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First results about on-ground calibration of the silicon tracker for the AGILE satellite

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ABSTRACT

The AGILE scientific instrument has been calibrated with a tagged γ-ray beam at the Beam Test Facility (BTF) of the INFN Laboratori Nazionali di Frascati (LNF). The goal of the calibration was the measure of the Point Spread Function (PSF) as a function of the photon energy and incident angle and the validation of the Monte Carlo (MC) simulation of the silicon tracker operation. The calibration setup is described and some preliminary results are presented.

1. The AGILE mission

AGILE (Astro-rivelatore Gamma a Immagini LEggero) is a Small Scientific Mission of the Italian Space Agency (ASI) launched on April 2007 and dedicated to high-energy astrophysics [1]. The AGILE satellite is designed to detect and image photons in the 18–60 keV, 30 MeV–50 GeV and 350 keV–100 MeV energy bands with excellent spatial resolution, timing capability, and large field of view.

AGILE is the most compact ($\approx 0.25\,\mathrm{m}^3$), light (120 kg for the instrument, 350 kg for the whole satellite) and low power ($\approx 60\,\mathrm{W}$) scientific instrument ever developed for high-energy astrophysics.

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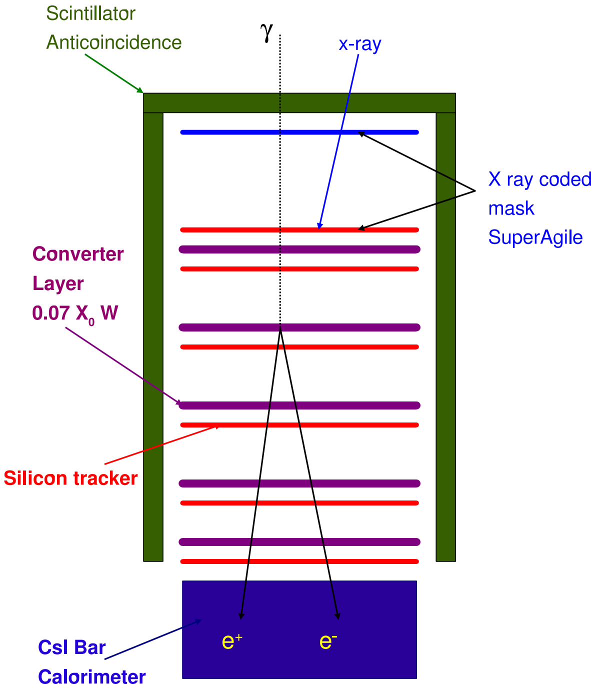

Fig. 1. A schematic view of the AGILE scientific instrument.

The AGILE scientific payload (shown in Fig. 1) consists of three detectors with independent detection capability. The Gamma-Ray Imaging Detector (GRID) consists of a Si–W converter-tracker [2] sensitive in the γ-ray energy range 30 MeV–50 GeV, a shallow ($1.5 X_0$ on-axis) CsI Calorimeter [3] and a segmented AntiCoincidence system based on plastic scintillators [4].

In addition to the GRID, a coded-mask hard X-ray imaging system (SuperAGILE), made of a Si detector plane and a W mask, ensures coverage in the range 18–60 keV [5].

The AGILE main feature is the combination of two co-aligned imaging detectors (SuperAGILE and GRID) sensitive in the hard X-ray and in the γ-ray ranges with large field of view (≈ 1.0 sr and ≈ 2.5 sr, respectively).

Moreover the CsI MiniCalorimeter (MCAL) can operate in stand alone "burst mode" in the 350 keV–100 MeV range to detect GRB.

On ground and subsequently on flight calibrations of a detector are essential to the interpretation of its results. The purpose of the calibration of a scientific instrument is to reproduce, under controlled condition, the detector response in operation.

This paper describes the on-ground calibration of the silicon tracker and some results on the instrument performances derived by it.

2. The silicon tracker

The core of the GRID is the Silicon Tracker (ST) that converts the $\gamma-$rays and measures the trajectories of the resulting e^+/e^- pairs [2–6]. The ST consists of 12 trays with distance between middle-planes equal to 1.9 cm optimized by simulation. The first 10 trays consist of a W converter layer 245 μm thick followed by pairs of single sided Si microstrip planes with strips orthogonal to each other to provide three dimensional points (corresponding to a total thickness $0.01(\mathrm{Si})+0.07(\mathrm{W})\,X_0$). The last two trays have no W converter layers since the GRID trigger logic requires at least three contiguous Si planes.

The detector unit is a $9.5 \times 9.5\,\mathrm{cm}^2$ tile, 410 μm thick with strip pitch 121 μm. Four tiles are bonded together to form a 'ladder'. Every ST plane consists of four ladders.

Only every second strip is readout to limit the power consumption. The non-readout strips contribute to the resolution through the principle of capacitive charge division.

Each ladder is read-out by three TAA1 ASICs, each operating 128 channels at low noise, low power configuration ($< 400\,\mu$W/channel), self-triggering ability and analog readout.

The ST position resolution is below 40 μm for a large range of particle incidence angles [6].

2.1. The GRID simulation

The GRID as mounted on the spacecraft and as installed in the test beam is simulated using the GEANT 3.21 package [7]. This package provides for a detailed simulation of the materials and describes with high precision the passage of particles through matter including the production of secondary particles.

The simulation output is formatted to be readable by the reconstruction programs used for the analysis of in-flight data.

2.2. Direction and energy reconstruction

The γ-ray direction reconstruction is obtained from the identification and the analysis of the e^+/e^- tracks stemming from the conversion vertex. Each microstrip silicon plane measures separately the X and Y hit coordinates.

The first step of the event analysis requires to find two tracks among the possible associations of the hits detected by the ST layers.

The second step consists in fitting the track trajectories through the hits accounting for the presence of energy loss and multiple scattering. These steps are performed separately for the X and Y coordinates producing four tracks, two for each projection. The three dimensional direction is obtained requiring a correct association of the two projections of each track.

The track parameters are fitted by a Kalman filter smooth algorithm [8]. A special implementation of the filter [9] exploits the measurement of the angular scattering of the $e^{\pm}$ due to the interactions with the material to estimate the track energies. Combining the track energies the γ-ray energy is estimated.

3. The γ-ray calibrations

3.1. Calibration goals

The goal of the calibration is to estimate the instrument response function by exposing it to a γ-ray beam with energy and direction known to an accuracy better than the resolving power of the instrument.

The required accuracy of ST is driven by its use during the AGILE mission: the systematic errors introduced by the calibration should be smaller than the statistic errors expected from a bright celestial source.

The detector properties to be evaluated by the calibration are: the detection efficiency, the angular resolution, the energy resolution. In this paper we concentrate on evaluating the Point Spread Function (PSF) as a function of the γ-ray energy and incident angle.

The calibration is also intended to validate the MC simulation program. This simulation will be required to complement the calibration data in the untested parts of parameter space. In particular the information above the maximum energy available at BTF can be obtained only through the simulation.