ANGULAR DISTRIBUTION OF μ^+ MESONS FROM $\pi-\mu$ DECAY

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At the Varenna (Italy) conference in 1957, Lattes reported on certain experimental data on angular distribution of μ^+ mesons from $\pi-\mu$ decay, and the possibility of asymmetry in such an angular distribution was discussed. In further experiments[1-4] it was found that the asymmetry parameter $b = 2(N_F - N_B)/(N_F + N_B)$ lies between the limits $b = -0.447 \pm 0.082$ and $b = 0.052 \pm 0.058$; here N_F and N_B are the numbers of μ^+ mesons emitted forwards and backwards, respectively, relative to the direction of the π^+-meson beam. At the Venice[5] conference it was noted that despite the wide scatter of values of b obtained by different authors there is, apparently, no asymmetry in the $\pi-\mu$ decay and the various values of b are caused by one or another systematic error.

In the present work we report on the results of an analysis of 10,000 cases of $\pi-\mu$ decays of π^+ mesons stopped in NIKFI type R emulsion. The emulsion layers were irradiated by the π^+-meson beam from the Laboratory for Nuclear Problems synchrocyclotron and were placed, during the exposure time, inside a steel screen which shielded them from the external magnetic fields.

Observation of $\pi-\mu$-decay events was carried out by aerial scanning with the MBI-3 microscope at an amplification of about 100. The identification of the $\pi-\mu$-decay events was carried out visually. Measurements were made of the projections onto the emulsion plane of the angles between the initial direction of the μ^+ meson and the direction of the collimator of the π^+-meson beam. The error in the measurement of the angular projections did not exceed ± 3°. The angular distribution obtained directly from scanning is shown in Fig. 1a; the asymmetry coefficient for this angular distribution is $b = -0.048 \pm 0.020$.

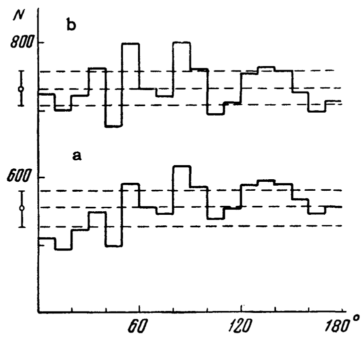

FIG. 1

In order to estimate systematic errors that could have been introduced in the process of emulsion scanning, we carried out two identical scannings of the same area at the suggestion of L. L. Gurevich. We measured the projection θ^* of the angle between the final direction of the π^+ meson and the initial direction of the μ^+ meson. The $\pi-\mu$-decay events found twice were identified, and the probability of observation of such a decay event was computed as a function of θ^*. It can be seen from Fig. 2 that the probability of observing a $\pi-\mu$-decay event decreases for small values of θ^*.

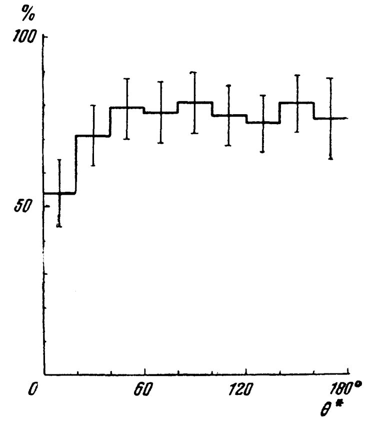

FIG. 2

The "direct" distribution of Fig. 1a was corrected by taking into account the scanning efficiency (Fig. 2) and the distribution found experimentally, of the angles between the initial and final π^+-meson directions. Figure 1b shows the projected angular distribution of the μ^+ mesons. Here the asymmetry coefficient is $b = +0.009 \pm 0.018$. It therefore follows that the angular distribution of μ^+ mesons from $\pi-\mu$ decays of stopped π^+ mesons is isotropic.

It appears probable that the cause of asymmetry observed by some authors can, at least partially, be related to the systematic error studied in this work.

