First Look:
Onboard Track Reconstruction

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This is a preview of work in progress.

Why onboard track recon?

- Onboard science!
  - Notably, GRB detection and localization in the LAT

(Refer to DC1 presentation by Jay and Jerry)

Basic Approaches

- Use existing 2-D projections from OnboardFilter to reconstruct 3-D tracks
  - Advantage: it's fast. Projections are already there, so we just have to put the right ones together.
  - Disadvantage: Filter prj finding may not be good enough for this purpose
- Develop a new track finding and recon method that is independent of OnboardFilter
  - Advantage: may be more accurate
  - Disadvantage: is the computing power there?

Using Filter Projections: Obvious "Tracks to Take"

- Approach 1: reconstruct all possible tracks from x-y projection pairs that:
  - Start in the same layer and same tower

  AND THEN:

  Pick the one with the most hits

- Approach 2: reconstruct all possible tracks from x-projection pairs that:
  - Start in the same layer and same tower

  AND THEN:

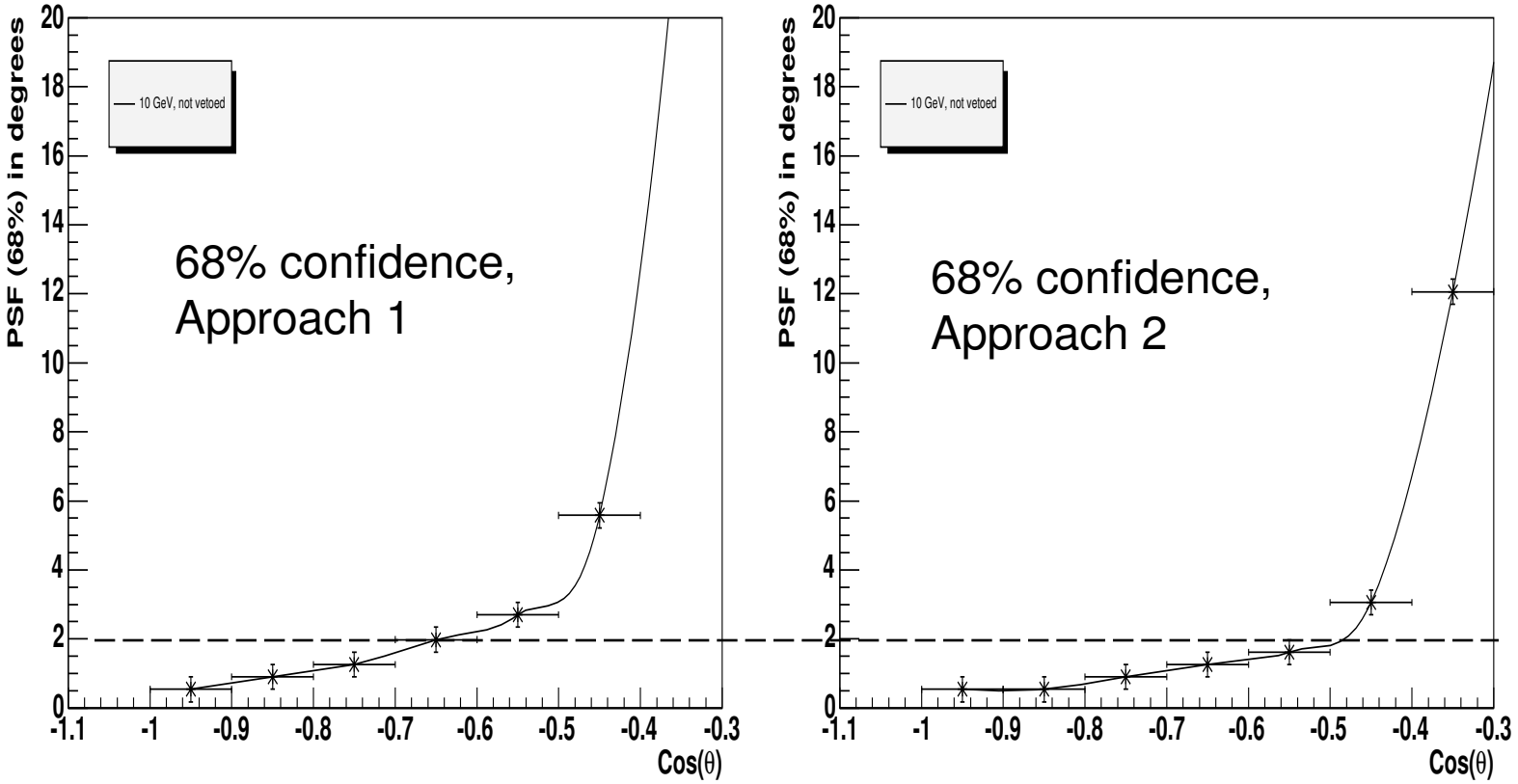
  Pick the one that starts in the highest layer

  Tie breakers sometimes necessary: highest layer, then most hits, then tower with most tracks, etc.

Preliminary Look at PSF

- Looked at 4 energies: 100 MeV, 1 GeV, 10 GeV, 100 GeV
  - Looking at PSF for events where
    - ground recon was decent (within 10 deg of Monte Carlo), and
    - not vetoed by OnboardFilter
    - …because I want to see how the method performs for events it can be expected to do well on
  - Also looking at PSF for any event not vetoed
    - because onboard science uses everything it gets
  - Later will add in albedo cuts for low E gammas

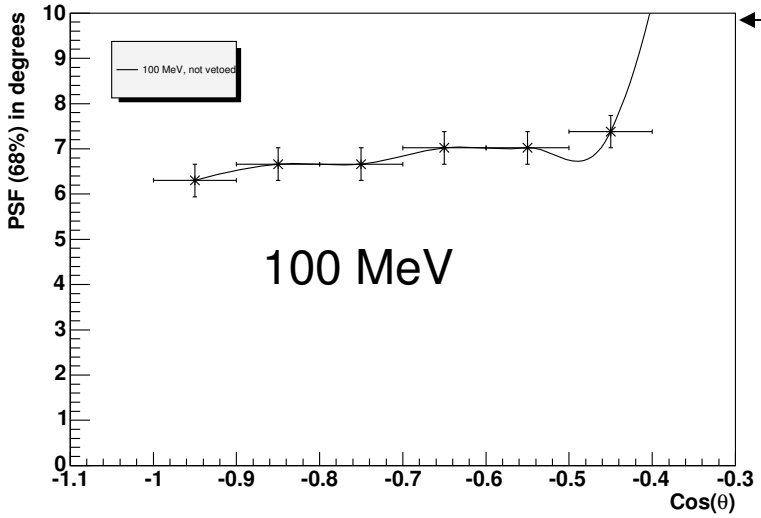
Some Sample PSF Plots and Distributions: Approach1 vs. Approach2



This is for 10 GeV gammas, well reconstructed on the ground.

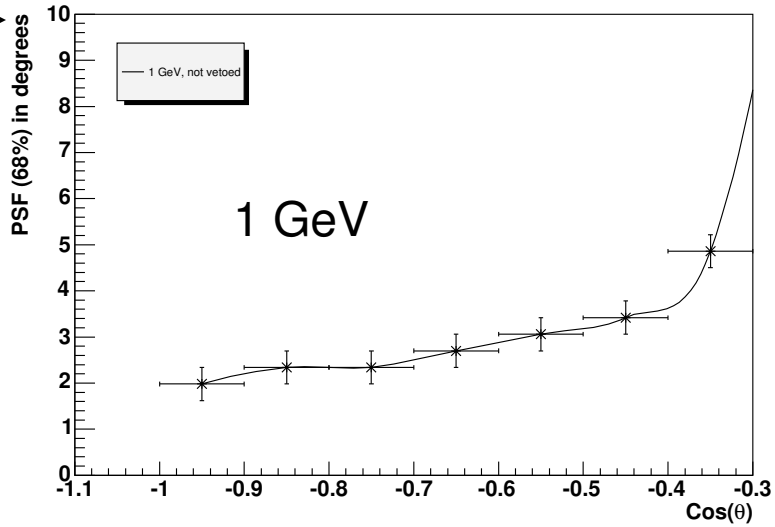
Approach 2 works better, and this is true at all energies

