Construction and Performance of the Si Tracker for the GLAST BeamTestEngineering Module

GLAST LAT
Construction
Beam Test Performance

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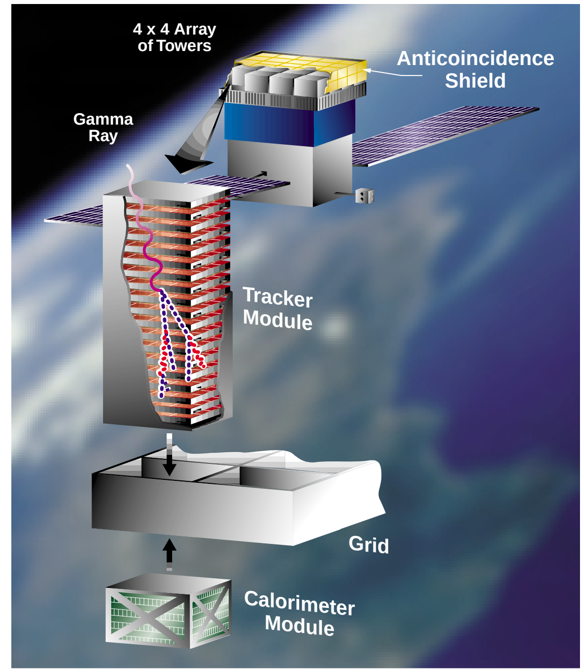
GLAST Gamma-Ray Large Area Space Telescope

An Astro-Particle Physics Partnership Exploring the High-Energy Universe



Design Optimized for Key Science Objectives

- Understand particle acceleration in AGN, Pulsars, & SNRs
- Resolve the γ-ray sky: unidentified sources & diffuse emission
- Determine the high-energy behavior of GRBs & Transients

Proven technologies and 7 years of design, development and demonstration efforts

- Precision Si-strip Tracker (TKR)
- Hodoscopic CsI Calorimeter (CAL)
- Segmented Anticoincidence Detector (ACD)
- Advantages of modular design
- NASA, DoE, DoD, INFN/ASI, Japan, CEA, IN2P3, Sweden

Challenges of Science in Space

- Launch
- Limited Resources
- Space Environment

GLAST Detector Concept: Pair Conversion Telescope

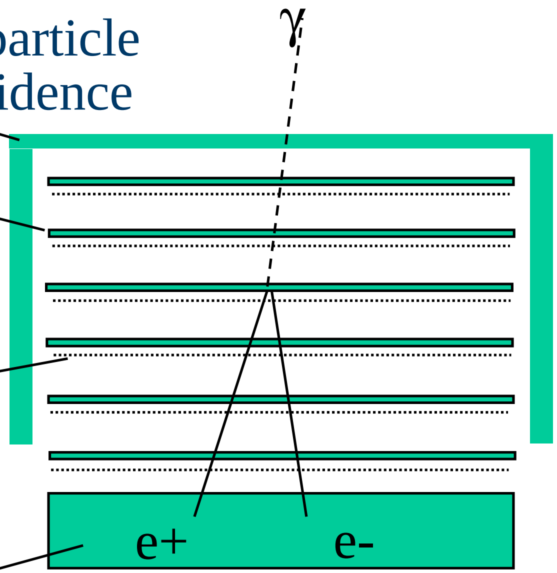
Gamma-rays convert into e^+e^- pairs,
are tracked and their energy measured
Gamma is reconstructed from e^+e^- tracks

