Forward Time of Flight Reconstruction Software for CLAS12

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Introduction

The goal of Jefferson Lab (JLab) is to understand how quarks and gluons form nucleons and nuclei. To reach this goal JLab is undergoing an upgrade that will double the electron beam energy to 12 GeV and upgrade the detector in Hall B, CLAS12. See Figure 1. CLAS12 is a large acceptance spectrometer meaning it can take data over a wide solid angle. The Forward Time of Flight (FTOF) component of CLAS12 is being enhanced in this upgrade. FTOF provides precise timing measurements which help identify particles. FTOF is composed of panels of scintillation paddles. A single incoming particle can deposit energy in multiple paddles. This poster describes work carried out to optimize how hits on adjacent scintillation paddles are combined in the FTOF reconstruction software. Efficiency is improved if each panel is treated separately and if more than two hits are combined, if necessary.

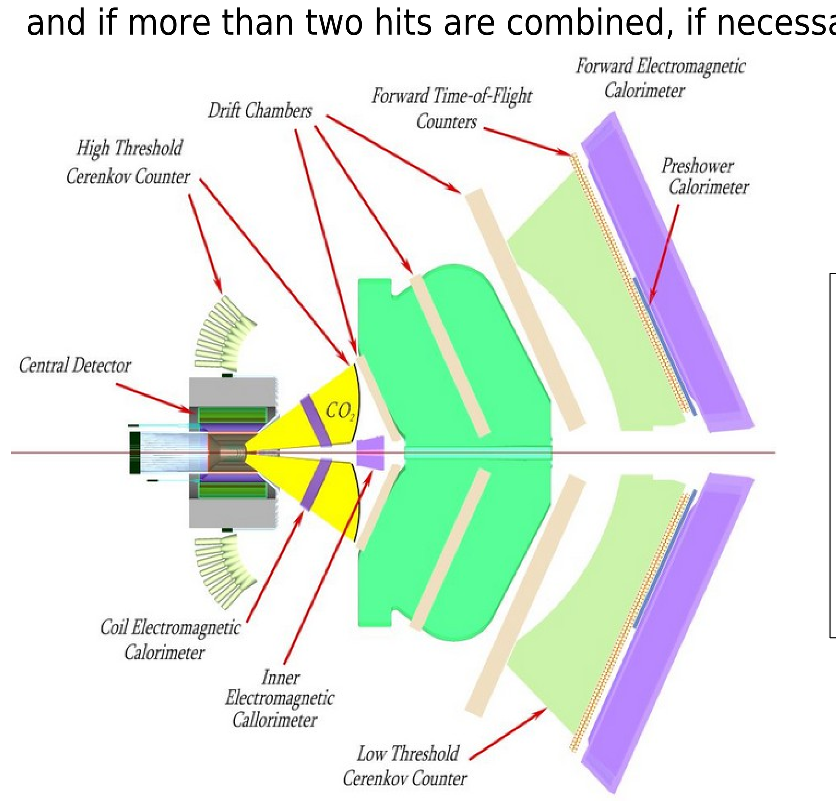


Figure 1 Horizontal slice through the CLAS12 particle detector. The electron beam enters from the left. [1]

FTOF Detector [1]

The FTOF component of CLAS12 is shown in Figure 2. It is divided into six triangular sectors. Within each sector are three panels of scintillation paddles. Panel-1b is shown in orange in Figure 2. It consists of 62 paddles, each 6cm wide by 6 cm thick with varying lengths. Panel-1a is located behind Panel-1b and covers approximately the same area. It consists of only 23 paddles, 15 cm wide and 5cm thick. Panel-1a is not visible in Figure 2. Panel-2 is located at wider angles. It is shown in red in Figure 2 and consists of 5 paddles, 22cm wide and 5cm thick. The panels and paddles of one sector can be seen on the right of Figure 3.

