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SPIN OBSERVABLES AT INTERMEDIATE ENERGIES: A TOOL IN VIEWING THE NUCLEUS

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In this paper I attempt to summarize some of the advances made in intermediate nuclear physics through measurements of spin observables, notably in the range of bombarding energies from 100 to 1000 MeV. I leave the discussion of the important nucleon-nucleon (NN) measurements to other speakers. Relative to measurements of cross section, spin observables offer a highly selective filter in viewing the nucleus. Their general utility is found in their sensitivity to particular nuclear transitions and is further augmented by their simple connections to the NN force. The advantage of higher energies is apparent from the dominance of single-step mechanisms even at large energy losses where general nuclear spin responses may be made. Experimentally, this is an energy range where efficient, high-analyzing-power polarimeters can be coupled with high resolution detection techniques.[1]

The first experiment to measure a complete set of spin observables for the elastic scattering of protons from a nucleus[2] provided the impetus for a Dirac description of the scattering process.[3] An apparent failure of the nonrelativistic KMT treatment of intermediate-energy proton elastic scattering data for cross sections and, most noticeably, analyzing powers had already been extensively investigated looking at numerous corrections in order to resolve the discrepancies. Furthermore, it was believed that the data were driven by the geometries of the nucleus such that the third independent observable for elastic scattering, the spin-rotation parameter, Q, would be predicted from the other two, cross section and analyzing power. The data for Q turned out to be in total disagreement with this prediction and not explained by the standard KMT analysis. Predictions of Q using the Dirac phenomenology, however, provided excellent agreement with the data.

As can be seen in Fig. 1, only small differences in the cross section are seen between a more recent relativistic impulse approximation[9] (solid curve) and nonrelativistic impulse approximation (dashed curve) predictions, whereas the analyzing power (or polarization P) and the spin rotation parameter (Q) are both qualitatively and quantitatively different. The underlying physics is quite different. The Dirac approach includes processes such as virtual pair production and annihilation in the field of the nucleus not present in nonrelativistic dynamics. The 500-MeV data markedly favor the Dirac treatment. It should be pointed out, however, that spin rotation data at other energies and on other targets are not in as good agreement, but it is precisely these type of data that are likely to shed light on this issue.

A great deal of effort has gone into planning a spin transfer experiment from a polarized nuclear target (^{13}C) where the relativity of the target may be tested in hope of finding identifiable differences in the nonrelativistic and relativistic approaches to nuclear physics.

