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About a new method for selection of EAS initiated by primary gamma-quanta with energies 10^2-10^4TeV

M.I. Brankova[1]**, and J.N. Stamenov**[1]

[1] *Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, 1784 Sofia, BULGARIA*

Abstract

A new method for selection of extensive air showers /EAS/ initiated by primary gamma-quanta with energies around 10^3 TeV , at mountain altitudes, is proposed. Conclusions are based on Monte Carlo simulated data, obtained by CORSIKA*5.20* code. The method consists in selection of muon poor events among EAS with fixed value of the shower parameter α_e and with limited relative shower size Ne/<Ne>.

1 Introduction:

The existence of gamma-quanta with ultra high energies is an extremely important question, connected with the future development of the UHE gamma-astronomy. Because of the exponential decreasing of cosmic rays energy spectrum, the only way of providing evidence for gamma rays with energies up then 1 TeV is the observation of the effects due to their passing through the atmosphere. Moreover, in the energy region E_0 > 100 TeV the main experimental information is obtained by registration of EAS.

The principal idea for selection of primary gamma-quanta initiated EAS is based on supposition, given by Maze and Zawadski (1960), that they are relatively poor in muons and hadrons, in comparison with EAS initiated by primary protons or other nuclei. Some years ago the Tien Shan team emphasized the selection of showers generated by primary photons as muon- and hadron-poor EAS (Nikolsky, Stamenov & Ushev, 1984, Nikolsky, Stamenov & Ushev, 1987). It was verified that the selection of hadronless EAS offers a real possibility for a full separation of gamma-initiated showers. Applying only the criterion $K\mu \leq 0.11$ to pick out muon poor EAS, the relative content of gamma-originating showers , with fixed size $Ne=4\times10^5$, at observation level X_0 = 700 $g.cm^{-2}$, is about 10% from the selected showers. Our goal was to increase efficiency of gamma-showers selection, based on information only about electron and muon components of the EAS.

2 The method:

A detailed Monte Carlo simulation of EAS is performed using CORSIKA 5.20 code. An extended data bank of simulated events for observation level X_0=700 $g.cm^{-2}$ is created. It contains EAS induced by primary photons, protons and other main groups of cosmic nuclei. Primary energy range 5×10^2 TeV $\leq E_0 \leq 10^4$ TeV is presented. Threshold energies are E_e^{thr} = 1.2 MeV for electrons and E_μ^{thr} = 5 GeV for muons, according Tien Shan array conditions. Zenith angle of shower direction θ is in the interval [0 °, 20°]. Mixed composition of primary nuclei with <A>=14.55 is supposed as: 50% protons, 15% helium nuclei, 15% oxygen nuclei and 20% iron nuclei.

The main shower characteristics are obtained. The electron and muon number fluctuations in EAS with fixed value of the shower parameter $\alpha_e(120)$=const (Procureur & Stamenov, 1995) ,

$\alpha_e(r_0) = r_0^2.\rho_e(r_0)/f_{NKG}(r_1,s_{5-70})$, r_0=120m, r_1=3m , are analysed and a new selection method for gamma-initiated events is developed. In the version *5.20* of CORSIKA code the photoproduction is not included. Therefore, for gamma-showers we evaluated parameters of muon fluctuation distribution, $<N\mu>$, average muon number, as a function of the primary energy E_0, and $\sigma(K\mu)$, fluctuation parameter, is assumed to have the experimentally obtained value $\sigma(K\mu)=0.54$ (Ushev, 1985).

Our method consists in selection of muon-poor events, according to the criterion $N\mu/<N\mu> \leq 0.17$, among EAS with fixed value of the shower parameter α_e (120) and with limited relative shower size value $Ne/<Ne>$. Here Ne and Nμ correspond to the number of electrons and the number of muons in a single shower and $<Ne>$, $<N\mu>$ are the average electron and muon sizes for all showers with the same $\alpha_e(120)$.

The primary energy difference between initiating gamma-quanta and mixed composition of nuclei is about 10% using selection $\alpha_e(120)$=const . For a given energy E_0 primary gamma-quanta generate EAS with larger electron sizes Ne than primary nuclei due to the difference in the shower development. So, the additional selection by $Ne/<Ne>$ in a given interval leads to an essential rejection of the hadronic background. By this way, the new method permits to estimate more precisely the primary gamma-quanta flux.

As an example, we could consider $\alpha_e(120)\in[562,1000]$. It corresponds to primary energy about 1.13×10^3 TeV. Taking into account contemporary experimental array reception conditions, which are usually about $\sigma_{rec}(Ne/<Ne>)=0.15$ for electron size estimation, we determined the additional selection criterion $Ne/<Ne>\in[1.6, 2.6]$. We have in this interval about 98% from gamma-originating events and only 7,5% from the hadronic ones. Then we analysed the interesting part of the muon fluctuation distribution, muon poor showers ($N\mu/<N\mu> \leq 0.17$). The reduction of the hadronic background using the new selection criteria is about 8 times, in comparison with selection Ne=const and $N\mu/<N\mu> \leq 0.11$ (Ushev, 1985).

