GLAST Large Area Telescope

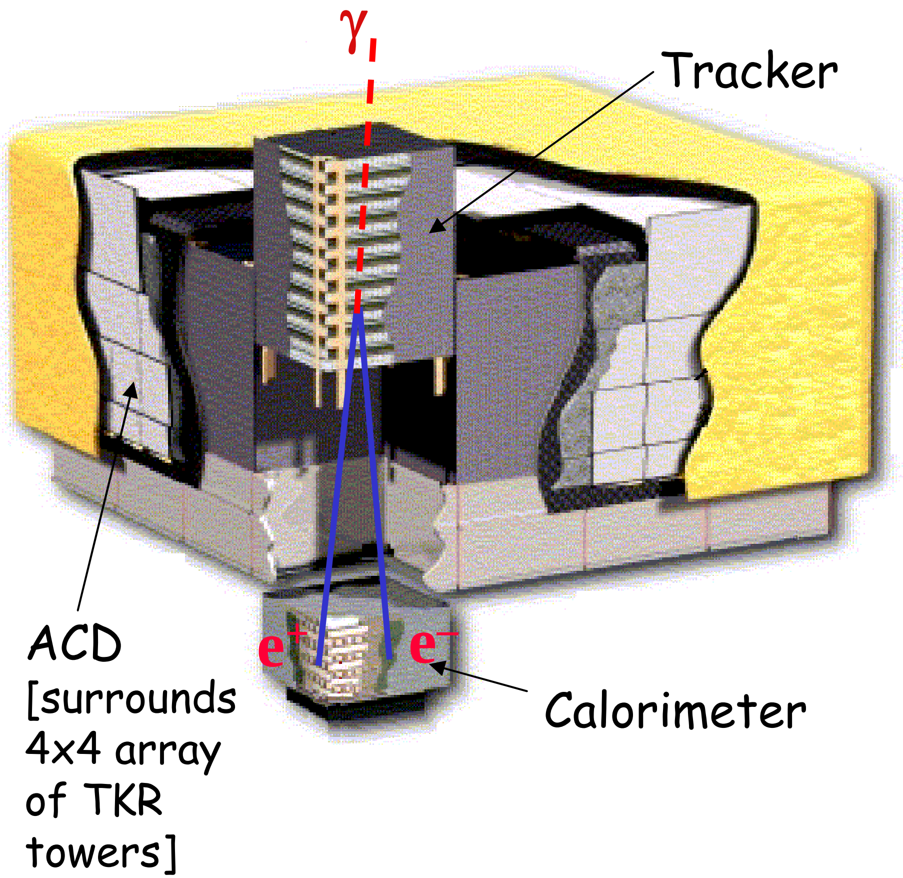
LAT Science Working Group Review
February 2, 2007

Analysis Overview

Leon Rochester, SLAC

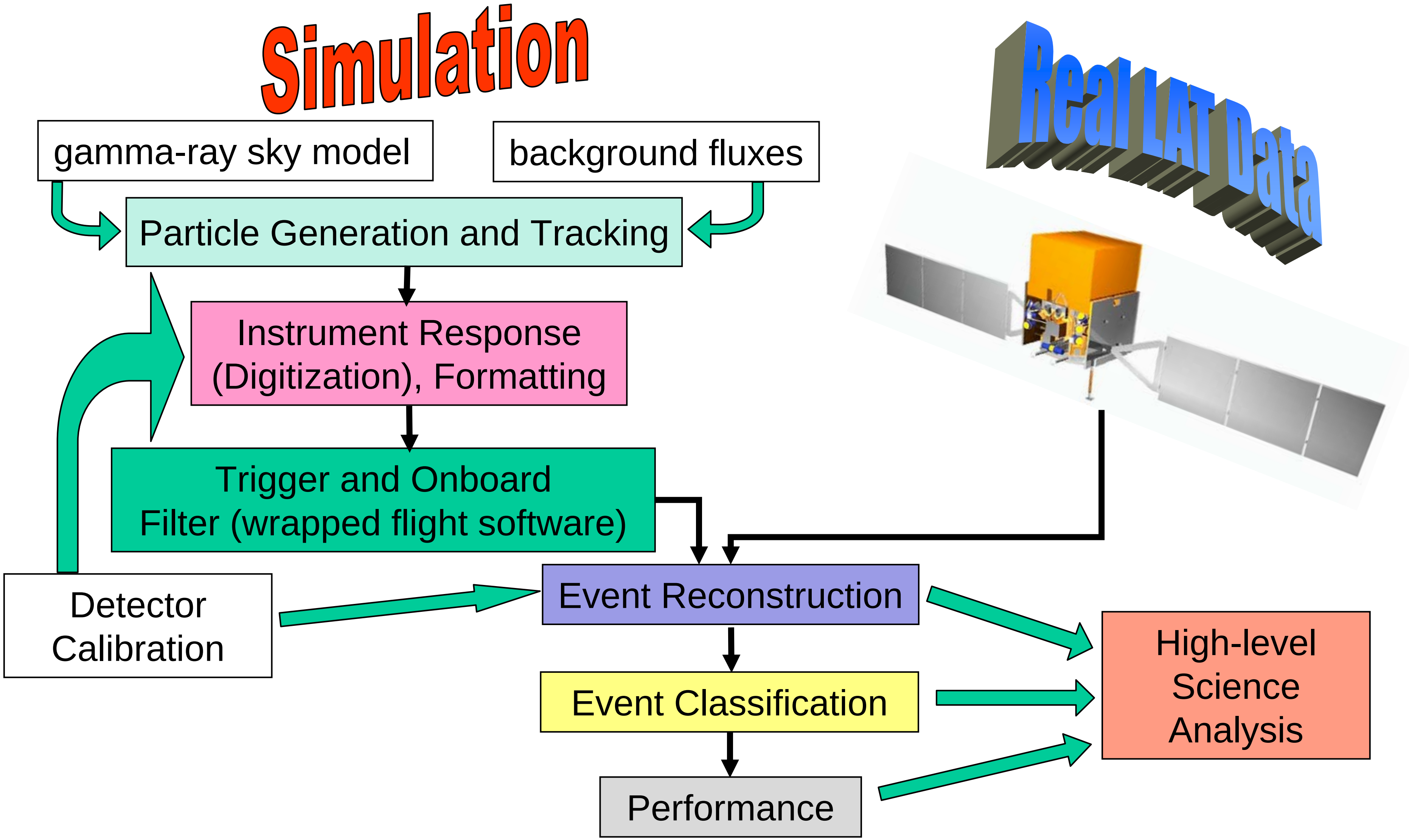
Components of the LAT

- **Precision Si-strip Tracker (TKR)** 18 XY tracking layers 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; images 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.

