Finding and Fitting

- A Recast of Traditional GLAST Finding: Combo
- A Recast of the Kalman Filter
- Setting the e^+e^- Energies
- Vertexing: How to put the tracks together
- Bottom Line: PSF & A_{eff}

Strips/Clusters to Space Points

A basic to GLAST is the 3-in-a-row trigger: 3 consecutive X-Y planes firing within a microsecond.

This yields possible space points.

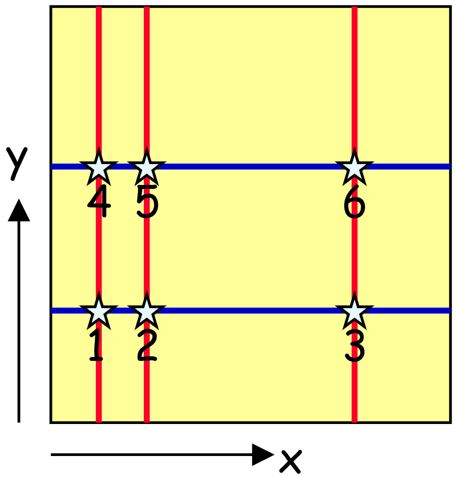
Step one: build an object which can cycle over the allowed X-Y pairing in a given GLAST measuring layer

a) Ordered just as they come X's then Y's

b) Ordered with reference to closeness to a given space point

Case a)

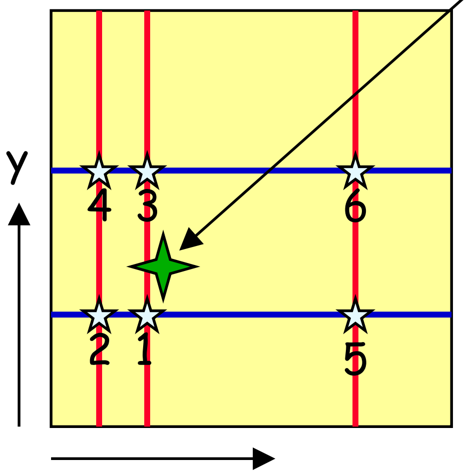
(nextHit)



Case b)

(x,y) Point from which to search

(nearestHit)



Combo Pat Rec - Kalman Overview

Pattern Recognition

First Pass Best Track — Calorimeter Based or Blind Search

Hit Flagging — Allow up to 5 shared Clusters

Second Pass All the others — Blind Search

Set Energies — Global Energy Constrained Track Energy

Track Fitting

Final Fits — Kalman Track Fit

γ Creation — Track Averaging: energy + errors determine weights (Not Vertexing)

The "Combo" Pat. Rec. (Details)

Starting Layer: One furthest from the calorimeter

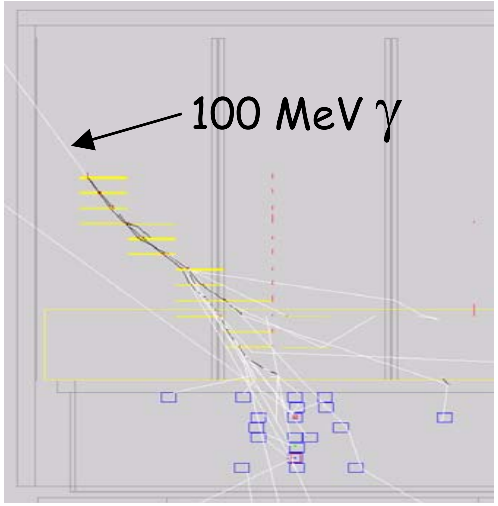
Two Strategies:

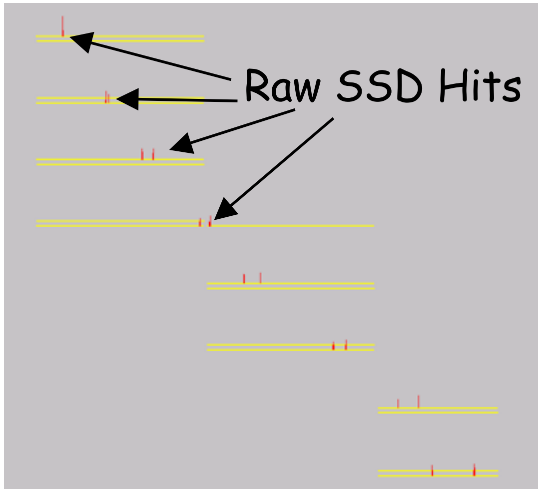
1) Calorimeter Energy present ⟹ An energy centroid (space point!)

