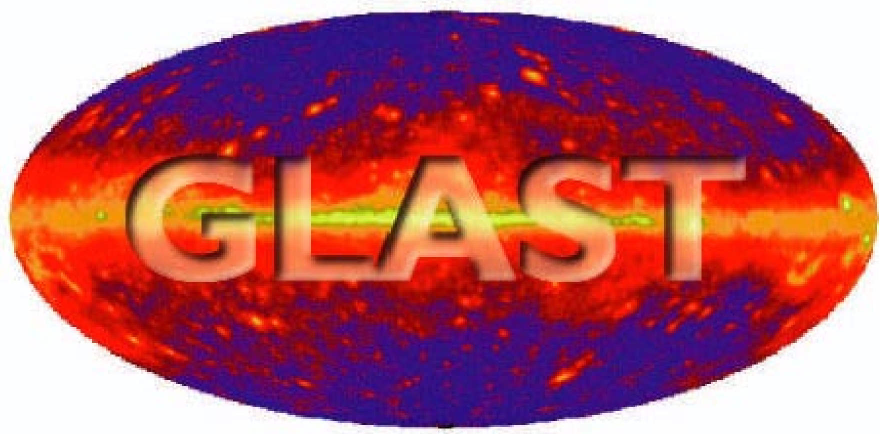
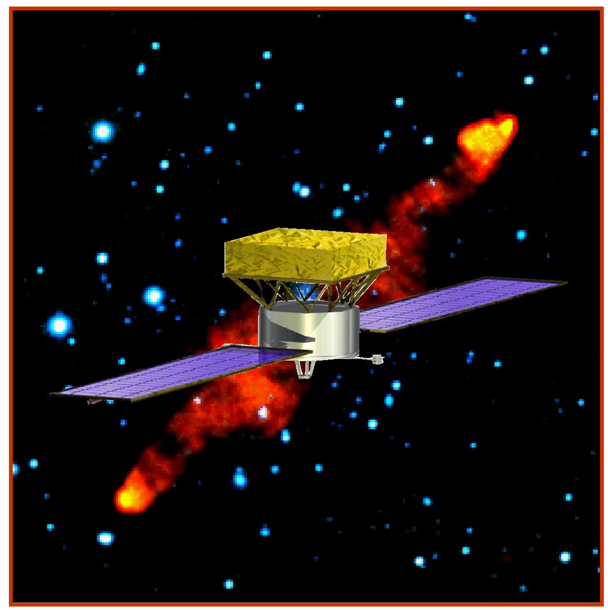


Technology Development II

Calorimeter and AntiCoincidence (ACD)



W. Neil Johnson
Naval Research Lab

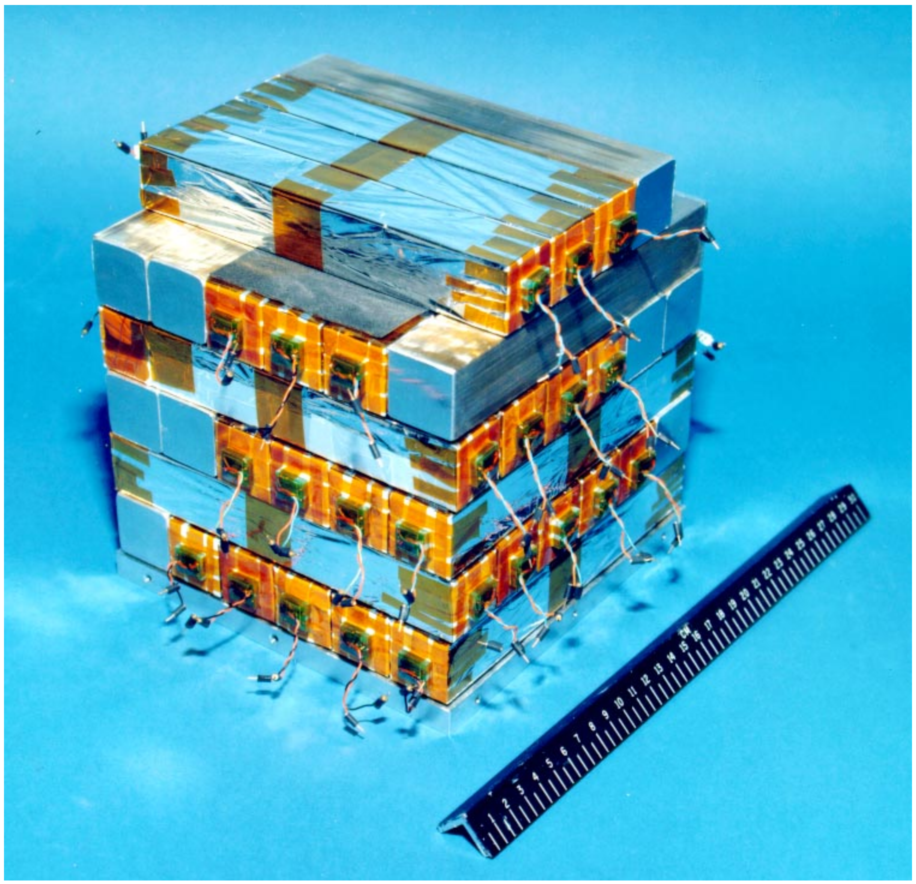
GLAST Council Mtg.
January 27, 1999

Presentation Outline

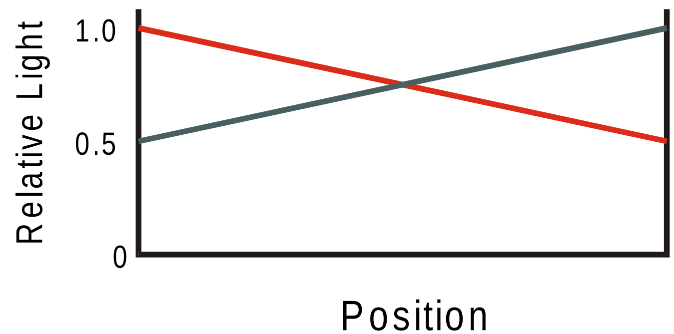
- **Calorimeter Technology**
  - Mechanical Design
  - Optimization - Beam Tests / Simulations
  - Electronics Design
  - Trade Studies
- **ACD Technology**
  - Mechanical Design
  - Optimization - Beam Tests / Simulations
  - Trade Studies
- **ATD Option I Objectives**
- **Conclusions**

