Proc. Sixth Int. Symp. Polar. Phenom. in Nucl. Phys., Osaka, 1985
J. Phys. Soc. Jpn. 55 (1986) Suppl. p. 808-809

3.3

Measurement of the Spin Correlation Coefficient A_{yy} by Elastic Scattering of 14 MeV Polarized Neutrons from a Polarized Proton Target

H. Kuiper[+], R. Schmelzer[+], M. Schöberl[+]
G. Mertens[++] and W. Tornow[++]

[+]Physikalisches Institut der Universität Erlangen-Nürnberg
Erwin-Rommel-Str.1, D-8520 Erlangen, F.R. Germany

[++] Physikalisches Institut der Universität Tübingen
Auf der Morgenstelle, D-7400 Tübingen, F.R. Germany

In spite of the wealth of data now available on n-p scattering in the low energy region, there are two phenomenological parameters that have resisted any precise determination so far. These are the $^3S_1$-$^3D_1$ mixing parameter ε_1 and the singlet phase shift $\delta(^1P_1)$, the effects of which are strongly correlated in the data base presently available. It should be possible, however, to disentangle these two quantities by making spin correlation measurements.

At a neutron energy of 14 MeV we are performing experiments to measure the spin correlation coefficient A_{yy} at 90°(c.m.), using the Erlangen tandem Van de Graaff accelerator. At this angle A_{yy} is independent of $\delta(^1P_1)$; a straightforward determination of ε_1 is therefore possible. The most important feature of our experimental set-up is the simultaneous detection of the scattered neutron and the recoil proton (from the polarized target) using a suitable fast coincidence technique. In this way a clear experimental definition of a "true" event is made, and it is possible to discriminate the n-p scattering events from the huge background of those neutrons that reach the detector either directly from the source or being scattered from other parts of the target arrangement.

The 14 MeV polarized neutron beam is obtained from the $^2H(\vec{d},\vec{n})^3He$ reaction at 0° by focussing the vector-polarized deuteron beam from the Erlangen Lamb shift source into a pressurized, LN_2-cooled deuterium gas cell. This polarized neutron source is mounted inside the polarized target cryostat at a distance of only 10 cm from the polarized target. The neutron polarization can be calculated[1)] from the deuteron beam vector polarization, as measured in front of the target by means of a carbon transmission polarimeter which is calibrated by an interchangeable helium polarimeter.

The polarized target itself is a $0.3\times6\times6$ mm³ lanthanum magnesium nitrate single crystal contained in a single mode microwave cavity resonating at about 70 GHz, that can be cooled to about 1.2 K by pumped liquid helium. At a magnetic field of about 1.8 T, produced by two superconducting coils in Helmholtz geometry, dynamic nuclear polarization of the protons in the crystal is obtained[2,3)]. The target proton polarization ranges between 0.5 and 0.6 and is measured at regular intervals by the internal field method, as described earlier[4)].

The recoil protons are detected by silicon surface barrier detectors located only about 5 cm from the polarized target. In order to reduce background due to neutron-induced nuclear reactions in the silicon, a ΔE-E counter telescope is used for the detection of the recoil protons. The coincidence signal from this telescope then serves as the start signal for a neutron time-of-flight measurement, which is stopped by a neutron signal from a NE 213 scintillation detector 60 cm apart from the center of the polarized proton target. In this way - although the uncorrelated neutron flux at the scintillation detector is more than a factor of 10^6 larger than the rate of the true n-p events - a 10:1 signal-to-background ratio is obtained, as has been demonstrated elsewhere[5)].

The direction of the neutron polarization is reversed every 50 seconds by reversing the deuteron beam polarization, while the direction of the proton polarization is kept constant over several days. Both polarizations are oriented perpendicularly to the scattering plane. For systematic reasons, however, measurements were made with the proton polarization parallel as well as antiparallel to the scattering normal.

