GLAST Large Area Telescope:

Overview of Instrument Design and Technical Status

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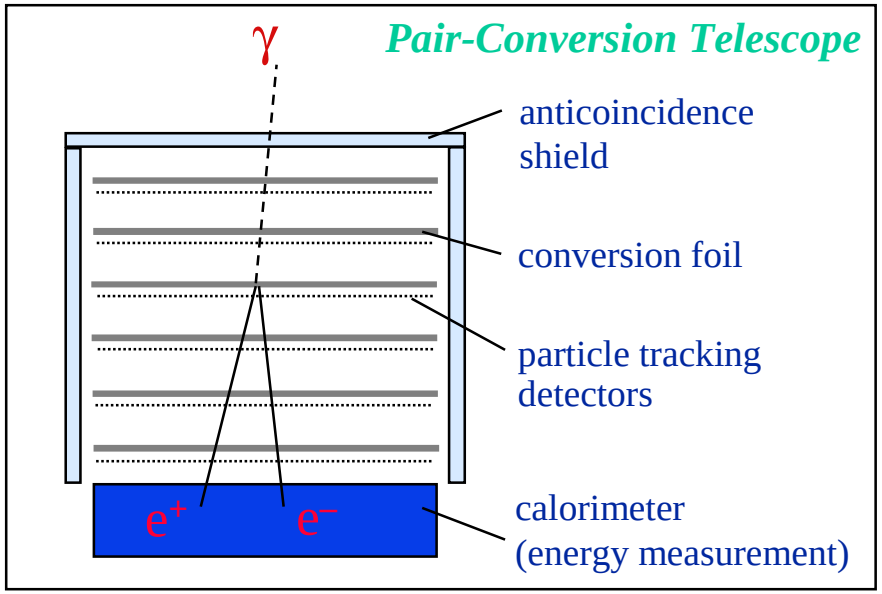
Outline

- Instrument design, simulation, early tests
- Overview by subsystem
  - Mechanical/Thermal
  - Tracker (TKR)
  - Calorimeter (CAL)
  - Anti-Coincidence Detector (ACD)
  - Electronics and Flight Software
  - Science Analysis Software (SAS)
  - Integration and Test (I&T)
- Summary

Experimental Technique

- Instrument must measure the direction, energy, and arrival time of high energy photons (from approximately 20 MeV to greater than 300 GeV):

  - photon interactions with matter in GLAST energy range dominated by pair conversion:
    - ➡ determine photon direction
    - ➡ clear signature for background rejection
  - limitations on angular resolution (PSF)
    - **low E: multiple scattering => many thin layers**
    - **high E: hit precision & lever arm**



Energy loss mechanisms:

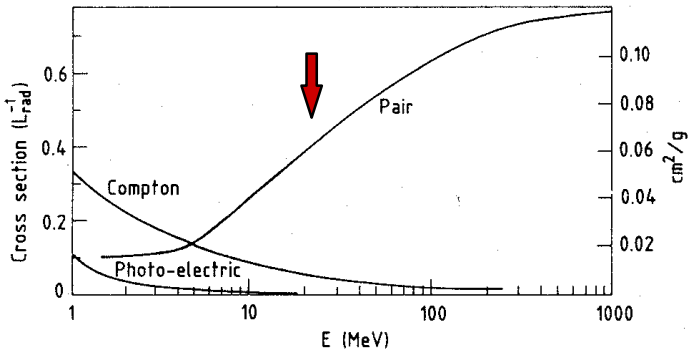


Fig. 2: Photon cross-section σ in lead as a function of photon energy. The intensity of photons can be expressed as $I = I_0 \exp(-\sigma x)$, where x is the path length in radiation lengths. (Review of Particle Properties, April 1980 edition).

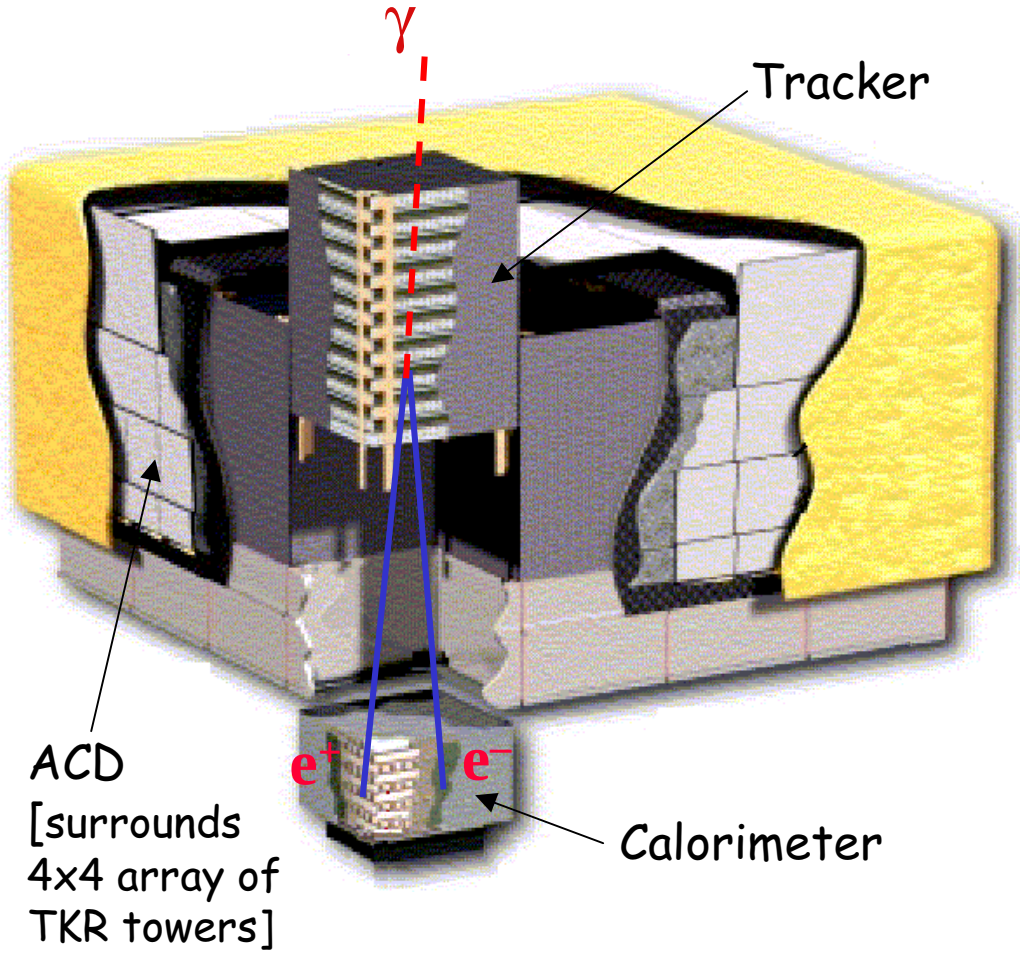
- must detect γ-rays with high efficiency and reject the much larger (~10^4:1) flux of background cosmic-rays;
- energy resolution requires calorimeter of sufficient depth to measure buildup of the EM shower. Segmentation useful for resolution and background rejection.

