Polarization transfer in quasifree $(\vec{p},\vec{n})$ reactions on C, Ca, and Pb targets at 197 MeV

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A complete set of polarization-transfer observables has been measured at 197 MeV in the quasifree region for the $(\vec{p},\vec{n})$ reactions on C, Ca, and Pb targets. Data have been obtained at laboratory scattering angles of 13°, 24°, 37°, and 48°, which span an energy-loss range up to 150 MeV, with a corresponding momentum-transfer range $q=0.75$–$2.4\ \mathrm{fm}^{-1}$. The empirical results are compared to the observables obtained from the free nucleon-nucleon data base. Derived spin-longitudinal and spin-transverse responses for Ca are compared with those previously obtained at 346 and 495 MeV incident energies.

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I. INTRODUCTION

In the previous paper [1], we have presented a complete set of polarization-transfer observables in the region of quasielastic scattering for the light nuclei ^{2}H and ^{3,4}He, results which in the ^{2}H case are amenable to be compared with *ab initio* calculations. In this paper we report on double differential cross sections and complete sets of polarization observables for the heavier targets C, Ca, and Pb, data which we compare to observables calculated using the free nucleon-nucleon (NN) data base. Theoretical random phase approximation (RPA) calculations on heavy targets indicate that for momentum transfers, $q \geqslant 1.0\ \mathrm{fm}^{-1}$, these targets should exhibit a strong enhancement in the spin-longitudinal response [2].

Polarization-transfer observables for quasifree $(\vec{p},\vec{n})$ reactions on C and Ca, have been obtained at 495 MeV and reported by Chen *et al.* [3] and later by Taddeucci *et al.* [4] at scattering angles of 12.5°, 18°, and 27° (q≈1.2, 1.7, and 2.5 fm^{-1}, respectively). Wakasa *et al.* [5] have also recently reported on a complete set of polarization-transfer coefficients measured for quasielastic $(\vec{p},\vec{n})$ reactions on C, Ca, and ^{208}Pb at a bombarding energy of 346 MeV and a laboratory scattering angle of 22°, $q \approx 1.7\ \mathrm{fm}^{-1}$.

We have measured a complete set of polarization-transfer data for quasielastic $(\vec{p},\vec{n})$ reactions at 197 MeV on natural C (98.9% ^{12}C), natural Ca (96.9% ^{40}Ca), and natural Pb at momentum-transfers between $q=0.75$–$2.4\ \mathrm{fm}^{-1}$. The natural C and natural Ca targets are essentially monoisotopic ^{12}C, ^{40}Ca targets and for purposes of studying quasielastic excitation, the natural Pb target may be considered a monoisotopic target ^{208}Pb.

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II. EXPERIMENTAL METHODS

The experiments were performed at the Indiana University Cyclotron Facility (IUCF) using the beam swinger, and two neutron polarimeters INPOL [6] and the Kent State "2π" neutron polarimeter [7]. The experiment was performed during several running time periods that span about 3 yr. Detailed descriptions of the INPOL facility and the neutron polarimeter systems can be found in Refs. [6,7]. A brief description of the experimental setup relevant to the present experiment is presented in the previous paper [1]. We indicate below only those aspects relevant to this experiment.

A. Targets

A complete set of polarization-transfer coefficients was measured for $(\vec{p},\vec{n})$ reactions on self-supported natural targets of C, Ca, and Pb each with a total thickness of 150, 590, and 980 $\mathrm{mg/cm}^2$, respectively. The beam intensity was limited to 350 nA especially for the Pb target because of the large radiation field created in the vicinity of the target area. Other solid targets were also used, such as ^{7}Li and ^{6}Li for purposes of normalization of the double differential cross section and calibration of the neutron polarimeter, respectively.

B. Polarized proton beam

The proton beam polarization was cycled between "normal" and "reverse" at 30 sec intervals. Superconducting solenoids located in the proton beam line were used to precess the proton spin polarization so as to have on target either of the three spin states, normal $\hat{N}$, sideways $\hat{S}$, and longitudinal $\hat{L}$. Values of the proton beam polarization were continuously measured with beamline polarimeters located immediately after the superconducting solenoids [8].

C. Neutron beam line

Dipole magnets, located after the target, were used to precess the longitudinal neutron spin into a direction normal to its momentum in order to make the longitudinal component measurable in the neutron polarimeters. To correct for possible geometrical polarimeter asymmetries, superconducting solenoids located after the target were used to flip the neutron spin direction.

Because of the target thicknesses used in this experiment, the empirical neutron energy resolution was determined by the beam energy loss in the targets, about 1 MeV for the C target and about 2.2 MeV for the Ca and Pb targets. The data taken during the experiments were stored on magnetic tapes, which were processed offline. The replay was conducted at several universities and some of the same data were replayed at least by two different groups. A more detailed description of the procedure and software used for the calibration may be found in Refs. [9,10].

III. DATA REDUCTION

The polarization-transfer coefficients $D_{ij}(i=S',N',L',j=S,N,L)$ relate the polarization of the outgoing neutron "i" to the polarization of the incident proton "j" according to the equations presented in the previous paper [1].

The incident proton beam was tuned so as to have a polarization with a single component on target. This was in general achieved and if the beam polarization, which was continuously monitored, had other components than the selected one to a level higher than 5%, the beam was stopped and retuned. Values for the analyzing power A_y, the polarization function P, and the transfer coefficient $D_{N'N}$, were obtained from results with normally polarized proton beam. The in-plane observables $D_{S'S}$, $D_{L'S}$, and $D_{L'L}$, $D_{S'L}$ are calculated using results obtained with sideways and longitudinal polarized proton beam, respectively. In what follows and for reasons of simplicity, we will denote these coefficients without the prime accent.

IV. EXPERIMENTAL RESULTS

All tabulated results have been transmitted to the National Nuclear Data Center, Brookhaven National Lab., where they can be retrieved from their CSISRS database at URL www.nndc.bnl.gov.

A. Double differential cross sections

Double differential charge exchange (p,n) cross sections have been measured at 197 MeV incident energy for C, Ca, and Pb targets. At 13° and 24° scattering angles, which corresponds to momentum transfers $q \approx 0.9$ and ≈ 1.3 fm^{-1}, respectively, the range in energy loss is between 0 to 100 MeV, while for 37° and 48°, $q \approx 2.0$ and ≈ 2.4 fm^{-1}, the range is between 0 to 150 MeV. In all cases the peak location of the quasielastic scattering is observed. An uncertainty of $\approx 10\%$ is estimated on the absolute cross section values.