charged particle anticoincidence shield

conversion foils

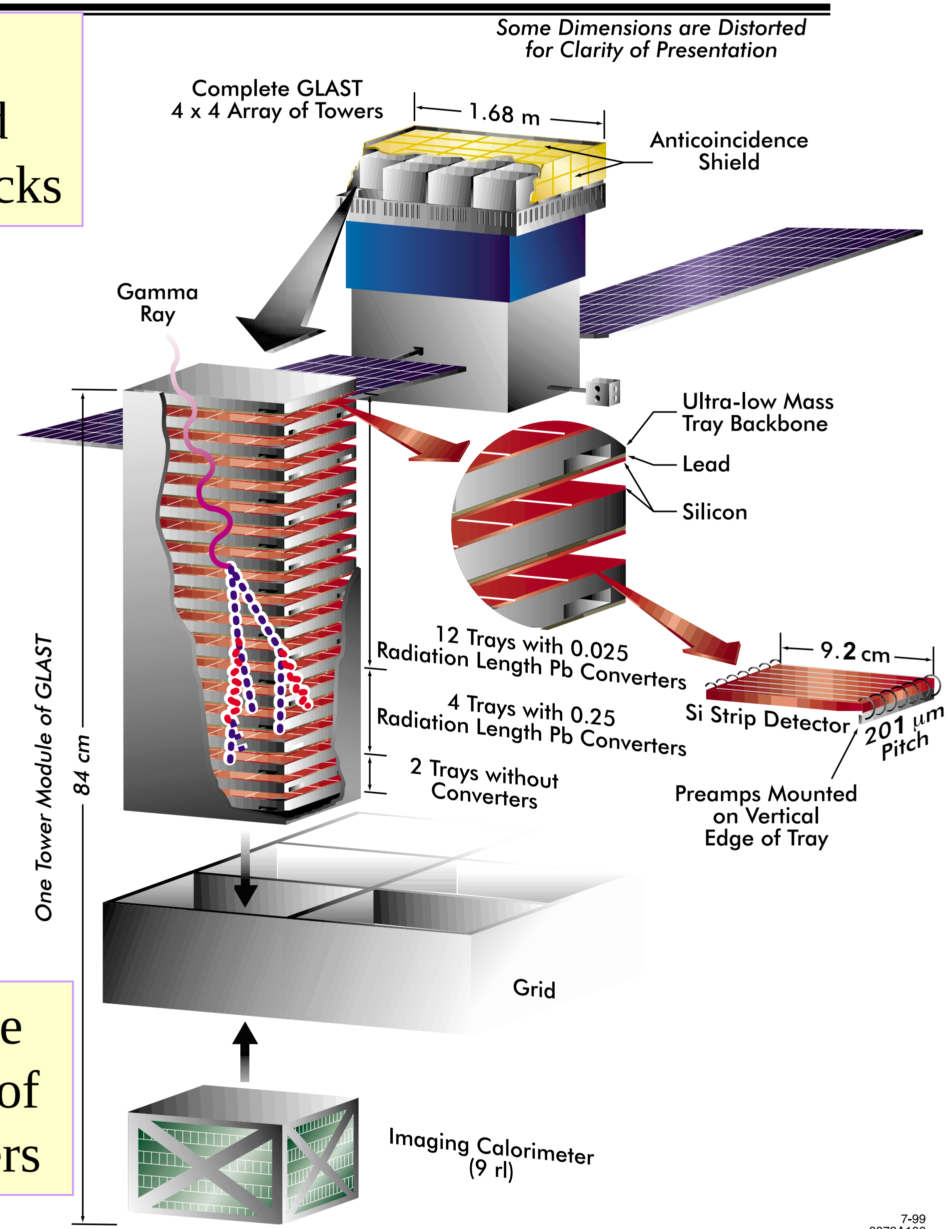
particle tracking detectors

calorimeter (energy measurement)



Converter Thickness t
Conversion Probability ~ t
Pointing RMS ~ √t

Maximize Number of Converters



Overview of TKR Baseline Design

- 16 towers, each with 37 cm × 37 cm of Si ($78m^2$ in all)
- 18 *x,y* planes per tower
  - 19 "tray" structures
    - 12 with 2.5% Pb on bottom
    - 4 with 25% Pb on bottom
    - 2 with no converter
  - Every other tray rotated by 90°, so each Pb foil is followed immediately by an *x,y* plane
    - 2mm gap between *x* and *y*

- Electronics on the sides of trays
  - Minimize gap between towers
  - 9 readout modules on each of 4 sides

- Trays stack and align at their corners
- The bottom tray has a flange to mount on the grid
- Carbon-fiber walls provide stiffness and the thermal pathway to the grid

One Tracker Tower Module

Tracker of the Beam Test Engineering Module

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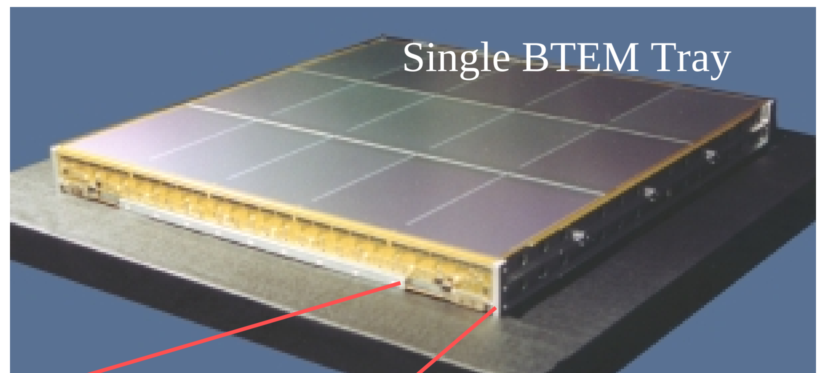
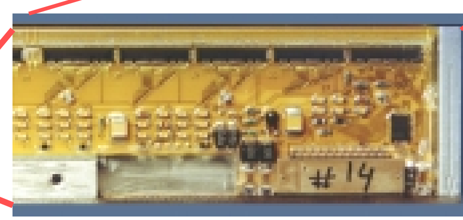
The BTEM Tracker, (~1/16 of the flight instrument) for the SLAC test beam (11/99 – 1/00)

- 2.7m^2 silicon, ~500 detectors, 42k channels
- all detectors are in 32 cm long ladders.





End of one readout hybrid.

