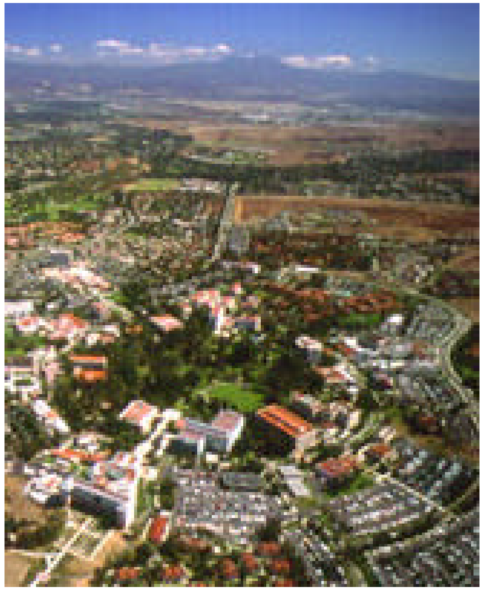
Studies on C.C. Quasi-Elastic and Inelastic Events by K2K Fine-Grained Detector



- Introduction
- C.C. Inelastic/Quasi-Elastic Events
- On-going Analyses
  - Low Energy (<1GeV) Events
  - Q^2 analysis, sensitivity to C.C.Quasi-Elastic M_A

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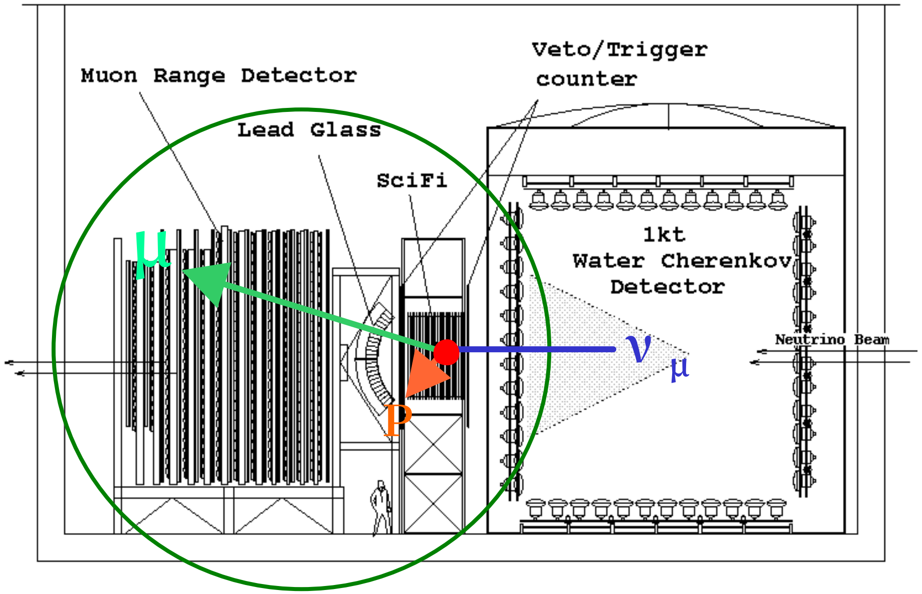
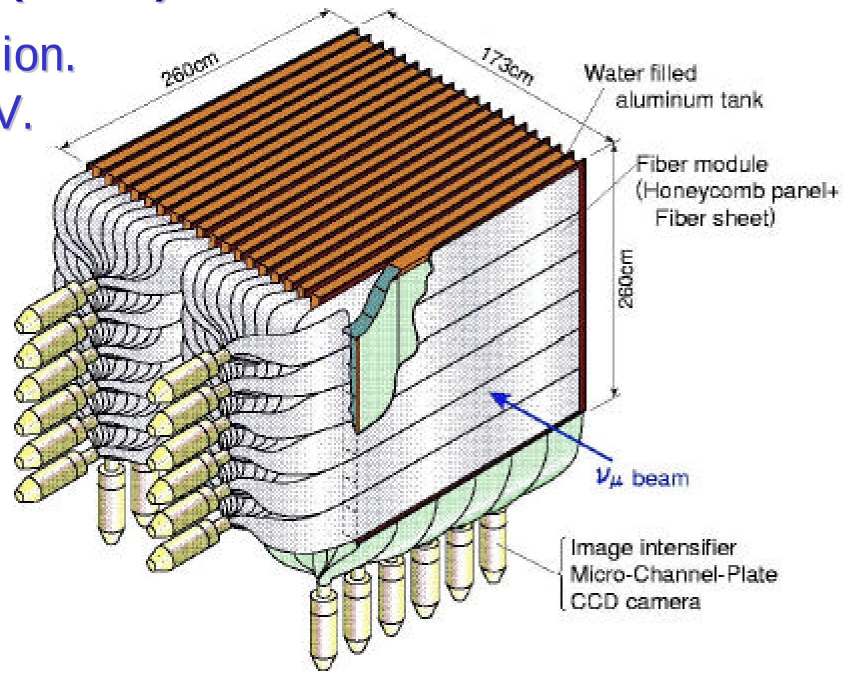
Introduction

K2K Fine Grained Detector (FGD)

- Neutrino beam properties at production.
- Neutrino Interactions at <E$_\nu$>=1.3GeV.





Core of FGD :
Scintillating Fiber Tracker
(Sci-Fi)

■ Progress after NuInt01:

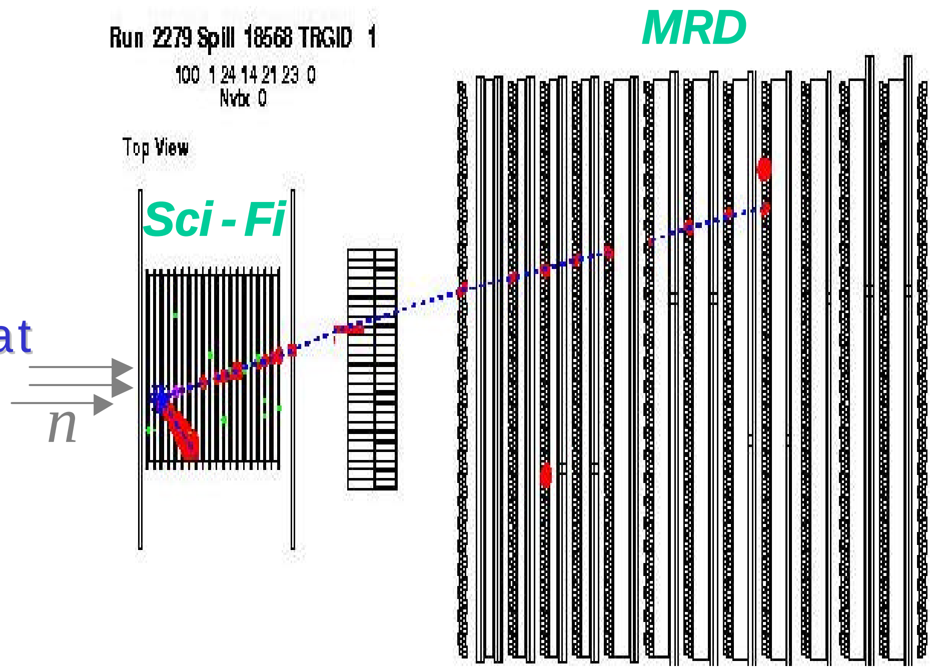
Neutrino Oscillation Analysis

- N_{SK} and $E_{\nu rec}(P\mu,\Theta\mu)$ of 1-Ring are evaluated with neutrino oscillation hypothesis.
- Front Detectors (1kt & FGD) provide neutrino beam properties at production (w/o oscillation), which are indispensable for the analysis:

