POSSIBLE VIOLATIONS OF THE HAEBERLI RULES IN REACTION (d,p) ON 1p SHELL NUCLEI AT LOW ENERGY

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In this paper we investigate the possibility of simultaneous description of the angular distributions of the cross section, the vector polarization and the vector analyzing power with DWBA, using various modifications deuteron Z-potentials and Perey, previously experimentally observed violations of rules Haeberli in the low-energy deuterons on the example of the reaction ^{9}Be(d,p)^{10}Be. Found that using DWBA this case can be described as a violation of the rules Haeberli at the low energy.

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1. INTRODUCTION

In previous papers [1] has been shown on the basis of experimental data that at energies below 4 MeV (Tab.1) is a violation of the rules Haeberli (Tab.2) performed at energies above 7 MeV in the reactions occurring mainly due to the direct process.

Table 1. *Signs of spin observables (VAP and VP) and slope of their angular distributions at main peak of reactions $^{9}Be(d,p_0)$ j_n=3/2, $^{9}Be(d,p_1)^{10}Be^*$ (3.37 MeV) j_n=3/2 and 1/2 and $^{12}C(d,p_0)$ j_n=1/2 in the problem area*

Problem area <4 MeV				
Spin observable	l_n...j_n	E_d MeV	Sign of $A_y(P_p)$ $\theta_m<\theta<2\theta_m$	Sign of slope
	1/2	2.8	−	(+)
A_y	1	2.8	−	+
VAP	3/2	2.5	+	+
		2.8	+	+
	1/2	3.2	−	+
P_p	1			
VP	3/2	2.5	+	+

Table 2. *Signs of spin observables (VAP) and slope of their angular distributions at main peak*

l	j=l±1/2	$A_y(\theta$ at $\theta_m<\theta<2\theta_m$	Sign of slope $A_y(\theta)$ at θ_m
1	1−1/2=1/2	+	+
1	1+1/2=3/2	−	−
2	2−1/2=3/2	−	−
2	2+1/2=5/2	+	+

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For the analysis of direct nuclear reactions the most widely used method of DWBA, which is based on the use of the optical model of elastic scattering. However, in very light nuclei this procedure occurs more difficult than for heavier nuclei. Using phenomenological found deuteron parameter set of the Z-potential [2] are showed an adequate description of the differential cross sections of the reaction ^{40}Ca(d,p) by the local approach of the zero range distorted waves method [4]. Heidelberg group [5], based on the parameterization of Z-potential, show possibility of applicability to describe the elastic scattering cross section and direct pick up reactions (d,t) and (d,^{3}He) on 1p-shell nuclei at an energy of 11.8 MeV deuterons with a slightly modified parameters (H1). Argonne group [6] showed their applicability to describe of the cross sections striping direct reactions (d,p) on 1p shell nuclei in the zero-range approximation using the cutoff radius R_{Co}=4 fm. Under these conditions of the calculation obtained spectroscopic factors similar to those found in a shell model with intermediate coupling [7]. Using corrections for the finite range (in the local energy approximation – LEP) in many cases improves the agreement between the calculated shape of the angular distribution of the cross section with experiment and justifies the use of the cutoff radius in the radial integral overlapping of the wave functions for the extraction of spectroscopic factors. However, they failed to uniquely determine the ratio of the spectroscopic factors for mixed transitions, and moreover, in case ^{40}Ca(d,p) [4], this somewhat increases the absolute value of the spectroscopic factors.

Continued use of Z-potential and its modifications associated with the influence of the polarization observables on its parameterization and with the role of spin-orbit interaction, at the description of the cross section and vector polarization (VP) in the elastic scattering of deuterons [8] the potential of Schwandt and Haeberli (SH) (Wisconsin) as well as vector analyzing power (VAP) of the direct stripping reactions (d,p) and (d,n) [9,10]. Found [9], that the empirical rule Haeberli, linking sign and magnitude VAP of stripping reaction (d,p) in a certain range of angles of emission of protons $\theta_m < \theta < 2\theta_m$ with the values of the transferred total angular momentum (see Tab.2), and well reproduced by zero range DWBA with deuteron potential type (SH) for the sd- and 2p1f-shells nuclei-targets. However, in some nuclei 1p shell (^{12}C) this rule is violated, that the authors of [9] is attributed to the influenced of non-optical-model effects (formation of a compound nucleus resonances).

A comparison of the experimentally observed VP – $P_p(\theta)$ and VAP – $A_y(\theta)$ at the same energy and with a distinct picture of the direct process in the angular distribution of the cross section for the reaction ^{9}Be(d,p)^{10}Be$_{g.s.}$ shows (Figs.1a,d and in [1,9]) that in the typical range of angles $\theta_m < \theta < 2\theta_m$ – the angle of the main stripping maximum) at E_dd $\geq$ 7 MeV for VAP Haeberli rule generally performed well. For the VP sign are opposed VAP.

