Gamma-ray Large Area Space Telescope

GLAST

A Partnership in Astrophysics and Particle Physics

Robert Johnson
University of California at Santa Cruz

Presentation to SLUO
July 15, 1998

GLAST Collaboration, July 1998

R. Arnold [a]
W. Atwood [t,b]
G Barbiellini [w]
L. Bergstrom [u]
D. Bertsch [n]
V. Bidoli [p]
E. Bloom [t]
J. Bonnell [n]
P. Bosted [a]
U. Bravar [w]
T. Burnett [z]
P. Caraveo [α]
P. Carlson [q]
C. Chaput [t]
A. Celotti [w]
D. Chenette [k]
L. Cominsky [s]
B. Costanzo [k]
C. Covault [c]
W. Craig [d]
J. Danzige [w]
S. Digel [n]
B.Dingus [y]
D. Dorfan [b]
A. Ferrari [x]
P. Fleury [f]
T. Francke [q]
Y. Fukazawa [v]
N. Gehrels [n]
M. Gliozzi [x]
G. Godfrey [t]
I. Grenier [e]
J. Grove [o]
H. Gursky [o]
C. Hailey [d]
R. Hartman [n]
J. Hernando [b]
M. Hirayama [b]
S. Hunter [n]
R. Johnson [b]
W. Johnson [o]
S. Kahn [d]
T. Kamae [v]
K. Kasahara [r]
N. Kawai [h]
T. Kifune [v]
W. Kroeger [b]
H. Kubo [h]
Y. Lin [t]
M. Lovellette [o]
J. Mattox [β]
H. Mayer-Hasselwander [l]
P. Michelson [t]
A. Moiseev [n]
M. Mori [v]
A. Morselli [p]
G. Nakano [k]
G. Navarra [x]
P. Nolan [t]
J. Norris [n]
T. Ohsugi [g]
R. Ong [c]
M. Oreglia [c]
J. Ormes [n]
J. Paul [e]
A. Perrino [p]
B. Phlips [o]
P. Picozza [p]
P. Ray [o]
E. Reali [p]
S. Ritz [d,n]
S. Rock [a]
H. Sadrozinski [b]
J. Scargle [m]
P. Schiavon [w]
F. Sciulli [d]
S. Severoni [p]
G. Share [o]
J. Skibo [o]
D. Suson [o]
Z. Szalata [a]
T. Takahashi [i]
T. Tamura [j]
M. Tavani [α, d]
D. Thompson [n]
S. Torii [j]
A. Vacchi [w]
M. Villata [x]
K. Wood [o]
A. Yoshida [h]
K. Yoshida [j]

91 Collaborators

[a] *The American University, Department of Physics, Washington, D.C.*

[b] *University of California, Santa Cruz, Department of Physics, Santa Cruz, California*

[c] *University of Chicago, Department of Physics, Chicago, Illinois*

[d] *Columbia University, New York, New York*

[e] *Commissariat a l'energie atomique (CEA), Saclay, France*

[f] *Ecole Polytechnique, Laboratoire de Physique Nucleaire des Hautes Energies (LPNHE), Palaiseau, France*

[g] *Hiroshima University, Department of Physics, Hiroshima, Japan*

[h] *The Institute of Physical and Chemical Research, Saitama, Japan*

[i] *The Institute of Space and Astronautical Science, Sagamihara, Japan*

[j] *Kanagawa University, Institute of Physics, Kanagawa, Japan*

[k] *Lockheed-Martin Solar and Astrophysics Laboratory, Lockheed-Martin Advanced Technology Center, Palo Alto, California*

[l] *Max-Planck-Institut für extraterrestrische Physik (MPE), Garching, Germany*

[m] *NASA Ames Research Center, Mountain View, California*

[n] *The NASA/Goddard Space Flight Center, Greenbelt, Maryland*

[o] *The Naval Research Laboratory, Washington, D.C.*

[p] *University of Rome, Department of Physics and Instituto Nazionale di Fisica Nucleare, Tor Vergata, Rome, Italy*

[q] *Royal Institute of Technology, Stockholm, Sweden*

[r] *Shibaura Institute of Technology, Department of Electronic Information Systems, Faculty of Systems Engineering, Shibaura, Japan*

[s] *Sonoma State University, Department of Physics and Astronomy, Rohnert Park, California*

[t] *Stanford University, Department of Physics; Hansen Experimental Physics Laboratory; Stanford Linear Accelerator Center, Stanford, California*

[u] *Stockholm University, Stockholm, Sweden*

[v] *University of Tokyo, Department of Physics, Institute for Cosmic Ray Research, Tokyo, Japan*

[w] *University of Trieste, Department of Physics, Instituto Nazionale di Fisica Nucleare and Scuola Internazionale Superiore di Studi Avanzati, Trieste, Italy*

[x] *University of Turin, Department of Physics, Osservatorio Astronomico, Turin, Italy*

[y] *University of Utah, Department of Physics, Salt Lake City, Utah*

[z] *University of Washington, Department of Physics, Seattle, Washington*

[α] *Instituto di Fisica Cosmica e Tecnologie Relative, CNR, Milano, Italy*

[β] *Boston University, Boston, Massachusetts*

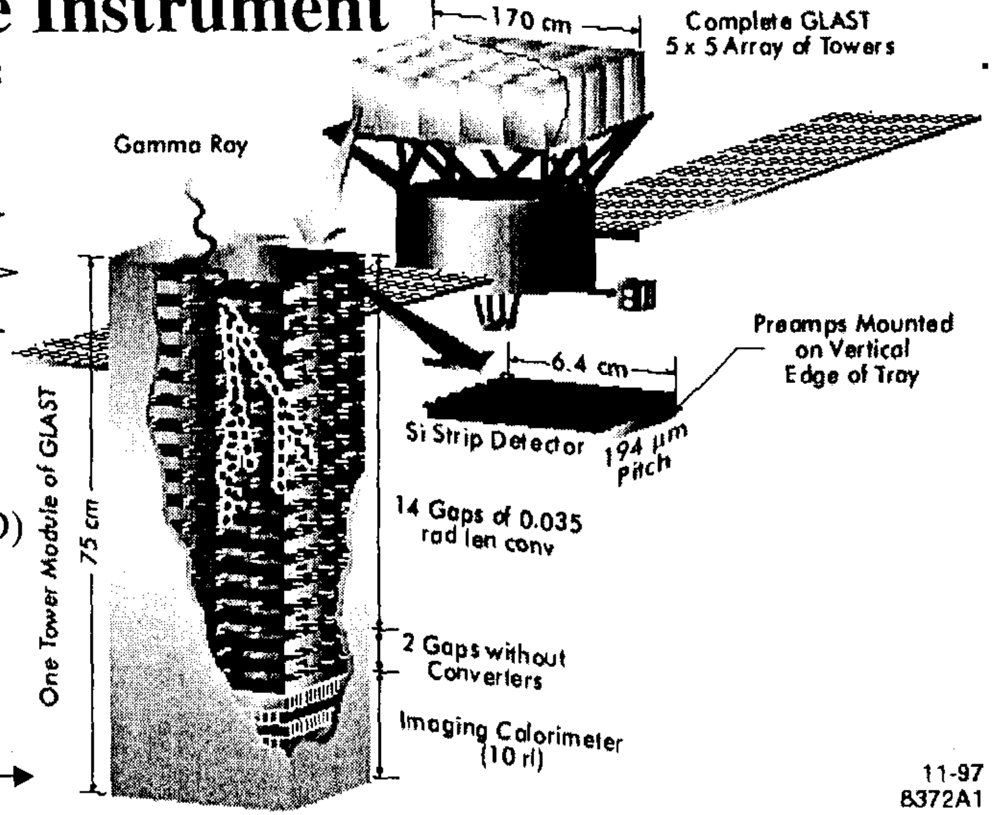
28 Institutions

GLAST Baseline Instrument

Pair Conversion Telescope followed by E-M calorimeter

- Scintillator anti-coincidence detector (ACD)
- Silicon strip tracker (0.7 r.l. distributed)
- Imaging Cs I calorimeter (10 r.l.)

