EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

MESON RESONANCE PRODUCTION IN p-p INTERACTIONS AT $\sqrt{s}$ OF 53 GeV

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Abstract

Resonance production in p-p interactions at $\sqrt{s}$ of 53 GeV has been studied at the CERN ISR. The apparatus consisted of a pair of magnetic spectrometers equipped with multiwire proportional chambers and utilizing time-of-flight for particle identification. The measured inclusive differential cross-sections $\frac{d\sigma}{dy}\big|_{y=1}$ for f^o, g^o, $K^{*o}(1420)$ and $\bar{K}^{*o}(1420)$ production are 0.58 ± 0.05 mb, 0.09 ± 0.05 mb, 38 ± 15 μb and 26 ± 13 μb. The corresponding total inclusive cross-sections are estimated to be 2.62 ± 0.26 mb, 0.40 ± 0.22 mb, 154 ± 60 μb and 107 ± 52 μb respectively. According to current models of particle production the observed $K^*(1420)$ cross-section would imply a total inclusive cross-section for charmed D(1.87) production in the range 3 - 25 μb.

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A variety of models exist for particle production in high energy ($\sqrt{s} \gtrsim 20$ GeV) hadronic interactions. In order to discriminate between these models production cross-sections for a range of masses and flavors are needed. In fact, apart from the -onia ψ and Υ states there is virtually no information to date on the production of mesons with mass abobe 1 GeV.We report here a measurement of the total inclusive cross-section for production of f^o, g^o, $K^{*o}(1420)$ and $\bar{K}^{*o}(1420)$ in proton-proton interactions at cm energy of 53 GeV.[1]

The experiment was carried out at the CERN ISR. The apparatus, (Fig. 1), consisted of two magnetic spectrometers, each furnished with four multiwire proportional chamber modules. The spectrometers S1 and S2 were in the horizontal plane on either side of beam 2 at 32^o and 44^o respestively. The spectrometer acceptances for high momentum particles were 11.6 msteradians and 25.2 msteradians respectively, with low momentum cut-offs at 0.5 GeV/c and 0.7 GeV/c respectively. Spectrometer S1 had a momentum resolution $\delta p/p$ of 2.9% (standard deviation) for 2 GeV/c pions. The momentum resolution of spectrometer S2 was $\delta p/p$ of 1.6% for 2 GeV/c pions. The mass resolution is determined by $\delta p/p$ and was calculated to be $\delta M/M$ of 0.017. The spectrometers have been described in detail elsewhere.[2,3]

Time-of-flight measurement was used in each spectrometer for particle identification. The measurement accuracy was δt of 0.5 nsec (standard deviation) for a path length of 6.5 in each spectrometer. Fig. 2 shows time-of-flight vs. momentum for a sample of negative tracks in spectrometer S1. The pion, kaon, and proton/antiproton identification criteria used in this analysis are indicated. Contamination of the kaon and proton-antiproton samples by other particles is estimated at less than 30% and 10% respectively.

The trigger requirement was at least one charged particle in each spectrometer. In 100 hours of ISR running at a center-of-mass energy of 53 GeV and an average luminosity of 1.5×10^{31} cm^{-2} sec^{-1}, a total of about 1.5×10^6 triggers were recorded. The integrated luminosity was obtained from a luminosity monitoring system operated during the data taking. The effective integrated luminosity was 2.7×10^{36} cm^{-2}, taking into account the efficiency of particle reconstruction and apparatus dead time. Data processing yielded 659,083 events with one track in each spectrometer. The fraction of pions, kaons, and proton/antiprotons in the events was 0.84, 0.05, and 0.11 respectively.

Figures 3a and 4a show invariant mass distributions for the 235,620 $\pi^+\pi^-$ and 28,462 $K^\pm\pi^\mp$ events respectively. The cut-off around 1 GeV/c^2 in invariant mass is due to acceptance. In order to detect the presence of resonances these experimental distributions have been compared with "background" distributions obtained by randomly combining particles from different events into pairs. This procedure takes into account the spectrometer acceptances and can give distributions with an order of magnitude more statistical precision than the actual data. A total of over 9×10^6 "background"events were generated and assigned a weight of 659,038, equal to the total number of experimental events. The smooth curves in Figs. 3a and 4a are the $\pi^+\pi^-$ and $K^\pm\pi^\mp$ background distributions.

