

Hadron-Nucleus Cross Sections and Ratios

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Abstract

Hadron-nucleus cross sections are discussed. Models based on optical approach as well as simplified Glauber theory are considered. Different GEANT4 models are compared with experimental data. Quasi-elastic and sing-diffration ratios are discussed.

1 Introduction

Here it is reported on verification of total and inelastic cross-sections for hadrons on different targets. The definitions are: $\sigma_{tot} = \sigma_{in} + \sigma_{el}$, and $\sigma_{in} = \sigma_{prod} + \sigma_{qel}$. GEANT4 has (historically) the following models:

1. G4HadronCrossSections class for **inelastic and elastic** hadron (inelastic and elastic) cross sections in the spirit of GHEISHA.
2. G4Proton/NeutronInelasticCrossSection class for HPW-Axen parametrization model. Inelastic cross section only.
3. G4Pi/ **Nucleon** NuclearCrossSection class for Barashenkov (optical) data interpolation for pions/nucleons on nuclei. Total, inelastic and elastic (tot-in) cross sections are available.
4. G4GlauberGribovCrossSection class for **total and inelastic** (also production and single-diffraction!) hadron cross sections in the spirit of Glauber model with Gribov correction. $\sigma_{el} = \sigma_{tot} - \sigma_{in}$.

Experimental data were taken from <http://wwwppds.ihep.su> IHEP-PDG database, and Dubna set <http://wwwnea.fr/html/dbdata/bara.html>.

2 Barashenkov Method

The Barashenkov interpolation is essentially based on quasi-optical model for high energies ($T > 2$ GeV) and on phenomenology like $\pi r_o A^{2/3}$, $r_o \sim 1$ fm with corrections. The total, inelastic (and elastic) cross sections are interpolated using:

$$\sigma(T, A) = \pi \left[r_o A^{1/3} + \lambda(T, A) \right]^2 f(T) \phi(A)^{\alpha(T)},$$

where λ is de Broglie length of projectile in CM system, T is the kinetic energy of projectile in laboratory system, A is the atomic weight, and $r_o \sim 1$ fm.

Functions $f(T)$, $\phi(A)$ and $\alpha(T)$ are series like:

$$\sum_i a_i T^{b_i} \quad \text{and} \quad \sum_i a_i A^{b_i}.$$

The general disadvantage of optical models is the prediction of constant cross-sections for very high energies. Experimental data show, however, small relativistic rise of hadron-nucleus cross-sections. This is the reason to consider Glauber model for the description of hadron-nucleus cross-sections in the high (more than 100 GeV) energy region.

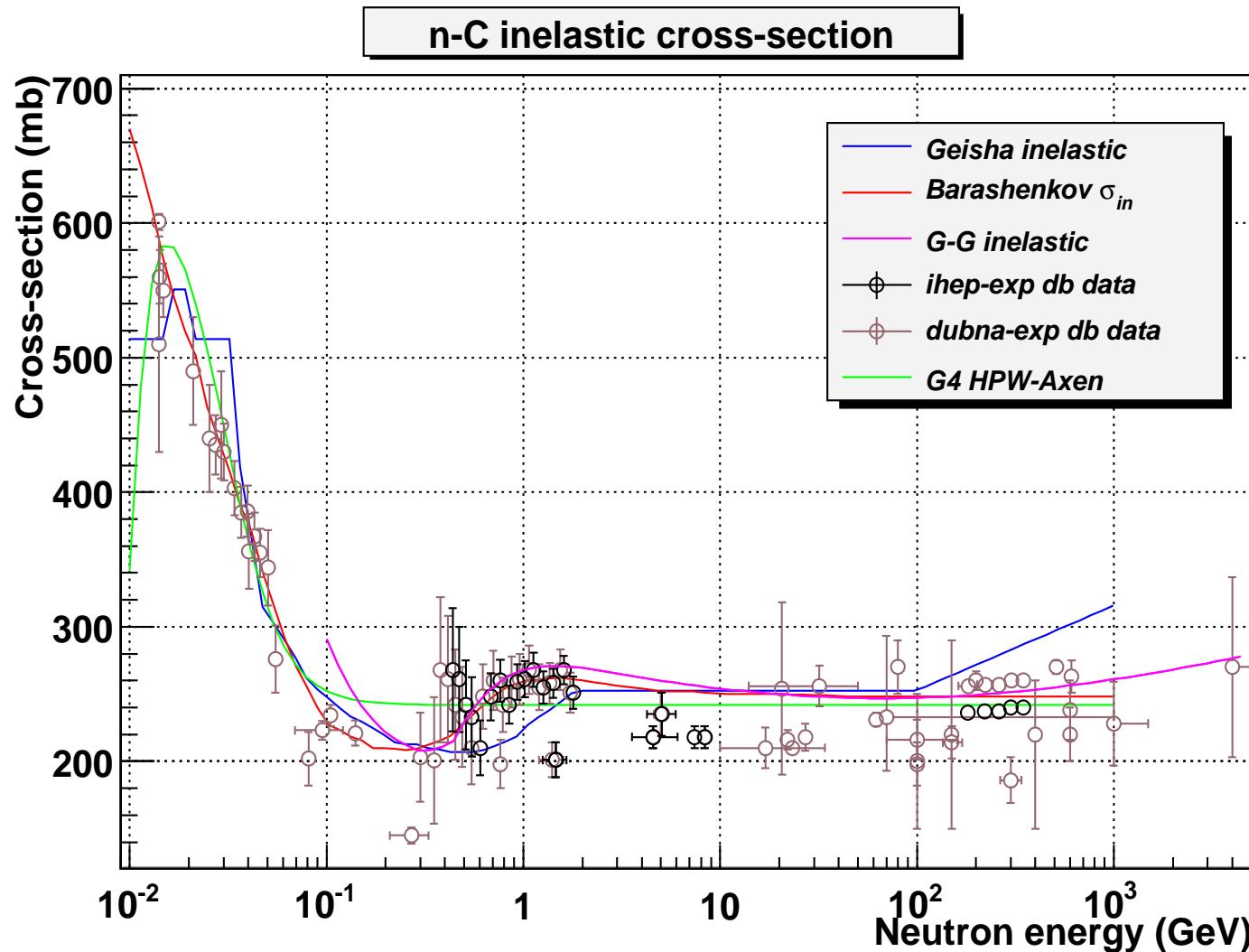
3 Simplified Glauber model

Simplified (Gauss distributed point-like nucleons) Glauber model cross sections read:

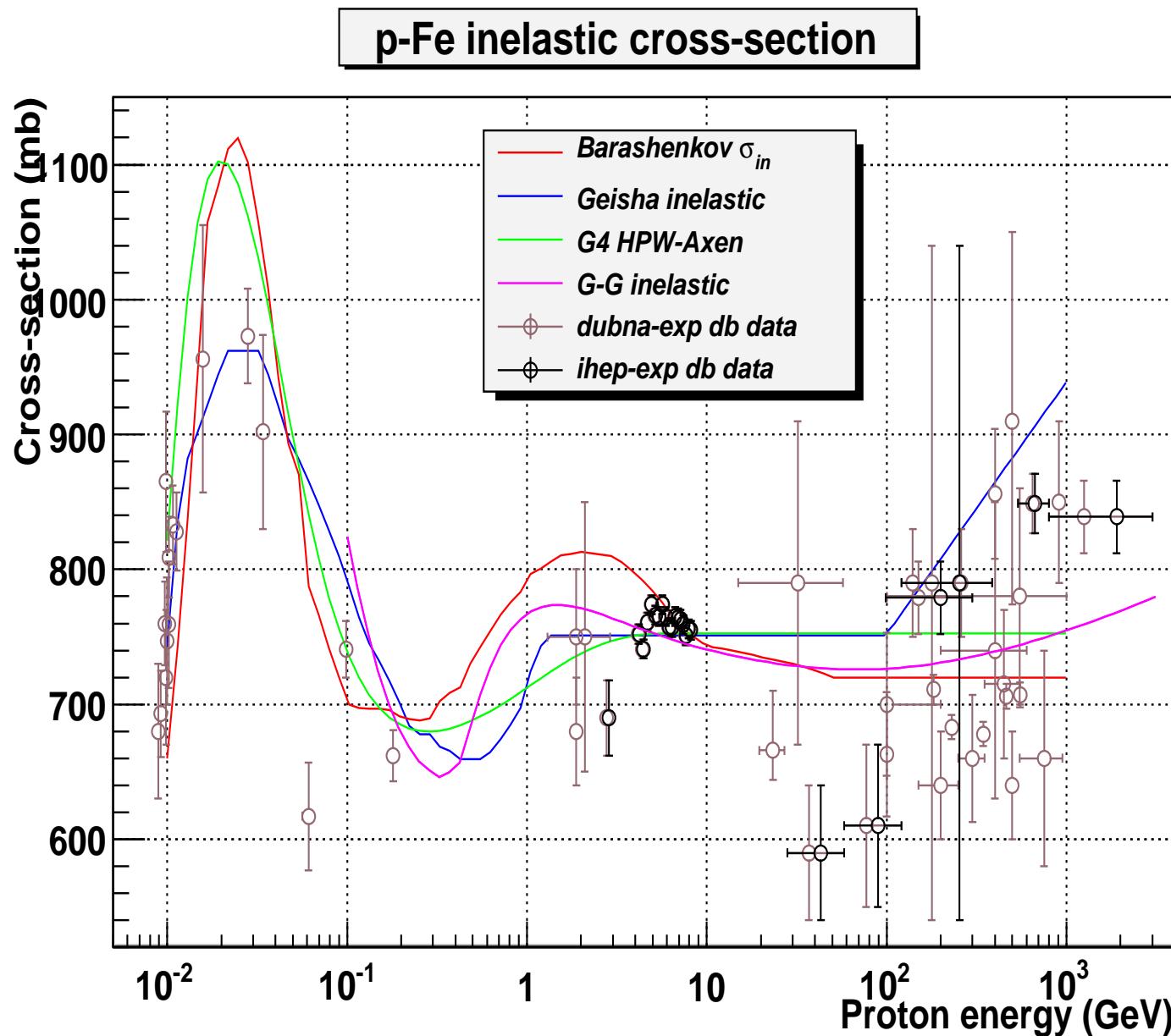
$$\sigma_{tot}^{hA} = 2\pi R^2 \ln \left[1 + \frac{A\sigma_{tot}^{hN}}{2\pi R^2} \right], \quad \sigma_{in}^{hA} = \pi R^2 \ln \left[1 + \frac{A\sigma_{tot}^{hN}}{\pi R^2} \right], \quad \sigma_{el}^{hA} = \sigma_{tot}^{hA} - \sigma_{in}^{hA}.$$