Some Sample PSF Plots : Improvement with Energy (Approach 2), Degradation with Angle

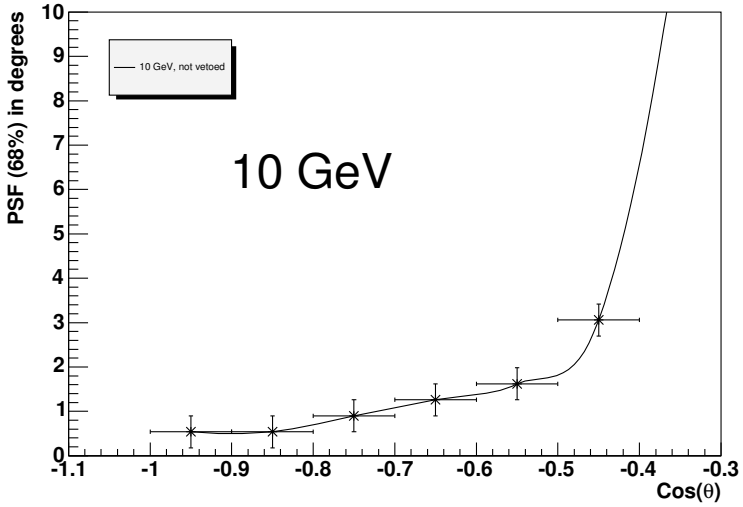


Scale:

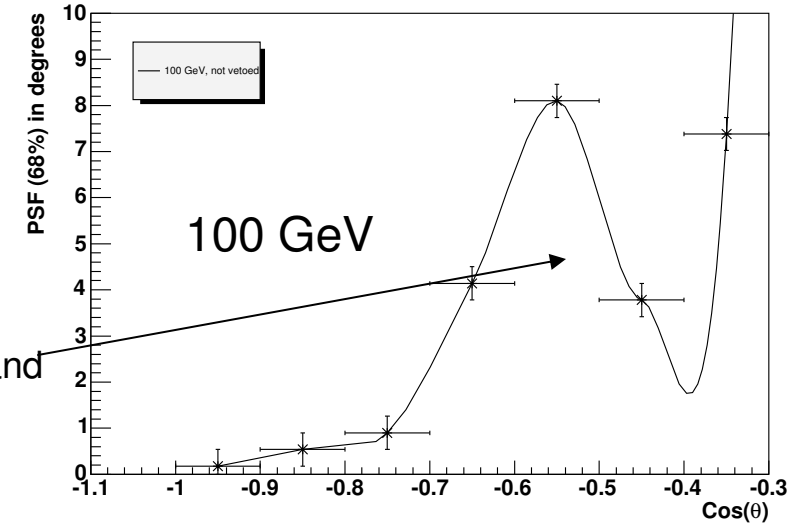
10 deg



68% Confidence PSF



Combination of poor reconstruction and low statistics



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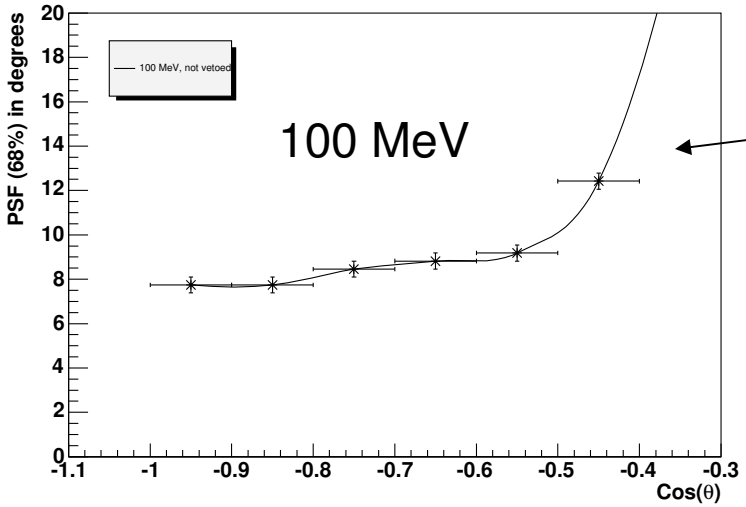
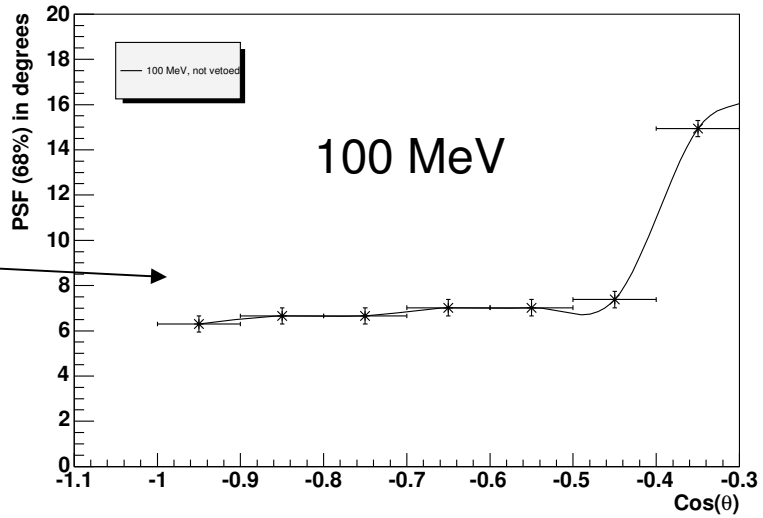
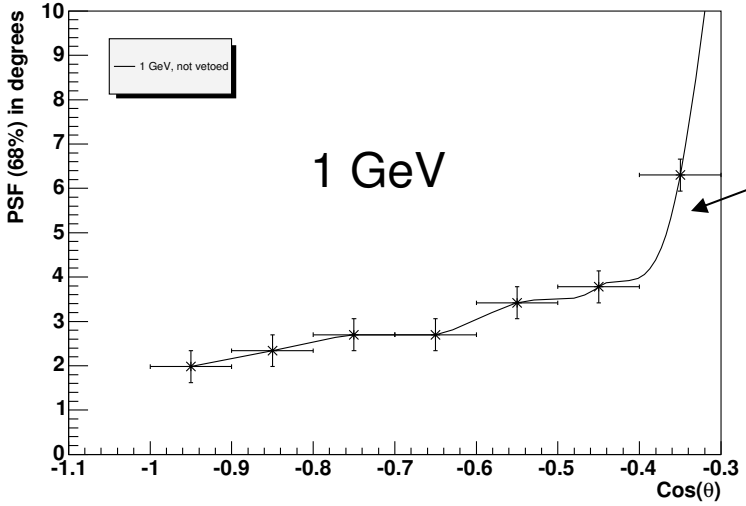
Some Sample PSF Plots : Well reconstructed (on ground) vs. all non-vetoed events, Approach 2



