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Correction on transverse leakage in Electromagnetic Calorimeter of AMS

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Abstract

AMS Electromagnetic Calorimeter (ECAL) will provide measurement of the energy of electrons and photons in cosmic rays. The acceptance of the ECAL is determined by its active area. Here we present analysis of Monte Carlo and testbeam data where we perform a transverse leakage correction of the energy deposited. The correction is done independently in each layer of the Calorimeter. The method allows to recover energy which leaks from ECAL in the peripheral region. Efficient correction for the transverse leakage will improve the current value of the active area.

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Contents

1 Introduction

The AMS Electromagnetic Calorimeter (ECAL) [2] will provide precise measurements of energy of electrons and photons. It is made of lead and a scintillator material mounted in a SPACAL structure with a total thickness of 16 radiation lengths. The external dimensions of the ECAL are: 65.8 × 65.8 × 16.65 *cm*. The signal read-out is performed with the use of photomultipliers (PM). Each PM contains four anodes which correspond to 4 pixels. In total there are 72 × 72 × 18 readout channels.

The ECAL is made of 9 superlayers. Every superlayer is divided into 2 layers. Each layer is made of pixels with 9 *mm* height and 9 *mm* width. Five superlayers collect signals from the fibers along y-direction and another four along x-direction. Superlayers are located alternately, ie. superlayers number 0, 2, 4, 6 and 8 collect the signals from fibers in y-direction, while superlayers 1, 3, 5 and 7 in x-direction. We decided to investigate transverse profile in y-direction because the transverse beam size of the 2002 beam test is smaller in this direction (about 9 *mm* ie. one pixel), which is important as we have no other information about incident particle position. So in y-direction we have more precise information on the particle position in the beam test data.

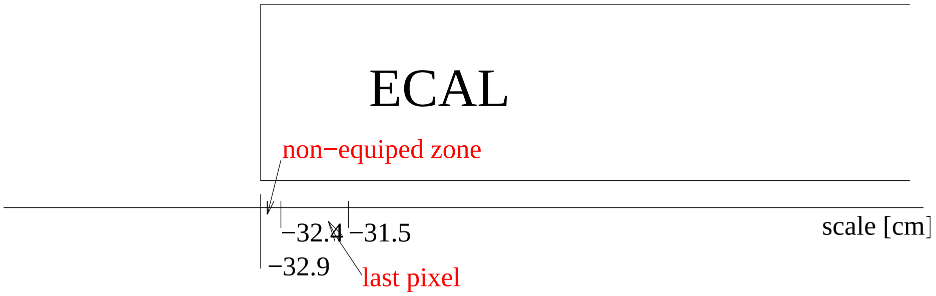

Figure 1: *Dimensions on the edge in a reference frame used in this note.*

To find a correction on transverse leakage in the ECAL first we have studied the Monte Carlo samples. We have found energy independent parametrization of transverse energy leakage. Then the proposed method was partially tested on the beam-test data.

In this note, if not marked, we are working in a MC-like coordinate system. This means that $x = 0$ *cm* and $y = 0$ *cm* is a point in the middle of the ECAL and the edge of the Calorimeter is at a point where $x = \pm 32.9$ *cm* or $y = \pm 32.9$ *cm*, however the last 5 mm are a non-equipped area (see Figure 1). The other used convention is that pixel, layer and superlayer numbers starts with 0.

2 Monte Carlo studies

2.1 Samples

Three samples of electrons with energies of 10, 50 and 120 GeV were generated. The incident angle of those particles is 0 deg and they are generated on the ECAL upper surface. A sample of 120 GeV electrons with incident angle ± 23 deg was also generated to check if our method does not depend on the incident angle. The standard AMS simulation program based on GEANT3 [1] were used to simulate detector (database and code version from February 2003).

Electrons were generated not on the whole ECAL surface but only inside an area defined by: $-33\ cm < y < 0\ cm$ and $-2\ cm < x < 2\ cm$. This shape of the area comes from the fact that we want to average effects over the PM scale (so width of the area is 4 cm) and we need a long arm to perform an efficient fitting (so the area is very long - half of the ECAL width). The LV1 trigger used in the simulation is unbiased ECAL trigger.

2.2 Methodology

To correct for transverse leakage we have chosen the method of correction per layer. The analysis consists of the following steps:

- Find out, with MC, the dependence of the energy deposited in the layer from the distance of the particle from the edge of the ECAL.
- Fit this dependence and find out the correction function.

The correction per layer has the following features:

- It can be easily translated to the case of particles with non-zero incident angle, as the correction is done in each layer independently.
- It allows to reconstruct correctly the longitudinal profile of the shower on the edge of the ECAL.
- It recovers energy resolution, which is affected by transverse leakage.
- It is simple, it uses only information about coordinate of the particles hit in the ECAL layer and energy deposited in the layer.

We will show here that correction per layer is an efficient and accurate estimator of the total energy of the particle hitting the edge of the ECAL.

2.3 Energy versus distance

On the Figure 2 the energy deposited in each layer as a function of the particle position is shown. The plot is prepared for 120 GeV electrons, and only layers oriented in y-direction are shown. At the edge the deposited energy becomes smaller due to leakage.

For the layers in x-direction (2, 3, 6, 7, 10, 11, 14 and 15) the similar procedure is performed. These layers behave differently and it will be discussed later.

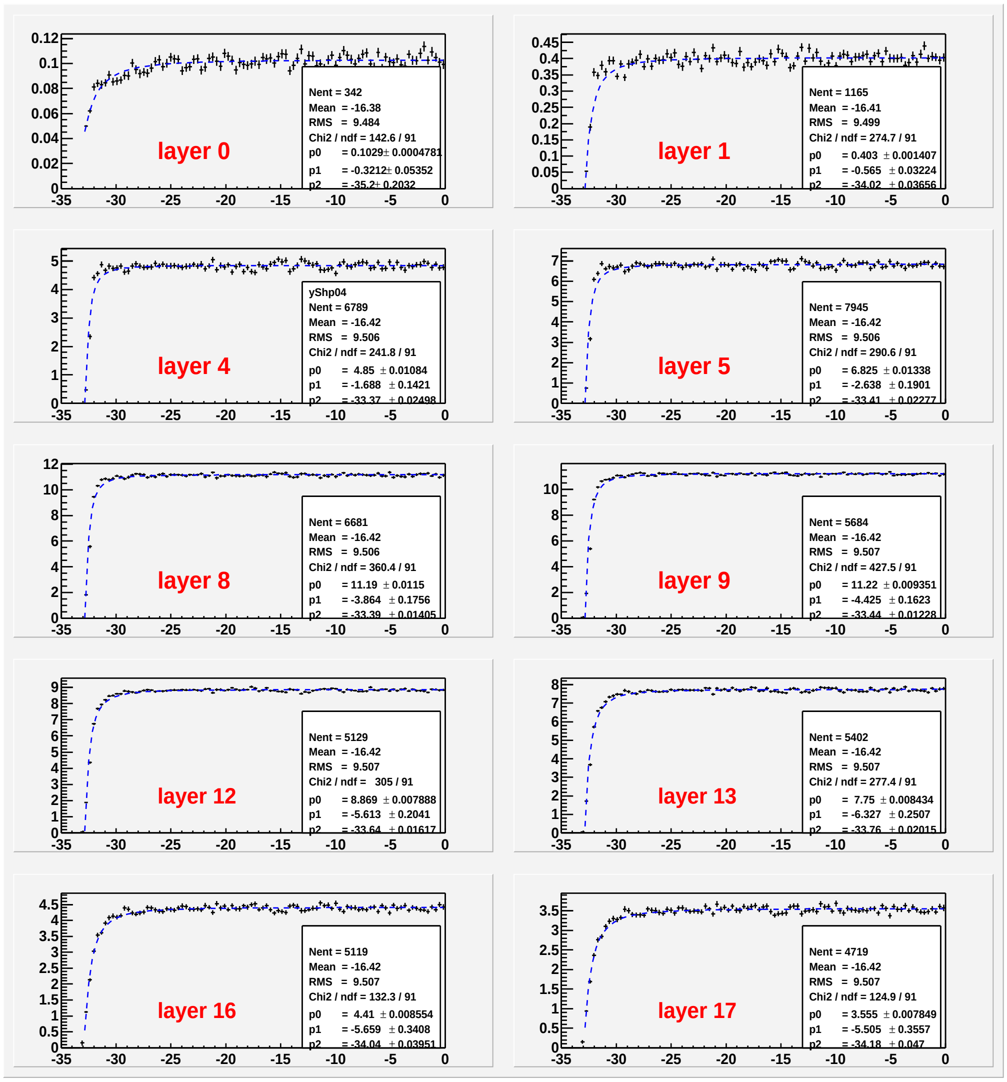

Figure 2: *Electrons with 120 GeV of energy. Deposit of energy in every layer in y-direction as a function of the distance of the particle from the edge of the ECAL (edge is at -32.9 cm). We see that for deep layers the leakage effect is more severe.*

