Available online at www.sciencedirect.com
ScienceDirect
Nuclear Instruments and Methods in Physics Research A 588 (2008) 17–21
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A
www.elsevier.com/locate/nima

Search of GRB with AGILE Minicalorimeter

F. Fuschino[a,*], C. Labanti[a], M. Galli[b], M. Marisaldi[a], A. Bulgarelli[a], F. Gianotti[a], M. Trifoglio[a], A. Argan[c], E. Del Monte[c], I. Donnarumma[c], M. Feroci[c], F. Lazzarotto[c], L. Pacciani[c], M. Tavani[c], A. Trois[c]

[a] *INAF-IASF Bologna, Via P. Gobetti 101, 40129 Bologna, Italy*
[b] *ENEA, Via Don Fiammelli 2, 40129 Bologna, Italy*
[c] *INAF-IASF Roma, Via del Fosso del Cavaliere 100, 00133 Roma, Italy*

Abstract

AGILE, the small scientific mission of the Italian Space Agency devoted to Hard-X and Gamma-ray astrophysics, was successfully launched on April 23, 2007. The AGILE payload is composed of a tungsten-silicon tracker (ST), operating in the gamma-ray energy range 30 MeV–50 GeV; Super-AGILE, an X-ray imager operating in the energy range 15–45 keV; the Minicalorimeter (MCAL) and an Anticoincidence shield. MCAL is a detector of about 1400 cm^2 sensitive in the range 0.3–200 MeV, that can be used both as a slave of the ST to contribute to the AGILE Gamma Ray imaging Detector (GRID operative mode) and autonomously for detection of transient events (BURST operative mode). MCAL is made of 30 CsI(Tl) bar-shaped scintillation detectors with photodiode readout at both ends, arranged in two orthogonal layers. Energy and position of interaction can be derived from a proper composition of the signals readout at the bar's ends, absolute time tagging can be achieved with a μs resolution. The Burst logic deals with various rate-meters on different time scales, energy bands, and MCAL spatial zones. Different algorithms can be chosen for Burst triggering considering also the contribution of other detectors like Super AGILE. In this paper the various trigger logic will be reviewed as well as their on-ground test performed with a dedicated experimental setup.

PACS: 95.55.Ka

Keywords: Gamma ray burst; Gamma ray detector

1. AGILE overview

The space program Astro-rivelatore Gamma ad Immagini LEggero (AGILE) [1] is a high-energy astrophysics mission of the Italian Space Agency (ASI) with scientific and programmatic participation by INAF, INFN, several Italian universities and industrial partners like Carlo Gavazzi Space, Alcatel-Alenia-Space-Laben, Oerlikon-Contraves, and Telespazio. The main scientific goal of the AGILE program is to provide a powerful and cost-effective mission with excellent imaging capability simultaneously in the 30 MeV–50 GeV and 15–45 keV energy ranges with a very large field of view. AGILE was successfully launched on 23 April 2007, with the Indian rocket PSLV, and now (September 2007) is concluding its Commissioning and Scientific validation phases. The AGILE instrument design is innovative and based on the state-of-the-art technology of solid state silicon detectors and associated electronics developed in Italian laboratories. The instrument is very compact and light with total mass of 350 kg (with only 120 kg of scientific payload). The large FOV ($\sim\frac{1}{5}$ of the whole sky) permits simultaneous observation of several objects. Furthermore, the fast AGILE electronic readout and data processing (resulting in detectors' dead-times smaller than ~200 μs) allows for the first time a systematic search for sub-millisecond gamma-ray/hard X-ray transients.

---

[*] Corresponding author.
E-mail address: fuschino@iasfbo.inaf.it (F. Fuschino).

0168-9002/$ - see front matter © 2008 Elsevier B.V. All rights reserved.
doi:10.1016/j.nima.2008.01.004

Fig. 1. Schematic view of AGILE Scientific Payload. SA is placed on the top of the payload, 12 trays of ST are placed in the middle and the MCAL is placed on the bottom of the payload, with detection planes facing ST and electric broad facing satellite shell.