Hodoscopic (Imaging) CsI Calorimeter

‘97 Beam Test Prototype (partial Stack)
3 x 3 x 19 cm blocks



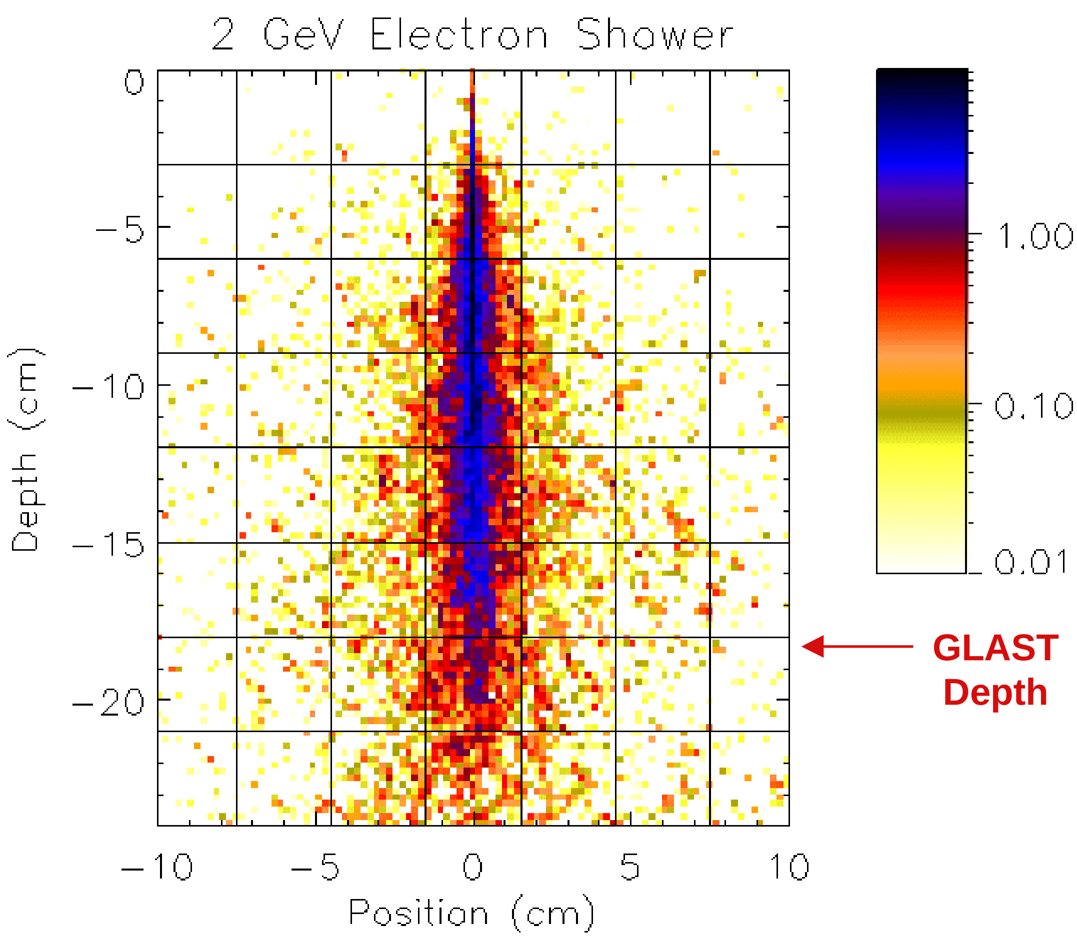
2.3 x 3 x 31 cm



$$\text{Position} = 0.5 + \frac{f * (A - B)}{(A + B)}$$

Development of Electromagnetic Shower

- Simulation of 2 GeV electron entering CsI 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 pixels in MeV.
- Maximum energy loss rate (shower max) occurs at depth of 10 cm for 2 GeV.



Beam Test '97 Calorimeter Configuration

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Calorimeter Technology Development Program

- **Mechanical Design - Survive launch (10 g loads)**
  - Most of the weight of the instrument is in the CsI crystals.
  - CsI has a large coefficient of thermal expansion, is mechanical maleable and is mildly hygroscopic
  - Minimize passive material and gaps between tower modules.
- **Optimization of Imaging capabilities - Enable / maximize science measurements**
  - Improve background rejection with better discrimination on hadronic showers.
  - Improve energy measurement and extend energy range via shower profile analysis.
  - Capture and image photons which do not convert in the Si tracker.
- **Electronics Design - Achieve performance within resource constraints**
  - Spectroscopy over a broad dynamic range, ~ 5×10^5
  - Low power, ~ 62 milliwatt per CsI crystal including all digital processing
  - Low deadtime, 10 μsec goal

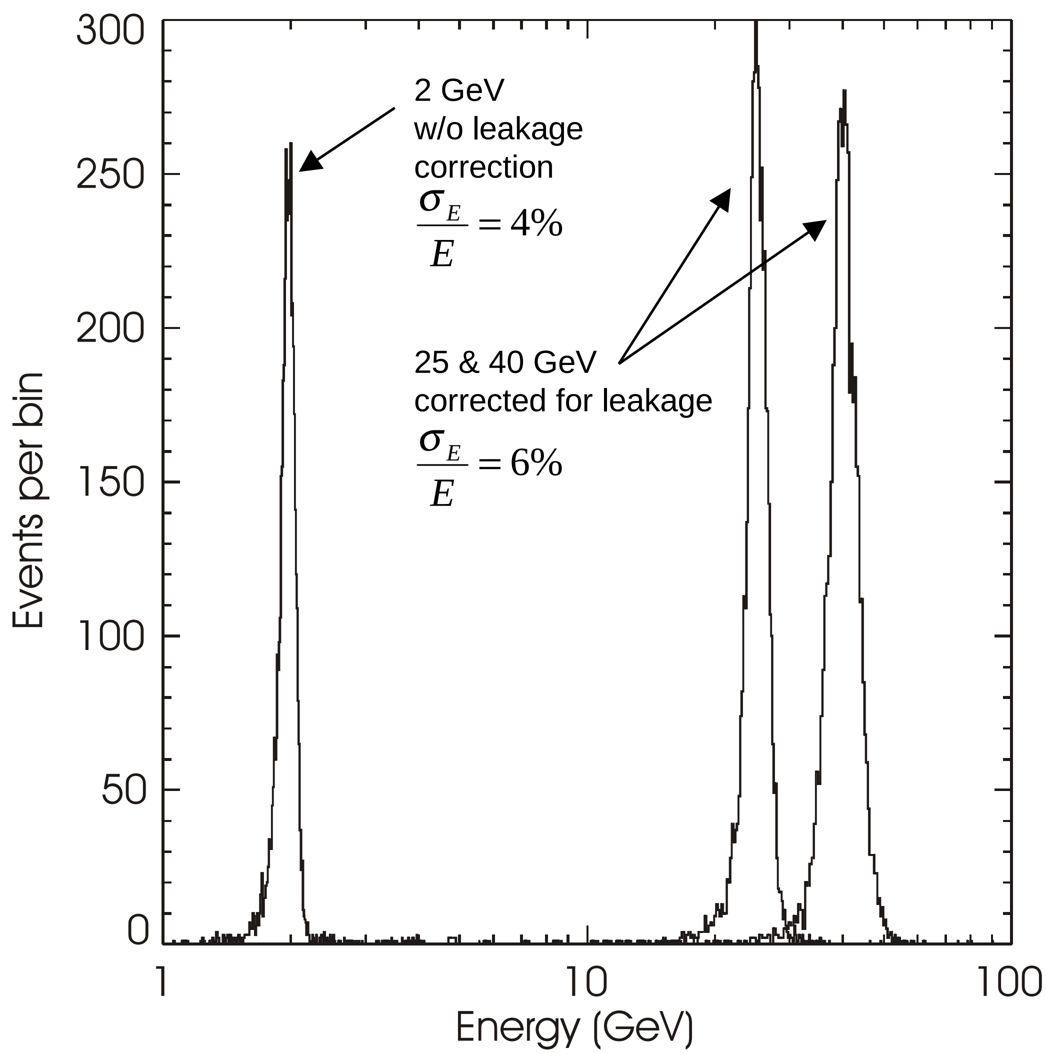
Energy Resolution with Shower Profile Fitting

- Segmented calorimeter can measure the longitudinal profile of the developing EM shower.

- Fitting the profile can correct for shower leakage due to calorimeter depth.

$$\frac{1}{E_o}\frac{dE}{dx} = b\frac{(bx)^{a-1}\,\mathrm{e}^{-bx}}{\Gamma(a)}$$

SLAC Beam Test '97 Results



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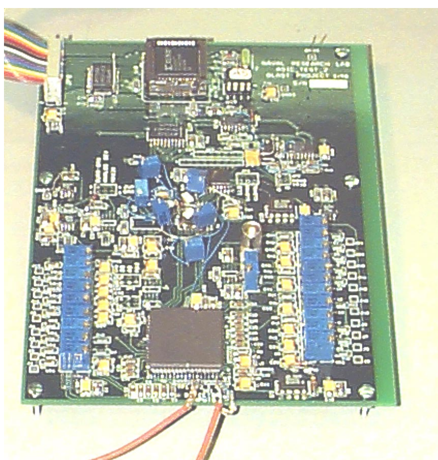
GLAST

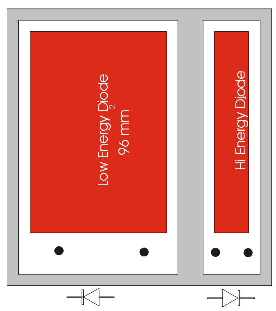
Calorimeter Design and Prototyping

Number of Channels:	160 / tower (80 CsI blocks, both ends)
Dynamic Range:	5×10^5
Noise goal:	0.4 MeV (2×10^3 e^-)
A to D Range:	2 MeV – 100 GeV
Power:	5 watts / tower
	~ 62 mW / CsI block

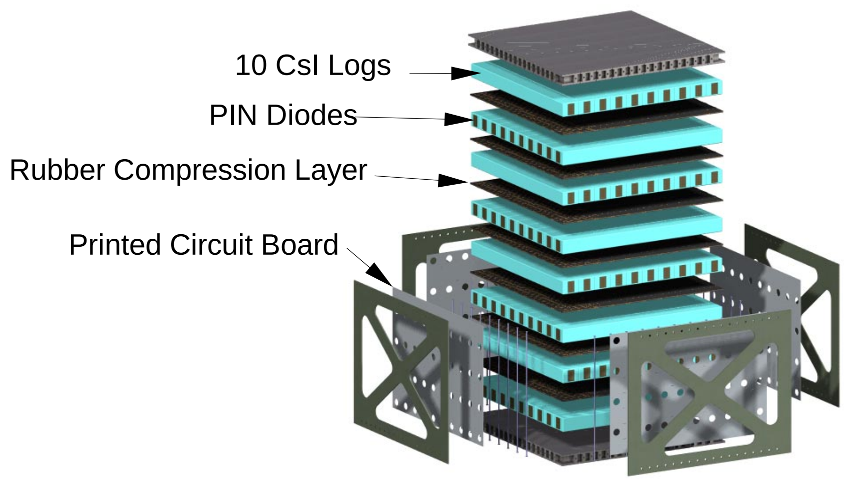
Achieve dynamic range, noise and power performance with dual PIN photodiodes and custom low-power application specific integrated circuit (ASIC) with multiple energy ranges.



