GLAST tracking reconstruction

Status Report

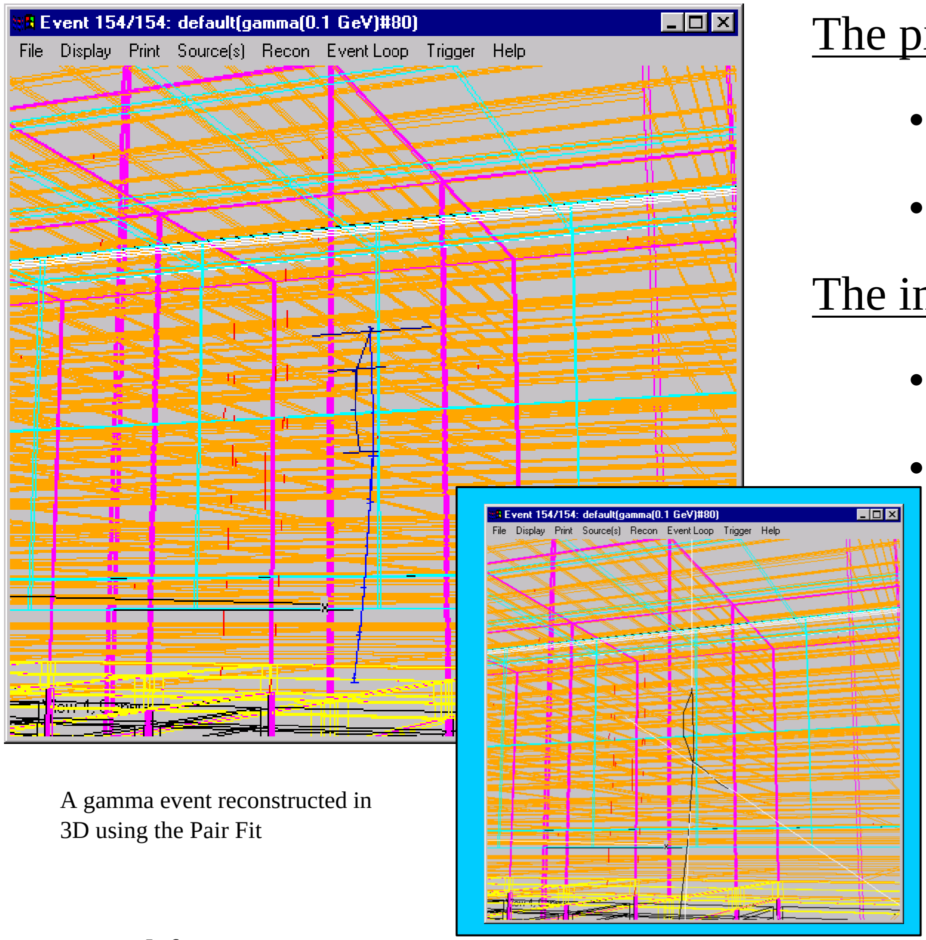
Bill Atwood, Jose A. Hernando, Robert P. Johnson, Hartmut Sadrozinski

Naomi Cotton, Dennis Melton

University of California, Santa Cruz

Tracking simulations

Outlook



A gamma event reconstructed in 3D using the Pair Fit

<u>The picture of the GLAST tracker reconstruction</u>

- The tree Dimensional Pair Fit
- Preliminary Results

<u>The importance of being a Vertex Detector</u>

- Fine pitch and Event Topologies
- Vertex Reconstruction

Tracking simulations

Tracking Reconstruction

Tracker Reconstruction:

Using the:

Silicon Hits

Energy measured in the Calorimeter

Should **reconstruct that trajectory of the charged particles traversing the detector.**

Should estimate:

Position and direction of the particles.

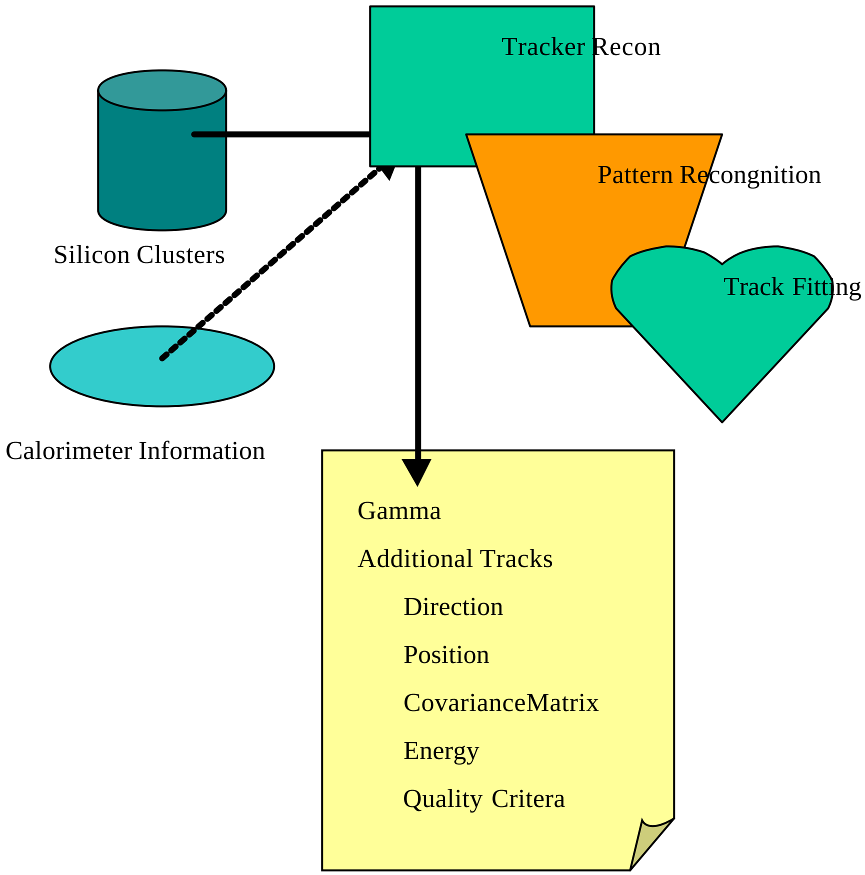
Covariance matrices

Energy (?)

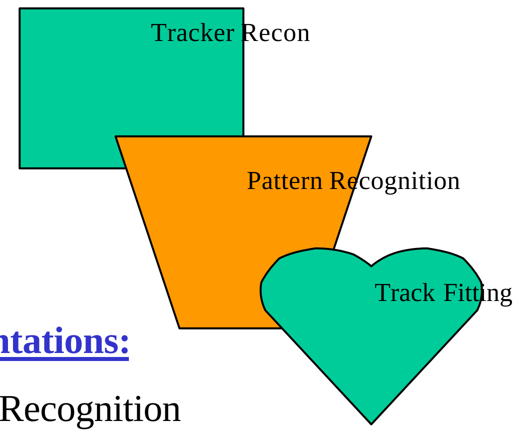
and should provide:

Quality Criteria of the reconstructed tracks.

Extrapolation to subdetectors



Tracking Reconstruction Scheme



The Physics inputs:

- Different range of Multiple Scattering

  Main parameter:

  pitch/distance

  Different ranges of Energy (1GeV)

- Fitting electrons

  The emission of bremsstralung photons

  5% of electron energy by plane

  The initial part of the electromagnetic cascade!

- Reconstructing the gamma

  The definition of the gamma using electron/positron tracks

  Unknown track energies

Implementations:

Pattern Recognition

Based on Gamma Identification

Fitting - Kalman Filter

Treatment of MS by plane

Natural link with Pattern Recognition

Energy estimation - track addition

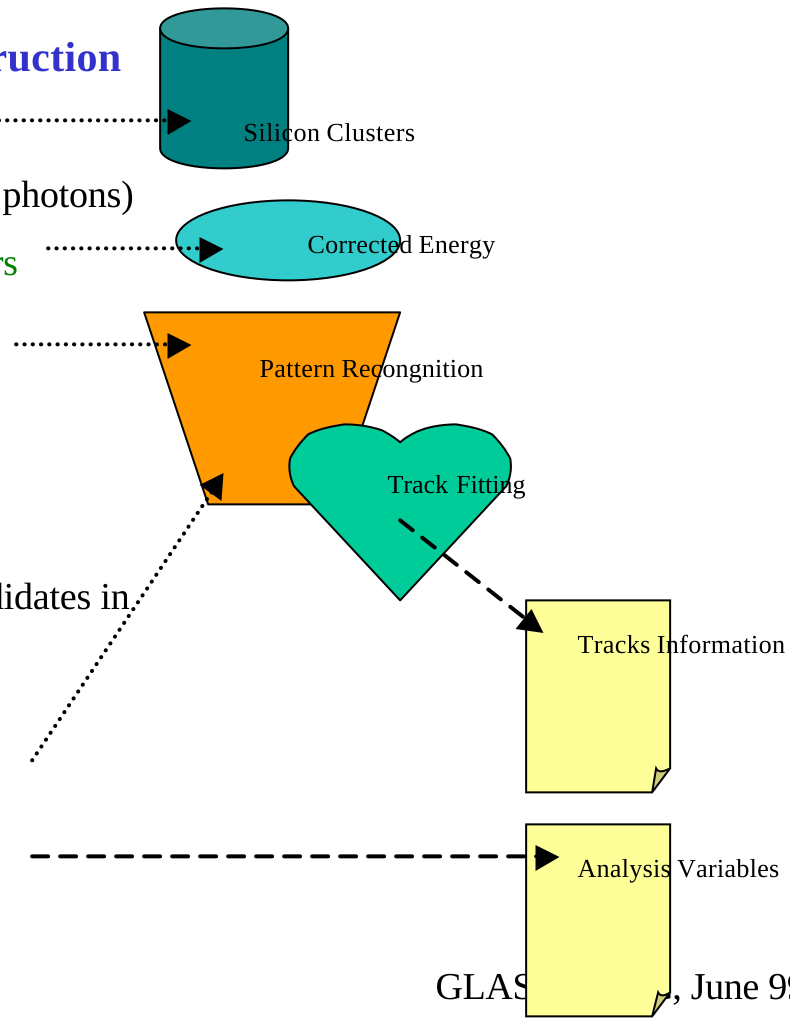
Based in Kalman Filter

Tracking simulations

Driver of the Tracking Reconstruction

Tracker Recon - steers the Tracking Reconstruction

- Creates the Silicon Clusters
- Computers the Corrected Energy (low energy photons)
  - Calorimeter clusters + # of Silicon clusters
- Search for a gamma interaction
  - Uses the 3D pair as Pattern Recognition
    - Loop all Si clusters as possible vertex
      - Searches for X-Y candidates
      - Searches for compatible X-Y candidates in 3Dimension
- Search for extra tracks (up to 5!)
  - Uses the 3D track Pattern Recognition
- Computes additional Analysis variables



