AGILE: the Scientific Instrument

G. Barbiellini[2], M. Tavani[1], G. Budini[2], P. Caraveo[1], V. Cocco[5], E. Costa[3], G. Di Cocco[4], M. Feroci,[3] C. Labanti[4], I. Lapshov[3], F. Longo[2], S. Mereghetti[1], E. Morelli[3], A. Morselli[5], A. Pellizzoni[6], F. Perotti[1], P. Picozza[5], C. Pittori[5], M. Prest[2], M. Rapisarda[7], A. Rubini[3], P. Soffitta[3], M. Trifoglio[4], E. Vallazza[2], S. Vercellone[1].

[1]*Istituto di Fisica Cosmica del CNR "G. Occhialini", Milano, Italy*
[2]*Dipartimento di Fisica, Università di Trieste and INFN, Italy*
[3]*Istituto di Astrofisica Spaziale del CNR, Roma, Italy*
[4]*Istituto di Tecnologie e Studio della Radiazione Extraterrestre, CNR, Bologna, Italy*
[5]*Dipartimento di Fisica, Università di Roma II,"Tor Vergata" and INFN, Italy*
[6]*Agenzia Spaziale Italiana,*
[7]*ENEA, Italy*

Abstract.
The scientific instrument of the AGILE mission is innovative in many ways. It is an integrated instrument based on three detecting systems: (1) a Silicon Tracker, (2) a Mini-Calorimeter, and (3) an ultralight coded mask system with Si-detectors (Super-AGILE). For a relatively low mass ($\sim$ 70 kg) and large ratio of expected performance over cost, AGILE is planned to provide

(i) Optimal imaging in the energy bands 30 MeV–50 GeV (5–10 arcmin for intense sources) and 10-40 keV (1–3 arcmin).
(ii) Optimal timing capabilities, with independent readout systems and minimal dead-times for the Silicon Tracker, Super-AGILE and Mini-Calorimeter.
(iii) A very large field of view for the gamma-ray imaging detector (3 sr) and Super-AGILE (1 sr).

INTRODUCTION

We present a brief outline of the baseline design for the AGILE scientific instrument. Its main goal is to provide an integrated system made of a Gamma-Ray Imaging Detector (GRID, Si-Tracker and Mini-Calorimeter) and Super-AGILE, with imaging capabilities in the energy ranges 30 MeV–50 GeV and 10–40 keV, respectively. The instrument is designed to be light ($\sim$ 70 kg) and with an optimal ratio of expected performance over cost because of the crucial detector development carried out by our group in previous years [1,2]. Timing capabilities of the whole instrument are optimized reaching $\lesssim 10\,\mu$s absolute time tagging (using an

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on-board GPS), and unprecedently small deadtimes ($\sim 100\ \mu$s for the GRID, and $10 - 20\ \mu$s for each detecting unit of the Mini-Calorimeter and Super-AGILE).

INSTRUMENT OVERVIEW

Fig. 1 shows schematically the AGILE configuration (with a height of ~ 50 cm, a Si-plane geometric area of 38×38 cm^2, and a weight of ~ 70 kg including Si-Tracker, Mini-Calorimeter, Anticoincidence system and electronic unit). The baseline instrument is made of the following elements.

- **Silicon-Tracker**, the gamma-ray converter/tracker is made of 14 Si-planes with microstrip pitch equal to 121 μm (readout pitch equal to 242 μm). The fundamental unit is a module of area 9.5×9.5 cm^2 and thickness 410 μm for a total of 384 readable microstrips. The first 12 planes are made of three layers: a first layer of tungsten ($0.07\ X_0$) for gamma-ray conversion, and two Si-layers with microstrips orthogonally placed to obtain the plane coordinates of charged particles produced by gamma-ray pair creation interactions. For each Si-plane there are then $2 \times 1,536$ readable microstrips. Since the GRID trigger requires at least three Si-planes to be activated, two more Si-planes are inserted at the bottom of the tracker without a tungsten layer. The total readable microstrip number for the GRID tracker is then $\sim 43,000$. The Front End Electronics (FEE) is based on commercially available TA1 chips. We emphasize that the use of TA1 chips makes available **both digital and analog** information for track analysis. The distance between mid-planes equals 1.6 cm as optimized by Montecarlo simulations. The AGILE photon tracking system has an *on-axis* total radiation length larger than $0.8\ X_0$ for an interaction probability above 400 MeV above 35%.

- **Mini-Calorimeter**, made of two planes of Cesium Iodide (CsI) bars, for a total (on-axis) radiation length of $1.5\ X_0$. The signal from each CsI bar is collected by two photodiodes placed at both ends. The aims of the Mini-Calorimeter (MCAL) are: *(i)* obtaining information on the energy deposited in the CsI bars by particles produced in the tracker, and therefore contributing to the determination of the total photon energy; *(ii)* detecting GRBs and other impulsive events with spectral and intensity information in the energy band $\sim 0.3 - 100$ MeV with optimal deadtime ($\sim 10 - 20\,\mu$s) for a readout system treating each CsI bar independently. We note that the problem of particle backscattering for this configuration is much less severe than in the case of EGRET. AGILE allows an efficient photon detection above 1 GeV.

