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SEARCH FOR NARROW RESONANCES DECAYING INTO $p\bar{p}$ IN THE REACTION $\pi^- p \to \bar{p}pn$

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CERN-MPI (Munich) Collaboration

SEARCH FOR NARROW RESONANCES DECAYING INTO $p\bar{p}$ IN THE REACTION $\pi^- p \to p\bar{p}n$

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Abstract

A sample of 41 000 $p\bar{p}$ events produced in the reaction $\pi^- p \to p\bar{p}n$ at 18.6 GeV has been reanalysed in a search for the production of narrow resonances. The data are mainly concentrated in the low p_T, $x \simeq 1$ region and extend from threshold to about 3.6 GeV $p\bar{p}$ invariant mass. No narrow resonance has been found. An upper limit of around 150 nb·MeV has been placed on narrow width resonance production in this reaction.

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I INTRODUCTION

The discovery of the narrow width resonances J/ψ and ψ' at 3.1 and 3.7 GeV[1,2], both in hadron induced reactions and e^+e^- storage ring experiments, might be explained by the existence of a fourth "charmed" quark. Various models[3] predict the existence of further narrow resonances with $\Gamma << 10$ MeV. In order to search for the possible production of narrow resonances with subsequent decay into $p\bar{p}$, we have reanalysed two sets of data recorded in 1971 and 1973.

II SELECTION OF EVENTS

The data were collected with the CERN-Munich wire spark chamber spectrometer. The $p\bar{p}n$ final state was selected with two atmospheric pressure gas Cerenkov counters suppressing π and K pairs. The neutron was not observed, but applying appropriate cuts on the missing mass we selected relatively clean samples of $p\bar{p}$ events. Table 1 lists the number of events and the background contribution.

Table 1.

	Sample 1	Sample 2
p_{Lab}	18.8 ± 0.3 GeV	18.4 ± 0.3 GeV
no. of events	10 700	30 500
$\pi^+\pi^-n$ background	1%	$\leq$ 0.5%
K^+K^-n "	4%	$\sim$ 1%
$\bar{p}p(n\pi^0)$ "	3%	$\leq$ 2%
Mass of K^0	497.7 ± 0.2 MeV	498.5 ± 0.3 MeV

Further details of the apparatus, selection criteria and data treatment are given in ref.[4]).

III ACCEPTANCE AND RESOLUTION

The apparatus was primarily designed for the study of peripheral production of quasi-two-body reactions. Fig.1 shows the acceptance for an isotropically decaying $p\bar{p}$ system as a function of mass at several values of the four-momentum transfer. The variation of the acceptance over the full range of the decay angles in the $p\bar{p}$ rest system is typically around 20% for masses below 3.2 GeV and $|t| < 1$ GeV^2. For higher masses and four-momentum transfer the apparatus does not permit the observation of the full range of decay angles.

Fig.2 displays the calculated mass resolution as a function of the $p\bar{p}$ mass. The resolution for the observed $p\bar{p}$ events should be slightly better because the missing mass was constrained to that of a neutron. In order to confirm the predicted mass resolution we analysed a sample of $K^0 \to \pi^+\pi^-$ decays (fig.3). The observed width of $\Gamma(= 2.3\sigma) = 5.0 \pm 0.5$ MeV is in good agreement with the calculated value of 4.8 MeV.

The mass values for the K^0's in the two samples differ by 0.8 MeV. Thus we estimate that the systematic shift in invariant mass from both samples is much smaller than the given resolution when adding both samples.

IV RESULTS

Figs. 4 and 5 display the observed and corrected spectra for $|t| < 2$ GeV^2. (Due to the mass dependent resolution different binning has been used). The final spectra are corrected for geometrical acceptance as well as various individual losses due to secondary interactions and δ-electrons detected by the veto counters. The acceptance correction was calculated by randomly rotating the observed events around their beam particle direction. The cross section for one event in the corrected mass spectrum corresponds to

$$\sigma(1 \text{ event}) = 0.08 \pm 0.01 \text{ nb}.$$

Above 3.2 GeV invariant mass we have no access to the full range of decay angles of the $p\bar{p}$ system. Therefore the displayed spectrum no longer corresponds to the true mass spectrum but only to a lower limit. For low spin states the losses are still small. No significant peak or dip is observed in the entire mass range between threshold and 3.5 GeV.

The events are all concentrated at $x \overset{\sim}{>} 1$ ($x = p_{\parallel}^{CM}/\sqrt{s}$) and small p_T as shown in the Perou plot in fig.6 (only raw data).

