About dd-elastic scattering in the S-wave Glauber theory

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1st-phase of SPD meeting, 10 June 2025

REFERENCES:

V. Franco, Phys. Rev. **175** , №4 (1968) 1376; *S-wave,normal and abnormal 2st scatt.*

G. Alberi et al., Nucl. Phys. B 17 (1970) 621-627; *S+D waves of the deuterons*

A.T. Goshaw et al. , PRD 2 (1970) 205.

G. Albery, G. Goggi , Phys. Rep. 74 (1981) 1-207

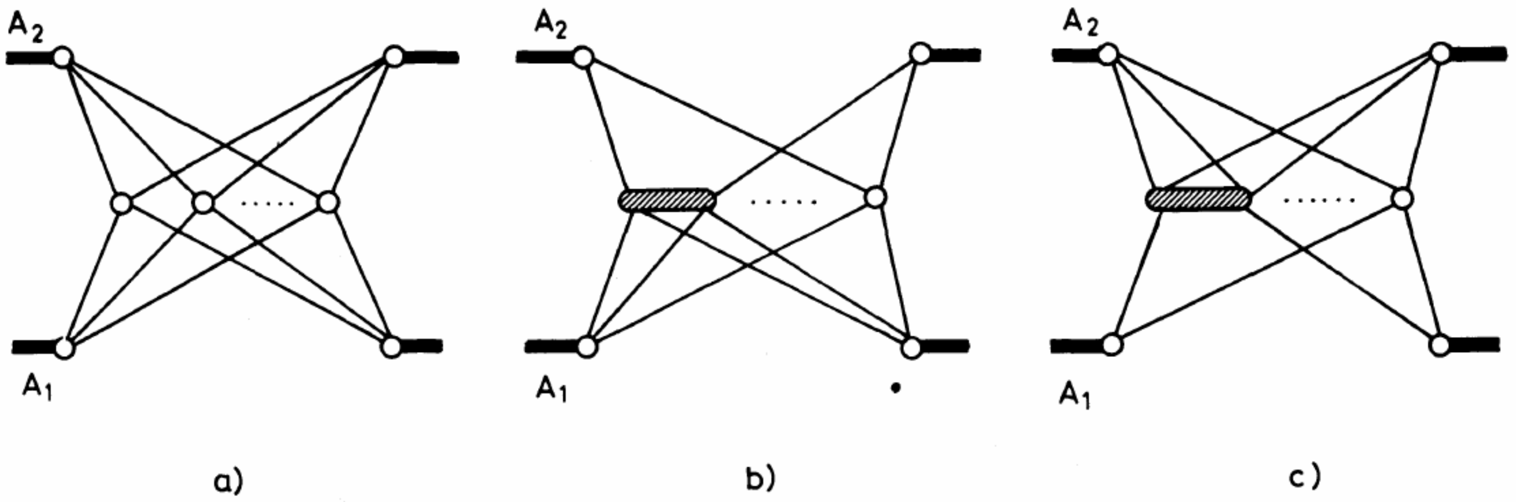


Fig. 3.47. (a) Feynman diagram representing “abnormal” multiple rescattering in nucleus–nucleus elastic scattering, (b), (c) “normal” multiple scattering diagrams with inelastic screening corrections. The nucleon excitation occurs in A_1 for (b) and in A_2 for (c).

dd-dd in S-wave approximation

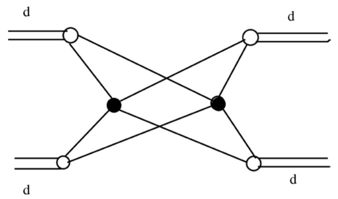
Yu. Uzikov, M. Platonova, A. Klimochkina, A. Kornev,
Double polarized deuteron-deuteron scattering and test of T-invariance,
Int. J. Mod Phys. E, Vol.33, N 11 (2024) 244003; **(S-wave**)

