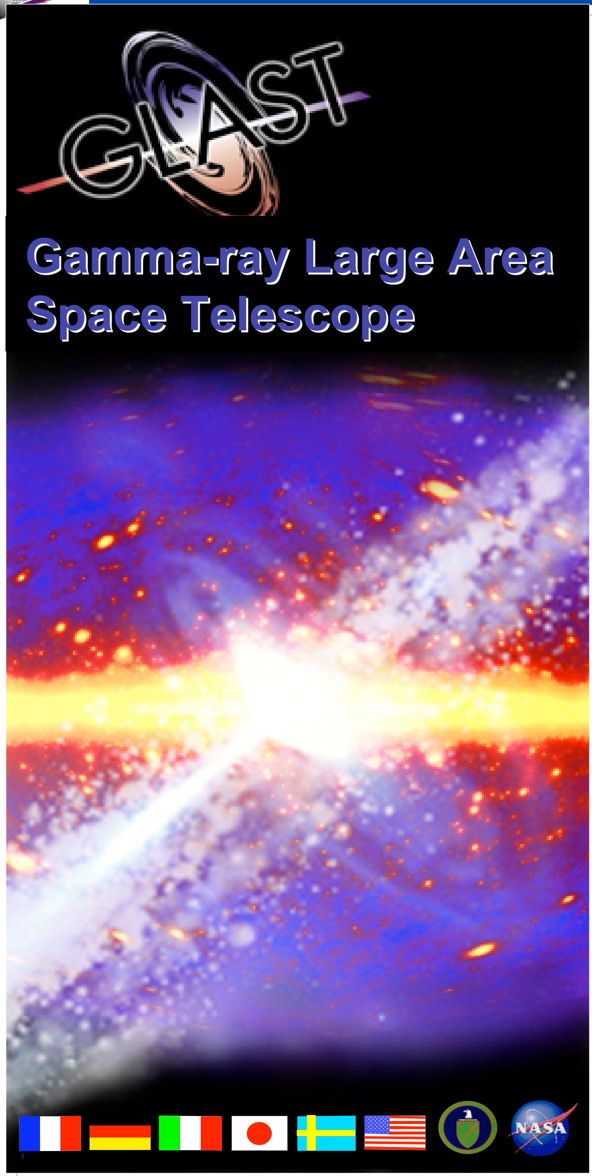


The Gamma Ray Large Area Telescope

Claudia Cecchi

University of Perugia and INFN Perugia

On behalf of the GLAST LAT Collaboration

GLAST Instrument Teams

LAT Collaboration

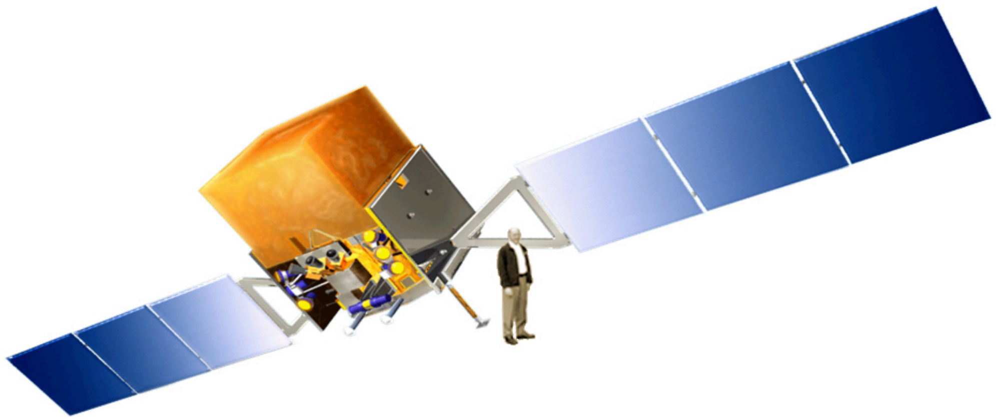
- **United States**
  University of California at Santa Cruz
  Goddard Space Flight Center
  Naval Research Laboratory
  Ohio State University
  Sonoma State University
  Stanford University (SLAC and HEPL/Physics)
  University of Washington
  Washington University, St. Louis
- **France**
  IN2P3, CEA/Saclay
- **Italy**
  INFN, ASI, INAF
- **Japanese GLAST Collaboration**
  Hiroshima University
  ISAS, RIKEN
- **Swedish GLAST Collaboration**
  Royal Institute of Technology (KTH)
  Stockholm University

GBM Collaboration

- **United States**
  Marshall Space Flight Center
  University of Alabama at Huntsville
- **Germany**
  Max-Planck-Institut für extraterrestrsche Physik

The GLAST mission

- **Next-generation high energy gamma-ray observatory**
  - **Field of view ˜1/fifth of the full sky, optimized for sky survey**
    - **Full sky every 3 hours.**
  - **Huge energy range, including largely unexplored 10 GeV - 100 GeV band**
  - **Unprecedented sensitivity**
  - **Will transform the HE gamma-ray catalog:**
    - **By > order of magnitude in number of point sources**
    - **Sub-arcmin localizations (source-dependent)**
    - **Map spatially extended sources**



Two Instruments:

Large Area Telescope (LAT)
http://glast.stanford.edu/
PI: P. Michelson (Stanford University)
20 MeV - 300 GeV
>2.5 sr FoV

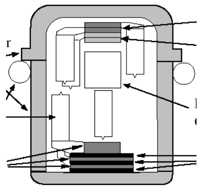
GLAST Burst Monitor (GBM)
http://f64.nsstc.nasa.gov/gbm/
PI: C. Meegan (NASA/MSFC)
Co-PI: G Lichti (MPE)
8 keV – 30 MeV
9 sr FoV

Launch: February 2008
Lifetime: 5 years (req), 10 years (goal)

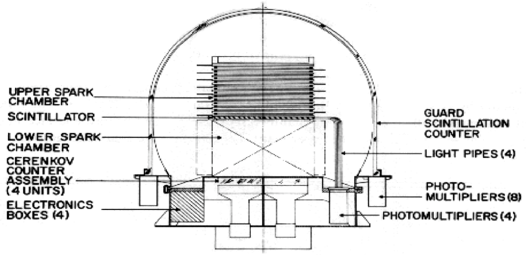
The discovery of the Gamma Ray sky

- **1967-1968, OSO-3**
  Detected Milky Way as an extended γ-ray source
  621 γ-rays
- **1972-1973, SAS-2,**
  ~8,000 γ-rays
- **1975-1982, COS-B**
  orbit resulted in a large and variable background of charged particles
  ~200,000 γ-rays
- **1991-2000, EGRET**
  Large effective area, good PSF, long mission life, excellent background rejection
  >1.4 _ 10^6 γ-rays