Si Detectors used:

HPK 296 (4”), 251 (6”)

Micron 5 (6”)

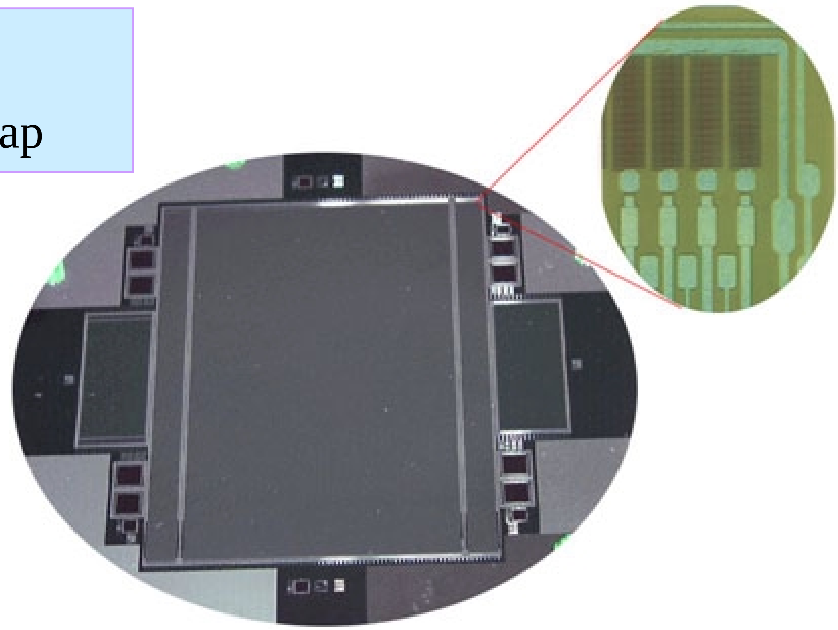
Leakage I: 300 nA/detector (HPK)

Bad strips: about 1 in 5000

Silicon-Strip Detectors (SSD)

GLAST SSD:
Simple, reliable, cheap

- 400 μm thick, single sided
- 8.95 cm × 8.95 cm (6” wafers)
- Strip pitch: 228 μm
- AC coupled with polysilicon bias (~50MΩ)
- Prototypes from HPK, Micron, STM

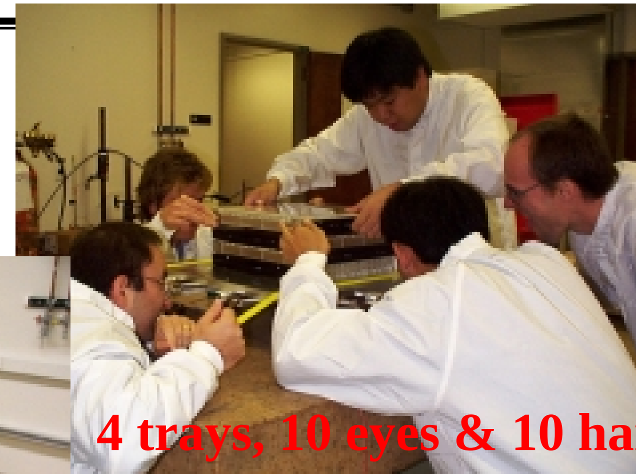


Schematic layout of the detector.
- *Square detectors*
- *Bypass strips will not be used.*
- *DC pads will increase in size.*
- *A second AC pad will be added on each strip, for probing and for a second chance at wire bonding.*

GLAST Needs:

- ~10k detectors from 6” wafers
- ~ 1M readout channels
- > 5M bonds

Assembly of BTEM Tracker at SCIPP



Assembly Challenge: QA, Yield, Alignment

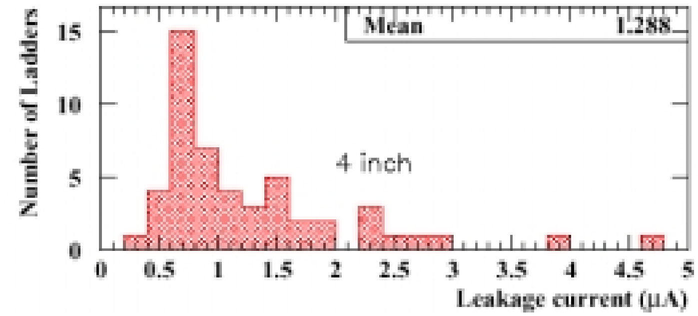
Bad Channels Fraction: 0.06%

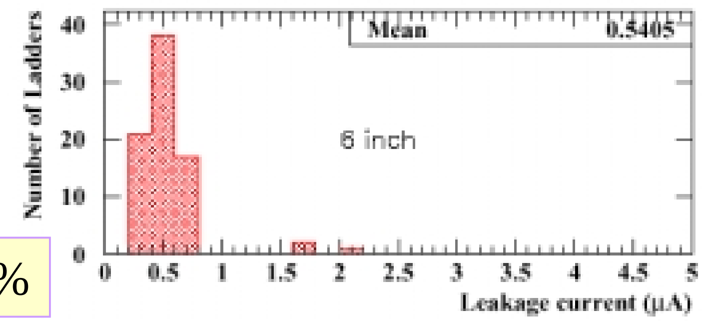
Number of defective strips			
Al open	Al short	Coupling short	Total
2	2	2	6
	11	8	19
2	13	10	25