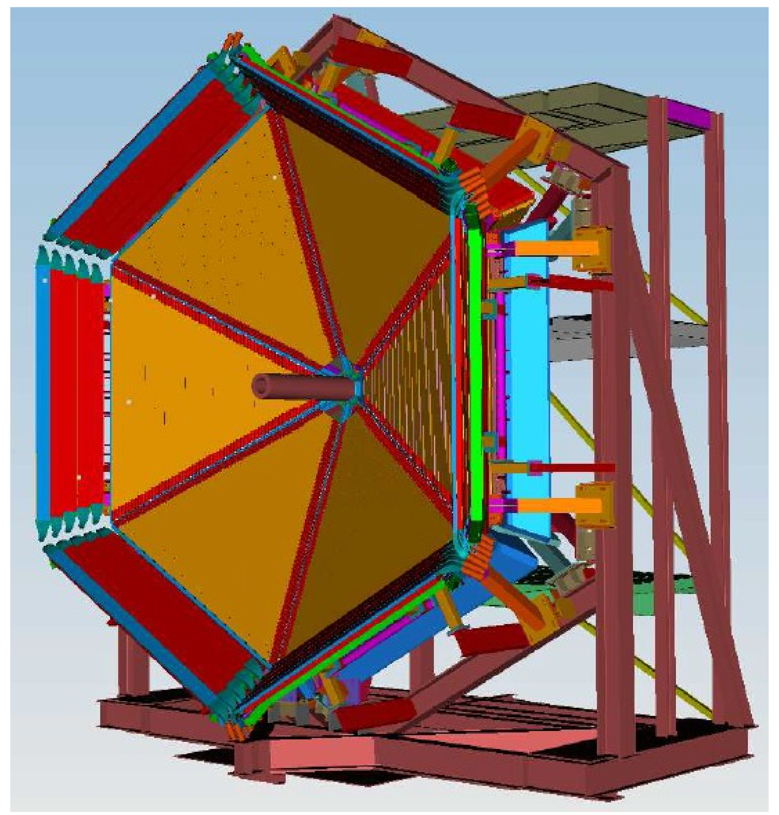


Figure 2 The FTOF component of the CLAS12 detector shown in isolation [1].

Each end of a TOF paddle is connected to a photomultiplier tube (PMT). Each PMT is read out using a time-to-digital converter (TDC) and a analog-to-digital converter (ADC), to provide energy and timing output, respectively. It is the discriminated signals from the ADCs and TDCs that are the input to the FTOF reconstruction software.

