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AN I = 1 ENHANCEMENT AT A MASS OF 1550 MeV IN THE $(\Lambda\pi)$ and $(\Sigma\pi)$-SYSTEMS

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ABSTRACT

Evidence is presented for an I = 1 anhancement observed in the reactions $K^- p \rightarrow \Lambda(\Sigma)K_1^o K^\pm\pi^\mp$ at 4.2 GeV/c incident momentum. The mass and width of the proposed new Y^* are, respectively, (1553 ± 7)MeV and (80 ± 30)MeV. A decay branching ratio $\Sigma\pi/\Sigma\pi + \Lambda\pi$ = (35 ± 12)% is also obtained.

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While analyzing the final states $\Lambda K_1^o K^\pm \pi^\mp$ and $\Sigma^o K_1^o K^\pm \pi^\mp$ in K^-p interactions at 4.2 GeV/c, we have observed in the $\Lambda\pi$ and $\Sigma^o\pi$ mass combinations a six-standard deviation enhancement which is well represented by a Breit-Wigner function with the following parameters: mass = (1553 ± 7) MeV; width = (80 ± 30) MeV. A branching fraction $\Sigma\pi/(\Sigma\pi + \Lambda\pi) = (35 \pm 12)\%$ is also obtained.

The data come from the large statistics experiment studying K^-p interactions at 4.2 GeV/c in photographs from the CERN 2m Hydrogen Bubble Chamber. From the total exposure (equivalent to 133 events/μb) only film corresponding to 100 events/μb has been used in the present analysis.

The events were taken as usual within a limited fiducial volume and to take account of scanning biases only V^o's with a projected decay length of more than 3 mm were kept for further analysis. Appropriate weights corrected for the events thus lost.

The events are highly constrained kinematically since they belong to topologies in which both the Λ and the K^o are seen to decay in the chamber. They are therefore subject to a very small ambiguity between different kinematical hypotheses except for the Λ/Σ^o ambiguity which occurs for about 15% of the events. A clean separation between competing hypotheses has been obtained mainly by comparing their probability distributions in parallel with distributions like that of the pulls of the incident beam momentum and of the missing mass calculated when the Λ measurements were ignored. The good quality of the final sample of events has been verified statistically through a check of the decay angular distributions of both the Λ and Σ^o and that of the well-known beam momentum. The number of events misidentified is estimated to be smaller than 5%.

After applying a cut at the 1% probability level, the final sample consists of the following number of events:

$\Lambda K_1^o K^+ \pi^-$	486	(569),	(1)
$\Lambda K_1^o K^- \pi^+$	597	(711),	(2)
$\Sigma^o K_1^o K^+ \pi^-$	210	(250),	(3)
$\Sigma^o K_1^o K^- \pi^+$	244	(293),	(4)

where the numbers in brackets refer to weighted events.

Fig. 1(a) shows the combined $\Lambda\pi^-$ and $\Sigma^o\pi^-$ mass distribution and also the separate $\Sigma^o\pi^-$ contribution to it, while in fig. 1(b) the same distributions appear for the $\Lambda\pi^+$ and $\Sigma^o\pi^+$ systems. Besides production of the $Y^*(1385)$, effects of varying statistical significance are seen in all four histograms at a mass of about 1550 MeV. Added together the two histograms $\Lambda(\Sigma)\pi^-$ and $\Lambda(\Sigma)\pi^+$ give at this mass an enhancement of about five standard deviations above a smooth background.

The possibility that significant contributions to the $Y^*(1385)$ or to the 1540 MeV enhancement are due to three-body decays of higher mass Ξ^*'s or N^*'s has been investigated with negative results. Neither have we found any evidence that the 1550 MeV enhancement results from reflections of $K^*(890)$, which is abundantly produced in the final states under consideration, or $\Xi^*(1820)$ which is also present in the final states. The recoiling $K\bar{K}$ system is broad and structureless.