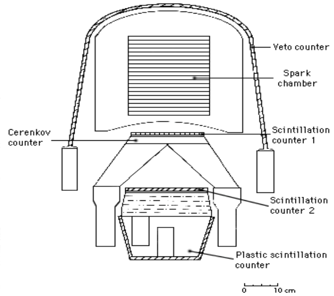
OSO-3



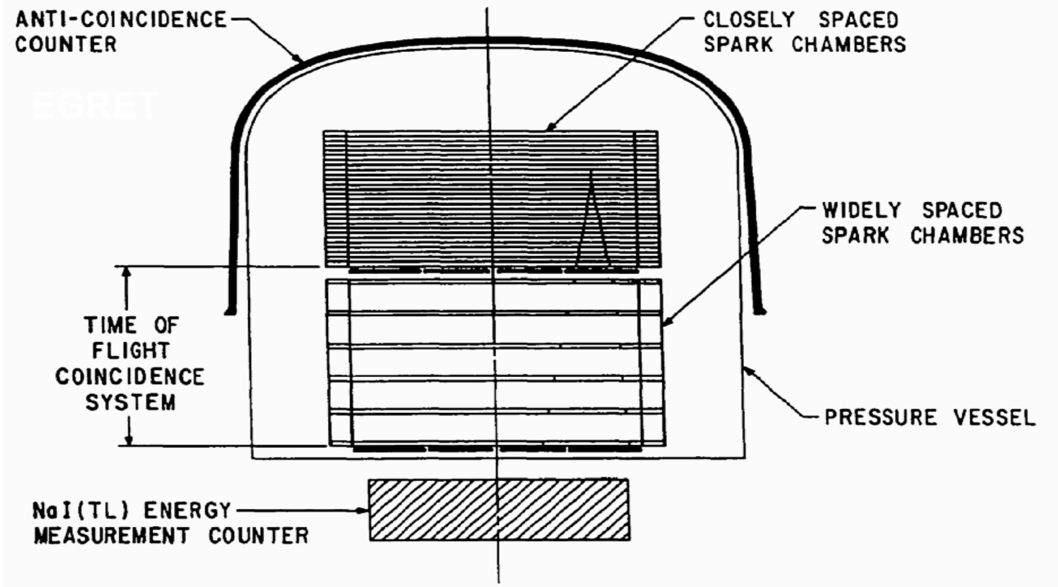
SAS-2



COS-B

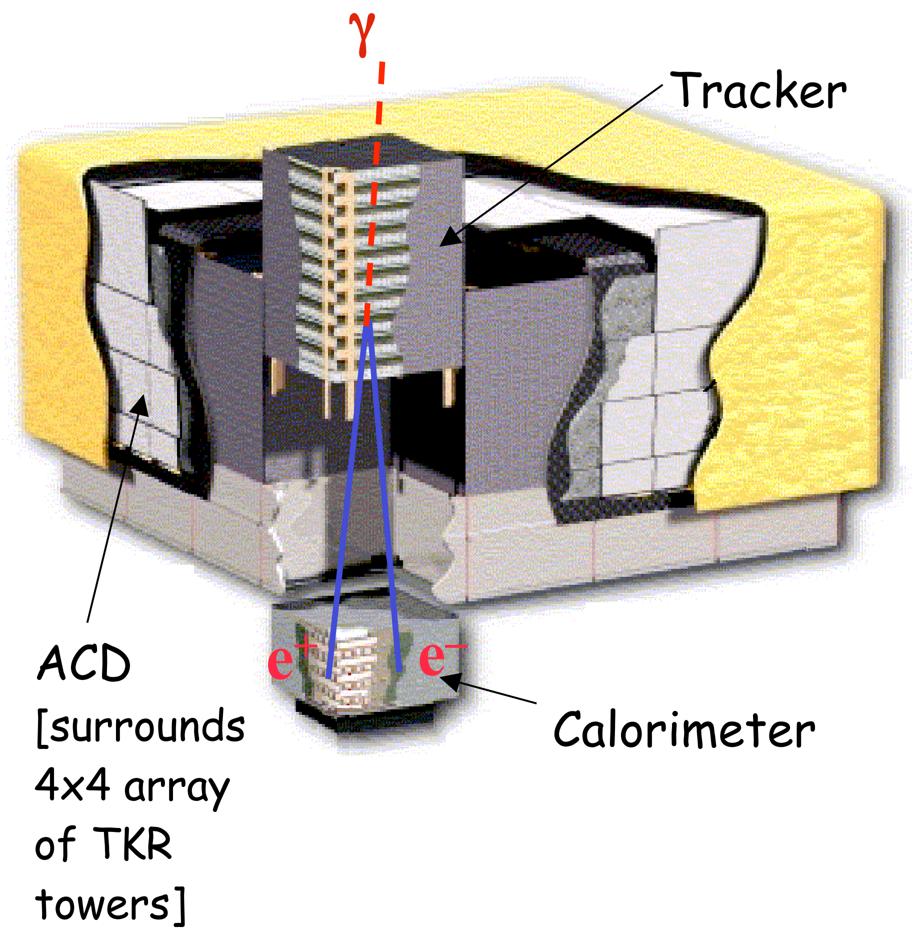


EGRET



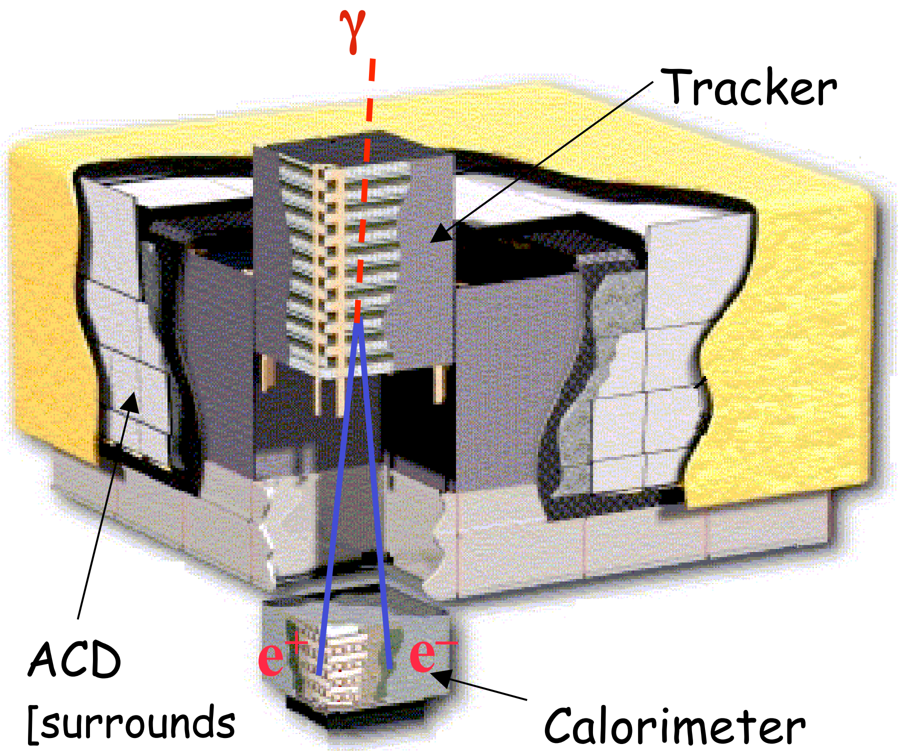
The LAT instrument

- **Precision Si-strip Tracker (TKR)**
  18 XY tracking planes with tungsten foil converters. Single-sided silicon strip detectors (228 µm pitch, 900k strips) Measures the photon direction; gamma ID.
- **Hodoscopic CsI Calorimeter(CAL)**
  Array of 1536 CsI(Tl) crystals in 8 layers. Measures the photon energy; image the shower.
- **Segmented Anticoincidence Detector (ACD)** **89 plastic scintillator tiles. Rejects background of charged cosmic rays; segmentation mitigates self-veto effects at high energy.**
- **Electronics System** **Includes flexible, robust hardware trigger and software filters.**



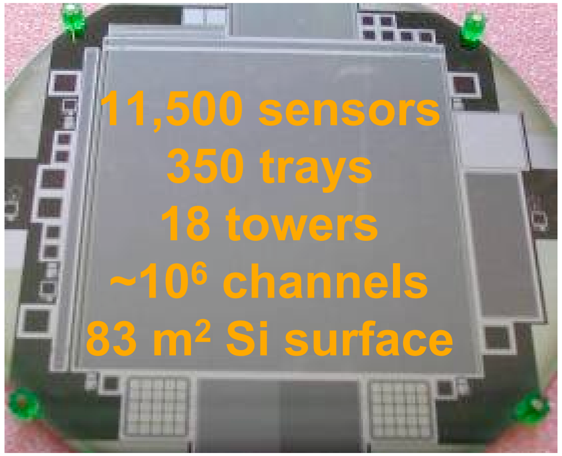
The systems work together to identify and measure the flux of cosmic gamma rays with energy ~20 MeV ~300 GeV.