Single Tower →



- **Almost 2π detector, looking away from the earth in scanning mode → all sky monitor.**
- **Modular in 25 identical towers → redundancy to avoid catastrophic failures.**
- **No consumables → long mission lifetime (> 5 years).**
- **Robust and well understood technologies → no surprises!**
- **Low detector noise → high efficiency, self triggering.**
- **Flexible programmable HEP type trigger → changing and multifaceted physics goals.**

GLAST R&D Program Overview

- *Simulation studies for optimization and verification of the conceptual design.*

- *Construction of a prototype tower over the next 18 months.*

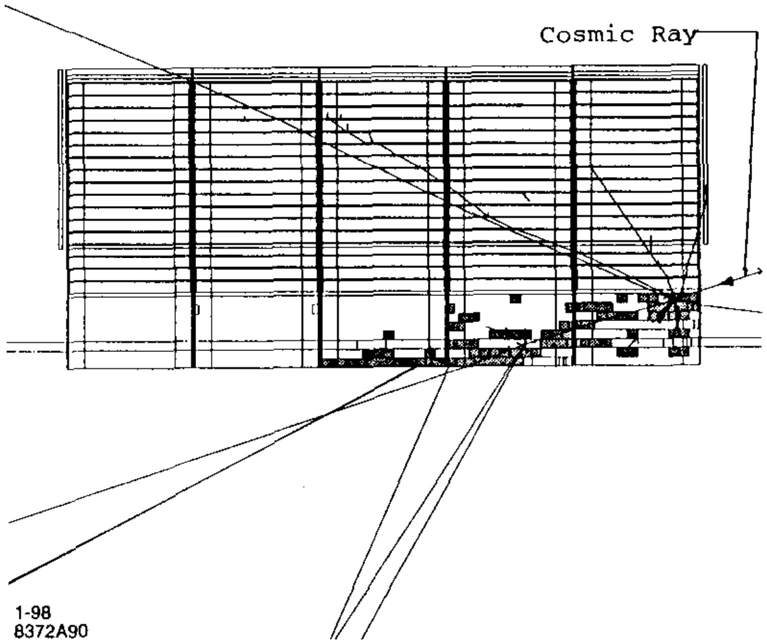
- *Beam tests at SLAC and CERN.*

- *Electrical, mechanical and thermal design for the full GLAST instrument.*

- *DAQ system design for the full GLAST instrument.*

Simulations

- The GLAST baseline concept has been thoroughly investigated and verified by detailed Monte Carlo simulation.
- Two years of work was put into this ***before*** any significant investment was made in hardware development.
- Summary:
  - Cosmic-ray rejection of $\approx 5 \cdot 10^5$:1 with 80% gamma-ray efficiency. Signal/Noise >20::1 for extragalactice diffuse gammas.
  - Solid predictions for effective area and resolutions (now verified by beam tests).
  - Workable scheme for triggering.
  - Design optimization.



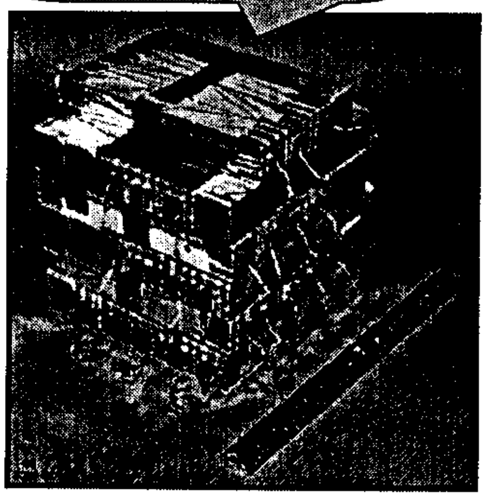
An example simulation of a 15-GeV cosmic ray proton striking the GLAST calorimeter.

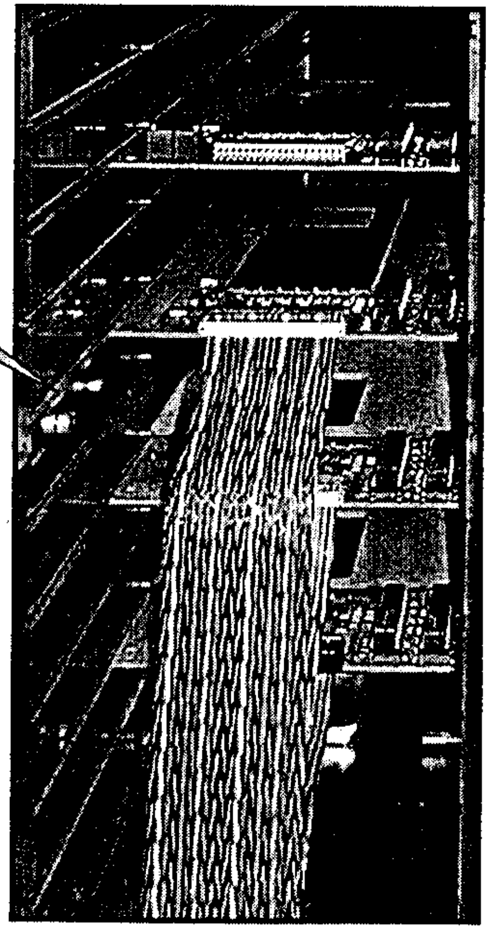
October 1997 Beam Test at SLAC

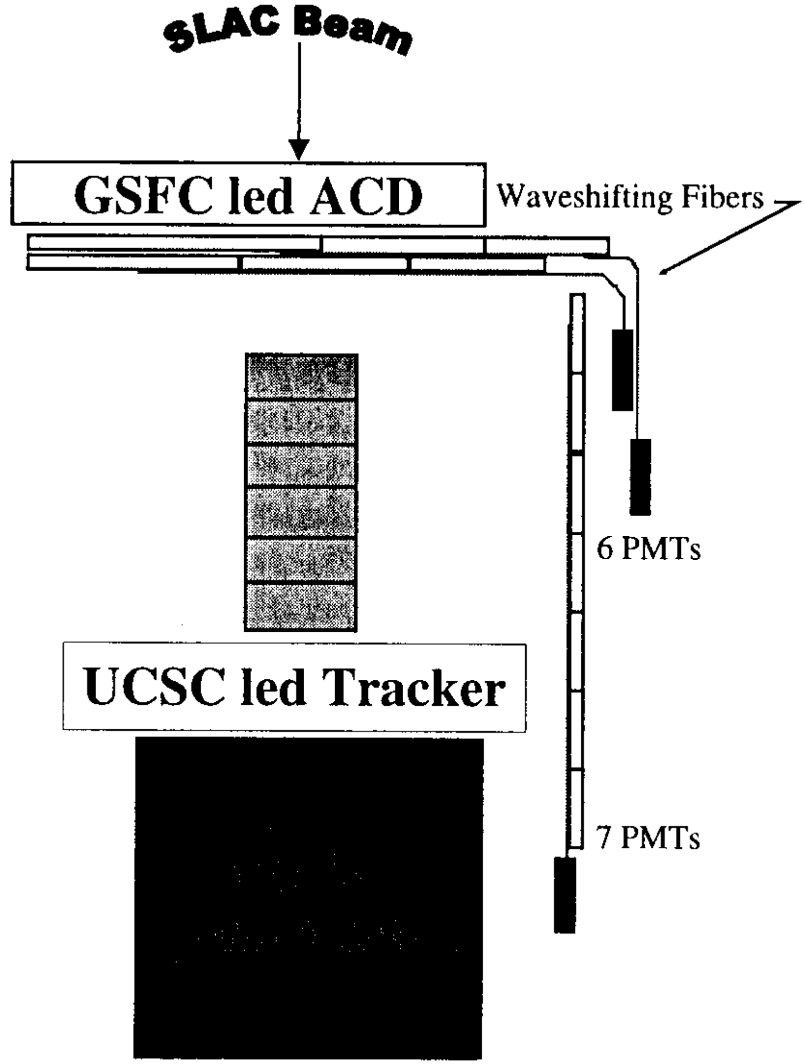
Broad participation across the collaboration.
Test of prototype components of the GLAST baseline design.

