Geometry Update for the Electromagnetic Calorimeter in CLAS12

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Abstract

We describe here the geometry of the forward electromagnetic calorimeter (EC) that will be part of the base equipment for the CLAS12 detector in Hall B at Jefferson Lab. The previous version of the EC geometry in CLAS6 and CLAS12 treated the plastic scintillators as one large, continuous slab. We have implemented individual scintillator strips for the EC in *gemc*, the physics-based CLAS12 simulation and tested their performance. We include another description of the EC geometry in a different coordinate system compatible with the other detector sub-systems in the CLAS12 geometry service.

Contents

1 Introduction

In this CLAS-NOTE we describe the implementation of the geometry of the forward electromagnetic calorimeter (EC) in `gemc`, the CLAS12 simulation package. The previous version of the EC geometry in CLAS6 and CLAS12 treated the plastic scintillators as one large, continuous slab. See for example, CLAS-NOTE 2011-019 [1]. We have implemented individual scintillator strips for the EC in *gemc*, the physics-based CLAS12 simulation. This update is being written to fully document the EC geometry for the geometry software service being written by the CLAS12 software group [2].

The purpose of the EC is (1) detection and triggering of electrons, (2) detection of photons (for reconstruction of other particles like π^0 and η), and (3) neutron detection. The information from the EC will be combined with data from the two threshold Cherenkov detectors (the high-threshold Cerenkov counter (HTCC) and the CLAS6 Cerenkov counter (CC)) to provide high electron detection efficiencies and large hadron rejection factors. The EC is an electromagnetic sampling calorimeter that consists of six, identical sectors and covers the forward region ($5° < \theta < 45°$) of each CLAS12 sector. The CLAS6 forward electromagnetic calorimeter will be reused in CLAS12 largely without modifications [3]. Relevant details can be found in Section 1.

Simulation of CLAS12 is an essential part of the design of the detector and is needed for the analysis of CLAS12 data. The precision of many experiments will be be limited by systematic uncertainties instead of statistical ones, so an accurate simulation is vital [4]. A robust, maintainable simulation for CLAS12 `gemc` is now being developed [5]. In the paper, we will describe in broad terms the CLAS12 forward electromagnetic calorimeter and then focus in great detail on the EC geometry. We then describe how this geometric information in implemented in `gemc` and our initial results measuring the features of the EC with the new simulation (*e.g.* sampling fraction,...) and conclude with a summary.

2 Description of the Electromagnetic Calorimeter

The EC is an electromagnetic sampling calorimeter that covers the forward region ($5° < \theta < 45°$) of each CLAS12 sector [6]. It is constructed from alternating layers of scintillator strips and lead sheets, with a total thickness of 39 *cm* of scintillator and 8.4 *cm* of lead, for a total thickness of 16 radiations lengths. The module construction is illustrated in Fig 1.

The lead sheets account for 90% of the 16 radiation length thickness. In each module, the scintillator/lead layers are contained in a volume having the shape of a nearly equilateral triangle. Each module contains 39 layers consisting of $10-mm$ thick scintillator and 2.2 *mm* of lead. The module was designed using a projective geometry, pointed at the nominal CLAS6 target position, such that the solid angle subtended by successive layers is approximately constant for the CLAS6 configuration. The entire detector will be placed about 200 *cm* further away from the nominal CLAS12 target position than the CLAS6 target position. The azimuthal (ϕ) coverage ranges from about 50% at forward angles to approximately 90% at large angles. Each layer consists of 36 scintillator strips oriented parallel to one side of the triangle, with the strip orientation being rotated by 120° in each successive layer (labeled U, V, and W in Fig 1).

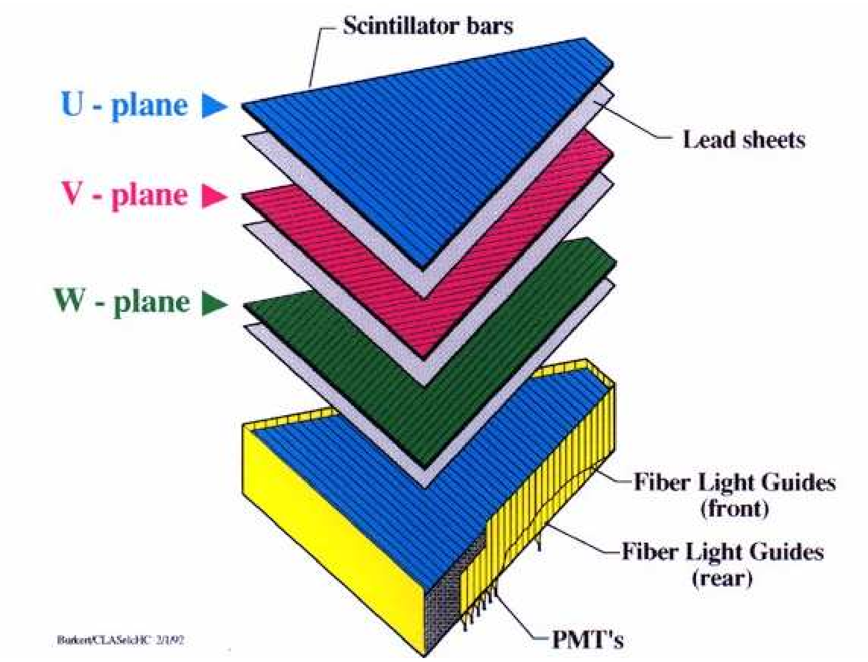

Figure 1: Exploded view of the electromagnetic calorimeter

The three orientations (or views) of scintillator strips are labeled U, V, and W. Each view contains 13 layers, which are subdivided into inner (5 layers) and outer (8 layers) stacks that provide longitudinal sampling. Each of the view/stack combinations are optically ganged and coupled to XP2262 PMTs (in CLAS6) via fiber optic cables. The optical readout of the EC in CLAS6 is illustrated in Fig 2. The 1296 PMT channels are read out by FASTBUS crates containing LeCroy 1881M ADC and LeCroy 1872A TDC boards (in CLAS6). Leading edge discriminators are used to provide timing signals to the TDC.

To reconstruct a hit in the EC in CLAS6, energy deposition is required in all 3 views of either the inner or outer layers of the module. Adjacent strips are placed into groups in each view if their deposited energy is above a software threshold. After grouping, the centroid and RMS for each group are computed. The intersection points of scintillator groups in different views are found. Intersections which contain groups from all 3 views correspond to hits. The energy deposited and time of the hit are calculated taking into account the path lengths from the hit location to the readout edge (to correct for signal propagation time and attenuation). If one group is involved in more than one hit, its energy is divided between hits with an appropriate weighting. A view of the CLAS6 EC showing reconstructed hits is shown in Fig 3.

3 EC Geometry in G4 Coordinates

In defining the CLAS12 EC geometry in this section our goal is produce a description compatible with the commands needed to implement the geometry in *gemc*, the physics-based, CLAS12 simulation that uses Geant4 [7]. Geant4 is a toolkit for the simulation of the passage

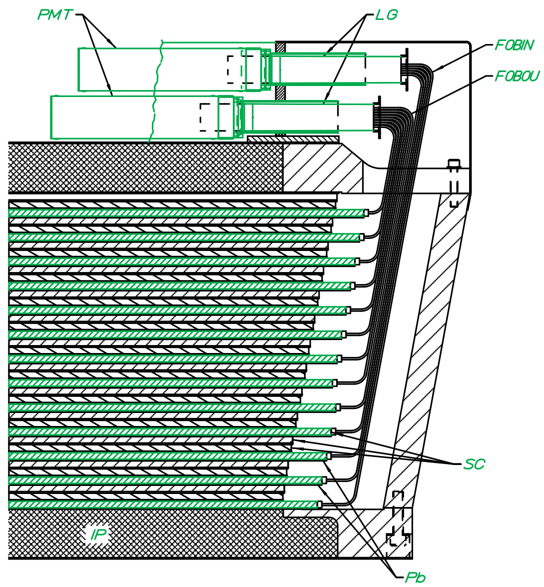

Figure 2: Side view of EC module, showing optical connections.

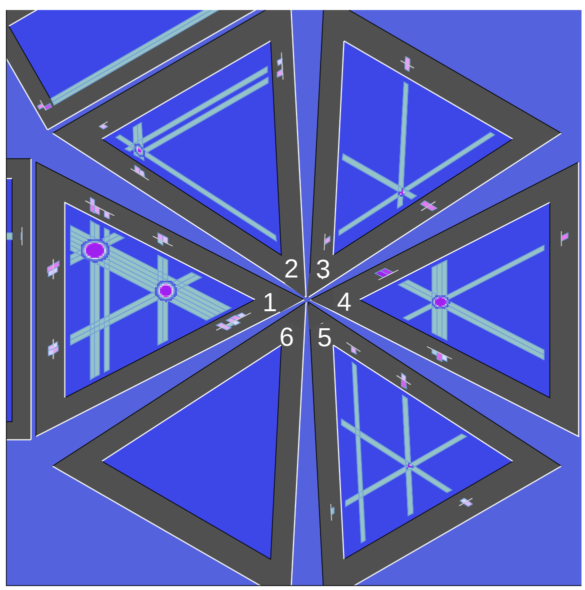

Figure 3: Event reconstruction in the EC. In sector 2,3,4,5 a single hit is found, while in sector 1, multiple hits are reconstructed.

of particles through matter and is one of the essential pieces of the CLAS12 simulation [8]. We draw on our experience with the CLAS6 version. Our description shares many features of the work of R. Minehart [9]. However, it is not identical (although the actual detector is) to Ref. [9], because we generate the parameters used by Geant4 to build the detector simulation in `gemc`. We do use the same notation as Ref [9] when it is appropriate.

We define here two coordinate systems needed to incorporate the EC geometry into *gemc*. For each sector of the EC we define a coordinate system we call the G4 sector coordinate system. These coordinates are different from the usual sector coordinate system used in, say, the drift chamber geometry, but they are consistent with the local EC coordinate system that is centered on the individual detector and used in Geant4 to define the volume of the detector. The z axis of the G4 sector coordinates is horizontal along the beam line and in the direction of the beam. The y axis is radially outward in the ideal midplane of the EC. The x axis is constructed to form a right-handed coordinate system. We define (for later use) the 'perpendicular point' P by a line drawn from the target point T at the origin (and nominal target center) to a point on the face of the first scintillator layer and perpendicular to that face. See Fig 4.

The G4 local EC coordinate system has its origin at the geometric center of the triangle formed by the three sides of the front face of the first scintillator (closest to the target) of the EC. The z axis of the G4 local EC coordinates is perpendicular to the face of the detector (and hence parallel to the line from the target point T to the perpendicular point P) and points away from the target. The negative y axis is parallel to the face of the first scintillator layer, passes through the origin, and passes through the vertex of the triangle-shaped scintillator layer that is closest to the beam line (small polar angle θ). The positive y axis passes through the origin and through the center of the side of the triangle farthest from the beam. It is also parallel to the face of the first scintillator layer. The x is oriented to form a right-handed coordinate system. The positive x axis points to the left as one is looking outward from the target (*i.e.* downstream) and along the z axis of the G4 local EC coordinates. Note that the y axis for both the G4 sector coordinates and the G4 local EC coordinates lie in the same plane.

We now begin constructing a description of the EC geometry. The nominal distance from the target point T at the CLAS12 target center to P is $L_1 = 7217.23\ mm$. The front face (and all the layers)of the EC makes an angle $\theta_{EC} = 25^\circ$ to a line perpendicular to the beam line so we construct a vector $\vec{L}_1$ in the G4 sector coordinate system

$$\vec{L}_1 = (0, L_1 \sin\theta_{EC}, L_1 \cos\theta_{EC}) = (0, 3050.13\ mm, 6541.03\ mm) \tag{1}$$

which goes from the target point T to P. Next, we construct a second vector $\vec{S}$ that goes from P to the geometric center of the face of the first EC scintillator (closest to the target)

$$\vec{S} = (0, -L_{PO} \cos\theta_{EC}, L_{PO} \sin\theta_{EC}) = (0, -861.79\ mm, 401.86\ mm) \tag{2}$$

where $L_{PO} = 950.88\ mm$ is the distance from the CLAS12 perpendicular point P to the geometric center of the front face of the first scintillator. See Fig 4. The distance L_{PO} is the length of the vector $\vec{S}$ in Fig. 4.

In the G4 local coordinate system we treat the active area of each EC layer as a triangle and define this triangle in terms of a trapezoid in Geant4. The y position of the geometric center of layer L is at

$$y_{cent}(L) = a_1(L-1) \tag{3}$$

where $a_1 = 0.0856\ mm$ and the units of $y_{cent}(L)$ are mm. Note that for $L = 1$, the center of the face of the scintillator is at the origin. The half-height in the y-direction (half the distance from the vertex closest to the beamline to the center of the opposite side of the triangle) is

$$\Delta y(L) = a_2 + a_3(L-1) \tag{4}$$

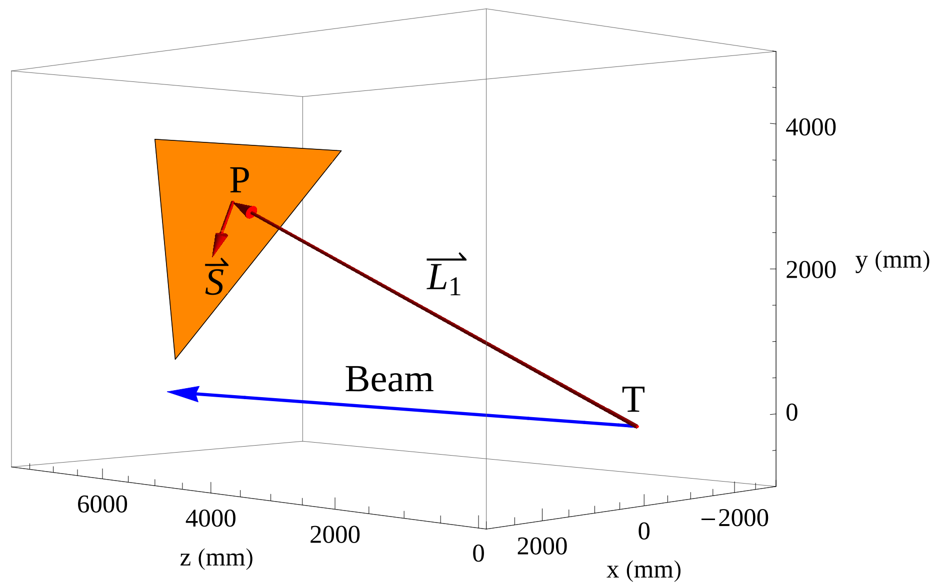

Figure 4: Drawing of the active area of the front face of the first EC scintillator. The vectors $\vec{L}_1$ and $\vec{S}$ determine the geometric center of the scintillator face. The G4 sector coordinate system is shown. The distance L_{PO} discussed in the text is the length of $\vec{S}$.

where $a_2 = 1864.65\ mm$, $a_3 = 4.45635\ mm$, and the units of $\Delta y(L)$ are mm.

To define a scintillator layer in Geant4 we need the half-width in the x direction at the vertex of the triangle closest to the beam (where it is zero) and the half-width in the x direction on the side of the triangle farthest from the beam (Δx). The active triangular region is bounded by three lines:

$$y_{pos}(L, x) = y_{cent}(L) - \Delta y(L) + (+\tan\theta_o)x \tag{5}$$

$$y_{neg}(L, x) = y_{cent}(L) - \Delta y(L) + (-\tan\theta_o)x \tag{6}$$

$$y_{outer}(L) = y_{cent}(L) + \Delta y(L) \tag{7}$$

where $\tan\theta_o = 1.95325$ and $\theta_o = 62.889°$ is the angle between sides of the triangle on the outside edge of the calorimeter (at large polar angle). The subscripts on the functions y_{pos} and y_{neg} refer to the slope of the line each function defines relative to the coordinate system here where the x axis points off to the left as one views the sector from the target. See Figure 5. Equations 37-36 define the left- and right-hand sides of the triangular active area of the first scintillator (as one looks outward from the target) and Equation 7 defines the outer edge of the active area of the first scintillator layer (at large polar angle θ). The thickness of each layer is constant at 12.38 mm so

$$\Delta z = \frac{d_{lead} + d_{scint}}{2} = \frac{12.38\ mm}{2} = 6.19\ mm \quad . \tag{8}$$

To define the geometry of the strips in each layer we start with the y coordinate of the lower edge of a U strip in layer number L. In Fig 6 we show the orientation of a single

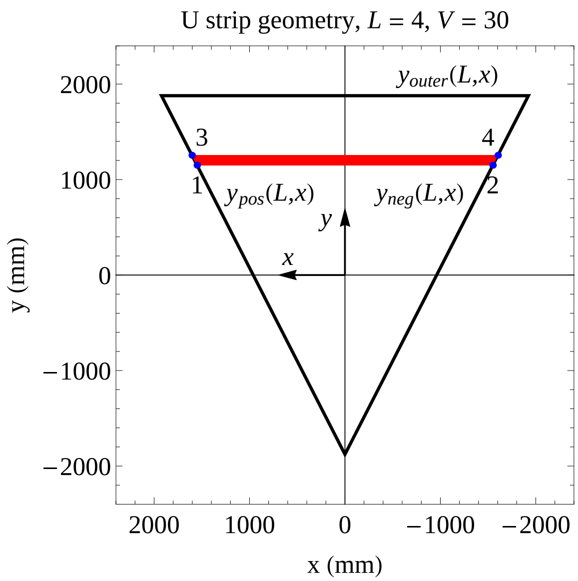

Figure 5: Scintillator layer showing lines used to define the layer. Red area is a single strip. Blue dots are the corners defining the strip trapezoid and labels show the numbering convention used in the software. View is looking out from the target.

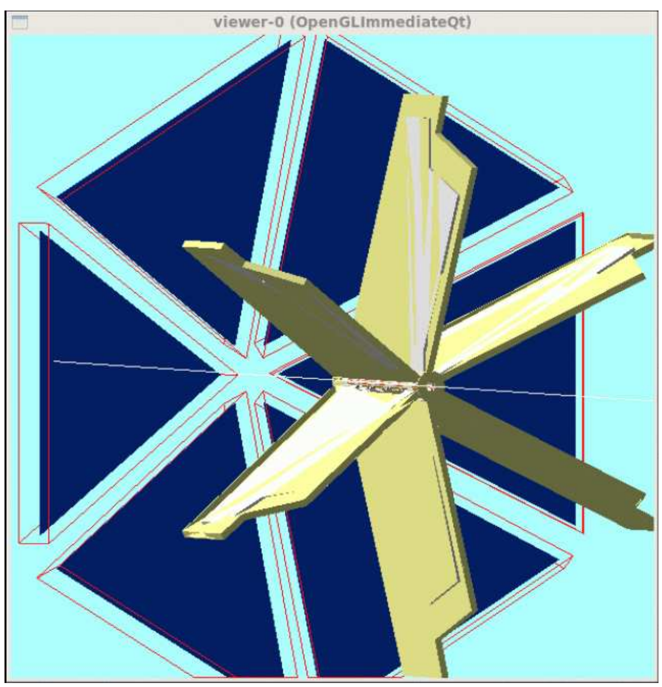

Figure 6: Display of a single layer (layer 17) from the EC for all six sectors (dark, blue triangles). The white line defines the beam axis and the torus is shown for comparison. The red wireframe is the EC mother volume.

EC scintillator layer in all six sectors. The white line marks the beam axis and the torus is shown to orient the reader. In the G4 local coordinates the lower edge of a U strip in layer number L is given by

$$y_U(L,U) = -a_2 - a_4(L-1) + (U-1)w_u(L) \tag{9}$$

where L is the layer number, U is the strip number, a_2 is defined above, $a_4 = 4.3708\ mm$, and

$$w_u(L) = a_5 + a_6(L-1) \tag{10}$$

is the strip width for the U strips in layer L and $a_5 = 103.655\ mm$ and $a_6 = 0.2476\ mm$. Equation 9 is for the y coordinate for the lower edge of the U strip. The upper edge of the strip is obtained by setting $U = U + 1$.

The edges of the V strips are given by the equation

$$y_V(L,V,x) = y_{cent}(L) - \Delta y(L) + w_v(L)(n_{strips} + 1 - V)\sqrt{1+\tan^2\theta_o} - \tan\theta_o x \tag{11}$$

where L is the layer number and V is the strip number ($V = V_{min} = 1$ is the shortest strip and $V = V_{max} = 36$ is the longest). The edges of the W strips are given by

$$y_W(L,W,x) = y_{cent}(L) - \Delta y(L) + w_w(L)(n_{strips} + 1 - n)\sqrt{1+\tan^2\theta_o} + \tan\theta_o x \tag{12}$$

where W is the strip number ($W = W_{min} = 1$ is the shortest strip and $W = W_{max} = 36$ is the longest). The widths of V and W strips are given by

$$w_v = a_7 + a_8(L-2) \tag{13}$$

where $a_7 = 94.70\ mm$ and $a_8 = 0.2256\ mm$ and

$$w_w = a_9 + a_8(L-3) \tag{14}$$

where $a_9 = 94.93\ mm$ and $a_8 = 0.2256\ mm$. Each strip has a trapezoidal portion on its light collection end that extends beyond the triangular region defined above. The trapezoid has right angles at the end of the strip, and distance from the end to the triangular region is given by two distances.

$$d_2, \qquad d_1 = d_2 + \frac{w}{2}\left(\frac{\tan^2(\theta_0) - 1}{\tan(\theta_0)}\right) \tag{15}$$

where w is the width of the strip. For the first 15 layers

$$d_2 = 36.4\ mm, \qquad L \leq 15 \tag{16}$$

and for the remaining layers

$$d_2' = 25.4\ mm, \qquad L > 15. \tag{17}$$

The z spacing between layers is (according to Cassim Riggs) 12.381 mm which is $2\Delta z$ so that the total depth of the detector along the z direction is

$$\Delta z_{total} = 2n_{layers}\Delta z + 2\Delta z_{scint} \tag{18}$$

where $n_{layers} = 39$ and $\Delta z_{scint} = 5\ mm$ is half the thickness of the plastic scintillators so the z coordinate of the front face of each layer of scintillator is

$$z(L) = 2\Delta z(L-1) \qquad . \tag{19}$$

The calorimeter can be viewed as being subdivided into triangular stacks. For CLAS6 each stack was directed back towards the target, but this is not true for CLAS12. A convenient labeling for these stacks is provided by the number N, where

$$N = U(U-1) + V - W + 1 \tag{20}$$

subject to the subsidiary condition for a valid combination that

$$S = U + V + W = 73\ or\ 74 \tag{21}$$

With this numbering scheme, the cell #1 is at the vertex near the beam, with $U = 1, V = W = 36,\ and\ S = 73$. The final cell in this scheme is at $U = V = 36$, $W = 1$, for which $N = 36^2 = 1296$. In general, if $U + S = 2U + V + W$ is even(odd) the triangular cell points toward(away from)the beam. The center of the cell is at

$$y = -a_2 - a_4(L-1) + (U-0.5)w_u(L) \tag{22}$$

$$x \tan\theta_0 = (W-V)w_u(L) \tag{23}$$

or

$$x = \frac{1}{\tan\theta_0}(W-V)w_u(L) \qquad . \tag{24}$$

The parameters defined in the text above and others are summarized in Table 1 below.

We now demonstrate two applications of the geometry parameters. The first application is to use the equations above and the parameters in Table 1 to calculate the positions of the corners of the individual strips that make up the scintillator layers (in the shape of a trapezoid) for each EC view (U, V, and W). To begin, for the U view of the calorimeter set $y_U(L,U)$ (Eq. 9) equal to $y_{neg}(L,x)$ (Eq. 6) and solve for x for the desired strip U (which gives the strip edge closest to the vertex near the beam of the triangle in Figure 5) and $U+1$ (to obtain the other edge). The result is

$$x_{corner} = \frac{y_{cent} - \Delta y + a_2 + a_4(L-1) - (U-1)w_u}{\tan\theta_0} \quad \text{and} \quad y_{corner} = y_{neg}(L, x_{corner}) \tag{25}$$

for the two values of U defining the two edges of the strip and using the functions and parameters defined above. For the other two corners of the strip replace y_{neg} with y_{pos}, follow the same procedure, and obtain the following result

$$x_{corner} = -\frac{y_{cent} - \Delta y + a_2 + a_4(L-1) - (U-1)w_u}{\tan\theta_0} \quad \text{and} \quad y_{corner} = y_{pos}(L, x_{corner}) \tag{26}$$

for the two values of U defining the two edges of the strip and using the functions and parameters defined above. Notice x_{corner} in Eq. 26 is the negative of x_{corner} in Eq. 25.

