UCRL- 9693

UNIVERSITY OF CALIFORNIA

Ernest O. Lawrence Radiation Laboratory

BERKELEY, CALIFORNIA

Submitted to Phys. Rev. Letters

UCRL-9693
Limited distribution

UNIVERSITY OF CALIFORNIA
Lawrence Radiation Laboratory
Berkeley, California

Contract No. W-7405-eng-48

SIGMA DECAY MODES OF THE PION-HYPERON RESONANCES

Pierre Bastien, Massimiliano Ferro-Luzzi, and Arthur H. Rosenfeld

May 8, 1961

SIGMA DECAY MODES OF THE PION-HYPERON RESONANCES*

Pierre Bastien, Massimiliano Ferro-Luzzi,† and Arthur H. Rosenfeld

Lawrence Radiation Laboratory and Department of Physics
University of California, Berkeley, California

May 8, 1961

During a study of K^-p interactions in the Lawrence Radiation Laboratory 15-inch hydrogen bubble chamber, we have analyzed a total of 249 three-body reactions of the type

$$K^- + p \rightarrow \Sigma^+ + \pi^- + \pi^0 \tag{1}$$

and

$$K^- + p \rightarrow \Sigma^- + \pi^+ + \pi^0 \tag{2}$$

at incident K^- momenta of 760 and 850 Mev/c. Reactions (1) and (2) are interesting in view of the existence of the resonant pion-hyperon state Y_1^*,[1-6] which is now known to influence strongly reactions such as

$$K^- + p \rightarrow \Lambda + \pi^+ + \pi^-. \tag{3}$$

It is of interest to compare the $\Sigma^\pm$ production via reactions (1) and (2) with the Λ production via (3) to obtain the Σ/Λ branching fraction R for Y_1^*.

On this subject, both current theories agree in predicting values of R largely undetermined but generally "small".[7,8] In particular, global symmetry favors R of the order of a few percent with an upper limit of 25%,[7] while the $\bar{K}N$ "bound-state" model yields generally larger values of R,[8] even if no real lower limit exists, because of the present uncertainty concerning the $\Lambda\Sigma$ parity and the validity of the zero-effective-range theory 50 Mev below the $\bar{K}N$ threshold.

Another interesting feature of reactions (1) and (2) is related to the fact that the dominant decay mode $Y_1^* \rightarrow \Lambda + \pi$ is accessible only to the Y_1^* of isotopic spin 1. However, pion-hyperon resonances in other isotopic spin states such as Y_0^* and Y_2^* can decay into $\Sigma + \pi$; Alston et al. have already reported evidence for the singlet resonance Y_0^*;[9] some evidence for $Y^{*0} \rightarrow \Sigma^{\pm} + \pi^{\mp}$ has also been reported by Eisenberg et al.[10]

Our kinematics program, Kick,[11] easily separates the three-body reactions (1) and (2) from the topologically similar two-body reactions $K^- + p \rightarrow \Sigma^{\pm} + \pi^{\mp}$, and from the four-body reactions $K^- + p \rightarrow \Sigma^{\pm} + \pi^{\mp} + \pi^0 + \pi^0$. A Dalitz plot of the 125 fitted three-body events produced at 850 Mev/c shows the now familiar highly populated bands corresponding to a mass of 1385 Mev for the $\Sigma\,\pi$ system. Figure 1 shows the mass histograms of these events. The upper histogram refers to the charged $\Sigma^{\pm}\,\pi^0$, and the lower to the neutral $\Sigma^{\pm}\,\pi^{\mp}$ system. A small sketch at the upper right represents the scatter diagram in mass space, from which these histograms were projected. The shaded area in the conspicuous $M^{\pm}$ peak is easily attributed to the decay mode $Y^{*\pm} \rightarrow \Sigma^{\pm} + \pi^0$. (In fact, as we shall discuss below, we are forced to conclude that it is only a statistical fluctuation.) From the same hopeful point of view one can explain the broader peak at the right of the $M^{\pm}$ histogram as the $Y^{*0} \rightarrow \Sigma^{\pm} + \pi^{\mp}$ band projected sideways (see sketch). The dashed lines in Fig. 1 represent phase space, normalized to the total number of events. They are seen to be a rather poor fit to the histograms, thus displaying more quantitatively the extra population in the Y^* bands. This fact is taken into account by the solid phase-space curve which refers to the number of events after subtraction of the excess events in the peaks (shaded area of both histograms). In the neutral histogram of Fig. 1, some suggestion of a peak appears at 1500 to 1540 Mev, which is where Y_2^* is expected. However, this is not supported either by our data at 760 Mev/c or by the data for reactions (1) and (2) of Alston et al. at 1150 Mev/c,[12] nor is it borne out by the configuration of events on any of the Dalitz plots. For the rest of this Letter, we shall discuss only the peaks near 1385 Mev and assume that they can be explained in terms of Y_1^* and perhaps the singlet Y_0^* which, according to Alston et al. shows up in the mass region of

