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The GLAST Tracker

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Abstract

The Gamma-ray Large Area Space Telescope (GLAST) is an international and multi-agency space mission that will study the cosmos in the energy range 20 MeV–1 TeV. GLAST is an imaging gamma-ray telescope more much capable than instruments flown previously. The main instrument on board of the spacecraft is the Large Area Telescope (LAT), a high energy pair conversion telescope consisting of three major subsystems: a precision silicon tracker/converter, a CsI electromagnetic calorimeter and a segmented anti-coincidence system. In this article, we present the status of the silicon tracker and the improvement on the physics that the silicon can bring in respect to the previous detectors.

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The Gamma-ray Large Area Space Telescope (GLAST) [1] is a next generation high-energy gamma-ray observatory designed for making observations of celestial gamma-ray sources in the energy band extending from 20 MeV to more than 300 GeV. The principal instrument of the GLAST mission is the Large Area Telescope (LAT) that is being developed as a mission involving an international collaboration of particle physics and astrophysics communities from 26 institutions in the United States, Italy, Japan, France and Germany. The main scientific objects are the study of all gamma ray sources such as blazars, gamma-ray bursts, supernova remnants, pulsars, diffuse radiation, and unidentified high-energy sources. Respect to the previous instrument EGRET, GLAST will have a higher effective area (6 times more), higher field of view, energy range and resolution, providing an unprecedented advance in sensitivity (a factor 30 or more). GLAST is scheduled to be launched in September 2006 and it will be operational for a period of at least 5 years. It will reside in a low earth circular orbit (550 km altitude) at a 28.5° inclination. Many years of refinement has led to the configuration of the apparatus shown in Fig. 1, where one can see the 4×4 array of identical towers each formed by:

- Si-strip Tracker detectors and converters arranged in 18 XY tracking planes for the measurement of the photon direction.
- Segmented array of CsI(Tl) crystals for the measurement the photon energy.
- Segmented Anticoincidence Detector (ACD).

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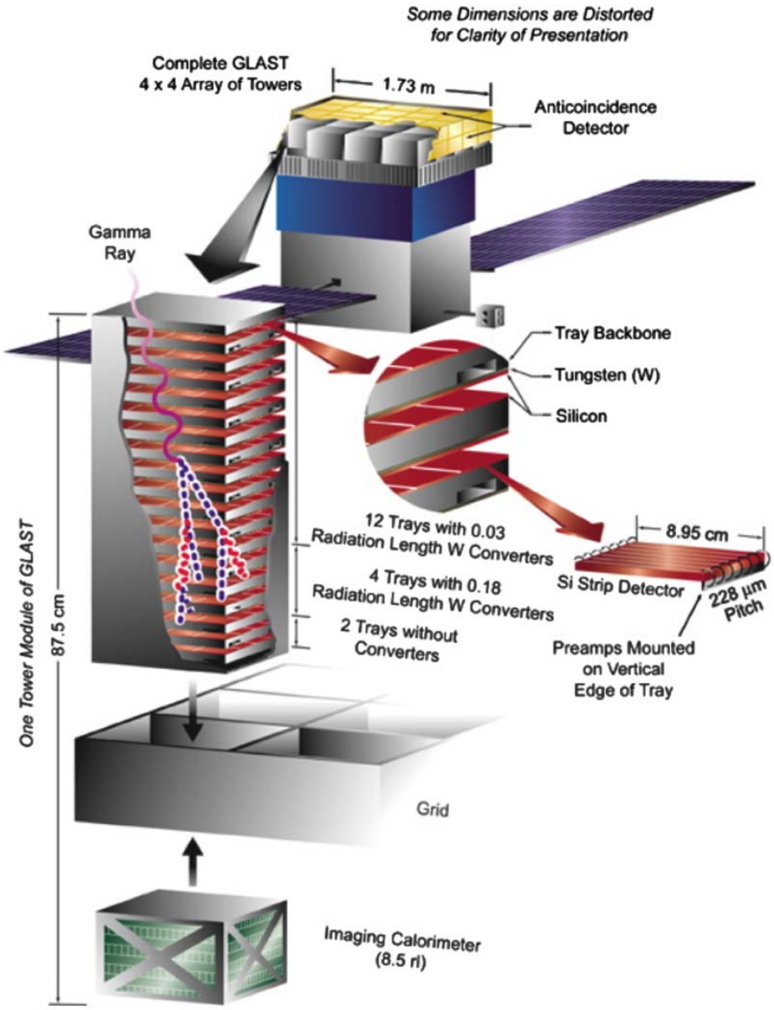

Fig. 1. The GLAST instrument.

