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IMPROVED RECONSTRUCTION ALGORITHM FOR THE CLAS FORWARD CALORIMETER

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ANSTRACT

A new algorithm for the cluster reconstruction of the CLAS forward electromagnetic calorimeter is presented. The new algorithm differs from the old one only in the determination of peaks of energy on the stereo readout views. It searches for peaks by analyzing the shape of the energy distribution. This new method allows effective reconstruction of two photon hits from high energy π^0 decays for pion energies up to 6 GeV. Unfortunately, to take advantage of the new algorithm, a full processing ("cooking") of the old data are needed. However, considering the importance of a reliable π^0 reconstruction and the separation of π^0s for single photons, it may be worth to reprocess e1-6, e1f, eg3, and e1-dvcs data sets.

CLAS FORWARD ELECTROMAGNETIC CALORIMETER

Forward electromagnet calorimeter (EC) of the CLAS detector is a lead-scintillator sandwich consist of 39 layers of scintillators and 38 layers of lead [1]. EC layer has a shape of an equilateral triangle. Each scintillator layer consist of 36 scintillator strips, about 10cm wide and up to 4.5 m long. In each following layer scintillator strips are oriented parallel to one of sides of the triangle. In this way they form 3-stereo read-out views (channels): U, V, and W. Corresponding strips in the first 5 U, V, and W stereo planes are read out by a single PMT and form "Inner" U, V, and W read-out layers. Remaining 8 U, V, and W views form "Outer" read-out layers, in the same way. There is one EC module in each CLAS sector and it covers polar angular range from 8^o to 45^o for straight tracks.

RECONSTRUCTION ALGORITHM

Reconstruction starts with converting ADCs and TDCs into energy and time, respectively and finding energy peaks on the U, V, and W views. In addition to two hardware layers (inner and outer), in the software, the third layer is formed by summing energies in corresponding read-out channels in the inner and outer layers (in each U, V, and W views). The software layer called "Whole". After energies in each strip are defined EC reconstruction algorithm searches for peaks of energy in each EC read-out view [2]. After finding clusters in each layer, correspondence between clusters in different layers is set.

Search for peaks of energy in each view (U, V, and W) starts with grouping strips with $E>E_{thr}$, separated at least one or more strips without detectable energy ($E<E_{thr}$). The number of strips for separation and the threshold energy are "tcl" controlled parameters. The energy of the found peak (group) is defined as a sum of the energies of each strip in the group, $E_G=\Sigma E_S$. The peak position is defined as a energy averaged position, $X_G=\Sigma X_S E_S/\Sigma E_S$. The direction of X_G is from the shortest to the longest strip. The width of the energy peak is calculated as a second moment of the energy distribution

. After peaks on all three views are resolved, Dalitz rule is applied to each combination of peaks on three views to find if three peaks on the edges intercept at a single point. In Fig.1 schematic diagram of the cluster reconstruction is presented. If peaks belong to a cluster (**O**), then:

$$\boldsymbol{D} = \frac{\boldsymbol{U}}{\boldsymbol{L_U}} + \frac{\boldsymbol{V}}{\boldsymbol{L_V}} + \frac{\boldsymbol{W}}{\boldsymbol{L_W}} = 2 \qquad (1)$$

where U is the distance of the peak on the U-side, measured from the corner opposite to the edge that U-strips are parallel to. Correspondingly, V is the distance of the peak on the V-side, and the W is the distance of the peak on the W-side. L_i's are the lengths of the triangle sides. The Dalitz rule is fulfilled if:

$$\boldsymbol{abs}(\boldsymbol{D}-2) < 2 \times \sqrt{\left(\frac{\boldsymbol{dU}}{\boldsymbol{L_U}}\right)^2 + \left(\frac{\boldsymbol{dV}}{\boldsymbol{L_V}}\right)^2 + \left(\frac{\boldsymbol{dW}}{\boldsymbol{L_W}}\right)^2} \quad (2)$$

Here dU, dV, and dW are the widths of peaks.

