The Large Area Telescope

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Stanford University
on behalf of the GLAST LAT Collaboration

GLAST Symposium, Stanford University, February 5-8, 2007

Outline

- The Large Area Telescope (LAT): a pair conversion telescope
- LAT performance
- Subsystems
  - tracker
  - calorimeter
  - anticoincidence detector (ACD)
  - trigger and data acquisition system
- LAT simulation & testing
- analysis software development

GLAST LAT Collaboration

United States
- California State University at Sonoma
- University of California at Santa Cruz - Santa Cruz Institute of Particle Physics
- Goddard Space Flight Center – Laboratory for High Energy Astrophysics
- Naval Research Laboratory
- Ohio State University
- Stanford University HEPL, KIPAC, and SLAC)
- Texas A&M University – Kingsville
- University of Washington

France
- CEA/Saclay
- IN2P3

Italy
- ASI
- INFN
- INAF

Japan GLAST Collaboration
- Hiroshima University
- Institute for Space and Astronautical Science
- RIKEN

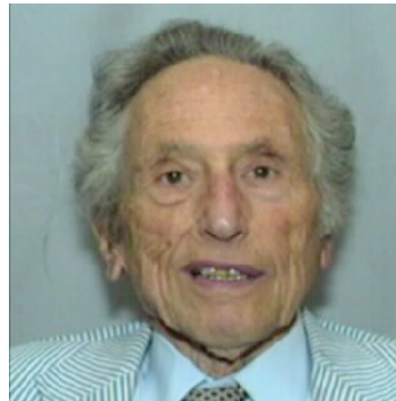
Swedish GLAST Consortium
- Royal Institute of Technology (KTH)
- Stockholm University

Cooperation between NASA and DOE, with key contributions from France, Italy, Japan, and Sweden

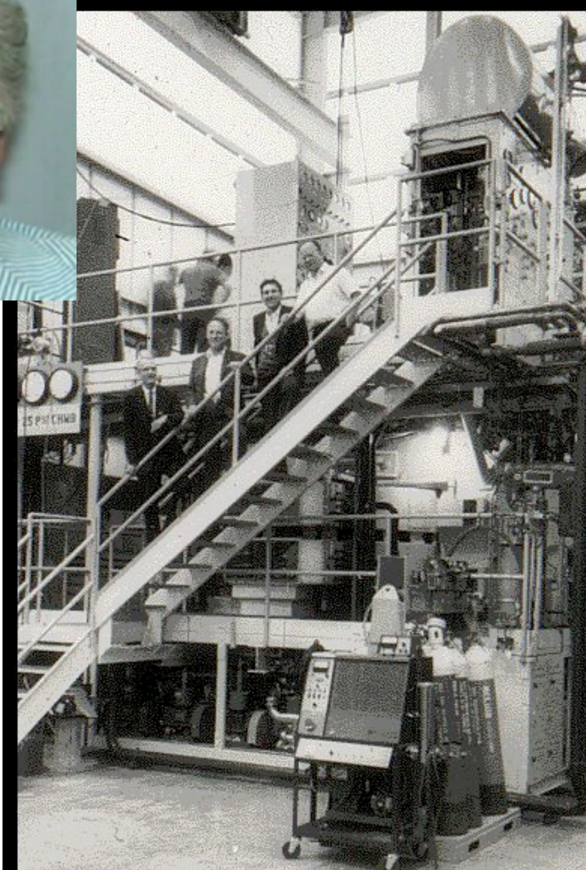
LAT instrument construction managed by the Stanford Linear Accelerator Center

Remembering two early sources of inspiration and support

Herbert Gursky (NRL)



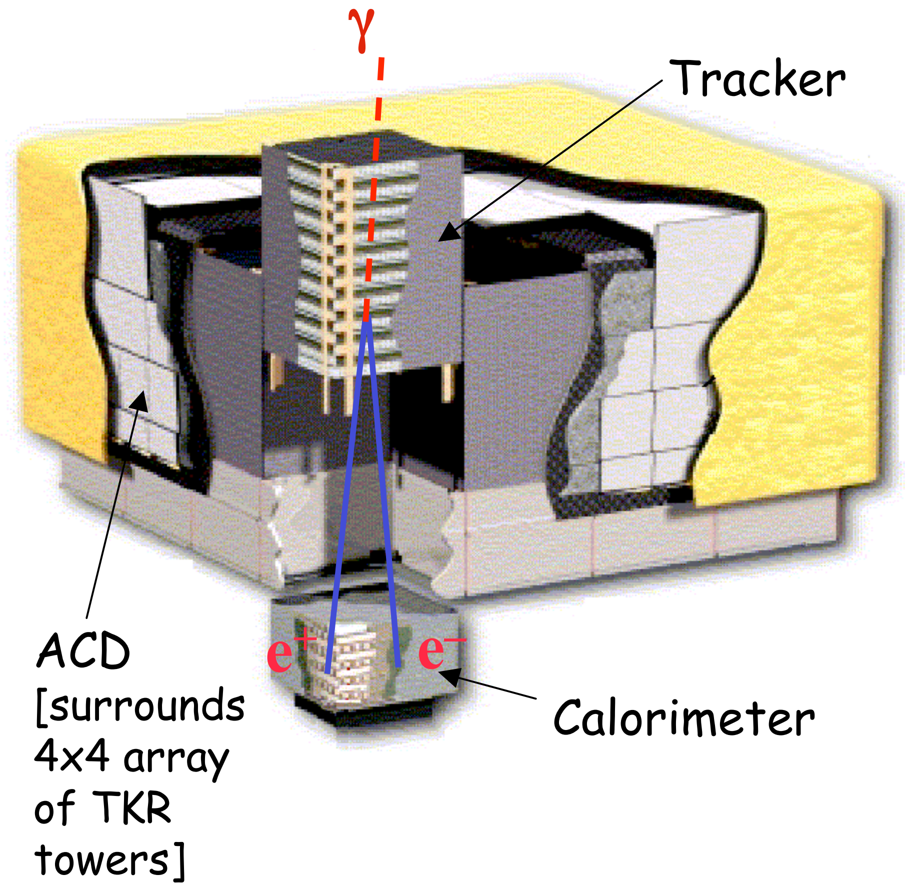
Joe Ballam (SLAC)



Pief Panofsky, Joe Ballam, Bob Watt, and Luis Alvarez (top to bottom) stand on the remodeled 72-inch (increased to 82-inch) bubble chamber after its transfer from Lawrence Radiation Laboratory to SLAC in 1967

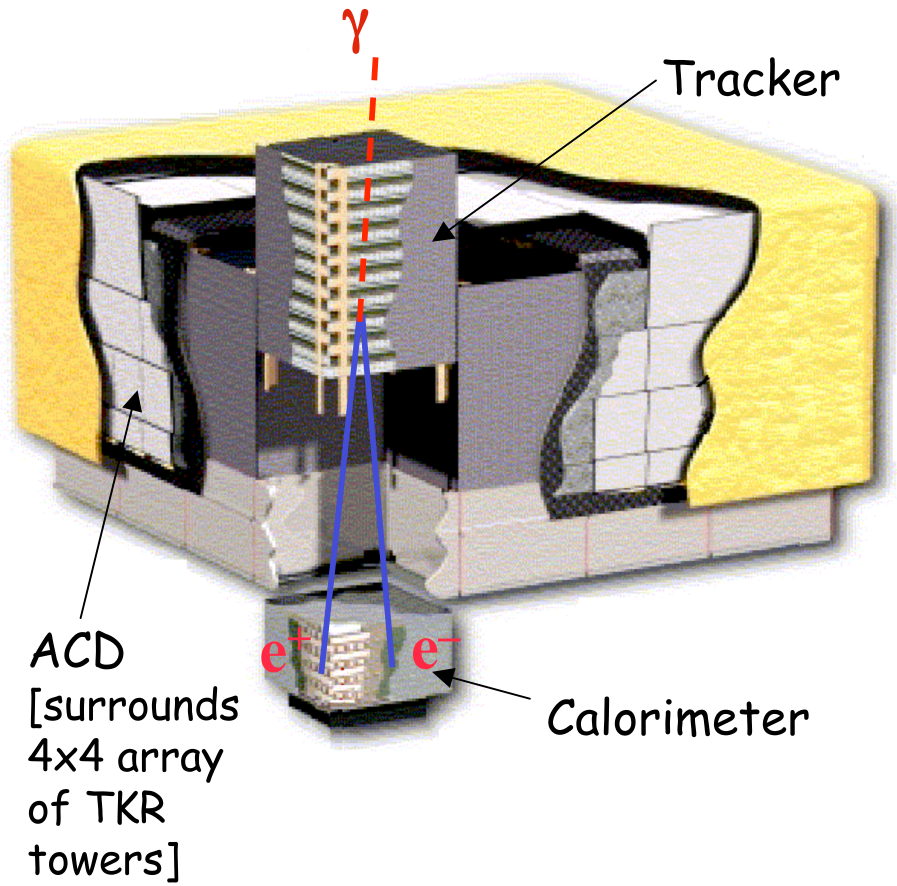
Components of the LAT

- **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.

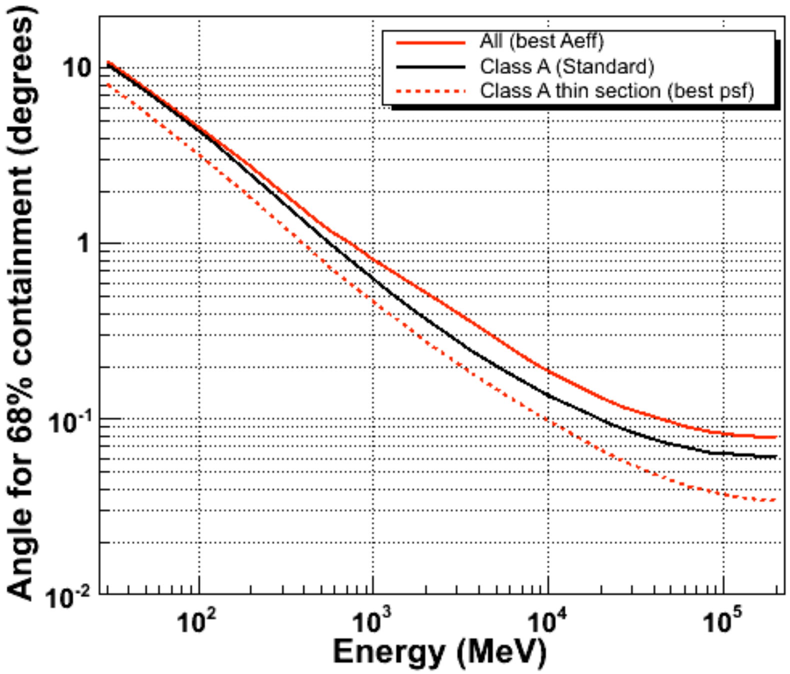
the real LAT

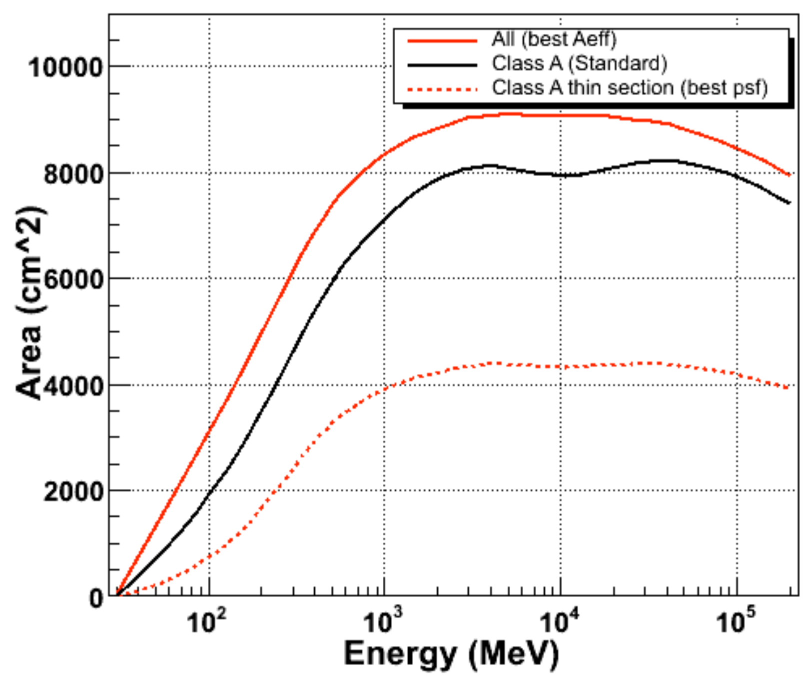

γ
Tracker
ACD
[surrounds
4x4 array
of TKR
towers]
e+
e−
Calorimeter

Key (Level 2) 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°)	<6%	~ 5%
PSF 68% 100 MeV on-axis	<3.5°	< 3.2°
PSF 68% 10 GeV on-axis	<0.15°	< .1
PSF 95/68 ratio	<3	< 3
PSF 55°/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}
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	

