

STRUCTURE OF ONE NUCLEON HALO LIGHT MIRROR NUCLEI ¹¹Be AND ¹¹N

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In present time the study of the properties of halo nuclei attracts an intent attention from both theoreticians and experimentalists because of their novel characteristics. Of them, ¹¹Be has a very intriguing feature that the ground state parity is exactly opposite to what one expects from a shell model type of calculation. The 1/2⁺ ground state of ¹¹Be is a clear indication of a reversal of 1p_{1/2} and 2s_{1/2} states for a valence neutron. Since the s-orbital motion of a neutron around the core nucleus has no centrifugal barrier, the wave function can spatially extend. Furthermore, from the small binding energy (503 keV) of the s state, its wave function is expected to have a very long range tail. Such a property of the s state seems to give a reasonable interpretation of the neutron halo structure of ¹¹Be. However, the problem is how to explain the mechanism by which the 2s_{1/2} orbit comes down by crossing the 1p_{1/2} orbit. There have been many theoretical attempts [1-4] to address the problem of parity inversion of the ground state and the first excited state of ¹¹Be and evaluating the extension of its neutron halo. But in spite of having a good amount of experimental information [5,6], there is no consistent theory so far. On the other hand, it is also very interesting to see how the anomalous level structure of ¹¹Be is observed in ¹¹N which is a proton-rich mirror nucleus of ¹¹Be. In present work the mirror nuclei ¹¹Be and ¹¹N are considered in the framework of the multiparticle shell model. The single-particle wave functions are calculated in both the Woods--Saxon potential and the self-consistent Hartree-Fock potential with Skyrme interactions [4]. The extremely strong spin-orbit interaction [7] was used in comparison with a standard one in order to raise the energy of 1p_{1/2} level. The binding and resonance states are calculated by a solving of the time-dependent Schrodinger equation, provided with the Sturm-Liouville method [8]. The result of our calculations presented in the following tables and figures. As we can see from the Fig. 1 one-particle 1p_{1/2} и 2s_{1/2} states of ¹¹Be are weak-bounded, but 1p_{1/2} и 2s_{1/2} states of ¹¹N are the resonance states and from the Fig.2 we can see, that this states in ¹¹N are under-barrier resonances. Widths of such resonance states was calculated with formula:

$$\Gamma_{obs} = \frac{V}{2R_t} W, \quad (1)$$

$$W = \exp\left(-\frac{2}{h} \int_{x_2}^{x_3} \sqrt{2m(U(r)-E_r)} dr\right).$$

Where **W** - a penetration of a barrier, **V/2R_t** - a number of the blows of nucleon on an inner wall of a barrier during 1 sec.

V – the nucleon speed at the resonance energy, $\mathbf{R}_1 = \mathbf{x}_2 - \mathbf{x}_1$

Here Γ_{sew} – a value of the width, at which the inner wave functions (real and imaginary parts)

$$\Gamma_{obs} = n\Gamma_{sew}W \quad (2)$$

are sewed with their asymptotical expressions,

n – number of the blows during (h/Γ_{sew}) sec.

The results of calculation have been shown in the table 2. There are time-depending wave functions [7] of the proton resonance $2s_{1/2}$ state in ^{11}N at the fig.3.