All Events

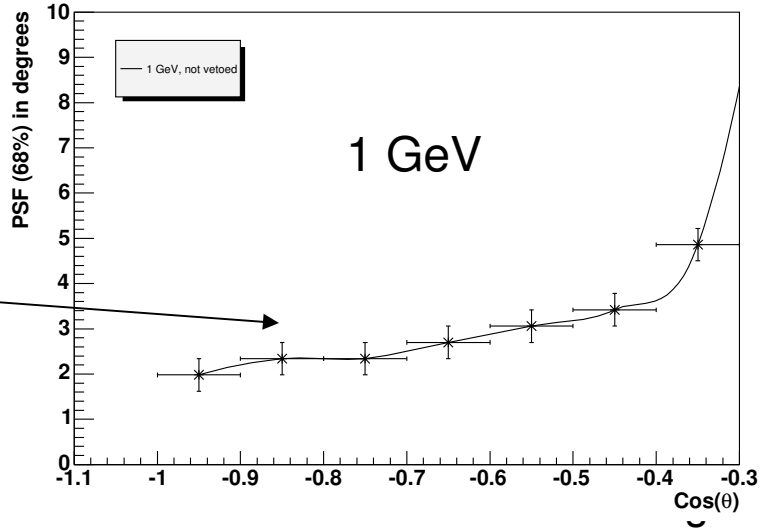
Well recon on ground





All Events

Well recon on ground



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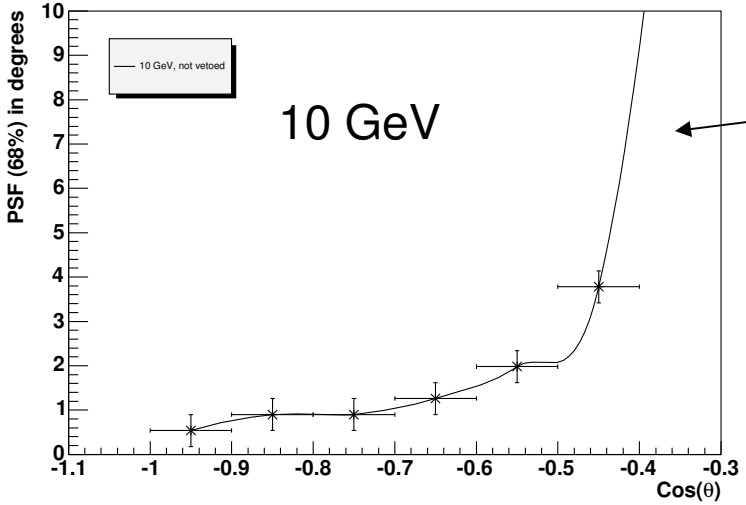
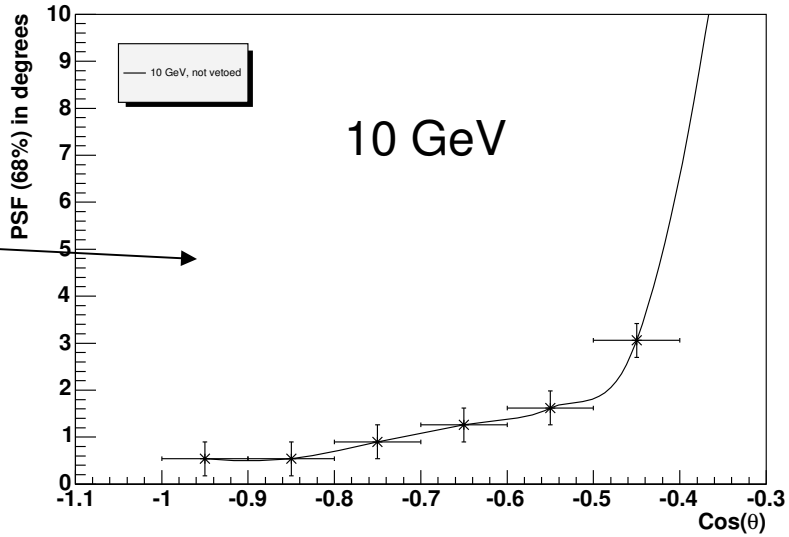
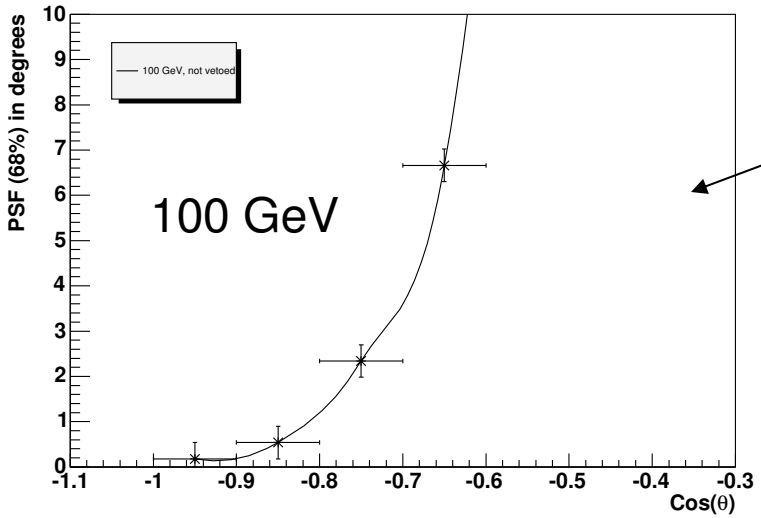
Some Sample PSF Plots : Well reconstructed (on ground) vs. all non-vetoed events, Approach 2



All Events

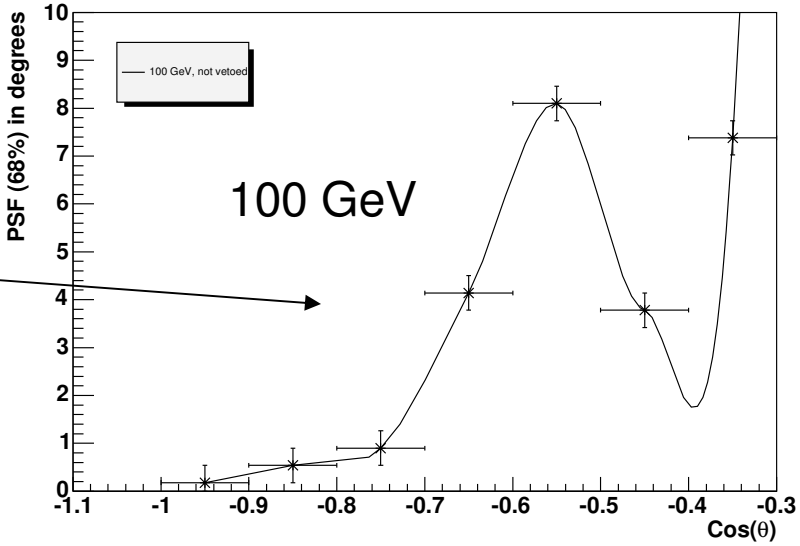
Well recon on ground





All Events

Well recon on ground



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General Trends

- PSF generally improves with energy, as we would expect
- PSF gets worse as incoming angle (w/ respect to LAT zenith) increases
  - Bigger problem at very high energies (100 GeV, for example)
- PSF is somewhat worse when considering all non-vetoed events, rather than restricted sample
  - But not as bad as one might have expected
- Approach 2 works better at all energies

Probable Cause for Degradation at Larger Angles

- OnboardFilter does not see across tower boundaries
  - Events at larger angles cross towers, not always producing 3-in-a-rows in the tower of conversion
  - Prjs are found in "secondary" towers,
    - Either found "farther down the track," so their direction is worse, or
    - are not the primary track at all

