Inelastic neutrino-nucleus scattering in the superscaling model

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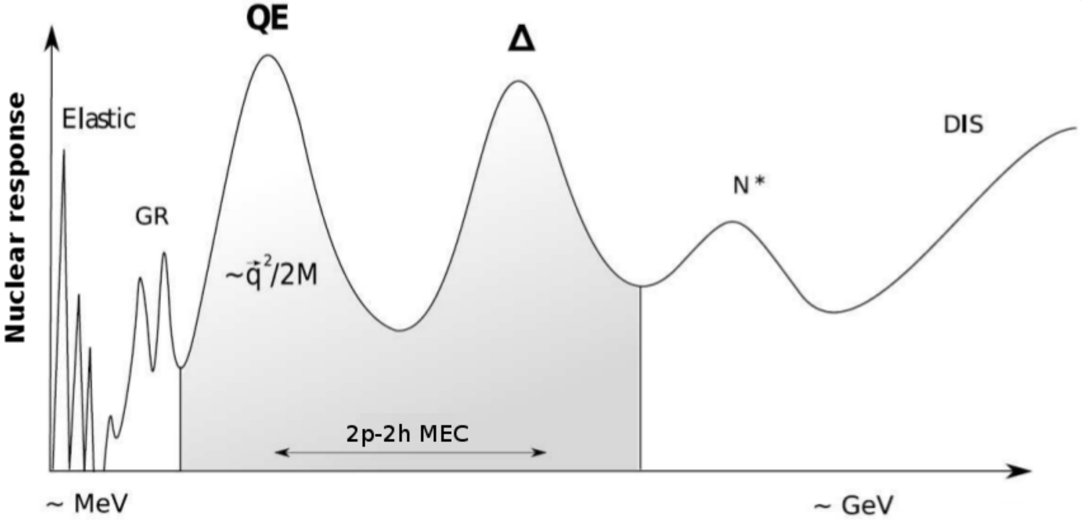
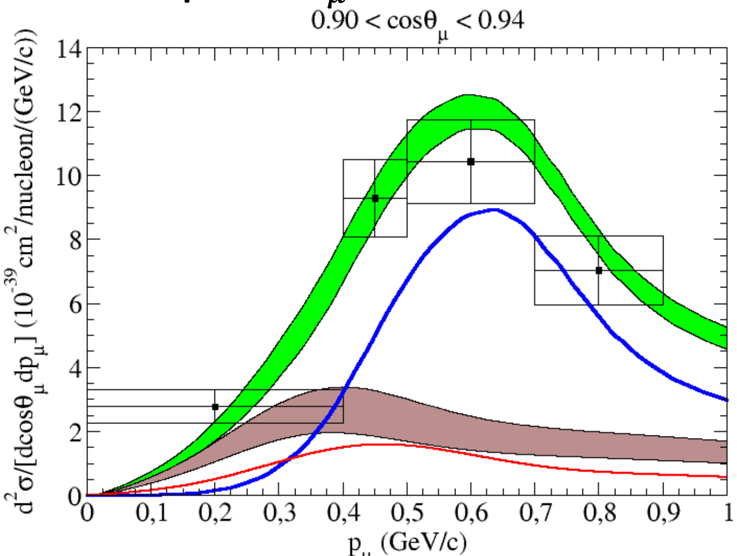
Introduction