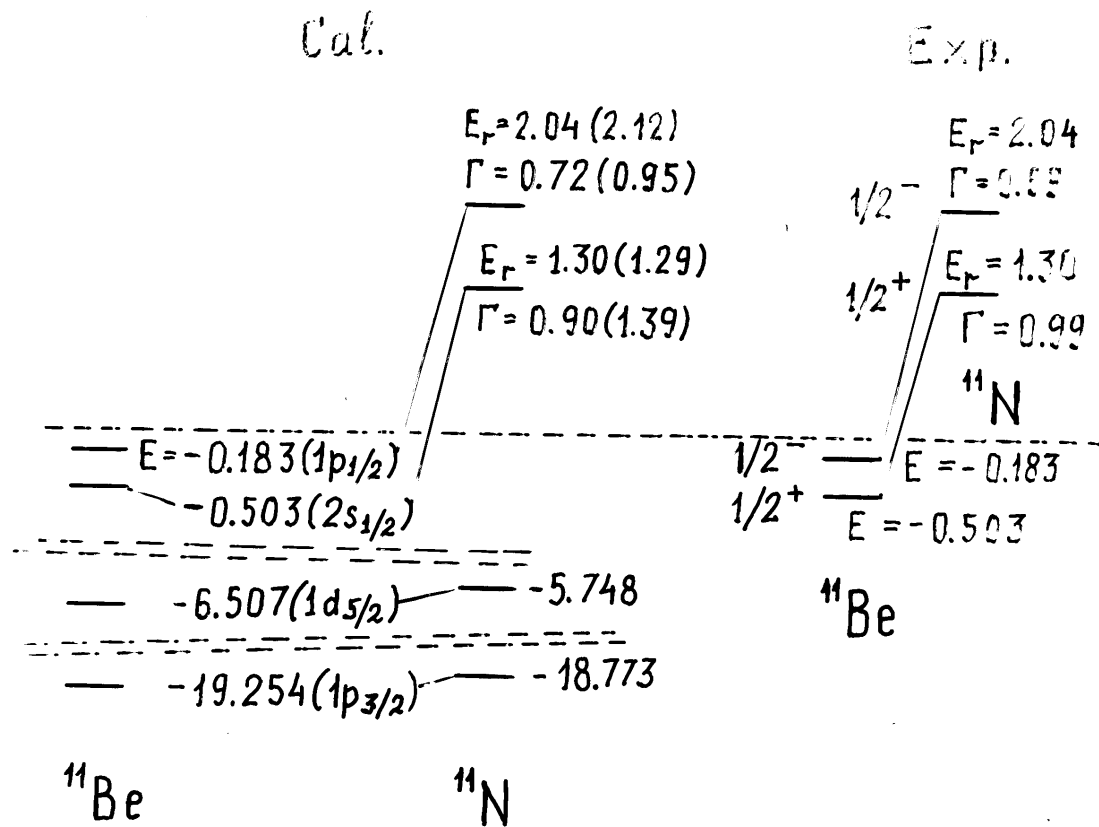


Fig. 1. Comparison the calculated levels of the ^{11}Be и ^{11}N nuclei with experimental data

Table 1. Woods-Saxon potential parameters for ^{11}Be and ^{11}N nuclei.

A	r_0	a	V_0	V_{ls}
	[fm]		[MeV]	
^{11}Be	1,20	0,65	61,40	53,38
^{11}N	1,20	0,65	65,46	54,40

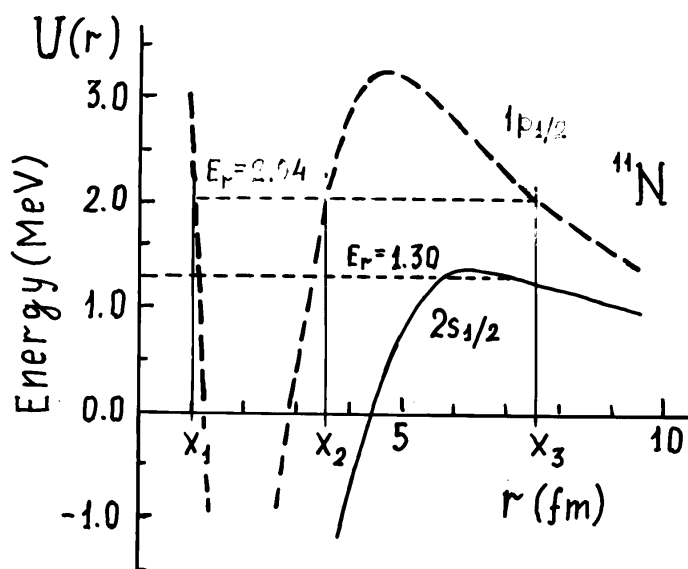


Fig 2. Potential and energy levels of ^{11}N .

Table 2. Energy levels, widths, one-particle root-mean-square (rms) radii of resonance states of ^{11}Be and ^{11}N nuclei.

A	state	E	Γ obs	Γ sew	$(\langle r^2 \rangle)^{1/2}$
		[MeV]			[fm]
^{11}Be	$2s_{1/2}$	-0,503	-	-	7,219
	$1p_{1/2}$	-0,183	-	-	5,877
^{11}N	$2s_{1/2}$	1,300	0,901	0,066	7,875
	$1p_{1/2}$	2,040	0,718	?	?

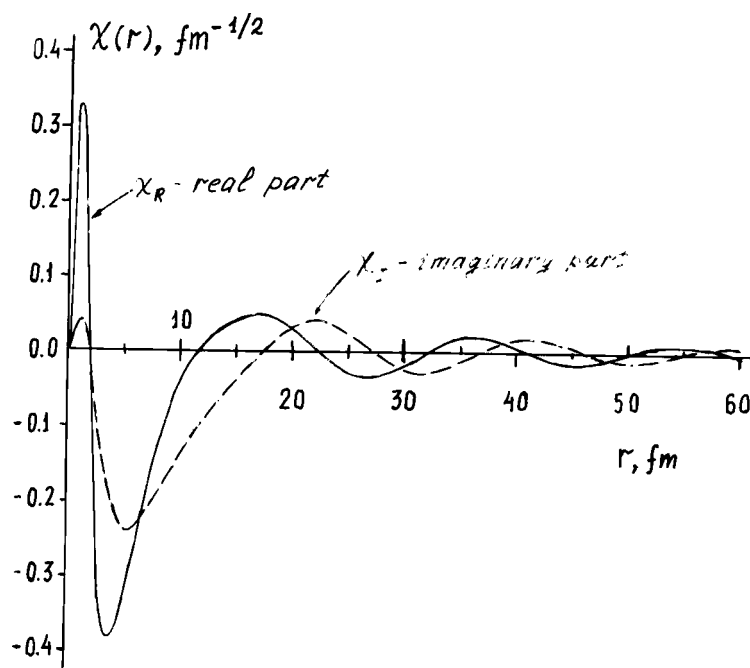


Fig.3. Wave functions of the proton $2s_{1/2}$ resonance states in ^{11}N .

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