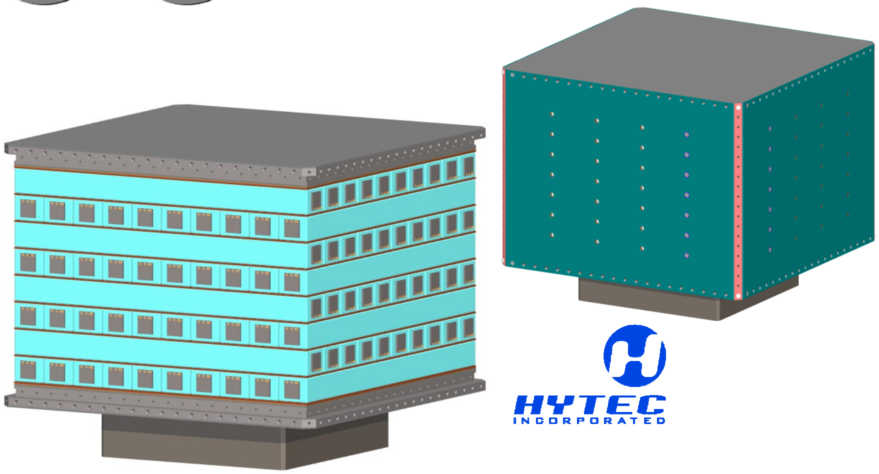
ASIC Development - prototype test board



Custom Dual PIN photodiode

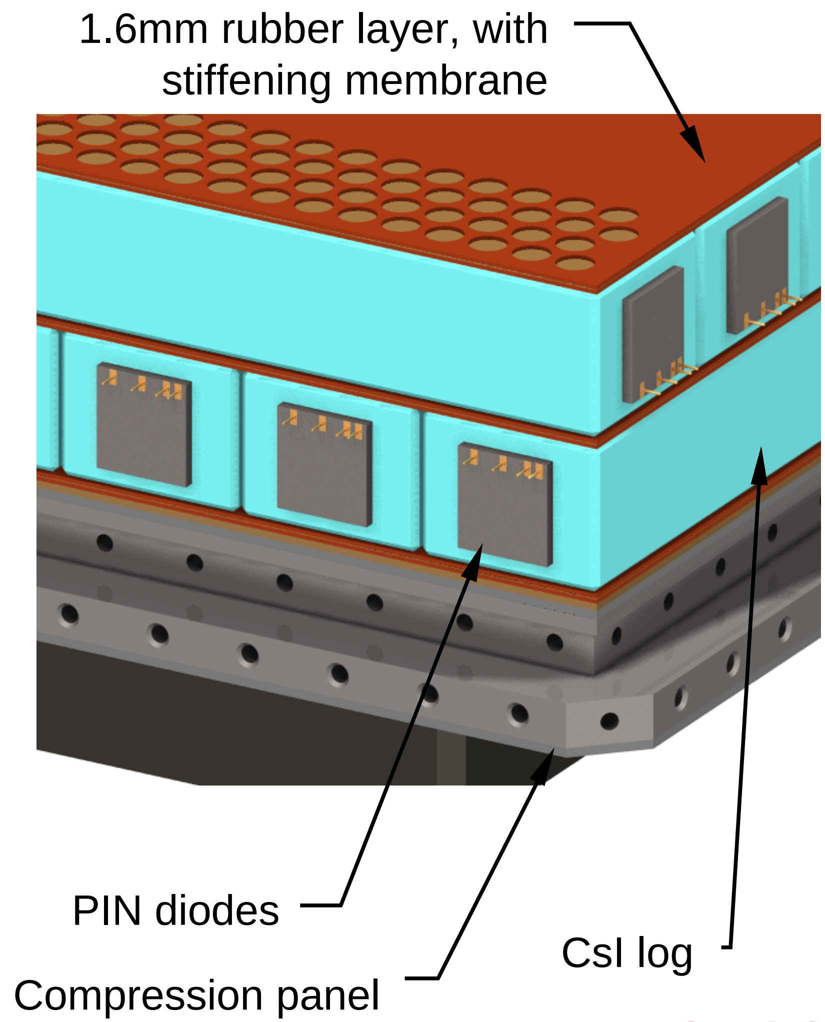


Calorimeter Mechanical Design

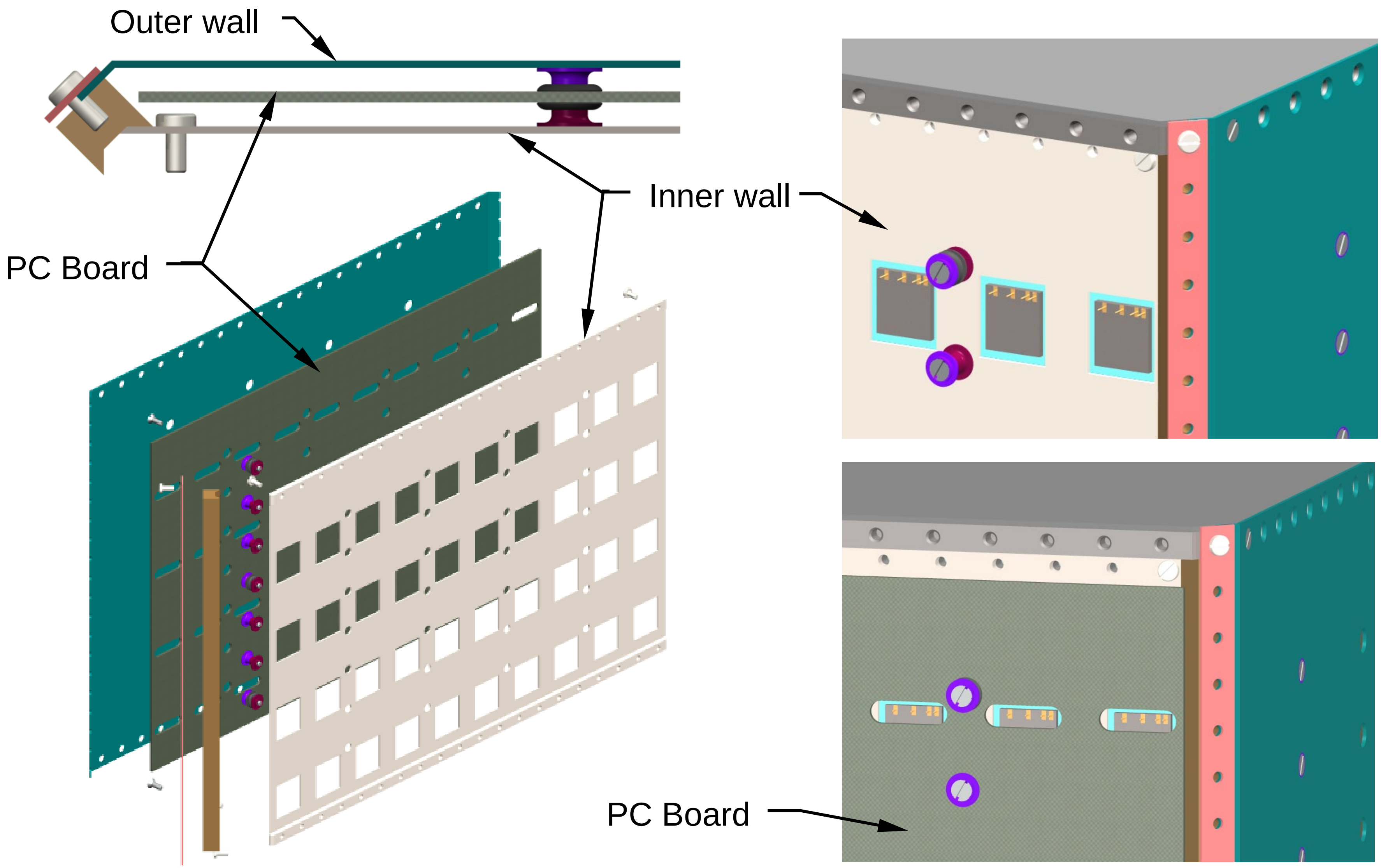


- Compression of crystal layers between compliant sheets keeps crystals from slipping from side to side during launch.
- Side sheer panels pre-stress the stack and act as a backup to prevent slippage of crystals.
- Ample room for readout circuitry around the sides of the cell.
- The design has been extensively analyzed, and critical components have been tested in the lab.
- Detailed engineering is in progress, with construction of the calorimeter structure of the prototype tower beginning.

