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SOME RESULTS ON 3 GeV/c K^+ INTERACTIONS IN HYDROGEN

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The Saclay 81 cm hydrogen bubble chamber has been exposed to a separated beam of fast K^+-mesons, the beam-momentum was $2.965 \pm .015$ GeV/c and the estimated π contamination averaged 6%[1].

I. General features

About 900,000 K^+ tracks (as deduced from the number of τ-decays) were photographed. Topological cross sections are listed below:

	Topology	Cross-sections (mb)
a	2 prong	11.2 ± 1
b	2 prong + V^o	$1.9 \pm .1$
c	4 prong	$3.6 \pm .2$
d	4 prong + V^o	$0.15 \pm .02$
e	6 prong	$0.05 \pm .02$
	Total	17 ± 1.5

We now present preliminary results for those topologies we have studied. A more detailed study of the 3- and 4-body reactions coming from topologies a and b is presented elsewhere[2].

Two-prong

About 15,000 of these events exist in the film. We have studied only a very small sample of 200 events, which allows us to give the following evaluation of cross sections:

+ On leave from Collège de France, Paris

Reaction	Cross-section (mb)
$K^+ p \rightarrow K^+ p$	$4.3 \pm .8$
$\rightarrow K^+ p \pi^o$	$1.7 \pm .4$
$\rightarrow K^+ n \pi^+$	$.9 \pm .3$

The other reactions are either $K^o p \pi^+$ (see below) or 4- (or more) body.

"2-Prong V^o events"

In the complete experiment around 3,000 such events were found, measured and analysed using the kinematical fitting programme GRIND. In most cases the event type could be unambiguously identified by the probability of the fit, but in all cases the events were examined to check that ionisation of the tracks was consistent with the assigned hypothesis. It was possible to classify all events as follows:

Reaction	Cross-section (mb)
$K^+ + p \rightarrow K^o + p + \pi^+$	$2.2 \pm .3$
$\rightarrow K^o + p + \pi^+ + \pi^o$	$2.5 \pm .3$
$\rightarrow K^o + n + \pi^+ + \pi^+$	$\sim .7$
$\rightarrow K^o(n,p) + 3$ or more π's	$\sim .5$

"4-Prong V^o events"

This category is much fewer in number ($\sim$250 events). More than 80°/o of the events are due to the simplest possible reaction:

$$K^+ + p \rightarrow K^o + p + \pi^+ + \pi^+ + \pi^- \qquad \sigma \sim .4 \text{ mb}$$

"4-Prong"

Around 5,000 of these events were found. The analysis of 1/4 of these events has been completed and the systematic study of the whole sample is under way.

These events fall mainly into the following categories:

Reaction	Cross-section (mb)
$K^+ + p \rightarrow K^+ + p + \pi^+ + \pi^-$	$2.3 \pm .4$
$\rightarrow K^+ + p + \pi^+ + \pi^- + \pi^o$	$\sim .8$

II. Production of neutral hyperons

The reaction $K^+ p \rightarrow K^+ K^+ Y^o$ of which, up to now, only one example had been seen[3], has been systematically searched for.

a) Experimental procedure

Candidates for this reaction have been found in the topology 2-prong + V^o, whose main features have been described above. From the decay dynamics, while most of the V^o's are consistent only with a K^o decay, about 150 are found to be consistent either with a Λ-decay only, or with both a Λ- and a K^o-decay. In a first step, some of these decays can be unambiguously classified as Λ or K^o's on the basis of the ionisation of the positive track of the decay. In a second step, all remaining Λ-candidates are examined with respect to the following possible production reactions:

K^o production: $K^+ p \rightarrow \left\{ \begin{matrix} p\ \pi^+\ K^o \\ n\ \pi^+\ \pi^+\ K^o \end{matrix} \right\}$ + possible extra π^o ('s)

Λ-production:

$K^+ p \rightarrow K^+ K^+ \Lambda$

$\rightarrow K^+ K^+ \Sigma^o$

$\rightarrow K^+ K^+ \Lambda\ \pi^o$) + possible extra π^o('s)

$\rightarrow \pi^+ K^+ \Lambda\ K^o$

$\pi^+ p \rightarrow \pi^+ K^+ \Lambda$

$\rightarrow \pi^+ K^+ \Sigma^o$

$\rightarrow \pi^+ K^+ \Lambda\ \pi^o$) + possible extra π^o('s)

$\rightarrow \pi^+ \pi^+ \Lambda\ K^o$

There is practically no ambiguity between K^o and Λ production, and the few ambiguous cases can be classified as K^o or Λ with the help of the ionisation of the positive secondary tracks at the interaction vertex.

