Neut

current status
and
plan for updates

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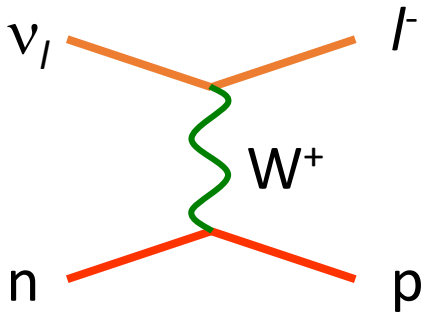
Interaction models in Neut #1 ~ Quasi-elastic scatterings ~

neutrino-nucleus charged current quasi-elastic scatterings



1) Global Simple Fermi-gas model

Formalization by Smith and Moniz

Vector Form factor

dipole & BBBA05, 07.

Axial form factor

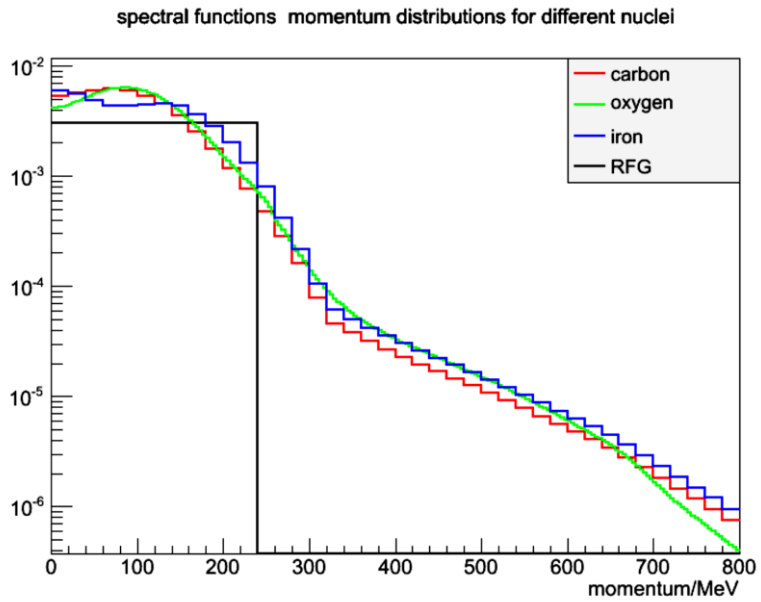
dipole (default M_A 1.0 ~ 1.2)

2) Spectral function

Model / parametrization by

A. Ankowski & O. Benhar

with helps from NuWro group.

