Simulating the Electromagnetic Calorimeter in CLAS12

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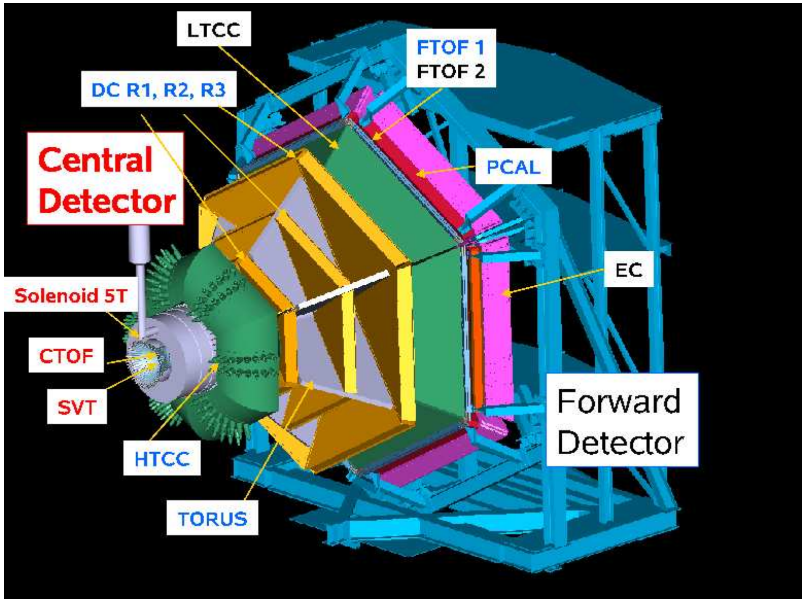
CLAS12 Software Group

Outline:

1. Physics Motivation.
2. Geometry.
3. Digitization.
4. Testing and Results.
5. Summary and Plans.

CLAS12 Simulation

- Essential tool for design and analysis (*e.g.* acceptance calculations).
- Quality of the results may be limited by systematic uncertainties (not statistics).
- Will need about four times as much Monte Carlo data as CLAS12 collects.



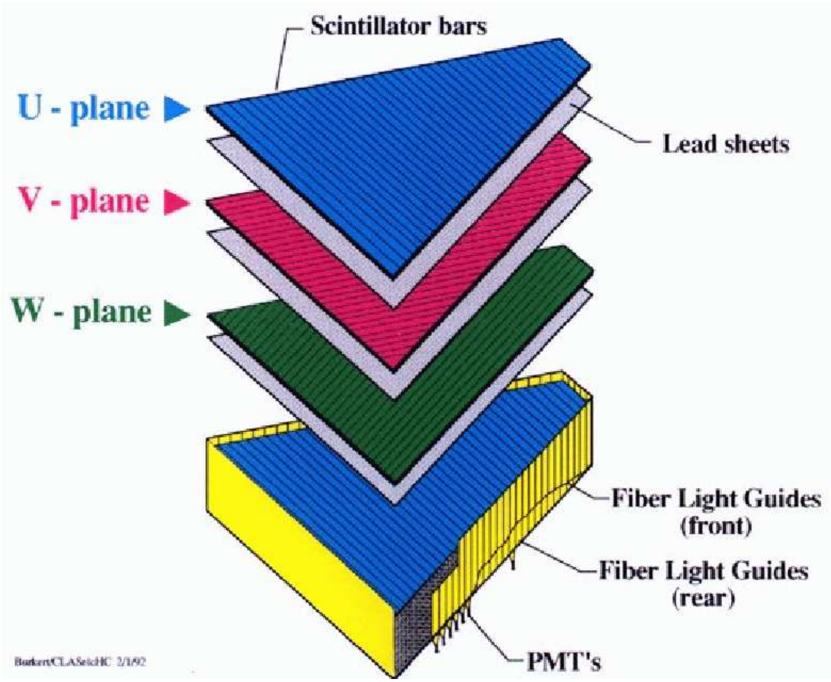
The CLAS12 detector.

gemc

- ◇ Modern, object-oriented, Geant4-based simulation.
- ◇ Still in development stage.
- ◇ Needed subsystems: ⟶
  - ♣ Electromagnetic calorimeter (EC) - It's in now! See below.
  - ♣ Pre-shower calorimeter (PCal).
  - ♣ Cerenkov counter (CC).

