GEANT4 ν_μ($\bar{\nu}_\mu$)-nucleus interaction model

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Abstract

Recent GEANT4 developments for muon neutrino hadronic interactions are discussed in the framework of structure function approach. Interface, process, models and cross-sections are implemented. Comparisons with experimental data are presented.

1 Outline

1. Lepton-nucleon Interaction model.
2. Interface (biasing)
3. Comparison with experimental data (total cross-sections, final state generator).
4. Summary.

2 Lepton-nucleon interactions model

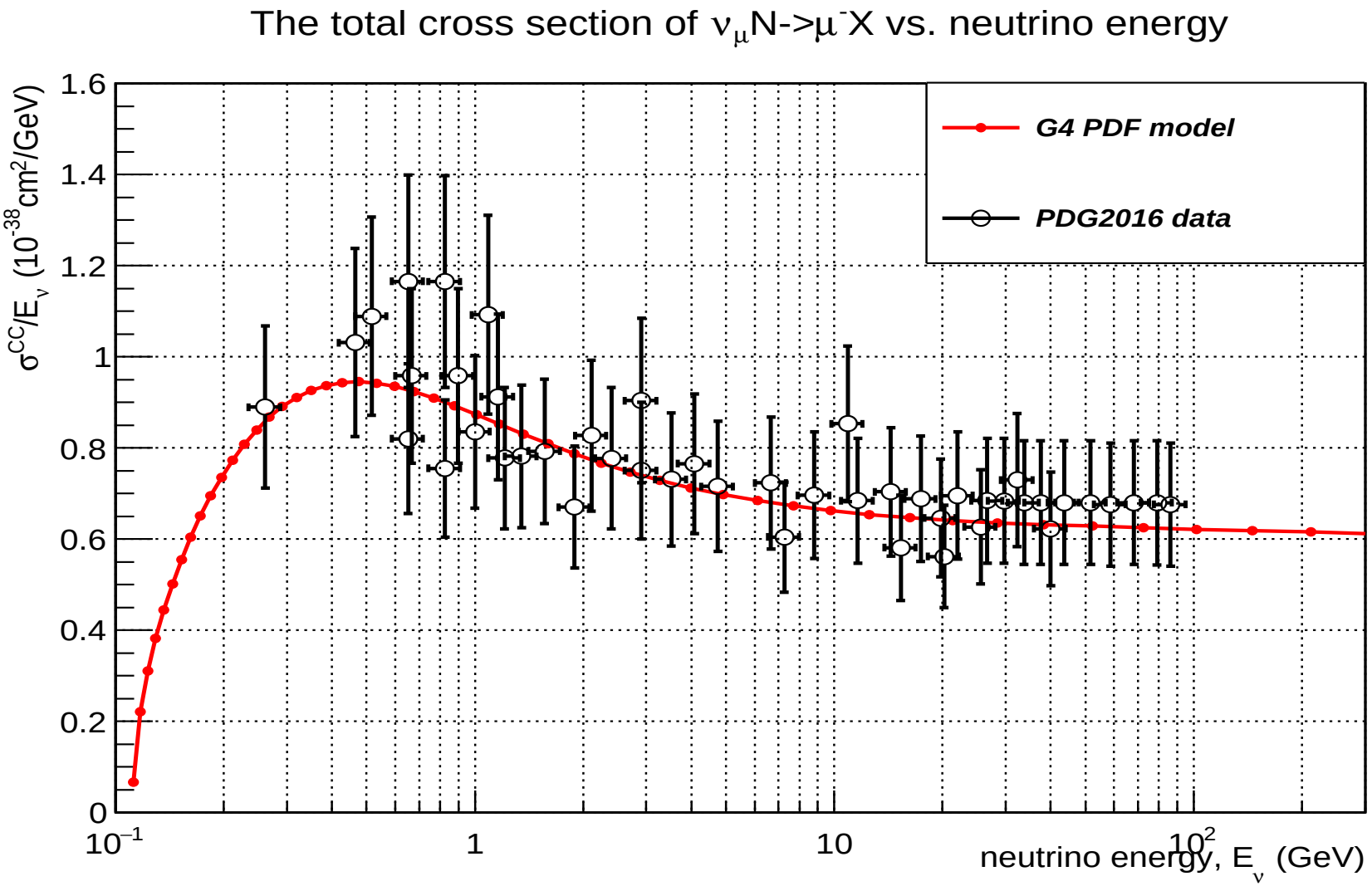
1. Lepton (gamma) hadronic interactions can be described based on the nucleon (nucleus) structure function (SF) approach developed for DIS region and extended to low energy-momentum transfer domain.
2. Low energy-momentum transfer extension (quasi-elastic, coherent pions, resonances) is based on the Capella-Kaidalov-Merino-Tanh (CKMT) approach with resonances included for some regions of x and Q^2.
3. Nucleons are considered to be bound. $1p1h$ and $2p2h$ are implemented with $p_F(A)$ parameterization.

