Research project on neutrino-nucleus interaction and J-PARC branch of KEK theory center

T. Sato (Osaka U.)

2014 Feb. 9, J-PARC

Neutrino physics as activity of the J-PARC branch, KEK theory center(2011~)

4 KEK staff members in hadron physics (A. Dote, K. Itakura, S. Kumano, O. Morimatsu)
5 Visiting staffs
(2011~2013) T. Harada, E. Hiyama, D. Jido, M. Oka, T. Sato(neutrino physics)
(2013~)T. Harada, S. Hirenzaki, A. Hosaka, K. Saito(neutrino physics), K. Tanaka

Workshop, collaboration meeting, seminar at J-PARC

- **Communications between theorists and experimentalists**
- **Promotion of J-PARC projects from theory side**

Research project ‘unification and development of the neutrino science frontier’ (2013~2018)

Measurement of neutrino oscillation using a neutrino beam from the J-PARC accelerator to the Super-Kamiokande detector

Measurement of neutrino oscillation by observation of reactor neutrinos and further application of the techniques to reactor monitoring technology.

Observation of atmospheric neutrinos. R&D of the next generation nucleon-decay and neutrino detector “Hyper-Kamiokande” is promoted.

Investigation of deep space by observation of ultra-high-energy cosmic neutrinos. We will advance research and development of detectors based on new technologies: 3D imaging andultra-high spatial and energy resolutions.

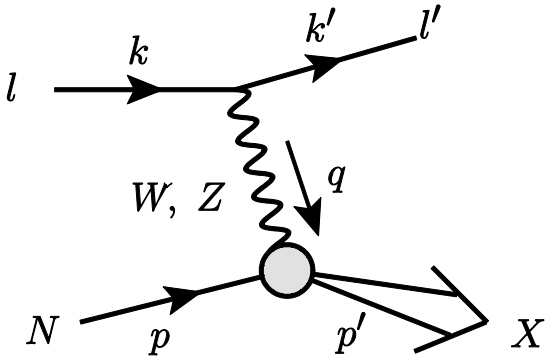
In theoretical studies, we will investigate theories to explain phenomena associated with neutrinos, nuclear structure and cosmology.

