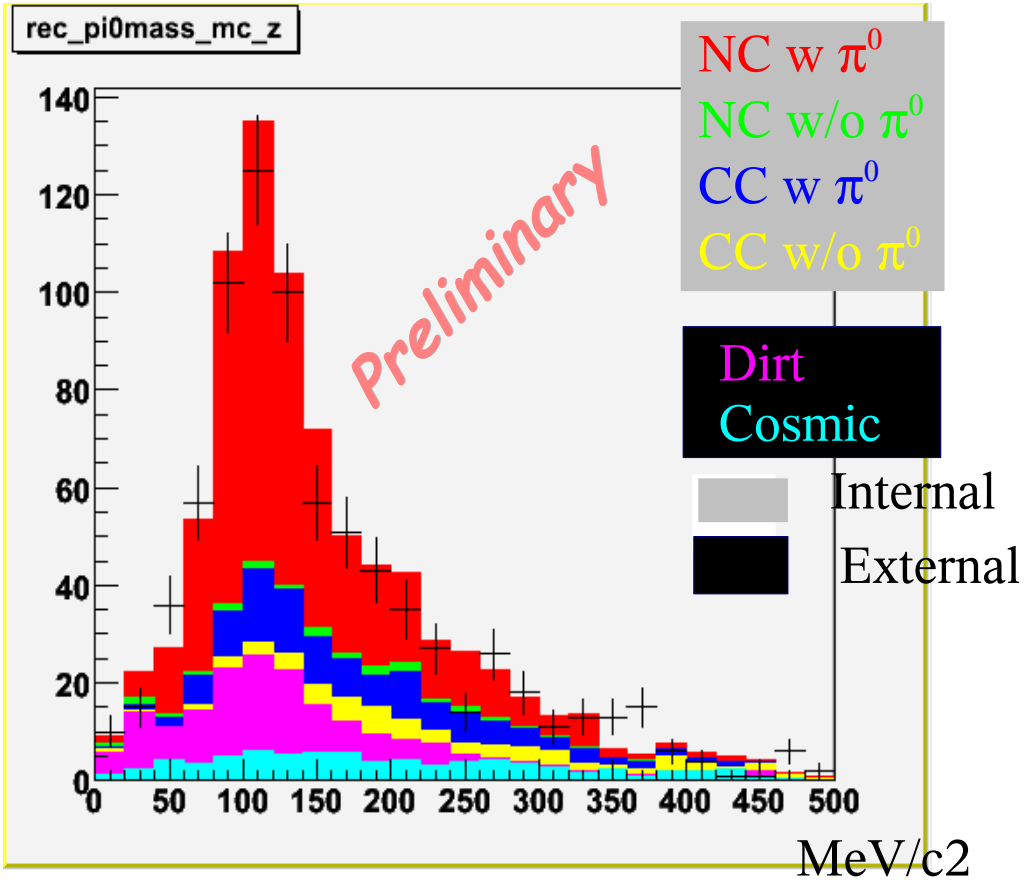
Reject 31 % of CC events

Keep 92 % of π^0 events (NC)

π^0 reconstruction at final sample

Reconstructed Mass

Dot : data



- Reconstructing mass using 2 tracks in SciBar after all event selection

Clear π^0 mass peak !
~850 events selected
~460 π^0 events (NC)

SciBar can reconstruct π^0 !!!

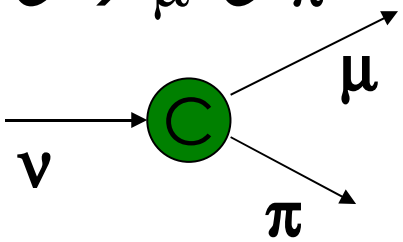
→ Cross section measurement

CC-coherent π^+ measurement

signal

CC-coherent π production

$\nu + C \rightarrow \mu + C + \pi^+$

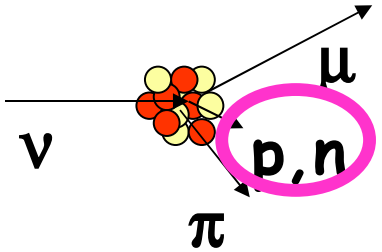


- No proton
- Small Q^2

background

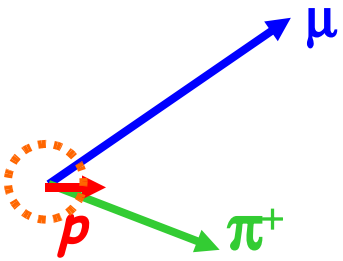
CC-resonant π production

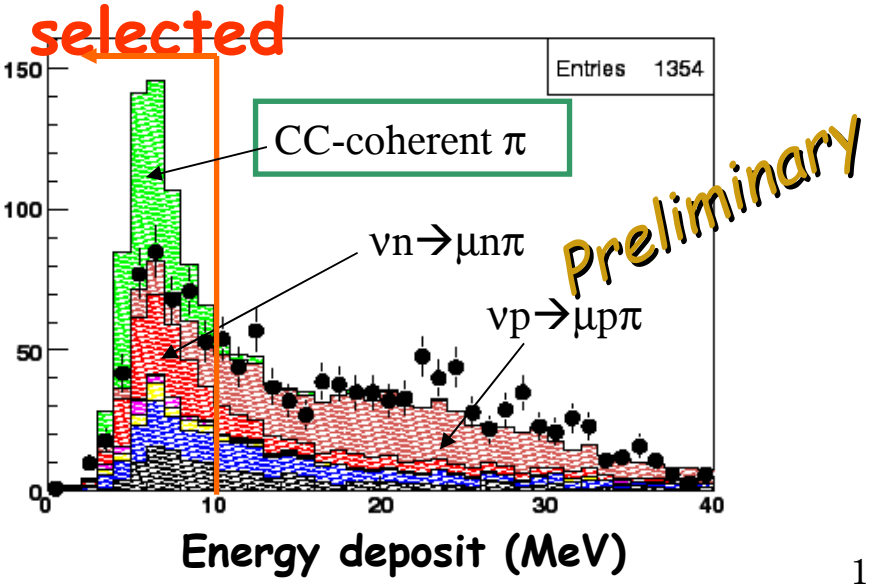
- $\nu + p \rightarrow \mu + p + \pi^+$
- $\nu + n \rightarrow \mu + n + \pi^+$



