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Production of Strange Particles by π^+- p Collisions at 2.08 GeV/c *

by

Horst W. J. Foelsche and Henry L. Kraybill

Yale University, New Haven, Connecticut

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This report summarizes the principal results to date from a study of the production of strange particles in hydrogen by 2.08 GeV/c positive pions. The interactions were photographed in the Brookhaven 20 inch bubble chamber operating in the electrostatically separated beam at the Brookhaven Alternating Gradient Synchrotron. Forty thousand pictures with an average of 18 tracks per picture have been scanned. A track length of 1.37×10^5 meters, or two microbarns per event, has been selected for determination of cross sections. A total of 393 reactions involving production of strange particles have been identified. Of these events, 304 have been used for determination of cross sections.

The cross sections for the various reactions producing strange particles are given in Table I. The total cross section, 0.72 mb, is much higher than that previously observed[1] at 1.39 GeV/c. However, the production of $\Sigma^+ K^+$ is weaker at 2.08 GeV/c than at 1.39 GeV/c. Figure 1 shows cross sections for the reaction $\pi^+ + p \rightarrow \Sigma^+ + K^+$, observed at various primary pion momenta. It is clear that the $\Sigma^+ K^+$ production cross section attains a maximum value at a pion momentum between 1.39 GeV/c and 2.08 GeV/c.

The angular distribution of the Σ^+ in the center of mass of the final state $\Sigma^+ K^+$ is shown in Figure 2. At 2.08 GeV/c, the hyperon shows a strong backward tendency, especially at small angles. For comparison, the angular distributions at 1.11 and 1.39 GeV/c are also shown.[1] The angular distributions at energies near threshold have been interpreted[1, 2] as a combination of S- and P- wave production states. At 1.39 GeV/c, the onset of higher momenta is indicated and at 2.08 GeV/c, high angular momenta clearly predominate. It appears profitable to attempt to interpret production at this higher energy in terms of a peripheral interaction model.

The reaction $\pi^+ + p \rightarrow \Sigma + K + \pi$ has three final charge states: $\Sigma^+ K^+ \pi^o$, $\Sigma^+ K^o \pi^+$, and $\Sigma^o K^+ \pi^+$. If charge independence is valid, triangular inequalities exist between the following three quantities: $2\sqrt{\sigma_{\Sigma^+ K^+ \pi^o}}$, $\sqrt{\sigma_{\Sigma^+ K^o \pi^+}}$, and $2\sqrt{\sigma_{\Sigma^o K^+ \pi^+}}$. It appears from Table I that these inequalities are satisfied.

The reaction $\pi^+ + p \rightarrow \Lambda^o + K^+ + \pi^o$ is strongly dominated by formation of the Λ - π resonance at mass 1385 MeV. Figure 3 shows a Dalitz plot of Λ^o- π^+ effective mass versus K^+ - π^+ effective mass for this reaction. Besides the pronounced concentration of events at Λ - π mass of 1385 MeV, there is a second more diffuse accumulation above 1600 MeV. This may be caused by the recently reported resonance [3] at 1660 MeV. If so, a study of this reaction at higher incident energy should give valuable information about the properties of this resonance. The distribution of $K^+ \pi^+$ mass within the Y^* events in Figure 3 shows symmetry of the pion decay with respect to the Y^* line of flight, suggesting that the Y^* decay is independent of the production.

Figure 4 shows the distribution of Λ^o - π^+ effective mass in the $\Lambda^o K^+ \pi^+$ final state. The absence of events between 1440 MeV and 1500 MeV indicates a very low background, certainly less than 10%, at the 1385 MeV Y^*. This circumstance should make this reaction at this energy very favorable for studying Y^* properties. The mass and width of a Breit-Wigner resonance formula have been adjusted so as to give highest likelihood to the data in Figure 4. Background was assumed negligible. The mass and width values obtained in this way are: mass of 1382 $\pm$ 4 MeV, and full width at half maximum of 28 $^{+8}_{-4}$ MeV. This value is smaller than the width reported by most other observers [4], and is not very consistent with the value of 50 MeV which is generally quoted.[5] Because of the small background and the absence of other known resonances in the final state $\Lambda^o K^+ \pi^+$, it is not likely that our narrow width is caused by interference. On the other hand, our value is consistent with the width of 26$\pm$ 5 MeV found in antiproton-proton reactions[6] at 3.69 GeV/c, and with some other experiments[7].

The angular distributions of the production and decay of the Y^* are shown in Figures 5 and 6. The Y^* is produced predominantly in the backward hemisphere in the center of momentum. Previous work[8] has determined the spin of the Y^* to be 3/2, with a high degree of probability. Assignment of spin greater than 1/2 is supported here by the anisotropy of the lambda with respect to the normal of the Y^* production plane, in the rest system of the Y^*, shown in Figure 6. The deviation from anisotropy is about 2.5 standard deviations.

We have also examined the three-body final states $\Sigma^+ K^+ \pi^o$ and $\Sigma^+ K^o \pi^+$ for evidence of other resonances. The 885 MeV K* is present in both of these states, as shown in Figures 7-10. However, the data are too meager to indicate either presence or absence of the 730 MeV resonance.[9] Also, the broad I = 3/2 nucleon resonance at mass 1920 MeV does not seem to influence the $\Sigma^+ K^+$ mass distribution in the final state $\Sigma^+ K^+ \pi^o$ (see Figure 11). In Figure 11, the peak that does occur near 1800 MeV appears to be a reflection of the K^*.

A hyperon resonance with mass 1500-1600 MeV and I-spin of 2 has been theoretically predicted.[10] Our $\Sigma^+\pi^+$ mass distribution for the $\Sigma^+ K^o \pi^+$ final state, shown in Figure 12, shows a broad peak centered at 1500 MeV. However, interference from the K^*, which dominates this reaction, must also be considered. If the K^* decays predominantly at large angles with respect to its line of flight, it will produce a broad peak in the $\Sigma^+ \pi^+$ mass distribution in the position shown. We therefore believe that we cannot draw any conclusion about an I = 2 resonance from these data.

