EXPERIMENT FOR DETERMINING *np*-SCATTERING LENGTH IN THE *n* + *d* → (*np*) + *n* REACTION

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1. INTRODUCTION

In the INR RAS experimental studies of nucleon-nucleon and three-nucleon interactions and effects of charge symmetry breaking are carried out [1, 2]. A test experiment to determine the *np*-scattering singlet length (a_{np}) on the neutron beam of the RADEX channel of the INR RAS was carried out. The experiment purpose is to determine a_{np} and virtual state energy E_{np} in the *nd*→(*np*)+*n* reaction and search for the influence of three-nucleon forces (3*NF*).

The influence of 3*NF* can be manifested in the difference between the a_{np} value obtained in the reaction with three particles in the final state and the value obtained in the forward np-scattering.

2. SIMULATION

We conducted a simulation of the *nd*→(*np*)+*n* reaction at low neutron energies (E_n=10 MeV). Kinematic simulation was carried out using the programs described in [3]. To study of neutron-proton final state interaction (FSI) in this reaction, it's necessary to gave a very small relative momentum *np*-pair. Neutron-proton FSI will manifest itself as a peak in the dependence of the reaction yield on the relative energy of *np*-pair

$$\varepsilon = \frac{1}{2}\left(E_n + E_p - 2\sqrt{E_n E_p}\cos\Delta\theta\right).$$

The shape of this dependence *N*(ε), according to the Migdal-Watson formula, is sensitive to E_{np} (fig.1).

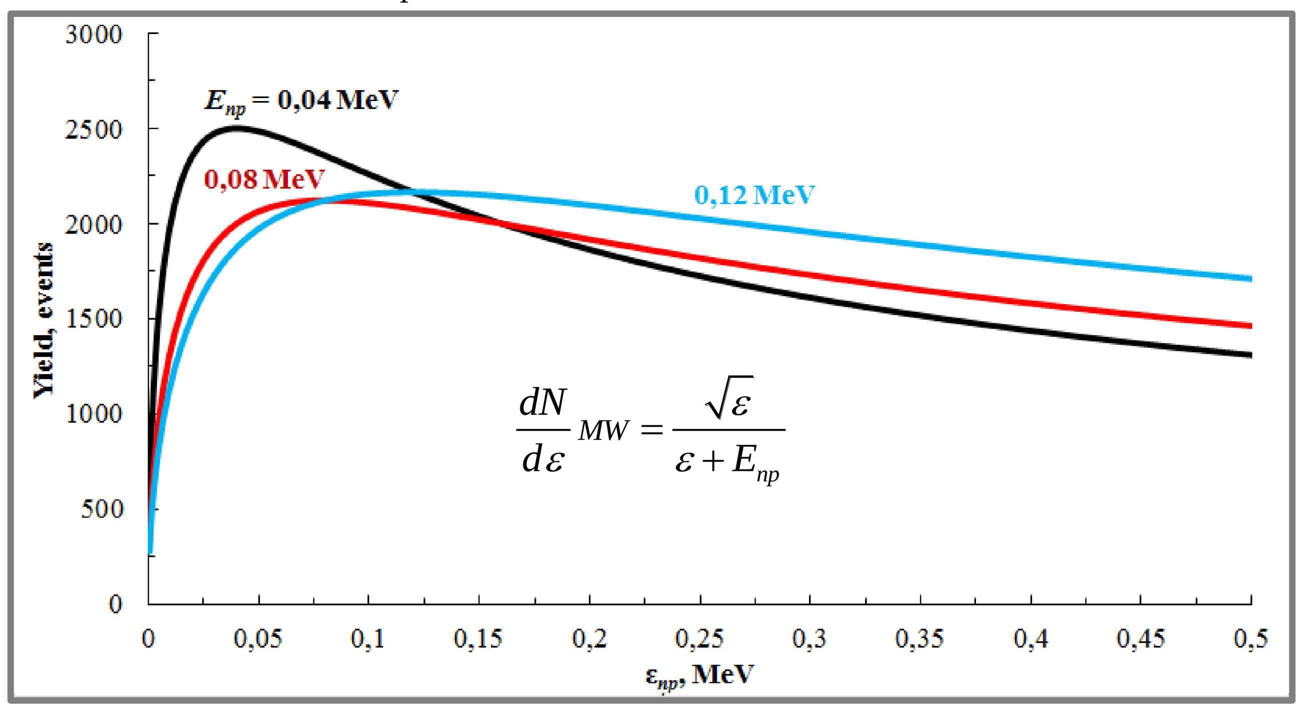

Fig.1. Migdal-Watson approximation for different E_{np}.

