The Gamma-Ray Large Area Space Telescope:

Anticoincidence Detector for GLAST

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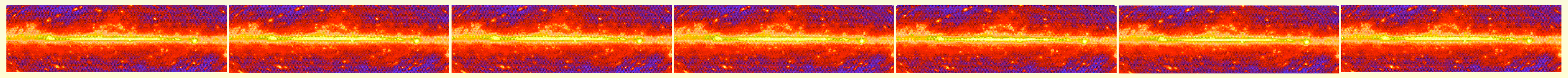

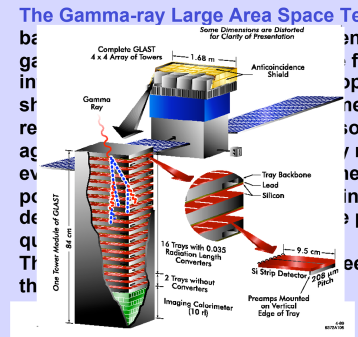

The Gamma-ray Large Area Space Telescope(GLAST) is a satellite-
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ga ... from **20 MeV to 300 GeV.** Our
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sh ... nent design is the utilization of
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Instrument is modular. Each module contains elements of the complete telescope:

- tracker (TKR): high-precision, single-sided silicon-strip detectors & converters, arranged in 18 *x,y* tracking planes;
- calorimeter (CAL): segmented, hodoscopic array of CsI(Tl) crystals, 10r.l. thick; readout with PIN photodiodes;
- anticoincidence shield (ACD): mosaic of plastic scintillator tiles covering front and sides of array;
- data acquisition system (DAQ): 16 identical boards in redundant network. Parallel serial readouts with FIFO buffers; minimum part types and low average power.

The design is based on years of detailed computer simulations, resulting in a clear understanding of all performance parameters *including* background rejection. Extensive beam tests have validated critical aspects of the simulation and hardware performance. A full-scale prototype tower is presently under construction, and will be completed by the end of this year.

The Anticoincidence Detector (ACD) is the outermost active detector on GLAST. It surrounds the top and sides of the tracker. The purpose of the ACD is to detect incident cosmic ray charged particles, which outnumber cosmic gamma rays by more than 5 orders of magnitude. Signals from the ACD can be used to either veto an event trigger or be considered later in the data analysis.

The ACD for GLAST is based on the heritage of the SAS-2, COS-B and EGRET telescopes. GLAST will be studying gamma radiation up to 300 GeV. Gamma-rays of such high energy create a huge number of secondary particles in the calorimeter of the telescope; some of them may interact in the ACD, causing self-veto and reducing dramatically the efficiency of the instrument for the detection of high energy photons. Instead of a monolithic scintillator dome as used in previous missions, the Anticoincidence Detector for GLAST is subdivided into smaller tiles to avoid the efficiency degradation at high energy.

ACD Constraints

- Mass 170kg - 200kg
- Electrical Power ≤ 70 W
- Dimensions: cover the top and the sides of the 170cm×170cm×60cm tracker
- Maintain overall dimensions of 178cm×178cm (thermal blanket and micrometeoroid shield included)
- Minimize the inert material outside the ACD to prevent additional instrumental background.
- Minimize inert material inside the ACD (structural) to reduce the fraction of gamma rays converted in non-optimal locations
- Robust to launch loads

Science requirements

Charged particle background rejection 10^5 :1 at system level. ACD should be able to reject at least 3×10^3 of them; additional rejection is provided by tracker+calorimeter. This requirement is determined mainly by the ratio of 10-20 GeV cosmic ray electrons to high latitude diffuse gamma rays.

