Wide Resonant States in ^{15}F

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Many important for nuclear astrophysics radiative capture reactions proceed through resonance states. The Breit-Wigner formula for analysis of resonant reactions is conventionally used. But it is correct for a narrow resonance. There are many important wide resonant states. This is a common situation for the resonances in nuclei on the drip lines, where the mistakes in the analysis of the resonances can result in the wrong conclusions on the nuclear structure.

In ^{15}F nucleus, the ground state ($1/2^+$) and the fist exited state ($5/2^+$) are wide resonances and poorly known. The $5/2^+$ state is narrower than state $1/2^+$, the earliest estimation was performed many years ago [1], the latest results are represented in [2,3].

In this report, we used three different methods: the scattering phase shift, scattering wave function and the pole of the S matrix in the complex energy plane to make calculations for ^{15}F. The scattering phase shift method is a standard one. In this method the resonance energy is determined by the point where the scattering phase shift is 90°. The resonance width is equal to $\Gamma=2/(d\delta/dE)$ calculated at $\delta = 90^\circ$. In the scattering wave function method, the scattering wave function is calculated at real energies and the resonance energy corresponds to the peak of the scattering wave function in the nuclear interior. In the third method, we calculated the Gamov wave functions for both resonance states ($1/2^+$, $5/2^+$) in the neighborhood of the complex energies $W=E-i\Gamma/2$ obtained by the phase shift method. For each resonance we found the complex energy at which the coefficient of the incoming wave is equal to zero. It corresponds to the pole of the S-matrix on the second sheet of the Reeman surface. Results for the energies and widths are shown in Table I. The calculations are made using the Wood-Saxon potential with the set of parameters from [2]. The potential generates the $s_{1/2}$ and $d_{5/2}$ states in ^{15}F.

Table I. The energies and widths of ^{15}F calculated by three different methods.

	E (MeV)	Γ (MeV)	Methods
	$1.290^{0.08}_{0.06}$	**0.7**	Ψ_{max}
Ground state $1/2^+$	**1.463**	**1.326**	$\delta=\pi/2$
	1.203	**0.538**	Pole of the S-matrix
	2.795 ± 0.045	**0.325 ± 0.06**	Ψ_{max}
First exited state $5/2^+$	**2.697**	**0.266**	$\delta=\pi/2$
	2.677	**0.257**	Pole of the S-matrix

One can conclude that the position and the width of the broad resonance, in contrast to the narrow resonance, is sensitive to the method of calculation.

In Ref. [3] the lowest states of isospin T=3/2 in A=15 were treated as a combination of one-particle, two-hole and three-particle, four-hole states with various percentage according to the shell model and the authors predicted the following energies : 1.19-1.29 MeV for $1/2^+$, and 2.75-2.78 MeV for $5/2^+$. The Gamov wave function of the resonance state is complex. Fig. 1 shows the real and imaginary parts of the Gamow wave function describing the $5/2^+$ state. We can see that the probability to find the proton inside the potential well is high and the solution of Schrödinger equation coincides with the outgoing wave in the nuclear exterior.

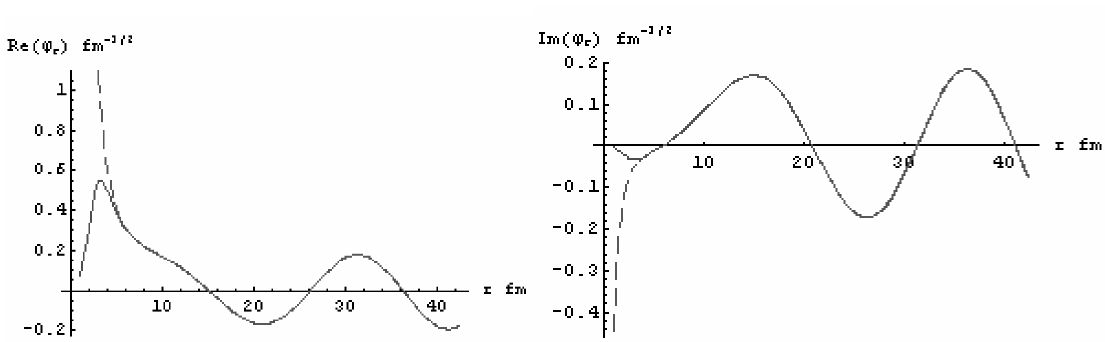

Figure 1. Real and imaginary parts of the wave function of the $5/2^+$ resonant state of ^{15}F. Solid line is the solution of the Schrödinger equation, dashed line is the outgoing Coulomb function (Whittaker function).

[1] G.J. KeKelis *et al.,* Phys. Rev. C **17**, 1929 (1978).

[2] V.Z. Goldberg *et al.,* Phys. Rev. C **69**, 031302(R) (2004).

[3] H.T. Fortune and R. Sherr, Phys. Rev. C **72**, 024319 (2005).