LAT performance summary



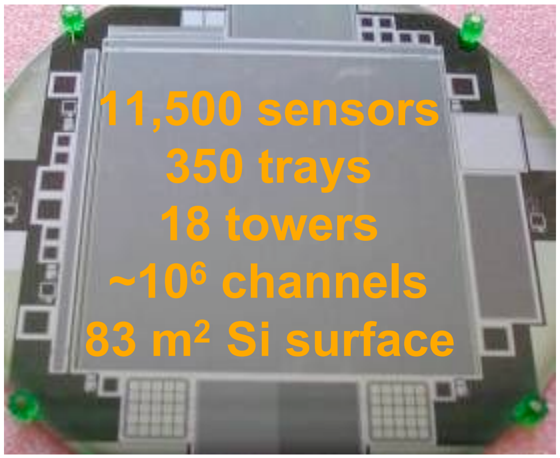


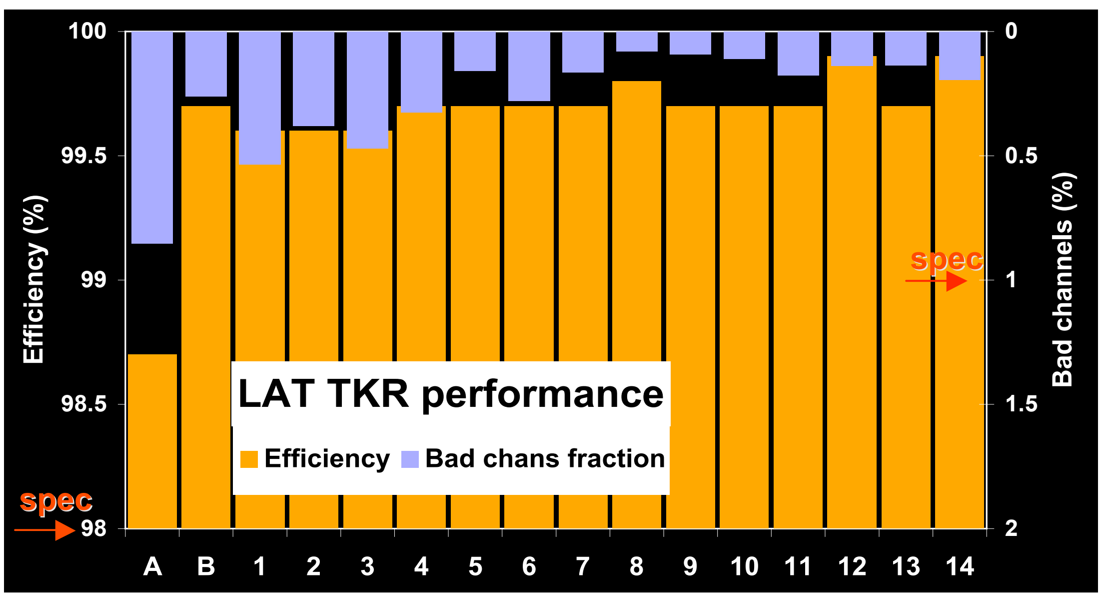
LAT performance plots available at
www-glast.slac.stanford.edu/software/IS/glast_lat_performance.htm

or google "LAT performance"

LAT Silicon Tracker

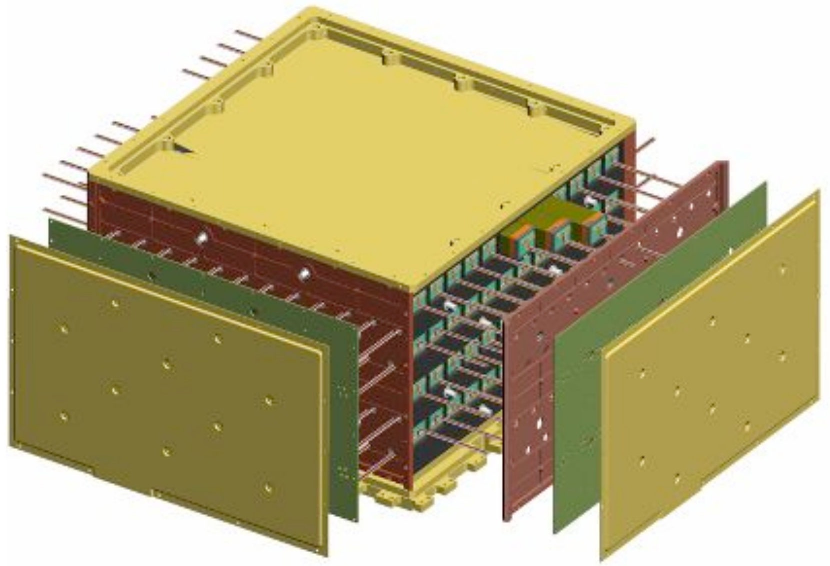
team effort involving physicists and engineers from the United States (UCSC & SLAC), Italy (INFN & ASI), and Japan

