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CERN NEUTRINO EXPERIMENT - PRELIMINARY BUBBLE CHAMBER RESULTS

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(presented by D. Perkins)

1. SUMMARY

In the present stage of the neutrino experiment the 500 litre heavy liquid bubble chamber[1] has been operated in the neutrino beam for about 664,000 pulses of the PS. From a fiducial volume of 220 litres, 136 events have been analyzed and provisionally attributed to neutrino interactions. Of these 68 have no pions along with the μ^- candidates, but only protons or evidence of neutrons, and are called "elastic". The other 68, of which 53 have one pion, and 15 more than one pion, are called "inelastic". In three events an electron emerges from the star, in one a possible positron, and three events have a single strange particle K^+, K^o, Λ and one a pair $\Lambda + K^o$. In addition to the 136 "neutrino" events, 8 events had a μ^+ candidate but no μ^-, and could be due to a background of anti-neutrinos and there were 11 events attributed to energetic neutrons, probably coming from neutrino interactions in the surroundings of the chamber volume.

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The preliminary analysis gives evidence that the number of elastic events is consistent with early predictions[2], that the Brookhaven-Columbia result[3] that $\nu_\mu \neq \nu_e$ is confirmed, and that the total inelastic cross-section rises rapidly with neutrino energy, perhaps as E_ν^2.

To the level of uncertainty of a few percent of the neutrino event rate we have found no evidence against lepton conservation, and no evidence for a neutral lepton current, neutrino flip or strange neutrinos, or violation of $\Delta S = + \Delta Q$. An upper limit to the magnetic moment of ν_μ of 10^{-7} Bohr magnetons is set by the absence of high energy recoil protons.

At this stage of the analysis there is no significant evidence for the proposed intermediate boson[4].

2. LAYOUT, SHIELDING, BUBBLE CHAMBER

The layout of the ejected proton beam, magnetic horn, decay tunnel, shielding and bubble chamber is shown in Fig. 1. Some 7×10^{11} protons per pulse of 24.8 GeV are focused on the horn target which is a copper rod 25 cm long and 0.4 cm diameter. For neutrino runs the horn focuses π^+ and K^+ into a decay tunnel, 25 m long with a half angle of 2° in front of a shielding of iron 25 m thick, designed to absorb muons up to about 28 GeV. The direct neutron flux in the neutrino direction is negligible but some leakage through the sides and rear of the bubble chamber can be expected.

The bubble chamber, which is in a magnetic field of 27 kG, is 1.15 m diameter, 0.5 m deep and of volume 500 litres. It was filled with freon CF_3Br of density 1.5 gm/cm^3 which has a radiation length of 11 cm and a nuclear interaction length of about 70 cm. Nearly all γ-rays and electrons originating in the fiducial volume of the chamber are detected by shower production, and roughly half of the energetic neutrons are detected by secondary interactions.

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Approximately every 600 expansions, synchronization and sensitivity of the chamber were tested with some of the negative defocused beam from the horn. To save film and scanning, two exposures were made per frame. 332,000 frames have been taken : 277,000 in ν-runs, for which positive particles were focused by the horn, and 55,000 in $\bar{\nu}$-runs.

3. SCANNING AND MEASUREMENT

The photos were scanned with a magnification of about 0·7, and the selected events measured on a scanning table with a digitized measuring device. A special version of the THRESH-GRIND analysis system was used for data reduction.[5]

For convenience in scanning the events were classified as :

a) Stars with no incoming track, and at least one negative muon candidate, i.e. a non-interacting negative secondary, are defined as "ν events".

b) Similarly "$\bar{\nu}$ events", which have a positive muon candidate.

c) "Neutral stars", which have no muon candidate but only protons or identified pions.

d) "Cosmic ray" interactions which are interactions of incoming charged particles.

e) In some 10 % of the cases ambiguity arose when the direction of motion of a charged possible primary could not be determined visually. Such events are termed A2 events and were classified separately, as were also events with electron secondaries.

4. SOURCES OF EVENTS - ENERGY DISTRIBUTION (Fig. 2)

From the photos taken with the horn focusing positive particles, 136 "ν events" have been found in the 220 litre fiducial volume, together

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with 8 "$\bar{\nu}$ events", 11 neutral stars with pion production and 141 neutral stars with no detected meson. In addition to the neutrinos, to be considered in the next sections, there are three important possible sources of nuclear interactions.

1) Cosmic rays.

From earlier test runs of a total of some 10^5 pictures it is known that the rate of neutral star production due to cosmic rays is < 1 % of the events produced by operation of the PS. No cosmic ray event was found which could be confused with a neutrino event. The background due to cosmic rays will therefore be neglected in the present analysis.

2) Low energy neutrons leaking round the shielding.

There were 141 small low energy stars involving only one or more protons which were all attributed to leakage neutrons. All have visible energy < 250 MeV and the energy distribution is shown in Fig. 2. It will be seen that it is very different from that of the presumed neutrino events. Extrapolation of this spectrum suggests that < 1 % of leakage neutrons are capable of pion production, and thus they are also a negligible source of background.

3) Secondary radiations induced by neutrinos.

Secondary radiations from neutrino interactions in the chamber walls and shielding could produce two sorts of background :

i) a pion entering the chamber could interact in such a way to be mistaken for a muon from a neutrino event, leaving. Incoming tracks are in general recognized as such by δ-rays, rate of change of curvature and ionization, or other possible indications. Only 15 events (A2) have been found where the direction of motion of the prospective μ^- candidate, if leaving the interaction, was backwards (i.e. towards the horn). Subsequently all 15 of

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these A2 events have been eliminated as neutrino events by kinematical analysis, as will be described later.

ii) secondary neutron star with π^- production. For the observed event spectrum the average probability that a pion secondary interacts before leaving the chamber is about 60 %. Only 6 neutral stars have been observed where the only negative track interacts, and where all other tracks are identified as π^+, π^o or proton. With these 6 identified neutron stars there must be associated about 4 events where the π^- left the chamber without interaction and which contaminate the 136 "ν events". We have preferred to accept this rather than to adopt more stringent criteria, such as on track length in individual events, with consequent loss in statistics.

The energy distribution in Fig. 2 of the 6 neutral stars with π^- emission, plus 5 other neutral stars with only π^+, π^o and protons emitted, shows that these events are of lower energy than the bulk of the "ν events". Comparison of these 11 events with the 12 neutron stars associated with "ν events" in the chamber confirms that all could be due to neutrons from neutrino interactions in the material around the chamber.

We conclude that none of the presumed sources of background, cosmic rays, leakage neutrons, incoming charged particles, or incoming fast neutrons would explain more than a few percent of the observed "ν events".

5. "ν EVENTS"

a) Interaction length of "μ^-"

In the fiducial volume the 142 events with negative secondaries π^- or μ^-, have a total track length of 55.4 m. Only 17 interactions,

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including scatters with transverse momentum transfer exceeding 50 MeV/c are observed, whereas the track length is about 79 times the nuclear interaction length. Of the 17 π^- identified by interactions, 6 are from the "neutral stars" in which all other tracks are identified as π^+ or π^0 or protons, and so are presumed due to energetic neutrons. The other 11 π^- come from events containing an additional negative non-interacting particle and so are presumed π^- from inelastic neutrino events. Thus we conclude that about 97 % of the 136 "ν events" contain a μ^- secondary, which is consistent with most of them being due to neutrino interactions.

b) Spatial distribution

If the 136 "ν events" are indeed due to neutrinos, then their spatial distribution in the chamber along the beam axis should be uniform, and would be hardly altered by the neutron background, which we have seen to be small. The spatial distribution in the plane normal to the beam axis is uniform, but in the beam direction there is a preponderance of events nearest to the beam window. The ratio of events in the front half to the back half of the chamber is 1.5 ± 0.25. After consideration of statistical fluctuations and scanning bias, our conclusion is that we attach no physical significance to the non-uniformity in the spatial distribution of the neutrino events in the chamber.

c) Kinematics

We now examine some kinematical tests of the postulate that the 136 "ν events" and the 15 doubtful "A2" events are due to the reactions :

$$\nu_\mu + n \longrightarrow \mu^- + p \qquad \text{"elastic"} \qquad (1)$$

and

$$\nu_\mu + N \longrightarrow \mu^- + N^* \qquad \text{"inelastic"} \qquad (2)$$

where N is a nucleon and N^* an assembly of strongly interacting particles.

The kinematics of reactions (1) and (2) are of course complicated in freon by i) the Fermi motion of the target nucleon, ii) scattering or secondary interactions of the recoil p or N^* on its way out of the nucleus, iii) undetected neutrons. From experiments with charged particle

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beams the energy carried off by undetected neutrons and heavy nuclear fragments is known to average about 10 % of the beam energy, in contrast to the large average momentum unbalance. Thus a measure of the neutrino energy E_ν is E_{vis}, the sum of the visible energy in the final state particles, counting only kinetic energy of protons.

The momentum transfer q^2 from lepton to baryon is

$$q^2 = 2E_\nu (E_\mu - p_\mu \cos\theta) - m_\mu^2 \tag{3}$$

where θ is the angle of emission of the muon.

If the reaction is assumed to take place on a single nucleon with Fermi momentum p_f, the maximum possible q^2 is (neglecting $m_\mu^2 \ll q^2$)

$$q^2_{max} \approx 4 E_\nu^2 \Big/ \left\{ 1 + \frac{2E_\nu}{M \mp p_f} \right\} \tag{4}$$

where the positive direction of $\vec{p_f}$ is parallel to $\vec{p_\nu}$. Fig. 3 shows q^2 vs E_{vis} for both "ν events" and A2 events. The area above the curved line represents the region in which q^2_{max} is allowed for $p_f = 250$ MeV/c. The straight line is the relation $q^2_{max} = 4 E_\nu^2$, i.e. equation (4) with $M = \infty$. Points lying below the curved line are excluded on kinematical grounds for a ν - nucleon collision. All the 15 A2 events can thus be rejected as ν events and must be attributed to charged (π) primaries, while all the unambiguous "ν events" are seen to lie in the kinematically allowed region.

If M' is the effective mass of N and M^* that of N^* in reaction (2),

$$M^{*2} = M'^2 - q^2 + 2 M' (E_\nu - E_\mu) \tag{5}$$

(assuming N is at rest in the lab).

Thus for elastic events $M'^2 = M^{*2}$ and

$$M' = q^2 / 2(E_\nu - E_\mu), \tag{6}$$

on the average, with some smearing due to Fermi motion (cf. Fig. 8).

Also
$$E_\nu^{el} = \frac{E_\mu - m_\mu^2 / 2M'}{1 - \frac{E_\mu}{M'} (1-\beta_\mu \cos\theta)} \tag{7}$$

is the neutrino energy calculated from the muon energy, angle (and velo-

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from the excited nucleus. Such neutrons, $E < 10$ MeV, would rarely be observed in their subsequent interactions in the chamber. In fact only 3 neutrons ($E > 50$ MeV) from the elastic events have interacted in the chamber.