The experimental signal remaining after background subtraction is displayed in Figs. 3b and 4b. In the $\pi^+\pi^-$ distribution (Fig. 3b) there is a prominent structure at about 1.25 GeV/c^2 and one less prominent around 1.7 GeV/c^2. These structures are most readily identifiable with f^o(1270) and g^o(1680) which are known to decay strongly to $\pi^+\pi^-$.[4] The structure in Figure 4b around 1.4 GeV/c^2 may correspond to K^{*o}(1420) and its charge conjugate.

In order to verify the production of these resonances the structures in Figs. 3b and 4b were fitted with a Breit-Wigner form; the Breit-Wigner amplitude was modified to include the dependence of invariant mass on acceptance as determined by a Monte Carlo calculation, (see below). The $\pi^+\pi^-$ mass spectrum in Fig. 3b was fitted with a coherent sum of two Breit-Wigner amplitudes. The masses of f^o and g^o were fixed at 1.27 GeV/c^2 and 1.63 GeV/c^2 corresponding to the centres of the observed structures, and compatible with measured values;[4] the widths were fixed at 0.25 GeV/c^2. The magnitudes and relative phase of the Breit-Wigner forms were varied in the fit. The fitted curve (Fig. 3b) corresponds to a total of 6564 ± 646 f^o events and 1399 ± 760 g^o events.

Figure 4c shows a Breit-Wigner fit to the structure at 1.4 GeV/c^2 in the $K^\pm\pi^\mp$ distribution. The mass and width of the K^{*o} as well as the number of resonance events were variables in the fit. A total of 360 ± 111 events are seen for a K^* of mass 1411 ± 14 MeV/c^2 and Γ

of 164 ± 68 MeV/c^2, consistent with the mass and width expected for the $K^{*o}(1420)$.[4] Similar fits to the separate $K^+\pi^-$ and $K^-\pi^+$ data are displayed in Figs. 4d, e. Results of the fits are summarized in Table I.

The acceptance of the apparatus for f^o, g^o and $K^*(1420)$ is limited to cm rapidity $y \simeq 0.9 - 1.2$. In order to determine the total production cross-section of these resonances it is necessary to know the dependence of the production process on y, p_T and particle mass. We have made a Monte Carlo calculation of the acceptance of our apparatus using the Bourquin-Gaillard (B-G) parametrization of $d^2\sigma/dydp_T$ as a model for particle production, and assuming isotropic decay of the resonances.[5] The resulting estimates of σ and $d\sigma/dy|_{y=1}$ are given in Table I.

The total cross-sections in Table I depend upon the validity of the Berquin-Gaillard parametrization of differential inclusive cross-sections. We remark that the B-G formula has been very successful in describing the inclusive distributions of the "non-leading" particles from π to J/ψ and ψ' over a wide range of energy.[5] We also note that the measured total inclusive cross-sections in Table I are in reasonable agreement with the predictions of the B-G cross-section formula:[5]

$$\sigma(cm^2) = 0.4 \times 10^{-20}\, y^2_{max} e^{-5.13/y^{0.38}_{max}} \frac{M}{(M + 2)^{12.3}}$$

For $K^*(1420)$ production a mass M of (1420 + 495) MeV/c^2 is used in this formula, reflecting Bourquin and Gaillard's assumption of the production of a composite S = 0 system, i.e. local conservation of strangeness. According to this formula the inclusive cross-section for charmed D-mesons production, σ_D, should be about 2% of the $K^*(1420)$ cross-section. The empirical form e^{-4M} gives σ_D of 0.17 σ_{K^*}.[6] Thus our measured $K^*(1420)$ cross-section implies $\sigma_D \simeq 3 - 25$ μb.