Meanwhile results are available from experimental runs over a total of 12 full days, yielding about 47 000 true events altogether, thus showing that this experiment is very time consuming indeed. On the other hand, it seems that the coincidence method is the only way at present to obtain clear-cut and unambiguously interpretable experimental results for n-p spin correlation parameters.

Data reduction was made, taking the following corrections into account:

1) Dead time effects were determined experimentally during the runs and the appropriate corrections applied to the data.
2) All count rates were corrected to equal neutron flux of the two neutron polarization states ("up" and "down") by normalizing them, using the neutron counts of two independent neutron monitor detectors placed at 0°.
3) The uncorrelated background from random coincidences was subtracted from the time-of-flight peak of the true n-p scattering events, leading to an about 10 % correction.

In order to define the scattering asymmetries, since two polarized particles are involved, it is practical to denote the spin "up" and "down" positions by vertical arrows attached to the count rates, the first arrow referring to the neutron, the second one to the proton. Thus, for instance, $n_{\uparrow\downarrow}$ denotes a count rate, where the neutron spin is "up" and the proton spin "down". Three more combinations are obviously possible. Using this notation and denoting by n a true n-p scattering event count rate, normalized as described above, we define the following two asymmetry expressions:

$$\varepsilon_+ = (n_{\uparrow\uparrow} - n_{\downarrow\uparrow})/(n_{\uparrow\uparrow} + n_{\downarrow\uparrow}) \qquad \text{and} \qquad \varepsilon_- = (n_{\downarrow\downarrow} - n_{\uparrow\downarrow})/(n_{\downarrow\downarrow} + n_{\uparrow\downarrow})$$

where ε_+ gives the asymmetry for the case that the proton (target) spin is "up", i.e. parallel to the scattering normal; ε_- describes the opposite case. These asymmetries relate the measured counts to the spin correlation parameter A_{yy}, thus

$$A_{yy} = \frac{\varepsilon_\pm}{p_b}\left(\frac{1}{p_t} \pm A_y\right) \mp \frac{A_y}{p_t} \qquad (1)$$

In this expression A_y denotes the n-p analyzing power, p_b and p_t the absolute values of the beam and target polarization, respectively. The value $A_y = 0.02$ was taken from the literature[6,7]. Applying eq.(1) to each one hour run of all our measurements we now obtain the following mean value for the spin correlation coefficient: $A_{yy} = 0.099 \pm 0.023$. Then, with the help of a formula given by Simmons[8], relating this spin correlation parameter to the mixing parameter ε_1 for $\theta = 90°$, we find

$$\varepsilon_1 = (0.5 \pm 0.9)°$$

where the phase shifts of Arndt et al.[9] have been used. Since the error of A_{yy} from our experiment is essentially statistical in nature, the measurements are carried on.

1) P.W.Lisowski,R.L.Walter,C.E.Busch and T.B.Clegg: Nucl.Phys. A242 (1975) 298
2) C.D.Jeffries: Ann.Rev.Nucl.Sci. 14 (1964) 101
3) M.Eisend,K.Frank,J.Kollmann,D.Kröniger,H.Kuiper,K.Kutschera,H.Obermeyer and B.Seidler: Nucl.Instr.Meth. 140 (1977) 227
4) K.Kutschera,H.Kuiper,D.Kröniger,K.Frank and B.Seidler: Nucl.Phys.A183 (1972)593 and 601
5) M.Schöberl,H.Kuiper,R.Schmelzer,G.Mertens and W.Tornow: J.Phys.G:Nucl.Phys.10 (1984) L247
6) W.Tornow,P.W.Lisowski,R.C.Byrd and R.L.Walter: Nucl.Phys.A340 (1980) 34
7) J.E.Brock,A.Chisholm,J.C.Duder,R.Garrett and J.L.Poletti: Nucl.Phys.A361 (1981)368
8) J.E.Simmons: Rev.Mod.Phys. 39 (1967) 542
9) R.A.Arndt,L.D.Roper,R.A.Bryan,R.B.Clark,B.J.VerWest and P.Signell: Phys.Rev. D28 (1983) 97