EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

SEARCH FOR D^0-MESON PRODUCTION IN p-p INTERACTIONS AT A CENTRE-OF-MASS ENERGY OF 53 GeV

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ABSTRACT

A search for D(1.87) mesons produced at $x \sim 0.1$ at the CERN ISR gave a null result. Cross-section upper limits of 9 μb and 8 μb at the 95% confidence level were measured for the processes $p + p \to D^0 + X$, $D^0 \to K^- + \pi^+$, and $p + p \to \bar{D}^0 + X$, $\bar{D}^0 \to K^+ + \pi^-$, respectively. Production of $f^0(1270)$ was observed with a cross-section of 1.9 ± 0.4 mb.

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The recent discovery of the charmed D(1.87) meson, with $K\pi$, $K\pi\pi$, and $K3\pi$ decay modes [1], has prompted us to search for this object in p-p collisions at a c.m. energy of 53 GeV at the CERN Intersecting Storage Rings (ISR).

Theoretical estimates for charmed meson production in p-p interactions at FNAL-ISR energies cover the range 1 to 100 μb [2-6]. Several searches for narrow $K\pi$ resonances in p-p interactions at $\sqrt{s} \gtrsim 20$ GeV have been reported*) [7-10]. These searches preceded the discoverey of D(1.87) and were focused primarily on the mass range $M_{K\pi} > 2$ GeV. Furthermore, several of these experiments were restricted to the x $(2p_L/\sqrt{s})$ range, $x \gtrsim 0.2$, which is expected to contain less than 10% of the inclusive D, $\bar{D}$ production cross-sections [5]. Amongst these experiments the most sensitive upper limit obtained in the D mass region was $\sigma_{D^0}\cdot B < 4$ μb and $\sigma_{\bar{D}^0}\cdot B < 5$ μb by Bintinger et al. at $\sqrt{s}$ of 28 GeV at Fermilab [9] (B is the branching ratio for $D^0 \to K^-\pi^+$). From the measured s-dependence of particle production rates it is expected that inclusive total cross-sections for D and $\bar{D}$ production should increase by approximately 2.5 over the c.m. energy range $28 < \sqrt{s} < 53$ GeV [5]. The sole ISR experiment at $\sqrt{s}$ of 53 GeV and $0.15 \lesssim x \lesssim 0.6$ does not quote any limits for D production but would appear to have a sensitivity in excess of 200 μb for $\sigma_{D^0}\cdot B$ and even larger for $\sigma_{\bar{D}^0}\cdot B$ [10].

In this experiment the apparatus (Fig. 1) consisted of two magnetic spectrometers, S1 and S2, at 32° and -44° relative to one of the circulating beams. The acceptance of both spectrometers for infinite momentum particles was about 20 msr. Particle trajectories were recorded with multiwire proportional chambers. The trigger requirement of at least one charged particle in each spectrometer was implemented with scintillation counter telescopes. The spectrometers have been described in detail in previous communications [11-12].

The lower momentum cut-off for spectrometers S1 and S2 was 0.5 GeV/c and 0.7 GeV/c, respectively. The momentum resolution $\delta p/p$ (standard deviation) averaged 0.030 and 0.015 for S1 and S2, respectively. The mass resolution depended primarily on $\delta p/p$ and was calculated to be $\delta M/M$ of 0.017 (standard deviation).

*) We do not list experimental searches at $\sqrt{s} \lesssim 7$ GeV because of the very small cross-sections expected in this energy range.

Time-of-flight measurements were used for particle identification; the accuracy was δt of 0.5 nsec (standard deviation) over a 6.5 m path length in each spectrometer. Figure 2 shows time of flight versus measured momentum for a sample of tracks in S1. The identification criteria for π, K, p, are indicated. In the following discussion, particles which have been classified as π, K, or p according to these criteria are referred to as "identified" particles. Contamination of the kaon and proton samples by other particles is estimated at less than 30% and 10%, respectively.

The x range for $D^0(1.87)$ particles in the two-spectrometer system was 0.07 < < x < 0.10; this follows from the relationship $M_{K\pi} \simeq 2p_K p_\pi\ (1 - \cos\theta_{K\pi})$ and from the limitation of kaon momentum imposed by spectrometer acceptance and identification criteria (see Fig. 2). The median p_T value for $M_{K\pi} \sim 1.9$ GeV was 0.3 GeV/c.

