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SEARCH FOR NARROW HIGH MASS HYPERONS IN K^-p INTERACTIONS AT 8.25 GeV/c

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ABSTRACT

We present the results of a search for S = -1 states with mass up to $\sim$ 3.5 GeV/c^2 decaying via $\Sigma K\bar{K}$ + pions, $\Lambda K\bar{K}$ + pions and ΞK + pions. The possible existence of a narrow ($\Gamma \leqslant$ 20 MeV) Y^* at a mass of 3170 MeV is discussed. The data come from a large statistics bubble chamber experiment and correspond to a sensitivity of $\sim$ 100 ev/μb.

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In the continuing analysis of a large bubble chamber experiment on K^-p interactions at 8.25 GeV/c (the present statistics is $\sim$ 100 events/μb) we have made a systematic search for quasi two-body processes of the type

$$K^- + p \rightarrow \pi + Y^* \qquad (1)$$

for the channels in which we have more than one strange particle in the final state.

The interest of this search comes from the fact that recent predictions have been made concerning the existence of five-quark baryon systems $qqqq\bar{q}$, sufficiently narrow to be easily detected in mass spectra [1-2]. These models predict multiparticle decays and for states containing three strange quarks $ss\bar{s}$, a dominant decay into three strange particles is foreseen. This should be a signature of these states in contrast to "normal" hyperons (qqs) where one would expect that one-strange-particle decays should be dominant. A review of the experimental situation concerning multiquark states can be found in ref. [3].

We present here the results on the observation of a narrow state at a mass of 3.17 GeV with a width of 20 MeV consistent with the experimental resolution. The effect has been observed in the mass spectrum of the system R^+ recoiling against a π^- for the kinematically constrained events that come from the reaction

$$K^- + p \rightarrow \pi^- + R^+, \qquad (2)$$

where R decays in five or six particles (six or seven-body final states).

The events are also required to contain more than one strange particle, i.e. Ξ signature or three strange particles coming from the production vertex. At least one neutral strange particle decay must be observed.

When more than one hypothesis remains after ionization consistency checks, we have retained the fit corresponding to the highest number of degrees of freedom, and within the same class of constraints the one with the highest probability. The results we give are largely independent of this selection.

Fig. 1(a) shows the mass spectrum of the system R^{+}, and a three-standard deviation effect is present at a mass of 3.17 GeV. This can be better seen in fig. 1(b), where the same spectrum is shown in the mass region 3.00 - 3.30 GeV. The width of the peak is consistent with our resolution, which at this mass is about 20 MeV.

In fig. 2 we give the π^{-} angular distribution in the total c.m. system for the signal region 3.16 - 3.18 GeV (fig. 2(b)), and for side regions 3.00 - 3.16 GeV (fig. 2(a)) and 3.18 - 3.30 GeV (fig. 2(c)). Compared with the distributions for the control regions the one in the 3.16 - 3.18 GeV region is much richer in events with the π^{-} backward in the c.m. system. Selecting events with the π^{-} in the backward hemisphere, we obtain the mass spectrum shown in fig. 3(a), where now the peak is more prominent. The number of events above the background is the same as that in the total sample, but the background is down by a factor of two. Fig. 3(b) shows the same distribution plotted in 5 MeV bins and the width of the peak is consistent with the calculated resolution. A maximum likelihood fit to the spectrum of fig. 3(a) gives 22 events in the peak with a statistical significance of $\sim$ 5.5 standard deviations; the level of significance is independent of the parametrization assumed for the background and the mass interval used. The mass of the peak has been fitted to be (3170 ± 5) MeV and we shall refer to it as R(3170). We do not see any signal for the three-body decay of the R(3170), even though the background is at about the same level. In the four-body decay, no effect is visible, but here the background is five times larger.

Careful studies have been made to check for spurious sources of the peak. Each event in the peak has been individually checked by physicists. All the events are consistent with a π^{-} for the recoil track; in addition, in 60% of the cases the track was unambiguously identified as a π^{-} by ionization. To show that our results are independent of any distortion produced by the kinematical fitting procedure, we present in fig. 3(c) the plot of the missing mass to the recoil track assumed to be a π^{-}. This has been calculated using measured quantities for the π^{-} and average values for the incoming K^{-}. The peak is still clearly seen, although reduced in height since in this case the experimental resolution is worse by about a factor two.

