K^0 PRODUCTION IN e^+e^- ANNIHILATIONS AT 30 GeV CENTER OF MASS ENERGY

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Inclusive K^0-production has been measured in e^+e^- annihilation at a center of mass energy of about W = 30 GeV. The ratio of $K^0 + K^0$ production to $\mu^+\mu^-$ production is R_{K^0} = 5.6 ± 1.1 (statist. error) ± 0.8 (system. error). This value is about a factor of three higher than R_{K^0} at W = 7 GeV. The cross sections $(s/\beta)\, d\sigma/dx$ is consistent with a scaling behaviour.

The identification of strange particles in the final state of e^+e^- collisions at high energies is important both for the spectroscopy of narrow states which decay via the weak interaction and for the understanding of the fragmentation process of quarks into hadrons. In a tracking device with sufficient resolution the detection of K^0's is easier than the identification of charged kaons, since it does not require the use of additional instrumentation such as time-of-flight or Cerenkov counters. In this letter we report on the inclusive yield of K^0's, identified by the $K^0_S \to \pi^+\pi^-$ decay in the TASSO detector.

The TASSO central detector used for tracking consists of 4 layers of cylindrical proportional chambers surrounded by 15 concentric layers of a drift chamber embedded in a solenoidal field of 0.5 T. The proportional chamber is close to the beam pipe of 13 cm radius; it covers a radial range from 18 cm to 29 cm. The average anode wire spacing is 3 mm. The drift chamber [1] extends from 36 cm to 122 cm in radius. It has 9 cylindrical layers with wires running parallel to the beam direction (0°) and 6 layers with wires oriented at approximately +4° or −4°, to provide stereoscopic views. All drift chamber cells have the same size. The drift space is ±1.6 cm. Right–left ambiguities are not resolved by hardware; single hit electronics are used for the read-out. The momentum resolution for charged particles is $\sigma_p/p = 0.02\, p$ (p in GeV/c) for momenta above 1 GeV/c. A more detailed description of the detector and the analysis procedure has been given elsewhere [2,3].

The measurements were performed at PETRA with center-of-mass energies W ranging from 29.9 GeV to 31.6 GeV. A sample of 812 hadronic events was selected using standard [2] cuts: 5 or more charged particles with momentum component $p_T > 0.1$ GeV/c transverse to the beam direction and polar angles θ satisfying $|\cos\theta| < 0.87$. The sum of charged particle momenta, $\Sigma\, |p_i|$, had to exceed 8 GeV/c to avoid contamination from two-photon processes. The interaction point in the plane perpendicular to the beam was determined for a series of runs rather than event by event. It was found to vary by less than 1 mm for the present data. $K^0_S \to \pi^+\pi^-$ decays in these events were selected by geometrical cuts in the plane transverse to the beam direction. First, the smallest distance between the interaction point and the circle describing a particle trajectory had to exceed 4 mm for both particles. Second, the angle α between the vector sum of the particle momenta, evaluated at the decay point and the line joining interaction and decay points was required to be $\alpha < 10°$. Decays with more than 45 cm distance between interaction and decay points were rejected. If the same particle was involved in more than one K^0 candidate, the pair with the smallest α was retained. Pairs in which one of the tracks had hits in front of a common intersection were rejected. In addition to these geometrical cuts we required that the invariant mass of pair of particles, considered as electrons, be less than 100 MeV.

Assuming all particles to be pions, the $\pi^+\pi^-$ invariant mass distribution of oppositely charged particle pairs satisfying these cuts was calculated. It shows (fig. 1a) a clear K^0 peak with (498 ± 3) MeV mean value and a standard deviation of 18 MeV, averaged over all momenta. The interval from 450 MeV to 550 MeV contains a signal of 90 kaons above a background of 26. The background was determined from the events in the side bands 0.4–0.45 GeV and 0.55–0.6 GeV. It is consistent with the number of pairs of same-charged particles in the central interval (25 pairs). The background subtraction was done separately for several momentum intervals. The momentum distributions of signal and background are shown in fig. 1b.