Mission Constraints Relevant to LAT Science Performance

- **Lateral dimension < 1.8m**
  Restricts the geometric area.
- **Mass < 3000 kg**
  Primarily restricts the total depth of the CAL.
- **Power < 650W**
  Primarily restricts the # of readout channels in the TKR (strip pitch, # layers), and restricts onboard CPU.
- **Telemetry bandwidth < 300 kbps orbit average**
  Sets the required level of onboard background rejection and data volume per event.
- **Center-of-gravity constraint** restricts instrument height, but a low aspect ratio is already desirable for science.
- **Launch loads and other environmental constraints.**

Overview of LAT

- Precision Si-strip Tracker (TKR)
  18 XY tracking planes. Single-sided silicon strip detectors (228 μm pitch)
  Measure the photon direction; gamma ID.
- Hodoscopic CsI Calorimeter(CAL)
  Array of 1536 CsI(Tl) crystals in 8 layers.
  Measure the photon energy; image the shower.
- Segmented Anticoincidence Detector (ACD) 89 plastic scintillator tiles.
  Reject background of charged cosmic rays; segmentation removes self-veto effects at high energy.
- Electronics System Includes flexible, robust hardware trigger and software filters.



Systems work together to identify and measure the flux of cosmic gamma rays with energy 20 MeV - >300 GeV.

Design Performance Validation: LAT Monte-Carlo Model

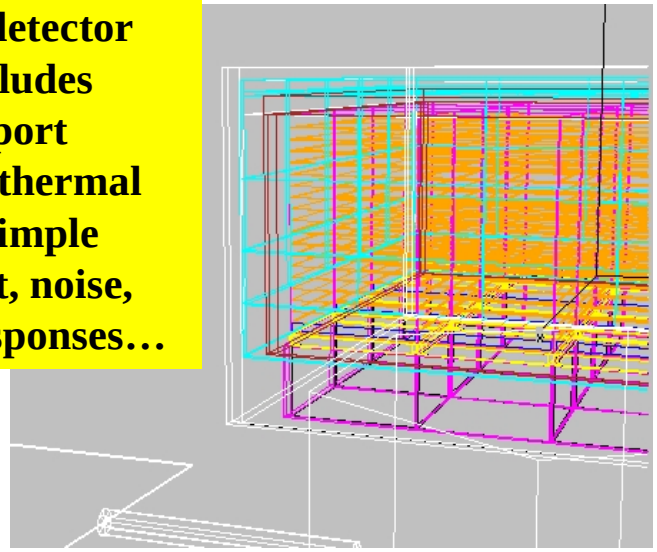
LAT design based on detailed Monte Carlo simulations.

Integral part of the project from the start.

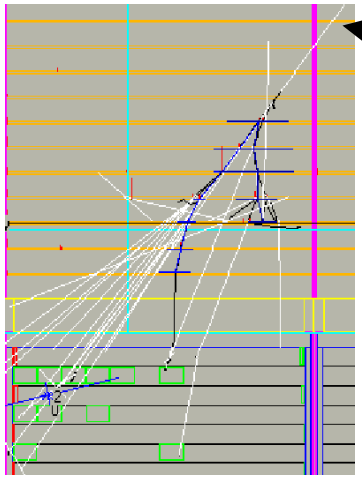
- **Background rejection**
- **Effective area and resolutions**
- **Trigger design**
- **Overall design optimization**

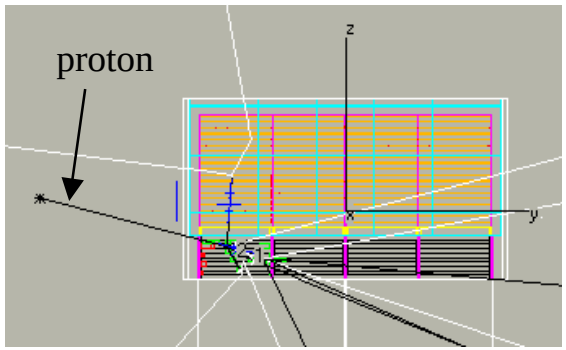
Simulations and analyses are all C++, based on standard HEP packages.

Detailed detector model includes gaps, support material, thermal blanket, simple spacecraft, noise, sensor responses…



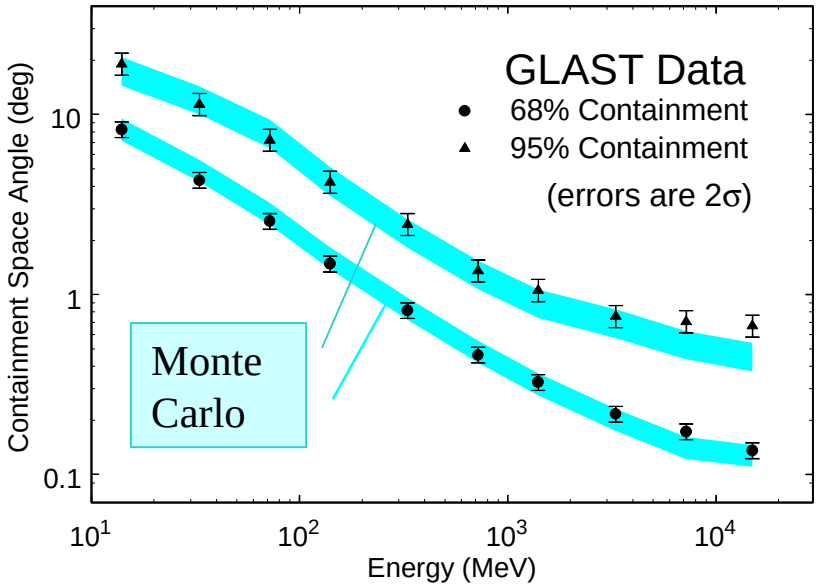
Instrument naturally distinguishes gammas from backgrounds, but details matter.