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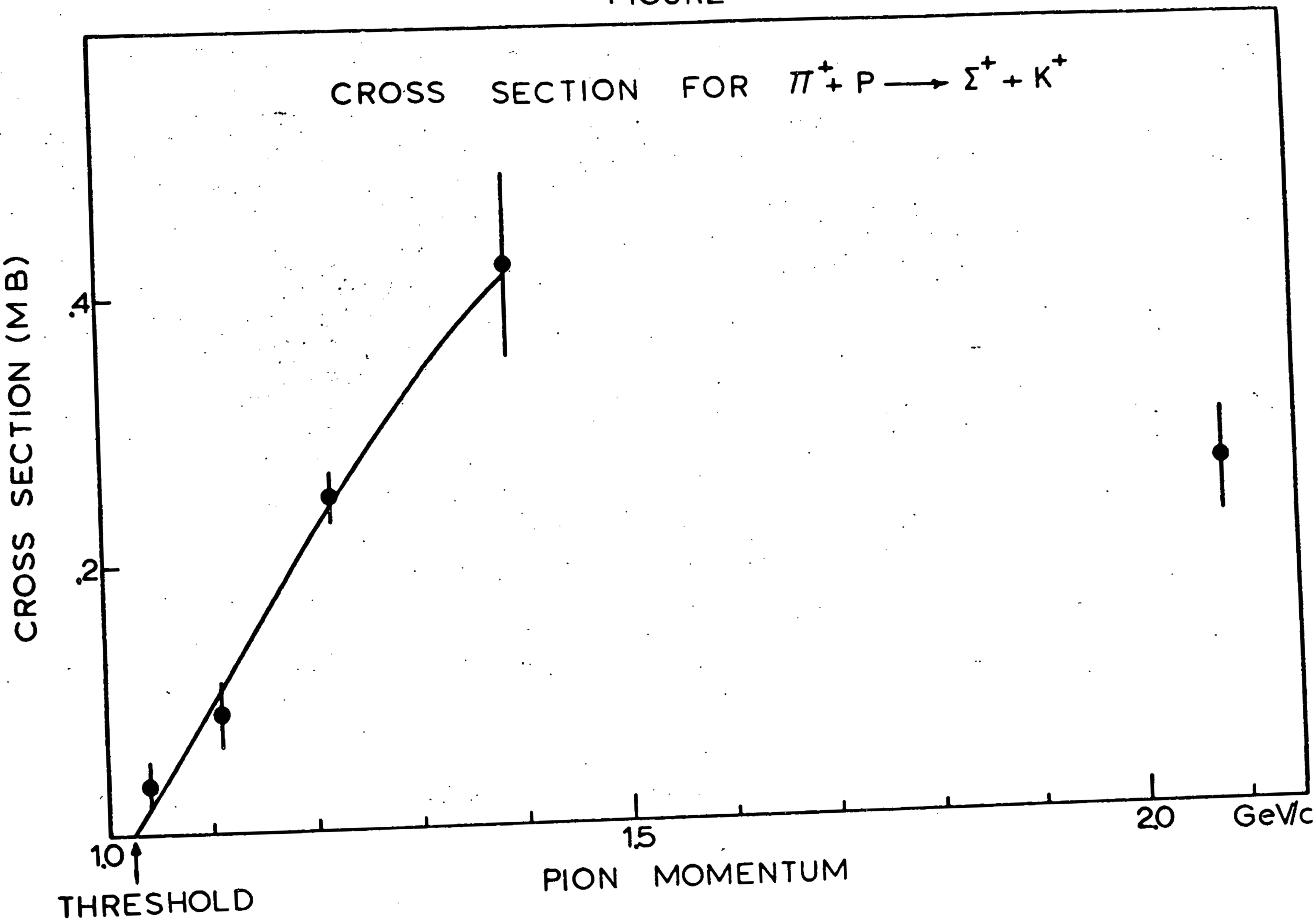
TABLE 1

CROSS SECTIONS FOR PRODUCTION OF STRANGE PARTICLES IN $\pi^+ + P$ COLLISIONS AT 2.08 BeV/c

PRODUCTS	σ (MICROBARNS)
$\Sigma^+ K^+$	260 ± 40
$\Sigma^+ K^+ \pi^0$	140 ± 25
$\Sigma^+ K^0 \pi^+$	70 ± 20
$\Sigma^0 K^+ \pi^+$	37 ± 20
$\Lambda^0 K^+ \pi^+$	130 ± 35
$P K^+ \overline{K^0}$	50 ± 25
$\Lambda^0 K^+ \pi^+ \pi^0$	15 ± 11
$\Lambda^0 K^0 \pi^+ \pi^+$	15 ± 11
TOTAL	720 ± 70

FIGURE 1



CROSS SECTION FOR $\pi^+ + P \longrightarrow \Sigma^+ + K^+$
CROSS SECTION (MB)
.4
.2
1.0
1.5
2.0
GeV/c
PION MOMENTUM
THRESHOLD