It has been shown[4]) that the $p\bar{p}$ pairs are dominantly produced by one pion exchange (OPE) and that partial waves with $1 \leq \ell \leq 5$ are present over the entire mass range (a $p\bar{p}$ S-wave state is forbidden to couple to $\pi^+\pi^-$ due to parity conservation). From the observation of the reactions $p\bar{p} \to \rho\pi, A_2\pi, f\pi, \ldots$ and time reversal one has also to expect some small contributions of other exchange processes besides OPE, e.g. also S-wave production. One might then expect that in the case of a $p\bar{p}$ decay of a narrow resonance, interference will play an important role.

Interference will lead to the following consequences for the possible observation of narrow resonances in the presence of "normally produced" background:

a) due to the limited resolution of the apparatus one will not be able to observe the typical interference pattern for a $\Gamma << 10$ MeV but only the net excess or deficit of events.
b) depending on the relative phase between the slowly varying background and a small width resonance one might see a strong enhancement, a dip, or even in the case of reasonable production amplitude, no effect at all in the mass spectrum.

In order to calculate upper limits for the production of narrow resonances in this experiment one has to make the assumption that these resonances add incoherently to the normal spectrum.

Taking the resolution of the apparatus into account we determined the following upper limits for $\sigma(\pi^- p \to Xn, X \to p\bar{p})$ as a function of mass:

M (GeV)	Limit
2.1	46 nb•MeV
2.4	127 nb•MeV
2.7	183 nb•MeV
3.0	149 nb•MeV
[3.3	260 nb•MeV]

for a confidence level of 95%. The upper limit at 3.3 GeV is calculated for an S- or P-wave state with a differential cross section $d\sigma/d|t| \sim e^{-8|t|}$.

We note that the sensitivity of this experiment is not high enough to observe J/ψ production and its decay into $p\bar{p}$ due to its small branching ratio of approximately 0.25%.

This experiment partly complements the experiment of Aubert et al.[5]) although the sensitivity is nearly 2 orders of magnitude inferior. Aubert et al. studied inclusive $p\bar{p}$ pair production around $x \overset{\sim}{\sim} 0$ and in a mass range between 2.3 and 4.8 GeV.

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Figure captions

Fig. 1 : Geometrical acceptance for an isotropic decaying $p\bar{p}$ system as a function of mass.

Fig. 2 : Mass resolution as a function of the $p\bar{p}$ mass for unconstrained events.

Fig. 3 : Invariant $\pi^+\pi^-$ mass spectrum for $K^0_S \to \pi^+\pi^-$ events.

Fig. 4 : Invariant $p\bar{p}$ mass spectrum for $|t| < 2$ GeV^2.

Fig. 5a : Invariant $p\bar{p}$ mass spectrum between threshold and 3.0 GeV; $|t| < 2$ GeV^2.

Fig. 5b : Invariant $p\bar{p}$ mass spectrum between 3.0 and 3.6 GeV; $|t| < 2$ GeV^2.

Fig. 6 : Perou plot for the $p\bar{p}$ events.