Name	Value	Equation	Description
θ_{EC}	$25°$	1, 2, 32, 33	Angle of each scintillator plane to the beam.
L_1	$7127.23\ mm$	1, 32	Perpendicular distance from the first scintillator face to the target point.
L_{PO}	$950.88\ mm$	2, 33, 36-38, 43, 44	Distance from perpendicular point P to center of first scintillator.
a_1	$0.0856\ mm$	3, 34	Spacing in local y coordinates between centers of each scintillator layer.
a_2	$1864.6\ mm$	4, 10, 35, 41	Half-height of scintillator layer 1 from near-beam vertex to midpoint of large-angle side.
a_3	$4.45635\ mm$	4, 35	Increase in half-height between adjacent scintillators.
θ_O	$62.88°$	5-8, 12, 13, 36, 37, 39	Angles between EC box sides at large scattering angle.
Δz	$6.19\ mm$	9, 40, 51	Half-thickness of each layer.
a_4	$4.3708\ mm$	10, 41	Shift in position of shortest side of a U strip between adjacent layers.
a_5	$103.66\ mm$	11, 42	Half-width of shortest side of first U strip.
a_6	$0.2476\ mm$	11, 42	Increase in half-width of shortest side of U strip for adjacent scintillators.
a_7	$94.701\ mm$	14, 45	Half-width of shortest side of V-strip.
a_8	$0.2256\ mm$	14, 15, 45, 46	Increase in half-width of shortest side of V and W strips for adjacent scintillators.
a_9	$94.926\ mm$	15, 46	Half-width of shortest side of W-strip.
d_{lead}	$2.381\ mm$	8, 40	Thickness of lead layers.
d_{scint}	$10.0\ mm$	8, 40	Thickness of scintillator layers.
n_{layers}	39	18, 50	Number of scintillator layers. There are 38 lead layers.
n_{strips}	36	11, 12, 43, 44	Number of scintillator strips in a layer.
d_2	$36.4\ mm$	16, 17	Length of short-side of trapezoid on end of strip to connect with PMT for Layer < 16.
d_2'	$25.4\ mm$	16, 18	Length of short-side of trapezoid on end of strip to connect with PMT for Layer > 15.

Table 1: Table of coefficients for equations in text along with additional EC parameters.

For the V view follow a similar procedure except set y_V (Eq. 11) equal to y_{outer} (Eq. 7) and solve for x for the desired strip V (which gives the strip edge closest to the vertex in the upper, left portion of Figure 5) and $V+1$ (to obtain the other strip edge). The result is

$$x_{corner} = \frac{-y_{outer} + y_{cent} - \Delta y + (n_{strips} + 1 - V)w_v\sqrt{1+\tan^2\theta_0}}{\tan\theta_0} \quad \text{and} \quad y_{corner} = y_{outer}(L) \tag{27}$$

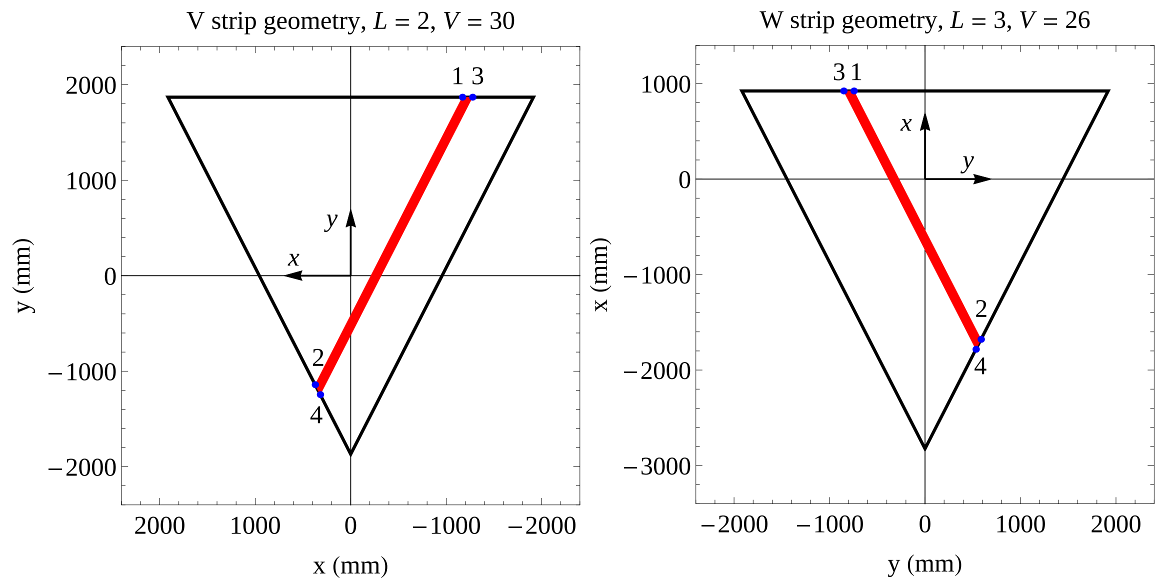

Figure 7: Geometry for V (left-hand-side) and W (right-hand-side) views of the EC. The numbering scheme used in the software is shown.

for the two values of V defining the two edges of the strip and using the functions and parameters defined above. For the other two corners of the strip replace y_{outer} with y_{pos}, follow the same procedure, and obtain the following result

$$x_{corner} = \frac{(n_{strips} + 1 - V)w_v\sqrt{1+\tan^2\theta_0}}{2\tan\theta_0} \quad \text{and} \quad y_{corner} = y_{pos}(L, x) \tag{28}$$

for the two values of V defining the two edges of the strip and using the functions and parameters defined above. An example is shown in in the left-panel of Figure 7. The Perl code used to calculate the corners used to define the EC geometry can be found in Appendix D. See the function `VstripCorner` in that Appendix.

For the W view follow a similar procedure except set y_W (Eq. 12) equal to y_{outer} (Eq. 7) and solve for x for the desired strip W (which gives the strip edge closest to the vertex in the upper, right of Figure 5) and $W + 1$ (to obtain the other strip edge). The result is

$$x_{corner} = \frac{y_{outer} - y_{cent} + \Delta y - (n_{strips} + 1 - W)w_w\sqrt{1+\tan^2\theta_0}}{\tan\theta_0} \quad \text{and} \quad y_{corner} = y_{outer}(L) \tag{29}$$

for the two values of W defining the two edges of the strip and using the functions and parameters defined above. For the other two corners of the strip replace y_{outer} with y_{neg}, follow the same procedure, and obtain the following result

$$x_{corner} = -\frac{(n_{strips} + 1 - W)w_w\sqrt{1+\tan^2\theta_0}}{2\tan\theta_0} \quad \text{and} \quad y_{corner} = y_{neg}(L, x) \tag{30}$$

for the two values of W defining the two edges of the strip and using the functions and parameters defined above. An example is shown in the right-hand panel of Figure 7. The

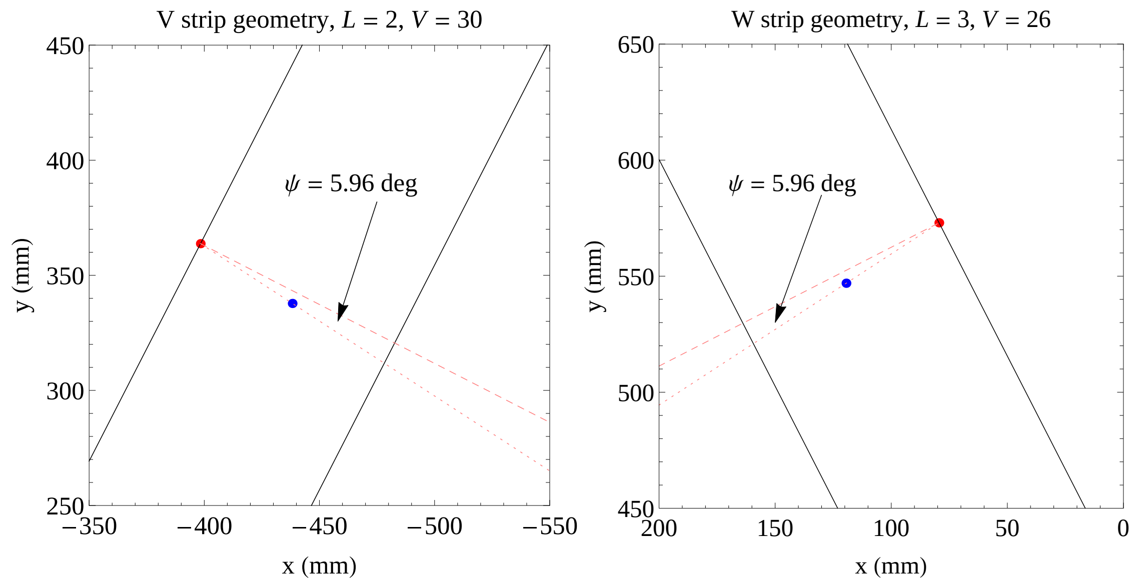

Figure 8: Geometry for offset angle, ψ, for the V view (left-hand-side) and W view (right-hand-side). In each panel the red point is the center of the strip edge, the blue point is the center of the entire strip, and the dashed line is perpendicular to the edge of the strip. The offset is zero for the U view.

Perl code used to calculate the corners used to define the EC geometry can be found in Appendix D. See the function `WstripCorner` in that Appendix.

The second application of the EC geometry parameters in Table 1 is to calculate an angle offset, ψ, for the V and W EC views. This offset is a product of a small asymmetry in the EC geometry. The angles of the two vertices at large polar angle of the triangle defining an EC layer are different from the angle at the near-beam, small-polar-angle vertex (62.889° versus 54.222° respectively). Consider a line drawn from the midpoint of the edge of a strip to the geometric center of the entire strip. For the V and W layers, this line is not perpendicular to the edge of the strip. See Figure 8. For the U layer, the offset is zero. This angle is used to define the G4Trap (trapezoid) volume for a scintillator strip in the V and W layers in Geant4 (see Appendix G).

To obtain ψ, (1) start with the corners of a V or W strip as calculated above. (2) Get the slope of the edge of the strip, m_{edge} using corners 1 and 2 or corners 3 and 4 (recall Figure 7). (3) Get the slope of the line perpendicular to the edge of the strip using $m_{perp} = -1/m_{edge}$. (4) Calculate the midpoint of the near-vertex strip edge. This is the edge of the strip closest to vertex of the layer triangle where the numbering starts for each view. This point is in the upper, right corner for the V view and the upper, left corner for the W view as shown in Figure 7. Obtain the value of the midpoint by averaging the positions of points 1 and 2. (5) Calculate the geometric center by averaging all four corners of the trapezoid. (6) Calculate the slope of the line from the midpoint of the strip edge to the center of the strip m_{e2c}. (7) Calculate the tangent of the offset using the following geometry theorem [10].

$$\tan\psi = \frac{m_{e2c} - m_{perp}}{1 + m_{e2c} m_{perp}} \tag{31}$$

See Figure 7 for an illustration and the code is in function `Angleoffset` in Appendix G.

4 Implementing the EC Geometry in *gemc*

In this section we summarize the current, physics-based CLAS12 simulation program called *gemc*, and how we construct the geometry database used in *gemc*. The physics-based CLAS12 simulation program `gemc` is a modern, object-oriented code. It is based on the C^{++} programming language and Standard Template Libraries for constructing objects. The parameters that define a particular simulation (geometry, materials, magnetic fields, step size, *etc.*) are stored external to the code and saved in a mysql database. This enable users to rapidly change the parameters of the simulation without having to recompile the code. The factory method is used for the processing individual hits in CLAS12, for digitizing those hits to mimic the data stream, and for the defining the input/output formats. We are using the Geant4 package from CERN for handling the passage of particles through matter [8]. Geant4 (for GEometry ANd Tracking) performs this task using Monte Carlo methods and is the successor to GEANT3 mentioned above. It uses object oriented programming, is written in C^{++}, and is well supported by CERN and the international Geant4 Collaboration. Geant4 includes facilities for handling geometry, tracking, detector response, run management, visualization and user interface.

To construct the EC in *gemc* we define the EC geometry using Geant4 and the CLAS12 mysql database. Geant4 provides methods for defining the physical volumes that make up the CLAS12 simulation and the information needed for a particular CLAS12 component is read from the database. For the EC we are using a generalized trapezoid (G4Trap method in Geant4) to represent the mother volume which encloses the entire EC module and the lead layer of the detector. For the scintillator layer, two methods of handling the individual strips are available. In the first version of the CLAS12 geometry, we used the same method used in CLAS6. The scintillator layer was treated as one large slab defined by the G4Trap volume and the strips that make up each scintillator layer are not defined until the digitization phase. The other option is to use the G4Trap volume to define the individual strips in each scintillator layer. The Geant4 parameters for G4Trap are shown in Table 2 and Fig 9 shows the generalized trapezoid. We use the same axes definitions as Geant4 for our G4 local EC coordinate system. To define these geometries Perl scripts (`ec_build.pl` in the area `gemc/production/database_io/clas12/geo/ec`) generate a file containing the mysql code needed to modify the mysql database which is called by a shell script (`go_table`). Two Perl scripts are included in the Appendix. The first (Appendix C) treats each scintillator layer of the EC as a continuous slab of material. The second script (Appendix D) breaks up each scintillator layer into strips as done in the real detector.

We performed a series of tests comparing the use of the single-slab geometry for the scintillator layers and the strip geometry [11]. We compared the difference in particle hit position between the two geometries. We ran simulations of both geometries using electrons aimed perpendicularly at the center of the EC with no magnetic field and no other components of CLAS12. In Figure 10 the number of hits in each strip of the U, V, and W layers is shown in the left-hand column for the different geometries. There is little difference between the two in the distribution of hits for each EC view. To make the comparison more rigorous

Name	Description	Name	Description
$pDx1$	Half x length of the side at $y = -pDy1$ of the face at $-pDz$	$pDx2$	Half x length of the side at $y = +pDy1$ of the face at $-pDz$
$pDx3$	Half x length of the side at $y = -pDy2$ of the face at $+pDz$	$pDx4$	Half x length of the side at $y = +pDy2$ of the face at $+pDz$
$pPhi$	Azimuthal angle of the line joining the center of the face at $-pDz$ to the center of the face at $+pDz$	$pTheta$	Polar angle of the line joining the centers of the faces at $\pm pDz$
$pDy1$	Half y length at $-pDz$	$pDy2$	Half y length at $+pDz$
$pAlp1$	Angle with respect to the y axis from the center of the side (lower endcap)	$pAlp2$	Angle relative to the y axis from the center of the side (upper endcap)
pDz	Half z length		

Table 2: Geant4 parameters for the G4Trap volume.

we took the difference between the hit distribution as a function of strip number for each geometry. The right-hand column in Figure 10 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.

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 in the range $2 - 10$ GeV. Figure 11 shows a computational time increase of 5% - 8% in the EC at the highest energies.

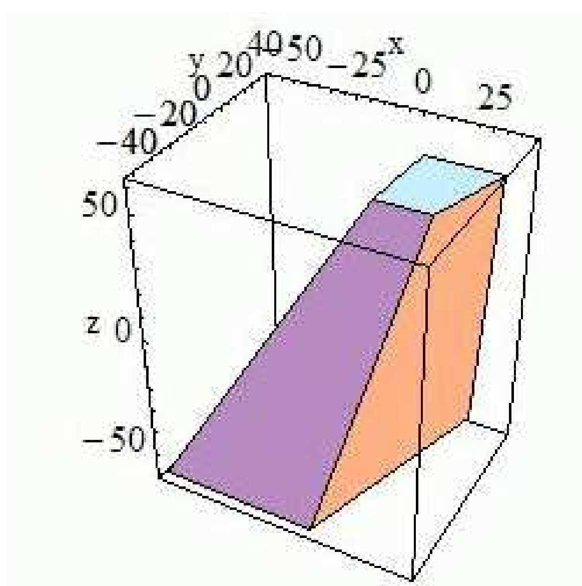

Figure 9: Geant4 generalized trapezoid.

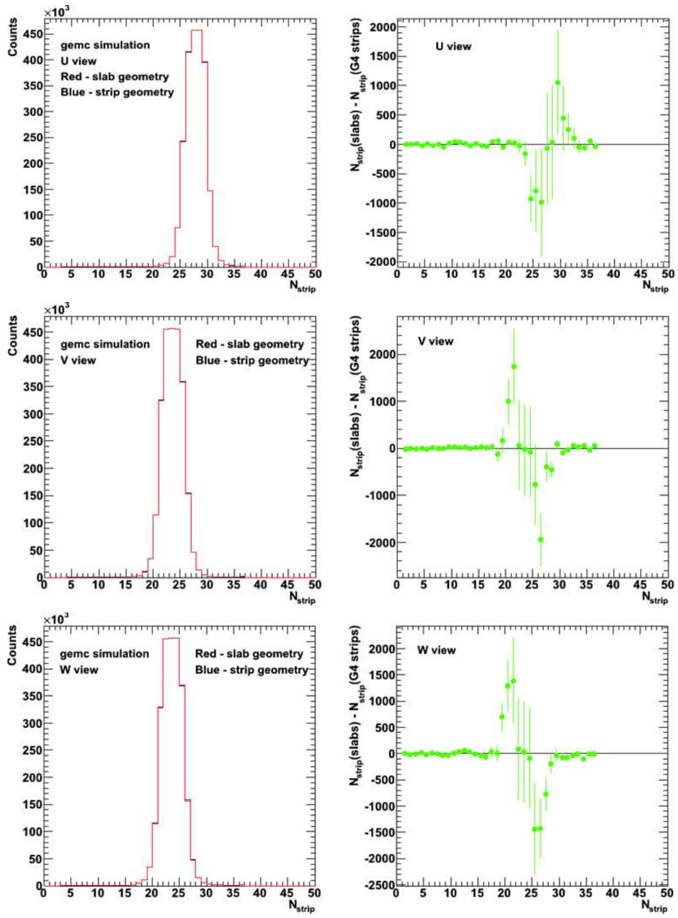

Figure 10: Comparison of single-slab scintillator geometry and strip geometry in the EC. The left-hand column shows histograms of the number of hits as a function of strip number for the U, V, and W views. The right-hand column shows the difference between the the two geometries as a function of strip number.

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. 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. We found that the new strip geometries were about 25% slower than the slab geometries.

To run *gemc* with the different EC geometries (scintillator slabs versus strips) requires simple changes to the simulation input. The program uses an input file or gcard file where the selection is made. To use the slab geometry set the database entry to 'EC'. To use the strip geometry set the database entry to 'ECwithG4strips'. An example input file ('EConly.gcard') is shown in Appendix E.

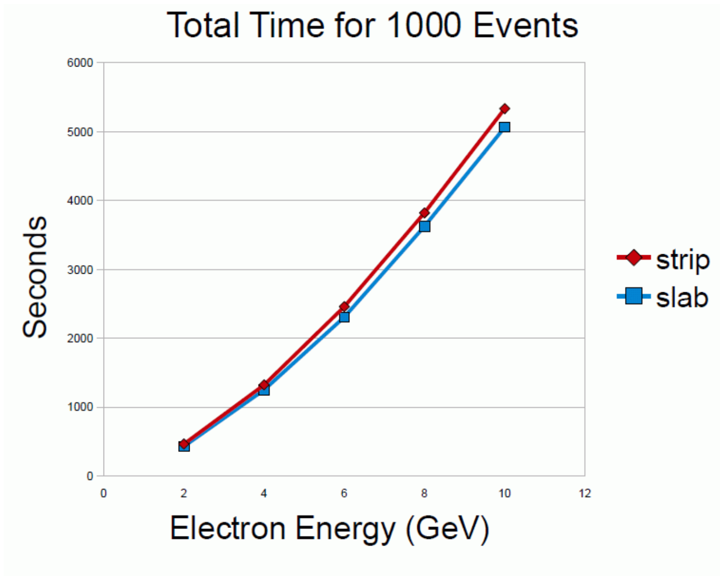

Figure 11: Comparison of computational speed for single-slab scintillator geometry and strip geometry in the EC.

5 EC Geometry in CLAS12 Service Coordinates

In defining the CLAS12 EC geometry in this section our goal is produce a description compatible with the geometry tools and definitions in the CLAS12 geometry service. The discussion here reproduces many parts from Section 3 so that it is more modular and can be read without referring back to Section 3. We define here two coordinate systems needed to incorporate the EC geometry into *gemc*. We use the same G4 sector coordinate as used in Section 3. These coordinates are different from the usual sector coordinate system used in, say, the drift chamber geometry. The z axis of the G4 sector coordinates is horizontal along the beam line and in the direction of the beam. The y axis is radially outward in the ideal midplane of the EC. The x axis is constructed to form a right-handed coordinate system. The 'perpendicular point' P is still defined by a line drawn from the target point T at the origin (and nominal target center) to a point on the face of the first scintillator layer and perpendicular to that face. See Fig 4.

The local EC service coordinate system is different from the G4 local EC coordinates. The local EC service coordinates have their origin at the perpendicular point on the front face of the first scintillator (closest to the target) of the EC. The z axis of the local EC service coordinates is perpendicular to the face of the detector, co-linear with the line from the target point T to the perpendicular point P (see Fig 4), and points away from the target. The negative x axis is parallel to the face of the first scintillator layer, starts at the origin, and passes through the vertex of the triangle-shaped scintillator layer that is closest to the beam line (small polar angle θ). The positive x axis passes through the origin and through the center of the side of the triangle farthest from the beam. It is also parallel to the face of the first scintillator layer. The y-axis is oriented to form a right-handed coordinate system so the positive y axis points to the right as one is looking outward from the target (*i.e.*

downstream) and along the z axis of the local EC service coordinates. Note that the y axis for the G4 sector coordinates and the x axis for local EC service coordinates lie in the same plane. See Fig 12.

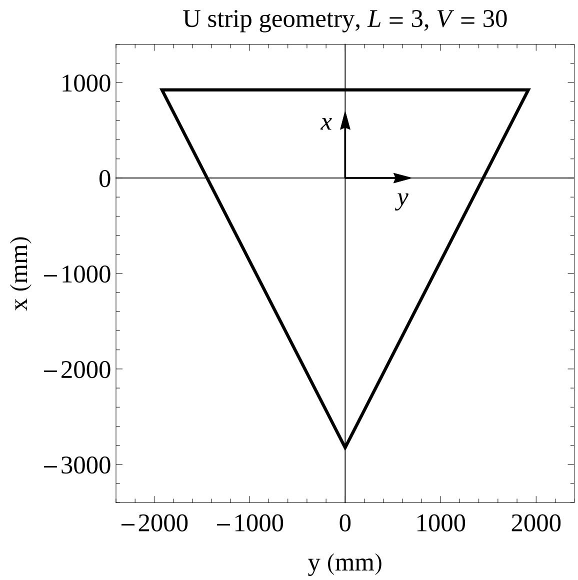

Figure 12: Scintillator layer showing lines used to define the layer.

We now begin constructing a description of the EC geometry. In the G4 sector coordinates this description is exactly the same as before in Section 3. The nominal distance from the target point T at the CLAS12 target center to P is $L_1 = 7217.23\ mm$. The front face (and all the layers)of the EC makes an angle $\theta_{EC} = 25°$ to a line perpendicular to the beam line so we construct a vector $\vec{L}_1$ in the G4 sector coordinate system

$$\vec{L}_1 = (0, L_1 \sin\theta_{EC}, L_1 \cos\theta_{EC}) = (0, 3050.13\ mm, 6541.03\ mm) \tag{32}$$

which goes from the target point T to P. Next, we construct a second vector $\vec{S}$ that goes from P to the geometric center of the face of the first EC scintillator (closest to the target)

$$\vec{S} = (0, -L_{PO} \cos\theta_{EC}, L_{PO} \sin\theta_{EC}) = (0, -861.79\ mm, 401.86\ mm) \tag{33}$$

where $L_{PO} = 950.88\ mm$ is the distance from the CLAS12 perpendicular point P to the geometric center of the front face of the first scintillator. See Fig 4. The distance L_{PO} is the length of the vector $\vec{S}$ in Fig. 4.

In the local EC service coordinate system we treat the active area of each EC layer as a triangle. The x position of the geometric center of layer L is at

$$x_{cent}(L) = a_1(L-1) - L_{PO} \tag{34}$$

where $a_1 = 0.0856\ mm$ and the units of $x_{cent}(L)$ are mm. Later, we will need the half-height in the x-direction (half the distance from the vertex closest to the beamline to the center of the opposite side of the triangle) is

$$\Delta x(L) = a_2 + a_3(L-1) \tag{35}$$

where $a_2 = 1864.65\ mm$, $a_3 = 4.45635\ mm$, and the units of $\Delta x(L)$ are mm.

