



FCal: Validation and Performances

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CERN-EP-LCD

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1 Detectors and Software

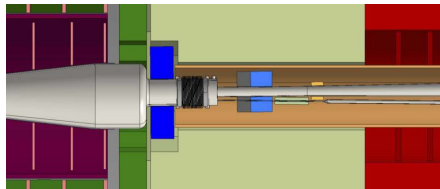
2 LumiCal Performance

- Polar Angle Resolution
- LumiCal Reconstruction with Overlaid Background

3 BeamCal Performance

4 Summary

- Performance studies of the **LumiCal** and **BeamCal** detector and reconstruction software



	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

LumiCalClusterer

- Nearest-neighbour clustering, optimised to separate Bhabha electrons from nearby final state radiation photons

BeamCalClusterReco

- Two reconstruction approaches: Nearest-neighbour clustering; shower fitting
- Different methods of generating incoherent pair background: Simulated bunch crossings, averages, Gaussian, parametrisation, *None*
- Subtraction of of incoherent pair background

Repository on Github <http://github.com/FCalSW/FCalClusterer.git>

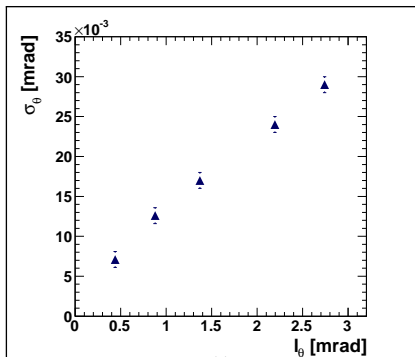
■ More automatic tests to ensure proper position reconstruction

```
Start 1: t_BeamCalReco
1/4 Test #1: t_BeamCalReco ..... Passed    4.88 sec
Start 2: t_LumiCalReco
2/4 Test #2: t_LumiCalReco ..... Passed    0.79 sec
Start 3: t_TestLumi2Clu
3/4 Test #3: t_TestLumi2Clu ..... Passed    0.82 sec
Start 4: t_NewLumimCalReco
4/4 Test #4: t_NewLumimCalReco ..... Passed    2.41 sec
```

LumiCal Parameters, Expected Performance



- Z: 2539 mm
- Inner Radius: 100 mm, 40 mrad
- Outer Radius: 340 mm, 134 mrad
- Radial cells: 64, 1.47 mrad
- Expect polar angle resolution of about 0.020 mrad

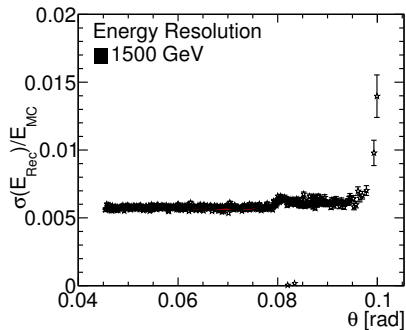
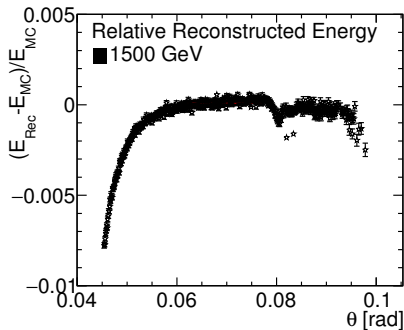


From LCD-Note-2009-002, 1.5 TeV electrons, optimised log constant

Energy Calibration



- Obtain fiducial volume based on constant reconstructed energy
- Change calibration factor until correct energy is reconstructed
- Bias in energy reconstruction, while resolution is constant in larger range
 - ▶ Shape after 80 mrad due to selection of well reconstructed events, reduced efficiencies because of beam-pipe shadow on LumiCal
- Used $62 \text{ mrad} < \theta < 77 \text{ mrad}$ to estimate energy resolution
- Limit further studies at the moment to $62.5 \text{ mrad} < \theta < 88 \text{ mrad}$ to limit reconstruction time



Polar Angle Resolution: Previously

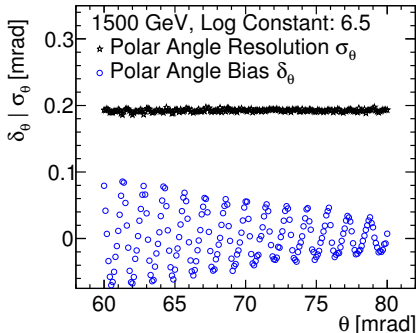


- Polar angle resolution 10 times worse than previously estimated
- Theta calculated from x/y/z average.

