SEARCH FOR CHARGED LEPTON PAIRS IN HIGH ENERGY NEUTRINO INTERACTIONS

G. Bernardini, H. Bienlein, G. von Dardel, H. Faissner, F. Ferroro, J. M. Gaillard, H. J. Gerver, B. Hahn, V. Kaftanov, F. Krienen, C. Manfredotti, M. Reinharz, R. A. Salmeron, J. Stein

CERN, Geneva, Switzerland
(Presented by J. M. GAILLARD)

If weak interactions are mediated by a boson W, it should be produced in present neutrino experiments, provided its mass is not too high. The reaction would be [1, 2]

$$\nu_\mu + p \rightarrow p + W^+ + \mu^-. \qquad (1)$$

The boson would then decay in about 10^{-18} sec into a neutrino and a charged lepton or into a system of pions and kaons.

$$W^+ \rightarrow \mu^+ + \nu_\mu; \qquad (2)$$

$$W^+ \rightarrow e^+ + \nu_e; \qquad (3)$$

$$W^+ \rightarrow \text{pions and (or) kaons}. \qquad (4)$$

In the CERN neutrino spark chamber, we have made a systematic search for lepton pairs, $\mu^+\mu^-$ and μ^-e^+ which would show up as a result of reactions (1) plus (2) or (3).

Fig. 1 shows the spark chamber set-up as it has been during the 1964 experiment.

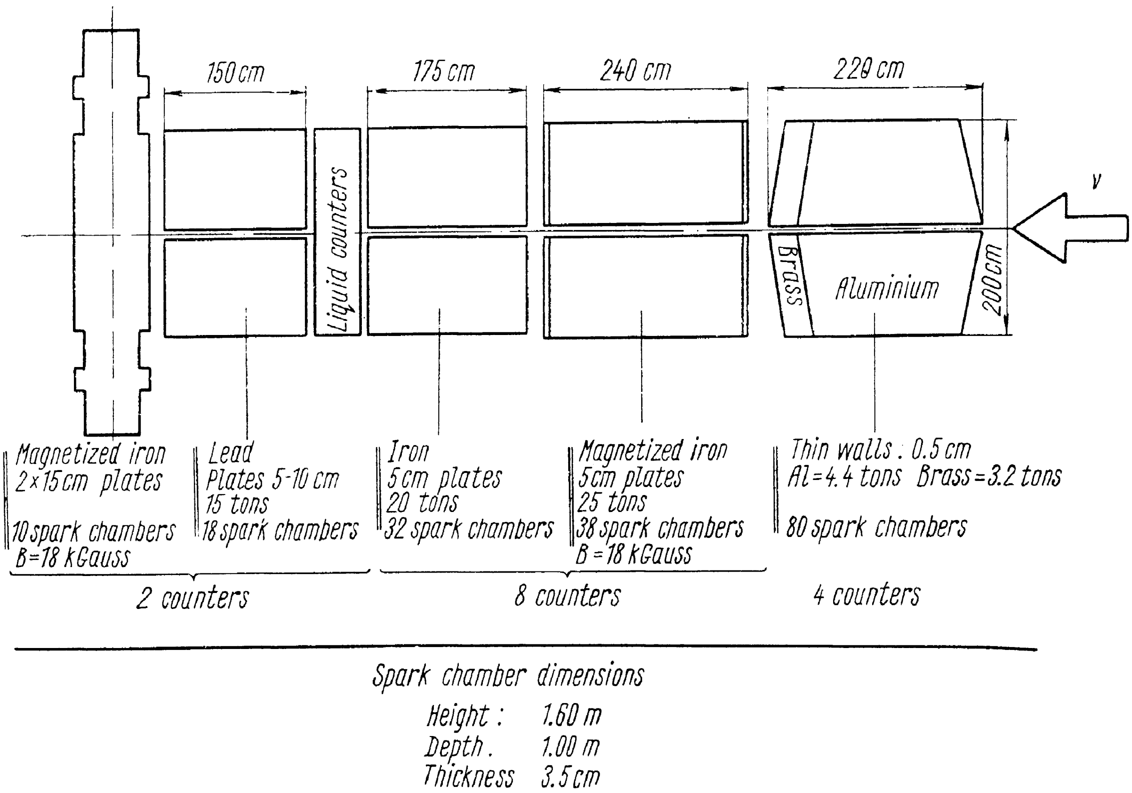

Fig. 1. Top-view of the apparatus as used in 1964.