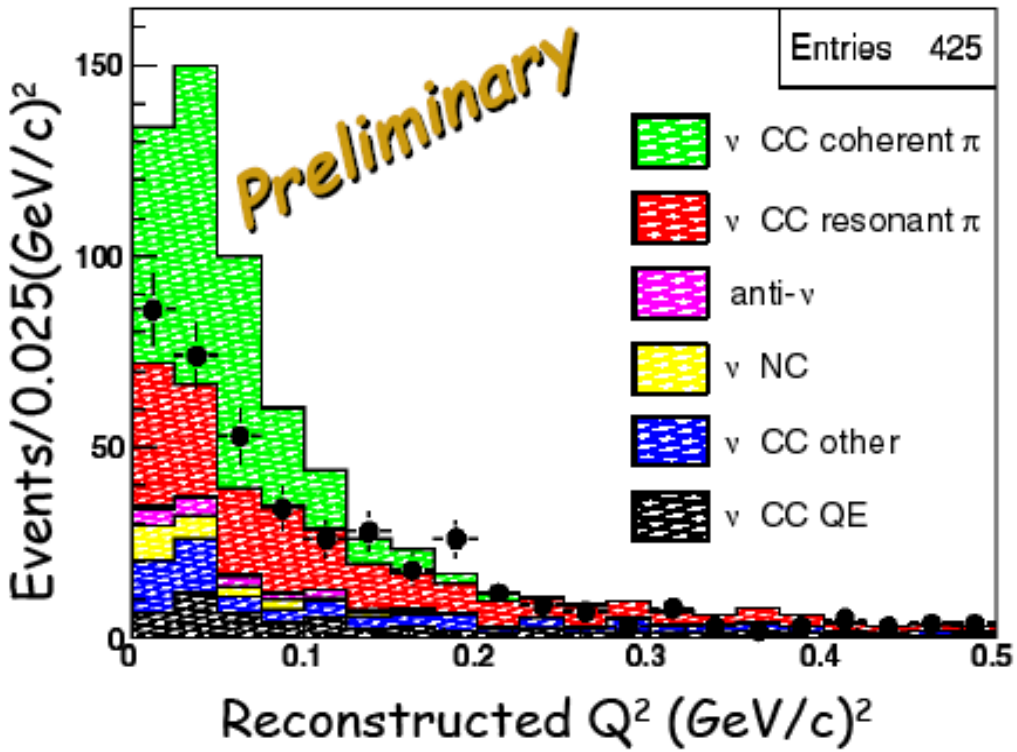
Vertex activity

Low energy proton is identified as a large energy deposit around the vertex





Final CC-coherent π sample



CC-coherent π

Efficiency 13%

Purity 40%

* Systematic error on background estimation is not included yet

Observed CC-coherent π sample in SciBooNE contains fewer events than our MC simulation, which is based on the Rein&Sehgal model

see K.Hiraide's ICHEP08 talk

http://www-sciboone.fnal.gov/documents/talks/talks.html

Summary

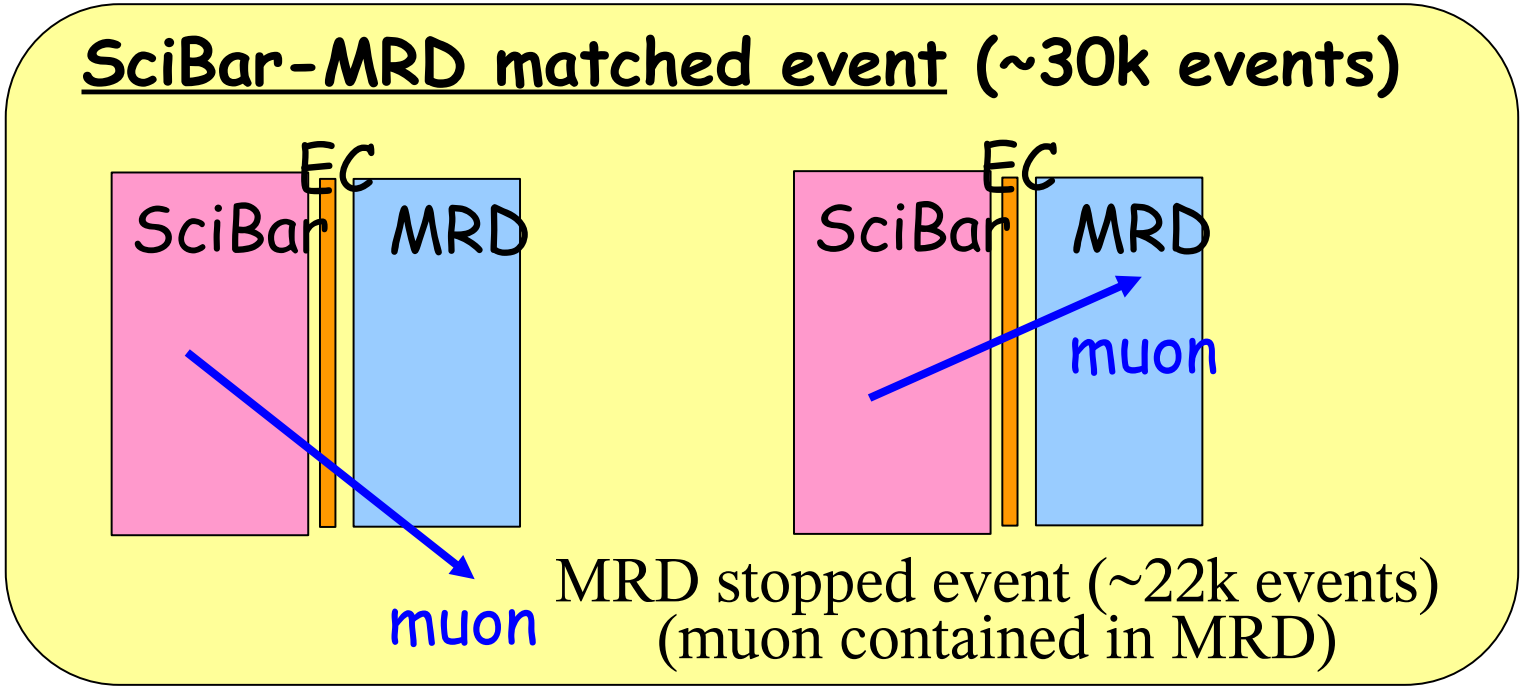
- SciBooNE measures neutrino and antineutrino cross sections near 1 GeV
- Data taking already was completed
- NC π^0 measurement
  - SciBar can reconstruct π^0
  - Next : cross section measurement
- Results will come soon
  - Many other analyses (CC1π, CCqE CCπ^0,NCelastic, ν_μ disappearance, ν_e rate) are on-going
  - Antineutrino measurements

Thank you !

Beer fight @ the day when we finished the operation !!!!

