NPA/Int. 64-36
Meyrin, 30th November 1964

SUMMARY OF DATA ON STRANGE PARTICLE PRODUCTION BY NEUTRINOS IN THE H.L.B.C.

Out of 454 events, observed in the fiducial volume of the heavy liquid Bubble Chamber during the 1963 and 1964 neutrino runs, 8 events are associated with strange particles. Two events, producing strange particles, have been observed outside the fiducial volume and they will be discussed in the following, but they are neglected when statistical considerations are made.

The relevant parameters of these 10 events are summarized in Tables 1 and 2.

1. Interpretation of the events

In almost all the events, the identification of at least one of the ejected particles was uncertain. In some cases (see table 1) they were consistent only with them being π^+ or K^+, in others with π^+, K^+ or protons. Their interpretation as μ^+ has been disregarded altogether.

When only one strange particle was seen, a K^+ possible candidate was assumed to be a K^+, provided that the other strange particle could be interpreted as one of strangeness - 1. We remark that in no case this procedure led to contradictions.

When there was more than one candidate, that of highest momentum was interpreted as K^+. This procedure is not justified by any physical reason but it does not affect appreciably the conclusions of the discussion reported below. In fact any of the alternative choices would have not changed the estimate of the total visible energy by more than 1 Gev, for the events listed in Table.1.

Gamma rays were considered as an evidence for the neutral decay of strange particles only if not pointing to the apex of the primary neutrino event, In events 462 and 486, two and one γ respectively were observed, in both cases not pointing to the origin and the interpretation as Λ was preferred to that of K^o, due to the large probability for γ's to materialize in CF_3Br.

2. Dynamical analysis of the events

The relevant dynamical data regarding the neutrino events and the observed strange particles are given in Table 2. They suggest the following comments.

a) Of the ten events listed in Table 1 and 2 four indicate the presence of two strange particles (106, 213, 462, 486). In each of these cases one of them was a charged K or a Λ decaying into a charged mode; the other decayed into neutral particles and was individuated by the fact that one or more γ's were observed which did not point to the primary neutrino event, thus excluding the possibility of originating from directly produced π^o's.

Five (197, 495, 518, 728, 803) have a clearly identified strange particle (Λ or K^o) and at least a K^+ possible candidate.

One (127) has a K^+ decaying in the chamber and no other visible candidate. Even in the case of associated production one should expect cases of K_2^o which would not be seen in the chamber.

Considering that a strange particle may not be detected i.e. because of its long lifetime (as in the case of K_2^o) or because the dynamical analysis did not permit its identification (fast K^+ cannot be distinguished in our chamber, from π^+'s), we estimate that ~ 5 events containing pairs of strange particles may be present in our sample of ν - events and have not been individuated.

b) E_{vis} - distribution. The majority of the events with strange particles have a large visible energy, i.e. the ratio

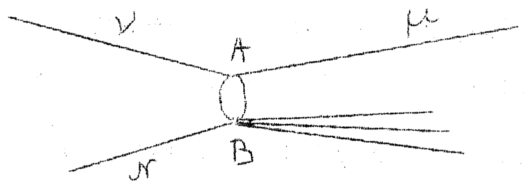
$$r(E_{vis}) = \frac{\text{Number of events with strange particles}}{\text{Number of inelastic events}}$$

increases with the neutrino energy, (see fig. 1). This fact, however, may not be very significant as we shall discuss later.

c) q^2-distribution. The q^2 distribution is similar to that of the inelastic events.

d) the M^* distribution (see fig. 2). (M^* being the invariant mass of the hadronic part of the final products) is grouped around 2 Gev. This is most probably a kinematical effect : on the low energy side the (associated) production of strange particle is limited by the threshold and on the high energy side by the decrease of the neutrino spectrum.

e) the E'-distribution. If the production of the strange particles is associated with the baryon vertex B



the neutrino energy E_ν (taken to be equal to E_{vis}) may not be the best parameter to allow a comparison with strange particle production by other radiations. We know for instance that a close analogy can be drawn between photo production and electron production of pions by displaying the events from electron production in terms of the energy of the equivalent real photon in the laboratory system

$$E_\gamma = \frac{M^{*2} - M^2}{2M}$$

where M is the mass of the target nucleon and M^* is the total energy of the photon and the nucleon in their CM - system. Thus to compare our data with the production of strange particle by other particles of mass m we plot our results as a function of

$$E' = \frac{M^{*2} - M^2 - m^2}{2M}$$

Up to pion masses, $m^2 \ll M^2$ and we can neglect it.
E' is then nothing else but M^{*2} displayed on a different scale.

