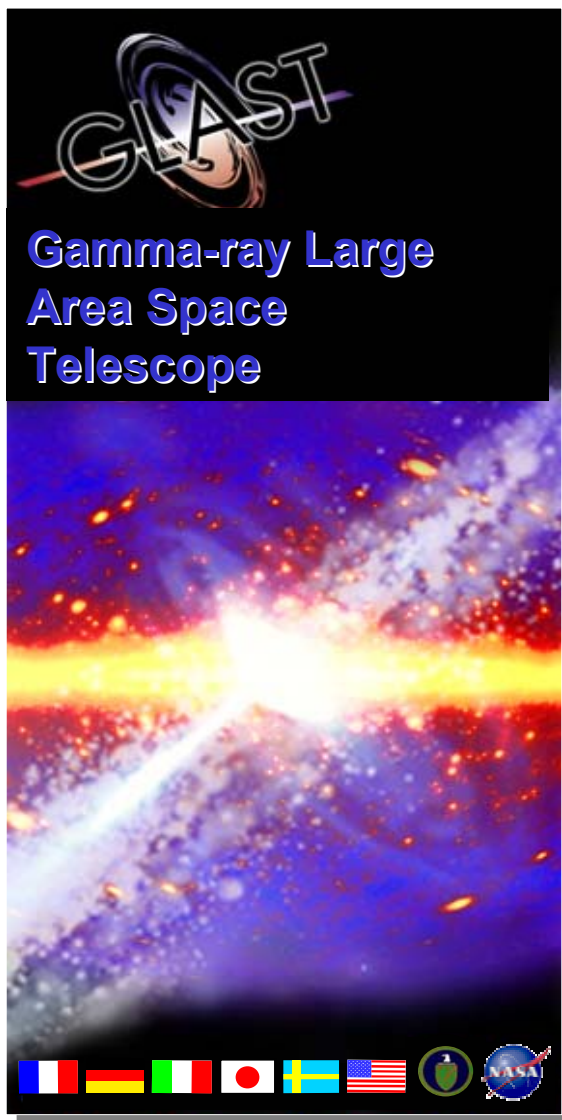


# DRAFT Rev 0

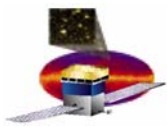


## GLAST Large Area Telescope:

### Science Requirements and Instrument Design

**Steven Ritz**  
**Goddard Space Flight Center**  
**LAT Instrument Scientist**

[ritz@milkyway.gsfc.nasa.gov](mailto:ritz@milkyway.gsfc.nasa.gov)



# Outline

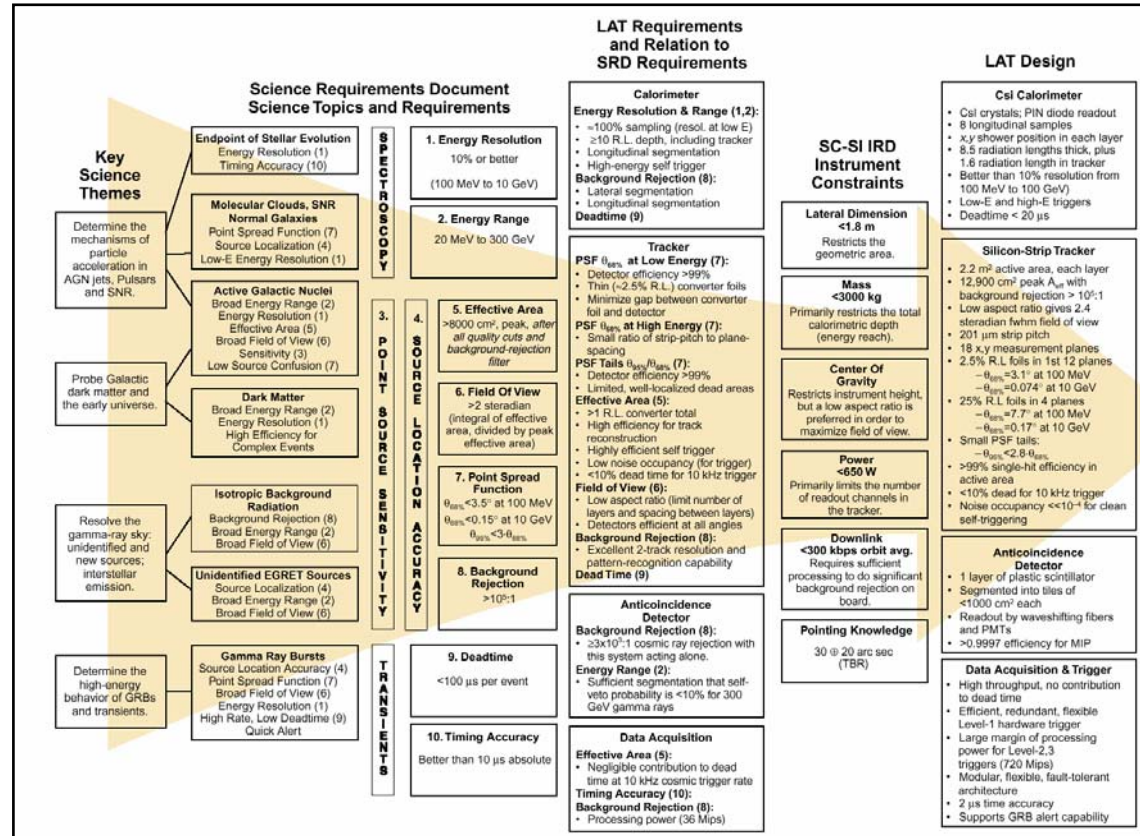
---

- Context: flow of requirements, definitions, design drivers**
- Instrument overview**
- Simulation**
- Follow the data:**
  - particle fluxes**
  - trigger**
  - onboard filtering**
  - ground-based filtering**
- Performance calculation results**
- Failure modes modeling**
- Ongoing studies, further work**

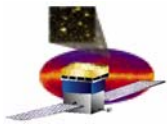
# From Science Requirements to Design

- Flow of instrument requirements from science goals and requirements was developed as part of the LAT proposal.

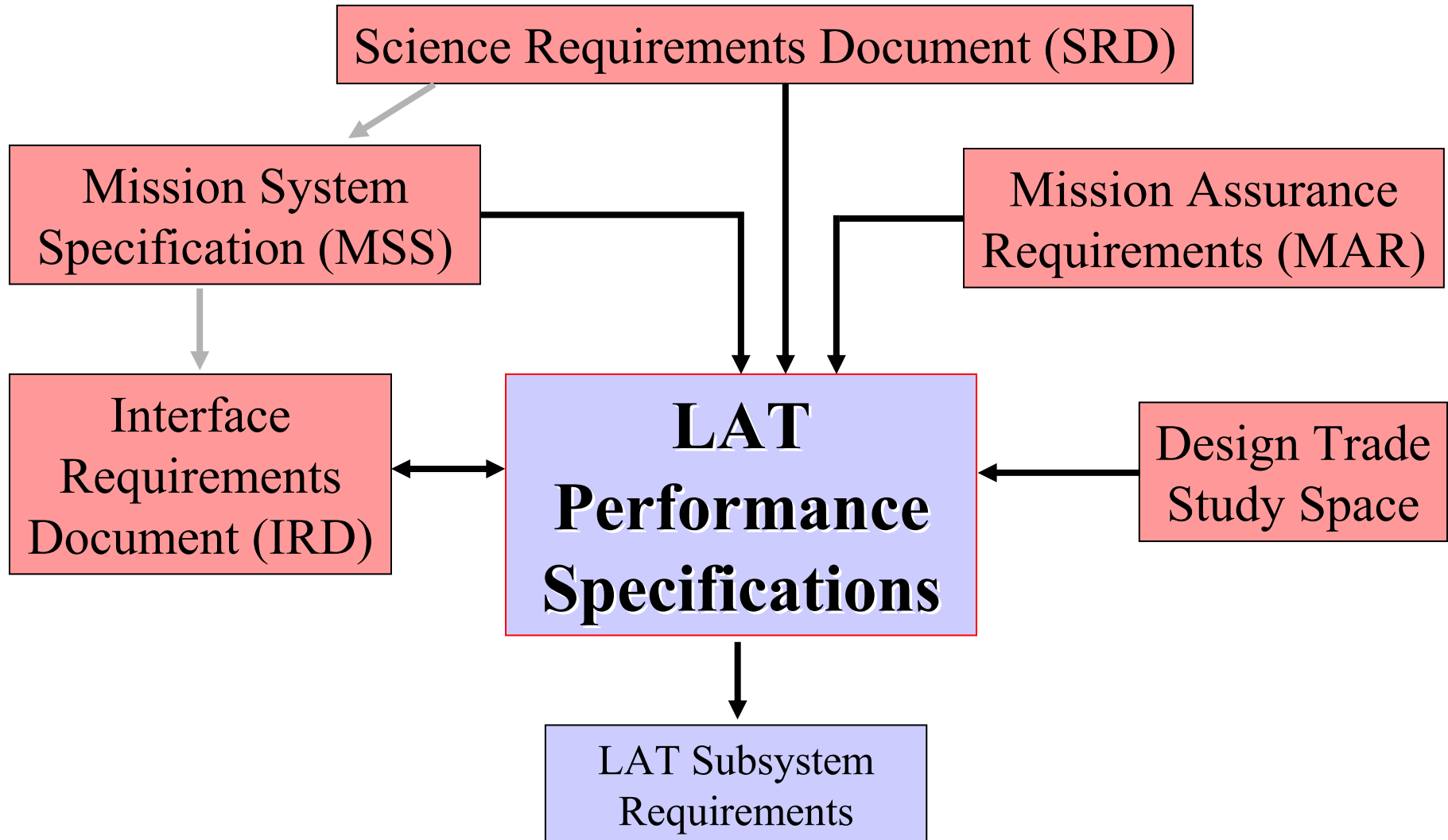
## From LAT proposal Foldout D:

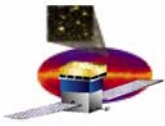


- This talk: LAT will meet or exceed requirements in GLAST Science Requirements Document (433-SRD-0001).



# Simplified Flow





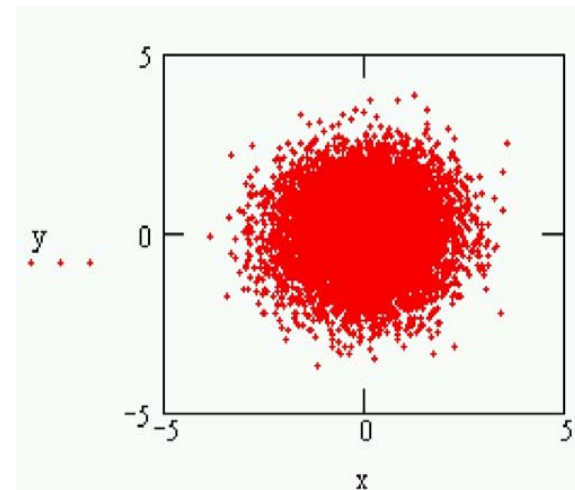
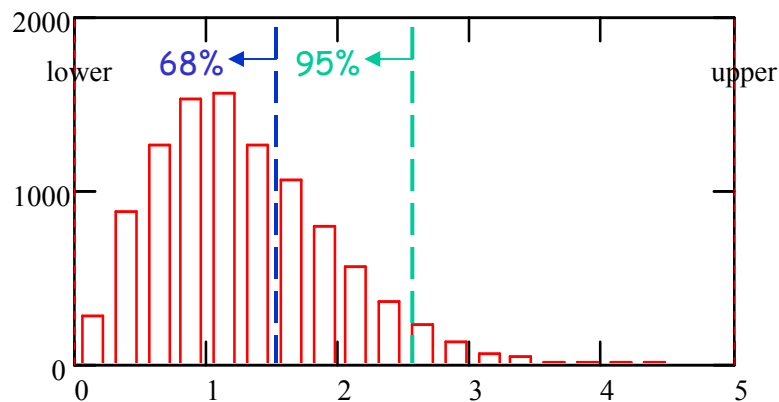
# Aside: some definitions

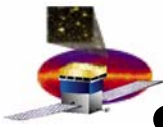
## Effective area

(total geometric acceptance) • (conversion probability) • (all detector and reconstruction efficiencies). Real rate of detecting a signal is (flux) •  $A_{\text{eff}}$

## Point Spread Function (PSF)

Angular resolution of instrument, after all detector and reconstruction algorithm effects. The 2-dimensional 68% containment is the equivalent of  $\sim 1.5\sigma$  (1-dimensional error) if purely Gaussian response. The non-Gaussian tail is characterized by the 95% containment, which would be 1.6 times the 68% containment for a perfect Gaussian response.

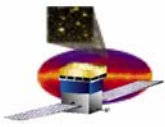




# Science Performance Requirements Summary

From the SRD:

Parameter	SRD Value
Peak Effective Area (in range 1-10 GeV)	>8000 cm <sup>2</sup>
Energy Resolution 100 MeV on-axis	<10%
Energy Resolution 10 GeV on-axis	<10%
Energy Resolution 10-300 GeV on-axis	<20%
Energy Resolution 10-300 GeV off-axis (>60°)	<6%
PSF 68% 100 MeV on-axis	<3.5°
PSF 68% 10 GeV on-axis	<0.15°
PSF 95/68 ratio	<3
PSF 55°/normal ratio	<1.7
Field of View	>2sr
Background rejection (E>100 MeV)	<10% diffuse
Point Source Sensitivity(>100MeV)	<6x10 <sup>-9</sup> cm <sup>-2</sup> s <sup>-1</sup>
Source Location Determination	<0.5 arcmin
GRB localization	<10 arcmin



# Experimental Technique

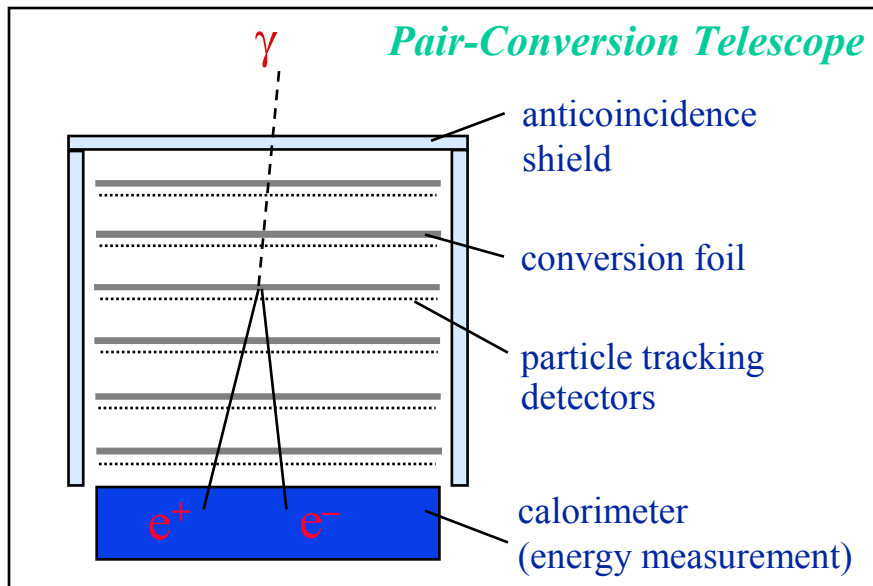
- Instrument must measure the direction, energy, and arrival time of high energy photons (from approximately 20 MeV to greater than 300 GeV):

- 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:

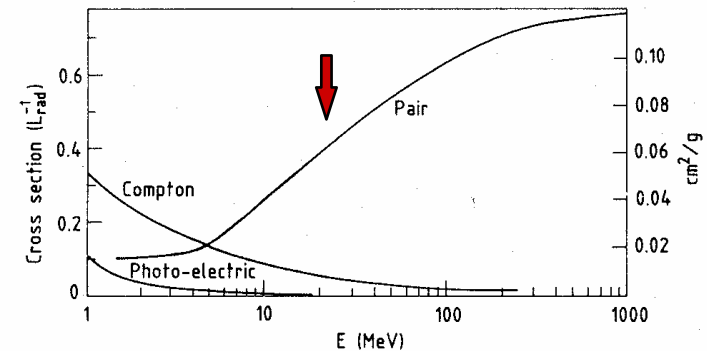


Fig. 2: Photon cross-section  $\sigma$  in lead as a function of photon energy. The intensity of photons can be expressed as  $I = I_0 \exp(-\sigma x)$ , where  $x$  is the path length in radiation lengths. (Review of Particle Properties, April 1980 edition).