1. Monte Carlo Tuning
2. Neutrino Flux **F(E_n)** at Production
3. C.C.Inelastic/Quasi-Elastic Ratio

R (non-QE/QE)

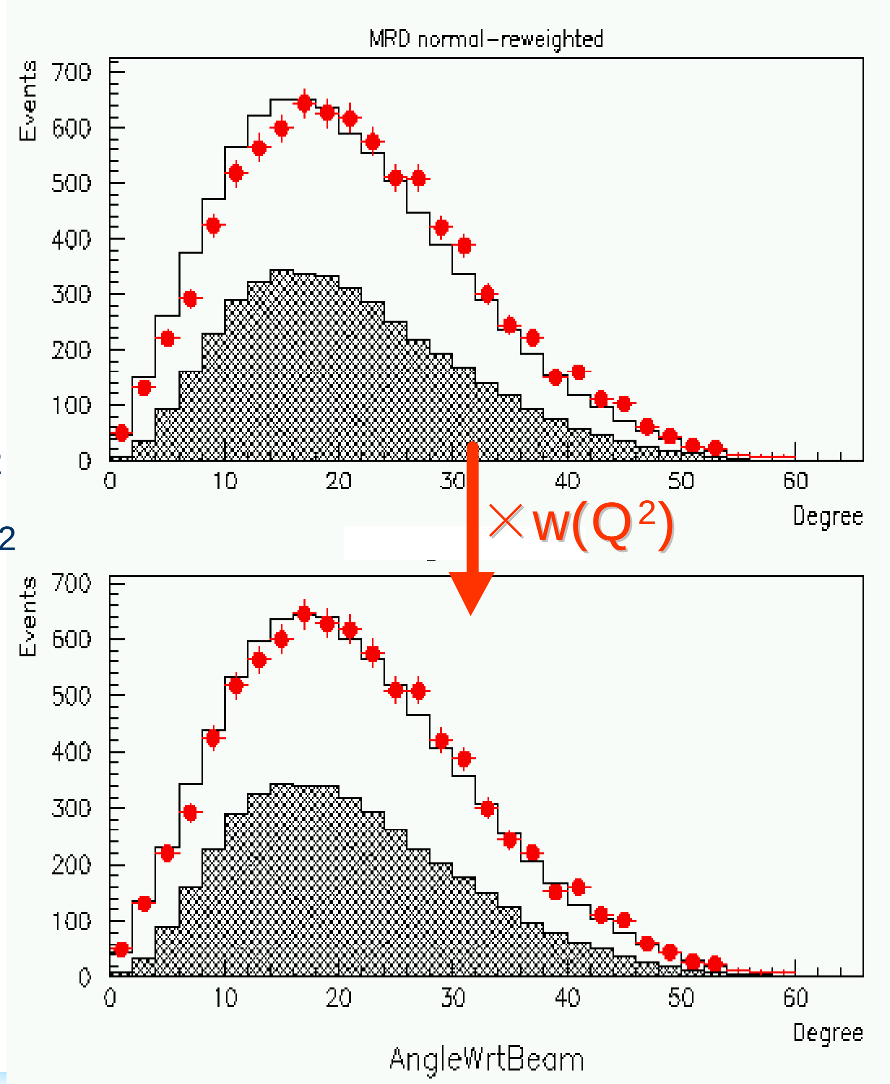
- FGD (MRD-matched) events are related to F (E_ν) and R in E_ν> ~1GeV.



A Typical FGD event

(a C.C.Quasi-Elastic candidate)

C.C. Inclusive q_m



Monte Carlo Tuning:

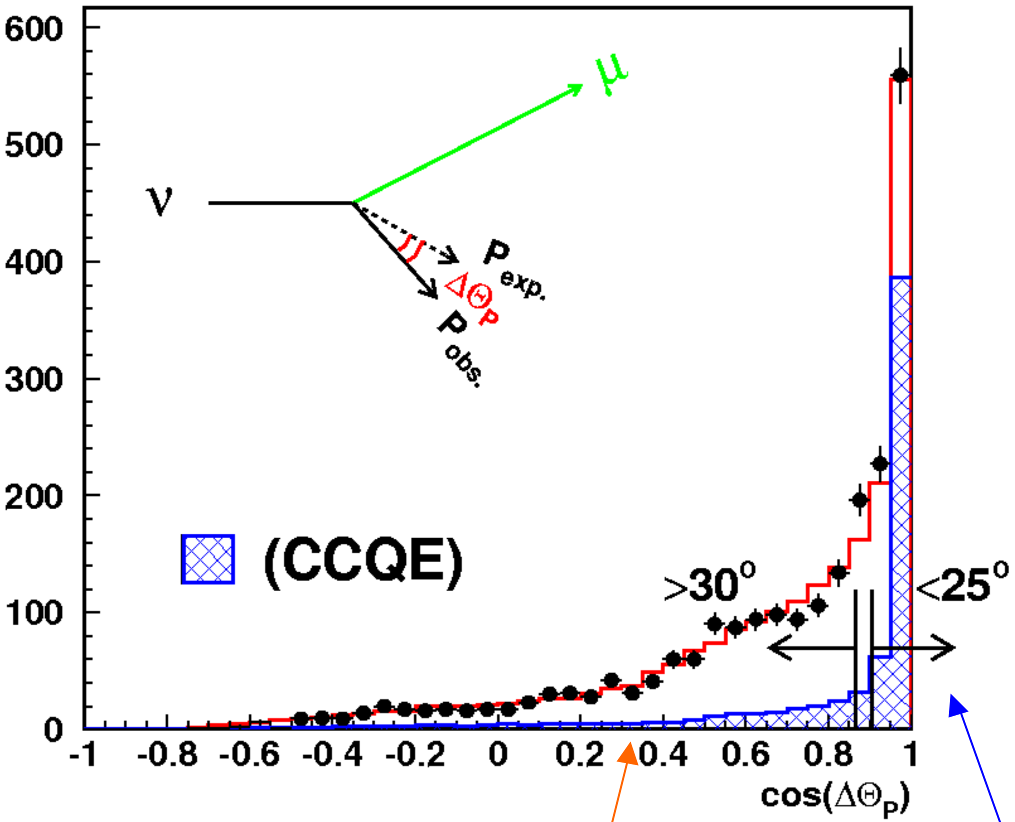
- Θμ problem is fixed by tuning NEUT Monte Carlo with "phenomenological" weight W as func. of Q^2 :
  - CCQE M_A 1.01→1.11GeV/c^2
  - CC1π M_A 1.01→1.21GeV/c^2
  - ...
- They aim to get better agreements to data, by making Q^2 dist. harder.

Studies on C.C. Inelastic/Quasi-Elastic Events

- χ^2-fit on 1kt & FGD ($P\mu$, $\Theta\mu$) distributions.
  - Outputs:
    - Neutrino Flux $F(E_{\nu i})$ ($= F \times \sigma_{\text{Quasi-Elastic}}$)
    - R(non-QE/QE), unique for entire E_n.

