Studies of Gamma Radiation Above 10^{14} eV From Hadron-less Air Shower at Chacaltaya

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Abstract

In the present paper we report analyzes with the SYS air shower experiment at Chacaltaya, Bolivia. Showers produced by gamma ray primaries, recorded between July 1990 and September 1996, were analyzed looking for excess above the background from 230 sources. Phase analyzes were also made to 8 binary sources; among them, the source X1822-377 shows a significant excess at 95% confidence level. What is more, we have analyzed showers with energies greater than 10^{16} eV looking for a possible origin of these energetic events.

1. Introduction

From the report of the detection of radiation gamma of the source Cygnus X-3, made by Samorski and Stamm in 1983 [1], many experiments dedicated to the cosmic ray studies changed its original mind, looking for gamma radiation of different sources. Those reports are characterized to select the events by the muon content: gamma ray initiated air shower makes electromagnetic cascade shower with a few muon content caused by photo-production muon.
However, at the energy region less than 10^{14} eV, muon discrimination for gamma-ray initiated showers is not so effective since its wider geometrical spread in the shower and a scanty of muon number. In contrast, the hadronic component

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concentrates in small areas near the core with steep lateral distribution, and, according to simulation results, a few number of hadrons is expected in gamma ray showers [2]. Because the hadron still is the energetic component in air shower, especially at the mountain level, the number of hadrons also correlates with the air shower development. Besides that, there is a close correlation between air shower age and the number of hadrons, so, age parameter can also be taken into account for an effective rejection of proton-nucleus initiated air showers. Fig. 1 shows the distribution of the age of selected showers, which is completely different from one originated by primary proton showers.

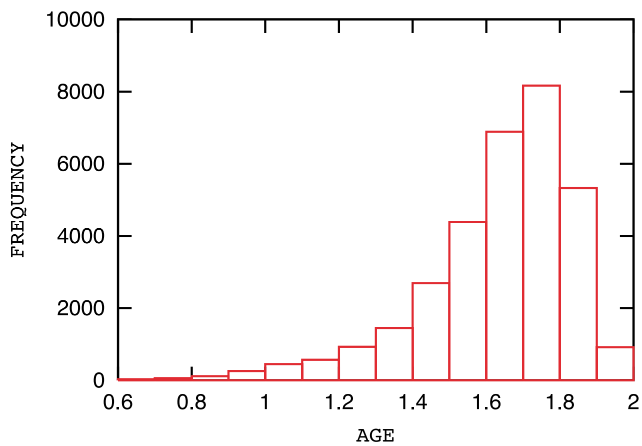

Fig. 1. The age s distribution of showers.

In 1988, the SYS group reported the observation of a burst-like emission from the binary source Sco X-1, on May 1986 [3], analyzing hadron-less showers. In the present article, we report analyzes made to gamma-ray air showers recorded between July 1990 and August 1996.

2. Methods

The SYS air shower array has been observing hadron-less sir showers from the beginning of 1986 in order to detect UHE gamma-rays with energies greater than 6×10^{14} eV, at Mt. Chacaltaya ($S16°21'$, $W68°08'$). The SYS air shower array consists of 45 plastic scintillators, which are distributed over a circular area of 50 m radius; the arrival direction of showers is determined with 13 fast timing detectors. For showers within zenith angle $\theta < 45°$, the accuracy of arrival direction has been estimated to be $\pm 3.5°$ and $\pm 2.2°$, for energies around 2×10^{14} eV and 4×10^{15} eV, respectively. Hadrons are detected with an $8m^2$ hadron detector, which consists of 32 units of plastic scintillator detectors ($50\ cm\ \times\ 50\ cm\ \times\ 5\ cm$ each), located under 15 cm thick of lead absorber. (See Ref. [4] for details.)

In order to detect gamma-ray initiated air showers we look for an excess of cosmic rays which are "hadron-less" with respect to the number of hadrons expected from hadron initiated showers. So, the selection of showers has been done for all showers with zero number of hadrons (i.e. no one out of 32 B detectors detected any particle, even the air shower core hit the central part of the hadron detector). We selected 157200 events, for 3.3 years running, under the following selection conditions:

No. of hadrons: $> NH = 0$
Size: $> Ne \geq 10^{3.0}$
Zenith angle: $> \theta \leq 45°$
Age: $> s \geq 0.6$
Shower core: $> -3m \leq X, Y \leq 3m$

3. Results

For the present analysis, all the showers within the declination band from $-50°$ to $+20°$ have been analyzed. The first analysis was made to around 235 sources located at the southern sky, including ones from Third EGRET Source Catalog [5]. Each source was located in the centre of a circular window with the following condition: $\alpha^2 + \delta^2 \leq 3^2$. Events collected inside such window are compared with the expected background estimated from events collected in 10 windows of similar dimensions, located at both sides of the source window and at same declination strip. In order to avoid biases, adjacent windows, to the source, have not been considered. The excess in each bin, above the expected background is determined with the statistics of Li and Ma [6]. No source shows any significant excess above the expected background.

Phase analysis were also done, using orbital periods for 8 X-ray binary sources. Only showers which arrived from within a window of $\alpha^2 + \delta^2 \leq 3^2$, centered on the source were selected. The Kolmogorov test [7], and Protheroe test [8], for analyzing circular data have been used for the analyzes. Figure 2 shows the frequency distribution as function of the period, for the binary source X1822-377. The excess at phase bins 0.7 to 0.9. is significant at 95% confidence level for both statistical tests, mentioned before.

Finally, we selected showers with Ne greater than 6.6×10^{16} eV and core locations inside of hadron detector, selecting 33 showers. There is no a definite answer for the origin of such energetic events, because it seems that those events are from random origin, even compared with EGRET sources.

4. Discussion

From the analyzes made to hadron-less air showers we can conclude that no source out of 230 shows any significant excess above the background. From phase analyzes for 8 sources made to 8 binary sources, X1700-377 show a significant

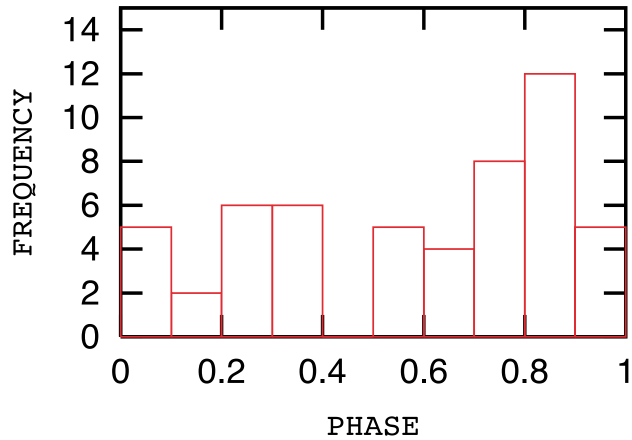

Fig. 2. Phase distribution for X1822-377.

excess at 95% C.L. However, i t is necessary to make further analyzes to confirm this result. We could not find any particular region for the origin of 33 energetic events. Some of them coincides with one of EGRET catalog source. However such coincidence does not guarantee that is only of stochastic nature.

5. Conclusions

The hadronic component is one of the important observable parameters in air showers, especially for the observation at mountain altitude. For an improvement of this kind of studies, for greater or smaller shower energies it is necessary larger area hadron detectors.

6. References

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