Compression Cell Design



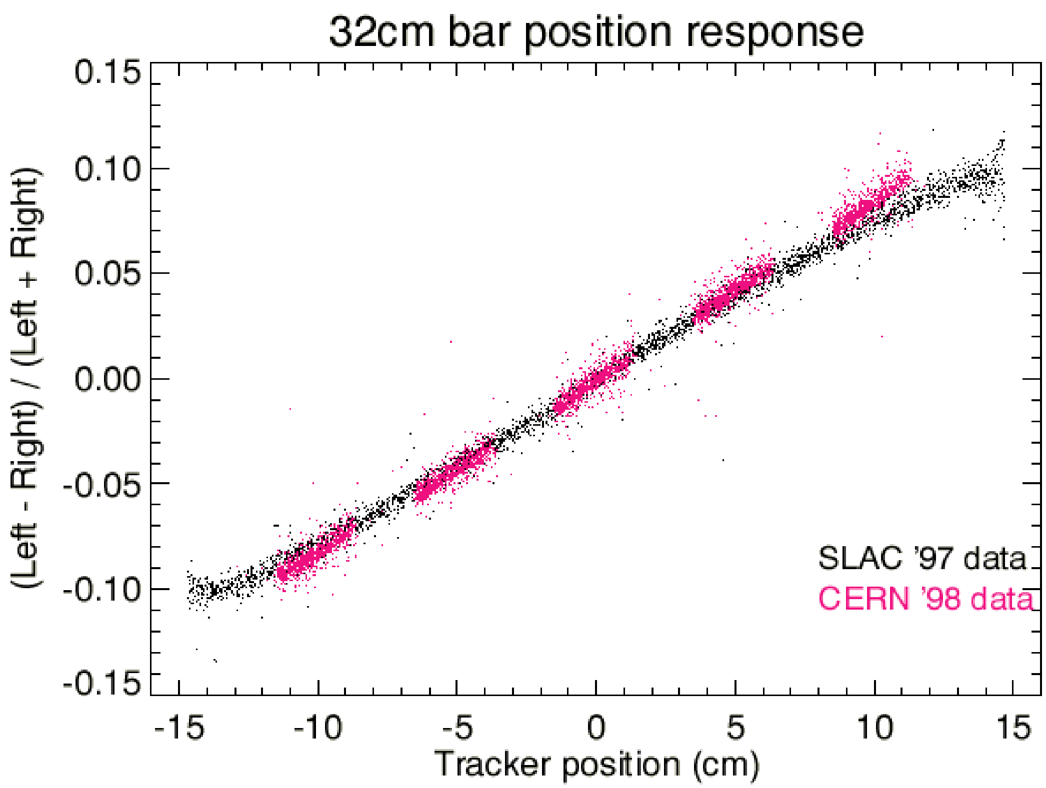
Calorimeter Mechanical Design



Calorimeter Optimization

Positioning with Light Asymmetry
32 cm CsI Bar Position Resolution

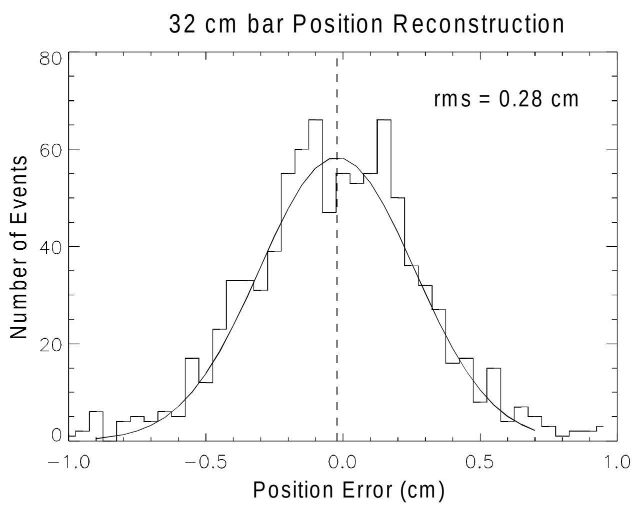
Light Asymmetry



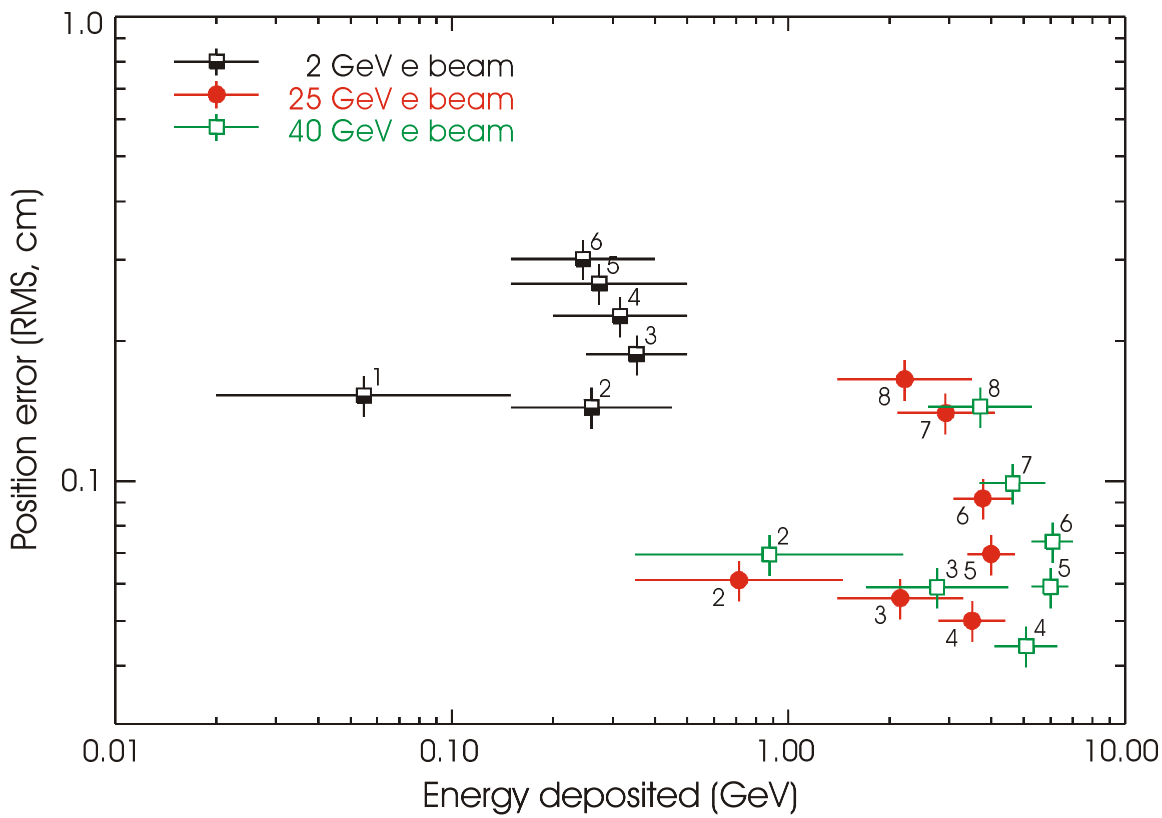
Position Resolution

SLAC e^- beam, 2 GeV

ΔE ~ 130 MeV



Position Resolution, SLAC '97



Position resolution is a function of:

- Slope of asymmetry;
- Energy deposited in crystal;
- Shower multiplicity;
- Transverse development of shower.