A total of 1.5×10^7 triggers were recorded in 100 hours of ISR running at a c.m. energy of 53 GeV and average luminosity $1.5 \times 10^{31}\ \mathrm{cm}^{-2}\ \mathrm{sec}^{-1}$. After data processing there remained a total of 659,083 events with a single identified track in each spectrometer. The fraction of pions, kaons, and protons/antiprotons in these events was 0.84, 0.05, and 0.11, respectively. The integrated luminosity was obtained from a luminosity monitoring system operated during the data-taking. Folding in the estimated efficiency of particle reconstruction gave an effective integrated luminosity of $3.4 \times 10^{36}\ \mathrm{cm}^{-2}$.

Figure 3 shows the invariant mass distributions for a) $K^+\pi^-$ and $K^-\pi^+$ combined, and b) $\pi^+\pi^-$. In order to determine the presence of resonances or other two-particle correlation effects, we have compared the experimental histograms with the distributions expected from uncorrelated particle pairs. These latter distributions were obtained from the experimental data by forming, in a random fashion, pairs of particles from different interactions. The smooth curves in Fig. 3 are the invariant mass spectra of these uncorrelated particle pairs generated with high statistics. Figures 3c and 3d show the data of (a) and (b) after subtraction of this "background", which is normalized in (a) to the total number of $K^\pm\pi^\mp$ events and in (b) to the total number of $\pi^+\pi^-$ events less the f^0 contribution.

The data in Fig. 3 are binned in 30 MeV intervals corresponding to the average r.m.s. mass resolution. No significant structure is seen in the mass region 1.82 to 1.90 GeV. The structure in $M_{K\pi}$ around 1.4 GeV is consistent with a resonance of mass 1.41 GeV and width 0.10 GeV, and presumably corresponds to $K^*(1420)$. The prominent structure in Fig. 3d at $M_{\pi\pi}$ about 1.2 GeV is well fitted by a Breit-Wigner form (corrected for acceptance) with M = 1.25 GeV and Γ = 0.20 GeV, and can obviously be interpreted as the f^0 meson.

In order to assess the magnitude of a possible D^0-meson contribution to the $K\pi$ spectrum, we fitted the $K^-\pi^+$ and $K^+\pi^-$ spectra over the mass range 1660-2100 MeV with a combined Gaussian and second-order polynomial. The shape of the polynomial was first determined by fitting a second-order polynomial to the smooth $K^-\pi^+$ and $K^+\pi^-$ background curves. Then the experimental $K\pi$ distributions were fitted by a linear combination of the resulting polynomial and a Gaussian of standard deviation 35 MeV; there were two free parameters in the fits -- the amplitudes of the Gaussian and polynomial. These fits gave upper limits at the 95% confidence level of 49 and 51 for $N_{D^0}\cdot B$ and $N_{\bar{D}^0}\cdot B$, respectively. The experimental $K\pi$ data are also well fitted by the polynomial alone.

The apparatus accepted only D mesons produced in the c.m. rapidity range $0.9 < y < 1.2$. We have used the Bourquin-Gaillard (B-G) parametrization of $d^2\sigma/dy\, dp_T$ to extrapolate in p_T and y and so determine an upper limit for $\sigma_D\cdot B$ for inclusive D^0-meson production [5]. This parametrization successfully describes differential inclusive cross-sections for a wide range of "non-leading" particles including π, K, $\bar{p}$, and J/ψ. Assuming isotropic $D \to K\pi$ decay and folding the geometrical acceptance into the B-G formula, we obtain an upper limit of 9 μb for $\sigma_{D^0}\cdot B$ and 8 μb for $\sigma_{\bar{D}^0}\cdot B$.

