Early Neutrino Data in the NOvA Near Detector

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Near Detector On the Surface (NDOS)

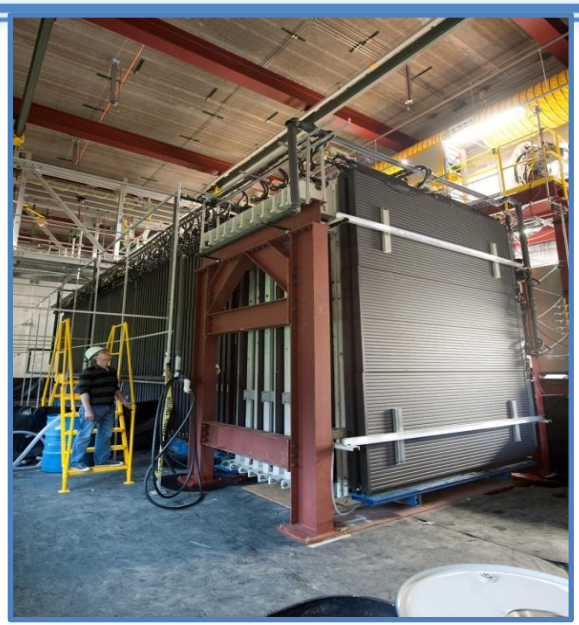
NOvA Near Detector prototype, commissioning ongoing

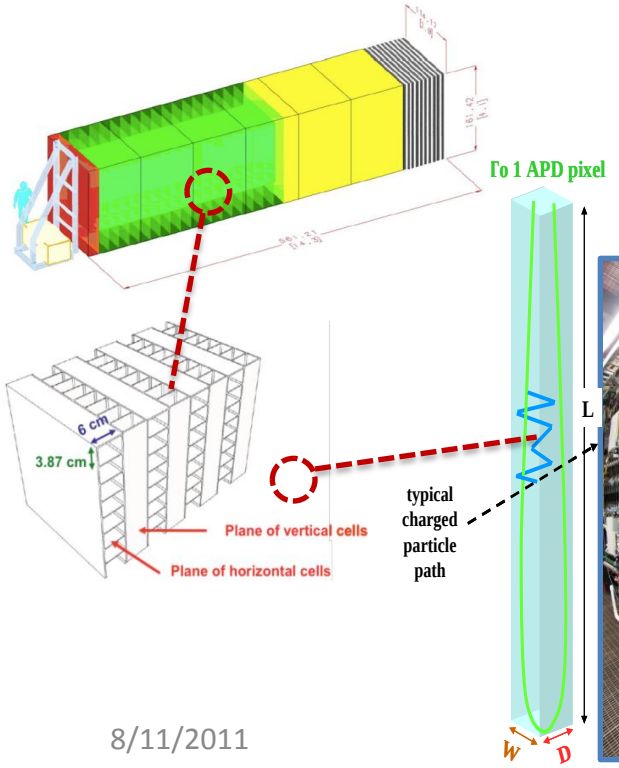
located on the surface at Fermilab

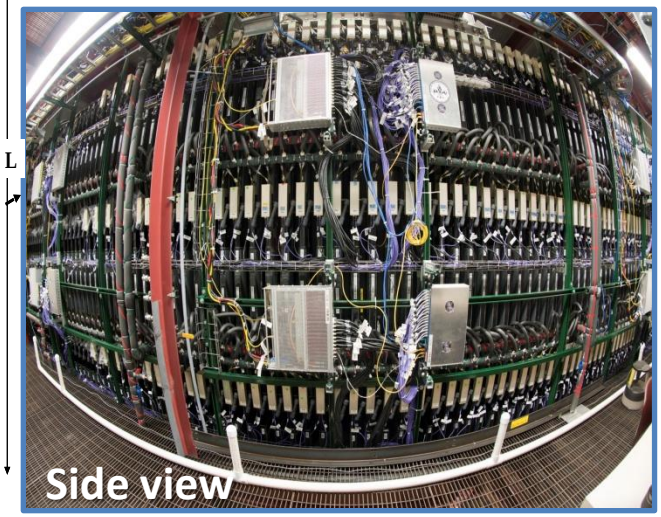
Detector made of rigid plastic(PVC)modules

Filled with liquid scintillator

Uses Avalanche photodiode (APD)







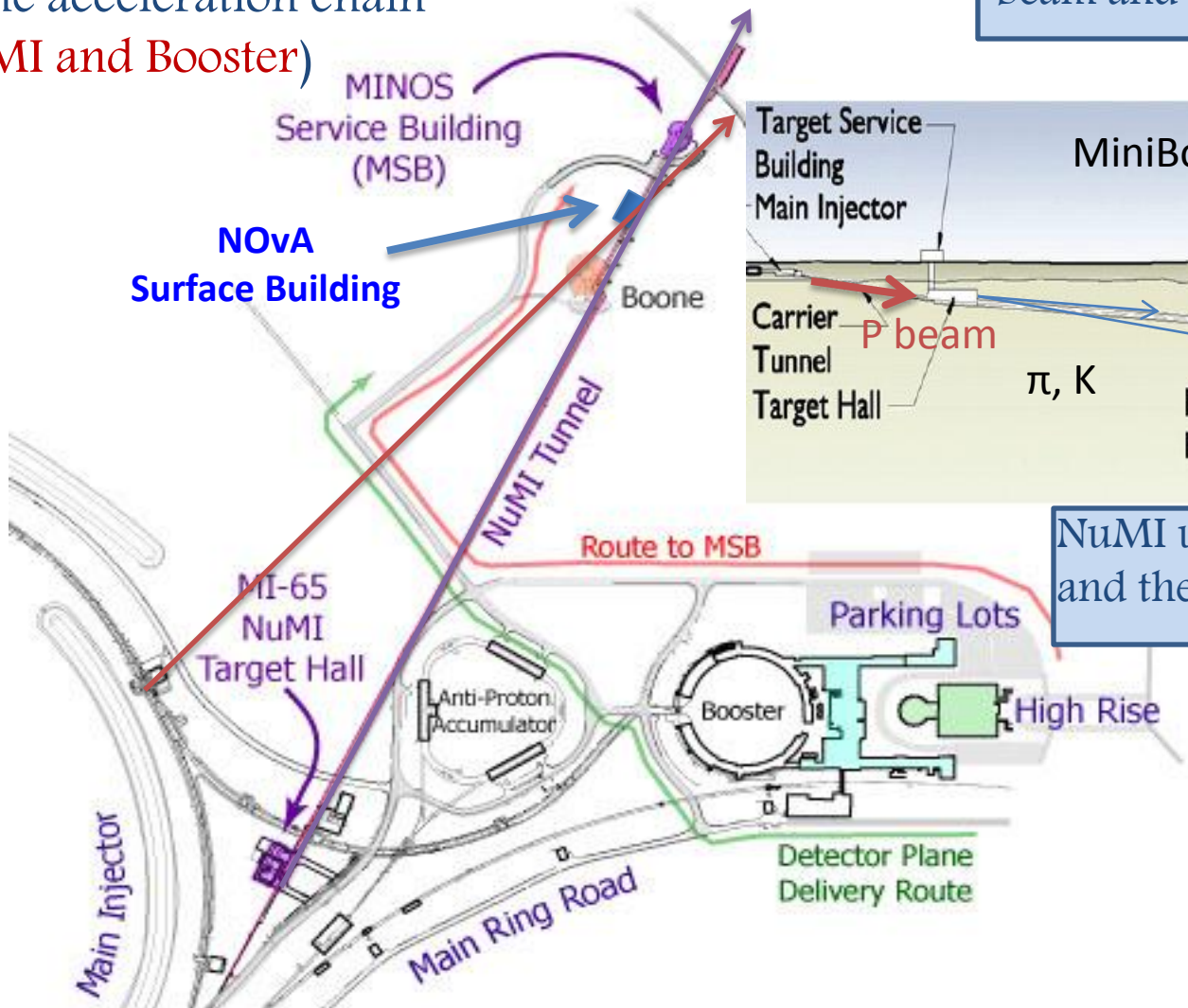
Prototype provides essential information on:

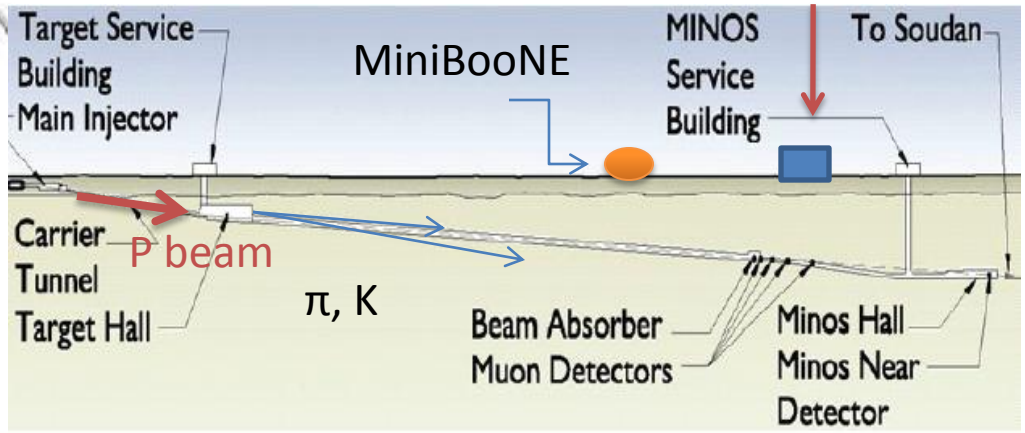
- Assembly technique
- Scintillator filling
- Light yield
- APD installation and functioning
- Electronics installation and functioning
- DAQ functioning

Taking data from two neutrino beams

Beams are produced at two different stages on the acceleration chain (NuMI and Booster)

NDOS is ~6.1° off axis of the NuMI beam and on axis of the Booster

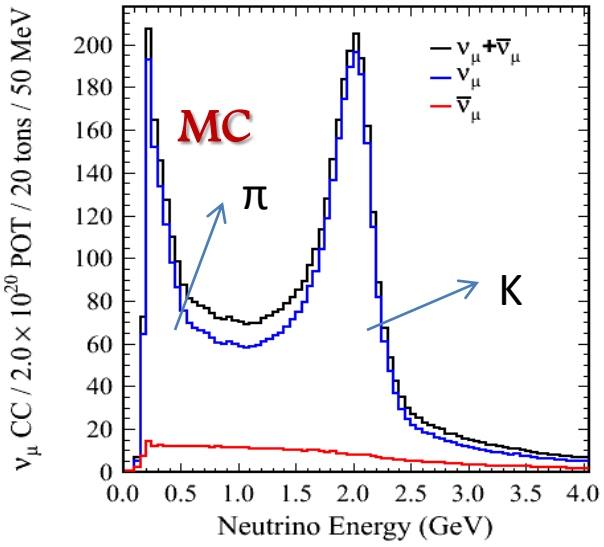




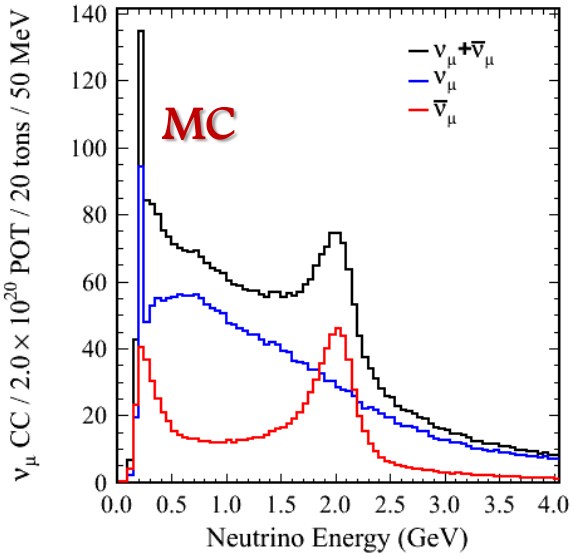
NuMI uses 120 GeV protons and the Booster uses 8GeV protons

Physics goals for NDOS

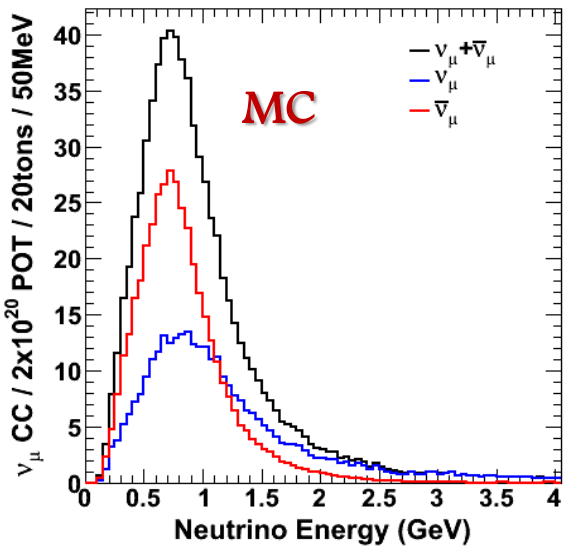
Neutrino run from NuMI



Antineutrino run from NuMI



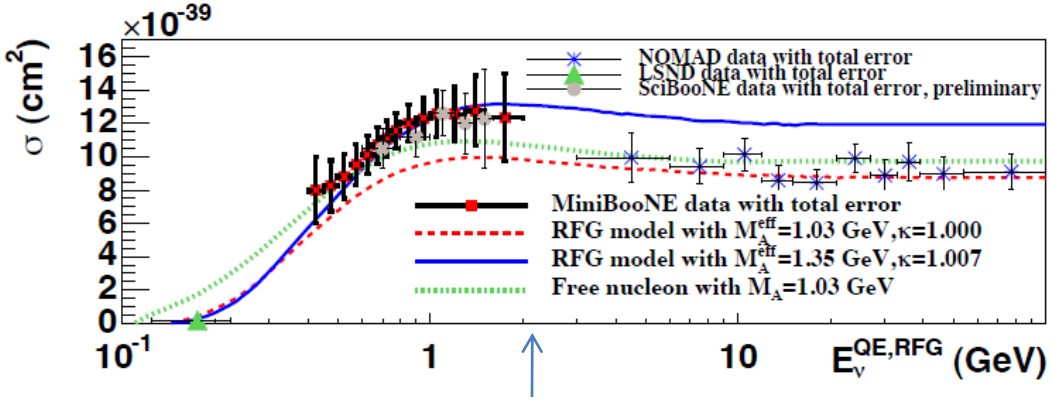
Antineutrino run from Booster



- Calibrate the detector and determine composition of the beam
- Investigate the detector sensitivity to cosmic ray background
- Study response of the detector to electron neutrinos
- Measure the rate of neutrino interactions for the quasi-elastic (QE) interactions

QE Studies in NDOS

- NDOS energy spectrum has a peak around 2GeV, an ideal energy to disentangle current cross section measurements



Energy peak for NDOS

- Proton tracks are visible, and vertex activity if tracks are not detected
- Measure ν_μ QE cross section at 2GeV
- QE studies in NDOS will help to develop the analysis for the θ_{23} and Δm^2_{32} NOvA measurements