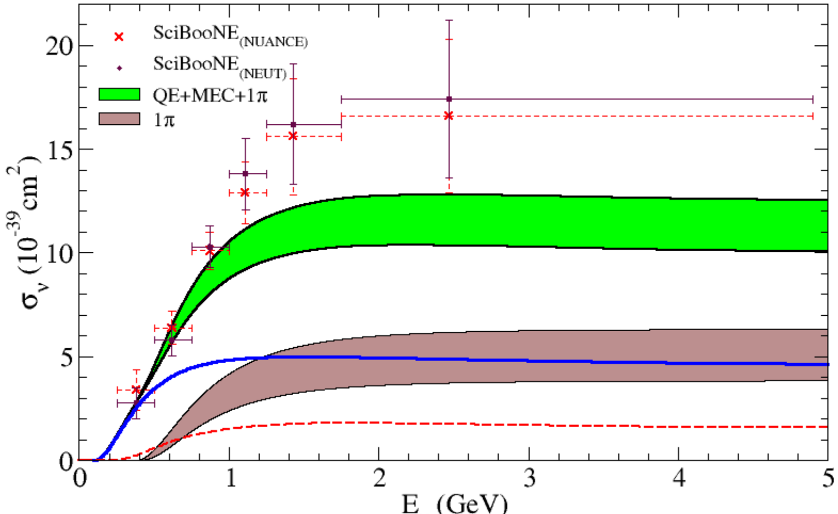


- Quasielastic region.
- 2p-2h excitations.
- **Δ** resonance, other resonances and DIS.

T2K CC ν_μ, $< E_{\nu_\mu} > \sim 0.8\ GeV$, inclusive data



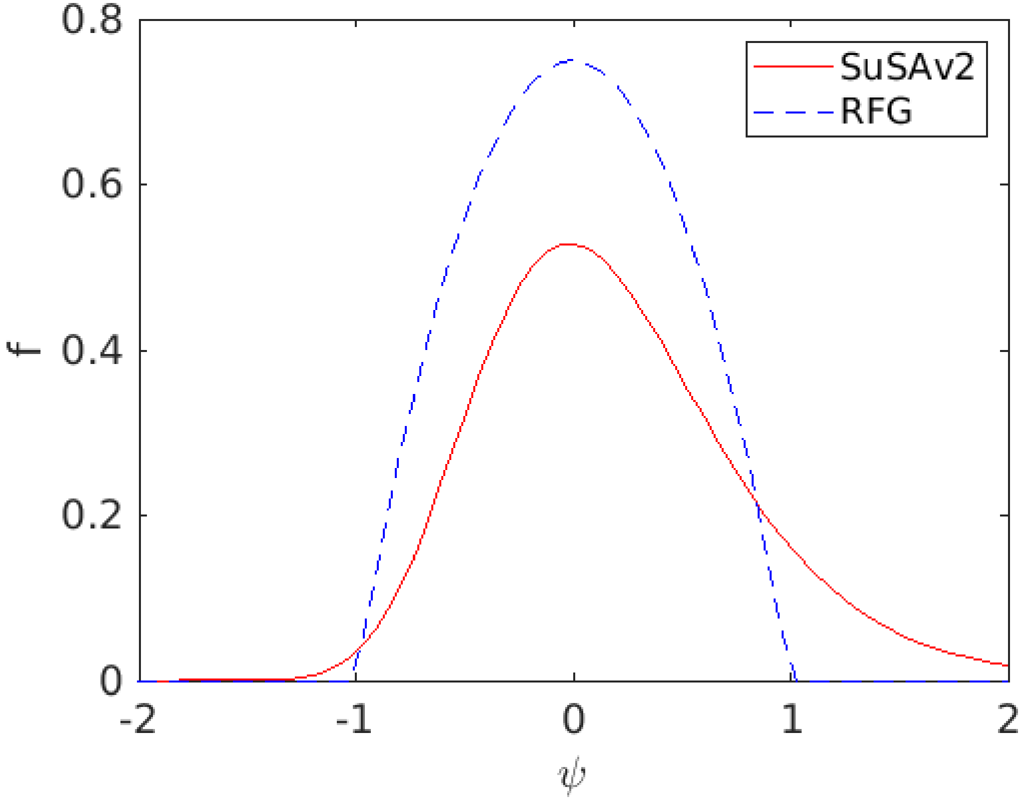
Total Inclusive Cross Section



Superscaling model with QE + 2p2h + 1π [M.V Ivanov et al., J. Phys. G 43, 045101 (2016)].

Introduction.

