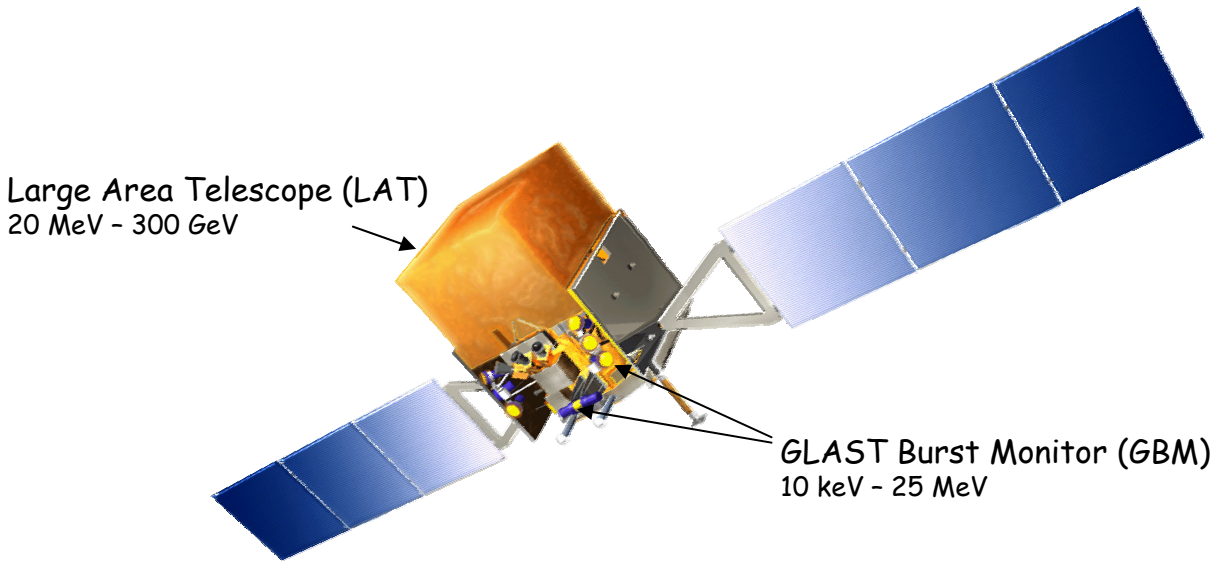
The Gamma-ray Large Area Space Telescope

Peter F. Michelson
Stanford University
LAT Spokesperson and Principal Investigator

peterm@stanford.edu
(650) 723-3004



GLAST: an international science mission

- LAT is an international project: France (IN2P3, CEA), Italy (INFN, ASI), Japan, Sweden, and United States (DOE, NASA)
  - GLAST is highest ranked initiative in its category in 2000 NRC Decadal Survey
- LAT fabrication project in transition from design/engineering model development to flight hardware production
- LAT collaboration very active: 125 members (including 62 affiliated scientists), 16 post-docs, 20 graduate students
- science community looking forward to GLAST data
  - beginning plans for multi-wavelength campaigns (e.g. with VERITAS, Magic, HESS, VLA, VLBA, Australian Compact Array, Allen Array, Parkes, + 15 others…)
  - science interest growing (~60 papers/year anticipating GLAST)
- extensive Education & Public Outreach program:
  - Web-based & printed teaching materials in hands >10,000 secondary school teachers;
  - co-sponsoring PBS Nova program on High-Energy Astrophysics and Black Holes

Space and High Energy Physics

- Marriage of High Energy Physics experience with NASA experience
  - each side has much to learn from the other's experience
- A pathfinder at SLAC for space-based instruments
  - new infrastructure required
  - this is also a pathfinder at our Japanese and European high energy physics partners

GLAST Participation

France Germany Italy Japan Sweden USA

NASA - DoE Partnership on LAT

LA onal team

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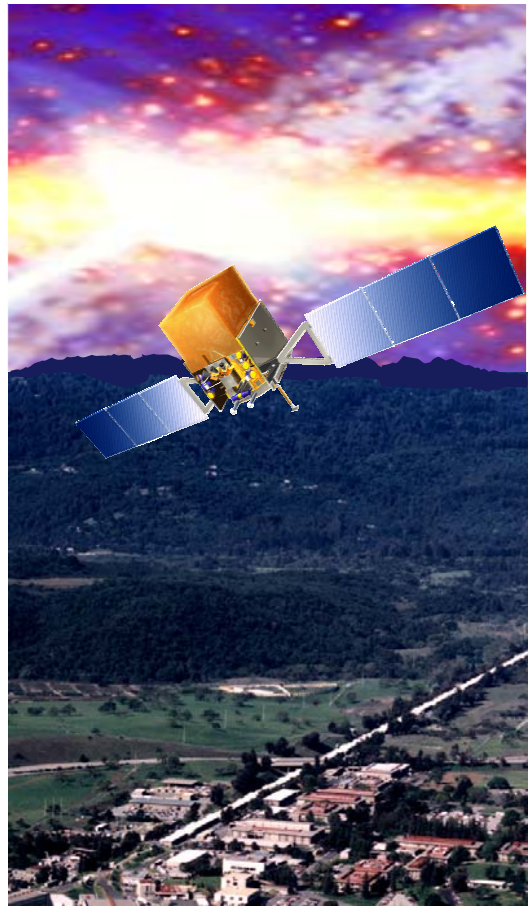
Spacecraft and integration - Spectrum Astro