- FGD: Nov.99- Jul01 data (4.8×10^{19} p.o.t.)
  - 1-track and 2-track events.
  - 2-track events are separated into two groups by using DQ_{Proton}, a kinematic variable of secondary track, which can separate C.C.Quasi-Elastic and Inelastic events efficiently.

DQP (2-track events)



Sample (3)

Sample (2)

(Pμ,Θμ) distributions of

(1) 1-track

5,951events/44points

(2) 2-track (DQP £ 25°)

761events/40points

(3) 2-track (DQP ³ 30°)

1,291events/40points

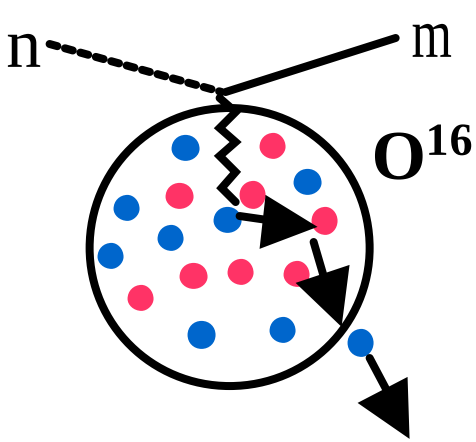
124 data points

~ 8,000 events in total.

- **R**(non-QE/QE) is constrained by (3) / (2)

D R < 10%

Effect of Proton Re-scattering

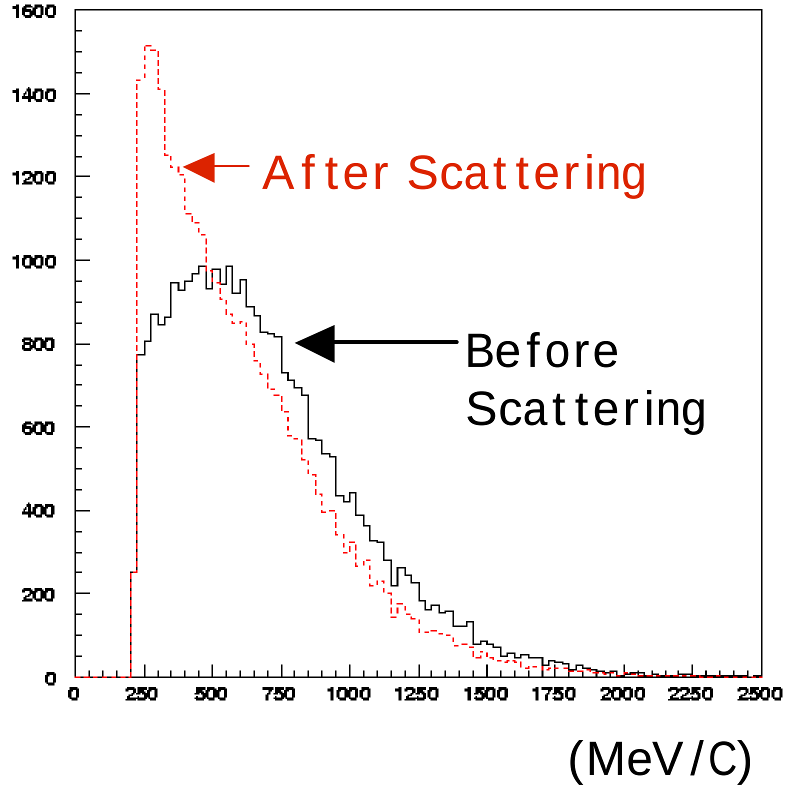


~40% of protons (Pp>400MeV) interact inside the nuclei.

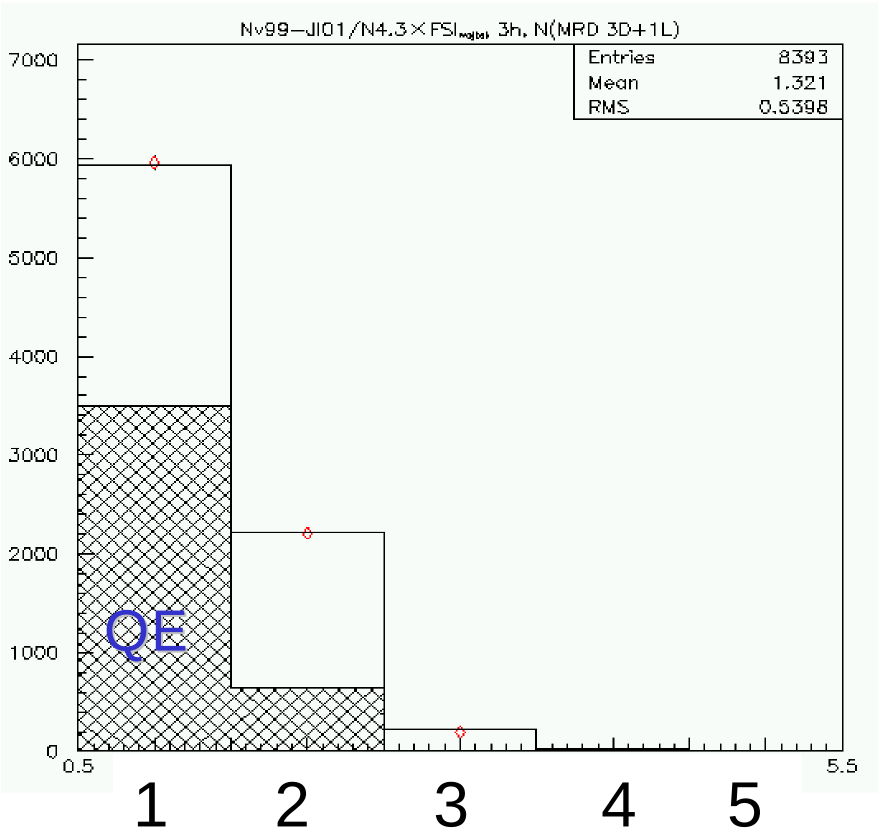
Effect On The Spectrum Analysis:

- Protons change direction
  (2) 2-track<25° → (3) 2-track>30°
- Lose Momentum (ΔPp= -90MeV)
  (2) 2-track<25° → (1) 1-track

Momentum of Proton Exiting from Nucleus
(C.W.Walter@NuInt01)

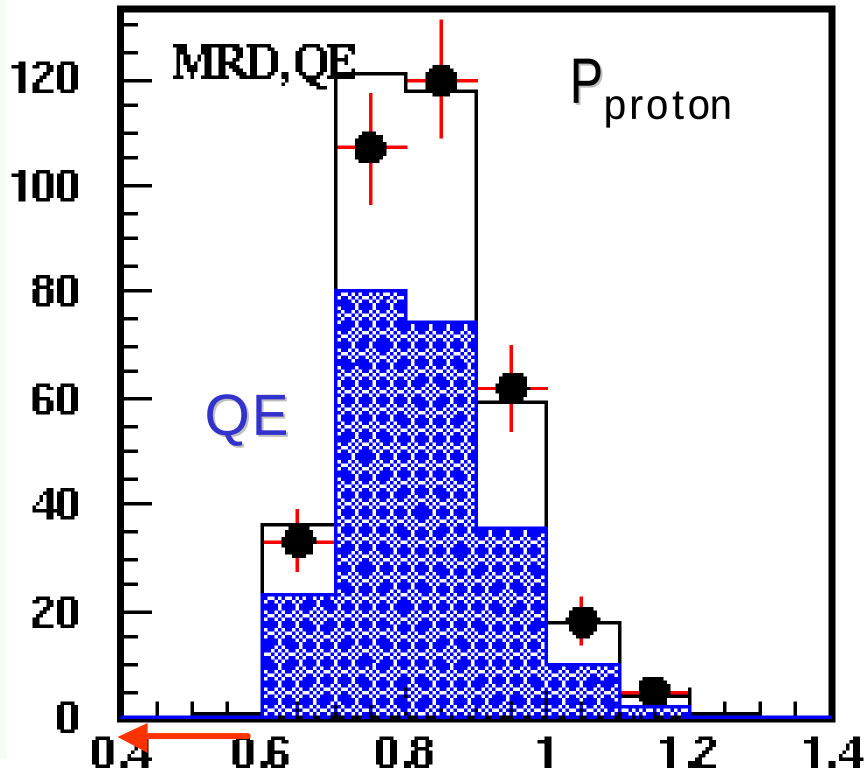


Number of Sci-Fi Tracks



Proton Momentum of (2)