- **Super-AGILE**, made of 4 Silicon detectors ($19 \times 19\,$cm^2 each) and associated FEE placed on the first GRID tray plus an ultra-light coded mask system supporting an Au mask placed at a distance of 14 cm from the silicon detectors. The Super-AGILE goals are: *(i)* photon-by-photon detection and imaging of

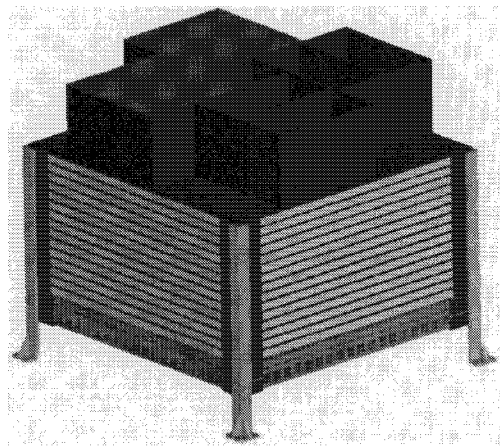

FIGURE 1. The AGILE baseline instrument (AC system and electronic boxes not shown). The GRID is made of 14 Si planes and a Mini-Calorimeter at the bottom of the istrument. Super-AGILE has its 4 Si-detectors on the first GRID tray, and the ultra-light coded mask system positioned on top. The baseline payload size is $\sim 53 \times 53 \times 50\,\mathrm{cm}^3$, including Super-AGILE.

sources in the energy range 10–40 keV, with a large field-of-view (FOV) of $\sim$ 1 sr, good angular resolution (1-3 arcmin, depending on source intensity and geometry), and good sensitivity ($\lesssim$ 10 mCrab for 50 ksec integration, and $\lesssim$ 1 Crab for a few seconds integration); *(ii)* simultaneous X/γ spectral studies of high-energy sources; *(iii)* excellent timing (1-10 μs); *(iv)* burst trigger for the GRID; *(v)* burst alert (and on-board quick positioning) capability.

- **Anticoincidence (AC) system**, aimed at both charged particle background rejection and preliminary direction reconstruction for triggered photon events. The AC system completely surrounds all AGILE detectors (Super-AGILE and GRID). Each lateral face is segmented with three overlapping plastic scintillator layers (0.6 cm thick) connected with photomultipliers placed at the bottom. A single plastic scintillator layer (0.5 cm thick) constitutes the top-AC whose signal is read by four light photomultipliers placed externally to the AC system and supported by the four corners of the structure frame.

DATA HANDLING

The GRID trigger logic for the acquisition of gamma-ray photon data and background rejection is structured in Level-1 and Level-2 trigger phases. The Level-1 phase is fast (1-2 μs) and requires a signal in at least three out of four contiguous tracker planes and a proper combination of fired FEE chip number and AC signals. An intermediate Level-1.5 stage is also envisioned (lasting $\sim 20\ \mu$s), with the acquisition of the event topology based on the identification of fired FEE chips. Both Level-1 and Level-1.5 have a hardware-oriented veto logic providing a first cut of background events. Level-2 data processing includes the complete FEE readout and pre-processing, "cluster data acquisition" (both the analog and digital information provided by the TA1 chips), and processing by a dedicated CPU. The Level-2 processing is asynchronous (estimated duration $\sim$ a few ms). The GRID deadtime is therefore $\sim$100 μs and is dominated by the tracker FEE readout.

In order to maximize the GRID FOV and detection efficiency for large-angle incident gamma-rays (and minimize the effect of particle backscattering from the mini-calorimeter), the data acquisition logic uses proper combinations of top and lateral AC signals and a coarse direction reconstruction in the Si-Tracker. For events depositing more than 200 MeV in the Mini-Calorimeter, the AC veto can be disabled to allow the acquisition of photon events with energy larger than 1 GeV.

Appropriate data buffers and burst search algorithms are envisioned to maximize data acquisition for impulsive gamma-ray events for all AGILE detectors (Si-Tracker, Mini-Calorimeter and Super-AGILE) independently.

Table 1: AGILE vs. EGRET

	EGRET	AGILE
Mass	1830 kg	70 kg
Energy band	30 MeV – 30 GeV	30 MeV–50 GeV; 10–40 keV
Field of view (FOV)	~ 0.8 sr	3 sr (GRID); 1 sr (Super-A)
PSF (68% containment radius)	5.5° 1.3° 0.5°	4.7° (@ 0.1 GeV) 0.6° (@ 1 GeV) 0.2° (@ 10 GeV)
$\Delta E/E$ at 400 MeV	~ 0.2	~ 1
Deadtime	$\gtrsim 100$ ms	$\lesssim 100\,\mu$s (GRID) $\lesssim 20\,\mu$s (MCAL, Super-A)
Sensitivity for pointlike γ-ray sources† ($\mathrm{ph\,cm^{-2}\,s^{-1}\,MeV^{-1}}$)	8×10^{-9} 1×10^{-10} 1×10^{-11}	6×10^{-9} (@ 0.1 GeV) 4×10^{-11} (@ 1 GeV) 3×10^{-12} (@ 10 GeV)
Super-A sensitivity (1 day)		$\lesssim 10$ mCrab (10-20 keV)
Pointing reconstruction	$\sim$10 arcmin	$\sim$1 arcmin

(†) Obtained for a typical exposure time near 2 weeks for both AGILE and EGRET.

REFERENCES

1. Barbiellini G. et al., *Nucl. Instrum. & Methods*, **354**, 547 (1995).
2. Golden R.L., Morselli A., Picozza P. et al., *Il Nuovo Cimento B*, **105**, 191 (1990)
3. Tavani, M., et al., *AGILE Phase A Report* (1998) (see also *Science with AGILE*, http://www.ifctr.mi.cnr.it/Agile).