Mission Management: NASA/GSFC

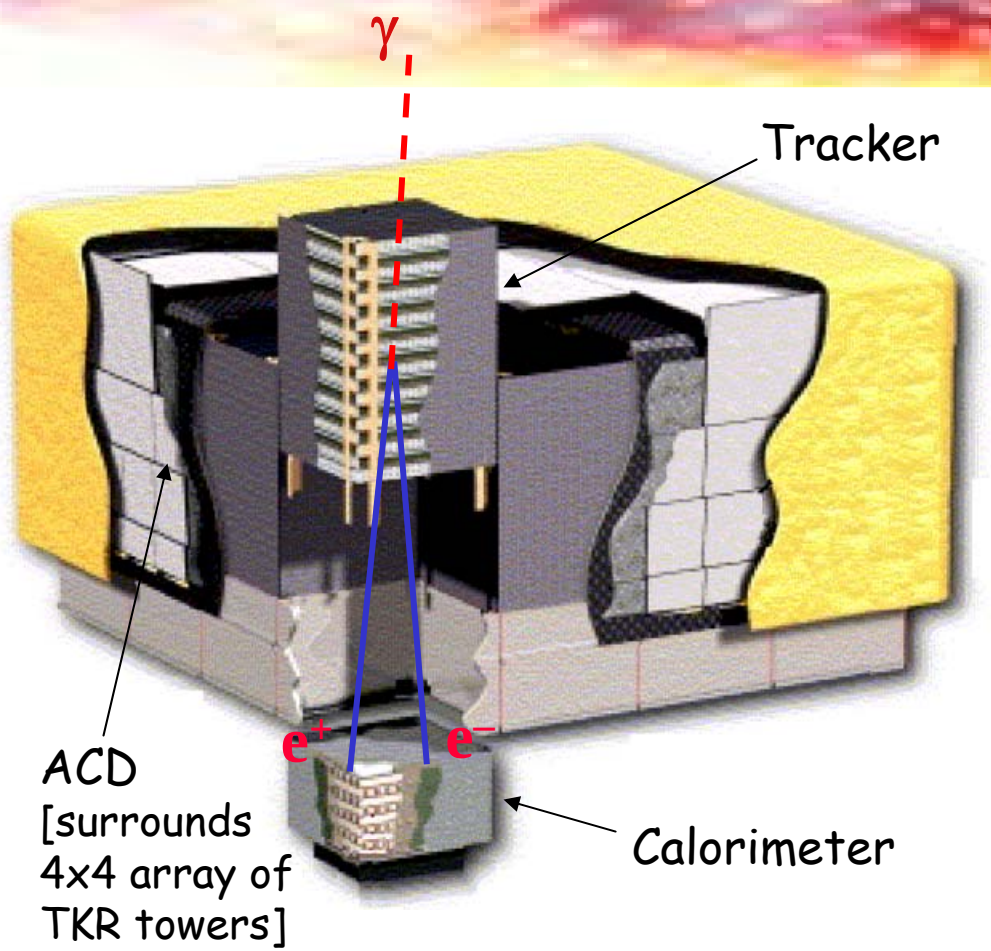


SLAC - host lab managing LAT development

Stanford University (campus & SLAC) – host for ISOC

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.



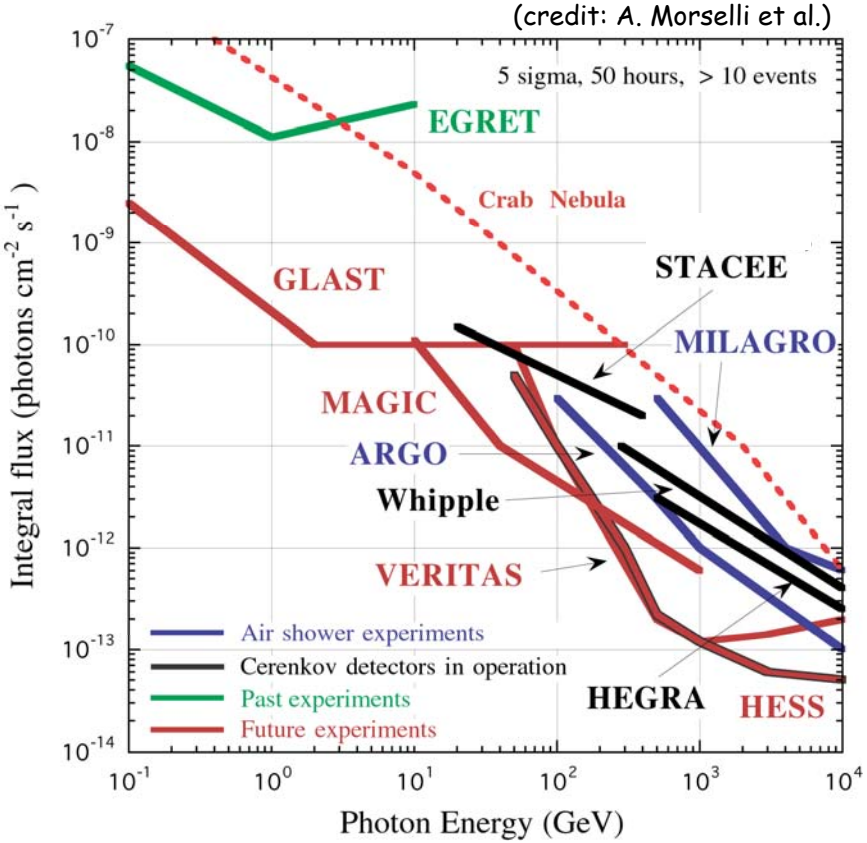
Systems work together to identify and measure the flux of cosmic gamma rays with energy 20 MeV - >300 GeV.

GLAST & next-generation ground-based experiments

Complementary capabilities

	ground-based		space-based
	ACT	EAS	Pair
angular resolution	good	fair	good
duty cycle	low	high	high
area	large	large	small
field of view	small	large	large+can reorient
energy resolution	good	fair	good, with smaller systematic uncertainties

(credit: A. Morselli et al.)

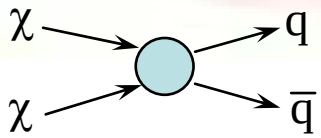


GLAST addresses a broad science menu

- **Systems with supermassive black holes & relativistic jets**
- **Gamma-ray bursts (GRBs): witness to the death of a massive star and the birth of a spinning black hole**
- **Probe the era of galaxy formation**
- **Pulsars**
- **Solar physics**
- **Origin of Cosmic Rays**
- **Solve the mystery of the high-energy unidentified sources**
- **Discovery! Particle Dark Matter? Large extra dimensions? Other relics from the Big Bang? Testing Lorentz invariance. New source classes**

Seth Digel will discuss more about GLAST science in breakout session

2 examples of discovery potential

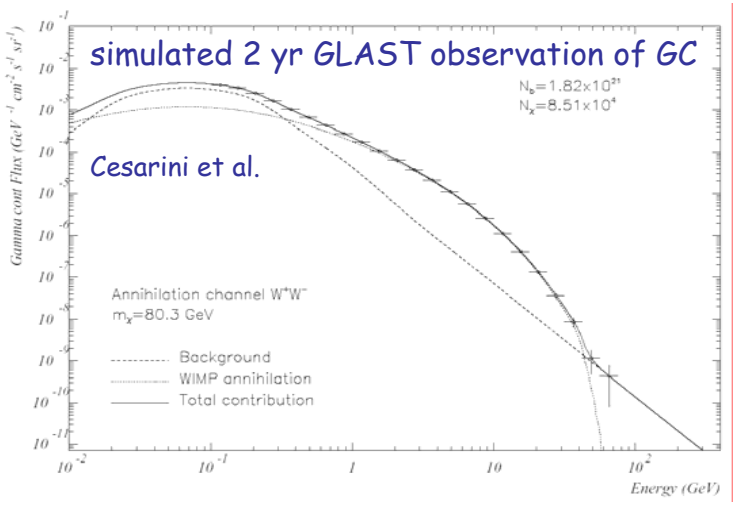


inclusive flux,
or γγ or Zγ "lines"?