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CONCERNING THE LETTER BY P. V. VAVILOV, "THE INTERACTION CROSS SECTION OF PI MESONS AND NUCLEONS AT HIGH ENERGIES"

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IN the articles cited[1] the total cross section for the interaction of pions with nucleons at infinitely large energies are calculated with the aid of a dispersion relation, usually called the inverse relation, which expresses the imaginary part of the forward-scattering amplitude in terms of the real part of this amplitude. The real part of the amplitude, on the other hand, is calculated in the work of Cool et al.,[2] which Vavilov uses, from experimental data on the total cross sections for the interaction of pions with nucleons, and the dispersion relation employed is direct with respect to the above-mentioned inverse relation.

Since experimental data on the total cross sections are available only up to 1770 Mev for positive pions and to 4500 Mev for negative ones, total interaction cross sections, extrapolated for infinite energies at a constant level of approximately 30 millibarns, are used in Ref. 2 to calculate the real part of the amplitude of the elastic forward scattering. No wonder therefore that the cross section obtained in Ref. 1 is $\sigma_\infty = 30$ millibarns. The result of such a calculation is not the prediction of a quantity not yet measured experimentally, but a verification of the compatibility of the employed direct and inverse dispersion relations. Such an agreement should obtain for any extrapolation of the total cross section, and is independent of the accuracy of the experimental quantities.

The contents of the note referred to can also be represented as a calculation of the sections $\sigma_\pm(\omega)$ with the aid of relations of the form

$$\sigma_\pm(\omega) = F_\pm(\omega) + \int_0^\infty \{K_{\pm,+}(\omega,\omega')\,\sigma_+(\omega') + K_{\pm,-}(\omega,\omega')\,\sigma_-(\omega')\}\,d\omega', \tag{1}$$

which are obtained when the real parts of the forward scattering amplitudes $D_\pm(\omega)$ are eliminated from the direct and inverse dispersion relations. But such an elimination, if one considers that

$$\int_{-\infty}^{\infty} dx/(x-a)(x-b) = \pi^2\delta(a-b), \tag{2}$$

yields

$$F_\pm(\omega) = K_{+,-}(\omega,\omega') = K_{-,+}(\omega,\omega') = 0,$$
$$K_{+,+}(\omega,\omega') = K_{-,-}(\omega,\omega') = \delta(\omega-\omega'),$$

and relation (1) turns into the identity $\sigma_\pm(\omega) = \sigma_\pm(\omega)$, which would be meaningless to verify experimentally.

To refute the widely held opinion that the dispersion relation yields results that are totally insensitive to the behavior of the cross sections at $\sigma \to \infty$, let us consider a simple example. Let us add to cross sections $\sigma_+(\omega)$ and $\sigma_-(\omega)$ a constant cross section σ_0 in the frequency interval $\omega > \omega_0$. Then, as can be readily verified, the real parts of the amplitudes $D_+(\omega)$ and $D_-(\omega)$ are increased by

$$\Delta D_\pm(\omega) = \sigma_0\frac{\sqrt{\omega^2-\mu^2}}{4\pi^2}\ln\frac{\sqrt{\omega_0^2-\mu^2}+\sqrt{\omega^2-\mu^2}}{\left|\sqrt{\omega_0^2-\mu^2}-\sqrt{\omega^2-\mu^2}\right|}. \tag{3}$$

This quantity is really small when $\omega \ll \omega_0$, but this does not necessarily hold for all frequencies. Inserting $\Delta D_\pm(\omega)$ into the inverse dispersion relation quoted by Vavilov, we find that the cross sections $\sigma_+(\omega)$ and $\sigma_-(\omega)$ are increased by zero when $\omega < \omega_0$, and increased by σ_0 when $\omega > \omega_0$, since at $\omega > \omega_0$

$$\int_0^\infty \frac{d\omega'}{(\omega'^2-\omega^2)\sqrt{\omega'^2-\mu^2}} \times \ln\frac{\left|\sqrt{\omega_0^2-\mu^2}-\sqrt{\omega'^2-\mu^2}\right|}{\sqrt{\omega_0^2-\mu^2}+\sqrt{\omega'^2-\mu^2}} = \frac{\pi^2}{2\omega\sqrt{\omega^2-\mu^2}} \tag{4}$$