DEUTSCHES ELEKTRONEN-SYNCHROTRON DESY

DESY 77/12
February 1977

受入
77-3-22
高工研図書室

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DASP Collaboration

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Abstract

The total cross section for $K^\pm$ production in e^+e^- collisions was measured for cms energies between 3.6 and 5 GeV and was found to increase by a factor of 2-3 from 3.6 to 4.1 GeV.

+) Now at SLAC
++) Now at CERN

The charmonium hypothesis for the J/ψ and ψ' predicts a threshold for charmed particle production in e^+e^- interactions not too far above the mass of the ψ'.[1] A sharp rise in the kaon yield at the charm threshold was expected since the weak decay of charmed quarks to strange quarks is strongly favoured. The behaviour of the total cross section suggested that the threshold occurs near a cms energy of 4 GeV. Meanwhile, associated production of charmed particles and events with a lepton-kaon correlation have been observed above 4 GeV.[2-4] However, evidence for a sharp increase in the overall K production has still been missing. In this paper we present cross section measurements for charged kaon production at cms energies $\sqrt{s}$ between 3.6 and 5 GeV. These data show that the $K^\pm$ yield rises by a factor of two to three between 3.6 and 4 GeV.*

The experiment was carried out with the double arm spectrometer DASP at the DESY storage ring DORIS. The apparatus and the data taking and analysis procedures are identical to those described in the preceding paper.[5] We repeat a few points pertinent to this study. Kaons were identified in the spectrometer by time-of-flight; π/K separation was possible for momenta up to 1.6 GeV/c. The minimum kaon momentum required to trigger the detector was 0.28 GeV/c. The data presented here on charged kaon production,

$$e^+e^- \to K^\pm X$$

were taken with a purely inclusive trigger: no requirement was imposed on the system X. The polar angle acceptance used in the analysis was typically $-0.55 < \cos\Theta < 0.55$. An isotropic angular distribution was assumed for the integration over the full solid angle. The systematic uncertainty in the overall normalization of the cross sections shown below is estimated to be ±10 %. The errors given are purely statistical and do not include this systematic uncertainty.

Fig. 1 shows for the sum of K^+ and K^- production the invariant cross section $E/4\pi p^2\, d\sigma/dp$ as a function of the particle energy E for different intervals of the total cms energy $\sqrt{s}$. The cross section points above 4 GeV lie significantly higher than those measured at 3.6 GeV. At 4.05 GeV the increase in K production occurs only at kaon energies below 1.1 GeV (Fig. 1b). This is consistent with a picture where the additional kaons come from the two and more body decay of a ~2 GeV mass particle which at 4.05 GeV is produced nearly at rest (e. g. $e^+e^- \to D\overline{D^*}$, $D^*\overline{D^*}$). At higher cms energies this effect will be washed out because of the increased momentum of the parent particle. Within errors the cross

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* A similar rise is seen by the PLUTO group for K^0 production.[6]

sections follow a simple exponential up to 1 GeV. This is in agreement with our results at the J/ψ and ψ'.[7] Correspondingly, the invariant cross sections were fitted to the form $E/4\pi p^2\ d\sigma/dp = c\ \exp(-bE)$ in order to extrapolate the cross section $d\sigma/dp$ to momenta below 0.3 GeV/c and to determine the total inclusive $K^\pm$ yield. The fraction of the $K^\pm$ yield below p = 0.3 GeV/c was typically 10 to 15 % of the yield above 0.3 GeV/c.

In Fig. 2 the $K^\pm$ cross section is shown as a function of the cms energy for K momenta between 0.3 and 1.6 GeV/c and extrapolated to all momenta. $K^\pm$ production is seen to rise about a factor of two to three between 3.6 and 4 GeV, then levels off between 4.3 and 5 GeV. Note that there is no evidence for an enhancement of the K yield at 4.4 GeV where the total cross section shows a structure[8,9].

