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DEPOLARIZATION AND THE SPIN-SPIN INTERACTION IN p-^{9}Be ELASTIC SCATTERING*

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We have determined the D-parameter to be less than 1.0 at four angles in p-^{9}Be elastic scattering at 25 MeV. These results strengthen considerably the evidence for the existence of a nucleon-nucleus spin-spin interaction.

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In this letter we report on definite evidence for the existence of a spin-spin term in the nucleon-nucleus optical model potential, which was first suggested by Feshbach [1]. For a nucleon of spin $\vec{\sigma}/2$ scattering from a nucleus of spin $\vec{I}$, both a spherically symmetric spin-spin term,

$$U_{SS}(r) = - V_{SS} F_o(r) \vec{\sigma}\cdot\vec{I}, \quad (1)$$

and a tensor term [2], analogous to the classical potential between two magnetic dipoles,

$$U_{ST}(r) = - V_{ST} F_T(r) [3(\vec{\sigma}\cdot\hat{r})(\vec{I}\cdot\hat{r}) - \vec{\sigma}\cdot\vec{I}]/2, \quad (2)$$

may be present.

Several investigations have been made of the spin dependence of total cross sections of polarized neutrons on polarized ^{165}Ho [3] and ^{59}Co [4] in attempts to determine the strength V_{SS} of the spherical interaction (1). The ^{59}Co results, summarized by Fisher et al. [4], showed the larger effects. However, the information obtained on V_{SS} was ambiguous because the calculation, which followed the treatment of Davies and Satchler [5], was unable to reproduce the energy dependence of the data from 0.3 to 8 MeV.

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The presence of spin-spin effects can also be detected by measurements of the depolarization parameter D [6], which has the value 1.0 for direct elastic scattering in the absence of a spin-spin interaction. Thus, deviations of D from unity can be evidence for the existence of such an effect. Katori _et al_. [7] have measured D in the scattering of 1.36 neutrons from several odd-mass nuclei, and large deviations from unity were observed. These were, however, attributed to the substantial contribution of compound elastic scattering that is known to be present at such low energies. Batty and Tschalär [8] and Beurtey _et al_.[9] have measured D in the scattering of 50 and 20 MeV protons, respectively, from nuclei. Only the latter results showed values of D differing significantly from unity, but these measurements were for a single scattering angle.

In recent calculations Sherif and Hussein [10] have included both the spherical (1) and tensor (2) spin-spin terms in the optical potential. The depolarizations calculated with the spherical term alone were consistently different from the experimental values near 20 MeV, suggesting that contributions from the tensor term were important. These calculations showed that angular distributions of D were needed to determine the strength of the tensor interaction. They also showed that other observables, such as cross sections, analyzing powers, and spin-rotation parameters, were relatively insensitive to the spin-spin interaction and that the D-parameter was the elastic scattering observable most sensitive in this respect.

We have measured D at several angles in the elastic scattering of 25-MeV polarized protons from ^{9}Be. With an incident beam of polarization p_o, the polarization p_1 of the scattered protons is given by

$$p_1(\theta) = [A_1(\theta) + D(\theta)\, p_o]/[1 + p_o\, A_1(\theta)], \qquad (3)$$

where $A_1(\theta)$ is the analyzing power of ^{9}Be. Both measured polarizations are perpendicular to the scattering plane and positive along the direction $\vec{k}_i \times \vec{k}_f$. The ^{9}Be target was approximately 1 MeV thick, and for each scattering angle it was positioned so as to minimize the energy spread of the scattered beam. The polarization $p_1(\theta)$ of the scattered protons was measured with a high efficiency, good resolution silicon polarimeter. It consisted of an analyzer in the form of a silicon detector and two side detectors positioned at left and right scattering angles of 27°. The analyzer detector was 1 mm thick, giving good scattering efficiency to the side detectors. The detectors in each combination of analyzer and side detector were operated in coincidence as a ΔE-E telescope, ensuring good intrinsic energy resolution and reduction of background. Thus, even though the analyzer was some 4.5 MeV thick to 23 MeV protons, resolution of 260-270 keV resolution was achieved in the polarimeter spectra at analyzer detector counting rates near 10^5/sec. Figure 1 shows an example of these spectra. The polarimeter was calibrated with protons of known polarization elastically scattered from ^{12}C. In the scattering from a spin-zero nucleus D has the value 1.0; so, with p_o and A_1 measured, p_1 is determined from eq. (3). The measured left-right asymmetry then determines the analyzing power of the polarimeter. Further details of the polarimeter performance and of the calibration procedure and results are reported elsewhere [11]. Data were taken at both left and right p-^{9}Be scattering angles and with alternately positive and negative beam polarization p_o. The D-parameter values were determined from the various sets of data in such a way as to eliminate first-order systematic errors.