As a result of this procedure, we end up with a total sample of 56 events, in which the V^o is a Λ-decay. Fig. 1 shows the distribution of the square of the mass of the proton-pion system, the X^2-distribution for the fit of this system to a Λ-decay pointing to the interaction, and the distribution of the angle of emission of the proton in the Λ rest-frame.

From the behaviour of these distributions, we think that our sample of Λ's is pure and unbiased.

b) Results on hyperon production

Λ-production can proceed via any of the reactions listed above; possible production by π^+ has to be taken into consideration, since, even with our rather pure beam, we expect about 12 cases of Λ-production by pions[4]. The results of the kinematical fits to production by incident K^+ and incident π^+ are:

Production by K^+ / Production by π^+	$K^+ K^+ \Lambda$	$K^+ K^+ \Sigma^0$	4 body	not ambiguous with K^+ production
$\pi^+ K^+ \Lambda$	0	0	0	5
$\pi^+ K^+ \Sigma^0$	2	3	0	1
4 body	7	2	9	9
not ambiguous with π^+ production	15	1	3	
Total	24	6	12	15

As expected, not all events can be unambiguously identified as produced by K^+ or π^+; in most cases ionisation does not help, since dynamical ambiguity comes from the fact that a fast particle has about the same total energy, be it considered as a π^+ or a K^+, and in both cases, ionisation is nearly minimum. Nevertheless, a few remarks may be made:

1) An event fitting $K^+ K^+ \Lambda$ (4 constraints) never fits also $\pi^+ K^+ \Lambda$; it may be ambiguous only with $\pi^+ K^+ \Sigma^0$ (2 constraints) and mostly with four-body π-produced final states (1 constraint). More generally a possible K-production never suffers competition from a dynamically better determined π-reaction.

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2) The total number of unambiguously π-produced events (15) checks well with what is expected from the π-contamination of the beam. On the basis of these two arguments, we are tempted to consider the events fitting $K^+ K^+ \Lambda$ and $K^+ K^+ \Sigma^0$ as practically pure K-produced events (argument 1 is not strong enough for the 4-body reaction).

3) As a check, figures 2 and 3 show for the 30 K K Λ and K K Σ^0 fits, the following distributions:

- squares of missing mass
- missing energy
- X^2
- fitted primary momentum

It is seen that these distributions compare very favourably with the corresponding distributions for events of the type $\pi^+ p K^0$, which are completely unambiguous and of which we have a very large sample.

We may conclude that our sample of K K Y^0 events is consistent with being pure, though we cannot prove it for all individual events. In other words, though almost half of the events may have been produced by incoming pions, the total number of really π-produced events is most probably much smaller, and may be zero.

We thus can give the following values for the cross sections:

$$\sigma (K^+ K^+ \Lambda) \simeq 24 \mu b$$
$$\sigma (K^+ K^+ \Sigma^0) \simeq 6 \mu b$$

Figure 4 shows the 30 events displayed on a Dalitz plot, where the coordinates are the squares of the masses of the $Y^0 K_1^+$, and the $Y^0 K_2^+$ systems, (K_1^+ is the faster of the two identical K^+). The projection on to the $Y^0 K^+$ axis (Fig. 5) does not show any significant structure, while the projection on to the $K^+ K^+$ axis exhibits a bump at the centre of phase-space (between 1.4 and 1.7 GeV^2). Whereas the possible presence of a few really π-produced events prevents us from assigning any number to the significance of this bump, it may be noted that the "ambiguous" events, among which these possible π-events would be, are present in this bump in the same proportion as in the total spectrum. Finally, Fig. 6, a scatter-diagram of the

centre-of-mass emission angle of the hyperon and of the mass of the $K^+ K^+$ system, shows that in general the hyperon goes strongly backward, this tendency seeming even more marked when the $K^+ K^+$ mass lies between 1.2 and 1.3 GeV.

This experiment would not have been possible without the efficient help of many people; we want especially to thank the PS staff and crew, the NPA separator group, the Saclay bubble chamber team and our colleagues from Ecole Polytechnique, Saclay, Oxford, Amsterdam, Imperial College and Glasgow for their cooperation in the setting-up of the beam and the run, also the IEP and computer groups and our scanning team for their participation in the analysis.

