Fermi LAT Event Reconstruction Gallery

Fermi Summer School
June 2011

Outline

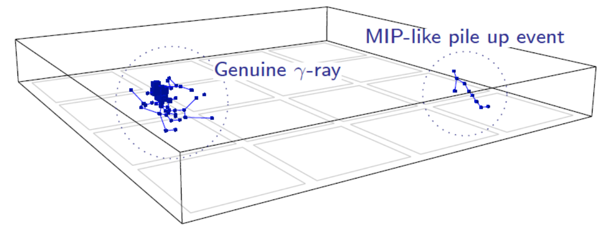
- Subsystem Reconstruction
  - CAL
  - TKR
  - ACD
- Event Level Reconstruction
  - Energy
  - Direction
  - Event Classification
- Caveats:
  - This talk shows a mix of things we are doing, and things we will do in the future
  - Lots of pictures, not many details

CAL RECONSTRUCTION

CAL Roles (Slide from Instrument Talk)

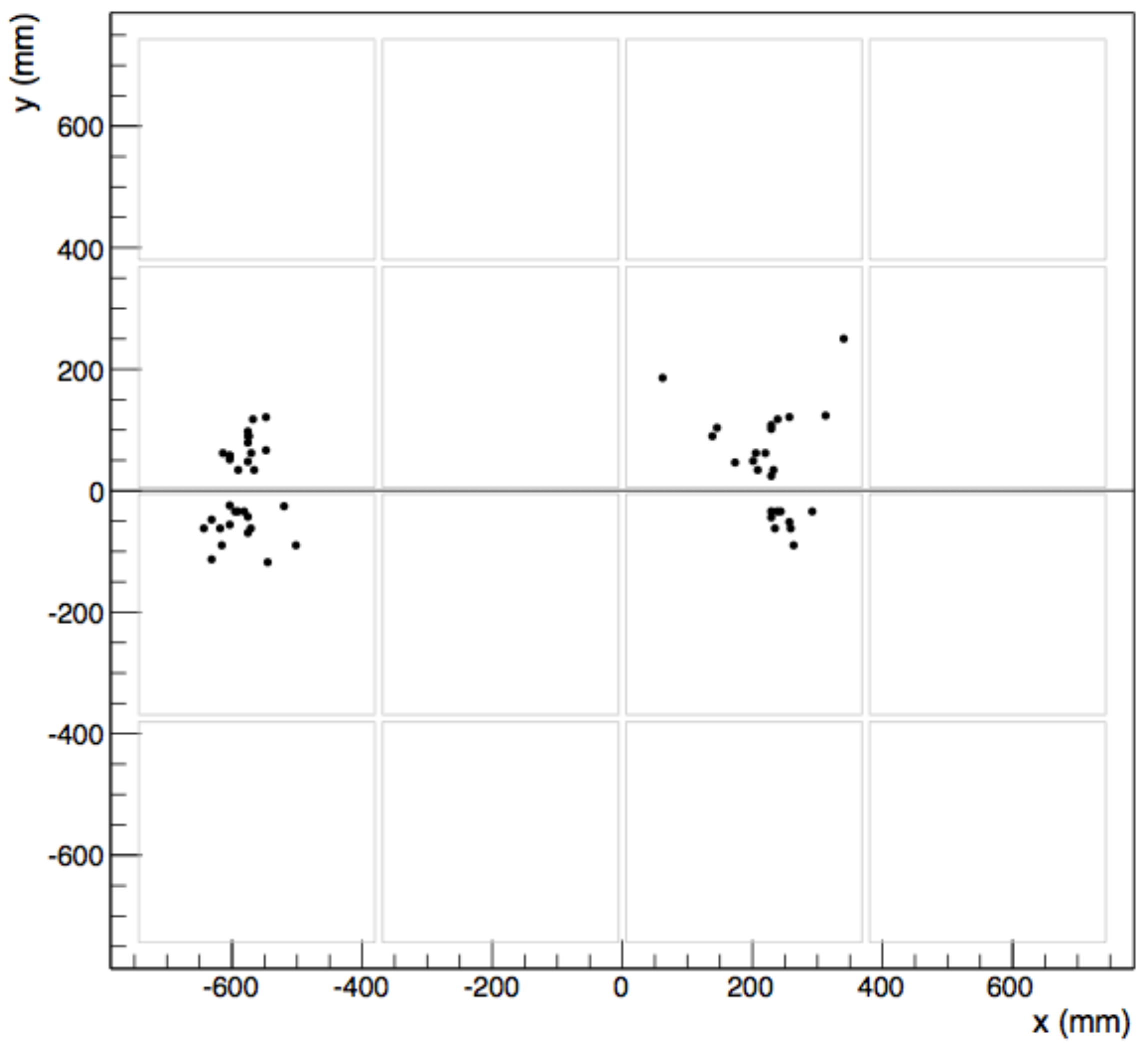
- **Primary Roles:**
  - Energy reconstruction
  - Contributes to event trigger
- **Other Roles:**
  - "Energy Flow" axis at high energy
    - Seeds tracker pattern-recognition in complicated events
  - Background rejection
    - Shower topology e^+e^- versus hadrons
    - Specific backgrounds
      - Up-going particles
      - Backsplash
  - Projection to ACD

CAL Reconstruction (Slide from Instrument talk)

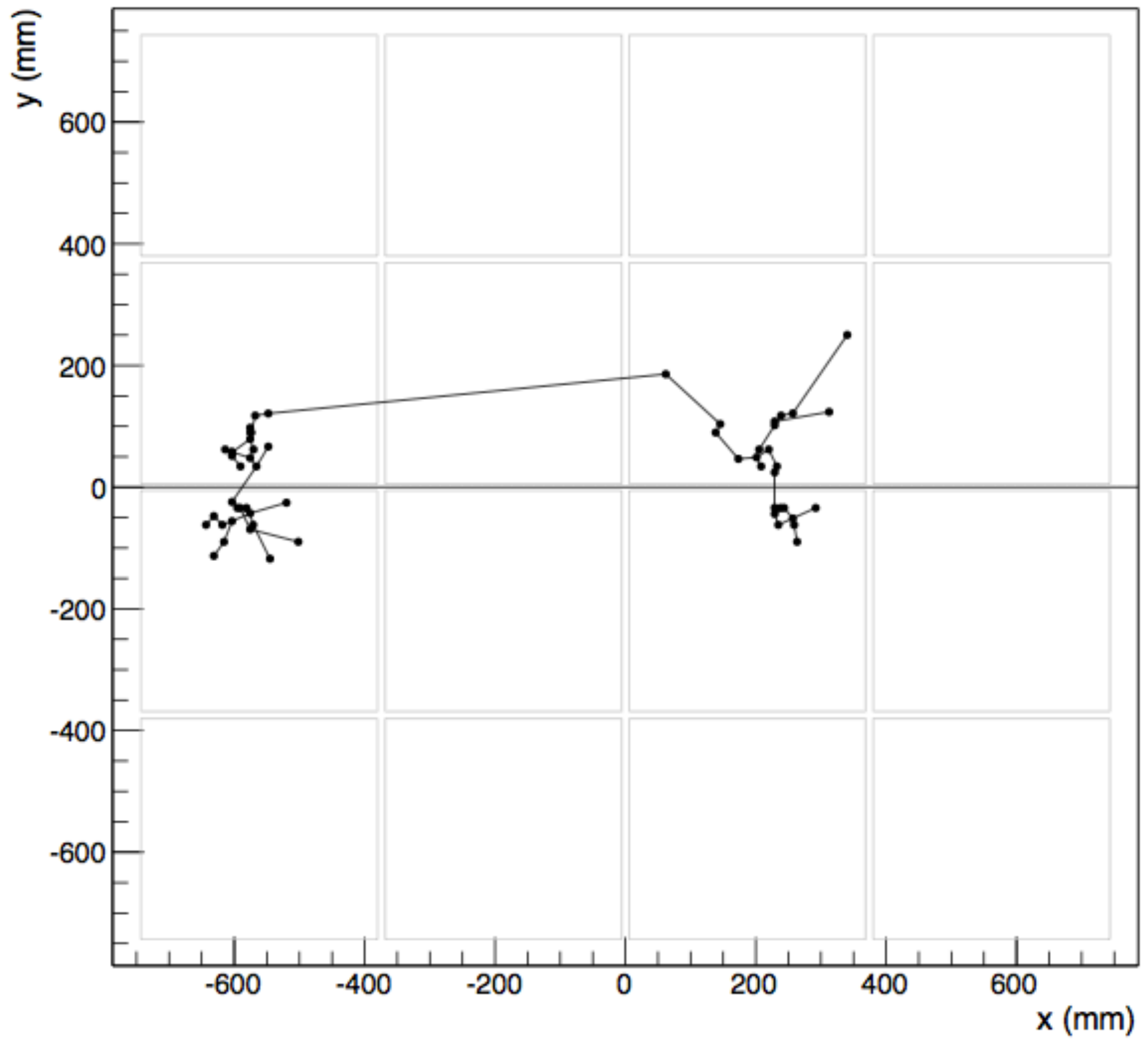


- Apply per-crystal calibration
- Clustering: group hits into clusters (TBD)
  - Up to now treat whole CAL as single cluster
- Moments analysis
  - Iterative procedure, minimize RMS w.r.t. shower axis
    - Cluster centroid (x,y,z)
    - Cluster axis (v_x,v_y,v_z)
    - Cluster moments and spread
      - Transverse, longitudinal RMS
- Energy Reconstruction (Multiple Methods)
  - Parametric correction for leakage out sides and gaps
  - Fit to cluster profile
  - Likelihood fit for event energy

