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The anti-coincidence detector for the GLAST large area telescope

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Abstract

This paper describes the design, fabrication and testing of the Anti-Coincidence Detector (ACD) for the Gamma-ray Large Area Space Telescope (GLAST) Large Area Telescope (LAT). The ACD is LATs first-level defense against the charged cosmic ray background that outnumbers the gamma rays by 3–5 orders of magnitude. The ACD covers the top and four sides of the LAT tracking detector, requiring a total active area of $\sim$8.3 m^2. The ACD detector utilizes plastic scintillator tiles with wavelength shifting fiber readout. In order to suppress self-veto by shower particles at high gamma-ray energies, the ACD is segmented into 89 tiles of different sizes. The overall ACD efficiency for detection of singly charged relativistic particles entering the tracking detector from the top or sides of the LAT exceeds the required 0.9997.
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1. Introduction

The Gamma-ray Large Area Space Telescope (GLAST) is a new gamma-ray observatory scheduled to be launched in 2007. Developed by an international collaboration, including contributions from the US National Aeronautics and Space Administration and Department of Energy, it contains two instruments: the Large Area Telescope (LAT) [1] and the GLAST Burst Monitor [2]. The LAT will detect celestial gamma-rays in the energy range from $\sim$20 MeV to >300 GeV with angular, energy, and time resolution that are substantially better than in the earlier Energetic Gamma Ray Experiment Telescope (EGRET) on the Compton Gamma Ray Observatory [3]. The scientific tasks for LAT originate from results obtained by EGRET and a number of other astrophysical space missions as well as results from TeV ground based gamma-ray instruments. LAT goals cover a wide range of topics: understanding of the mechanisms of charged particle acceleration in active galactic nuclei, pulsars, and supernova remnants, determining the nature of the still-unidentified EGRET sources, detailed study of gamma-ray diffuse emission (both Galactic and extragalactic, as well as that produced in molecular clouds), high energy emission from gamma-ray bursts, transient gamma-ray sources, probing dark matter and the early Universe.

The LAT consists of three main detector systems, a silicon strip tracker, a CsI calorimeter, and an Anti-Coincidence Detector (ACD). The conceptual design of the LAT is shown in Fig. 1. The tracker, in which the gamma rays interact by pair production, provides instrument triggering and determines the arrival direction of detected photons. The calorimeter also provides instrument triggering and measures the energy of detected photons. The ACD

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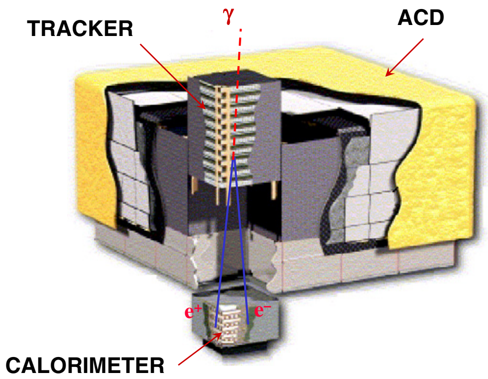

Fig. 1. GLAST LAT schematic. The instrument contains 16 identical tracker and calorimeter towers, one of which is shown exploded.

