Nuclear Data for Science and Technology (1988 MITO), 1205-1208, Copyright © 1988 JAERI.

ON THE CHARGE SYMMETRY CONSERVATION AND THE d-D REACTION CHANNELS

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Abstract: Measurements on the angular distributions are reported for $D(d,n)^3He$ and $D(d,p)^3H$ reactions with E_d ranging from 3 to 6 MeV. The angular range imposed on detection of ^3He and ^3H in the two reactions respectively was 10° - 40° degrees in the laboratory frame of refence.
The evaluated branching ratio $\sigma(d+D\rightarrow{}^3He+n)/\sigma(d+D\rightarrow{}^3H+p)$, differing in magnitude from the expected value of 1, seemingly suggest the nuclear charge symmetry breaking.

(nuclear charge symmetry, violation, d-D reaction, angular distribution, branching ratio)

Introduction

During the past few years some experimental evidences expressed the need for verification of the symmetry laws of strong interactions by new and more precise experimental studies. In particular, experimental results concerning the properties of the few nucleons systems seem to indicate the breaking of nuclear charge symmetry and charge independence.

To verify these symmetry laws an intercomparison of the properties of mirror nuclei and of nuclear reactions, involving mirror system with few-nucleons is the most suitable technique. The d-D reaction, for which coulomb effects are expected to be small, is the simplest one to be considered.
It is widely known that the d-D reaction results in the following two "mirror" channels:

$$d+D \rightarrow \begin{cases} {}^3He + n;\ Q= +3.269\ MeV \\ {}^3H + p;\ Q= +4.033\ MeV \end{cases}$$

The former has been studied extensively mainly because it is largely used as a monoenergetic neutron source.

If the charge symmetry law holds the differential cross sections, the polarization observables and the binding energy of the mirror nuclei, are expected to be the same. In particular, the branching ratio of the d-D reaction channels:

$$R = \frac{\sigma(d+D\rightarrow {}^3He+n)}{\sigma(d+D\rightarrow {}^3H+p)} \qquad (1)$$

should be 1.

In the past many experimental and theoretical efforts were made to verify the validity of nuclear charge symmetry and independence laws by the d-D reaction. The results of the very extensive studies were summarized by L. Rosen[1] pointing out that "at low energy there does seem to be a difference. However, at higher energy these differences vanish except possibly at the very small angles. The disparities which do exit may be partially at least accounted for by coulomb effects in the stripping process".

The recent, empirical evidences[2], however, seem not to be in agreement with Rosen's conclusion.

In order to verify experimentally the validity of nuclear charge symmetry law at low energies, we are carrying out precise measurements of the angular distribution of d-D reaction products in the energy range from 3 to 25 MeV. In this paper, we report the first results obtained utilizing the 7 MV Van de Graaff CN accelerator at the INFN-Laboratori Nazionali di Legnaro, Legnaro - Padova, Italy, with 3 to 6 MeV deuterons and ^3He,^3H angular range from 10° to 40° degrees in the laboratory system.

Experimental Apparatus

The ^3He and ^3H nuclei resulting from the d-D reaction are simultaneously detected by silicon surface barrier detector DE-E telescope. Use is made of thin (50-90 $\mu gr/cm^2$) home made self supporting deuterated polyethylene targets with carbon backing (20 $\mu gr/cm^2$). The experimental arrangement is shown in Fig. 1 and is described elsewhere[3].

According to the kinematics of the reaction and the deuteron beam energies involved, the thickness of the SSB detectors has been chosen in a way that ^3He and ^3H recoil ions are stopped in a 27.5 µm ΔE and a 100 µm E detector, respectively, producing the largest pulses with respect to other particles (p, d, α). In such a way, ^3He and ^3H are well separated from other ions and the peak yield can be accurately evaluated. The detector pulses passing through pre-amplifier-linear-amplifier system are recorded by a PDP11/34 on-line computer. The beam current is measured by a current intergrator. The deuteron beam is stopped in the Farady cup, 1.0 m apart from the target.
For the angular distribution measurements during the different beam time alloted, several point check runs were recorded.

Results

Fig. 2 shows the differential cross section in the c.m. system based on ^3He and ^3H measurements for deuteron energy E_d=3.5 MeV. For comparison sake, the Blair [4] data for the same dueteron energy are displayed in Fig. 3. It can be seen that the data are in good agreement.

