MASTER

LBL-11545

CONF-800824--27

Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA

Rapporteur's Report, presented at the Fifth International Symposium on Polarization Phenomena in Nuclear Physics, Santa Fe, NM, August 11-15, 1980

POLARIZATION EFFECTS IN LIGHT NUCLEI

H. E. Conzett

September 1980

NUCLEAR SCIENCE DIVISION

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

Prepared for the U.S. Department of Energy under Contract W-7405-ENG-48

Rapporteur's Report, presented at the
Fifth International Symposium on Polarization
Phenomena in Nuclear Physics,
August 11-15, 1980, Santa Fe, New Mexico

POLARIZATION EFFECTS IN LIGHT NUCLEI

(Session 5)

H. E. Conzett
Lawrence Berkeley Laboratory
University of California, Berkeley, CA 94720

The discussion during the session on Polarization Effects in Light Nuclei was limited to the following topics:

1. The deuteron D-state.
2. The three nucleon system.
3. Polarization vs. analyzing-power in the $^{15}N(p,n)^{15}O$ reaction.

DEUTERON D-STATE

The D-state of the deuteron recived the most discussion, probably because there has been a flurry of activity concerning it, both theoretical and experimental, during the past two years. In separate papers, Amado and Friar suggested that the D-state probability, P_D, is not really accessible to experimental determination. At about the same time, Amado, Locher, and Simonius showed that ρ_D, the asymptotic D to S-state ratio of the deuteron wave-function, was experimentally determinable. This ratio is defined as:

$$\rho_D \equiv [U_2(r)/U_o(r)]_{r=\infty},$$

where $U_2(r)$ and $U_o(r)$ are the deuteron D and S-state radial wave-functions, respectively. Although their first prescription for the determination of ρ_D had to be changed a bit, the method is very clear and direct. First, measure the differential cross-section and the tensor analyzing-power component $T_{22}(\theta)$ in elastic $\vec{d}$-p scattering. Then, construct the function

$$f(z) = k^2\,\sigma(z)\;T_{22}(z)\;(z-z_p)^2/(1-z^2), \qquad (1)$$

where $z = \cos\theta$. Next, extropolate $f(z)$ to the nucleon exchange pole at $z_p = -(5/4+9B/4E_d)$, with B and E_d the deuteron binding energy and the deuteron lab. energy, respectively. Then one deduces ρ_D directly from

$$f(z_p) = -\,0.0542\;\rho_D.$$

This manuscript was printed from originals provided by the author.
This work supported by the U.S. Department of Energy under Contract W-7504-ENG-48.

To an experimentalist, there is hardly ever such a beautifully direct connection between his data and a physical parameter of a nuclear system. How does the function f(z) achieve this magic? It becomes a bit more transparent if one notes that

$$T_{22}(z) \propto [\sigma_{xx}(z) - \sigma_{yy}(z)]/\sigma(z),$$

where $\sigma_{xx}(z)$ and $\sigma_{yy}(z)$ are the (spin-dependent) cross sections for incident deuterons aligned along the x and y axes, respectively (Fig. 1). Then,

$$f(z) \propto k^2[\sigma_{xx}(z) - \sigma_{yy}(z)](z-z_p)^2/(1-z^2), \tag{2}$$

and f(z) would be zero for an S-state deuteron whose spherical symmetry would make $\sigma_{xx}(z)$ equal to $\sigma_{yy}(z)$. Thus, f(z) is an observable that provides a direct measure of the D-state paramater. In the vicinity of the nucleon exchange-pole, the scattering amplitude is dominated by it, so there

$$a(z) = N/(z-z_p).$$

Thus, the factor $(z-z_p)^2$ in Eqn. (2) cancels the pole denominator in the cross sections and $(1-z^2)$ removes the zeros of $T_{22}(z)$ at $z = \pm 1$. We see from the Zürich data in Fig. 2 that this construction does, indeed, produce a nice smooth f(z) for extrapolation, whereas the z-dependences of $\sigma(z)$ and $T_{22}(z)$ are much more violent.

