Evaluation Activities at JCPRG

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Abstract

In this report, we briefly summarize the evaluation activities in Japan Charged-Particle Nuclear Reaction Data Group (JCPRG) in 2018. Along with nuclear data compilation, the evaluation is also one of the important activities that are carried out at JCPRG. The evaluation at JCPRG covers the theoretical investigation on a wide range of nuclear systems close to the stability line, at and beyond the driplines.

1 Introduction

Evaluation of nuclear reaction data requires a vigilant process of correlation, selective collection, renormalization and averaging of the available experimental data, supported by theoretical calculations. The extensive challenge that theoretical approaches bump into is the expensive computational cost. Thanks to the major advancements in the nowadays technology, which have some what eased the situation over this challenge by providing accesses to the super computers at various computing facilities. We at JCPRG [1] deal with various theoretical approaches and evaluate nuclear data used for various applications like positron emission therapy (PET) and to improve the EXFOR database, such as missing data, wrong order of data etc.

This report presents the activities on the evaluation of the nuclear data at JCPRG in 2018. The report is organized as follows: section 2 describes the analysis of $^{16}\mathrm{O}+p$ reaction using the continuum discretized coupled channel (CDCC) method [2]. Section 3 presents the two-neutron correlations in the ground state of the weakly-bound two-neutron ($2n$) halo nucleus $^{22}\mathrm{C}$ sitting at the edge of the neutron dripline and also in the $2n$-unbound nucleus $^{26}\mathrm{O}$ sitting beyond the neutron dripline [3, 4]. Finally, section 4 presents our conclusions.

2 Analysis of $^{16}\mathrm{O}+p$ reaction using CDCC method

In this fiscal year, we applied the CDCC analysis to the proton induced reaction on a $^{16}\mathrm{O}$ target with the incident proton energy up to 70 MeV. The $^{16}\mathrm{O}(p,\, pn)^{15}\mathrm{O}$ reaction is studied within the three-body ($^{15}\mathrm{O}+n+p$) framework of the CDCC approach. We calculate the $^{16}\mathrm{O}+p$ elastic angular distribution and breakup cross sections of the $^{16}\mathrm{O}(p,\, pn)^{15}\mathrm{O}$ reaction. The breakup cross sections as a function of the incident energy are shown in Fig. 1. The obtained results are in good agreement with the experimental data [5–9].

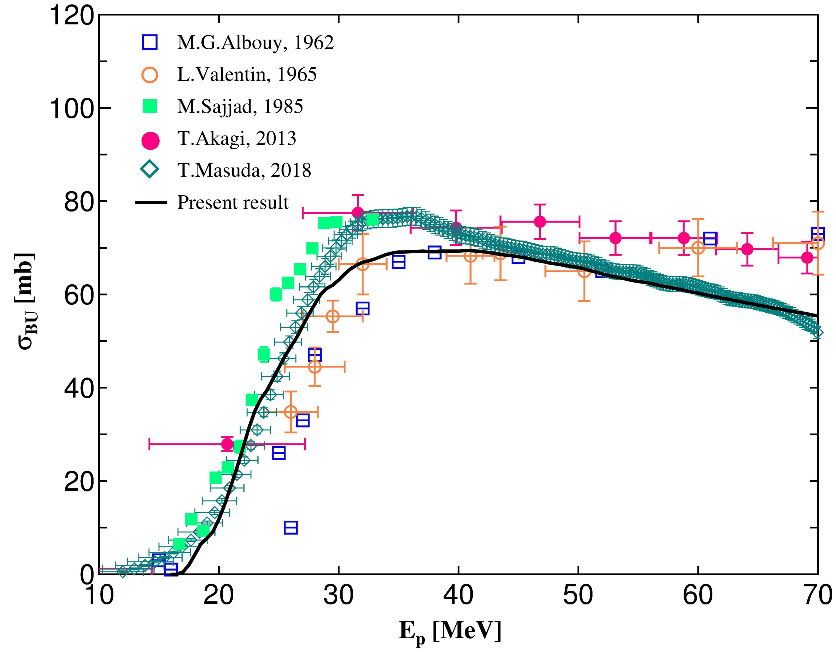

Figure 1: The integrated breakup cross sections of the $p+$ ^{16}O reaction.

