Efficiency of Selection of Gamma - Quanta from a Proton Background in Experiment SHALON on Observation Results of Extragalactic Sources NGC1275, MKN501 and Galactic Sources Crab Nebula, Geminga, Tycho SNR

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Abstract

We discuss some results of the observations of the gamma-quanta sources and the discrimination methods between gamma-rays and protons. Selection of showers produced by gamma-quanta from background has made according the following criteria 1) α <20; 2) length/width > 1.6; 3) int0 >0.6; 4) int1 >0.8; 5) distance is <3.5. The experimental distribution of image parameters on used criteria are presented. The time analysis of observation data on NGC 1275, Mkn 501, Crab Nebula, Cygnus X-3 has shown that the contribution of cosmic ray background into observable gamma-quanta does not exceed – 10 - 15%. $I_{Geminga} = (0.48 \pm 0.17) \bullet 10^{-12} cm^{-2} s^{-1}$ and $I_{Tycho} = (1.89 \pm 0.56) \bullet 10^{-13} cm^{-2} s^{-1}$. The obtained Tycho's spectrum compare with theoretical predictions.

More than ten years ago the project of the mirror Cherenkov telescope SHALON (Sinitsyna, 1987) was suggested and the first observations were started in 1991 at the ALATOO mountain observatory at the height 3338m (Sinitsyna, 1992-2002). A distinctive property of the telescope is a large full angle due to a relatively large size of photomultipliers matrix (144 pixels, full angle 8^o)(fig. 1, 2). The comparison of SHALON PMT matrix with other experiments presented at fig. 2. This allows to detect extensive air showers coming at to the distance up to 120 m from an optical axis of the telescope, that increases the statistics from the sources of very high energy gamma-quanta. In addition such a large full angle of an image matrix allows to research an isotropic background of extensive air showers from charged particles of cosmic rays (OFF data) simultaneously

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with the observation of gamma-quanta local sources (ON data) at the same optical characteristics of atmosphere. It is particularly important because in our research of gamma-sources the extensive air showers generated by gamma-quanta are selected not only according to exceeding flux of showers in a small angle, but also according to the differences of the evaluation in the atmosphere depth of electron-photon cascades generated by protons and by nuclei of cosmic rays.