More details see Gavin's talk and Nick's talk

Event Rates in NDOS

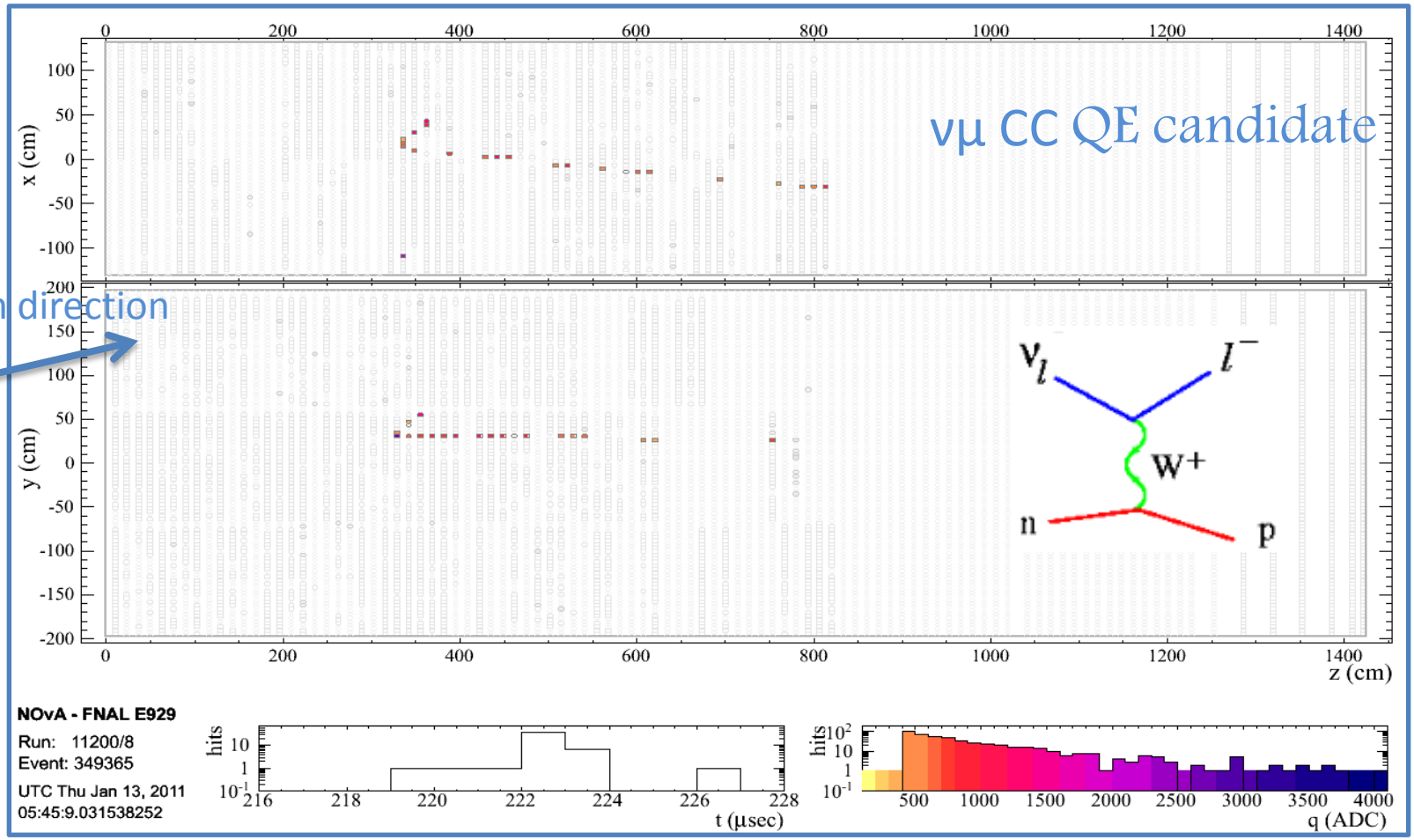
- NDOS will collect data for a year

$2x10^{20}$POT 20 tons	NuMI Neutrino	NuMI Anti-Neutrino	Booster Anti-Neutrino
ν_μ+anti-ν_μ CC	4500	3300	735
In 2GeV peak	1500	800	
ν_e+anti-ν_e CC	200	160	10
NC	2000	1600	392

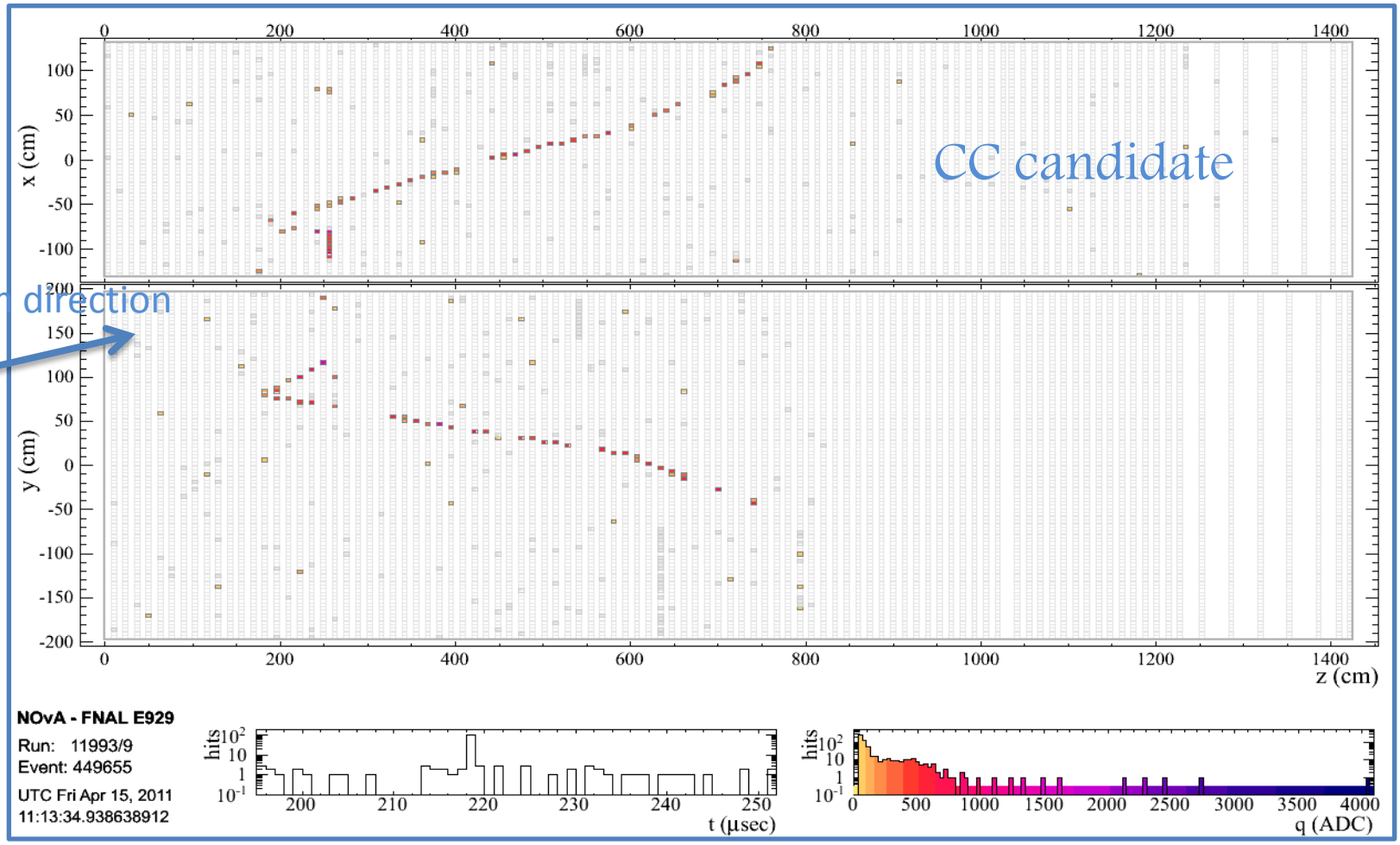
- We will have a significant sample of ν_μ CC QE

Detector during commissioning

Beam direction

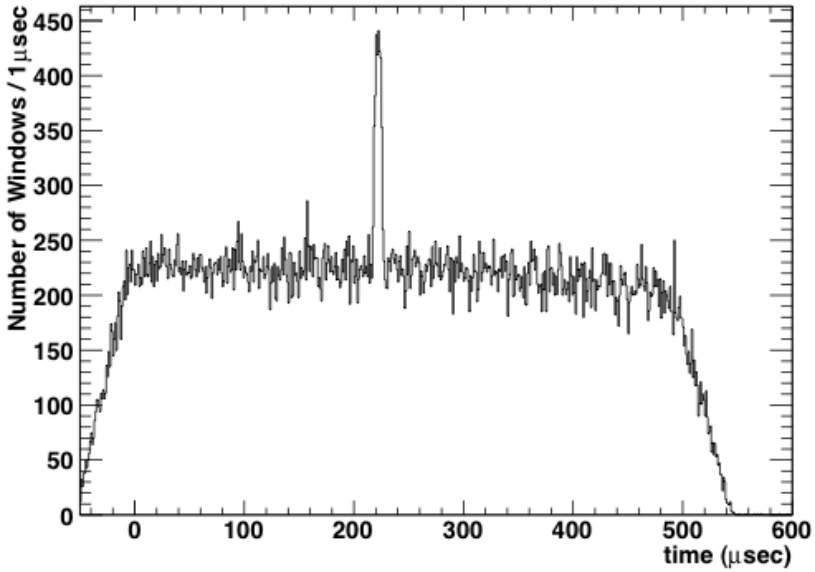


Detector during commissioning



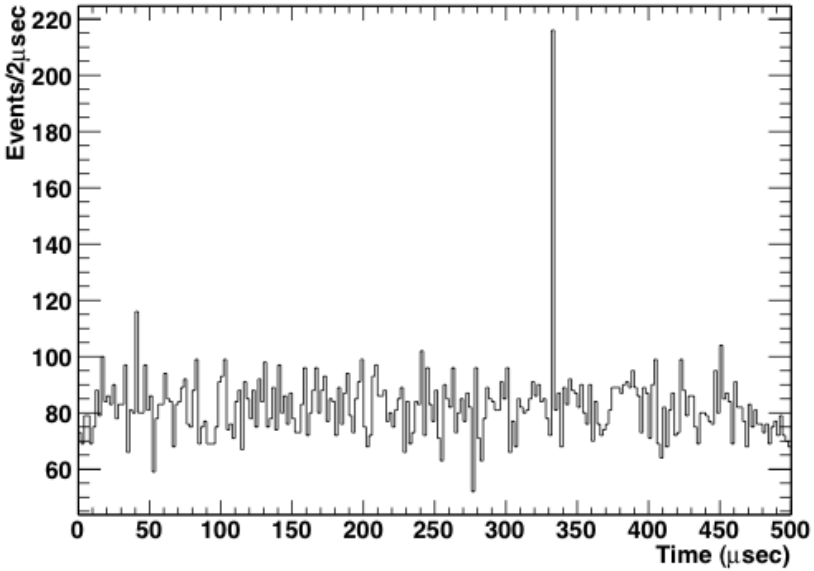
Neutrino signal in NDOS

Time distribution for NuMI neutrinos



Selection: Require to have 4 hits in each view
Fiducial|x|<110cm, y<140cm and z>50cm and z<770 cm

