Figures c/o B. French

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A search for heavy hyperon resonances produced by 5.7 GeV/c antiprotons in hydrogen

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The Saclay 80 cm hydrogen bubble chamber was exposed to a separated beam of 5.7 GeV/c antiprotons from the CERN P.S. and a total of 300,000 pictures ($\sim$ 13 $\bar{p}$, 0.3 π^- and 1 μ^- per picture) have been scanned and analysed for hyperon-producing interactions. In this letter we present the results on the mass distributions of final state systems with S = -1, B = +1 (and their charge conjugates).

1638 events in a fiducial volume were identified among the selected topologies 002, 201, 202, 211, 220, 420 (where the digits indicate the numbers of charged secondaries, decaying $V^{\pm}$ and V^{o}, respectively). An additional 150 events gave several acceptable fits and are not considered here. A list of the reactions studied in this paper is shown in Table I along with the number of events in each channel[(1)].

The c.m. energy in the present experiment is 3.55 GeV, so that interactions of the type $\bar{p}p \longrightarrow \bar{\Lambda} + Y^*$ can occur for a Y^* mass up to 2.44 GeV. Reactions (1) to (4) are investigated here for the possible existence of heavy resonances decaying into (KN) and (KNπ). By this approach, channels yielding resonances below the (KN) threshold, i.e. Y_1^* (1385), Y_o^* (1405) are eliminated. Furthermore, these reactions do not seem to be dominated by resonant behaviour in the other possible particle combinations.

The effective mass distribution of all neutral (KN) combinations is shown in Fig. 1a[(2)]. The Y_o^* (1520) is produced strongly, together with enhancements in the regions of the Y_1^* (1660) and the Y_o^* (1815). There is

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also a peak at a mass of 2.1 GeV, about 2 standard deviations above the estimated background.

Fig. 2a shows the mass spectrum of all $(KN\pi)$ combinations, and a peak at 2.1 GeV ($\sim$ 2 standard deviations) is again visible. In addition, we notice two more enhancements, each with a significance of about two standard deviations, at 1.94 and 2.30 GeV. The sum of the histograms in Figs. 1a and 2a, shown in Fig. 3a, demonstrates the peaks at 2.1 and 2.3 GeV more clearly. Their significance depends on our estimate of background, particularly for the enhancement at 2.3 GeV, where distortion of invariant phase space seems important. Certainly for the peak at 2.1 GeV the effect exceeds 3 standard deviations. The Gaussian ideogram (Fig. 3b) indicates that both enhancements separate from the background despite folding in an overestimated $\pm$ 15 MeV resolution function.

Considering the mass distributions for the separate reactions (Figs. 1b, 1c, 2b, 2c), it is seen that most of the contribution to the 2.10 GeV peak comes equally from the neutral (KN) and $(KN\pi)$ combinations[3]. The enhancement is weaker in the case of the charged $(KN\pi)$ combinations, shown in Fig. 2c. The charged (KN) combinations do not exhibit any deviations from phase space.

The peak at 2.3 GeV comes mainly from the channel $\bar{\Lambda}^0(KN\pi)^0$. The peak at 1.94 GeV occurs equally in the $(KN\pi)$ charged and neutral combinations, but is absent in (KN) combinations of all charges. The fact that the initial $\bar{p}p$ state has isotopic spin $T = 0$ or 1 and both the 2.3 GeV and 1.94 GeV peaks are produced in association with a Λ^0 limits their isotopic spins to 0 or 1 and 1 respectively.

We have studied the mass distributions of the (KN), $(N\pi)$ and $(K\pi)$ combinations coming from the events with $(KN\pi)$ masses in the regions of 1.94 GeV, 2.1 GeV and 2.3 GeV and find no significant evidence for their decay into known resonances.

Properties related to production and decay angular distributions of events in the enhanced regions have been compared to those of events in the adjacent control regions. No distinguishing features could be observed. However, effects of the peripheral nature of the interactions should be difficult to observe in the region of large momentum transfer under study. Furthermore, the limited statistics and high background are likely to mask possible decay angular correlations in our case.

Fig. 4 shows the total $(\Sigma^{\pm} \pi^{\pm})$ combinations from reactions (5) to (8) of Table I. The known light resonances appear abundantly in the channels accessible to them, as is true in general for high energy antiproton reactions. Apart from a small bump in the region of 1.94 GeV there is, however, no evidence for enhancement in the mass regions discussed above. Furthermore we find no indication for other kinematically allowed decay modes such as $\Lambda\pi$, $\Lambda\pi\pi$ and $\Sigma\pi\pi$.