(2nd Track Length)



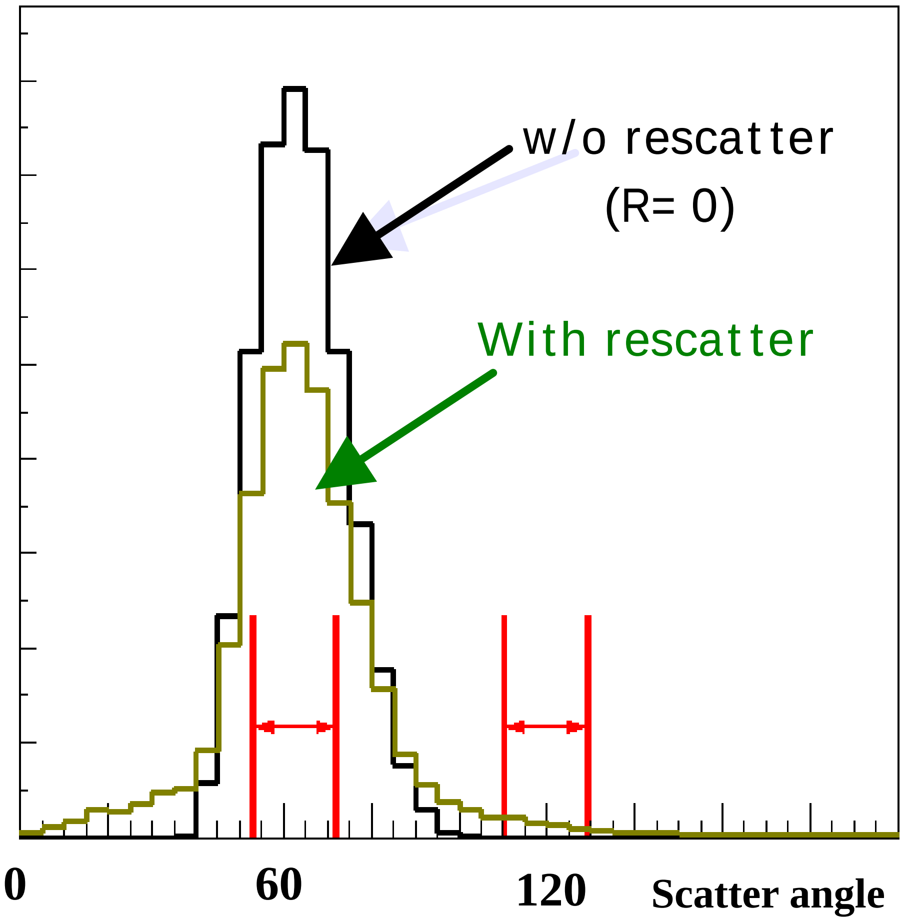
$\Delta p_{proton} \sim 30MeV$ (P_p>600MeV)
(to be reduced to ~400MeV)

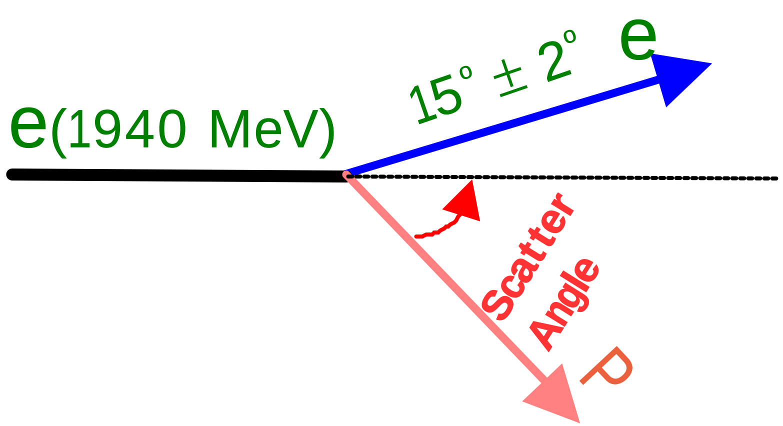
- Data agree well with MC.
- 10% error is allowed for re-scattering probability, which is based on e-P scattering data ⇔ Neut MC.

Proton Rescattering in $e + {}^{12}C$ ® $e' + p + X$

(Alanakyan et al. Physics of Atomic Nuclei 61,2,1998)

Yerevan electron synchrotron





$R_{exp}(120\pm8^o\ /\ 66\pm8^o)$
$= 0.019\pm0.001$

R_{MC}
$= 0.017$ (Neut×FSI)