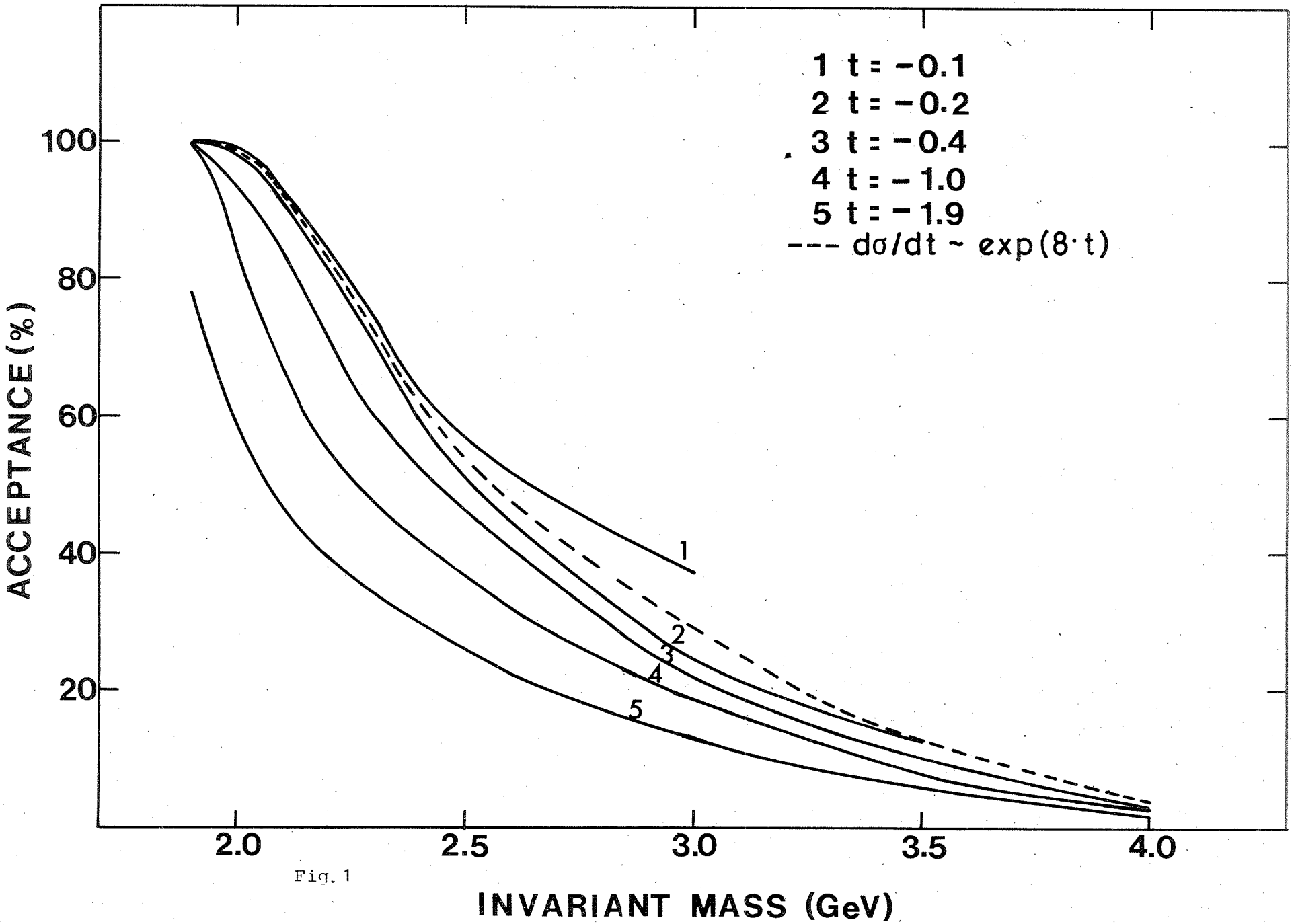
1 t = -0.1
2 t = -0.2
3 t = -0.4
4 t = -1.0
5 t = -1.9
--- dσ/dt ~ exp(8·t)
ACCEPTANCE (%)
100
80
60
40
20
1
2
3
4
5
2.0
2.5
3.0
3.5
4.0
INVARIANT MASS (GeV)