Since ρ_D must be independent of E_d, the incident deuteron energy, it is important to do the experiment over a range of E_d in order to evaluate the consistency of the extrapolation procedure. The Zürich group reported very consistent results from measurements at ten energies between E_d = 5 and 45.4 MeV. Their final result is

$$\rho_D = 0.0259 \pm 0.0007, \tag{3}$$

where the error includes both statistical and data-normalization uncertainties. This value is in excellent agreement with the earlier Berkeley result

$$\rho_D = 0.0263 \pm 0.0013. \tag{4}$$

In a completely different experiment, the Wisconsin group have determine ρ_D from measurements of the tensor analyzing powers in the $^{208}Pb(\vec{d},p)^{209}Pb$ stripping reaction at sub-Coulomb energies. In the DWBA calculations these analyzing power scale directly with ρ_D, and the calculated fits to these data have yielded

$$\rho_D = 0.02649 \pm 0.00043 \tag{5}$$

as their latest value. This is some 14% larger than their original (1975) value, and I assume that data taken at lower energies and more complete DWBA calculations are responsible for the change. Clearly, (3) (4) and (5) are in complete agreement. I would, however, caution that once the experimental uncertainties are reduced to the level of (3) and (5), one must be concerned with the "theoretical" uncertainties of the extrapolation procedure, on one hand, and of the DWBA calculations, on the other.

This experimental value of ρ_D is now very satisfactorily provided by the most recent meson-exchange nucleon-nucleon potentials:

de Tourreil and Sprung (1975):	$\rho_D = 0.0260$
Bonn (1979)	$\rho_D = 0.0258-0.0260$
Paris (1980)	$\rho_D = 0.02608$

This shows, principably, that the intermediate and longe range parts of the interaction are well tied down, but can anything more be said about the deuteron D-state from this very accurate determination of ρ_D? The answer is yes. Klarsfeld et. al. (in a recent preprint) have, from the quadrupole moment and ρ_D, established a lower bound on the D-state probability. They show in a model-independent way, in the sense of any triplet-even interaction that agrees with one-pion exchange for distances $R \geq 2.0$f., that $P_D \geq 3.5\%$.

THREE NUCLEON SYSTEM

The discussion on the three-nucleon system centered on the present state of agreement or disagreement between experimental results and results calculated with the Faddeev equations (principally by Doleschall). Recent measurements of deuteron break-up cross sections in the ^{2}H(p,2p)n reaction at 26 MeV were reproduced very well by the calculations. Doleschall discussed the major outstanding disagreement in elastic nucleon-deuteron scattering. The cross-sections and the nucleon and deuteron analyzing powers have been measured at several energies up to $E_N = 23$ MeV. The major discrepancy between experiment and theory is found with the nucleon analyzing power $A_y(\theta,E)$. Fig. 3 shows, qualitatively, the problem. Part (a) shows the typical angular distribution of A_y, the solid curve for a lower energy, the dashed curve for a higher energy. Part (b) shows the energy dependence of the maximum value of $A_y(\theta)$, A_y^{max}. The solid line is drawn through the experimental $\vec{p}$d values, and the dashed line represents the calculated $\vec{n}$d values. Above $E_N = 10$ MeV there is a clear and increasing difference with increased energy, which certainly can not be repaired by including the Coulomb interaction in the calculations. The usual concern is that not enough NN partial waves are included, but a calculation which included F-waves gave essentially the same result for $A_y(\theta)$ as the calculation which omitted them. All is not lost, however, since the $^3P_{0,1,2}$ waves and the $^3S_1$-$^3D_1$ mixing parameter ϵ_1 are still not firmly pinned down by the lower energy NN scattering data. In fact, high precision $\vec{p}$p analyzing power data reported here (paper 1.9) are not fitted by the most up-to-date NN potentials. Some adjustment of the ^{3}P-waves is very likely necessary and it is known that the $\vec{N}$d $A_y(\theta)$ is quite sensitive to these. So, between that and ϵ_1 there may still be enough flexibility to bring experiment and calculation into agreement for the $\vec{N}$d analyzing powers.

