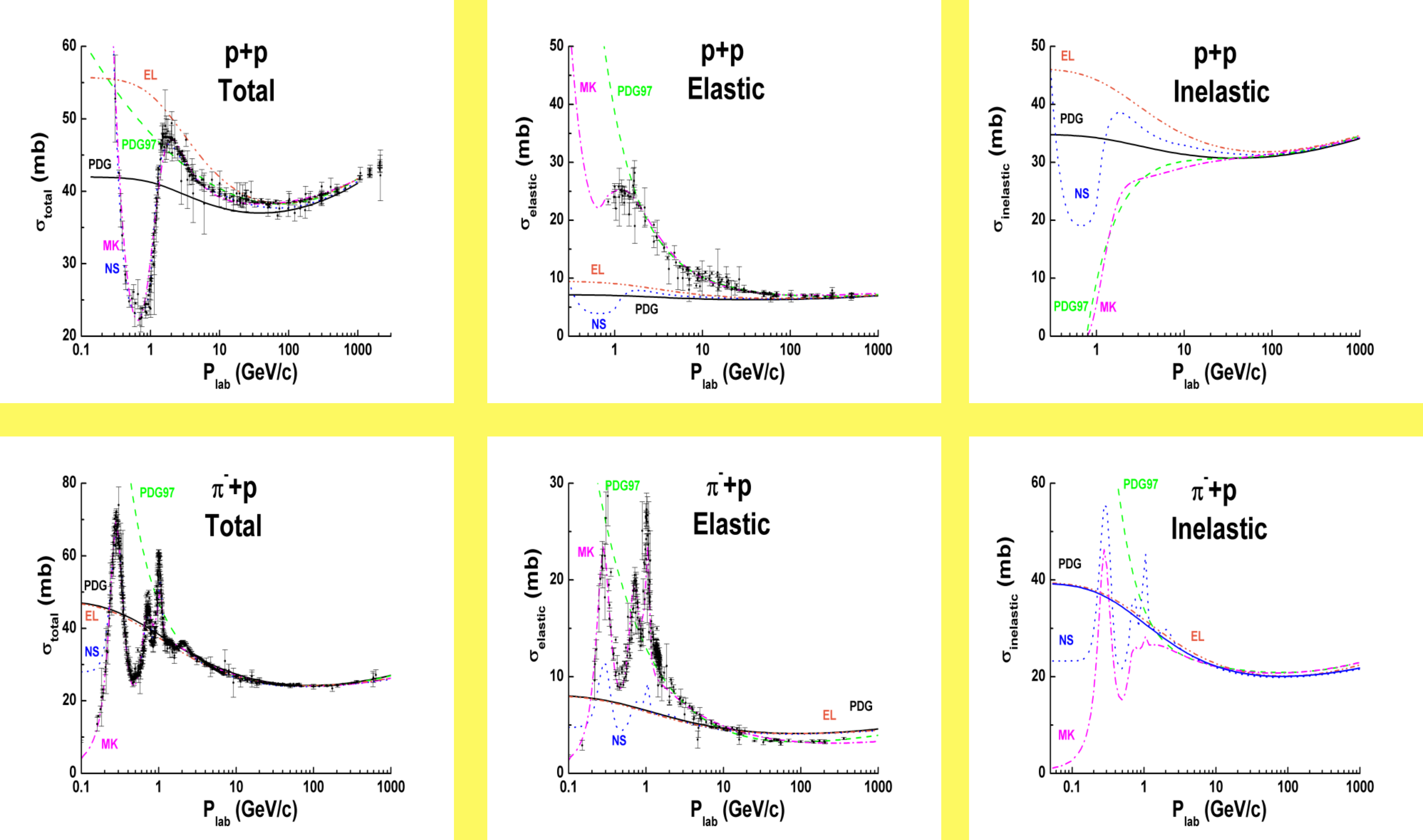
Cross section re-design

1. Technical Details of Implementation and Unification of Geant4 Hardonic Cross Sections

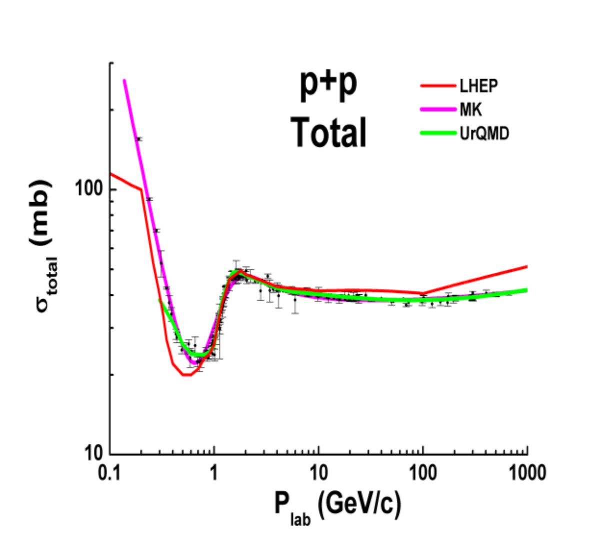
2. Hadron-Nucleus and Nucleus-Nucleus Cross Sections

