Study of the Alpha Cluster State in 28Si by the Inversed Kinematic Method

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I. 4. Study of the Alpha Cluster State in ^{28}Si by the Inversed Kinematic Method

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The clustering phenomena is one of the common features in many-body systems. In the nuclear clustering, the alpha cluster structure often appears in various light nuclei due to the high binding energy of the alpha particle. The alpha cluster states also affect the nucleosynthesis in the stellar evolution. For example, the process of the carbon creation strongly depends on the structure of the second excited state in ^{12}C, which is considered to be a dilute 3-α gas-like structure and called the Hoyle state. The ^{12}C nucleus is produced by the two-step process via the Hoyle state as $\alpha + \alpha \rightarrow {}^{8}\mathrm{Be}$, ${}^{8}\mathrm{Be} + \alpha \rightarrow {}^{12}\mathrm{C}^*(\mathrm{Hoyle}) \rightarrow {}^{12}\mathrm{C} + 2\gamma$. In this study, we aimed to investigate the ^{24}Mg + α structure in ^{28}Si. The ^{28}Si has various cluster structures such as ^{24}Mg + α, ^{12}C + ^{16}O, and ^{20}Ne + ^{8}Be. Among them, the ^{24}Mg + α cluster has two types of configurations. One is the configuration of the prolate shape, in which an α cluster is located to the position along the major axis of the prolate ^{24}Mg cluster. The other is that of the oblate shape, in which an α cluster is placed to the position along the minor axis of the ^{24}Mg cluster. The ground state of ^{28}Si is considered to have the duality of the oblate deformed mean-field structure and cluster structures as the ^{24}Mg + α and ^{20}Ne + ^{8}Be configuration1). Therefore, states excited by inelastic scattering are mainly the oblate type of ^{24}Mg + α cluster states. In this experiment, we try to determine J^{π} values of ^{24}Mg + α cluster states by measuring the angular correlation function for the α decay in the ^{12}C(^{28}Si, α^{12}C)^{24}Mg reaction.

The experiment was performed at the 41 course in CYRIC using the large scattering chamber. The $^{28}\mathrm{Si}^{9+}$ ions were produced by the 10 GHz ECR ion source using a quartz (SiO_2) rod2) and accelerated up to 280 MeV by the 930 AVF cyclotron. The ^{28}Si beam bombarded to a natural carbon foil with a thickness of 50 μg/cm^2 in the scattering chamber. Figure 1 shows the experimental set-up in the scattering chamber. The recoiling ^{12}C and decay α particles were detected in double-sided silicon detectors with a size of 40 × 40 mm^2 and a thickness of 1000 μm (DSSD1) and with a size of 50×50 mm^2 and a thickness of 1500 μm (DSSD2, DSSD3), respectively. DSSD1 has horizontally and vertically 40 channel strips in each side. To reduce numbers of readout channels, two or three strips were connected into a channel. Total readout channels of DSSD1 were 32 channels. ^{12}C particles were identified using the time of flight method (TOF). In front of DSSD2, DSSD3, aluminum plates with a thickness of 125 μm and plastic scintillators with a thickness of 30 μm were installed in order to stop scattered ^{28}Si and ^{24}Mg particles and to identify the α particle, respectively. Figure 2 shows the typical two-dimensional histogram of the plastic scintillator and DSSD2. α particles are clearly identified in Fig. 2. The accidental coincidence events were neglected, since they were less than 1% compared to the true events extracted using TDC information as shown in Fig. 3. The true region in Fig. 3 was used in the analysis. The angle and energy of the decay ^{24}Mg particle were obtained by the calculation of the kinematics, assuming the detected α particle came from the $^{28}\mathrm{Si}^* \rightarrow {}^{24}\mathrm{Mg} + \alpha$ decay channel.

Figure 4 shows the excitation energy spectrum of ^{28}Si in coincidence with an α particle in DSSD2 or DSSD3 obtained by the missing mass method calculated from the recoiling ^{12}C energy and angle. The excitation energy over 14 MeV was not covered in this experimental setting. The tail below the ^{24}Mg + α breakup threshold energy of 9.9 MeV might come from accidental coincidence events. In order to extract the excitation energy of the ^{24}Mg + α cluster state, the excitation energy region was divided into four 1 MeV bins as 10-11, 11-12, 12-13, and 13-14 MeV. To determine the J^π value of the state, the angular correlation of the decay α with respect to the momentum transfer direction will be obtained. The analysis is in progress.

