加速器データを用いたニュートリノ相互作用シミュレーションの研究

東京大学宇宙線研究所
宇宙ニュートリノ観測情報融合センター
金行健治
共同研究者　宇宙線研　梶田隆章、奥村公宏、早戸良成
カリフォルニア大　峰俊一

申請額　旅費 20万円　　交付額　5万円

- ニュートリノ相互作用シミュレーション
  - QE interaction
  - $\Delta \rightarrow N\gamma$ decay
  - (atmospheric neutrino flux)
- SciBooNE 実験

ν相互作用シミュレーションの研究

実験データ
e 散乱等
ν 相互作用事象

理論
ν相互作用モデル
π、K等の核内相互作用

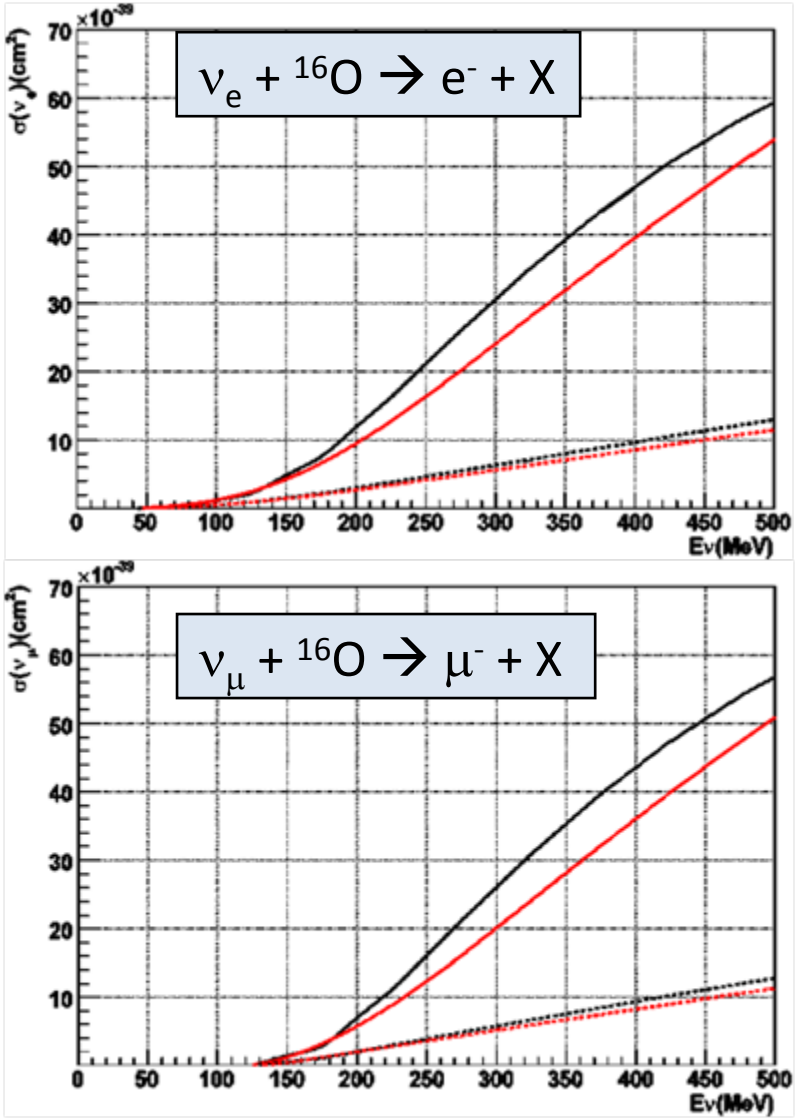
ν相互作用の理解
ν interaction simulation (NEUT)の改良
核内相互作用simulationの改良

ニュートリノ振動
大気ニュートリノ
長基線ニュートリノ実験
核子崩壊の探索

Quasi-elastic interaction

- Smith-Moniz model
  - nuclear effects are too simple
- New model (J.Nieves et al)
  - Random phase approximation (RPA) and Final State interaction (FSI) are applied. (good agreement with electron scattering data
- This work is done by Mitsuka and M.Varverde (Univ. of Granada, Spain)