The forward production of the R(3170) implies that the resonance is produced via I = 3/2 baryon exchange. If we assume: (a) that this production mechanism is the dominant one and (b) I = 1 for the R(3170), we can predict what we expect in the channels

$$K^- + p \to \pi^+ + R^- \qquad (3)$$

$$K^- + p \to \pi^0 + R^0 \quad . \qquad (4)$$

Inspection of the appropriate mass spectra gives results consistent with this picture. In fact, we expect a negligible effect in the R^- mass spectrum $\sigma(R^-) = 1/9\ \sigma(R^+)$ and indeed the mass spectrum does not show any structure. We expect the cross section $\sigma(R^0)$ to be $4/9\ \sigma(R^+)$, but the worse experimental resolution in this case ($\sim$ 60 MeV) makes the comparison difficult. A fit to the mass spectrum taking into account the resolution gives $N(R^0) = (16 \pm 8)$ events.

The observed decay modes of the R(3170) are given in table 1, in terms of the baryon present in the final states, together with those of the control regions. We did not find evidence for possible sequential decays to known resonances or to states of the same type with lower masses via pion emission.

The absence of known resonances in the decay products of the R(3170) can be used in the case of Ξ events to reinforce the interpretation of the peak as a real effect. Fig. 4 gives the mass distribution of the $(\Xi\pi)^{\bar{0}}$ system in the R and control regions. While copious production of $\Xi^*(1530)$ is present in the control regions, no evidence of the state is present in the resonance region where we expect seven $\Xi^*(1530)$ events if we normalize to the total number of events in this bin. Because no other resonance is produced as strongly as the $\Xi^*(1530)$ in the Ξ channels, the comparison cannot be made at the present level of statistics for the other channels.

The cross section for production of the R(3170) on the basis of the 22 observed events correcting for visibilities and efficiencies is

$$\sigma = (0.7 \pm 0.3)\mu b \quad . \qquad (5)$$

This number should be corrected for losses due to: (a) decays in the same number of bodies (five or six), but with more than one invisible particle in the final states and (b) for possible decays into a smaller number of particles. No signal is seen in the corresponding mass spectra. A third source of losses is due to the fact that in our experiment we measure only events with at least one V^0, so for example, decays of the type $\Sigma^{\pm}K^{+}K^{-}m\pi$ are not measured.

The decay rate into three strange particle final states (F_1) should be compared with that for final states containing only one strange particle (F_2). In fact, for "normal" hyperons F_2 should be dominant. We have studied the $(\Lambda m\pi)^+$, $(\Sigma^0 m\pi)^+$, $(K^0 pm\pi)^+$ and $(K^0 nm\pi)^+$ systems recoiling against π^- for constrained events applying the same production angular cuts. No structure at this mass is seen and the following upper limits at the 95% CL can be given

$$\sigma(R(3170) \rightarrow \Lambda m\pi) < 0.6\ \mu b, \qquad m = 1, 2, 3, 5 \tag{6}$$

$$\sigma(R(3170) \rightarrow K^0 pm\pi) < 1.3\ \mu b, \qquad m = 1, 2, 3, 5 \tag{7}$$

$$\left.\begin{aligned} &\sigma(R(3170) \rightarrow \Sigma^0 m\pi) < 0.1\ \mu b, \qquad m = 1, 3, 5 \\ &\sigma(R(3170) \rightarrow K^0 nm\pi) < .7\ \mu b, \qquad m = 1, 3, 5. \end{aligned}\right. \tag{8}$$

The channels mentioned above are the only suitable ones measured in our experiment.

It is clear that no quantitative statements can be made about the relative ratios of F_2 and F_1 due to losses of events with more than one undetected particle and the incomplete availability of all possible final states. However, on the basis of the numbers we have measured, we can conclude that F_2 cannot be significantly larger than F_1.

In conclusion, we can summarize our results in the following way. We have observed a statistically significant (> 5 σ) enhancement at a mass of (3170 $\pm$ 5) MeV and with a width of $\leqslant$ 20 MeV in the mass spectrum of the recoil to a π^- in K^-p interactions at 8.25 GeV/c. This system is produced via I = 3/2 baryon exchange. The decay characteristics of the state makes it a plausible candidate for a hadron having a more complicated internal structure than that of "normal" hyperons.

REFERENCE

[1] H. Högaasen and P. Sorba, Nucl. Phys. B145 (1978) 119.

