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INVESTIGATION OF (d,d) AND (d,t) REACTIONS ON 11B NUCLEI AT ENERGY OF 14.5 MeV

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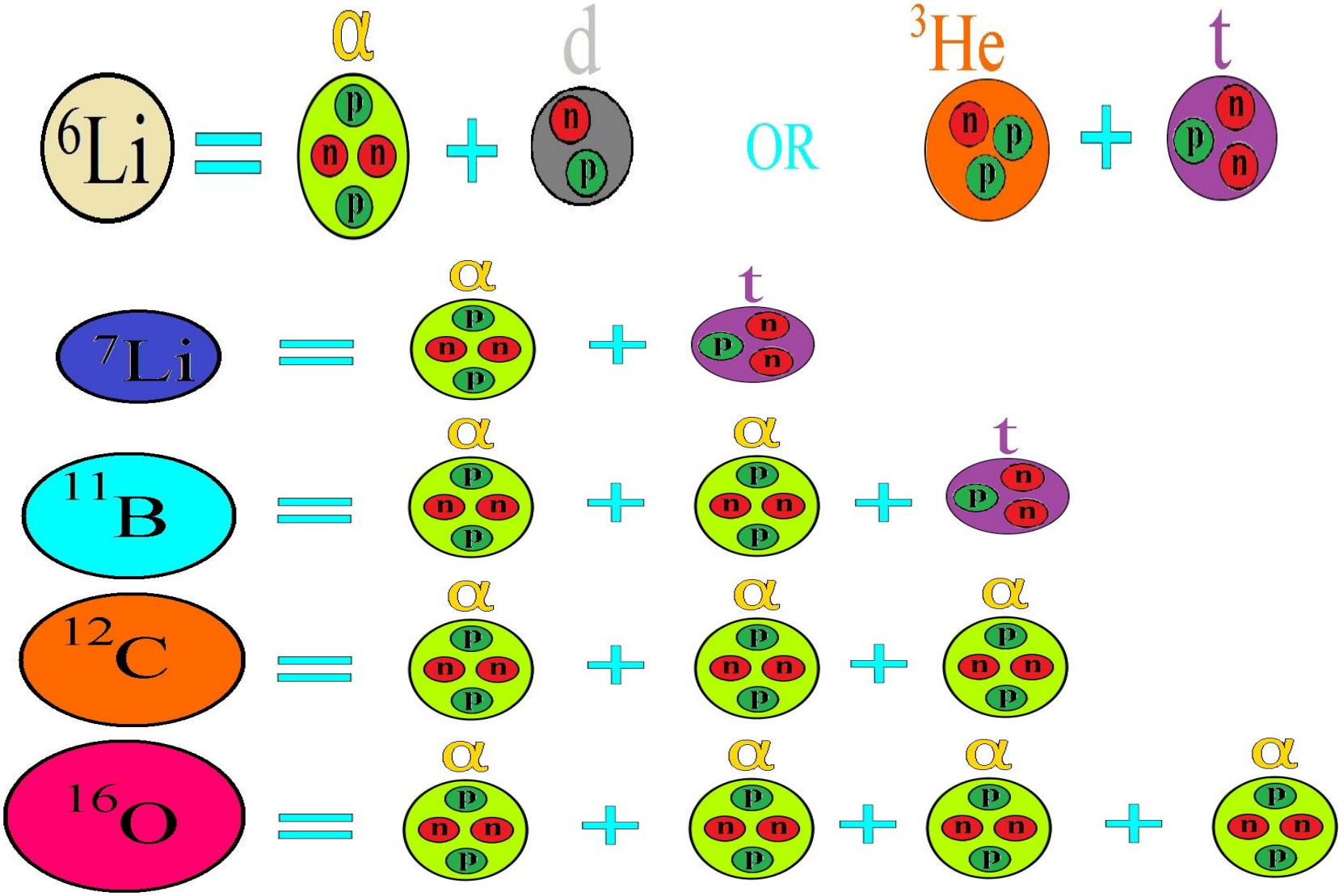
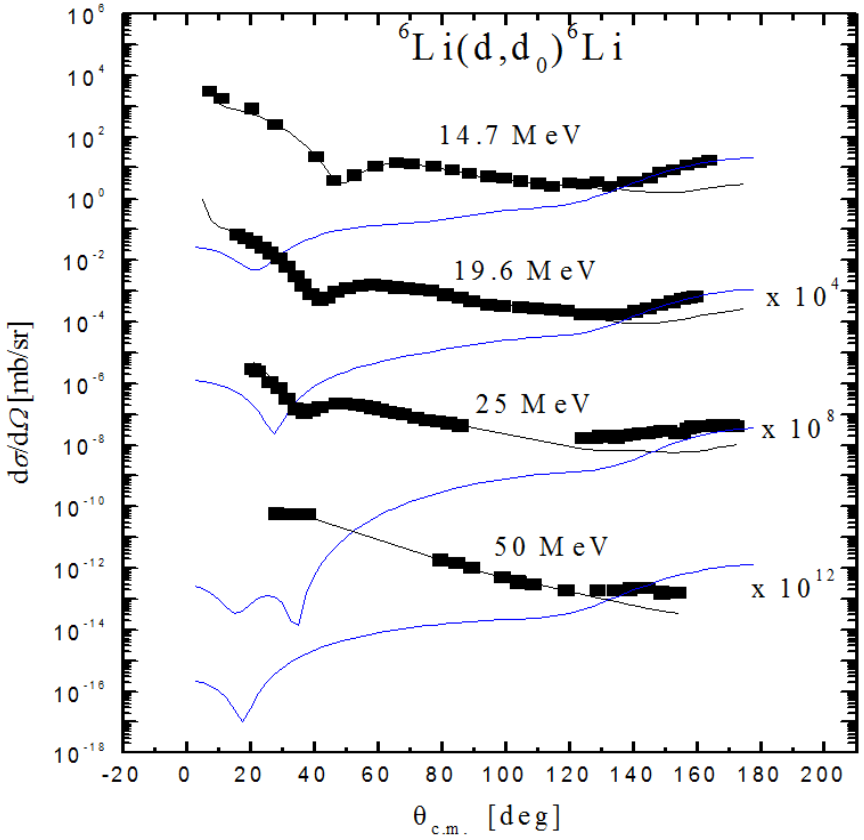
The relevance of research:

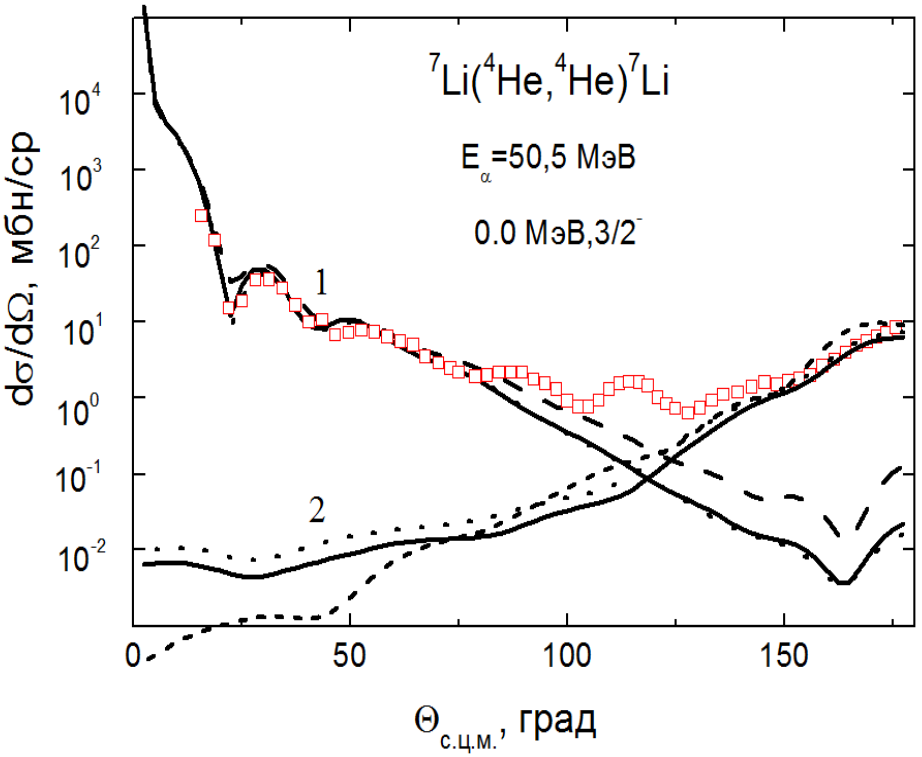
Light nuclei have a pronounced cluster structure.

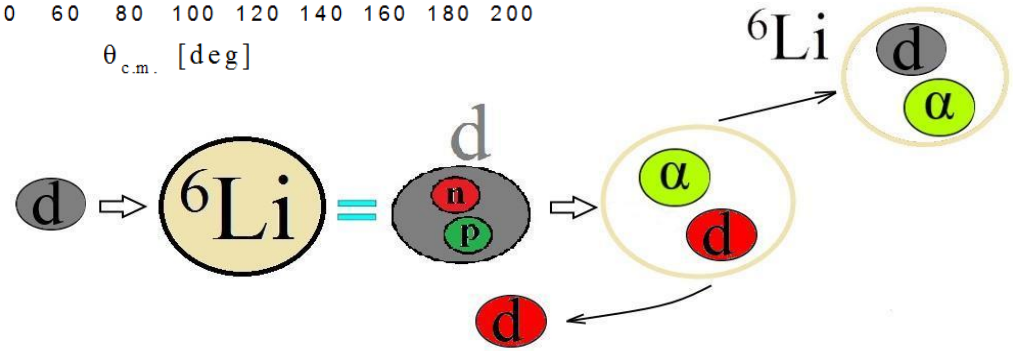


Therefore, cluster structure has a strong influence on the formation of cross sections of nuclear reactions.

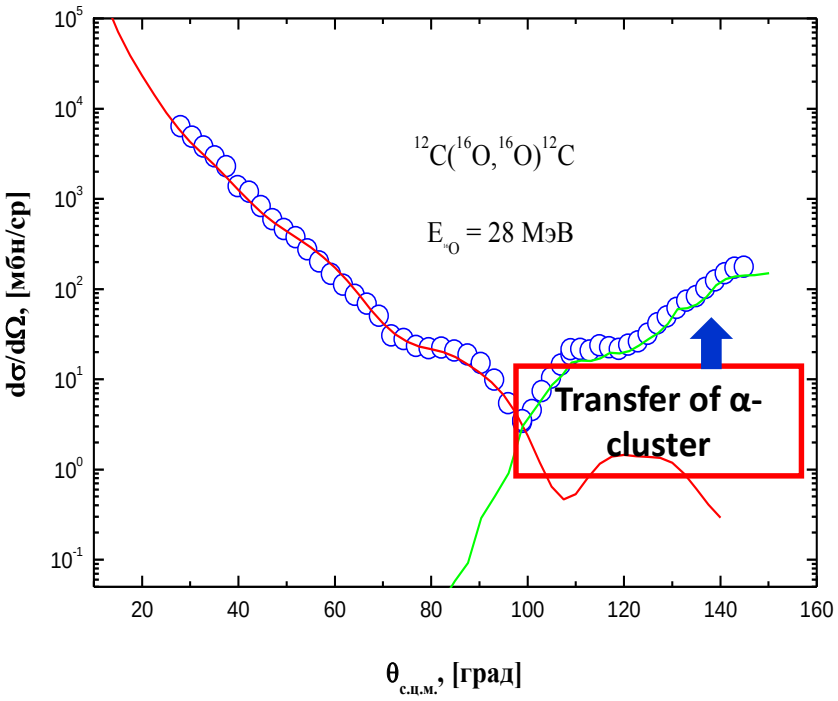
For example, in elastic scattering of deuterons and alpha particles by lithium isotopes, an abnormal growth of the cross section at large angles is observed.

