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Short Communication

The polarization effects of the *n-^{9}Be* neutron elastic scattering

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The differential cross section of the *n-^{9}Be* neutron scattering and polarization effects is calculated in the framework of the eikonal approximation theory. In this paper by taking explicitly into account the composite quark structure of nucleons exchange effects we eliminate some discrepancies between the theory and the data that were recently pointed out.

Key words: Neutron scattering, polarization, quark, eikonal approximation, cross section.

INTRODUCTION

The reactions with neutron have been used to study several topics in nuclear structure and fundamental symmetries. Cross-section for these reactions is of applied interest in areas such as the embrittlement of reactor containment vessels.

The specific feature of this kind of reaction is that the transition amplitude is in general a sum of several nucleon contributions, each with its own phase and amplitude. The available experimental data point to the absence of the energy interval of scattering. This makes a basis for the hypothesis about the existence of a non-zero polarization research on the future accelerators will provide information about the structure of the nucleon interaction at large distances. For the more correct description of characteristics elastic and inelastic scattering in high energy baryons and π^+_- mesons on nuclei He, Li and Be within the framework of Glauber diffraction models have been used cluster wave function (WF), well reproducing the structure of these nuclei.

Using the WF, calculated in potential cluster models, in the form of the expansion as to gauss multidimensional and as the input parameters of Glauber theory lets to write down the operator of interaction in the form of the row of multiple scattering not on individual nucleons, and on nucleons and clusters. And this, in turn, allows us to calculate the scattering amplitude analytically, without loss of accuracy that occurs when excision of the multiple scattering and the calculation of multidimensional integrals. Application to the Glauber theory of cluster WF allows for a more detailed investigation of the calculated characteristics: to clarify the reasons for filling the diffraction minimum in the cross section, to link the behavior of cross sections with the behavior of WF on the asymptotic and central parts of the nucleus, to clear up the role of small component in the WF, etc.

On the other hand, in work (Shabalin, 1984) was performed the Glauber description of direct reactions and was shown that main discrepancies between theory and data, in particular, the position of diffraction minimum, be adjusted as additional members contributing to the scattering amplitude, if the nucleon is treated as a composite object.

Thus, the use of cluster WF nuclei lead to more detailed analysis of the available experimental data and make some calculations that are predictive in nature and designed for future experiments. Further study of the elastic and inelastic scattering of hadrons on light nuclei requires systematic experimental data in the energy range from hundreds MeV to 1 GeV as the cross-section and on polarization characteristics: the vector and tensor analyzing powers spin rotation functions.

In this paper we regard the quark cluster model results for the polarization effects of *n-^{9}Be* scattering. Early, it was shown (Abdulvahabova and Rasulov, 2002) that in the framework of the hypothesis concerning the existence of quark bag in nuclei we managed to describe the behaviour of the form factors of nuclei at large q and structure functions of nuclei.

THE MODEL FORMALISM

A nucleus in the quark cluster model is described as a system of many clusters- completely antisymmetrized with respect to the quark variables (Dorokhov et al., 1989). Each cluster consists of three quarks and the nucleon quantum number, namely it has symmetry for spin-isospin SU (4), symmetry for colour SU (3), and SU (3) symmetry for the radial part. The parameters of quark distribution in the bag at $k \gg k_0$ (the parameter k_0 may in principle be different for different bags) extracted from the data on form factors and on deep inelastic scattering of nucleons on nuclei proved to be very close.

In the eikonal approximation (Sitenko, 1973), which is usually sufficient for practical purposes, the scattering amplitude is

$$f(\mathbf{q}) = \frac{ik}{2\pi}\int \exp(i\mathbf{q}\mathbf{b})\langle\Psi|\Gamma(\mathbf{b})|\Psi\rangle d\mathbf{b}\,, \qquad (1)$$

$$\Gamma(\mathbf{b}) = 1 - \prod_{j=1}^{A}\left[1 - \gamma_j(\mathbf{b} - \mathbf{s_j})\right] \qquad (2)$$

Here **q** is the momentum transfer, **k** is the value of the wave vector of the neutron, **b** is the impact-parameter vector, $\Psi(\mathbf{r}_1, \mathbf{r}_2, ..., \mathbf{r}_A)$ is the ground state wave function of the nuclei, $\Gamma(\mathbf{b})$ is the total neutron–nuclei interaction profile function, $\gamma_j(\mathbf{b})$ is the profile function for the neutron-nucleon interaction, brackets $\langle || \rangle$ mean interactions over the nucleon coordinates.