Evidence for this follows…

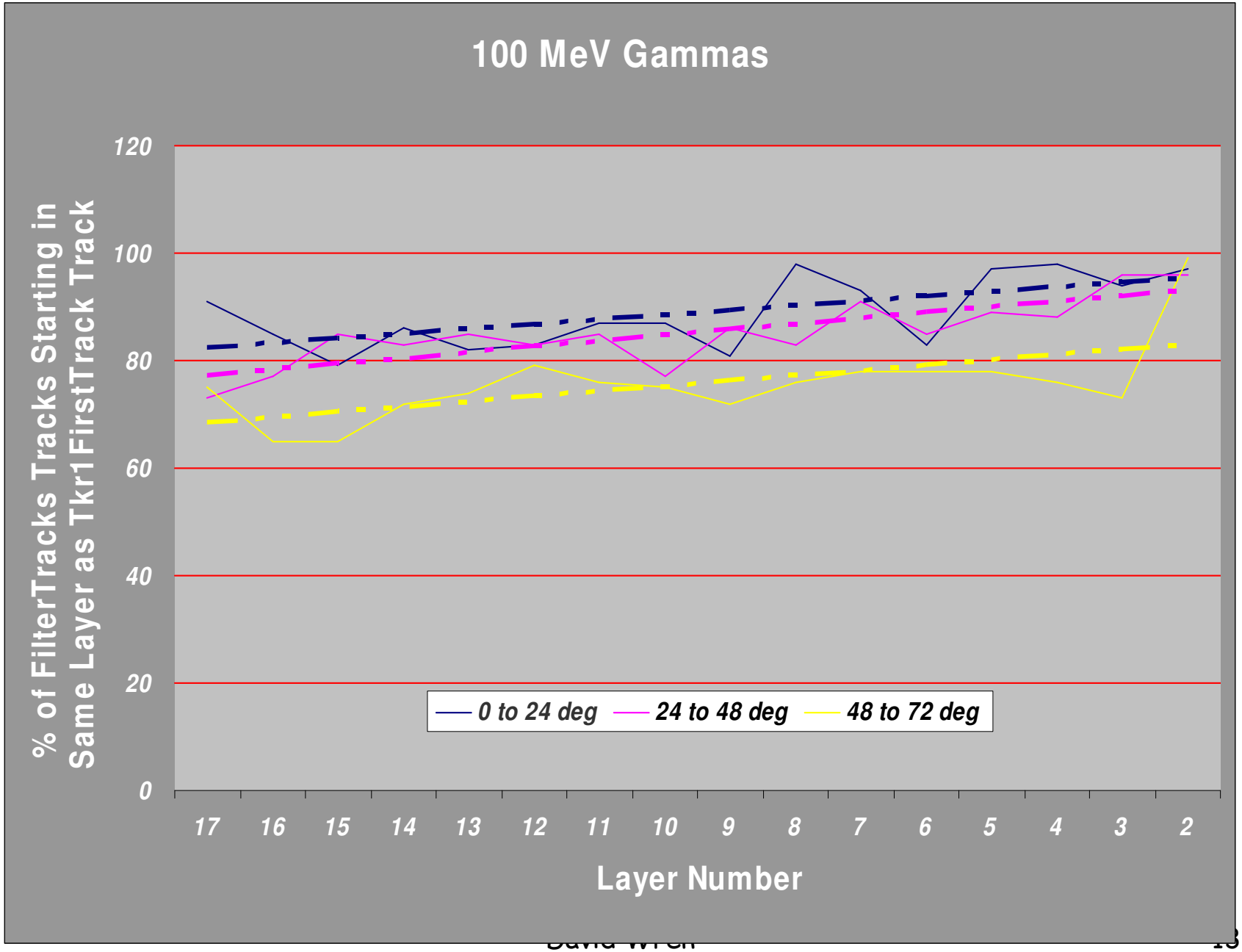
Starting Layer of Tracks

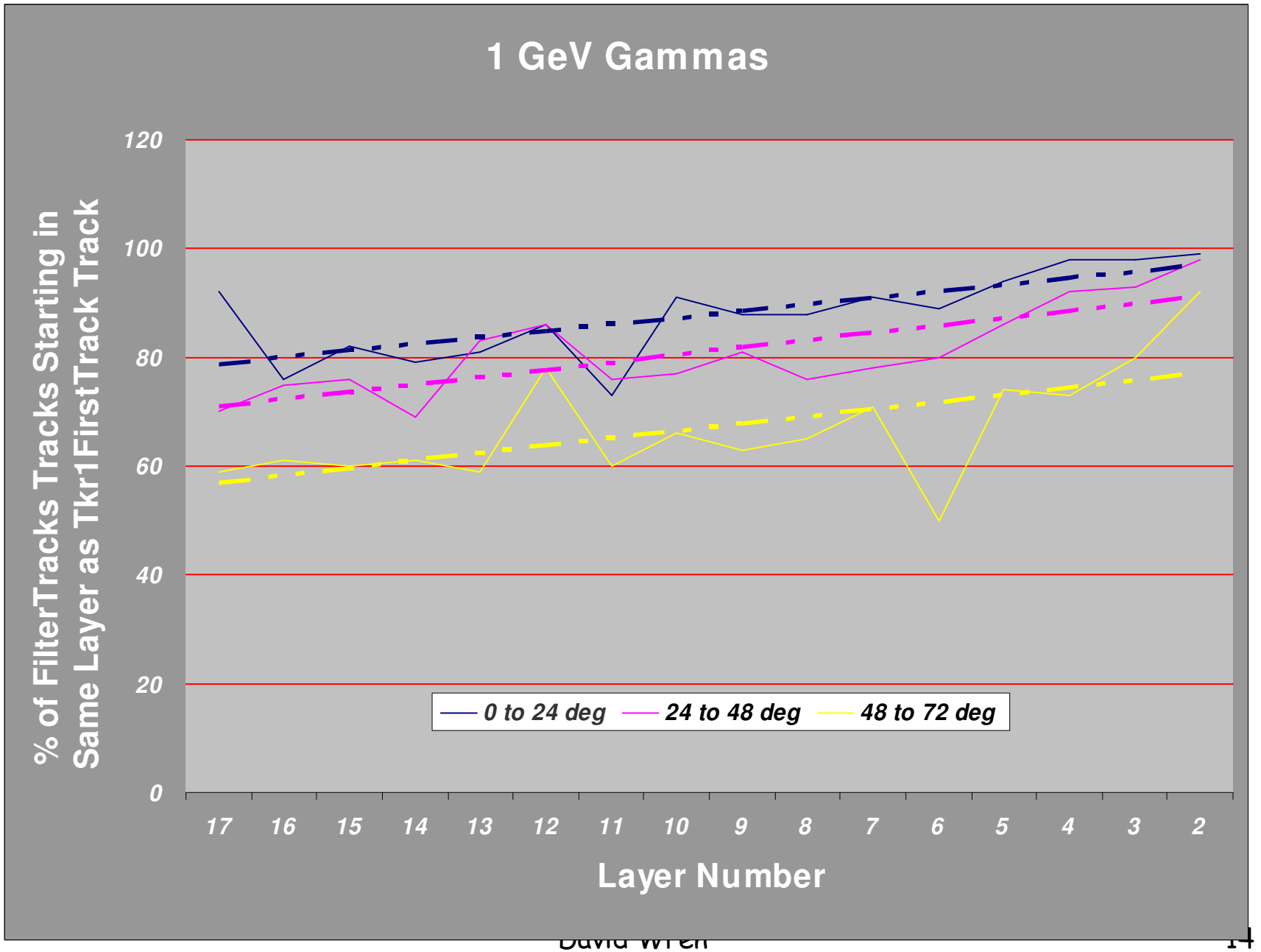
- Following plots are:

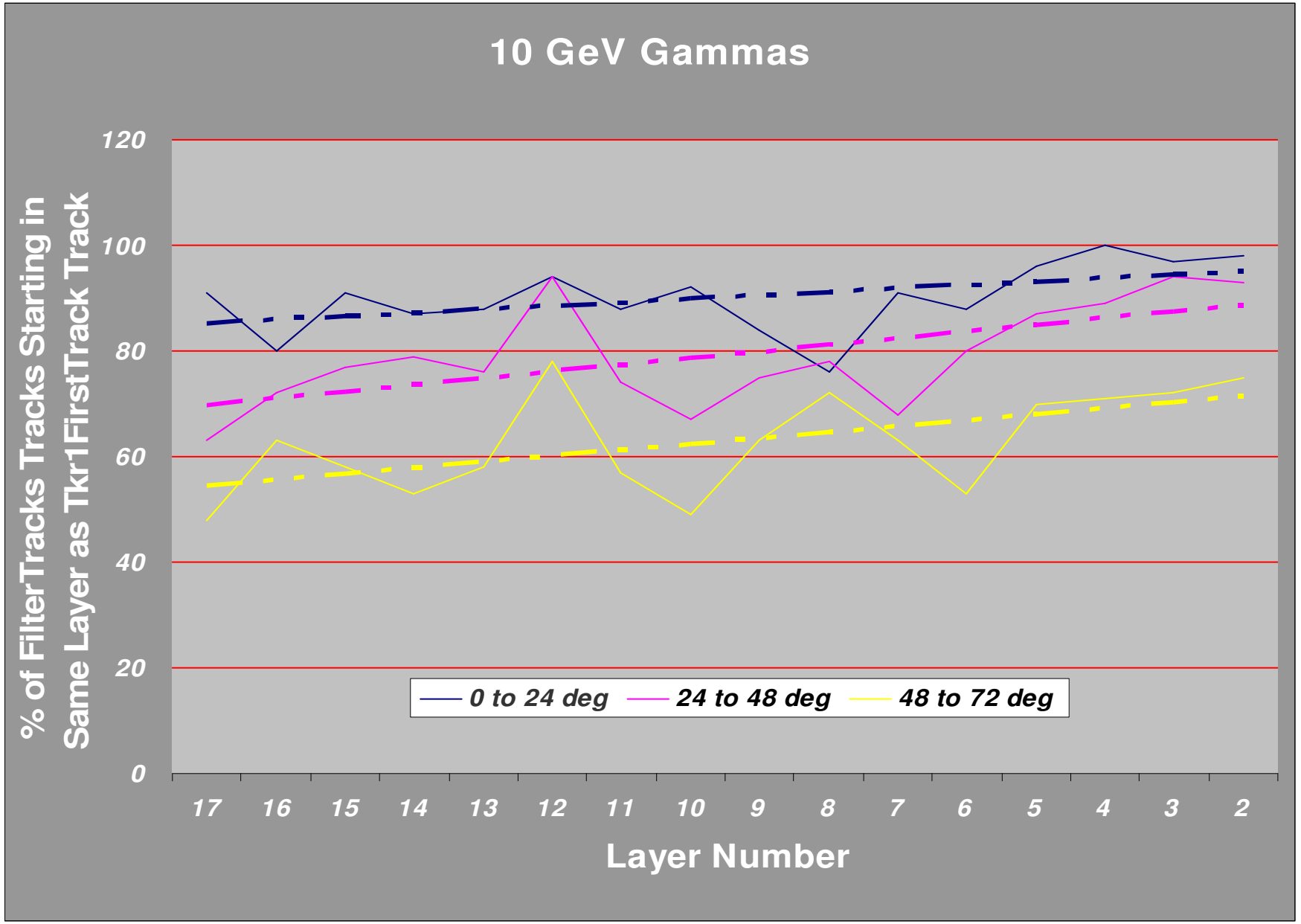
  Percentage of Filter Tracks that start in the same layer as the primary Tkr Recon track (used ntuple variable: Tkr1FirstLayer, corrected to use Glast layer convention)