Comparison between SuSAv2 and RFG scaling function.



$$f(\psi) = k_F \frac{\left(\frac{d^2\sigma}{d\Omega dw}\right)}{\left(\frac{d^2\sigma}{d\Omega dw}\right)_{s.n}}$$

The scaling function does not depend explicitly on the transferred momentum or the nuclear species [J. E. Amaro et al., J. Phys. G 47, 124001 (2020), G. D. Megias, PhD Thesis (2017)].

SuSAv2 model comes from RMF.

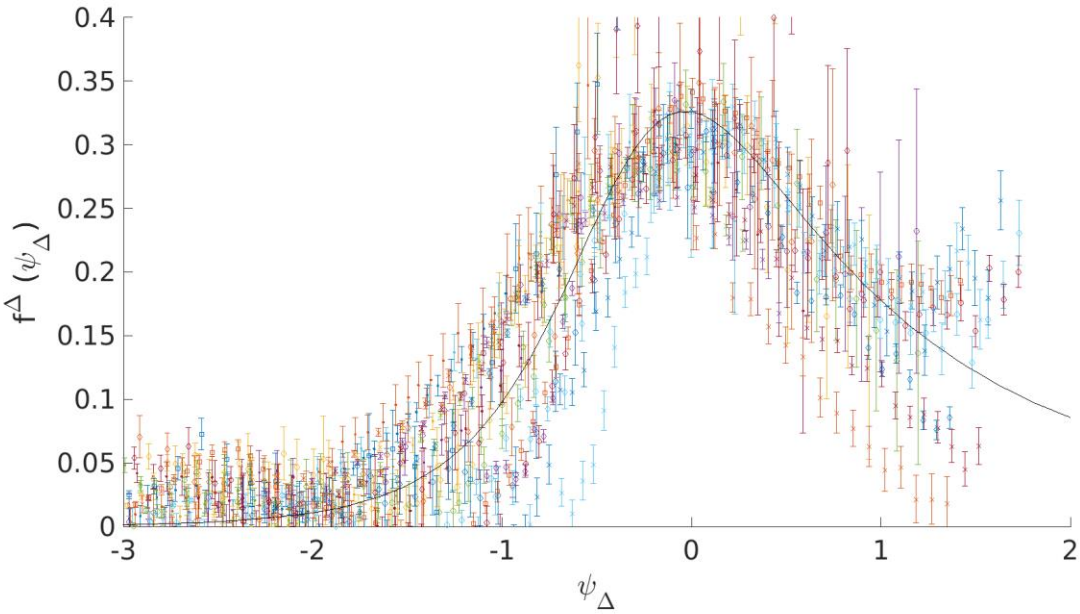
SuSAv2-QE scaling function is going to be implemented in the inelastic regime.

Model: 1π- fΔ

In order to describe Δ resonance region, a Δ pion production model [PRC 71, 015501 (2005)] is used with a phenomenological scaling function.

$$[W^{\mu\nu}]^{\Delta} = \frac{1}{2}\Lambda_0 f^{model} U^{\mu\nu}$$

$$\left(\frac{d^2\sigma}{d\Omega d\omega}\right)^{\Delta} = \left(\frac{d^2\sigma}{d\Omega d\omega}\right)^{exp} - \left(\frac{d^2\sigma}{d\Omega d\omega}\right)^{QE} - \left(\frac{d^2\sigma}{d\Omega d\omega}\right)^{MEC} - \left(\frac{d^2\sigma}{d\Omega d\omega}\right)^{DIS}$$



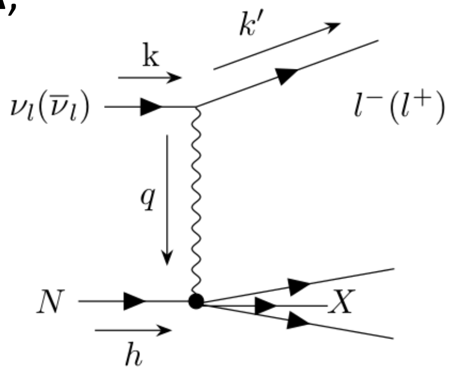
$$f^{\Delta}(\psi_{\Delta}) = k_F \frac{\left(\frac{d^2\sigma}{d\Omega d\omega}\right)^{\Delta}}{\sigma_{Mott}(\upsilon_L G_L^{\Delta} + \upsilon_T G_T^{\Delta})}$$