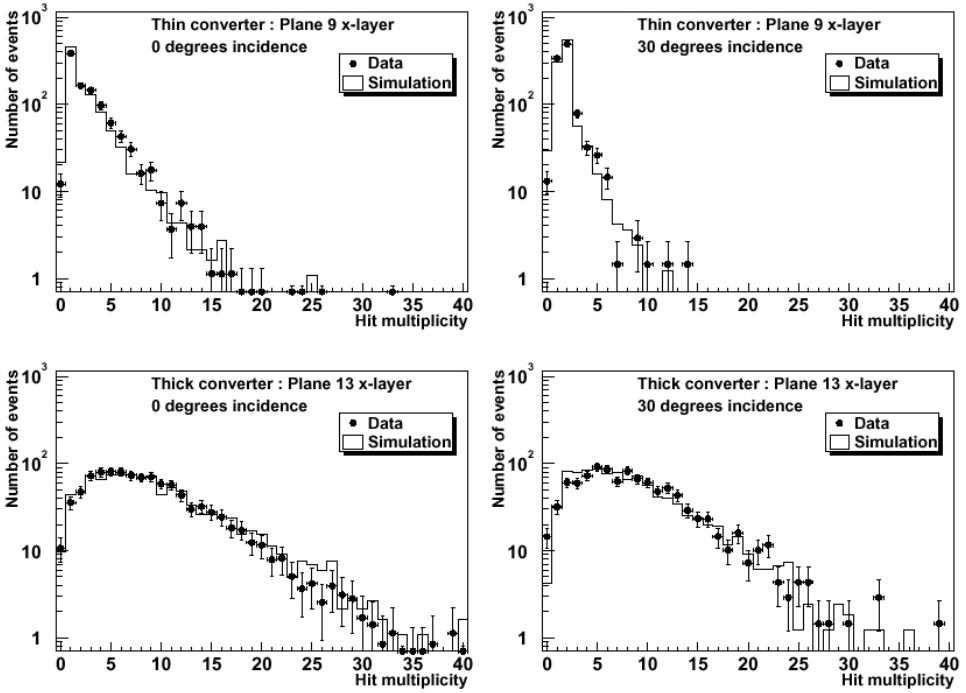
Monte Carlo Modeling Verified in Detailed Beam Tests

High-level performance parameters (e.g., PSF)



1997 SLAC beam test
(photons, positrons)
Demonstrate silicon conversion telescope principle
Published in NIM A446

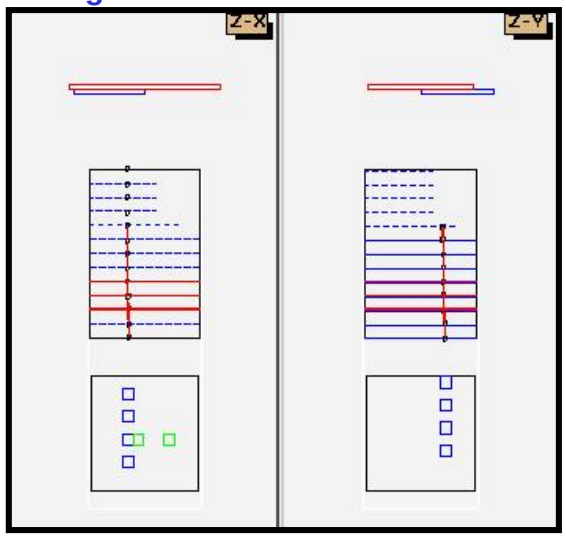
Detailed detector characteristics (e.g., hit multiplicities)



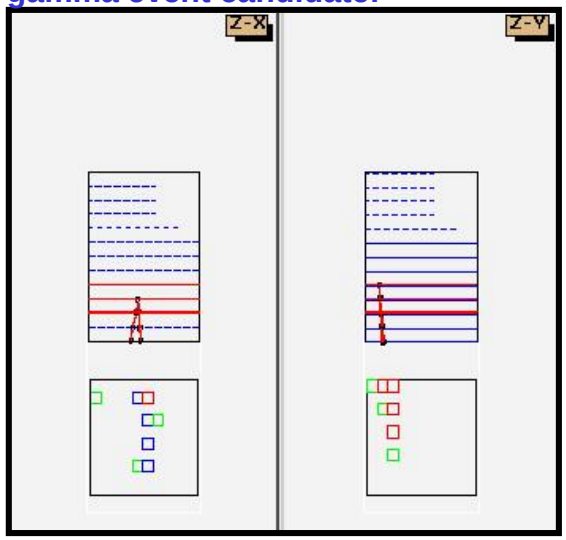
1999-2000 SLAC beam test
(photons, positrons, protons)
flight-scale tower
Published in NIM A474

LAT Balloon Flight: Goals

background event candidate:



gamma event candidate:



Purpose of balloon test flight: expose prototype LAT tower module to a charged particle environment similar to space environment and accomplish the following objectives:

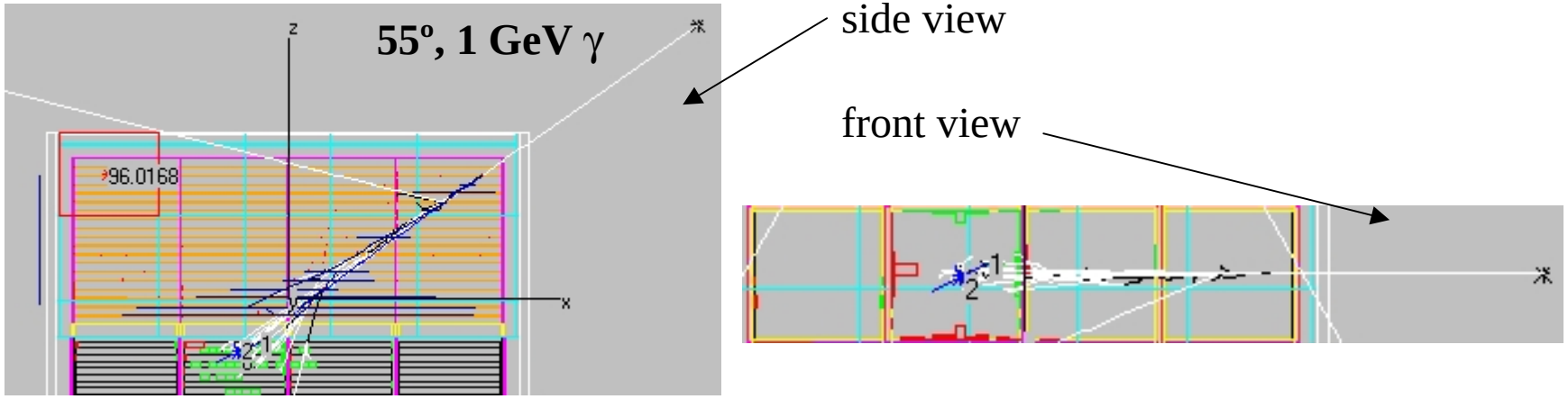
- Help validate the basic LAT design at the single tower level.
- Demonstrate the ability to take data in the isotropic background flux of energetic particles in the balloon environment.
- Record events for use as a background event data base.

