The reconstruction code for the electromagnetic calorimeter in ATRECON

Version 97_3

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Last update: 22 March 1997

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Chapter 1

Introduction

This note describes the algorithms used in the reconstruction code for the electromagnetic (EM) calorimeters in ATRECON, the available output quantities and some routines useful for the user's analysis.

The philosophy of the EM reconstruction code is to provide the user with reconstructed quantities containing our best knowledge of the detector and of the reconstruction algorithms, with all relevant corrections. The definition of the reconstructed quantities and of the algorithms has benefitted from the writing of the TDR, for which some needs were identified.

The current reconstruction code takes into account this experience. It is compatible at least with events generated with DICE 96_11 or later versions.

Chapter 2

Description of the EM reconstruction code

2.1 Description of the program flow

Figure 2.1 shows the program flow in ATRECON. The routines with a name starting with "calo" are common to all calorimeters. The routines with a name starting with "ecal" are specific to the EM reconstruction.

The reconstruction proceeds in two steps:

- the DIGIs are put into matrices after a cell to cell calibration and, optionally, the addition of electronic noise and a threshold cut. The output of this step is a set of matrices, one per region of uniform granularity. An alternative solution would be to have a linear list of cells.
- starting from the matrices, clusters are found and analyzed. A sliding window is used as clustering algorithm, with the window sliding on a "combined" matrix, which sums the energies of all samplings, without the presampler, after mapping of the cells onto the granularity of sampling 2. The output of the clustering algorithm is a list of (η, ϕ)'s, around which subsequent quantities are computed.

The following sections describe all the steps and algorithms.

2.2 Cell to cell energy calibration

A cell to cell calibration is needed as a first step to bring all the energies from the various parts of the calorimeters to a common scale before any clustering algorithm can be applied.

The total energy seen in the calorimeters plus presamplers is:

$$E_{tot} = \alpha(\beta E_{PS} + E_1 + E_2 + E_3)$$

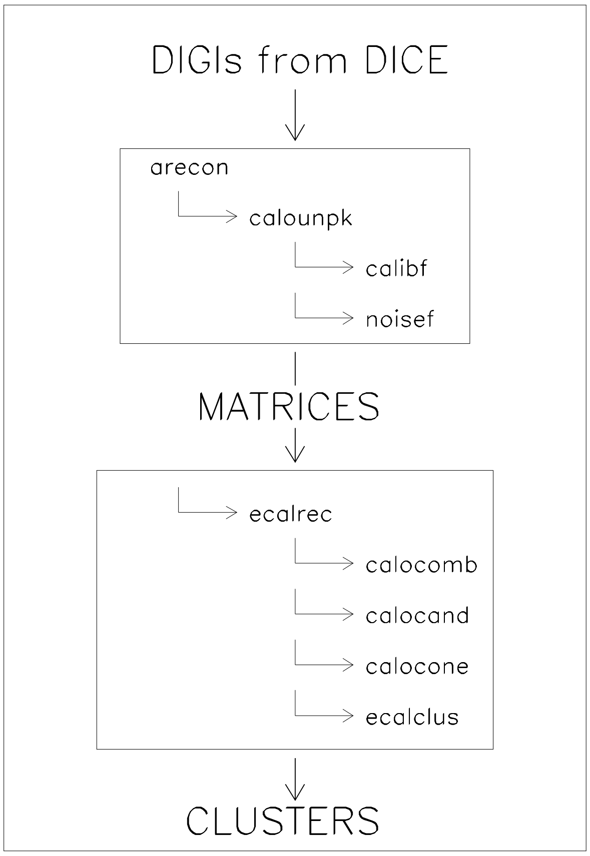

Figure 2.1: Program flow

The parameters α and β were determined on 50 GeV E_T photons. β is determined to minimize the resolution and α is set to obtain $E_{tot} = E_{true}$ on average. Their values as a function of η are shown on figure 2.2 and 2.3.

Figures 2.4 and 2.5 shows the precision of the calibration as a function of eta for the photons used to determine the calibration factors and, as a check, for 40 and 10 GeV E_T electrons. The loss of energy in the crack at $\eta = 0$ and in the barrel - endcap overlap region, as well as the 1% difference in calibration for electrons between 10 and 40 GeV E_T are not corrected for at this level.

2.3 Clustering

The clustering algorithm is the sliding window algorithm running on the combined matrix. By default, a 5x5 window is used in this matrix, and the threshold for clusters is $E_T = 1.1$, the value which leads to less than 0.1 fake cluster per event due to electronic noise at low luminosity, as shown on figure 2.6. These defaults can be changed by datacards as described below.

2.4 Measurement of the cluster energy

Around each cluster position, windows are set in each sampling, and energies and positions are computed in the windows. These quantities are computed for 6 different window sizes, as detailed in table 2.1.