The fitted function has the form:

$$E_{layer}^{measured}(y) = p0 + \frac{p1}{(y - p2)^2} \tag{1}$$

where p0, p1 and p2 are free parameters of the fit. Meaning of the parameters is the following:

- p0 estimates the average energy deposited in the layer if there is no transverse leakage: tracing p0 in layers one obtains the longitudinal profile of the shower. (In fact, if we assume that the particle hitting the middle of the ECAL gives no transverse leakage, the energy deposited is $p0 + \frac{p1}{p2^2}$, but the additional term is smaller than 1% event in the case of 120 GeV electrons). p0 depends strongly on energy of the initial particle.

- p1 is a quadratic term contribution. It depends strongly on energy.

- p2 is a asymptotic line of the fitted function - we can say that it gives information about the geometrical active area of the ECAL, ie. if $|p2|$ is larger then the detector has a larger active area. p2 has weak dependence on energy of the incident particle.

The function is usually fitted in a range of -33 cm to 0 cm. Starting conditions of the fit parameters are chosen to optimize the time of fitting and χ^2. The allowed parameter range is also set to avoid unreasonable fits. In Table 1 the values of the parameters p0, p1 and p2 for every layer and for every investigated energy are presented.

The fit parameters are very weakly correlated. The typical fit covariance matrix (for layer 8, energy 120 GeV) is shown in Table 2. Some correlation between parameters p1 and p2 can be observed (for all layers and energies), but it is very weak, what justifies our choice of the fitting function.

In the Figure 3 values of the p2 parameter as a function of the layer number, for three energies are shown. The absolute values of p2 are higher for low energies which means that the Calorimeter active area is larger for low energies.

The values of the parameter p2 already give an idea of how much leakage can be corrected with this method. Surely leakage cannot be corrected for $|y| > |p2|$. There is more discussion about range of correction in the next section.

We tried also other parameterizations of energy leakage:

$$E_{layer}^{measured}(y) = p0 + \frac{p1}{y - p2}, \quad E_{layer}^{measured} = p0 + \frac{p1}{(y - p2)^4}, \quad etc... \tag{2}$$

But we have chosen Formula (1), because it performs the fits faster and gives reasonable χ^2.

Table 1: *Fit parameters for layers in y-direction (p0, p1 and p2), position for which correction factor is equal to 2:* $y_{corr=2}$ *and value of the correction factor in the middle of the last pixel* $corr_{(y=-31.95cm)}$. *Only superlayers oriented in y direction are presented.*

layer	p0	p1	p2	$y_{corr=2}$ (cm)	$corr_{(y=-31.95cm)}$
	Electrons 10 GeV				
0	0.055	-0.013	-34.307	-33.616	1.044
1	0.158	-0.052	-33.437	-32.626	1.175
4	0.895	-0.341	-33.401	-32.528	1.221
5	1.028	-0.417	-33.428	-32.528	1.228
8	0.966	-0.512	-33.553	-32.524	1.259
9	0.850	-0.523	-33.621	-32.512	1.282
12	0.478	-0.507	-33.920	-32.464	1.375
13	0.388	-0.495	-34.039	-32.443	1.412
16	0.179	-0.417	-34.605	-32.449	1.491
17	0.138	-0.384	-34.886	-32.530	1.473
	Electrons 50 GeV				
0	0.075	-0.096	-34.707	-33.108	1.201
1	0.287	-0.090	-33.367	-32.575	1.185
4	2.748	-0.782	-33.313	-32.559	1.181
5	3.624	-1.301	-33.383	-32.536	1.211
8	4.932	-1.961	-33.434	-32.542	1.220
9	4.726	-2.206	-33.495	-32.529	1.243
12	3.312	-2.493	-33.717	-32.490	1.317
13	2.810	-2.639	-33.837	-32.467	1.357
16	1.482	-2.197	-34.148	-32.427	1.441
17	1.173	-2.065	-34.281	-32.406	1.477
	Electrons 120 GeV				
0	0.103	-0.341	-35.284	-32.714	1.420
1	0.397	-0.205	-33.519	-32.503	1.265
4	4.839	-1.866	-33.403	-32.525	1.223
5	6.812	-2.694	-33.414	-32.525	1.226
8	11.189	-3.666	-33.374	-32.565	1.192
9	11.223	-4.181	-33.417	-32.554	1.209
12	8.873	-5.449	-33.625	-32.517	1.280
13	7.753	-6.053	-33.740	-32.491	1.321
16	4.414	-5.499	-34.027	-32.449	1.405
17	3.555	-5.337	-34.160	-32.428	1.442

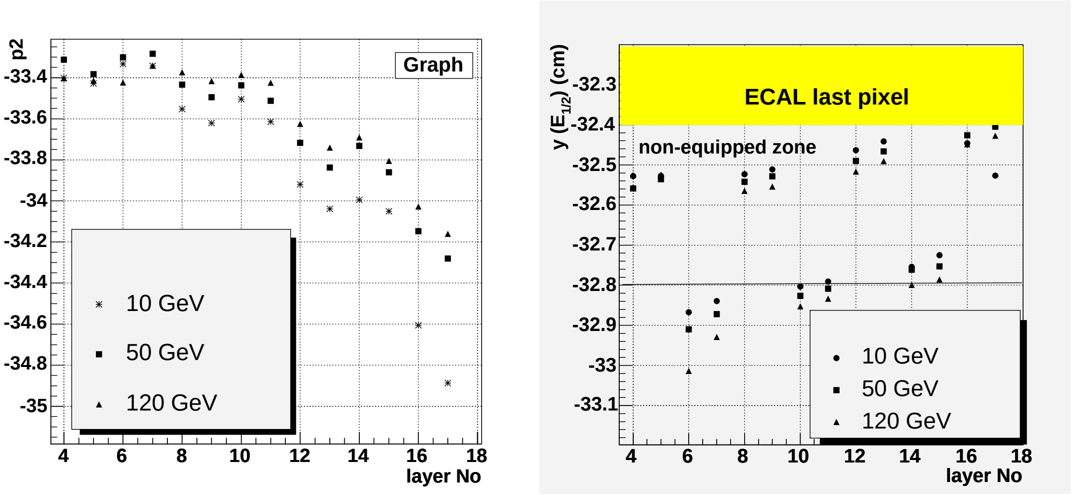

Figure 3: *Left plot: values of the fit parameter p2, as it changes along the ECAL and with the incident particle energy. It shows that Calorimeter has a larger geometrical active area for lower energies of particles. Right plot: values of particle position for which energy leakage is 50%, for each layer. On both plots the first two layers are not shown due to large statistical errors on measurements in these layers. On both plots also the difference between superlayers oriented in x and y directions are clearly visible.*

2.4 Parametrization of correction coefficient

We would like to perform the transverse leakage correction by the formula:

$$E_{layer}^{corrected} = E_{layer}^{measured} \cdot corr_{layer}(y, E_{layer}^{measured}) \tag{3}$$

which means that we would like to use multiplicative correction. In this case, following the Equation 1 and assuming that there is no transverse leakage in the middle of the ECAL, the correction factor is equal to:

$$corr_{layer}(y, E_{layer}^{measured}) = \frac{p0 + \frac{p1}{p2^2}}{(p0 + \frac{p1}{(y-p2)^2})} \tag{4}$$

The correction coefficients for layers 4, 8, 12 and 16 are shown in Figure 4. One can see that correction factors depend weakly on energy, even if the parameters separately are energy-dependent. Correction is slightly higher for low energy particles (red line: 10 GeV) than for high energy (black line: 120 GeV). Therefore it is good approximation: $corr_{layer}(y, E_{layer}^{measured}) = corr_{layer}(y)$. The dependence of the correction coefficient on the layer number is much stronger than its dependence on energy of the incident particle. Corrections are more important for deep layers as the shower develops.