Fig. 1

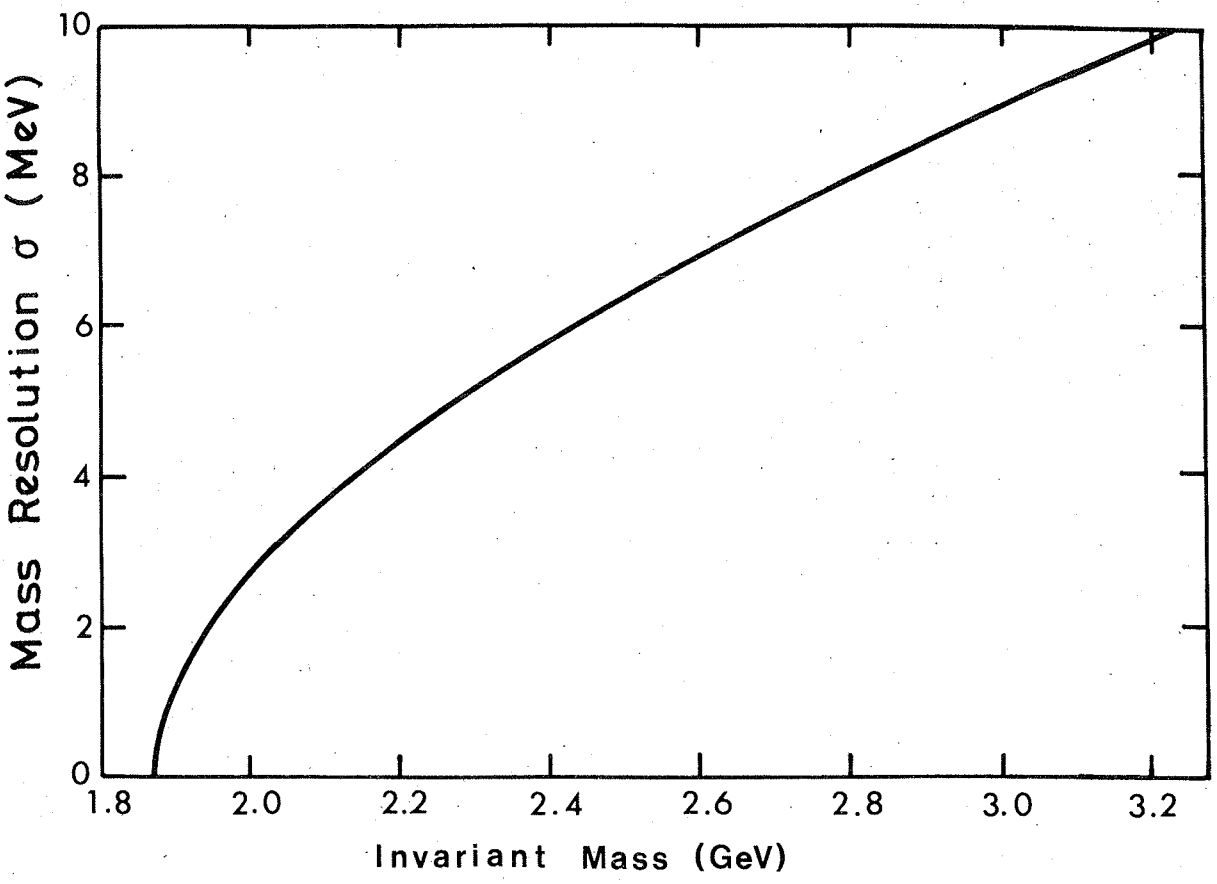
Mass Resolution σ (MeV)
10
8
6
4
2
0
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
Invariant Mass (GeV)

Fig. 2

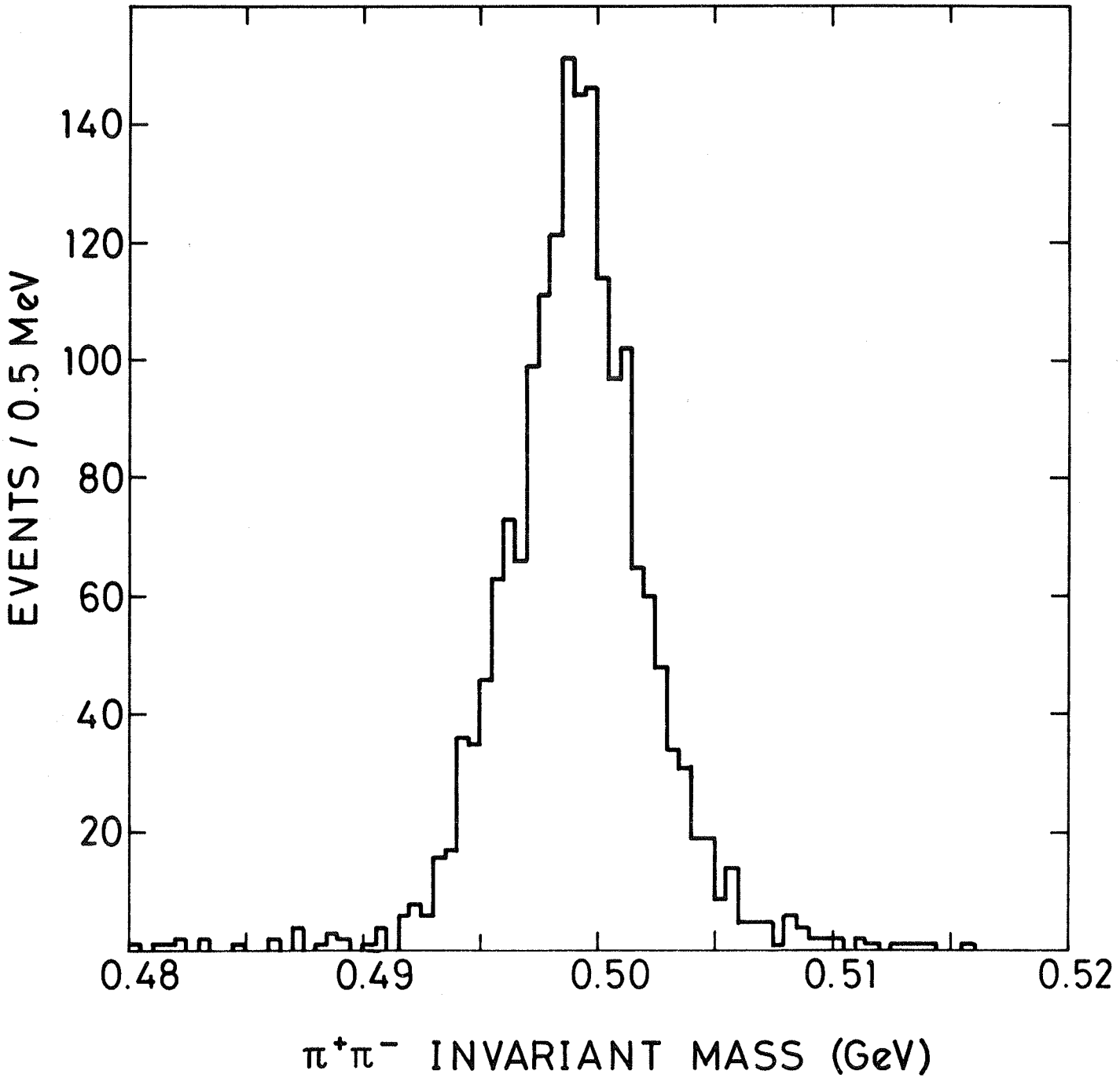
EVENTS / 0.5 MeV
140
120
100
80
60
40
20
0.48
0.49
0.50
0.51
0.52
π⁺π⁻ INVARIANT MASS (GeV)