[2] M. De Crombrugghe, H. Högaasen and P. Sorba, Nucl. Phys. B, (in press).

[3] H. Högaasen and P. Sorba, CERN report, TH 2586 (1978); a complete bibliography on states with more than three quarks can be found in this paper.

TABLE 1

Decay modes of the R^+ system in the R(3170) and side mass regions in term of the baryon present in the final state.

Mass region GeV	3.00 - 3.16	3.16 - 3.18	3.18 - 3.30
Λ	8	8	25
Σ	5	11	15
Ξ	25	9	40
p	1	1	2
total	39	29	82

FIGURE CAPTIONS

Fig. 1 (a) Mass spectrum of the R^+ system recoiling against a π^-. For the definition of R^+ see text.

(b) Mass region 3.00 - 3.30 GeV on an expanded scale. The continuous line is the result of a polynomial fit to the spectrum.

Fig. 2 Production angular distribution of the recoil π^- in the centre of mass system for the mass regions: (a) 3.00 - 3.16 GeV, (b) 3.16 - 3.18 GeV and (c) 3.18 - 3.30 GeV.

Fig. 3 (a) Mass spectrum of R^+ for events in which $\cos\theta^*(\pi^-, \text{beam}) < 0$. The continuous line is the result of a ML fit that finds 22 events in the 3.17 GeV peak.

(b) Shows the mass spectrum for R^+ for the same events of (a) in 5 MeV bins. The continuous line is obtained by adding to a smooth background the resolution function centred at 3.17 GeV.

(c) Same as (b) but computing the missing mass to the π^- using measured quantities.

Fig. 4 Mass distribution of the $(\Xi\pi)^o$ system for Ξ events in the R^+ mass region: (a) 3.00 - 3.16 GeV, (b) 3.16 - 3.18 GeV and (c) 3.18 - 3.30 GeV.

