SEARCH FOR LOW ENERGY MUONS PRODUCED DIRECTLY BY NEUTRAL COSMIC RAYS

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Over the past few years the cosmic ray group at the Catholic University of America have reported the existence of a process of the form

$$\text{neutral} + \text{proton} \rightarrow \text{neutron} + \text{muon}$$

The initial detectors used were large volume liquid and plastic scintillators surrounded by anticoincidence shields and a plot of the rate of occurrence of events showed the existence of peaks in sidereal time suggesting that the neutral radiation originated from sources on the celestial sphere[1)2)3)4)]. With a more elaborate detector they have also produced maps of the celestial sphere in the declination range - 10° to + 70° showing the celestial coordinates of several possible sources[5)6)].

The present experiment using the apparatus shown in figure 1 was undertaken to search for evidence for the above process. The apparatus, which was originally used to search for heavy mass particles (quarks), is situated under a thin roof at sea level. Events are selected by the coincidence requirement VCD $\overline{CI}$ $\bar{B}$ plus a delayed pulse from C, D or E in the range 0.26 to 5.5 μs. With this selection the target region is formed by the material between a fraction of the Cerenkov counter thickness (depending on the discriminator setting used) and the bottom of scintillator V(a total of 20.38 g cm^{-2} of material of mean atomic weight 25.3). The Cerenkov counter CI was supported by an8.4 g cm^{-2} thick steel plate which is not shown in figure 1. The region in which stopping muons or pions are selected is D, F_6, E, F_7, F_e. The scanning criteria for an acceptable event are that a single charged track should leave the target region and that when projected backwards this track should pass through the whole thickness of counter B. Also on stopping the charged track should give rise to a visible decay electron in the flash tubes. A visible decay electron is defined as a minimum of two tubes flashed, one in each of two adjacent flash tube layers. Measurements on stopping muons made with the anti-coincidence detectors turned off show that 16% of muons stopping in the region D to F_e give rise to a visible decay electron as defined above in the time interval 0.26 to 5.5 μs.

During a running time of 140 hours 5 events satisfied the selection criteria. Of these 3 were observed to undergo a single large angle scatter of more than 12^o between production and stopping (specifically, 37^o, 15^o and at least 12^o) and it is highly likely that these are pions produced by neutrons ($n + p \rightarrow n + n + \pi^+$). Although all scintillator and Cerenkov pulse heights were recorded the time resolution of the electronic display system did not allow π-μ decay to be directly observed although the μ-e decay pulses were observed.

The remaining two particles, which may not be pions, but lead to μ-e decay, can be used to estimate the intensity of the cosmic rays that produce them (assuming a cross section for the reaction). For an isotropic radiation the intensity is of the order of 7.2×10^{-7} $cm^{-2}sec^{-1}sterad^{-1}MeV^{-1}$, for a cross section of 10^{-28} cm^2/nucleon[1]. For point sources in the declination range + 32.5^o to + 77.5^o the corresponding flux is $2.9 \cdot 10^{-6}$ $cm^{-2}sec^{-1}MeV^{-1}$. In deriving the above values, which apply to muons of kinetic energies in the range 120 - 170 MeV, account has been taken of the overall muon detection efficiency of 16%.

Comparison can now be made with the results of Cowan et al[1]. For an assumed interaction cross section of $10^{-28} cm^2$/nucleon these workers derive a neutral particle flux of about $10^{-3} cm^{-2} sec^{-1} MeV^{-1}$, that is, much greater than the flux quoted here. Furthermore, our observation of the highly scattered particles indicates that the background due to what appear to be pions is so high as to cast doubt on the existence of any directly produced muons.

We consider that a rather sophisticated experiment would be necessary in order to detect a small fraction of directly produced muons in the presence of a pion background. What has been said does not prove that a unique phenomenon has not been detected by Cowan et al. because it is based also on an apparent sidereal variation of the neutral primaries. Our own data on this point are too weak statistically to be useful. If the sidereal effect is genuine such a variation of the neutron flux would also be an important and novel phenomenon.

