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SEARCH FOR BEAUTY MESONS

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ABSTRACT

A search for the production of beauty mesons in 190 GeV/c π^-N interactions has been made by examining various candidate decay channels containing a J/ψ meson.

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The Υ mesons are interpreted as bound states of a beauty (b) and an antibeauty ($\bar{b}$) quark [1]. Indirect evidence for the existence of beauty mesons (B), which carry the beauty quantum number, has been found at CESR [2]. However, in meson channels, no beauty meson signal has been observed in a mass plot of B-decay products.

We report on a search for B mesons undertaken at the CERN Super Proton Synchrotron. A large, open-geometry, magnetic spectrometer was triggered on opposite-sign muons produced in π^-Be collisions with a beam momentum of 185, 192, and 195 GeV/c (190 GeV/c average). A description of our spectrometer has been presented elsewhere [3].

Beauty mesons are expected to decay into final states containing a ψ meson and a kaon with an aggregate branching fraction of 1 to 5% [4,5]. The B^- quark line diagram for this process is shown in fig. 1.

We have recorded 38,000 ψ mesons with low background (see fig. 2) through their $\mu^+\mu^-$ decay channels. A segmented CO_2 Čerenkov counter is used to distinguish accompanying $K^\pm$ mesons from $\pi^\pm$ mesons in the momentum range 5-30 GeV/c; below 17 GeV, protons are not separated from the K sample. Neutral kaons decaying into $\pi^+\pi^-$ are identified as secondary vertices. Neutral pions are not detected.

An important feature of our experiment is an excellent B mass resolution, with σ between 21 and 27 MeV depending upon the particular decay. We have checked this by measuring the resolution and masses for $\psi \to \mu^+\mu^-$, $K^0 \to \pi^+\pi^-$, $\phi \to K^+K^-$, $\psi' \to \psi\pi^+\pi^-$, and $\chi \to \psi\gamma$. The $\chi \to \psi\gamma \to \psi e^+e^-$ decays are measured for both the $J^{PC} = 1^{++}$ and 2^{++} states, which we are able to resolve [6]. The results are given in table 1; note that final states containing a ψ are from observations of the $\mu^+\mu^-$ decay of the ψ and use a ψ mass constrained to be 3097 MeV. The B mass combinations shown below also use constrained masses.

Our measured masses are in excellent agreement with the reference values [7-10]. All measured widths are consistent with values expected from the precision of our spectrometer.

Table 2 lists the upper limits on cross-section (σ) times branching ratio (BR) at one standard deviation for 10 beauty decay channels. There B_s and B_c refer to beauty mesons in which the non-beauty quark is a strange quark or a charmed quark, respectively. The B mass distributions are shown in fig. 3. There is no prominent signal in the range between 5.175 and 5.287 GeV expected from the CESR measurements of Υ'' and Υ''' [11]*). Figure 4 shows $B_s \to \psi K^+K^-$ and $B_c \to \psi\pi^\pm$; no mass peak is observed; there are only 13 events between 4.8 and 5.8 GeV for $B_s \to \psi\phi \to \psi K^+K^-$. For all plots presented the $\sigma \cdot BR$ limits are obtained by fitting the mass distribution with a Gaussian having a fixed mass of 5.25, 5.40, and 6.45 GeV for B, B_s, and B_c, respectively. The width was fixed at the expected experimental resolution (21 to 27 MeV). The acceptance is calculated by assuming that the $B\bar{B}$ system is produced according to a gluon-gluon fusion model of Carlson and Suaya [13]. This model predicts the mass and x_f dependence of the $B\bar{B}$ system. The transverse momentum distribution was parametrized by

$$\frac{d\sigma}{dp_T} = 0.49\ p_T \left[1 + \left(\frac{p_T}{1.7}\right)^2\right]^{-3.2} .$$

During the early part of our experiment we collected a limited data sample of 9000 ψ mesons at a lower beam momentum of 147 GeV/c and observed a possible B signal at 5.3 GeV in the channels $\psi K^\pm\pi^\mp$ and $\psi K^0\pi^\pm$ [14]. The new data sample presented here shows that this enhancement was a statistical fluctuation.

