

## High-angular-precision gamma-ray astronomy and polarimetry above the pair-creation threshold

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2<sup>nd</sup> INTERNATIONAL CONFERENCE ON MICRO PATTERN GASEOUS DETECTORS,  
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## High-angular-precision gamma-ray astronomy and polarimetry above the pair-creation threshold

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**ABSTRACT:** We are developing a concept of a “thin” detector as a high-angular-precision telescope and polarimeter for cosmic  $\gamma$ -rays above the pair-creation threshold.

**KEYWORDS:** Polarimeters; Polarisation; Gamma telescopes; Time projection chambers

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Since its launch in 2008, the *Fermi* Large Area Telescope (LAT) has been exploring the  $\gamma$ -ray emission from cosmic sources in the range 0.1–300 GeV [1]. The mission has renewed our understanding of pulsars, active galactic nuclei, globular clusters, gamma-ray bursts, binary stars, supernova remnants and diffuse  $\gamma$ -ray sources. The design life is 5 years and the goal for mission operations is 10 years. It is time to consider what could be the next space-based mission after *Fermi*.

### 1 A $\gamma$ -ray telescope

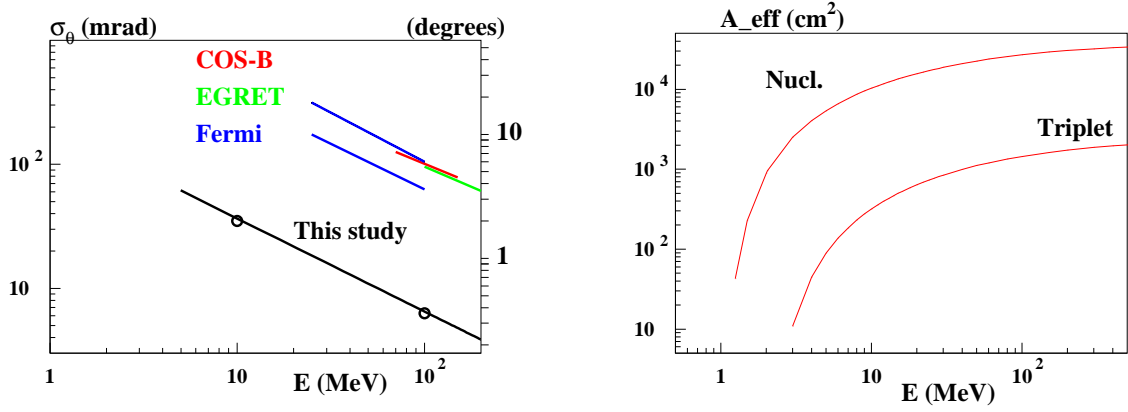
The LAT is a detector with an effective area of almost one square meter above 1 GeV. While, in principle, it can operate down to 20 MeV, its detection efficiency strongly decreases at low energies after the photon selection, needed to reject the huge background, is applied. The drastic degradation of the sensitivity of  $e^+e^-$  pair telescopes from the GeV down to the MeV, together with the drastic degradation of the sensitivity of Compton telescopes above the MeV, is a well known issue in X/ $\gamma$ -ray astronomy, and is referred to as the “sensitivity gap” [2]. The way out, as far as pair telescopes are concerned, is to improve the angular resolution, so as to improve the background rejection for pointlike sources.

At last the observation of  $> 70$  MeV  $\gamma$ -ray expected in some galactic sources from  $\pi^0$  decays from high-energy proton collisions with matter at rest might solve the mystery of the origin of cosmic rays [3].

### 2 Polarimetry

$\gamma$ -rays are emitted by cosmic sources in a variety of non-thermal processes. Radiative processes, such as synchrotron radiation or inverse Compton scattering, provide linearly polarized radiation to some extent, while nuclear interactions end up with non polarized photons. At lower energies, polarimetry is a key diagnostic in understanding the properties of a source; e.g., the turbulence of the magnetic field decreases the observed average polarization fraction. For  $\gamma$ -rays, this tool is badly missing. Polarimetry would provide new insight in the understanding of a variety of sources such as pulsars [4, 5],  $\gamma$ -ray bursts (GRBs, e.g. [6, 7]), AGN [8].

