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Measurement of the optical properties of the EB Module 0 tiles

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Abstract

Optical properties of the tiles equipping the Tilecal Extended Barrel Module 0 (EB0) assembled at IFAE (Barcelona) have been measured. The light yield as a function of the tile size, the uniformity of the tile response and the stability of the production process are presented.

1 Introduction

To equip the EB0 modules assembled in 1997, a new batch of tiles was produced by IHEP (Protvino) and wrapped with masked tyvek envelopes at Michigan State U. About a third of the sample, approximately 1600 tiles, was used for the EB0 assembled in Barcelona. The optical properties of the tiles were measured with a movable ^{90}Sr source before their insertion in the module, in April and May 1997.

The goals of the measurements were several:

- to evaluate the spread of the response of each tile type to check the uniformity of the production process;
- to study the tile response as a function of the tile size and check the effectiveness of the tile masking, by measuring the light output along the central line of each tile type (see figure 1);
- to investigate the tile response in regions that are relevant for the source calibration data, and the data taken with muons impinging at 90^o at the tile plane at the center of the tiles.

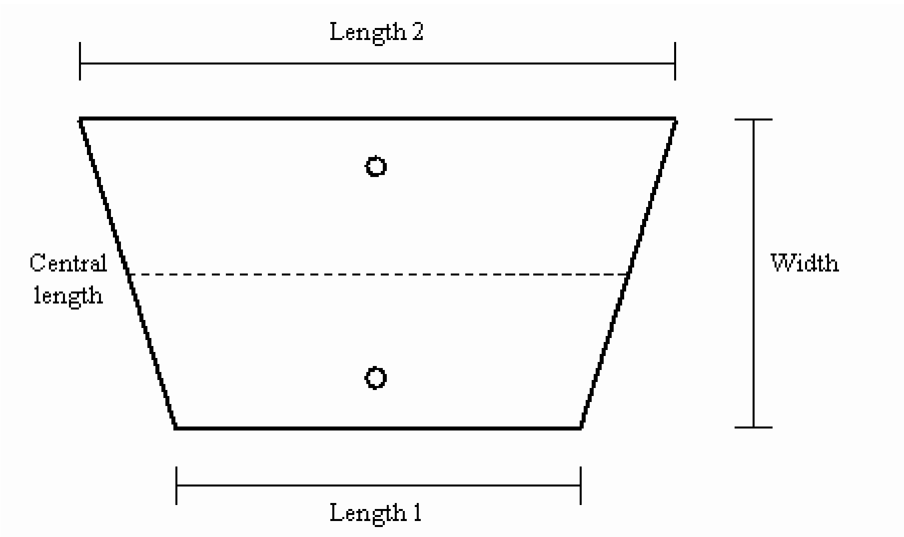

Figure 1: Schematic view of a tile

2 Experimental Setup

The measurements were performed with a setup schematized in figure 2. Mechanically, the setup consisted of a plotter, with a precision of positioning of 25 μm. The pen is substituted by a collimator containing a ^{90}Sr radioactive source with an activity of 2 mCi. The collimator is cylindrical with 6 mm thick steel walls that shield transversally the radioactive source. It is covered by a 5 mm thick steel cap, with a 1 mm diameter hole