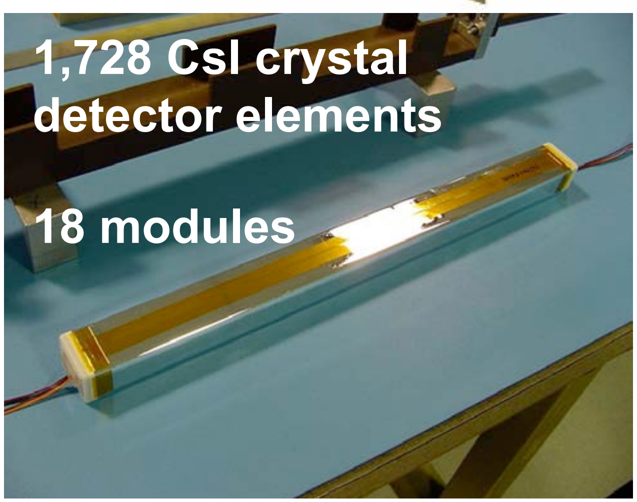


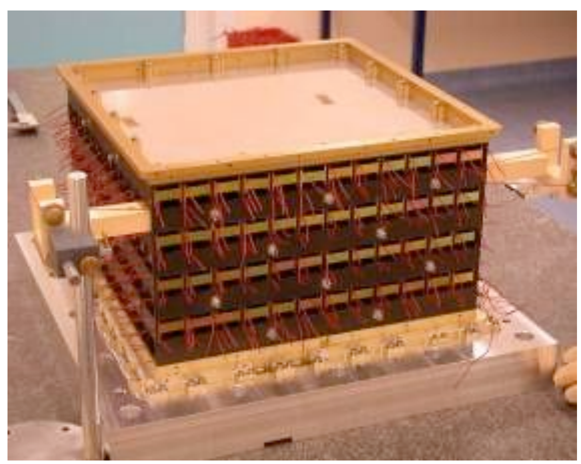


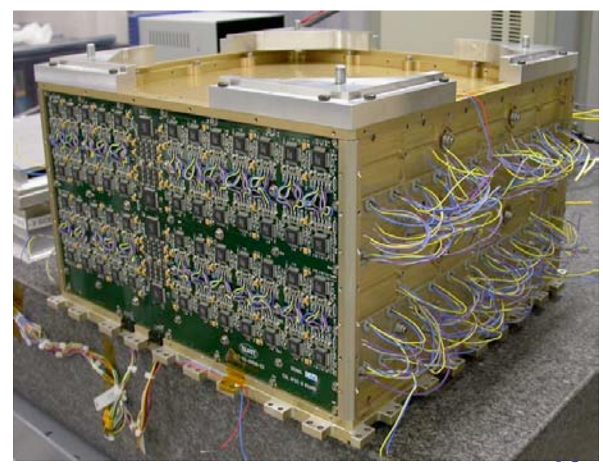
LAT Calorimeter

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

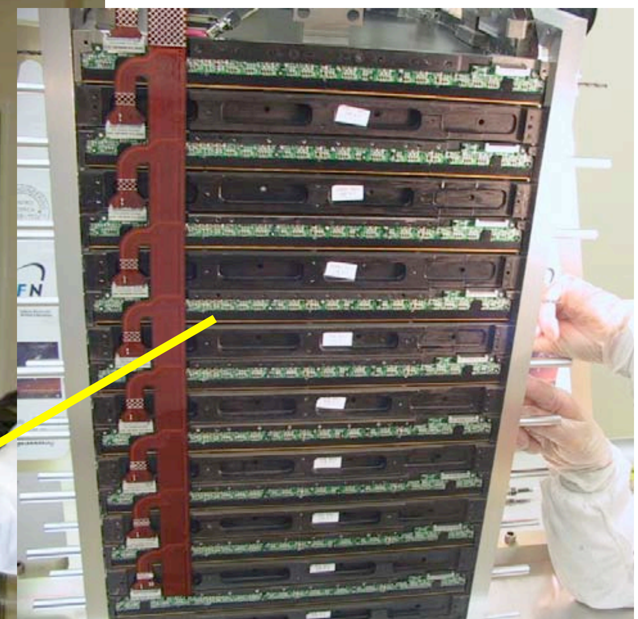






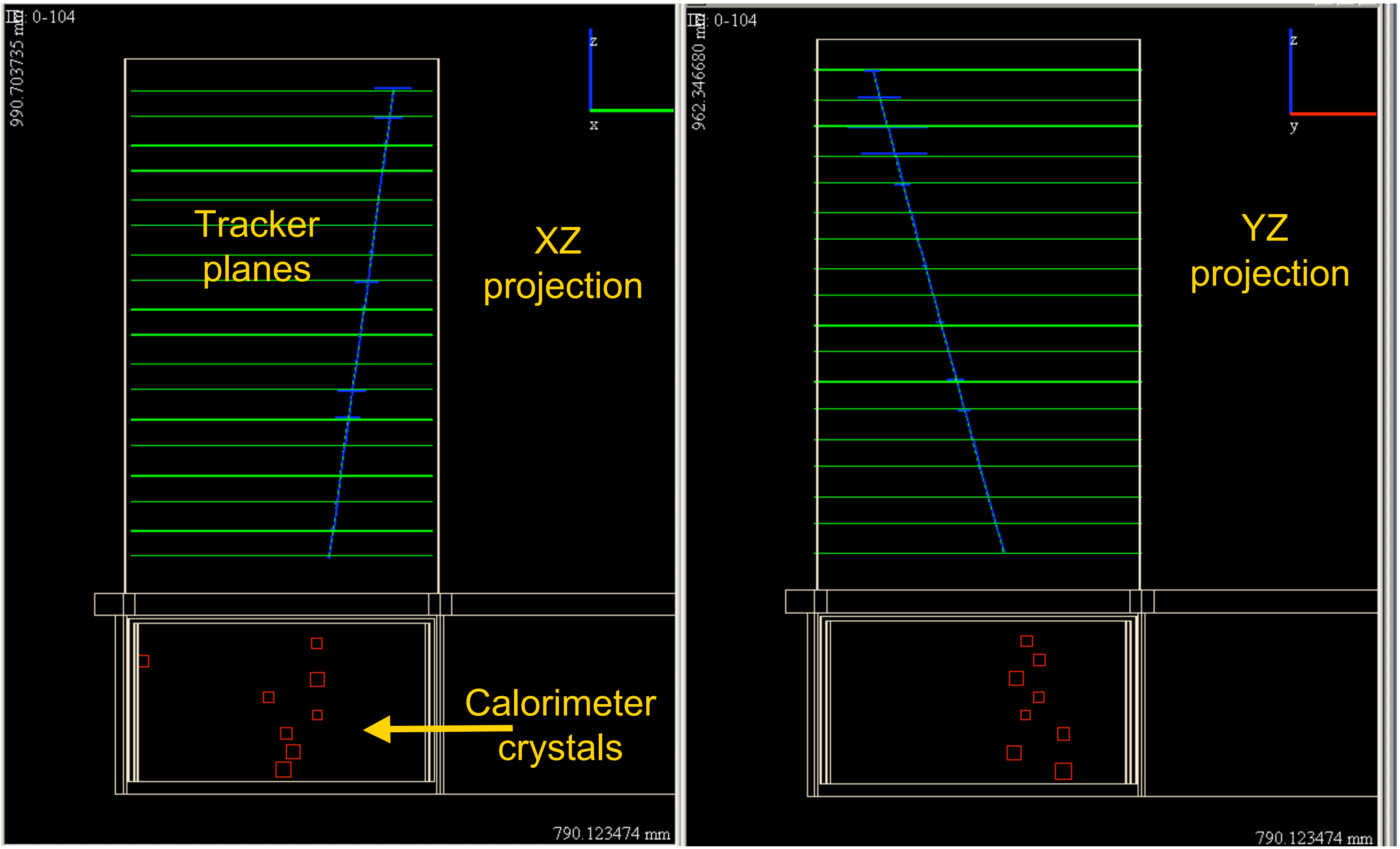


First Flight Tower in I&T

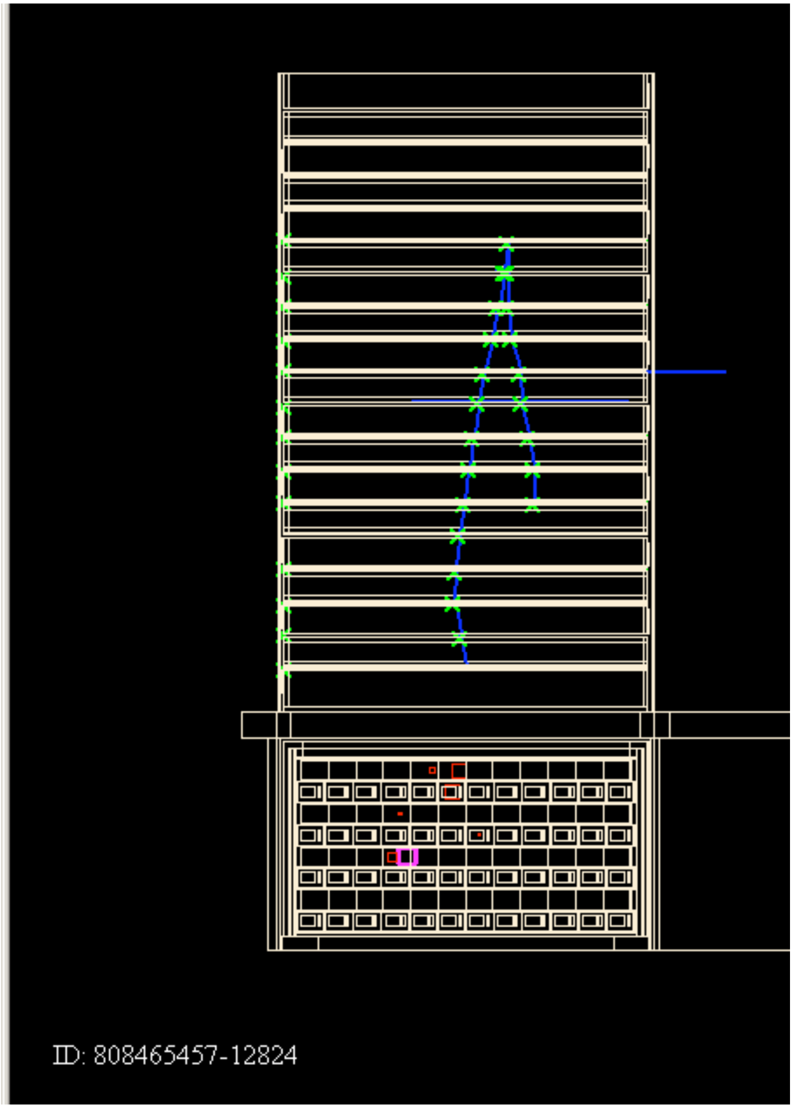


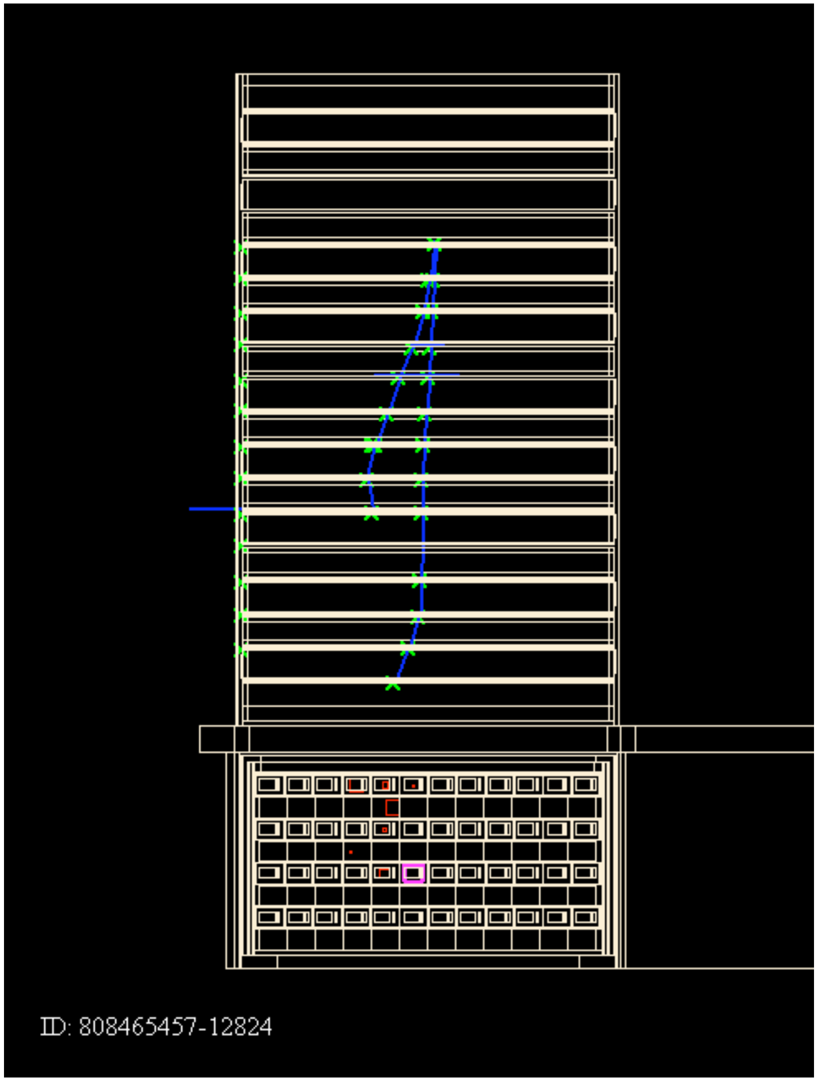
March 2005

First Integrated Tower – Muon Candidate Event



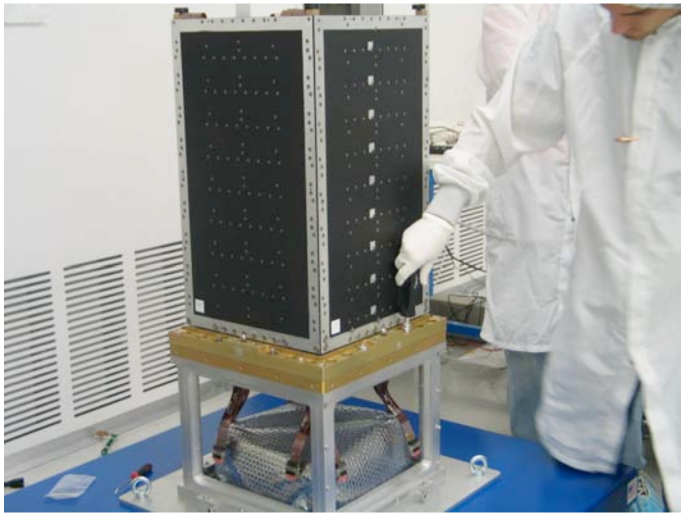
First integrated tower: Gamma-ray pair conversion