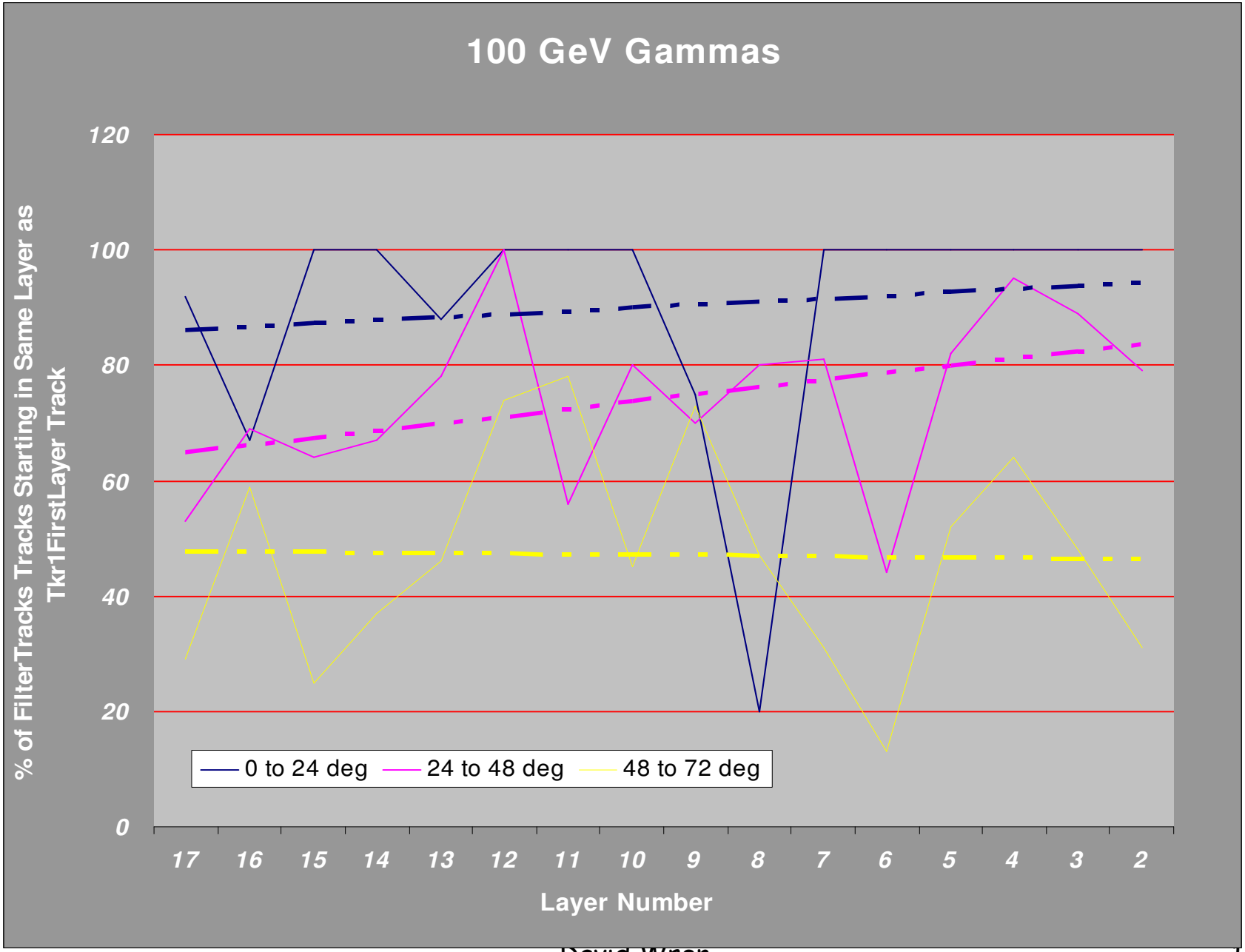
  Results are binned by incoming angle:
  0 to 24 degrees, 24 to 48 degrees, and 48 to 72 degrees from zenith

  And then a linear fit is provided, just to show the general trend


100 MeV Gammas
% of FilterTracks Tracks Starting in Same Layer as Tkr1FirstTrack Track
120
100
80
60
40
20
0
0 to 24 deg
24 to 48 deg
48 to 72 deg
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
Layer Number


1 GeV Gammas
% of FilterTracks Tracks Starting in Same Layer as Tkr1FirstTrack Track
120
100
80
60
40
20
0
0 to 24 deg
24 to 48 deg
48 to 72 deg
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
Layer Number


10 GeV Gammas
% of FilterTracks Tracks Starting in Same Layer as Tkr1FirstTrack Track
120
100
80
60
40
20
0
0 to 24 deg
24 to 48 deg
48 to 72 deg
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
Layer Number


100 GeV Gammas
% of FilterTracks Tracks Starting in Same Layer as Tkr1FirstLayer Track
120
100
80
60
40
20
0
0 to 24 deg
24 to 48 deg
48 to 72 deg
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
Layer Number