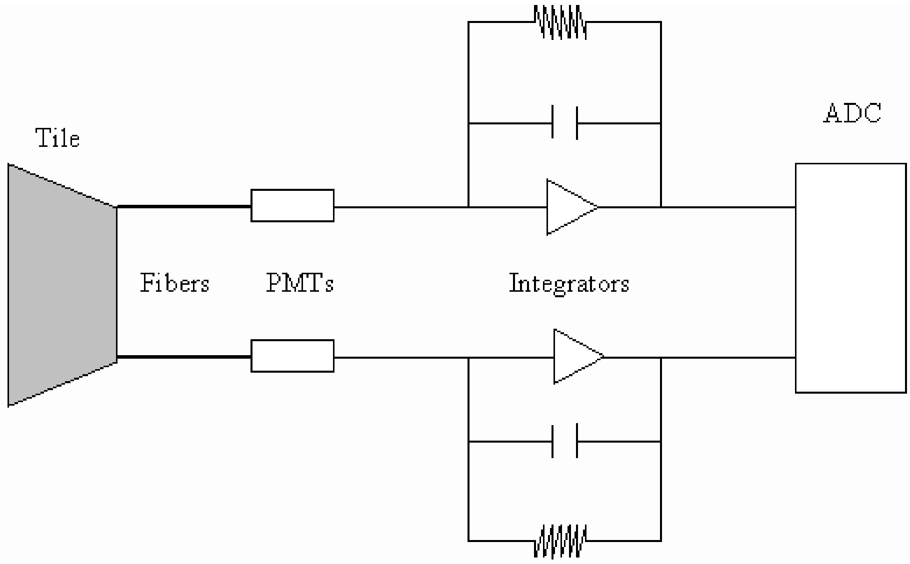

Figure 2: Experimental Setup

Tile type	length_1 (mm)	length_2 (mm)	Width (mm)	Area (cm^2)	Width/Area (cm^{-1})
1	221	231	97	219.2	.04425
2	231	241	97	228.9	.04237
3	241	251	97	238.6	.04065
4	251	262	128	328.3	.03899
5	262	274	128	343.0	.03731
6	274	287	128	359.0	.03565
7	287	301	147	432.2	.03401
8	301	316	147	453.5	.03241
9	316	331	147	475.6	.03091
10	331	351	188	641.1	.02933
11	351	367	188	674.9	.02786

Table 1: Dimensions of the 11 tile formats used in EB0, the notations are defined in figure 1

in the center. A support structure holds the tile above the plotter, at a distance of about 1-2 mm from the collimator. The light produced by the β source in the tiles , is collected at the edges by two optical fibers that channel the light to the PMT's (Phillips XP2012). These WLS Y11(200)M fibres of Kuraray were inserted into the new profiles used in the assembly of the EB0 modules. Good contact between the fibers and the tiles was ensured by the use of small steel clips that pressed the profiles against the tile. All the above elements were contained in a light-tight black box.

The current at the anode of the PMT is integrated by an electronic circuit that provides a DC voltage proportional to the mean current of the PMT. A VME ADC, digitizes the voltage after every plotter movement. The speed of the plotter is approximately 1 step (5mm) every 5 seconds. The Data Acquisition is controlled by Labview running in a PC that controls the plotter and the VME crate. The digitized data are written to a file for further analysis.

3 Measurements and available data

The dimensions of all tile types are summarized in table 1. A subset of 154 tiles of the full sample used to equip the EB0 assembled in Barcelona, was scanned:

- every tile of two tile rows (#5 and #6) of the cell B12 has been scanned (altogether 60 tiles), before installing them in the EB0.
- the full batch was sampled, at the rate of 1 out of 17, or a sample of 94 tiles; these tiles were not installed in the EB0.

The granularity of the scans, one step every 5 mm, was a compromise between time and precision. Each tile scan lasted about 20 minutes; half of the time was needed for stabilization of the pedestals.

To monitor the stability of the system , one tile was chosen as reference and was measured three times per day. The system was stable during the measurement of the tiles of the cell B12. The RMS of the response of the reference tile as measured with PMT1 and PMT2 was 1.6% and 1.3%, respectively. This reflects not only the stability of the gain of the PMT but also the repeatability of the tile-fiber coupling. For the measurement of the full EB0 sample, some instability appeared. It is illustated in figure 3. Table 2 summarizes the results.

RMS of the response		
	PMT 1 (%)	**PMT 2** (%)
Cell B12	1.6	1.3
Full EB0		
Stability period	0.9	2.4
Non-stability period	7	4

Table 2: System stability , in terms of the RMS of the response of the reference tile for the two scanning periods.

For the cell B12 the average signal of PMT1 and PMT2, has been used as reference. For the full EB0 sample, PMT1 was used as reference for the stable period, and PMT2 for the unstable period correcting for the monotonic decrease in gain.