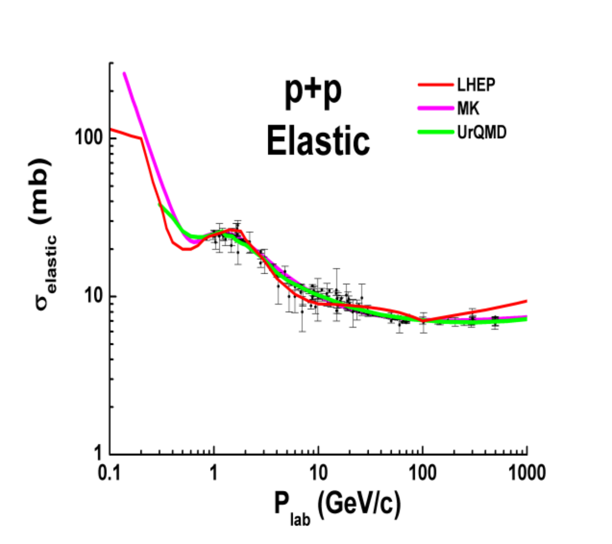
3. Current Status of Hadron-Hadron Cross Section Theory

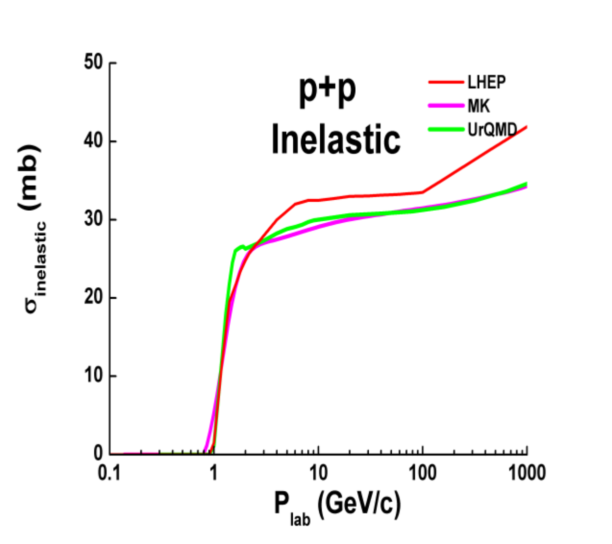
Technical Details of Implementation and Unification of Geant4 Hardonic Cross Sections

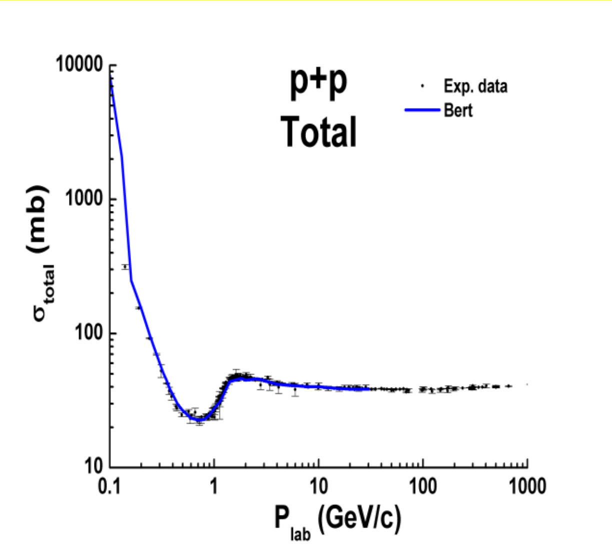


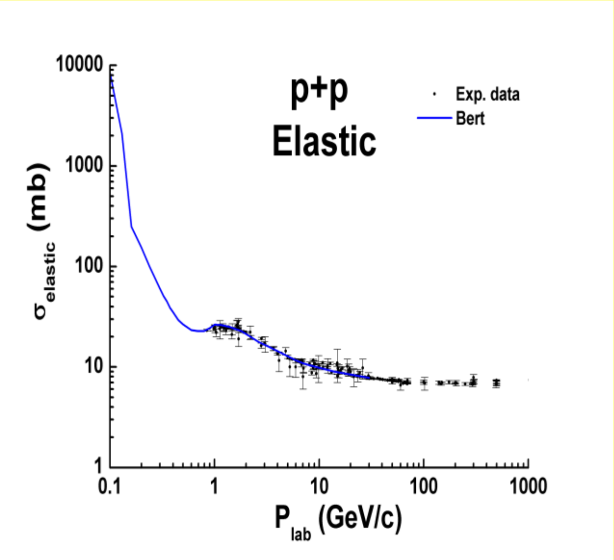
Technical Details of Implementation and Unification of Geant4 Hardonic Cross Sections











T (GeV)	σ_{pp}^{tot} (mb)	σ_{pp}^{el} (mb)	σ_{np}^{tot} (mb)	σ_{np}^{el} (mb)
0.0	17613.0	17613.0	20357.0	20357.0
0.01	302.9	302.9	912.6	912.6
0.013	257.1	257.1	788.6	788.6
0.018	180.6	180.6	582.1	582.1
0.024	128.4	128.4	415.0	415.0
0.032	90.5	90.5	272.0	272.0
0.042	66.1	66.1	198.8	198.8
0.056	49.4	49.4	145.0	145.0
0.075	36.9	36.9	100.4	100.4
0.1	29.6	29.6	71.1	71.1
0.13	26.0	26.0	58.8	58.8
0.18	23.1	23.1	45.7	45.7
0.24	22.6	22.6	38.9	38.9
0.32	23.0	23.0	34.4	34.4
0.42	27.0	26.3	34.0	31.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Technical Details of Implementation and Unification of Geant4 Hardonic Cross Sections

There are various parameterization of cross sections in Geant4. Own hN cross sections are used in Bertini and Binary models. PDG93 is used in FTF model. Quasi-eikonal model (not exact) is ised in QGSM.

Is it needed to make an unification of the parameterizations?

Is there any problem with hadron-nucleus cross sections?

How can nucleus-nucleus cross sections be implemented?

Is this job actual?

Hadron-Nucleus and Nucleus-Nucleus Cross Sections

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).