In conclusion, we find evidence for a hyperon resonance at 2097 ± 6 MeV $(T = 0,1)$ with a width at half height of $\Gamma \lesssim 38$ MeV decaying mainly via the neutral KN and KNπ channels. Two other peaks are seen at 1.94 GeV $(T = 1)$ and at 2.30 GeV $(T = 0,1)$ in the KNπ systems, that at 1.94 GeV decaying via the neutral and charged modes and that at 2.30 GeV decaying mainly via the neutral combinations. Table II summarises these results.

Independent evidence for the presence of hyperon resonances in the mass region 1.9 - 2.3 GeV has been recently reported, both in formation and production experiments.

A study of the reaction $K^- p \rightarrow K^0 n$ by Wohl et al.[(4)] at 1.2, 1.4, 1.5, 1.6, 1.7 GeV/c, suggests resonant behaviour in the differential cross sections, with a broad enhancement in A_6 (coefficient of P_6 in a Legendre expansion) centred in the region of c.m. energy $\sim$ 2060 MeV. $J \geq 7/2$ is then suggested for a resonance in this region. Our resonance at 2097 MeV, observed partly in the KN channel, may be related to the effect observed by Wohl et al. If so, this resonance might correspond to the Regge recurrence of the Y_0^* (1520), namely, a state of $J = 7/2^-$, $I = 0$. In this case the Λ_δ, Λ_α and Λ_γ trajectories would then have similar slopes.

In the 2.1 GeV mass region the KN total cross-section shows a broad hump in the K^-p but not in the K^-n system[(5)]. Enhancements in the total cross section for the reaction $\gamma + p \rightarrow K^+ + (Y)$ in the above c.m. energy region have previously been reported by Blanpied, et al.[(6)] In particular, two Y^* states of mass $\sim$ 2022 and 2245 MeV are suggested. Furthermore, an enhancement in the invariant mass spectrum of $(\Sigma^{+} \pi\pi)^{+}$ combinations at $\sim$ 2065 MeV/c, from the reaction $K^{-} + p \rightarrow \Sigma^{+} + \pi^{-} + \pi^{+} + \pi^{-}$ at 2.5 GeV/c, was observed by Eberhard[7]. A Y_1^* of mass $\sim$ 1940 MeV has been predicted by Gyuk and Tuan[8] and Bardakci et al.[9] as a consequence of SU_6.

References and Notes

1. Preliminary results on cross-sections of various channels were given at the Dubna International Conference on High Energy Physics (to be published).

2. The curve on each figure shows the weighted sum of invariant phase spaces normalised to 75 o/o of the total number of events for the reactions considered. This figure of 75 o/o is arbitrary but seems to give a reasonable fit to the estimated background. However, these curves are shown for guidance only, since resonance production and the peripheral nature of the interactions is known to distort the phase space. All histograms are unweighted.

3. Some of the events in Figs. 1-3 contribute twice, both to the KN and KNπ histograms. However, the events in a given peak are independent in the two plots since the (KN) and (KNπ) combinations cannot have the same effective mass. In events which have a Λπ mass in the region of the Y_1^* (1385), we have tried using only the (KN) combinations, but the selection can be wrong in 50 o/o of the cases due to high background. In any case, the conclusions are not changed if we adopt this procedure.

4. C.G. Wohl, F.T. Solmitz and M.L. Stevenson, Bull. Am. Phys. Soc. Series II, 10, 529 (1965).

5. V. Cook, B. Cork, T.F. Hoang, D. Keefe, L.T. Kerth, W.A. Wenzel and T.F. Zipf, Phys. Rev. 123, 320 (1961).

6. W.A. Blanpied, J.S. Greenberg, V.W. Hughes, P. Kitching, D.C. Lu and R.C. Minehart, Phys. Rev. Letters, 14 741 (1965).

7. P. Eberhard, Interactions between Negative K-mesons and Protons in the region 2.5 GeV/c. Invited paper, Bull. Am. Phys. Soc. Series II, 10, 478 (1965).