3 Reanalysis of the experimental Tien Shan data:

We applied this new selection method on experimental Tien Shan data. Because of the lack of electron flux detectors at distance 120m form the array centre we were obliged to define and to use the $\alpha_e(70)$, (r_0=70m, r_1=10m) , shower parameter instead of $\alpha_e(120)$, essentially loosing on the resolving power of the proposed new method. Selecting EAS with α_e (70)=const permits to pick up showers with constant energy (with accuracy about 30%) independently on the initiating particle mass. Figure 1 shows the comparison between simulated and Tien Shan experimental data, presenting the dependence of $\alpha_e(70)$ on shower size Ne.

Taking into account the reception condition $\sigma_{rec}(Ne/<Ne>)=0.28$, obtained by comparison between simulated and experimental data, a procedure for selection by the value of the relative shower size $Ne/<Ne>\in[1.0, 2.2]$ was developed. The recalculated criterion for muon poor showers (in the case of selection with $\alpha_e(70)$=const) is $N\mu/<N\mu> \leq 0.14$. The muon fluctuation distribution $W(K\mu)$ for EAS with $\alpha_e(70)\in[5.62\times10^3,10^4]$, which corresponds to primary energy about 1.5×10^3 TeV, for the Tien Shan experimental data is presented on Figure 2. The analysed interval $\alpha_e(70)\in[5.62\times10^3,10^4]$ contains 1944 events. Applying the new selection criteria $\alpha_e(70)\in[5.62\times10^3,10^4]$, $Ne/<Ne>\in[1.0, 2.2]$ the background in the region $N\mu/<N\mu> \leq 0.14$ is pushed down. From 50 muon poor EAS with fixed $\alpha_e(70)$ after selection $Ne/<Ne>\in[1.0, 2.2]$ remain only 26 showers as candidates for gamma-initiated events.

In the previous works, selecting poor on hadrons EAS, the Tien Shan team estimated the ratio $n_\gamma/n_A=(3.3\pm 1.2)\times10^{-3}$ which was interpreted as a real ratio between primary gamma-quanta and other primary nuclei initiated EAS with $E_0\geq10^3$ TeV. Applying only selection of muon poor showers they obtained the ratio $n_\gamma/n_A=(3.3\pm 1.2)\times10^{-2}$. In the present paper we deduce $n_\gamma/n_A=(1.3\pm 0.25)\times10^{-2}$. We could conclude, that the application of the new selection method permits to estimate more precisely the primary gamma-quanta flux, using information only about electron and muon components of the EAS.

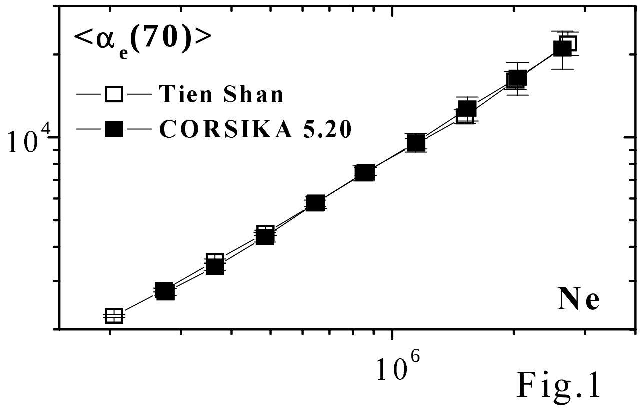

Fig.1

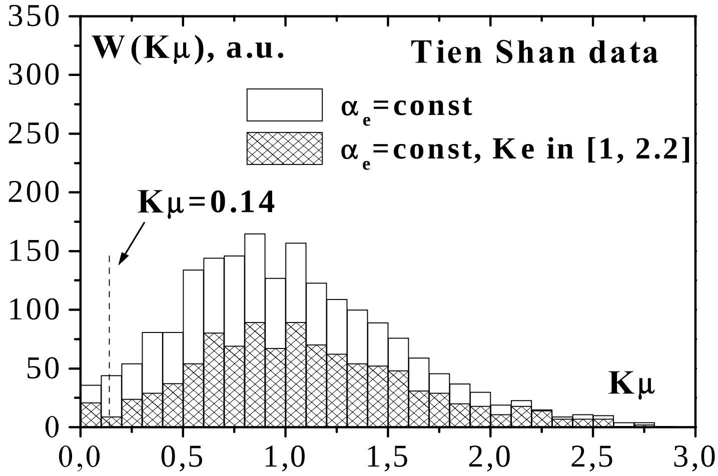

Fig.2

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