Tracking simulations

Pattern Recognition

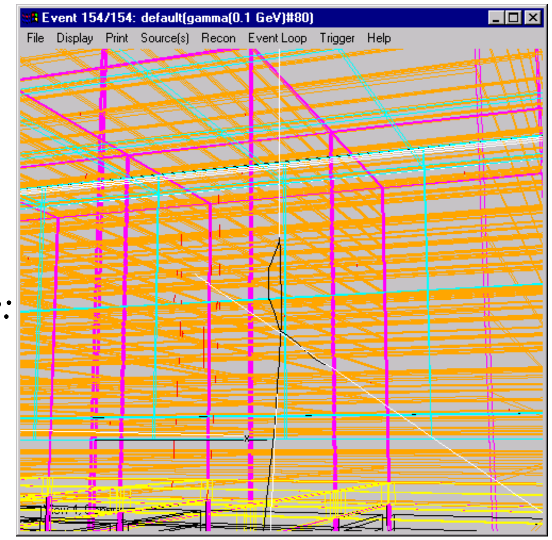
Pattern Recognition - Toolkit of Tracking Classes

A family of related classes that can construct:

A Track	**A Pair Event**
A 3D track	**A 3D Pair Event**

The idea: *the Pattern Recognition should recognize the gamma signature:*

two tracks split from a common vertex or an initial segment.



A gamma conversion onto electron/positron

The Pattern Recognition main elements:

- Uses a Ray (Vector + Direction) as an input seed

  Information from the Calorimeter and neighbor hits

- The search is based in plane by plane basic

  step() function : depends on the Track Objects (Track or Pair)

- The search is controlled by an unique parameter

  m_sigmaCut : maximum distance in standard deviations at which a hit is located away from a prediction point

- All Tracking Classes provide a common output data

  GFdata : → Vertex, Direction, Energy, Covariance Matrix

They can be re-use as an initial seed

Tracking simulations
The Pair Fit

Pattern Recognition - Pair Fit

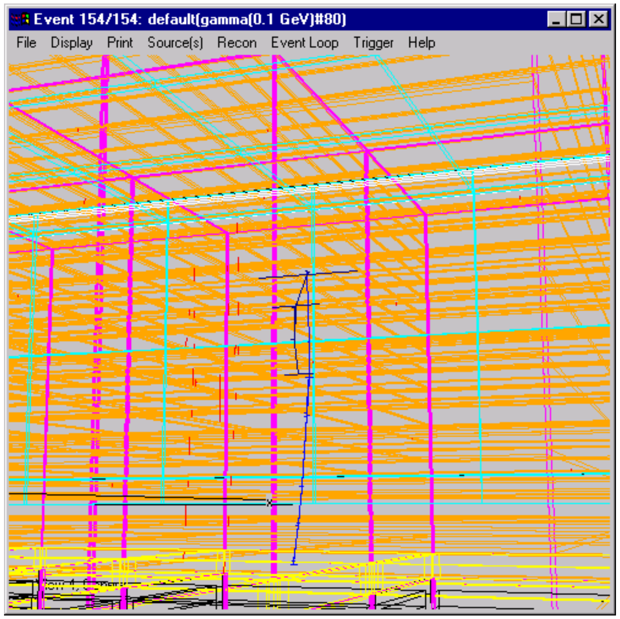
- A "pair" tracks is created when:

  A second segment can be constructed in the vicinity of N-first hits of the "best" track.

- ***Step()*** function propagates both tracks into the same plane
- The tracks do a competition for hits:
  - selfish or generous criteria?: (selfish of course!)

The 3D Pair Fit

- 3D "loose" connection :
  - A check is perform to guaranty that X-Y Si clusters of a connected track are in the same tower
- The 3D pair are ambiguous (4 X-Y combinations) unless:
  - Topological identification (hard)
    - One track crosses to a neighbor tower
    - One track stops
  - Energy criteria (soft)
    - Connection of the "best" tracks in both projection



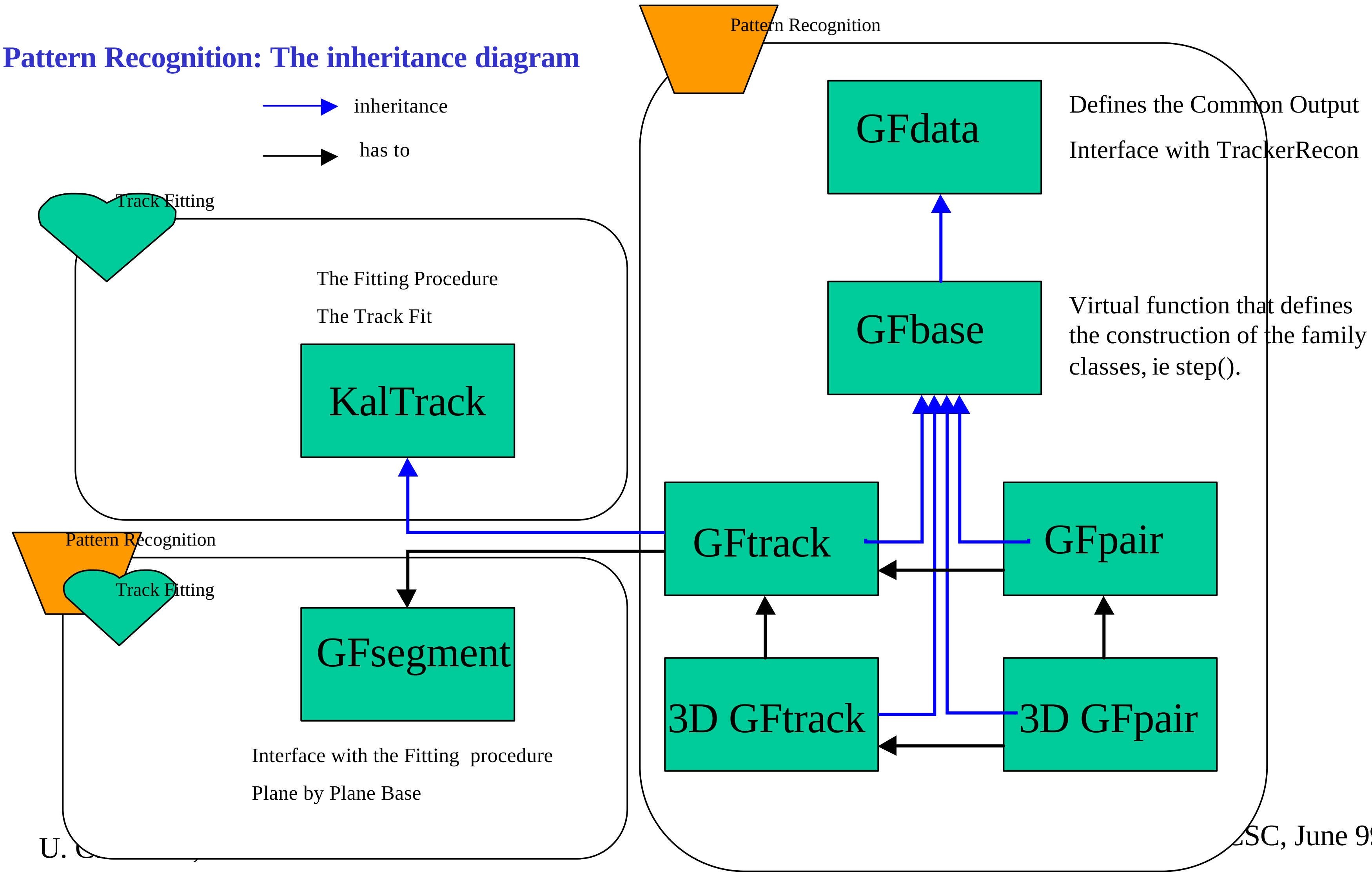
The 3D pair Fit reconstruction of a gamma event

- Versatility: (The 3D identification (combinatory or topology) is a free parameter)