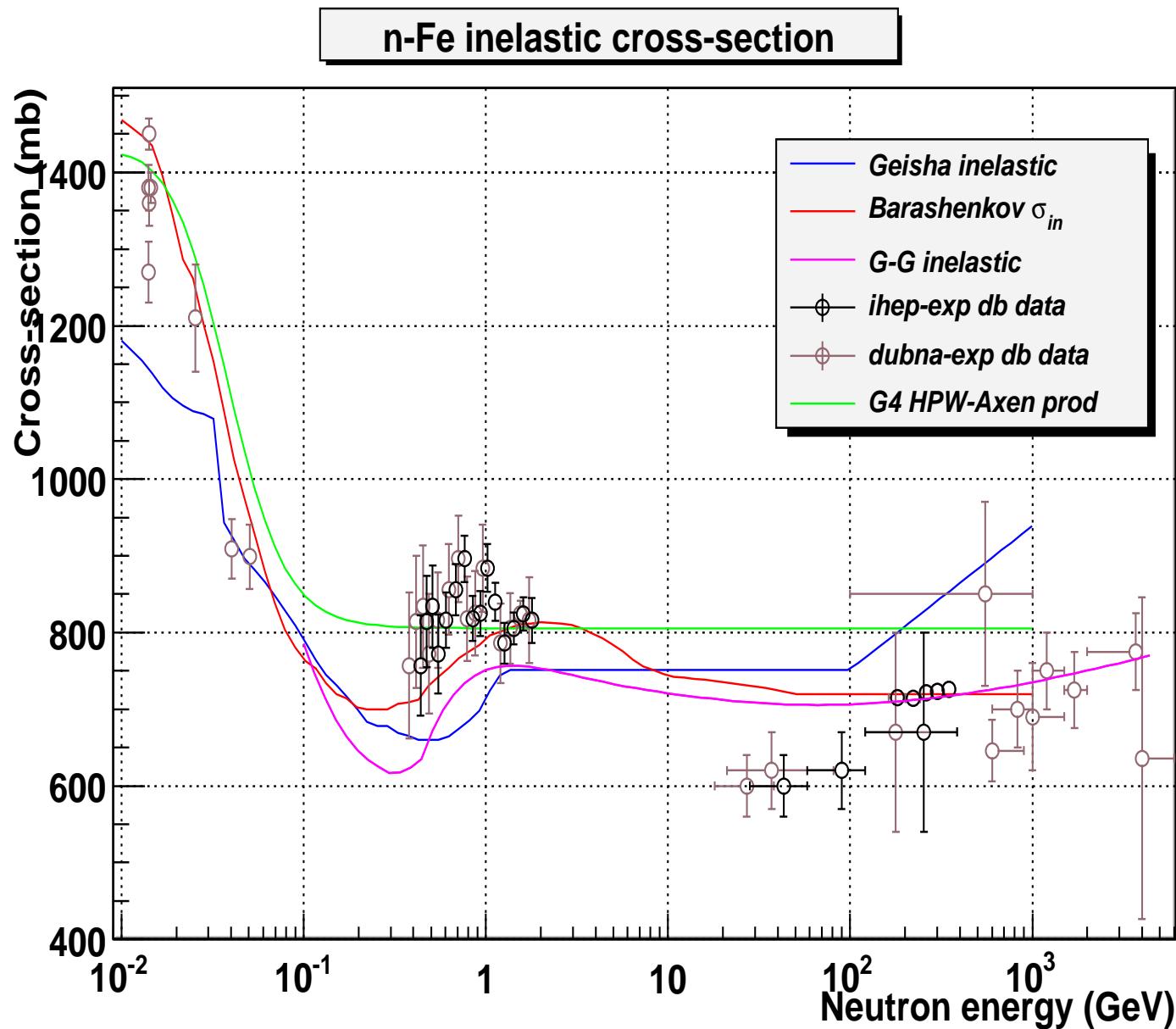
Where σ_{tot}^{hA} , σ_{in}^{hA} , and σ_{el}^{hA} , are total, inelastic and elastic cross sections, respectively.

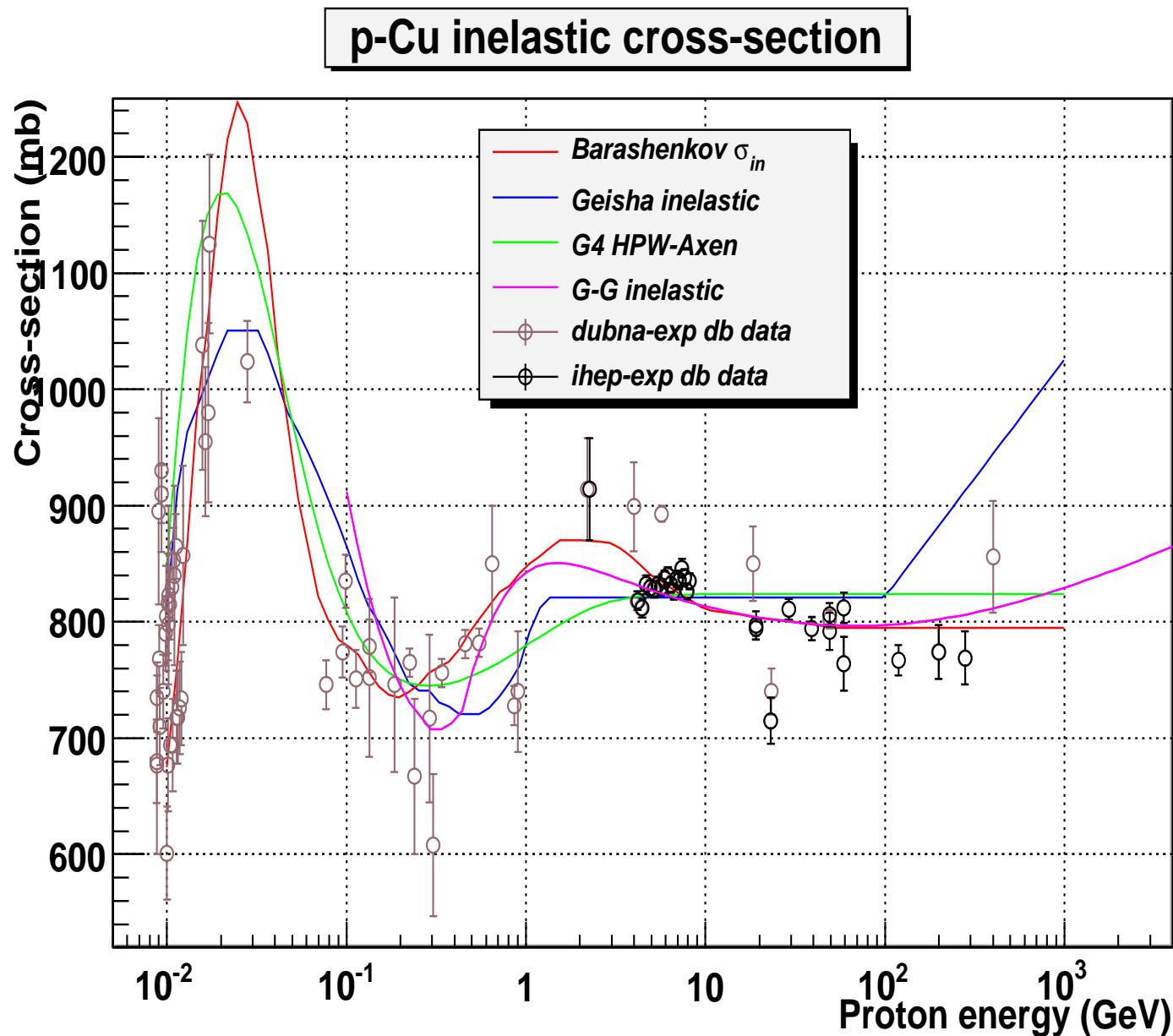
The model is reduced to the selection of σ_{tot}^{hN} and $R(A)$ values. We use the latest edition of PDG and GEANT4 parameterizations for σ_{tot}^{hN} , including the total cross sections of p , \bar{p} , n , π^\pm , K^\pm and Σ^- on protons and neutrons (<http://pdg.lbl.gov/2006/reviews/hadronicrpp.pdf>). For known cross sections on proton and neutron, $A\sigma_{tot}^{hN} = N_p \sigma_{tot}^{hp} + N_n \sigma_{tot}^{hn}$, where N_p and N_n are the number of protons and neutrons in the nucleus. The nuclear radius is parametrized by $R(A) = r_o A^{\frac{1}{3}} f(A)$, $r_o \sim 1.1 \text{ fm}$, where for $A > 21$, $f(A) < 1$, while in the opposite case $3 < A < 21$, $f(A) > 1$ in the limits of 20%. Below are the model predictions for the total neutron cross sections on different targets.

