MOMENTUM ANALYSIS OF KAON AND PION PAIRS PRODUCED FROM TIME-LIKE PHOTONS AT 1.6 GeV ENERGY

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We present results for the total cross section of e^+e^- annihilation into two hadrons at 1.6 GeV: $\sigma_{\pi\pi} = \sigma_{KK} = (1.8 \pm 1.1) \times 10^{-33}$ cm^2. From these values we obtain the time-like electromagnetic form factors of these mesons: $|F_\pi|^2 = 0.24 \pm 0.14$ and $|F_K|^2 = 0.46 \pm 0.26$.

We report preliminary results on collinear charged kaon and pion pairs produced in the reaction:

$$e^+e^- \to K^+K^- \qquad \pi^+\pi^- \tag{1}$$

The experiment was done with the ADONE magnetic apparatus MEA at center of mass energy $2E = 1.6$ GeV; here we present a first sample of events for a total integrated luminosity $\mathcal{L} = 8.45$ nb^{-1}.

In spite of the poor statistics it has been possible, using momentum analysis, interactions in heavy plate chambers and time of flight information, to obtain clear signals of kaons and pions pair production. Our results are in agreement with the value of pion and kaon electromagnetic form factors obtained by a previous experiment [1].

The MEA apparatus has already been described [2]; its main features are: a solenoid (radius $R = 1$ m) with the axis perpendicular to the beams direction; large gap spark chambers with thin electrodes (0.15 radiation length), placed inside, for curvature measurements; thick spark chambers interleaved with lead and iron plates (9.1 radiation lengths and 1.5 collision lengths) outside the coil for particles identification.

The solenoid was operated at 2 Kgauss; the total solid angle was $\Delta\Omega = 0.33 \times 4\pi$ for momentum analysis and $\Delta\Omega = 0.27 \times 4\pi$ for particles identification.

The momentum measurement accuracy was tested with the muon pairs produced at the same energy. The momenta are distributed (fig. 1) with a standard deviation $\sigma = 0.06$ GeV/c; the percentage error results $\Delta p/p = 7.8\%$.

In order to identify $\pi^+\pi^-$ and K^+K^- final states, which are quite rare, it was essential to reject with high efficiency the rather large background due to other two-body final states: particular e^+e^- wide angle events, as they are two orders of magnitude more frequent than the hadronic ones, and muon pairs. In addition, contamination can occur from the cosmic rays accepted by the apparatus, and from the multihadronic events.

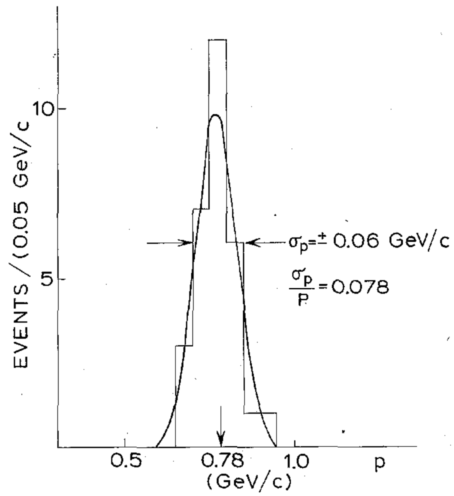

Fig. 1. Experimental momentum distribution of muons from $e^+e^- \to \mu^+\mu^-$, collected by MEA apparatus at $2E = 1.6$ GeV.

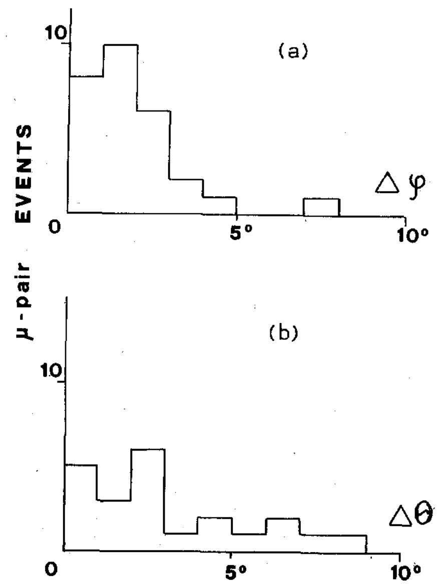

Fig. 2. (a) The $\Delta\phi$ acoplanarity distribution for the reaction $e^+e^- \to \mu^+\mu^-$ at $2E = 1.6$ GeV ($\Delta\phi$ is the difference between the azimuthal angles of the μ^+ and μ^- tracks; (b) the $\Delta\theta$ non-collinearity distribution for the same events ($\Delta\theta$ is the difference between the polar angles of the μ^+ and μ^- tracks).

The collinear events were accepted by means of time of flight selection, by requiring a suitable timing with the bunches and a correct source-point [2].

Candidates for hadronic pairs were also required to exhibit:

(1) two single tracks coplanar with the beams within $\Delta\phi = 8°$ and collinear within $\Delta\theta = 10°$ (these cuts have been deduced from the $\Delta\theta$, $\Delta\phi$ distributions of $e^+e^- \to \mu^+\mu^-$ events, figs. 2a and 2b); $\Delta z \leqslant 6$ mm, where Δz is the difference between the z-coordinates of interaction-point along the beam line reconstructed from h^+h^- tracks (this cut has been deduced from Δz-distribution of $\mu^+\mu^-$ pairs).

(2) Momenta ranging from a minimum value of 465 MeV/c (3σ below the kaon nominal momentum, $p_k = 629$ MeV/c, to a maximum of 990 MeV/c (3σ above the pion nominal momentum, $p_\pi = 788$ MeV/c).

