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A SEARCH FOR THE $\Delta^{-}$ WAVE-FUNCTION COMPONENT IN LIGHT NUCLEI

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We have studied the $(\pi^{+}, p \pi^{-})$ reactions on $^{3}\text{H}$, $^{4}\text{He}$, $^{6}\text{Li}$, and $^{7}\text{Li}$ at incident energy 500 MeV in quasi-free kinematics. A signature attributable to pre-existing $\Delta^{-}$ components of the ground state wave function is observed.

Meson models of nuclear binding predict both excess pions and excited nucleons in nuclear matter. Results from a new method of measuring the $\Delta^{-}$ component of the nuclear wave function using the pion double charge exchange (DCX) reaction $(\pi^{+}, \pi^{-})$ are reported in this paper.

If the nucleus contains only nucleons, two like-charge nucleons must participate in the DCX process. If the nuclear wave function contains a $\Delta^{-}$, the $(\pi^{+}, \pi^{-})$ process can occur in a single step. Recent measurements on a range of nuclei have yielded evidence for this effect. In the current work we have extended these studies to $^{3}\text{H}$, $^{4}\text{He}$, $^{6}\text{Li}$, and $^{7}\text{Li}$.

The experiment was performed using a 500 MeV beam at the Clinton P. Anderson Meson Physics Facility. Pions from $(\pi^{+}, p \pi^{-})$, NCX, and $(\pi^{+}, p \pi^{-})$, DCX, reactions were observed at an angle of 50$^\circ$ in coincidence with protons at 52$^\circ$ using two magnetic spectrometers, in the kinematics of free $\pi p$ scattering. The sum of the pion and proton energies was required to exceed 400 MeV.

An estimate of the probability for pre-existing $\Delta^{-}$'s can be obtained from the data by integrating the cross sections and forming the ratio $R = \sigma_{\text{DCX}}/\sigma_{\text{NCX}}$:

$$P_{\Delta} = R \left( \frac{Z N_{\Delta^{-}}}{A N_{\Delta^{-}}} \right) \left( \frac{\sigma(\pi^{+} + p \rightarrow \pi^{+} + p)}{\sigma(\pi^{+} + \Delta^{-} + \pi^{-} + p)} \right) \left( \frac{k_{\Delta^{-}}}{k_F} \right)^2$$

(1)
Table 1: Measured cross section ratios and extracted values of $P_\Delta$.

<table>
<thead>
<tr>
<th>Target</th>
<th>$\sigma_{DCX}/\sigma_{NCX}$ (x10^3)</th>
<th>$P_\Delta^-$ (%)</th>
<th>$P_\Delta$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^3$H</td>
<td>8.9(6)</td>
<td>1.72(12)</td>
<td>3.44(24)</td>
</tr>
<tr>
<td>$^4$He</td>
<td>0.90(18)</td>
<td>0.26(5)</td>
<td>1.04(20)</td>
</tr>
<tr>
<td>$^6$Li</td>
<td>0.67(13)</td>
<td>0.20(4)</td>
<td>0.73(15)</td>
</tr>
<tr>
<td>$^7$Li</td>
<td>5.4(5)</td>
<td>1.68(15)</td>
<td>4.22(40)</td>
</tr>
</tbody>
</table>

where $P_\Delta$ is the sum of the probabilities for all $\Delta$ charge states, $N_{\Delta^-}/N_\Delta$ is the fraction of $\Delta^-$'s, $Z$ and $A$ are the proton and nucleon numbers, and $k_\Delta$ and $k_F$ characterize the momentum spreads of the $\Delta$'s and nucleons. We have used measured branching ratios$^3$ for $N^*(1520) \rightarrow \pi+N$ and $N^*(1520) \rightarrow \pi+\Delta(1232)$ to estimate the cross-section ratio, and have taken $k_F = 200$ MeV/c and $k_\Delta = 400$ MeV/c, the peak of the momentum distribution predicted for the calculated pion excess.$^1$ The ratios of $\Delta$ charge states have been obtained by generalizing arguments given in$^4$ to give:

$$\frac{N_{\Delta^-}}{N_\Delta} = \frac{3}{4} \left( 1 + \frac{Z}{2(N-1)} + \frac{Z(Z-1)}{N(N-1)} \right)^{-1},$$

where $N$ is the neutron number of the nucleus. The measured cross section ratios and resulting $\Delta$ probabilities are given in Table 1.

The $\Delta^-$ probability in $^3$H is found to agree roughly with theoretical expectations.$^5$ Moreover, the $\Delta^-$ probabilities in the light self-conjugate nuclei are approximately an order of magnitude smaller than those in the $T=1/2$ nuclei. This is presumably because only core-excited two-particle configurations or $\Delta\Delta$ excitations can contribute to the $\Delta$ probabilities for neutron pairs coupled to $J=0$ within the s-shell.

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References