Longitudinal position resolution:

- 3 x 3 x 19 cm crystals.
- σ_x = 0. 4 mm – 4 mm

Light attenuation length:

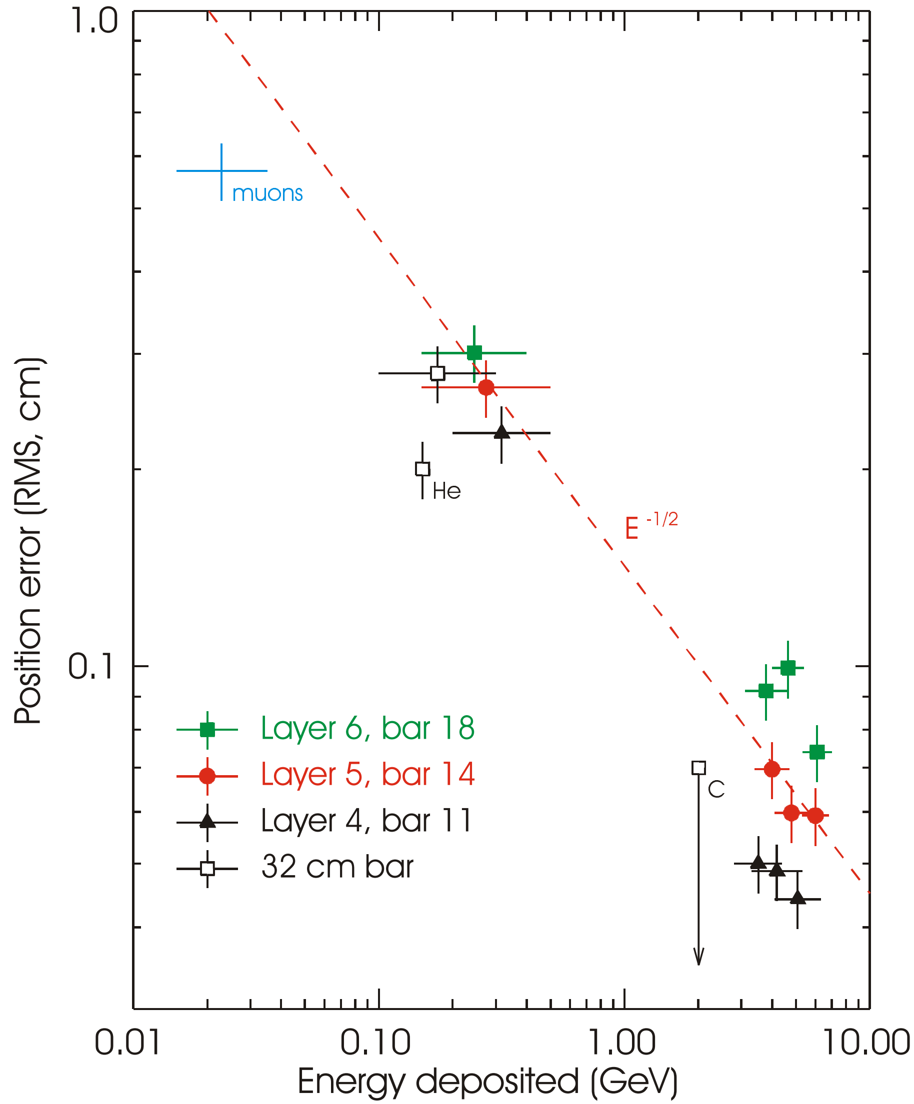
- $x = \lambda \times (R–L) / (R+L)$

Position Resolution Summary

Beam Test '97 at SLAC (EM Showers)

Beam Test '98 at Michigan State
(hadronic beams - p, He, C)

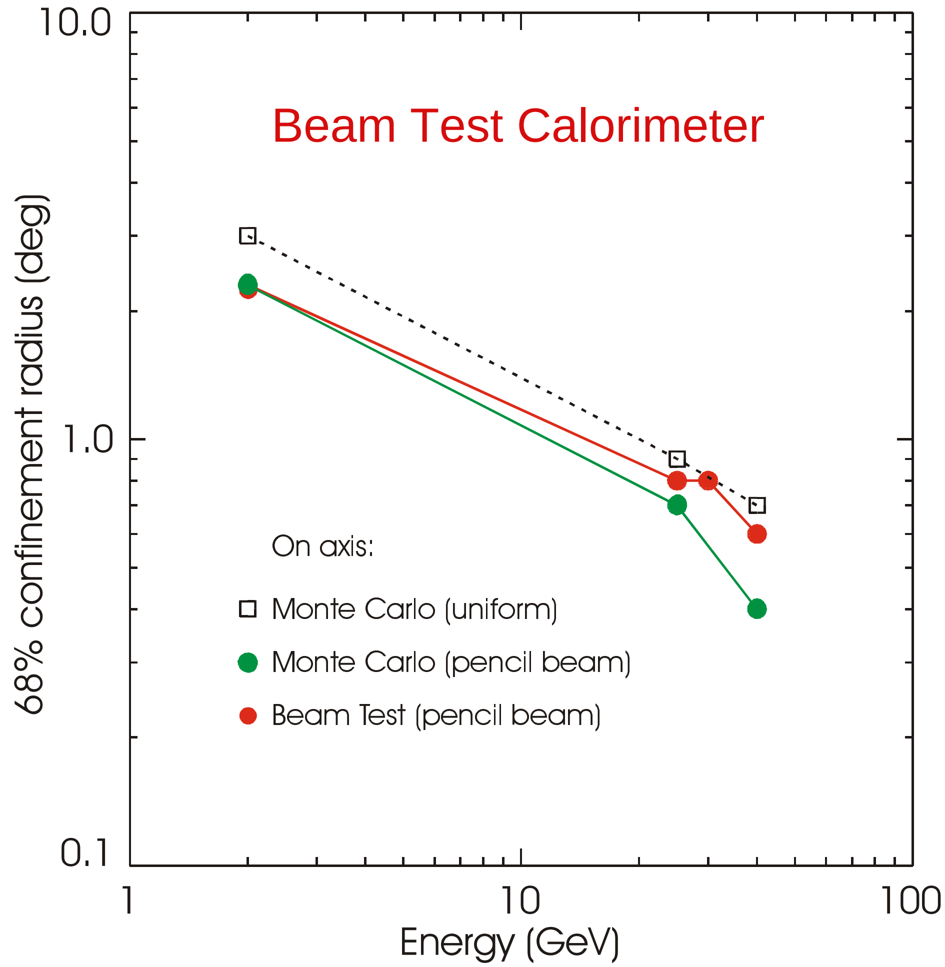
- For a given CsI bar, position resolution does indeed scale roughly as 1/√E.
- EM Shower characteristics limit resolution



1997 Beam Test of Calorimeter

Angular Resolution for Calorimeter Alone

- In the high-energy range, we can achieve better than 2° angular resolution on photons that do not convert in the tracker, more than doubling the effective area.
- The beam-test data validate the Monte Carlo simulation.



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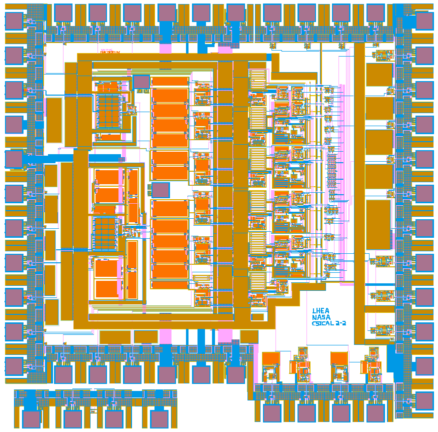
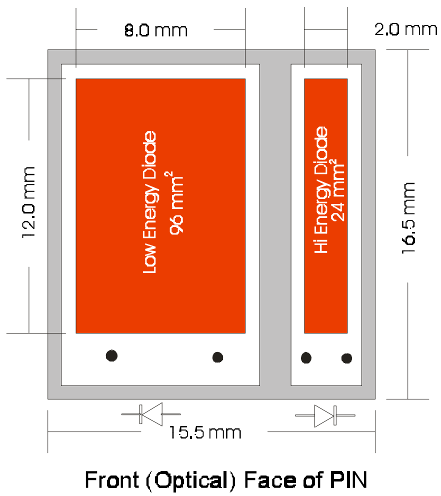
Calorimeter Electronics Development

Divide and Conquer

- **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: 40 MeV - 100 GeV
- **Custom front end ASIC**
  - 1 preamp, 3 shaping amps, 2 peak/hold and 4 discriminators per PIN
  - mux'ed output to ADC
- **Use COTS (commercial off the shelf) ADC**
  - 12 bit, successive approximation, low power
- **Custom dual PIN photodiode for GLAST from Hamamatsu.**
  - Based on 3590 PIN, 180 μm thick
  - Package is 15.5 mm x 16.5 mm ceramic carrier
    - Large diode area - 96 mm^2, ~70 pf
    - Small diode area - 24 mm^2, <20 pf

