GLAST Large Area Telescope
Calorimeter Subsystem

1.0 Introduction & Overview

W. Neil Johnson
Naval Research Lab, Washington DC
Calorimeter Subsystem Manager

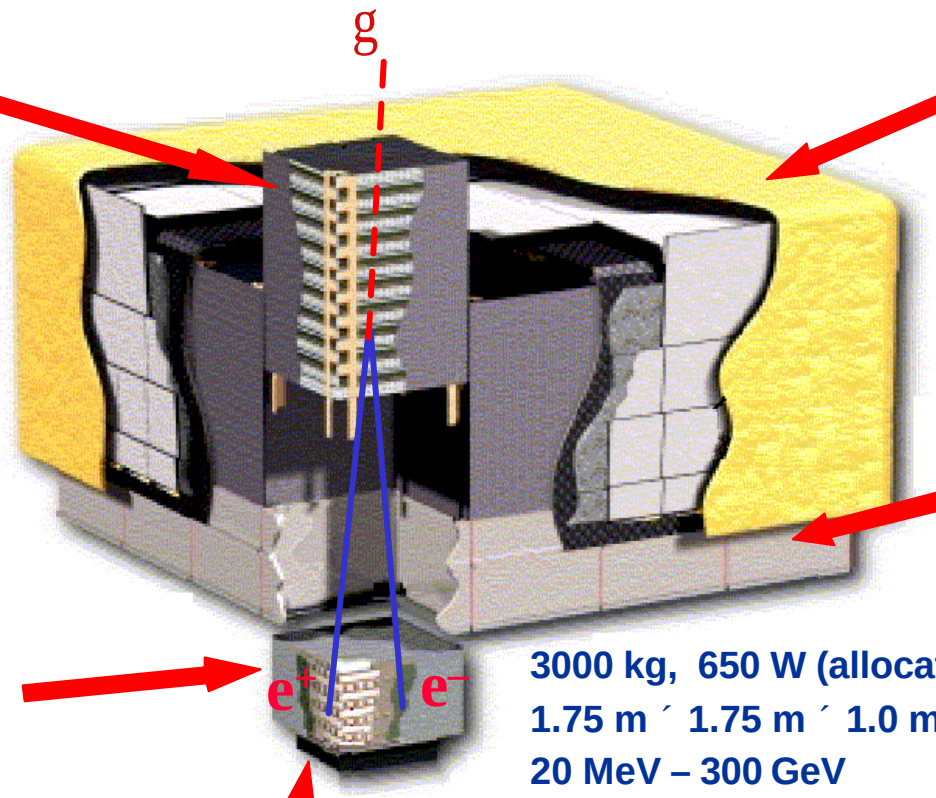
neil.johnson@nrl.navy.mil
(202)–767–6817

Outline

- Introduction
- LAT Overview
- Calorimeter Subsystem
- Level III Requirements
- Design Heritage
- Reviews, Status of PDR RFAs
- Changes since Delta PDR

Instrument Design: 4x4 modular array

Si Tracker
pitch = 228 μm
$8.8\ 10^5$ channels
12 layers × 2.8% X_0
+ 4 layers × 19% X_0
+ 2 layers



ACD
Segmented scintillator tiles
0.9997 efficiency
- minimize self-veto

Mechanical Sys. (inc. Grid & Thermal Radiators)

3000 kg, 650 W (allocation)
1.75 m ´ 1.75 m ´ 1.0 m
20 MeV – 300 GeV

CsI Calorimeter
Hodoscopic array
$8.4\ X_0$ 8 × 12 bars
2.0 × 2.7 × 32.6 cm
- ⇒ cosmic-ray rejection
- ⇒ shower leakage correction