4 Uniformity of the tile samples

To study the uniformity of the tile response in a production batch, the light output was measured for a sample of each tile type, by moving the source along the central line (see

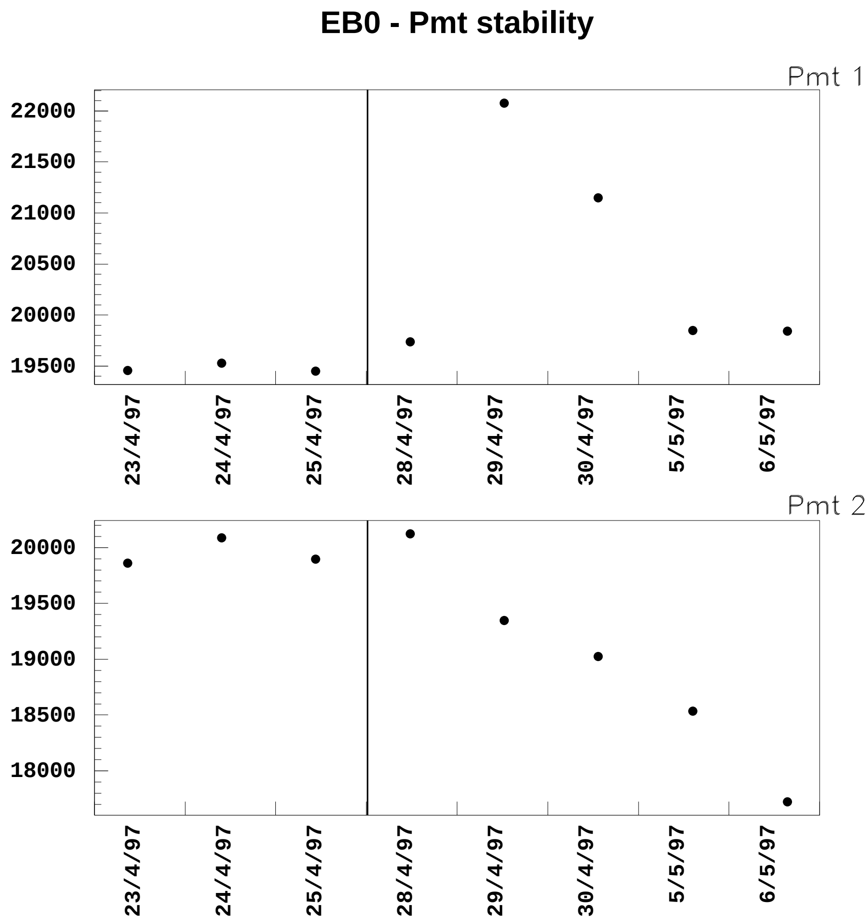

Figure 3: System stability. Response of the "reference tile" as a function of time, during the scanning of the full EB0 tile sample. Each point corresponds to the average of the three daily measurements. The vertical axis gives the tile response in ADC counts. The vertical line separates the measurements in two sets. In the first set where both PMT's were stable. The second set, the response of PMT2 decreased monotonically, whilst the other was more irregular.

figure 1, central length) in steps of 5 mm. An example of the signal output from the two fibers, together with their sum, is shown in figure 4.

The characteristic response of a tile was obtained by summing all measurements along the central line from the two fibers after pedestal substraction (this sum is only used for comparison of tiles of the same type). The spread of the tile response for each tile type is summarized in table 3: the gaussian σ as well as the number of tiles with a light yield differing from the mean more than 3σ are given (in these cases the measured light yield is always smaller than the average), and the RMS of the full sample for each tile type are quoted. Figure 5 shows, as an example, the correlation between measurements from the two PMTs for all tiles of size # 9. There is a clear correlation between the signals of the two PMTs for the tiles that present a response different smaller than the average. This was true for all such cases.

The results show that the response of the tiles examined is uniform within a few percent. From the 154 tiles measured, only 8 were off by more than 3σ from the average response of the corresponding tile type.