Fig. 2 shows a view of a tracker tower module. The tray structure is a low mass carbon-composite assembly formed of a closeout, face sheets and vented Al honeycomb core. The tray structure holds the W converters, and is instrumented with silicon strip detectors (SSDs) on top and bottom and front-end electronics. In Fig. 3 there is a sample of photon track reconstructed in GLAST. The pair-converted positron and electron of the gamma, are tracked through the silicon and tungsten of the tracker with the goal of find the best one or two trajectories, depending on the incident energy. Multiple scattering is key to this analysis, in that it is the dominant error contribution below a few GeV. The Tracker provides the principal trigger for the LAT, converts the gamma rays into electron–positron pairs, and measures the direction of the incident gamma ray from the charged-particle tracks. It is crucial in the first levels of background rejection for providing track information to extrapolate cosmic-ray tracks to the ACD scintillator tiles, and it is important for further levels of background analysis due to its capability to provide highly detailed track patterns in each event. The main characteristics of the detector, extensively studied with Monte Carlo

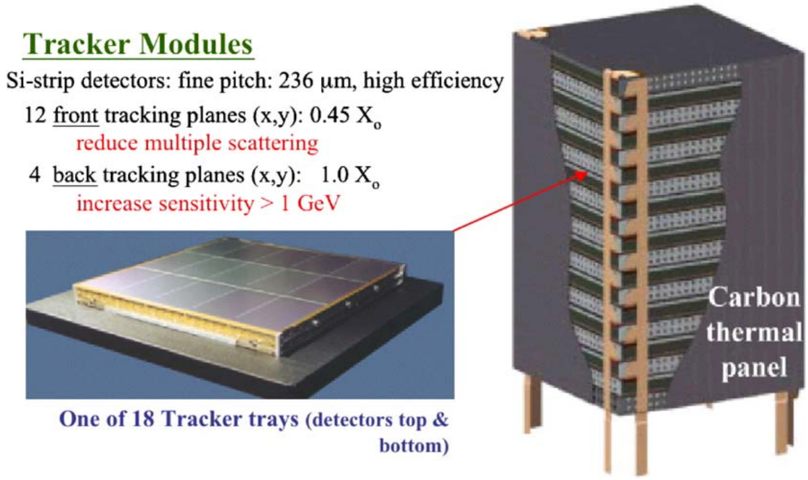

Fig. 2. The GLAST traker tower.

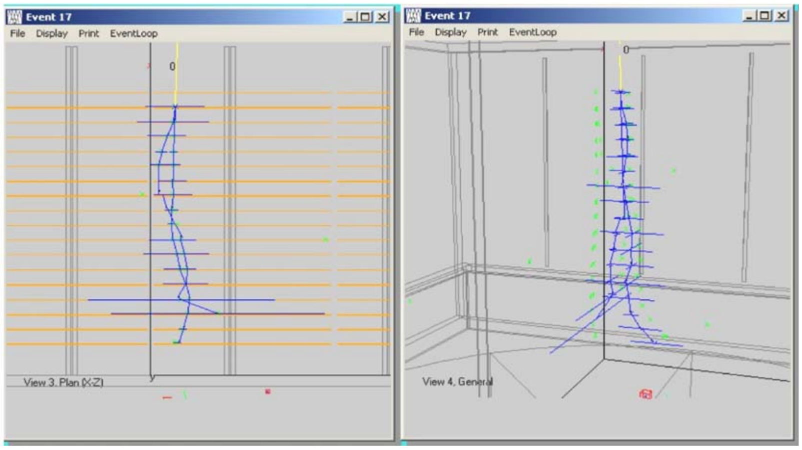

Fig. 3. 100 MeV gamma tracked in the GLAST-LAT.