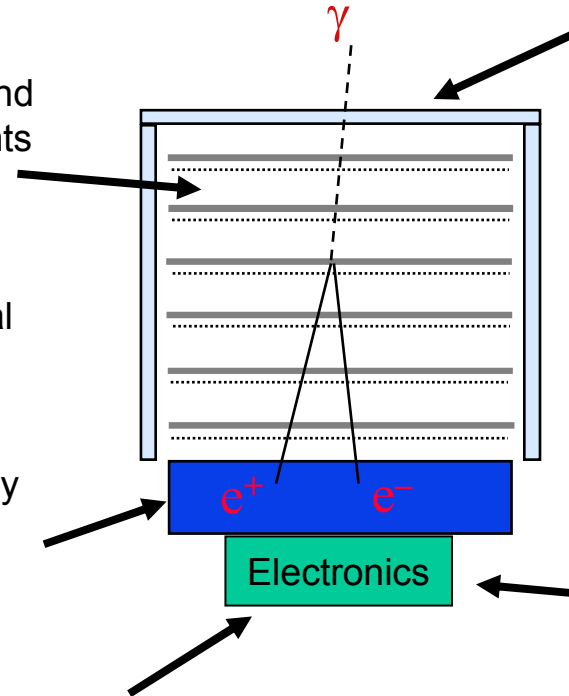
- must detect  $\gamma$ -rays with high efficiency and reject the much larger ( $\sim 10^4:1$ ) flux of background cosmic-rays, etc.;
- energy resolution requires calorimeter of sufficient depth to measure buildup of the EM shower. Segmentation useful for resolution and background rejection.

# Science Drivers on Instrument Design

Effective area and PSF requirements drive the converter thicknesses and layout. PSF requirements also drive the sensor performance, layer spacings, and drive the design of the mechanical supports.

Energy range and energy resolution requirements bound the thickness of calorimeter

On-board transient detection requirements, and on-board background rejection to meet telemetry requirements, are relevant to the electronics, processing, flight software, and trigger design.



Background rejection requirements drive the ACD design (and influence the calorimeter and tracker layouts).

Field of view sets the aspect ratio (height/width)

Time accuracy provided by electronics and intrinsic resolution of the sensors.

Instrument life has an impact on detector technology choices.

Derived requirements (source location determination and point source sensitivity) are a result of the overall system performance.

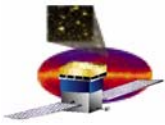




# IRD and MSS Constraints Relevant to LAT Science Performance

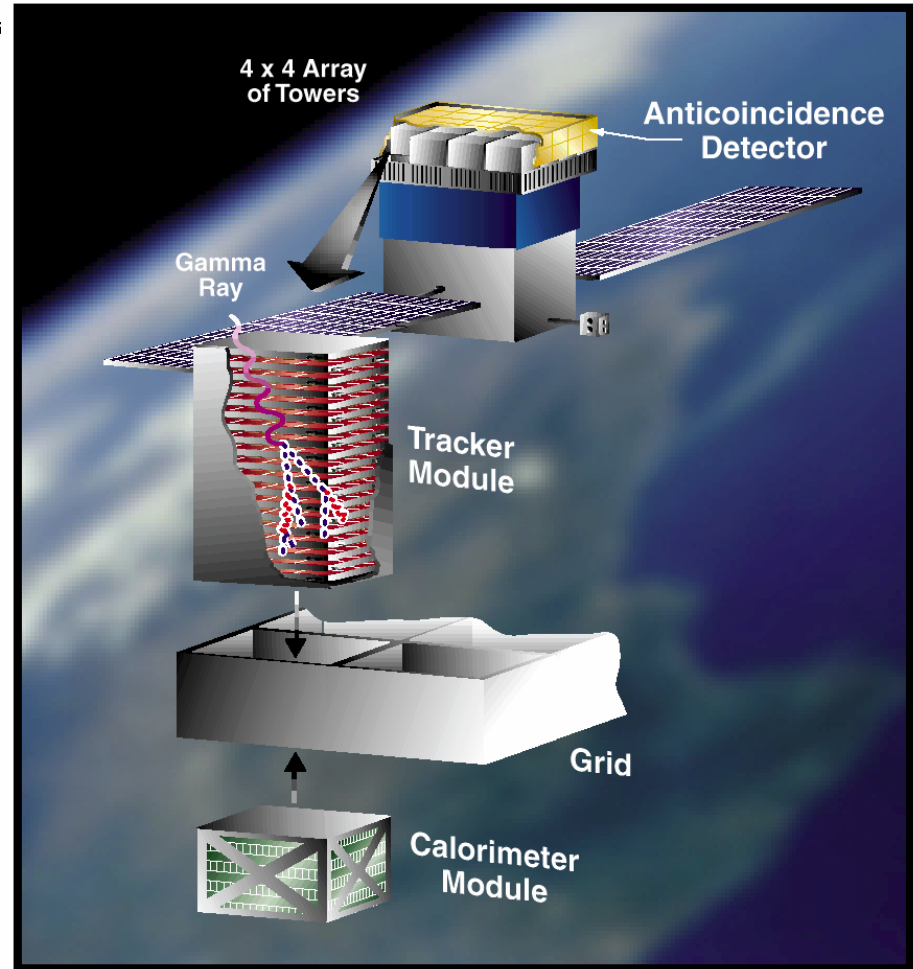
---

- **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.**

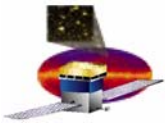


# Overview of LAT

- 4x4 array of identical towers Advantages of modular design.
- Precision Si-strip Tracker (TKR) Detectors and converters arranged in 18 XY tracking planes. Measure the photon direction.
- Hodoscopic CsI Calorimeter(CAL) Segmented array of CsI(Tl) crystals. Measure the photon energy.
- Segmented Anticoincidence Detector (ACD) First step in reducing the large background of charged cosmic rays. Segmentation removes self-veto effects at high energy.
- Electronics System Includes flexible, highly-efficient, multi-level trigger.



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



# Detector Choices

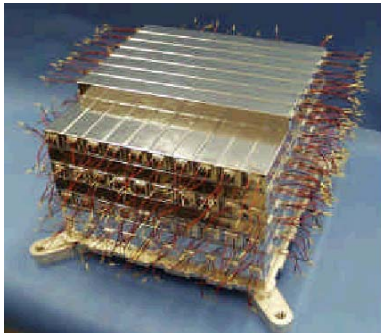
---

- **TRACKER**

**single-sided silicon strip detectors** for hit efficiency, low noise occupancy, resolution, reliability, readout simplicity. Noise occupancy requirement primarily driven by trigger.

- **CALORIMETER**

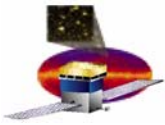
**hodoscopic array of CsI(Tl) crystals with photodiode readout**



for good resolution over large dynamic range; modularity matches TKR; hodoscopic arrangement allows for imaging of showers for leakage corrections and background rejection pattern recognition.

- **ANTICOINCIDENCE DETECTOR**

**segmented plastic scintillator tiles with wavelength shifting fiber/phototube readout** for high efficiency (0.9997 flows from background rejection requirement) and avoidance of 'backsplash' self-veto.

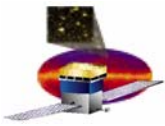


# Tracker Optimization

---

- Radiator thickness profile iterated and selected.
- Resulting design: **“FRONT”**: 12 layers of 3.0% r.l. converter  
**“BACK”**: 4 layers of 18% r.l. converter  
followed by 2 “blank” layers
- Large  $A_{\text{eff}}$  with good PSF and improved aspect ratio for BACK.
- Two sections provide measurements in a complementary manner: FRONT has better PSF, BACK greatly enhances photon statistics.
- Radiator thicknesses, SSD dimensions (pitch 228 microns), and instrument footprint finalized.

**TKR has ~1.5 r.l. of material.  
Combined with ~8.5 r.l. CAL provides 10 r.l. total.**



# Design Performance Validation: LAT Monte-Carlo Model

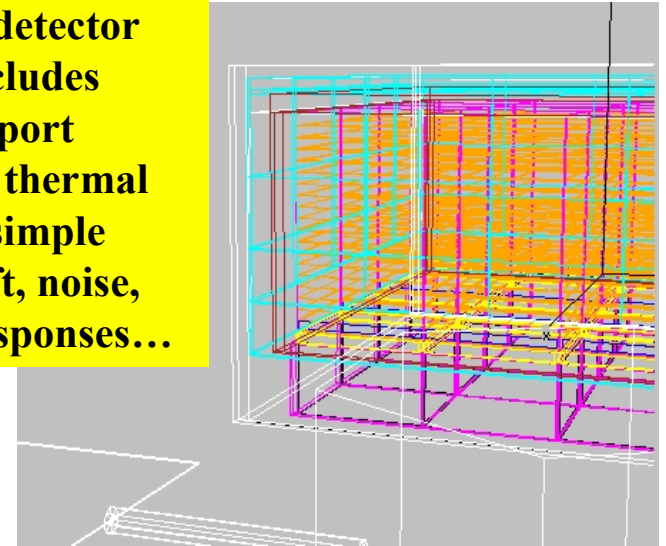
The LAT design is based on detailed Monte Carlo simulations.

Integral part of the project from the start.

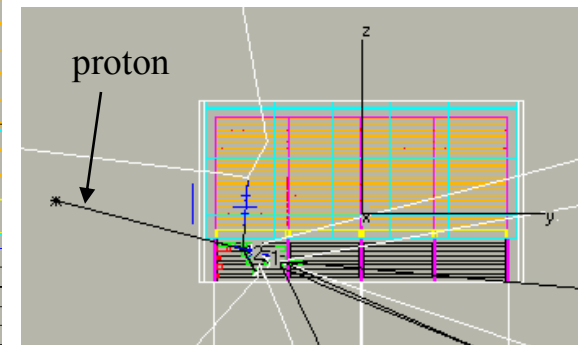
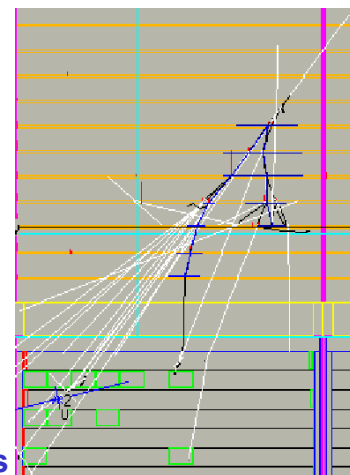
- **Background rejection**
- **Calculate effective area and resolutions (computer models now verified by beam tests). Current reconstruction algorithms are existence proofs -- many further improvements under development.**
- **Trigger design.**
- **Overall design optimization.**

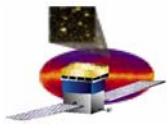
Simulations and analyses are all C++, based on standard HEP packages.

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



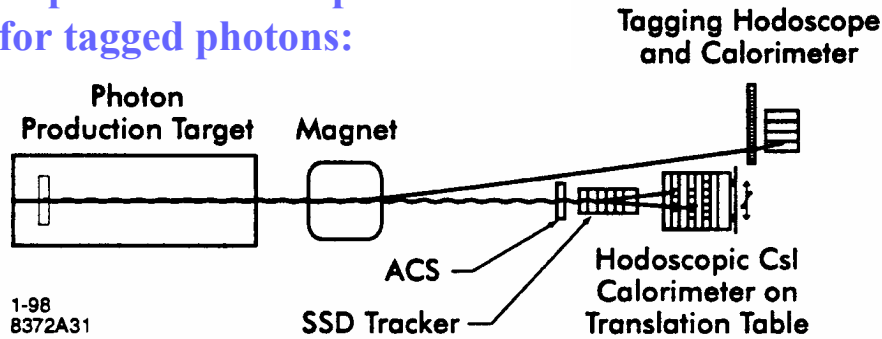
Instrument naturally distinguishes gammas from backgrounds, but details matter.



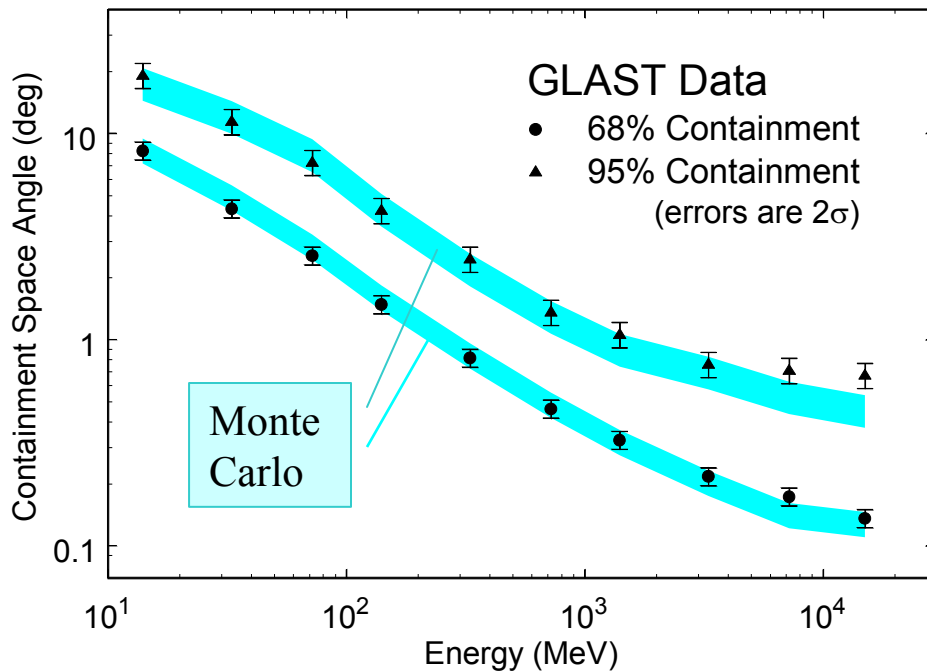


# Monte Carlo Modeling Verified in Detailed Beam Tests

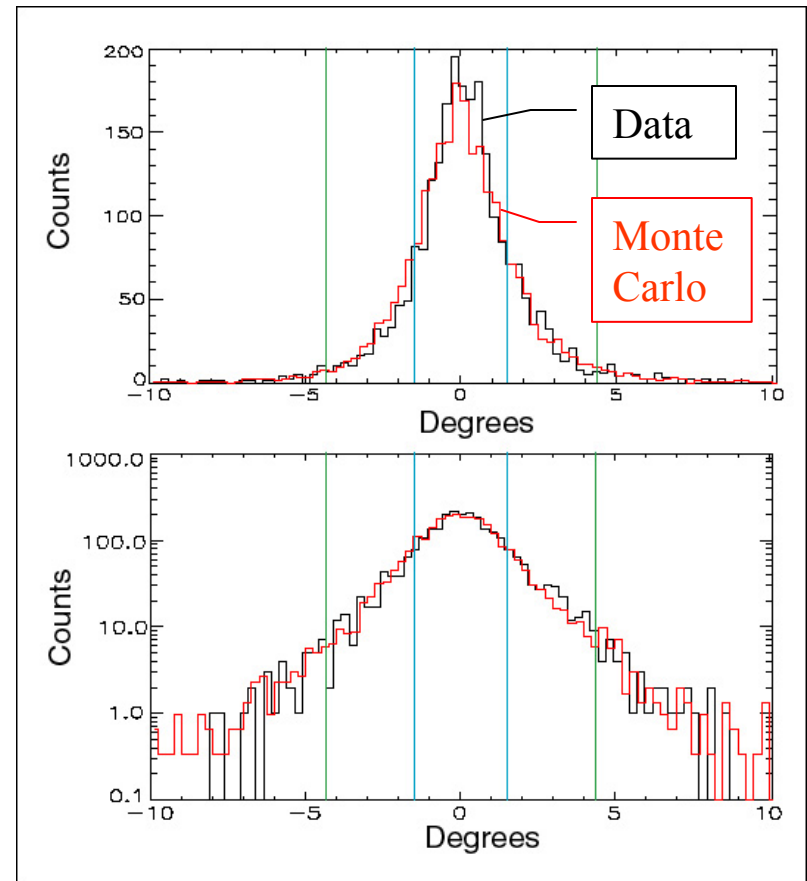
## Experimental setup in ESA for tagged photons:



1-98  
8372A31



X Projected Angle  
3-cm spacing, 4% foils, 100-200 MeV

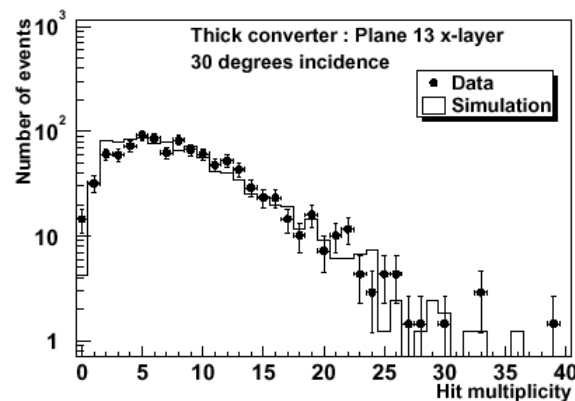
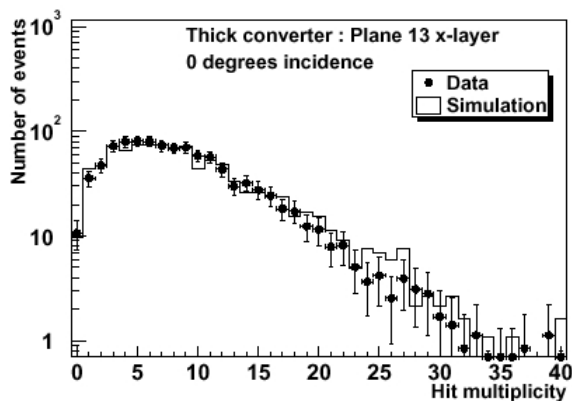
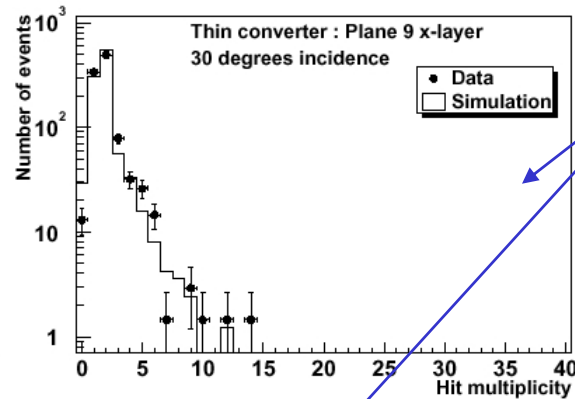
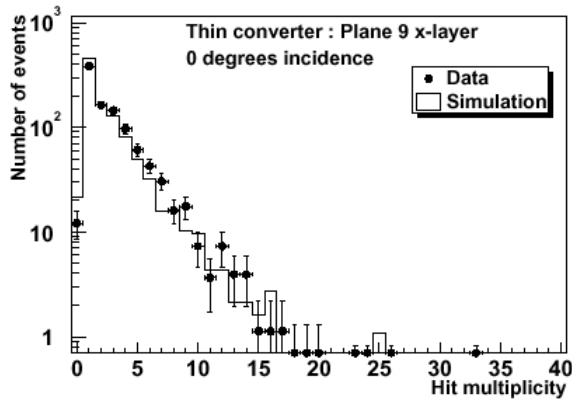


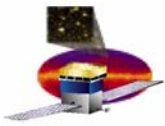
Published in NIM A446(2000), 444.

