Update of the forward calorimeter reconstruction at CLIC

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CERN-EP-LCD

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Outline

Focusing on LumiCal reconstruction

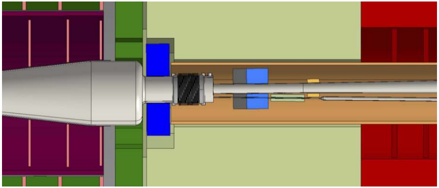
1. Introduction and Previous Studies

2. Polar Angle Reconstruction
   - Polar Bias at Different Energies

3. Summary and Outlook

Forward Calorimeters

- Performance studies of the LumiCal and BeamCal detector and reconstruction software
- LumiCal: radial pads: 64, $\Delta_\theta = 1.47\,\mathrm{mrad}$



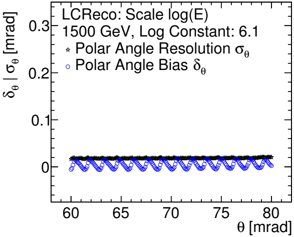
	Z_{start} [mm]	Z_{end} [mm]	R_{in} [mm]	R_{out} [mm]	θ_{min} [mrad]	θ_{max} [mrad]
LumiCal	2539	2710	100	340	39	134
BeamCal	3181	3441	32	150	10	46

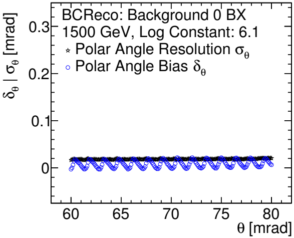
Previously…

Previously reported polar angle reconstruction for LumiCal:

- resolution $\sigma_\theta = 20\,\mu\text{rad}$
- bias δ_θ fluctuating from $\approx -2\,\mu\text{rad}$ to $20\,\mu\text{rad}$
  - Same result with `LumiCalClusterer` or `BeamCalClusterReco`
- depends on where in the LumiCal pad layout the shower has its core

…this time, looking more systematically at polar angle reconstruction in LumiCal





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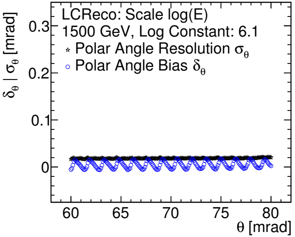
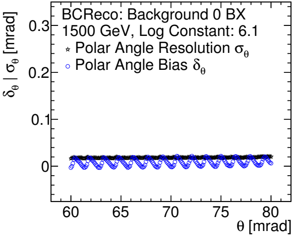




- bias in the angular measurements (systematic shift to be quantified)

(From W. Lohmann: Introduction to the Workshop)

Reconstruction and Simulation

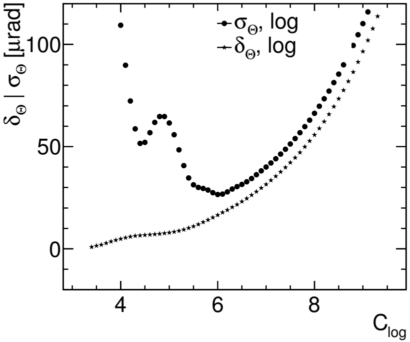
- Simulation done using LCGEO and DD4HEP
- Reconstruction done with `BeamCalClusterReco` from the FCALCLUSTERER package based on MARLIN
- LumiCal from the CLIC_o3_v14 detector model
- 100k electrons with fixed 1.5 TeV from 60 mrad to 80 mrad, flat in theta
- All angles given in the LumiCal frame of reference
- Averages and variances calculated from distribution, no fits done
  - Calculations done with `boost::accumulators` or `ROOT::TProfile`

Polar Angle Reconstruction I

- Logarithmic weighting of pad energy E_i divided by cluster energy E_{tot}

$$w_i = \max\left(0, C_{\log} + \log\left(E_i / E_{tot}\right)\right) \quad (1)$$

- Scanning over $C_{\log}$ lets us find optimal value with minimal resolution: $C_{\log} = 6.7$
- Bias strongly increases with growing $C_{\log}$
- Optimum $C_{\log} = 6.0$, $\sigma_\theta = 27\,\mu\text{rad}$, $\delta_\theta = 17\,\mu\text{rad}$