2) Too little Cal. Energy ⟹ use only Track Hits

"Combo" Pattern Recognition - Processing an Example Event:

The Event as produce by GLEAM

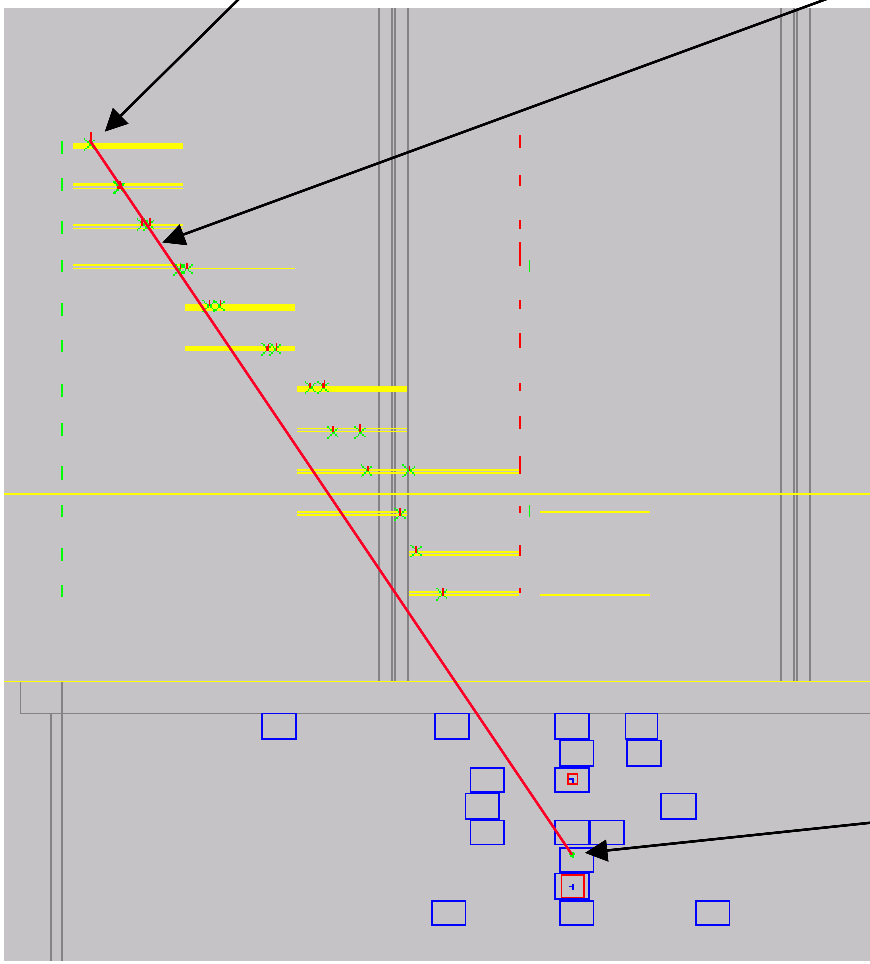


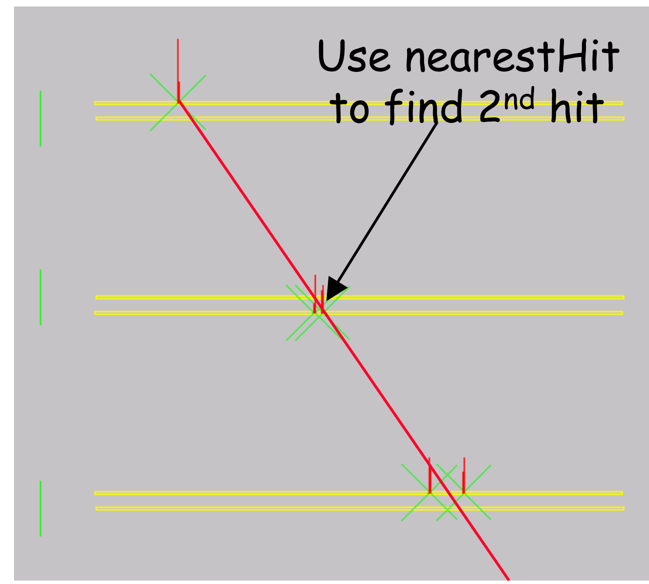


The “Combo” Pat. Rec. (Details)