A recent study of ω^0, ρ^0 and $K^*(890)$ production in proton-proton interactions at $\sqrt{s}$ of 53 GeV gave a ratio 0.5 ± 0.2 and 0.36 ± 0.13 for K^*/ρ and K^*/ω respectively.[7] In reference 7 it was argued that ρ, ω and $K^*(890)$ production may be comparable since these mesons are members of the same SU(3) nonet. We note however that although f^o and $K^*(1420)$ belong to the $(J^P)C_n=(2^+)+$ nonet the ratio $K^*(1420)/f^o$ is 0.06 ± 0.02.

TABLE I. Masses, widths and cross-sections for f^o, g^o and $K^*(1420)$ measured in this experiment. The data has been corrected for unobserved decay modes. The last column shows the cross-sections predicted by the Bourquin-Gaillard particle production model (5).

Resonance	Mass (a) (MeV/c^2)	Width (a) (MeV/c^2)	Observed events	$\frac{d\sigma}{dy}\Big\|_{y=1}$	σ	σ_{B-G}
f^o	1270	250	6564±646	0.58±0.05 mb	2.62±0.26 mb	1.48 mb
g^o	1630	250	1399±760	0.09±0.05 mb	0.40±0.22 mb	.42 mb
$K^{*o}(1420)$	1407±15	61±32	197±77	38±15 μb	154±60 μb	167 μb
$\bar{K}^{*o}(1420)$	1412±30	109±61	156±76	26±13 μb	107±52 μb	167 μb
$K^{*o}+\bar{K}^{*o}$	1411±14	82±34	360±111	65±20 μb	261±81 μb	334 μb

(a) f^o and g^o masses and widths were fixed.

References

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3) L. Baum et al., Phys. Lett. 60B (1976) 485.

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6) F. Halzan, Proceedings of the VIIth International Colloquium on Multi-Particle Reactions, Intzing, Germany (June 1976).

7) G. Jancso et al., Nucl. Phys. B126 (1977) 1.

Figure captions

Fig. 1. 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. Tiem-of-flight is expressed relative to that for $\beta = 1$ particles.

Fig. 3. (a) Invariant mass plot for $\pi^+\pi^-$; the smooth curve is a background distribution as described in the text.

(b) Difference between observed and background distribution in (a).

(c) Same as (b) with fit of two coherent Breit-Wigner amplitudes.

Fig. 4. (a) Invariant mass plot for $K^+\pi^-$ and $K^-\pi^+$ combined; the smooth curve is a background distribution as described in the text.

(b) Difference between observed and background distribution in (a).

(c) Same as (b) with superimposed Breit-Wigner.

(d) Same as (c) for $K^+\pi^-$.

(e) Same as (c) for $K^-\pi^+$.