Quasi-elastic interaction



NEUT(Smith-Moniz)
Nieves et al.
solid: ν, dashed: $\overline{\nu}$

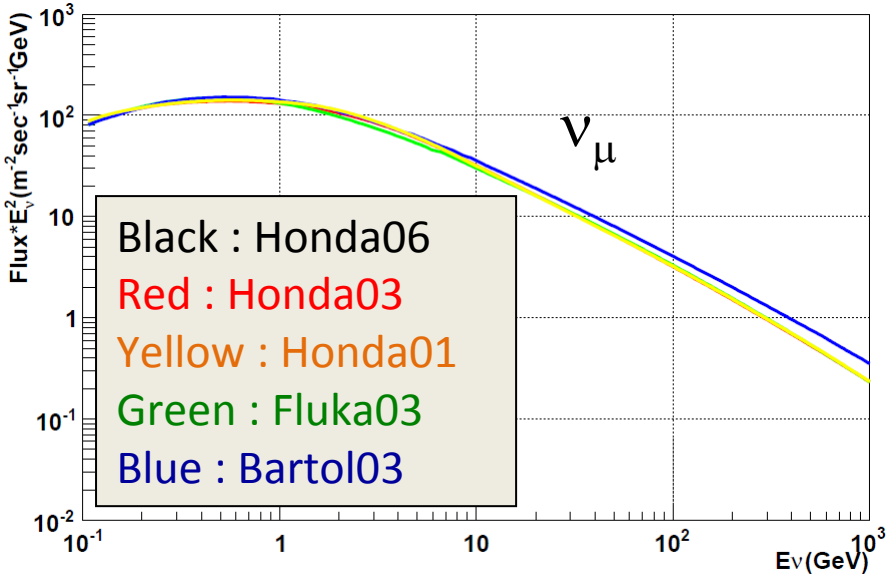
systematic error の評価に使用

$\Delta \rightarrow N\gamma$ decay

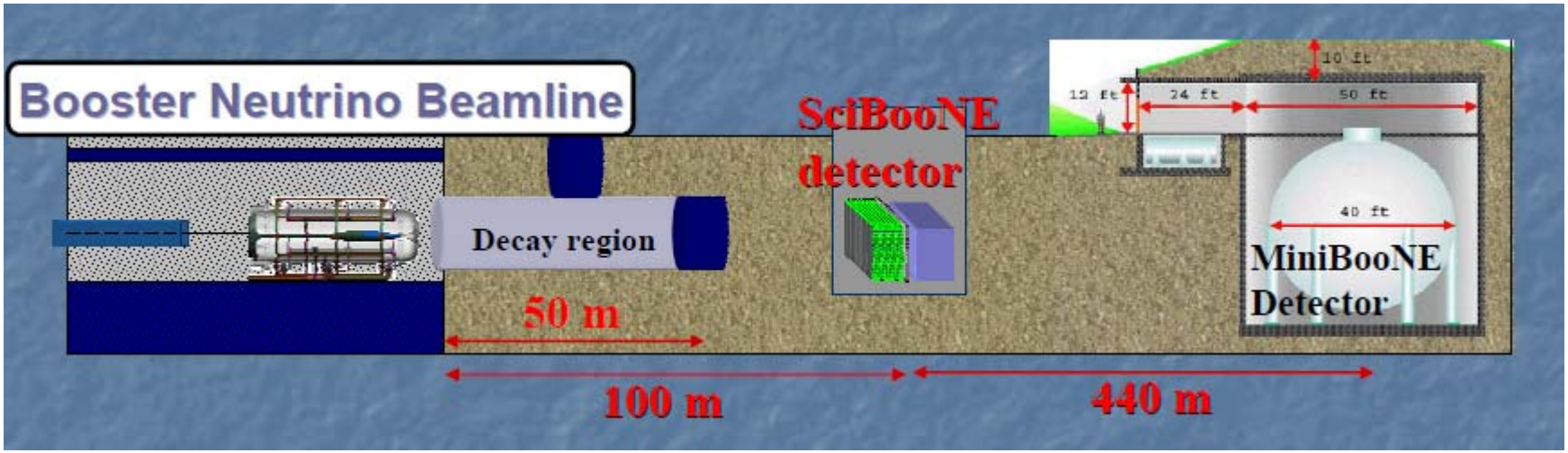
- Br~<0.5%
- But NC $\Delta \rightarrow N\gamma$ can be background events in $\nu_\mu \rightarrow \nu_e$ appearance search
- Following modes are considered
  - CC : $\nu + n \rightarrow l^- + p + \gamma$
  - NC : $\nu + n \rightarrow \nu + n + \gamma$
  - NC : $\nu + p \rightarrow \nu + p + \gamma$

atmospheric neutrino flux update

- Honda flux for atmospheric ν is updated (Honda06)
  - It take the most reasonable primary flux model
  - Hadron interaction model is modified
    It reproduces the observed μ fluxes
  - Calculation for solar modulation is updated with the BESS observation



SciBooNE実験

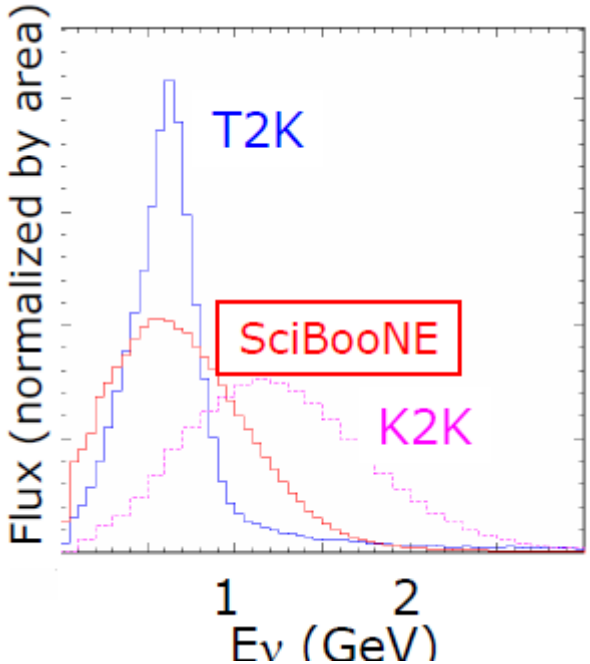


SciBooNE (FNAL E954)