3 GEANT4 interface

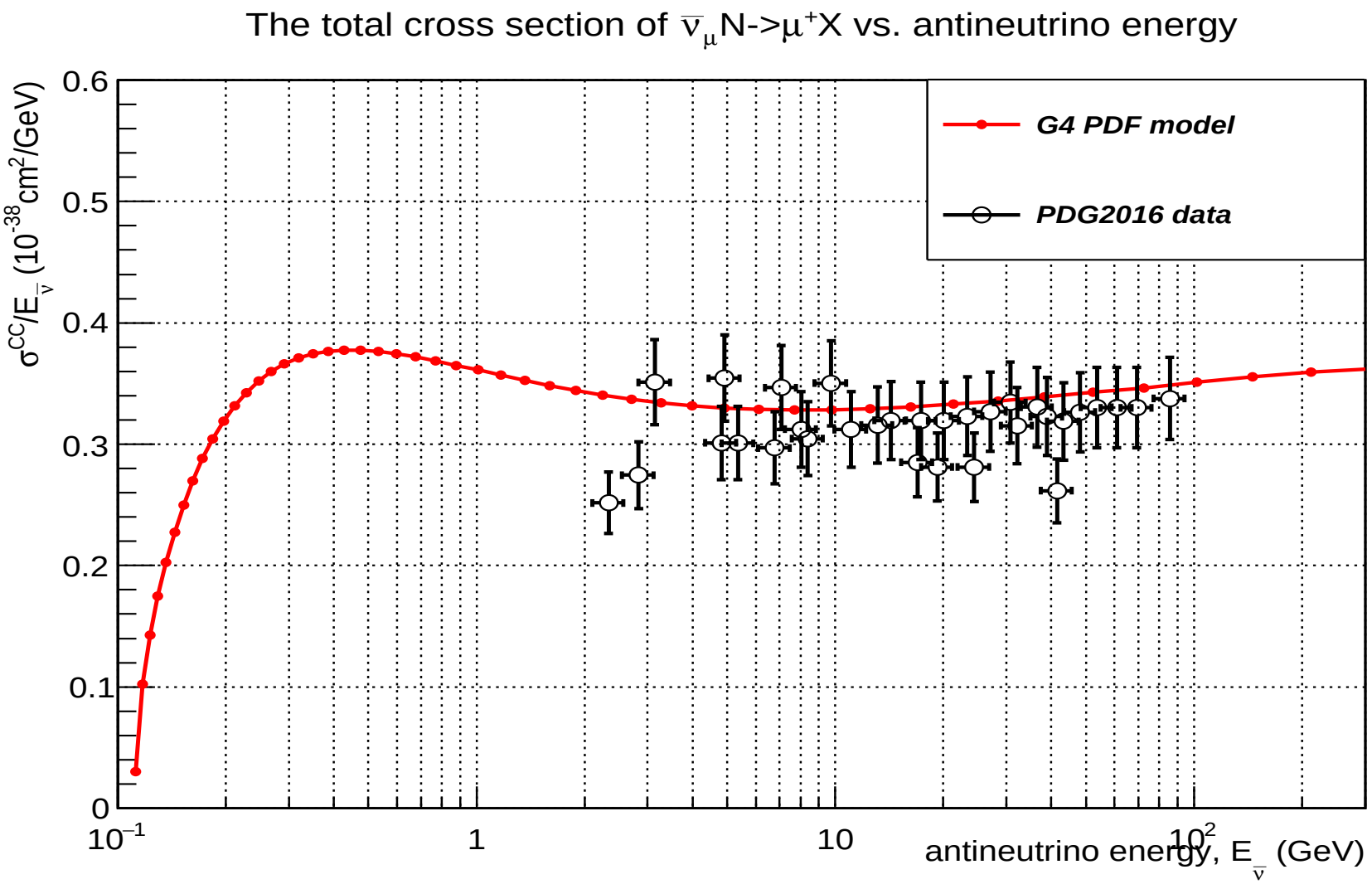
The GEANT4 toolkit provides the user interface with commands, implemented in the *G4EmMessenger* class, that define the configuration of neutrino-nucleus interactions. Here is an example of the command set (in the domain */physics_lists/em/*) that are used in a simulation macro file.

```
/physics_lists/em/NeutrinoActivation    true
/physics_lists/em/NuDetectorName        gTarget # G4Region name
/physics_lists/em/NuNucleusBias         1.e12
```