REFERENCES

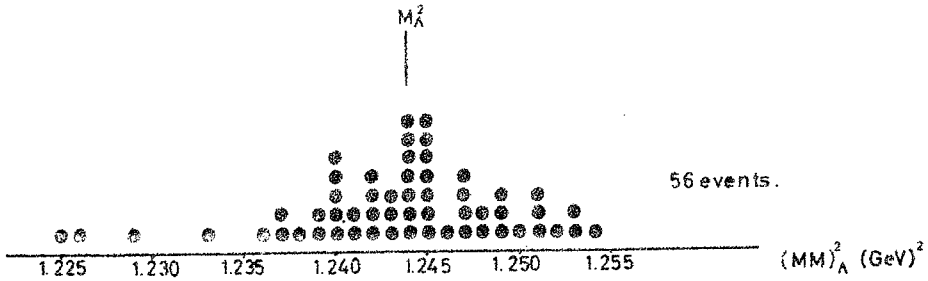
1. J. Goldberg and J.-M. Perreau, "Un faisceau d'usage général à deux étages de séparation électrostatique au PS" (CERN 63-12).

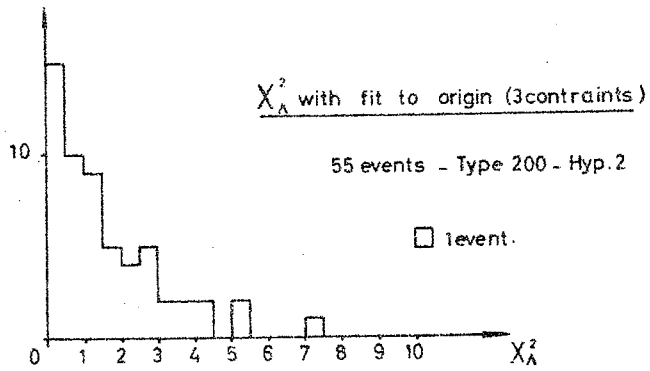
2. M. Ferro-Luzzi et al., Proceedings of the Sienna Conference (1963).

3. Pevsner, private communication. This event was found with 2.3 GeV/c K^+, while at 1.96 GeV/c, S. Goldhaber et al. found no example of hyperon production.

4. This number is derived from the total number of 2-prong V^o events produced by 2.7 GeV/c π^+ in the same chamber, in a run of similar total flux. We thank the Orsay group for communication of this result.

Λ_DECAYS FOUND IN 3 GeV/c K^+ EXPERIMENT.





Proton distribution in Λ rest frame.