- **Particle Dark Matter**

  Particle physics models with SUSY could solve the dark matter problem. If correct, these new particle interactions could produce an observable flux of gamma rays.

  High-Energy excesses detected (1 GeV-EGRET & TeV-Whipple) from Galactic Center are intriguing; possible contributions from extended Galactic halo may be detectable [Ullio et al, astro-ph/0207125]



- **Large extra dimensions**

  theories with large (sub-mm) extra dimensions: a way to solve the hierarchy problem of particle physics

  - move the Planck scale to near the weak scale
  - observed weakness of gravity due to presence of *n* new spatial dimensions large compared to electroweak scale (Arkani-Hamed, Dimopoulos & Dvali 1998)

  recently pointed out that SNe would produce Kaluza-Klein gravitons, generic for these theories, that would be gravitationally bound to SN core (i.e, neutron star) → KK particle halo - KK gravitons decay ($\tau \sim 10^9$ years) to νν, e^+e^-, and γγ

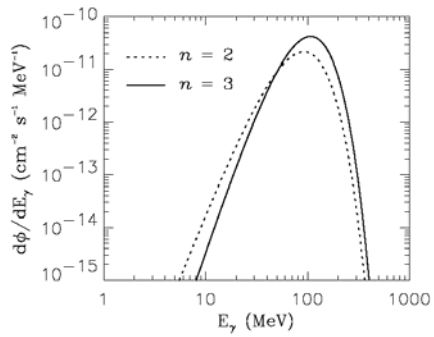


FIG. 2. The γ-flux from RX J185635-3754 for $f_{KK} = 10^{-7}$ and an assumed SN core temperature of 30 MeV.

Hannestad & Raffelt (2002)
Casse et al, PRL 92 (2004)

GLAST Master Schedule

- Completion of the LAT July 2005
  - to NRL for environmental testing
- Delivery to Observatory Integration December 2005
  - mate with spacecraft and GBM and test
- Launch February 2007
  - Kennedy Space Flight Center
- Science operation begins May 2007

