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The FiberGLAST Detector: A fiber instrument concept for NASA's Gamma-ray Large Area Space Telescope

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Abstract

FiberGLAST is one of two instrument concepts currently under development for NASA's Gamma-ray Large Area Space Telescope (GLAST) mission. The detector utilizes scintillating fibers to combine a photon pair tracking telescope and a calorimeter into one instrument module. The detector is composed of modular layers of thin sheets of tantalum and orthogonal layers of scintillating fibers read out with multianode photomultiplier tubes. The design offers a large effective area and good angular resolution for high-energy (10MeV<E<300GeV) gamma rays. The sensitivity of the instrument is ~30 times that of EGRET and has a wide field of view extending to ~ 80 degrees from the detector axis. We present an overview of the FiberGLAST design and report on the current status of engineering tests.

1 Introduction:

The Compton Gamma-ray Observatory (CGRO) and the SIGMA/GRANAT experiment have brought a wealth of new information on many phenomena in the gamma-ray energy spectra. The highly successful Energetic Gamma Ray Experiment Telescope (EGRET) on CGRO detected high-energy gamma rays from active galaxies whose emission at most wavebands is dominated by nonthermal processes. Over fifty of these "blazars" have now been detected including BL Lacertae objects, highly polarized quasars (HPQs), and optically violent variable (OVV) quasars (Mukherjee, et al., 1997). Gamma-ray bursts, active galactic nuclei (AGN), and as yet unidentified sources have led to a need to increase the sensitivity, energy resolution, effective area, and angular resolution for future gamma-ray astronomy missions.

NASA has made a new gamma-ray observatory a top priority for the next several years. The Gamma-ray Large Area Space Telescope (GLAST) is in the conceptual development stage and is scheduled for a New Start in the FY 2001 budget with a planned launch in 2005. The telescope will cover an energy range from 10 MeV to 300 GeV. There are currently two instrument design concepts for GLAST: SiliconGLAST and FiberGLAST. Both designs are pair production telescopes, which use a detector to track the converted pair and its associated electromagnetic shower to determine the incident angle of the incoming photon and its energy. SiliconGLAST utilizes silicon strip detectors and a CsI(Tl) calorimeter. FiberGLAST utilizes scintillating fibers for both a tracker and a calorimeter.

In a planned five-year mission, GLAST will detect over 1000 active galactic nuclei adding greatly to the current knowledge of AGN structure and variability. The instrument will also detect over 100 gamma-ray bursts a year and quickly provide ground-based observatories with position information to look for an optical counterpart to the GRB. GLAST will also examine pulsars and supernova remnants as well as study the gamma-ray background radiation to determine if it is composed of point sources or a diffuse cosmic component. With improved angular resolution and sensitivity over EGRET, GLAST should be able to identify a large number of the EGRET unidentified sources (Pendleton, et al., 1998).