Compton polarimetry is efficient up to a couple of MeV, and projects of Compton polarimetry do exist [11], but the Compton polarization asymmetry decreases asymptotically as the inverse of



**Figure 1.** Angular resolution as a function of photon energy compared to past and existing telescopes (the two *Fermi* curves correspond to “front” and “back” events, respectively). The black line is our analytical prediction while the two points are obtained from simulation (left). Effective area of a 1 ton Argon-based thin detector, as a function of photon energy, for perfect efficiency ( $\epsilon = 1$ ) (right).

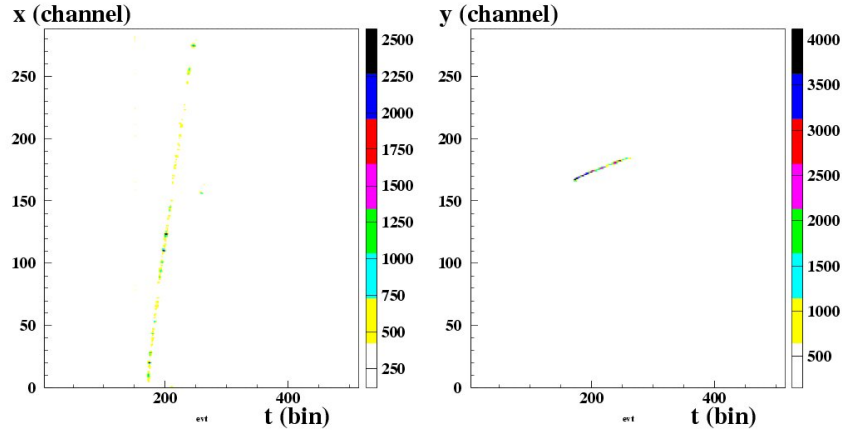
the energy of the incident photon. Here the (linear) polarization fraction of the incoming radiation is obtained from a study of the distribution of the azimuthal angle of the recoiling electron, in the case of triplet conversions, i.e.,  $\gamma e^- \rightarrow e^- e^+ e^-$  [9, 10].

### 3 The detector

A high-pressure time projection chamber (TPC) i.e., an homogeneous, 3D finely instrumented detector is a well suited detector.

- The effective area is larger than one square meter per ton over most of the energy range (figure 1, right), i.e. larger than that of the LAT.
- The angular resolution is improved by one order of magnitude (figure 1, left), and therefore the background rejection factor for point-like sources by two orders of magnitude.
- A TPC is a deadtime-free GRB detector, as even two simultaneous incoming photons can be easily detected.
- A TPC is a thin detector<sup>1</sup> (Compton, “nuclear” pair, triplet processed are not in competition with each other), with effective area simply proportional to the cross section. It has a high efficiency, a  $4\pi$  sr acceptance (reduced to  $2\pi$  sr if operated close to the earth). It is radiation-hard and flux-hard enough to be used in HEP, more than enough for use in space.
- The energy measurement that is obtained from the multiple measurement of multiple scattering of the tracks in the detector at low energy must be complemented by an additional system at higher energy, which will be chosen to be a “thin” system too, so as to not kill the mass budget, i.e., either a magnetic spectrometer, or a transition-radiation detector (TRD), that can operate up to hundreds of GeV [17].

<sup>1</sup>The interaction length, on the energy range considered, is smaller than the thickness.



**Figure 2.** Cosmic ray crossing the demonstrator. Left:  $(x, t)$ . Right:  $(y, t)$ .

#### 4 The present “ground” phase of the project

A demonstrator is presently being commissioned, consisting of a 5 bar Argon-based cubic TPC, with a size of 30 cm, and with a pitch, sampling frequency and diffusion-induced resolution of about 1 mm. The amplification is performed with a “bulk” micromegas mesh [14], the signal collected by two orthogonal strip sets, and digitized with a chip [12] developed for T2K [13].

After we have characterized its performance as a tracker under (charged) cosmic rays in the laboratory, we will expose it to a beam of linearly polarized  $\gamma$  rays [15, 16], aiming at:

- validating the technique ( $\gamma$  astronomy and polarimetry).
- obtaining the first measurement of the polarization asymmetries in the low energy part of the spectrum (few-MeV – few 10’s MeV), where the signal peaks, given the spectra of cosmic sources and where the polarization asymmetry is rapidly increasing, and the approximations used in the theoretical calculations (screening, Born) are to be validated.

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