SUBMITTED TO PHYSICS LETTERS

CERN/TC/PHYSICS 65-10
11.5.1965

EVIDENCE FOR A MESON RESONANCE WITH STRANGENESS +2

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In the course of a systematic study of the high energy K^+p interaction, we have investigated in some detail the strangeness +2 meson system - KK. This system is found in reactions of the type $K^+p \rightarrow KKY$ (or KKY plus pions), where Y is a strangeness -1 hyperon. Reactions of this type are seen to occur with a very low rate, even when well above their threshold, the typical cross-section being of the order of 20 μb in the momentum region 3 to 5 GeV/c. Although the statistics that we have assembled is rather limited, the behaviour of the effective mass spectrum for the KK system indicates the occurrence of a doubly strange meson resonance. The resonance occurs both in 3- and 4-body reactions, has a mass of $\sim$1280 MeV with full width of $\sim$110 MeV, and isotopic spin of 1. This resonance, which we call M_1, appears to be produced predominantly at low values of the momentum transfer, in striking contrast with the production mechanism observed for KK mass values outside the resonant region. In addition to M_1, the KK mass spectrum indicates the presence of a second enhancement, M_2, at a mass of $\sim$1050 MeV with a full width of $\sim$60 MeV, again in isospin 1. This second enhancement is not as statistically significant as the first; furthermore, being near the KK threshold, it may be due to a strong S-wave interaction between the two K-mesons. Our limited statistics are not able to give strong support to one or other interpretation.

This study has been performed by means of $\sim$400,000 pictures taken in the 80 cm Saclay hydrogen bubble chamber exposed to separated K^+ beams at 3, 3.5 and 5 GeV/c at the CERN proton synchrotron. Some preliminary evidence on the outcome of this study has been presented earlier[(1)]. Results of the analysis

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of more common types of interactions in the same film can be found in Ref. (2). Table I gives the details of the exposures.

The interesting reactions are those involving at least three strange particles in the final state, with or without additional pions. In practice, at our energies, this study is limited to the following processes :

$$K^+p \dashrightarrow K^+K^+\Lambda \qquad (1a)$$
$$K^+K^+\Sigma^o \qquad (1b)$$
$$K^+K^o\Sigma^+ \qquad (1c)$$

$$K^+p \dashrightarrow K^+K^+\Lambda\pi^o \qquad (2a)$$
$$K^+K^o\Lambda\pi^+ \qquad (2b) .$$

In the above list we have left out the 4-body final states with a Σ, those reactions with more than one pion and the events with three K's, all these reactions being either too scarce to be useful or too underconstrained to be kinematically identifiable. Prior to this experiment only one such event (of the type (1a)) had been found at 2.3 GeV/c incident K^+ momentum[5], and none at 1.96 GeV/c[6].

In order to eliminate a very serious source of ambiguity arising in the kinematical fitting, we required that the event should exhibit the decay of the hyperon. This condition results in the exclusion of one-third of the Λ events from reactions (1) and (2). We also required that a visible K^o decay be present for reaction (1c), thus reducing by two-thirds the sample of Σ^+ events accepted. The above criteria limit our sample to the topology "2-prong V^o" with and without charged decays on the primary prongs (except for the case of reaction (2b), where topologies with 2 V^o were also accepted).

Furthermore, since the much more abundant reactions of the type $K^op\pi^+$ (and $K^oN\pi$ plus pions) still dominate this topology by a factor of ~ 100 with respect to our reactions, an additional selection was imposed in order to reduce the number of background events to be measured. At the scanning stage only those events were accepted in which, from simple ionization and kinematic criteria, either the V^o could possibly be a Λ or one of the primary prongs presented a kink compatible with a Σ^+ decay. The application of the above criteria allowed a pre-measurement rejection of $\sim 85^o/o$ of the background. The remaining $\sim 15^o/o$ was regularly measured and processed through the geometry and kinematics programs. Tests have been done in order to insure that the rejected events were indeed only K^o's; several thousands of unselected events were measured and checked. No bias could be detected and we feel sure that all desired events have survived the selection criteria.

The measured events were processed through the standard CERN geometry and kinematics programs and then re-examined on the scanning table in order to verify if the observed ionization and that required by the fitted hypothesis were consistent for all tracks.

There are three main classes of ambiguities which may beset our analysis :

i) Between the wanted $YKK(\pi)$ reactions and the much more frequent $K^oN\pi(\pi)$ reactions. Fortunately, the difference in track ionizations between the two competing hypotheses is sufficient to resolve the ambiguity in practically all cases.

ii) Between two different wanted hypotheses, for instance between $\Lambda K^+K^+\pi^o$ and $\Lambda K^+\pi^+K^o$. Not all such cases could be settled on the basis of ionization only, since the possible ionization difference occurs only for one track, and practically vanishes at momenta above 750 MeV/c.

iii) Between a wanted reaction and a competing hypothesis where the hyperon is produced by a contamination pion, for instance between ΛK^+K^+ and $\Lambda K^+\pi^+(\pi^o)$. The remark concerning ionization made in ii) applies here, but supplementary help in the present case is provided by a Cerenkov counter installed in the beam, and set for π and μ mesons. When there was no signal from this counter (whose indication was recorded on each picture), the π-hypothesis could safely be eliminated. Since the beam contamination was less than $5^o/o$ and the number of tracks per picture less than 15, the indications of this counter were useful in more than $50^o/o$ of the cases. In the remaining ambiguous cases a probability criterion was applied : an interpretation was considered correct if the product of the χ^2-probability for its fit times the square of the number of constraints was better, by a factor of at least 5, than the same product for the competing interpretations (*). By means of the described procedure only a few events remained ambiguous. These events were inspected in order to find what possible effects their inclusion would have, in particular on the effective mass spectra. After satisfying ourselves that their presence was not determining in the interpretation of any of our results, we simply included them with the unambiguous events, assigning them to the most probable interpretation (in the sense described above). The number of these ambiguous events attributed to reactions (1a), (1b), (1c), (2a) and (2b), are respectively 10, 5, 0, 8 and 8.

Table II gives the number of events so identified at each momentum and for each reaction, together with the corresponding cross-section corrected for the invisible decay modes. The cross-sections were derived from the comparison between the number of τ-decays counted in a given volume and the number of events found in the same volume, properly corrected for losses due to invisible decay modes.

