Evaluation Activities at JCPRG

ODSUREN Myagmarjav, EBATA Shuichiro, DAGVADORJ Ichinkhorloo
Meme Media Laboratory, Hokkaido University

MAKINAGA Ayano, KATŌ Kiyoshi, AIKAWA Masayuki
Faculty of Science, Hokkaido University

Abstract

Theoretical studies on nuclear reaction and structure are important for nuclear physics and other applications. This report presents brief results of the evaluation activities based on various theoretical approaches. The purpose of the evaluation activities is to assess nuclear data and to complement important and required data.

1 Introduction

Over the last several years, theory-based approaches have increasingly challenged. During that time, theory-based approaches have demonstrated promise in helping evaluators address for various field of physics, such as light and heavy nucleus structure and nuclear reactions of the nuclei. Historically, the interest of JCPRG has been especially focused on the compilation of charged particle induced reaction data, which were performed in Japanese research centers, universities and institutes. Recent years, theory-based approaches to the evaluation have been developed as one of the interesting subject of JCPRG.

This report includes several applications of theory-based approaches to evaluation for nuclear physics which have been developed at the Hokkaido University Nuclear Reaction Data Centre (JCPRG). The member of JCPRG, who are scientists, are encouraged to develop, especially those interested in applications of the complex scaling method (CSM) [1] to solve resonant and scattering problems in the few-body quantum systems, in utilization of the canonical-basis time-dependent Hartree-Fock-Bogoliubov (Cb-TDHFB) [2] to the Pygmy dipole [3], in consumption of the continuum-discretized coupled-channel (CDCC) method [4] to neutron induced light nuclear reaction and the investigation of systematic study for nuclear transmutation.

In this report, we show the results of scattering cross section of α-n system, photo-absorption reaction cross section of ^{172}Yb, total cross section of ^{6,7}Li-n reaction and calculation of proton or neutron induced reaction on the heavy nuclei by using the TALYS code [5].

2 Scattering cross section of α-n system

The scattering cross section is fundamentally important for full understanding of nuclear systems. The main purpose of this study is to determine a general feature of the scattering problems, in which the nuclear structure arises in the two-body system. Using CSM, the scattering cross section of α-n system is calculated as the function of energy in the center-of-mass frame, and the result

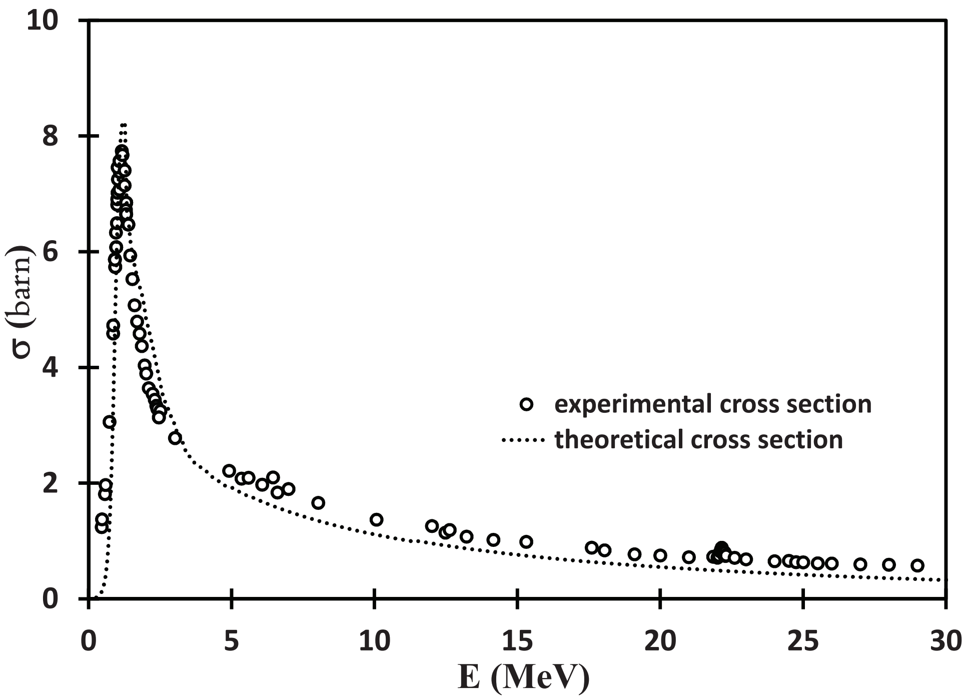

Fig. 1: Total cross sections as functions of relative energy of the α-n system. The dotted-line is the present calculation and open circles are experimental data [6].