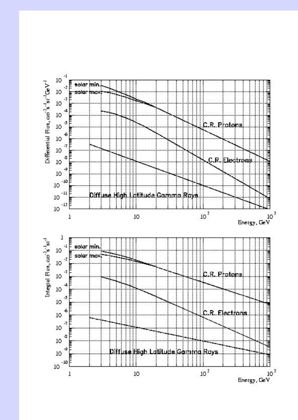
- calorimeter can discriminate photons from cosmic ray protons, but not from electrons which create showers in the calorimeter identical with photon showers. Only the ACD with the help of the tracker protects against electrons
- thus, the required efficiency for charged particles (detector efficiency + hermeticity) is > 0.9995

Backsplash avoidance.

High energy gamma rays hitting the calorimeter produce showers with back-splash (mainly 0.2-2 MeV photons). Such photons can Compton scatter in the ACD producing a signal comparable to the energy deposit by a *mip*. If the location of the ACD hit cannot be distinguished from the arrival direction of the gamma ray (determined by the tracker), then the event may be self-vetoed.

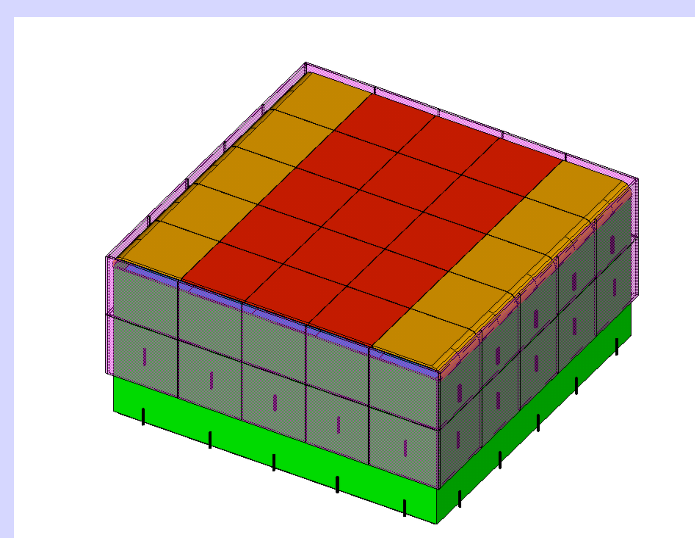
such backsplash reduced the EGRET effective area by 50% at 10 GeV compared to 1 GeV

requirement: segment the ACD such that the backsplash effect gives a “false” veto for ***not more than 10%*** of good gamma ray events over the entire energy range up to 300 GeV



Differential and integral spectra of cosmic rays

Flight Design
(preliminary)



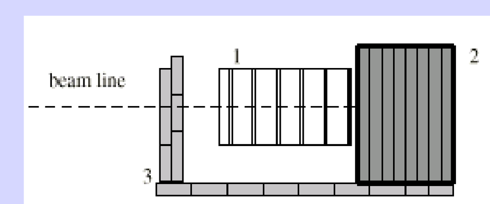
Design Approach

Segmented plastic scintillator (Bicron-408) with wave-shifting fiber (BCF-91MC) + photomultiplier tube (Hamamatsu R1635, R5900) readout; each segment (tile) has a separate light tight housing.

- segmentation localizes backsplash
- separate tile housings provide resistance to accidental puncture by micrometeoroids; the loss of one tile will not be fatal (both EGRET and COS-B would have lost the entire ACD if this had happened)
- wave-shifting fiber readout provides the best light collection uniformity within the space constraints and minimizes the inert material
- ACD “hat” covers the top and the sides of the tracker down to the calorimeter, shielding also a gap between tracker and calorimeter where the massive grid is.
- size of the tiles is such that self-veto due to backsplash does not exceed 10% at 300 GeV
- possible gaps between tiles should not align with the gaps between tracker towers for hermeticity

1997 Beam test at SLAC

Backsplash effect up to 25 GeV incident photon energy was studied during a 1997 GLAST beam test at SLAC (submitted to NIM) and in extensive Monte Carlo simulations



‘97 beam test set-up. 1- tracker, 2 - CsI calorimeter, 3 - ACD scintillator paddles

Area of the tile.