Components of the Analysis



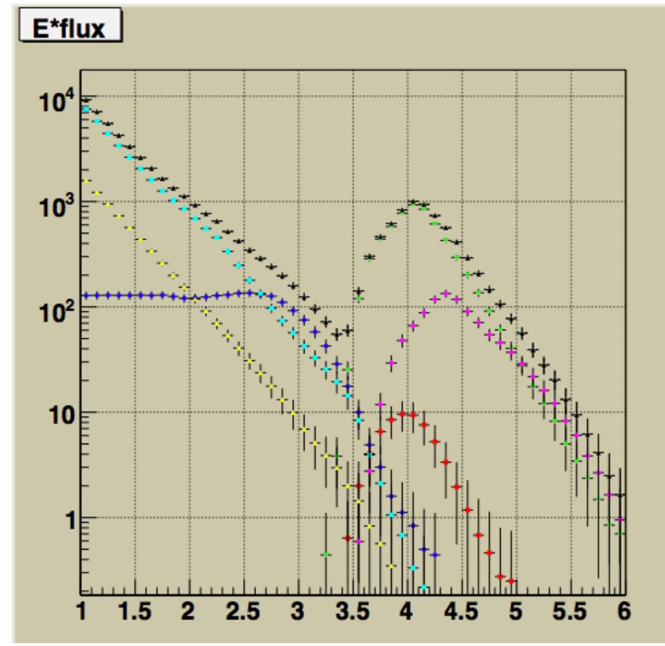
Evolution of the Background Flux Calculation

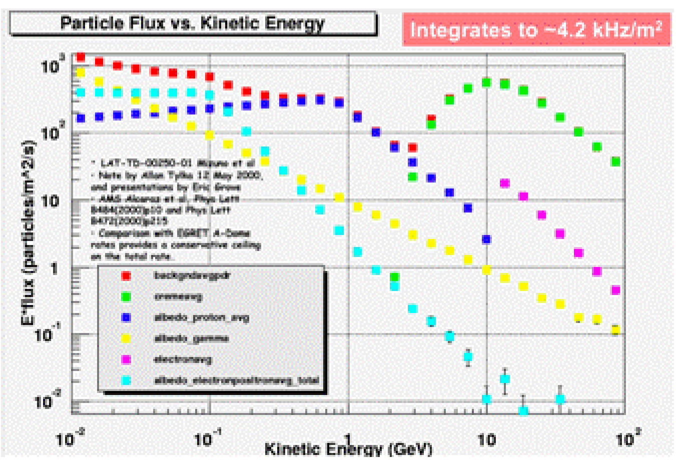
Background Flux Review

J. Ormes et al., LAT-TD-08316-01

- Albedo e+e- flux a factor >3 larger than for PDR.
- Primary cosmic proton flux is higher
- New Albedo γ flux

DC2 (2006)





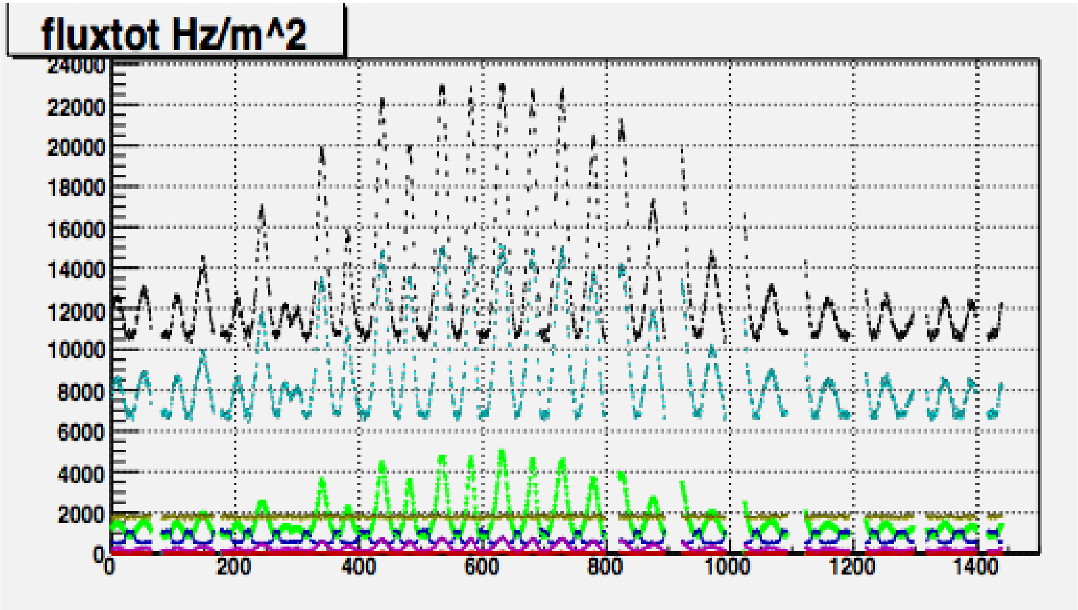
CDR & PDR (2000)

Updated integrated flux 13000 Hz/m2

PDR flux ~4200 Hz/m2

Some Highlights of the Updated Fluxes

Variations over one day:



total (black)
galactic CR protons (green)
He+CNO (purple)
galactic CR e+e- (red)
albedo (reentrant+splashback) p+pbar (dark blue)
albedo (reentrant+splashback) e+e- (light blue)
albedo gamma (yellow)

Update of Albedo γ spectrum

Petry, D., 2005, AIP Conf. Proc. **745**, 709-714, astro-ph/0410487

Plus: simulation of South Atlantic Anomaly, satellite rocking

Simulation: Based on GEANT4

Geometry Detail

Over 45,000 volumes, and growing!