Tracking simulations

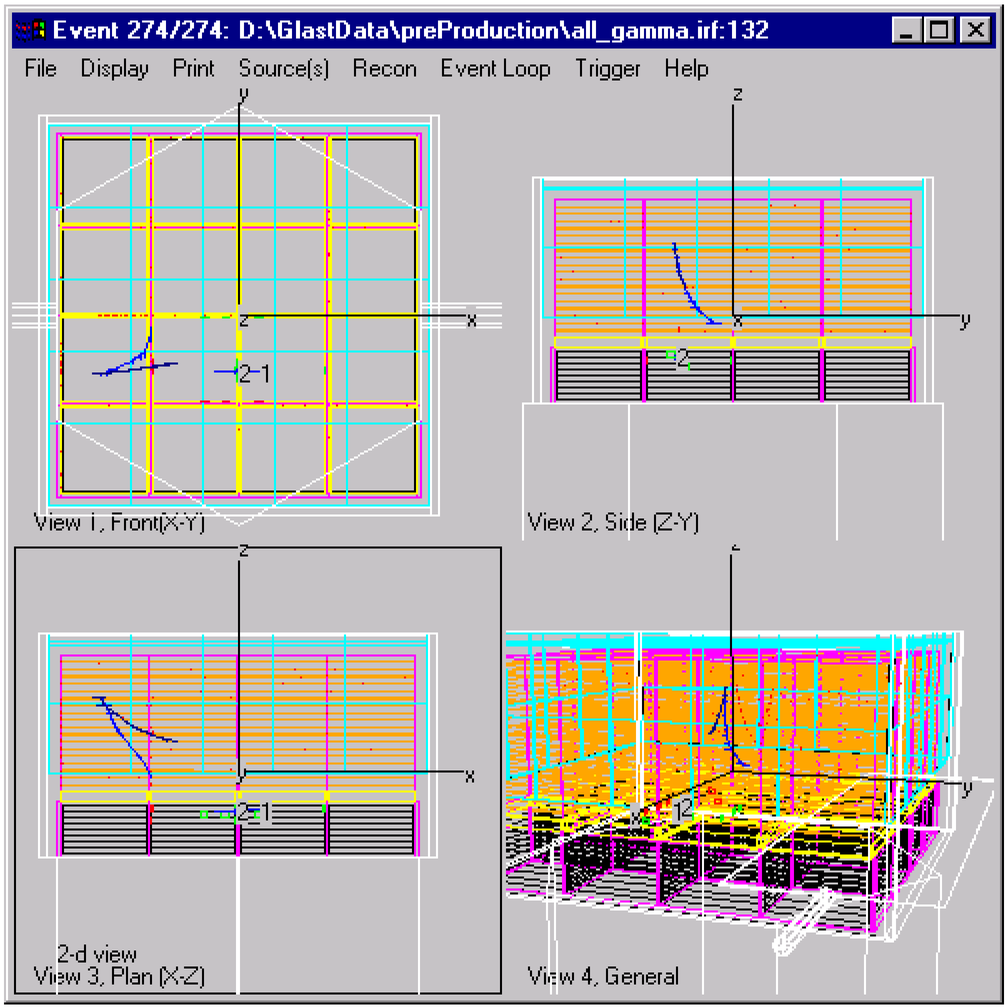
Tracking Reconstruction Classes Organization

Pattern Recognition: The inheritance diagram



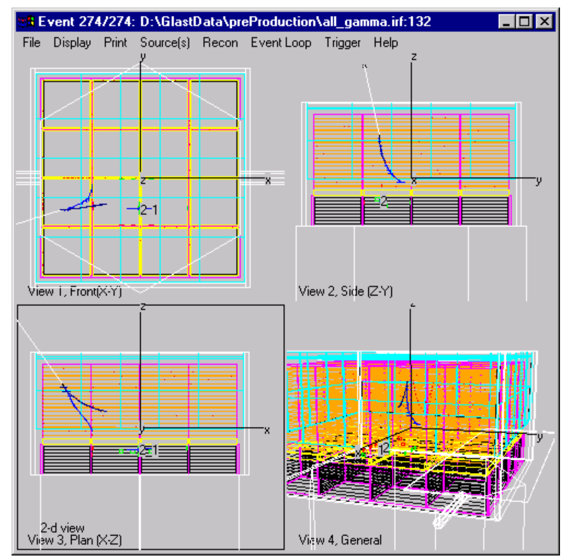
Tracking simulations

Example of a reconstructed gamma



The projection and 3D view of a reconstructed gamma event

Example of a 3D Pair Fit



Tracking Fitting procedure: The Kalman Filter

Track Fitting: Kalman Filter

- Is a track follower algorithm.

  It is a Filter

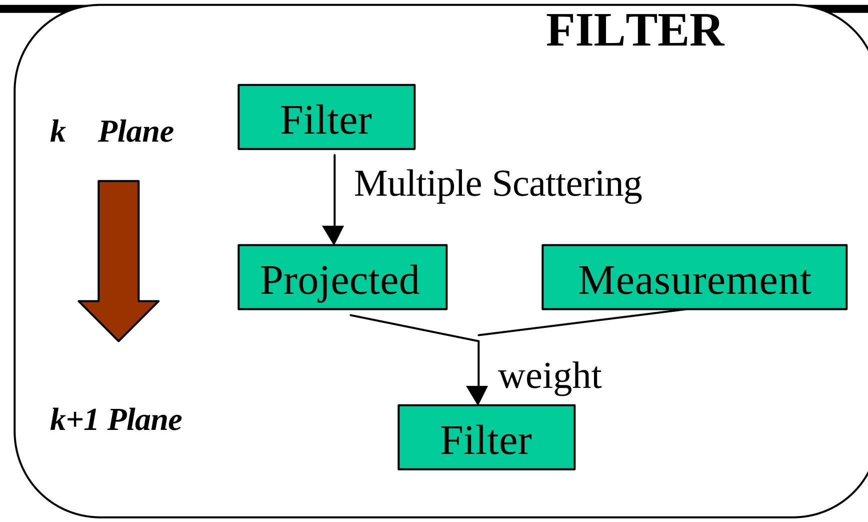
  Each measurement is incorporated each time

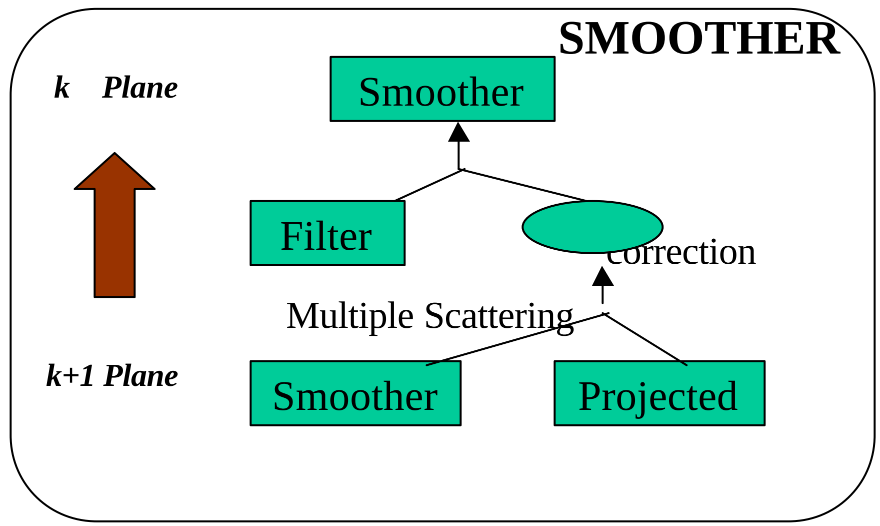
- It solves the problem of incorporate "random" noise between two measurements (ie Multiple scattering)