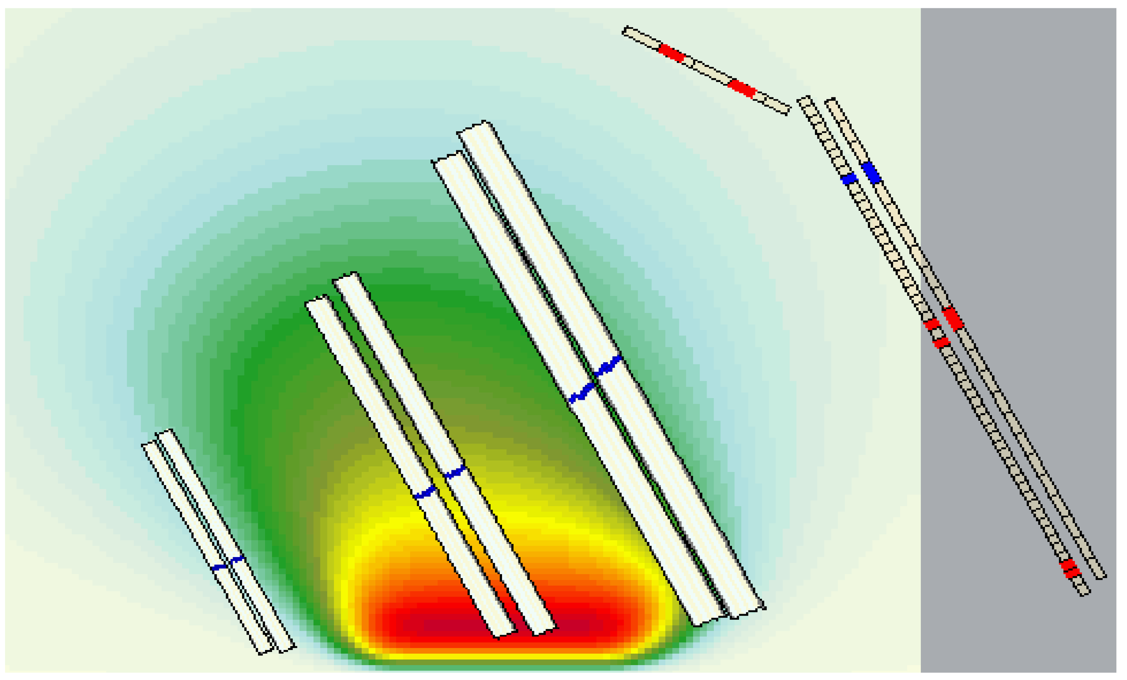


Figure 3 Illustration of signals left by particles in a single sector of the CLAS12 detector. The 3 FTOF panels are located to the right of the diagram. Proton hits are shown in blue. The six larger white rectangles are the sections of the Drift Chamber (DC) detector. Behind the DC, the strength of the magnetic field is shown, with white meaning no field and the darkest red 2.6 T.

Steps of the FTOF Reconstruction Software

The basic steps of the reconstruction software are the following:

1. For each PMT on the end of a paddle, convert the ADC value to energy and the TDC value to time.

2. Combine the time and energy from both ends of a paddle into a single hit time, energy and position.

3. Combine adjacent related hits into clusters. Clusters have an energy equal to the sum of the hit energies.

4. Output the results of steps 1-3.

The current algorithm has been adapted from the algorithm for the previous detector, CLAS6. The new CLAS12 FTOF has a different geometry - panel-1b is new to CLAS12 (see Figure 2) and is located in front of panel-1a which is being reused from CLAS6. Panel 2, at large scattering angles, is also being reused from CLAS6. These geometry differences have led to the development of a new clustering algorithm.

The Clustering Problem

Ideally, hits on adjacent paddles should only be combined into clusters if they are caused by a single incoming particle. As shown in Figure 4, adjacent paddles can also be triggered by two particles coincidentally going in side by side. The reconstruction software must distinguish between these two cases, using only differences in the hit time and the hit position along the length of the paddle (y coordinate). Clustering only occurs if these differences are less than a given value.