The ratio r , plotted as a function of E' is shown in fig. 3. For comparison the corresponding ratio (r_π) for strange particle production by pions are shown. For neutrino events the data are restricted to the events "inside" the fiducial volume. The statistics is too poor and the two processes need not be related as they are in the example quoted above to allow a definite conclusion. It seems to indicate, however, that strange particles are produced by neutrinos at a relative rate which is higher than by pions.

f) Associated and single production of strange particles by neutrinos. As discussed above all events are consistent with associated production. This conclusion is essentially based on the fact that no event is seen below the threshold energy for associated production whereas neutrinos are certainly plentiful in the region around and below that energy.

This is in agreement with the $\Delta Q/\Delta S = +1$ rule which forbids the production of single hyperons by neutrinos. A single K, however, may be produced (not a $\bar{K}$). In fact a process of the type

$$\nu + N \longrightarrow \ell^- + K + N$$

has $\Delta S = +1$ $\Delta Q = +1$ and does not violate the selection rule. We expect the number of these events in our sample to be small (0.1 o/o of the elastic events: see G.R. Henry, J. Løvseth, J.D. Walecka, CERN preprint, 9243 - TH. 451, 1964). Since the number of elastic events observed in our fiducial volume is 130, we cannot expect an appreciable contribution from this effect. Event 127 might possibly be an example.

g) Secondary production of strange particles. Some of the strange particle events may be due to secondary production by pions interacting inside the same nucleus in which they are produced by the primary neutrino interaction.

Rough estimates based on the observed number of fast pions indicate that such an effect should be negligible (see the CERN Bubble Chamber report at Dubna). A more accurate estimate of it is in progress. However, it should not affect any of our main conclusions as the comparison with pion production was also based on data some of which were obtained in heavy nuclei.

A number of discussions with Prof's. Cabibbo, Prentki, Salin and Veltman are gratefully acknowledged.

C. Franzinetti
J. Keren
G. Myatt
M. Paty

/fv

<u>Distribution</u> : (closed)
Scientific Staff of N.P.A.

Figure Captions

Fig. 1 $\gamma(E_{vis}) = \dfrac{\text{Number of events with strange particles}}{\text{Number of inelastic events}}$ plotted as a function of E_{vis}

Fig. 2 M^* versus E_{vis} distribution for events producing strange particles compared with that of inelastic events

Fig. 3 The ratio r as a function of E'. The line represents the same ratio for pion production (r_π)