Includes: tracker electronics boards
mounting holes in ACD tiles
spacecraft details
and much more

Interaction Physics

QED: derived from GEANT3 with extensions to higher and lower energies (alternate models available)

Hadronic: based on GEISHA (alternate models available)

Propagation

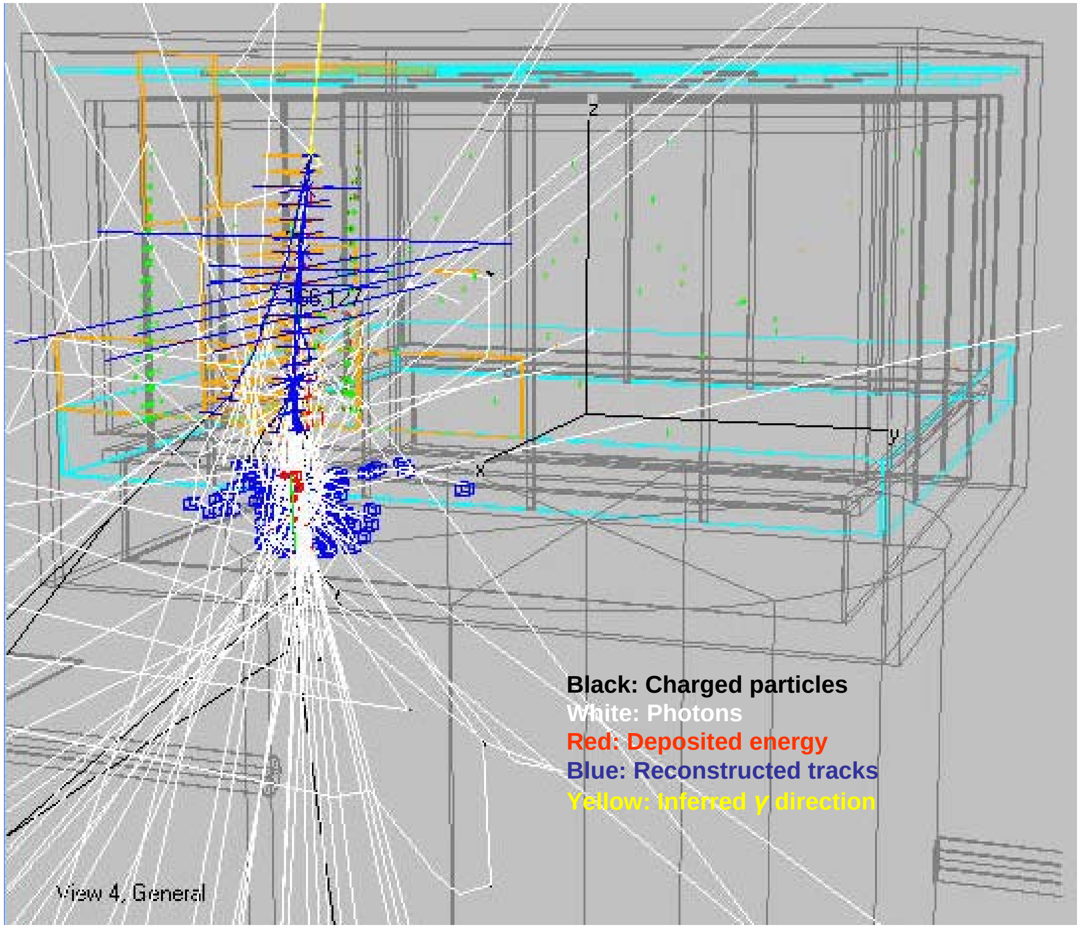
Full treatment of multiple scattering
Medium-dependent range cut-off
Surface-to-surface ray tracing.

Includes information from actual LAT tests

detailed instrument response
dead channels
noise
etc.

Overall Deadtime Effects

High-energy γ interacts in LAT



Instrument Response

- **We turn the energy deposit given by GEANT into the signals that we would record in the detectors:**
  - **Tracker:**
    - **tower triggers**
    - **hits strips when energy is above threshold**
    - **time-over-threshold ORs with correct gains**
  - **Calorimeter**
    - **correct sharing of signal between two ends of crystals (attenuation)**
    - **signals in small and large diodes, each with two ranges**
  - **Anticoincidence Detector**
    - **signals from tiles to both phototubes**
    - **correct sharing of signals between two ends of ribbons (attenuation)**

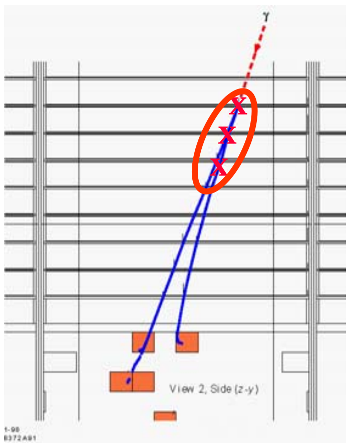
Instrument Triggering and Onboard Data Flow

Hardware Trigger → On-board Processing

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

Function: • "did anything happen?"
• keep as simple as possible

Combinations of trigger primitives:



- **TKR 3 x•y pair layers in a row**
  workhorse γ trigger
- **CAL:**
  LO – independent check, energy info.
  HI – indicates high energy event:

Upon a trigger, all subsystems are read out in ~27μs

Instrument Total Rate: <3 kHz>*

Onboard filters: reduce data to fit within downlink, provide samples for systematic studies.