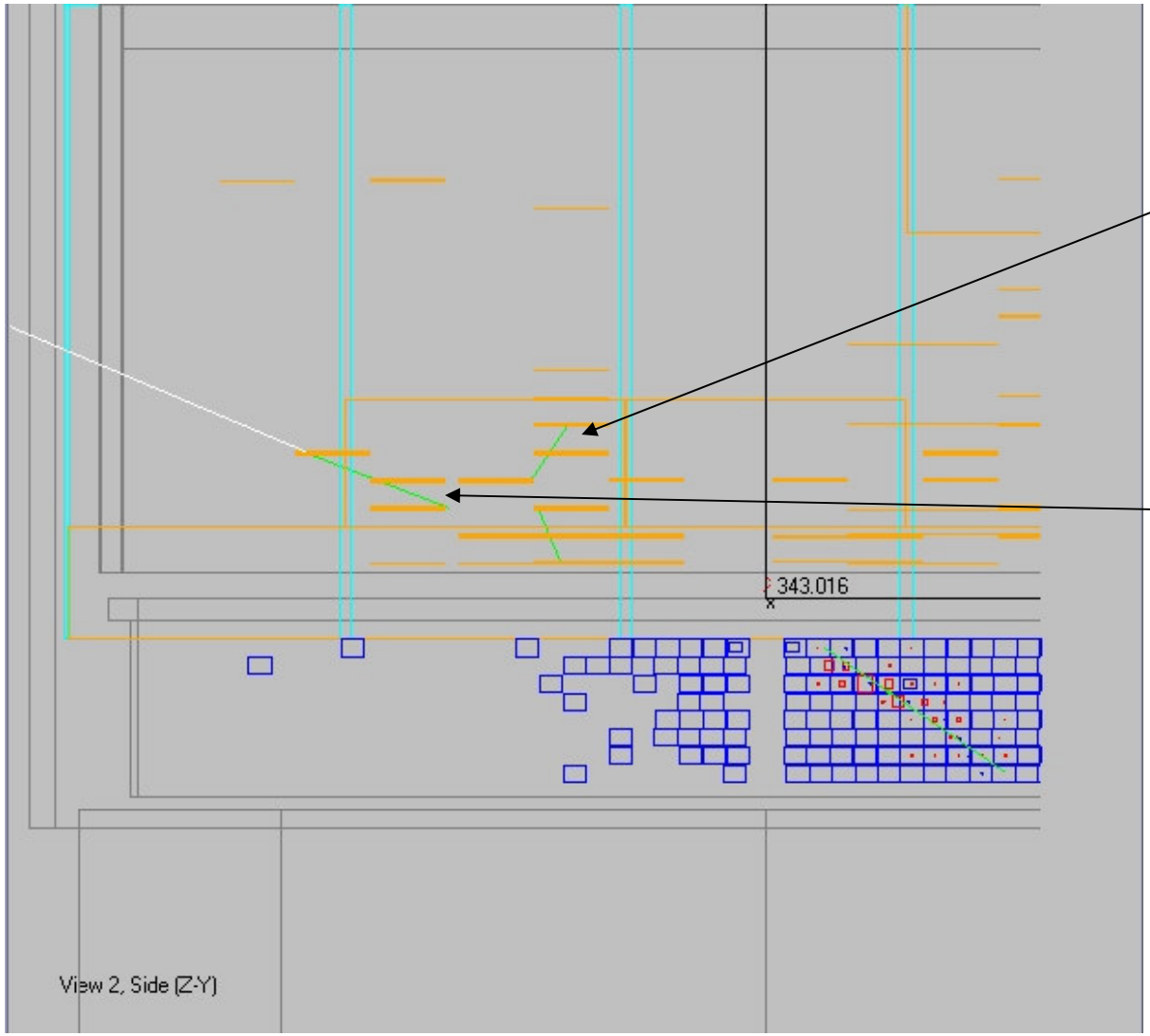
- Things to note in previous plots
  - The greater the incoming angle, the fewer Filter tracks start in the same layer as ground tracks
    - Effect more pronounced as energy increases
  - The higher the layer, the fewer Filter tracks start in the same layer as ground tracks
- These things lend credibility to the theory that the "correct" track is not being found some of the time
  - The degradation also corresponds to the increased PSF at larger angles

Resolving the Tower Crossing Problem

- One method (inspired by Tkr recon and Jay and Jerry) is to anchor the track in the Cal
  - Generate a crude centroid to help pick track
  - Or anchor the track in the cal, and use the uppermost hits in the tracker
  - Or some variation or combination of both

Under Development!

Sample Event that Would Benefit from Anchoring in the Cal

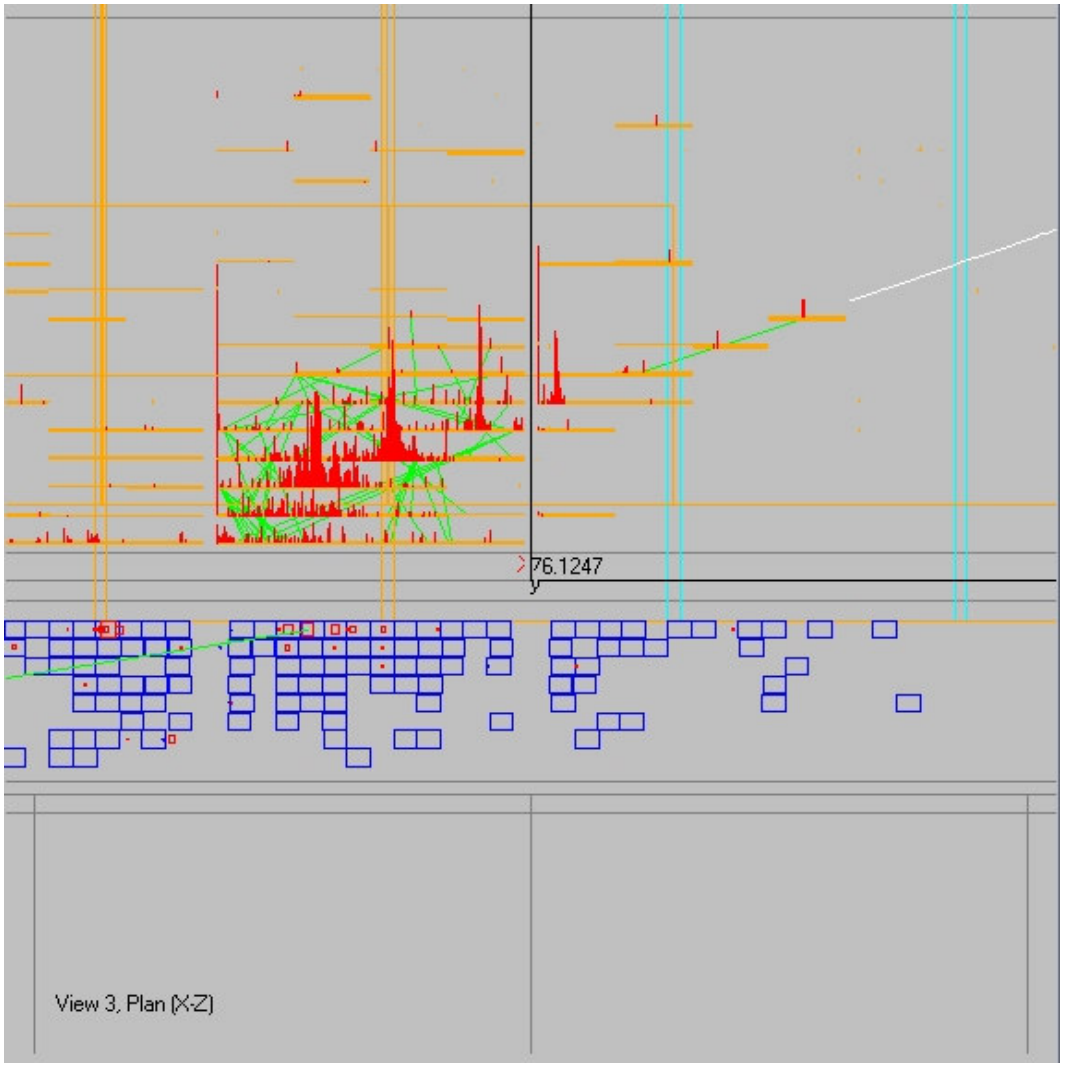


This track was selected because it was highest

…but this track would have been selected if the Cal had been used

Other Improvement Under Consideration

- At high energy, do additional averaging/clustering of hits
  - Might help with events like this:



Beyond OnboardFilter

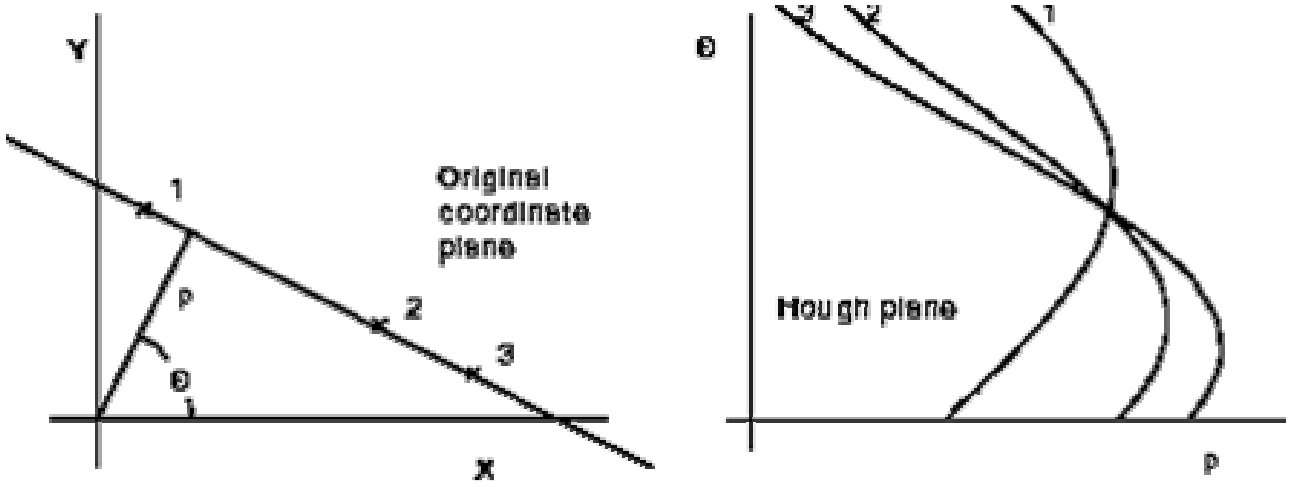
- Alternate approach: don't use OnboardFilter projections, instead develop new method
  - Would have to be simple and fast