Fig. 3

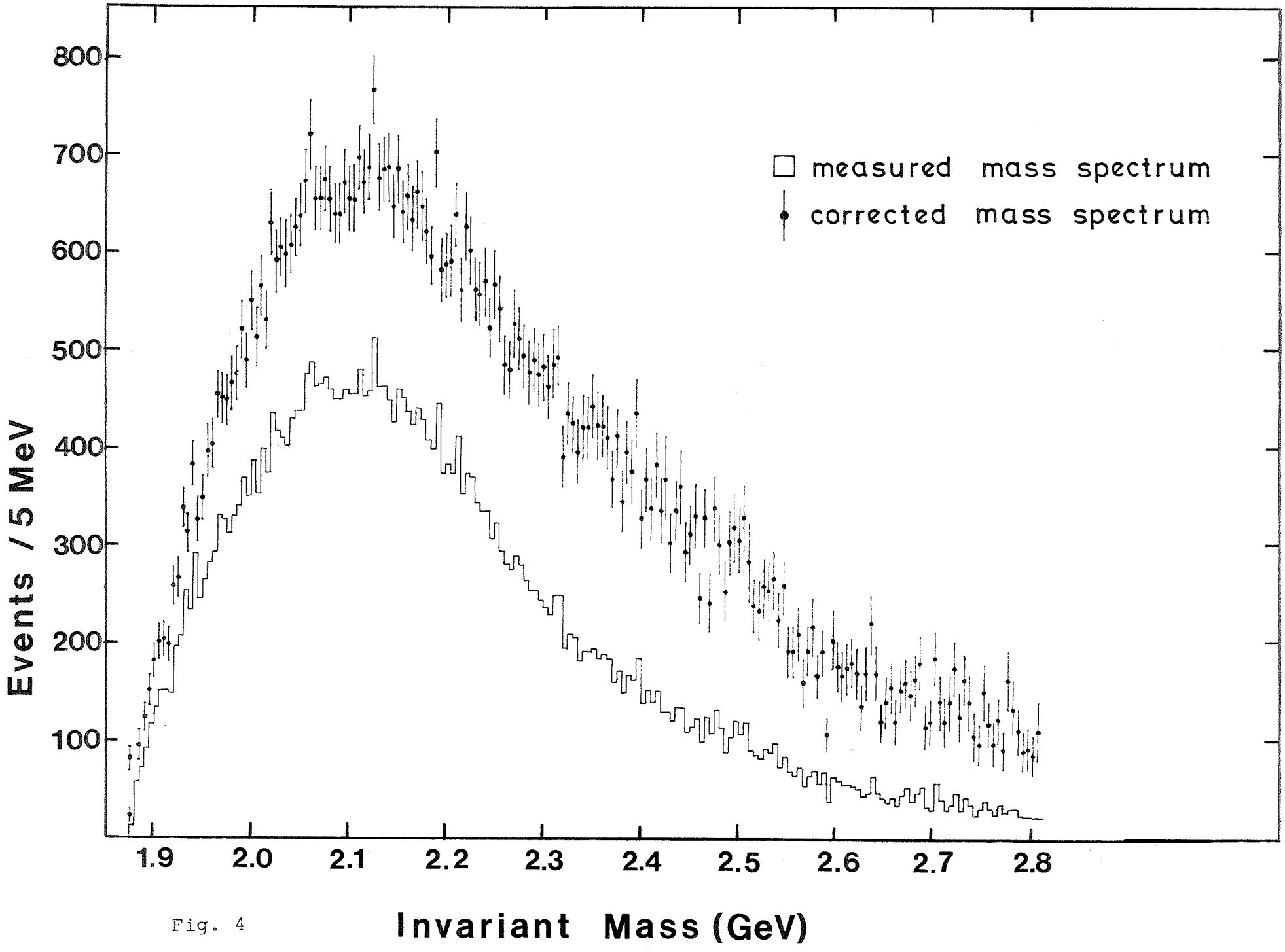
measured mass spectrum
corrected mass spectrum
Events / 5 MeV
Invariant Mass (GeV)
800
700
600
500
400
300
200
100
1.9
2.0
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8