1380 to 1430 Mev, partly overlapping Y_1^*.[9] Note that the charged peak can come from $Y_1^{*\pm}$ only, whereas the neutral peak is the sum of contributions from Y_1^{*0} and Y_0^*. We shall discuss the unique charged peak first and determine from it the Y_1^* branching fraction, R.

In the 850 Mev/c column of Table I, the number of events in the shaded area have been used to compute $R^{\pm}$, which is defined as

$$R^{\pm} = \frac{n(Y^{*+} \to \Sigma^+ \pi^0) + n(Y^{*-} \to \Sigma^- \pi^0)}{n(Y^{*+} \to \Lambda \pi^+) + n(Y^{*-} \to \Lambda \pi^-)} .$$

Charge symmetry requires

$$R^{\pm} = R^0 = \frac{n(Y^{*+} \to \Sigma^0 \pi^+) + n(Y^{*-} \to \Sigma^0 \pi^-)}{n(Y^{*+} \to \Lambda \pi^+) + n(Y^{*-} \to \Lambda \pi^-)} .$$

Values of R^0 derived at various momenta[4, 12] from the study of the reaction $K^- + p \to \Sigma^0 + \pi^+ + \pi^-$ are also given in row E of Table I. The 124 events at 760 Mev/c have been treated in the same way and are displayed in Fig. 2. At this momentum neither the Dalitz plot nor the histograms show such a convincing peak structure; the solid lines in Fig. 2 represent phase space and are seen to fit the data adequately. Nevertheless some real peaking may be present, particularly because at 760 Mev/c the Y^* bands in the mass scatter diagram are less well separated, so that they are less easily resolved and are also subject to the interference effects already well known to occur in reaction (3) at the same beam momentum.[13]

The five values of the branching fraction R shown in rows D and E of Table I can now be combined to give an average of (2 ± 2)%. This average must be used with some reservation, since the five input data are not very consistent; their χ^2 value is 8 (its average expected value is 4), and the probability for this fluctuation is only about 10%. However, it is consistent with the value ≈ (5 ± 3)%

observed in deuterium by Levine et al.[14] Therefore, we are inclined to believe that there is substantial evidence that R is less than a few percent and conclude that the 850 Mev/c charged peak is a fluctuation. If R only is a few percent, we can show now that very few of the events in the neutral peak can be attributed to Y_1^{*0}. The argument is as follows: In the production reaction $K^- + p \rightarrow Y^* + \pi$, the $I = 1$ channel cannot produce any Y_1^{*0}, and the $I = 0$ channel gives equal numbers of Y_1^{*0}, Y_1^{*+}, and Y_1^{*-}. From this it can easily be shown that in order to explain the neutral peaks as $Y_1^{*0} \rightarrow \Sigma^\pm + \pi^\mp$, we must assume that the production is dominantly in the $I = 0$ channel and $R \simeq 10\%$. However, Dalitz and Miller have given good arguments in favor of the predominance of the $I = 1$ channel,[14] and furthermore we have just concluded that R is only a few percent.