The above considerations and the R distribution (equation 8 and Fig. 7) show that q^2_{vis} is on the average close to the true q^2_ν. $R = q^2_{vis}/q^{2\,el}_\nu$ is the ratio of q^2_{vis} to the q^2 computed for a ν-free nucleon collision from the momentum and angle of the muon. Since the muon should be essentially unaffected in its passage through the nucleus, $q^{2\,el}_\nu$ should equal q^2_ν on the average with a symmetrical distribution due to Fermi motion. Fig. 7 confirms this for the elastic events. (Note also that the effect of a final state mass $M^* > M$ is to skew the R distribution to the right for the inelastic events; that the symmetry of the elastic distribution thus suggests only a small contamination of inelastic events where the pion was absorbed; that the asymmetry of the C events suggests that at least half are inelastic).

The M^* distribution (equation 5, Fig. 14) also confirms the elasticity of the "elastic" events in contrast to that of the "inelastic" events. The M^* distribution for the elastic events is centred on M_p with a spread consistent with Fermi motion effects. The A2 events all have small M^*; they could be rejected in this way as well as by q^2_{max}.

The M' distribution (Fig. 8, equation 6) shows that the target mass for the elastic events is compatible with $M' = M_p$ with a random spread due to Fermi motion, if events are taken with $P_T < 300$ MeV (to avoid missing neutrons) and $q^2 > 4\, p_f^2$ (> 0.25 GeV^2) to avoid discrimination by the Pauli principle in favour of p_f parallel to p_ν at low q^2.

e) <u>Conclusion</u>

This preliminary study, therefore suggests that the 68 "elastic" events are consistent with the kinematics of reaction (1), as modified by the above effects due to nucleon targets bound in nuclei, the q^2 distribution and total event rate are consistent with theoretical predictions based on the theoretical elastic cross-sections[2] and on the neutrino spectrum computed by van der Meer.

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7. INELASTIC NEUTRINO EVENTS

In the fiducial volume a total of 68 inelastic events has been observed, composed of 53 single pion events and 15 multipion events.

a) Energy spectrum : inelastic cross-section

Fig. 9 shows the observed integral energy spectrum for inelastic events, together with the elastic events for comparison. The curves in the diagram show the spectra computed from the calculated neutrino fluxes for (i) $\sigma = \sigma_{elastic}$ (Lee and Yang) (ii) $\sigma \propto E_\nu$ (iii) $\sigma \propto E_\nu^2$. For inelastic events (a), the cross-section is seen to rise approximately as E_ν^2, but this conclusion depends on the validity of the calculated neutrino fluxes. These fluxes are as yet poorly known at high energies, so this result should be considered extremely preliminary. However if one includes only events with $E_\nu < 3$ GeV, where the calculated flux may be more reliable, the inelastic cross-section seems still to rise approximately as E_ν^2.

This rise in $\sigma_{inel.}$ might be explained by :

i) A form factor effect associated with a hard nucleon core (e.g. in F_A) manifested only in the inelastic events. Fig. 10 however shows that the mean range of q^2 rises rather slowly with E_ν.

ii) The effect of increasing inelasticity. As the mass of the final state M* increases in the reaction $\nu + N \rightarrow \mu^- + M^*$ the cross-section may rise as more and more inelastic channels open (decay of the state M*). One can compute M* from equation (5). Fig. 11 shows the dependence of final state mass M* on E_ν, and again a slow increase is observed. The curve shows the kinematical limit on M* imposed by conservation of energy and momentum.

The statistical weight of the data is not as yet sufficient to support an interpretation.

(a) The empirical relation chosen is $\sigma_{inel.} = 0.37\, E_\nu^2 \cdot 10^{-38}$ cm^2 per neutron.

Thus, at $E_\nu = 10$ GeV, $\sigma_{inel.} = \frac{37}{0.75} = 50\, \sigma_{el}$.

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b) q^2 distribution

The distribution is shown in Fig. 12. Comparison with Fig. 6 shows that the distribution extends to much higher values, and that there is no peak in the distribution at low q^2, as the Pauli principle is no longer operative.

c) One pion events

The single pion produced may come[7] from the strong interaction vertex, possibly via a nucleon isobar, or from the weak vertex, via virtual π or ρ exchange. For an $I = 3/2$ πN state, $N_{\pi^+} / N_{\pi^o} = 5$, for an $I = 1/2$ state $N_{\pi^+} / N_{\pi^o} = 2$, and for ρ or π exchange $N_{\pi^+} / N_{\pi^o} = 1$. The observed ratio is 4 ± 1.5.

It is possible to estimate the mass of the state by several methods : (i) from the invariant mass of π and proton (if there are several protons, the resultant momentum vector is used); (ii) from equation (5); (iii) for the events in which the final nucleon is a neutron, the conservation laws can be used to obtain the invariant mass of neutron and pion. These methods lead to mass distributions peaking in the region of the 3/2 isobar mass (Fig. 13). However a not too different distribution is expected merely from phase space considerations, so that most evidence in favour of the 3/2 state comes from the sign ratios given above.

d) High multiplicity events

Fig. 14 shows the distribution in final state mass M^* (equation 5) in elastic events, one pion events and multipion events. The significance, if any, of the apparent peaking around 2 GeV in the multipion case is not clear. (The multipion events also include 9 one pion events which have, in addition to a pion, a fast positive particle which could be a pion or proton).

e) Strange particle production

Among the 68 inelastic events, a few examples of strange particles are observed : one case of $\Lambda^o + K^o$ associated production and three cases of single Λ^o, K^o and $K_{\mu 2}$. In each case, other tracks in the event could be ascribed to strange particles, so that we have no evidence for strangeness non-conserving interactions.

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f) Electron events (e^-)

Three cases have been observed in which the only negative lepton candidate was a high energy electron. The background due to ν_e (from K_{e3} decay) among the inelastic events is expected to be ~ 2 events.

g) Intermediate boson candidates

The intermediate boson which has been postulated in connection with a structure in the weak interaction would have the decay modes :

$$B^+ \longrightarrow \mu^+ + \nu_\mu \qquad 1)$$
$$\longrightarrow e^+ + \nu_e \qquad 2)$$
$$\longrightarrow n\pi\text{'s etc} \qquad 3)$$

The status of the evidence for decays of type 1) and 2) will be fully discussed in the report on the spark-chamber data. Among the bubble chamber events, there is only one possible case of reaction 2), namely $\nu_\mu + p \longrightarrow \mu^- + p + B^+ \hookrightarrow e^+ + \nu_e$. In addition reactions of the type $\nu + n \longrightarrow \mu^- + n + B^+ \hookrightarrow \mu^+ + \nu_\mu$ + etc. have been considered. In this case, track length statistics on the positive mesons (π^+ or μ^+) show no strong evidence for muon pair production (5 interactions on 5 m positive track length, for events of $E_\nu > 3$ GeV, $q^2 > 1$ GeV, p (π^+ or μ^+) > 1 GeV/c).

The distribution of p_T and p_L in the inelastic events (Fig. 15) has also been examined. In this diagram, the generally positive values of p_L indicate the existence of missing neutrons projected into the forward hemisphere. If in a leptonic boson decay, 1) or 2), a neutrino were emitted at wide angle to the incident ν-beam, a negative value of p_L (and large value of p_T) would result. There is no evidence at all for such events from Fig. 15 but the boson would be expected(4) only rarely to emit a neutrino at wide angle.

One can conclude provisionally that the frequency of electronic decays of the intermediate boson, if there are any at all, is less than 1 % of the total event rate, and of muonic decays, $<$ 5 - 10 %.

The invariant mass distribution of combinations of secondary pions (with unit net positive charge) has been examined for evidence of pionic decay modes of the boson, (see Fig. 16). There is no clear evidence from this data to indicate an intermediate boson of unique mass.

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8. $\bar{\nu}$ EVENTS

Only a small proportion of the running time to-date has been devoted to antineutrinos for which negative particles are focused by the horn. There are about 15 $\bar{\nu}$ events, from the $\bar{\nu}$-run and from background in the ν-runs. From this sample the general characteristics appear similar to those of the ν events, but attempts at quantitative analysis must be deferred until more statistics are accumulated.

9. CONCLUSIONS

1) Lepton conservation

Upper limits can be set for lepton non-conserving processes such as :

$$\nu_\mu + N \longrightarrow N + \pi\text{'s} \qquad \ldots\ldots\ldots \quad (1)$$

$$\nu_\mu + N \longrightarrow \mu^+ + \text{etc} \qquad \ldots\ldots\ldots \quad (2)$$

With regard to (1), we restrict ourselves to events of $E_{vis} > 1$ GeV. Only one neutral event is observed with an identified pion and no lepton candidate. One can estimate that there will be a further neutral event in which the lepton candidate is in fact a negative pion which does not interact, out of a total of 101 neutral events of $E_{vis} > 1$ GeV. The 2 events in question are attributed to neutrons, but alternatively one can set an upper limit to reaction (1) of 2/101 = 2 %.

For reaction (2), we have to consider the 8 events in the ν-runs with a μ^+ candidate, and no μ^- candidate. This rate is consistent with the calculated $\bar{\nu}$ background of 4 events. Alternatively, an upper limit on reaction (2) is 8/136 = 6 %.

2) ν_e and ν_μ

The distinction between electron and muon neutrinos was demonstrated by the Brookhaven experiment[3]. In our present experiment, no elastic events in which the lepton is an electron have yet been observed. On the other hand, 68 elastic events contain a negative muon. Among the

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<u>inelastic</u> events, 3 cases of e^- were observed, compared with 68 events with a μ^-. The number of e^- events expected from the decay K^+_{e3} is $\sim$2. Hence, the Brookhaven results are confirmed.

3) <u>Neutrino flip, strange neutrinos</u>

According to this hypothesis, the kaons undergo decay into electron neutrinos : $K \rightarrow \mu^+ + \nu_e$. The number of events due to neutrinos from kaons is estimated to be about 20 % of the total number of neutrino events (136). As the number of e^- events is only 3, we confirm that the spin flip hypothesis is untenable.

It has also been suggested that the neutrino associated with strange particle decay should produce only strange baryons, e.g. $\nu + n \longrightarrow \Sigma^+ + \mu^-$. We have observed no Σ^+ production event. We have no evidence that ν from K and π decay behave differently.

4) <u>$\Delta Q/\Delta S$ rule</u>

Neutrinos and antineutrinos can give rise to the inverse decay processes involving hyperons, such as :

a) $\bar{\nu} + p \longrightarrow \Lambda^0 + \mu^+$

b) $\nu + n \longrightarrow \Sigma^+ + \mu^-$

Reaction a) is allowed, while b) is forbidden under the $\frac{\Delta Q}{\Delta S} = +1$ rule. No event attributable to reaction b) has been observed. If the $\Delta Q/\Delta S$ rule were disregarded, one might have expected(7) a few percent of the elastic events to be of type b). Hence we have no evidence of violation of the $\Delta Q/\Delta S$ rule for values of $q \sim 1$ GeV (compared with $q \sim 0.1$ GeV in decay processes). Until examples of $\nu + p \longrightarrow \Lambda^0 + \mu^+$ are observed in subsequent $\bar{\nu}$-runs, however, we cannot set an upper limit to the possible degree of violation.