Any limits on the beauty meson production cross-sections themselves clearly depend upon knowing branching ratios of these mesons. Theoretical calculations give branching ratios in the range of 3% [4,5] for the decay $B \to \psi X$ with dominant modes of $X = K\pi$ or $X = K^*$ [4,15]. Using a branching ratio of 3% we obtain from the channels $\psi K^\pm\pi^\mp$, $\psi K^{*\pm}$, ψK^{*0}, cross-section limits for $B\bar{B}$ production of 18, 30, and 8 nb, respectively. These are lower than the first theoretical estimates of 80 nb [16] but compatible with recent perturbative QCD estimates of 2 nb [17] or a few nb [18]. A 12 nb upper limit has been found for $B\bar{B}$ production in π^-N

*) A recent measurement [12] of the Υ mass of 9459.7 ± 0.6 MeV/c^2 at Novosibirsk was reported at the 21st International Conference on High Energy Physics, Paris, 1982. The B meson mass limits are adjusted to this mass.

interactions at 225 GeV/c by the Chicago-Princeton beam-dump experiment [19]*). This 225 GeV/c result is however more sensitive to the assumed $B\bar{B}$ production process with possible correlations between B and the $\bar{B}$, since fragments from both B and $\bar{B}$ decays must be observed.

We wish to thank CERN for the highly favourable running conditions which enabled us to complete this high-statistics experiment. We acknowledge the assistance of Mme F. Bernasconi in handling the computation of the large amount of data.

*) This paper gives the upper limit of $2\sigma(B\bar{B}) \cdot BR(B \to \psi X) \cdot BR(B \to \mu X) < 81$ pb. Using the measured branching ratio $BR(B \to \mu X) = 12\%$ and the theoretical estimate $BR(B \to \psi X) = 3\%$, the $\sigma(B\bar{B})$ limit is 12 nb.

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Table 1

Measured masses and resolutions

Decay	Measured mass (MeV)	Reference mass (MeV)	Reference No.	Mass resolution σ (MeV)
$\psi \to \mu^+\mu^-$	3098.4 ± 2.0	3096.93 ± 0.09	7	31
$K^0 \to \pi^+\pi^-$	497.6 ± 0.5	497.67 ± 0.13	8	8
$\phi \to K^+K^-$	1019.7 ± 0.3	1019.6 ± 0.1	8	3
$\psi' \to \psi\pi^+\pi^-$	3686.7 ± 1.2[a)]	3686.00 ± 0.10	7	6
$X(1^{++}) \to \psi\gamma$	3507.4 ± 1.7	3508.4	9	7
$X(2^{++}) \to \psi\gamma$	3553.4 ± 2.2	3553.9	9	7

a) This comes from our direct measurement of 589.7 ± 1.2 MeV for the mass difference between ψ' and ψ [10] which can be compared with a reference value of 589.07 ± 0.1 MeV [7].

Table 2

Limits on beauty production

Decay	Upper limit of cross-section × BR (nb)
$B^{\pm} \to \psi K^{\pm}$	0.21
$B^{0} \to \psi K^{0}$	0.17
$B^{\pm} \to \psi K^{0}\pi^{\pm}$	4.7
$B^{0} \to \psi K^{\pm}\pi^{\mp}$	0.54
$B^{\pm} \to \psi K^{\pm}\pi^{\pm}\pi^{\mp}$	2.3
$B^{0} \to \psi K^{0}\pi^{+}\pi^{-}$	3.5
$B^{\pm} \to \psi K^{*\pm}$	0.9
$B^{0} \to \psi K^{*0}$	0.23
$B_s^{0} \to \psi K^{+}K^{-}$	0.1
$B_s^{0} \to \psi \phi$	0.07
$B_c^{\pm} \to \psi \pi^{\pm}$	0.04

Figure captions

Fig. 1 : The quark line diagram for B^- decay into states containing a ψ and a kaon.

Fig. 2 : The measured $\mu^+\mu^-$ invariant mass spectrum; the inset shows the same data on a logarithmic scale with fitted curve to guide the eye.

Fig. 3 : Invariant mass distributions for B-decay channels.

Fig. 4 : Invariant mass distributions for decays of B_s and B_c.

