TB2003 Topological Clustering Algorithms for Electrons in Position 4L

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1 Introduction

This document presents a first look at eight different topological clustering algorithms for electrons in the 4L position, to give confidence to this clustering algorithm, with the future intent of analyzing the remaining positions with topological clustering. The results presented in this document are post-athena, post-merger, post beam-cleaning and beam envelope cuts. However the halfling timing cuts have not been applied (these had a larger effect on pions anyway). This analysis was carried out in Athena 13.0.40. The electron energy distributions are shown in ADC counts, and are fit to a 6-parameter double Gaussian (vs the now standard 4-parameter double Gaussian, as with each clustering configuration the input constraining parameters would need to be changed slightly). The pion peak in the electron distributions is not included in the fit (as previously shown this had little effect on the resulting fit parameters because of good beam cleaning), this has been neglected because the pion data is still running. For comparison, when possible, results when clustering with an 8 cm cylinder cluster are presented with the same cuts as above (this will result in slightly different numbers from those published in the final paper). Only cells clustered in FCal1 are considered.

1.1 Seed, Neighbor, Cell Noise Sigma Cuts

In the topological clustering algorithm clusters are formed based on the cell energy over noise significance. In the default algorithm, a cluster is seeded in the hadronic calorimeters by a cell if it has an energy over noise significance greater than four. A 4σ cut implies that statisically only 0.006 % of clusters will be seeded by a noise and not true signal energy. A cluster is expanded upon by examining the cell energy significance of neighboring cells. Neighboring cells in the FCal are cells that share a common edge of the same FCal module (typically the 4 cells above, below, to the left and right, and the 4 cells on the corners for a total of 8 neighboring cells), and cells that are located in the previous or next module that cover the same η and ϕ region. By default for the hadronic calorimeters a neighbor cell energy significance of two is required to expand the cluster. The last configurable option is the cell energy significance, these are neighboring cells that are included by default in the cluster if they neighbor a cell that is already included in the cluster. By default, this value for the cell energy significance is zero. The FCal is considered a hadronic calorimeter in the Athena software, and as such has a default topological clustering configuration of: seed/neighbor/cell = $4\sigma/2\sigma/0\sigma$. It will be interesting to study some different seed/neighbor/cell configurations to verify the default selection. It should be noted that for electromagnetic calorimeters the default is seed/neighbor/cell = $6\sigma/3\sigma/3\sigma$, but typically the FCal is seen as a fully hadronic calorimeter, and this configuration is never used, hence it has not been tested.

In the test beam 2003 we use noise files generated on a run-by-run and cell-by-cell basis to identify the noise in a given cell for a given run.

2 Energy Distributions, Linearity and Residual

Sample energy distributions for topological clustering 4/2/0 is shown in Figure 1. Similar distributions and fit exist for the other topological clustering configurations. One concern with the topological clustering technique was the noise subtraction, since the topocluster clusters a different number of cells each event, the worry was that the noise distribution (summing the energy from pedestal runs of the same cells that are clustered in the physics data) would not be centered at zero, or would have some non-Gaussian shape. The noise distributions for 4/2/0 are shown in Figure2, where there are similar distributions for the other configuraitons. The distributions appear to be Gaussian, and well behaved like the cylinder clustering technique. Therefore, in calculating the energy resolution the noise has been subtracted in quadrature from the signal rms. In the fits the beam energy for the 150 GeV electron beam is taken to be 147.8 GeV, and the 200 GeV electron beam is taken to be 193.1 GeV.

The linearity and residual from the linearity fit are shown in Figures 3 and 4, respectively. Note that the channel-to-channel correction (which is the mean fitted energy divided by 0.987) has been applied. For the 8 cm cylinder clustering, with the same cuts applied, the linearity yields a slope of 12.075 ADC/GeV and an intercept of -12.258 ADC. For reference, the published 4L 8 cm cylinder cluster results have a slope of 12.074 ADC/GeV and an intercept of -12.270 ADC.