The simulation of the output of *nd*-breakup yield is carried out in two stages. At the first stage, the formation of a *np*-pair with an effective invariant mass $M_{np}=m_n+m_p+\varepsilon$ in a two-particle reaction *nd*→(*np*)+*n* is considered. The dependence of the reaction yield on ε is taken into account by the number of simulation events with different ε according to Migdal-Watson formula for a specific E_{np} value. Thus, the dependence of the form of the yield distribution on E_{np} value is introduced.

At the second stage, the (*np*)→*n*+*p* breakup of the np-system is considered. Fig.2 shows the simulated dependence of the reaction yield on the relative energy for different E_{np}, taking into account al the experimental conditions.

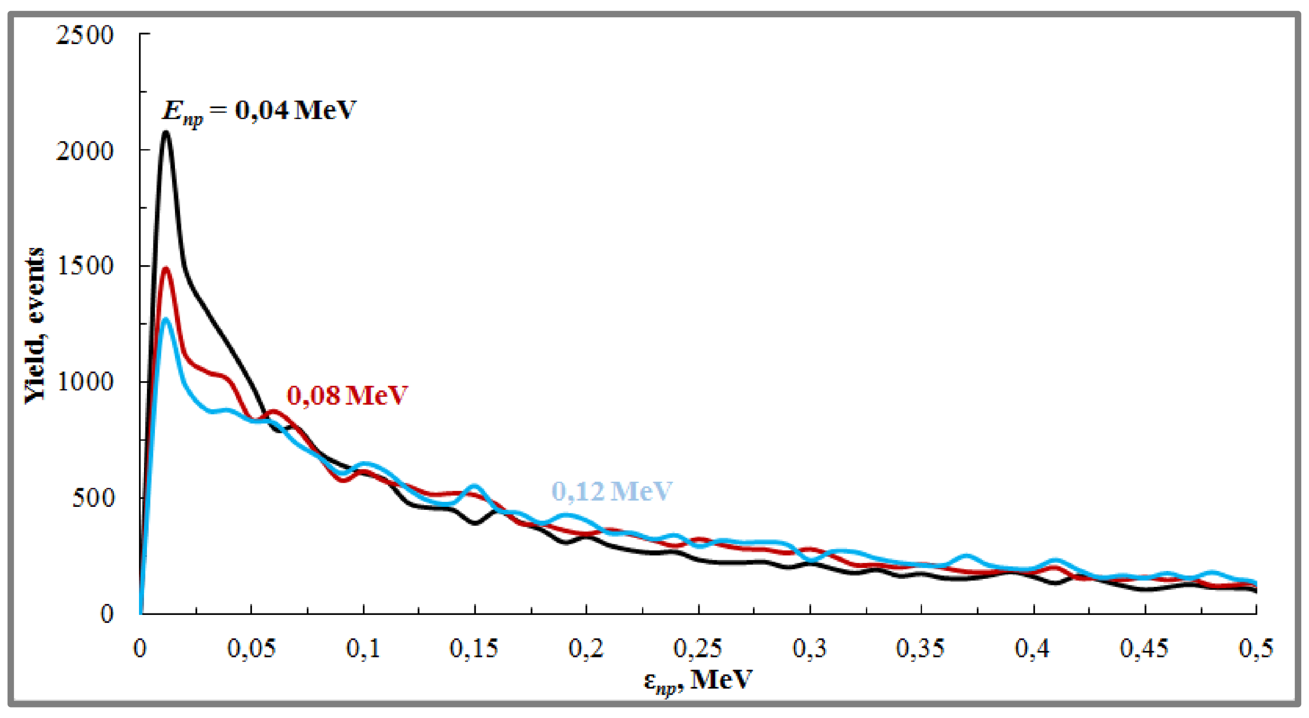

Fig.2. Simulated distribution of the reaction yield on the relative energy depends on E_{np}.

It can be seen that the shape of the spectra for different values E_{np} is noticeably different, especially at low values of the relative energy.

Therefore, it is possible to introduce a shape factor (SF), defined as the ratio of the sum of events covering the entire region of the peak at small ε (for example from 0 to 0.05 MeV) to the sum of events over a wide region (for example from 0 to 0.4 MeV).

