Simulation of the Scintillator Geometry in the Electromagnetic Calorimeter in the CLAS12 Detector

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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 beam energy to 12 GeV and upgrade the detector in Hall B, CLAS12. See Figure 1. We are running simulations to understand how the new detector will work. Here we describe our work to make the simulation of one component, the electromagnetic calorimeter(EC), more realistic. The EC from the existing detector CLAS6 will be reused in the new CLAS12.

- CLAS12 is a large acceptance spectrometer allowing it to take data over a large solid angle.
- An important component of CLAS12 is the electromagnetic calorimeter which is composed of alternating layers of plastic scintillators and lead. The EC measures the hit position and energy of charged particles and the hit position of neutral particles.
- To model CLAS12's behavior we are using a simulation called *gemc* which is based on the package Geant4 (G4) to simulate particle tracks.

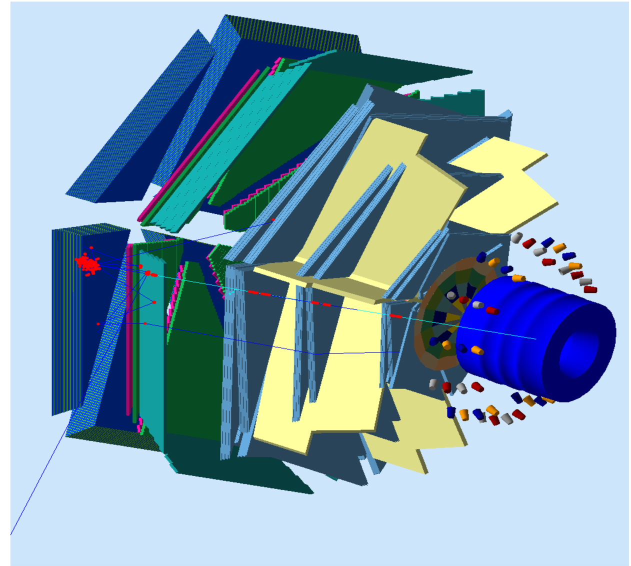


Figure 1. This image illustrates what a simulation of an event in CLAS12 looks like in *gemc.* The cluster of red dots on the left side are particle hits in the EC.

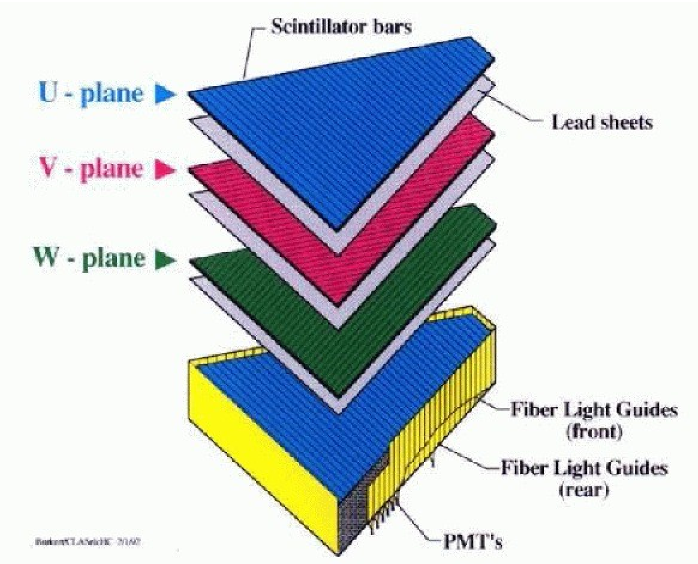
Importance of Accurate Simulation and the EC

The accuracy of many experiments in CLAS12 will be limited by systematic uncertainties, not statistical ones. Understanding the response of CLAS12 is essential for separating physics effects from artifacts of the device.

The EC consist of 39 alternating layer of scintillator and lead. Each scintillator is built of 36 parallel strips that form the triangular shape of each sector of the EC. Consecutive scintillator layers have strips rotated by 120 degrees allowing for the particle position to be found by overlapping the layers. Figure 2 shows the alternating layers of lead and scintillator and how the strips are rotated between scintillators creating U,V, and W layers. The measurements of charged particles taken by the EC can be explained in three main steps.

- A charged particle hits one of the lead layers in the EC which causes it to burst into a shower of other particles that continue to travel through the EC.
- When the particles from the shower pass through a layer of scintillator they produces light that is collected by a photo multiplier tube(PMT).
- The PMT converts and amplifies it to a measurable electronic signal that can then be recorded for further analysis.
- Figure 3 shows how the overlap of layers allows the EC to locate particle hits. Light blue strips have been hit and the intersection of all three strips at purple dots indicate a particle hit.