Time distribution for Booster neutrinos

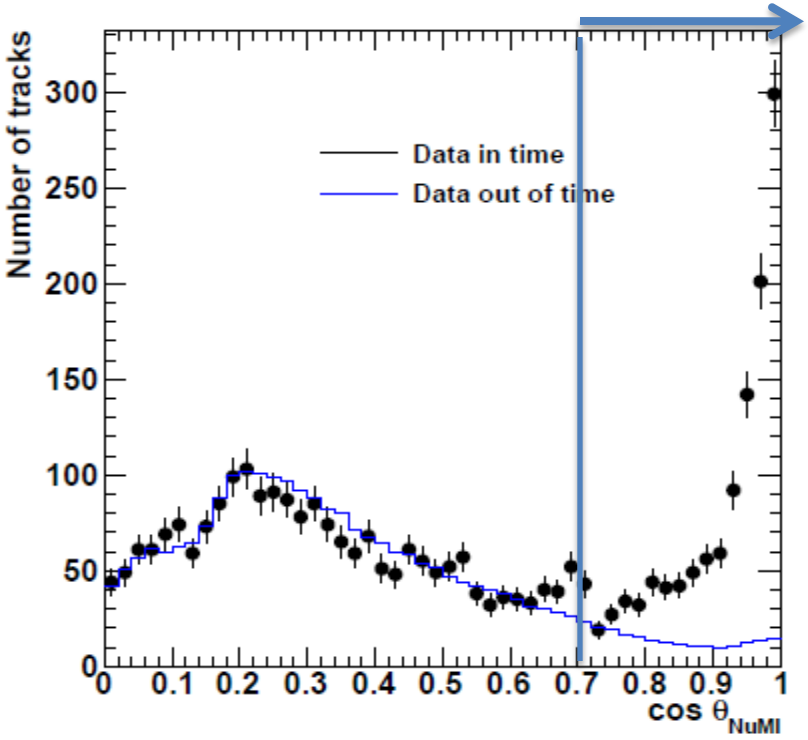


Selection: Require to have 4 hits in each view
Fiducial|x|<110cm, y<140cm and z>50cm and z<770cm

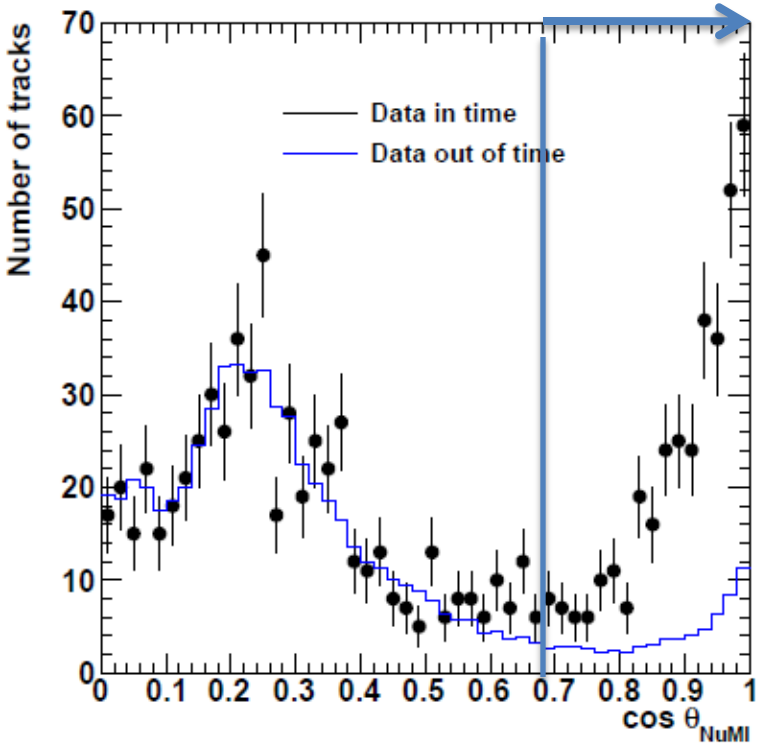
NuMi Beam Neutrino Interactions

Reconstructed particle tracks angle with respect to the beam direction

AntiNeutrino Run



Neutrino Run



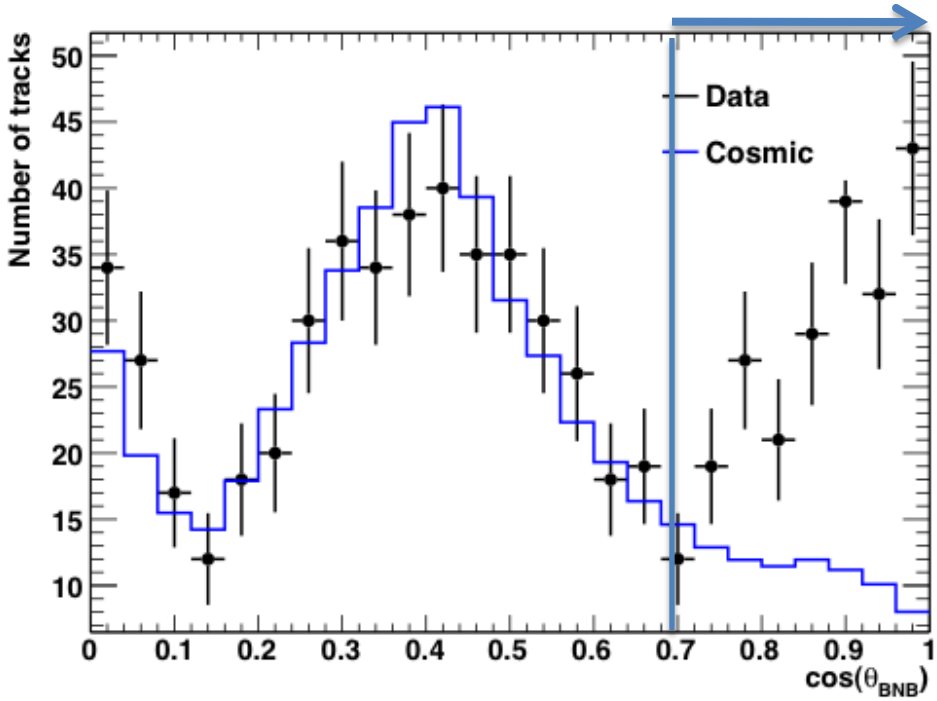
5.6×10^{19} protons on target during antineutrino run, 1001 NuMI events and 69 cosmic BG

8.4×10^{18} protons on target during neutrino run, 253 NuMI events and 39 cosmic BG

Booster Beam Neutrino Interactions

Reconstructed particle tracks angle with respect to the beam direction

AntiNeutrino Run

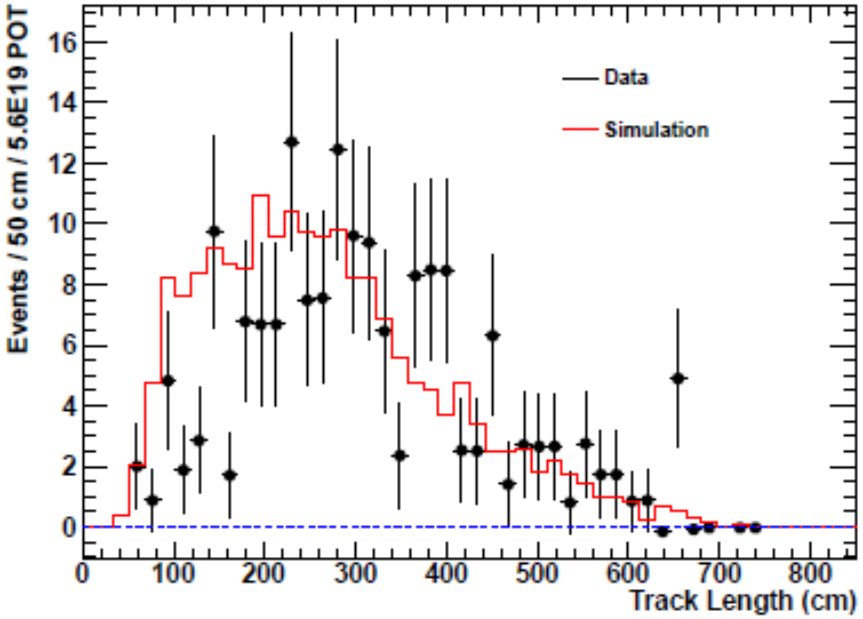


$3x10^{19}$ protons on target during antineutrino run, 222 booster events and 92 cosmic BG