8. I.P. Gyuk and S.F. Tuan, Phys. Rev. Letters 14, 121 (1965).

9. K. Bardakci, J.M. Cornwall, P.G.O. Freund and B.W. Lee, Physics Letters 15, 79 (1965).

Table I

No.	Final State including Charge Conjugate	Topology	Number of Events	Cross-section (μb)
1.	$\Lambda^o\ K^+\ \bar{p}$	201	110	29 ± 4
	$\Lambda^o\ K^o\ \bar{n}$	002	62	70 ± 11
2.	$\Sigma^o\ K^+\ \bar{p}$	201	36	15 ± 3
	$\Sigma^+\ K^o\ \bar{p}$	211	30	20 ± 5
3.	$\Lambda^o\ K^o\ \bar{p}\ \pi^+$	201, 202	104	39 ± 4
	$\Lambda^o\ K^+\ \bar{n}\ \pi^-$	201	60	18 ± 3
	$\Lambda^o\ K^+\ \bar{p}\ \pi^o$	201	90	30 ± 3
	$\Sigma^o\ K^o\ \bar{p}\ \pi^+$	202	8	8 ± 4
4.	$\Sigma^+\ K^o\ \bar{p}\ \pi^o$	211	25	19 ± 4
	$\Sigma^+\ K^o\ \bar{n}\ \pi^-$	211	41	25 ± 5
5.	$\Sigma^+\ \bar{\Lambda}^o \pi^-$	211	119	60 ± 6
	$\Sigma^-\ \bar{\Lambda}^o \pi^+$	211	45	22 ± 4
6.	$\Lambda^+ \bar{\Sigma}^o\ \pi^-$	211	37	18.5 ± 3
	$\Lambda^- \bar{\Sigma}^o\ \pi^+$	211	24	15 ± 3
7.	$\Sigma^+\ \bar{\Lambda}^o\ \pi^-\ \pi^o$	211	105	48 ± 6
	$\Sigma^-\ \bar{\Lambda}^o\ \pi^+\ \pi^o$	211	67	27 ± 4
8.	$\Sigma^+\ \overline{\Sigma^-}\ \pi^+\ \pi^-$	420	24	15 ± 3
	$\Sigma^+\ \overline{\Sigma^+}\ \pi^-\ \pi^-$	420	26	

Table II

Mass (MeV)	Main Decay Modes	Observed Exp. Width Γ_{exp} (MeV)	Unfolded Width Γ (MeV)	I-spin
2097 ± 6	$(KN)^0$ $(KN\pi)^0$	34 ± 11	$24 {+14 \atop -24}$	0,1
2299 ± 6	$(KN\pi)^0$	35 ± 12	$21 {+17 \atop -21}$	$0,1^*$
1942 ± 9	$(KN\pi)^{\pm}_{0}$	43 ± 18	$36 {+20 \atop -36}$	1^*

(*) T = 2 for these systems is excluded since they are produced with a Λ (or $\bar{\Lambda}$) from a $\bar{p}p$ initial state.

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Figure captions:

Fig. 1 The effective mass distribution of neutral KN combinations

(a) from all events
(b) from 3 body final states
(c) from 4 body final states

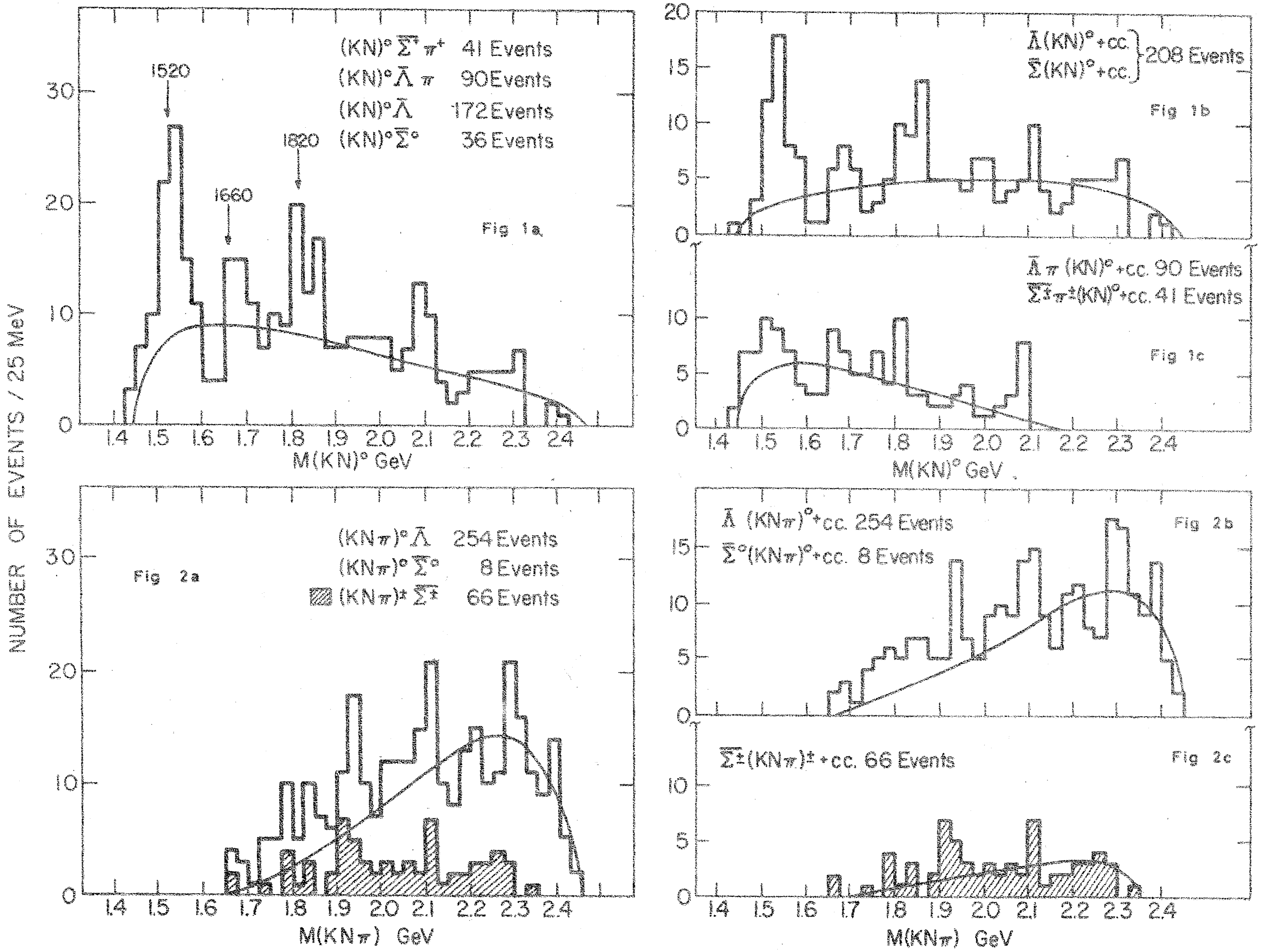
Fig. 2 The effective mass distribution of KNπ combinations

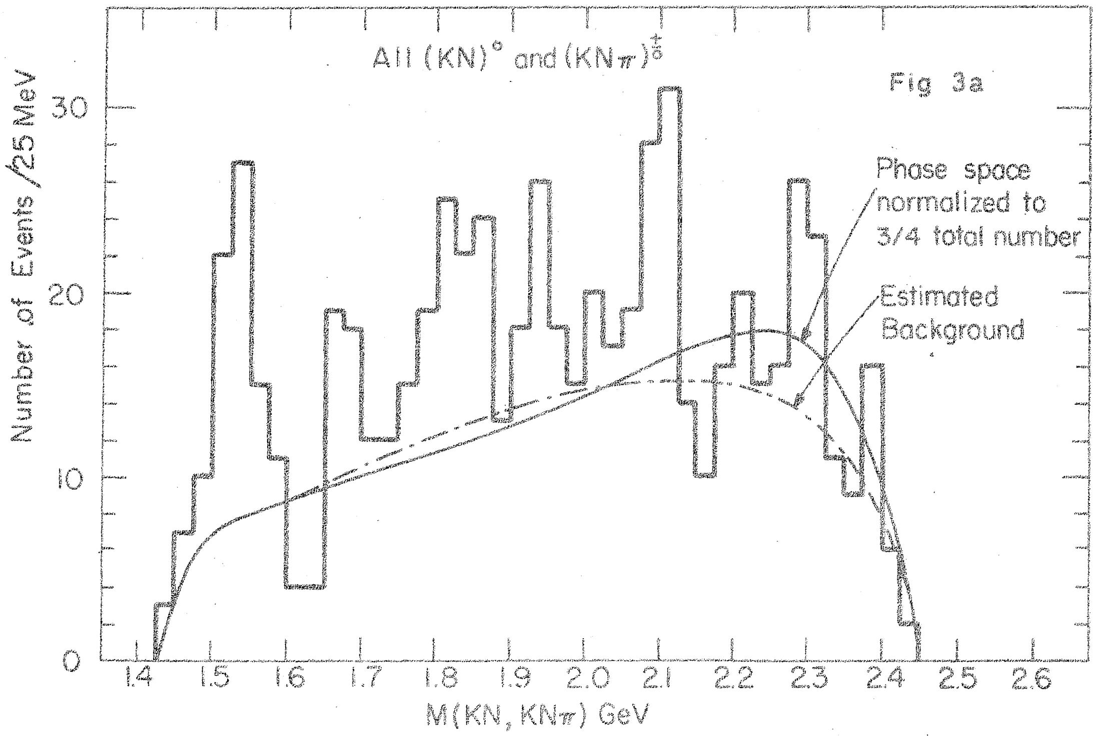
(a) neutral and charged combinations (the charged combinations are shown shaded)
(b) neutral combinations
(c) charged combinations