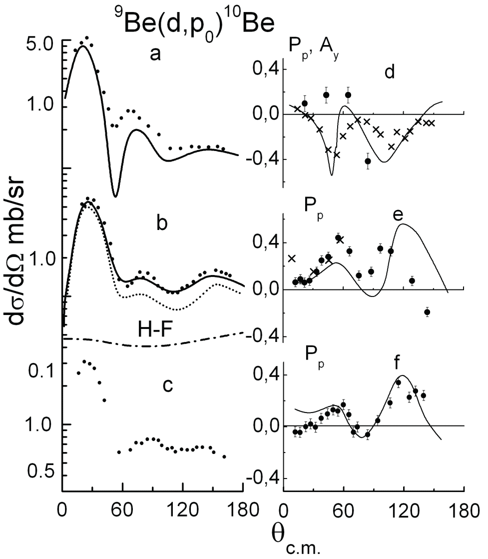

Fig.1. *Energy dependence of the angular distributions cross section, polarization (P_p) and vector analyzing power (A_y) and their comparison with DWBA calculations with modify Z optical-model potential parameters for energy range from* 4.0 *to* 8.0 *MeV. Experimental date for: a,d)* 7...8 *MeV (YH – Be) [9,30], b,e)* 5.25...5.5 *MeV (D_2 + P6) [11,16], c,f)* 4.5...4.0 *MeV (D_2 + P6) [11, 16]. Results calculation coincident with work [17,30]. Sign polarization corresponds to the Basel Convention*

This may indicate that in this energy region sign rule for the VP or not performed or may be other. Such a change in the sign confirmed by experimental data for the VP ^{9}Be(d,p) [30] (see Fig.1,d) and (d,n) reactions on the target nuclei 1p$_{1/2}$-shell [11], as well as on some nuclei 1p$_{3/2}$-shell [13] at low energies, in particular for ^{9}Be (Figs.1,e,f).

Experimentally, we found [15] what angular distributions VAP of (d,p) reaction in the interaction of 2.5- and 2.8-MeV deuteron with ^{9}Be confirm this exception to the rule Haeberli and for VAP (see Tab.1). Detailed analysis VP (d,n)-reactions on nuclei 1p$_{1/2}$ within DWBA using the parameters of the deuteron potential equivalent family of type 44 (classification Meyer [12]) allows to reproduce the above rule violation Haeberli for VP in the j_p=1/2 transitions, as well as using the Z-potential in the analysis cross section and VP (d,n$_0$) reaction on ^{12}C, held Wilmore and Hodgson [14].

The aim of this work was to try to find an opportunity to describe the rule violation Haeberli by optical model and DWBA using deuteron potential parameters Z, H, and SH and their modifications and, if possible, to find a settlement conditions in DWBA in which these occur simultaneously qualitative effects in the angular distributions cross section, VP and VAP, which are close to the experimentally observed in the elastic scattering and reactions (d,p) on the target nucleus of 1p$_{3/2}$ shell (^{9}Be) at energies below 4 MeV.

2. COMPARISON OF THE DWBA WITH OUR EXPERIMENTAL DATA AT LOW ENERGIES

Based on the parameterization DWBA calculations found to describe the angular distributions of the cross section on the number of nuclei of the 1p$_{3/2}$ shell at E_d=5.25 MeV [16], we repeated the calculations involving experimental data on the polarization [11] (see Figs.1,b,c,e,f), which also reproduce well the violation of the rule Haeberli in the observed polarization and repeat the calculation results Bondouk (Cairo-Bucharest) [17]. Next, we modeled the dynamics of change in the behavior of the angular distributions of the cross section and VAP reaction ^{9}Be(d,p$_0$) and elastic scattering in the transition from a deuteron energy of 5.5 MeV to 2.8 MeV of our experiment (see Figs.2,b,c).

Comparison with experimental reaction cross section (see Fig.2,a) shows that there is a problem with the description of the position and magnitude of the second peak in the reaction cross section using zero range DWBA with spin-orbit interaction. In this approximation, at low energies there is a degeneration of the second peak with the formation of a broad minimum between the 1-st and 3-rd maxima in the cross section that is clearly correlated with the disappearance of a negative minimum in the angular distribution VAP (see Fig.2,b). So it is a significant change in the behavior of the angular dependence of the cross section for elastic scattering and polarization (see Fig.2,c) at constant parameters of the optical potentials.

