

STUDY OF HIGH ENERGY COSMIC RAY NEUTRINOS.  
STATUS AND POSSIBILITIES OF BAKSAN UNDERGROUND  
SCINTILLATION TELESCOPE

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Baksan Underground Scintillation Telescope come into operation. Possibilities of time-of-flight method for distinguish muons produced by neutrino interactions in the surrounding rock from large flux of atmospheric muons are discussed. Efficiency of triggering system for upward particles recording is measured. Examples of events observed so far are given.

I. Introduction. Underground Scintillation Telescope (Alexeyev et al.1979) put into operation at Baksan Neutrino Observatory give many possibilities to study cosmic ray muons. In particular it is proposed to investigate muon flux from lower hemisphere. Upward muons are produced by atmospheric neutrinos crossing the Earth globe and interacting in the surrounding rock not far from installation. The possibility of detection of natural neutrinos by large area detector placed deep underground was pointed out by M.A.Markov (Markov, 1960; Markov and Zheleznykh, 1961). The horizontal intensity of neutrino induced muons was measured by two groups (Krishnaswamy et al.,1971; F.Reines et al, 1971) and was found  $\sim 4 \cdot 10^{-13} \text{ cm}^{-2} \text{ sec}^{-1} \text{ st}^{-1}$ .

At present the interactions of neutrino with matter are studied at the accelerators up to energy 200 GeV with good accuracy. Using these results it is possible to predict muon flux produced by atmospheric neutrinos. Observation of this flux can have two purposes.

At first the distance between detector (telescope) and neutrino source is about  $10^4 \text{ km}$ , therefore experiment with cosmic ray neutrinos has a high sensitivity to neutrino oscillations (Bilenky and Pontecorvo 1977). If neutrino oscillation length is short enough, muon flux from atmospheric neutrino will be reduced. The neutrino intensity  $I(P, R)$  with momentum  $P$  at distance  $R$  for case of two neutrino types is

$$I_{\nu}(P, R) = I_{\nu}(P, 0) \left[ 1 - \frac{1}{2} \sin^2 2\theta (1 - \cos 2\pi \frac{R}{L}) \right]$$

where  $\theta$  is a mixing angle and  $L = 4\pi R / |m_1^2 - m_2^2|$  is the oscillation length ( $m_1$  and  $m_2$  are masses of different neutrino types). If  $\theta = \pi/4$  and  $R \sim L$ , then  $\int I_\nu(\rho, R) d\rho \approx \frac{1}{2} \int I_\nu(\rho, 0) d\rho$ . Average value of momentum  $\langle P \rangle$  for atmospheric neutrinos is 10 GeV and  $\langle R \rangle$  is about  $10^4$  km, then  $\Delta m^2 = m_1^2 - m_2^2 \approx 10^{-3} \text{ eV}^2$ . This value is ten times lower than present experimental limit.

At second, new installation allows to discover local high energy muon neutrino source, if neutrino luminosity exceeds  $10^{40}$  erg/sec and the source is located in our Galaxy. Possible existence of local neutrino sources with large flux of high energy neutrinos during a few month after supernova explosions was suggested recently (Berezinsky and Prilutsky 1976).

The expected for the telescope flux of neutrino induced upward muons is negligibly small ( $1.5 \cdot 10^{-6} \text{ sec}^{-1}$ ) as compared with atmospheric muon flux ( $15 \text{ sec}^{-1}$ ). The efficiency of time-of-flight method to distinguish such a big ratio is discussed by Andreyev et al (1979).

**II. Triggering system.** Triggering system for recording upward particles must satisfy following requirements: (i) cover most part of solid angle below horizon; (ii) trigger must be fast to record pulse shape on multitrace oscilloscope; (iii) trigger must cut off flux of downward particles as completely as possible.