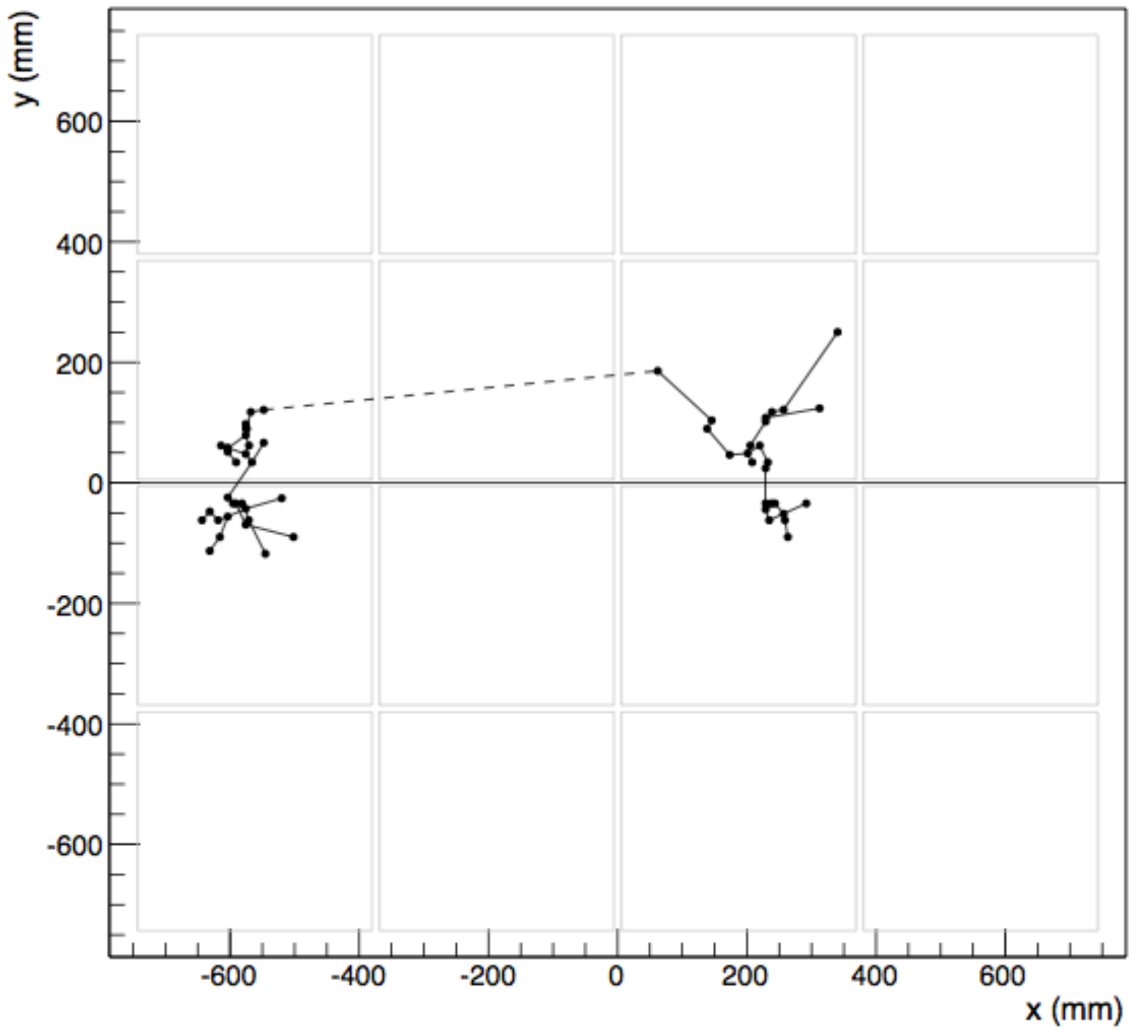
Minimal Spanning Tree Clustering



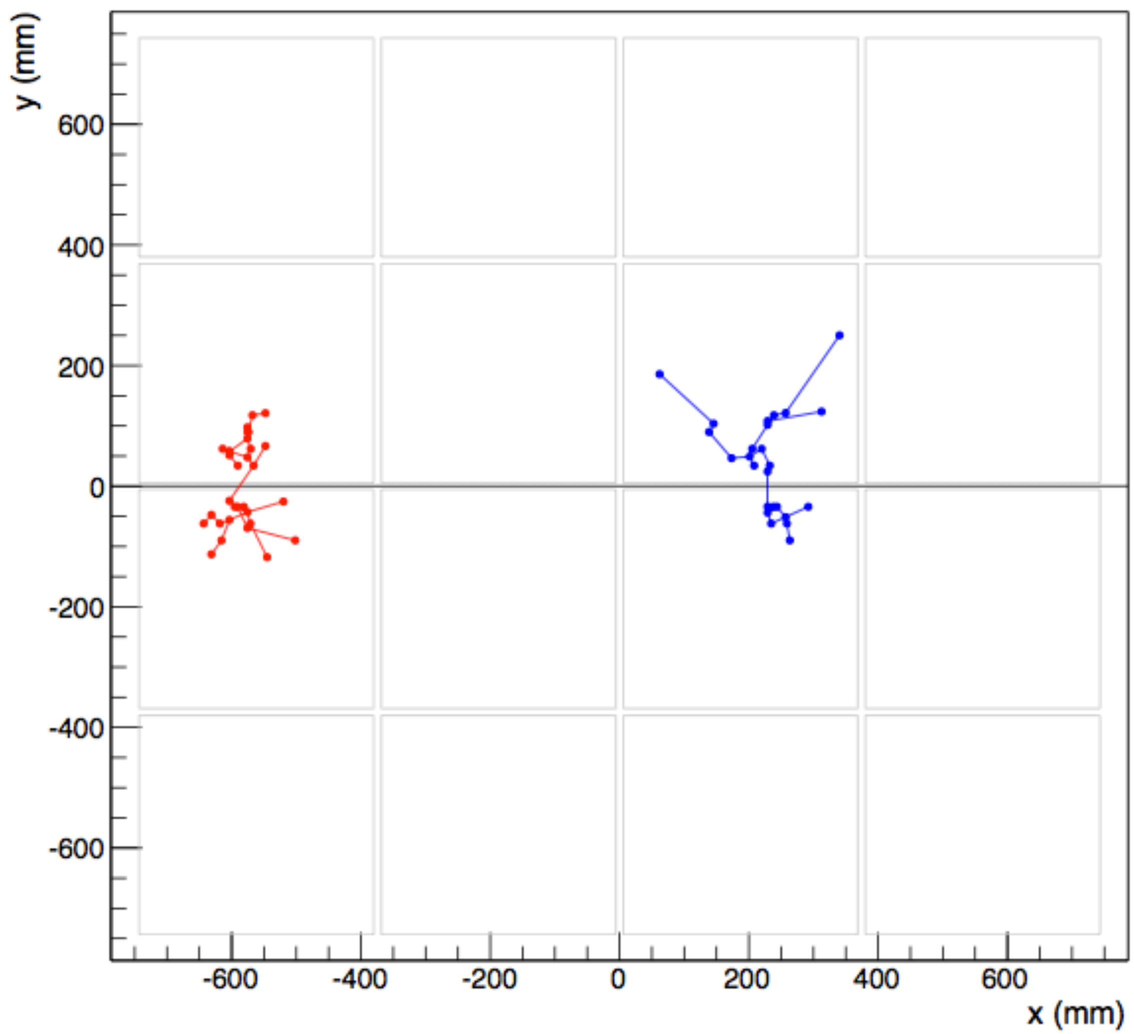
MST: Link Creation



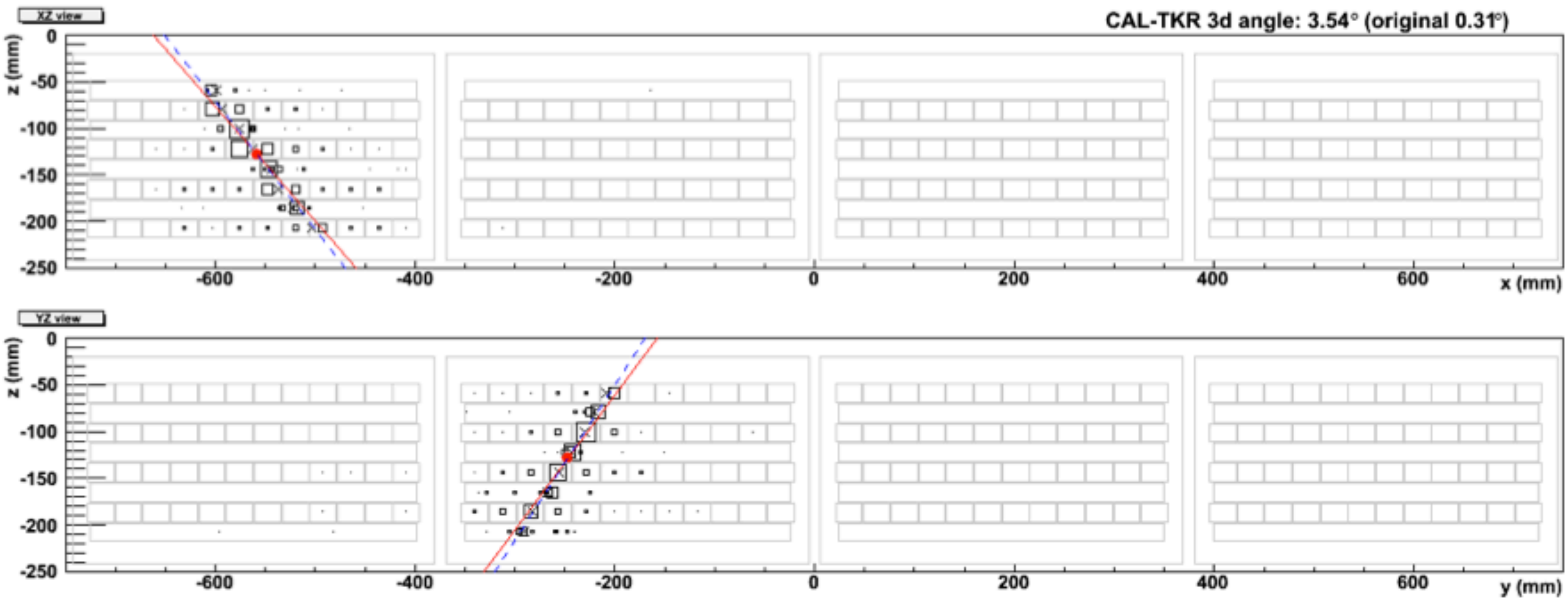
MST: Link Trimming



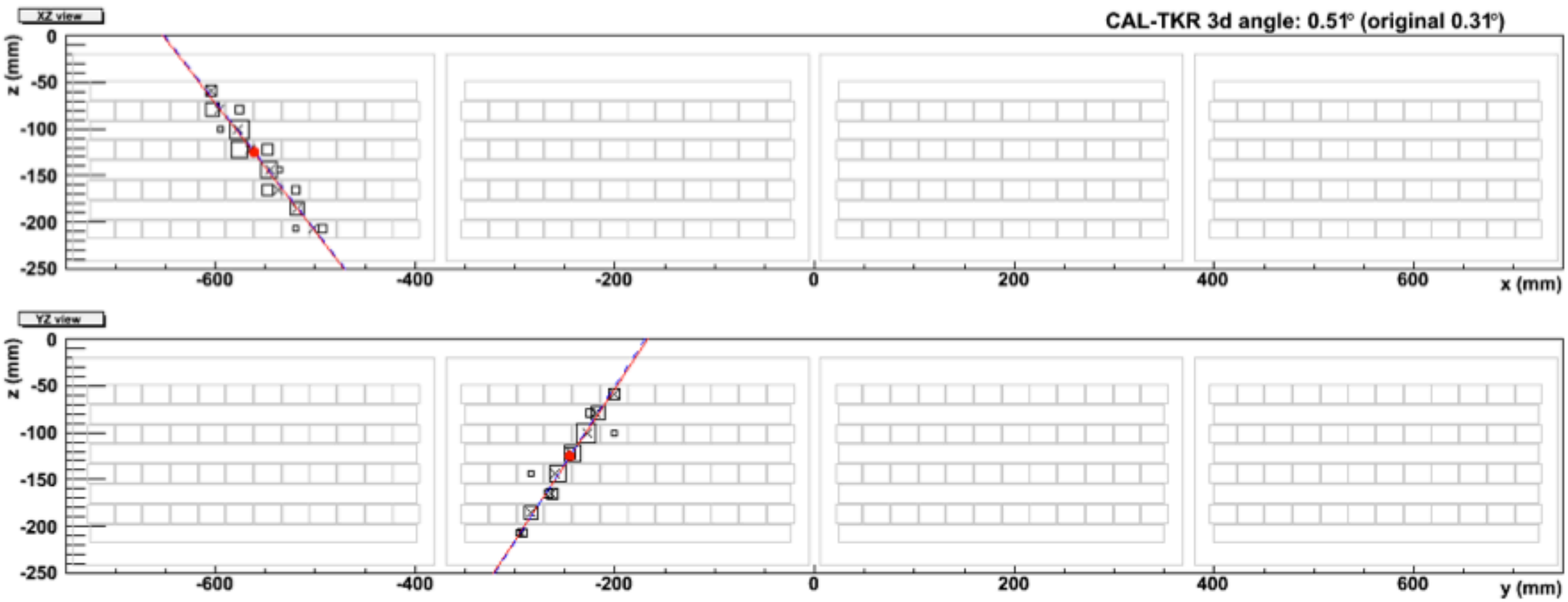
MST: Final Clusters



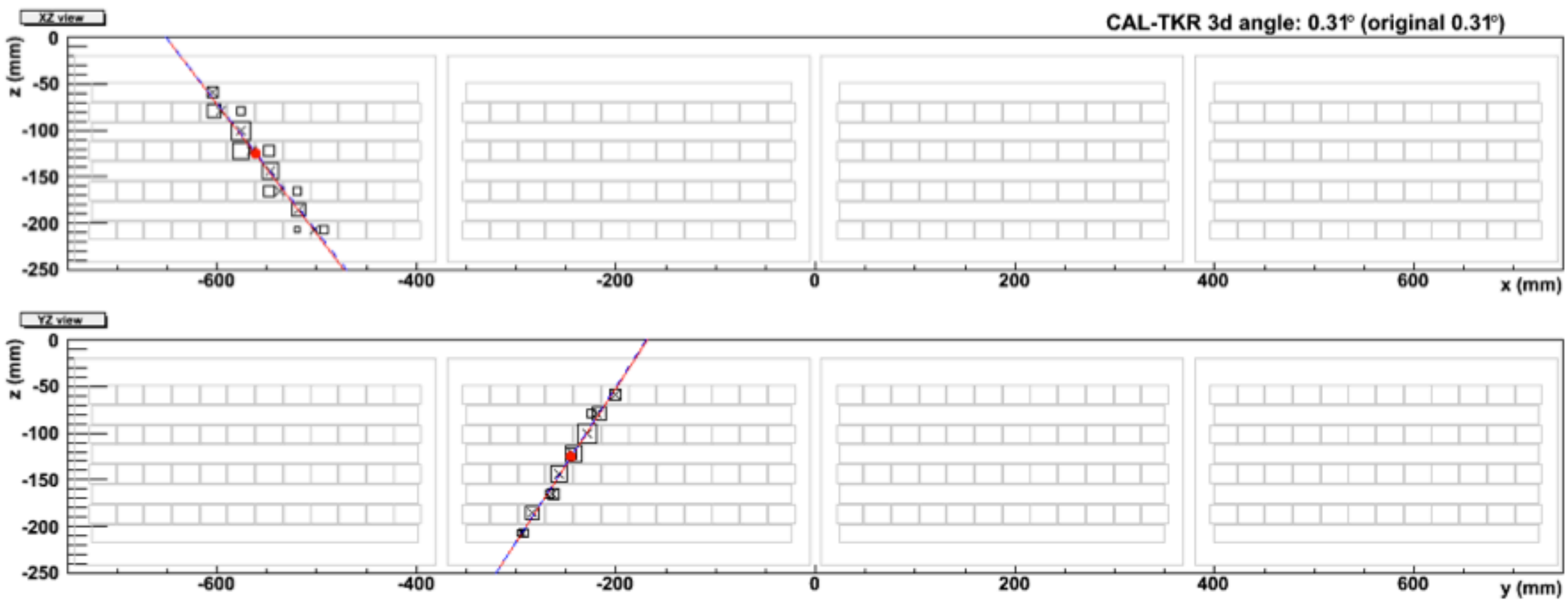
Cluster Moments Analysis: 1st Iteration