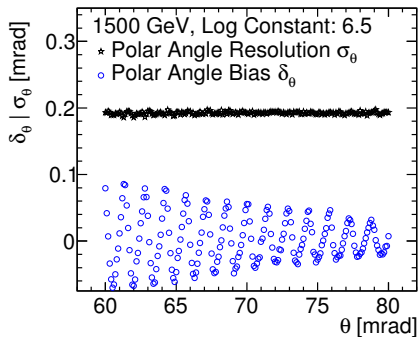
$$\bar{x}_i = \frac{\sum_{\text{Hits}} w_{\text{Hit}} x_{\text{Hit}}}{\sum_{\text{Hits}} w_{\text{Hit}}}$$

Energy weighted by

$$w_{\text{Hit}} = \max\left(0.0, \log\left(C + \frac{E_{\text{Hit}}}{E_{\text{Cluster}}}\right)\right)$$



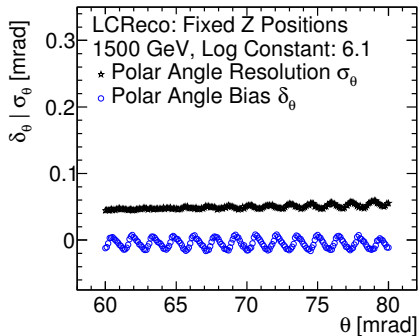
■ Previously



Bugs, Fixes, and Resolutions



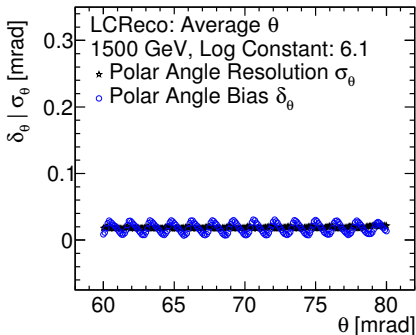
- Previously
- Fix Z-position of layers, fix layer starting with 0, place hit in middle of sensitive



Bugs, Fixes, and Resolutions



- Previously
- Fix Z-position of layers, fix layer starting with 0, place hit in middle of sensitive
- Average over polar angle instead of Cartesian coordinates. Recovered previously estimated polar angle resolutions



Weighting Cells by cell Area



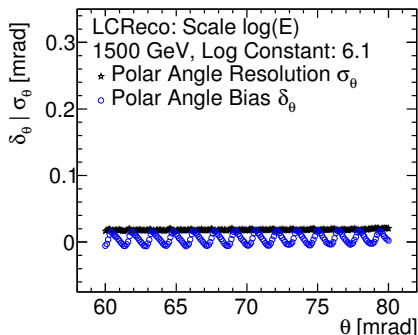
- Cell area grows by radius, larger cells receive larger energy deposit

$$A = R_{\text{cell}} \Delta\phi \Delta R \quad (1)$$

ΔR and $\Delta\phi$ are constant, area only scales by R . Neglecting $(\Delta R)^2$ term for arc segments.

- Scale cell weights with $R_{\text{min}}/R_{\text{cell}}$

$$w_{\text{Hit}} = \max\left(0.0, \log\left(C + \frac{E_{\text{Hit}}}{E_{\text{Cluster}}}\right) \frac{R_{\text{min}}}{R_{\text{cell}}}\right)$$



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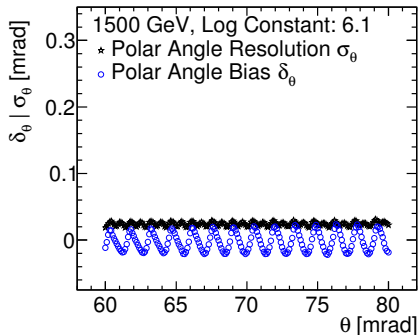
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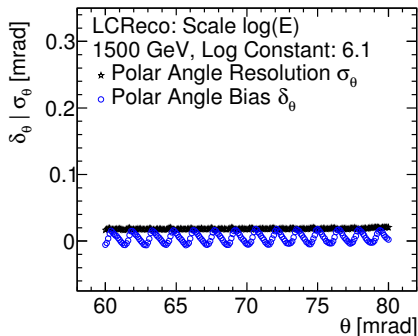
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- Chose to keep this scaling implemented