UCSC led SSD tracker with 6 x,y planes and interchangeable converter foils

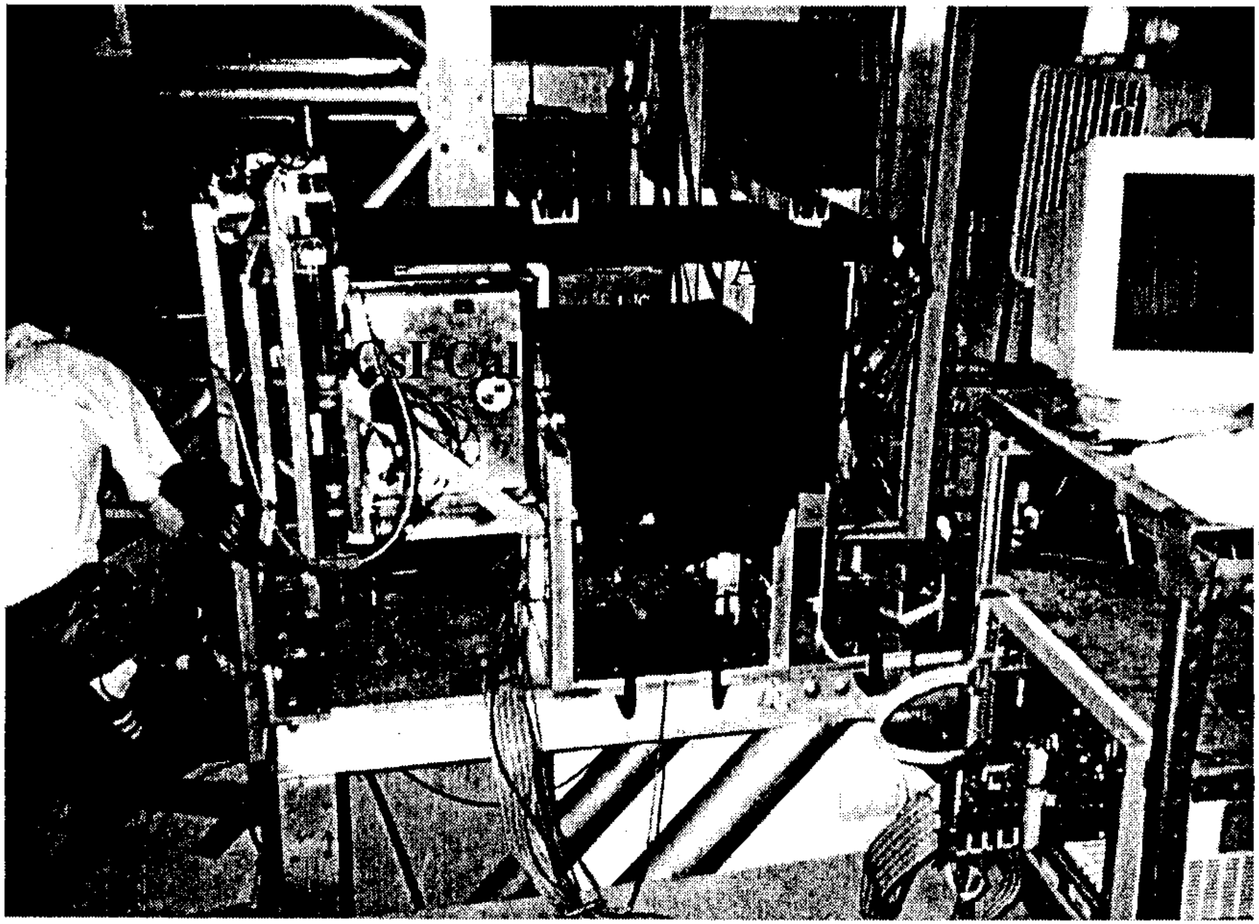
NRL led Hodoscopic CsI Calorimeter







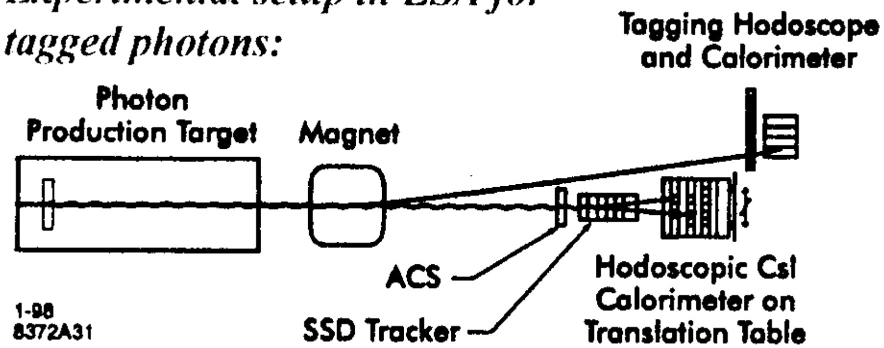
October 1997 Beam Test: SLAC-ESA



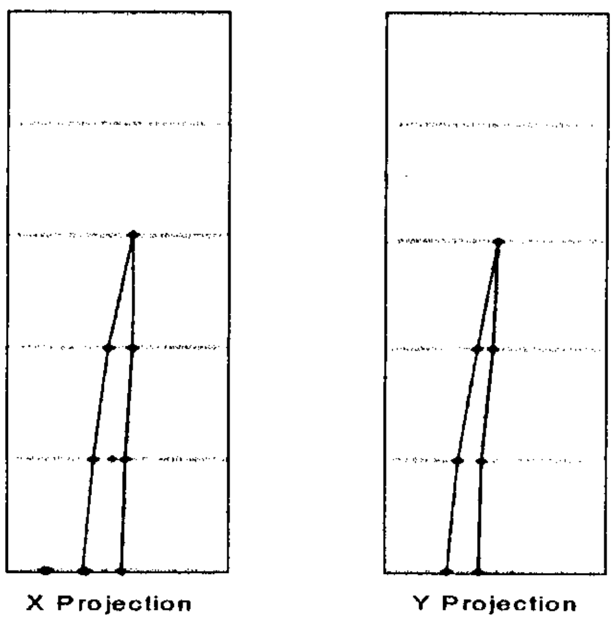
All elements of a prototype tower in *miniature* designed to play together.