Table 2: *Example of the fit covariance matrix for layer 8 for energy 120 GeV. Weak correlations between parameters is observed.*

	p0	p1	p2
p0	0.000264	0.001309	-0.000100
p1	0.001309	0.056614	-0.004634
p2	-0.000100	-0.004634	0.0003832

The values of the correction coefficients change by about 40% from the external to the internal (closer to the ECAL center) edge of the last pixel. The average correction on the last pixel is between 30% and 50%. The correction at the edge of the pixel number 1 is less then 30%. For the same position the leakage is more important for deeper layers.

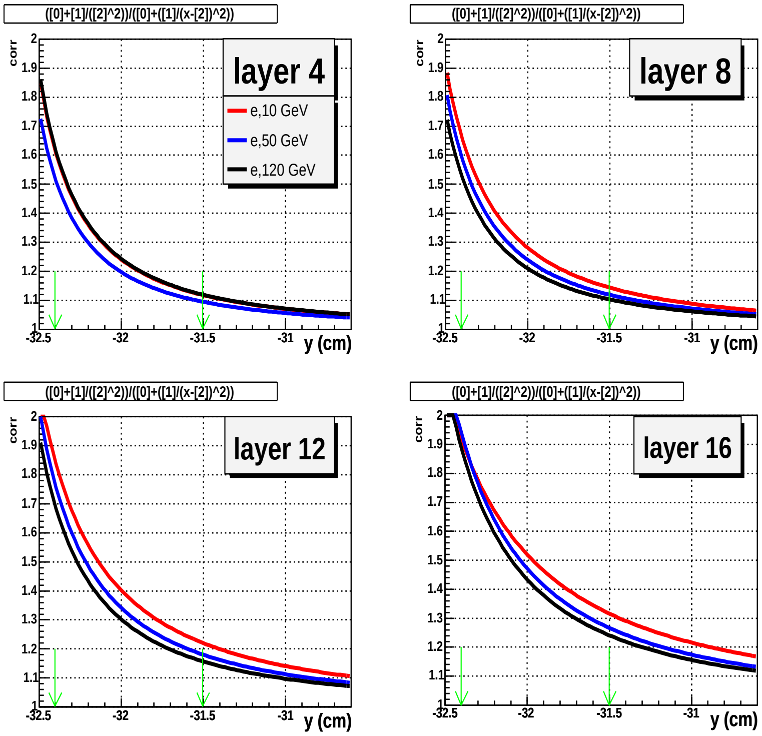

Figure 4: *Correction coefficients as a function of the particle position (y [cm]), for particles hitting the edge of the ECAL. Green arrows mark position of the last pixel (from -32.4 cm to -31.5 cm).*

In Figure 5 the correction factors for two layers in direction x are shown. The values of the correction factors for x-layers are systematically about 30 to 40%

smaller than for layers in y-direction. Probably leakage is partly compensated here by stronger signal in PMs, which, in this case, are covered by the shower.

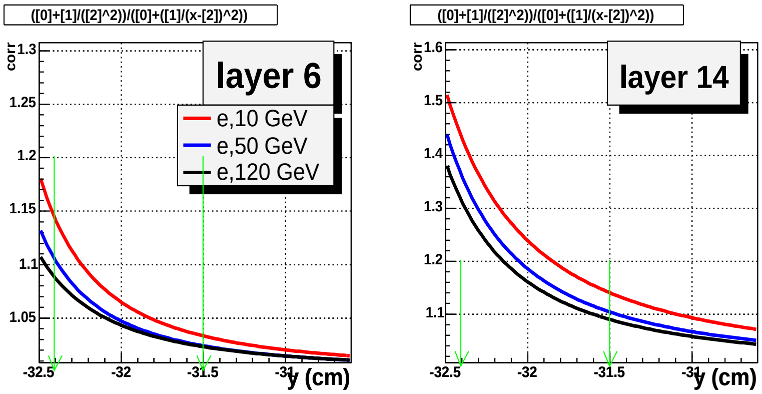

Figure 5: *Correction coefficients as a function of the particle position (y [cm]), for particles hitting the edge of the ECAL. Presented for two layers in x-direction.*

The multiplicative energy correction is a good first estimator of the energy. It can be a starting point to more sophisticated, energy-dependent corrections, with p0=p0(E) and p1=p1(E).

The fact that the correction factors depend very weakly on the energy justifies use of multiplicative correction coefficients rather then correction by the formula:

$$E^{corrected}_{layer}(y, E^{real}_{layer}) = p0(E^{real}_{layer}) + \frac{p1(E^{real}_{layer})}{(y - p2)^2} \tag{5}$$

In the above approach we would be obliged to know the parametrization of p0 and p1 as a function of energy (we would need to have an estimator of real energy in this case, it can be the result of the correction with Formula 3), while the total correction in the multiplicative approach is almost energy-independent.

2.5 Energy correction

The range of the method we present here can be estimated with the criteria:

$$corr_{layer}(y) < 2, layer = 0...17 \tag{6}$$

ie. we will not correct events for which the correction coefficient for any layer is larger than 2. We find that this condition implies that we will not correct energy of the events hitting outside the last pixel of the ECAL (even if there is active material there). In the last column of Table 1 the values of the position ($y_{corr=2}$) for which correction factor, $corr_{layer}(y)$ is equal to 2 are shown. In most cases they are close to y=-32.4 cm, just behind the area covered by the last pixel. This is also visualized on the right plot of Figure 3. Note that for superlayers oriented in x-direction the correction factors equal 2 appears in places more distanced from the ECAL active volume than for superlayers oriented in y-direction.

The example of the global effect of the energy correction is shown in Figures 6 (for 10 GeV), 8 (for 50 GeV) and 10 (for 120 GeV). In the first row the distribution of the deposited and corrected energy is presented for particles which are hitting outside the ECAL active area. The non-equipped ECAL area but also the electronics and support structure are enough for electrons to interact and some part of the shower is contained in ECAL. According to condition 6 these are not recoverable events. The method we use is no longer justified in this area (because of huge correction factors but also because of residues of the fitted functions).

The correction is not performed on the signal in layer 0 and 1 due to low energy deposit in these layers and large energy fluctuations. The fit quality is deteriorated in these two layers but at the same time they can be neglected in the total deposited energy budget.

One can note that for higher energies the correction is difficult in the most external part of the last pixel. To see more precisely what happens in the last pixel, we have divided it into 6 bins of 1.5 mm each. The total energy reconstructed and corrected for the last two bins is presented in Figure 7 for 10 GeV, Figure 9 for 50 GeV and Figure 11 for energy of 120 GeV. The bins which are more distanced from the ECAL edge are reconstructed even better, so we not present them here. We can conclude that up to energy of incident particle of 120 GeV even the energy of particles hitting the middle of the last pixel can be efficiently corrected.

The effects of the different sets of coefficients corresponding to the various sets of MC data implied on 10 GeV and 120 GeV sample are shown in Figure 12. The mean values of the corrected peaks differ by less than 5% in case of use of different correction coefficients. This also justifies use of the energy-independent set of coefficients.

