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著者	Asano Y., Tamae T., Kimura R., Konno O., Hirota K., Maeda K., Miyase H., Nishikawa I., Terasawa T., Tsubota H., Yamazaki H.
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Study of (e,e′ α) Reaction on ^{9}Be

Y. Asano[1], T. Tamae[1], R. Kimura[2], O. Konno[1]*, K. Hirota[1], K. Maeda[2], H. Miyase[2], I. Nishikawa, T. Terasawa[1], H. Tsubota[2] and H. Yamazaki[1]

[1]*Laboratory of Nuclear Science, Tohoku University, Mikamine, Taihaku-ku, Sendai 982-0826*
[2]*Physics Department, Graduate School of Science, Tohoku University, Aramaki, Aoba-ku, Sendai 980-0845*

The (e,e′ α) cross section has been measured at energy transfers from 10.0 to 28.4 MeV and a momentum transfer of 99 MeV/c, using a 197 MeV continuous electron beam. The cross section rapidly increases with decreasing energy at angles smaller than 25°, while it appears flat at larger angles. The forward-peaked angular distribution was observed below 18 MeV, and the forward peak shrinks at higher energies. An amount of α particles from decay of ^{5}He is estimated.

§ 1. Introduction

There has been a growing interest in the study of neutron-halo and neutron-skin structure. Very recently, the RI Beam Factory project has started at RIKEN to explore this subject. The nucleus ^{11}Be is known as a neutron-halo nucleus [1], and there are several microscopic and macroscopic attempts at describing Be isotopes in a unified framework of two α particles and extra neutrons. The ^{9}Be nucleus is the simplest isotope, which has one extra neutron, and is known to have a typical $\alpha+\alpha$+n cluster structure. Therefore the nucleus has already been investigated in various models.

The photo-disintegration of ^{9}Be is categorized in three separate mechanisms: (1) threshold to 5 MeV, where sharp resonances correspond to direct excitations of the unpaired neutron; (2) 5-18 MeV, where weak coupling of the unbound neutron to ^{8}Be dominates; (3) above 18 MeV, where a core is excited. The photo-nuclear reaction has been investigated in the (γ, n) [2-5], (γ, p) [6], (γ, d) [6], (γ, t) [6] and (γ, ^{3}He) [6] channels. However, no (γ, α) cross section has been measured, presumably because the decayed α particles of ^{5}He that partly overlap on the spectrum make the analysis difficult. The threshold of the (γ, α) reaction is 2.53 MeV; this is the only charged-particle emission channel below 16 MeV. The cross section is expected to be large enough for measurement.

The residual nucleus ^{5}He of the ^{9}Be (e,e′ α) reaction is same as the ^{6}Li (e,e′p) reaction, which we investigated several years ago [7]. However, the missing energy spectra of both reactions may be different from each other, because they reflect their reaction mechanisms. We measured ^{9}Be (e,e′ α) cross section at eleven angles at transferred energies between 10.0 and 28.4 MeV as a test experiment.

§ 2. Experimental procedure

The experiment was performed using a 197 MeV continuous electron beam from a stretcher-

*Department of Electrical Engineering, Ichinoseki National College of Technology, Hagiso, Ichinoseki 021-8511

booster ring (STB). Electrons scattered with a 1.8 mg/cm^2 thick natural beryllium foil were analyzed with a magnetic spectrometer (LDM) at 30°. Missing energies were set at two energies: phase 1 (10.0 ~ 21.0 MeV), phase 2 (17.6 ~ 28.4 MeV). Corresponding momentum transfers are 98.60 MeV/c for phase 1 and 99.10 MeV/c for phase 2. Ejected α particles were measured with eleven SSD counter telescopes composed of two surface-barrier type SSD's (one 50 μm SSD + one 1 mm SSD at eight angles, and two 1 mm SSD's at three angles), out-of the scattering plane (ϕ_α = 90°). The solid angle of the telescopes is 4.8 msr. Due to insufficient machine time, no measurement between 90° and 180° was made in this run.

§ 3. Results and Discussion

Figure 1 shows missing energy spectra at the momentum transfer direction; a peak at 2.5 MeV corresponds to α particle emission leaving the residual nucleus at the ground state of ^{5}He. A tail toward higher missing energies is observed in the spectrum for the lower energy transfer region; more structures can be seen in the spectrum for the higher energy transfer region. Considering a resolution of the experiment, events below E_m = 7 MeV were treated as α_0 events.