Neutrino Spectrum Measurement

Using Charged Current Events



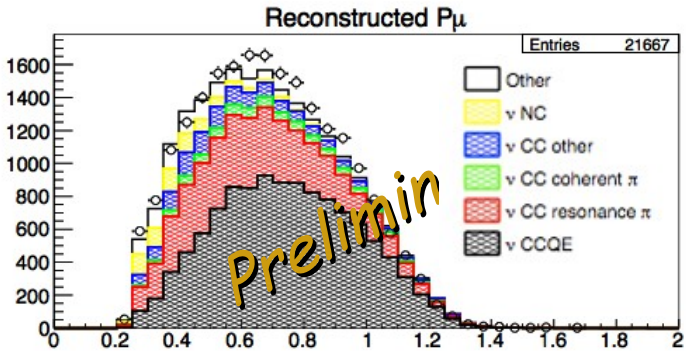
96 % pure Charged Current inclusive sample

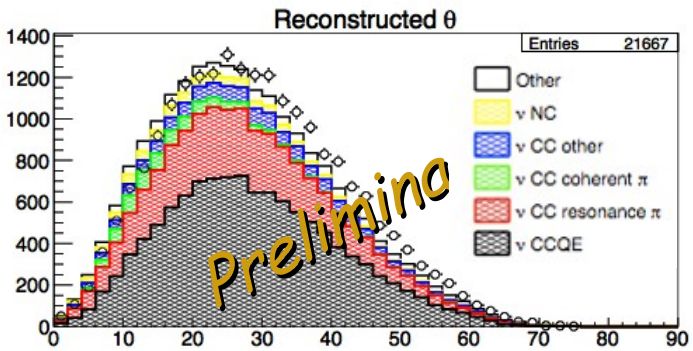
The number of SciBar-MRD matched event is used for normalizing MC

Neutrino Spectrum Measurement

Muon Kinematics of the MRD stopped sample

Y.Nakajima





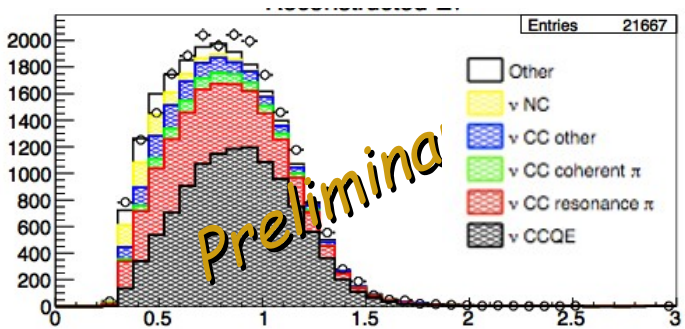
$\sigma(P\mu)$~50MeV/c

$\sigma(\theta\mu)$~0.9degree

M_A=1.1 GeV/c^2

Pμ (GeV/c) θμ (degree)

Reconstructed neutrino energy assuming Charged Current Quasi Elastic scattering



$E\nu^{rec}$ (GeV)

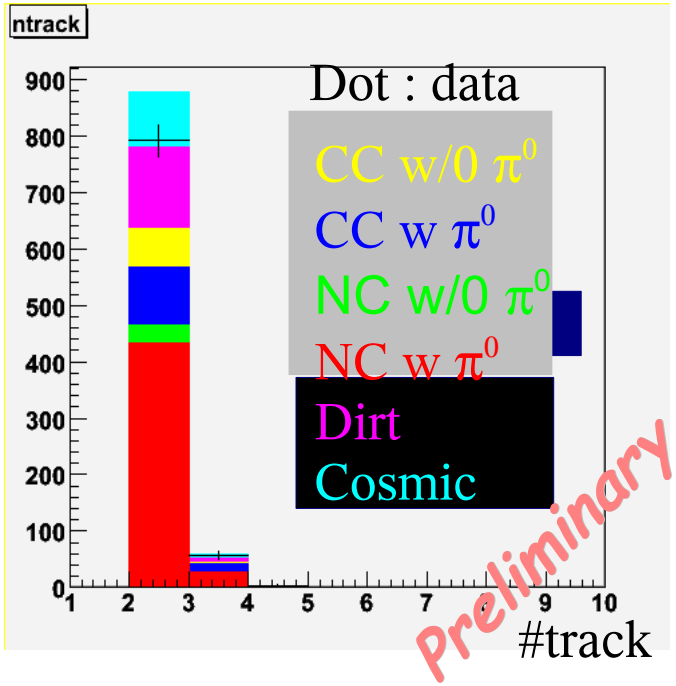
MC is normalized to SciBar-MRD matched sample

Fit Pμ, θμ distribution to get neutrino spectrum for ν_μ disappearance

Result will come soon

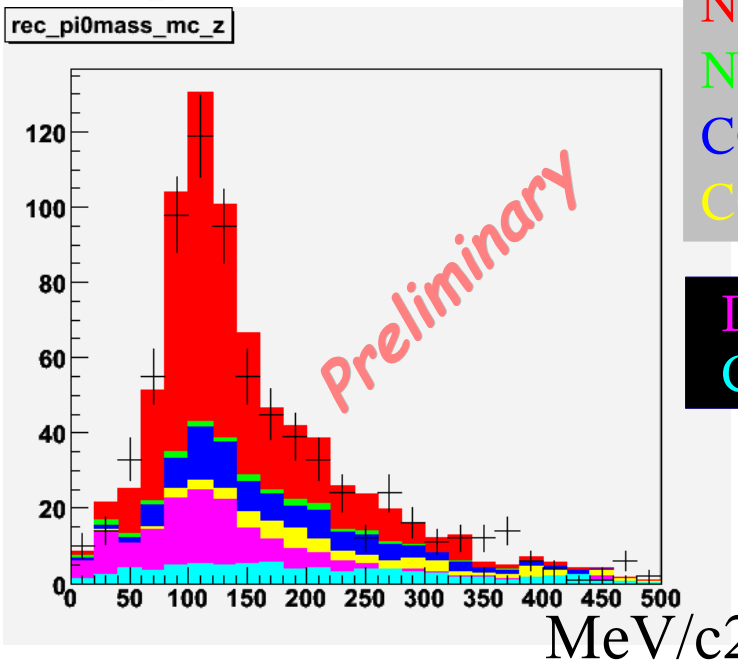
Track Multiplicity

Track Multiplicity after selection



Pi0 Mass (Detail)