Start with good SSD's
QC during Assembly

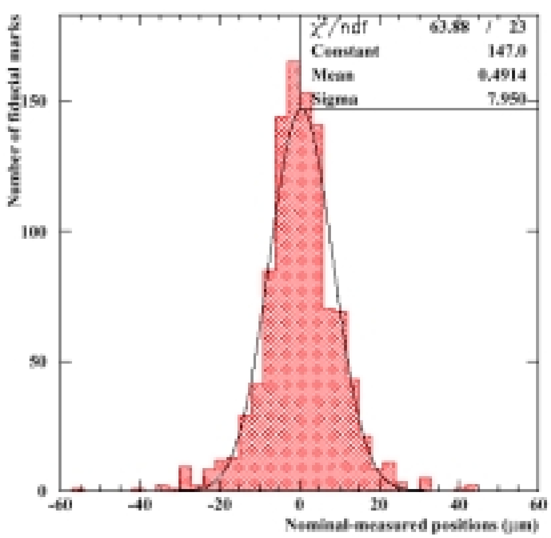
End up with good ladders

Leakage current
on 32cm long ladders after assembly





Simple Mechanical Alignment:
RMS: 8um

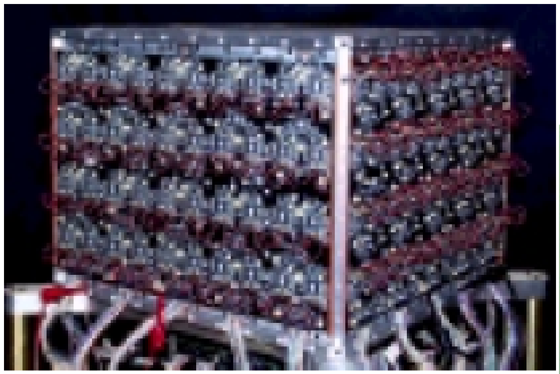


Assembly Yield: 98%

Description	4 inch		6 inch		Total	
	Number	%	Number	%	Number	%
Good quality detectors	289	97.7	251	98.8	540	98.1
Runaway or unstable leakage current	1	0.3	0	0	1	0.2
Unstable current after ladder assembly	5	1.7	3	1.2	8	1.5
Losses due to accident	1	0.3	0	0	1	0.2
Total	296	100.0	254	100.0	550	100.0

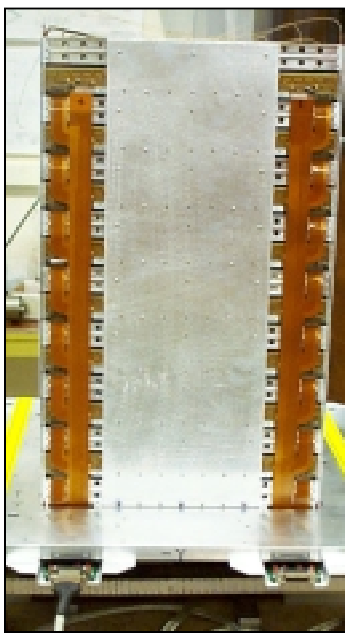
Installation of the BTEM at SLAC

Beam Test in SLAC's Endstation A (Dec 1999/Jan 2000)

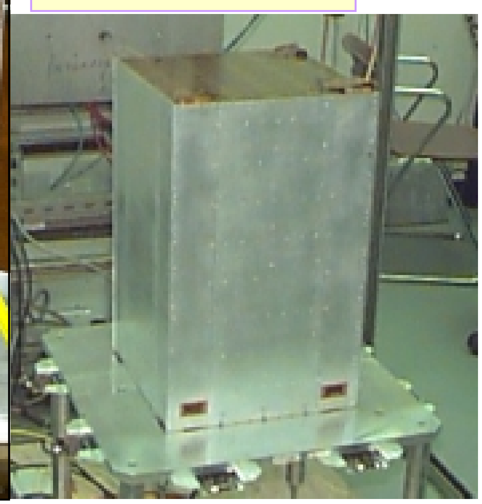


CsI Calorimeter

- Test Fabrication Methods
- Verify Performance
  - Resolutions
  - Trigger
  - MC Programs