All Objectives met by Balloon Flight on August 4, 2001 (3 hrs at 38 km float)

All subsystems performed properly.
Trigger rate <1.5 kHz, well below BFEM 6 kHz capability.

Calibration Strategy

- **Every LAT science performance requirement has a draft defined test.**
- **LAT energy range and FOV are vast. Beam tests are used to sample the performance space and to verify the detailed simulation; analysis with the simulation is used to verify the full range of performance parameters.**
- **Every LAT science performance requirement can be verified in this manner. All the science performance requirements can be verified in beam tests using four towers. Full-LAT tests are <u>functional</u> tests.**



Subsystem Development

Subsystem development follows systematic progression:

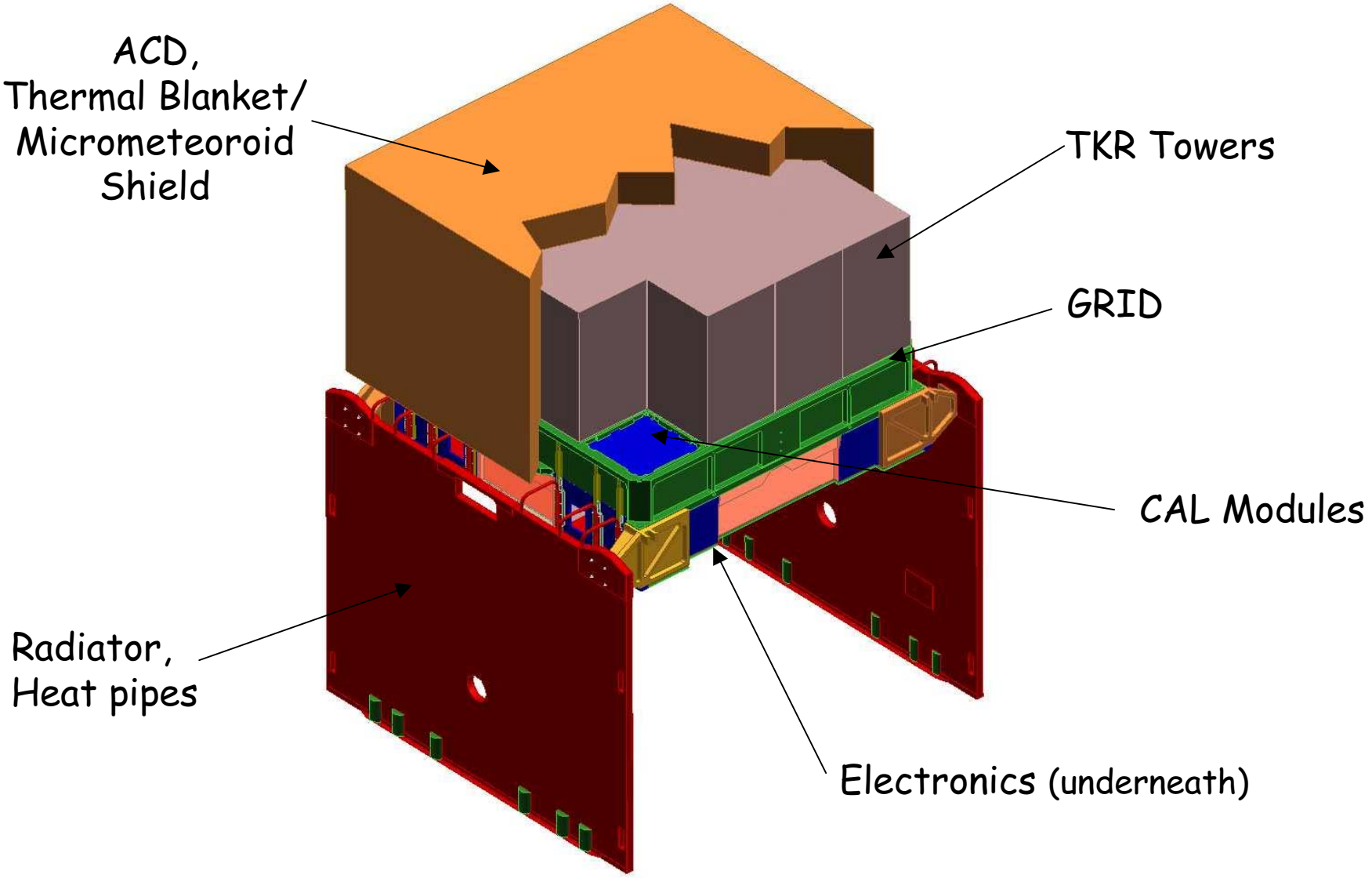
- early test articles (proving concepts of components)
- component beam tests
- single tower balloon flight & beam test
- mechanical prototypes and engineering model (**EM**) ⟵ now
- qualification units (2 towers)
- flight units (16 towers)

System Engineering and Design Engineering

- System Engineering:
  - Spacecraft interfaces
    - spacecraft partner selected (Spectrum Astro) Fall 2002
    - major activity on interface definition. Proceeding well to closure prior to Critical Design Review (CDR) April 2003.
  - Manage and document internal interfaces between subsystems
  - Requirements management
  - Verification planning
  - Technical resources tracking (mass, power, etc.)
  - Risk management

- Design Engineering:
  - supports integrated design across subsystems
  - monitors, manages and resolves technical issues