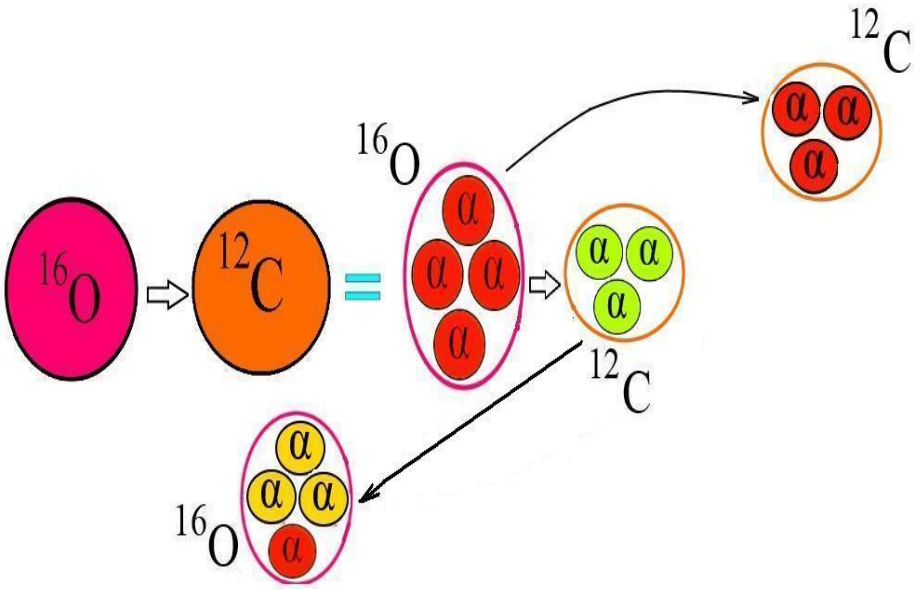






Elastic scattering $^{16}O+^{12}C$ (consisting of four and three alpha particles), an abnormal growth of the cross section at large angles is observed





Thus, the anomalous increase in the elastic scattering cross section at large angles is explained by the mechanism of cluster exchange between interacting nuclear systems.

The main aim of the work is an experimental and theoretical study of the influence of cluster structures of stable lithium and boron isotopes on the formation of outputs of nuclear reactions in interactions with deuterons and α-particles.

The objectives of the study.

1. Measurements of differential cross sections for scattering of deuterons and reactions (d, t) ^{11}B nuclei at energies of 7-10 MeV/nucleon at the isochronous cyclotron U150M of the Institute of Nuclear Physics (Almaty, Kazakhstan);

2. Determination of global parameters of optical and folding potentials for the interaction of nuclear systems "d + ^{11}B" from the analysis of experimental data on elastic scattering;

3. Extraction of deformation parameters for the excited states of ^{11}B nuclei from the analysis of experimental data on inelastic scattering;

- 1. Differential cross sections of nuclear reactions $^{11}B(d,d)^{11}B$ (elastic) and $^{11}B(d,t)^{10}B$ at an energy of 14.5 MeV and their analysis according to the optical model of the nucleus and the method of distorted waves, eliminates the discrete ambiguity of the real part of the potential for the systems, "d+^{11}B " in a wide energy range.

- 2. The established values of the quadrupole deformation parameters of the ^{11}B (β_2=-0.80±0.2), taking into account the channel coupling between the ground and excited states of the studied nuclei, reduce the deviations of the calculated cross sections from experimental ones in the range of average angles to 20– 30%.

Scientific novelty

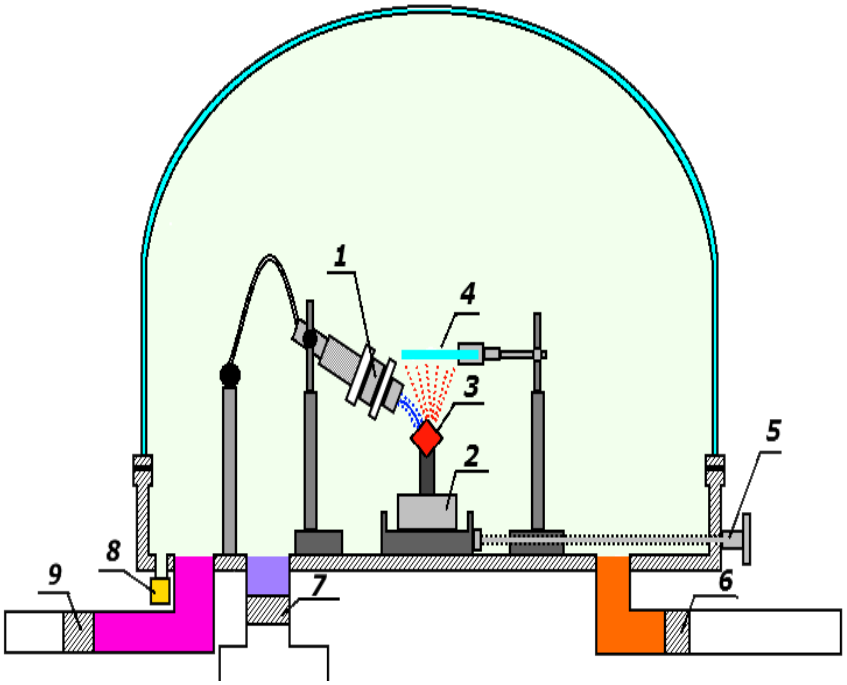
- 1. For the first time, the differential cross sections for nuclear reactions $^{11}B(d,d)^{11}B$, $^{11}B(d,t)^{10}B$ at 14.5 MeV which were used to refine the interaction potential for the "d+^{11}B" system.