To define a scintillator layer the active triangular region is bounded by three lines:

$$x_{pos}(L, y) = x_{cent}(L) - \Delta x(L) - L_{PO} + (+\tan\theta_o)y \tag{36}$$

$$x_{neg}(L, y) = x_{cent}(L) - \Delta x(L) - L_{PO} + (-\tan\theta_o)y \tag{37}$$

$$x_{outer}(L) = x_{cent}(L) + \Delta x(L) - L_{PO} \tag{38}$$

where $\tan\theta_o = 1.95325$ and $\theta_o = 62.889^\circ$ is the angle between sides of the triangle on the outside edge of the calorimeter (at large polar angle). The subscripts on the functions x_{pos} and x_{neg} refer to the slope of the line each function defines relative to the coordinate system here where the x axis points up and the y axis points off to the right as one views the sector from the target. See Fig 13. Equations 5-6 define the left- and right-hand sides of

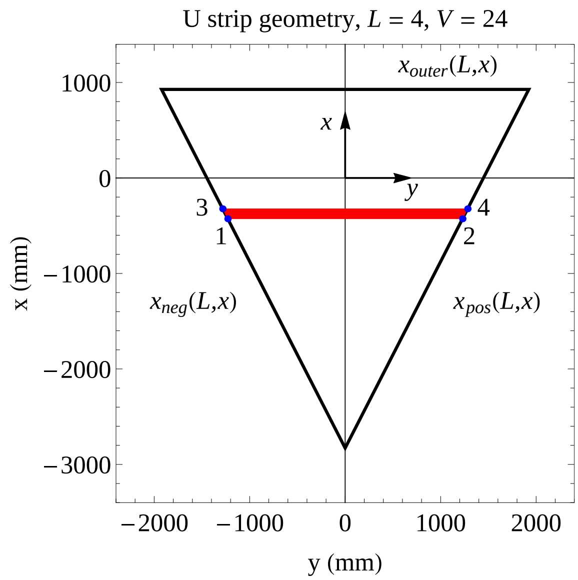

Figure 13: Scintillator layer showing lines used to define the layer. Red area is a single strip. Blue dots are the corners defining the strip trapezoid and labels show the numbering convention used in the software. View is looking out from the target.

the triangular active area of the first scintillator (as one looks outward from the target) and Equation 7 defines the outer edge of the active area of the first scintillator layer (at large polar angle θ). The half-width in the y direction on the side of the triangle defined by Equation 7 (the side of the triangle farthest from the beam) is

$$\Delta y = \frac{2\Delta x}{\tan\theta_o} \tag{39}$$

where Δx is defined in Equation 35. The thickness of each layer is constant at 12.38 mm so the half-thickness is

$$\Delta z = \frac{d_{lead} + d_{scint}}{2} = \frac{12.38\ mm}{2} = 6.19\ mm \qquad . \tag{40}$$

To define the geometry of the strips in each layer we start with the x coordinate of the lower edge of a U strip in layer number L. In the local EC service coordinates the lower edge of a U strip in layer number L is given by

$$x_U(L,U) = -a_2 - a_4(L-1) + (U-1)w_u(L) \tag{41}$$

where L is the layer number, U is the strip number, a_2 is defined above, $a_4 = 4.3708\ mm$, and

$$w_u(L) = a_5 + a_6(L-1) \tag{42}$$

is the strip width for the U strips in layer L and $a_5 = 103.655\ mm$ and $a_6 = 0.2476\ mm$. Equation 41 is for the x coordinate for the lower (small polar angle θ) edge of the U strip. The upper edge of the strip is obtained by setting $U = U+1$.

The edges of the V strips are given by the equation

$$x_V(L,V,y) = x_{cent}(L) - \Delta x(L) - L_{PO} + w_v(L)(n_{strips}+1-V)\sqrt{1+\tan^2\theta_o} + \tan\theta_o y \tag{43}$$

where L is the layer number and V is the strip number ($V = V_{min} = 1$ is the shortest strip and $V = V_{max} = 36$ is the longest). The edges of the W strips are given by

$$x_W(L,W,y) = x_{cent}(L) - \Delta x(L) - L_{PO} + w_w(L)(n_{strips}+1-n)\sqrt{1+\tan^2\theta_o} - \tan\theta_o y \tag{44}$$

where W is the strip number ($W = W_{min} = 1$ is the shortest strip and $W = W_{max} = 36$ is the longest). The widths of V and W strips are given by

$$w_v = a_7 + a_8(L-2) \tag{45}$$

where $a_7 = 94.70\ mm$ and $a_8 = 0.2256\ mm$ and

$$w_w = a_9 + a_8(L-3) \tag{46}$$

where $a_9 = 94.93\ mm$ and $a_8 = 0.2256\ mm$. Each strip has a trapezoidal portion on its light collection end that extends beyond the triangular region defined above. The trapezoid has right angles at the end of the strip, and distance from the end to the triangular region is given by two distances.

$$d_2, \qquad d_1 = d_2 + \frac{w}{2}\left(\frac{\tan^2(\theta_0)-1}{\tan(\theta_0)}\right) \tag{47}$$

where w is the width of the strip. For the first 15 layers

$$d_2 = 36.4\ mm, \qquad L \le 15 \tag{48}$$

and for the remaining layers

$$d_2' = 25.4\ mm, \qquad L > 15. \tag{49}$$

The z spacing between layers is (according to Cassim Riggs) 12.381 mm which is $2\Delta z$ so that the total depth of the detector along the z direction is

$$\Delta z_{total} = 2(n_{layers}-1)\Delta z + 2\Delta z_{scint} \tag{50}$$

where $\Delta z_{scint} = 5\ mm$ is half the thickness of the plastic scintillators and $U_{max} = V_{max} = W_{max} = n_{strips} = 36$ as before so the z coordinate of the front face of each layer of scintillator is

$$z(L) = 2\Delta z(L-1) \tag{51}$$

The calorimeter can be viewed as being subdivided into triangular stacks, each one directed back towards the target. A convenient labeling for these stacks is provided by the number N, where

$$N = U(U-1) + V - W + 1 \tag{52}$$

subject to the subsidiary condition for a valid combination that

$$S = U + V + W = 73 \text{ or } 74 \tag{53}$$

With this numbering scheme, the cell #1 is at the vertex near the beam, with $U = 1, V = W = 36,\ and\ S = 73$. The final cell in this scheme is at $U = V = 36$, $W = 1$, for which $N = 36^2 = 1296$. In general, if $U + S = 2U + V + W$ is even(odd) the triangular cell points toward(away from)the beam. The center of the cell is at

$$x = -a_2 - a_4(L-1) + (U-0.5)w_u(L) \tag{54}$$

$$y \tan\theta_0 = (W-V)w_u(L) \tag{55}$$

or

$$y = \frac{1}{\tan\theta_o}(W-V)w_u(L) \quad . \tag{56}$$

The parameters defined in the text above and others are summarized in Table 1.

We now demonstrate an application of the geometry parameters. It is to use the equations above and the parameters in Table 1 to calculate the positions of the corners of the individual strips that make up the scintillator layers (in the shape of a trapezoid) for each EC view (U, V, and W). To begin, for the U view of the calorimeter set $x_U(L, U)$ (Eq. 41) equal to $x_{neg}(L, x)$ (Eq. 37) and solve for y for the desired strip U (which gives the strip edge closest to the vertex near the beam of the triangle in Figure 13) and $U + 1$ (to obtain the other edge). The result is

$$y_{corner} = \frac{x_{cent} - \Delta x - L_{PO} + a_2 + a_4(L-1) - (U-1)w_u}{\tan\theta_0} \quad \text{and} \quad x_{corner} = x_{neg}(L, y_{corner}) \tag{57}$$

for the two values of U defining the two corners of the strip (points 1 and 3 in Fig 13) and using the functions and parameters defined above. For the other two corners of the strip replace x_{neg} with x_{pos}, follow the same procedure, and obtain the following result

$$y_{corner} = -\frac{x_{cent} - \Delta x - L_{PO} + a_2 + a_4(L-1) - (U-1)w_u}{\tan\theta_0} \quad \text{and} \quad x_{corner} = x_{pos}(L, y_{corner}) \tag{58}$$

for the two values of U defining the two corners of the strip (points 2 and 4 in Fig 13) and using the functions and parameters defined above. Notice y_{corner} in Eq. 58 is the negative of y_{corner} in Eq. 57.

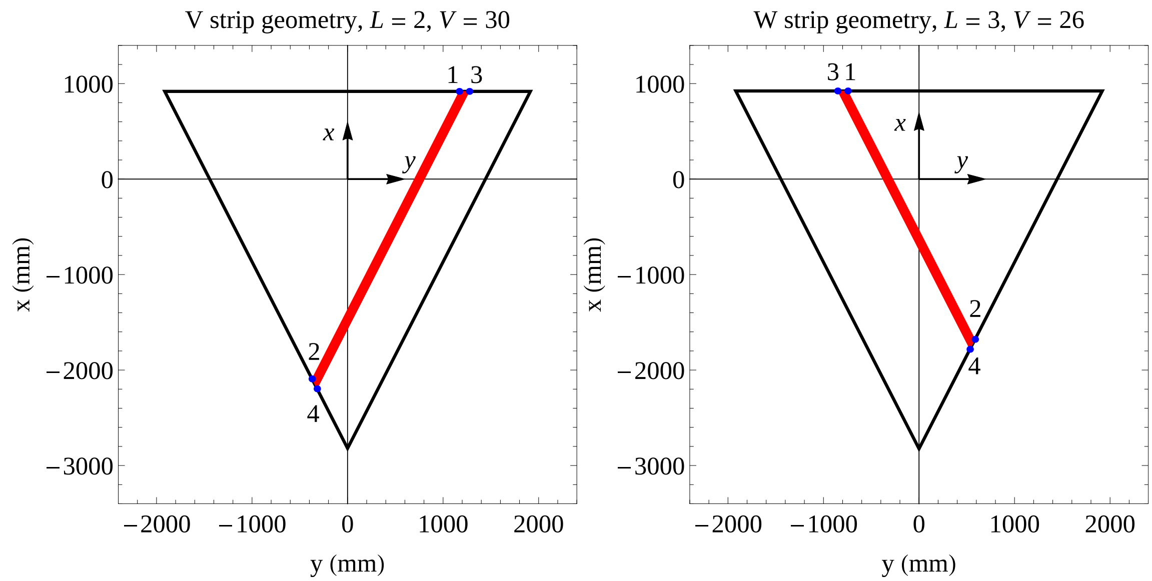

Figure 14: Geometry for V (left-hand-side) and W (right-hand-side) views of the EC. The numbering scheme used in the software is shown.

For the V view follow a similar procedure except set x_V (Eq. 43) equal to x_{outer} (Eq. 38) and solve for y for the desired strip V (which gives the strip edge closest to the vertex in the upper, left portion of the left-hand-side of Figure 14) and $V+1$ (to obtain the other strip edge). The result is

$$y_{corner} = \frac{x_{outer} - x_{cent} + \Delta x + L_{PO} - (n_{strips} + 1 - V) w_v \sqrt{1 + \tan^2\theta_0}}{\tan\theta_0} \quad \text{and} \quad x_{corner} = x_{outer}(L) \tag{59}$$

for the two values of V defining the two corners of the strip (points 1 and 3 in the left-hand-side of Fig 14) and using the functions and parameters defined above. For the other two corners of the strip replace x_{outer} with x_{neg} (Eq 37), follow the same procedure, and obtain the following result

$$y_{corner} = -\frac{(n_{strips} + 1 - V) w_v \sqrt{1 + \tan^2\theta_0}}{2\tan\theta_0} \quad \text{and} \quad x_{corner} = x_{neg}(L, y_{corner}) \tag{60}$$

for the two values of V defining the two corners of the strip (points 2 and 4 in the left-hand-side of Fig 14) and using the functions and parameters defined above.

For the W view follow a similar procedure except set x_W (Eq. 44) equal to x_{outer} (Eq. 38) and solve for y for the desired strip W (which gives the strip edge closest to the vertex in the upper, right of the right-hand-side of Figure 14) and $W+1$ (to obtain the other strip edge). The result is

$$y_{corner} = -\frac{x_{outer} - x_{cent} + \Delta x - L_{PO} - (n_{strips} + 1 - W) w_w \sqrt{1 + \tan^2\theta_0}}{\tan\theta_0} \quad \text{and} \quad x_{corner} = x_{outer}(L) \tag{61}$$

for the two values of W defining the two corners of the strip (points 1 and 3 in the right-hand-side of Fig 14) and using the functions and parameters defined above. For the other two corners of the strip replace x_{outer} with x_{pos}, follow the same procedure, and obtain the following result

$$y_{corner} = \frac{(n_{strips} + 1 - W) w_w \sqrt{1 + \tan^2 \theta_0}}{2 \tan \theta_0} \quad \text{and} \quad x_{corner} = x_{pos}(L, y_{corner}) \tag{62}$$

for the two values of W defining the two corners of the strip (points 2 and 4 in the right-hand-side of Fig 14) and using the functions and parameters defined above.

We have used the calculations described above to create Figs 13-14 and tables of selected strips for comparison with other calculations. Those tables are in Appendices A-C. The calculations were performed with *Mathematica* and the code is available in the CLAS12 repository at the following site.

`https://clas12svn.jlab.org/repos/users/gilfoyle/ECgeomCalcs`.

6 Summary

In this CLAS-NOTE we describe the implementation of the CLAS12 electromagnetic calorimeter in the physics-based simulation of the detector called *gemc*. We provide a short description of the workings of the EC and a streamlined version of the geometry that builds on previous work of Minehart [9]. To incorporate the EC into *gemc* we use the Geant4 package from CERN to calculate the passage of radiation through the CLAS12 volumes. For the previous implementation each scintillator layer of the EC is treated in the geometry as a large, continuous piece of material. In this work, we have also developed a second geometry that divides the scintillator layer into individual strips like those in the existing EC. We present a comparison of the performance of *gemc* for the two approaches. The impact of the strip geometry is small.

WE also include a second description of the EC geometry that uses a different coordinate system to be compatible with the one preferred in the development of the EC geometry service. The implementations in Sections 3 and 5 are very similar, but the differences are enough that to warrant including both here.

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A Strip Corners for U view

Table of layer number, strip number, positions of corners of selected strips (see Fig 13) for the U view. *Mathematica* notebooks for testing these calculations are available in the CLAS12 repository under `https://clas12svn.jlab.org/repos/users/gilfoyle/ECgeomCalcs`.

L	U	y1	x1	z1	y2	x2	z2	y3	x3	z3	y4	x4	z4
1.	1.	0.e-3	-2815.53	0.e-3	0.e-3	-2815.53	0.e-3	-53.07	-2711.87	0.e-3	53.07	-2711.87	0.e-3
1.	1.	0.e-3	-2815.53	12.38	0.e-3	-2815.53	12.38	-53.07	-2711.87	12.38	53.07	-2711.87	12.38
1.	2.	-53.07	-2711.87	0.e-3	53.07	-2711.87	0.e-3	-106.14	-2608.21	0.e-3	106.14	-2608.21	0.e-3
1.	2.	-53.07	-2711.87	12.38	53.07	-2711.87	12.38	-106.14	-2608.21	12.38	106.14	-2608.21	12.38
1.	15.	-742.99	-1364.29	0.e-3	742.99	-1364.29	0.e-3	-796.06	-1260.63	0.e-3	796.06	-1260.63	0.e-3
1.	15.	-742.99	-1364.29	12.38	742.99	-1364.29	12.38	-796.06	-1260.63	12.38	796.06	-1260.63	12.38
1.	16.	-796.06	-1260.63	0.e-3	796.06	-1260.63	0.e-3	-849.13	-1156.97	0.e-3	849.13	-1156.97	0.e-3
1.	16.	-796.06	-1260.63	12.38	796.06	-1260.63	12.38	-849.13	-1156.97	12.38	849.13	-1156.97	12.38
1.	35.	-1804.4	708.91	0.e-3	1804.4	708.91	0.e-3	-1857.47	812.57	0.e-3	1857.47	812.57	0.e-3
1.	35.	-1804.4	708.91	12.38	1804.4	708.91	12.38	-1857.47	812.57	12.38	1857.47	812.57	12.38
1.	36.	-1857.47	812.57	0.e-3	1857.47	812.57	0.e-3	-1910.54	916.23	0.e-3	1910.54	916.23	0.e-3
1.	36.	-1857.47	812.57	12.38	1857.47	812.57	12.38	-1910.54	916.23	12.38	1910.54	916.23	12.38
4.	1.	0.e-4	-2828.64	37.14	0.e-4	-2828.64	37.14	-53.45	-2724.24	37.14	53.45	-2724.24	37.14
4.	1.	0.e-4	-2828.64	49.52	0.e-4	-2828.64	49.52	-53.45	-2724.24	49.52	53.45	-2724.24	49.52
4.	2.	-53.45	-2724.24	37.14	53.45	-2724.24	37.14	-106.9	-2619.84	37.14	106.9	-2619.84	37.14
4.	2.	-53.45	-2724.24	49.52	53.45	-2724.24	49.52	-106.9	-2619.84	49.52	106.9	-2619.84	49.52
4.	15.	-748.31	-1367.	37.14	748.31	-1367.	37.14	-801.76	-1262.6	37.14	801.76	-1262.6	37.14
4.	15.	-748.31	-1367.	49.52	748.31	-1367.	49.52	-801.76	-1262.6	49.52	801.76	-1262.6	49.52
4.	16.	-801.76	-1262.6	37.14	801.76	-1262.6	37.14	-855.21	-1158.2	37.14	855.21	-1158.2	37.14
4.	16.	-801.76	-1262.6	49.52	801.76	-1262.6	49.52	-855.21	-1158.2	49.52	855.21	-1158.2	49.52
4.	35.	-1817.33	721.05	37.14	1817.33	721.05	37.14	-1870.78	825.46	37.14	1870.78	825.46	37.14
4.	35.	-1817.33	721.05	49.52	1817.33	721.05	49.52	-1870.78	825.46	49.52	1870.78	825.46	49.52
4.	36.	-1870.78	825.46	37.14	1870.78	825.46	37.14	-1924.23	929.86	37.14	1924.23	929.86	37.14
4.	36.	-1870.78	825.46	49.52	1870.78	825.46	49.52	-1924.23	929.86	49.52	1924.23	929.86	49.52
7.	1.	0.e-3	-2841.75	74.29	0.e-3	-2841.75	74.29	-53.83	-2736.61	74.29	53.83	-2736.61	74.29
7.	1.	0.e-3	-2841.75	86.67	0.e-3	-2841.75	86.67	-53.83	-2736.61	86.67	53.83	-2736.61	86.67
7.	2.	-53.83	-2736.61	74.29	53.83	-2736.61	74.29	-107.66	-2631.46	74.29	107.66	-2631.46	74.29
7.	2.	-53.83	-2736.61	86.67	53.83	-2736.61	86.67	-107.66	-2631.46	86.67	107.66	-2631.46	86.67
7.	15.	-753.64	-1369.72	74.29	753.64	-1369.72	74.29	-807.47	-1264.57	74.29	807.47	-1264.57	74.29
7.	15.	-753.64	-1369.72	86.67	753.64	-1369.72	86.67	-807.47	-1264.57	86.67	807.47	-1264.57	86.67
7.	16.	-807.47	-1264.57	74.29	807.47	-1264.57	74.29	-861.3	-1159.43	74.29	861.3	-1159.43	74.29
7.	16.	-807.47	-1264.57	86.67	807.47	-1264.57	86.67	-861.3	-1159.43	86.67	861.3	-1159.43	86.67
7.	35.	-1830.26	733.2	74.29	1830.26	733.2	74.29	-1884.09	838.34	74.29	1884.09	838.34	74.29
7.	35.	-1830.26	733.2	86.67	1830.26	733.2	86.67	-1884.09	838.34	86.67	1884.09	838.34	86.67
7.	36.	-1884.09	838.34	74.29	1884.09	838.34	74.29	-1937.92	943.49	74.29	1937.92	943.49	74.29
7.	36.	-1884.09	838.34	86.67	1884.09	838.34	86.67	-1937.92	943.49	86.67	1937.92	943.49	86.67

L	U	y1	x1	z1	y2	x2	z2	y3	x3	z3	y4	x4	z4
10.	1.	0.e-3	-2854.87	111.43	0.e-3	-2854.87	111.43	-54.21	-2748.98	111.43	54.21	-2748.98	111.43
10.	1.	0.e-3	-2854.87	123.81	0.e-3	-2854.87	123.81	-54.21	-2748.98	123.81	54.21	-2748.98	123.81
10.	2.	-54.21	-2748.98	111.43	54.21	-2748.98	111.43	-108.42	-2643.09	111.43	108.42	-2643.09	111.43
10.	2.	-54.21	-2748.98	123.81	54.21	-2748.98	123.81	-108.42	-2643.09	123.81	108.42	-2643.09	123.81
10.	15.	-758.96	-1372.43	111.43	758.96	-1372.43	111.43	-813.17	-1266.54	111.43	813.17	-1266.54	111.43
10.	15.	-758.96	-1372.43	123.81	758.96	-1372.43	123.81	-813.17	-1266.54	123.81	813.17	-1266.54	123.81
10.	16.	-813.17	-1266.54	111.43	813.17	-1266.54	111.43	-867.38	-1160.65	111.43	867.38	-1160.65	111.43
10.	16.	-813.17	-1266.54	123.81	813.17	-1266.54	123.81	-867.38	-1160.65	123.81	867.38	-1160.65	123.81
10.	35.	-1843.19	745.34	111.43	1843.19	745.34	111.43	-1897.4	851.23	111.43	1897.4	851.23	111.43
10.	35.	-1843.19	745.34	123.81	1843.19	745.34	123.81	-1897.4	851.23	123.81	1897.4	851.23	123.81
10.	36.	-1897.4	851.23	111.43	1897.4	851.23	111.43	-1951.61	957.12	111.43	1951.61	957.12	111.43
10.	36.	-1897.4	851.23	123.81	1897.4	851.23	123.81	-1951.61	957.12	123.81	1951.61	957.12	123.81
13.	1.	0.e-3	-2867.98	148.57	0.e-3	-2867.98	148.57	-54.59	-2761.35	148.57	54.59	-2761.35	148.57
13.	1.	0.e-3	-2867.98	160.95	0.e-3	-2867.98	160.95	-54.59	-2761.35	160.95	54.59	-2761.35	160.95
13.	2.	-54.59	-2761.35	148.57	54.59	-2761.35	148.57	-109.18	-2654.72	148.57	109.18	-2654.72	148.57
13.	2.	-54.59	-2761.35	160.95	54.59	-2761.35	160.95	-109.18	-2654.72	160.95	109.18	-2654.72	160.95
13.	15.	-764.28	-1375.14	148.57	764.28	-1375.14	148.57	-818.87	-1268.51	148.57	818.87	-1268.51	148.57
13.	15.	-764.28	-1375.14	160.95	764.28	-1375.14	160.95	-818.87	-1268.51	160.95	818.87	-1268.51	160.95
13.	16.	-818.87	-1268.51	148.57	818.87	-1268.51	148.57	-873.47	-1161.88	148.57	873.47	-1161.88	148.57
13.	16.	-818.87	-1268.51	160.95	818.87	-1268.51	160.95	-873.47	-1161.88	160.95	873.47	-1161.88	160.95
13.	35.	-1856.12	757.48	148.57	1856.12	757.48	148.57	-1910.71	864.11	148.57	1910.71	864.11	148.57
13.	35.	-1856.12	757.48	160.95	1856.12	757.48	160.95	-1910.71	864.11	160.95	1910.71	864.11	160.95
13.	36.	-1910.71	864.11	148.57	1910.71	864.11	148.57	-1965.3	970.74	148.57	1965.3	970.74	148.57
13.	36.	-1910.71	864.11	160.95	1910.71	864.11	160.95	-1965.3	970.74	160.95	1965.3	970.74	160.95
16.	1.	0.e-3	-2881.09	185.72	0.e-3	-2881.09	185.72	-54.97	-2773.72	185.72	54.97	-2773.72	185.72
16.	1.	0.e-3	-2881.09	198.1	0.e-3	-2881.09	198.1	-54.97	-2773.72	198.1	54.97	-2773.72	198.1
16.	2.	-54.97	-2773.72	185.72	54.97	-2773.72	185.72	-109.94	-2666.34	185.72	109.94	-2666.34	185.72
16.	2.	-54.97	-2773.72	198.1	54.97	-2773.72	198.1	-109.94	-2666.34	198.1	109.94	-2666.34	198.1
16.	15.	-769.61	-1377.86	185.72	769.61	-1377.86	185.72	-824.58	-1270.48	185.72	824.58	-1270.48	185.72
16.	15.	-769.61	-1377.86	198.1	769.61	-1377.86	198.1	-824.58	-1270.48	198.1	824.58	-1270.48	198.1
16.	16.	-824.58	-1270.48	185.72	824.58	-1270.48	185.72	-879.55	-1163.11	185.72	879.55	-1163.11	185.72
16.	16.	-824.58	-1270.48	198.1	824.58	-1270.48	198.1	-879.55	-1163.11	198.1	879.55	-1163.11	198.1
16.	35.	-1869.05	769.62	185.72	1869.05	769.62	185.72	-1924.02	877.	185.72	1924.02	877.	185.72
16.	35.	-1869.05	769.62	198.1	1869.05	769.62	198.1	-1924.02	877.	198.1	1924.02	877.	198.1
16.	36.	-1924.02	877.	185.72	1924.02	877.	185.72	-1978.99	984.37	185.72	1978.99	984.37	185.72
16.	36.	-1924.02	877.	198.1	1924.02	877.	198.1	-1978.99	984.37	198.1	1978.99	984.37	198.1

Table of layer number, strip number, positions of corners of selected strips (see Fig 13) for the U view.