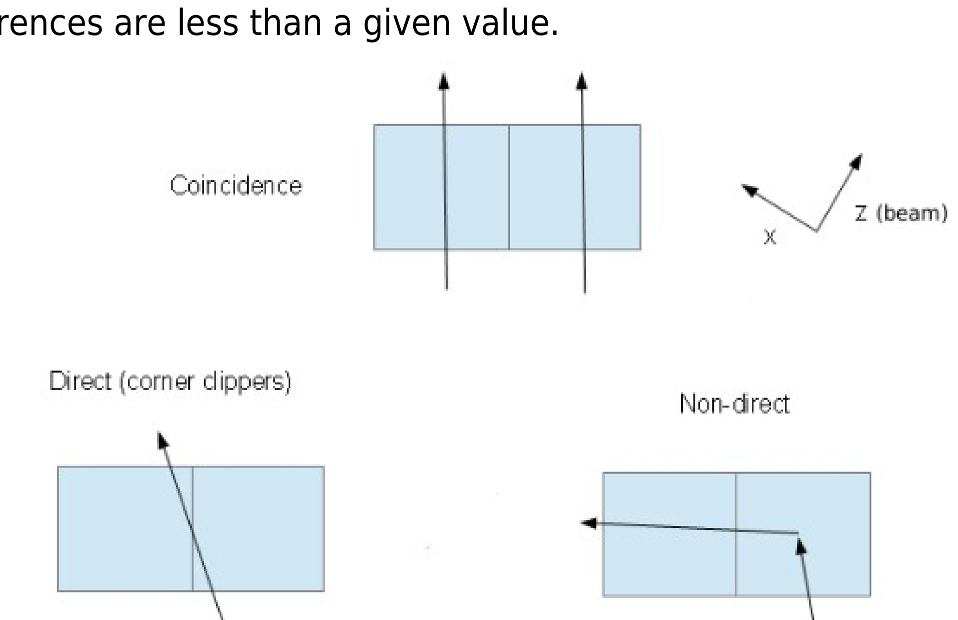
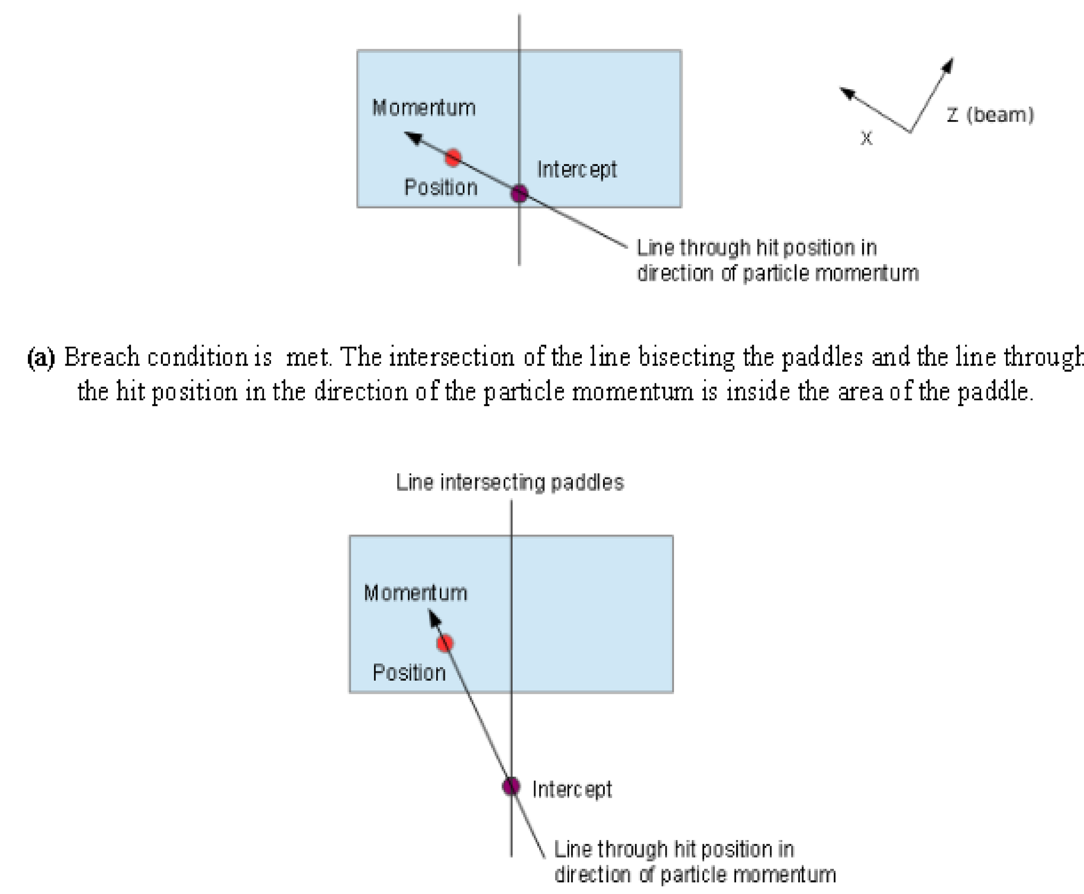


Figure 4 Ways in which two adjacent FTOF paddles can be triggered. Arrows represent the movement of particles.

Solving the Clustering Problem using Simulation

From Figure 4 it is clear that a single incoming particle triggering two paddles will necessarily have one or more particles crossing the intersection between paddles. This "breach condition" was converted into code, with the CLAS12 simulation software GEMC providing the necessary input - the exact hit position and the exact hit momentum, information unavailable in a real experiment. This code is shown graphically in Figure 5.



(a) Breach condition is met. The intersection of the line bisecting the paddles and the line through the hit position in the direction of the particle momentum is inside the area of the paddle.

(b) Breach condition fails. The intersection of the line bisecting the paddles and the line through the hit position in the direction of the particle momentum is outside the area of the paddle.

Figure 5 Visual representation of the GEMC breach condition that determines if a single particle caused two adjacent paddle hits.