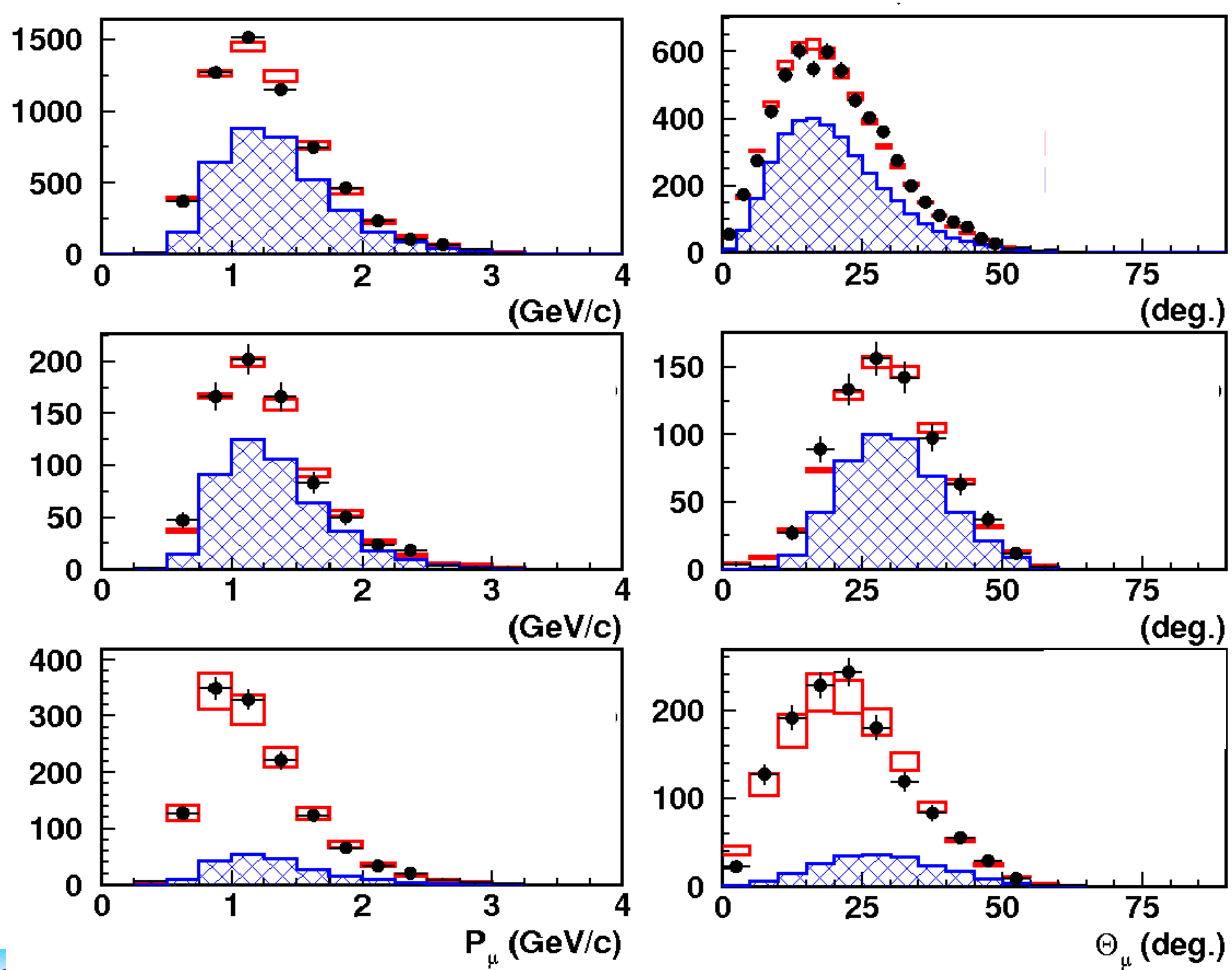
Fitting Results

P$_\mu$ | Q$_m$

(1) 1-track

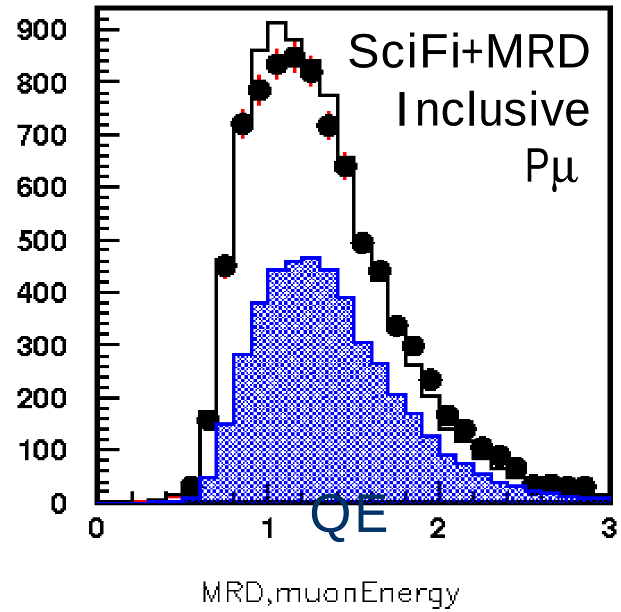
(2) 2-track
DQP £ 25°

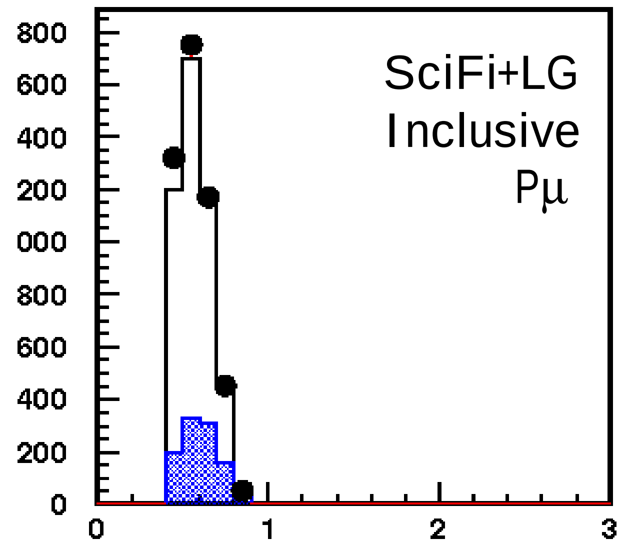
(3) 2-track
DQP ³ 30°



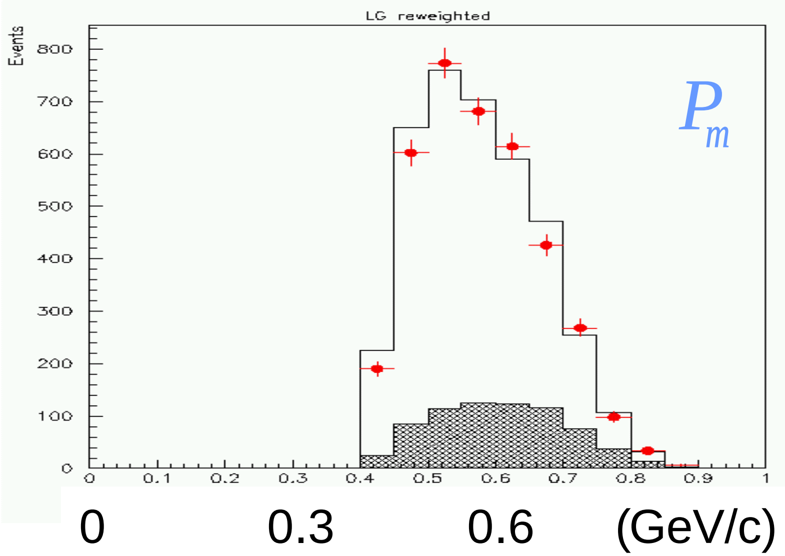
On-going Analyses

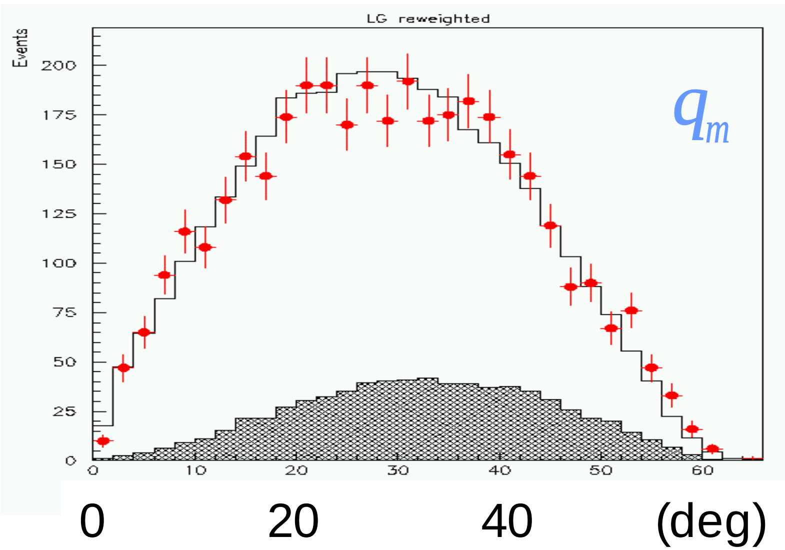
- FGD Low-Energy Events
  - To increase sensitivity to lower energy we are studying "Lead-Glass(LG) stopping" events thus far obtained.
  - +45% events in Eν < 1GeV
- Runs w/o LG will be started very soon (this December).

