The efficiency for recording showers in each chamber is

$$q_1 = 0.95 \pm 0.05 \text{ and } q_2 = 0.94 \pm 0.05$$

(for chambers with interelectrode distances of 90 and 70 mm, respectively).

A spark chamber operating under similar conditions does not record particles entering at large angles to the direction of the electric field.[2,3] For this reason, the definition of the shower efficiency of the chamber Q as the ratio of the number of recorded particles to the number of particles passing through its effective volume was used only for angles < 40°. Since, in our case, the number of electrons produced in the electrode between the chambers is small, the efficiency Q is defined as

$$Q_1 = n/n_{H_2} \text{ and } Q_2 = n/n_{H_1},$$

where n_H is the number of sparks in the lower chamber from particles passing through both chambers, and n is the number of pairs of sparks in the upper and lower chambers produced by the same particle. To determine Q_2, the positions of the chamber were interchanged.

In this way we have calculated the shower efficiencies for both chambers: $Q_1 = 0.78 \pm 0.06$ and $Q_2 = 0.73 \pm 0.17$ with the mean numbers of particles in the chambers equal to 18.6 ± 2.1 and 20.0 ± 5.7. Figure 2 shows the distribution of showers recorded in the spark chamber as a function of the number of particles.

Figure 3 shows the dependence of the shower efficiency on the number of particles passing through the chamber. It is seen that within the limits of statistical error, this quantity remains unchanged up to several tens of particles in a shower.

It can be assumed that the particles entering at angles < 40° are recorded more efficiently than follows from the experimental data. The decreased shower efficiency could possibly be a consequence of the fact that the particles traveling through the upper chamber at large angles without being recorded are scattered in the central electrode and, upon passing through the lower chamber at smaller angles, are recorded. This effect can be important in showers under the lead, which have a large number of low-energy electrons. We carried out an analysis in which sparks occurring far from the shower axis in the lower chamber were not counted as shower particles. The shower efficiency proved to be $Q_1 = 0.92 \pm 0.07$. One month after the spark chamber was filled, its efficiency for recording showers changed only slightly.

The authors thank Prof. A. I. Alikhanyan for constant interest in the work and for valuable comments, A. P. Shmeleva and L. P. Kotenko for discussions of the results, S. A. Vartanyan for preparation of the large-size plastic scintillators used in the experiment, and K. M. Smyslov for aid in preparing the equipment.

[1] Bolotov, Daĭon, Devishev, Klimanova, Luchkov, and Shmeleva, PTÉ, in press.

[2] Borisov, Dolgoshein, and Luchkov, PTÉ, No. 2, 170 (1962).

[3] S. Fukui and S. Miyamoto, Nuovo cimento **11**, 113 (1959).

Translated by E. Marquit
267

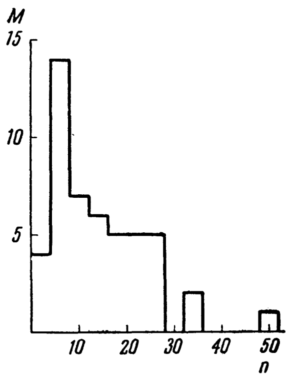

FIG. 2

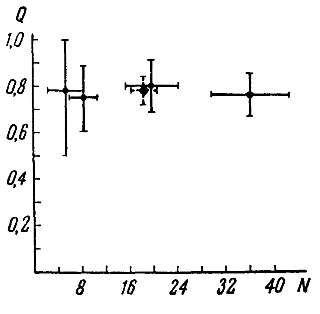

FIG. 3

FIG. 2. Distribution of the number of particles recorded per shower in a spark chamber.

FIG. 3. Dependence of the shower efficiency on the number of particles passing through the effective volume of the spark chamber.

STUDY OF $\pi\pi$ *RESONANCES IN* π^--p *COLLISIONS AT* 3.5 GeV/c

M. S. AĬNUTDINOV, S. M. ZOMBKOVSKIĬ, Ya. M. SELEKTOR, and V. N. SHULYACHENKO

Institute of Theoretical and Experimental Physics

Submitted to JETP editor September 12, 1963

J. Exptl. Theoret. Phys. (U.S.S.R.) **45**, 1682-1684 (November, 1963)

By means of a 25-cm liquid hydrogen bubble chamber, we studied the reactions

$$\pi^- + p \rightarrow \pi^- + \pi^0 + p, \quad (1)$$

$$\pi^- + p \rightarrow \pi^- + \pi^+ + n. \quad (2)$$

The momentum of the incident π^- mesons was 3.5 GeV/c. We obtained ~ 80,000 pictures. Two-prong stars with tracks of length greater than 3 cm were analyzed on an automatic measuring machine. The error in the momentum measurements of the particles corresponded to an error of $50\,\mu$ (actual value in the chamber) in the sag of the trajectory. For reaction (1) we also measured the proton range.