With the pretext of data presentation as the branching

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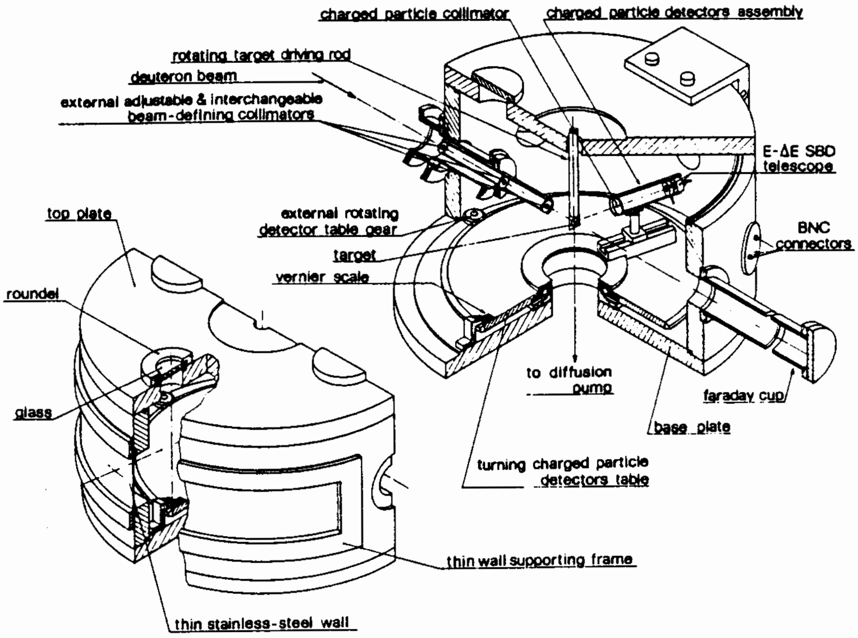


Fig. 1 Experimental Apparatus

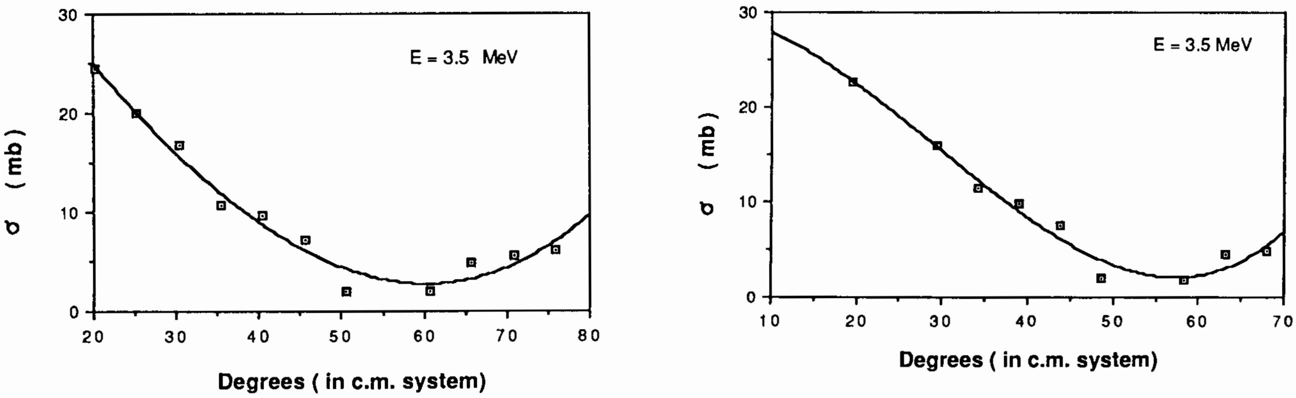


Fig. 2 Differential cross section in c.m. system for $D(d,n)^3He$ and $D(d,p)^3H$ for 3.5 MeV deuteron

