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INVESTIGATION OF LIGHT NEUTRON-RICH NUCLEI VIA THE (^{7}Li,^{7}Be) REACTION*

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Studies of ^{15}C and ^{11}Be nuclei has been dealt with the (^{7}Li,^{7}Be) charge exchange reaction at 57 MeV. The energy spectrum at 10° of ^{15}C nucleus is presented and discussed in comparison with the ^{11}Be one. An explanation of the ^{15}C energy spectrum is proposed in relation to Dynamical Core Polarization calculations for the single particle strength function.

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1. Introduction

Among the challenges of modern nuclear physics that of the description of the structure of nuclei far from the line of β-stability is most intriguing. For light neutron-rich nuclei, the unusual combination of high charge asymmetry, weak binding energy and proximity of the particle continuum may lead to the less effective confinement of the outermost neutrons. An example is given by halo nuclei [1]. In particular, one-neutron halo nuclei are the main candidates suited to study the interaction between the weak bound nucleon and the core nucleus. Experimental evidence [2] and theoretical studies [3] show as Dynamical Core Polarization (DCP) effects, which are well established in stable nuclei [4], become particularly important approaching the drip lines, because the core itself can be already far

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from stability. The ^{15}C nucleus, not properly recognized as a halo nucleus, represents as weakly bound system ($S_n = 1.218$ MeV) an interesting intermediate case between the well-bound ^{12,13,14}C nuclei and the exotic ^{19}C [5]. The ground state spin-parity of ^{15}C is $J^{\pi}{=}1/2^{+}$ and shell model calculations using WBP interaction reproduce the inversion between $0d_{5/2}$ and $1s_{1/2}$ orbitals [6]. When a configuration with three neutrons coupled to an hard core of 3α particles is taken into account for ^{15}C isotope, at low excitation energy an important part of the phase space is represented by the coupling of two neutrons with the hard core and the consequent formation of ^{14}C core plus one unpaired neutron. Under these conditions the high polarizability of the soft core together with the low binding of the external neutron make possible the independent excitation of the core and single neutron degrees of freedom. In a phenomenological approach, one observes in the energy spectrum narrow resonances well beyond the neutron emission threshold. They can be described as excitation of bound states embedded in the continuum (BSEC [7]), resulting from almost pure excitation of the core states. Similar effects have been noticed for the ^{11}Be [2].

2. Results on ^{15}C

Since the (^{7}Li,^{7}Be) charge exchange reaction is a well known spectroscopic probe [2], we used 57 MeV ^{7}Li^{+++} beam provided by the Tandem Van der Graf accelerator at IPN-Orsay and a Melamine ($C_3H_6N_6$) ^{15}N enriched target for studying the excited states of ^{15}C nucleus via the ^{15}N(^{7}Be,^{7}Li)^{15}C reaction. The ^{7}Be ejectiles were detected by a $\Delta E - E$ Si-telescope set at 10°. At 10° supplement runs with ^{12}C and standard Melamine target were performed to measure the background due to the presence of ^{12}C and ^{14}N impurities. The final ^{15}C spectrum at 10° after the background subtraction is shown in Fig. 1 as a function of excitation energy. The background from ^{15}N(^{7}Li, n^7Be)^{14}C was also calculated and subtracted assuming a non resonant 3-body phase space. The overall energy resolution was 90 keV. The ground and the first excited state (0.74 MeV) are clearly visible. Peaks marked by an asterisk refer to transitions in which ^{7}Be is in the 0.43 MeV first excited state. Because of the strong presence of the background above 2 MeV we observed only a resonance centered at 8.5 MeV ($\Gamma \sim 0.3$ MeV). A large bump remains centered at $\sim$10 MeV ($\Gamma \sim 10$ MeV). Comparing the ^{15}C spectrum with the ^{11}Be one via the (^{7}Li,^{7}Be) at the same bombarding energy, it is interesting to note in both cases the presence of a narrow resonance very far from the neutron emission threshold. In Ref. [2] we concluded that the state at 6.05 MeV cannot be considered as a single particle excitation on ^{10}Be inert core. Due to the softness of the core bound states in the continuum can be populated. The softer the core, the lower is the energy