L	U	y1	x1	z1	y2	x2	z2	y3	x3	z3	y4	x4	z4
19.	1.	0.e-3	-2894.2	222.86	0.e-3	-2894.2	222.86	-55.35	-2786.09	222.86	55.35	-2786.09	222.86
19.	1.	0.e-3	-2894.2	235.24	0.e-3	-2894.2	235.24	-55.35	-2786.09	235.24	55.35	-2786.09	235.24
19.	2.	-55.35	-2786.09	222.86	55.35	-2786.09	222.86	-110.7	-2677.97	222.86	110.7	-2677.97	222.86
19.	2.	-55.35	-2786.09	235.24	55.35	-2786.09	235.24	-110.7	-2677.97	235.24	110.7	-2677.97	235.24
19.	15.	-774.93	-1380.57	222.86	774.93	-1380.57	222.86	-830.28	-1272.45	222.86	830.28	-1272.45	222.86
19.	15.	-774.93	-1380.57	235.24	774.93	-1380.57	235.24	-830.28	-1272.45	235.24	830.28	-1272.45	235.24
19.	16.	-830.28	-1272.45	222.86	830.28	-1272.45	222.86	-885.64	-1164.34	222.86	885.64	-1164.34	222.86
19.	16.	-830.28	-1272.45	235.24	830.28	-1272.45	235.24	-885.64	-1164.34	235.24	885.64	-1164.34	235.24
19.	35.	-1881.98	781.77	222.86	1881.98	781.77	222.86	-1937.33	889.88	222.86	1937.33	889.88	222.86
19.	35.	-1881.98	781.77	235.24	1881.98	781.77	235.24	-1937.33	889.88	235.24	1937.33	889.88	235.24
19.	36.	-1937.33	889.88	222.86	1937.33	889.88	222.86	-1992.68	998.	222.86	1992.68	998.	222.86
19.	36.	-1937.33	889.88	235.24	1937.33	889.88	235.24	-1992.68	998.	235.24	1992.68	998.	235.24
22.	1.	0.e-3	-2907.32	260.	0.e-3	-2907.32	260.	-55.73	-2798.46	260.	55.73	-2798.46	260.
22.	1.	0.e-3	-2907.32	272.38	0.e-3	-2907.32	272.38	-55.73	-2798.46	272.38	55.73	-2798.46	272.38
22.	2.	-55.73	-2798.46	260.	55.73	-2798.46	260.	-111.46	-2689.6	260.	111.46	-2689.6	260.
22.	2.	-55.73	-2798.46	272.38	55.73	-2798.46	272.38	-111.46	-2689.6	272.38	111.46	-2689.6	272.38
22.	15.	-780.26	-1383.28	260.	780.26	-1383.28	260.	-835.99	-1274.42	260.	835.99	-1274.42	260.
22.	15.	-780.26	-1383.28	272.38	780.26	-1383.28	272.38	-835.99	-1274.42	272.38	835.99	-1274.42	272.38
22.	16.	-835.99	-1274.42	260.	835.99	-1274.42	260.	-891.72	-1165.56	260.	891.72	-1165.56	260.
22.	16.	-835.99	-1274.42	272.38	835.99	-1274.42	272.38	-891.72	-1165.56	272.38	891.72	-1165.56	272.38
22.	35.	-1894.91	793.91	260.	1894.91	793.91	260.	-1950.64	902.77	260.	1950.64	902.77	260.
22.	35.	-1894.91	793.91	272.38	1894.91	793.91	272.38	-1950.64	902.77	272.38	1950.64	902.77	272.38
22.	36.	-1950.64	902.77	260.	1950.64	902.77	260.	-2006.37	1011.63	260.	2006.37	1011.63	260.
22.	36.	-1950.64	902.77	272.38	1950.64	902.77	272.38	-2006.37	1011.63	272.38	2006.37	1011.63	272.38
25.	1.	0.e-3	-2920.43	297.14	0.e-3	-2920.43	297.14	-56.11	-2810.83	297.14	56.11	-2810.83	297.14
25.	1.	0.e-3	-2920.43	309.52	0.e-3	-2920.43	309.52	-56.11	-2810.83	309.52	56.11	-2810.83	309.52
25.	2.	-56.11	-2810.83	297.14	56.11	-2810.83	297.14	-112.23	-2701.22	297.14	112.23	-2701.22	297.14
25.	2.	-56.11	-2810.83	309.52	56.11	-2810.83	309.52	-112.23	-2701.22	309.52	112.23	-2701.22	309.52
25.	15.	-785.58	-1386.	297.14	785.58	-1386.	297.14	-841.69	-1276.39	297.14	841.69	-1276.39	297.14
25.	15.	-785.58	-1386.	309.52	785.58	-1386.	309.52	-841.69	-1276.39	309.52	841.69	-1276.39	309.52
25.	16.	-841.69	-1276.39	297.14	841.69	-1276.39	297.14	-897.8	-1166.79	297.14	897.8	-1166.79	297.14
25.	16.	-841.69	-1276.39	309.52	841.69	-1276.39	309.52	-897.8	-1166.79	309.52	897.8	-1166.79	309.52
25.	35.	-1907.84	806.05	297.14	1907.84	806.05	297.14	-1963.95	915.65	297.14	1963.95	915.65	297.14
25.	35.	-1907.84	806.05	309.52	1907.84	806.05	309.52	-1963.95	915.65	309.52	1963.95	915.65	309.52
25.	36.	-1963.95	915.65	297.14	1963.95	915.65	297.14	-2020.06	1025.26	297.14	2020.06	1025.26	297.14
25.	36.	-1963.95	915.65	309.52	1963.95	915.65	309.52	-2020.06	1025.26	309.52	2020.06	1025.26	309.52

Table of layer number, strip number, positions of corners of selected strips (see Fig 13) for the U view.

L	U	y1	x1	z1	y2	x2	z2	y3	x3	z3	y4	x4	z4
28.	1.	0.e-3	-2933.54	334.29	0.e-3	-2933.54	334.29	-56.49	-2823.2	334.29	56.49	-2823.2	334.29
28.	1.	0.e-3	-2933.54	346.67	0.e-3	-2933.54	346.67	-56.49	-2823.2	346.67	56.49	-2823.2	346.67
28.	2.	-56.49	-2823.2	334.29	56.49	-2823.2	334.29	-112.99	-2712.85	334.29	112.99	-2712.85	334.29
28.	2.	-56.49	-2823.2	346.67	56.49	-2823.2	346.67	-112.99	-2712.85	346.67	112.99	-2712.85	346.67
28.	15.	-790.9	-1388.71	334.29	790.9	-1388.71	334.29	-847.4	-1278.36	334.29	847.4	-1278.36	334.29
28.	15.	-790.9	-1388.71	346.67	790.9	-1388.71	346.67	-847.4	-1278.36	346.67	847.4	-1278.36	346.67
28.	16.	-847.4	-1278.36	334.29	847.4	-1278.36	334.29	-903.89	-1168.02	334.29	903.89	-1168.02	334.29
28.	16.	-847.4	-1278.36	346.67	847.4	-1278.36	346.67	-903.89	-1168.02	346.67	903.89	-1168.02	346.67
28.	35.	-1920.77	818.2	334.29	1920.77	818.2	334.29	-1977.26	928.54	334.29	1977.26	928.54	334.29
28.	35.	-1920.77	818.2	346.67	1920.77	818.2	346.67	-1977.26	928.54	346.67	1977.26	928.54	346.67
28.	36.	-1977.26	928.54	334.29	1977.26	928.54	334.29	-2033.75	1038.89	334.29	2033.75	1038.89	334.29
28.	36.	-1977.26	928.54	346.67	1977.26	928.54	346.67	-2033.75	1038.89	346.67	2033.75	1038.89	346.67
31.	1.	0.e-3	-2946.65	371.43	0.e-3	-2946.65	371.43	-56.87	-2835.57	371.43	56.87	-2835.57	371.43
31.	1.	0.e-3	-2946.65	383.81	0.e-3	-2946.65	383.81	-56.87	-2835.57	383.81	56.87	-2835.57	383.81
31.	2.	-56.87	-2835.57	371.43	56.87	-2835.57	371.43	-113.75	-2724.48	371.43	113.75	-2724.48	371.43
31.	2.	-56.87	-2835.57	383.81	56.87	-2835.57	383.81	-113.75	-2724.48	383.81	113.75	-2724.48	383.81
31.	15.	-796.23	-1391.42	371.43	796.23	-1391.42	371.43	-853.1	-1280.33	371.43	853.1	-1280.33	371.43
31.	15.	-796.23	-1391.42	383.81	796.23	-1391.42	383.81	-853.1	-1280.33	383.81	853.1	-1280.33	383.81
31.	16.	-853.1	-1280.33	371.43	853.1	-1280.33	371.43	-909.97	-1169.25	371.43	909.97	-1169.25	371.43
31.	16.	-853.1	-1280.33	383.81	853.1	-1280.33	383.81	-909.97	-1169.25	383.81	909.97	-1169.25	383.81
31.	35.	-1933.7	830.34	371.43	1933.7	830.34	371.43	-1990.57	941.43	371.43	1990.57	941.43	371.43
31.	35.	-1933.7	830.34	383.81	1933.7	830.34	383.81	-1990.57	941.43	383.81	1990.57	941.43	383.81
31.	36.	-1990.57	941.43	371.43	1990.57	941.43	371.43	-2047.44	1052.51	371.43	2047.44	1052.51	371.43
31.	36.	-1990.57	941.43	383.81	1990.57	941.43	383.81	-2047.44	1052.51	383.81	2047.44	1052.51	383.81
34.	1.	0.e-3	-2959.77	408.57	0.e-3	-2959.77	408.57	-57.25	-2847.94	408.57	57.25	-2847.94	408.57
34.	1.	0.e-3	-2959.77	420.95	0.e-3	-2959.77	420.95	-57.25	-2847.94	420.95	57.25	-2847.94	420.95
34.	2.	-57.25	-2847.94	408.57	57.25	-2847.94	408.57	-114.51	-2736.1	408.57	114.51	-2736.1	408.57
34.	2.	-57.25	-2847.94	420.95	57.25	-2847.94	420.95	-114.51	-2736.1	420.95	114.51	-2736.1	420.95
34.	15.	-801.55	-1394.14	408.57	801.55	-1394.14	408.57	-858.8	-1282.3	408.57	858.8	-1282.3	408.57
34.	15.	-801.55	-1394.14	420.95	801.55	-1394.14	420.95	-858.8	-1282.3	420.95	858.8	-1282.3	420.95
34.	16.	-858.8	-1282.3	408.57	858.8	-1282.3	408.57	-916.06	-1170.47	408.57	916.06	-1170.47	408.57
34.	16.	-858.8	-1282.3	420.95	858.8	-1282.3	420.95	-916.06	-1170.47	420.95	916.06	-1170.47	420.95
34.	35.	-1946.63	842.48	408.57	1946.63	842.48	408.57	-2003.88	954.31	408.57	2003.88	954.31	408.57
34.	35.	-1946.63	842.48	420.95	1946.63	842.48	420.95	-2003.88	954.31	420.95	2003.88	954.31	420.95
34.	36.	-2003.88	954.31	408.57	2003.88	954.31	408.57	-2061.13	1066.14	408.57	2061.13	1066.14	408.57
34.	36.	-2003.88	954.31	420.95	2003.88	954.31	420.95	-2061.13	1066.14	420.95	2061.13	1066.14	420.95
37.	1.	0.e-3	-2972.88	445.72	0.e-3	-2972.88	445.72	-57.63	-2860.31	445.72	57.63	-2860.31	445.72
37.	1.	0.e-3	-2972.88	458.1	0.e-3	-2972.88	458.1	-57.63	-2860.31	458.1	57.63	-2860.31	458.1
37.	2.	-57.63	-2860.31	445.72	57.63	-2860.31	445.72	-115.27	-2747.73	445.72	115.27	-2747.73	445.72
37.	2.	-57.63	-2860.31	458.1	57.63	-2860.31	458.1	-115.27	-2747.73	458.1	115.27	-2747.73	458.1
37.	15.	-806.88	-1396.85	445.72	806.88	-1396.85	445.72	-864.51	-1284.27	445.72	864.51	-1284.27	445.72
37.	15.	-806.88	-1396.85	458.1	806.88	-1396.85	458.1	-864.51	-1284.27	458.1	864.51	-1284.27	458.1
37.	16.	-864.51	-1284.27	445.72	864.51	-1284.27	445.72	-922.14	-1171.7	445.72	922.14	-1171.7	445.72
37.	16.	-864.51	-1284.27	458.1	864.51	-1284.27	458.1	-922.14	-1171.7	458.1	922.14	-1171.7	458.1
37.	35.	-1959.55	854.62	445.72	1959.55	854.62	445.72	-2017.19	967.2	445.72	2017.19	967.2	445.72
37.	35.	-1959.55	854.62	458.1	1959.55	854.62	458.1	-2017.19	967.2	458.1	2017.19	967.2	458.1
37.	36.	-2017.19	967.2	445.72	2017.19	967.2	445.72	-2074.82	1079.77	445.72	2074.82	1079.77	445.72
37.	36.	-2017.19	967.2	458.1	2017.19	967.2	458.1	-2074.82	1079.77	458.1	2074.82	1079.77	458.1

Table of layer number, strip number, positions of corners of selected strips (see Fig 13) for the U view.

B Strip Corners for V view

Table of layer number, strip number, positions of corners of selected strips (see Fig 14) for the V view. *Mathematica* notebooks for testing these calculations are available in the CLAS12 repository under `https://clas12svn.jlab.org/repos/users/gilfoyle/ECgeomCalcs`.

L	V	y1	x1	z1	y2	x2	z2	y3	x3	z3	y4	x4	z4
2.	1.	-1916.22	918.31	12.38	-1915.03	920.63	12.38	-1809.83	918.31	12.38	-1861.84	816.73	12.38
2.	1.	-1916.22	918.31	24.76	-1915.03	920.63	24.76	-1809.83	918.31	24.76	-1861.84	816.73	24.76
2.	2.	-1809.83	918.31	12.38	-1861.84	816.73	12.38	-1703.44	918.31	12.38	-1808.64	712.83	12.38
2.	2.	-1809.83	918.31	24.76	-1861.84	816.73	24.76	-1703.44	918.31	24.76	-1808.64	712.83	24.76
2.	15.	-426.75	918.31	12.38	-1170.3	-534.02	12.38	-320.36	918.31	12.38	-1117.1	-637.92	12.38
2.	15.	-426.75	918.31	24.76	-1170.3	-534.02	24.76	-320.36	918.31	24.76	-1117.1	-637.92	24.76
2.	16.	-320.36	918.31	12.38	-1117.1	-637.92	12.38	-213.97	918.31	12.38	-1063.91	-741.83	12.38
2.	16.	-320.36	918.31	24.76	-1117.1	-637.92	24.76	-213.97	918.31	24.76	-1063.91	-741.83	24.76
2.	35.	1701.06	918.31	12.38	-106.39	-2612.09	12.38	1807.45	918.31	12.38	-53.2	-2716.	12.38
2.	35.	1701.06	918.31	24.76	-106.39	-2612.09	24.76	1807.45	918.31	24.76	-53.2	-2716.	24.76
2.	36.	1807.45	918.31	12.38	-53.2	-2716.	12.38	1913.84	918.31	12.38	0.e-3	-2819.9	12.38
2.	36.	1807.45	918.31	24.76	-53.2	-2716.	24.76	1913.84	918.31	24.76	0.e-3	-2819.9	24.76
5.	1.	-1929.9	931.94	49.52	-1928.72	934.25	49.52	-1822.75	931.94	49.52	-1875.14	829.61	49.52
5.	1.	-1929.9	931.94	61.91	-1928.72	934.25	61.91	-1822.75	931.94	61.91	-1875.14	829.61	61.91
5.	2.	-1822.75	931.94	49.52	-1875.14	829.61	49.52	-1715.6	931.94	49.52	-1821.57	724.96	49.52
5.	2.	-1822.75	931.94	61.91	-1875.14	829.61	61.91	-1715.6	931.94	61.91	-1821.57	724.96	61.91
5.	15.	-429.79	931.94	49.52	-1178.66	-530.79	49.52	-322.64	931.94	49.52	-1125.08	-635.44	49.52
5.	15.	-429.79	931.94	61.91	-1178.66	-530.79	61.91	-322.64	931.94	61.91	-1125.08	-635.44	61.91
5.	16.	-322.64	931.94	49.52	-1125.08	-635.44	49.52	-215.49	931.94	49.52	-1071.51	-740.09	49.52
5.	16.	-322.64	931.94	61.91	-1125.08	-635.44	61.91	-215.49	931.94	61.91	-1071.51	-740.09	61.91
5.	35.	1713.23	931.94	49.52	-107.15	-2623.72	49.52	1820.38	931.94	49.52	-53.58	-2728.37	49.52
5.	35.	1713.23	931.94	61.91	-107.15	-2623.72	61.91	1820.38	931.94	61.91	-53.58	-2728.37	61.91
5.	36.	1820.38	931.94	49.52	-53.58	-2728.37	49.52	1927.53	931.94	49.52	0.e-3	-2833.01	49.52
5.	36.	1820.38	931.94	61.91	-53.58	-2728.37	61.91	1927.53	931.94	61.91	0.e-3	-2833.01	61.91
8.	1.	-1943.59	945.56	86.67	-1942.4	947.87	86.67	-1835.67	945.56	86.67	-1888.45	842.48	86.67
8.	1.	-1943.59	945.56	99.05	-1942.4	947.87	99.05	-1835.67	945.56	99.05	-1888.45	842.48	99.05
8.	2.	-1835.67	945.56	86.67	-1888.45	842.48	86.67	-1727.76	945.56	86.67	-1834.49	737.1	86.67
8.	2.	-1835.67	945.56	99.05	-1888.45	842.48	99.05	-1727.76	945.56	99.05	-1834.49	737.1	99.05
8.	15.	-432.83	945.56	86.67	-1187.02	-527.57	86.67	-324.92	945.56	86.67	-1133.07	-632.96	86.67
8.	15.	-432.83	945.56	99.05	-1187.02	-527.57	99.05	-324.92	945.56	99.05	-1133.07	-632.96	99.05
8.	16.	-324.92	945.56	86.67	-1133.07	-632.96	86.67	-217.01	945.56	86.67	-1079.11	-738.35	86.67
8.	16.	-324.92	945.56	99.05	-1133.07	-632.96	99.05	-217.01	945.56	99.05	-1079.11	-738.35	99.05
8.	35.	1725.4	945.56	86.67	-107.91	-2635.35	86.67	1833.31	945.56	86.67	-53.96	-2740.74	86.67
8.	35.	1725.4	945.56	99.05	-107.91	-2635.35	99.05	1833.31	945.56	99.05	-53.96	-2740.74	99.05
8.	36.	1833.31	945.56	86.67	-53.96	-2740.74	86.67	1941.22	945.56	86.67	0.e-3	-2846.13	86.67
8.	36.	1833.31	945.56	99.05	-53.96	-2740.74	99.05	1941.22	945.56	99.05	0.e-3	-2846.13	99.05

L	V	y1	x1	z1	y2	x2	z2	y3	x3	z3	y4	x4	z4
11.	1.	-1957.27	959.19	123.81	-1956.09	961.49	123.81	-1848.6	959.19	123.81	-1901.75	855.36	123.81
11.	1.	-1957.27	959.19	136.19	-1956.09	961.49	136.19	-1848.6	959.19	136.19	-1901.75	855.36	136.19
11.	2.	-1848.6	959.19	123.81	-1901.75	855.36	123.81	-1739.93	959.19	123.81	-1847.42	749.23	123.81
11.	2.	-1848.6	959.19	136.19	-1901.75	855.36	136.19	-1739.93	959.19	136.19	-1847.42	749.23	136.19
11.	15.	-435.87	959.19	123.81	-1195.39	-524.35	123.81	-327.19	959.19	123.81	-1141.05	-630.48	123.81
11.	15.	-435.87	959.19	136.19	-1195.39	-524.35	136.19	-327.19	959.19	136.19	-1141.05	-630.48	136.19
11.	16.	-327.19	959.19	123.81	-1141.05	-630.48	123.81	-218.52	959.19	123.81	-1086.72	-736.61	123.81
11.	16.	-327.19	959.19	136.19	-1141.05	-630.48	136.19	-218.52	959.19	136.19	-1086.72	-736.61	136.19
11.	35.	1737.57	959.19	123.81	-108.67	-2646.97	123.81	1846.24	959.19	123.81	-54.34	-2753.11	123.81
11.	35.	1737.57	959.19	136.19	-108.67	-2646.97	136.19	1846.24	959.19	136.19	-54.34	-2753.11	136.19
11.	36.	1846.24	959.19	123.81	-54.34	-2753.11	123.81	1954.91	959.19	123.81	0.e-3	-2859.24	123.81
11.	36.	1846.24	959.19	136.19	-54.34	-2753.11	136.19	1954.91	959.19	136.19	0.e-3	-2859.24	136.19
14.	1.	-1970.95	972.82	160.95	-1969.78	975.11	160.95	-1861.52	972.82	160.95	-1915.06	868.24	160.95
14.	1.	-1970.95	972.82	173.33	-1969.78	975.11	173.33	-1861.52	972.82	173.33	-1915.06	868.24	173.33
14.	2.	-1861.52	972.82	160.95	-1915.06	868.24	160.95	-1752.09	972.82	160.95	-1860.34	761.37	160.95
14.	2.	-1861.52	972.82	173.33	-1915.06	868.24	173.33	-1752.09	972.82	173.33	-1860.34	761.37	173.33
14.	15.	-438.9	972.82	160.95	-1203.75	-521.12	160.95	-329.47	972.82	160.95	-1149.04	-628.	160.95
14.	15.	-438.9	972.82	173.33	-1203.75	-521.12	173.33	-329.47	972.82	173.33	-1149.04	-628.	173.33
14.	16.	-329.47	972.82	160.95	-1149.04	-628.	160.95	-220.04	972.82	160.95	-1094.32	-734.87	160.95
14.	16.	-329.47	972.82	173.33	-1149.04	-628.	173.33	-220.04	972.82	173.33	-1094.32	-734.87	173.33
14.	35.	1749.73	972.82	160.95	-109.43	-2658.6	160.95	1859.17	972.82	160.95	-54.72	-2765.48	160.95
14.	35.	1749.73	972.82	173.33	-109.43	-2658.6	173.33	1859.17	972.82	173.33	-54.72	-2765.48	173.33
14.	36.	1859.17	972.82	160.95	-54.72	-2765.48	160.95	1968.6	972.82	160.95	0.e-3	-2872.35	160.95
14.	36.	1859.17	972.82	173.33	-54.72	-2765.48	173.33	1968.6	972.82	173.33	0.e-3	-2872.35	173.33
17.	1.	-1984.64	986.44	198.1	-1983.46	988.73	198.1	-1874.44	986.44	198.1	-1928.37	881.12	198.1
17.	1.	-1984.64	986.44	210.48	-1983.46	988.73	210.48	-1874.44	986.44	210.48	-1928.37	881.12	210.48
17.	2.	-1874.44	986.44	198.1	-1928.37	881.12	198.1	-1764.25	986.44	198.1	-1873.27	773.5	198.1
17.	2.	-1874.44	986.44	210.48	-1928.37	881.12	210.48	-1764.25	986.44	210.48	-1873.27	773.5	210.48
17.	15.	-441.94	986.44	198.1	-1212.12	-517.9	198.1	-331.75	986.44	198.1	-1157.02	-625.51	198.1
17.	15.	-441.94	986.44	210.48	-1212.12	-517.9	210.48	-331.75	986.44	210.48	-1157.02	-625.51	210.48
17.	16.	-331.75	986.44	198.1	-1157.02	-625.51	198.1	-221.56	986.44	198.1	-1101.92	-733.13	198.1
17.	16.	-331.75	986.44	210.48	-1157.02	-625.51	210.48	-221.56	986.44	210.48	-1101.92	-733.13	210.48
17.	35.	1761.9	986.44	198.1	-110.19	-2670.23	198.1	1872.1	986.44	198.1	-55.1	-2777.85	198.1
17.	35.	1761.9	986.44	210.48	-110.19	-2670.23	210.48	1872.1	986.44	210.48	-55.1	-2777.85	210.48
17.	36.	1872.1	986.44	198.1	-55.1	-2777.85	198.1	1982.29	986.44	198.1	0.e-3	-2885.46	198.1
17.	36.	1872.1	986.44	210.48	-55.1	-2777.85	210.48	1982.29	986.44	210.48	0.e-3	-2885.46	210.48

Table of layer number, strip number, positions of corners of selected strips (see Fig 14) for the V view.