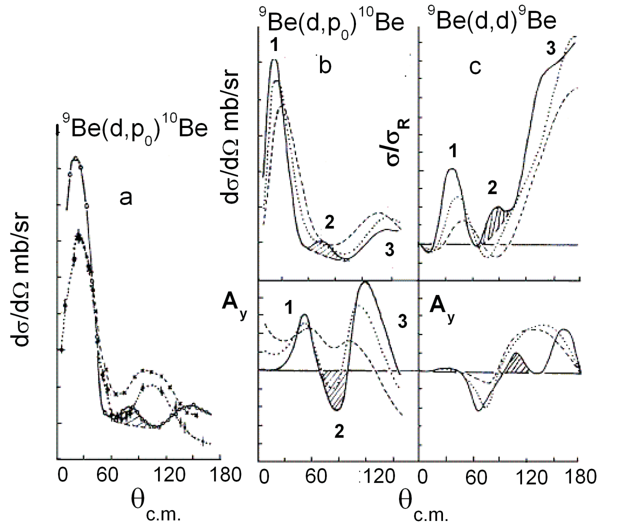

Fig.2. *Modeling of the angular distributions of differential cross section and VAP in the range energies from 5.5 to 2.8 MeV. a) Experimental data: $--\circ--$ $E_d = 5.5\,MeV$ [16]; ....•.....-$E_d = 3.6\,MeV$ [21]; $- - \times - - -$-$E_d = 2.8\,MeV$ [15]. b) DWBA zero range calculation with modify Z-potential from [22] (D_2 + $P6$) without energy dependence for $^9Be(d,p0)^{10}Be_{g.s.}$. $j_n = 3/2$. c) Optical-model calculation with modify Z-potential (D_2) of the elastic cross section $\sigma(\theta)/\sigma_R(\theta)$ and VAP ($A_y = P$) (polarization) for ^9Be: ______-$E_d = 5.5\,MeV$; ....-$E_d = 3.6\,MeV$; $- - - -$-$E_d = 2.8\,MeV$. Dashed aria is angle aria near second pic of cross-section of the reaction $^9Be(d,p_0)^{10}Be$*

First, we show the comparison results of our calculations with the above noted deuteron set of optical-model parameters (D2, Tab.4) selected for the calculation of cross sections and VAP the local zero range DWBA with spin-orbit interaction (Fig.3) for mixed on jn transition at a relatively low value of Q-reaction in ^{9}Be(d,p$_1$)^{10}Be (3.37 MeV). Results of the comparison show: a) taking into account the contribution of the formation of the compound nucleus (see Fig.3,b) joint description cross section and VAP achieved when mixing ratio by j p$_2$=1.85 (line 2), confirming the results of the analysis of data obtained VAP at energies above 10 MeV [18]. This value p=S$_{3/2}$/S$_{1/2}$, corresponds to shell model calculations with intermediate coupling [7] and with the effective forces of two-particle interactions (6-16)2BME. b) In the case of p$_1$= 0.21 (line 1) obtained a good description of the cross section in area of the main striping peak, which coincides with the results of calculations at higher energies [6,16]. However, with a complete mismatch with the VAP data (line 1 in Fig.3) indicates that preference should be given to (6-16)2BME interaction.

In this case, the sign and shape of the angular dependence of VAP does not comply with rule Haeberli, but similar to that observed experimentally VP reactions (d,n) [12] nuclei 1p$_{1/2}$ shell.

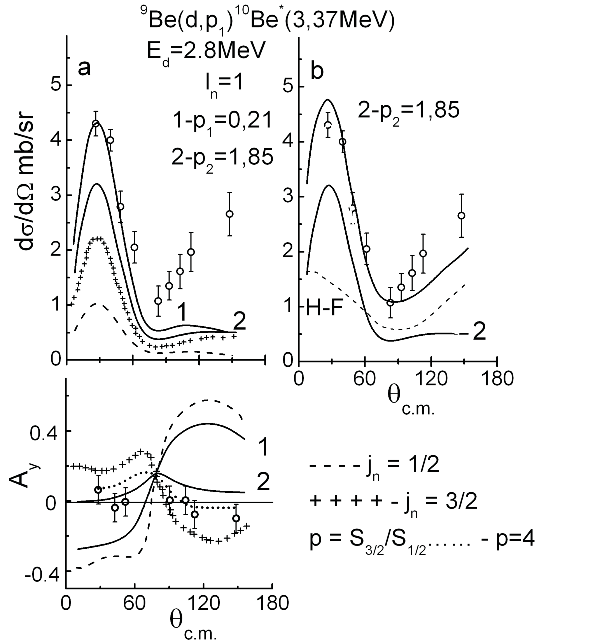

Fig.3. *Mixed by j transition in direct reaction $^9Be(d,p1)^{10}Be\,(3.339\,MeV)$ at $E_d = 2.8\,MeV$. Zero range DWBA theoretical calculation with spin-orbit coupling, the potentials of $D_3 + P10$. a - Determination of mixing by j - p using VAP - Ay. The solid lines correspond to the two mixing ratios of the shell model theory: 1 - for $p_1 = 0.21$, and 2 - $p_2 = 1.85$*