Table 2.1: Size of the cluster in each sampling ($\Delta\eta \times \Delta\phi$)
1.5 ϕ region means that 1 or 2 regions are used (half of the time), depending on the ϕ position measured in sampling 2.

window type	name	Window size ($\Delta\eta \times \Delta\phi$)			
		presampler	sampling 1	sampling 2	sampling 3
1	3x3	3 cells $\times$ 1.5 ϕ region	0.075 $\times$ 1.5 ϕ region	3x3 cells	2x3 cells
2	3x5	3 cells $\times$ 1.5 ϕ region	0.075 $\times$ 1.5 ϕ region	3x5 cells	2x5 cells
3	3x7	3 cells $\times$ 2 ϕ regions	0.075 $\times$ 2 ϕ regions	3x7 cells	2x7 cells
4	5x5	5 cells $\times$ 1.5 ϕ region	0.125 $\times$ 1.5 ϕ region	5x5 cells	3x5 cells
5	5x7	5 cells $\times$ 2 ϕ regions	0.125 $\times$ 2 ϕ regions	5x7 cells	3x7 cells
6	7x7	7 cells $\times$ 2 ϕ regions	0.175 $\times$ 2 ϕ regions	7x7 cells	4x7 cells

The energy measured in these finite size windows is smaller than the true energy. Figure 2.7 shows the ratio between the true energy and the energy in the window as the a function of η for the various window sizes.

Between 2 and 4% of the energy is lost outside a 7x7 window for 50 GeV photons (averaging over converted and non converted photons), and more energy is lost