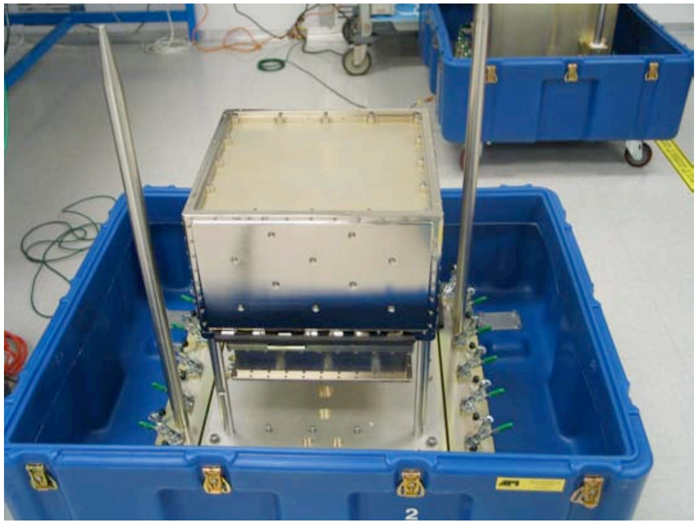


LAT Flight Hardware Integration at SLAC


Preparation of flight grid for TCS integration


Flight Tracker in Cleanroom

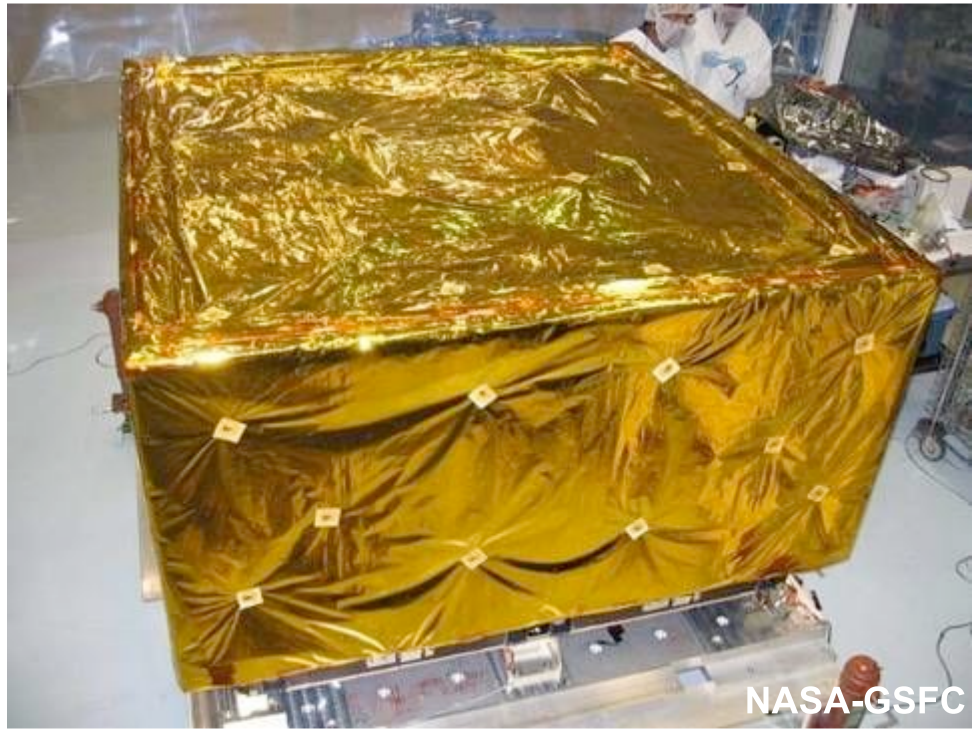

LAT Integration stand with PAP ready for proof test


Flight Calorimeter

LAT Anti-Coincidence Detector

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

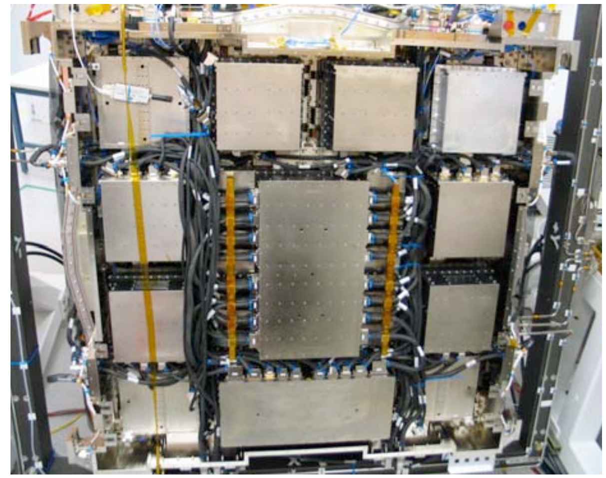
ACD before installation of Micrometeoroid Shield



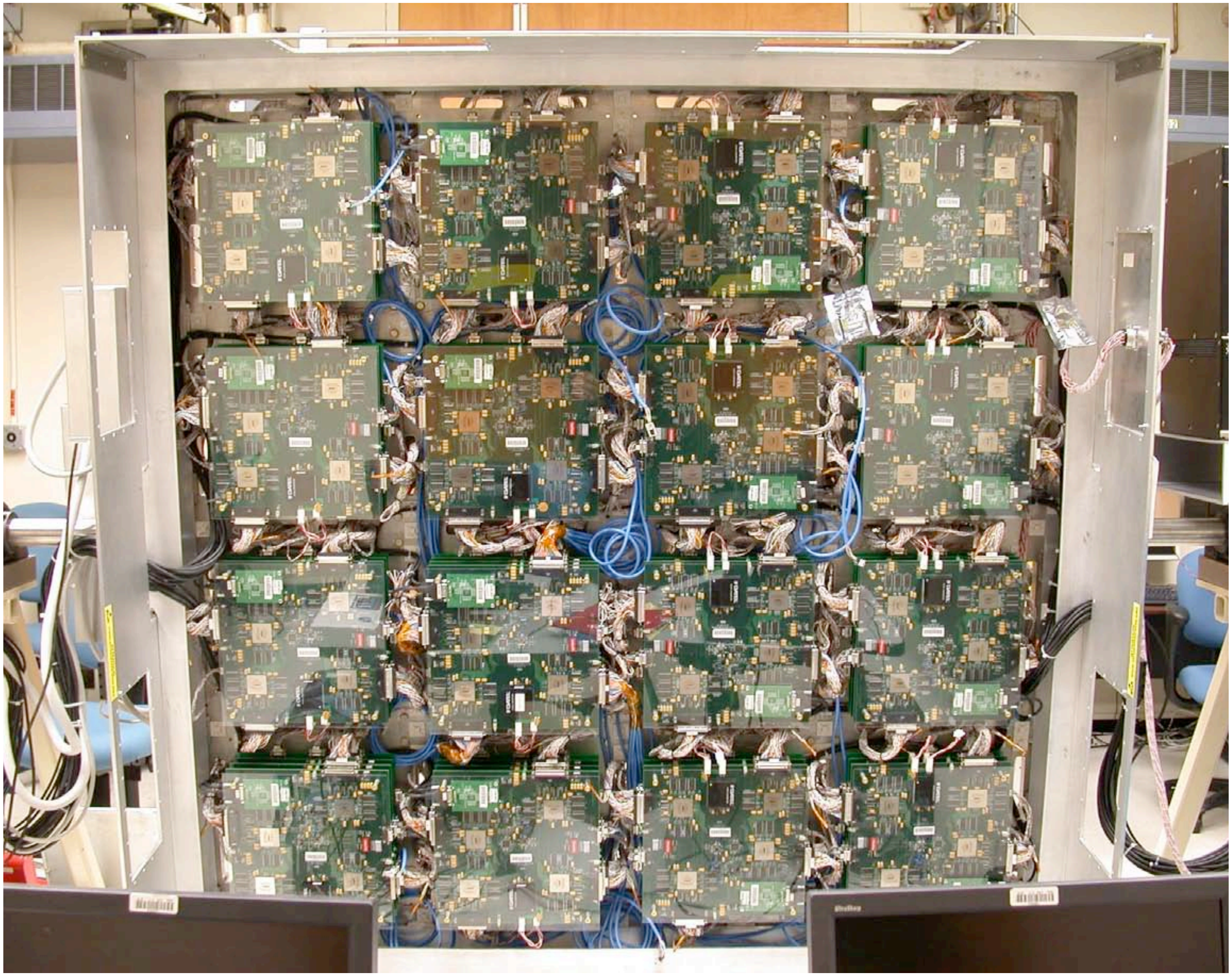
ACD with Micrometeoroid Shield and Multi-Layer Insulation (but without Germanium Kapton outer layer)