Start with hits in outer most layer

First Guess: connect hit with
Cal. Centroid

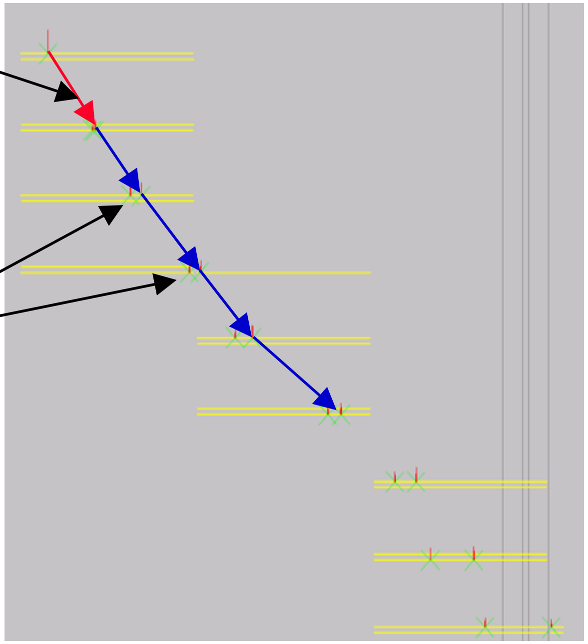


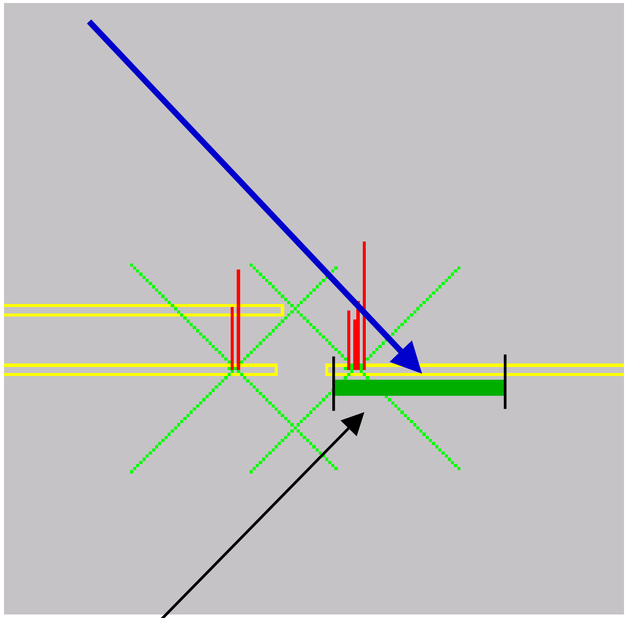


Sufficient Cal. Energy (42 MeV)
Use Cal. centroid

The “Combo” Pat. Rec. (Details)

Initial Track Guess:
Connect first 2 Hits!





Project and Add
Hits Along the
Track within
Search Region

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

The default region is 9σ (set very wide at this stage)

The “Combo” Pat. Rec. (Details)

The Blind Search proceeds similar to the Calorimeter based Search

- •1st Hit found found - tried in combinatoric order
- •2nd Hit selected in combinatoric order
- •First two hits used to project into next layer -
- •3rd Hit is searched for -
- •If 3rd hit is found, track is built by “finding - following” as with Calorimeter search

In this way a list of tracks is formed.

Crucial to success, is ordering the list!

(Optimization work still in progress)