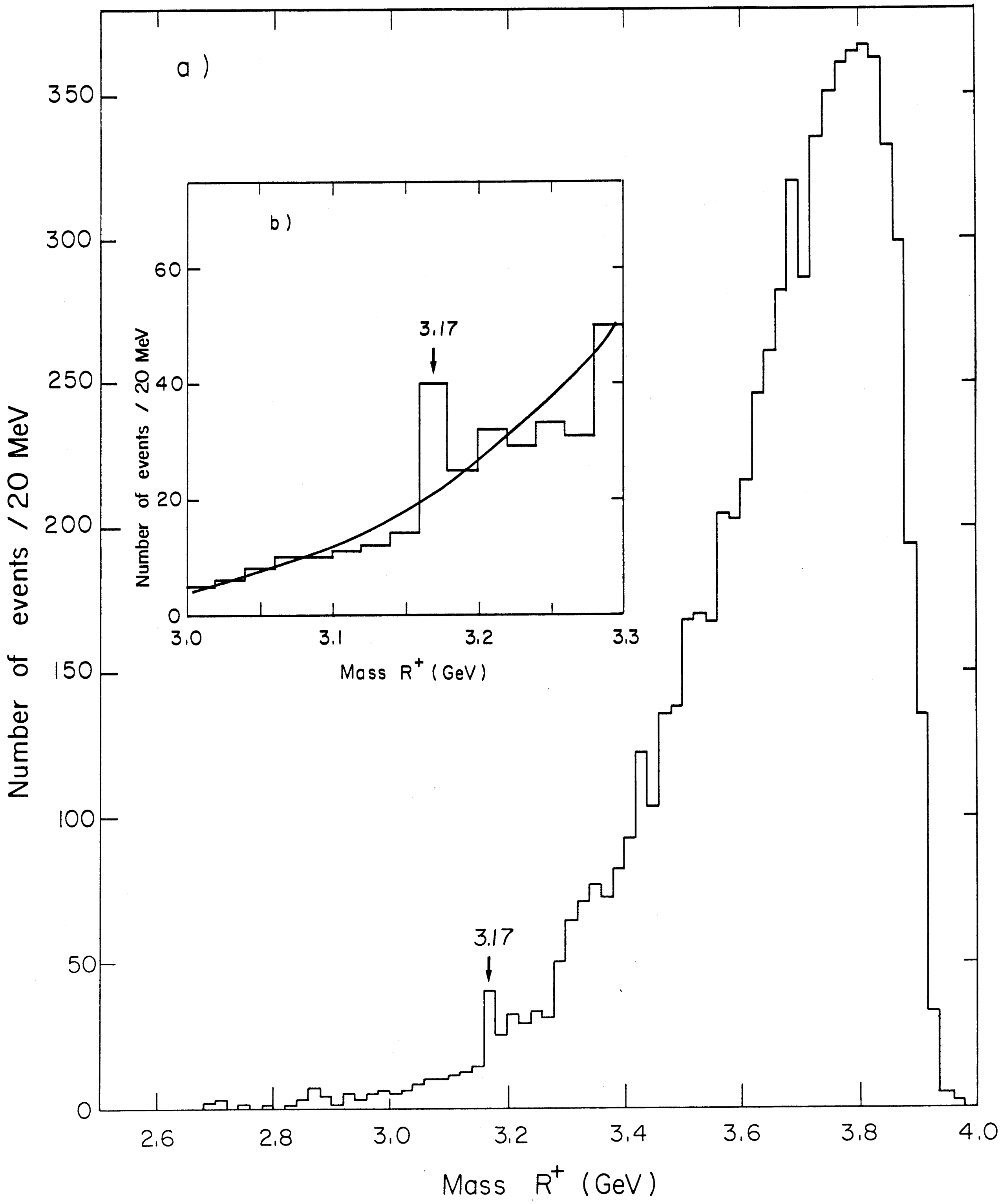

a)
b)
3.17
3.17
Number of events / 20 MeV
Mass R+ (GeV)
Number of events / 20 MeV
Mass R+ (GeV)
0
50
100
150
200
250
300
350
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0
0
20
40
60
3.0
3.1
3.2
3.3

fig.1

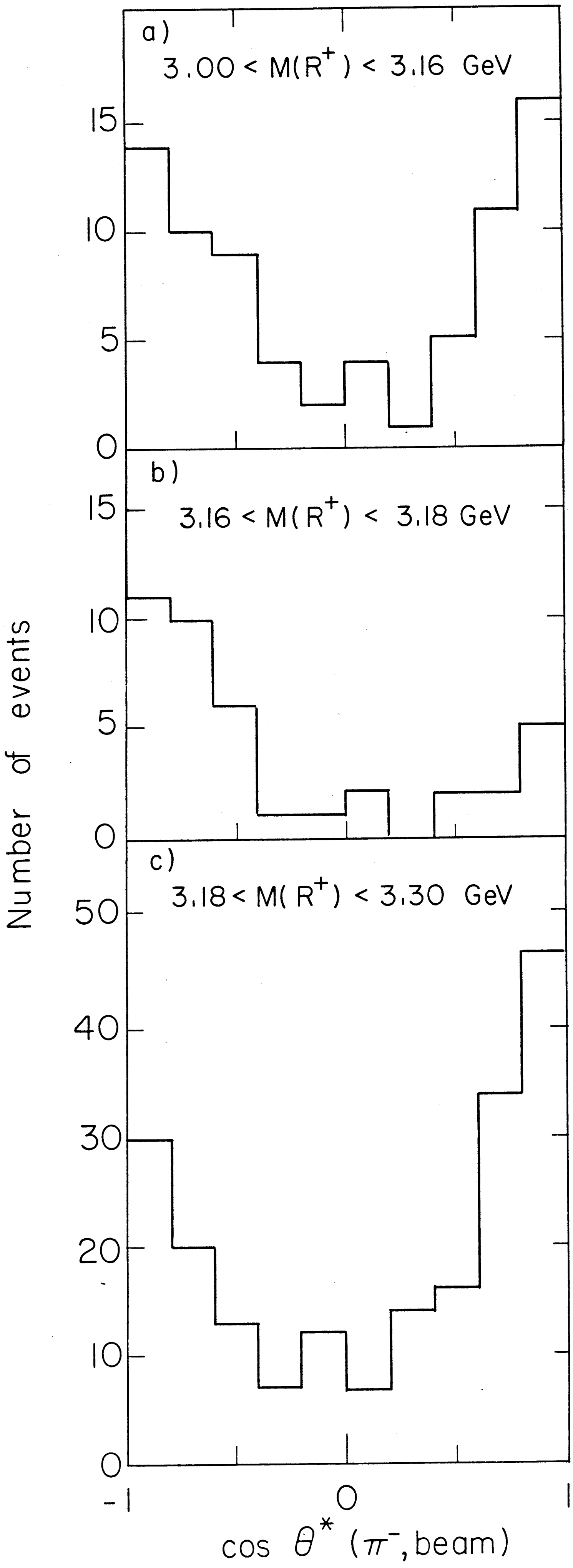

a)
3.00 < M(R+) < 3.16 GeV
b)
3.16 < M(R+) < 3.18 GeV
c)
3.18 < M(R+) < 3.30 GeV
Number of events
0
5
10
15
20
30
40
50
-1
0
1
cos θ* (π⁻, beam)