Model:SuSAv2-inelastic

SuSAv2-inelastic model describes the full inelastic spectrum (Δ, other res. And DIS)[G. D. Megias, PhD Thesis (2017), M. B. Barbaro et al. Phys. C 69, 035502 (2004)]. Good agreement with (e,e') data.

$$R^K_{inel}(\kappa,\tau) = \frac{N}{\eta_F^2\kappa}\xi_F \int_{\mu_X^{min}}^{\mu_X^{max}} d\mu_X f^{model}(\psi'_X) U^k$$

The hadronic response is given by an integration of the single-nucleon tensor over the invariant mass.

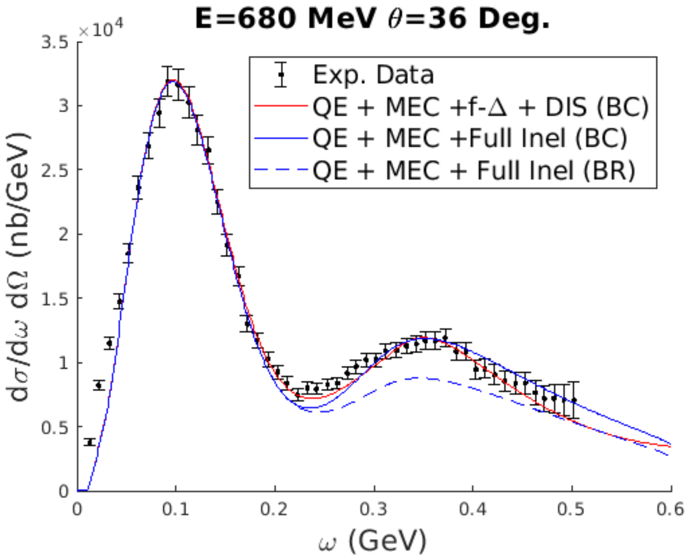


Inelastic Feynmann Diagram