L	V	y1	x1	z1	y2	x2	z2	y3	x3	z3	y4	x4	z4
20.	1.	-1998.32	1000.07	235.24	-1997.15	1002.35	235.24	-1887.37	1000.07	235.24	-1941.67	894.	235.24
20.	1.	-1998.32	1000.07	247.62	-1997.15	1002.35	247.62	-1887.37	1000.07	247.62	-1941.67	894.	247.62
20.	2.	-1887.37	1000.07	235.24	-1941.67	894.	235.24	-1776.41	1000.07	235.24	-1886.2	785.64	235.24
20.	2.	-1887.37	1000.07	247.62	-1941.67	894.	247.62	-1776.41	1000.07	247.62	-1886.2	785.64	247.62
20.	15.	-444.98	1000.07	235.24	-1220.48	-514.67	235.24	-334.03	1000.07	235.24	-1165.	-623.03	235.24
20.	15.	-444.98	1000.07	247.62	-1220.48	-514.67	247.62	-334.03	1000.07	247.62	-1165.	-623.03	247.62
20.	16.	-334.03	1000.07	235.24	-1165.	-623.03	235.24	-223.08	1000.07	235.24	-1109.53	-731.39	235.24
20.	16.	-334.03	1000.07	247.62	-1165.	-623.03	247.62	-223.08	1000.07	247.62	-1109.53	-731.39	247.62
20.	35.	1774.07	1000.07	235.24	-110.95	-2681.86	235.24	1885.02	1000.07	235.24	-55.48	-2790.22	235.24
20.	35.	1774.07	1000.07	247.62	-110.95	-2681.86	247.62	1885.02	1000.07	247.62	-55.48	-2790.22	247.62
20.	36.	1885.02	1000.07	235.24	-55.48	-2790.22	235.24	1995.98	1000.07	235.24	0.e-3	-2898.57	235.24
20.	36.	1885.02	1000.07	247.62	-55.48	-2790.22	247.62	1995.98	1000.07	247.62	0.e-3	-2898.57	247.62
23.	1.	-2012.	1013.69	272.38	-2010.83	1015.97	272.38	-1900.29	1013.69	272.38	-1954.98	906.87	272.38
23.	1.	-2012.	1013.69	284.76	-2010.83	1015.97	284.76	-1900.29	1013.69	284.76	-1954.98	906.87	284.76
23.	2.	-1900.29	1013.69	272.38	-1954.98	906.87	272.38	-1788.58	1013.69	272.38	-1899.12	797.77	272.38
23.	2.	-1900.29	1013.69	284.76	-1954.98	906.87	284.76	-1788.58	1013.69	284.76	-1899.12	797.77	284.76
23.	15.	-448.02	1013.69	272.38	-1228.84	-511.45	272.38	-336.31	1013.69	272.38	-1172.99	-620.55	272.38
23.	15.	-448.02	1013.69	284.76	-1228.84	-511.45	284.76	-336.31	1013.69	284.76	-1172.99	-620.55	284.76
23.	16.	-336.31	1013.69	272.38	-1172.99	-620.55	272.38	-224.59	1013.69	272.38	-1117.13	-729.65	272.38
23.	16.	-336.31	1013.69	284.76	-1172.99	-620.55	284.76	-224.59	1013.69	284.76	-1117.13	-729.65	284.76
23.	35.	1786.24	1013.69	272.38	-111.71	-2693.48	272.38	1897.95	1013.69	272.38	-55.86	-2802.58	272.38
23.	35.	1786.24	1013.69	284.76	-111.71	-2693.48	284.76	1897.95	1013.69	284.76	-55.86	-2802.58	284.76
23.	36.	1897.95	1013.69	272.38	-55.86	-2802.58	272.38	2009.67	1013.69	272.38	0.e-3	-2911.69	272.38
23.	36.	1897.95	1013.69	284.76	-55.86	-2802.58	284.76	2009.67	1013.69	284.76	0.e-3	-2911.69	284.76
26.	1.	-2025.69	1027.32	309.52	-2024.52	1029.59	309.52	-1913.21	1027.32	309.52	-1968.28	919.75	309.52
26.	1.	-2025.69	1027.32	321.91	-2024.52	1029.59	321.91	-1913.21	1027.32	321.91	-1968.28	919.75	321.91
26.	2.	-1913.21	1027.32	309.52	-1968.28	919.75	309.52	-1800.74	1027.32	309.52	-1912.05	809.91	309.52
26.	2.	-1913.21	1027.32	321.91	-1968.28	919.75	321.91	-1800.74	1027.32	321.91	-1912.05	809.91	321.91
26.	15.	-451.06	1027.32	309.52	-1237.21	-508.22	309.52	-338.59	1027.32	309.52	-1180.97	-618.07	309.52
26.	15.	-451.06	1027.32	321.91	-1237.21	-508.22	321.91	-338.59	1027.32	321.91	-1180.97	-618.07	321.91
26.	16.	-338.59	1027.32	309.52	-1180.97	-618.07	309.52	-226.11	1027.32	309.52	-1124.73	-727.91	309.52
26.	16.	-338.59	1027.32	321.91	-1180.97	-618.07	321.91	-226.11	1027.32	321.91	-1124.73	-727.91	321.91
26.	35.	1798.41	1027.32	309.52	-112.47	-2705.11	309.52	1910.88	1027.32	309.52	-56.24	-2814.95	309.52
26.	35.	1798.41	1027.32	321.91	-112.47	-2705.11	321.91	1910.88	1027.32	321.91	-56.24	-2814.95	321.91
26.	36.	1910.88	1027.32	309.52	-56.24	-2814.95	309.52	2023.35	1027.32	309.52	0.e-3	-2924.8	309.52
26.	36.	1910.88	1027.32	321.91	-56.24	-2814.95	321.91	2023.35	1027.32	321.91	0.e-3	-2924.8	321.91

Table of layer number, strip number, positions of corners of selected strips (see Fig 14) for the V view.

L	V	y1	x1	z1	y2	x2	z2	y3	x3	z3	y4	x4	z4
29.	1.	-2039.37	1040.94	346.67	-2038.21	1043.22	346.67	-1926.13	1040.94	346.67	-1981.59	932.63	346.67
29.	1.	-2039.37	1040.94	359.05	-2038.21	1043.22	359.05	-1926.13	1040.94	359.05	-1981.59	932.63	359.05
29.	2.	-1926.13	1040.94	346.67	-1981.59	932.63	346.67	-1812.9	1040.94	346.67	-1924.97	822.04	346.67
29.	2.	-1926.13	1040.94	359.05	-1981.59	932.63	359.05	-1812.9	1040.94	359.05	-1924.97	822.04	359.05
29.	15.	-454.1	1040.94	346.67	-1245.57	-505.	346.67	-340.86	1040.94	346.67	-1188.95	-615.59	346.67
29.	15.	-454.1	1040.94	359.05	-1245.57	-505.	359.05	-340.86	1040.94	359.05	-1188.95	-615.59	359.05
29.	16.	-340.86	1040.94	346.67	-1188.95	-615.59	346.67	-227.63	1040.94	346.67	-1132.34	-726.17	346.67
29.	16.	-340.86	1040.94	359.05	-1188.95	-615.59	359.05	-227.63	1040.94	359.05	-1132.34	-726.17	359.05
29.	35.	1810.58	1040.94	346.67	-113.23	-2716.74	346.67	1923.81	1040.94	346.67	-56.62	-2827.32	346.67
29.	35.	1810.58	1040.94	359.05	-113.23	-2716.74	359.05	1923.81	1040.94	359.05	-56.62	-2827.32	359.05
29.	36.	1923.81	1040.94	346.67	-56.62	-2827.32	346.67	2037.04	1040.94	346.67	0.e-3	-2937.91	346.67
29.	36.	1923.81	1040.94	359.05	-56.62	-2827.32	359.05	2037.04	1040.94	359.05	0.e-3	-2937.91	359.05
32.	1.	-2053.05	1054.57	383.81	-2051.89	1056.84	383.81	-1939.06	1054.57	383.81	-1994.9	945.51	383.81
32.	1.	-2053.05	1054.57	396.19	-2051.89	1056.84	396.19	-1939.06	1054.57	396.19	-1994.9	945.51	396.19
32.	2.	-1939.06	1054.57	383.81	-1994.9	945.51	383.81	-1825.06	1054.57	383.81	-1937.9	834.18	383.81
32.	2.	-1939.06	1054.57	396.19	-1994.9	945.51	396.19	-1825.06	1054.57	396.19	-1937.9	834.18	396.19
32.	15.	-457.14	1054.57	383.81	-1253.93	-501.78	383.81	-343.14	1054.57	383.81	-1196.94	-613.11	383.81
32.	15.	-457.14	1054.57	396.19	-1253.93	-501.78	396.19	-343.14	1054.57	396.19	-1196.94	-613.11	396.19
32.	16.	-343.14	1054.57	383.81	-1196.94	-613.11	383.81	-229.15	1054.57	383.81	-1139.94	-724.44	383.81
32.	16.	-343.14	1054.57	396.19	-1196.94	-613.11	396.19	-229.15	1054.57	396.19	-1139.94	-724.44	396.19
32.	35.	1822.74	1054.57	383.81	-113.99	-2728.36	383.81	1936.74	1054.57	383.81	-57.	-2839.69	383.81
32.	35.	1822.74	1054.57	396.19	-113.99	-2728.36	396.19	1936.74	1054.57	396.19	-57.	-2839.69	396.19
32.	36.	1936.74	1054.57	383.81	-57.	-2839.69	383.81	2050.73	1054.57	383.81	0.e-3	-2951.02	383.81
32.	36.	1936.74	1054.57	396.19	-57.	-2839.69	396.19	2050.73	1054.57	396.19	0.e-3	-2951.02	396.19
35.	1.	-2066.74	1068.2	420.95	-2065.58	1070.46	420.95	-1951.98	1068.2	420.95	-2008.2	958.38	420.95
35.	1.	-2066.74	1068.2	433.34	-2065.58	1070.46	433.34	-1951.98	1068.2	433.34	-2008.2	958.38	433.34
35.	2.	-1951.98	1068.2	420.95	-2008.2	958.38	420.95	-1837.23	1068.2	420.95	-1950.82	846.31	420.95
35.	2.	-1951.98	1068.2	433.34	-2008.2	958.38	433.34	-1837.23	1068.2	433.34	-1950.82	846.31	433.34
35.	15.	-460.17	1068.2	420.95	-1262.3	-498.55	420.95	-345.42	1068.2	420.95	-1204.92	-610.62	420.95
35.	15.	-460.17	1068.2	433.34	-1262.3	-498.55	433.34	-345.42	1068.2	433.34	-1204.92	-610.62	433.34
35.	16.	-345.42	1068.2	420.95	-1204.92	-610.62	420.95	-230.67	1068.2	420.95	-1147.54	-722.7	420.95
35.	16.	-345.42	1068.2	433.34	-1204.92	-610.62	433.34	-230.67	1068.2	433.34	-1147.54	-722.7	433.34
35.	35.	1834.91	1068.2	420.95	-114.75	-2739.99	420.95	1949.67	1068.2	420.95	-57.38	-2852.06	420.95
35.	35.	1834.91	1068.2	433.34	-114.75	-2739.99	433.34	1949.67	1068.2	433.34	-57.38	-2852.06	433.34
35.	36.	1949.67	1068.2	420.95	-57.38	-2852.06	420.95	2064.42	1068.2	420.95	0.e-3	-2964.14	420.95
35.	36.	1949.67	1068.2	433.34	-57.38	-2852.06	433.34	2064.42	1068.2	433.34	0.e-3	-2964.14	433.34
38.	1.	-2080.42	1081.82	458.1	-2079.26	1084.08	458.1	-1964.9	1081.82	458.1	-2021.51	971.26	458.1
38.	1.	-2080.42	1081.82	470.48	-2079.26	1084.08	470.48	-1964.9	1081.82	470.48	-2021.51	971.26	470.48
38.	2.	-1964.9	1081.82	458.1	-2021.51	971.26	458.1	-1849.39	1081.82	458.1	-1963.75	858.45	458.1
38.	2.	-1964.9	1081.82	470.48	-2021.51	971.26	470.48	-1849.39	1081.82	470.48	-1963.75	858.45	470.48
38.	15.	-463.21	1081.82	458.1	-1270.66	-495.33	458.1	-347.7	1081.82	458.1	-1212.9	-608.14	458.1
38.	15.	-463.21	1081.82	470.48	-1270.66	-495.33	470.48	-347.7	1081.82	470.48	-1212.9	-608.14	470.48
38.	16.	-347.7	1081.82	458.1	-1212.9	-608.14	458.1	-232.18	1081.82	458.1	-1155.15	-720.96	458.1
38.	16.	-347.7	1081.82	470.48	-1212.9	-608.14	470.48	-232.18	1081.82	470.48	-1155.15	-720.96	470.48
38.	35.	1847.08	1081.82	458.1	-115.51	-2751.62	458.1	1962.6	1081.82	458.1	-57.76	-2864.43	458.1
38.	35.	1847.08	1081.82	470.48	-115.51	-2751.62	470.48	1962.6	1081.82	470.48	-57.76	-2864.43	470.48
38.	36.	1962.6	1081.82	458.1	-57.76	-2864.43	458.1	2078.11	1081.82	458.1	0.e-3	-2977.25	458.1
38.	36.	1962.6	1081.82	470.48	-57.76	-2864.43	470.48	2078.11	1081.82	470.48	0.e-3	-2977.25	470.48

Table of layer number, strip number, positions of corners of selected strips (see Fig 14) for the V view.

C Strip Corners for W view

Table of layer number, strip number, positions of corners of selected strips (see Fig 14) for the W view. *Mathematica* notebooks for testing these calculations are available in the CLAS12 repository under `https://clas12svn.jlab.org/repos/users/gilfoyle/ECgeomCalcs`.

L	W	y1	x1	z1	y2	x2	z2	y3	x3	z3	y4	x4	z4
3.	1.	1920.78	922.85	24.76	1919.59	925.17	24.76	1814.14	922.85	24.76	1866.27	821.02	24.76
3.	1.	1920.78	922.85	37.14	1919.59	925.17	37.14	1814.14	922.85	37.14	1866.27	821.02	37.14
3.	2.	1814.14	922.85	24.76	1866.27	821.02	24.76	1707.49	922.85	24.76	1812.95	716.87	24.76
3.	2.	1814.14	922.85	37.14	1866.27	821.02	37.14	1707.49	922.85	37.14	1812.95	716.87	37.14
3.	15.	427.76	922.85	24.76	1173.08	-532.94	24.76	321.12	922.85	24.76	1119.76	-637.1	24.76
3.	15.	427.76	922.85	37.14	1173.08	-532.94	37.14	321.12	922.85	37.14	1119.76	-637.1	37.14
3.	16.	321.12	922.85	24.76	1119.76	-637.1	24.76	214.48	922.85	24.76	1066.44	-741.25	24.76
3.	16.	321.12	922.85	37.14	1119.76	-637.1	37.14	214.48	922.85	37.14	1066.44	-741.25	37.14
3.	35.	-1705.12	922.85	24.76	106.64	-2615.97	24.76	-1811.76	922.85	24.76	53.32	-2720.12	24.76
3.	35.	-1705.12	922.85	37.14	106.64	-2615.97	37.14	-1811.76	922.85	37.14	53.32	-2720.12	37.14
3.	36.	-1811.76	922.85	24.76	53.32	-2720.12	24.76	-1918.41	922.85	24.76	0.e-3	-2824.27	24.76
3.	36.	-1811.76	922.85	37.14	53.32	-2720.12	37.14	-1918.41	922.85	37.14	0.e-3	-2824.27	37.14
6.	1.	1934.46	936.48	61.91	1933.28	938.79	61.91	1827.06	936.48	61.91	1879.58	833.9	61.91
6.	1.	1934.46	936.48	74.29	1933.28	938.79	74.29	1827.06	936.48	74.29	1879.58	833.9	74.29
6.	2.	1827.06	936.48	61.91	1879.58	833.9	61.91	1719.65	936.48	61.91	1825.87	729.01	61.91
6.	2.	1827.06	936.48	74.29	1879.58	833.9	74.29	1719.65	936.48	74.29	1825.87	729.01	74.29
6.	15.	430.8	936.48	61.91	1181.45	-529.72	61.91	323.4	936.48	61.91	1127.75	-634.61	61.91
6.	15.	430.8	936.48	74.29	1181.45	-529.72	74.29	323.4	936.48	74.29	1127.75	-634.61	74.29
6.	16.	323.4	936.48	61.91	1127.75	-634.61	61.91	215.99	936.48	61.91	1074.04	-739.51	61.91
6.	16.	323.4	936.48	74.29	1127.75	-634.61	74.29	215.99	936.48	74.29	1074.04	-739.51	74.29
6.	35.	-1717.29	936.48	61.91	107.4	-2627.6	61.91	-1824.69	936.48	61.91	53.7	-2732.49	61.91
6.	35.	-1717.29	936.48	74.29	107.4	-2627.6	74.29	-1824.69	936.48	74.29	53.7	-2732.49	74.29
6.	36.	-1824.69	936.48	61.91	53.7	-2732.49	61.91	-1932.09	936.48	61.91	0.e-3	-2837.38	61.91
6.	36.	-1824.69	936.48	74.29	53.7	-2732.49	74.29	-1932.09	936.48	74.29	0.e-3	-2837.38	74.29
9.	1.	1948.15	950.11	99.05	1946.97	952.41	99.05	1839.98	950.11	99.05	1892.88	846.78	99.05
9.	1.	1948.15	950.11	111.43	1946.97	952.41	111.43	1839.98	950.11	111.43	1892.88	846.78	111.43
9.	2.	1839.98	950.11	99.05	1892.88	846.78	99.05	1731.82	950.11	99.05	1838.8	741.14	99.05
9.	2.	1839.98	950.11	111.43	1892.88	846.78	111.43	1731.82	950.11	111.43	1838.8	741.14	111.43
9.	15.	433.84	950.11	99.05	1189.81	-526.5	99.05	325.68	950.11	99.05	1135.73	-632.13	99.05
9.	15.	433.84	950.11	111.43	1189.81	-526.5	111.43	325.68	950.11	111.43	1135.73	-632.13	111.43
9.	16.	325.68	950.11	99.05	1135.73	-632.13	99.05	217.51	950.11	99.05	1081.65	-737.77	99.05
9.	16.	325.68	950.11	111.43	1135.73	-632.13	111.43	217.51	950.11	111.43	1081.65	-737.77	111.43
9.	35.	-1729.45	950.11	99.05	108.16	-2639.22	99.05	-1837.62	950.11	99.05	54.08	-2744.86	99.05
9.	35.	-1729.45	950.11	111.43	108.16	-2639.22	111.43	-1837.62	950.11	111.43	54.08	-2744.86	111.43
9.	36.	-1837.62	950.11	99.05	54.08	-2744.86	99.05	-1945.78	950.11	99.05	0.e-3	-2850.5	99.05
9.	36.	-1837.62	950.11	111.43	54.08	-2744.86	111.43	-1945.78	950.11	111.43	0.e-3	-2850.5	111.43

L	W	y1	x1	z1	y2	x2	z2	y3	x3	z3	y4	x4	z4
12.	1.	1961.83	963.73	136.19	1960.65	966.03	136.19	1852.9	963.73	136.19	1906.19	859.65	136.19
12.	1.	1961.83	963.73	148.57	1960.65	966.03	148.57	1852.9	963.73	148.57	1906.19	859.65	148.57
12.	2.	1852.9	963.73	136.19	1906.19	859.65	136.19	1743.98	963.73	136.19	1851.73	753.28	136.19
12.	2.	1852.9	963.73	148.57	1906.19	859.65	148.57	1743.98	963.73	148.57	1851.73	753.28	148.57
12.	15.	436.88	963.73	136.19	1198.18	-523.27	136.19	327.95	963.73	136.19	1143.71	-629.65	136.19
12.	15.	436.88	963.73	148.57	1198.18	-523.27	148.57	327.95	963.73	148.57	1143.71	-629.65	148.57
12.	16.	327.95	963.73	136.19	1143.71	-629.65	136.19	219.03	963.73	136.19	1089.25	-736.03	136.19
12.	16.	327.95	963.73	148.57	1143.71	-629.65	148.57	219.03	963.73	148.57	1089.25	-736.03	148.57
12.	35.	-1741.62	963.73	136.19	108.93	-2650.85	136.19	-1850.55	963.73	136.19	54.46	-2757.23	136.19
12.	35.	-1741.62	963.73	148.57	108.93	-2650.85	148.57	-1850.55	963.73	148.57	54.46	-2757.23	148.57
12.	36.	-1850.55	963.73	136.19	54.46	-2757.23	136.19	-1959.47	963.73	136.19	0.e-3	-2863.61	136.19
12.	36.	-1850.55	963.73	148.57	54.46	-2757.23	148.57	-1959.47	963.73	148.57	0.e-3	-2863.61	148.57
15.	1.	1975.51	977.36	173.33	1974.34	979.65	173.33	1865.83	977.36	173.33	1919.49	872.53	173.33
15.	1.	1975.51	977.36	185.72	1974.34	979.65	185.72	1865.83	977.36	185.72	1919.49	872.53	185.72
15.	2.	1865.83	977.36	173.33	1919.49	872.53	173.33	1756.14	977.36	173.33	1864.65	765.41	173.33
15.	2.	1865.83	977.36	185.72	1919.49	872.53	185.72	1756.14	977.36	185.72	1864.65	765.41	185.72
15.	15.	439.92	977.36	173.33	1206.54	-520.05	173.33	330.23	977.36	173.33	1151.7	-627.17	173.33
15.	15.	439.92	977.36	185.72	1206.54	-520.05	185.72	330.23	977.36	185.72	1151.7	-627.17	185.72
15.	16.	330.23	977.36	173.33	1151.7	-627.17	173.33	220.55	977.36	173.33	1096.85	-734.29	173.33
15.	16.	330.23	977.36	185.72	1151.7	-627.17	185.72	220.55	977.36	185.72	1096.85	-734.29	185.72
15.	35.	-1753.79	977.36	173.33	109.69	-2662.48	173.33	-1863.48	977.36	173.33	54.84	-2769.6	173.33
15.	35.	-1753.79	977.36	185.72	109.69	-2662.48	185.72	-1863.48	977.36	185.72	54.84	-2769.6	185.72
15.	36.	-1863.48	977.36	173.33	54.84	-2769.6	173.33	-1973.16	977.36	173.33	0.e-3	-2876.72	173.33
15.	36.	-1863.48	977.36	185.72	54.84	-2769.6	185.72	-1973.16	977.36	185.72	0.e-3	-2876.72	185.72
18.	1.	1989.2	990.98	210.48	1988.02	993.27	210.48	1878.75	990.98	210.48	1932.8	885.41	210.48
18.	1.	1989.2	990.98	222.86	1988.02	993.27	222.86	1878.75	990.98	222.86	1932.8	885.41	222.86
18.	2.	1878.75	990.98	210.48	1932.8	885.41	210.48	1768.31	990.98	210.48	1877.58	777.55	210.48
18.	2.	1878.75	990.98	222.86	1932.8	885.41	222.86	1768.31	990.98	222.86	1877.58	777.55	222.86
18.	15.	442.96	990.98	210.48	1214.9	-516.82	210.48	332.51	990.98	210.48	1159.68	-624.69	210.48
18.	15.	442.96	990.98	222.86	1214.9	-516.82	222.86	332.51	990.98	222.86	1159.68	-624.69	222.86
18.	16.	332.51	990.98	210.48	1159.68	-624.69	210.48	222.06	990.98	210.48	1104.46	-732.55	210.48
18.	16.	332.51	990.98	222.86	1159.68	-624.69	222.86	222.06	990.98	222.86	1104.46	-732.55	222.86
18.	35.	-1765.96	990.98	210.48	110.45	-2674.1	210.48	-1876.4	990.98	210.48	55.22	-2781.97	210.48
18.	35.	-1765.96	990.98	222.86	110.45	-2674.1	222.86	-1876.4	990.98	222.86	55.22	-2781.97	222.86
18.	36.	-1876.4	990.98	210.48	55.22	-2781.97	210.48	-1986.85	990.98	210.48	0.e-3	-2889.83	210.48
18.	36.	-1876.4	990.98	222.86	55.22	-2781.97	222.86	-1986.85	990.98	222.86	0.e-3	-2889.83	222.86

Table of layer number, strip number, positions of corners of selected strips (see Fig 14) for the *W* view.