In order to satisfy these requirements we use three triggering systems. Fig.1 shows logic circuits of triggering systems. Zero-crossing discriminators (D) determine the moment of particle crossing given plane. Eight D-output ( $D1 + D8$ ) correspond to each plane of telescope and are used for triggering and also for measuring of time-of-flight. Other discriminators ( $D11 + D13$ ) correspond to three "belts". (Detectors placed on vertical planes between horizontal planes are united by "belt" summator). Besides there are circuits of delayed coincidence (CDC) in order to select events when below detectors give signal earlier than any above. First trigger (T1) is corresponds to the case when there are signals from more than two planes and from two or more CDC. Trigger T2 arises if there are signals from two planes only and from one CDC. Trigger T3 selects events near horizontal. In this case signals from two vertical planes and one "belt" are required. Three triggering systems cover zenith angle from  $80^\circ$  up to  $180^\circ$ . In order to know the efficiency of triggering it is possible to invert delay system and to measure rate ( $N_1$ ) for downward particles. The comparison of  $N_1$  with the ordinary counting rate  $N_2$ , when no timing is required, gives the ratio  $N_1/N_2 = 0.95$ .

Fig.2 shows this ratio as a function on zenith angle.

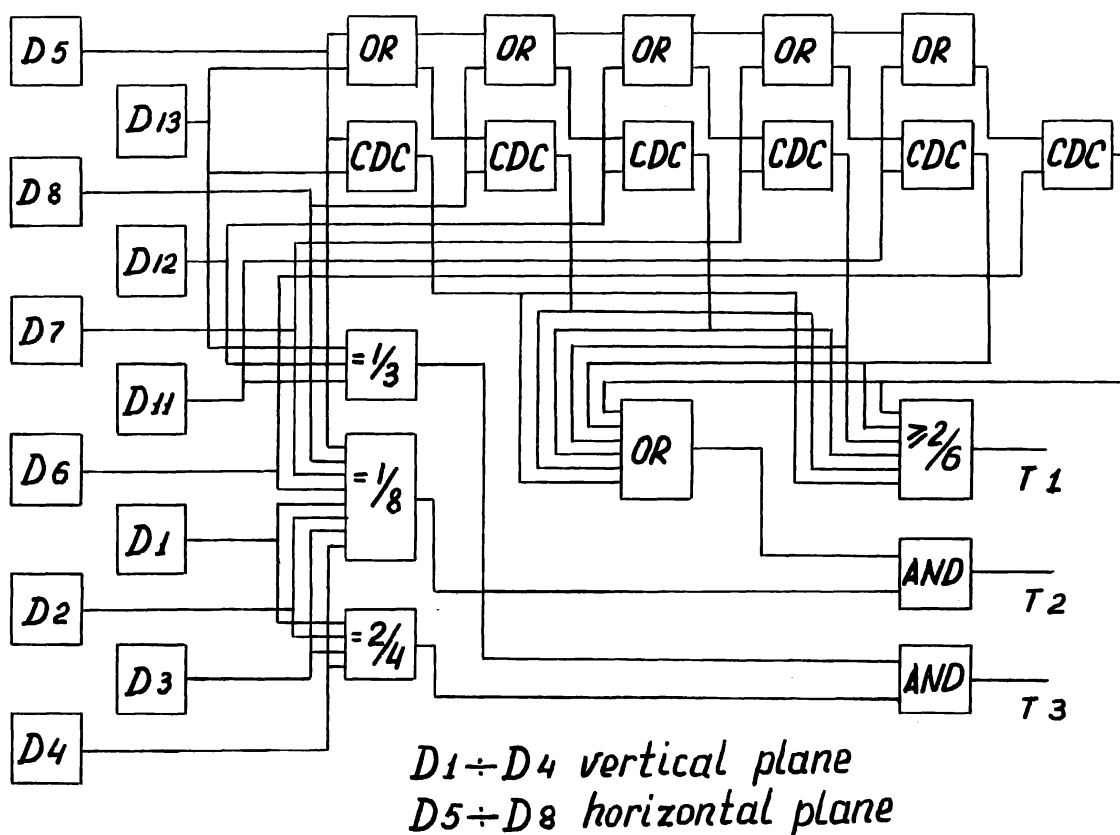
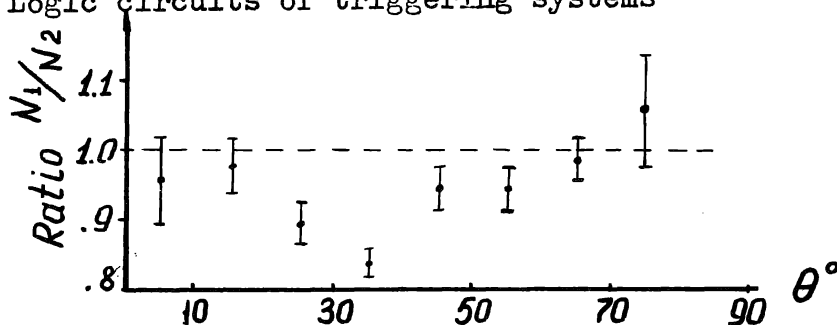