GLAST Beam Test, Tracker Performance

Experimental setup in ESA for tagged photons:



3-cm spacing, 400 MeV photon

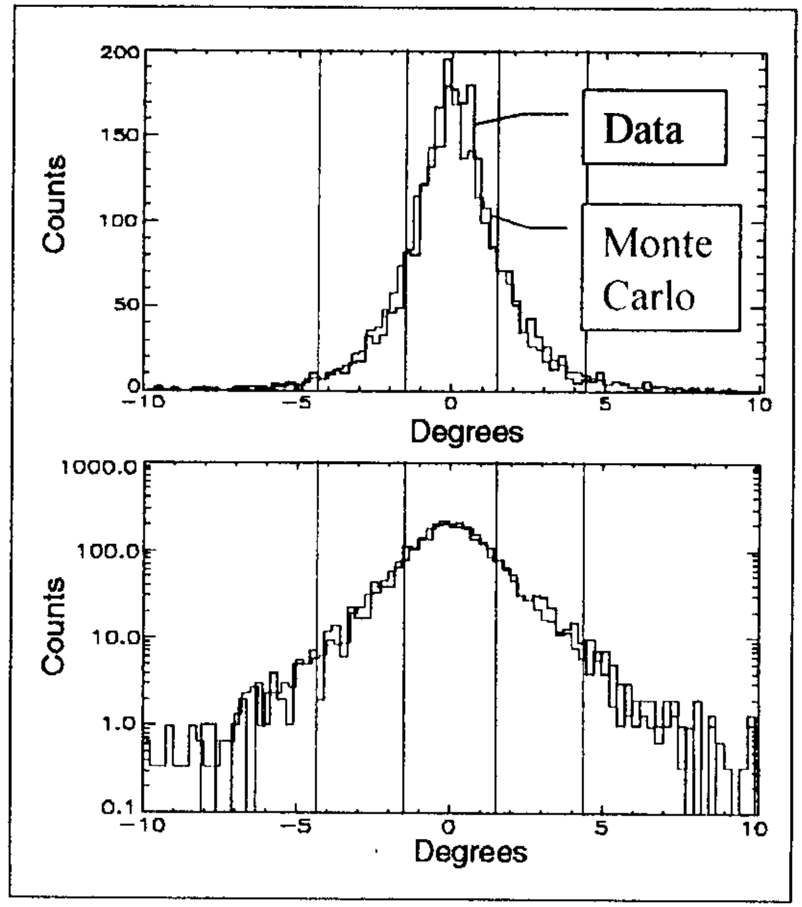


To scale

400 MeV

X Projected Angle

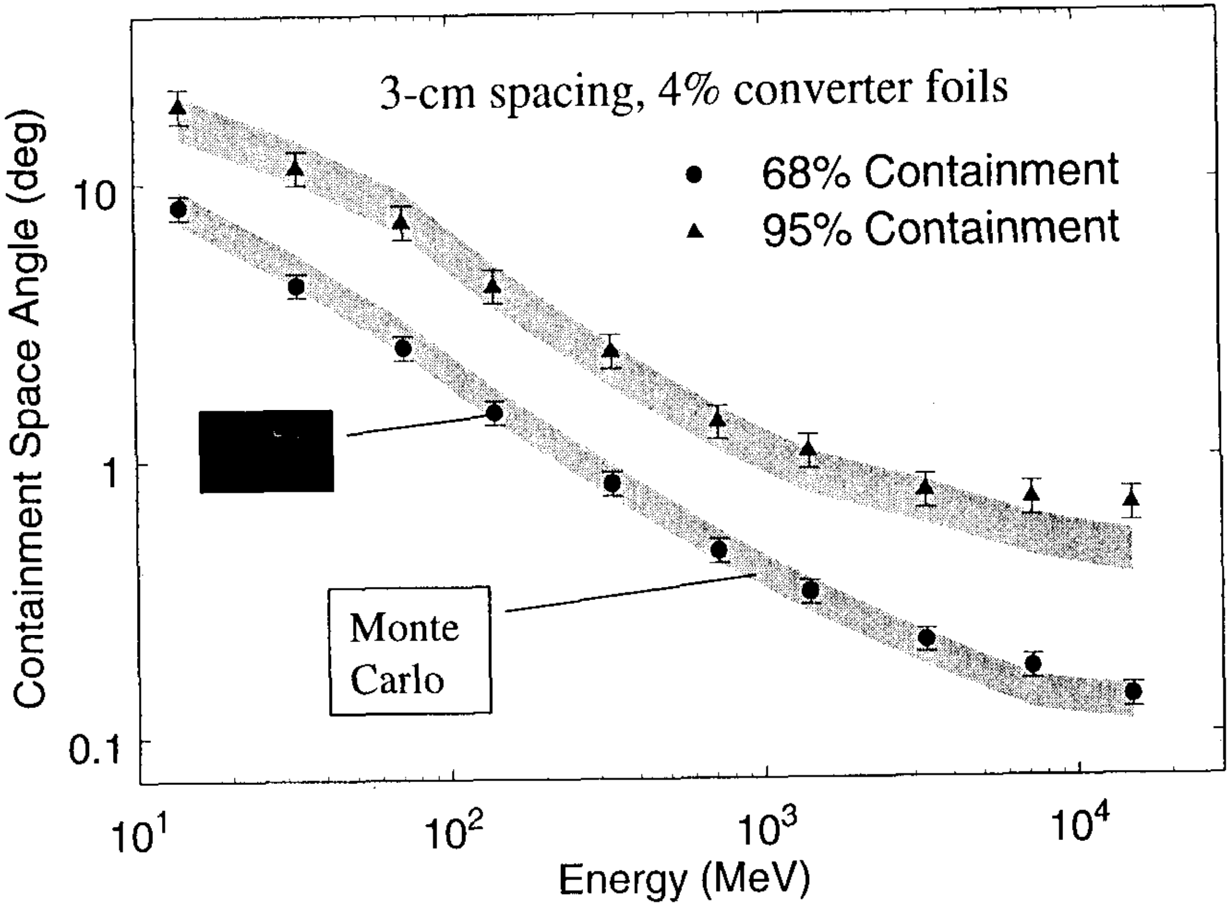
3-cm spacing, 4% foils, 100-200 MeV



Excellent agreement of data with MC

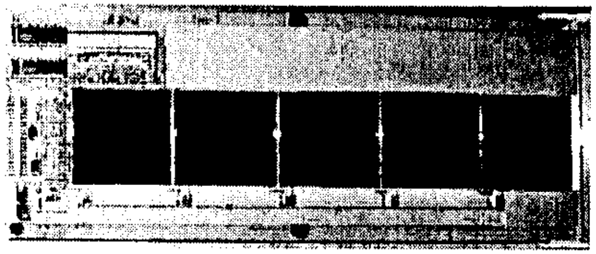
(Note that the performance shown differs from that of the full-scale device, due to severe edge effects in the beam test tracker.)

