Cross section re-design

1. Cross sections are needed:
   for tracking (elastic, inelastic, total, fission, capture)
   for models (internal)

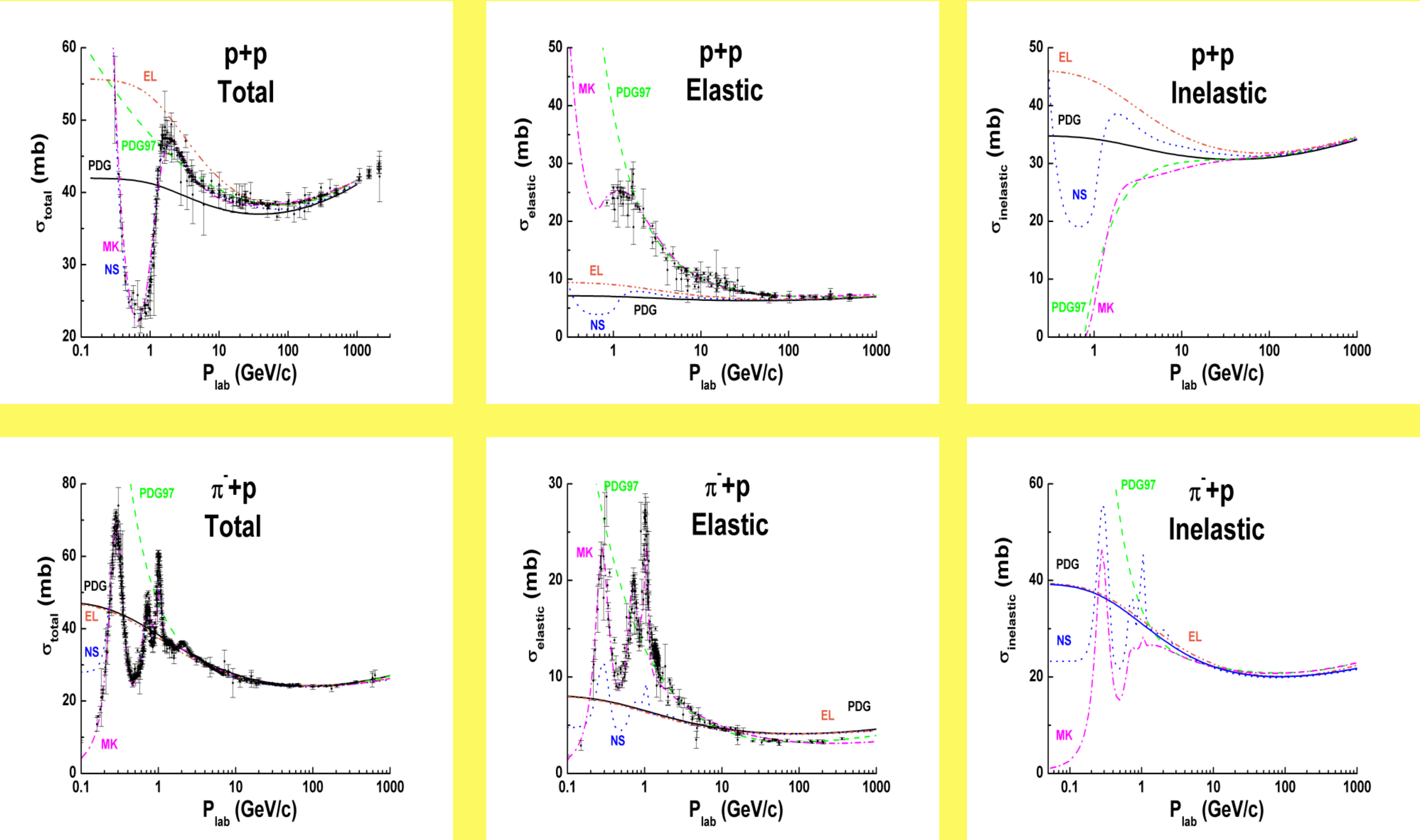
2. For an unification of hadron-nucleus (nucleus-nucleus?) cross section access re-design is needed