Figure 2. Expanded view of the EC showing lead and scintillator layers.



Strip vs. Slab

In past simulations of the EC for CLAS6 the scintillators have been defined as single slabs due to limitations in computing power. When using the slab geometries for the simulation an algorithm is required to calculate the strip that would have been hit. This is accomplished by saving the particles position as it passes through the EC and then calculating the hit position.

We redefined the scintillators as strips to have more accurate simulations. The slab algorithm failed to properly handle tracks at large angles to the normal of the scintillators that may enter adjacent strips. The trade off for using strips is they require more computing power. Figures 3 and 4 shown the difference between strips and slabs respectively.

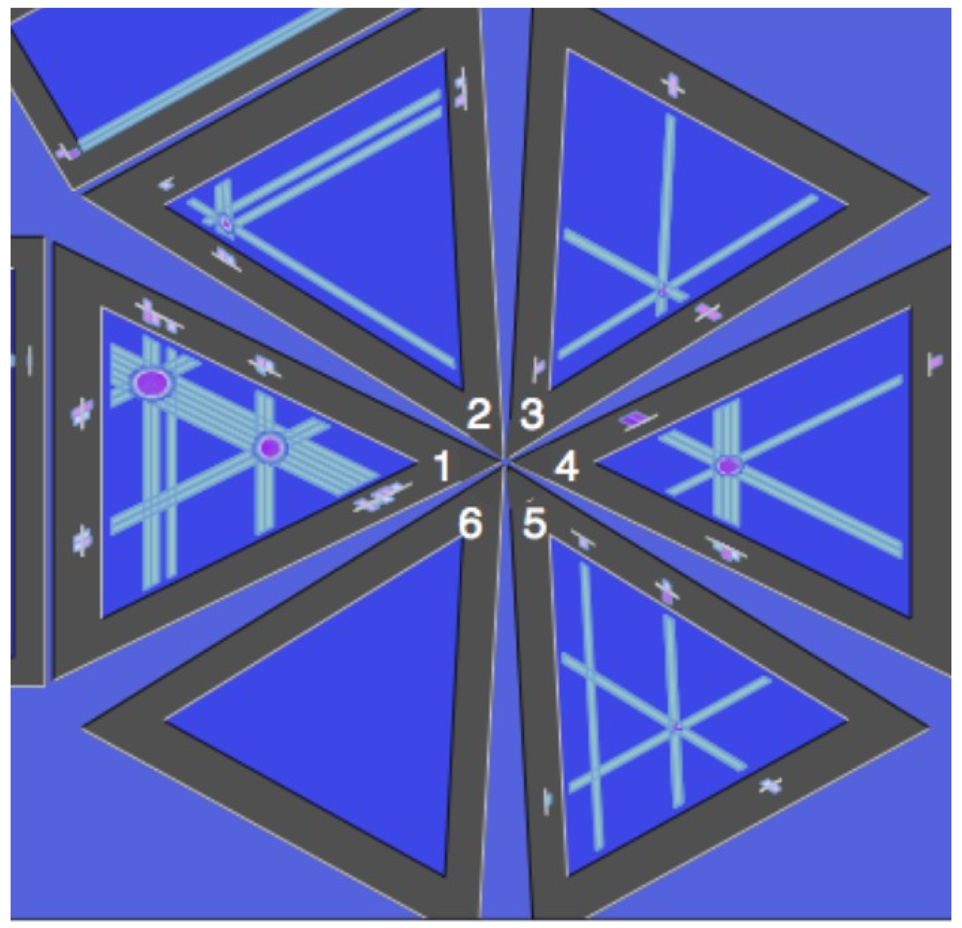


Figure 3. Data from the EC in CLAS6 showing strip hits used to determine particle hits.

Figure 4. The above image shows what the first layer of scintillator looks like in *gemc* when using the slab geometries.

Redefining the Scintillator Geometries

To simulate events in CLAS12 we use a program called *gemc* which is based on a package called Geant4. It was developed at JLab for the purpose of simulating events in CLAS12. Geant4 simulates particle tracks and their interactions with materials as well as defining the geometries of CLAS12 components used in *gemc.* All the geometry parameters are stored in a MYSQL database. To simulate the scintillators as strips there were three files that had to be edited and a new table was created in the MYSQL database.

ec.config – This file was edited so that the new strip geometries would be put in the correct database and table that was created for them.

ec_build_strips.pl – This perl script was adapted from ec_build.pl which was used to create the slab geometries. It now runs a series of loops to create the parameters for a layer of scintillator strips before creating a lead layer. These geometries are then loaded into the database.