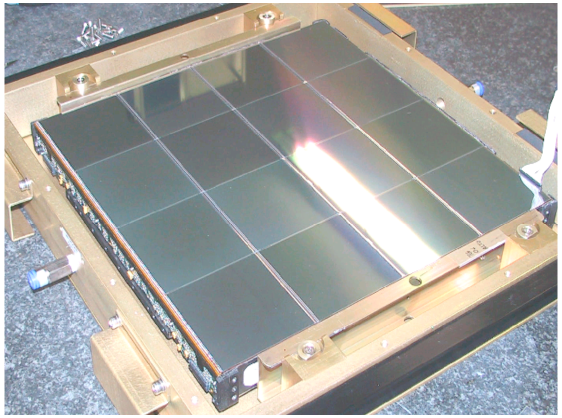
LAT: from design to reality

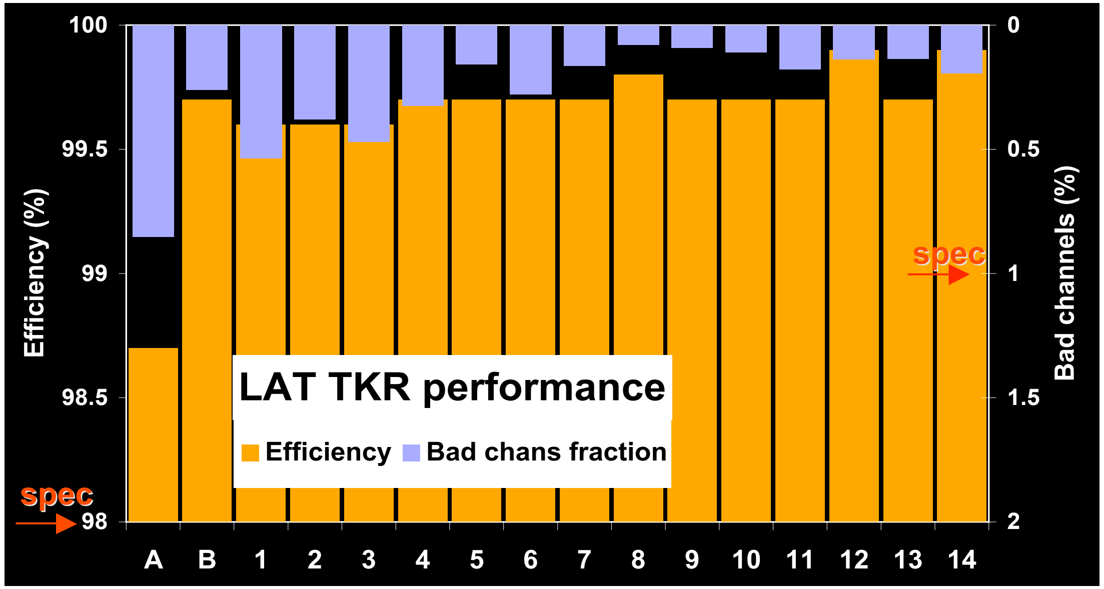


LAT silicon tracker

team effort involving physicists and engineers from the United States (UCSC & SLAC), Italy (INFN & ASI), and Japan

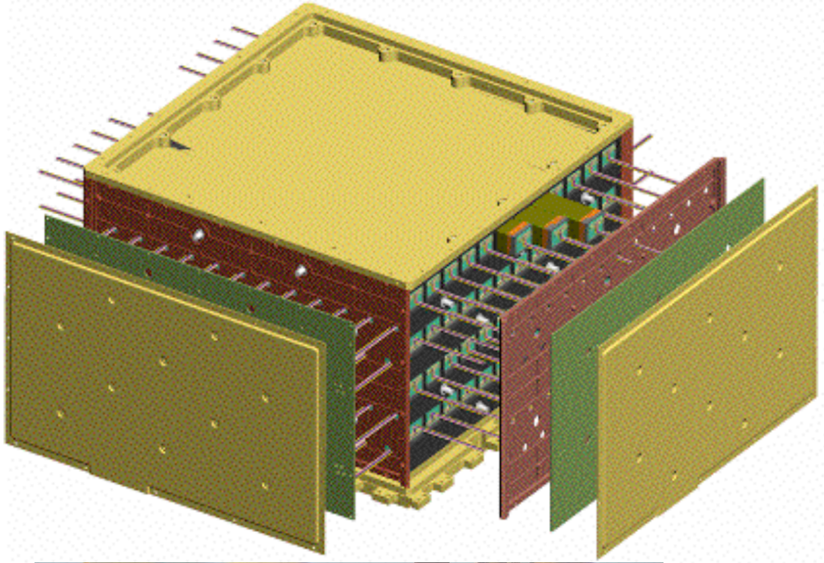


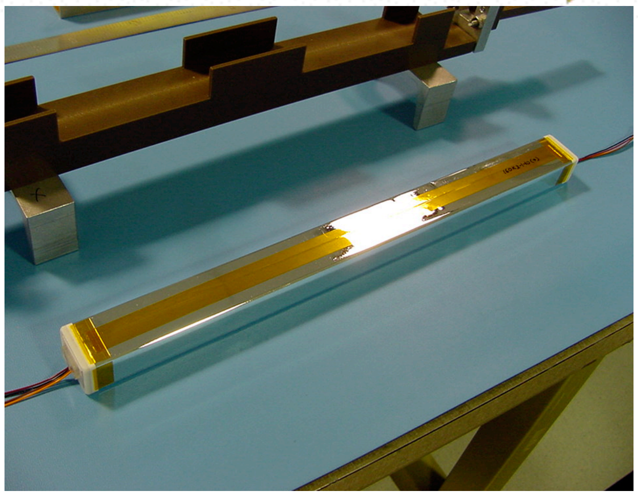


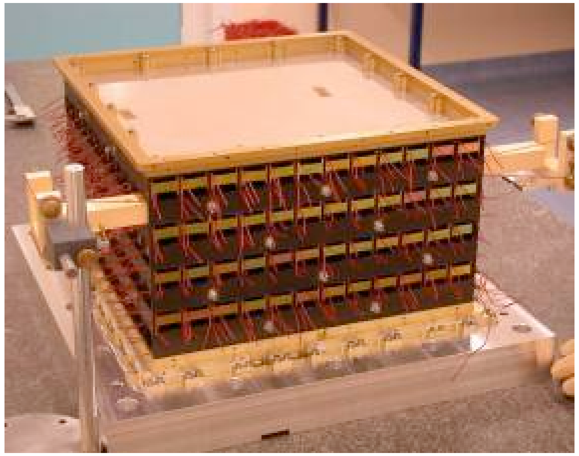


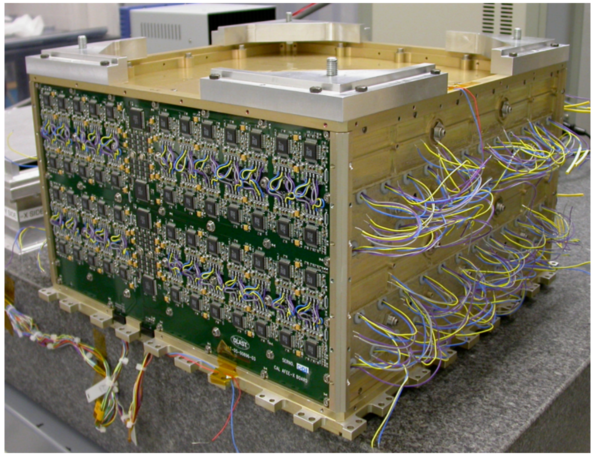
LAT calorimeter

team effort involving physicists and engineers from the United States (NRL), France (IN2P3 & CEA), and Sweden