- It is based on minimum residual estimators

  It is an optimal method with gaussian errors

  It is equivalent to the LSQ method in absence of "random" noise

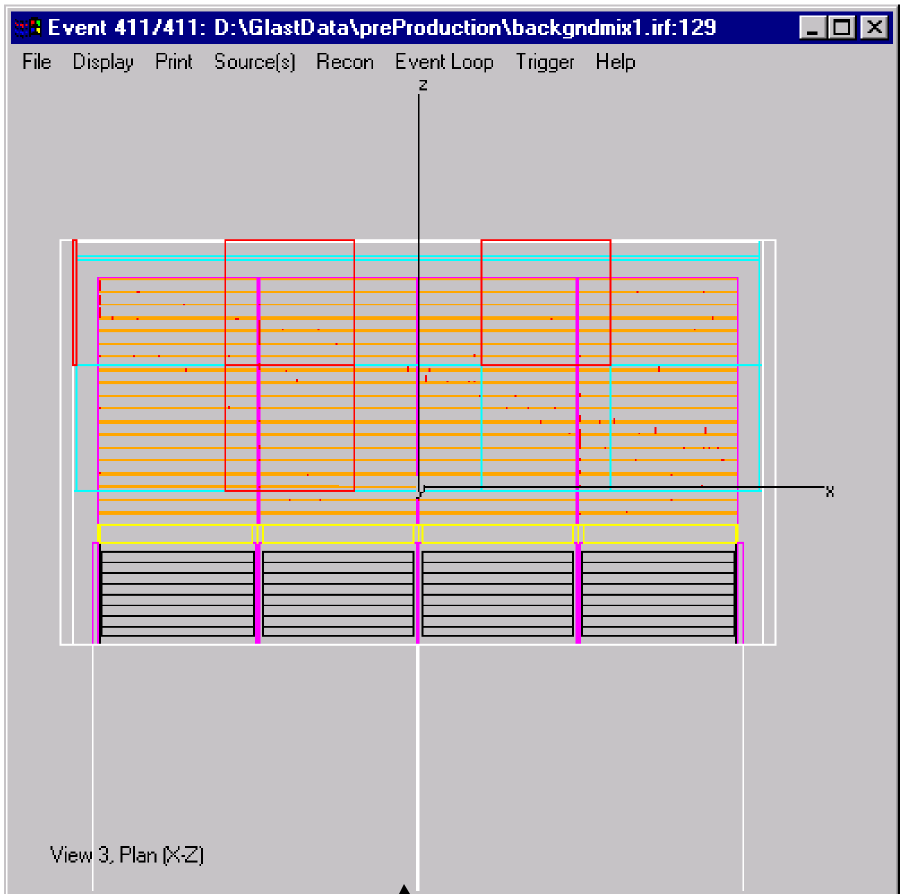




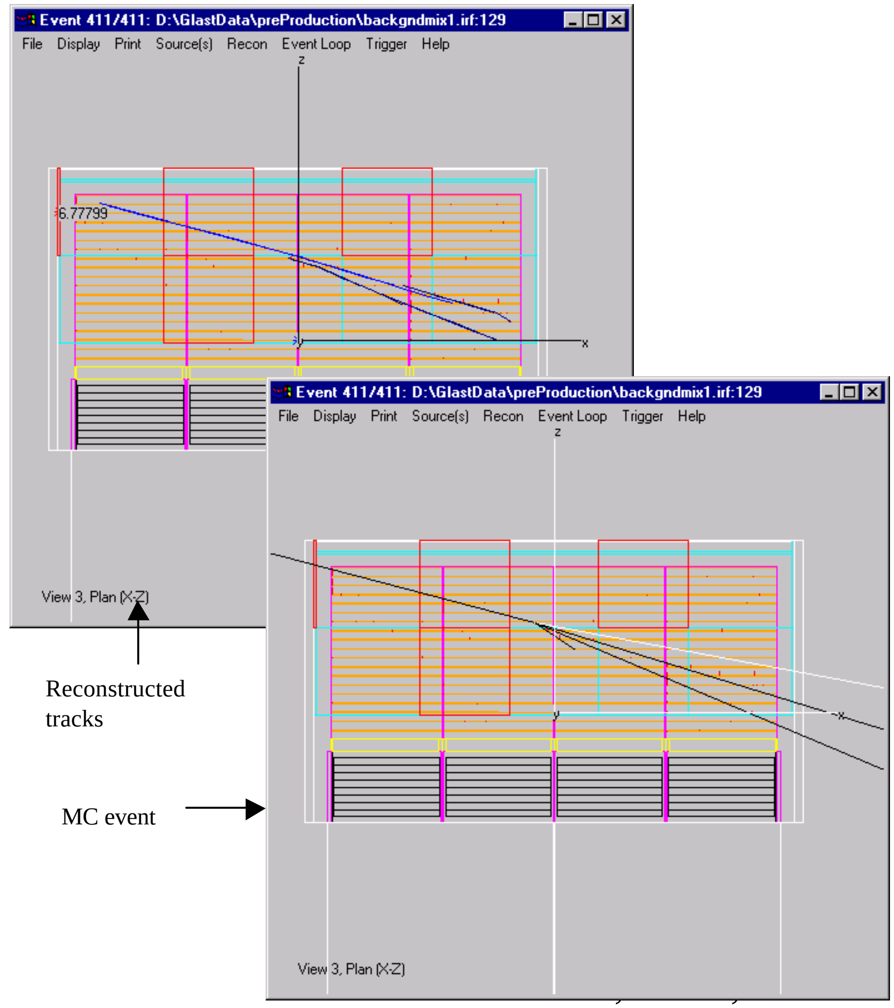
Tracking simulations

An example of a reconstructed cosmic event

Reconstruction of cosmic Background - protons



Recorded hits on the Silicon detector.



Reconstructed tracks

MC event

Tracking simulations

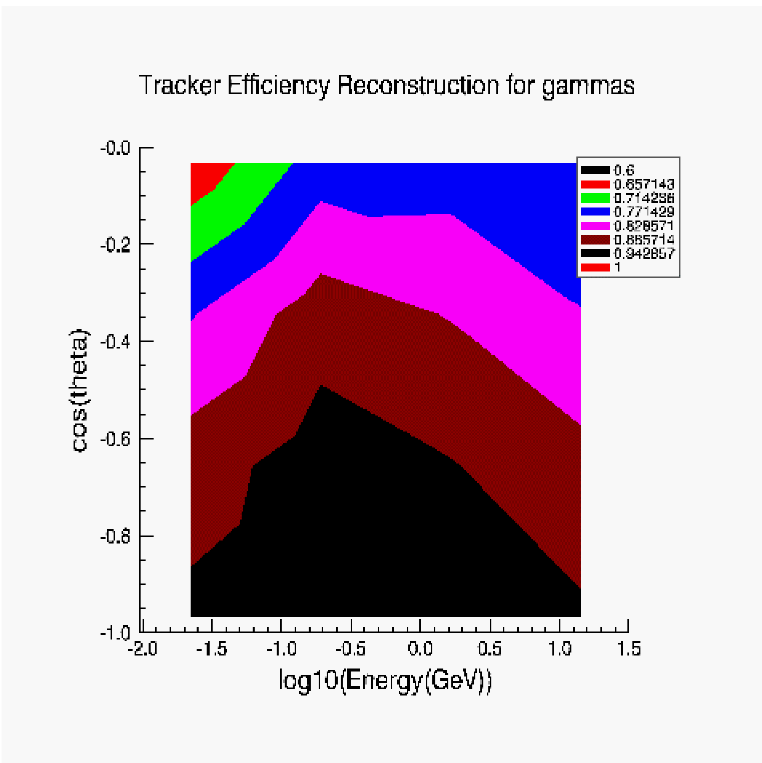
Tracking efficiencies

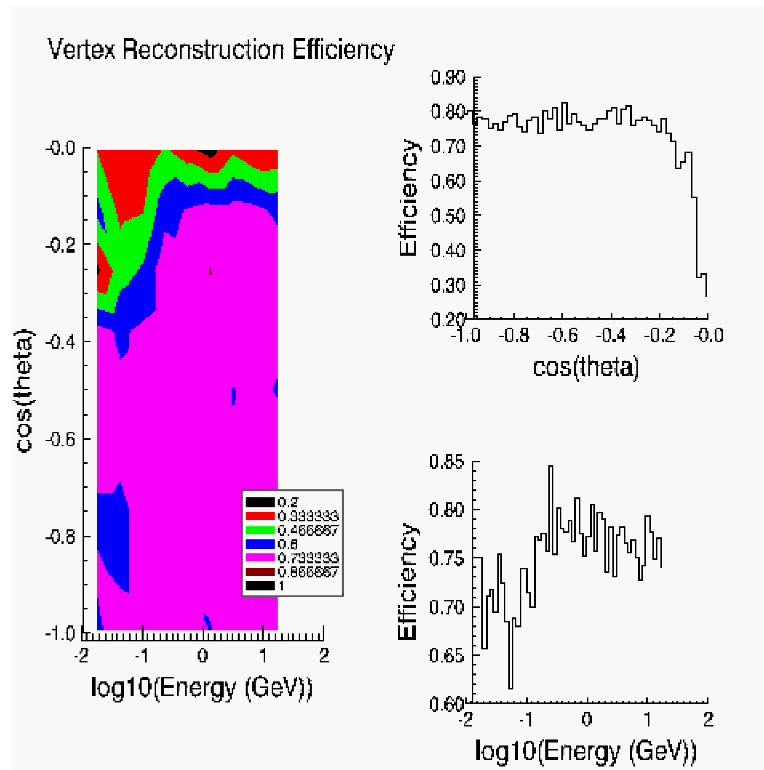
Tracking Efficiency:

- 95% for angles ? < 45 deg
- 80% for angles ? < 80 deg
- almost flat with energy

Vertex Efficiency:

- ~80% for angles ? < 80 deg
- Almost invariant with energy and incident angle.

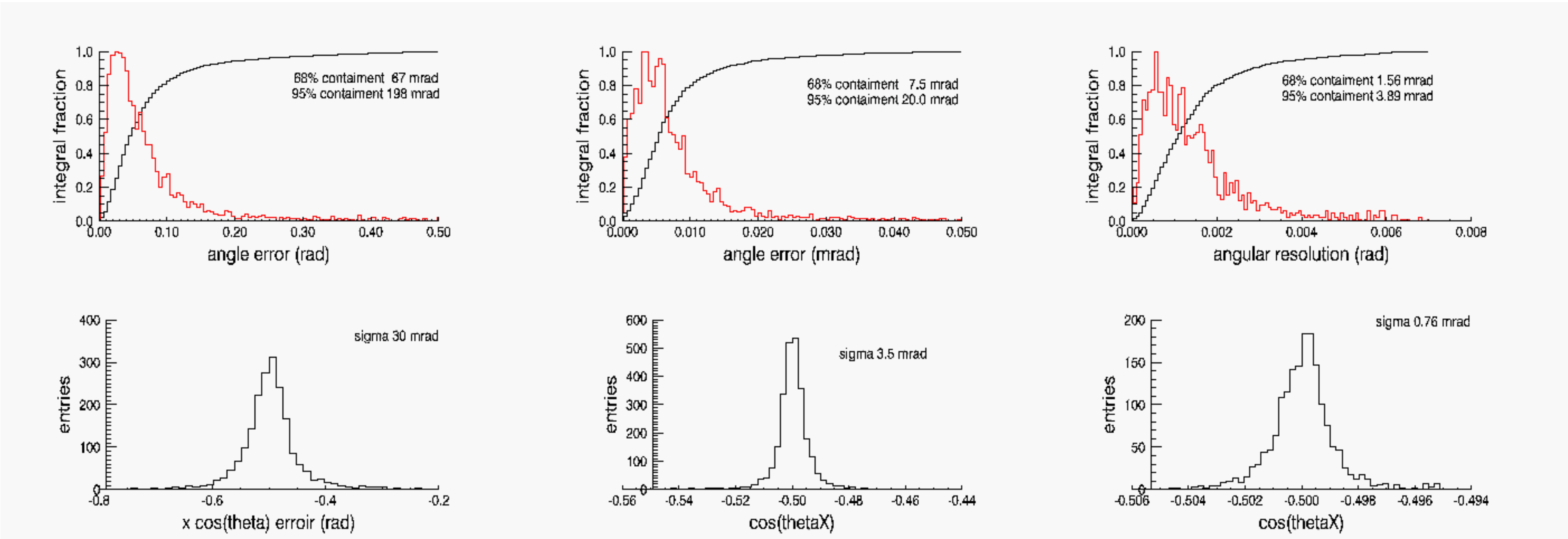




Tracking simulations

Angular distributions

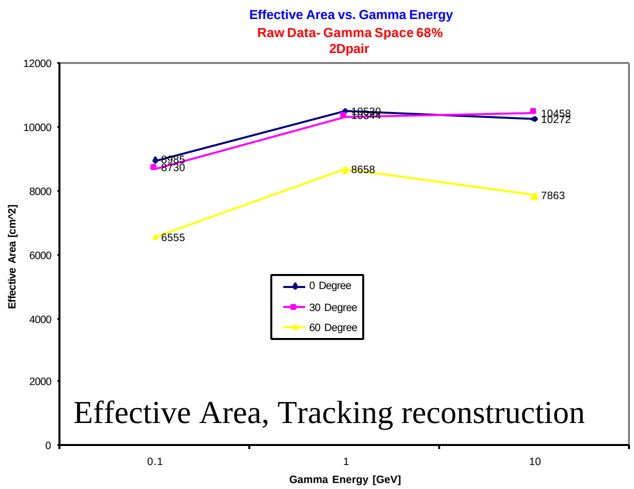
Angular distributions for gamma 30 degrees incident angle in X direction