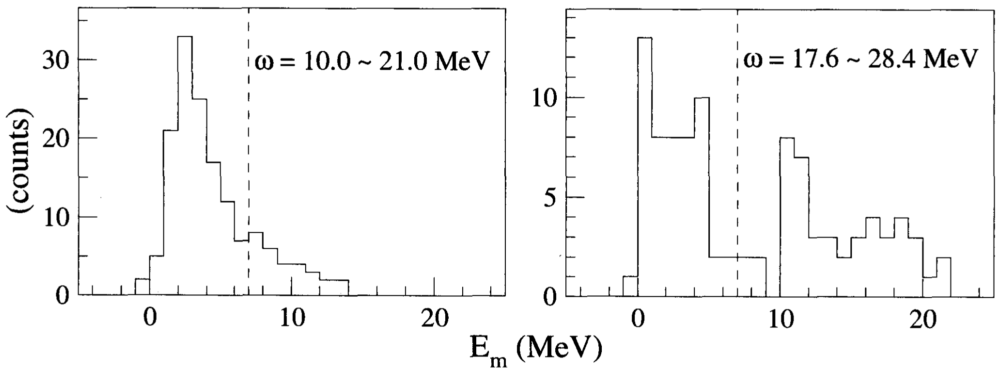

Fig.1. Missing energy spectra at 0°. A peak at 2.5 MeV corresponds to (e,e'α_0) reaction.

A transferred energy dependence of the differential (e,e'α_0) cross sections is shown in Fig.2. At forward angles, the cross section becomes larger as the energy decreases; while no such rise can be seen at backward angles. angular dependence of the differential cross section is shown in Fig.3. At low energies, a strong forward peaking is observed; data at backward angles are lacking because energies of the α particles are lower than the threshold energy of the detectors there.

In the (e,e'α) ^{5}He reaction, the residual nucleus ^{5}He decays into n + α; this α particles partly overlap on the α particles of the (e,e'α) ^{5}He reaction. Simulated missing energy spectra of both α particles are demonstrated in Fig.4. In this calculation several assumptions were made:

(1) The angular distribution of the ^{9}Be (e,e'α) ^{5}He reaction has a forward-backward symmetry in the center of mass system; Legendre parameters has been obtained by fitting the measured angular

distributions with even-order Legendre functions up to $l = 4$.

(2) The angular distribution of the α particle due to $\alpha+\alpha$+n decay of ^{5}He is isotropic in the center of mass system.

The lowest peak in Fig.4 corresponds to α particles from the ^{9}Be (e,e′ α) ^{5}He reaction; the higher missing-energy part of two-peaked structure corresponds to decay products of ^{5}He. Alpha-particles emitted toward the detector direction make the lower peak, while those to the opposite direction do the higher peak. The structure changes slowly at other angles. The two-peaked structure shifts toward higher missing-energies as the transferred energy ω increases. The missing energy spectra folded in the regime of the measurements are shown in Fig.5, where the structure is smeared in resolution (1 MeV FWHM). A tail in higher energy part for ω = 10 ~ 21 MeV in Fig.1 is reproduced in this

