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U. Fasoli(*), G. Galeazzi, P. Pavan(*), D. Toniolo(*), G. Zago(*) and R. Zannoni, L. Badan, G. Bressanini: THE DEFORMATION EFFECT IN THE FAST NEUTRON TRANSMISSION THROUGH AN ALIGNED ^{59}Co TARGET IN THE ENERGY RANGE 0.8 - 20 MeV.

The "deformation effect" in neutron transmission is defined as the difference between the neutron total cross section of a nuclear target respectively aligned and not aligned. It is due to the lack of sphericity, or deformation, of the radial distribution of the nucleons in the nucleus. Its determination therefore offers information on the shape of nuclei which is complementary, but in principle different, to that obtained by other processes, as for example the Coulomb excitation or the photoneutron production, related to the electric charge nuclear radial distribution.

The deformation effect was first observed in the neutron transmission on ^{165}Ho by Wagner et al.(1), and later also in this laboratory(2), where the first observation of the deformation effect in neutron scattering(3) was recently made. Although the results obtained on holmium were very interesting a systematic extension of this type of experiment was arrested by the technical difficulties of orienting other nuclei.

The recent progress in low temperature physics allowed Fisher et al.(4) to aligne a cobalt monocrystal and to measure the deformation effect in neutron transmission on ^{59}Co at five spot energies between 1 and 2 MeV and at 15.9 MeV. Although the number of the experimental points was not large and the explored energy region, where large fluctuations are present, was rather limited, the results confirmed the potentiality of the method in obtaining information on nuclear shape.

In the experiment here described the effect on ^{59}Co was measured in the energy interval varying continuously from 0.8 up to 20 MeV with largely improved statistics, on a target having an alignment more than twice that of ref. (4). The orientation was obtained by cooling monocrystalline cobalt by means of a ^{3}He-^{4}He dilution refrigerator constructed in this laboratory for this purpose(5). The target was formed of two cobalt monocrystals, grown in this laboratory using the Czochralsky method, having the form of truncated cones with a total mass of 45 g. The c axes of the crystals were parallel to the axes of the cones. The two crystals were soft soldered inside a small copper block forming the lower part of the mixing chamber of the refrigerator. The total

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thickness of the two crystals was 2.370 cm and the common "c" axes was located parallel to the neutron beam direction.

The temperature of the cobalt target during the measurement was controlled by means of Speer type carbon resistors previously calibrated by means of a cerium magnesium nitrate thermometer and by a ^{60}Co nuclear orientation thermometer(6) soft soldered to the mixing chamber. The average temperature of the target during the experiment was 18.5 mK, with variations not exceeding ± 1 mK. The corrisponding degree of nuclear alignment, calculated as in ref. (4) was $B_2/B_{2\,max} = 0.34 \pm 0.02$. The neutron beam impinging on the target was generated by means of reaction $^7Li(d,n)\,^8Be$ on a natural methal lithium target 1 mm thick.The incident deuterons were accelerated to 4.5 MeV by means of the Van de Graaff accelerator at the University of Padua (Legnaro). The accelerator was pulsed at the frequency of 1 MHz, with pulses of 2 ns FWHM, to allow the use of the neutron time-of-flight technique. The thick lithium target, where the deuterons were stopped, gave rise to a "white" neutron spectrum with energies extending from 0.8 up to 20 MeV(7).

The neutron source was located inside a cavity in an iron cubic block in order to reduce the neutron and gamma ray background. Two holes of 1 cm diameter in the iron block at ± 15° with respect to the deuteron beam direction defined two symmetrical neutron beams, one impinging in the cobalt sample and in the main detector and the other in the neutron monitor. The two neutron detectors were both made of liquid scintillator NE213. Conventional time-of-flight electronics was used with a flight base of 4.35 m.

The measuring procedure consisted in comparing the neutron transmission through the monocrystal target to that of a second polycrystalline, and therefore not aligned, cobalt target, having the same areal density, located laterally parallel and near to the first.

In order to compare the two transmissions in identical experimental conditions the two targets were exposed alternatively to the same neutron beam by moving the whole refrigerator laterally on wheels running on precision rails. The alternating period of a few minutes was sufficiently short to render negligible the temporal drifts of the electronics and of the whole pulsing apparatus. The exposure of the two targets to the neutron beam was controlled by an integrator of the deuteron beam current and the countings, corrected for background which never exceeded 2%, normalized by means of the neutron monitor.