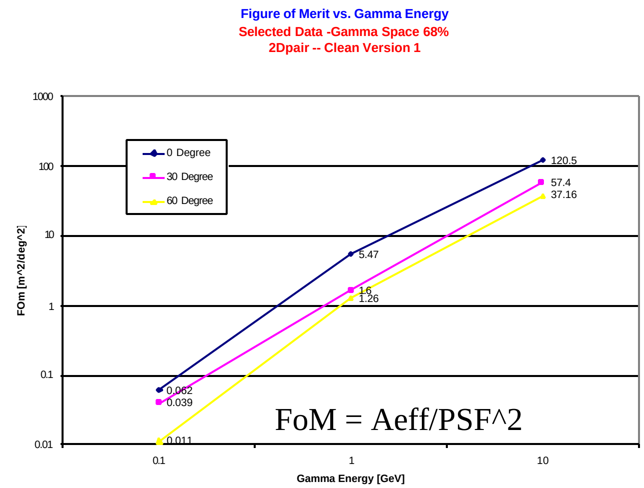


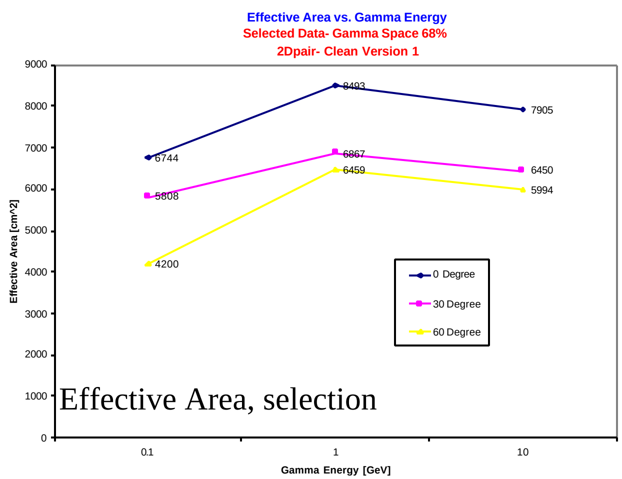
Tracking simulations

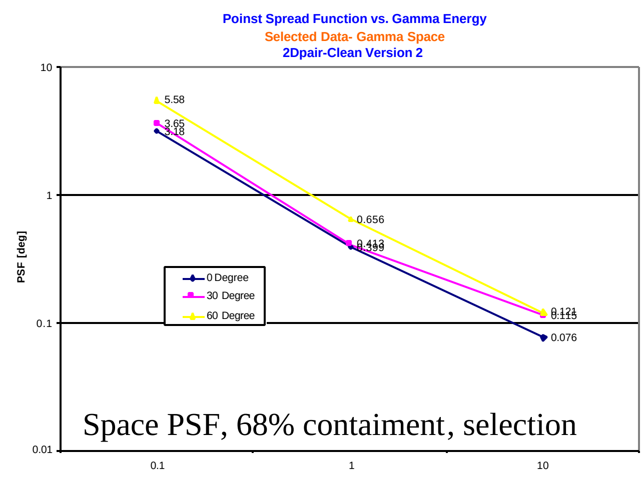
PSF and Effective area

2D pair reconstruction results - current repository









Tracking simulations

Status and Future plans

Status of the Tracking Reconstruction :

- The tracker reconstruction works for AO purposes.
- The Pair-Fit reconstruction should be tuned up, understood and it potential explored.
- The actual reconstruction works a strong framework for further improvements and additions.

But, there is still a lot of work to do:

- *PSF Studies based on topological criteria.*
- *Studies of low energy gamma (PSF and the addition of the electron/positron tracks).*
- *Understanding the Pair-Fit efficiency and causes of tracking failures.*
- *Estimation of the energy using the tracker information.*
- *Tracks extrapolation to other subdetectors.*
- *Background rejection based on topological criteria*

The tracking reconstruction and the background rejection

The Background rejection variables: (surplus_hit_ratio, csi_err_nrm, etc)

- They contain a relevant part of the legacy of Bill Atwood's great work.
- For historical reasons they were calculated (most of them) in TrackerRecon
- They combine tracker/ACD/Calorimeter information and they are used for background rejection.
- They have been broken with the new-reconstruction but nobody has paid attention to them.
- And the A0 is almost there.

Proposal:

- Lets not panic! (yet)
- There are only some decens of lines of code that we should be able to understand and corrected it (it would maybe require the collaboration of people working in reconstruction and background rejection).

Status:

- After Bill's fix last Thursday (two lines of code), they almost look OK.
- The main variable broken is csi_corrected_energy.

For the future (not for the AO):

- The GlastSim output is a Ntuple that is not convenient for analysis that relies on fundamental reconstruction parameters.
- In order to be able to perform an effective background rejection analysis, as well as other studies: (I.e. efficiencies) we need a reconstruction output similar to most HEP experiments (I.e. list of track and its extrapolation to ACD and calorimeter)
- As the panel recommended.

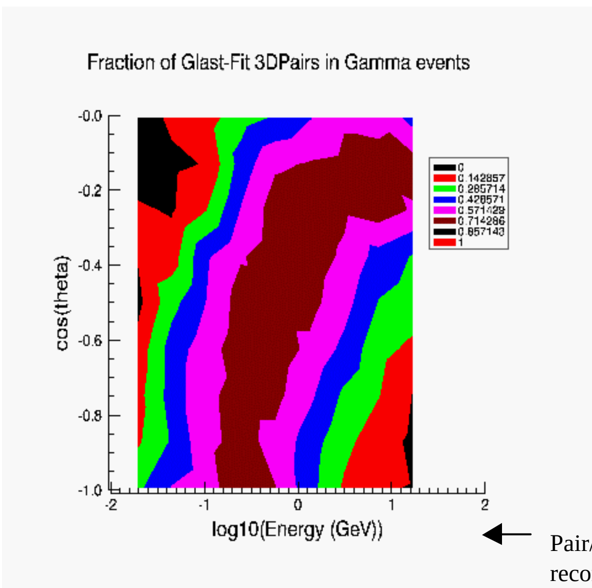
Pair Fit reconstruction use: Background rejection

Background Rejection using the Pair Signature (Atwood)

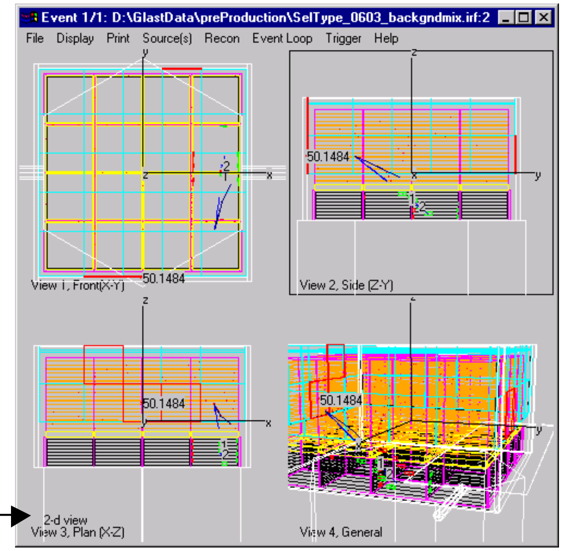
The data should be classified using topological criteria

A clean Pair Fit signature will not be easily mimic by cosmic background

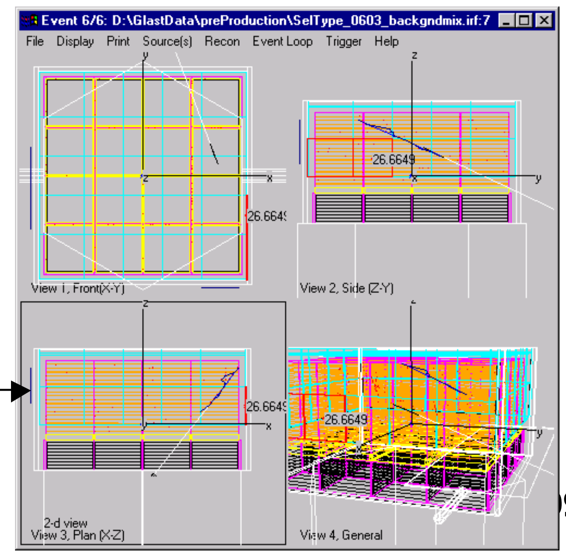
all_gamma	56% are Pair Fit
backgroundmix	2% are Pair Fit (1/2cosmics, 1/2 albedo)



Pair/One track reconstructed ratio for gamma events



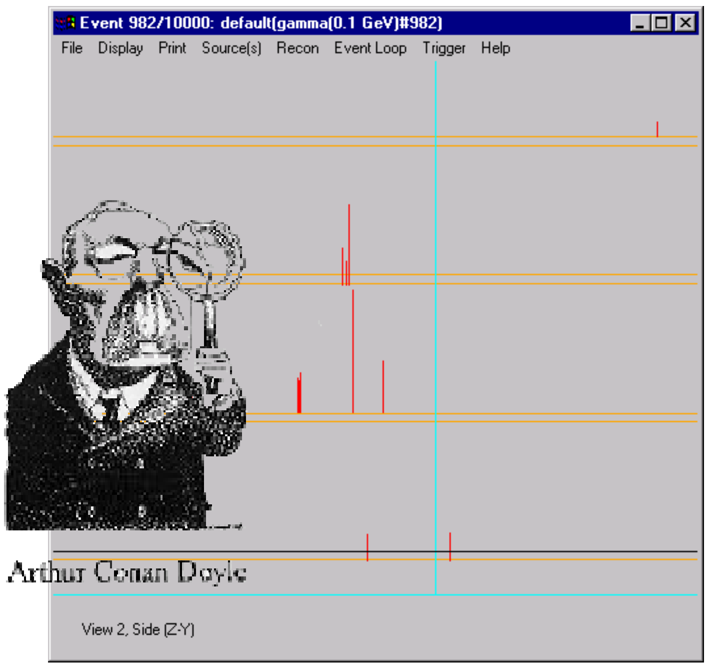
Cosmic event entering from the bottom, a second track reconstructed. But It is a mip in the calorimeter



An albedo gamma entering from the bottom and converting into a Pair.