1. SEARCH FOR MUON PAIRS

1.1. Interaction analisis. In the thin plate region we have selected all events satisfying the following conditions:

i) There are only two tracks which have a visible range $>0.5\Lambda_0$ (Λ_0 = geometrical interaction length.

ii) The longer track must have a range $>1.5\Lambda_0$, the shorter one a range $>0.8\Lambda_0$.

iii) The projected angles of the two tracks with the neutrino direction are smaller than 45° in both stereoviews, in order to avoid possible biases in the interaction detection.

This sample contains about 350 events. An example is shown in Fig. 2. These events would include 70% of the muonic decays of elastically produced intermediate bosons. We study the events for visible interactions (scattering $>10°$ and stars) in order to determine whether the observed number of interactions is compatible with the assumption that there are no muon pairs in the sample, i. e. that every event contains at least one strongly interacting particle.

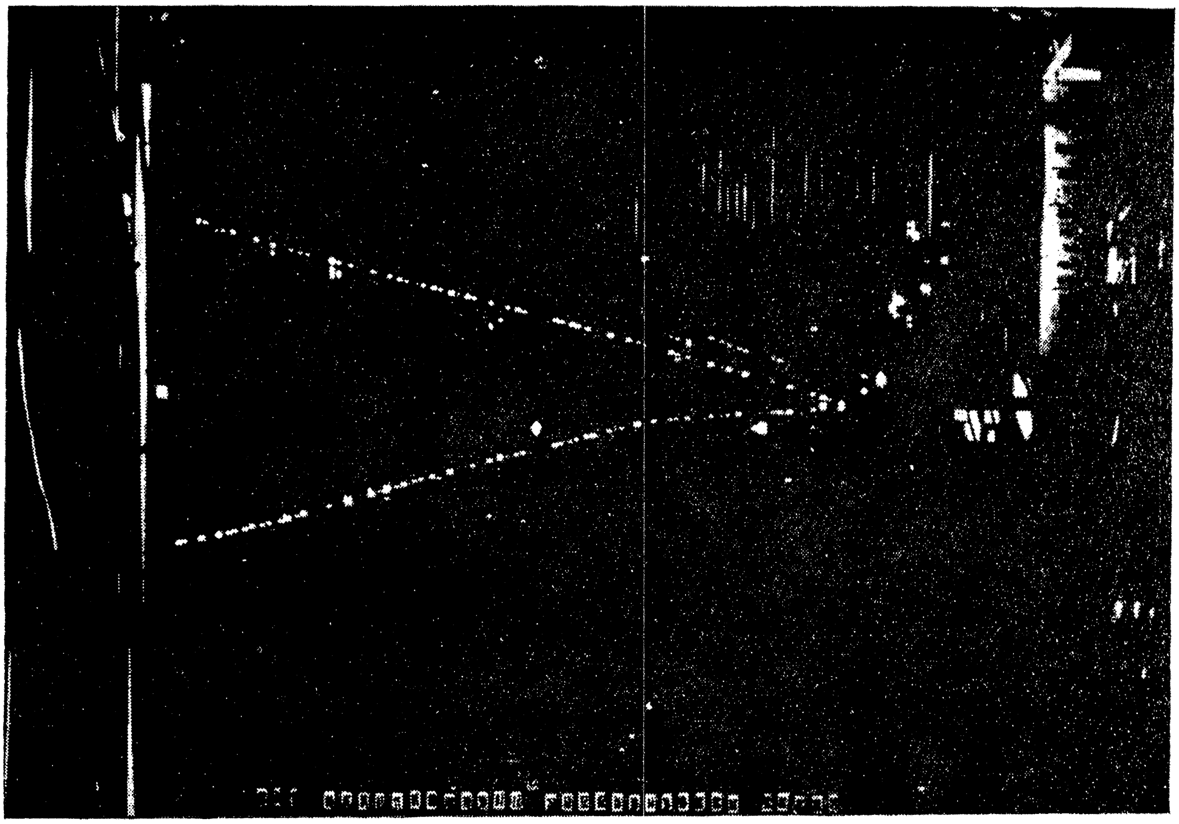

Fig. 2. Event satisfying the selection criteria used in the muon-pair search. The lower track shows an interaction.

For each event we consider one track which contributes a certain amount of track length and possibly an interaction. If there is no interaction we choose the track which gives the smaller track length contributions.