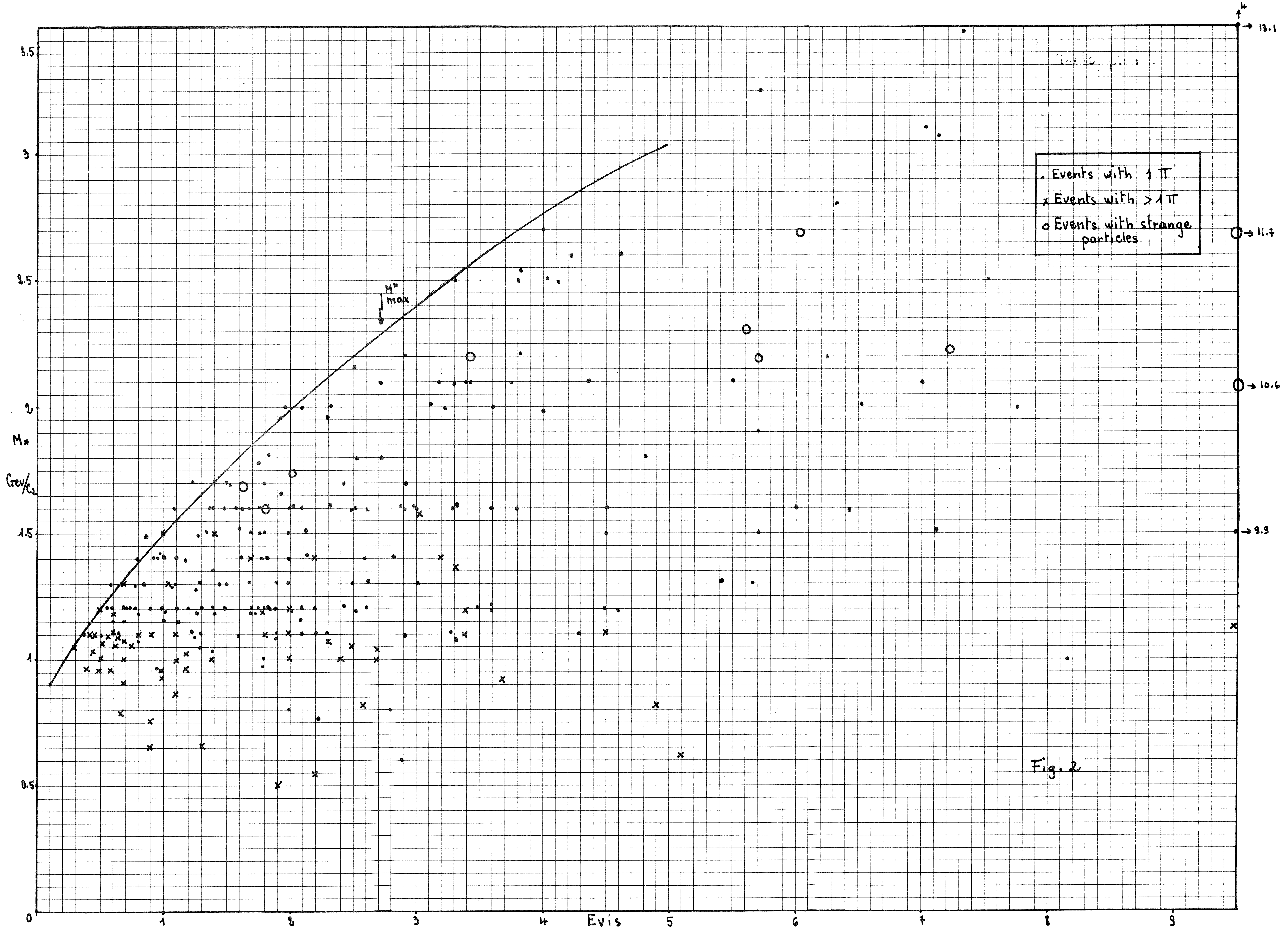


Fig. 2

SIS/R/9790

SIS/R/9788

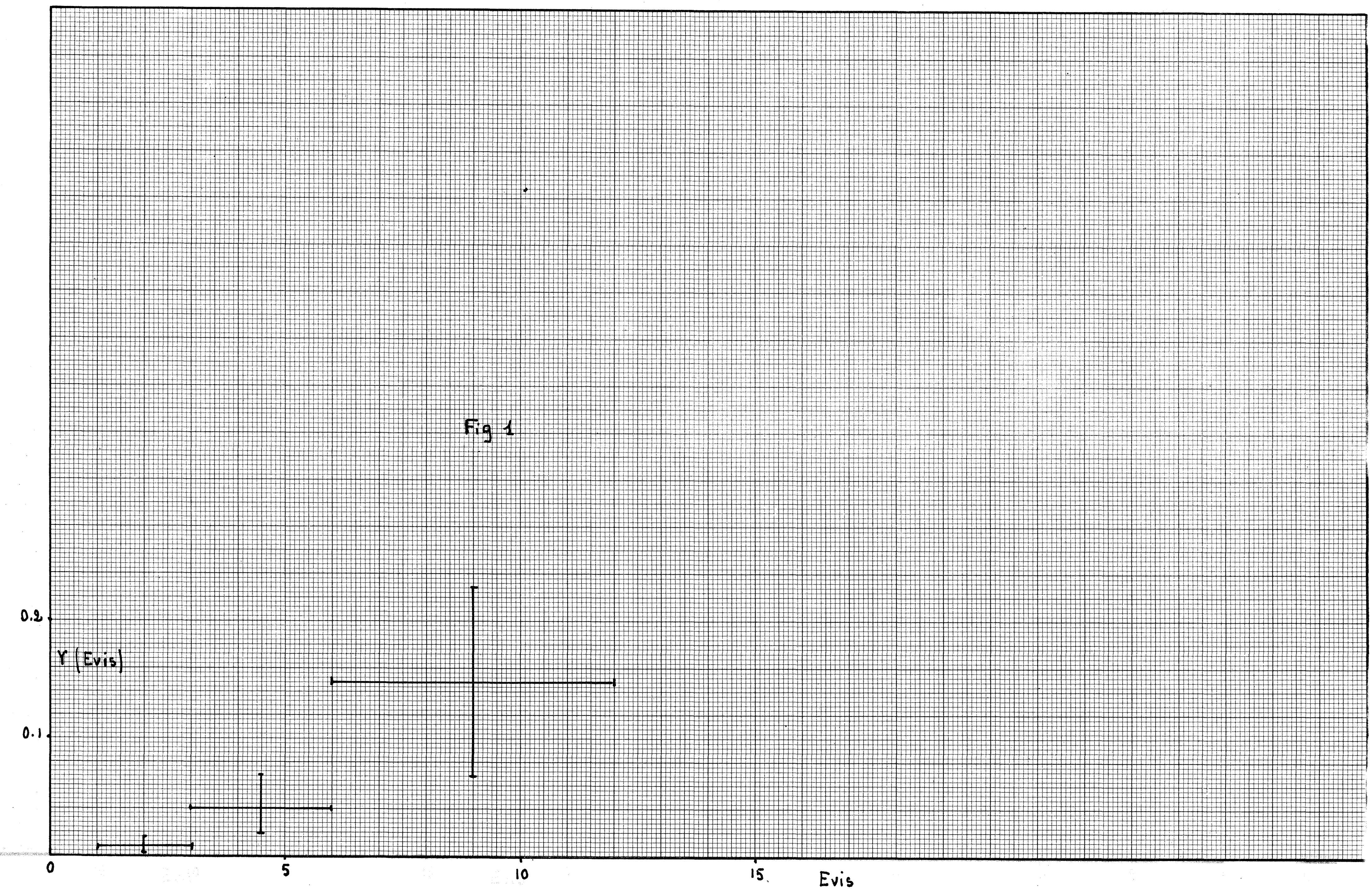


Fig 1

Fig. 3

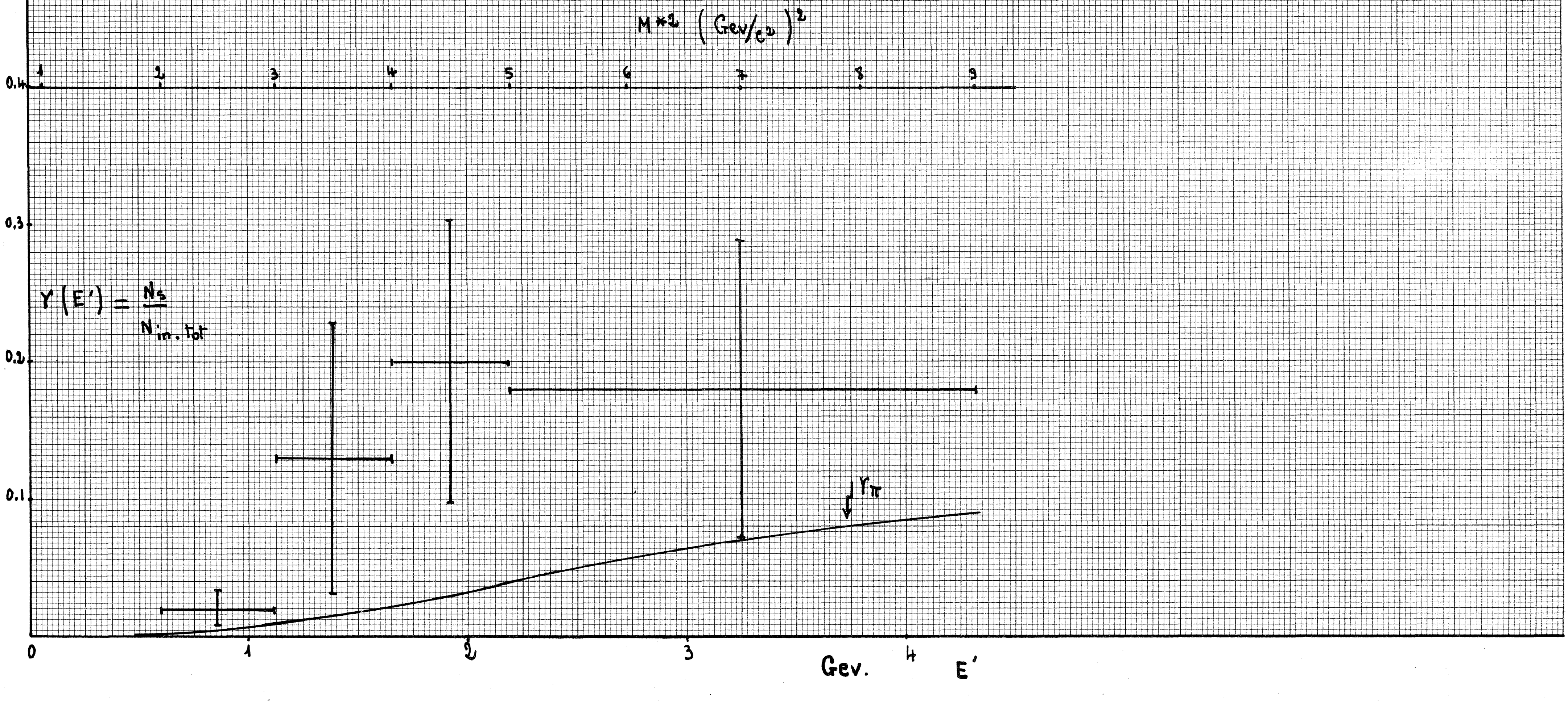


Table 1

Run	Code No	Inside or Outs. Fid.Vol	Description of the event	Interpretation	Details on the observed decays
4	106	In	$\mu^-\;p\;(+)\;(+)\;K^0\;\binom{K^0}{\Lambda^0}$	$\mu^-\;p\;p\;\pi^+\;K^0\;\bar{K}^0$	$K^0 \rightarrow \pi^+ + \pi^-$; $K^0 \rightarrow \pi^0 + \pi^0$ (the interpretation of the 4 γ's as due to $\Lambda^0 \rightarrow \pi^0 + n$ and an independent π^0 could not be excluded)
4	127	Out	$\mu^-\;\pi^+\;\gamma\gamma\gamma\;n\;K^+$	$\mu^-\;\pi^+\;\pi^0\;\pi^0\;n\;K^+\;(K^0_2)$	$K^+ \rightarrow \mu^+ + \nu$; the three γ's point to the primary event
5	197	In	$e^-\;ppp\;(+)\;(+)\;\gamma\gamma\gamma\;\Lambda^0$	$e^-\;ppp\;\pi^+\;\gamma\gamma\gamma\;K^+\;\Lambda^0$	$\Lambda^0 \rightarrow \pi^- + p$; the three γ's point to the primary event (the Λ^0 may originate from a $\Sigma^0 \rightarrow \Lambda^0 + \gamma$ decay)
6	215	In	$\mu^-\;pppppp\;\pi^+\;\pi^-\;\pi^-\;\Lambda^0\;K^0$	$\mu^-\;pppppp\;\pi^+\;\pi^-\;\pi^-\;\Lambda^0\;K^0$	$\Lambda^0 \rightarrow \pi^- + p$; $K^0 \rightarrow \pi^0 + \pi^0$
8	462	Out	$\mu^-\;ppp\;K^+\;\gamma\gamma$	$\mu^-\;ppp\;K^+\;\Lambda^0$	$K^+ \rightarrow \mu^+ + \pi^0 + \nu$; $\Lambda^0 \rightarrow \pi^0 + n$ (from 2 γ's not pointing to the primary event)
8	486	In	$\mu^-\;p\;(+)\;\gamma\;K^+$	$\mu^-\;pp\;\Lambda^0\;K^+$	$K^+ \rightarrow \mu^+ + \nu$; $\Lambda^0 \rightarrow \pi^0$ + [illegible] on the basis of one γ not pointing to the origin
8	495	In	$\mu^-\;p\;\pi^+\;(+)\;\binom{K^0}{\Lambda^0}$	$\mu^-\;p\;\pi^+\;K^+\;\bar{K}^0$	$K^0 \rightarrow \pi^+ + \pi^-$; it interacts in flight and is scattered backwards