We now estimate the fraction of the total cross section associated with K production. For this purpose we shall assume (a) the $K^\pm$ yield to be the same as for $K^o,\overline{K^o}$ which is supported by the data from PLUTO on $K^o,\overline{K^o}$ [6], and (b) the fraction of events with only one or more than two kaons in the final state to be negligible. Under these assumtions the integrated inclusive $K^\pm$ cross section, $\sigma_{K^\pm} \equiv \sigma_{K^+} + \sigma_{K^-}$, equals the total cross section for events with kaons (charged or neutral) in the final state.

Fig.3a shows the ratio $R = \sigma^{tot}/\sigma_{\mu\mu}$ ($\sigma_{\mu\mu}$ = μ pair cross section) minus 2.5 units,

$$R^{new} = R - 2.5,$$

as measured by the PLUTO group[9]. The 2.5 units account for the size of R measured by SLAC-LBL between 2.4 and 3.7 GeV [8] and by PLUTO at 3.6 GeV.[9] Near 4 GeV the ratio R rises sharply to values between 4 and 5.Note, that the R values of SLAC-LBL (not shown) in the 4.0 - 4.4 GeV region are systematically higher by 0.5 - 1 units.[8]

Assume the increase found in the K cross section is due to the same new phenomenon that causes the step in ^{tot} at 4 GeV. Then the K contribution produced by the new mechanism is given by

$$R_K^{new}\ (\sqrt{s}) = R_K(\sqrt{s}) - R_K(3.6)$$

where $R_K \equiv (\sigma_{K^+} + \sigma_{K^-})/\sigma_{\mu\mu}$. The quantity R_K^{new} as determined in this experiment is shown by the full points in Fig.3a. Roughly 60 - 80 % of the final states produced by the new phenomenon, R_{new}, contain kaons. With the σ^{tot} data from SLAC the corresponding Figure is 50 - 80 %. For comparison, at 3.6 GeV only 25 % of the final states contain kaons (R(3.6 GeV) = 2.5, R_K(3.6 GeV) = 0.68 ±0.13).

So far we have tacitly assumed that a single mechanism is responsible for the increase of σ^{tot} near 4 GeV. If there exists a heavy lepton with mass near 2 GeV part of the increase is due to heavy lepton pair production. Fig. 3b presents R^{new} after subtracting the heavy lepton contribution. The heavy lepton mass was assumed to be 1.95 GeV. We see that R_K^{new} is close to R^{new} which suggests that each final state produced by the new mechanism contains a $K\bar{K}$ pair. This would be in agreement with the charm hypothesis.

Acknowledgement

We are indebted to all the engineers and technicians of the collaborating institutions who have participated in the construction and maintenance of DASP. The invaluable cooperation of the technical support groups and the computer center at DESY is gratefully acknowledged. We are indebted to the DORIS machine group for their excellent support during the experiment. The non-DESY members of the collaboration thank the DESY directorate for their kind hospitality.

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   published.

Figure Captions

1. Invariant cross sections $E/4\pi p^2\ d\sigma/dp$ as a function of kaon energy for the sum of K^+ and K^- production at cm energies $\sqrt{s}$ of 3.6, 4.05, 4.2, 4.44, 4.6 and 5.0 GeV.

2. The cross section for the sum of K^+ and K^- production versus cm energy for momenta between 0.3 and 1.6 GeV/c (♁) and for all momenta (♦) (see text).

3. Comparison between the total cross section, σ^{tot}, and the cross section for K production, $\sigma_K = \sigma_{K^+} + \sigma_{K^-}$, both normalized to the μ pair cross section, $\sigma_{\mu\mu}$. The data for σ^{tot} are taken from Ref. 9. The solid points (♦) show R_K^{new} defined as $R_K^{new}(\sqrt{s}) = R_K(\sqrt{s}) - R_K(3.6\ \text{GeV})$ where $R_K \equiv \sigma_K/\sigma_{\mu\mu}$.