The Breit-Wigner fit to the $\pi^+\pi^-$ mass plot in Fig. 3d leads to an estimate of $(7.3 \pm 0.6) \times 10^3$ events with $f^0 \to \pi^+\pi^-$ production in this experiment. The f^0 production occurs at $0.05 < x < 0.07$ and with median p_T of 0.22 GeV/c. As with the D-meson production above, we have used the B-G universal form for $d^2\sigma/dy\, dp_T$ to evaluate the acceptance of the apparatus for f^0 mesons. We obtain a cross-section σ_f of 1.9 ± 0.4 mb for inclusive f^0 production. We note that the B-G parametrization, with the same over-all normalization as used for π and ρ cross-sections, gives 1.4 mb for σ_f.

In conclusion, we obtain upper limits of 9 μb and 8 μb with a 95% confidence level for the D^0 and $\bar{D}^0$ production cross-section times the branching ratio at a c.m. energy of 53 GeV. We also report the first measurement of the inclusive f^0 production cross-section, σ_f = 1.9 ± 0.4 mb, in the FNAL-ISR energy range.

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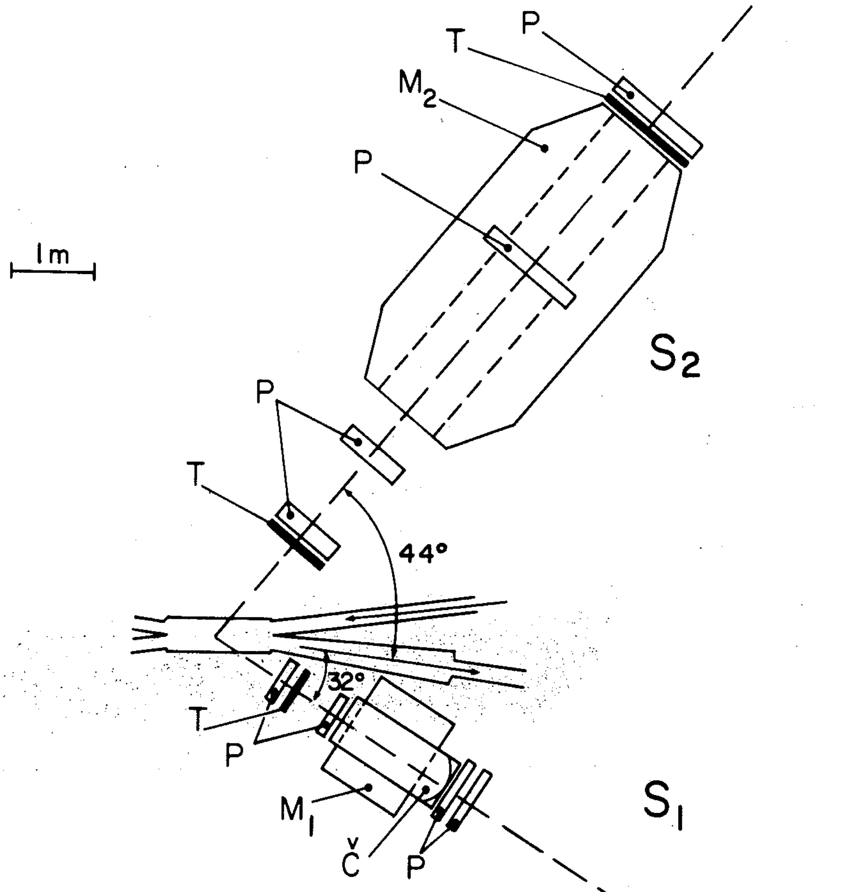
Figure captions

Fig. 1 : Sketch of the spectrometers S1 and S2 at intersection I6 of the CERN ISR.

Fig. 2 : Time of flight versus momentum for a sample of negative particles in the spectrometer S1. Identification criteria for π, K, and p are indicated. Time of flight is expressed relative to that for $\beta = 1$ particles.

Fig. 3 : Invariant mass plots for a) $K^-\pi^+$ and $K^+\pi^-$ combined, and b) $\pi^+\pi^-$; the smooth curves are background distributions as described in the text. Figures (c) and (d) show the difference between experimental and calculated distributions in (a) and (b), respectively. The Breit-Wigner fit to $M_{\pi^+\pi^-}$ around 1.25 GeV is indicated in (d).

