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PRESENTATION OF THE AGILE RECONSTRUCTION METHOD AND KALMAN FILTER ALGORITHMS FOR GAMMA-RAY SILICON DETECTORS IN SPACE

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ABSTRACT

The AGILE REconstruction Method (AREM) is a method of γ-ray direction reconstruction to be applied to high-resolution Silicon Tracker detectors in space. AREM correctly addresses three points of the analysis relevant for off-axis incidence angles: 1) intrinsic ambiguity in the identification of the 3-D tracks and conversion plane; 2) proper identification of the 3-D reconstructed γ direction; 3) careful choice of an energy weighting scheme for the 3-D tracks. The excellent spatial resolution obtained by the AGILE Silicon Tracker allows to improve the angular resolution by a factor ~ 2 at energies $\gtrsim 400\ MeV$ with respect to previous spark chamber detectors (e.g. EGRET).

1 Introduction

AGILE (Astro-rivelatore Gamma a Immagini LEggero) is a Small Scientific Mission of ASI (Agenzia Spaziale Italiana) with a γ-ray imaging system based on state-of-the-art Silicon strip technology [1] and it will have an unprecedently large field of view, $\sim$ 3 sr, and a very good intrinsic spatial resolution. CERN testbeams show that, by using the analog readout, which gives information on the charge distribution in Si-microstrips, one can achieve a spatial resolution of order of $\sim 40\ \mu$m [2]. Despite the relatively small dimensions and effective area, the AGILE goal is to obtain the best sensitivity ever reached for off-axis events, preserving a on-axis sensitivity comparable to that of EGRET. Therefore, the angular resolution optimization becomes a crucial point to fulfil the mission scientific objectives.

2 The AREM method

The γ-ray direction reconstruction is based on the process of pair production, and is obtained from the analysis of the e^+/e^- tracks originating from a common vertex. The current customary "2-D projection method" of analyzing separately the two tracks projections in the ZX and ZY Tracker views induces two kinds of systematic error in the photon direction reconstruction: A) the intrinsic ambiguity in the proper identification of the two 3-D tracks; B) the problem of the identification of the true 3-D reconstructed γ direction. Finally, we emphasize the importance of the: C) choice of track weighting scheme. In general, the photon energy is not evenly divided between the two particles. Since the direction of the most energetic particle is closer to that of the incident photon, an "energy-weighted" reconstructed direction should be computed[1].

As for the point A), we note that when the e^+/e^- pair hits simultaneously the active Tracker layers, the signal will correspond to two projected track points in each ZX and ZY view, but it could correspond to two possible couples of points in space, as shown in Fig. 1-A. This gives rise to an ambiguity in the conversion plane identification. The "projection problem", point B), stems from the fact that in previous γ-ray experiments, after the identification of the two projected tracks in each view, the next step was to take their (eventually weighted) bisectors and compose them to obtain the reconstructed γ-ray direction. As illustrated in Fig. 1-B, the true 3-D bisector is different from the one obtained from the two bisecting lines in each projected view. As shown in

[1]For simplicity, in the following we illustrate points A) and B) in case of an even energy sharing, i.e., when the photon direction coincides with the bisector.