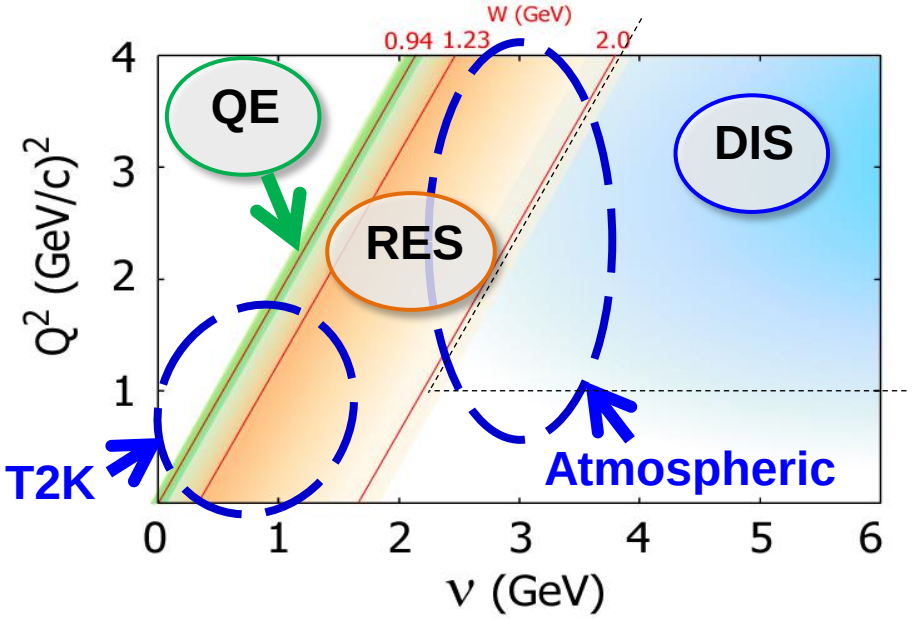
C02

Neutrino-nucleus reaction from MeV to GeV

Collaboration at J-PARC Branch of KEK theory center

Objective: construct reaction model





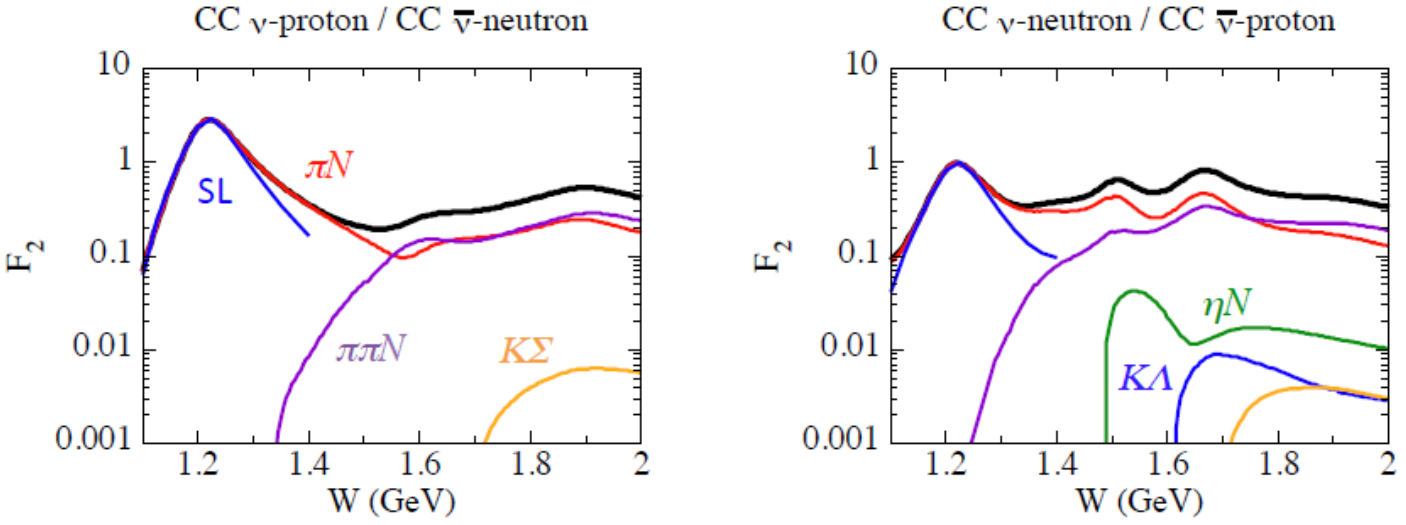
RES : W<2GeV
DIS : W>2GeV, Q^2>1GeV^2

Extension of ANL-Osaka dynamical model of meson production reaction for neutrino reaction on nucleon

H. Kamano et al. PRD86 097503(2013)

Predict F_2(Q^2=0,W) for neutrino-nucleon reaction

pion, kaon, eta, two-pion production in the resonance region



T. –S. H. Lee's talk

Extraction of neutrino flux

T. Murata, T. Sato (Osaka U.)
in preparation

Exercise: muon distribution of inclusive reaction in QF and resonance region

$$\nu_\mu + {}^{12}C \rightarrow \mu^- + X$$

$$\left(\frac{d\sigma}{d\Omega dE_\mu}\right)_{obs} = \int dE_\nu \left(\frac{d\sigma(E_\nu)}{d\Omega dE_\mu}\right) \phi_{\nu_\mu}(E_\nu)$$