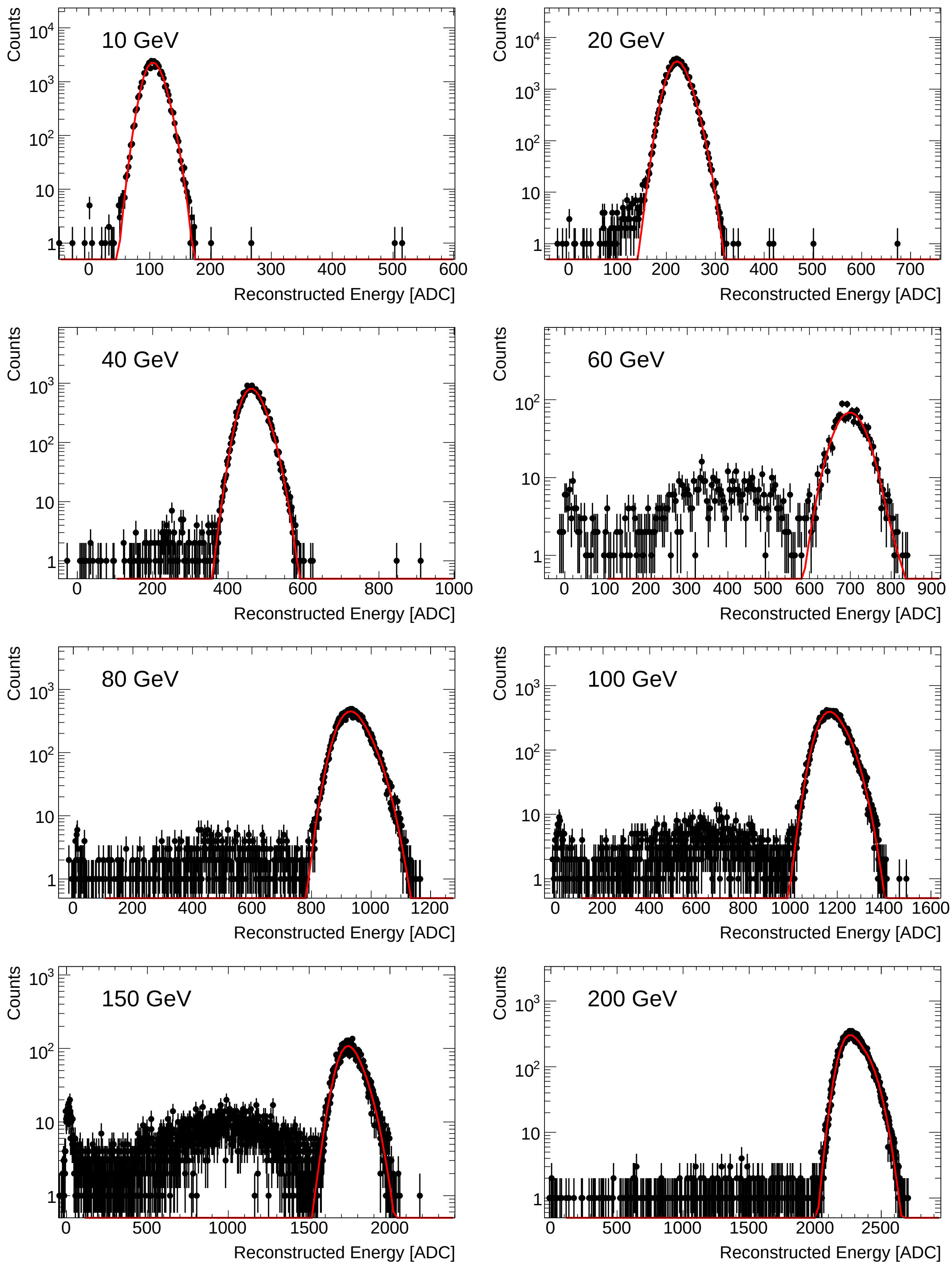


Figure 1: Electron energy distributions (in ADC) when the data are clustered using topological clustering configuration 4/2/0. The double Gaussian fit results are superimposed.

