HELICITY OF μ^- MESONS FROM π -MESON DECAY

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The current theory of weak interactions with a single two-component neutrino and lepton conservation predicts a positive helicity for negative μ mesons observed in the rest frame of the parent π meson.¹ Recent measurements by Alikhanov et al.² are consistent with this prediction. We report here a measurement of the helicity of negative μ mesons arising from the decay of π mesons produced by the CERN proton synchrotron.

The method used in this experiment was to measure the spin dependence of the differential cross section for the scattering of polarized μ mesons on polarized electrons, by reversing the magnetization in iron sheets to change the spin orientation of the electrons. We measured the energy of the knock-on electrons. This theoretical cross section is given^{3,4} by

$$\sigma(E, \vec{P}_e \cdot \vec{P}_\mu) dE = \frac{2\pi r_0^2 m_0 c^2}{\beta_\mu^2 E^2} \left\{ 1 - \beta_\mu^2 \left(\frac{E}{E_m} \right) + \frac{1}{2} \left(\frac{E}{E_\mu} \right)^2 \right. \\ \left. - \vec{P}_e \cdot \vec{P}_\mu \frac{E}{E_\mu} \left(1 - \frac{E}{E_m} + \frac{E}{2E_\mu} \right) \right\} dE, \quad (1)$$

where E is the kinetic energy of the struck electron, E_m the maximum possible energy transfer, E_μ the total energy of the incident μ meson, and $\vec{P}$ the polarization.

The polarized μ -meson beam was obtained with the arrangement shown in Fig. 1. π mesons from the target T , in the momentum band 12.1 ± 0.3 GeV/ c , were focused by the synchrotron magnets $A_1 A_2$ onto the 2-cm wide slot S in an 80-cm long lead collimator. This beam of some 8×10^5 nega-

tive particles per pulse was then collimated by a pair of quadrupoles $Q_1 Q_2$. After a decay path of some 45 m, the 11-GeV/ c μ mesons (emitted forward by the π mesons) were focused by a second pair of quadrupoles $Q_3 Q_4$ through a 760-cm graphite filter F . The μ mesons lost about 3 GeV in traversing the filter. A magnet M before the filter dispersed the beam so that with a pair of 7×7 -cm² counters $C_1 C_2$ it was possible to define a μ -meson beam of 8 GeV/ c . The beam had about 15% momentum spread, an intensity of 2×10^3 particles per pulse, and a calculated longitudinal polarization of $|\vec{P}_\mu| = 0.85$. The flux of π mesons counted by $C_1 C_2$ was measured to be about 3×10^{-5} of the μ -meson flux. The number of μ mesons in this beam from the decay of K mesons was estimated to be negligible.

To produce, and measure the energy of, the knock-on electrons we used a total absorption shower detector D which consisted of 20 interleaved layers of iron and plastic scintillator sheets. The sheet dimensions were $1 \times 30 \times 40$ cm³, and they were inclined at an angle of 30° with respect to the beam axis. The induction in the iron was $\pm 2 \times 10^4$ gauss. The energy dependence of the detector's output signal was measured with incident electrons of known energy; it was essentially linear in the range 1 to 10 GeV. The resolution, $\Delta E/E$, changed from 50% to 10% in this range.

The experiment was designed to minimize systematic instrumental asymmetries from such causes as change of gain with magnetic field. Measurements taken throughout the experiment showed that such asymmetries were significantly smaller than our statistical errors.

FIG. 1. Experimental arrangement. P , circulating proton beam; A , synchrotron magnets; S , Pb collimator; Q , quadrupoles; M , dispersing magnet; F , graphite filter embedded in concrete; C , counters; D , detector.

FIG 2. Asymmetry of shower production cross section, $(N_a - N_p)/(N_a + N_p)$, with magnetic field reversal vs shower energy.

The energy spectrum of μ -meson-produced showers above 0.5 Gev was recorded with a pulse-height analyzer. It showed the features predicted by Eq. (1) with a contribution of high-energy showers due to μ -meson bremsstrahlung. At the maximum energy of the knock-on electrons, bremsstrahlung contributes about 30% to the total cross section. These results will be reported elsewhere.

Figure 2 shows the measured difference in shower production cross sections (knock-on electrons and bremsstrahlung) with reversal of the magnetic field as a function of the shower energy. About 1.2×10^7 μ mesons were recorded in the 12.5 hours of normal machine operation during which the data shown in Fig. 2 were collected. The solid curve is the calculated difference for positive helicity. From these data and another run with a beam of 62% polarized μ mesons, the helicity is determined to be

$$\mathcal{H}(\mu) = +1.17 \pm 0.32 \text{ (standard deviation),}$$

which is in agreement with the theoretical prediction of +1.

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