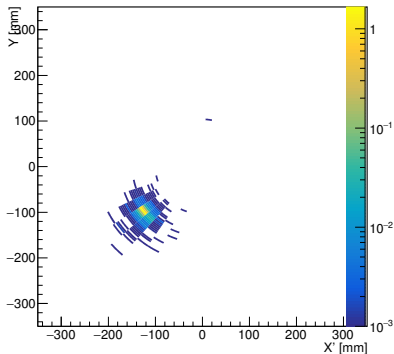


LumiCal Reconstruction with Background

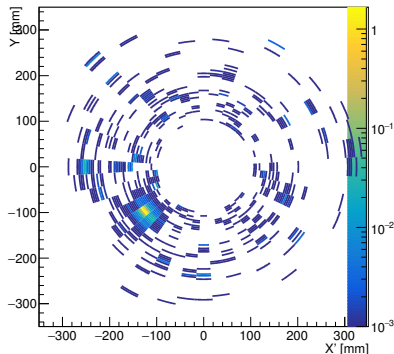


- Many particles from $\gamma\gamma \rightarrow$ hadrons impact the LumiCal

No background



30 BX $\gamma\gamma \rightarrow$ hadrons background



- LumiCal clustering does not gracefully handle more than 2 showers, merges them all in to a single cluster

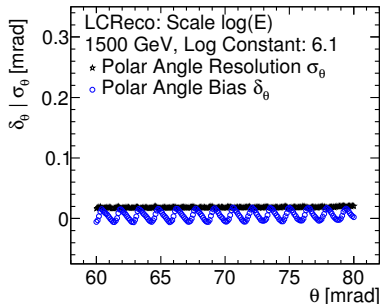
- ▶ Very hard to disentangle

→ Apply reconstruction for BeamCal to LumiCal: better control over cluster merging



- Improved polar angle reconstruction in BeamCal Reco: log-weighting
- Implement reading segmentation class of LumiCal
- Add maximum distance cut for pad merging

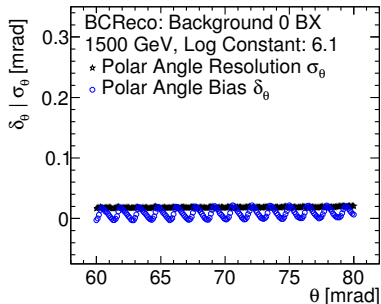
- Polar angle with LumiCal reconstruction



Polar Angle Resolutions



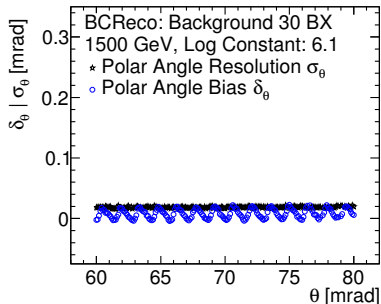
- Polar angle with BeamCal reconstruction



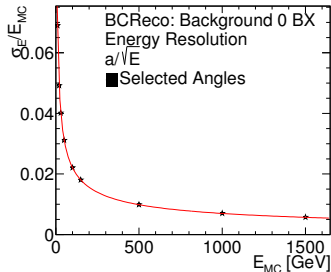
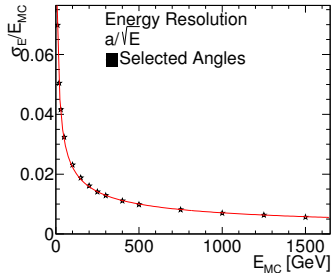
Polar Angle Resolutions



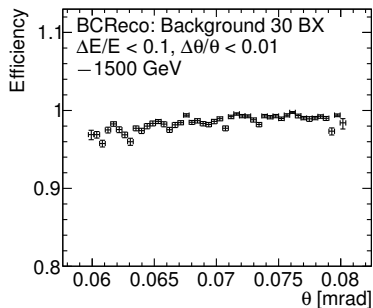
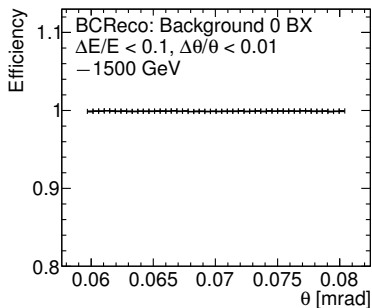
- Polar angle with BeamCal reconstruction and background overlaid



