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A new view to the structure of ^{19}C

R. Kanungo[1,a], M. Chiba[1], B. Abu-Ibrahim[2], S. Adhikari[3,4], D.Q. Fang[5], N. Iwasa[6], K. Kimura[7], K. Maeda[6], S. Nishimura[1], T. Ohnishi[1], A. Ozawa[8], C. Samanta[3,4], T. Suda[1], T. Suzuki[9], Q. Wang[10], C. Wu[10], Y. Yamaguchi[1], K. Yamada[1], A. Yoshida[1], T. Zheng[10], and I. Tanihata[1,b]

[1] RIKEN, 2-1, Hirosawa, Wako-shi, Saitama 351-0198, Japan
[2] Department of Physics, Cairo University, Giza 12613, Egypt
[3] Saha Institute of Nuclear Physics, 1/AF, Bidhannagar, Kolkata 700064, India
[4] Virginia Commonwealth University, Richmond, VA 23284, USA
[5] Sanghai Institute of Nuclear Research, Chinese Academy of Sciences, Shanghai 201800, PRC
[6] Department of Physics, Tohoku University, Miyagi 980-8578, Japan
[7] Department of Electric, Electronics and Computer Engineering, Nagasaki Institute of Applied Science, Nagasaki 851-0193, Japan
[8] Institute of Physics, University of Tsukuba, Ibaraki, 305-8571, Japan
[9] Department of Physics, Saitama University, Saitama 338-8570, Japan
[10] Department of Technical Physics, Peking University, Beijing 100871, PRC

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Abstract. The observation of longitudinal momentum distribution ($P_{||}$) from two-neutron removal in ^{19}C with a Be target at 64 A MeV is reported. Analysis in terms of Glauber model considering $^{19}C_{gs}(J^{\pi} = 1/2^{+})$ shows that neutron evaporation is necessary to explain the data.

PACS. 25.60.Dz Interaction and reaction cross-sections – 25.60.Gc Breakup and momentum distributions

1 Introduction

The existence of one-neutron halo structure has been well established in two nuclei, namely, ^{11}Be [1] and ^{15}C [2], having abnormal ground-state spin $J^{\pi} = 1/2^{+}$. Such structures have been described by the core + n halo model. The "core" nucleus in these examples are nuclei whose valence neutron orbital is filled. For sd-shell nuclei close to dripline, the "core" is a more complex nucleus. It is therefore a question of a core + n decoupling is possible for them. One way to investigate this is the study of two-neutron removal from the nucleus of interest.

The isotopic chain of carbon nuclei interestingly shows an abrupt increase in interaction cross-section for two isotopes, namely ^{15}C and ^{19}C [3]. This feature, together with the relatively narrow momentum distribution [4, 5, 6] for one-neutron removal suggested this nucleus to have a one-neutron halo structure. The large Coulomb dissociation cross-section [7] also favoured the halo nature. These investigations suggested a ground-state spin of $J^{\pi} = 1/2^{+}$ for ^{19}C which is supported by shell model (WBP interaction) predictions [5]. The deformed Skyrme Hartree-Fock calculations however suggest ^{19}C to have an oblate deformed structure with a ground-state spin of $3/2^{+}$ [8], "nearly degenerate" with the $1/2^{+}$ excited state (320 keV).

In this article, we present a different view to the structure of ^{19}C by measuring the $P_{||}$ from two-neutron removal. Interestingly, it appears that the distribution cannot be explained by a $J = 1/2^{+}$ spin with ^{18}C core primarily in its ground state, a structure necessary to form a halo.

2 Experiment

The experiment was performed at the RIKEN Ring Cyclotron facility. The secondary beam of ^{19}C was produced by fragmentation of ^{22}Ne primary beam on a 2.5 mm thick Be target. The ^{19}C beam further interacted with a 2 mm Be target placed at the first achromatic focus of the fragment separator. The momentum of the ^{17}C fragment after the reaction target was derived from time-of-flight (TOF) measured using ultra-fast timing plastic scintillators. The momentum resolution was 10 MeV/c (σ). The particle identification was done using ΔE-TOF-E with ionisation chamber (for ΔE) and NaI(Tl) (for E) in addition to the scintillators. The details are described in ref. [6].

[a] Conference presenter; *Present address*: TRIUMF, 4004 Wesbrook Mall, Vancouver, BC V6T 2A3, Canada; e-mail: `ritu@triumf.ca`

[b] *Present address*: Argonne National Laboratory, 9700S Cass Avenue, Argonne, IL 60439, USA.