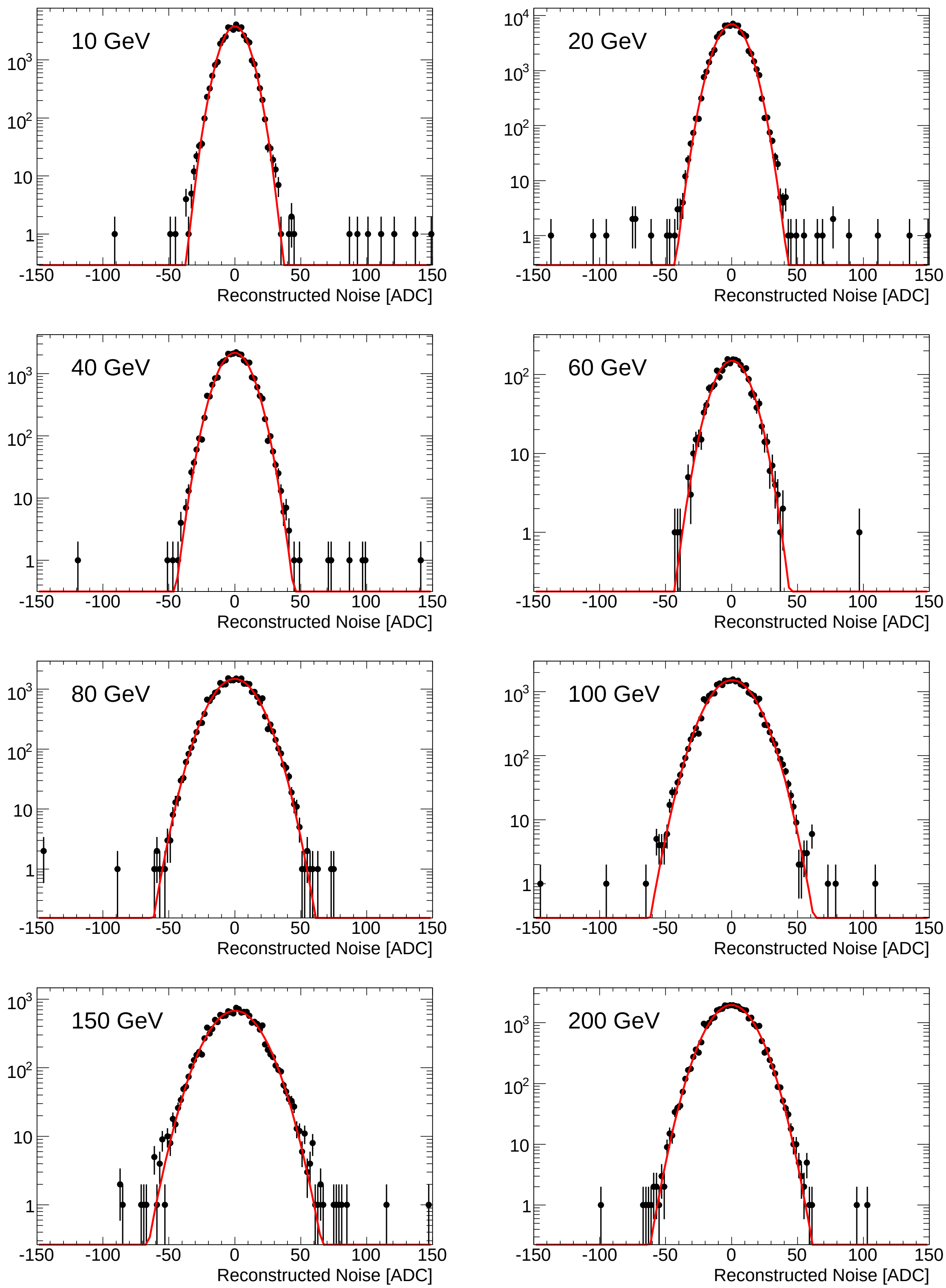
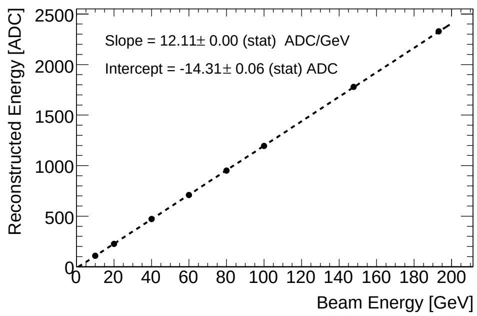
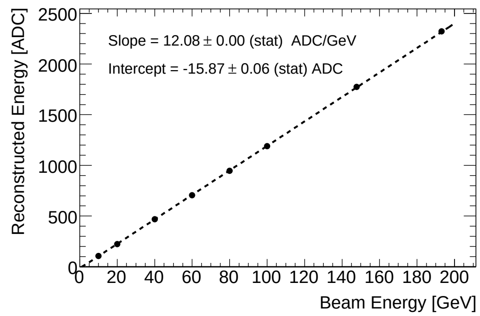