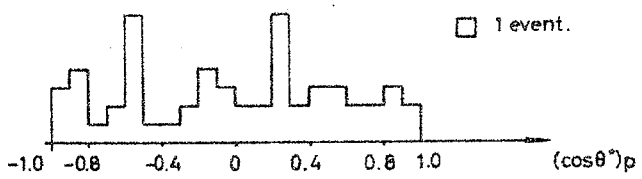


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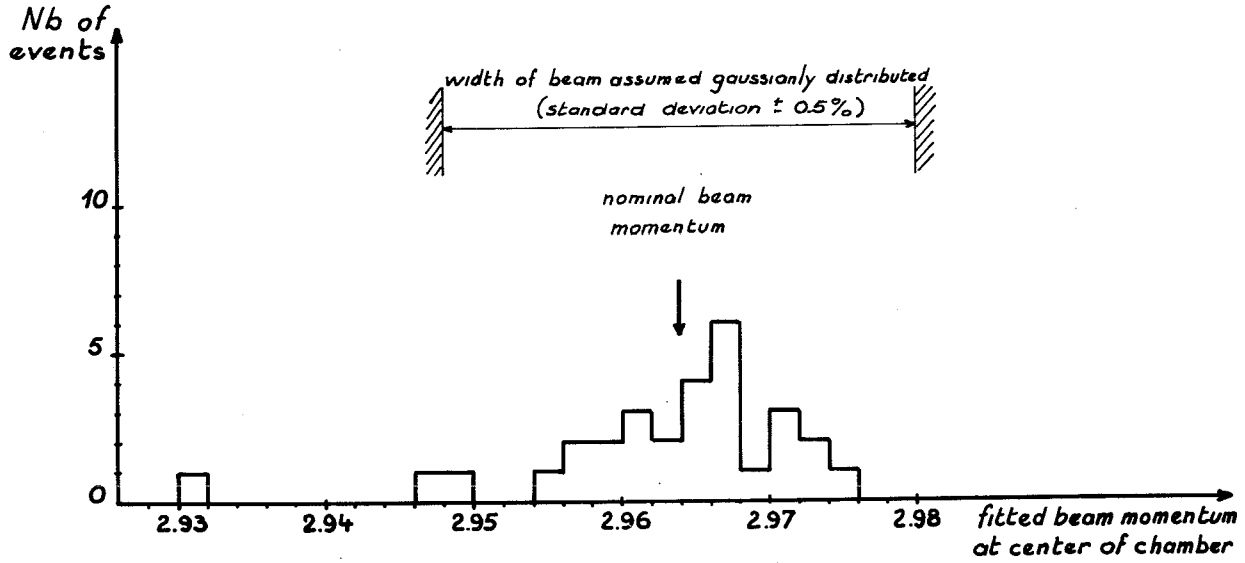
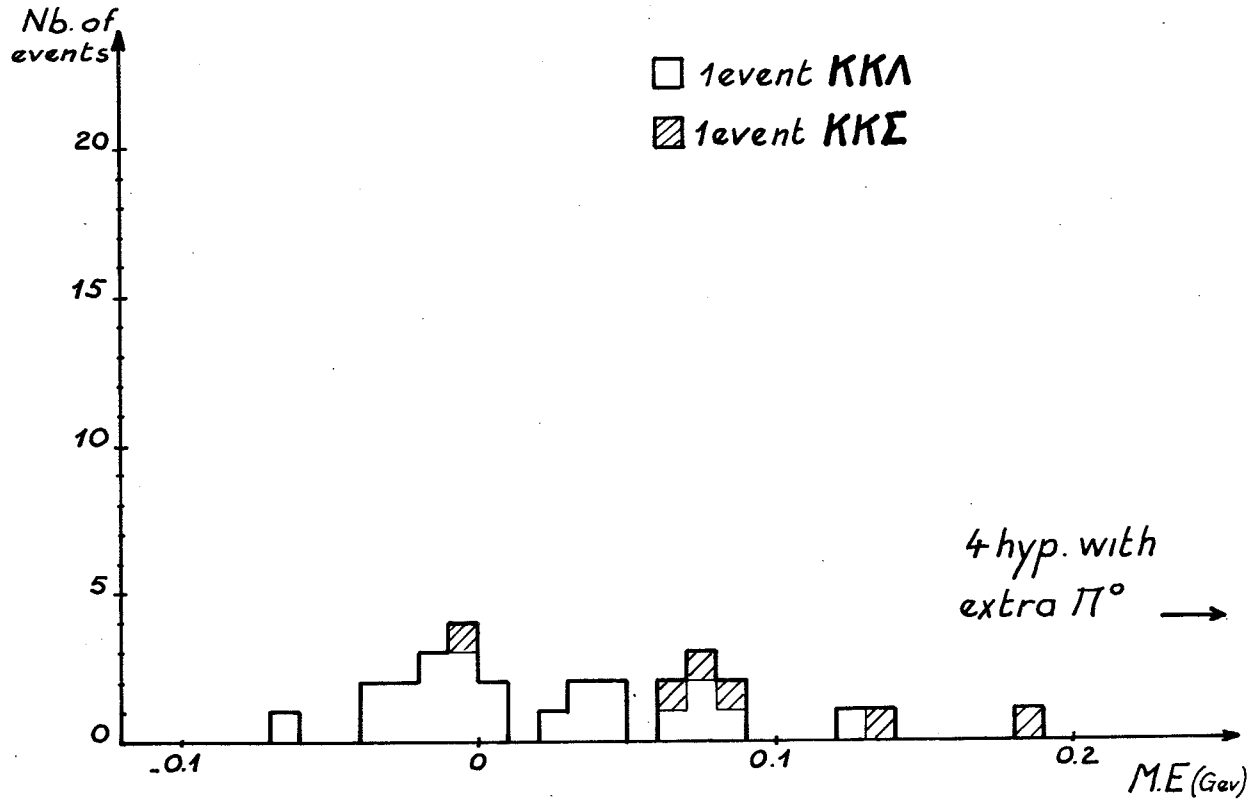
FIG. 1

