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The role of ^{13}C excited states in α+^{9}Be reaction and scattering cross sections

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Abstract. The spectroscopy of ^{13}C excited states above the alpha emission threshold has been investigated by studying data on ^{9}Be(α,α)^{9}Be and ^{9}Be(α,n)^{12}C collisions at bombarding energies in the range E_α ≈2-10 MeV. A multichannel *R*-matrix fit allowed us to better constrain the spectroscopy of ^{13}C states above the α threshold (10.65 MeV). Preliminary results on this analysis will be discussed.

1 Introduction

The study of the structure of light isotopes allows us to understand the effects of clusterization in light non-self-conjugated nuclei [1–10]. The presence of rotational bands built on molecular states has been suggested in several papers [11–13]. Furthermore, in recent times, some theoretical works [12, 14] predicted the possible existence of states corresponding to the coupling of valence neutrons to the ^{12}C Hoyle state. The analysis of resonant elastic scattering with a gas target in inverse kinematics [2, 15], of α-transfer reactions with magnetic spectrometers [16, 17], and of cluster correlations with high segmentation hodoscopes [18–22], represent powerful tools to shed light on these aspects. In this framework, we performed a comprehensive *R*-matrix fit of α+^{9}Be elastic (α_0) and inelastic (α_1 and α_2) scattering data in the energy range E≃ 3.5 – 10 MeV at several angles [23, 24]. To carefully determine the partial decay widths of states above the α decay threshold we included in the fit procedure also ^{9}Be$(\alpha, n_0)^{12}$C$_{gs}$ and ^{9}Be$(\alpha, n_1)^{12}$C$_{4.44}$ cross section data taken from [25, 26]. With the exception of ^{9}Be$(\alpha, n_2)^{12}$C$_{7.65}$ (that is open above E_α =2.8 MeV) and radiative capture reactions, these reaction channels are the only ones open at low energies. This analysis allows us to improve the (poorly known) spectroscopy of excited states in ^{13}C in the E$_x$ ≃12-17 MeV region [27]. Furthermore, a better knowledge of high-energy resonance parameters (especially for broad states) can improve low-energy extrapolations of the ^{9}Be$(\alpha, n)^{12}$C reaction *S*-factor, that plays a key role in the description of ^{12}C nucleosynthesis during a supernova explosions via the triple process ^{4}He(αn,γ)^{9}Be followed by ^{9}Be$(\alpha, n)^{12}$C [25]. This reaction has also a strong importance in applied physics, being at the basis of standard neutron sources [28]. Preliminary results of these studies will be discussed.

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2 Selection of experimental data

The main part of data that we included in the *R*-matrix analysis were obtained with an experiment done at the TTT3 tandem accelerator in Napoli [29]. Details concerning the experimental configuration are reported in Ref. [23]. Our data set was complemented with low energy data of Ref. [30] and by including also neutron data from Ref. [25] and [26].

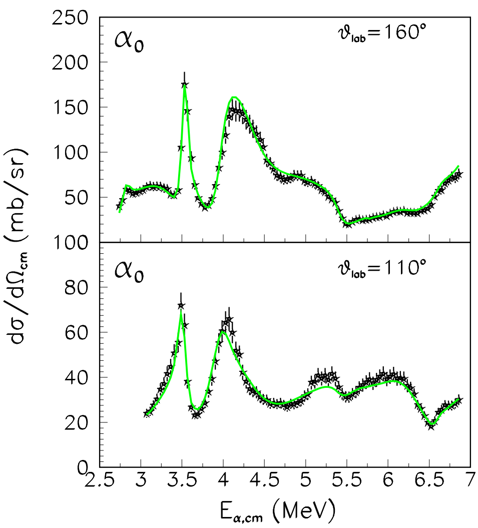

Figure 1. α+^{9}Be elastic scattering differential cross section at 160° and 110°. Open stars: experimental data. Green line: preliminary *R*-matrix best fit.

3 *R*-matrix fit of data: preliminary results

Experimental data described in Section 2 were fitted simultaneously with the *R*-matrix code AZURE2 [31, 32]. Details of the adopted procedure will be given in a forthcoming paper. We used the table of states reported in Ref. [27], complemented by more recent results of Ref. [2] as starting parameters for the states included in the *R*-matrix analysis. A few J^π values that were tentatively reported in the literature were varied to better describe all the details of excitations functions. The overall data reproduction is quite satisfactory, as reported for example, in Figure 1 for the elastic scattering differential cross section at 160° and 110°.

Some preliminary considerations can be drawn from the *R*-matrix analysis reported here. The small peak at $E_{cm} \simeq$2.76 MeV can be attributed to a $9/2^-$ state at 13.41 MeV, in agreement with the tentative value given by Ref. [33]. In this way we can reproduce simultaneously well all the excitation functions studied here. Analogously, the main peak, seen at $E_{cm} \simeq$3.5 MeV, is attributed to the presence of a $5/2^-$ state at 14.13 MeV, having a total width of about 94 keV and a vanishingly small neutron partial width. This J^π value is in contrast with the $9/2^-$ tentative assignment made in Ref. [12] to fulfill the E_x versus $J(J + 1)$ relationship typical of rotational bands. Further and much more extended details on the present data analysis will be reported in a future work.

4 Conclusions

In this proceeding we report some preliminary results on the investigation of ^{13}C spectroscopy at excitation energies larger than the α emission threshold ($E_x > 10.648$ MeV). We performed a simultaneous R-matrix fit of various reaction channels related to α and neutron emission. Thank to this analysis, it was possible to remove some ambiguities in J^π assignments for some states that are candidates for a molecular structure configuration, e.g. for the 14.13 MeV state.

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