Table 1
Schematic MCAL detector scientific performance

Minicalorimeter (MCAL)	
Energy range	0.3–50 MeV
Electronic noise	~1000 e^- rms
Energy resolution	13% FWHM at 1.3 MeV
Power consummation	4.5 W
Absolute time resolution	~2 μs
Deadtime (for single detectors)	~20 μs

1.1. *Scientific instruments*

The AGILE scientific payload is made of three detectors combined into one integrated instrument with broadband detection and imaging capabilities (see Fig. 1). The Anticoincidence and Data Handling systems complete the instrument. The Gamma-Ray Imaging Detector (GRID) is sensitive in the energy range ~30 MeV–50 GeV and consists of a Silicon–Tungsten Tracker, a scintillator CsI(Tl) Calorimeter, and the Anticoincidence system. The hard X-ray imager (Super-AGILE) [2] is a peculiar design of AGILE payload. This light coded mask imager is placed on top of the GRID detector and is sensitive in the 15–45 keV band. The main characteristic of AGILE will then be the possibility of simultaneous gamma-ray and hard X-ray source detection with arcminute positioning and on-board GRB/transient source alert capability using the ORBCOMM telecommunication satellites. The Mini-calorimeter (MCAL) is a part of the GRID instruments, but is also capable of independently detecting GRBs and other transients in the 300 keV–50 MeV energy range with optimal timing performance but without imaging capabilities. Table 1 shows a schematic description of MCAL characteristics.

2. MCAL description

The active core of AGILE MCAL [3] is composed of a detection plane made of 30 CsI(Tl) scintillator detectors with the shape of a bar each one 15 × 23 × 375 mm in size, arranged in two orthogonal layers, for a total thickness of 1.5 radiation lengths. In a bar the readout of the scintillation light is accomplished by two custom PIN Photodiodes (PDs) coupled one at each small side of the bar. For each bar the PDs signals are collected by means of low noise charge preamplifier, and then conditioned in the Front End Electronics (FEE). The circuits have been optimised for best noise performance, fast response, combined with low power consumption and a wide dynamic range. The MCAL bar surfaces are polished and wrapped to exhibit an exponential light attenuation law. Event's position and energy, for each bar, are calculated with proper combination of both PD signals. The accuracy of these evaluations depend on the signal amplitude, and on both the statistical and the electronic noise. MCAL works in two possible operative modes:

- In GRID mode a trigger issued by the ST starts the collection of all the detector signals in order to determine the energy and position of particles converted in the Tracker and interacting on MCAL.
- In BURST mode each bar behaves as an independent self-triggering detector and generates continuously the stream of information of gamma events in the energy range 300 keV–50 MeV. In the data handling system these data are used to detect impulsive variation of count rates.

Both operative modes can be active at the same time. MCAL setting and operations are managed by the logic of Telecommands implementation while Housekeeping preparation and transmission to PDHU allow monitoring of the health of the system. MCAL FEE has the task to produce simultaneous data stream for both GRID and BURST operation mode by PDs signals. For BURST operations the amplified signals from the two PDs of a bar detector are summed and fed a programmable threshold discriminator. An event will be completely described adding to the two PD amplitude, the address of the bar and a time mark. The data produced in this way are stored in a derandomizing FIFO and then sent to the PDHU where they are continuously processed for detection of fast transients and for scientific ratemeters (RMs) generation. MCAL FEE includes also ancillary function for its setting and monitoring as Housekeeping data generation; this data includes voltages, temperature monitoring and many ratemeters to keep track of the trigger rate of the various discriminators. Due to telemetry limitations BURST data are not sent on ground on a photon-by-photon basis unless a trigger for a transient is issued. However BURST data are continuously used to build a broad band energy spectrum (Scientific RMs) arranged onboard with a time resolution of 1 s. Scientific RMs are expected to provide significant information on the high energy (HE) gamma-ray background in space and its modulation through orbital phases. RMs are arranged in 11 bands for each of the two MCAL detection planes: 170–350 keV; 350–700 keV; 700–1400 keV and so on.