LAT Mechanical Design Overview



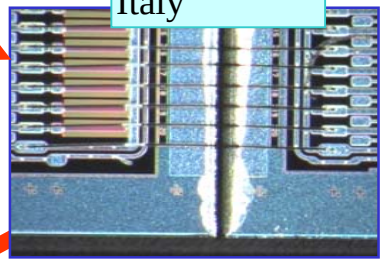
Tracker Components

Tower Structure
Italy, SLAC

SSD Procurement, Testing
Japan, Italy, SLAC

10,368

SSD Ladder
Assembly
Italy



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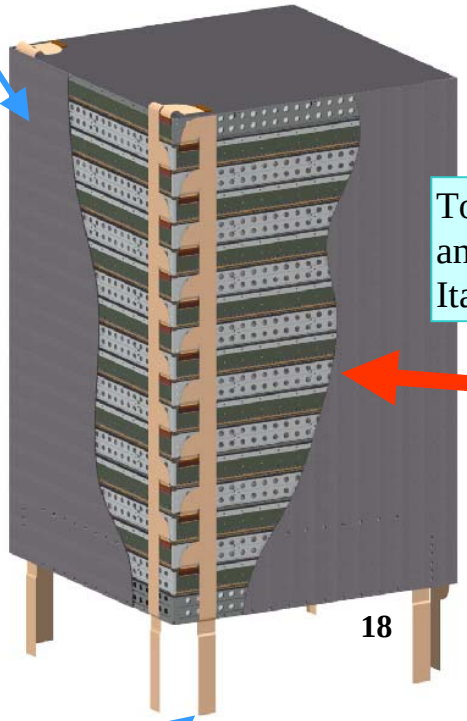
Tower Assembly
and Test
Italy (18)



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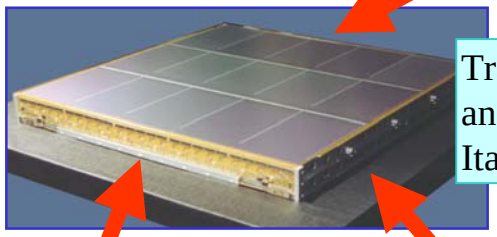

Tray Assembly
and Test
Italy

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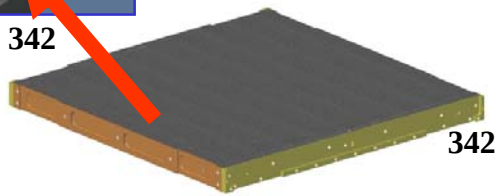

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Electronics Design,
Fabrication & Test
UCSC, SLAC

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Composite Panel & Converters
Italy, SLAC

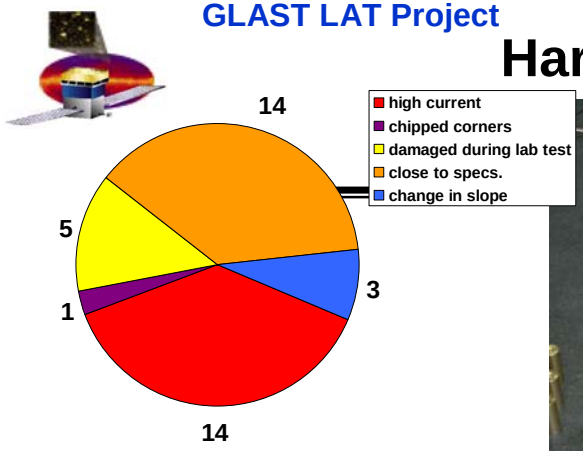
Cable Plant
UCSC

16 flight modules + 2 spares

Tracker Technical Status

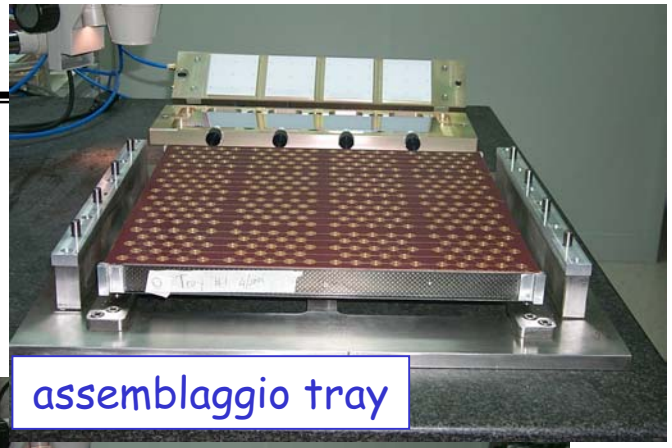
- Expertise from Japan key contribution for SSD design, prototyping, and procurement.
- Half of the flight sensors are already in hand and tested in Italy. Remainder in 2003.
- EM ladders complete; tray, tower production underway in Italy.
- EM front-end electronics commercial assembly underway.
- Flight hardware commercial manufacturing processes being validated, starting up.
- Flight ASICs in fabrication.
- Remaining mechanical design issue (bottom tray interface with Grid) being addressed.