# 1999-2000 Beam Test at SLAC

Using beams of positrons, tagged photons and hadrons, with a  $\sim$ flight-size tower, studies of

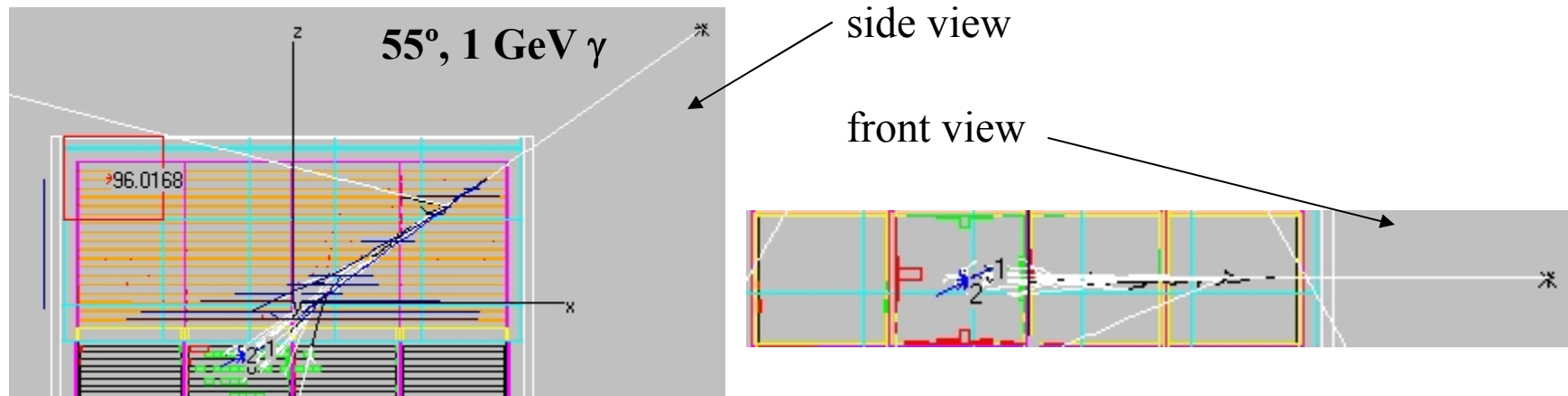
- data system, trigger
- hit multiplicities in front and back tracker sections
- calorimeter response with prototype electronics.
- time-over-threshold in silicon
- upper limit on neutron component of ACD backplash
- hadron tagging and first look at response



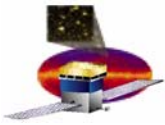


# Calibration Strategy

- Every LAT science performance requirement has a draft defined test.
- LAT energy range and FOV are vast. Testing will consist of a combination of simulations, beam tests, and cosmic ray induced ground-level muon tests. It is neither practical nor necessary to verify by direct test the full range of LAT performance space. Instead, the beam tests are used to sample the performance space and to verify the detailed simulation; analysis using the simulation is used to verify the full range of performance parameters.
- With this strategy, every LAT science performance requirement can be verified. All the science performance requirements can be verified in beam tests using four towers. Full-LAT tests are functional tests.



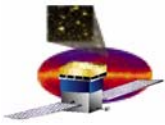




# Work Since Proposal

---

- **Full set of performance parameters calculated prior to proposal using the detailed instrument simulation and earlier reconstruction algorithms.**
- **Why do it again for PDR/Baseline?**
  - **quantitative assessment of performance impact of incremental design changes**
  - **better modeling of backgrounds**
  - **failure modes effects analysis for design decisions**
  - **check results and make improvements. move analysis forward.**
  - **side benefits: opportunity to use and improve software tools. Simulation and reconstruction have undergone major architectural changes to move from a proposal and R&D tool toward support of flight project and flight data processing.**

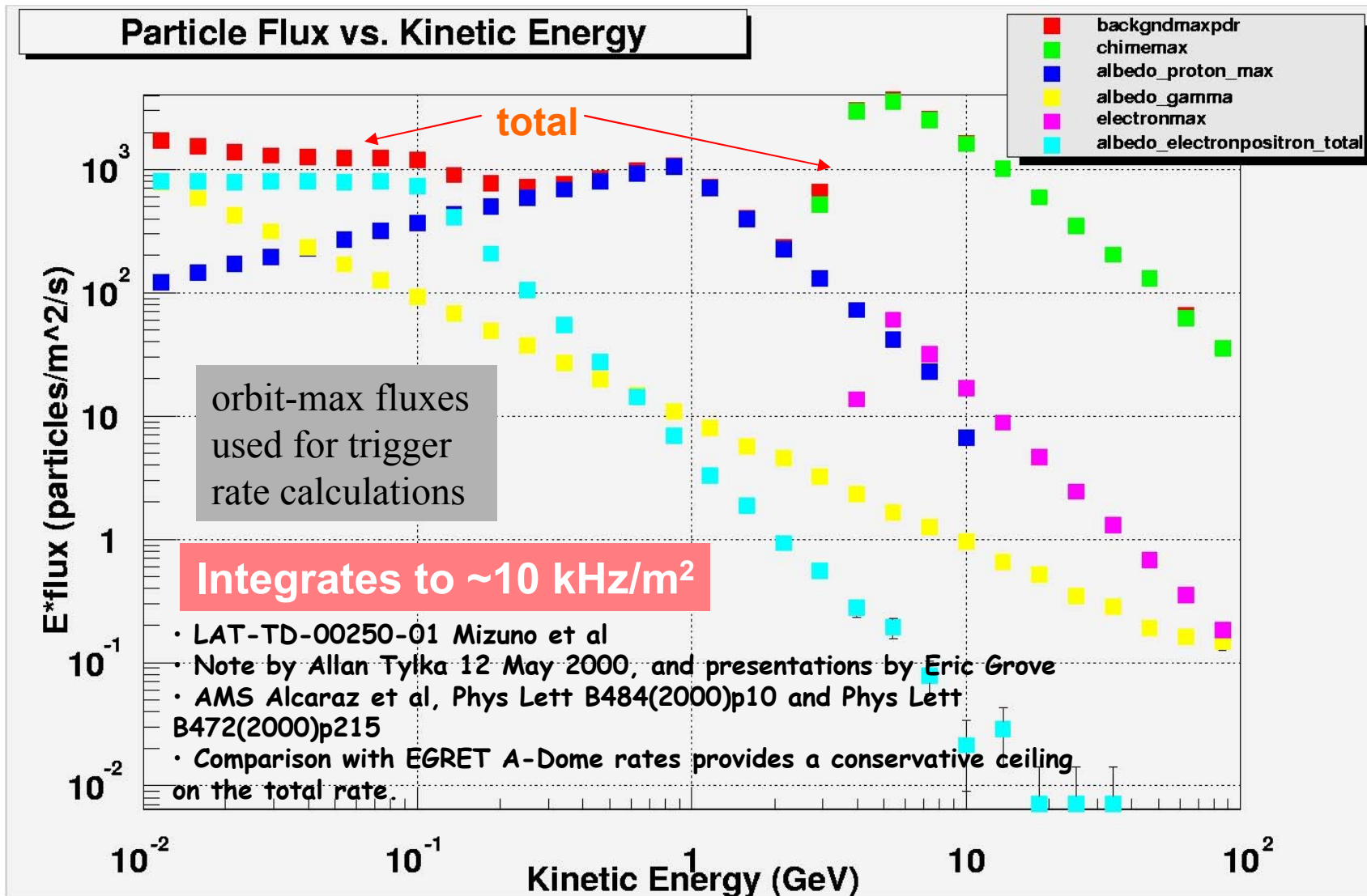


# Presentation Flow

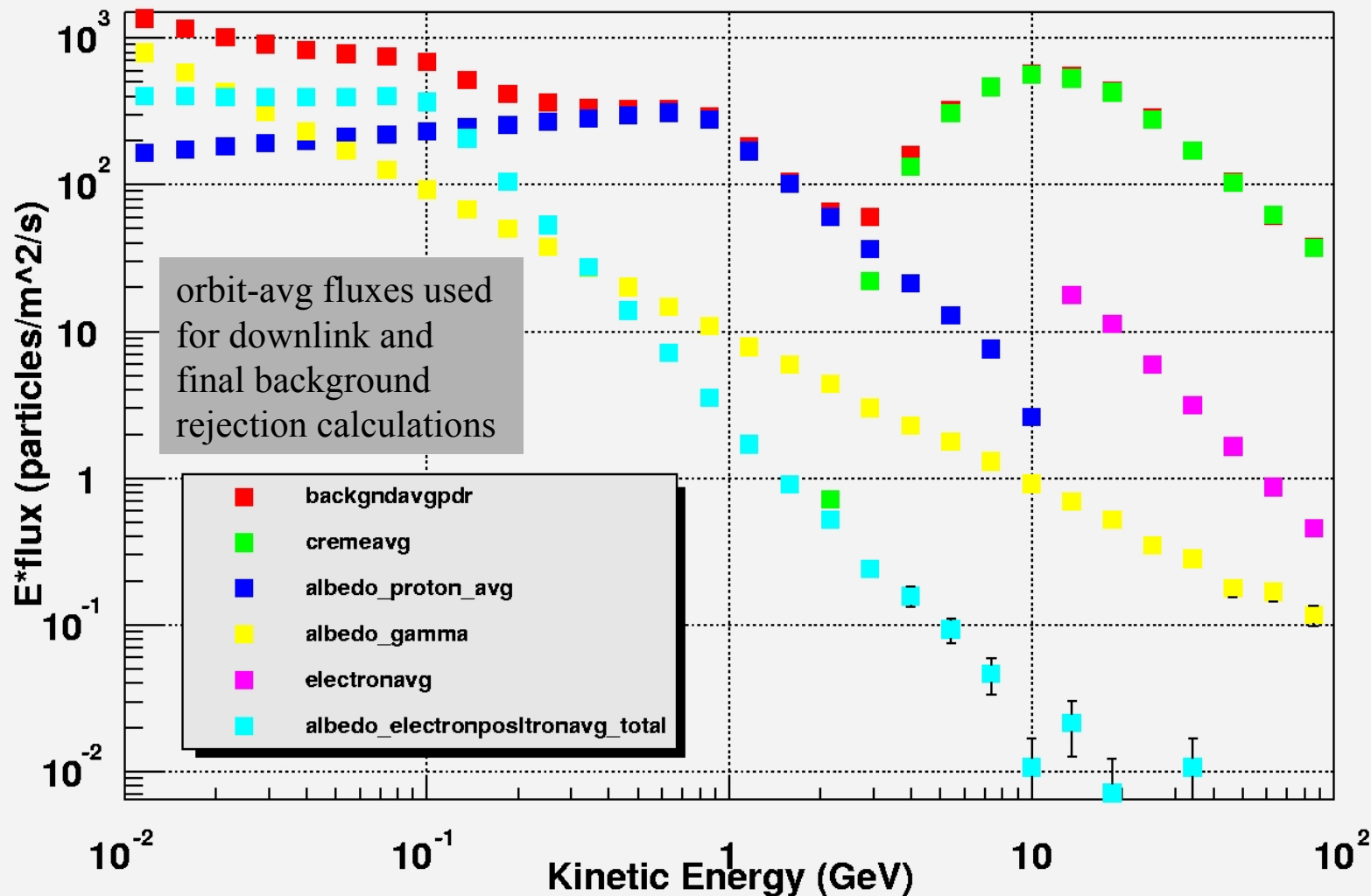
---

- **Input particle fluxes**
- **Instrument model**
- **Hardware triggers**
- **On-board filtering**
- **Ground-based analysis**
- **Current performance results**