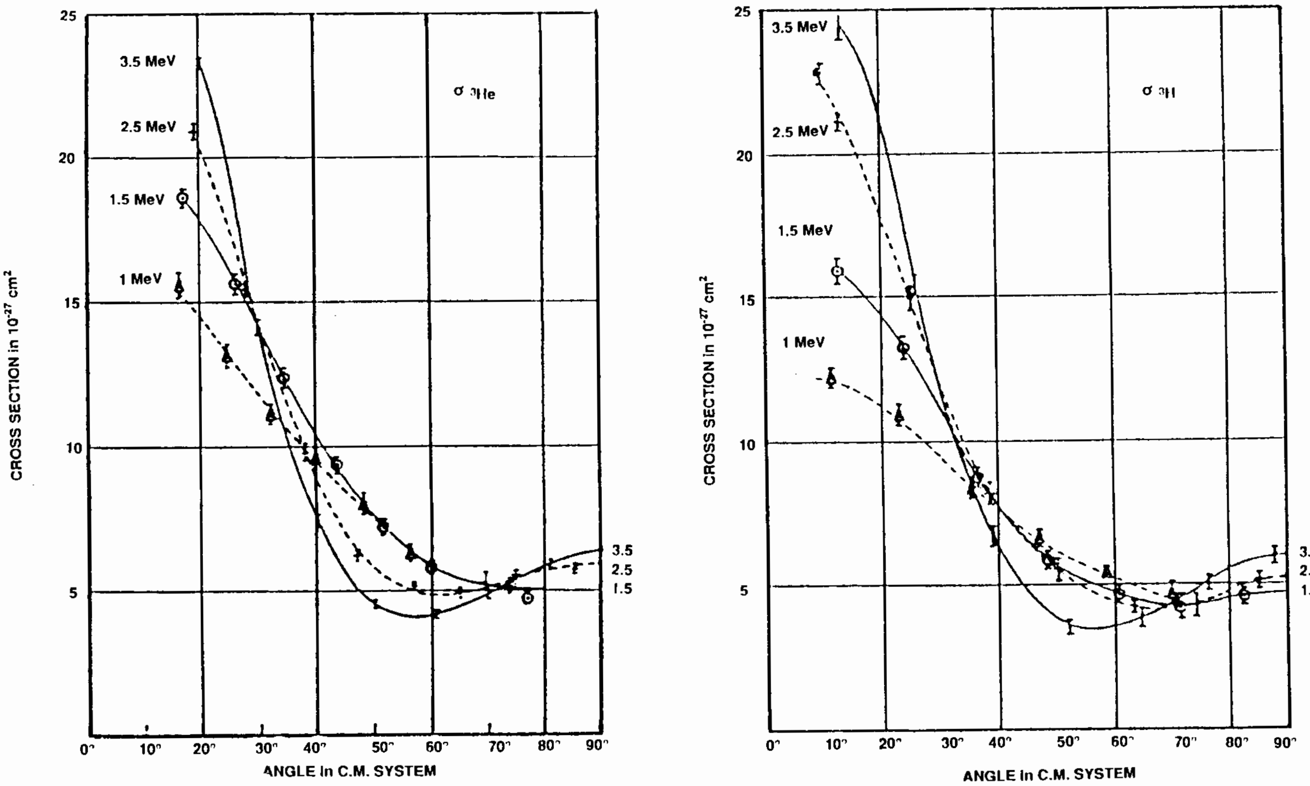
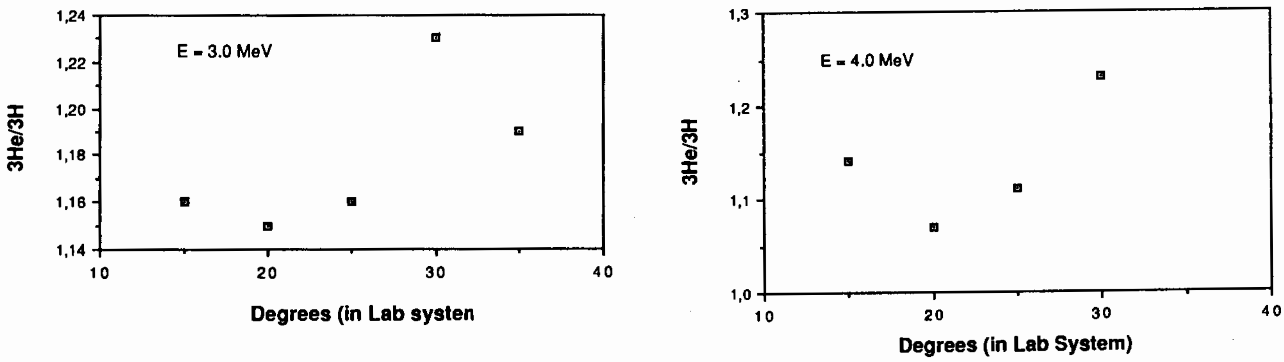


Fig. 3 Differential cross section in c.m. system of Blair et al. (ref. 4) for deuteron energy 1 to 3.5 MeV.