L	W	y1	x1	z1	y2	x2	z2	y3	x3	z3	y4	x4	z4
21.	1.	2002.88	1004.61	247.62	2001.71	1006.89	247.62	1891.67	1004.61	247.62	1946.11	898.29	247.62
21.	1.	2002.88	1004.61	260.	2001.71	1006.89	260.	1891.67	1004.61	260.	1946.11	898.29	260.
21.	2.	1891.67	1004.61	247.62	1946.11	898.29	247.62	1780.47	1004.61	247.62	1890.5	789.68	247.62
21.	2.	1891.67	1004.61	260.	1946.11	898.29	260.	1780.47	1004.61	260.	1890.5	789.68	260.
21.	15.	445.99	1004.61	247.62	1223.27	-513.6	247.62	334.79	1004.61	247.62	1167.66	-622.21	247.62
21.	15.	445.99	1004.61	260.	1223.27	-513.6	260.	334.79	1004.61	260.	1167.66	-622.21	260.
21.	16.	334.79	1004.61	247.62	1167.66	-622.21	247.62	223.58	1004.61	247.62	1112.06	-730.81	247.62
21.	16.	334.79	1004.61	260.	1167.66	-622.21	260.	223.58	1004.61	260.	1112.06	-730.81	260.
21.	35.	-1778.13	1004.61	247.62	111.21	-2685.73	247.62	-1889.33	1004.61	247.62	55.6	-2794.34	247.62
21.	35.	-1778.13	1004.61	260.	111.21	-2685.73	260.	-1889.33	1004.61	260.	55.6	-2794.34	260.
21.	36.	-1889.33	1004.61	247.62	55.6	-2794.34	247.62	-2000.54	1004.61	247.62	0.e-3	-2902.95	247.62
21.	36.	-1889.33	1004.61	260.	55.6	-2794.34	260.	-2000.54	1004.61	260.	0.e-3	-2902.95	260.
24.	1.	2016.56	1018.23	284.76	2015.4	1020.51	284.76	1904.6	1018.23	284.76	1959.41	911.17	284.76
24.	1.	2016.56	1018.23	297.14	2015.4	1020.51	297.14	1904.6	1018.23	297.14	1959.41	911.17	297.14
24.	2.	1904.6	1018.23	284.76	1959.41	911.17	284.76	1792.63	1018.23	284.76	1903.43	801.82	284.76
24.	2.	1904.6	1018.23	297.14	1959.41	911.17	297.14	1792.63	1018.23	297.14	1903.43	801.82	297.14
24.	15.	449.03	1018.23	284.76	1231.63	-510.37	284.76	337.07	1018.23	284.76	1175.65	-619.72	284.76
24.	15.	449.03	1018.23	297.14	1231.63	-510.37	297.14	337.07	1018.23	297.14	1175.65	-619.72	297.14
24.	16.	337.07	1018.23	284.76	1175.65	-619.72	284.76	225.1	1018.23	284.76	1119.66	-729.07	284.76
24.	16.	337.07	1018.23	297.14	1175.65	-619.72	297.14	225.1	1018.23	297.14	1119.66	-729.07	297.14
24.	35.	-1790.3	1018.23	284.76	111.97	-2697.36	284.76	-1902.26	1018.23	284.76	55.98	-2806.71	284.76
24.	35.	-1790.3	1018.23	297.14	111.97	-2697.36	297.14	-1902.26	1018.23	297.14	55.98	-2806.71	297.14
24.	36.	-1902.26	1018.23	284.76	55.98	-2806.71	284.76	-2014.23	1018.23	284.76	0.e-3	-2916.06	284.76
24.	36.	-1902.26	1018.23	297.14	55.98	-2806.71	297.14	-2014.23	1018.23	297.14	0.e-3	-2916.06	297.14
27.	1.	2030.25	1031.86	321.91	2029.08	1034.14	321.91	1917.52	1031.86	321.91	1972.72	924.04	321.91
27.	1.	2030.25	1031.86	334.29	2029.08	1034.14	334.29	1917.52	1031.86	334.29	1972.72	924.04	334.29
27.	2.	1917.52	1031.86	321.91	1972.72	924.04	321.91	1804.79	1031.86	321.91	1916.36	813.95	321.91
27.	2.	1917.52	1031.86	334.29	1972.72	924.04	334.29	1804.79	1031.86	334.29	1916.36	813.95	334.29
27.	15.	452.07	1031.86	321.91	1239.99	-507.15	321.91	339.34	1031.86	321.91	1183.63	-617.24	321.91
27.	15.	452.07	1031.86	334.29	1239.99	-507.15	334.29	339.34	1031.86	334.29	1183.63	-617.24	334.29
27.	16.	339.34	1031.86	321.91	1183.63	-617.24	321.91	226.62	1031.86	321.91	1127.27	-727.33	321.91
27.	16.	339.34	1031.86	334.29	1183.63	-617.24	334.29	226.62	1031.86	334.29	1127.27	-727.33	334.29
27.	35.	-1802.46	1031.86	321.91	112.73	-2708.99	321.91	-1915.19	1031.86	321.91	56.36	-2819.08	321.91
27.	35.	-1802.46	1031.86	334.29	112.73	-2708.99	334.29	-1915.19	1031.86	334.29	56.36	-2819.08	334.29
27.	36.	-1915.19	1031.86	321.91	56.36	-2819.08	321.91	-2027.92	1031.86	321.91	0.e-3	-2929.17	321.91
27.	36.	-1915.19	1031.86	334.29	56.36	-2819.08	334.29	-2027.92	1031.86	334.29	0.e-3	-2929.17	334.29

Table of layer number, strip number, positions of corners of selected strips (see Fig 14) for the W view.

L	W	y1	x1	z1	y2	x2	z2	y3	x3	z3	y4	x4	z4
30.	1.	2043.93	1045.49	359.05	2042.77	1047.76	359.05	1930.44	1045.49	359.05	1986.02	936.92	359.05
30.	1.	2043.93	1045.49	371.43	2042.77	1047.76	371.43	1930.44	1045.49	371.43	1986.02	936.92	371.43
30.	2.	1930.44	1045.49	359.05	1986.02	936.92	359.05	1816.96	1045.49	359.05	1929.28	826.09	359.05
30.	2.	1930.44	1045.49	371.43	1986.02	936.92	371.43	1816.96	1045.49	371.43	1929.28	826.09	371.43
30.	15.	455.11	1045.49	359.05	1248.36	-503.93	359.05	341.62	1045.49	359.05	1191.61	-614.76	359.05
30.	15.	455.11	1045.49	371.43	1248.36	-503.93	371.43	341.62	1045.49	371.43	1191.61	-614.76	371.43
30.	16.	341.62	1045.49	359.05	1191.61	-614.76	359.05	228.14	1045.49	359.05	1134.87	-725.59	359.05
30.	16.	341.62	1045.49	371.43	1191.61	-614.76	371.43	228.14	1045.49	371.43	1134.87	-725.59	371.43
30.	35.	-1814.63	1045.49	359.05	113.49	-2720.61	359.05	-1928.12	1045.49	359.05	56.74	-2831.45	359.05
30.	35.	-1814.63	1045.49	371.43	113.49	-2720.61	371.43	-1928.12	1045.49	371.43	56.74	-2831.45	371.43
30.	36.	-1928.12	1045.49	359.05	56.74	-2831.45	359.05	-2041.61	1045.49	359.05	0.e-3	-2942.28	359.05
30.	36.	-1928.12	1045.49	371.43	56.74	-2831.45	371.43	-2041.61	1045.49	371.43	0.e-3	-2942.28	371.43
33.	1.	2057.61	1059.11	396.19	2056.45	1061.38	396.19	1943.37	1059.11	396.19	1999.33	949.8	396.19
33.	1.	2057.61	1059.11	408.57	2056.45	1061.38	408.57	1943.37	1059.11	408.57	1999.33	949.8	408.57
33.	2.	1943.37	1059.11	396.19	1999.33	949.8	396.19	1829.12	1059.11	396.19	1942.21	838.22	396.19
33.	2.	1943.37	1059.11	408.57	1999.33	949.8	408.57	1829.12	1059.11	408.57	1942.21	838.22	408.57
33.	15.	458.15	1059.11	396.19	1256.72	-500.7	396.19	343.9	1059.11	396.19	1199.6	-612.28	396.19
33.	15.	458.15	1059.11	408.57	1256.72	-500.7	408.57	343.9	1059.11	408.57	1199.6	-612.28	408.57
33.	16.	343.9	1059.11	396.19	1199.6	-612.28	396.19	229.65	1059.11	396.19	1142.47	-723.86	396.19
33.	16.	343.9	1059.11	408.57	1199.6	-612.28	408.57	229.65	1059.11	408.57	1142.47	-723.86	408.57
33.	35.	-1826.8	1059.11	396.19	114.25	-2732.24	396.19	-1941.05	1059.11	396.19	57.12	-2843.82	396.19
33.	35.	-1826.8	1059.11	408.57	114.25	-2732.24	408.57	-1941.05	1059.11	408.57	57.12	-2843.82	408.57
33.	36.	-1941.05	1059.11	396.19	57.12	-2843.82	396.19	-2055.3	1059.11	396.19	0.e-3	-2955.39	396.19
33.	36.	-1941.05	1059.11	408.57	57.12	-2843.82	408.57	-2055.3	1059.11	408.57	0.e-3	-2955.39	408.57
36.	1.	2071.3	1072.74	433.34	2070.14	1075.	433.34	1956.29	1072.74	433.34	2012.64	962.68	433.34
36.	1.	2071.3	1072.74	445.72	2070.14	1075.	445.72	1956.29	1072.74	445.72	2012.64	962.68	445.72
36.	2.	1956.29	1072.74	433.34	2012.64	962.68	433.34	1841.28	1072.74	433.34	1955.13	850.36	433.34
36.	2.	1956.29	1072.74	445.72	2012.64	962.68	445.72	1841.28	1072.74	445.72	1955.13	850.36	445.72
36.	15.	461.19	1072.74	433.34	1265.09	-497.48	433.34	346.18	1072.74	433.34	1207.58	-609.8	433.34
36.	15.	461.19	1072.74	445.72	1265.09	-497.48	445.72	346.18	1072.74	445.72	1207.58	-609.8	445.72
36.	16.	346.18	1072.74	433.34	1207.58	-609.8	433.34	231.17	1072.74	433.34	1150.08	-722.12	433.34
36.	16.	346.18	1072.74	445.72	1207.58	-609.8	445.72	231.17	1072.74	445.72	1150.08	-722.12	445.72
36.	35.	-1838.97	1072.74	433.34	115.01	-2743.87	433.34	-1953.98	1072.74	433.34	57.5	-2856.19	433.34
36.	35.	-1838.97	1072.74	445.72	115.01	-2743.87	445.72	-1953.98	1072.74	445.72	57.5	-2856.19	445.72
36.	36.	-1953.98	1072.74	433.34	57.5	-2856.19	433.34	-2068.98	1072.74	433.34	0.e-3	-2968.51	433.34
36.	36.	-1953.98	1072.74	445.72	57.5	-2856.19	445.72	-2068.98	1072.74	445.72	0.e-3	-2968.51	445.72
39.	1.	2084.98	1086.36	470.48	2083.83	1088.62	470.48	1969.21	1086.36	470.48	2025.94	975.55	470.48
39.	1.	2084.98	1086.36	482.86	2083.83	1088.62	482.86	1969.21	1086.36	482.86	2025.94	975.55	482.86
39.	2.	1969.21	1086.36	470.48	2025.94	975.55	470.48	1853.44	1086.36	470.48	1968.06	862.49	470.48
39.	2.	1969.21	1086.36	482.86	2025.94	975.55	482.86	1853.44	1086.36	482.86	1968.06	862.49	482.86
39.	15.	464.23	1086.36	470.48	1273.45	-494.25	470.48	348.46	1086.36	470.48	1215.57	-607.32	470.48
39.	15.	464.23	1086.36	482.86	1273.45	-494.25	482.86	348.46	1086.36	482.86	1215.57	-607.32	482.86
39.	16.	348.46	1086.36	470.48	1215.57	-607.32	470.48	232.69	1086.36	470.48	1157.68	-720.38	470.48
39.	16.	348.46	1086.36	482.86	1215.57	-607.32	482.86	232.69	1086.36	482.86	1157.68	-720.38	482.86
39.	35.	-1851.14	1086.36	470.48	115.77	-2755.49	470.48	-1966.91	1086.36	470.48	57.88	-2868.56	470.48
39.	35.	-1851.14	1086.36	482.86	115.77	-2755.49	482.86	-1966.91	1086.36	482.86	57.88	-2868.56	482.86
39.	36.	-1966.91	1086.36	470.48	57.88	-2868.56	470.48	-2082.67	1086.36	470.48	0.e-3	-2981.62	470.48
39.	36.	-1966.91	1086.36	482.86	57.88	-2868.56	482.86	-2082.67	1086.36	482.86	0.e-3	-2981.62	482.86

Table of layer number, strip number, positions of corners of selected strips (see Fig 14) for the W view.

D Lead Sheet Dimensions

The lead sheets are on the average 2.387 mm thick. They are cut to cover the active triangular area as well as the extension on the light collection side of the layer defined by the length d_2. Layers 4,7,10 etc. have the vertex at the beam side clipped off. Their dimensions do not follow a simple formula. On average, the z coordinate of the front surface of each layer of lead is 100.0 mm greater than the z coordinate of the front surface of the preceding layer of scintillator. In the following table layer 2 of the lead is between scintillator 1 and 2, etc. There is no layer 1 of lead. Measurements are from [9].

Layer	*Base*	*Height*	*Truncation*	*Layer*	*Base*	*Height*	*Truncation*
2	152.096	147.264	0	21	158.527	154.821	0
3	152.454	148.890	0	22	158.975	155.258	1.00
4	152.948	149.372	1.440	23	159.246	155.523	0
5	153.174	149.636	0	24	159.605	155.873	0
6	153.532	149.943	0	25	160.054	156.311	1.00
7	154.033	150.433	1.448	26	160.324	156.575	0
8	154.252	150.007	0	27	160.683	156.926	0
9	154.610	150.996	0	28	161.130	157.363	1.00
10	155.118	151.492	1.455	29	161.400	157.628	0
11	155.328	151.379	0	30	161.760	157.979	0
12	155.688	152.048	0	31	162.208	158.415	1.00
13	156.203	152.552	1.462	32	162.478	158.681	0
14	156.406	152.750	0	33	162.838	159.032	0
15	156.766	153.101	0	34	163.286	159.468	1.00
16	156.820	153.153	1.00	35	163.556	159.733	0
17	157.090	153.417	0	36	163.916	160.084	0
18	157.449	153.768	0	37	164.364	160.521	1.00
19	157.898	152.206	1.00	38	164.634	160.786	0
20	158.168	154.470	0	39	164.994	161.137	0

E Walls of the Containment Box

The side walls of the containment box can be represented by six planes of 1.5"thick aluminum. The vertices of the planes can be represented by 12 points at the rear of the box, six for the outside and six for the insides surfaces. The labeling of these points is indicated in the figure. The coordinates of the points in the local detector frame are shown in the next table. Measurements are from [9].

P1	2079.19	2076.73	0.	P7	2259.10	2255.70	480.72
P2	-2079.19	2076.73	0.	P8	-2259.10	2255.70	480.72
P3	-2139.49	1959.89	0.	P9	-2319.43	2138.86	480.72
P4	-65.02	-2092.05	0.	P10	-65.02	-2264.50	480.72
P5	65.02	-2092.05	0.	P11	65.02	-2264.50	480.72
P6	2139.49	1959.89	0.	P12	2319.43	2138.86	480.72
P1'	2043.41	2036.06	0.	P7'	2223.31	2215.06	480.72
P2'	-2043.41	2036.09	0.	P8'	-2223.31	2215.06	480.72
P3'	-2089.43	1946.89	0.	P9'	-2269.36	2125.85	480.72
P4'	-42.34	-2051.61	0.	P10'	-42.34	-2224.05	480.72
P5'	42.34	-2051.61	0.	P11'	42.34	-2224.05	480.72
P6'	2089.43	1946.89	0.	P12'	2269.36	2125.85	480.72

The six surfaces can be characterized by the following outward pointing normal vectors:

n_1	0	$\cos(20.42)$	$-\sin(20.42)$
n_2	0.87848	-0.44975	-0.161259
n_3	-0.87848	-0.44975	-0.161259
n_4	0.79367	0.40978	-0.44693
n_5	-0.79367	0.40978	-0.44693
n_6	0	-0.94217	-0.33765

F Perl script for generating EC geometry using scintillator slabs

```
#!/usr/bin/perl -w
#
# Perl sctipt used to generate a file (EC.txt) that is an input to
# the shell script go_table which. puts the EC geometry in the mysql
# database for gemc to use. Modified from original by C.Musalo 7/16/10
# load libraries
```

```
#use strict;
use lib ("$ENV{GEMC}/database_io");
use geo;
use geo qw($pi);
use Getopt::Long;
use Math::Trig;

# local quantities.

my $envelope = 'EC';
my $file     = 'EC.txt';
my $rmin = 1;
my $rmax = 1000000;
#
# parameters first. These are described in CLAS-Note 2010-?? by Gilfoyle et al.
#
# Face of the EC is tilted 25 degrees, the large angle side is rotated towards detector,
# and the small angle vertex is rotated away from detector.
#
#  large angle side(top) -->  /\
#                            \ \
#     Side view               \ \
#                              \ \
#                               \ \
#                                \_\   <-- small angle vertex(bottom)
#  target  |
#
# We are using the Hall B coordinate system with the origin at the target center.

$thetaEC_deg = 25.0;                  # angle of EC face to a line perpendicular to the beamline.
$thetaEC = $thetaEC_deg*$pi/180;      # angle of EC face to a line perpendicular to the beamline in radians.
$theta0 = 62.889041*$pi/180;             # angle between sides of EC at large scattering angle (angles opposite the beamside vertex) in radians.
$a1 = 0.08555;                         # see CLAS-Note 2010-
$a2 = 1864.65;
#$a3 = 4.627;   # corrected 10/3/10
$a3 = 4.45635;
#$a4 = 4.3708;                        # Used to get the position of the u strips.
#$a5 = 103.66;                        # Used to get the width of the u strips.
#$a6 = 0.2476;                        # Used to get the width of the u strips.
#$a7 = 94.701;                        # Used to get the width of the v strips.
#$a8 = 0.2256;                        # Used to get the width of the v and w strip;
#$a9 = 94.926;                        # Used to get the width of the w strips.

$dlead = 2.381;                       # thickness of lead layers in mm.
$dscint= 10.0;                        # thickness of scintillator layers in mm.
$nlayers = 39;                        # number of scintillator layers, there are 38 lead layers (no lead layer 1).
$L1 = 7217.23;                        # length of line perpendicular to EC face that passes through the CLAS12 target.
$ypo = 950.88;                        # distance from perpendicular point to the geometric center of the front face of the first scintillator.
$MUoffset = 5000.0;                  # the CLAS12 target is at +5m (or -2 m??) in the gemc coordinates.

#derived quantities.

$tantheta = tan($theta0);             # tangent of angle between sides of EC at large scattering angle (angles opposite the beamside vertex).
$gamma1 = $pi - 2*$theta0;                              # angle between sides of EC at small scattering angle.
$totaldepth = ($nlayers-1)*($dscint+$dlead) + $dscint; # total thickness of lead and scintillator. There are 39 scintillator layers and 38 lead layers.

my %detector = ();    # hash (map) that defines the gemc detector
$detector{"rmin"} = $rmin;
$detector{"rmax"} = $rmax;

# Mother Volume - description of parameters for Geant4 G4Trap volume.
#
# pDx1    Half x length of the side at y=-pDy1 of the face at -pDz
# pDx2    Half x length of the side at y=+pDy1 of the face at -pDz
# pDz    Half z length
# pTheta  Polar angle of the line joining the centres of the faces at -/+pDz
# pPhimom Azimuthal angle of the line joining the centre of the face at -pDz to the centre of the face at +pDz
# pDy1    Half y length at -pDz
# pDy2    Half y length at +pDz
# pDx3    Half x length of the side at y=-pDy2 of the face at +pDz
# pDx4    Half x length of the side at y=+pDy2 of the face at +pDz
# pAlp1   Angle with respect to the y axis from the centre of the side (lower endcap)
# pAlp2   Angle with respect to the y axis from the centre of the side (upper endcap)
#
# Note on pAlph1/2: the two angles have to be the same due to the planarity condition.
#
# all numbers are in mm or deg as specified in the $detector{"dimensions"} statement.

my $pDzmom    = $totaldepth/2.0;                          # half z length
my $pDy1mom   = &sycenter($nlayers) + &spDy($nlayers);  # maximum half y length at -pDz.
my $pDy2mom   = $pDy1mom;                                 # half y length at +pDz.
my $pDx1mom   = 0.001;            # should be zero, but that makes gemc crash.
my $pDx2mom   = &spDx2($nlayers); # Half x length of the side at y=+pDy1 of the face at -pDz.
my $pThetamom = 0;                # Polar angle of the line joining the centres of the faces at +/-pDz
my $pPhimom   = $pThetamom;       # Azimuthal angle from the centre of the face at -pDz to the centre of the face at +pDz.
my $pDx3mom   = $pDx1mom;         # half x length of the side at y=-pDy2 of the face at +pDz
my $pDx4mom   = $pDx2mom;         # Half x length of the side at y=+pDy2 of the face at +pDz
my $pAlp1mom  = $pThetamom;       # angle with respect to y axis from centre of side(lower endcap)
my $pAlp2mom  = $pThetamom;       # angle with respect to y axis from centre of side(uppder endcap)

# Geant4 builds mother volume in one sector, than rotates the contents in the
# 1st sector to form 6 total sectors. Sector orientations shown below looking
```

```
# in the direction of the beam.
#
#             TOP                     ^  y
#              .                      |
#           .  .  .                   |
#        .     .     .          x <----
#     .        .        .
# .       2    .    3       .
# .   .        .        .   .
# .      .     .     .      .
# .         .  .  .         .
# .   1        .       4    .  z/beam - into page
# .         .  .  .         .
# .      .     .     .      .
# .   .        .        .   .
# .       6    .    5       .
#     .        .        .
#        .     .     .
#           .  .  .
#              .

# We place the origin at the geometric center of each layer. The z axis runs along the beam line,
# the y axis points vertically straight up from beam line and the x axis points left looking out along
# the beam line. Calculate the position of the center of first scintillator face as the origin.
#
#     1. Get the vector from the target center to the front face of the first scintillator and perpendicular to the face.
my@L1vec = ( 0, $L1*sin($thetaEC), $L1*cos($thetaEC));
#     2. Vector that takes you from perpendicular point at L1vec to geometric center of Clas12 EC layer 1.
my@Svec = ( 0,-$ypo*cos($thetaEC), $ypo*sin($thetaEC));
#     3. Now add L1vec+Svec.
my@CLAS12front = ($L1vec[0]+ $Svec[0], $L1vec[1]+ $Svec[1], $L1vec[2]+ $Svec[2]);
#     4. Get vector from center of front face to the midpoint in the z direction
my@toCenter = (0, $totaldepth*sin($thetaEC),$totaldepth*cos($thetaEC));
#     5. Get final vector from target to center of the mother volume with origin at the center of the front face.
#        MUoffset is needed since the target is at z = 5000 mm and not at the origin.
my@CLAS12center = ($CLAS12front[0]+$toCenter[0],$CLAS12front[1]+$toCenter[1],$CLAS12front[2]+$toCenter[2]-$MUoffset);

# array used to calculate pdX values for Geant4. Some lead layers are truncated at the small angle vertex.
@beamVertexCut=(0.00001, 0.0000001, 1.440, 0.0000001, 0.000001, 1.448, 0.000001, 0.000001, 1.455, 0.001,
    0.000001, 1.462, 0.000001, 0.000001, 1.0, 0.000001, 0.00001, 1.0, 0.000001, 0.000001, 1.0, 0.000001, 0.000001,
    1.0, 0.000001, 0.000001, 1.0, 0.001, 0.000001, 1.0, 0.000001, 0.000001, 1.0, 0.000001, 0.000001, 1.0, 0.000001, 0.000001);

# generate red mother volume wireframe box, and write to a file.
$detector{"name"}        = "EC";
$detector{"mother"}      = "sector";
$detector{"description"} = "Forward Calorimeter";
$detector{"pos"}         = "${CLAS12center[0]}*mm ${CLAS12center[1]}*mm ${CLAS12center[2]}*mm";
$detector{"rotation"}    = "$thetaEC_deg*deg 0*deg";# pure rotation about the geometric center of EC mother volume.
$detector{"color"}       = "ff1111";
$detector{"type"}        = "G4Trap";
$detector{"dimensions"}  = "${pDzmom}*mm ${pThetamom}*deg ${pPhimom}*deg ${pDy1mom}*mm ${pDx1mom}*mm ${pDx2mom}*mm ${pAlp1mom}*deg
                            ${pDy2mom}*mm ${pDx3mom}*mm ${pDx4mom}*mm ${pAlp2mom}*deg";
$detector{"material"}    = "Air";
$detector{"mfield"}      = "no";
$detector{"ncopy"}       = 1;
$detector{"pMany"}       = 1;
$detector{"exist"}       = 1;
$detector{"visible"}     = 1;
$detector{"style"}       = 0;
$detector{"sensitivity"} = "no";
$detector{"hit_type"}    = "";
$detector{"identifiers"} = "";

#print "\nStreamlined Results: \n\n";
#print "pDzmom=",$pDzmom," pThetamom=",$pThetamom," pPhimom=",$pPhimom," pDy1mom=",$pDy1mom," pDy2mom=",$pDy2mom,"\n";
#print "pDx1mom=",$pDx1mom," pDx2mom=",$pDx2mom," pDx3mom=",$pDx3mom," pDx4mom=",$pDx4mom," pAlp1mom=",$pAlp1mom," pAlp2mom=",$pAlp2mom,"\n\n";

print_det(\%detector, $file);

# now start to do the alternating layers of scintillator and lead. Set up inputs first.

# All volumes produced are now placed in mother volume's coordinate sytem.
#  The Mother volume coordinate system has it's y axis running from the mother
#  volumes small angle vertex straight up to form a perpendicular angle at the
#  midpoint of the large angle side.
#
#
#                large angle side(top).
#         ...........................
#         \            |            /
#          .           |           .
#          \           |           /
#           .          |          .
#           \          |y_axis    /
#            .         |         .
#            \         |         /
#             .        |        .
#             \        |        /
#        _____________ o________x_axis____
#               \      |       /
#                .     |      .
#                \     |      /
#                 .    |     .
```

```
#                \     |     /
#                 .    |    .
#                 \    |    /
#                  .   |    .
#                  \   |   /
#                    .  |   .
#                   \  |  /
#                    . |  .
#                    \ | /
#                    . | .
#                     \|/
#                      .
#             small angle vertex(bottom)
#
my $subname;
my $submother = "EC";;
my $description;
my $pos;
my $rotation = "0*deg 0*deg 0*deg";
my $color = "0147FA";
my $type = "G4Trap";
my $dimensions;
my $material ="Air";
my $mfield = "no";
my $ncopy = 1;
my $pMany = 1;
my $exist = 1;
my $visible = 1;
my $style = 1;
my $sensitivity = "no";
my $hit_type = "";
my $identifiers = "";

# a scintillator layer first. set the G4Trap parameters.
#
my $pDx1   = 0.001;  # should be zero, but that makes gemc crash.
my $pDx2   = &spDx2(1);
my $pDz    = $dscint/2.0;  #<-------------------------------------
my $pTheta = 0;
my $pPhi   = $pTheta;
my $pDy1   = &spDy(1);
my $pDy2   = $pDy1;
my $pDx3   = $pDx1;
my $pDx4   = $pDx2;
my $pAlp1  = $pTheta;
my $pAlp2  = $pTheta;

my $i = 1;
my $view   = &ECview($i);
my $stack  = &ECstack($i);

# fill the Geant4 description of the volume and write the results into the file.

my $xscint = &sxcenter($i);
my $yscint = &sycenter($i);
my $zscint = &szcenter($i);

$subname = "EClayerScint${i}";
$description ="Forward Calorimeter scintillator layer ${i}";
$pos = "$xscint*mm $yscint*mm $zscint*mm";
$detector{"name"}        = $subname;
$detector{"mother"}      = "EC";
$detector{"description"} = $description;
$detector{"pos"}         = $pos;
$detector{"rotation"}    = $rotation;
$detector{"color"}       = "0147FA";
$detector{"type"}        = "G4Trap";
$detector{"dimensions"}  = "${pDz}*mm ${pTheta}*deg ${pPhi}*deg ${pDy1}*mm ${pDx1}*mm ${pDx2}*mm ${pAlp1}*deg ${pDy2}*mm
                             ${pDx3}*mm  ${pDx4}*mm  ${pAlp2}*deg";
$detector{"material"}    = "Scintillator";
$detector{"mfield"}      = "no";
$detector{"ncopy"}       = 1;
$detector{"pMany"}       = 1;
$detector{"exist"}       = 1;
$detector{"visible"}     = 1;
$detector{"style"}       = 1;
$detector{"sensitivity"} = "EC";
$detector{"hit_type"}    = "EC";
$detector{"identifiers"} = "sector ncopy 0 stack manual $stack view manual $view strip manual 36";

#print "\nStreamlined Results for scint 1: \n\n";
#print "pDz=",$pDz," pTheta=",$pTheta," pPhi=",$pPhi," pDy1=",$pDy1," pDy2=",$pDy2,"\n";
#print "pDx1=",$pDx1," pDx2=",$pDx2," pDx3=",$pDx3," pDx4=",$pDx4," pAlp1=",$pAlp1," pAlp2=",$pAlp2,"\n\n";


print_det(\%detector, $file);

#for loop loops over layers and generates Geant4 parameters for each scint and lead layer.

for ($i = 2; $i <= $nlayers; $i++) {

# lead layer
```

```
    my $xlead = &sxcenterPb(${i});
    my $ylead = &sycenterPb(${i});
    my $zlead = &szcenterPb(${i});

    $subname = "EClayerLead${i}";
    $description = "Forward Calorimeter lead layer ${i}";
    $pos = "${xlead}*mm ${ylead}*mm ${zlead}*mm";         #position of center of trapezoid.
    $pDz = $dlead/2.0;
    $pDy1 = &spDy($i) - $beamVertexCut[$i-2];
    $pDy2 = $pDy1;
    $pDx1 = $beamVertexCut[$i-2]*tan($gamma1/2);
    $pDx3 = $pDx1;
    $pDx2 = &spDx2($i);
    $pDx4 = $pDx2;
    $pTheta = 0;
    $pPhi   = $pTheta;
    $pAlp1  = $pTheta;
    $pAlp2  = $pTheta;
    $detector{"name"}        = $subname;
    $detector{"mother"}      = $submother;
    $detector{"description"} = $description;
    $detector{"pos"}         = $pos;
    $detector{"rotation"}    = $rotation;
    $detector{"color"}       = "7CFC00";
    $detector{"type"}        = "G4Trap";
    $detector{"dimensions"}  = "${pDz}*mm ${pTheta}*deg ${pPhi}*deg  ${pDy1}*mm ${pDx1}*mm  ${pDx2}*mm  ${pAlp1}*deg
                               ${pDy2}*mm ${pDx3}*mm  ${pDx4}*mm  ${pAlp2}*deg";
    $detector{"material"}    = "Lead";
    $detector{"mfield"}      = "no";
    $detector{"ncopy"}       = 1;
    $detector{"pMany"}       = 1;
    $detector{"exist"}       = 1;
    $detector{"visible"}     = 1;
    $detector{"style"}       = 1;
    $detector{"sensitivity"} = "no";
    $detector{"hit_type"}    = "";
    $detector{"identifiers"} = "";
#write values to a file.
    print_det(\%detector, $file);

# scintillator layer

    $xscint = &sxcenter($i);
    $yscint = &sycenter($i);
    $zscint = &szcenter($i);

    $subname = "EClayerScint${i}";
    $description ="Forward Calorimeter scintillator layer ${i}";
    $pos = "${xscint}*mm ${yscint}*mm ${zscint}*mm";
    $pDz = $dscint/2.0;
    $pDy1 = &spDy($i);
    $pDy2 = $pDy1;
    $pDx1 = 0.001;
    $pDx3 = $pDx1;
    $pDx2 = &spDx2($i);
    $pDx4 = $pDx2;
    $pTheta = 0;
    $pPhi   = $pTheta;
    $pAlp1  = $pTheta;
    $pAlp2  = $pTheta;
    $detector{"name"}        = $subname;
    $detector{"mother"}      = $submother;
    $detector{"description"} = $description;
    $detector{"pos"}         = $pos;
    $detector{"rotation"}    = $rotation;
    $detector{"color"}       = "0147FA";
    $detector{"type"}        = "G4Trap";
    $detector{"dimensions"}  = "${pDz}*mm ${pTheta}*deg ${pPhi}*deg  ${pDy1}*mm ${pDx1}*mm  ${pDx2}*mm  ${pAlp1}*deg  ${pDy2}*mm
                               ${pDx3}*mm  ${pDx4}*mm  ${pAlp2}*deg";
    $detector{"material"}    = "Scintillator";
    $detector{"mfield"}      = "no";
    $detector{"ncopy"}       = 1;
    $detector{"pMany"}       = 1;
    $detector{"exist"}       = 1;
    $detector{"visible"}     = 1;
    $detector{"style"}       = 1;
    $detector{"sensitivity"} = "EC";
    $detector{"hit_type"}    = "EC";

    $view = &ECview($i);
    $stack= &ECstack($i);
    $detector{"identifiers"} = "sector ncopy 0 stack manual $stack view manual $view strip manual 36";

    if ($i == 1) {
       print "\nStreamlined Results for scint ",$i,": \n\n";
       print "pDz=",$pDz," pTheta=",$pTheta," pPhi=",$pPhi," pDy1=",$pDy1," pDy2=",$pDy2,"\n";
       print "pDx1=",$pDx1," pDx2=",$pDx2," pDx3=",$pDx3," pDx4=",$pDx4," pAlp1=",$pAlp1," pAlp2=",$pAlp2,"\n";
       print "xscint=",$xscint," yscint=",$yscint,"  zscint=",$zscint,"\n\n";
    }

    print_det(\%detector, $file);

   }
```

```
#
#subroutines ************************************************************************
#
# scintillator positions:
# gives the x position of each scintillator layers geometric center inside the mother volume.
sub sxcenter($){
    my $xcent = 0;
    return $xcent;
}
#gives the y position of each scintillator layers geometric center inside the mother volume.
sub sycenter($){
    my $ycent = $a1*($_[0] - 1);
    return $ycent;
}
#gives the z position of each scintillator layers geometric center inside the mother volume.
sub szcenter($){
    my $layer = $_[0];
    my $zcent = -$totaldepth/2 + ($layer - 1)*($dscint + $dlead) + $dscint/2;
    return $zcent;
}

# lead positions.
#gives the x position of each lead layers geometric center inside the mother volume.
sub sxcenterPb($){
    my $xcentPb = 0;
    return $xcentPb;
}
#gives the y position of each lead layers geometric center inside the mother volume.
sub sycenterPb($){
    my $ycentPb = &sycenter($_[0]) + $beamVertexCut[$_[0]-2]/2;
    return $ycentPb;
}
#gives the z position of each lead layers geometric center inside the mother volume.
sub szcenterPb($){
    my $zcentPb = -$totaldepth/2 + ($_[0] - 2)*($dscint + $dlead) + $dscint/2 + ($dscint+$dlead)/2;
    return $zcentPb;
}

# half-widths of lead and scintillator layers.
#
# gives half y distance of trapezoidal EC layer $i,
sub spDy($){
    my $ywidth = $a2 + $a3*($_[0] - 1);
    return $ywidth;
}
# gives half x distance of trapezoidal EC layer $i;
sub spDx2($){
    my $xwidth = (2*&spDy($_[0]))/($tantheta);
    return $xwidth;
}



sub ECview($) {
    # using the layer to generate a number (1,2,3) for the different views (U, V,W).

    my $layer = $_[0];
    my $mod = $layer%3;

    my $view = 4;
    if ($mod == 1) {$view = 1;}
    if ($mod == 2) {$view = 2;}
    if ($mod == 0) {$view = 3;}

    if ($view == 4) {print "**** WARNING: No View assignment made. ****\n";}

    return $view;

}

sub ECstack($) {
    # using the layer to generate a number (1,2,3) for the inner and outer stacks in the EC.

    my $layer = $_[0];

    my $stack = 3;
    if ($i <= 15) {$stack = 1;}
    if ($i >  15) {$stack = 2;}
    if ($stack == 3) {print "**** WARNING: No Stack assignment made. ****\n";}

    return $stack;

}
```