and beam tests, are an energy range between 20 MeV and 300 GeV, a field of view of ~ 3 sr, an energy resolution of $\sim$ 5% at 1 GeV, a point source sensitivity of 2×10^{-9} (ph cm^{-2} s^{-1}) at 0.1 GeV, an event deadtime of 20 μ s and a peak effective area of 10000 cm^2, for a required power of 600 W and a payload weight of 3000 kg. A more detailed description of the main GLAST parameters can be found in Ref. [2].

GLAST will dramatically extend the number of observed Active Galactic Nuclei (AGN), as well as the energy range over which they can be observed. Indeed, GLAST might be called the "Hubble Telescope" of gamma-ray astronomy as it will be able to observe AGN sources up to $z \sim 4$ and beyond, if such objects actually existed at such early times in the universe. Extrapolation from EGRET AGN detections shows that about 5000 AGN sources will be detected in a 2 years cumulative scanning mode observation by GLAST, as compared to the 85 that have been observed by EGRET in a similar time interval. This large number of AGN's covering a redshift range from $z \sim 0.03$ up to $z \sim 4$ will allow to disantangle an intrinsic cutoff effect, i.e., intrinsic to the source, from a cut-off derived from the

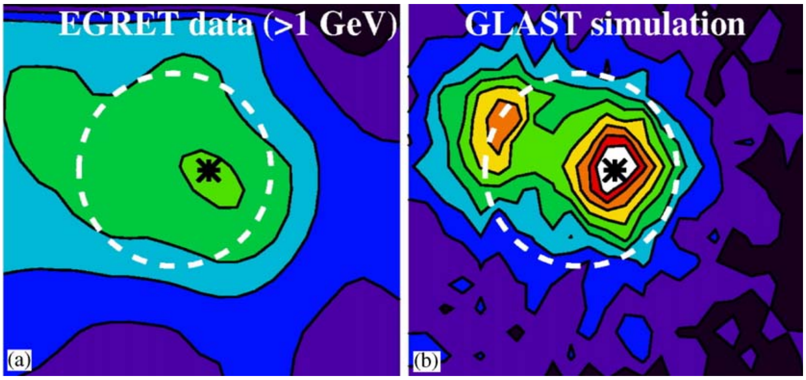

Fig. 4. (a) Observed (EGRET) and (b) simulated GLAST-LAT (1-yr sky survey) intensity in the vicinity of γ-Cygni for energies > 1 GeV. The coordinates and scale are the same as in the images of γ-Cygni in the box at left. The dashed circle indicates the radio position of the shell and the asterisk of a possible pulsar candidate.

interaction with the extra galactic background light, or EBL. Only by observing many examples of AGN, and over a wide range of redshifts, one can hope to untangle these two possible sources of cutoff. Determination of the EBL can provide unique information on the formation of galaxies at early epochs, and will test models for structure formation in the Universe.

GLAST will discover many gamma-ray pulsars, potentially 50 or more, and will provide definitive spectral measurements that will distinguish between the two primary models proposed to explain particle acceleration and gamma-ray generation: the outer gap and polar cap models. Because the gamma-ray beams of pulsars are apparently broader than their radio beams, many radio-quiet, Geminga-like pulsars likely remain to be discovered.

As an example of the improvement of GLAST in respect to EGRET, for SuperNovae Remnants (SNR) candidates, the GLAST-LAT sensitivity and resolution will allow mapping to separate extended emission from the SNR from possible pulsar components (see Fig. 4). Energy spectra for the two emission components may also differ. Resolved images will allow observations at other wavelengths to concentrate on promising directions.

Another example is in the search for Dark Matter candidates. In Ref. [4] it is shown how GLAST offers good possibilities to perform the search for a signature in the gamma-ray spectrum due to the annihilation of supersymmetric dark matter particles in the Milky Way halo and how this search will explore a significant portion of the Minimal Supersymmetric Standard Model parameter space.