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

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

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

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

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

For given total cross-sections of a hadron on protons and neutrons, $A\sigma_{tot}^{hN} = N_p\sigma_{tot}^{hp} + N_n\sigma_{tot}^{hn}$, where N_p and N_n are the number of protons and neutrons in the nucleus, respectively ($N_p = Z$, where Z is atomic number). The nuclear radius is parametrized, as a function of A, by:

$$R(A) = r_o A^{\frac{1}{3}} f(A), \quad r_o \sim 1.1\ fm,$$

where the correction factor $0.8 < f(A) < 1$ for $A > 21$, while in the opposite case, $3 < A < 21$, $1 < f(A) < 1.1$.

Hadron-Nucleus and Nucleus-Nucleus Cross Sections

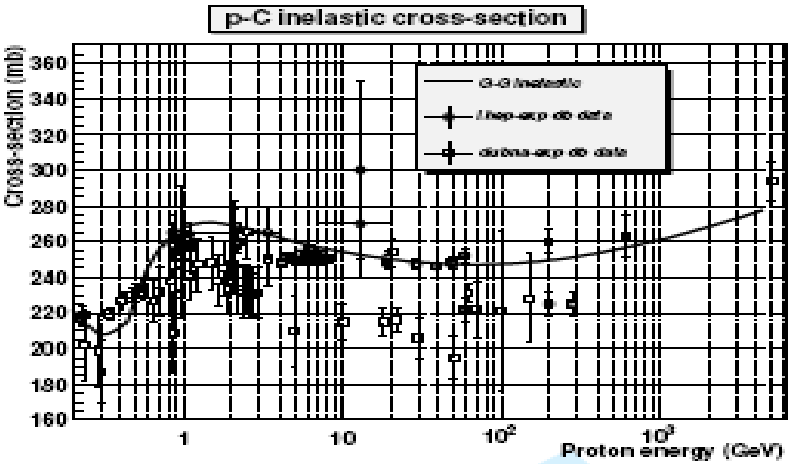


Fig. 2. The integral inelastic cross-section for protons on carbon target versus the proton kinetic energy. Experimental data (open points and squares) from [11, 12]; the line corresponds to the simplified Glauber model.

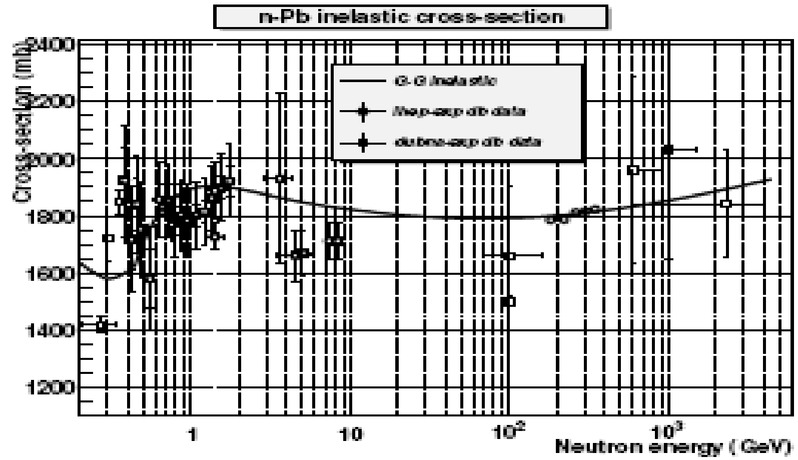


Fig. 4. The integral inelastic cross-sections for neutrons on lead target versus the neutron kinetic energy. Experimental data (open points and squares) from [11,12]; the line corresponds to the simplified Glauber model.

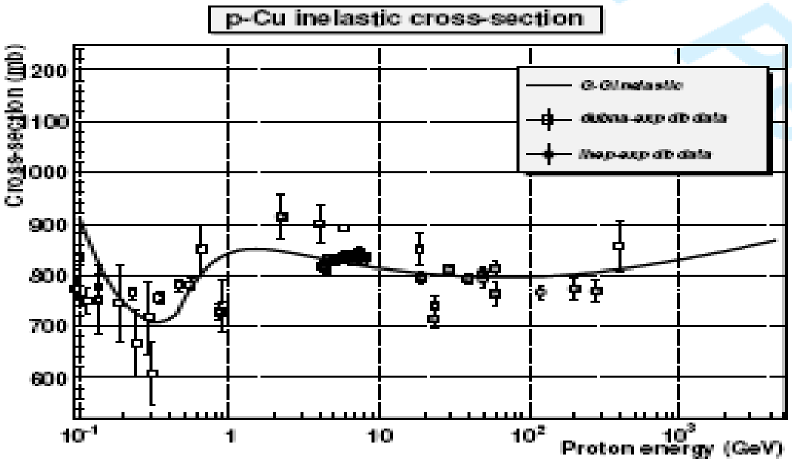


Fig. 3. The integral inelastic cross-sections for protons on copper target versus the proton kinetic energy. Experimental data (open points and squares) from [11, 12]; the line corresponds to the simplified Glauber model.