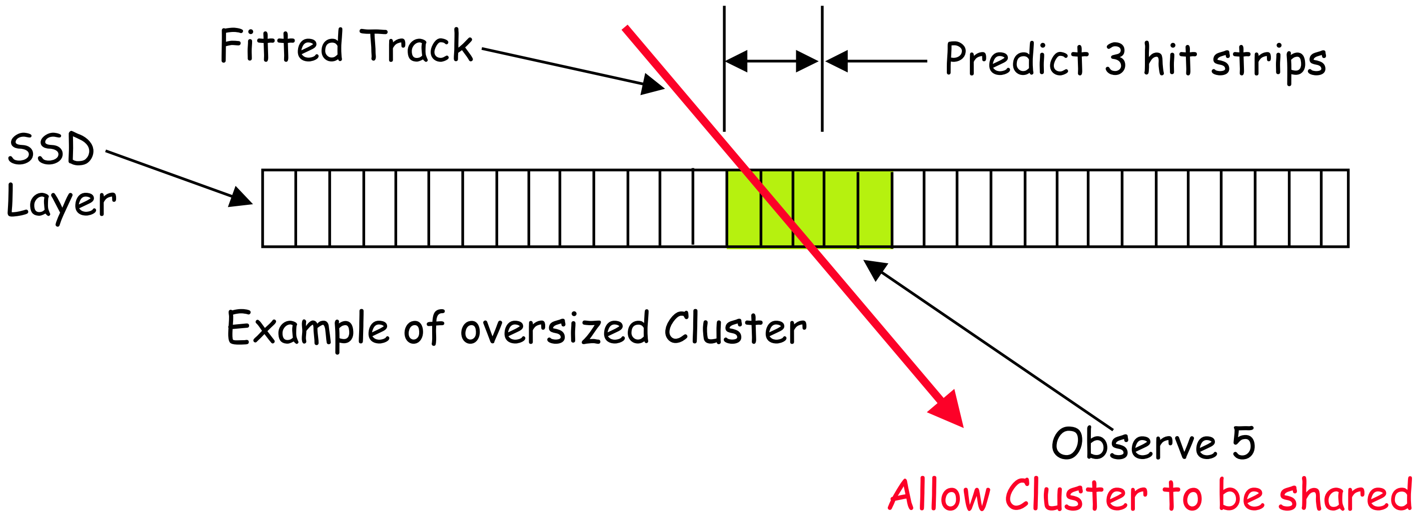
Hit Sharing

Hit Flagging (or Sharing)

In order not to find the same track at most 5 clusters can be shared

The first X and Y cluster (nearest the conversion point) is always allowed to be shared

Subsequent Clusters are shared depending on the cluster width and the track's slope



Kalman Filter

The Kalman filter process is a successive approximation scheme to estimate parameters

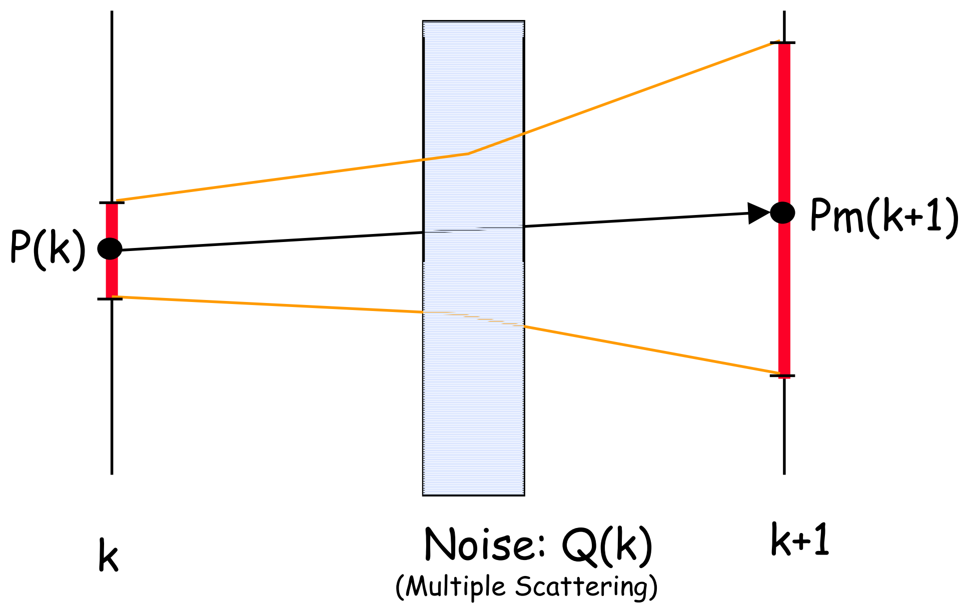
Simple Example: 2 parameters - intercept and slope: $x = x_0 + S_x * z$; $P = (x_0, S_x)$

Errors on parameters x_0 & S_x: covariance matrix: $C = \begin{pmatrix} Cx\text{-}x & Cx\text{-}s \\ Cs\text{-}x & Cs\text{-}s \end{pmatrix}$