Cluster Moments Analysis: 2nd Iteration

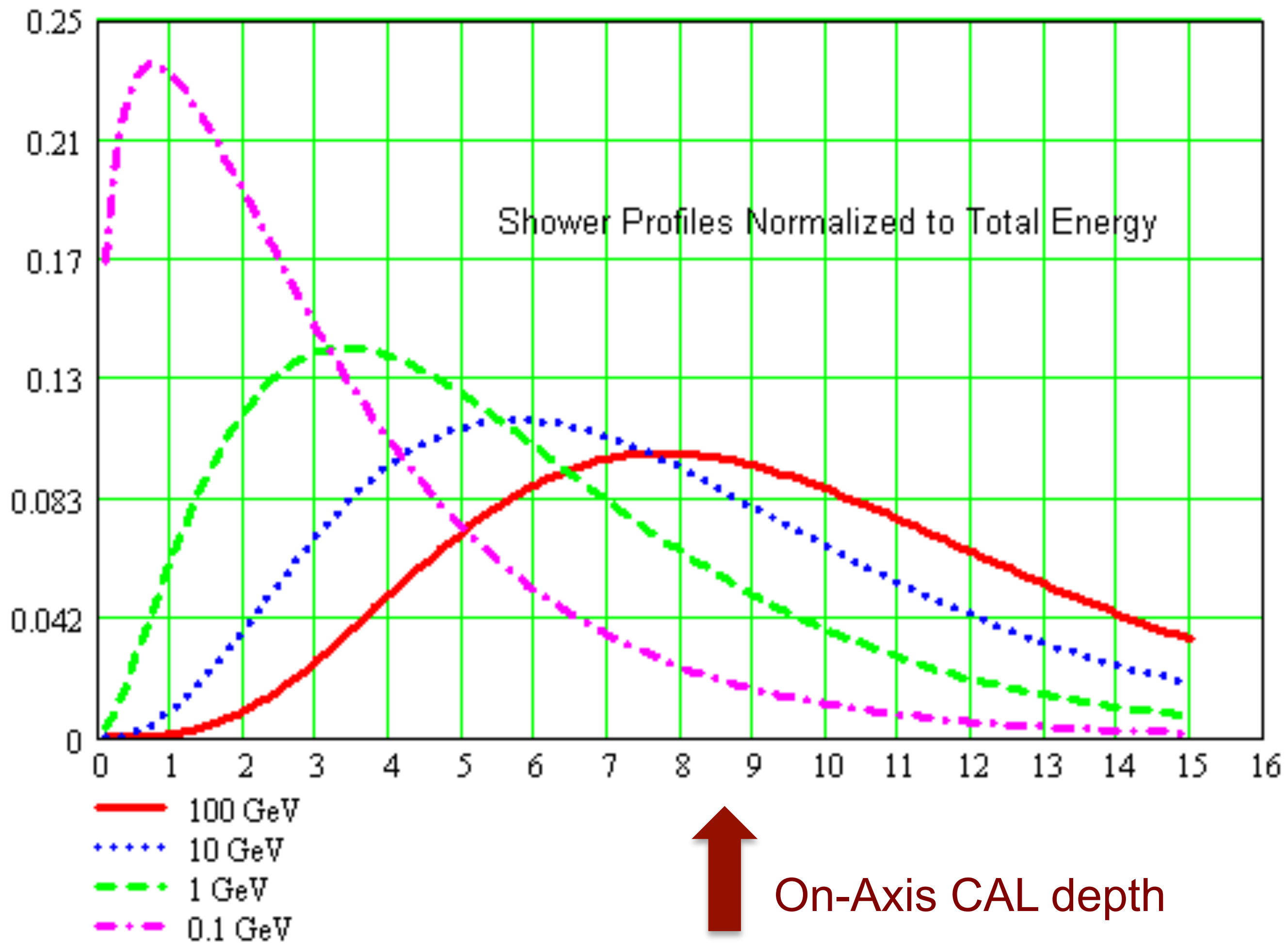


Cluster Moments Analysis: 3rd Iteration

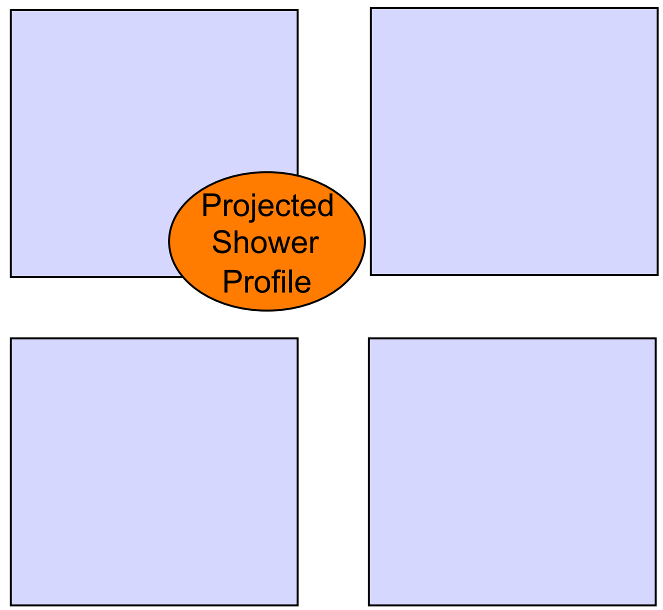


Energy Reconstruction

The Shower Profile from 100 MeV -> 100 GeV



Leakage Between Towers



TKR Reconstruction

TKR Roles (Slide from Instrument Talk)