In fig.3 shows the dependence of the SF on various values of the virtual state energy E_{np} taking into account all experimental conditions

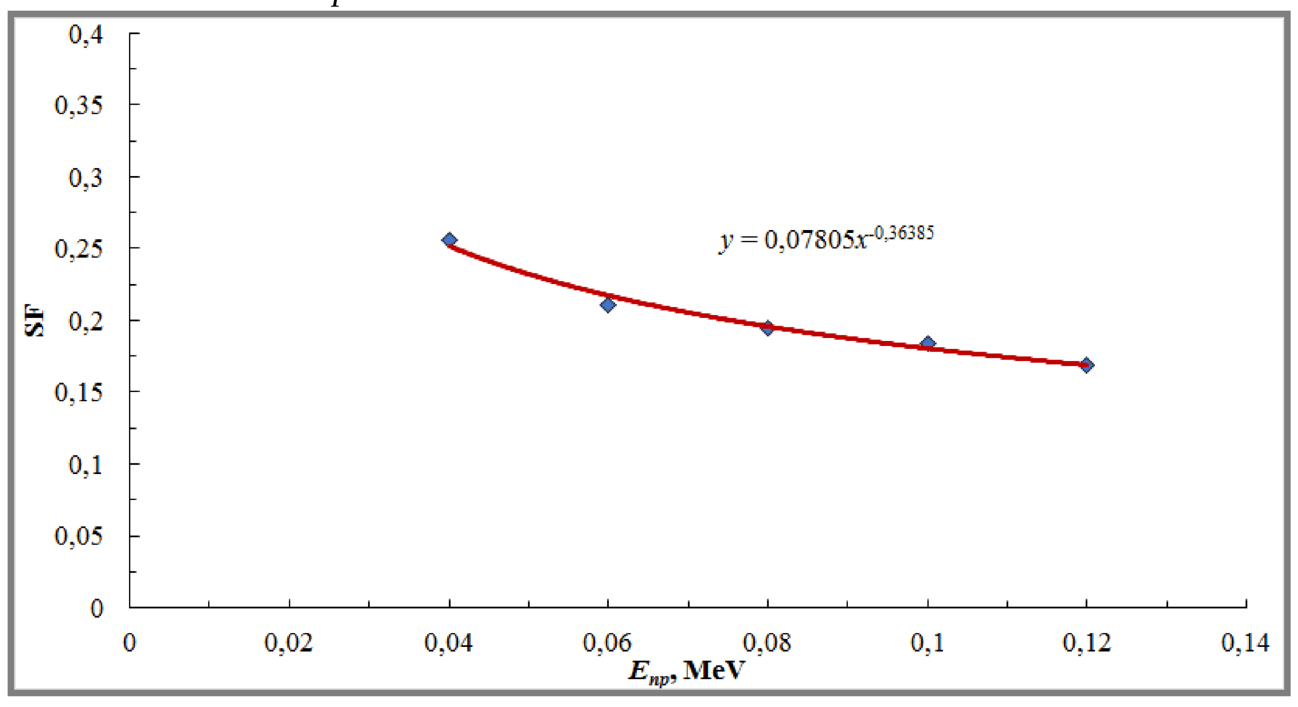

Fig. 3. Dependence of Shape Factor on E_{np}.

Thus, comparison of the experimental value of the SF with the simulated one will make it possible to determine the energy E_{np}, and, accordingly, the value of the scattering length.

3. TEST EXPERIMENT

An test experimental setup was created based on the simulation results (fig.4).