5) <u>Neutral lepton currents</u>

$\nu + p \longrightarrow \nu + p$ .... (1)

$\nu + p \longrightarrow \nu + n + \pi^+$ .... (2)

$\nu + e \longrightarrow \nu + e$ .... (3)

With regard to process (1), it will be remembered that no neutral events involving only protons or neutrons have visible energy > 250 MeV (Fig. 2). One can make comparison with events of type $\nu + n \longrightarrow \mu^- + p$,

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where the proton kinetic energy again exceeds 250 MeV. There are 31 events in this category. Thus the cross-section for (1), compared with that for the normal elastic process, is $< 3\%$. Similarly, the number (11) of neutron stars with identified pions is consistent with the number to be expected from secondaries of the normal elastic and inelastic neutrino interactions, but even if all these events were due to process (2) its rate would be $< 8\%$ of the total neutrino event rate.

For process (3), it will be remembered that only 3 cases are observed with high energy negative electrons, corresponding to at most 3 % of the normal process. In addition to the weak interaction (second order in the absence of neutral currents), an electromagnetic interaction would occur[8] if the neutrino possessed a magnetic moment. A search for electrons of energy > 25 MeV, was made on about 7 % of the total film taken. None was found, which sets an upper limit to the magnetic moment of ν_μ of $\sim 10^{-6}$ Bohr magneton. The result that no single proton of energy above 250 MeV was seen sets an upper limit of ν_μ of $\sim 10^{-7}$ Bohr magneton. The upper limit on that of the $\bar{\nu}_e$ is 1.4×10^{-9} Bohr magneton, from a reactor experiment[8].

6) Form factors and cross-sections

At this stage of the analysis the distribution of q^2 in the elastic events is consistent with the Hofstadter electromagnetic form factors of the nucleon. There is no evidence for a substantial contribution from a hard nucleon core, but this depends on the assumed value of the mass of the intermediate boson.

In the q^2 distribution for inelastic events there is a tail up to ~ 6 GeV^2, and the inelastic cross-section at $E_\nu \sim 10$ GeV appears to be nearly two orders of magnitude greater than the asymptotic elastic cross-section (numerically $\sigma \sim 0.4\, E_\nu^2$ in units of 10^{-38} cm^2). This last conclusion depends on the calculated neutrino fluxes which have not been verified experimentally. In the absence of better statistics the increase in σ might perhaps be accounted for in terms of the increasing range of q^2 and M^{*2} ($M^* =$ final state mass) at high energy.

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7) One pion processes

The observed π^+/π^0 ratio suggests that the contribution from peripheral interactions (π or ρ exchange) is unimportant, and that pion production is dominated by the $I = 3/2$ pion nucleon state.

8) Cowan resonance

Experiments by Cowan have suggested[9] that a resonance effect exists whereby low energy neutrinos ($\sim$150 MeV) have interaction cross-sections 3 orders of magnitude greater than those considered here (10^{-38} cm^2). Our knowledge of the neutrino spectrum in that region is vague, but we have observed no muons of $E < 130$ MeV in elastic events.

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Finally we acknowledge gratefully the untiring and unstinted efforts of our technical and scanning colleagues during the long preparation and in the runs for this experiment.

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FIGURE CAPTIONS

Fig. 1	Neutrino beam layout
Fig. 2	Distribution in $E_{visible}$ in neutral events
Fig. 3	q^2 plotted against E_ν for elastic, inelastic and A2 events
Fig. 4	Distribution in E_{vis} in elastic events
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Fig. 14	Final state mass spectrum in elastic, one-pion and multipion events
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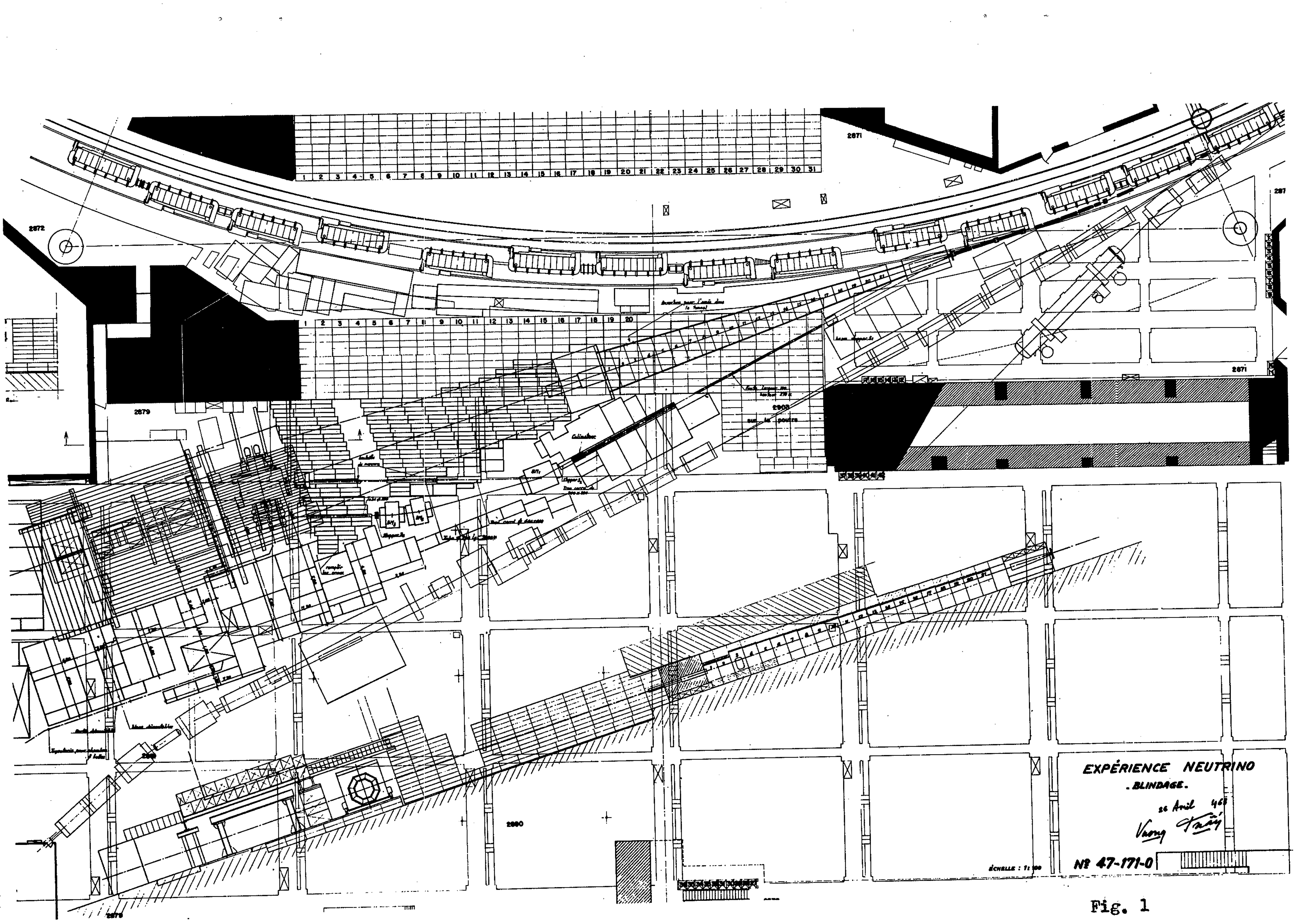
Fig. 16	Invariant mass spectrum of pion combinations with unit positive charge



EXPÉRIENCE NEUTRINO
.BLINDAGE.
Nº 47-171-0
ÉCHELLE : 1:100
2871
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Fig. 1

