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The study of the ^{12}C states from the reaction ^{11}B(^{3}He, d)^{12}C

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Abstract. The experiment was done to study ^{11}B(^{3}He, d)^{12}C reaction with energy E(^{3}He)=25 MeV. The aim of the experiment is to determine the properties of ^{12}C states at high excitation energies and in particular to verify which of the conflicting spin-parity assignments of the 13.35 MeV state (2^- or 4^-) should be assigned. Behavior of the experimental angular distribution and also the DWBA calculation correspond to spin parity 4^- for 13.35 MeV state.

1. Introduction

Recently ^{12}C become the key nucleus in the study and description of alpha- clustering in light nuclei. For instance, identification of the states with abnormally large radii, observation of alpha-cluster rotational bands and the prevailing absence of adequate understanding of the structure of the famous Hoyle state (0^+_2, $E^* = 7.65$ MeV), evoked numerous theoretical and experimental studies.

This paper raises the question of spin-parity value of the 13.35 MeV state in ^{12}C. Presently the spin-parity assignment of the 13.35 MeV state remains unknown. The contradicting reports define either 2^- [1, 2, 3, 4] or 4^- [5, 6]. Unambiguous determination of the spin-parity of the 13.35 MeV state is necessary to define its possible contribution to the part of the spectrum that we have previously identified as a new level in ^{12}C with excitation energy of 13.75 MeV [7].

To determine the spin-parity of the 13.35 MeV state we have chosen reaction ^{11}B(^{3}He, d)^{12}C. Our calculations have shown that optimal energy for spin determination is E(^{3}He)=25 MeV (figure 1). As one can see from figure 1, the shape of the first oscillations corresponding to the transferred angular momenta L=0 and L=2 are quite different and measurements in the angular interval 5 - 60 deg(CM) would be optimal for determining the spin-parity of the 13.35 MeV state.

Reliable identification of the spin-parity of the 13.35 MeV state is of great importance also for other tasks. Recently it has been suggested that if its spin-parity is 4^-, this state is a member of the negative branch: 3^- (9.64 MeV) – 4^-(13.35 MeV) – 5^- (22.4 MeV) [10] (marked as stars in the figure 2).) of the rotational band of the ground state (0^+ (g.s.) – 2^+(4.44MeV) – 4^+ (14.08 MeV)).

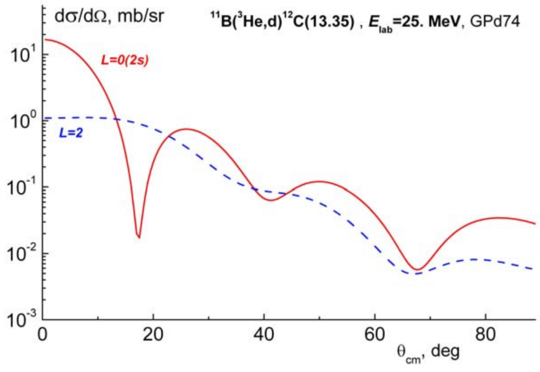

Figure 1. DWBA calculations of the differential cross-sections of the transfer reaction $^{11}B(^3He, d)^{12}C$ at $E(^3He)$=25 MeV. The red solid curve corresponds to transferred momentum L = 0 (case of spin-parity 2^-) and blue dashed curve corresponds to transferred momentum L = 2 (case of spin-parity 4^-).

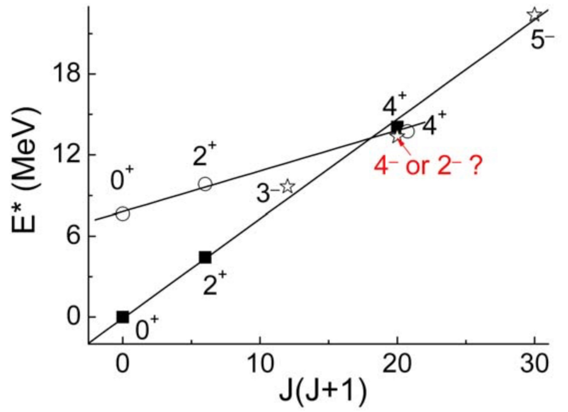

Figure 2. The rotational bands in ^{12}C. Black dots – the rotational band based on the ground state 0^+. Open stars – hypothetical negative branch of the ground state band. Open dots – the rotational band based on 7.65 MeV state 0^+.