- Precise study of neutrino-nucleus cross section around 1GeV
- Combination of Booster Neutrino Beam at FNAL and SciBar Detector used in K2K

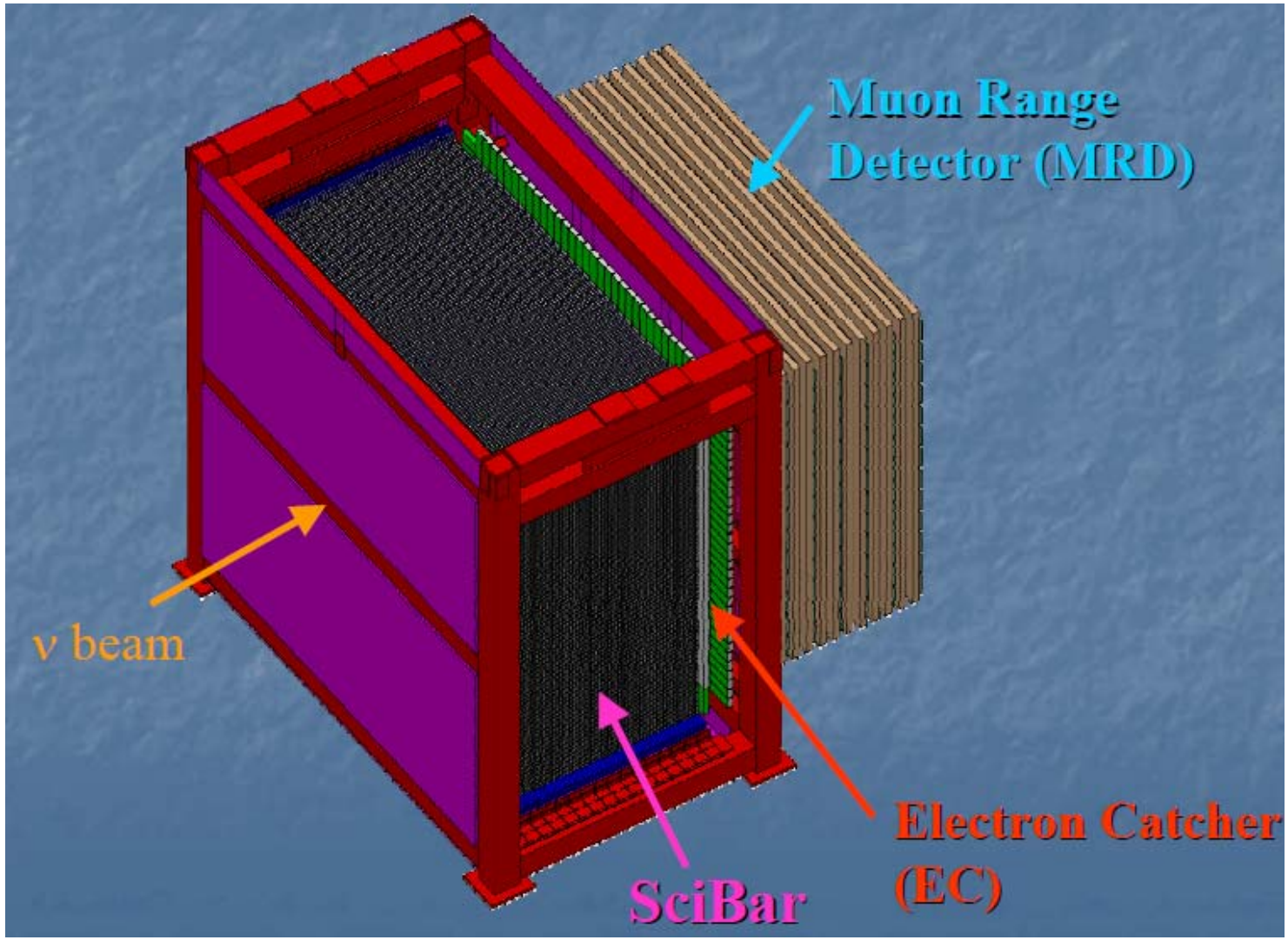
Physics motivation

- Precision study of neutrino cross section for T2K
- Anti-neutrino run
- MiniBooNE near detector



- $1x10^{20}$ POT for neutrino
- $1x10^{20}$ POT for anti-neutrino

SciBooNE 検出器



SciBooNE

- Sep/2006 Ground breaking
- Apr/2007 Detector installation
- May/2007 Commissioning
- Jun/2007 anti-neutrino data run
- Oct/2007 neutrino data run