EXPERIMENTAL SET-UP



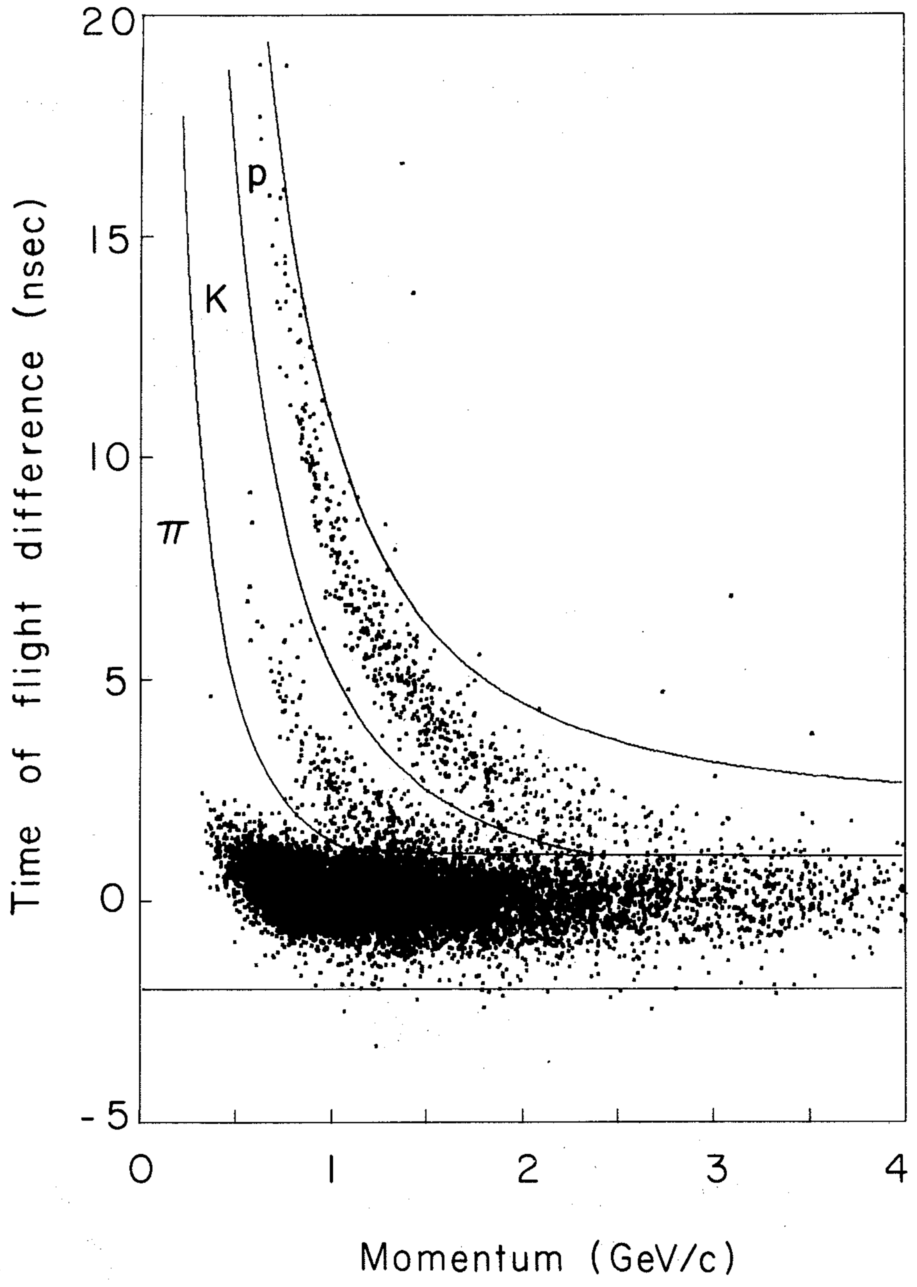
$M_{1,2}$ = MAGNETS

P = PROPORTIONAL CHAMBERS

Č = CERENKOV COUNTER

T = TIME of FLIGHT COUNTERS

Fig. 1



20
15
10
5
0
-5
Time of flight difference (nsec)
p
K
π
0
1
2
3
4
Momentum (GeV/c)