Non-antisymmetrized wave function for the ^9Be in the oscillator-cluster model can be written as;

$$\Psi_{^9Be} = \phi_{N_1}(r_1, r_2, r_3)\Lambda\, \phi_{N_9}(r_{25}, r_{26}, r_{27}) \cdot \chi(R_1, R_2, ..., R_9), \qquad (3)$$

Where the nucleus is pictured as a bag with radius R_h, located at R_A enclosing A nucleons. Using the relations

$$R = \frac{r_{3i-2} + r_{3i-1} + r_{3i}}{3}, \quad i=1,2,\dots,9 \qquad (4)$$

and

$$\phi(r) = (\sqrt{\pi}R_h^2)\exp(-r^2/R_h^2)\,, \qquad (5)$$

We can write (3) in a factorised form

$$\Psi_{^9Be} = \prod_{j=1}^{9}\exp[\frac{r_{3j-2}^2 + r_{3j-1}^2 + r_{3j}^2}{R_h} - 2i\left(\frac{1}{R_A^2} - \frac{1}{R_h^2}\right)\cdot(\mathbf{s}_{3j-2} + \mathbf{s}_{3j-1} + \mathbf{s}_{3j})]P_n(r_j)Y_{lm}(\vartheta, \varphi) \qquad (6)$$

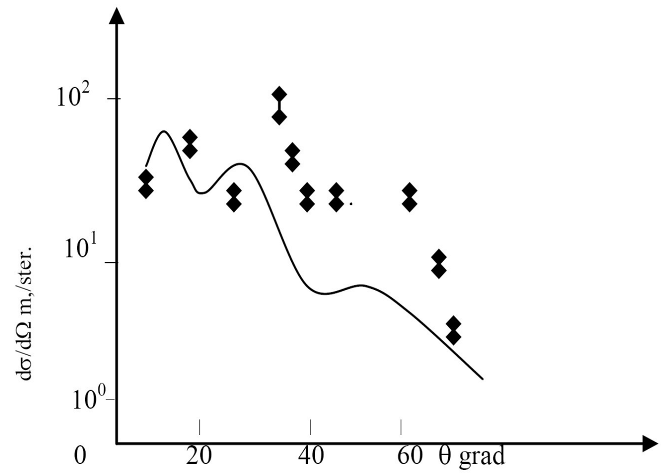

Figure1. The differential cross section of the n-^9Be reaction (composite nucleon model yields better agreement).

Then scattering amplitude (1) may be written in the form

$$f(q) = (ik/2\pi)\int d\mathbf{b}\exp(i\mathbf{q}\mathbf{b})(\delta_{mn}\delta_{MN}) - Det\left|\delta_{mn}\delta_{MN} - \left\langle M \,|\prod_{i=1}^{3}\prod_{j=1}^{3}(1 - \gamma(\mathbf{b} - \mathbf{s}_i + \mathbf{r}_j))|\, N\right\rangle\right| \qquad (7)$$

The matrix element of the profile function between the single particle states described by the quantum numbers *M* and *N*.

Use of the spin-non-flip amplitude of the n-^9Be reaction, obtained from the formulae (7) permits us to calculate the correct picture of polarization scattering neutron. We consider the case where spin-flip is neglected. It is important to emphasise that the case of the nucleon-nuclei scattering the leading asymptotic terms of the spiral amplitudes is also determined by the contribution of the quark cluster with the evident replacement of $f(q)$ by the pion-nucleon scattering amplitudes.