EC_hitprocess.cc – This C++ file is used for the digitization of the signals produced by the EC in the simulation. It is where the algorithm for calculating the strip number was located for the slab geometries. That part of the algorithm no longer exist, instead it just calls for and returns the strip number that was hit.

ECwithG4strips – This is the new MYSQL table that was created to hold the strip geometries. By allowing the strip geometries to have their own table it makes it very easy to switch between using the slab geometries and the strip geometries. This enables us to compare the performance of *gemc* with and without the new geometry.

Testing the Strip Geometries

Hit Position Test

We compared the difference in particle hit position between the two geometries. We ran simulations of both geometries using electrons aimed perpendicularly at the EC with no magnetic field and no other components of CLAS12. The graphs in Figure 5 show the number of hits in each strip of the U, V, and W layers in the left-hand column. There is little difference between the two geometries in the distribution of hits for each EC view. To make the comparison more rigorous we took the difference between the hit distribution as a function of strip number for each geometry. We took the number of events in a strip for the slab geometry and subtracted the equivalent value for the strip geometry. The right-hand column in Figure 5 shows the results for each view. We observe shifts between the two geometries consistent with the strips being located 200 microns radially closer to the beam line with no measurable difference in the azimuthal direction.

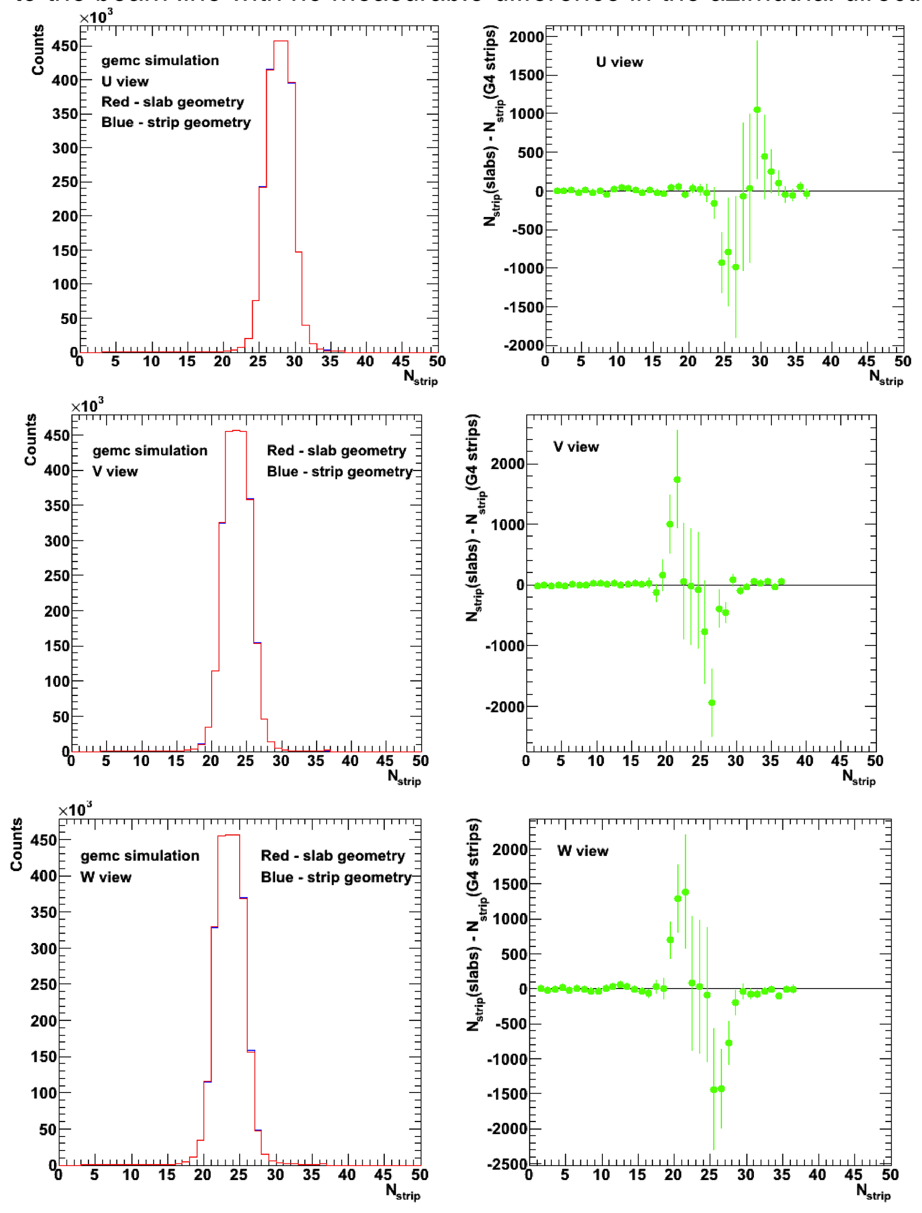


Figure 5. Results of the hit position test.