In Figure 13 a longitudinal profile of the shower is shown. The black line represents an uncorrected profile for the electrons hitting the last pixel, the red line represents the corrected profile and the blue line represents the profile for the particles which hit the center of the ECAL (no transverse leakage). As expected the transverse leakage affects more the deeper layers, and the accuracy of determination of the shower maximum is strongly affected. The corrected longitudinal profile is in agreement with the profile obtained in the center of the ECAL where transverse leakage is negligible.

In Figure 14 the energy resolution as a function of the distance from the last pixel edge is presented. The edge is placed at -32.4 cm (see Figure 1). The last pixel is divided into 6 equal bins. For every bin the energy resolution before (circles) and after (squares) correction is plotted. The red line represents the expected energy resolution for energy of 120 GeV [2]. The method allows to recover the energy resolution even in the distance 1.5-3 mm from the last pixel edge, and partly recover energy resolution within the last 1.5 mm.

2.6 Non-zero incident angle

To check if our method is, as expected, independent of the particle incident angle, the correction has been performed on the electrons with incident angles ±23 deg. Results are presented in Figure 15. The low energy tail correspond to particles with projected traces exit by the side of the ECAL (they escape ECAL before hitting the last layer). This Figure should be compared with Figure 10. Peak is better reconstructed in Figure 15 than in case of $\Theta = 0\,\mathrm{deg}$ because some fraction of particles are in fact well-contained in the ECAL (if they move toward the ECAL center).

In conclusion the proposed procedure works very well on the particles hitting ECAL with non-zero angle.

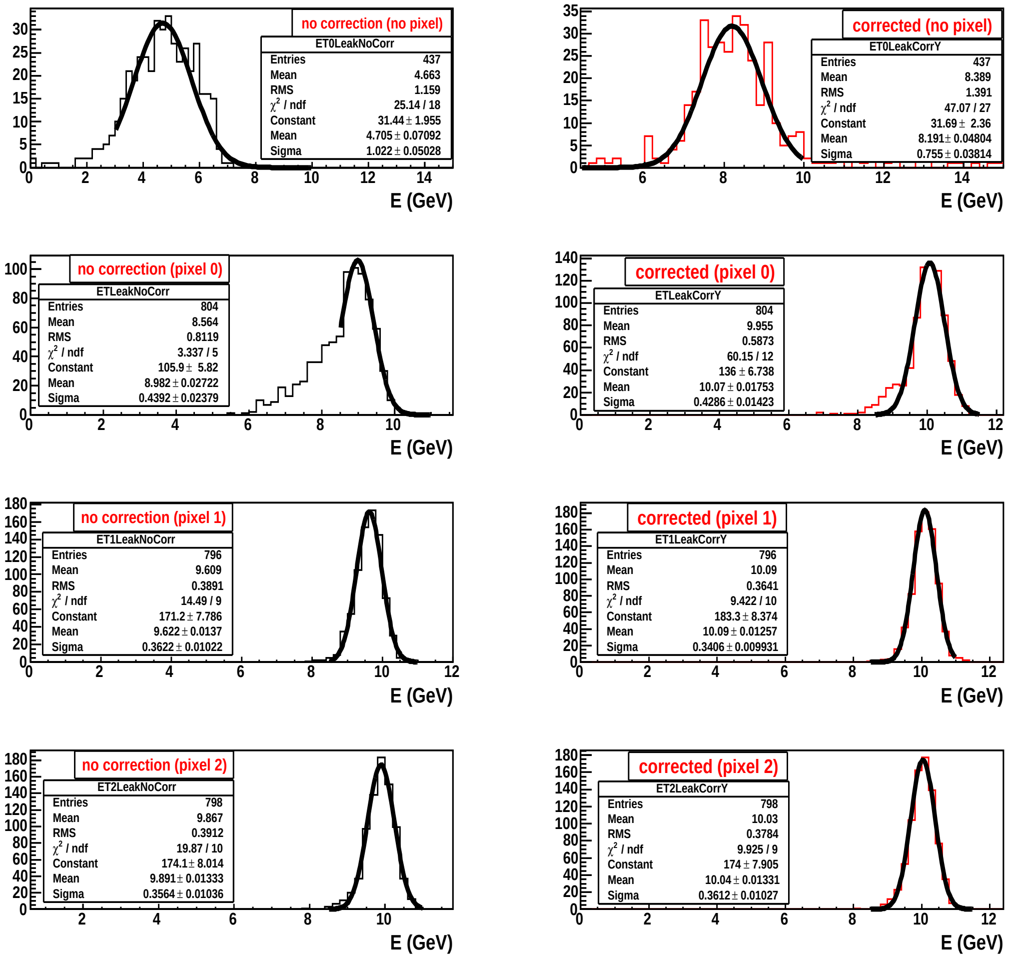

Figure 6: *Electrons with 10 GeV of energy. Total deposit of energy. Left column does not contain correction for leakage, right column does. In the first row the electrons do not hit active area of the ECAL but interact in the material around and give some signal in this way. In the second row electrons hit the first pixel from the edge, in the third row the second pixel is hit. The fourth row presents results for the third pixel hit.*

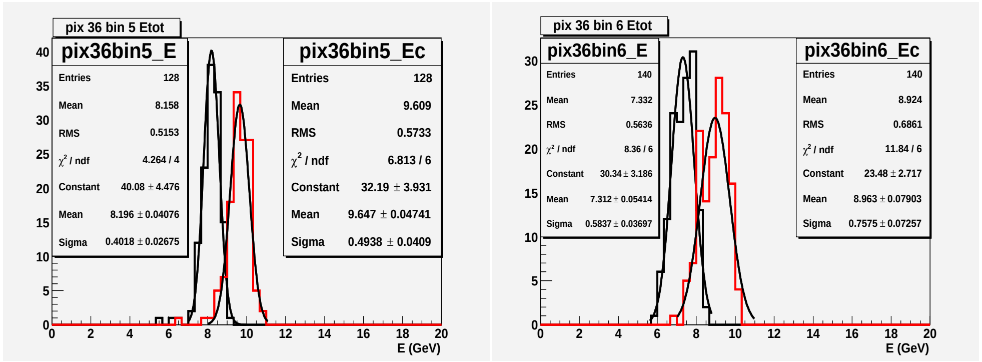

Figure 7: *Electrons with 10 GeV of energy. Correction in the last 2 bins of the last pixel (divided into 6 bins - see text for details). Size of each bin is 1.5 mm.*