Polar Angle Reconstruction II

- LumiCal sensor pad area grows with increasing radius

$$A(R) = \frac{\phi}{2}(2R\Delta_\mathrm{R} + \Delta_\mathrm{R}^2) \qquad (2)$$

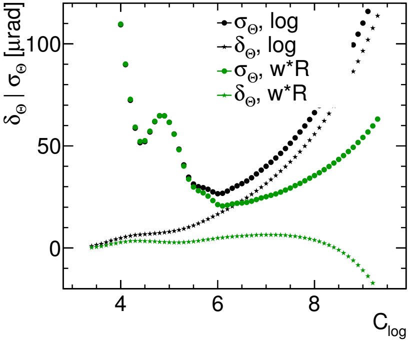
- Scale weight from eq. (1)

$$w_i^{S1} = \max\left(0, \frac{A(R_\mathrm{min})}{A(R_\mathrm{pad})}\left(C_\mathrm{log} + \log\left(\frac{E_i}{E_\mathrm{tot}}\right)\right)\right) \qquad (3)$$

(yes, actually multiplying w, not just the result of log, not sure if this is a bug or feature)

  - ϕ cancels, $\Delta_\mathrm{R}^2 \ll 2R\Delta_\mathrm{R}$, basically scaling R_min/R

- Optimum $C_\mathrm{log} = 6.1$, $\sigma_\theta = 20\,\mu\mathrm{rad}$, $\delta_\theta = 6\,\mu\mathrm{rad}$
- Better resolution, smaller bias

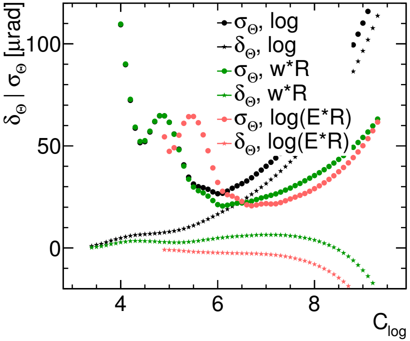


Polar Angle Reconstruction III

- Scale energy ratio from eq. (1)

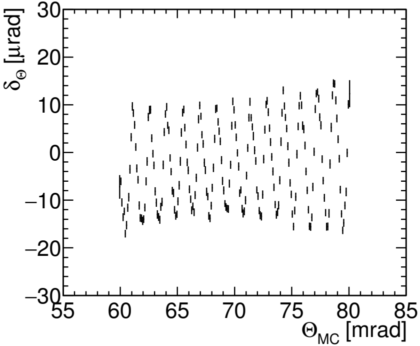
$$w_i^{S2} = \max\left(0, C_{\log} + \log\left(\frac{E_i}{E_{\mathrm{tot}}}\frac{A(R_{\min})}{A(R_{\mathrm{pad}})}\right)\right) \quad (4)$$

- Different scaling moves curves with respect to $C_{\log}$
- Optimum $C_{\log} = 6.7$, $\sigma_\theta = 20\,\mu\mathrm{rad}$, $\delta_\theta = -2\,\mu\mathrm{rad}$
- I also tried this before, but did not scan full $C_{\log}$ range, so discarded then, but actually this makes more sense



Polar Angle Bias

- Achieved very small average bias, but polar angle bias depends on polar angle
- Luminosity measurement depends on the bias at the *edges* of the fiducial volume
- Can we correct for this behaviour…

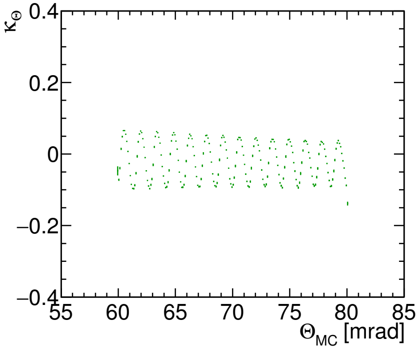


Correcting Polar Angle Bias I

- Define κ as the difference in the energy of the shower above and below the *reconstructed* polar angle

$$\kappa = \frac{E_{\text{Above}} - E_{\text{Below}}}{E_{\text{Above}} + E_{\text{Below}}} \qquad (5)$$