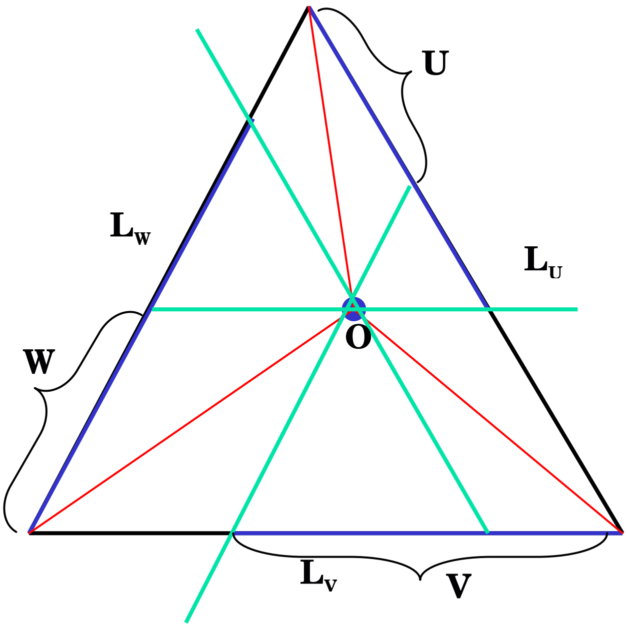

Fig.1 Schematic representation of the cluster reconstruction on EC layer using 3-stereo vies.

After cluster is found, the distances from the center of the cluster to the U, V, and W sides are calculated. Then the energy of each strip in the cluster is corrected for the attenuation of the scintillator light from the point of energy deposition to the end of the scintillator strip. The energy of the cluster and the moments of energy distributions of peaks on the stereo read out sides are recalculated after the attenuation correction.

In Fig.2 reconstructed two-cluster event from data is shown. Peaks on V and W views were resolved, on the U-side only one peak was reconstructed. The energy of the U-view was shared between two clusters according to the energy fraction of each cluster in V and W sum.

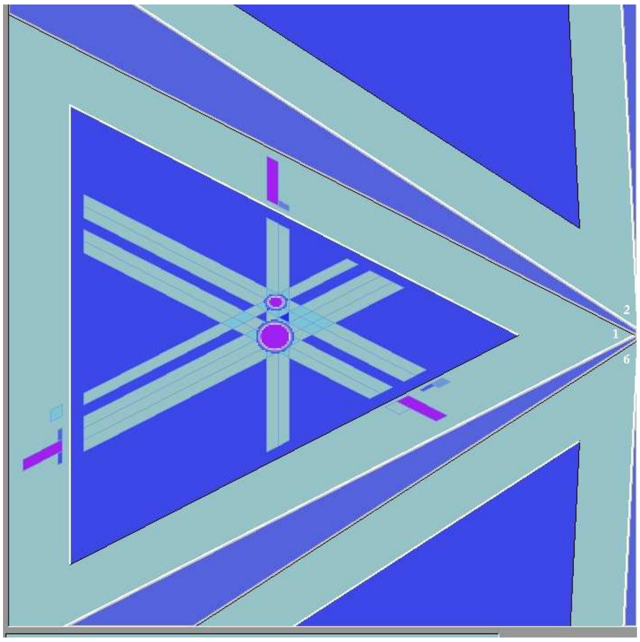

Fig.2 Reconstruction of two clusters in the EC layer. Peaks from clusters were separated only on two views, V and W..

NEW ALGORITHM FOR RECONSTRUCTION OF PEAKS

The above method of peak finding fails to work when two clusters start to get close to each other. For example, photons from high energy π^0 decay end up very close to each other on the EC plane and due to an overlap of showers there will be no strips between peaks on the edges without considerable energy. In this case, two-cluster event from pion decay will be reconstructed as a single cluster.

To solve this problem, a new peak-finding algorithm was developed. The new algorithm searches for peaks by analyzing energy distribution pattern (1 dimensional) on the stereo readout views. First, it orders strips on the edges by decreasing energy. Then, starting from the highest energy strip, steps left and right by the neighboring strips and collects them into a group until the next adjacent strip has no energy ($E<E_{th}$) or has more energy then previous strip. Then, it goes to the next highest energy strip, which was not already included into any of groups, and looks strips left and right the same way. Strips on the ends are treated separately, depending on the energy distribution scenario. In such separation of peaks, for overlapping clusters there are always strips that carry energy

from both clusters. The energy of such a strip is divided between two clusters based on the energy of clusters calculated without the energy of that strip. After peaks are found, the rest of the reconstruction (clustering, attenuation correction, energy determination and time reconstruction) follows to the same steps as before.