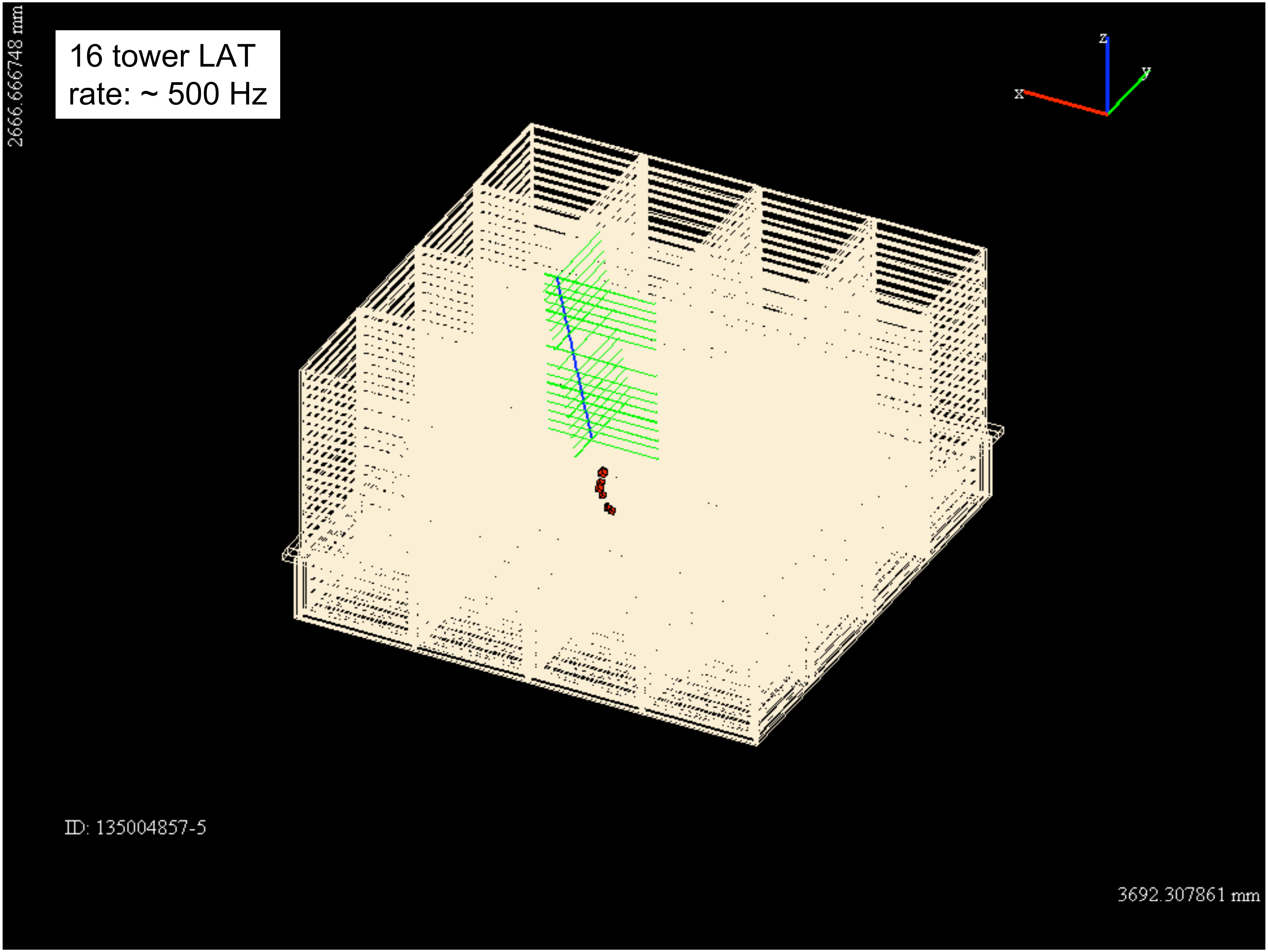
LAT complete

assembly and environmental testing complete: September 2006

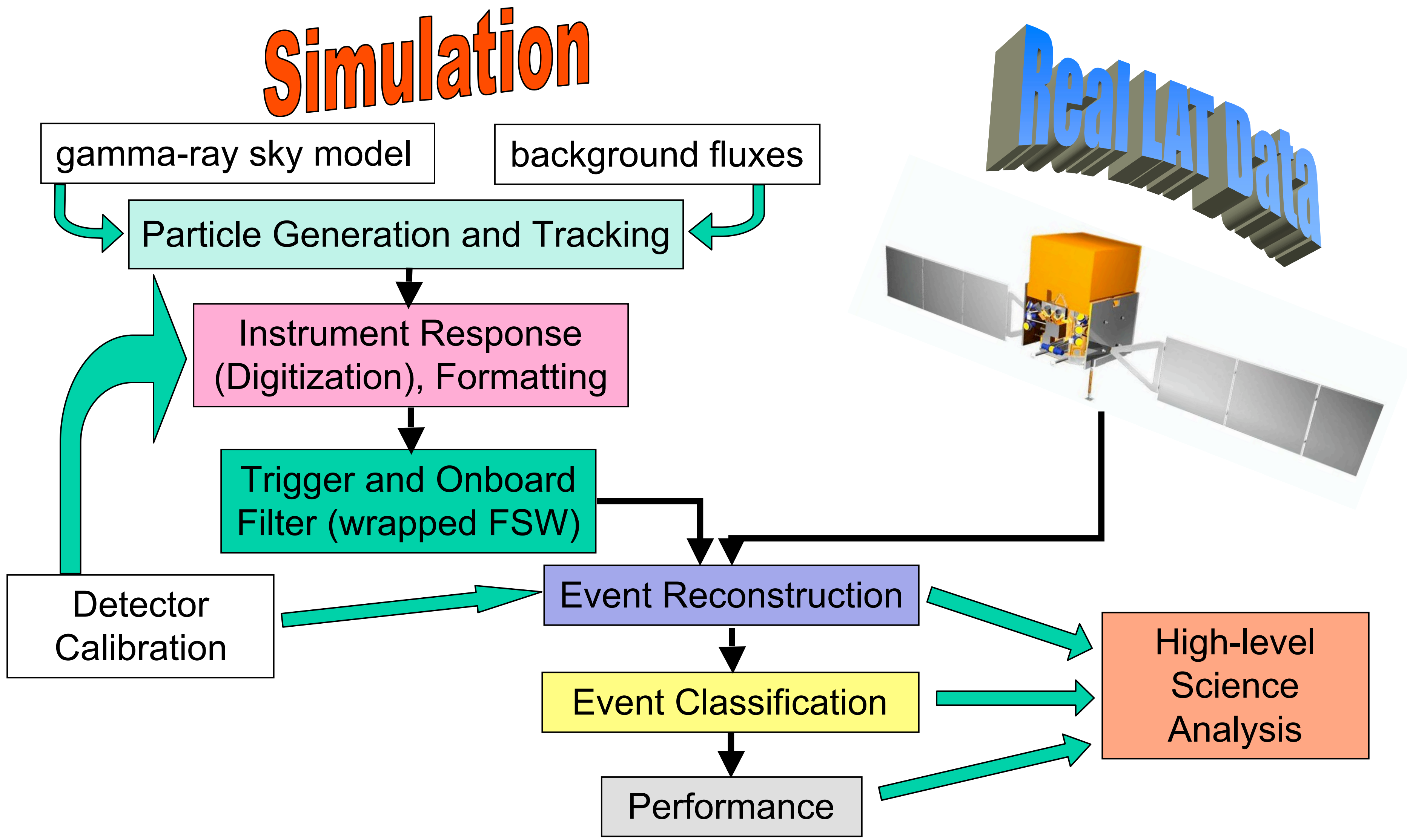


LAT Data Acquisition System Testbed




16 tower LAT
rate: ~ 500 Hz
2666.666748 mm
z
x
y
ID: 135004857-5
3692.307861 mm

Components of Simulation & Analysis



GLAST LAT Simulation

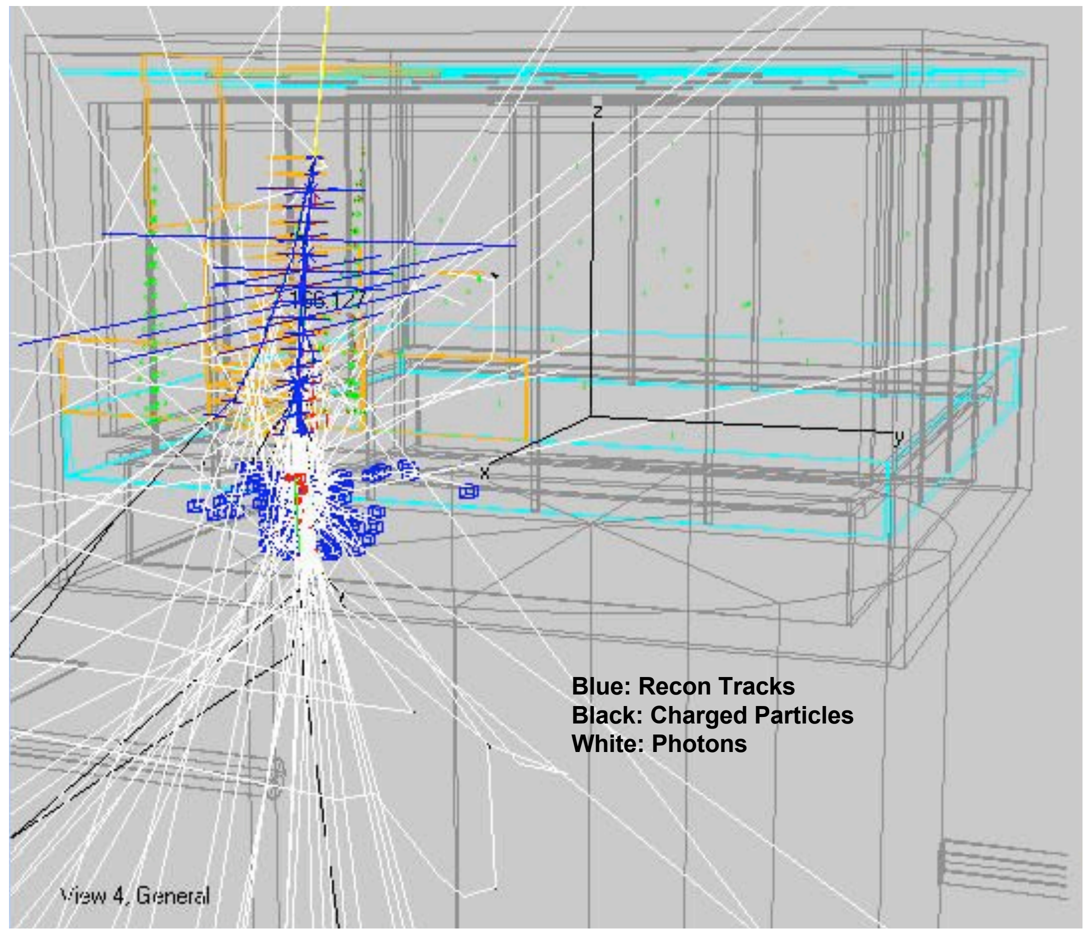
High energy γ interacts in LAT

Geometry Detail
> 500k Volumes
Includes Tracker Electronics Boards
Mounting Holes in ACD Tiles!
Spacecraft details
and much, much more

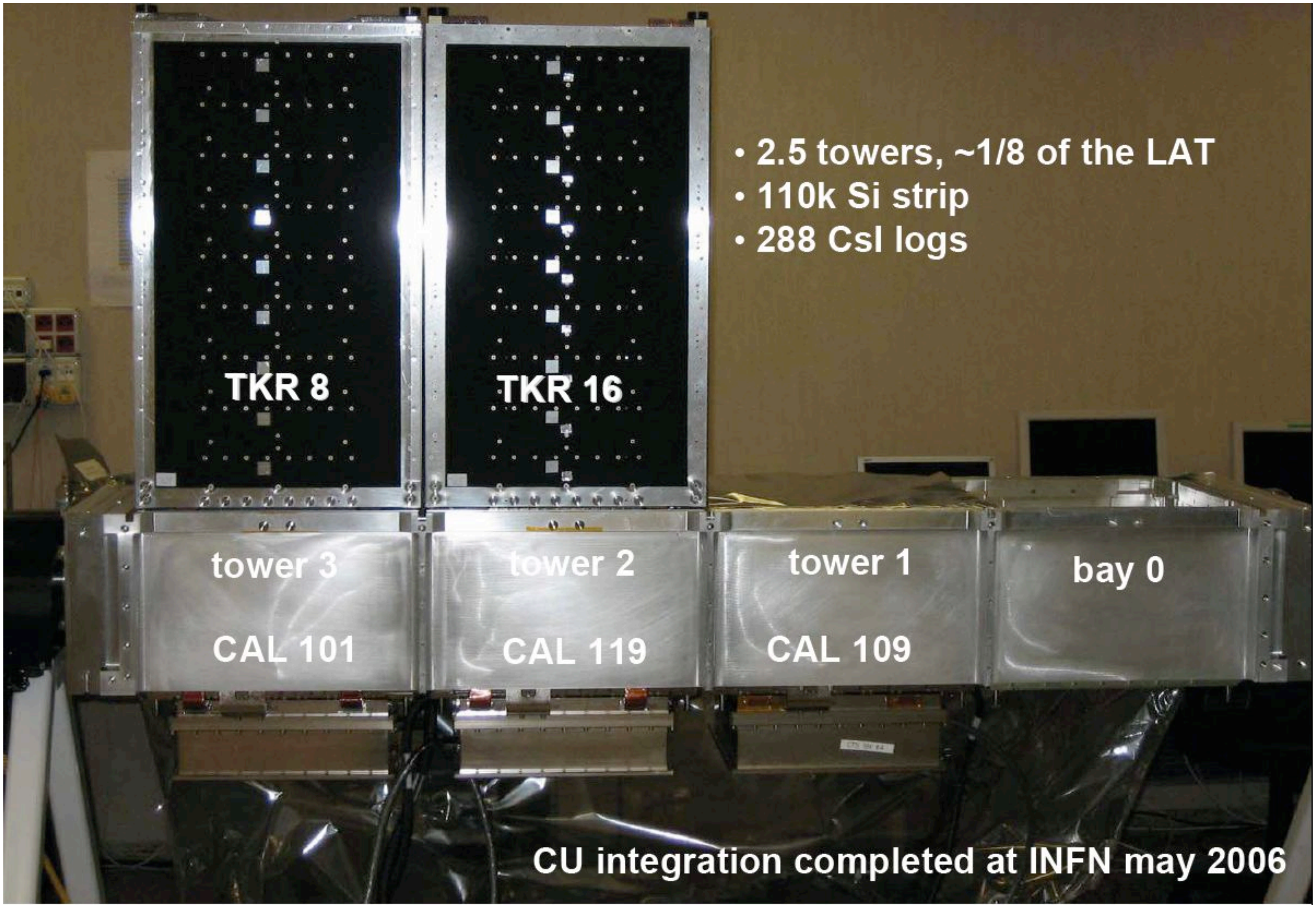
Geant 4 Interaction Physics
QED: based on original EGS code)
Hadronic: based Geisha (can use FLUKA as well as others)

Propagation
Full treatment of multiple scattering
Surface-to-surface ray tracing.