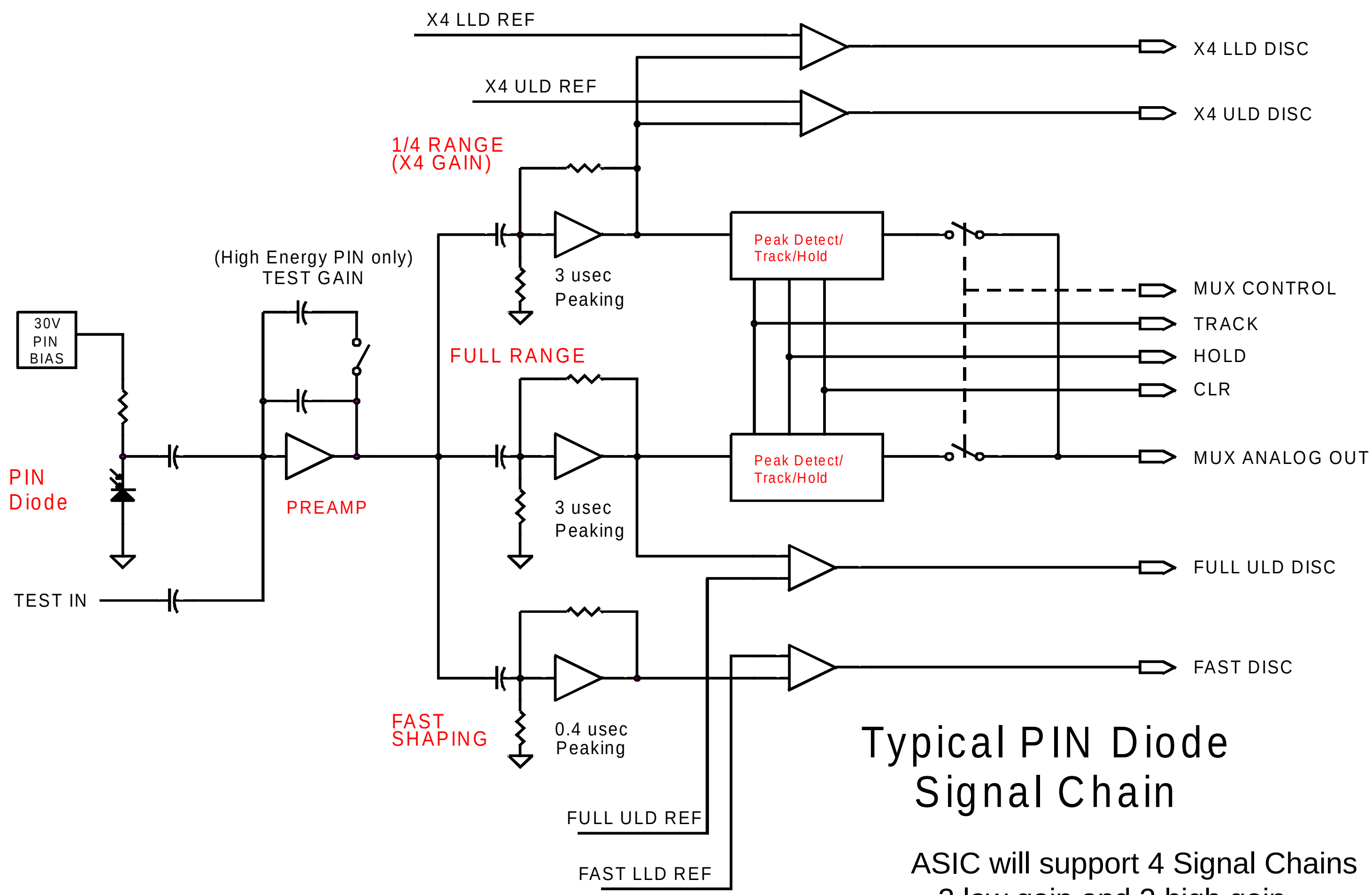


GSFC Calorimeter Front-end ASIC



Custom Dual PIN photodiode

Prototype ASIC PIN Signal Chain

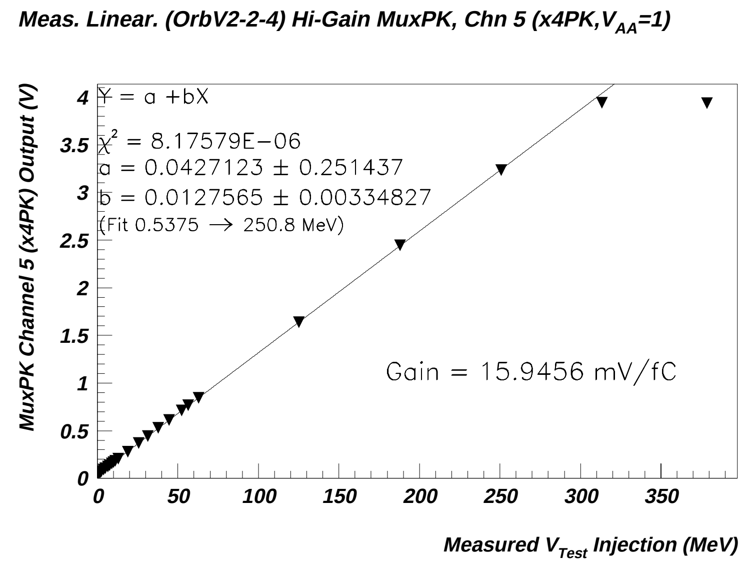


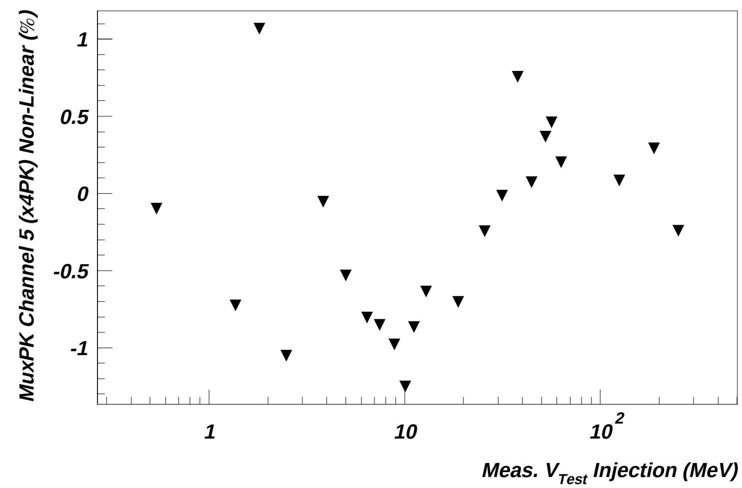
Typical PIN Diode Signal Chain

ASIC will support 4 Signal Chains
- 2 low gain and 2 high gain.

Prototype Tower Calorimeter Status

- **ASIC second-round prototype is in hand (12/98) and is undergoing testing:**
  - linearity within 2-3% over full dynamic range for step impulses (expect better for CsI signal)
  - all analog functionality needed for flight; present design can support 1999 beam test.
  - one more iteration planned early 1999 in ORBIT 1.2 micron process.
- **Front end PC boards for testing ASIC, ADCs and digital control / readout have been fabricated and tests are in progress.**
- **PIN diodes from Hamamatsu Photonics have been received by Univ. of Hiroshima; shipment to NRL by end of January.**
- **CsI is being procured from the Ukraine and from France (Crismatec). Prototypes have been received, manufacture is under way.**
- **Wire-chamber muon telescope fabricated for testing and calibration of CsI detectors.**
- **Layout of PC boards is in progress.**
- **Detailed mechanical drawings have been produced by Hytec and are being reviewed.**