In Fig.3 reconstruction of two cluster event with old algorithm is shown. In this event on all three views there were no peaks separated with strips without detectable energy and the event is reconstructed as a single cluster. The same event reconstructed with the new algorithm is shown in Figure 4. Peaks are separated on two stereo views and two clusters are reconstructed. The new algorithm extends the capability of EC to reconstruct two photon clusters from higher energy pion decays to 6 GeV of pion energy (before it was limited to 2.5 GeV to 3 GeV). In Figure 5, two cluster reconstruction efficiency from π^0 decay is presented as a function of pion energy. The blue points are the reconstruction results with the old algorithm and the black points are the reconstruction results with the new peak finding algorithm. After 2.5 GeV/c to 3 GeV/c two cluster reconstruction efficiency of the old algorithm slides down, while the new algorithm keeps 85% to 90% efficiency for high energy pions. (The efficiency is not 100% were it should be in terms cluster separation because for some fraction of events one of photons is not reaching to EC).

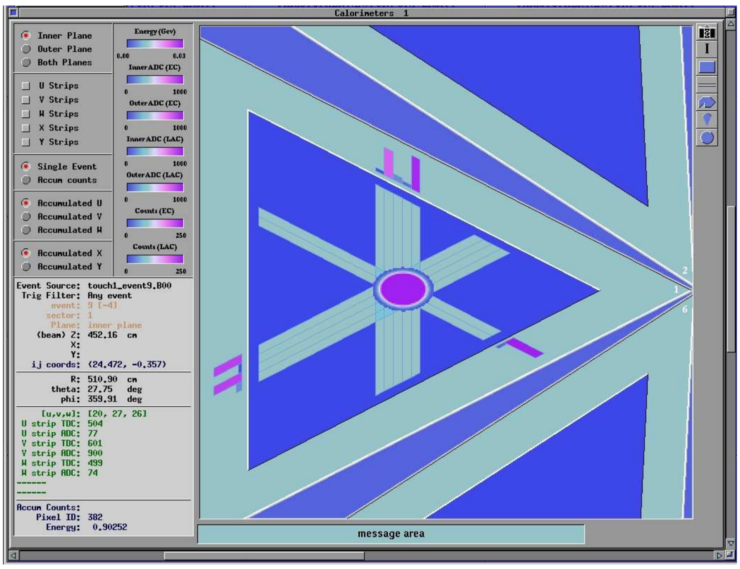

Fig. 3 Two photons seen as a single cluster using the old algorithm. There are no peaks on the edges separated with strips with no energy.

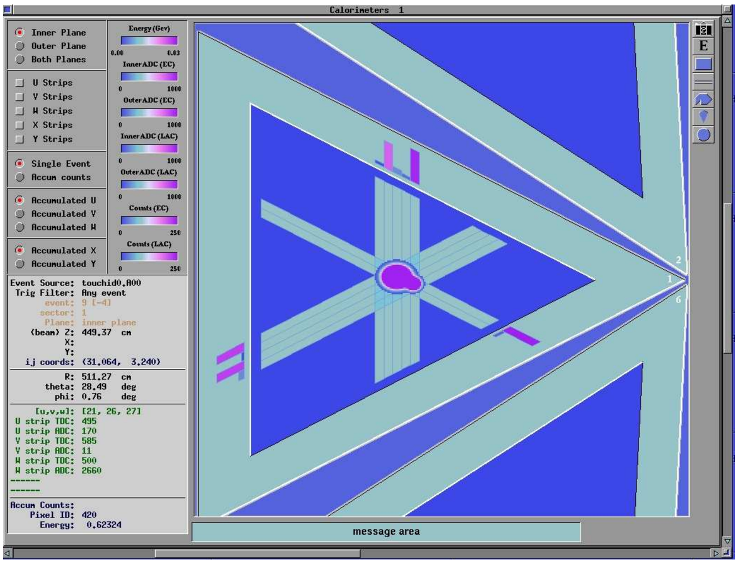

Fig. 4 The same event as in Figure 4 with new algorithm. On two views, U and V, two peaks are resolved and two clusters are reconstructed.