The "cold" runs, with the target aligned, were preceded and followed by two series of "warm" runs respectively at 77 K and 1 K (alignment zero), made in order to control the absence of spurious effects.

The results of the warm runs, equal within errors, are summed up and represented in Fig. 1a. The average relative variation of the transmission through the two not aligned target was $(0.6 \pm 0.3) \times 10^{-3}$. The spurious effect was therefore negligible in comparison with the deformation effect which was of the order of some percent.

The deformation effect $\Delta\sigma_{def}$, reported in Fig. 1b, was calculated by the formula:

$$\Delta\sigma_{def} = \frac{1}{nt}\,\ell n\,\frac{T_{un}}{T_{a\ell}}$$

where $n = 0.896 \times 10^{23}$ is the number per cm^3 of the cobalt nuclei in the target, $t = 2.370$ cm its thickness and $T_{a\ell}$ and T_{un} the neutron transmissions through the aligned and unaligned targets respectively.

The results obtained by Fisher et al.(4) are also reported in Fig. 1b. They are normalized to our alignment degree (0.34 against 0.16), by supposing $\Delta\sigma_{def}$ proportional to the alignment degree. The agreement is good if one takes into account the large fluctuations present in the low energy region.

The dotted curve of the figure is the theoretical effect calculated by Fisher et al.(4) using a DWBA calculation. The curve agree only qualitatively with the experimental data.

A better agreement is apparent with the continuous curve which is a theoretical prevision of the effect performed recently at Padua(10) by employing the semiempirical model devised by Marshak et al.(1) to describe

