curve is arbitrarily normalized to the same maximum value as the Landau distribution.

The surprisingly broad distribution with a high energy tail is due to the non-negligible probability of collisions in which the charged particle imparts large kinetic energy to the electron. This reduces radically the number of primary collisions, thus increasing the width of the statistical distribution, and in addition gives rise to the high energy tail. Note in Fig. 1 the maximum allowable energy loss in a single collision is, in this particular case, approximately twice the average total energy loss of the proton in the counter. This is in sharp contrast to the very narrow pulse-height distributions that have been observed in the case in which the charged particle expends its entire track in the counter because, in this case, the statistical fluctuations are due only to the variations in the ratio of energy loss in ionization to energy loss in excitation.

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† U. S. Atomic Energy Commission Predoctoral Fellow.
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Correlation between Electron and Recoil Nucleus in He^6 Decay*

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A STUDY of the correlation between the electron and the recoil nucleus in the He^6-Li^6 decay has been made to determine whether the tensor or axial vector interaction should be retained in the formulation of beta-theory. The remaining interactions, scalar, polar vector, and pseudoscalar, are forbidden for this particular transition on the basis of the allowed ft value of 815 ± 70 seconds[1] and the nuclear spin change[2] $\Delta I=1$. A mixture of the Gamow-Teller interactions is not expected, as there is no evidence from the shape of allowed spectra for the existence of the energy dependent, Fierz interference term.[3,4]

The He^6 gas was produced by bombarding $Be(OH)_2$ powder with fast neutrons from the Brookhaven pile. The end-point energy[1] is 3.50 ± 0.05 Mev and the half-life[5] 0.823 sec. A search for γ-emission accompanying the decay was made by the authors, and also independently by Knox,[6] with negative results. Measurements of the β-spectra and the half-life indicate that the contribution to the counting rate at any energy above 0.5 Mev caused by impurities is less than 3 percent.

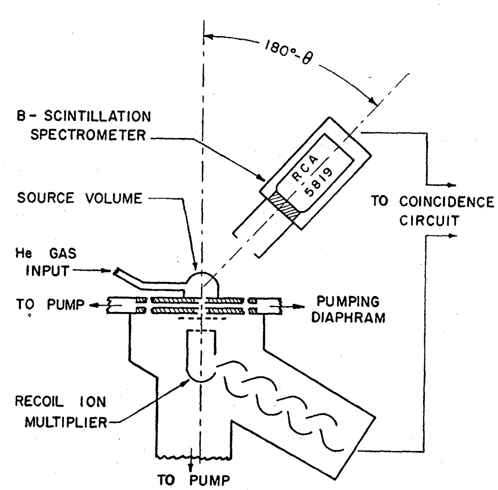

FIG. 1. Simplified schematic of the apparatus.

A schematic diagram of the apparatus is shown in Fig. 1. A semicylindrical source of He^6 gas was defined by a 0.2 mg per cm^2 aluminum foil and a differential pumping diaphragm which also served to collimate a beam of recoil ions from the source region. All structural parts of the source were constructed of polystyrene and evaporated with a thin coating of aluminum to minimize the scattering of electrons and source charging effects. The recoil nuclei were detected by a twelve-stage, Allen-type electron multiplier. The direction and energy of the electrons were determined by a stilbene scintillation spectrometer which could be positioned at any angle between 100 and 180 degrees from the direction of the recoil beam. A coincidence circuit selected those events in which the recoil detector was activated from 0.08 to1.15 microseconds after the scintillation spectrometer. To prevent gas scattering, the apparatus was continuously evacuated; during each run, pressure measurements were made to insure that the mean free path of the particles was large compared to the geometrical dimensions of the apparatus.