FIGURE 2

ANGULAR DISTRIBUTION OF Σ^+ IN $\pi^+ + P \longrightarrow \Sigma^+ + K^+$

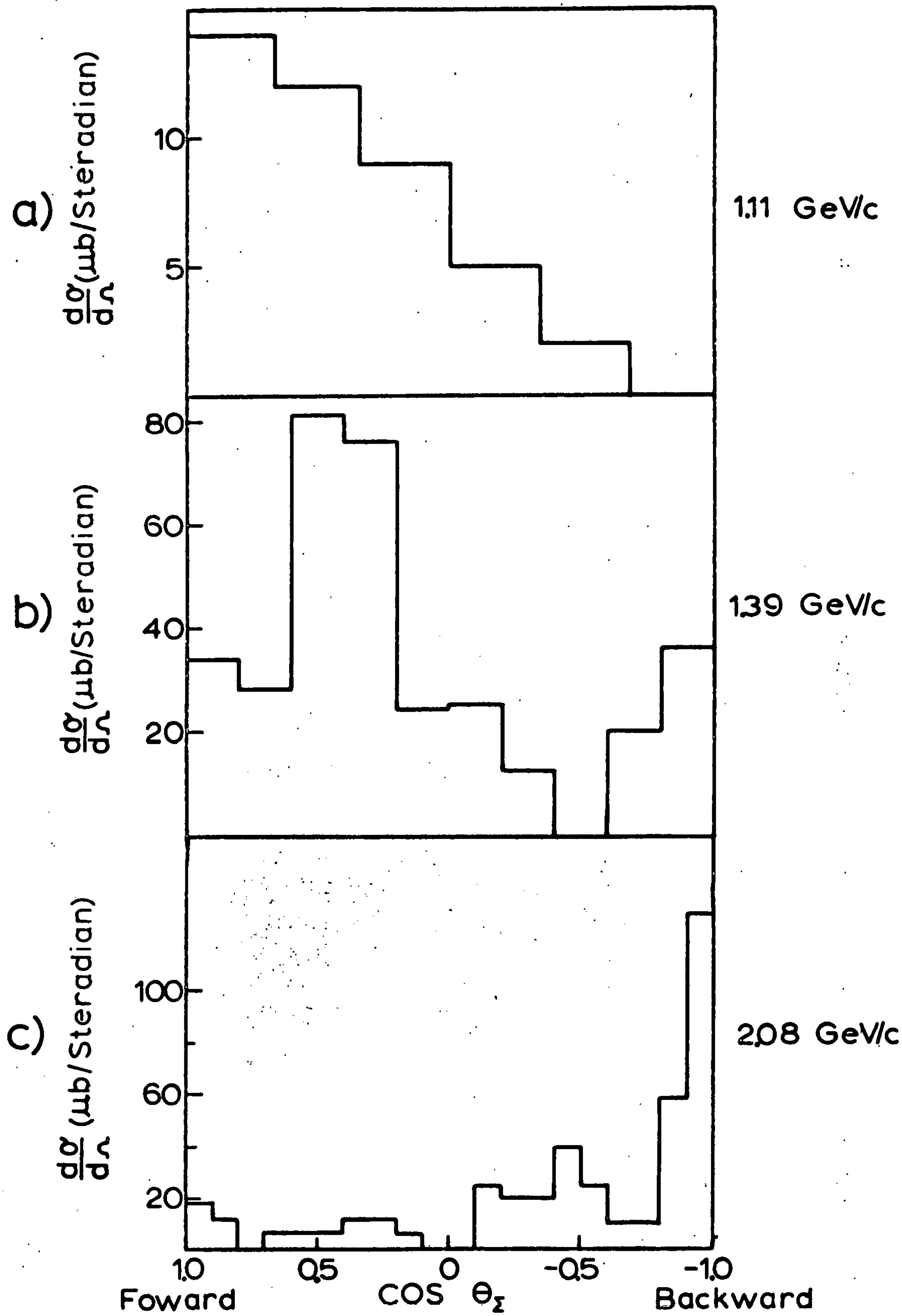
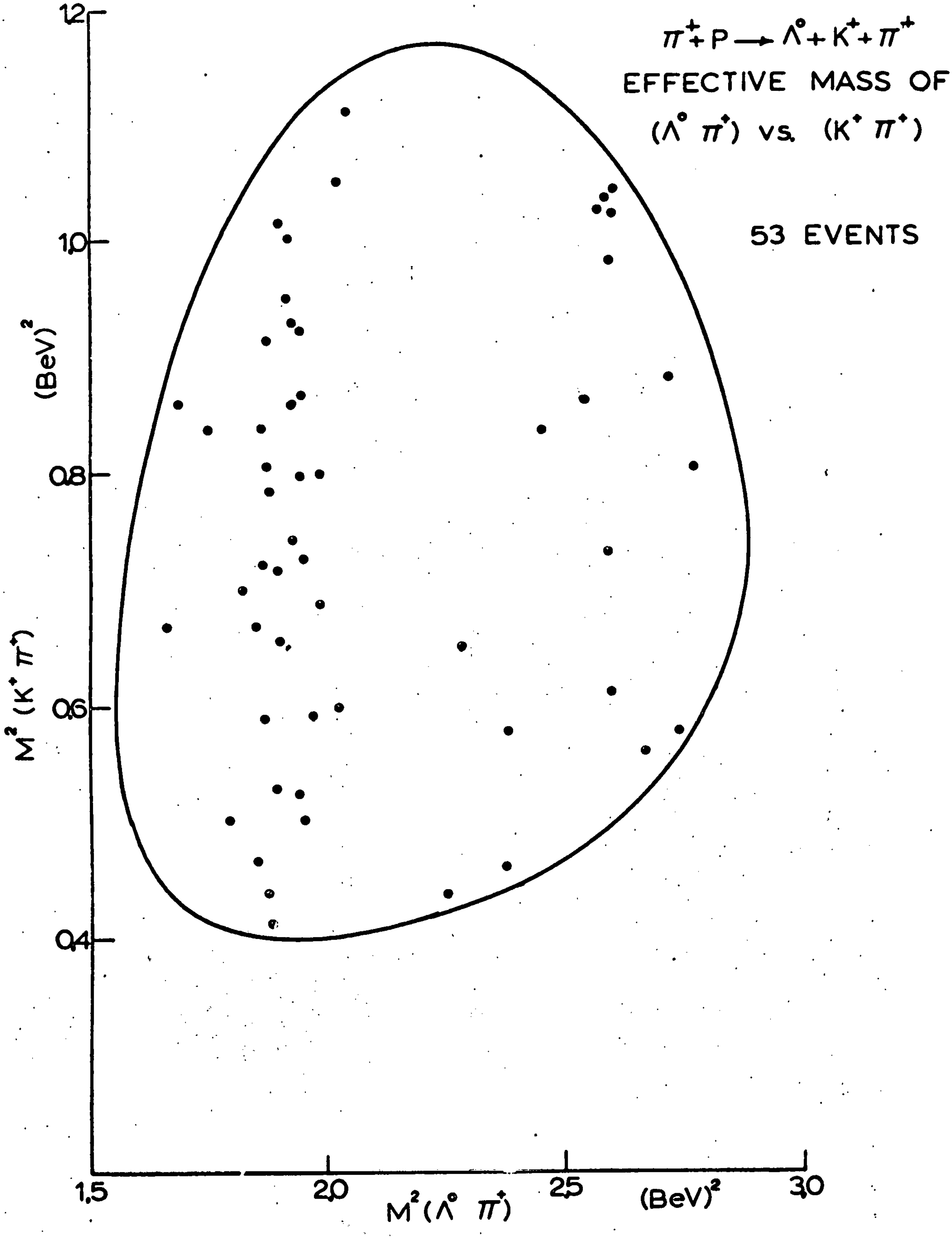


FIGURE 3



$\pi^+ + P \rightarrow \Lambda^0 + K^+ + \pi^+$
EFFECTIVE MASS OF
(Λ^0 π^+) vs. (K^+ π^+)
53 EVENTS
1.2
1.0
0.8
0.6
0.4
M^2 (K^+ π^+) $(BeV)^2$
1.5
2.0
2.5
3.0
M^2(Λ^0 π^+) $(BeV)^2$