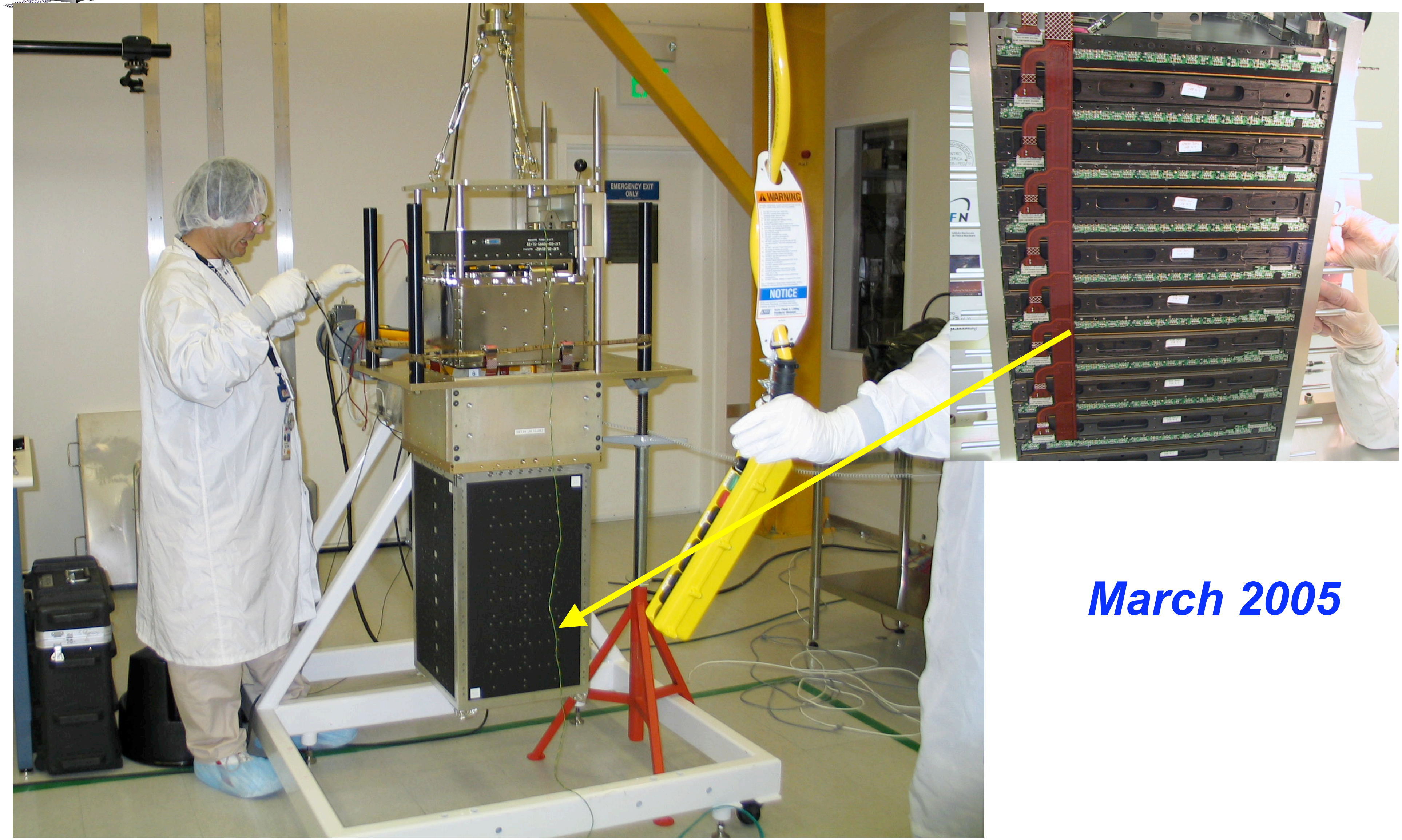
LAT anticoincidence detector

team effort involving physicists and engineers from Goddard Space Flight Center, SLAC, and Fermi Lab

ACD before installation of Micrometeoroid Shield

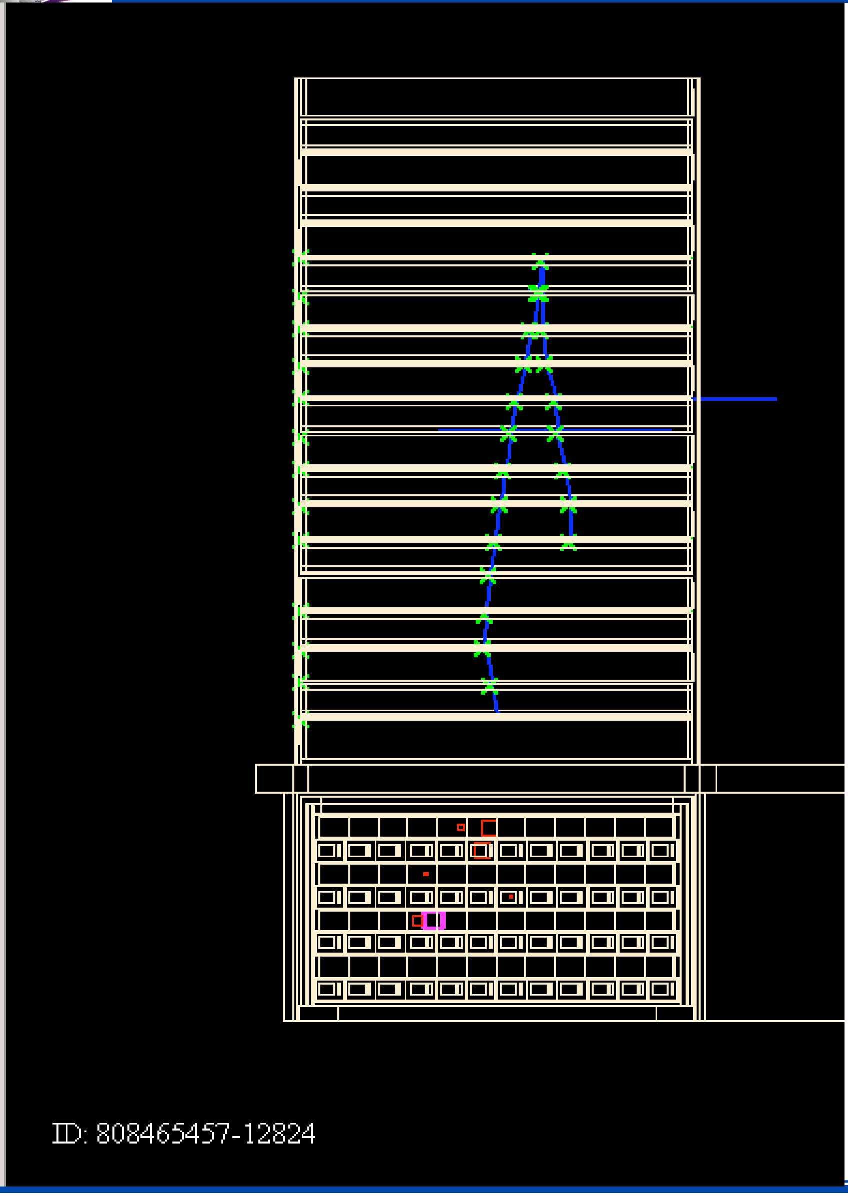
ACD with Micrometeoroid Shield and Multi-Layer Insulation (but without Germanium Kapton outer layer)