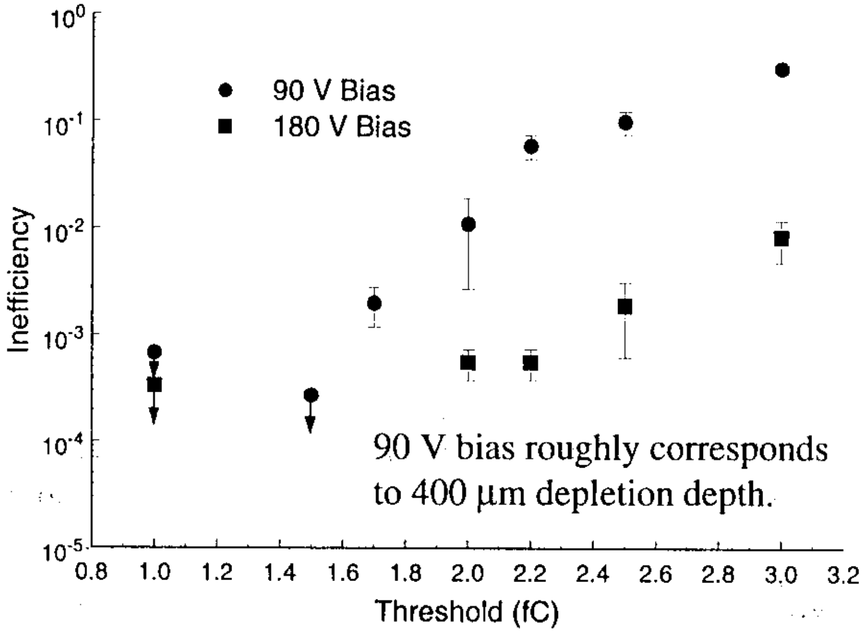
Tagged Photons



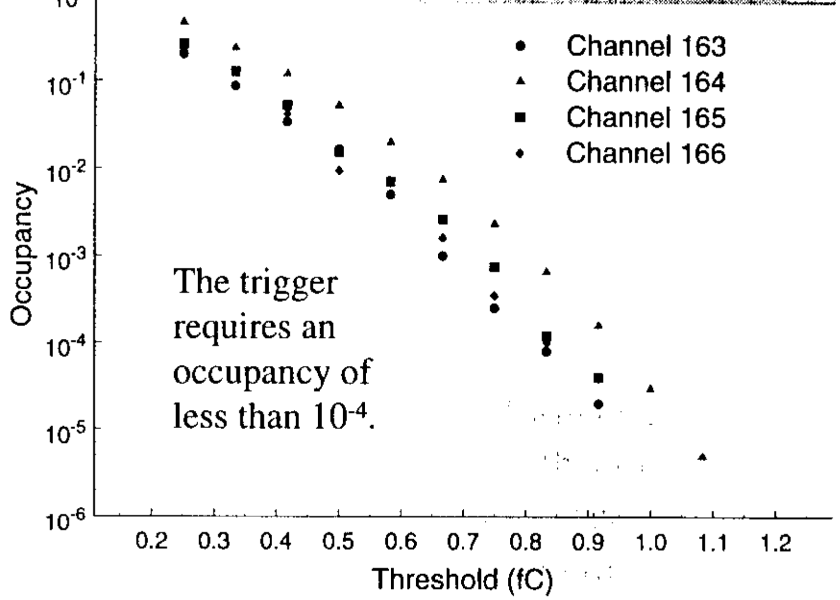
GLAST Beam Test, Tracker Performance

Tracker electronics performance measured with a 30 cm long detector ladder.





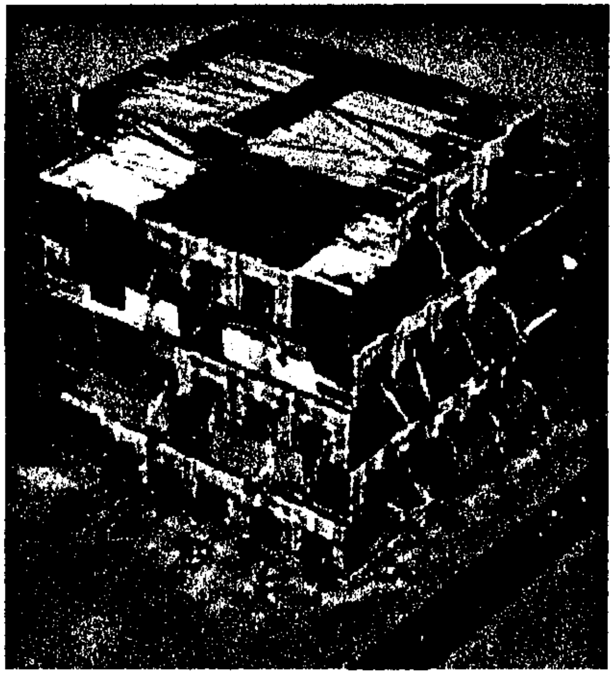
Inefficiency for detection of minimum ionizing electrons at normal incidence in a single detector plane. The nominal threshold used is 1.5 fC.

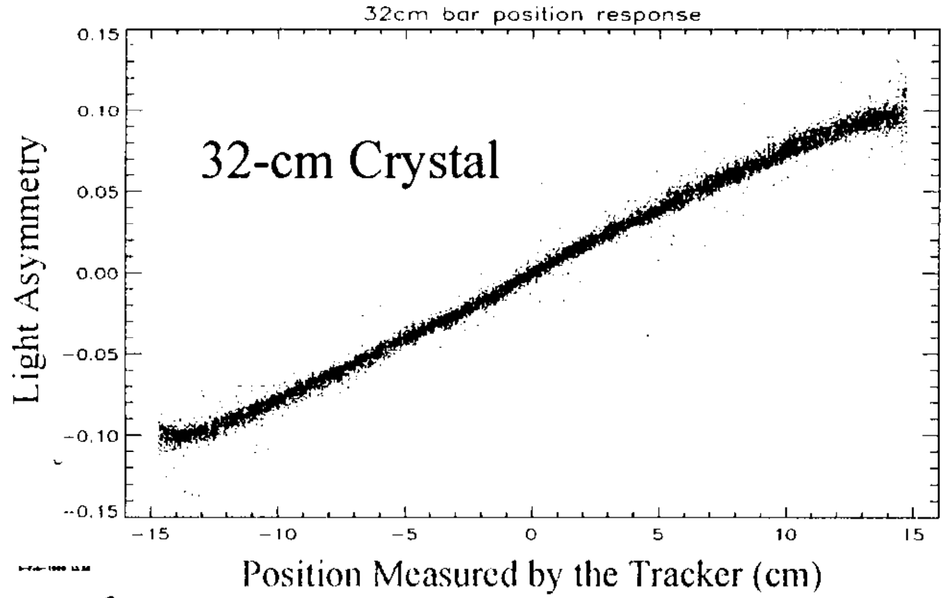


Noise occupancy, in a 1 μs window, versus threshold for four different channels connected to 30 cm long detector strips.

GLAST Beam Test, Calorimeter Performance

Imaging Calorimeter Concept





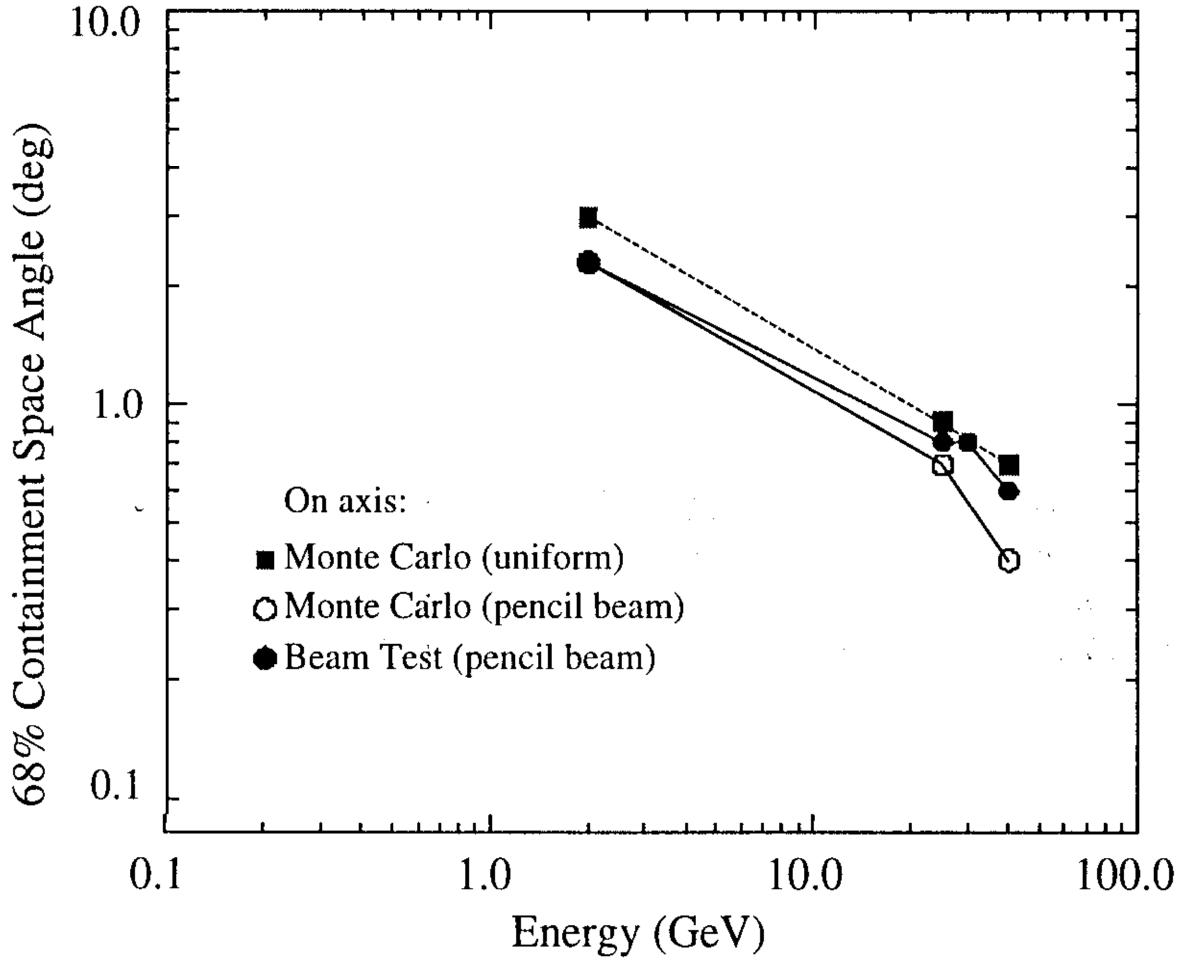
- Hodoscopic CsI calorimeter stack.
- 24 19-cm long CsI crystals.
- PIN diode readout on each end of each crystal, for measurement of the position from light asymmetry.
- A single 32-cm long crystal was also tested.