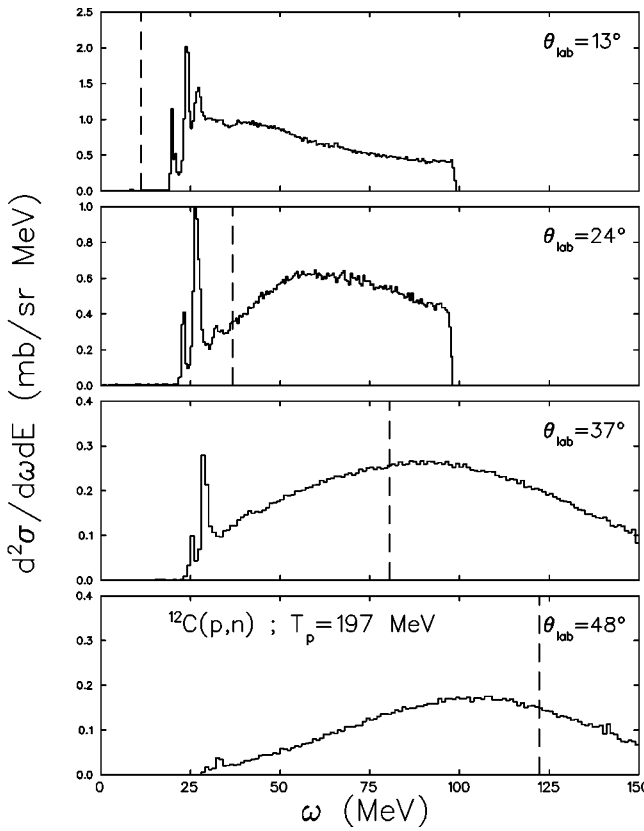

FIG. 1. Laboratory double differential cross section for the C(p,n) reaction measured at $E_p=197$ MeV and scattering angles $\theta_{\rm lab}=13°,24°,37°$, and 48° as a function of energy loss ω. The vertical dashed lines correspond to the energy loss for free np scattering.

Preliminary results for the C$(\vec{p},\vec{n})$ reaction have been reported by Cooper [9]. We also have previously reported on (p,n) quasifree excitations in p-shell nuclei at 186 MeV [11], including C. These data have also been deposited at the National Nuclear Data Center.

We present in Figs. 1–3 double differential cross section data taken on these targets at the indicated angles. The dashed vertical lines mark the energy loss for free np scattering. In all cases, it occurs at a lower energy loss than the peak of the quasifree distribution, except for the $C(p,n)$ spectrum measured at $\theta_{\rm lab}=48°$ where the energy loss for free np scattering is above the observed peak of the quasifree distribution. A similar observation has been reported by Wang *et al.* [11] in the (p,n) quasifree excitations in p-shell nuclei at 186 MeV.

B. Polarization-transfer coefficients

Values for A_y, P, and all D_{ij}, polarization-transfer coefficients, are presented in Figs. 4–7. In all cases the dotted vertical lines mark the energy loss for free np scattering. In almost all cases the D_{ij} for the three nuclei are indistinguishable from each other. In the top right frame of each figure,

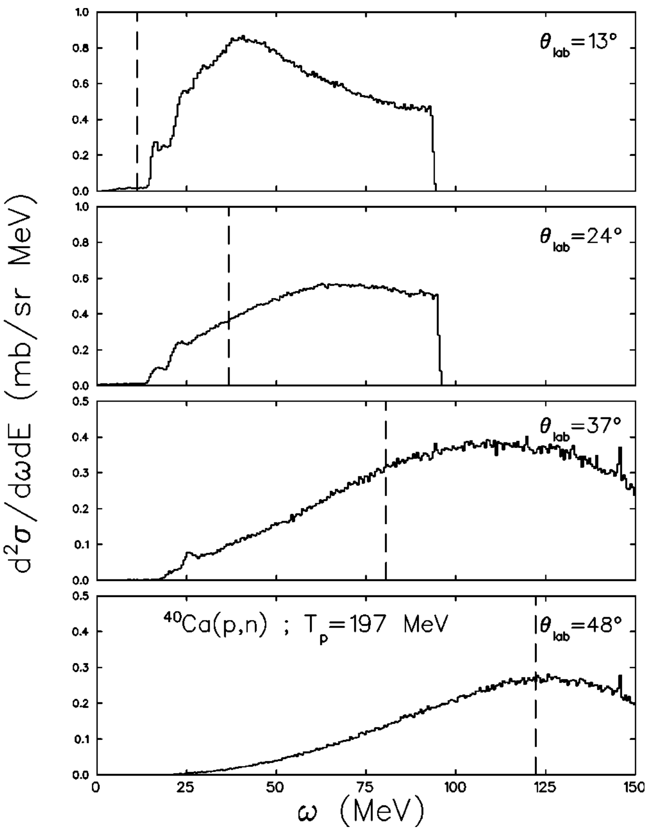

FIG. 2. Same as Fig. 1 but for Ca(p,n).

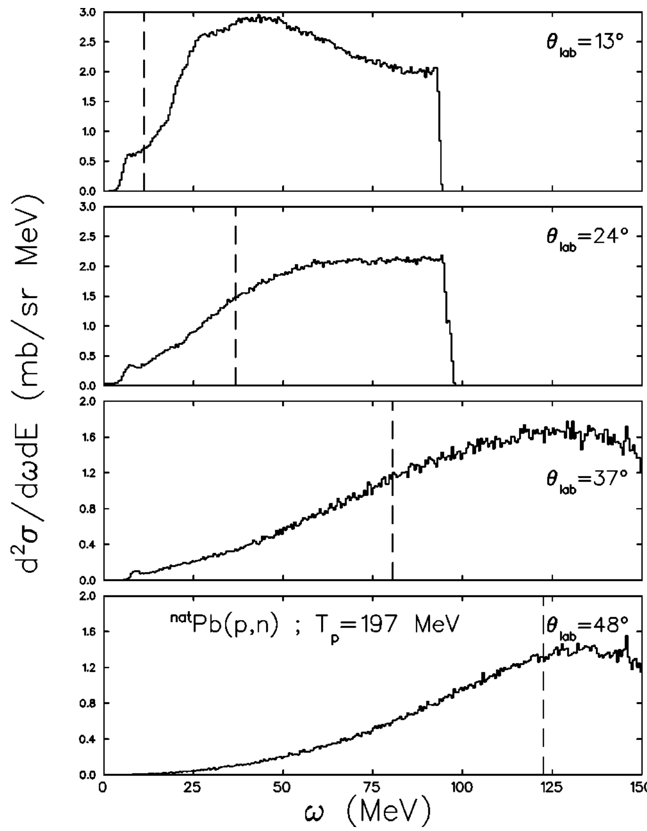

FIG. 3. Same as Fig. 1 but for Pb(p,n).

values for A_y and P are presented. The latter ones have been offset by 3 MeV in energy loss, in order to visualize them properly. The induced polarization P and analyzing power A_y are in general not the same, suggesting that the (p,n) quasielastic scattering on these targets may not be assumed to be a two-body process as in free np elastic scattering. Thus, the difference of P and A_y can probe noncollective behavior. In the energy loss region studied here, the quantity $(P-A_y)$, is in general negative at 13°, it is close to zero at 24° and positive at 37° and 48°. It is also positive in the 346 MeV $(\vec{p},\vec{n})$ data reported by Wakasa *et al.* [5] at 22°. We do not have *ab initio* D_{ij} calculations for these nuclei. The solid curves correspond to the optimal frame free np values from the CD Bonn potential phase shift solutions, to be discussed later.