FIGURE 4

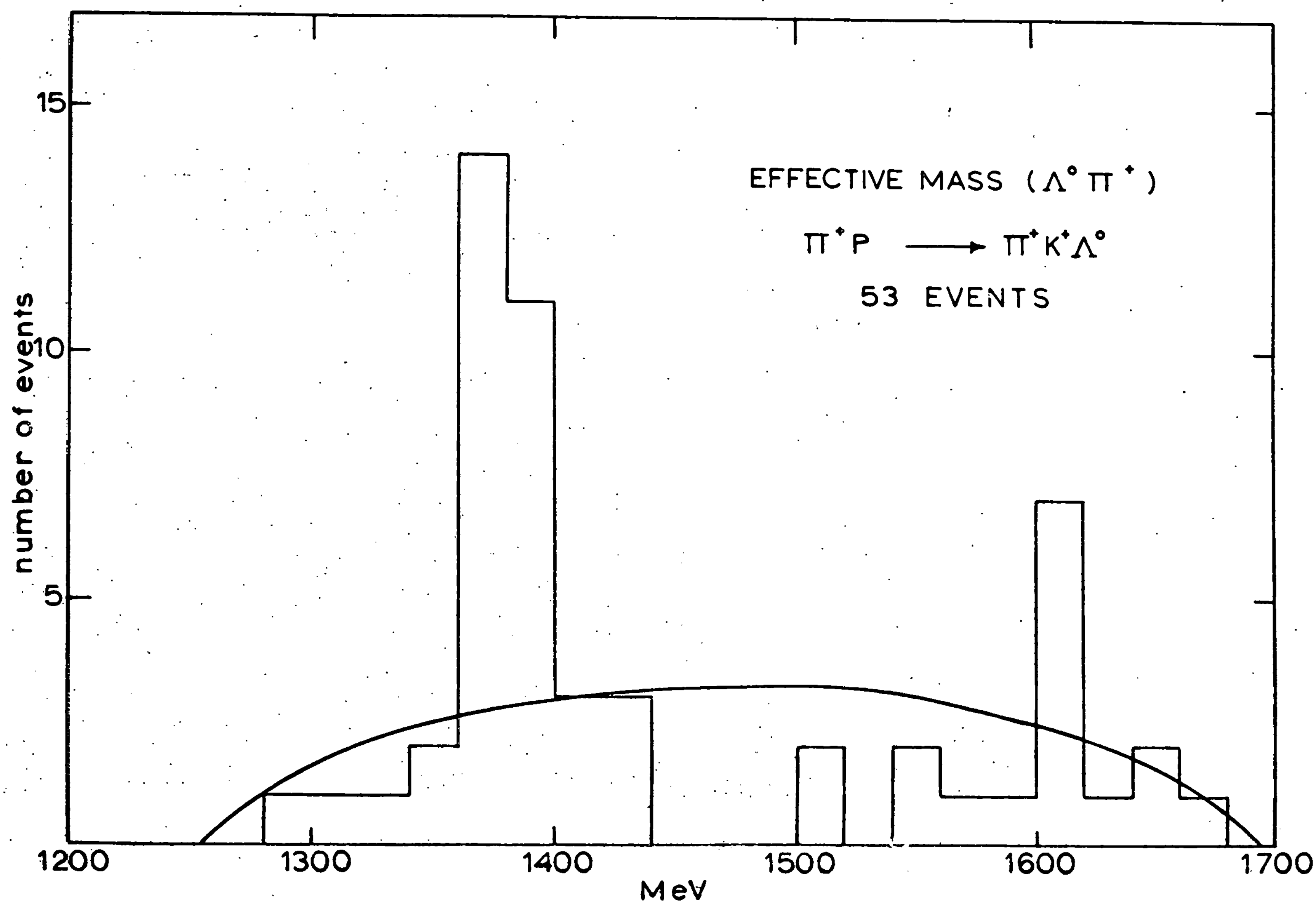
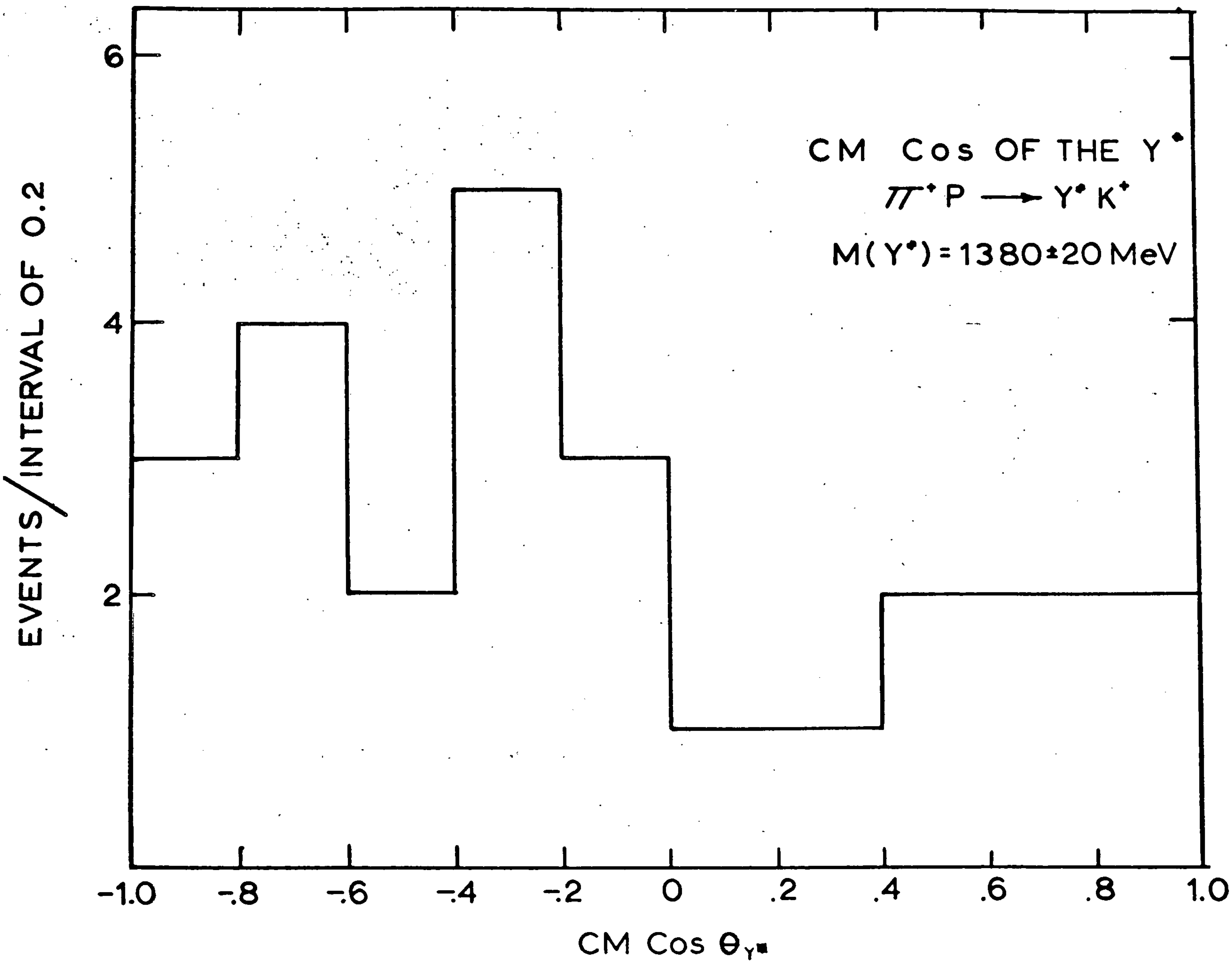

EFFECTIVE MASS ($\Lambda^\circ \pi^+$)
$\pi^+ P \longrightarrow \pi^+ K^+ \Lambda^\circ$
53 EVENTS
number of events
15
10
5
1200
1300
1400
1500
1600
1700
MeV