3. K-meson-nucleus cross sections

4. Anti-proton-nucleus cross section

5. Nucleus-nucleus cross sections

Various cross sections parameterization at high energies



Hadronic cross section re-design
G. Folger, V. Ivanchenko, D. Wright

- Too many classes in cross_sections subdirectory
- Function of classes are mixed
- Not easy identify what class can be used in Physics List, what inside a model, what combined class
- Not possible to exchange internal cross section between models
- Authorship problem

Simplest and backward compatible solution was chosen:

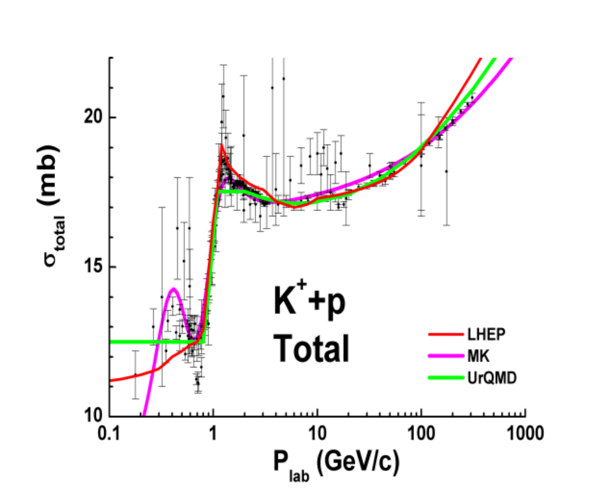
- Directory structure is not changed
- G4VCrossSectionDataSet interface was extended
- New G4VComponentCrossSection interface is added
- It is agreed that cross_section library should not depend on any model library
- Model library can depend on cross_section library

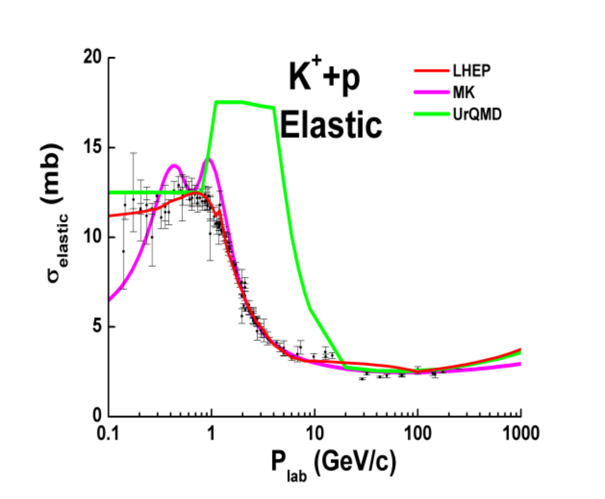
Extension of G4VCrossSectionDataSet

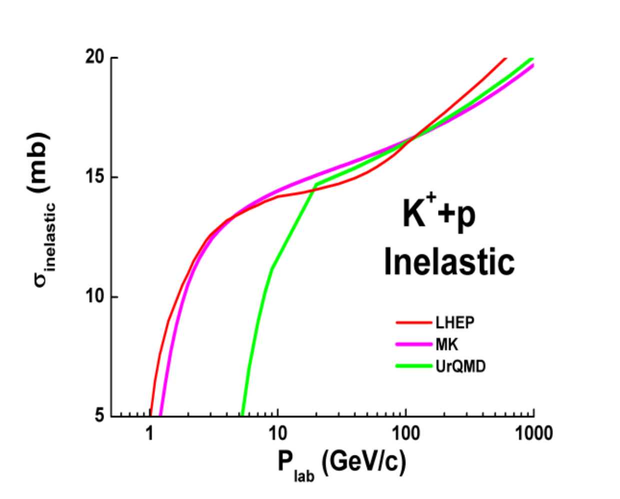
- New methods are added:

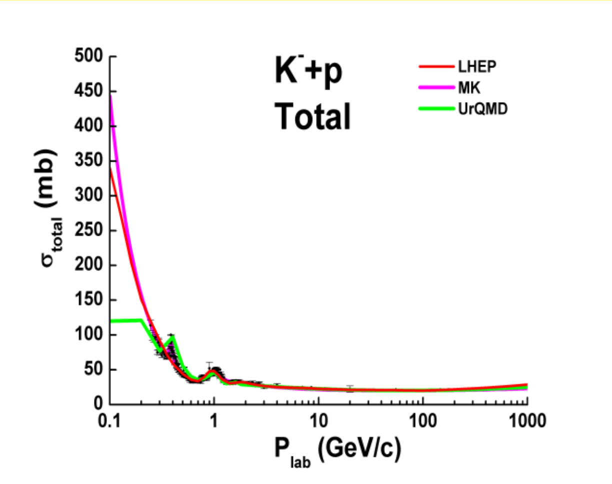
G4VComponentCrossSection interface

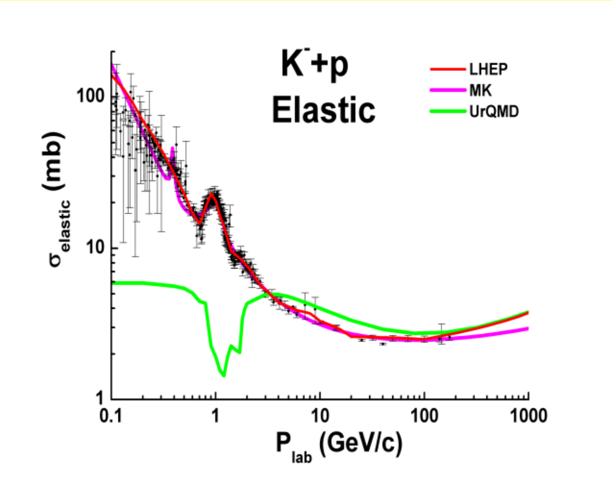
K-meson-nucleus cross sections

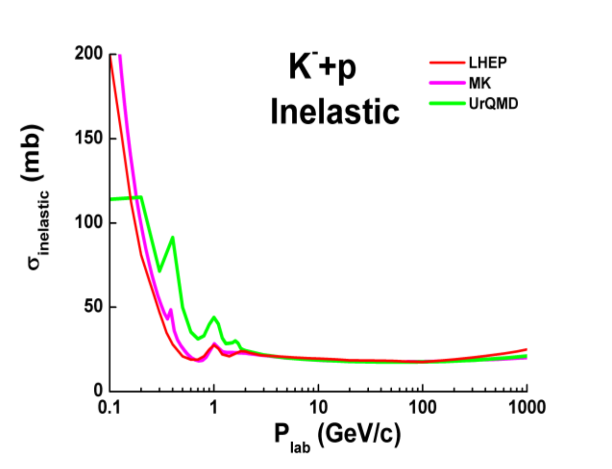






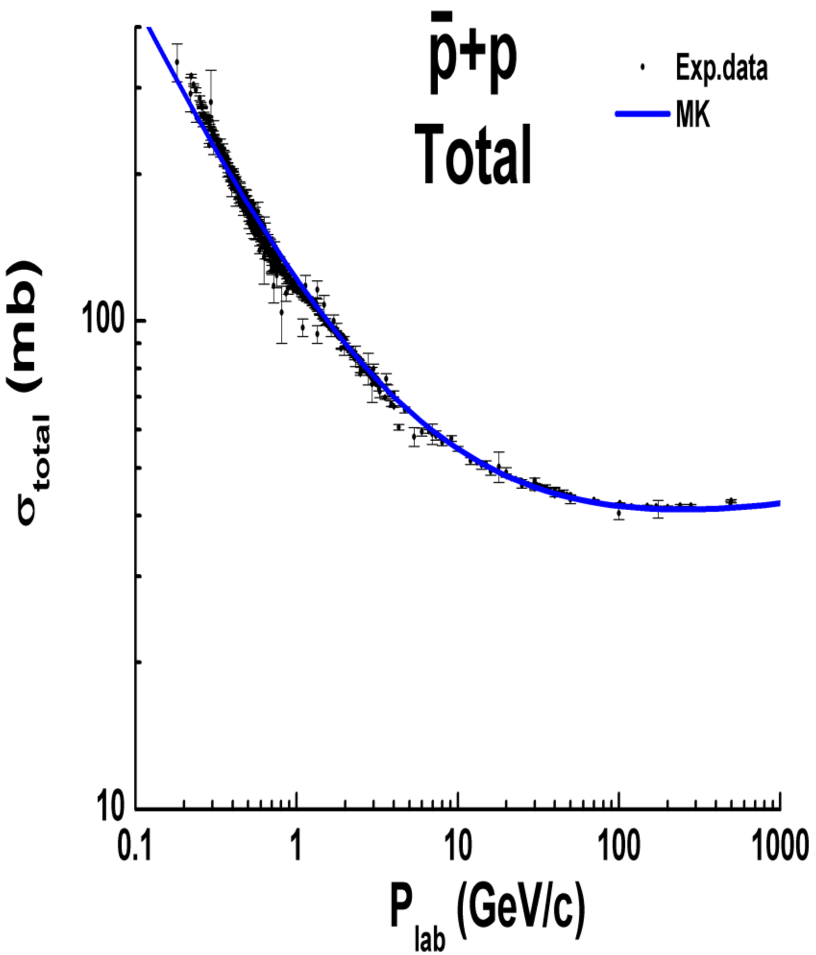


