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Charge exchange reaction induced by ^{6}He

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Abstract: The charge exchange reaction p(^{6}He,^{6}Li)n has been measured. No clear signature of a halo structure was found in the present data, due to the lack of large angle measurement.

1 Introduction

The (p,n) charge exchange reaction has been a privileged tool to explore nuclear structure and nuclear interactions. This reaction is highly selective since only isobaric analog states (IAS) and Gamow-Teller (GT) resonances are strongly populated. The transition to the IAS is a $\Delta T=1$, $\Delta S=0$ non spin flip Fermi transition (F), whereas the excitation of GT resonances proceeds via a $\Delta T=1$, $\Delta S=1$ spin flip transition, induced respectively by the V_τ and $V_{\sigma\tau}$ components of the nucleon-nucleon interaction. In particular, these studies provide information on the spectroscopic strength of the states involved in these reactions, on the fraction of the sum rule exhausted by these transitions, and on the interactions V_τ and $V_{\sigma\tau}$ [1].

Both the ground state of ^{6}He and its isobaric analog state in ^{6}Li are expected to behave like halo states [2-5], therefore two reasons motivated us for the study of the p(^{6}He,^{6}Li)n reaction: one is the possibility to get information on the interactions V_τ and $V_{\sigma\tau}$ in a low density region, the other is the sensitivity of the transition leading to the IAS with respect to the differences between the neutron and proton density distributions, as this was shown for example for a series of Sn isotopes [6]. Taking into account the significant effect observed for very small differences of radii in the Sn case, we would expect very strong effects in the case of the halo nuclei considered here.

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The experimental method has been described in another contribution to this compilation.

The charge exchange reaction cross section can be compared to β decay strength. This comparison for Fermi and GT transitions provides an essentially model independent means to extract the V_τ and $V_{\sigma\tau}$ interactions or more precisely their volume integral. A detailed review of this aspect can be found in ref. [1].

We have studied in the case of the present data for the p(^{6}He,^{6}Li)n reaction if we could extract a signature of the presence of a halo structure in $^6He_{g.s.}$ and its IAS in ^{6}Li, from the ratio of the cross sections for the Fermi and GT transitions. Indeed, the ratio R defined by the relation

$$R^2=\widehat{\sigma_{GT}}/\widehat{\sigma_F} \tag{2}$$

where σ is a unit cross section depending on the incident energy and the target mass, is closely related to the ratio of the volume integral J_τ and $J_{\sigma\tau}$ of the interactions V_τ and $V_{\sigma\tau}$. It can be expressed as:

$$R=\left|\frac{J_{\sigma\tau}}{J_\tau}\right|\left(\frac{N_{\sigma\tau}}{N_\tau}\right)^{1/2}\approx\left|\frac{J_{\sigma\tau}}{J_\tau}\right| \tag{3}$$

where N_τ and $N_{\sigma\tau}$ are distortion factors defined by the ratio of the plane wave to distorted wave amplitudes. At the present energy, the ratio $N_{\sigma\tau}/N_\tau$ is close to 1.

As shown is ref. [1], R can be determined experimentally and it is related to the 0° cross sections by the relation:

$$R^2=\frac{\sigma_{GT}(0°)(N-Z)}{\sigma_F(0°)B(GT)} \tag{4}$$

A compilation of the ratio R obtained using equation (4) for N=Z+2 nuclei is shown on Fig. (1). The data corresponding to ^{7}Li, ^{14}C, ^{18}O, ^{26}Mg(p,n) reactions are from ref [7-10],

