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DETECTION OF VERY SMALL (n, γ) ASYMMETRIES WITH POLARIZED NEUTRONS

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Résumé. — Les impuretés de non-conservation de la parité dans les états nucléaires peuvent être mises en évidence grâce à une très petite asymétrie dans la distribution des rayons γ émis lors de la capture de neutrons lents polarisés par certains noyaux. La précision expérimentale requise se situe à la limite des possibilités actuelles. Les critères suivis dans le développement des méthodes utilisées pour le retournement de la polarisation des neutrons, l'acquisition des données, ainsi que les expériences de vérification, sont exposés.

Abstract. — Parity non-conserving admixtures in nuclear states may be revealed from a very small asymmetry in the distribution of gamma-rays emitted after the capture of polarized neutrons in certain nuclei. An experimental accuracy at the limit of present possibilities is required. The criteria followed in developing the methods for reversing the neutron polarization and for the data collection and the control measurements are described.

The following methods have been developed to perform a type of experiment on parity non-conservation in nuclear interactions, in which one attempts to detect a very small asymmetry in the emission of gamma-rays from levels formed by capture of polarized neutrons in certain nuclei. The outline of the experiment is the following [1].

A beam of 80 % vertically polarized neutrons is obtained by reflection from a magnetized Co-Fe mirror [2]. The neutrons travel to the target traversing a spin rotator device, where the neutron spins are adiabatically turned to the left or to the right. The (n, γ) target is viewed by a left and a right scintillation counters. The four gamma-ray spectra a_1 , a_2 and b_1 , b_2 measured by the counters A and B during alternate periods of left and right polarization t_1 and t_2 , are accumulated in a multigroup analyzer. The asymmetry is derived as :

$$A = (a_1 - a_2)/2(a_1 + a_2) - (b_1 - b_2)/2(b_1 + b_2).$$

Care was taken to ensure that systematic effects and other perturbations were negligible in comparison with the attainable statistical error, the latter being in the range $(0.5 \sim 1) \cdot 10^{-4}$. To this purpose various kinds of possible perturbations have been examined separately : *a*) Variations acting symmetrically on the two counters, such as, mainly, variations in the (n, γ) rate, tend to cancel out. However, second order errors in A might be introduced if the counting losses are relevant and do not vary proportionally in the two

channels, due to unequal electronic dead times or unequal counting rates, for instance; *b*) Variations in the background of external radiation and drifts like photomultiplier gain drifts and temperature electronic drifts may have only a partial cancellation. Effects of this type can be attenuated by reducing the polarization alternation period. It was estimated and observed experimentally that a 2 s period was largely sufficient to make all previous effects negligible; *c*) Systematic effects may be introduced by the alternation of the polarization cycles. Possible changes in the photomultiplier gains induced by a reversed magnetization of the spin rotator and guides are considered later in detail. Any defect of symmetry of the electronic system when the analyzer group selection is changed must be prevented.

The group selection is obtained by the application of external logic signals. To be sure, the power supply of the logic circuitry (controlling also the magnetizing currents) is separate from the amplifying and discriminating chains. As much as possible, it is avoided to rely on the symmetry of the internal functions of the analyzer. The pulse amplitudes from the two counting channels are fed to the unique analyzer input through external linear gates. In some high intensity experiments ($\text{Cd}(n, \gamma)$, f.i.), the rate of chance coincidence between the two channels is relevant. In this case only one of the two gates is allowed, the other being inhibited by means of a "priority discriminator", acting, with a sub-nanosecond accuracy [3], so that bad mixing or wrong preference are avoided.

FIG. 1. — Sketch of the neutron spin rotator and guide.

The spin rotator, placed at the polarizer output, is sketched in figure 1.

A regular field rotation along the neutron trajectory is obtained by the composition of a vertical decreasing and an horizontal increasing field components. The vertical is obtained in the gap between two iron strips coupled at one end with the polarizer magnet poles, and terminating inside an iron tunnel where, by means of a winding, the horizontal component is generated. The latter increases toward the output, due to a convergence of the side walls. A field of ~ 30 G rotating by $\pi/2$ in a path length of ~ 30 cm is obtained. Reversing the winding current permits to obtain left or right polarization.

Due to the small ratio R of the field rotation frequency to the spin precession frequency, the decrease of polarization degree ($< R^2/2$) of slow neutrons is negligible ($< 10^{-3}$). Along the neutron guide, between the rotator and the target, the field is gradually attenuated down to ~ 5 G. The guide section fronting the scintillation counters is externally wrapped with two 0.3 mm mumetal foils. Each scintillation counter

(a $3'' \times 3''$ NaI crystal directly coupled to a Dumont 6363 or RCA 2064 photomultiplier equipped with a standard magnetic shield) is completely enclosed in mumetal can, 1 mm thickness. It was found convenient to short circuit the three last multiplier stages, to be able to operate at low mean current ($< 10^{-7}$ A), to improve the long term stability, but using high accelerating voltages, especially across the input stages, to attenuate the magnetic field sensitivity. A symmetry test of the whole detection system was done measuring a ^{60}Co source, in place of the (n, γ) target, and comparing the counts under the two halves of the photopeaks.

In this measurement, the sensitivity to gain shifts is enhanced by a factor $30 \sim 40$. The equalization of the two counting channel gains over alternate periods of opposite polarization was found accurate within a 10^{-6} relative standard error. The reliability of the system in detecting asymmetries was, of the rest, confirmed within a statistical error of $\sim 5 \times 10^{-5}$, in the $D(n, \gamma)$ experiment [1], where the physical asymmetry is likely to be smaller by an order of magnitude, at least.

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