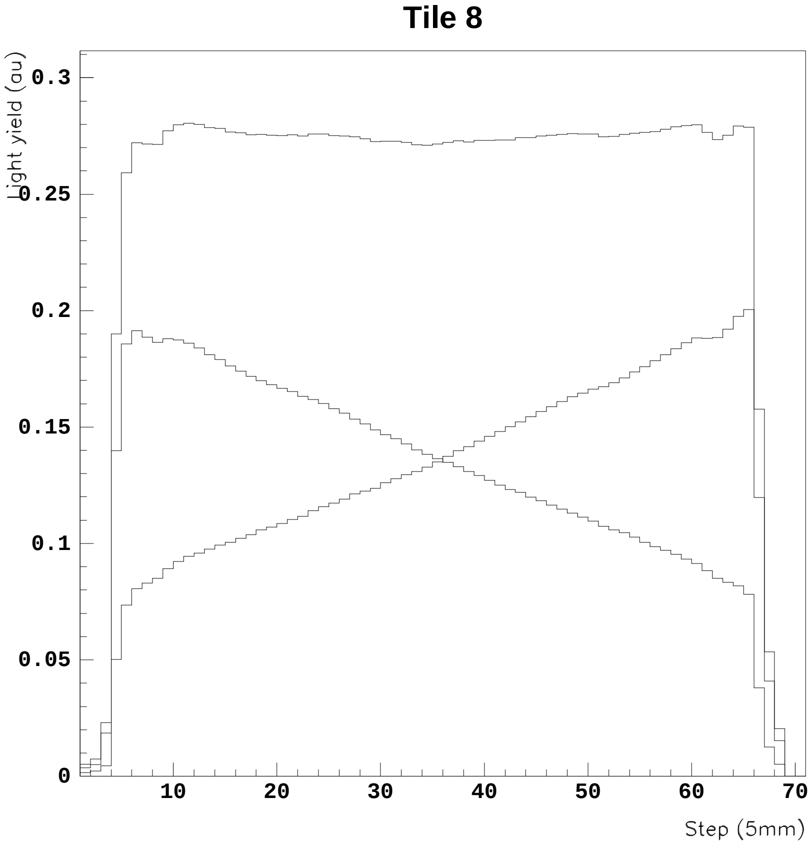

Figure 4: Signal output (au) from the central tile scan. The signal from the two fibers together with the sum are shown.

5 Effect of the Tile Masking

For the '97 batch, the masking was optimized based on the experience from the masking of the '96 batch [3]. We measured the uniformity of the tile response along the central line. The results are presented in figure 6. They show an improved uniformity compared to the '96 case (Module 0) [3], where only tile types from #6 to #11 were masked.

A good uniformity of the plateau [1] (of the order of 1-2%, see table 4) is obtained with the masking for all tile sizes.

6 Light Yield vs w/A

Using the mean value from the scanned tiles of each type [2], we parametrized the light output as a function w/A (or equivalently the inverse of the central length of the tile, see

[1]The plateau is defined as the region where signal collected by each PMT is 5% smaller than the maximum measured signal, in order not to be sensitive to the effect of the masking, provided that the source position is inside the region below the scanned tile.

[2]the tiles with a light yield differing by more than 3 σ from the mean have not been taken into account in this analysis

Tile nr	Nr of tiles	Gaussian spread (%)	Tiles with values beyond 3σ	Total RMS(%)
Cell B12				
5	30	3.6	0	3.6
6	30	1.5	1	3.4
EB0				
1	8	3.9	0	3.9
2	8	3.2	0	3.2
3	8	3.0	0	3
4	9	1.8	2	4.5
5	7	1.8	1	7
6	8	1.9	0	1.9
7	9	2.2	0	2.2
8	9	2.9	2	4.6
9	10	3.3	1	5.2
10	9	2.7	1	4.4
11	9	2.7	0	2.7

Table 3: Tile-to-tile response fluctuation. The spread in the tile response for each tile type, for the cell B12 and for the full EB0 sample of the Barcelona module

Tile response vs source position	
Tile nr.	RMS(%)
1	0.9
2	1.0
3	1.1
4	0.8
5	0.6
6	0.4
7	0.6
8	0.8
9	1.0
10	1.8
11	2.4

Table 4: RMS of the plateau. Response of the tile versus the source position along the length direction.

figure 1), as suggested in reference [1]. Two methods of analysis have been applied. The firsts consists in taking as response of a tile the average over the region as displayed in figure 6. In this case, the resulting parameterization is (- 0.1864+ 20.925·w/A), where [w/A] is given in cm^{-1}, and the light output is given in arbitrary units. The other method