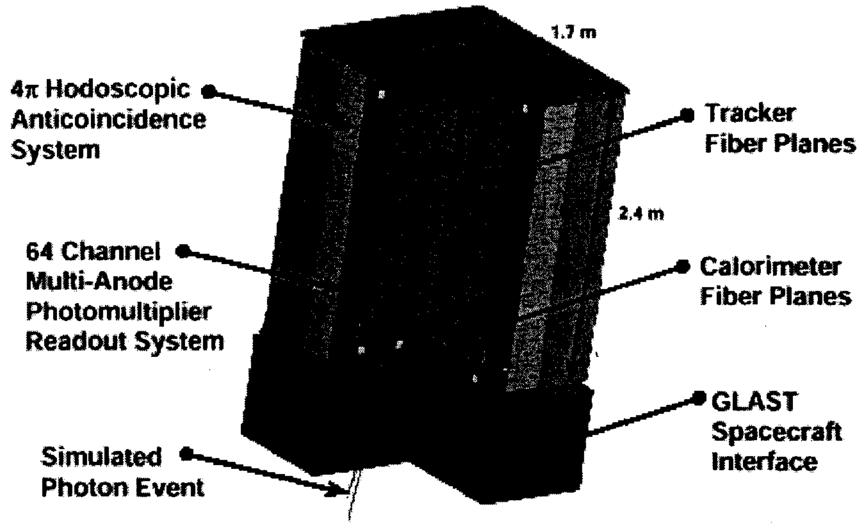

Figure 1 - FiberGLAST Instrument

2 FiberGLAST Instrument Concept:

The FiberGLAST instrument is composed of three main parts: the tracker, the calorimeter, and the anti-coincidence shield (see figure 1). The tracker is composed of ninety detector modules spaced 2cm apart in the vertical direction. The detector modules for both the tracker and the calorimeter are simple components. Figure 2 shows a close-up view of a detector plane. Each module has a converter plate of thin tantalum foil on top that stimulates pair production of high energy photons and bremsstrahlung of high energy electrons. Directly beneath this plate are two orthogonal layers of scintillating fibers with an active area of 1.7 m^2 used to detect the passage of minimum ionizing particles. Plastic honeycomb or foam material fills the rest of the space between each detector plane so that they are fully supported over their entire area. Each fiber is readout by an anode of a multianode photomultiplier tube (MAPMT).

An incident gamma ray will interact with the tantalum foil by pair production. The resulting electron-positron pair will be detected by the scintillating fibers which will provide the x-y position in the detector. As the pair proceeds through the ninety layers, the electromagnetic shower will be detected and can be reconstructed in three dimensions. The tracker will have almost two radiation lengths of interaction material. A low energy tracker is also being developed, which would be composed of a few tracker detector modules at the top of the instrument that would have extremely thin tantalum sheets and would be separated by a larger vertical spacing. This would allow for better angular resolution and less back scattering for photons at the low energy range.

The calorimeter is composed of thirty-six detector modules with thicker tantalum sheets and are only spaced 0.5cm apart in the vertical direction. Two fibers will be readout by each anode of a MAPMT and the signal will be pulse height analyzed to provide additional energy deposition information. The calorimeter will contain ~5 radiation lengths of interaction material.

The anti-coincidence system features six plastic scintillator panels that cover all four sides, top and bottom of the detector stack. Each panel has two layers of orthogonal plastic scintillator elements. Optical fibers conduct scintillation light to MAPMTs. The system of segmented panels will provide the instrument with the ability to distinguish and reject incident charged particles including the high cosmic-ray background that is expected from the particles created by the shower which are uncontained.