EC Geometry Implemented In gemc - 1

- The CLAS6 EC will be re-used in CLAS12.
- Placed farther downstream from the target center than CLAS6 (7217.23 mm versus 5103.2 mm).
- EC geometry:
  1. 39 scintillators layers (10 mm thick).
  2. Each layer divided into 36 strips .
  3. 3 views formed.
  4. Inner views (5 layers) and outer views (8 layers) ganged together.
  5. 38 layers of lead (2.2 mm thick, 16 radiation lengths).
  6. Projective geometry.
  7. Geant4 generalized trapezoid parameters stored in mysql database.



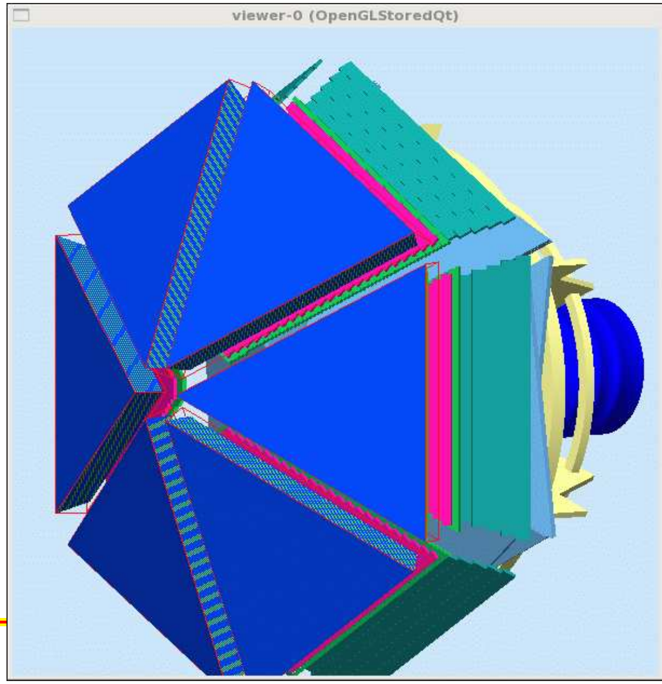
- Steamlined Perl scripts for generating geometry

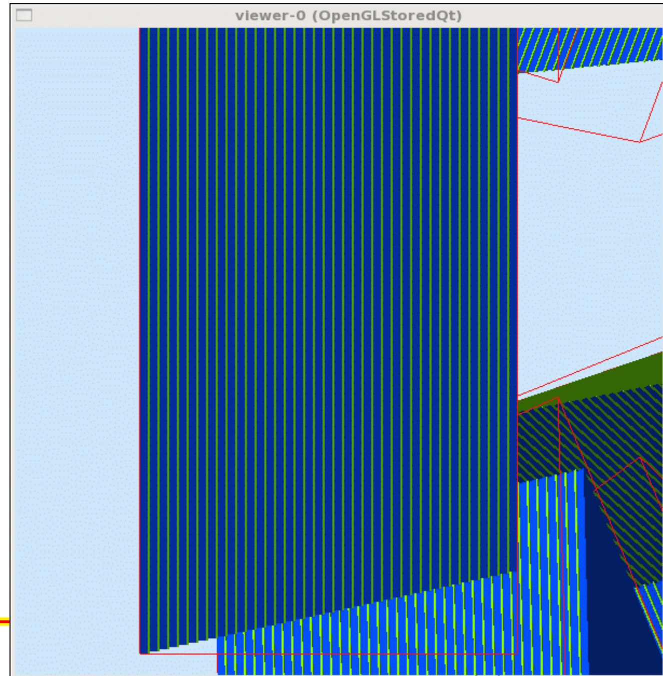
EC Geometry Implemented In gemc - 2

- EC banks:

Etot	Deposited energy	<x>,<y>,<z>	global position
<t>	Time	<lx>,<ly>,<lz>	local position
pid	Particle ID	vx,vy,vz	vertex position
E	Track energy	mpid	mother ID
sector	Sector	mvx,mvy,mvz	mother vertex
stack	Inner, outer	view	U, V, W
EC_ADC	ADC	EC_TDC	TDC

- Results:





EC Geometry Implemented In gemc - 2

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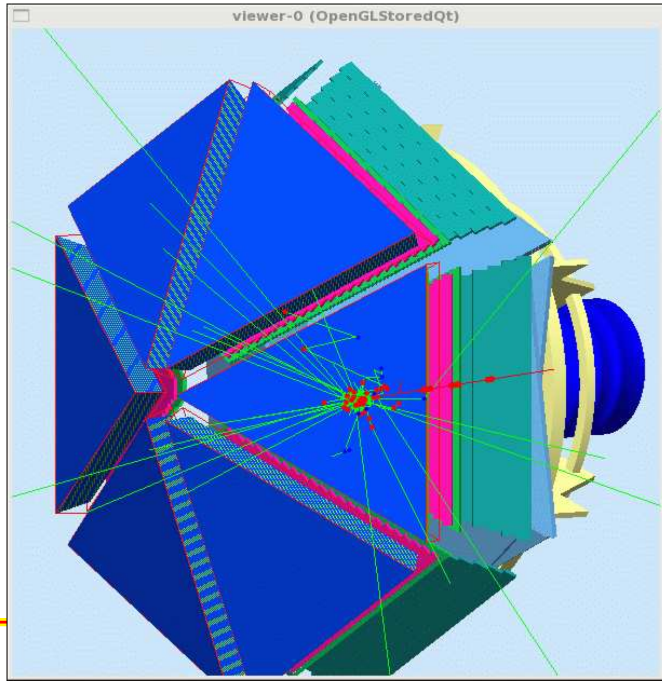
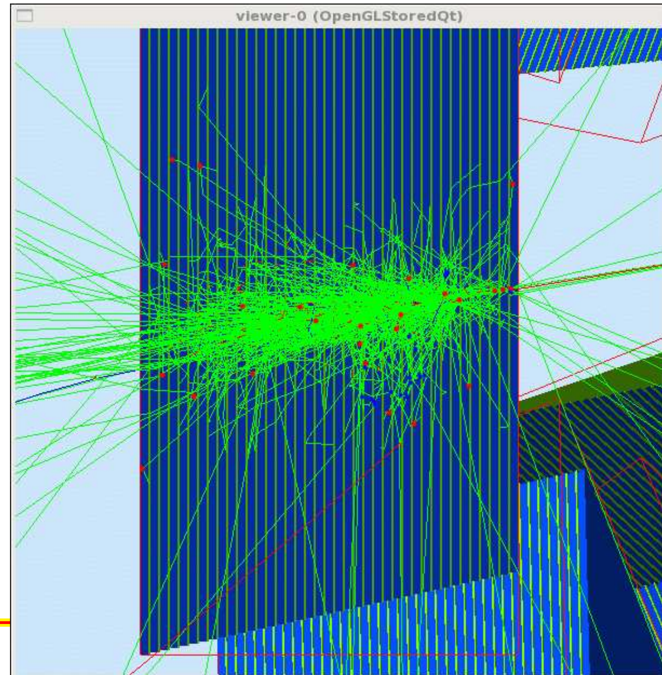
EC_ADC	ADC	EC_TDC	TDC

- Results:





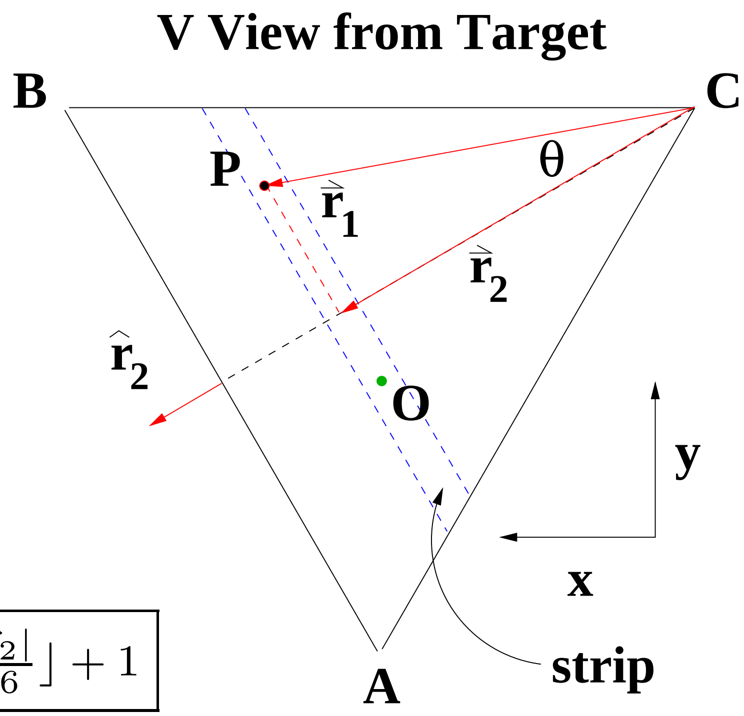
EC Digitization in gemc - 1

1. Modified the identifiers in the geometry database to reflect stacking (inner/outer) and views (U, V, W) of the EC.
2. As the track is integrated determine the identifiers of the 'hit' at each step:
   - Sector: already known.
   - Stack: layers 1-15 $\rightarrow$ inner; layer 16-39 $\rightarrow$ outer.
   - View: use $layer % 3 to determine view from layer.
   - Strip: 36 strips in each layer.

$$\vec{P} = (x, y) \text{ (the hit)}$$
$$\vec{A} = (x_A, y_A) = (0, -pDy1)$$
$$\vec{B} = (x_B, y_B) = (pDx2, pDy1)$$
$$\vec{C} = (x_C, y_C) = (-pDx2, pDy1)$$

$$\vec{r}_1 = \vec{P} - \vec{C}$$
$$\hat{r}_2 = \frac{(y_B - y_A, x_A - x_B)}{\sqrt{(y_B - y_A)^2 + (x_A - x_B)^2}}$$
$$\cos\theta = \frac{\vec{r}_1 \cdot \hat{r}_2}{|\vec{r}_1|}$$
$$|\vec{r}_2| = |\vec{r}_1| \cos\theta$$

$$strip = \lfloor \frac{|\vec{r}_2|}{36} \rfloor + 1$$



EC Digitization in gemc - 2

3. ADC signal.

   (a) Calculate expected number of photons from deposited energy ($3.5\ \mathrm{photons/MeV}$).

   (b) Use Poisson statistics to simulate the number of photons.

   (c) Apply photon attenuation ($\lambda_0 = 3760\ mm$).