- 2. The values of the quadrupole deformation parameters of the nuclei ^{11}B (β_2=-0.80±0.2 with a negative sign) were determined, which made it possible to significantly improve the descriptions of the studied angular distributions in the region of average scattering angles.

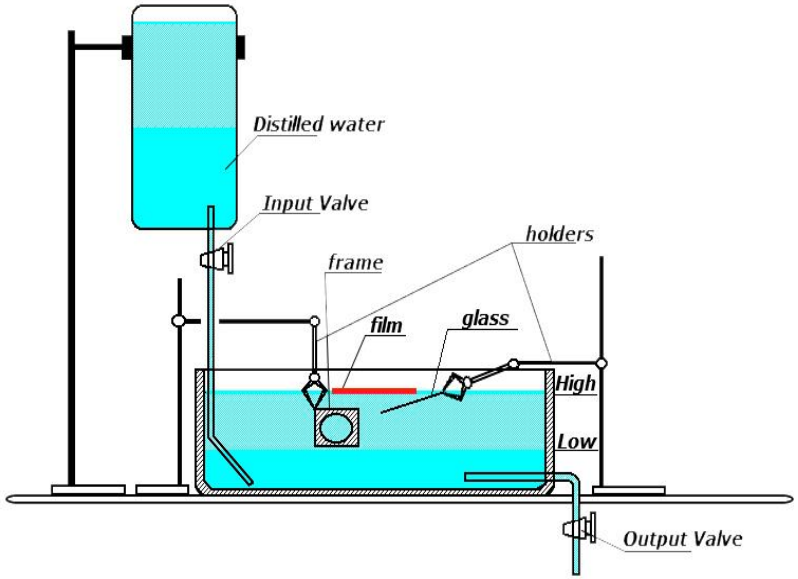
Experimental Setup Cyclotron U-150M

- **Equipment:**
- Detectors:
- **E**=1mm,2mm;
- **ΔE**=15mkm,50mkm,100mkm;
- Target producing:
- VUP4 (Vacuum universal Post 4)
- ^{7}Li Target thickness=0.39 mg/cm^{2}
- ^{11}B Target thickness = 0.24 mg/cm^{2}
- Angle region lab. from 18° to 154°.