COMPARISON WITH THE EXPERIMENTAL DATA

Figure 1 compares the results of the calculation based on formula (7), with the experimental data for n-^9Be scattering (Ableev, 1995). The solid line corresponds to the cross section calculated equation (7). The sign corresponds to the experimental data. Figure 1 shows that the composite model of the nucleon leads to satisfactory - dependence with the θ-dependence of the calculated cross section and its experimental data. But the quark model predicts a somewhat smaller value for the cross section compared with that observed experimentally. In addition, the experiment is not clearly defined minimum. Experimental cross section has insignificant flexure in θ = 23 grad. It is known that the nucleus ^9Be hasn't spherical symmetry, and one of the reasons may

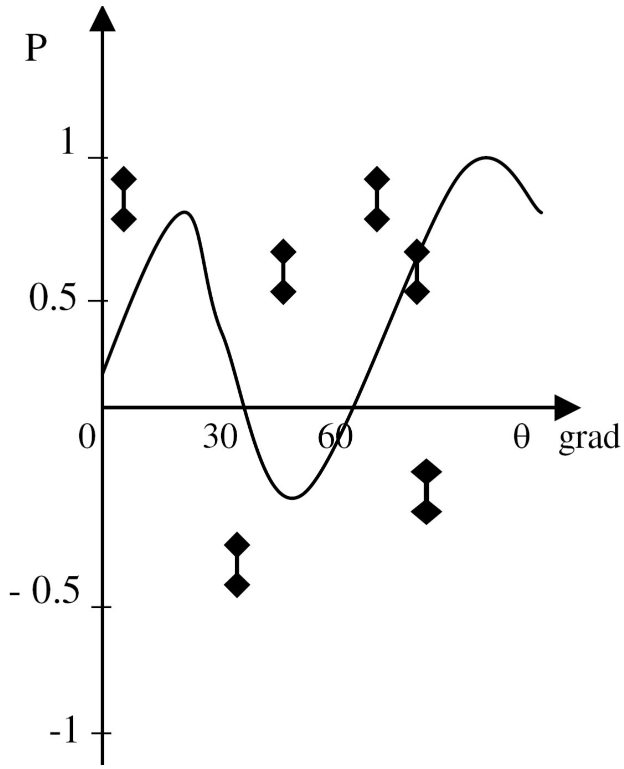

Figure 2. The polarization of the neutron in n-^{9}Be scattering.

be a significant deformation of the nucleus, with significant quadruple moment Q = 53 *mb*. Other causes are the minimum required increase of the ratio of the real part of the elementary scattering amplitude to the imaginary and the presence of some incoherent scattering channels.

However, formula (7) represents the overall ratio for the differential cross section, which can be obtained in the quark model without any constraints on the relative values of different quark amplitudes. This ratio should be carried out throughout the field transmitted pulses in the diffraction cone. Comparing this relation with experiment would, in principle, to verify the validity of the basic assumptions of the quark model for nuclear reaction.

The model prediction for the polarization of elastic *n*-^{9}Be scattering, corresponding to the experimental data is shown in Figure 2. Note that the model predicts a large polarization at high energies in the range of the diffraction peak. The analysis shows that when the pre-asymptotic corrections are absent, we have the zero polarizations. Observed in sections of the proton resonances associated with excited states of nuclei having certain quantum characteristics. As was said to, one of these characteristics is the spin J, which for s-protons can take two values $J = l \pm 1/2$.

In experiments with polarized neutrons and nuclei of the solution of this problem reduces to determining the sign of the polarization functions in resonance.

We can conclude from Figures 1 and 2, that the theory predicts well the data on the spectra and polarization in the quasi-elastic region. But at large angles predicted by the small cross section and too high amplitude of polarization, indicating the importance of the effects of even higher order. In the experiments, which measured the polarization dependence of the energy, it was found that the sign of polarization changes between quasi-elastic and deep inelastic energy region. This is explained by the interference of the spin transfer from the positive and negative scattering angles.

The analysis shows that when the pre-asymptotic corrections are absent, we have the zero polarisations.

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