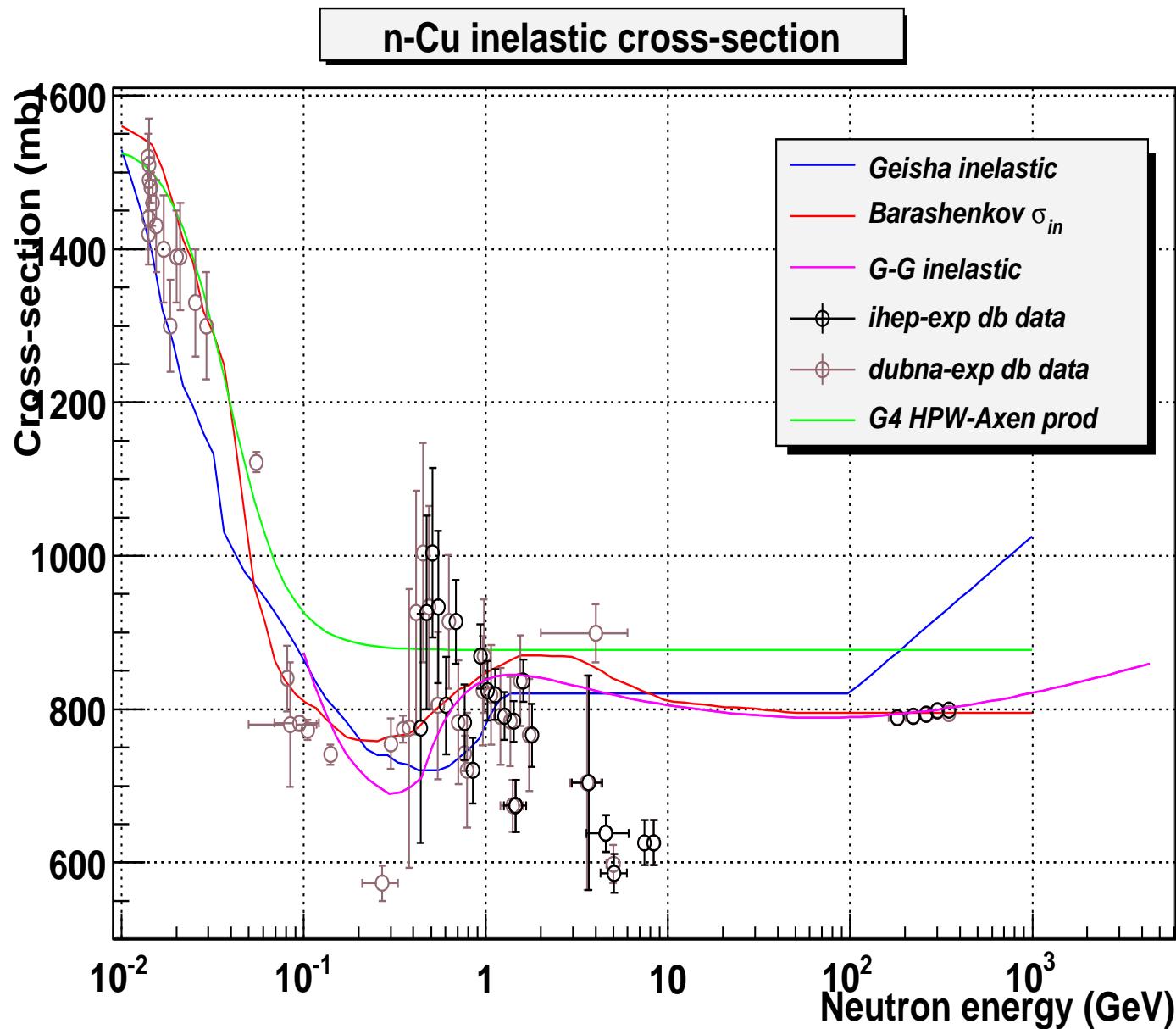


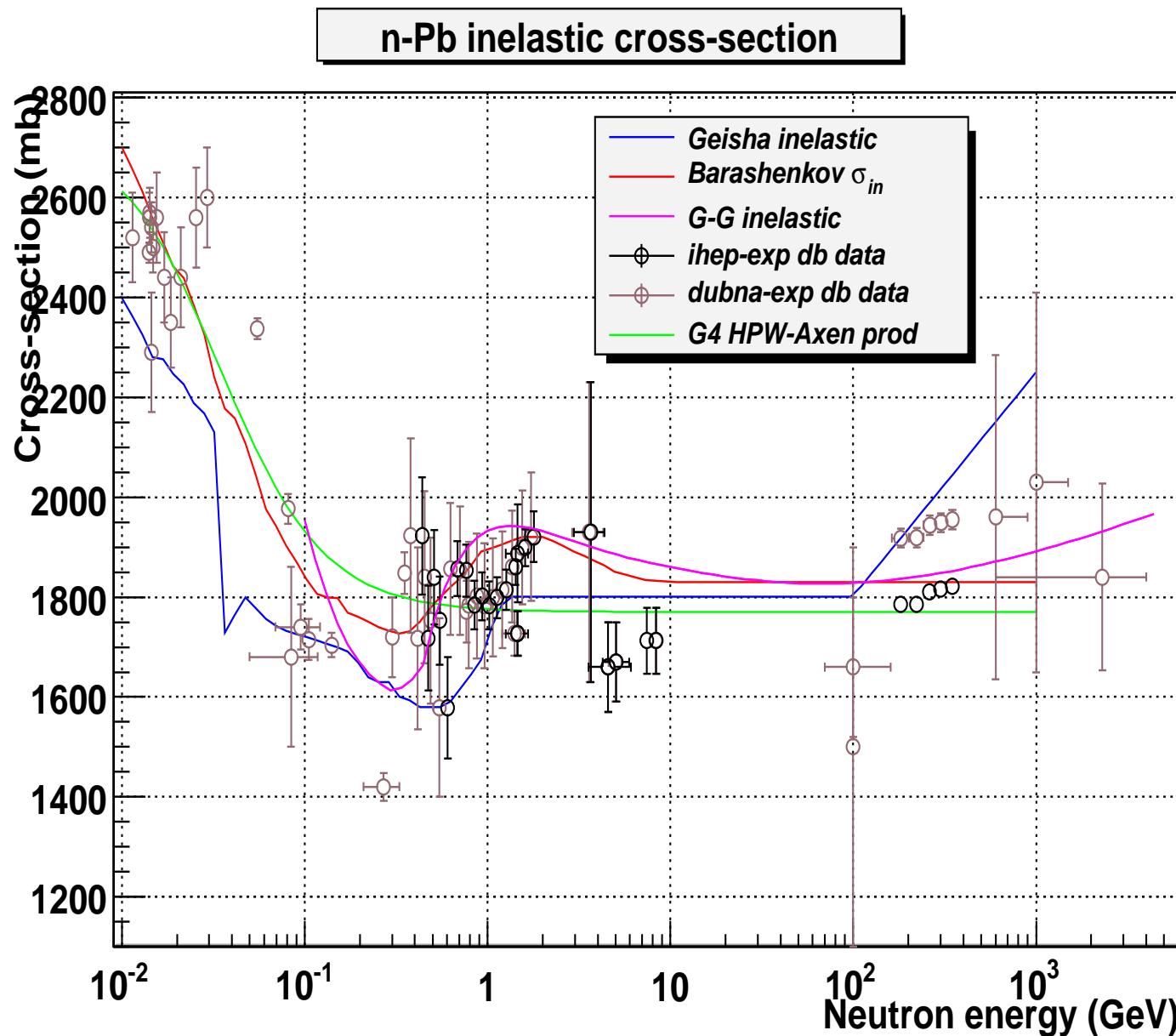
In some cases (see below) inelastic data from <http://wwwnea.fr/html/dbdata/bara.html> are corrected on quasi-elastic cross sections in the form $0.1\pi r_o^2 A^{2/3}$