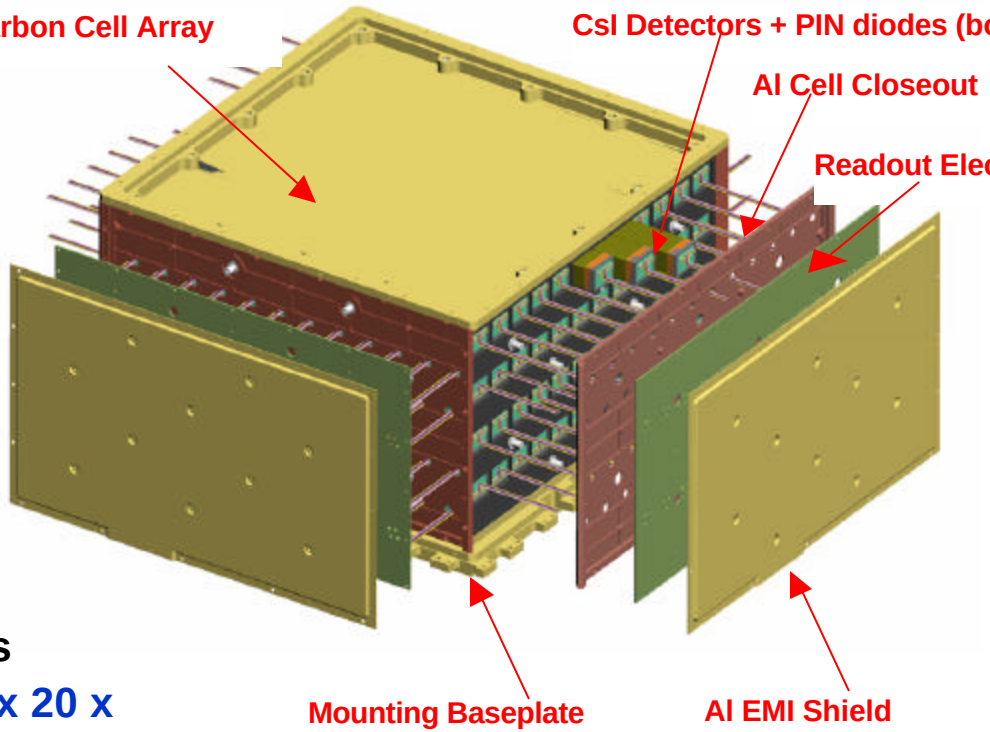
Electronics, Data Acquisition, & Flight Software

Flight Hardware
16 Tracker Flight Modules
16 Calorimeter Modules
1 Flight Anticoincidence Detector
Data Acquisition Electronics + Flight Software

