π^0 reconstruction in the GLD calorimeter

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The baseline design of the GLD calorimeter has active layers made of 5×1cm scintillator strips. Adjacent layers have strips orientated in orthogonal directions. An algorithm is being developed to perform clustering in this geometry, which should give an effective granularity of almost 1×1 cm.

1 Introduction

Many physics processes produced at ILC are expected to produce hadronic jets, and the success of the ILC physics program depends in part on the precise measurement of their energies. GLD plans to use a PFA based approach to the measurement of jet energies. The identification of π^0 decays to pairs of photons is expected to lead to some improvement of the jet energy resolution, since a kinematic fit can be applied to the two photons, constraining their invariant mass to be equal to the known π^0 mass, and thereby improving the estimate of the photons' energies.

The identification of high energy π^0 decays requires a calorimeter of fine granularity, since the two photons may only be separated by a small distance ($\sim$cm). The GLD calorimeter seeks to achieve this granularity by means of a strip structure, where alternate layers of the calorimeter consist of long scintillator strips orientated in orthogonal directions.

This paper describes the current status of an algorithm which is being developed to perform clustering in such a strip calorimeter, initially applied to the identification of π^0 decays.

2 Strip clustering

We develop a clustering algorithm which attempts to reconstruct maximal information about calorimetric shower shapes; later stages of the algorithm will decide which groupings of energy deposits correspond to single incident particles. Clustering in a strip calorimeter presents some complications with respect to calorimeters with square cells. Two nearby clusters (from the two photons from π^0 decay, for example) may be resolved in layers of one polarity, but merged into a single cluster in the other layers.

The algorithm proceeds as follows:

- perform a nearest neighbour clustering separately in each calorimeter layer.
- look for evidence of substructure in the resulting clusters: considering only strips with an energy deposit above some value (half the maximum energy deposit in the cluster, for example), perform a second nearest neighbour clustering. If this reclustering gives more than one cluster, split the original cluster, assigning low energy cells below the energy cutoff to the closest cluster.

- search for neighboring clusters in the layers immediately above and below the one being considered; if neighbours are found both above and below, check if these two are also each others neighbors: if yes, make a "triplet" with these three clusters.
- if a single cluster is the central member of more than one triplet, split it cell-by-cell, assigning cells to the closest triplet.
- a figure-of-merit ("quality") is then defined for each identified triplet, considering all combinations of the three clusters which make up the triplet. This essentially tests how many cells in the clusters are each others neighbours, and weights this with the cells' energies.

Once a series of triplets has been identified in the calorimeter, the next step is to combine them, in a step we call calorimeter "tracking". Starting from the innermost triplet, we search for triplets starting in the next layer, whose first two clusters are the same as the last two layers of the initial triplet. We continue to move deeper into the calorimeter in this way, adding matching triplets to the "track". In cases where more than one triplet matches a track, the one with highest "quality" is chosen. When one "track" has finished, the innermost unassigned triplet is used as the seed triplet for the next "track". If this seed triplet is matched to an existing track (but was not used because of low "quality"), a "mother"/"daughter" relationship between the two tracks is established.

3 Photon–π^0 separation

The performance of this algorithm was studied by comparing single 10 GeV photon events to single 10 GeV π^0 events, fully simulated in the GLD detector. The distance between the two photons from a 10 GeV π^0 decay at the front face of the ECAL (at a radius of 210cm in the barrel) is expected to be around 6cm, just a little larger than the length of the scintillator strips (of size 5×1 cm). The extent to which the algorithm could distinguish two photons in the π^0 decays was measured. To do this, we consider only calorimeter "tracks" which start in the first two layers of the calorimeter, and do not have any "mothers". In photon events, we expect to find only one such track, in π^0 events we expect to find two, one from each photon.

Figure 1 is an event display of a single 10 GeV π^0 event, reconstructed in three different ways. The first two use a 1×1 cm cell size, the first reconstructed with the current GLD clustering algorithm, the second with the new "track" clustering algorithm. The standard algorithm (based on nearest neighbours) resolves only a single cluster, while the "track" clustering detects much more substructure. The third figure shows the results of "track" clustering with strips of 5×1 cm size. The structure is again reconstructed, although it also looks rather fragmented: many tracks are found inside the cluster. More work is clearly needed to combine these small tracks together to create a pair of photon objects.