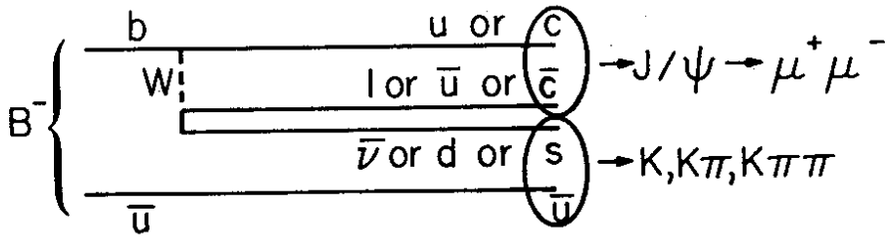

Fig. 1

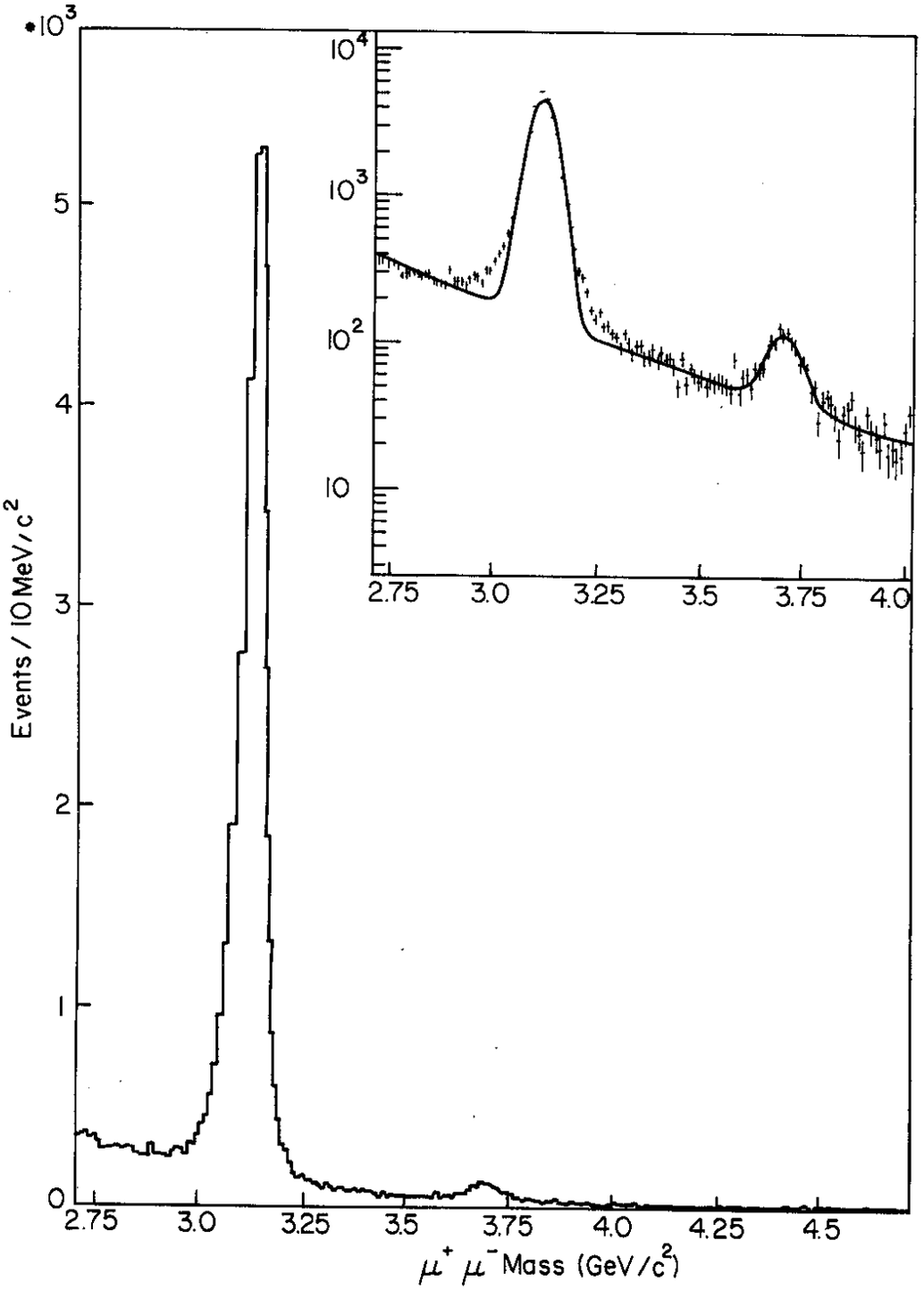
•10³
5
4
3
2
1
0
Events / 10 MeV/c²
2.75
3.0
3.25
3.5
3.75
4.0
4.25
4.5
μ⁺ μ⁻ Mass (GeV/c²)
10⁴
10³
10²
10
2.75
3.0
3.25
3.5
3.75
4.0