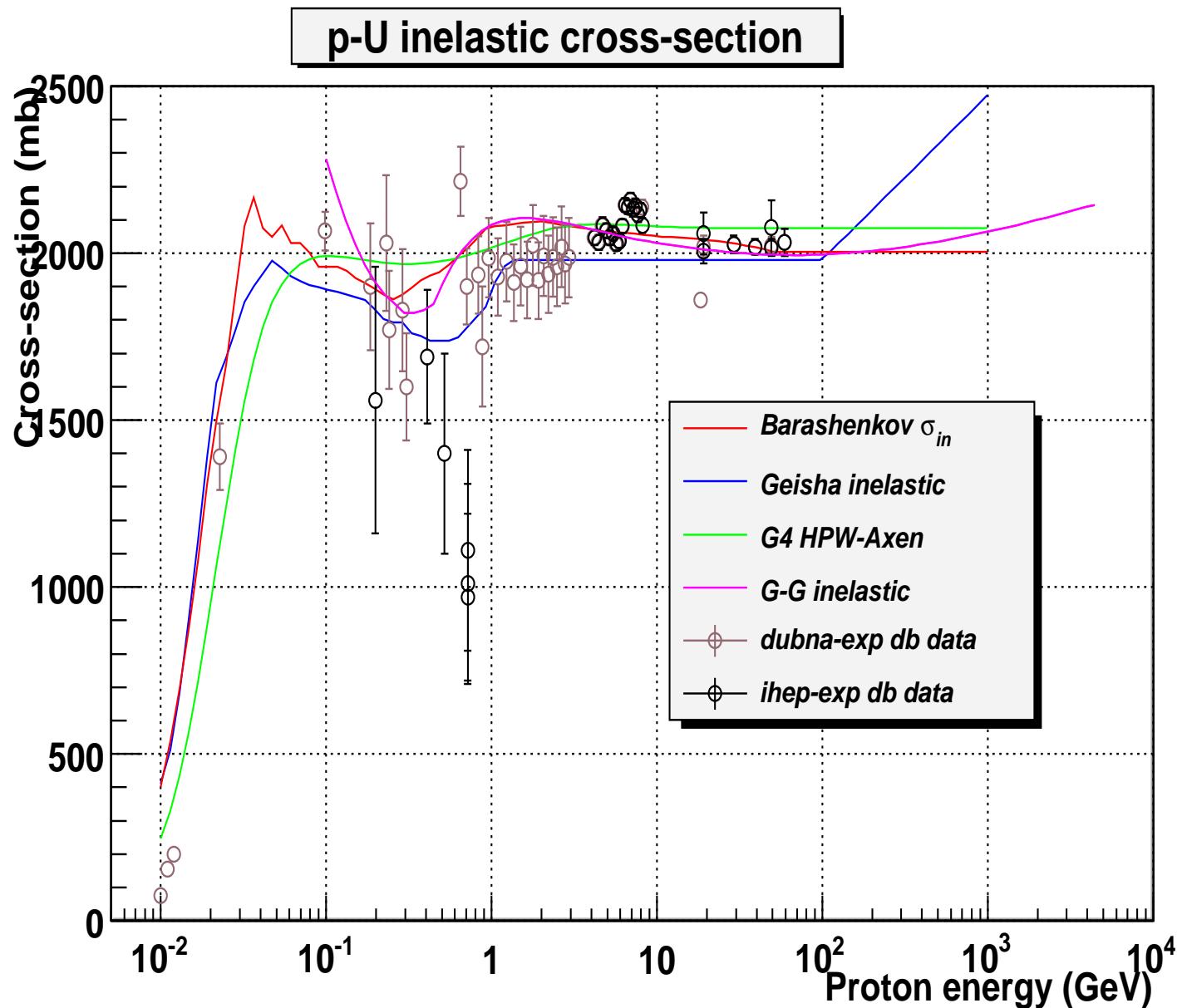


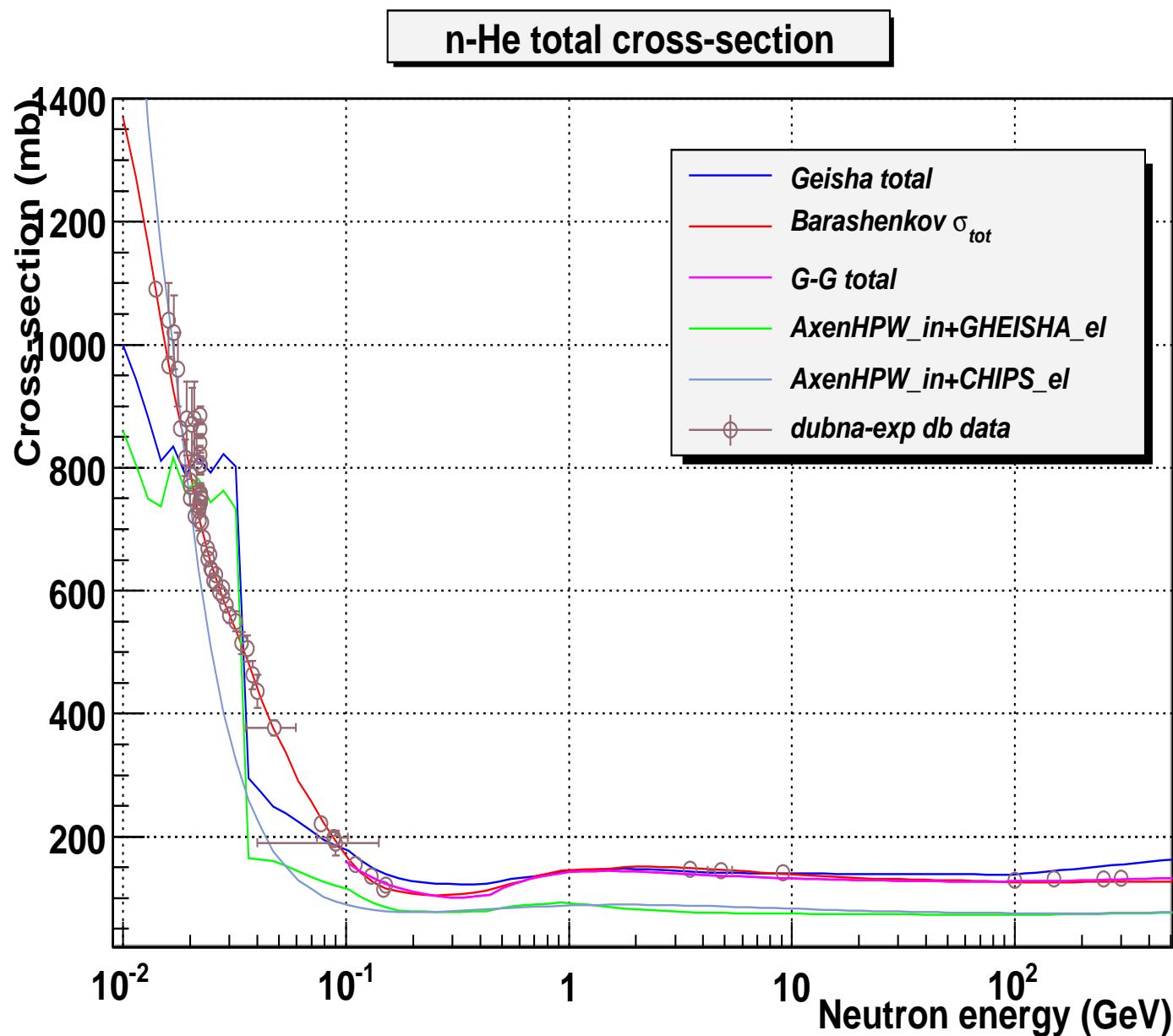


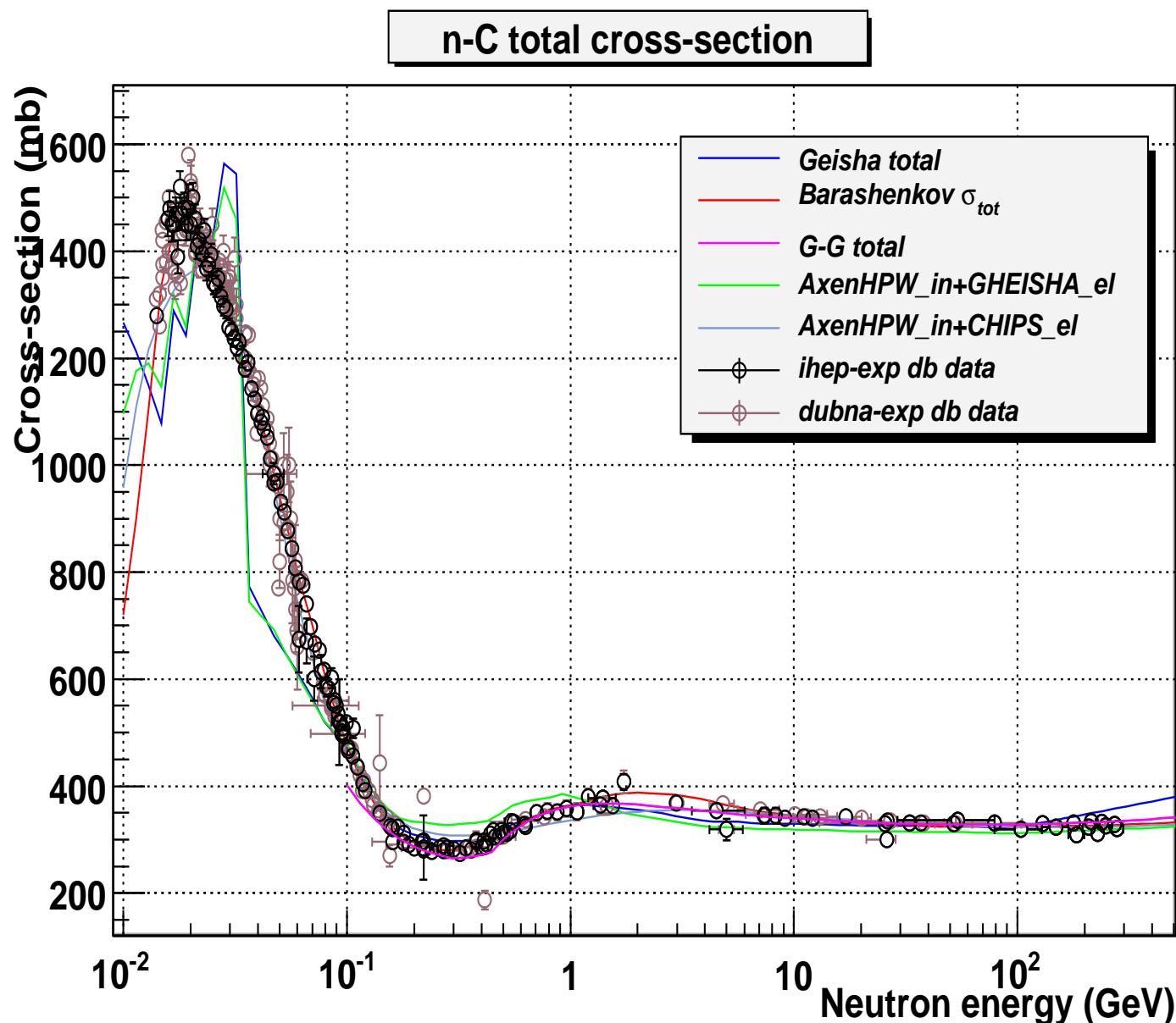


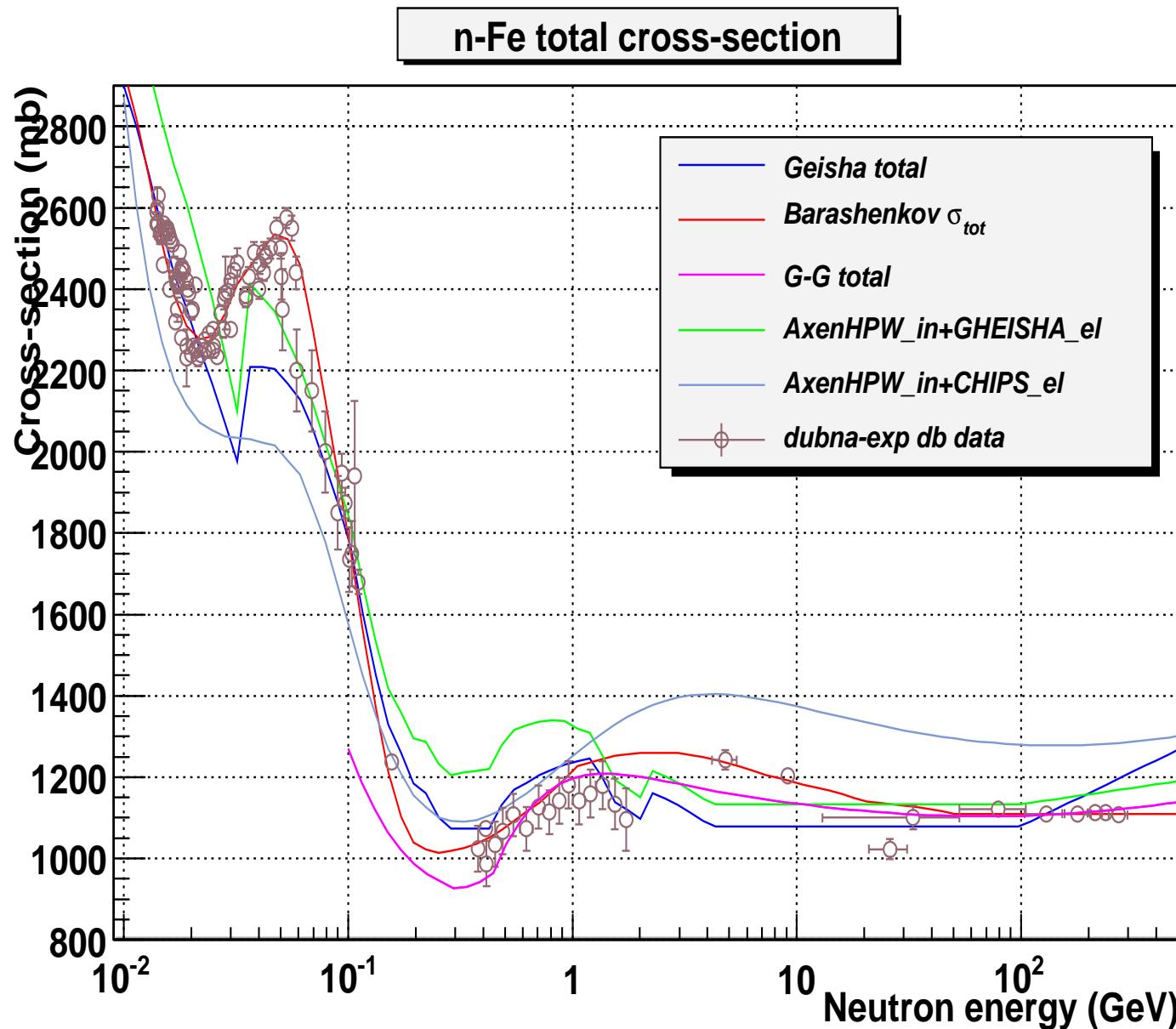


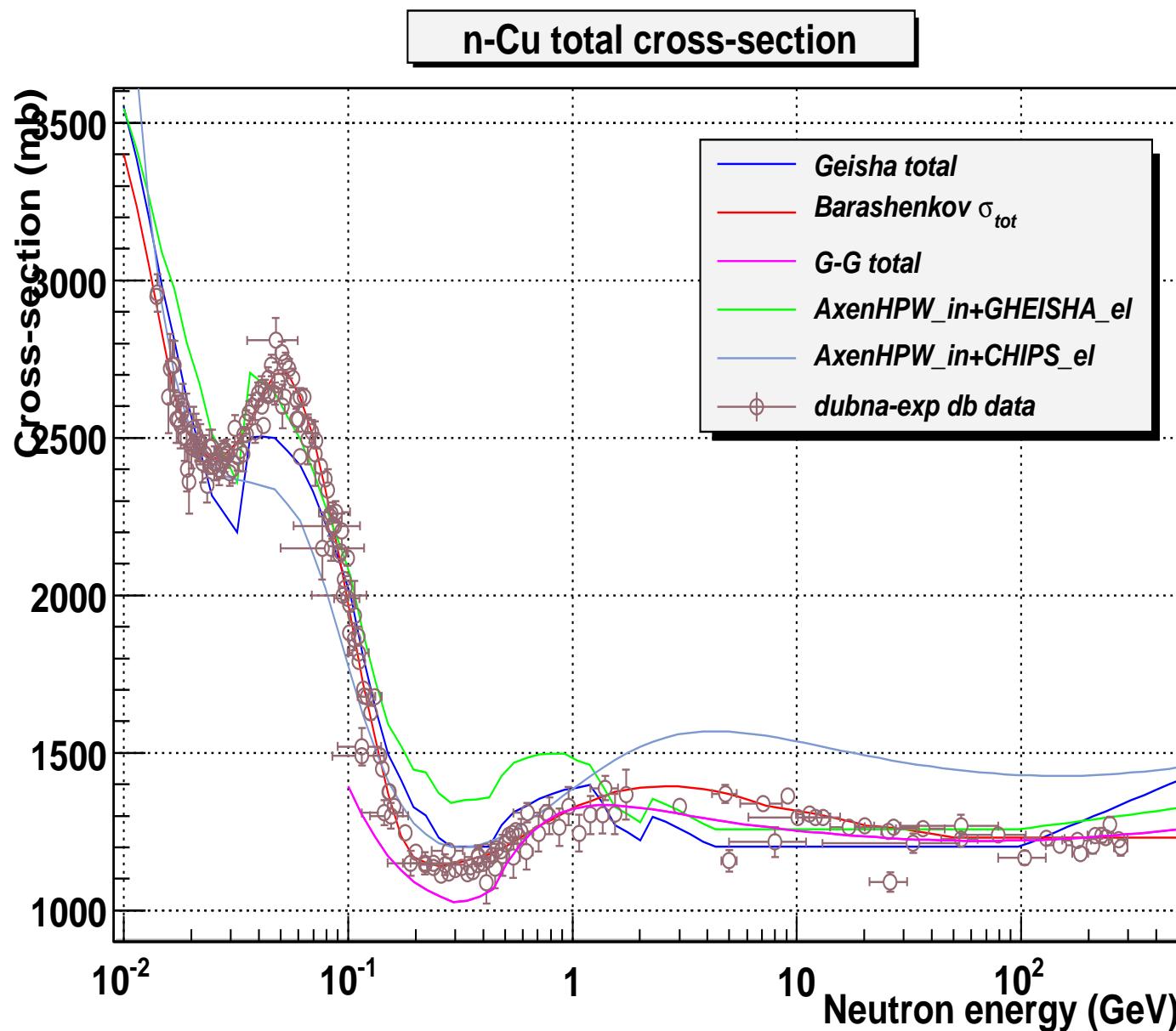


