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THE CASCADE $\chi(3515) \to J/\psi\gamma$ PRODUCED IN π^-Be COLLISIONS AT $\sqrt{s}$ = 17.8 GeV/c²

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ABSTRACT

Indications of the production of $\chi(3515) \to J/\psi\gamma$ have been observed in the Goliath spectrometer leading to the ratio $(\chi \to J/\psi\gamma)/J/\psi$ = = 0.11 ± 0.04 (statistical errors only).

* * *

In an analysis of 10650 J/ψ events (62.5% obtained at 150 GeV/c incident pion momentum, 37.5% at 175 GeV/c) we have found 445 $\gamma \to e^+e^-$ conversions identified as V°'s in the large acceptance, high resolution spectrometer "Goliath" [described by Abolins et al.[1]]. Here the "γ-detector" is the beginning of the spectrometer itself: the beryllium target (which is divided into three parts), the WH/WB scintillators, the MWPCs, and a 1 mm lead foil inserted upstream of the MWPCs for 14% of the data sample. These various converters (see Fig. 1) have the following radiation lengths:

– Target 1	8.35% RL
– Target 2	10.33% RL
– Target 3	7.95% RL
– Scintillators, air, MWPCs (gas, mylar, wires)	3.9 % RL
– Lead	17% × 14% = 2.38% RL.

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We require the γ to come from these materials, excluding the main vertex target, in order to get a clean separation between the two vertices.

Figure 2 shows the $\mu\mu$ mass spectrum. Masses ranging from 2.95 to 3.25 GeV/c² are taken as J/ψ's (our J/ψ resolution is 88 MeV FWHM). The events in this mass range are constrained to have the correct J/ψ mass of 3097 GeV/c².

Photon identification: All our V°'s are plotted in Fig. 3a, which shows the e^+e^- effective mass hypothesis versus the $\pi^+\pi^-$ effective mass hypothesis. The K°'s, γ's, and the Λ reflection can clearly be seen. Figure 3b is the projection on the $M_{e^+e^-}$ axis. The low-mass peak is the γ signal, and the peak centred at 0.4 GeV is the K° signal obtained using the wrong mass assignment for the decay products. Figure 3c is the projection on the $M_{\pi^+\pi^-}$ axis where the γ signal peaks at 0.3 GeV, and the K° signal is obvious.

The V°'s with $M_{e^+e^-}$ < 55 MeV are taken as γ's and we constrain the e^+e^- mass to be zero. Figure 4a shows the $J/\psi\gamma$ effective mass spectrum. The background is shown in Fig. 4b. This is computed by combining each γ with the J/ψ from each of the four preceding events. A $J/\psi\gamma$ signal appears above the background at 3.5 GeV/c².

Energy correction: We have corrected the electron energies for dE/dx losses along their paths. Electron pairs corrected by more than 15% are rejected. Figure 5a shows the spectrum obtained after energy correction, while Fig. 5b shows the corrected background distribution. A peak-plus-background fit has been performed in the following way: first a polynomial is fitted to the background (Fig. 5b). This background (with free scale parameter) is added to a Gaussian (Fig. 5a). The results are:

Mass = 3520 MeV/c^2
Width = 22 MeV/c^2 FWHM
Signal = 15 events
Background (in range $\pm 2\sigma$) = 9 events .

This signal is compatible with the $\chi(3515)$ [2].

We have checked that a 1% correction on the electron energy shifts the χ mass by less than 2 MeV in this region. We thus exclude the possibility that the observed signal is the $\chi(3556)$ shifted down in energy. A shift of this magnitude would require an additional 20% RL of unidentified material.

Acceptance, χ/ψ ratio, cross-section: The geometrical and conversion acceptances have been computed using the following assumptions:

i) the χ has the same distribution in x_F and in p_T as the J/ψ;

ii) the χ decays isotropically into $J/\psi\gamma$.