Fig. 2

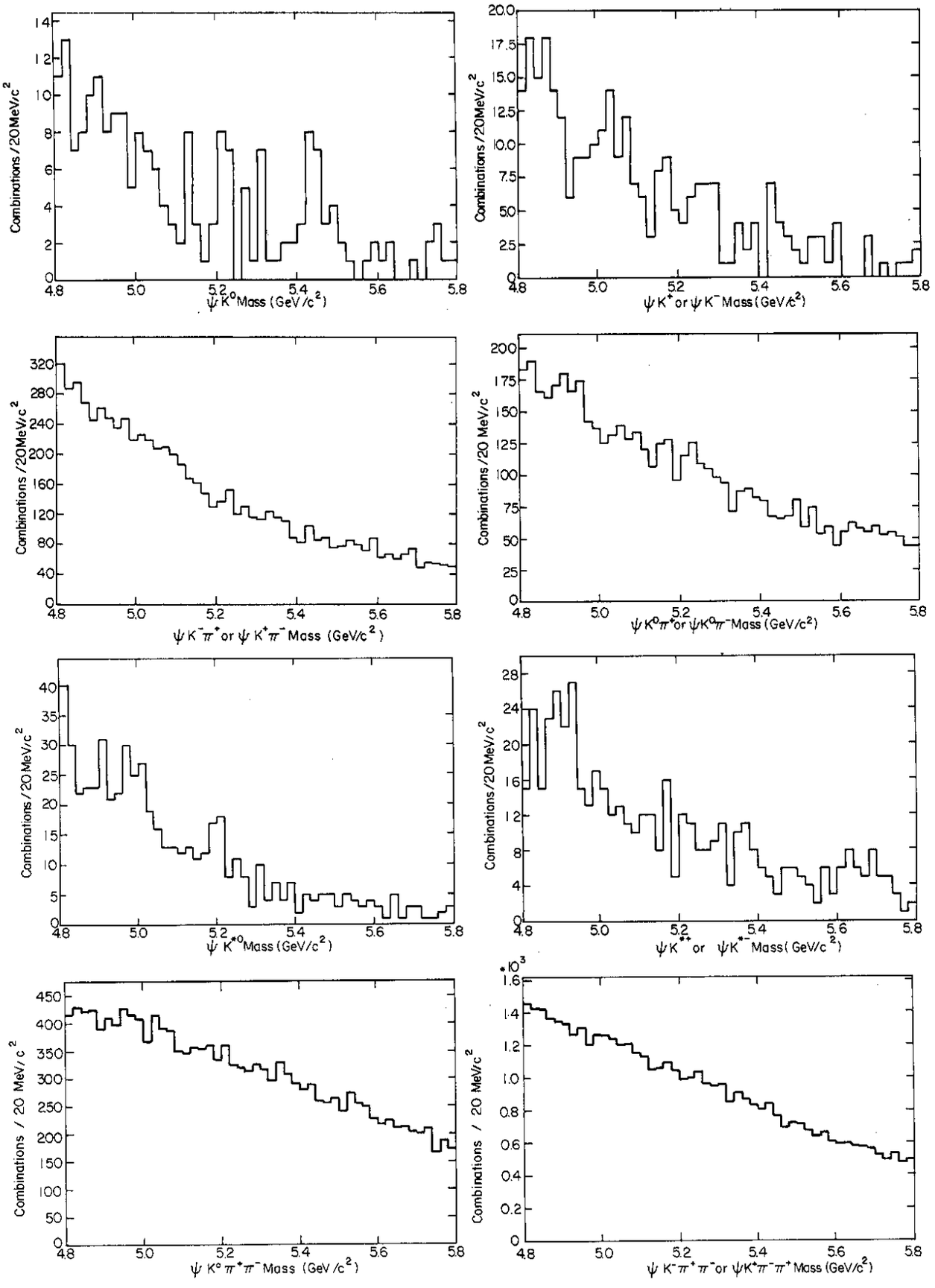
Combinations /20MeV/c²
ψ K⁰Mass (GeV/c²)
Combinations /20MeV/c²
ψ K⁺ or ψ K⁻ Mass (GeV/c²)
Combinations /20MeV/c²
ψ K⁻π⁺ or ψ K⁺π⁻ Mass (GeV/c²)
Combinations /20 MeV/c²
ψ K⁰π⁺ or ψ K⁰π⁻ Mass (GeV/c²)
Combinations /20MeV/c²
ψ K*⁰ Mass (GeV/c²)
Combinations /20MeV/c²
ψ K*⁺ or ψ K*⁻ Mass (GeV/c²)
Combinations / 20 MeV/c²
ψ K⁰π⁺π⁻ Mass (GeV/c²)
Combinations / 20 MeV/c²
*10³
ψ K⁻π⁺π⁻ or ψ K⁺π⁻π⁺ Mass (GeV/c²)