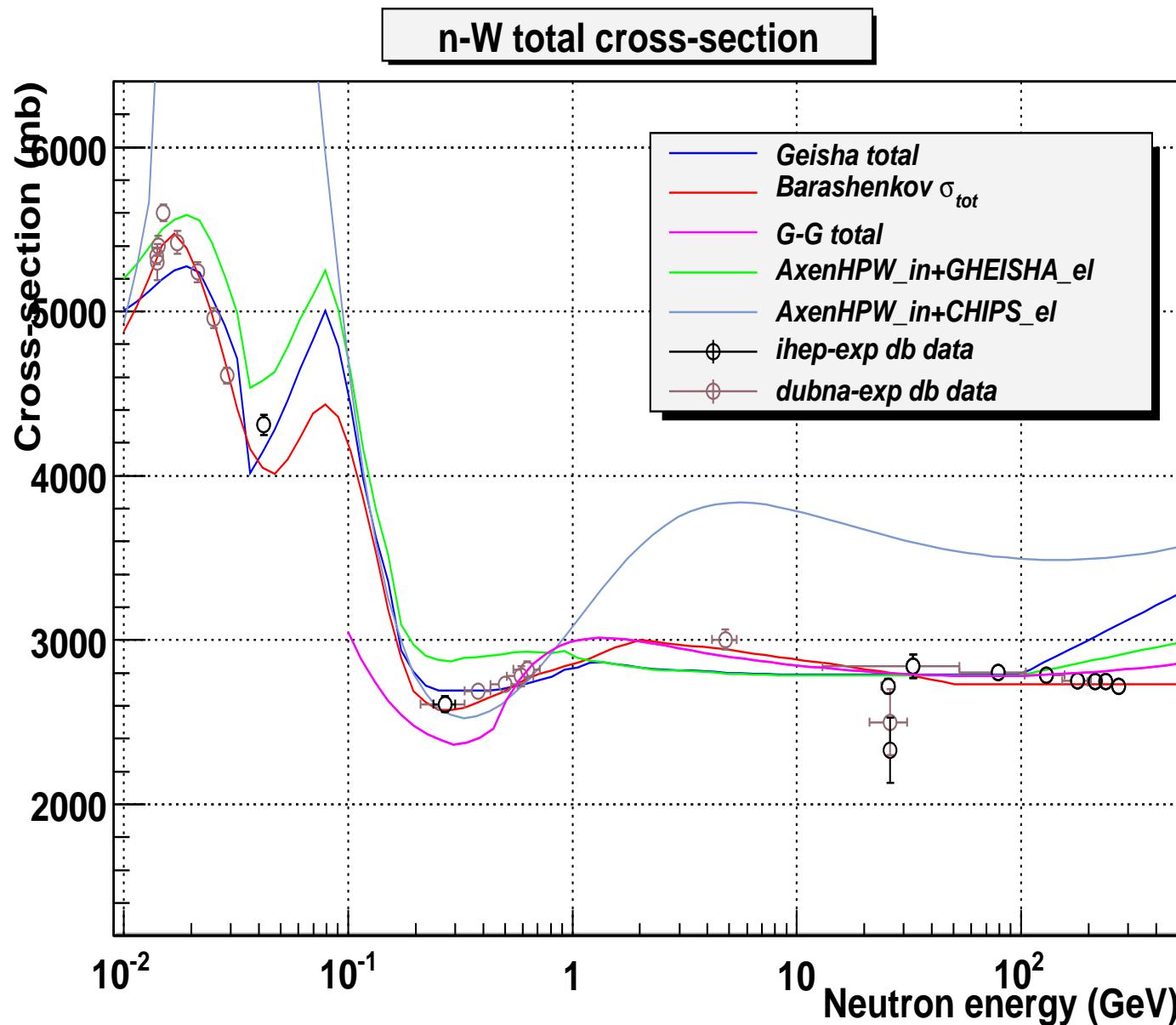


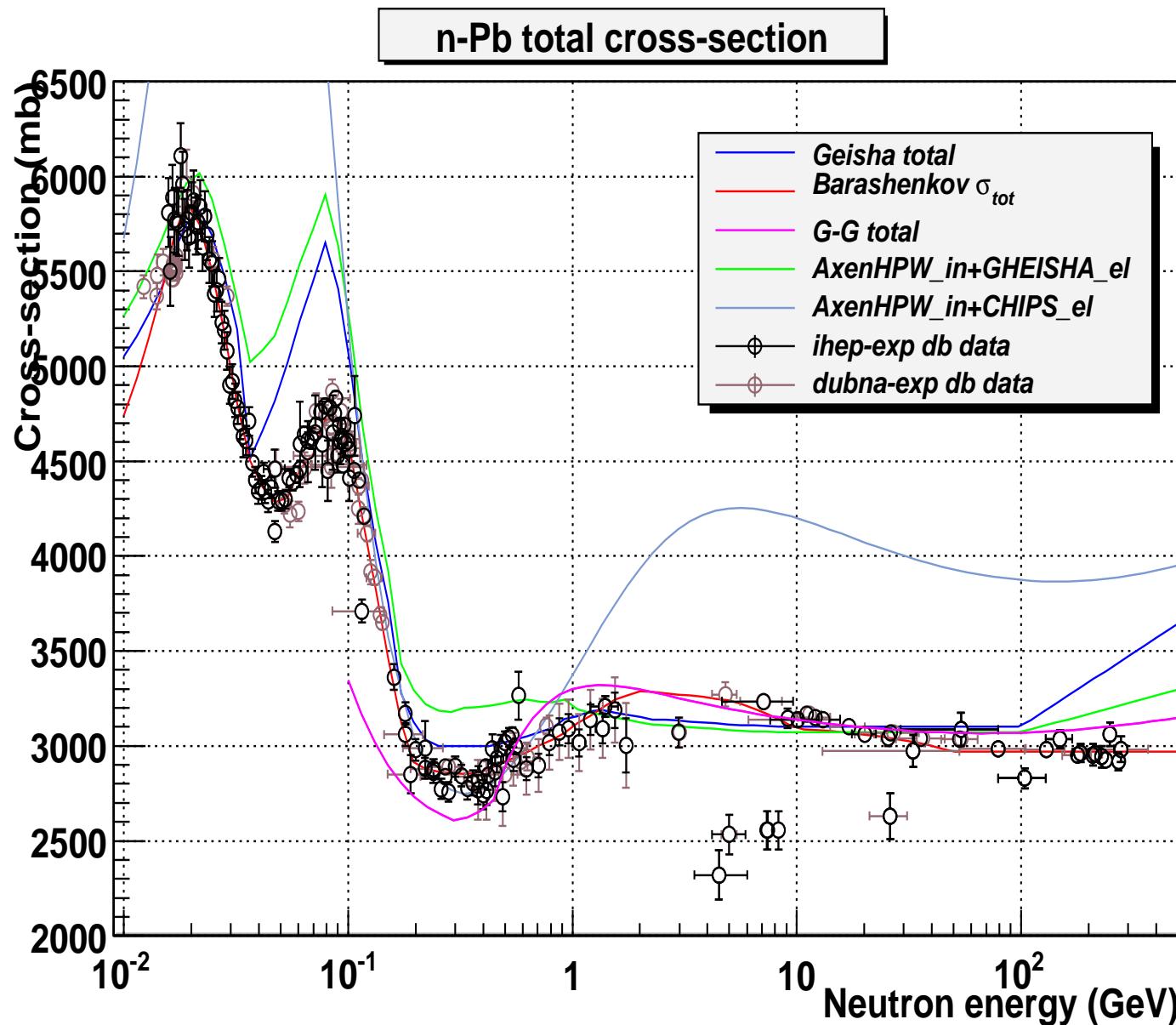


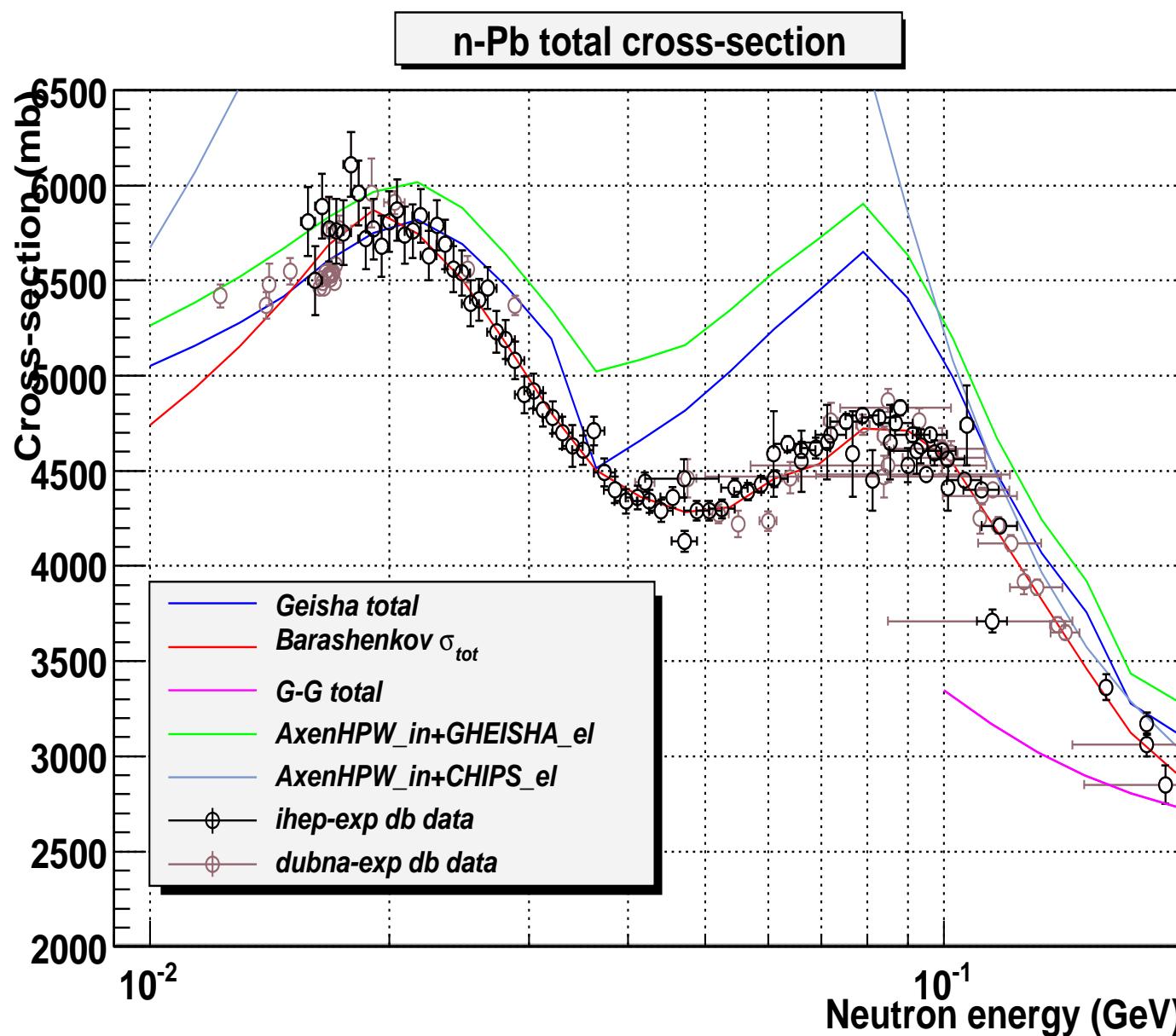


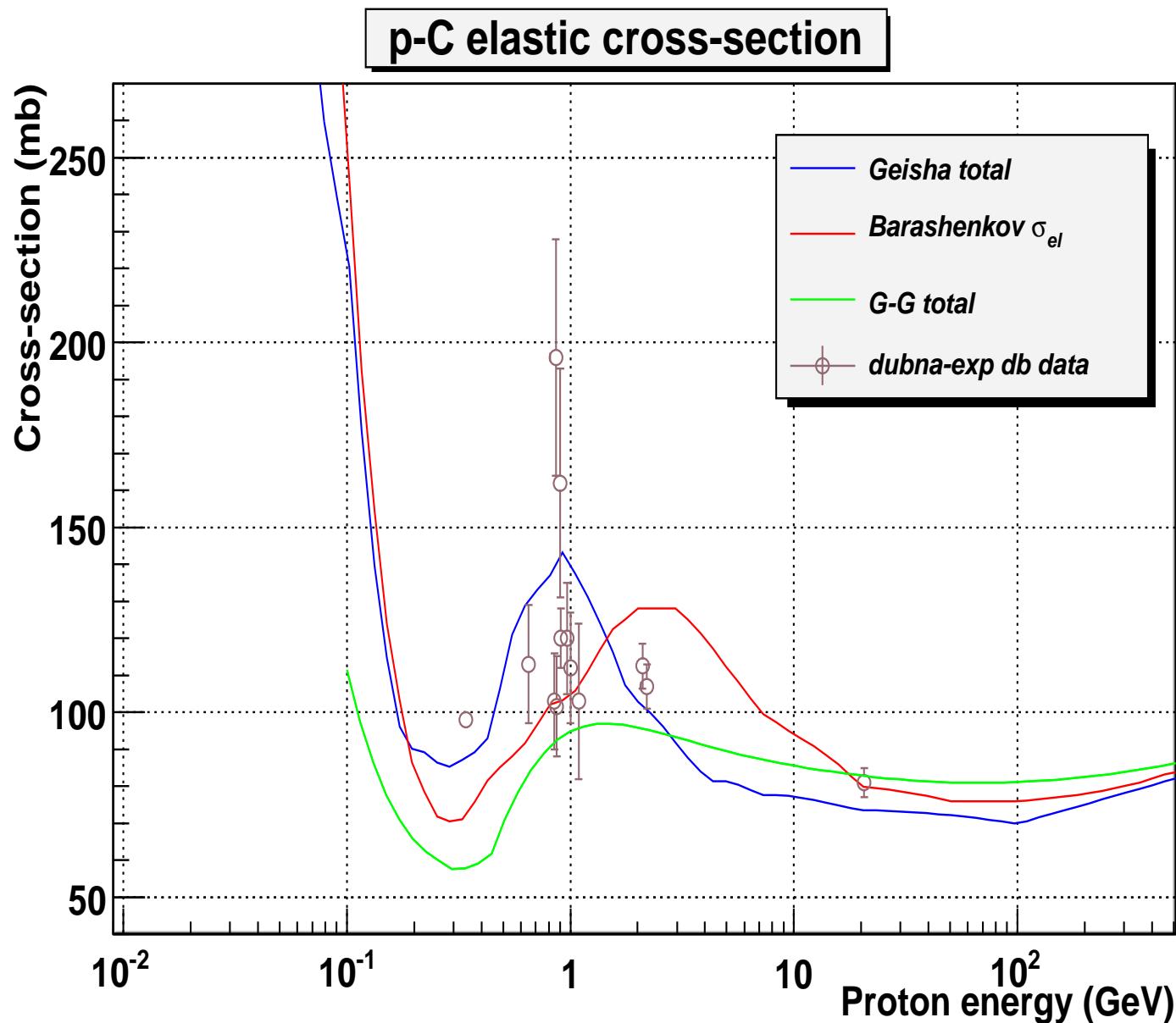