(3) Momenta of the two tracks within two standard deviations from their medium value.

(4) Nuclear scattering or correct range in the thick plate chambers.

Due to the possibility to observe π(2%) and K(16%) decays in the thin chambers inside the solenoid, we also accepted as hadronic the collinear events with at least one track satisfying the previous criteria ((1), (2), (4)), and other exhibiting a clear decay pattern.

Muon pairs and cosmic rays contaminations are drastically reduced by criteria (4), and (2), (4), respectively: their probability to simulate a hadronic-pair in the proper momentum range was estimated to be $< 2 \times 10^{-3}$ from a test with the cosmic rays.

The contamination from e^+e^- events is negligible. The probability for a poor shower to simulate a hadronic pattern was measured from collinear events with at least one clear shower termination. The probability for an e^+e^- pair to simulate a hadronic pair turns out to be $\leqslant 7 \times 10^{-4}$. The possible contamination from multihadron events was calculated from crossed analysis of momentum, collinearity and coplanarity distribution of the whole two-track set. This probability is 4×10^{-3}, and therefore this contamination is practically zero in our sample.

The hadronic candidate events were divided in pion and kaon pairs, according to the momentum values. Moreover we required kaon pairs to have a proper range in the thick plate chambers and a consistent β value from time of flight measurements.

In order to give the cross sections of the reaction (1), we checked the efficiency of the apparatus with the reaction $e^+e^- \to \mu^+\mu^-$. The measured cross section is

Table 1

	Cosmic rays	Electrons	Muons	2 tracks multihadrons
Number of events	< 4	770	40	16
Maximum percentage contamination	2×10^{-3}	7×10^{-4}	2×10^{-3}	4×10^{-3}
Maximum number of background events in h^+h^- sample	–	0.53	0.08	0.06

$$\sigma_{\mu^+\mu^-} = \frac{N_{\hat{\mu}^+\mu^-}}{\mathcal{L}\epsilon_{\mu^+\mu^-}} = (28 \pm 5)\ \text{nb},$$

in good agreement with the value $\sigma = 33$ nb calculated in the μ–e universality hypothesis.

The detector efficiency of the apparatus $\epsilon_{\mu^+\mu^-} = 0.17$ was evaluated with the Monte Carlo simulation; the same value was also practically found for pions and kaons.

The total collected luminosity $\mathcal{L} = (8.45 \pm 0.3)\ \text{nb}^{-1}$ was calculated from the rate of wide angle Bhabha events in the apparatus and is in good agreement with the value, $\mathcal{L} = 8.8\ \text{nb}^{-1}$, provided by the fast machine monitor from the small angle Bhabha events.

From the number of the events, 3 pion pairs and 3 kaon pairs, after subtraction of the background (see table 1), we obtained the cross sections of the reactions (1) and the relative electromagnetic form factors, reported in table 2. The pion and kaon form factors are also shown in fig. 3 and fig. 4, respectively, including previous values from different experiments [1, 3–7] and are here compared with theoretical models predictions.

The data show that, in the energy region above $s = 1\ \text{GeV}^2$, the electromagnetic form factors of the charged pseudoscalar mesons lie above the tails of the well established vector meson ρ, ω, ϕ. Nevertheless, the analysis of the form factors seems at present a method inadequate to decide on the existence of new vector mesons because their elasticity into the two hadrons channels may be very depressed.

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Table 2

Channel	σ (nb)	$\lvert F\rvert^2$
$e^+e^- \to \pi^+\pi^-$	1.8 ± 1.1	0.24 ± 0.14
$e^+e^- \to K^+K^-$	1.8 ± 1.1	0.46 ± 0.26

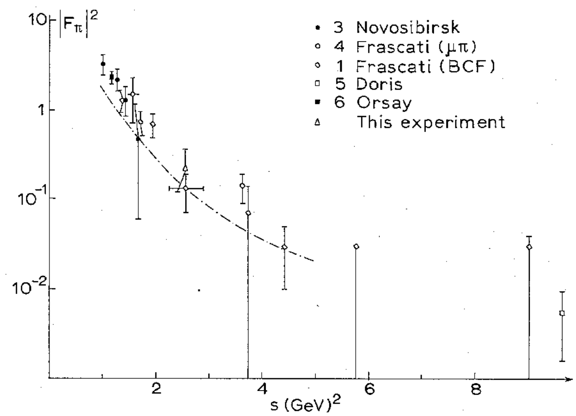

Fig. 3. The experimental electromagnetic form factor of the pion $|F_\pi|^2$, versus s, the squared total c.m. energy, above 1 GeV^2. The line is the ρ-tail according to Gounaris and Sakurai [8].

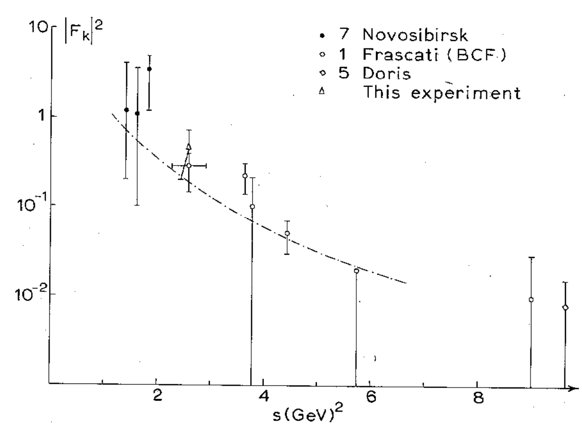

Fig. 4. Kaon electromagnetic form factor $|F_K|^2$, versus s, the squared total c.m. energy. The line is the theoretical expectation based on the ρ, ω, ϕ tails [1].

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