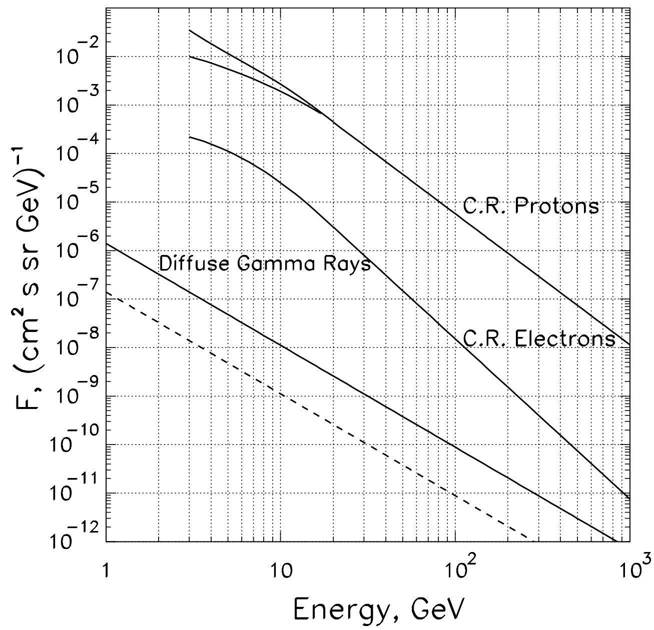

Fig. 2. Differential spectra of primary cosmic rays. Solar modulation effect is shown for energy below 15 GeV; for protons the maximum and minimum solar modulation are shown. The dashed line shows 0.1 of the extragalactic diffuse gamma-ray flux. The extragalactic diffuse gamma-ray spectrum is extrapolated beyond the upper range of 120 GeV measured by EGRET.

surrounds the tracker and provides rejection of charged particles. One challenging feature of the LAT is that it does not have a specially designed directional trigger system, as for example the time-of-flight system in EGRET. The LAT hardware trigger is created by the tracker from the coincidence of signals in three consecutive tracker XY layers, or by the calorimeter if the energy deposition there exceeds some pre-selected level. This approach results in very high rate of first-level triggers, up to 10 kHz, mainly caused by primary and Earth albedo cosmic rays (protons, helium and other nuclei, electrons), which over the energy range of interest outnumber gamma-rays by 3–5 orders of magnitude. Most of this charged particle background must be removed on-board, prior to transmission of data to the ground, to make the event rate consistent with the available data downlink rate. This requirement makes the task of charged particle identification and rejection one of the main problems in designing the instrument. This responsibility is primarily assigned to the ACD.

2. ACD requirements

2.1. Charged particle detection efficiency

The purpose of the ACD is to provide charged particle background rejection. This purpose dictates its main requirement to have high charged particle detection efficiency. The LAT specification is to have any residual background or "fake photons" at the level of no more than 10% of the diffuse gamma-ray background intensity.

Fig. 2 compares the differential spectra of cosmic ray protons [4] and electrons [5] to that of the extragalactic diffuse gamma-ray background [6] (extrapolated beyond the measured limit of 120 GeV). These spectra are shown with an approximation of the geomagnetic cutoff for the GLAST low-Earth orbit with 28° inclination and altitude of 565 km (orbital decay has little effect). Also shown is the required background level, 10% of this diffuse flux. In order to meet this requirement, LAT needs a factor of $\sim 10^6$ suppression of protons and $\sim 10^4$ suppression of electrons. Proton rejection is provided by the ACD along with the tracker and the calorimeter. Calculations indicated that the LAT calorimeter and tracker provide proton suppression by at least a factor of 10^3, employing event patterns in the tracker and shower shapes in the calorimeter. The ACD must provide the remaining factor of 10^3.

Since the cascades of electrons and gamma rays will appear very similar in the calorimeter, the ACD and the tracker will be the primary tools against electrons. The electron spectrum is steeper than the photon spectrum, so for lower energies the requirement is tighter. At 3 GeV, approximately the lowest energy for which primary cosmic ray electrons can reach the LAT in its orbit, the requirement becomes that no more than 1 in $\sim 3 \times 10^4$ electrons can be classified as a gamma ray in the LAT. This is equivalent to an electron detection (recognition) efficiency of 0.99997 for the LAT.

The tracker can help in rejecting this electron background, but this rejection comes at some expense of photon detection efficiency. The tracker can be used as an anti-coincidence barrier by requiring that the pair production conversion layer be clearly identifiable by the absence of a signal in the outer layer or layers, projecting backwards the path defined following the conversion. Events that project directly back to inefficient zones in the ACD can be identified and "cut out" of the data sets. We estimate that this approach can provide charged particle suppression by at least 10. Nevertheless, electrons represent the most challenging background to remove, and drive the efficiency requirements for the ACD. As a result of these considerations, the ACD is required to provide at least 0.9997 effi-

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