EXPERIMENTAL SET-UP

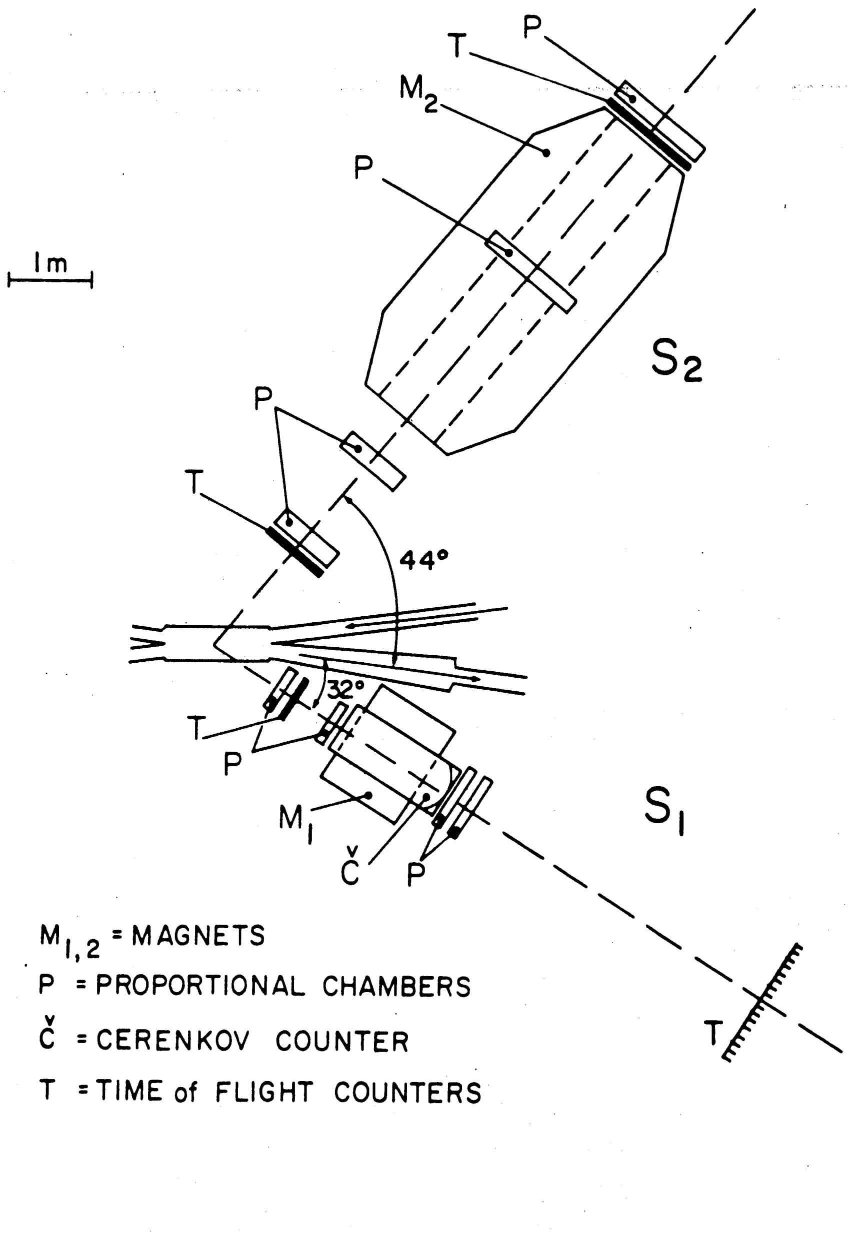