3 Two-neutron correlations in the ground state of neutron-rich nuclei

In recent years, there has been rapidly increasing interest in the study of the Borromean nuclei sitting right on the top of neutron dripline and two-neutron ($2n$) decays of unbound systems beyond the neutron dripline. These systems demand a three-body ($3b$) description with a proper treatment of continuum, the conventional shell-model assumptions being insufficient. Very recently a high precision measurement of interaction cross-sections for ^{22}C was made on a carbon target at 235 MeV/nucleon [11] and also the unbound nucleus ^{26}O has been investigated, using invariant-mass spectroscopy [12] at RIKEN Radioactive Isotope Beam Factory. These high precision measurements give us the motivation for selecting these systems for the present study. We have studied the pairing collectivity in the ground state of the Borromean nucleus ^{22}C and in the $2n$-unbound system ^{26}O.

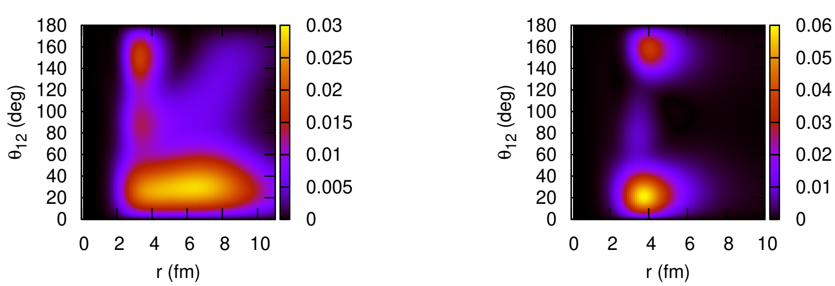

Figure 2: Two-particle density for the ground state of ^{22}C (left-panel) and ^{26}O (right-panel) as a function $r_1 = r_2 = r$ and the opening angle between the valence neutrons θ_{12}.

For this study we have used our recently implemented $3b$-structure model (core$+n+n$) for ground and continuum states of the Borromean nuclei [13, 14].

The neutron single-particle unbound *spdf*-continuum states of the ^{21}C and ^{25}O system are calculated in a simple shell model picture for different continuum energy cut-off's of $5, 10$ and 15 MeV by using a Dirac delta normalization and are checked with a more refined phase-shift analysis. The sensitivity of the (core$+n$) potential has been explored for the emergence of different dominant configurations in the ground states of ^{22}C and ^{26}O. After fixing convergence with the continuum energy cuts and bin size, a reasonable energy cut of 5 MeV and bin size of 0.1 MeV is used for the present study. These (core$+n$) continuum wavefunctions are used to construct the two-particle ^{22}C and ^{26}O states by proper angular momentum couplings and taking contribution from different configurations. Our results show that, the ground state displays a collective nature, taking contribution from many different oscillating continuum states that coherently sum up to give an exponentially decaying bound wavefunction in ^{22}C and an oscillating unbound wavefunction in case of ^{26}O.

The two particle density of ^{22}C and ^{26}O as a function of two radial coordinates, r_1 and r_2, for valence neutrons, and the angle between them, θ_{12} in the LS-coupling scheme is calculated by following Refs. [14, 15]. The distribution at smaller and larger θ_{12} are referred to as "di-neutron" and "cigar-like" configurations, respectively. One can see in Fig. 2 that the two-particle density is well concentrated around $\theta_{12} \leq 90°$, which is the clear indication of the di-neutron correlation and the di-neutron component has a relatively higher density in comparison to the small cigar-like component for both ^{22}C and ^{26}O. The reflection of dominance of s-component in the ground state of ^{22}C can be seen in the left panel of Fig. 2 showing extended di-neutron component in comparison to ^{26}O (in the right panel of Fig. 2), which has sharper dineutron component due to the mixing of $l > 0$ components in its ground-state [3, 4].

4 Summary

For the study of the $^{16}\mathrm{O} + p$ reaction, the calculated breakup cross sections give a satisfactorily good agreement with the available experimental data. For the two-neutron correlations study, our results show the emergence of the bound $2n$-halo ground state of ^{22}C from the coupling of seven unbound *spdf*-waves in the continuum of ^{21}C and $2n$-unbound ground state of ^{26}O from the coupling of three unbound *pdf*-waves in the continuum of ^{25}O due to presence of pairing interaction. Also two-neutron correlation for these systems showing dominance of the di-neutron component is discussed. More investigations are needed to study the $2n$-decay properties.

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