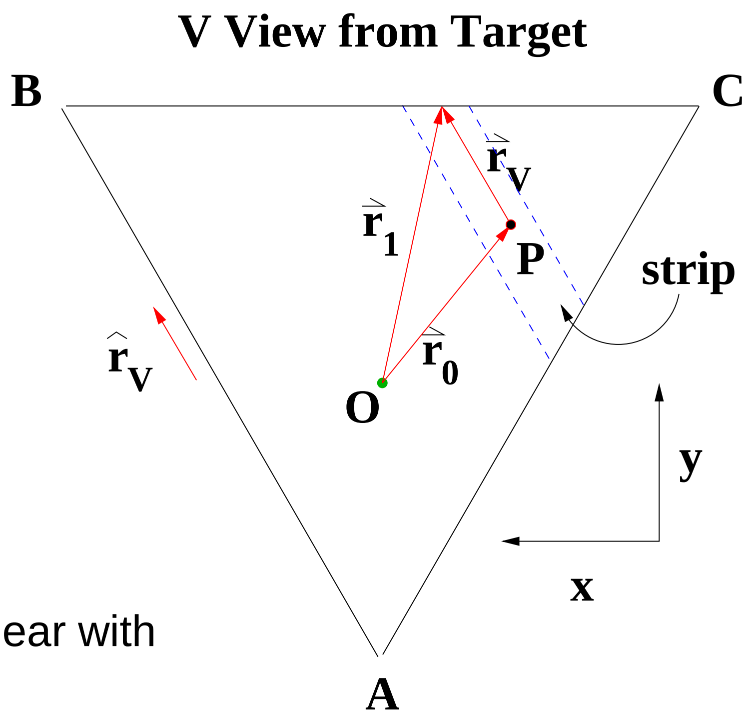
   $$\vec{P} = (x, y)$$
   $$\vec{A} = (x_A, y_A) = (0, -pDy1)$$
   $$\vec{B} = (x_B, y_B) = (pDx2, pDy1)$$
   $$\vec{C} = (x_C, y_C) = (-pDx2, pDy1)$$

   Equation of $\overline{BC}$: $y = y_{BC} = pDy1$.

   Equation of $\vec{r}_1$: $\vec{r}_1 = \vec{r}_0 + l\hat{r}_V$

   where $\hat{r}_V = \frac{\vec{B}-\vec{A}}{|\vec{B}-\vec{A}|}$.

   Set $y_{BC} = y_1$ and solve for l.



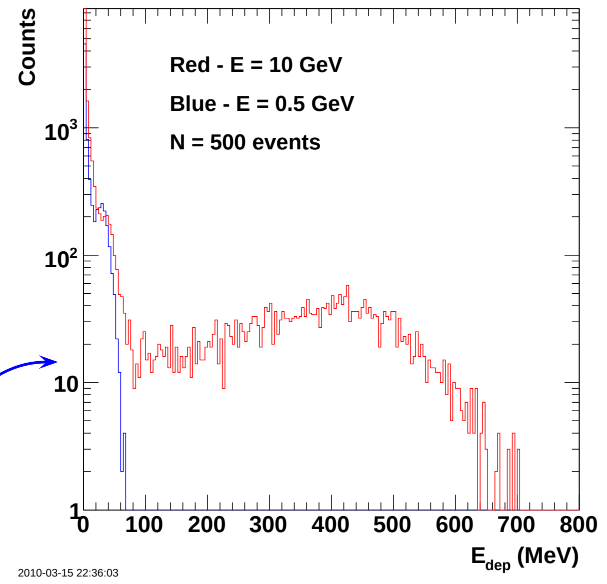
   (d) Apply PMT gain (10 channels/MeV) and smear with PMT resolution (use GSIM parameters).

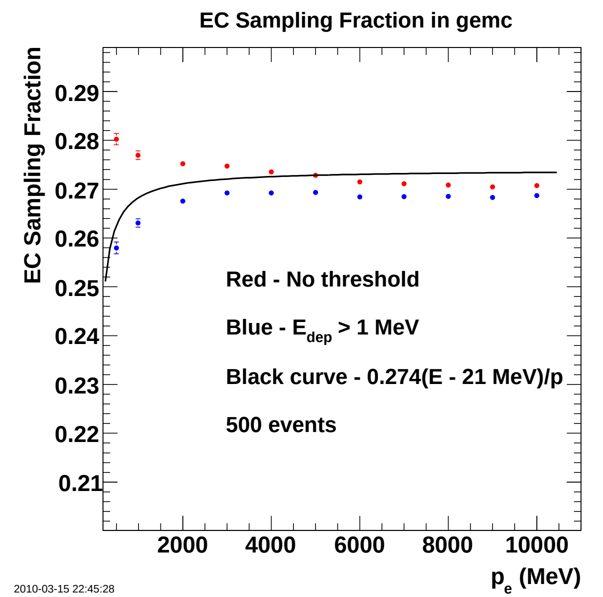
4. TDC signal - convert time of hit to TDC signal using 20 ns/channel.