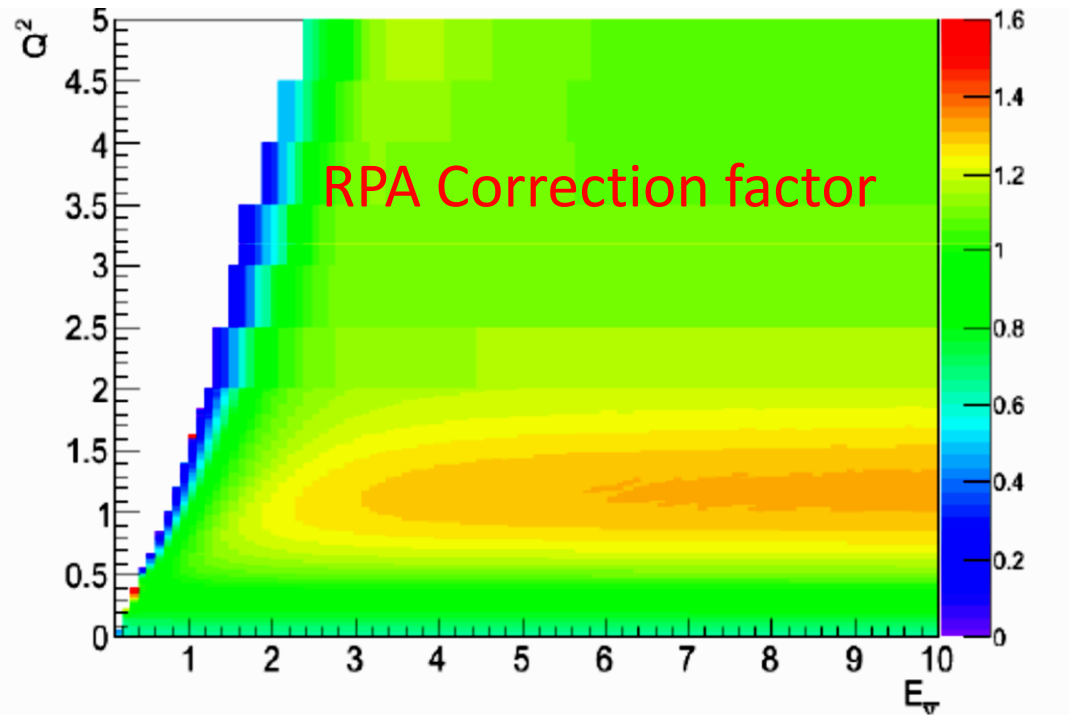


Interaction models in Neut #1 ~ Quasi-elastic scatterings ~

neutrino-nucleus charged current quasi-elastic scatterings

RPA effect as correction for Fermi-gas model
as a function of energy and q^2
(Based on the calculation by J. Nieves et al.)

Recently, we realized that the treatment of
the binding energy is different from our default.
(Neut has been using rather
deep binding energy
compared to the one
used by Nieves et al.)
Therefore, we will adjust
the parameter.



Interaction models in Neut #1 ~ Quasi-elastic scatterings ~

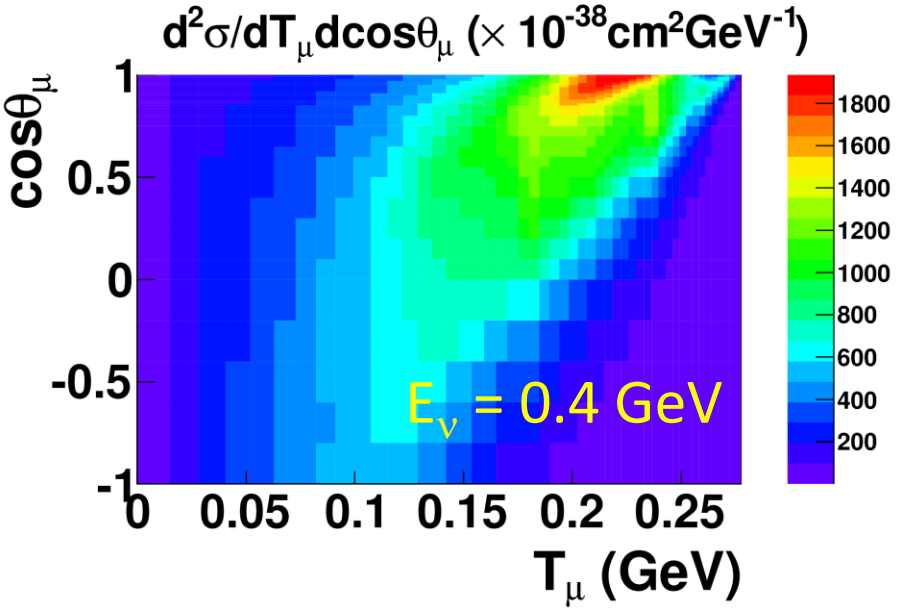
neutrino-nucleus charged current quasi-elastic scatterings

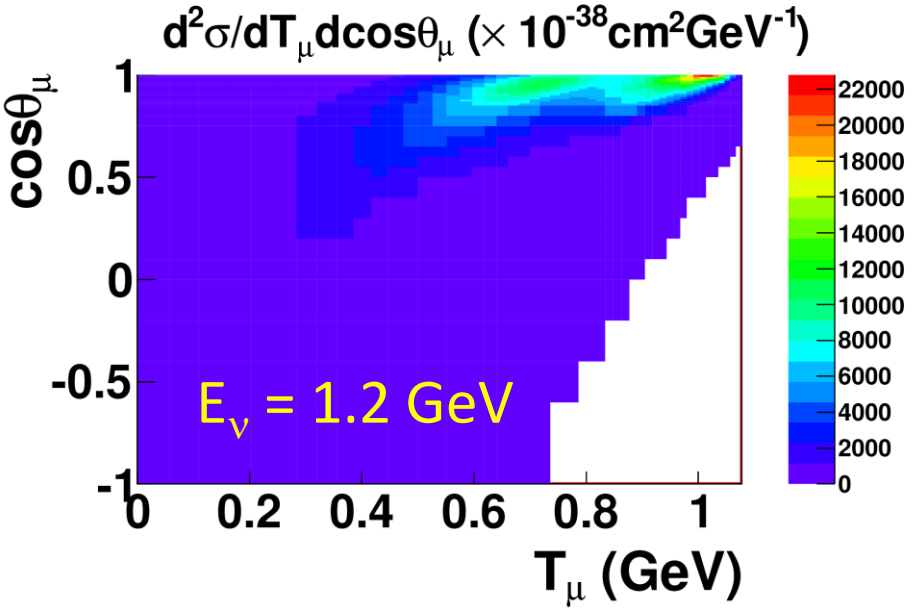
Neut has 2p-2h contribution

(R. Gran et al., Phys. Rev. D88 113007 (2013))

Kinematics of hadrons by J. Sobczyk.