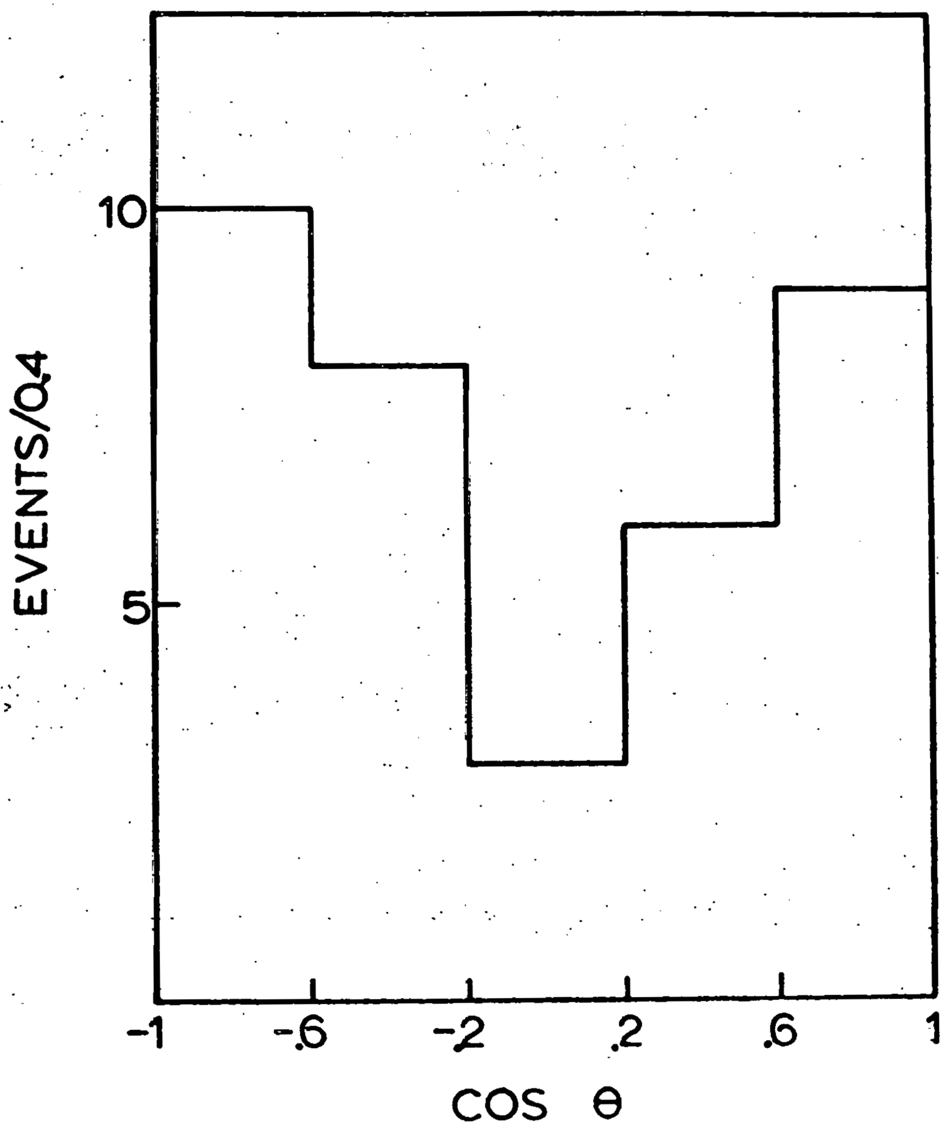
FIGURE 5



CM Cos OF THE Y*
π⁺ P ⟶ Y* K⁺
M(Y*) = 1380±20 MeV
EVENTS/INTERVAL OF 0.2
6
4
2
-1.0
-.8
-.6
-.4
-.2
0
.2
.4
.6
.8
1.0
CM Cos θ_Y*

FIGURE 6

$\pi^+ + P \longrightarrow K^+ + Y^*$, $Y^* \longrightarrow \Lambda^\circ + \pi^+$



COS θ WITH BEAM CROSS Y^* of Λ IN Y^*CM.