- Same energy resolution with LCReco(top) or BCReco(bottom) without background
 - ▶ $\sigma E/E = a/\sqrt{E[\text{GeV}]}$
 - ▶ $a = 0.22$, constant term negligible, no gaps or noise
- With backgrounds (not shown) worse energy resolution, larger bias
 - ▶ need to recalibrate
 - ▶ Some samples not reconstructed yet



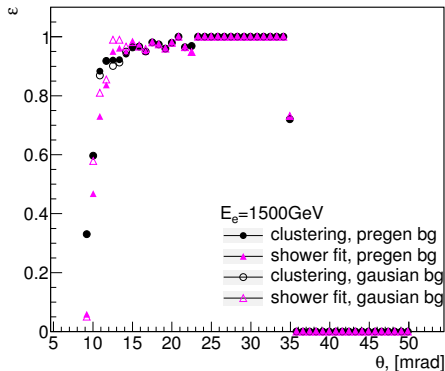
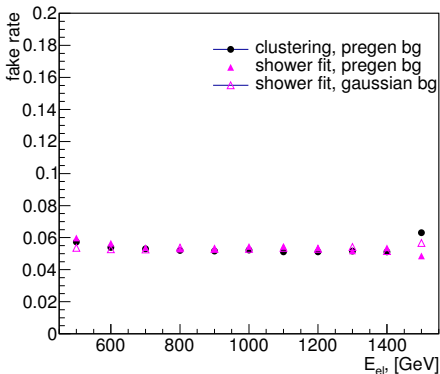
■ Reconstruction efficiencies affected by background



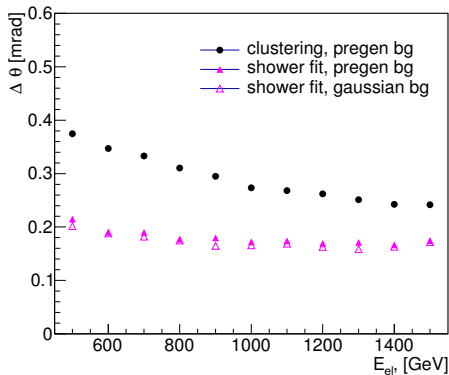
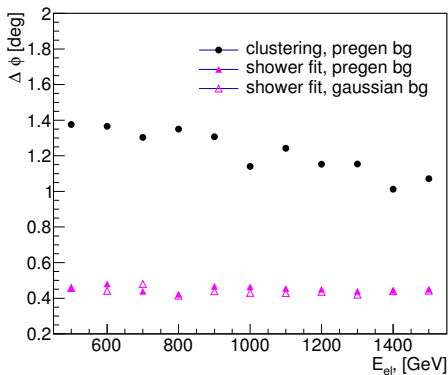
BeamCal Reconstruction Efficiency



- Fake rate and reconstruction efficiency of 1.5 TeV electrons with 40 BX of CLIC 3 TeV incoherent pair background
- Reconstruction can be tuned to reduce fake rate or increase efficiency



■ Angular resolutions generally better with shower fitting reconstruction



LumiCal Reconstruction

- Recovered previously estimated polar angle resolution
- Successfully adapted BeamCal clustering for LumiCal, including $\gamma\gamma \rightarrow$ hadrons background
- Background affects resolutions and efficiencies

BeamCal Reconstruction

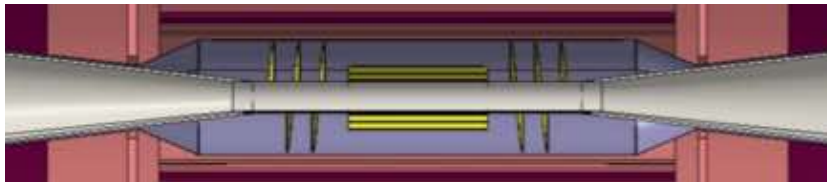
- No major changes for BeamCal reconstruction
- Added 380 GeV background file

Acknowledgements



Many thanks to Yorgos Voutsinas, Alon Joffe, Jean-Jacques Blaising for their pointing out problems in the reconstruction, bugs and solutions

Backup Slides



- Last part of cylindrical beampipe cuts into LumiCal acceptance at $R=29.4$ mm, $Z=337$ mm, corresponds to 79 mrad including Lorentz Boost