We then interpret the neutral peaks either as a statistical fluctuation or as evidence for the singlet Y_0^* reported by Wojcicki et al.[9] The excess events in the neutral peaks at each of the three momenta are listed in row F of Table I. The *a priori* probability for this fluctuation is actually quite small; however, such probabilities can give illusory results, so we prefer to illustrate the situation through Fig. 3, which is a combined mass histogram of all the currently available $\Sigma^\pm \pi^\mp \pi^0$ data. It does seem to constitute mild support for Y_0^*. In this connection two disconcerting facts should be noted: (a) The Y_0^* production cross section $\sigma(Y_0^*)$ (row G of Table I) is rather small in comparison with (Y_1^*) (row H). (b) If Y_0^* shows up so strongly in the two small-statistics, four-body final states reported by Alston , et al.,[9] it is disappointing that the larger three-body samples do not confirm it more strongly.

This work is part of a continuing study of low-energy K^-p interactions carried out in collaboration with J. P. Berge, O. Dahl, J. Kirz, D.H. Miller, J. J. Murray, R. D. Tripp, and M. Watson. We thank L. W. Alvarez and many members of his group for their help. In particular, we want to acknowledge close collaboration with the group who ran the 1150 Mev/c experiment: M. H. Alston, L. W. Alvarez, P. Eberhart, M. L. Good, W. Graziano, H. K. Ticho, and S. G. Wojcicki.

Table 1. Data from $K^- + p \rightarrow \Sigma^\pm + \pi^\mp + \pi^0$

	P_K (lab) (Mev/c)	760	850	1150[a]
A.	Total number of events	124	125	111
B.	$\sigma(\Sigma^-\pi^+\pi^0) + \sigma(\Sigma^+\pi^-\pi^0)$(mb)	0.9±0.2	1.7±0.3	1.8±0.2
$Y_1^{*\pm} \rightarrow \Sigma^\pm + \pi^0$				
C.	Events in shaded area	6±7	20±7	-3±5
D.	$R^\pm$ (%)	2±2	15±6	-2±3
E.	R^0 (from $\Sigma^0\pi^+\pi^-$) (%)	1±5	-5±5	unreliable[b]
$Y^{*0} \rightarrow \Sigma^\pm + \pi^\mp$				
F.	Events in shaded area	17±8	16±8	9±10
G.	$\sigma(K^- + p \rightarrow Y^{*0} + \pi^0)$ (mb)	0.12±0.06	0.22±0.11	0.15±0.17
H.	$\sigma(K^- + p \rightarrow Y_1^{*\pm} + \pi^\mp)$ (mb)	2.4±0.15	1.9±0.2	3.1±0.4

---

[a] See reference 12.

[b] The data of row E are plagued with the difficulty of Λ vs Σ^0 separation; the fraction of ambiguous events increases quickly with beam momentum, and at 1150 Mev/c only an upper limit $R^0 < 8\%$ can be stated.

FOOTNOTES

*Work done under the auspices of the U. S. Atomic Energy Commission.

†National Academy of Sciences Fellow.