ASIC Linearity Test Results

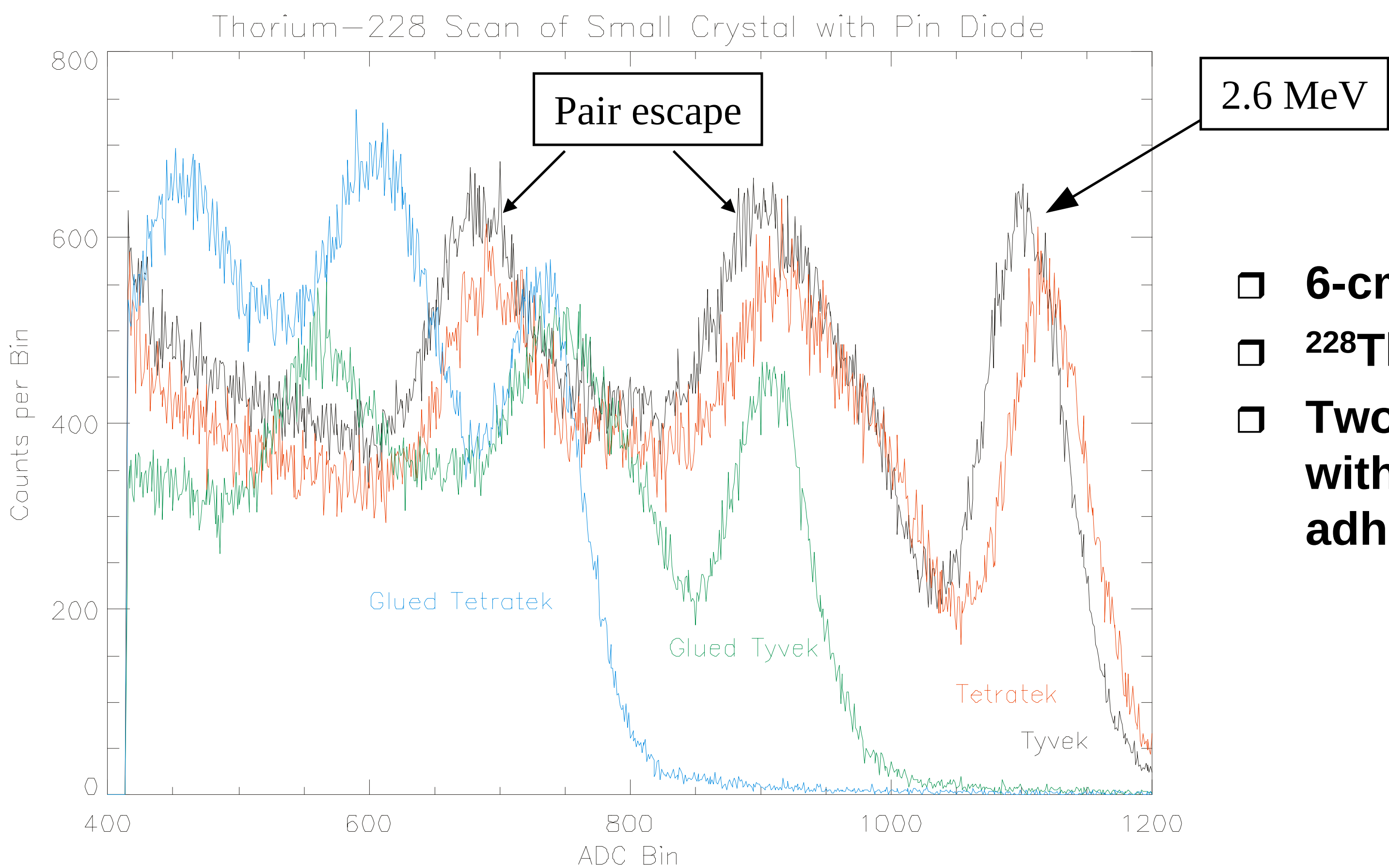
Calorimeter Trade Studies

- **Instrument Configuration:**
  - Calorimeter inside or outside the Grid.
  - Calorimeter technology – CsI vs. Scintillating Fiber.
  - Vertical crystals vs. imaging hodoscopic layout.
  - CsI Imaging optimization – CsI dimensions, number of planes, logs per plane, SSD
  - Vertex with and without a large gap after the first CsI layer.
- **Calorimeter Optimization:**
  - Mechanical Design.
    - "Jail bars" Compression cell
    - Unidirectional Compression cell — baseline and prototype tower.
    - Carbon shells — currently under investigation in France
  - CsI Light Collection – Wrappings, compression, tapering.
- **Calorimeter Readout:**
  - Required dynamic range of electronics.
  - Achieving the dynamic range with a system that can be calibrated.
  - Front-End ASIC design.
  - Digital readout and DAQ interface. Role played in trigger.

Trade Study - Compression Cell Design

- **Study of compressive load impact on light collection for various wrapping techniques**
  - Short-term loss not significant, stabilizes after ~10 days
- **Study of light collection impact of various crystal wrapping techniques:**
  - treatment of CsI block ends vs light output
  - Tyvek, Tetratek, and paints
  - Tyvek & Tetratek laminated with Aluminized mylar
  - laminates attached to crystals with adhesives
  - Paints are out, laminates show promise
- **Shake test performed with Tyvek, Tetratek and laminate with adhesive**
  - slippage with Tyvek (coeff. of friction is ~0.16, need >0.5)
  - Tetratek tests successful - no slippage to limit of shaker.

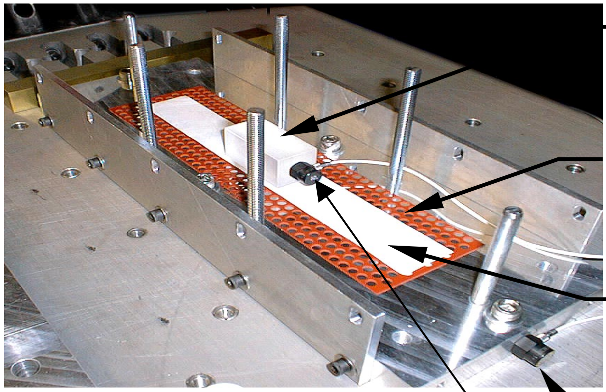
CsI Light Collection vs. Wrapping Techniques

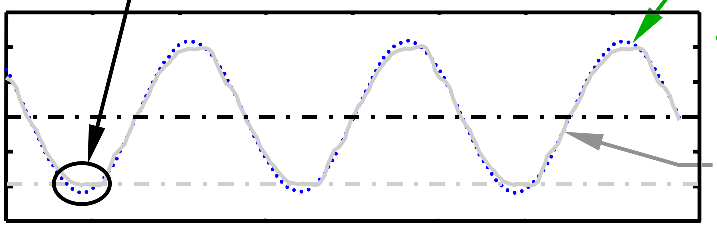


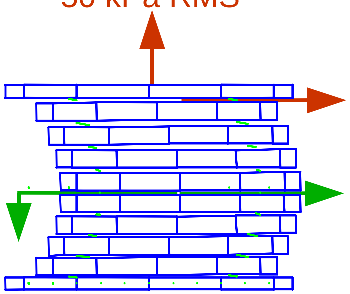
- 6-cm CsI Detector
- ^{228}Th source
- Two wrappings with and without adhesives

Testing the Compression Cell Concept

- Measurements of degradation of light collection with various compressed crystal wrappings: only about 15% loss.
- Measurements of friction coefficients between crystal wrappings and compliant layers.
- Random vibration testing of wrapped crystals held by friction between compliant layers.
- Dynamic analysis of the compression cell mechanical structure (f_0=88 Hz, Q~4).
- The concept works well, and final engineering is in progress to apply it to the prototype tower.





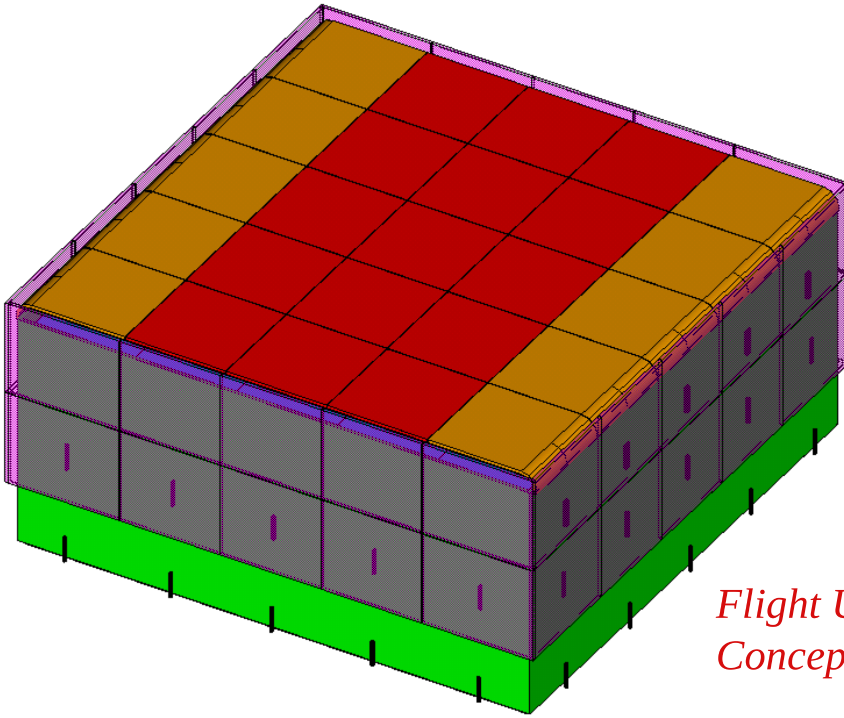


AntiCoincidence Detector (ACD) Technology Development

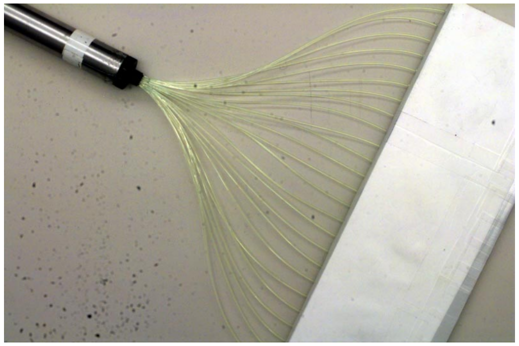
- **Optimization of Performance - Simulations / Beam Tests**
  - Achieve particle background rejection efficiency of 0.999. Entire GLAST requirement is 0.99999 (1 in 10^5), goal is 1 in 10^6
  - Study segmentation of ACD and area of coverage. Addresses “backsplash” effects which limit GLAST sensitivity at high energies.
  - Support calibration of calorimeter with hi-Z cosmic ray tagging.
  - Support for side-entering electron rejection
- **Mechanical Design**
  - Detector selection, segmentation and read out
  - Mechanical structure - light shield, thermal blanket, micrometeoroid shield
  - System integration
- **Electronics Design**
  - Front end electronics
  - Trigger interface
  - Data Acquisition (DAQ) interface