$Cx\text{-}x = \langle (x-x_m)(x-x_m) \rangle$

In general

$C = \langle (P - P_m)(P-P_m)^T \rangle$



Propagation:

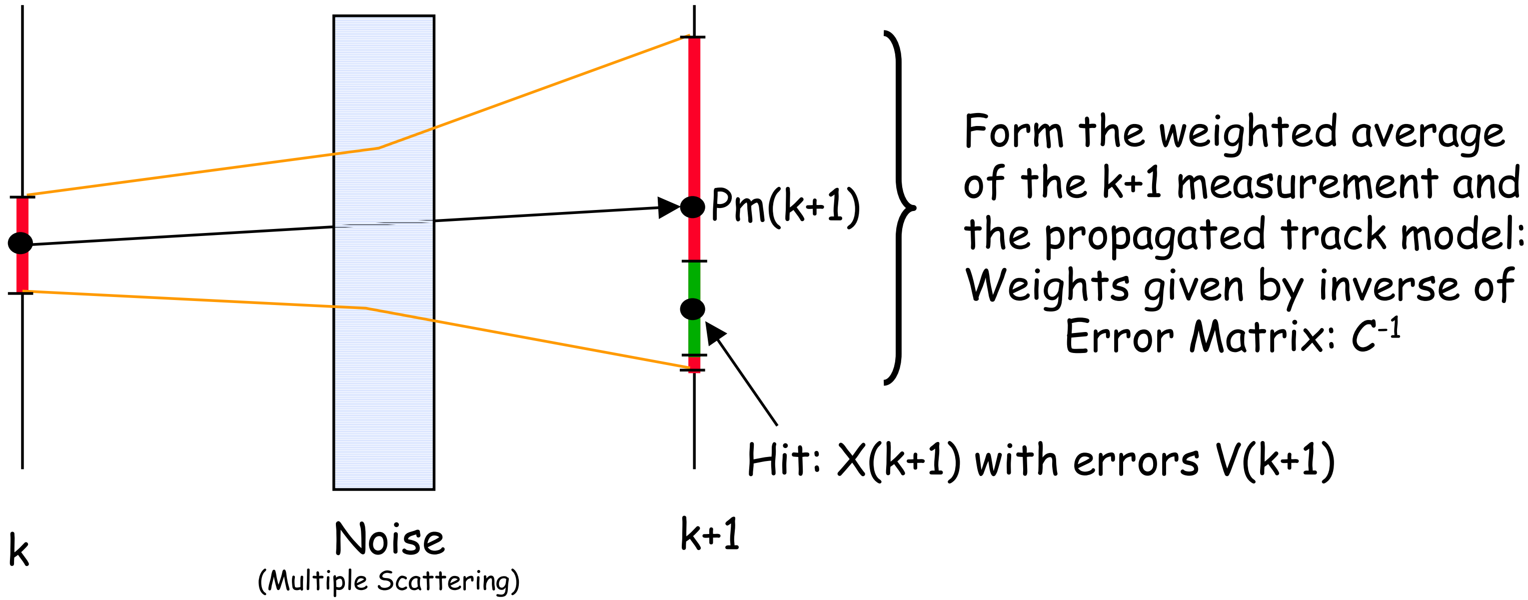
$x(k+1) = x(k)+Sx(k)*(z(k+1)-z(k))$

$Pm(k+1) = F(\delta z) * P(k)$ where

$$F(\delta z) = \begin{pmatrix} 1 & z(k+1)-z(k) \\ 0 & 1 \end{pmatrix}$$

$$Cm(k+1) = F(\delta z) * C(k) * F(\delta z)^T + Q(k)$$

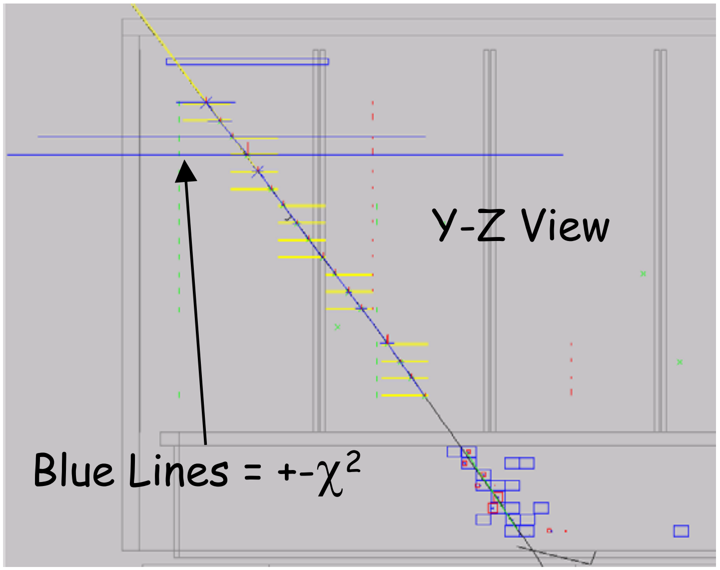
Kalman Filter (2)