# Implemented Orbit-max Background Fluxes

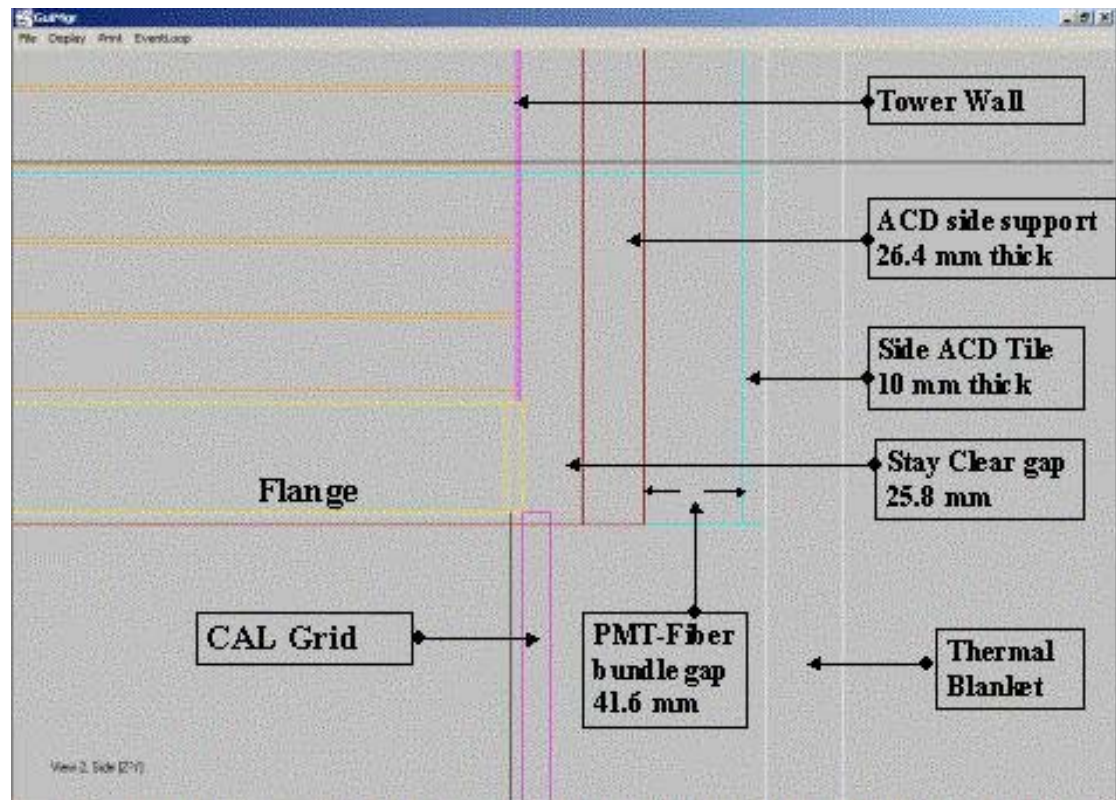


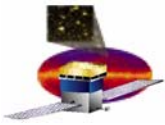
# Implemented Orbit-average Fluxes

**Particle Flux vs. Kinetic Energy****Integrates to ~4.2 kHz/m<sup>2</sup>**

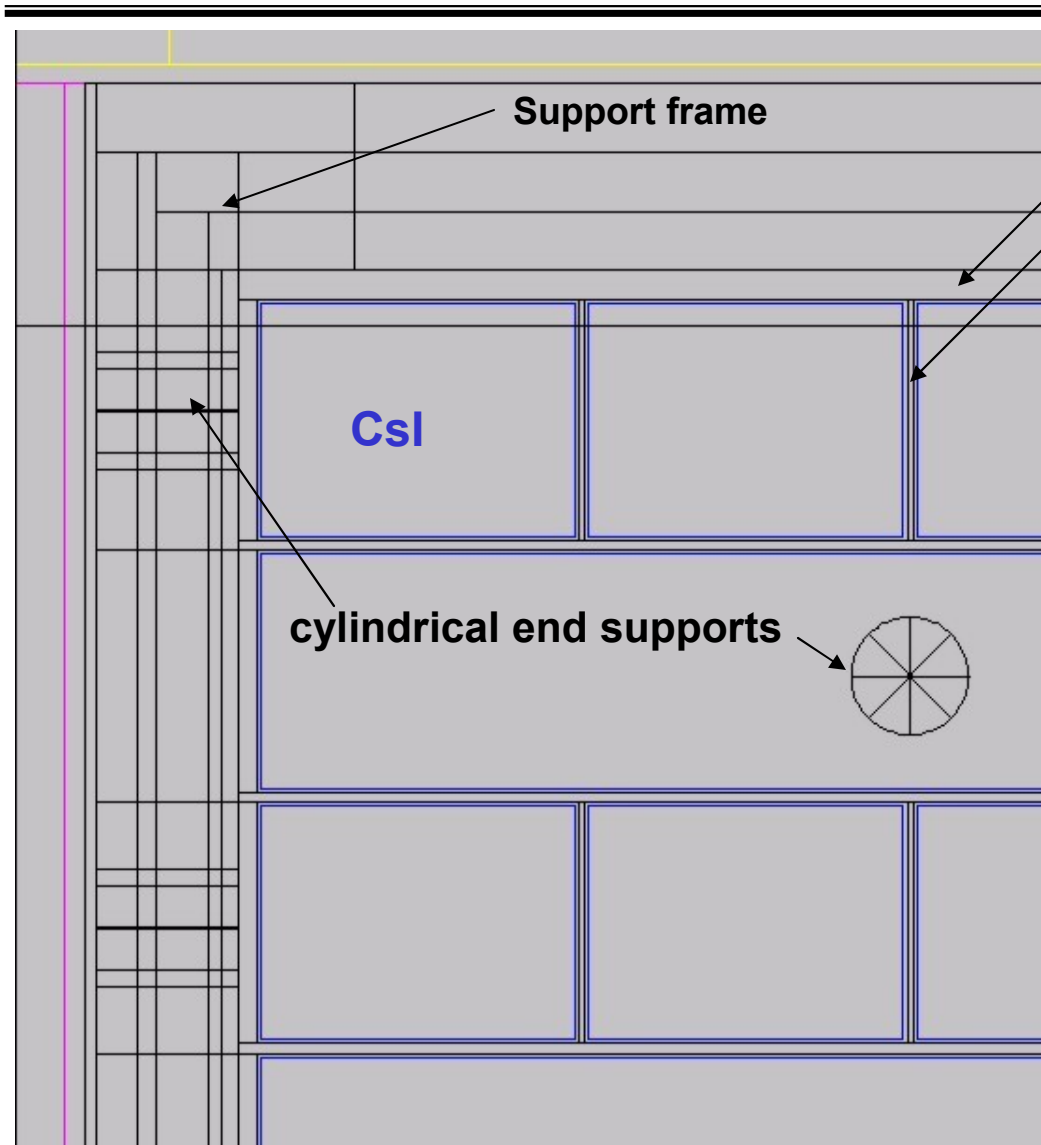
# ACD and GRID Geometry Updates

- Includes ACD support structure and thermal blanket.
- The gap between the tiles and the towers reflects the current design.
- Back-most side rows now single tiles.

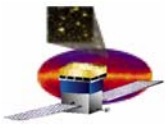




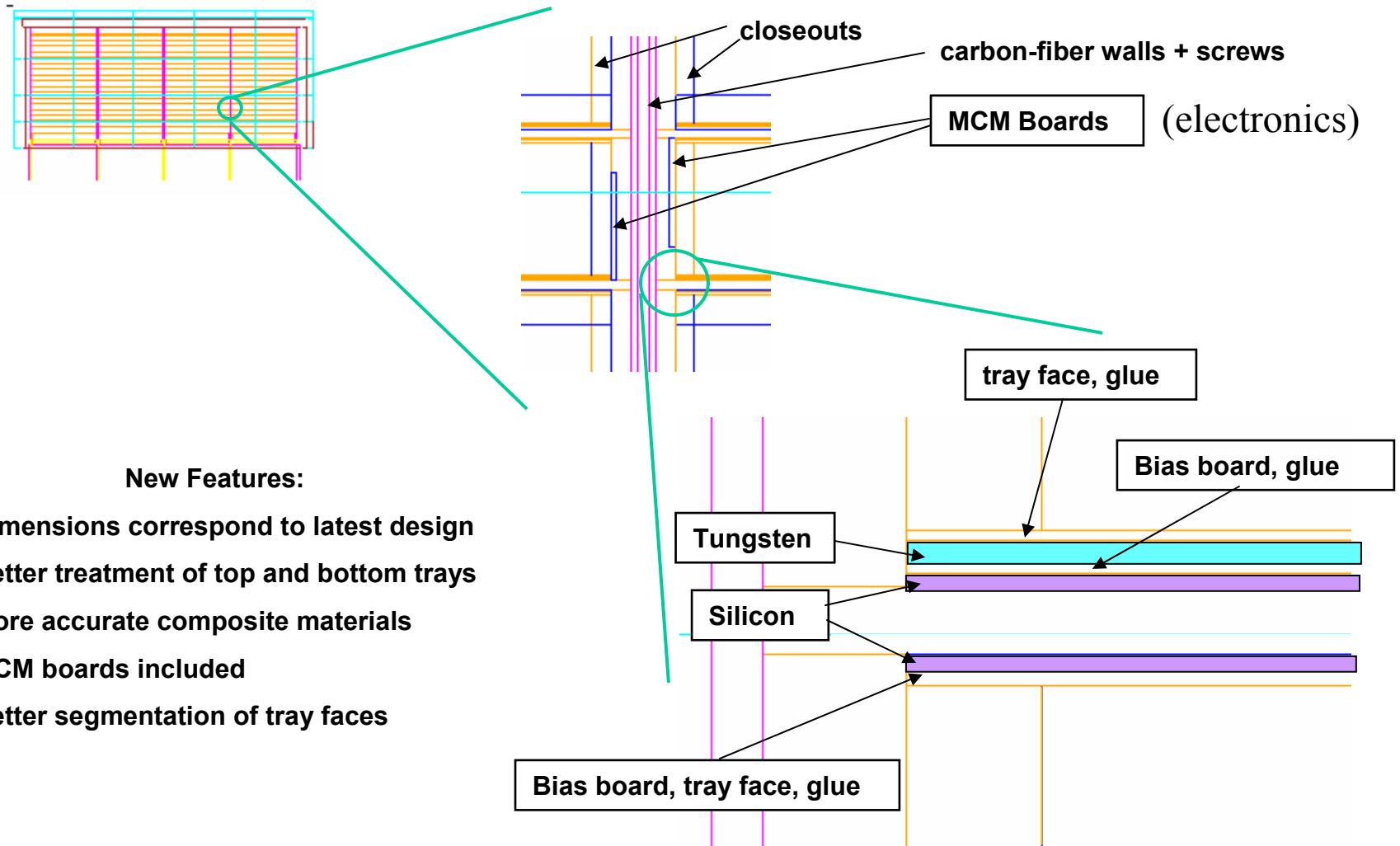
# CAL Geometry Update



- new carbon cell design implemented
- detailed description of top and bottom supporting frames
- detailed description of cell closeout and electronics compartment at the sides of towers.
- all calorimeter dimensions are up-to-date.



# TKR Geometry Update



## New Features:

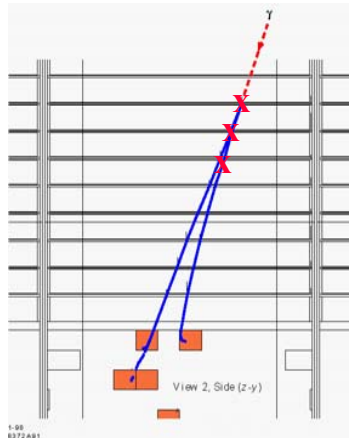
- ✓ Dimensions correspond to latest design
- ✓ Better treatment of top and bottom trays
- ✓ More accurate composite materials
- ✓ MCM boards included
- ✓ Better segmentation of tray faces

# Instrument Triggering and Onboard Data Flow

## Level 1 Trigger

Hardware trigger based on special signals from each tower; initiates readout

- Function:
- “did anything happen?”
  - keep as simple as possible



- TKR 3  $x \cdot y$  pair planes in a row\*\*
- workhorse  $\gamma$  trigger

**OR**

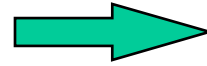
- CAL:
  - LO – independent check on TKR trigger.
  - HI – indicates high energy event → disengage use of ACD.

Upon a L1T, all towers are read out within 20 $\mu$ s

**Instrument Total L1T Rate: <4 kHz>**

\*\*4 kHz orbit averaged without throttle (1.8 kHz with throttle); peak L1T rate is approximately 13 kHz without throttle and 6 kHz with throttle)

LAT-PR-00660-00



## On-board Processing

full instrument information available to processors.

Function: reduce data to fit within downlink

Hierarchical process: first make the simple selections that require little CPU and data unpacking.

- subset of full background rejection analysis, with loose cuts
- only use quantities that
  - are simple and robust
  - do not require application of sensor calibration constants
- complete event information
- signal/bkgd tunable, depending on analysis cuts:
  - $\gamma$ : cosmic-rays ~ 1:~few

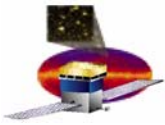
**Total L3T Rate: <25-30 Hz>**

(average event size: ~8-10 kbits)

On-board science analysis:  
transient detection (AGN flares, bursts)

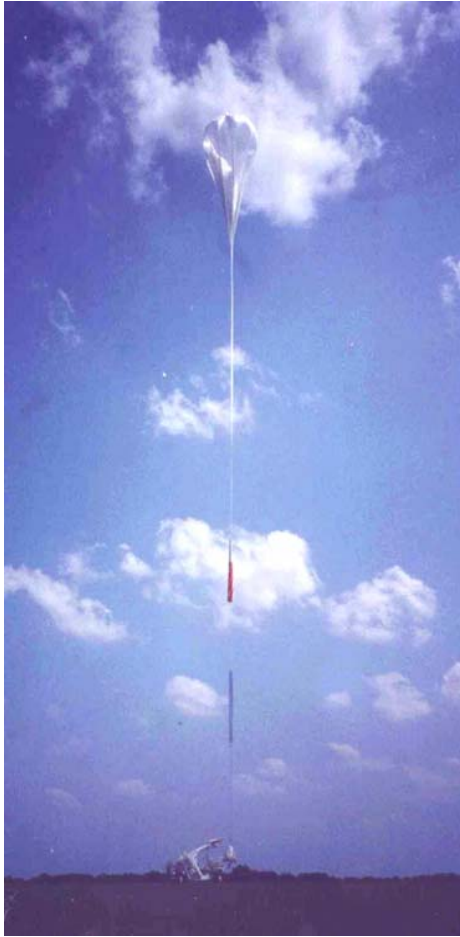
**Spacecraft**





# LAT Balloon Flight: Goals

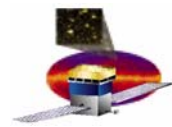
---



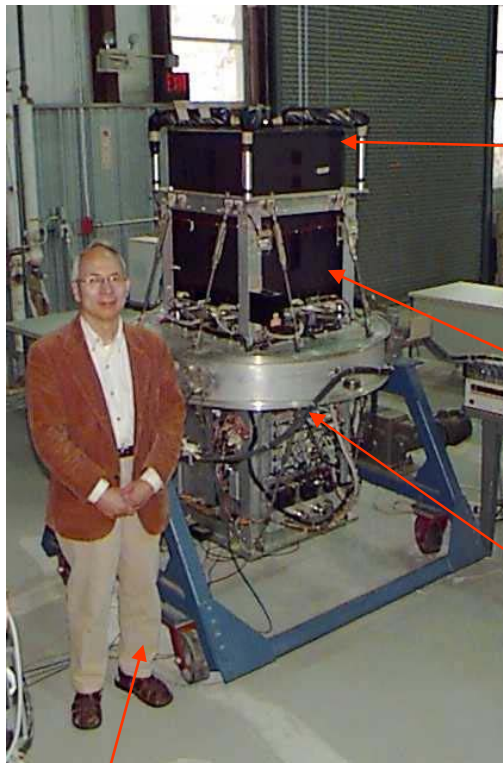
**Purpose of balloon test flight: expose prototype LAT tower module to a charged particle environment similar to space environment and accomplish the following objectives:**

- Validate the basic LAT design at the single tower level.**
- Show the ability to take data in the high 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**



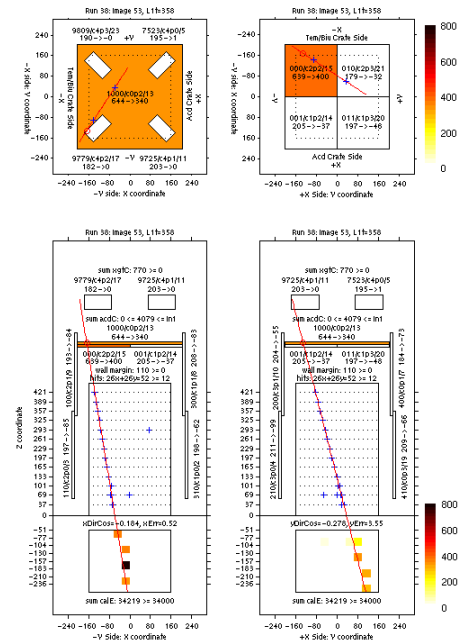
# LAT Balloon Flight Payload



Anticoincidence Detector (ACD) Shield

Tracker Module (TKR)

Calorimeter Module (CAL)

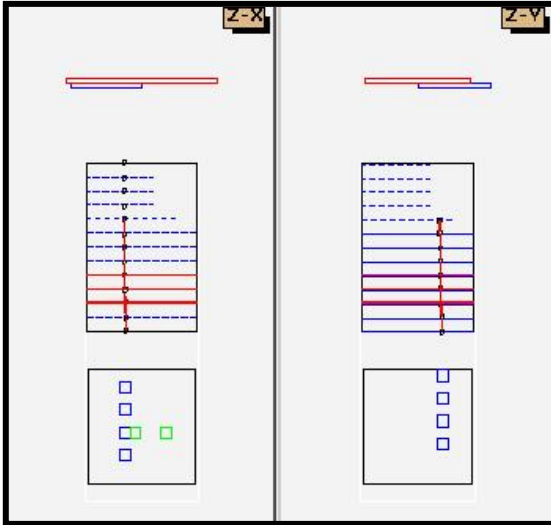


Real-time event display of a muon track

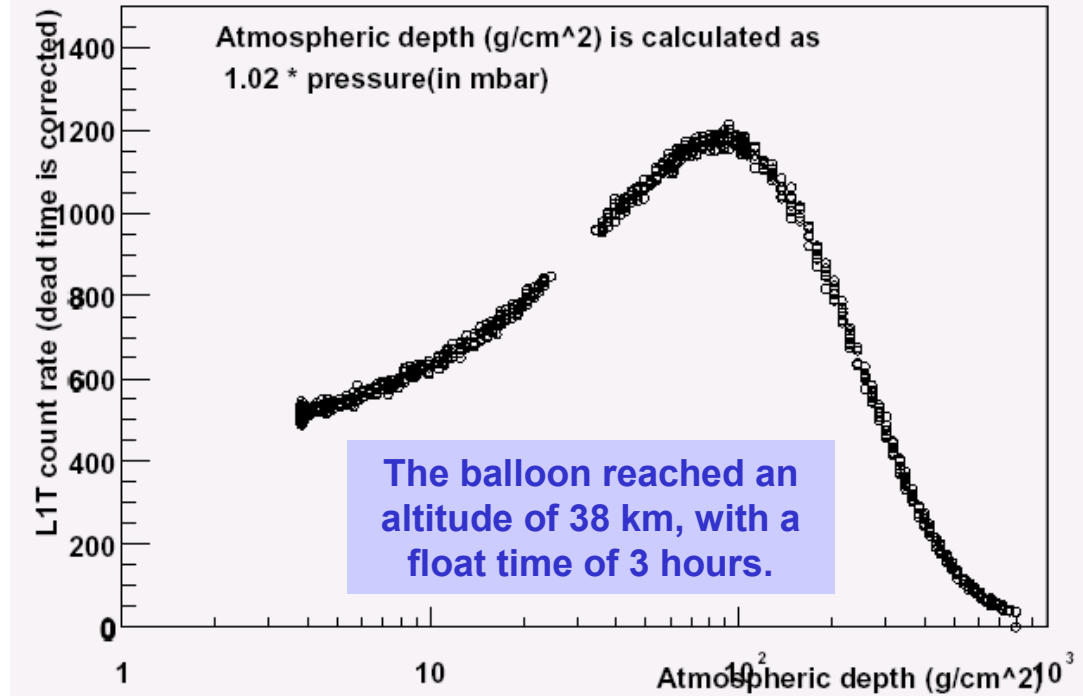
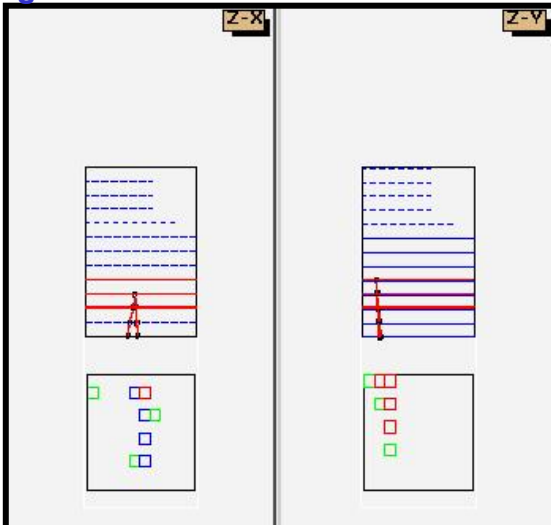
Instrument Technical Manager,  
Tuneyoshi Kamae  
(Tokyo/Stanford University/SLAC)

# Balloon Flight and Operation: Launch on August 4, 2001

background event candidate:

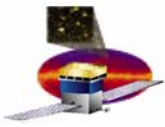


gamma event candidate:



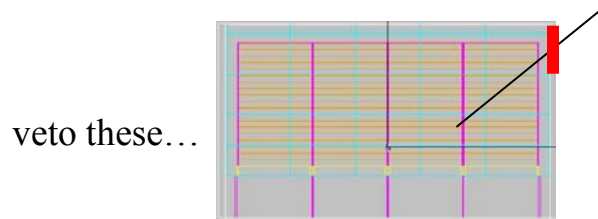
First results (real-time data): trigger rate as a function of atmospheric depth. The trigger rate never exceeded 1.5 KHz, well below the BFEM capability of 6 KHz.