Testing and Results

1. Sampling Fraction (f_s)
   (a) Ratio of energy deposited in the EC to the energy of the electron (E/p).
   (b) Test conditions for gemc:
      i. No $\vec{B}$ field (new option for gemc).
      ii. Fix electron momentum p_e, $\theta_e = 25^\circ$, $\phi_e = 0^\circ$.
      iii. Convert EVIO output to Root Trees.
      iv. Histogram the deposited energy.
      v. Scan p_e $(0.5 - 10\ \mathrm{GeV})$.
2. Integrate the distribution of E_{dep} and divide by p_e to get the sampling fraction.

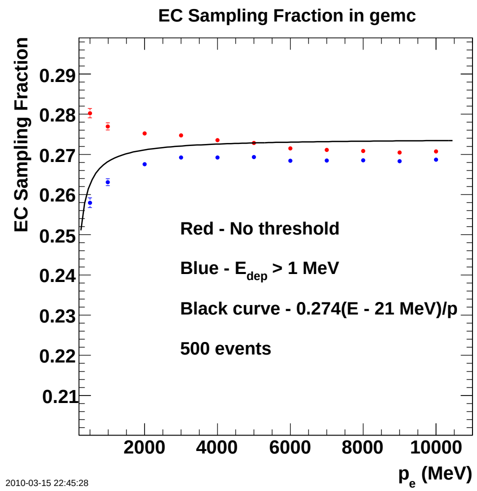
   $f_s = \frac{\sum n_i E^i_{dep}}{E_e}$ where n_i is the number of counts in the top panel.
3. Drop observed at low p_e due to threshold on E_{dep}.

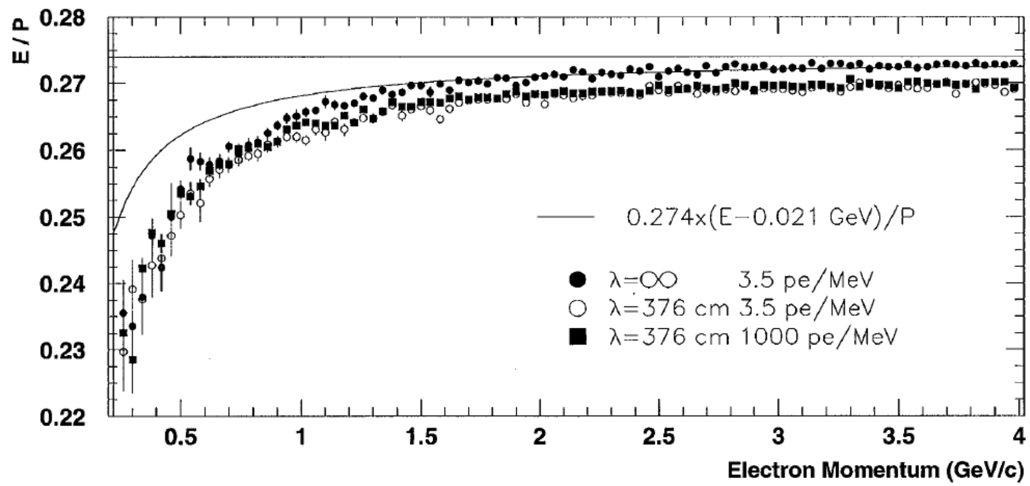




Comparison with CLAS6 - Sampling Fraction

1. CLAS6 results from EC NIM paper (NIM A460 (2001) 239-265) using GSIM.
2. Black curve in each plot based on ionization energy loss in materials preceding the EC.
3. Caveats: (1) electrons passed through different material, (2) $\vec{B}$ field off in the CLAS12 simulation and $\vec{B}$ field on in the CLAS6 simulation, (3) tracking used in CLAS6 simulation while Monte Carlo information used for CLAS12, (4) energy loss out the back, ...
4. Note different horizontal ranges.





gemc and GSIM sampling fractions are consistent to 10-15%.