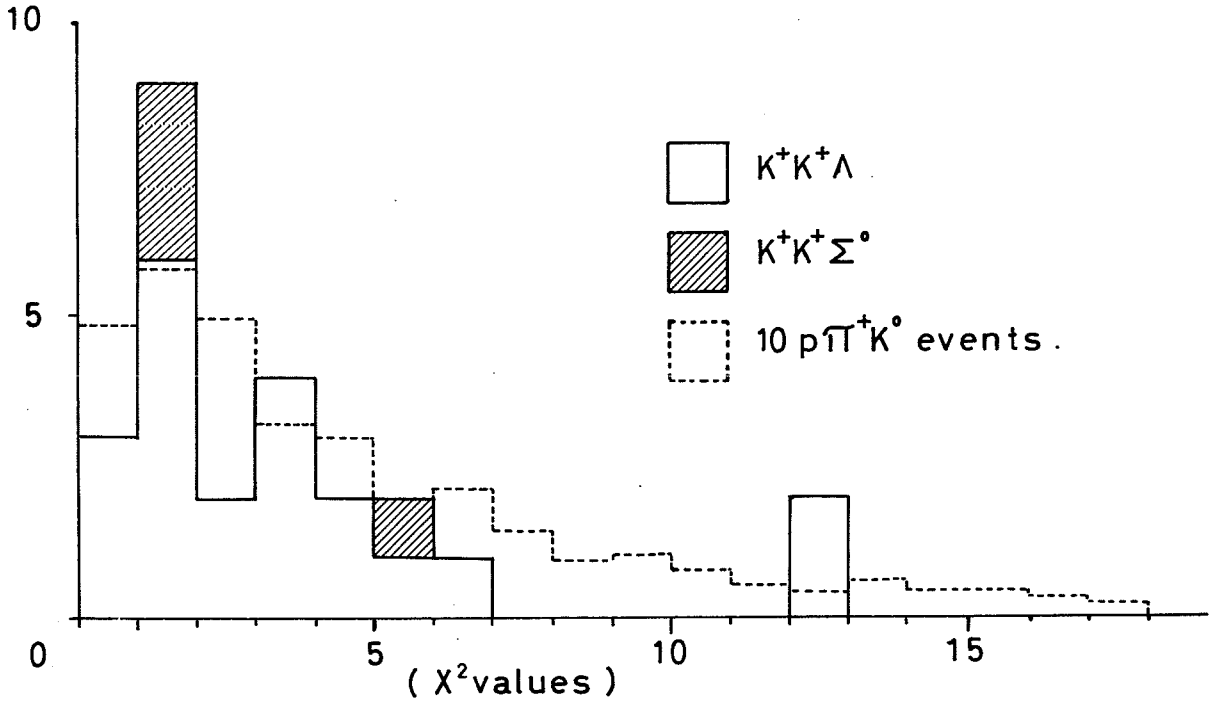
Fig 2

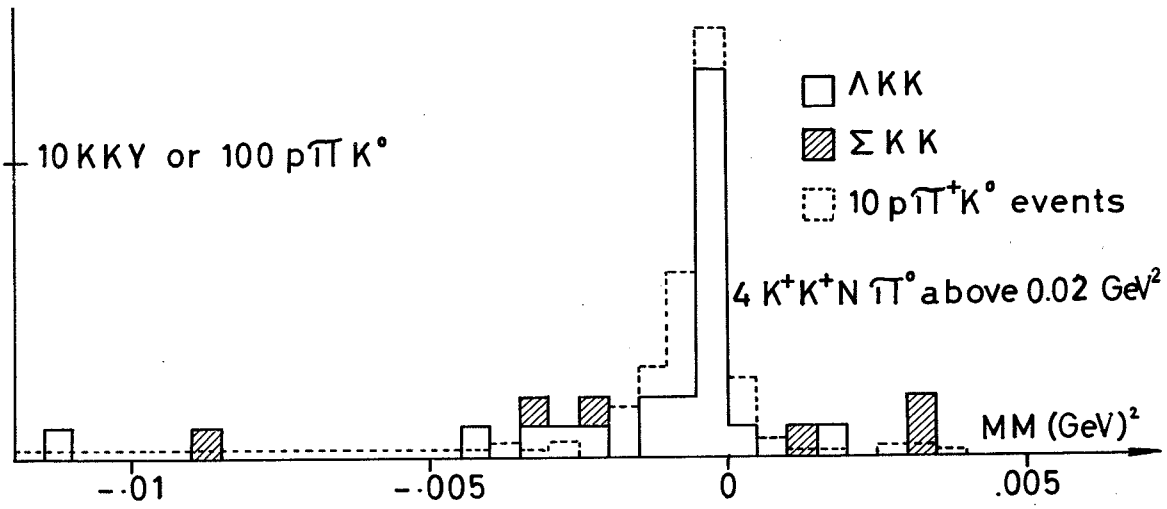




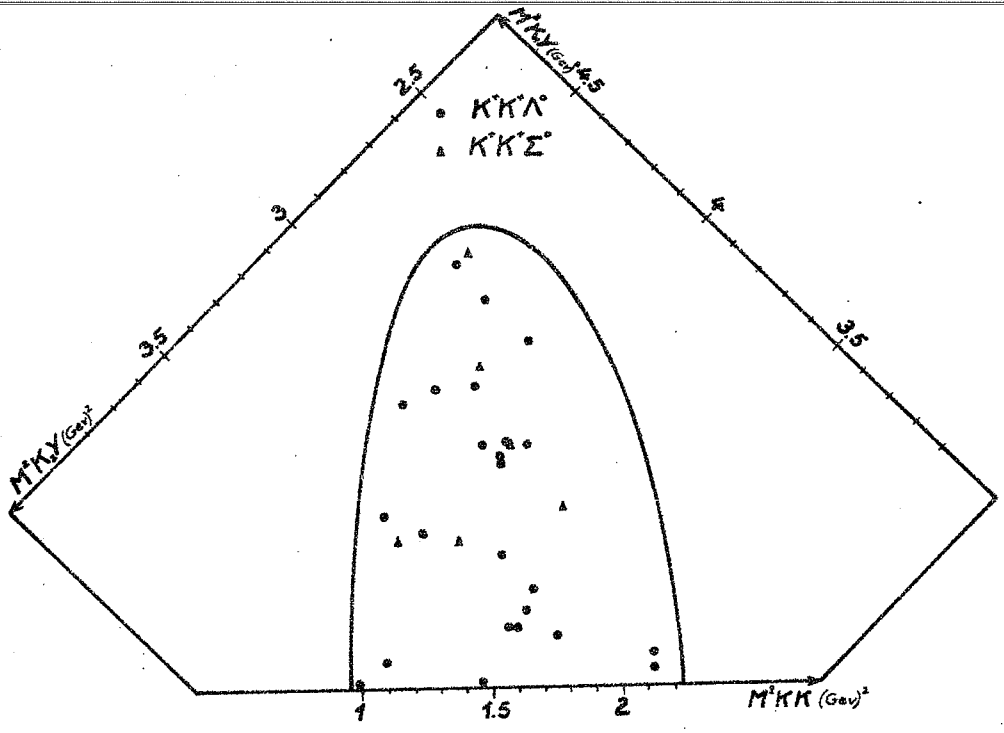