The detection efficiency for $K^0 \to \pi^+\pi^-$ decays as a function of the K momentum was determined in two ways. First, the production of hadrons, as well as their subsequent decays, interactions and scatters were simulated by a Monte Carlo program. Events generated in this way were reconstructed by the same chain of programs as the data. In a second method, wire hits due to pions from a K^0-decay were generated, superimposed to real events and these modified events reconstructed. The K^0's were generated with an average transverse momentum of 0.3 GeV/c with respect to the reconstructed jet axis. In this method the multiplicity is

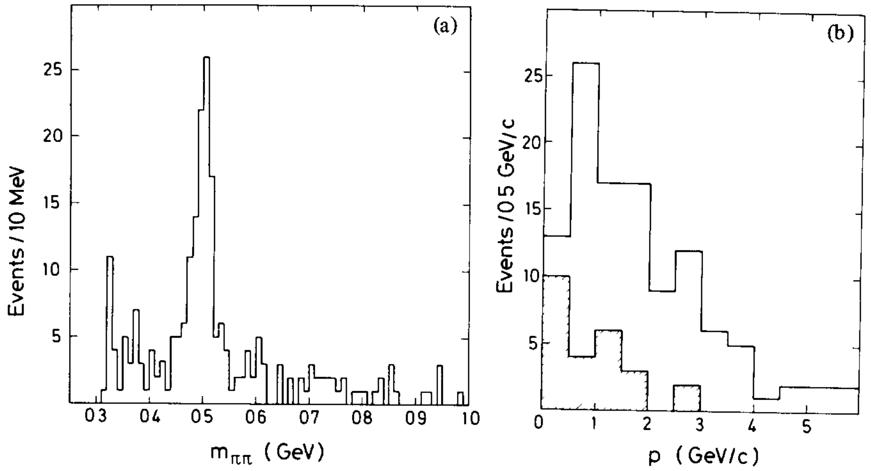

Fig. 1. (a) Mass distribution of pairs of oppositely charged particles assumed to be pions and satisfying the cuts described in the text. (b) Momentum distribution of $\pi^+\pi^-$ pairs satisfying 0.45 GeV $< m_{\pi\pi} <$ 0.55 GeV. The dashed area shows the background yield as taken from $\pi^+\pi^-$ pairs in the intervals 0.40 GeV $< m_{\pi\pi} <$ 0.45 GeV and 0.55 GeV $< m_{\pi\pi} <$ 0.60 GeV.

artificially increased by two units. Since there is a considerable loss of K^0's due to the overlap of tracks the effect of the increased multiplicity on the efficiency had to be corrected for. The two methods were then found to give consistent results. The efficiency for $K_S^0 \rightarrow \pi^+\pi^-$ detection had a maximum value of 26% at 2 GeV/c and decreased to 15% at 0.25 GeV/c and at 5 GeV/c. The K_S^0 lifetime calculated with these efficiencies agrees with the standard value.