   (a) $R^{new} = \sigma_{tot}/\sigma_{\mu\mu} - 2.5$ (♁)

   (b) $R^{new} = \sigma_{tot}/\sigma_{\mu\mu} - 2.5$ with the heavy lepton contribution subtracted (♁). The heavy lepton mass was assumed to be 1.95 GeV.

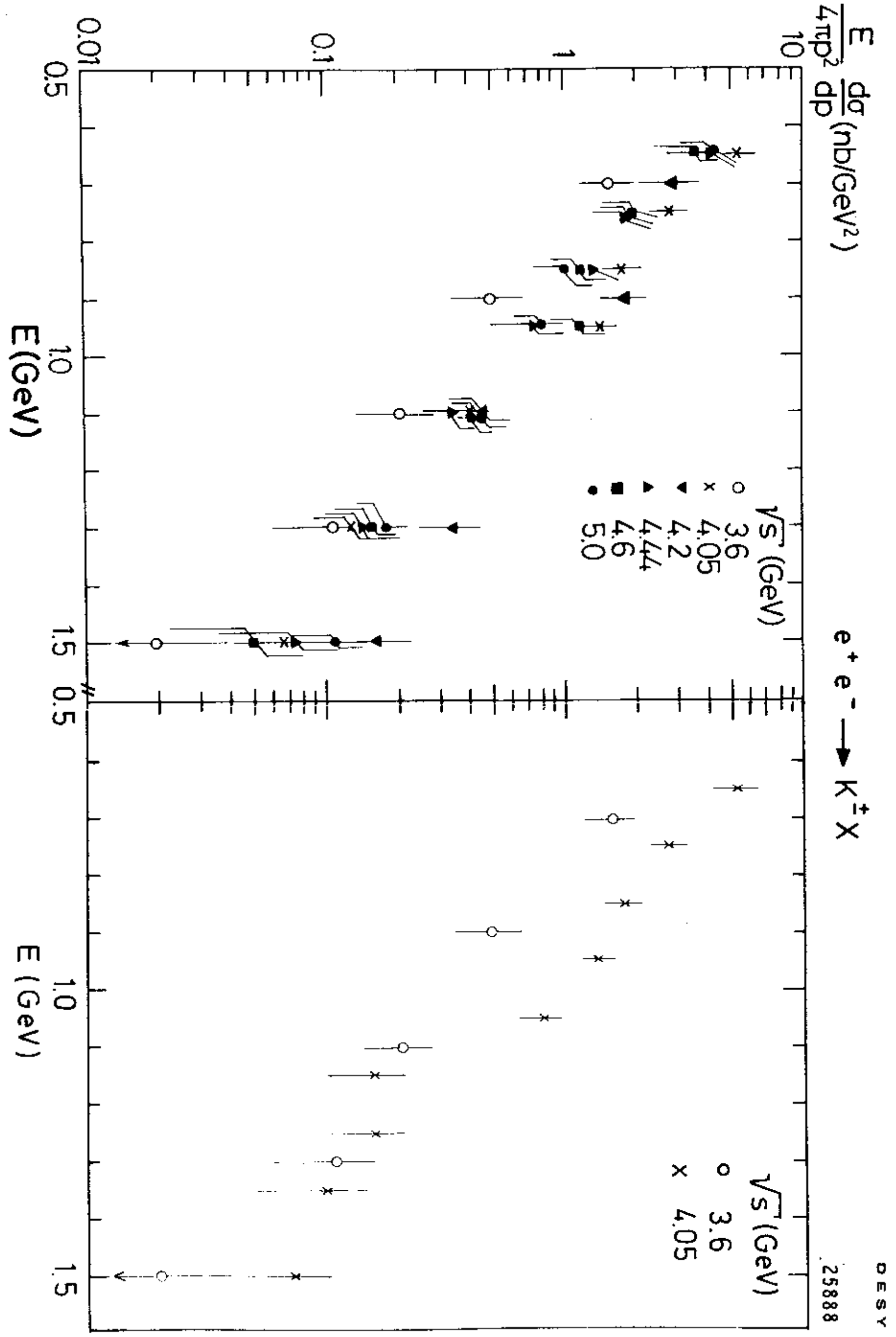

Fig 1

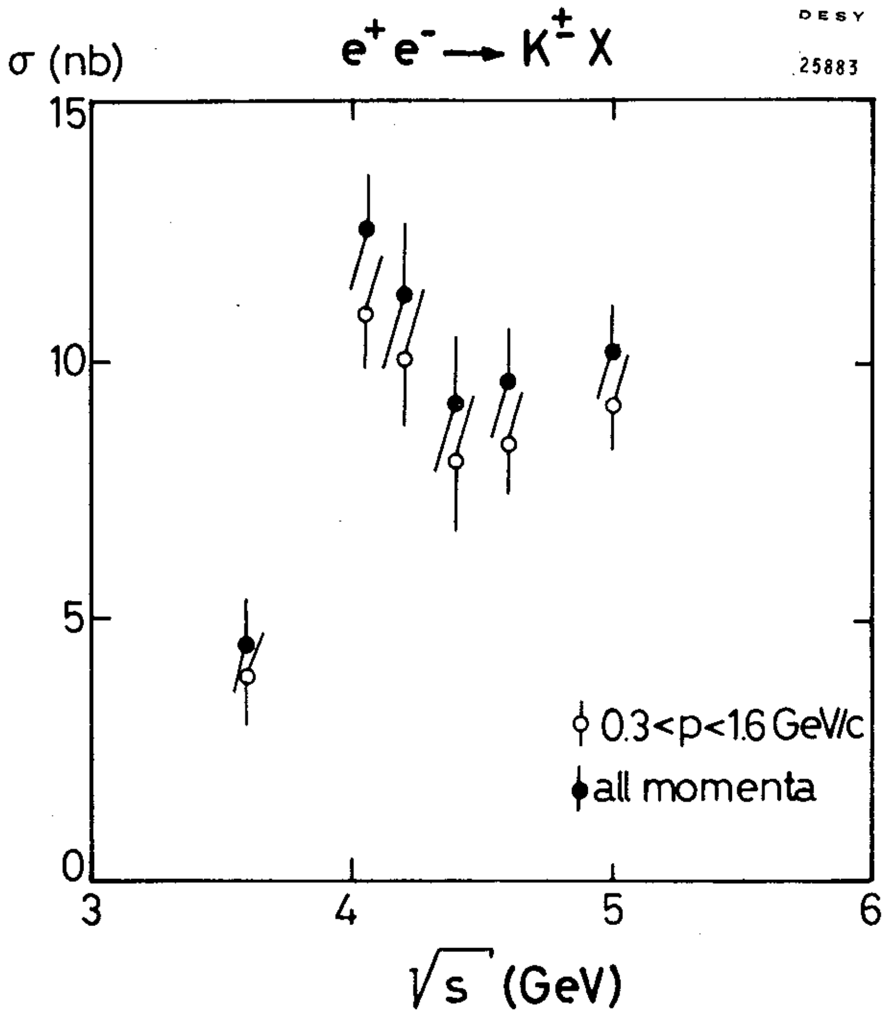
DESY
25883
σ (nb)
e+e- → K± X
15
10
5
0
3
4
5
6
0.3<p<1.6 GeV/c
all momenta
√s (GeV)