Missing Energy for ΛKK hypothesis

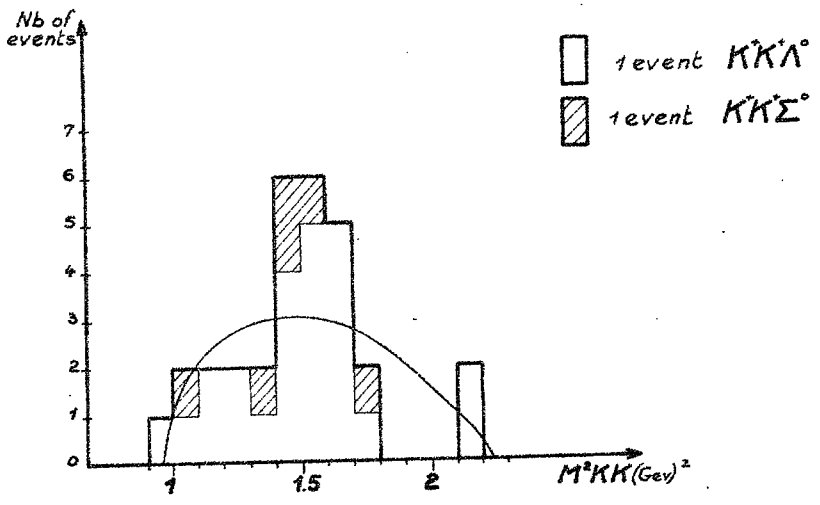
Fig. 3





Square of Missing mass in 3 body hypothesis.