An average value of 1.3% acceptance has been computed. This value is preliminary and further detailed Monte Carlo calculations are required before we can estimate its uncertainty and its sensitivity to the above assumptions. For this reason we quote only statistical errors on χ/ψ ratio and cross-section. The signal of 15 ± 5 events then yields a ratio

$$\frac{\chi \to J/\psi\gamma}{J/\psi} = 0.11 \pm 0.04 \text{ (statistical error only)}$$

for an average $\sqrt{s}$ value of 17.8 GeV . With the known branching ratio $\chi_{3.51} \to J/\psi\gamma$ of 23.4% [4] and an average J/ψ cross-section of 100 ± 10 nb [1], we find

$$\sigma(\chi_{3.51}) = 47 \pm 17 \text{ nb}.$$

Use of a Pb scintillator sandwich calorimeter: In an independent analysis of a sample of 2700 J/ψ's obtained at 150 GeV/c, the information given by a Pb scintillator sandwich calorimeter was used. Photon energies were measured using the pulse height from the sandwich counters, whose measured energy resolution was $0.5/\sqrt{E}$ FWHM. The photon position at the calorimeter was measured using a proportional wire chamber which followed a 16 mm Pb converter. The spatial precision is approximately 50 mm FWHM.

The $J/\psi\gamma$ mass is plotted in Fig. 6a together with the "background". This background was estimated by combining photons of each event with J/ψ's from the previous 50 events.

Two cuts were applied to the data:

i) if a charged particle, reconstructed in Goliath, intersects the same calorimeter module as the photon, then the photon is excluded;

ii) photons are accepted only if their energy exceeds 1 GeV.

In Fig. 6b we show the $J/\psi\gamma$ mass with background subtracted. There is no significant χ signal; however, in what follows we argue that the data are consistent with the analysis using photon conversions in Goliath.

The excess of events around 3.55 GeV/c^2 is at most a 2σ effect, but it is consistent with the estimated χ mass resolution of 100 MeV/c^2 FWHM. If the excess is interpreted as a χ signal, this represents 60 ± 32 events on a background of 768. We correct this figure for acceptance using the following factors:

i)	effect of charged particle cut:	0.73
ii)	shower-finding efficiency in calorimeter:	0.63
iii)	geometrical acceptance:	0.58

This yields a corrected signal of 225 ± 121 χ events, which, expressed as a fraction of J/ψ's, gives 8 ± 4%, to be compared with 11 ± 4% above.

Conclusion: Owing to our excellent $J/\psi\gamma$ mass resolution, we have found an indication of the contribution of the $\chi(3515)$ to the J/ψ hadronic production, giving a ratio $(\chi \to J/\psi\gamma)/J/\psi$ of 0.11 ± 0.04 (statistical error only). The ψ' contribution to the χ signal has been excluded: we have measured the ratio $\sigma(\psi')/\sigma(J/\psi) = 15\%$ [1]. With the known branching ratios our χ cross-section is too high to have originated entirely from ψ' decays.

REFERENCES

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F.L. Sharre, SLAC-Pub 2321 (1979).

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T.B. Kirk et al., Phys. Rev. Lett. 42, 619 (1979).

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FIGURE CAPTIONS

Fig. 1 Plan view of apparatus.

Fig. 2 μμ mass spectrum.

Fig. 3 Scatter plot for V^0 masses under two hypotheses: a) $M_{\pi^+\pi^-}$ versus $M_{e^+e^-}$; b) Projection on $M_{e^+e^-}$ axis; c) Projection on $M_{\pi^+\pi^-}$ axis.

Fig. 4 Raw J/ψ γ spectra. a) Real events; b) Background formed by uncorrelated combinations.

Fig. 5 Energy-corrected J/ψ γ spectra. a) Real events with fitted curve; b) Background formed by uncorrelated combinations.

Fig. 6 J/ψ γ mass spectra obtained using Pb scintillator calorimeter:
a) J/ψ γ mass with background curve superimposed;
b) J/ψ γ mass, background subtracted.