The apparent interaction length Λ of pions, protons and kaons has been determined in the various thin plate set-ups (brass, aluminium and aluminium brass mixture). The pion and proton calibration curves are shown in Fig. 3. From the bubble chamber results we know that for the events of our sample at least 50% of the track length is not due to protons. We assume for what follows that 50% of the track length is due to protons and 50% to pions. The momentum of the particles is not known, therefore one has to use the maximum value of the apparent interaction length for each set-up.

If Λ_{av} is the average of this value over the different set-ups weighted by the total track length in each set up, and L is the total track length, then one defines the minimum expected number of interactions by:

$$I_{expected} = \frac{L}{\Lambda_{av}}$$

Under the assumption that there is at least one strongly interacting particle in every event, the observed number of interactions should be greater or equal to $I_{expected}$. The results are given in Table 1. They supposed preliminary numbers given earlier [3].

Table 1

Experiment	$I_{expected}$	$I_{observed}$
1963	63	56
1964	33	36
Total . .	96	92

Clearly this result cannot be considered as an evidence that muon pairs are produced but the method is too coarse to be used for setting a limit on the W mass.

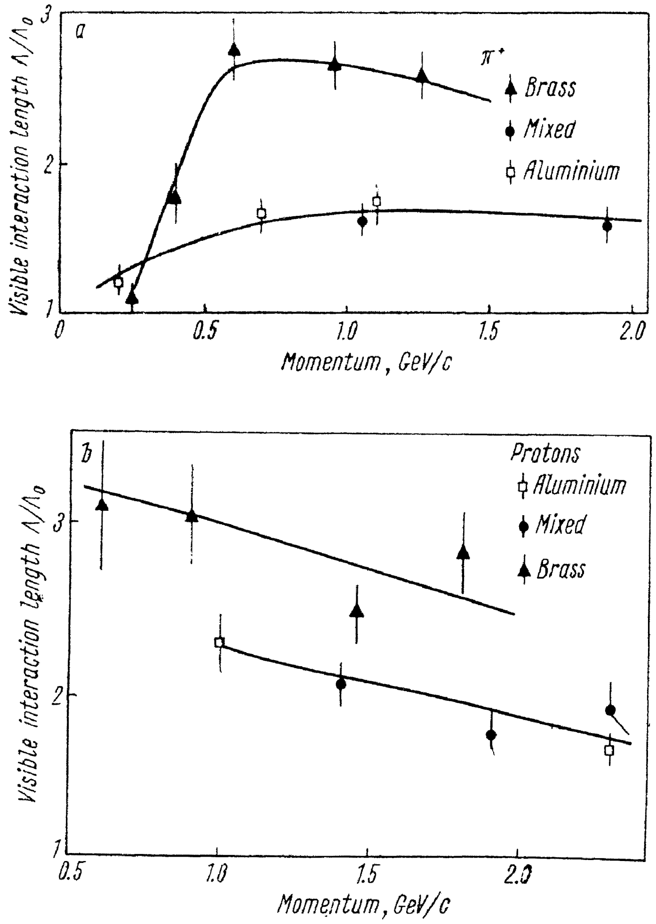

Fig. 3. Apparent interaction length of pions and protons as a function of momentum.

2.2) Sign analysis: A more powerful method makes use of the information on the sign of the charge supplied by the magnets. A muonic decay of an intermediate boson would lead in general to the following configuration

— a long positive non interacting track (μ^+)

— a somewhat shorter negative track, also non interacting (μ^-).

Among the events produced during the 1964 experiment in the first part of the magnetized iron (15 tons) and in the first part of the thick plate chamber (15 tons), we looked for events which fulfill the following conditions:

(a) There are two non-interacting tracks of ranges greater than 7 Λ_0 and 2.4 Λ_0 respectively (1200 MeV/c out 475 MeV/c for muons).

(b) One of the tracks, having a range greater than 7 Λ_0, but not necessarily the longest in the event, can be positive.

With such large ranges the background due to neutrino or antineutrino events of the type (μ p) or ($\mu\pi$) is extremely small. In fact we find no event which fulfills our conditions. The number one should expect depends on four factors: the mass of the boson, the detection efficiency, the neutrino spectrum at high energies and the branching ratio between leptonic and non leptonic decays.

The detection efficiency for muonic decays of W-events has been determined for our geometry. Using the kinematics computed by Bell and Veltmann [2] we find that the efficiency is 11% for $M_w - 1.3$ GeV, it should not change much for slightly higher masses.