fig. 2

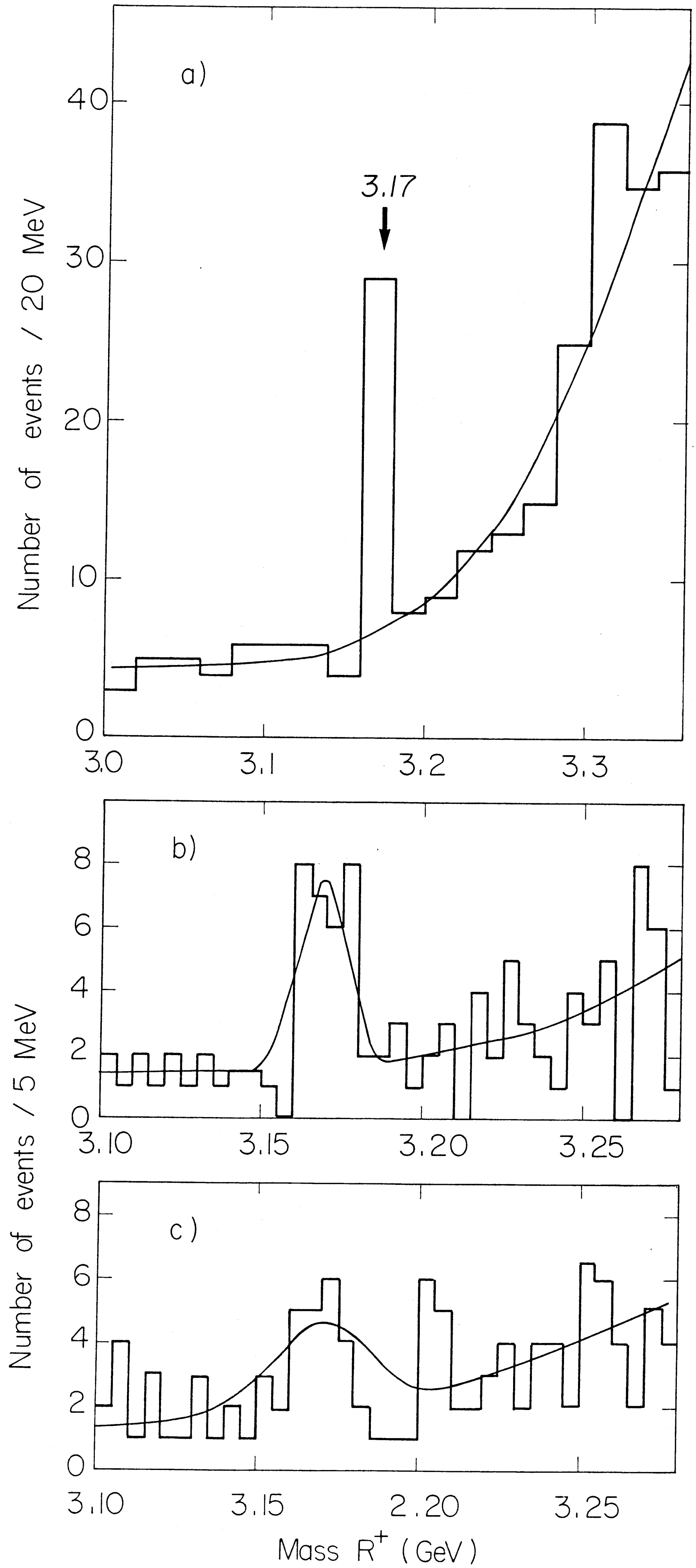
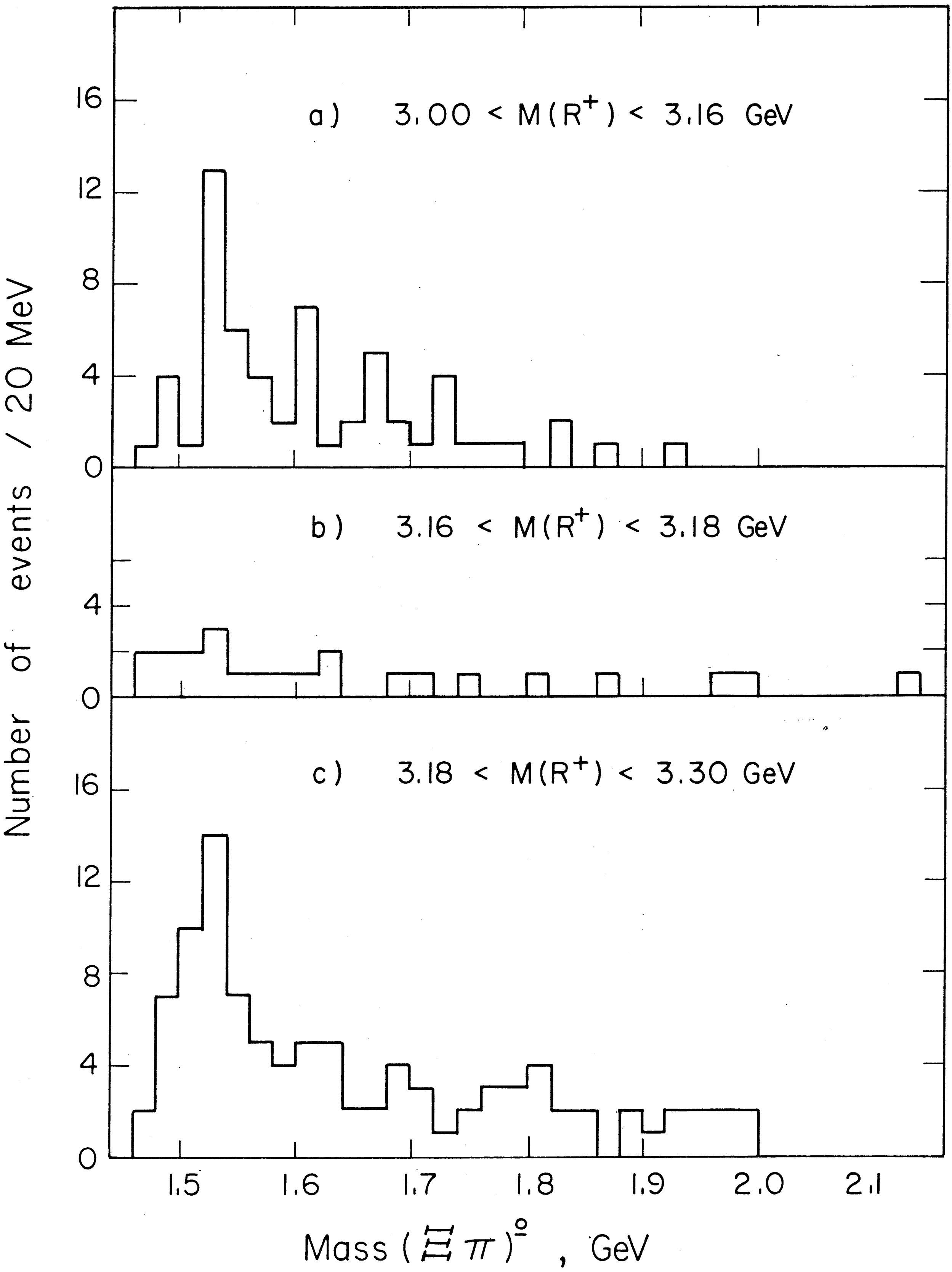

a)
3.17
Number of events / 20 MeV
0
10
20
30
40
3.0
3.1
3.2
3.3
b)
8
6
4
2
0
3.10
3.15
3.20
3.25
Number of events / 5 MeV
c)
8
6
4
2
0
3.10
3.15
2.20
3.25
Mass R^+ (GeV)

fig.3



a) 3.00 < M(R⁺) < 3.16 GeV
b) 3.16 < M(R⁺) < 3.18 GeV
c) 3.18 < M(R⁺) < 3.30 GeV
Number of events / 20 MeV
16
12
8
4
0
1.5
1.6
1.7
1.8
1.9
2.0
2.1
Mass (Ξπ)°, GeV

fig.4