Summary

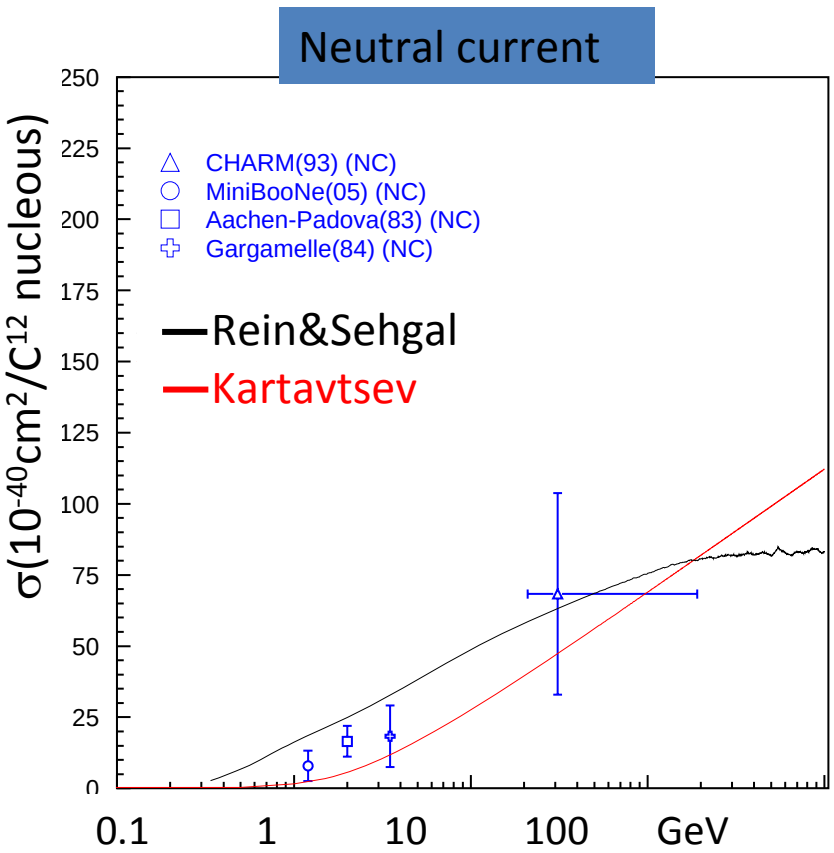
- neutrino interaction simulation is updated
  - QE interaction model (systematic study)
  - $\Delta \rightarrow N\gamma$
  - atmospheric neutrino flux
  - etc
- SciBooNE experiment
  - neutrino/anti-neutrino beam around 1GeV
  - precise information will be obtained
- T2K will start from Apr/2009