Hardware Assembly and Test in Italy

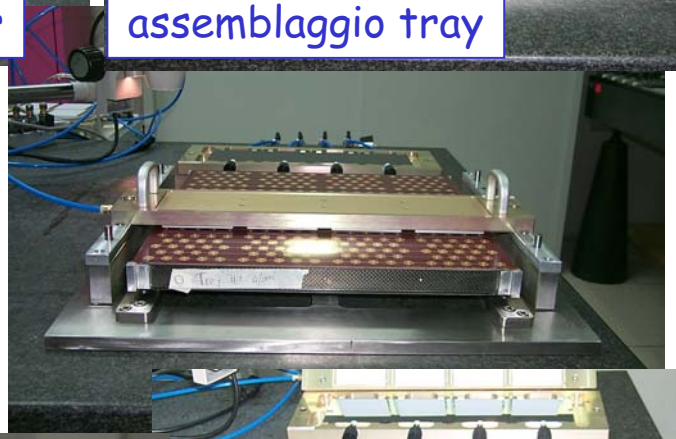


test ottici ed elettrici:
37/3500 ~ 1% SSD rejected

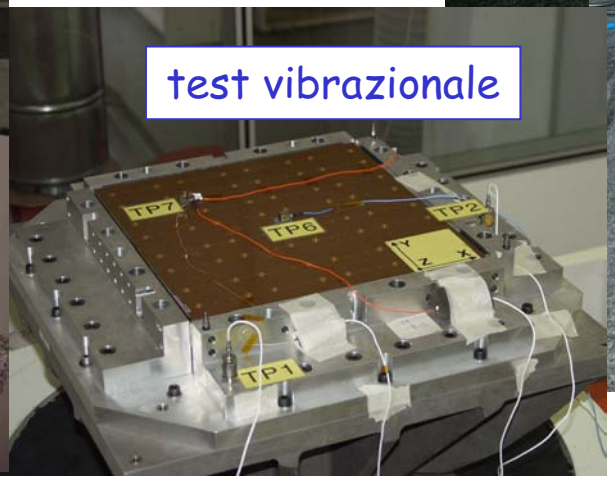
assemblaggio ladder



assemblaggio tray



assemblaggio torre

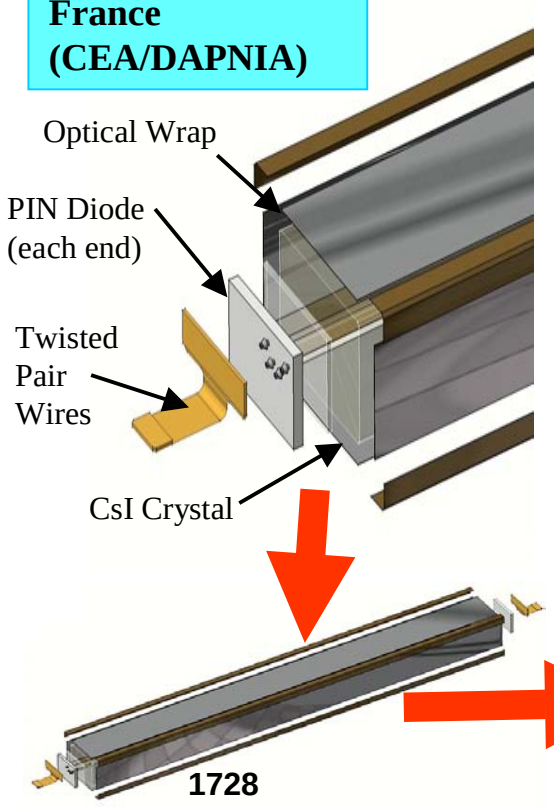


test vibrazionale

Calorimeter Production Overview

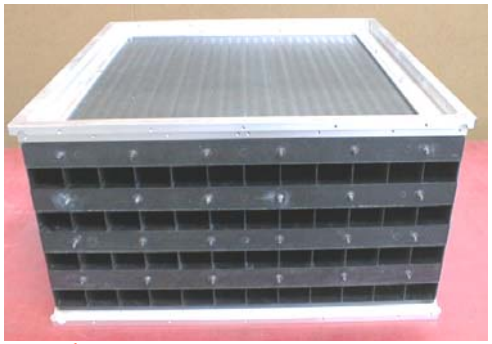
CsI Crystals
Sweden (KTH)

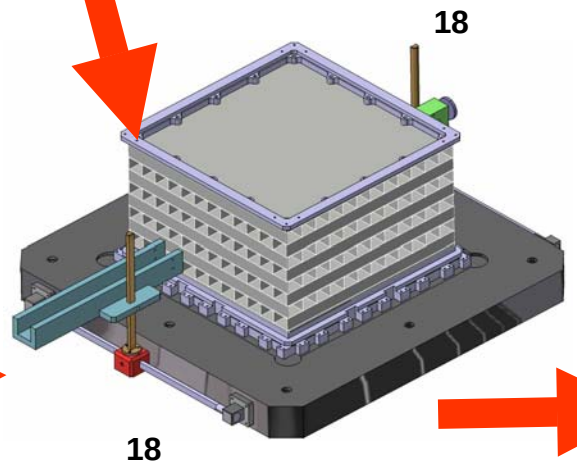
CDE Assembly
France (CEA/DAPNIA)



16 flight modules + 2 spares

Mechanical Structure
France (IN2P3/Ecole Polytechnique)





PEM Assembly
NRL

Front-End Electronics
NRL, SLAC

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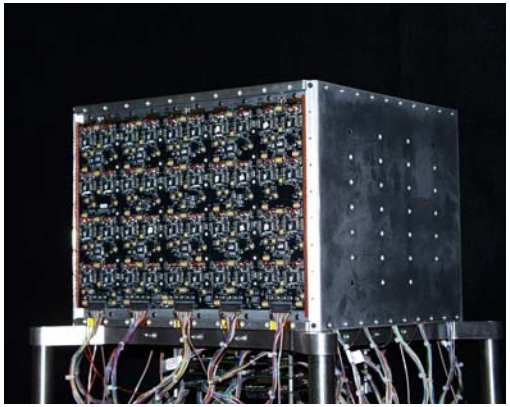
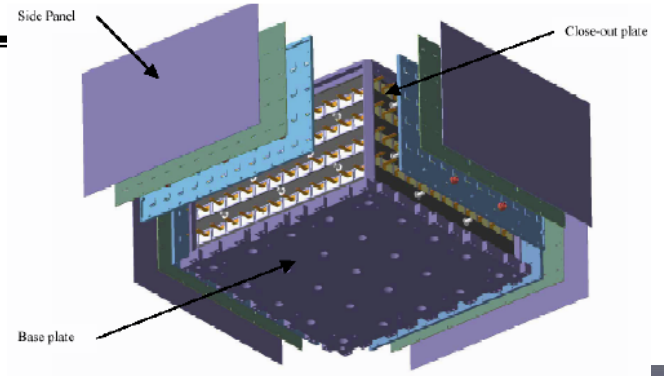
Module Assembly
and Test, **NRL+collab**

