OPTICAL POTENTIAL MODEL FOR THE ELASTIC $\vec{d}p$ SCATTERING AT INTERMEDIATE ENERGIES

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(within LNS project at LHE, JINR)

Goals

- √ Obtaining more information about intermediate- and short-range NN interaction;
- √ Probing of the deuteron structure at small distances (current work);
- √ Investigation of the significance of $3N$-forces and its nature.

Problems

- √ No reliable quantitative model for NN-interaction above the inelastic threshold;
- √ It is no longer three-body problem above the pion production threshold;
- √ Difficulties in performing relativistic Faddeev calculations at higher energies.

Theoretical framework

Faddeev equation: $\boxed{U = PG_0^{-1} + PTG_0U}$

$U = U_{\mu'_d\mu'_N,\mu_d\mu_N}(\vec{q}', \vec{q})$ – amplitude of elastic dp-scattering,

μ_d, μ_N – spin quantum numbers,

$\vec{q}$ – relative momentum in the proton-deuteron c.m.;

T – NN scattring matrix,

$G_0 = (E - H_0 + i\epsilon)^{-1}$ – free propagator of $3N$ system,

and $P \equiv P_{12}P_{23} + P_{13}P_{23}$ – permutation operator.

Framework of the optical potential model: $\boxed{U = V_{\rm opt} + V_{\rm opt}G_dU}$

$V_{\rm opt} = PG_0^{-1} + PT_cG_0V_{\rm opt}$ – pd optical potential.

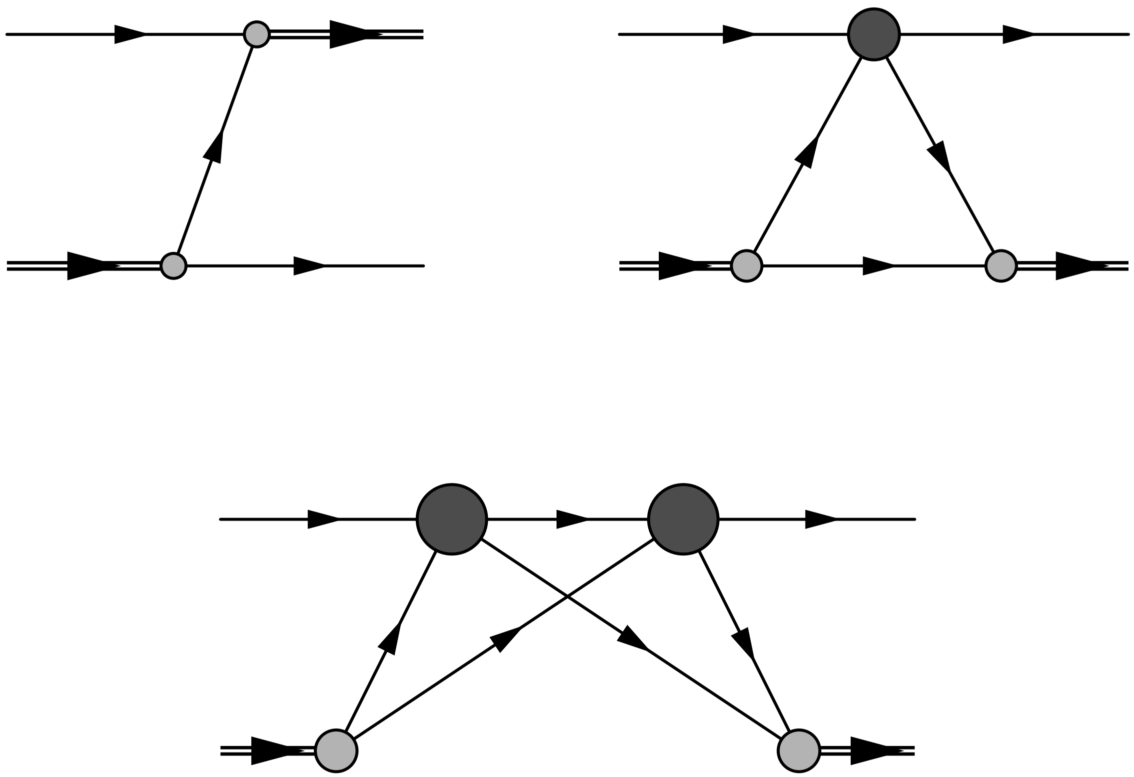
Series expansion:

$$V_{\rm opt} = PG_0^{-1} + PT_cP + PT_cG_0PT_cP + \ldots...$$

T_c – NN T-matrix with subtracted deuteron pole term;