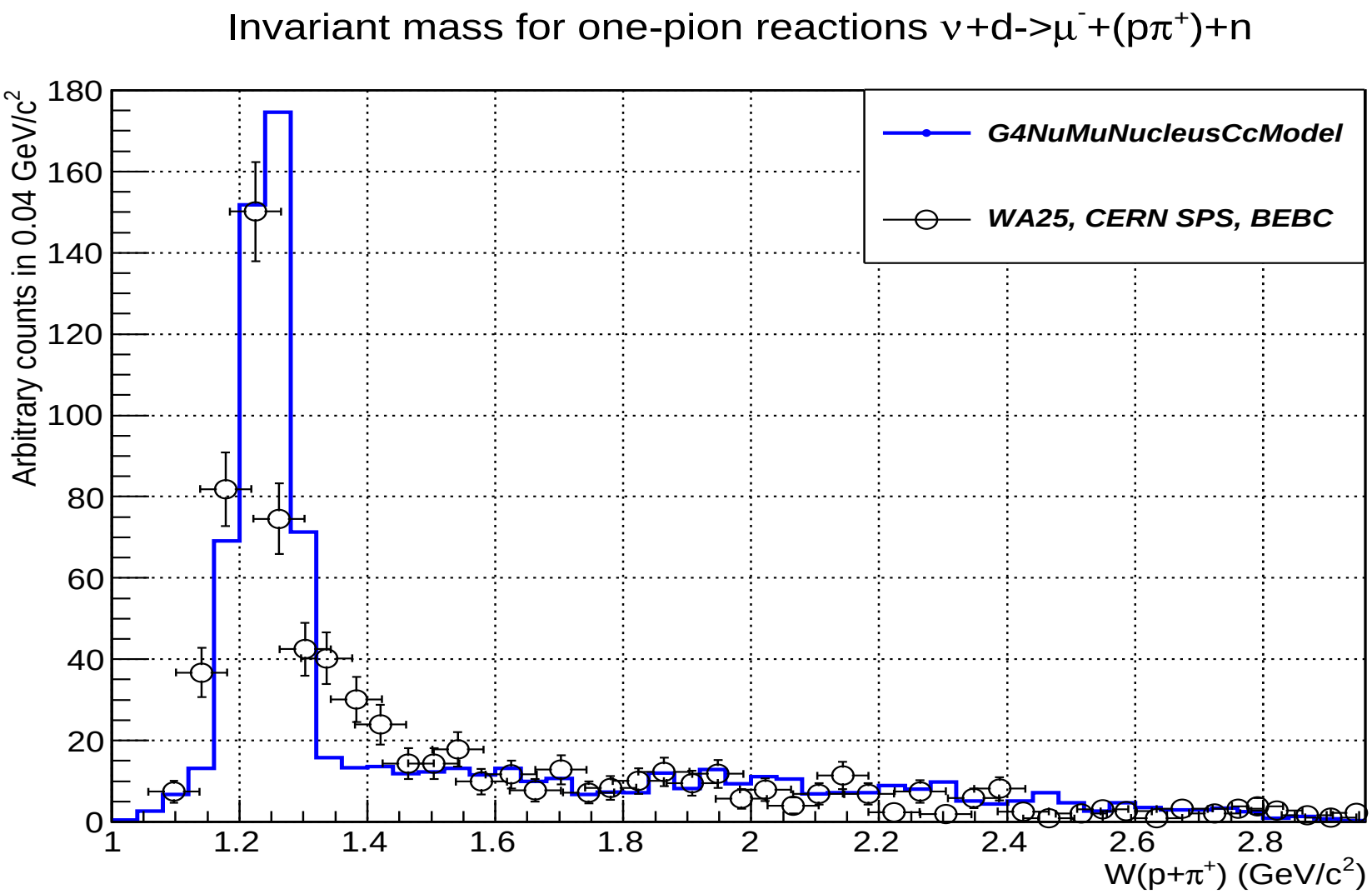
That activates muon neutrino nucleus process and connects it with corresponding cross-sections and models in *G4EmExtraPhysics* class. The νA total cross-sections (class $G4MuNeutrinoNucleusTotXsc$) will be biased ($\cdot 10^{12}$) in the *G4Region* named $gTarget$. The process $G4MuNeutrinoNucleusProcess$ manages charge and neutral current models implemented in classes $G4NuMuNucleusCc(Nc)Model$ with x and Q^2 distributions stored in $G4PARTICLEXSDATA/neutrino/nu_mu data set.