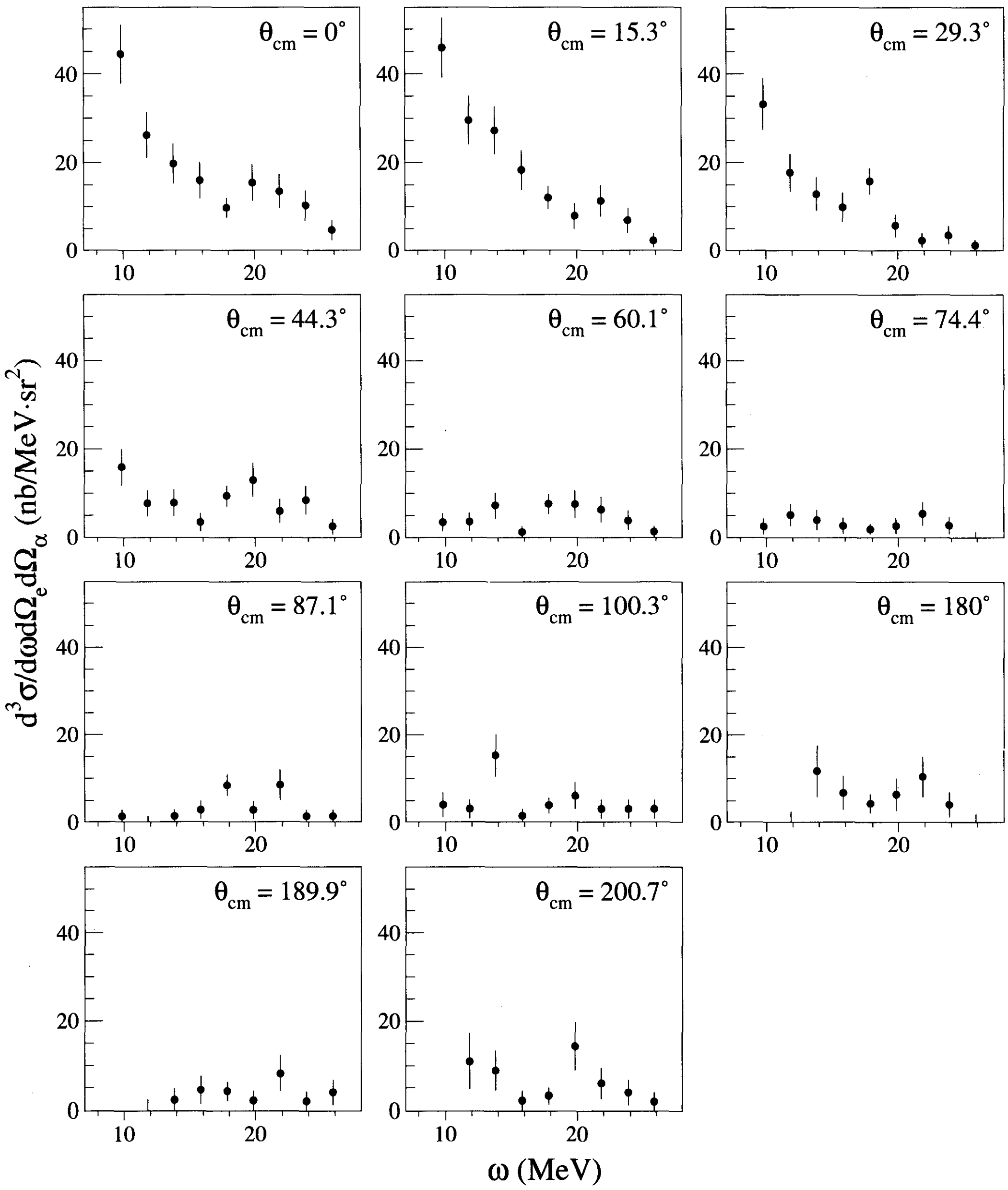

Fig.2. The ^{9}Be (e, e′ α_0) differential cross sections.

simulation. In case $\omega = 17.6 \sim 28.4$ MeV, the part $E_m > 10$ MeV cannot be reproduced in the simulation although the measured spectrum has large statistical errors. It may be a contribution of α particles from the ^{9}Be (e,e′n) ^{8}Be (16.6 MeV) $\rightarrow 2\ \alpha$.

We wish to thank the accelerator group and the computer group for their assistance during the measurements.