In an attempt to isolate better the signal from the background and learn something about the production mechanism, different cuts have been applied to the data. No criterion had been found that distinguishes sharply between the 1550 MeV mass region and adjoining ones. Nevertheless, on the simple assumption that the production may be broadly due to one-particle exchange, the events in each channel have been split into two classes depending on the collision c.m. orientation of the $\Lambda(\Sigma)\pi$-system with respect to the incident K^- direction: that of events in which the $\Lambda(\Sigma)\pi$-system is produced in the forward hemisphere and that in which is is produced in the backward hemisphere. For the 1550 MeV enhancement statistically significant effects are seen only in the forward hemisphere for the $\Lambda(\Sigma)\pi^-$-system ($\sim 4\sigma$) and in the backward hemisphere ($\sim 3\sigma$) for the $\Lambda(\Sigma)\pi^+$-system. In our simple picture this can be explained if baryon exchange predominates for the negatively charged state and K^* exchange for the positive one. It has to be noticed however that this simple idea does not apply completely to $Y^*(1385)$ production; indeed $Y^*(1385)^-$ production is significant at all angles and peaks both in the very forward and backward directions, while the $Y^*(1385)^+$ althrough peaking strongly at backward angles shows significant production over the whole angular range indicating, perhaps, Δ^{++} exchange.

The separation of events into the two-production hemispheres leads, nevertheless, to an improvement in the signal to noise ratio for the 1550 MeV enhancement and thus we make use of it to determine its mass and width and branching ratio.

The histogram of fig. 2(a) is the result of adding the $\Lambda(\Sigma^0)\pi^-$ events produced in the forward hemisphere and those $\Lambda(\Sigma)\pi^+$ events produced in the backward hemisphere. Fig. 2(b) represents the contribution of $\Sigma^0\pi^\mp$ events to the histogram of fig. 2(a).

Both histograms have been fitted with two simple Breit-Wigner functions - each with free mass and width - added incoherently to a polynomial of the second degree.

The following results have been obtained:

(a) Combined ($\Lambda\pi + \Sigma^0\pi$) mass distribution of fig. 2(a):

$Y^*(1385)$ Mass = (1394 ± 5) MeV
Width = (53 ± 14) MeV
No. of events: 242 ± 20.

1550 enhancement Mass = (1553 ± 7) MeV
Width = (79 ± 30) MeV
No. of events: 121 ± 20.

(b) $\Sigma^0\pi$ mass distribution of fig. 2(b):

$Y^*(1385)$ Mass = (1391 ± 6) MeV
Width = (30 ± 13) MeV
No. of events: (22 ± 5).

1550 enhancement Mass = (1551 ± 11) MeV
Width = (35 ± 20) MeV
No. of events: (25 ± 8).

The resulting branching ratios $R = \frac{\Sigma\pi}{\Sigma\pi + \Lambda\pi}$ are

$R(1385) = (0.17 \pm 0.04)$,

in good agreement with the accepted value of (0.14 ± 0.02) and

$R(1550) = (0.35 \pm 0.12)$.

In calculating R we have multiplied by two the $\Sigma^o\pi$ rate to include the $\Sigma^\pm\pi^o$ decay mode but we have not corrected for centrifugal barrier effects arising from mass differences. These should not affect R by more than 10%.

With the data combined in this way, the 1550 MeV enhancement has a cross section of (7 ± 2)μb after correcting for undetected Λ and K^o decays and allowing for the unobserved $\Sigma^\pm\pi^o$ decay modes. Under the same conditions the $Y^*(1385)$ cross section is (13 ± 2)μb.

The histogram of fig. 3, complementary to that of fig. 2(a), shows strong production of $Y^*(1385)$ but no statistically significant effect is observed in the 1550 MeV region.

Measurements of the I = 1 $\bar{K}N$ total cross section in Brookhaven [1] have indicated the presence of structures in this mass region. The first consists of a narrow peak (Γ = 15 MeV) at a mass of (1583 ± 4) MeV; it corresponds very likely to the spin-parity $3/2^-$ $\Lambda\pi^o$ resonance observed at the same mass and with the same width by Litchfield [2] in a K^-p formation experiment. Litchfield finds, albeit with a large uncertainty, no $\Sigma\pi$ decay mode. The differences between these values and comparable ones obtained in the present analysis make it difficult to consider that they refer to the same object.

A second Brookhaven structure, however, occurs at a mass of about 1550 MeV but, as the authors remark, uncertainties in the cross section measurements below their mass range do not allow to assert its significance.

In an update of baryon resonances in $SU(6)_W$, Litchfield et al. [3] have recently pointed that the $(70,1^-)$ representation has no well established $J^P = \frac{1}{2}^-$ Σ-states. They predict that if such a state exists in the neighbourhood of 1600 MeV its elasticity should be small and could thus explain why it has not been seen in formation experiments. Our statistics does not allow a meaningful J^P determination and therefore the identification of the resonance we are proposing with this prediction is only a conjecture.