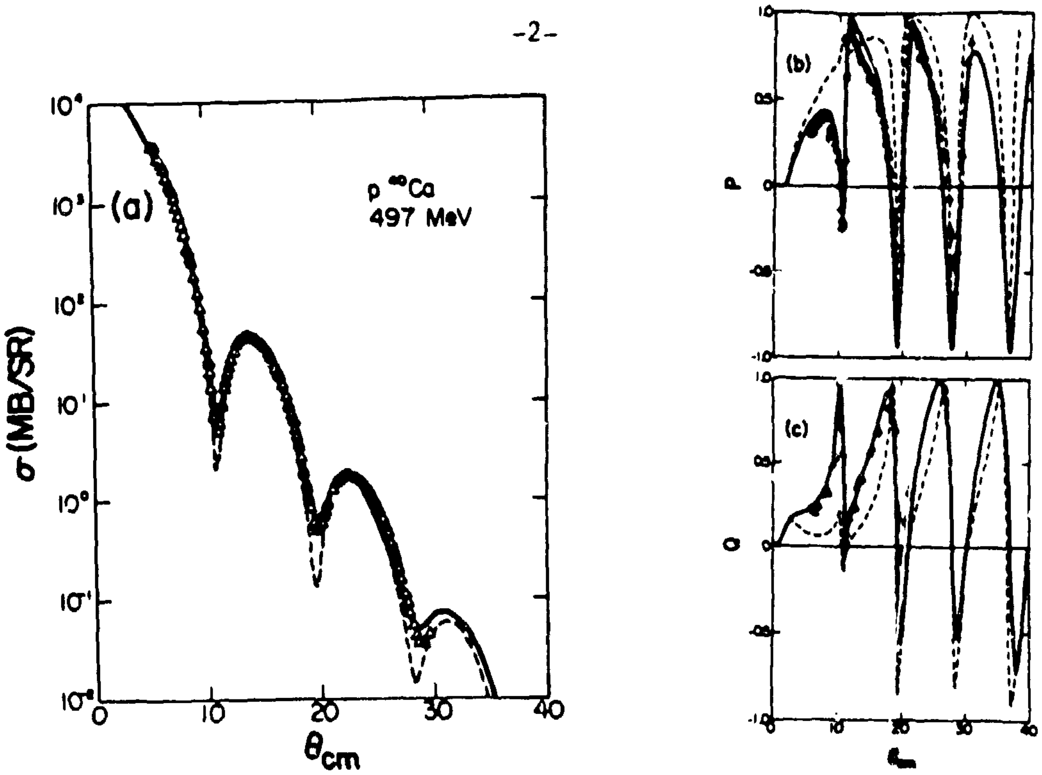

Fig. 1. $^{40}Ca(p,p)$ scattering at 500 MeV with relativistic (solid curve) and nonrelativistic calculations for cross section, analyzing power, and spin rotation parameter from Ref. 4.

A direct connection can be made between spin observables and the squared moduli of the coefficients of the effective NN scattering amplitude given by

$$M(q) = A + B\sigma_{1n}\sigma_{2n} + C(\sigma_{1n} + \sigma_{2n}) + E\sigma_{1q}\sigma_{2q} + F\sigma_{1p}\sigma_{2p} \quad , \qquad (1)$$

where 1(2) denotes the target (projectile) nucleon and the unit vectors $(\hat{n},\hat{q},\hat{p})$ are in the $\vec{K}\times\vec{K}'$, $\vec{K}-\vec{K}'$, and $\vec{q}\times\vec{n}$ directions, with $K(K')$ the relative momentum in the NN system before(after) collision. For unnatural parity transitions, it has been shown[5,6] that in the static limit

$$I_o = (C^2 + B^2 + F^2)X_T^2 + E^2X_L^2 \quad , \qquad (2.1)$$

$$I_oD_{nn} = (C^2 + B^2 - F^2)X_T^2 - E^2X_L^2 \quad , \qquad (2.2)$$

$$I_oD_{pp} = (C^2 - B^2 + F^2)X_T^2 - E^2X_L^2 \quad , \qquad (2.3)$$

$$I_oD_{qq} = (C^2 - B^2 - F^2)X_T^2 + E^2X_L^2 \quad , \qquad (2.4)$$

$$I_oD_{no} = I_oD_{on} = 2X_T^2\mathrm{Re}(BC^*) \quad , \qquad (2.5)$$

$$I_oD_{qp} = -I_oD_{pq} = 2X_T^2\mathrm{Im}(BC^*) \quad . \qquad (2.6)$$

where $X_L^2(X_T^2)$ is the static longitudinal(transverse) form factor. One can see from Eq. 2 that if the nuclear structure is known (i.e. X_L^2 and X_T^2), the q dependence of the effective NN interaction may be mapped out by measuring a complete set of spin observables to discrete final states at several momentum transfers. Although Eqs. 2 are strictly valid in the plane wave impulse approximation (PWIA), full distorted wave (DWIA) calculations have shown that distortion or details of the transition density have little effect on the spin observables for a transition dominated by a single multipolarity near the peak of the associated form factor. Thus, Eqs. 2 are expected to still be valid under these conditions.

The first complete set of spin observables at intermediate energy for inelastic scattering used the two lowest 1^+ states in ^{12}C at 500 MeV to map the q dependence of the individual coefficients of the NN spin-dependent interaction for both isospin channels.[7] The results were consistent with the free NN amplitudes. Further measurements are needed to improve the accuracy of these results as well as extending them to larger q by choosing states of higher multipolarity. In principle one can be divorced from uncertainties in nuclear structure by doing similar measurements in quasi-free scattering.[8] It is no longer possible to make the isospin decomposition in (p,p′) directly, but similar measurements will soon be possible in the (p,n) reaction, which is purely isovector in nature.[9] The combination of (p,p′) and (p,n) would be complimentary and both would require only modest energy resolution.

Spin observables have also been shown to be more sensitive to convection ($\vec{J}$) and composite ($\vec{J} \times \vec{\sigma}$) currents than unpolarized cross sections alone.[10] Observables such as $\sigma(P-A)$ and $\sigma(D_{ls}+D_{sl})$ have been found to be most useful in detecting and confronting composite currents. Nonrelativistic and relativistic theories all contain these currents at some level of approximation, although the relativistic treatment gives rise to these currents in a more natural way through the lower component.