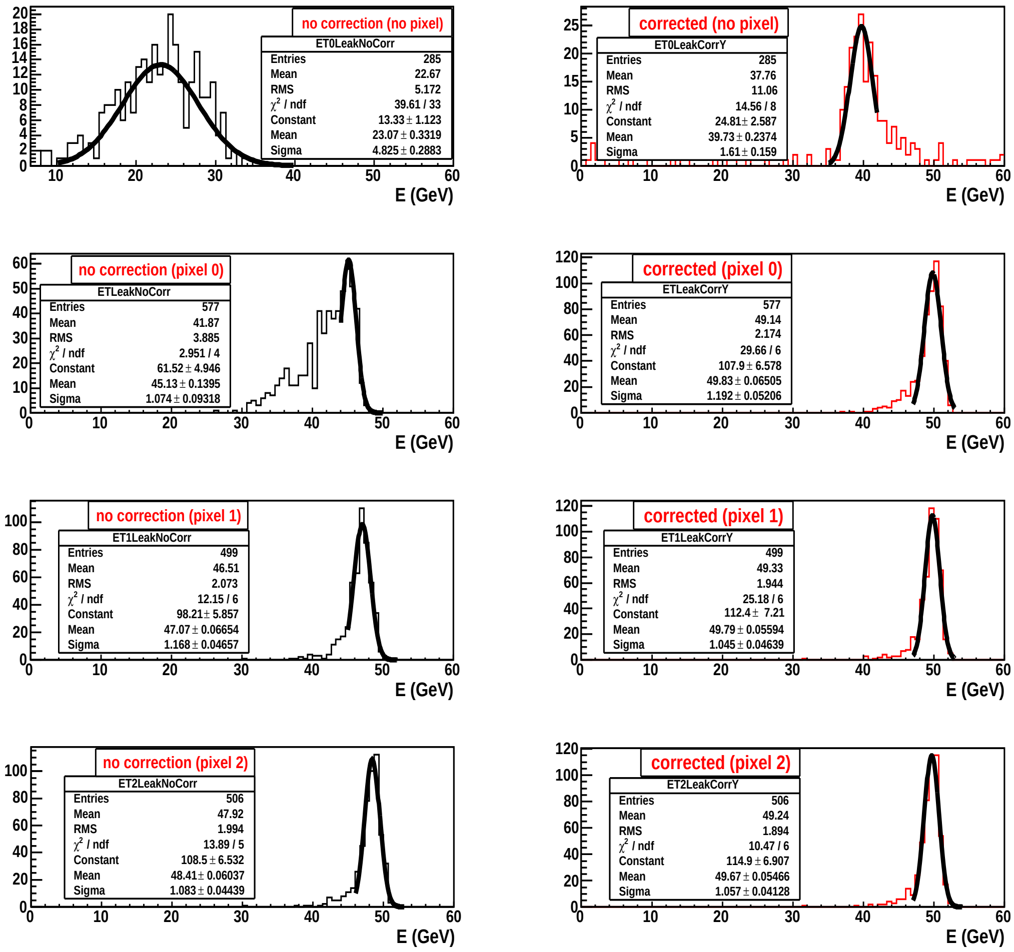

Figure 8: *Electrons with 50 GeV of energy. Total deposit of energy. Left column does not contain correction for leakage, right column does. In the first row the electrons do not hit the active area of the ECAL but interact in the material around and give some signal in this way. In the second row electrons hit the first pixel from the edge, in the third row the second pixel is hit. The fourth row presents results for the third pixel hit.*

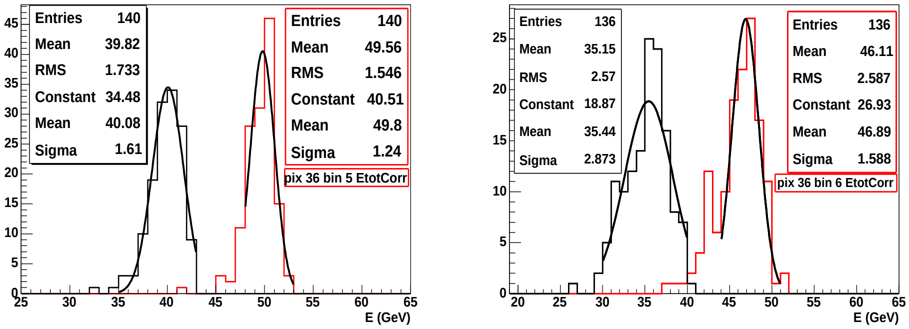

Figure 9: *Electrons with 50 GeV of energy. Correction in the last 2 bins of the last pixel (divided into 6 bins - see text for details). Size of each bin is 1.5 mm.*

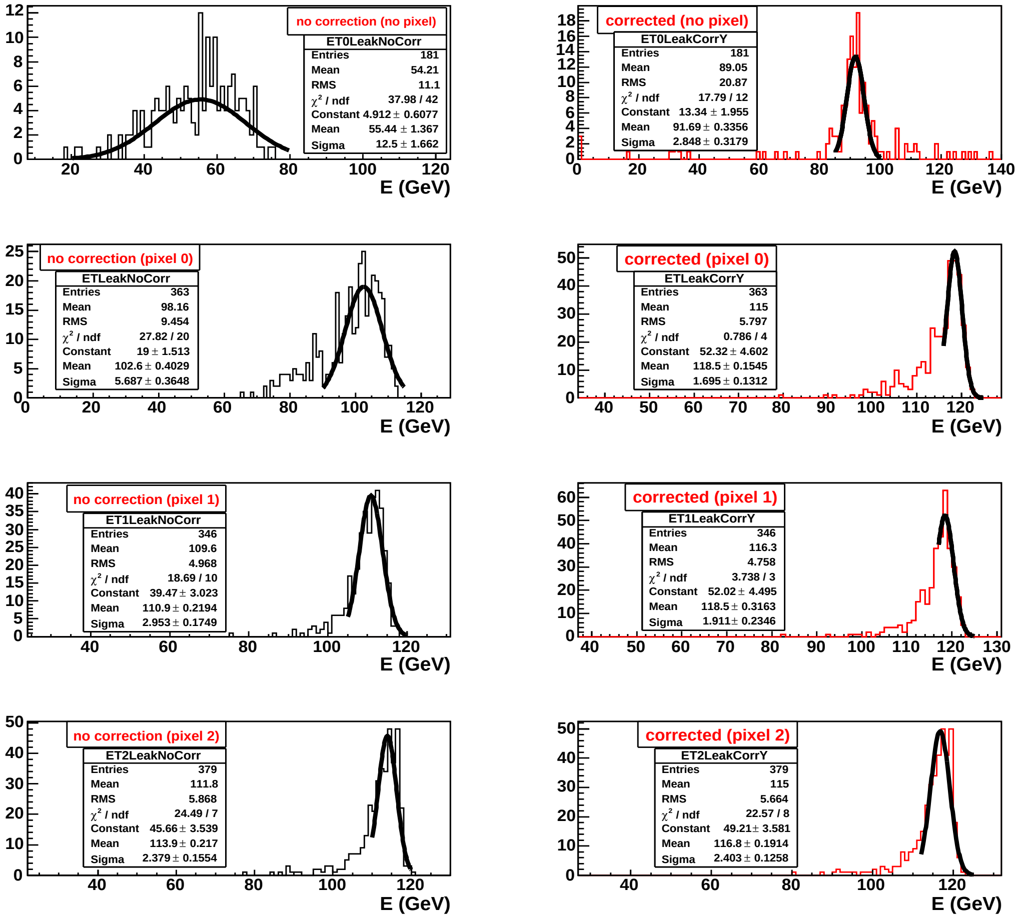

Figure 10: *Electrons with 120 GeV of energy. Total deposit of energy. Left column does not contain correction for leakage, right column does. In the first row the electrons do not hit the active area of the ECAL but interact in the material around and give some signal in this way. In the second row electrons hit the first pixel from the edge, in the third row the second pixel is hit. The fourth row presents results for the third pixel hit.*

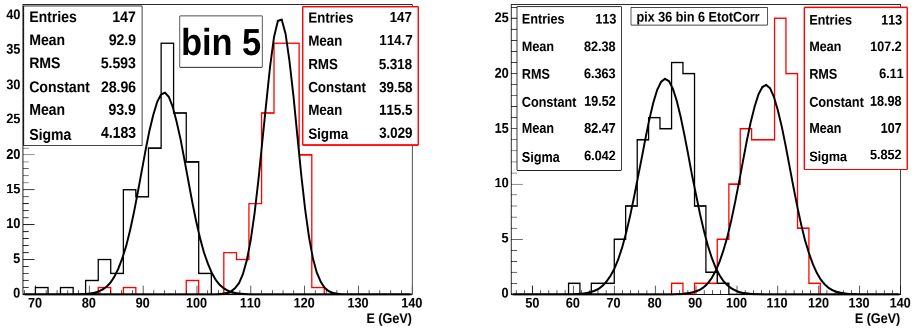

Figure 11: *Electrons with 120 GeV of energy. Correction in the last 2 bins of the last pixel (divided into 6 bins - see text for details). Size of each bin is 1.5 mm.*