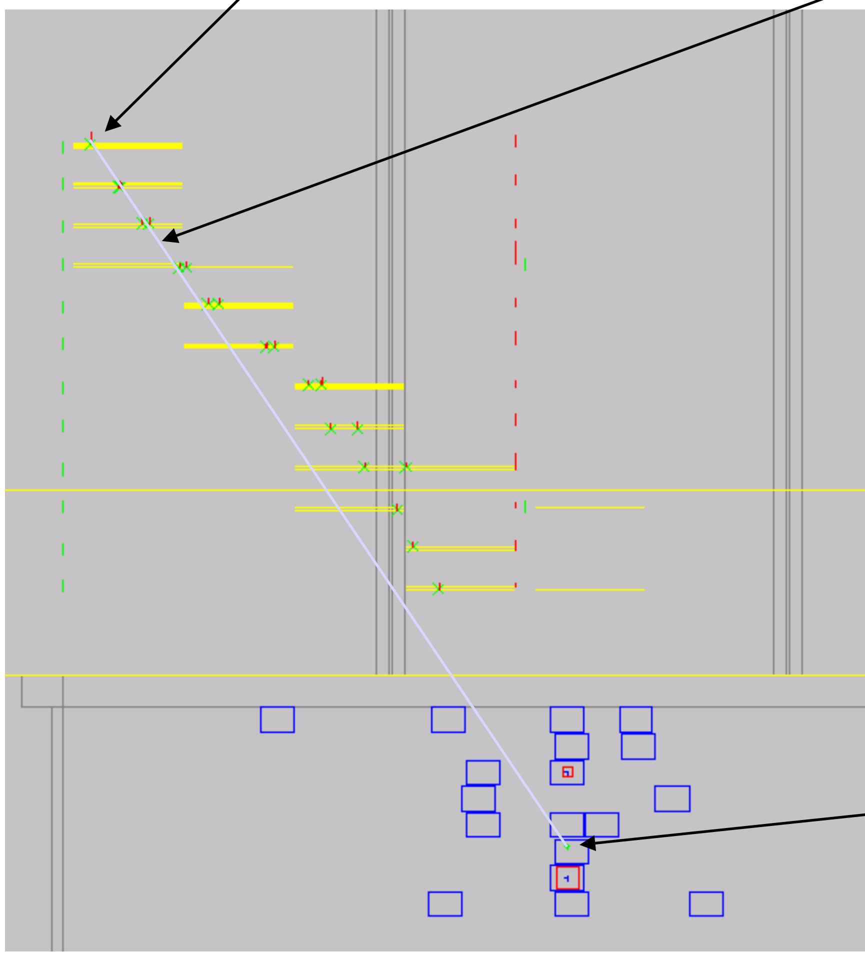
- **Primary Roles:**
  - **Direction reconstruction**
  - **Main event trigger**
- **Other roles:**
  - **Projection to CAL, ACD**
  - **Background rejection**
    - **pair-conversion**
      - **conversion vertex found?**
    - **(pre-)shower topology, e^+e^- versus hadrons**
    - **specific backgrounds**
      - **backsplash from CAL**
      - **Up-going heavy ions stopping in TKR**

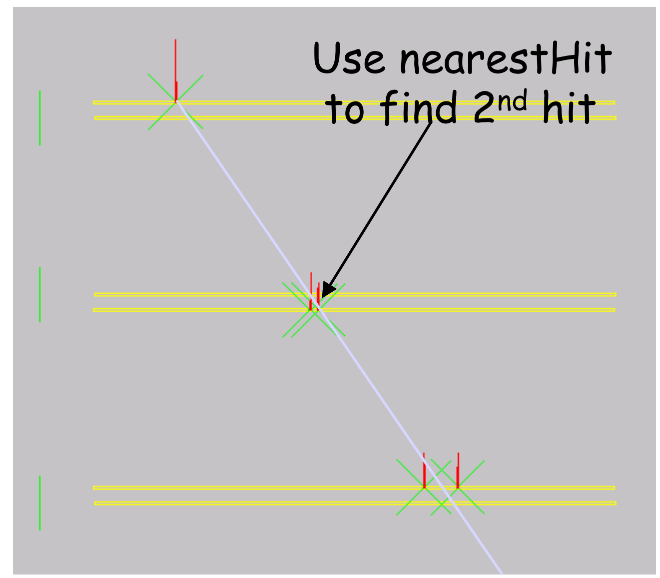
TKR Reconstruction (Slide from Instrument Talk)

- Hit clustering
  - combine adjacent hit strips in clusters
- Start with CAL direction, if available
  - useful seed for high energy events, which are complicated
- Combinatoric search for straight(ish) lines
- Propagate lines to next plane, add hits as possible
- Kalman fit/filter technique
  - Combine information (hits) with loss of information (multiple scattering)
    - Requires energy estimate to handle multiple scattering
- Order tracks by "quality"
  - Favor longest, straightest track
    - Most likely to come from event origin
- Vertexing: try to combine 2 best tracks into single item

Starting the Combinatorial Search

First Guess: connect hit with Cal. Centroid



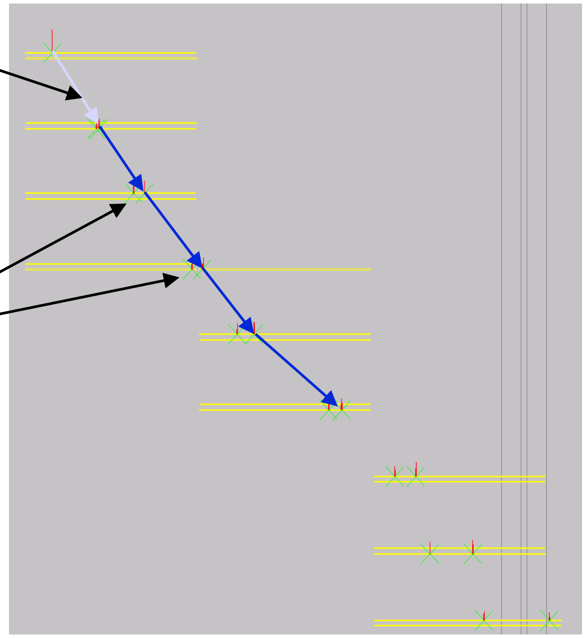


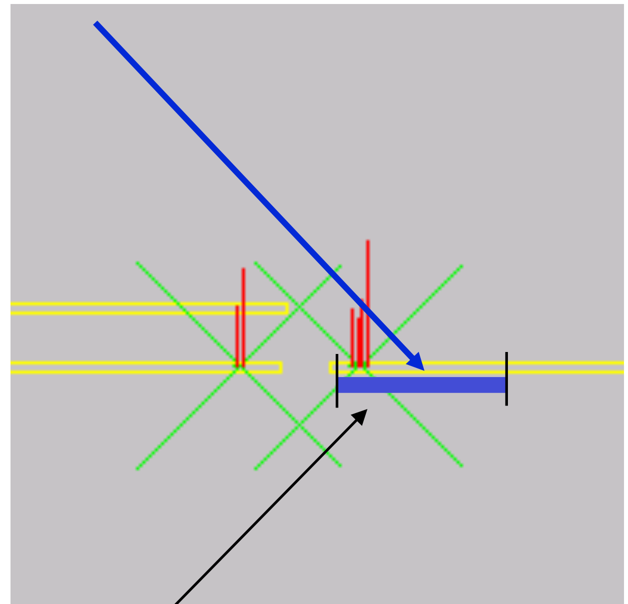
Sufficient Cal. Energy (42 MeV)
Use Cal. centroid

Progressing Layer to Layer

Initial Track Guess:
Connect first 2 Hits!