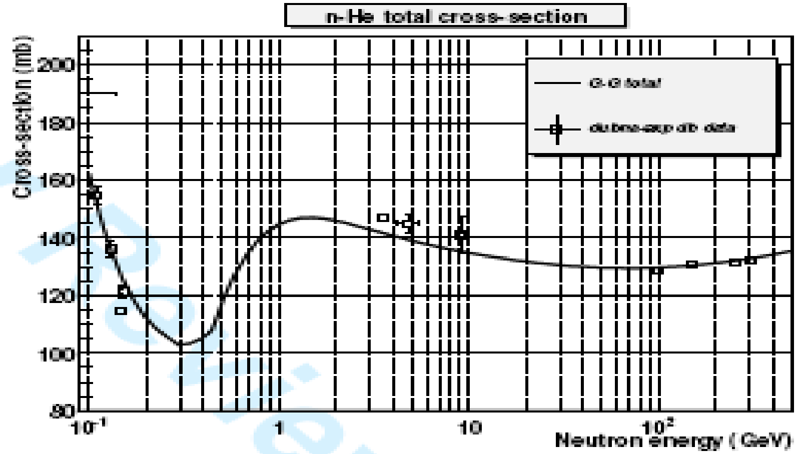


Fig. 5. The integral total cross-sections for neutrons on helium target versus the neutron kinetic energy. Experimental data (open points and squares) from [11,12]; the line corresponds to the simplified Glauber model.

For Peer Review

Hadron-Nucleus and Nucleus-Nucleus Cross Sections

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

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

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

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

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

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.

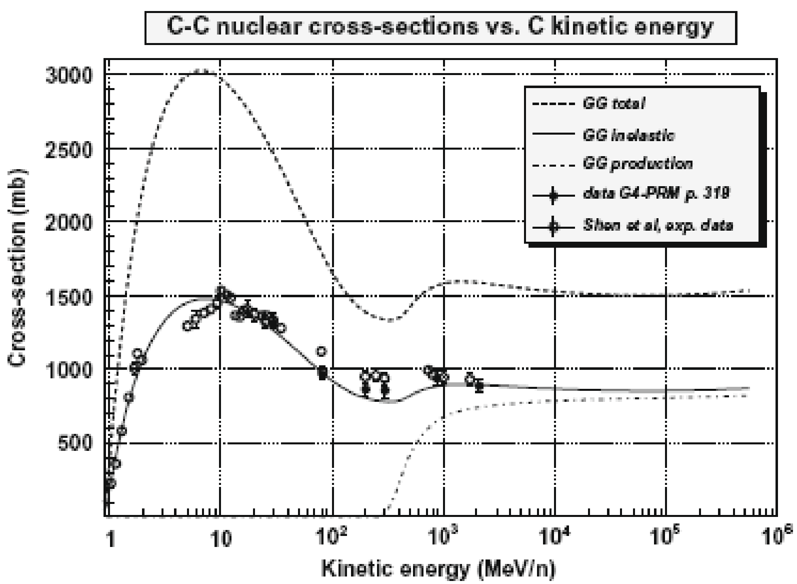


Fig. 2. The integral cross-sections for carbon ions on carbon target versus the carbon ion kinetic energy. Experimental data (open and closed points) from [2,10]; the dash-dash, solid and dash-dot lines correspond to the simplified Glauber model for the total, inelastic and production cross-sections, respectively.

BGG is included in Geant4

Validation of AA cross sections?

Comparison with Glauber calc?

Hadron-Nucleus and Nucleus-Nucleus Cross Sections

DIAGEN: generator of inelastic nucleus-nucleus interaction diagrams.
S.Yu. Shmakov, V.V. Uzhinskii, A.M. Zadorozhny
Comput. Phys. Commun. 54 (1989) 125

The algorithm is implemented in DPMJET.

GLISSANDO: Glauber initial-state simulation and more..
W. Broniowski, M. Rybczynski, P. Bozek,
Comput.Phys.Commun.180:69-83,2009.
e-Print: **arXiv:0710.5731 [nucl-th]**

Cross sections can be calculated at high energies with present level of our understanding of hN- cross sections and nuclear parameters, but they must be properly parameterized and tabulated.

Interested community and sources of support of the job should be found.

Current Status of Hadron-Hadron Cross Section Theory

N+N, Pi+N, K+N, Lambda+N, Sigma+N, Xi+N
Pbar+N/A, Dbar+N/A

INCL/ABLA

Cugnon NIM B111 (1996) 215

$$\sigma_{pp}^{tot} = 34(P_{lab}/0.4)^{-2.104} \quad 0.1\ GeV/c < P_{lab} < 0.4\ GeV/c$$

$$\sigma_{pp}^{tot} = 23.5 + 1000(P_{lab} - 0.7)^4 \quad 0.4\ GeV/c < P_{lab} < 0.8\ GeV/c$$

$$\sigma_{pp}^{tot} = 23.5 + 24.6/\left[1 + exp\left(-\frac{P_{lab} - 1.2}{0.1}\right)\right] \quad 0.8\ GeV/c < P_{lab} < 1.5\ GeV/c$$

$$\sigma_{pp}^{tot} = 41 + 60(P_{lab} - 0.9)e^{-1.2P_{lab}} \quad 1.5\ GeV/c < P_{lab} < 5\ GeV/c$$

$$\sigma_{pp}^{el} = \sigma_{pp}^{tot} \quad P_{lab} < 0.8\ GeV/c$$

$$\sigma_{pp}^{el} = 1250/(P_{lab} + 50) - 4(P_{lab} - 1.3)^2 \quad 0.8\ GeV/c < P_{lab} < 2\ GeV/c$$

$$\sigma_{pp}^{el} = 77/(P_{lab} + 1.5) \quad 2\ GeV/c < P_{lab}$$

$$\sigma_{np}^{tot} = 6.3555 P_{lab}^{-3.2481} * exp(-0.377(ln(P_{lab}))^2) \quad 0.05\ GeV/c < P_{lab} < 0.4\ GeV/c$$

$$\sigma_{np}^{tot} = 33 + 196|P_{lab} - 0.95|^{2.5} \quad 0.4\ GeV/c < P_{lab} < 1\ GeV/c$$