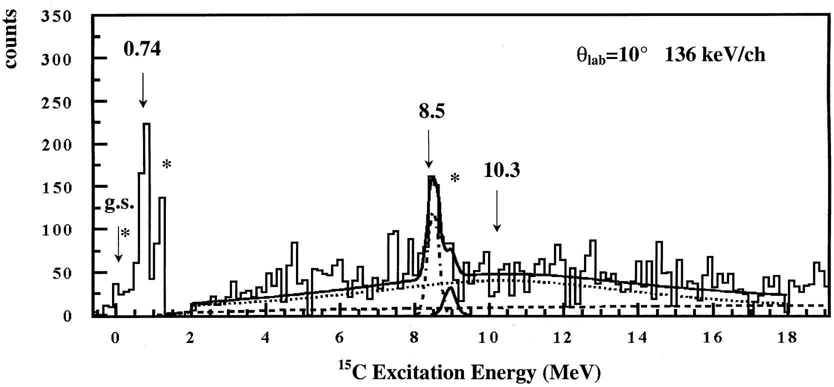

Fig. 1. Excitation energy spectrum of ^{15}C at 57 MeV and 10°. Curves regarding fit in the continuum are visualized; dashed line is 3-body phase space contribution as given in Ref. [8]; the dotted line is the fit of the resonance at 10.3 MeV; the structure at 8.5 MeV has been modelled with two Gaussians (see text); the full thick line is the convolution of all the previous curves.

where one expects to observe such structures. In order to give a quantitative interpretation of the observed spectrum a microscopic nuclear structure model has been set up including DCP effects in describing ^{15}C, using the QRPA formalism as in Ref. [11]. Single particle configurations with respect to a vibrating core nucleus were investigated theoretically by using a microscopic version of quasiparticle-core coupling (QPC) model [10]. The results obtained for $s_{1/2}$ and $d_{5/2}$ single particle strength distributions in ^{15}C up to 14 MeV excitation energy are shown in Fig. 2, where the coupling to the

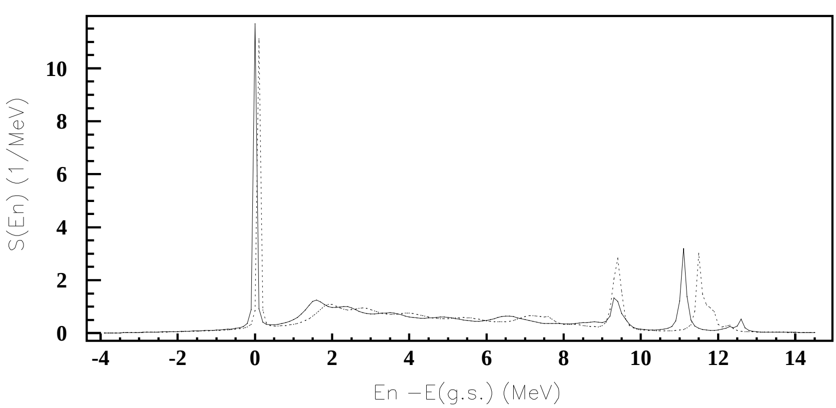

Fig. 2. Single particle strength $1/2^+$ (full line) and $5/2^+$ (dotted line) of ^{15}C for natural parity states of the ^{14}C core ($J \leq 4$); the energy scale corresponds to excitation energy of the ^{15}C nucleus.

natural parity states of the ^{14}C core up to total angular momentum $J = 4$ is taken into account. As the main result, strong fragmentation of the strength has been obtained between 8 and 14 MeV excitation energy. The comparison with the excitation energy spectra measured via the ^{15}N(^{7}Be,^{7}Li)^{15}C charge exchange reaction at 57 MeV indicates that the observed narrow structure at 8.5 MeV, which cannot be justified within a single particle model [9], is explained within the DCP framework.

3. Conclusion

The first and 0.74 MeV state of ^{15}C, together with a structure at 8.5 MeV ($\Gamma \sim 0.3$ MeV), have been clearly observed via the ^{15}N(^{7}Li,^{7}Be)^{15}C charge exchange reaction at 57 MeV. The sharp resonance at 8.5 MeV indicates a behaviour similar to that of ^{11}Be nucleus. The present experimental results, even though mainly limited by the strong presence of the background associated to the ^{12}C impurity in the target, has been recently confirmed by the preliminary results of a measurement of the same reaction at 52 MeV at different angles using a pure ^{15}N gas target. The results of DCP calculations in ^{15}C nucleus reproduce qualitatively well the low energy spectrum. Both for $s_{1/2}$ and $d_{5/2}$ strength distributions, narrow resonances well beyond the neutron emission threshold appear when the coupling of the unpaired neutron to the natural parity states of the ^{14}C is considered. In particular, the model predicts the narrow resonance observed at 8.5 MeV, thus offering new perspectives in the interpretation of the spectroscopy of neutron-rich nuclei.

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