REFERENCES

[1] A.S. Carroll et al., Phys. Rev. Letters 37 (1976) 806.

[2] P.J. Litchfield, Phys. Letters 51B (1974) 509.

[3] P.J. Litchfield et al., Proc. of Topical conference on baryon resonances, Oxford 1976, p. 477.

FIGURE CAPTIONS

Fig. 1 (a) The combined $\Lambda\pi^-$ and $\Sigma^o\pi^-$ weighted mass distribution for the complete sample of events. The lower histogram shows the $\Sigma^o\pi^-$ contribution.

(b) As fig. 1(a) for the $\Lambda\pi^+$ and $\Sigma^o\pi^+$ systems.

Fig. 2 (a) Weighted mass distribution for events with the $\Lambda(\Sigma^o)\pi^-$ system produced in the forward hemisphere added with those events with the $\Lambda(\Sigma^o)\pi^+$ produced in the backward hemisphere.

(b) The contribution of the $\Sigma^o\pi^\mp$ systems to the previous histogram.

The smooth curves are the result of the fit described in the text.

Fig. 3 Weighted mass distribution for events not included in the histogram of fig. 2(a).

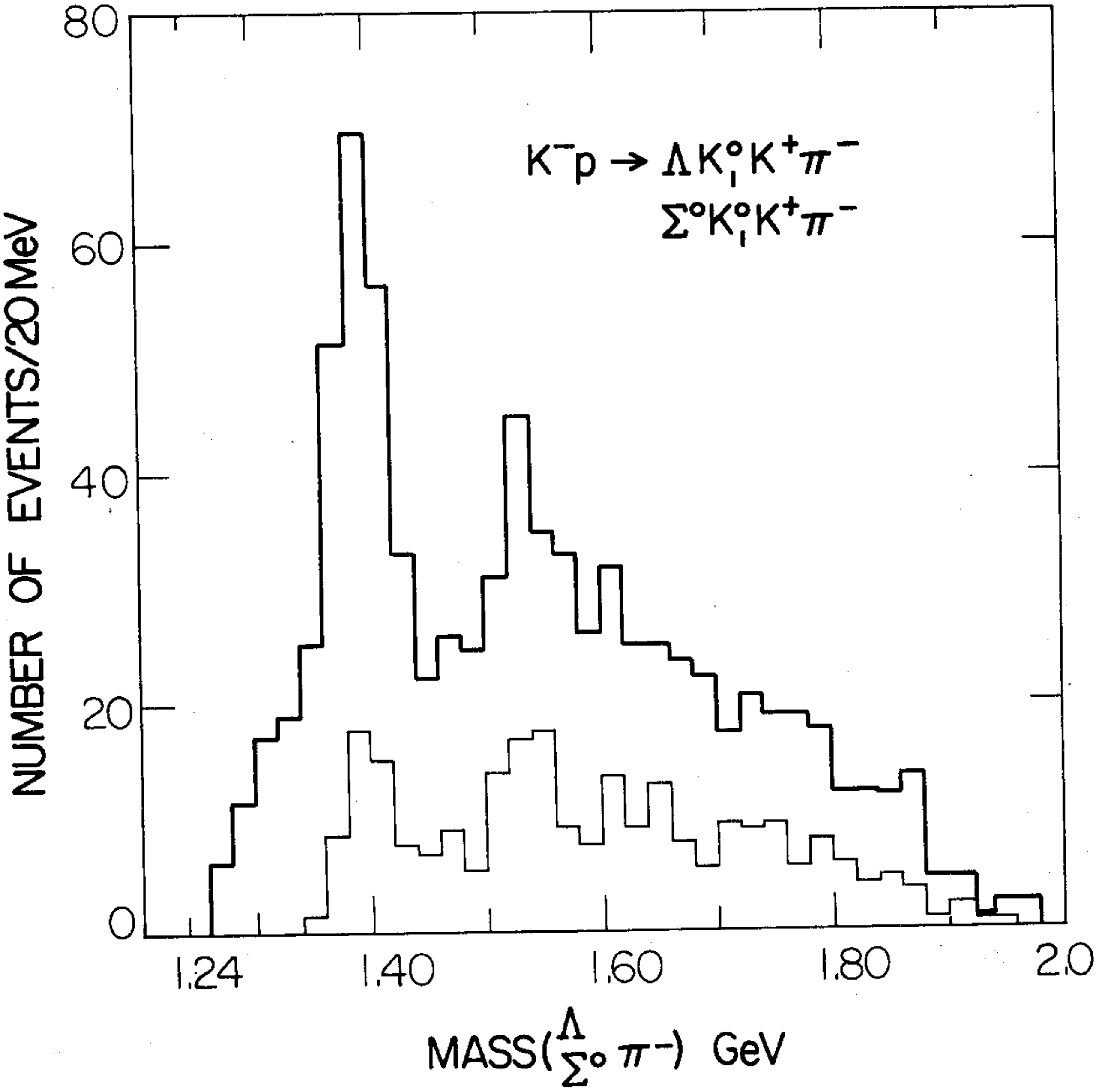
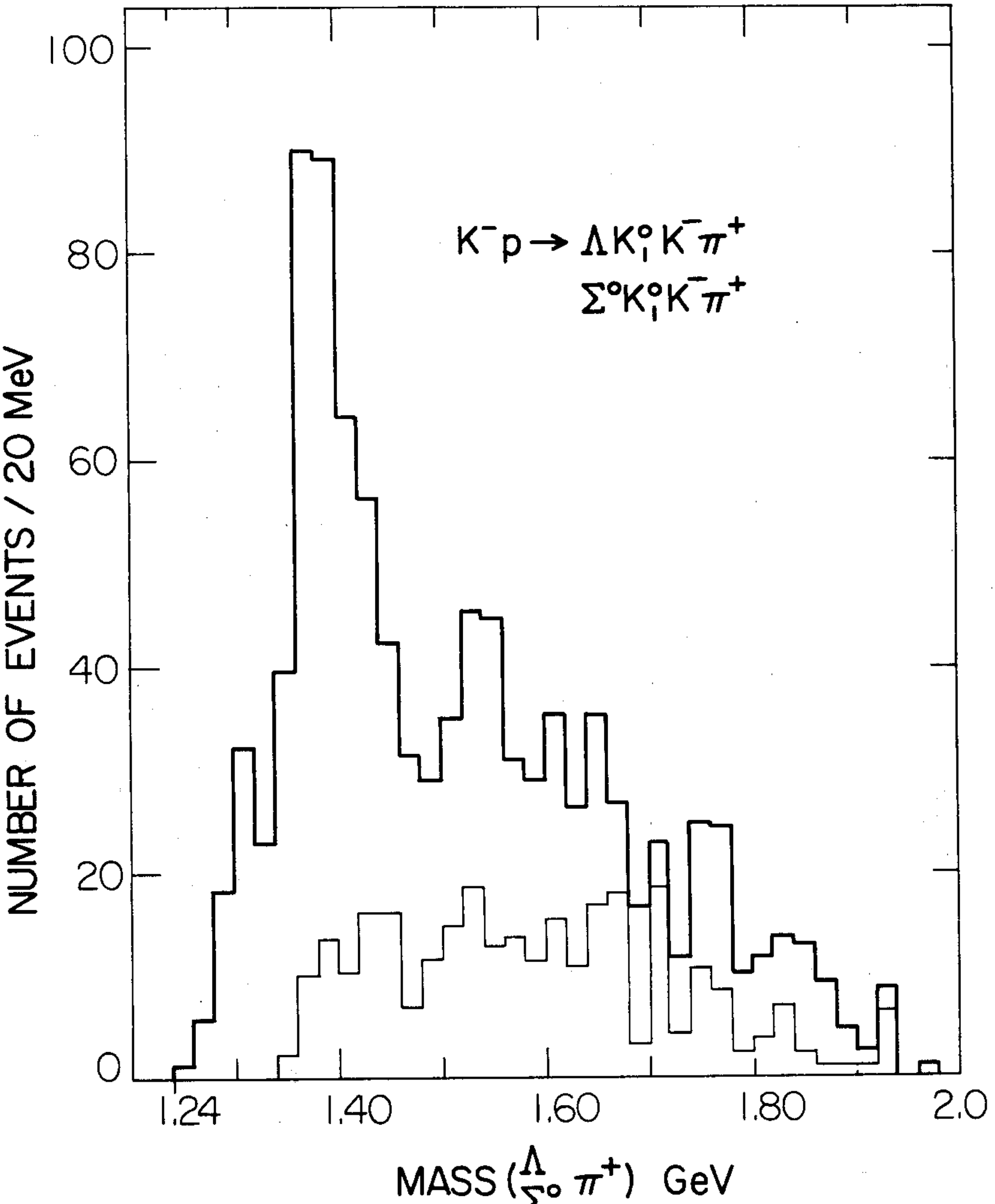