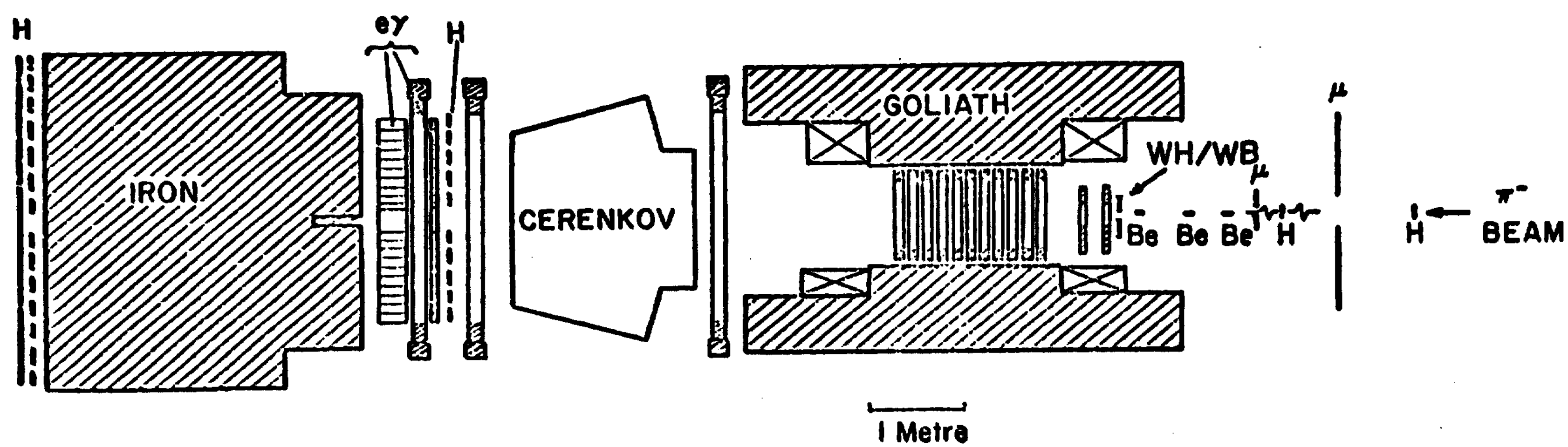


FIG. 1