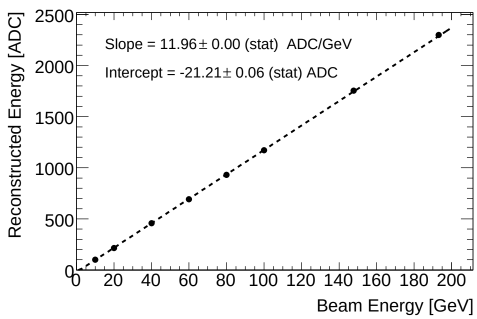
Figure 2: Electron noise energy distributions (in ADC) when the data are clustered using topological clustering configuration 4/2/0. The single Gaussian fit results are superimposed.



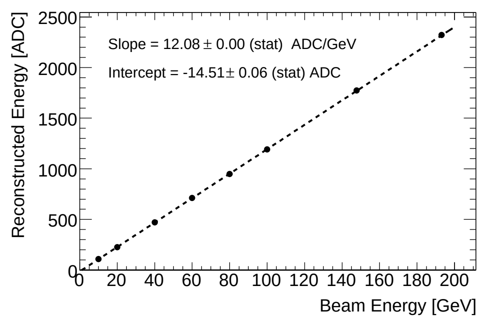
(a) t420



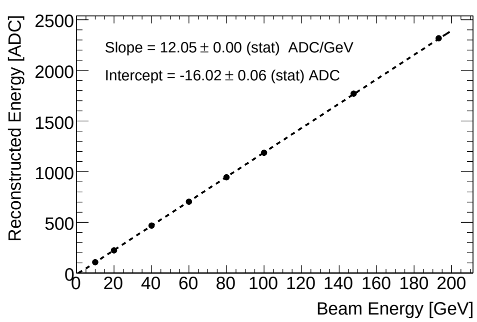
(b) t421



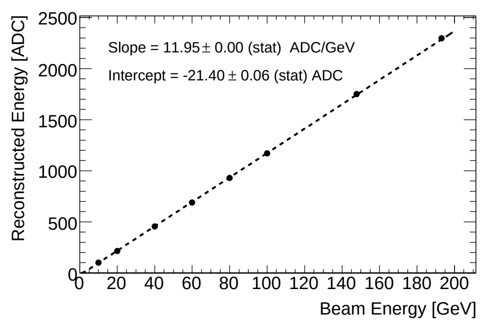
(c) t422



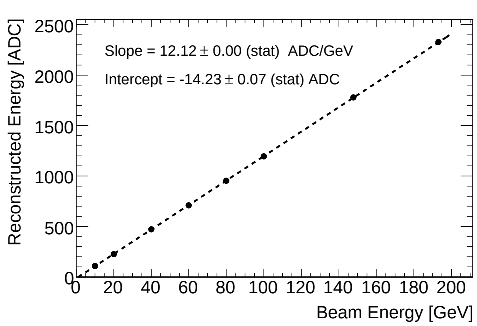
(d) t430



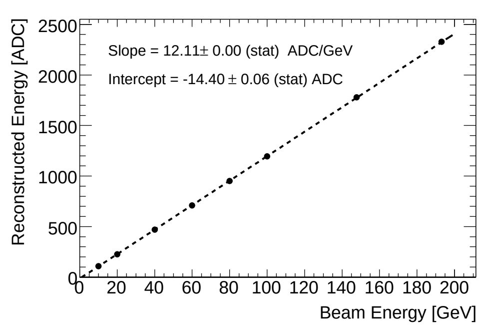
(e) t431



(f) t432

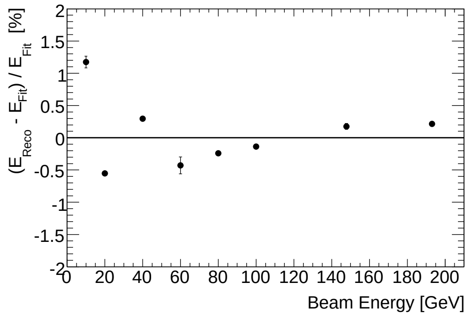


(g) t320

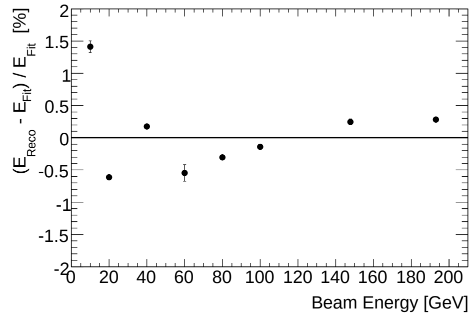


(h) t520

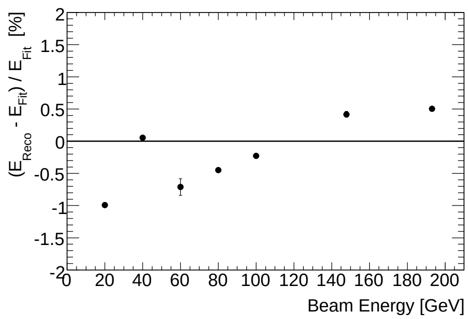
Figure 3: Electron linearity (reconstructed mean energy [ADC] vs beam energy [GeV]), for the various topological clustering algorithms.