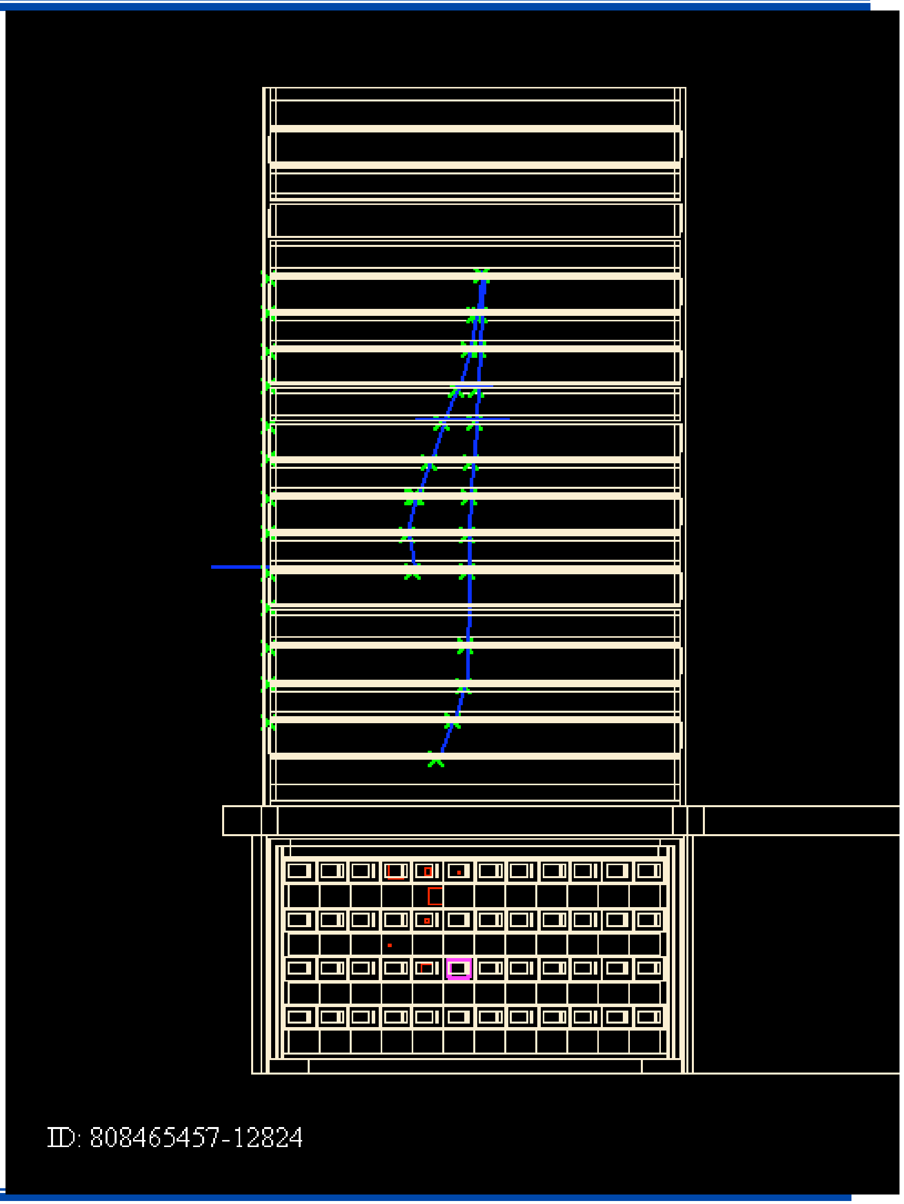
First flight tower in I&T



March 2005

First integrated tower: γ-ray pair conversion

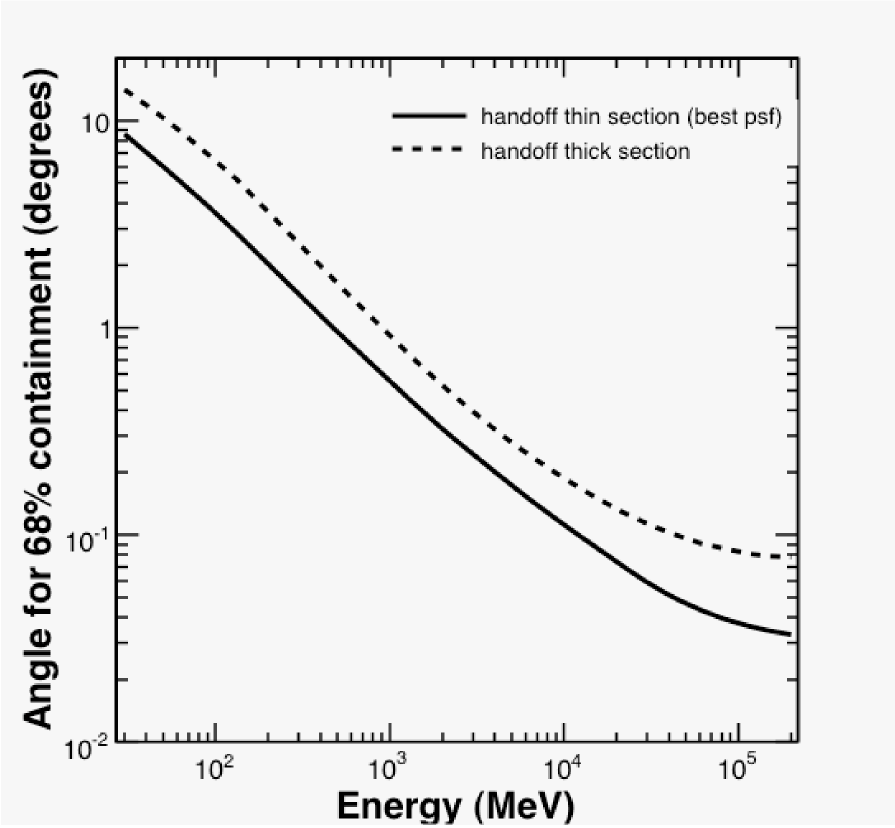


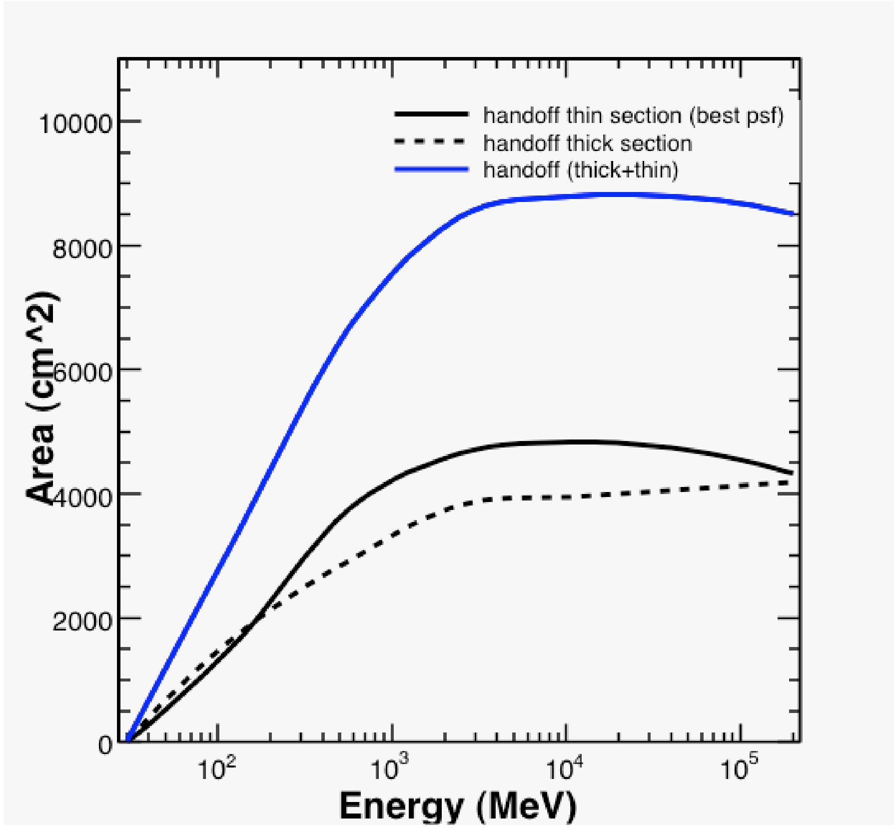


Key science performance requirements summary

Parameter	SRD Value	Current Best Estimate
Peak Effective Area (in range 1-10 GeV)	>8000 cm^2	~ 9000 cm^2
Energy Resolution 100 MeV on-axis	<10%	~ 10%
Energy Resolution 10 GeV on-axis	<10%	< 6%
Energy Resolution 10-300 GeV on-axis	<20%	< 8%
Energy Resolution 10-300 GeV off-axis (>60^o)	<6%	~ 5%
PSF 68% 100 MeV on-axis	<3.5°	< 3.2^o
PSF 68% 10 GeV on-axis	<0.15°	< .1^o
PSF 95/68 ratio	<3	< 3
PSF 55^o/normal ratio	<1.7	< 1.5
Field of View	>2sr	> 2 sr
Background rejection (E>100 MeV)	<10% diffuse	<10% (after residual subtraction)
Point Source Sensitivity(>100MeV)	<6x10^{-9} cm^{-2}s^{-1}	< 4 x 10^{-9} cm^{-2}s^{-1}
Source Location Determination	<0.5 arcmin	< 0.4 arcmin
GRB localization	<10 arcmin	< 5 arcmin
Instrument Time Accuracy	<10 µsec	<< 10 µsec (current 1σ = .7µs)
Dead Time	<100 µsec/evt	26.5 µsec/event nominal
GRB notification time to spacecraft	<5 seconds	Design Meets Requirement