By using the GEMC breach condition between all pairs of adjacent triggered paddles, it is possible to estimate how many paddles a single incoming particle has triggered. Results are shown in Figure 6.

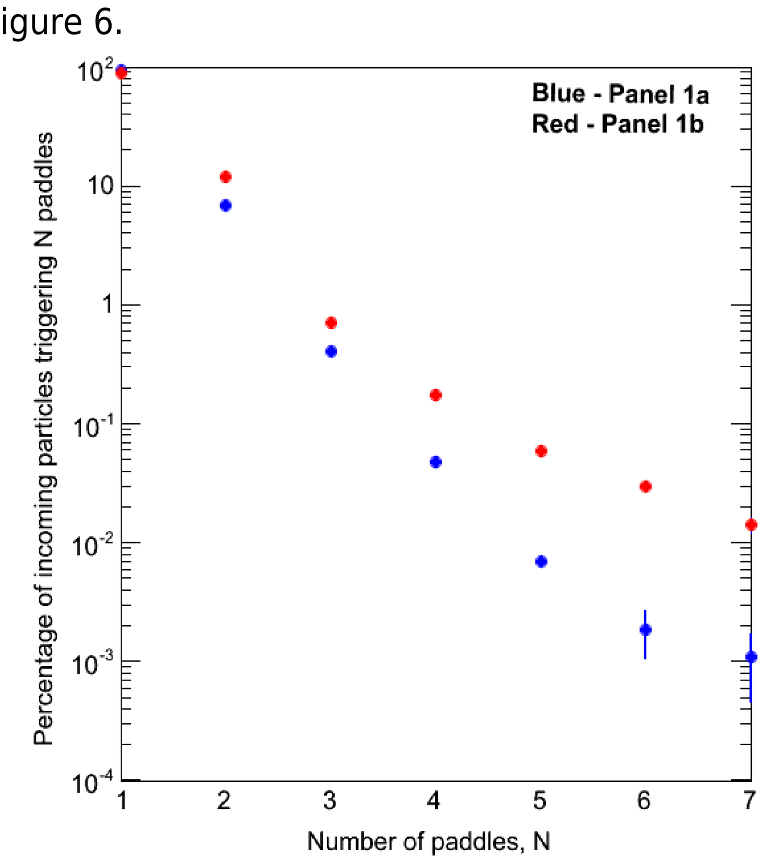


Figure 6 Number of paddles triggered by a single incoming particle

Figure 6 shows that particles hit more paddles in Panel-1b, which is not surprising given that the Panel-1b paddles are both thicker and narrower, so a particle is more likely to cross to the adjacent paddle before exiting altogether. These (and other) results show that it might be best to treat each panel separately when clustering. The previous software did not. These results also show that, as particles hit more than two paddles 1 % of the time, it makes sense to make clusters from more than two hits. The previous software only used two. The efficiency of these alterations has been measured.

Clustering Efficiency Improvements

Clustering efficiency has been calculated using the percentage of non-isolated hits extracted from the simulated data and correctly allocated to clusters where the 'true' clusters are those found using the GEMC breach condition of Figure 5 between all pairs of adjacent paddles. Figure 7 shows the relative number of correct clustering decisions made for a range of hit time differences and hit y positions for each panel. Values above 1 indicate that more correct clustering decision were made versus the previous algorithm, below 1, less correct decisions. Note that these graphs are quite different, indicating that to get maximal efficiency each panel must use its own set of time and y position differences. When combined with the concept of having increased length clusters, the efficiency of the altered algorithm increases by up to 10% versus the previous algorithm as shown in Table 1.