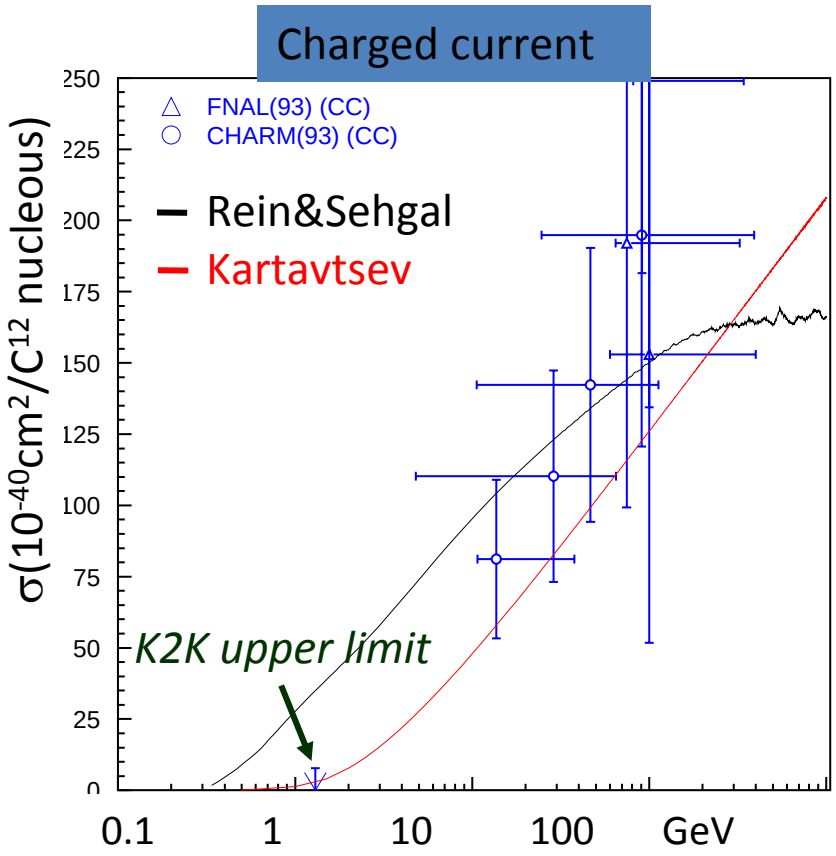
backup

Coherent pion production

Comparison of Rein & Sehgal and Kartavtsev, Paschos & Gounars model

by Mitsuka、Hayato

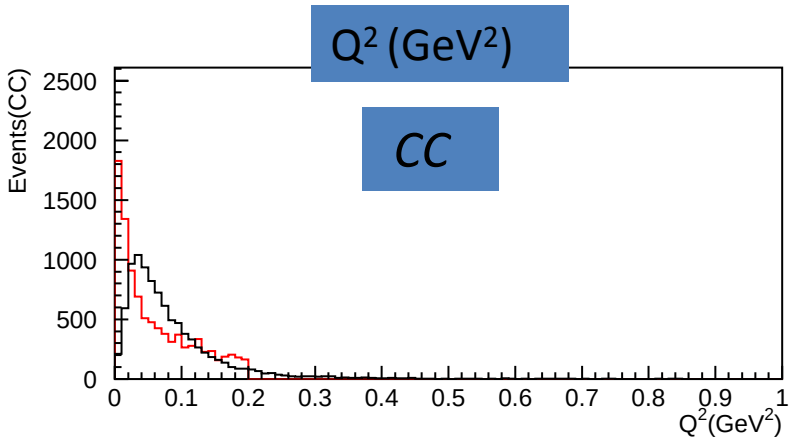


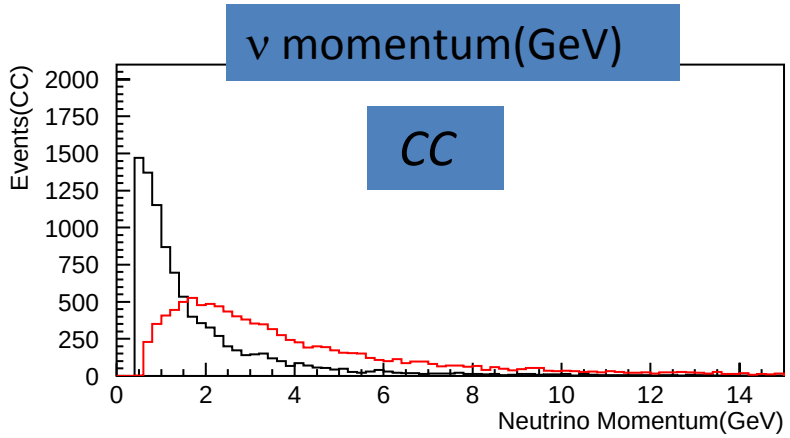


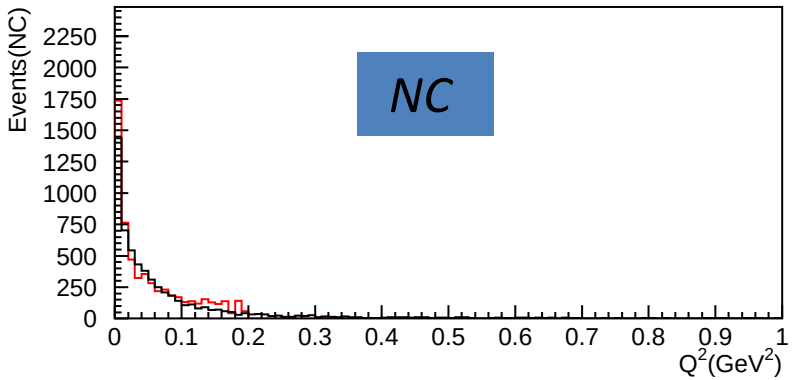
- Both Rein&Sehgal and Kartavtsev model agree experimental data in view of the large experimental errors, except for K2K result in CC
- *Kartavtsev model agrees K2K result*

