positron computation of this note on a much firmer basis than a similar computation for an antinucleon, which would presumably give a much larger effect.

[4]In actuality, screening of the nuclear charge by the atomic electrons will cause $F(q)$ to decrease from 1 to 0 as q decreases from the reciprocal atomic radius to zero; this has a negligible effect on the value of the integral in Eq. (1).

EXPERIMENTAL TEST OF TIME-REVERSAL INVARIANCE IN STRONG INTERACTIONS

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A comparison of the polarization (P) and the asymmetry (A) in the scattering of protons by nuclei can be used as a test of invariance under Wigner time reversal in the nuclear interaction. The target nucleus cannot be chosen arbitrarily for a significant test; for example, if the nucleus has zero spin, time-reversal invariance has no bearing on the equality of P and A. Bell and Mandl[1] have considered the case in which the target nucleus has spin 1/2. They show that invariance under time reversal and spatial rotation constitutes a necessary and sufficient condition for equality of P and A. In the case of p-p scattering, they further deduce a relationship that gives a lower limit to the magnitude of the T-noninvariant term of the scattering matrix, when one knows $|P-A|$, the differential cross section, and a certain combination of the invariant amplitudes. Finally, Phillips[2] has shown that, if the first four partial waves are sufficient to describe p-p scattering, the T-noninvariant term can be specified by one real parameter that is directly related to $|P-A|$.

The first experimental evidence on this point can be found in the original p-p polarization measurements of Oxley.[3] In the course of the experiment, asymmetries in double scattering were obtained for a first target of carbon and a second target of hydrogen, as well as for the targets in opposite sequence. On the assumption that $P=A$ for the carbon scattering, one observes that the former measurement gives A and the latter P for the hydrogen scattering. From Oxley's results, one finds that $P-A=0.01\pm0.06$, and can conclude that the T-noninvariant term is not large at the angle and energy of the measurement.

Recently, Hillman[4] and collaborators have reported a more precise determination of the hydrogen polarization. At 180 Mev and at 30.9 degrees center of mass, they obtain $P=0.264\pm0.014$; they compare this with $A=0.257\pm0.018$, deduced for their energy from an interpolation of existing data.

We have independently measured P and A in p-p scattering at 210 Mev and 30 degrees center of mass. Our procedure was again essentially that of Oxley and of Hillman. A liquid hydrogen target of thickness 0.8 g/cm^2 was used, and we employed carbon both as the polarizer in the A measurement and as the analyzer in the P measurement. The incident unpolarized beam in the P measurement was degraded with CH_2 so as to have the same energy at the center of the hydrogen target as the polarized beam had in the A measurement. The detection geometry after second scattering was the same in both measurements, a precaution that tended to reduce systematic errors associated with finite solid angle. The analyzing power of the carbon target for the energy at which it scattered in the P experiment was separately determined by a double-scattering experiment in which both targets were carbon and the first-scattered beam was degraded to the appropriate energy. The polarizing power of the carbon target in the A measurement is well known from previous work at this laboratory.

As a result of these measurements, we obtain $A=0.308\pm0.005$ and $P=0.279\pm0.017$, the latter being the average of data taken at two scattering angles in the analyzer. The errors are statistical. We note that the asymmetry is in good agreement with the result of Baskir,[5] who obtained $A=0.311\pm0.010$ at the same energy and angle.

If we assume that the energy dependence of the polarization-asymmetry difference is not rapid, the results of this experiment can be combined with the 31° results of Hillman et al.[4] to obtain $P-A=-0.014\pm0.014$. Woodruff,[6] using the method of Phillips[2] and the nucleon-nucleon potential of Gammel and Thaler, has developed formulas from which the T-noninvariance parameter λ, defined by Phillips, can be deduced. For the energy and angle of these experiments, the expression developed is $I_0(P-A)=0.9\sin 2\lambda$, where I_0 is the p-p differential cross section. From the $(P-A)$ result given above, we find λ to have the value 2.0 ± 2.0 degrees. It can then be concluded that the T-noninvariant term of the scattering matrix has a magnitude no more than a few percent of the average magnitude of invariant terms.