G Perl script for generating EC geometry using scintillator strips

```
#!/usr/bin/perl -w
# BAD!
# Perl script used to generate a file (ECwithG4strips.txt) that is an input to
# the shell script go_table which puts the ECwithG4strips geometry in the mysql
# database for gemc to use. G.P.Gilfoyle 8/16/12
# load libraries

use strict;

use lib ("$ENV{GEMC}/database_io");
use geo;
use Getopt::Long;
use Math::Trig;


my $config_file = 'ec.config';

# Load configuration
my %configuration = load_configuration($config_file);

# Load parameters from mysql database
my %parameters    = download_parameters(%configuration);

# Assign paramters to local variables
my $thetaEC_deg = $parameters{"thetaEC_deg"};


# local quantities.

my $envelope = 'ECwithG4strips';
my $file     = 'ECwithG4strips.txt';
my $rmin = 1;
my $rmax = 1000000;
#
# parameters first. These are described in CLAS-Note 2010-?? by Gilfoyle et al.
#
# Face of the EC is tilted 25 degrees, the large angle side is rotated towards detector,
# and the small angle vertex is rotated away from detector.
#
#  large angle side(top) -->  /\
#                             \ \
#      Side view               \ \
#                               \ \
#                                \ \
#                                 \_\   <-- small angle vertex(bottom)
#  target  |
#
# We are using the Hall B coordinate system with the origin at the target center.

my $thetaEC = $thetaEC_deg*$pi/180;      # angle of EC face to a line perpendicular to the beamline in radians.
my $theta0 = 62.889041*$pi/180;           # angle between sides of EC at large scattering angle (angles opposite the beamside vertex) in radians.
my $a1 = 0.08555;                         # see CLAS-Note 2011-019
my $a2 = 1864.65;
#my $a3 = 4.627;   # corrected 10/3/10
my $a3 = 4.45635;
my $a4 = 4.3708;                        # Used to get the position of the u strips.
my $a5 = 103.66;                        # Used to get the width of the u strips.
my $a6 = 0.2476;                        # Used to get the width of the u strips.
my $a7 = 94.701;                        # Used to get the width of the v strips.
my $a8 = 0.2256;                        # Used to get the width of the v and w strip;
my $a9 = 94.926;                        # Used to get the width of the w strips.

my $dlead = 2.381;                       # thickness of lead layers in mm.
my $dscint= 10.0;                        # thickness of scintillator layers in mm.
my $nlayers = 39;                        # number of scintillator layers, there are 38 lead layers (no lead layer 1).
my $nstrips = 36;                        # number of scintillator strips in a layer.
my $L1 = 7217.23;                        # length of line perpendicular to EC face that passes through the CLAS12 target.
my $ypo = 950.88;                        # distance from perpendicular point to the geometric center of the front face of the first scintillator.
#my $MUoffset = 5265.0;                  # the CLAS12 target is at +5m (or -2 m??) in the gemc coordinates.
my $MUoffset = 5000.0;

# Lid of EC box

my $d_steel1 = 1.75;
my $d_steel2 = 1.75;
my $d_foam   = 76.2;
my $d_lid    = $d_steel1 + $d_foam + $d_steel2;

#derived quantities.

my $tantheta = tan($theta0);           # tangent of angle between sides of EC at large scattering angle (angles opposite the beamside vertex).
my $sqrttantheta = sqrt(1+($tantheta**2));    # term used several times in later subroutines.
my $gamma1 = $pi - 2*$theta0;                               # angle between sides of EC at small scattering angle.
my $totaldepth = ($nlayers-1)*($dscint+$dlead) + $dscint; # total thickness of lead and scintillator. There are 39 scintillator layers and 38 lead layers.
my $totalvol = $totaldepth+2*$d_lid;
my $offset = &Angleoffset();       # angle between the midpoint on the edge of a strip and the absolute middle of the strip.
```

```
my %detector = ();    # hash (map) that defines the gemc detector
$detector{"rmin"} = $rmin;
$detector{"rmax"} = $rmax;

# Mother Volume - description of parameters for Geant4 G4Trap volume.
#
# pDx1    Half x length of the side at y=-pDy1 of the face at -pDz
# pDx2    Half x length of the side at y=+pDy1 of the face at -pDz
# pDz    Half z length
# pTheta  Polar angle of the line joining the centres of the faces at -/+pDz
# pPhimom Azimuthal angle of the line joining the centre of the face at -pDz to the centre of the face at +pDz
# pDy1    Half y length at -pDz
# pDy2    Half y length at +pDz
# pDx3    Half x length of the side at y=-pDy2 of the face at +pDz
# pDx4    Half x length of the side at y=+pDy2 of the face at +pDz
# pAlp1   Angle with respect to the y axis from the centre of the side (lower endcap)
# pAlp2   Angle with respect to the y axis from the centre of the side (upper endcap)
#
# Note on pAlph1/2: the two angles have to be the same due to the planarity condition.
#
# all numbers are in mm or deg as specified in the $detector{"dimensions"} statement.

my $pDzmom    = $totalvol/2.0;                        # half z length
my $pDy1mom   = &sycenter($nlayers) + &spDy($nlayers);  # maximum half y length at -pDz.
my $pDy2mom   = $pDy1mom;                              # half y length at +pDz.
my $pDx1mom   = 0.001;            # should be zero, but that makes gemc crash.
my $pDx2mom   = &spDx2($nlayers); # Half x length of the side at y=+pDy1 of the face at -pDz.
my $pThetamom = 0;                # Polar angle of the line joining the centres of the faces at +/-pDz
my $pPhimom   = $pThetamom;       # Azimuthal angle from the centre of the face at -pDz to the centre of the face at +pDz.
my $pDx3mom   = $pDx1mom;         # half x length of the side at y=-pDy2 of the face at +pDz
my $pDx4mom   = $pDx2mom;         # Half x length of the side at y=+pDy2 of the face at +pDz
my $pAlp1mom  = $pThetamom;       # angle with respect to y axis from centre of side(lower endcap)
my $pAlp2mom  = $pThetamom;       # angle with respect to y axis from centre of side(uppder endcap)

# Geant4 builds mother volume in one sector, than rotates the contents in the
# 1st sector to form 6 total sectors. Sector orientations shown below looking
# in the direction of the beam.
#
#             TOP                     ^  y
#              .                      |
#           .  .  .                   |
#        .     .     .          x <----
#     .        .        .
# .       2    .    3       .
# .   .        .        .   .
# .      .     .     .      .
# .         .  .  .         .
# .   1        .       4    .  z/beam - into page
# .         .  .  .         .
# .      .     .     .      .
# .   .        .        .   .
# .       6    .    5       .
#     .        .        .
#        .     .     .
#           .  .  .
#              .

# We place the origin at the geometric center of each layer. The z axis runs along the beam line,
# the y axis points vertically straight up from beam line and the x axis points left looking out along
# the beam line. Calculate the position of the center of first scintillator face as the origin.
#
#     1. Get the vector from the target center to the front face of the first scintillator and perpendicular to the face.
my@L1vec = ( 0, $L1*sin($thetaEC), $L1*cos($thetaEC));
#     2. Vector that takes you from perpendicular point at L1vec to geometric center of Clas12 EC layer 1.
my@Svec = ( 0,-$ypo*cos($thetaEC), $ypo*sin($thetaEC));
#     3. Now add L1vec+Svec.
my@CLAS12front = ($L1vec[0]+ $Svec[0], $L1vec[1]+ $Svec[1], $L1vec[2]+ $Svec[2]);
#     4. Get vector from center of front face to the midpoint in the z direction
my@toCenter = (0, 0.5*$pDzmom*sin($thetaEC), 0.5*$pDzmom*cos($thetaEC));
#     5. Get final vector from target to center of the mother volume with origin at the center of the front face.
#        MUoffset is needed since the target is at z = 5000 mm and not at the origin.
my@CLAS12center = ($CLAS12front[0]+$toCenter[0],$CLAS12front[1]+$toCenter[1],$CLAS12front[2]+$toCenter[2]-$MUoffset);

# array used to calculate pdX values for Geant4. Some lead layers are truncated at the small angle vertex.
my @beamVertexCut=(0.00001, 0.0000001, 1.440, 0.0000001, 0.000001, 1.448, 0.000001, 0.000001, 1.455, 0.001,
    0.000001, 1.462, 0.000001, 0.000001, 1.0, 0.000001, 0.00001, 1.0, 0.000001, 0.000001, 1.0, 0.000001, 0.000001,
    1.0, 0.000001, 0.000001, 1.0, 0.001, 0.000001, 1.0, 0.000001, 0.000001, 1.0, 0.000001, 0.000001, 1.0, 0.000001, 0.000001);

# generate red mother volume wireframe box, and write to a file.
$detector{"name"}         = "EC";
$detector{"mother"}       = "sector";
$detector{"description"}  = "Forward Calorimeter";
$detector{"pos"}          = "${CLAS12center[0]}*mm ${CLAS12center[1]}*mm ${CLAS12center[2]}*mm";
$detector{"rotation"}     = "$thetaEC_deg*deg 0*deg";# pure rotation about the geometric center of EC mother volume.
$detector{"color"}        = "ff1111";
$detector{"type"}         = "G4Trap";
$detector{"dimensions"}   = "${pDzmom}*mm ${pThetamom}*deg ${pPhimom}*deg ${pDy1mom}*mm ${pDx1mom}*mm ${pDx2mom}*mm ${pAlp1mom}*deg ${pDy2mom}*mm ${pDx3mom}*mm ${pDx4mom}
$detector{"material"}     = "Air";
$detector{"mfield"}       = "no";
$detector{"ncopy"}        = 1;
$detector{"pMany"}        = 1;
$detector{"exist"}        = 1;
```

```
$detector{"visible"}      = 0;
$detector{"style"}        = 0;
$detector{"sensitivity"}  = "no";
$detector{"hit_type"}     = "";
$detector{"identifiers"}  = "";


#print "\nStreamlined Results: \n\n";
#print "pDzmom=",$pDzmom," pThetamom=",$pThetamom," pPhimom=",$pPhimom," pDy1mom=",$pDy1mom," pDy2mom=",$pDy2mom,"\n";
#print "pDx1mom=",$pDx1mom," pDx2mom=",$pDx2mom," pDx3mom=",$pDx3mom," pDx4mom=",$pDx4mom," pAlp1mom=",$pAlp1mom," pAlp2mom=",$pAlp2mom,"\n\n";

print_det(\%detector, $file);

# now start to do the alternating layers of scintillator and lead. Set up inputs first.

# All volumes produced are now placed in mother volume's coordinate sytem.
#  The Mother volume coordinate system has it's y axis running from the mother
#  volumes small angle vertex straight up to form a perpendicular angle at the
#  midpoint of the large angle side.
#
#
#                large angle side(top).
#          ...........................
#         \            |            /
#          .           |           .
#          \           |           /
#           .          |          .
#           \          |y_axis    /
#            .         |         .
#            \         |         /
#             .        |        .
#             \        |        /
#        _____________ o________x_axis____
#              \       |       /
#               .      |      .
#               \      |      /
#                .     |     .
#                \     |     /
#                 .    |    .
#                 \    |    /
#                  .   |   .
#                  \   |   /
#                   .  |   .
#                   \  |  /
#                    . |  .
#                    \ | /
#                    . | .
#                     \|/
#                      .
#              small angle vertex(bottom)
#
my $subname;
my $submother = "EC";
my $description;
my $pos;
my $rotation = "0*deg 0*deg 0*deg";
my $color = "0147FA";
my $type = "G4Trap";
my $dimensions;
my $material ="Air";
my $mfield = "no";
my $ncopy = 1;
my $pMany = 1;
my $exist = 1;
my $visible = 1;
my $style = 1;
my $sensitivity = "no";
my $hit_type = "";
my $identifiers = "";

# now put in the G4Trap parameters for the components of the EC box. set the G4Trap parameters.
#
my $pDx1   = 0.001;  # should be zero, but that makes gemc crash.
my $pDx2   = &spDx2(1);
my $pDz    = $dscint/2.0;  #<------------------------------------
my $pTheta = 0;
my $pPhi   = $pTheta;
my $pDy1   = &spDy(1);
my $pDy2   = $pDy1;
my $pDx3   = $pDx1;
my $pDx4   = $pDx2;
my $pAlp1  = $pTheta;
my $pAlp2  = $pTheta;

my $i = 1;
my $j = 1;
my $view   = &ECview($i);
my $stack  = &ECstack($i);

# fill the Geant4 description of the volume and write the results into the file.

my $xscint = &sxcenter($i);
my $yscint = &sycenter($i);
```

```
my $zscint = &szcenter($i);

my $pDzlid = $d_steel1/2;
my $x_lid = $xscint;
my $y_lid = $yscint;
my $z_lid = $zscint-$pDz-$d_steel2-$d_foam-$d_steel1/2;

#Generate first stainless cover using first scintillator dimensions
$detector{"name"}        = "ECLID1";
$detector{"mother"}      = "EC";
$detector{"description"} = "Stainless Steel Skin 1";
$detector{"pos"}         = "${x_lid}*mm ${y_lid}*mm ${z_lid}*mm";
$detector{"rotation"}    = $rotation;
$detector{"color"}       = "FCFFF0";
$detector{"type"}        = "G4Trap";
$detector{"dimensions"}  = "${pDzlid}*mm ${pTheta}*deg ${pPhi}*deg ${pDy1}*mm ${pDx1}*mm ${pDx2}*mm ${pAlp1}*deg ${pDy2}*mm ${pDx3}*mm  ${pDx4}*mm  ${pAlp2}*deg";
$detector{"material"}    = "StainlessSteel";
$detector{"mfield"}      = "no";
$detector{"ncopy"}       = 1;
$detector{"pMany"}       = 1;
$detector{"exist"}       = 1;
$detector{"visible"}     = 1;
$detector{"style"}       = 1;
$detector{"sensitivity"} = "no";
$detector{"hit_type"}    = "";
$detector{"identifiers"} = "";

print_det(\%detector, $file);

$pDzlid = $d_foam/2;
$z_lid = $zscint-$pDz-$d_steel2-$d_foam/2;
#Generate Last-a-Foam layer using first scintillator dimensions
$detector{"name"}        = "ECLID2";
$detector{"mother"}      = "EC";
$detector{"description"} = "Last-a-Foam";
$detector{"pos"}         = "${x_lid}*mm ${y_lid}*mm ${z_lid}*mm";
$detector{"rotation"}    = $rotation;
$detector{"color"}       = "EED18C";
$detector{"type"}        = "G4Trap";
$detector{"dimensions"}  = "${pDzlid}*mm ${pTheta}*deg ${pPhi}*deg ${pDy1}*mm ${pDx1}*mm ${pDx2}*mm ${pAlp1}*deg ${pDy2}*mm ${pDx3}*mm  ${pDx4}*mm  ${pAlp2}*deg";
$detector{"material"}    = "LastaFoam";
$detector{"mfield"}      = "no";
$detector{"ncopy"}       = 1;
$detector{"pMany"}       = 1;
$detector{"exist"}       = 1;
$detector{"visible"}     = 1;
$detector{"style"}       = 1;
$detector{"sensitivity"} = "no";
$detector{"hit_type"}    = "";
$detector{"identifiers"} = "";

print_det(\%detector, $file);

$pDzlid = $d_steel2/2;
$z_lid =  $zscint-$pDz-$d_steel2/2;
#Second stainless steel cover using first scintillator dimensions
$detector{"name"}        = "ECLID3";
$detector{"mother"}      = "EC";
$detector{"description"} = "Stainless Steel Skin 2";
$detector{"pos"}         = "${x_lid}*mm ${y_lid}*mm ${z_lid}*mm";
$detector{"rotation"}    = $rotation;
$detector{"color"}       = "FCFFF0";
$detector{"type"}        = "G4Trap";
$detector{"dimensions"}  = "${pDzlid}*mm ${pTheta}*deg ${pPhi}*deg ${pDy1}*mm ${pDx1}*mm ${pDx2}*mm ${pAlp1}*deg ${pDy2}*mm ${pDx3}*mm  ${pDx4}*mm  ${pAlp2}*deg";
$detector{"material"}    = "StainlessSteel";
$detector{"mfield"}      = "no";
$detector{"ncopy"}       = 1;
$detector{"pMany"}       = 1;
$detector{"exist"}       = 1;
$detector{"visible"}     = 1;
$detector{"style"}       = 1;
$detector{"sensitivity"} = "no";
$detector{"hit_type"}    = "";
$detector{"identifiers"} = "";

print_det(\%detector, $file);

#now for loop is over layers and generates Geant4 parameters for each scint and lead layer.

for ($i = 1; $i <= $nlayers; $i++) {

# lead layer
    if( $i >= 2){   # skip the 'first' lead layer since there is one more scint layer than lead.  Compare this with EC!!
    my $xlead = &sxcenterPb($i);
    my $ylead = &sycenterPb($i);
    my $zlead = &szcenterPb($i);

    $subname = "EClayerLead${i}";
    $description = "Forward Calorimeter lead layer ${i}";
    $pos = "${xlead}*mm ${ylead}*mm ${zlead}*mm";         #position of center of trapezoid.
    $pDz = $dlead/2.0;
    $pDy1 = &spDy($i) - $beamVertexCut[$i-2];
    $pDy2 = $pDy1;
```

```
    $pDx1 = $beamVertexCut[$i-2]*tan($gamma1/2);
    $pDx3 = $pDx1;
    $pDx2 = &spDx2($i);
    $pDx4 = $pDx2;
    $pTheta = 0;
    $pPhi   = $pTheta;
    $pAlp1  = $pTheta;
    $pAlp2  = $pTheta;
    $detector{"name"}         = $subname;
    $detector{"mother"}       = $submother;
    $detector{"description"}  = $description;
    $detector{"pos"}          = $pos;
    $detector{"rotation"}     = $rotation;
    $detector{"color"}        = "7CFC00";
    $detector{"type"}         = "G4Trap";
    $detector{"dimensions"}   = "${pDz}*mm ${pTheta}*deg ${pPhi}*deg  ${pDy1}*mm ${pDx1}*mm  ${pDx2}*mm  ${pAlp1}*deg  ${pDy2}*mm ${pDx3}*mm  ${pDx4}*mm  ${pAlp2}*deg";
    $detector{"material"}     = "Lead";
    $detector{"mfield"}       = "no";
    $detector{"ncopy"}        = 1;
    $detector{"pMany"}        = 1;
    $detector{"exist"}        = 1;
    $detector{"visible"}      = 1;
    $detector{"style"}        = 1;
    $detector{"sensitivity"}  = "no";
    $detector{"hit_type"}     = "";
    $detector{"identifiers"}  = "";

#write values to a file.
    print_det(\%detector, $file);
} # end of if on lead layer.

    my $remainder = $i % 3;  # used in upcoming if statments to determine if a U,V, or W layer is built.

    if( $remainder == 1 )
    {
for( $j = 1; $j < $nstrips+1; $j++ ) {   # loop over the strips for the U layer

    $pDx1   = &UspDx2($i,$j);
    $pDx2   = &UspDx2($i,$j+1);
    $pDz    = $dscint/2.0;
    $pTheta = 0;
    $pPhi   = $pTheta;
    $pDy1   = &UspDy($i)/2.0;
    $pDy2   = $pDy1;
    $pDx3   = $pDx1;
    $pDx4   = $pDx2;
    $pAlp1  = $pTheta;
    $pAlp2  = $pTheta;


    $view   = &ECview($i);
    $stack  = &ECstack($i);

# fill the Geant4 description of the volume and write the results into the file.

    $xscint = &sxcenter($i);
    $yscint = &Usycenter($i, $j);
    $zscint = &szcenter($i);

    $subname = "EClayerScint${i}strip${j}";
    $description ="Forward Calorimeter scintillator layer ${i}";
    $pos = "$xscint*mm $yscint*mm $zscint*mm";
    $detector{"name"}         = $subname;
    $detector{"mother"}       = $submother;
    $detector{"description"}  = $description;
    $detector{"pos"}          = $pos;
    $detector{"rotation"}     = $rotation;
    $detector{"color"}        = "0147FA";
    $detector{"type"}         = "G4Trap";
    $detector{"dimensions"}   = "${pDz}*mm ${pTheta}*deg ${pPhi}*deg ${pDy1}*mm ${pDx1}*mm ${pDx2}*mm ${pAlp1}*deg ${pDy2}*mm ${pDx3}*mm  ${pDx4}*mm  ${pAlp2}*deg";
    $detector{"material"}     = "Scintillator";
    $detector{"mfield"}       = "no";
    $detector{"ncopy"}        = 1;
    $detector{"pMany"}        = 1;
    $detector{"exist"}        = 1;
    $detector{"visible"}      = 1;
    $detector{"style"}        = 1;
    $detector{"sensitivity"}  = "EC";
    $detector{"hit_type"}     = "ECwithG4strips";
    $detector{"identifiers"}  = "sector ncopy 0 stack manual $stack view manual $view strip manual $j";

    print_det(\%detector, $file);
}  # end of U layer strips loop