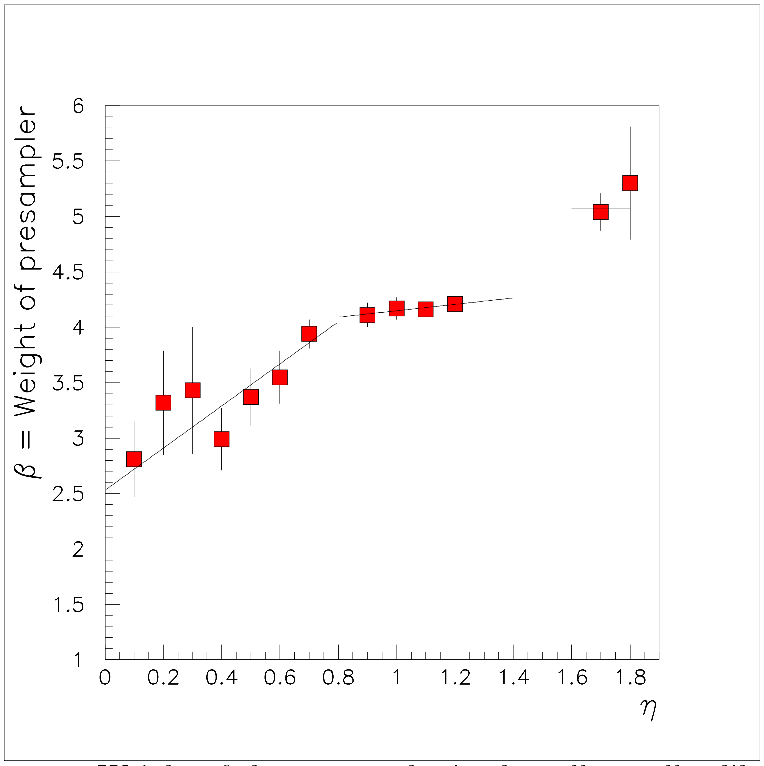

Figure 2.2: Weight of the presampler in the cell to cell calibration

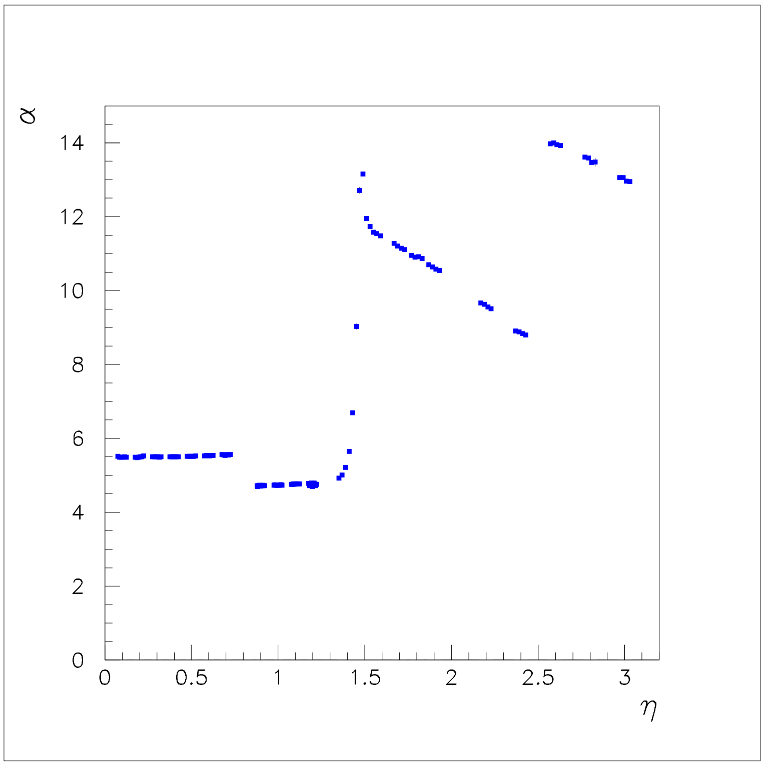

Figure 2.3: Cell to cell calibration factor

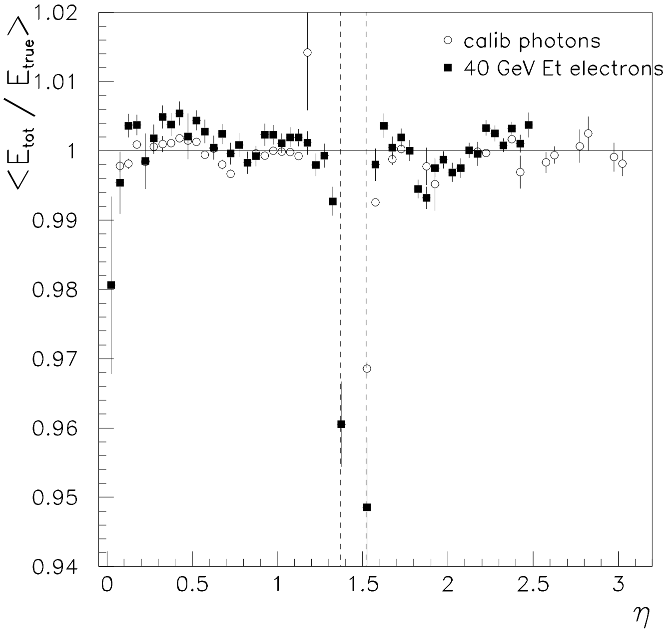

Figure 2.4: Average total energy as a function of η for 50 GeV E_T photons and 40 GeV E_T electrons

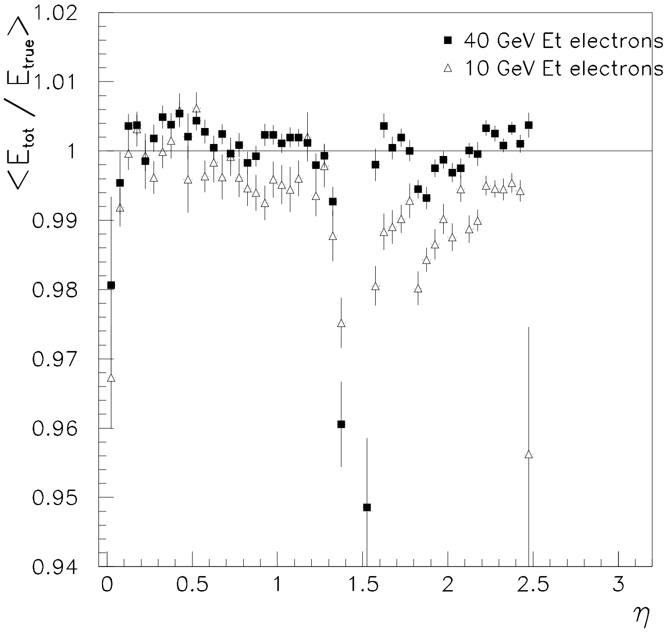

Figure 2.5: Average total energy for 40 and 10 GeV E_T electrons as a function of rapidity

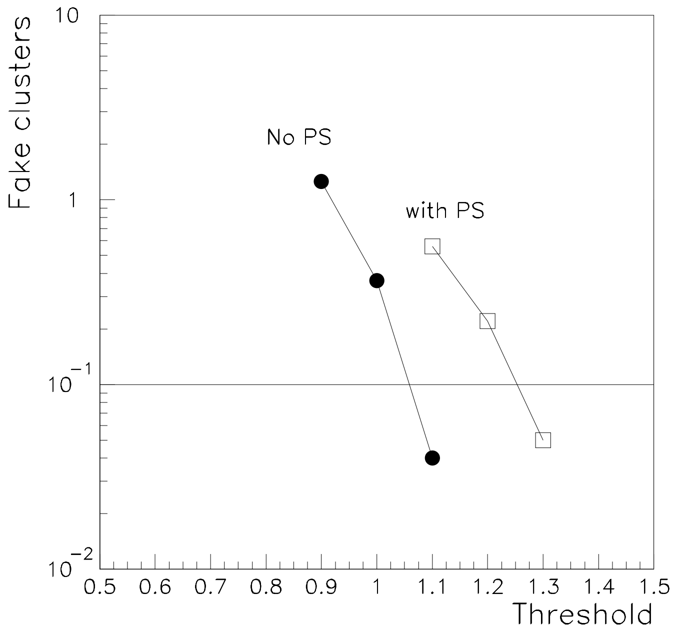

Figure 2.6: Number of fake clusters per event due to electronic noise at low luminosity, as a fucntion of the threshold used by the sliding window algorithm.

