Improving GEMC model of CLAS12 using electron radiation

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Task force wiki page:
https://clasweb.jlab.org/wiki/index.php/Hall-B_Task_Forces_2020#tab=e-_Radiation

Radiated photons

- Radiated photons accompanying the scattered electrons can be observed
- At the point of radiation the photon has the same angles as the electron
- The radiated photons are identified by analyzing the differences of the angles of the electrons and the neutral hits
- It is important to understand the sources of these radiations.
- The goal is to better describe the CLAS12 detector in GEANT4 model. With correct positions and thickness, the electron radiation and the energy loss of hadrons can be better reproduced.

Detected radiated photons

- Inbending 10.6 GeV rga Fall 2018 data was used as measured data and the common large scale MC SIDIS production used for the first publications was used as simulated data
- Radiated photons in the ECal can be identified by plotting θ and ϕ diference of every detected electron and neutral particle
- In the longitudinal field of the solenoid, at the point of the radiation, the polar angle of the electron is the same as at the production vertex:

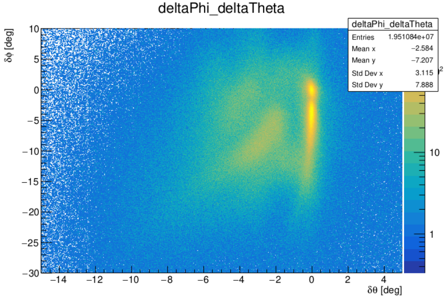
$$\theta_\gamma \approx \theta_e^r \approx \theta_e^v$$

- The azimuthal angular difference is more complicated - solenoid field, electron momentum, location of the radiation points

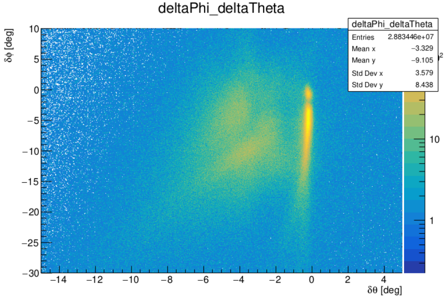
$$\phi_\gamma \approx \phi_e^r \neq \phi_e^v$$

Detected radiated photons

- $\delta\theta = \theta_\gamma - \theta_e^v$
- $\delta\phi = \phi_\gamma - \phi_e^v$
- Narrow peak at $\delta\theta = 0$ with $\sigma = 0.17°$ - Radiated photon: $|\delta\theta| < 0.7°$



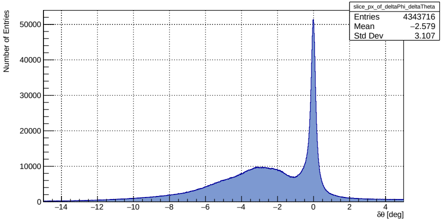
Data



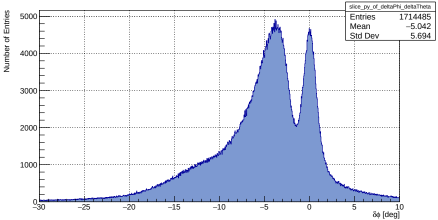
Simulation

Detected radiated photons

- $\delta\theta = \theta_\gamma - \theta_e^v$
- $\delta\phi = \phi_\gamma - \phi_e^v$
- Narrow peak at $\delta\theta = 0$ with $\sigma = 0.17°$ - Radiated photon: $|\delta\theta| < 0.7°$



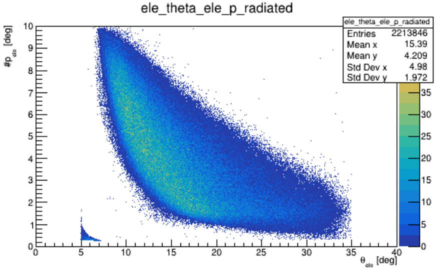
$\delta\theta$



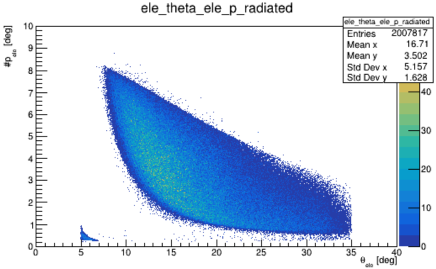
$\delta\phi$ with $|\delta\theta| < 0.7°$