Then, consider the comparison of predictions DWBA both with zero range, and a mended on a finite range (LEP) and nonlocality of optical potentials, as well as the inclusion of the cutoff radius R$_{Co}$ with their reflection in our experimental data for the ^{9}Be(d,p$_0$)^{10}Be (Fig.4). Comparison of calculations with experimental data shows that: a) in the calculations, as well as in the case of simulation (see Fig.2,b) when we use the potential parameters of the distortion waves in the entrance and exit channels (D$_2$+P15 or P19) (see Tab.4 and 5) in the approximation of zero range with the spin-orbit interaction cannot properly describe the position and the size of the 2-nd peak in the cross section, and only qualitatively reproduce the behavior of the polarization observables although spectroscopic factor gets close to those given by the shell model (Tab.3); b) Inclusion of the cutoff radius R$_{Co}$=4 fm in zero range approximation gives the correct position of the 2nd peak in the cross section, but with a small amplitude. While polarization observables are reproduced qualitatively correctly in the forward hemisphere. c) In the case of inclusion a finite range and no locality of optical potentials amendments to the DWBA calculations with specially selected phenomenological parameters of proton potentials (P15 and P19, see Tab.5) and the modified Z-D$_2$ potential can be simultaneous description of our data on the cross section, VP and VAP, which are contrary to the rule Haeberli. However, are somewhat inflated values of the spectroscopic factors (see Tab.3).

__Table 3.__ Comparison of spectroscopic factors found in our work with the literature data

theory [7]	2.5 MeV [19]	2.5 MeV [20]	2.5 MeV [20]	5.25 MeV [16]	0.9...3.1 MeV [19]	2.5 MeV our	2.8 MeV our	2.5...2.8 MeV our	2.8 MeV our	2.8 MeV our
	Z+P1 No corr.	Z No corr.	H+P1 without V_{so}	D_2+P6 without corr. +H-F	Method Baucock for DWBA	D_2+P14 without corr. +H-F	D_2+P15 s.o. No corr.	average XR+ RCO	D_2+P19 corr. +H-F	D_2+ P19 corr.
2.36	1.102	1.85	1.65	2.356	2.26	2.52	2.18	2.3±25%	2.72	3.12

Allowance for the contribution of the compound nucleus formation (Fig.5) approximates the magnitude of the obtained spectroscopic factors to shell-model values [7].

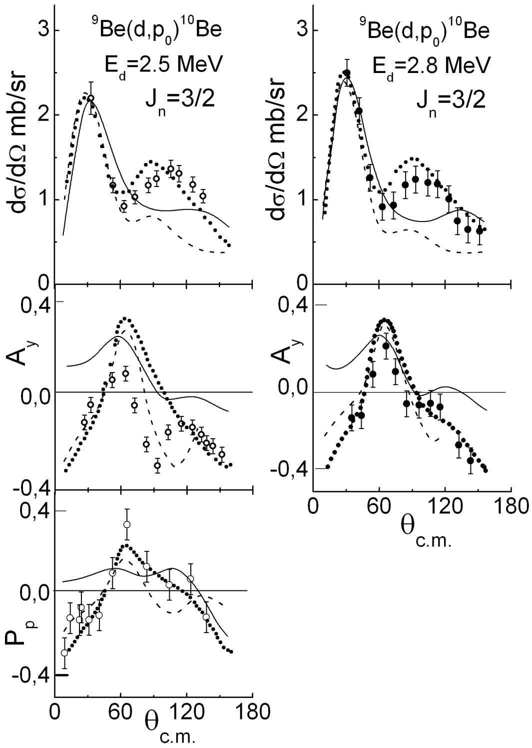

Fig.4. *Angular dependences 0f the cross-section , VAP (Ay) and VP (Pp) [15] emitted protons from reaction $^9Be(d,p_0)^{10}Be$ at $E_d = 2.5$ and $2.8\,MeV$.*
a) $E_d = 2.5\,MeV$ ($D_2 + P14$),conditions of calculation: − − −− − $R_{co} = 4\,fm$; • • •• − the sum of the corrections for the non-locality of the optical potentials and finite range; ______ − Zero range;
b) $E_d = 2.8\,MeV$, conditions of calculation:
______ − ($D_2 + P15$), zero range; • • •• - modifications to nonlocality and finite range ($D_2 + P19$); − − −− − $R_{co} = 4\,fm$

Contribution to the cross section of a compound nucleus by Hauser-Feshbach in the back angles at an energy of 2.8 MeV several worsens agreement with experiment. These results may indicate that in the case of the reaction ^{9}Be(d,p$_0$) is preferably occur by the surface direct process by transmitting one total angular momentum j=3/2. A negative value of VP and VAP in the front angles, near the main striping peak (300), associated with the amendments shearing the polarization observable at the front and back angles to the range of negative values (see Fig.4 and 6), but it does not connected with rules Haeberli.