All Subsystems Performed Properly

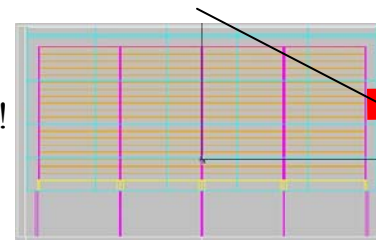


# Level 1 Trigger and Throttles

- TKR 3-in-a-row
- CAL-LO = any single log with recorded energy  $> 100$  MeV (adjustable)
- CAL-HI = any tower with 3-layers-in-a-row each with  $>0$  logs with recorded energy  $> 1$  GeV (adjustable) (see LAT-TD-00245-01, 16 July, Chekhtman and Grove)
- Need an *option* to throttle TKR trigger:
  - if trigger is in first silicon layer AND a hit in matching ACD tile, AND no CAL-HI, veto the event
  - in outer tower with a 3-in-a-row, if geographic match with hit ACD tile, AND no CAL-HI, veto the event:



.... but not these!



...and, ignore back-most row of ACD tiles for these preselections to preserve gammas whose products scatter out the side.

- also, count number of tiles hit NOT in the back-most two rows.
- Note: removing events with zero cal energy is another potential option under study for additional safety margin. Does not appear necessary right now.

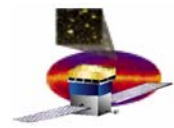


# Orbit Max L1 Rates

	all	chimemax	albedo_p_max	albedo gamma	CR e- max	albedo e+e-
flux (kHz/m <sup>2</sup> )	9.9	4.2	2.6	0.92	0.043	2.2
L1T (Hz)	13,134	7,419	3,501	242	79	1,893
L1T frac	1	0.56	0.27	0.02	0.01	0.14
L1V Throttle (Hz)	5,510	2811	1,679	190	37	793
L1V Throttle frac	1	0.51	0.30	0.03	0.01	0.14

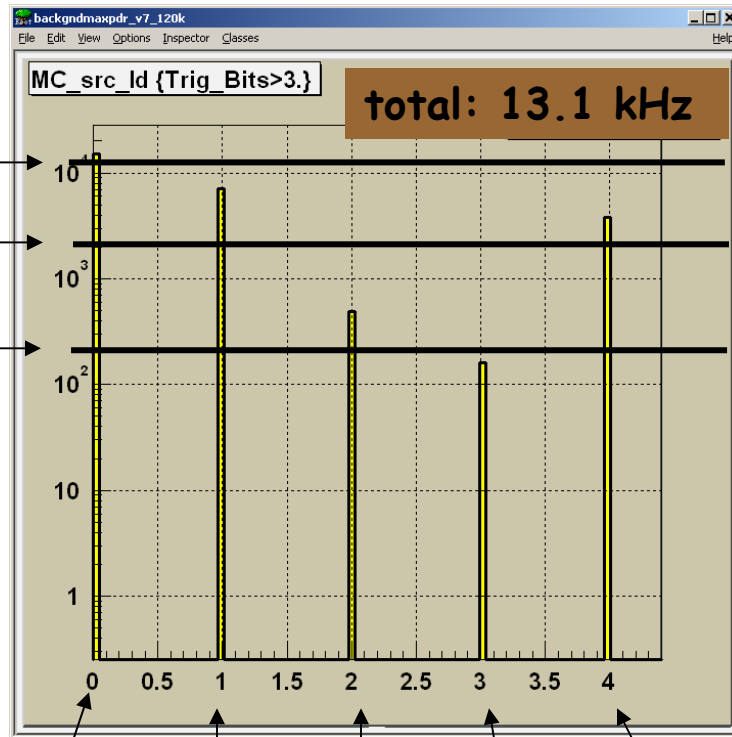
## Notes:

- with the ACD throttle on the TKR trigger, the total max rate is <6 kHz.
- albedo gamma rate is for zenith pointed - more on this later, as a function of rocking angle.



# Orbit Max L1 Rates

## L1T unthrottled



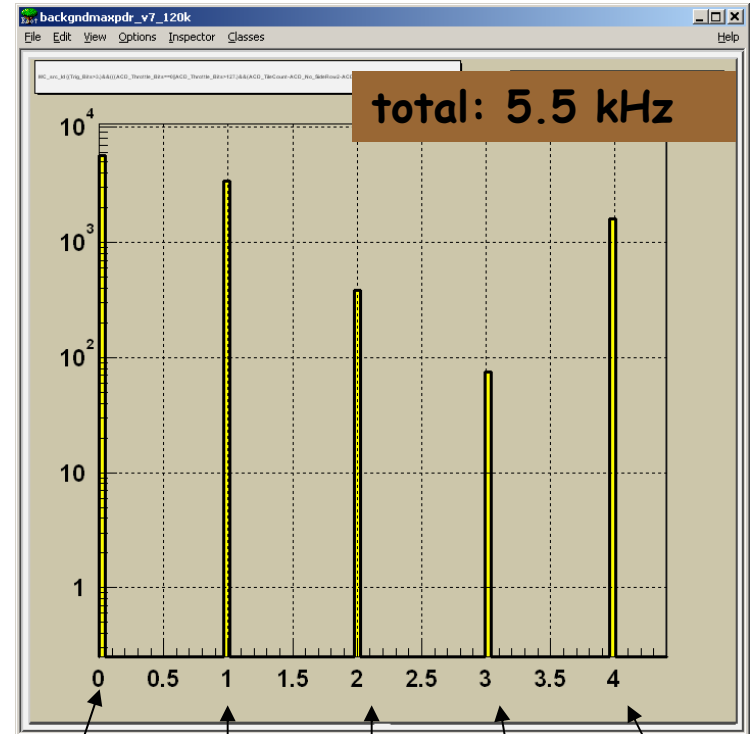
5 kHz line →

1 kHz line →

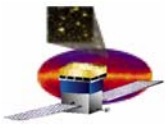
100 Hz line →

chime    albedo    albedo    CRe    albedo  
           p             $\gamma$              $e+e-$

## L1T with Throttle

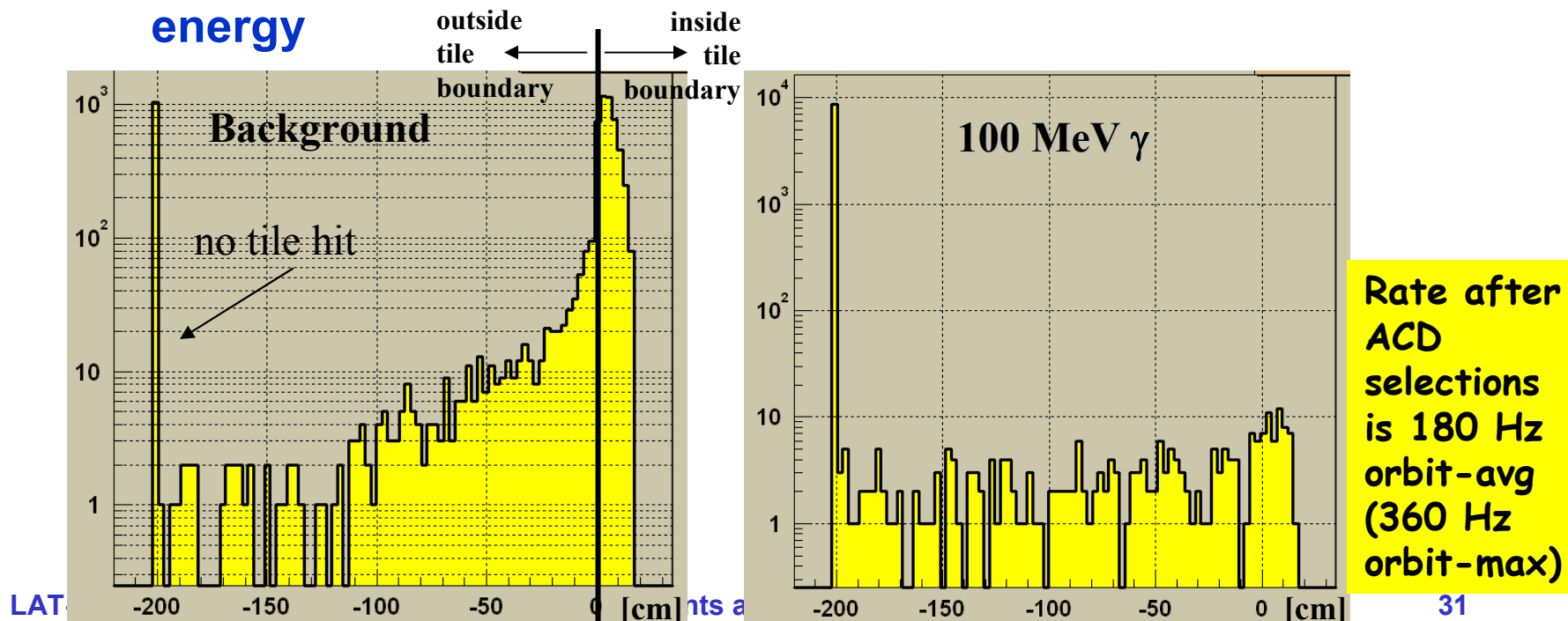


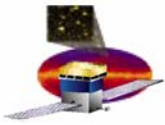
chime    albedo    albedo    CRe    albedo  
           p             $\gamma$              $e+e-$



# On-board Filters

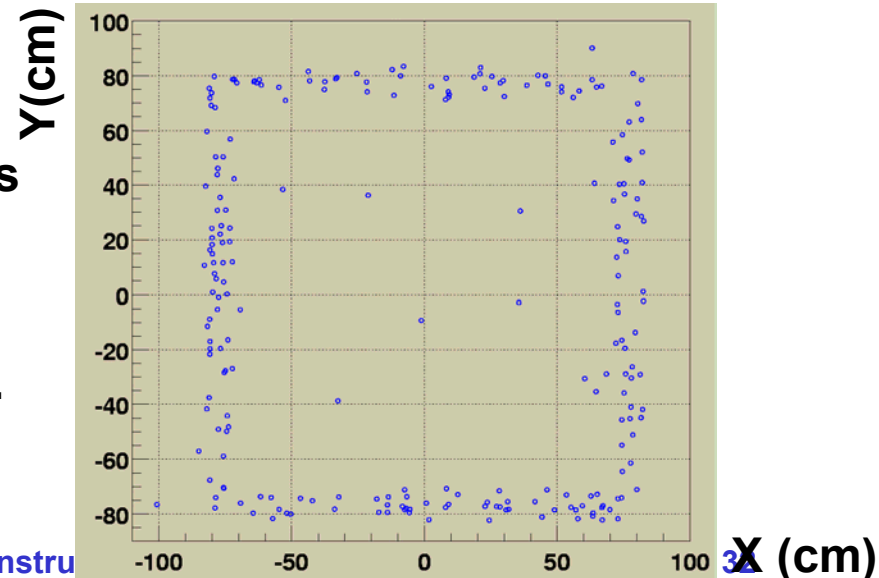
- select quantities that are simple to calculate and that do not require individual sensor calibration constants. Filter scheme is flexible – current set is basis for flight implementation.
- order of selections to be optimized. Grouped by category for presentation purposes:
  - **ACD info: match track to hit tile, count # hit tiles at low energy**



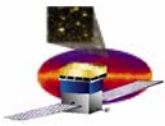


## On-board Filters (II)

- **CAL info:** most of the residual rate at this point is due to albedo events and other upward-going energy events. Require track-CAL energy centroid loose match, fractional energy deposit in front layer reasonably consistent with downward EM energy flow. If no CAL energy, require track pattern inconsistent with single-prong. Rate after CAL selections is ~80 Hz orbit-avg (130 Hz orbit-max)
- **TKR info:** low-energy particles up the ACD-TKR gap easily dealt with:
  - project track to CAL face and require XY position outside this band; for low CAL energy, require TKR hit pattern inconsistent with single prong.



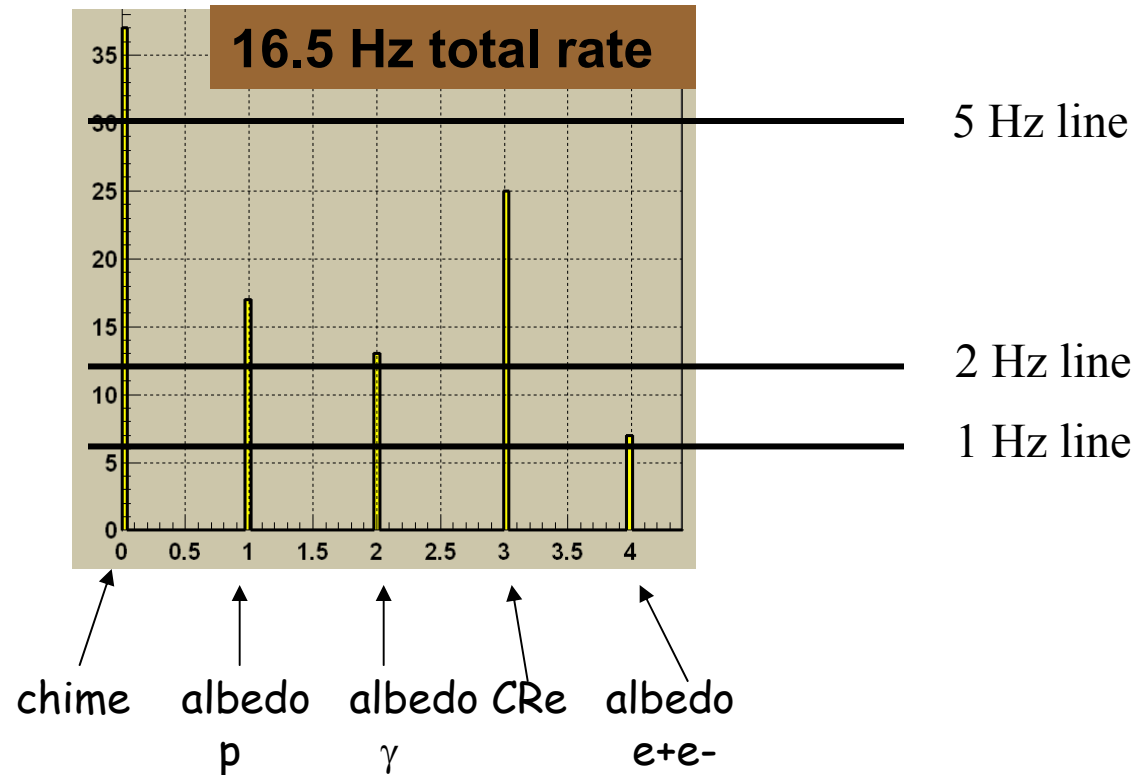




# On-board Filters Results

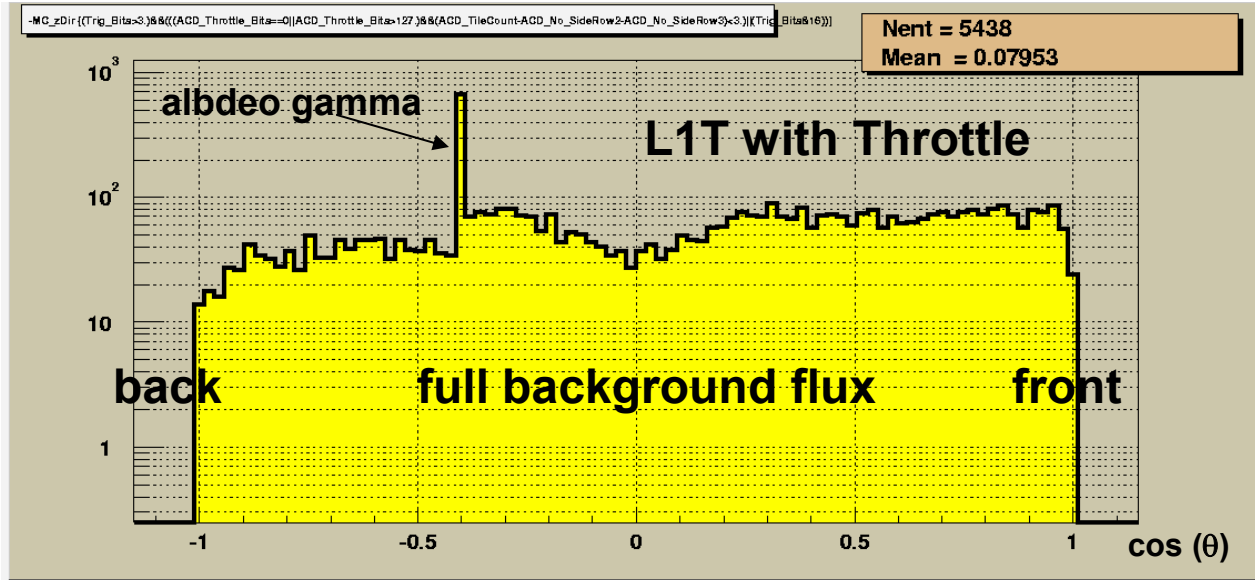
- After all selections, orbit-average background rate is 17 Hz.