Calorimeter Module Overview

Modular Design

4 x 4 array of calorimeter modules

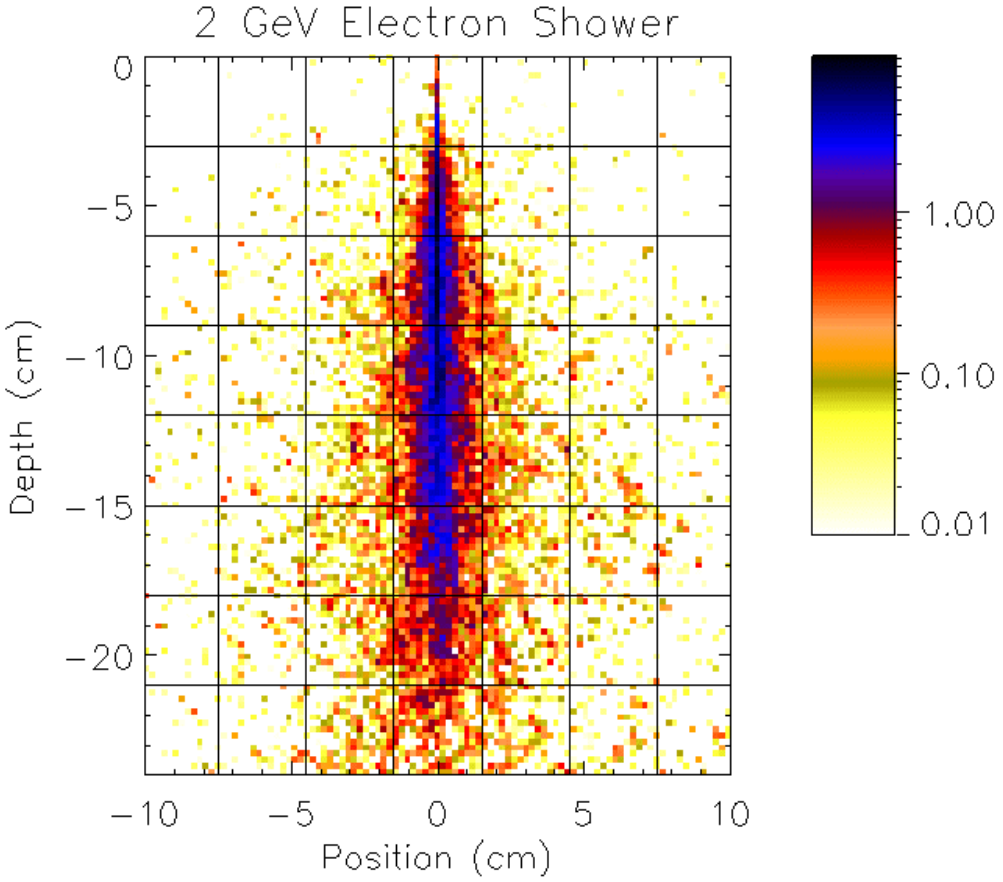


Each Module

- 8 layers of 12 CsI(Tl) Crystals
  - Crystal dimensions: 27 x 20 x 326 mm
  - Hodoscopic stacking - alternating orthogonal layers
- Dual PIN photodiode on each end of crystals.
- Mechanical packaging – Carbon Composite cell structure
- Electronics boards attached to each side.
- Electronic readout to connectors at base of calorimeter.
- Outer wall is EMI shield and provides structural stiffness as well.

Development of Electromagnetic Shower in the GLAST Calorimeter

- Simulation of 2 GeV electron entering calorimeter from the top.
- Grid represents the segmentation of the calorimeter into 3 cm blocks
- Color coding shows the projected total energy deposited in 2 mm voxels in MeV.
- Maximum energy loss rate (shower max) occurs at depth of 10 cm.



CAL Level III Requirements

Reference: LAT-SS-00018

Parameter	Requirement	Verification	Expected Performance
Energy Range	20 MeV – 300 GeV 20 MeV – 1 TeV (goal) 5 MeV – 100 GeV, single crystal	Simulation, Beam Tests	Required performance ~2 MeV threshold (BOM)
Energy Resolution (1 sigma)	< 20% (20 MeV < E < 100 MeV) < 10% (100 MeV < E < 10 GeV) < 6% (10 GeV < E < 300 GeV, incidence angle > 60 deg)	Simulations and EM and LAT calib unit Beam Tests	Simulations demonstrate required performance
Energy Resolution (1 sig) Single Crystal	< 2% for Carbon Ions of energy >100 MeV/nuc at a point.	EM (and Calib Unit) beam test	< 0.5% (correlation of ends removes Landau)
Design	Modular, hodoscopic, CsI > 8.4 RL of CsI on axis	Inspection	8.6 RL
Active Area	>1050 cm^2 per module < 16% of total mass is passive mtrl.	Inspection	1080 cm^2 per module < 14% is passive
Position Resolution	< 3 cm in 3 dims, min ionizing particles, incident angle < 45 deg.	Test with cosmic muons, all modules	< 1.5 cm in longitudinal measurement
Angular Resolution	15 ´ cos(q) deg, for cosmic muons in 8 layers	Test with cosmic muons, all modules	8 ´ cos(q) deg
Dead Time	< 100 ms per event < 20 ms per event (goal)	Test	< 22 ms per event

CAL Level III Requirements (cont)