Fig. 4

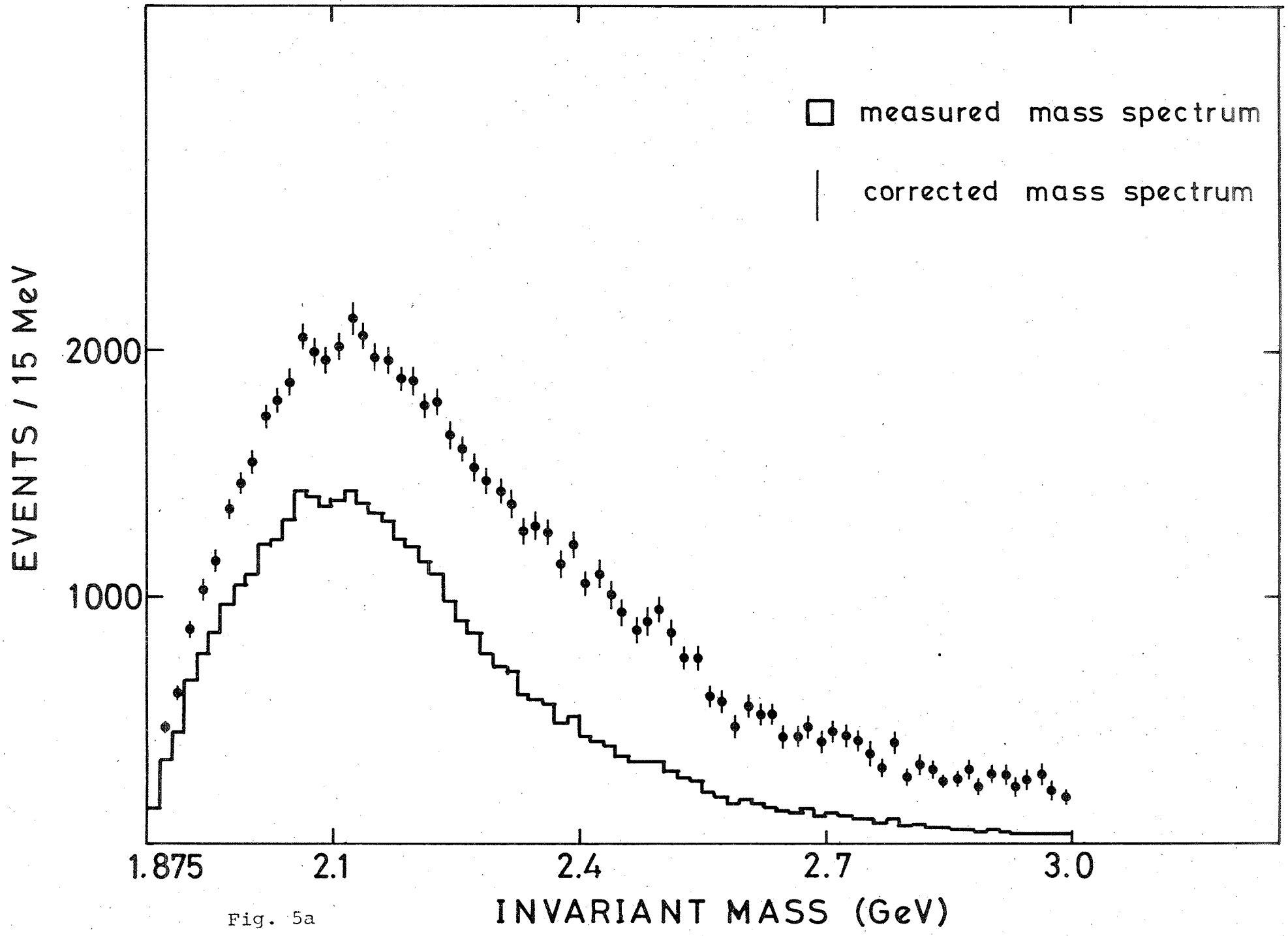
measured mass spectrum
corrected mass spectrum
EVENTS / 15 MeV
2000
1000
1.875
2.1
2.4
2.7
3.0
INVARIANT MASS (GeV)