Only one pair in a events



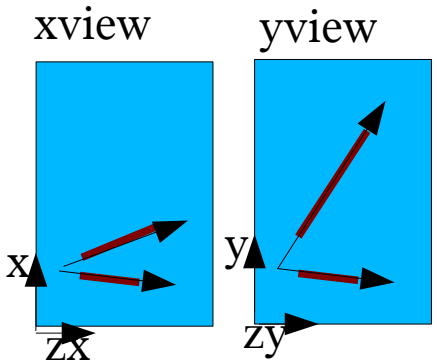
NC w π^0
NC w/o π^0
CC w π^0
CC w/o π^0

Dirt
Cosmic

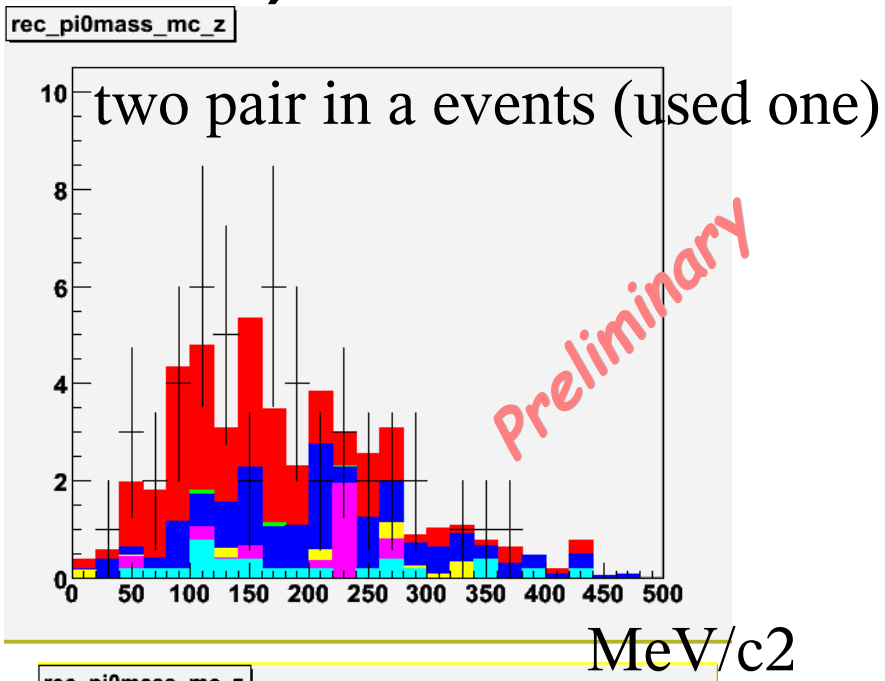
Dot : data

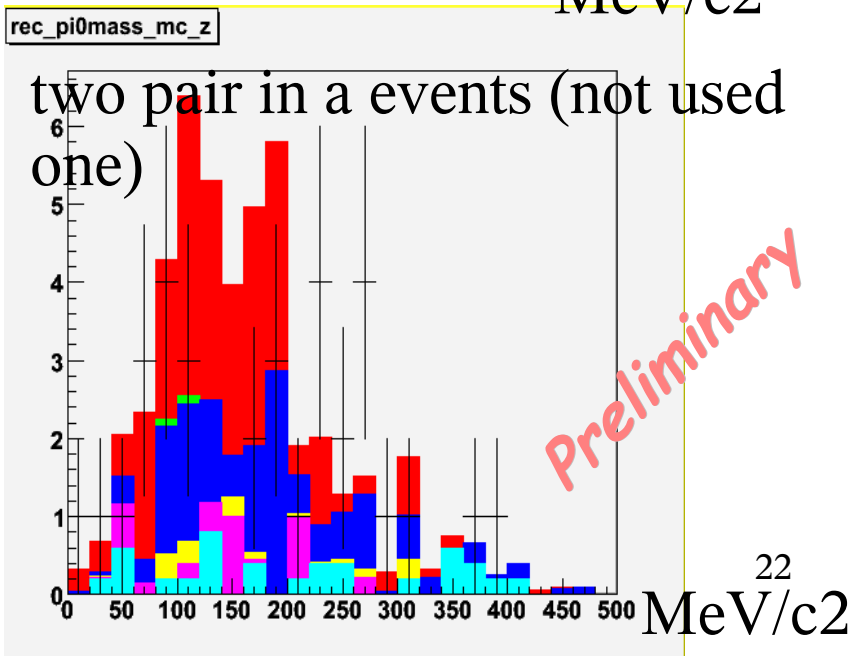
choose a pair with minimum |zx-zy|

zx,zy: the z position of the intersection of extrapolated tracks for each view

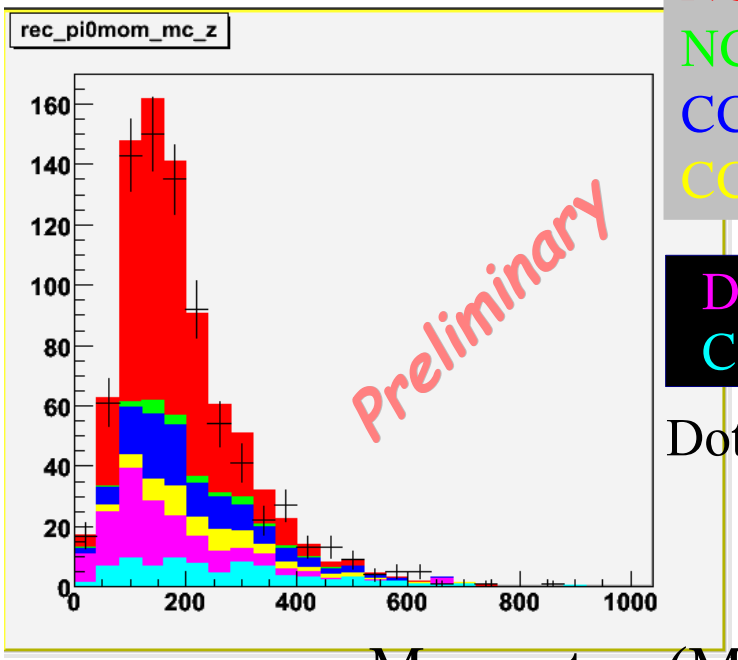


z: beam direction