$$\sigma_{np}^{tot} = 24.2 + 8.9P_{lab} \quad 1\ GeV/c < P_{lab} < 2\ GeV/c$$

$$\sigma_{np}^{tot} = 42 \quad 2\ GeV/c < P_{lab}$$

$$\sigma_{np}^{el} = \sigma_{np}^{tot} \quad P_{lab} < 0.8\ GeV/c$$

$$\sigma_{np}^{el} = 31/\sqrt{p_{lab}} \quad 0.8\ GeV/c < P_{lab} < 2\ GeV/c$$

$$\sigma_{np}^{el} = 77/(P_{lab} + 1.5) \quad 2\ GeV/c < P_{lab}$$

proposed

Cugnon Chen NP A379 (1982) 553, PR 166 (1968) 949

$$\sigma(\pi^+ p \to \Delta^{++}) = \frac{326.5}{1 + 4\left(\frac{\sqrt{s} - 1.215}{0.110}\right)^2} \frac{q^3}{q^3 + (0.18)^3}$$

$$\sigma^{in} = \sigma(\pi N \to \pi\pi N) = 74(P_{lab} - 0.555)^2/P_{lab}^{4.04} \quad P_{lab} 0.5 - -1.5 \quad GeV/c$$

Current Status of Hadron-Hadron Cross Section Theory

PHYSICAL REVIEW D **79**, 096003 (2009)

Test of universal rise of hadronic total cross sections based on πp, Kp and $\bar{p}p$, pp scatterings

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(Received 1 March 2009; published 4 May 2009)

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Universal rise of hadronic total cross sections based on forward πp and $\bar{p}p(pp)$ scatterings

Muneyuki Ishida [a,*], Keiji Igi [b]

$$\sigma_{\rm tot}^{(+)} \simeq Z^{ap} + B\log^2\frac{s}{s_0}$$

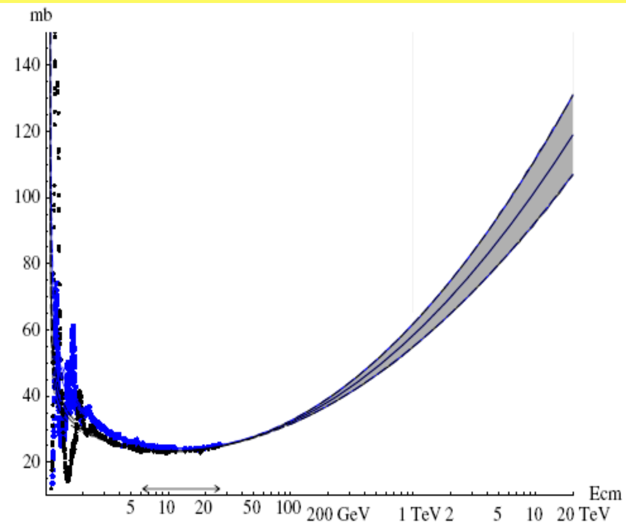


FIG. 4 (color online). Prediction of $\sigma_{\rm tot}^{\pi p}$ without the FESR. The data points are given with no error bars. The big blue points (line) are data (best-fitted curve) for $\pi^- p$. The black points and lines are for $\pi^+ p$. The horizontal arrow represents the energy region of the fitting. The shaded region corresponds to the uncertainty of the prediction by the best fit, where $c_2 = (164 \pm 29) \times 10^{-5}$. The c_2 has large uncertainties since it is not determined well by direct fitting of the data above $k = 20$ GeV ($E_{\rm cm} = 6.2$ GeV).

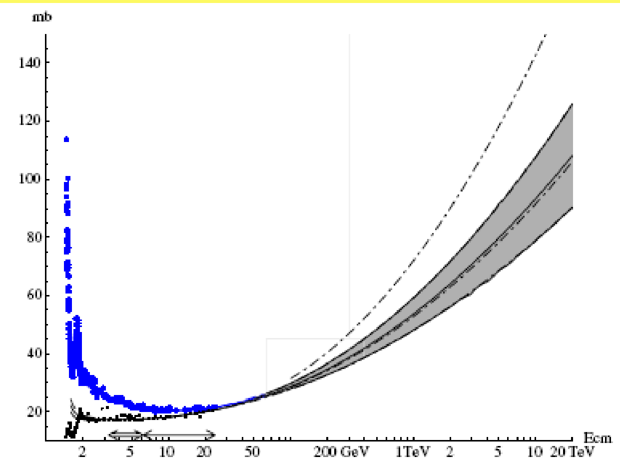


FIG. 8 (color online). Prediction of $\sigma_{\rm tot}^{Kp}$ with the FESR in the case of $\bar{N}_1 = 5$ GeV as a constraint: The big blue points (line) are data (best-fitted curve) for $K^- p$. The black points and lines are for $K^+ p$. The single horizontal arrow represents the energy region of the fitted data, while the double horizontal arrow represents the energy region of the FESR integral, $k = \bar{N}_1$ through $\bar{N}_2$ ($= 20$ GeV). The data points are given with no error bars. The uncertainty of the prediction by the best fit, shown by the shaded region, is improved from that without the FESR, represented by the dot-dashed line. The best-fitted c_2 is $c_2 = (176 \pm 49) \times 10^{-4}$. The inclusion of the information of low-energy data by the FESR is essential to improve the estimation of c_2.

