j Dependence of the Vector Analyzing Power for (d, ^{3}He) and (d,t) Reactions*

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Angular distributions of cross sections and vector analyzing powers were measured in the reactions ^{208}Pb(d,^{3}He)^{207}Tl and ^{208}Pb(d,t)^{207}Pb at 30 MeV. The vector analyzing powers show a strong j dependence in both reactions. The distorted-wave Born approximation provides qualitative fits to the data for several transitions in ^{208}Pb.

We report here the results of an investigation that shows a strong j dependence of the vector analyzing power in the reactions ^{208}Pb(d, ^{3}He)^{207}Tl and ^{208}Pb(d, t)^{207}Pb induced with vector-polarized deuterons. A number of experiments have shown that the vector analyzing power for (d, p) and (p, d) reactions with polarized incident particles depends strongly on the j value of the transferred neutron for a given orbital-angular-momentum transfer.[1,2] Recently, this property, along with distorted-wave Born-approximation (DWBA) fits to measured analyzing powers, has been exploited to provide spin assignments to a substantial number of states populated by these reactions in nuclei with A ranging from 40 to 187.[3] Also, J^π assignments of several states in ^{209}Pb have been confirmed with this method.[4] It has been shown that the neutron-pickup reaction ^{208}Pb(d, t)^{207}Pb near 12 MeV also shows a strong j dependence of the vector analyzing power.[4,5] Since the same states can be reached via the (p, d) reaction, either reaction can be selected, in principle, to provide J^π assignments for the product nuclear states.

The (d, ^{3}He) proton-transfer reaction, of course, could provide another large number of states whose J^π values could be assigned or confirmed if the expected similar j dependence of the vector analyzing power were established; the present lack of polarized neutron beams makes the analogous (n, d) experiment unfeasible. One should note that the j dependence of the polarization or vector analyzing power in proton-transfer reactions has not yet been experimentally demonstrated, whereas a few (d, n) experiments with polarized d or n have been performed.[6] Data on the reaction ^{208}Pb(d, t)^{207}Pb were taken concurrently so as to extend to higher energies the study of the j dependence in this reaction.

The experiment was performed with a 30-MeV vector-polarized deuteron beam from the Berkeley 88-in. cyclotron. The target was a 0.85-mg/cm^2 ^{208}Pb foil. Left-right asymmetry data were taken simultaneously at two angles separated by 20°, using pairs of ΔE-E silicon-detector telescopes. In order to eliminate instrumental asymmetries, alternate runs were taken with the spin vector of the beam oriented up and down with respect to the reaction plane. Particle identification was used to gate the ^{3}He and tritons into separate spectra. The beam polarization was monitored continuously with a polarimeter placed downstream of the main scattering chamber. The analyzer used was ^{4}He, whose analyzing power in the d-^{4}He elastic scattering, measured previously,[7] was 0.974 ± 0.016 at 30 MeV and $\theta_L = 135°$. The vector polarization of the beam was typically $p_y \simeq 0.52$.

The (d, ^{3}He) and (d, t) reactions populate[8] essentially the $3s_{1/2}$, $2d_{3/2}$, $1h_{11/2}$, and $2d_{5/2}$ proton hole

TABLE I. Parameters used in DWBA calculations for ^{208}Pb(d,^{3}He)^{207}Tl and ^{208}Pb(d,t)^{207}Pb.[a]

	V_r	r_R	a_R	W_v	W_{SF}	r_I	a_I	V_{so}	r_{so}	a_{so}
d	84.78	1.05	0.85	0.0	23.44	1.32	0.826	6	1.0	0.5
^{3}He	158.1	1.2	0.72	42.2	0.0	1.4	0.88	2.5	1.2	0.72
t	159.0	1.2	0.72	13.7	0.0	1.4	0.86	2.5	1.2	0.72

[a]The notation is that of Ref. 10. The transferred particle is bound in a Woods-Saxon potential with radius $r = 1.25$ fm, diffuseness $a = 0.65$ fm, and spin-orbit factor $\lambda = 25$. The depth of this potential is adjusted in order to reproduce the binding energy of the bound particle.

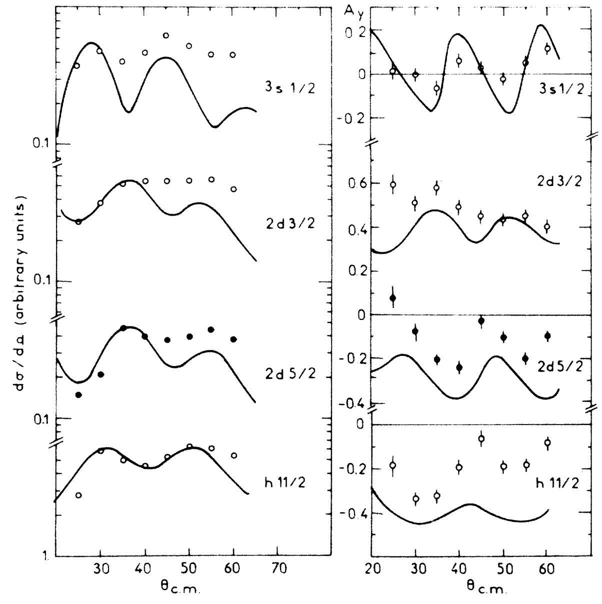

FIG. 1. Angular distributions of cross sections and vector analyzing powers for the reaction ^{208}Pb($\boldsymbol{d}$, ^{3}He)^{207}Tl at 30 MeV, and DWBA predictions.