1. M. Alston, L. W. Alvarez, P. Eberhard, M. L. Good, W. Graziano, H. K. Ticho, and S. G. Wojcicki, Phys. Rev. Letters 5, 520 (1960).
2. O. Dahl, N. Horwitz, D. H. Miller, J. J. Murray, and P. G. White, Phys. Rev. Letters 6, 142 (1960).
3. H. J. Martin, L. B. Leipuner, W. Chinowsky, F. T. Shively, and R. K. Adair, Phys. Rev. Letters 6, 283 (1961).
4. J. P. Berge, P. Bastien, O. Dahl, M. Ferro-Luzzi, J. Kirz, D. H. Miller, J. J. Murray, A. H. Rosenfeld, R. D. Tripp, and M. Watson, Phys. Rev. Letters (in press).
5. R. P. Ely, S. Y. Fuong, G. Gidal, Y. L. Pan, W. M. Powell, and H. White, Bull. Am. Phys. Soc. 6, 291 (1961).
6. M. M. Block, E. B. Brucker, R. Gessaroli, T. Kikuchi, A. Kovacs, C. M. Meltzer, R. Kraemer, M. Nussbaum, A. Pevsner, P. Schlein, R. Strand, H. O. Cohn, E. M. Harth, J. Leitner, L. Lendinara, L. Monari, and G. Puppi, submitted to Nuovo cimento.
7. D. Amati, B. Vitale, and A. Stanghellini, Phys. Rev. Letters 5, 524 (1960).
8. R. H. Dalitz, Phys. Rev. Letters 6, 239 (1961).
9. M. Alston, L. W. Alvarez, P. Eberhard, M. L. Good, W. Graziano, H. K. Ticho, and S. G. Wojcicki, Lawrence Radiation Laboratory Report UCRL-9686, April 28, 1961; submitted to Phys. Rev. Letters.
10. Y. Eisenberg, G. Yekutieli, P. Abrahamson, and D. Kessler, Weizmann Institute of Science, Rehovoth, Israel, private communication.
11. J. N. Snyder and A. H. Rosenfeld, Lawrence Radiation Laboratory Report UCRL-9098, February 16, 1960, submitted to Rev. Sci. Instr.

12. M. Alston, L. W. Alvarez, P. Eberhard, M. L. Good, W. Graziano, H. K. Ticho, and S. G. Wojcicki, Lawrence Radiation Laboratory Report UCRL-9675, April 24, 1961; submitted to Phys. Rev. Letters.

13. R. H. Dalitz and D. H. Miller, Lawrence Radiation Laboratory Report UCRL-9644, April 7, 1961; Phys. Rev. Letters (in press).