Our results are shown in fig. 2. Deviations of D from unity are small but significant. The solid and dashed curves represent calculations by Sherif [12] with the optical-model parameters for ^{9}Be as given by Montague et al. [13]. Both the depth, V_{SS} = 0.1 MeV, and a Woods-Saxon form for $F_o(r)$ were fixed from single-particle model estimates. For the tensor term, a Woods-Saxon form was taken for $F_T(r)$, and the depth V_{ST} was determined by fitting the single data point [9] $D(63.5^\circ) = 0.940 \pm 0.016$ at 21.4 MeV. As seen in fig. 2, these calculations at 25 MeV, with the same values of V_{SS} and V_{ST} that were used at 21.4 MeV, provide good fits to our data for either sign of V_{ST}. At 21.4 MeV the predicted [10] value of $D(63.5^\circ)$ was 1.0 for $V_{ST} = 0$, so these data clearly indicate the need for the tensor interaction term in the calculation. As was noted by Hussein and Sherif [10], the magnitude of V_{ST} is much greater than expected, since Satchler's [14] estimate for ^{59}Co predicts the tensor strength to be weaker than that of the spherical interaction. It remains to be seen whether some other effect can explain the apparently large tensor strength.

The calculated results displayed in fig. 2 show relatively little sensitivity to the sign of V_{ST}. However, the calculated D-parameter values in p-^{10}B scattering show much more sensitivity, so measurements there can provide more definite and detailed information on the spin-spin tensor interaction. We have recently made measurements [15] to compare with the p-^{10}B predictions, and these results and their analysis will be reported in a forthcoming publication.

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FOOTNATES AND REFERENCES

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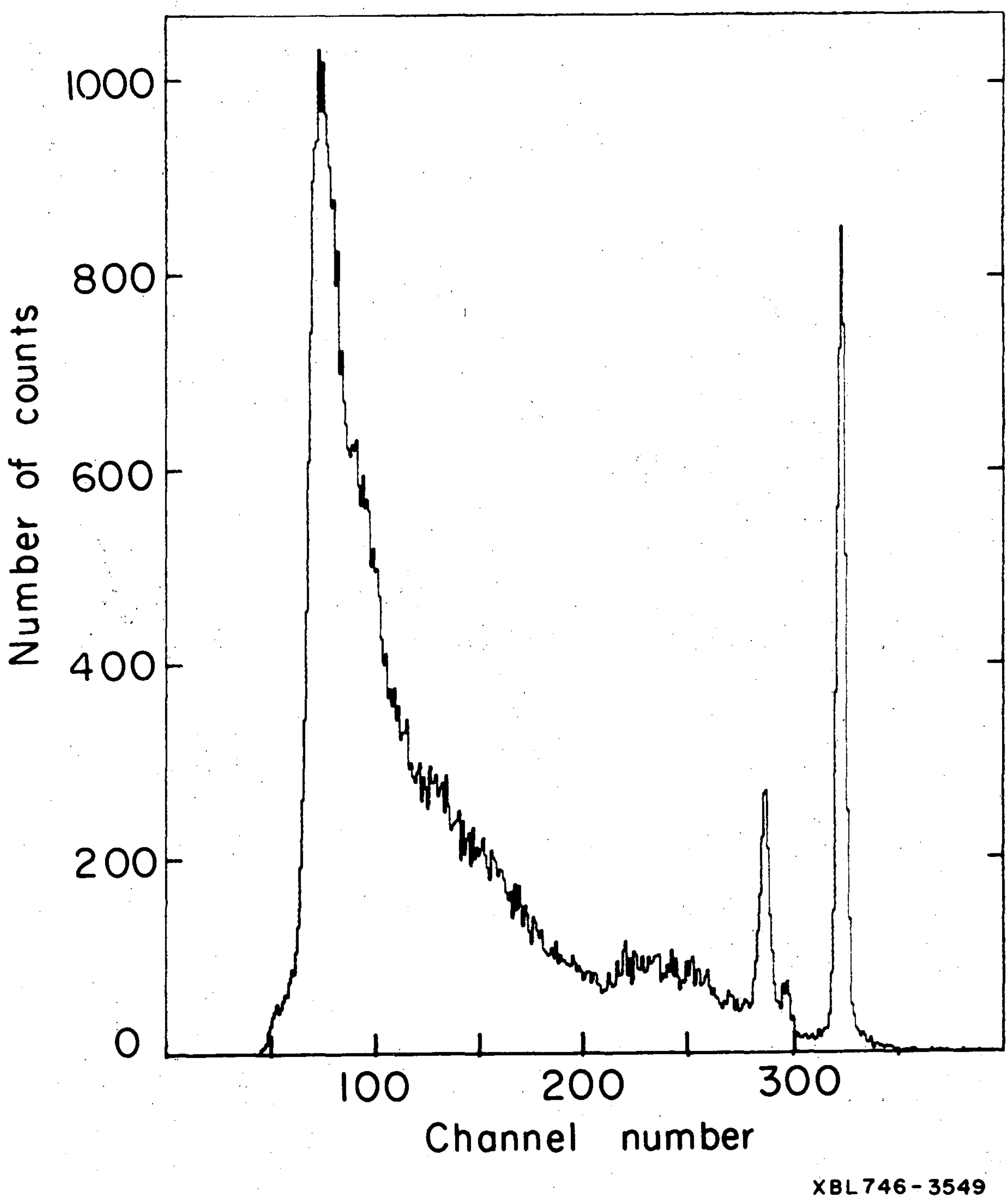
FIGURE CAPTIONS

Fig. 1 Silicon polarimeter spectrum from $^9Be(\vec{p},\vec{p})$ at E = 25.3 MeV, $\theta_{LAB} = 45°$, with a 53.4 mg/cm^2 ^{9}Be target and a 1 mm thick silicon analyzer detector. The elastic peak at channel 320 corresponds to a proton energy of 22.6 MeV. The peak at channel 285 corresponds to inelastic scattering to the 2.43 MeV state of ^{9}Be, and that near channel 295 to inelastic scattering to the 1.78 MeV level of ^{28}Si.