A first attempt:

Global Hough Transform

Hough Transform

- The basic idea:
  - Transform a coordinate in Cartesian space into a line in (rho, theta) parameter space.
  - Collinear points in Cartesian space have intersecting lines in parameter space
  - Pick out the point of intersection in parameter space, and one gets the line (track) in Cartesian space

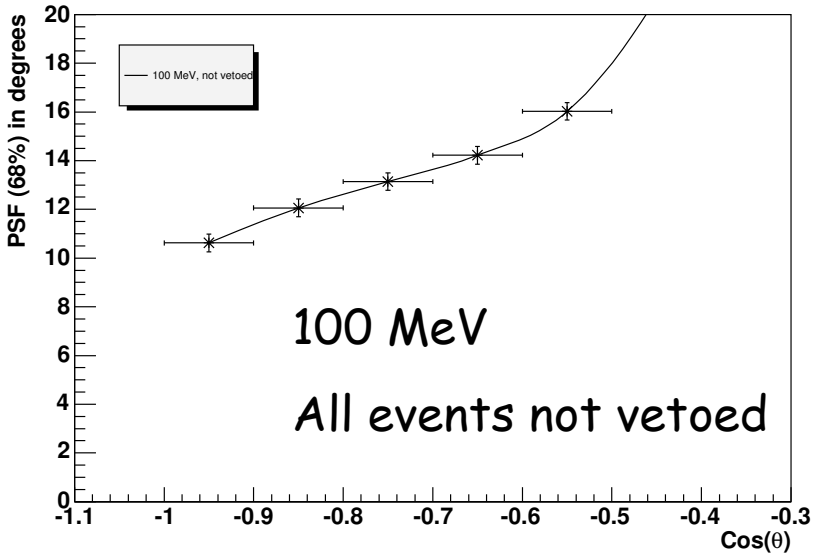


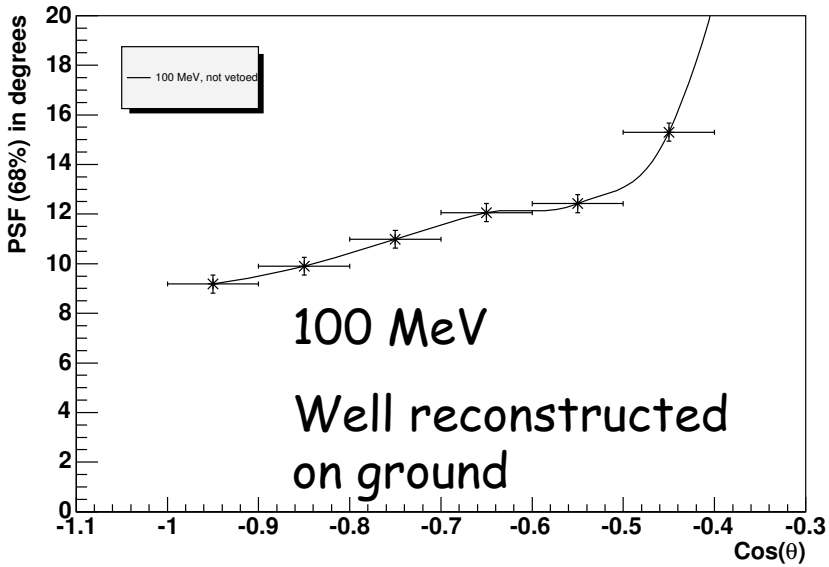
Preliminary Algorithm Details

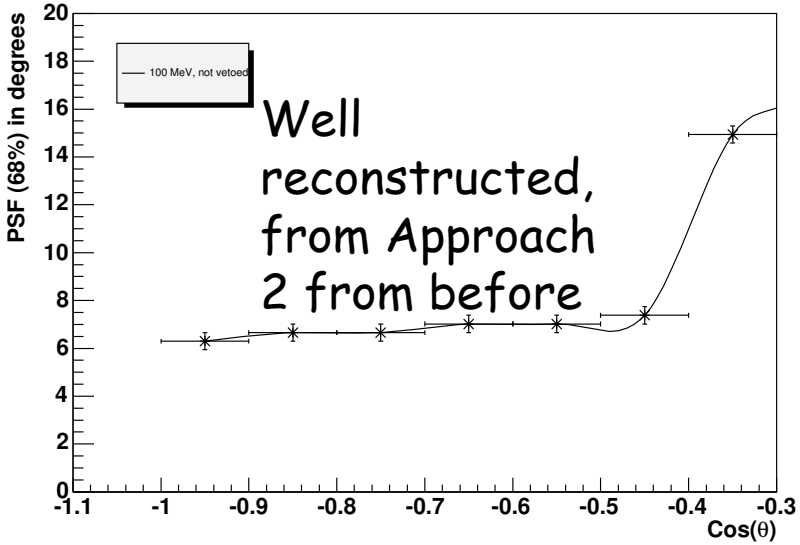
- Very simple: two loops
  - Loop over clusters, and
    - Loop over theta (0 to 180)
      - Rho[theta] = x*cos(theta) + y*sin(theta)
      - Fill appropriate (x view or y view) rho, theta array that represents the binned Hough plane
  - Find maximum value in each array
  - Reconstruct x prj, y prj, and 3-D track
    - For now, just use the center of the (rho, theta) bin to get a direction. Refinements planned.

One important note: theta within 15 deg of tracker planes is ignored…because collinear hits in planes would fool the algorithm.

