200 ps, i.e., approximately the same as the lifetime of the free Λ particle. In any event, the present experiment provides an upper limit of about 20 μb for the 0° production cross section of other γ-emitting hypernuclear states in the (K^-, π^-) reaction at 1.7 GeV/c, and demonstrates conclusively that present technology is sufficient to measure such small cross sections in particle-γ coincidence experiments with currently available kaon beams.

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Difference in Analyzing Powers for (p,t) Reactions Due to a Phase Change of Interference between Direct and Indirect Processes in Two-Nucleon Transfer Reactions

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A marked difference between analyzing powers for reactions ^{128}Te$(p,t)^{126}$Te(2_1^+) and ^{110}Pd$(p,t)^{108}$Pd(2_1^+) with polarized protons has been observed, while the ground-state transitions have shown similar analyzing powers. The difference is accounted for as a result of a phase change of the interference between direct and inelastic multistep processes in two-neutron pickup reactions. The origin of this phase change is elucidated on the basis of the microscope description of the collective quadrupole oscillation of nuclei.

The interference between a direct process and inelastic multistep processes (nucleon transfer followed by inelastic scattering and the inverse) in two-nucleon transfer reactions is quite sensitive to the nuclear structure involved. The neutron-number (N) dependence of this type of interference in excitation of the first 2^+ (2_1^+) states has been extensively studied for the nuclei of $N \approx 82-50$ by using (p,t) reactions on the isotopes of $^{A+2}$Nd$(A+2=150-142)$,[1,2] Te$(A+2=130-122)$,[3,4] Sn(118, 116),[3,5] Cd(116–112),[3,5] and Pd(110–104).[5,6] In consequence, a phase change from constructive to destructive interference has been found in the Pd isotopes.[6] The phase change has been interpreted as a result of a sign change of the form factor of the direct transfer process in going from Te, Sn, and Cd to Pd isotopes on the basis of the BCS and quasiparticle-RPA (random-phase approximation) model.[6,7]

The experimental and theoretical results mentioned above are all due to the measurements of the differential cross sections of the (p,t) reactions leading to the ground states (0_g^+) and the 2_1^+ states. Measurements of analyzing powers for (p_{pol},t) reactions leading to the same 2_1^+ states are expected to provide a sensitive probe to detect whether the nature of the interference is constructive or destructive. Such measurements are of fundamental importance in understanding the microscopic structure of vibrational characters[5] of nuclei as well as the reaction dynamics of the processes.

Analyzing powers for the reactions ^{128}Te$(p_{\text{pol}},t)^{126}$Te$(0_g^+$ and $2_1^+)$ and ^{110}Pd$(p_{\text{pol}},t)^{108}$Pd$(0_g^+$ and $2_1^+)$ were measured at $E_p = 22.0$ MeV. The nuclei ^{128}Te and ^{110}Pd were chosen as targets because the previous measurements of the differential cross sections showed that the ^{128}Te$(p,t)^{126}$Te(2_1^+) transition[3,4] had constructive interference while ^{110}Pd$(p,t)^{108}$Pd(2_1^+)[6] had destructive. A polarized proton beam was produced with a Lamb-shift ion source[8] and was accelerated with the University of Tsukuba 12UD Pelletron. The beam intensity was about 50 nA on target and

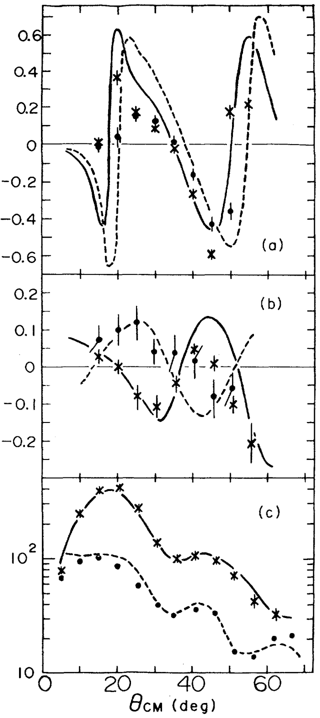

FIG. 1. Experimental and calculated analyzing powers $A(\theta)$ and cross sections $\sigma(\theta)$ for reactions ^{128}Te(p, t)^{126}Te and ^{110}Pd(p,t)^{108}Pd at $E_p = 22.0$ MeV. The 0_g^+ transitions are in (a) and the 2_1^+ transitions in (b) and (b). The crosses [circles] are for ^{128}Te(p,t) [^{110}Pd(p, t)] transitions. The solid [dashed] curves are CCBA calculations of $A(\theta)$ and $\sigma(\theta)$ for the ^{128}Te(p,t) [^{110}Pd(p, t)] transitions.

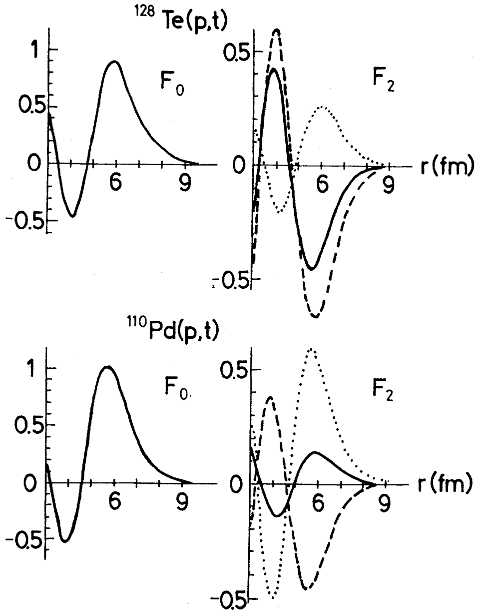

FIG. 2. Radial dependence of transfer form factors $F_0(0_g^+ \to 0_g^+)$ and $F_2(0_g^+ \to 2_1^+)$. On the right side for the F_2, dashed and dotted curves show the contributions from the RPA forward- and backward-scattering amplitudes, respectively, and solid curves are sums of the two contributions.

the degree of polarization of the proton beam was (85 ± 2)%. The ^{128}Te and ^{110}Pd targets were enriched metallic films of 0.5 mg/cm^2 thickness. The emitted tritons were analyzed with a magnetic spectrograph and detected with a silicon position-sensitive detector mounted in the focal plane. The energy resolution was 40 keV with an angular spread of $\Delta\theta = \pm 1.5°$.