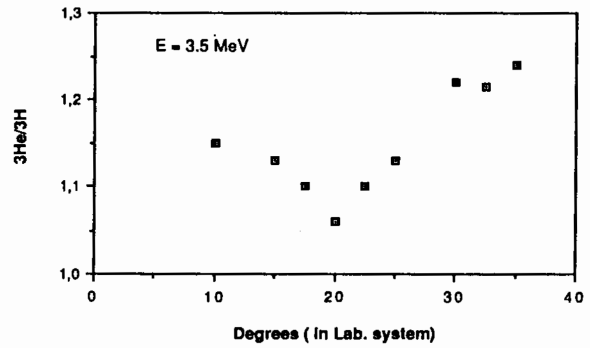


Fig. 4 $^3He/^3H$ ratios in Lab system for deuteron energy of 3.0, 3.5 and 4.0 MeV ratios in the c.m. system, it is to be pointed out that due to the different Q-values of the two reaction channels the c.m. angles corresponding to a given laboratory angle are different for ^3He and ^3H recoil ions. It is therefore necessary to fit the measured $\sigma_{c.m.}$ values.

Fig. 4 and 5 show the ratios in the lab and in the c.m. systems for E_d=3.0, 3.5 and 4.0 MeV. The differencies from the expected value of 1, cannot be acounted for by coulomb effects. It seems to suggest the invalidity of nuclear charge symmetry assumption, in agreement with the trend of some recent works.

Measurements at higher energies, up to 25 MeV, and data analysis are in progress.

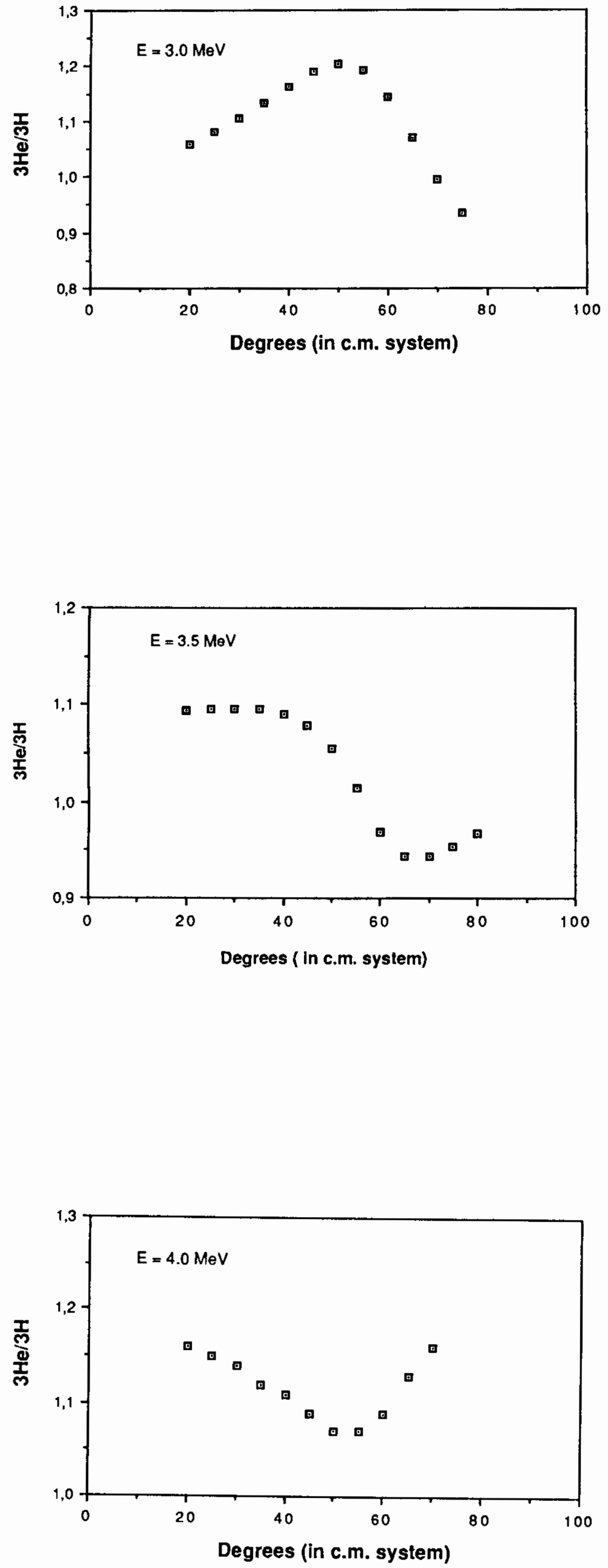


Fig. 5 $^3He/^3H$ ratios in c.m. system for deuteron energy of 3.0, 3.5 and 4.0 MeV

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