Tracking simulations

The importance of being a Vertex detector



The PSF depends on the event topology

- Classification depending on the number of hits in the initial Vertex,

  *Atwood's **first_hit_count** variable*

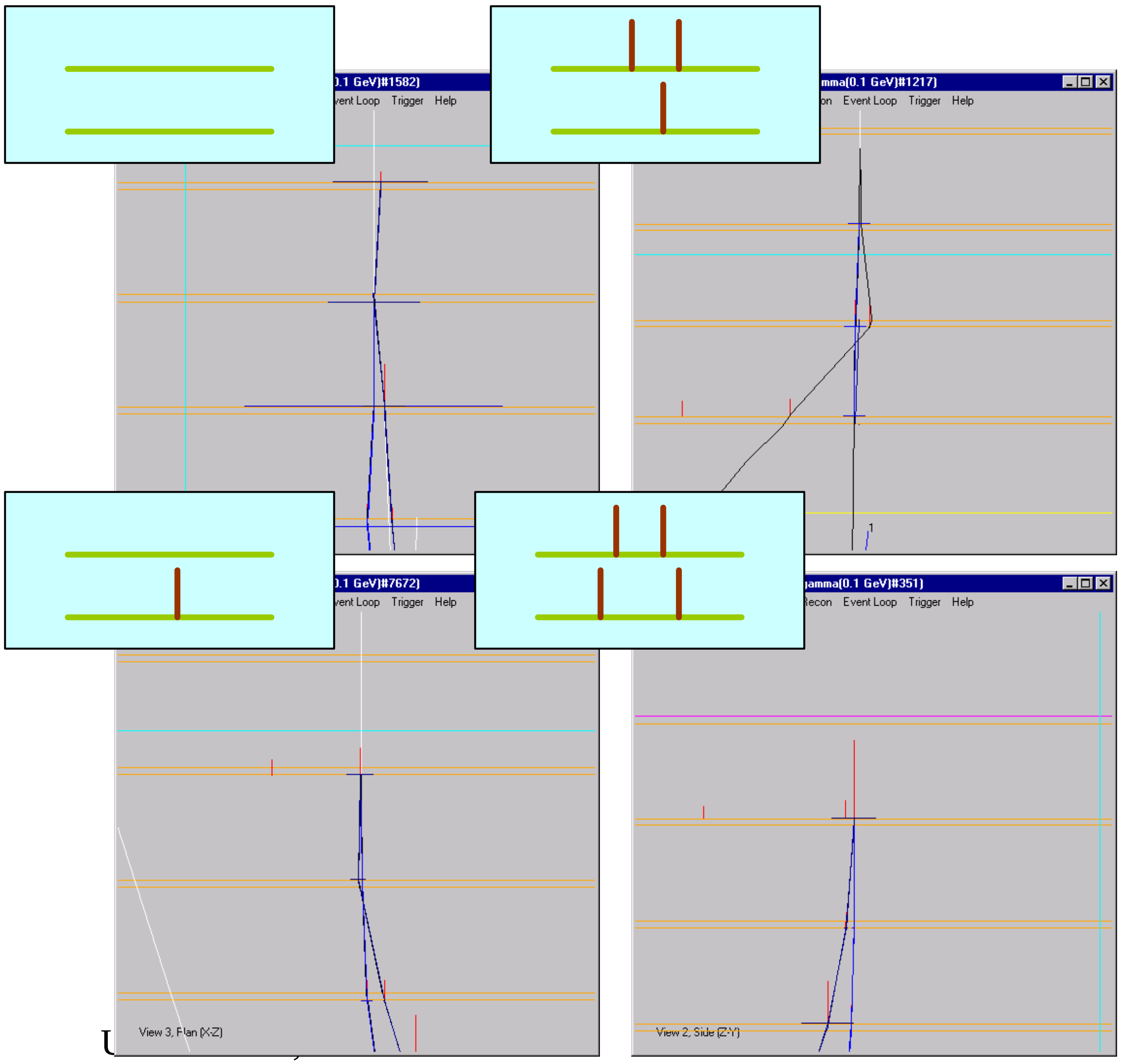
- How important is determinate the initial vertex and the cracks.

  An example with 100 MeV, normal incident gammas

- The impact in the aspect ratio of GLAST

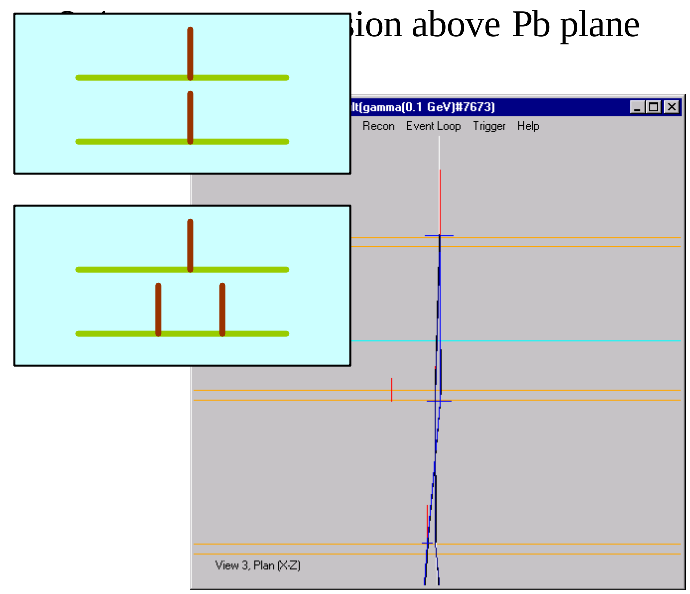
Tracking simulations

First Hit Count - Topologies



First Hit Count (Atwood's): Number of Hits (X+Y) in the first Conversion Layer

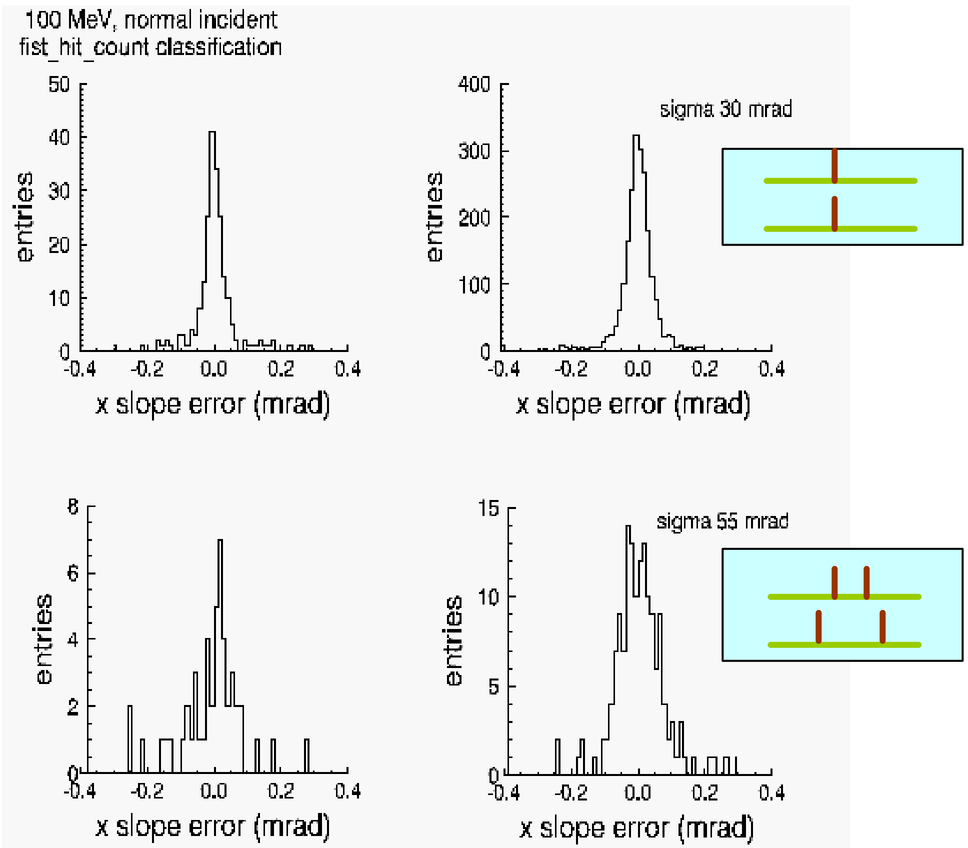
first_hit_count	topologies
0	incorrect tower association
1	conversion in 2nd Si plane
2-2.5	pure conversion
	ion above Pb plane