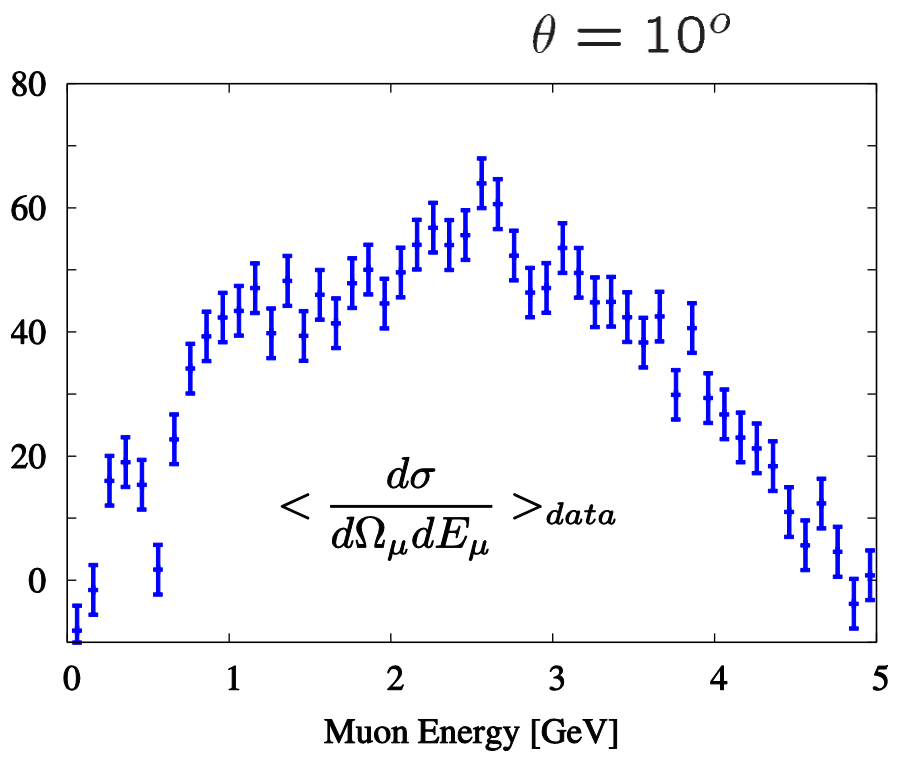
MEM

To test the method:

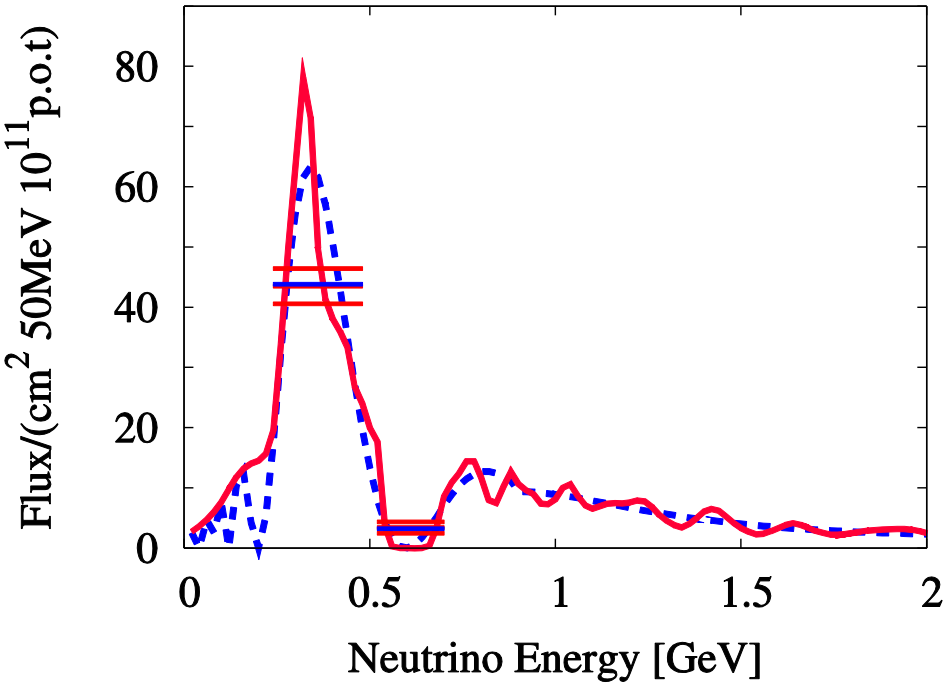
'obs' muon energy and angular distributions:generated by using T2K flux + QE+1pi(dynamical model)+structure function.