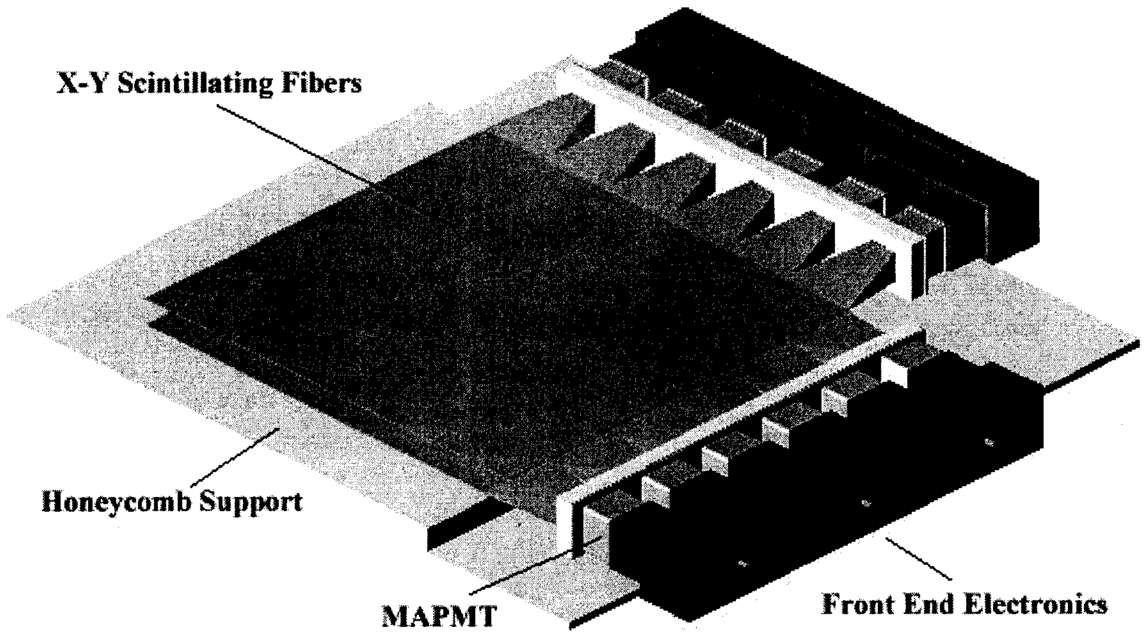

Figure 2 - Closeup of Detector Module Corner

3 FiberGLAST Instrument Characteristics and Performance:

The FiberGLAST instrument provides a significant improvement in sensitivity, effective area, and angular resolution over EGRET. The greatest asset of the FiberGLAST instrument concept is its large effective area which is the product of geometric detector area and photon detection efficiency. The current instrument design and triggering algorithm allows the detector to have an effective area of over 12,000 cm^2 depending upon the incident angle and the energy of the photon. Several types of events will be measurable by FiberGLAST. A fraction of events will have a significant energy deposition in the calorimeter and another class of events will be primarily contained in the tracker. Both of these types will have good energy resolution (<10%). The last type are events which are only partially contained in the tracker but have enough fiber hits to permit an energy measurement. These events are called wide field photons. At high energies, a large fraction of the photons detected at large source viewing angles are wide field photons. Wide field photons will tend to have poorer energy resolution (20-80%) and poorer angular resolution than constrained events from directions closer to normal incidence. The large effective area allows FiberGLAST to measure ~4 times the number of photons required by the baseline instrument performance specifications. However, many of these additional photons will be wide field photons. It is important therefore, to identify which science objectives will be effectively addressed by this additional wide field photon capability.

Wide field photons will be valuable for source limited science. In particular, these data will be valuable for the study of AGN variability. The measurement of flux amplitude and power-law spectral index will allow the effective study of AGN variability on the inter-day and intra-day time scales. Known sources can be monitored for outbursts at higher energy and used to trigger observations at other wavelengths. Wide field photons will also be useful for the study of prompt emission from GRB's since this emission is generally source limited. Pulsars of known frequency can also be monitored for changes over shorter time intervals where source limited statistics dominate. FiberGLAST's superb low energy resolution and wide field of view (~80° from zenith) allow for excellent source detection and distinction from other nearby active sources.

A detailed description of the FiberGLAST detector performance and characteristics given by current simulations can be found in these proceedings (Kippen, et al., 1999).

4 Current status of FiberGLAST engineering tests:

An engineering test apparatus of the tracker composed of twenty small detector planes is planned for testing earlier this summer using the tagged photon beam at Thomas Jefferson National Laboratory. The apparatus used 0.75mm square scintillating fibers with tantalum conversion material and was readout using 20 MAPMTs. The triggering electronics were also tested to realistically simulate the full design. This apparatus will also be tested this fall in combination with a scintillating fiber calorimeter. Preliminary results will be presented at the confernce.

The basic fiber/MAPMT assembly has undergone a number of engineering tests to verify its ability to operate in the extremes of space. Thermal, vacuum, and vibration tests have been completed. The fiber /MAPMT system has been fully characterized to determine its efficiency at detecting minimum ionizing particles using electrons, Sr90 betas and atmospheric muons (Rielage, et al., 1999).

A low-power application specific integrated circuit (ASIC) is being developed by the collaboration to read out the MAPMT signals (Visser, et al., 1999). The trigger logic has been developed and will continue to be improved with results from the two beam tests. Mechanical and thermal studies are continuing for the full instrument.

References

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