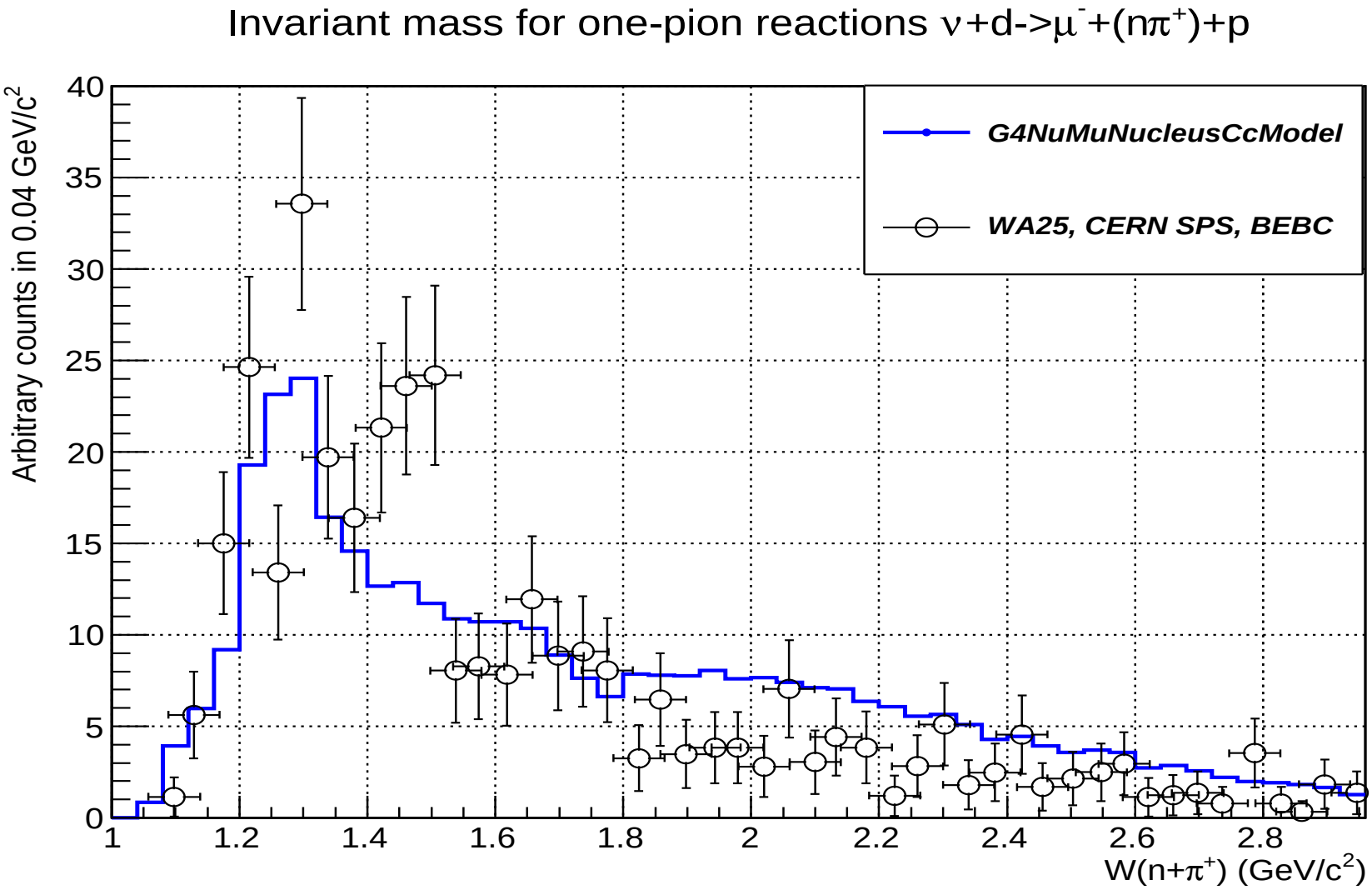
The total (Cc) cross-section of muon neutrino on nucleons.



