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Anomalous Showers Deep Underground

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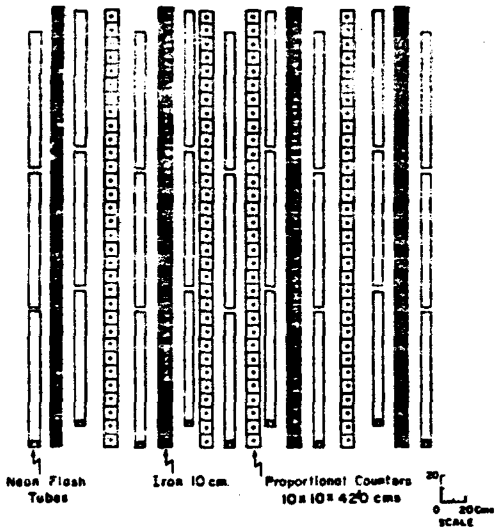
Several studies of high energy interactions using particle telescopes placed deep underground have been carried out. Some have operated in various arrangements for as much as ten years (Kolar Gold Field detectors in India[1-4]; Chase-Wits-Irvine detectors in South Africa[5]). Others have come into operation recently (The Baksan telescope in the Caucasus, USSR[6], the Homestake Mine detector, S. Dakota, USA[7,8]. These detectors, in general, have capabilities which can include, (a) multiple track recording and reconstruction; (b) determining the direction of the primary giving rise to the event; and (c) particle identification: whether a given track or tracks imply a muon, a hadron or an electromagnetic shower (e or γ). They are in general relatively large, either in acceptance or in their "mass" or both, and are located at great depths under rock (greater than 850 hg/cm^2 or about > 1 TeV equivalent muon energy needed to penetrate the depth). A variety of detector elements have been used, including crossed flash tube arrays; proportional chambers; and scintillator counters, generally interspersed with absorbing material to form a crude calorimeter as well as a directional hodoscope.

In what follows we discuss some interesting events that have been collected in the Kolar Gold Field (KGF) experiment. The more recent experiments (Homestake and Baksan) have yet to report on their "unusual" events if any. We summarize KGF observations on anomalous cascades deep underground.

These consist of steeply inclined showers traversing detectors placed at depths of 3375, and 7000 hg/cm^2. The telescopes have vertical detector planes of crossed proportional counters, flash tubes and/or scintillators with lead or iron absorbers interspersed. In figure 1 an edge on view of the detector is shown. At 3375 g/cm^2, in a total exposure of 1.68×10^9 m^2 sec and an angular range from 30° to greater than 90° (upwards), four events have been observed. The visible energy of these events is greater than several hundred GeV. The observed spectrum of bursts, when extrapolated to the energy range of these anomalous events gives a flux which is at least an order of magnitude less than that implied by these four events. Two of the four events were obtained prior to 1977 and two have been observed recently 1979 with improved apparatus in about one-third as much running time as the first run.

At a greater depth of 7000 hg/cm^2, in 1.8 x 10^9 m^2 sec, two events at $\theta > 45^\circ$ were observed with more than 1000 particles in each, again corresponding to several hundred GeV. At this depth, in the same running time only ten other showers were seen, and they had energies less than 30 GeV.



If we assume that the two events at this deeper depth are due to muon bursts, one would expect to see 20 to 30 events at the shallower depth contrary to observations.

Figure 1

A schematic rendering of three of the showers at 3.37 x 10^5 g/cm^2 in the new apparatus is shown in figure 2. For each event the east view as well as the west view of the detector is shown. The top figure shows the locations of proportional chambers (P.C.), the neon flash tube arrays (N.F.T.) and the lead and iron absorbers.

The unusual features of these events are summarized as follows:

1) High energy of the cascades, $\gtrsim$ 500 GeV
2) Broad angular distribution
3) Frequency of occurrence independent of depth
4) High event rate.

The flux of these events seems to be depth-independent and much greater than that which could be predicted from muon interactions or from ordinary neutrino interactions. Could these events indicate occurrence of new neutrino induced processes?