80
60
40
20
0
NUMBER OF EVENTS/20 MeV
$K^-p \rightarrow \Lambda K_1^0 K^+ \pi^-$
$\Sigma^0 K_1^0 K^+ \pi^-$
1.24
1.40
1.60
1.80
2.0
MASS$\left(\begin{smallmatrix}\Lambda \\ \Sigma^0\end{smallmatrix} \pi^-\right)$ GeV

Fig. 1a



$K^-p \rightarrow \Lambda K_1^0 K^- \pi^+$
$\Sigma^0 K_1^0 K^- \pi^+$
NUMBER OF EVENTS / 20 MeV
0
20
40
60
80
100
1.24
1.40
1.60
1.80
2.0
MASS $(\frac{\Lambda}{\Sigma^0}\pi^+)$ GeV

Fig. 1b

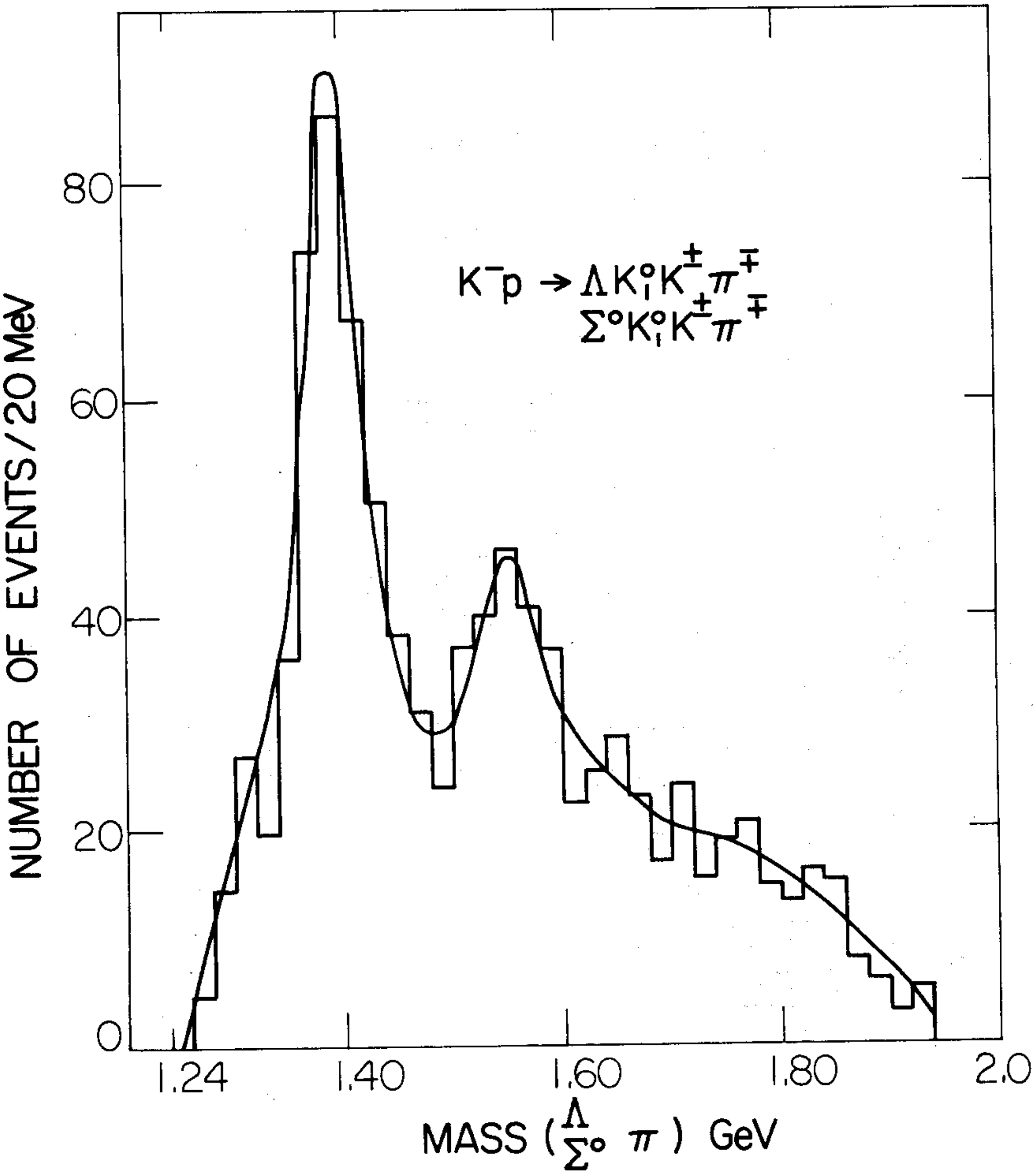

NUMBER OF EVENTS / 20 MeV
0
20
40
60
80
$K^-p \rightarrow \Lambda K_1^\circ K^\pm \pi^\mp$
$\Sigma^\circ K_1^\circ K^\pm \pi^\mp$
1.24
1.40
1.60
1.80
2.0
MASS ($\frac{\Lambda}{\Sigma^\circ}$ π) GeV

Fig. 2a

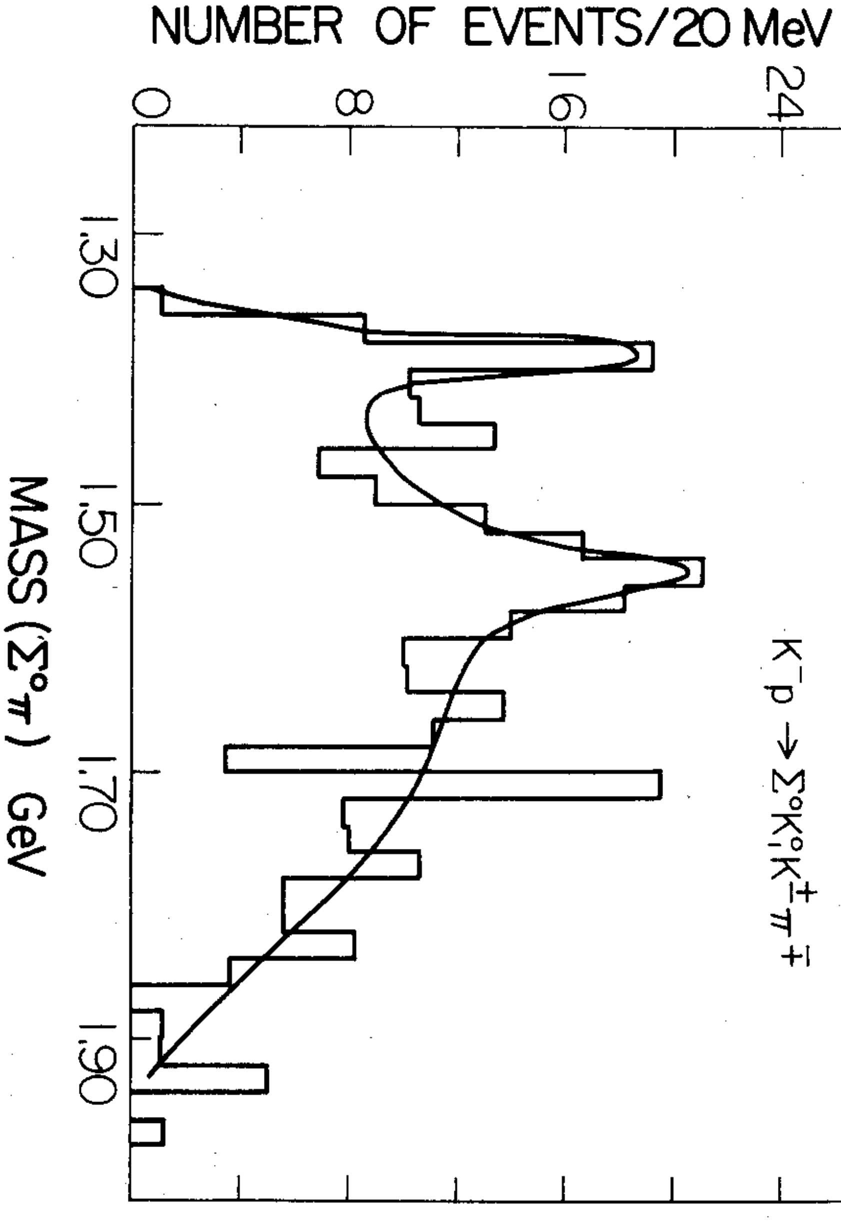

NUMBER OF EVENTS/20 MeV
0
8
16
24
1.30
1.50
1.70
1.90
MASS ($\Sigma^0\pi$) GeV
$K^-p \rightarrow \Sigma^0 K_1^0 K^\pm \pi^\mp$