GLAST is now in the transition phase from design to flight hardware fabrication (for details on the tracker construction see Ref. [3]). The GLAST-LAT Instrument had completed its Critical Design Review for approval to begin flight hardware construction. It is expected to take some 18 months, with integration into the 16 tower LAT beginning in mid 2004, handoff to the spacecraft for integration into the Observatory in late 2005 and the launch scheduled for fall 2006.

In Fig. 5 the sensitivities of present and future detectors in the gamma-ray astrophysics are shown. The predicted sensitivity of a number of operational and proposed Cherenkov telescopes, CELESTE, STACEE, VERITAS, Whipple is for a 50 h exposure on a single source. EGRET, GLAST, MILAGRO, ARGO, AMS and AGILE sensitivity is shown for 1 year of all sky survey. For AMS only the extimate for two points exist [5]. The first, at 1 GeV, is for the AMS-conversion mode and the second, at 10 GeV, is for the calorimeter mode (see Ref. [5] for details. The diffuse background assumed is 2×10^{-5} photons cm^{-2} s^{-1} sr^{-1}(100 MeV$/E)^{1.1}$, typical of the background seen by EGRET at high

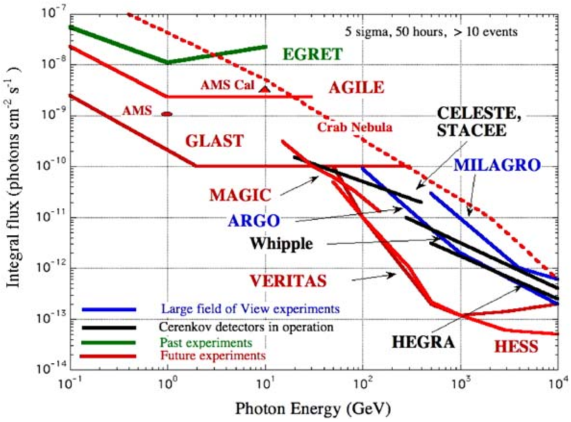

Fig. 5. Sensitivity of present and future detectors in the gamma-ray astrophysics.

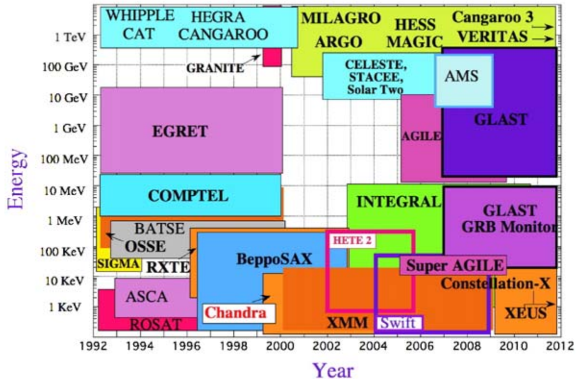

Fig. 6. Timeline schedule versus the energy range covered by present and future detectors in X and gamma-ray astrophysics.

galactic latitudes. The source differential photon number spectrum is assumed to have a power law index of -2, typical of many of the sources observed by EGRET and the sensitivity is based on the requirement that the number of source photons detected is at least 5 sigma above the back-ground. Note that on ground only MILAGRO and ARGO will observe more than one source simultaneously. The Home Pages of the various instruments are at http://www-hfm.mpi-hd.mpg.de/CosmicRay/CosmicRaySites.html. In Fig. 6 it is shown the time of operation and energy range of space X-ray satellite and gamma-ray experiments. Note that AGILE and GLAST will cover an interval not covered by any other experiments. Note also the number of other experiments in other frequencies that will allow extensive multifrequency studies.

In summary:

- GLAST will be an important step in gamma ray astronomy ($\sim$10 000 sources compared to $\sim$200 of EGRET).
- It is a partnership between High Energy Physics and γ-Astrophysics.
- Beam tests and software development well on the way.
- It will bring a wide range of possible answers/discoveries.
- It will be a gold era for multiwavelength studies.

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