The data presented in the above figures are binned in 5, 10, or 20 MeV intervals depending on the statistics achieved at each angle. The statistics are best around the peak of the quasifree scattering cross section, which is the region with the largest double differential cross section. Typical uncertainties for the D_{ij} coefficients are about ± 0.03.

V. DISCUSSION AND COMPARISON WITH CALCULATIONS

As in Ref. [1] we also choose in this work to compare the spin observable results with calculations for these values using free np results obtained with modern nucleon-nucleon (NN) phase shift solutions and calculated in the "optimal frame." As indicated in Ref. [1], this optimal frame takes into account the struck nucleon's Fermi momentum. In Fig. 8 we show values obtained in the optimal frame for momentum transfer q, effective laboratory kinetic energy, and effective center-of-mass angle as a function of energy loss ω for each of the four scattering angles in this study. This figure with values for Ca, which may also be used for either C or Pb, is slightly different from a similar figure shown in the previous paper [1], which was obtained for the reaction ^{2}H(p,n). The figure gives an indication of the range of effective kinetic energies and effective scattering angles needed in the NN phase shift solutions.

In the last few years a set of potentials, very well adjusted to NN data up to 300 MeV, has been studied resulting in a $\chi^2 \approx 1$ fit to the data. Among such potentials we find the Nijmegen93 [14], the AV18 [15], the CD Bonn [16], and the Ardnt potential [17]. Sample calculations for optimal frame D_{ij} observables for the ^{2}H$(\vec{p},\vec{n})$ reaction at $E_p = 200$ MeV and $\theta_{\rm lab} = 37°$ using all the above potentials show excellent agreement [18]. The free np results in the optimal frame using the CD Bonn phase shift solutions are shown as solid lines in Figs. 4–7, describing the empirical D_{ij} results.

The empirical spin observables in quasielastic $(\vec{p},\vec{n})$ reactions reported at 346 [5] and 495 MeV [3] are transformed to spin-longitudinal and spin-transverse responses within a framework of a plane-wave impulse using eikonal and optimal factorization approximations. These responses are then compared to theoretical spin responses obtained with RPA calculations. The ratio of the empirical evaluated spin-

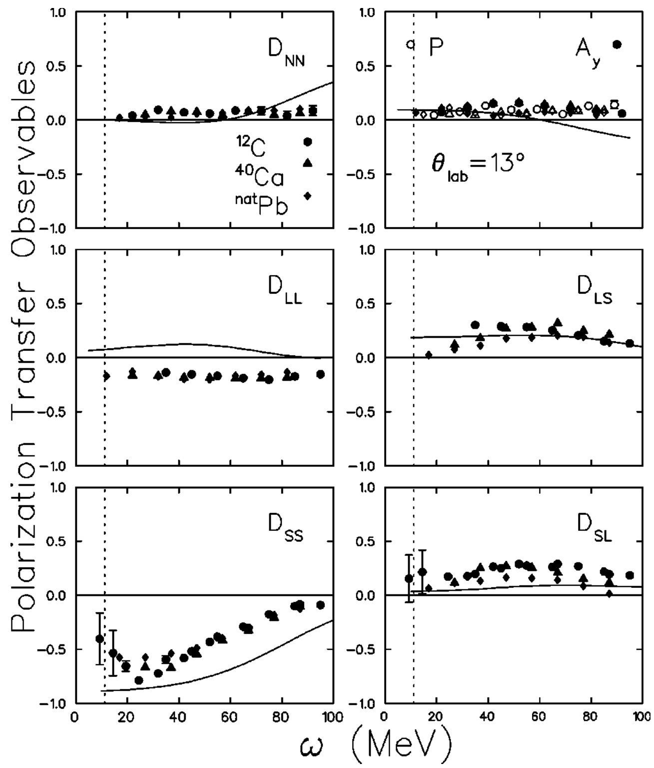

FIG. 4. Polarization-transfer coefficients, analyzing power, and induced polarization for the $(\vec{p},\vec{n})$ reactions on C, Ca, and Pb targets measured at $E_p=197$ MeV and at $\theta_{\rm lab}=13°$, $q\approx$ 0.8 fm^{-1}. The vertical dashed lines correspond to the energy loss for free np scattering. If not shown, error bars are smaller than the size of the data points. The solid curves correspond to the optimal frame free np values from the CD Bonn potential phase shift solutions.

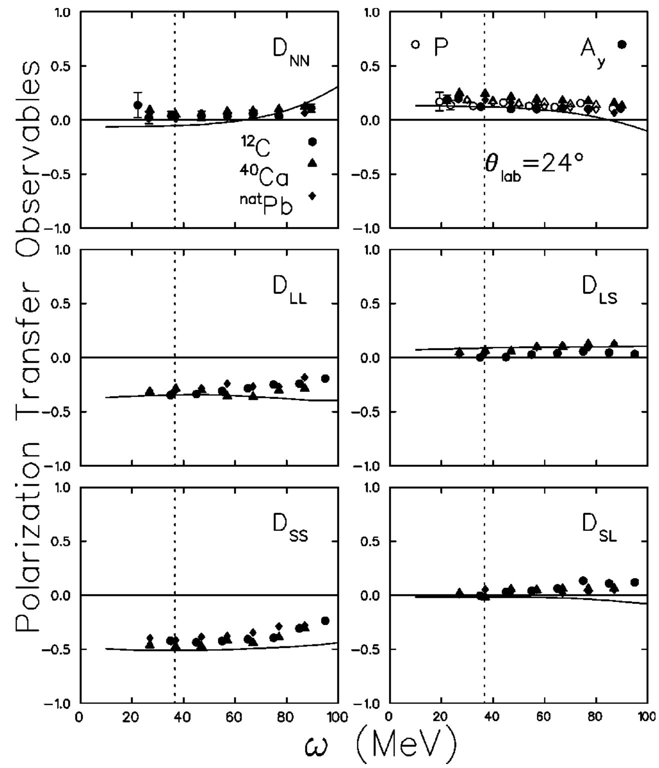

FIG. 5. Same as Fig. 4 but at $\theta_{\rm lab}=24°$, $q\approx1.4$ fm^{-1}.

responses is close to 1.0, in contradiction with the expected spin-longitudinal nuclear enhancement due to pionic effects within the RPA framework [2]. References [4,5], indicate a large excess in the observed spin-transverse response compared to the RPA calculations which seems to mask the enhancement in the ratio of the responses making them close to unity.