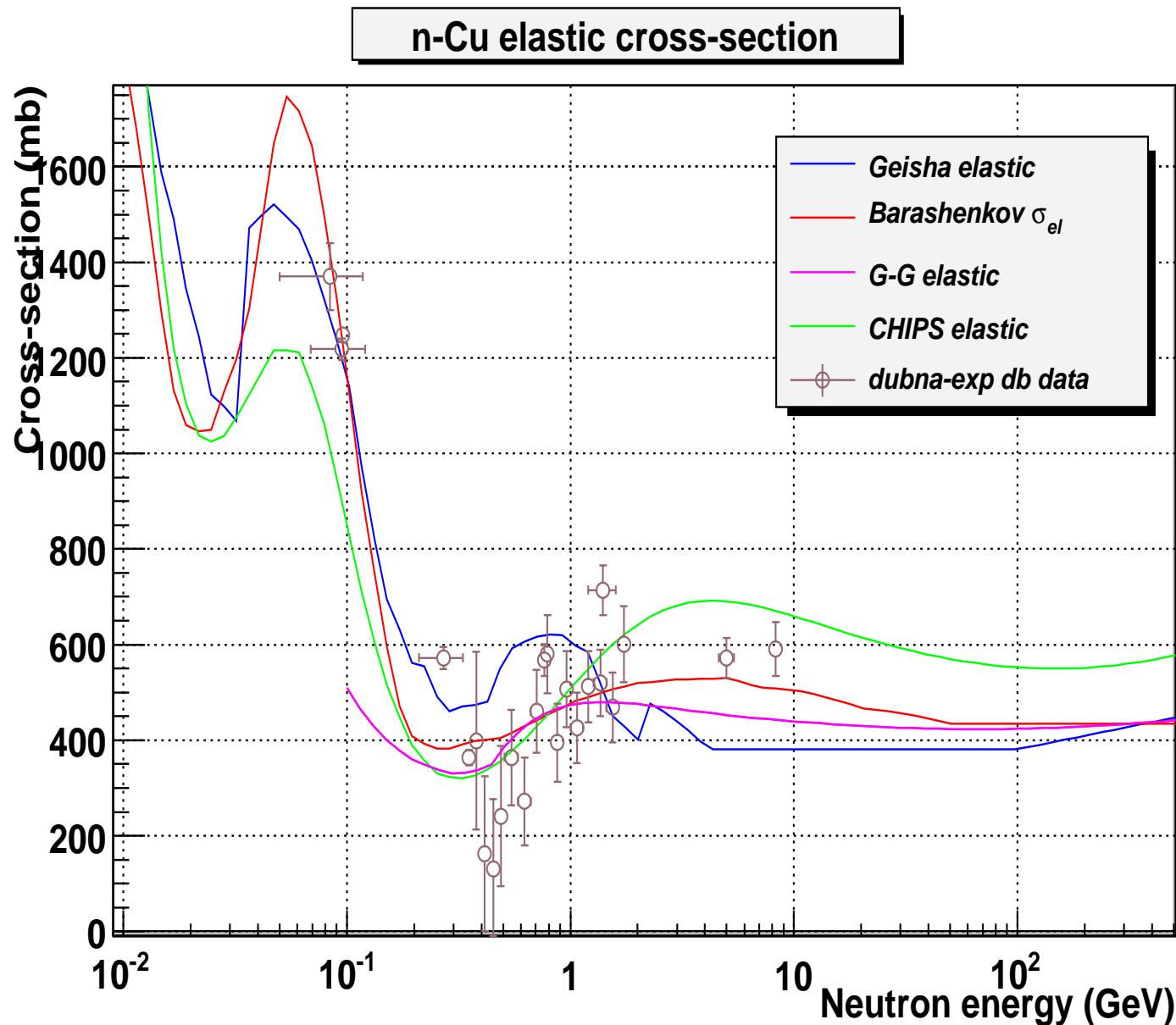












4 Simplified Glauber model cross section ratios

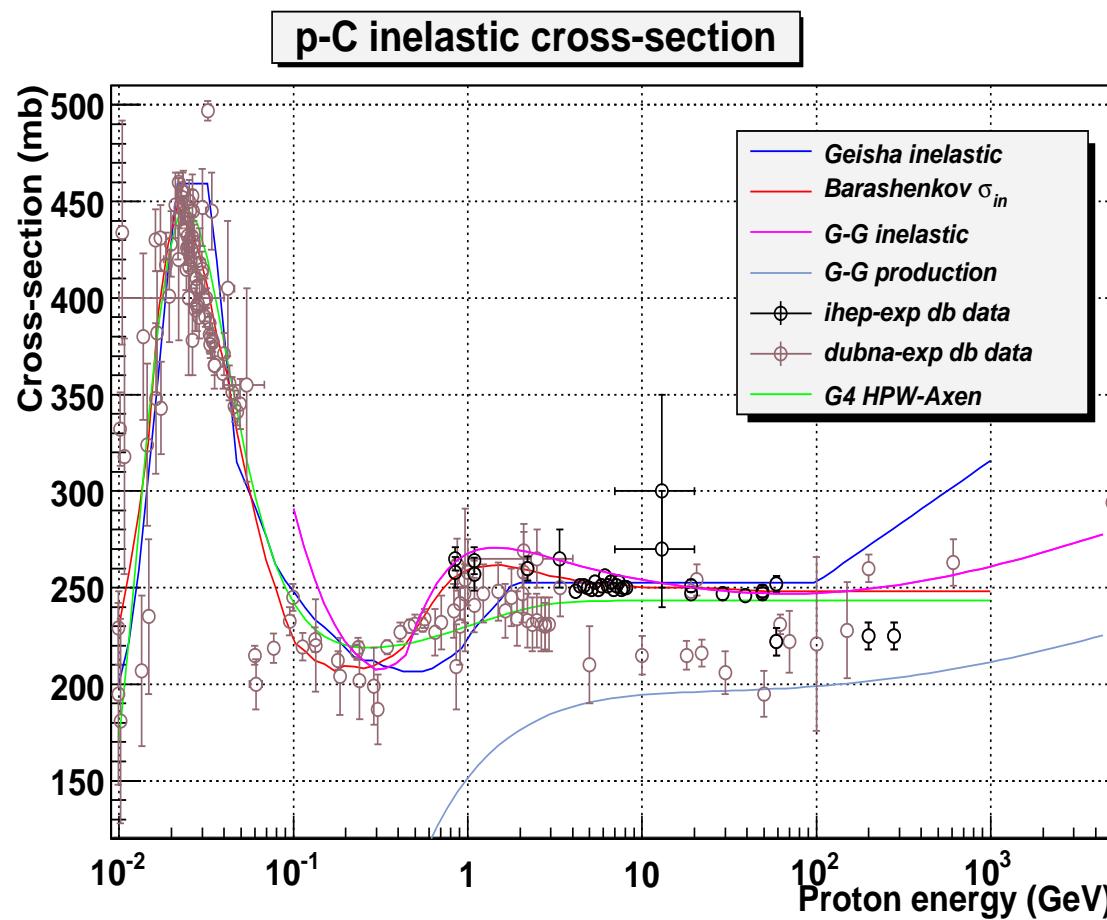
In the framework of simplified Glauber-Gribov model the cross sections read:

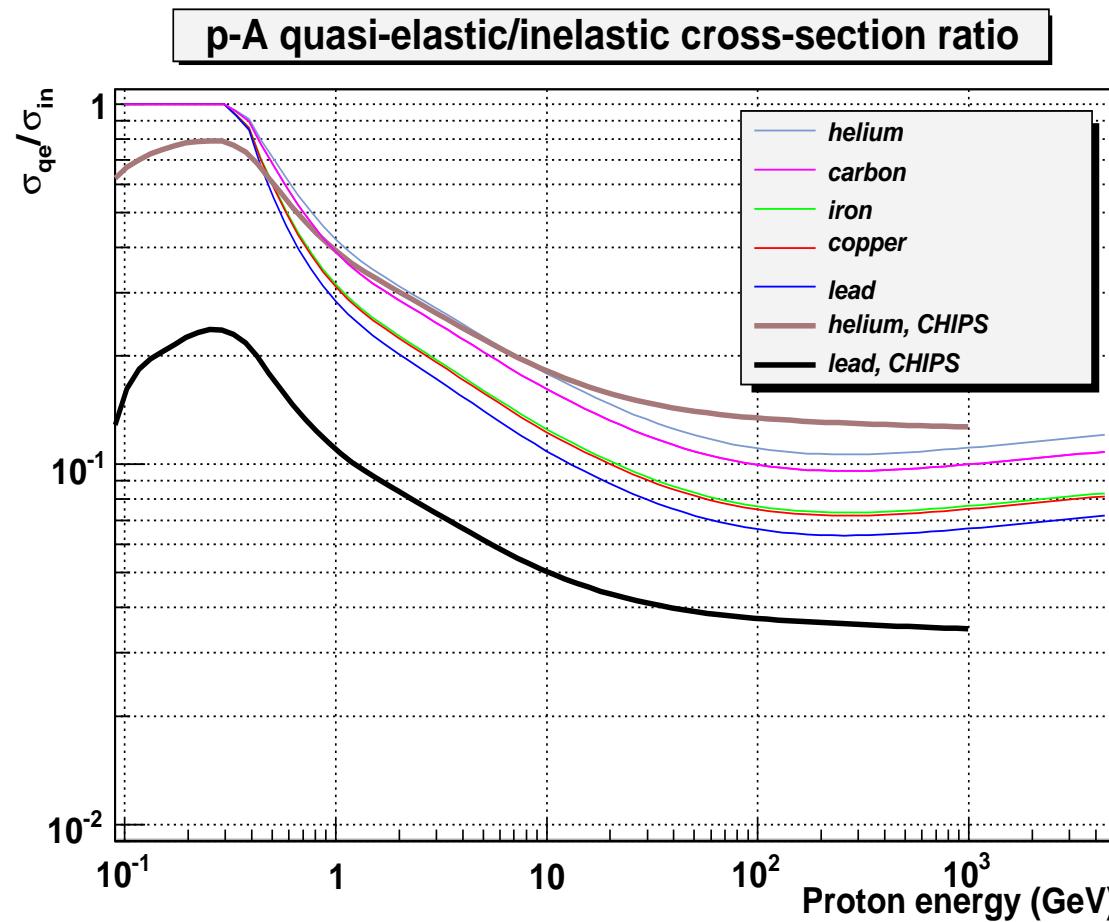
$$\sigma_{tot}^{hA} = 2\pi R^2 \ln \left[1 + \frac{A\sigma_{tot}^{hN}}{2\pi R^2} \right], \quad \sigma_{in}^{hA} = \pi R^2 \ln \left[1 + \frac{A\sigma_{tot}^{hN}}{\pi R^2} \right].$$

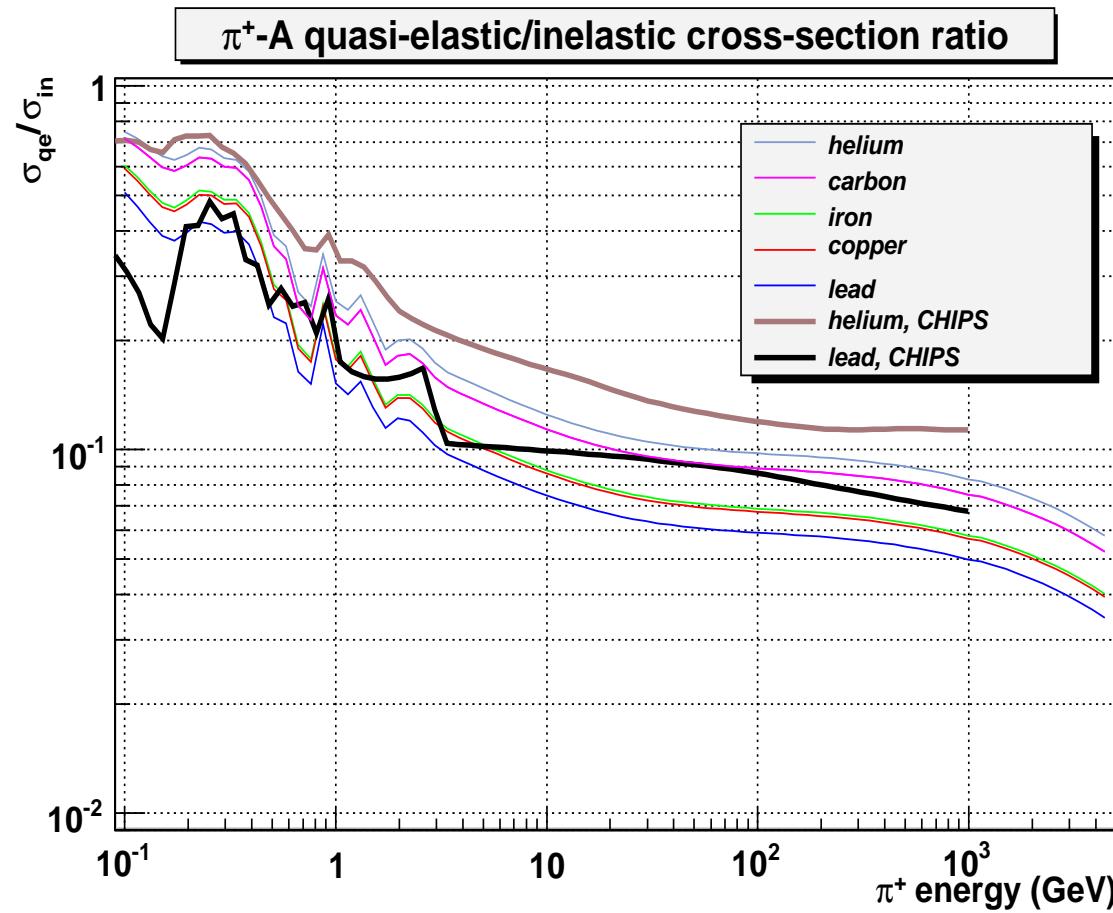
$$\sigma_{prod}^{hA} = \pi R^2 \ln \left[1 + \frac{A\sigma_{in}^{hN}}{\pi R^2} \right], \quad \sigma_{qe}^{hA} = \sigma_{in}^{hA} - \sigma_{prod}^{hA}$$

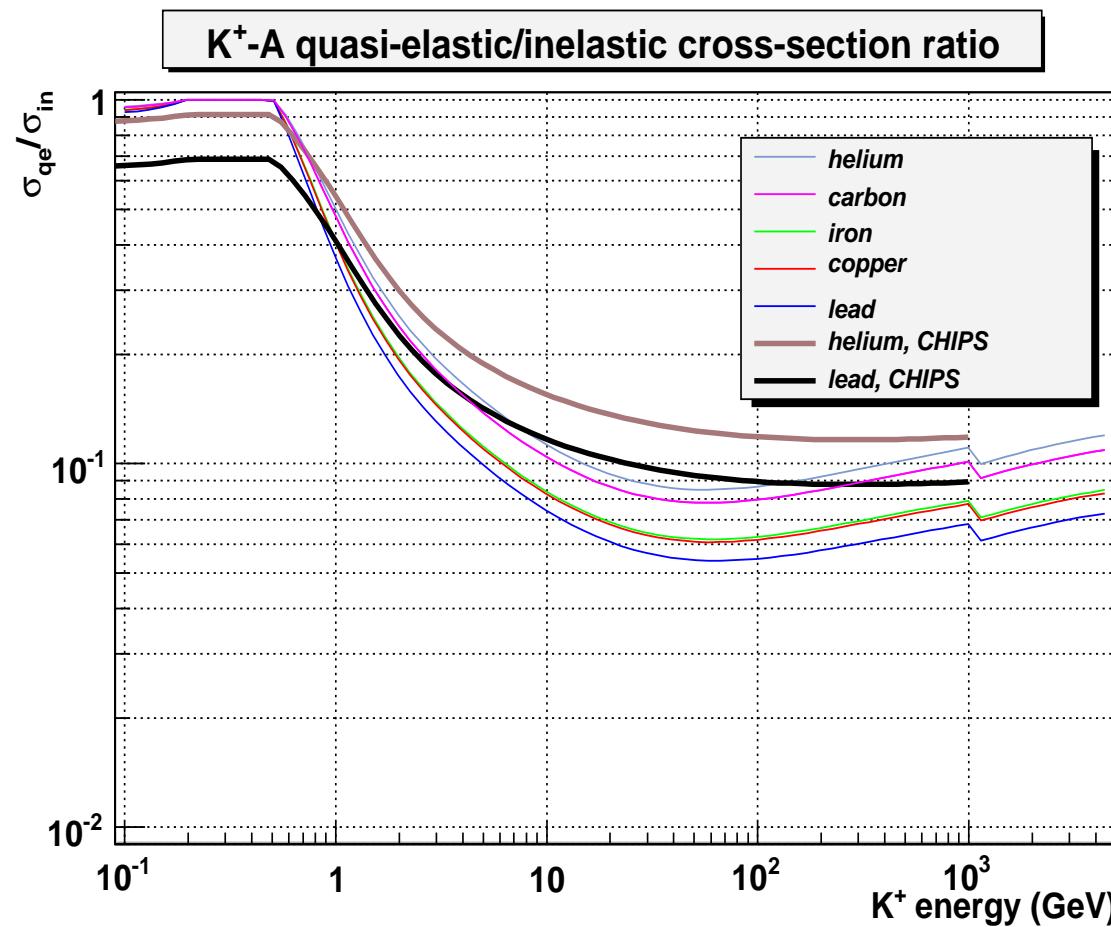
$$\sigma_{sd}^{hA}(hA \rightarrow XA) = \pi R^2 \{ \alpha - \ln [1 + \alpha] \}, \quad \alpha = \frac{A\sigma_{tot}^{hN}}{2\pi R^2 + A\sigma_{tot}^{hN}}.$$