The limits of this integral are

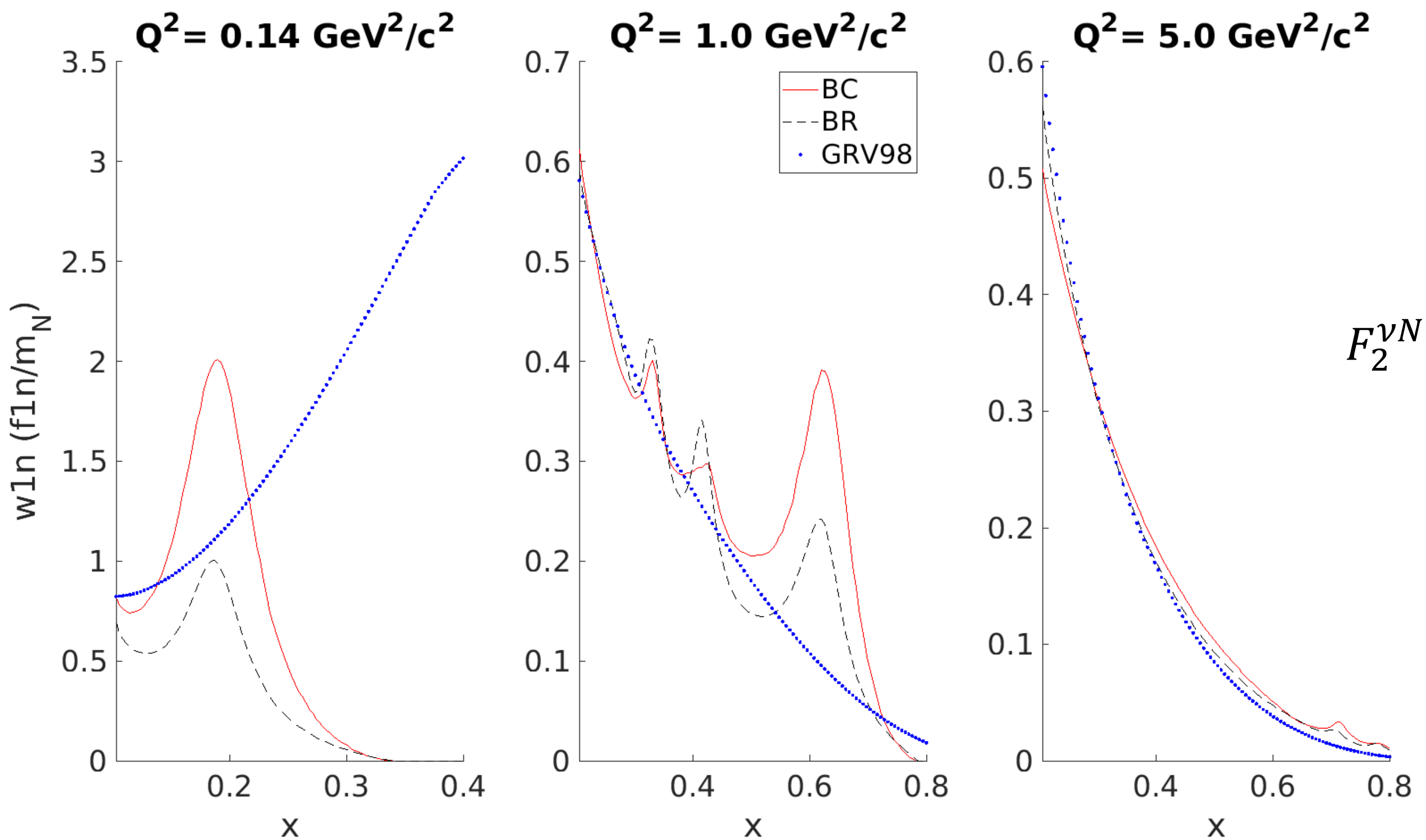
$$\mu_X^{min} = 1 + \frac{m_\pi}{M_N}, \mu_X^{max} = 1 + 2\lambda - \frac{E_S}{M_N}$$

This limits can be changed to work alongside a resonance model.



BR and BC parametrizations (specially BC) work well. PDF gets closer at high ω , but it is not suited to describe Δ region.

Model:SuSAv2-inelastic



$$F_2^{\nu N}(x) \approx \frac{18}{5} F_2^{eN}(x)$$

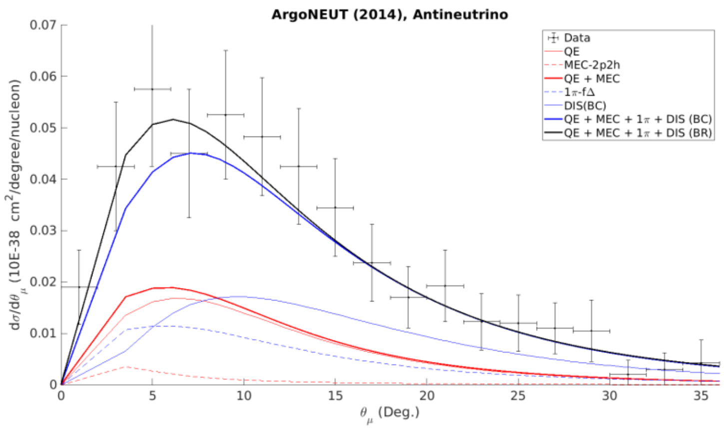
Bodek-Ritchie parametrization [PRD 23, 1070 (1981)].