A. Polarization observables

We follow the procedure outlined by Ichimura and Kawahagishi [19] which uses relativistic transformations of observables to define four c.m. frame polarization observables D_k, in terms of the laboratory frame polarization-transfer coefficients D_{ij}. The equations for these polarization observables have been presented in the previous paper [1].

The calculated c.m. polarization observables D_k, are plotted in Figs. 9–12 at the four studied angles as a function of ω, energy loss. The solid curves were derived in the optimal frame using the free NN values from the CD Bonn potential. These values have been computed for a target mass of $A=40$. In general the empirical D_k's are similar to each other independent of target and have a similar dependence with energy loss. It is noted that the spin independent observable D_o consistently increases in magnitude with scattering angle, reaching values close to 0.3 at 48°, which are similar to values for the other polarization observables. This implies that as the momentum transfer increases, the spin independent double differential cross section ID_o increases in magnitude to values equal to the spin dependent double differential cross sections ID_q, ID_p, or ID_n.

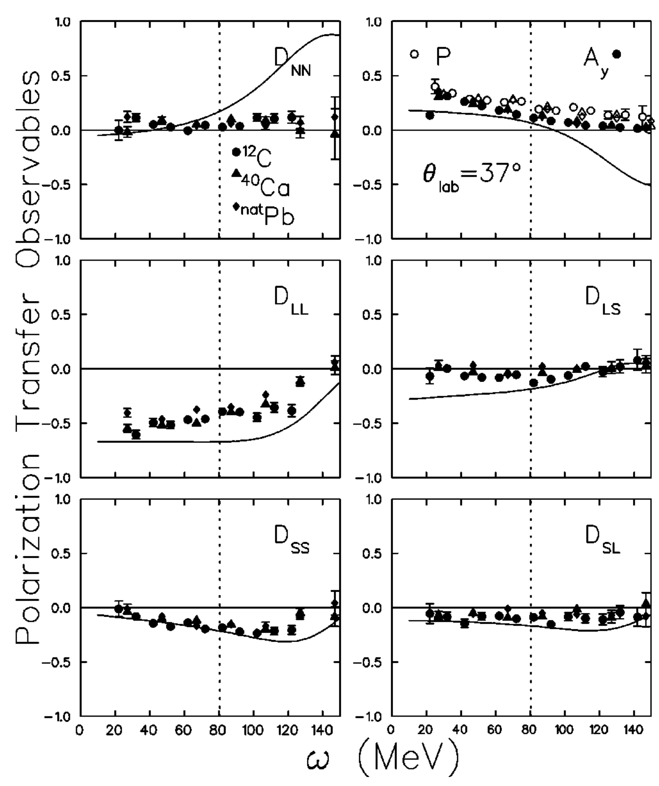

FIG. 6. Same as Fig. 4 but at $\theta_{\rm lab}=37°$, $q\approx2.0$ fm^{-1}.

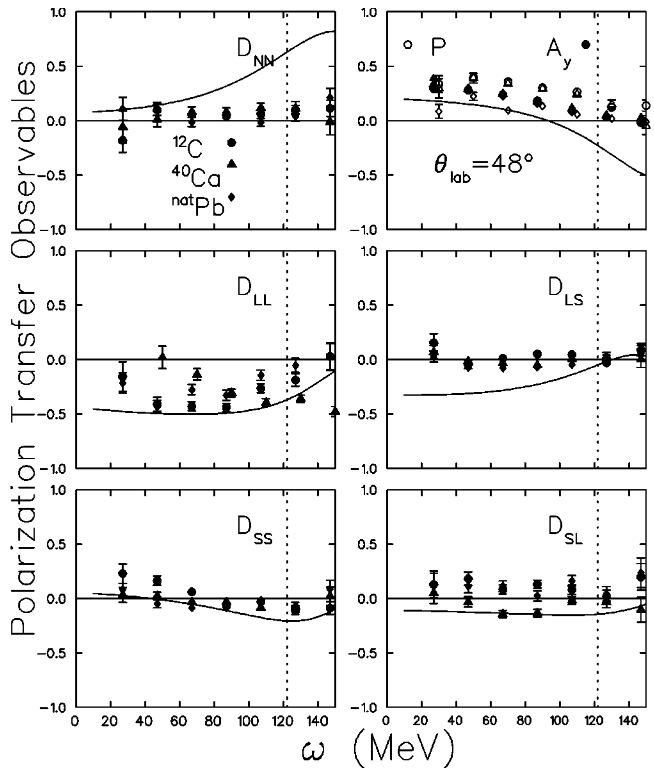

FIG. 7. Same as Fig. 4 but at $\theta_{\rm lab}=48°$, $q\approx 2.4\ \ {\rm fm}^{-1}$.

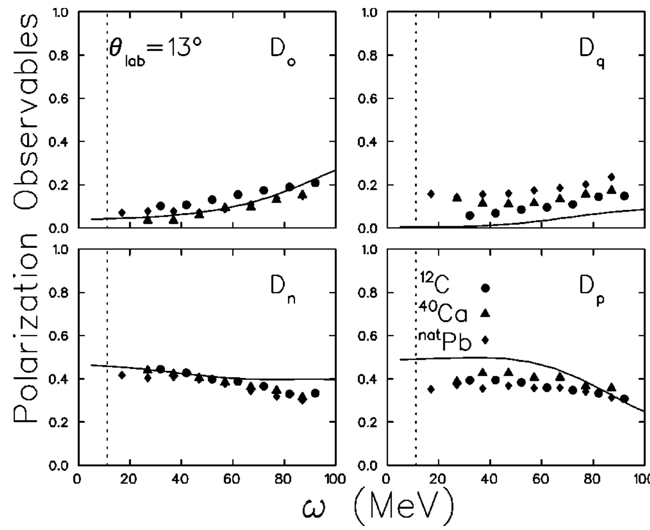

FIG. 9. Polarization observables for the $(\vec{p},\vec{n})$ reactions on C, Ca, and Pb targets at $E_p=197$ MeV and at $\theta_{\rm lab}=13°$, $q\approx 0.8\ \ {\rm fm}^{-1}$, compared to results obtained from optimal frame free *np* values (solid lines) using the CD Bonn potential. The vertical dashed lines correspond to the energy loss for free *np* scattering.