As an example of the selectivity and sensitivity of spin observables to particular nuclear transitions, consider Fig. 2, which is the spectrum of inelastic states in ^{12}C at 397 MeV from 7 to 23 MeV in excitation. This is seen in the top portion of the figure. The spectrum is dominated by the natural parity $\Delta S=0$ transitions at 7.6 and 9.6 MeV. General symmetry properties of the scattering amplitude imply that for transitions involving spin-parity transfer of $J^\pi=0^-$, $D_{NN}=-1$, and for transitions involving $J^\pi=0^+$, $D_{NN}=+1$. In general a positive value of D_{NN} is a signature of $\Delta S=0$ strength, while $\Delta S=1$ transitions yield a negative or zero value of D_{NN}. This is seen directly in the botton portion of Fig. 2 for the spin-flip cross section, $d\sigma/d\Omega \cdot S_{NN}$, where $S_{NN}=(1-D_{NN})/2$ is the transverse spin-flip probability. The natural parity $\Delta S=0$ transitions in the top spectrum are completely suppressed in the spin-flip cross section. Only the unnatural parity $\Delta S=1$; 1^+ and 2^- and natural parity $\Delta S=1$; 2^+ states persist.

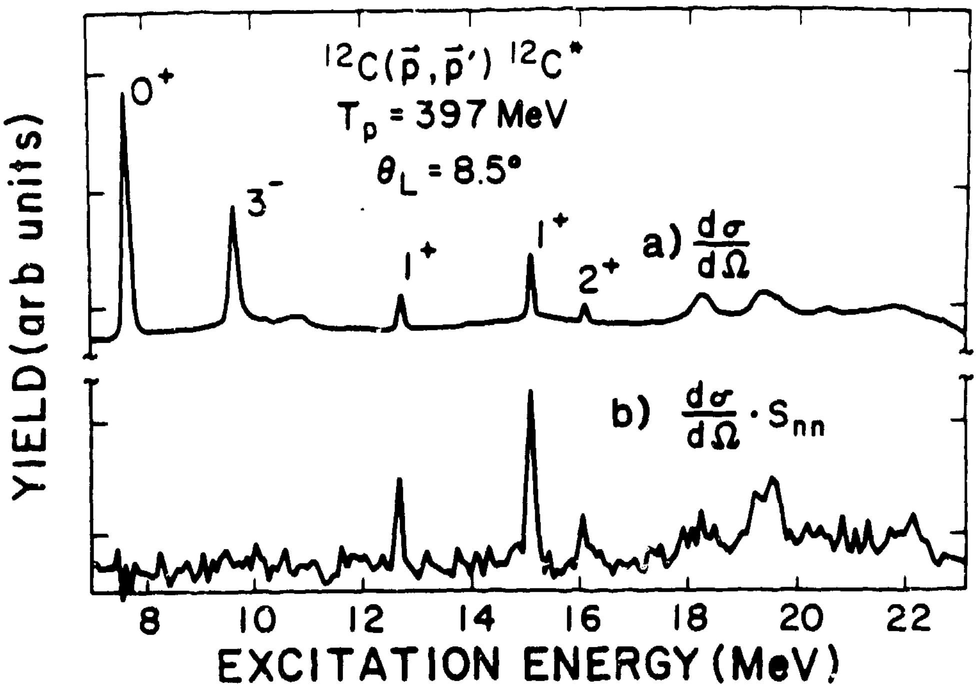

Fig. 2. $^{12}C(p,p)$ scattering at 397 MeV showing yield spectrum (top) and spin-flip cross section (bottom) from Ref. 28.

This selective technique of picking out only the spin-flip strength has been applied to continuum studies using the (p,p') and (p,n) reactions, in particular in the investigation of the Gamow-Teller (GT) and closely related M1 missing strength problem. The proportionality between intermediate energy (p,n) 0° cross section and beta decay transition strengths has provided a direct means of measuring GT strength in a wide range of nuclei.[11,12] The surprising feature, of course, has been the apparent lack of GT strength. Less than two thirds of the predicted strength based on an essentially model-independent sum rule has systematically been observed.[13] Explanations of this effect range from conventional nuclear mixing to delta-isobar admixtures to the nuclear wave functions. Resolution of this problem seems to rest with experiments that are sensitive to thinly distributed GT strength in the continuum. Cross-section angular distributions are primarily sensitive to the orbital angular momentum transfer ΔL rather than the total angular momentum transfer ΔJ. D_{NN} is sensitive to the spin transfer ΔS, hence it provides information on ΔJ=ΔL+ΔS. Its simple prediction and interpretation make it a powerful tool for these types of investigation. Figure 3 shows a $^{90}Zr(p,n)$ cross section and polarization transfer cross section at 160 MeV. The 0^+ (ΔL=0,ΔS=0) isobaric analog state (IAS) is seen with its corresponding D_{NN}=1. Virtually all of the remaining cross section corresponds to ΔS=1 transitions as evidenced by its D_{NN}≤0. The observed value for D_{NN} in the region of the giant GT resonances further demonstrates that it is essentially all GT in nature, without other contributions. RPA calculations have been done for $^{90}Zr(p,n)$ cross section at