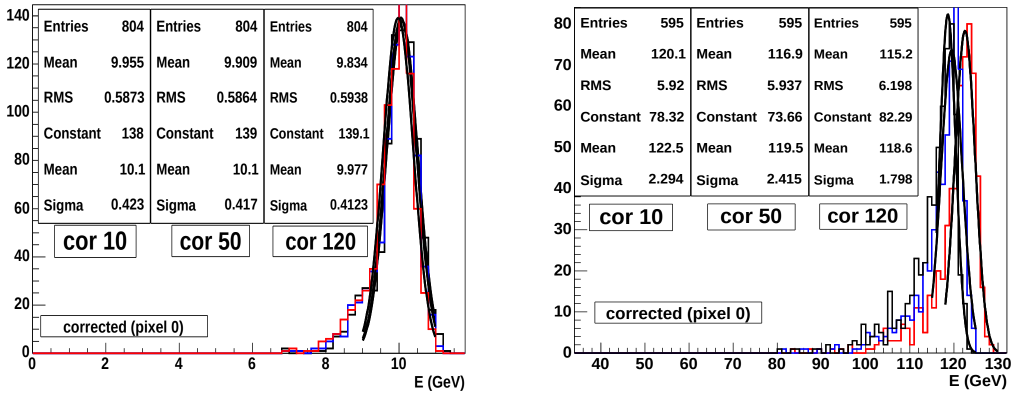

Figure 12: *Electrons with 10 GeV (left plot) and 120 GeV (right plot) of energy corrected with correction factors obtained for 10, 50 and 120 GeV. Different sets of correction coefficients give similar reconstruction of the deposited energy.*

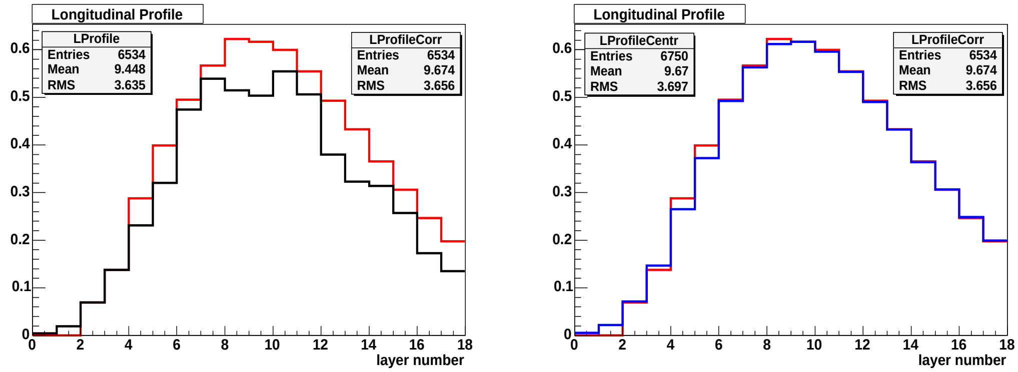

Figure 13: *Longitudinal shower profile for electrons with energy 120 GeV. Black line: electrons hit the last pixel, red line: electrons hit the last pixel and the energy correction per layer is done (with exception of the first two layers), blue line: electrons hit middle of the ECAL (no transverse leakage).*

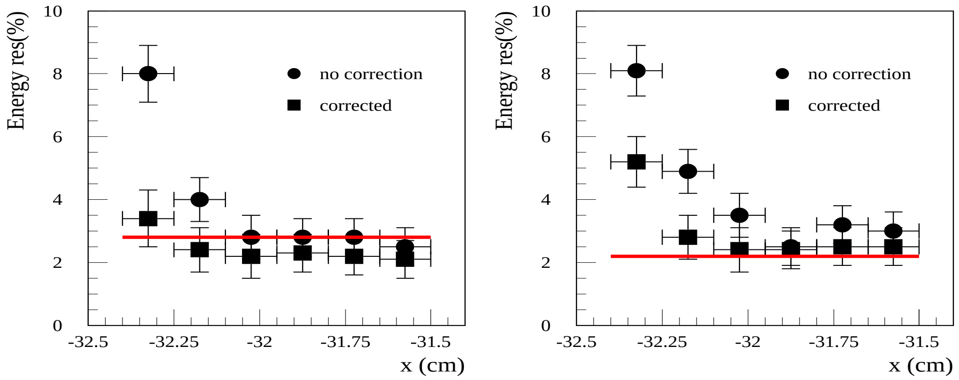

Figure 14: *Energy resolution as a function of position within the last pixel for energy 50 GeV and 120 GeV. Circles represent measurements without correction for transverse leakage, squares represent corrected measurements. Red line corresponds to energy resolution as measured in beamtest [4].*

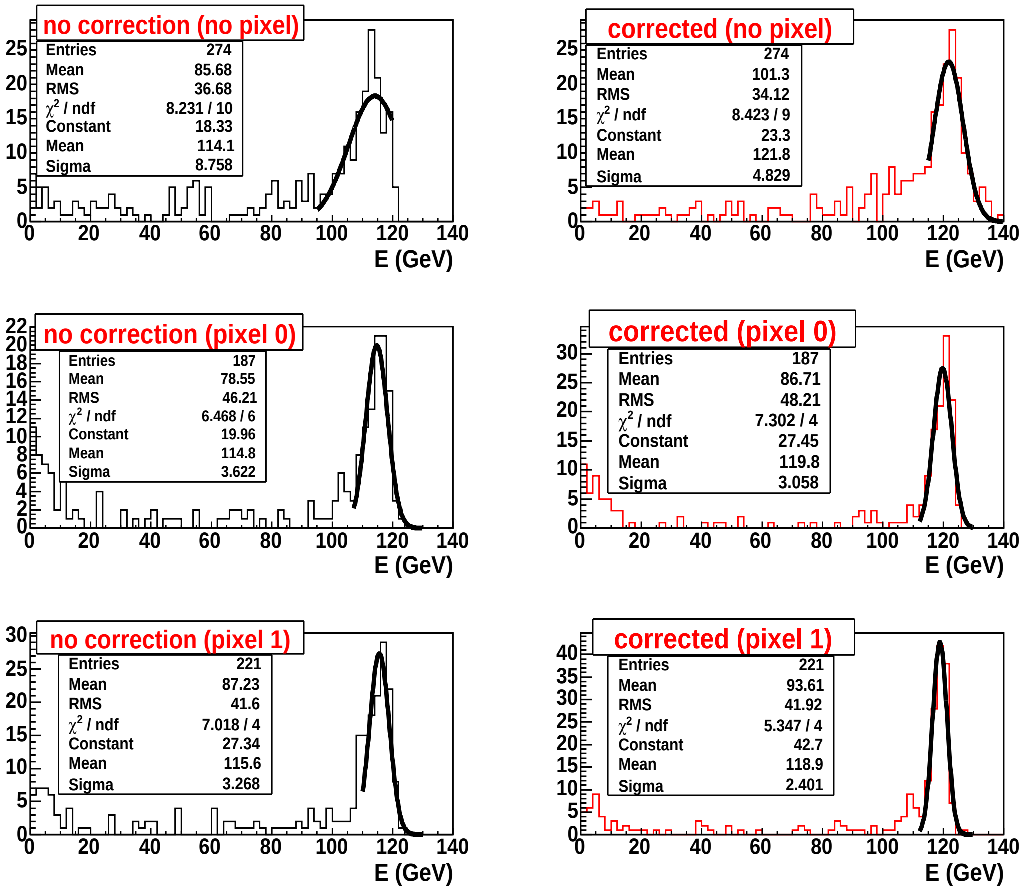

Figure 15: *Electrons with 120 GeV of energy. Particles were generated with an incident angle* $\Theta \pm 23$ *deg. The low energy tails are produced by electrons leaving the ECAL by side.*

3 Testbeam data

During the Summer 2002, the ECAL was tested in the SPS-beam at CERN. The testbeam setup consisted of trigger scintillators, Cerenkov counters (CEDAR) and the ECAL. The Cerenkov counter can be used to identify the particles only for low energies, so for high energies the beam is not too clean. Some of the test runs were performed at the border of the ECAL to check for the amount of the transverse leakage.

We have chosen to analyze electron runs with energies 10, 50 and 120 GeV. There were some runs for each of these energies which were hitting on the edge of the ECAL. The other runs, with showers contained in the Calorimeter, were also analyzed as a control sample.

