

ATD Review 20 Mar 2000

GLAST Calorimeter ATD Program Review 20 March 2000

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Calorimeter Technology Program

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- **D** Program Elements
 - Science performance verification and optimization through simulations examine several concepts and configurations.
 - CsI(Tl) and PIN photodiode detector module performance and packaging.
 - Low-power, analog and data acquisition electronics.
 - Mechanical design and packaging of the calorimeter.
- **D** Program Goals
 - Identification of key performance drivers
 - Full scale prototype
 - Beam test performance demonstration
- □ Major Participants
 - NRL (mgmt, detectors, electronics, assembly, GSE and test)
 - GSFC (custom analog ASIC design and test, simulations)
 - Hytec, Inc. (mechanical design and fab)
 - France IN2P3 (alternate concepts, simulations, beam tests)





Calorimeter Prototype Concept

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GLAST Calorimeter



- □ 8 layers of 10 CsI Crystals
 - Crystal dimensions: 30 x 23 x 310 mm
 - Hodoscopic stacking alternating orthogonal layers
- **D**ual PIN photodiode on each end of crystals.
- □ Mechanical packaging compression cell.

- Dual side-walls form stiff side support
- Inner side-wall holds compression (1 mm Al)
- Outer wall is EMI shield as well.
- **□** Electronics are supported between walls

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Prototype Calorimeter Assembly

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Derived Calorimeter Requirements

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GLAST Calorimeter

Calorimeter Depth	10 (8.5) radiation lengths
Number of CsI Crystals	80 (96) (8 layers of 10 [12])
Crystal Dimensions	$30 \times 23 \times 310 \text{ mm} (28 \times 20 \times 352)$
Number of Electronics Channels:	320 (384) / tower (each CsI xtal, both ends, 2 PIN
	each)
Dynamic Range:	$5 \ge 10^5$ (noise to max signal)
Noise goal:	1 MeV RMS $(3x10^3 e^{-})$
A to D Range:	~2 MeV – 100 GeV
Trigger Rate: (GLAST)	Ave: 5500 Hz (2000 Hz w/ ADC veto)
	Peak: 9000 Hz (3400 Hz w/ ACD veto)
Self trigger delay:	< 1 µsec
Trigger Dead time:	20 µsec
Power:	5 (6) watts / tower (conditioned)
Mass	~ 98 kg/ tower
Nominal Operating Temperature	$\sim 0 - 10 \deg C$, in orbit
	$\sim 0 - 30 \deg C$, in ground test
Storage Temperature Range	~ -20 to $+50$ deg C
(survival range)	

Numbers in parenthesis (red) are for flight design 38-cm towers.





Derived Calorimeter Requirements (Divide and Conquer)

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- Achieve dynamic range with 4 PIN diodes per log and 2 gain ranges in preamp and subsequent processing (640 chans/tower)
 - Low Energy Range: 2 800 MeV
 - High Energy Range: 100 MeV 100 GeV
- **Custom front end ASIC**
 - 1 preamp, 3 shaping amps, 2 peak/hold per PIN
 - mux'ed output to ADC
- □ Use COTS (commercial off the shelf) ADC
 - 12 bit, successive approximation
- □ The dual PIN photodiode for GLAST from Hamamatsu.
 - Based on 3590 PIN, 180 µm thick (active)
 - Package is 15.5 mm x 16.5 mm ceramic carrier
 - Large diode area 96 mm², ~70 pf
 - Small diode area 24 mm^2 , < 20 pf
 - Ceramic carrier has been selected for lowest noise and cross-talk



Custom Dual PIN 96 / 24 mm Areas





Positioning with Light Asymmetry

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- Improve energy resolution by shower profile fitting.
- Imaging events without supporting tracker direction.





CsI Crystal Selection

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- Identify sources of CsI crystals and their ability to deliver material to specification.
 - Two vendors (Crismatec & ISC Kharkov) were used, both found acceptable.
 - 90 crystals purchased and tested.
- Map crystal response as a function of position.
 - ²²Na source scanned along length of crystal.
 - Red-sensitive PMTs at both ends.
 - Fully automated scanner acquires map in 40 minutes.
 - After required processing, the light yield of the ISC Kharkov crystals were indistinguishable from the Crismatec crystals.