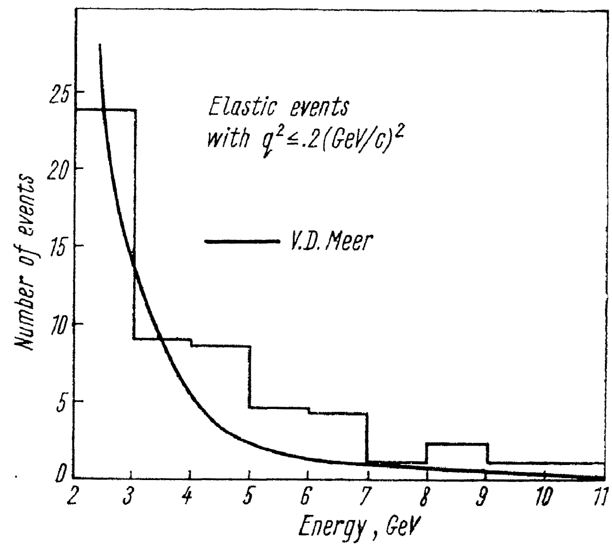

Fig. 4. Energy distribution of elastic events with $q^2 \lesssim 0.2$ (GeV/c)^2. The curve follows from Van der Meer's spectrum [3] using Block's cross section [5].

Van der Meer has computed the neutrino spectrum at the spark chamber position [4]. We have also tried to determine experimentally the high energy part of the spectrum using «elastic» neutrino events produced in the thin plate region. The method makes use of the fact that for low momentum transfers the cross section does not depend much on the form factors. We have used all the events produced inside the fiducial volume of the thin plate chamber which contain a muon going through the entire magnetic chamber. The criteria for the selection of elastic events have been discussed in the previous paper [5]. The square of the form momentum transfer q^2 has been computed in each case from the muon angle and momentum. This momentum was deduced from range and (or) sagita measurements. The energy distribution of the events is shown by the histogram of Fig. 4.

The distribution has been corrected for escape probability; the average cross-section amounts to 20%. The curve drawn in Fig. 4 gives the expected rate computed using the Van der Meer spectrum and the cross section for low q^2 as evaluated by M. Block [6]. Among the «elastic» events there is a contamination due to inelastic events as discussed previously [5]; in this case the contamination could be as high as 50% especially for the highest energy part of the spectrum. Neutrinos which could produce intermediate bosons have energies from 4 GeV up. From our measurement we conclude that the spectrum computed by Van der Meer is very likely a lower limit in that energy range.

Table 2

Expected number of $\varrho^+\varrho^-$ pairs

M_W, GeV	Spectrum	
	V. der Meer	Low q^2
1.3	21	51
1.5	11	26
1.8	4	9

2. SEARCH FOR μ e EVENTS

We choose to use for this analysis only the events produced in the aluminium thin plate region. In the other sections of the set up the