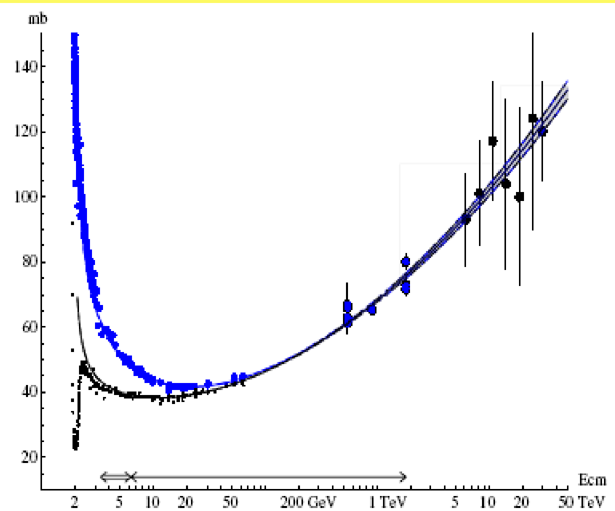


FIG. 10 (color online). Prediction of $\sigma_{\rm tot}^{\bar{p}p,pp}$ with the FESR: The data up to the Tevatron energy are fitted simultaneously. The single horizontal arrow represents the energy region of the fitting. The big blue points (line) are data (best-fitted curve) for $\bar{p}p$. The black points and lines are for pp. The data points are given with no error bars. The double horizontal arrow represents the energy region of the FESR integral, $k = \bar{N}_1$ ($= 5$ GeV in this case) through $\bar{N}_2$ ($= 20$ GeV). The shaded region corresponds to the uncertainty of our prediction in the best fit, where $c_2 = (504 \pm 26) \times 10^{-4}$.

Current Status of Hadron-Hadron Cross Section Theory

A.A. Arkhipov - 9911533v2[1].

At the first step, we made a weighted fit to the experimental data on the proton-antiproton total cross sections in the range $\sqrt{s} > 10\,GeV$. The data were fitted with the function of the form predicted by the Froissart bound in the spirit of our approach[3]

$$\sigma^{tot}_{asmpt} = a_0 + a_2 \ln^2(\sqrt{s}/\sqrt{s_0}) \tag{44}$$

where $a_0, a_2, \sqrt{s_0}$ are free parameters. We accounted for the experimental errors δx_i (statistical and systematic errors added in quadrature) by fitting to the experimental points with the weight $w_i = 1/(\delta x_i)^2$. Our fit yielded

$$a_0 = (42.0479 \pm 0.1086) mb, \quad a_2 = (1.7548 \pm 0.0828) mb, \tag{45}$$

$$\sqrt{s_0} = (20.74 \pm 1.21) GeV. \tag{46}$$

The fit result is shown in Fig. 2.

---

[3]Recently, from a careful analysis of the experimental data and comparative study of the known characteristic parameterizations, Bueno and Velasco have shown that statistically a "Froissart-like" type parameterization for proton-proton and proton-antiproton total cross sections is strongly favoured [29].

After that we made a weighted fit to the experimental data on the slope of diffraction cone in elastic $p\bar{p}$ scattering. The experimental points and the references, where they have been extracted from, are listed in [30]. The fitted function of the form

$$B = b_0 + b_2 \ln^2(\sqrt{s}/20.74), \tag{47}$$

which is also suggested by the asymptotic theorems of local quantum field theory, has been used. The value $\sqrt{s_0}$ was fixed by (46) from the fit to the $p\bar{p}$ total cross sections data. Our fit yielded

$$b_0 = (11.92 \pm 0.15) GeV^{-2}, \quad b_2 = (0.3036 \pm 0.0185) GeV^{-2}. \tag{48}$$

The fitting curve is shown in Fig. 3.

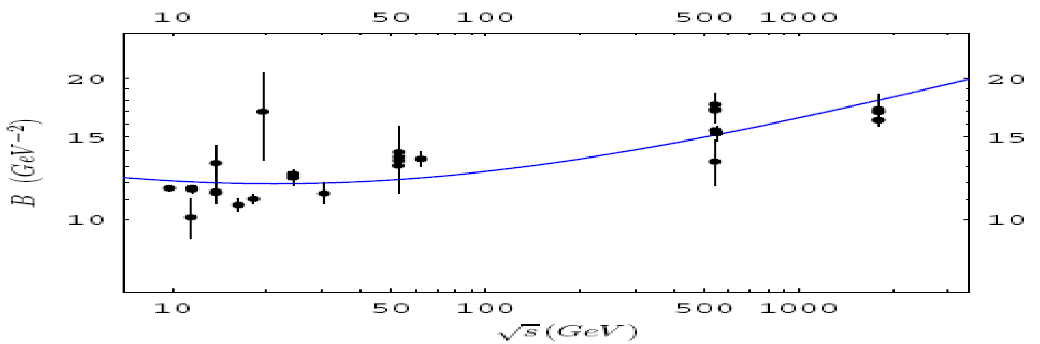


Figure 3: Slope B of diffraction cone in $p\bar{p}$ elastic scattering. Solid line represents our fit to the data.

Current Status of Hadron-Hadron Cross Section Theory

A.A. Arkhipov - 9911533v2[1].

At the final stage we build a global (weighted) fit to the all data on proton-antiproton total cross sections in a whole range of energies available up today. The global fit was made with the function of the form

$$\sigma_{p\bar{p}}^{tot}(s) = \sigma_{asmpt}^{tot}(s)\left[1 + \frac{c}{\sqrt{s-4m_N^2}R_0^3(s)}\left(1+\frac{d_1}{\sqrt{s}}+\frac{d_2}{s}+\frac{d_3}{s^{3/2}}\right)\right] \quad (49)$$

where m_N is proton (nucleon) mass,

$$R_0^2(s) = \left[0.40874044\sigma_{asmpt}^{tot}(s)(mb) - B(s)\right]\,(GeV^{-2}), \quad (50)$$

$$\sigma_{asmpt}^{tot}(s) = 42.0479 + 1.7548\ln^2(\sqrt{s}/20.74), \quad (51)$$

$$B(s) = 11.92 + 0.3036\ln^2(\sqrt{s}/20.74), \quad (52)$$

c, d_1, d_2, d_3 are free parameters. Function (49) corresponds to the structure given by Eq. (32).