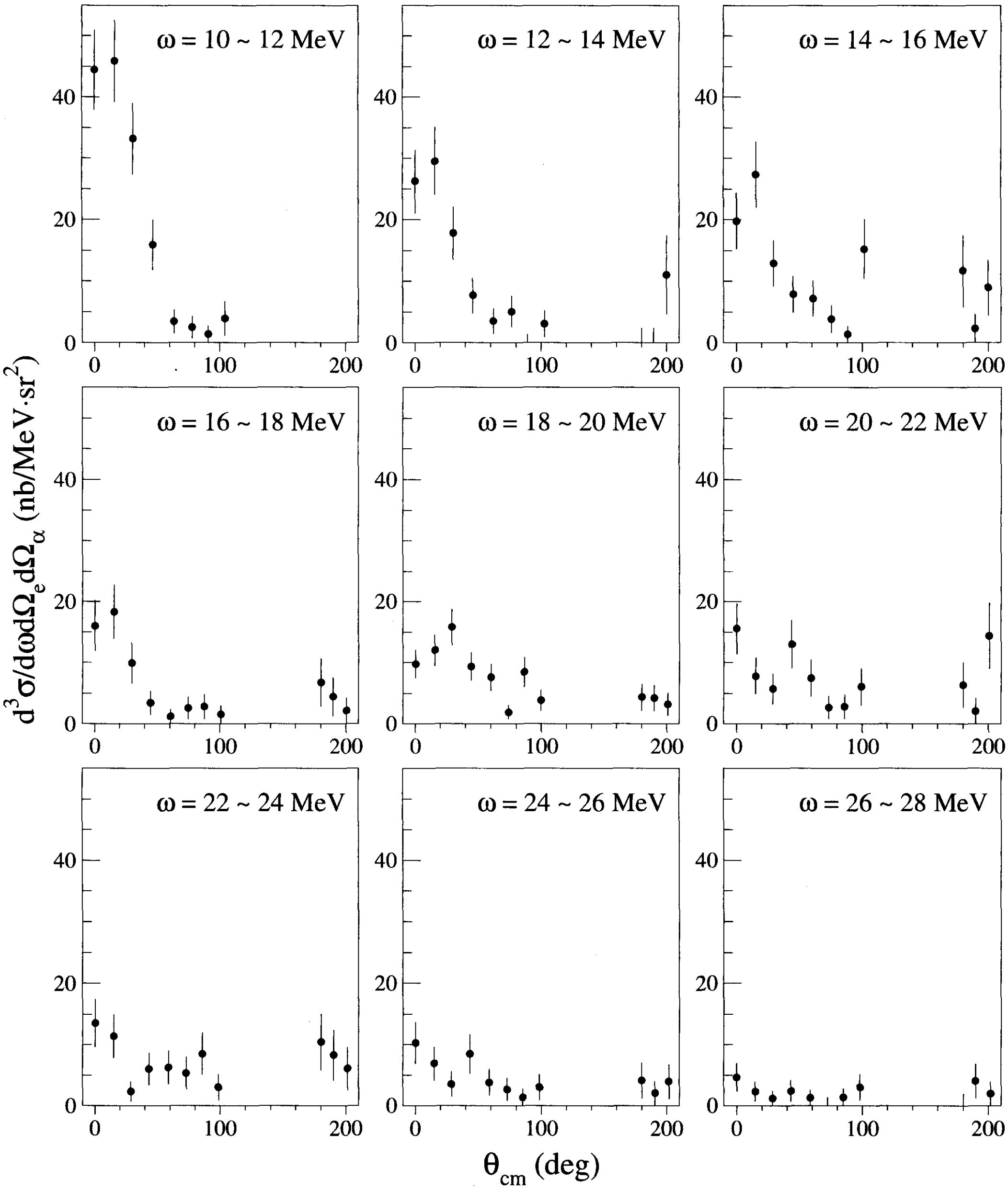

Fig.3. Angular distributions of the ^{9}Be (e, e′ α_0) reaction.