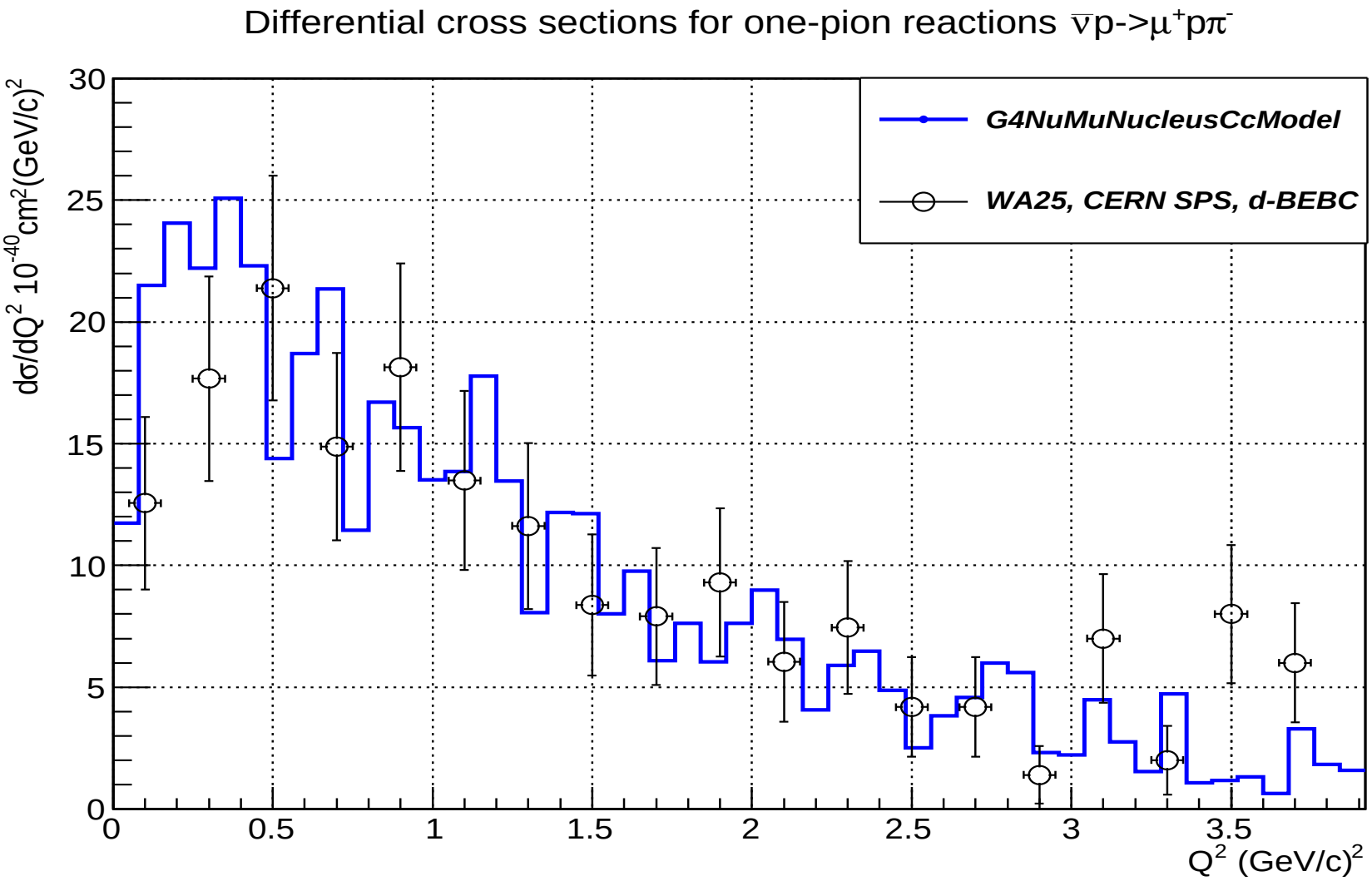
The total (Cc) cross-section of muon anti-neutrino on nucleons. Nc based on the Llewellyn Smith rules. $Tot = Cc + Nc$ and Cc/Tot.