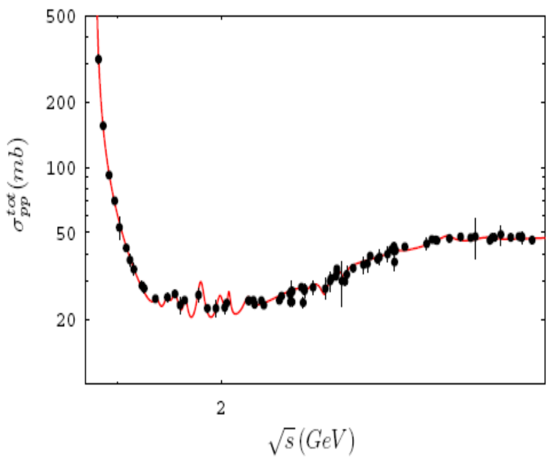


Figure 5: The proton-proton total cross-section versus $\sqrt{s}$ at low energies. Solid line corresponds to our theory predictions.

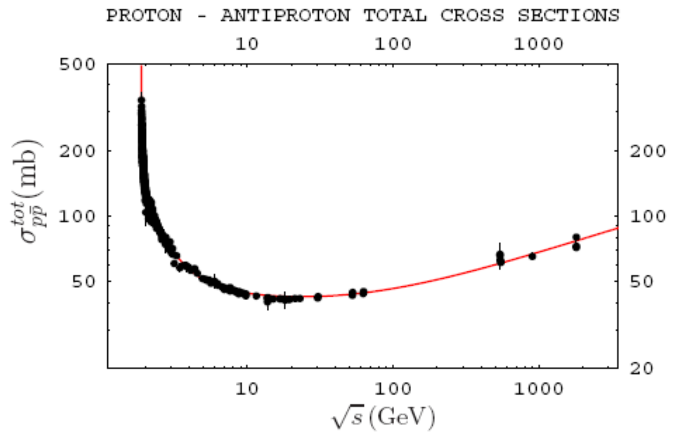
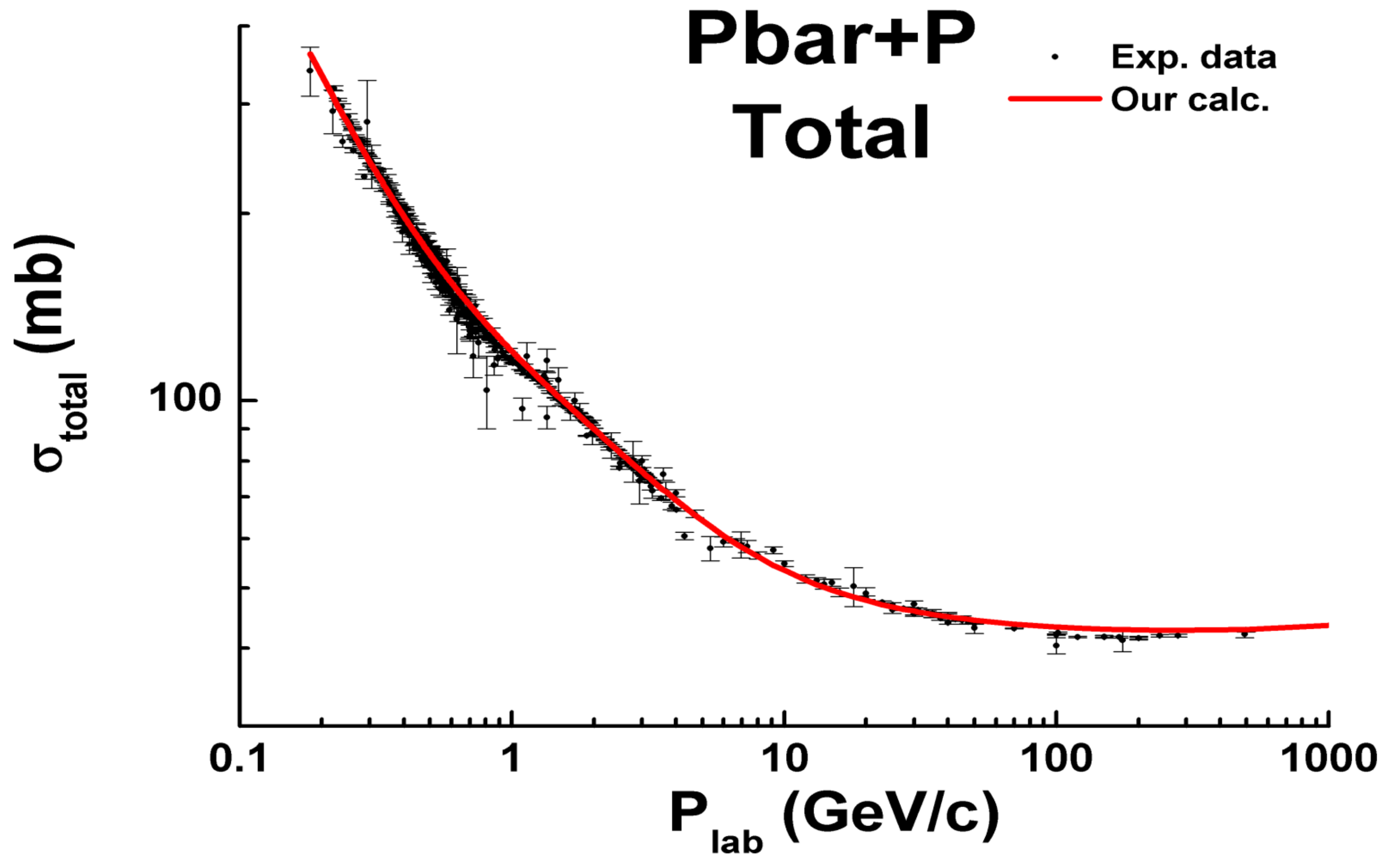