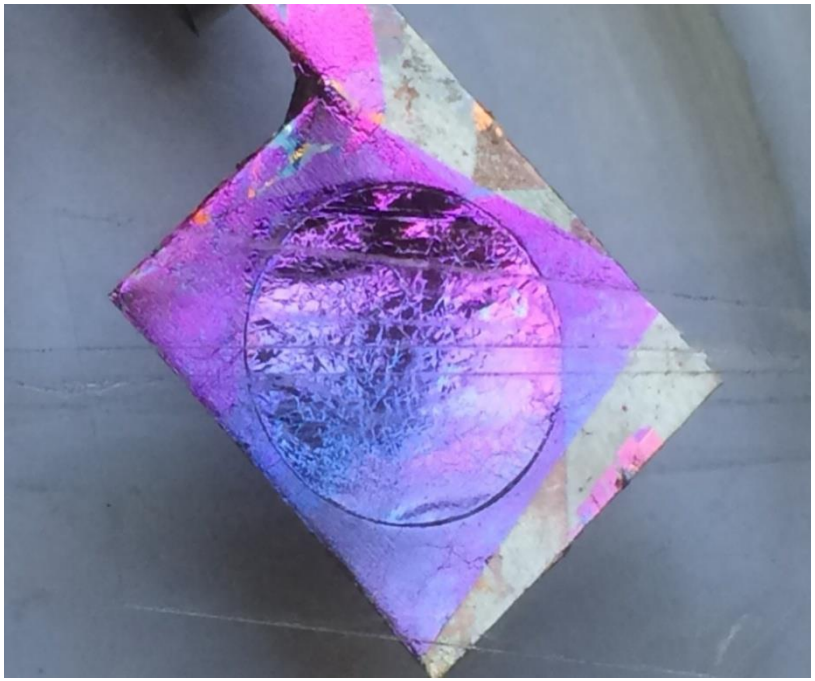
Target Making Procedure



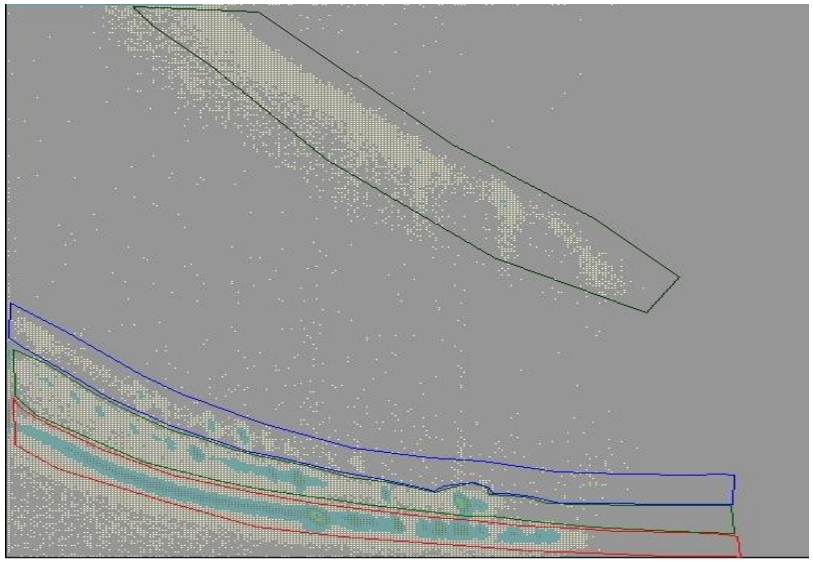
Electric Gun Sample Evaporation



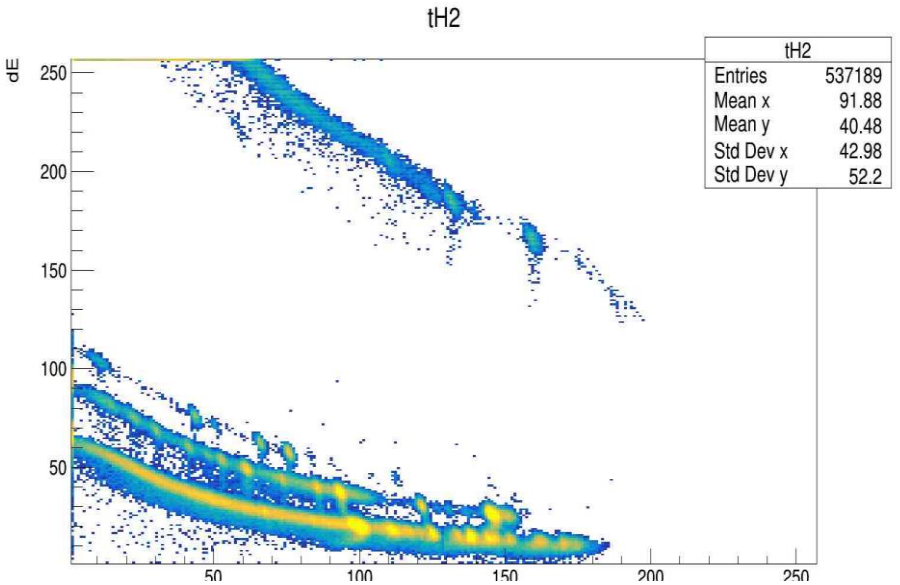
Extracting thin film from glass

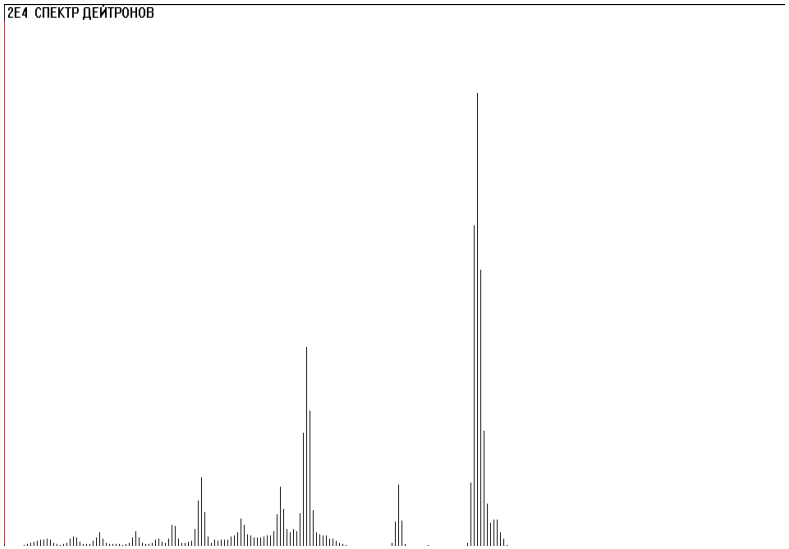


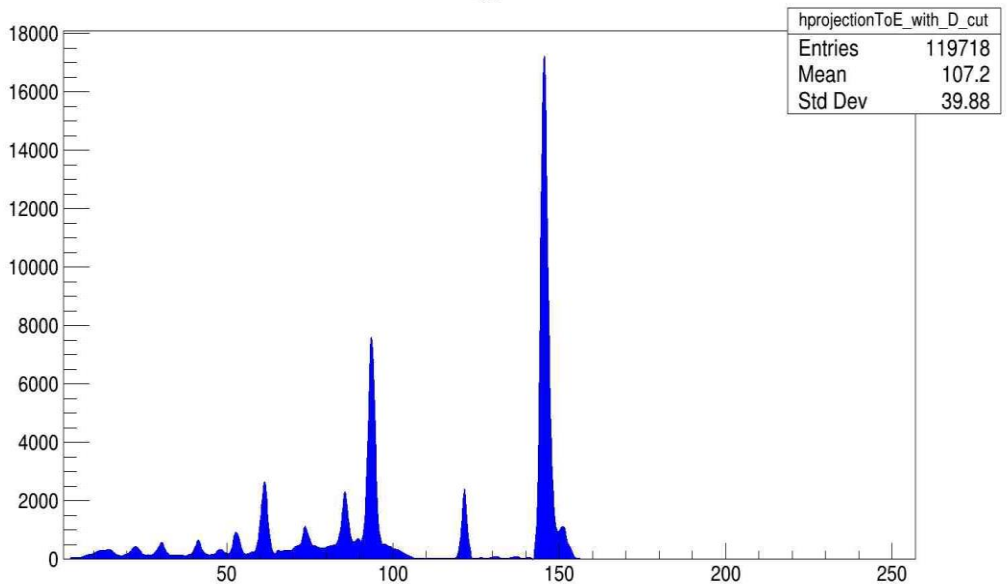
OLD: *Uzbekistan Win EdE 1995*
Architecture: Windows XP(only)