Project and Add
Hits Along the
Track within
Search Region

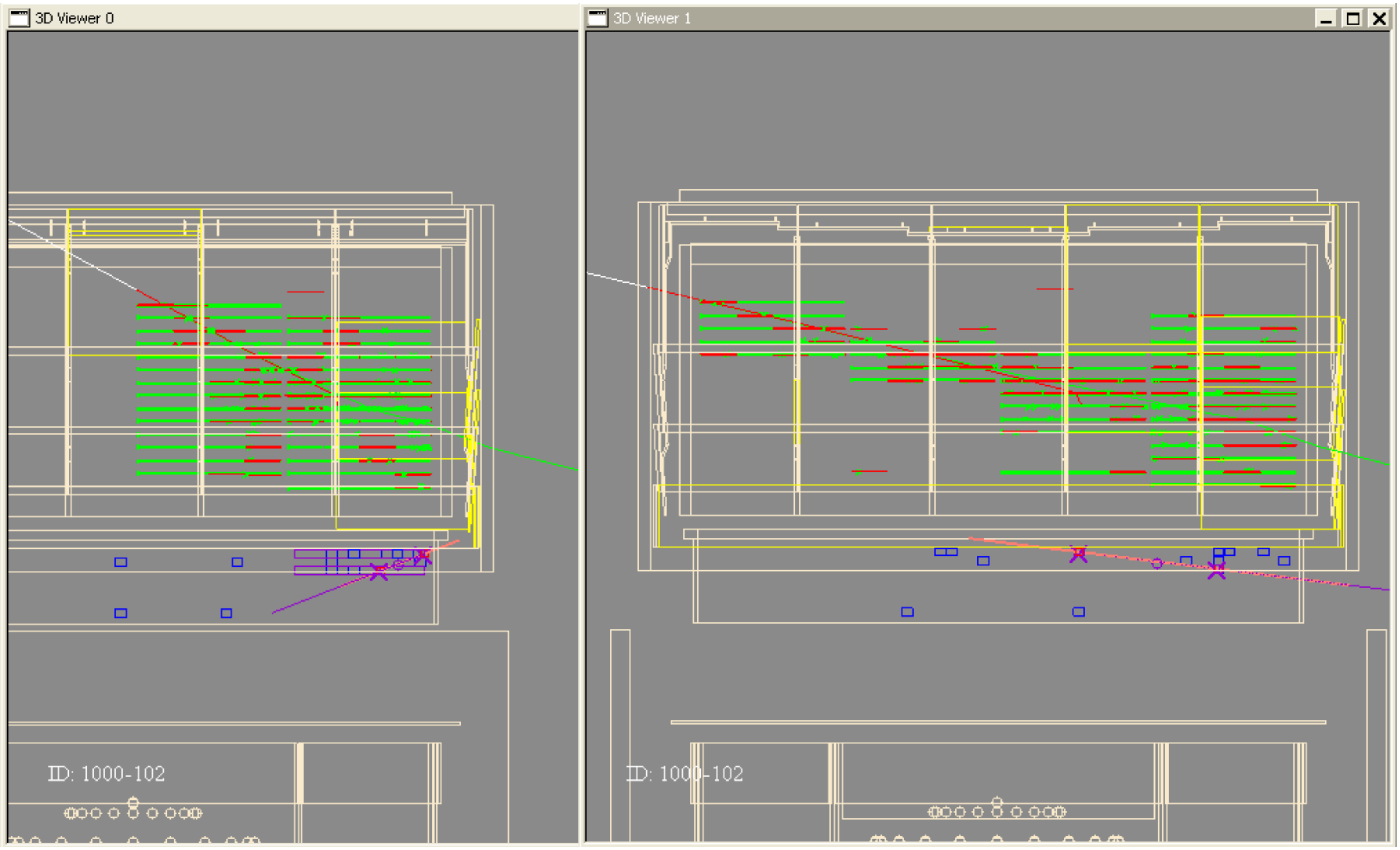




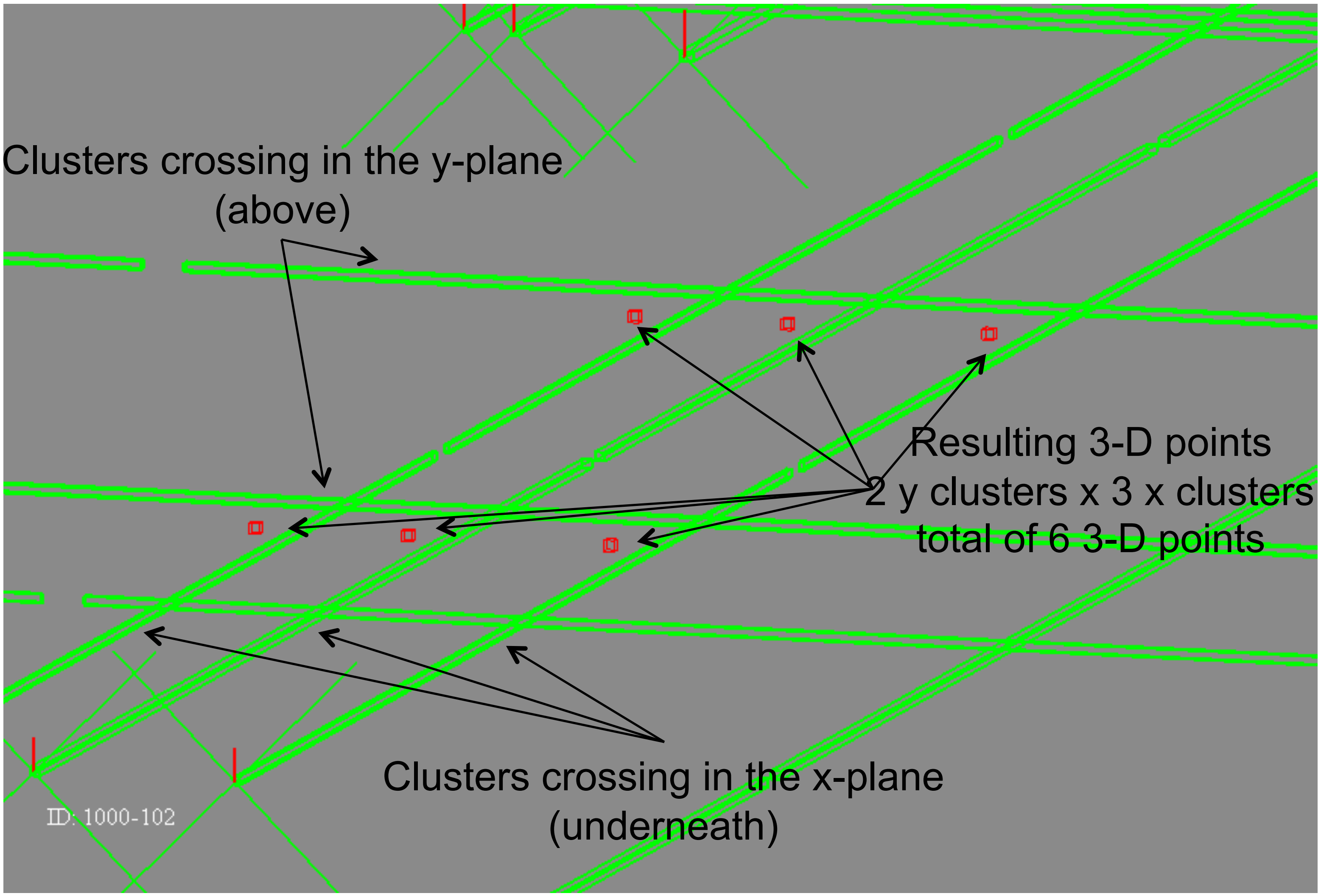
The search region is set by propagating the track errors through the GLAST geometry.