Fig. 5a

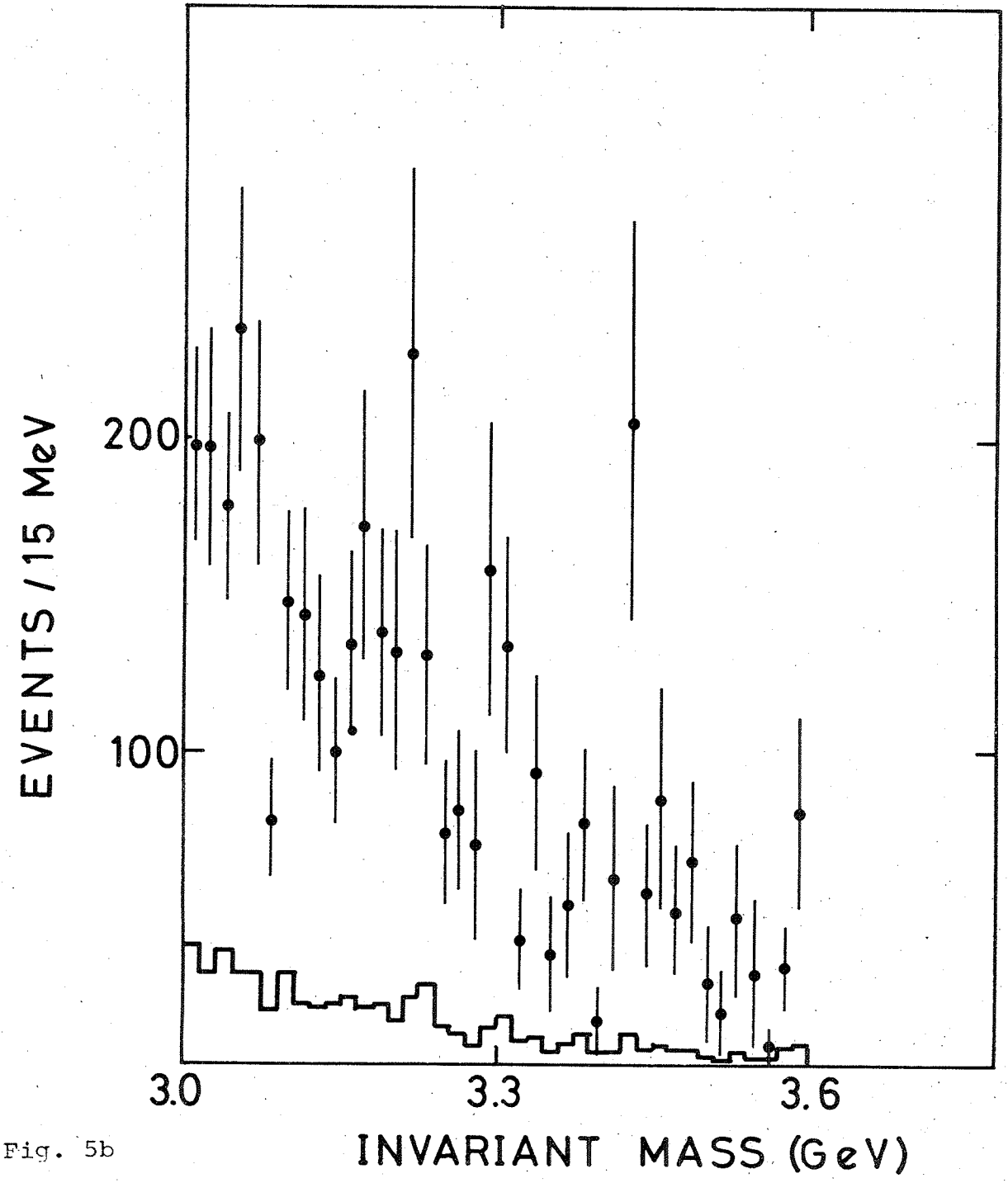

Fig. 5b

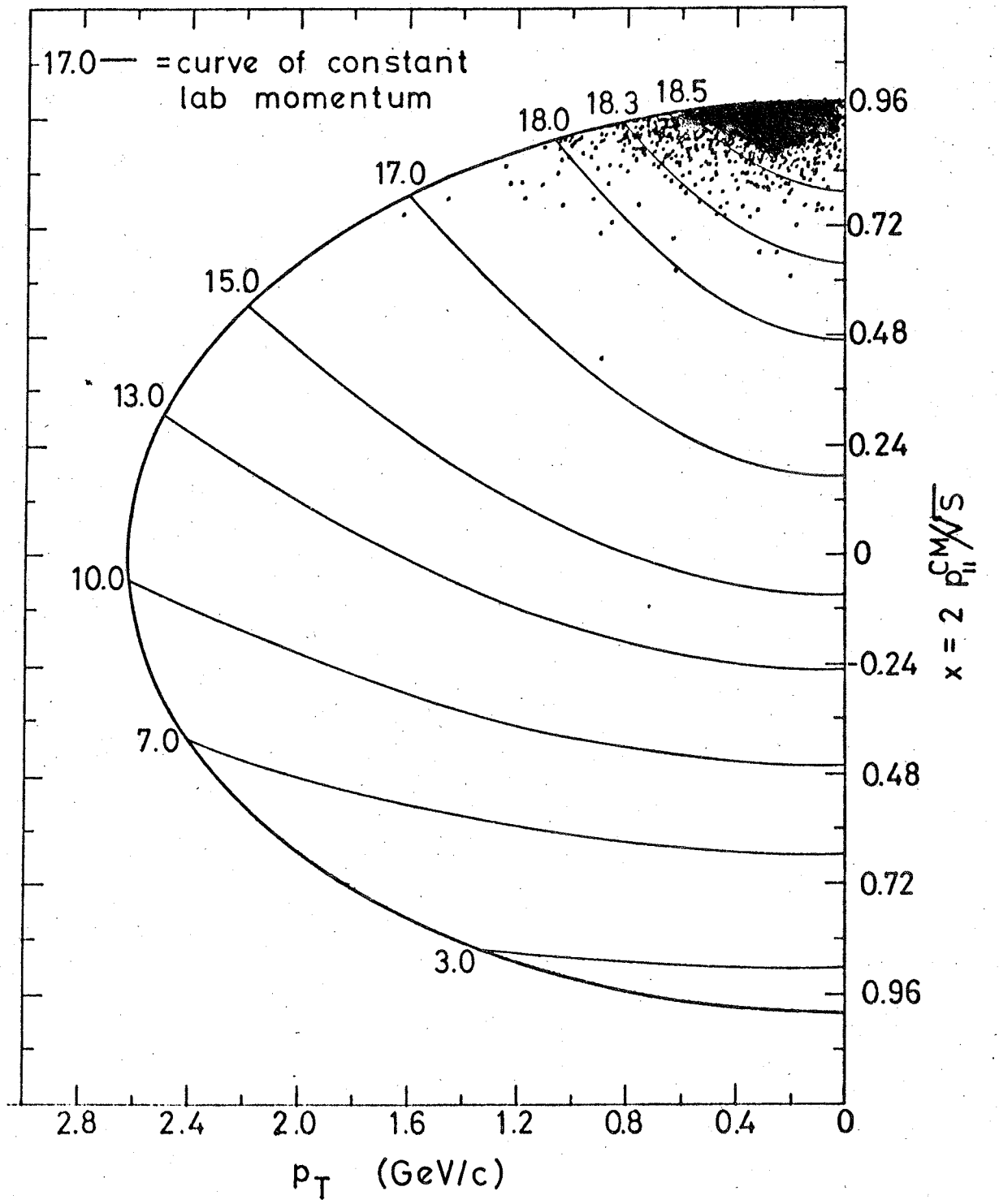
17.0— =curve of constant lab momentum
18.0
18.3
18.5
17.0
15.0
13.0
10.0
7.0
3.0
0.96
0.72
0.48
0.24
0
-0.24
0.48
0.72
0.96
$x = 2 p_{\parallel}^{CM}/\sqrt{s}$
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0
p_T (GeV/c)

Fig. 6