Fig. 2

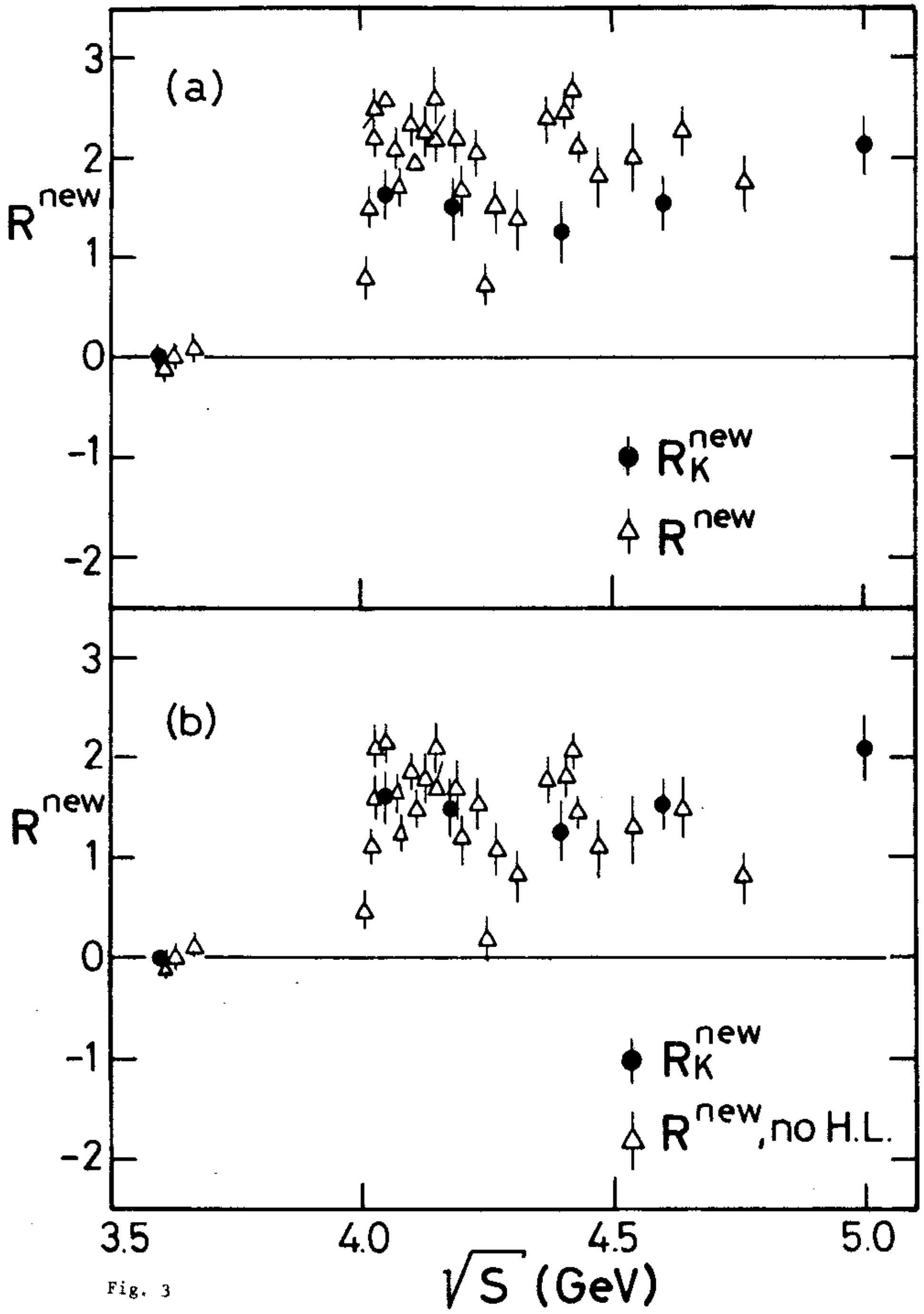
(a)
R^new
3
2
1
0
-1
-2
R_K^new
R^new
(b)
R^new
R_K^new
R^new, no H.L.
3.5
4.0
4.5
5.0
√S (GeV)

Fig. 3