Fig.1. Logic circuits of triggering systems

Fig.2. Ratio  $N_1/N_2$  versus zenith angle (see text)

III. Separation of downward and upward particles. Using the above mentioned triggering system one cannot expect to illuminate all spurious effects. Actually the upward trigger rate is  $10^{-3} \text{ sec}^{-1}$  thus only  $\sim 10^4$  times smaller, than downward rate. This upward trigger rate is caused by muon bundles, which occur to be 100% distinguishable. It is possible to obtain direction and particles velocity for each recorded event. Fig.3 shows the distribution of events as a function of  $c/v$  ( $c$  is light velocity and  $v$  is measured velocity). Value  $c/v = 1$  corresponds to downward particles and  $c/v = -1$  to upward particles. One can see that telescope distinguish direction

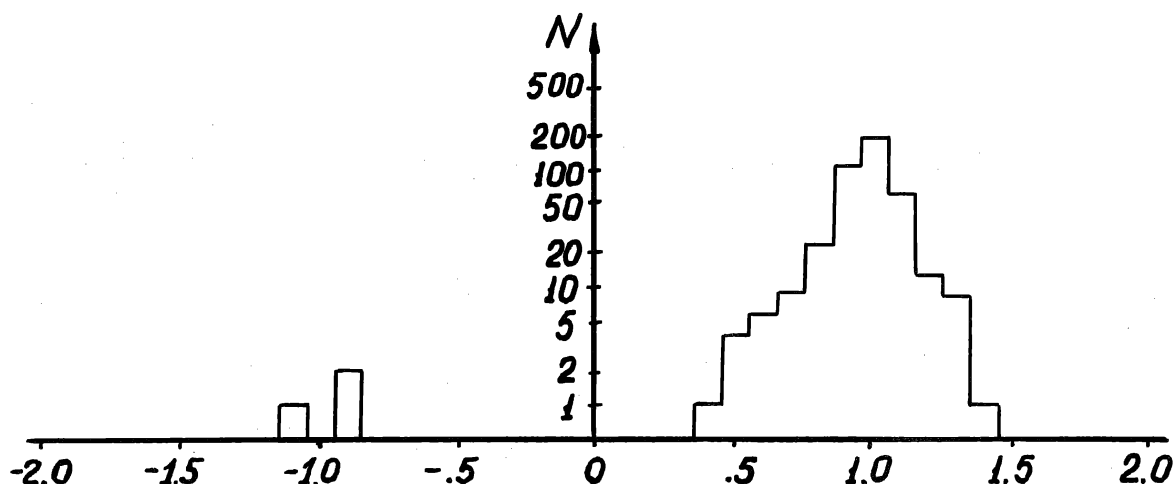


Fig.3. Distribution of events as a function of  $c/v$ . (Trigger T1 only). Left part ( $c/v < 0$ ) corresponds to period 600h, right part ( $c/v > 0$ ) period 100h.

of motion of particles with high reliability. Three events are near  $c/v = -1$ . These ones we interpret as muon from neutrino interaction. On Fig.4 two neutrino events (b,c) and example of background event containing five trajectories are shown.

Unlike background events neutrino events found so far have one trajectory only. In the event (b) muon crosses four horizontal planes, hence it had energy  $> 1.5$  GeV. In the event (c) muon crosses three planes and stops, which corresponds to  $\sim 1$  GeV. In both events muons had small angle to vertical, consequently neutrinos went distance about globe diameter before interactions.