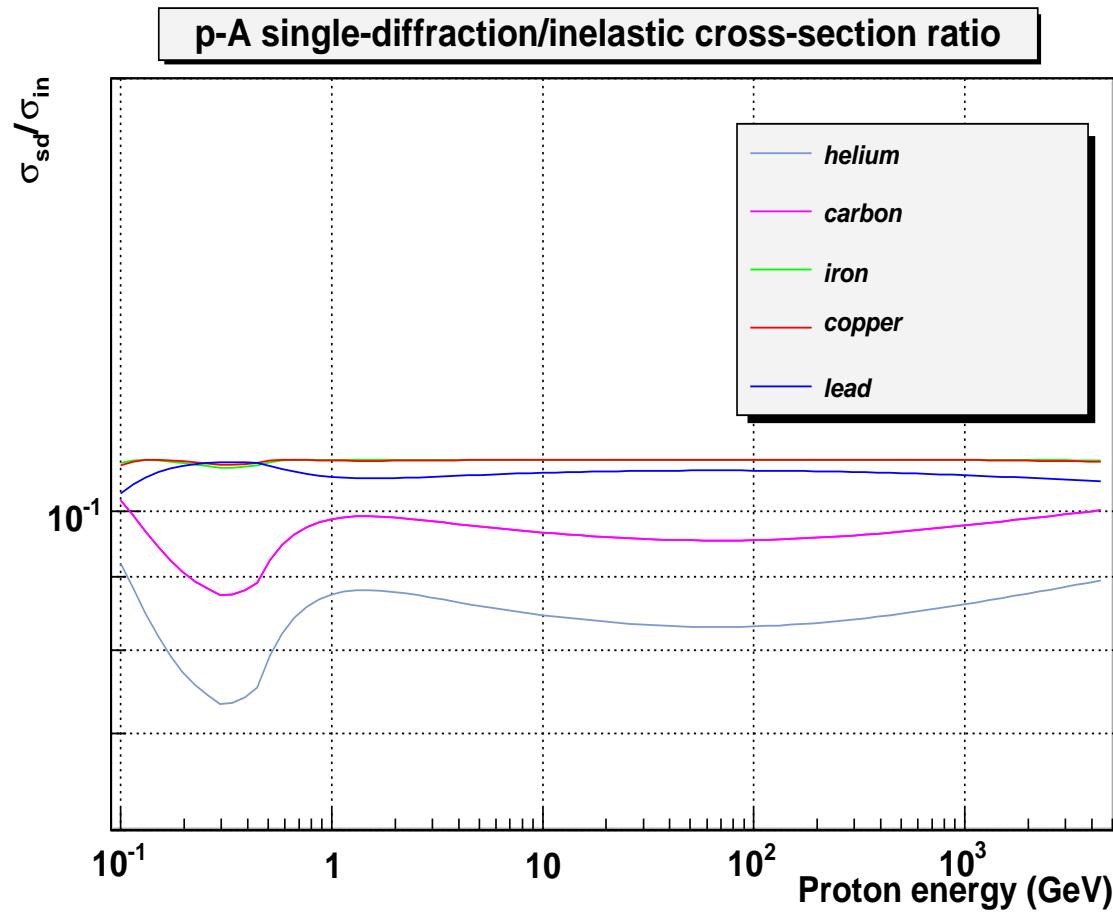
Where σ_{tot}^{hA} , σ_{in}^{hA} , σ_{prod}^{hA} , σ_{qe}^{hA} and $\sigma_{sd}^{hA}(hA \rightarrow XA)$ are the total, inelastic, production, quasi-elastic and single-diffraction cross section of a hadron on a nucleus A, respectively. They depend essentially on the hadron-nucleon cross sections, σ_{tot}^{hN} and now for the production cross section σ_{in}^{hN} . R is the RMS radius of nucleon distribution inside the nucleus.

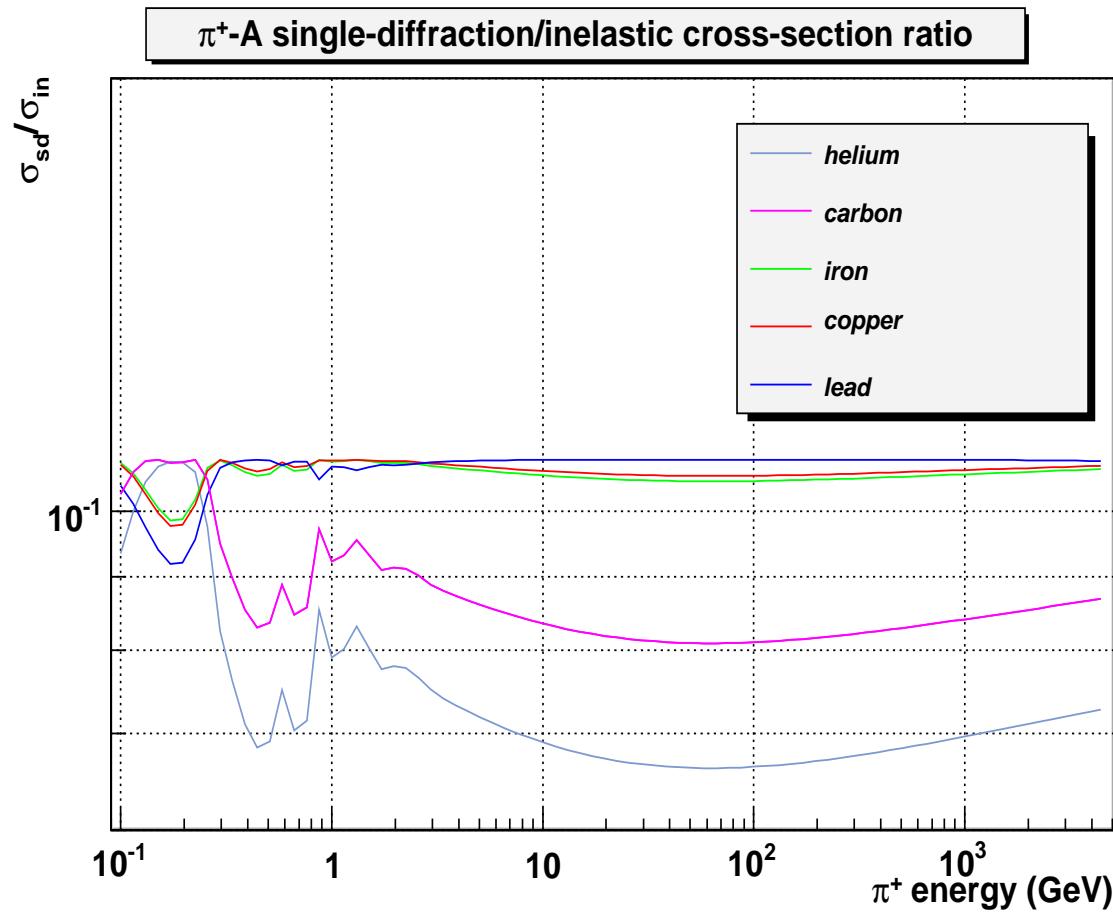


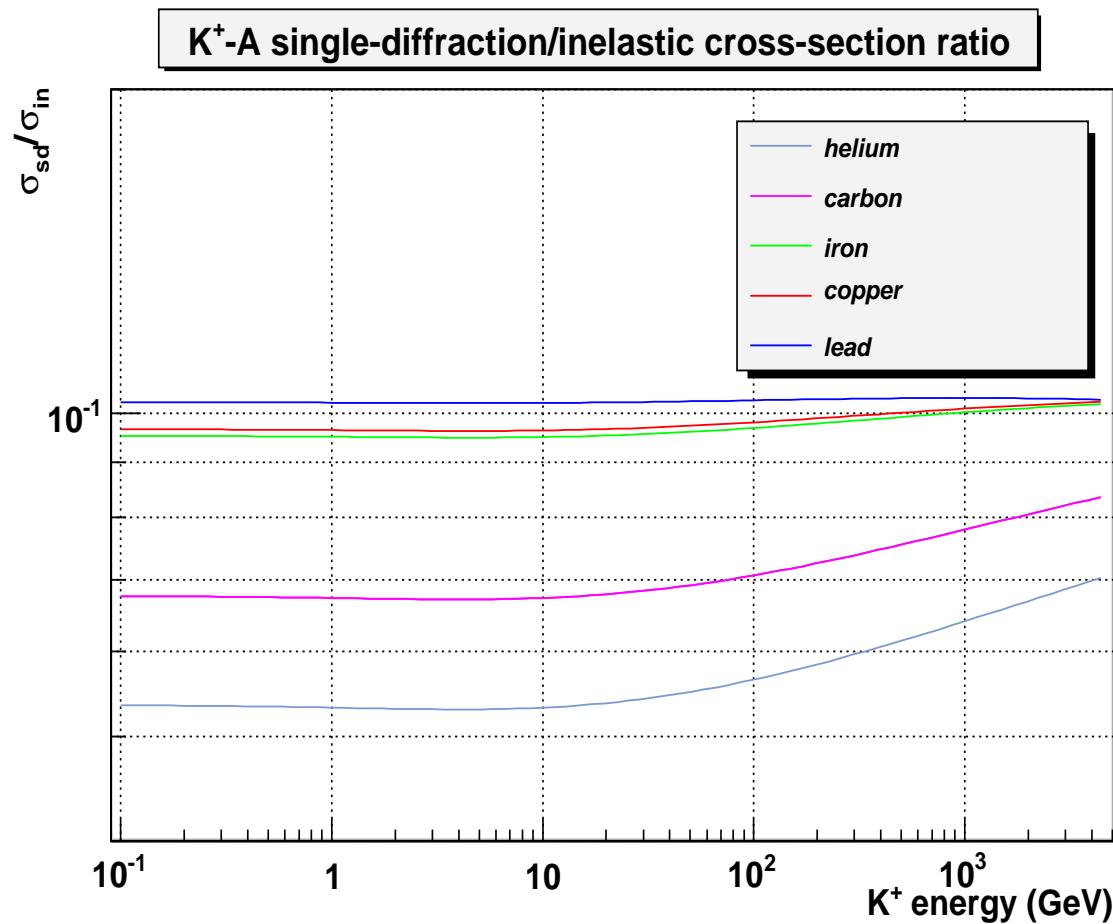












5 Conclusions

1. G4Pi/NucleonNuclearCrossSection classes based on Barashenkov parametrization show good agreement with experimental data for total, inelastic and elastic cross sections in the wide energy range 10 MeV - 1 TeV.
2. Simplified Glauber model can be used as prolongation of Barashenkov cross sections for the energy range > 100 GeV.
3. Simplified Glauber model was extended for the description of h-A production and single-diffraction cross sections.
4. The quasi-elastic/inelastic and single-diffraction/inelastic cross section ratios are available for different projectiles and targets. It is in qualitative agreement with CHIPS predictions in the energy range 1-100 GeV.