Study of continuum nuclear structure of $^{12}C(p,p'x)$ reaction at intermediate energy

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Pre-equilibrium process is one of the major processes in nucleon induced reactions. Although the direct and equilibrium mechanism are understood rather exactly, that of the pre-equilibrium is too complex to be interpreted. Inclusive nucleon spectra at intermediate energies show a very large continuum region which corresponds to the pre-equilibrium process. As the major part of nucleons come from the pre-equilibrium, the study of this process is of importance to grasp the gross feature of reaction mechanism. Nucleon inelastic continua have been extensively investigated, and many theoretical models have been proposed to understand pre-equilibrium processes in the scattering. BUU (Boltzmann-Uehling-Uhlenbeck), QMD (Quantum Molecular Dynamics) and AMD (Anti-symmetrized Molecular Dynamics) models have been developed to study complicated rection processes of heavy-ion collisions at intermediate and high energies by simulating the reaction microscopically.

The pre-equilibrium process of nucleon induced reactions has been investigated extensively below 200 MeV. In an energy range of 0.8–1.5 GeV, neutron continua from proton induced reactions have been measured systematically at KEK PS in recent years. However, few studies were performed in a range 200–400 MeV. In this energy range, the characteristics of highly excited nucleons and the behavior of Δ inside the nucleus will be investigated through systematic measurements. In the present work, proton induced continua at intermediate energy were investigated and experimental results were reported.

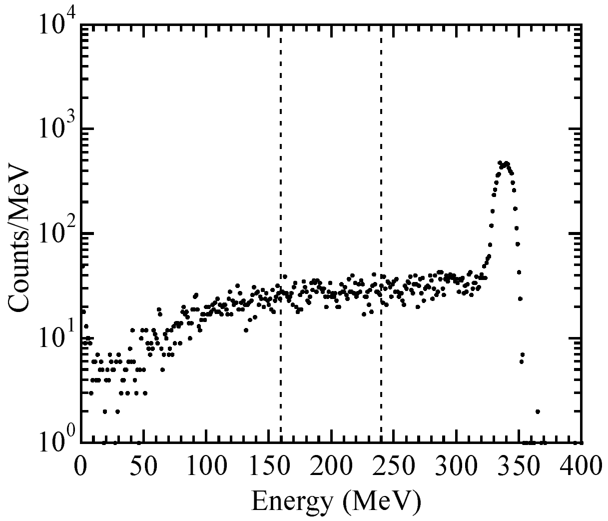

Figure 1: Energy spectrum for 339 MeV protons. The dotted lines are indicating energies correspoding to the proton range of 43 mm and 86 mm.

We have developed a stacked GSO(Ce) scintillator spectrometer as a full energy detector[1, 2] on purpose to measure the protons continua over a wide energy range. Under the result of the test experiment[3], optimization of the spectrometer was made for this experiment. The spectrometer used consisted of three plastics and three GSO(Ce) crystals of two cubic GSO(Ce) crystals of $43\times43\times43$ mm^3 and a cylindrical GSO(Ce) crystal of 62 mm diameter by 12 mm length. The plastic plates produced trigger signals. One of them had an aperture of 15 mm diameter and acted as an active slit to determine the solid angle of the spectrometer. In the experiment, measurement of the continuum spectra was made by the use of 392 MeV unpolarized proton beam provided by the ring cyclotron for ^{12}C, ^{27}Al, ^{93}Nb, ^{197}Au target nuclei at 13 angles from 19.7 deg to 104.1 deg in lab. frame. Energy calibration was made with an approximately monoenergetic protons obtained by elastic *pp* scattering from H(p,2p) reaction in polyethylene target. 12 monoenergetic protons were measured corresponding 12 scattering angles from 19.7 deg to 66.1 deg in the lab. frame. A typical response function to proton is plotted in Figure 1. Figure 2 shows the obtained energy spectra of double differential cross sections for ^{12}C(p,p$'x$) reaction at 19.7 deg in lab. frame. It is found that the protons which come from the ground state in p+^{12}C was observed at 387 MeV. The experiment are compared with the result of the calculation with QMD model. Much difference between the experiment and calculation is found at an energy region higher than the peak at about 340 MeV which corresponds to the quasi-free proton+N scattering.

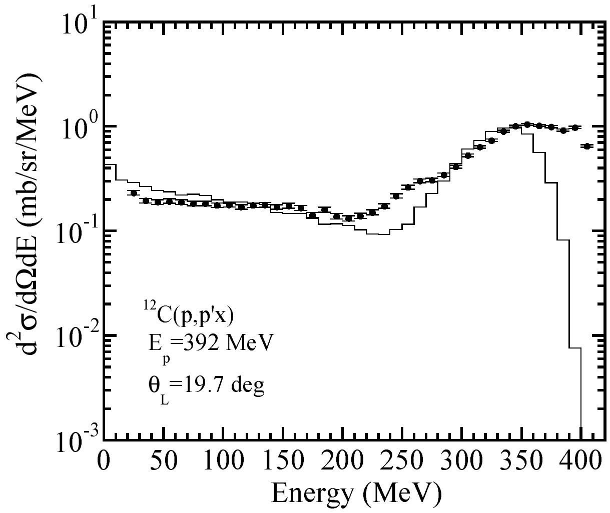

Figure 2: Double differential cross section for ^{12}C(p,p$'x$) reaction at 392 MeV. Closed circles and solid line represent experimental data and result of calculation with QMD model, respectively.

References

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[3] H. Yoshida *et al.*, RCNP Annual Report 1996, p.121.