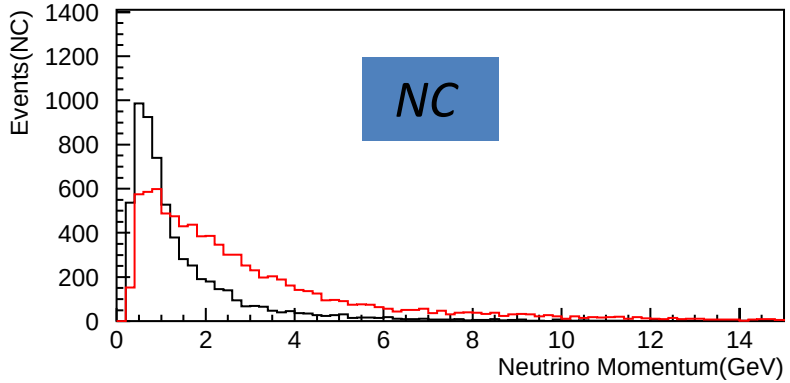
Coherent pion production

Black : Rein&Sehgal, Red : Kartavtsev *(normalized by number of events)*





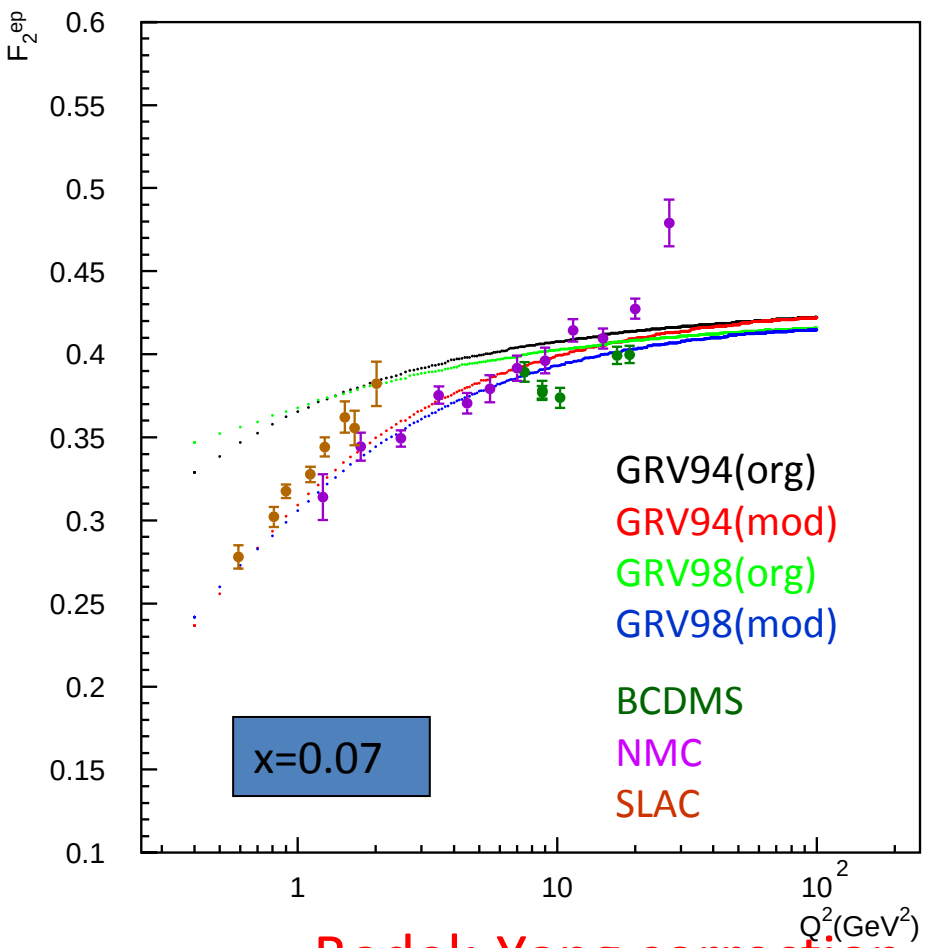


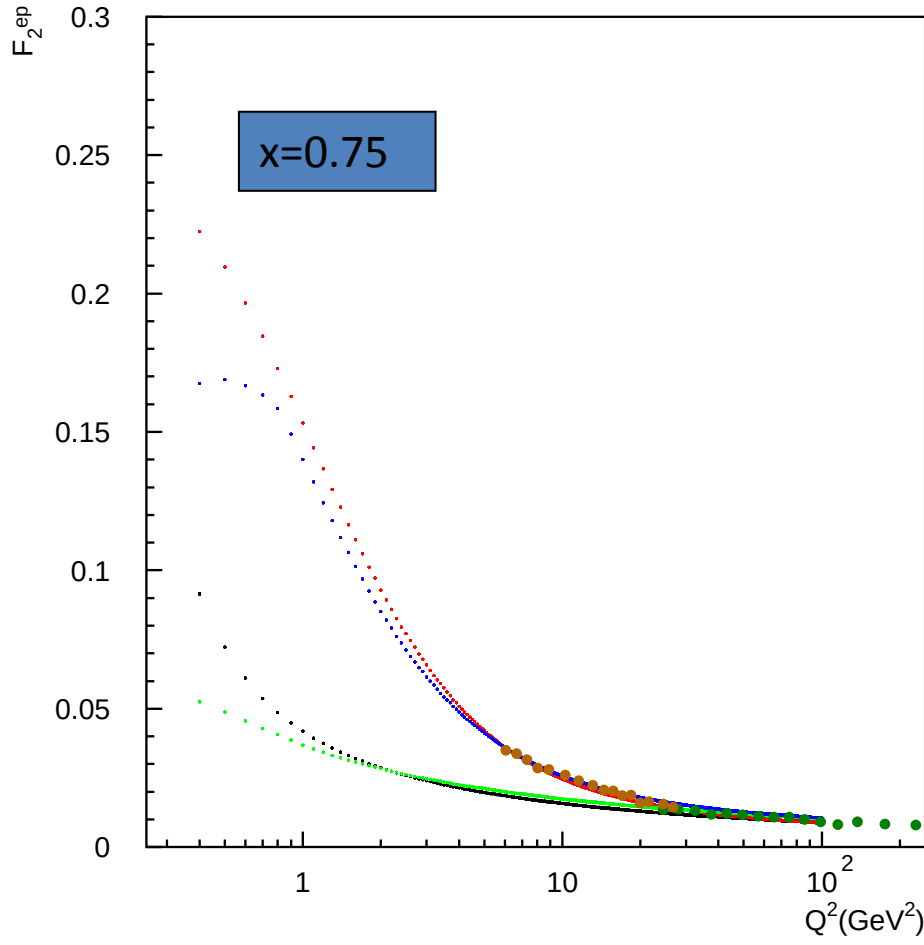


We need more data and study of the effect for neutrino oscillation study.