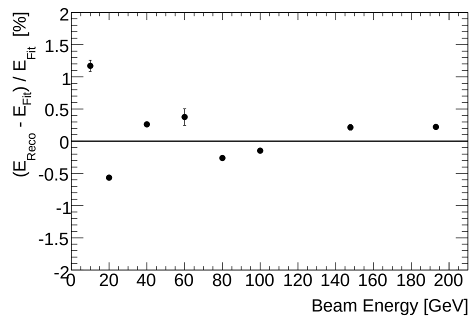
(a) t420



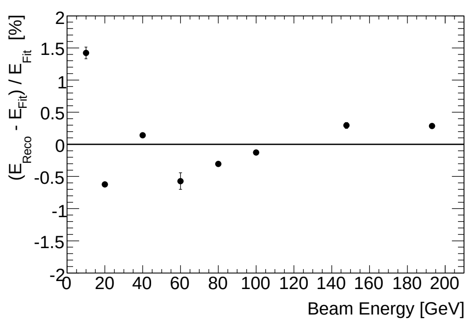
(b) t421



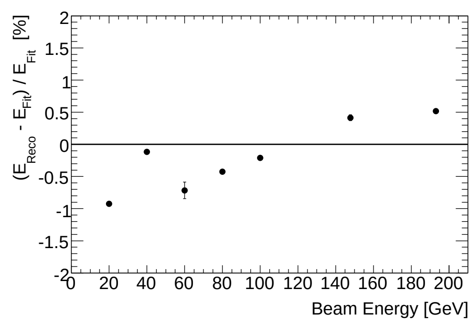
(c) t422



(d) t430



(e) t431



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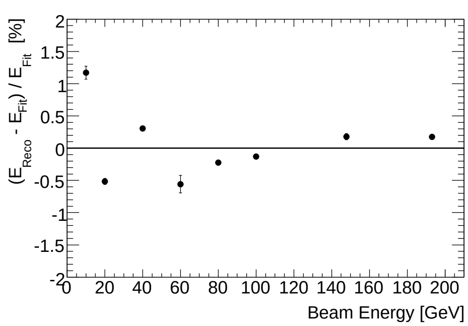
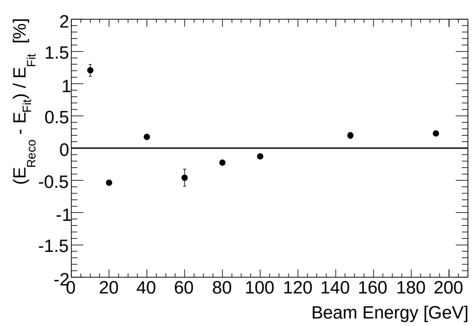


(g) t320



(h) t520

Figure 4: Electron residual, difference from linearity fit, for the various topological clustering algorithms.

3 Energy Resolution

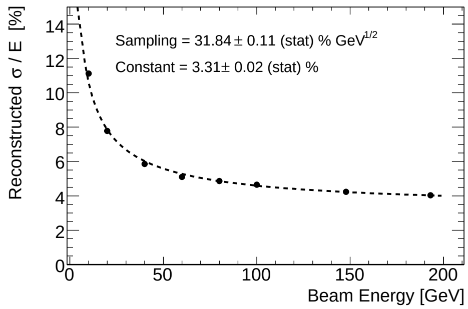
The (noise subtracted) energy resolution points used for all energies for each clustering configuration are shown in Table 1. These points are fit to the noise subtracted energy resolution function:

$$\frac{\sigma}{E} = \frac{a}{\sqrt{E}} \oplus b \tag{1}$$

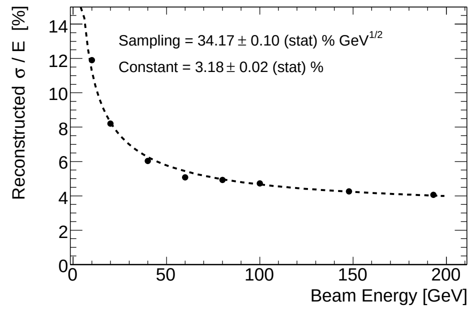
where as is the sampling term and b is the constant term. The resulting fits for a and b are shown on the respective energy resolution figures for each clustering type, shown in Figure 5. For reference, the 8 cm cylinder cluster (with the same cuts as above) had fit results for the sampling term of 28.34 % GeV$^{1/2}$ and a constant term of 3.51 %.