y: vertical (to sky)
x: horizontal





π0 Kinematices

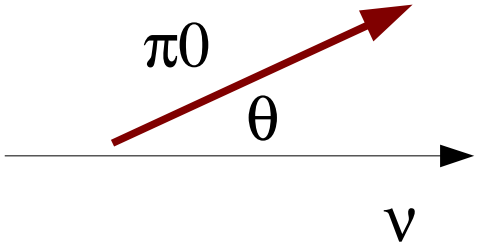


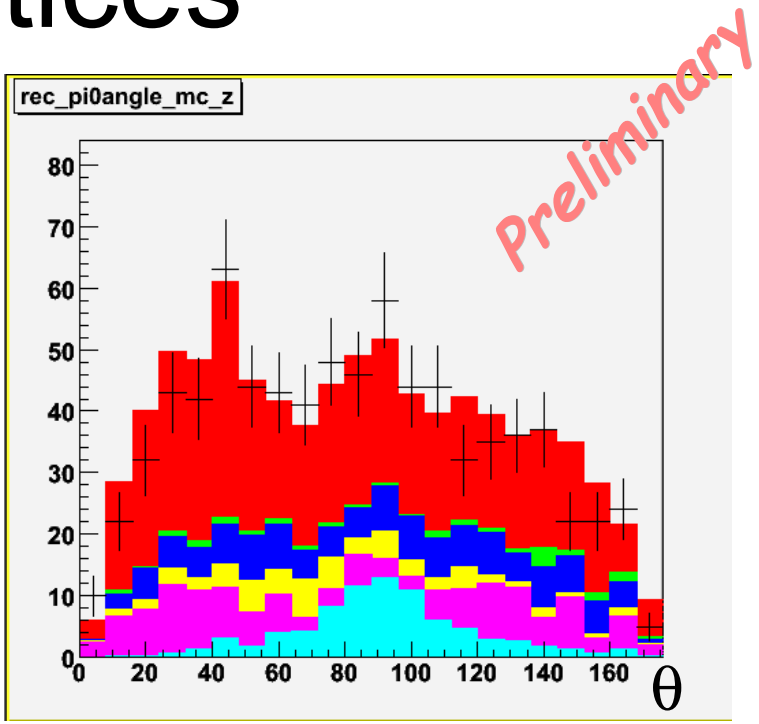
NC w π^0
NC w/o π^0
CC w π^0
CC w/o π^0

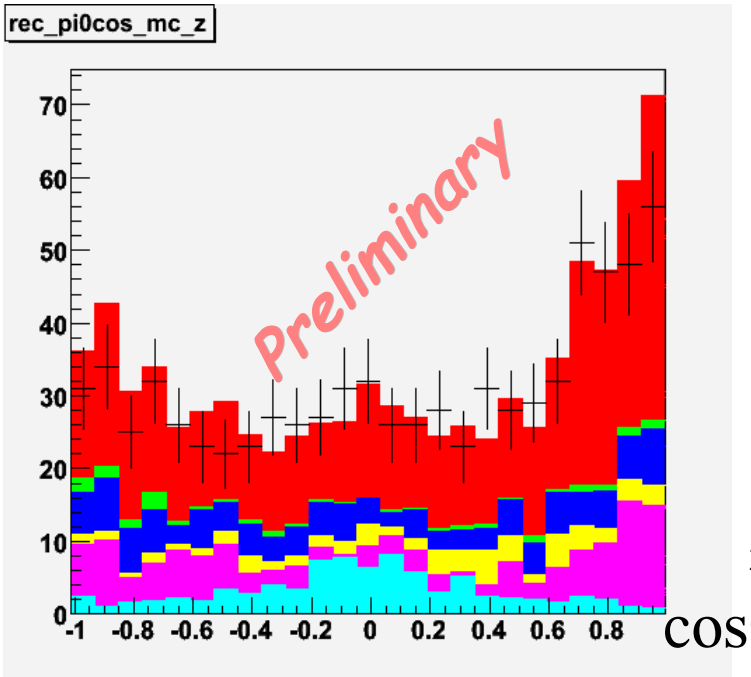
Dirt
Cosmic

Dot : data

Momentum(MeV/c)

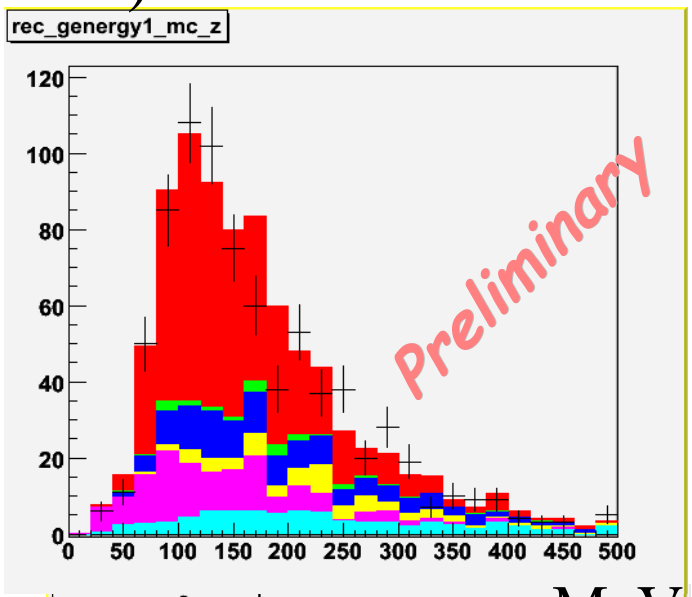


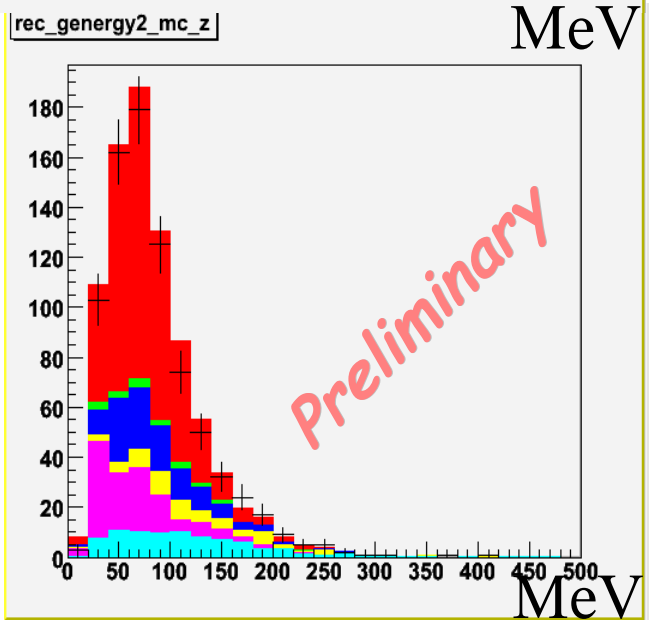




Gamma Kinematices

Energy
E1,E2 (E1>E2)