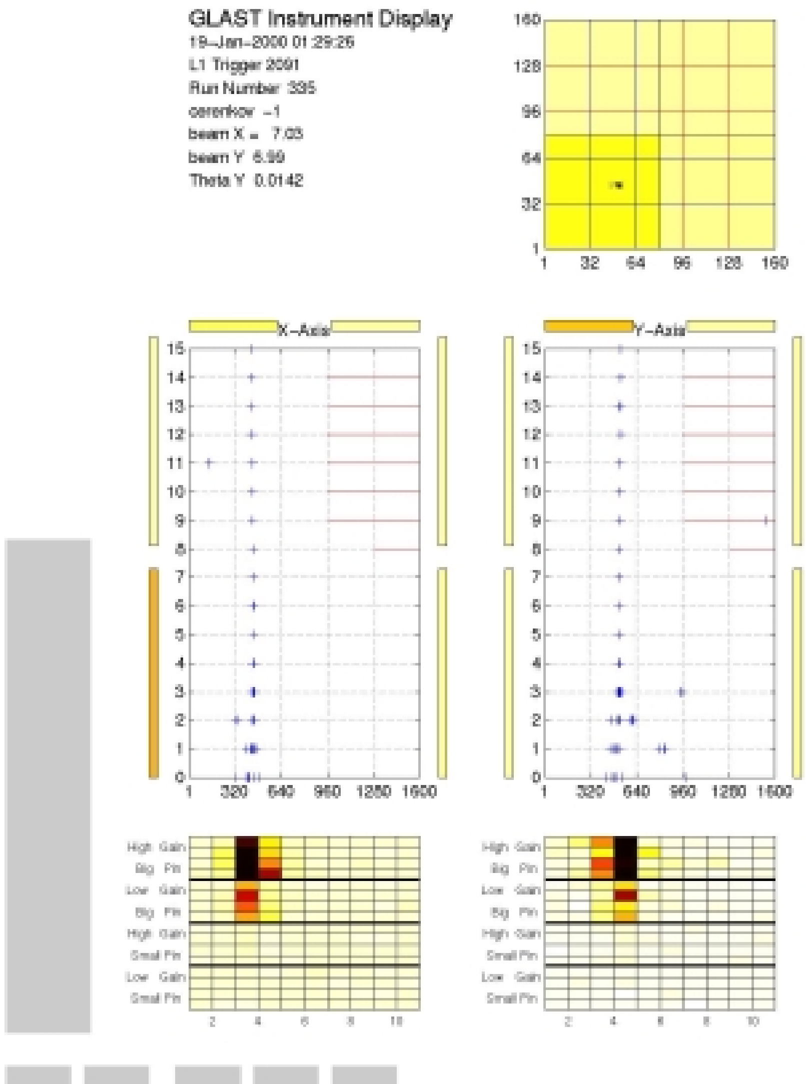


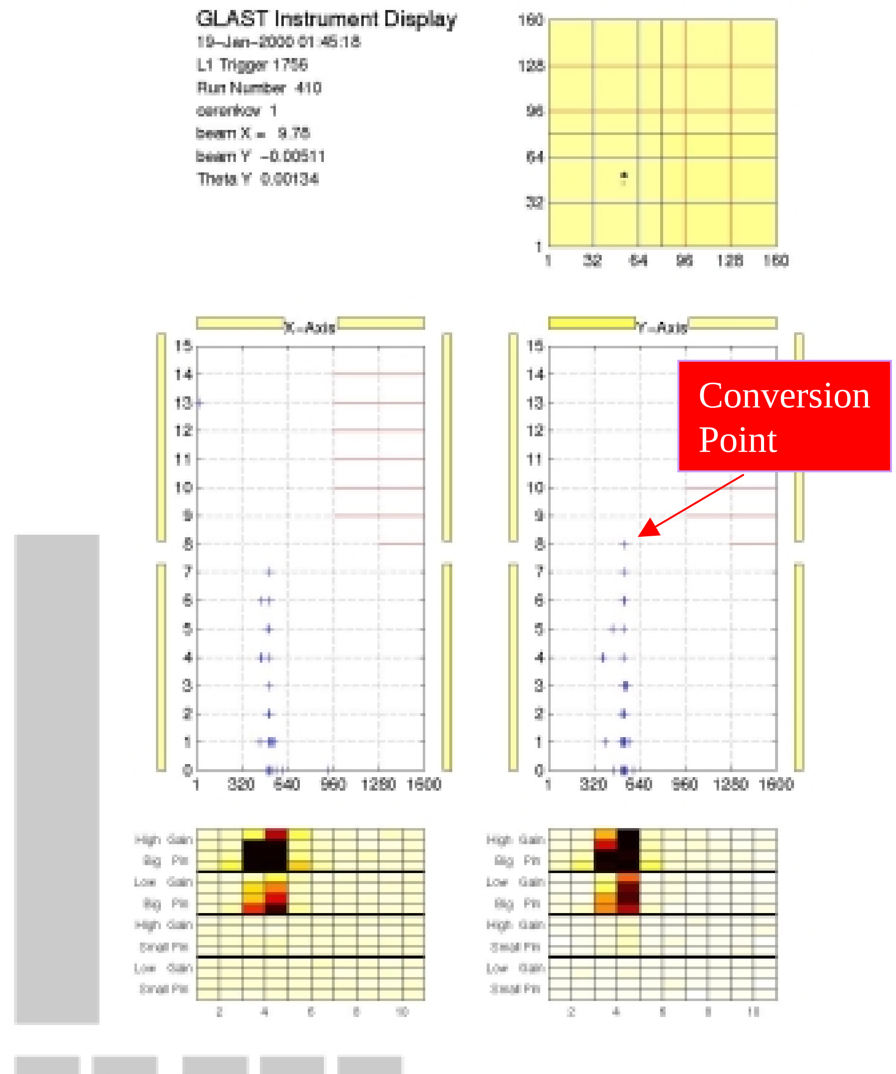
Silicon Tracker



Beam Test at SLAC 1999/2000: e^+ and γ in BTEM

High efficiency (99.9%), low noise occupancy ($\approx 10^{-5}$)