GLAST Beam Test, Calorimeter Performance

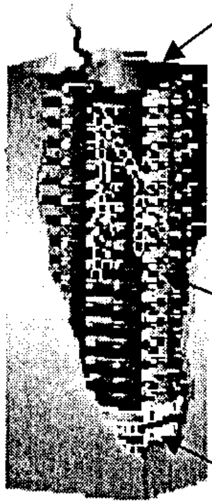
Calorimeter-Only Angular Resolution

In the high-energy range, we can achieve better than 1° 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.

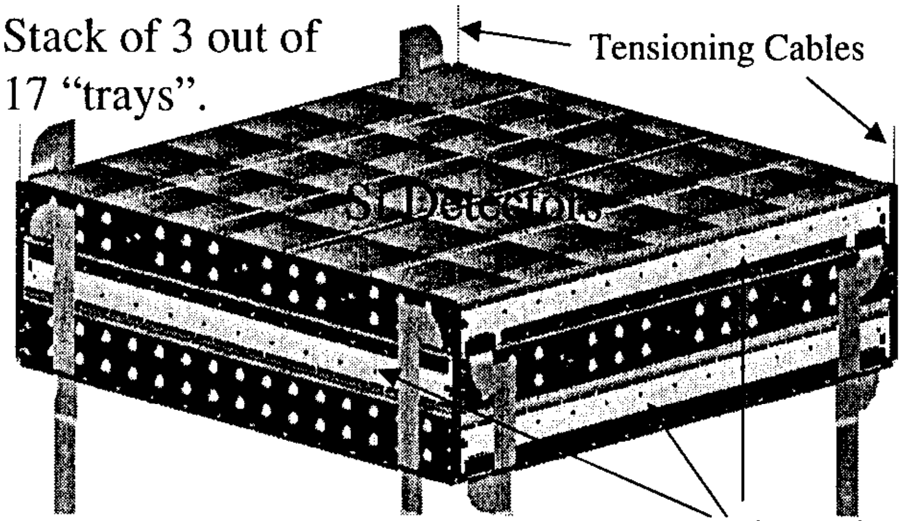


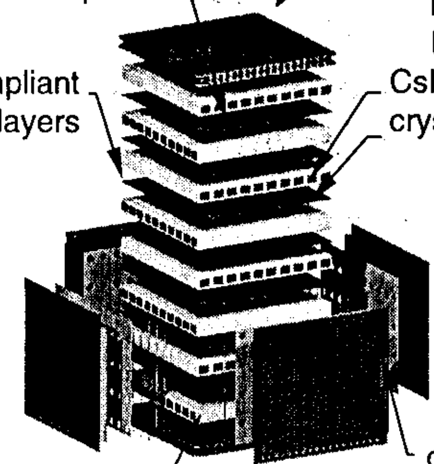
Prototype Tower Design

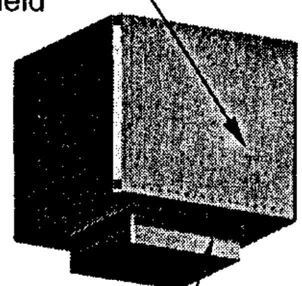


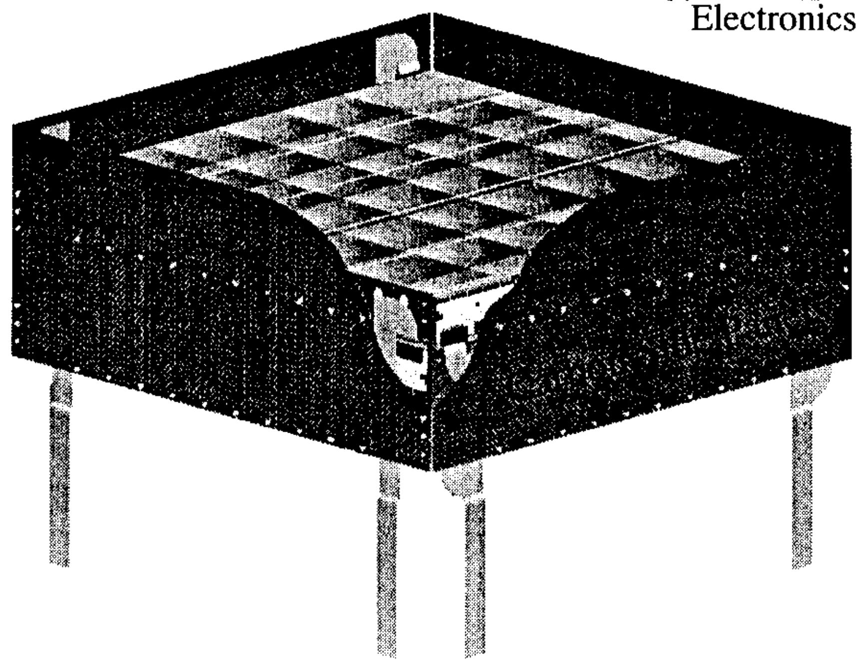
Mechanical design is by collaboration of Hytec Inc., SLAC, NRL, and GSFC.

Stack of 3 out of 17 "trays".