Fig. 2 Angular distribution of the D-parameter for $\vec{p}$-^{9}Be elastic scattering at 25 MeV. The curves are calculated values from ref. 12, the solid curve with V_{SS} = 0.1 MeV, V_{ST} = - 3.75 MeV and the dashed curve with V_{SS} = 0.1 MeV, V_{ST} = + 3.8 MeV.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1000
800
600
400
200
0
100
200
300
Channel number
XBL746-3549

Fig. 1

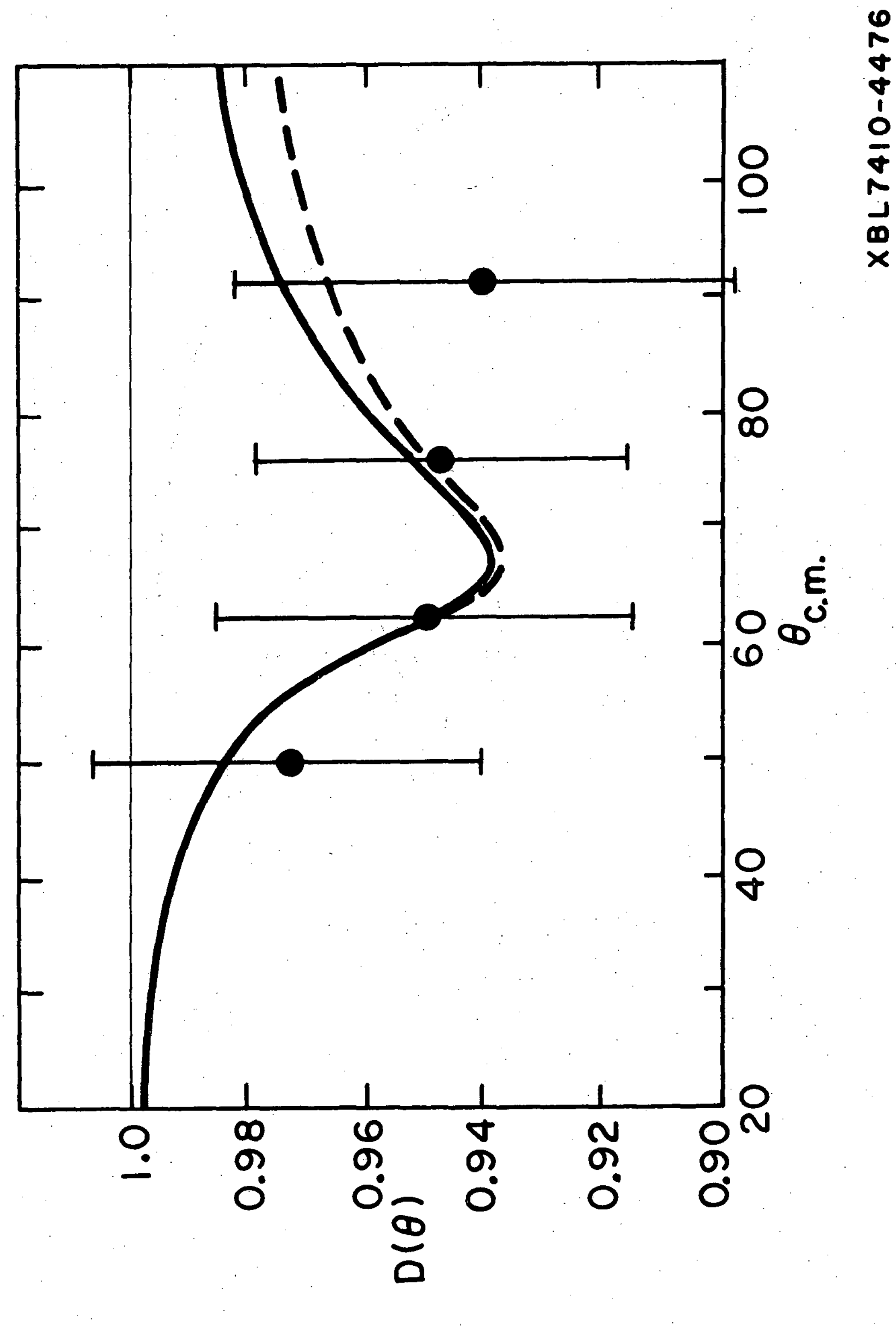

Fig. 2