(*) This procedure has to be explained in two respects. First, from other studies on the same pictures[2], we find that multiplying the probability for the fit by the square of the number of constraints is an empirically reliable way of taking into account the greater ease for an event to fit a less constrained hypothesis. For example, reaction : $K^+p \rightarrow K^+K^+\Lambda$, which leads to a 4c-fit, is often ambiguous with reaction $\pi^+p \rightarrow \pi^+K^+\Lambda\pi^0$, which is a 1c-fit (but rarely with reaction $\pi^+p \rightarrow \pi^+K^+\Lambda$, which is a-priori equally probable, but is a 4c-fit). Second, comparing, as we do, the a-posteriori probabilities is justified when the a-priori probabilities are comparable; this is roughly the case for competing KKY(π) hypotheses (see Table II). As for the a-priori probability of a hyperon to be produced by a π, it can be calculated from the beam contamination and the cross-section for hyperon production by pions, and turns out to be smaller than the probability for production by K^+'s. Thus, setting these a-priori probabilities equal amounts to introducing a safety factor against contamination of our events by π-produced event. On the other hand, this could result in interpreting some K-produced events as π-produced. However, the number of such wrong interpretations must be small since our procedure results in recognizing about as many π-produced events as expected.

Let us examine first the 3-body reactions (1a), (1b) and (1c). Fig. 1 gives an overall view of the KK effective-mass spectrum for these reactions at different energies. Separate combinations are also given for the mass spectra of the individual reactions summed over all energies, and of all reactions, together at each different energy. One notices that a persistent enhancement occurs in almost every spectrum at a mass value of $\sim$1280 MeV, as indicated by the arrows. We refer to this enhancement as M_1 and intend to prove that it is due to a resonance with strangeness +2 decaying strongly into two K-mesons.

Although the presence of M_1 in almost every mass spectrum of Fig. 1 is, by itself, very encouraging, the meagre statistics available in each one case does not allow further speculation on the individual reactions. Instead, we centre our attention on the combined plot appearing in the lower right side of Fig. 1. This spectrum, containing 161 events, is reproduced in Fig. 2e. Making the usual assumption that a phase-space distribution would be expected in the absence of resonances or final state interactions among the three particles produced, we can calculate the statistical significance of the M_1 enhancement. We use the binomial distribution, as one should when the statistics is not very large, and find that such an accumulation of events in any interval occupying the same portion of phase-space as the enhancement has a probability of 0.6 °/o to occur by chance. To check that this structure does not originate from a distortion of phase-space due to an interaction in the KΛ system (from which we would expect, for example, formation of N^*_{1688}), we have examined the mass spectrum of this system, together with the distribution of events on the Dalitz plot. We do not find any effect strong enough to justify the observed shape of the KK mass distribution. The presence of N^*_{1688}, in particular, is not noticeable.

A second indication in favour of the interpretation of M_1 as a resonance comes from its production angular distribution. In Figs. 2a to 2d we show the Δ^2 distribution of the KK system over four mass intervals ($-\Delta^2$ is the momentum transfer from the incident K^+ to the KK system). The M_1 enhancement corresponds to 2c. These distributions show a striking difference between the four mass regions : a strongly peripheral mechanism is at work in the M_1 region, whereas no comparable effect is noticeable in the outside regions. It is eminently reasonable to suppose that the sudden change in production mechanism is a consequence of the occurrence of a quasi-two-body process in the M_1 region as opposed to a 3-body process in the other regions.

The two preceding arguments can, of course, be combined. The dashed histogram of Fig. 2e represents the mass spectrum for those events with $\Delta^2 < 1\ (\mathrm{GeV}/c)^2$; here the M_1 peak is much more pronounced than in the overall spectrum. If we make use of the phase-space distribution modified so as to take into account the cut in Δ^2, the probability quoted above drops to a low 0.03°/o.

At this point something should be said about the smaller peak in the KK spectrum near the beginning of phase-space. We shall refer to this peak as M_2. If M_1 is indeed a resonance, then one is entitled to subtract the events corresponding to the M_1 peak from the spectrum of Fig. 2e and ask now what is the probability for M_2 to be a statistical fluctuation. We find that this probability is ~ 2°/o. It should be pointed out, however, that the aforementioned arguments concerning the peripheral production of M_1 are not valid for M_2, as can be seen from Fig. 2a. On the other hand, anticipating the discussion on the 4-body reactions, independent evidence exists against the dismissal of M_2 as a statistical fluctuation. The curve on Fig. 2e gives a maximum likelihood fit to the hypothesis of a 3-body phase-space background plus Breit-Wigner resonances at M_1 and M_2. The best values for the mass, width and percentage (f) of each resonance are :

$$\begin{cases} \text{mass}\ (M_1) = (1280 \pm 20)\ \text{MeV}, & \Gamma(M_1) = (110 \pm 40)\ \text{MeV}, \quad f(M_1) = (25 \pm 10)\,°/\text{o} \\ \text{mass}\ (M_2) = (1055 \pm 20)\ \text{MeV}, & \Gamma(M_2) = (\ 60 \pm 25)\ \text{MeV}, \quad f(M_2) = (10 \pm 4\ )\,°/\text{o} \end{cases}$$

The question if M_2 is a resonance or, more likely, the effect of a strong scattering in the S-wave interaction of the KK system, remains completely open, due to insufficient statistics. An effective range formula of the type $\sigma \sim [k^2 + (-\frac{1}{a} + \frac{1}{2} r_o k^2]^{-1}$, where $\hbar k$ is the relative momentum of the 2K's in the KK system, gives values of the scattering length a from 0.4 to 1 fermi, and effective range r_o from 2 to 4 fermi; needless to say, a Breit-Wigner resonance formula fits the data equally well.

Next we examine the 4-body reactions (2a) and (2b). Fig. 3 gives, in analogy to Fig. 1, the individual and combined KK mass spectra for these reactions. Because of insufficient statistics, the data at 3 GeV/c have been combined with those at 3.5 GeV/c. Here again, the position of M_1 is marked with an arrow and persistent enhancements are again visible at the expected mass. It is now impossible to ignore the presence of the M_2 peak at the beginning of phase-space. Here, however, the interpretation of the peaks is less simple than in the 3-body case. The particles present in the final states of these reactions, taken two by two, can all be possible decay products of several resonances. Fig. 4 illustrates this situation showing all possible 2-body combinations for these reactions summed over all energies. Thus we see that a considerable amount of Y^*_{1385} is certainly present among the $\Lambda\pi$ final states, together with a small amount of Y^*_{1660}. The K^*_{890} is also apparent in the I = 1/2 $K\pi$ combinations, and, finally, a certain amount of N^*_{1688} is visible among the charged $K\Lambda$ combinations.