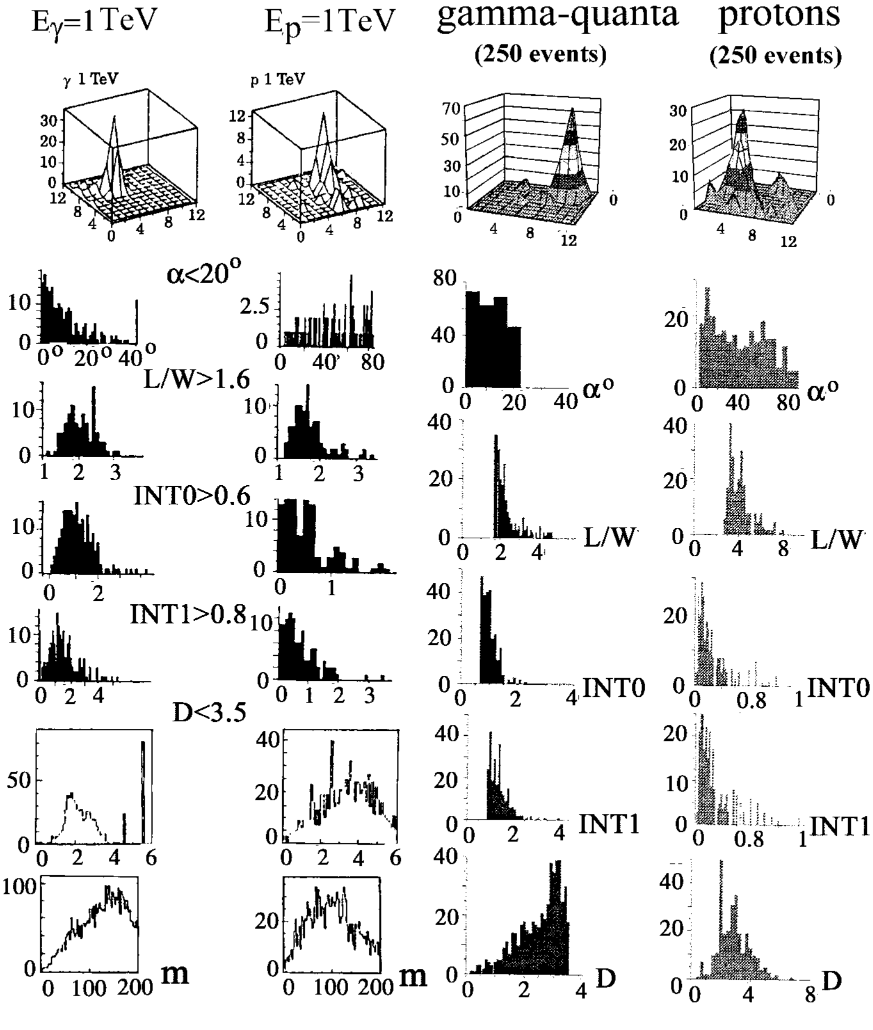


Fig. 1. The Monte Carlo and experimental distributions of showers on image parameters.

Such additional selection of electron-photon showers among extensive air showers of cosmic rays can be carried out by the analysis of a light image (generally of an elliptic spot in a lightreciever matrix) in comparison with developed characteristic parameters of distributions for both showers from gamma - quanta

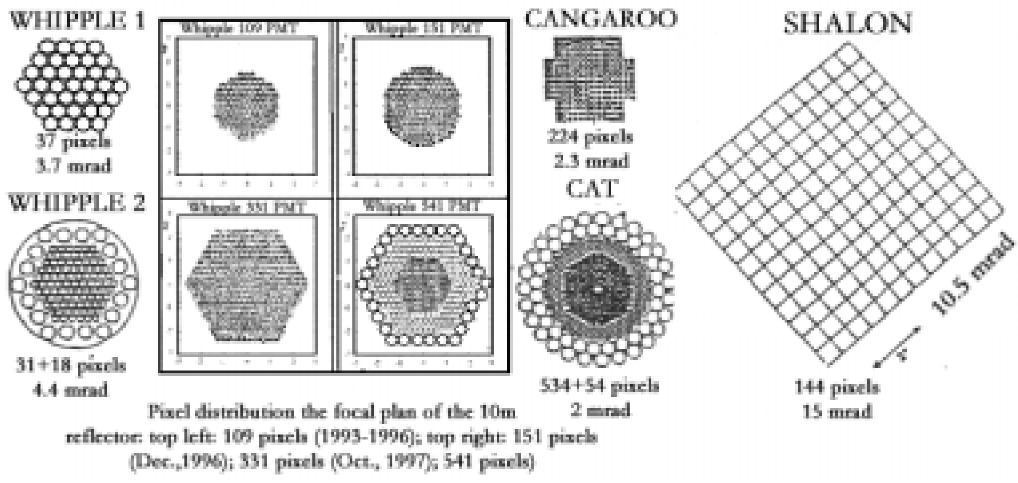


Fig. 2. Evolution of PMT arrays to record images seen in Cherenkov light.

and showers from protons and nuclei. Selection of gamma-quanta showers from a background of showers produced by protons (Fig. 1) is performed according to the following: 1) α <20; 2) length/width > 1.6; 3) relation of Cherenkov light intensity in pixel with max light to the light in eight pixels around it is int0 >0.6; 4) relation of Cherenkov light intensity in pixel with max light to light intensity in all pixels except nine in the center is for int1 >0.8; 5) distance is <3.5 in pixels.