composition:



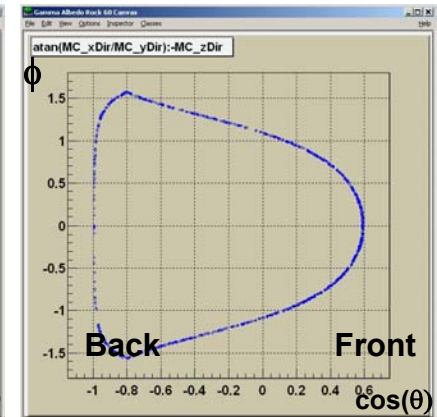
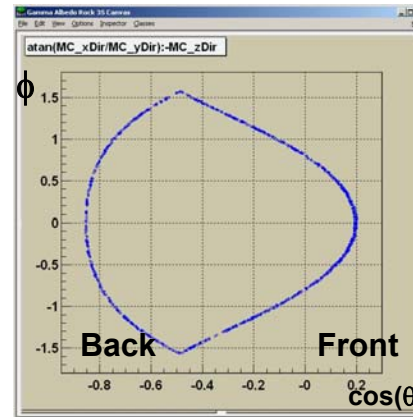
Additional margin available: much of the residual rate is due to high-energy proton and electron events with CAL  $E > 5 \text{ GeV}$  -- if apply ACD selections onboard to higher energy, rate can be cut in half (to 8 Hz), with  $\sim 5\%$  reduction in  $A_{\text{eff}}$  at 10 GeV.

# Effects of Rocking: Albedo Gammas



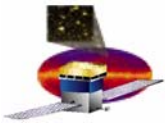
As we rock, the spike spreads in  $\theta, \phi$ :

At zenith, earth horizon is at 113 degrees. Study what happens when observatory rocks to 35 and 60 degrees off zenith.



35 degree rock

60 degree rock



# Albedo Gamma Rates

	L1T rate [Hz]	L1T rate with Throttle [Hz]	After filters [Hz]	After fiducial cut [Hz]
zenith	250	190	2	2 (no cut)
rock 35°	260	200	3	3 (no cut)
rock 60°	300	250	8	1 (<45°) 3 (<53°)

## Notes:

- rates for other backgrounds will be reduced somewhat by the same angle cut, not taken into account here.
- small incremental L1T rate not a problem
- calculating the gamma direction only happens at a relatively low rate, if needed (after other filters), so incremental CPU load not a problem.
- can reduce the downlink contribution to whatever we need with a tighter fiducial cut.



# Ground-based Background Rejection Analysis

---

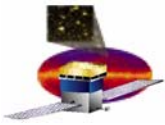
- Evaluation of the performance parameters ( $A_{\text{eff}}$ , PSF, etc.) requires the final background rejection analysis.
- Different science analyses will likely optimize final background rejection selections differently. **The most stringent requirement driver is the extragalactic diffuse flux.** [Example, diffuse flux analysis will use CAL energy measurement, so ignore events with no CAL energy deposit here. We still plan to bring No-CAL events to the ground, however.]
- **Significant software infrastructure necessary:** generate 50M background events, with a unique tag for each. Machinery to cull lists of events, single event display, analysis infrastructure.
- Also generate adequate sample of extra-galactic diffuse photon flux and pass it through the analysis chain.



# Summary of Ground-Based Background Rejection Analysis

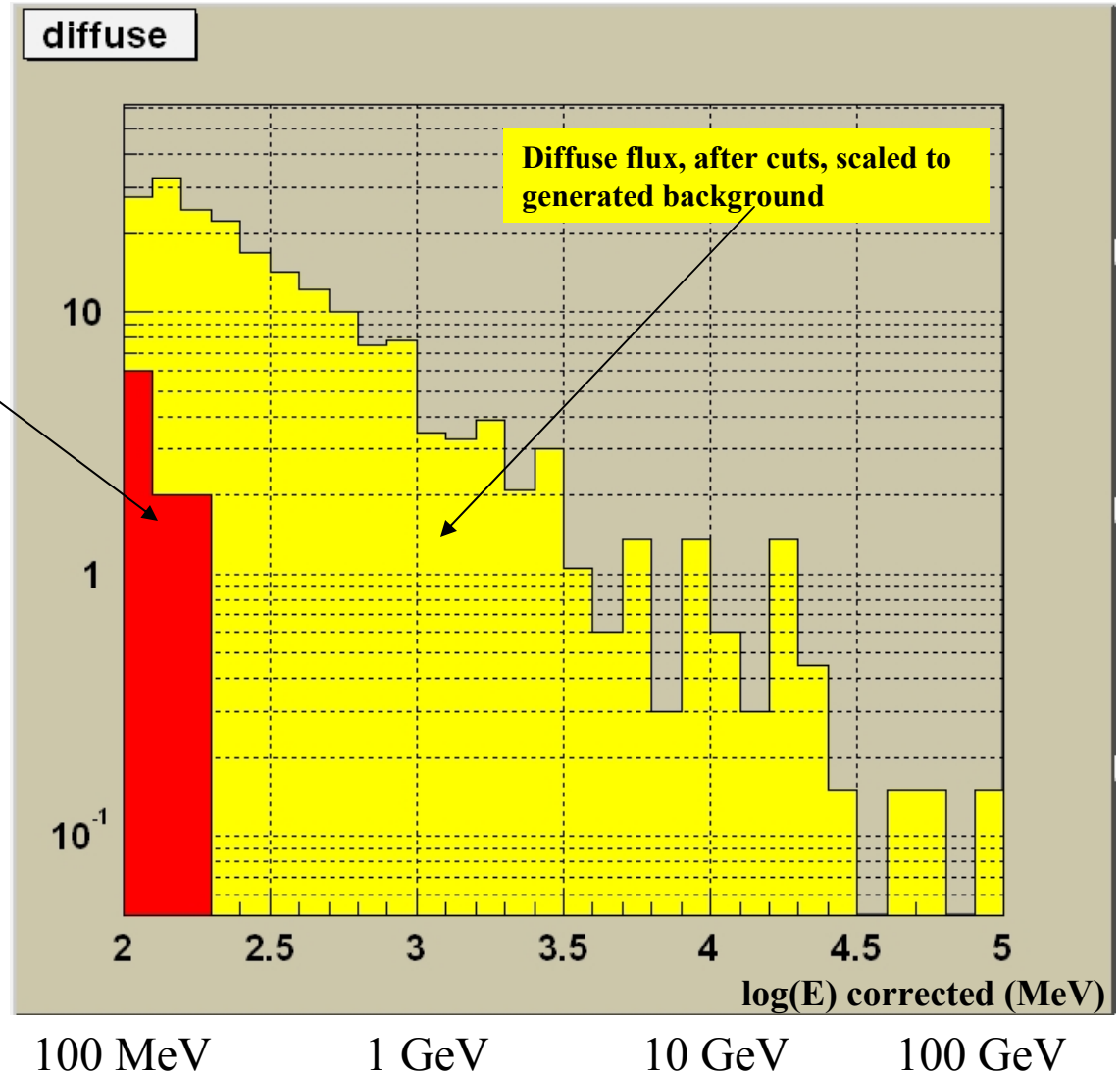
---

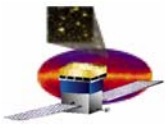
- The reconstruction tools are still under development, and the actual analysis will be much more sophisticated, effective, and efficient.
- Current selections using subsystem info:
  - **TKR:** use information from track fits, hit pattern inconsistent with single track at low energy, PSF cleanup cuts, location cuts, loose consistency between track multiple scatter and CAL energy.
  - **CAL:** require xtal hit patterns (shower shapes) to be consistent with downward-going EM showers; more precise track-CAL energy centroid matching.
  - **ACD:** very low energy events require quiet ACD; hidden shower rejection.



# Background Rejection Results

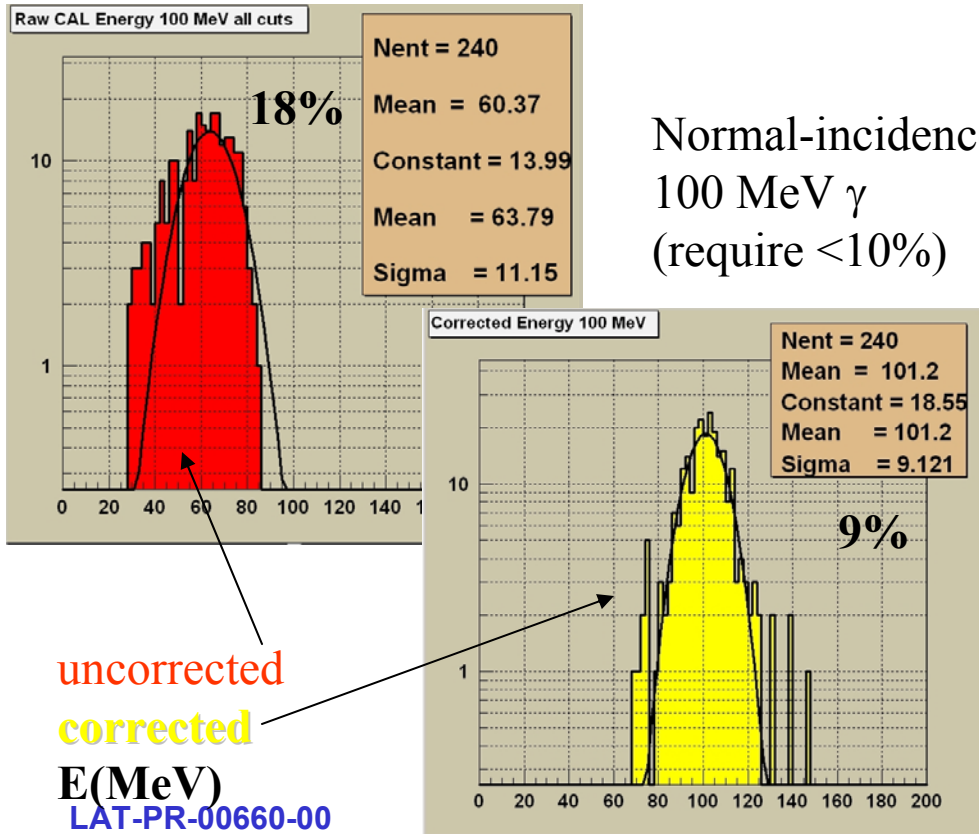
- Requirement: <10% contamination of the measured extragalactic diffuse flux for  $E > 100$  MeV
- Residual background is 5% of the diffuse (6% in the interval between 100 MeV and 1 GeV). Important experimental handle: large variation of background fluxes over orbit – compare diffuse results over orbit.
- Below 100 MeV [no requirement], without any tuning of cuts for low energy, fraction rises to 14%. This will improve.
- Peak effective area: 10,000 cm<sup>2</sup> (at ~10 GeV).
- Effective area at 300 GeV: 8,000-10,000 cm<sup>2</sup>, depending on analysis selections.
- At 20 MeV, effective area after onboard selections is 630 cm<sup>2</sup>. Different physics topics will require different (and generally less stringent) background rejection on the ground.



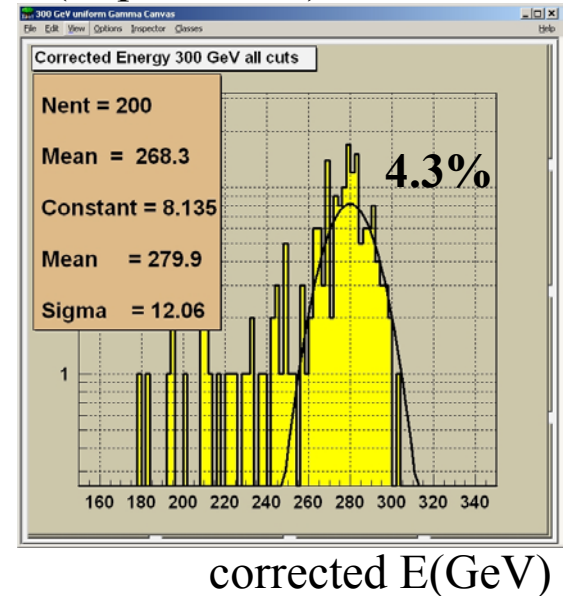


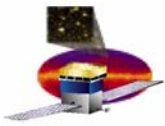
# Energy Resolution

- Energy corrections to the raw visible CAL energy are particularly important for
  - depositions in the TKR at low photon energy (use TKR hits)
  - leakage at high photon energy (use longitudinal profile)

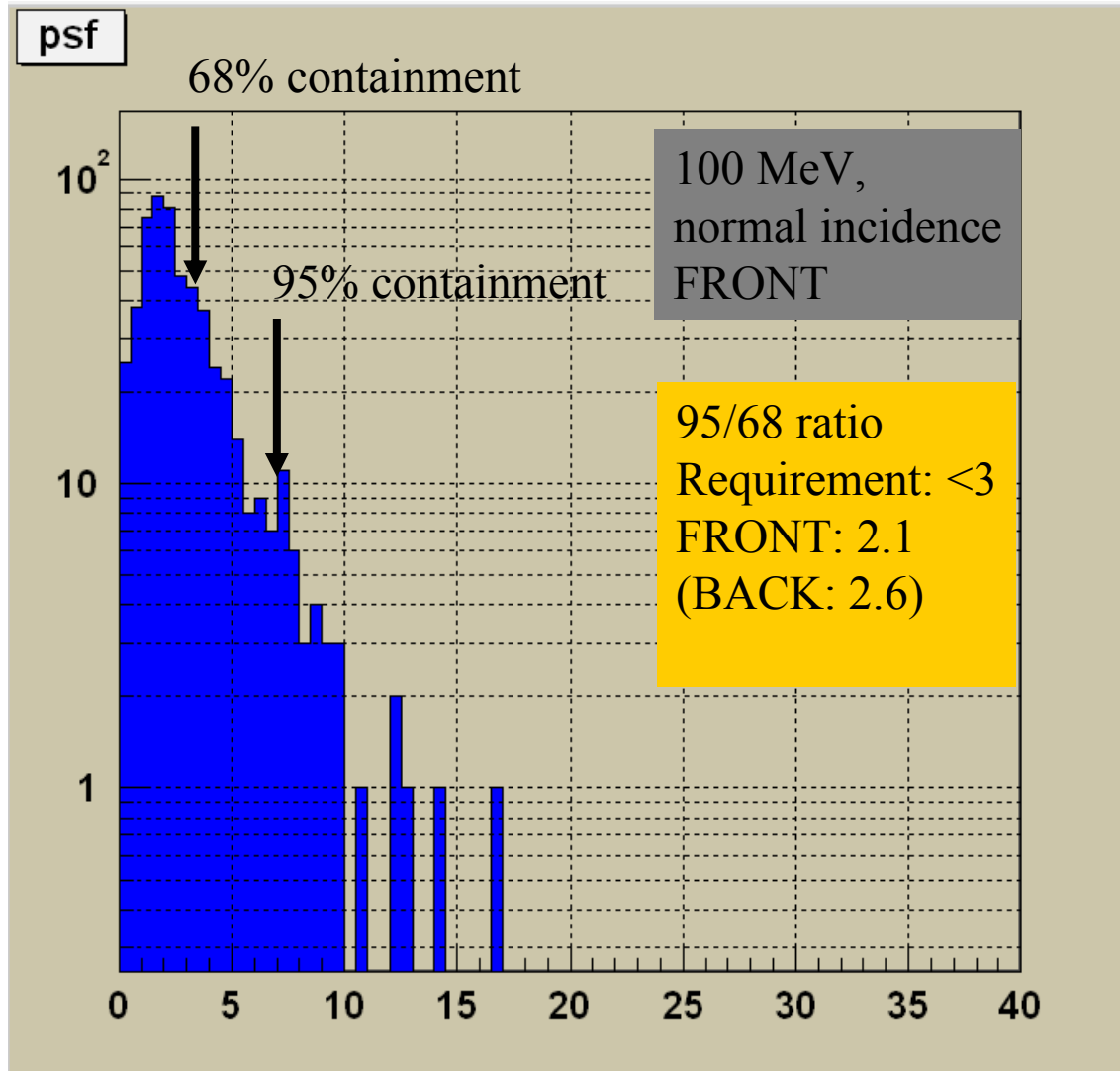


>60° off-axis 300 GeV  $\gamma$   
(require <6%)