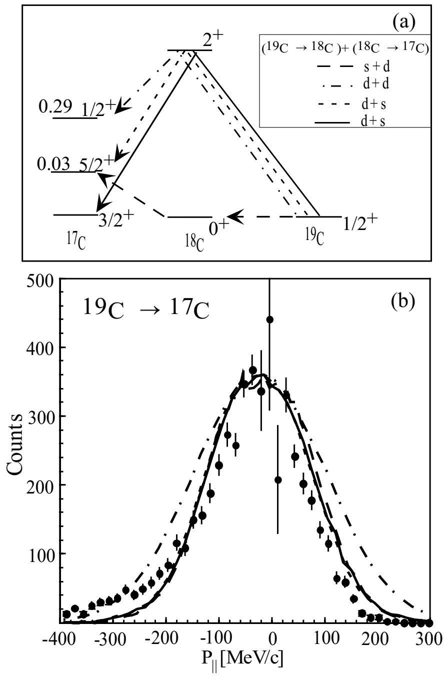

Fig. 1. (a) The possible paths for emitting two neutrons from ^{19}C through the ground state and bound excited states of the "core" nucleus ^{18}C. (b) The $P_{||}$ data (filled circles) for $^{19}\mathrm{C} \rightarrow {}^{17}\mathrm{C}$. The different curves show the Glauber model calculations for the respective emission paths shown in (a).

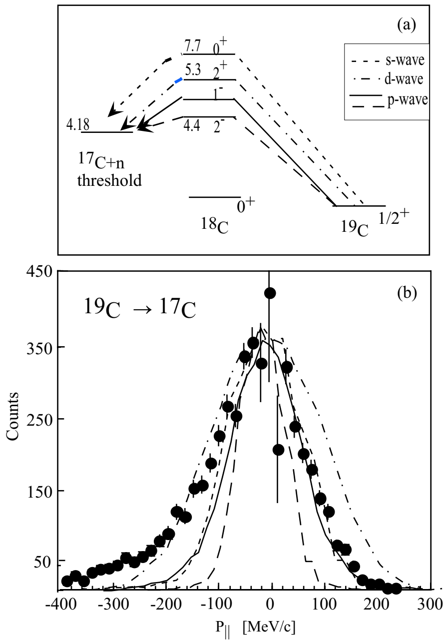

Fig. 2. (a) The possible paths for emitting two neutrons from ^{19}C by neutron evaporation through unbound resonances of the intermediate nucleus ^{18}C. (b) The $P_{||}$ data (filled circles) for $^{19}\mathrm{C} \rightarrow {}^{17}\mathrm{C}$. The different curves show the Glauber model calculations for the respective emission paths shown in (a).

3 Results and analysis

Figure 1 shows the $P_{||}$ data from two-neutron removal having a width (Γ) of 203 ± 10 MeV/c. The data is analysed in the framework of the few-body Glauber model [9]. Two different kinds of neutron removal processes have been considered. In the first approach, we consider neutron emission through bound states of the "core" ^{18}C. The possible emission paths with $J^{\pi}(^{19}\mathrm{C}) = 1/2^{+}$ are shown in fig. 1a. The states of ^{17}C are based on shell model predictions. The resultant $P_{||}$ are shown, normalized to the peak of the data in fig. 1b. All the emission paths lead to distributions which are wider than the data. The solid curve has a width $\Gamma = 300$ MeV/c while the others have widths around $\Gamma = 240$ MeV/c.

Another process of two-neutron emission is by neutron evaporation, *i.e.* through unbound excited states of the ^{18}C core. The resonances of ^{18}C have not yet been observed. They have thus been considered based on shell model predictions [10] (fig. 2a). Figure 2 shows the paths and the $P_{||}$ (normalised to the peak of data) for the different evaporation paths. It is observed that processes involving emission of d-wave neutrons lead to much wider ($\Gamma = 260$ MeV/c) distributions than the data. The s-wave emission ($\Gamma = 182$ MeV/c) and p-wave emissions ($\Gamma = 165$ MeV/c for $p_{3/2}$) are in agreement with the higher momentum side of the data. The emission from $p_{1/2}$ ($\Gamma = 115$ MeV/c) is narrower than the data.

The above discussion suggests that the configuration of ^{19}C having a ground-state spin of $1/2^{+}$ with the ^{18}C core in the ground state and/or bound excited states only, cannot explain the $P_{||}$ from two-neutron removal. The explanation of the data is possible with the neutron evaporation process through unbound excited states of the ^{18}C core. Thus, in the core + n model for $^{19}\mathrm{C}(J^{\pi} = 1/2^{+})$, the ^{18}C core needs to be placed in unbound excited states too. This probably suggests that ^{18}C is not a good "core" for ^{19}C. That maybe expected, since the ground state of ^{18}C nucleus ($J^{\pi} = 0^{+}$) itself has quite a complex structure. In a $^{17}\mathrm{C} + \mathrm{n}$ model, the ^{17}C core must be mainly in the excited states ($5/2^{+}$ or $1/2^{+}$) with the neutron in $d_{5/2}$ or $2s_{1/2}$ orbitals respectively, because the ground-state spin of ^{17}C is known to be $3/2^{+}$.

It must be mentioned that the data might also be explained by other ground-state spin considerations for ^{19}C whose investigation is underway.

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