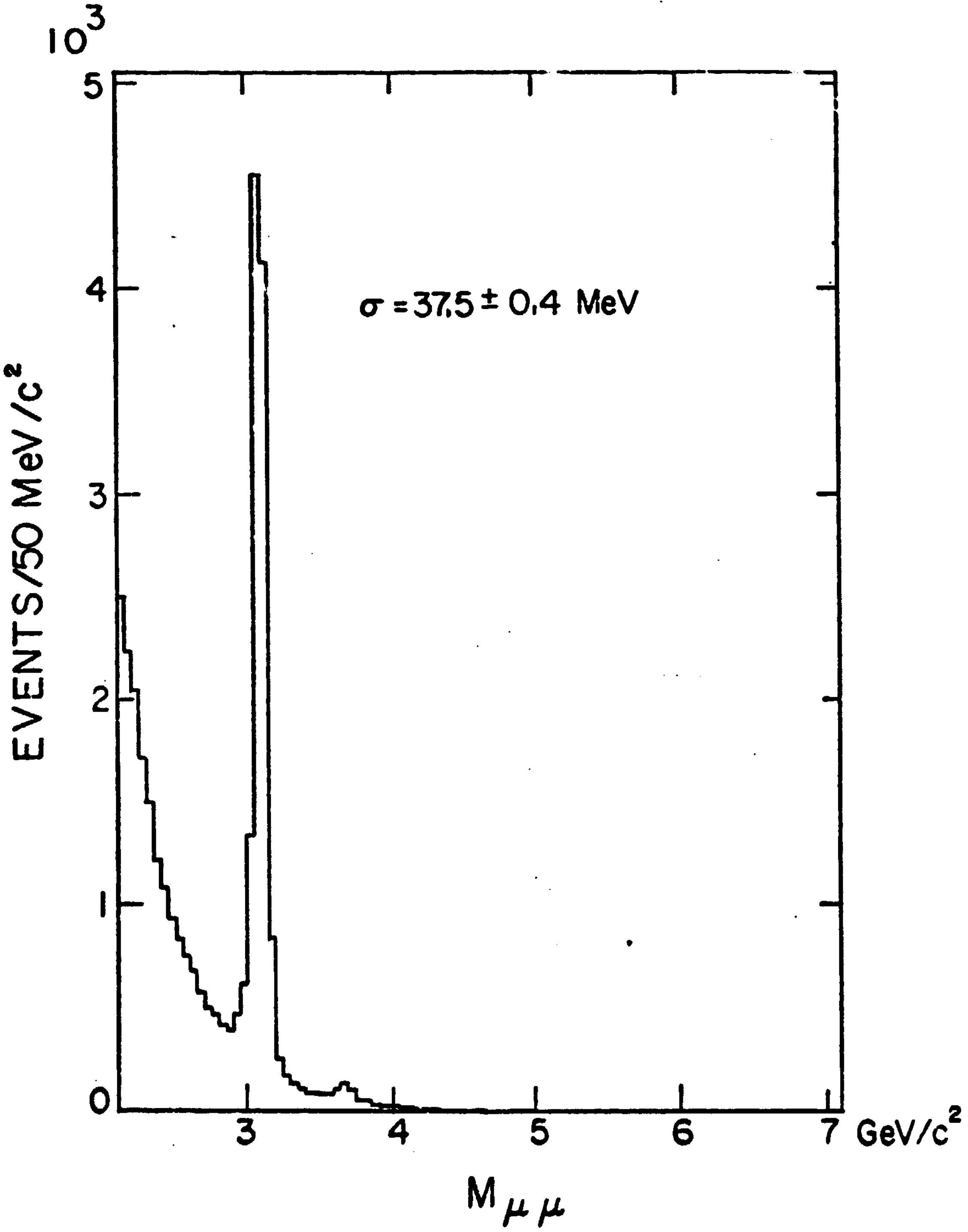


FIG.2