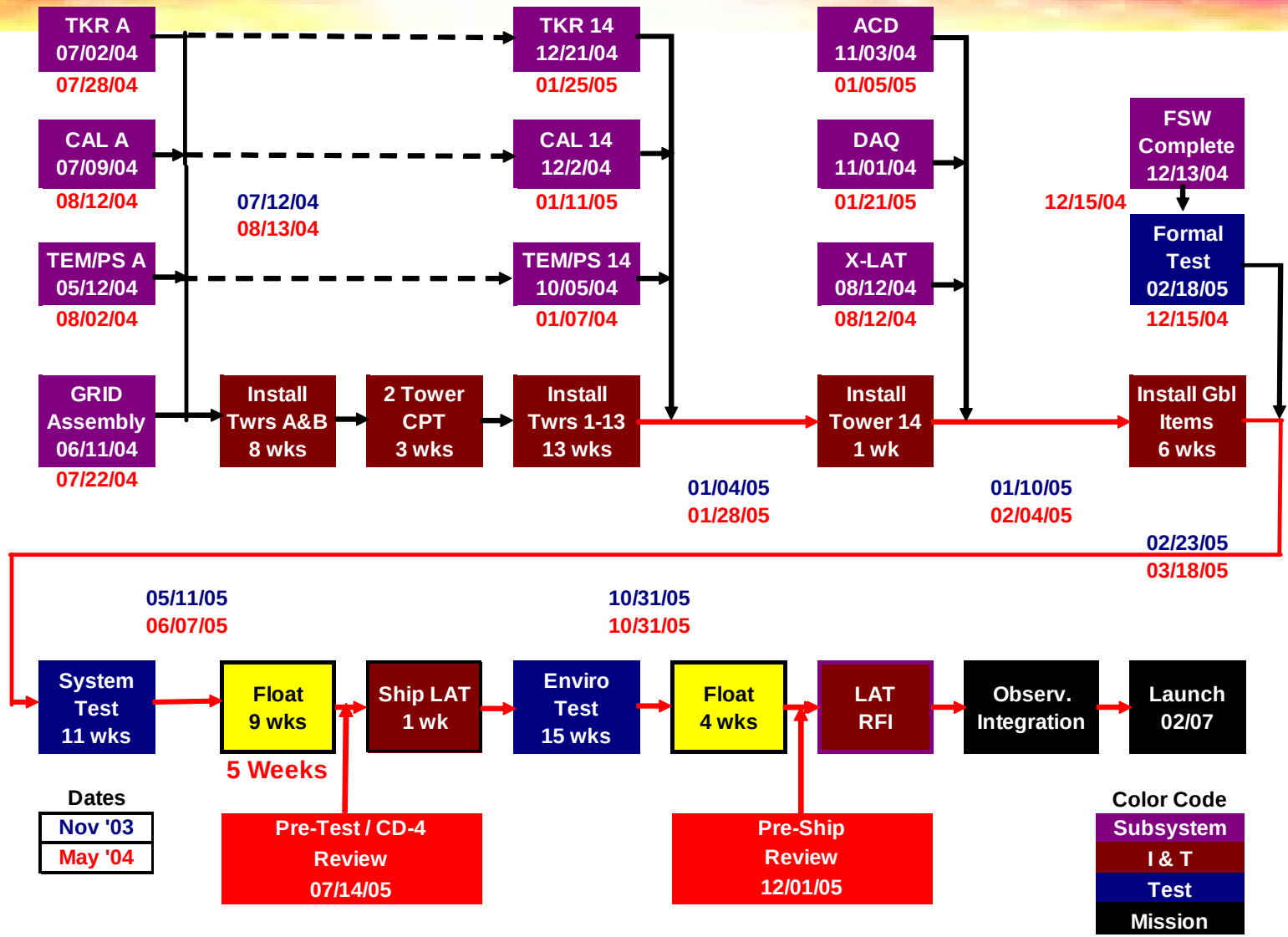
Gravity Probe B Launch on Delta II

Level 1 and Level 2 Milestones

Milestone		Plan	Float
Level 1 Milestones – DOE/NASA Joint Oversight Group			
DOE Critical Decision (CD) 0 Approval	June 25, 2001	June 25, 2001	Actual
CD-1 Approval	July 23, 2002	July 23, 2002	Actual
CD-2 Approval	November 8, 2002	November 8, 2002	Actual
CD-3 Approval	August 31, 2003	August 31, 2003	Actual
Flight Grid Complete	September 15, 2004	July 22, 2004	8 weeks
CD-4 Approval	March 15, 2006	June 7, 2005*	40 weeks
Level 2 Milestones – Federal Project Managers			
Launch Balloon Flight	August 1, 2001	August 1, 2001	Actual
Instrument Preliminary Design Review	January 8, 2002	January 8, 2002	Actual
Instrument Critical Design Review	May 16, 2003	May 16, 2003	Actual
Start LAT Integration	August 24, 2004	August 2, 2004	3 weeks
Pre Environmental Test Review	July 14, 2005	June 7, 2005	5 weeks
Instrument Pre-Ship Review	December 1, 2005	October 1, 2005	9 weeks

* The CD-4 Review is planned for June 7, 2005 and the CD-4 Approval will occur after validation by DOE.

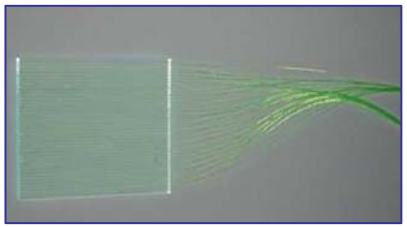
Working Schedule



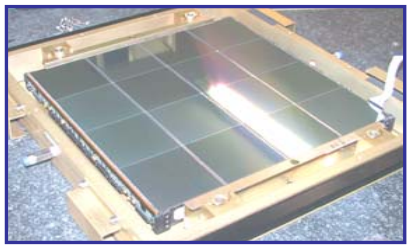
LAT Project Status

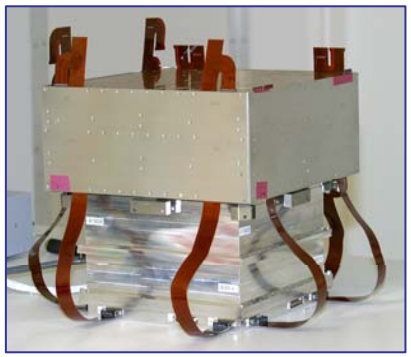
- in the difficult transition from design / engineering model validation to flight hardware production
  - focus now on completion and delivery to I&T of 1st flight towers
- schedule still shows positive float
  - working to optimize the schedule in the integration & test phase as well as to develop mitigation plans should further schedule slips occur.
  - need to complete the transition to first flight component production and establish the production rate for follow-on components in order to evaluate the risk to the July 2005 delivery date.
- we believe that the next Lehman review in September will be the time at which this issue can be fully addressed.

LAT Engineering Model Examples

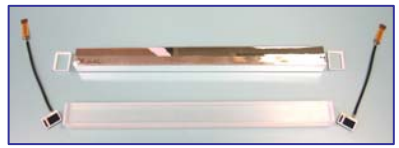


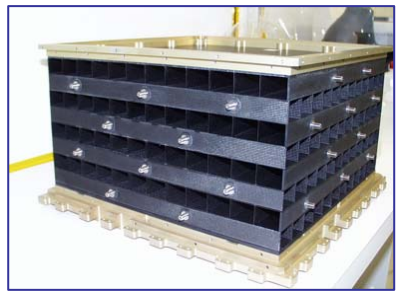
ACD Tile Detector Assembly

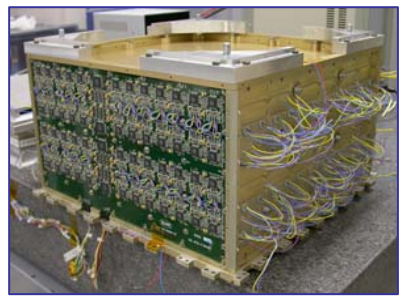




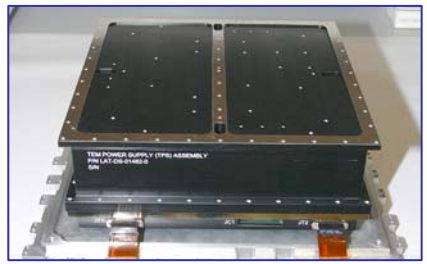
Tracker mini-tower

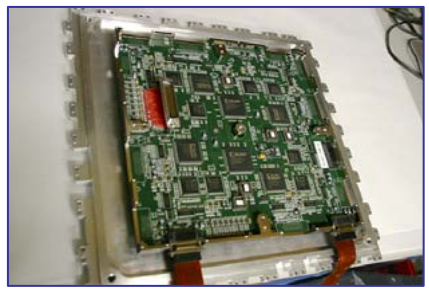






Calorimeter module



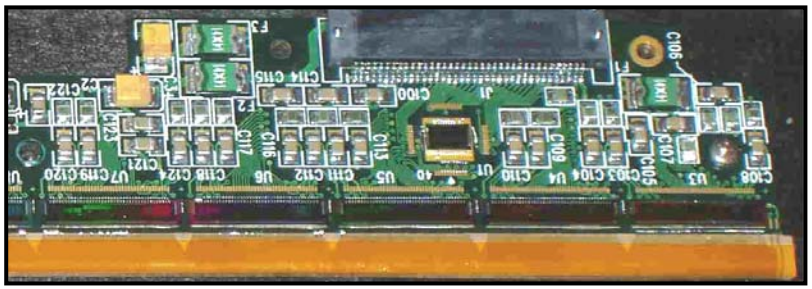


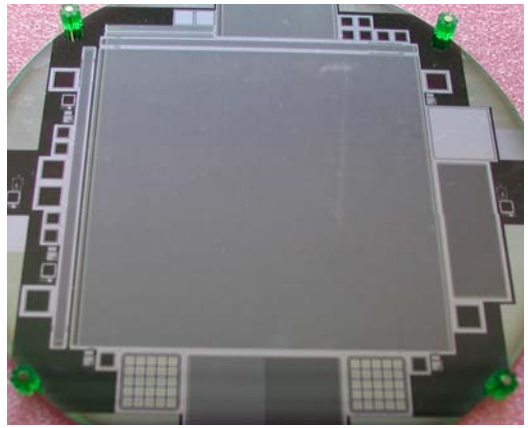
Tower Electronics Module (TEM)