	10 GeV	20 GeV	40 GeV	60 GeV	80 GeV	100 GeV	150 GeV	200 GeV
t420	11.122	7.783	5.860	5.101	4.864	4.649	4.237	4.033
t421	11.908	8.202	6.029	5.080	4.925	4.720	4.256	4.054
t422	10.838	8.435	6.150	5.212	5.061	4.803	4.341	4.031
t430	10.729	7.687	5.837	nan	4.843	4.612	4.207	4.033
t431	11.623	8.071	5.991	5.088	4.931	4.702	4.255	4.076
t432	12.318	8.394	6.146	5.176	5.047	4.796	4.329	4.107
t320	12.814	8.446	6.089	5.102	5.048	4.731	4.290	4.073
t520	11.211	7.780	6.453	5.036	4.846	4.635	4.243	4.034
c8	9.724	7.243	5.636	4.960	4.738	4.592	4.227	4.041

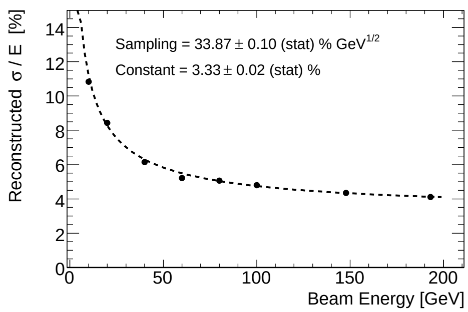
Table 1: Energy resolution (sigma/mean) [%] after noise has been subtracted in quadrature for the various topological seed/neighbor/cell configurations. Note the fitted rms for the 60 GeV point for t430 had some problems (this is a very low statistics energy point), resulting in a bad energy resolution value. For comparison the 8 cm cylinder clustering is shown, where the same cuts have been applied.