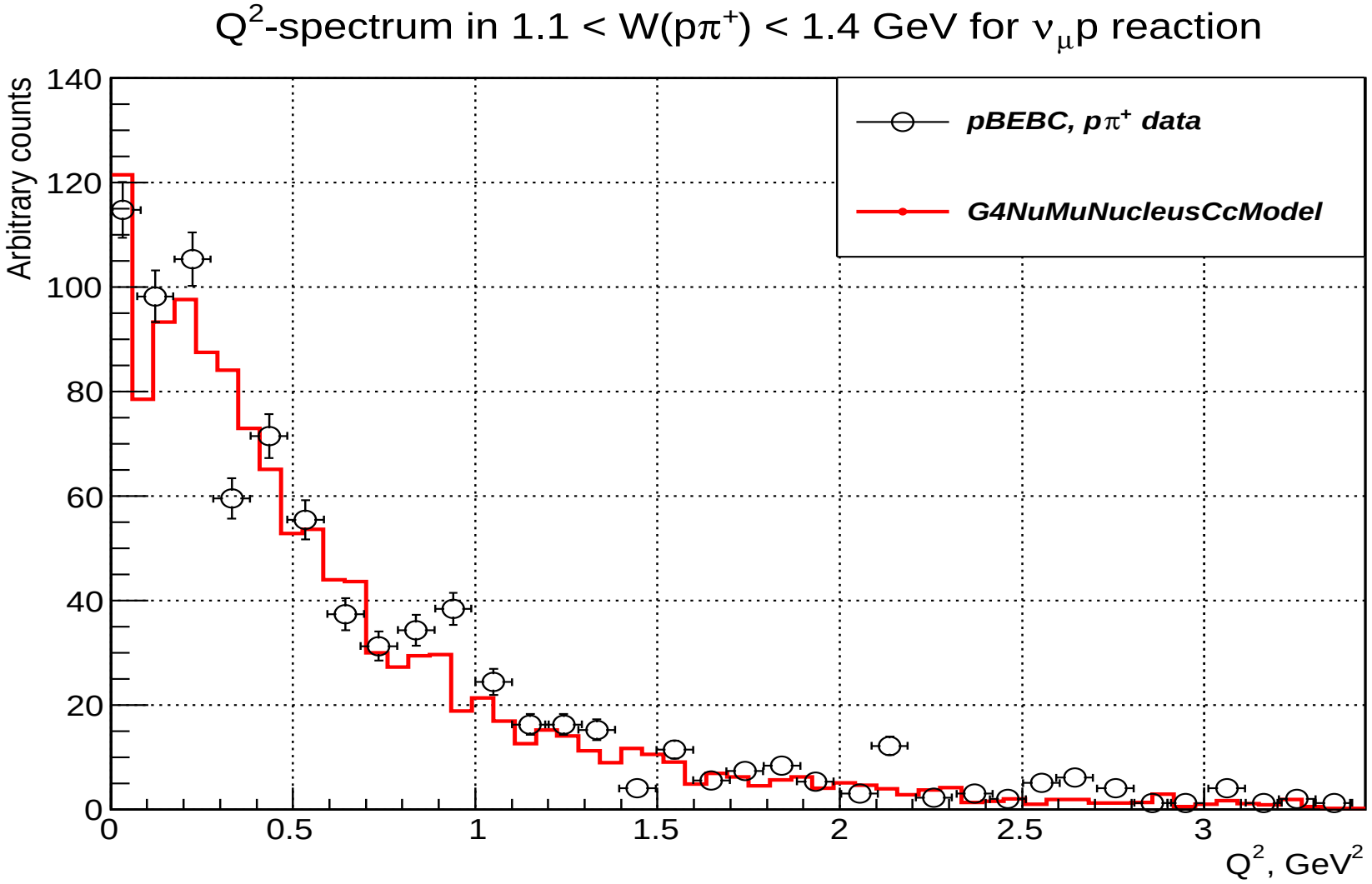
Effective mass distribution for $(p + \pi^+)$ in reaction $(\nu_\mu d \to \mu^- np\pi^+)$