Flight Hardware Production

Tracker Multi-Chip Modules

(648; 40 produced; 16,848 ASICs)



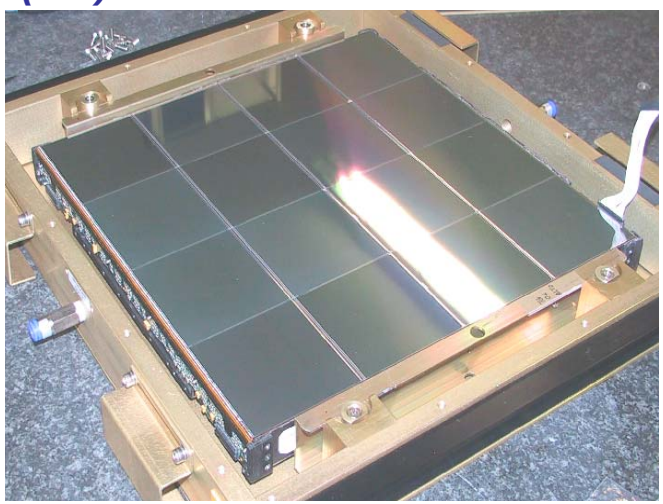


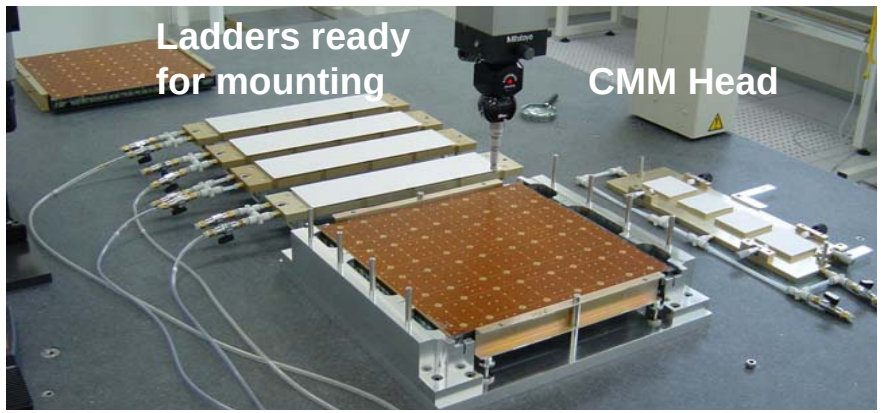
Silicon Strip Detectors

(10,368; 9,500 tested; 46 rejects)

Tray Assembly at G&A, Italy

(324)





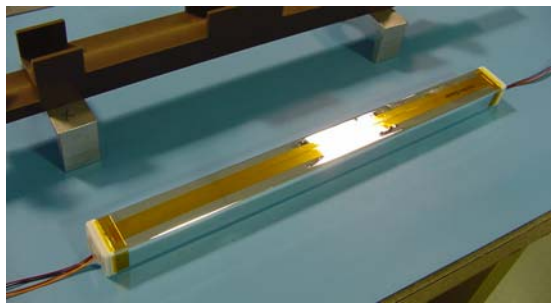
Silicon Detector Ladder production at G&A and Mipot, Italy

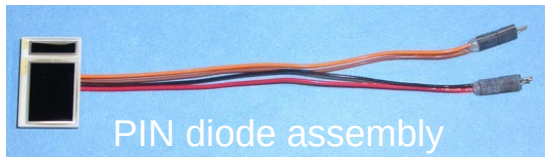
(2,592; 967 assembled & tested; 16 rejects)

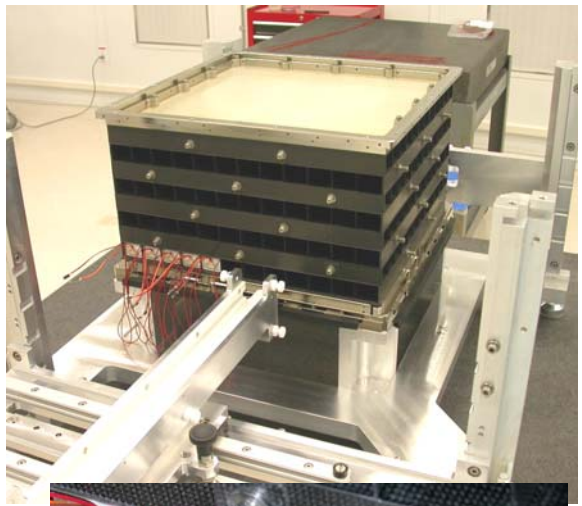
Flight Hardware Production

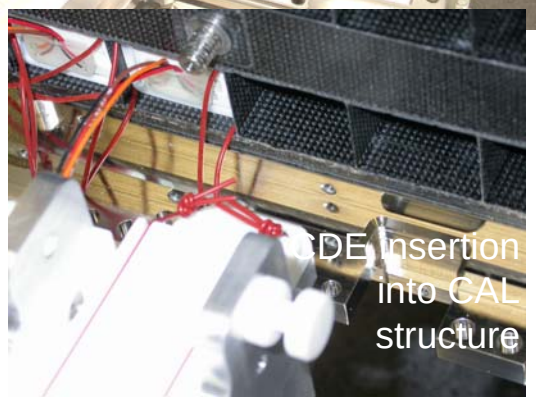
Calorimeter Crystal Detector (CDE) assembly at Swales Aerospace

(1,728)







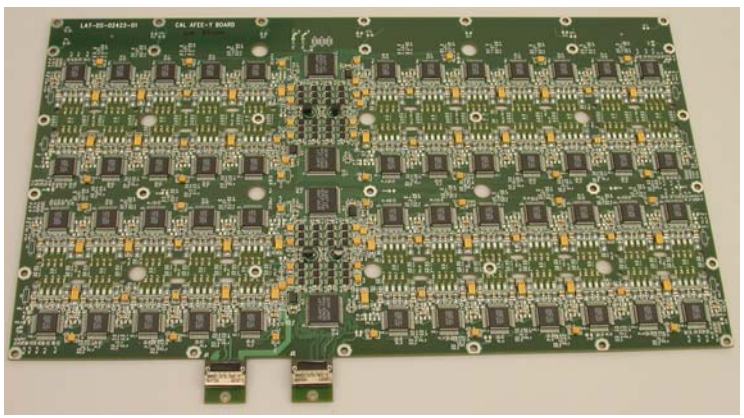


Assembly of first Flight Module at NRL

(18)