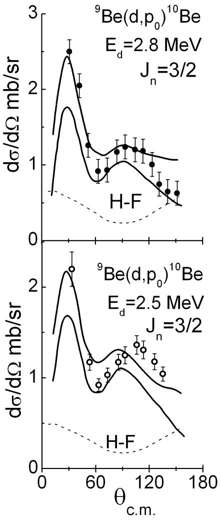

Fig.5. *Allowance for the contribution of the formation of the compound nucleus in the reaction $^9Be(d,p_0)^{10}Be$*

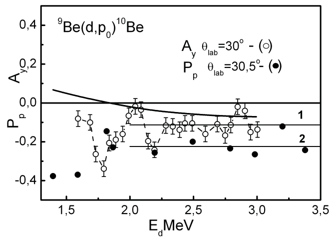

Fig.6. *Comparison of excitation functions for the polarization P_p [11] • - and VAP Ay - ○ in the reaction $^9Be(d,p_0)^{10}B_{eg.s.}$ Lines 1 and 2 - average values VAP and polarization, respectively, for the energy range of 2.0...3.0 MeV. $< Ay > = -0.113$, $< Pp > = -0.224$. Continuous curve - DWBA theoretical calculation Ay (D_2 + P19 potentials with all corrections) for $j_n = 3/2$*

Sufficiently smooth running of the energy dependence of VP and VAP in the energy range 2.2...3.1 MeV can also point to the prevalence of the direct process in this energy region.

2.1. NEUTRON BOUND STATE

It is assumed that the neutron is captured on the shell-model orbit with orbital angular momentum l and total angular momentum j=l±1/2. We take this orbit such that it is eigenstate in the Wood-Saxon potential well, so that the wave function is somewhat dependent on the choice of parameters for this well. For the calculations presented here, we assumed that same radius (1.25A$^{1/3}$ fm) and diffusivity (0.65 fm) as well as those that are commonly used for the proton optical potential. For a more precise definition was also included spin-orbit coupling is 25 times stronger than Tomason term and which corresponds to the force V_{so}≈8 MeV. These parameters were used in all calculations. Well depth was chosen such that the binding energy to give equal energy neutron separation.

2.2. ENTRACE DEUTERON CHANNEL

To assess the distorted wave functions in the entrance channel were found experimentally [22] angular distributions of the cross section and VAP elastic scattering deuteron at energies 2.0, 2.3, 2.5 and 2.8 MeV. The cross sections are in good agreement with the data of [23] (Cairo) for energies below 2.5 MeV. Analysis of experimental data [23] conducted in the University of Warsaw [25] showed that one can obtain the averaged energy parameters of the modified optical potentials without spin-orbit interaction H, SH and P (Tab.4), relating with different source lines parameterization, and about equally describing them (E_d=1.8 MeV Figs.8-10). The first two lines correspond to the parameterization of Z-potential, which are compared with the requirements of parameterization Perey P [26].

Fig.7 shows a comparison of our experimental data with the calculations of the optical model, using empirical parameters (Tab.4) what we found [24] and other authors. With the aim of improving search consent optical model calculations with experiment was evaluated different parameterization deuteron potentials. To do this, we first of all tried to do χ^2 minimization procedure to get an equally good description of the cross sections and VAP for elastic scattering in the front and back angles, using as a starting potential (SH)', that best describes of the experimental data at 2.8 MeV (Fig.9). The result of analysis (Fig.7) gives the potential P4, which is good for the description cross section and do not can describe VAP in the back angles because there are the last two points in the cross section data. There's also, for comparison, results of the calculation with the parameters Z-C (see Tab.4) which best describes in the potential approach a purely shape scattering cross section of deuterons on ^{12}C at 2.8 MeV [3], and showing that at correct description of the VAP in front and back angles but the cross section shows a discrepancy with our experimental data. Parameter set D_2 by comparison with experiment shows that in contrast to cases with potentials (P)‘, (SH)‘ and (H)‘ (Fig.8-10), where under the influence of spin-orbit interaction of the main interference minimum shifts to back angles from the second maximum in the cross section (i.e. it become the third minimum, where there is a strong and destructive interference), it shows the opposite behavior.

To compensate for this destructive interference in the cross section were used two-mode approximation [24], taking into account the contribution of compound nucleus formation using statistical Hauser-Feshbach theory, which does not contribute to VAP (Fig.11). Fig.11 shows that while minimizing by χ^2, the selected portion of the shape scattering, it is possible to achieve a good description of the experimental cross section throughout the entire range of angles, and VAP in the back angles. ПП3 potential, obtained by optimizing a set of parameters of the potential (P)‘.

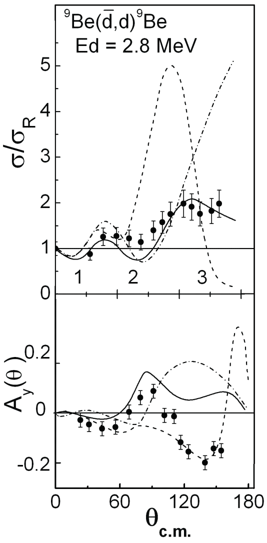

Fig.7. *Elastic scattering of deuterons at an energy of 2.8 MeV on ^9Be. The relative cross section σ/σ_R and VAP (A_y). - - - Optical model calculation: ______ – χ^2 minimizing the potential for П4; – · – · – – D_2 [15] potential; – – – –Potential Z-C [3]*