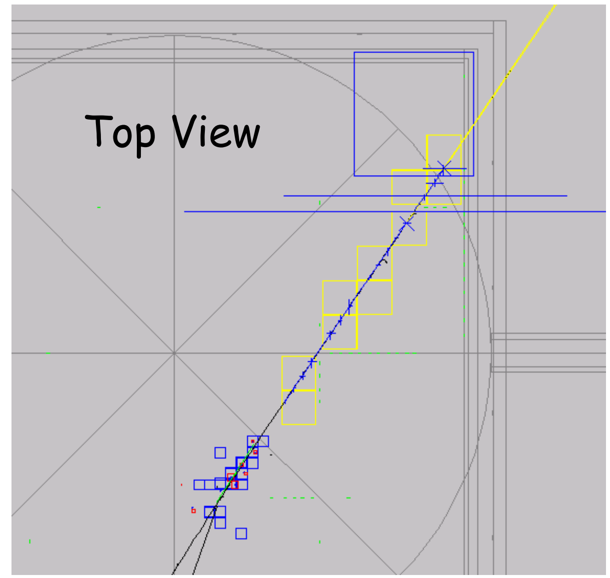


$$P(k+1) = \frac{Cm^{-1}(k+1)*Pm(k+1) + V^{-1}(k+1)*X(k+1)}{Cm^{-1}(k+1) + V^{-1}(k+1)} \quad \text{and} \quad C(k+1) = (Cm^{-1}(k+1) + V^{-1}(k+1))^{-1}$$

Now its repeated for the k+2 planes and so - on. This is called FILTERING - each successive step incorporates the knowledge of previous steps as allowed for by the NOISE and the aggregate sum of the previous hits.

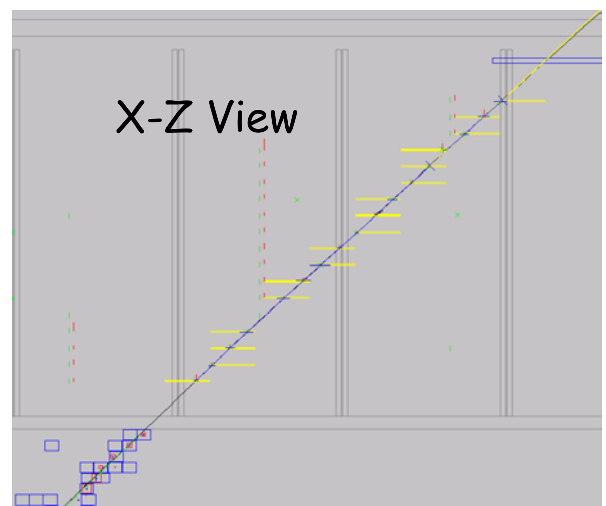
χ^2 and the 1-Event Display





3 Views of a 1 GeV μ^+

Note: χ^2 = (Residual)^2



Kalman Filter: Sea Trials

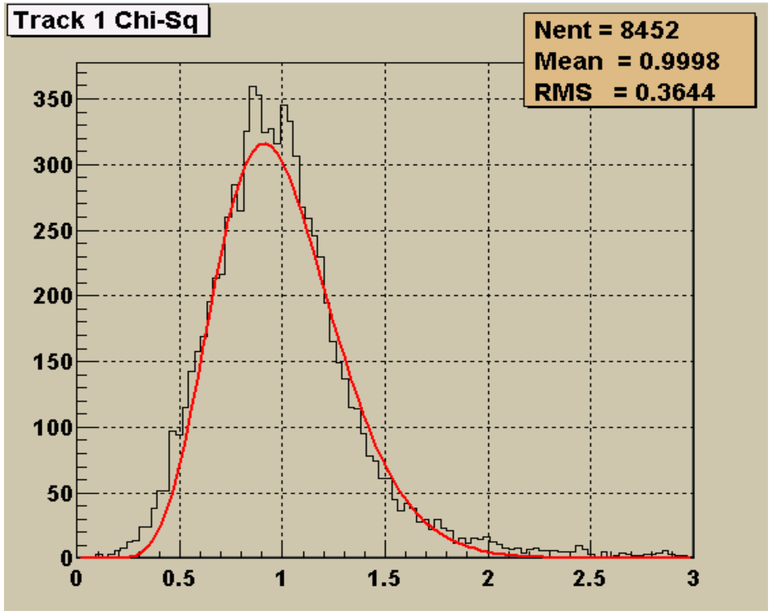
Use μ's and give the true energy to Kalman Filter