- Identify controlling parameters for light attenuation or light tapering along length of crystal.
 - ISC Kharkov crystals were polished. NRL applied light tapering with sanding.
 - Black ends improve light tapering uniformity at the expense of lost light.
- Test light yield for crystals of GLAST geometry and identify wrapping and packaging drivers to light yield.
 - Tetratek and Tyvek wraps best.
 - Don't wet surface.
 - No wrap is x2 loss in light.







CsI Light Yield vs Environment

- Determine environmental influence on light yield - temperature, radiation damage, compression aging.
 - 0.5% loss / deg C drop in temperature,
 - 25% loss of light after 10 kRad,
 - relatively quick loss of ~ 5-10% which then appears to stabilize.
- Study bonding techniques for PIN diode to crystals and impact on light yield.
 - Need bond air gap is x2 loss in light.
 - Hard epoxies are fine but problem w/ CTE of CsI over temperature bonds break.
 - Silicone pads best.







CsI Crystal Processing

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- □ Acceptance testing.
 - inspection, metrology.
 - light yield vs position w/ ²²Na source (PMT dry mount, both ends).
- Surface processing (Ukrainian crystals only, Crismatec delivered with light taper).
- □ Crystal resizing (Ukrainian only).
- □ End treatment.
 - blacken with aperture for PIN photodiode or
 - white Tetratek.
- **\Box** Light yield vs position w/ ²²Na source.
- □ Mount PIN photodiodes.
- □ Final optical wrap.
 - Tetratek (2 x 10 mil).
 - Aluminized mylar with adhesive.
- $\Box \quad \text{Muon testing (and } ^{228}\text{Th source).}$



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Distribution of Light Yields

- Light yield of Crismatec and Amcrys bars, with final surface treatment and final wrap.
 - Variation from bar to bar is small.
 - rms light yield in big PIN = 4%.
 - Crismatec and Amcrys bars are *indistinguishable*, despite the obvious difference in optical opacity: Crismatec bars are clear, while Amcrys bars are milky!
 - Mean yield
 - in $1 cm^2 PIN = 3000 e/MeV$.
 - in $\frac{1}{4}$ -cm² PIN = 750 e/MeV.
 - Note crystals with low yields in small PIN...







Distribution of Light Yields

- □ Some optical bonds to small PIN were poor.
 - Poor bonds not detected in bench checkout because ²²⁸Th photopeak is not detectable in small PIN.
 - Next time: check all bonds with muons immediately.
 - Fractional difference in yield in small PIN relative to corresponding big PIN:
 - $f = (4Y_{S} Y_{B}) / Y_{B}$
 - Factor of 4 accounts for difference in geometric area.
 - Rejected crystals based on this ratio, or placed them in top of BTEM calorimeter, where small PIN is less useful.







Distribution of Slopes (Light Attenuation Lengths)

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- Fit linear model to light yield as a function of position for each end of crystal.
- Crismatec and Amcrys bars with final surface treatment and wrap.
 - Mean slope = 1.5% per cm
 - rms of slope = 0.3% per cm (20% of mean slope)
 - Mean slope corresponds to end-to-end attenuation of ~0.4, i.e. response at far end is 40% of response at near end.



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- Compression cell design provided by Hytec, Inc in collaboration with NRL.
- Design problem is dealing with large CTE of CsI relative to mechanical structure in expected temperature variations during ground handling, test, and launch.
- Solution: compression cell with elastomeric pads. Used extensively in CGRO/OSSE.
 - Compression is applied vertically.
 - Friction against rubber pads constrains the crystals horizontally. Side walls provide "backstop" in the event of motion.



Program: Fabricate two compression cells.

- Populate one with dummy crystals and perform acceptance level vibration testing.
- Build beam test prototype with other.





Mechanical Design (cont'd)

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1.6mm rubber layer, with stiffening membrane



- Top and bottom compression panels are honeycomb with facesheets
- □ Inner side-wall holds compression
- Rubber sheet with holes is placed above and below each layer to provide for thermal variation in CsI depth (CTE mismatch of x4).
- □ Al shim between layers of rubber is used to set initial compression.





Mechanical Assembly





- □ Crystals stacked with alignment fixture (Dummy crystals shown here.)
- Compression applied and shims are adjusted to get the correct compressed height.
- □ Side compression containment panels are attached. External compression is released.





