Cherenkov Radiation of Extencive Air Showers Observed at Large Zenith Angles by SHALON

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Abstract

The analysis of results of observation of extensive air showers at height of 3338 m above the sea level by means of gamma-telescope SHALON at the zenith angles $72^o, 76^o, 84^o, 96^o$ are presented. The observation results are compared with the data of detection of showers according to the direction into the zenith. The observation has been carried out at high mountainous Tien -Shan station (3338 m) with SHALON -1 gamma-telescope functioning since 1992 and with coming into operation SHALON-2. The SHALON mirror telescopic system consists of composed mirror with area of $11.2m^2$. It is equipped with 144 photomultipliers lightreceiver with 0.5^o angular resolution, that has the most in the world angular size - 8^o. It allows to control the background of cosmic ray particle emission and the atmospheric transparency continuously with observation that means the increasing of observation efficiency. So it is the telescope characteristics that permit to start the search of local neutrino sources with energy $10^{12} - 10^{15}$ eV on EAS generating in mountain-range located at some 5 and more kilometers from gamma-telescope (in Russian the abbreviation SHALON means - the Extensive Air Showers from Neutrino)

The gamma-sources search is the first step of the astronomy to the very high energy range. Only neutrino astronomy in the future can complete the search and investigation of galactic and metagalactic objects where the proton and nuclei processes are realized. These processes accompanied by generation of gamma-quanta and neutrino witch are not scattered in Universe magnetic field, that gives an addition possibilities of investigation of the properties of active stelar objects at a very high energy.

The observations are carried out on P.N. Lebedev Physical Institute Tien -Shan high-mountainous station with gamma-telescope SHALON-1 acting since a 1992 and started operating SHALON-2 [1-6]. The SHALON telescopes feature is the large full angle that enlarges the observation area, increases the statistical

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accuracy and allows to control the background of EAS, generated by protons and cosmic ray nuclei, during observation. The SHALON mirror telescopic system consists of composed mirror with area of 11.2 m^2. It is equipped with the 144 photomultipliers lightreceiver with 0.6^o angular resolution, that has the most in the world angular size more than 8^o. It allows to control the background of cosmic ray particles emission and the atmospheric transparency continuously within the observations that means the increasing of observation efficiency. It allows to begin search of the local sources of neutrino with energy of $10^{12}-10^{15}$ eV on extensive air showers, generated in mountain range on distance up to five and more kilometers from gamma-telescope (an abbreviation SHALON is extensive air showers from neutrino). By this reason the first telescope SHALON is put in such a way that it is possible to observe cascade from under the mountain.

The Observation of Cherenkov Bursts at the Zenith Angle 97^o

In actual conditions the mirror telescope placement (Fig. 1) the distance till the opposite slope of the gorge is ~ 6.3 km or ~ 16 radiation units of length, that is quite enough for the development of an electromagnetic cascade till the structure characteristic for the rarefied atmosphere. The purpose of carried out observations was revealing of background conditions when anthropogenic sources of light are absent. During 61 hours of observations no one event was detected which possessed expected angular characteristics of a light burst of an electron-photon cascade developing within a telescope observation angle (Fig. 1). All 101 events of detection of short-range light bursts in the atmosphere have no a narrow angle light direction and are chaotically distributed along the whole matrix or its part of a light-receiver (Fig. 2). These events may be interpreted as a reflection of a Cherenkov burst from a snow mountain slope or as an ionization luminescence of the atmosphere while an extensive air showers transition within a telescope observation angle.

Extensive Air Showers under a Large Zenith Angle

The observation of extensive air showers under a large zenith angle attracts the investigator attention at least by two reasons. On the one hand, the cascade development till the maximum of its development in a rarefied atmosphere changes the structure and properties of extensive air showers. On the other hand, the possibility to observe showers by means of simple of systems of wide-angle detectors of Cherenkov radiation separated at large distance seems attractive. A mirror telescope SHALON due to the trigger control of the detection of bursts of a short-range (8 nsec) signal in ~ 4 photomultipliers of the light-receiver matrix allows one to know the number of observed bursts without observation of conditions of an angular picture of a Cherenkov burst. While observing into the