- **flexible, loose cuts**
- **The actual FSW filter code is wrapped and embedded in the full detector simulation**
- **signal/background can be tuned**
- **leak a fraction of otherwise-rejected events to the ground for diagnostics, along with events ID for calibration**

γ rate: a few Hz

Total Downlink Rate: <~400 Hz> **

On-board science analysis:
transient detection (bursts)

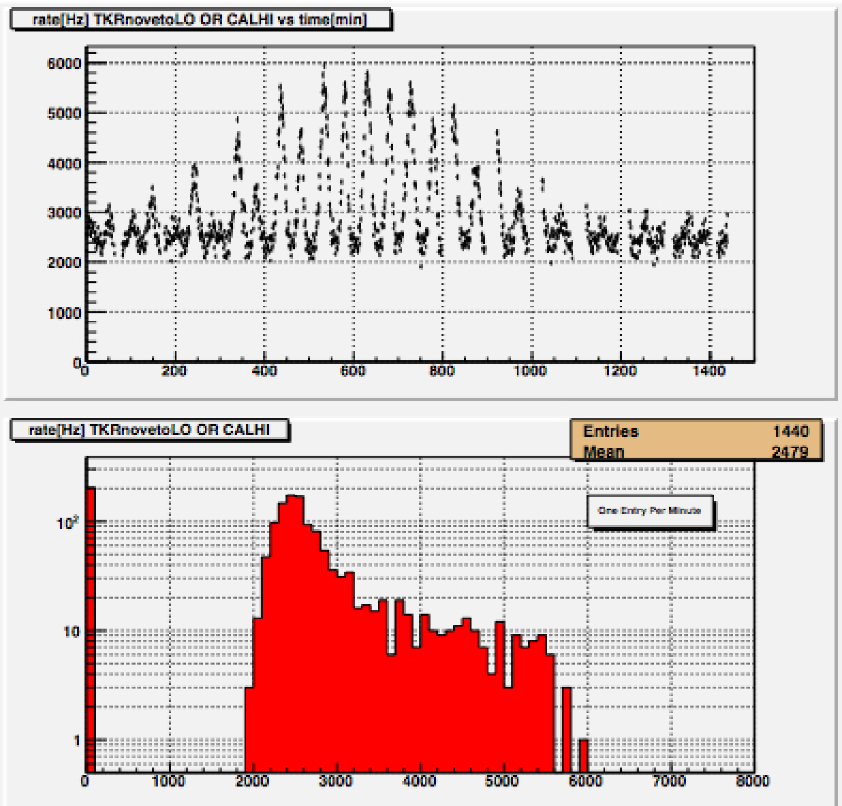
Spacecraft

***using ACD veto in hardware trigger**

****current best estimate, assumes compression, 1.2 Mbps allocation.**

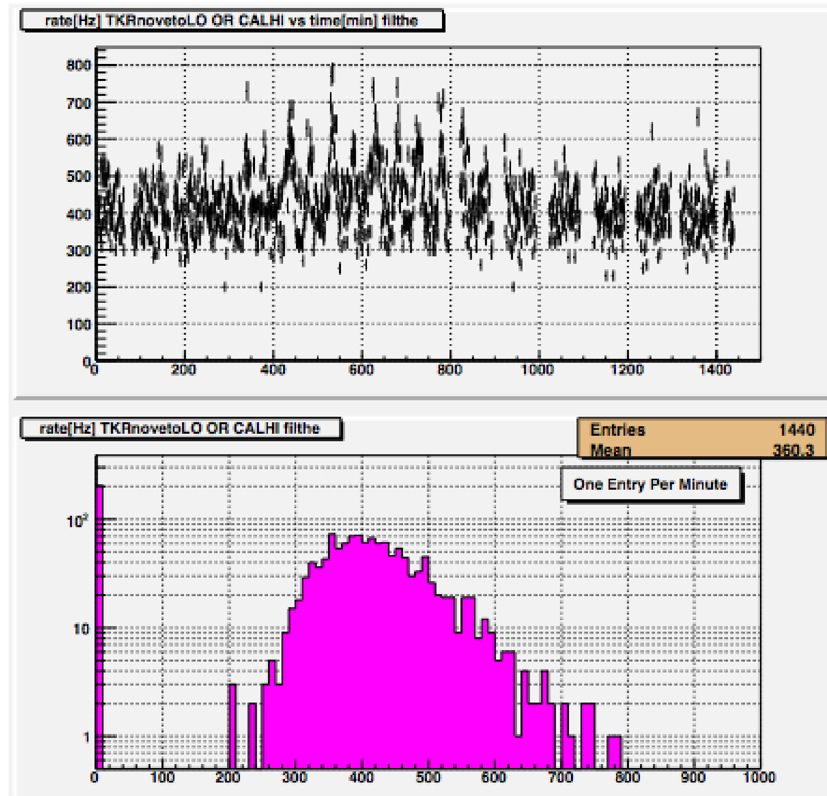
Trigger and Filter Rates Summary

Trigger



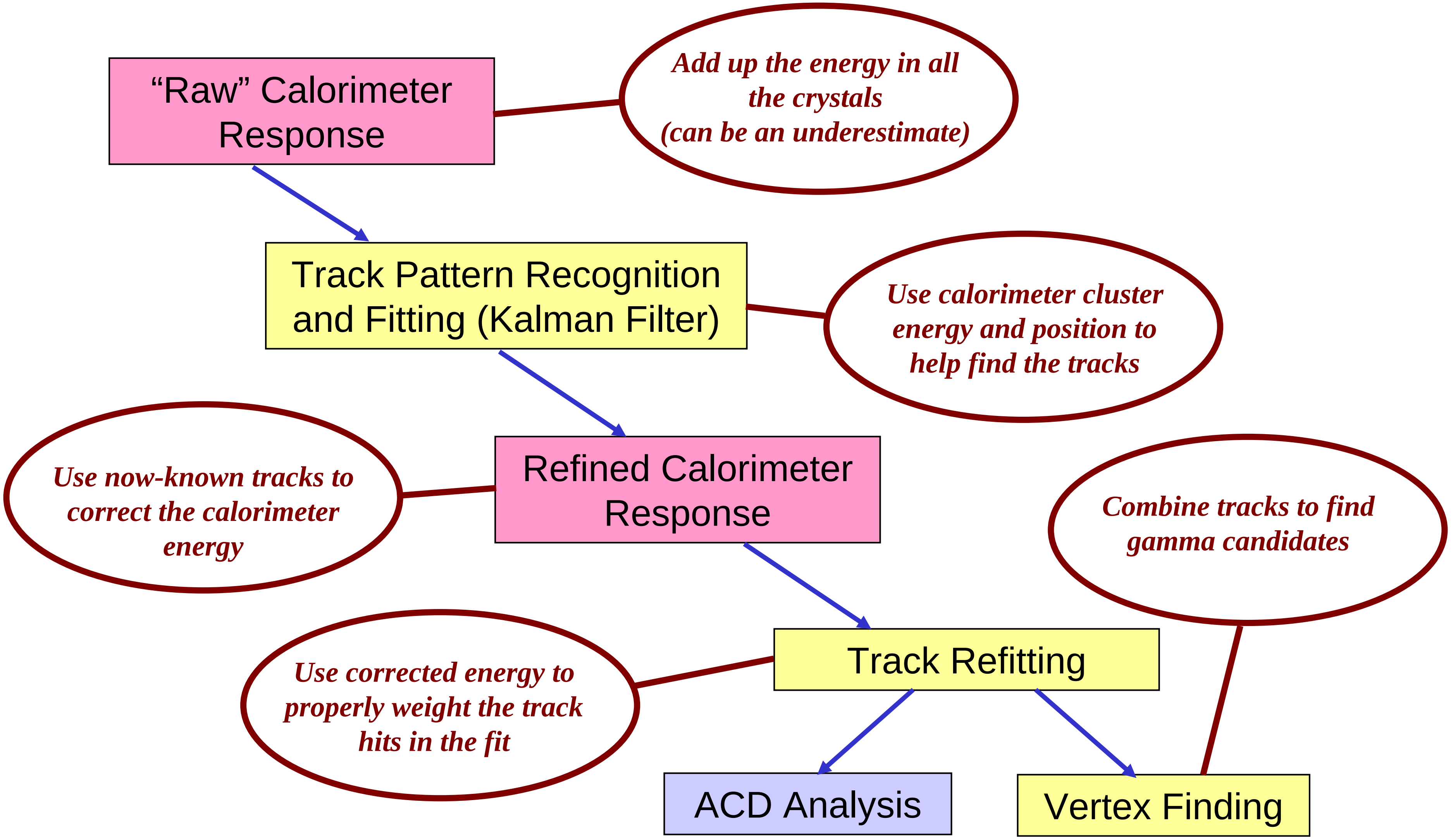
- Operating daily-average rate is 2.9kHz
- Peak rate is 6 kHz (watch deadtime)
- For this simulated day, 201 minutes spent in SAA (14%).