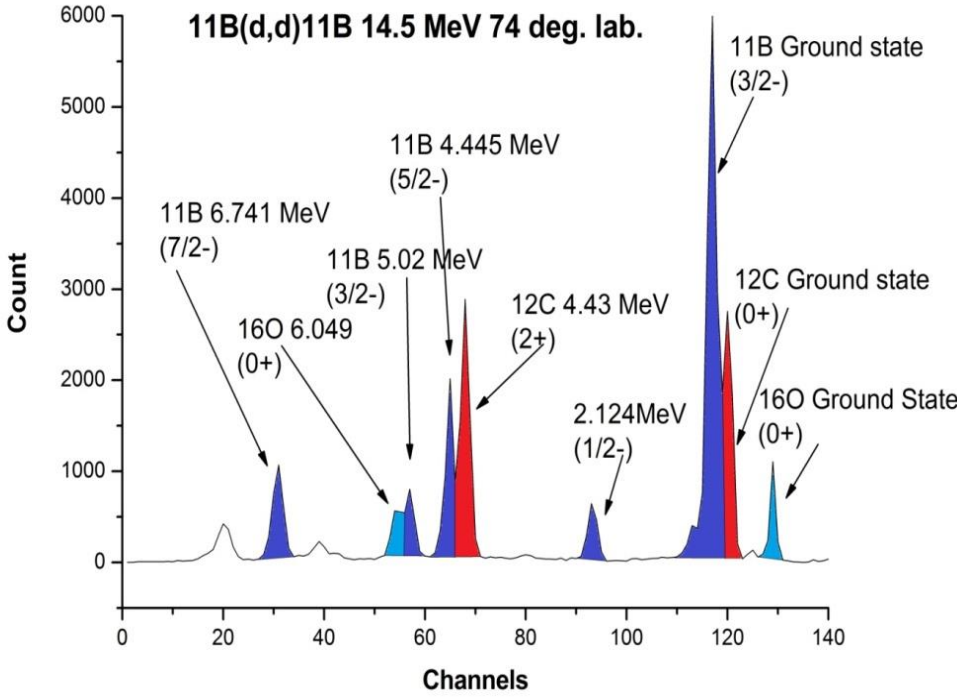
NEW: *CERN Root Software 2020*
Architecture: Windows 7-10, Linux

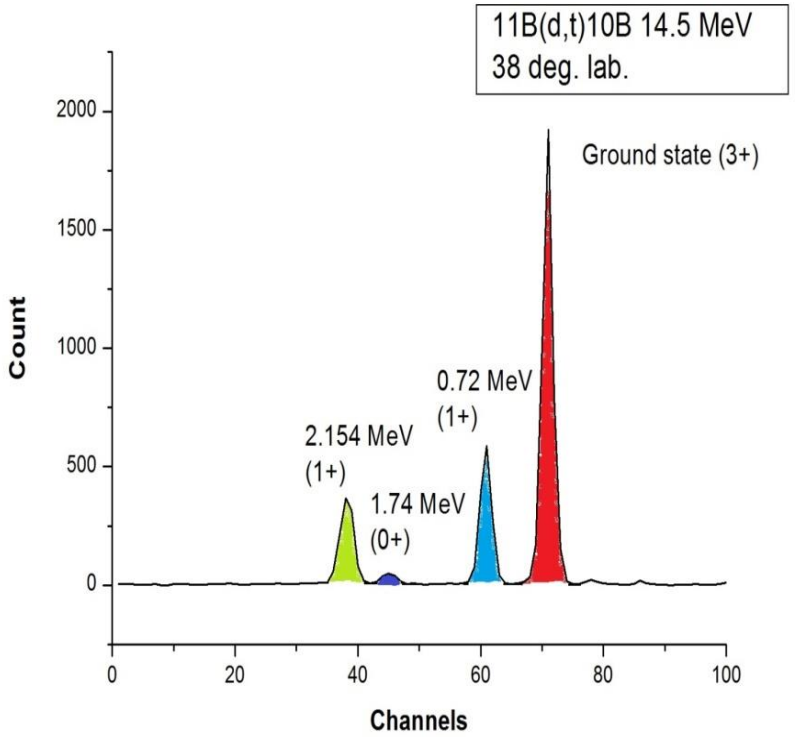




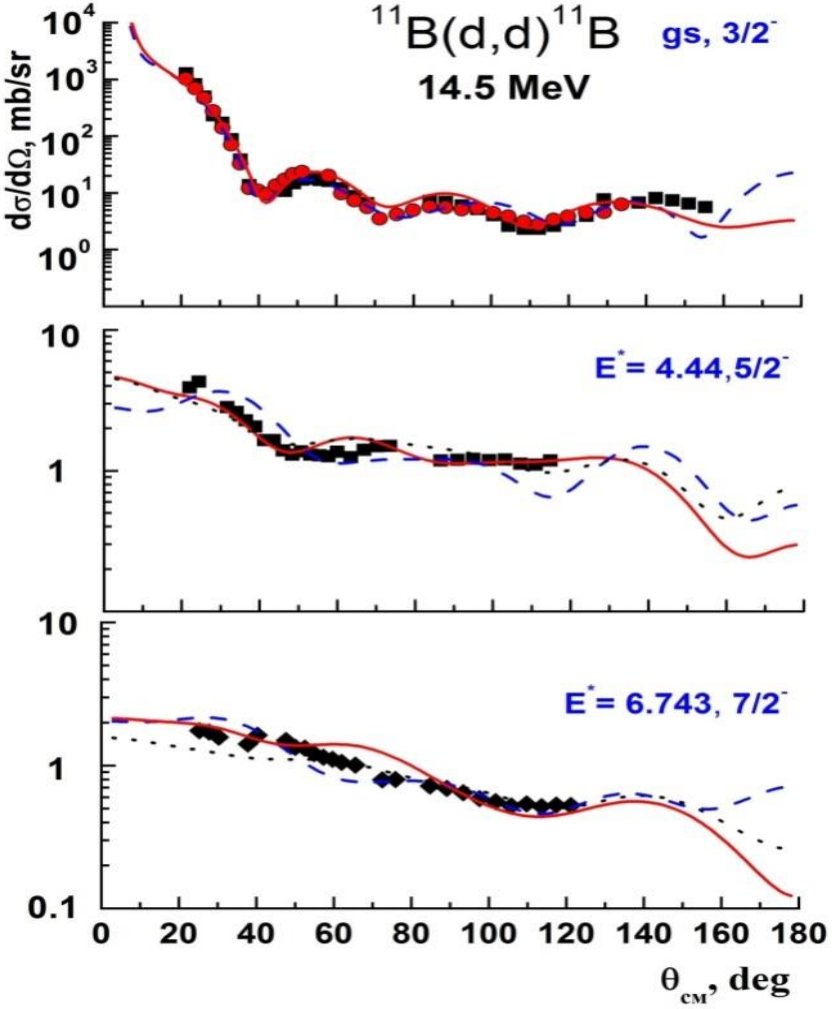


Energy Spectrum of $^{11}B(d,d)^{11}B$ and $^{11}B(d,t)^{10}B$ reaction at 14.5 MeV