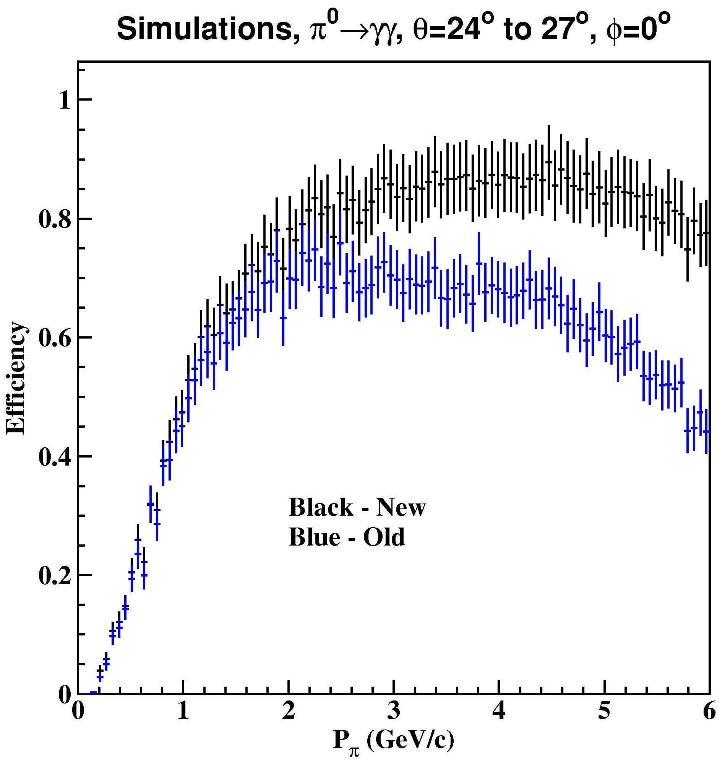

Fig. 5 Two cluster reconstruction efficiency for the old, blue, and for the new, black, peak finding algorithms for the simulated data.

EFFICIENCY OF TWO PHOTON RECONSTRUCTION FROM E1-DVCS DATA

The new reconstruction algorithm has even more dramatic effect on the real data. One of E1-dvcs runs, #46586, was processed with the new EC reconstruction algorithm. Reconstruction of π^0s in the reaction ep→epπ^0, with two decay photons detected in EC, were compared with results from old pass1 processed data. The pass 1 and the new processing were done with the same calibration constants [3]. In the top portion of Figure 6, two photon invariant mass is plotted vs. their energy sum. The left graph is from pass-1 processed data of run #46586. The right graph is from the new processed data. The ratio of the number reconstructed events with the old and new algorithms as a function of pion energy is shown in the lower graph of Figure 6. Clear advantage of the new algorithm is seen. Similar results were obtained using e1-6 data processed [4].