Comparison with CLAS6 - Resolution

1. CLAS6 results from EC NIM paper (NIM A460 (2001) 239-265) using GSIM.
2. Caveats: (1) electrons passed through different material, (2) $\vec{B}$ field off in the CLAS12 simulation and $\vec{B}$ field on in the CLAS6 simulation, (3) tracking used in CLAS6 simulation while Monte Carlo information used for CLAS12, (4) energy loss out the back, ...
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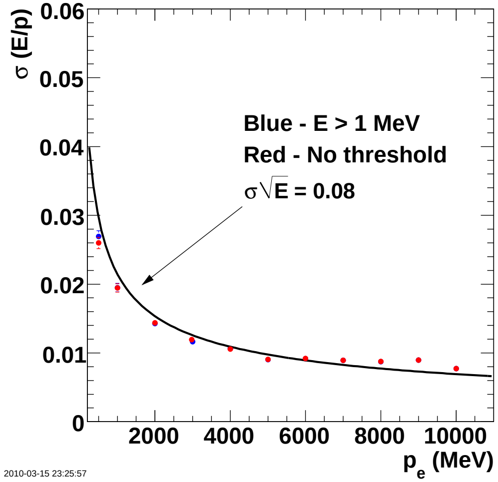
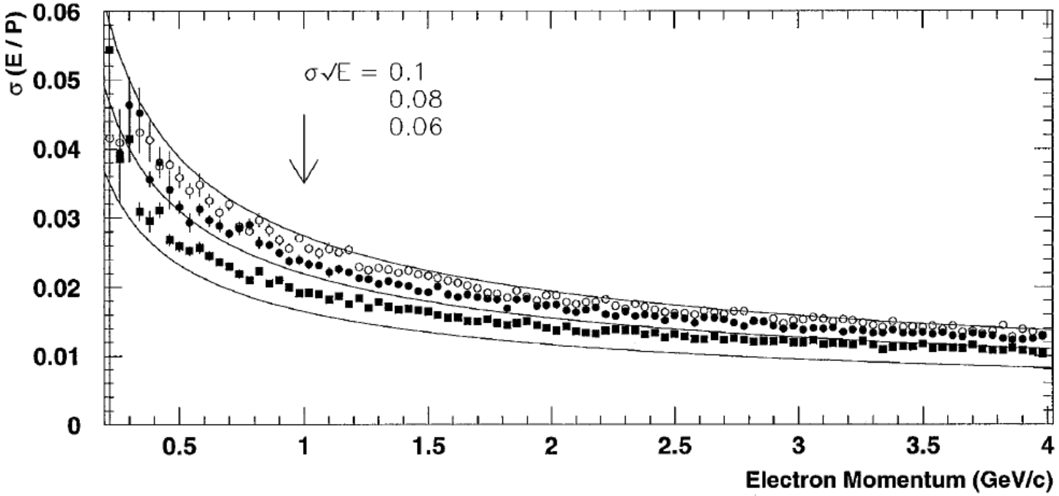
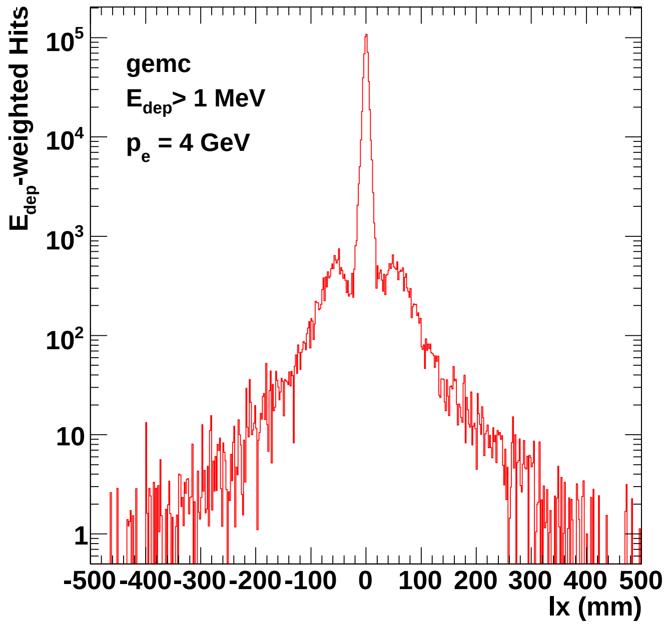