The distribution of the effective masses of the $\pi^-\pi^0$ and $\pi^+\pi^-$ systems for reactions (1) and (2) are shown in Fig. 1. The $\pi^-\pi^0$ mass distribution was constructed for events in which the square of the 4-momentum transfer was $\leq (200\ \text{MeV/c})^2$.

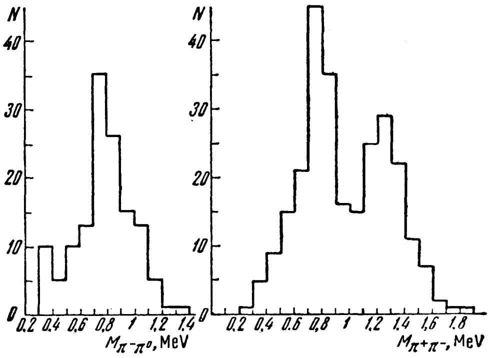

FIG. 1. Effective mass distribution of di-pions: a) for reaction (1), 134 events; b) for reaction (2), 257 events.

The mean error in the determination of the $\pi^+\pi^-$ masses was ~ 60 MeV at $M_{eff} = 760$ MeV and ~ 80 MeV at $M_{eff} = 1200$ MeV. Events for which the error δ in the values of M_{eff} corresponded to the extreme errors in the distribution ($\delta > 180$–200 MeV) were not included in the distribution of Fig. 1b.

From the distribution of the effective masses of the $\pi^-\pi^0$ system, we observe a clear maximum at $M_{eff} = 770$ MeV corresponding to the production of the ρ^- meson. In the M_{eff} distribution for the $\pi^+\pi^-$ system, we observe two maxima corresponding to the production of the ρ^0 and f^0 mesons. The half-width of the f^0 maximum is $\Gamma/2 \sim 120$ MeV and is determined primarily by the resolution of the measurements.

It is of interest to determine the spin of the f^0 meson. Since all the experimental data up to the present time indicate that the f^0 is observed only in one charged state,[1-5] we can, with confidence, assign an isospin T = 0 to the f^0 meson. Consequently, the spin of the f^0 meson can take only even values. Figure 3 shows the angular distribution of the π^- mesons in the dipion rest frame for three intervals of di-pion mass: 900–1100, 1100–1400, and 1400–1800 MeV. In the mass region for the f^0 (1100–1400 MeV), the distribution has an appreciable anisotropy, which indicates that the spin of the f^0 is greater than zero. The obtained distribution can be described by a D wave superimposed on an isotropic background, which is evidence that the f^0 has a spin 2, although the value 4 cannot be completely rejected. These results are not in contradiction with other results.[2-5] The data available at the present time indicate that the spin 4 is highly improbable.

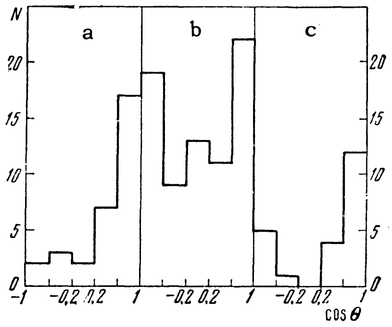

FIG. 2. Angular distribution of π^- mesons in the di-pion rest frame for reaction (2): a) for 0.9 GeV < $M_{\pi\pi}$ < 1.1 GeV, 31 events; b) for 1.1 GeV < $M_{\pi\pi}$ < 1.4 GeV, 74 events; c) for $M_{\pi\pi}$ < 1.4 GeV, 22 events.

We checked whether the maximum in the region of 1250 MeV in Fig. 1b was not due to an isobar. To do this, we constructed the distribution of the effective masses of the π^-n and π^+n system for cases of reaction (2) in which M_{eff} lay within the limits of 1150–1350 MeV. No noticeable maximum in the region of known isobars was found in these distributions.

In conclusion, we consider it our pleasant duty to express our gratitude to A. I. Alikhanov for his constant interest and many discussions and to R. S. Guter for performing the calculations.

[1] Ya. Ya. Shalamov and A. F. Grashin, Proc. Intern. Conf. on High Energy Physics at CERN, 1962, p. 58.

[2] Selove, Hagopian, Brody, Baker, and Leboy, Phys. Rev. Lett. **9**, 272 (1962).

[3] J. J. Veillet, T. Hennessy et al., Phys. Rev. Lett. **10**, 29 (1963).

[4] L. Bondar, K. Bondartz et al., Physics Letters **5**, 153 (1963).

[5] Z. G. T. Guiragossian, Phys. Rev. Lett. **11**, 85 (1963).

Translated by E. Marquit
268