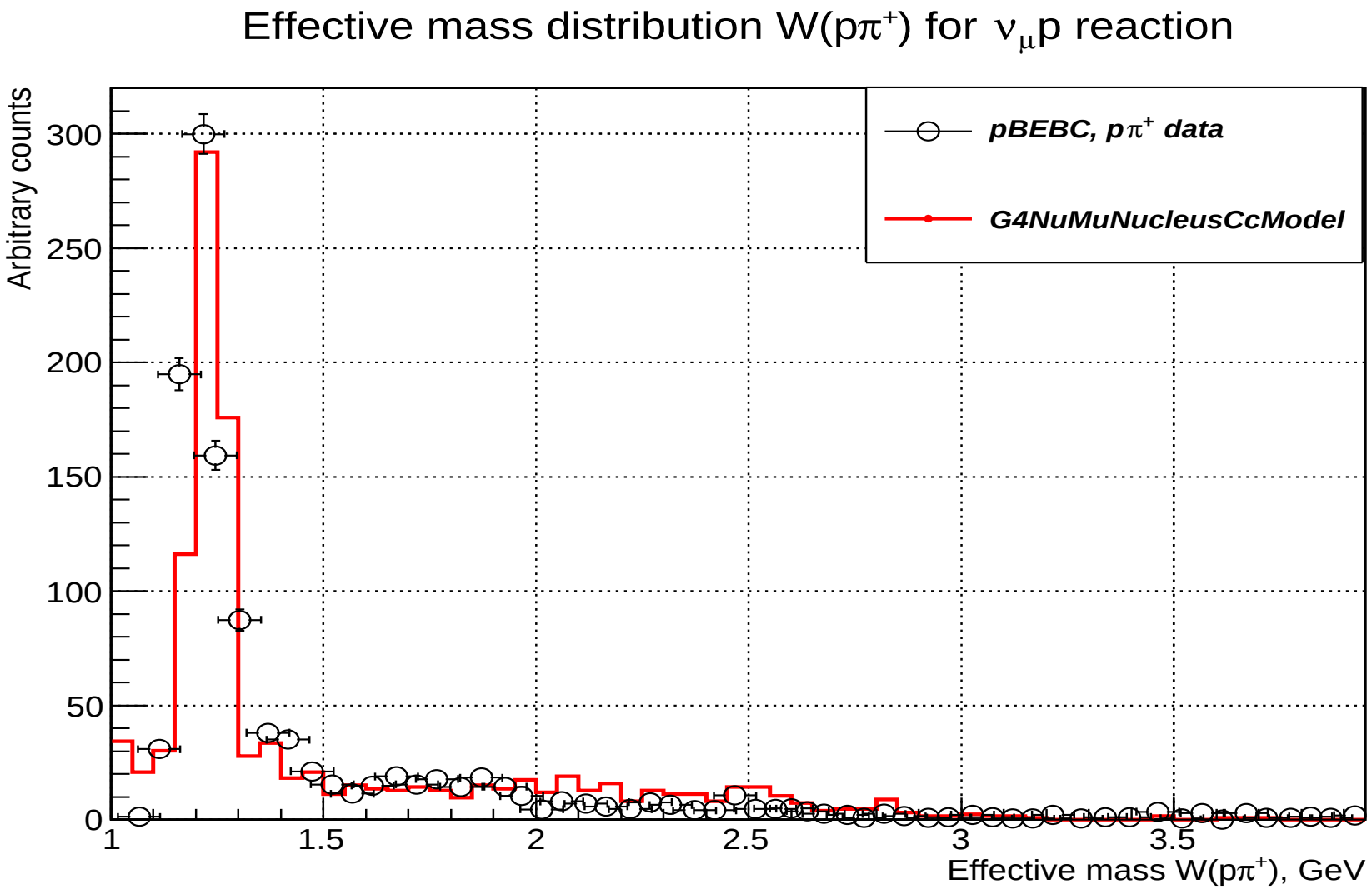
Effective mass distribution for $(n + \pi^+)$ in reaction $(\nu_\mu d \to \mu^- p n \pi^+)$