Differences between data and simulation

- Kinematics for every radiated electron
- There is a small difference in the kinematic coverage between the simulated and measured data



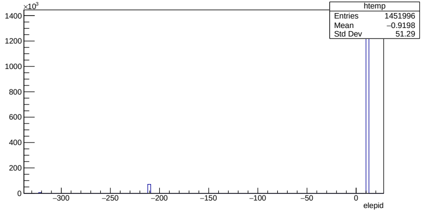
Data



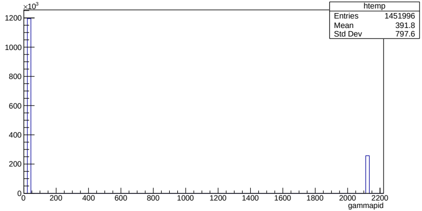
Simulation

Particle identification

- Radiated photon tagging can be used to study particle identification
- Neutral and negative particles that have same θ angles are misidentified photons and electrons
- The 4-momenta of these particles were recalculated during the analysis

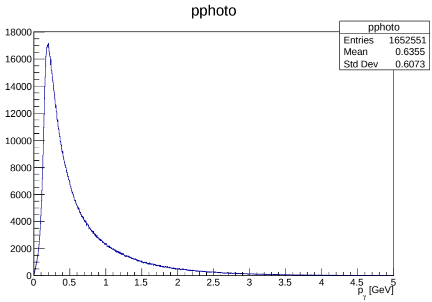


Radiated electrons EB PID

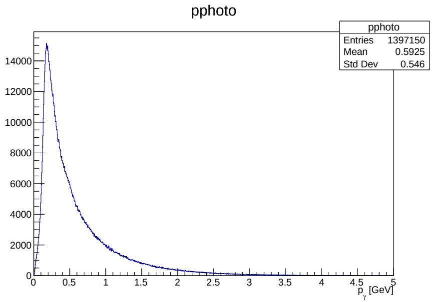


Radiated photons EB PID

Energy distribution of the radiated photons

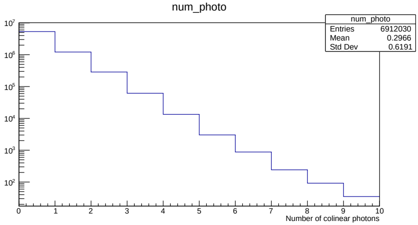


Data

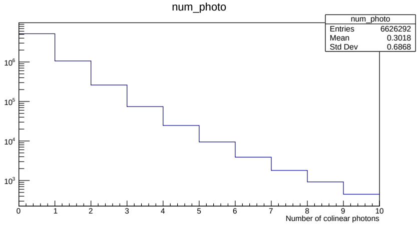


Simulation

Number of radiated photons per electron



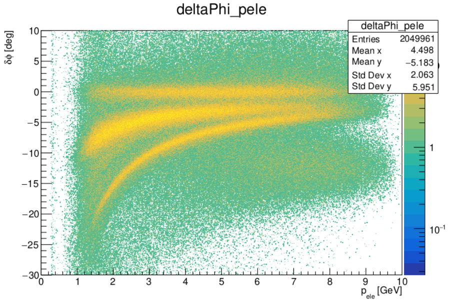
Data



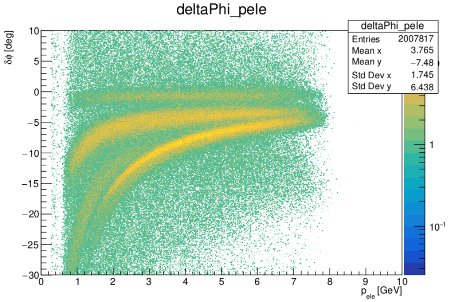
Simulation

- Electrons that radiated (data): 22.7%
- Electrons that radiated (simulation): 21.7%