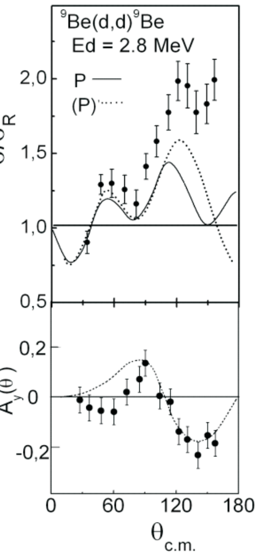

Fig.8. *Cross section and VAP deuteron elastic scattering on ^9Be at E_d=2.8 MeV. Optic model calculation with potential P – a solid line and (P)' with V_{so}=15 MeV – dot line*

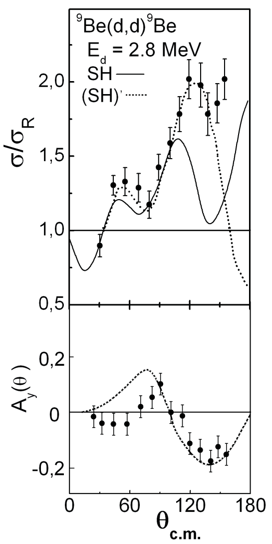

Fig.9. *Cross section and VAP deuteron elastic scattering on ^9Be at E_d=2.8 MeV. Optic model calculation with potential SH – a solid line and (SH)' with V_{so}=15 MeV – dot line*

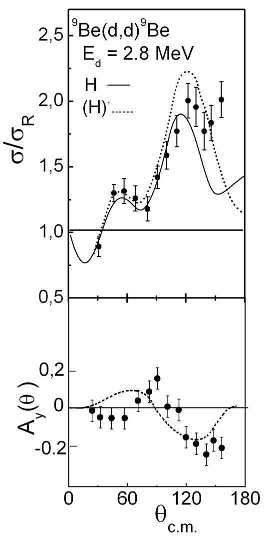

Fig.10. *Cross section and VAP deuteron elastic scattering on ^9Be at E_d=2.8 MeV. Optic model calculation with potential H – a solid line and (H)' with V_{so}=6 MeV – dot line*

Table 4. Parameters of optical potentials with spin-orbital interaction for deuteron elastic scattering on ^{9}Be at $E_d \leq 2.8$ MeV [46]. Surface absorption and r_c=1.3 fm

E_d, MeV	Sets of the parameters	V_0, MeV	r_0, fm	a_0, fm	W_s, MeV	r_w, fm	a_w, fm	V_{so}, MeV	r_{so}, MeV	a_{so}, fm	Line of the parameterization
1.8(2.8)	H (H)‘	114.2	0.869	1.01	16.0	2.16	0.323	6.0	0.869	1.01	Hilderberg [24,25]
1.8(2.8)	SH (SH)‘	102.0	1.05	0.90	10.0	1.93	0.46	15.0	1.05	0.9	Wisconsin [24,25]
1.8(2.8)	P (P)‘	95.44	1.15	0.81	10.80	1.575	0.585	10.0	1.15	0.81	Perey [23,25,26]
8	YH-Be	89.6	1.16	0.93	18.0	1.53	0.43	15.2	1.16	0.93	[9]
5.25	D_2	170.0	0.90	0.90	12.0	2.10	0.50	7.5	1.20	0.90	Powell-Robson[16]
5.25	D_3	150.0	0.90	0.90	12.0	2.10	0.50	7.5	1.20	0.90	[16]
2.8	Z-C	112.5	0.90	0.90	4.25	2.861	0.493	6.0	0.90	0.90	Satchler [13]
2.8	П4	89.6	1.05	0.931	10.0	1.80	0.60	10.0	0.90	0.60	(SH)‘→П4 [24]
2.4	ППЗ	93.49	1.14	0.86	1073	1.70	0.685	9.55	0.90	0.60	P‘→ППЗ [24]

The underlined values - parameters of spin-orbital of interaction added to sets of parameters H, SH and P for 1.8 MeV, proceeding from consideration Figs.8-10.

Table 5. Parameters of optical potentials with spin orbital interaction for the elastic scattering of protons on ^{10}Be, mentioned in the text. Surface absorption

E_p, MeV	Sets of the parameters	V_0, MeV	r_0, fm	a_0, fm	W_s, MeV	r_w, fm	a_w, fm	V_{so}, MeV	r_{so}, MeV	a_{so}, fm	r_c, fm	References
8.5	P1	52.0	1.17	0.75	5.433	1.523	0.523	6.2	1.01	0.75	1.3	[19]
	P6	49.0	1.25	0.65	7.0	1.25	0.47	6.0	1.25	0.65	1.25	[16]
5.0	P10	50.0	1.38	0.65	11.9	1.50	0.37	7.3	1.35	0.33	1.33	[27]
7.0	P14	32.4	1.54	1.01	21.9	1.82	0.18	4.9	1.67	0.27	1.09	[28]
7.0	P15	48.7	1.40	0.48	10.3	1.466	0.53	8.41	1.35	0.31	1.50	[29]
8.0	P18	46.6	1.39	0.51	10.6	1.49	0.50	5.67	1.30	0.36	1.50	[28]
7.5	P19	34.0	1.49	0.9	17.5	1.755	0.22	4.9	1.625	0.28	1.09	[29]