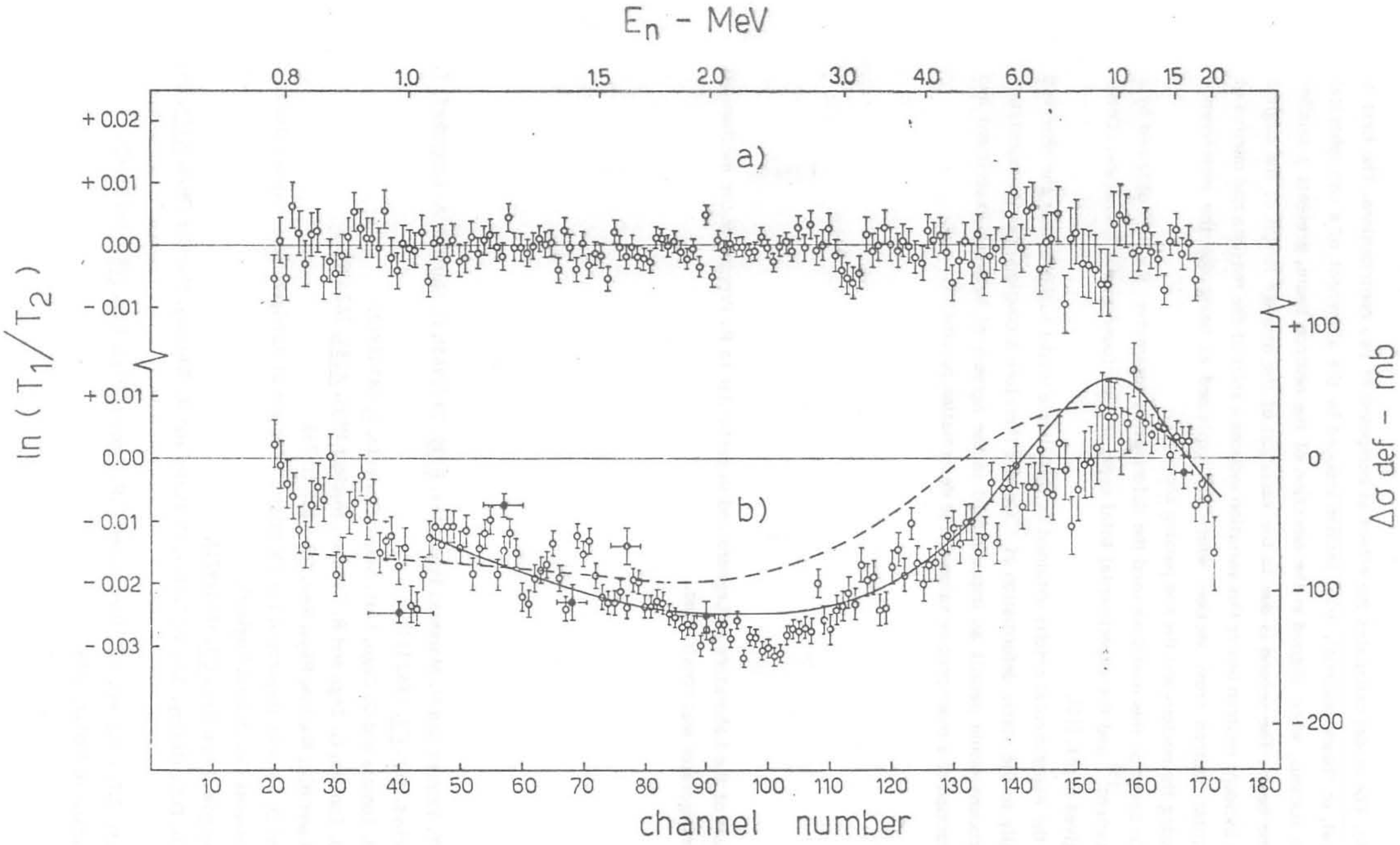

FIG. - 1 The deformation effect $\Delta\sigma_{def} = 4.71 \ln(T_1/T_2)$ barn (see text), in the neutron transmission through a sample of ^{59}Co, aligned with an alignment degree $B_2/B_{2\ max} = 0.34$, as a function of the incident neutron energy E_n. T_1 and T_2 are the neutron transmissions through the polycrystalline and monocrystalline sample respectively. The results in a) and b) are relative respectively to the "warm" runs with the two targets not aligned, and to the "cold" runs with the monocrystal target aligned. The full points are the results of Fisher et al.(4) normalized to our alignment degree. The continuous curve represents a theoretical prevision of the effect performed by means of the model described in the text. The dotted curve is the theoretical effect calculated by Fisher et al.(4) by a DWBA calculation.

the deformation effect on ^{16}Ho. The model calculates the effect as composed of two contributions. The first is the variation of the geometrical, or "black nucleus", cross section induced by the alignment of a non spherical nucleus; for example a prolate nucleus, when aligned in the direction of the neutron beam, presents a smaller geometrical cross section to the beam. The second is due to the variation of the average lenght of the aligned nucleus in the direction of the incident neutron beam; this variation induces a shift of the maxima and minima of the giant resonances in the total neutron cross section, which are explained as being due the interference between the neutron wave crossing the nucleus and the one passing around it.

In our calculation for ^{59}Co based on this model we used the deformation parameter $\beta = 0.19$ obtained by a photoneutron production experiment$^{(3)}$ and the experimental total cross section found in the literature. Other details of the calculation are given in ref. (10).

The fair agreement with the experimental results obtained by this simple model suggests that the observed effect is attributable essentially to the static deformation of ^{59}Co and therefore a coupled channel calculation taking this fact more into account would permit an improvement in the agreement between experiment and theory and eventually the extraction of a more precise value of the deformation parameter.

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REFERENCES

(1) R. Wagner, P.D. Miller, T. Tamura and H. Marshak, Phys. Rev. B139, 29 (1965); H. Marshak A. Langsdorf, T. Tamura and C.Y. Wong, Phys. Rev. C2, 1862 (1970).

(2) U. Fasoli, G. Galeazzi, D. Toniolo and G. Zago, Lett. Nuovo Cimento, 6, 485 (1973).

(3) U. Fasoli, G. Galeazzi, D. Toniolo, G. Zago and R. Zannoni, Nuclear Phys. A284, 282 (1977).

(4) T.R. Fisher, A.R. Poletti and B.A. Watson, Phys. Rev. C8, 1837 (1973).

(5) U. Fasoli, G. Galeazzi and D. Toniolo, Reports of the XV Intern. Congress of Refrigeration, Venezia (1979).

(6) Supplied by Oxford Instruments Co. Oxford, England.

(7) D.G. Foster and D.W. Glasgow, Phys. Rev. C3, 576 (1971).

(8) T.R. Fisher, H.A. Grench, D.C. Healey, J.S. McCarthy, D. Parks and R. Whitney, Nuclear Phys. A179, 241 (1972).

(9) S.C. Fultz, R.L. Bramblett, J.T. Caldwell, N.E. Hansen and C.P. Jupiter, Phys. Rev. 128, 2345 (1962).

(10) S. Da Giau, Thesis, University of Padua, 1978.