Track Length for NuMI signal events

Track length for the fully contained events

Antineutrino Run



MC : fully contained events normalized to Data Exposure

	NuMI	Cosmic BG	MC
Fiducial	1001	69	861
Fully contained	184	12	187

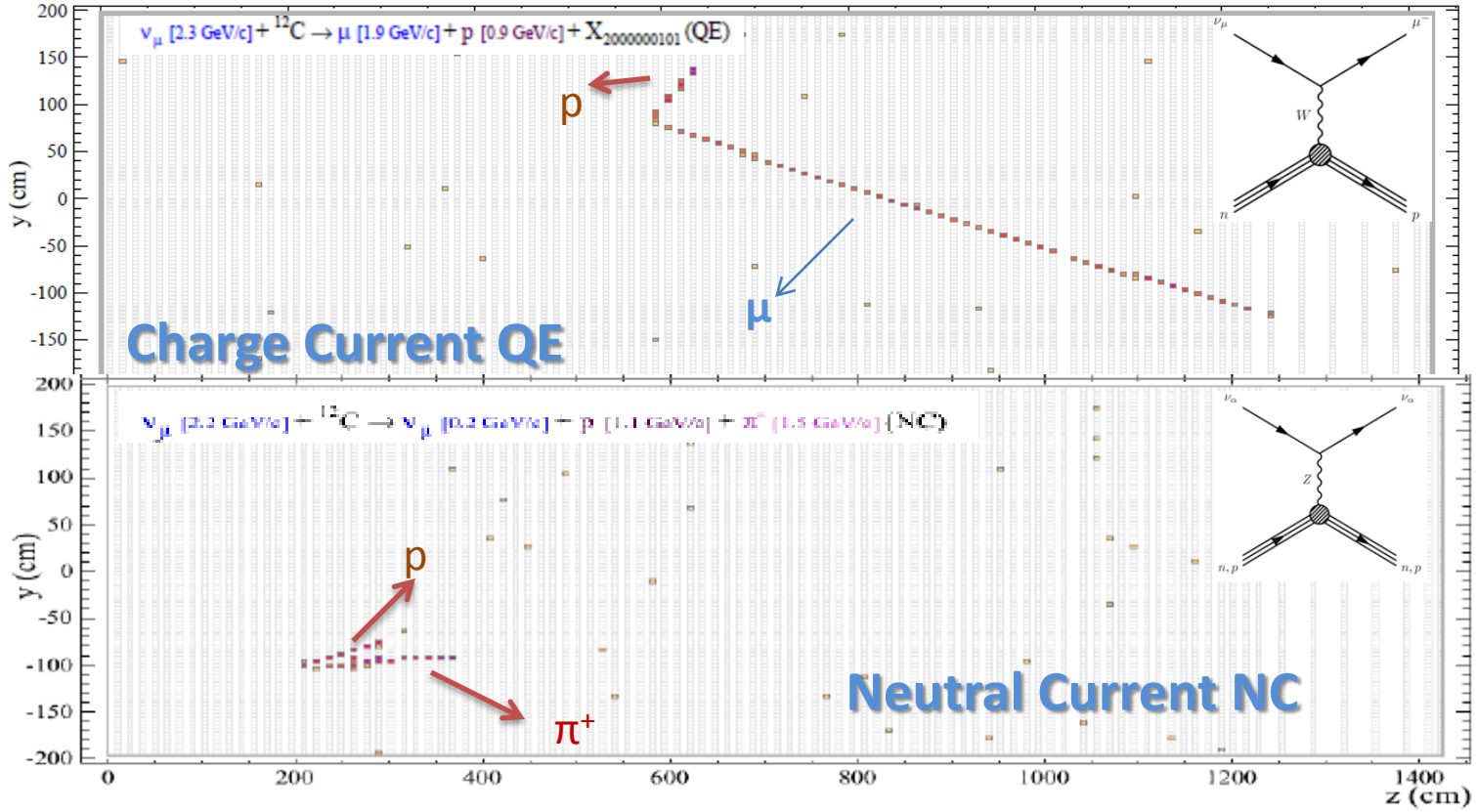
Fully contained: Events with vertex and end of the track inside of fiducial region

- We have a selection criterion to find neutrino candidates and separate them from cosmic background
- Developing a selection to identify the ν_μ charge current CC interactions using Monte Carlo MC

CC studies in NDOS

- Understanding the background for CC interactions

MC Events



Selection Method

- Currently developing a selection criterion to select charge current CC interactions from neutral current interactions NC
- Base on a simple likelihood method which uses as input three probabilities density functions (PDFs)
- An event separation is defined:

$$S = (ln(P_{CC}) - ln(P_{NC}))$$

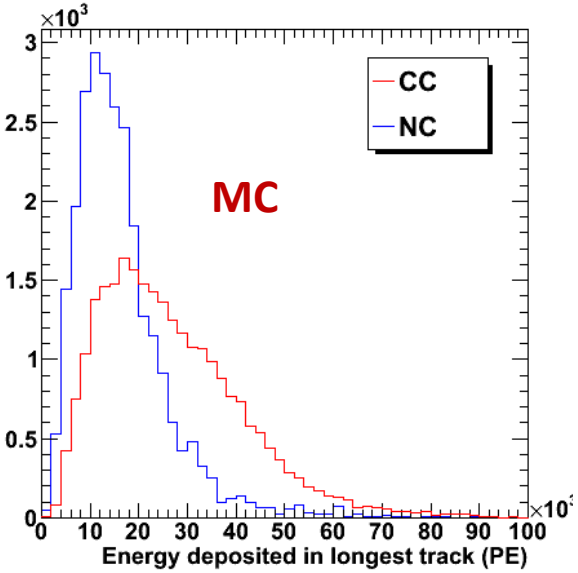
Where P_{CC} or P_{NC} are the probabilities $P_{CC,NC} = \prod_{i=1}^{3} f_i(x_i)_{CC,NC}$ and $f_i(x_i)$ are the individual PDFs for CC and NC

Variables

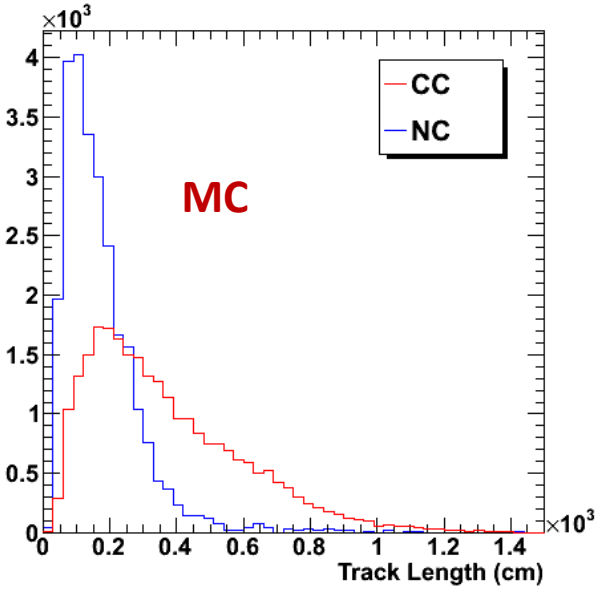
Using Antineutrino MC

Distributions normalized by area

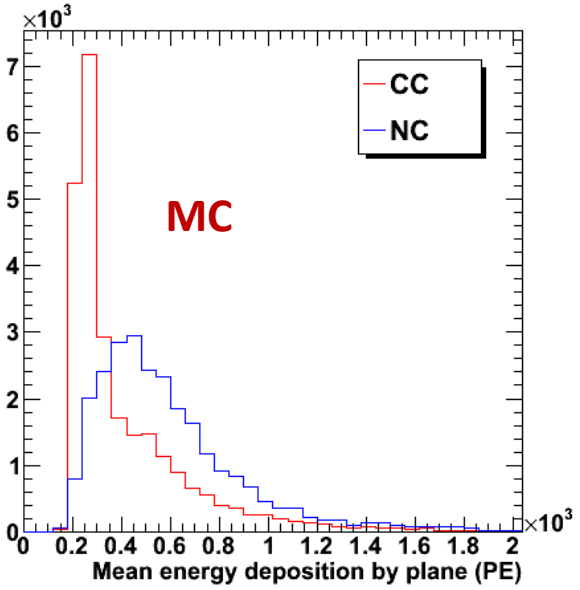
Energy deposited in longest track (PE)