is shown in in Fig. 1. In Fig. 1, we compare the calculated cross section to the experimental one. Here, the experimental data are taken from Ref. [6]. It is found that the calculated cross section is in good agreement with the experimental data in a wide energy region. The low energy cross section dominantly comes from $\ell = 1$ partial waves. A very sharp peak at the low energy around 2 MeV and a long tail distribution in higher energies are well reproduced by our calculation.

3 Photo-absorption reaction cross section

The canonical-basis time-dependent Hartree-Fock-Bogoliubov theory (Cb-TDHFB) [2] is one of time-dependent approaches and can include nuclear pairing correlation with nuclear dynamics. Furthermore, the calculation can be performed in the three-dimensional Cartesian coordinate space with the advantage of a small numerical cost. Fig. 2 shows the photo-absorption reaction cross section of ^{172}Yb as an example of linear response calculation using Cb-TDHFB. ^{172}Yb is a relatively heavy nucleus with a deformed shape and the open shell configuration. The cross section has a characteristic giant dipole peak of deformed nucleus which composes two parts, in both theoretical (lines) and experimental (points) results. ^{172}Yb has a prolate shape in its ground state, and the fluctuations along long (K=0) and short (K=1) axes appear in its $E1$ excited states. Therefore, we can carry out systematic investigations without any restrictions for the mass number, shell structures and the deformation. Indeed, we apply our method to systematic study of $E1$ mode and investigate the behavior of low-lying $E1$ modes which is often called the Pygmy dipole resonance.

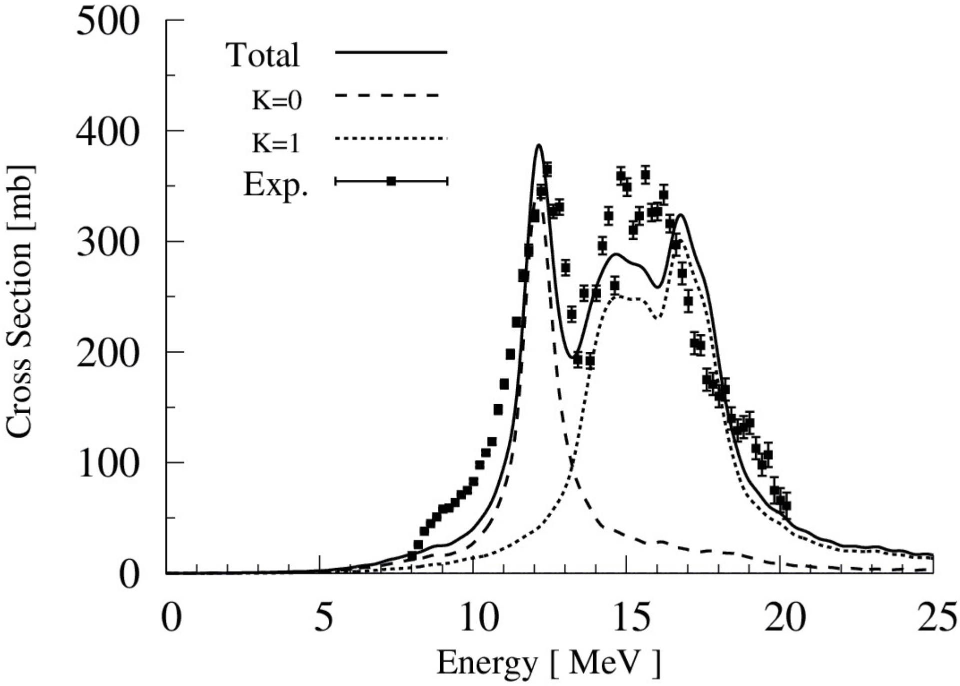

Fig. 2: The photo-absorption reaction cross section of ^{172}Yb. The solid-line is the present calculation of total cross section and dotes are experimental data [7].