$p_{K^+} = 3$ GeV/c

$K^+ p \to K^+ K^+ Y^\circ$

30 events

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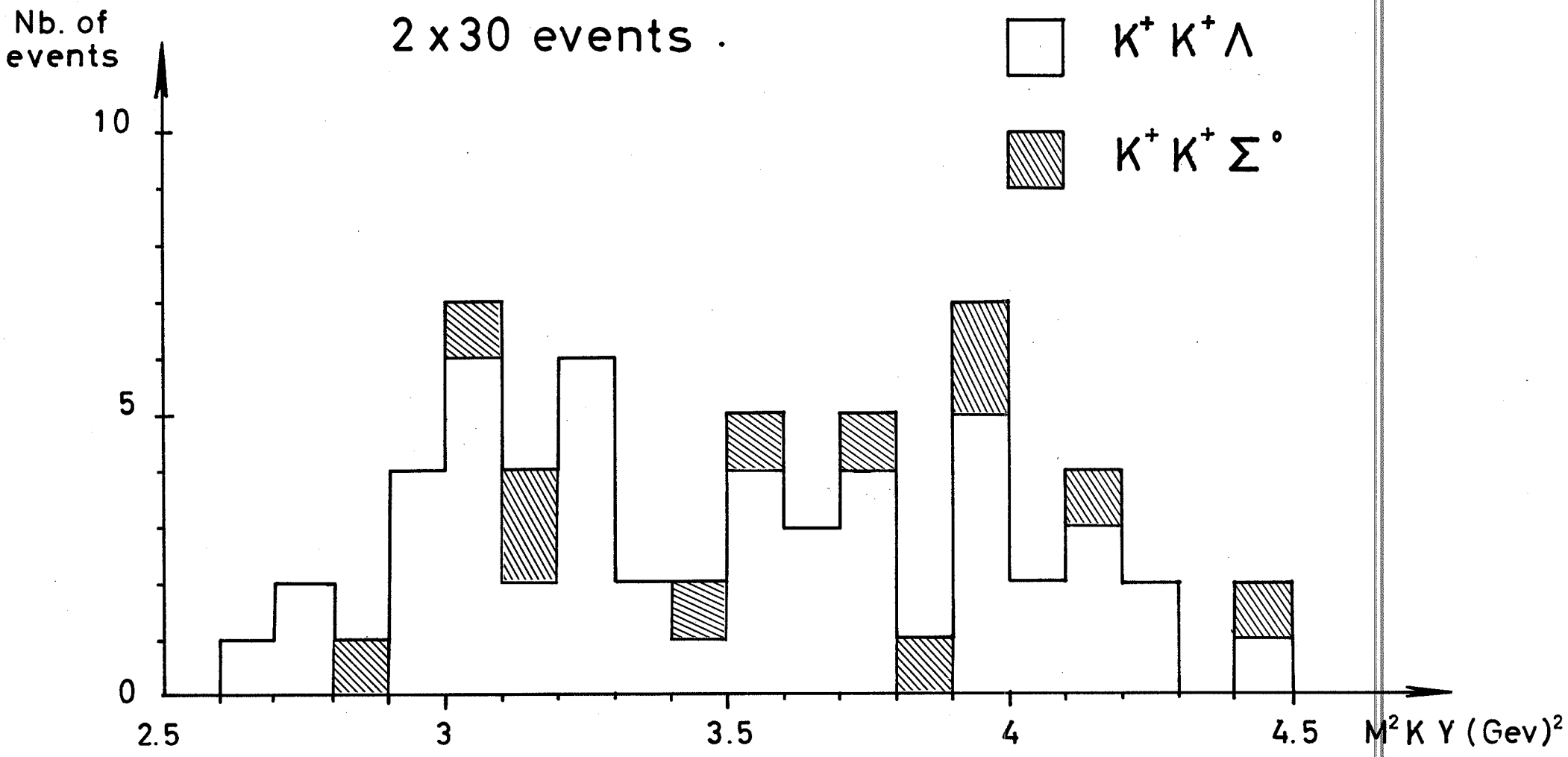
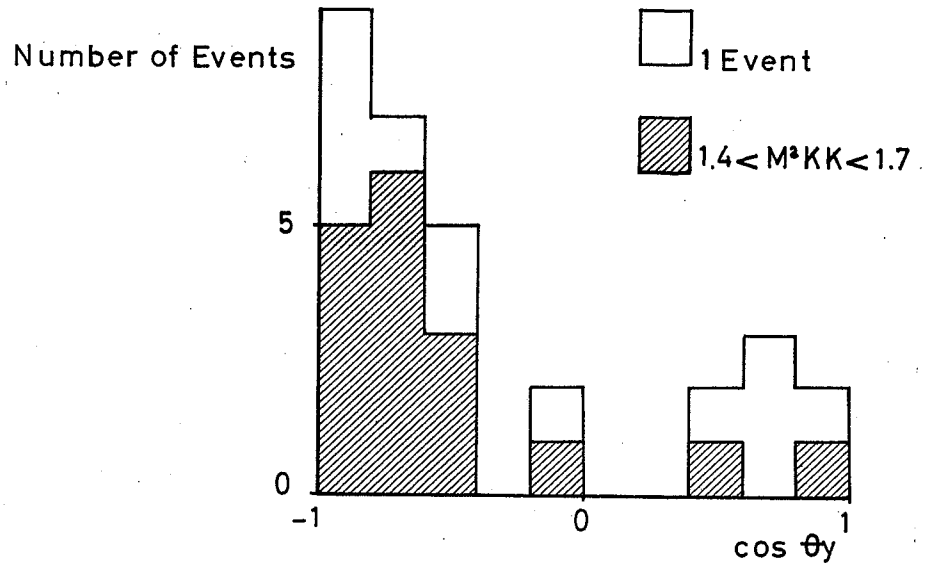
FIG. 4