Fig. 2

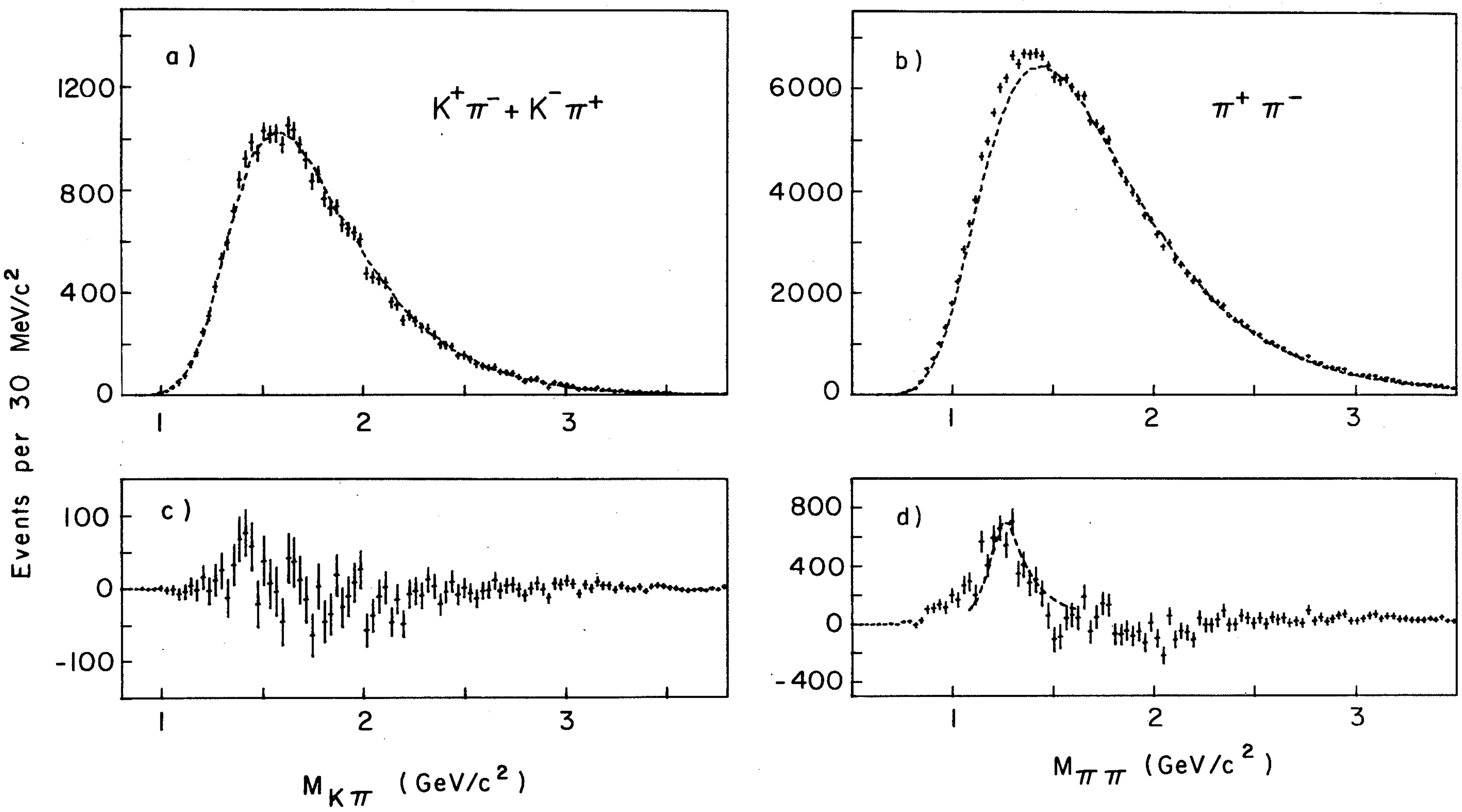

a)
$K^+\pi^- + K^-\pi^+$
b)
$\pi^+\pi^-$
c)
d)
Events per 30 MeV/c²
1200
800
400
0
6000
4000
2000
100
-100
-400
1
2
3
$M_{K\pi}$ (GeV/c²)
$M_{\pi\pi}$ (GeV/c²)

Fig. 3