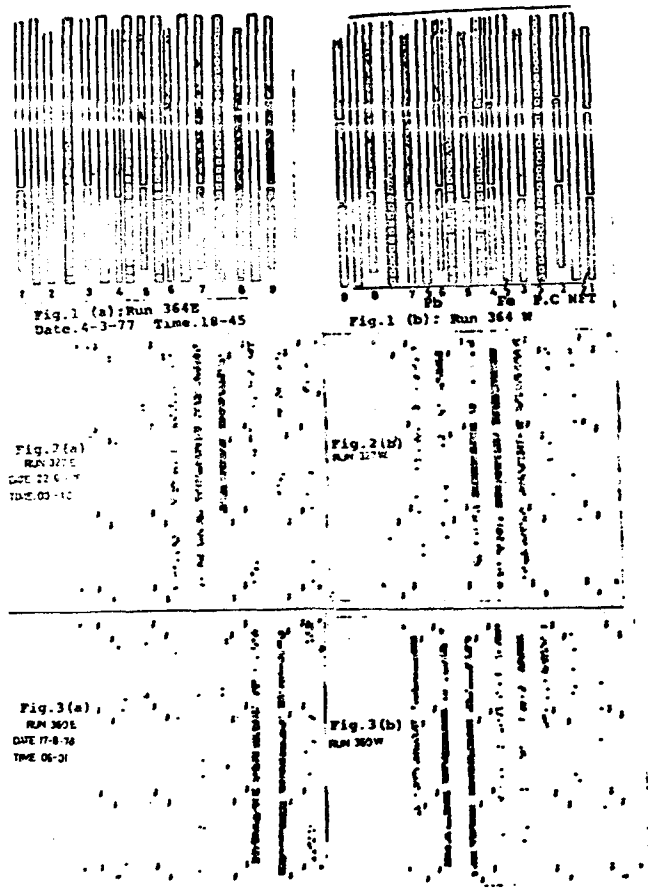


Figure 2

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PROPERTIES OF NEUTRINOS DERIVED FROM EXPERIMENTS IN NATURE

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ABSTRACT

Our early work on the role of neutrinos of finite rest mass in astrophysics and cosmology is reviewed briefly. The main results are:

a) The neutrinos are sufficiently stable against radiative decay to survive for periods much longer than the age of the Universe, or more explicitly, $\tau_o > 10^{23}$s if $m_\nu \sim 1$ eV/c^2, $\tau_o > 10^{24}$s if $m \approx 20$ eV/c^2 and $\tau_o/m_\nu c^2 > 10^{17}$ s/eV irrespective of their mass.

b) The sum of the masses of all the various types of neutrinos is less than 35 eV/c^2.

c) If indeed any of the neutrinos should have a finite rest mass of $\sim$ 1-10 eV/c^2 it can be responsible for causing the apparent virial mass discrepancy in large clusters of galaxies.

These early ideas are extended to the case of the newly discovered τ-neutrino to show that it also conforms to the limits indicated above.

INTRODUCTION

Astrophysics is usually the science in which the well-known laws of physics are assumed to hold good even on the macroscopic scale of the astronomical bodies and on this premise we try to understand the nature and properties of the celestial objects. However, the inverse situation where studies are done outside the man-made laboratories in nature, has yielded many insights into basic physics and, in particular, into the properties of the fundamental particles. I have been motivated by this idea and today I shall review some of my early work on the neutrinos of finite rest mass specific to the interest of this conference.

Neutrinos of finite rest mass have fascinated physicists for a long time and we are probably indebted to Markov (1964), Gerstein and Zeldovich (1967) and to Bahcall, Cabibbo and Yahil (1971) for some of the very first applications to astrophysics and cosmology. Markov and also Bhadman (1974) had reviewed the field until then and suggested the possibility of neutrino stars.[1,2] Gerstein and Zeldovich[3] presented the first qualitative ideas and showed that the