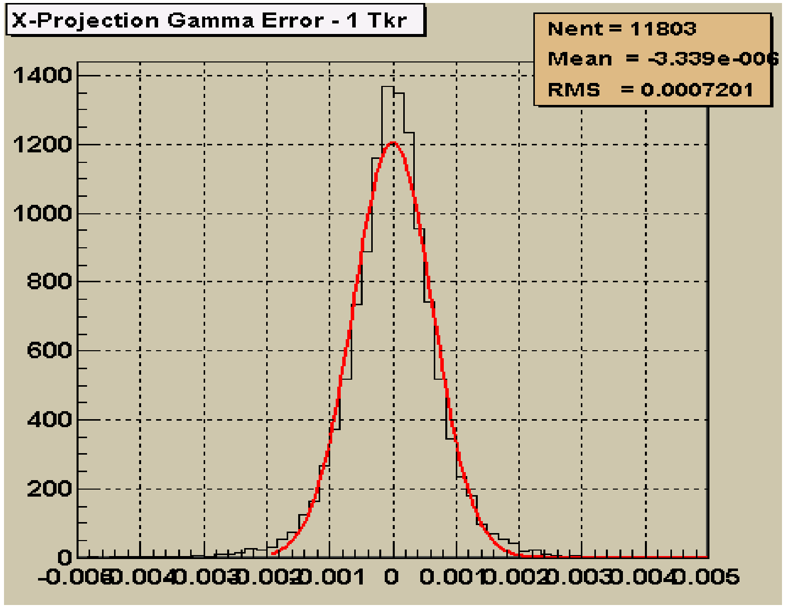
Several Problems discovered During "Sea Trails" Phase

- Proper setting of measurement errors
- Proper inclusion of energy loss (for μ's - Bethe-Block)
- Proper handling of over-sized Clusters

End Results: Example 10 GeV μ's

$\langle N_{hits} \rangle = 24$ $\langle \chi^2 \rangle = 1.0/\text{DoF}$ $\langle \sigma_{FIT} \rangle = .63$ mrad





Setting the Energies

Track energies are critical in determining the errors
(because of the dominance of Multiple Scattering)

A Three Stage Process:

- Kalman Energies: compute the RMS angle between 3D Track segments
  Key: include material audit and reference energy back to first layer
  Results: $\sigma_{E\text{-Kalman}}$ ~ 35% @ 100 MeV (!)

- Determine Global Energy:
  E_{Global} ⇨ Hit counting + Calorimeter Energy
  (Resolution limited by Calorimeter response)
  Results: Depends on Cuts - Best ~ 12% at 100 MeV

- Use Global Energy to Constrain the first 2 track energies:
  $E_{Golbal} = E1_{Kal} + x1{*}\sigma 1_{Kal} + E2_{Kal} + x2{*}\sigma 2_{Kal}$
  $\chi^2 = x1^2 + x2^2$
  Determine x1 & x2 by minimizing χ^2

The Constrained Energies are then used in the FINAL FIT

The Final Fits & Creating a γ

A second pass through the Kalman Fit is done

- Using the Constrained Energies for the First two tracks - others use the default Pat. Rec. energy
- The Track hits are NOT re-found - the hits from the Pat. Rec. stage are used

Creating a γ: (Note this isn't true "Vertexing")

- Tracks are MS dominated - NOISE Dominated Verticizing - adding NOISE coherently
- Use tracks as ~ independent measures of γ direction
- Process:
  - Check that tracks "intersect" - simple DOCA Calc.
  - Estimate Combined direction using Track Errors and Constrained Energies to form the weights

The Bottom Line: How does it all Work?