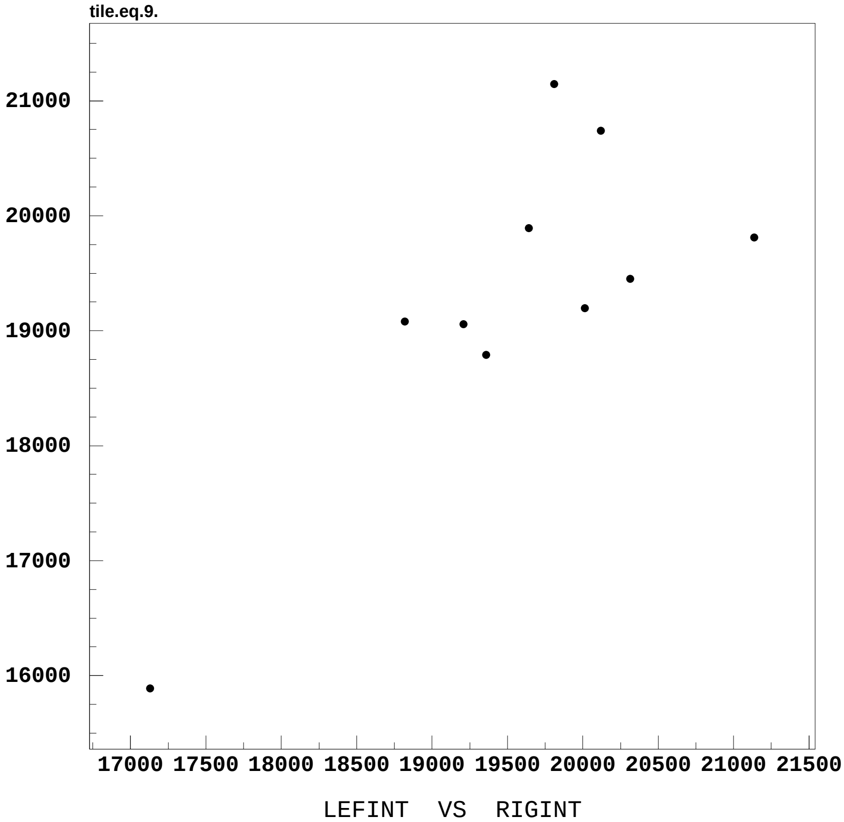

Figure 5: Correlation between the measurements from the two PMT's for 10 tiles of size # 9: The integrals are given in ADC counts.

consists of using the average light output of the three central points as the characteristic light output; this gives the parameterization, (-0.1854 + 20.96·w/A), consistent with the first result. Both sets of results are shown in figure 7, where they are compared with the light yield of the 1996 production (Barrel Module 0); measured by exciting the tiles with the source at their centre [2]. The light yield parametrized with the second method (central points average) is also compared in figure 7, with the light yield of a sample of the 1997 tile production scanned at CERN [2]. From the comparison, it is observed that the CERN light yield measurements presents a rather flatter dependence on the tile size. It must be noted that in the CERN measurements [2], the tile-fibre coupling is slightly different: on the two lateral edges where the fibres are connected, a small piece of aluminized Mylar was put (fixed with adhesive tape in the two sides) to keep the fibers in place.

The attenuation length has been measured for three tile types, #5, #8 and #11. The signal from one fiber was fitted by a single exponential, leaving out the masked region close to the edge. The measured attenuation lengths are 359, 364 and 373 mm (± 30 mm) for tile type: #5, #8 and #11 respectively. This result is compatible with the value measured in [4] (350 mm for tile size # 11) and also with the measurement of the attenuation length of the largest tile (384 mm) of the Barrel Module 0 [3].