9	518	In	$\mu^-\;pp\;(+)\;\pi^-\;\binom{\pi^+}{K^+}\;K^0$	$\mu^-\;pp\;\pi^+\;\pi^-\;K^+\;\bar{K}^0$	$K^0 \rightarrow \pi^+ + \pi^-$
10	728	In	$\mu^-\;p\;(+)\;\gamma\;\binom{K^0}{\Lambda^0}$	$\mu^-\;p\;K^+\;\Lambda^0\;\gamma$	$\Lambda^0 \rightarrow \pi^- + p$; it may originate from $\Sigma^0 \rightarrow \Lambda^0 + \gamma$ the Λ^0 interacts in flight
11	803	In	$\mu^-\;\binom{\pi^+}{K^+}\binom{\pi^+}{K^+}\;\gamma\gamma\gamma\;\Lambda^0$	$\mu^-\;\pi^+\;\gamma\gamma\gamma\;K^+\;\Lambda^0$	$\Lambda^0 \rightarrow \pi^- + p$; the 3 γ's point to the primary event

N.B. The symbol (+) indicates unidentified positive track

Table 2

Code #	Momentum of the observed strange particle (Gev/c)	Primary neutrino event					Comments
		E_{vis} (Gev)	q^2 $(Gev/c)^2$	P_{imb} Gev/c	M^* Gev/c^2	E' Gev	
106	$K^0 \rightarrow \pi^+ + \pi^-$: 1.71 ± 0.09 $K^0 \rightarrow 2\pi^0$: 0.55 ± 0.07	5.57 ± 0.70	3.16	1.29	2.28	2.32	
