First Operation of SGARFACE, a ground based experiment to search for γ-ray bursts of energies larger than 200MeV with durations of less than 100μs

Stephan LeBohec[1], Frank Krennrich[1] , Roy McKay[1] and Gary Sleege[1]
(1) Department of Physics and Astronomy, Iowa State University Ames, IA, 50011-3160, USA

Abstract

The Short GAmma Ray Front Air Čerenkov Experiment (SGARFACE) provides sensitivity to γ-ray bursts of energies larger than $\sim$ 200MeV with durations of less than 100μs. SGARFACE is operated since March 2003.

1. Introduction

Atmospheric Čerenkov imaging telescopes can be made sensitive to γ-ray bursts with durations of less than $\sim 100\mu s$, a range of time scales mostly unexplored [2]. A sensitivity as low as 0.1 γ-ray m^{-2} can be achieved through this technique which therefore is complementary to the next generation space-based detectors. When a large number of γ-rays (with energies larger than the atmospheric critical energy for ionisation loss) impacts the top of the atmosphere, the resulting small showers produce faint Čerenkov flashes which accumulate in a glow detectable from the ground. This idea goes back to Porter and Weekes [6] and has been realized in the Short GAmma Ray Front Air Čerenkov Experiment (SGARFACE) by combining imaging capability and pulse shape recording. In this paper, we describe the experiment and how it is operated.

2. The experiment

The experiment was previously described in detail [5,3]. It is implemented in the Whipple 10m Very High Energy Gamma Ray Telescope [1] as a piggy back experiment. Signals from the 389 photo-multipliers of the focal plane detector are duplicated before they reach the electronics system used for TeV γ-ray observations. Since the glow produced by a γ-ray burst is quite extended (1^o), it is possible to sacrifice the high angular resolution provided by the Whipple 10m telescope camera ($\sim 0.13^o$) to cost effectiveness. The photo-multipliers are subdivided in 55 clusters of seven for which the analog signal sum is formed, providing an effective angular resolution of $\sim 0.4^o$. The resulting signals are sent to a VME based γ-ray burst search dedicated electronics system. The signals are first

---

pp. 2971–2974

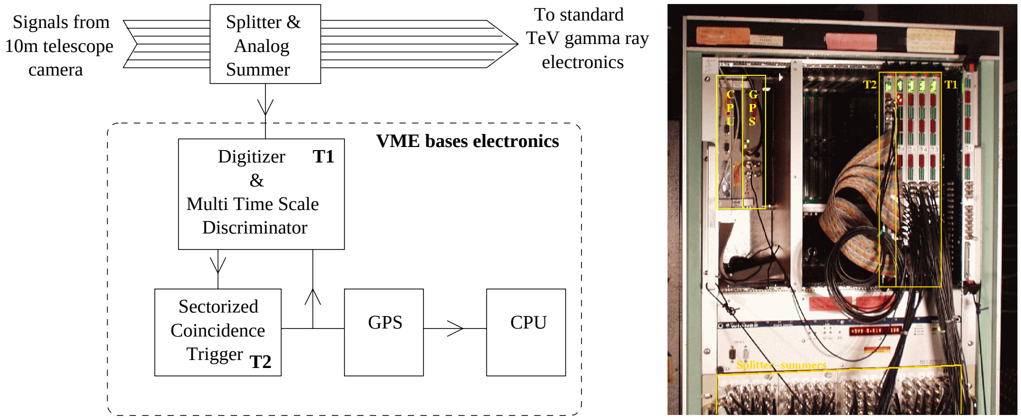

Fig. 1. Photomultiplier signals are received by the splitter-summers in NIM crates, to be directed to the VME based multi-time-scale discriminator (T1). The coincidence unit (T2) responds to high multiplicity coincidence by stopping the T1 units and notifying the VME control through a GPS module.

digitized at a 50MHz rate in the multi-time-scale discriminator units [4] which are also programmed to fire a logical level whenever the pulse integrated over one of the 6 active time scales (60ns, 180ns, 540ns, 1620ns, 4860ns and 14580ns) exceeds some predefined threshold. The discriminator signals are collected by a coincidence unit which is made sensitive to clusters of neighboring pixels in order to further reduce accidentals. When a trigger occurs, the digitized pulses stored in the discriminators memory are frozen and the VME controller is notified that some fresh data has to be read before restarting the system. Each event consists of $\sim$ 100kb of VME data. The reading and storing of an event takes approximately 300ms.

3. Data taking

The coincidence unit is programmed to be sensitive to any close packed group of 3 channels covering a region $\sim 0.8^o$ across to match the expected burst image size [2]. In order to determine the optimal threshold for the different time scales, we measured the trigger rates obtained for each time scale as a function of the threshold. When we increase the threshold, the rate decreases very fast at first and slower for larger values of the threshold after a relatively sharp break in the slope (figure 2). For small threshold values, triggering predominantly results from noise fluctuations. When we increase the threshold beyond the slope transition, cosmic rays are becoming the main cause of triggering. In this regime the rate can well be described by a power law as a function of the threshold. Cosmic rays are producing Čerenkov pulses which are extremely brief (less than 30ns) and our longest time scales should not have any sensitivity to them. The sensitivity