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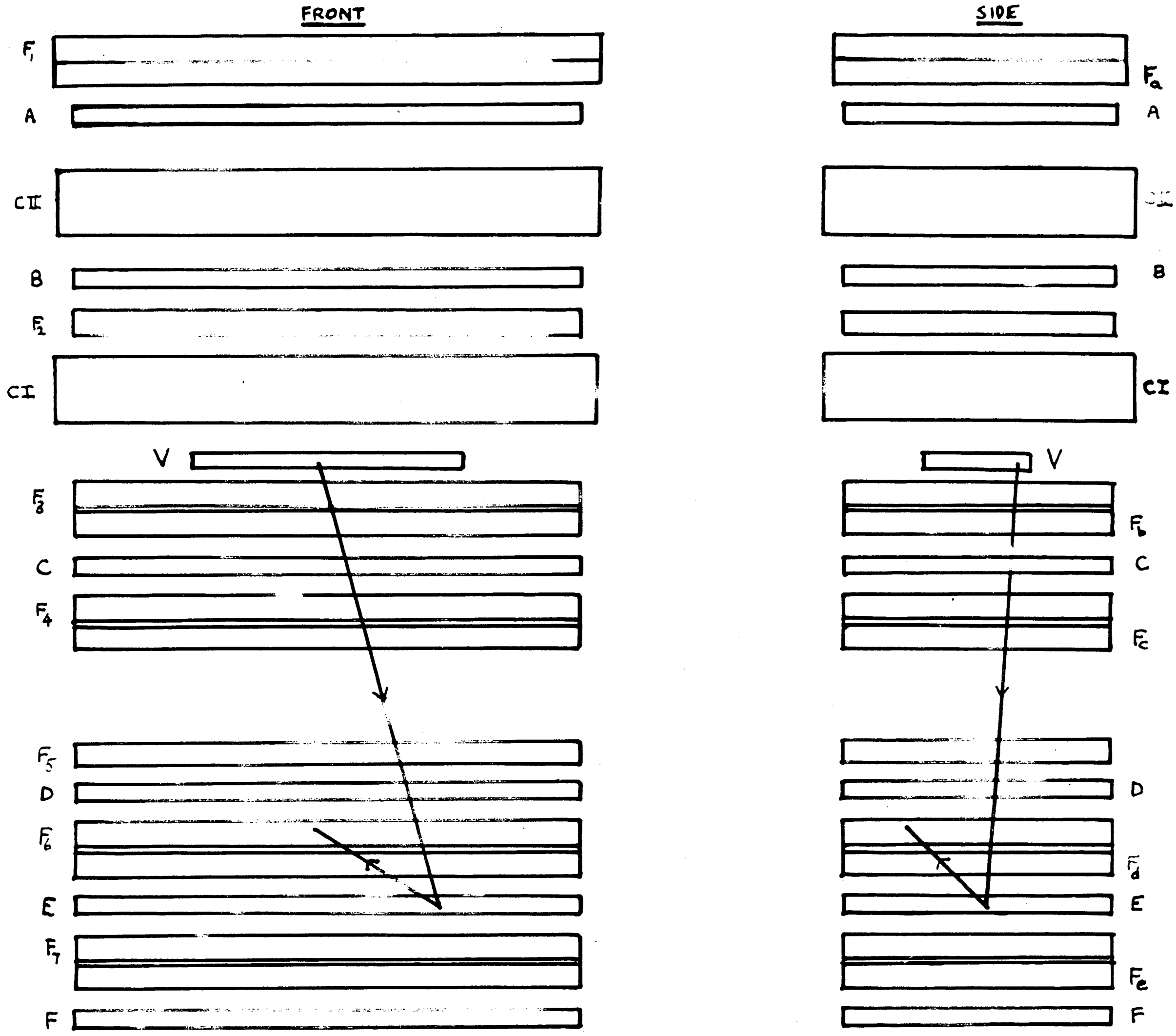

Figure 1. Apparatus. F_1–F_7, F_a–F_e, flash tubes; A–F, V, scintillators; CI, CII, water Cerenkov counters. The front plane of the detector is 20°E of geographic N.