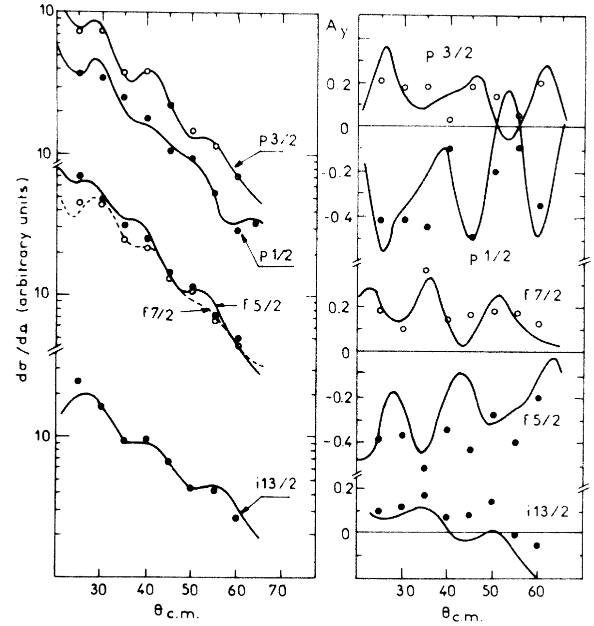

FIG. 2. Angular distributions of cross sections and vector analyzing powers for the reaction ^{208}Pb($\boldsymbol{d}$,t)^{207}Pb at 30 MeV, and DWBA predictions.

states and the $3p_{1/2}$, $2f_{5/2}$, $3p_{3/2}$, $1i_{13/2}$, and $2f_{7/2}$ neutron hole states in ^{207}Tl and ^{207}Pb, respectively. The angular distributions of the vector analyzing power, $A_y(\theta)$, exhibit a strong j dependence for the $2d$ states populated by the (d, ^{3}He) reaction (Fig. 1) and for the $3p$ and $2f$ states from the (d, t) reaction (Fig. 2). The sign of $A_y(\theta)$ for $j=l+\frac{1}{2}$ is opposite to that for $j=l-\frac{1}{2}$ over most of the angular range studied, so the ease and unambiguity of j assignment from such measurements is clearly demonstrated. Moreover, the DWBA calculation gives a good qualitative count of this effect. In the DWBA calculations shown in Figs. 1 and 2, the deuteron optical potential (Table I) was generated by fitting cross sections of deuteron elastic scattering from ^{208}Pb at 27.5 MeV [10]; the ^{3}He and triton optical-potential parameters (Table I) were those derived by Becchetti and Greenlees[9] from a global optical-model analysis. Actually, the effect of a spin-orbit potential of 2.5 MeV in the ^{3}He or t channel is quite negligible both on the cross section and on the analyzing power. The magnitude of the calculated analyzing power for the transition to the $3s_{1/2}$ state is roughly proportional to the deuteron spin-orbit term; but this term has a much smaller effect on the analyzing power for $l\neq 0$ states.

In summary, a strong j dependence of the vector analyzing power in (d, ^{3}He) reactions has been experimentally established for $l=2$ transitions in ^{208}Pb. Thus, this reaction can be used to determine the spins of the many nuclear states that can be reached via proton transfer, in the same manner as has been so successful in neutron-transfer experiments.

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Further Observation of Muonless Neutrino-Induced Inelastic Interactions*

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We report here additional positive results of a search for muonless neutrino- and antineutrino-induced events using an enriched antineutrino beam and a muon identifier of relatively high geometric detection efficiency. The ratio of muonless to muon event rates is observed to be $R = 0.20 \pm 0.05$. We observe no background derived from ordinary neutrino or antineutrino interactions that is capable of explaining the muonless signal.

The investigation reported here is a search for inelastic neutrino and antineutrino interactions at a mean energy of 40 GeV that differ from the usual processes by the absence of a muon in the final state.[1] A previous search for such events yielded a positive signal. Muonless events have also been reported in a CERN-Gargamelle experiment at a mean energy in the range of 2 to 4 GeV.[2]

The experiment was carried out at the National Accelerator Laboratory, where collisions of 300-GeV protons with an aluminum target produced secondary hadrons that were focused by a single magnetic horn to provide a beam enriched in antineutrinos.[3] The experimental apparatus [Fig. 1(a)] is a modified version of the arrangement described previously.[1,4] The modifications are (1) the addition of 35 cm of iron immediately downstream of the ionization calorimeter to form a muon identifier (μ_1) consisting of counter B and spark chamber 4, and (2) doubling of the area of counter C and replacement of the 5.3-m^2 narrow-gap spark chambers in the magnetic spectrometer with 8.4-m^2 wide-gap chambers to increase the solid angle of the second (original) muon identifier (μ_2).

The experiment was triggered by the deposition of energy (E) in the ionization calorimeter greater than a preset minimum value,[5] with counter A in anticoincidence. The hadron cascade of an actual event is illustrated in Fig. 1(b) and the track pattern observed in spark chambers SC1–SC8 is illustrated in Fig. 1(c) which shows one of the three stereoscopic views of the event. Events were verticized by extrapolation of tracks in the two $\pm 7.5°$ stereo views and in the 90° stereo view, and consistency was required between the z position obtained from the visual reconstruction of the vertex and the calorimeter pulse-height information.

The z dependence of all triggers was observed to be uniform except for a small excess of events in the first segment (module) of the target detector, which is consistent with the small (5%) geometrical inefficiency of counter A. There is no evidence of neutrons or photons, unaccompanied by charged particles, entering the front of the target. Since each segment of the calorimeter corresponds to approximately 0.6 nuclear collision lengths, to provide additional protection