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

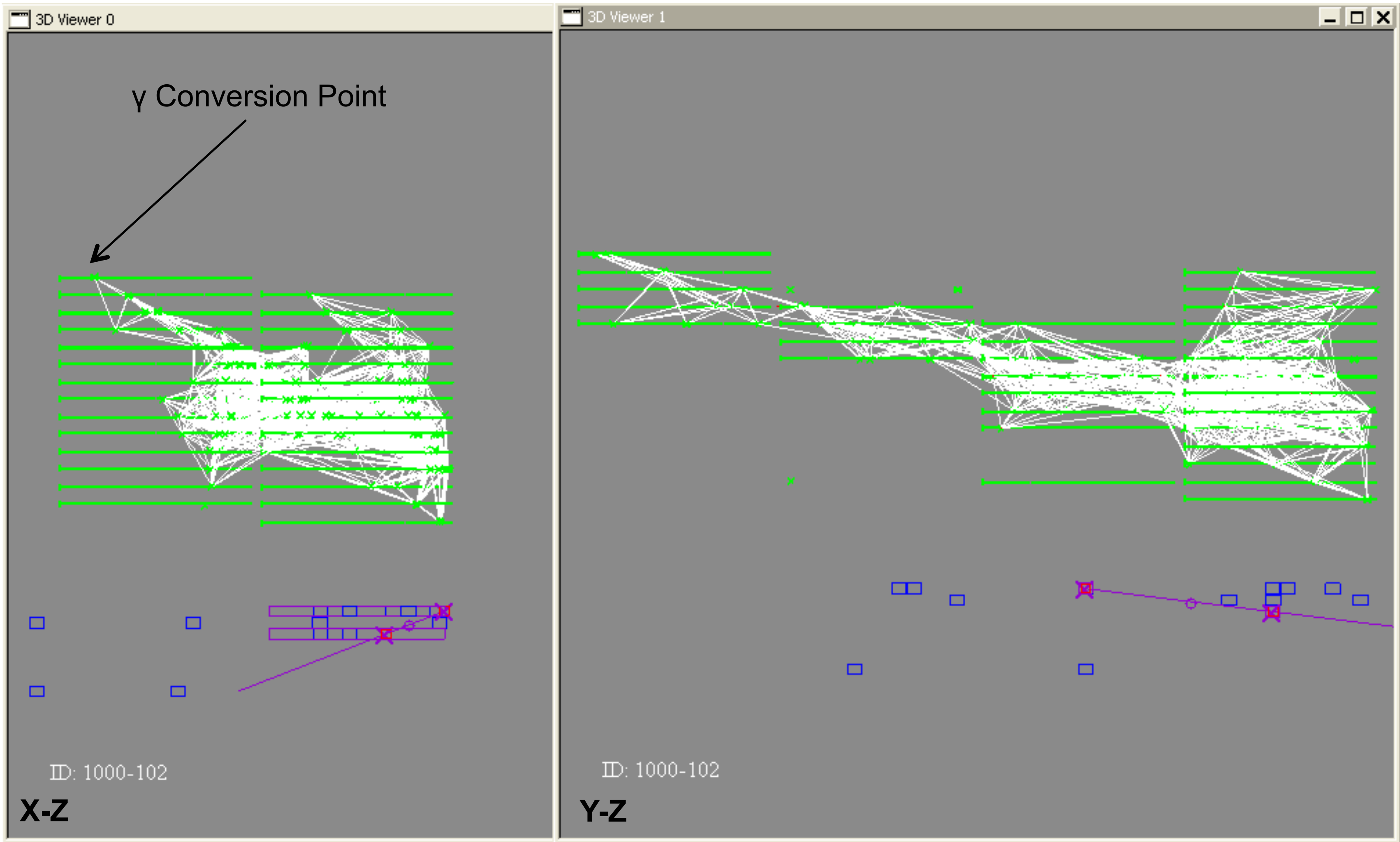
A typical 10 GeV Event in the TKR



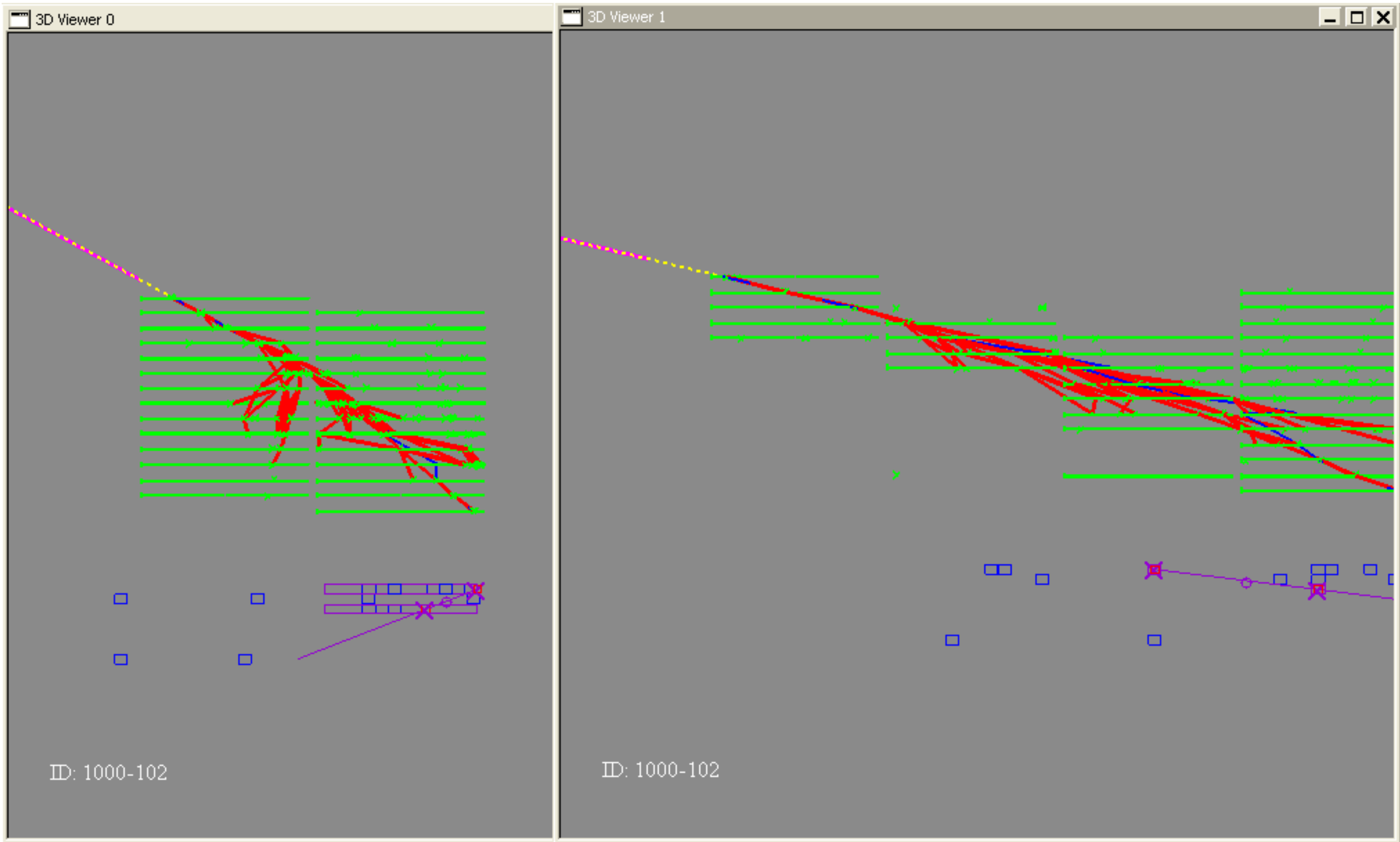
Creating Space Points from Strips



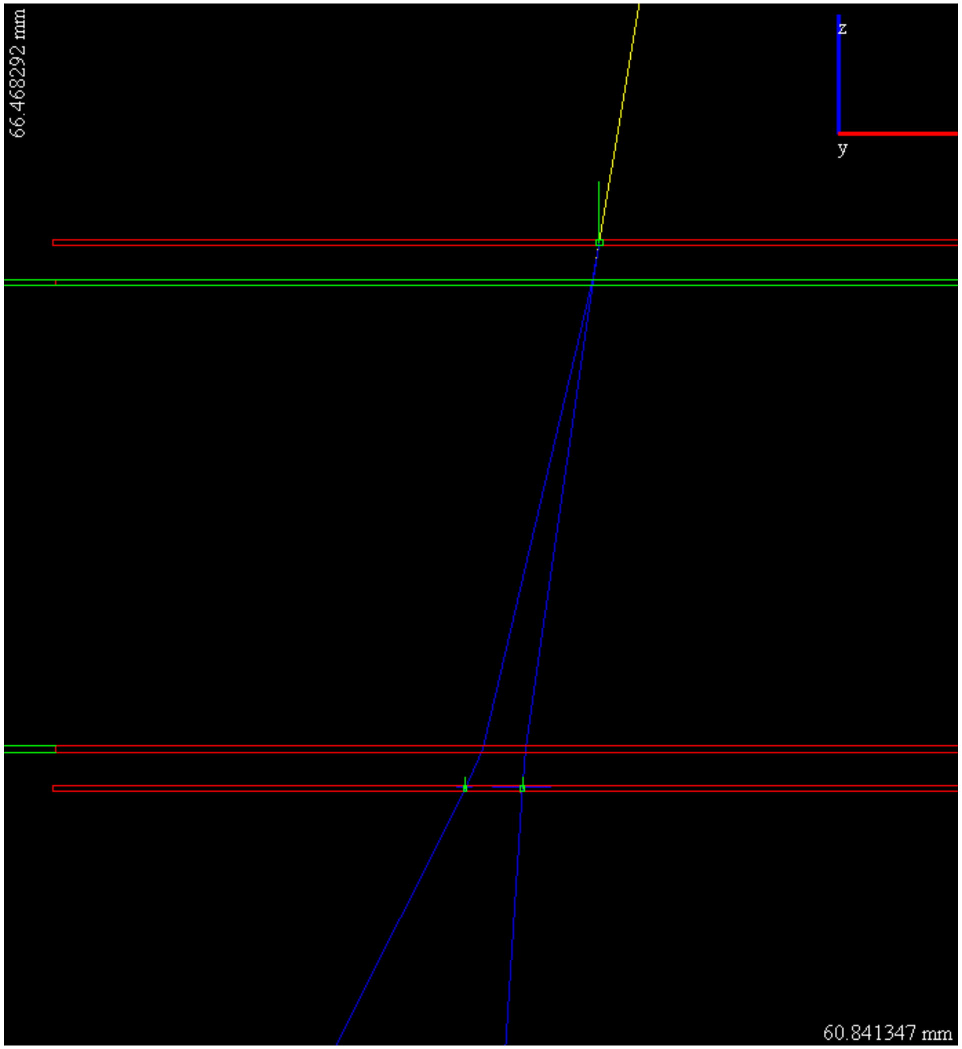
Vector Links (Tree-Based)



Trimming the Tree



Vertexing (More Tomorrow)



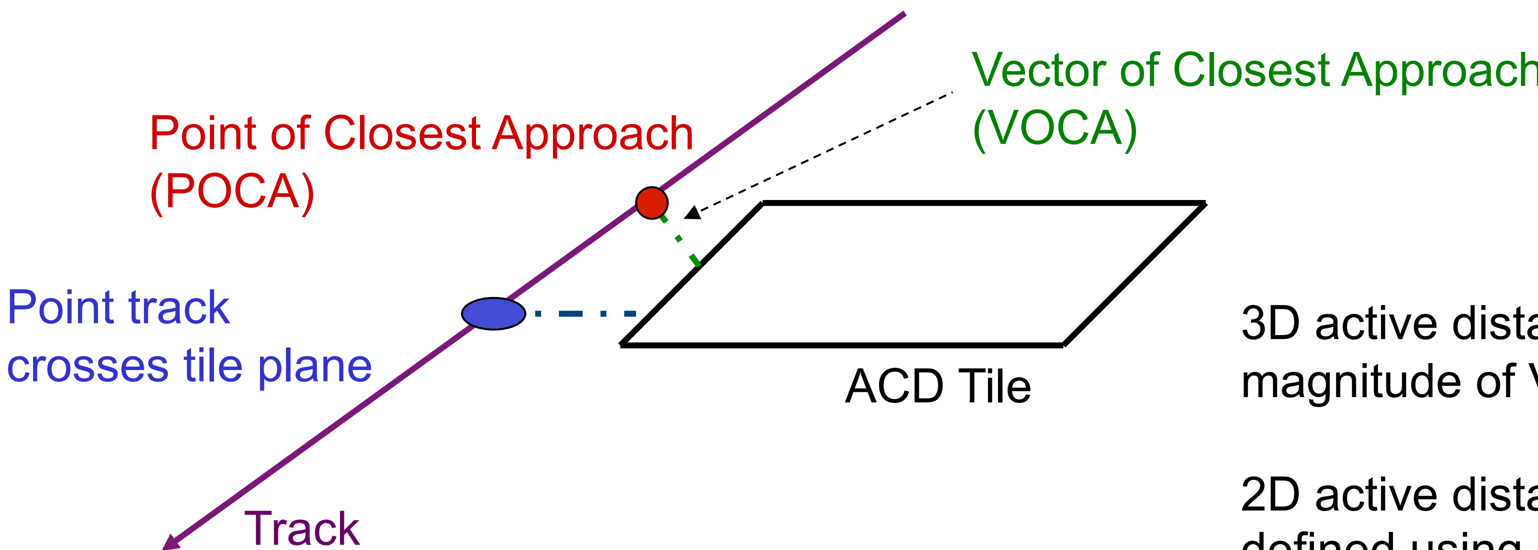
ACD Reconstruction

ACD Roles (Slide from Instrument Talk)

- **Primary Roles:**
  - **Offline background rejection**
  - **Hardware & onboard filter veto**
- **Other Roles**
  - **Identifying Heavy Ion (C,N,O + up) calibration events**

ACD Reconstruction (Slide from Instrument Talk)

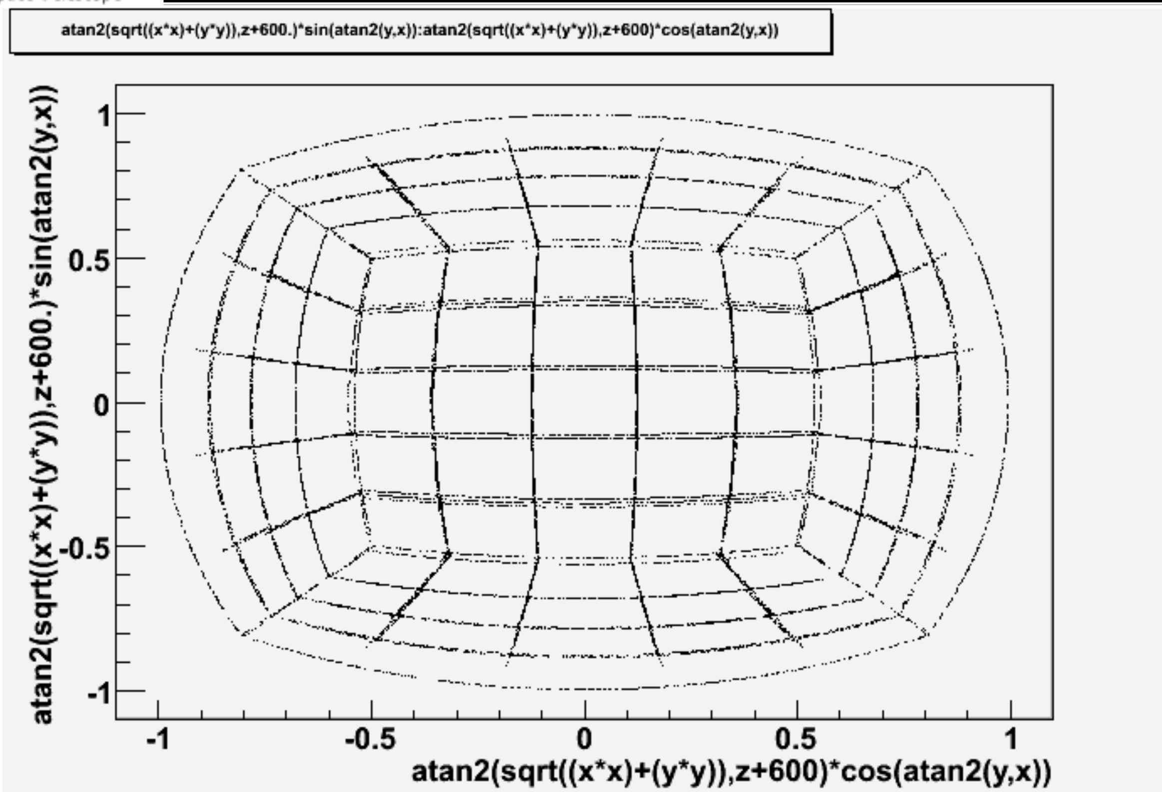
- **Apply tile calibrations**
- **Look for reason to veto event**
  - **Track extrapolation to ACD hit?**
  - **Compare ACD energy to CAL energy**
    - **Catches events where TKR direction is bad**