G_d – deuteron contribution in the spectral decomposition of the two-body Hamiltonian.

Graphical representation : Initial state $|i\rangle \equiv |\vec{q}; \mu_d \mu_N\rangle_{1(23)}$



$$\langle f|V_{\rm opt}|i\rangle = {}_{2(31)}\langle f|G_0^{-1}|i\rangle + {}_{1(23)}\langle f|T_c^{2(31)}|i\rangle + {}_{1(23)}\langle f|\widetilde{T}_c|i\rangle + {}_{1(23)}\langle f|\widetilde{T}_c G_0 T_c^{2(31)}|i\rangle + {}_{1(23)}\langle f|T_c^{2(31)} G_0 \widetilde{T}_c|i\rangle + {}_{2(31)}\langle f|T_c^{1(23)} G_0 T_c^{2(31)}|i\rangle$$

One – nucleon exchange :

$$ {}_{2(31)}\langle f|G_0^{-1}|i\rangle = -G_N^{-1}\Psi_{13}\left(\vec{q}+\frac{1}{2}\vec{q}'\right)\Psi_{23}\left(\vec{q}'+\frac{1}{2}\vec{q}\right) $$

$$ q' = q = \left(\frac{T_{\rm lab}M_N^2(T_{\rm lab}+2M_d)}{(M_N+M_d)^2+2M_NT_{\rm lab}}\right)^{1/2}, $$

$T_{\rm lab}$ – kinetic energy of deuteron in lab.

Single scattering :

$$ {}_{1(23)}\langle f|T_c|i\rangle = \int\frac{\mathrm{d}^3\mathrm{p}}{(2\pi)^3}\Psi_{23}\left(\vec{p}+\frac{1}{4}\vec{k}\right)T_c\left(\vec{q}',\vec{p}-\frac{3}{4}\vec{q}'+\frac{1}{4}\vec{q};\vec{q},\vec{p}-\frac{3}{4}\vec{q}+\frac{1}{4}\vec{q}'\right)\Psi_{23}\left(\vec{p}-\frac{1}{4}\vec{k}\right) $$

$k = \vec{q}-\vec{q}'$ – transferred momentum.

Modified impulse approximation:

$$ T_c^{\rm cm}\left(\mathcal{L}^{-1}q',\mathcal{L}^{-1}q;E_{eff}\right) = T_c^{\rm cm}(t,u), $$

t, u - kinematical invariants.

Continuation on mass-shell - $\boxed{s = 4M_N^2 - t - u}$.