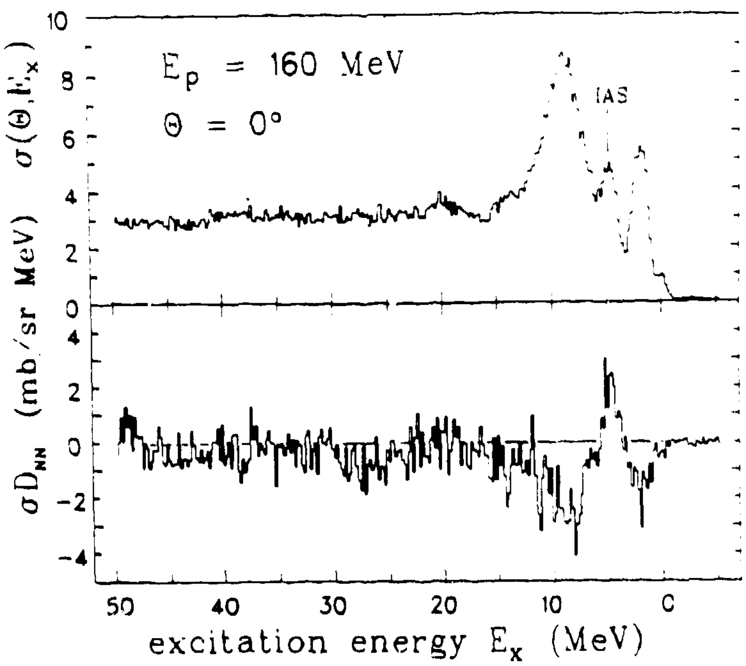

Fig. 3. $^{90}Zr(p,n)$ reaction at 160 MeV showing cross section (top) and polarization transfer cross section (bottom) from Ref. 29.

200 MeV[14,15] and have found no evidence for a need to include quenching due to delta-isobars with the proviso that the S_{β^+} strength obtained from the (n,p) reaction (as yet unmeasured) is small. However, this same calculation predicts only a small amount of 1^- and 2^+ natural parity strength in the 0^- cross section in contradiction of the (p,n) results at 160 MeV. Further analysis of these types of spin transfer measurements as well as their angular distributions is certainly needed, as well as (n,p) and higher energy data where the delta region can be investigated directly.[9]

A similar program exists in (p,p′) addressing the question of M1 giant resonances.[16] These resonances have been reportedly seen in (p,p′) spectra on a variety of medium-to-heavy nuclei.[17] With only cross-section data available, the assignment of M1 is based primarily on the characteristic ΔL=0 angular distribution and on the centroid and width of the distributions. These giant resonances are not systematically observed in back-angle electron scattering, presumably sensitive to M1 strength. If these giant resonances are indeed M1 in nature, they should exhibit large ΔS=1 strength over their region of excitation. Spin-flip cross sections appear to be an ideal tool for resolving this controversy.

Equation 2 may also be viewed as a way of getting nuclear structure information if the effective interaction is known. An investigation of the nuclear continuum using polarized protons [18,19] uses this approach to relate high energy (200 GeV) deep inelastic lepton scattering (DILS) to nucleon scattering at intermediate energies (500 MeV). The connection between the two is through explanations of the European Muon Collaboration (EMC) effect and their implications for inclusive proton scattering. The EMC effect is the apparent modification of the nucleon structure function, or quark distribution, when the nucleon is embedded in the nuclear medium. This is reflected as an enhancement of the ratio of F_2 structure functions for a heavy nucleus compared to deuterium as measured in DILS at small values of the scaling variable x--scattering from the sea quarks--and a corresponding depletion at large x--scattering from the valence quarks. Most explanations of this effect either invoke a dynamic rescaling or increased confinement size of a nucleon within the nucleus or a more conventional approach involving enhancement of the pion field within the nucleus. The second has a certain intuitive appeal since each nucleon is surrounded by a cloud of pions contributing to DILS (as a $q\bar{q}$ pair of sea quarks). When embedded in the nuclear medium, the net number of pions per nucleon may increase, either due simply to exchange of pions with neighboring nucleons providing binding to the system, or by a nuclear many-body enhancement of the πNN vertex through an attractive NN interaction. It has been further suggested that dynamic rescaling simply mimics the pionic effects.