In Fig. 2 we show the number of such early, mother-less tracks reconstructed in single 10 GeV photon and π^0 events, when different strip sizes are used, from 1×1 cm to 20×1 cm, and some configurations with larger strip width. We see that for photon events (left hand plot), the number of such tracks is indeed usually 1, with some fraction of events reconstructed with either zero or two tracks. The number of misreconstructed events depends relatively weakly on the strip length: for longer strips, more events are reconstructed with two tracks. The reason for this feature is not yet fully understood.

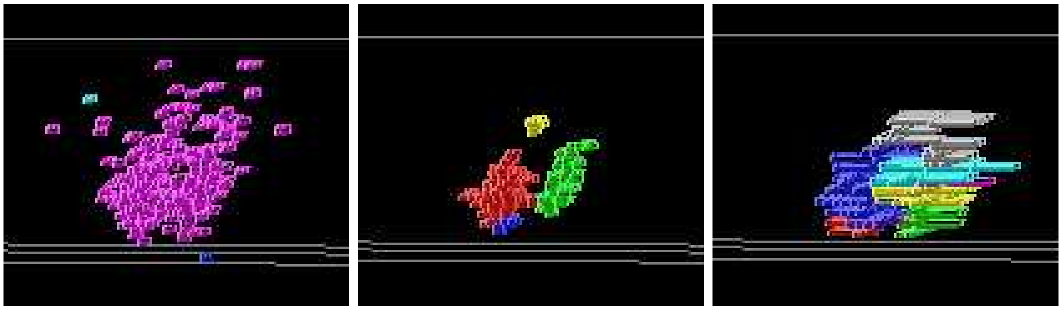

Figure 1: Display of a single 10 GeV π^0 event. Left: standard GLD clustering with 1×1 cm cell size; Centre: “track” clustering with 1×1cm cell size; Right: “track” clustering with 5×1 cm cell size. Different colours denote separate “tracks”.

The right hand plot, for π^0 events, shows that these events are usually reconstructed with two early tracks, although a relatively large fraction is reconstructed with only one. Smaller fractions are reconstructed with zero or 3 tracks. The relative populations of two-track and one-track events depend quite strongly on the strip size and shape: when the strips are larger, the event is more often reconstructed with only a single “track”: this is to be expected, since the granularity of the calorimeter is less fine, and the photons more difficult to resolve.

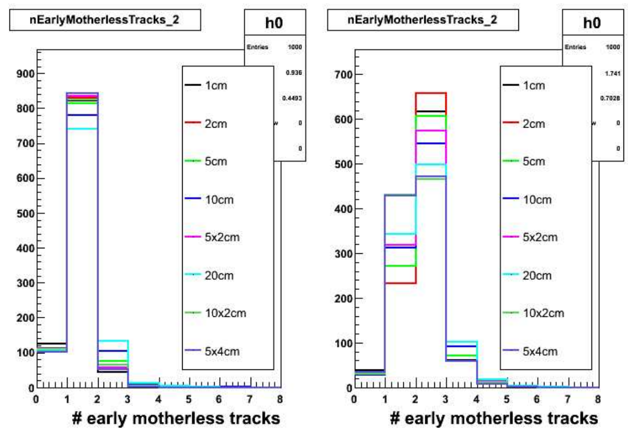

Figure 2: Number of early mother-less tracks reconstructed in 10 GeV photon (left) and π^0 (right) events. Different color histograms are the results of different strip shapes and sizes.

4 Conclusion

We are developing a clustering algorithm to be used in the GLD strip calorimeter. We are studying its performance in single photon and π^0 events, attempting to distinguish the two types of events. Preliminary results look reasonable: the two photons from a 10 GeV π^0 decay can usually be resolved, and the performance depends on the strip size in the expected way. The algorithm will be further developed, and eventually be integrated in a full PFA algorithm.