  - Split the energy in the central ring around the reconstructed polar angle into above and below
- κ shows similar behaviour to δ_θ, due to definition shifted by half a phase



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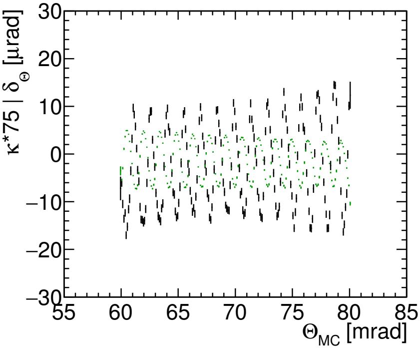

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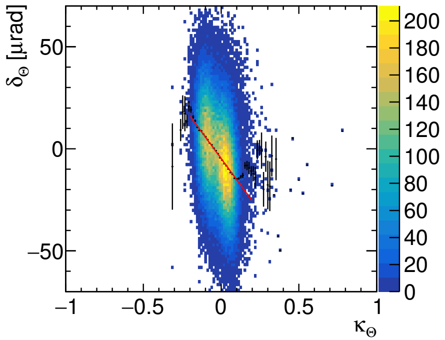
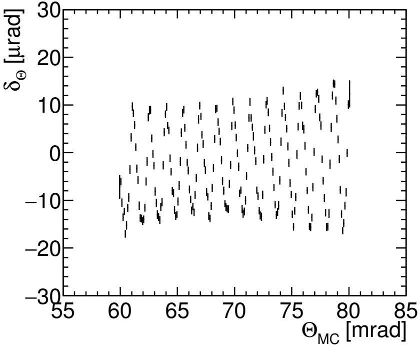
- Use linear function the obtain relation ship between κ and δ_θ, contains MC information
- Not really great correlation, very broad in δ_θ



Correcting Polar Angle Bias II

- Use fitted relation between κ and δ_θ to correct polar angle
- **Before:**
  - $\sigma_\theta = 20.6\,\mu\text{rad}$
  - $\delta_\theta = -2.7\,\mu\text{rad}$
- After:
  - $\sigma_\theta = 19.0\,\mu\text{rad}$
  - $\delta_\theta = 0.05\,\mu\text{rad}$
- While it reduces the average bias, and somewhat the amplitude, the behaviour is still not flat
- Needs further work, maybe a correction depending on κ and θ_{reco}
  - Interested to see work by A. Joffe



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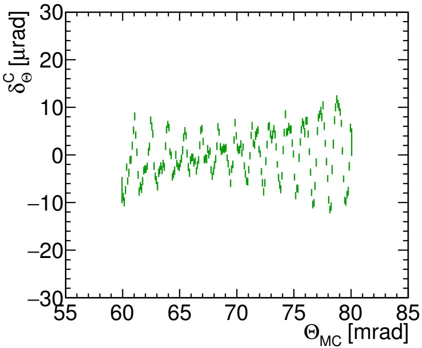

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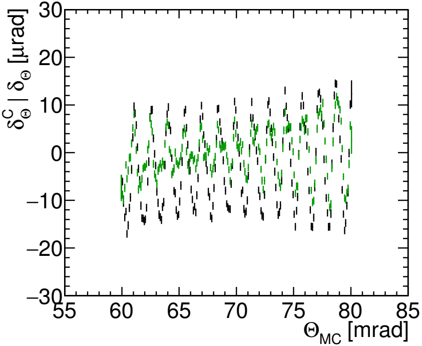
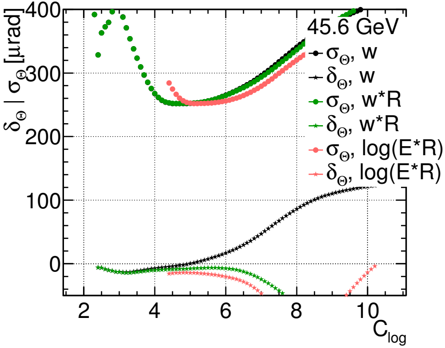