**1V. Conclusion.** New installation, Baksan Underground Scintillation Telescope, allows to select upward particles by time-of-flight method. Triggering system has high efficiency and covers total solid angle below horizon. Large area of telescope enables to measure intensity and angle distribution of neutrino produced muons.

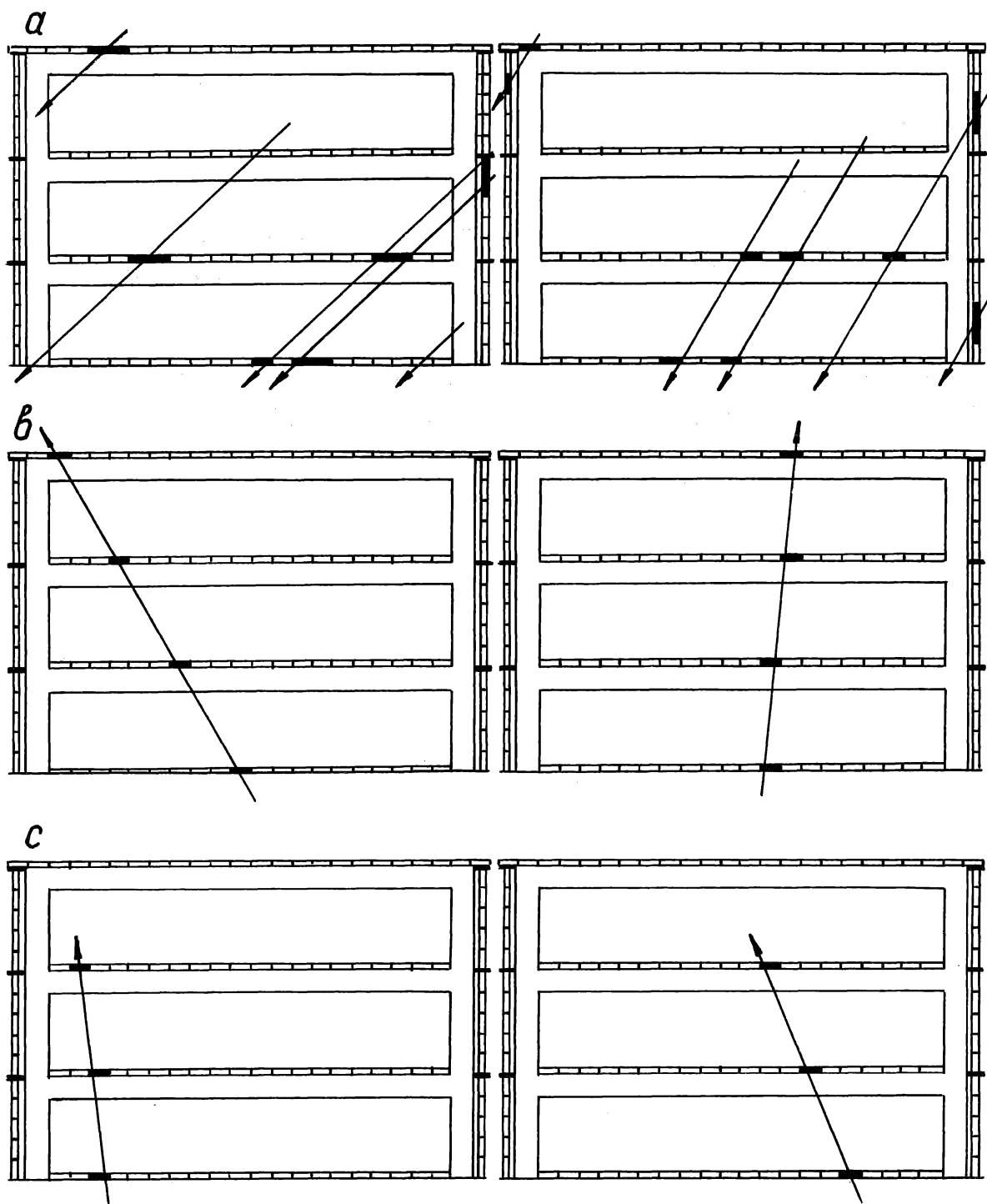


Fig.4. Examples of background (a) and neutrino (b,c) events

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