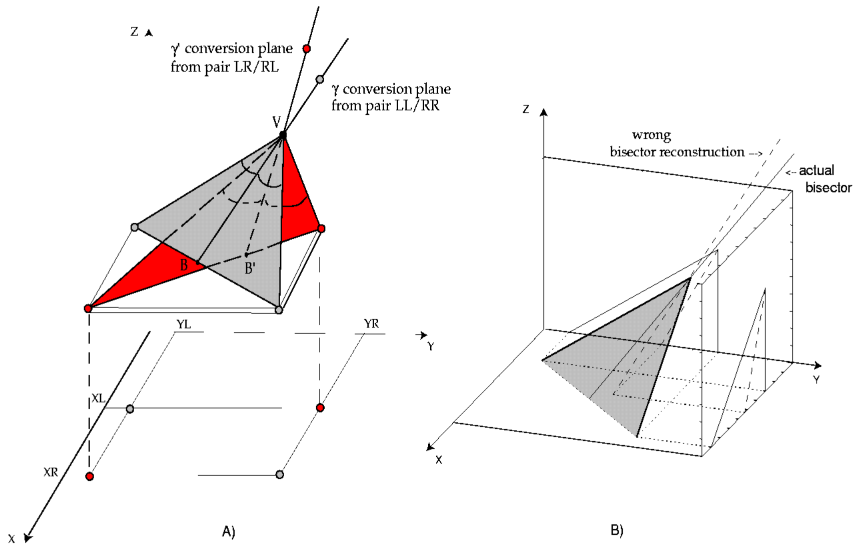

Figure 1: *A) The "conversion plane problem": make the right choice for one out of two possible conversion planes in 3-D. B) The "projection problem": the projections of the bisector are different from the bisectors of the projections.*

ref. [3], this systematic effect increases for increasing off-axis angles and large opening angles, up to values of $\sim 0.5°$, and it would have a significant impact for AGILE. Furthermore, with high resolution Si-detectors it is possible to estimate the e^+/e^- energies from a few MeV to the GeV scale, by measuring deviations due to multiple scattering. This fact allows to properly define the weight of each track for the direction reconstruction (point C).

As described in detail in ref. [4], AREM is a 3-D reconstruction method, which takes into account these three points of the analysis. Several approaches are under study: *(i)* first n-Planes Resolution, using only information from the first hit planes (2PR, 3PR, ...), *(ii)* algorithms based on the Kalman filter [5] for an optimal use of the information from all hit planes. The Monte Carlo simulations of the AGILE-GRID imaging performance were done using the GEANT 3.21 code [6]. In Fig. 2 we show, as an example, the 3-D PSF obtained by using only information from the first 3 hit Tracker planes (3PR) for near-on-axis events at $E_\gamma = 1$ GeV. In Fig. 3 we show the 3-D PSF distribution profiles obtained from the AGILE Kalman filters algorithms (AKF) for several angles and energy values. The 3PR provides a satisfactory PSF for near on-axis events,

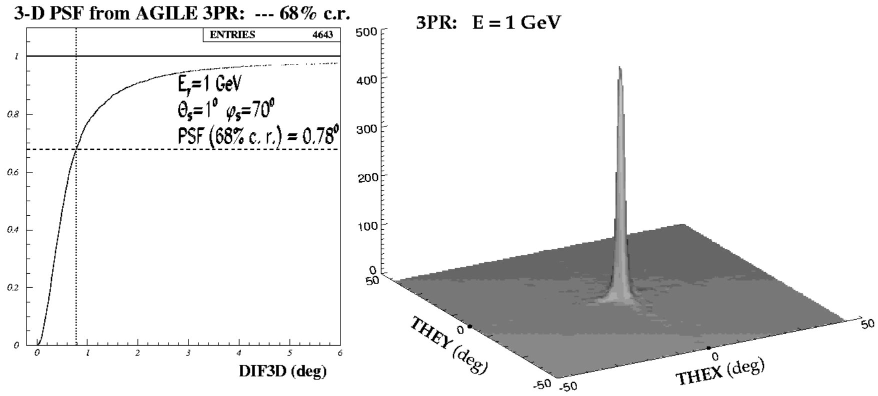

Figure 2: *AGILE on-axis 3-D PSF from the 3PR reconstruction for* $E_\gamma = 1$ GeV. *The left panel curve represents the integral distribution of the difference between true and reconstructed direction of each photon.*

compatible with AKF, even though with a lower reconstruction efficiency. The AKF provides a good event reconstruction with very high efficiency (above 90% for $E_\gamma > 200$ MeV) for a variety of incidence angles. Finally, in Fig. 4 we compare the preliminary AGILE angular resolution, between 0° and 50° off-axis, with that of EGRET on-axis. The figure shows the 3-D 68% containment radius as a function of energy. The AGILE 3-D PSF is better than that of EGRET by a factor of ~ 2 above 400 MeV.

