Current status of the scalers: Towards the detection of GRBs with Auger?

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Abstract

The detection of a high energy tail of photons from GRB should be possible with the single particle counting technique. A group of detectors would detect a higher rate of events on a short time scale, of the order of the second. Scalers were implemented on the whole array on 30th March 2005. This note reports the first analysis of this data, and describes ways to improve it significantly.

1 Introduction

Since their discovery at the end of the 60's[1], the Gamma Ray Bursts (GRB) have been of high interest to astrophysics. A GRB is characterized by a sudden emission of gamma rays during a very short period of time (between 0.1 and 100 seconds). The luminosity reached during this flare is typically between 10^{51} and 10^{55} ergs, should the emission be isotropic. The astrophysical source of these bursts is still not clear but candidates could be coalescence of compact objects (neutron stars), and mechanisms based on internal shocks of relativistic winds in compact sources give good agreement between theory and observations.

A first large data set of GRB was provided by the BATSE instrument on board the Compton Gamma Rays Observatory (1991-2000). More GRB were then detected by BEPPO-SAX (1997-2002). Current GRBs are registered by HETE, INTEGRAL and Swift. In the last 5 years, afterglows were observed allowing a

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much better understanding of the GRB phenomena. Most observations have however been done below a few GeV of energy, and the presence of a high energy (above 10 GeV) component in the GRB spectrum is still a mystery.

GLAST will be the next generation of GRB satellite experiment and should be launched in May 2007. Its sensibility should allow to get individual GRB spectra up to 300 GeV. In the meantime, the only way to get to the high energy emission of GRB is to work at ground level.

A classical method to use is called “single particle technique”. When high energy photons from a GRB reach the atmosphere, they produce a cosmic ray cascade that can be detected. The energies are still quite low to produce a shower detectable at ground level (even at high altitudes). However, we expect a lot of these photons to arrive during the burst, in a short period of time (typically, one second). Some of them could produce a shower which would give a few hits in a ground based detector, on a time scale of one second. One would therefore see an increase of the background rate on all the detectors on this time scale. This technique has already been applied in INCA[2] in Bolivia and ARGO[3] in Tibet. A general study of this technique can be found in [4]. Up to now, it has only been applied to arrays of scintillators. We have already presented the advantages of using a Water Cherenkov Detector [5]. Its main advantage is its sensitivity to photons, which represent 90% of the particles at ground level for high energy photon initiated showers.

2 The Scalers

On 30th March 2005, a first version of the “scalers” were implemented in the local station (LS) code. The “scalers” are simple counters that can be set like any other trigger. They are read every second and sent to the Central Data Acquisition System (CDAS). At CDAS, they are stored in specific files and, once per day, a scaler file is built. This file is available as:
`/Raid/monit/Sd/YYYY/MM/scaler_YYYY_MM_DD_00h00.dat.bz2`
with `YYYY`, `MM` and `DD` the year, month and day of the data. It is a `bzipped` file, which can be uncompressed with `bunzip2`. The resulting file is in `ASCII` format, with one line per second. The first field is the GPS second, the second one the total number of counts for that second, the third field is the total number of tanks sending data, and the field number *i* is the number of counts of tank Id *i*.

2.1 Current settings

The current setting for the scalers is 1-fold (1 PMT), 3 ADC counts (ie triggering whenever a signal is 4 counts above the baseline or more). The average rate over the array is of about 3.6 kHz per detector.

2.2 Limitations

In the current implementation, there is a very serious limitation. The scalers count the number of times the threshold is passed, and once per second they are read and reset. This operation of reading and resetting happens when the first T1 of a second occurs. This means that the time during which the scalers have been counting is of about a second, but is not constant. With a rate of T1 of about 100 Hz, the period of counting will fluctuate for each detector by about 1%.

Another limitation is that the process has a low priority, and every minute (more exactly, 61 seconds) the LS has something more important to do (during the calibration, which is done whenever a second counter is > 60, ie every 61 seconds). This means that after one minute, the LS will do a few things before reading the scaler, producing this way a very long "second". Next "second" will on the contrary be very short. This clearly appears on the counting rates as a positive spike followed by a negative one. Figure 1 shows the phenomena.

