INTERACTION OF MUONS PRODUCED BY ATMOSPHERIC NEUTRINOS*)

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(presented by F. Reines)

This paper is a status report on the Case-Wits experiment[1] to detect the high-energy neutrinos produced in the earth's atmosphere by the interaction of primary cosmic rays. Our interest is at least twofold: to study these neutrinos which are a background for perhaps other more interesting high-energy neutrinos of extraterrestrial origin, and to learn whether the interaction cross-section increases in a significant way with energy in a range not available at current electronuclear machines.

The design of the experiment depends, quite obviously, on the characteristics of the atmospheric neutrino flux as well as the minimum expected interaction cross-section. Fortunately, the neutrino spectrum is reasonably well known[2], perhaps to within 20%, so that the primary uncertainty lies in the cross-section. If we conservatively assume the elastic value of 10^{-38} cm^2, the detector mass required for several events a year is several thousand tons. The signal in such an experiment as we describe is that of the energetic product muon:

$$\nu_\mu + \text{nucleus} \rightarrow \text{nucleus}' + \mu \ .$$

An enhancement of the cross-section by inelastic processes such as the production of multiple pions or by an intermediate boson would, of course, raise the counting rate, but we do not rely on this possibility to produce a detectable result.

Our approach**) is to use a rock target and detect the muons produced in the rock by a large area (100 m^2) scintillation detector. To eliminate the background due to natural radioactivity we use energy discrimination on the pulses. Cosmic-ray muons are reduced first by going very deep underground (8,400 m.w.e., 10,492 ft below the surface) and then by looking at zenith angles > 45°. Since the total number of cosmic-ray muons expected to traverse our detector is estimated to be $\gtrsim$ 300/year, the number inclined at > 45° at these great depths is quite reasonably expected to be $\lesssim$ 1/year. In any event we expect to measure the total muon flux as well as something about its angular distribution so as to check this point directly.

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**) For some time, since 1960, we had been considering an experiment in which cosmic-ray muons would be eliminated by an anticoincidence arrangement. The simpler scheme adopted here occurred to us when we learned in 1962 of the extremely low levels indicated by Tata results at 8,400 m.w.e. in the Kolar Gold Fields.

We have built and installed a detector array composed of 36 liquid scintillation elements like that shown in Fig. 1. This element consists of a plexiglas box 5.5 m long × 60 cm high × 12.5 cm deep, filled with a mineral oil-based scintillator, viewed from the ends by four, five inch photomultiplier tubes. Each element is housed in a separate, reasonably light tight enclosure. Figure 2 shows an end view of the array in place in the tunnel. It is three elements high and six long, or 18 on each side of the tunnel. Figure 3 illustrates a kind of event to which the detector is sensitive. Depicted is an energetic neutrino interacting in the surrounding rock producing a muon which penetrates the rock and two detector elements. Such an event would result in an eightfold coincidence between the photomultiplier tubes of the two detector elements.

The data are to be recorded by two systems so as to avoid error and to give us the necessary confidence in our results. In one system we photograph the pulses from each photomultiplier tube when a suitable coincidence occurs. In the parallel system we store the pulse-height information on capacitors which are then interrogated and recorded on a pulse-height analyser. The system has been in partial operation for a few months with too little run time to allow any significant conclusions to be drawn from the absence of neutrino-produced muons to date (20 January, 1965).

Note added after conference

On February 23, 1965, after running with a steadily increasing detector area, an eightfold coincidence of the type expected from a muon produced by a horizontally directed neutrino was observed. The data do not readily admit of other interpretations.

REFERENCES

1) Plans for this experiment were first described in a paper presented at the Jaipur Conference on Cosmic Rays, Jaipur, India, December, 1963.

2) Proceedings of the International Conference on Instrumentation for High-Energy Physics, p. 209, Berkeley (1960).
G.T. Zatsepin and V.A. Kusmin, JETP 39, 1677 (1960), and others.

FIGURE CAPTIONS

Figure 1 : The detector array composed of 36 liquid scintillation elements.

Figure 2 : End view of the array in place in the tunnel.

Figure 3 : Sketch of imagined neutrino induced event.

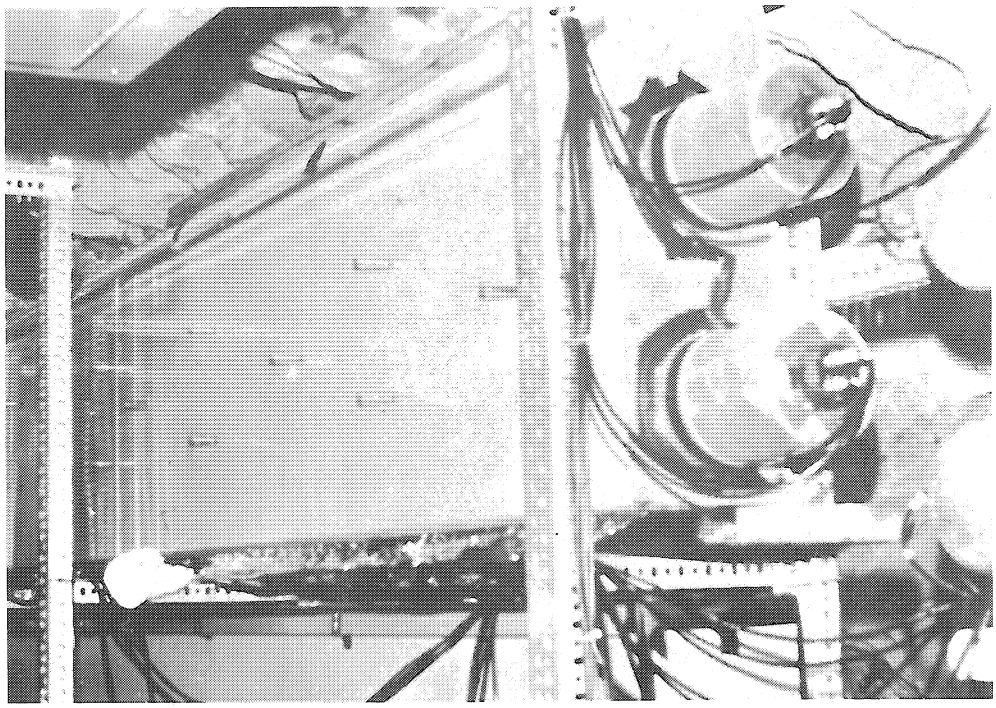

Fig. 1

Fig. 2

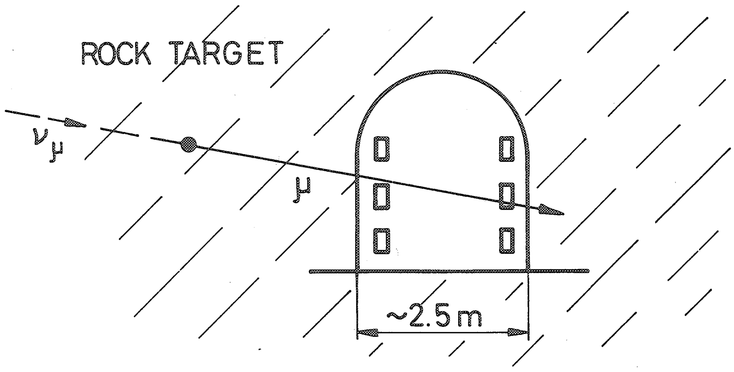

Fig. 3