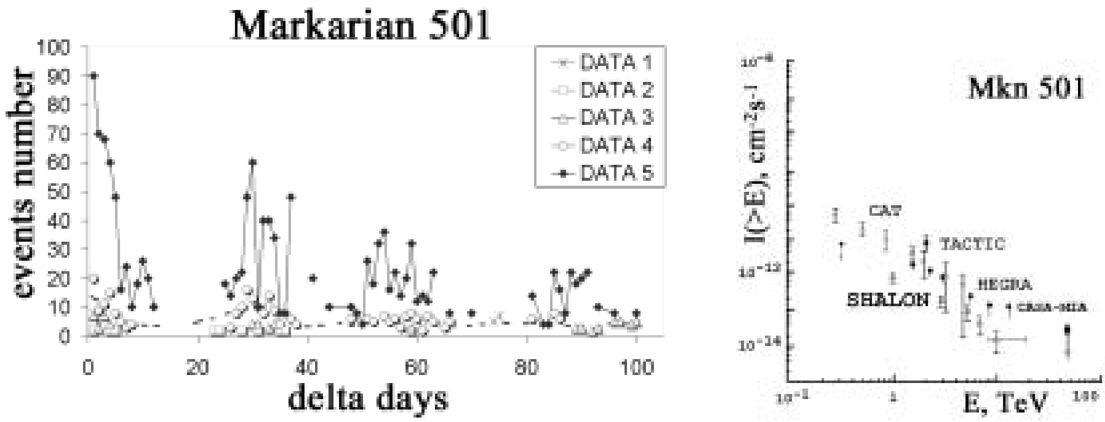


Fig. 3. left–AGN Markarian 501 time diagram 1996-2000. DATA 5 - gamma-quanta events sum 1996, 1997, 1998, 1999, and 2000 SHALON; DATA 1,2,3,4 - background events of showers produced by cosmic ray protons (large full angle of observations gives an opportunity to carry out ON and OFF observations simultaneously) 1996, 1997, 1998 and 1999 accordingly; right – gamma-quanta integral spectra of Markarian 501 by SHALON-1;

On Fig. 1 experimental distribution of image parameters for proton and gamma showers data obtained with the SHALON telescope is shown. At the left is Monte Carlo distributions of particles both gammas and protons on selection criteria. And on the right the gamma-quanta (250 events) from point sources observed by SHALON and selected by criteria and far the cosmic ray protons (250 events) from zenith SHALON observations are represented. As the analysis of this particle distributions on five criteria of selection used in experiment SHALON has shown that the contribution of background proton events into gamma events is not more than 10%, i.e. 90% of a background is cut, whereas the separation of gamma - quanta according to carried out estimations is not more than 6% (Fig. 1). The Fig. 3, 4, 5 presents the results of the time analysis on Markarian 501, NGC 1275 and Crab Nebula. The time analysis shows number of event (gamma or background), coming with the certain time interval (delta days). At ON data in all sources groups of peaks with common average 5-10 days width were detected with the period to multiple 24-26 days. These peaks can be interpreted as periods connected with the fact that observations are being carried out only by moonless nights. As one can see from presented at Fig. 3 the contribution of cosmic rays background (dashed line) into observable gamma-quanta with energies > 0.8 TeV doesn't exceed 10% - 15%.