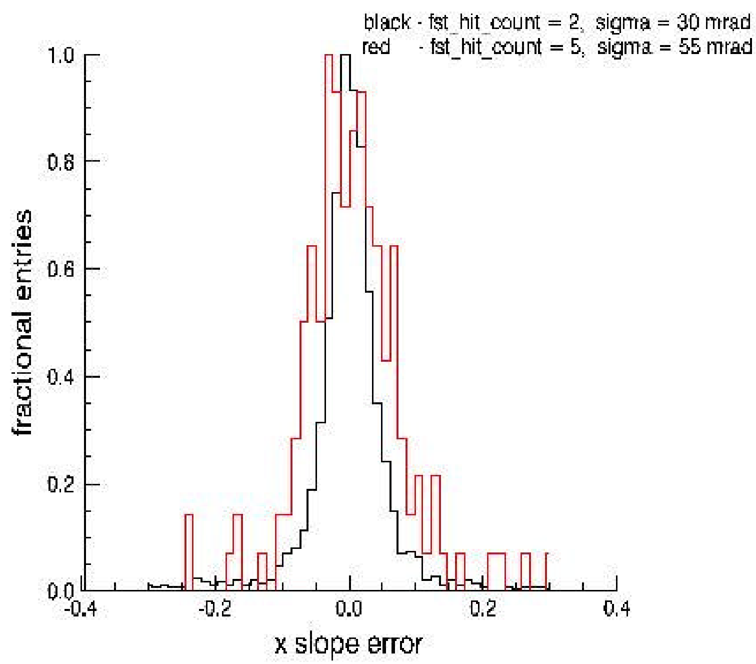


Tracking simulations

First Hit Count - Topologies

X Slope 100 MeV, normal incident angle, for the different topologies

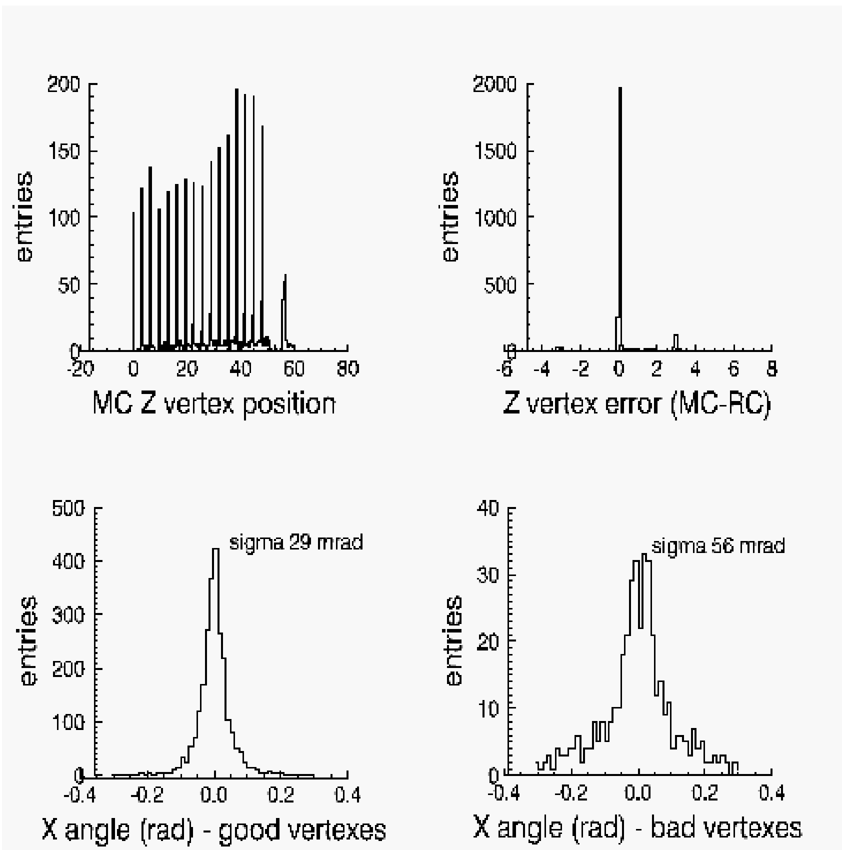




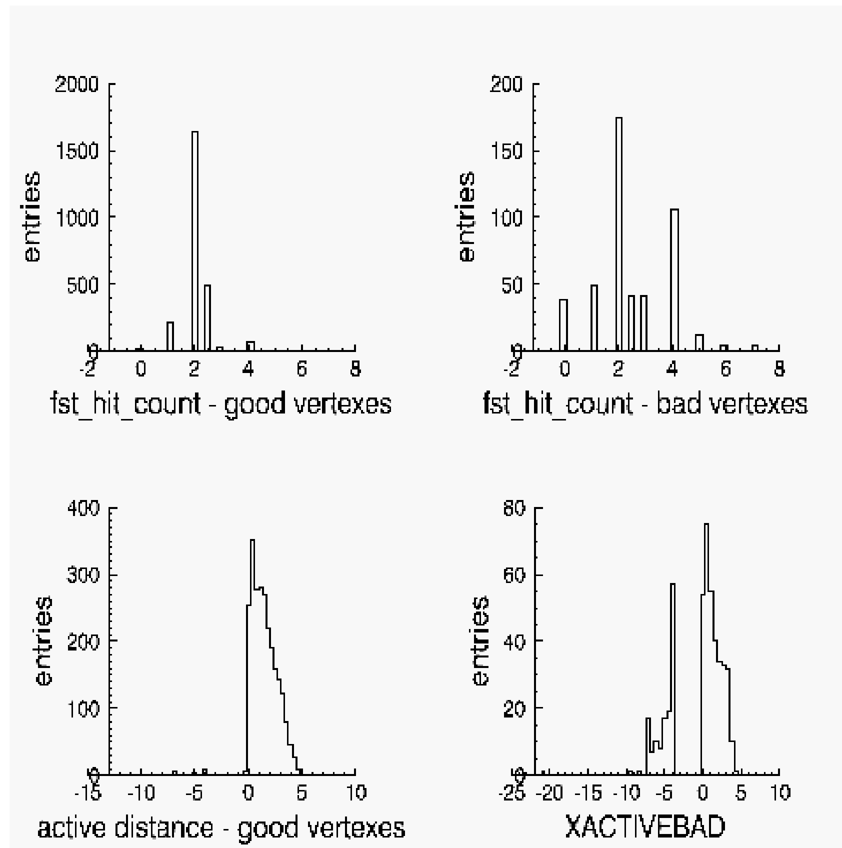
Tracking simulations

Vertex Determination Studies

X slope distributions for the well reconstructed and erroneous vertexes



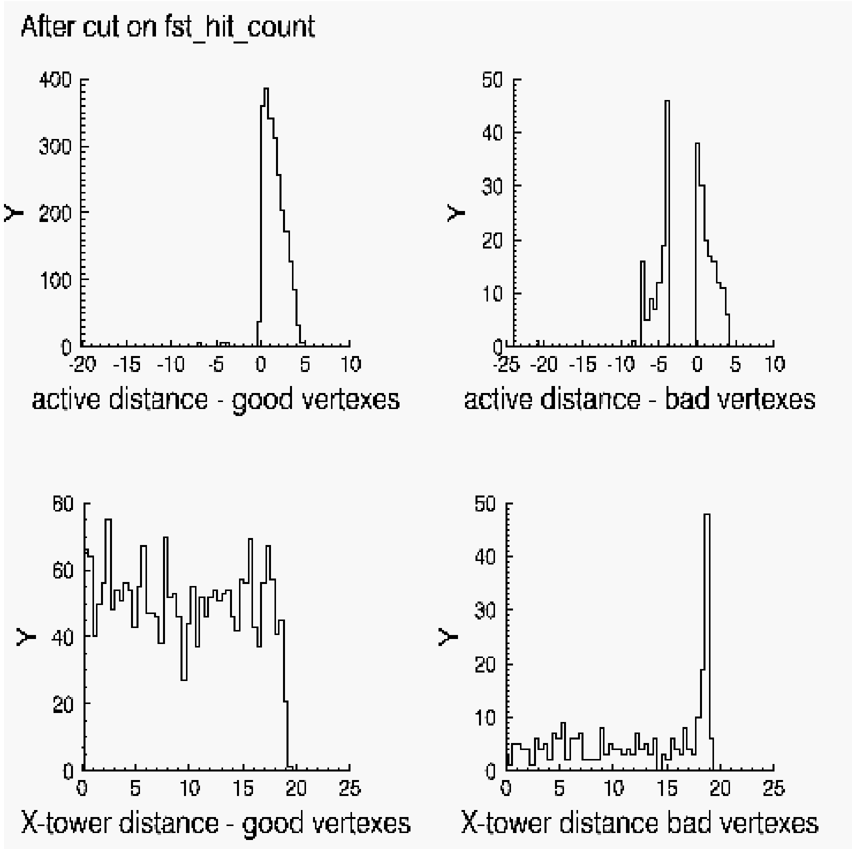
First Hit Count and *Active Distance* for well reconstructed and erroneous vertexes



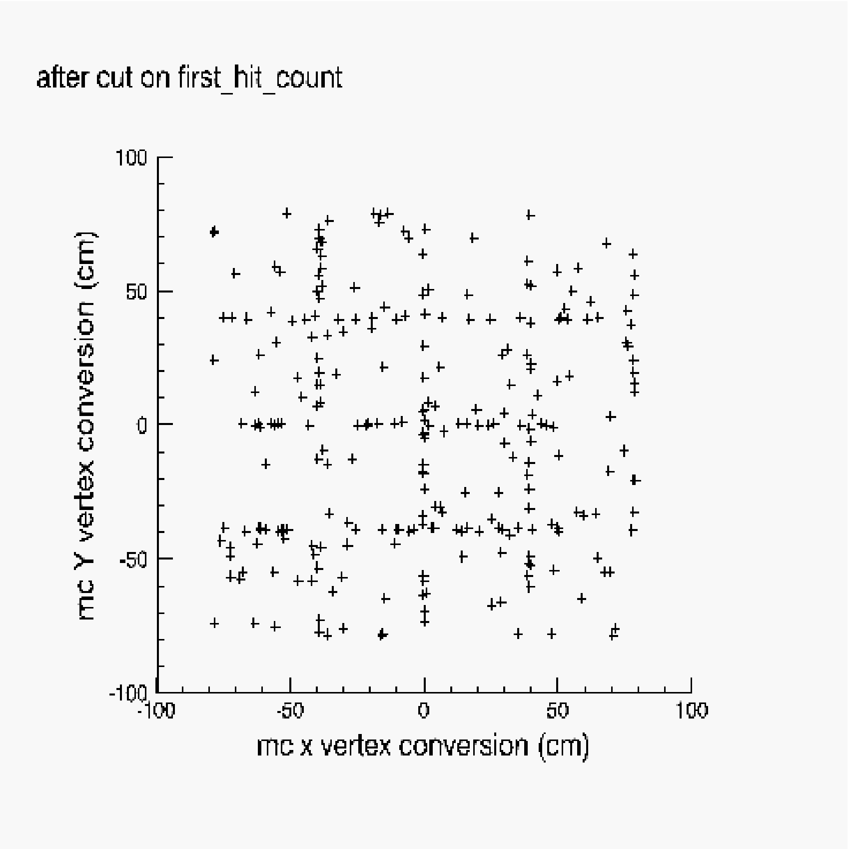
Tracking simulations

Vertex Determination Studies

Active Distance and *distance to the tower boundary* for the well reconstructed and erroneous vertexes after the cut on *first hit count*



