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NEUTRON-NUCLEUS SPIN-SPIN INTERACTION STUDIED WITH POLARIZED NEUTRONS AND POLARIZED ^{59}Co NUCLEI

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We measured the spin-spin cross section of polarized ^{59}Co for polarized neutrons of 0.39–2.88 MeV in the perpendicular geometry. Comparing our results with existing data we conclude that the spin-spin potential is of the spherical type.

In this letter we report on measurements concerning the search for a spin-spin dependent term in the optical potential as has been suggested by Feshbach [1]. The two simplest forms are the spherical one

$$U_{ss}^s(r) = -V_{ss}^s F_s(r) \sigma \cdot I / I, \quad (1a)$$

and the tensor form

$$U_{ss}^t(r) = -V_{ss}^t F_t(r) \{3(\sigma \cdot \hat{r})(I \cdot \hat{r}) - \sigma \cdot I\} / 2I. \quad (1b)$$

Two different types of experiments have been done in recent years to look for such potentials, i) measurements of the depolarization parameter D of polarized nucleons scattered from nuclei, and ii) transmission measurements of polarized nucleons through targets containing polarized nuclei. The motivation for the depolarization measurements was the conviction that at higher energies deviations of D from unity can only be caused by a spin-spin term in the optical potential. Recently another mechanism has been proposed by Blair, Baker and Sherif [2] through which this parameter can deviate from unity for nuclei with $I > 1/2$.

A number of experiments of the second type have been carried out with polarized neutrons in the MeV region. Two types of geometries are possible, i) with neutron and nuclear spins along the beam direction (longitudinal geometry), and ii) with these polarizations along a direction perpendicular to the beam (perpendicular geometry). In both cases the transmission is measured with parallel and antiparallel polarizations of the neutrons and nuclei in order to derive the transmission effect

$$\epsilon = (N_{\uparrow\uparrow} - N_{\uparrow\downarrow}) / (N_{\uparrow\uparrow} + N_{\uparrow\downarrow}), \quad (2)$$

in which $N_{\uparrow\uparrow}$ and $N_{\uparrow\downarrow}$ are the counting rates of the

transmitted beam with parallel and antiparallel polarizations, respectively. For small effects and neglecting higher-order nuclear orientation parameters, which is usually allowed, the transmission effect is given by:

$$\epsilon = -P_n N t \sigma_{ss} P_t, \quad (3)$$

where P_n and P_t are the neutron and nuclear target polarizations, Nt is the target thickness in nuclei per cm^2 and σ_{ss} is the spin-spin dependent part of the total cross section.

Transmission experiments have been carried out by Fisher et al. [3] in the longitudinal geometry using a polarized ^{59}Co target covering the energy range 0.26 to 1.76 MeV in small steps and at two energies of about 3 and 8 MeV. In the perpendicular geometry transmission experiments have been done by Nagamine et al. [4] for two energies between 1 and 2 MeV but with rather poor statistics; effects were not observed.

We report on similar experiments in the perpendicular geometry also with polarized ^{59}Co and polarized neutrons. The energy range of 0.39 to 2.88 MeV was covered in steps of approximately 30 keV with an energy resolution of about 35 keV. We used a cobalt-iron single crystal (95% Co, 5% Fe) weighting 210 g^{*1} . This sample was cooled to a temperature of 0.05 K and magnetized by applying a magnetic field of 7.5 to 9 kOe in a direction perpendicular to the beam and along a direction of easy magnetization in the crystal. The degree of nuclear polarization was derived from the nuclear orientation effect of the γ -radiation from a small amount of ^{60}Co incorporated in the sample. Its value was $P_t = 0.28 \pm 0.03$. The polarized neutrons were produced with the 6 MV –

^{*1} Borrowed from the "reactor Centrum Nederland", Petten (N.H.)

Fig. 1. The quantity $\sigma_{ss} P_t$ measured for polarized neutrons through a target of ^{59}Co nuclei polarized at 0.05 K (open circles) and unpolarized at 1 K (crosses). The indicated uncertainties are statistical. The curve is drawn to guide the eye.

Van de Graaff machine in our institute using the $^7\text{Li}(p, n)$ reaction and accepting neutrons under a laboratory angle of 40° with respect to the proton beam. The neutron spins were rotated about 90° in both directions using a solenoid^{‡2}. The neutrons were detected with an NE213 liquid scintillator. Pulse-shape discrimination was used to reduce the γ -ray background. In our analysis neutron polarization data of Thornton et al. [5] and of Elwyn and Lane [6] were used. Several small corrections were necessary to arrive at the final experimental data plotted in fig. 1. Here the results are presented for $\sigma_{ss} P_t$ rather than σ_{ss} because firstly, ϵ may not be proportional to P_t when higher-order polarizations are present (although these may be neglected in our experiment) and secondly, to be consistent with other authors. We also measured ϵ with unpolarized nuclei obtained by increasing the temperature to 1 K but with all other conditions unaltered. These data points show that the experiment was free from instrumental asymmetries. The average of the warm measurements is $\langle \sigma_{ss} P_t \rangle_{\text{warm}} = -1.8 \pm 2.3$ mb. The low-temperature data show strong fluctuations with energy. Such fluctuations can be ascribed to fluctuations in the widths and spacings of the compound nuclear levels as has been shown by Fisher et al. [3].

The measured points were averaged over 300 keV

intervals in order to get rid of the fine structure (fig. 2). We selected the same energy intervals as those used by the authors of ref. [3] in averaging their data. The averaged points of ref. [3] are also shown in fig. 2. To account for the different target polarizations present in the two experiments (here: $P_t = 0.28 \pm 0.03$,

Fig. 2. Averaged spin-spin cross sections over intervals of 300 keV. The indicated uncertainties include those in P_t . The theoretical curves are taken from ref. [3].

^{‡2} Borrowed from the "Vrije Universiteit", Amsterdam.

ref. [3]: $P_t = 0.33 \pm 0.03$), we give here the results for σ_{ss} . The cross sections are remarkably equal for the two geometries in the common intervals (the agreement is lost at smaller energy resolution). Fisher showed [7] that large differences can be expected in the case of a tensor interaction; the effects should be virtually equal for a spherical interaction. Hence, we conclude that the comparison of the two experiments indicates that the spin-spin term is largely of the spherical type. The theoretical curves in fig. 2 have been taken from ref. [3]. Our new points at higher energy are in favor of a small positive value of V_{ss}^s . However, it seems to be impossible to obtain an overall fit.

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References

- [1] H. Feshbach, *Nuclear Spectroscopy*, part B, ed. F. Ajzenberg-Selove (Academic Press, New York, 1960) p. 1033.
- [2] J.S. Blair, M.P. Baker and H.S. Sherif, *Phys. Lett.* 60B (1975) 25.
- [3] T.R. Fisher et al., *Nucl. Phys.* A179 (1972) 241.
- [4] K. Nagmine, A. Uchida, and S. Kobayashi, *Nucl. Phys.* A145 (1970) 203.
- [5] S.T. Thornton, C.L. Morris, J.R. Smith and R.P. Fogel, *Nucl. Phys.* A169 (1971) 131.
- [6] A.J. Elwyn and R.O. Lane, *Nucl. Phys.* 31 (1962) 78.
- [7] T.R. Fisher, *Phys. Lett.* 35B (1971) 573.