Filter

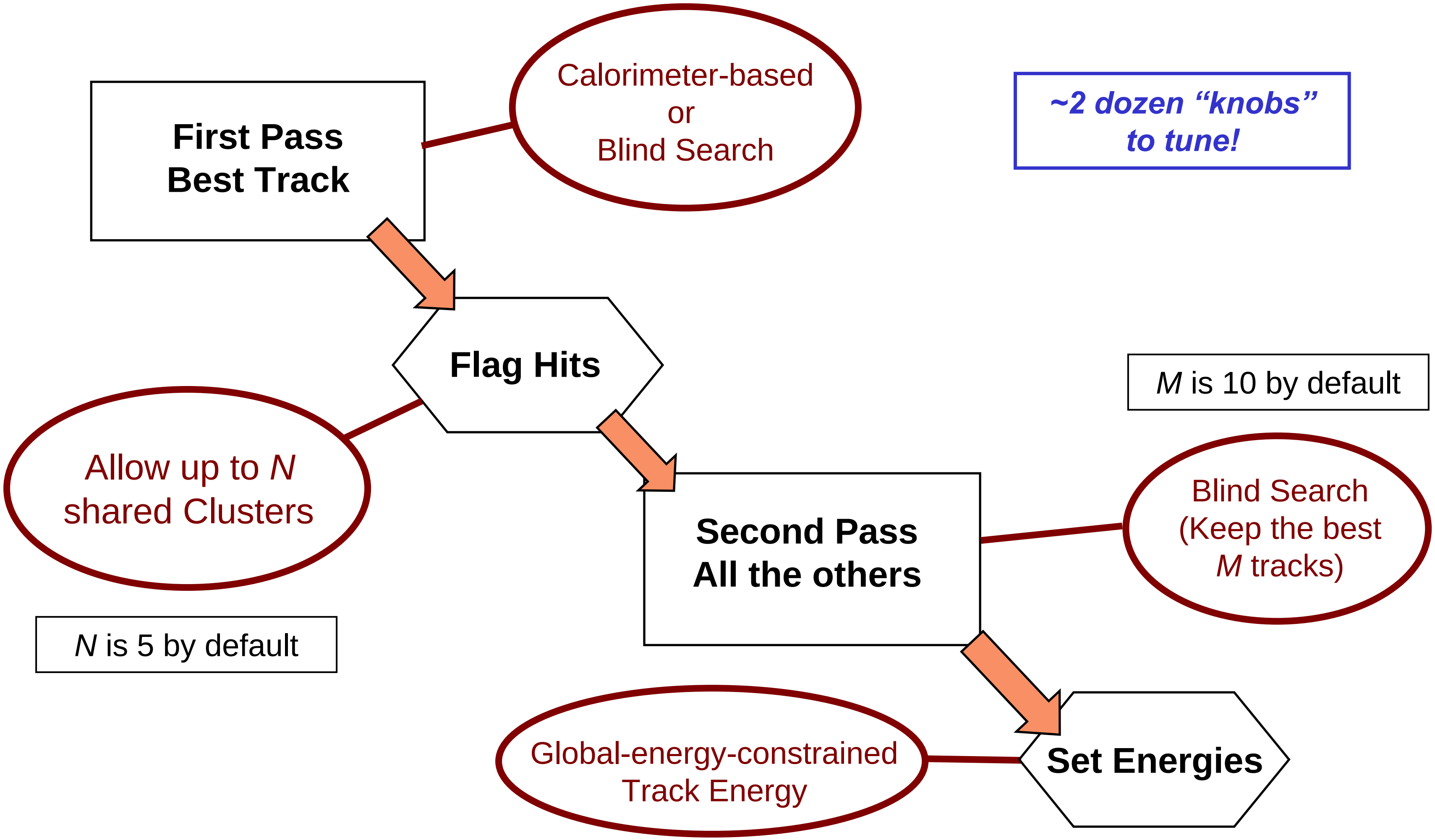


- Gamma filter rate in this configuration is 360 Hz
- Pass any event w/ E>20 GeV: +40 Hz
- Plus other filters for mips and heavy ions
- Handles to reduce this rate significantly if needed

Event Reconstruction



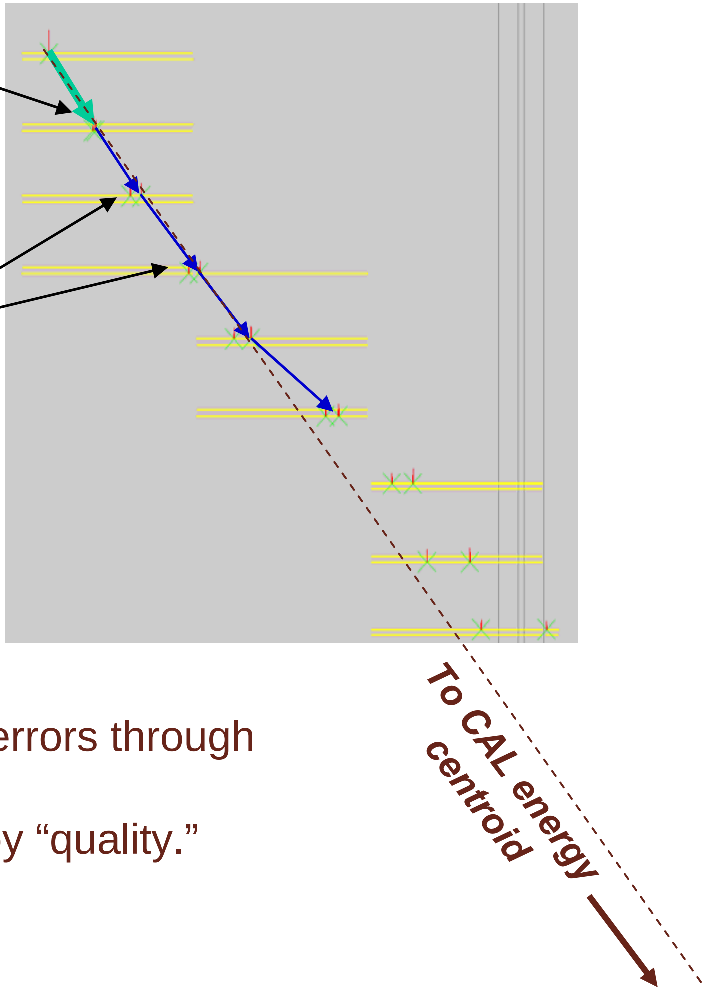
Pattern Recognition



Finding/Fitting a Track

Initial track guess:
connect first 2 x-y “hits”
(quasi-space points)

Project (Kalman Filter)
and add nearest hits
along the track within the
search region.