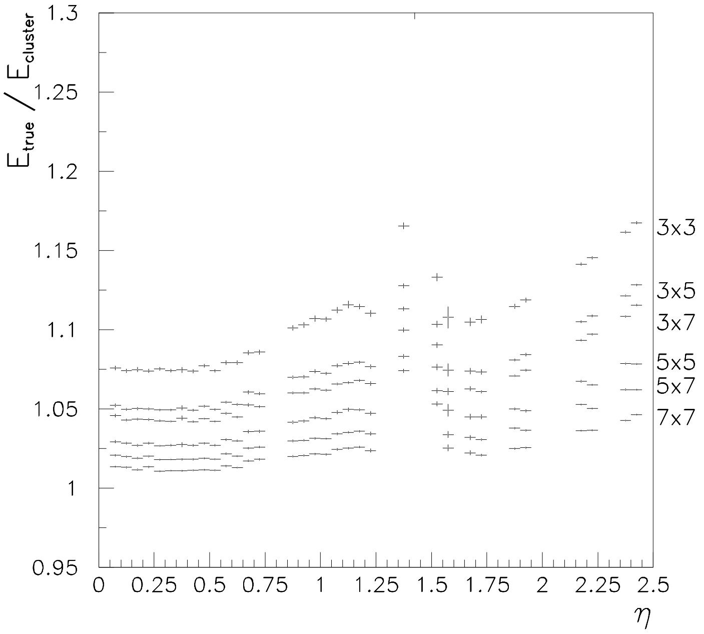

Figure 2.7: True energy divided by the energy in a window for 50 GeV E_T photons

outside smaller windows. An η dependent factor is applied to the window energies to correct for this finite containment.

Then, the modulations of the response which depend on the position in η of the cluster within a cell ("η" modulations) are corrected for. These modulations are shown in figures 2.8 and 2.9 for the barrel and 2.10 and 2.11 for the endcaps. The modulations, which depend only on the size of the window in the η direction, are clearly visible when 3 cells are used in this direction, and become smaller when the energy is computed in larger windows.

Finally, a correction for the loss of energy in the cracks (only available for the time being for the barrel - endcap region) is applied. Figure 2.12 shows the fraction of energy seen in the various clusters before this correction. The barrel-endcap scintillator is not used yet.

The precision of the calibration for the various window sizes is shown in figure 2.14 for 50 GeV E_T photons and 40 GeV E_T electrons.

Figure 2.15 shows the calibration of the calorimeter at $\eta = 0.3$ for low energy photons (converted or not).

2.5 Measurement of the cluster position

The measurement of the cluster position in ϕ is done in sampling 2 as described in the Calorimeter Performance TDR[1] for a 3x7 window.

The measurement of the positions in η, from which the direction of the shower is computed, is also done as described in the TDR[2]. The S-shape corrections measured for a "3x7" window are used for all window sizes, and may thus not be optimal for the other window sizes.