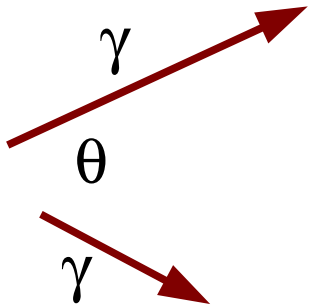


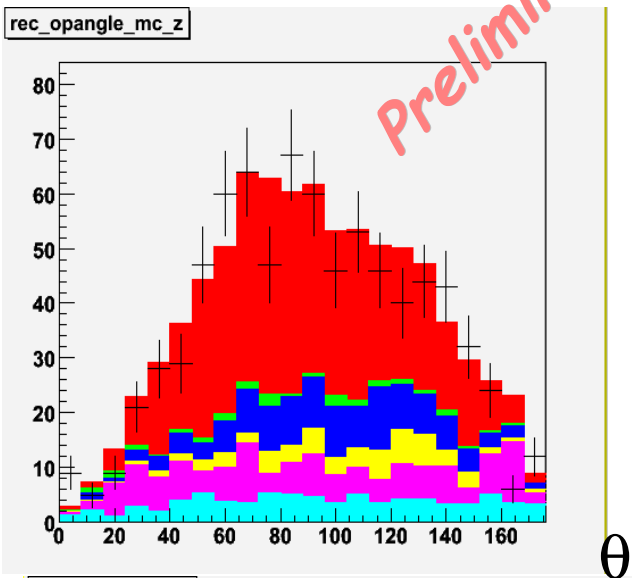


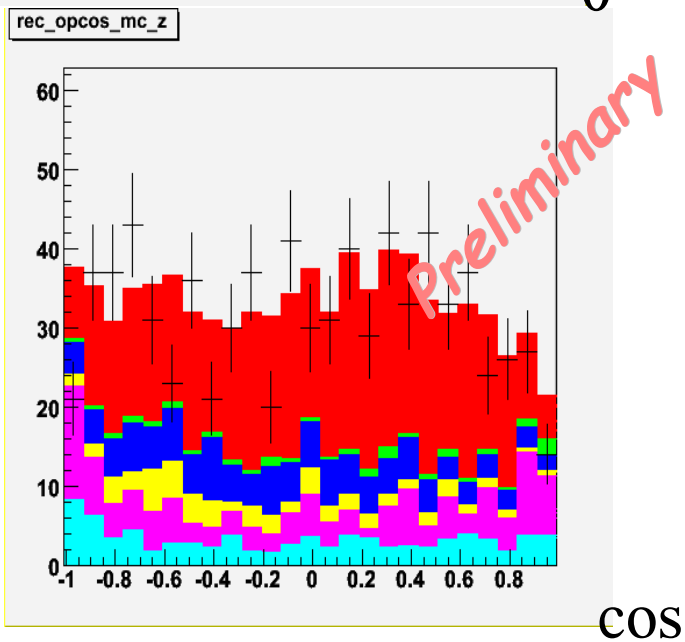
NC w π^0
NC w/o π^0
CC w π^0
CC w/o π^0

Dirt
Cosmic

Dot : data



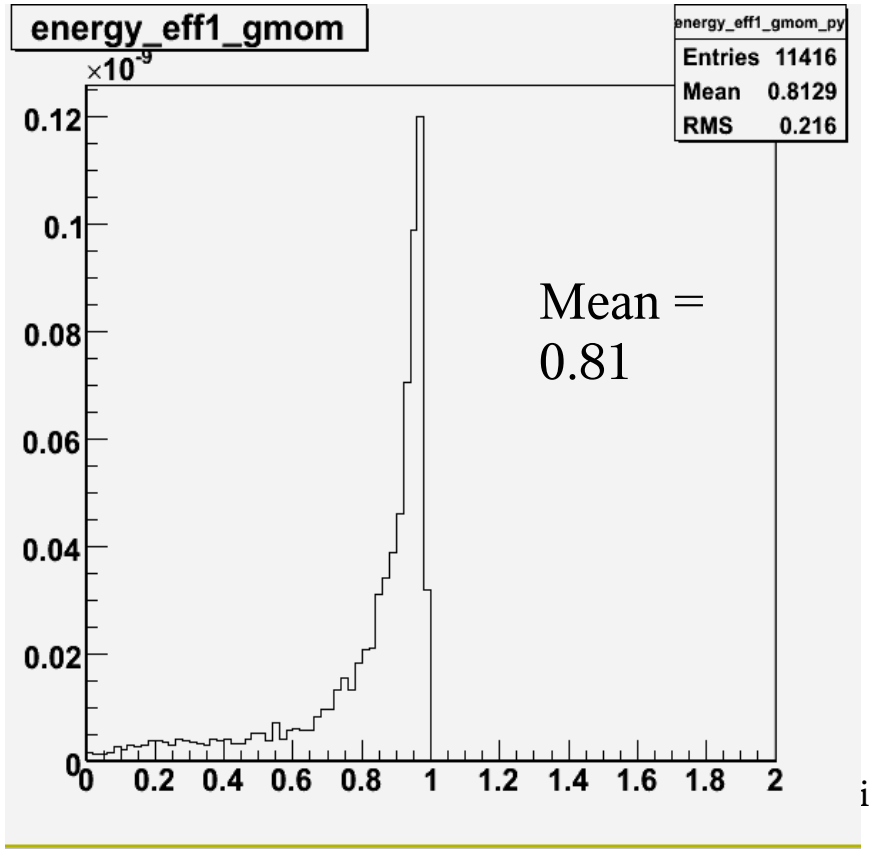




γ reconstruction performance using Extended Track (1)

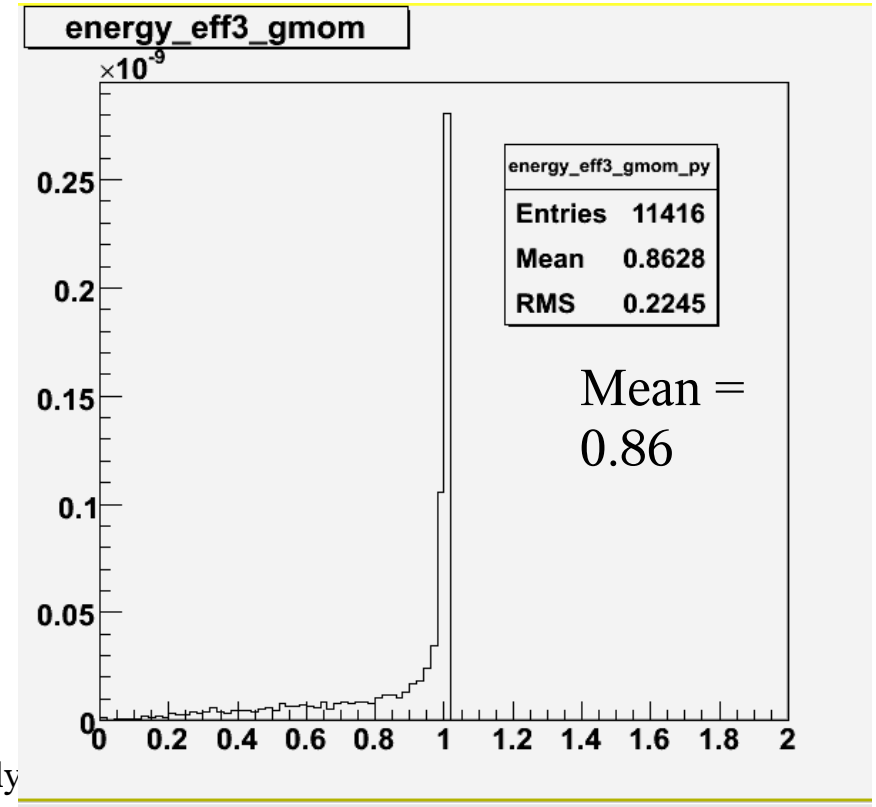
Energy Collection Efficiency

$$= \frac{\text{Energy due to } \gamma \text{ in ETrack}}{\gamma \text{ energy loss in SB}}$$