Deep inelastic scattering

Comparison in $F_2(e^- \rightarrow p)$

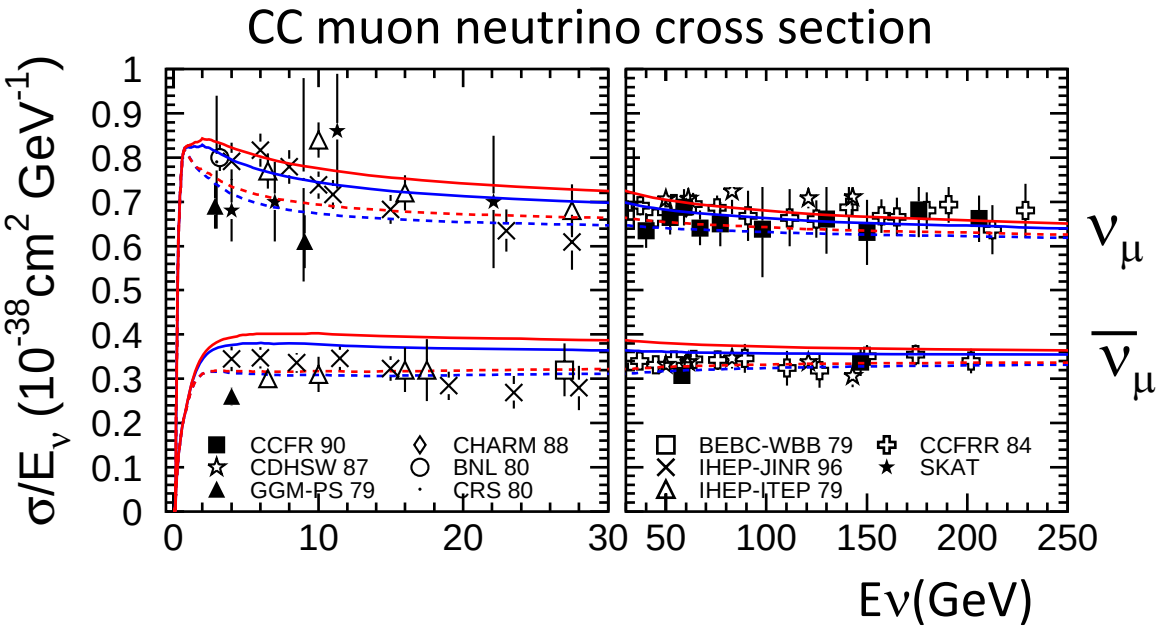




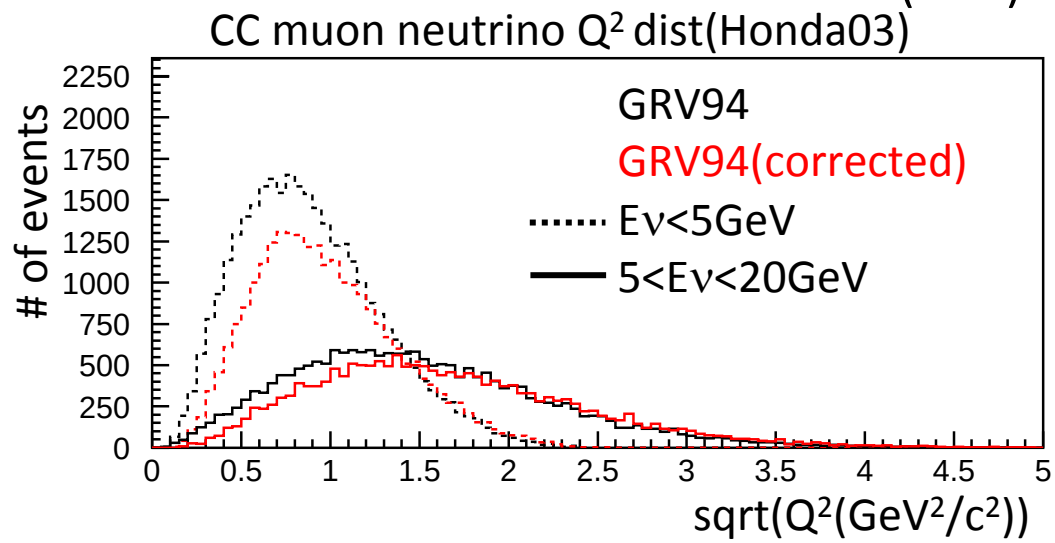
Bodek-Yang correction

Corrected PDFs show good agreement with experimental data in both x region

Deep inelastic scattering



GRV94
GRV94(corrected)
GRV98
GRV98(corrected)



Deep inelastic scattering

Summary of Bodek-Yang correction

1. Bjorken scaling x→ x_w

$$x_w = x\frac{Q^2 + B}{Q^2 + Ax}$$

A : target mass effect
higher twist effect
B : nonzero F_2 as $Q^2 \to 0$

2. Structure function F_2

$$F_2(x) \to \frac{Q^2}{Q^2 + C} F_2(x_w)$$

In order to fit both intermediate-x and low-x

3. d/u ratio

$d_v \to d'_v(d_v, u_v)$
$u_v \to u'_v(d_v, u_v)$

Correction for conversion $F_2^d \to F_2^n$

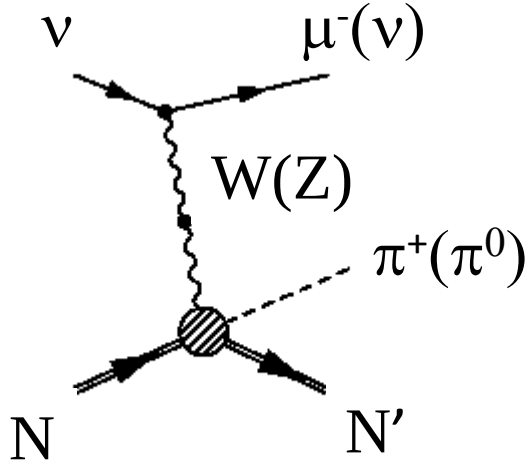
4. Longitudinal R

Correction for spin of target particle

$$2xF_1 = F_2 \frac{1 + 4Mx^2/Q^2}{1 + R}$$

Coherent pion production

- K2K-SciBar group reports that CC coherent pion production is not observed at about 1GeV
- In CC, $\nu + {}^{16}O \rightarrow l^{-(+)} + {}^{16}O + \pi^{+(-)}$ produces a charged lepton, effect of lepton mass on cross section is not negligible at lower energy