However, the presence of these other resonances does not explain the enhancements at the M_1 and M_2 positions : this is clear for Y^*, which just changes a 4-body phase-space to a 3-body phase-space, and it can be verified that the reflection of K^* and/or N^* in the KK mass spectrum does not introduce any bump in that spectrum. This is shown in another way in Fig. 5, which represents the total KK mass-spectrum; the shaded histogram, which shows the same spectrum after removal of all events containing $K^*(890)$ and/or $N^*(1688)$, displays even more clearly the M_1 and M_2 peaks.

We have attempted to fit the four effective mass-distributions : $\Lambda\pi$, ΛK, $K\pi$ (in I-spin 1/2) and KK, under the assumption that the resonances present in the final state are M_1, M_2, Y^*_{1385}, Y^*_{1660}, N^*_{1688} and K^*_{890}, with the guiding idea that the main contribution comes from quasi two-body processes, Y^*M and K^*N^*.

A good fit can be found with a χ^2-probability equal to 82°/o against 0.7°/o, for phase-space. The percentages of the different final states are given in Table IV, as well as the probabilities for the individual fits of each mass-spectrum. The corresponding mass-distributions are displayed on Figs. 4 and 5.

As for the Δ^2 dependence of these reactions, no effect is observed comparable to that which occurs for the 3-body case; here, however, both the type of reaction and the condition of the background are different from the 3-body case.

Let us now examine the evidence concerning the quantum numbers of M_1. The isotopic spin of the resonance must be 1 because of its appearance in reaction (1a). A check of this assignment is in principle provided by the ratios of reactions like $\Sigma^+ M_1^+$ and $\Sigma^o M_1^{++}$ or $Y^{*+}_{1385} M_1^+$ and $Y^{*o}_{1385} M_1^{++}$. However, it should be remembered that a subdivision of our data into partial channels reduces the statistics to such an extent that the obtained ratios, although in good agreement with those expected, are not very significant. The strong decay of M_1 in two identical bosons implies that the parity of M_1 is even and limits the values of its spin to J = 0, 2, or higher even values. Let us restrict our considerations to the more likely values, 0 and 2, and let us try to see if the decay angular distributions of M_1 are capable of discriminating between them. It is most convenient to study the angular distributions in the frequently used reference system defined as the rest frame of the resonance, with the y-axis parallel to the direction of the production normal and the z-axis parallel to the direction of the incident K^+ transformed into this rest frame. The direction of one of the decay particles of the resonance will be specified in this system by the polar (θ) and azimuthal (φ) angles. Fig. 6 shows the angular distributions for these angles in the mass interval from 1.2 to 1.35 GeV, the shaded histograms corresponding to values of $\Delta^2 < 1$ $(\text{GeV/c})^2$ (only 3-body events have been used, as the background present in the 4-body case represents a serious drawback for such an analysis). Both distributions are isotropic within statistics, thereby allowing the spin to be 0, although of course higher values cannot be ruled out. The peripheral production of M_1 suggests that an exchange mechanism could perhaps explain the angular distributions; in particular, one could expect that K or K^* (alone or combined) contribute essentially to the exchange process. Table III gives the form of the expected cos θ and φ distributions in the case of K and K^* exchange[7].

Comparing the distributions of Table III with those on Fig. 6, one would be tempted to conclude that, if the exchange mechanism is indeed limited to one of the above cases, the value J = 0 is favoured though a particular mixture of K and K^* exchange could explain the angular distributions in the case of $J = 2$(**).

A few words should also be said about the quantum numbers of M_2. Here again, the isospin must be 1 and the parity even, by the same reasons given for M_1. As for the spin of M_2, we have examined the angular correlations of the 4-body events with a KK mass falling between 1.0 and 1.1 GeV. Here again, we find that the cos θ and φ distributions are isotropic, thus suggesting, within our very limited statistics, that J = 0, a not surprising result in view of the small Q-value of M_2, and its possibility of being an S-wave interaction rather than a resonance.

(**) In the framework of SU_3 a S = +2, I = 1 meson has to lie in a 27 multiplet. If M_1 (1280 MeV) had spin 2, such a multiplet could contain, together with M_1, the resonances f_0(1250 MeV), A_2(1310 MeV), K^*(1400 MeV)[8], and eventually the $K\pi\pi$ at 1230 MeV[9], with only a mesonic resonance with S = 0, I = 2 and mass ~1500 MeV missing.

On the other hand, from our preliminary results[1], Dyson and Xuong[10] note that this KK resonance (which they also call M_1) could lie in either the 189 or the 405 multiplets of SU_6.

Acknowledgments

This experiment greatly benefited from the efficient collaboration of the engineers and crews of the CERN proton synchrotron and the Saclay hydrogen bubble chamber. Our thanks go also to our scanning and measuring staff, as well as to Drs. R. Böck and F. Beck for the ameliorations they brought to the computer programs. We are also pleased to thank Drs. W. Koch and J. Prentki for enlighening discussions, Drs. R. Armenteros, B.P. Gregory and Ch. Peyrou for their continued interest, and Dr. R. Budde for his contribution to the conception of the experiment.

Table I

Details of the Exposures : The pictures have been taken in the period February 1963 - February 1964.

Nominal momentum (GeV/c)	Beam used[a]	Actual measured momentum[b] (GeV/c)	C.M. energy (GeV)	Number of pictures	Average K^+ per picture	Yield (event/μb)
3	m_2 (c)	2.97	2.60	190,000	10	3.3
3.5	m_2	3.46	2.78	140,000	15	3.5
5	o_4 (d)	4.97	3.24	80,000	11	1.5

(a) for each exposure the dispersion of the beam momentum was less than $\pm$ 0.5°/o and the pion contamination less than 5°/o.

(b) from τ-decays and 4-constraint fits.

(c) see ref. (3).

(d) see ref. (4).

Table II

Cross-sections in μb and number of events (in parenthesis) for reactions (1a) to (2b).