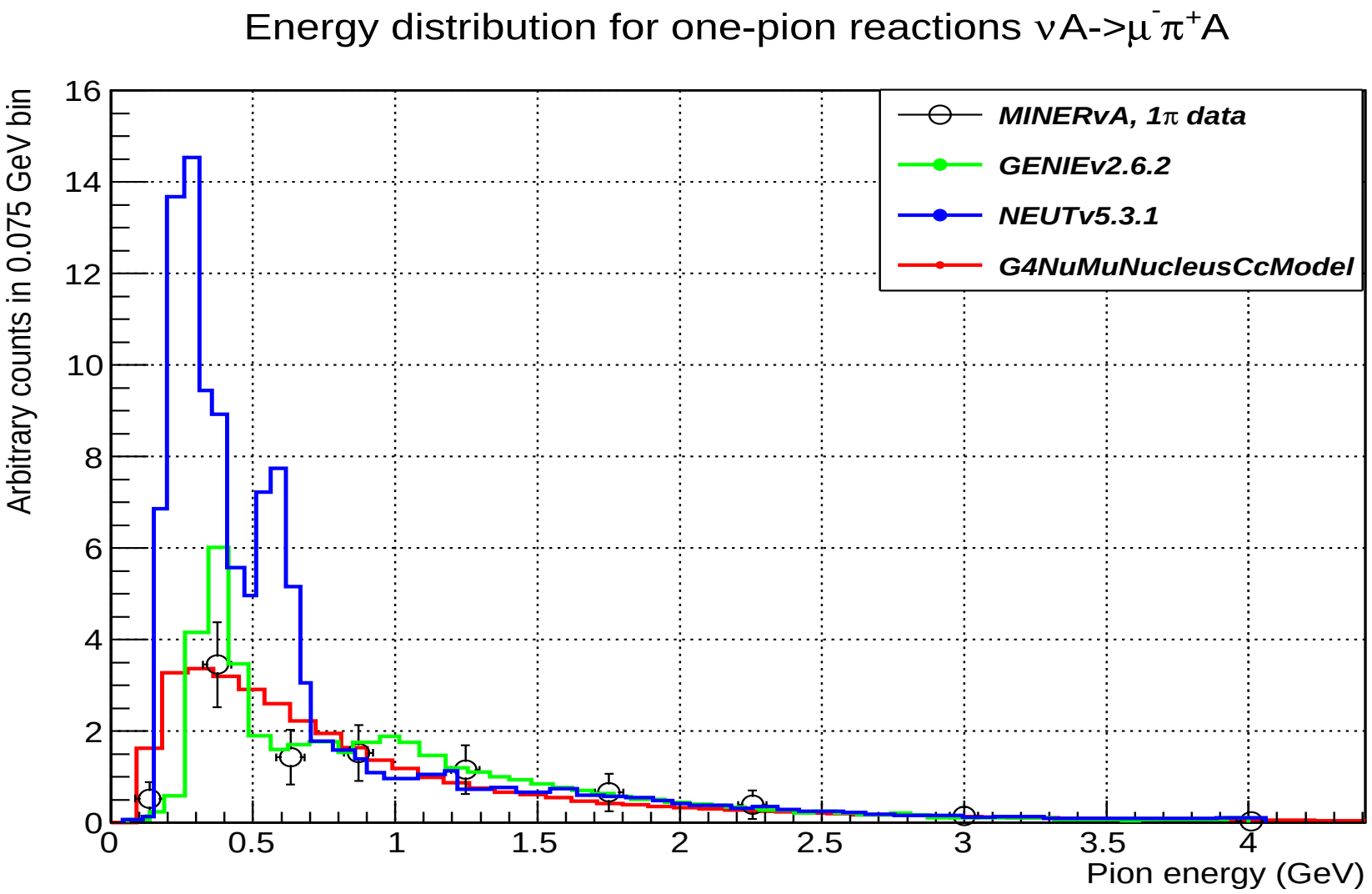
Q^2-distribution for $(p + \pi^+)$ final states in reaction $(\nu_\mu d \to \mu^- np\pi^+)$



Differential Q^2-distribution at 1.1< $W(p+\pi^+)$ <1.4 GeV (pBEBC data).
$(\nu_\mu p \to \mu^- X)$



Spectrum of invariant mass for the pion-proton system (pBEBC data).



Spectrum of coherent pions (MINERνA, FNAL).

4 Summary

1. Muon neutrino nucleon cross-sections and final spectra are satisfactory described based on the SF approach.
2. GEANT4 R&D is under progress to combine different SF representations in one consistent set.
3. Performance is an issue in some cases for the sampling of final state (two dimensional sampling x, Q^2). Pre-computed distributions are used (\$G4PARTICLEXSDATA/neutrino/nu_mu), resulting, however, in some lost of accuracy.
4. GEANT4 status: $(\nu_e, \nu_\mu, \nu_\tau)$-electron interactions and ν_μ-nucleus interactions were committed.