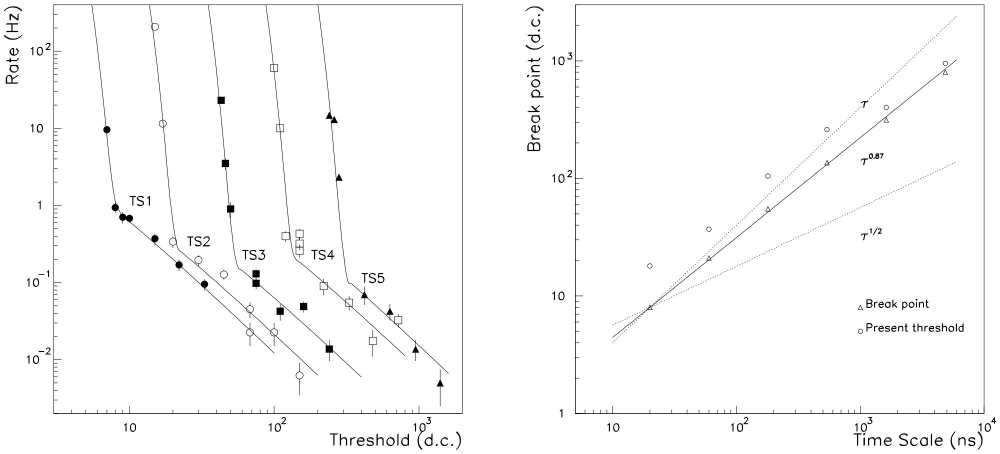

Fig. 2. The trigger rate is shown on the left as a function of the threshold for each time scale. The breakpoint position is shown as a function of the time scale on the right. The solid line is a power law fit to the data while the dotted lines are power laws in indices 1 and 1/2 respectively.

to cosmic rays we observe, results from an electronics artifact associated with the TeV astronomy electronics. Extra events recorded because of this are easily rejected at the analysis level. For each time scale we measured the breakpoint position to be our threshold. These values were increased by 30% to get away from the noise dominated region which may show some instabilities. The resulting thresholds settings were used for data taking. The breakpoints and the presently used thresholds are shown to the right in figure 2. The optimal threshold value does not scale with the square root of the time scale as one would expect from purely Poisson noise fluctuations and we are investigating this.

However, the sensitivity is excellent. A threshold of 20 digital (one digital count corresponds to $\sim$ 2 photoelectrons) counts as for the second time scale (180ns) approximately corresponds to 0.1 γ-rays m^{-2} at a 1GeV energy while a threshold of 900 digital counts as for the longest time scale (15μs) corresponds to 4 γ-rays m^{-2}. Under these conditions, the event rate is 0.3Hz on average corresponding to a $\sim$ 10% dead time. A full 8 hours night of observations produces $\sim$ 800Mb of data.

4. Data analysis

The data analysis is in progress. The first task is to efficiently reject all events which are presenting a fast pulse, signature of the Čerenkov flash from an individual shower. In figure 3, a typical pulse from an individual shower is compared to an artificial pulse we generated with a LED flasher located at the center of the 10m telescope dish. The time profile discrimination will be

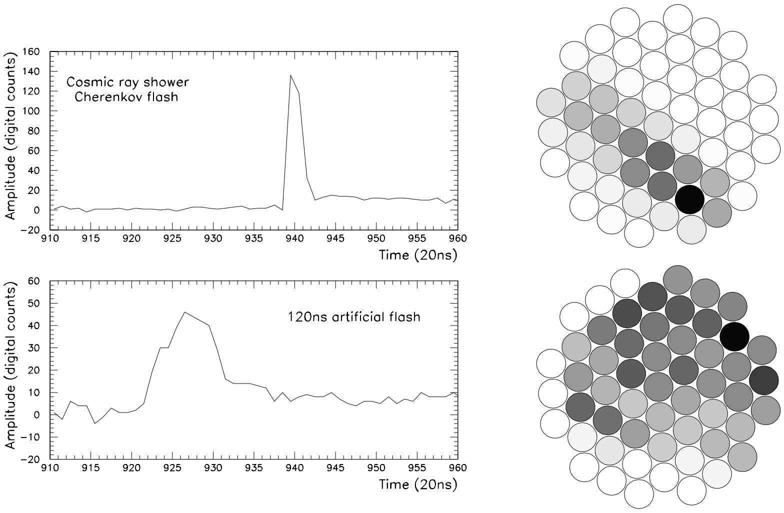

Fig. 3. The pulse profile at the top results from the shower shown on the right. The pulse profile at the bottom resuls from an artificial 120ns flash.

done using standard wavelet analysis. Further discrimination can be obtained by requiring the pulses in all channels to be identical and simultaneous. Finally, the image has to be roundish, slightly elongated in the direction perpendicular to the Earth magnetic field.

5. Conclusion

The SGARFACE experiment is now in the data taking phase. The analysis is being developed and we will present the first results at the 28^{th} ICRC.

6. Acknowledgments

This research is supported by the U.S. Department of Energy Office of High Energy Physics and Iowa State University.

7. References

1. Cawley, M.F., et al., 1990, Exp. Astron., 1, 173
2. Krennrich, F., et al., 2000, ApJ, 529,506
3. LeBohec, S. et al., 2001a, Proc. of the 27th ICRC, OG 2.05,263
4. LeBohec, S. et al., 2001b, Proc. of the 27th ICRC, OG 2.04,216
5. LeBohec, S. et al., 2002, Proc. of The Universe Viewed in Gamma-Rays, in press.
6. Porter, N. A., & Weekes, T. C. 1978, MNRAS, 183, 205