Momentum dependence of $\delta\phi$



Data



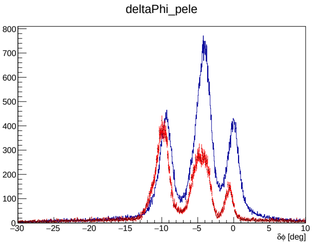
Simulation

- Momentum independent band at $\delta\phi = 0$ - prompt radiation at the vertex
- Momentum dependent bands - radiation downstream the vertex

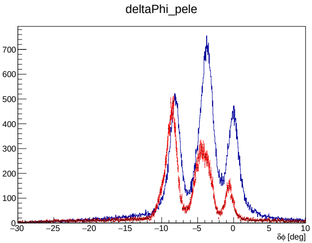
Momentum dependence of $\delta\phi$

- Binning in electron momentum and θ
- blue - data
- red - simulation
- The simulation was scaled to have the same number of radiated photons

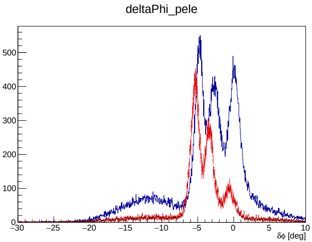
Momentum dependence of $\delta\phi$



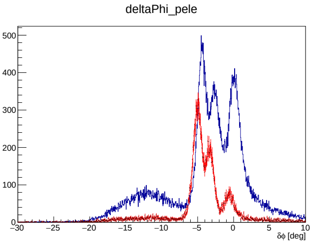
$3 < p < 3.5$



$3.5 < p < 4$

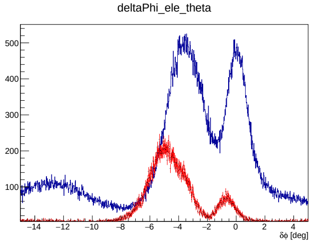


$6 < p < 6.5$

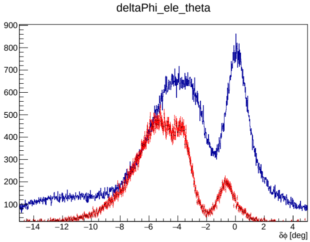


$6.5 < p < 7$

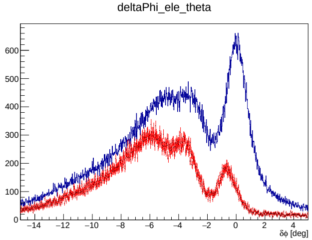
θ dependence of $\delta\phi$



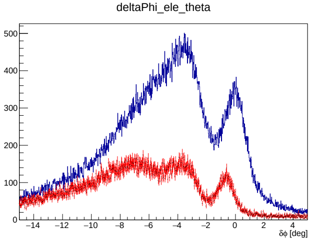
$7.5 < \theta < 10$



$10 < \theta < 12.5$



$12.5 < \theta < 15$



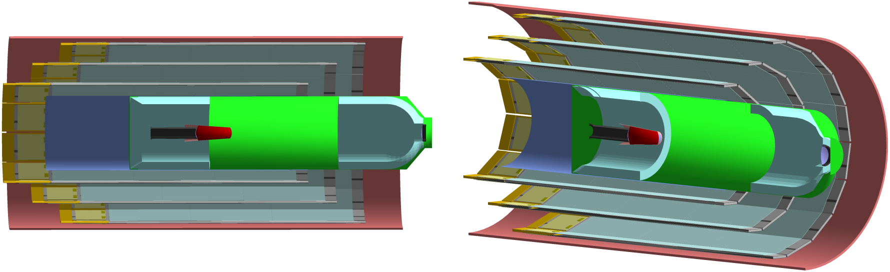
$15 < \theta < 17.5$

Differences between data and simulation - GEMC simulations

- The distribution are very similar in data and simulation, but the relative intensities and the structures are different
- To identify which detector part contribute to a certain peak, simulations were performed with detector parts missing
- 10 million events, rga 2019 spring setting
- Internal generator:
  electrons with 1 GeV<p<11 GeV and $5^\circ < \theta < 31^\circ$