Figure 7: The experimental data on the proton-antiproton total cross-section vs $\sqrt{s}$ [7]. Solid line represents our global fit [18] to the data. Statistical and systematic errors added in quadrature.

Current Status of Hadron-Hadron Cross Section Theory

A.A. Arkhipov - 9911533v2[1].



Current Status of Hadron-Hadron Cross Section Theory

PHYSICAL REVIEW D, VOLUME 65, 074024

Hadronic scattering amplitudes: Medium-energy constraints on asymptotic behavior

J. R. Cudell,[1] V. V. Ezhela,[2] P. Gauron,[3] K. Kang,[4] Yu. V. Kuyanov,[2] S. B. Lugovsky,[2] B. Nicolescu,[3] and N. P. Tkachenko[2]
(COMPETE* Collaboration)

$$\sigma^{a\mp b} = \frac{1}{s}\left(\mathrm{R}^{+ab}(s) \pm \mathrm{R}^{-ab}(s) + \mathrm{P}^{ab} + \mathrm{H}^{ab}(s)\right),$$

where

$$\mathrm{R}^{+ab}(s) = Y_1^{ab}\cdot(s/s_1)^{\alpha_1}, \text{ with } s_1 = 1\ \mathrm{GeV}^2,$$

Current Status of Hadron-Hadron Cross Section Theory

PHYSICAL REVIEW C **79**, 024604 (2009)

Microscopic study of neutron elastic scattering from 12C, 40Ca, and 208Pb at intermediate energies

M. A. Alvi, M. R. Arafah, J. H. Madani, and I. Ahmad

$$\sigma_{pp} = 13.73 - \frac{15.04}{v} + \frac{8.76}{v^2} + 68.67\, v^4, \qquad (21)$$

$$\sigma_{pn} = -70.67 - \frac{18.18}{v} + \frac{25.26}{v^2} + 113.85\, v, \qquad (22)$$

where σ_{pp} and σ_{pn} are in mb. To calculate α_{pp} and α_{pn}, we use the parametrizations of Ahmad *et al*. [15]

$$\alpha_{pp} = -0.386 + 1.224\, e^{-\frac{1}{2}\left(\frac{k-0.427}{0.178}\right)^2} + 1.01\, e^{-\frac{1}{2}\left(\frac{k-0.592}{0.638}\right)^2}, \qquad (23)$$

$$\alpha_{pn} = -0.666 + 1.437\, e^{-\frac{1}{2}\left(\frac{k-0.412}{0.196}\right)^2} + 0.617\, e^{-\frac{1}{2}\left(\frac{k-0.797}{0.291}\right)^2}, \qquad (24)$$

where k is the incident nucleon lab momentum in GeV/c. The values of β have been taken from [16].

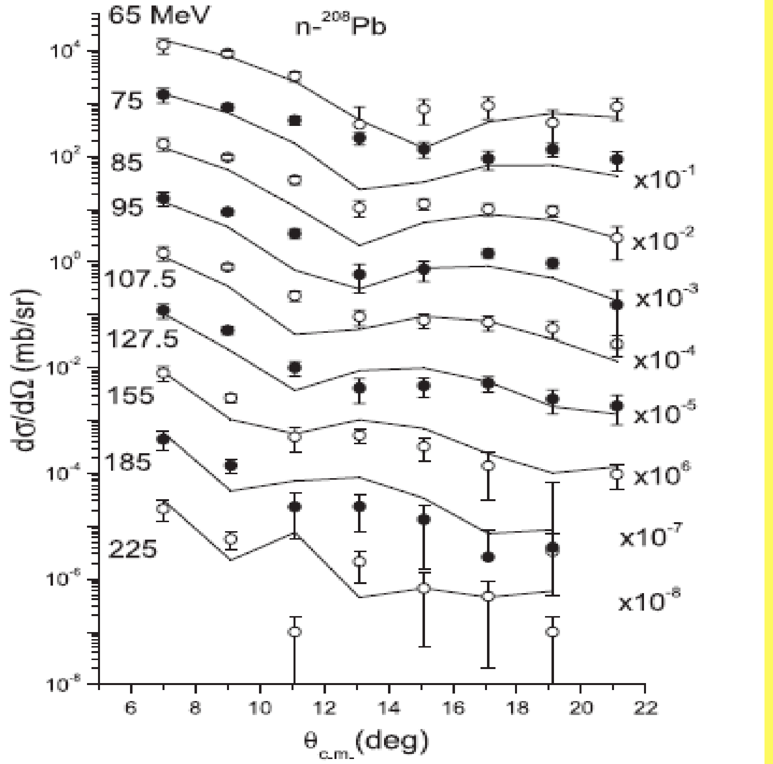


FIG. 3. Comparison of experimental data [2] (open and solid circles) for n-^{208}Pb with a prediction of our formulation taking into account the pair correlation as described in the text.