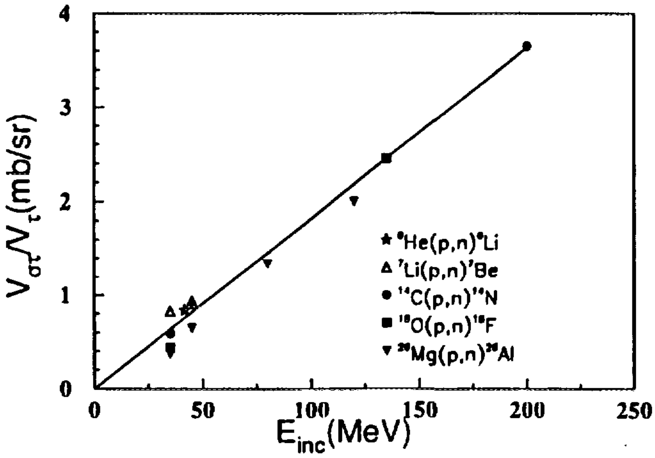
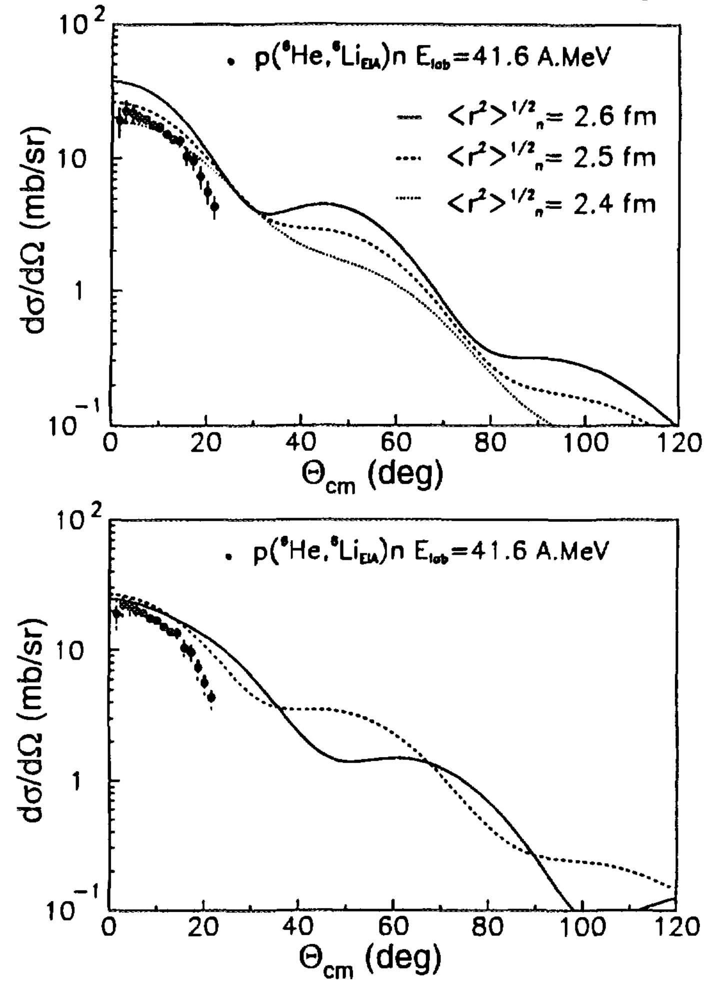


Fig. (1): Compilation of the reduced transition strength ratio R of GT and Fermi charge exchange transitions in light nuclei as a function of the incident energy of the proton.

and the calculation used the B(GT) values from Taddeucci et al [1]. The linear energy dependence of R is a well established behaviour observed for many stable nuclei [1] and has been attributed to the energy dependence of the V_τ potential. Brown, Speth and Wambach [11] have shown, using a meson exchange model, that this energy dependence arises essentially from a two pion exchange contribution to the V_τ potential.

The ratio R was also computed for the transitions measured in the present experiment, by applying equation (4). The value of B(GT) which is necessary to compute R was obtained from β decay lifetime measurements and is given in ref. [1] for the inverse β decay transition ^{6}Li--->^{6}He.

It is known that the volume integral of the spin-isospin term $J_{\sigma\tau}$ measured for ^{6}Li(n,p)^{6}He ground state (GT) transition is in good agreement with the values obtained for other systems [12], as well as with the theoretical predictions of Nakayama and Love [13]. The ratio R, or $\left|\frac{J_{\sigma\tau}}{J_\tau}\right|$ measured in the present experiment is in agreement with the systematic behaviour established for T=1 nuclei. This means that the isospin term J_τ also shows no deviation from the values obtained for stable nuclei. Therefore we conclude that, from the ratio of the cross sections at 0°, we can not see any difference between a transition connecting two halo states, or one halo state and a standard one, and finally two standard states[14].



Fig(2): Top, Influence of the r.m.s. radius of the density distribution on the charge exchange density distribution. Bottom, Influence of the shape of the density distribution (see text)

The upper part of Figure (2) presents the angular distribution measured for the Fermi transition connecting the ^{6}He ground state and its isobaric analog state compared to the predictions obtained by using the JLM optical potential for the entrance and exit channel, and by estimating the transition potential with the Lane equations [15]. The different curves correspond to different values of the r.m.s. radius for the ^{6}He density distribution, which was assumed for these calculations of gaussian shape.

The rather large differences observed between the different curves show that the angular distribution is very sensitive on the complete angular range to the value of the r.m.s. radius of the density distribution. However differences in the detailed shape of the densities manifest themselves only at large angles. The lower part of Figure (2) compares the angular distributions obtained for different density distributions of ^{6}He and ^{6}Li having the same r.m.s. radius but different shape in the tail: the dashed line corresponds to gaussian shape, whereas the solid line corresponds to the density distributions calculated by Arai et al.[5]. The calculated angular distributions differ significantly only above Θ_{cm}=40°, whereas the present data do not extend above Θ_{cm}=20°. Therefore it would be extremely interesting to obtain new data at larger angles.

3 Conclusions

From the analysis of the (p,n) charge exchange reaction at 0° connecting the ^{6}He ground state and the ^{6}Li ground state or the IAS at 3.56 MeV, we conclude that the presence or absence of a halo structure does not influence the transition strength in a (p,n) reaction. The influence of the halo seems to manifest itself only in the backward part of the angular distributions of the charge exchange reaction.

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