As indicated in Ref. [3], the significance of the c.m. observables D_k, is appreciated in their application to free *NN* scattering. In their standard form [12], the c.m. *NN* charge-exchange scattering amplitude is expressed as

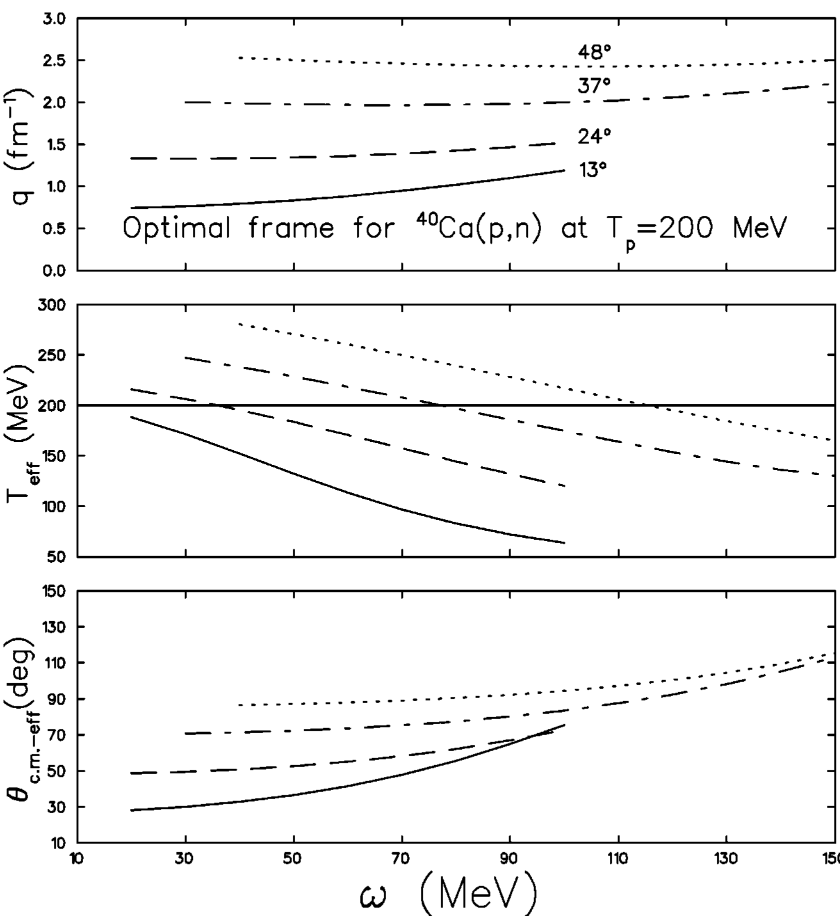

FIG. 8. Kinematic values calculated for the Ca(p,n) reaction in the optimal frame at 197 MeV incident energy. Momentum-transfer q, effective laboratory kinetic energy $T_{\rm eff}$, and effective c.m. angle $\theta_{\rm c.m.\ eff}$ are presented as a function of energy loss, ω.

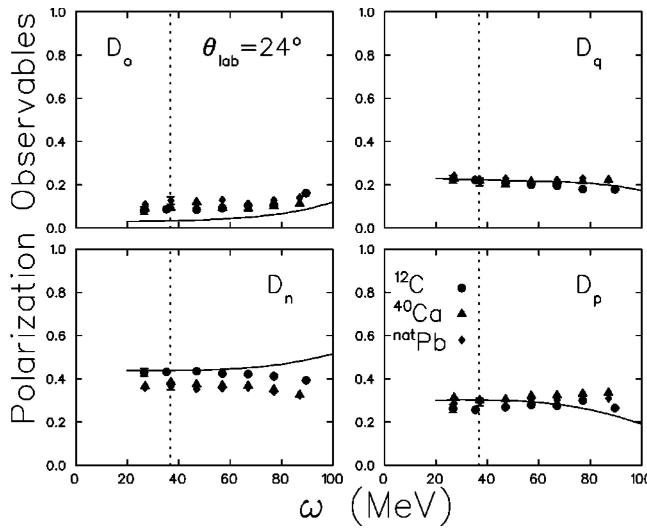

FIG. 10. Same as Fig. 9 but for at $\theta_{\mathrm{lab}}=24°$, $q\approx 1.4$ fm^{-1}.

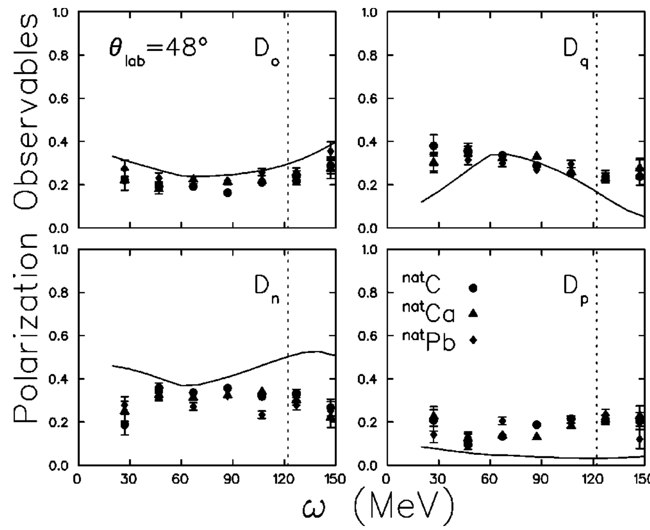

FIG. 12. Same as Fig. 9 but for at $\theta_{\mathrm{lab}}=48°$, $q\approx 2.4$ fm^{-1}.

$$M(q)=A+C(\sigma_{0n}+\sigma_{1n})+B\sigma_{0n}\sigma_{1n}+E\sigma_{0q}\sigma_{1q}+F\sigma_{0p}\sigma_{1p}, \tag{1}$$

where σ_0 and σ_1 are the Pauli spin matrices for the projectile and target nucleons projected onto the NN c.m. coordinate axes (q,n,p). In this case the NN c.m. partial cross sections

$$I_o^{NN}=I^{NN}D_o^{NN}=|A|^2+|C|^2, \tag{2}$$

$$I_n^{NN}=I^{NN}D_n^{NN}=|B|^2+|C|^2, \tag{3}$$

$$I_q^{NN}=I^{NN}D_q^{NN}=|E|^2, \tag{4}$$

$$I_p^{NN}=I^{NN}D_p^{NN}=|F|^2, \tag{5}$$

select simple combinations of amplitudes. The subindex "o" represents the spin independent component, the subindex "q" the spin-longitudinal component, while "n" and "p" represent the two spin-transverse components. The sum of the polarization components $\Sigma_k D_k^{NN}=1$.

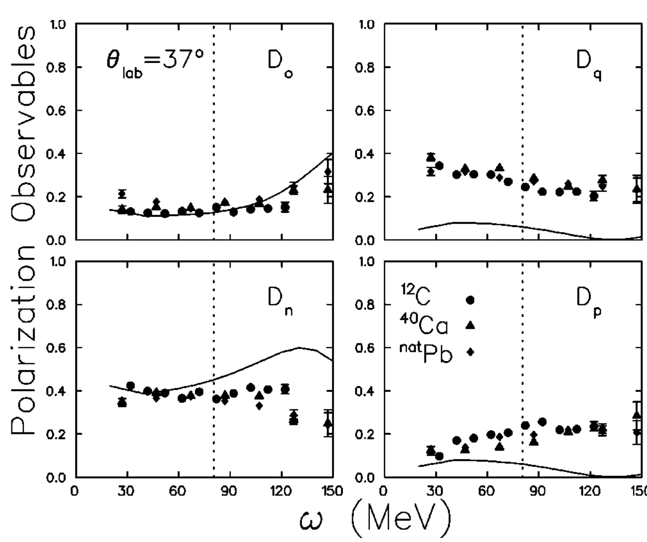

FIG. 11. Same as Fig. 9 but for at $\theta_{\mathrm{lab}}=37°$, $q\approx 2.0$ fm^{-1}.

