Study of Deuteron Spectra from Proton Induced Reactions at Intermediate Energies

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In recent years, nuclear data in the intermediate energy are required from various fields of basic physics and nuclear technologies. Double-differential cross sections are needed for calculations of particle transport in matter. There are currently some available proton data of proton-induced reactions, but few systematic measurements above 200 MeV of incident energy. Data of complex particles, such as deuteron and alpha, are less than nucleon data. It is interesting to study the mechanism of high energy deuterons production, since a deuteron consists of a proton and a neutron with a small binding energy. In order to develop a calculation code that is able to simulate the nuclear reactions as accurately as possible, comprehension of the process of deuteron production becomes important.

The beam experiment was performed at the Research Center for Nuclear Physics (RCNP), Osaka University. Protons accelerated up to 300 MeV and 392 MeV by the ring cyclotron were bombarded onto targets set at the center of a vacuum chamber. The measurements were made for targets, ^{12}C, ^{27}Al, ^{93}Nb and ^{197}Au. We measured energy spectra from 19.7 to 104.1in laboratory frame. The stacked GSO(Ce) scintillator spectrometer was used in the measurements.

We compared the measured data with QMD (Quantum Moleculer Dynamics) and INC (Intra-Nuclear Cascade) model calculations, which are powerful to investigate particle emissions from a non-equilibrium process in intermediate-energy nuclear reactions. As shown in Fig.1, the QMD fails to reproduce the deuteron spectra. It is noteworthy that the QMD underestimates the experiments by two orders in the highest energy domain. The QMD model includes indirect pick-up process. The large differences should be ascribable to a deuteron-cluster knockout process. The INC model includes a small number of preformed deuterons inside the target nucleus. In Fig.2 is shown the INC model calculation show agreement with experiments. Especially, INC at $Ed < 250$ MeV is in good agreements with experimental spectra at 20.

As a conclusion, inclusive ^{12}C(p,dx) spectra were measured at 300 MeV, and were compared with theoretical calculations, QMD and INC. The INC that includes a small number of preformed deuterons inside the target nucleus show comparatively agreement with experiments. But the QMD show overall disagreement with experiments. The cause of the results should be ascribable to a deuteron-cluster knockout process.

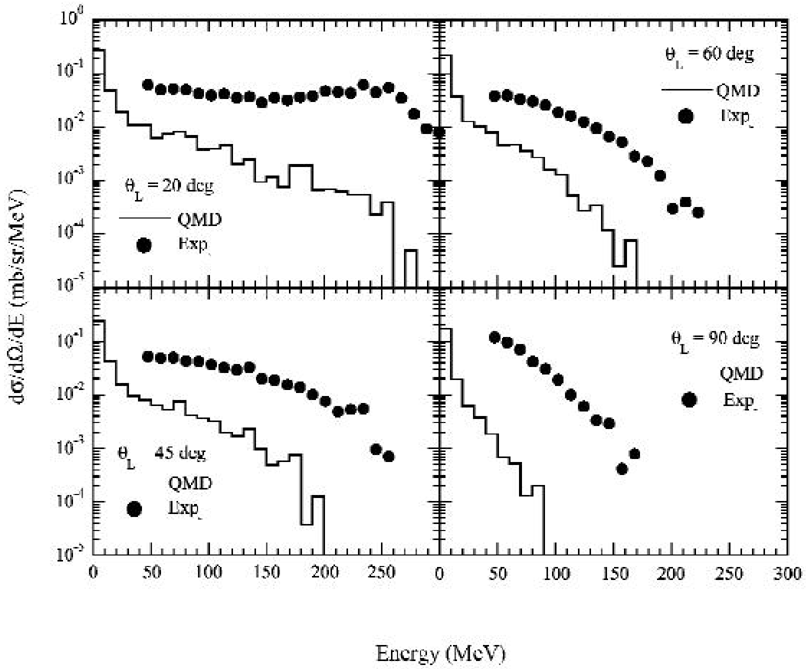

Figure 1: Energy spectrum of ^{12}C(p,dx) at 300 MeV, 20,40,60and 90. Measured data (dots) are compared with QMD (line)

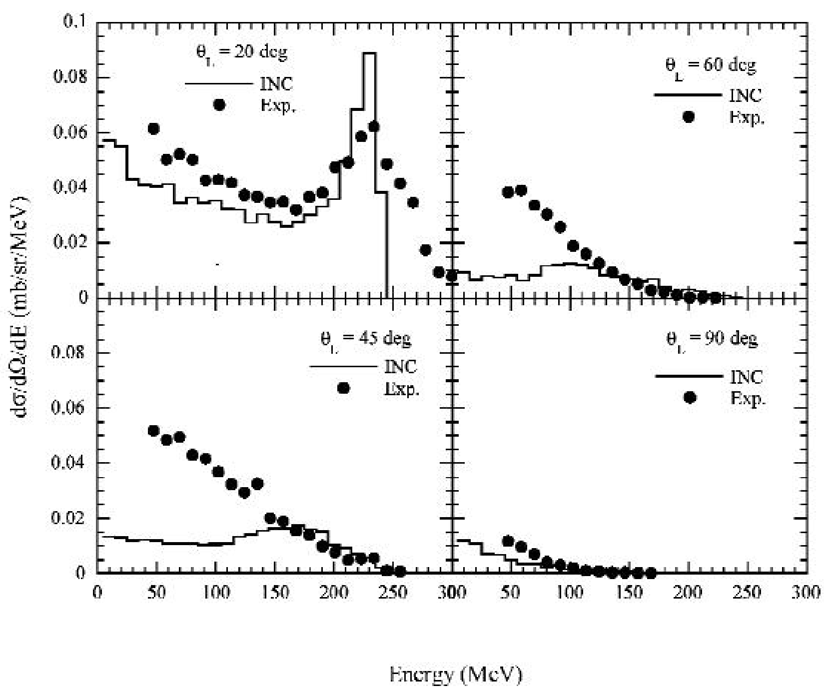

Figure 2: Energy spectrum of ^{12}C(p,dx) at 300 MeV, 20,40,60and 90. Measured data (dots) are compared with INC (line)