3D active distance is magnitude of VOCA

2D active distance is defined using point track crosses tile plane

Pattern Recognition I: Projecting the ACD



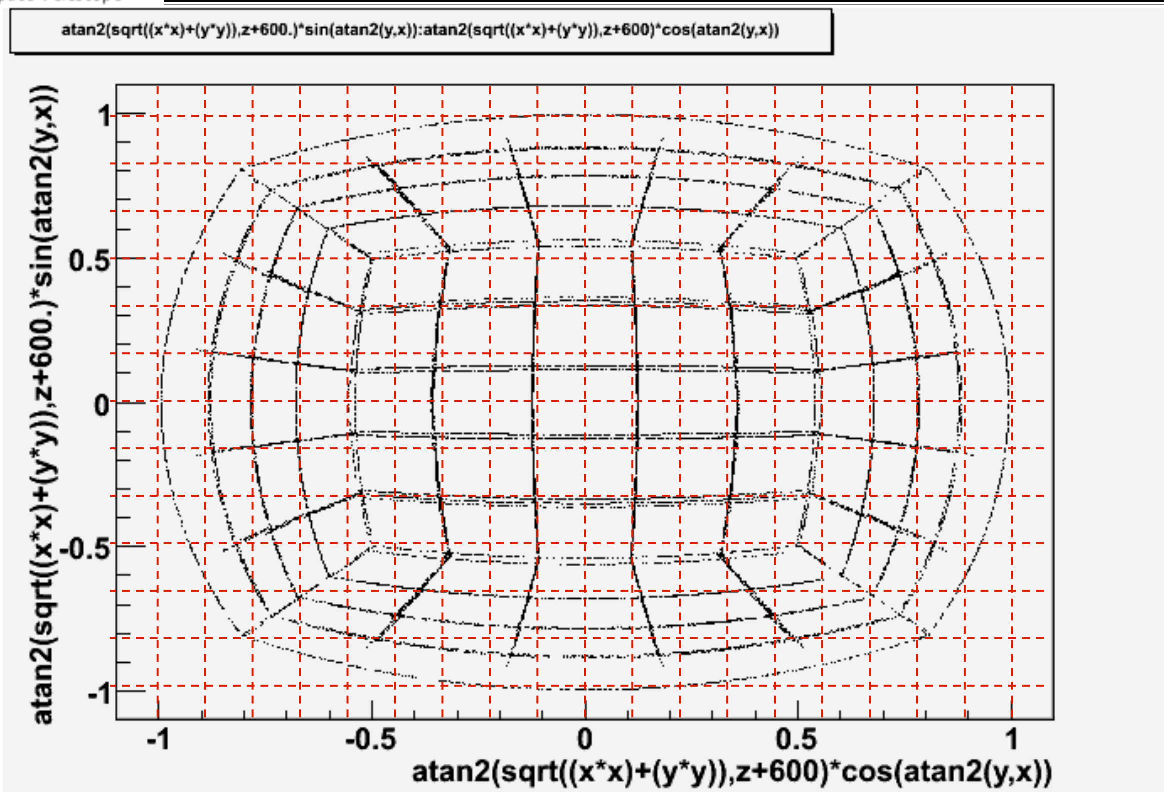
This figures shows a fisheye view of the ACD

The point is to project the ACD onto a plane

For Kicks: here is the transformation

```
r = sqrt(x*x+y*y);
zVal = z + 600.;
rho = atan2( r , zVal );
u = rho * ( x / r );
v = rho * ( y / r );
```

Pattern Recognition II: building the hash set

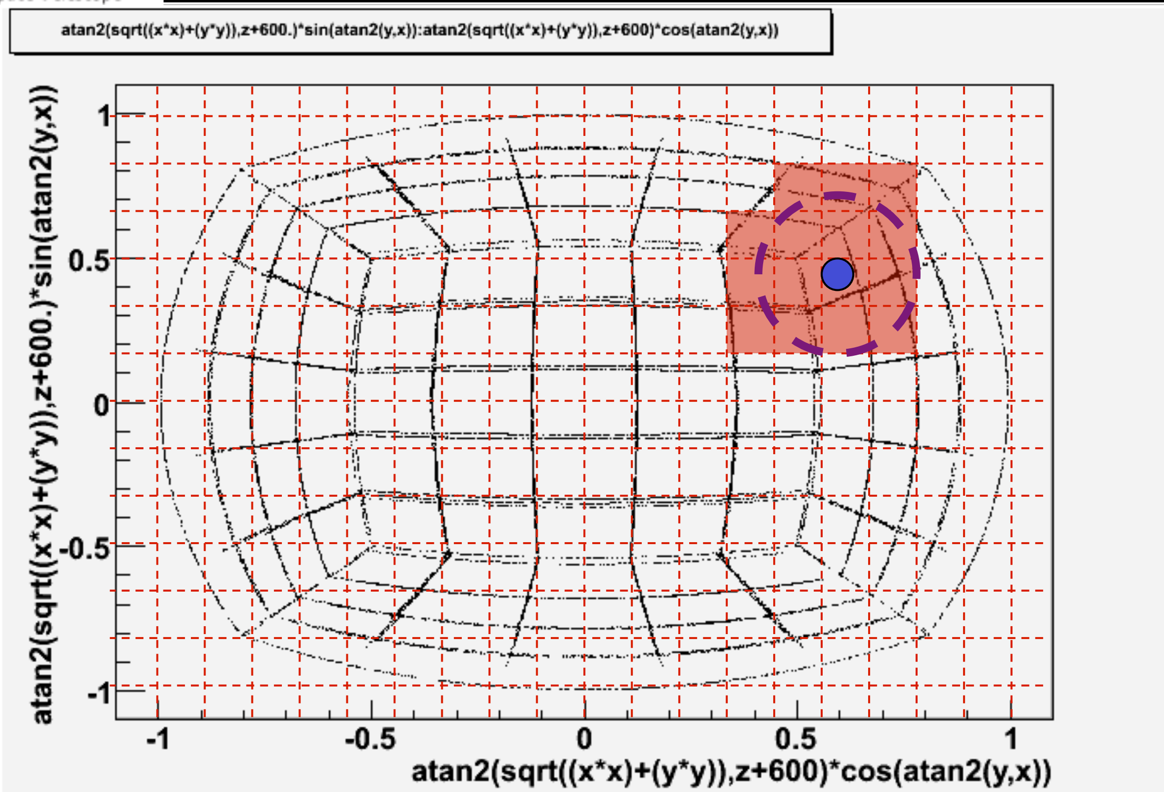


During initialization we divide the projection into small squares, and calculate which ACD elements occupy which squares

This figure is heuristic, actual algorithm uses
20x20 grid and artificial expands the ACD elements by 50mm

Average square contains 1-3 tiles

Pattern Recognition III: getting the search set



Blue dot shows point where track crosses nominal ACD volume

Purple circle shows search area around intersection point

Red shaded region shows searched squares

This is a very conservative algorithm.
Most searches result in 5-12 ACD elements being found.

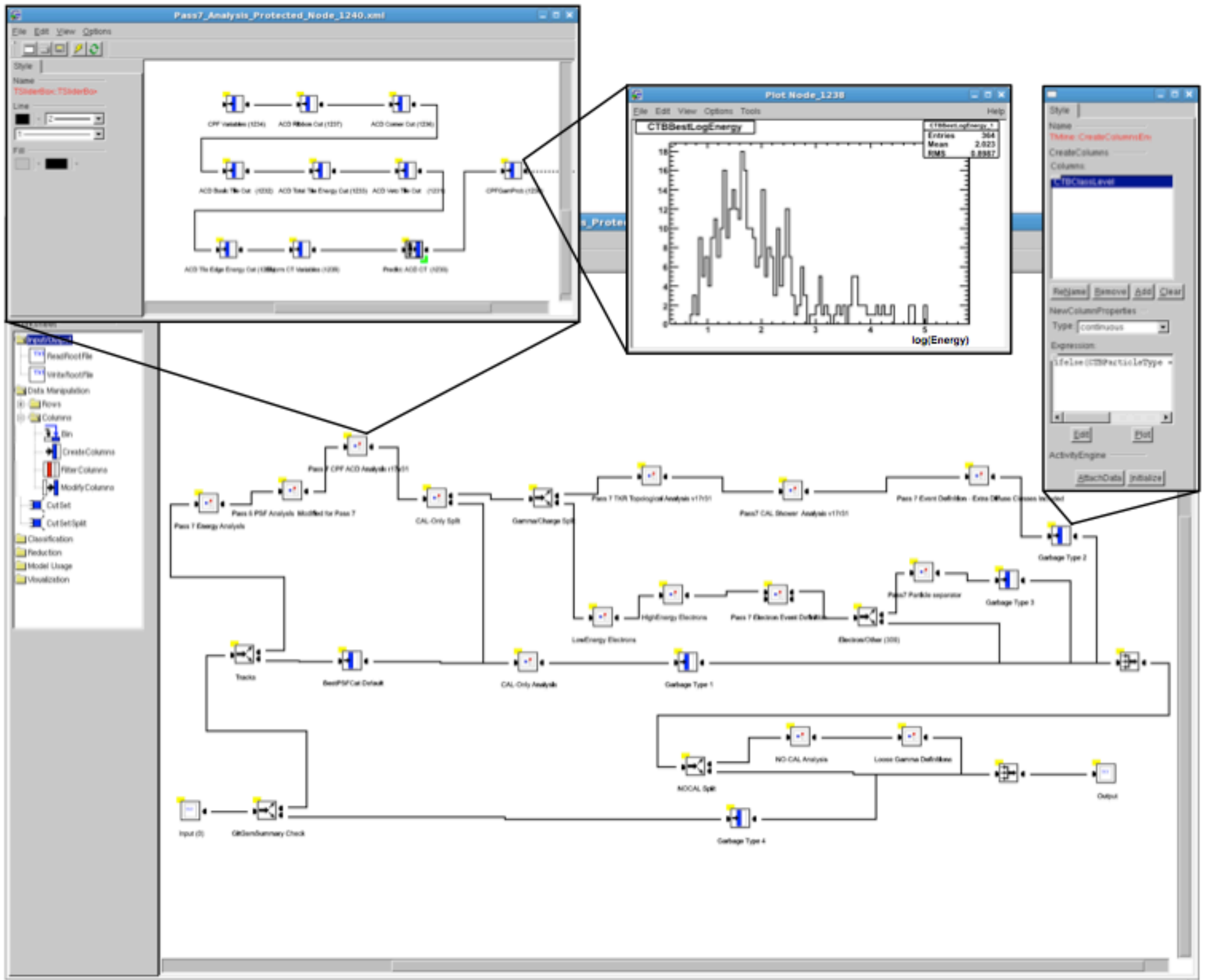
We calculate tile plane intersections and 3D POCAe for all of each of these elements.