(Phys. Rev. C 86 015504 (2012))



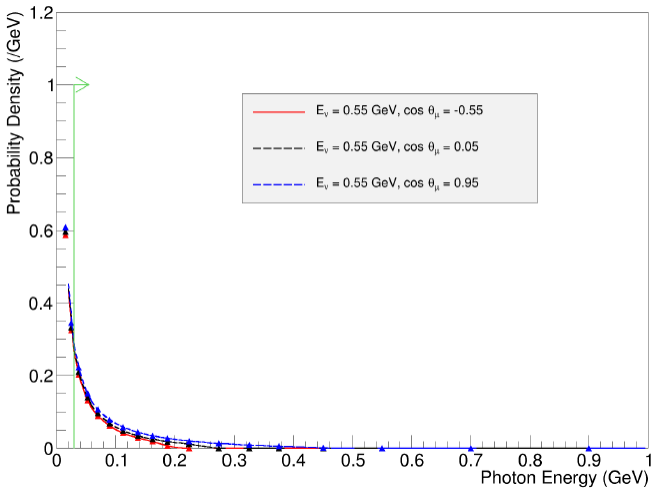


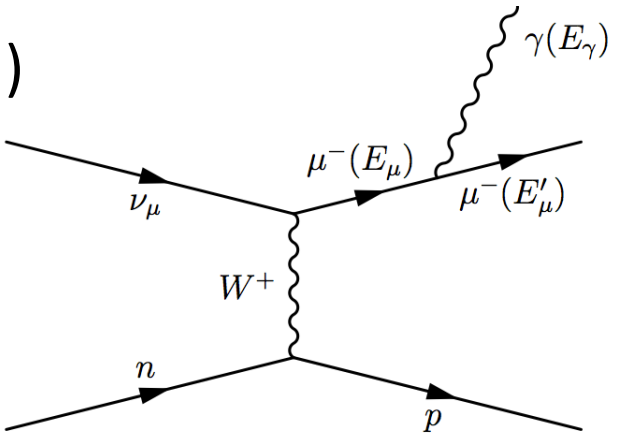
Interaction models in Neut #1 ~ Quasi-elastic scatterings ~

Radiative CCQE is also included

(not as default but available, already)

Work by K. McFarland and K. Iwamoto.





Implement of one consistent model based on J. Nieves et al.

(quasi-elastic + RPA + 2p-2h contribution)

is in preparation.

A group of people lead by F. Sanchez and R. Terri are working

Interaction models in Neut #2 ~ Single π production ~

Attempts to improve the vector form factor in Rein-Sehgal model

- Code to calculate the helicity amplitude
  Provided by the authors
- Calculation of the cross-section ($d\sigma/dq^2dW$)
  Follow the formula in the publications
  Add helicity amplitudes as proposed in the original article
  to take into account the interference of the resonances
- Lepton mass corrections by the same authors
  have been included
- Two form factors are implemented
  Original form factor by Rein & Sehgal
  M_A = 1.21 GeV/c^2 was chosen
  Revised form factor by K.M. Graczyk and J.T. Sobczyk

Interaction models in Neut #2 ~ Single π production ~

For the interaction in nucleus,
initial interactions are modified

- Pauli-blocking effect is taken into account
  Momentum of nucleon after the decay of delta
  has to be larger than the Fermi surface momentum.
  (2 ~ 3 % of the interactions are prohibited.)
- Pion-less delta decay has been implemented
  20% of the delta are assumed to be absorbed.

$$\nu\, N \rightarrow l\, \Delta$$

$$\Delta\, N \rightarrow N\, N$$

~ no pion is produced but lepton and nucleon are ejected
for the interaction in nucleus.

*) When meson exchange current interaction is on,
this feature is turned off by default.

Now, we are trying to include model by M. Kabirnezhad .
Also, model by T. Sato et al. is under consideration.