Detector parts taken out

- Parts removed:
  - SVT tungsten shield - dark blue
  - SVT neopreme insulation - red
  - Foam scattering chamber - blue



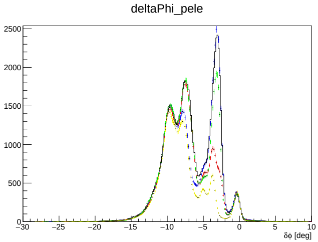
GEMC rendring of the target, scattering chamber, and the SVT

Detector parts taken out

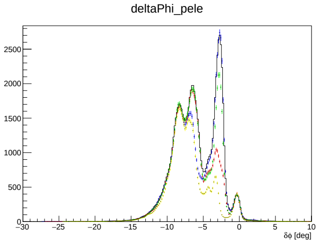
- black - full detector
- blue - SVT neopreme insulation missing
- red - SVT tungsten shield missing
- green - Foam scattering chamber missing
- yellow - all 3 missing

- Normalized with total number of detected electrons

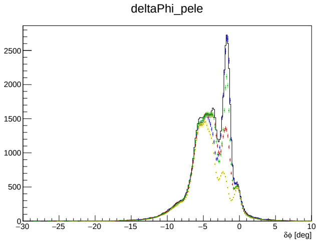
Momentum dependence of $\delta\phi$



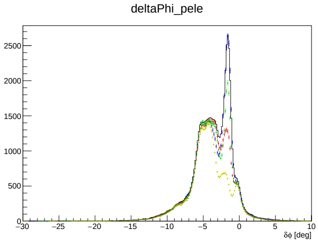
$3 < p < 3.5$



$3.5 < p < 4$

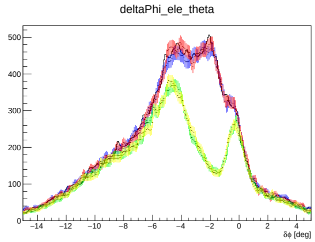


$6 < p < 6.5$

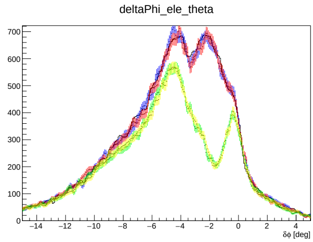


$6.5 < p < 7$

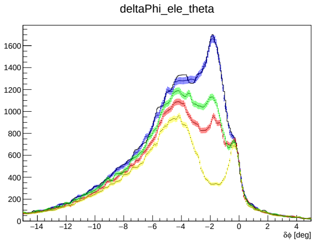
θ dependence of $\delta\phi$



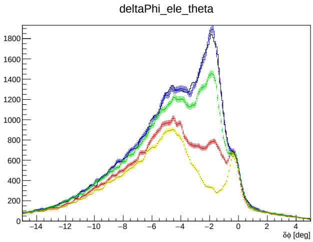
$12.5 < \theta < 15$



$15 < \theta < 17.5$



$20 < \theta < 22.5$



$22.5 < \theta < 25$

Detector parts taken out

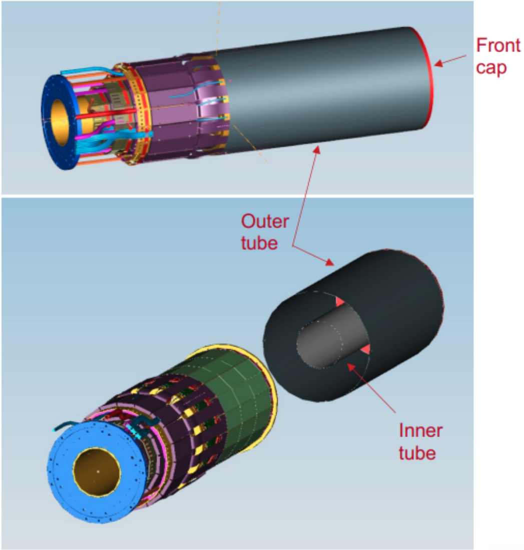
- The scattering chamber has bigger effect at smaller angles
- The SVT shield has bigger effect at higher angles
- They both contribute mainly to the first peak
- The neopreme insulation is responsible for the second peak

