CHARGE-EXCHANGE REACTIONS

INVESTIGATION OF ISOVECTOR AXIAL RESPONSE VIA POLARIZATION TRANSFER IN THE $(\vec{p},\vec{n})$ REACTION

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The curse of nucleon-nucleus scattering has always been the enormous complexity of the elementary nucleon-nucleon interaction. Few if any other forces involve such a wide range of basic fields. Recently, however, a revolution of experimental technique has shown that this diversity may prove to be the ultimate promise of medium-energy nucleons as probes of the nuclear response. In just the past four years the development of high-efficiency, high-resolution instruments for acquiring complete sets of polarization-transfer observables in proton scattering has already suggested basic changes in our thinking about nuclear dynamics. Measurements of these observables in the elastic channel were singularly responsible for the consideration of relativistic N-nucleus impulse approximations.[1] Polarization transfer studies in inelastic proton scattering have also uncovered extremely interesting problems with our basic approaches to nuclear structure. E.g., they have provided tantalizing evidence for considerable unanticipated spin-flip strength in the low-lying nuclear continuum.[2] Most recently a complete set of high-precision polarization transfer observables for proton scattering to the quasielastic sector has been used to provide the first separation of the spin-longitudinal $(\vec{\sigma}\cdot\vec{q})$ and spin-transverse $(\vec{\sigma}\times\vec{q})$ components of the nuclear response.[3] The former quantity is uniquely accessible via nucleon scattering and plays a pivotal role in explanations of the EMC effect based on "excess" nuclear pions. Surprisingly these measurements cast serious doubt on the validity of such explanations and also suggest that the momentum dependence of the residual spin-isospin interaction is still at best only poorly understood.

In short, (p,p′) polarization transfer observables have shown us a means for disentangling the various spin-dependent components of N-nucleus interactions. But, excepting a few select cases, proton scattering typically involves a nontrivial combination of isoscalar and isovector transition densities. Furthermore even when purely isovector (p,p′) transitions can be found they often involve large excitation energies and are thus subject to heavy competition from numerous, usually uninteresting neighboring levels. The (p,n) reaction, on the other hand, admits only $\Delta T=1$ and strongly favors $\Delta S=1$ modes for beam energies near 200 MeV. The number of possible N-N interaction components is considerably limited here. Also many analogues of isovector (p,p′) excitations are ground state-to-ground state transitions in (p,n) and so are free of background from neighboring states. In conjunction with polarization transfer the charge exchange reaction should therefore offer a relatively simpler and more sensitive tool than inelastic scattering for investigating the isovector spin-dependent aspects of N-nucleus interactions.

In order to pursue such studies we are developing a generalized polarimetry system for measurement of complete sets of polarization transfer observables in $(\vec{p},\vec{n})$ reactions at IUCF energies. This includes commissioning of arbitrary beam polarization orientation at IUCF and design and implementation of a neutron double-scattering polarimeter with an upstream, cycling neutron spin precessor for cancellation of systematic effects.

As currently designed the polarimeter will consist of at least three planes each 1.0m long x 1.0m high x 10cm thick oriented normal to the incident neutron flux. Each plane consists of a thin-walled stainless steel tank of liquid scintillator subdivided into ten individual cells 1.0m long x 10cm high x 10cm thick and viewed at both ends by 2" phototubes. Each cell is optically isolated from its neighbors by thin, lucite-black paper-lucite sandwiches which permit only total internal reflection. This emphasizes prompt light and leads to optimum intracell timing/position resolution without sacrificing energy resolution needed for key polarimetry cuts. With our insitigation Bicron has developed a new mineral-oil-based liquid scintillator for these detectors. With its H:C ratio of 1.7, density of $0.86 g/cm^3$, attenuation length >5m and light output >64% of anthracene it provides an ideal active analyzer for polarimetry based on $^1H(n,n)^1H$ scattering.

The first plane in this system is the "analyzer" wherein elastic scattering of the incident neutrons from the protons in the liquid scintillator is to be emphasized. Two abutted planes located approximately one meter downstream from the analyzer form the "catcher". This segmentation of the catcher is necessary to obtain the required time-of-flight resolutions. Only neutrons scattered from the analyzer plane are accepted in either of the two rear catcher planes through active interplane charged-particle vetoes. Vertical and horizontal position information is obtained for each event from both analyzer and triggered catcher planes. In each case time differences between the ends of the struck cells is used to determine the horizontal position while the vertical position is derived from mere indentification of the struck cells. From these two sets of coordinates polar and azimuthal second-scattering angles are calculated, and both transverse polarization components at the polarimeter are simultaneously analyzed in manner similar to that used in wideband proton polarimetry systems.[4] Absolute measurement of the scattered neutron velocity between the analyzer and catcher planes also facilitates selection of $^1H(n,n)$ scatterings over $^{12}C(n,n'X)$ reactions with uselessly small analyzing power. By suitable spin-precession of the neutrons between the target and polarimeter all three final-state polarization components originating from the target may be obtained. Furthermore this spin-precessor can be used to periodically "flip" the outgoing neutron polarization and thereby cancel numerous systematic effects much as in proton-beam polarimetry.

Thusfar near-unit-analyzing power proton beam polarimeters have been developed and calibrated, and one scheme of beam polarization orientation has been implemented and used in IUCF experiments E235 and E245. Dipole and superconducting solenoidal magnets for the neutron spin precessor have been chosen: the dipole is currently being retrofitted while the solenoid is being manufactured to our specifications as a new instrument. We have also prototyped the polarimeter design with two three-cell planes. With 160-MeV incident neutrons a simple time difference between cell ends gives $\lesssim$5cm of position resolution along the cell axes. The time sum from both ends has an overall ~600 psec resolution, and the detection medium shows the same efficiency per unit volume as the more standard NE-102. These should represent worst case parameter values since we have not yet taken advantage of events involving two or more adjacent cells. While finalizing the detector geometry we are also refining the electronics and trigger definition with an eye towards gaining the maximum information possible from these detectors.

Other subsystems currently under design/development include a cosmic-muon trigger array for continuous tracking of the detector performance and an optical pulsing system for setup and on-line monitoring. In the early part of 1985 we will undertake construction of the final detection system, layout of a dedicated end station and remote counting house, mapping of the Swinger dump field region to be traversed by the detected neutron, and development of high-level acquisition and control software including interfaces to the neutron spin precessor and peripheral instrumentation. Our current goals are to begin installation of system componenets at IUCF in mid-1985 and to have virtually all hardware in place by the last quarter of 1985.

1) S.J. Wallace, in Proceedings of the Seventeenth LAMPF Users Group Meeting, Los Alamos National Laboratory, 1983, ed. J.A. Bradberry (LANL Report LA-10080-C), and refs. therein.

2) S.K. Nanda et al., Phys. Rev. Lett. 51, 1526 (1983).

3) T.A. Carey et al., Phys. Rev. Lett. 53, 144 (1984).

4) J.B. McClelland et al., Los Alamos Unclassified Report LA-UR-84-1671, Los Alamos National Laboratory, 1984.