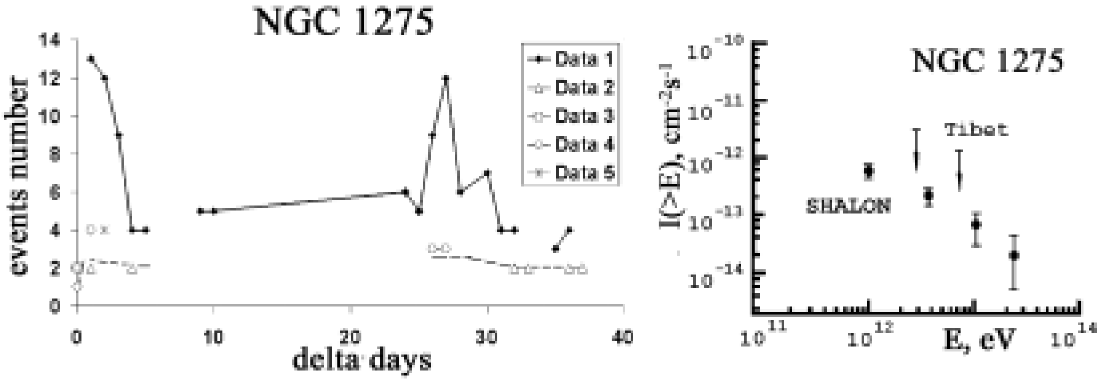
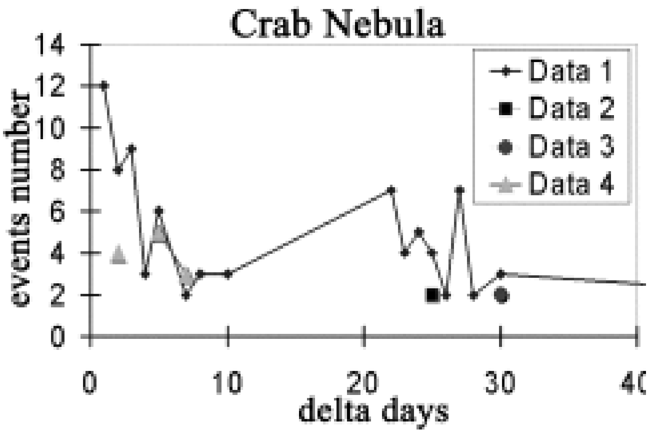


Fig. 4. left–NGC 1275 time diagram 1996-2000: DATA 1 - gamma-quanta events sum 1996, 1997, 1998, 1999, 2000; DATA 2,3,4,5 - background events of showers produced by cosmic ray protons (large full angle of observations gives an opportunity to carry out ON and OFF observations simultaneously) 1996, 1997, 1998 and 1999 accordingly (see text; right – gamma-quanta integral spectra of NGC 1275 by SHALON-1;

The SHALON-1 observations at Tien-Shan high-mountainous station were carried out since 1992 during this period 12 metagalactic and galactic sources were observed. Among them are galactic sources Crab Nebula (the supernova remnant), Cygnus X-3 (binar), Tycho Brage (supernova remnant), Geminga (radio-weak pulsar) and metagalactic ones Markarian 501 (blazar), Markarian 421(blazar), NGC 1275 (Seyfert galaxy), 3c454.3 (quasar) and 1739+522 (quasar) (see tabl.1 these Proc.). The results of observation data analysis are integral spectrum, time analysis of events from the source (ON) and background ones (OFF) observed simultaneously and the sources images. At 1998 at SHALON observation there was a new metagalactic gamma-quanta with energies >0.8 TeV source with flux $(0.78\pm0.13)\bullet10^{-12}$ detected. This source coincides by its coordinates with the active nucleus galaxy NGC 1275 fig.4. The energy spectrum of active galactic nuclei NGC 1275 was measured at energy interval of 0.8 to 30 TeV, $k_\gamma = -1.19 \pm 0.19$ (these Proc.), time analysis was performed. The observable energy distribution of gamma-quanta from local sources of NGC 1275 is $dF/dE_\gamma \sim E^{-2.19\pm0.19}$. The observed spectrum of the gamma-quanta including the 10%-15% contribution of the proton showers is for NGC 1275 $dF/dE_{on} \sim E^{-2.36\pm0.16}$. It is differs from observed simultaneously spectrum for cosmic rays $dF/dE \sim E^{-2.71\pm0.19}$. Firstly detected by SHALON telescope extragalactic source NGC1275 also was observed at Tibet installation. The NGC 1275 image at energy range >0.8 TeV is presented at these proceedings. At the energy region from 0.8 to 10 TeV there were detected new metagalactic sources 1739+522, z=1.375 and 3c454.3, z=0.859 with fluxes $(0.43 \pm 0.17) \bullet 10^{-12}$ and $(0.47 \pm 0.18) \bullet 10^{-12}$ accordingly.