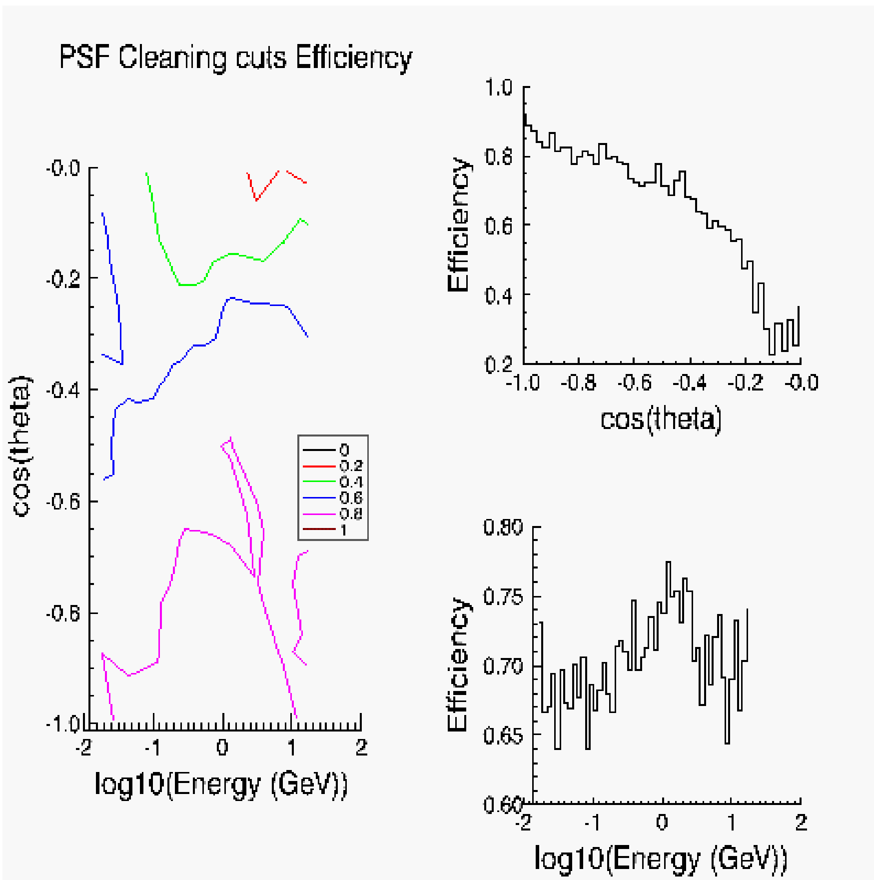
MC position of the erroneous vertexes after the cut on *first hit count*



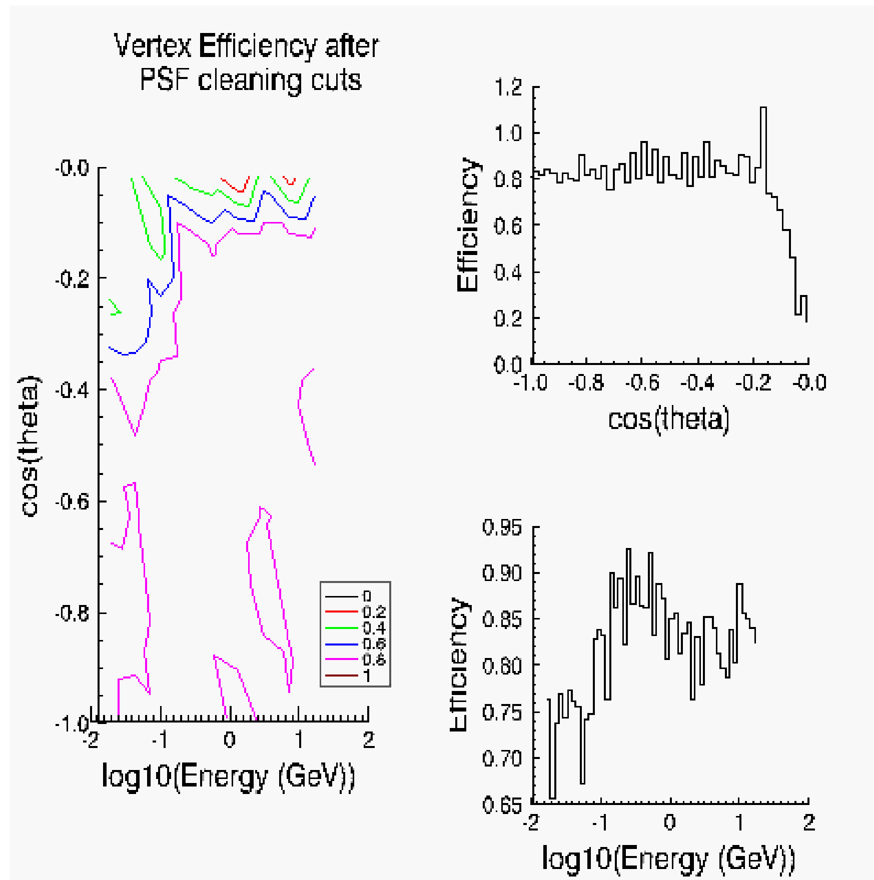
Tracking simulations

Vertex determination studies

First hit count Cut efficiency as a function of energy and incident angle



First hit count Cut enhancement as a function of energy and incident angle



Tracking simulations

GLAST acceptance

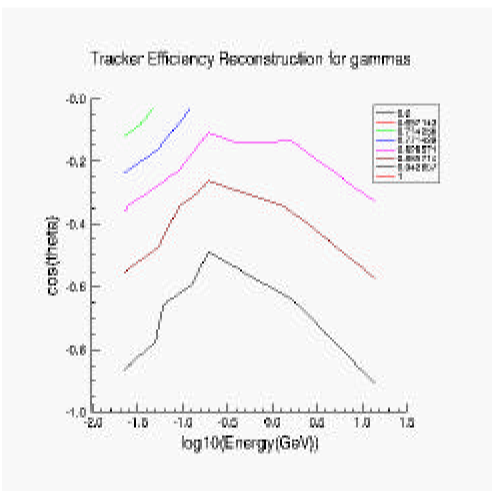
The aspect ratio (high/width) of GLAST

The main design parameter of the tracker is

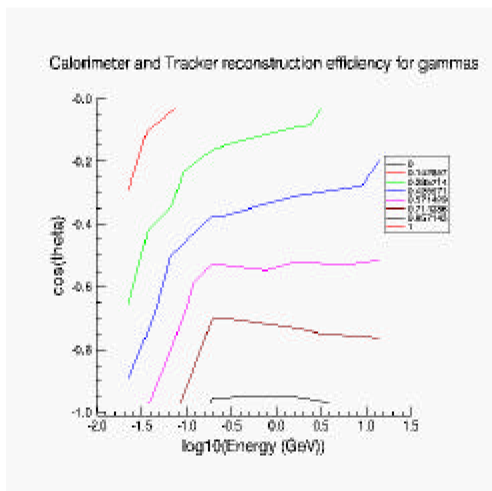
the ratio ***pitch/gap*** between planes

The smaller the pitch, the lower the distance between gaps.

That **enhances** the **FoV** and the **acceptance** of the Detector

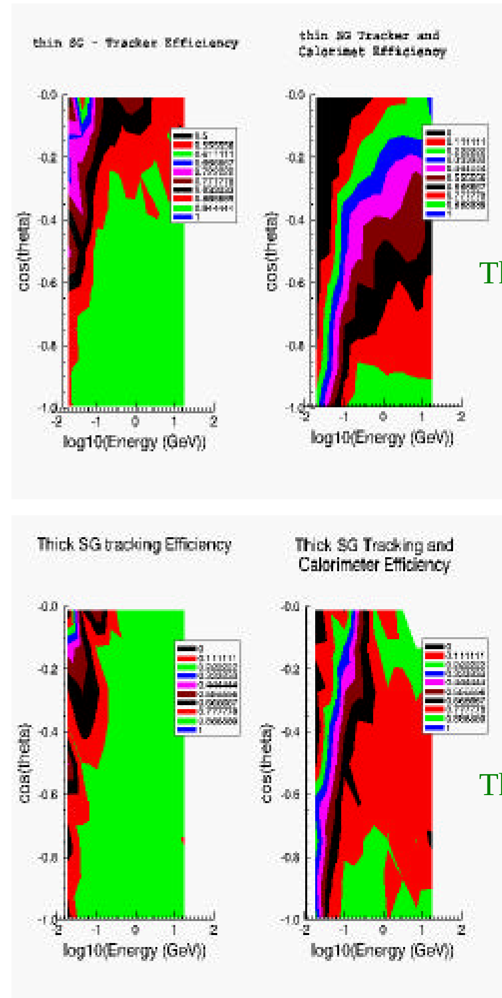


Tracking Efficiency Reconstruction (Baseline)



Tracking and Calorimeter Efficiency Reconstruction (Baseline)

U. California, Santa Cruz



Thin converters

Thick converters

Tracking Efficiency (left) and Calorimeter (right) (SuperGLAST)

Tracking simulations

Conclusions

The Pair Fit/Kalman Filter reconstruction

- works in acceptable level for the A0 y it is very efficient.
- It serves as a solid framework for further developments.
- It a good approximation to our tracking reconstruction problem.
- It needs to be tune up, understood, and its potential explored.
- There are problems with analysis variables that need to be understood immediately.

GLAST is a Vertex detector

- The PSF (specially at low energies) depends on the event topology.
- In order to be able to separate and identify the different gamma conversion topologies, GLAST needs a precise determination of the interaction vertex
- Or in other words, GLAST should be a fine granularity (fine pitch) tracking detector.
- GLAST should accurate determinate the conversion vertex.

Tracking simulations

Angular distributions

Angular distributions for normal incident angles