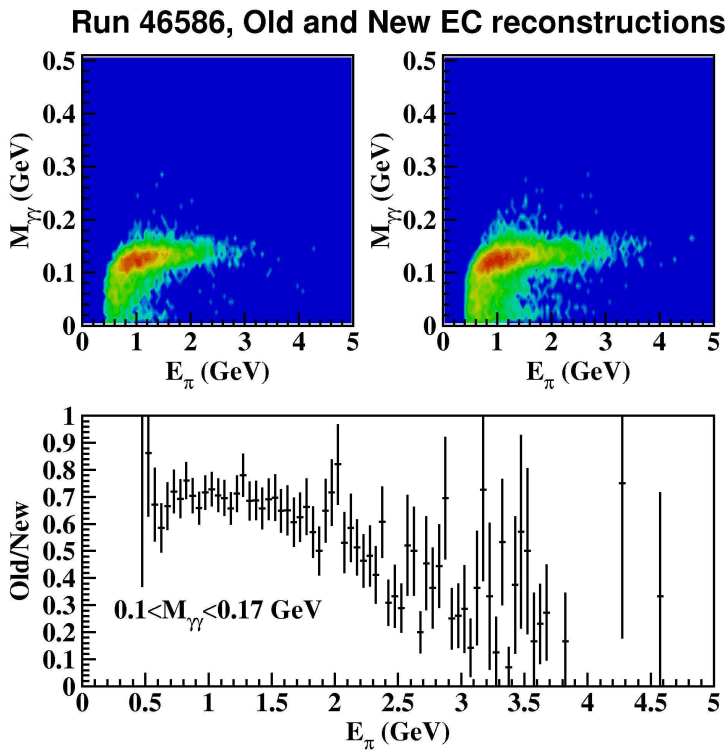

Fig. 6 Run #46586 from e1-dvcs run period. Reconstruction of ep→epπ^0 events with new and old algorithms, when both photons from π^0 decay are detected in EC. Top graphs are dependences of two photon invariant mass on the pion energy for old (left) and new (right) algorithms. Bottom graphs shows the ratio of the reconstructed events with old and new algorithms as a function of pion energy.

Electron energy spectra for the same sample of events from the new and old processed data are shown in Figure 7. There is slight increase of number of electrons with new algorithm, which could be just a result of selection. More detail studies of the effect on electron reconstruction should be done.

SUMMARY

Advantage of the new algorithm for the EC cluster reconstruction was shown. For analysis of reactions requiring reliable reconstruction of high energy π^0s by their two photon decays, it is recommended to re-process data with new EC algorithm. This will mostly effect data sets from high energy eg1, e1-6, e1f, eg3, and e1-dvcs run periods.

The only routine that was added to the EC package is group_0.F. Change was made to the routine ecfsp.F to group.F be called when variable "touch_id=0". To run reconstruction with the new peak-finding algorithm "tcl" variable should be set to 0:

set touch_it 0;

[1] The CLAS Forward Electromagnetic Calorimeter, NIM A **460**, 239 (2001).
[2] EC reconstruction algorithme, http://clasweb.jlab.org/offline/offline_libs.html.
[3] Maurizio Ungaro processed both data sets.
[4] Analysis of e1-6 data processed with the new and old EC reconstruction algorithms were performed by Harut Avagyan.

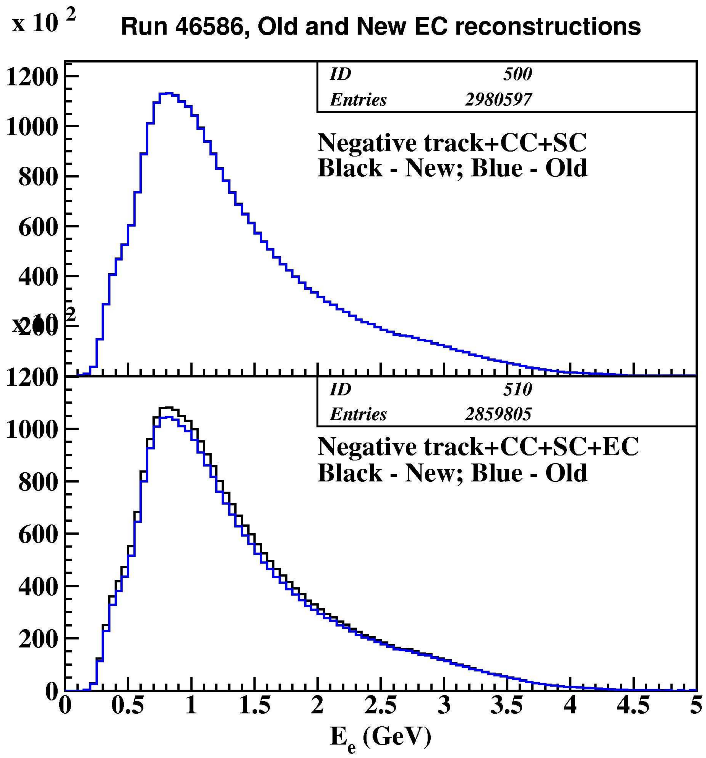

Figure 7. Energy dependence of detected electrons for the sample of events from the pass-1 (black) and the new processing of data.