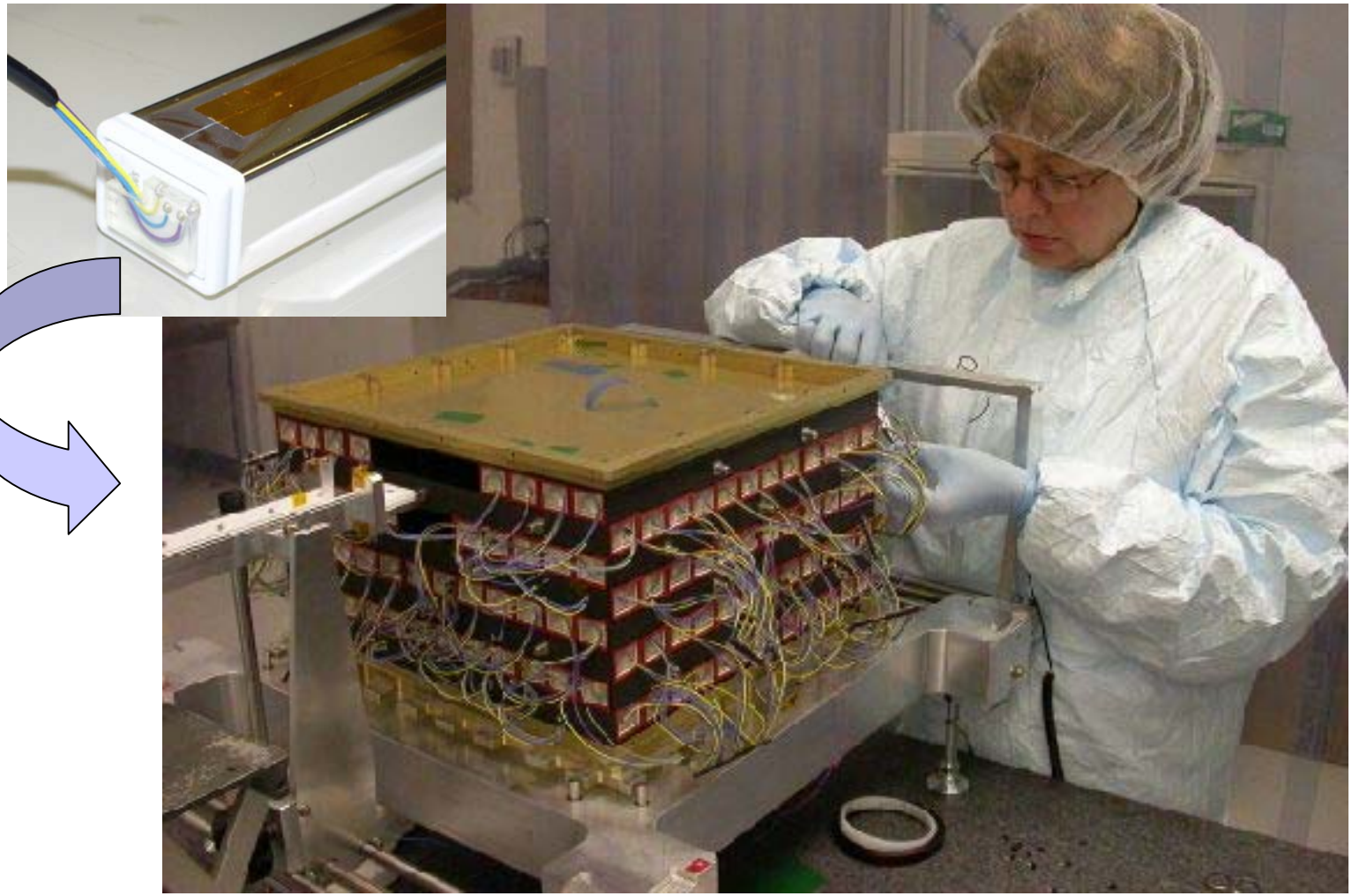


Calorimeter Technical Status

- Environmental testing (vibe and thermal) of CAL module prototypes successfully completed.
- Crystal Detector Elements (CDE) for Engineering Model complete.
- PIN diodes flight parts procurement readiness review conducted 13 February.
- PIN diode-crystal bonding procedure developed and tested.
- EM front-end boards fabricated and in testing.
- Flight ASICS in fabrication.
- Mechanical components for engineering model complete. EM assembly underway.



CAL Engineering Model in Production

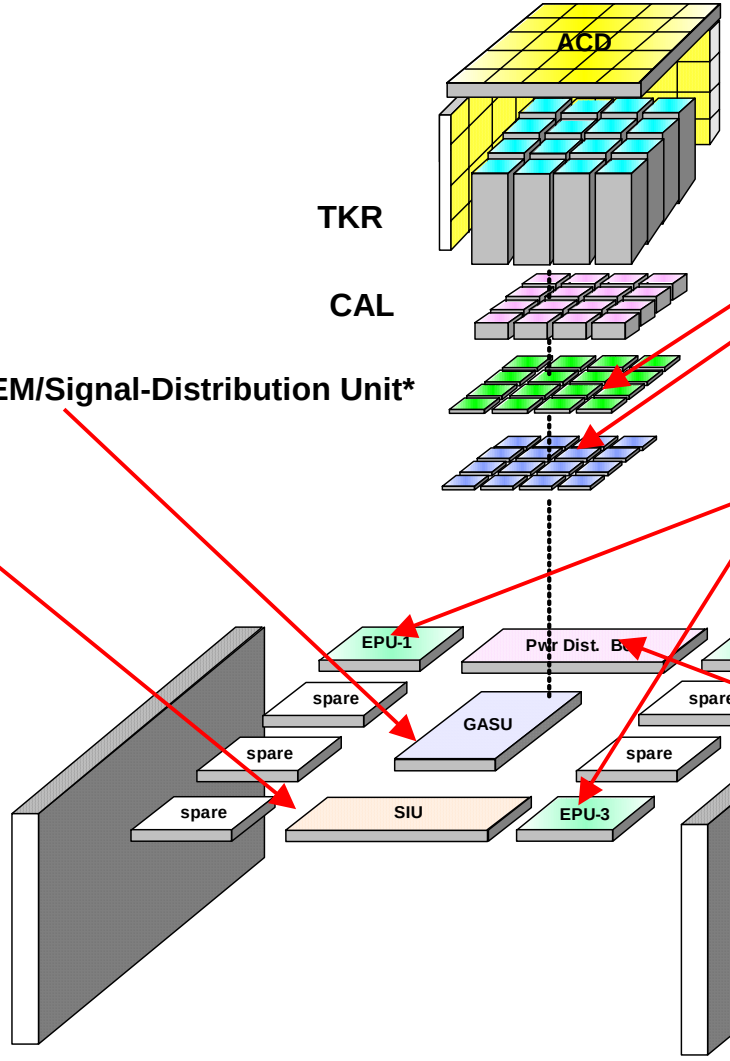


ACD Technical Status

- GSFC, with critical ASIC help from SLAC and collaboration with Washington University on fibers
- Environmental tests of components complete
- First subsystem through its CDR (January)
- Long-lead flight procurements in progress
- Finalizing manufacturing plan
- Closing remaining details of systems environmental requirements
- ACD Electronics Module: EM1 version designed, built, and tested; EM2 version (interfaces, functions, and components as flight-version) in design.