14. R. D. Levine, J. J. Murray, D. H. Miller, and J. Schwartz, Lawrence Radiation Laboratory, private communication.

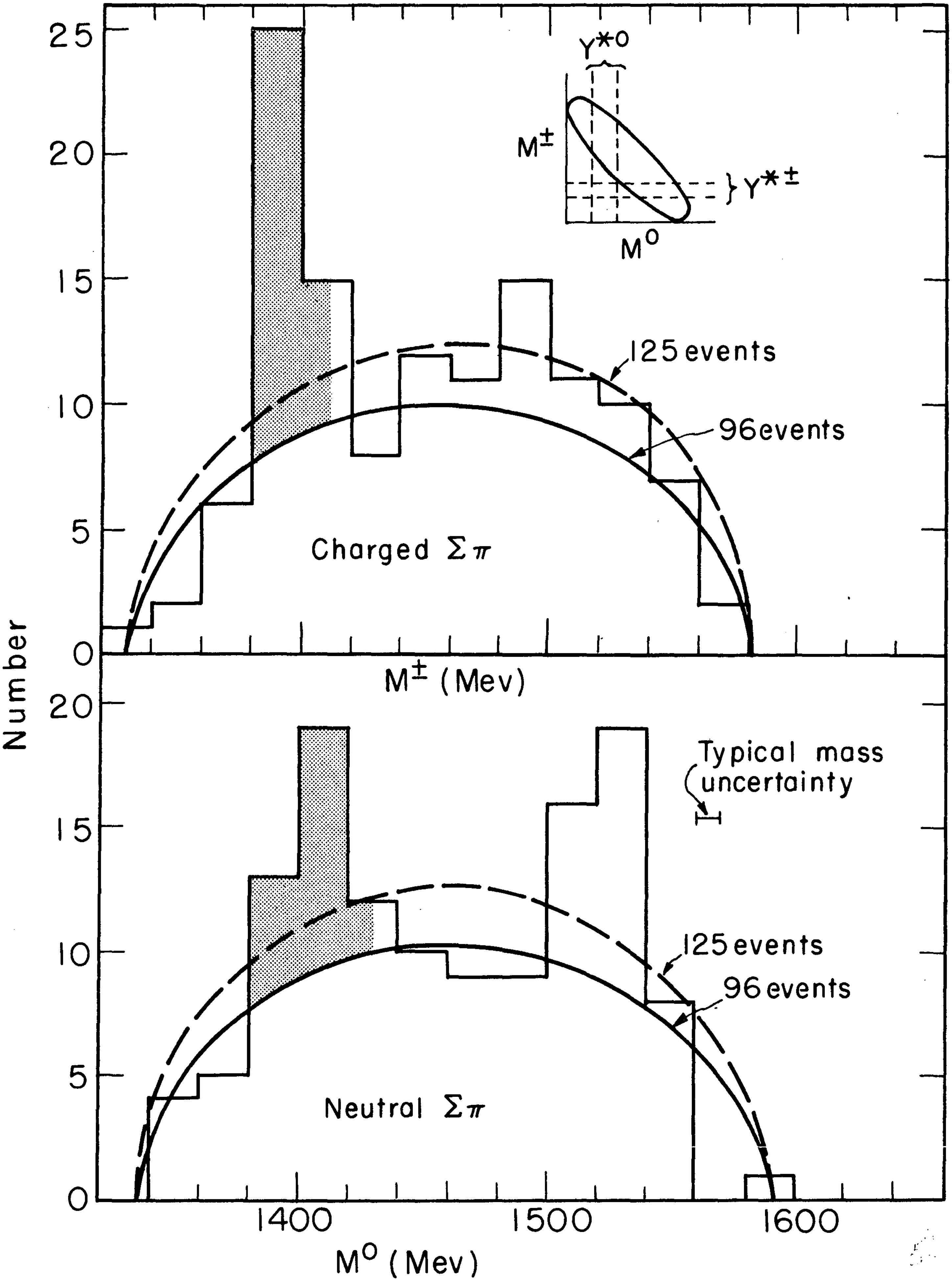
FIGURE CAPTIONS

Fig. 1. Upper histogram: Sum of the mass spectrum for the $\Sigma^+ \pi^0$ and $\Sigma^- \pi^0$ systems based on 49 reactions (1) and 76 reactions (2) at P_K = 850 Mev/c. Lower histogram: Sum of $\Sigma^+ \pi^-$ and $\Sigma^- \pi^+$ masses from the same reactions. The dashed curve labeled "125 events" represents phase space normalized to all 125 events. The solid curve labeled "96 events" allows for the subtraction of the shaded areas in the Y^* peaks. For clarity, only the phase space for reaction (2) is shown; the difference from that for reaction (1) is negligible. The shaded area for charged $\Sigma \pi$ ranges from 1380 to 1410 Mev, which are the limits seen experimentally in the $Y_1^{*\pm} \rightarrow \Lambda + \pi^\pm$ mass distribution;[4] the neutral shading runs from 1380 and 1430, as suggested by Alston et al.[9] for the Y_0^*.

Fig. 2. Data from 55 reactions (1) and 69 reactions (2) at P_K = 760 Mev/c. The same considerations as for Fig. 1 apply here.