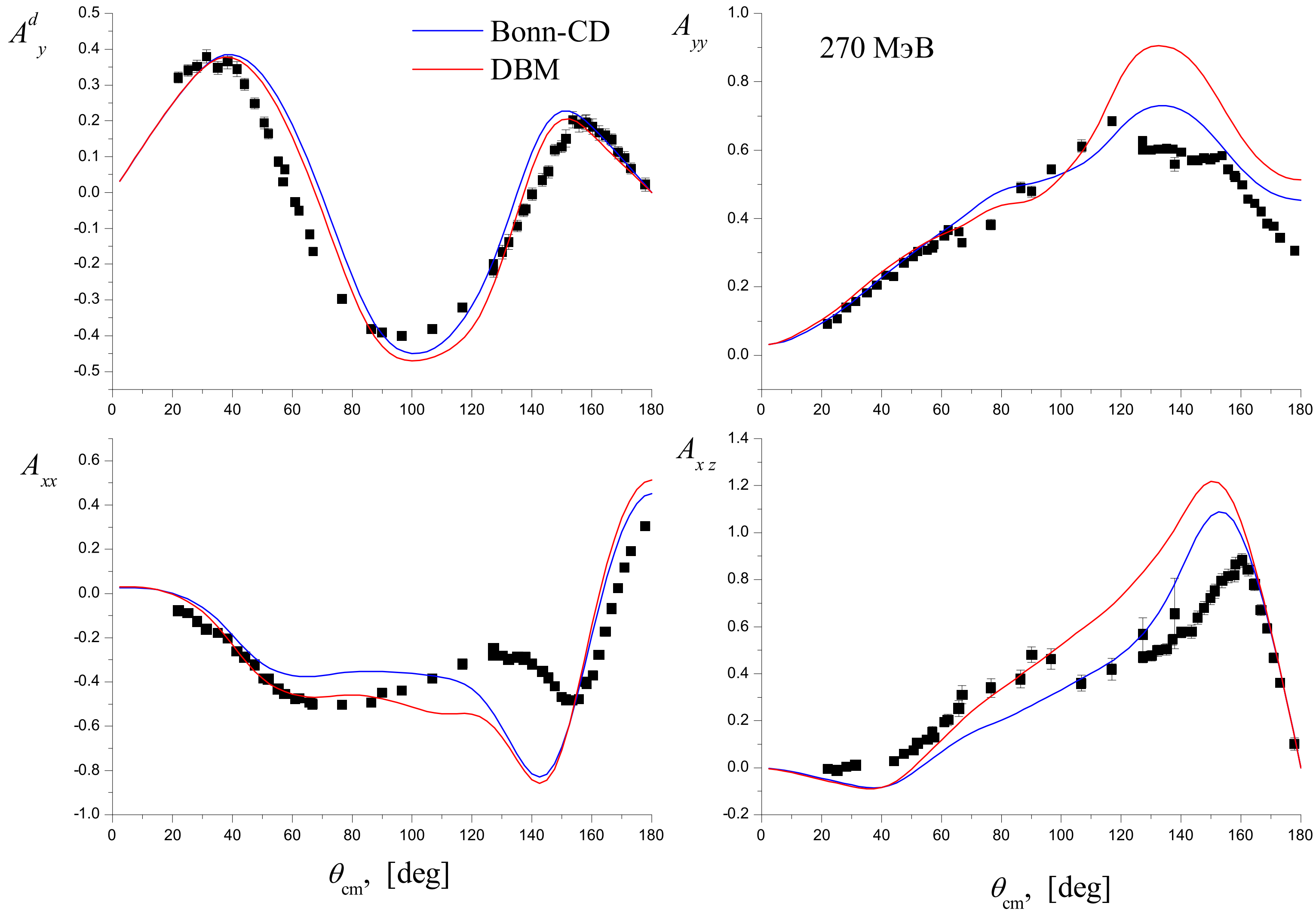
Double scattering term :