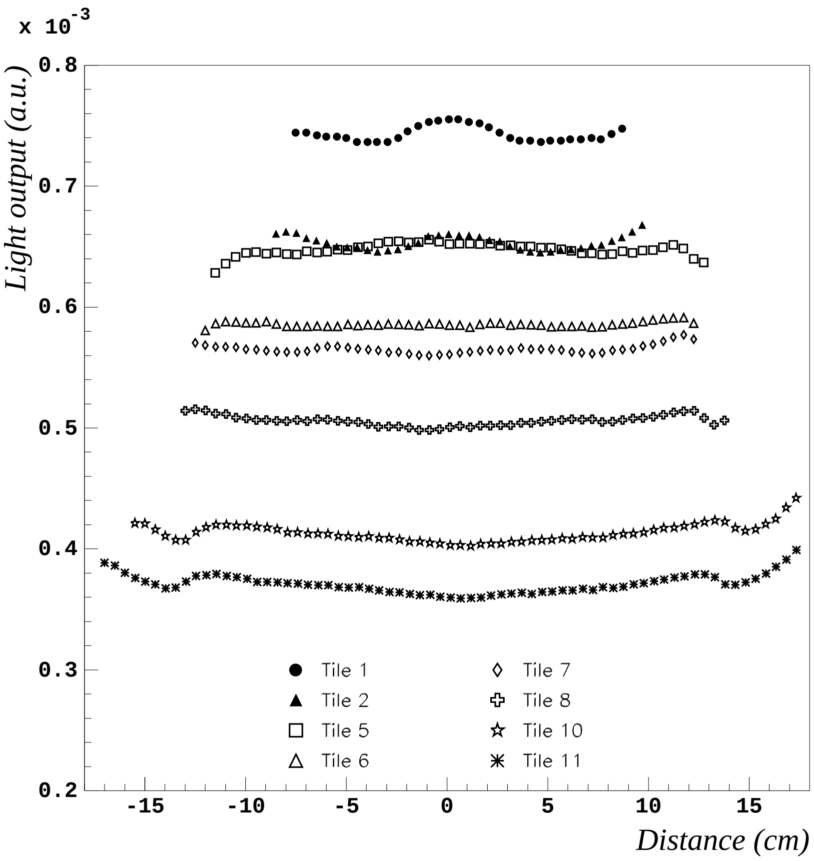

Figure 6: Light yield average vs source positions, for different tile types

7 Tile Response along the width

The motivation of such a scan is to measure the tile response in the region relevant fot the Cs source calibration and the data taken with muons impinging at 90 degrees at the center of the tile. The scans were done along three vertical lines (see figure 8). One passing exactly at the center of the tile across the holes, and the other two on each side of the central line. The distance between the lines is 1cm. The step between measurements in each line is 5 mm.

A typical output from the PMTs for this type of scan (tile # 1) is shown in figure 9.

The line # 2 passes through the center of the tile, across the two holes. They can be clearly seen (in figure 9) in the valleys of the response of the two channels. For the lines 1 and 3 the effect of the holes depends whether the signal is collected on the same side (plateau with a small slope), or on the other side of the holes: some small structure due to the reflection of the light on the surface of the holes, appears in the plateau.

The light yield in a tile is higher when the light is produced close to the longer edge of the trapezoid. The difference, with the other edge, is about 10 %. The response of each tile type versus the source position has been fitted by a straight line (using line 1 for PMT2 and line 3 for PMT1), and the average slopes for all tiles of each type were