ENERGY SPECTRUM OF NEUTRAL EVENTS

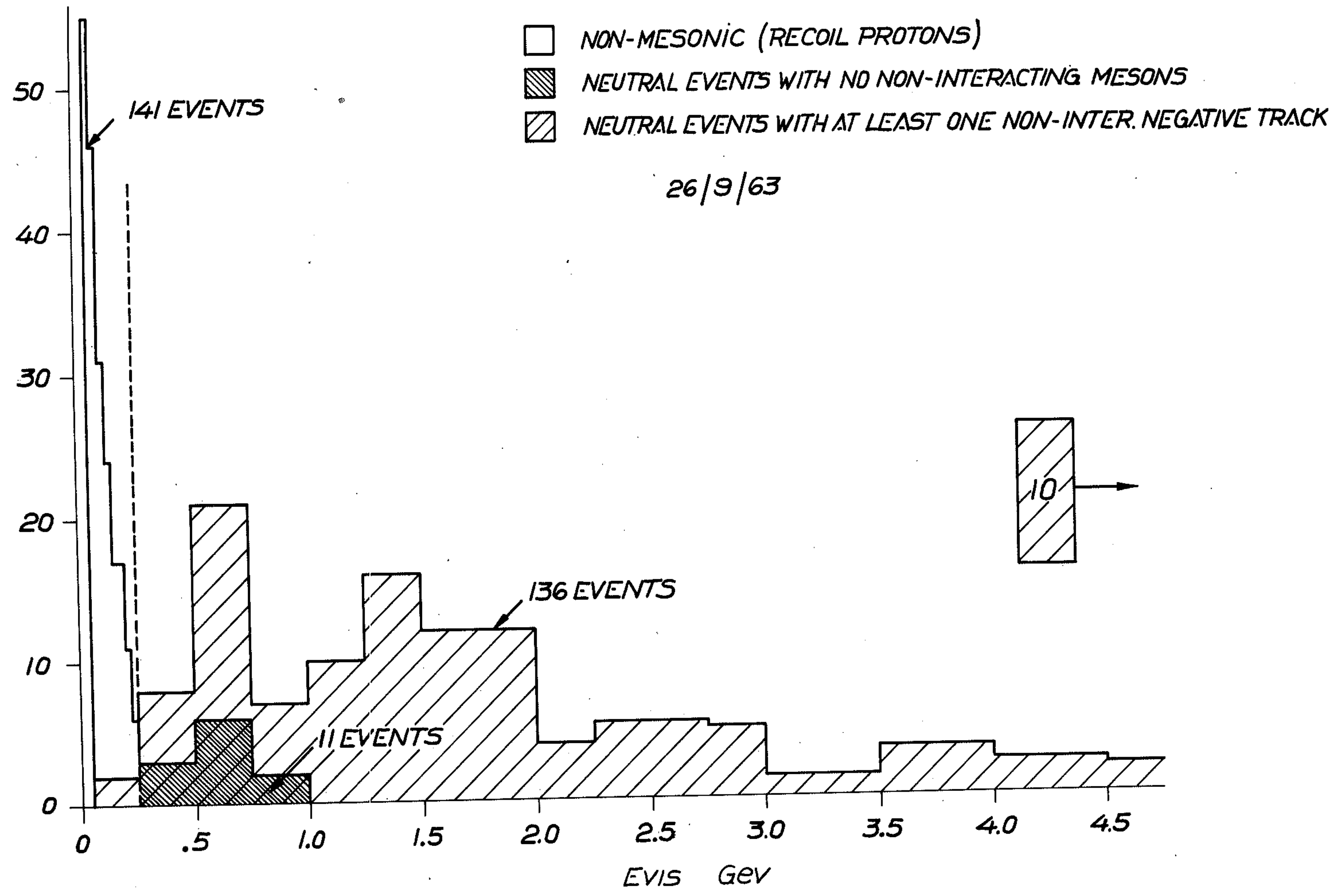

Fig. 2

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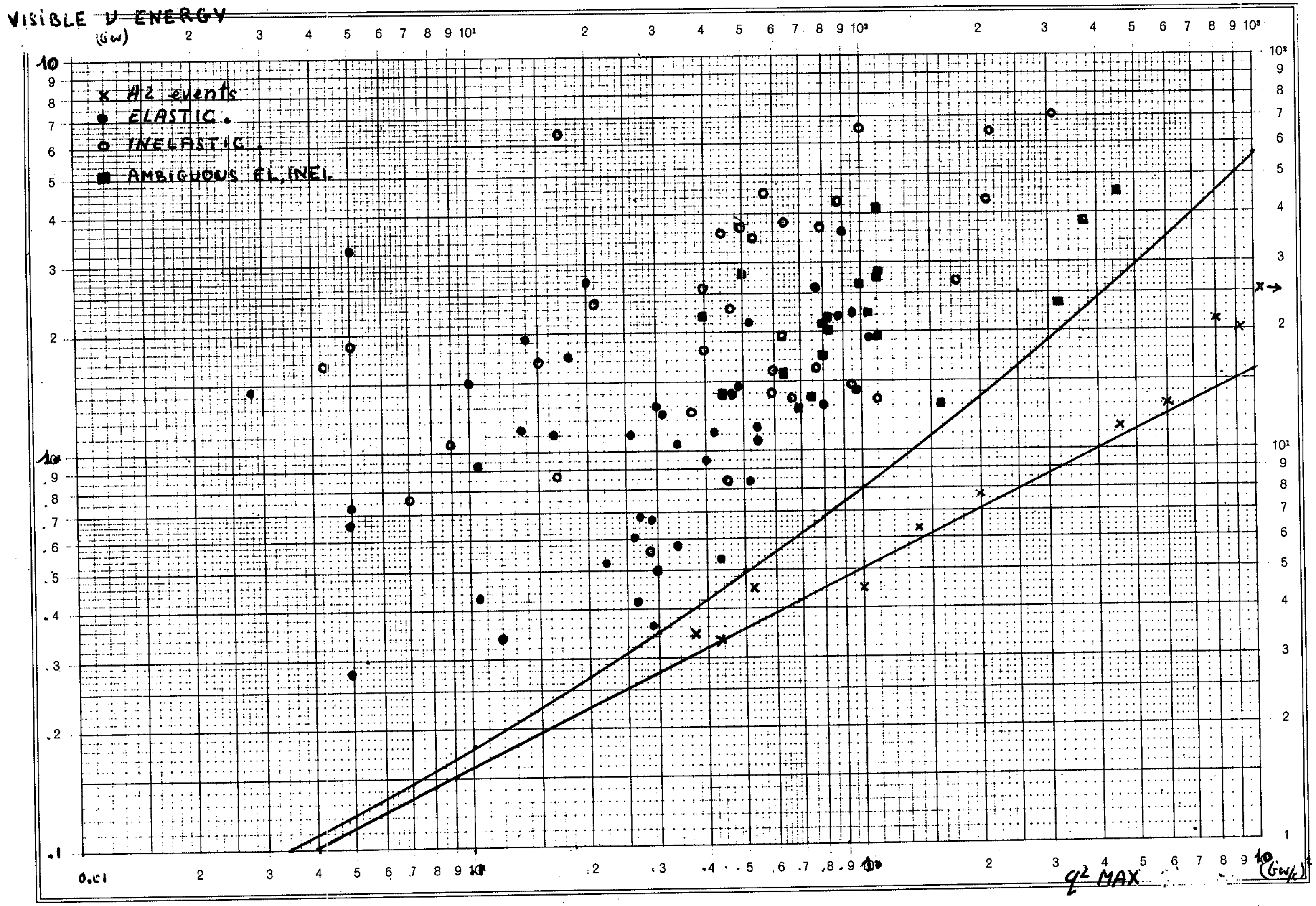


Fig. 3

DIA 18573

SIS/R/7064

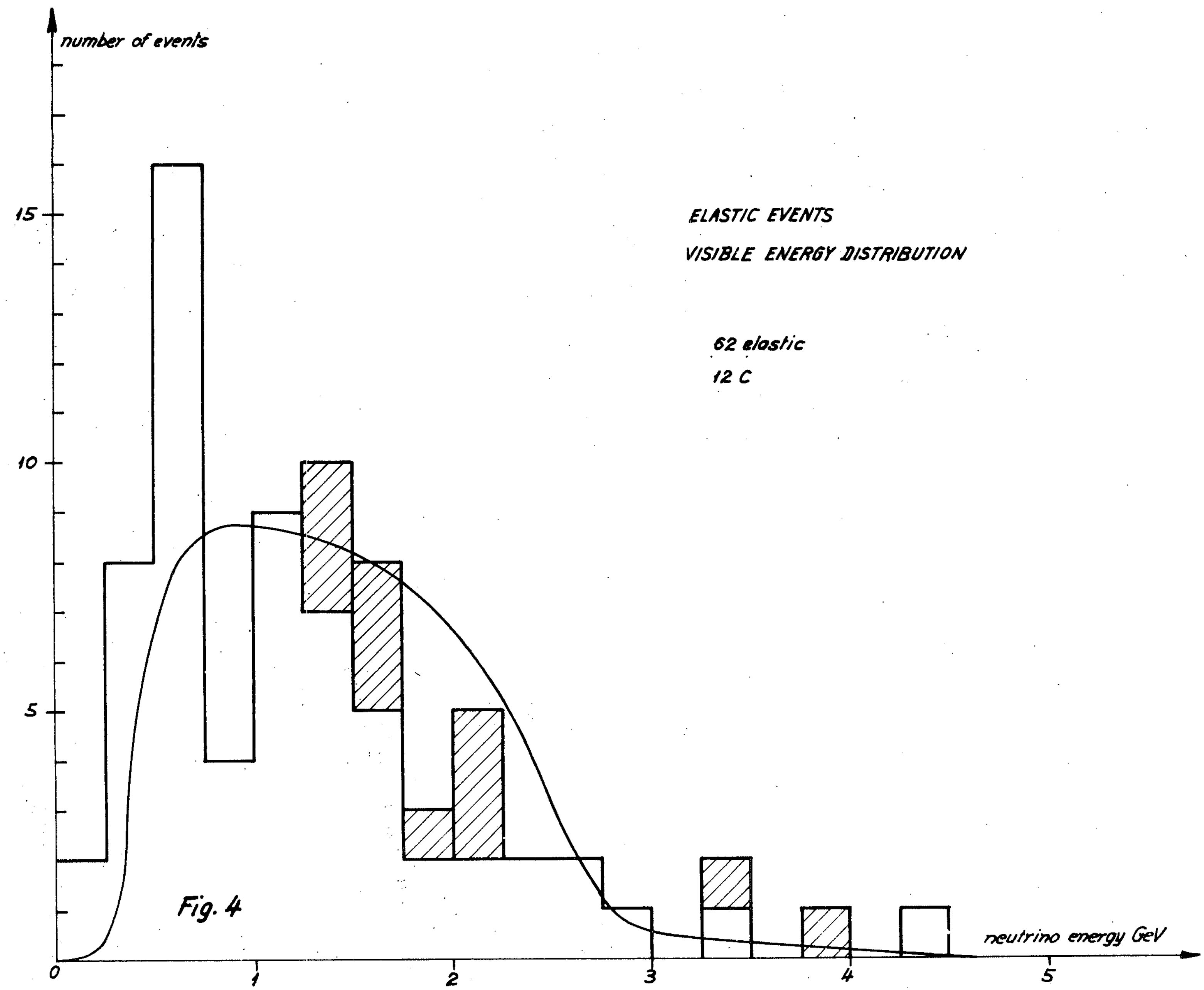

number of events
15
10
5
0
1
2
3
4
5
neutrino energy GeV
ELASTIC EVENTS
VISIBLE ENERGY DISTRIBUTION
62 elastic
12 C