# PSF



68% containment radius:

100 MeV

Requirement:  $<3.5^\circ$

$3.37^\circ$  FRONT

$4.64^\circ$  Total

10 GeV

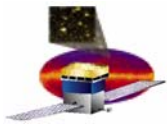
Requirement:  $<0.15^\circ$

$0.08^\circ$  FRONT

$0.115^\circ$  Total

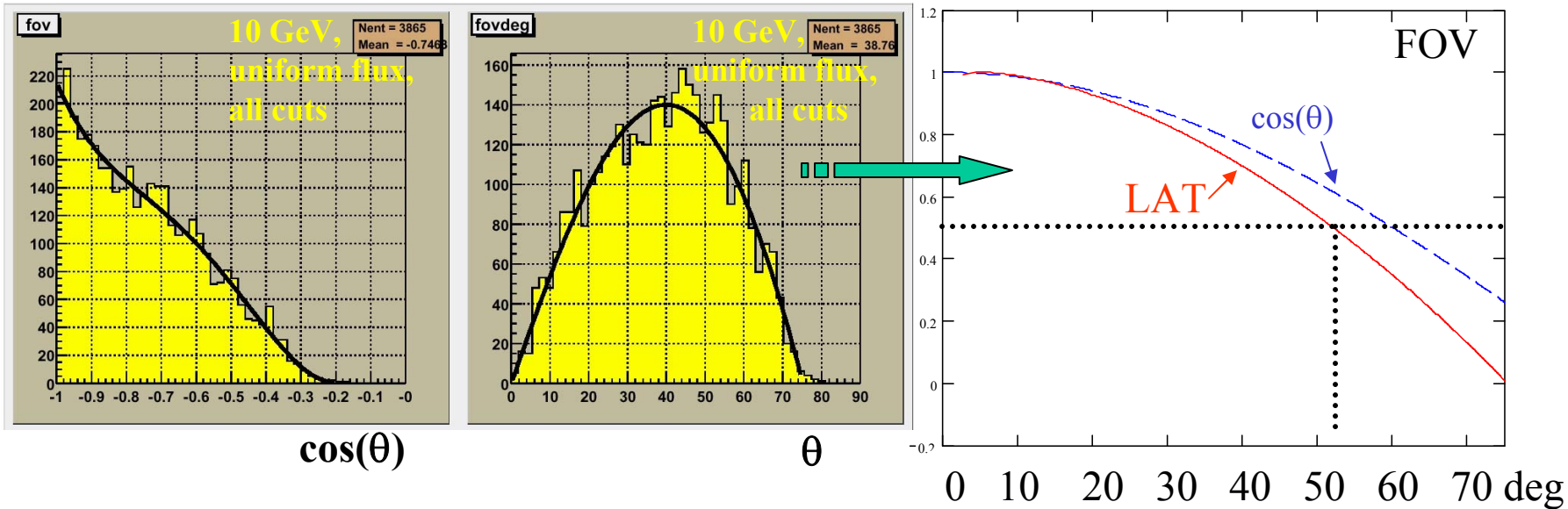
**NOTE:** With current version of TKR reconstruction software, the present 95/68 ratio is not  $<3$  everywhere (particularly at high energy). This is a software issue, not an instrument design issue. TKR reconstruction software under upgrade to improve hit association and more precise vertexing.



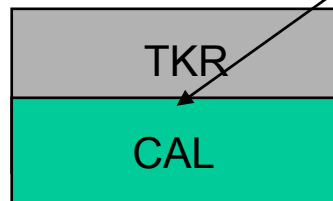
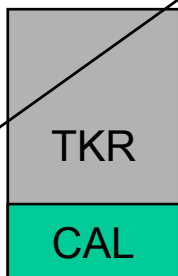


# Field of View

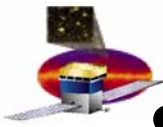
- Defined as the integral of effective area over solid angle divided by peak effective area:



Favorable LAT aspect ratio provides large FOV



**Requirement: >2 sr**  
**LAT current: 2.4 sr**



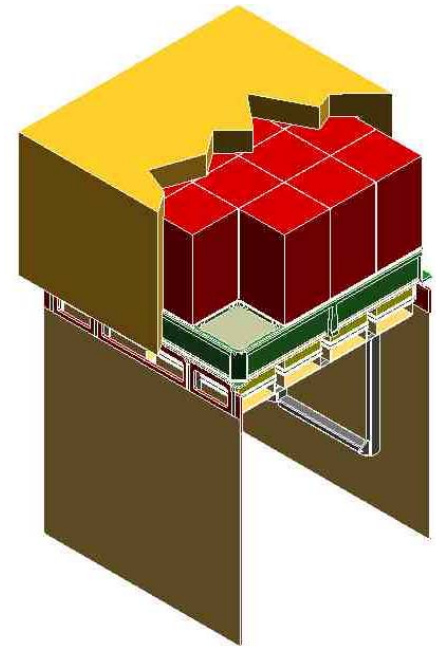
# Science Performance Requirements Summary

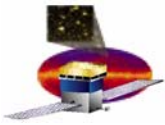
From the SRD:

Parameter	SRD Value	Present Design Value
Peak Effective Area (in range 1-10 GeV)	>8000 cm <sup>2</sup>	10,000 cm <sup>2</sup> at 10 GeV
Energy Resolution 100 MeV on-axis	<10%	9%
Energy Resolution 10 GeV on-axis	<10%	8%
Energy Resolution 10-300 GeV on-axis	<20%	<15%
Energy Resolution 10-300 GeV off-axis (>60°)	<6%	<4.5%
PSF 68% 100 MeV on-axis	<3.5°	3.37° (front), 4.64° (total)
PSF 68% 10 GeV on-axis	<0.15°	0.086° (front), 0.115° (total)
PSF 95/68 ratio	<3	2.1 front, 2.6 back (100 MeV)
PSF 55°/normal ratio	<1.7	1.6
Field of View	>2sr	2.4 sr
Background rejection (E>100 MeV)	<10% diffuse	6% diffuse (adjustable)
Point Source Sensitivity(>100MeV)	<6x10 <sup>-9</sup> cm <sup>-2</sup> s <sup>-1</sup>	3x10 <sup>-9</sup> cm <sup>-2</sup> s <sup>-1</sup>
Source Location Determination	<0.5 arcmin	<0.4 arcmin (ignoring BACK info)
GRB localization	<10 arcmin	5 arcmin (ignoring BACK info)

# Failure Modes Modeling for FMEA

- Can analyze identical events with/without failure turned on. Difficult part is putting awareness into the reconstruction (as we would if failure really happens).
- Highest priority has been ACD: loss of a single tile. Potential impact on trigger rates and downlink volume – could we operate? Needed primarily for micrometeoroid shield reliability requirements. →
- Now studying:
  - TKR: impact of loss of a layer on trigger efficiency.
  - TKR+CAL loss of a tower.



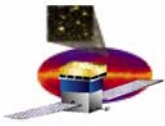


# ACD Tile Failures

Main issue here is the micrometeoroid shield reliability analysis. Can we tolerate loss of a single tile? **YES**

Damage	After L1T throttle	After filters [Hz]	After simple mitigation [Hz]
none	1.8 kHz	17	N/A
center top tile	1.9 kHz	27	19
corner top tile	1.9 kHz	24	17

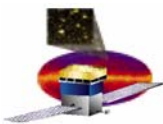
Simple mitigation when a top tile is whacked: require found track NOT to start in silicon layer directly underneath. Loss of effective area is small. For implementation on-board, look at just using TKR geographic trigger bit for affected towers instead of full track finding. **Additional cuts possible, if needed.**



# Work Underway, Next Steps

---

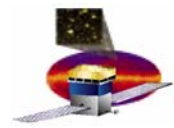
- **TKR reconstruction being improved significantly – the heart of our analysis – to improve efficiency, pattern recognition power, PSF 68% and 95% containment tails at all energies (mainly improve hit associations and recognition of conversion location).**
- **New tools becoming available. Example: RCParticle “propagator”(Atwood)—use, e.g., to remove residual upward-going proton albedo much more efficiently. Will also improve PSF.**
- **Provide integrated tools support to flight software group for filter design, and finish flight filter design. Wrap on-board software implementations into offline code to study performance.**
- **Simulate calibration tasks (ground and on-orbit)**
- **On-board science studies.**
- **Reparameterize detailed instrument performance functions to support high-level science studies.**



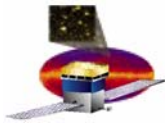
# Summary

---

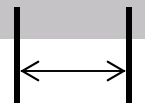
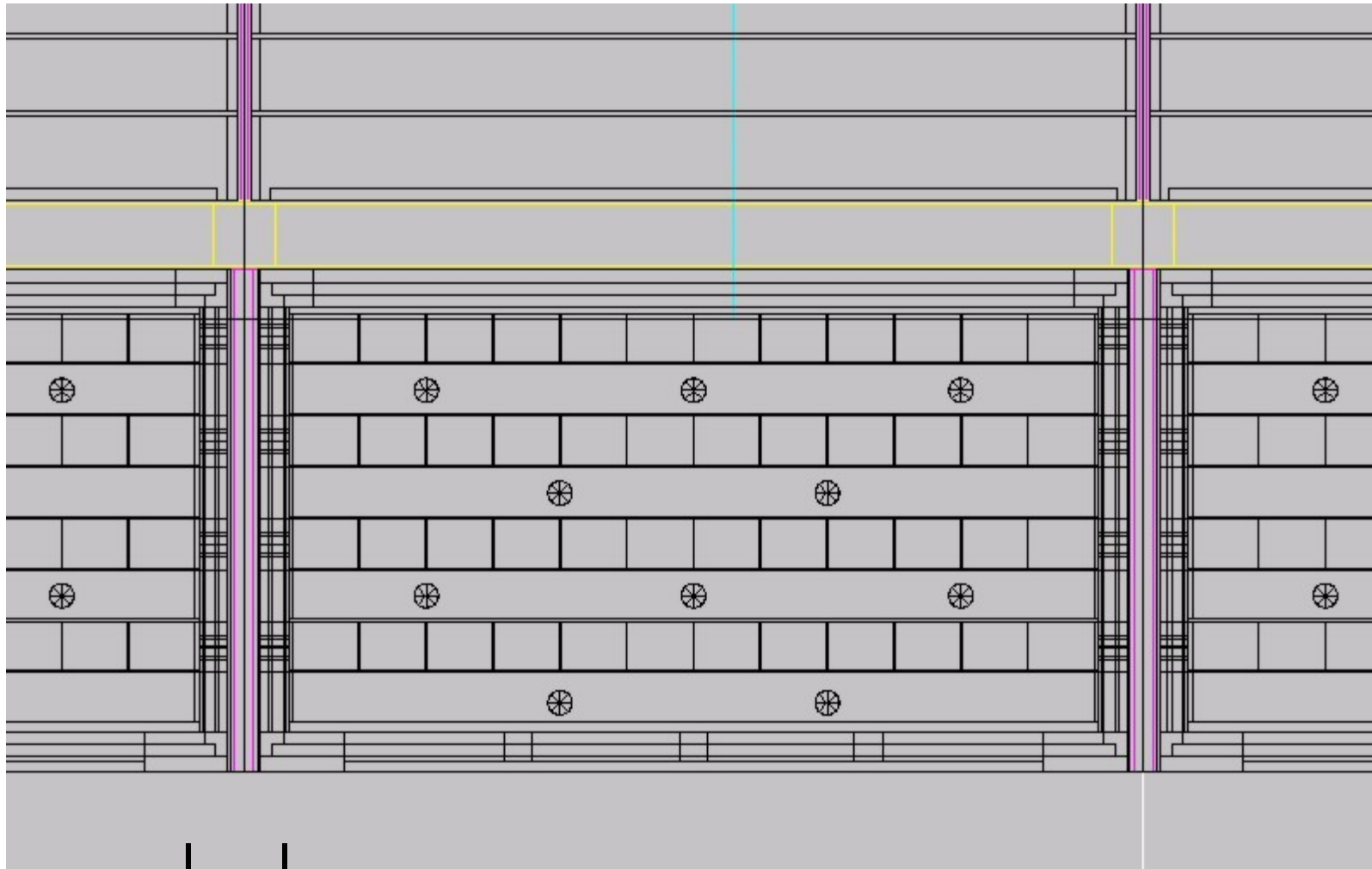
- **LAT will meet or exceed science requirements from the SRD.**
- **Additional important analysis tools coming on line now, and additional experimental information (e.g., TKR Time-over-threshold info) not yet exploited, will improve the performance values.**
- **In addition to design optimization and performance evaluation, detailed simulation is being used as a system engineering tool, e.g., supporting FMEA.**