(proto) Flight AFEE Card

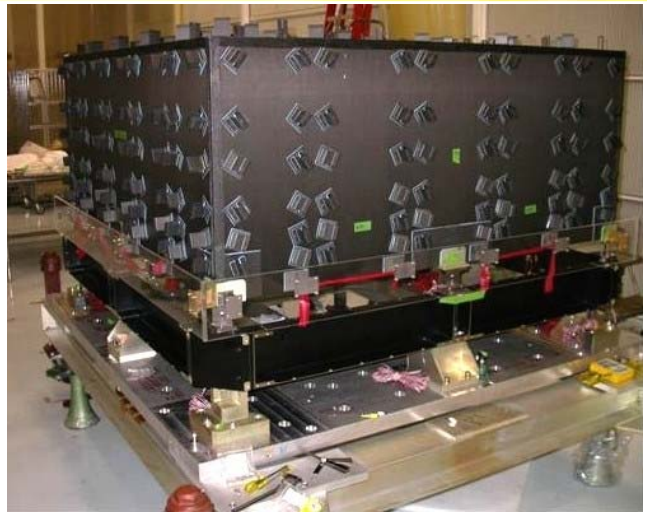
(72)



Flight Hardware Production

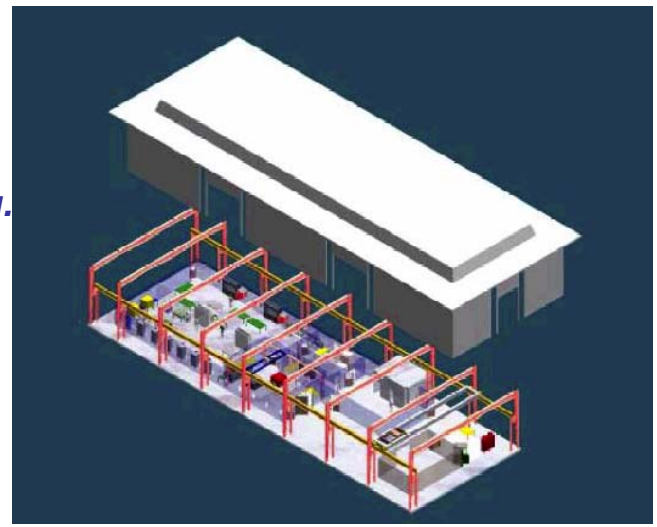
GRID Final Machining

ACD Shell ready for vib test at GSFC



Data Acquisition test bed

Integration and Test Facility at SLAC, Bldg. 33



Collaboration Status: preparations to do science

- looking forward to doing science: planning for Operations Phase underway
  - Robert Cameron has accepted position of ISOC Manager; arrives mid-August
    - extensive experience from CGRO/OSSE and Chandra flight operations
    - William Craig (KIPAC/SLAC) is acting manager
  - Collaboration science analysis organizational plans
    - presented at LAT Collaboration meeting in Rome, September 15-17, 2003
    - focus of face-to-face SSAC meeting in May 2004 and collaboration meeting, September 27-30, 2004
- Collaboration supporting I&T activities and development of software for data analysis; data challenges
  - planning meeting for I&T data analysis; SLAC, June 7-8, 2004
  - 1st Data Challenge successfully completed

LAT Collaboration Status

- new collaboration members from Ohio State University:
  - R.E. Hughes, B.L. Winer; - considerable experience (Fermilab, CDF II) in design, production, testing of high speed trigger electronics and software
  - contributing to LAT DAQ & Flight Software (commissioning of Front-End Simulator; design and run tests of DAQ system; test on-board filter algorithms; maintain simulator for certification of software/firmware updates during flight)
  - will participate in science effort (initial interests: indirect dark matter detection and GRBs)
- International partners meeting commitments; next year's commitments reaffirmed at LAT IFC meeting, March 5-6, 2004 (as well as Common Fund planning)
  - France: Calorimeter structure and calibration (IN2P3) and analysis software development (CEA, IN2P3)
  - Italy: tracker tower manufacture, analysis software development (INFN, ASI)
  - Japan: Si-strip detectors
  - Sweden: CsI xtals for calorimeter

Operations Phase Organizations

- LAT Instrument Science Operations Center (ISOC)
  - **LAT Operations Facility (LOF);** health & safety, commanding
  - **Science Operations Group (SOG):** configuration management of Level-1 data pipeline; calibration, performance optimization
  - **Science Analysis Software (SAS):** develops and maintains analysis software; Level-1 pipeline
  - core of ISOC activities located at Stanford University (SLAC & campus)
- Collaboration Science Analysis Working Groups
  - analysis coordinator is rotating (~yearly) collaboration position
  - ~ 10 working groups; each with 2 co-leads, one resident at Stanford
    - organization driven by scientific papers expected during 1st year of operations – analysis and paper-writing machines!
  - development of multi-wavelength plans underway: Dave Thompson & Roger Blandford co-chairs of Ad Hoc collaboration working group

Data Challenges

Support readiness by launch of software tools to do all 1st year science.

- LAT analysis software development: joint effort of GSSC and LAT team, managed by LAT; core of tools for science community
- 3 data challenges planned: DC1: 2003-04; DC2: 2005; DC3: 2006