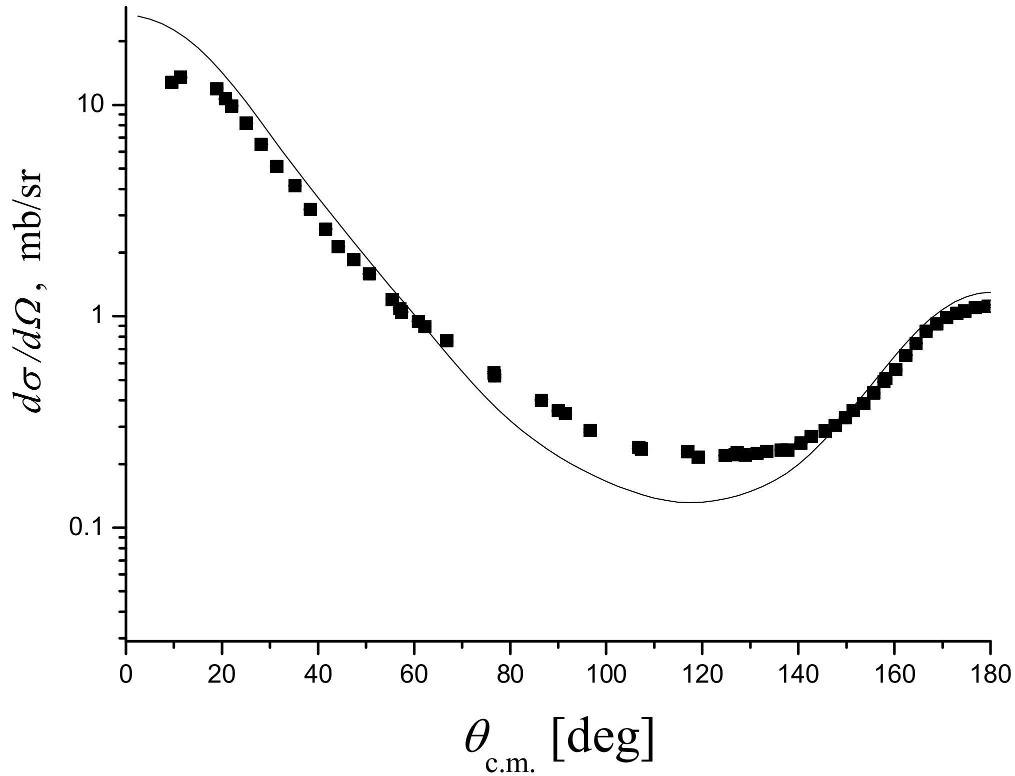
$$
{}_{1(23)}\langle f|T_2 G_0 T_1|i\rangle = \int \frac{\mathrm{d}^3\mathrm{p}}{(2\pi)^3}\frac{\mathrm{d}^3\mathrm{p}'}{(2\pi)^3}\frac{\mathrm{d}^3\mathrm{q}''}{(2\pi)^3}\delta^3\left(\vec{p'} + \vec{p} - \frac{1}{2}\vec{q''} + \frac{1}{4}\vec{q'} + \frac{1}{4}\vec{q}\right)
$$

$$
\times\ \Psi_{23}\left(\frac{\vec{p'}-\vec{p}}{2} - \frac{3}{8}\vec{q'} - \frac{1}{8}\vec{q} + \frac{1}{2}\vec{q''}\right) T_2\left(\vec{q'}, \vec{p'} - \frac{3}{4}\vec{q'} + \frac{1}{4}\vec{q''}; \vec{q''}, \vec{p'} - \frac{3}{4}\vec{q''} + \frac{1}{4}\vec{q'}\right) G_0
$$