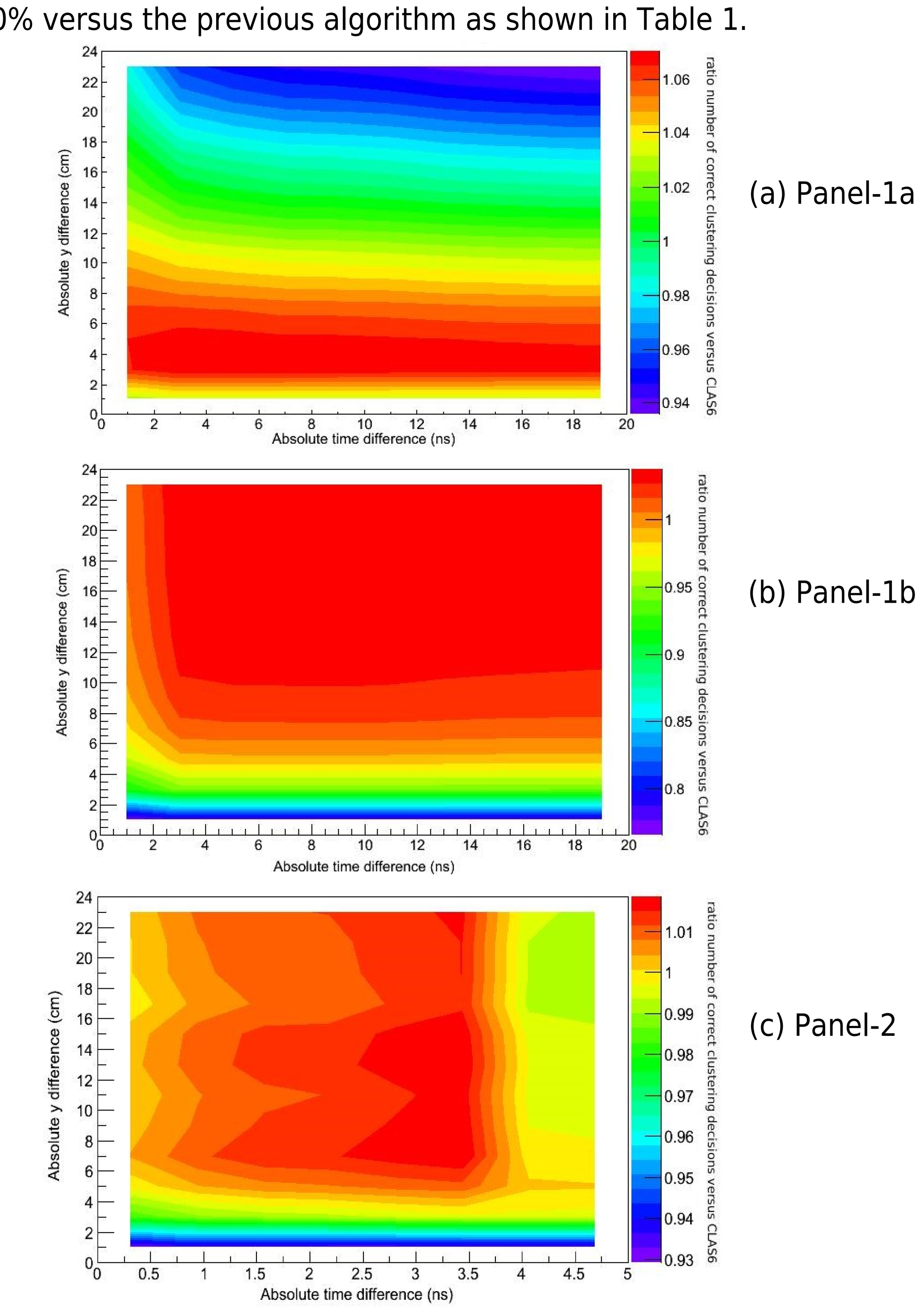


Figure 7 Number of correct clustering decisions versus previous clustering algorithm for a range of time and y differences

	Panel 1a	Panel 1b	Panel 2
Clustering efficiency (%)	68.9 +-0.2	80.0 +-0.1	87.0 +-0.6
Change in efficiency versus CLAS6 (%)	+7.1 +-0.5	+10.1 +-0.1	+2.2 +-0.9

Table 1 Absolute and relative clustering efficiency when using optimal time and y differences (calculated from Figure 5) and variable cluster length.

Conclusion

Simulation has been used to optimize the CLAS12 FTOF reconstruction software clustering algorithm. Clustering efficiency has been improved by up to 10% by treating each panel separately and by forming clusters from variable numbers of hits.

[1] 'CLAS12 Technical Design Report', www.jlab.org/Hall-B/ , accessed on 01/06/2013