In the nucleon-nucleus (NA) case, the NN amplitudes are chosen to be those in the optimal NN scattering frame. The NA double differential cross section, I, can be represented as a sum of terms [3,5,13,20]

$$I=ID_0+ID_q+ID_n+ID_p, \tag{6}$$

where the D_k are the polarization components [21].

Ichimura and Kawahigashi [19], using a PWIA with eikonal and optimal factorization approximations, derive the following expressions for ID_k, the partial polarized cross sections

$$ID_0=8C_K(2J_A+1)N_{\mathrm{eff}}(|A^\eta|^2R_0+|C_2^\eta|^2R_n), \tag{7}$$

$$ID_n=8C_K(2J_A+1)N_{\mathrm{eff}}(|B^\eta|^2R_n+|C_1^\eta|^2R_0), \tag{8}$$

$$ID_q=8C_K(2J_A+1)N_{\mathrm{eff}}(|E^\eta|^2R_q+|D_1^\eta|^2R_p), \tag{9}$$

$$ID_p=8C_K(2J_A+1)N_{\mathrm{eff}}(|F^\eta|^2R_p+|D_2^\eta|^2R_q), \tag{10}$$

where C_K is a kinematic factor, J_A is the target spin, N_{eff} is a distortion factor representing the effective number of neutrons, R_k are the nuclear spin-responses, and the A^η-F^η are the optimal frame t-matrix amplitudes. Taddeucci *et al.* [3,4] and Wakasa *et al.* [5] have used the above expressions to define the "experimental" spin-response functions. By considering the relative magnitude between the t-matrix components in the optimal frame these expressions are greatly simplified. In particular, neglecting the small contributions of D_1^η and D_2^η, the spin polarized cross sections ID_q and ID_p are directly related to the spin responses R_q and R_p, respectively. The first two equations, Eqs. (7) and (8), may be used to obtain, with some approximations [5], that R_n is proportional to ID_n. In Fig. 13 we display the square of the np amplitudes at $\theta_{\mathrm{lab}}=37°$ in the optimal frame calculated using the CD Bonn phase-shift solution. The components are derived according to the optimal frame kinematics for the

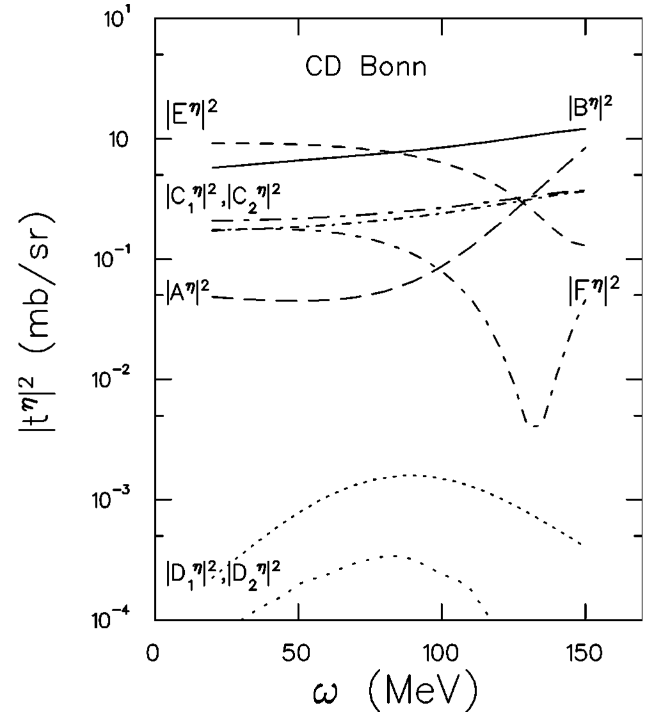

FIG. 13. Square np amplitudes at $\theta_{\mathrm{lab}}=37°$ in the optimal frame using the CD Bonn phase-shift solution. The components are derived according to the optimal frame kinematics for the ^{40}Ca(p,n) reaction at an incident energy of 197 MeV.

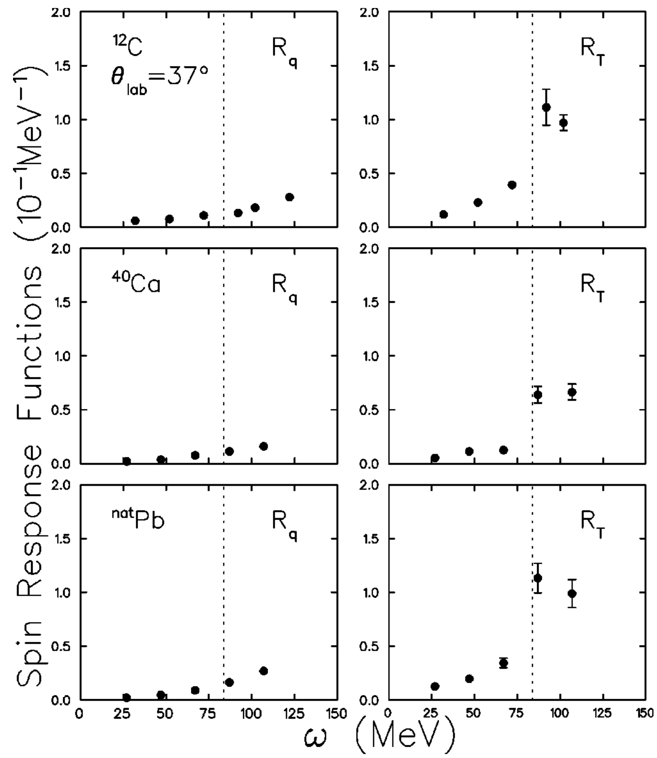

FIG. 14. Spin response functions obtained for C, Ca, and Pb at $\theta_{\mathrm{lab}}=37°$, $q\approx2.0\ \mathrm{fm}^{-1}$. The spin-longitudinal R_q and the spin-transverse, R_T, are plotted as a function of energy loss, ω. The transverse spin-response R_T is an average of the two spin-transverse responses R_n and R_p. The vertical dashed lines correspond to the energy loss for free np scattering.

^{40}Ca(p,n) reaction at an incident energy of 197 MeV. These components have also been calculated using other free np phase-shift solutions giving very similar results [10]. It is clear from the figure that the values for the amplitudes D_1^{η} and D_2^{η} are small compared to the other amplitudes and may be neglected as assumed above. At 197 MeV, both amplitudes E^{η} and F^{η} depend strongly on energy loss, ω, becoming rather small at larger ω values. At incident energies of 346 [5] and 495 MeV [3] these amplitudes are large and almost independent of energy loss.