Momenta (GeV/c)	3	3.5	5
Reactions			
(1a) $K^+K^+\Lambda$	23 ± 4.5 (44)	22 ± 4.5 (47)	18 ± 6 (14)
(1b) $K^+K^+\Sigma^o$	7.5 ± 2.5 (13)	7 ± 2.5 (9)	6 ± 3 (4)
(1c) $K^+K^o\Sigma^+$	15 ± 5 (11)	8 ± 4 (12)	23 ± 9 (7)
(2a) $K^+K^+\Lambda\pi^o$	7.5 ± 2.5 (11)	9.5 ± 3 (20)	30 ± 8 (26)
(2b) $K^+K^o\Lambda\pi^+$	12.5 ± 3.5 (23)	24 ± 4.5 (41)	36 ± 9 (36)

Table III

Form of the expected cos θ and φ distributions for K and K^* exchange.

Spin of M	Possible Exchanged Particle	cos θ	φ
J = 0	K	Isotropic	Isotropic
J = 2	K	$(3 \cos^2 \theta - 1)^2$	Isotropic
	K^*	$\sin^2 \theta \cos^2 \theta$	$a + b \cos 2\varphi$

Table IV

System		KK: M_1	KK: M_2	KK: KK	Kπ: K^*	Total	Probabilities: Phase-space	Probabilities: Fit
Λπ	Y^*_{1385}	14	18	15	-	47		
	Y^*_{1660}	6.5	0	4	-	10.5	5°/o	75°/o
	Λπ	10	9	0	-	19		
KΛ	N^*_{1688}	-	-	-	23.5	23.5	56°/o	71°/o
Total		30.5	27	19	23.5			
Probabilities	Phase-space	4°/o			4°/o			
	Fit	35°/o			92°/o			

Percentages of the various final states involved in the reactions $K^+p \dashrightarrow K^+K^{\substack{+\\0}}\Lambda\,\pi^{\substack{0\\+}}$, and probabilities for the individual fits of each mass spectrum shown in Figs. 4 and 5 compared to the probabilities for phase-space. Note that the percentages apply to the total 157 events (from 2 reactions each at 3 momenta) and should then be interpreted as an average of what happens for individual reactions.

References

(1) M. Ferro-Luzzi, R. George, Y. Goldschmidt-Clermont, V.P. Henri, B. Jongejans, D.W.G. Leith, G.R. Lynch, F. Muller and J.-M. Perreau, Proc. Sienna International Conference on Elementary Particles, Vol. 1, 182 (1963), and Proc. International Conference on High-Energy Physics at Dubna (1964), to be published.

(2) M. Ferro-Luzzi, R. George, Y. Goldschmidt-Clermont, V.P. Henri, B. Jongejans, D.W.G. Leith, G.R. Lynch, F. Muller and J.-M. Perreau, Phys.Letters 9, 359 (1964); 12, 255 (1964); Nuovo Cimento 35, 1101 (1965), and CERN Preprint TC 65-5 (Nuovo Cimento, to be published).

(3) J. Goldberg and J.-M. Perreau, "Un faisceau d'usage général à deux étages de séparation électrostatique au P.S.", CERN 63-12, April 9, 1963.

(4) E. Keil and W.W. Neale, "A high momentum separated particle beam for use with the 1.50 metre British National Hydrogen Bubble Chamber at CERN", CERN Preprint, TC 63-3 (1963).

(5) R. Kramer, L. Madansky, I. Miller, A. Pevsner, C. Richardson, R. Single and R. Zdains, Proceedings of the Conference on Recently Discovered Resonant Particles, 1963, Athens, Ohio, p. 130.

(6) S. Goldhaber, Proceedings of the Conference on Recently Discovered Resonant Particles, 1963, Athens, Ohio, p. 92.

(7) J.D. Jackson, Nuovo Cimento 34, 1644 (1964).

(8) N. Haque et al., Physics Letters 14, 338 (1965), and L.M. Hardy et al., Phys.Rev.Letters 14, 401 (1965).

(9) R. Armenteros et al., Physics Letters 9, 207 (1964).

(10) F.J. Dyson and N.H. Xuong, Phys.Rev.Letters 13, 815 (1964).

Figure Captions

Fig. 1 Mass spectra for the KK system in 3-body reactions. The incident K^+ momentum, the type of reaction and the number of events are indicated on the figure. The dark histograms are superpositions of different reactions or different momenta. The overall histogram is given in the lower right-hand corner. The arrow indicates a mass of 1280 MeV.

Fig. 2 Δ^2-distributions (a, b, c, d) and mass spectrum (e) of the KK system in reactions of the type $K^+p \dashrightarrow KKY$. All three incident K^+ momenta and the three different reactions (1a), (1b) and (1c) have been used. The Δ^2-distributions refer to the following KK mass intervals (in GeV): (a) $M(KK) < 1.1$, (b) $1.1 \leq M(KK) < 1.2$, (c) $1.2 \leq M(KK) < 1.35$, (d) $1.35 \leq M(KK)$. The shaded histogram in (e) represents the KK mass spectrum for the events with $\Delta^2 < 1\ (GeV/c)^2$. The arrows indicate mass values of 1050 and 1280 MeV. The curve represents the result of a maximum-likelihood fit to Breit-Wigner resonances at 1050 and 1280 MeV, superposed to a 3-body phase-space background (dashed curve).

Fig. 3 Mass spectra for the KK system in 4-body reactions. The incident K^+ momentum, the type of reaction and the number of events are indicated on the figure. The dark histograms are superpositions analogous to those of Fig. 1. The arrow indicates a mass of 1280 MeV.

Fig. 4 Mass spectra for the $\Lambda\pi$ (a), $K\pi$ in isospin $I = \frac{1}{2}$ (b) and $K\Lambda$ (c) systems in reactions of the type $K^+p \dashrightarrow KKY\pi$. All three incident K^+ momenta and both reactions (2a) and (2b) have been used. Arrows indicate the position of the known resonances. Shaded regions represent contributions from different charge states of the same systems. The curves are mass-distributions computed with the final state interpretation given in Table IV, normalized to the number of entries on the histograms. There is one entry per event in (a), one entry per $K^+K^0\Lambda\pi^+$ and two per $K^+K^+\Lambda\pi^0$ in (b), two entries per event in (c).

Fig. 5 Mass spectrum for the KK system in 4-body reactions. All three incident K^+ momenta and both reactions (2a) and (2b) have been used. The curve is the mass-distribution computed as described for Fig. 4, normalized to the total number of events on the histogram (157). The shaded region corresponds to events with the mass of the $K\pi$ system

Figure Captions

Fig. 5 (contd.) (in $I = \frac{1}{2}$ combinations) outside the interval (867 - 917) MeV and the mass of the ΛK system outside the interval (1638 - 1738) MeV.

