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DISCUSSION SESSION: NUCLEON- AND ANTINUCLEON-NUCLEUS INELASTIC SCATTERING AND CHARGE EXCHANGE

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INTRODUCTION

This short article summarizes one part of the discussion session concerning nucleon- and antinucleon-nucleus inelastic scattering and charge exchange. Assigned an unconstrained role somewhere between that of rapporteur and "rioteur" I've decided to use a few highlights of the conference to stage a number of personal opinions regarding our current status in this game and where we might be going. This written version dispenses with figures by referencing other talks and also incorporates ensuing discussion.

THE NUCLEON-NUCLEUS CASE

Based on what we've heard at this conference I think it's fair to say that polarization transfer is opening entirely new avenues in nucleon-nucleus inelastic scattering and charge exchange. At the 1982 Telluride meeting J. Moss argued that by measuring the polarization transfer observables for excitation of select final states with "known" nuclear structure we should be able to resolve the individual components of the impulse approximation effective interaction.[1] The first tests of this hypothesis showed that at least for surface-peaked transitions excited by ~500-MeV nucleons this effective interaction was essentially the free one.[1,2] As this is the essence of the impulse approximation we have now struck out to use it for probing new features of the nuclear response.

These new studies have notably concentrated on unraveling the nature of the nuclear continuum. Most thorough in this regard is the precise measurement of complete sets of polarizaton transfer observables for quasielastic $(\vec{p},\vec{p}')$.[3] We've argued that they can be used to extract detailed structure information such as the individual axial-longitudinal and transverse form factors for nuclear spin modes. Yet in spite of the extreme accuracy of this data we've sofar concentrated on ratios of these form factors in order to circumvent both theoretical and experimental uncertainties. The model for quasielastic scattering used in this analysis was oversimplified mostly for lack of machinery to do better calculations. To get at the individual factors we need to bring our techniques for predicting continuum excitations somewhere near the level of sophistication now regarded as commonplace for transitions to specific final states. At least then if we're going to start with an impulse approximation we can quantitatively assess the potential impact of distortions, off-shell effects, uncertainties due to incomplete knowledge of the NN amplitudes, etc., in a well defined manner. Note also that while it is fair to ask the experimentalists to remove the last concern it would be much more fruitful in the context of present interests to know specifically which NN observables should be measured in what ranges, especially since the community has spent nearly 30 years attempting to fully characterize the simplest case of pp elastic scattering!

The past two years have also brought the first measurements of polarization transfer in $(\vec{p},\vec{n})$ reactions.[4,5,6] Although they have been limited to only D_{NN} at only 0^o this quantity takes on fairly distinctive values depending on whether or not spin transfer is involved in such a reaction, so these studies provide a reasonable starting point. Values of D_{NN} for sharp Gamow-Teller and Fermi transitions in light nuclei are completely in line with expectations based on impulse approximation calculations. These results have provided the first direct evidence for the dominance of spin-transfer in 0^o (p,n).

Once again we have pushed towards exploiting these new tools for investigating the composition of the nuclear continuum. At moderate excitation energies ($E_x \simeq$ 20-30 MeV) use of D_{NN} to separate the (p,n) spectrum into spin-flip and non-spin-flip components reveals broad structures which are not apparent at all in the overall cross section.[4] While in several cases they hint at enticing correspondences with theoretical predictions only further investigation will allow them to be definitively characterized. Perhaps the most pervasive feature of the (p,n) spectrum is that at excitation energies above ~30 MeV D_{NN} is almost universally zero, corresponding to transverse spin-flip probability S_{NN} = 1/2 independent of the target. Watson[5] has argued that for spin-saturated targets this is a signature of quasifree scattering: if the 0^o neutrons corresponding to large target excitation are the result of a sort of knock-on exchange then we might expect D_{NN} = 0 since the target neutrons are are on average unpolarized. This is certainly intuitively appealing, but is it reasonable based on what we know? I. e., "quasifree" scattering suggests that there should be some vestige of NN scattering present, so what does the available NN data tell us? In fact, Prof. Arndt[7] has gone to a lot of trouble to compute error corridors for virtually everything he calculates, so we should all take advantage of this wherever possible. My point here is not to judge but rather to remind everyone that our ideas should always be guided by either what we know or by damned good reasons to question its applicability or validity.