Track Length



Mean energy deposition by plane (PE)

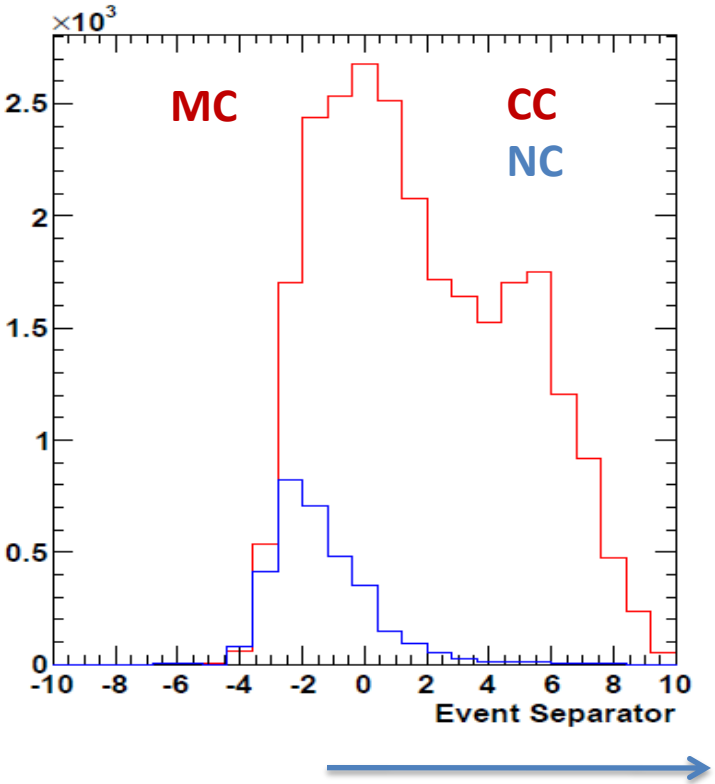


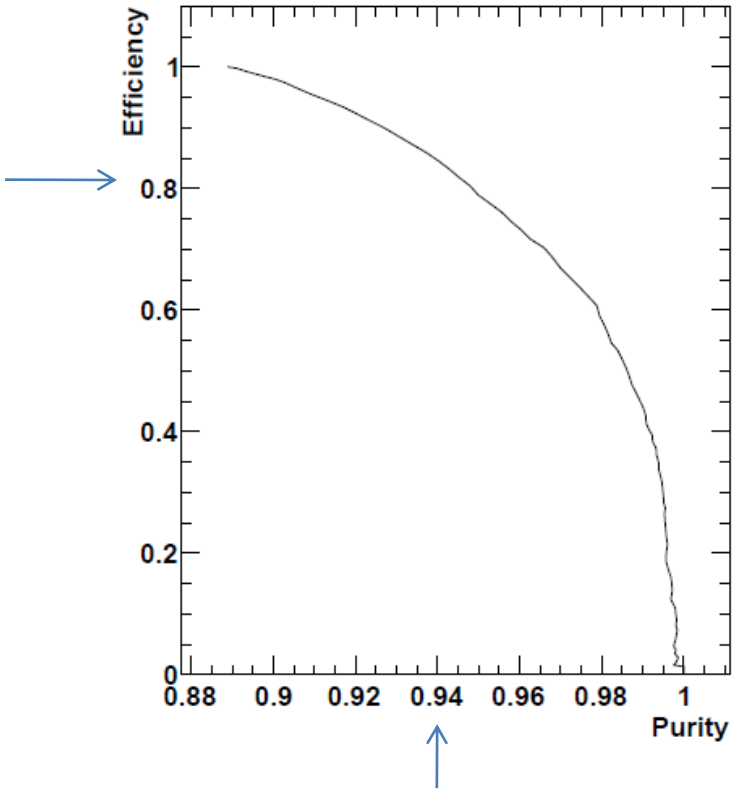
Variables after Pre-selection cuts: Events in fiducial region, nhitx>4 and nhity>4 and cosNuMI>0.7

Using fully contained events and partially contained events

Event Separator

Selecting CC interactions





As an example a cut above –1.5 gives a Purity 94% and Efficiency 80%

An alternative visual scanning method was used to select CC events, this method gives 92% of purity and 85% of efficiency

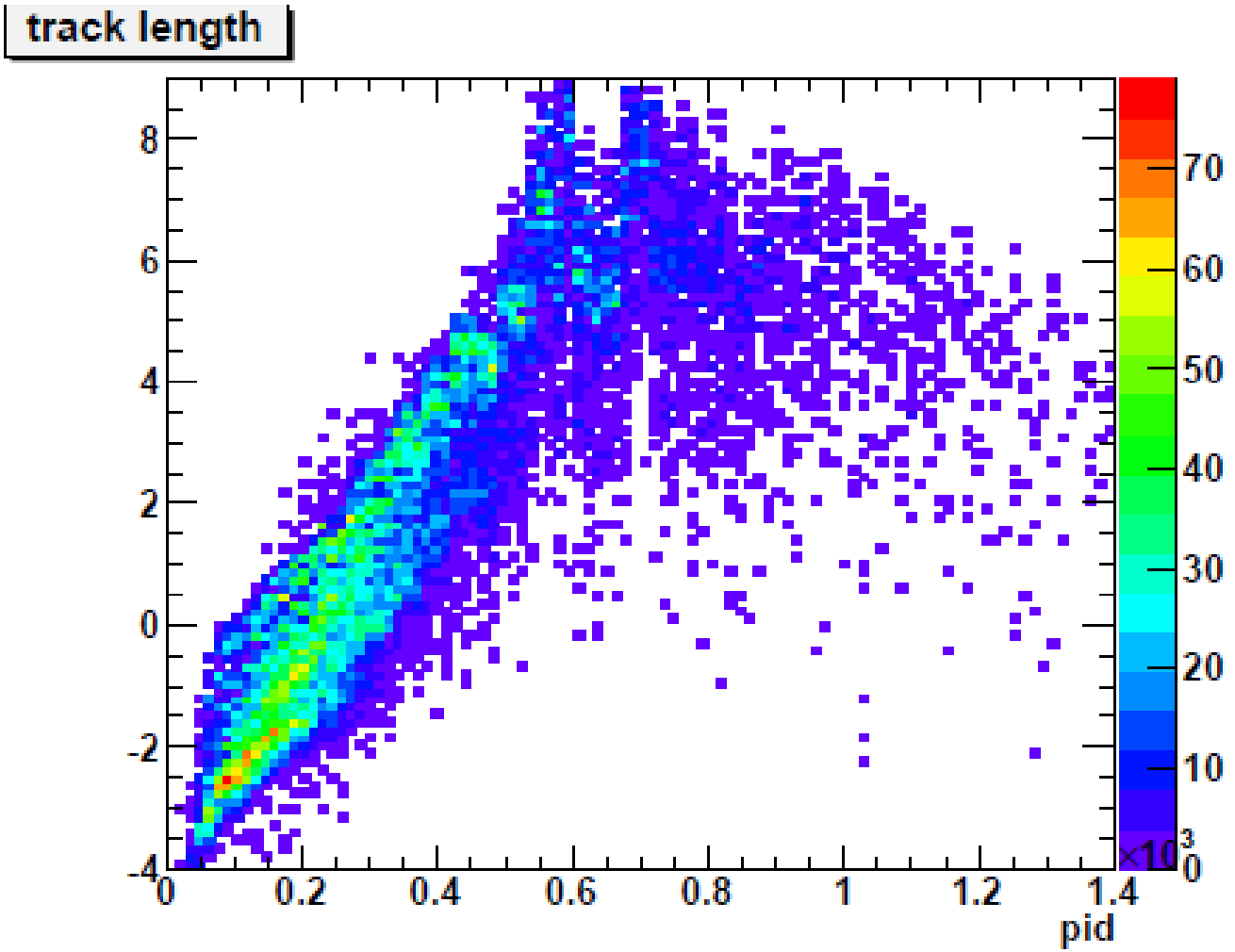
Future work

- Preliminary CC selection method, this method will improve as the quality of the event reconstruction method improves
- Improve the $\pi^{+,-}$ rejection:
  - Using Michel electron
- Identify charge current quasi elastic interactions