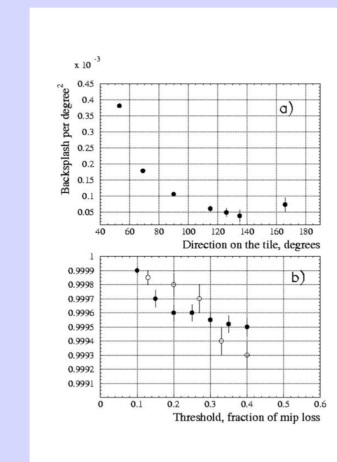
- The tile size of 1000 cm² is sufficiently small for the top surface of the ACD to have backsplash caused self-veto be less than 10%;
- tiles on the sides should be smaller due to shorter distance to the calorimeter - source of the backsplash ($A \propto 1/r^2$)
- The backsplash-caused self-veto depends on the pulse-height threshold in the ACD electronics; here we are operating with the threshold of 20% of the mean minimum ionizing particle *(mip)* energy loss
- Preliminary results of a beam test at CERN at energy up to 250 GeV confirm the extrapolation to higher energy.

Efficiency of scintillating tiles with wave-shifting fiber + PMT readout was measured in the beam test at SLAC:

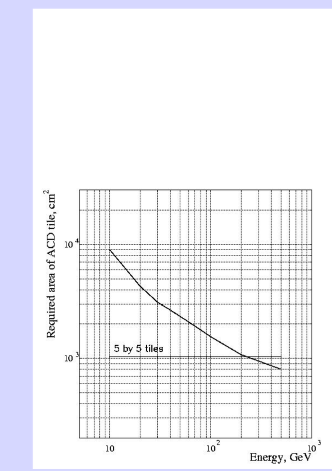
- measured value of ≥ 0.9995 was achieved
- mean number of photoelectrons per one *mip* is estimated as > 30
- further improvement - increasing of the light collection (optimization of the fiber pattern, use of double cladding fibers) is under way

Results:

- readout (wave-shifting fibers + PMT) is chosen and proven
- the backsplash effect is studied both in the beam test and in the simulations; recommendations for the tile size are developed to meet the science requirements
- efficiency of >0.9995 has been demonstrated both in the direct measurements in the beam test and in the laboratory and by measuring the number of photoelectrons
- two layer design gives a factor of ~3 reduction of the self-veto, but requires >40% additional mass and more complicated design



a) backsplash angular distribution
b) efficiency of scintillator paddle with WSF readout; filled circles - measured in a beam, opened circles - measured with C.R. muons



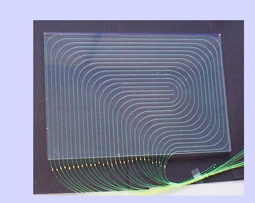
Area of ACD tile required to maintain 90% efficiency - extrapolation of beam test results by Glastsim simulations

November 1999 Beam Test at SLAC

Design Consideration: Build a complete ACD that can be flown on a balloon with minimum modification

Goals:

- verify simulations of the ACD design
  - efficiency
  - leakage
  - backsplash avoidance (measure backsplash spectrum, test possible direct detection of backsplash by fibers and phototubes)
- test and validate Data Acquisition System interface design concepts
- study bending, routing and mounting of wave-shifting fibers
- test attachment of scintillator to structure



One of the tiles to be used in ‘99 beam test (not wrapped to see fibers)

Mechanical structure of the ACD “hat”

Summary

Requirements for the flight ACD:

efficiency of mip detection > 0.9995

leakage (non-hermeticity) < 3×10^{-4}

area of ACD tiles on the top ≤ 1000 cm²

Status:

conceptual baseline ACD flight design is completed

advanced ACD design with finer segmentation on the sides (for high precision energy measurements of high energy photons which enter the calorimeter at large angles and have a long path) is under detailed consideration within the mass and power constraints

preparation for the November 1999 beam test is in progress

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