In connection with our reaction model(s) we have been ardently discussing the need for a "relativistic impulse approximation" based on the Dirac Equation as opposed to the old standard utilizing the nonrelativistic Schroedinger Equation as a starting point. Before we debate "relativistic versus nonrelativistic", however, we should first assess the differences in 'relativists' approximations versus nonrelativists' approximations". In particular, the relativists cannot justifiably maintain that nonlocal current terms arise "naturally from the lower components of the Dirac four-spinors" in their approach[8] when to see them they must also retain the dependence of the scattering amplitude on the target nucleon momentum that the nonrelativists neglect at the outset (cf. Eqns. (3.6-3.7) of KMT[9].) Nor can we quantitatively argue the importance of "exchange nonlocalities" when in the nonrelativistic approach we start with an explicitly antisymmeterized representation for the NN interaction which then forces us to calculate its exchange matrix elements for consistency, while in the relativistic approach we only consider direct matrix elements but of a t-matrix. Clearly, as the farmers would say, "We need parity first!" Also, while removing these discrepancies we should be opportunistic and overhaul our representation for the basic interaction in accordance with our latest pictures for NN scattering.[10] One of the principle reasons for studying N-nucleus scattering is to determine whether or not the nuclear medium has any fundamental impact (beyond Pauli blocking) on NN dynamics, so why not start with as much physics as possible?

The future holds many experimental challenges, too. As most of the issues I've discussed involve questions of spin-dependence it's obvious that polarization transfer studies will play a leading role. But testing second-generation theories will require second-generation experiments; we must strive for data having at least the quality of the new IUCF measurements.[11] The full 100 MeV-to-1 GeV energy range should be investigated, and data for a diverse collection of well-chosen excitations spanning as broad a range of momentum transfer as possible must be obtained. Notably, the first measurements of Q for elastic p-nucleus scattering at 1 GeV will soon be undertaken at Saclay.[12] The $(\vec{p},\vec{p}')$ facility at LAMPF has recently been upgraded to permit an order-of-magnitude increase in beam intensity on target, thus removing a previously serious practical impediment to high-precision data.[13] A broad-range polarimetry system has been installed on the improved Medium Resolution Spectrometer at TRIUMF,[14] and similar systems are in the design for the detection arrays of the new IUCF spectrometers.[15] On the charge exchange side a generalized neutron polarimetry system for obtaining complete sets of spin-transfer observables in $(\vec{p},\vec{n})$ is currently under development at IUCF and should be operational early next year.[16] It will later be integrated into a new time-of-flight facility for 200-800 MeV neutrons at LAMPF. And, to be really brash, we can probably also think about polarization transfer in (n,p) somewhere down the road. To summarize for the theorists, the elastic Q-measurements were only the first blow!

ANTINUCLEON-NUCLEUS SCATTERING --- TELLURIDE 0?

In the context of inelastic scattering and nuclear structure studies we've only glimpsed the possibilities offered by N-nucleus scattering, so my remarks here will be commensurately brief.

Mere comparison between the $\bar{N}N$ and NN amplitudes suggests that antinucleons can be a rich probe of the nuclear response with interesting complementarity to the features offered by nucleons.[17] However, as in the case of nucleons, their full exploitation for these studies will eventually require the use of polarized beams. And long before their serious application in this vein we must sort out considerable uncertainties in the basic $\bar{N}N$ interaction. This is especially true as to how various models for the annhilation channel reflect on, e. g., $|t_{\sigma\tau}/t_{\tau}|^2$.[17,18]

Experimentally we have barely gotten out of the starting blocks, with literally only a few hours of LEAR antiprotons on target sofar. But already considerable improvements in intensity, energy resolution, etc., are in the works.[19] And we've even heard about efforts towards measuring antineutron scattering at BNL![20]

Given its very early stage of development the key to progress in this area will lie in carefully chosen, selective studies which draw heavily on the experience gleaned from nucleon-nucleus scattering wherever applicable. Such a new endeavor represents an ideal opportunity for experiment and theory to develop hand in hand. At the same time we should not be fearful of small cross sections. After all we're now obtaining N-nucleus polarization transfer data for specific nuclear excitations with absolute uncertainties in the few percent range; viewed as triple scattering measurements in the not so distant past this would have been regarded as impossible. So why not polarization transfer in ($\bar{p}$,π)...?

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