Parameter	Requirement	Verification	Expected Performance
Low Energy Trigger	>90% efficiency for 1 GeV photons traversing 6 RL of CsI < 2 ms trigger latency	Simulations	> 93% < 1 ms
High Energy Trigger	>90% efficiency for 20 GeV photons depositing at least 10 GeV < 2 ms trigger latency	Simulations, Calib unit test in beams	> 91% < 1 ms
Size (module)	< 364 mm in width (stay clear) < 224.3 mm in height (stay clear)	Inspection	363 mm 224 mm
Mass	< 1440 kg (90.0 kg/module)	Test	1376 kg
Power	< 91 Watts (conditioned) ** (5.69 W/module)	Test	< 54 Watts (conditioned)
Temperature Range	– 10 to +25 C, operational – 20 to +40 C, storage – 30 to +50 C, qualification	Subsystem TV Test 4 cycles, acceptance 12 cycles, qualification	Required performance
Reliability	> 96% in five years	Analysis	> 98% in five years (15/16 modules) LAT-TD-00464-03

*** Modified to 64 Watts, pending CCB action***

Calorimeter Heritage

- **CsI Detector Systems in Space**
  - 1970's – HEAO 1 & 3 (CsI (Na))
  - 1990's – CGRO OSSE (CsI (Na))
  - 2002 – Integral IBIS (CsI(Tl)+PIN diodes)
- **CsI Calorimeters in High Energy Physics**
  - B-Factory experiments at Cornell, SLAC and KEK
- **GLAST LAT Experience (NASA ATD Program)**
  - 1996 16 crystal prototype in SLAC beam test
  - 1997 24 crystal hodoscopic prototype in SLAC beam test
  - 1998 2 beam tests – MSU (heavy ions) and CERN (muons)
  - 1999 CERN beam test
  - 1999 – 2000 full sized (80 crystal) hodoscopic prototype w/ flight-like electronics (BTEM CAL) in LAT tower beam test at SLAC
  - 2000 GSI beam (heavy ions – C, Ni) BTEM CAL
  - 2001 Balloon Flight of the BTEM CAL

Reviews

- **Past Reviews:**
  - **LAT System Requirement Review (SRR)- May 2001**
  - **CAL Peer Review – July 2001**
    - 20 RFA's – All closed out
  - **LAT PDR/Baseline Review – January 2002**
    - 3 Recommendations – All closed out
  - **LAT Stanford Linear Accelerator Center Internal Review - April 2002**
  - **LAT Delta PDR/Baseline Review - July 2002**
    - 2 Recommendations – All closed out
  - **CAL Dual PIN Photodiode Production Readiness Review – Feb 2003**
    - Production approved
  - **CAL CsI Crystal Production Readiness Review – Feb 2003**
    - Production approved, minor documentation improvements recommended.
- **Future Reviews:**
  - **LAT Critical Design Review (CDR) - April 2003**
  - **CAL Pre-Environmental Review (PER) – ????**
  - **CAL Pre-Ship Review (PSR) – ????**
  - **LAT Pre-Environmental Review (PER) - February 2005**
  - **LAT Pre-ship Review (PSR) - July 2005**

DeltaPDR/Baseline Review Recommendations

- Continue to work with Saclay to finalize the Memorandum of Agreement and optimize the subsystem schedule in coordination with the French partners.
  - MoA among NRL, CEA and Stanford signed Jan 10, 2003.
  - (MoA among NRL, IN2P3 and Stanford signed Jul 21, 2002)
  - LoA between NASA and CNES is in signature process, all issues have been resolved.
- NRL and Saclay should continue to work closely on procedures for CDE assembly allowing Saclay to contribute completed CDEs to the engineering model.
  - CEA delivered 14 CDE for EM assembly.
  - CEA and NRL CDE have identical performance.
  - CEA investigating tooling differences for improved manufacturing of flight CDE.

Changes since Delta PDR

- Interconnect between CDE PIN diode and the Analog Front End board has been changed from flex cable to 4 28-gauge wires.
  - Presented at Delta PDR as a likely change.
  - Provides improved AFEE card layout for low noise performance.
- The Dual PIN Photodiode optical window encapsulant has changed from hard epoxy to silicone resin.
  - Unsuccessful in resolving thermal cycling stresses in the DPD and the resultant cracking and delamination of the hard epoxy window.
  - New silicone resin has been tested and meets GLAST requirements. Hamamatsu has experience with it.
- Base plate tabs that interface with the LAT grid have been redesigned to reduce stiffness and resultant stresses on the bolted joints.