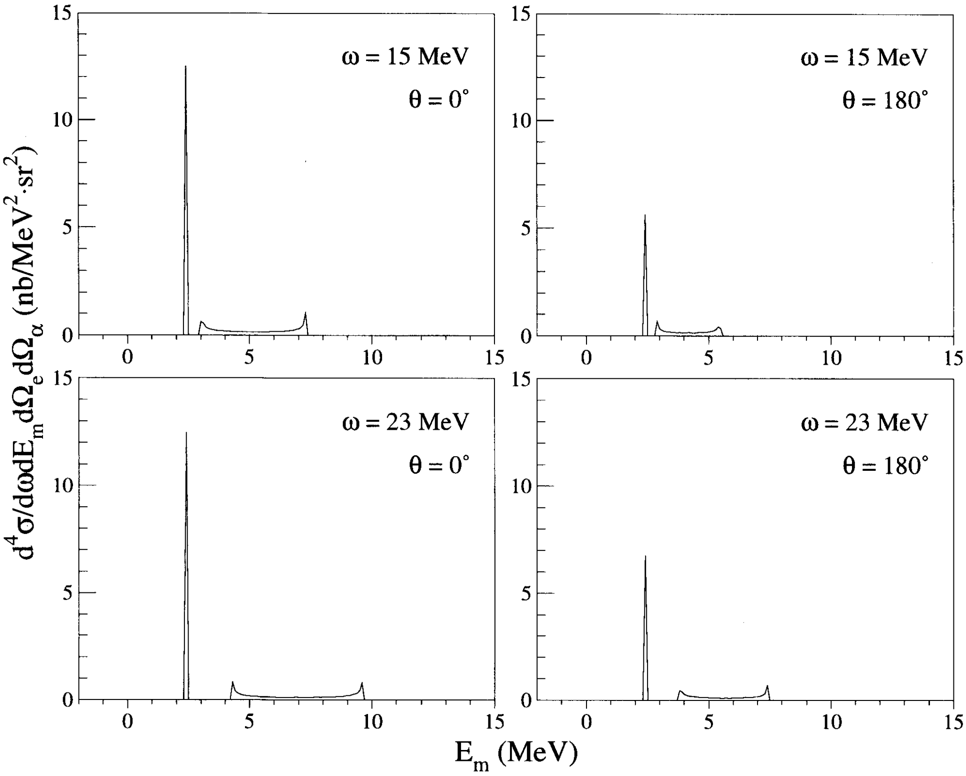

Fig.4. Simulated missing energy spectra of the ^{9}Be (e, e' α_0) reaction (a peak at E_m = 2.5 MeV) and the α emission from ^{5}He (two-peaked part at higher missing energies).

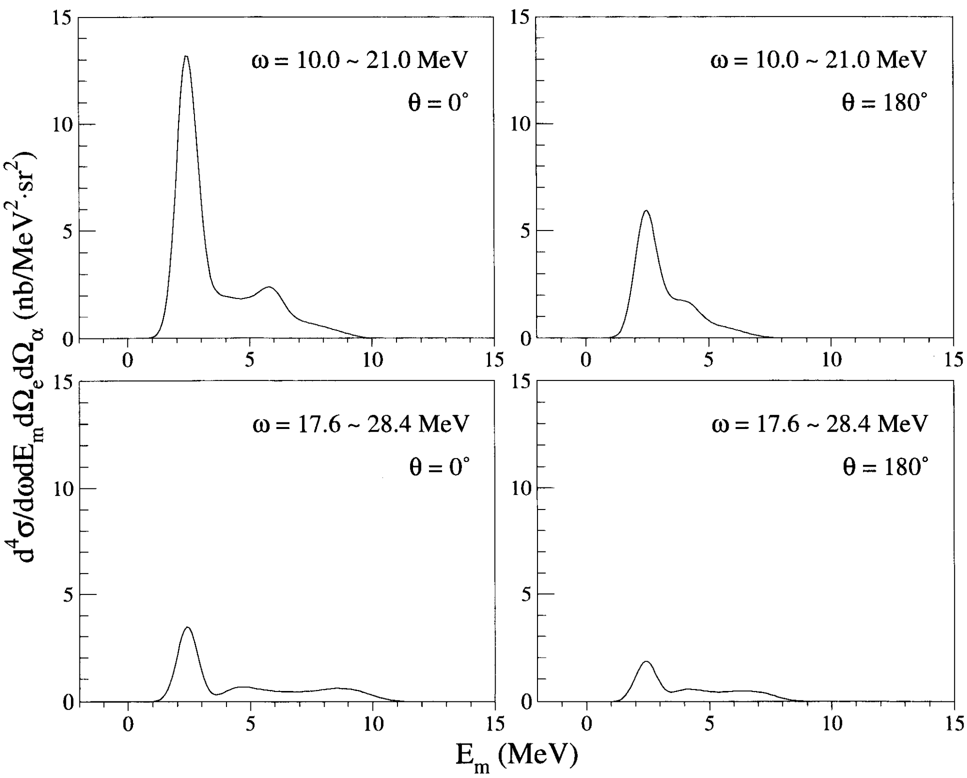

Fig.5. Simulated missing energy spectra folded in the regime of the measurements, which are smeared with a resolution of 1 MeV FWHM.

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