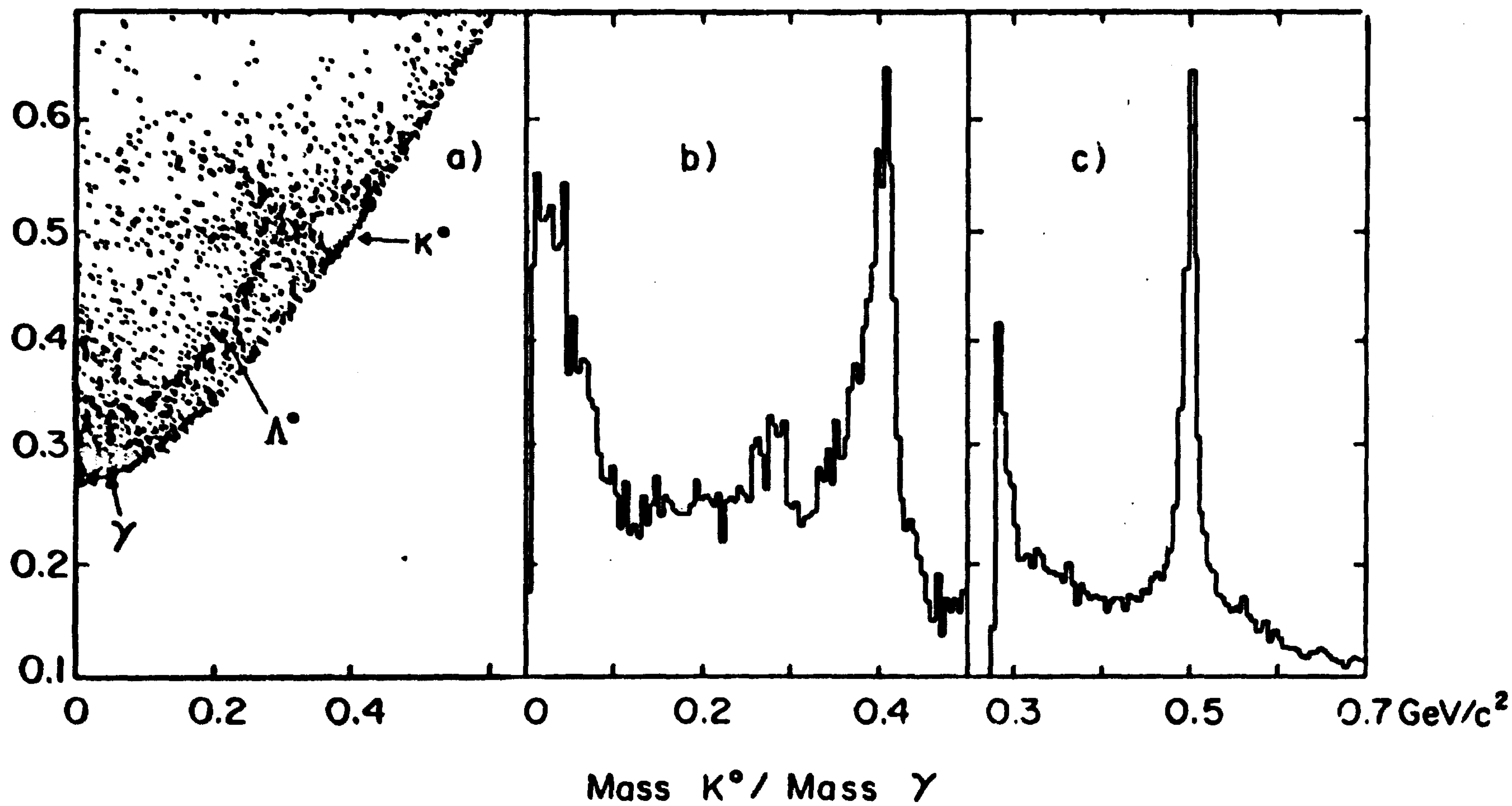


FIG. 3

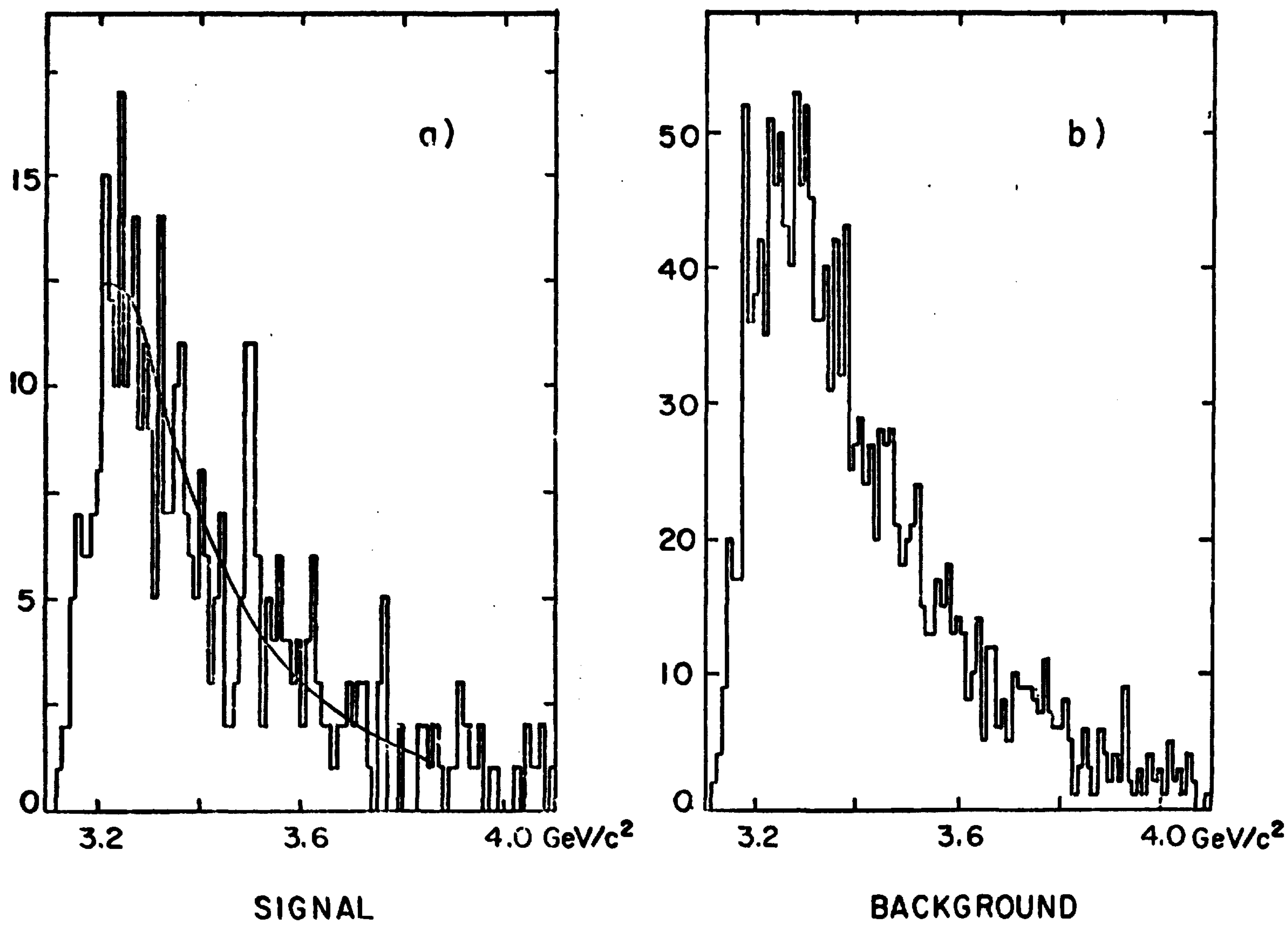