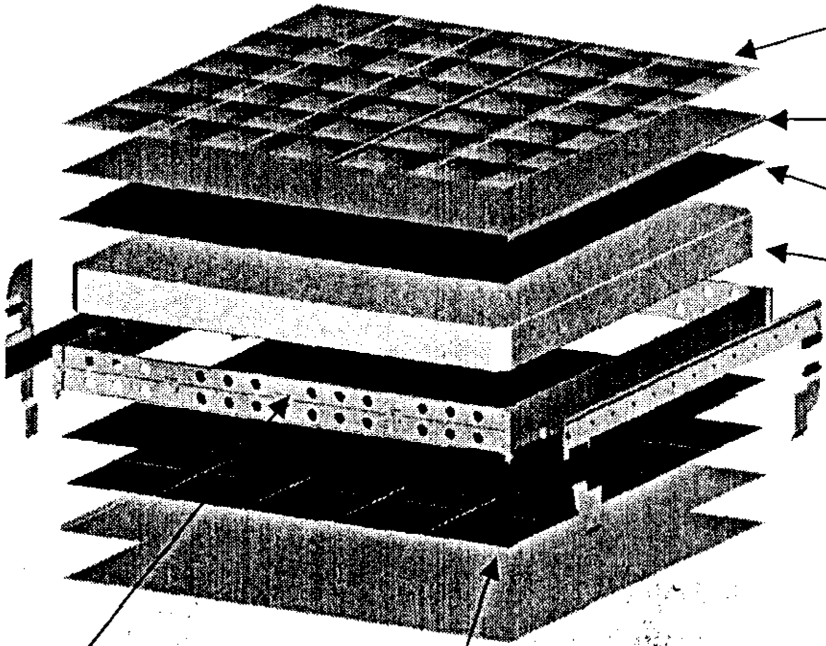




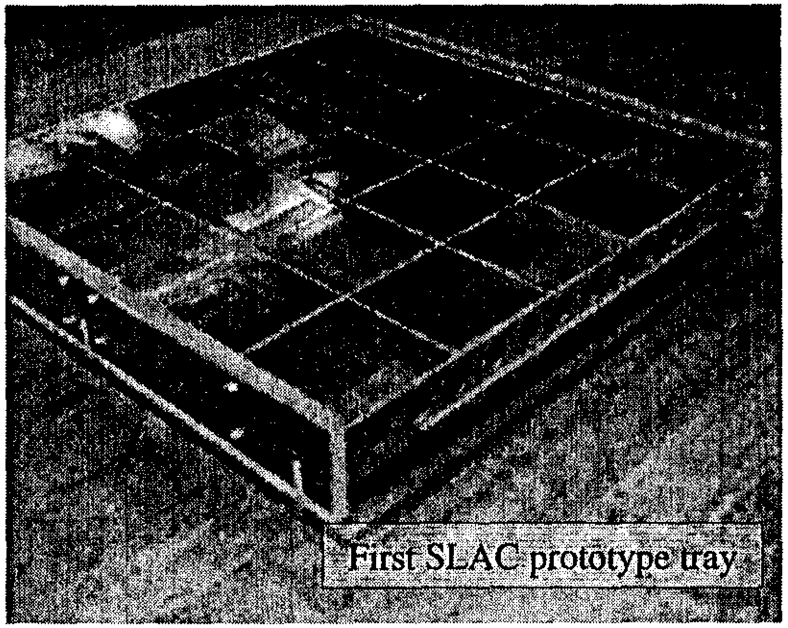




Tracker Tray Design



The first fully functional tray, complete with detectors and electronics, will be completed this September.



SLAC has fabricated several prototypes of an earlier design. One of these is now being outfitted with reject detectors for assembly and mechanical studies.

Tracker Readout Electronics

Hybrid circuit mounted on the tray side.

2 readout-controller chips

Connections to 2 redundant cables

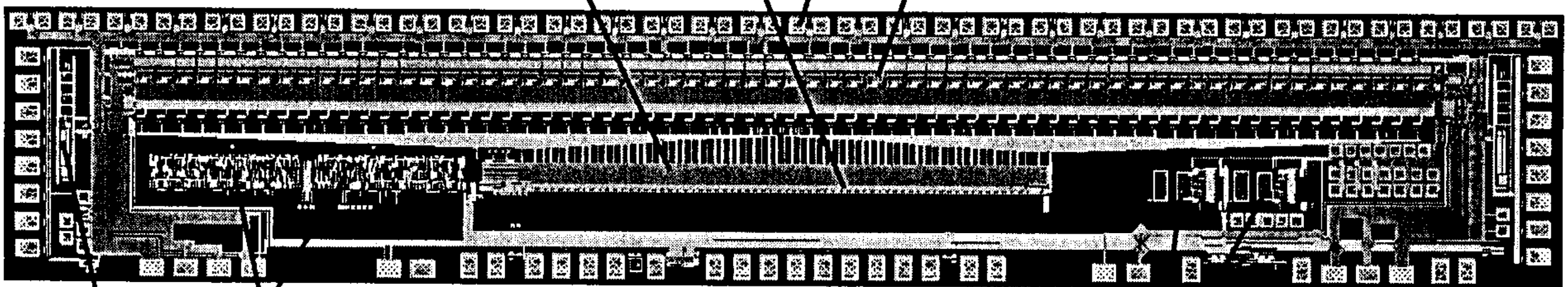
25 front-end chips

Input pads for 195 μm pitch detectors

Two redundant readout registers

64 amplifier-discriminator channels, proven in beam test

Buffering for 8 events



Dual redundant serial command decoders

Low Voltage Differential Signaling

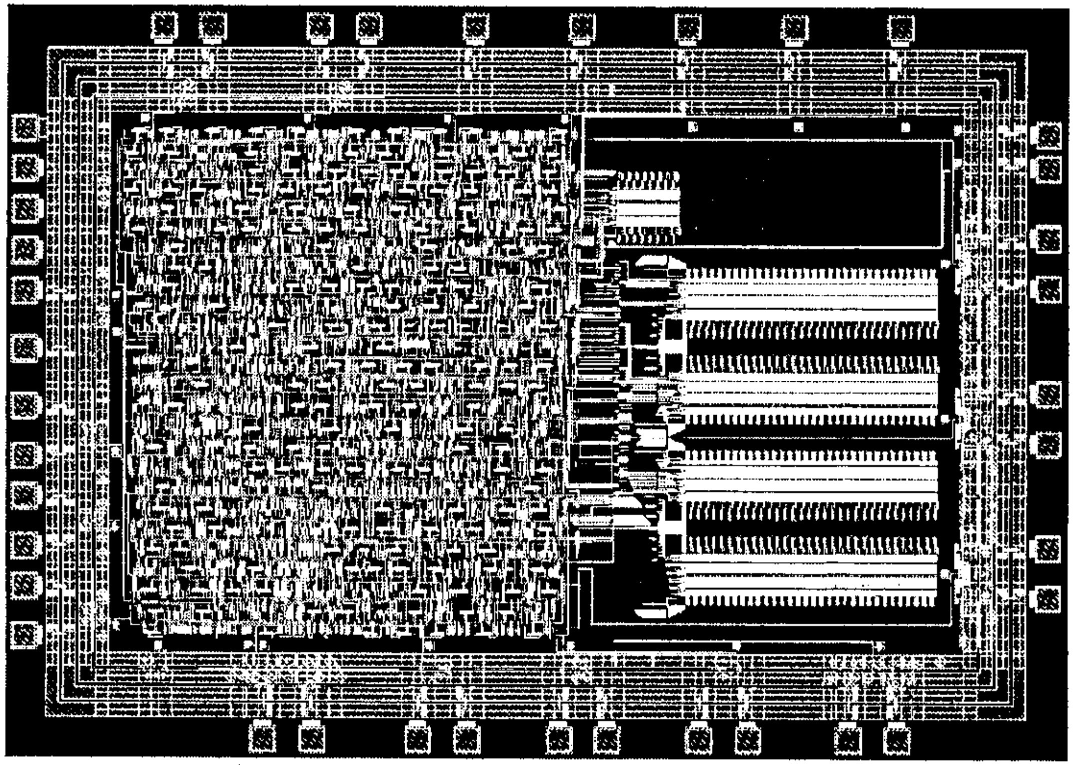
DACs for threshold and calibration levels

Front-end readout chip. Prototypes have been tested and are fully functional.