Preliminary result

Muon energy distribution



Extracted neutrino-flux

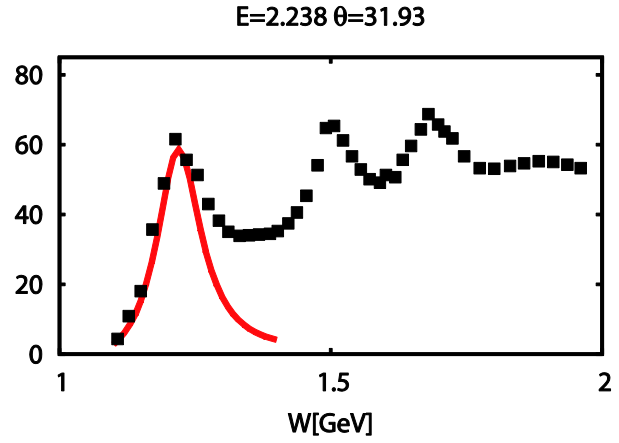


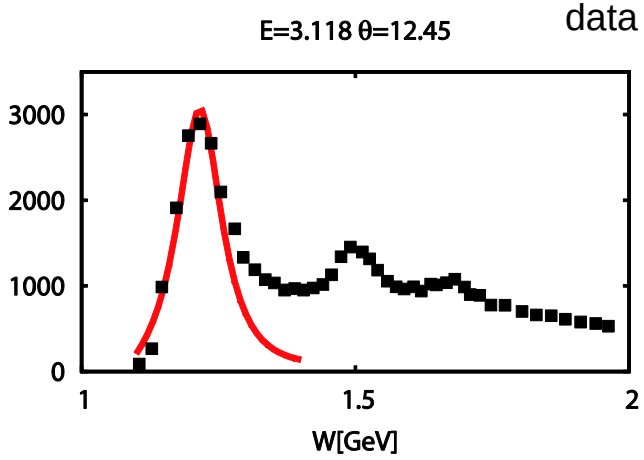
Collaboration at J-PARC Branch of KEK theory center and JSPS project

Y. Hayato(ICRR, U. of Tokyo),
M. Hirai(Tokyo Science U.),
Y. Horiuchi(Hokkaido U.),
H. Kamano(RCNP,Osaka U.),
S. Kumano(KEK),
S. Nakamura(YITP,Kyoto U.),
K. Saito(Tokyo Science U.),
T. Sato(Osaka U.),
M. Sakuda(Okayama U.)

Model of Delta_33 resonance alone: miss strength W>1.3GeV

$p(e,e')X \quad d^2\sigma/d\Omega dE[nb/(srGeV)]$





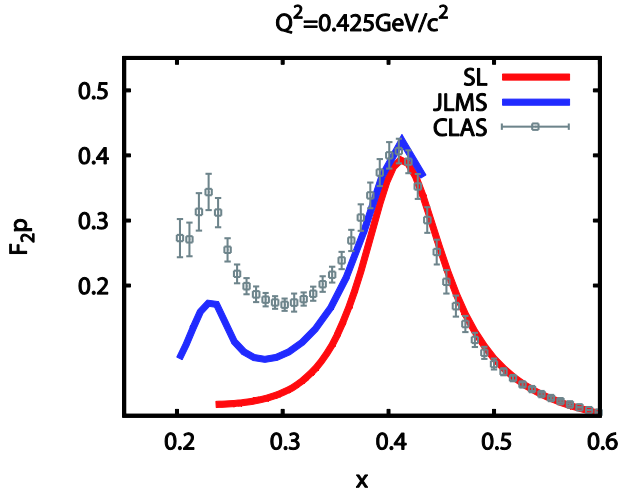
data :PRC81 055213

SL-Model

→ fill gap between QE and DIS

by extending EBAC to include Axial current

Data: hep-ph/0309052



Increasing importance of 2pion production above delta

DCC analysis (2006-2009)

From H. Kamano ELPH, Sendai

γN, πN, ηN, $\pi\Delta$, ρN, σN coupled-channels calculations were performed.