M.N. Platonova, Yu. N. Uzikov,
Time-reversal invariance violation effect in dd scattering,
Chinese Physics C, v. 49. N 3 (2025) 034108 **(S+D –waves**)

See also talk of V. Uzhinsky on IX-SPD Collaboration Meeting (15 May,2025) /not published/

G. Alberi et al. Nucl. Phys. B 17 (1970) 621-627

$$F_{dd} = 8f(\mathbf{q})S^2\left(\frac{1}{2}\mathbf{q}\right) + \frac{2i}{\pi k}\left[4S\left(\frac{1}{2}\mathbf{q}\right)\int S(\mathbf{q}_1)f\left(\mathbf{q}_1 + \frac{1}{2}\mathbf{q}\right)f\left(-\mathbf{q}_1 + \frac{1}{2}\mathbf{q}\right)d^2\mathbf{q}_1 \right.$$
$$\left. + 2\int S^2(\mathbf{q}_1)f\left(\mathbf{q}_1 + \frac{1}{2}\mathbf{q}\right)f\left(-\mathbf{q}_1 + \frac{1}{2}\mathbf{q}\right)d^2\mathbf{q}_1\right]$$
$$- \frac{8}{\pi^2 k^2}\int S(\mathbf{q}_1)S(\mathbf{q}_2)f\left(\frac{1}{2}\mathbf{q} - \mathbf{q}_1\right)f(\mathbf{q}_1 + \mathbf{q}_2)f\left(\frac{1}{2}\mathbf{q} - \mathbf{q}_2\right)d^2\mathbf{q}_1 d^2\mathbf{q}_2$$
$$- \frac{2i}{\pi^3 k^3}\int S(\mathbf{q}_1)S(\mathbf{q}_2)f\left(\frac{1}{2}\mathbf{q} - \mathbf{q}_1 - \mathbf{q}_3\right)f(\mathbf{q}_3)f(\mathbf{q}_1 + \mathbf{q}_2 + \mathbf{q}_3)$$
$$\times f\left(\frac{1}{2}\mathbf{q} - \mathbf{q}_2 - \mathbf{q}_3\right)d^2\mathbf{q}_1 d^2\mathbf{q}_2 d^2\mathbf{q}_3,$$



pN—elastic amplitude

$$f(\mathbf{q}, k) = \frac{k\sigma}{4\pi}(\alpha + i)\exp\left\{-\frac{\beta\mathbf{q}^2}{2}\right\}$$

Deuteron form factor

$$u(r) = r\sum_{i=1}^{5} C_i \exp(-A_i r^2). \tag{3}$$

In the S-wave approximation, the deuteron form factor takes the following form:

$$S(q) = \int_0^\infty u^2(r) j_0(qr)\, dr = \sum_{i,j} \xi_{i,j} \exp\left\{-\frac{\lambda_{i,j} q^2}{4}\right\}, \tag{4}$$

where

$$\xi_{i,j} = \frac{\sqrt{\pi}}{4}\frac{C_i C_j}{(A_i + A_j)^{3/2}}, \quad \lambda_{i,j} = \frac{1}{A_i + A_j}. \tag{5}$$

$$B_{ij} = \frac{\lambda_{ij}}{4} + \beta, \quad E_{ij} = \exp(-\lambda_{ij}\mathbf{q}^2/16), \tag{A.1}$$

and substituting Eqs. (1), (4) and (5) into Eq. (2), we obtain the following expression for the dd scattering amplitude:

$$\begin{aligned} F_{dd} = k \sum_{i,j,k,l} \xi_{ij}\xi_{kl} \Bigg\{ & 8\left[\frac{\sigma(i+\alpha)}{8\pi}\right] \exp\left(-\frac{\beta\mathbf{q}^2}{2}\right) E_{ij}E_{kl} \\ & + \left[\frac{\sigma(i+\alpha)}{8\pi}\right]^2 4i\exp\left(-\frac{\beta\mathbf{q}^2}{4}\right)\left(\frac{E_{kl}}{B_{ij}} + \frac{E_{ij}}{B_{kl}} + \frac{1}{B_{ij}+B_{kl}-\beta}\right)\frac{1}{(\hbar c)^2} \\ & - 8\left[\frac{\sigma(i+\alpha)}{8\pi}\right]^3 \exp\left(-\frac{\beta\mathbf{q}^2}{4}\right)\frac{1}{B_{ij}B_{kl}-\beta^2/4}\exp\left(\frac{\beta^2\mathbf{q}^2(B_{ij}+B_{kl}-\beta)}{16(B_{ij}B_{kl}-\beta^2/4)}\right)\frac{1}{(\hbar c)^4} \\ & + \left[\frac{\sigma(i+\alpha)}{8\pi}\right]^4 (-i)\exp\left(-\frac{\beta\mathbf{q}^2}{8}\right)\frac{1}{\beta(B_{ij}-\beta/2)(B_{kl}-\beta/2)}\frac{1}{(\hbar c)^6}\Bigg\}. \end{aligned} \tag{A.2}$$

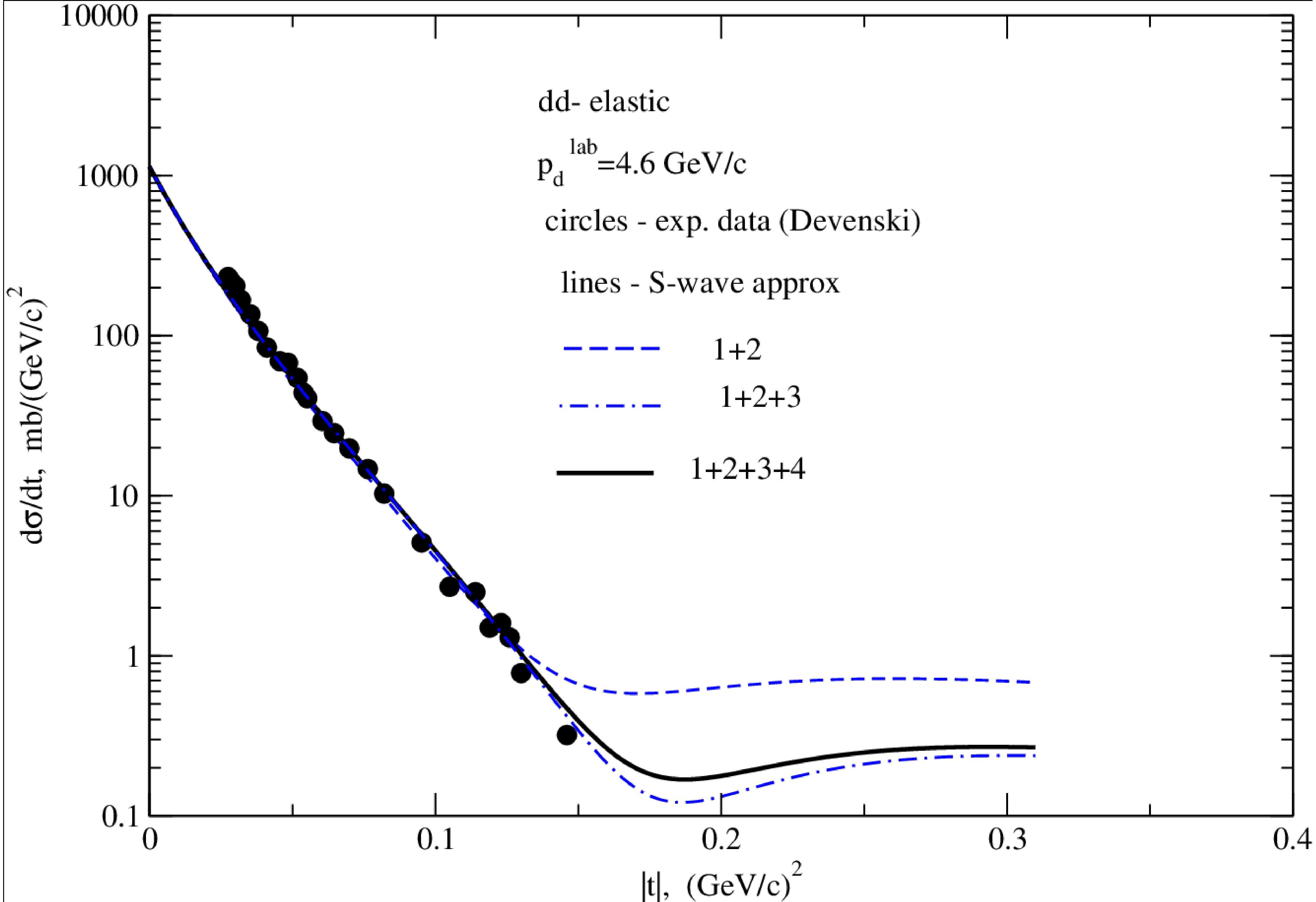
Fortran-code:

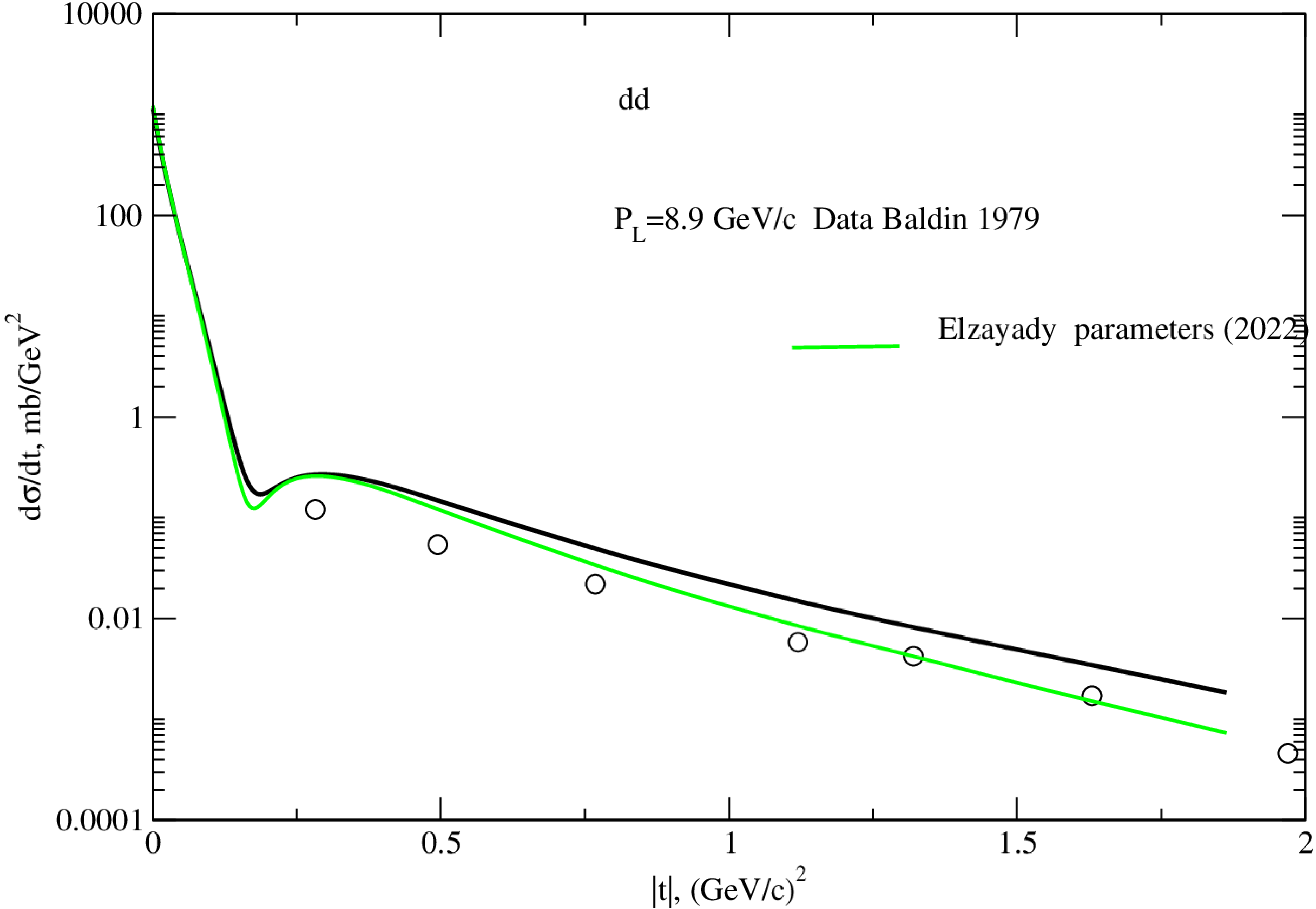
Yu. U., M.Platonova, A. Kornev, A.Klimochkina, IJMPE 33(2024) 2441003