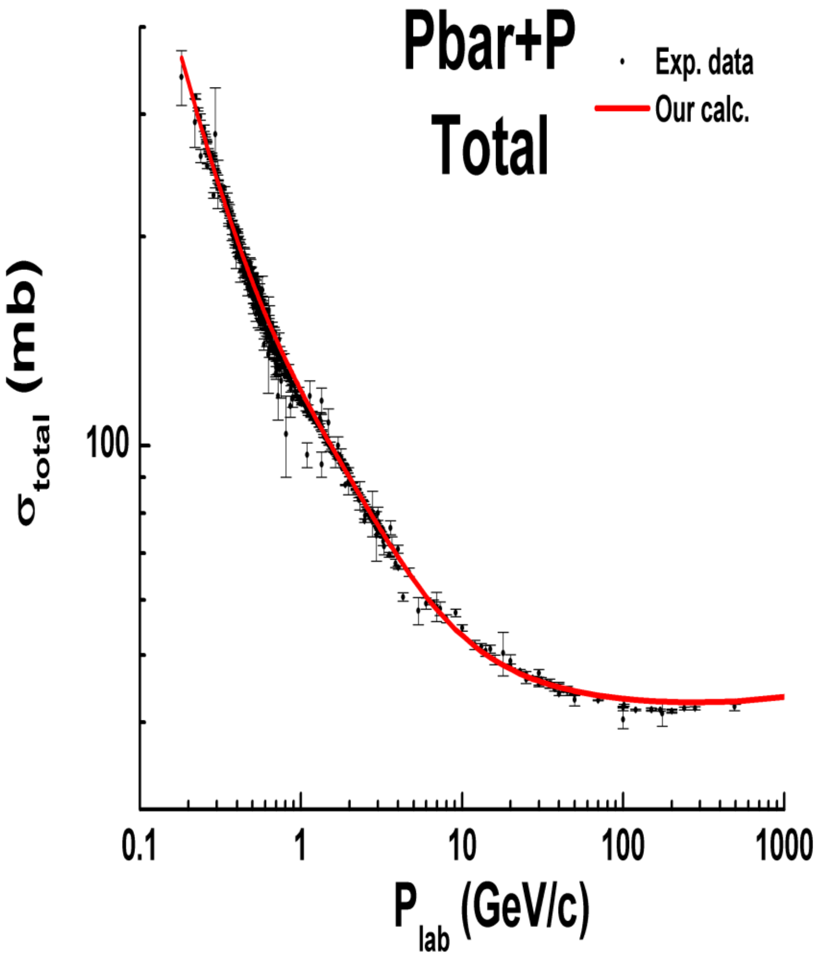




There are parameterization alternative to CHIPS.
There are problems in other approaches.

Anti-proton-proton cross sections





There are parameterization alternative to CHIPS.
There are problems in other approaches.