Angular distributions of the analyzing powers $A(\theta)$ are shown in Figs. 1(a) and 1(b). The most striking features of the $A(\theta)$ observed are the following: (i) A pronounced difference exists between the $A(\theta)$ for ^{128}Te(p_{pol},t)^{126}(2_1^+) and ^{110}Pd(p_{pol},t)^{108}Pd(2_1^+) transitions, viz., the sign of the analyzing power is almost opposite in the two cases [Fig. 1(b)]; (ii) on the other hand, the $A(\theta)$ for the ^{128}Te(p_{pol},t)^{126}Te(0_g^+) transition is quite similar to that for the ^{110}Pd(p_{pol},t)^{108}Pd(0_g^+) transition [Fig. 1(a)].

The (p_{pol},t) transitions to the 0_g^+ and 2_1^+ states are analyzed in terms of coupled-channel Born-approximation (CCBA) calculations.[9] Under the BCS and quasiparticle-RPA model the nuclear wave functions for the 0_g^+ and 2_1^+ states are constructed by using both the monopole pairing interaction and the Q-Q interaction.[10] Details on the procedure are found in Refs. 4, 5, 7, and 11. Transfer form factors $F_0(0_g^+ \to 0_g^+)$ and $F_2(0_g^+ \to 2_1^+)$ together with the contributions to $F_2(0_g^+ \to 2_1^+)$ from the RPA forward- and backward-scattering amplitudes are shown in Fig. 2. Form factors for transitions between the 2_1^+ states are assumed to be proportional to those of the ground-states transitions as in the cases of Refs. 4 and 6.

It should be noted that the radial form factor $F_2(0_g^+ \to 2_1^+)$ at the nuclear surface ($r \sim 6$ fm) changes its sign in going from ^{128}Te(p,t) to ^{110}Pd(p,t), while the other form factors $F_0(0_g^+ \to 0_g^+)$ and $F_L(2_1^+ \to 2_1^+)$ do not. The sign change is ascribed to an increase of the contribution from the backward-scattering amplitudes in the Pd isotopes (Fig. 2). This change can be traced to the sign change in the spectroscopic amplitude for the direct transfer process,[12]

$$B(jj'; 0_g^+(A+2) \to 2_1^+(A)) = \sqrt{5}[-V_jV_{j'}x(jj') + U_jU_{j'}y(jj')],$$

where the x's and y's are the forward- and backward-scattering amplitudes in RPA, respectively, and V_j (U_j) is the occupied (unoccupied) amplitude of the j orbit. The amplitude B is determined by the competition between the forward contributions VVx and the backward contributions UUy. The latter exceeds the former[13] in the case of the Pd isotopes because (i) the UU are larger than the VV near the beginning of the major shell $N=50-82$, and (ii) the y's become considerably large because of an increase of ground-state correlations in the Pd isotopes; indeed deformation parameters β_2 for the quadrupole oscillation of the Pd isotopes are as large as[14] $\beta_2=0.25$. The spectroscopic amplitude for the inelastic transition in the multistep processes is expressed as

$$B(jj';0_g^+(A)\rightarrow 2_1^+(A)) \propto U_jV_{j'}x(jj')+V_jU_{j'}y(jj').$$

Therefore the inelastic form factor at the nuclear surface does not change its sign in going from Te to Pd isotopes.[13] Actual calculations for the analyzing power and cross section for the 2_1^+ state of ^{108}Pd are done by the use of the form factor $F_2(0_g^+\rightarrow 2_1^+)$ which has been determined[6] by fitting the experimental 2_1^+ cross section for 52-MeV protons.[15]

Optical-potential parameters for protons are obtained from the work of Becchetti and Greenlees[16] and those for tritons are from Flynn *et al.*[17] Calculated analyzing powers are shown in Figs. 1(a) and 1(b). The essential features of the experimental analyzing powers described in (i) and (ii) (similarity between the two 0_g^+ transitions and difference between the two 2_1^+ transitions) are well reproduced by the calculations, although there is room for improvement in fitting the 2_1^+ analyzing powers.[18] In addition, the 2_1^+ cross sections [Fig. 1(c)] are also well reproduced by the CCBA calculations both in angular distributions and intensities.

In conclusion, analyzing powers for (p_{pol},t) reactions are very powerful for detecting the interference mode (phase) between direct and inelastic multistep processes in two-nucleon transfer reactions. The difference between constructive and destructive interference appears distinctly as a difference in sign of the analyzing powers. The phase change of the interference is attributed to the neutron-number dependence of the occupation probability of single-particle orbits and that of ground-state correlations of the quadrupole oscillation of nuclei. In this sense the (p_{pol},t) analyzing power is a sensitive probe for detecting the microscopic characteristics of collective oscillations of nuclei.

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