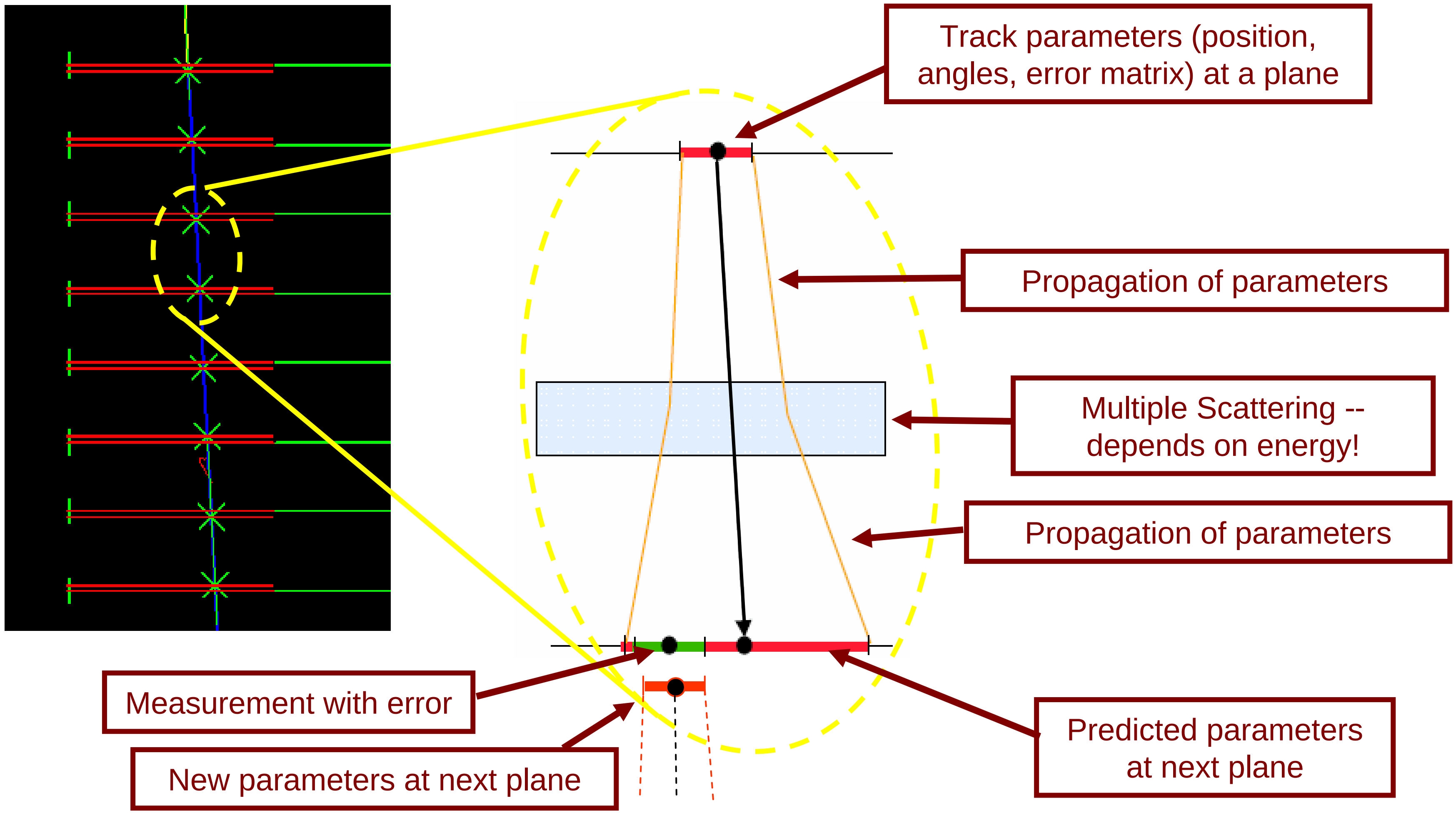


The search region is set by propagating the track errors through the LAT geometry.

Loop over all x-y combinations; order candidates by “quality.”
(quality = f(χ^2, track length, gaps, …)