The analyzed set of runs is presented in Table 3.

Table 3: *Beam test runs chosen for analysis. Beam position is shown in beamtest reference frame.*

run No	beam y position (cm)	beam x position (cm)	y-pixel	pedestal run
	electrons, 10 GeV			
751	89.1	247.9	1	754
	electrons, 50 GeV			
1222	80	287	0	1223
1242	89	242	1	1241
1240	154	302	4	1241
	electrons, 120 GeV			
825	79.9	287	0	829
826	89.1	287	1	829
812	152	305	4	811

As already mentioned, we have not been measuring the position of the particles during the beam test. The accuracy of the determination of the position is equal to the granularity of the ECAL, ie. 9 mm. So the correction factor used for beam test data was calculated for the center of the pixel hit by the beam. This affects results especially for the last pixel, where the value of the correction factor changes by even 50%, within the last pixel area. For the moment no other estimators of the particle position were used [1].

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[1] For possible estimator based on center of gravity see [6]

The analysis was performed with use of the latest set of intercalibration coefficients [4]. The $ADC \to MeV$ coefficient used is equal to $0.9\frac{MeV}{ADC(highgain)}$. The transverse leakage correction is the same as found in MC.

In Figure 16 the blue areas correspond to ECAL zones affected by dead or noisy PMs. The fat lines represent dead PMs while the thin lines represent PMs with only one dead/noisy channel. There is a dead PM in the interesting zone. It is the PM which collects the signal in y-direction (giving position in x) and its number according to the beam test numbering scheme is 6020. Runs touching this PM should be treated with care. The affected runs have beam in position $256 < x < 274\ cm$ (see the red coordinates in Figure 16). The PM is in sixth superlayer, where the shower is already developed, so it can also affect runs with beam not covering the PM area directly. In practice, only runs with $x > 280\ cm$ should be taken into account. Unfortunately we have not found any run which fulfills this condition for energy 10 GeV.

There is a photomultiplier, number 5010, which gives a signal of low quality. This PM, not shown in Figure 16, is difficult to calibrate [7, 5], and the quality of its signal can affect our results.

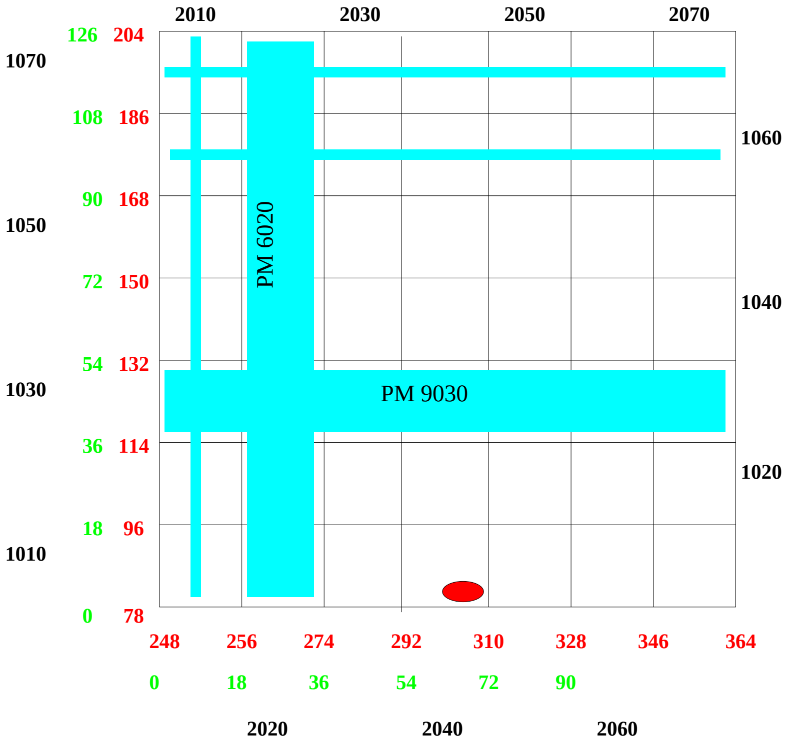

Figure 16: *Dead channels and PMs during the beam test. Blue bars mark the affected areas. Red ellipse is the area with the discussed beamtest runs. The red numbers are coordinates in the same coordinate system as in Table 3.*

The complete list of dead channels from [5]: PM 1070 (one channel), PM 2010 (one channel), PM 6020 (dead PM), PM 9030 (dead PM), PM 9060 (one channel), and PM 9070 (one channel).

3.1 Electrons, 10 GeV

This is difficult energy because of the lack of data. For this energy the cut on Cerenkov detector is valid (it does not reject too much data). There is one 10 GeV run (751) which touches pixel 1 (not pixel 0). But this run hits the corner of the ECAL so the leakage is on both sides (x and y). In addition this run is in the area with dead readout channels. There is a dead channel in PM 2010 and just next to the area covered by run 751 there is dead PM 6020. Due to all these problems we decided not to show any results for energy of 10 GeV.

3.2 Electrons, 50 GeV

For 50 GeV electrons, the Cerenkov cut can still be useful, however for this energy already a lot of good events are rejected. Run number 1222 is short (about 5000 events), so we are not using cut on signal from the Cerenkov detector here (see Figure 18 for the cut efficiency). Beam purity without any selection is at the level of 90%.

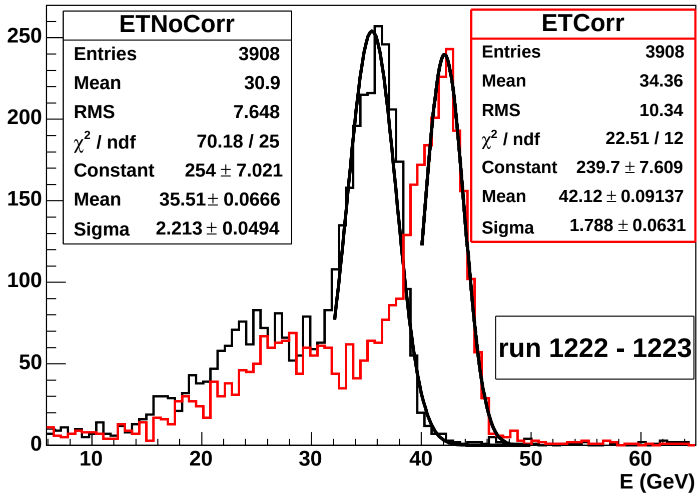

Figure 17: *Electrons with 50 GeV of energy from the beam test (run 1222), with and without leakage correction. No cut on Cerenkov detector signal. Correction coefficient has value corresponding to the middle of the last pixel, ie. y=-31.95 cm.*

Among the 50 GeV runs there are runs touching pixel 0, but no runs shooting into pixel 1 (the run 1242 is in the corner, so the leakage is in x and in y). In Figure 17 the results of the run 1222 is presented for the correction coefficient corresponding to the middle of the last pixel (this is accuracy we can have for the beamtest).

The mean value of the uncorrected distribution is equal to 35.5 GeV and approximately corresponds to MC electrons hitting the 6th bin of the last pixel (see Figure 9). A tail in the energy distribution is observed, however no explanation for this tail has been found. It might come from a special configuration of the beam in this case.

The correction coefficient is not the right one because the corrected peak position is only 42 GeV. The assumption that beam hits the middle of the pixel is wrong. In Figure 18 the correction coefficient, following the MC suggestion, has been taken as if beam were hitting the ECAL 0.75 mm from the last pixel edge (y=-32.325 cm). Reproduction of the mean value of the total energy is much better in this case: 47.8 GeV. But let us stress again that the beam transverse size is 9 mm. The proper procedure should associate the separate coefficient to every particle, and the "global" coefficient we are using here is a strong approximation.