2. Experiment and methods of the data analysis

The measurements have been done on the K 130 cyclotron of Jyvaskyla University, Finland using the Large Scattering Chamber[8][8] with several sets of ΔE-E telescopes.

Six telescopes were used simultaneously covering approximately the angular range of 8 deg in CM. The thin 380 μm and 250 μm silicon pin diodes were operating as ΔE detectors and 3.6 mm lithium-drifted silicon detectors as E detectors.

The differential cross-sections of the $^{11}B(^3He, d)^{12}C$ reaction are presented in the figure 4.

Also theoretical analysis using the "Finite Range Distorted Wave Born Approximation" [9] and the FRESCO program [10], with a coherent account of all allowed combinations of transmitted angular moments and spins (LSJ) is present in the figure 4.

As can be seen from figure 4 the theoretical calculations are in good agreement with the behaviour of the differential cross sections for ground and 4.44 MeV states.

We can see from figure 4, that for 13.35 MeV state the DWBA calculation with the

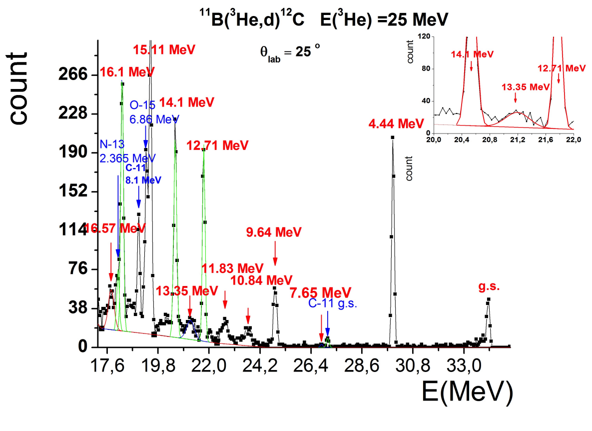

Figure 3. Typical excitation energy deuterons spectrum from the reaction $^{11}B(^3He, d)^{12}C$ at $E(^3He)$=25 MeV. The insert on the right corresponds to increased spectral regions for near the 13.35 MeV state

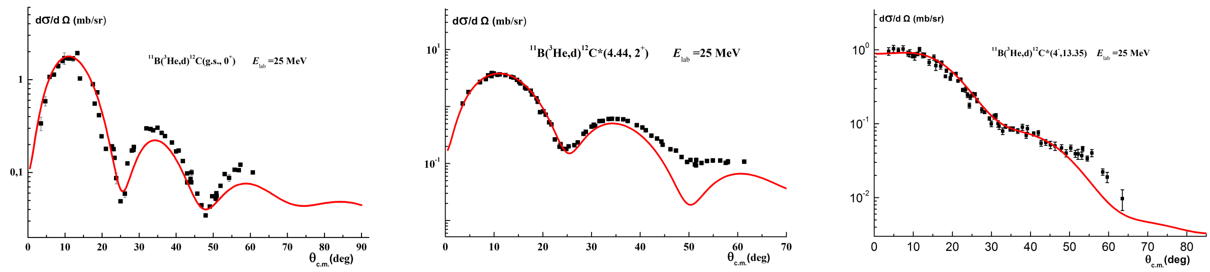

Figure 4. Differential cross-sections of the transfer reaction ^{11}B(^{3}He, d)^{12}C at E(^{3}He)=25 MeV for ground state (left figure), 4.44 MeV state (central figure) and 13.35 MeV state (right figure). The red solid curve corresponds to DWBA calculations.

transmitted moment L=2 adequately describe the behavior of the experimental differential cross section. It means that the spin-parity value of this state is 4^-.

3. Conclusion

Angular distributions for ^{11}B(^{3}He, d)^{12}C reaction at E(^{3}He)=25 MeV, with leading to the excitation of the ground, 4.44 MeV and 13.35 MeV states in ^{12}C were obtained. It was shown that for the state 13.35 MeV the spin-parity value is 4^-.

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