[1] CERN/LHCC/96-40, section 2.5.1

[2] section 2.5.2

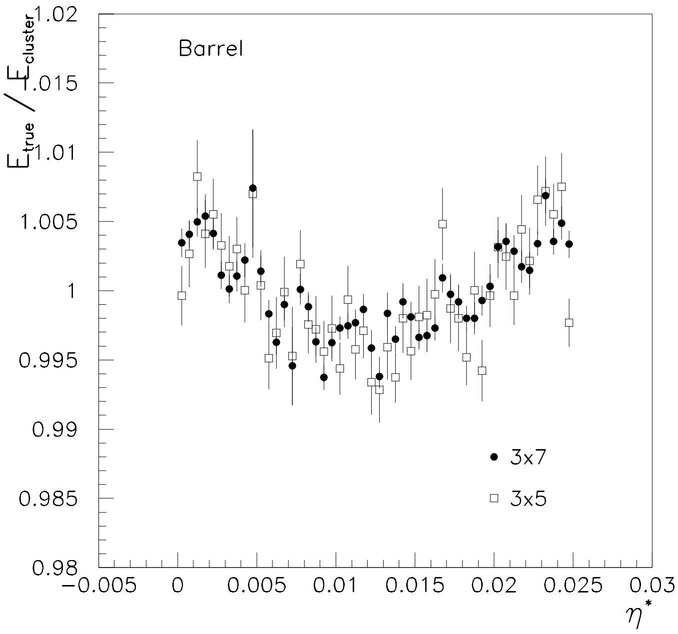

Figure 2.8: η modulations in the barrel for 3x5 and 3x7 windows

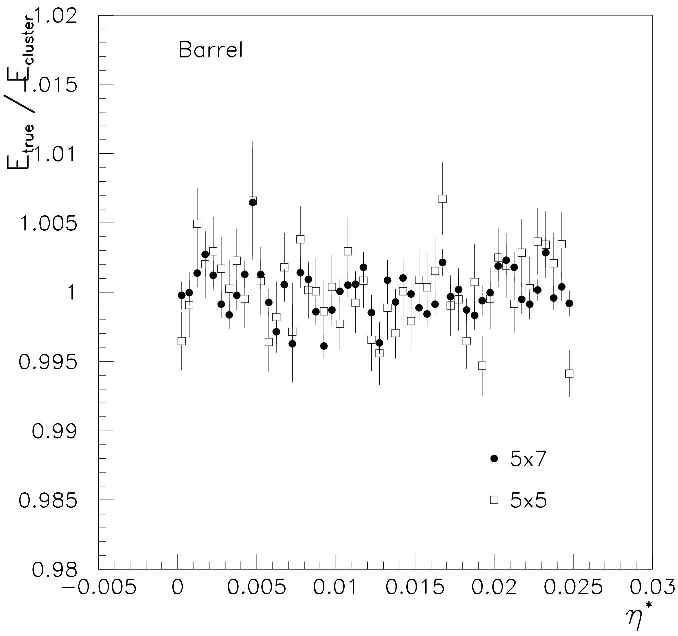

Figure 2.9: η modulations in the barrel for 5x5 and 5x7 windows

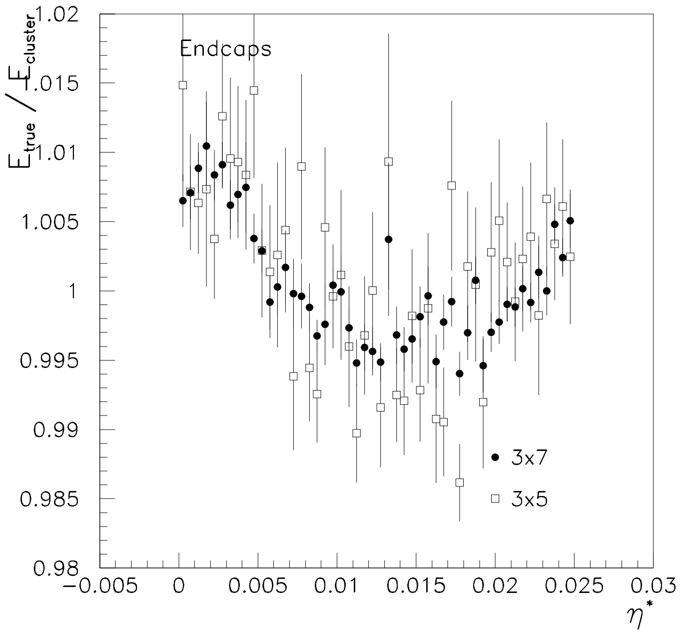

Figure 2.10: η modulations in the endcaps for 3x5 and 3x7 windows

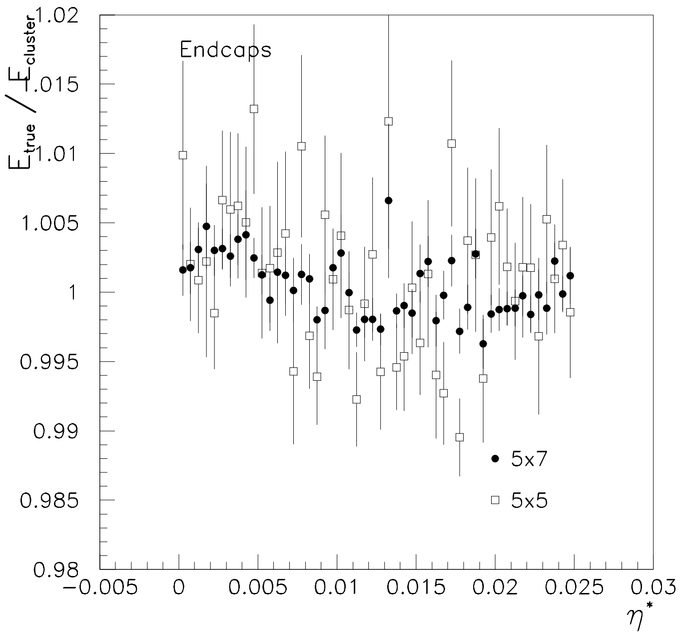