127	$K^+ \rightarrow \mu^+ + \nu$: 0.25 ± 0.05	7.22 ± 1.35	1.97	1.51	2.25	2.31	
197	$\Lambda^0 \rightarrow p + \pi^-$: 0.64 ± 0.01	6.04 ± 0.80	2.71	0.75	2.68	1.60	
213	$\Lambda^0 \rightarrow p + \pi^-$: 0.46 ± 0.01 $K^0 \rightarrow 2\pi^0$: 0.21 ± 0.03	5.71 ± 0.42	0.15	0.28	2.22	2.1	
462	$K^+ \rightarrow e^+ \pi^0 + \nu$: 0.411 ± 0.01	1.61 ± 0.21	0.42	0.52	1.67	1.0	
486	$K^+ \rightarrow \mu^+ + \nu$: 0.63 ± 0.05	1.83 ± 0.38	0.99	1.61	1.61	0.88	
495	$K^0 \rightarrow \pi^+ + \pi^-$: 0.30 ± 0.05	10.65 ± 1.24	4.01	1.28	2.17	2.0	
518	$K^0 \rightarrow \pi^+ + \pi^-$: 3.37 ± 0.30	3.37 ± 0.30	0.66	0.41	2.21	2.1	
728	$\Lambda^0 \rightarrow p + \pi^-$: $(0.79 \pm 0.03)^*$	2.01 ± 0.28	1.10	0.63	1.76	1.2	* It interacts and subsequently it decays. The momentum given is that at decay.
803	$\Lambda^0 \rightarrow p + \pi^-$: 1.67 ± 0.18	11.72 ± 1.14	0.90	0.42	2.72	3.5	