Data for 100 MeV, Nrm. Inc.

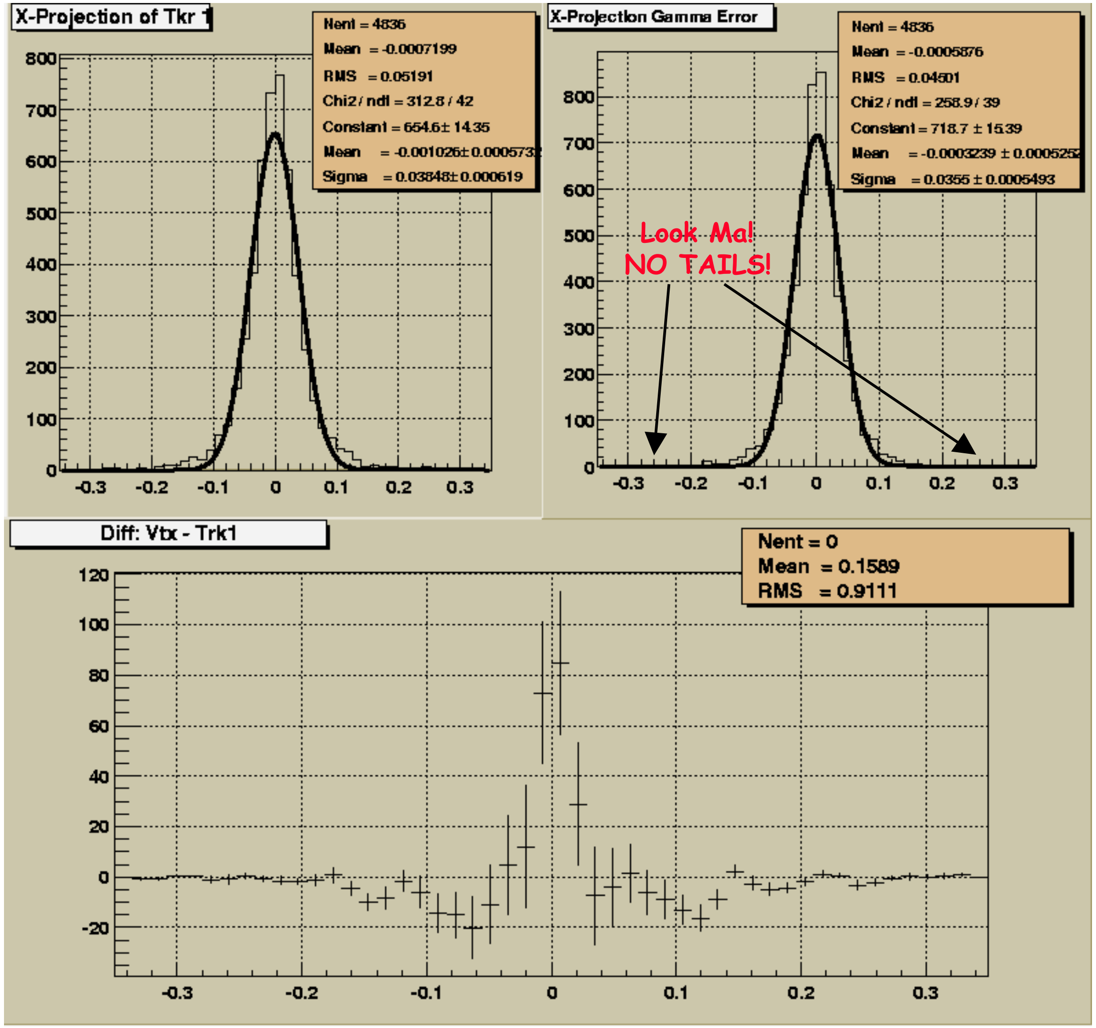
Thin Section Only - Req. All Events to have 2 Tracks which formed a "vertex"
Results: A_{eff} ~ 3000 cm^2

Best Track Resolution:
39 mrad (PSF ~ 3.3 Deg.)

γ Resolution:
35 mrad (PSF ~ 3.0 Deg)

Difference Plot Shows the Improvement!

But… the story is even Better!



GLAST

Dialing in Your PSF!

The PSF for γ's turn out to depend on the
Opening Angle between the 2 Tracks

In retrospect this is now Obvious! - Parallel Tracks ⇨ minimal MS!