EVENT LEVEL RECONSTRUCTION

Extracting discriminating variables

- Extract useful information from tracks, clusters, and associations
  - We have used 200-500 different quantities for each event. Some examples:
    - Tkr1Chisq (χ^2 of best track in event)
    - Tkr1SSDVeto (# of hits in cone above best track)
    - AcdTrk1ActiveDist (distance from track to hit ACD tile)
    - CalTransRms (Transverse shower size in CAL)
    - CalTrackDoca (distance from track to CAL centroid)
    - etc…

Event Level Analysis



Complex multivariate analysis

Uses Classification Trees (CT) in conjunction with cuts

30+ individual cuts, in addition to CTs

Broken into many sub-sections

Outputs of the event level analysis

Direction Analysis:
Decides which direction solution (vertex or non-vertex, TKR or TKR + CAL) is best
Gives estimate of quality of direction estimate
P_{CORE} = "prob." that direction is within R68%

Energy Analysis
Decides which energy method (Parametric or Profile) is best
Gives estimate of quality of energy estimate
$P_{BestEnergy}$ = "prob." event is within P68%

Charged Particle Analysis
Reject charged particles using ACD,TKR,CAL
P_{CPFGAM} = "prob." event is a photon

Topology Analysis
Reject hadrons using TKR, CAL
P_{TKRGAM}, P_{CALGAM} = "prob." event is a photon

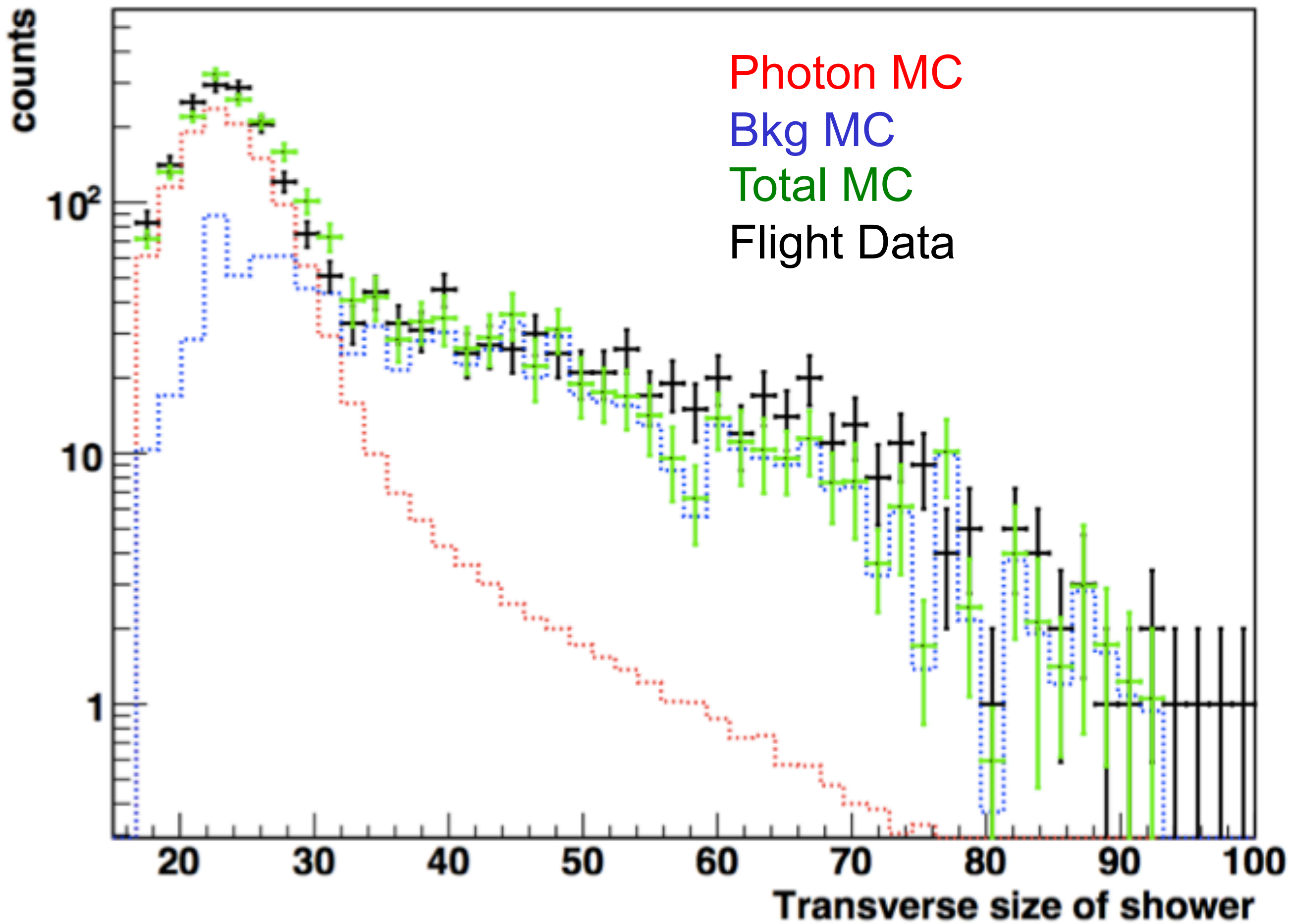
Photon Analysis
Combine everything

P_{ALL} = "prob." that event is a photon

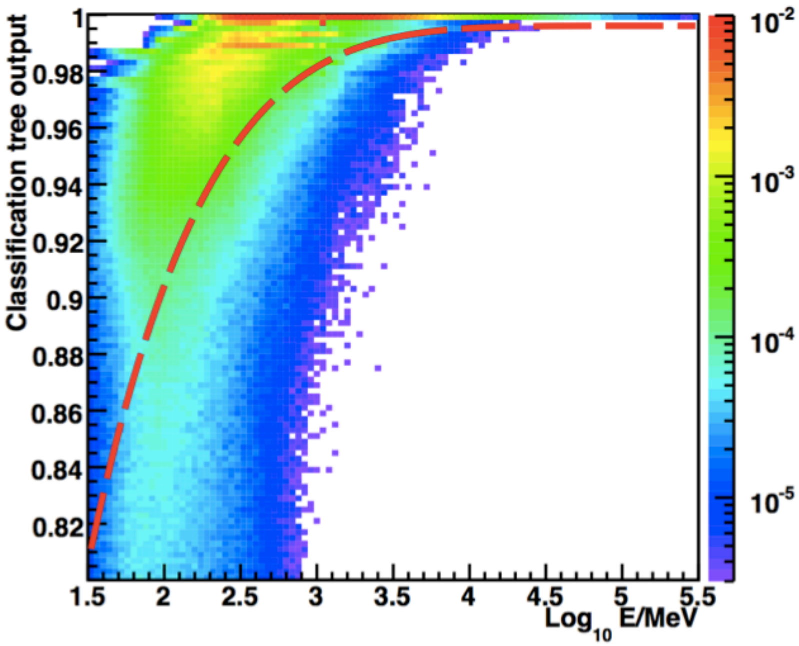
Photon Samples
Apply cuts tuned to for particular samples

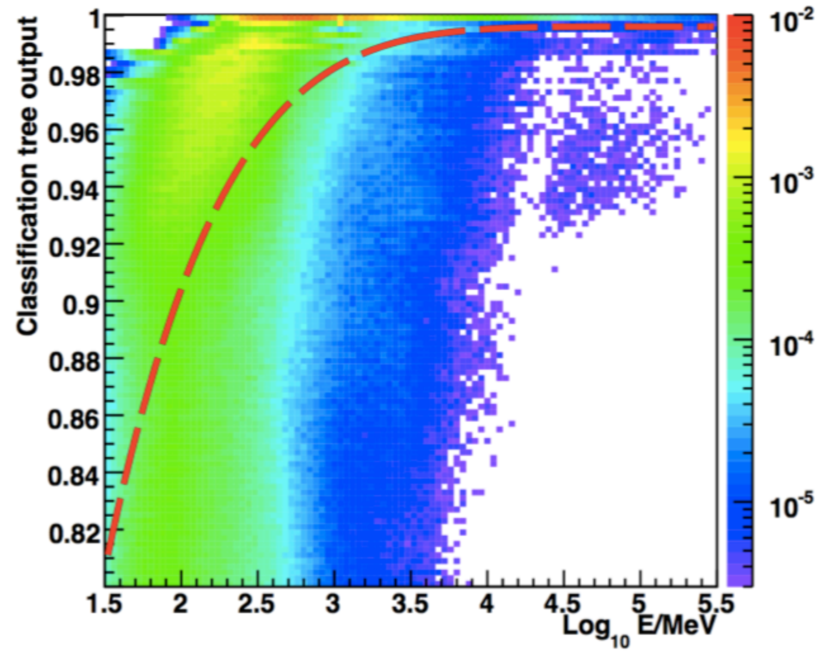
Might require good direction, energy recon in addition to high photon "prob."

Data / MC comparisons



Tuning Cuts using Flight Data





Photon Rich Sample
(Galactic Ridge)

Energy Dependent cut rejects 5% of event at all energies

Photon Poor Sample
(High Latitude)

Cut rejections many more events

OTHER ISSUES

Reconstruction Design Considerations

- Some algorithms require or benefit from information from other sub-systems
  - Determines execution order
  - Complicates validation
    - Independent samples are always nice for validation
- Huge number of events to reconstruct
  - Acquire events for downlink at 400Hz
    - => Need 200 cores running at 3 Hz to have 50% margin in processing time to keep up w/ data
    - Finite processing time for each event