Further research associated with the study of the behavior of cross section, VP or VAP at energies of 4...8 MeV for comparison with the results obtained by us at energies below 3 MeV. Using the parameters deuteron potentials found in the works of other authors in the two-mode analysis of elastic scattering of ^{9}Be(d,d) and DWBA description of nuclear reaction ^{9}Be(d,p_0) [16], we modeled the angular distributions VAP=VP shape scattering (set D_3) and from the description of the direct reaction (d,p) (set D_2) (Fig.12). For purely shape scattering of deuterons the main become the this interference minimum cross section at the back angles, which masked by the contribution from the compound nucleus formation, and, as seen in Fig.12 (right column) associated with deep negative minimum VAP (A_y) at $\theta_{min3} \sim 120^o$, similar to that observed in our analysis of our experiment at an energy of 2.8 MeV at $\theta_{min3} \sim 120^o$ (see Figs.8-11). When the energy of 8 MeV and higher the main in cross sections is the 2-nd minimum, to which should correspond a deep negative minimum VAP (VP) in the same range of angles. This situation is well described by the optical model at E_d=12 MeV [18]. As seen from Fig.12 occur shifts of the main interference minimum, according to the calculated VAP, in the energy region 6.5...8.0 MeV. The reason for this shift may be associated with changes in family of potentials, which requires a special study.

Phenomenological analysis of our polarization data for of elastically scattered deuterons requires increased force of the spin-orbit interaction.

2.3. INFLUENCE OF SPIN-ORBIT INTERACTION AND THE CUT OFF RADIUS ON THE SHAPE AND PARAMETERS OF THE ANGULAR DEPENDENCE OF THE OBSERVED VALUES IN THE LOCAL DWBA

In order to determine the characteristic features of the simultaneous description of the angular dependence of the cross section, VP and VAP in the studied reaction ^{9}Be(d,p_0)^{10}Be, having a non-standard features, zero range DWBA modeling was conducted with the separation of the contributions from the spin-orbit interactions in different channels of the direct reaction using the above discussed lines parameterization (H)’, (SH)’, (P)’ in the entrance deuteron channel and at the same proton potential P1 (Fig.13) which was used in the description of this reaction in [19,25] (Warsaw).

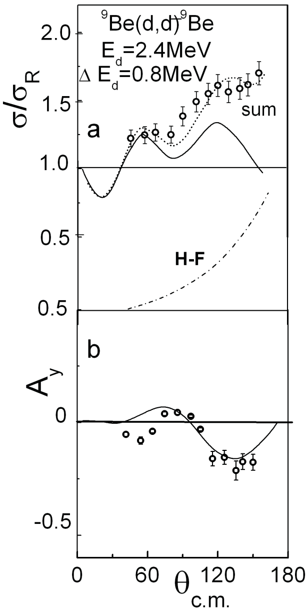

Fig.11. *Two-mode description averaged energy cross section (sum) and VAP elastic scattering on ^{9}Be at an average energy E_d=2.4 MeV, taking into account the contribution of the compound nucleus in the statistical theory of Hauser-Feshbach (H-F) with the potential ПШ3 [24]*

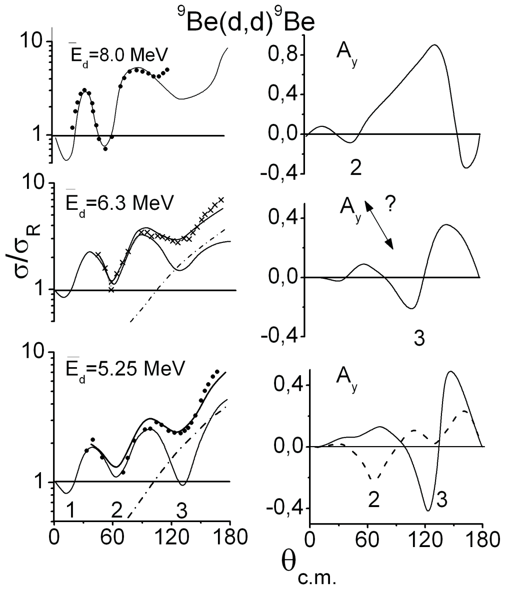

Fig.12. *Angular dependence of the measured elastic scattering cross sections σ/σ_R and VAP ($A_y(\theta)$) calculated using the parameters of the optical potentials from works: E_d=5.25 MeV (D_4) [16], E_d=6.3 MeV [16] and E_d=8.0 (7.8) MeV (YH-Be) [9,30] – a solid line in the right column and - - - corresponds to the calculations with the parameters D_2 potential at 5.25 MeV that best describe (d,p) reaction under DWBA [16]. The dot-dash line (left column) is incoherent contribution from the formation of a compound nucleus. Figures – numbers lows in the angular dependence of the cross section σ/σ_R potential scattering*