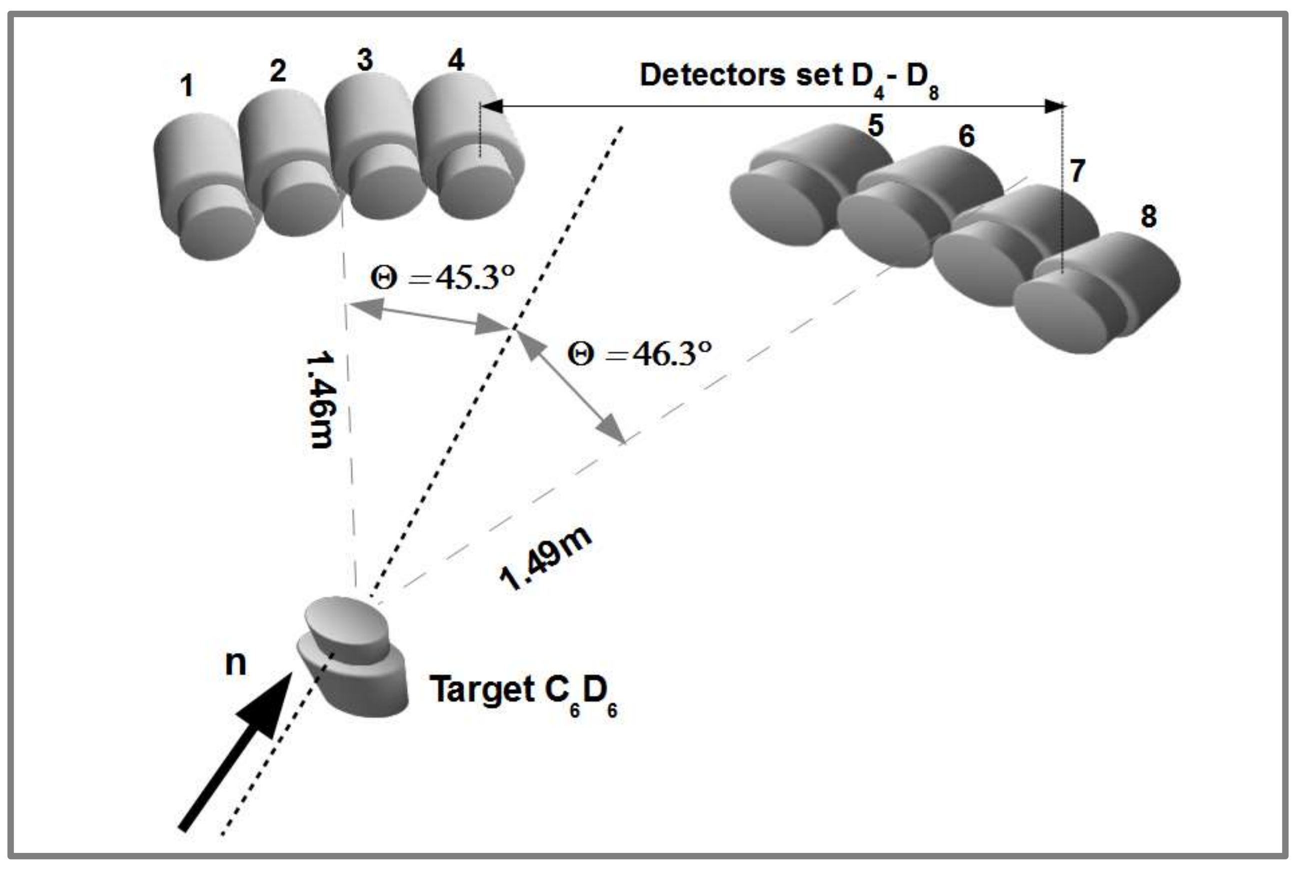

Fig. 4. Test experimental setup.

The experiment was carried out at low neutron energies of 10±2 MeV using a C_6D_6 scintillator as an active deuterated target. The experiment consists in the registration of a recoil neutron and a neutron from the breakup of the *np*-system as well as the fact of registration of a breakup proton in a deuterated target.

The energy of the neutron beam, the energy and emission angle of the proton are recovered from the kinematics of the reaction *n*+*d*→*n*+*p*+*n*. The relative energy of the *np*-system is calculated for each event and then the dependence of the reaction yield on the relative energy is plotted. The experimental dependence is compared with the simulation results which depend on the *np*-scattering length.

The test experiment showed the possibility of registration in the coincidence of two neutrons and a proton in an active target. Unfortunately, the short measurement time doesn't allow to make certain conclusions even now, but with sufficient statistics and a stable neutron beam, it is possible to determine the value of a_{np} and compare this value with the value obtained in forward *np*-scattering.

List of publications

1. *Konobeevski E. et al* // Few-Body Syst. 2017. V. 58. Art. No. 107.
2. *E.S. Konobeevski et al* // Phys. At. Nucl. 2020. V. 83. No. 4. P.523.
3. *S.V. Zuyev et al* // Bull. Russ. Acad. Sci. Phys. 2017. V. 81. No. 6. P. 679