Figure 2.11: η modulations in the endcaps for 5x5 and 5x7 windows

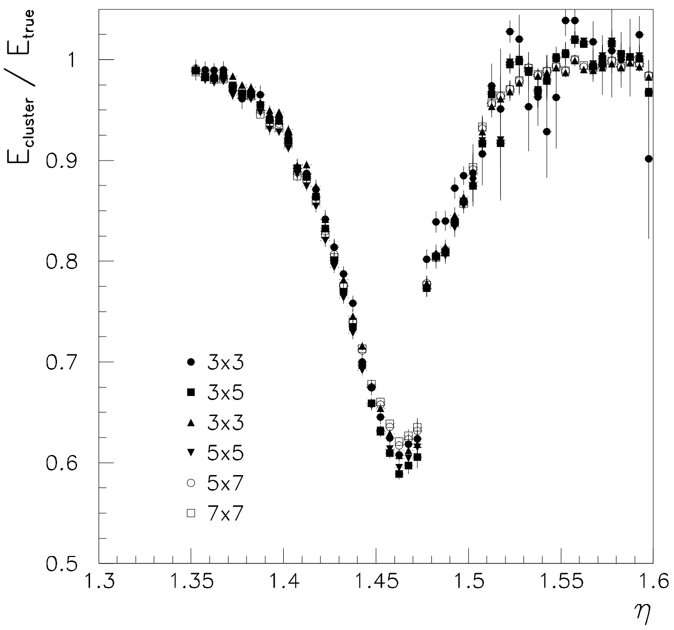

Figure 2.12: Energy measured in the barrel-endcap overlap region

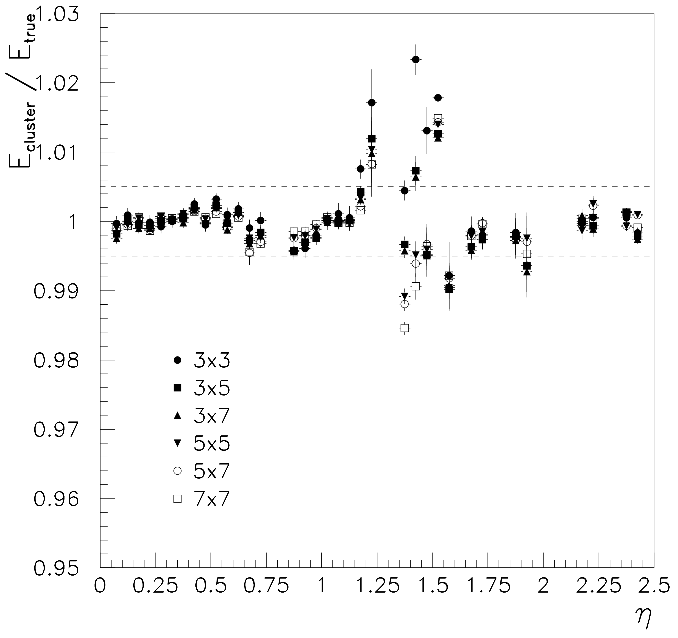

Figure 2.13: Measured energy divided by true energy, as a function of η, for 50 GeV E_T photons.

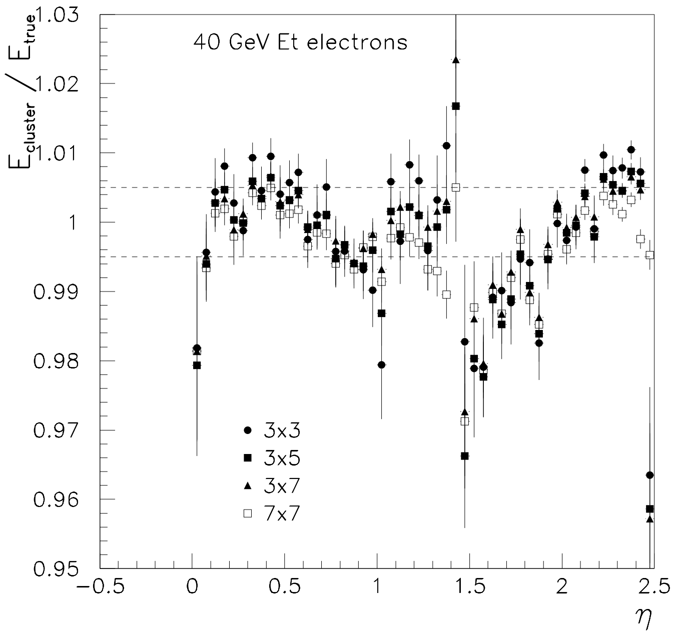

Figure 2.14: Measured energy divided by true energy, as a function of η, for 40 GeV E_T electrons.