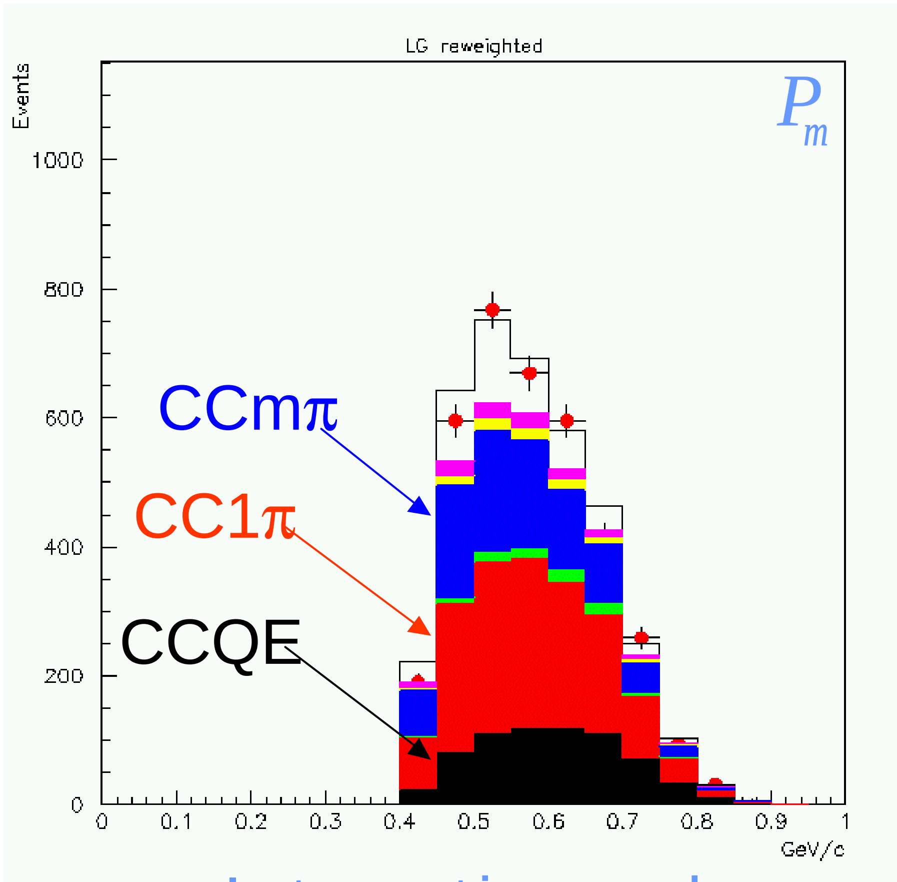




Inclusive P_μ and Θ_μ distributions (SciFi+LG)

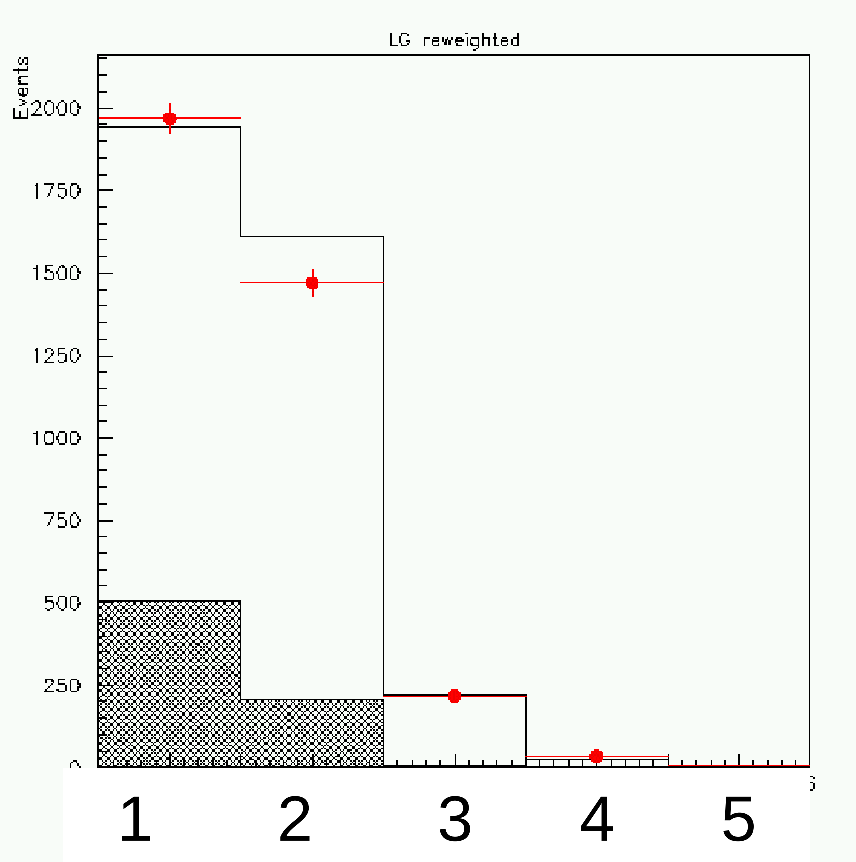


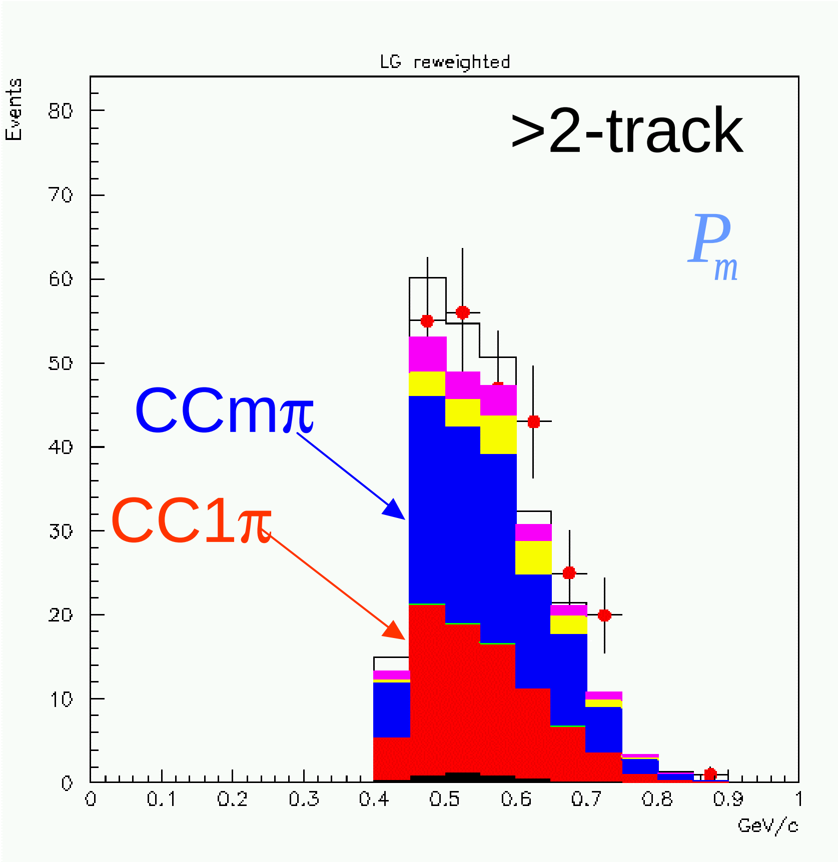




Interaction modes

Number of track distributions (SciFi+LG)