Glauber model can be used for hA cross section estimations with following Grichine's parameterization

A simple model for integral hadron-nucleus and nucleus-nucleus cross-sections. V.M. Grichine, Nucl. Instrum. Meth. B267: 2460 (2009).

A simplified Glauber model for hadron-nucleus cross sections. V.M. Grichine, Eur. Phys. J. C62:399 (2009).

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

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

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

$$\sigma_{sd}^{hA}(hA \to XA) = \pi R^2 \{\alpha - \ln[1+\alpha]\},$$

$$\alpha = \frac{A\sigma_{tot}^{hN}}{2\pi R^2 + A\sigma_{tot}^{hN}},$$

$$\sigma_{tot}^{A_pA_t} = 2\pi(R_p^2 + R_t^2)\ln\left[1 + \frac{A_pA_t\sigma_{tot}^{NN}}{2\pi(R_p^2+R_t^2)}\right],$$

$$\sigma_{in}^{A_pA_t} = \pi(R_p^2 + R_t^2)\ln\left[1 + \frac{A_pA_t\sigma_{tot}^{NN}}{\pi(R_p^2+R_t^2)}\right],$$

$$\sigma_{prod}^{A_pA_t} = \pi(R_p^2 + R_t^2)\ln\left[1 + \frac{A_pA_t\sigma_{in}^{NN}}{\pi(R_p^2+R_t^2)}\right],$$

The parameters R_p and R_t depend on the nuclear weights A_p and A_t, respectively, according to [2]:

$$R(A) = \begin{cases} r_0(1 - A^{-2/3})A^{1/3}, & A < 50, \\ r_0 A^{0.27}, & A \geqslant 50. \end{cases}$$

For low energies, the total and inelastic nucleus–nucleus cross-sections are corrected for the Coulomb barrier, B_c:

$$\sigma_{tot/in}^{A_pA_t} \to \sigma_{tot/in}^{A_pA_t}\left[1 - \frac{B_c}{T_{kin}^{cm}}\right], \quad B_c = \frac{Z_pZ_te^2}{R_{min}},$$

where T_{kin}^{cm} is the projectile kinetic energy in the center of mass system, $R_{min} \sim R_t + R_p$ and e is the electron charge.

Hadron-Nucleus and Nucleus-Nucleus Cross Sections

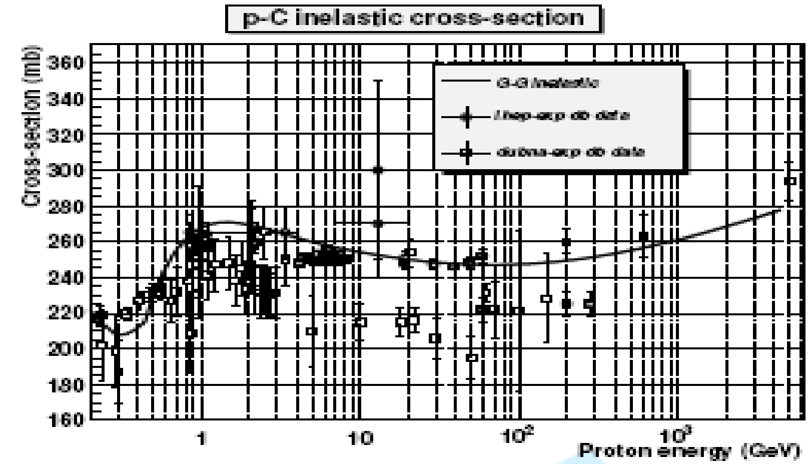


Fig. 2. The integral inelastic cross-section for protons on carbon target versus the proton kinetic energy. Experimental data (open points and squares) from [11, 12]; the line corresponds to the simplified Glauber model.