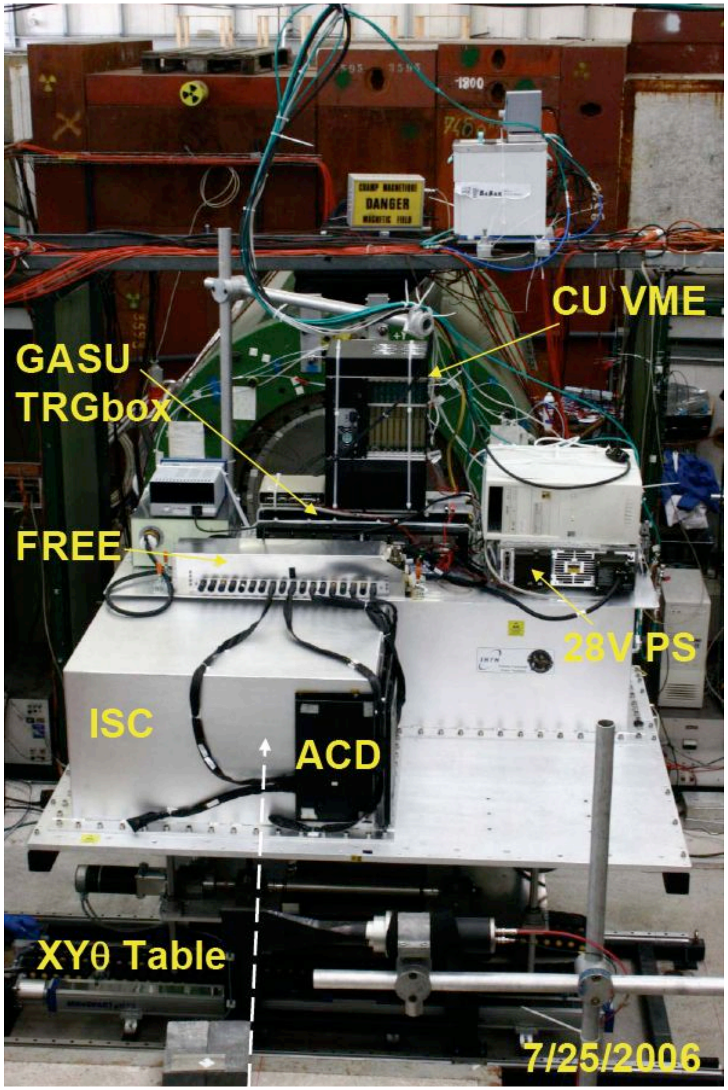
Connection to detector Response
Energy deposits in Active Volumes
Parametric Detector response based on energy and location



The GLAST-LAT Calibration Unit

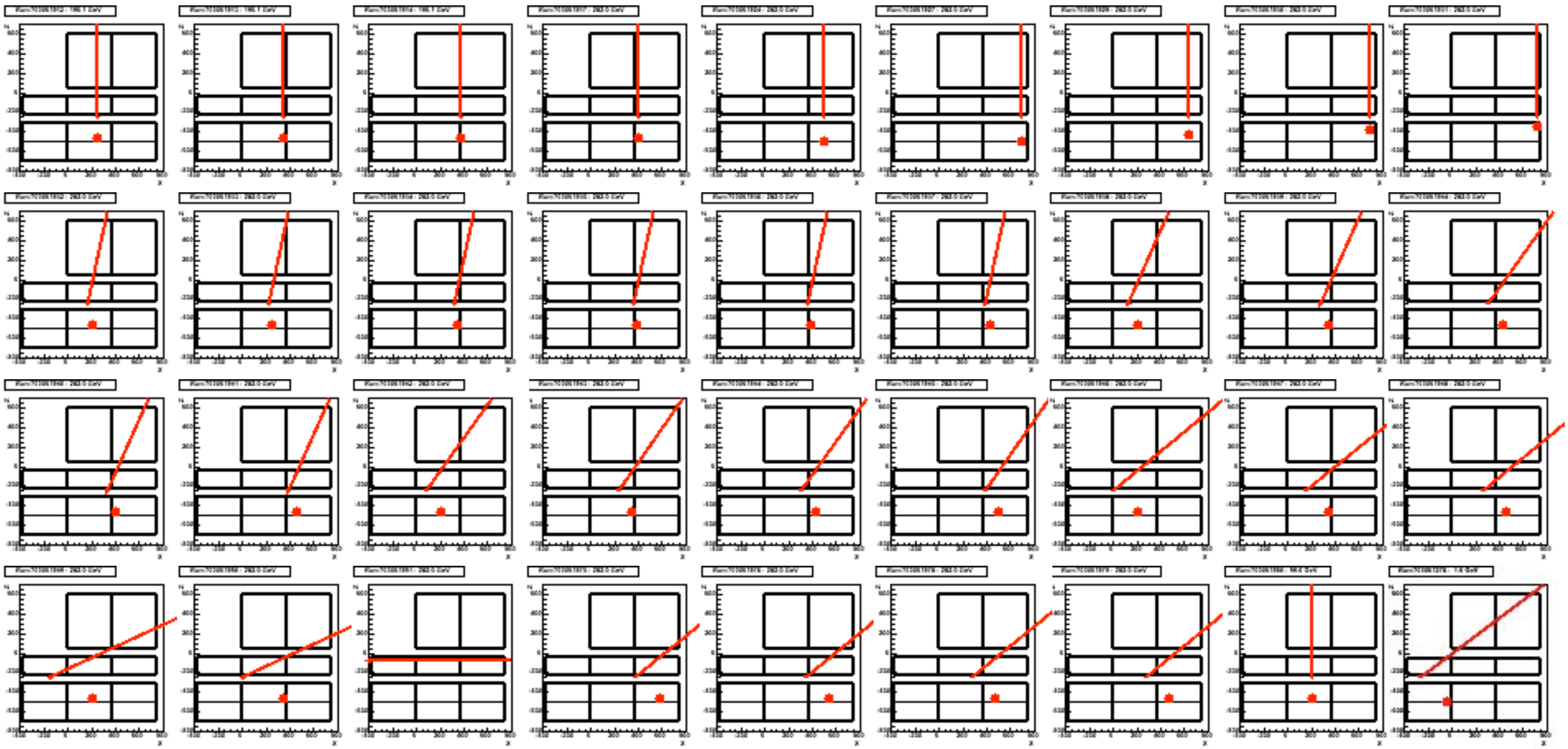


The CERN campaign



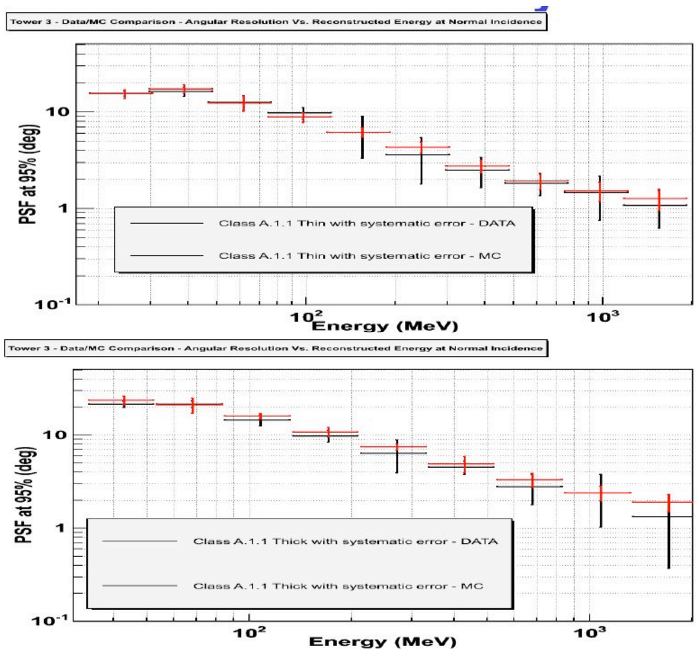
- 4 weeks at PS/T9 area (26/7-23/8)
  - Gammas @ 0-2.5 GeV
  - Electrons @ 1,5 GeV
  - Positrons @ 1 GeV (through MMS)
  - Protons @ 6,10 GeV (w/ & w/o MMS)
- 11 days at SPS/H4 area (4/9-15/9)
  - Electrons @ 10,20,50,100,200,280 GeV
  - Protons @ 20,100 GeV
  - Pions @ 20 GeV
- Data, data, data…
  - 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

Tested many configurations..

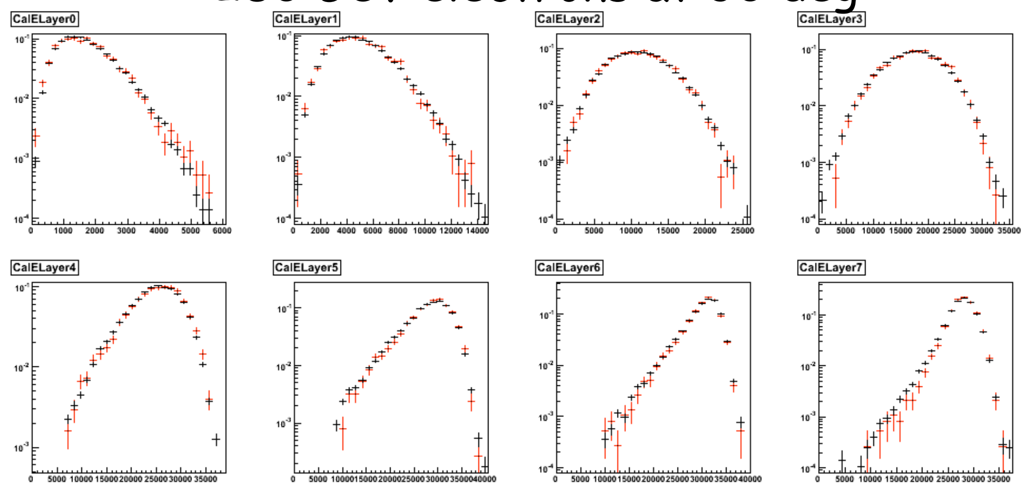


Comparisons with MC Simulation

PSF

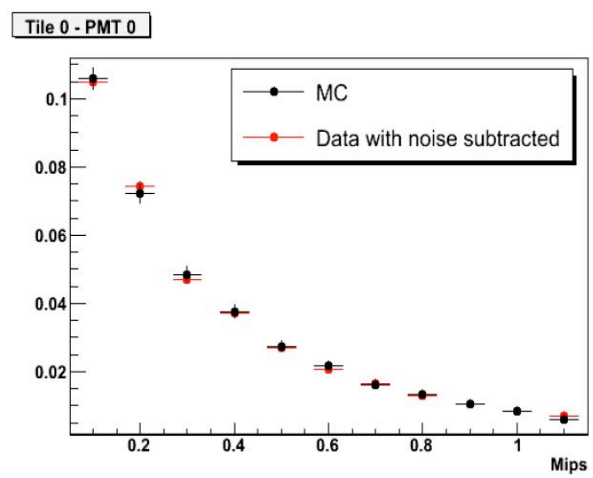


280 GeV electrons at 30 deg

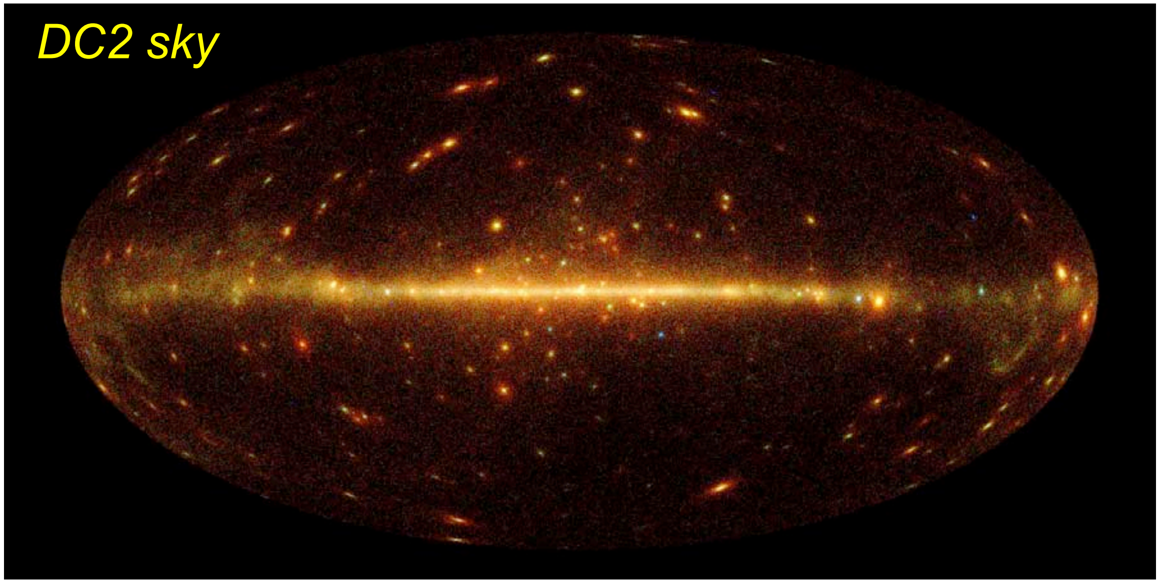


preliminary

ACD Backsplash



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**
    - **<u>source variability</u> (AGN flares, pulsars) added. lightcurves and spectral studies. correlations with other wavelengths. add GBM. study detection algorithms. benchmark data processing/volumes.**