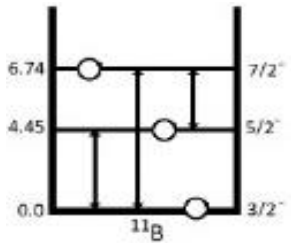




Deuteron scattering on ^{11}B nuclei at beam energy of 14.5 MeV

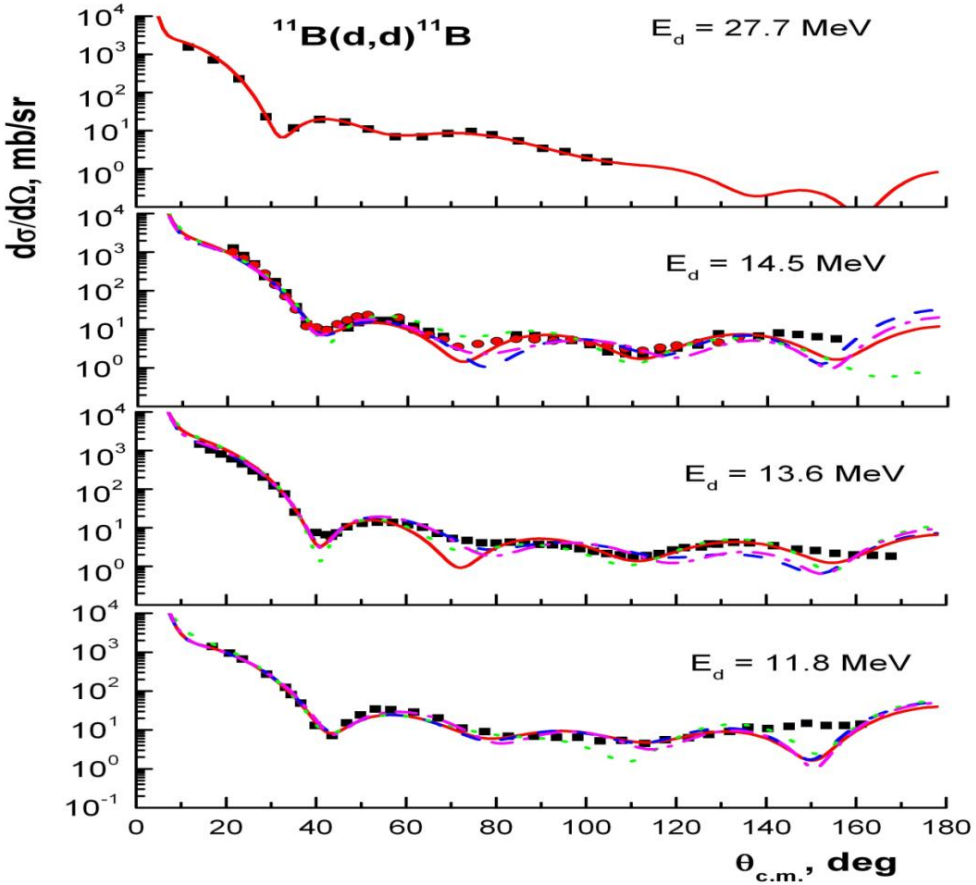


Red and black dots - correspond to two series of measurements of elastic scattering cross sections. Solid red, dashed blue, and dotted black curves - calculation by the coupled channel method(CRC). The inset shows the communication scheme used in the calculations β_2=0.60±0.2