References

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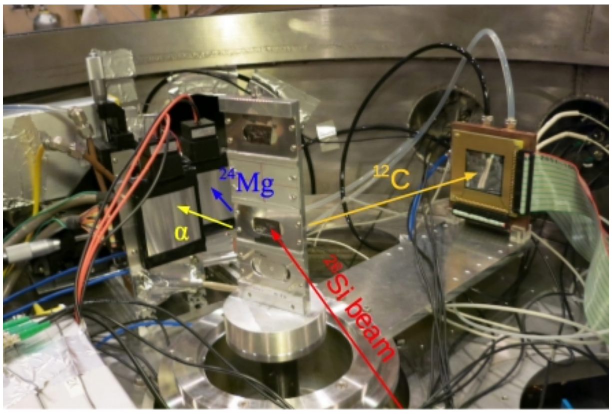

Figure 1. Experimental set-up.

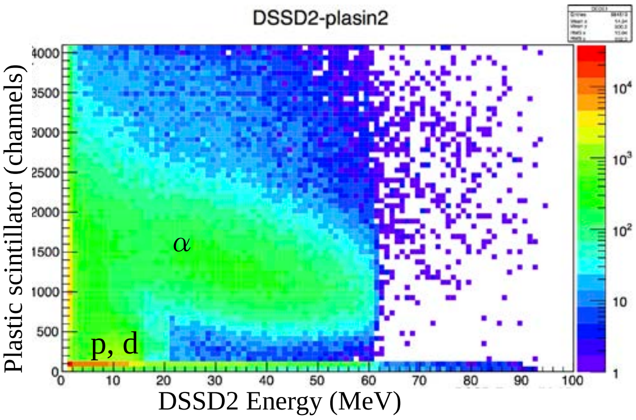

Figure 2. Two-dimensional histogram of ADC channels of the plastic scintillator and energy obtained by DSSD2.

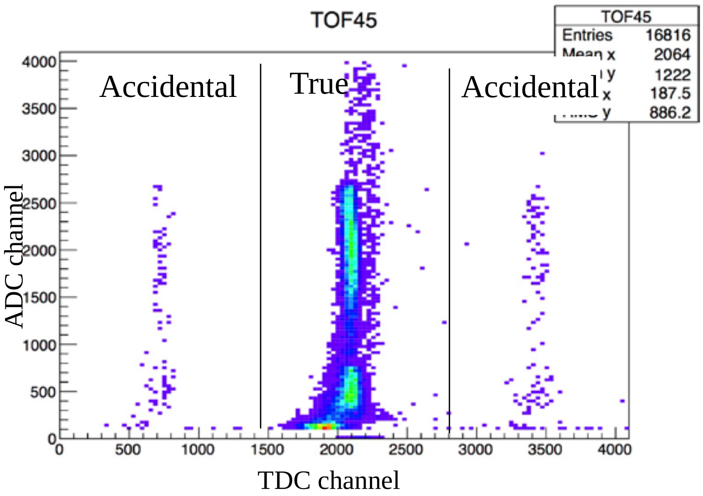

Figure 3. The TOF spectrum for DSSD2

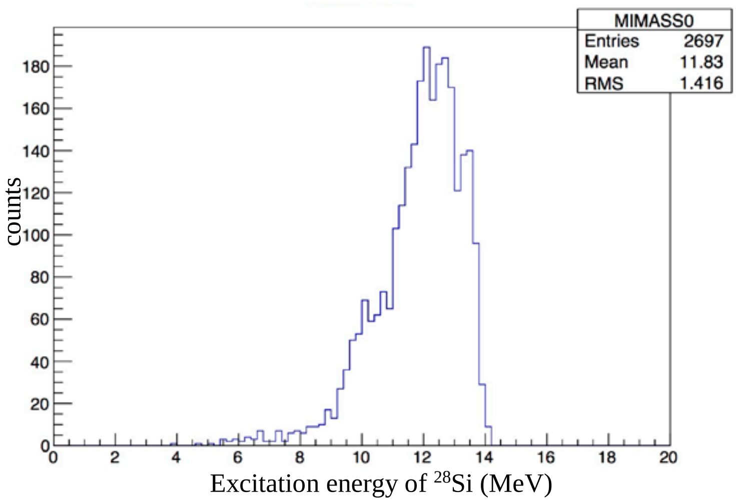

Figure 4. Excitation energy spectrum of ^{28}Si