3. Burst search logic

In the PDHU a dedicated strategy is set up to detect impulsive events based on the assumption that bursts are phenomena producing count rates above a threshold determined by the current background value. Since the burst signal is strongly energy and timescale dependant and different results for the different RMs are expected, the crucial first task of the Burst Search (BS) software algorithm is the formation of several background RMs. These are evaluated integrating events on different time windows called Search Integration Times (SITs). RMs can be handled by Hardware (Sub-millisecond, 1 and 16 ms) or by Software (64, 256, 1024 and 8192 ms). The RMs are generated depending on the detector, the events energy and position of interaction:

- Nine RMs for MCAL detector covering three ranges of energy respectively, from 0.3 to about 1.4 MeV (Low Energy, LE), from 1.4 to about 3 MeV (Medium Energy, ME), and above 3 MeV (HE); the limits of the ranges are fully programmable. Events in the first two energy ranges contribute to generate different RMs depending on the place of interaction on MCAL; in this case MCAL is divided into four zones. The HE events contribute to a single RM.
- Eight RMs are generated with Super-AGILE data following a criteria similar to that used for MCAL.

The SA and the MCAL BS can be enabled separately at the SW level. The SA BS inhibition involves the contribution of the SA RMs to the Burst-START and the Burst-STOP generation. MCAL can alert transient events, practically on the whole sky, but without any position information; while SA in his FOV can determine the position, with some arcmin resolution, and communicate on ground these data via ORBCOMM system. A description of the SA BS logic can be found in Ref. [4]. The Trigger Logic shall be based on two alternative strategies to identify the Burst-START:

- Adaptive Trigger Logic: determining for every periodic time the current background B for each of the MCAL and SA RMs, and checking whether the condition
  $$R > B + N\sigma \tag{1}$$
  is satisfied, with N indicating the number of standard deviations $\sigma = \sqrt{B}$ above the background.
- Static Trigger Logic: determining for every periodic whether the current values of the R are larger than a pre-assigned threshold values S summed to background contribution B if required by programmed logic, i.e., testing the condition
  $$R > \alpha B + S, \tag{2}$$
  where α shall be set, for each RM, to 0 or 1 as determined by configuration.

These conditions are checked at periodic times depending on the SIT duration. The background values to which the RMs are compared are derived, for every SIT, from the counts measured during a Background Estimation Time (BET) that can range between 8 and ~250 s and can be delayed with respect to the current SIT time. Each second the BET value is stored in a dedicated buffer and this value is normalised to every SIT duration. When a Burst-START occurs MCAL data are stored in cyclic buffer. The RMs triggering configuration generate a valid Burst-START only if they pass validation criteria defined in a Look Up Table (LUT) stored in the PDHU and related to single or simultaneous trigger on several energy bands and timescales.

After a valid Burst-START the BS check for Burst-STOP condition which is logically similar to START condition, verifying that all RMs value, reach the normal background level. If the STOP is not generated after a programmable interval or at the saturation of data buffer the data acquisition is forced to STOP; in this case a new background estimation is done. The burst data stored in the cyclic buffer are sent in telemetry together with some pre-burst and post-burst events. Burst data informations are completed with other RMs from other subsystems (AC and ST). The whole Burst trigger logic is very flexible and fully programmable.

4. BS experimental test

The BS software algorithm was preliminarily tested on the PDHU functional model. Then MCAL Burst branch was experimentally tested in fully integrated payload. A dedicated setup was built to generate transient events using a radioactive source. The basic principle is to make a radioactive source to rise and fall in front of a properly shaped lead collimator by means of a stepper motor. Changing the motor velocity allows one to generate Burst with duration between 32 ms and about 2 s. A set of Monte

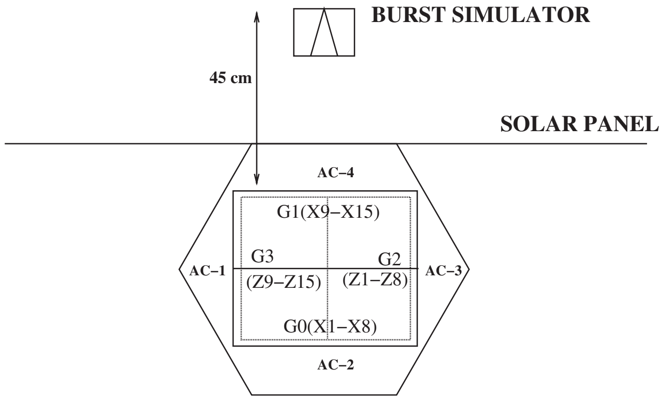

Fig. 2. Schematic experimental setup. The radioactive source and the collimator are positioned in front of the solar panels at the MCAL level. MCAL spatial segmentation is also shown. Solid line: top (X) plane, divided into zones G0 and G1. Dotted line: bottom (Z) plane, divided into zones G2 and G3.

