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J. Berger(x), G. Bizard(o), A. Boudard(+), J. Duflo(x), F. L. Fabbri, J. Goldzahl(x), C. Le Brun(o), J. Oostens(*), P. Picozza, F. Plouin(x) L. Satta, M. Van den Bossche(*), L. Vu Hai(*), Y. Terrien(+): ANGULAR DISTRIBUTION MEASUREMENT OF THE REACTION $\alpha p \longrightarrow {}^3$He d AT 3.98 GeV/c.

ABSTRACT: -The angular distribution of the reaction $\alpha + p = {}^3$He + d has been measured with 3.98 GeV/c incident alphas (434 MeV/nucleon). The results are compared with DWBA calculations.

Reactions involving the transfer of one nucleon between light nuclei at medium energy have been said to be a choice testing ground to observe the presence of N^* in nuclei (1, 2). The simplest of such reactions, p+d=d+p, has already been studied, and the results can be interpreted by means of a N^* component in the deuteron(2). Such an hypothesis could be confirmed by the study of d+d=^{3}He+n and p+^{4}He=d+^{3}He. Those two reactions are part of a program in progress at Saturne to investigate nucleon exchange processes. In this paper, we will present the results concerning ^{4}He+p=^{3}He+d at 3.98 GeV/c. For this particular incident energy, and in the domain of momentum transfer under investigation, it is not possible to draw information about the present of N^*. We do think, however, that it is necessary to have data at all energies since one has to be able to give good account of the one-neutron transfer reaction at the energies where N^* resonances do not play a role if one wants to extract information about N^* in nuclei from same reaction done

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at higher energies and higher momentum transfer. Indeed, even the "regular" neutron pick-up reaction is not trival to interpret at intermediate energies, since the use of the Distorted Wave Born Approximation (DWBA) may be not satisfactory and, almost, the high momentum components of the wave-function of neutrons in nuclei are not known (A plane wave calculation shows that we need to known the wave function in the range of 1.7-3.0 fm^{-1} of the momentum space).

On the experimental point of view, the transfer of a nucleon between ^{4}He and ^{3}He can be studied in several different ways: we have available at Saturne beams of protons, deuterons and alpha, and corresponding targets of ^{4}He, ^{3}He and protons. We have chosen to use an incident beam of alpha of 3.98 GeV/c (434 MeV/nucleon) with detection of the outgoing ^{3}He. The choice of this configuration presents a number of experimentally interesting features: (a) The ^{3}He leaves the target with plenty of energy; (b) The whole kinematical region is confined within 25° in the laboratory; (c) Background problems are minimized, as one observes a doubly charged particle.

An achromatic spectrometer with 1% FWHM momentum resolution(4) allows the measurement of the momentum of the ^{3}He after identification by time of flight and rate of energy loss. The observation angle of outgoing ^{3}He by respect to the incident beam can be varied from 0 to 15° in the laboratory, corresponding to a coverage from 0 to 55° in the center of mass. At fixed laboratory angle, the ^{3}He from $\alpha p = {}^3$He d show up as a narrow peak at the upper end of a continuum corresponding to the breakup of incident alphas(5). The experimental spectra were fitted with the sum of a second degree polynominal describing the tail of the break-up, and a gaussian representing the peak due to the two-body reaction (Fig. 1). Our measurement of the

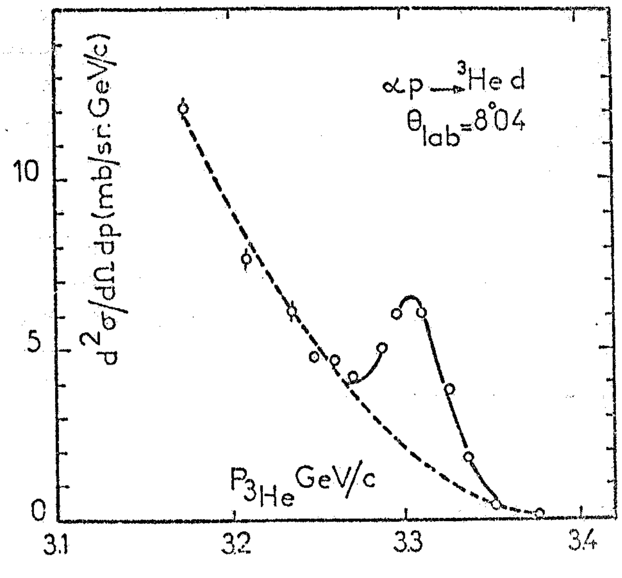

FIG. 1 - Momentum spectra of ^{3}He produced at 8.04° in the laboratory by α - p interaction at 3.98 GeV/c. Error bars have been omitted whenever they were smaller than the symbol used.

differential cross sections are presented in Table I. Nuclear absorption corrections of the order of 6% have been included.