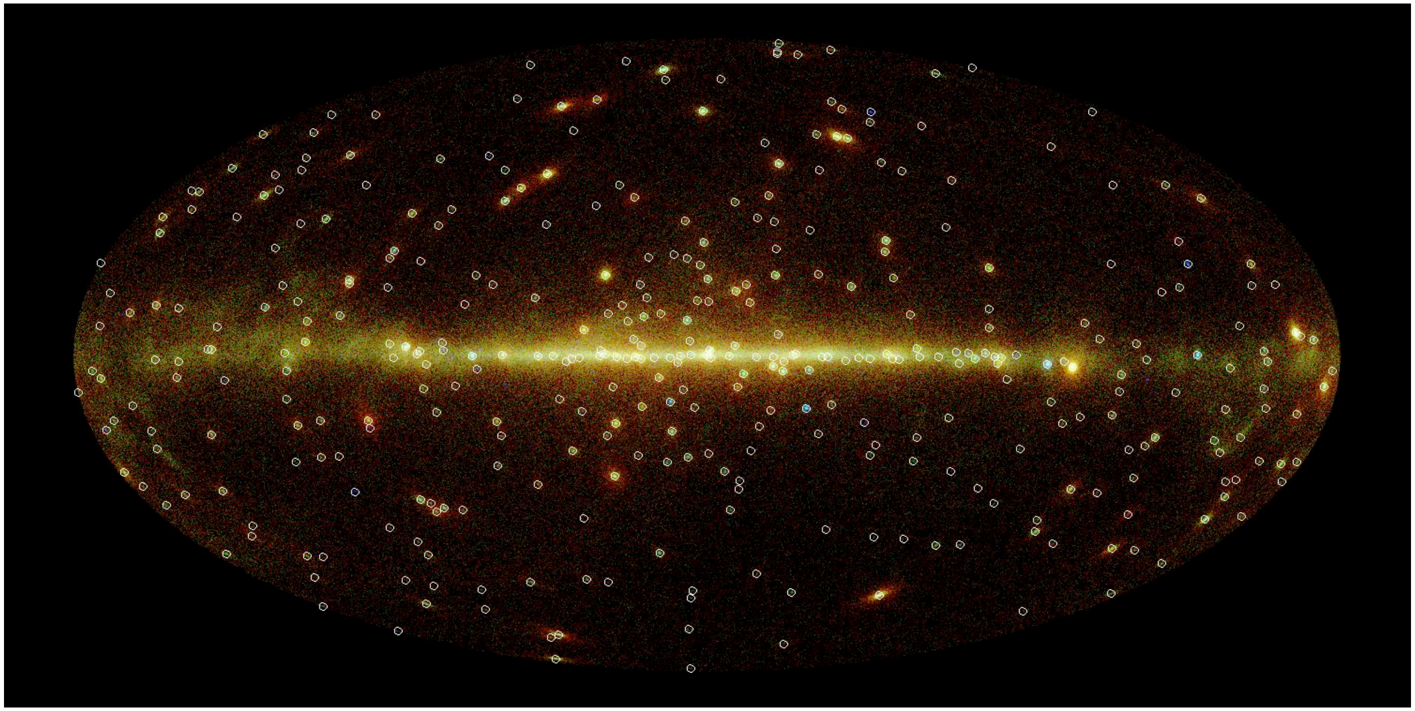
+ Users Committee beta test of the tools in November

DC2 Point Source Catalog

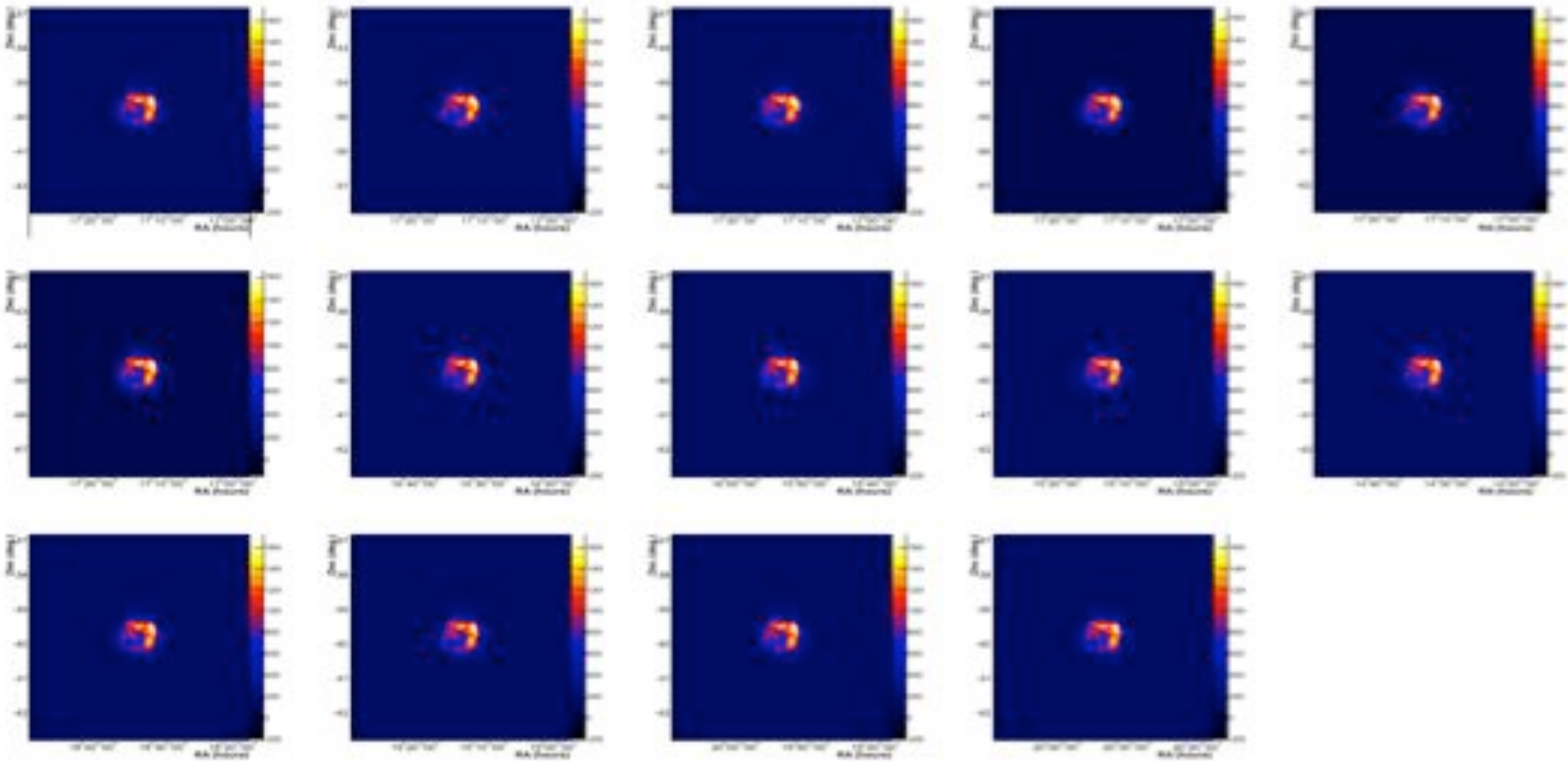
Catalog analysis pipeline (Saclay) runs a source detection algorithm and then runs likelihood analysis to produce a table of the basic gamma-ray properties of each source.

Released at the beginning of DC2, it provided a starting point for a large fraction of the more detailed source analysis and was a reference for population/source detection type studies.