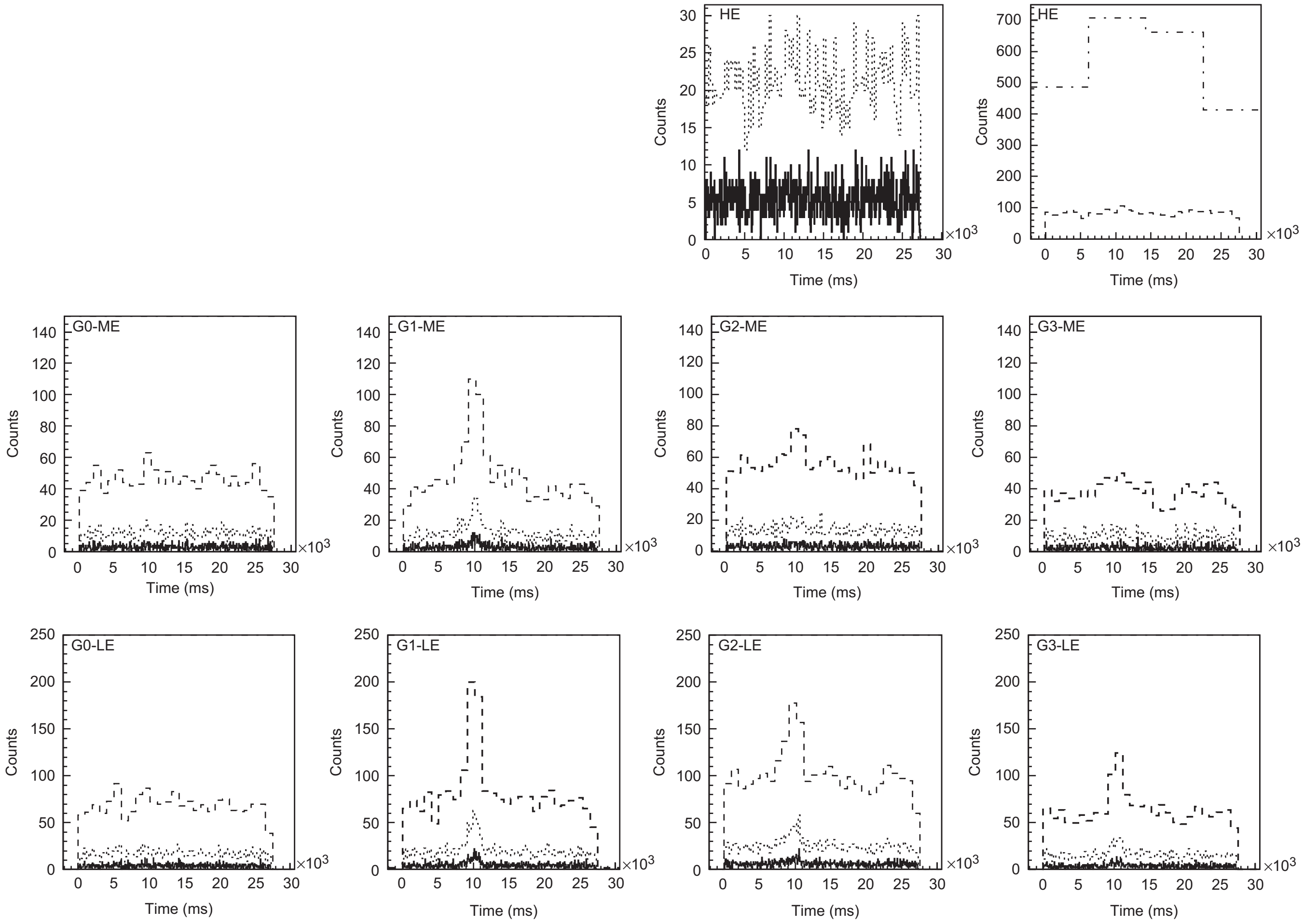

Fig. 3. Ratemeters for different geometrical regions, energy bands and SITs, for a burst obtained with the burst test setup described in the text. The label on each plot indicates the ratemeter it refers to. G0, G1, G2 and G3 refer to the MCAL geometrical regions, as indicated in Fig. 2. LE, ME and HE refer to the low-, medium- and high-energy bands, respectively. In each plot, the RMs for different SITs are shown, according to the following line styles. Solid line: 64 ms; dotted line: 256 ms; dashed line: 1024 ms; dot-dashed line: 8192 ms, shown for HE plot only.

Carlo simulations has also been carried out to figure out the trigger capabilities of this experimental setup with the different available radioactive sources. Fig. 2 shows a schematic view of the experimental setup, together with spatial segmentation of MCAL RMs.

With this experimental setup it was possible to test several features of the BS algorithm:

- Single trigger on different SITs and RMs.
- Simultaneous trigger on different SITs and RMs.
- Different START and STOP strategies.
- Test of the correct SW behaviour during special phases along the orbit (e.s SAA, Ground Contact).

A dedicated test on short SIT was also carried out lowering the trigger thresholds and correlating burst trigger rate with the number of detected photons and verifying a statistical agreement.

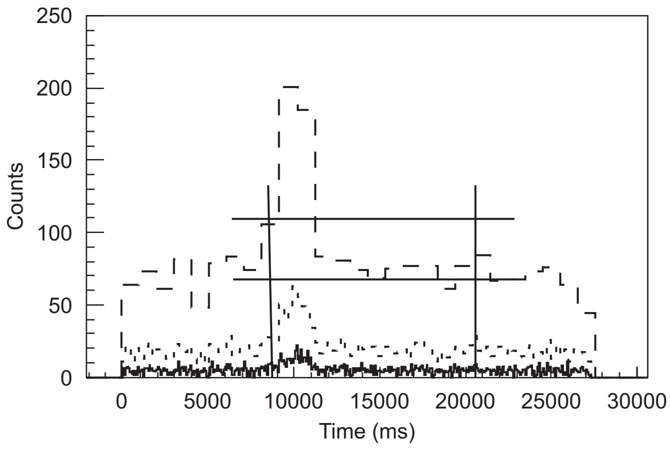