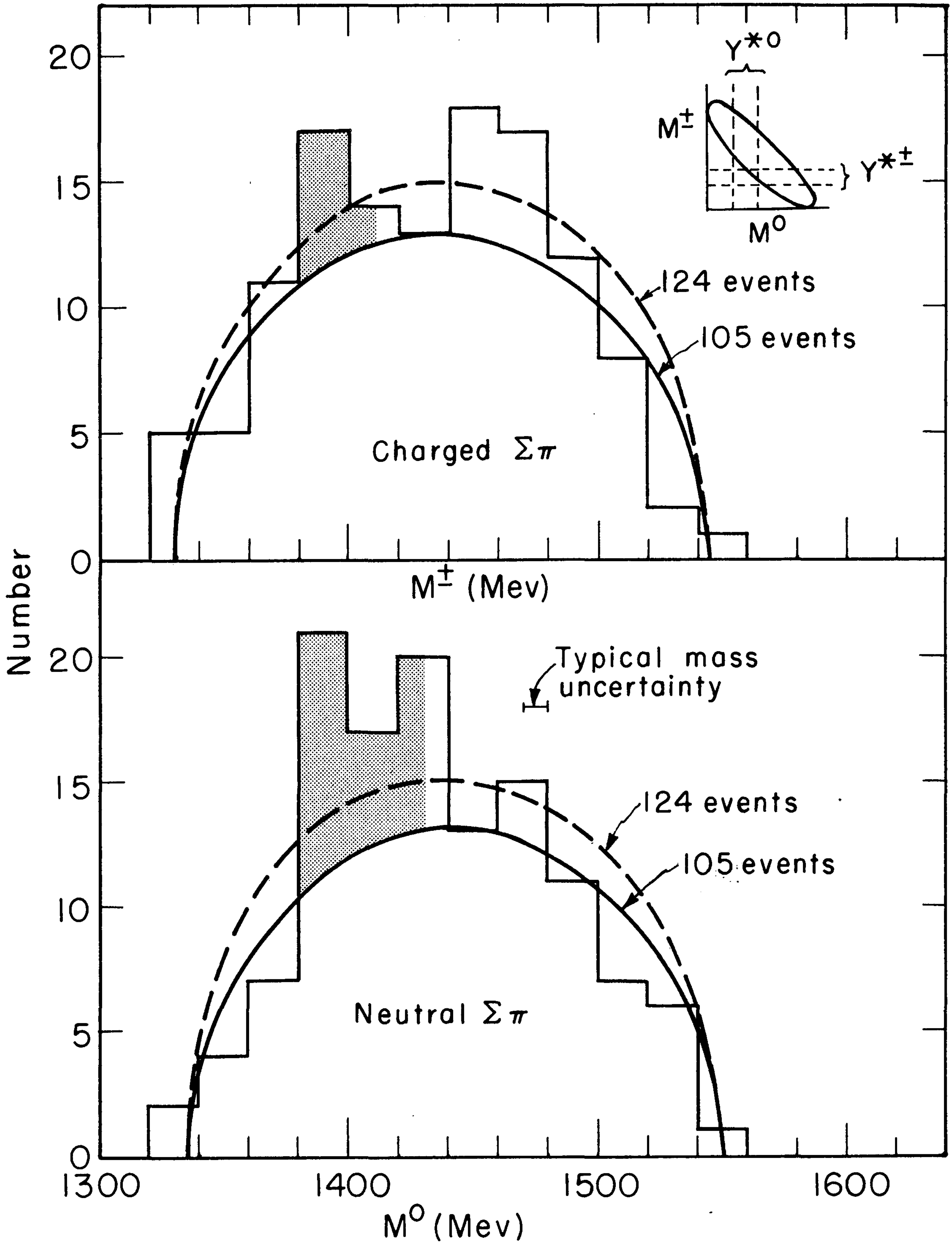
Fig. 3. Combined histogram of 305 $\Sigma^\pm \pi^\mp$ pairs at 760, 850, and 1150 Mev/c. The neutral pairs from Figs. 1 and 2 have been added to those in Fig. 2 of Alston et al. (1150 Mev/c).[13] The dashed curve, labeled "305 events" is the sum of the dashed phase-space curves of our Figs. 1 and 2 and Fig. 2 of Alston et al. The solid curve is the sum of our solid curves (in which we assume the existence of a neutral peak containing 17 events at 760 Mev/c and 16 at 850) and a corresponding curve that assumes 19 events at 1150 Mev/c, as shown in Table I.