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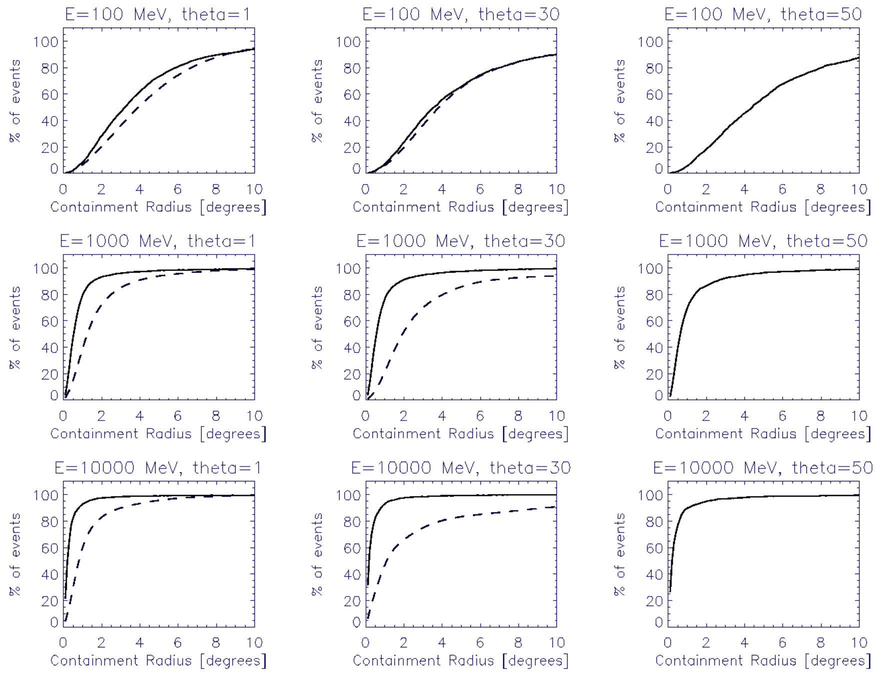

Figure 3: *3-D integral PSF profiles obtained with the AGILE-GRID Kalman filters algorithms (solid curve) compared to the corresponding EGRET values (dashed curve) when available (public data).*

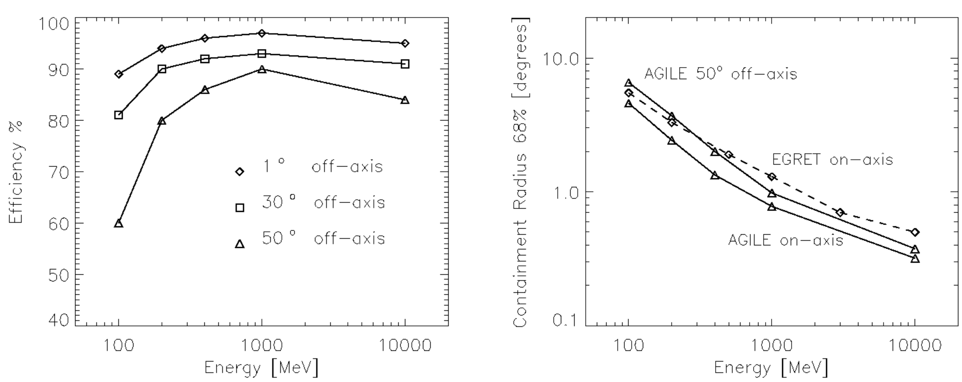

Figure 4: *Left panel: Reconstruction efficiency of the AGILE Kalman filters algorithms for different off-axis directions. Right panel: Preliminary results for the AGILE 3-D containment radius (68%).*