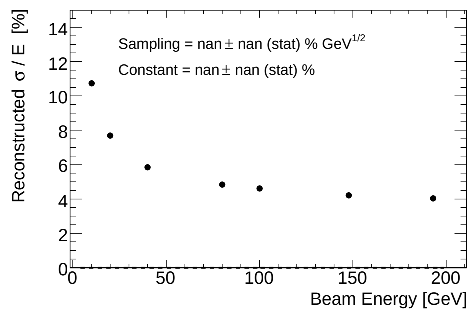
(a) t420



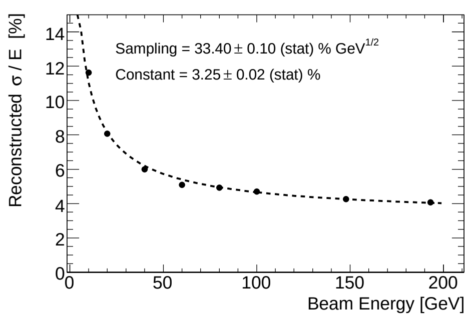
(b) t421



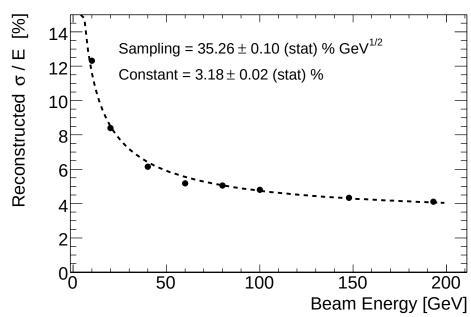
(c) t422



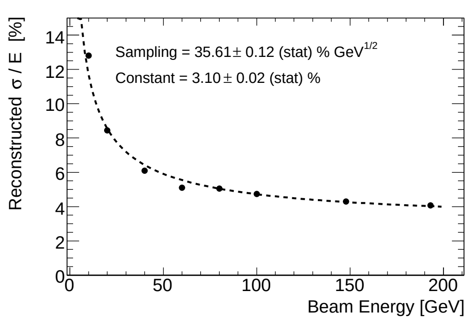
(d) t430



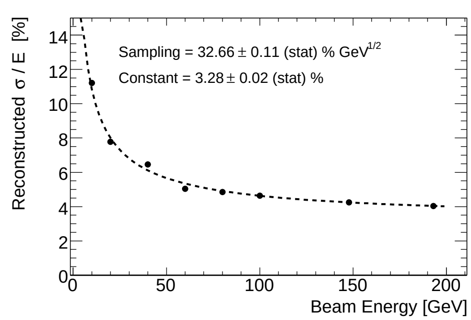
(e) t431



(f) t432



(g) t320



(h) t520

Figure 5: Electron energy resolution functions for the various topological clustering algorithms.

4 Summary

It appears that the different topological clustering algorithms converge as one gets to higher beam energies (looking at the energy resolution). At these high energies the topological clustering agrees well with the cylinderical clustering. In looking at the reconstructed mean energy, for low energies the topological clustering does not cluster as much energy as the cylinder cluser, which might be expected due to the poor signal over noise in most channels (vs the fixed cylinder size). Overall the topological clustering algorithm yields good results for the FCal TB, and can be considered equivalent to that of the cylinder clustering. The results validate the use of the topological clustering for future analyzes. The seed/neighbor/cell configuration of 4/2/0 appears to result in sampling and constant tersm comparable to the other configurations studied here, and can be used as the default clustering configuration, with others used as a systematic check.