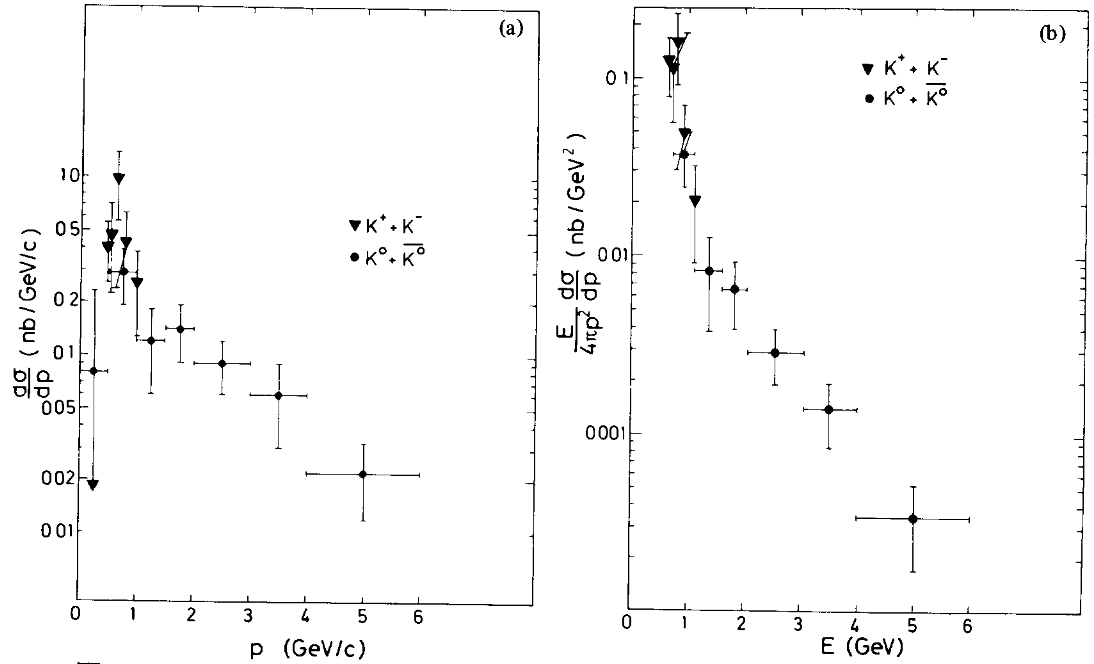

Fig. 2. $K^0 + \overline{K^0}$ production. Also shown is the invariant cross section for $K^+ + K^-$ production measured in this experiment [4]. (a) Differential cross section $d\sigma/dp$. (b) Invariant cross section $(E/4\pi p^2)\, d\sigma/dp$.

Differential cross sections for ($K^0 + \overline{K^0}$)-production were calculated using the known branching ratio ($K^0_S \to \pi^+\pi^-$)/($K^0_S \to$ all) and corrected by a factor 2 for the unobserved K^0_L decays. For normalization we used the value of 3.9 for $R = \sigma(e^+e^- \to \text{hadrons})/\sigma_{\mu\mu}$ where $\sigma_{\mu\mu} = 4\pi\alpha^2/3\,W^2$, measured in this experiment at the same energies [3]. The cross sections presented below have an overall normalization error of 15% due to the uncertainty in the K^0 detection efficiency and the uncertainty in R.

In fig. 2 the differential cross section $d\sigma/dp$ and the invariant cross section $(E/4\pi p^2)\,d\sigma/dp$ are presented for the sum of K^0 and $\overline{K^0}$ production. Also given are the cross sections for the sum of K^+ and K^- production, measured in this experiment [4]. The behaviour of the invariant cross section for $E > 1$ GeV is consistent with a simple exponential, $(E/4\pi p^2)\,d\sigma/dp \sim \exp(-0.9 \pm 0.4)\,E$. For $E < 1$ GeV the slope appears to be steeper. The cross sections for charged and neutral kaon production are the same within errors.

The scaling cross section $(s/\beta)\,d\sigma/dx$ ($s = W^2, \beta = p/E, x = 2E/W$) is given in fig. 3a. Also shown is the measurement from ref. [5] at lower energies, namely $W = 6.8$–7.6 GeV. The low energy points which cover x values $x > 0.2$ are in agreement with the high energy measurements within errors. In other words, inclusive K^0 production appears to scale in the region where the data overlap, namely for $0.2 < x < 0.4$.