In both scattering processes the enhancement of the πNN vertex arises in the same way, and any explanation of the EMC effect invoking enhanced pion fields within the nucleus must confront the lower-energy hadron scattering data.

One model of the pionic enhancement uses the spin-isospin responses of Alberico, Ericson, and Molinari (AEM)[20,21] which is calculable for quasi-free scattering in infinite nuclear matter. The separation between spin-longitudinal and spin-transverse provides additional selectivity to the $\vec{\sigma} \cdot \vec{q}$ and $\vec{\sigma} \times \vec{q}$ parts of the residual interaction given by

$$V_L^{res}(q,\omega) \sim \frac{f_\pi^2}{m_\pi^2}\left[g' - \frac{q^2}{q^2 + m_\pi^2 - \omega^2}\right] \qquad (3.1)$$

$$V_T^{res}(q,\omega) \sim \frac{f_\pi^2}{m_\pi^2}\left[g' - \left(\frac{f_\rho^2/m_\rho^2}{f_\pi^2/m_\pi^2}\right)\frac{q^2}{q^2 + m_\rho^2 - \omega^2}\right] \qquad (3.2)$$

(to within vertex form factors). Since $m_\rho \approx 5.5 m_\pi$, these two pieces of the interaction have very different q-dependences as seen in Fig. 4a along with the corresponding response functions (4b) for $g'=.7$ at $1.75\ \mathrm{fm}^{-1}$, the momentum transfer corresponding to the largest enhancement in this model. Figure 4(c) is the ratio of spin-longitudinal to spin-transverse response functions in this model. It is this proposed attractive behavior of V_L^{res} which enhance the pion field in the nucleus giving rise to the EMC effect.[22] It should be noted that other models of V^{res} do not exhibit this attractive behavior[23] and hence would not predict any excess pions.

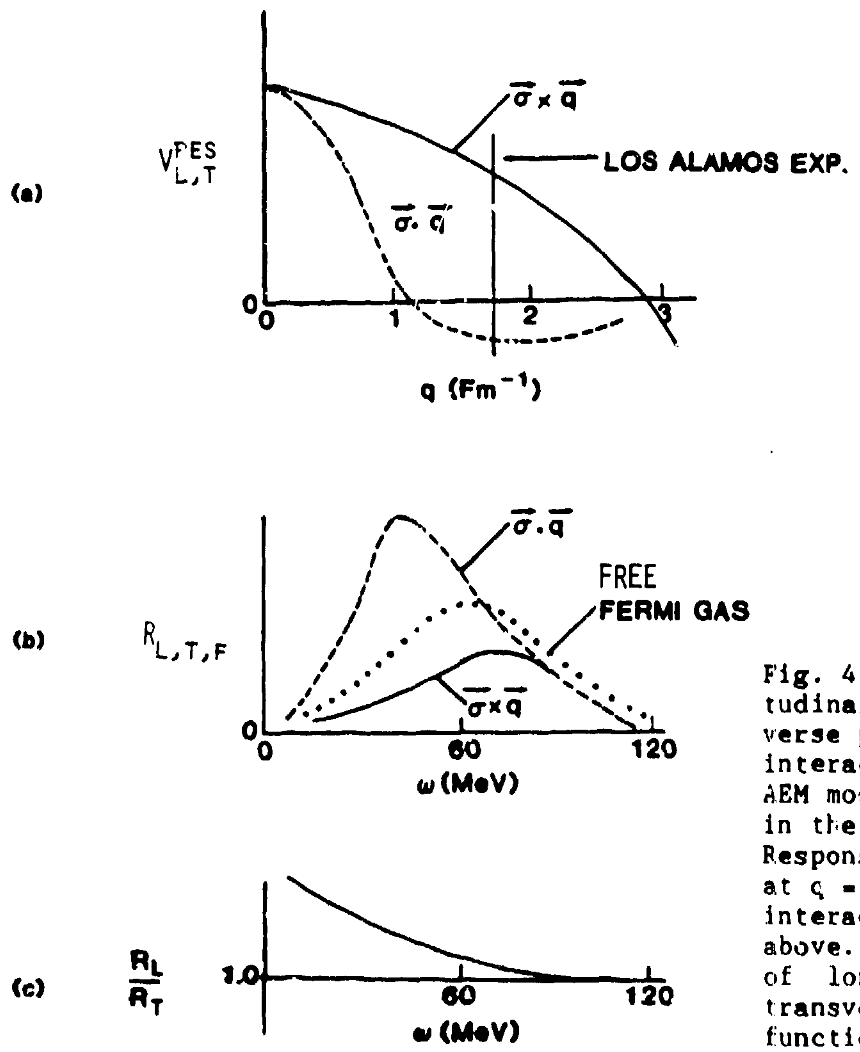

Fig. 4. (a) Longitudinal and transverse particle-hole interaction in the AEM model described in the text. (b) Response functions at $q = 1.75\text{fm}^{-1}$ for interactions shown above. (c) Ratio of longitudinal to transverse response functions.