Time Test

The effect of the new strip geometries on the simulation speed of *gemc* was measured. We used the UNIX 'time' command while running 1000 events using only the EC in *gemc* without using the graphics. We ran this test in intervals of 2 GeV in the incident electron energy starting at 2 GeV and going up to 10 GeV. Figure 6 shows a computational time increase of 5% - 8% in the EC at the highest energies.

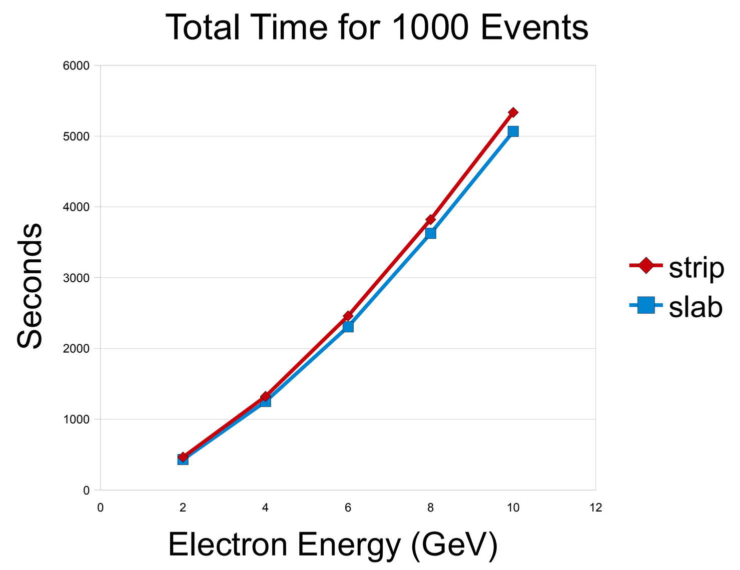


Figure 6. The difference in computational time at different energies for the strip and slab geometries.

Graphics Field Test

We performed a field test on the speed of the interactive graphics in *gemc* comparing the new strip geometry to the old slab geometry. We took frame rate measurements using *glxgears* (see figure 7). The program prints out the overall frames per second (FPS) of the of the *glxgears* window in 5 second intervals. We allowed it to run for 30 seconds to give us a base line frame rate. Next we ran *gemc* with the graphics and only the EC while interacting with the graphics for 30 seconds. The results are shown in the table below. We found that the new strip geometries were about 25% slower than the slab geometries.

Base Line FPS	Slab FPS	Strip FPS
$(4.17 \pm 0.02) \times 10^3$	$(3.23 \pm 0.02) \times 10^3$	$(2.61 \pm 0.09) \times 10^3$

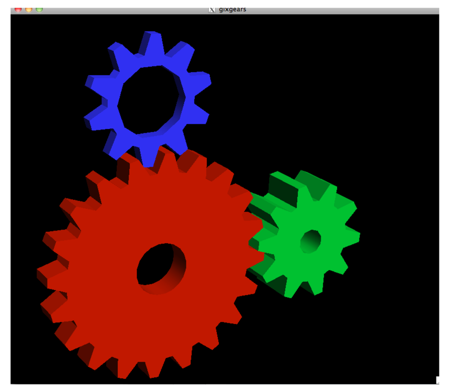


Figure 7. Image of the program *glxgears* that we used to test change in frame rate.

Conclusion

We have modified the scintillator geometry of the simulation of the CLAS12 electromagnetic calorimeter to use individual strips in each layer. This change is closer to the physical geometry of the device. Our tests show this modified geometry is still close in position to the previous version within about 200 microns. The computational time is a few percent longer at high electron energies with the simulated strips and the graphics response is about 25% slower.

References

Ungaro, M. (2012). Gemc. https://gemc.jlab.org/gemc/Home.html

G.P. Gilfoyle et. al. CLAS-NOTE 2010-019, Jefferson Lab, 2011