occur in the $nn$ quasifree scattering (QFS) and in the $nd$ STAR (three nucleons are flying in the c.m. system with momenta of equal magnitude) geometries. The final state interaction (FSI) geometry is widely used for determination of singlet $nn$-scattering length characterizing the $nn$ scattering at zero energy. Data for $a_{nn}$ together with analogous data for $pp$ scattering length $a_{pp}$ (difference $a_{nn} - a_{pp}$) define a quantitative measure of the charge symmetry breaking (CSB) of nuclear forces.

The goal of our study is the determining characteristic parameters of neutron-neutron interaction, as well as obtaining new accurate estimation of CSB effect. To study the $n+d \rightarrow p+n+n$ reaction the experimental setup allowing registration of all secondary particles in different kinematical arrangements was installed at neutron channel of Moscow Meson Factory of the Institute for Nuclear Research. A beamstop of 200-MeV protons of INR linear accelerator is used as a neutron source. Neutrons produced in a 60-mm-thick tungsten target are collimated at an angle of $0^\circ$ on a length of 12 m, forming a beam with a diameter of $\sim 50$ mm at the measuring CD target. In our setup liquid deuterated scintillator EJ-315 is used not only as the target but also as a detector of secondary protons in the $nd \rightarrow pnn$ reaction. The signal produced by proton also serves as a start signal for time-of-flight spectrometer of secondary neutrons.

Neutrons in the setup are detected by a two-arm hodoscope consisted of five detectors located at angles of $29^\circ - 42^\circ$ on the left and a single detector at an angle of $\sim 55^\circ$ on the right of the incident neutron beam axis. Registration of two neutrons in the left arm of hodoscope (FSI geometry, $\Phi_{nn}=0^\circ$) and the proton in the active target allow us to determine the neutron-neutron scattering length. Registration of one neutron in the right detector and one neutron in one detector of the left arm of the godoscope (QFS geometry, $\Phi_{nn}=180^\circ$) at an additional condition of low energy of the proton (proton-spectator) allows us to investigate the reaction of quasifree $nn$ scattering at various combinations of scattering angles. The first preliminary data obtained in the neutron-neutron FSI and QFS geometries showed the possibility of our setup to obtain new data on neutron-neutron interaction in broad region of neutron energy.


THEORETICAL INVESTIGATION OF ELASTIC SCATTERING OF $\alpha$-PARTICLES ON $^{6,7}\text{Li}$ NUCLEI AT LOW ENERGIES

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Low energy scattering of $\alpha$-particles on the weakly bound $^6\text{Li}$ and $^7\text{Li}$ isotopes has a great fundamental and applied importance. From the fundamental side the scattering in $\alpha+^6\text{Li}$ system is interesting, first of all, owing to anomalous low binding energy of $^6\text{Li}$ by $\alpha+d$ channel ($\varepsilon_0 = 1.47$ MeV), i.e. the proximity to disintegration threshold. This means the relative easiness of $^6\text{Li}$ excitation into the states of $\alpha-d$ continuum in the process of interaction with incident $\alpha$-particle. In turn, such an excitation of $\alpha-d$ continuum leads to the great contribution of intermediate three cluster $\alpha+\alpha+d$ states in the scattering process at low energies. And the three cluster
configurations are virtually the excited states of $^{10}\text{B}$ nucleus. That is why it is possible to predict the strong transitions (for example, radiation) of $\alpha$-$^{6}\text{Li}$ continuum states into the ground state of $^{10}\text{B}$.

From the other side such a process of a particle and weakly bound nucleus interaction is typical for interaction of non-stable (radioactive) nuclei as $^{9,11}\text{Li}$, $^{10,12}\text{Be}$ and others with stable targets. That is why we can think that it is better to understand the features of such interactions of the stable particle with non-stable (weakly bound) nucleus by investigation of interaction with well investigated cluster nucleus such as $^{6}\text{Li}$ which has an anomalous low binding energy.

From the applied side, the nuclear reactions of nucleons and $\alpha$-particles with $^{6}\text{Li}$ nucleus are important for the better understanding of elements evolution in the framework of the Big Bang theory and at super nova outburst. This is closely connected to the old problem of abundance of $^{6}\text{Li}$ isotopes in the Universe, observed in the “iron” stars, in comparison with the predictions of the standard astrophysical models. It is clear that for sure estimations of $^{6}\text{Li}$ isotopes abundance it is necessary to know as possible exact the probability of its synthesis and its disintegration in different nuclear reactions. And the channel $\alpha+^{6}\text{Li}$ is one of the main channels.

We investigated the role of the excited intermediate states of the $^{6}\text{Li}$ target in the framework of the three-particle model for the ($\alpha+^{6}\text{Li}$)-scattering process. The simple general physical considerations show that these $\alpha$–d continuum states should provide an essential contribution to elastic and inelastic $\alpha+^{6}\text{Li}$ cross-sections, and also in radiation capture $\alpha+^{6}\text{Li} \rightarrow ^{10}\text{B} + \gamma$ reaction. Since the direct solution of the scattering problem in the three-particle ($\alpha+\alpha+d$)–system at low energies is too tedious and time-consuming because of the large Coulomb effects, we carried out the wave-packet reduction [1] of the problem. So, we projected the states of the three-particle continuum onto the discrete basis of the wave packets and employed, instead of the solution of the three particles Schrödinger equation, the coupled channel problem. Thus, we used the method of stationary wave packets as applied to the ($\alpha+\alpha+d$) three-body coupled-channel scattering case.

We limited here by the intermediate $\alpha d$–continuum with $\ell = 0$. The account of the states of the intermediate continuum was found to smooth noticeably [2] the sharp oscillations of the differential cross-sections, typical for folding model potential and makes the obtained cross-section closer to the empirical cross-sections found on the base of potentials extracted from solution of inverse scattering problem. Thus, account for the intermediate continuum essentially approximates the exact solution of the three-particle model. At low energies of order of several MeV the account of the dynamic polarization of particles in the reactions of elastic scattering and radiation capture affects cross-sections even stronger [3].

In the framework of the folding model the interaction potentials are constructed for the considering systems with account of only central part of interaction for the partial interactions potentials. There is a comparison between two results: the folding model and the wave-packet continuum discretization method (account only one state of $\alpha d$-continuum).

The present authors are planning in the near future to carry out the similar calculations for elastic scattering of $\alpha$-particles on $^{6}\text{Li}$ nuclei with account of d-wave of the $\alpha d$–continuum, and also for scattering of $\alpha$-particles on $^{7}\text{Li}$ nuclei.