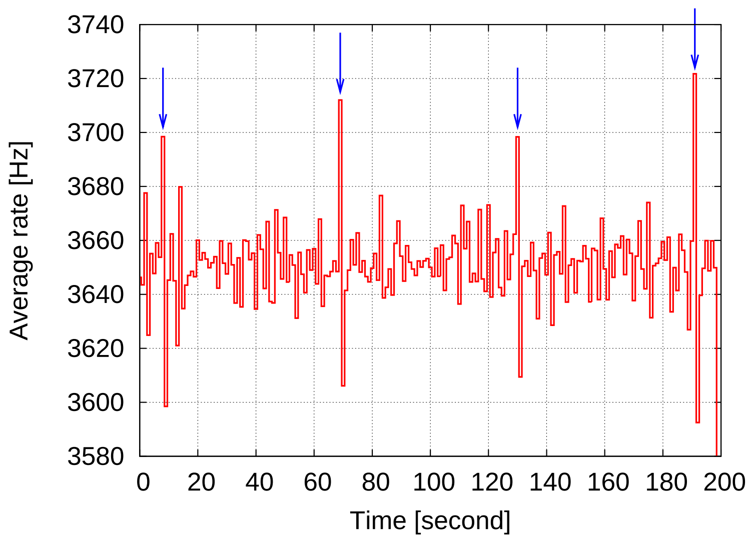

Figure 1: A few seconds of scalers: average counting rate over the array as a function of time. Every 61 seconds, a peak followed by a dip can clearly be seen. This is the effect of the low priority of the scaler process with respect of the calibration one.

3 Data analysis

The idea is to go through the scaler files and determine the deviation from the mean for each second, looking at important deviations. As the counting rate in itself is not well defined, the fluctuations will be bigger than expected, and one cannot use the square root of the rate as an estimation of the variations in order to compute deviations in terms of sigmas. In the period studied, the number of tanks did not increase that much (from 600 to 750), and a global study will be done using percent of fluctuations instead of sigmas.

The average rate expected is determined by a $\sigma - \delta$ method, with $\sigma = 5$ counts and $\delta = 0.1$ counts: every second, the counting rate is computed over the whole array and compared to the current average. The average is adjusted by $\pm\delta$ if the counting rate for that second is at more than $\pm\sigma$ from the average. Some specific data cuts are applied to keep only stable periods of time:

1. Only LS with between 1000 and 10000 counts are taken into account
2. A second is processed only if the array was considered stable for the previous 30 seconds, and is stable for 30 seconds afterward
3. If less than 400 stations are sending scaler data, the array is considered unstable
4. If the total number of stations sending scaler data changes in one second by more than 1%, the array is considered unstable
5. If in the last 50 seconds, the $\sigma - \delta$ method made a change of more than 2.9 in any direction, the array is considered unstable

In addition, if at a specific moment there is an excess of more than 1% in the counting rate (from the counting rate distribution the probability of such an event is 5×10^{-5}), one checks the next second. If the next second has a deficit of more than 1% in the counting rate, both seconds are ignored as it is the symptoms of the second limitation seen previously. The probability of losing a GRB due to this cut is also 5×10^{-5}, clearly negligible. In some cases, the 1% limit is not enough to detect this effect. Whenever an excess (deficit) of more than 1% happens and is not followed (preceded) by a similar deficit (excess), the time of occurrence is compared to the previous excess (deficit). If it is exactly 61 seconds, then the data is ignored. Note that this methods works only because the whole array is synchronized (ie the array had been turned on by a broadcast *Start T2*), and most of the tanks operate their calibration at the same time. A finer analysis would look at each individual LS to find out at which moment it is calibrating and remove the data from this LS only. However, the significance is too low with respect to the fluctuation for this effect to be seen on individual stations. One therefore has to work with the complete array.

4 Results

Applying the cuts defined previously, 92.8% of the period from the 30th of March 2005 to the 8th of July 2005 could be used safely. We know that 2 seconds every 61 are thrown away due to the calibration process (losing 3.3% of the data set). The other quality cuts on the stability of the array therefore removed 3.9% of the data set.

Figure 2 shows the resulting counting excesses in percent for the whole period of time (7.4×10^6 seconds of data). A somewhat Gaussian histogram is obtained, with some larger Gaussian tails. As the data fluctuations are not easy to understand, depending on how many stations have their calibration synchronized in time, we did not try to model this histogram.

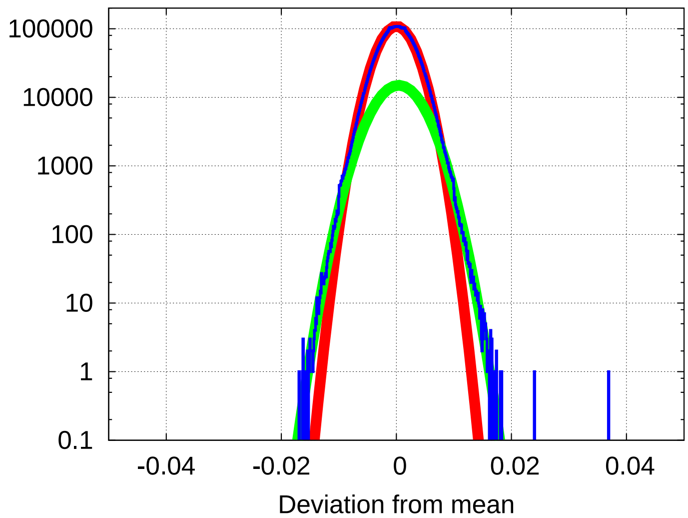

Figure 2: Histogram of the deviations of the scaler counting rate with the expected average counting rate, in blue, with underlying 2 Gaussian fits of different region of the data.