The proton experiment consists of precise determination of the complete set of polarization-transfer coefficients for 500 MeV inclusive scattering from Pb, Ca, and ^{2}H at a momentum transfer of $q = 1.75\text{fm}^{-1}$. The spin-longitudinal and spin-transverse spin-flip probabilities are constructed using

$$IS_L = 1/4\ [1 - D_{NN} + (D_{SS} - D_{LL})\sec\Theta_{lab}]\ , \qquad (4.1)$$

$$IS_T = 1/4\ [1 - D_{NN} + (D_{SS} - D_{LL})\sec\Theta_{lab}] \qquad (4.2)$$

For free NN scattering these combinations will isolate pure spin-longitudinal and spin-transverse couplings of the two nucleon system. For intermediate energy nucleon-nucleus interactions the following prescription is used:

$$IS_L = I^{NN}S_L^{NN}R_L(q,\omega)\ N_e \quad , \tag{5.1}$$

$$IS_T = I^{NN}S_T^{NN}R_T(q,\omega)\ N_e \quad , \tag{5.2}$$

$$I = I^{NN}R(q,\omega)\ N_e \quad , \tag{5.3}$$

where NN refers to the nucleon-nucleon values. N_e is the effective number of participating nucleons. The spin-longitudinal, transverse, and total response functions per nucleon in the A-nucleon system are defined as

$$R_L(q,\omega) = |\langle q,\omega| f(\vec{r})\vec{\sigma}\cdot\vec{q}e^{i\vec{q}\cdot\vec{r}}|o\rangle|^2 \quad , \tag{6.1}$$

$$R_T(q,\omega) = |\langle q,\omega| f(\vec{r})\vec{\sigma}\times\vec{q}e^{i\vec{q}\cdot\vec{r}}|o\rangle|^2 \quad , \tag{6.2}$$

$$R(q,\omega) = \frac{C^2 + B^2 + F^2}{I^{NN}} R_T + \frac{E^2}{I^{NN}} R_L + \frac{A^2 + C^2}{I^{NN}} R_o \quad , \tag{6.3}$$

It should be noted that R_L is new nuclear structure information not available in (e,e′) or (π,π') scattering. Taking the same approach as in the EMC experiment, the isospin-averaged values for S_L^{NN} and S_T^{NN} were experimentally determined by quasi-free scattering from ^2H in order to eliminate any uncertainties in the phase shift values of these quantities. From these data the ratio of $R_L(q,\omega)/R_T(q,\omega)$ was extracted by

$$S_L^{Pb}/\langle S_L^D\rangle = R_L(q,\omega)/R(q,\omega) \quad , \tag{7.1}$$

$$S_T^{Pb}/\langle S_T^D\rangle = R_T(q,\omega)/R(q,\omega) \quad , \tag{7.2}$$

where A refers to the heavy target, D to the deuterium data, and < > implies an average over ω.

Even at the level of the individual spin-flip probabilities, S_L and S_T for the heavy target show no difference from ^2H, and hence no effect is seen in in the ratio of responses derived from them. (Recall that the response functions are normalized to unity for free NN scattering).

Several corrections must be made to the proton data, however, before the level of sensitivity to the predicted enhancement of R_L can be determined. It is expected that a density correction must be made to account for the surface peaking of protons scattering from the nucleus at these energies. Two methods were employed, a local Fermi gas approximation where the interaction profile is calculated using a detailed Intranuclear Cascade code[24] and the Semi-Infinite Slab model,[25] which accounts well for medium-energy p-nucleus continuum data.[26] Both yield essentially identical results for the ratio of R_L/R_T. It also demonstrates that the Ca data provide as good a density profile as Pb at these energies.