Tracker Electronics, Readout Controller Chip

Readout Controller

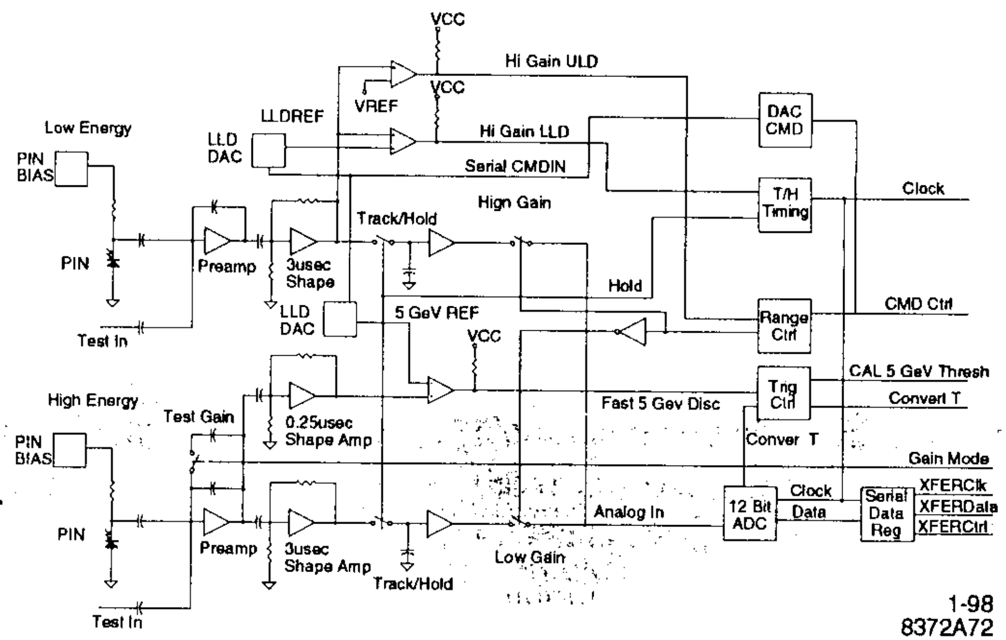
- Full custom CMOS IC.
- Logic design and layout uses DoD standard cells.
- ***The first prototype has been tested and is fully functional.***
- Functions:
  - Zero suppression and formatting of the data.
  - Command and clock interface to the front-end chips.
  - Sequencing and buffering of the readout.
  - Time-over-threshold of the Fast-OR trigger output.
  - Communication via low-voltage differential signaling (LVDS).



Cadence layout of the GLAST Tracker Readout Controller chip (GTRC). The left half is logic made from standard cells, while the right half is memory for buffering.

Calorimeter Electronics Development

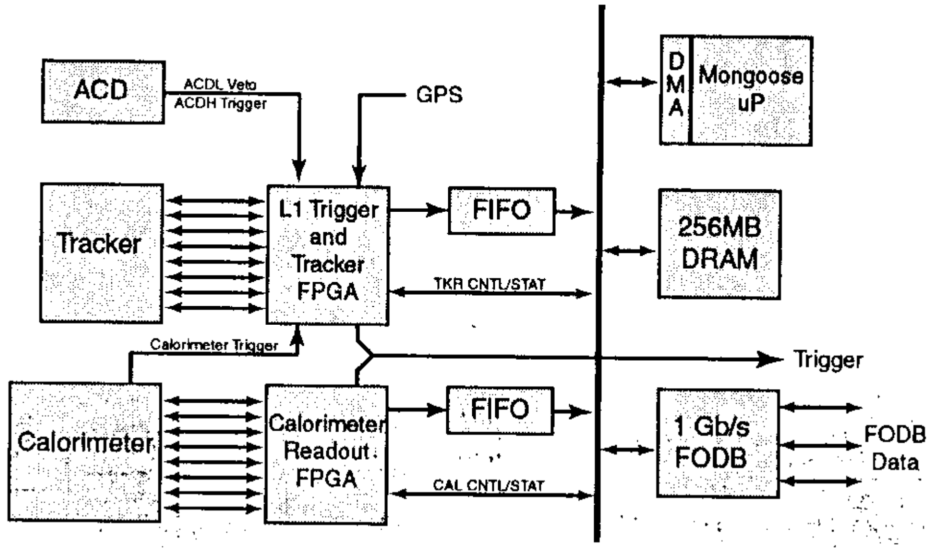
- The main challenge is the large dynamic range requirement (1 MeV to 40 GeV for current prototype specification), together with a small per-channel power allocation.
- A CMOS ASIC front-end is being developed to meet the requirements.
- Each end of a CsI crystal has two PIN diodes, for two gain ranges.
- A separate fast amplifier channel provides a signal that can be used for triggering.
- A first partial prototype is in hand and is undergoing testing.



Conceptual block diagram of the CsI calorimeter front-end electronics.

Data Acquisition Development

- Monte Carlo simulations of rates and detector occupancy.
- Robust level-1 trigger design, using an FPGA.
- Conceptual design of tracker and calorimeter readout, with an average dead time of less than 10μs per event.
- Optimization of low-power performance (<150 W allocated). Continuing investigation of ultra-low power CMOS.
- VME based prototyping system at Stanford. First prototypes to be delivered in September.
- ARGOS flight test bed.



Top level block diagram of the data acquisition system architecture.

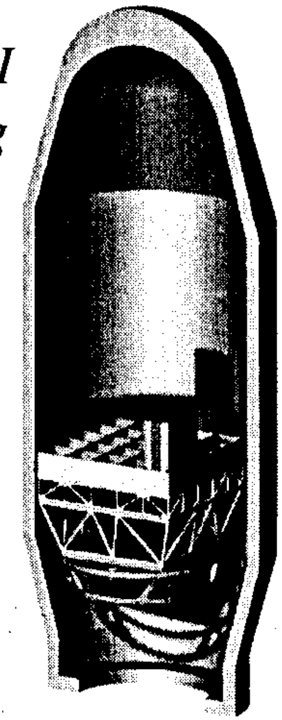
GLAST Mechanical Integration

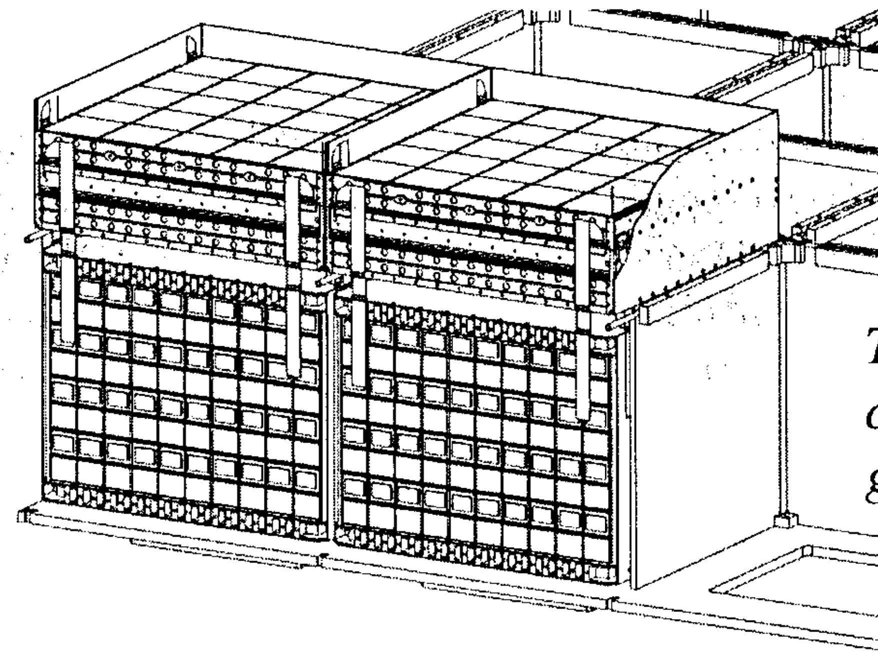
Work is in progress to study the mechanical structure from the spacecraft support ring to the instrument support grid, and on up through the calorimeter, tracker, and ACD.

This includes extensive FEA and dynamical calculations.

The design includes a cooling system involving conductive panels, heat pipes in the support grid, and radiator panels on the exterior.

Delta-II Fairing





Tracker, calorimeter, grid integration

Conclusions

- The GLAST baseline design has already been well supported by a vigorous R&D program:
  - Extensive simulations for evaluation of the performance and optimization of the design parameters.
  - A conceptual design for an ***integrated instrument***, with viable triggering and readout schemes worked out in detail.
  - Successful proof-of-principle test of the critical technology: low power, low noise readout for silicon strip detectors,
  - Highly successful beam test of prototype components from all subsystems.
- The next major milestone is to build and test a complete full-scale tower module.
  - Detailed engineering integration of all subsystems.
  - Development of fabrication procedures.
  - Tests in accelerator beams of the telescope performance and background rejection.
  - Validation of most aspects of the instrument design.
- Increasing attention to the engineering of the full scale 25-tower instrument.