Fig. 6 Polar and azimuthal distribution for the decay of M_1 (1280). The great majority of the events decay into two identical particles (K^+K^+). In such a case, the direction of the decay-particles is determined only within π in the φ distribution; thus, for instance, the φ distribution lies between $-\pi/2$ and $\pi/2$. When the φ-angle is fixed, cos Θ is fully determined, in the range -1 to +1. Now, parity conservation requires that both the φ and cos Θ distributions be symmetrical with respect to zero, so the distributions shown are folded around zero. The shaded area corresponds to the events with $\Delta^2 \lesssim (1\ \mathrm{GeV}/c)^2$.

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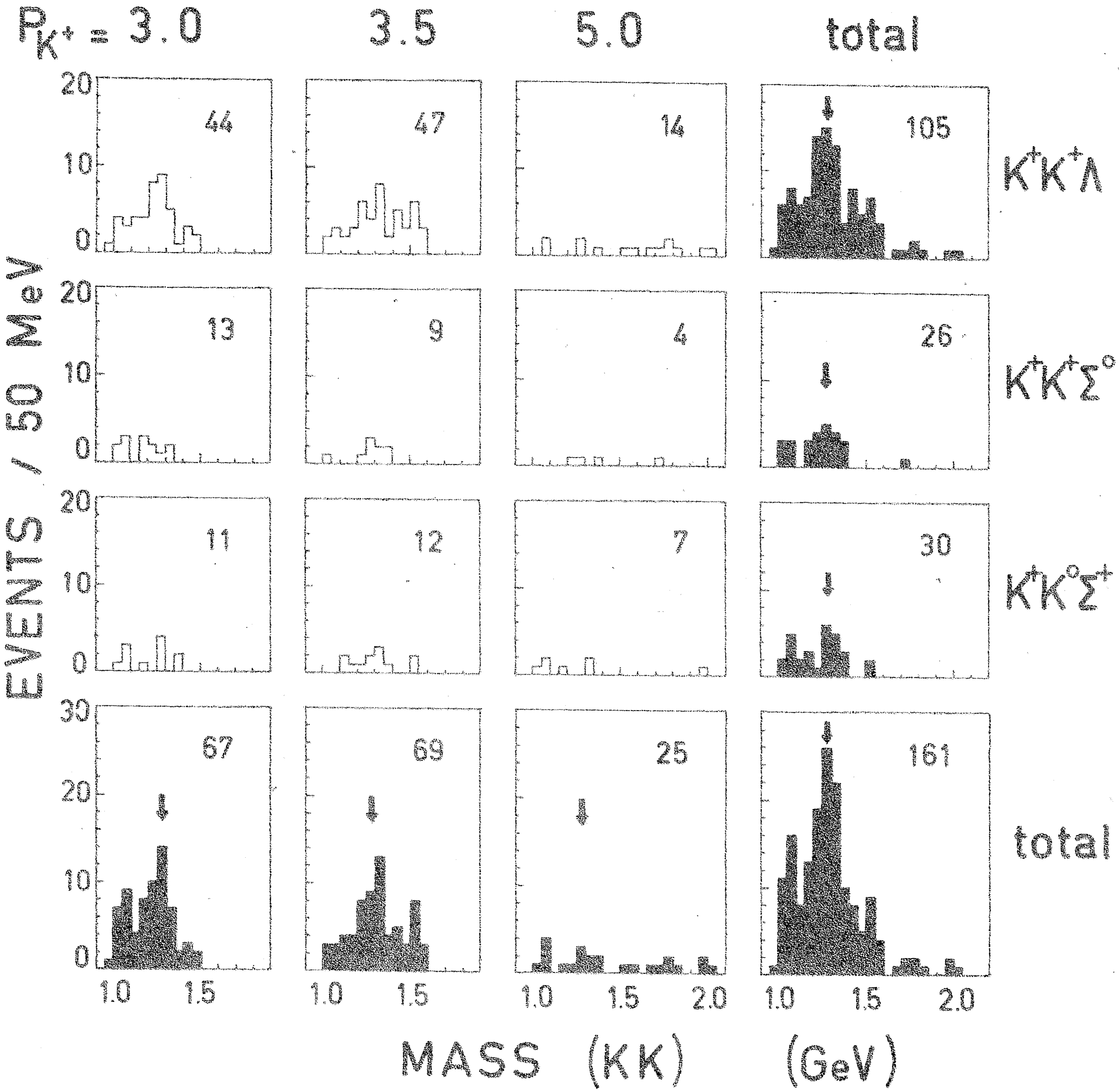

P_{K^+} = 3.0
3.5
5.0
total
44
47
14
105
13
9
4
26
11
12
7
30
67
69
25
161
$K^+K^+\Lambda$
$K^+K^+\Sigma^0$
$K^+K^0\Sigma^+$
total
EVENTS / 50 MeV
MASS (KK) (GeV)