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HELICITY OF THE PROTON FROM Λ^0 DECAY*

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Since both the Λ^0 and its decay proton possess spins, the nonconservation of parity for the decay process manifests itself in two ways. The first effect is the unsymmetrical emission of the decay products with respect to the polarization direction of the Λ^0. This asymmetry has been measured and reported[1,2] in terms of the decay pion. It is a function of the quantity $(\alpha \cdot P)$, where α is the parity mixing parameter[3] and P is the Λ^0 polarization. The second effect is the appearance of a longitudinal polarization for the decay proton which remains finite even in the absence of a polarization for the parent hyperon. When P=0, this longitudinal polarization, in the rest system of the Λ^0, is given by[4] $-\alpha$. We report here the magnitude of the longitudinal polarization and its sign (i.e., the proton helicity) as determined from the nuclear scattering of the decay protons in iron.

The Λ^0 hyperons used in this measurement were produced in a multiplate cloud chamber (17 half-inch iron plates) that was exposed to high-energy (1.2 Bev-1.9 Bev) negative pions from the Cosmotron. The observed nuclear scattering of the decay protons in the iron plates is utilized as an analyzer for polarization transverse to the proton momentum. However, it is the proton longitudinal polarization (i.e., the polarization parallel to the momentum direction $\vec{k}^*$ of the decay proton in the rest system of the Λ^0) which characterizes parity violation in Λ^0 decay. Therefore, for hyperons that decay at rest, it is impossible to use nuclear scattering for the measurement of α. In this experiment, however, the observed hyperons decay in flight with velocities as large as 0.8c; this has the effect of pulling the laboratory momentum direction ($\vec{k}$) away from the polarization direction ($\vec{k}^*$). For the 54 events used in the present analysis, the average value of $|\vec{k}\times\vec{k}^*|$ is 0.83. Hence the proton longitudinal polarization in the Λ^0 rest frame becomes a measurable transverse polarization in the laboratory system.

For a zero-spin nucleus, such as iron, the differential proton scattering intensity $(dI/d\Omega)$, at a given polar scattering angle (μ), depends on the initial proton polarization vector ($\vec{\sigma}$), as follows[5]:

$$dI/d\Omega = (1/4\pi)[1 + \vec{\sigma}\cdot\vec{S}_{Fe}(\mu)], \quad (1)$$

where

$$\vec{S}_{Fe} = (S_{Fe})\,\vec{k}_i\times\vec{k}_f/|\vec{k}_i\times\vec{k}_f| \equiv (S_{Fe})\,\vec{n}.$$

The analyzer factor ($\vec{S}_{Fe}$) is the polarization which appears when an unpolarized proton beam is scattered from an initial direction $\vec{k}_i$ into a final direction $\vec{k}_f$. Since the scattering interaction conserves parity, this polarization is along an axial vector: $\vec{n} = (\vec{k}_i\times\vec{k}_f)/|\vec{k}_i\times\vec{k}_f|$. The polarization analyzer strength (S_{Fe}) for protons scattered on iron has been measured in several laboratories at momenta of about 520,[6] 560,[7] and[8] 830 Mev/c. These results were used as a calibration for the scattering observed in the present experiment.

Scattering events suitable for a proton polarization measurement were selected as follows:

(1) All events with scattering angles larger than the expected rms Coulomb scattering angle were examined and assigned an "effective analyzer strength" (S), viz:

$$S = \gamma S_{Fe},$$

where γ is the probability that the observed event resulted from nuclear rather than Coulomb scattering.[9]

(2) Those events with $S > 0.10$ were selected for the final sample.

Pertinent features of the complete Λ^0 sample are summarized in Table I, and Table II gives the main characteristics of the final group of events utilized for the polarization measurement.

The analysis of the proton polarization is based primarily on the construction of a likelihood function (L) for the observed data in terms of the basic form (1) of the scattering probability. The likelihood function of N scattering events is the product of N independent probabilities, each of