Secondly, the calculated ratio is purely isovector. Corrections must be made for the mixed isospin contributions for (p,p′) scattering. This is accomplished using the isospin decomposition of the NN interaction from the 500-MeV phase-shift solution of Arndt. The results for $q = 1.75 fm^{-1}$ are (in terms of the coefficients in Eq. 1)

$$E^2_{T=1}/E^2_{T=0} = 3.62 \tag{8.1}$$

$$E^2_{T=1}/E^2_{T=0} = 1.15 \tag{8.2}$$

The longitudinal interaction is dominantly isovector but the transverse consists of nearly equal mixtures of both isospins. We define

$$\tilde{R}_L = \frac{1}{4.62}(3.62 R_L^{T=1} + R_L^{T=0}) \tag{9.1}$$

and

$$\tilde{R}_T = \frac{1}{2.15}(1.15 R_T^{T=1} + R_T^{T=0}) \tag{9.2}$$

and all isoscalar responses are assumed to be the free, non-interacting functions. The calculated ratios of $\tilde{R}_L/\tilde{R}_T$ are shown in Fig. 5 along with the data for the quasi-free experiment. The different curves represent different values of g′. Recent analysis of the EMC data requires g′= 0.55 in order to fit the low-x region,[27] in disagreement with the proton data. In fact the data

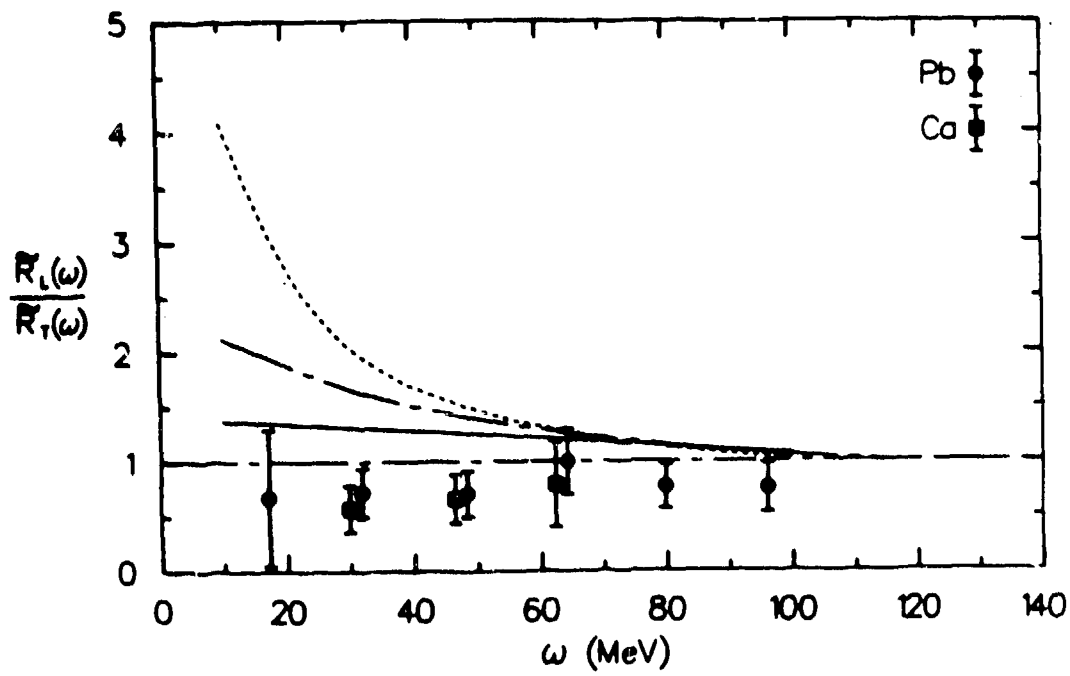

Fig. 5. Comparison of theory and proton scattering data for the ratio $\tilde{R}_L/\tilde{R}_T$. Calculations are for values of g′= 0.55 (dotted), g′= 0.7 (dot-dashed), and g′= 0.9 (solid).

favor a large value of $g' = 0.9$ at this momentum transfer. It should be noted that most of our knowledge of g' comes from $q = 0$ and the q-dependence is essentially undetermined.

Many other possible sources of "theoretical error" have been investigated. These include verifying the validity of the approximations at small ω, coupling of longitudinal and transverse modes in a finite nucleus, distortion effects, and differential range effects for one-π and one-ρ exchange potentials. These are detailed in Ref. 19. None of these effects seem to account for the lack of enhancement in the proton data predicted by those pion models used to explain the EMC effect. Such comparisons could not be made, however, without spin-transfer measurements.

It seems clear that spin observables at intermediate energies will provide the required detailed information needed to address important fundamental questions in nuclear physics today. These programs are relatively new, but have already made significant impact. Many laboratories are now pursuing them with great vigor and enthusiasm.

The work and ideas presented here include those of many of my colleagues and collaborators. I would especially like to acknowledge helpful discussions with Joel Moss, Tom Carey, Terry Taddeucci, and Charles Glashausser.