Fig. 2b

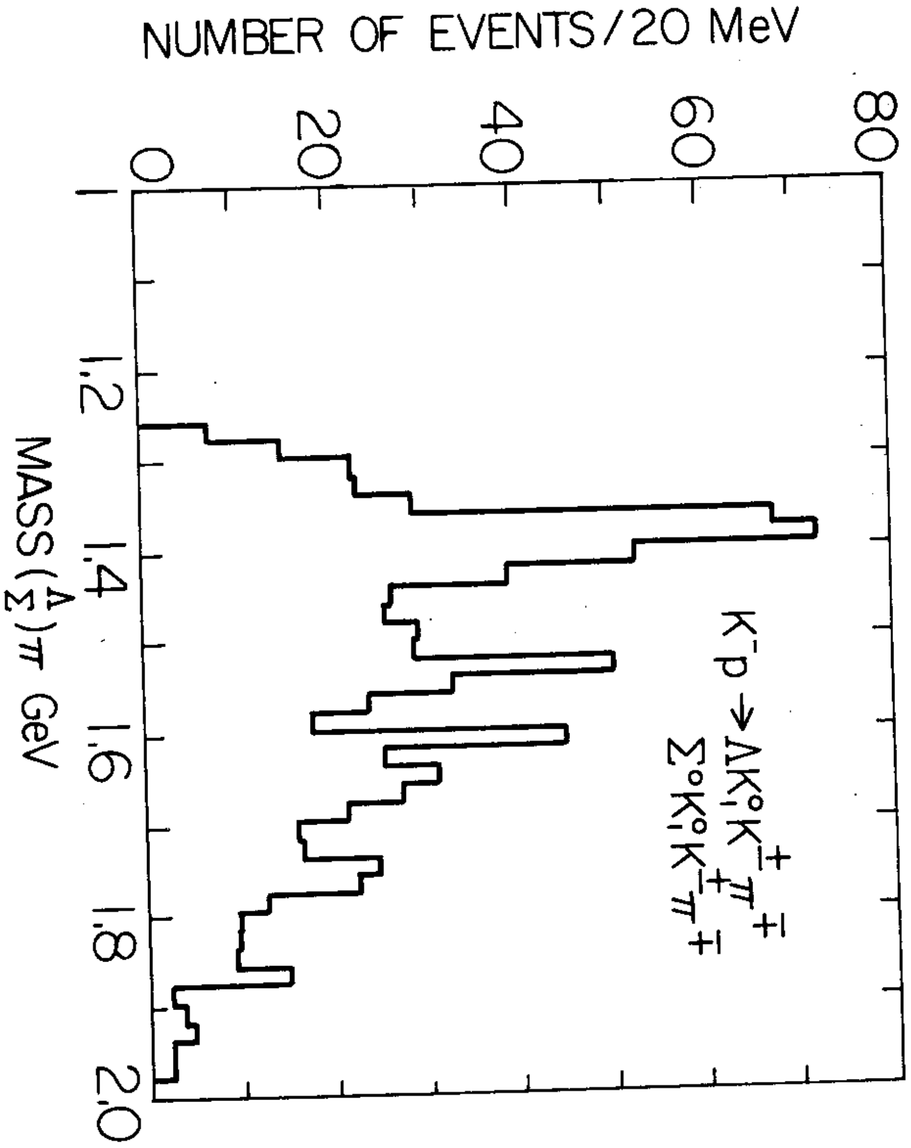

NUMBER OF EVENTS/20 MeV
0
20
40
60
80
1.2
1.4
1.6
1.8
2.0
MASS $\binom{\Lambda}{\Sigma}\pi$ GeV
$K^-p \rightarrow \Lambda K_1^0 K^\pm \pi^\mp$
$\Sigma^0 K_1^0 K^\pm \pi^\mp$

Fig. 3