LAT Performance Summary





LAT performance plots available at
www-glast.slac.stanford.edu/software/IS/glast_lat_performance.htm
or google “LAT performance”

Components of simulation and anlysis

Simulation

gamma-ray sky model

background fluxes

Particle Generation and Tracking

Instrument Response (Digitization), Formatting

Trigger an Onboard Filter (wrappe FSW)

Detector Calibration

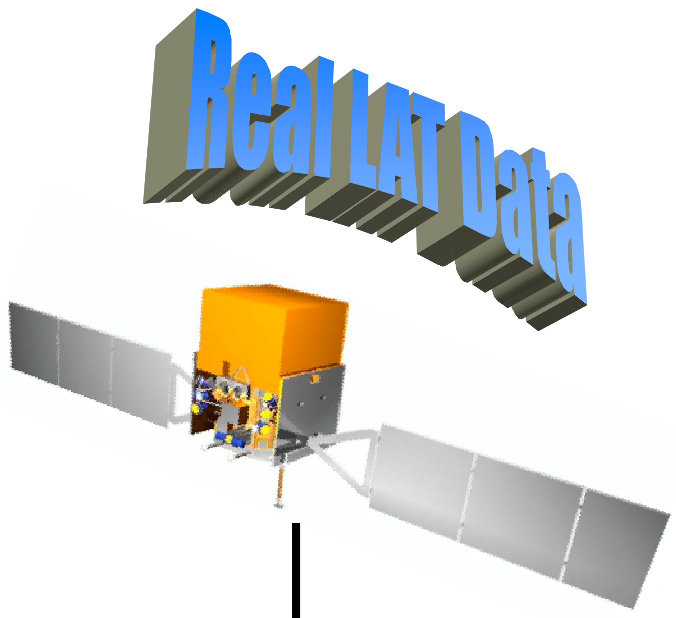
Event Reconstruction

Event Classification

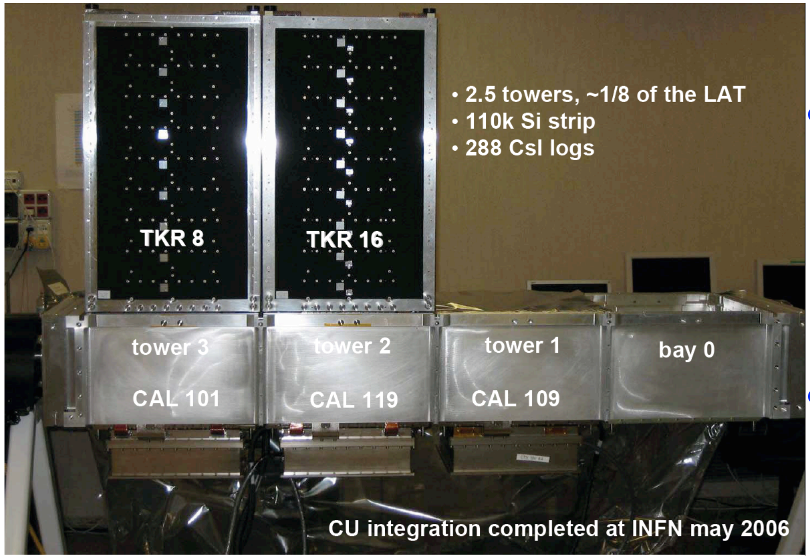
Performance

High-level Science Analysis

(ASI- ASDC Mirror)

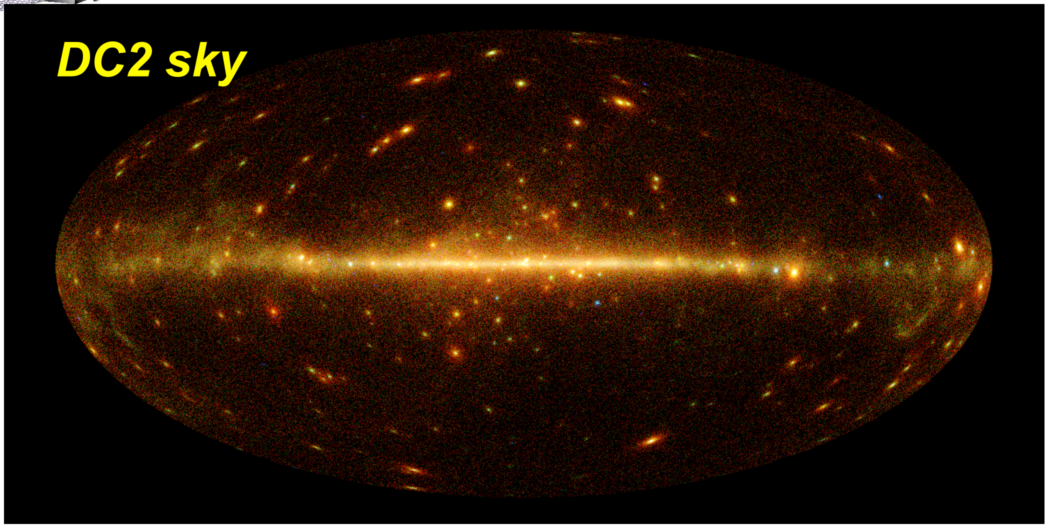


The CERN Beam Test campaign



- 4 weeks at PS/T9 area (26/7-23/8)
  - Gammas @ 0-2.5 GeV
  - Electrons @ 1,5 GeV
  - Positrons @ 1 GeV (through MMS)
  - Protons @ 6,10 GeV (w/ & w/o MMS)
- 11 days at SPS/H4 area (4/9-15/9)
  - Electrons @ 10,20,50,100,200,280 GeV
  - Protons @ 20,100 GeV
  - Pions @ 20 GeV
- Data, data, data…
  - 1700 runs, 94M processed events
  - 330 configurations (particle, energy, angle, impact position)
  - Mass simulation
- A very dedicated team
  - 60 people worked at CERN
  - Whole collaboration represented