FIGURE 7

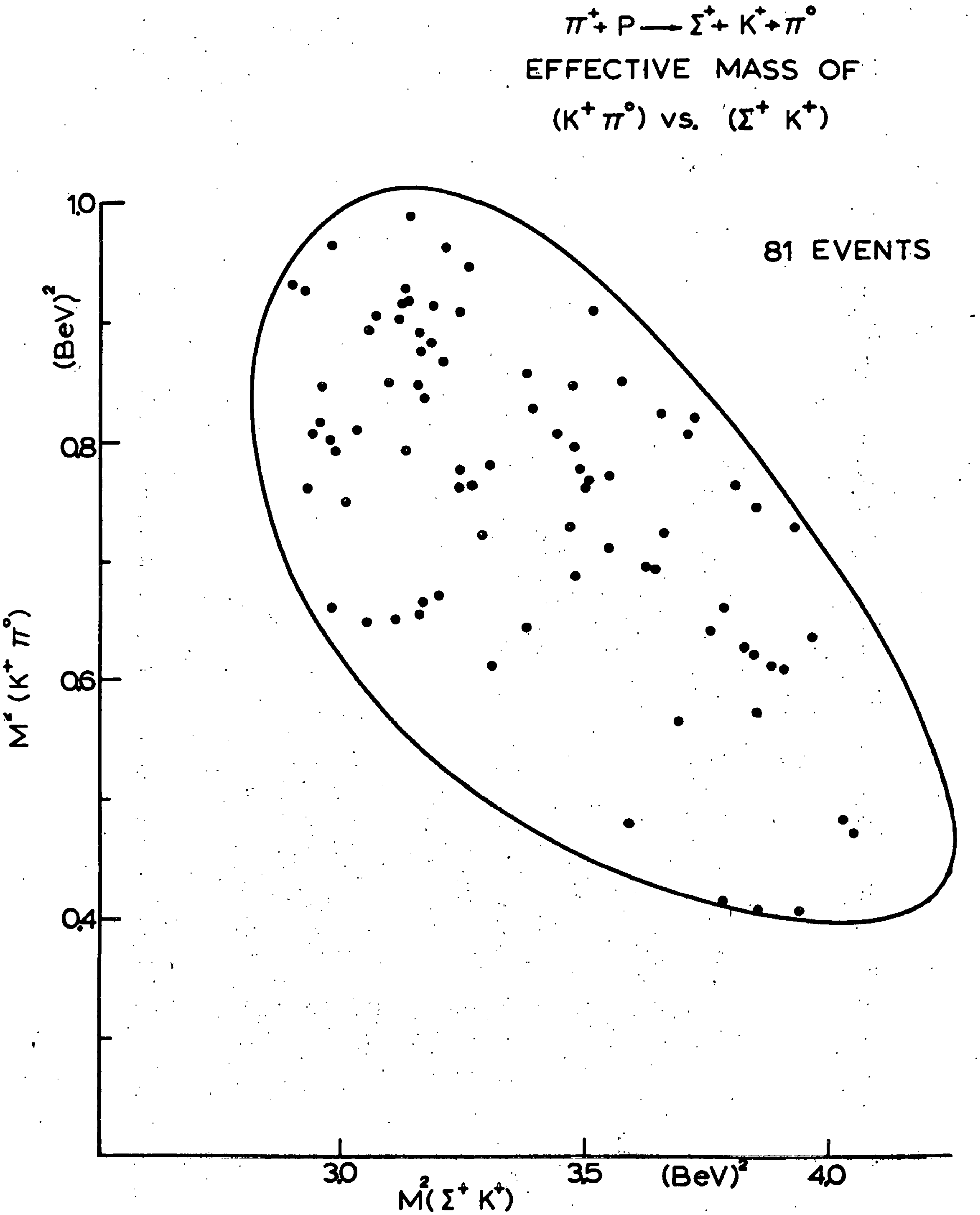
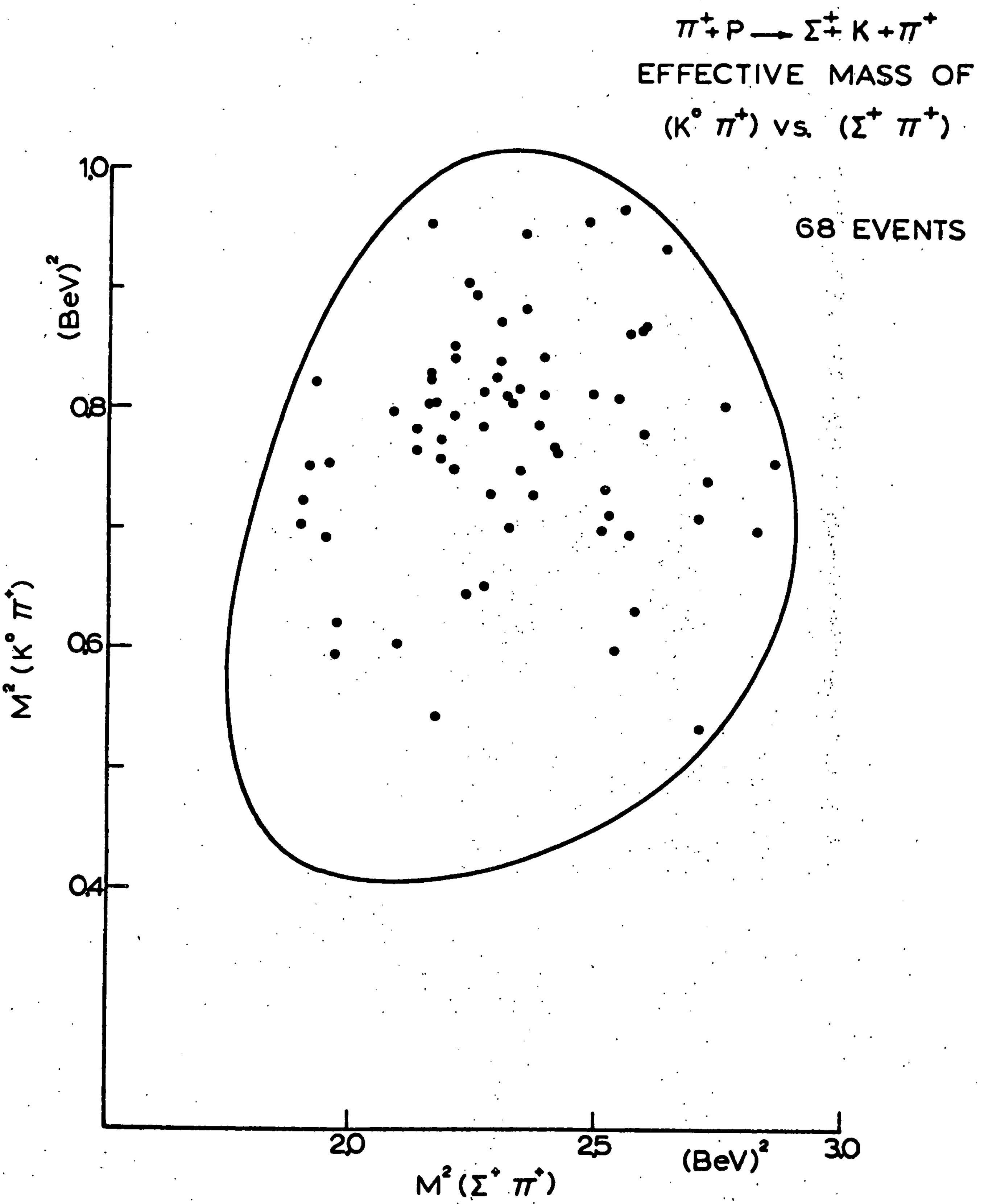
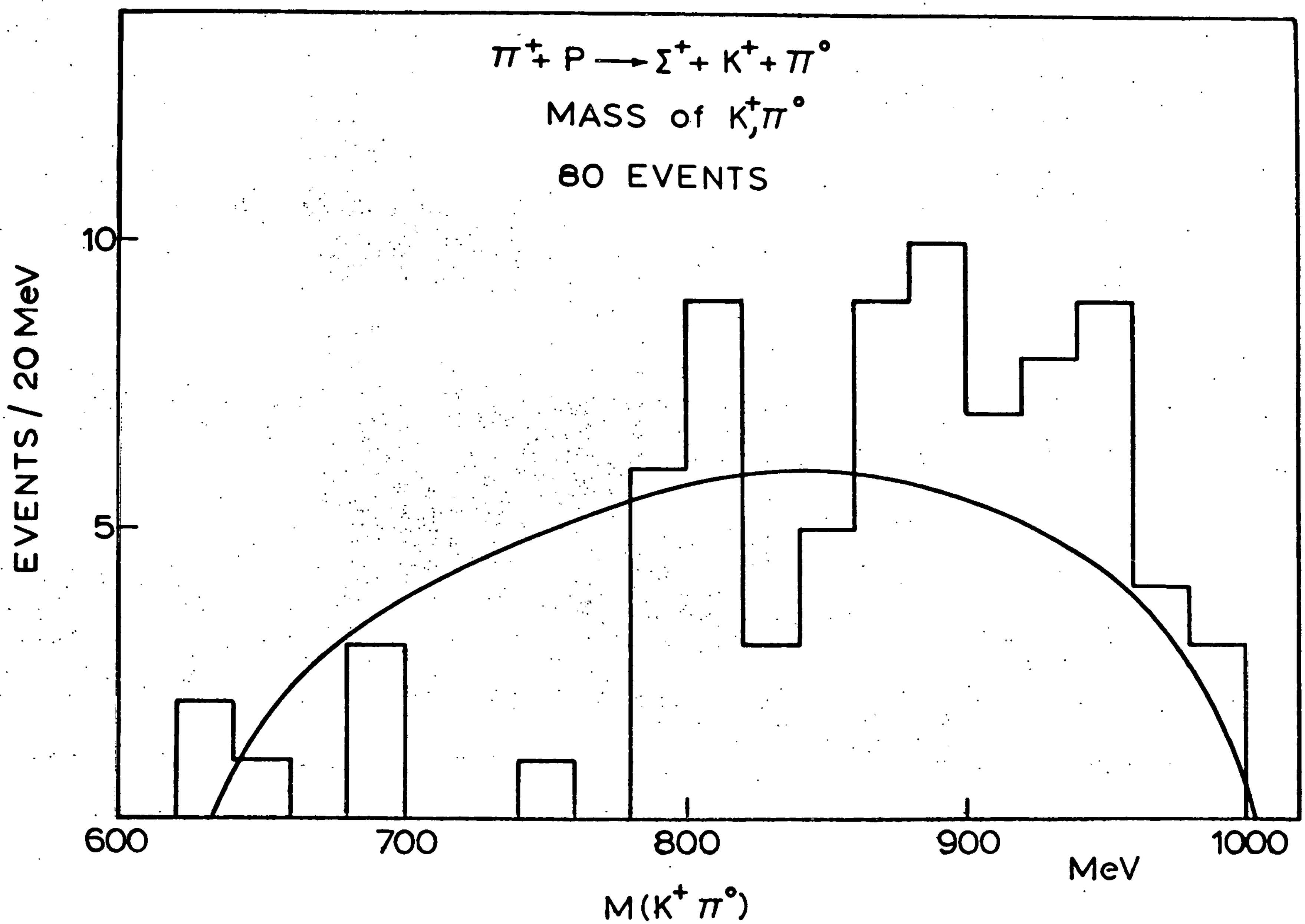