- Some material is missing from the SVT geometry
- The neopreme insulation is too dense

New SVT Faraday cage geometry - Raffaella

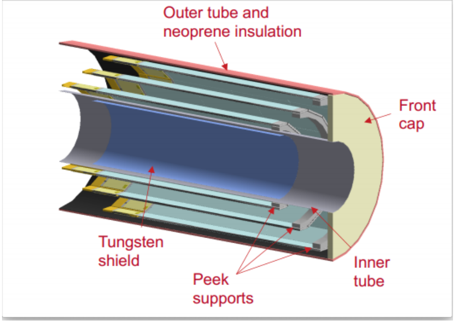
- Composed of:
  - Inner tube made of aluminized mylar:
    - Thickness = 250 um
    - ρ = 1.4 g/cm³
  - Outer carbon fiber tube
    - Thickness =0.5 mm
    - ρ = 1.75 g/cm³
  - Front cap disk made of rohacell with aluminum coating
    - Thickness = 10 mm
    - ρ = 0.11 g/cm³
  - Neoprene thermal insulation:
    - Thickness = 2.7 mm
    - ρ = 1.23 g/cm³

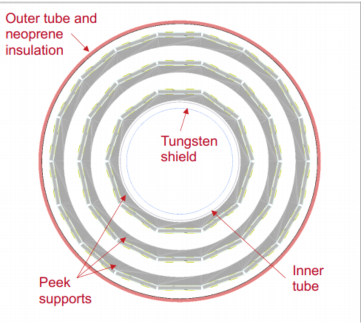
CAD rendering



New SVT geometry - Raffaella

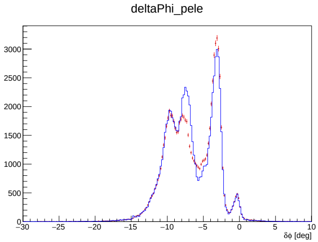
- The thicknesses and densities were updated
- Missing peak support structures were added
- Updated geometry will appear in next GEMC release for CLAS12
- Modified version is available for testing



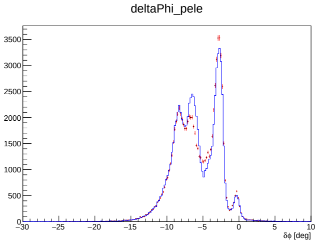


GEMC rendering of the new geometry

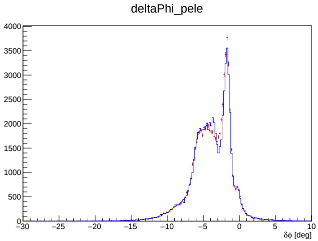
Momentum dependence of $\delta\phi$ - old(blue), new(red)



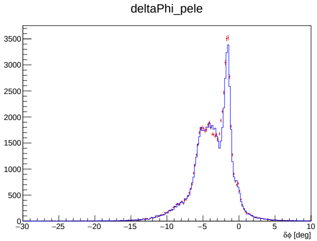
$3 < p < 3.5$



$3.5 < p < 4$

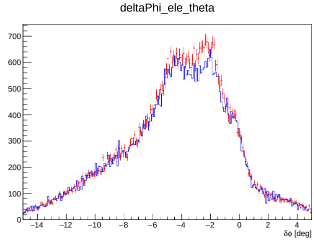


$6 < p < 6.5$

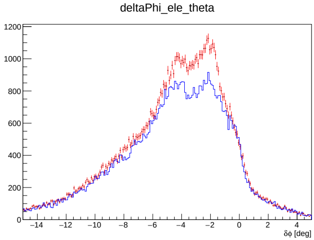


$6.5 < p < 7$

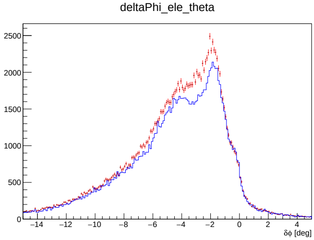
θ dependence of $\delta\phi$ - old(blue), new(red)