Hadronic part

- ✓ $\pi N \rightarrow \pi N$: Analyzed to construct a hadronic part of the model up to W = 2 GeV
  Julia-Diaz, Lee, Matsuyama, Sato, PRC76 065201 (2007)
- ✓ $\pi N \rightarrow \eta N$: Analyzed to construct a hadronic part of the model up to W = 2 GeV
  Durand, Julia-Diaz, Lee, Saghai, Sato, PRC78 025204 (2008)
- ✓ $\pi N \rightarrow \pi\pi N$: Fully dynamical coupled-channels calculation up to W = 2 GeV
  Kamano, Julia-Diaz, Lee, Matsuyama, Sato, PRC79 025206 (2009)

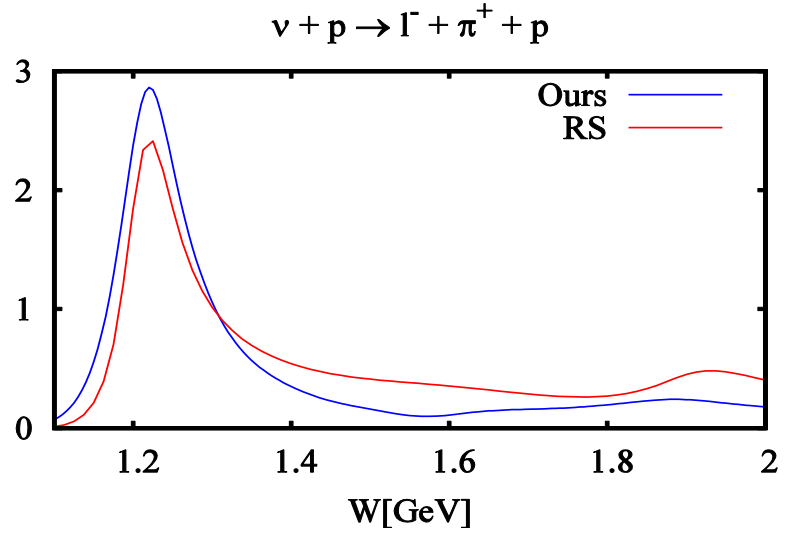
Electromagnetic part

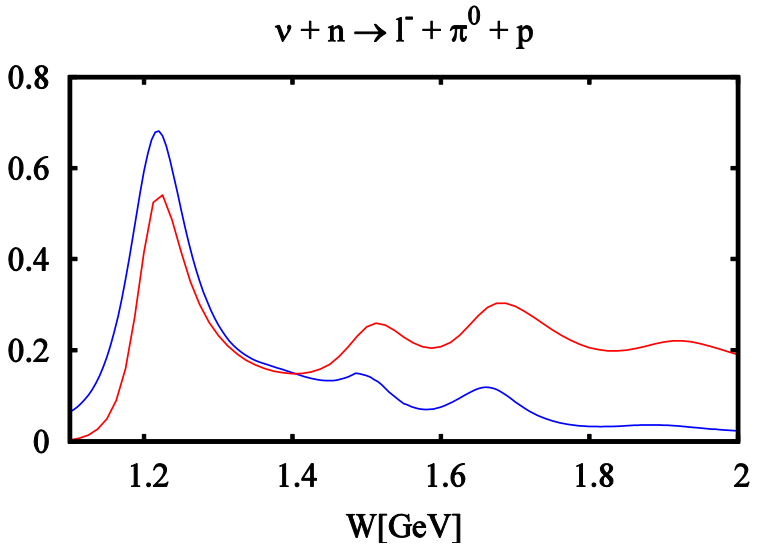
- ✓ $\gamma^{(*)} N \rightarrow \pi N$: Analyzed to construct a E.M. part of the model up to W = 1.6 GeV and Q^2 = 1.5 GeV^2
  (photoproduction) Julia-Diaz, Lee, Matsuyama, Sato, Smith, PRC77 045205 (2008)
  (electroproduction) Julia-Diaz, Kamano, Lee, Matsuyama, Sato, Suzuki, PRC80 025207 (2009)
- ✓ $\gamma N \rightarrow \pi\pi N$: Fully dynamical coupled-channels calculation up to W = 1.5 GeV
  Kamano, Julia-Diaz, Lee, Matsuyama, Sato, PRC80 065203 (2009)