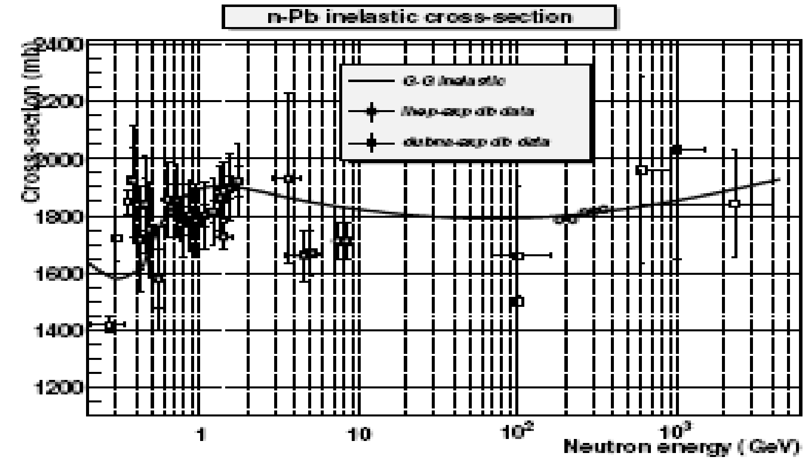


Fig. 4. The integral inelastic cross-sections for neutrons on lead target versus the neutron kinetic energy. Experimental data (open points and squares) from [11,12]; the line corresponds to the simplified Glauber model.

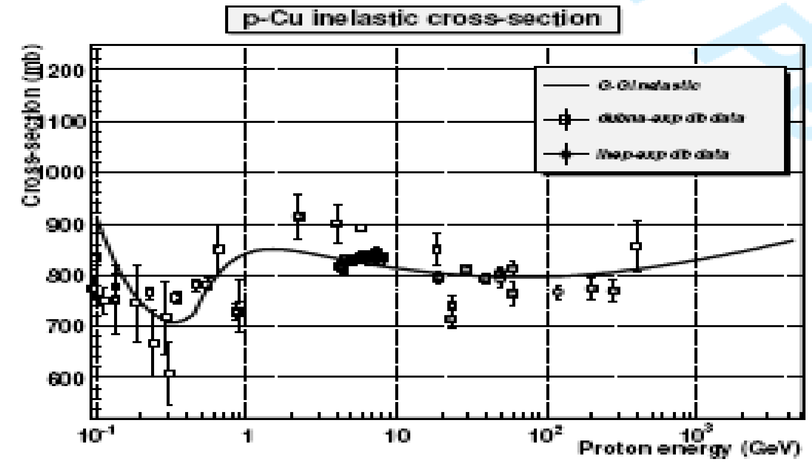


Fig. 3. The integral inelastic cross-sections for protons on copper target versus the proton kinetic energy. Experimental data (open points and squares) from [11, 12]; the line corresponds to the simplified Glauber model.

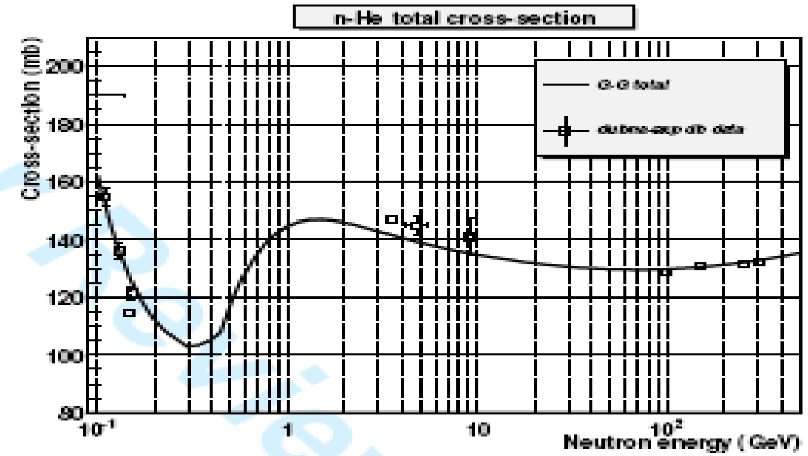


Fig. 5. The integral total cross-sections for neutrons on helium target versus the neutron kinetic energy. Experimental data (open points and squares) from [11,12]; the line corresponds to the simplified Glauber model.

Summary

1. Access to the hadron-nucleus cross section is re-designed

2. K-meson-nucleus, anti-proton-nucleus and nucleus-nucleus cross sections would be well to estimate in the Glauber approximation.

3. The cross sections can be parameterized using Grichine's approach.