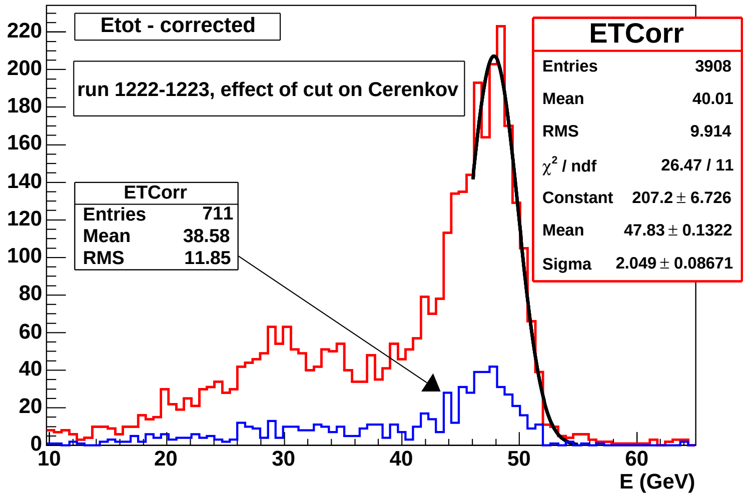

Figure 18: *Electrons with 50 GeV of energy from the beam test (run 1222), corrected for the leakage as if beam is hitting ECAL 0.75 mm from the last pixel border (y=-32.325 cm). The blue histogram is made with additional cut on signal from Cerenkov detector and presents how much statistics is lost when using this cut for this energy.*

The energy resolution for 50 GeV, as predicted in [4], should be equal to about 2.8%. The uncorrected distribution for the run 1222 gives resolution of about 5.5%, while the corrected one is much better and equal to about 4.1%. Thanks to transverse leakage correction procedure we can recover a part of the energy resolution at the ECAL edge (especially that the procedure we use is very approximative, we could do better having more information about particle position).

3.3 Electrons, 120 GeV

For electron energy of 120 GeV there are few interesting runs. For this energy the information from Cerenkov counter is very inefficient so we do not use it. The beam purity, according to measurement performed during the beamtest, is about 50%, but the impurities a mainly located in the tail of the deposited energy distribution.

In Figure 19 electron run number 825 is shown. Correction procedure moves the peak of the distribution of the total deposited energy from 78.6 GeV to 91.3 GeV. Longitudinal leakage for 120 GeV electrons is at the level of 9% [3], ie. the peak, corrected for the transverse leakage should be placed around 110 GeV, as on the left plots of Figure 10. Therefore the correction on the transverse leakage is not sufficient. This is due to the fact that we use the value for the center of the last pixel (y=-31.95 cm), while the run 825 hit ECAL closer to the edge. The uncorrected value of 81.8 GeV correspond to MC electrons hitting within the first 1.5 mm of the last pixel (see Figure 11).

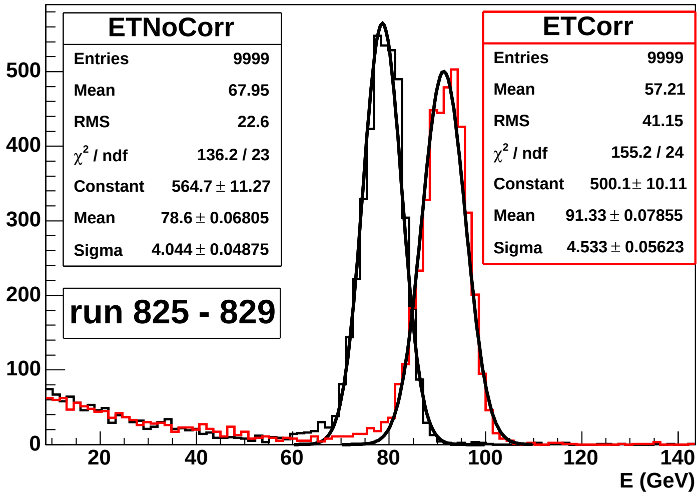

Figure 19: *Electrons with 120 GeV of energy from the beam test (run 825), with and without leakage correction. Correction coefficient as if electrons hitting the middle of the last pixel. Cerenkov information not included during selection.*

To prove this conclusion we used the correction factor for the position of 0.75 mm from the last pixel edge (y=-32.325 cm). The results are presented in Figure 20. For such correction factor, the corrected distribution reproduces the expected mean value of the deposited energy much better.

The expected energy resolution for energy of 120 GeV is equal to about 2.3% [4]. The uncorrected energy distribution for the run 825 has energy resolution of about 5% while the corrected one has about 4.8%. So in this case only small part of energy resolution is recovered.

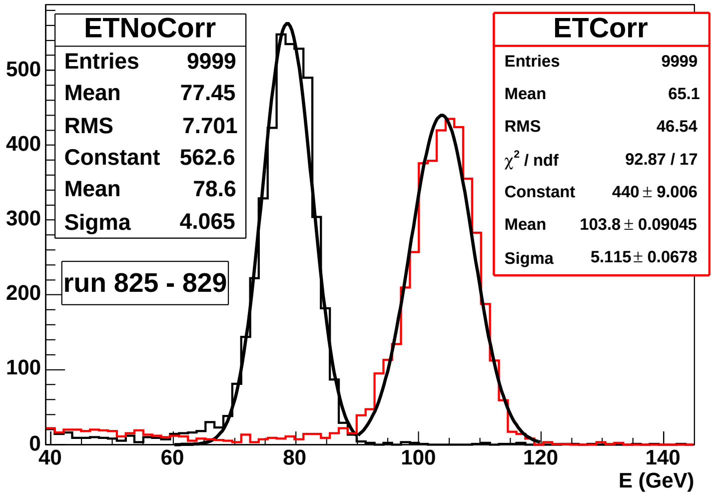

Figure 20: *Electrons with 120 GeV of energy from the beam test (run 825), with and without leakage correction. Correction coefficient used correspond to distance of the particles from the ECAL edge equal to 0.75 mm (y=-32.325 cm). Cerenkov information not included during selection.*

4 Summary and Conclusions

The analysis presented in this note allows us to draw a few interesting conclusions:

- Firstly, quite precise corrections on transverse leakage in the ECAL are energy independent and can be applied as multiplicative factors different for each layer of the Calorimeter.
- The method can be used for particles with a non-zero incident angle.
- In this approach the correction can be used even in the area close to the last pixel edge up to energy of incident particle equal to 120 GeV. The method does not work for particles hitting the non-equipped zone of the ECAL.
- This method allows us to correct reconstruction of the longitudinal shape of the cascade, which is important, for instance, for the proton rejection power of the ECAL.
- This method allows for partial recovery of the energy resolution even within the last pixel.
- The method improves the energy resolution for MC. This effect is smaller in data.

The geometrical active area (no cuts on particle reconstruction) of the ECAL (equipped zone) is 4200 cm^2. Without any leakage correction the last pixel would be lost for electrons of 120 GeV (0 deg incident angle), which would give the geometrical active are of about 3970 cm^2 (without taking into account the fact that at the corners the leakage is from two sides) which is 94% of the initial value. With correction for transverse leakage about 80% of the last pixel surface can be recovered, what gives the geometrical active area of about 4160 cm^2 which is about 99% of the initial value.

In future, a more sophisticated procedure using the first estimation of energy presented here (ie. energy-dependent correction) and other available information (like correlations between layers) may lead to even better results.

A remaining open question is the estimation of the particle impact point in the ECAL. In the real conditions, in the case of electrons, the estimation of the entry point can be made from track measured in the tracker. A study of the influence of the magnetic field on the shape of the electromagnetic cascade in the ECAL should be made, but we can foresee that the effect may be not large because lead is a diamagnetic material.

The impact position in case of photons (in single photon mode) is based only on the ECAL information and further study concerning the position resolution on the edge of the ECAL is necessary.

No real conclusion from MC/data comparison can be drawn. The particle position is known with a precision of one pixel in the testbeam, and within the last pixel the correction coefficients change by even 50% between the external and internal edge. From the comparison made here, we can only conclude that testbeam data are not in contradiction with MC results. When applying the MC coefficients on the beamtest data, the measured energy estimation improves.

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