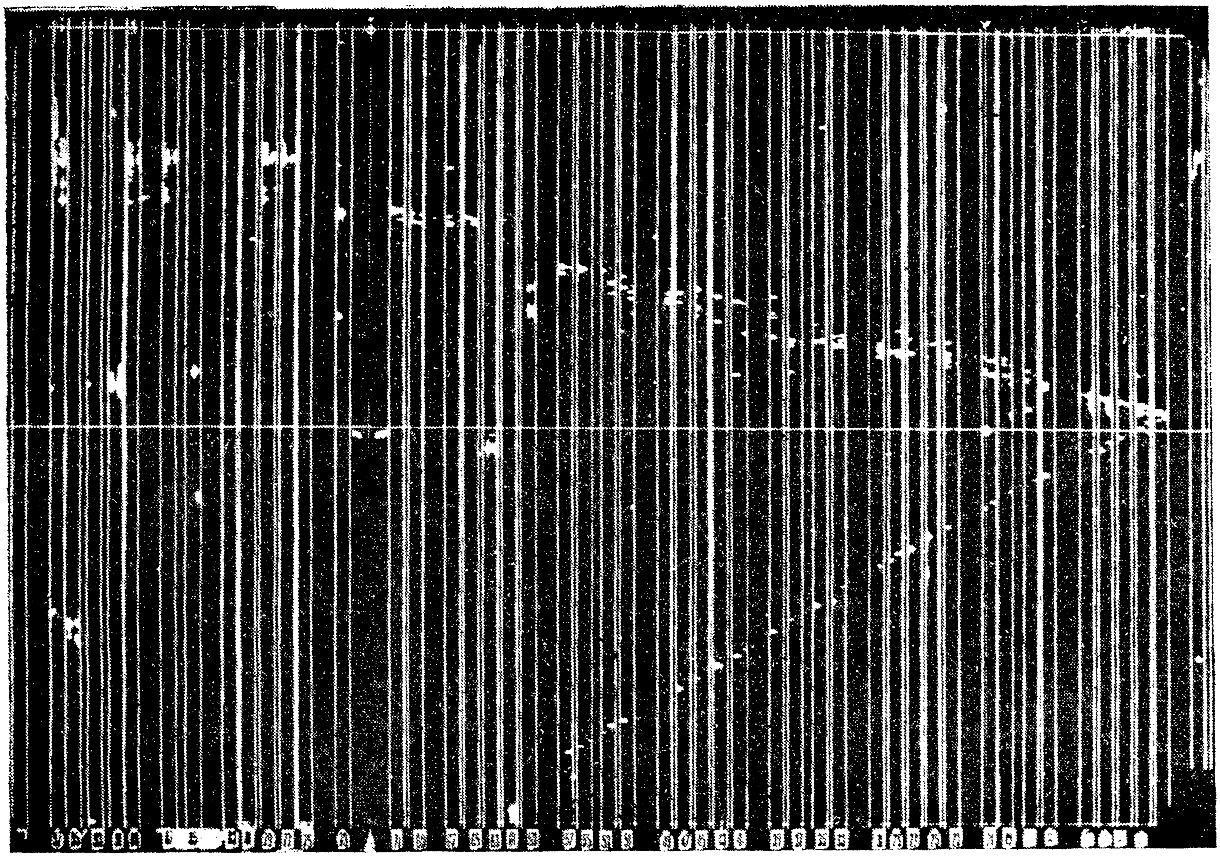

Fig. 5. An example of a (μe) candidate.

background of showers due to π^0's and single γ's is large.

From a total of 1500 events produced in aluminium we have found 6 events which satisfy the following conditions:

i) One shower which shows sparks in or before the third gap from the apex. (Because of the spark robbing effect near the apex, the shower may start from it without showing sparks in the two first gaps.) The shower energy is greater than 500 *MeV*.

The branching ratio R ($W \to \pi$'s)/R ($W \to$ $\to$ leptons) is not known. In what follows we shall assume a branching ratio equal to 1. The bubble chamber group [7] has given a limit on the W mass for R ($W \to$ leptons) = 0.

Under these conditions Table 2 gives the expected number of events which should fulfill our criteria in function of the W mass to deduce the spectrum from the low q^2 measurement qn inelastic contamination of 30% has been subracted from the histogram of Fig. 4.

ii) One track with a range greater than 0.8 Λ_0 and no other track with a range greater than 0.5 Λ_0. The projected angles of the longer track with the neutrino direction are smaller than 45° in both views.

This sample should include about 70% of the electronic decays of the boson. Fig. 5 shows one of the 6 events.

From the π^0 spectrum [4] we have computed the backgroun due to the following causes:

(a) the two γ's of a π^0 convert close to apex and overlap in both views.

(b) one γ converts close to the apex and the other one escapes from the chamber.

(c) one γ has an energy too low to be detected; the other converts close to the apex.

(d) Dalitz pair decay of a π^0, the γ escaping or overlapping.

(e) Internal bremsstrahlung ($\mu\gamma$).

This background amounts to one event. But another kind of background must be added; it consists in cases for which one gamma converts at a distance from the apex but a track makes a bridge between the shower and the apex and is afterwards burried inside the shower. This background should contribute one or two events. Finally in one of the events the track shows on interaction and clearly this is not a (μe); furthermore to get the amount of track length corresponding to the interaction we have to subtract at least one event.

With the uncertainties in all those subtractions, we set an upper limit of 3 for the number of (μe) events in our sample. One should notice that the events produced in the aluminium-brass mixture would lead to a similar maximum (μe) rate.

Therefore for $M_w = 1.8$ GeV and under the assumption that R $(W \rightarrow \pi's)/R$ $(W \rightarrow \rightarrow \text{leptons}) = 1$, we get the numbers listed in Table 3.

Table 3

Events	Expected		Observed
	V. der Meer	Low q^2	
μe	6	16	$\lesssim 3$
$\mu\mu$	4	9	0

We conclude that under the assumption that R $(W \leftarrow \pi's)$ / R $(\omega \rightarrow \text{leptons}) \leqslant 1$, the mass of the intermediate boson is greater than 1.9 GeV.

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