Polar Bias at Different Energies

- Following up to yesterday's presentations, brief look also at different energies: 45.6 GeV and 250 GeV
- Using the same CLIC_o3_v14 detector model, same reconstruction parameters
- Larger radial pad sizes in the CLIC LumiCal lead to worse resolution than in LumiCal's optimised for different detectors

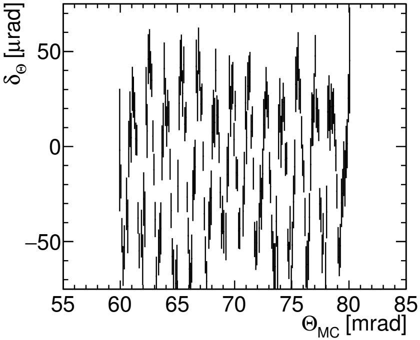
45.6 GeV

- Bias becomes larger with scaling according to eq. (4)
  - Need to implement a flag to chose which scaling to use



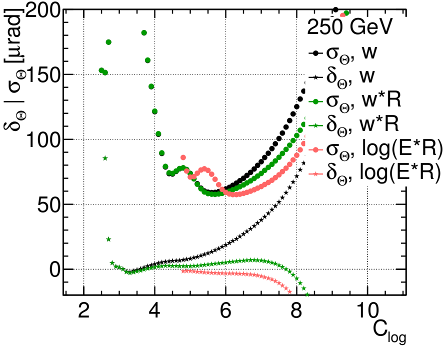
45.6 GeV

- Bias becomes larger with scaling according to eq. (4)
  - Need to implement a flag to chose which scaling to use
- Also for these electrons, polar angle bias depends on polar angle, at least in this geometry



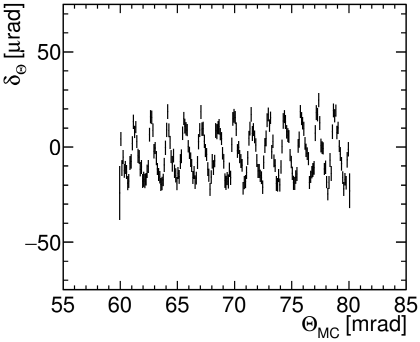
250 GeV

- For 250 GeV eq. (4) gives smaller bias



250 GeV

- For 250 GeV eq. (4) gives smaller bias
- And also fluctuation depending on polar angle

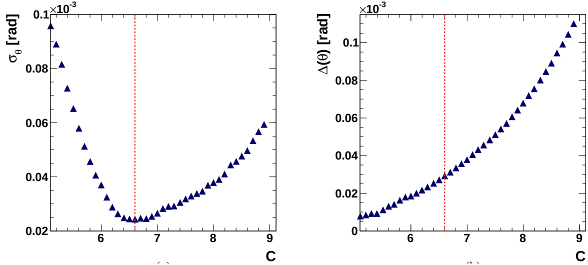


Summary and Outlook

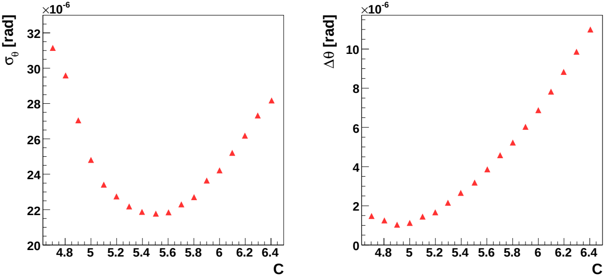
- Depending on the weighting used to reconstruct polar angle, resolution and bias can be greatly affected
- Average polar angle bias can be reduced to so μrad levels for CLIC LumiCal at 1.5 TeV
- Further work needed to reduce the polar angle dependent bias
- Study performance of LumiCal and BeamCal reconstruction with combined $\gamma\gamma \to$ hadron and incoherent pair backgrounds

Backup Slides

Polar Angle Reconstruction



LCD-Note-2009-002, 1.5 TeV electrons, LumiCal for CLIC



I. Sadeh, MsC, 250 GeV electrons, LumiCal for ILC