Fig. 4

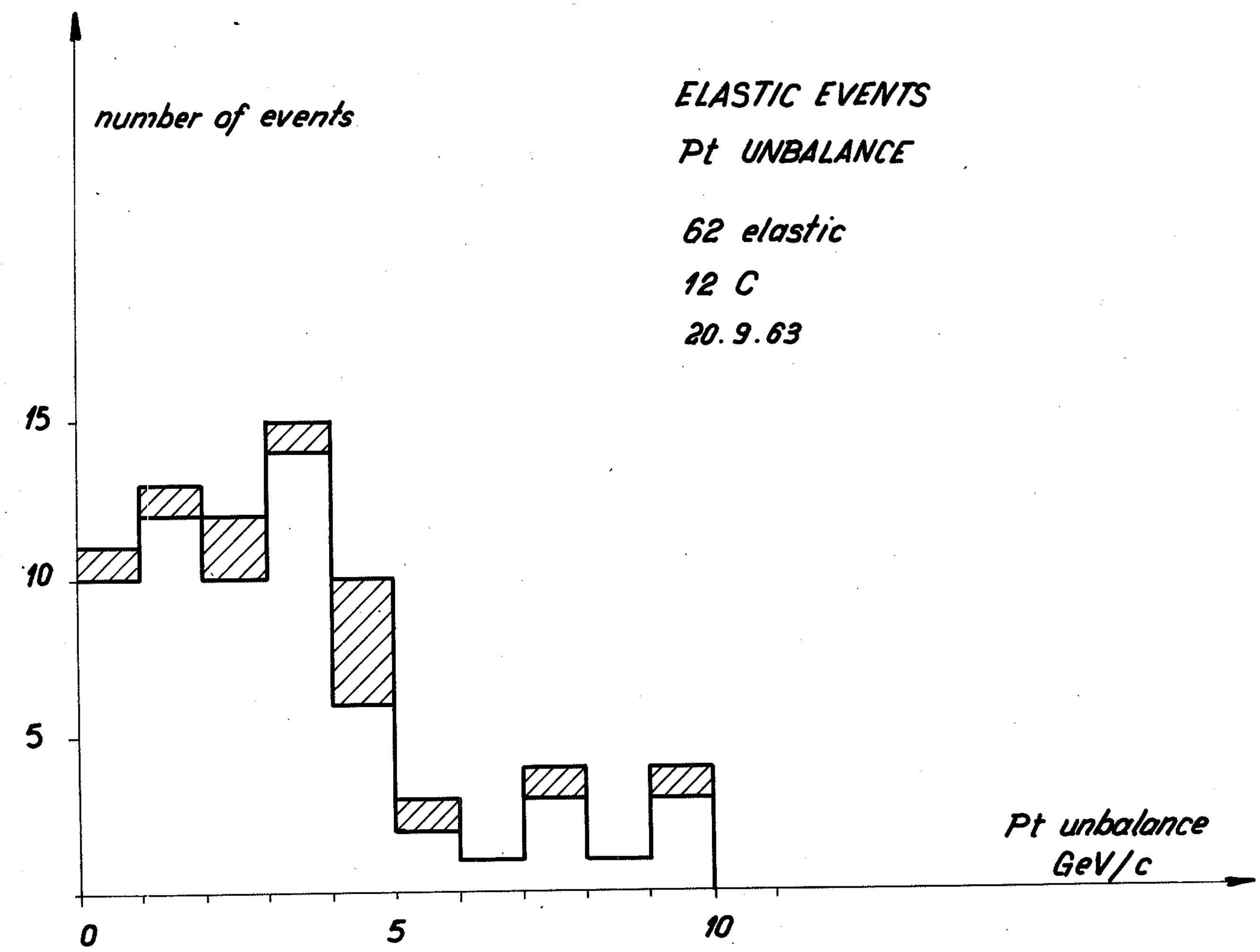
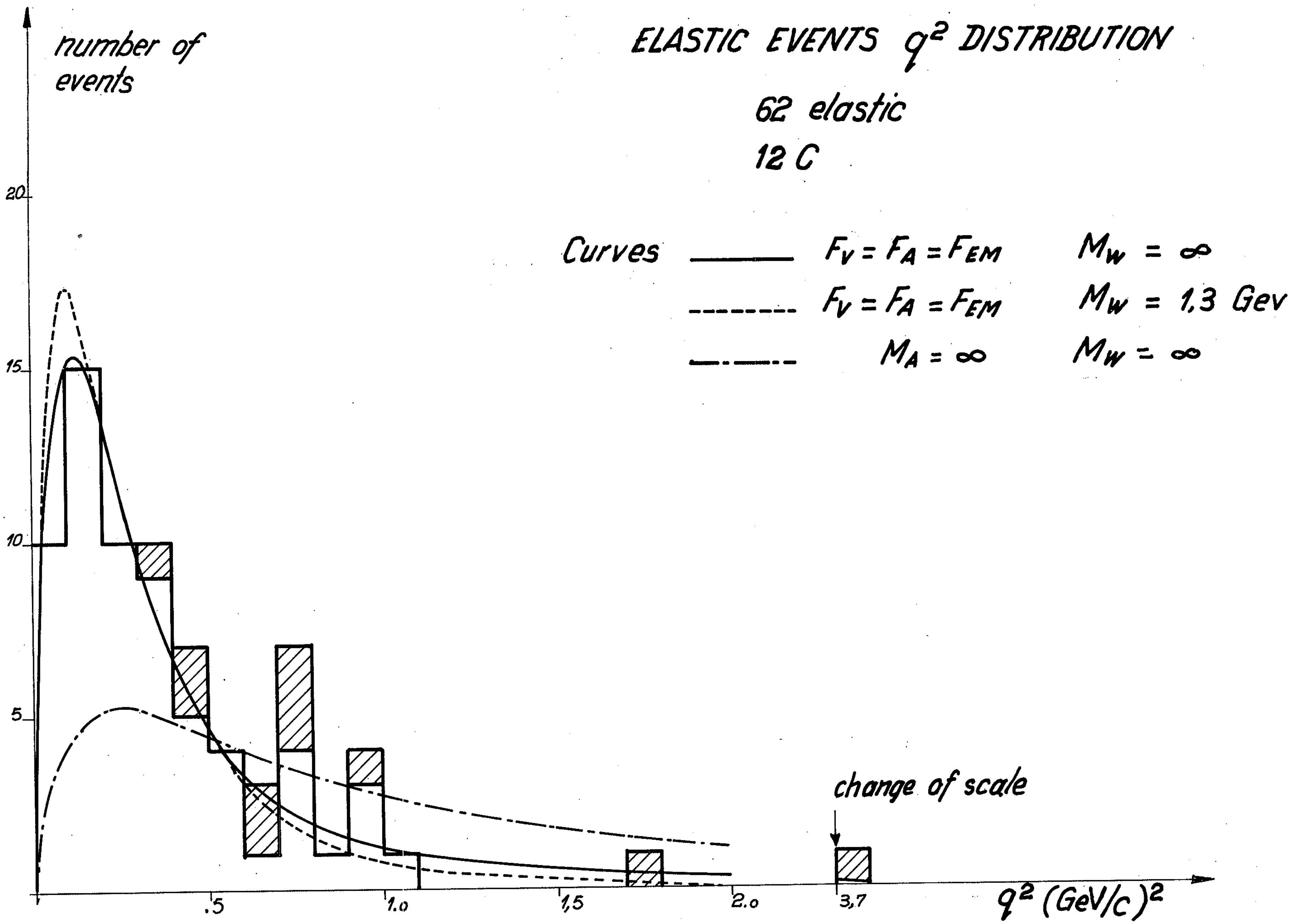

number of events
ELASTIC EVENTS
Pt UNBALANCE
62 elastic
12 C
20.9.63
15
10
5
0
5
10
Pt unbalance
GeV/c

Fig. 5



ELASTIC EVENTS q^2 DISTRIBUTION
62 elastic
12 C
Curves
$F_V = F_A = F_{EM}$ $M_W = \infty$
$F_V = F_A = F_{EM}$ $M_W = 1,3$ Gev
$M_A = \infty$ $M_W = \infty$
number of events
20
15
10
5
.5
1,0
1,5
2.0
3,7
change of scale
q^2 $(GeV/c)^2$