4 Total cross section of the ^{6,7}Li-n reactions

The Li-n reactions are important not only in the basic research interest but also in the application point of view. Lithium isotopes will be used as a tritium-breeding material in d-t fusion reactors. Therefore, accurate nuclear data are required for n- and p-induced reactions.

In this analysis, we calculate the total cross sections for the ^{6,7}Li-n reactions by using CDCC [4] with the microscopic Jeukenne-Lejeune-Mahaux effective nucleon-nucleon (JLM) interaction [8] for incident energies from 5 to 150 MeV. The cross section data can be reproduced by the present CDCC calculations with one normalization parameter for the imaginary part of the JLM effective interaction. Based on the analyses of the total cross section, it is found that the required normalization factor λ_w is large as $\lambda_w \approx 1.0$ from 30 to 150 MeV. The calculated total cross sections for ^{6,7}Li-n reactions are good agreement with the observed data. We also calculate the integrated inelastic scattering cross sections for 4.652 MeV of ^{7}Li in incident energies from 5 to 24 MeV. The calculated data can be reproduced with $\lambda_w \approx 1.0$ over 14 MeV and without imaginary part below 14 MeV using the JLM interaction.

5 Systematic study of nuclear data for nuclear transmutation

One of problematic radio active wastes from spent nuclear fuels is the long-lived fission products (LLFPs). Because the LLFPs have long half-lives, special techniques of the safe management and/or the disposal way are required. A promising way to solve this problem is the "nuclear transmutation technology". Basic concept of this technology is to change the LLFPs into the "short-lived nuclei"

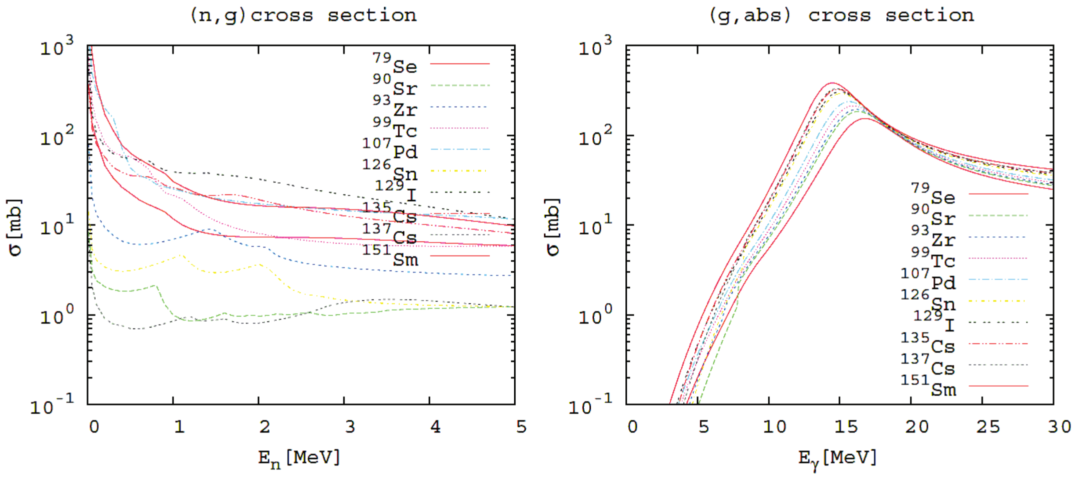

Fig. 3: Calculation of (n,γ) cross sections and (γ,abs) cross sections for the LLFPs by using the code TALYS.

or "stable nuclei" by using various kinds of particle beams. Recently, ADS (Accelerator-driven System) has been studied for this purpose in the world. In Japan, J-PARC plans to develop the ADS technique.

From the viewpoint of the nuclear data, various kinds of cross section data sets for LLFPs are needed to design the nuclear transmutation system. However, only few experimental data sets exist, because their cross section measurements can be hardly obtained due to the difficulty in preparing enriched targets and the treatments of the activities. One possible way to access these cross sections is the inverse reaction method. For example, neutron capture cross section can be estimated by the reactions of photo-disintegration. Another possibility is to use the proton or unstable beam. JCPRG has investigated the current states of the experimental data and performed calculations of the (γ,abs), (n,γ), (p,tot), (p,n), (p,α) and (p,p) reactions for the LLFPs (^{79}Se, ^{90}Sr, ^{93}Zr, ^{99}Tc, ^{107}Pd, ^{126}Sn, ^{129}I, ^{135}Cs, ^{137}Cs, ^{151}Sm) using the calculational code "TALYS" [5] as shown in Fig. 3 and 4. In near future, detailed studies of these reactions will be needed.