Fig. 3

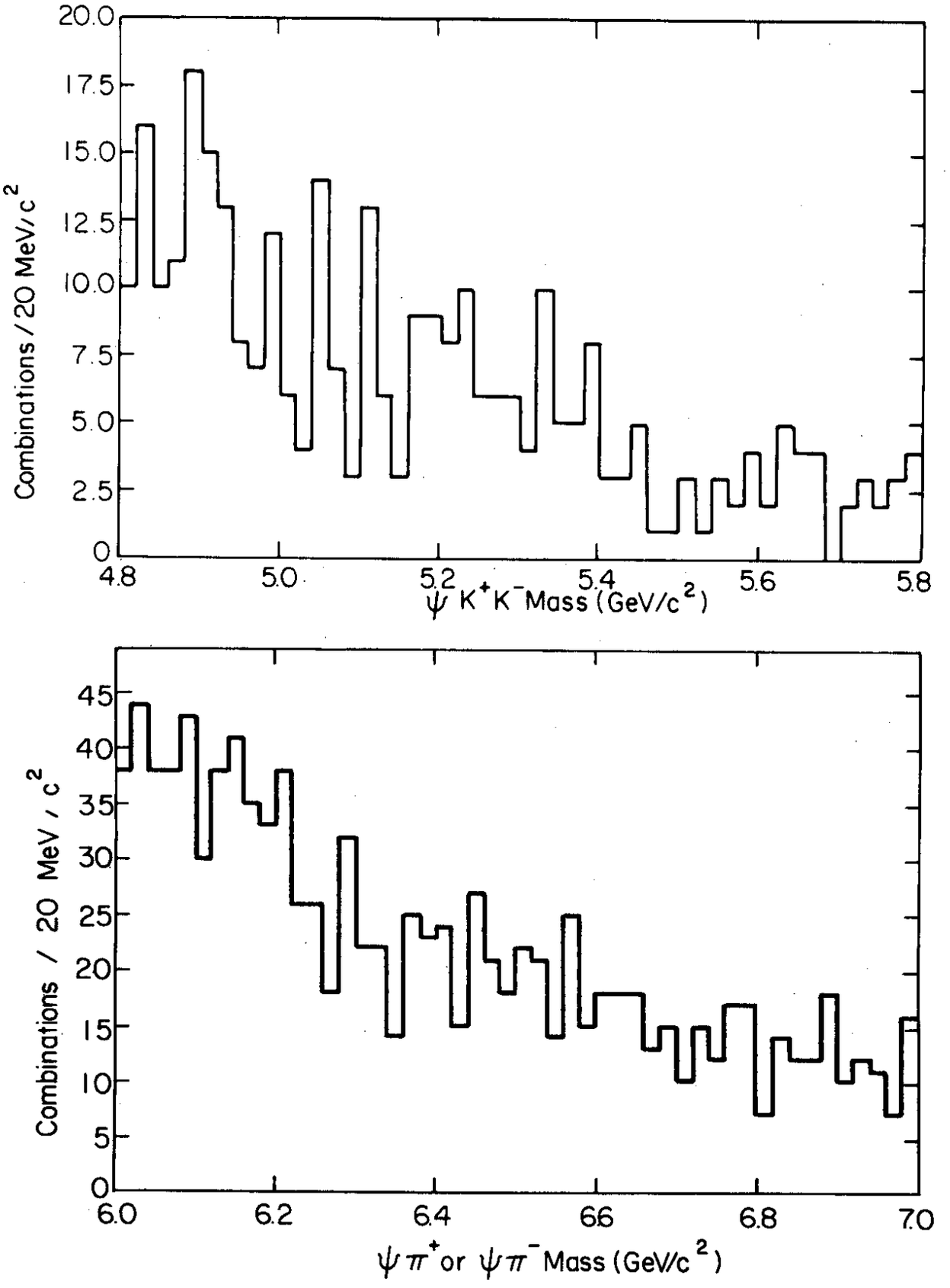
Combinations / 20 MeV/c²
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0
4.8
5.0
5.2
5.4
5.6
5.8
ψ K⁺K⁻ Mass (GeV/c²)
Combinations / 20 MeV / c²
45
40
35
30
25
20
15
10
5
0
6.0
6.2
6.4
6.6
6.8
7.0
ψ π⁺ or ψ π⁻ Mass (GeV/c²)

Fig. 4