REFERENCES

1. J. B. McClelland et al., "A Polarimeter for Analyzing Nuclear States in Proton-Nucleus Reactions Between 200 and 800 MeV," Los Alamos National Laboratory Report No; LA-UR-84-1671 (May 1984); T. N. Taddeucci, et al., Nucl. Instrum. Methods A241, 448 (1985).
2. A. Rahbar et. al., Phys. Rev. Lett. 47, 1811 (1981).
3. Proceedings of the LAMPF Workshop on Dirac Approaches to Nuclear Physics, Los Alamos National Laboratory document LA-10438-C (May 1985).
4. S. J. Wallace, "Development of the Relativistic Impulse Approximation," Proceedings of the LAMPF Workshop on Dirac Approaches to Nuclear Physics, Los Alamos National Laboratory document LA-10438-C (May 1985).
5. J. M. Moss, Phys. Rev. C26, 727 (1982).
6. E. Bleszynski, M. Bleszynski, and C. A. Whitten, Jr., Phys. Rev. C26, 2063 (1982).
7. J. B. McClelland et. al., Phys. Rev. Lett. 52, 98 (1984).
8. C. Horowitz and M. Iqbal, "Relativistic Effects on Spin-Observables in Quasielastic Proton Scattering," to be published.
9. J. B. McClelland, et al., "Development Plan for the Nucleon Physics Laboratory Facility at LAMPF," Los Alamos National Laboratory report LA-10278-MS (February 1986).
10. W. G. Love and Amir Klein, "Nuclear Currents in Inelastic Scattering: Relativistic and Nonrelativistic Approaches," Proceedings of the LAMPF Workshop on Dirac Approaches to Nuclear Physics, Los Alamos National Laboratory document LA-10438-C (May 1985); D. A. Sparrow, et al., Phys. Rev. Lett. 54, 2207 (1985).

11. C. D. Goodman et. al., Phys. Rev. Lett. 44, 1755 (1980).
12. T. N. Taddeucci et. al., Phys. Rev. C25, 1094 (1982).
13. C. D. Goodman and S. D. Bloom, in "Spin Excitations in Nuclei," editied by F. Petrovich (Plenum, New York); C. Gaarde, J. S. Larsen, and J. Rapaport, ibid.; J. Rapaport, in The Interaction Between Medium Energy Nucleons in Nuclei-1982, edited by H. O. Meyer, AIP Conference Proceedings No. 97 (American Institute of Physics, New York, 1983).
14. F. Osterfeld, D. Cha, and J. Speth, Phys. Rev. C31, 372 (1985).
15. Amir Klein, W. G. Love, and N. Auerbach, Phys. Rev. C31, 710 (1985).
16. C. Glashausser, Comments Nucl. Part. Phys. 14, 39 (1985).
17. See, for example, C. Djalali, Proceedings Int. Conf. Highly Excited States and Nucl. Struc., Orsay, 1983 (Editions du Physique, Paris, 1984),; and A. Lichter, Nucl. Phys. A374, 177c (1982).
18. Los Alamos Experiment #741, T. A. Carey, K. W. Jones, J. B. McClelland, J. M. Moss, L. B. Rees, N. Tanaka, and A. D. Bacher (1984).
19. T. A. Carey et. al., Phys. Rev. Lett. 53, 144 (1984); L. B. Rees et. al., "Continuum Polarization Transfer in 500 MeV Proton Scattering and Pionic Collectivity in Nuclei," Los Alamos National Laboratory report LA-UR-86-35 (December 1985), accepted for publication Phys. Rev. C.
20. W. M. Alberico, M. Ericson, and A. Molinari, Nucl. Phys. A379, 429 (1982).
21. W. M. Alberico, M. Ericson, and A. Molinari, Phys. Rev. C30, 1776 (1984).
22. M. Ericson and A. W. Thomas Phys. Lett. 128B, 112 (1983).
23. J. Speth et. al., Nucl. Phys. A343, 382 (1980); M. Rho, Annu. Rev. Nucl. Part. Phys. 34 (1984); G. E. Brown.
24. Calculations performed with the Los Alamos version of ISABEL by Y. Yariv and Z. Fraenkel.
25. G. F. Bertsch and O. Scholten, Ann. Phys. 157, 255 (1984).
26. J. M. Moss et. al., Phys. Rev. Lett. 48, 789 (1982).
27. D. Stump, G. F. Bertsch, and J. Pumplin in "Hadron Substructure in Nuclear Physics," American Institute of Physics, New York (1984), p. 339.
28. S. J. Seestrom-Morris et. al , Phys. Rev. C26, 2131 (1982).
29. T. N. Taddeucci et. al. Phys. Rev. C33, 746 (1986).