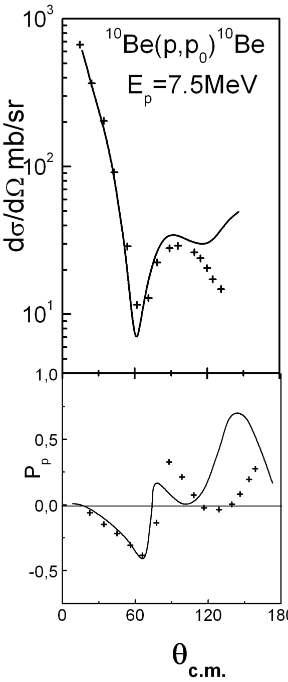

Fig.13. *Optic model calculation of cross section and WAP elastic scattering of protons on ^{10}Be with potential P1 [19] at E_p=7.5 MeV – a solid line; +++ – Experiment for ^{9}Be at E_p=8 MeV [27]*

4. CONCLUSIONS

The simulation results give: a) Taking into account the strong spin-orbit interaction (V_{so}≈10...15 MeV is obtained from our polarization data of elastic scattering) separately in each channel gives a different sign for the maximum polarization observables at θ_{max} (P_p, or A_y)≈ θ_{min} (dσ/dΩ). The positive sign of the polarization observables arises due to the spin-orbit coupling only in the exit channel and the negative (corresponding rule Haeberli) when the spin-orbit coupling only in the deuteron entrance channel. b) When using the deuteron potential (H)' with a mean value of the spin-orbit interaction (V_{so}≈5...6 MeV quite well simultaneously describing our elastic scattering experimental cross section and VP data), together with the proton potential P1, we obtain the angular dependence of the polarization observables with behavior similar to those that match the rule Haeberli. Inclusion of spin-orbit coupling in both channels, in this case, does not significantly alter the behavior of the angular dependence of the polarization observables. c) In all above mentioned cases, the angular dependence of the cross section in area of the 2-nd peak does not correspond to the experimentally observed position. Angular dependence of polarization observables is correlated with the specific behavior of the cross section. d) With the introduction of the cutoff radius R_{co} in the integral of overlap radial parts of the wave functions zero range DWBA with spin-orbit interaction for the case b), when it is increasing to a value close to the size of the nucleus R_{co}≥3.5 fm, there is an abrupt change in shape and sign of the polarization observables from that which corresponds to the rule Haeberli, up to that which qualitatively reproduces our experimental data on the VAP and the data of [10] on the VP at an energy E_d=2.5 MeV. Now the form of the angular dependence cross section is changes, now the position and shape of the 2nd peak are reproduced (other than amplitude). A similar change occurs with other examined deuteron potentials (SH)' and (P)'. This confirms the effects obtained at the description of our and from world literature of the experimental data using a modified Z-potential. This yields spectroscopic factors close to the shell-model one.

All this gives reason to believe that obtained by us the experimental discrepancy with rule Haeberli may be explained by a direct surface process described within DWBA with the spin-orbit interaction and corrections on the finite range and no locality of optical potentials. The reasons for the use of "non-standard" parameter sets can be associated with a change in the localization of l-space [31] what require further theoretical study.

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О ВОЗМОЖНОМ НАРУШЕНИИ ПРАВИЛА ХАБЕРЛИ В РЕАКЦИИ (d,p) НА ЯДРАХ 1p-ОБОЛОЧКИ ПРИ НИЗКИХ ЭНЕРГИЯХ

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Исследуется возможность одновременного описания угловых распределений сечения, векторной поляризации и векторной анализирующей способности в рамках БПИВ, с использованием различных модификаций дейтонного Z-потенциала и потенциала Перея, ранее экспериментально наблюдаемых нарушений правила Хаберли в области малых энергий дейтронов на примере реакции ^{9}Be(d,p)^{10}Be. Найдено, что с помощью БПИВ можно описать нарушение правила Хаберли при низкой энергии.

ПРО МОЖЛИВЕ ПОРУШЕННЯ ПРАВИЛА ХАБЕРЛІ В РЕАКЦІЇ (d,p) НА ЯДРАХ 1p-ОБОЛОНКИ ПРИ НИЗЬКИХ ЕНЕРГІЯХ

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Досліджується можливість одночасного опису кутових розподілів перерізу, векторної поляризації і векторної аналізуючої здатності в рамках БПІВ, з використанням різних модифікацій дейтонного Z-потенціалу і потенціалу Перея, раніше експериментально спостережуваних порушень правила Хаберлі в області малих енергій дейтронів на прикладі реакції ^{9}Be(d,p)^{10}Be. Знайдено, що за допомогою БПІВ можна описати порушення правила Хаберлі при низькій енергії.