Interaction models in Neut #3 ~ coherent π production ~

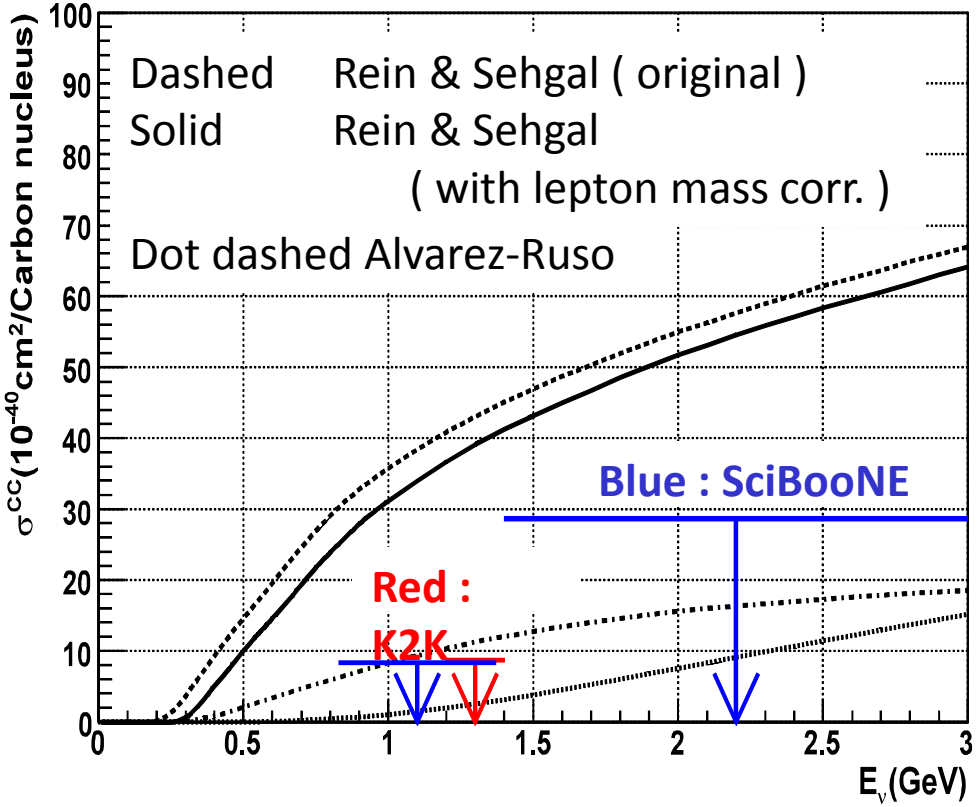
Rein-Sehgal model has been used as default.

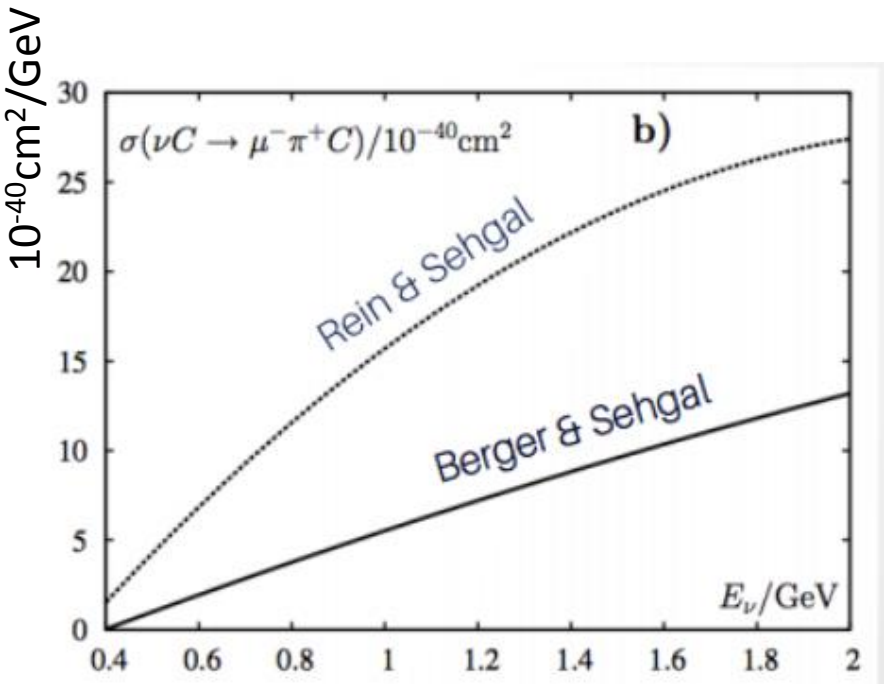
(as a placeholder)

Recently, Berger-Sehgal model is prepared (next release)

(P. Martens with helps from NuWro group.)