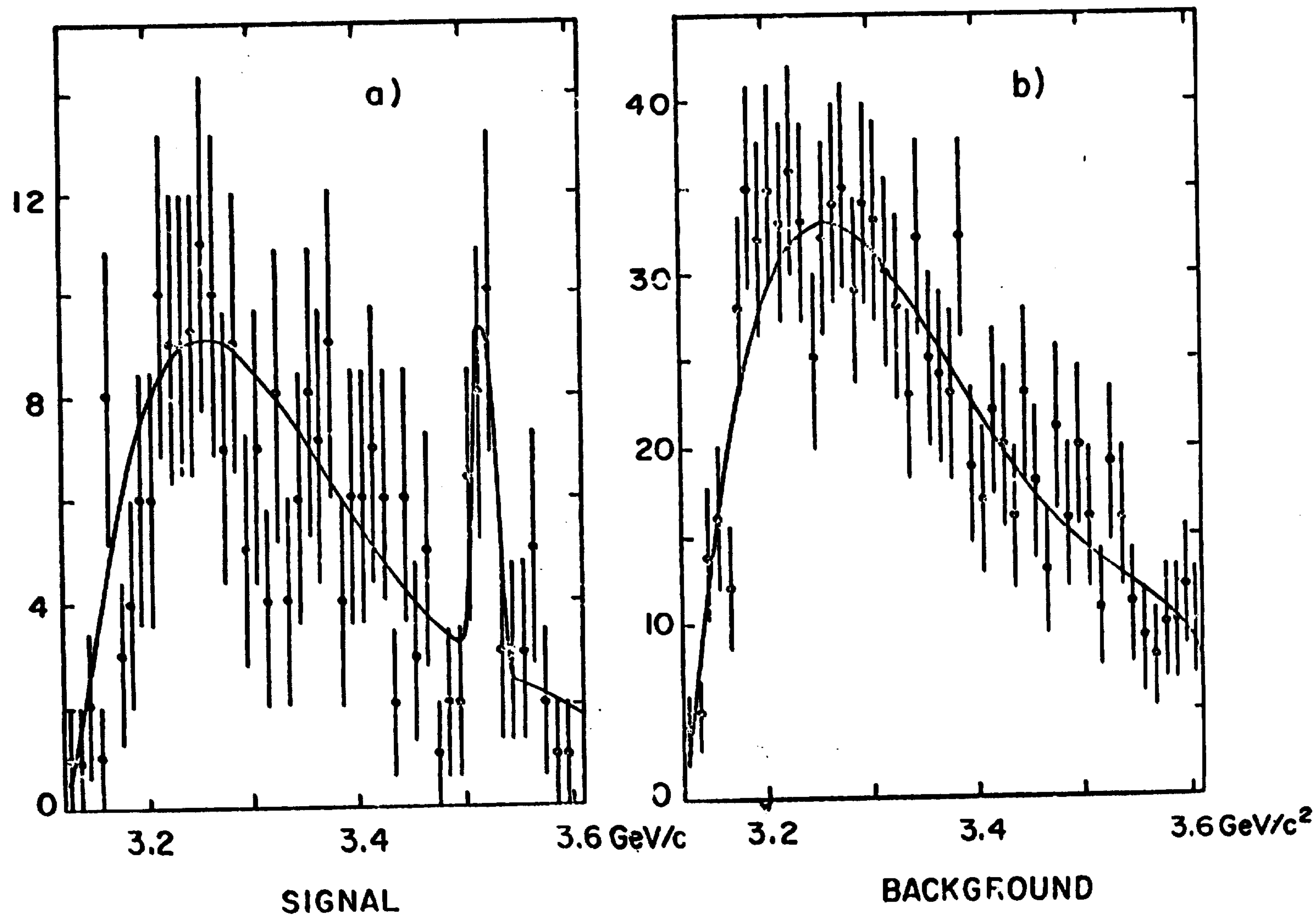