Hough Transform: Preliminary Results

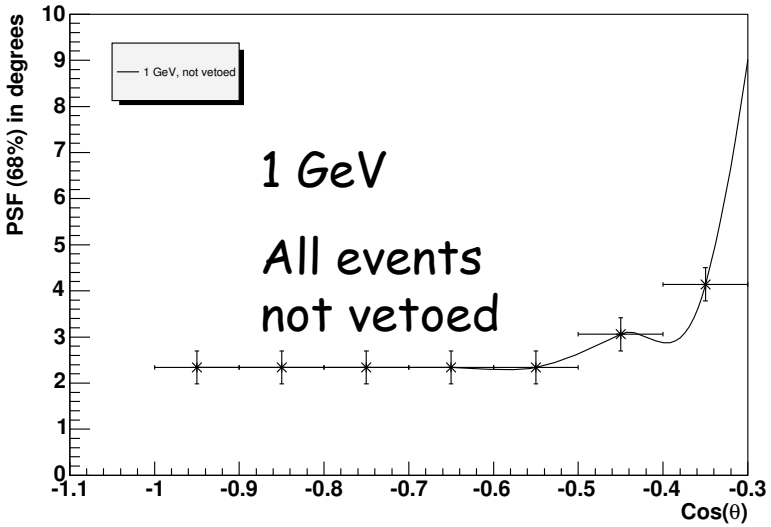


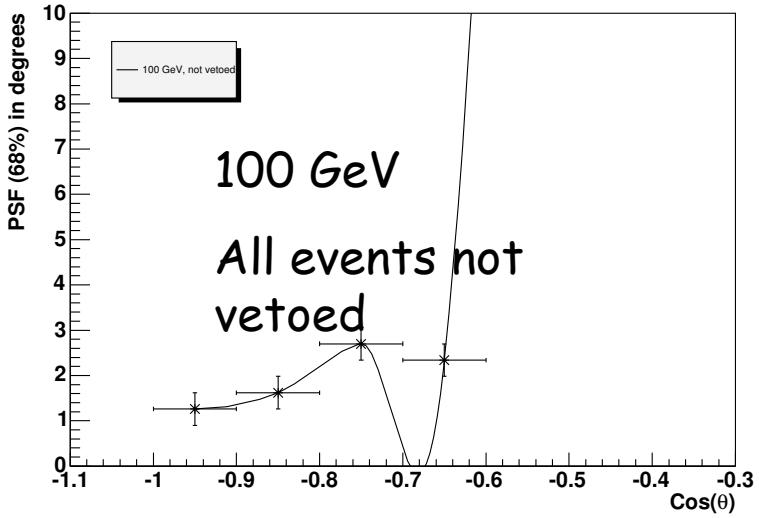


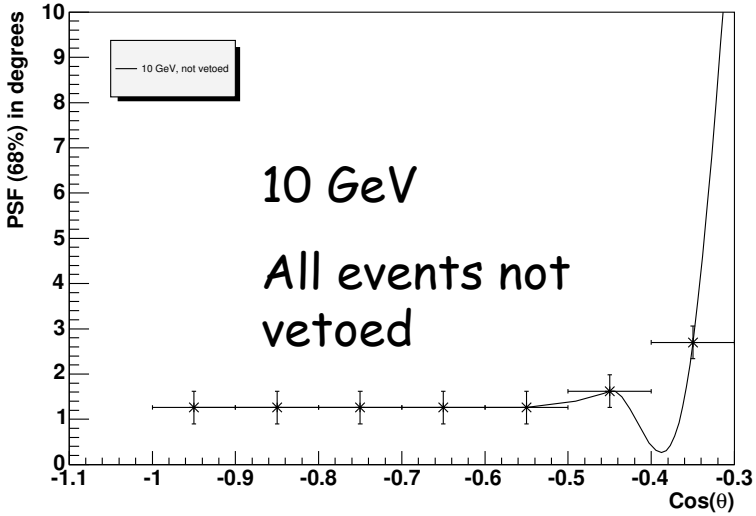


Current incarnation of Hough Transform does not work well at low energies. Reason unknown, but possibly because actual hits are not used to reconstruct track – Hough bins are used

Hough Transform: Preliminary Results for All Events not Vetoed

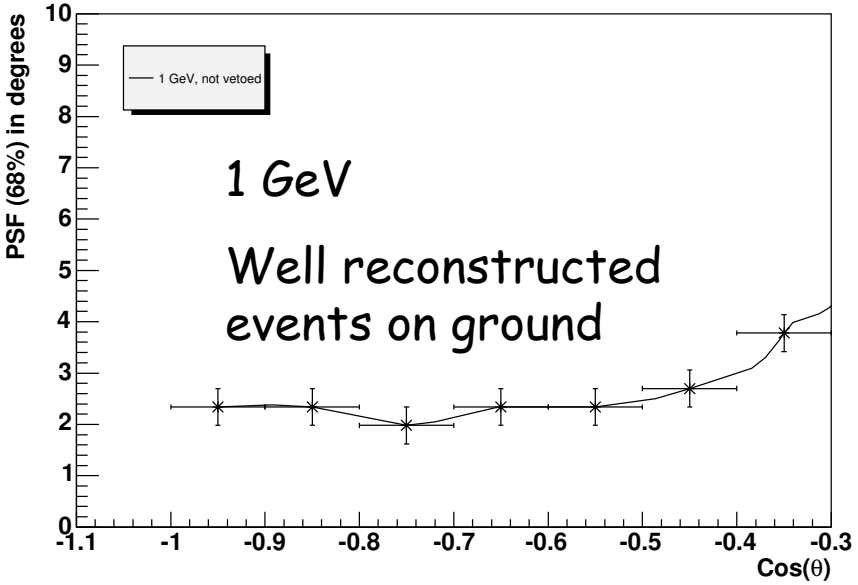


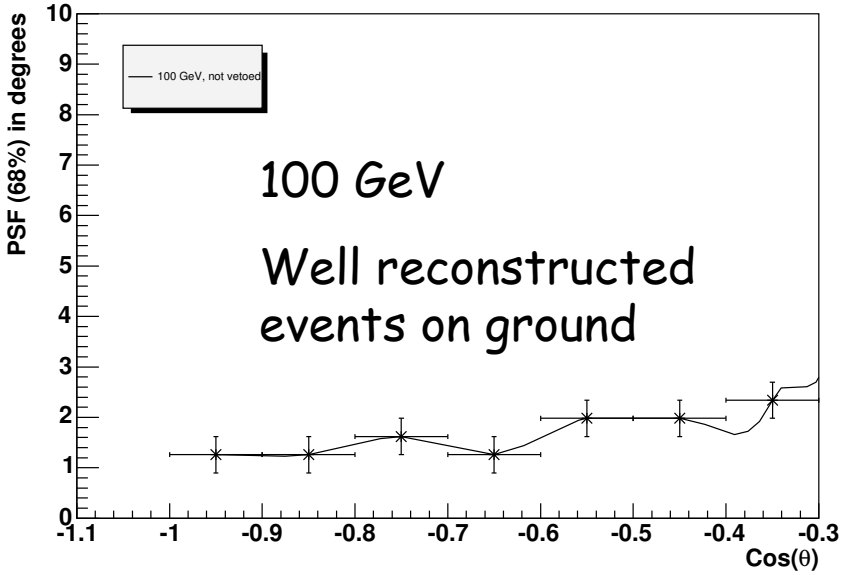


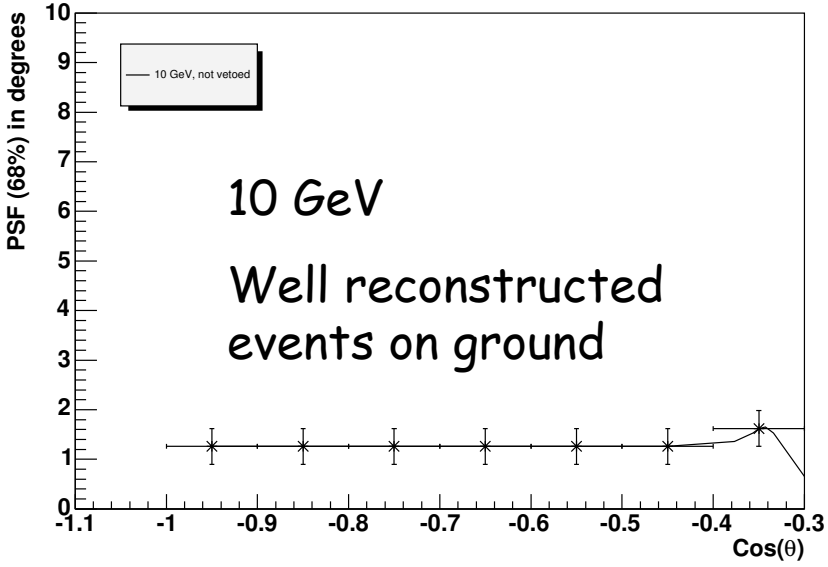


Hough starts to perform well around 1 GeV, but still has trouble at extreme angles at 100 GeV

Hough Transform: Preliminary Results for Events that are Well Reconstructed on Ground







Hough is relatively flat out to 72 degrees for all energies. In comparison to Approach 2, Improvement at 100 GeV is most notable.

Hough Transform: Comments

- Does especially well at high energy, with relatively flat PSF across all angles
- Current, crude incarnation depends heavily on binning
- Not known if processing power will be available, but…
  - Alg has few operations, repeated many times
    - Clever coding can help to a degree (lookup tables, unfolding loops, use pointers to keep track of max array value on the fly, etc.)
  - May be possible to ignore hits in lower Tkr layers (which are messy), speeding it up further
  - May be useful mostly at high energy, reducing frequency at which it is enacted
  - May be able to make binning crude, and then use individual hits, within zone determined by bin, to determine the track direction
    - Would decrease computing load, and could increase accuracy

Summary

- Currently evaluating two methods that use OnboardFilter projections
  - Using the "highest track" method works best, and performance is not bad until higher energy
  - May be possible to improve results by anchoring in calorimeter and/or clustering hits
- Hough Transform may be an alternate method to consider
  - Performs well, but processing power may not be there
- Current projects: more complete method evaluation, more Hough testing and refinements, and implementation of Cal anchor and/or hit clustering