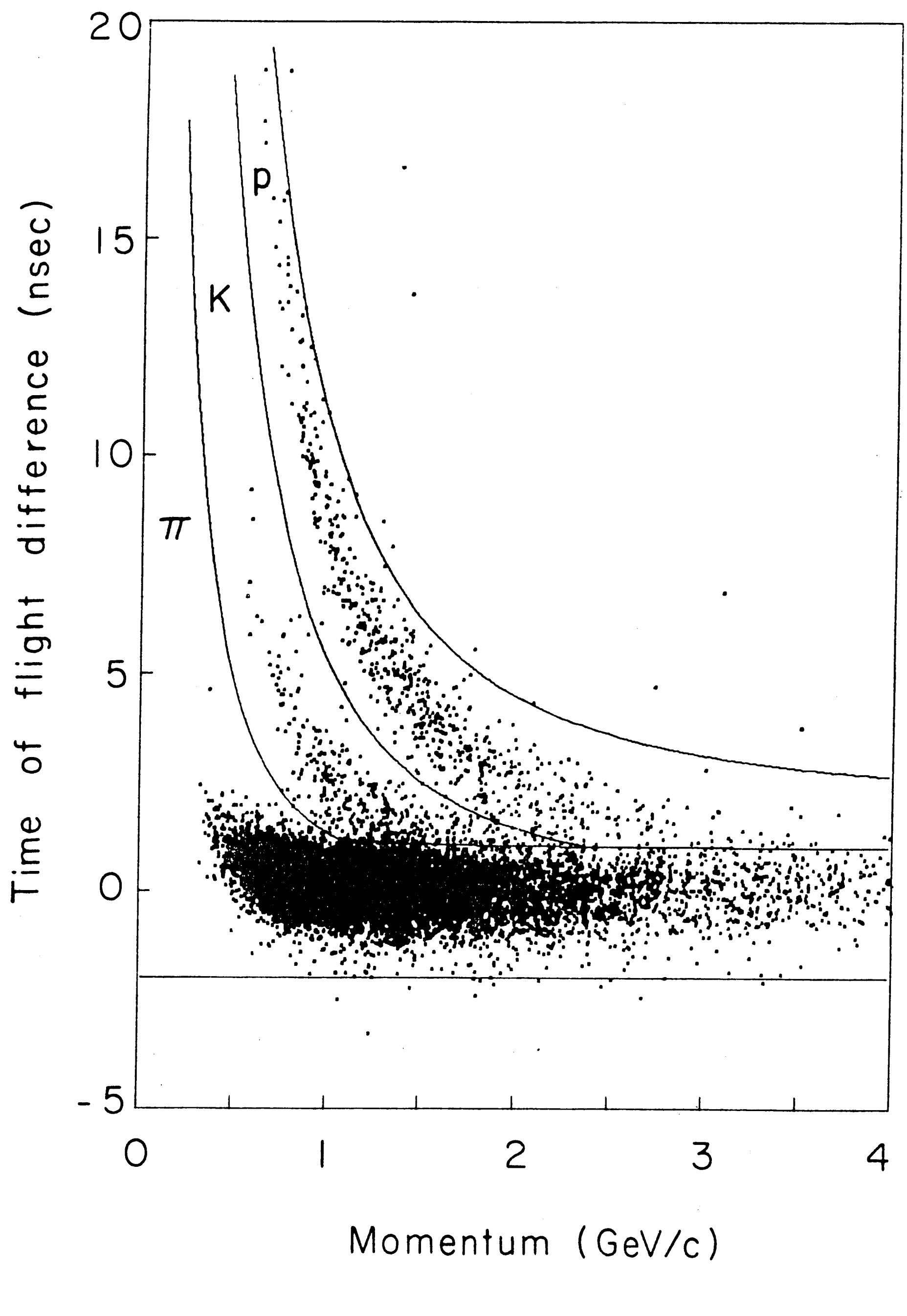