FIG. 4



a)
b)
12
8
4
0
40
30
20
10
0
3.2
3.4
3.6 GeV/c
3.2
3.4
3.6 GeV/c²
SIGNAL
BACKGROUND

FIG. 5

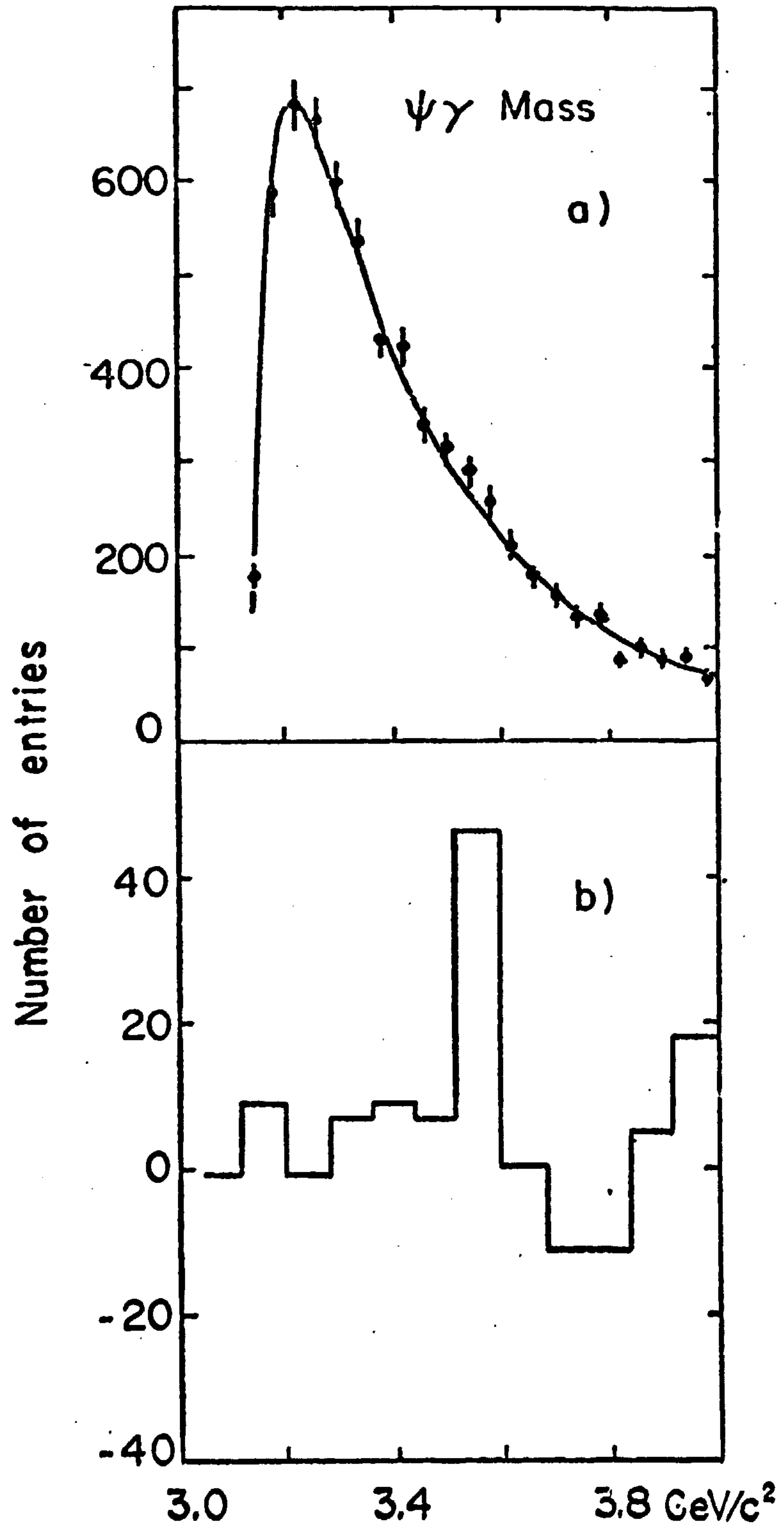

ψγ Mass
a)
b)
600
400
200
0
40
20
0
-20
-40
Number of entries
3.0
3.4
3.8 GeV/c²

FIG. 6