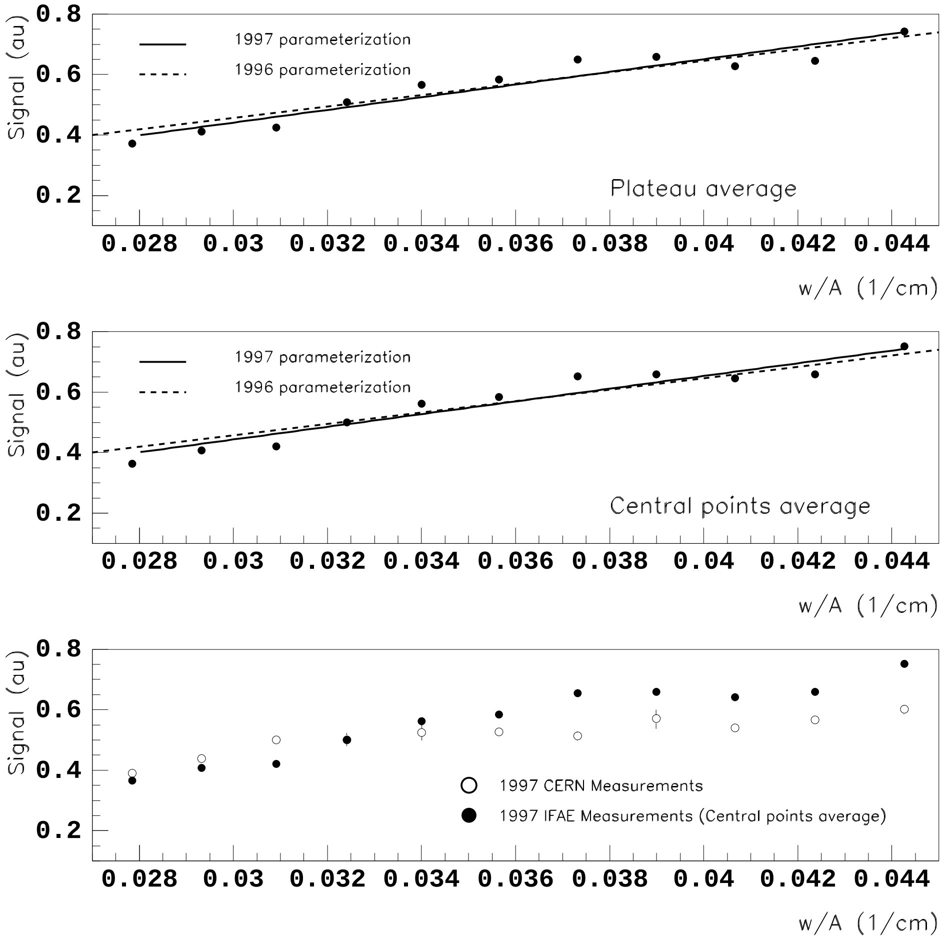

Figure 7: Tile output vs w/A. For each size, the average response, calculated by two different methods (see text) is given and compared to the result obtained for the batch of tiles produced in 1996 to equip the barrel module 0. For both sets of results, the light yield of the tile type #4 has been used to normalize the two methods to the results of the 1996 study. The 1997 (IFAE) measurements are compared with the 1996 (CERN) measurements, again using tile #4 for normalization.

calculated, they are shown in figure 10. The errors in figure 10 are obtained combining in quadrature the errors of the fits to the points of line 1 and line 3.

Figure 10 shows that the slope tends to decrease as the tile size increases. The change of slope is not related to the increase of the thickness of the larger tiles towards the outer edge, which is reported in [4], because most of the ^{90}Sr electrons do not traverse the tile.