    } # end of if to select U view.

    if( $remainder == 2 )
    {
for( $j = 2; $j <= $nstrips+1; $j++ ) {  # loop over the strips for the V view. Start at strip 2 and go to 37

    $pDx1   = &VXedgelength($i,$j-1);
    $pDx2   = &VXedgelength($i,$j);
    $pDz    = $dscint/2.0;
    $pTheta = 0;
```

```
    $pPhi   = $pTheta;
    $pDy1   = &Vwidth($i)/2.0;
    $pDy2   = $pDy1;
    $pDx3   = $pDx1;
    $pDx4   = $pDx2;
    $pAlp1  = $offset; # angle of offset between strip absolute center and edge center.
    $pAlp2  = $offset; # angle of offset between strip absolute center and edge center.

    $view   = &ECview($i);
    $stack  = &ECstack($i);

# fill the Geant4 description of the volume and write the results into the file.

    $xscint = &Vsxcenter($i, $j);
    $yscint = &Vstripedge($i, $j - 0.5, $xscint);
    $zscint = &szcenter($i);

    # multiply $xscint by negative 1 to get the right sign.
    $xscint = -1*$xscint;

    $subname = "EClayerScint${i}strip${j}";
    $description ="Forward Calorimeter scintillator layer ${i}";
    $pos = "$xscint*mm $yscint*mm $zscint*mm";
    $detector{"name"}         = $subname;
    $detector{"mother"}       = $submother;
    $detector{"description"}  = $description;
    $detector{"pos"}          = $pos;
    $detector{"rotation"}     = "0*deg 0*deg 117.110959*deg";
    $detector{"color"}        = "0147FA";
    $detector{"type"}         = "G4Trap";
    $detector{"dimensions"}   = "${pDz}*mm ${pTheta}*deg ${pPhi}*deg ${pDy1}*mm ${pDx1}*mm ${pDx2}*mm ${pAlp1}*deg ${pDy2}*mm ${pDx3}*mm  ${pDx4}*mm  ${pAlp2}*deg";
    $detector{"material"}     = "Scintillator";
    $detector{"mfield"}       = "no";
    $detector{"ncopy"}        = 1;
    $detector{"pMany"}        = 1;
    $detector{"exist"}        = 1;
    $detector{"visible"}      = 1;
    $detector{"style"}        = 1;
    $detector{"sensitivity"}  = "EC";
    $detector{"hit_type"}     = "ECwithG4strips";
    $detector{"identifiers"}  = "sector ncopy 0 stack manual $stack view manual $view strip manual $j";

    print_det(\%detector, $file);

} # end of V layer strips loop
    }# end of 'if' to select V view.

    if( $remainder == 0 ){
for( $j = 2; $j <= $nstrips+1; $j++ ) {  # loop over the strips for the W layer. Start strip at 2 and go to 37

    $pDx1   = &WXedgelength($i,$j);
    $pDx2   = &WXedgelength($i,$j-1);
    $pDz    = $dscint/2.0;
    $pTheta = 0;
    $pPhi   = $pTheta;
    $pDy1   = &Wwidth($i)/2.0;
    $pDy2   = $pDy1;
    $pDx3   = $pDx1;
    $pDx4   = $pDx2;
    $pAlp1  = -1 * $offset; # angle of offset between strip absolute center and edge center.
    $pAlp2  = -1 * $offset; # angle of offset between strip absolute center and edge center.


    $view   = &ECview($i);
    $stack  = &ECstack($i);

# fill the Geant4 description of the volume and write the results into the file.

    $xscint = &Wsxcenter($i, $j);
    $yscint = &Wstripedge($i, $j - 0.5, $xscint);
    $zscint = &szcenter($i);

    # multiply $xscint by negative 1 to get the right sign.
    $xscint = -1*$xscint;

    $subname = "EClayerScint${i}strip${j}";
    $description ="Forward Calorimeter scintillator layer ${i}";
    $pos = "$xscint*mm $yscint*mm $zscint*mm";
    $detector{"name"}         = $subname;
    $detector{"mother"}       = $submother;
    $detector{"description"}  = $description;
    $detector{"pos"}          = $pos;
    $detector{"rotation"}     = "0*deg 0*deg 62.889041*deg";
    $detector{"color"}        = "0147FA";
    $detector{"type"}         = "G4Trap";
    $detector{"dimensions"}   = "${pDz}*mm ${pTheta}*deg ${pPhi}*deg ${pDy1}*mm ${pDx1}*mm ${pDx2}*mm ${pAlp1}*deg ${pDy2}*mm ${pDx3}*mm  ${pDx4}*mm  ${pAlp2}*deg";
    $detector{"material"}     = "Scintillator";
    $detector{"mfield"}       = "no";
    $detector{"ncopy"}        = 1;
    $detector{"pMany"}        = 1;
    $detector{"exist"}        = 1;
    $detector{"visible"}      = 1;
    $detector{"style"}        = 1;
```

```
    $detector{"sensitivity"}  = "EC";
    $detector{"hit_type"}     = "ECwithG4strips";
    $detector{"identifiers"}  = "sector ncopy 0 stack manual $stack view manual $view strip manual $j";

    print_det(\%detector, $file);

} # end of W layer loop
    }# end of 'if' to select W view.

}# end of 'for' loop over lead-scint layers.


#
#subroutines *********************************************************************
#
# scintillator positions:

# gives the x position of each scintillator layers geometric center inside the mother volume.
sub sxcenter($){
    my $xcent = 0;
    return $xcent;
}

# gives the x center position of V layer strips inside the mother volume.
sub Vsxcenter($){
    # get the corners for the desired V strip.
    my $layer = $_[0];
    my $strip = $_[1] - 1; # to be consistent with Keegan's conventions.
    my @corners = &VstripCorners($layer,$strip);
    my @point1 = ($corners[0],$corners[1]);
    my @point2 = ($corners[2],$corners[3]);
    my @point3 = ($corners[4],$corners[5]);
    my @point4 = ($corners[6],$corners[7]);

    # average the corner positions to get the geometric center of the strip.
    my @stripAve = (($point1[0]+$point2[0]+$point3[0]+$point4[0])/4,($point1[1]+$point2[1]+$point3[1]+$point4[1])/4);
    my $Vxcent = $stripAve[0];

    return $Vxcent;
}

# gives the x center position of W layer strips inside the mother volume.
sub Wsxcenter($){
    # get the corners for the desired W strip.
    my $layer = $_[0];
    my $strip = $_[1] - 1; # to be consistent with Keegan's conventions.
    my @corners = &WstripCorners($layer,$strip);
    my @point1 = ($corners[0],$corners[1]);
    my @point2 = ($corners[2],$corners[3]);
    my @point3 = ($corners[4],$corners[5]);
    my @point4 = ($corners[6],$corners[7]);

    my @stripAve = (($point1[0]+$point2[0]+$point3[0]+$point4[0])/4,($point1[1]+$point2[1]+$point3[1]+$point4[1])/4);
    my $Wxcent = $stripAve[0];

    return $Wxcent;
}

# gives the y position of each scintillator layers geometric center inside the mother volume.
sub sycenter($){
    my $ycent = $a1*($_[0] - 1);
    return $ycent;
}

# gives the y position of each U strip geometric center within the mother volume.
sub Usycenter($){
    # average the y positions for the bottom and top of strip n. See eq. 10.
    my $Uycent = -$a2 - $a4*($_[0] - 1) + ($_[1] - 0.5)*Uwidth($_[0]);

    return $Uycent;
}

# gives the y position of V strips inside the mother volume.
sub Vstripedge($){
    # get the corners for the desired V strip.
    my $layer = $_[0];
    my $strip = $_[1];
    my @corners = &VstripCorners($layer,$strip);
    my @point1 = ($corners[0],$corners[1]);
    my @point2 = ($corners[2],$corners[3]);
    my @point3 = ($corners[4],$corners[5]);
    my @point4 = ($corners[6],$corners[7]);

     # average the corner positions to get the geometric center of the strip.
    my @stripAve = (($point1[0]+$point2[0]+$point3[0]+$point4[0])/4,($point1[1]+$point2[1]+$point3[1]+$point4[1])/4);
    my $Vycent = $stripAve[1];

    return $Vycent;
}

# gives the y position of W strips inside the mother volume.
sub Wstripedge($){
    my $Wycent = &sycenter($_[0]) - &DeltaY($_[0]) + (&Wwidth($_[0]) * (37 - $_[1]) * $sqrttantheta) + ($tantheta * $_[2]);
```

```
    return $Wycent;
}

#gives the z position of each scintillator layers geometric center inside the mother volume.
sub szcenter($){
    my $layer = $_[0];
    my $zcent = -$totaldepth/2 + ($layer - 1)*($dscint + $dlead) + $dscint/2;
    return $zcent;
}

sub DeltaY($){
my $dy = $a2 + $a3 * ($_[0] - 1);
return $dy;
}

# lead positions.
# gives the x position of each lead layers geometric center inside the mother volume.
sub sxcenterPb($){
    my $xcentPb = 0;
    return $xcentPb;
}

#gives the y position of each lead layers geometric center inside the mother volume.
sub sycenterPb($){
    my $ycentPb = &sycenter($_[0]) + $beamVertexCut[$_[0]-2]/2;
    return $ycentPb;
}

#gives the z position of each lead layers geometric center inside the mother volume.
sub szcenterPb($){
    my $zcentPb = -$totaldepth/2 + ($_[0] - 2)*($dscint + $dlead) + $dscint/2 + ($dscint+$dlead)/2;
    return $zcentPb;
}

# half-widths of lead and scintillator layers.
#
# gives half y distance of trapezoidal EC layer $i,
sub spDy($){
    my $ywidth = $a2 + $a3*($_[0] - 1);
    return $ywidth;
}

# gives half x distance of trapezoidal EC layer $i;
sub spDx2($){
    my $xwidth = (2*&spDy($_[0]))/($tantheta);
    return $xwidth;
}

# gives half y distance of trapezoidal U layer strips in layer $i,
sub UspDy($){
    my $Uywidth = $a5 + $a6*($_[0] - 1);
    return $Uywidth;
}

# gives half x distance of trapezoidal EC layer $i;
sub UspDx2($){
    my $Uxwidth = -((&UYminus($_[0]) - &UYbottom($_[0], $_[1]))/($tantheta));
    if( $Uxwidth == 0 ) {
return 0.00000000000001; # should return zero but that makes gemc crash
    }else{
return $Uxwidth;
    }
}

# gives absolute minimum y value of U layer $i
sub UYminus($){
    my $Uymin = -$a2 - $a4*($_[0] - 1);
    return $Uymin;
}

# gives y value for bottom side of a U strip.
sub UYbottom($){
    my $Uy = &UYminus($_[0]) + ($_[1] - 1)*(&UspDy($_[0]));
    return $Uy;
}

# gives x half length values for the V strip edges.
sub VXedgelength($){
    # get the corners for the desired V strip.
    my $layer = $_[0];
    my $strip = $_[1] - 1; # shift the strip to be consistent with KS.
    my @corners = &VstripCorners($layer,$strip);
    my @point1 = ($corners[0],$corners[1]);
    my @point2 = ($corners[2],$corners[3]);
    my @point3 = ($corners[4],$corners[5]);
    my @point4 = ($corners[6],$corners[7]);

    # get the position of the midpoint of the near-V-vertex edge of the strip and
    # then calculate the distance from there to one of the corners along that edge.
    my @ave34 = (($point3[0]+$point4[0])/2,($point3[1]+$point4[1])/2);
    my $Vx    = sqrt(($ave34[0] - $point4[0])**2 + ($ave34[1] - $point4[1])**2);

    if( $Vx == 0 ) {
```

```
return 0.00000000000001;   # should return zero but that makes gemc crash
    }else{
return $Vx;
    }
}

# gives x half length values for the W strip edges.
sub WXedgelength($){
    # get the corners for the desired W strip.
    my $layer = $_[0];
    my $strip = $_[1] - 1; # shift strip to be consistent with KS.
    my @corners = &WstripCorners($layer,$strip);
    my @point1 = ($corners[0],$corners[1]);
    my @point2 = ($corners[2],$corners[3]);
    my @point3 = ($corners[4],$corners[5]);
    my @point4 = ($corners[6],$corners[7]);

    # get the position of the midpoint of the near-V-vertex edge of the strip and
    # then calculate the distance from there to one of the corners along that edge.
    my @ave34    = (($point3[0]+$point4[0])/2,($point3[1]+$point4[1])/2);
    my $Wx = sqrt(($ave34[0] - $point4[0])**2 + ($ave34[1] - $point4[1])**2);

    if( $Wx == 0 ) {
return 0.00000000000001;   # should return zero but that makes gemc crash
    }else{
return $Wx;
    }
}

# gives the width of the U strips in layer $i,
sub Uwidth($){
    my $Uwidth = $a5 + $a6*($_[0] - 1);
    return $Uwidth;
}

## gives the width of the V strips.
sub Vwidth($){
    my $Vwidth = $a7 + $a8*($_[0] - 2);
    return $Vwidth;
}
# gives the width of the W strips.
sub Wwidth($){
    my $Wwidth = $a9 + $a8*($_[0] - 3);
    return $Wwidth;
}

sub Angleoffset($){
    # set parameters. The offset is the same for all strips (V and W) so just pick one
    # strip/layer combination to do the calculation.
    my $layer=2;
    my $strip=30;
    my $pi=3.141592654;

    my @corners = &VstripCorners($layer,$strip);
    my @point1 = ($corners[0],$corners[1]);
    my @point2 = ($corners[2],$corners[3]);
    my @point3 = ($corners[4],$corners[5]);
    my @point4 = ($corners[6],$corners[7]);

    # get the midpoint of edge of the strip closest to the vertex for that view.
    my @edgeAve = (($point1[0]+$point2[0])/2,($point1[1]+$point2[1])/2);
    # get the geometric middle of the strip by averaging all the corners.
    my @stripAve = (($point1[0]+$point2[0]+$point3[0]+$point4[0])/4,($point1[1]+$point2[1]+$point3[1]+$point4[1])/4);

    # get the slopes of the line perpendicular to the strip edge (slope12), the slope of the line from the midpoint
    # of the edge of the strip to the middle of the strip (slope2middle), then extract the angle between those lines.
    my $slope12 = ($point2[1]-$point1[1])/($point2[0]-$point1[0]); # slope of the edge of the strip;
    my $slope12perp = -1/$slope12; # slope of the normal to the edge of the strip;
    my $slope2middle = ($stripAve[1]-$edgeAve[1])/($stripAve[0]-$edgeAve[0]); # slope of line for midpoint of strip edge to midpoint of entire strip.
    my $tanpsi = ($slope2middle - $slope12perp)/(1 + ($slope2middle*$slope12perp)); # tangent of angle between the lines.
    my $offset = atan($tanpsi)*180/$pi;

    return $offset
}

sub ECview($) {
    # using the layer to generate a number (1,2,3) for the different views (U, V,W).

    my $layer = $_[0];
    my $mod = $layer%3;

    my $view = 4;
    if ($mod == 1) {$view = 1;}
    if ($mod == 2) {$view = 2;}
    if ($mod == 0) {$view = 3;}

    if ($view == 4) {print "**** WARNING: No View assignment made. ****\n";}

    return $view;

}

sub ECstack($) {
```

```
    # using the layer to generate a number (1,2,3) for the inner and outer stacks in the EC.

    my $layer = $_[0];

    my $stack = 3;
    if ($i <= 15) {$stack = 1;}
    if ($i >  15) {$stack = 2;}
    if ($stack == 3) {print "**** WARNING: No Stack assignment made. ****\n";}

    return $stack;

}

# the three lines that define the edges of the triangular layer.
#
# border of scintillator layer at large polar angle.
sub youter($){
    my $y_outer = &sycenter($_[0]) + &DeltaY($_[0]);
    return $y_outer;
}

# left border of scintillator layer as you look outward from the target.
sub yleft($){
    my $y_left = &sycenter($_[0]) - &DeltaY($_[0]) - $tantheta*$_[1];
    return $y_left;
}

# right border of scintillator layer as you look outward from the target.
sub yright($){
    my $y_right = &sycenter($_[0]) - &DeltaY($_[0]) + $tantheta*$_[1];
    return $y_right;
}


sub VstripCorners($){

    # get the four corners of the strip using the equations in CLAS-NOTE 2011-019.
    #      1. set eq 7 = eq 12 with n = strip number and solve for x. y is given by eq 7. This is the strip edge closest to the V vertex.
    #      2. set eq 6 = eq 12 with n = strip number and solve for x. y is given by eq 6. This is the strip edge closest to the V vertex.
    #      3. set eq 7 = eq 12 with n = strip number + 1 and solve for x. y is given by eq 7. This is the strip edge farthest from the V vertex.
    #      4. set eq 6 = eq 12 with n = strip number + 1 and solve for x. y is given by eq 6. This is the strip edge farthest from the V vertex.
    #
    # The number scheme is the following.        3   1
    #                                            -----
    #                                             \   \
    #                                              \   \
    #                                               \   \
    #                                                \   \
    #                                                 -----
    #                                                 4   2

    my $layer = $_[0];
    my $strip = $_[1];

    my @Vcorner1 = ((-&youter($layer) + &sycenter($layer) - &DeltaY($layer) + (37-$strip)*&Vwidth($layer)*$sqrttantheta)/$tantheta,&youter($layer));
    my $xvalue1 = (37-$strip)*&Vwidth($layer)*$sqrttantheta/(2*$tantheta);
    my @Vcorner2 =  ($xvalue1,&yright($layer,$xvalue1));
    my @Vcorner3 = ((-&youter($layer) + &sycenter($layer) - &DeltaY($layer) + (37-($strip+1))*&Vwidth($layer)*$sqrttantheta)/$tantheta,&youter($layer));
    my $xvalue2 = (37-($strip+1))*&Vwidth($layer)*$sqrttantheta/(2*$tantheta);
    my @Vcorner4 =  ($xvalue2,&yright($layer,$xvalue2));

    my @Vcorners = (@Vcorner1, @Vcorner2, @Vcorner3, @Vcorner4);
    #print "Vxcent = ",$Vxcent," myVxcent = ", $myVxcent,"\n";
    # return the corner arrays as a 1D array since perl does not do 2D arrays.
    return @Vcorners;
}

sub WstripCorners($){

    my $layer = $_[0];
    my $strip = $_[1];

    # get the four corners of the strip using the equations in CLAS-NOTE 2011-019.
    #      1. set eq 7 = eq 13 with n = strip number and solve for x. y is given by eq 7. This is the strip edge closest to the W vertex.
    #      2. set eq 5 = eq 13 with n = strip number and solve for x. y is given by eq 5. This is the strip edge closest to the W vertex.
    #      3. set eq 7 = eq 13 with n = strip number + 1 and solve for x. y is given by eq 7. This is the strip edge farthest from the W vertex.
    #      4. set eq 5 = eq 13 with n = strip number + 1 and solve for x. y is given by eq 5. This is the strip edge farthest from the W vertex.
    #
    # The number scheme is the following.        1   3
    #                                            -----
    #                                           /   /
    #                                          /   /
    #                                         /   /
    #                                        /   /
    #                                       -----
    #                                       2   4

    my @Wcorner1 = ((&youter($layer) - &sycenter($layer) + &DeltaY($layer) - (37-$strip)*&Wwidth($layer)*$sqrttantheta)/$tantheta,&youter($layer));
    my $xvalue1  = -(37-$strip)*&Wwidth($layer)*$sqrttantheta/(2*$tantheta);
    my @Wcorner2 =  ($xvalue1,&yleft($layer,$xvalue1));
    my @Wcorner3 = ((&youter($layer) - &sycenter($layer) + &DeltaY($layer) - (37-($strip+1))*&Wwidth($layer)*$sqrttantheta)/$tantheta,&youter($layer));
    my $xvalue2  = -(37-($strip+1))*&Wwidth($layer)*$sqrttantheta/(2*$tantheta);
    my @Wcorner4 =  ($xvalue2,&yleft($layer,$xvalue2));
```

```
    my @Wcorners = (@Wcorner1, @Wcorner2, @Wcorner3, @Wcorner4);
    #print "Vxcent = ",$Vxcent," myVxcent = ", $myVxcent,"\n";
    # return the corner arrays by reference since perl does not do 2D arrays.
    return @Wcorners;
}
```

H Example of gcard input file

In this example only the EC, torus magnet, and Moeller shield are turned on for the simulation. Note that the choice of 'EC' is commented out here 'ECwithG4strips' is active.

```
<gcard version= "1.0"  date= "2010-7-08" author= "gilfoyle">

<!-- Forward Detectors: -->
        <sqltable name="SECTOR"/>
<!--    <sqltable name="EC"/> -->
        <sqltable name="ECwithG4strips"/>

<!-- Magnets: -->
<!--   <sqltable name="solenoid"/> -->
       <sqltable name="torus"/>

<!-- Beam Line: -->
          <sqltable name="moeller_shield"/>

</gcard>
```