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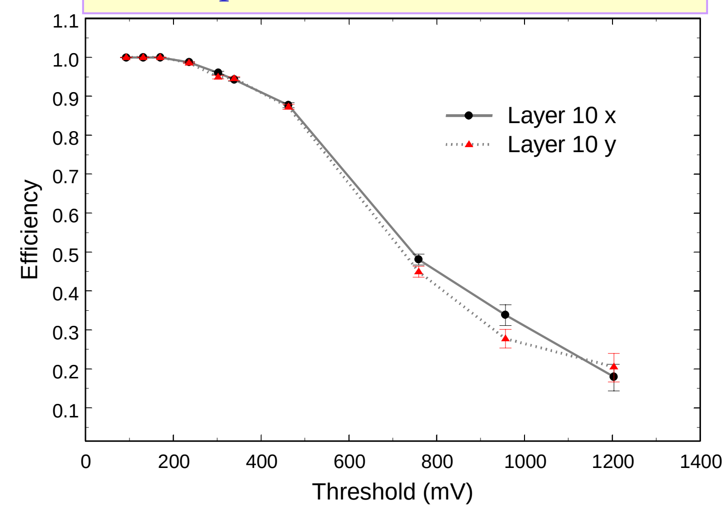
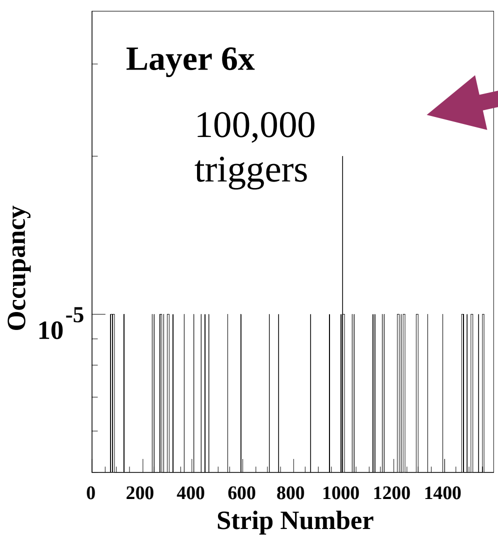
Challenge: Tracker Noise and Efficiency

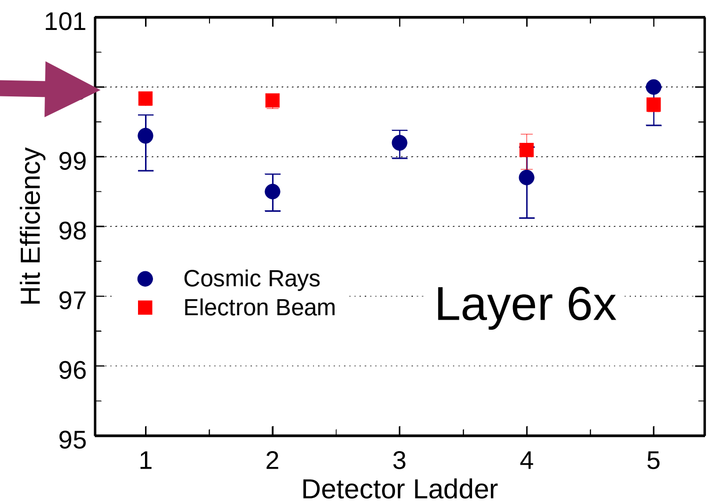
- Noise occupancy determines the noise rate of the LVL1 trigger, a coincidence of 6 OR'd layers.
- Noise RMS $\sigma = 130 + 21*C/pF\ [e^-]$, $\tau = 1.3\mu s$
- Hit efficiency was measured using single electron tracks and cosmic muons.
- The requirements were met: 99% efficiency with $<<10^{-4}$ noise occupancy.

Hit efficiency versus threshold for 5 GeV positrons.





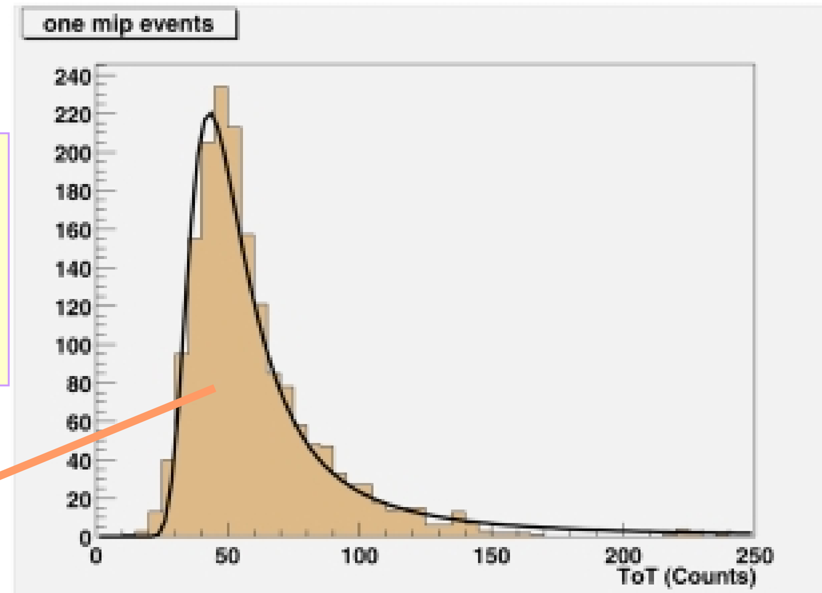
Noise occupancy and hit efficiency for Layer 6x, using in both cases a threshold of 170 mV. No channels were masked.

