A Parametric Energy Recon for GLAST

A 3rd attempt at Energy Reconstruction

Keep in mind:
1) The large phase-space of GLAST –
   20 MeV – 300 GeV, FoV ~ 2.5 str, etc.

2) The multiple detector features
   - Tracker Thin & Thick layers
   - Large gaps between Cal Modules
   - Lack of depth (8.5 r.l. Cal at normal inc.)
MC Sources

To help separate out various effects and run MC efficiently a new type of source was made: All trajectories pass through a designated piece of the detector.

$\Delta \Omega$: $\cos(\theta) < -0.2$

(CalX0, CalY0) is the reconstructed entry point on the top Cal Face.
Shower Model

Wallet Card: \[ \frac{dE}{dt} = E_0 b \frac{(bt)^{a-1} e^{-bt}}{\Gamma(a)} \] where \( t \) is the depth in rad. lens.

\( a \) and \( b \) are parameters:
- \( b \) scales the radiation length
- \( a \) set the location of the energy centroid: \( \langle t \rangle = \frac{a}{b} \)

Data: Verticle at the \((\text{CalX0}, \text{CalY0}) = (180, 180)\)

Variation in depth due to Track conversion point adding .1 \( \rightarrow \) 1.5 rad. lens.

Monte Carlo Shower Profiles

Data: Verticle at the \((\text{CalX0}, \text{CalY0}) = (180, 180)\)

Variation in depth due to Track conversion point adding .1 \( \rightarrow \) 1.5 rad. lens.

\( b \) Parameter Fits

Linear: \( b = .44 + .03 \log_{10}(E/1000) \)

Quad: \( b = .453 - .024 \log_{10}(E/1000) + .026 \log_{10}(E/1000)^2 \)
Shower Model

The Shower Profile from 100 MeV -> 100 GeV

The Leakage Fraction

Bill Atwood, SCIPP/UCSC, May, 2005
Xtal Shower Profiles – Conversion in Thin Tracker

A Full CAL Module - 1 GeV Verticle Gammas in the center of the CAL
Fits to Transverse Profiles – Thin Conversions

Note growth as depth increases
Xtal Shower Profiles – Conversion in Thick Tracker

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Fits to Transverse Profiles – Thick Conversions

These are narrower...
**Correction Algorithms**

**Losses due to Gaps and Transverse Shower Spread**

Estimate the fraction of the shower in a Gap at each layer

**Simple Case**

CAL Module

Projected Shower Profile

The fraction outside is

\[ f(\text{outside}) = \frac{1}{2} - \frac{y}{r} \sqrt{1 - \left(\frac{y}{r}\right)^2} - \sin^{-1}\left(\frac{y}{r}\right) \]

**Real Case**

Projected Shower Profile

**Ellipse: Simpson Integration of Simple Case**

**X-Y Edges: Treat separately – Subtract overlap**

**Energy dependence on Radius: Below 1 GeV – broaden by ~ 2 by 100 MeV**

**Transverse Energy Density: 2 samples – .8*R_m and 1.8*R_m**

\( (R_m \text{ is the Moliere Radius } \sim 50 \text{ mm}) \)

**Dip Angle Dependence: Close-up gaps as cos(\theta)**
Correction Algorithms

Edge Loss Correction
at 100 MeV

Edge Loss Correction
at 10 GeV

Becomes more abrupt
Correction Algorithms

Losses due to Shower Leakage

The set of $E_{obs}$ (observed energy), $<t>$ (Cal energy centroid in rad. len.), and $t_{TOTAL}$ (Cal + Tracker rad. len.) form a consistent set to predict $E_0$ (the incoming energy) using the Gamma Function Shower Model:

$$E_{obs} = \int_0^{t_{TOTAL}} E_0 b(bt)^{a-1} e^{bt} dt \quad \text{and} \quad a = b\langle t \rangle$$

This can be inverted via iterating:

$$E_0 = E_{obs}$$

$$a = b(E_0) \cdot \langle t \rangle$$

$$E_0 = E_{obs} \frac{1}{t_{TOTAL}} \int_0^{t_{TOTAL}} b(bt)^{a-1} e^{-bt} dt$$

For convergence to $< 1\%$ requires a few iterations at $1$ GeV and $\sim 10$ iterations at $100$ GeV
Correction Algorithms

Examples of Contained Fractions at 10 GeV

As $\theta$ increases so does $t_{TOTAL}$ and leakage goes down (contained fraction increases)

For tracks near vertical ($\cos(\theta) < -0.9$) as track gets near the gap, $t_{TOTAL}$ goes down and the leakage goes up (contained fraction decreases)

Critical to have a good estimate of $t_{TOTAL}$ and $<t>$

Achieved by Simpson Integration/Sampling of Calorimeter

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Tracker Energy

Tracker treated as a Sampling Calorimeter:

- every $\Delta \chi$ count the number of tracks

Complications:

1) Large gaps between samples
   *This leads to large losses "out the sides"
2) Super Layers are $\sim 4.3$ time thicker in rad. lens.
   *This leads to balancing the two sections

Process: Estimate energy in Tracker from that observed in Cal.

Ratio of slopes is constance $\sim 4.3$

Fix the ratio:
Thick/Thin = 4.3
Tracker Energy

Next – set overall size to flatten energy vs layer number:

Problem: Increasing Tracker contribution flattens response, BUT it creates a "pedestal" of \( \sim 4\%-5\% \)

CalEneSumCorr vs TkrEnergyCorr

\[
\begin{align*}
\text{norm} &= .68 \\
\text{norm} &= .80
\end{align*}
\]
Glast Energy

Survey of Correction from 100 MeV → 100 GeV

100 MeV

Full

Cos(θ) Dependence
CalX0 > 50

CalX0 Dependence
Cos(θ) < -0.80

Thick Layers
Cos(θ) < -0.9
CalX0 > 70

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Glast Energy

1 GeV

Full

All Layers

$\cos(\theta) < -0.8$

$\text{CalX0} > 50$

$\cos(q) < -0.80$

$\text{CalX0 Dependence}$

$\text{CalX0} > 50$

$\text{Cos(\theta) Dependence}$
Glast Energy

10 GeV

Full

All Layers

\[ \cos(\theta) < -0.8 \]

CalX0 > 50

\[ \cos(q) < -0.80 \]

CalX0 Dependence

CalX0 > 50

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Glast Energy

100 GeV

Full

CalX0 > 50

Cos(θ) Dependence

CalX0 > 50

Cos(q) < -.8

CalX0 Dependence