Conclusions

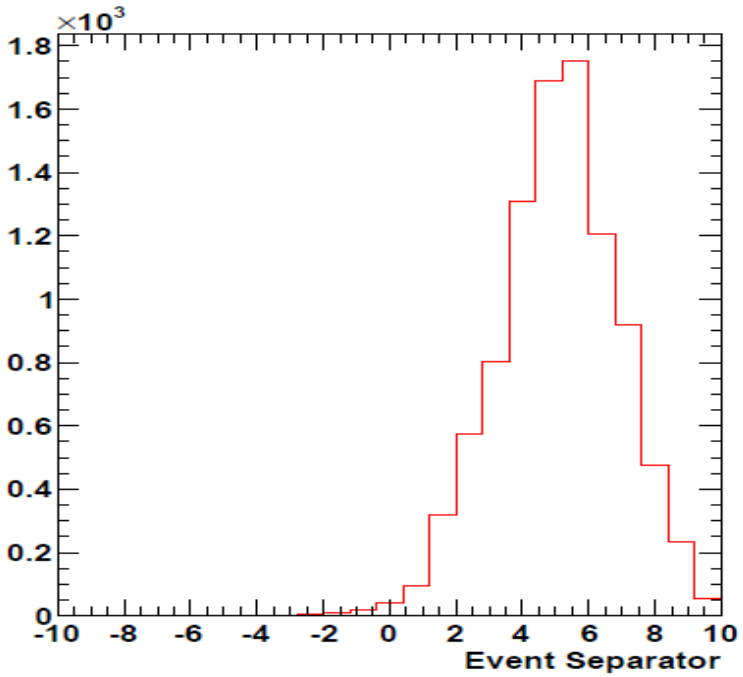
- NOvA has a working detector, taking neutrino and cosmic data
- We are taking data for NuMI and Booster neutrino beams
- Developing analysis methods:
  - Currently developing a CC selection
- Near Detector will be built and will collect much higher statistics

Track Length vs PID (CC)