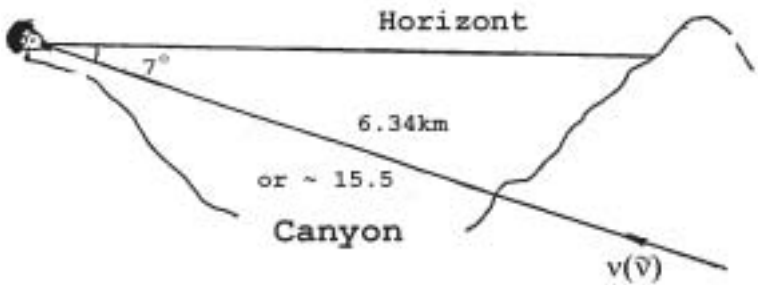

Fig. 1. The geometry of subhorizontal observation sessions

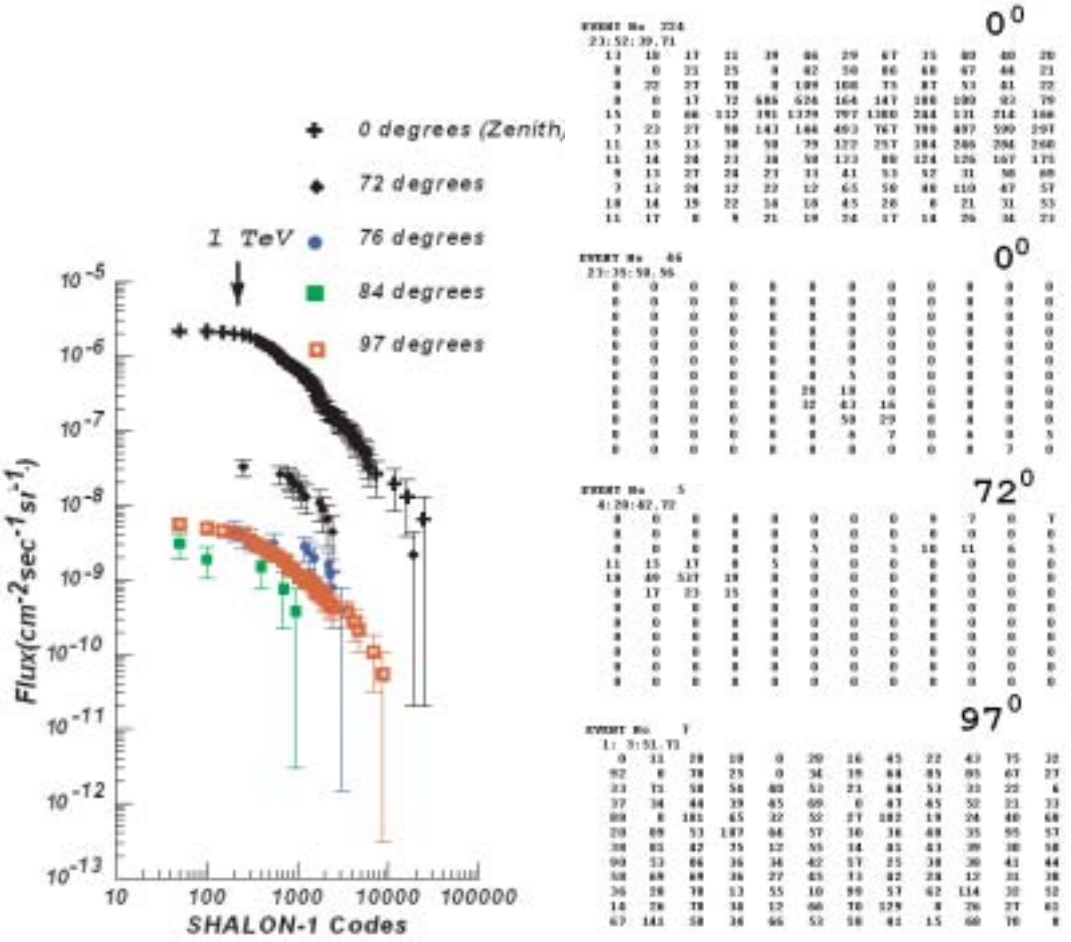

Fig. 2. The spectrum of extensive air showers Cherenkov radiation by telescope SHALON observation within 8^0 full angle. PMT amplitude arbitrary units are laid off along the abscissa.

zenith the number of such bursts is similar to the number of evens, identified as a Cherenkov burst from an extensive air shower radiating in the atmosphere at the distance less than 10 km above the telescope. In observation by means of a

telescope directed at the mountain slope under a zenith angle $\sim 97^o$ such cases were not observed. While observing under a smaller zenith angles a fraction of such events presented at Fig.2 increases. However, one should point out, that a number of detected showers within a telescope observation angle decreases while increasing of a zenith angle more considerably than it is expected while neglecting by absorption and dissipation of Cherenkov photons in the atmosphere (10 times at the angle 76^o).

Carrying out of the observation allows one to make the following conclusion. At first, a night star sky doesn't produce any background events, preventing the observations of electron-photon cascades coming from under the earth surface. Secondary, the observation of Cherenkov bursts from extensive air showers under the large zenith angles, for example using of horizontal extensive air showers for investigation of an energy spectrum of ultra-high energy cosmic rays is complicated by absorption of Cherenkov photons by a large atmosphere thickness.

It is supposed to overcome the main difficulty of observation , in conditions of high mountainous observations, of generated by neutrino EAS, connected with the small cross section of neutrino-nuclei inelastic collisions. The showers generating by neutrino in mountain range are observed by telescope SHALON from near horizontal directions on distance of 8 - 15 km. The hadron cascades are generated by neutrino in the ground of mountain range on ground thickness $< 300 g/cm^2$ at direction on gamma-telescope, placed on direction of 8 - 15 kms from a mountain slope. These cascades are observed by gamma-telescope as usual extensive air showers generated in a mountain slope of the 1 km area. The appearing of one shower on ~ 100 observation hours is expected if the flux of neutrino from local sources is $10^{-15} cm^{-2} s^{-1}$ [1-7].

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