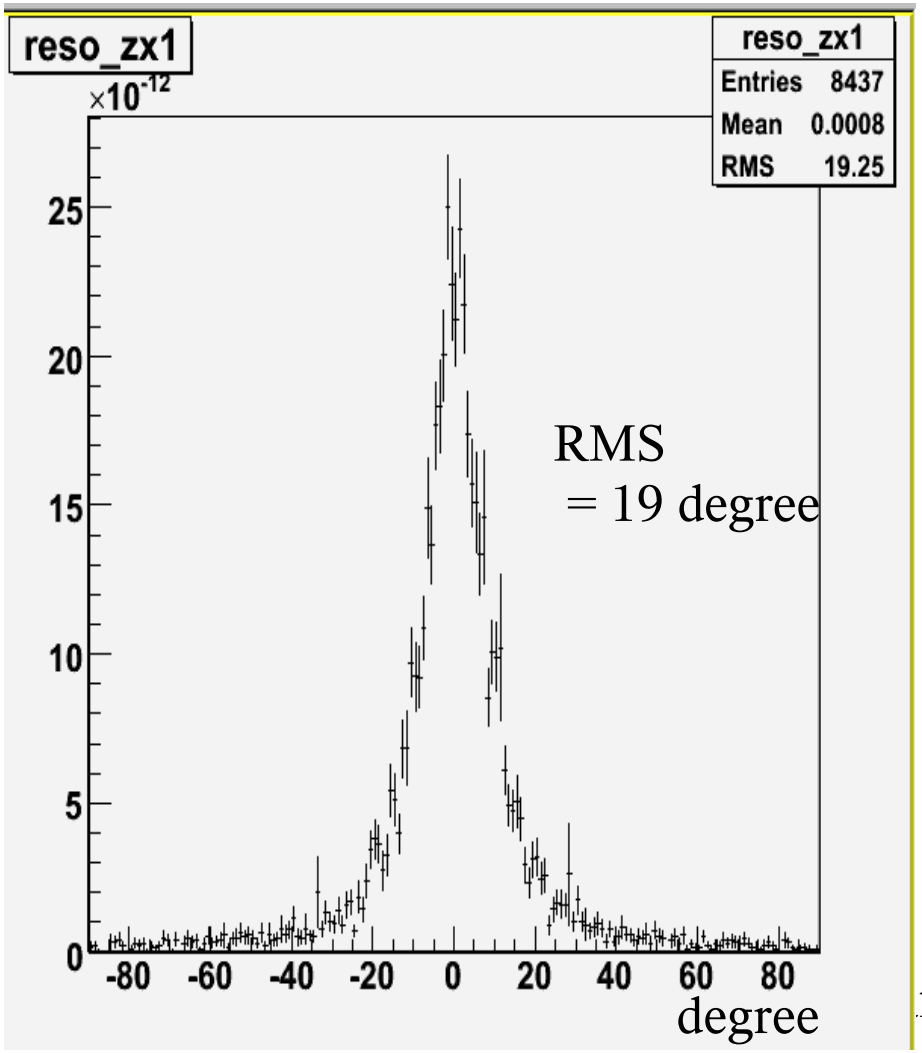
Purity of γ hits

$$= \frac{\text{Energy due to } \gamma \text{ in ETrack}}{\text{Energy in ETrack}}$$

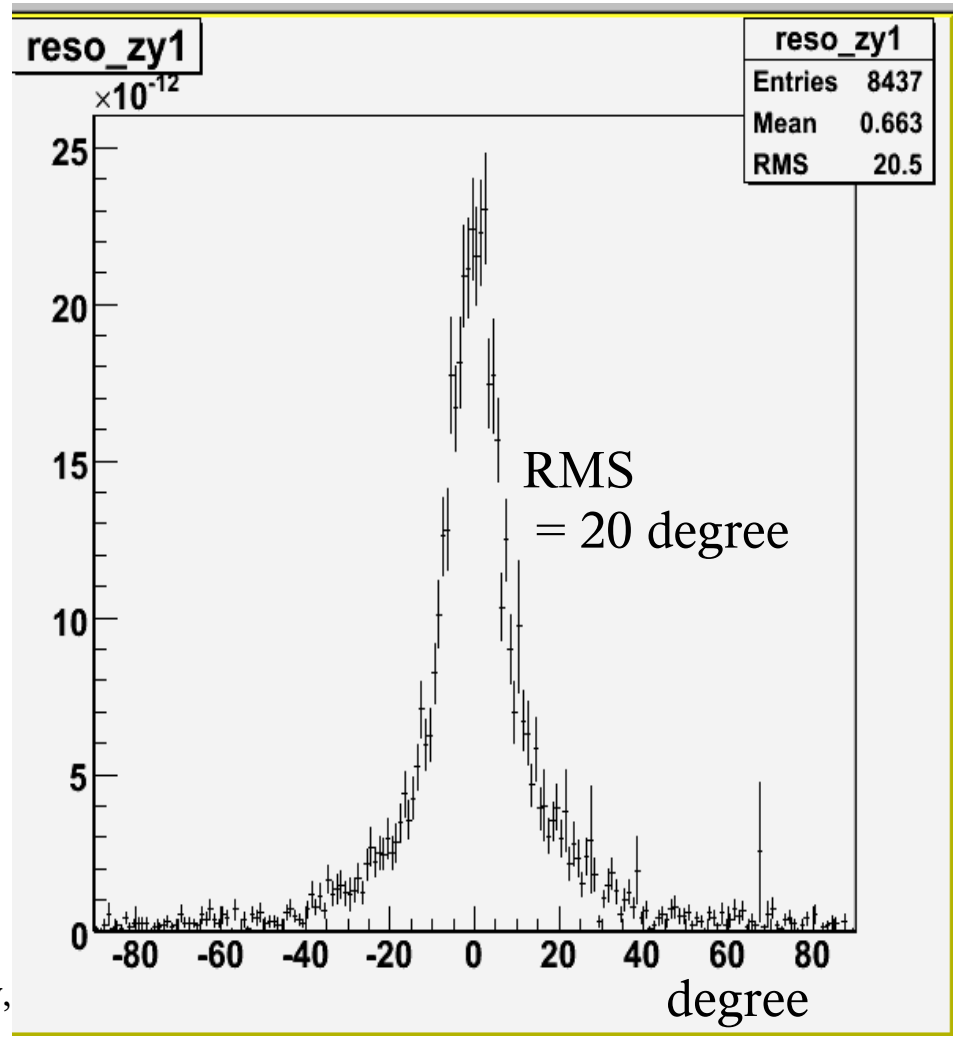


γ reconstruction performance using Extended Track (2)