Data Challenges



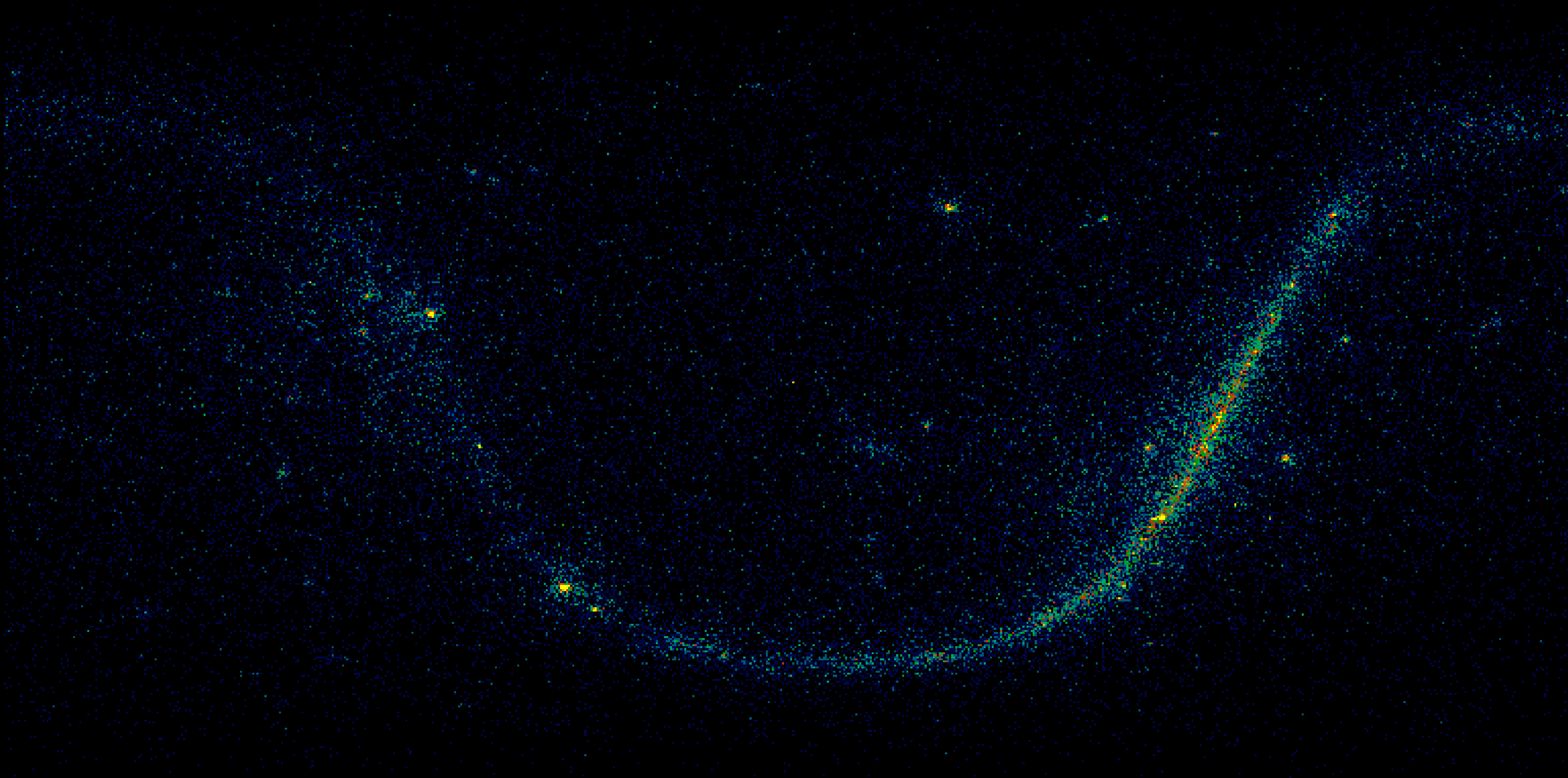
Data challenges provide excellent testbeds for science analysis software.

Full observation, instrument, and data processing simulation.

Team uses data and tools to find the science. "Truth" revealed at the end.

- **A progression of data challenges.**
  - **DC1 in 2004: 1 simulated week all-sky survey simulation.**
    - **find the sources, including GRBs**
    - **a few physics surprises**
  - **DC2 in 2006: 55 simulated days all-sky survey.**
    - **first catalog**
    - **source variability (AGN flares, pulsars) added. lightcurves and spectral studies. correlations with other wavelengths. add GBM. study detection algorithms. benchmark data processing/volumes.**

Simulated gamma-ray sky



Galactic diffuse emission, AGN, SNR, X-ray binaries, galaxy clusters, starburst galaxies, pulsars, dark matter, solar flares, moon, gamma-ray bursts

Each frame is one day (~provides sensitivity to EGRET threshold!)

GLAST LAT Science

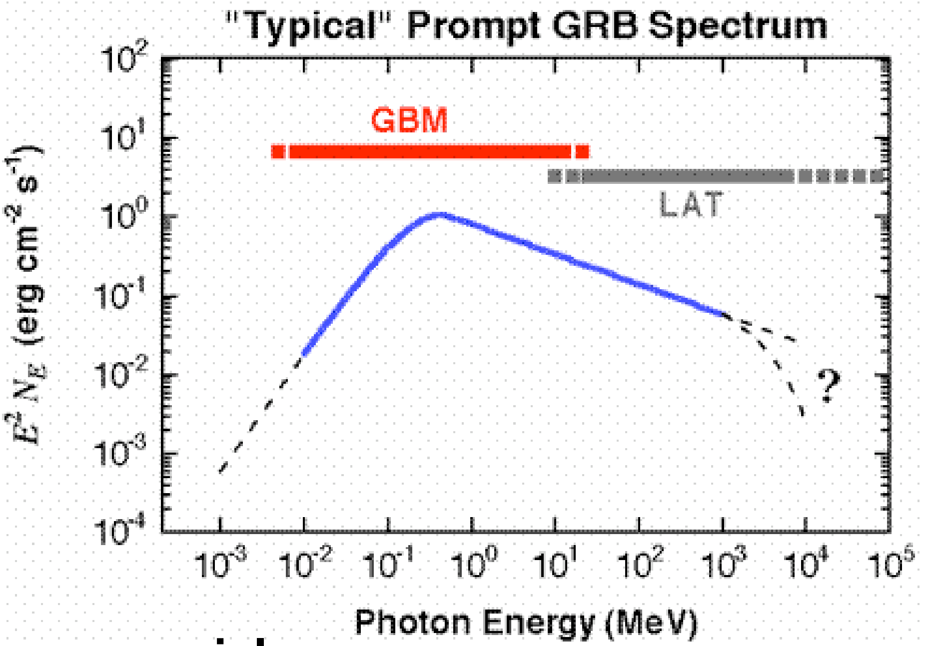
- **GLAST-LAT will have a very broad menu that includes:**
  - Systems with supermassive black holes (AGN)
  - Gamma-ray bursts (GRBs)
  - Pulsars
  - Solar physics
  - Origin of Cosmic Rays
  - Probing the era of galaxy formation, optical-UV background light
  - Solving the mystery of the high-energy unidentified sources
  - Discovery! New source classes. Particle Dark Matter? Other relics from the Big Bang? Testing Lorentz invariance.
- **Huge increment in capabilities**

Gamma Ray Bursts

GLAST will provide superb prompt GRB spectra over a wide energy range (8 keV - 300 GeV)

Spacecraft can autonomously slew to the GRB location to allow measurement of high energy afterglows.