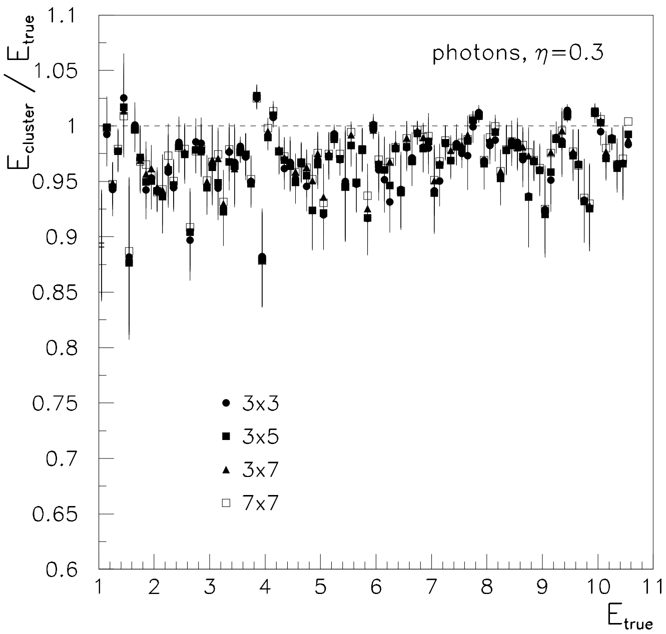

Figure 2.15: Measured energy divided by true energy for low energy photons, at $\eta = 0.3$.

Chapter 3

Description of the output quantities

During the reconstruction, several ZEBRA banks are filled with quantities which can be accessed in the user's analysis. This section, however, does NOT describe all these banks because some of them are rather for internal use and because other ones contain quantities which are now obsolete and are kept only for backward compatibility.

Table 3.1 lists all the banks which are filled by the EM reconstruction code and gives their status. It is recommended not to use the banks flagged as internal or obsolete.

Table 3.1: List of the banks filled by the EM reconstruction code

bank	description	status
CCAL	parameters used at unpacking	useful
CREG	matrices	useful
EPAR	parameters used for EM reco.	internal
COMB	combined matrix	internal
ECAL	summary of EM reco.	useful
CLUS	general information per cluster	useful
CTYP	information per cluster	obsolete
CISO	cluster isolation	useful
EMFL	parameters for "refined" analysis	internal
EMCL	"refined" quantities	useful

The banks flagged as useful are described below.

3.1 EM matrices

The information about the matrices is kept in banks **/DETM/CALO/CCAL(ical)** and **/DETM/CALO/CCAL(ical)/CREG(ireg)**. They are described in table 3.2 and 3.3.

Table 3.2: Description of the **CCAL** bank

Quantity	Description	Comment
Version	version number	$= 1$
Ical	calo number in global list	
Cset	subsystem name	
Cdet	sensitive detector name	
Calmod	calibration mode	$= 1$
Inoi	noise	
Nreg	number of uniform regions	
ThrCe	threshold on cell energy	$= 0$
ThrNo	threshold in units of σ(noise)	$= 0$

Table 3.3: Description of the **CREG** bank

Quantity	Description
Ireg	region number
EtaMin	minimum η
EtaMax	maximum η
deta	granularity in η
dphi	granularity in ϕ
Neta	number of cells in η
Nphi	number of cells in ϕ
Etot	total energy in the region
Ener(Nphi,Neta)	energy per cell

3.2 EM reconstruction summary

A summary of the EM reconstruction is written in bank **/RECB/SECT/ECAL(1)** (see table 3.4).

Table 3.4: Description of the **ECAL** bank

Quantity	Description	Comment
Nclus	number of clusters found	
Thr	threshold for clustering	copied from EPAR bank
Etot	total energy in combined matrix	
Ettot	total transverse energy in comb. matrix	
Eneb		
Enee		
Ettb		
Ette		

3.3 Raw cluster information

For each cluster, some raw information is kept in bank **/RECB /SECT /ECAL(1) CLUS(iclus)**, as described in table 3.5. A list of cells in a cone of $\Delta R = 0.1$ is kept with each cluster, allowing for subsequent studies. For each cell in the list, the cell ID $10 * ical + ireg$, the position of the center of the cell, its energy and its distance to the cluster are available.

Table 3.5: Description of the **CLUS** bank

Quantity	Description	Comment
Id	matrix type used for clustering	copied from EPAR bank
Icx	cluster position in η in comb. matrix	cell units
Icy	cluster position in ϕ in comb. matrix	cell units
Ene	transverse energy of the cluster	
Ete	transv. energy in local matrix around the cluster	
K	dimensions of local matrix	
Cmat(K,K)	local matrix	
N	number of active cells in the cluster	
IDce(N)	cell ID	
ETce(N)	η of center of cell	
PHce(N)	ϕ of center of cell	
ENce(N)	energy in cell	
Dist(N)	ΔR between cell and center of cluster	

Energies in cones of various sizes around each cluster are available in **/RECB /SECT /CLUS(iclus) /CISO(iso)**, with *iso* going from 1 to 4, corresponding to radii 0.1, 0.2, 0.3 and 0.4, as described in table 3.6.