$\pi^+ + P \longrightarrow \Sigma^+ + K^+ + \pi^\circ$
EFFECTIVE MASS OF
$(K^+ \pi^\circ)$ vs. $(\Sigma^+ K^+)$
81 EVENTS
1.0
0.8
0.6
0.4
$M^2(K^+ \pi^\circ)$ $(BeV)^2$
3.0
3.5
4.0
$(BeV)^2$
$M^2(\Sigma^+ K^+)$

FIGURE 8



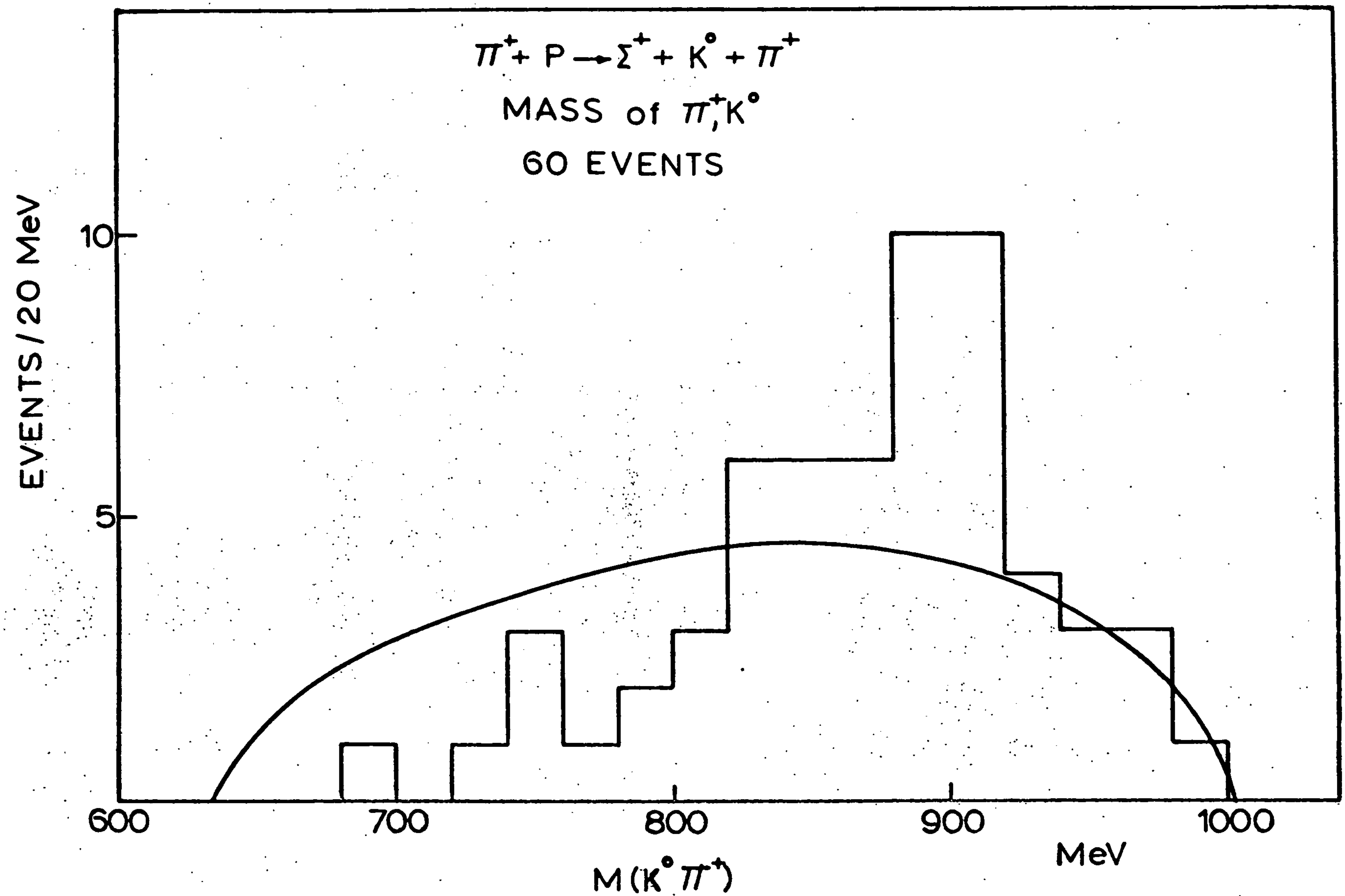
π⁺ + P → Σ⁺ + K + π⁺
EFFECTIVE MASS OF
(K° π⁺) vs. (Σ⁺ π⁺)
68 EVENTS
1.0
0.8
0.6
0.4
(BeV)²
M² (K° π⁺)
2.0
2.5
3.0
(BeV)²
M² (Σ⁺ π⁺)

FIGURE 9



$\pi^+ + P \longrightarrow \Sigma^+ + K^+ + \pi^\circ$
MASS of K^+, π°
80 EVENTS
EVENTS / 20 MeV
10
5
600
700
800
900
1000
MeV
$M(K^+ \pi^\circ)$

FIGURE 10



π⁺ + P → Σ⁺ + K° + π⁺
MASS of π⁺, K°
60 EVENTS
EVENTS / 20 MeV
10
5
600
700
800
900
1000
MeV
M (K° π⁺)