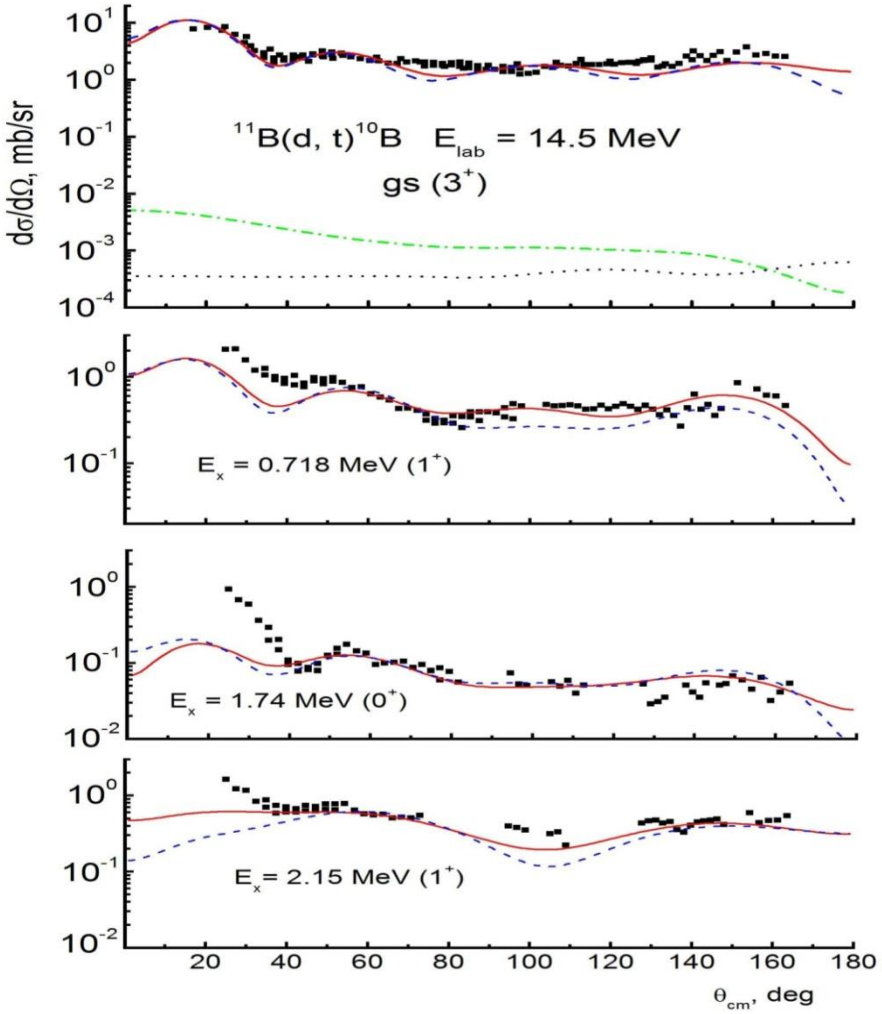


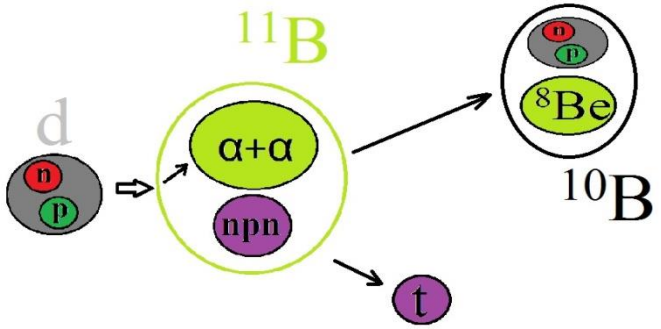
№	V, MeV	r_V, Fm	a_V, Fm	W, MeV	r_W, Fm	a_W, Fm	r_C, Fm	$J_V/2A$, MeV*F m^3	$J_W/2A$, MeV*F m^3	χ^2/N
1	83.47	1.15	0.9	S25.6	1.916	0.354	1.3	594	385	11.1
2	72.21	1.15	0.9	V22.0	1.216	0.81	1.3	514	157	14.0
3	111.5	0.904	1.04	S10.6	1.779	0.505	1.3	648	202	8.3

Cross section behavior for different energies 11B(d,d): 11.8, 13.6,14.5, 27.7 MeV



$^{11}B(d, t)^{10}B$ reaction at 14.5 MeV





Solid curves - calculation by the method of coupled reaction channels. The dashed curves show the calculated cross sections with disabled reaction (d, t) bonds with the excited states of the ^{11}B nucleus. To transition to the ground state of the ^{10}B nucleus, the dashed curve is the cross section calculated in the case of the exchange mechanism of transfer of the ^{8}Be heavy cluster, the dash-dot curve is the calculation for the two-stage mechanism with sequential transfer of α particles

Optical potentials used in the calculations of the ^{11}B (d, t) ^{10}B reaction at an energy of 14.5 MeV

№	$A+a$	V, MeV	r_V, fm	a_V, fm	W, MeV	r_W, fm	a_W, fm	r_C, fm	Ref.
1	^{11}B+d	83.47	1.15	0.90	D23.6	1.916	0.35	1.3	[pres.work]
2	^{10}B+t	138.0	0.85	0.704	2.98	2.06	0.72	1.4	[2, p. 35]
3	^{6}Li+^{7}Li	109.0	1.13	0.50	23.0	1.206	0.45	1.9	[2, p. 35]

Spectroscopic amplitudes used in the calculations of the ^{11}B (d, t) ^{10}B reaction at an energy of 14.5 MeV

System	E_x, MeV	J^π,T	nL_j	SA	Theory prediction
$t \rightarrow d + n$	0.00	$1/2^+$,1/2	$1S_{1/2}$	1.23	1.23 [94, p. 300]
^{10}B$\rightarrow^{11}$B - n	0.00	3^+,0	$1P_{3/2}$	1.15	1.05 [173, p.10]
	0.718	1^+,0	$1P_{3/2}$	0.59	0.27 [173, p.10]
			$1P_{1/2}$		0.44 [173, p.10]
	1.74	0^+,1	$1P_{3/2}$	1.46	0.80 [173, p.10]
	2.15	1^+,0	$1P_{3/2}$	0.95	0.68 [173, p.10]
			$1P_{1/2}$		0.26 [173, p.10]
^{10}B$\rightarrow d + ^8$Be	0.00	3^+, 0	$1D_2$	1.0	none
^{6}Li$\rightarrow d + \alpha$	0.00	1^+, 0	$2S_0$	1.06	1.06 [94, p. 300]
^{10}B$\rightarrow^6$Li + α	0.00	3^+, 0	$1D_2$	1.0	none
t$\rightarrow^{11}$B - ^{8}Be	0.00	$1/2^+$, 1/2	$2P_1$	1.0	none
^{7}Li$\rightarrow^{11}$B - α	0.00	$3/2^-$, 1/2	$2S_0$	1.0	none
t$\rightarrow^7$Li - α	0.00	$1/2^+$, 1/2	$2P_1$	1.09	1.09 [94, p. 300]

Conclusions

- ✓ 1. Experimental data on the differential cross sections of nuclear processes ^{11}B (d, t) ^{10}B at energies of 7-10 MeV/nucleon was obtained.
- ✓ 2. Values of the parameters of the optical potentials for the "d + ^{11}B" system in a wide energy range eliminated the discrete ambiguity of the real part of the potential was refined.
- ✓ 3. It has bee found that parameters of the quadrupole deformation of ^{11}B nuclei (with a negative sign) specify the channel coupling between the ground and excited states of the studied nuclei.

THANK YOU FOR YOUR ATTENTION!