The total yield of ($K^0 + \overline{K^0}$) was obtained by integration of the momentum spectrum. Correcting for an estimated 3% loss at momenta above 6 GeV/c we observe 1.4 ± 0.3 (statist. error) ± 0.14 (system. error) neutral kaons per event. The systematic error is mainly due to the uncertainty of the reconstruction efficiency. The inclusive cross section relative to muon pair production is (fig. 3b)

$$R_{K^0} = (\sigma(K^0X) + \sigma(\overline{K^0}X))/\sigma_{\mu\mu} = 5.6 \pm 1.1 \pm 0.8\ .$$

This is considerably higher than the R_{K^0} value measured near $W = 7$ GeV, $R_{K^0} = 2.10 \pm 0.14$ [5]. The observed rise in K^0 yield is comparable to the growth [7] of the charged particle multiplicity $\langle n_{ch}\rangle$ which increases from $\langle n_{ch}\rangle = 4.5$ to 13 over the same energy interval (shaded area in fig. 3b). We also note that the K^0 momentum spectrum as measured in this experiment is in good agreement with the prediction of a quark–antiquark gluon model [8] based on the fragmentation model by Field and Feynman [9].

In summary, we have measured K^0 production in e^+e^- annihilation at c.m. energies of 30 GeV. The invariant cross section $(E/4\pi p^2)\,d\sigma/dp$ behaves like $\exp(-0.9 \pm 0.4)\,E$ for K^0 energies $E > 1$ GeV. The cross section $(s/\beta)\,d\sigma/dx$ when compared with the low energy data is found to be consistent with scaling for $0.2 < x < 0.4$. The total ($K^0 + \overline{K^0}$) yield is $R_{K^0} = 5.6 \pm 1.1 \pm 0.8$ which is almost three times as large as observed

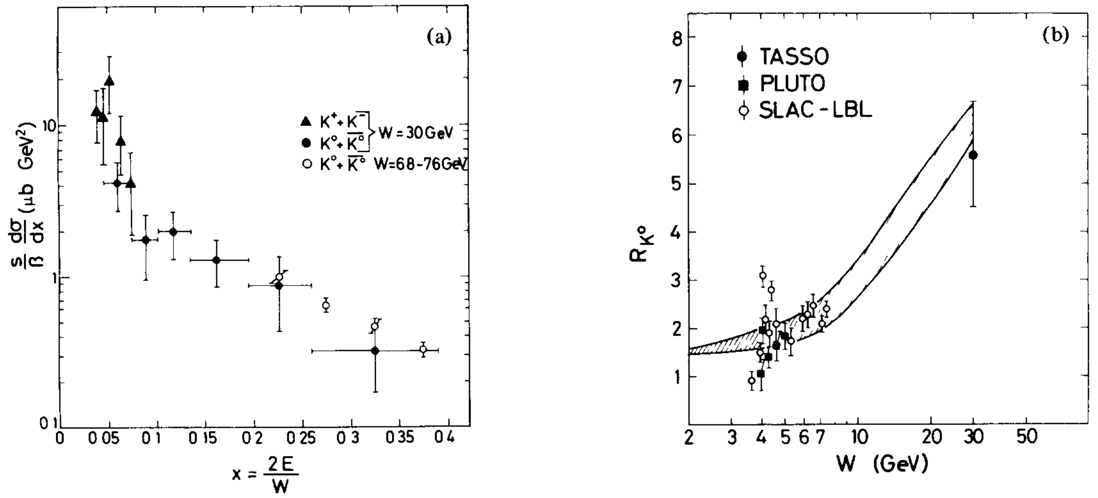

Fig. 3. $K^0 + \overline{K^0}$ production. (a) Scaling cross section $(s/\beta)\,d\sigma/dx$ where $s = W^2$, $\beta = p/E$ and $x = 2E/W$. (b) Total cross section relative to the muon pair cross section, $R_{K^0} = (\sigma(K^0X) + \sigma(\overline{K^0}X))/\sigma_{\mu\mu}$. The shaded band represents the relative increase of the charged particle multiplicity [7]; the scale has been adjusted to reproduce the R_{K^0} values in the interval 5.5 GeV < W < 7.5 GeV. The low energy data points were taken from refs. [5,6].

near 7 GeV. This relative increase is similar to the relative growth of the charged particle multiplicity.

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