ACD Design

- **Plastic scintillator tiles**
  - ~ tower sized tiles, single layer
  - 65 tiles cover top and sides of tracker
  - light collection via redundant sets of waveshifting fibers
- **Read out by PMT**
  - 2 PMT per tile (redundancy)
- **Electronics**
  - ASIC front end
  - two-level trigger (MIP & hi-Z)
  - pulse height measurements
  - Redundant, independent interfaces to data acquisition system
- **Mechanical**
  - Composite structure with tiles attached
  - Mounts as "hat" over array of towers



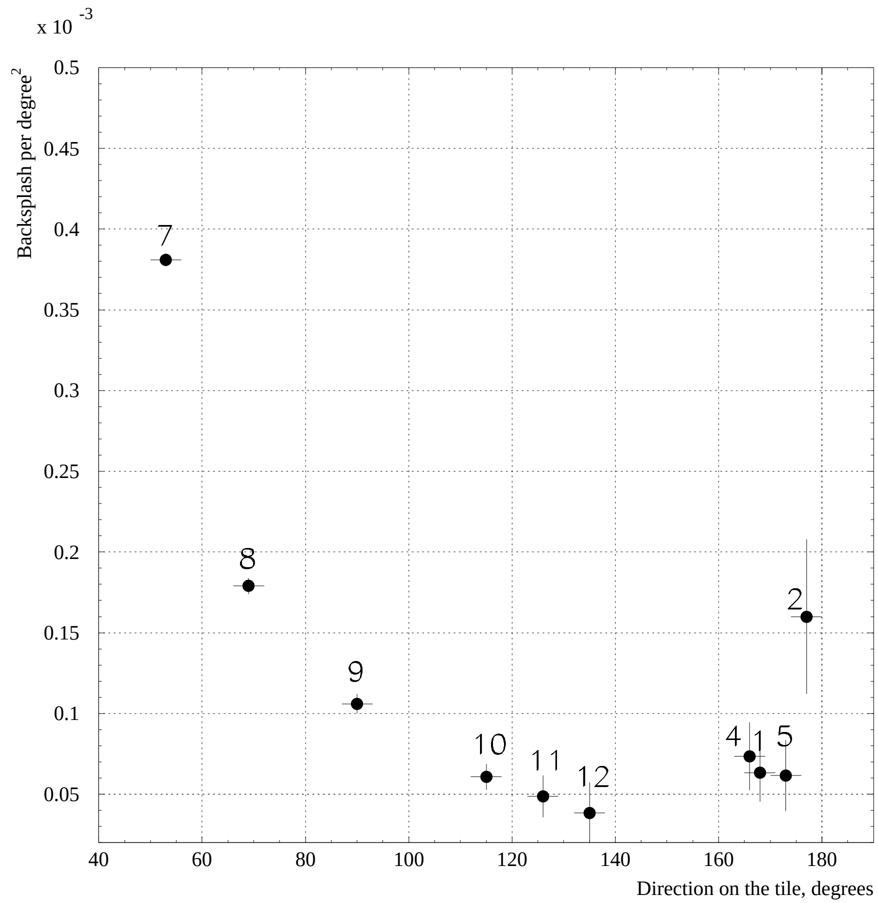
Flight Unit Concept



Scintillation Tile w/ waveshifting fiber-PMT readout

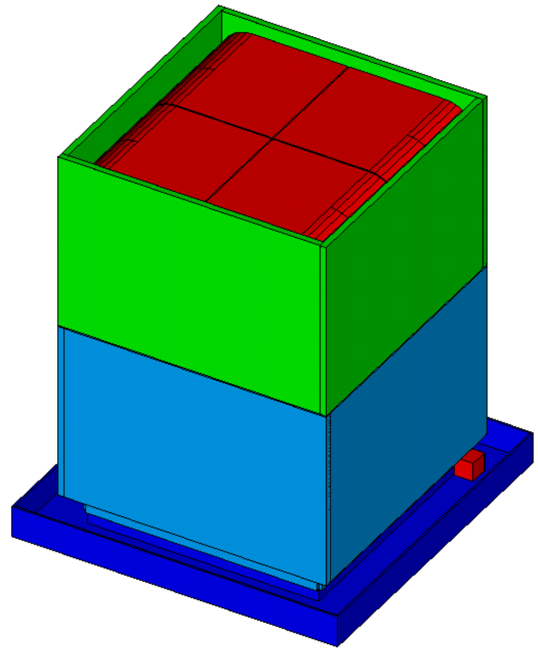
1997 Beam Rest Results

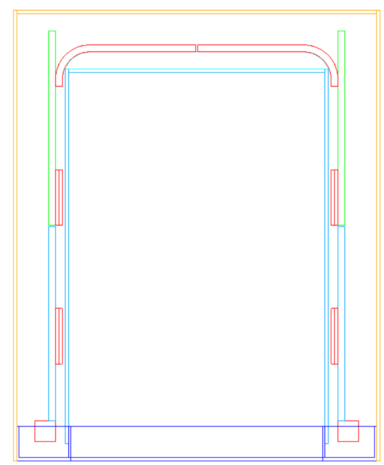
- **Single layer ACD adequate vis-à-vis backscatter**
- **Segmentation requirement determined**
  - tower-scale segmentation maintains > 80% efficiency to 300 GeV
- **False veto rates and angular distribution of backsplash agree with Monte Carlo studies to within factor of 2**
  - Allows extrapolation from beam energies to >300 GeV using GLASTSIM
- **Waveshifting fiber readout provides uniform response, efficiency > 0.9995**



Backsplash rate per solid angle for 20-25 GeV photon-initiated showers, as measured in the 1997 SLAC beam test.

ACD Beam Test Prototype Objectives





Verify Simulations

- Efficiency
- Leakage
- Backsplash avoidance
  - measure backsplash spectrum
  - test backsplash angular distribution
  - test direct detection in fibers and PMT
- Validate DAQ interface

Secondary Goals

- Study EMI/EMC
- Study bending/routing of fibers
- Gain experience with mini PMTs

Prototype Tower ACD Status

- **Beam tests and simulations demonstrate the ability to achieve >10^3 rejection against charged particles**
  - Internal pattern recognition utilizing tracker and calorimeter information as well achieves system goal of 10^6
- **Conceptual design of mechanical support system, fiber routing, PMT selection and electronics exists**
- **Fabrication of mechanical support, fibers, PMTs and electronics will begin soon to meet beam test unit schedule**
  - Interfaces have been defined
  - Electronics breadboarding and simulations of single channel chain are being performed

ACD Trade Studies

- **Configuration:**
  - One layer or two layers? - Requirements met with one layer.
  - Cover the calorimeter? - No, not necessary.
  - Central system, or separate system per tower? - Central, Redundant
  - Optimal Segmentation? - Study in progress, ~ tower-sized OK.
- **Trigger Veto:**
  - Use the ACD in trigger level 1? - Backup capability for level 1 veto.
- **Mechanical:**
  - Locations of the phototubes.
  - Support structure—derive some support from tracker towers?

ATD Option I Objectives

- ★ **Complete the prototype tower and test in the SLAC beams.**

- ❒ **Perform environmental testing on prototype calorimeter.**
  - Vibration to launch qualification levels
  - Thermal testing
- ❒ **Complete trade studies of alternate calorimeter mechanical design (Ecole Polytechnique)**
  - Fabricate prototype of carbon shell mechanical design
  - Test performance in CERN beam test
  - Perform vibration testing
- ❒ **Continue with calorimeter and ACD front-end electronics development**
  - Complete functionality of FEE chip - add programmable DACs and range control
  - Investigate alternate ASIC processes
  - Test radiation hardness and latchup susceptibility
- ❒ **Complete Monte Carlo optimization of ACD design, system rejection of backgrounds, and photon identification algorithms**
  - optimize thickness of side ACD including thermal blanket
  - optimize mechanical design and layout of ACD tiles

Conclusions

- **Beam tests of the calorimeter and ACD systems have shown good agreement with simulation predictions.**

- **The prototype calorimeter for the 1999 beam test will test all key technology issues for the calorimeter:**
  - viability of the mechanical design
  - electronic system performance
  - imaging and other scientific performance

- **The ACD for the 1999 beam test will provide more precise measurements of efficiency, leakage, and backsplash for further refinement of the ACD design.**

★ **The calorimeter and ACD technologies are well in hand. There are no significant road blocks to a flight design of these GLAST systems.**