6 Summary

We have investigated the scattering cross sections in four different approaches. First one is the the two-body α-n system with Gaussian basis. Second, the linear response phenomena was obtained on the photo-absorption reaction cross section of heavy, deformed nuclei (^{172}Yb) by applying Cb-TDHFB method. Third, the total cross sections of the ^{6,7}Li-n reactions were calculated for the wide energy range $5 - 150$ MeV by using CDCC with the microscopic JLM effective nucleon-nucleon interaction. All the calculated results can reproduce the experimental data well. Furthermore, fourth, a systematic analysis of neutron and charged particle induced reaction cross section and also photo-absorption reaction cross sections were investigated by TALYS code.

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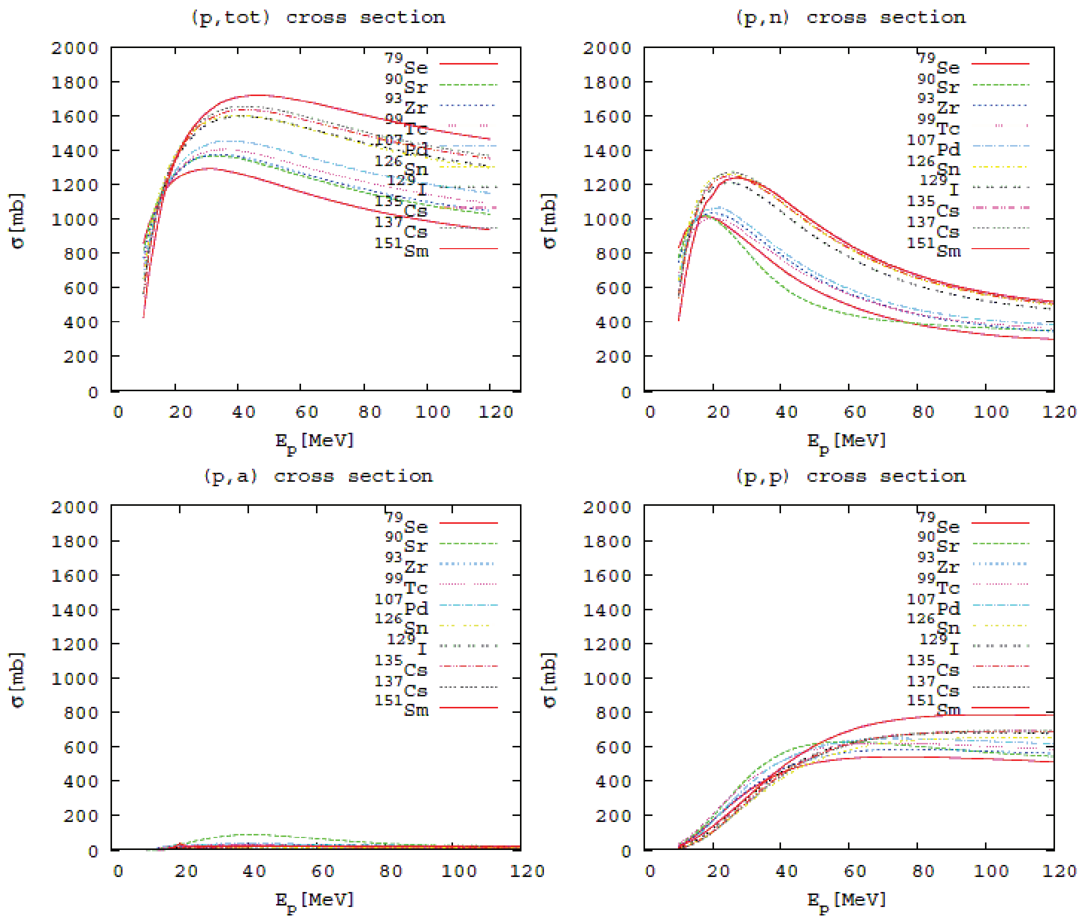

Fig. 4: Calculation of (p,tot), (p,n), (p,α) and (p,p) cross sections for the LLFPs by using the code TALYS.

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