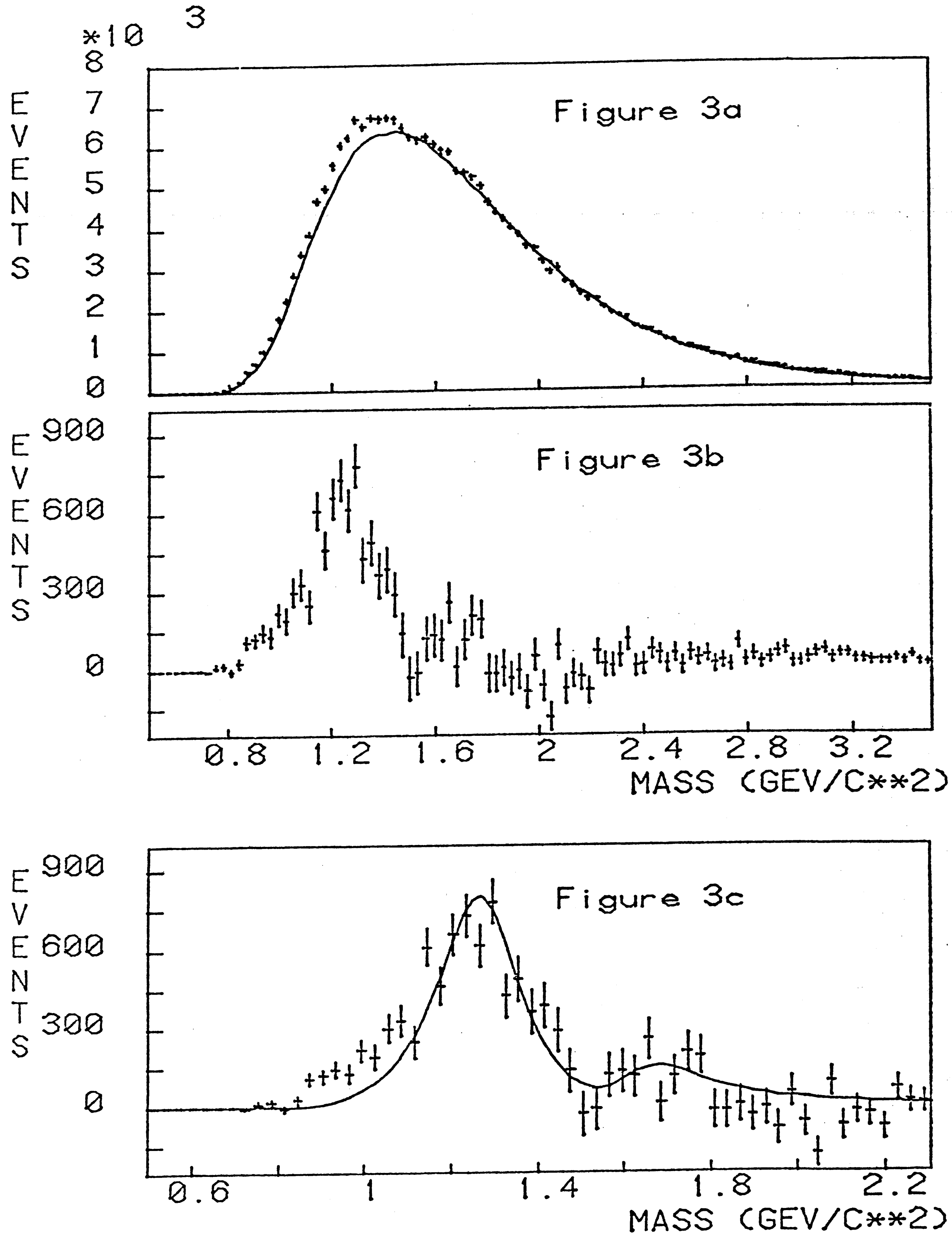