γ angular resolution (x 2D) $\theta_{xz}^{rec}-\theta_{xz}^{true}$

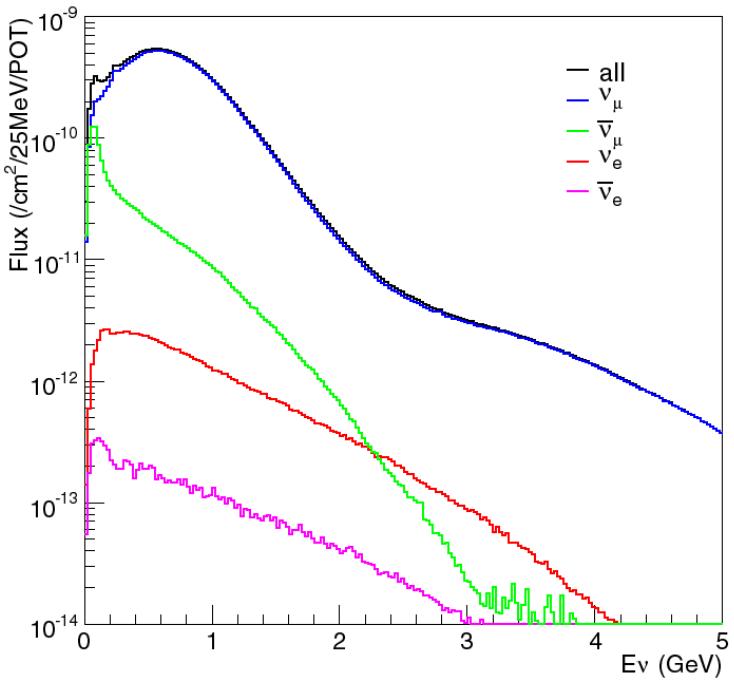


γ angular resolution (x 2D) $\theta_{yz}^{rec}-\theta_{yz}^{true}$

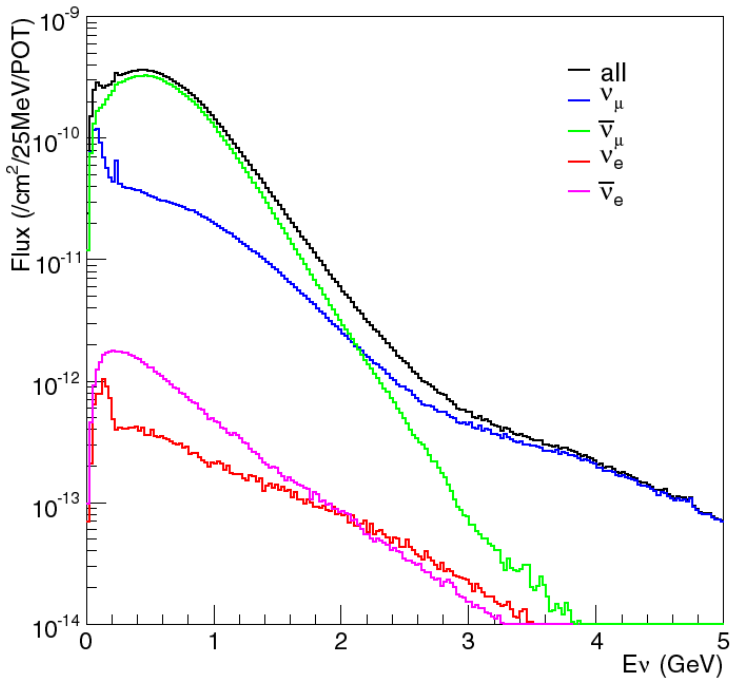


Neutrino Flux at SciBooNE

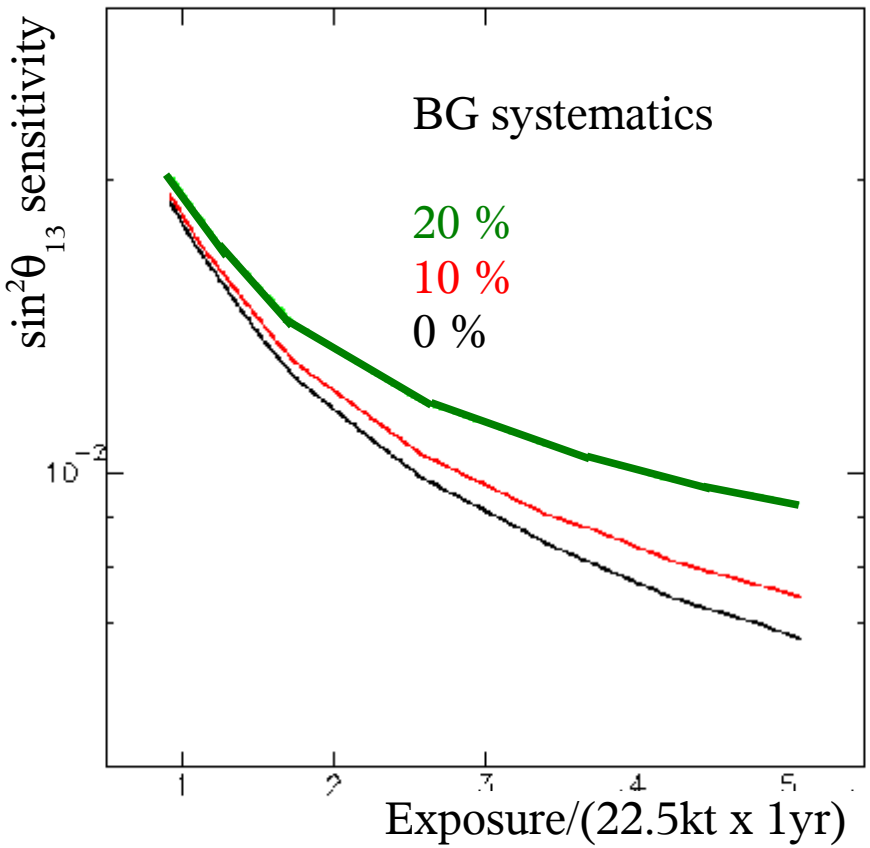
neutrino mode



antineutrino mode



For T2K experiment



Oscillation probability

$P(\nu_\mu \to \nu_e)$

$\sim \sin^2 2\theta_{13} \sin^2\theta_{23}$

$\times \sin^2(1.27\Delta m_{13}^2 L(km)/E(GeV))$

- Want to reduce uncertainty in $\sigma(NC\pi^0)$ from 20% to 10 %
- improvement of factor of 2 in ultimate T2K sensitivity to θ_{13}
- or 2.5 years vs. 4 years to 10^{-2}

Event Summary

	Data	NC w p۰	BG (internal)	Dirt	Cosmic	efficiency(%)
Generated		١٢٠٦٤				
Pre-Selection	٤٢٢٨	١٢٢١	٢٣٨٩	٧١٨	١٧٩	١٠.١
p rejection	٢١٥٢	٧٨١	٩٥٣	٥٠٧	١٥٤	٦.٥
μ rejection	١٥٧٢	٧١٩	٣٦١	٤٨٥	١٣٧	٦.٠
disconnection	١٣٥٧	٦٦٤	٢٥٢	٤٦٣	١١٦	٥.٥
Trk merge	٨٥٢	٤٦٢	٢٢٠	١٥١	١٠٦	٣.٨