Fig. 6

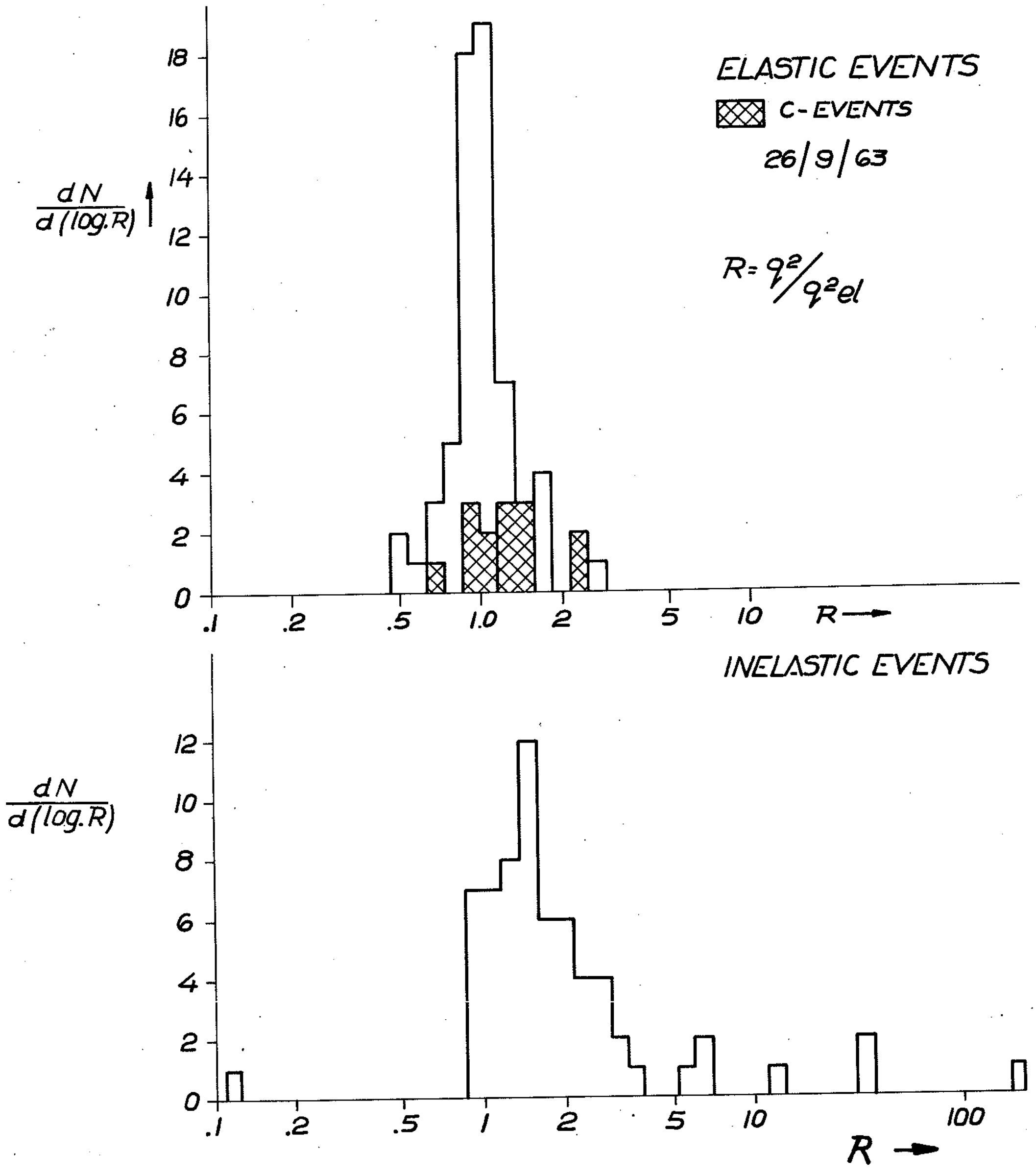


Fig. 7

DIA 18914

SIS/R/7085

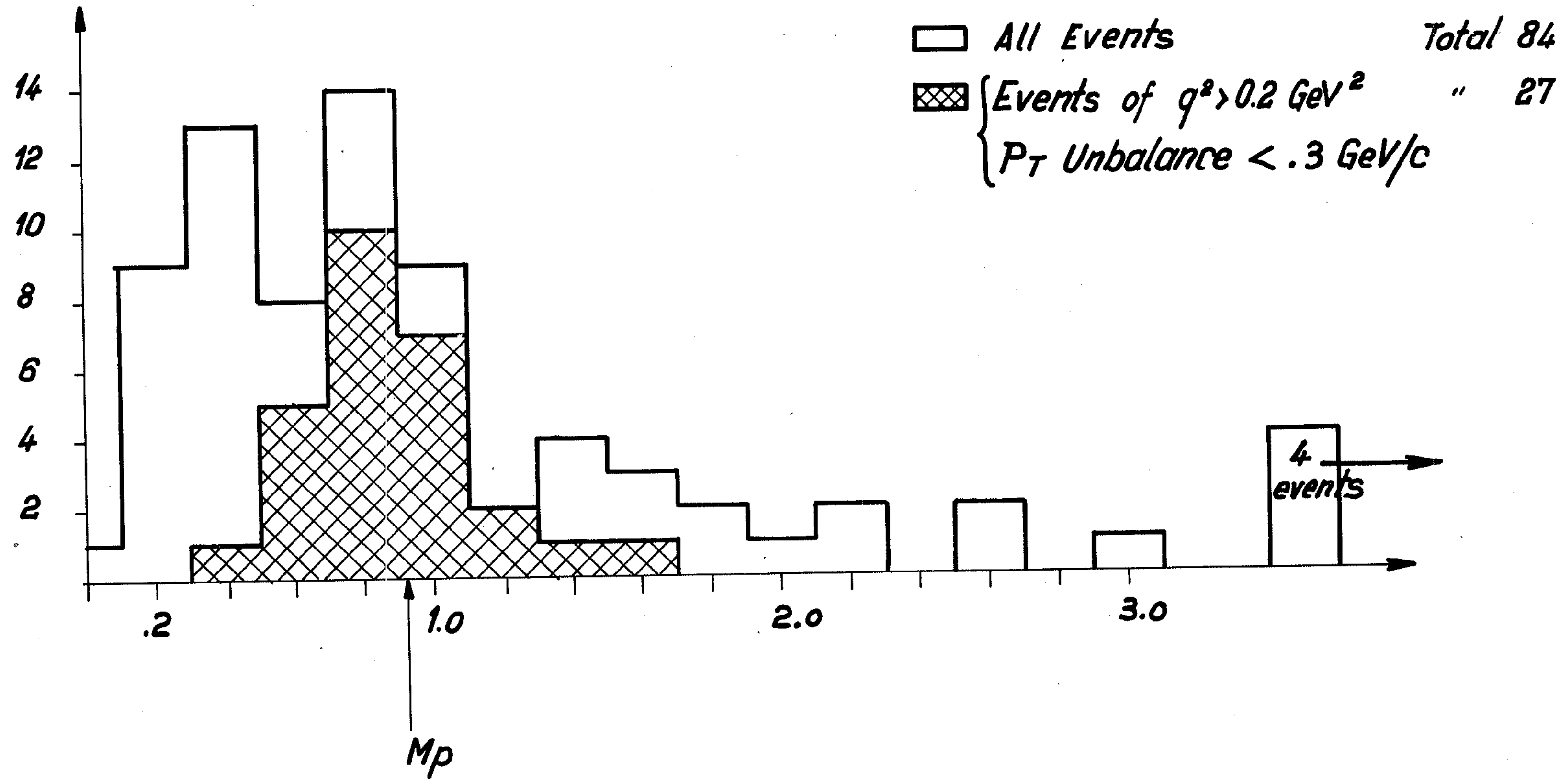

All Events
Total 84
Events of q²>0.2 GeV²
" 27
P_T Unbalance <.3 GeV/c
14
12
10
8
6
4
2
.2
1.0
2.0
3.0
4 events
Mp

Fig.8

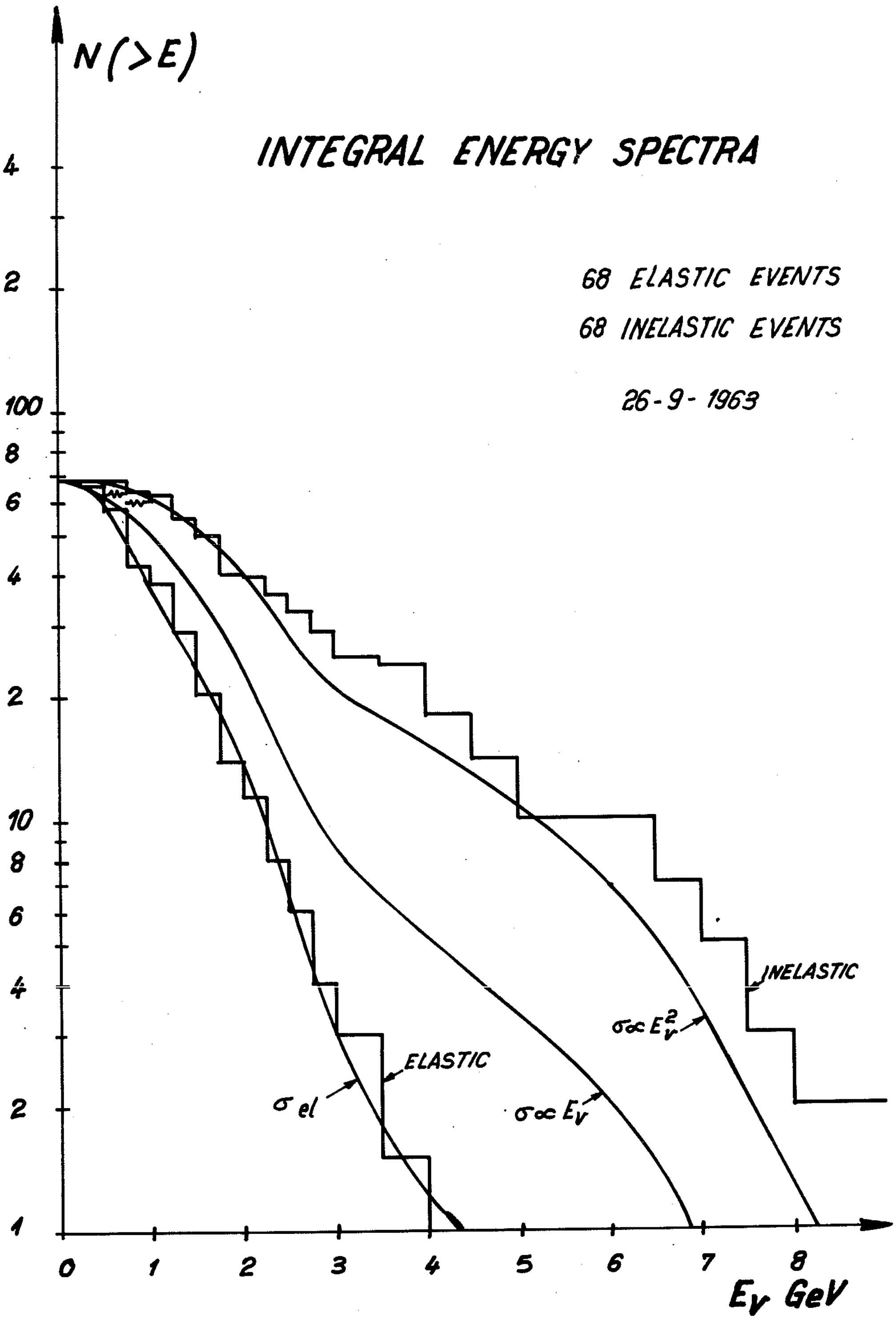
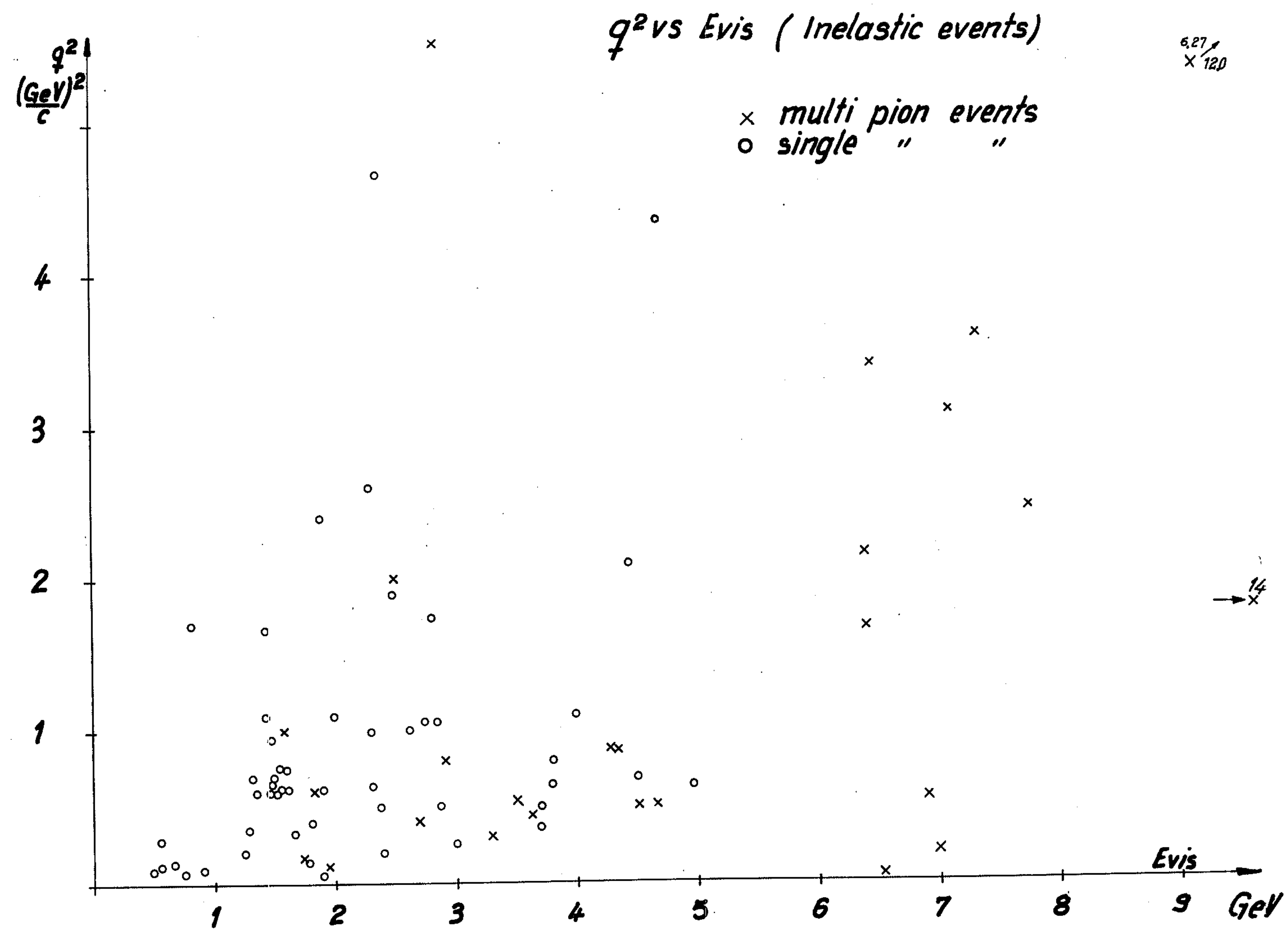


Fig. 9

DIA 18300

SIS/R/7068


q^2 vs Evis (Inelastic events)
× multi pion events
o single " "
q^2 $(\frac{GeV}{c})^2$
Evis
GeV
6,27 12,0
14
1
2
3
4
5
6
7
8
9