Fig. 1

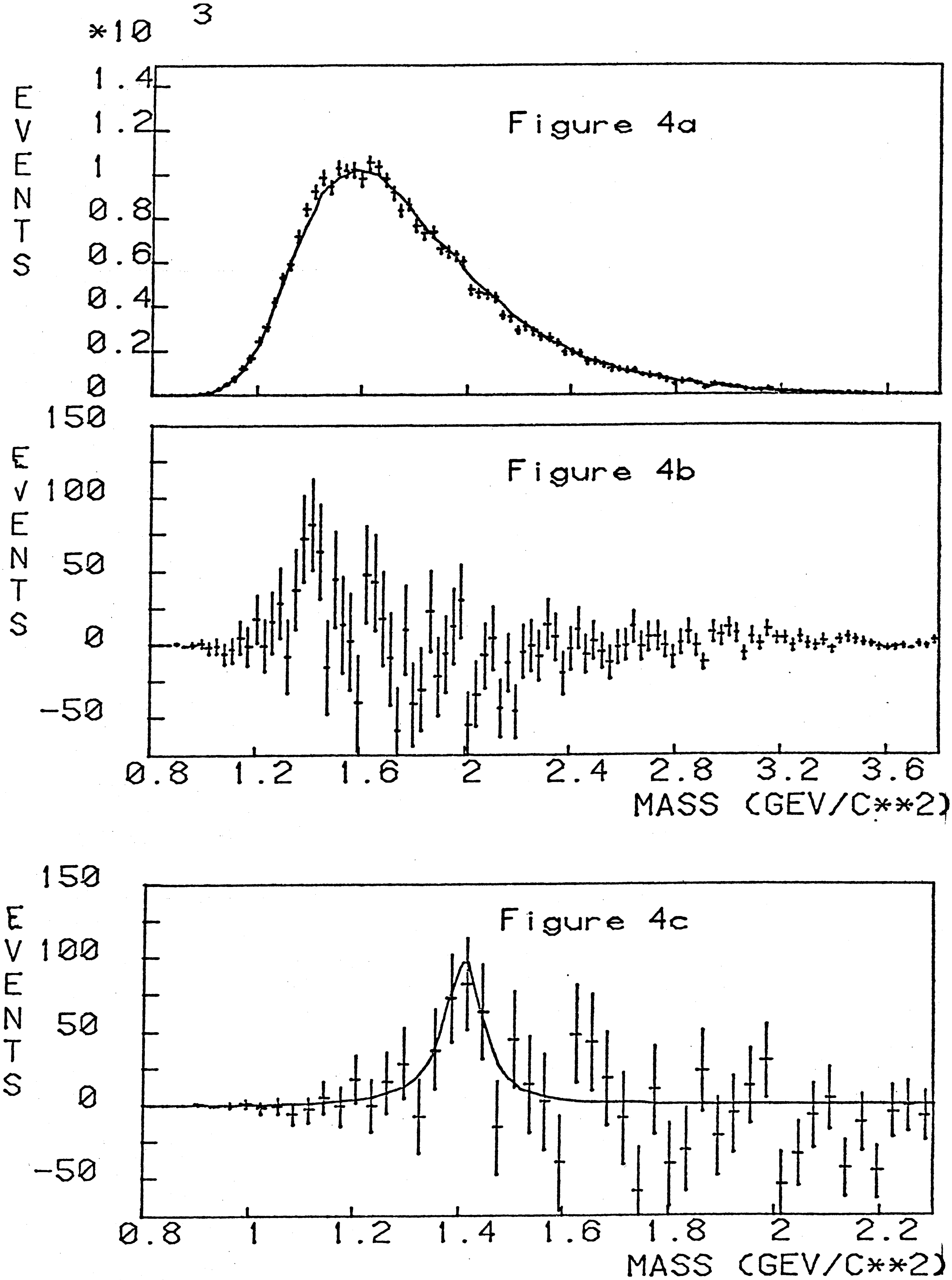


20
15
10
5
0
-5
Time of flight difference (nsec)
π
K
p
0
1
2
3
4
Momentum (GeV/c)

Fig. 2



*10 3
EVENTS
8 7 6 5 4 3 2 1 0
Figure 3a
EVENTS
900 600 300 0
Figure 3b
0.8 1.2 1.6 2 2.4 2.8 3.2
MASS (GEV/C**2)
EVENTS
900 600 300 0
Figure 3c
0.6 1 1.4 1.8 2.2
MASS (GEV/C**2)



*10 3
EVENTS
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Figure 4a
150
100
50
0
-50
Figure 4b
0.8
1.2
1.6
2
2.4
2.8
3.2
3.6
MASS (GEV/C**2)
150
100
50
0
-50
Figure 4c
0.8
1
1.2
1.4
1.6
1.8
2
2.2
MASS (GEV/C**2)