P-A in $^{15}N(p,n)^{15}O$

There was a brief discussion of the polarization versus analyzing power in the $^{15}N(p,n)^{15}O$ reaction, specifically

$$P_n \quad \text{in} \quad ^{15}N(p,\vec{n})^{15}O \quad \text{and}$$

$$A_p \quad \text{in} \quad ^{15}N(\vec{p},n)^{15}O \;.$$

Their difference is given by

$$P\text{-}A = (\sigma^{-+} - \sigma^{+-})/\sigma,$$

with σ^{-+} the cross-section for the nucleon transverse spin flip from down to up and σ the unpolarized cross-section. Since P-A = 0 follows from time-reversal invariance and charge symmetry, the large P-A differences found in this reaction for $E_p \approx 5$ to 9 MeV (e.g. paper 6.14) were quite unexpected and exciting. As was detailed in Philpott's talk earlier in this conference, these differences are very nicely explained qualitatively via microscopic shell-model calculations which include the necessary non-central nucleon-nucleon interaction and isospin mixing. It is noteworthy that almost 25 years ago Wilkinson selected this $^{15}N(p,n)^{15}O$ reaction as a prime candidate for isospin mixing at the excitation energies spanned in this experiment. Even though either time-reversal violation or charge-symmetry breaking could lead to P-A $\neq 0$, in view of the very satisfying explanation in terms of isospin mixing I would be the last person at this conference to even suggest that time-reversal violation might, also, be involved.

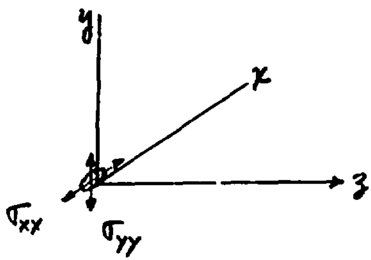

Fig. 1

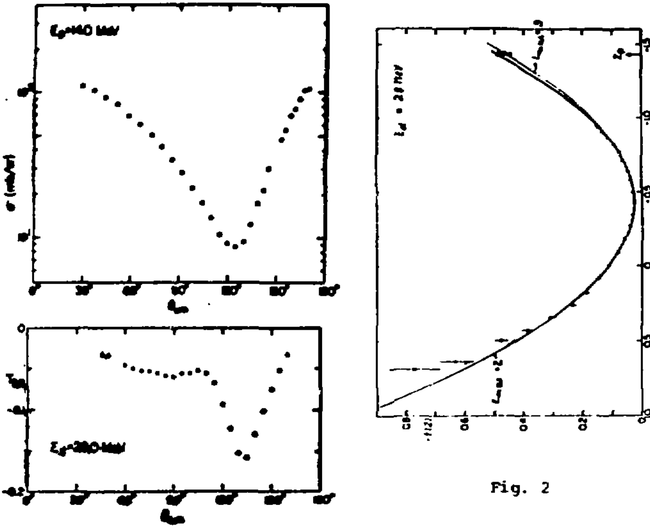

Fig. 2

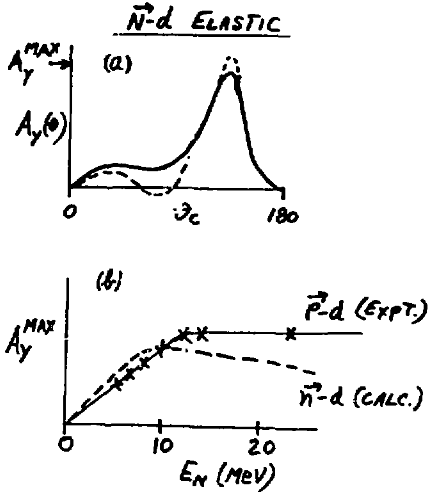
N-d ELASTIC
(a)
A_y^{MAX}
$A_y(\theta)$
0
ϑ_c
180
(b)
A_y^{MAX}
P-d (EXPT.)
n-d (CALC.)
0
10
20
E_N (MeV)

Fig. 3