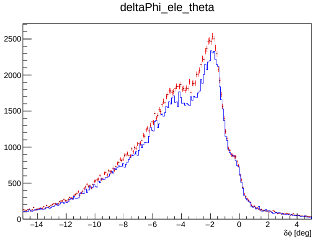
$12.5 < \theta < 15$



$15 < \theta < 17.5$



$20 < \theta < 22.5$



$22.5 < \theta < 25$

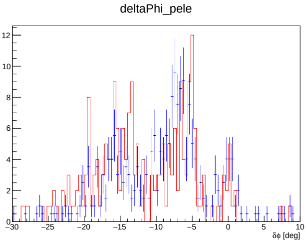
Effects of the new geometry

- More radiation in the first peak
- Less radiation in the second peak

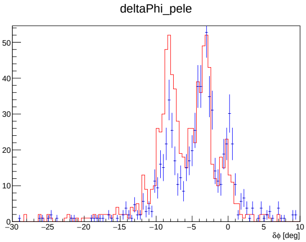
- Comparison between data and simulation with the new geometry
  - SIDIS generator with correct internal radiative effects
  - Slightly different electron distribution - sampling in p-θ bins
    - 10 bins in θ: 10-30
    - 7 bins in momentum: 2-9
    - Only keep lower half: 40 bins in total
    - Maximum 1000 detected electrons per bin

- Normalization: number of events in the histograms
- blue - data
- red - simulation

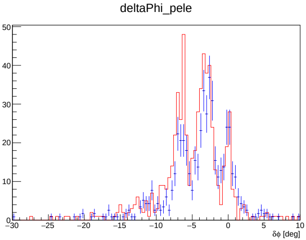
Momentum dependence of $\delta\phi$



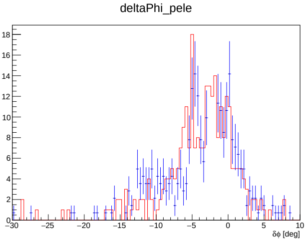
$1.5 < p < 2$



$3.5 < p < 4$

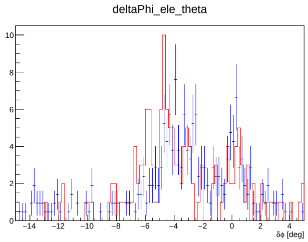


$4.5 < p < 5$

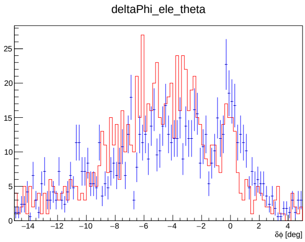


$6 < p < 6.5$

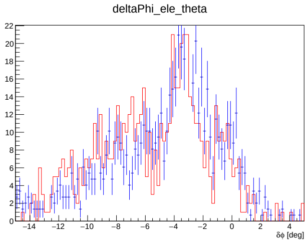
θ dependence of $\delta\phi$



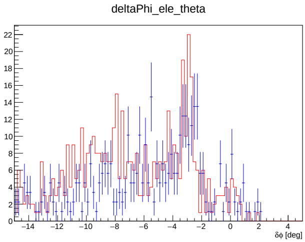
$7.5 < \theta < 10$



$12.5 < \theta < 15$



$17.5 < \theta < 20$



$25 < \theta < 27.5$

Summary and outlook

- Main sources of the radiation were identified
- In the second peak there is still more radiation in the simulation, but the data is much better reproduced with the new SVT geometry
- With this the first phase of this work is done - a note will be written and posted in the CLAS12 note archive

- We plan to continue the studies to correctly implement other parts of the detector that can be identified by studying electron radiation (HTCC inner cone and windows, R1 DC windows, ...)