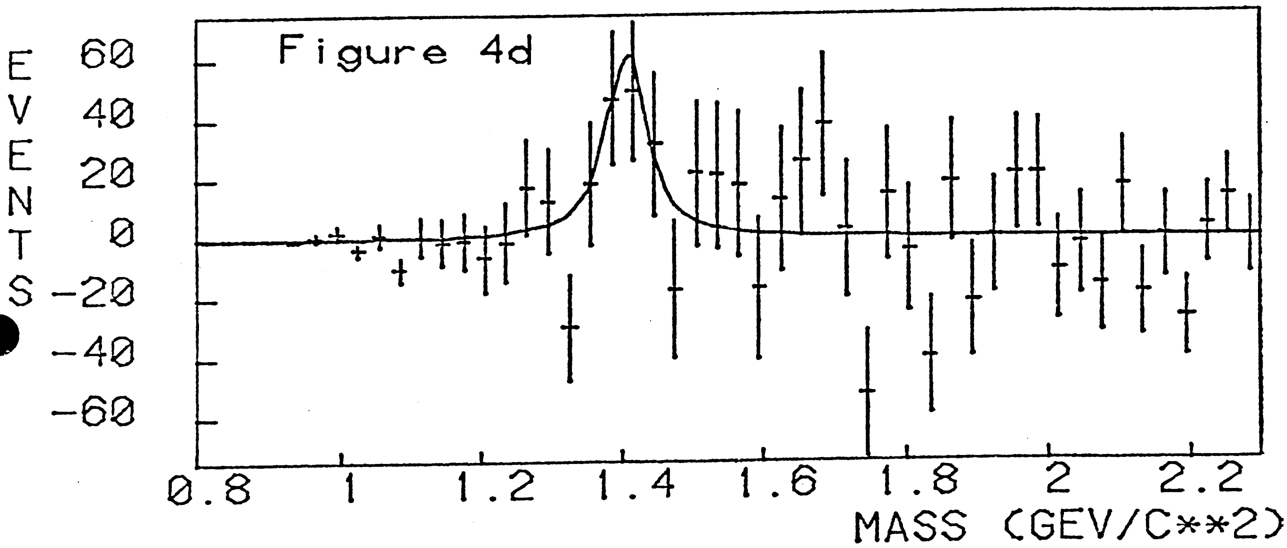


Figure 4d
EVENTS
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40
20
0
-20
-40
-60
0.8
1
1.2
1.4
1.6
1.8
2
2.2
MASS (GEV/C**2)

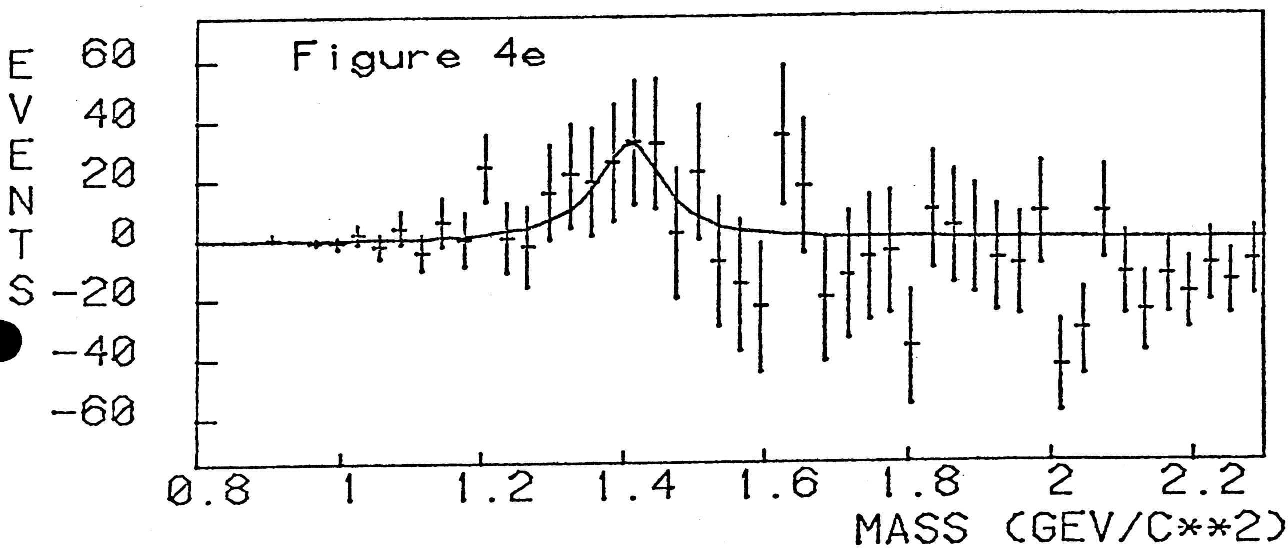
Figure 4e
EVENTS
60
40
20
0
-20
-40
-60
0.8
1
1.2
1.4
1.6
1.8
2
2.2
MASS (GEV/C**2)