· Fig. 10

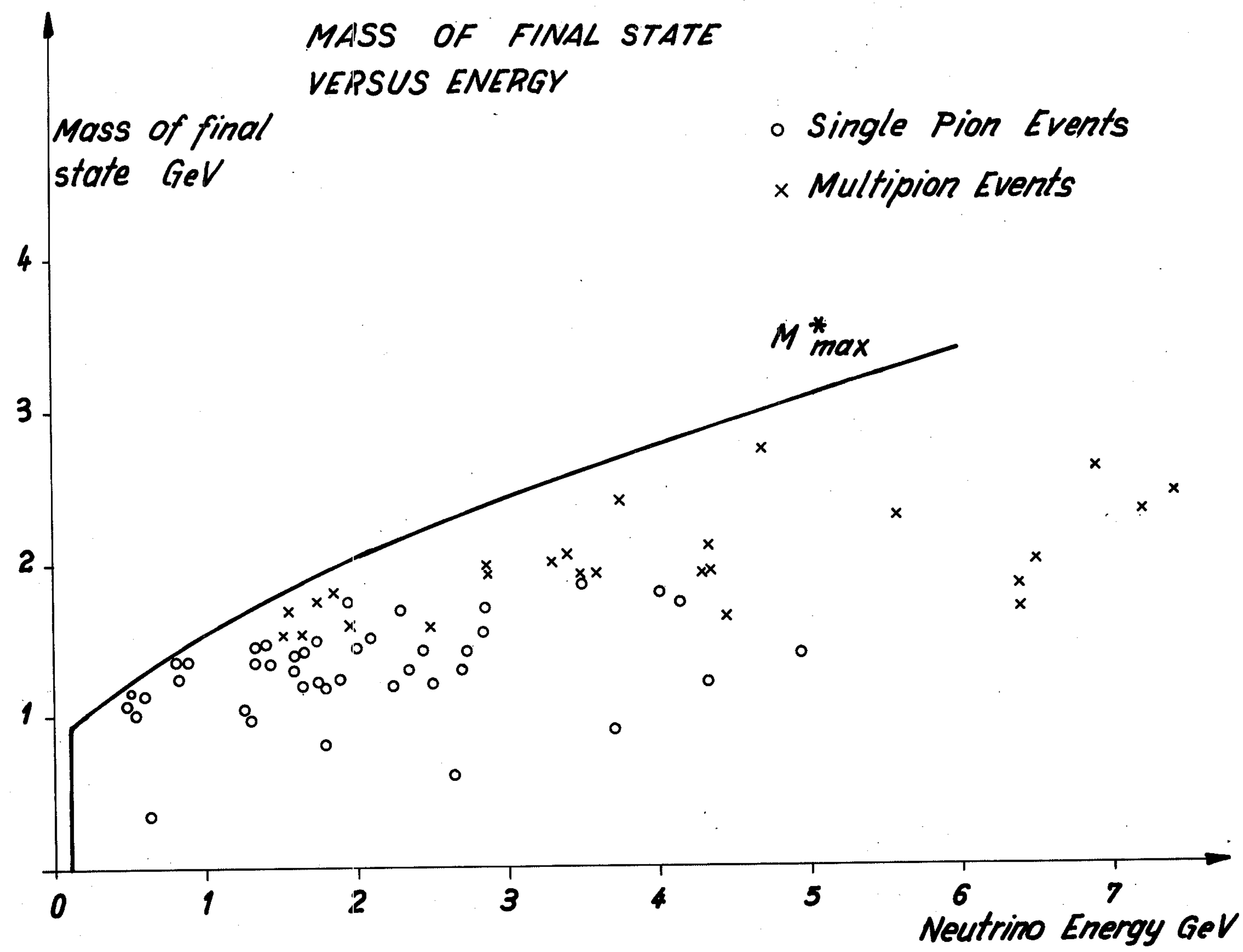

MASS OF FINAL STATE
VERSUS ENERGY
Mass of final
state GeV
o Single Pion Events
× Multipion Events
M*max
4
3
2
1
0
1
2
3
4
5
6
7
Neutrino Energy GeV