Table 3.6: Description of the **CISO** bank

Quantity	Description
Rad	radius of the cone
Ener(1:6)	energy in the cone in each calorimeter

3.4 Refined cluster information

The refined cluster information is kept in bank **...CLUS(iclus)/CTYP(ityp) /EMCL**, with *ityp* going from 1 to 6, as described in table 2.1. The quantities available are described in table 3.7.

Table 3.7: Description of the **EMCL** bank

Quantity	Description	Comment
Phi2	ϕ measured in second sampling	
Eta1	η measured in first sampling	
Eta2	η measured in second sampling	
Zrec	extrapolated z vertex	
Ezrec	error on z vertex	
Point	direction in η	
Depth	longitudinal shower depth	
Es0	energy in presampler	
Es1	energy in first sampling	
Es2	energy in second sampling	
Es3	energy in third sampling	

Chapter 4

How to modify the reconstruction parameters

The reconstruction parameters used by default can be changed by datacards:

- **To add electronic noise**
  By default, no electronic noise is added. Electronic noise can be added at unpacking level by the following datacard:
  ***DETP 'CALO' 'CCAL(ical).Inoi='** *value*
  where *ical* is 1,2 or 3 for the barrel presampler, the barrel EM and the endcap EM (the noise in the endcap presampler is not available yet), and with *value* = 1 (resp. 2) for noise at low (resp. high) luminosity.

- **To put a threshold on the energy per cell**
  By default, no threshold is put on the energy per cell. This can be done by
  ***DETP 'CALO' 'CCAL(ical).ThrNo='** *value*
  or by
  ***DETP 'CALO' 'CCAL(ical).ThrCe='** *value*
  In the first case, *value* is a number of sigmas of the noise, in the second case *value* is an energy. *value* may be negative.

- **To remove the cell to cell calibration**
  The cell to cell calibration is applied by default and can be removed by:
  ***DETP 'CALO' 'CCAL(ical).Calmod='** 0

- **To change the threshold on the transverse energy of the clusters**
  During clustering, only the windows (in the combined matrix) with a transverse energy greater than 0.72 GeV are considered. This default can be changed by:
  ***DETP 'ECAL' 'epar(1).Thr='** *value* (GeV)

- **To change the range in which the clusters are searched for**
  By default, the combined matrix inh which clusters are searched for covers the η range from -3.2 to +3.2. As the search for the clusters is a dominant part in the reconstruction time per event, the range can be reduced for special purposes by:
  ***DETP 'ECAL' 'epar(1).Etamin='** *value* **'epar(1).Etamax='** *value*

- **To change the size of the window used for the clustering**
  The default window size in the combined matrix used by the sliding window algorithm is 5x5 cells, which is well suited for the search for clusters isolated enough. Particular studies, such as the search for two nearby photons coming from the decay of the η particle, may require a different window size, which can be obtained by:
  ***DETP 'ECAL' 'epar(1).Id0='** *value*
  where *value* is $100 \times int(N_\eta/2) + int(N_\phi/2)$ (for example 101 should be used for a 3x3 window. Only odd window sizes are available).

- **To remove (some) of the corrections applied to the clusters**
  The various corrections on the energy and position measurements available in the EMCL banks can be removed by:
  ***DETP 'ECAL' 'emfl(1).flag=** 0.
  where flag is one of the words below:

  - **Econ:** Energy containment in the cluster
  - **Ecra:** Energy loss in the barrel-endcap overlap region
  - **Eeta:** Modulations in η
  - **Ephi:** Modulations in ϕ (not available yet)
  - **PhiSsh:** S-shapes in ϕ (not available yet)
  - **Phioff:** Offset in ϕ
  - **EtaSsh:** S-shapes in η
  - **EtaOff:** Offset in η (not available yet)

Only one *DETP 'ECAL' and one *DETP 'CALO' cards can be present in the datacards. If several defaults have to be changed, it should be done in one datacard, split in several lines in necessary, as for example:
***DETP 'CALO' 'CCAL(1).Inoi=' 2.**
'CCAL(2).Inoi=' 2. 'CCAL(3).Inoi=' 2.
'CCAL(1).Thrno=' 1. 'CCAL(2).ThrNo=' 1.
'CCAL(3).ThrNo=' 1.
which adds electronic noise and put a threshold at 1 sigma on the cell energies.

Chapter 5

Some useful routines

The following, hopefully useful, routines are available:

- **QWGEOM** prints a summary of the geometry of the calorimeters
- **QWEMCL** prints the list of clusters found in the EM calorimeters, with some information taken from the EMCL bank, for a 3x7 window.