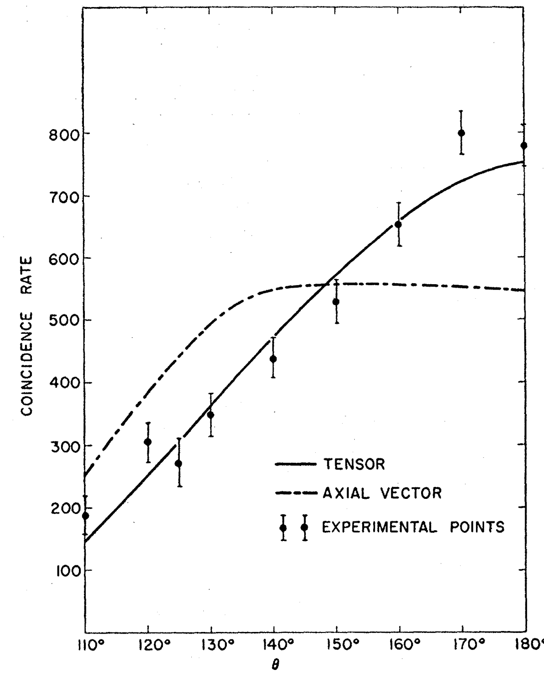

FIG. 2. Coincidence counting rate *versus* angle between electron and recoil nucleus for beta-rays in the range 2.5–4.0 mc^2.

The coincidence rate measured at angles from 110 to 180 degrees between the directions of the electron and the recoil nucleus is shown in Fig. 2. The spectrometer was adjusted to accept electrons only in the energy range between 2.5 and 4.0 mc^2. The experimental points represent the summation of ten individual runs over the angular range.

In Fig. 3, the coincidence counting rate at the angle of 180 degrees between the electron and recoil nucleus is plotted against the energy of the beta-ray. The channel width accepted by the pulse-height analyzer was 1 mc^2.

Curves calculated on the basis of the tensor and the axial vector interactions are presented for comparison with the experimental data. The curves represent the calculated electron-recoil

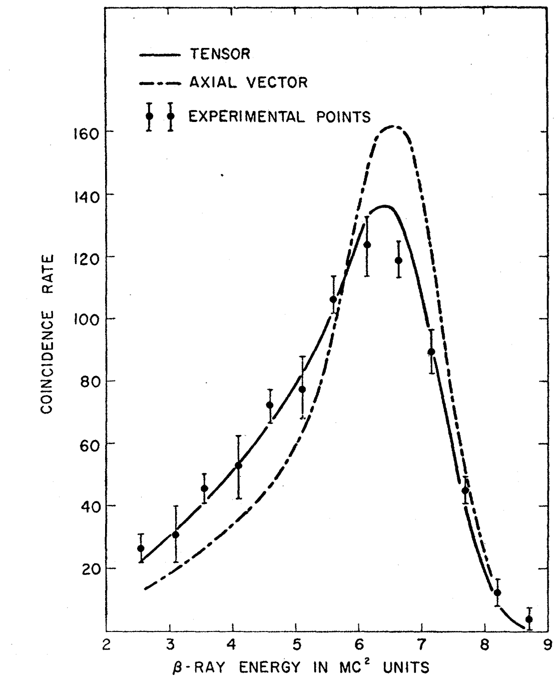

FIG. 3. Coincidence counting rate at 180 degrees between electron and recoil nucleus *versus* energy of beta-ray.

correlation integrated numerically over the solid angles subtended by the detectors and the energy resolution of the scintillation spectrometer. The consistency of both experiments makes it unlikely that instrumental discrimination resulting from the variation of angular position or energy selection systematically affected the data. The agreement between the experimental data and the tensor interaction curves in these experiments indicates that the tensor interaction dominates. This is in agreement with recent data reported by Allen.[7] A complete report covering this work is in preparation.

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A Test for Charge Independence in High Energy Nucleon-Nucleon Scattering

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IN a paper on high energy proton-proton scattering, Chamberlain *et al.*[1] mention the inequality,

$$\sigma_{pp}(90°) \leqslant 4\sigma_{np}(90°), \tag{1}$$

as one which must hold if charge independent central forces act between two nucleons. The purpose of this letter is to point out that the inequality (1) holds under much less restrictive conditions and is, in fact, a direct consequence of the assumptions of charge independence and parity conservation for the nucleon-nucleon interaction. In other words, if np and pp interactions are the same, (1) will be true, no matter what the spin or velocity dependence of the force may be.