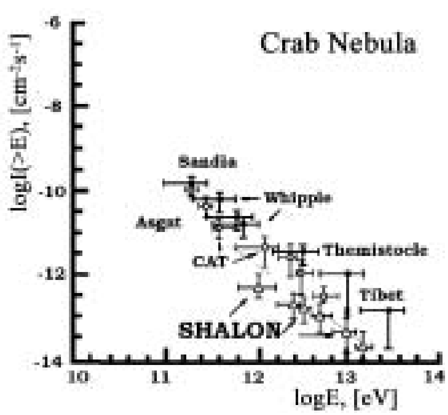


Fig. 5. left–Crab Nebula time diagram 1994-2000 SHALON: Line 1 - gamma-quanta events sum 1994, 1996, 1998, 1999, 2000; (large full angle of observations gives an opportunity to carry out ON and OFF observations simultaneously) Lines 2,3,4 - background events 1994, 1998 and 1999 accordingly; right – gamma-quanta integral spectra of Crab Nebula by SHALON-1;

The efficiency of selection gamma-quanta from cosmic ray background in experiment SHALON has allowed to observe the gamma-sources like Tycho Brage,

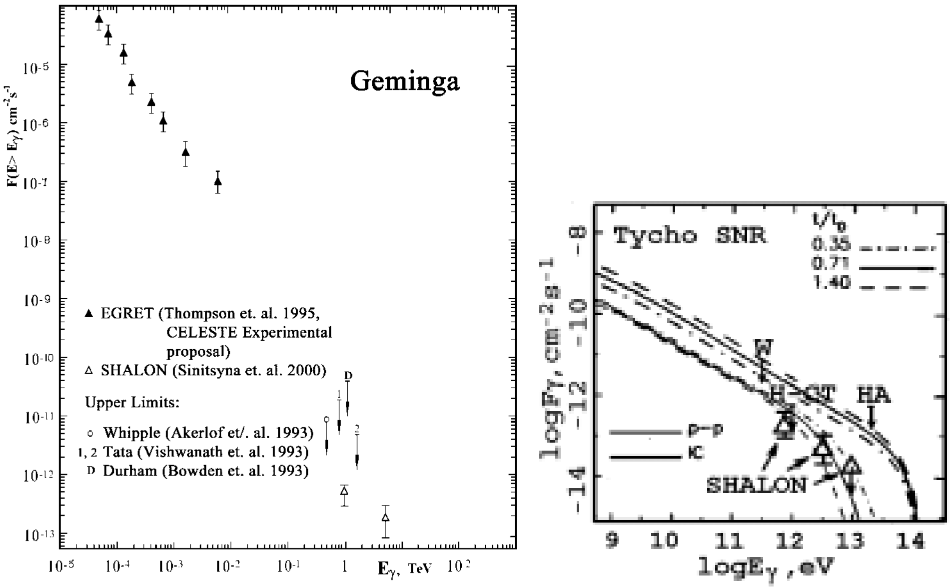


Fig. 6. left–gamma-quanta integral spectra of Geminga by SHALON-1 and other experiments; right – gamma-quanta integral spectra of Tycho Brage by SHALON-1 with experimental upper limits W – Whipple, H-CT – HEGRA IACT- system, HA – HEGRA AIROBICC and theoretical calculations from [5];

Geminga (fig. 6) and Cygnus X-3 (these Proc.).

The obtained experimental data about local sources of gamma-quanta are characteristic by the following fact. Though the observed metagalactic sources (active galactic nuclei) are $10^6 - 10^7$ times more powerful, unlike the galactic one, the gamma-quanta energy spectra from both galactic and metagalactic sources can be averaged with spectrum index $F(> E_\gamma) \sim E_\gamma^{-1.3\pm0.15}$. This result puts under doubt the assumption about the galactic origin of observable cosmic ray flux. The uniform cosmic ray spectrum is forming in "infinite" number of elastic (or inelastic) collisions with relict photons in intergalactic space, where the cosmic rays are 0.999 part of their time as the common volume of extragalactic space exceeds more than thousand times the total galactic volume in Universe. Accordingly, the observable spectrum distribution has index of $(2.72 \pm 0.02) = 2.718...$, that is Nipper's number.

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