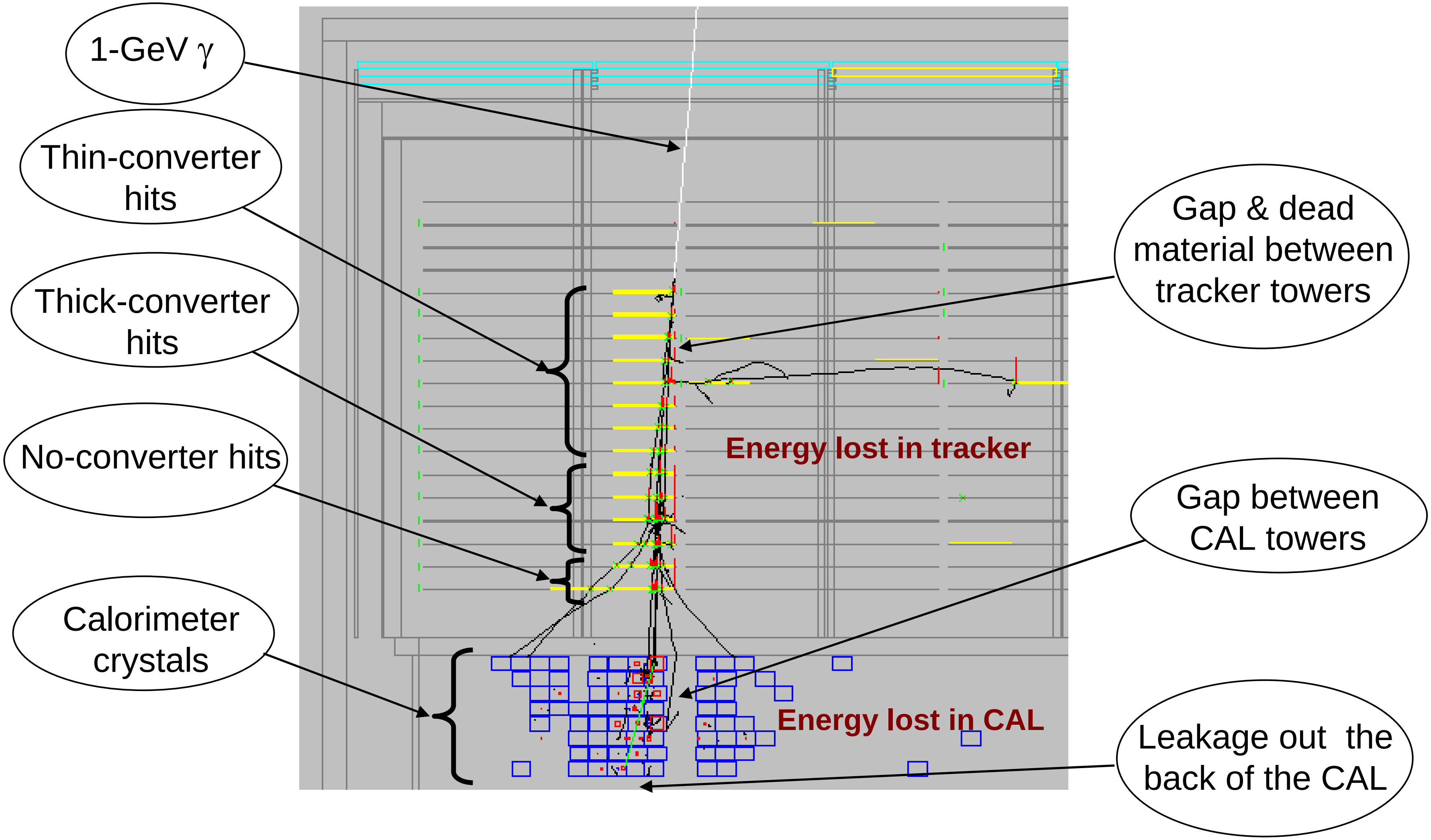
Loop over succesive layers

Kalman Fit: Incorporates Errors and Correlations



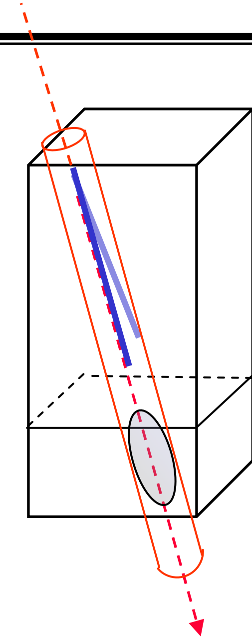
Data Analysis Techniques for High Energy Physics, R. Fruhwirth et al., (Cambridge U. Press , 2000, 2nd Edition)

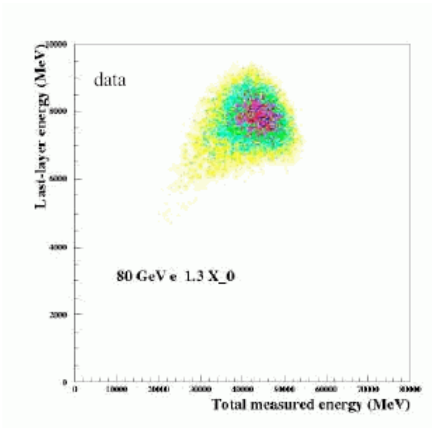
Measuring the Event Energy

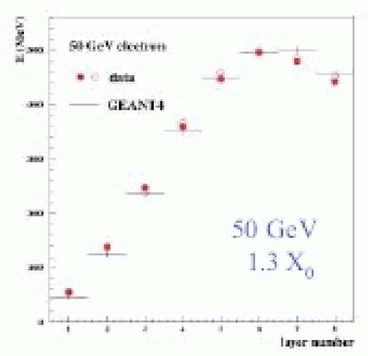


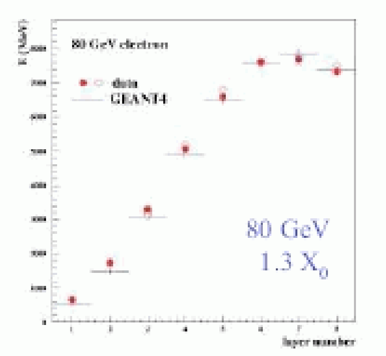
Measuring the Energy Deposit in the Calorimeter

- Three methods
  - Parametric Correction (can be used for any track)
    - Use the tracks to characterize the shower
      - Position, angle
      - radiation lengths traversed
      - Proximity to gaps
    - Correct "raw" energy
  - "Likelihood" (limited energy and angular range)
    - uses relation between energy deposit in last layer and in the rest of the shower. Below about 50 GeV, last-layer energy is proportional to the leaked energy.
  - Profile Fitting (limited angular range)
    - Fit layer-by-layer deposit to shower shape
    - Best if shower peak is contained in CAL
- Choose best answer among available methods
  - based on expected error for each method



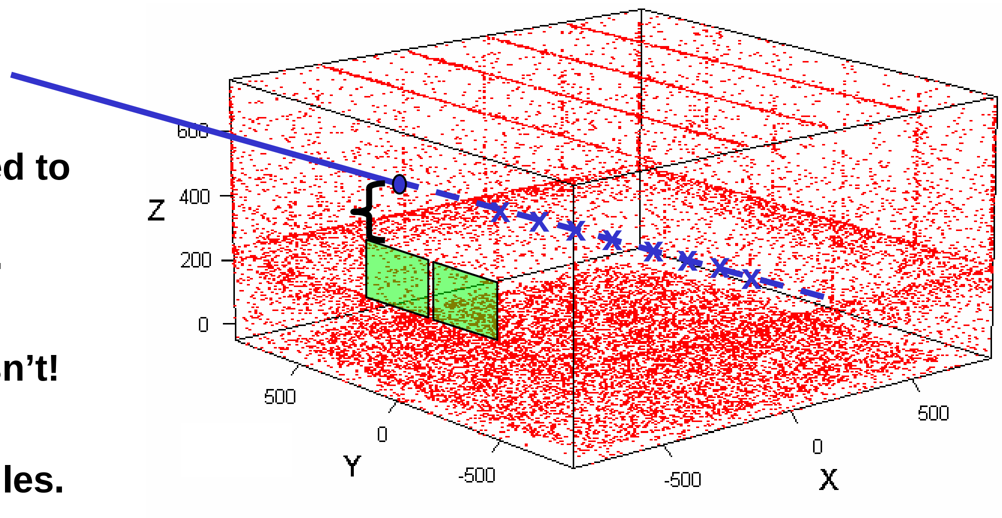






ACD Analysis

Dots show intersection of tracks with planes of ACD tiles.



We project the track back to the tiles, and ask how close it comes to the nearest struck tile, if any.

Because of backsplash, there may be struck tiles that are not associated with the tracks. Segmentation of the ACD allows us to salvage such events.

The ACD has been measured to be ~99.97% efficient for minimum-ionizing particles.

So what's most interesting about the ACD is where it isn't!

Dots show intersection of tracks with planes of ACD tiles.

Because of gaps in the ACD coverage, charged tracks may fail to produce a signal in any tile.

The ACD analysis identifies these gaps to remove sources of background.

X

Summary

- Event reconstruction gives us measurements of the energy, direction and position of the incoming photon.
- In addition, it provides very detailed information about each event.
- Given the hardware response, the "performance" of the instrument depends on the analysis strategy.
  - The rich description of the events allows us to construct variables to tune the analyses to reject background while optimizing the signal.
  - The strategy chosen will depend on the science being studied.
- This process will be explored in the next talk.