Fig. 11

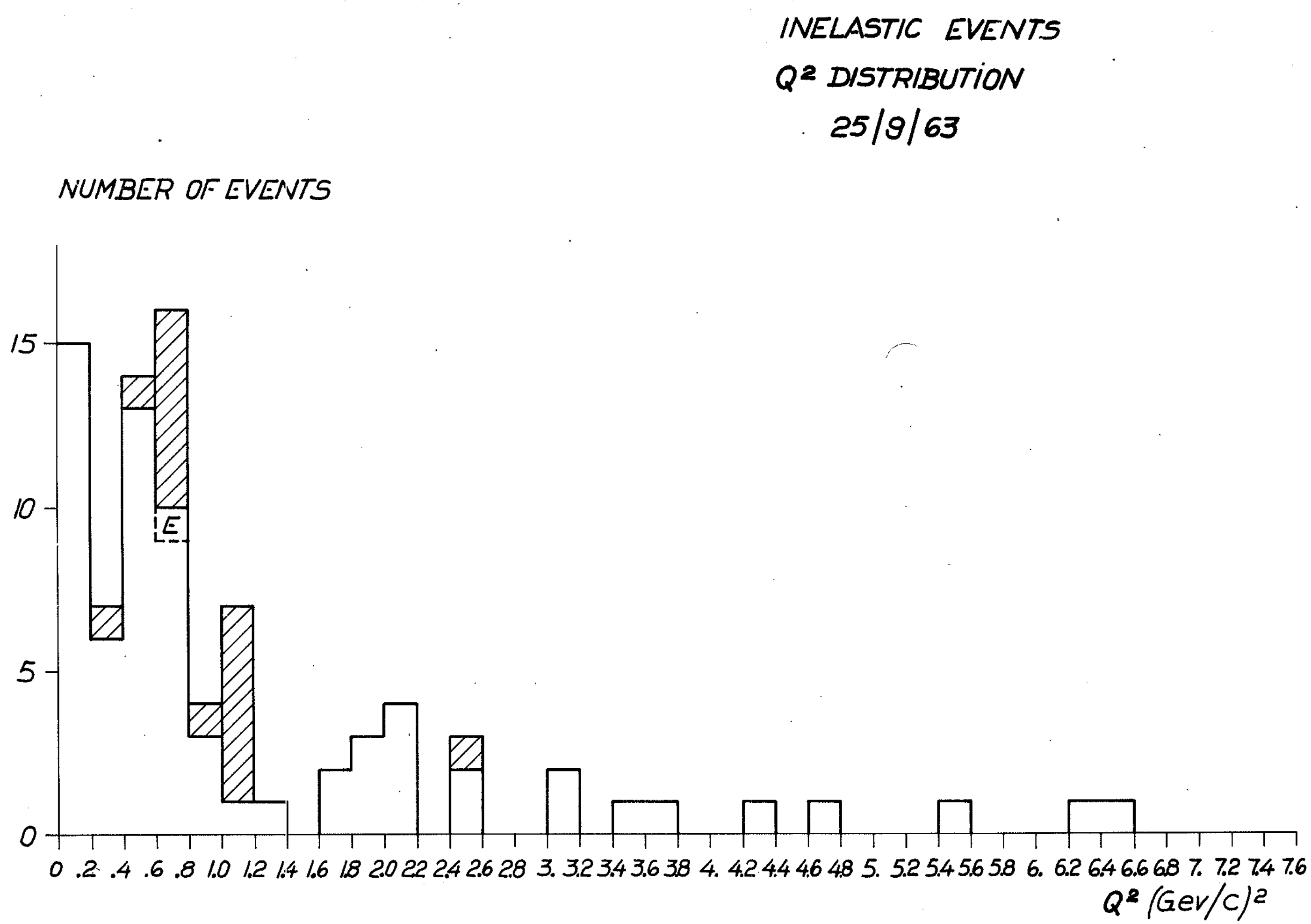


Fig.12

DIA 18304

SIS/R/7071

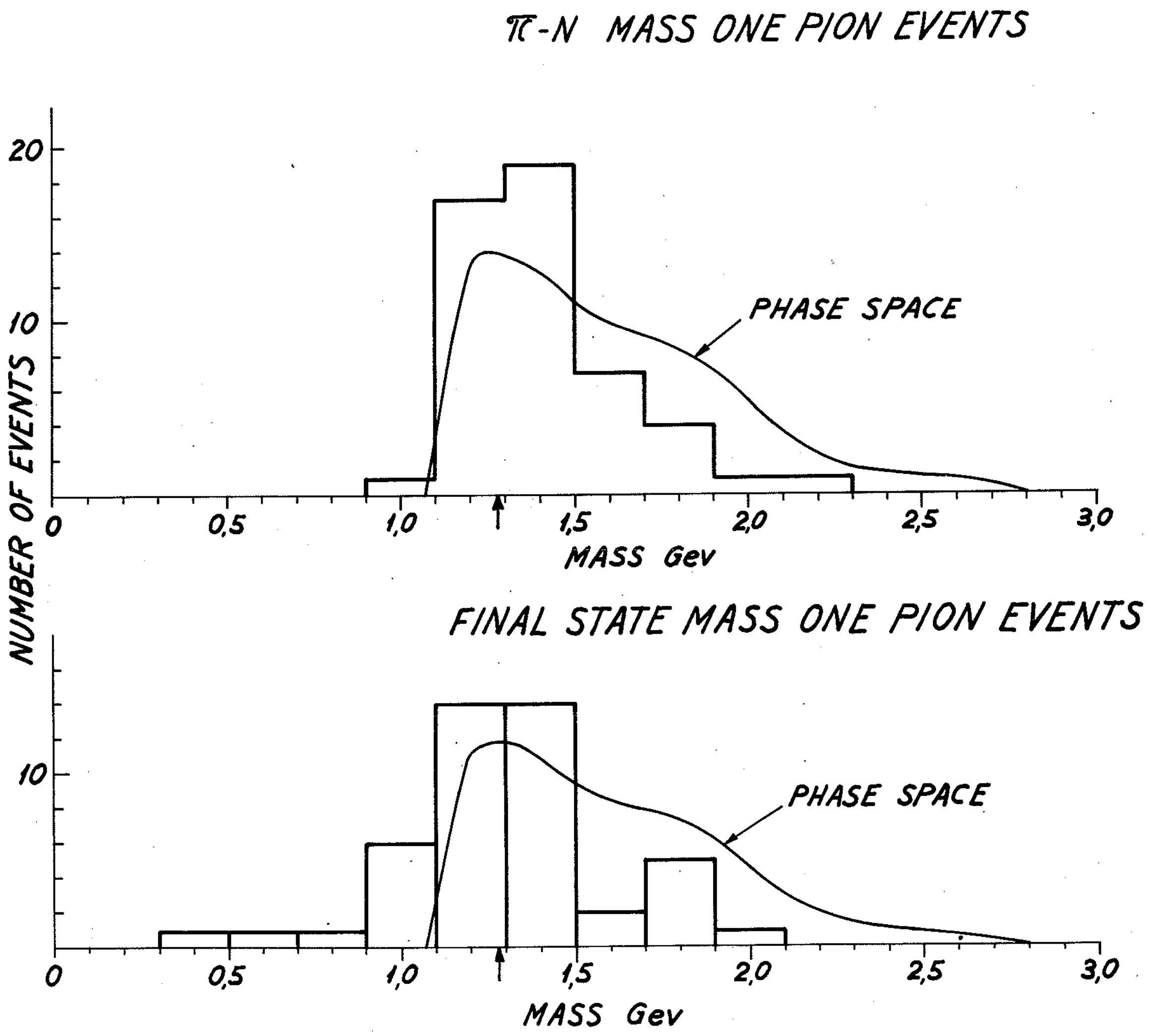


Fig. 13

DIA 18896

SIS/R/7072

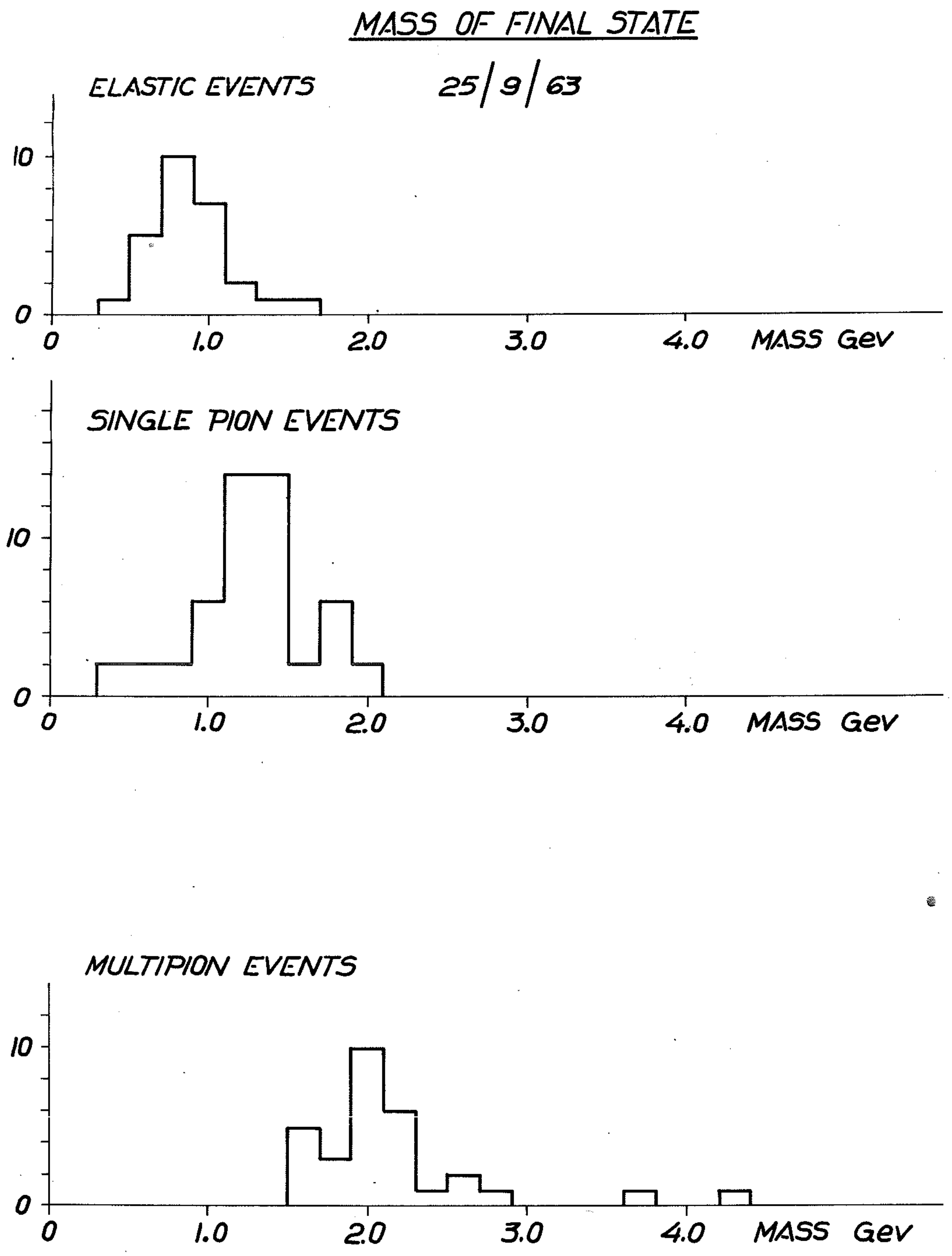


Fig. 14

DIA 18898

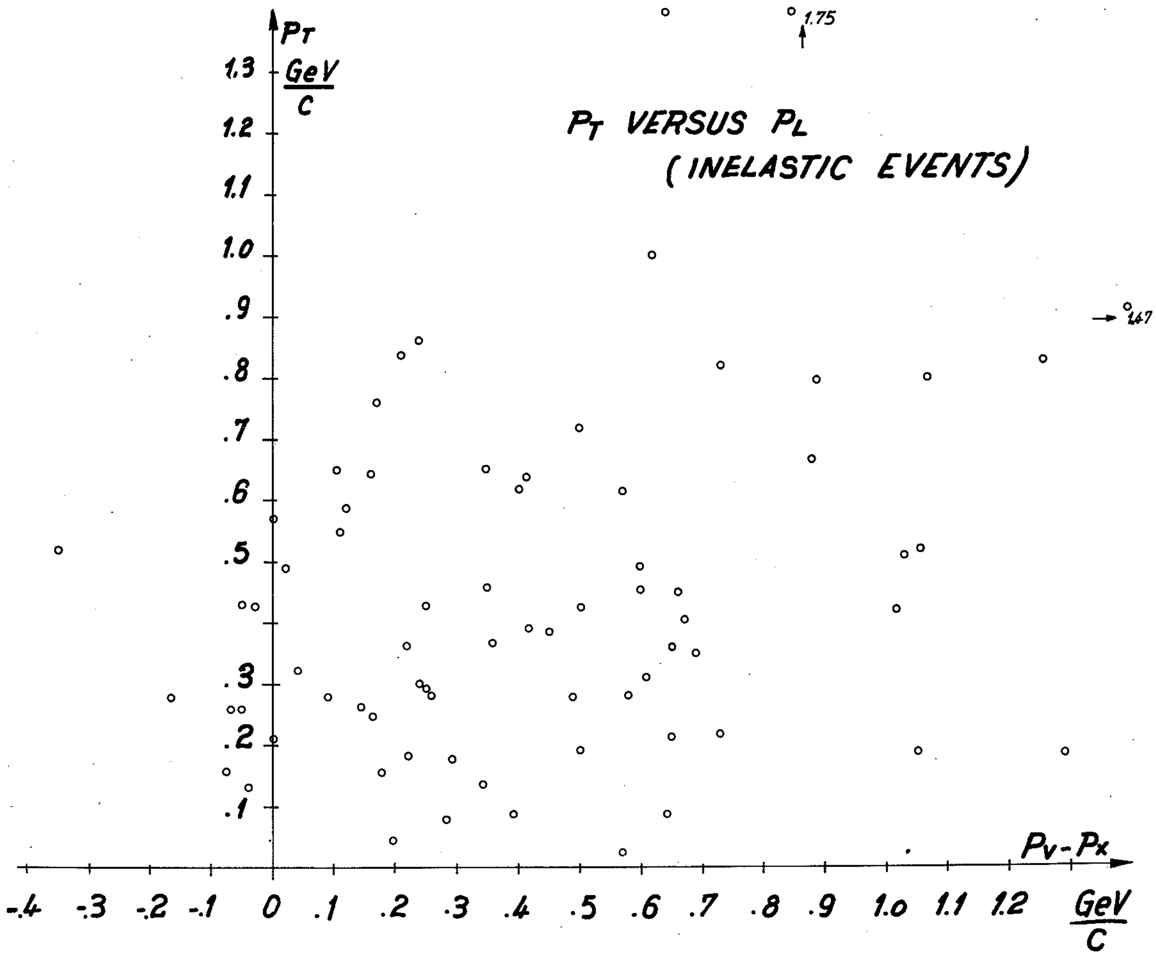


Fig. 15

DIA 18915

SIS/R/7074

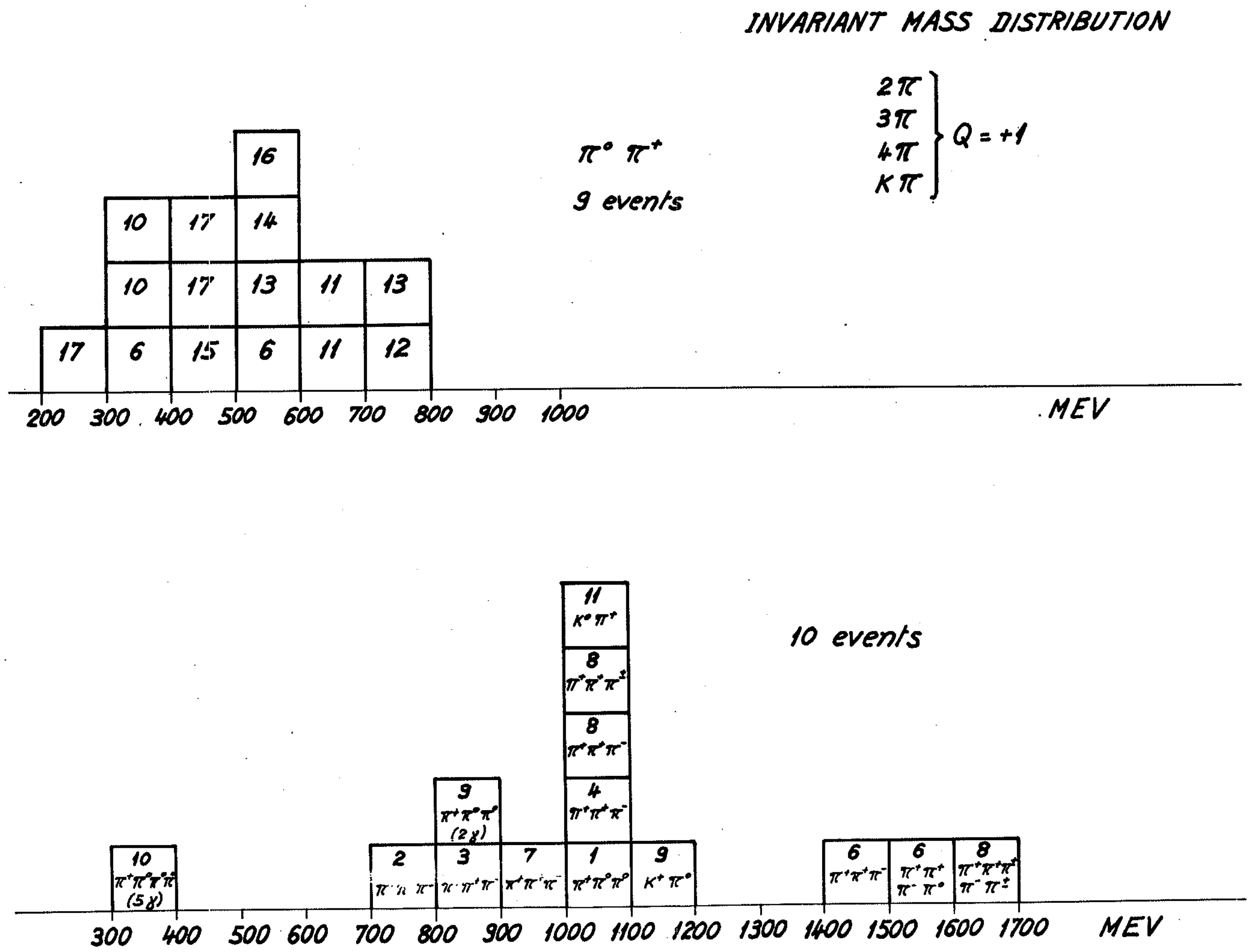


Fig. 16

DIA 18913

SIS/R/7075