# Appendix

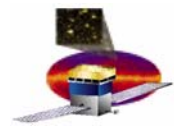


# CAL Geometry Update (II)

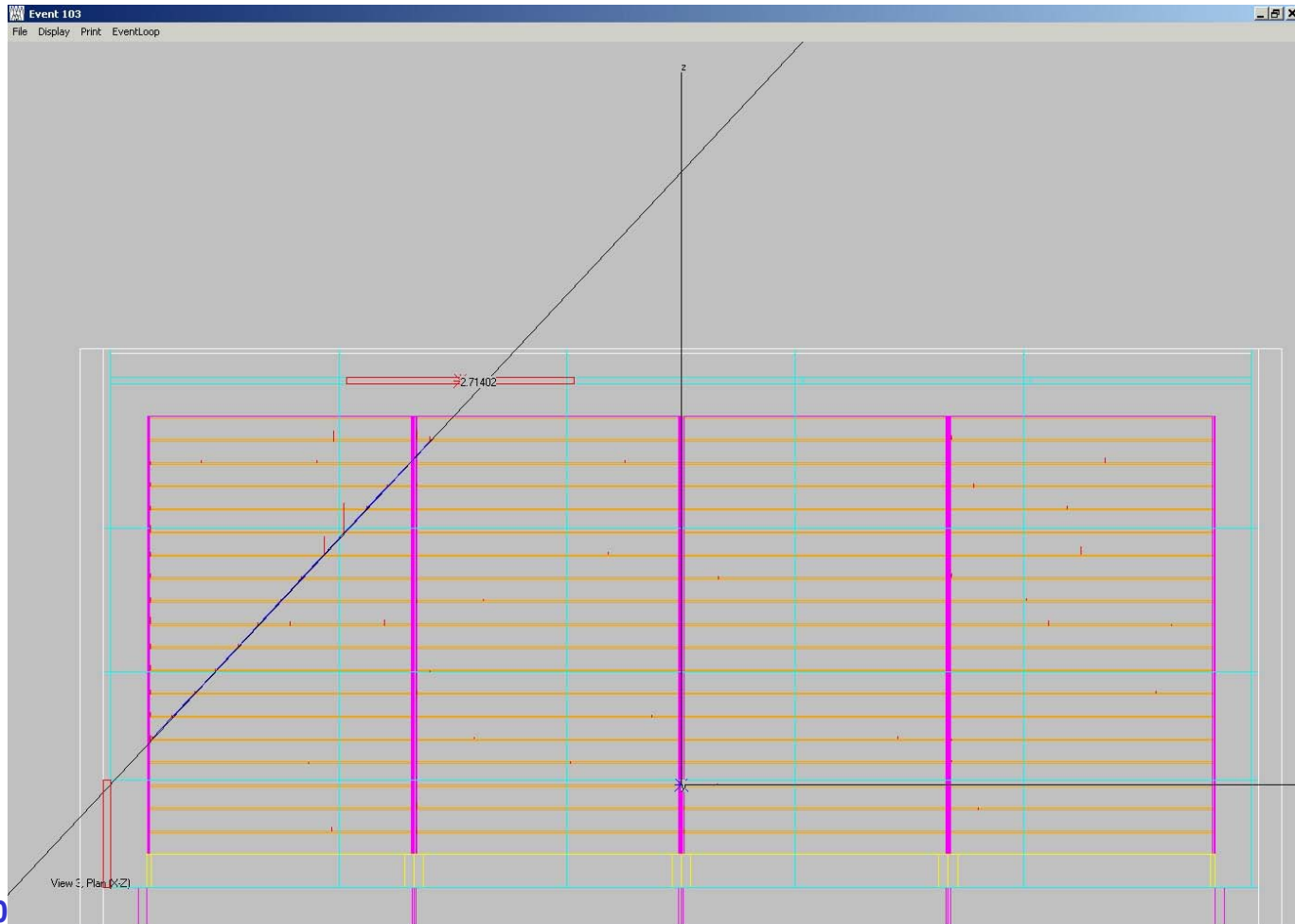


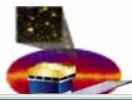
41.5 mm



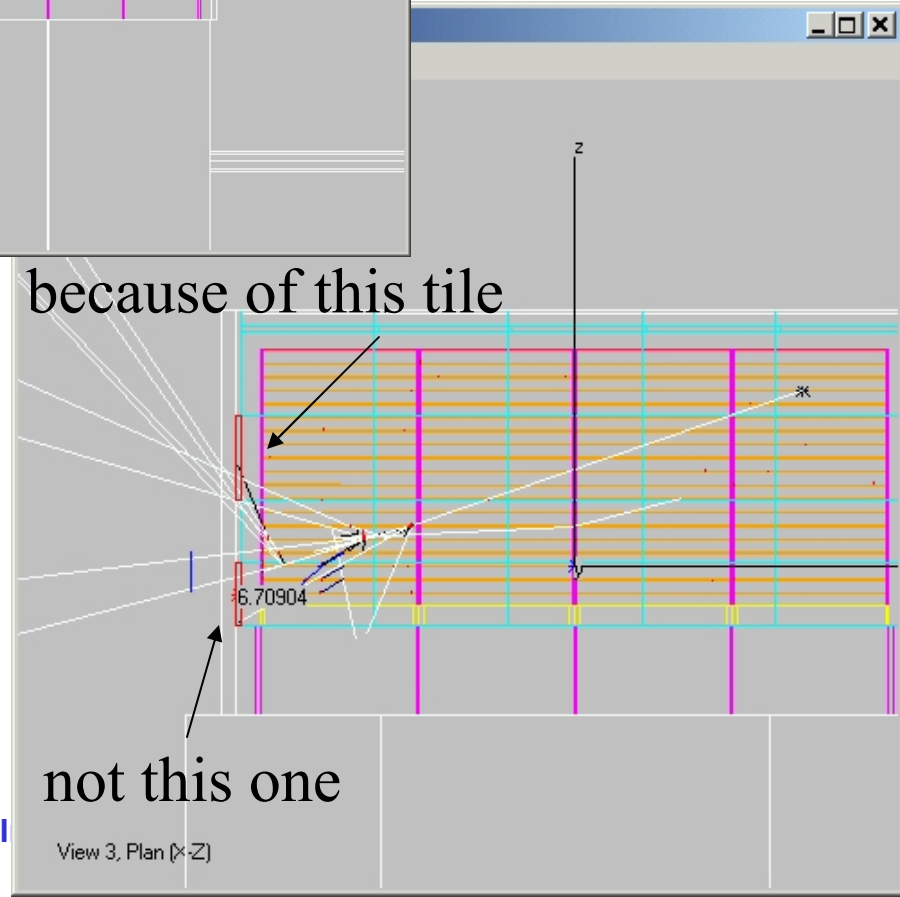
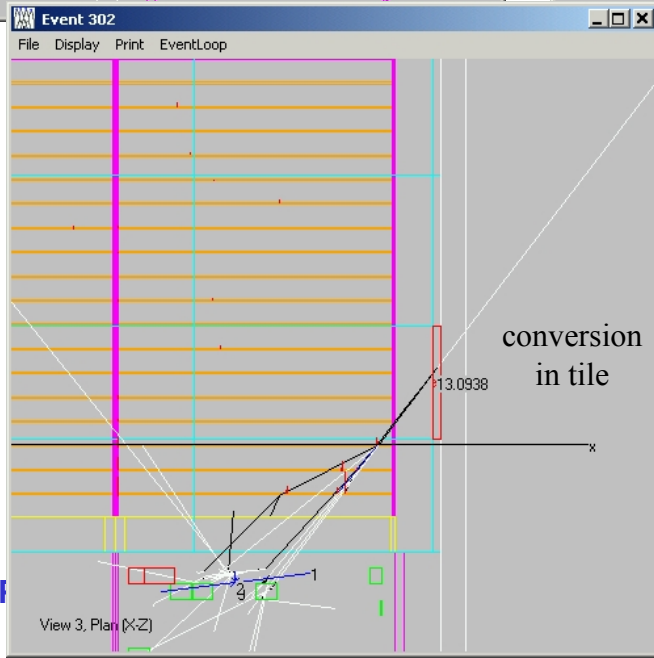
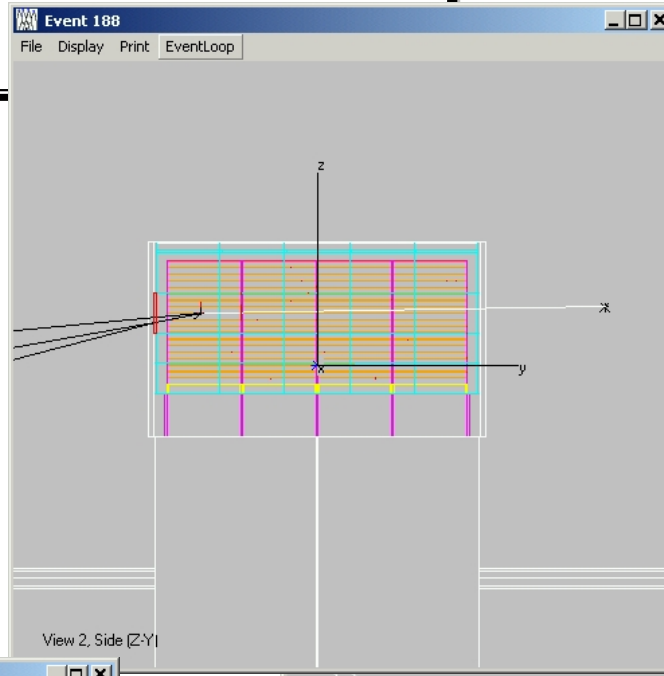
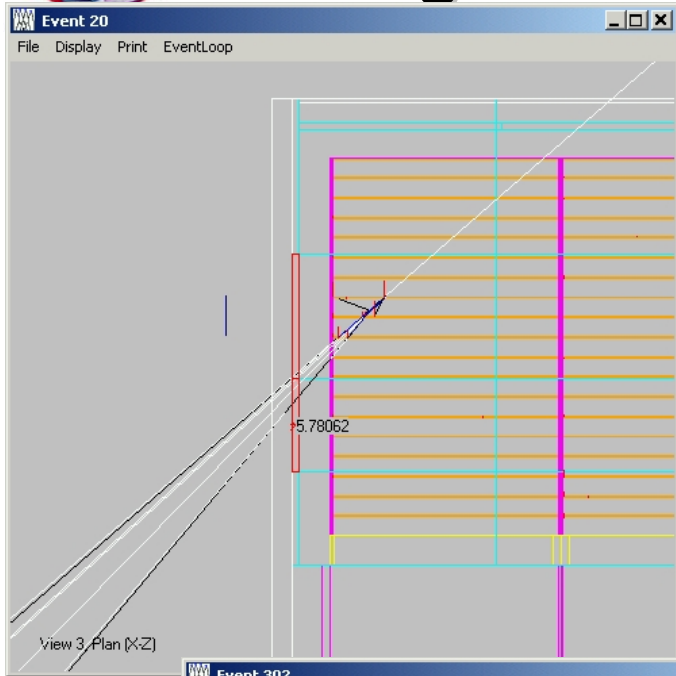


# What background sneaks through throttle?





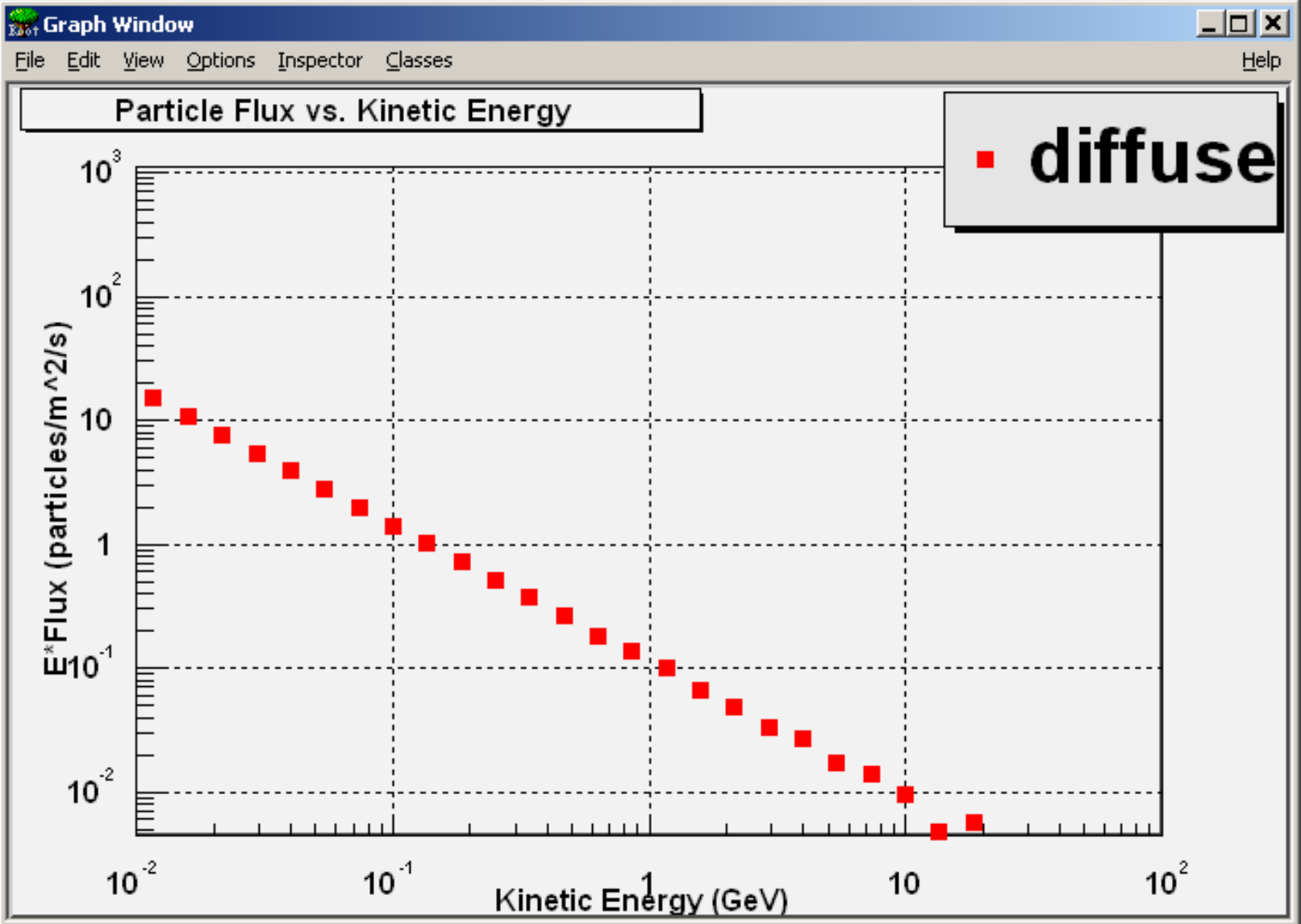
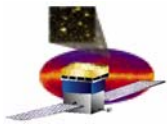
# What gamma events don't pass throttle?



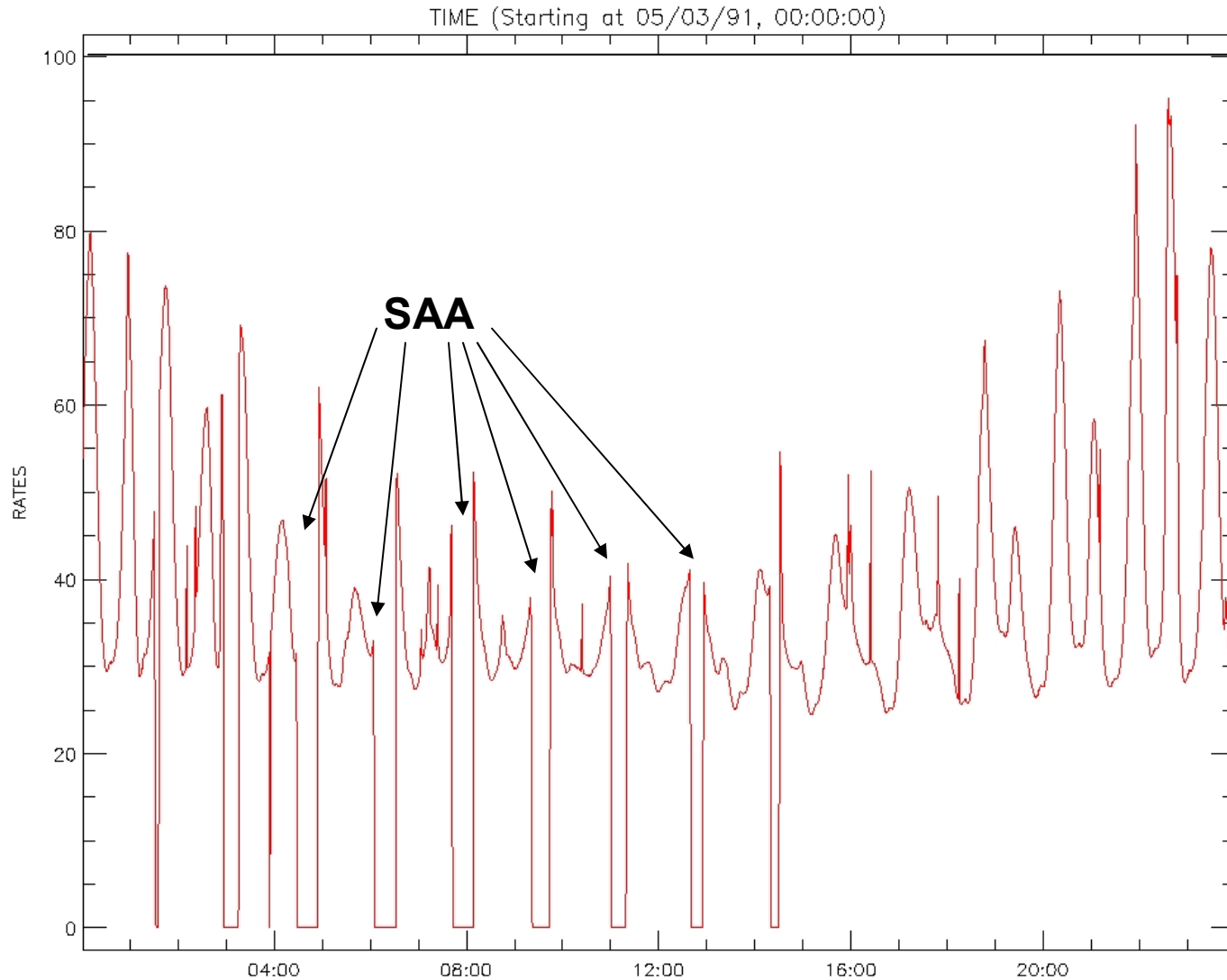
# L1 Rates by Trigger Type [orbit max]

Trigger	L1T rate[Hz]	w /Throttle[Hz]
TKR	11,221	3,642
CAL-LO	5,297	2,662
CAL-LO and NOT TKR	1,913	1,868
CAL-HI	84	84
CAL-HI and NOT TKR	10	10

- Throttle does not affect CAL-Hi rate (by design)
- Throttle has little effect on Cal-Lo only rate (by design)
- With throttle engaged, Cal-Lo gives a large fractional incremental rate. We will look at adjusting the threshold, and re-evaluate the use of Cal-Lo.
- Cal-Hi incremental L1T rate is tiny, but large for downlink. Allow onboard filters to have a simple look at Cal-Hi triggers to reduce (use measured energy deposition instead of Cal-Hi bit at software filter level – a finer knife). No special filters appear to be needed.



# EGRET A-dome Rates (from D. Bertsch, EGRET team)



A-dome has an area of  $\sim 6 \text{ m}^2$ , so orbit max rate (outside SAA and no solar flares) corresponds to  $\sim 16 \text{ kHz/m}^2$

This represents a conservative upper-limit for us, since the A-dome was sensitive down to 10's of keV.

Note peak rate is at (24.7,260)