The effective number of neutrons participating in the nuclear reaction was empirically evaluated using $N_{\mathrm{eff}}=0.85\sqrt{N}$, where N is the number of neutrons in the target. This expression was determined in (p,n) reactions on several targets between ^{12}C and ^{208}Pb, induced with 400 MeV protons [23]. It also agrees well with N_{eff} experimentally evaluated values, obtained in (p,n) reactions at 186 MeV reported by Wang *et al.* [11].

Empirical responses for the C, Ca, and Pb targets at $\theta_{\mathrm{lab}}=37°$, $q\approx2.0\ \mathrm{fm}^{-1}$, are displayed in Fig. 14. The spin response labeled R_T correspond to the average of the two spin-transverse responses R_n and R_p. Values for these responses at energy loss above the value for free np scattering are not reliable, because above this energy in the optimal frame E^{η} and F^{η} amplitudes become rather small and the approximations used in this approach are no longer valid. Responses at other momentum-transfers are reported in Ref. [10].

B. Comparison with results at other energies

Complete sets of polarization-transfer observables in the quasifree region have been reported at 346 MeV by Wakasa *et al.* [5] and at 495 MeV by Chen *et al.* [5] at about the same momentum transfer $q\approx1.7\ \mathrm{fm}^{-1}$. Data obtained by Wakasa *et al.* [5], are shown in Fig. 15 for the ^{12}C, ^{40}Ca, and ^{208}Pb targets. Data obtained by Chen *et al.* [5], are shown in Fig. 16 for the ^{12}C, and ^{40}Ca targets. The present data obtained at $\theta=37°$, $q\approx2.0\ \mathrm{fm}^{-1}$ are presented in Fig. 17, including data for ^{4}He; see Ref. [1].

A comparison of these three figures indicates that irrelevant of incident energy, in general all targets report almost identical values for all the polarization-transfer observables. Also the values reported at 346 MeV and the values reported at 495 MeV ($q\approx1.7\ \mathrm{fm}^{-1}$) are almost identical. The present D_{ij} coefficients obtained at 197 MeV and $q\approx2.0\ \mathrm{fm}^{-1}$, including ^{4}He, are all except D_{SS} almost identical to the values at the other energies. This seem to imply that for incident proton energies in the region between 197 and 495 MeV, empirical D_{ij} coefficients obtained in $(\vec{p},\vec{n})$ reactions at a momentum transfer $q\approx1.7\ \mathrm{fm}^{-1}$, are almost independent of nuclei and energy. This is in contrast with optimal frame free np results obtained with modern NN phase shift solutions, which differ with incident energy.

VI. SUMMARY

We have reported on a complete set of polarization-transfer coefficients measured at 197 MeV in the quasifree region for the $(\vec{p},\vec{n})$ reactions on C, Ca, and Pb targets. Data

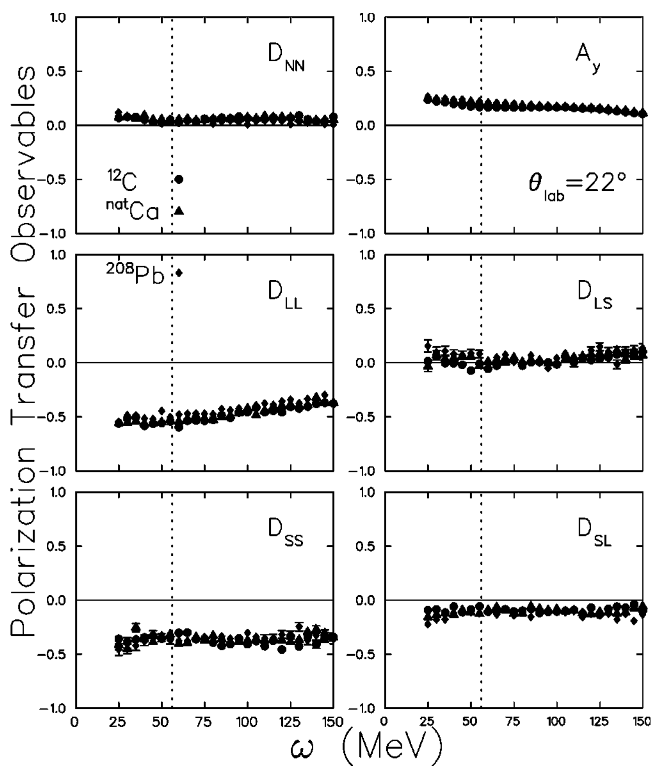

FIG. 15. Polarization-transfer observables for the $(\vec{p},\vec{n})$ reactions on C, Ca, and Pb targets at $E_p=346$ MeV and at $\theta_{\rm lab}=22°$, $q\approx1.7$ fm^{-1}, reported by Wakasa *et al.* [5]. The vertical dashed lines correspond to the energy loss for free np scattering.

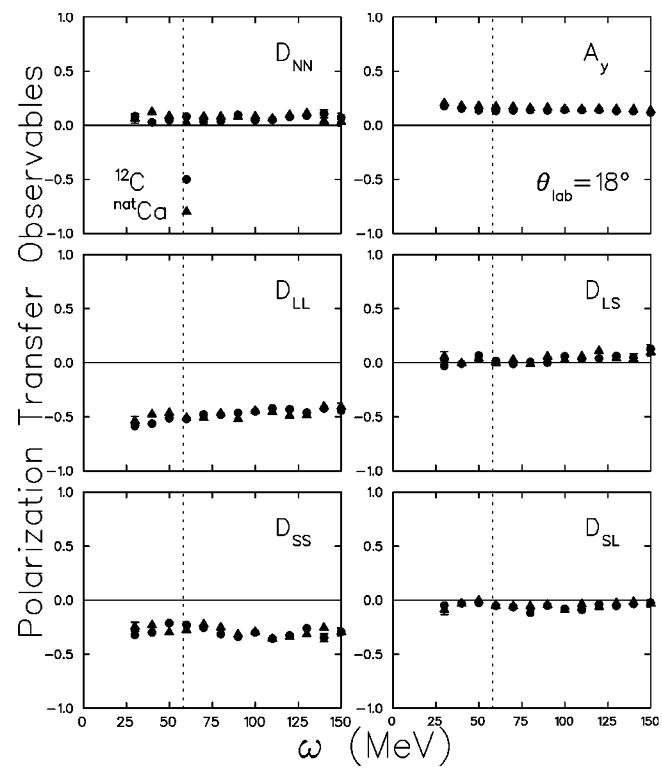

FIG. 16. Polarization-transfer observables for the $(\vec{p},\vec{n})$ reactions on C and Ca targets at $E_p=495$ MeV and at $\theta_{\rm lab}=18°$, $q\approx1.7$ fm^{-1}, reported by Chen *et al.* [3]. The vertical dashed lines correspond to the energy loss for free np scattering.