Q^2 analysis

- The differential cross section for the C.C.Quasi-Elastic reaction $n_m + n \to m^- + p$

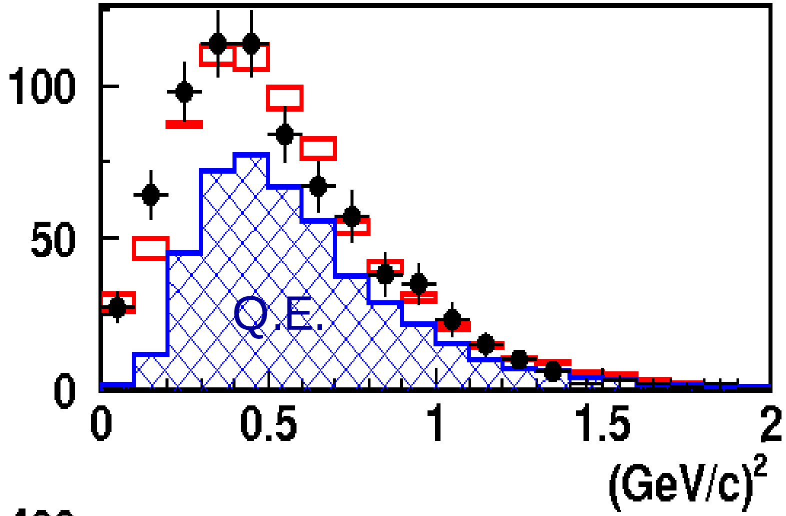
$$\frac{ds}{dQ^2}(E_\nu, Q^2) = \frac{M^2G^2\cos^2 q_c}{(8pE_n^2)}\left[A(Q^2) - B(Q^2)(s-u) + C(Q^2)(s-u)^2\right]$$

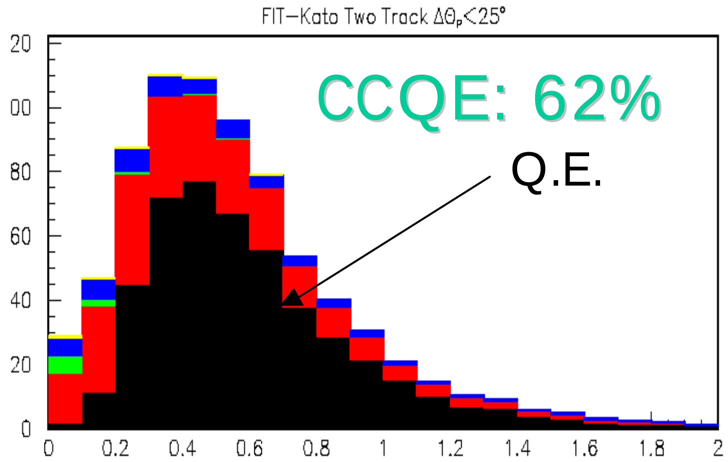
  is studied in terms of Axial-Vector Mass MA.
- This is the first measurement of M_A with water target
- Entire Q^2 region of FGD samples (1), (2) and (3) are fitted simultaneously.
- For $Q^2<0.2(\mathrm{GeV/c})^2$, the free-neutron cross section is corrected by the factor R (Q^2) to account for the Pauli exclusion principle.