FIGURE 11

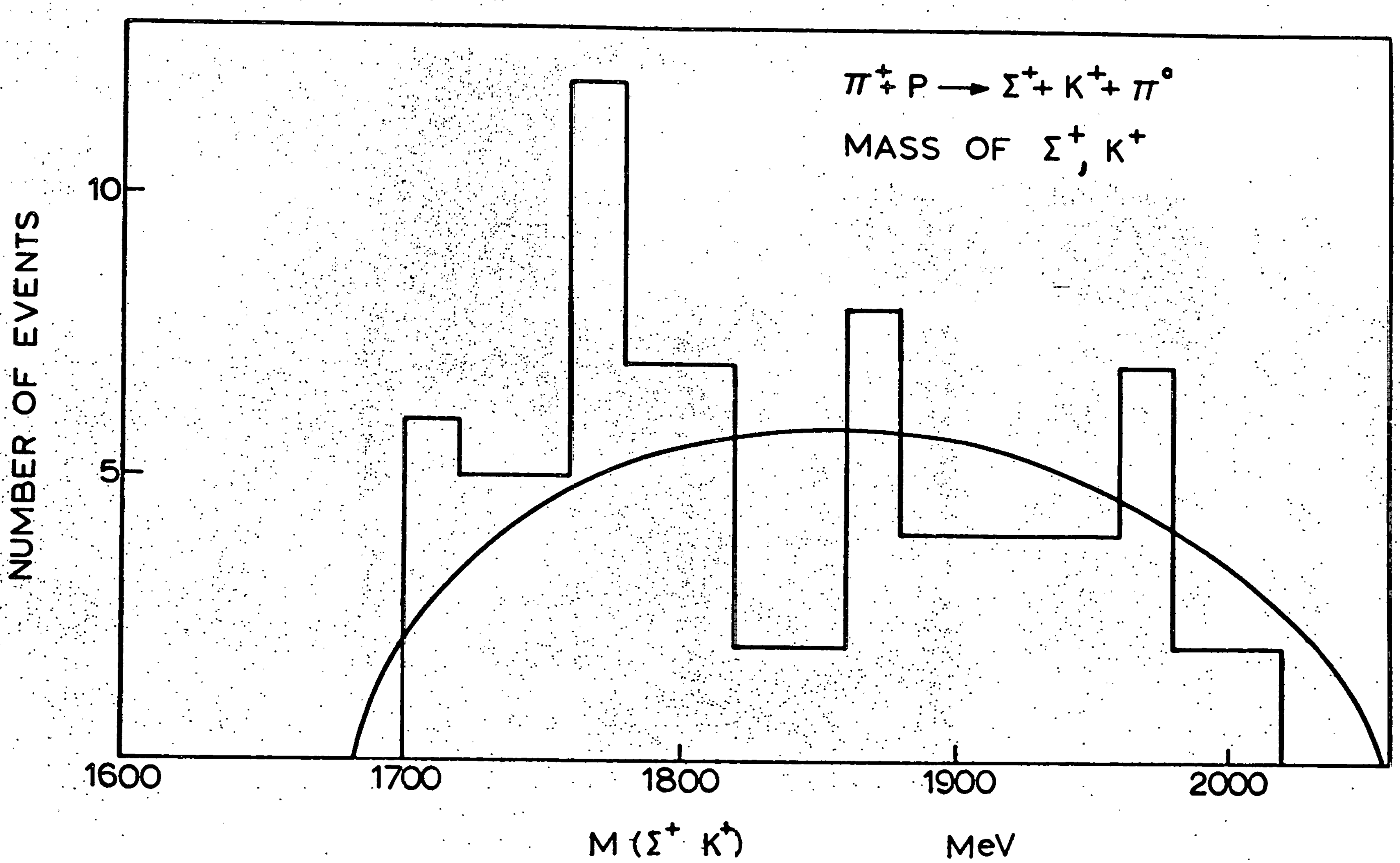
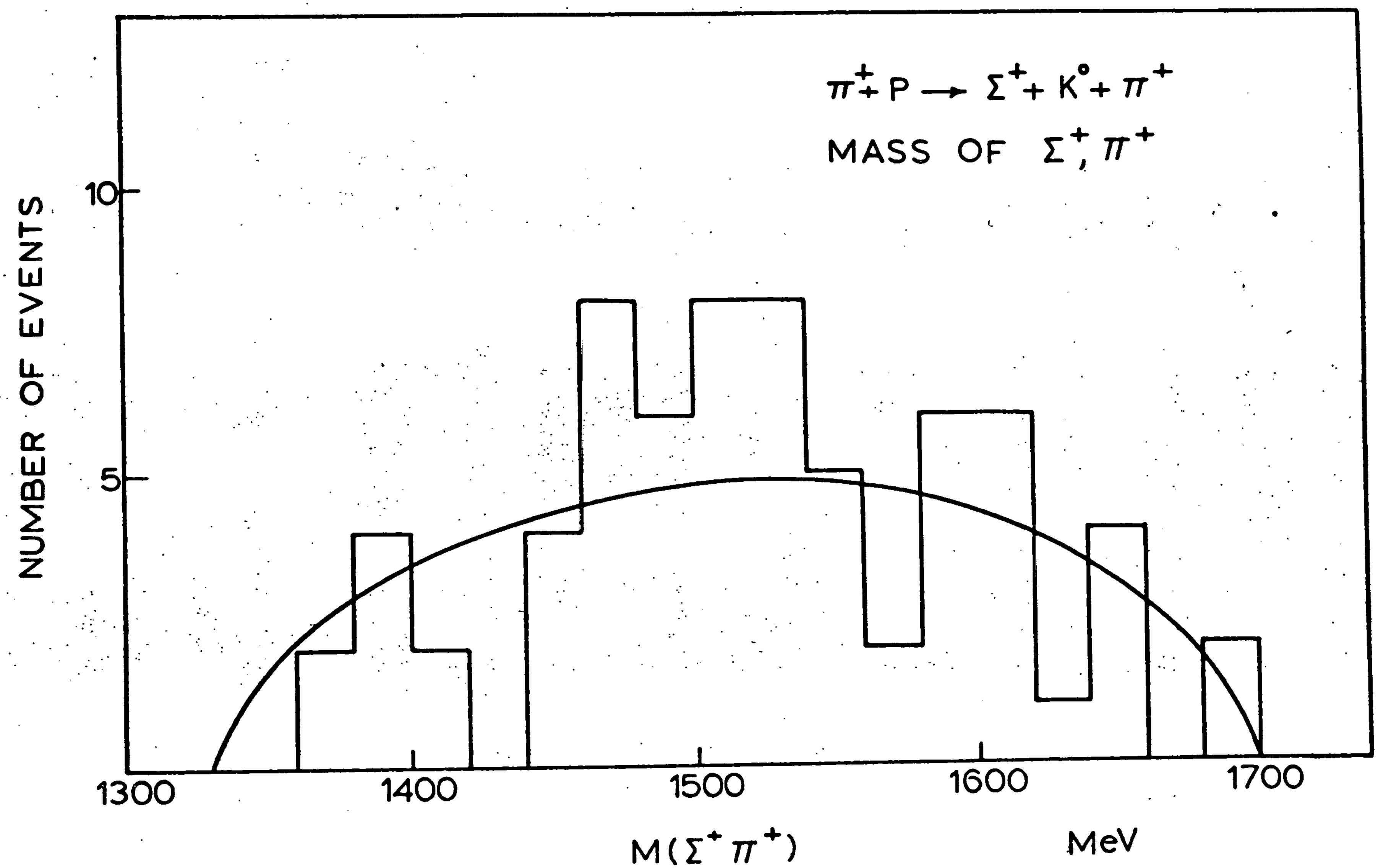

π⁺+ P → Σ⁺+ K⁺+ π°
MASS OF Σ⁺, K⁺
NUMBER OF EVENTS
10
5
1600
1700
1800
1900
2000
M (Σ⁺ K⁺)
MeV

FIGURE 12



$\pi^+ + P \longrightarrow \Sigma^+ + K^0 + \pi^+$
MASS OF Σ^+, π^+
NUMBER OF EVENTS
10
5
1300
1400
1500
1600
1700
$M(\Sigma^+ \pi^+)$
MeV