380 sources



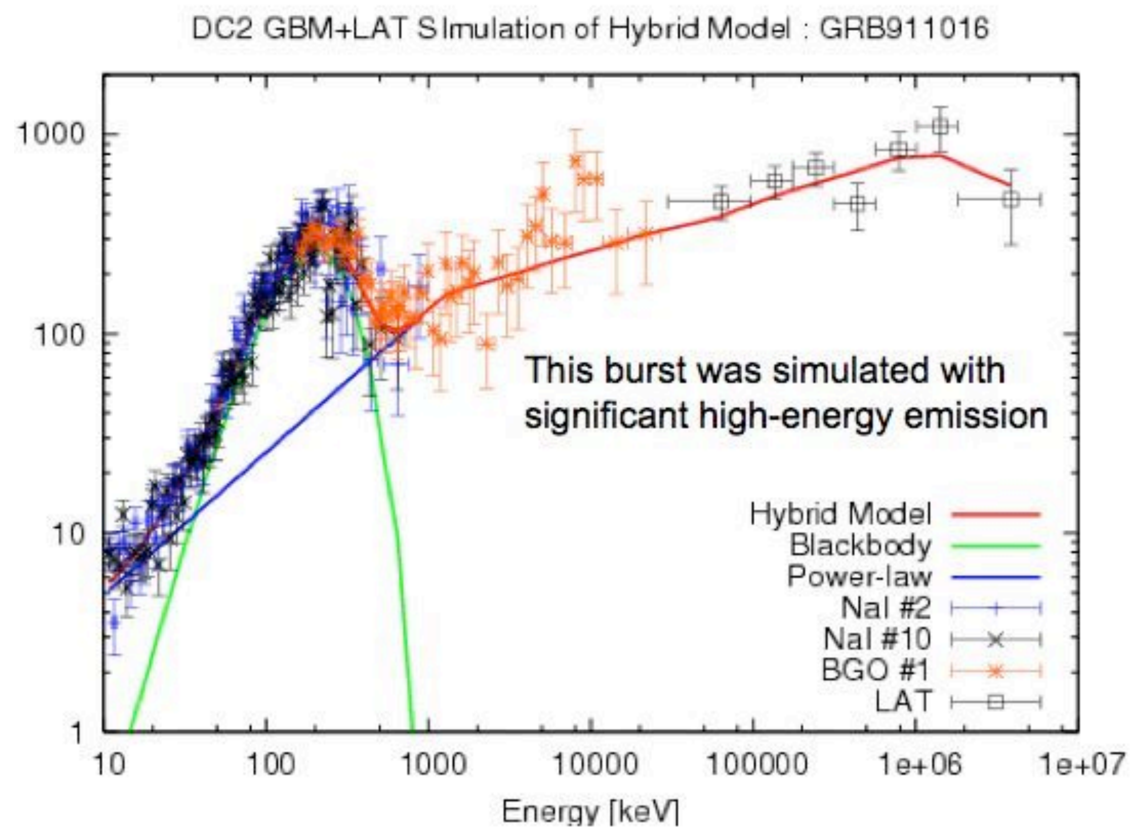
Systematic studies: SNR



Set of simulations of SNR RXJ 1713.7-3946 each with a different spectral model

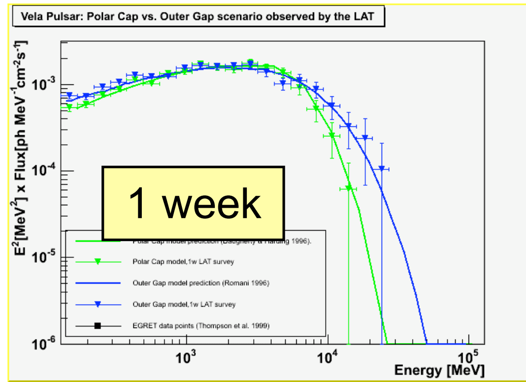
GRB Spectral Models

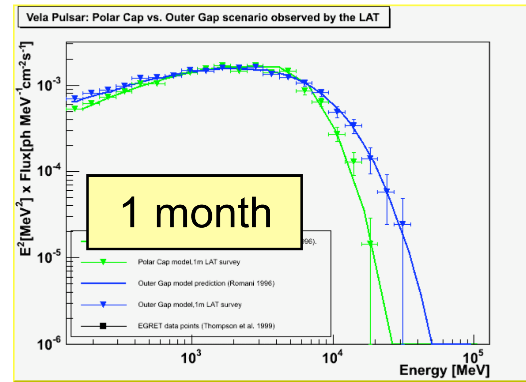
- **Developing methods to measure spectral features and using systematic simulation studies to evaluate performance**



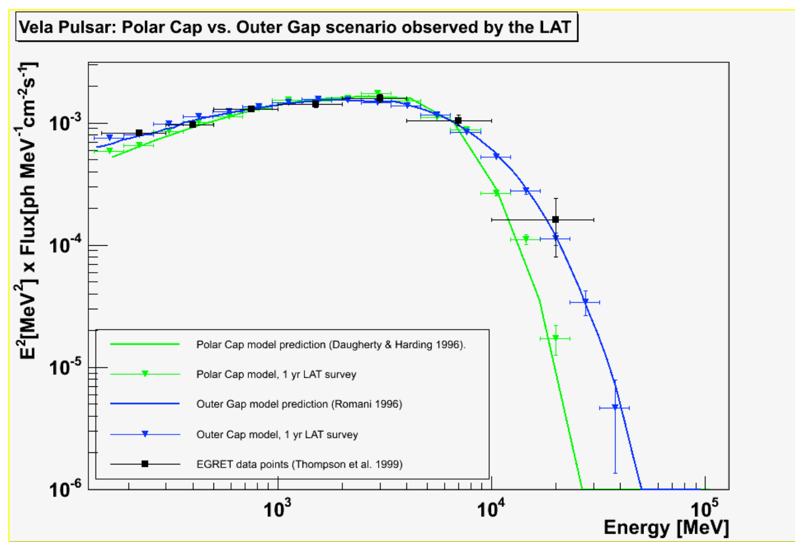
Pulsar simulations and analysis

- **Razzano and Harding - simulations to illustrate the ability of LAT observations to distinguish between pulsar emission models.**
- **Develop analysis methods to quantify this.**
- **Additional simulation improvements**
  - **Adding models for binary pulsars**
  - **Including noise and glitches**



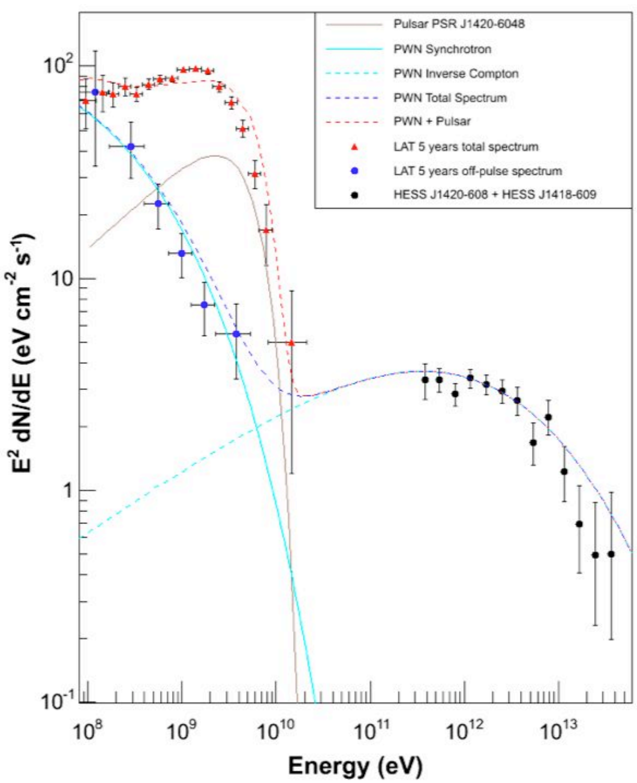


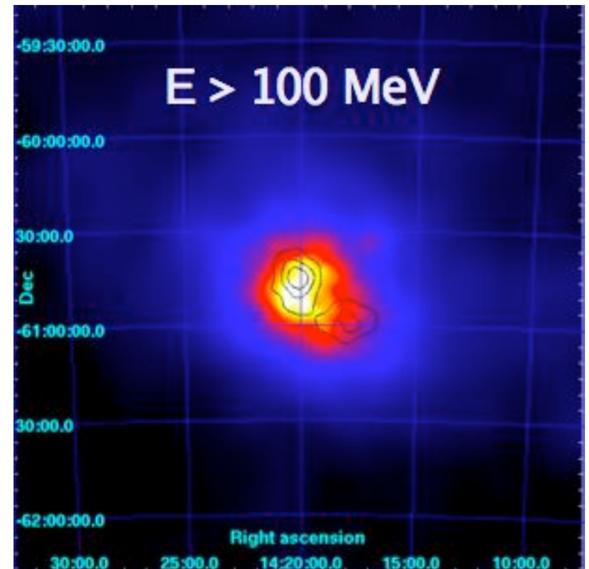
1 week (left) and 1-month Vela observation and 1 year Vela observation.

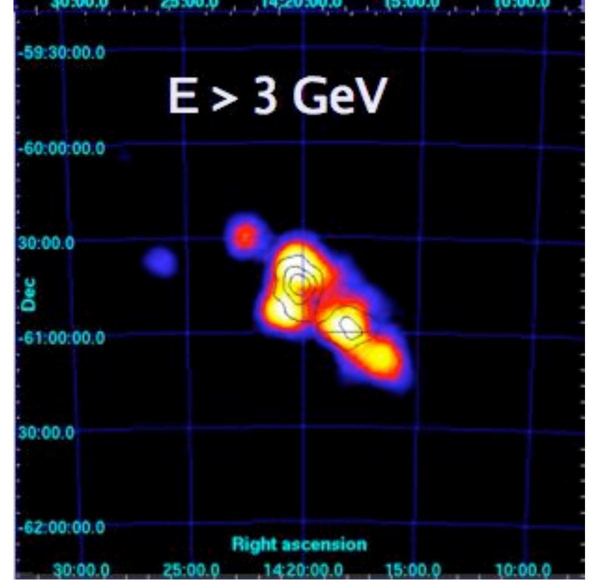


Pulsar Wind Nebula Studies

- **Simulations of the kookaburra region which contains a pulsar and a pulsar wind nebula, illustrating how phase resolved spectral studies or energy resolved spatial studies can distinguish between the two components**

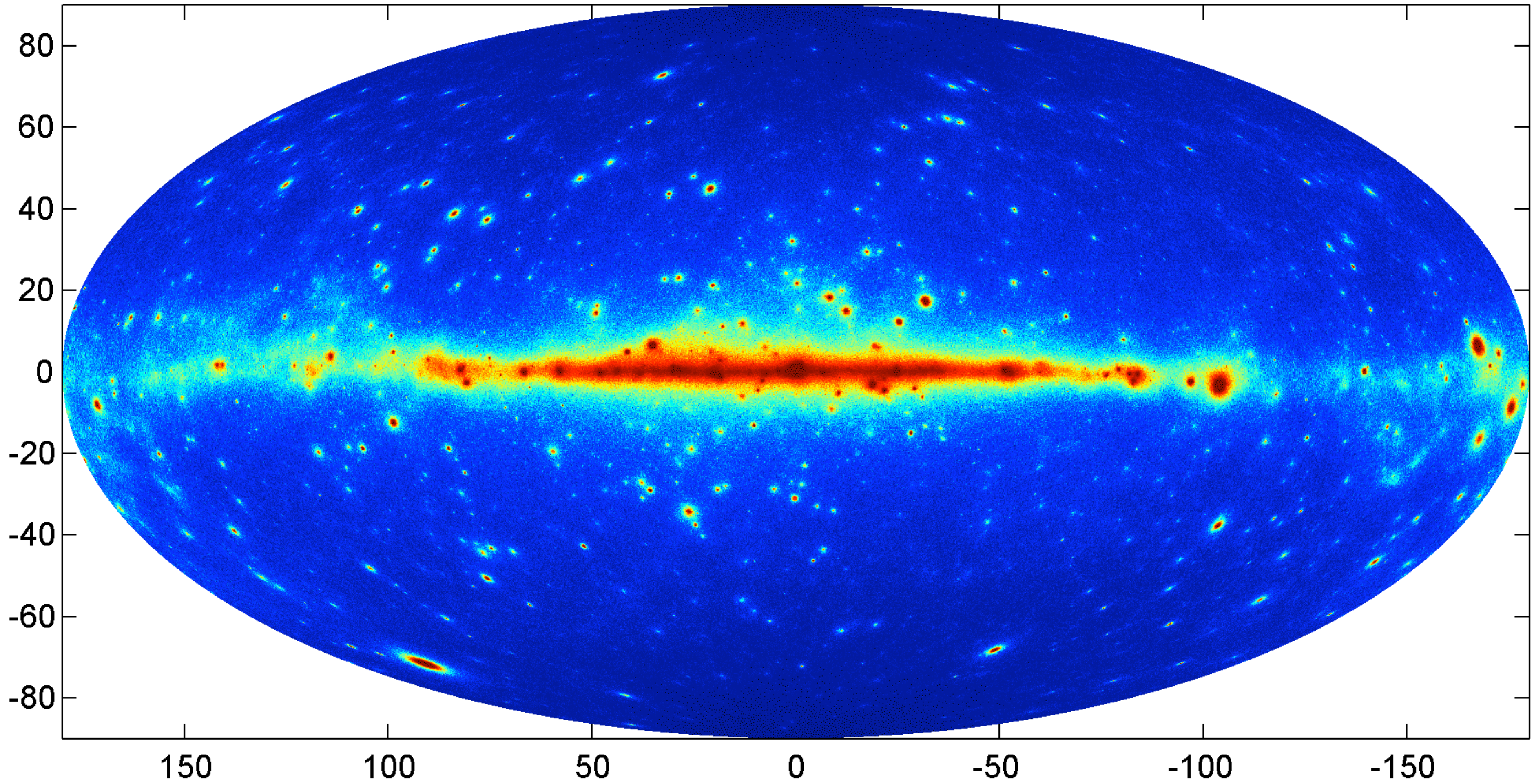






Service Challenge

1 year sky simulation



- the [movie]

Launch: t – 10 months and counting