Full-scale mock-up of ACD being used for tile placement and fiber routing

LAT DAQ Architecture



16 Tower Electronics Modules
- DAQ electronics module (DAQ-EM)
- Power-supplies for tower electronics

Global-Trigger/ACD-EM/Signal-Distribution Unit*

3 Event-Processor Units (2+1 spare)
- Event processing CPU
- LAT Communication Board

Spacecraft Interface Unit*
- Spacecraft Interface Board (SIB): Spacecraft interface, control & data
- LAT control CPU
- LAT Communication Board (LCB): LAT command and data interface

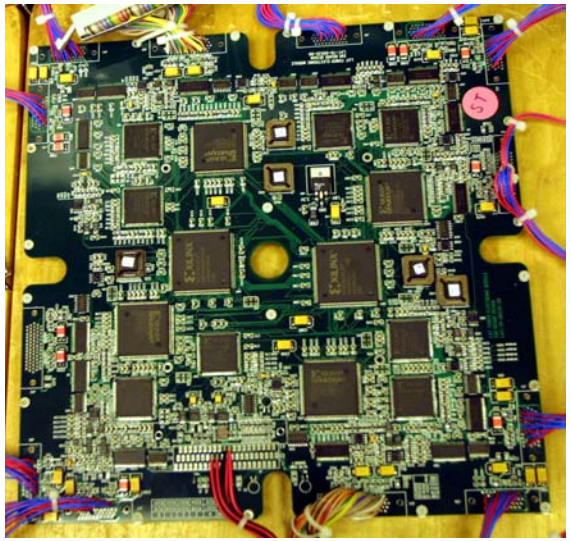
Power-Distribution Unit (PDU)*
- Spacecraft interface, power
- LAT power distribution
- LAT health monitoring

*** Primary & Secondary Units shown in one chassis**

Electronics/Flight Software Technical Status

Electronics

- Tower Electronics Module (TEM) Engineering models built and operating. Used for interface testing with subsystem prototypes.
- Flight-Processors baselined
- TKR, CAL and ACD flight design ASICs in production. Schedule is very tight. EEE parts approval process being worked.



EM1 version of TEM

Flight software:

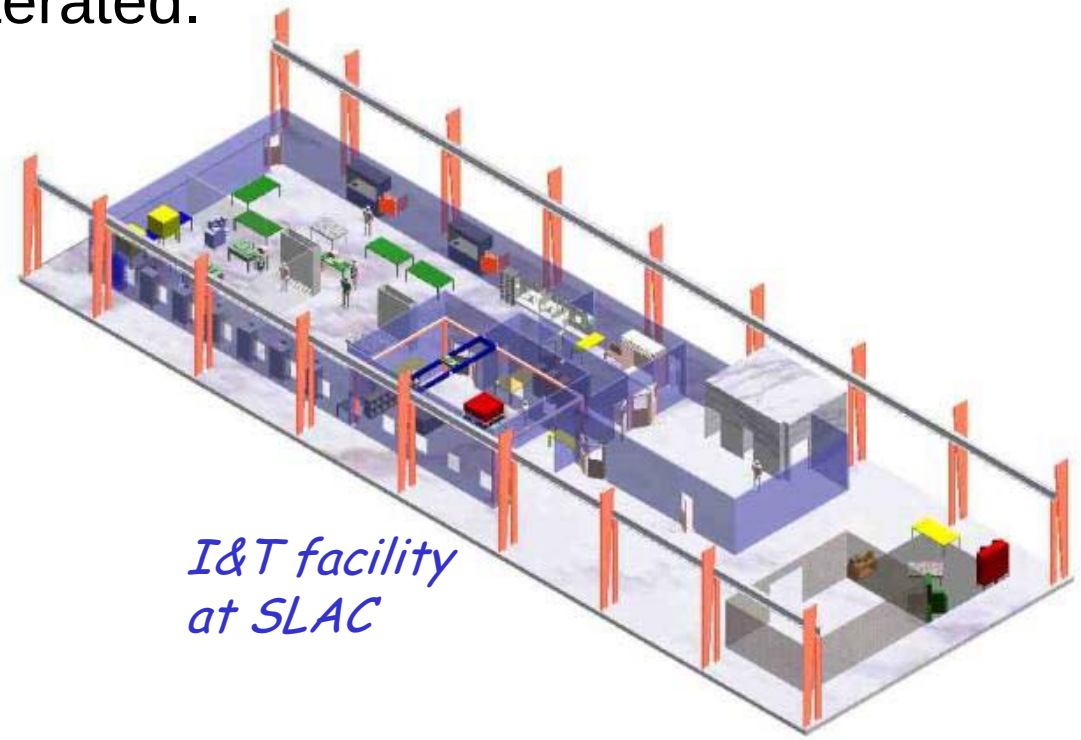
- Engineering model DAQ hardware will provide excellent testbed for flight software
- Event filtering code in progress, approaching production quality

Science Analysis Software Technical Status

- Key contributions from Italy and France in many areas of SAS, distributed across institutions => frequent meetings via vrvs.
- New version of the simulation and recon packages: GLEAM
  - Geant4 for particle transport
  - revised reconstruction with many improvements underway
- Support for calibrations planning
  - infrastructure under development and testing for EM
  - database implementation underway. TKR hot/dead strip lists being used as first client
- Data processing facility prototyped for use with EM
- Science tools support
  - defining requirements for higher level analysis tools. Review in September 2002.
  - end-to-end testing, “Mock Data Challenge”, in formulation

I&T Technical Status

- Preparing Engineering Model I&T testbed, with collaboration participation
- Clean room and integration infrastructure ready to accept EM
- Technical Plan documents drafted. Calibration tasks and verification testing being iterated.
- Test support equipment (EM1 EGSE Release 1) has been delivered to subsystems
- Need support from the collaboration resident at SLAC during I&T (especially for beam tests).



I&T facility at SLAC

Analysis Group Formed

- Initial purposes and tasks:
  - grow the base of people using the simulation and reconstruction
  - as organized users, important interactions with SAS: quick feedback on functionality, documentation, usability, etc.
  - evaluate, improve, parameterize instrument performance
  - background rejection analysis improvements
  - calibration/verification tasks simulations
  - GLEAM higher-level checkout
  - onboard filtering studies support
  - instrument issues as they arise

- Participation from across LAT team. Meets regularly via vrvs to facilitate participation across many timezones.

Summary

- Talents, expertise, and resources from across the collaboration have been an essential element of the project since its inception.
- Design is mature. Engineering Model hardware nearing completion. In transition to flight hardware production.
- I&T is around the corner.
- Looking forward to launch and science operations.