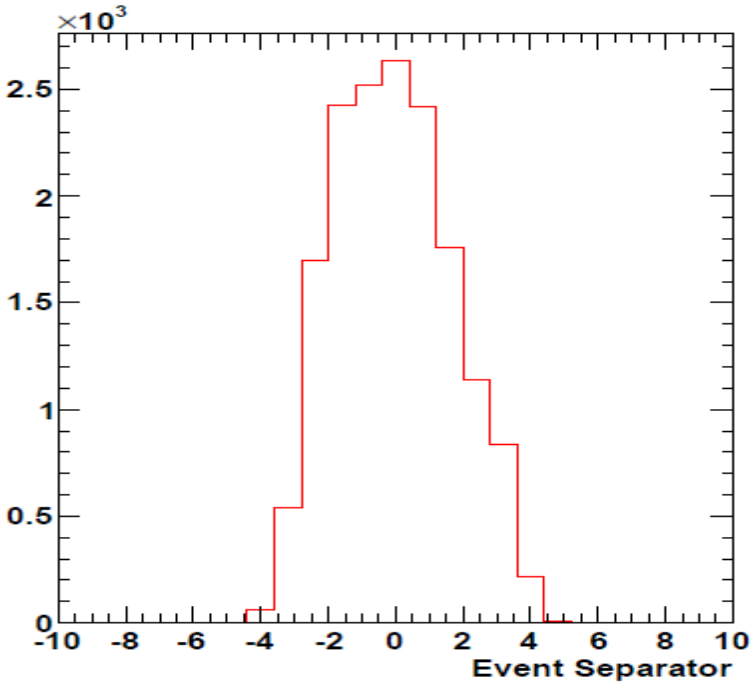


Event Separator

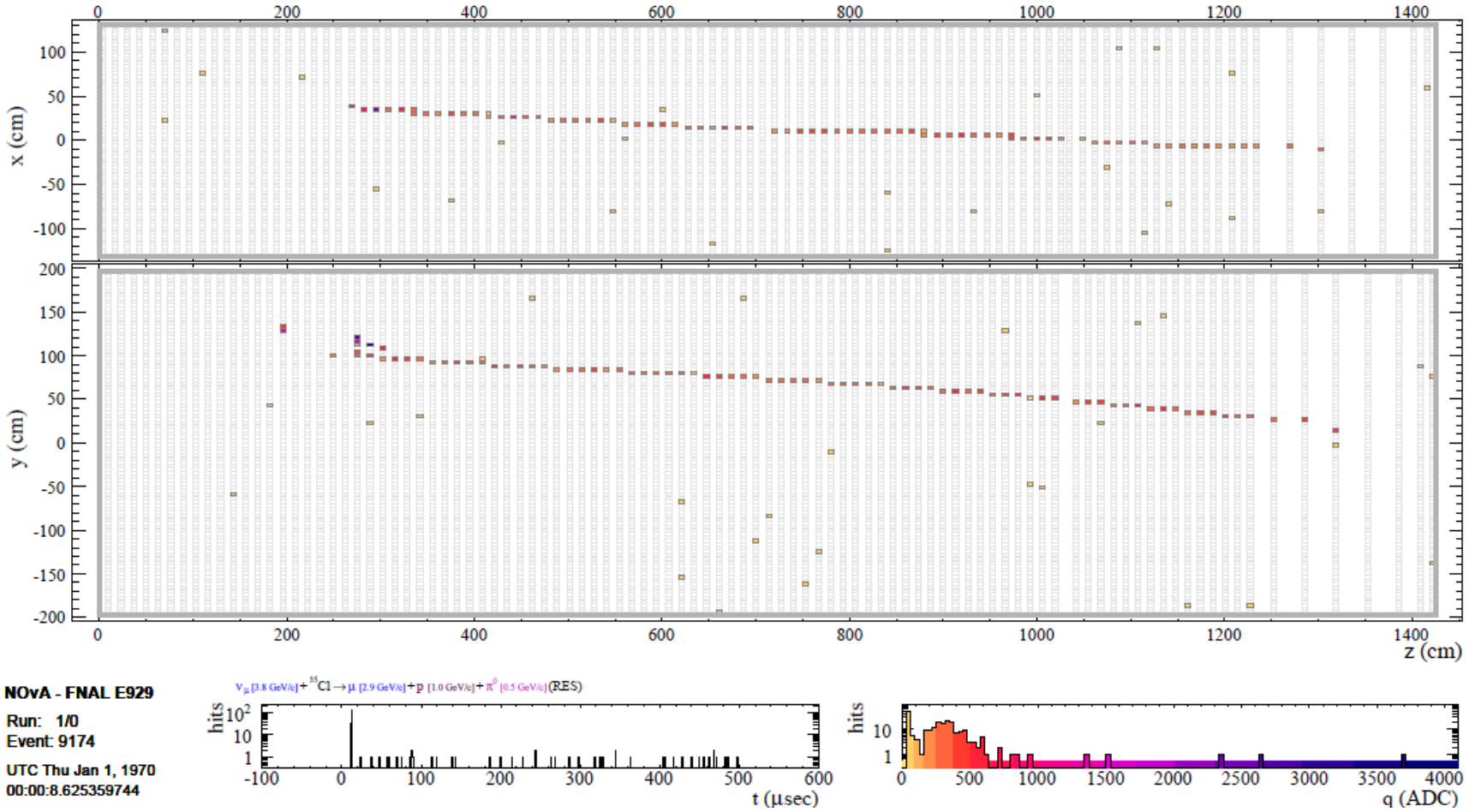
For track length>400 cm



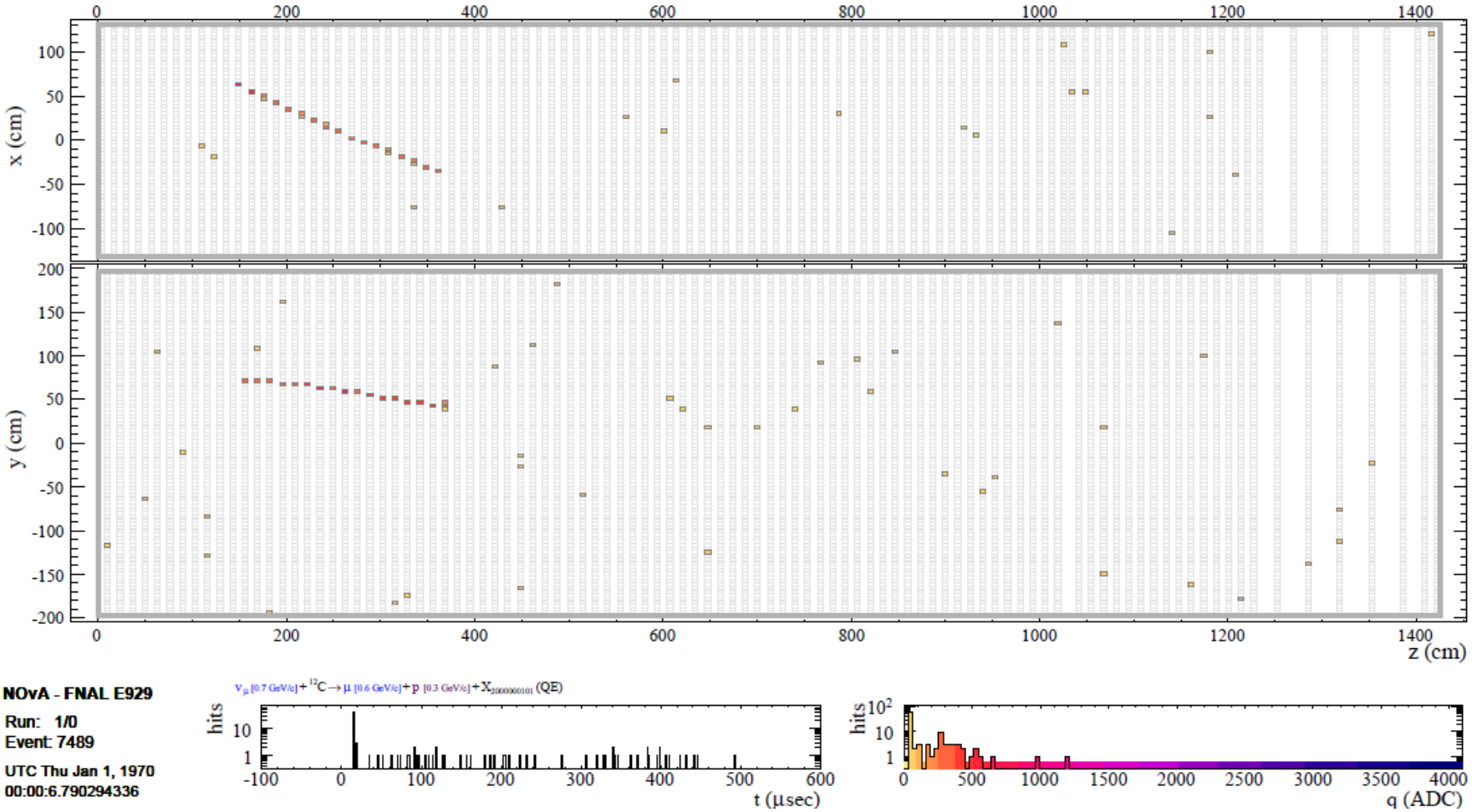
For track length <400 cm



CC Interaction (MC)

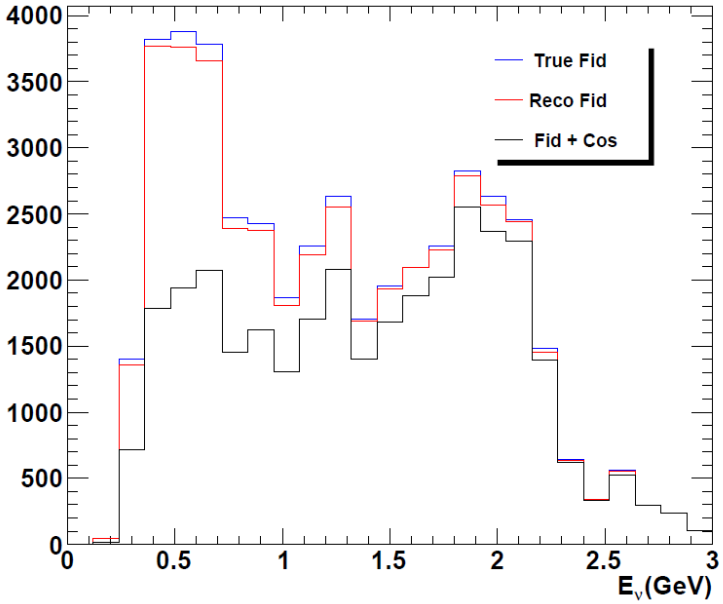


CC Interaction (MC)

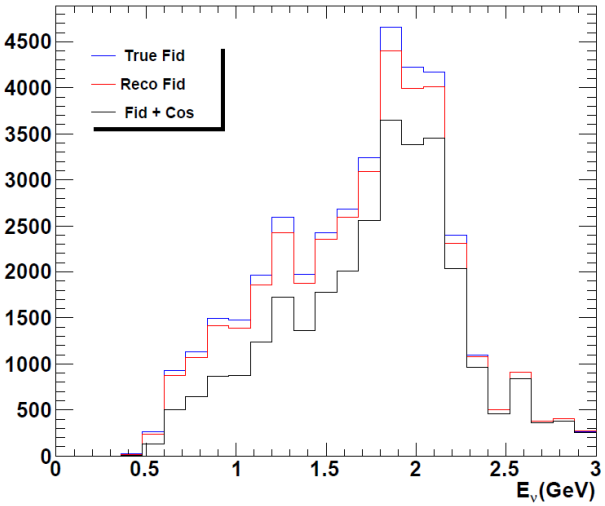


CC Interactions after Pre-selection cuts

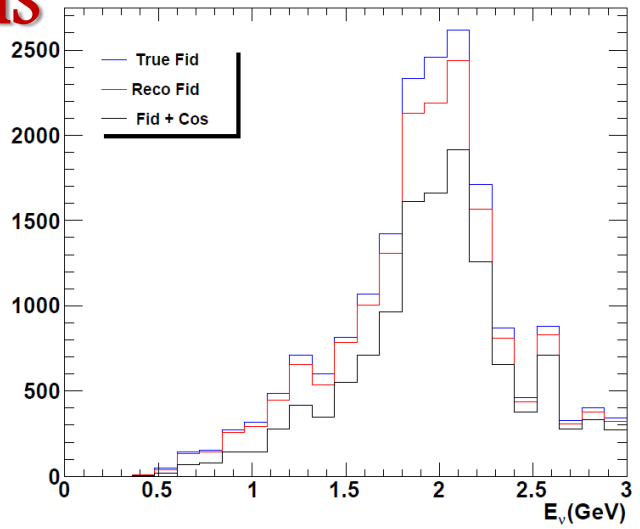
CC QE



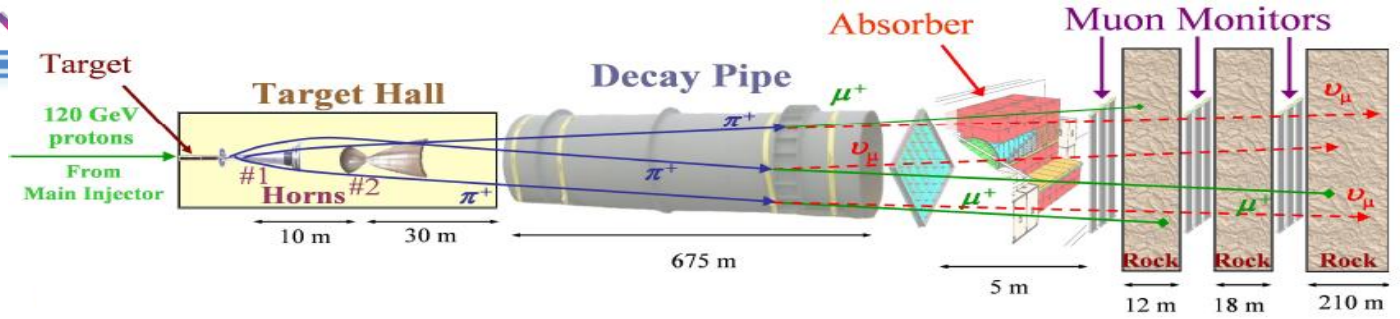
CC RES



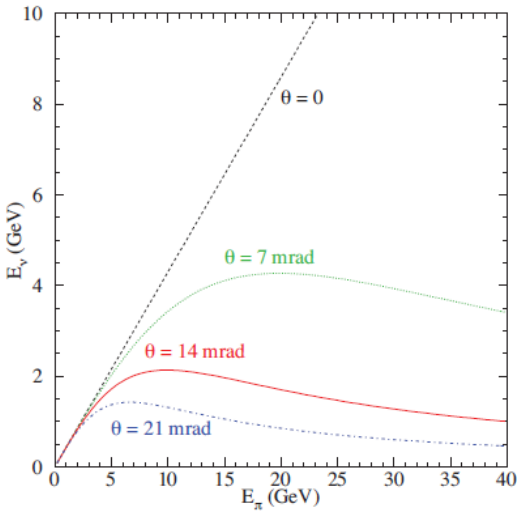
CC DIS



Neutrino production



- 120 GeV protons from the Fermilab Main Injector hit a 1 m graphite target, producing pions (π) and kaons (K)
- Magnetic horns to focus charged π and K
- Nova experiment uses off-axis design (14mrad off-axis angle) and medium energy



$$E_\nu = \frac{0.43 E_\pi}{1 + \gamma^2 \theta^2}.$$