Fig. 1

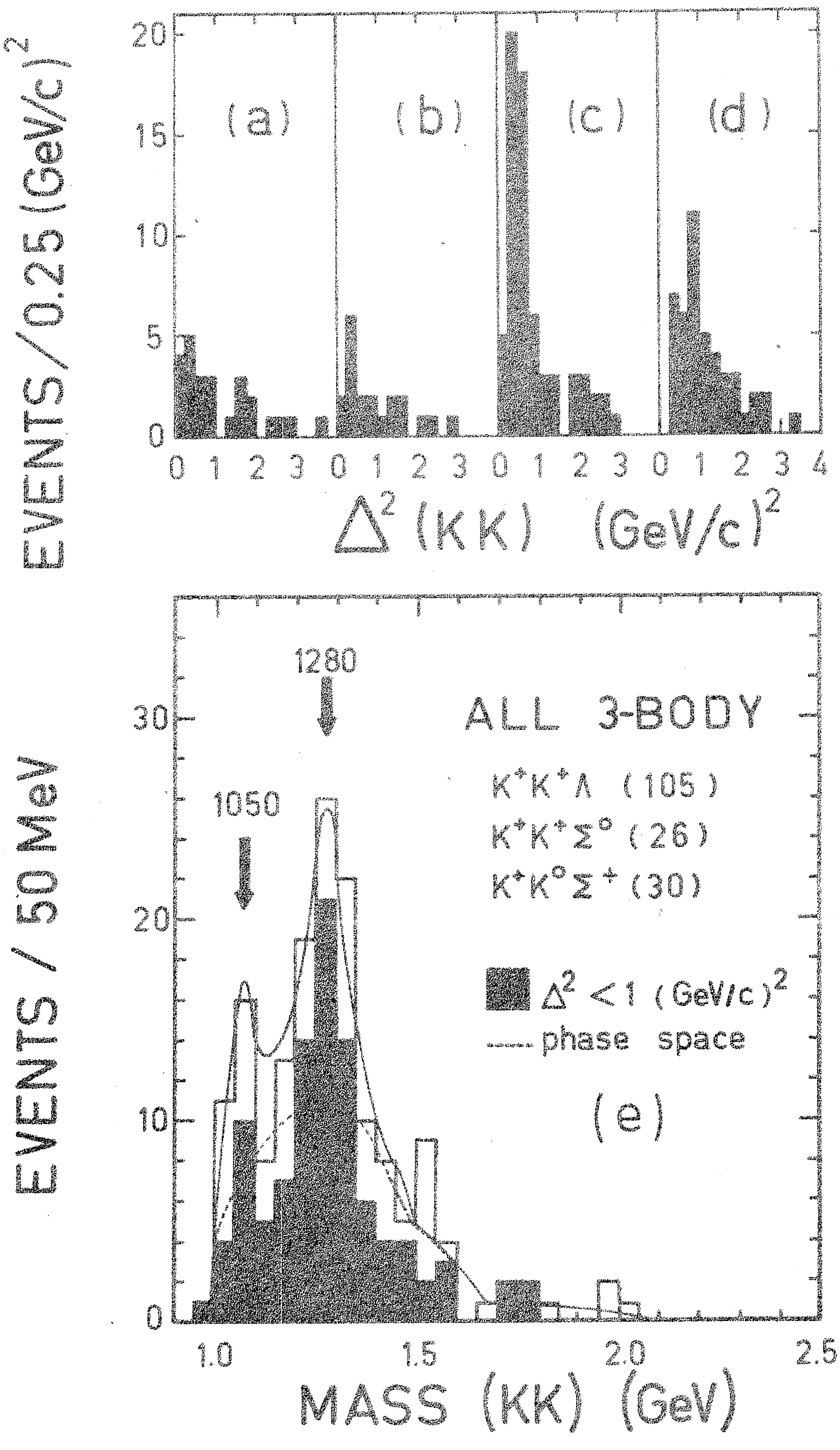

Fig. 2

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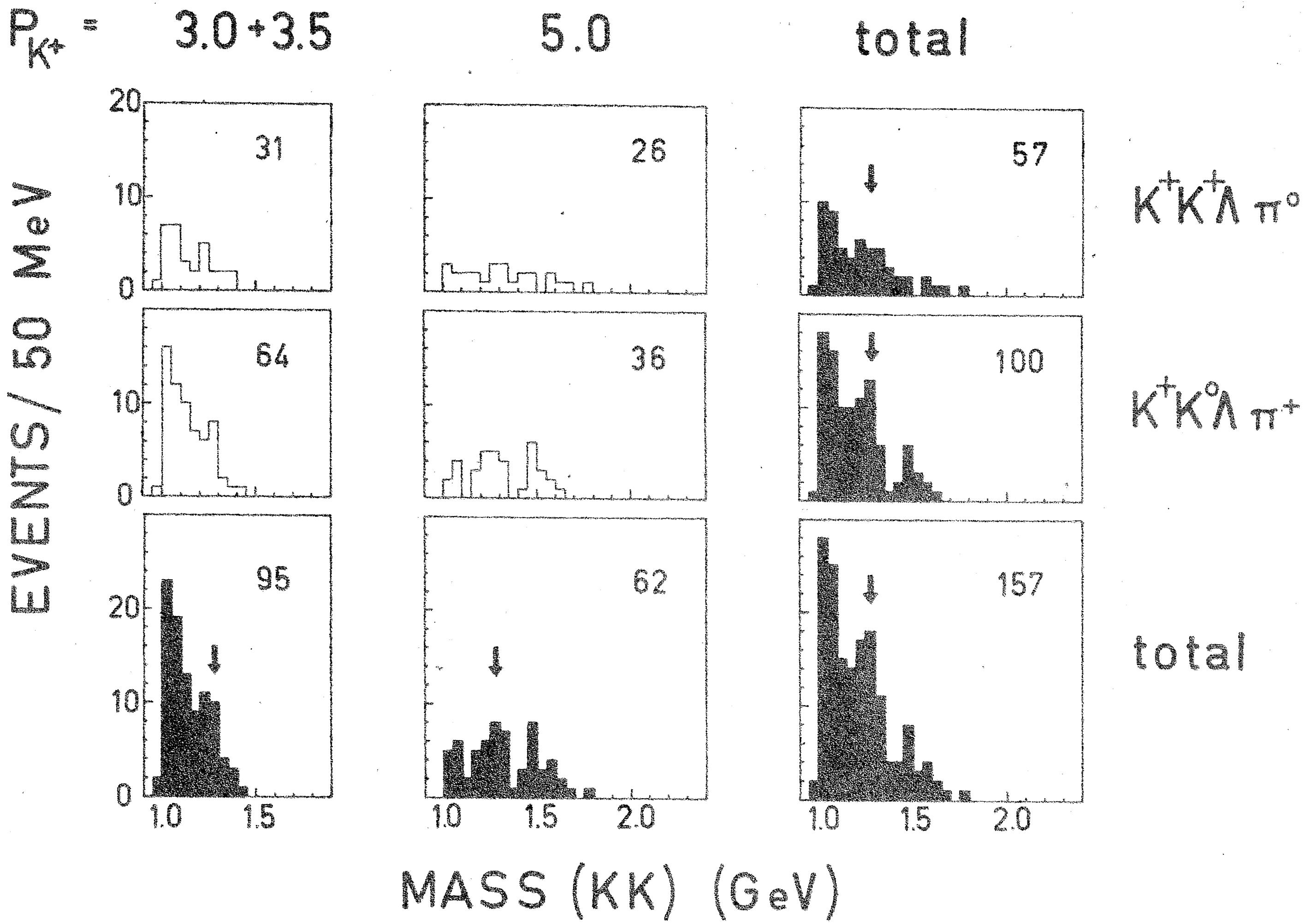
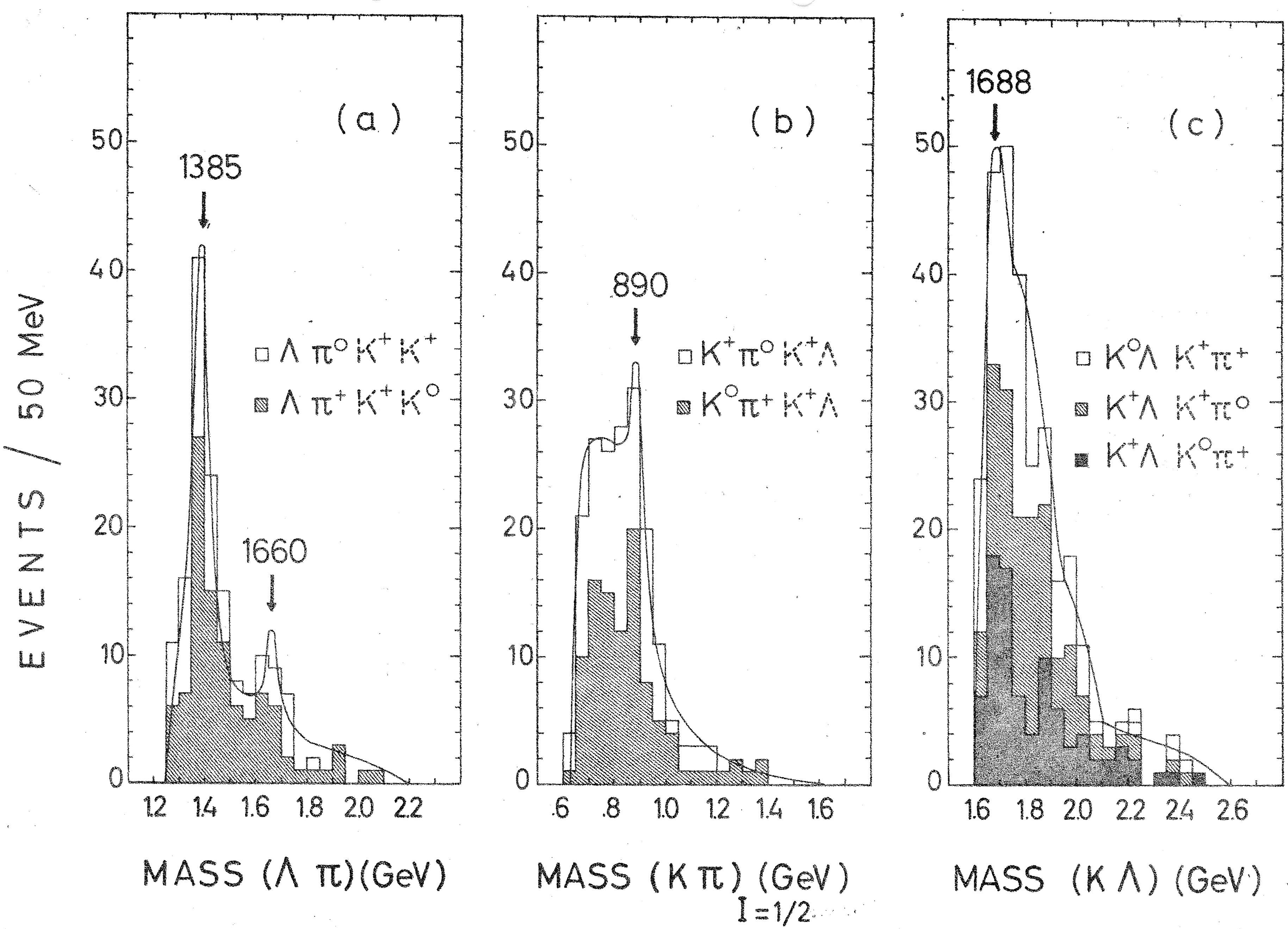

P K+ =
3.0+3.5
5.0
total
EVENTS / 50 MeV
20
10
0
31
26
57
K+K+Λ π°
64
36
100
K+K°Λ π+
95
62
157
total
1.0
1.5
2.0
MASS (KK) (GeV)

Fig.3



EVENTS / 50 MeV
(a)
1385
1660
□ Λ π° K⁺ K⁺
▨ Λ π⁺ K⁺ K°
MASS (Λ π)(GeV)
(b)
890
□ K⁺ π° K⁺ Λ
▨ K° π⁺ K⁺ Λ
MASS (K π) (GeV)
I = 1/2
(c)
1688
□ K° Λ K⁺ π⁺
▨ K⁺ Λ K⁺ π°
■ K⁺ Λ K° π⁺
MASS (K Λ) (GeV)