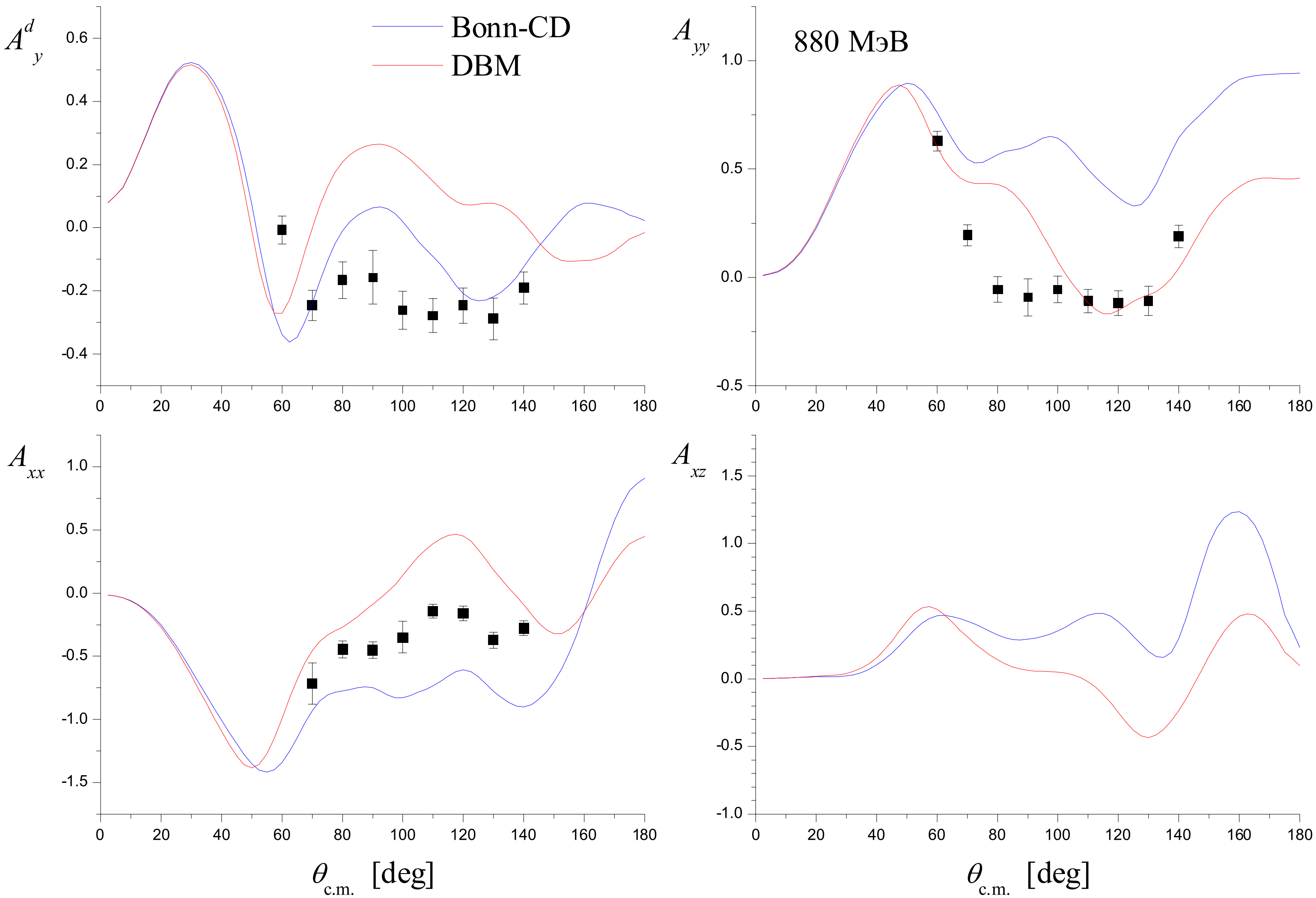
$$
\times\ T_1\left(\vec{q''}, \vec{p} - \frac{3}{4}\vec{q''} + \frac{1}{4}\vec{q}; \vec{q}, \vec{p} - \frac{3}{4}\vec{q} + \frac{1}{4}\vec{q''}\right) \Psi_{23}\left(\frac{\vec{p'}-\vec{p}}{2} + \frac{3}{8}\vec{q} + \frac{1}{8}\vec{q'} - \frac{1}{2}\vec{q''}\right).
$$