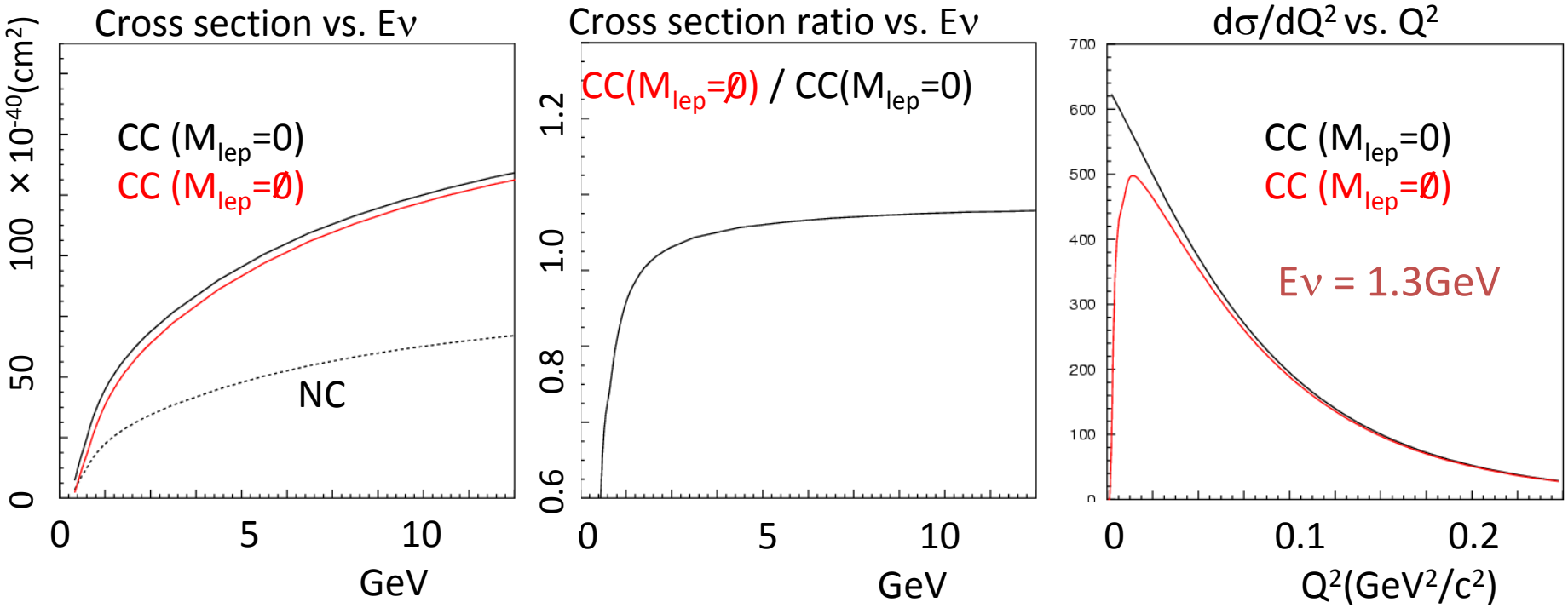
CC NC

$$\frac{d\sigma^{\pi+}}{dxdy} = 2\frac{d\sigma^{\pi 0}}{dxdy} \times \left\{ \left(1 - \frac{1}{2}\frac{Q^2_{\min}}{Q^2 + m^2_\pi} \right)^2 + \frac{1}{4} y \frac{Q^2_{\min}\left(Q^2 - Q^2_{\min}\right)}{\left(Q^2 + m^2_\pi\right)^2} \right\}$$

x,y : Bjorken scaling where $Q^2_{\min} \propto m_{lepton}, y$ $Q^2 \propto x, y$

(Rein & Sehgal Nucl. Phys. B233,29 Rein & Sehgal hep-ph/0606185)

Coherent pion production



- Lepton mass correction reduces cross section by 15% at 1GeV, 5% at 3GeV
- Effect is appeared in small Q^2 region(<~0.1GeV^2/c^2)
- Difference between Rein&Sehgal model(M_{lep}=0) and K2K results becomes smaller, but not compatible

Coherent pion production

- Kartavtsev, Paschos & Gounaris model is tried (Phys. Rev. D **74**, 054007 (2006)) as one option
- Kartavtsev model describes kinematics and cross section taking into account lepton mass

Summary of Kartavtsev model

- Based on the partial conservation of axial current(PCAC), same as Rein & Sehgal
- Adler relation(formula for weak current cross section) is not used
- need π-nucleus scattering experimental data