Vibration Test Setup

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□ Vibration tests performed at NRL

2 axes - thrust axis (z-axis) using vertical shaker, transverse axis using horizontal shaker.

- 25 accelerometers
- Test fixture simulated mounting configuration for flight:
 - 4 points on bottom and 4 points on top
- □ Tests
 - low-level random
 - qualification level sine burst
 - random vibration levels as specified in the General Environmental Verification Specification (GEVS)



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Modal Analysis Results

GLAST Calorimeter

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	Matlab	E	xperiment	al
Mode	FREQ (HZ)	FREQ (HZ)	Damp Ratio	Quality Factor
1 st Trans Shear	88.1	91	9.3%	5.4
2 nd Trans Shear	172.5	187	1.9%	26.3
3 rd Trans Shear	251.2	292	6.1%	8.2
1 st Vertical (Accordian)	305.4	218.5	4.1%	12.2
2 nd Vertical (Accordian)	598.9	524	1.4%	35.7





Blue line is Experimental Transfer function and green line is estimated transfer function

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- GLAST Calorimeter
 - $\Box \quad \text{Large dynamic range } (\sim 3 \ge 10^5)$
 - break into multiple gain ranges 2 PINs per crystal end
 - custom ASIC that breaks each PIN signal into two gain ranges to get desired ADC resolution on each.
 - Total of four gain ranges covering 2 MeV 300 GeV
 - □ Low power allocation per detector (~30 mW per crystal end including digital readout)
 - custom CMOS ASIC for front end analog processing
 - COTS low-power successive approximation ADCs
 - □ Low event processing time (dead time) requirement (< 20μ sec)
 - simultaneous digitization of 160 signals from the crystal ends.
 - High bandwidth transfer to DAQ using multiple serial links.
 - □ Performance monitoring and Calibration on the ground and in orbit.
 - Internal charge injection calibration system
 - test gain setting
 - low threshold for cosmic muon testing
 - in flight calibration with high Z cosmic rays.







Analog ASIC Signal Chain







Prototype Calorimeter Trigger Event Data Readout

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- 160 ADCs readout simultaneously to cal controller
 - Xfer time ~ $3.5 \ \mu sec (3 4 \ MHz)$
 - form 20 "columns" of 8 ADC values with flags
- 20 Columns transferred simultaneously to DAQ
 - 128 bit messages at 20 MHz (6.4 µsec)
 - transfer can overlap acquisition of new event
- DAQ I/F merges 20 columns into ordered sequence of 160 16-bit words
 - load into event buffering FIFOs
- DAQ performs event sparsification for readout







AFEE Circuit Card

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- □ 16 Layer board
- 40 CsICAL ASICs, 80 PIN diodes connections
- □ 10 V-I/I-V ASICs
- **4**0 ADCs
- **D** 16 DACs
- □ Misc buffers, biasing, filters
- □ 5 Nanonics connectors
- □ Total of ~ 1400 components on both sides.





Dead Time

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Front End Data Capture - BB

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Partially Assembled BTEM Calorimeter

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Assembled Calorimeter

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□ Completed Assembly

- mass: 98 kg
- power: 5 watts

Tracking cosmic muons

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- Display shows all four energy ranges.
 - Both crystal ends are shown.
 - Color code indicates energy deposition.
- □ Incident beam is ~12 positrons in a single pulse from 20 GeV beam
- **\Box** Beam incident at ~ 50 deg angle

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- □ Lowest range is saturated
- □ Highest range not saturated





Multi-Particle Energy Spectra

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Running self-triggered

- See muons in low energy range
- See multiplicity of particles up to 600 GeV
 - Each peak in the lower two plots represents a integer multiplicity of positrons. Average multiplicity was varied between ~10 and 30 during this run of 10 GeV positrons.





Conclusions

- Design of calorimeter meets the requirements for flight system
- □ Some modifications to design are required
 - Calorimeter size and depth have changed in flight unit modest impact.
 - More functionality is required in analog ASIC digital control, internal DACs and autoranging to be designed by CEA/Saclay.
 - Compression adjustment capability prior to launch is desired.
 - PIN bonding with silicone pads requires modification to PIN mounting.
 - DAQ and interface to DAQ are under review; calorimeter data compression (zero suppression) is desired.
- Alternate mechanical design for the calorimeter is being considered -IN2P3/Ecole Polytechnique.



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