Results of calculations

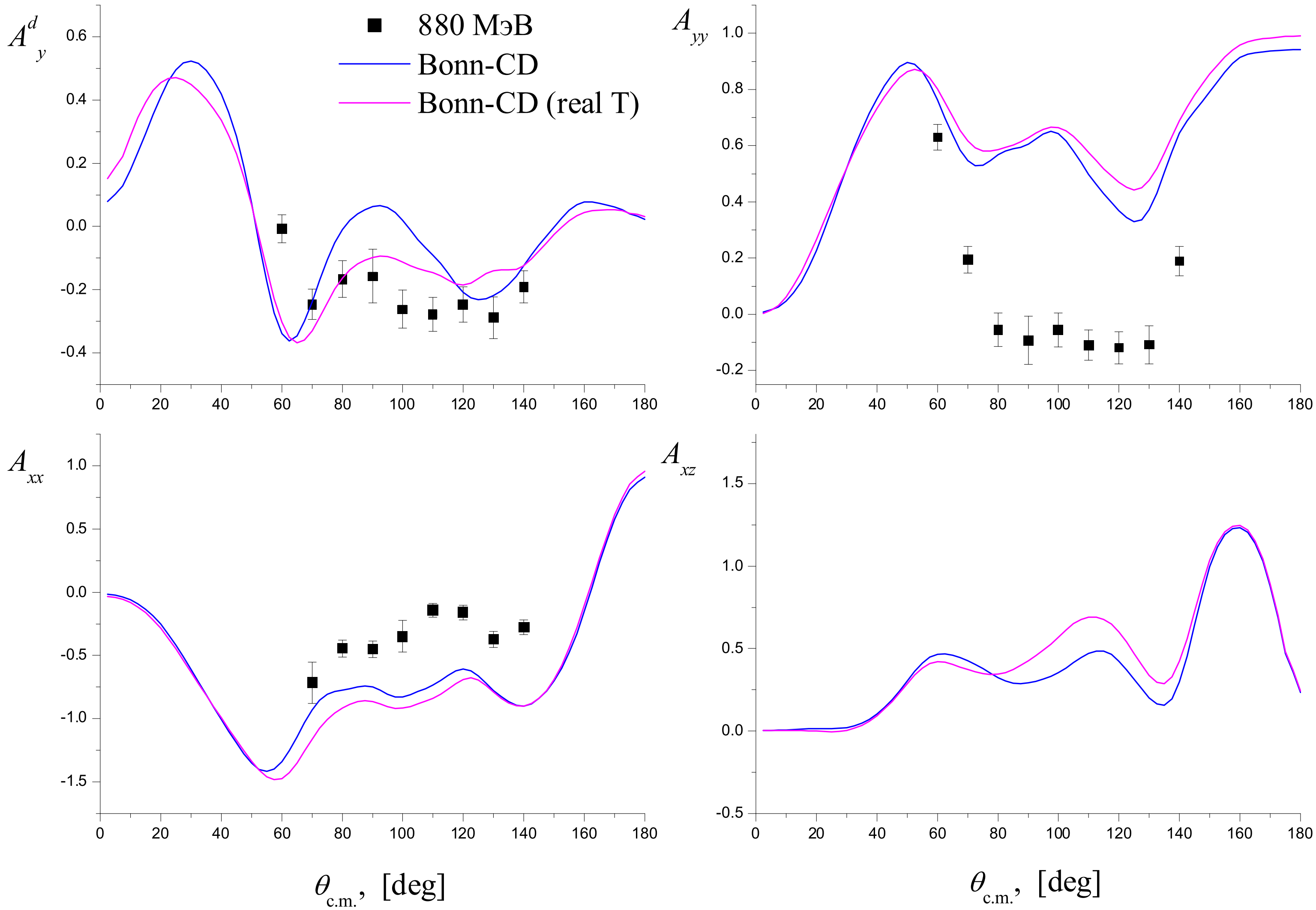




10
1
0.1
0
20
40
60
80
100
120
140
160
180
$d\sigma/d\Omega$, mb/sr
$\theta_{c.m.}$ [deg]



Bonn-CD
DBM
880 МэВ
A^d_y
A_{yy}
A_{xx}
A_{xz}
$\theta_{c.m.}$ [deg]
$\theta_{c.m.}$ [deg]



A^d_y
A_{yy}
A_{xx}
A_{xz}
880 МэВ
Bonn-CD
Bonn-CD (real T)
$\theta_{c.m.}$, [deg]
$\theta_{c.m.}$, [deg]

Conclusions

- √ Good description of the data at 270 MeV.
- √ High dependence of the observables on short-range behavior of the deuteron wave function.
- √ Strong influence of the double-scattering terms in the optical potential.
- √ Quite high value of total angular momentum J ($J = 37/2$) to obtain convergent results, that prevents direct employing of Faddeev calculations in partial-wave basis.
- √ But not very drastic sensitivity to higher NN partial waves with $J > 3$.
- √ The observables are not very sensitive to inelasticities in NN-channel (that comes in the model through the complex values of NN-phase shifts).