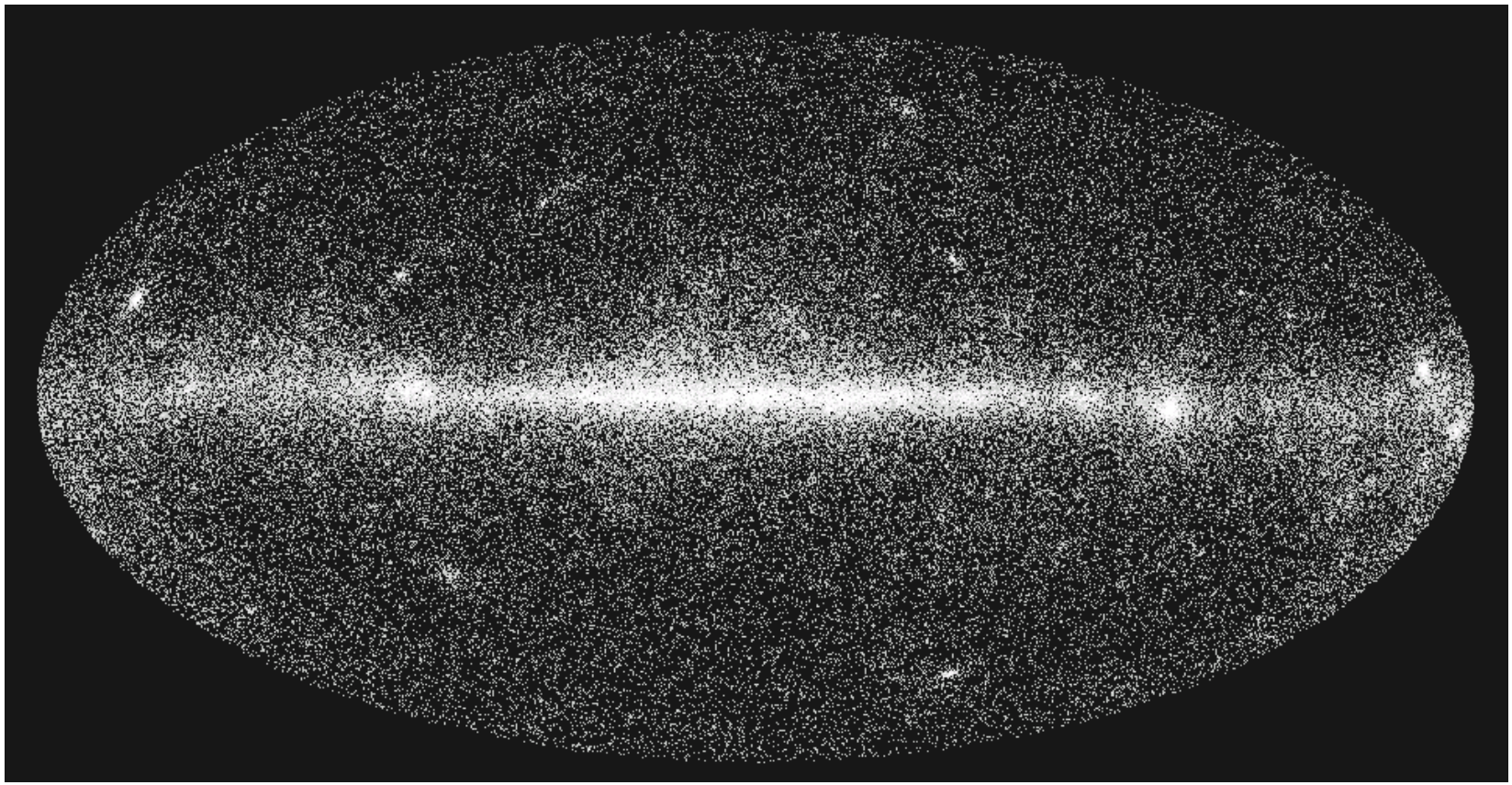
Purposes of Data Challenges

- "End-to-end" testing of analysis software
- familiarize team with data content, formats, tools and realistic details of analysis issues (both instrumental and astrophysical)
- if needed, identify and develop additional methods for analyzing LAT data
- provide feedback to the Science Analysis Software group on what works and what is missing from the data formats and tools
- uncover systematic effects in reconstruction and analysis

Participants in DC1 Closeout meeting

successful multi-cultural event: particle physicists and astrophysicists from 4 continents working together

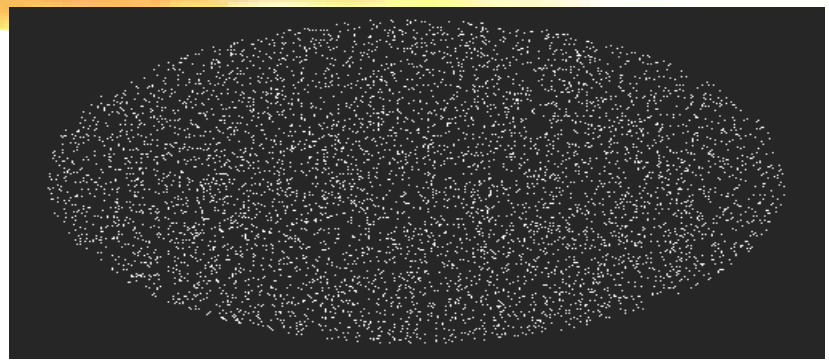
Data Challenge I: the data



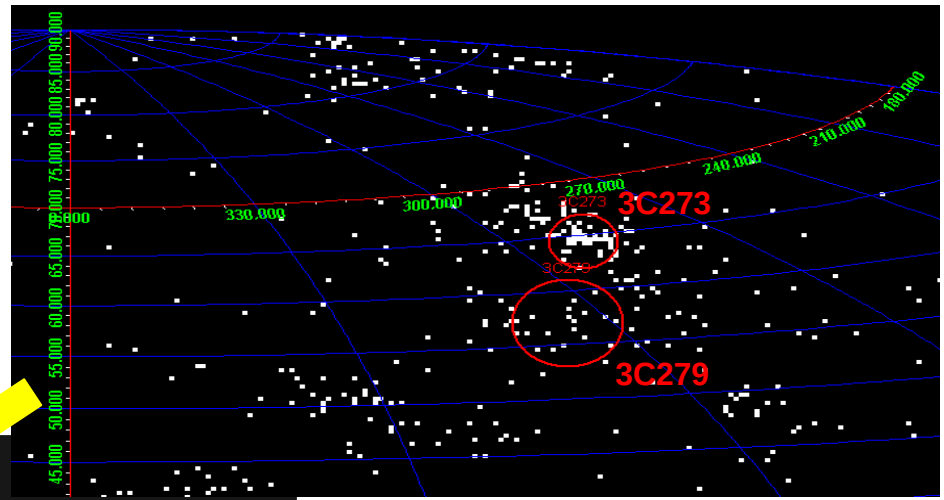
all-sky data (E>20 MeV): one day exposure