gemc and GSIM resolutions are consistent to 5-10%.

Comparison with CLAS6 - Shower Size

1. CLAS6 shower size ≈ 4 cm diameter for 2.4 GeV electron (*e.g.* 95% of shower energy contained within 2 cm of centroid (EC NIM paper).
2. Caveats: (1) electrons passed through different material, (2) $\vec{B}$ field off in the CLAS12 simulation and $\vec{B}$ field on in the CLAS6 simulation, (3) tracking used in CLAS6 simulation while Monte Carlo information used for CLAS12, (4) energy loss out the back, ...
3. Use E_{dep}-weighted distribution in local x for $\theta_e = 25°$, $\phi_e = 0°$.



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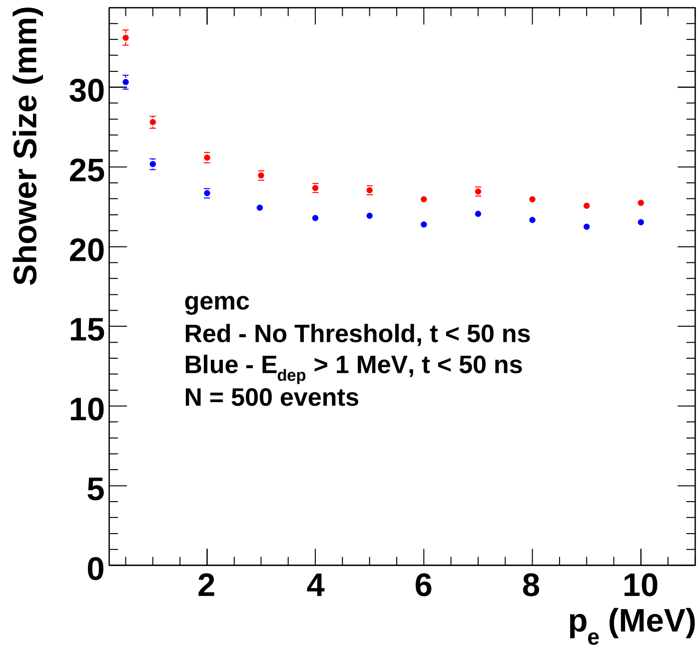

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gemc and GSIM shower sizes are consistent to 5-10%.

Plans

1. Complete EC implementation:
   - Test photon attenuation, measure energy loss.
   - Layer tests.
   - Additional structures: cover plate, supports, PMT-related structures.
   - Scintillator strips connection to PMTs.
   - Other??
2. Reconstruction of electrons and protons.
3. PCal (Mike Wood).
4. Cerenkov counters.
5. Neutron efficiency.

CLAS12 Software Workshop*

- Goals:
  - Broad view of the state-of-the-art in offline analysis.
  - Status of the CLAS12 software program.
  - Opportunities for users to join that program.
- Tutorials on CLAS12 software; free DVD for participants.
- To be held at the University of Richmond, May 25-26, 2010.
- Travel funding available for students and post-docs.

*Supported by the JSA/SURA Initiatives Fund.

Website: `http://conferences.jlab.org/CLAS12Software/index.html`