Spin observables in NN, pd and dd scattering at SPD NICA

O.V. Selyugin, Yu. N. Uzikov

Spin-amplitudes of the elastic NN scattering constitute a spin portrait of the nucleon and dynamics of NN interactions. Without knowledge of the spin NN-amplitudes it is not possible to understand spin obserbvables of nucleon scattering off nuclei. Available information on spin amplitudes on elastic pN scattering and the results of the partial wave analysis are accumulated in the SAID base date (1) up to proton energies $T_p = 3$ GeV for pp- and up to 1.3 GeV for pn-scattering, respectively. Above 3 GeV the information is rather pure and related mainly to the pp-scattering, although some parameterizations for NN-amplitudes were suggested (2).

Using existing model of nucleon elastic scattering at high energies $\sqrt{s} > 9$ GeV - 14 TeV (3) which involves minimum of free parameters, we are going to develop its extended version aimed to describe all available data on cross sections and spin-correlation parameters at lower energies down to SPD NICA region. The model will be based on usage of known information on generalized parton distributions in the nucleon, electromagnetic and gravotomagnetic form factors of the nucleon taking into account analyticity and unitarity requirements and providing compatibility with the high energy limit, where the pomeron exchange dominates. Later on this model will be used as a basis to study such subtle effects as violation of dispersion relations and T-odd phenomena in NN-scattering.

Experimental information about pn-scattering amplitudes can be obtained from pd collisions. Both elastic $pd \to pd$ (4; 5) and quasi- elastic scattering $p + d \to \{pp\}_s + n$ (6) with formation of the $\{pp\}_s$ pair at small relative energy $E_{pp} < 3$ MeV are of interest. In the internal motion of the $\{pp\}_s$ pair the $^1S_0$ state dominates and its zero spin provides considerable simplification of theoretical analysis of the considered process. Spin amplitudes of the elastic NN- scattering can be studied in the the elastic deuteron-deuteron scattering $d + d \to d + d$ and quasi-elastic reaction $d + d \to \{pp\}_s + \{nn\}_s$ with formation of two pairs in the $^1S_0$-state. Comparison of results of theoretical calculations based on the Glauber theory with corresponding experimental data will allow us to test/justify existing and new paramaterizations of pp- and pn- scattering amplitudes (see (6; 5)).

Our project is aimed to provide theoretical support in preparation of a proposal of experiment for search of null-test signal of T-invariance violation under P-parity conservation in pd (and possible in 3He-d) double polarized collision at energies of the SPD NICA. The null-test signal is the integrated cross section of interaction of transversely polarized proton (or 3He nucleus) with tensor-polarized deuteron (P_{xz}). A similar experiment is under preparation at COSY at lower energies about 100 MeV in pd-scattering. Search for this signal at energies corresponding to early Universe was never performed before. An observation of T-odd P-even effects at the level of 10^{-6} would be a direct indication

to new sources of CP violation beyond the Standard Model. Theoretical calculation of the modulating factors caused by ordinary T-invariant NN-interactions is necessary to extract unknown T-violating constants from the expected data. These calculations will be performed for NICA energies using spin amplitudes of pN scattering and properly modified formalism of Refs. (7).

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