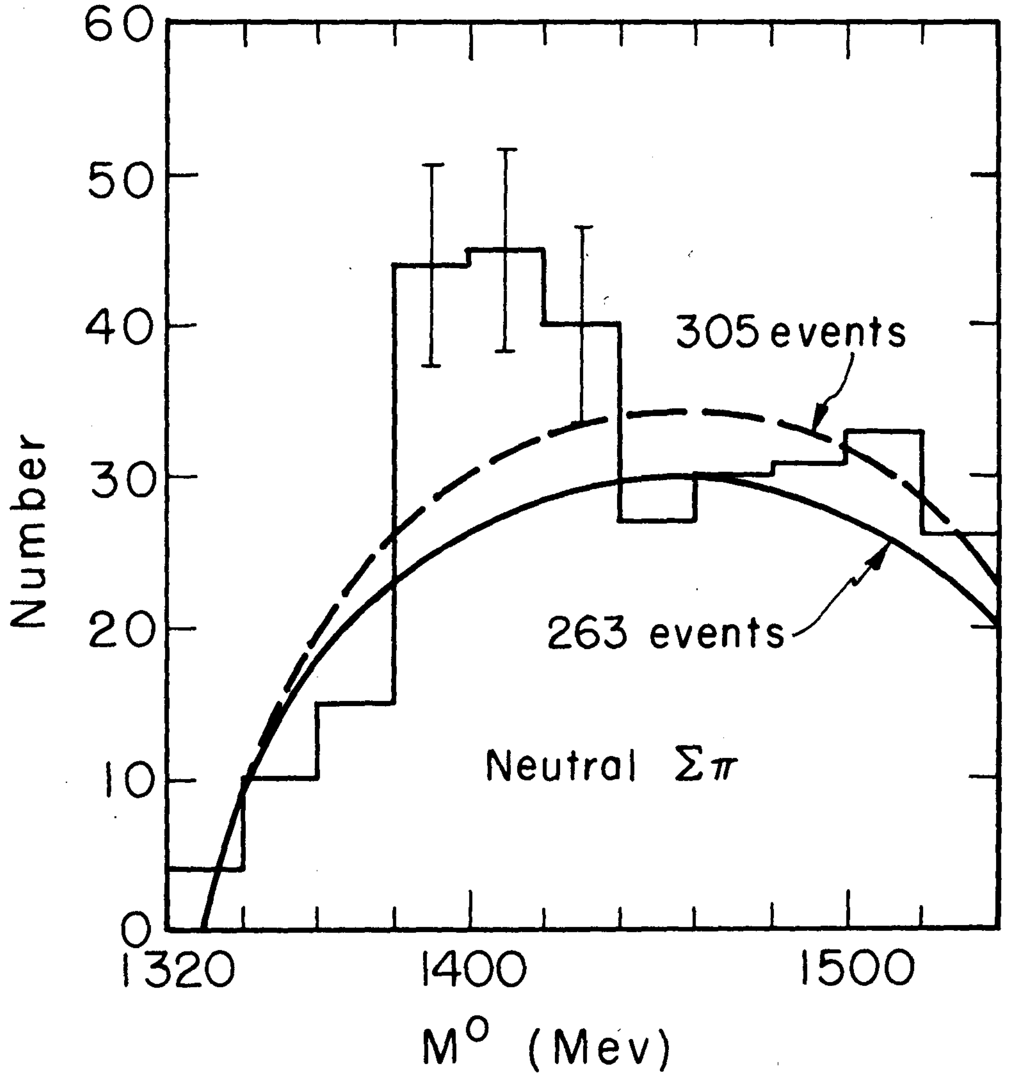
F. 1


Number
25
20
15
10
5
0
Y*0
M±
Y*±
M0
125 events
96 events
Charged Σπ
M± (Mev)
20
15
10
5
0
Typical mass uncertainty
125 events
96 events
Neutral Σπ
1400
1500
1600
M0 (Mev)

[illegible]

Fig 2


Number
20
15
10
5
0
Y*o
M±
Y*±
M0
124 events
105 events
Charged Σπ
M± (Mev)
Typical mass uncertainty
Neutral Σπ
1300
1400
1500
1600
M0 (Mev)


60
50
40
30
20
10
0
Number
1320
1400
1500
M^0 (Mev)
305 events
263 events
Neutral $\Sigma\pi$