Fig 4

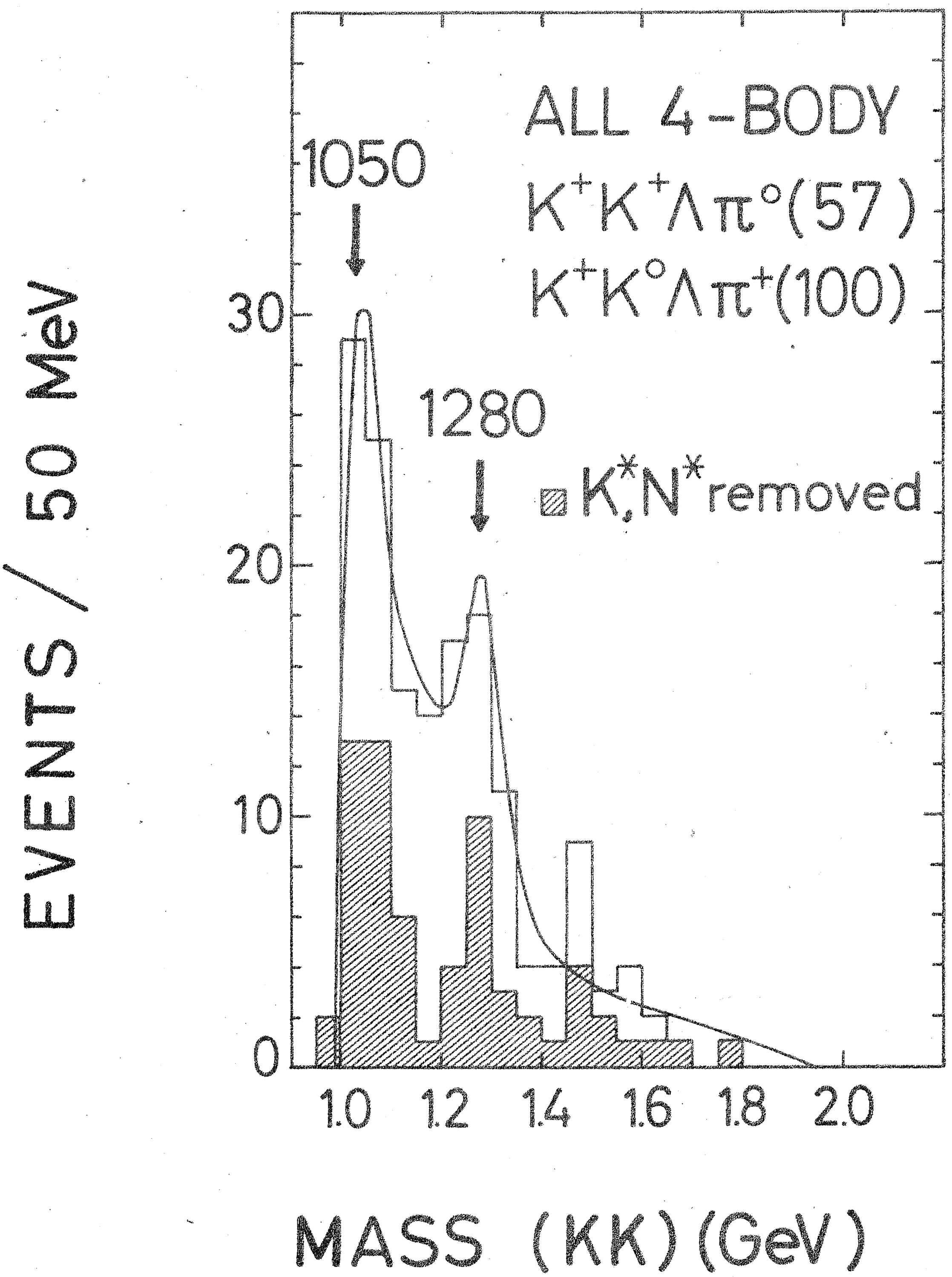


Fig. 5

DIA 23582
PS/4897/mkg

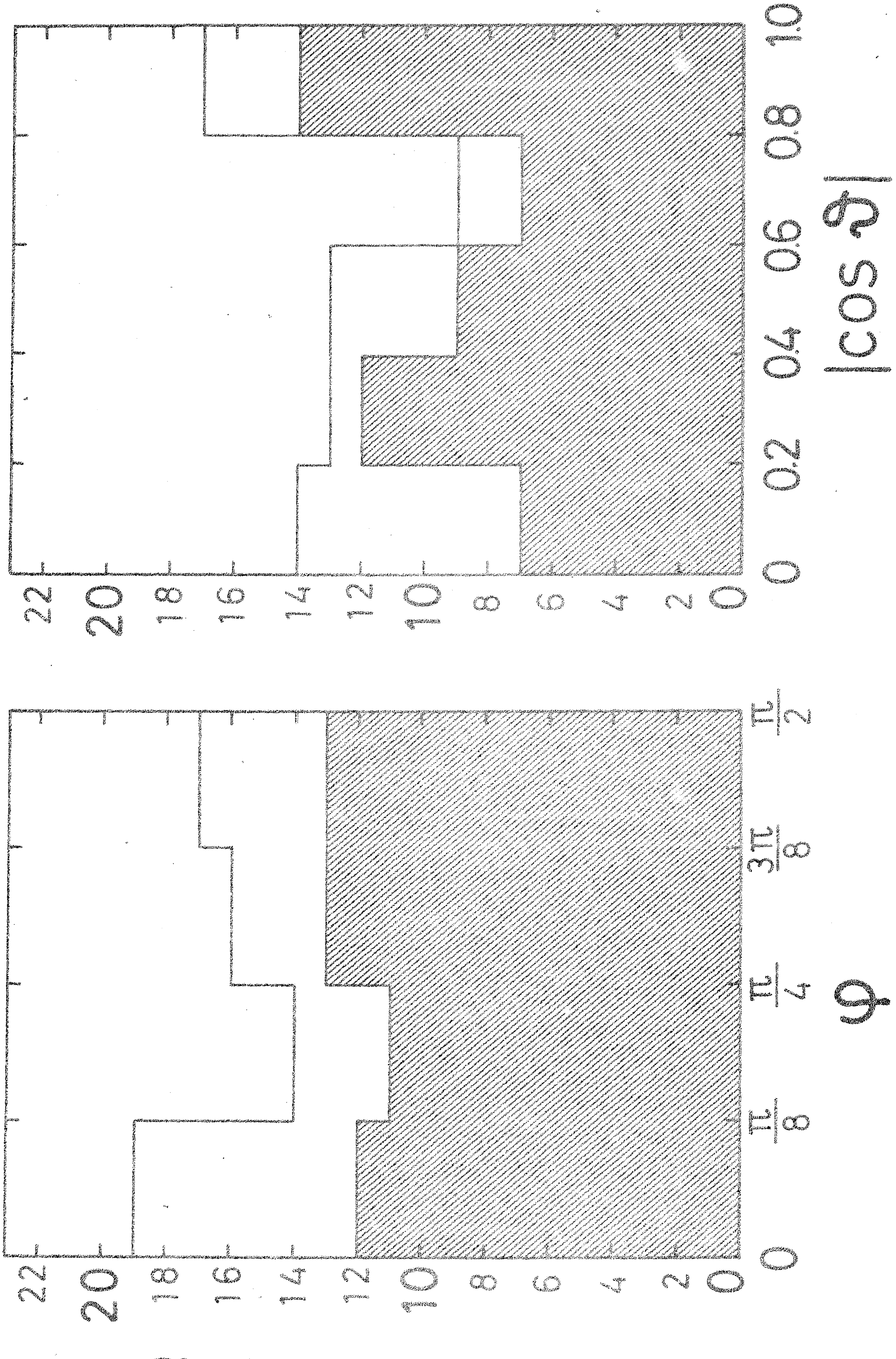


Fig.6

DIA 23583
PS/4897/mhg