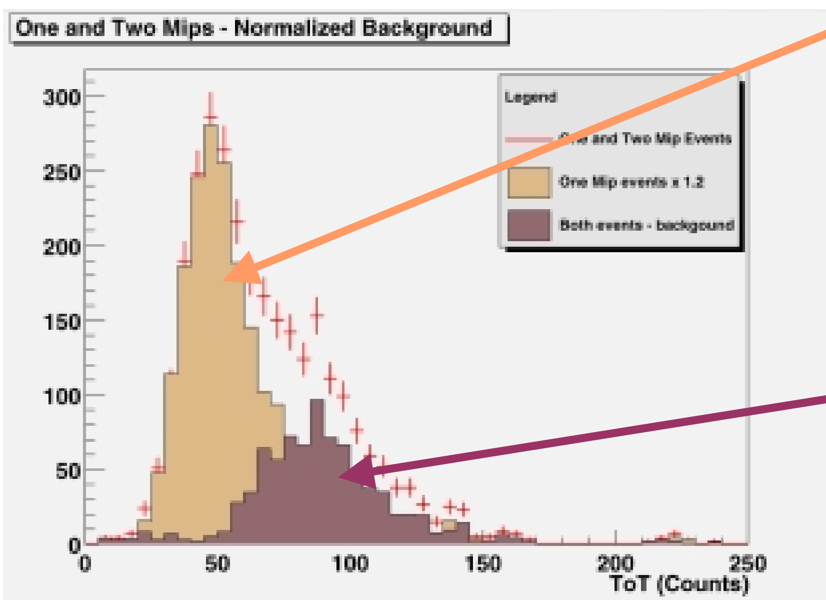


Determine Conversion Point

Time-over-Threshold ToT
is a Measure of the Pulse Height

ToT of Tracks away from the Conversion Point:
Single MIP's
Follow a Landau curve





ToT at the Conversion Layer:
2 tracks in one strip:
2MIP Signal

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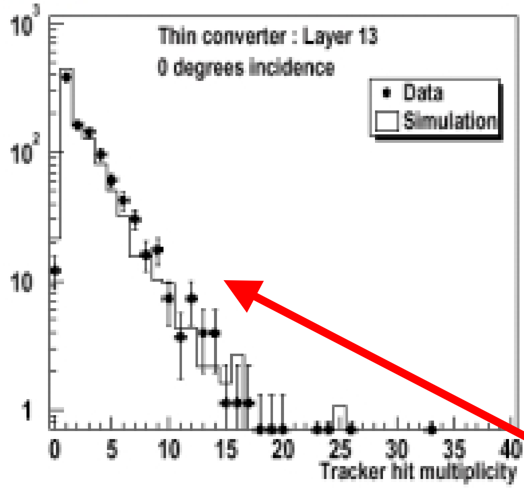
Follow Tracks after Conversion

After Gamma Conversion,
Electron-Positron Pair develop Showers

L13



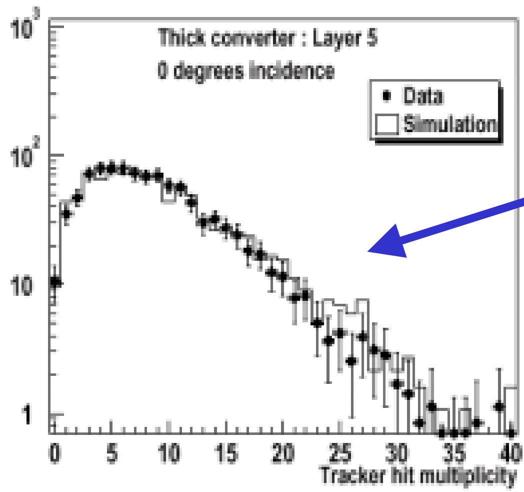
Distribution of # of hits along the track of a 5GeV positron agrees well with prediction at the