Given the width of the histogram, we decided to call burst whatever is above 2% of fluctuations. This is a very high threshold, as it means the array has seen an average excess of 75 particles per tank. This seems however the safest threshold we can use given the current quality of the data. We got in the period 2 bursts, at GPS seconds 799216018 and 799217846 (with 3.7 and 2.4% excess). Note that no “anti-burst” with deficit below 2% was recorded.

The 2 bursts were recorded on GPS seconds 799216018 and 799217846, on the 4th of May 2005, between 4h and 5h AM. They both only impact a small portion of the array, as can been seen on figure 3. The origin of these bursts is clearly not a GRB, which should affect the whole array. Looking at SD files, one can see the events 1332968 and 1332969 where a huge fraction of the array was hit by a typical “lightning” event, at second 799216018, and events 1333021 and 1333022 for second 799217846. These scaler bursts are clearly produced by lightning, and counting undershoots might be a way to get rid of them in the future, as lightning events are characterized by numerous baseline crossings.

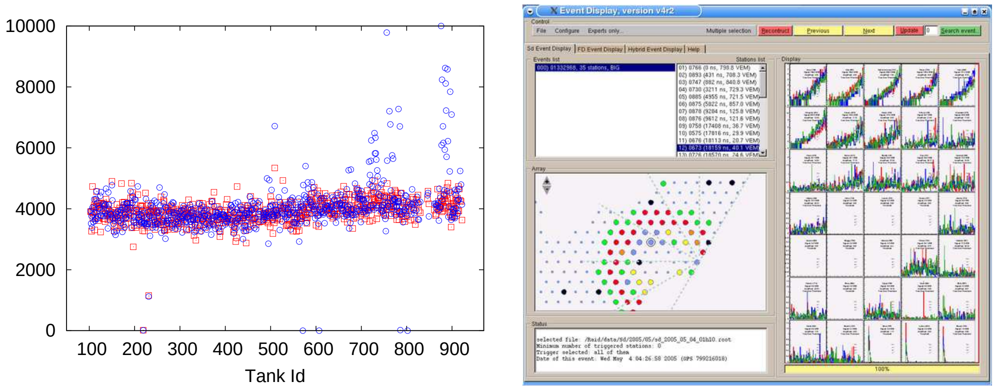

Figure 3: Burst of GPS second 799216018, with a 3.7% excess in counting rate. Left: in blue circles, the rate for all the tanks for second 799216018, compared to the rate 5 seconds earlier, in red squares. The excess happens only on a limited subset of the array. Right: view of the Event Display for event 1332968, happening at the same time.

5 Conclusions and Perspectives

A simple analysis method has been implemented to use the scaler data in the search of bursts. The current data quality limits severely the detection threshold and there is little hope to see events producing less than tens of particles per tank without change in the data acquisition of the LS.

There are a few necessary changes that will increase drastically the detection threshold (at 5 σ, with 700 LS and 3.6 kHz of average counting rate, one should get a detection threshold of about 10 particles per tank, 7 times lower than the current one).

1. prioritize the scaler process with respect to the calibration. A version of the LS software with such a modification was available when the previous

software was installed on the whole array end of March, but was not tested enough to be installed. It should be tested again and installed on the whole array.

2. implement a lightning detector in the LS software, which would count undershoots. Even if this is currently not a priority, we might get a lot of lightning bursts in the summer months of January and February.

3. use a second scaler, counting events above a higher threshold, for example 20 ADC counts above the baseline. This second scaler would be very insensitive to the GRB photons shower secondaries, while it would still be very efficient to trigger on muons. By doing the difference of both scalers, one would get only small events, getting rid of a large fraction of the noise.

Point 3 stresses even more the advantage of Water Cherenkov Detectors over scintillators. Not only is a WCD sensitive to photons, which represent 90% of the shower particles, and therefore has a signal close to 10 times stronger than a scintillator, but a WCD can also discriminate muons from isolated electromagnetic particles by their signal intensity, and therefore strongly reduce the noise.

Until these changes (at least point 1) are implemented, there is little hope to see a GRB with Auger, as a powerful closeby GRB would probably manifest itself as an increase of the background rate of about 10 particles per tank.

The method described in this note is running automatically in Lyon on any new scaler data found and the results are available on the web site of the Bariloche Auger newspaper, El Auger Cordillerano [6].

References

[1] Kleidesabel et. al, 1973, ApJ 182, 85

[2] Cabrera et. al, 1999, A&AS 138, 599

[3] Bacci et. al, 1999, A&AS 138, 597

[4] Verneto, 2000, APh 13, 75

[5] Allard et. al, ICRC 2005

[6] http://cabtep8.cnea.gov.ar/cordillerano/