$$xF_3 = F_2 \; - 2\bar{Q}$$

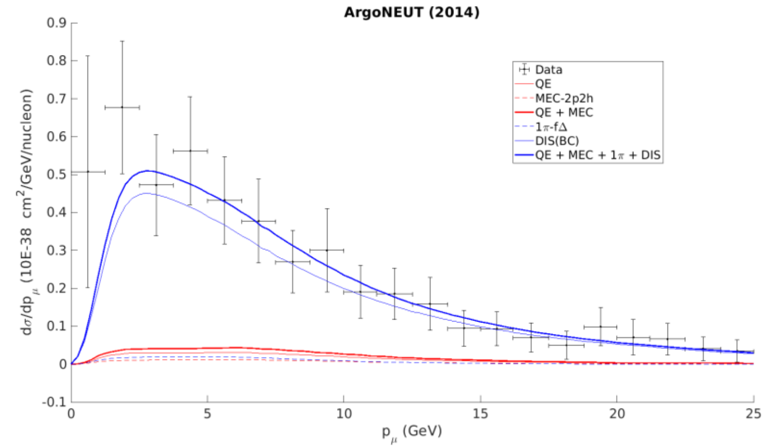
Antiquarks distribution.

Parton Distribution Function. $xF_3^{\nu p(n)} = 2x(d(u) \; + s \; - \bar{u}\,(\bar{d}) \; - \; \bar{c})$

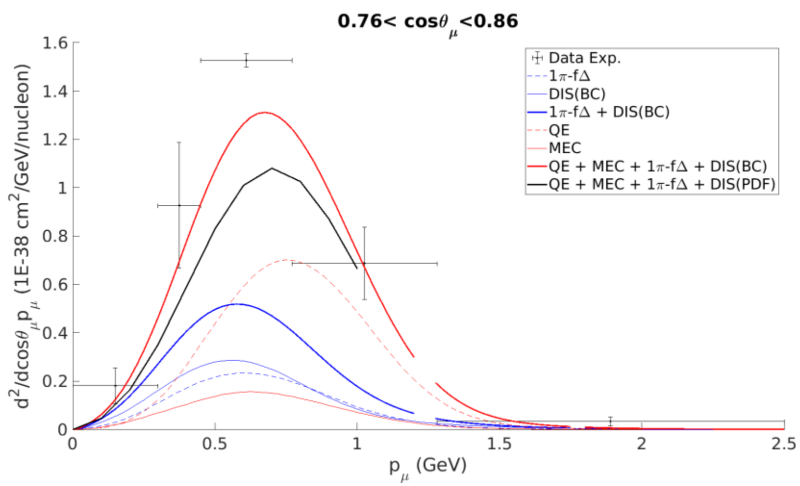
Results



ArgoNEUT CC$\bar{\nu}_\mu$, $< E_{\nu_\mu} > \sim 3.6\ GeV$



ArgoNEUT CC ν_μ, $< E_{\nu_\mu} > \sim 9.6\ GeV$



MicroBOONE CC ν_μ, $< E_{\nu_\mu} > \sim 0.8\ GeV$

Using 1π-fΔ and the SuSA2-inelastc model (DIS). In the case of ArgoNEUT these contribution are needed to explain the experimental data.

Conclusion

- It is necessary to include an analysis of the inelastic scattering to explain the neutrino cross section at certain kinematics.
- The SuSAv2-inelastic works well for electrons and it is expected to performs well for neutrinos.
- In the case of neutrinos, the best option is use a resonance model to reproduce Δ contributions and the SuSAv2-inelastic BC for higher contributions.
- It is necessary better parametrization model at intermediates energies.