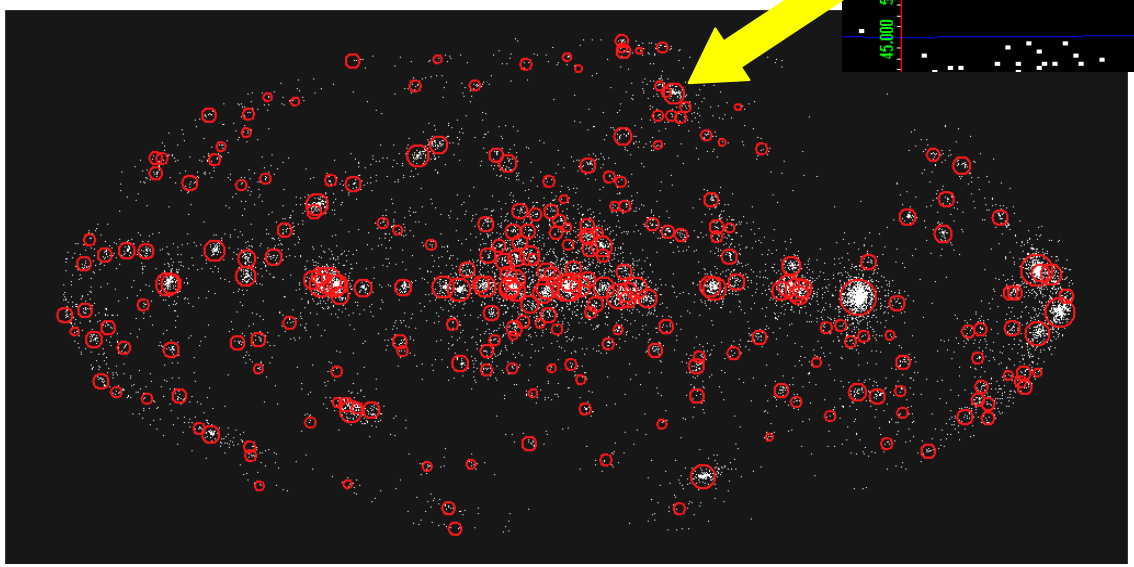
- **exercise exposure, orbit/attitude handling, data processing pipeline components, analysis tools**

the “truth”



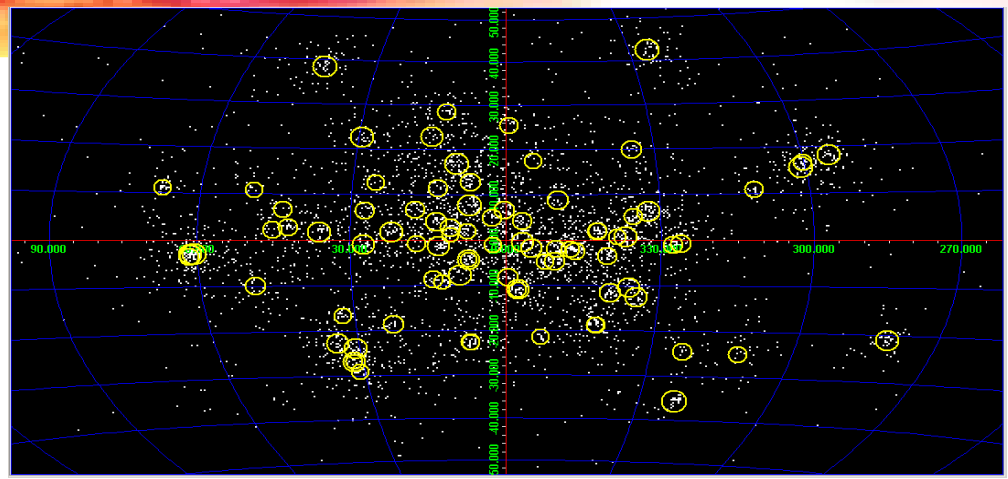
isotropic diffuse





Sources – 3EG and more, with a twist

Other surprises

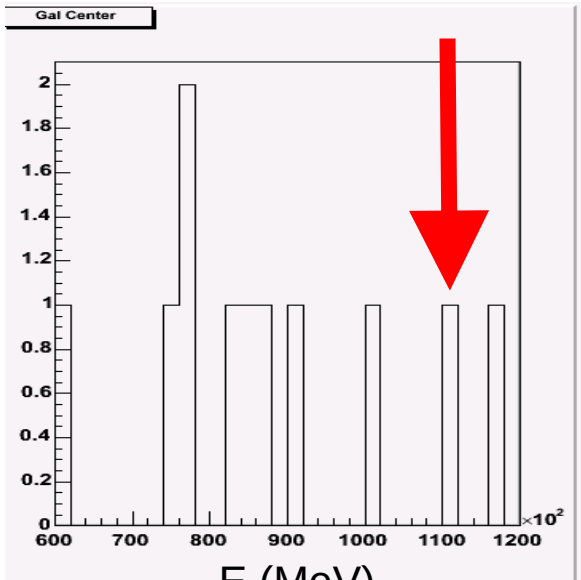


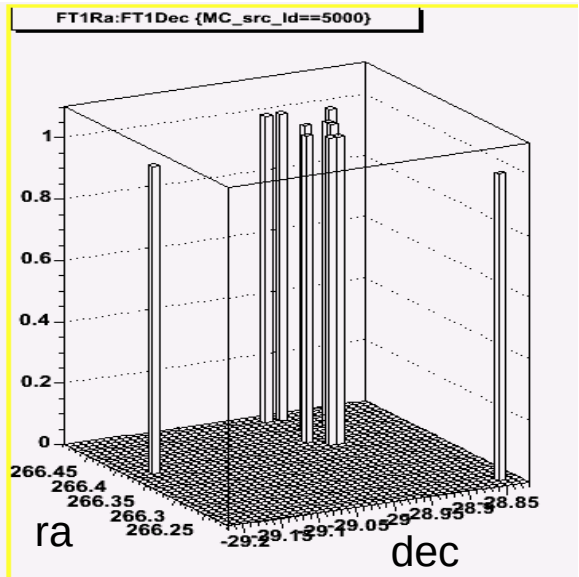
Low latitude, halo sources

susy from Gal Center

truth: E=110 GeV, l=b=0

5x10^{-8} photons/cm^2/s





Summary

- LAT instrument fabrication project in the difficult transition to flight hardware production
  - often a difficult transition for projects
  - true for GLAST: technically challenging project with qualification of design to space requirements; international project
  - need to complete transition with first flight modules delivered to I&T and establish production rate for subsequent components
  - schedule is very tight and must be managed closely
- Responding to challenges by
  - adding key experienced people to meet the challenge
  - responding to schedule setbacks with reprogramming both at the subsystem level and at the instrument level
  - Not compromising testing, review, or rigor to achieve schedule
- Collaboration very actively preparing for science operations and data analysis phase
  - Data Challenge 1 a success; planning for DC2 next year
  - planning I&T data analysis support