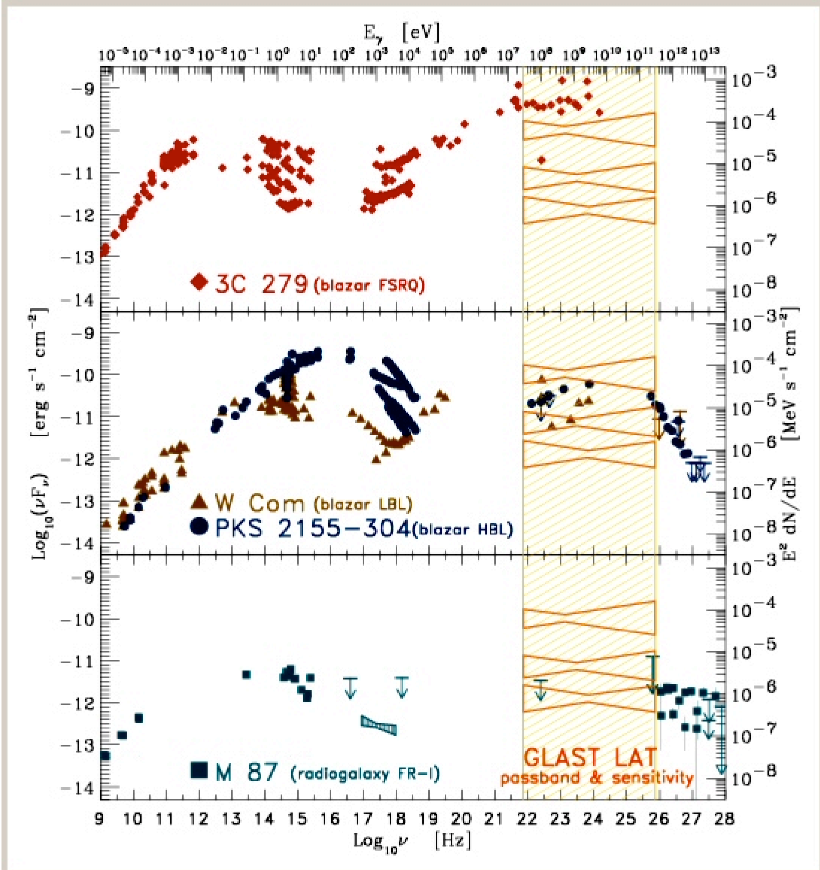
GBM will trigger on ~215 GRB per year of which ~70 will lie within LAT FoV.



- **Multiwavelength follow up observations are crucial**
  - This will be challenging for GRB detected in the GBM only (position uncertainty of a couple degrees)
  - GRB detected by the LAT will have much better measured locations (10s arcmin)
  - Optimally a GRB is triggered in both Swift and GLAST: GLAST will provide good prompt spectra and high energy afterglow measurements, Swift will provide good location and afterglow observations.

Gamma Ray Blazars

- EGRET context
  - Discovered flaring from >60 AGN
  - Highly variable
    - Timescale ~ day, but limited by sensitivity
  - Multiwavelength variability
  - Note: now there are ~ dozen known flaring TeV blazars
- LAT expectation
  - Predict >1000 blazar detections
  - Sensitivity to monitor variability on hour timescales from bright flares
- Fundamental questions
  - What is structure and composition of jet?
    - Leptons or hadrons?
  - Where is γ-ray production site?
- Multiwavelength studies
  - "Two-component" spectrum
    - Low energy peak ranges from below IR to X-ray
    - High energy peak at GeV to TeV



SEDs for four gamma-ray sources and the average expected LAT passband and sensitivity for 1 day, 1 month and 1 year of observations.

Operation Phases, Guest Observers, Data

- First year science ops: sky survey beginning after initial on-orbit checkout, verification, and calibrations
  - Viewing plan = sky survey
    - Every region of the sky viewed for ~30 minutes every 3 hours
    - Repoints for bright bursts and burst alerts enabled
    - Extraordinary ToOs supported
  - Data releases, catalogs
    - Data on flaring sources, transients, and ~20 selected sources will be released
      - See *http://glast.gsfc.nasa.gov/ssc/data/policy/LAT_Year_1_Data_Release.html*
    - Preliminary LAT source catalog
      - High-confidence sources
        - » Position, avg flux, peak flux, spectral index, associated errors
      - Released ~ six months into year 1 (in advance of Cycle 2 proposals)
  - Workshops for guest observers on science tools and mission characteristics for proposal preparation
- Subsequent years: observing plan driven by guest observer proposal selections by peer review. Default is sky survey mode.
  - All data publicly released within 72 hours through the Science Support Center (GSSC: provides data, software, documentation, workbooks and training to community. See *http://glast.gsfc.nasa.gov/ssc*)

MW Info and Coordination

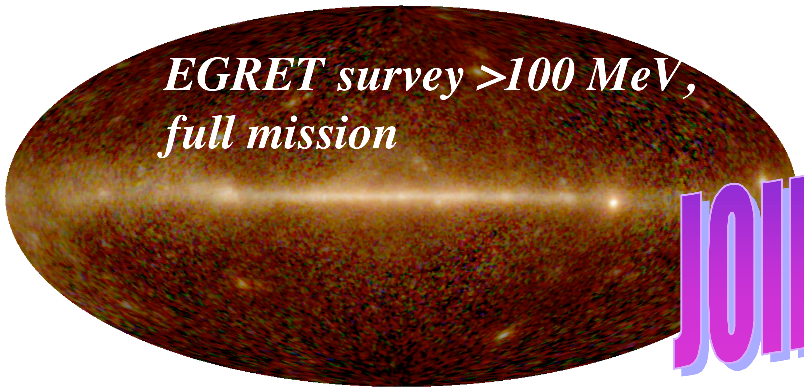
- **Multiwavelength observations are key to many science topics for GLAST.**
  - **GLAST welcomes collaborative efforts from observers at all wavelengths**
    - **For campaigners' information and coordination, see** ***http://glast.gsfc.nasa.gov/science/multi***
    - **To be added to the Gamma Ray Multiwavelength Information mailing list, contact Dave Thompson,**

    djt@egret.gsfc.nasa.gov

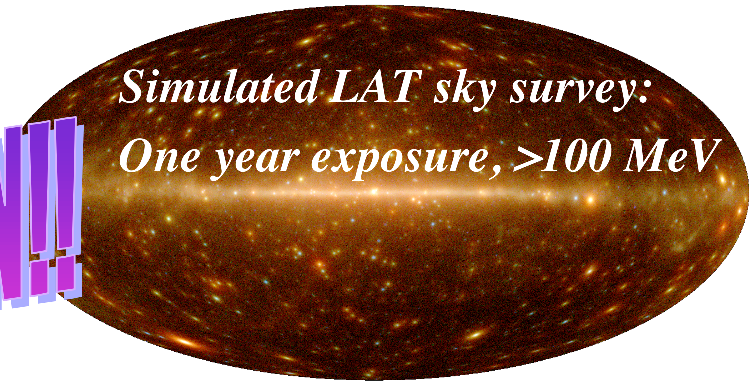
- **GI Program will support correlative observations and analysis**
  - **See** ***http://glast.gsfc.nasa.gov/ssc/proposals***

Conclusions

- GLAST will provide a huge leap in capabilities compared with previous high energy gamma-ray missions.
  - Lots more gamma-ray sources
  - More classes of gamma-ray sources
  - Lots more details on the gamma-ray properties of these sources
    - Gamma-ray observations will become relevant to a lot more people.
- See http://glast.gsfc.nasa.gov/ for more information on the mission and on guest investigator support.
- Launch early 2008



JOIN THE FUN!!



LAT physics concept

- **Pair production telescope for high energy gamma rays**
  - **Tracker, calorimeter, and anti-coincidence shield work together to measure direction and energy of γ-rays and reject background**
  - **Optimization**
    - **Angular resolution: many thin layers of small-pitch silicon TKR**
    - **Energy resolution: as thick as possible CAL, hodoscopic geometry to measure shower profile**
    - **Rejection: efficient ACD particle detection, segmented to minimize self-veto from γ-ray shower backsplash**

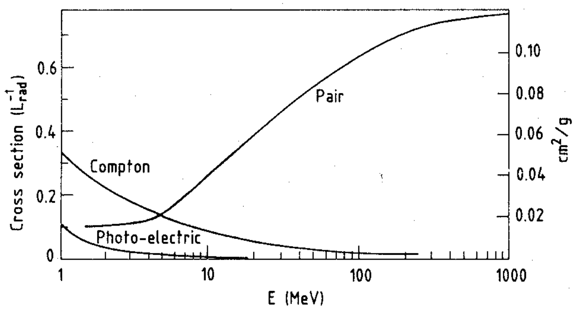


Fig. 2: Photon cross-section σ in lead as a function of photon energy. The intensity of photons can be expressed as $I = I_0 \exp(-\sigma x)$, where x is the path length in radiation lengths. (Review of Particle Properties, April 1980 edition).