Extraction of N* parameters

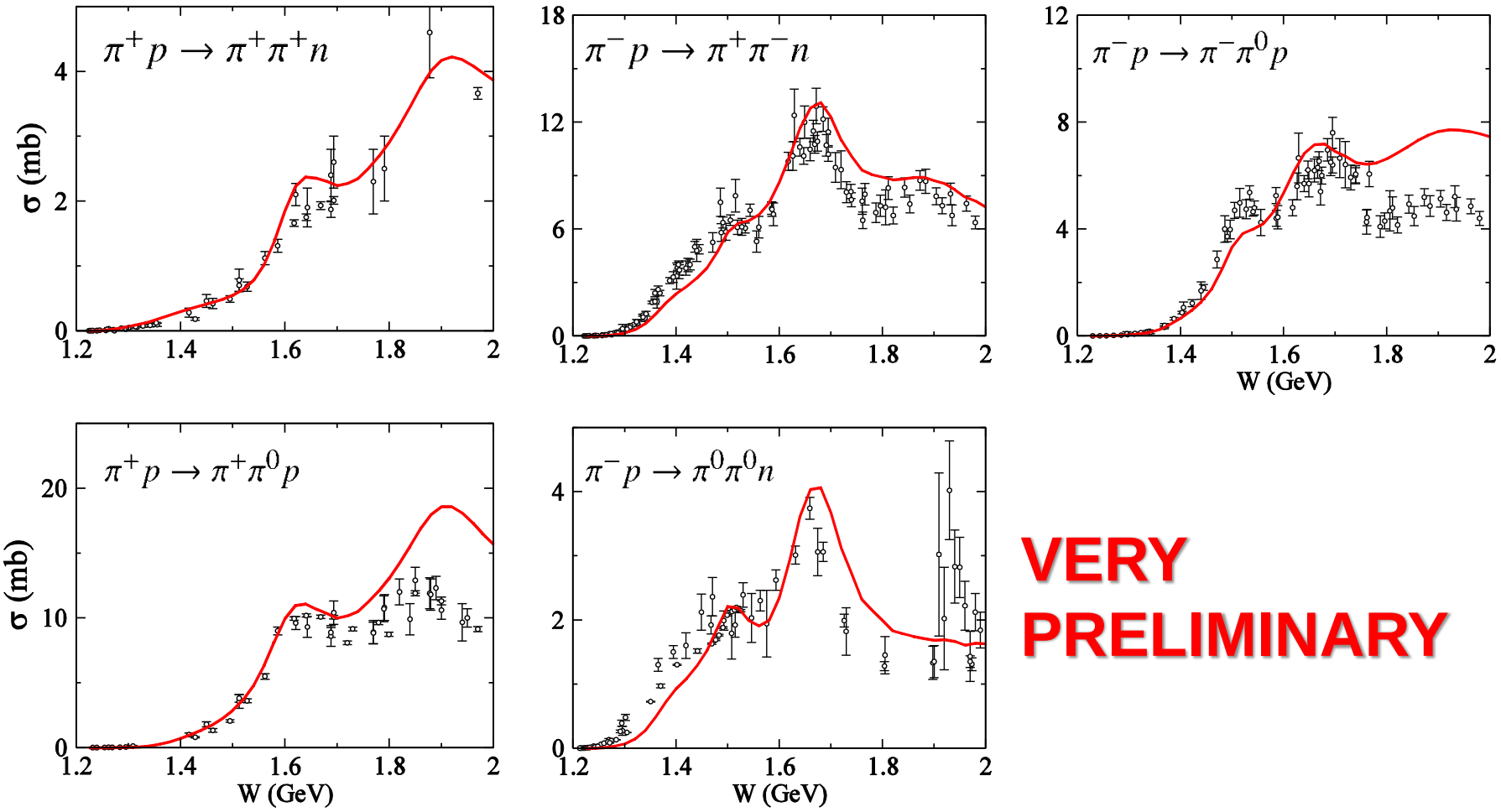
- ✓ Extraction of N* pole positions & new interpretation on the dynamical origin of P11 resonances
  Suzuki, Julia-Diaz, Kamano, Lee, Matsuyama, Sato, PRL104 065203 (2010)
- ✓ Stability and model dependence of P11 resonance poles extracted from pi N → pi N data
  Kamano, Nakamura, Lee, Sato, PRC81 065207 (2010)
- ✓ Extraction of $\gamma N \rightarrow$ N* electromagnetic transition form factors
  Suzuki, Sato, Lee, PRC79 025205 (2009); PRC82 045206 (2010)

Compare ours with Rein-Sehgal Model for single pion production(F_2)





Predictions for πp → ππN total cross sections



VERY PRELIMINARY

From H. Kamano ELPH, Sendai