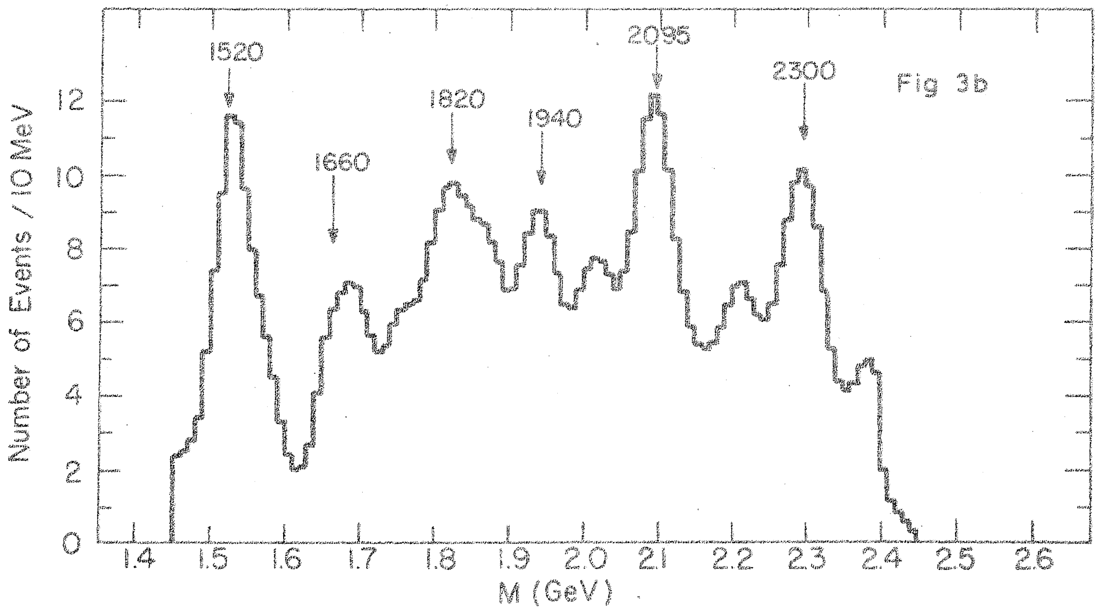
Fig. 3 The effective mass distribution of KN and KNπ combinations (the sum of Figs. 1a and 2a)

(a) as a histogram
(b) as a Gaussian ideogram (ΔM = 15 MeV)

Fig. 4 The effective mass distribution of neutral $\Sigma\pi$ combinations from 3 and 4 body final states


NUMBER OF EVENTS / 25 MeV
$(KN)^0 \overline{\Sigma}^{+}\pi^{+}$ 41 Events
$(KN)^0 \overline{\Lambda}\pi$ 90 Events
$(KN)^0 \overline{\Lambda}$ 172 Events
$(KN)^0 \overline{\Sigma}^0$ 36 Events
1520
1660
1820
Fig 1a
M(KN)° GeV
$\overline{\Lambda}(KN)^0$ + cc.
$\overline{\Sigma}(KN)^0$ + cc.
208 Events
Fig 1b
$\overline{\Lambda}\pi\,(KN)^0$ + cc. 90 Events
$\overline{\Sigma}^{\pm}\pi^{\pm}(KN)^0$ + cc. 41 Events
Fig 1c
M(KN)° GeV
$(KN\pi)^0 \overline{\Lambda}$ 254 Events
$(KN\pi)^0 \overline{\Sigma}^0$ 8 Events
$(KN\pi)^{\pm} \overline{\Sigma}^{\pm}$ 66 Events
Fig 2a
M(KNπ) GeV
$\overline{\Lambda}\,(KN\pi)^0$ + cc. 254 Events
$\overline{\Sigma}^0(KN\pi)^0$ + cc. 8 Events
Fig 2b
$\overline{\Sigma}^{\pm}(KN\pi)^{\pm}$ + cc. 66 Events
Fig 2c
M(KNπ) GeV