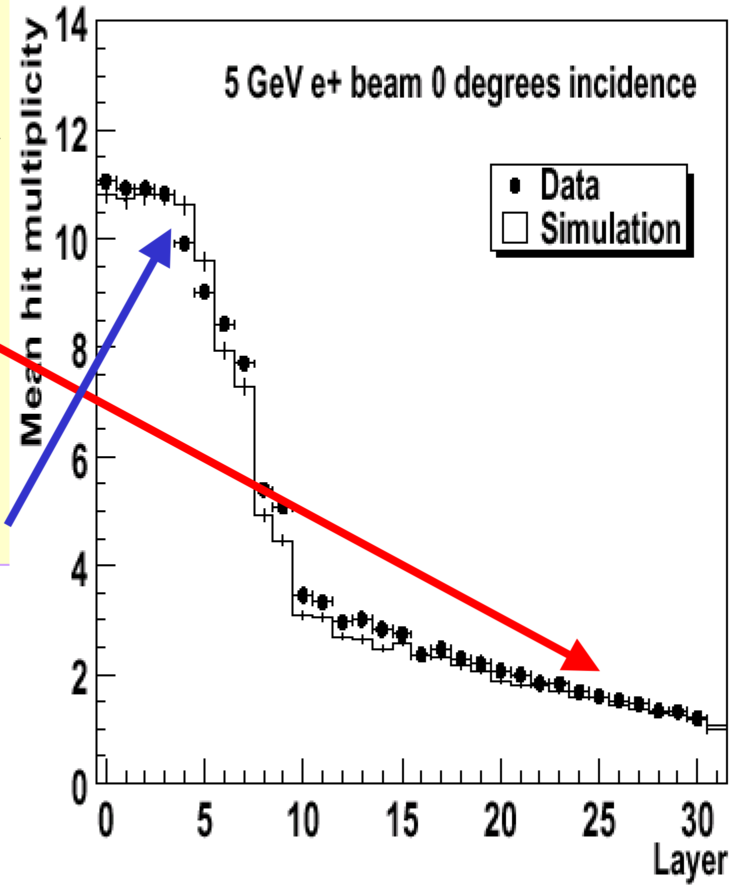
Start of the track

and

End of the track

L5

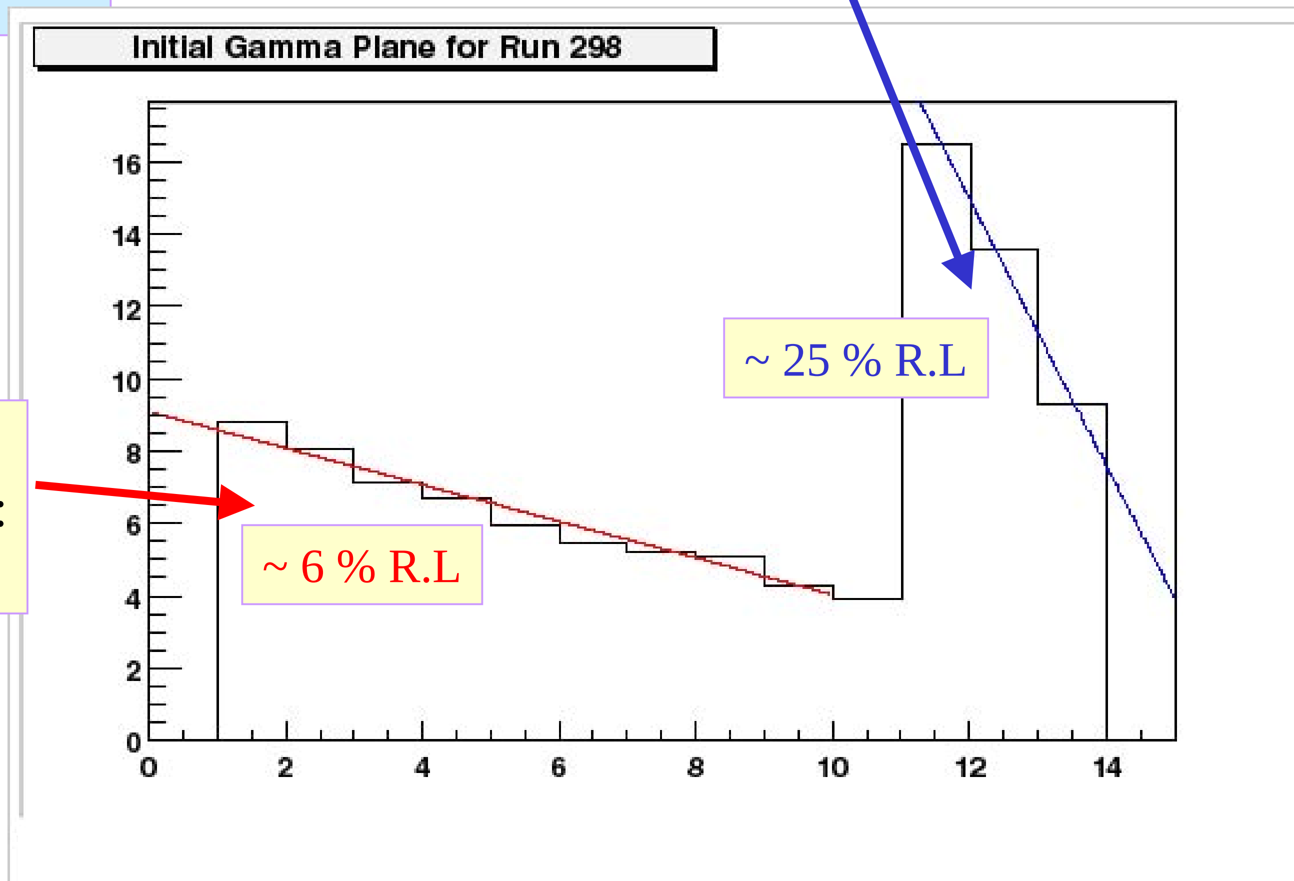




Effective Area

Effective Area:
Vertex Distribution reflects the Converter Distribution shows expected Attenuation of the γ Beam

Back Section:
3 layers of thick Efficient Conversion before calorimeter



Front Section:
10 layers of thin converters:
Precision Tracking

GLAST Schedule

After successful Beam Test and Verification of Prediction:

- Finalize the design
- Build Engineering Model
- Start Construction