  R~45% at $Q^2=0(\mathrm{GeV/c})^2$

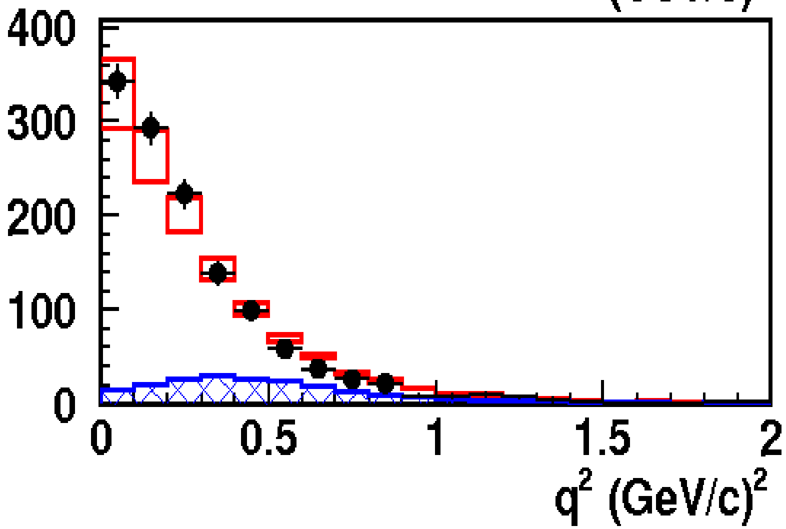
Q^2 distributions of 2-track samples

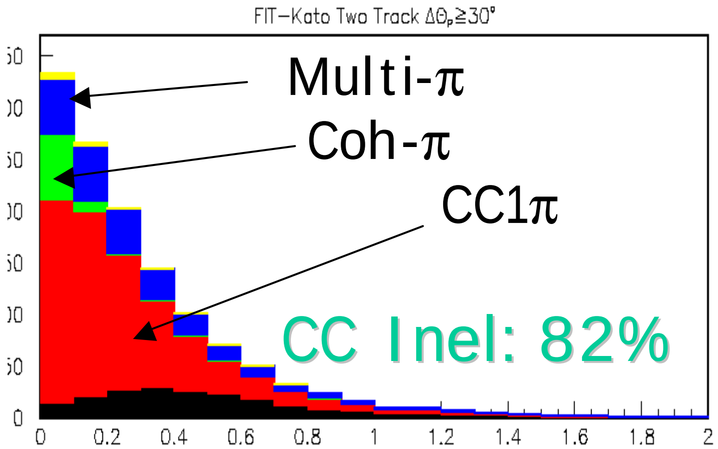
(2) 2-track
DQP £ 25°



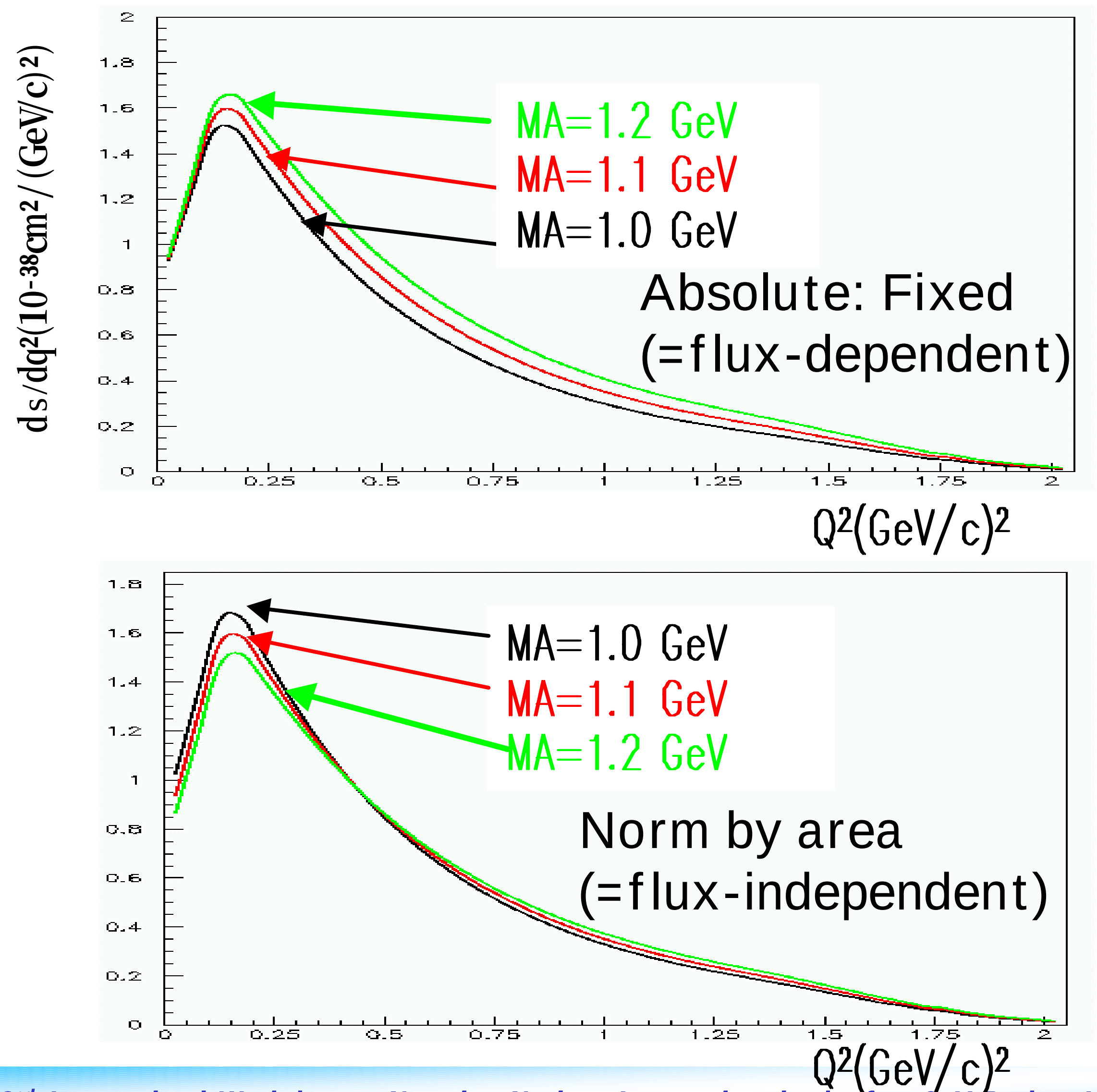


(3) 2-track
DQP ³ 30°

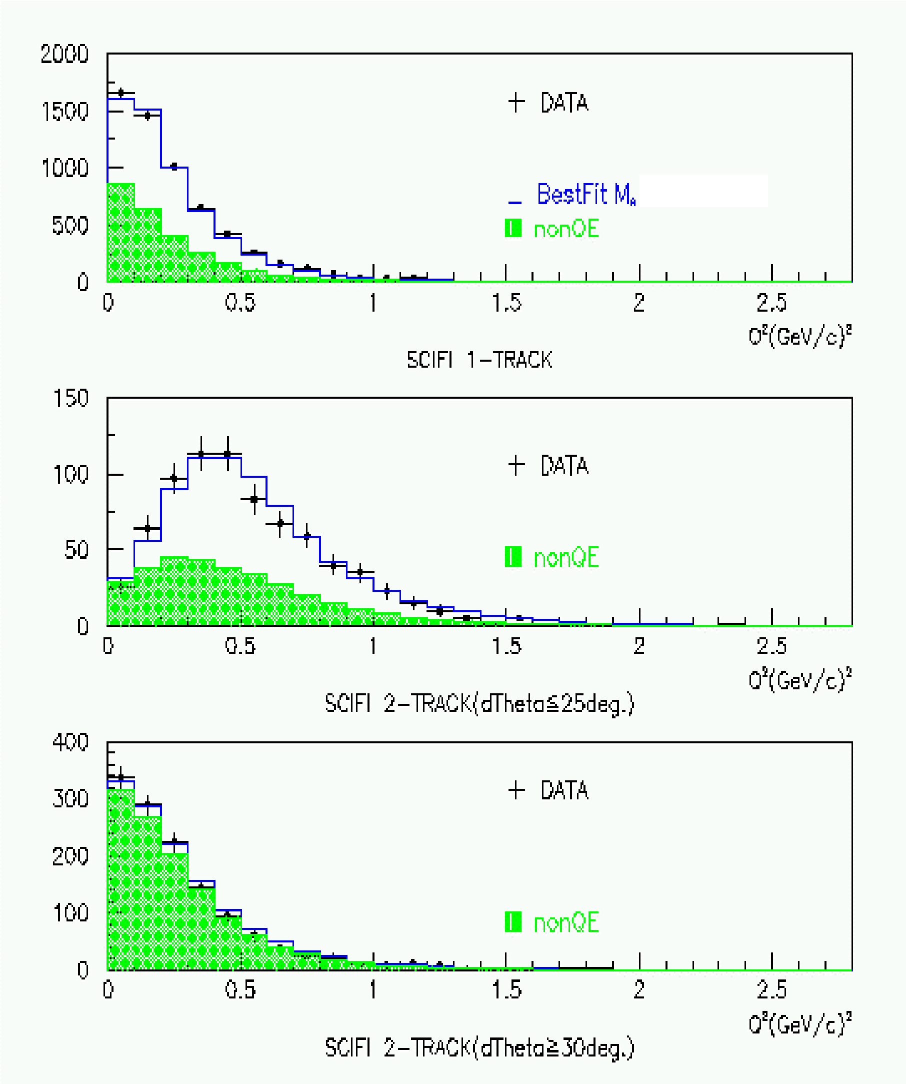




CCQE cross section at Eν=1.3 GeV



Best Fit Distributions (Preliminary)



- Fits give $\Delta(M_A)$ to be $\sim .2 GeV/c^2$, where
  $\Delta(M_A)$stat. $\sim .06 GeV/c^2$.
  $\Delta(M_A)$sys. $\sim .15 GeV/c^2$.
- Systematic errors mainly come from:
  - Uncertainty in single π $M_A^{1\pi}$
  - Uncertainty in nuclear effect.

Summary

- On the way of K2K oscillation analysis, FGD events provide neutrino flux F and R(nonQE/QE) in $E\nu$>1GeV region.
- They can determine R(nonQE/QE) with < 10% accuracy.
- We are making efforts to reduce energy threshold by using LG stopping samples. We get +45% more events in $E\nu$<1GeV. Basic distributions are shown, whose Data-MC agreements are good.
- Runs without LG will be started this December and we will obtain more low energy events in E_ν<0.5GeV as above.
- Q^2 analysis will determine C.C.Quasi-Elastic M_A with accuracy of ~ 0.2GeV/c^2 (0.06GeV/c^2 stat.only). Efforts to reduce systematic uncertainties are needed.