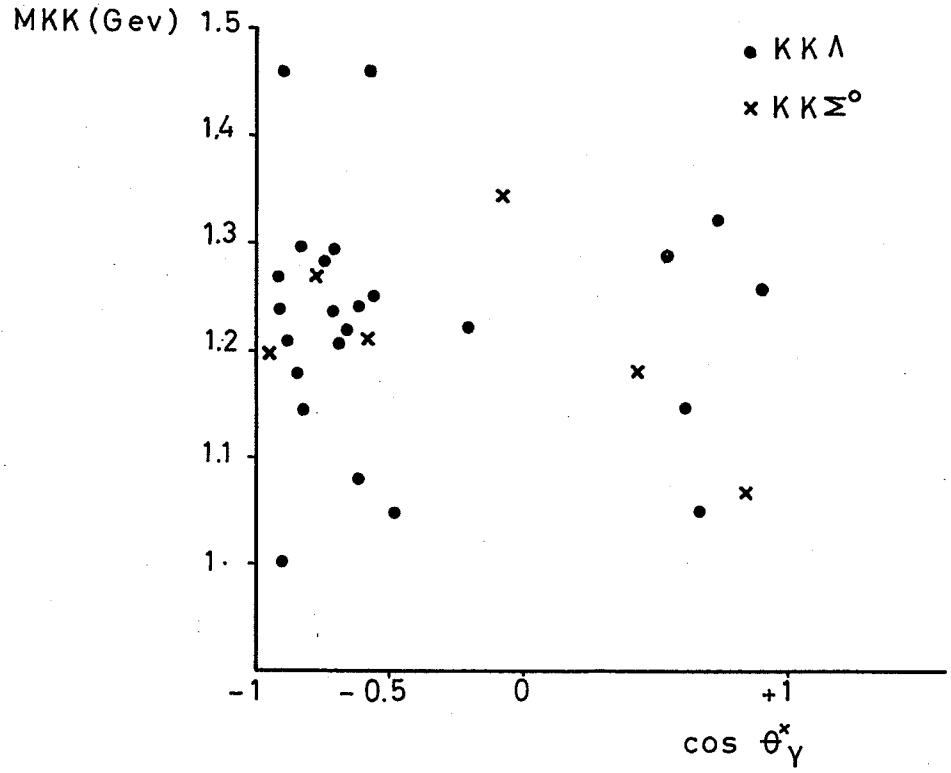
Fig. 5



$K^+K^+\Lambda$ or $K^+K^+\Sigma^\circ$ Systems (K^+p at Gev/c)

ANGLE of Production of Hyperon in C M





MKK(Gev)