Thanks for your attention

Limits of the inelastic region

Kinematically allowed region, recoiling of the daughter nucleus

$$\max[\varepsilon(0), 0] \leq \varepsilon \leq \varepsilon(\pi)$$

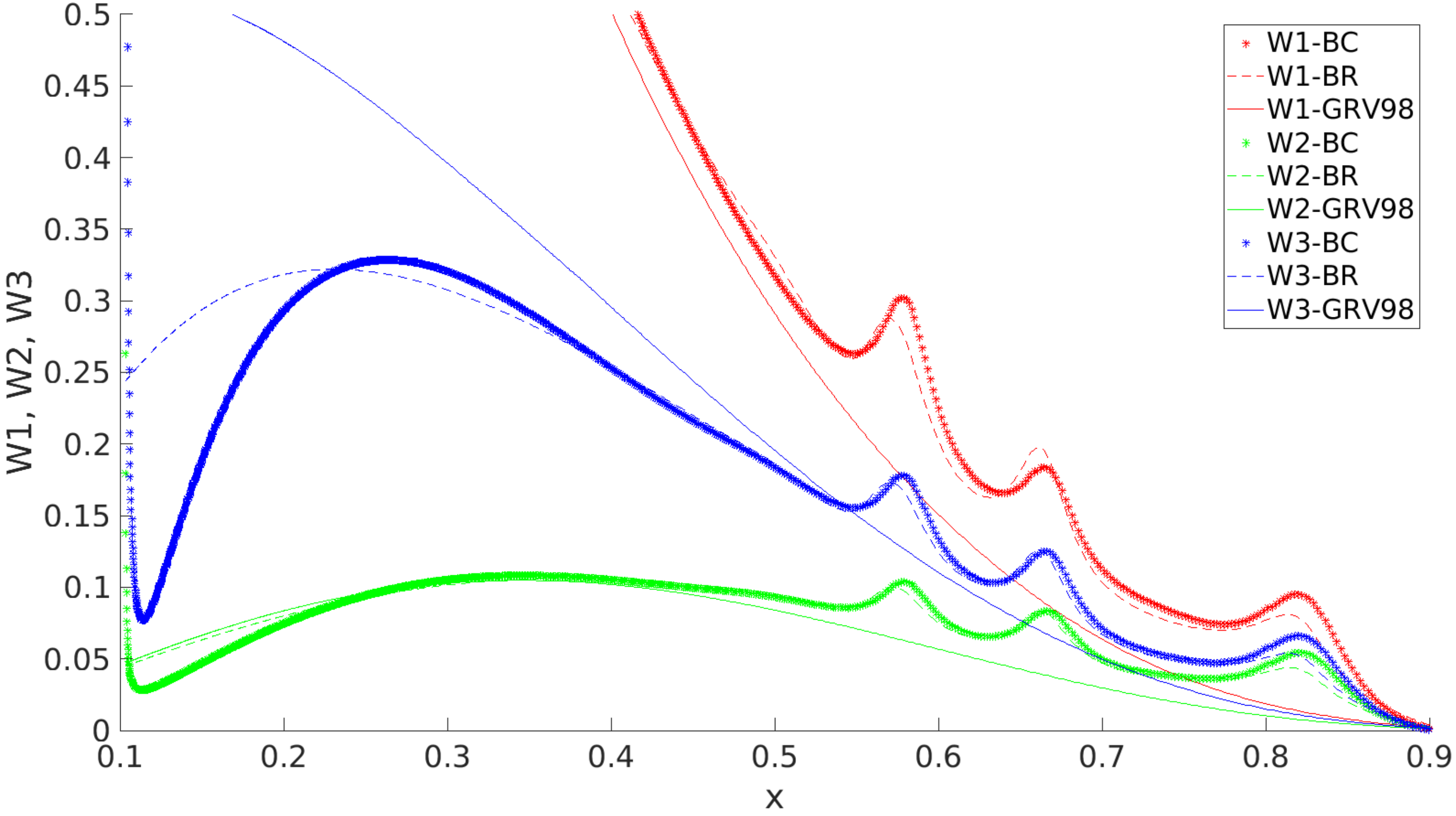
Considering that the mass of daughter nuclei is infinite

$$\varepsilon_{\infty}(\theta) = m_N + \omega - \sqrt{W_X^2 + q^2 + p^2 + 2pq\cos\theta}$$

Considering the limits

$$m_N + m_{\pi} \leq W_X \leq m_N + \omega - E_S$$

W1, W2 and W3



W1-BC
W1-BR
W1-GRV98
W2-BC
W2-BR
W2-GRV98
W3-BC
W3-BR
W3-GRV98
W1, W2, W3
x
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9