TABLE I

θ^* in degrees	$(t_{max}-t)$ in $(GeV/c)^2$	$\frac{d\sigma}{dt}$ in mb $(GeV/c)^{-2}$
8.8	0.016	0.802 ± 0.039
17.1	0.056	0.597 ± 0.059
20.	0.082	0.450 ± 0.046
28.	0.154	0.156 ± 0.006
32.	0.202	(0.636 ± 0.015) x 10^{-1}
36.	0.254	(0.244 ± 0.006) x 10^{-1}
44.5	0.371	(0.160 ± 0.006) x 10^{-1}
51.1	0.481	(0.114 ± 0.006) x 10^{-1}
54.	0.530	(0.650 ± 0.060) x 10^{-2}

The accuracy of the results is of the order of ± 10%. Most of the uncertainty comes from the procedure used to subtract the continuous background. The systematic scaling errors due to the absolute calibration of the incident flux by radio-chemical method(6) and to the determination of the solid angle can be estimated to ± 5% each.

We present in Fig. 2 a calculation made in the framework of the DWBA.

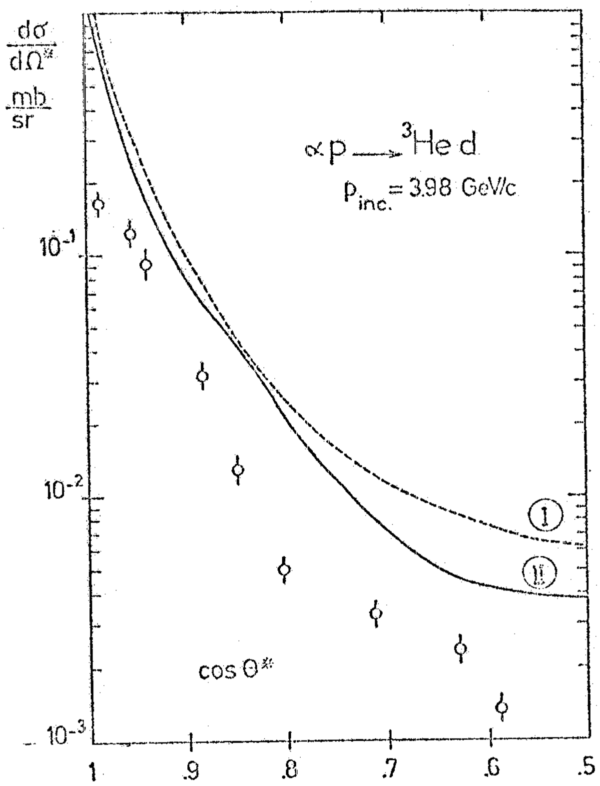

FIG. 2 - Differential cross section for the reaction α+p=^{3}He + d at 3.98 GeV. o: Our experimental data; I: Calculation using T. K. Lim's form factor(7); II: Calculation using the overlap of ^{3}He and ^{4}He wave functions(8).

That calculation (same as it has been done for $p+{}^{12}C \longrightarrow d+{}^{11}C$ in the first paper of ref. (3)) has been done with the code DWUCK which contains the zero-range approximation, i. e. the form factor is factorized as follows:

$$\langle p\ {}^{4}He \,|\, V \,|\, d\ {}^{3}He \rangle = D\sqrt{2}\ \phi^{*}(\bar{r}_{n})\ \delta(\bar{r}_{np}) ,$$

where $\phi(\bar{r}_n)$ is the wave function of the transferred neutron (the factor $\sqrt{2}$ comes from the fact that there are 2 such neutrons in ^{4}He), and D contains all the information about S and D- states of the deuteron (D=60 MeV fm$^{3/2}$). The optical potentials used are complex volume Woods-Saxon potentials, the parameters of which being V= + 36. 8 MeV, r = 0. 95 fm, a = 0. 25 fm, W = -37. 8 MeV, r' = 0. 94 fm, a' = 0. 23 fm for the proton channel and V = 92. 6 MeV, r = 1. fm, a = 0. 25 fm, W =-21. 7 MeV, r' =0. 93 fm, a' = 0. 20 fm, for the deuteron channel. They were derived by interpolation from an analysis of various data of p + ^{4}He elastic scattering. For the deuteron, we used the approximation that $V^{deut.}_{opt.}(E_d) \simeq 2\ V^{proton}_{opt.}(E_d/2)$. The main problem is perhaps in the choice of $\phi(r_n)$, since high momentum components of the neutron in ^{4}He are not known. However, in the very symmetric ^{4}He nucleus, it is reasonable to do the approximation that protons and neutrons have the same wave-function. Thus we took for $\phi(r_n)$ the function describing a proton in ^{4}He as calculated by T. K. Lim(7) to give a good account of e - ^{4}He elastic scattering. The result of the calculation is given by the curve I in Fig. 2. Another calculation (curve II on Fig. 2) has been done by using for $\phi(r_n)$the overlap of ^{4}He and ^{3}He wave functions as was described in ref. (8). Those wave-functions describe ^{3}He and ^{4}He as composed of single particles with short-range correlations. The parameters are adjusted to fit electron elastic scattering data on ^{3}He and ^{4}He up to $q = 4.5\ fm^{-1}$. One can see from Fig. 2 that the fit to our ^{4}He(p, d)^{3}He data is very similar with both choices for $\phi(r_n)$. However, the poor quality of the fit shows that the neutron pick-up reaction at intermediate energies is still not well understood and required careful attention.

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