METHOD OF MEASURING THE HELICITY OF THE ANTINEUTRINO

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Through a remarkable experiment, Goldhaber, Sunyar, and Grodzins measured the helicity of the neutrino by measuring the circular polarization of the resonance-scattered gamma rays from a solid source of Eu^{152} decaying by an electron-capture–gamma cascade.[1]

As a possible extension of this method, one may expect to be able to measure the helicity of the antineutrino by performing a similar experiment on an isotope decaying by negative beta emission. However, the experiment is now complicated by the fact that two particles, the beta ray and the antineutrino, are emitted preceding the photon. It is therefore necessary to fix the directions of both the electron and the antineutrino simultaneously and also to measure the gamma-ray polarization. Since the polarization of the electron is well known, it is possible, in principle, to account for this and hence to deduce the polarization of the antineutrino.

An experiment of this type has not been reported, quite presumably because of practical difficulties. In such an experiment, the direction of the electrons has to be fixed by a beta counter. Thus, it requires the combining of a polarization measurement of resonance gamma rays with a beta-gamma coincidence. The use of a coincidence technique makes it impossible to use a strong source required for adequate count rates. If the lifetime of the intermediate state is not shorter than 10^{-13} sec, a solid or liquid source is not suitable for a resonance-fluorescence experiment. A close scrutiny of the various isotopes having a fairly long lifetime shows that no isotope suitable for such an experiment in liquid or solid form is available. Having to use a gaseous source is an additional handicap.

The purpose of this Letter is to show that the need for a coincidence arrangement, which is the most serious difficulty in a measurement of this kind, may be eliminated. This would also allow the use of a gaseous source, which is quite inconvenient in a coincidence experiment.

In the experiment of Goldhaber, Sunyar, and Grodzins, use was made of the fact that nuclear resonance fluorescence for the gamma rays can be observed only in those transitions in which the neutrino and the gamma ray are emitted in nearly opposite directions. In these cases the recoil of the nucleus due to neutrino emission can compensate for the recoil loss during the gamma emission. The suggestion here is that for some beta emitters, in which the maximum beta-ray energy is somewhat less than or approximately equal to the gamma-ray energy, a similar situation exists. In most of the transitions in which the gamma ray is resonantly scattered, both the electron and the antineutrino responsible for the recoil compensation must have traveled approximately opposite to the gamma ray. The instances in which either the electron or the antineutrino travels in the same "hemisphere" as the gamma ray, and still satisfies the recoil compensation condition of resonance fluorescence, are relatively few. This condition may be expressed as

$$p_\beta \cos\beta + p_\nu \cos\nu + E_\gamma / c = 0, \tag{1}$$

where β and ν are the respective angles made by the beta-ray and antineutrino directions with the direction of the gamma ray. Under favorable conditions, the average values of both β and ν approach 180° and we are able to perform effectively a triple-coincidence measurement with all the advantages of a singles experiment.

The measurement of the circular polarization of the resonance-scattered gamma rays then yields an estimate of the polarization of the antineutrino, since the longitudinal polarization of the beta rays is known. Except for Coulomb and relativistic effects, beta-decay theory involves beta-ray and neutrino momenta in a symmetric manner. If the beta-gamma circular-polarization angular correlation is expressed as[2]

$$W(\beta) = 1 + A\tau(v/c)\cos\beta, \tag{2}$$

the antineutrino-gamma angular correlation may be expected to have the form

$$W(\nu) = 1 + \Theta_{\bar{\nu}} A\tau \cos\nu, \tag{3}$$

where $\Theta_{\bar{\nu}}$ is the helicity of the antineutrino. Therefore, if the circular polarization of the resonance gamma rays (average β and ν nearly 180°) is measured, one obtains the factor $A(\bar{v}/c+\Theta_{\bar{\nu}})$, where $\bar{v}$ is the average speed of the electrons in the entire beta spectrum.[3] $\Theta_{\bar{\nu}}$ is therefore obtained, if A is known.

An experiment is in progress at the University of Michigan in which a gaseous source of Hg^{203} (47 days) is used. The 208-keV beta decay is followed by a 279-keV gamma transition. The intermediate nuclear excited state has a mean lifetime $\tau_\gamma=(3.4\pm0.5)\times10^{-10}$ sec.[4] At a pressure less than a tenth of an atmosphere, the effect of thermal collisions is negligible. For Hg^{203}, $\bar{v}/c$ is approximately 0.5 and A has been reported to be -0.37 ± 0.19.[5] A more precise value of A is expected from a current experiment at the University of Cincinnati. The most serious disadvantage with using Hg^{203} as the source is that Rayleigh scattering dominates nuclear resonance scattering by a factor of 10. Other isotopes may also be found which are suitable for such an investigation. The principle of this method may be extended for the measurement of the helicity of the neutrino in positron decay.

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[1]M. Goldhaber, L. Grodzins, and A. W. Sunyar, Phys. Rev. 109, 1015 (1958).

[2]K. Alder, B. Stech, and A. Winther, Phys. Rev. 107, 728 (1957).

[3]M. Morita, Nucl. Phys. 6, 132 (1958).

[4]J. C. Palathingal and M. L. Wiedenbeck, to be published.

[5]B. Faldum, Z. Physik 176, 159 (1963).

SU(3) REACTION INEQUALITIES AT HIGH ENERGIES*

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SU(3) reaction inequalities which had been thought to be violated are re-examined and found to agree with experiment at high energy. The comparison is made for both integrated and forward amplitudes. The apparent validity of SU(3) puts limits on the high-energy behavior of the amplitude differences $|M(K^-+p\to K^-+p)-M(\pi^-+p\to\pi^-+p)|$ and $|M(K^++p\to K^++p)-M(\pi^++p\to\pi^++p)|$.

The SU(3) two-body reaction inequalities[1]

$$M(K^-+p\to\Sigma^++\pi^-)\geqslant|M(\pi^-+p\to\pi^-+p)-M(K^-+p\to K^-+p)| \quad (1)$$

and

$$M(\pi^++p\to\Sigma^++K^+)\geqslant|M(\pi^++p\to\pi^++p)-M(K^++p\to K^++p)| \quad (2)$$

relate a single inelastic amplitude to the difference between πp and Kp elastic amplitudes. These relations should hold for both total elastic and inelastic amplitudes (i.e., integrated over scattering angles), and for the forward amplitudes as well. We re-examine the validity of these relations using the latest available data. Contrary to the oft-stated claim that these relations are violated,[2-4] we find that they are, in fact, satisfied within experimental errors to the highest energies for which data exists, for both the integrated amplitudes and the forward amplitude.

Two sets of comparisons with theory are made for each of the relations (1) and (2). The first relates total inelastic and elastic cross sections, whereas the second involves only forward amplitudes (forward refers to the boson scattering angle). Both comparisons are made as a function of Q,[5] the available center-of-mass energy, $Q=s^{1/2}-m_{\text{out}}$, where s is the square of the center-of-mass energy and m_{out} is the total mass of the final state.

Experimental values of the elastic cross sections are given in Table I. We extract the in-