Although the proof is easily carried through without it, we shall use the isotopic spin notation. We notice first that, since the wave function must be antisymmetric in all variables, conservation of parity and isotopic spin (T) implies conservation of the magnitude of ordinary spin (S). Then the wave functions in the c.m. frame which represent two nucleons approaching each other along the z axis are

$$\Psi_{ST}{}^{M_S M_T} \rightarrow \{[e^{ikz} - (-1)^{S+T} e^{-ikz}]\chi_S{}^{M_S} + (e^{ikr}/r)\Sigma_{M_S'} F_{ST}{}^{M_S M_S'}(\mathbf{n})\chi_S{}^{M_S'}\}\varphi_T{}^{M} . \tag{2}$$

In (2) the χ's are spin functions, the φ's are isotopic-spin functions, and S and T may each be 0 or 1. In the scattering amplitudes F, the quantum number M_T has been omitted, since the scattering is supposed to be independent of orientation in charge-space. Because of the total antisymmetry of the wave function ($\mathbf{n}$ is a unit vector in the scattering direction),

$$F_{ST}(\mathbf{n}) = (-1)^{S+T+1} F_{ST}(-\mathbf{n}). \tag{3}$$

Now all that need be done is to write down the pp and np cross sections in this notation. Equation (2) yields

$$\sigma_{pp}(\mathbf{n}) = \tfrac{1}{4}[\Sigma_{M_S M_S'} |F_{1,1}{}^{M_S M_S'}(\mathbf{n})|^2 + |F_{0,1}(\mathbf{n})|^2], \tag{4}$$

$$\sigma_{np}(\mathbf{n}) = \tfrac{1}{16}[\Sigma_{M_S M_S'} |F_{1,1}{}^{M_S M_S'}(\mathbf{n}) + F_{1,0}{}^{M_S M_S'}(\mathbf{n})|^2 + |F_{0,1}(\mathbf{n}) + F_{0,0}(\mathbf{n})|^2]. \tag{5}$$

The interference terms spoil any simple comparison of (4) and (5). However, using (3) we can find the following condition necessary for charge-independence:

$$2[\sigma_{np}(\theta) + \sigma_{np}(\pi-\theta)] - \sigma_{pp}(\theta) = \sigma_{T=0}(\theta) \geqslant 0. \tag{6}$$

The angular distributions for high energy scattering make (6) most restrictive at $\theta = 90°$ (c.m.). In Fig. 1, the relevant high energy data[2] are plotted as functions of the energy. Although the present data satisfy (1) and are therefore consistent with charge independence, the curves show that one would hesitate to predict that (1) will be satisfied for energies greater than about 300 Mev.

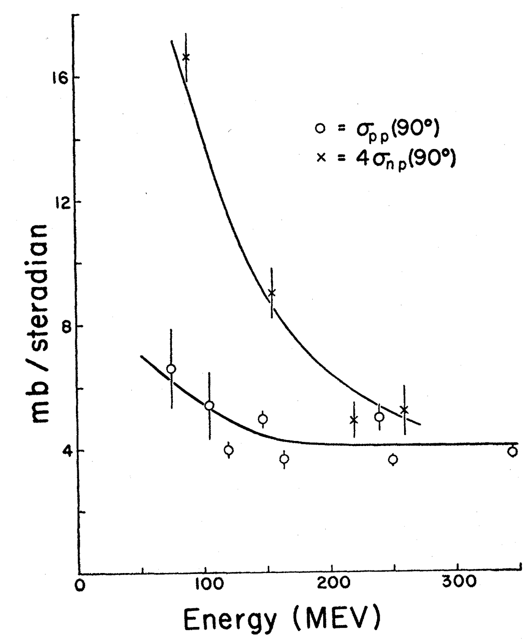

FIG. 1. σ_{pp} and $4\sigma_{np}$ at 90° (c.m.) as functions of the energy. If the scattering is charge independent, the crosses must lie above the circles at all energies.