obtained on these targets at all angles seem to indicate that the polarization-transfer coefficients D_{ij} are, within statistics, not different from each other independent of nuclei. The resulting c.m. polarization D_k, which are linear combinations of the above observables are subsequently also similar. Response functions are presented at $\theta_{\rm lab}=37°$, $q\approx2.0$ fm^{-1}, in Fig. 14. Similar "experimental" responses have been reported at 346 MeV incident energy [5] and at 495 MeV incident energy [4] at a similar momentum transfer $q\approx1.7$ fm^{-1}. A comparison between these responses which should be incident energy independent is presented in Fig. 18. In this figure, R_T represents the average value of the two spin-transverse R_n and R_p responses. A reasonable agreement is observed among the three data sets. In all cases the ratios of the spin-longitudinal to the spin-transverse response functions reveal no enhancement. Wakasa *et al.* [5] compare their results for C and Ca to RPA response functions. The spin-longitudinal response agrees with the theoretically enhanced response, but the experimental spin-transverse response is substantially larger than the RPA calculation.

The present set of data completes a study of the spin response for $(\vec{p},\vec{n})$ quasielastic excitation that has been conducted at incident energies between 197 and 495 MeV, a region in which distortions of the nuclear mean field and the nucleon-nucleus interaction changes considerably. The present study has been done at a set of momentum-transfers between 0.75 to 2.4 fm^{-1} and energy loss ω, up to 150 MeV. It is observed that at all incident energies and almost independent of nuclei, the measured set of polarization-transfer coefficients at a given momentum transfer, are about the same. These D_{ij} coefficients are then used to obtain the polarization observables D_k leading to similar values for these coefficients. The response functions are calculated using these D_k resulting in ratios of responses that show no enhancement.

Recent RPA calculations [24] reasonably reproduce the observed ID_q of C and Ca$(\vec{p},\vec{n})$ at 495 and 346 MeV, which is consistent with the predicted enhancement of the spin-longitudinal response function R_q. However, the observed ID_p is much larger than the calculated one.

Unless we can find a theoretical explanation why the spin-transverse response should be equally enhanced to the spin-longitudinal response, independent of nucleus, in a large region of momentum transfer and at a variety of incident energies, the RPA model used to predict this enhancement may need to be modified. Koltun [22] has suggested that the Landau parameter $g'\approx0.6$ [which gives such a collectivity in the region studied in the (p,n) reaction] used in the RPA calculations may be too low. In his paper, he presents results leading to a much reduced sensitivity of nuclear reactions to the nuclear correlations that are responsible for pion excess, specifically that the expected effects in (p,n) reactions are smaller than the experimental uncertainties.

More recently Toki, Sugimoto, and Ikeda [25] have in-

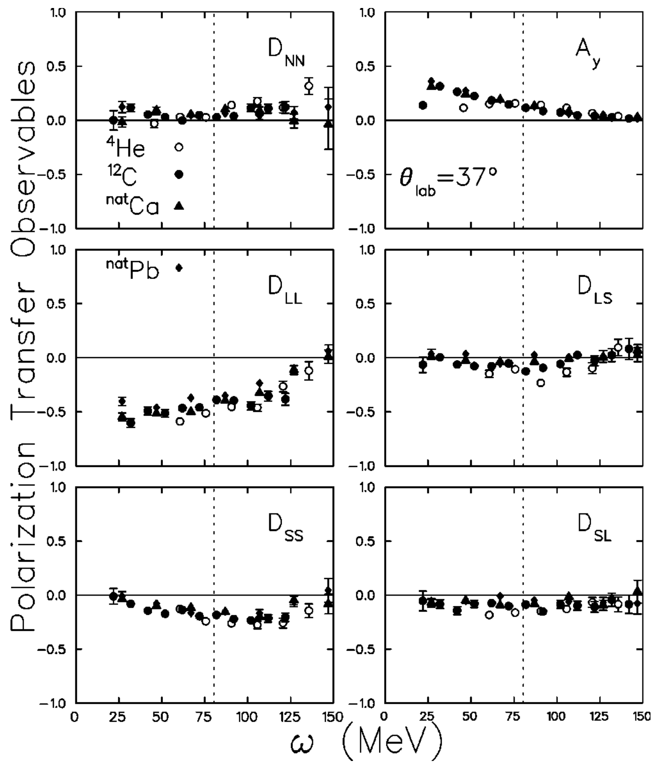

FIG. 17. Polarization-transfer observables for the $(\vec{p},\vec{n})$ reactions on ^{4}He, C Ca, and Pb targets at $E_p=197$ MeV and at $\theta_{lab}=37°$, $q\approx 2.0$ fm^{-1}. The vertical dashed lines correspond to the energy loss for free np scattering.

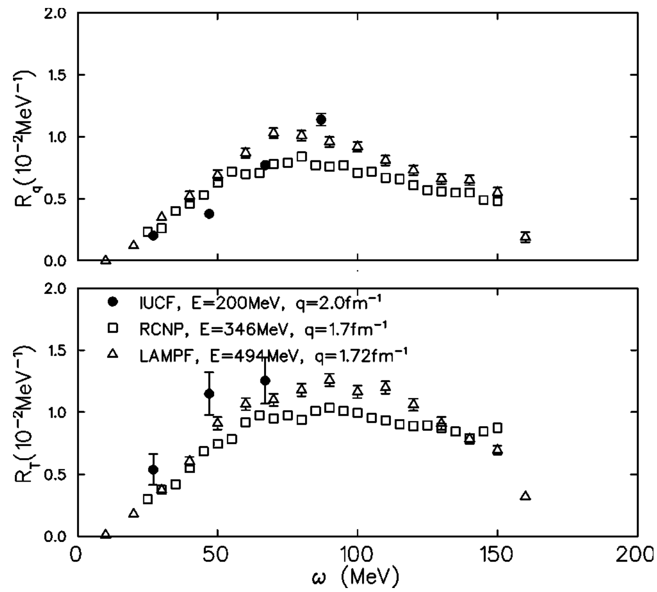

FIG. 18. Comparison of the spin responses R_q and R_T obtained from $(\vec{p},\vec{n})$ reactions on Ca at 197, 346, and 495 MeV and at a momentum transfer $q\approx 2.0$ fm^{-1}. The spin response R_T represents the average of the spin-transverse responses R_n and R_p.

cluded the π meson field in the nuclear relativistic mean field theory and show that the spin-response functions have a strikingly small pionic enhancement indicating that pionic correlations are exhausted in the ground state and the correlations are not left in the spin transitions. This model seems to be in better agreement with the present data, but differs substantially from the RPA calculations reported by Alberico *et al.* [2] and more recently by Kawahigashi *et al.* [24].

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