$\nu + {}^{12}C \rightarrow l^- + {}^{12}C + \pi^+$





Interaction models in Neut #4 ~ multi hadron production ~ ~ decay of resonances, SIS and DIS ~

	W < 2GeV	W > 2GeV
# of π = 1	Rein & Sehgal	PDF + Custom kinematics (Bodek & Yang Corr.)
# of π > 1	Use PDF + PYTHIA (Bodek & Yang Corr.)	Use PDF + PYTHIA (Bodek & Yang Corr.)

W < 2GeV : Consider # of mesons larger than 1

Use multiplicity function as a function of W

(Single meson productions have been already taken care of by the other model already.)

Experimentally determined multiplicity function is used.

Current version: S. J. Barish et al. Phys. Rev D.17,1 (1978)

$$\langle n_\pi \rangle = 0.09 + 1.83 \ln(W^2)$$

W > 2GeV : Use (old) PYTHIA to generate vectors.

As reported, C. Bronner-san is working on to improve this part.

Also, update PYTHIA from CERNLIB version : By T. Katori.

Interaction models in Neut #5 ~ π re-scattering in nucleus ~

Pion interactions in nucleus, which change the observables.

- Simulated with the cascade model
  - inelastic scattering
    - incl. charge exchange & particle production ($\pi\ N \rightarrow \pi\ \pi\ N$)
  - absorption
- Interaction probability ~ Mean free paths
  - P_π < 500 MeV/c
    - Density dependent mean free path
      - Originally from E. Oset et. al. model
      - Scaled by fitting the π A scattering data
  - P_π > 500 MeV/c
    - Density independent mean free path
      - π-N scattering data + π A scattering data
- Kinematics determination
  - π N phase shift analysis with medium correction (R. Seki et al.)

We will use the results from DUET for further improvements.

Plan for improvement #1 ~ Primary interactions ~

1) Interactions on Deuteron

Discussing the best way

Dedicated model only for Deuteron and Hellium?

2) Quasi-elastic – like (incl. multi-particle interactions)

Implement Local Fermi gas with RPA correction ***(Started!)***

a) *R. Gran, J. Nieves, F. Sanchez, MJ Vicente Vacas*

b) *M. Martini, M. Ericson*

TEM model (*A. Bodek, M. E. Christy, B. Coopersmith*)

3) Single pion production

Model by M. Kabirnezhad will be implemented in ~ year.

(not near term) Nakamura – Sato model

4) Single K production

strangeness violating process ***(Work started)***

5) Single ¥eta production **(Pending)**

new model (currently using resonance decay

using Rein-Sehgal resonance production)

Plan for improvement #1 ~ Primary interactions ~

6) Deep inelastic scattering

Better fragmentation with new data & new PYTHIA

Work started by C. Bronner and T. Katori

Update Bodek-Yang correction

Pending (Need to be included at the same time.)

Plan for improvement #2 ~ Secondary interactions & others

1) pion interactions in nucleus

Validation of the kinematics

Still using rather old “medium correction”

on the pion phase shift analyses results

Validation of the interactions in high momentum region

(P_π > 500 MeV/c)

Model with higher resonances (available??)

Uncertainty of the multiplicity from high momentum pions

(simple cascade model may produce

large number of pions from high momentum pions)

Interactions of energetic pions are getting important for the study of mass hierarchy , octant, and CPV using a few GeV atmospheric neutrinos.

Some work has been started using new DUET data.

Plan for improvement #2 ~ Secondary interactions & others

2) nucleon re-scattering

Current model is so simple.

Correct (better) way to “justify” the current model
and/or “evaluate” uncertainties

Implement more “realistic” model

nucleon emission and re-scatterings are important
not only for the study of accelerator neutrinos
and also in the proposed SK upgrade
to add Gd in the water.

(Neutrons are captured by Gd
and # of neutrons will be another interests
in the analyses.)

Status of the software distribution

We have received several requests to use Neut from experiments.

Super-Kamiokande and T2K collaboration have agreed to provide the software upon the requests.

We are not planning to distribute the software freely because we don't have resources for user support.

Moreover, we don't have appropriate documents for outside.

Therefore, we are planning to assign one corresponding person for each request.