pN—elastic spin amplitudes

$$\begin{aligned} M_{ij}(\mathbf{q}) = & A_N + C_N(\boldsymbol{\sigma}_i \cdot \hat{\mathbf{n}}) + C'_N(\boldsymbol{\sigma}_j \cdot \hat{\mathbf{n}}) \\ & + B_N(\boldsymbol{\sigma}_i \cdot \hat{\mathbf{k}})(\boldsymbol{\sigma}_j \cdot \hat{\mathbf{k}}) \\ & + (G_N + H_N)(\boldsymbol{\sigma}_i \cdot \hat{\mathbf{q}})(\boldsymbol{\sigma}_j \cdot \hat{\mathbf{q}}) \\ & + (G_N - H_N)(\boldsymbol{\sigma}_i \cdot \hat{\mathbf{n}})(\boldsymbol{\sigma}_j \cdot \hat{\mathbf{n}}). \end{aligned}$$

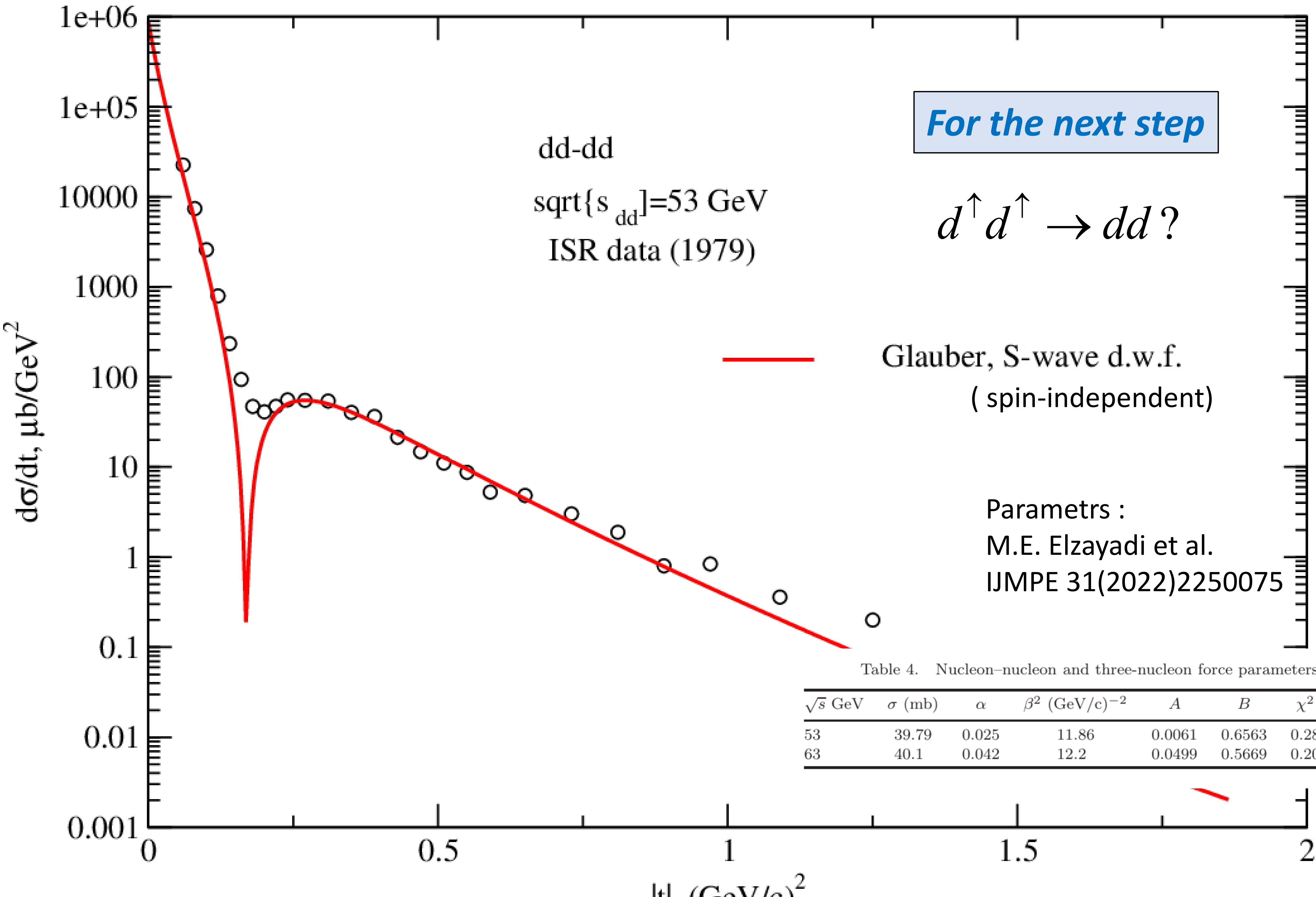
$$\mathbf{k} = \frac{1}{2}(\mathbf{p} + \mathbf{p}'), \quad \mathbf{q} = \mathbf{p} - \mathbf{p}', \quad \mathbf{n} = [\mathbf{p}' \times \mathbf{p}],$$


dd- elastic
p_d lab=4.6 GeV/c
circles - exp. data (Devenski)
lines - S-wave approx
1+2
1+2+3
1+2+3+4
dσ/dt, mb/(GeV/c)^2
|t|, (GeV/c)^2
10000
1000
100
10
1
0.1
0
0.1
0.2
0.3
0.4


dd
P_L=8.9 GeV/c Data Baldin 1979
Elzayady parameters (2022)
dσ/dt, mb/GeV^2
|t|, (GeV/c)^2
10000
100
1
0.01
0.0001
0
0.5
1
1.5
2

For the next step

$d^{\uparrow}d^{\uparrow} \rightarrow dd\,?$



(spin-independent)

Parametrs :
M.E. Elzayadi et al.
IJMPE 31(2022)2250075

Table 4. Nucleon–nucleon and three-nucleon force parameters.

$\sqrt{s}$ GeV	σ (mb)	α	β^2 (GeV/c)$^{-2}$	A	B	χ^2	Refs.
53	39.79	0.025	11.86	0.0061	0.6563	0.28	40
63	40.1	0.042	12.2	0.0499	0.5669	0.20	41

THANK YOU FOR ATTENTION!

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Double polarized deuteron–deuteron scattering and test of *T*-invariance

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