All (KN)° and (KNπ)$^{+}_{0}$
Fig 3a
Phase space normalized to 3/4 total number
Estimated Background
Number of Events /25 MeV
M(KN, KNπ) GeV


1520
1660
1820
1940
2095
2300
Fig 3b
Number of Events / 10 MeV
M (GeV)

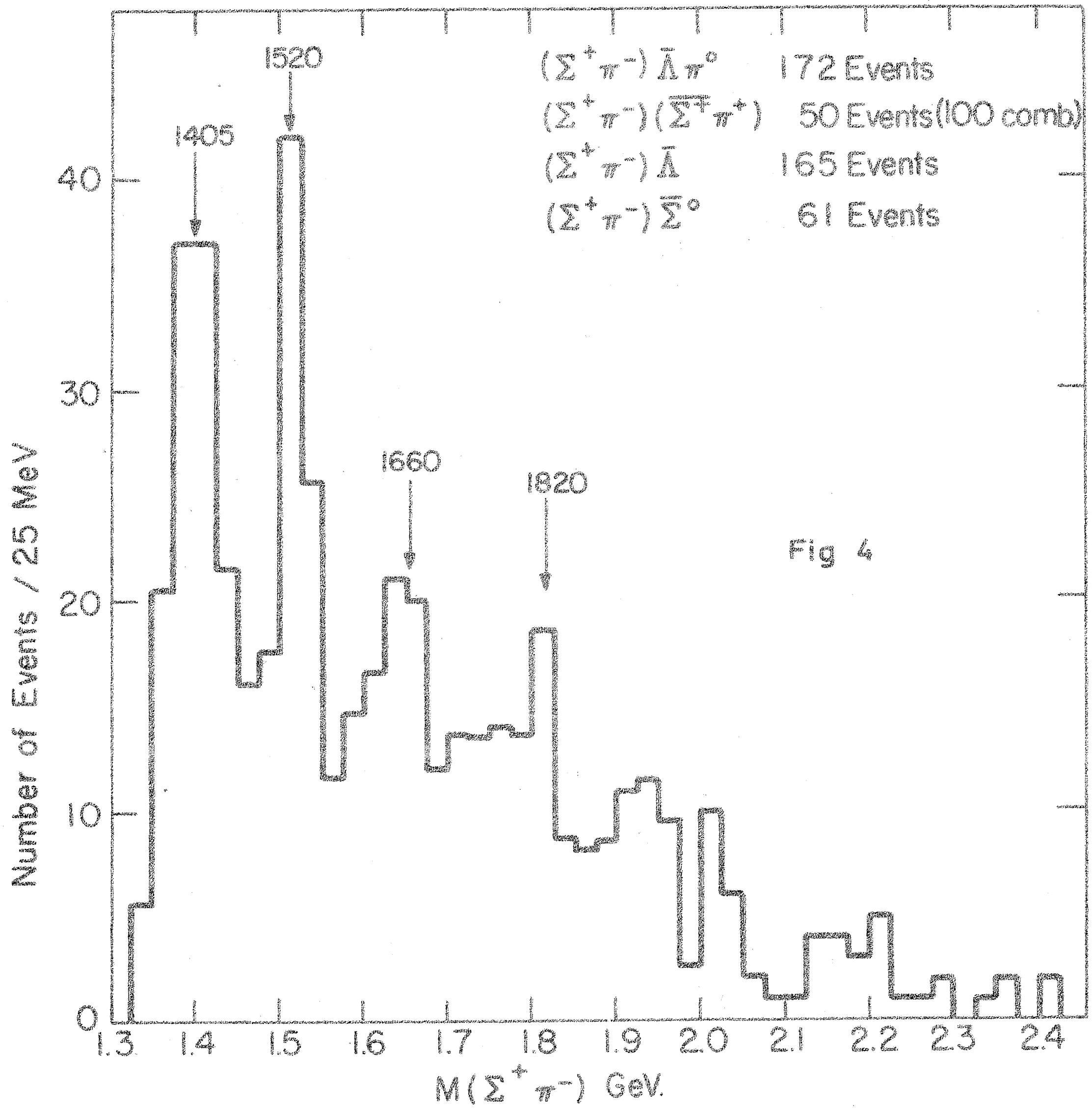


Fig 4

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