Fig. 4. G1-LE ratemeter for a burst obtained with the burst test setup described in the text. Different SITs are shown, according to the line styles defined in caption of Fig. 3. Burst-START, brust-STOP time (vertical solid lines), background level and 5 sigma threshold (horizontal solid lines) are also shown.

5. Conclusions

The main target of the experimental MCAL burst tests was to verify the results previously obtained at software level with tests carried out on the PDHU functional model. Fig. 3 shows the various RMs during a fake burst produced with the dedicated setup described above and a ^{22}Na source. For each geometrical region and energy band the RMs for different SITs are shown. The burst successfully triggered the BS logic and enabled photon-by-photon data download. The trigger was detected on the RM relative to zone G1, low energy (G1-LE), on the 1024 ms SIT, as expected from the position of the test setup (see Fig. 2). Fig. 4 shows an enlarged view of the G1-LE RMs, together with the estimated background level and expected threshold value. Test on MCAL Burst Search has demonstrated the ability of this instrument to detect autonomously fast transient events and to properly collect the relative data with high time resolution on a wide energy band.

References

[1] M. Tavani, et al., SPIE Proc. 6266 (2006).

[2] M. Feroci, et al., Nucl. Instr. and Meth. A 581 (2007) 728.

[3] C. Labanti, et al., SPIE Proc. 6266 (2006).

[4] E. Del Monte, et al., Proceedings of Science with Next Generation of High Energy Experiments, Frascati Physics Series, vol. XLV, 2007, p. 201.