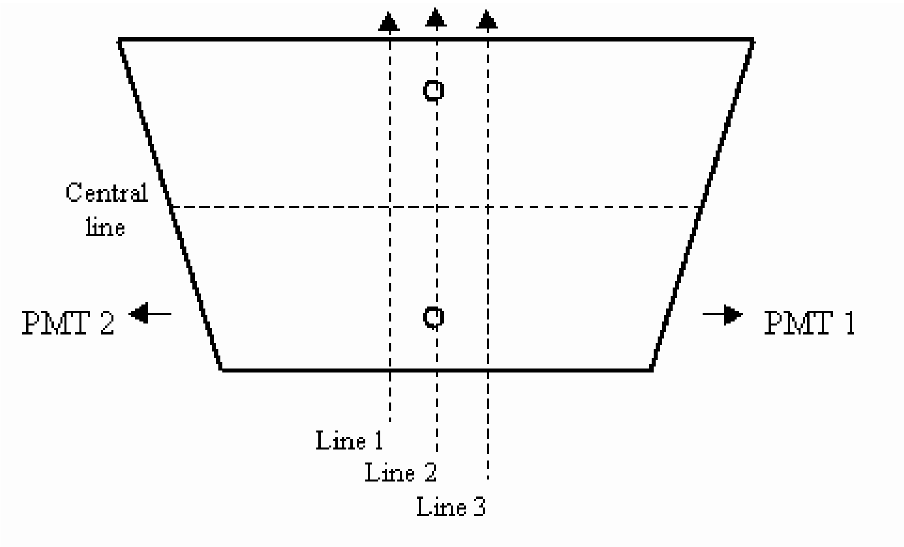

Figure 8: Vertical Scan

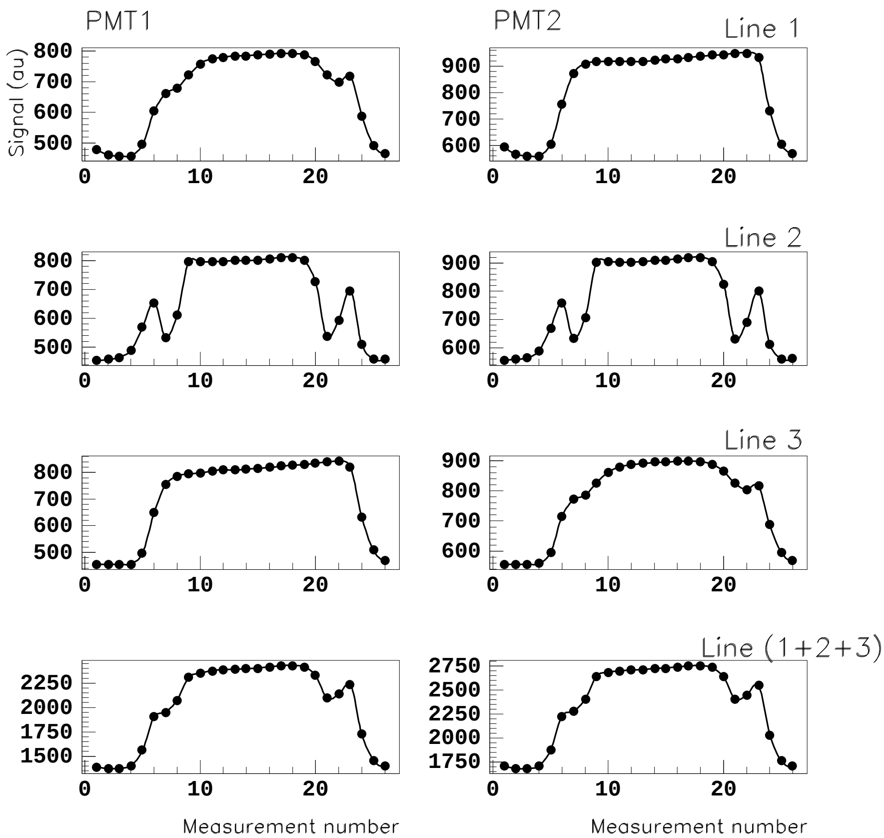

Figure 9: Typical result of a vertical scan. Tile type # 1.

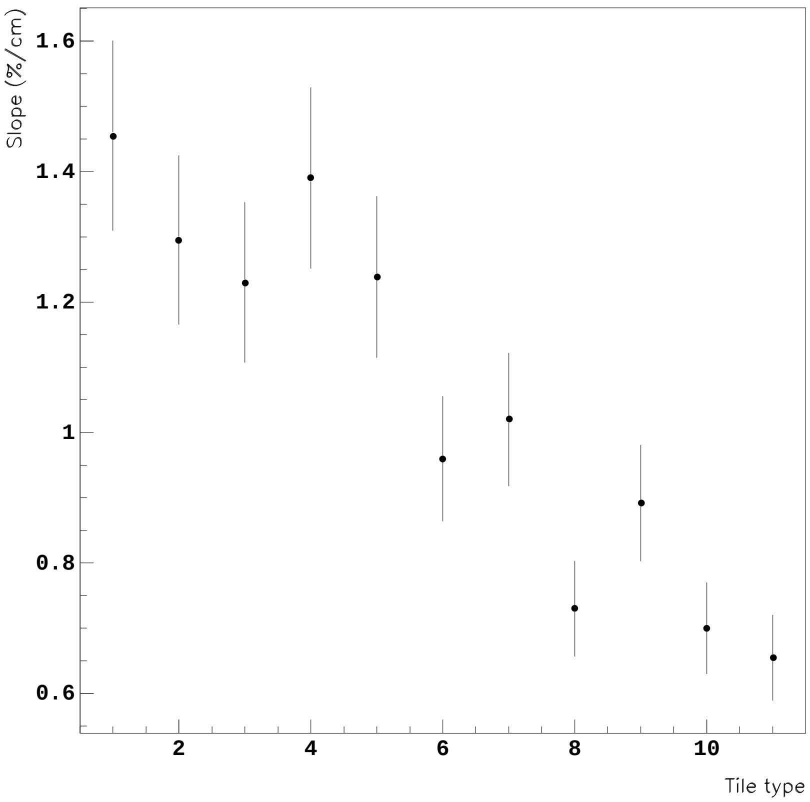

Figure 10: Tile response along the width. The average slopes and their errors for each tile type are obtained as explained in the text.

8 Muons vs Cs Source Calibration Zone Response

To quantify the effects of the tile non-uniformity on the two calorimeter calibration procedures (Cs source and muons), we have compared the light output from the zones around the holes, top and bottom (see figure 11), with the response at the center of the tile. The responses of each zone are averaged over the number of points scanned by the source (16 points around the bottom and top region, and 18 points in the central zone).

The results are shown in table 5 and figure 12, were the the signal of each zone is given relatively to the signal at the center of the tile for each tile type. The results may be summarized as follows:

- The tile response around the holes is smaller than in the central zone for most of the tiles except for the largest ones.
- The light collection in the center of smaller tiles benefit from reflection on the hole surface, as also seen in figure 6.
- The difference in response between the upper and lower hole regions is roughly 10%, independently of the tile size. This fact is useful in analysing "light budget" data obtained with Cs source scans [5].

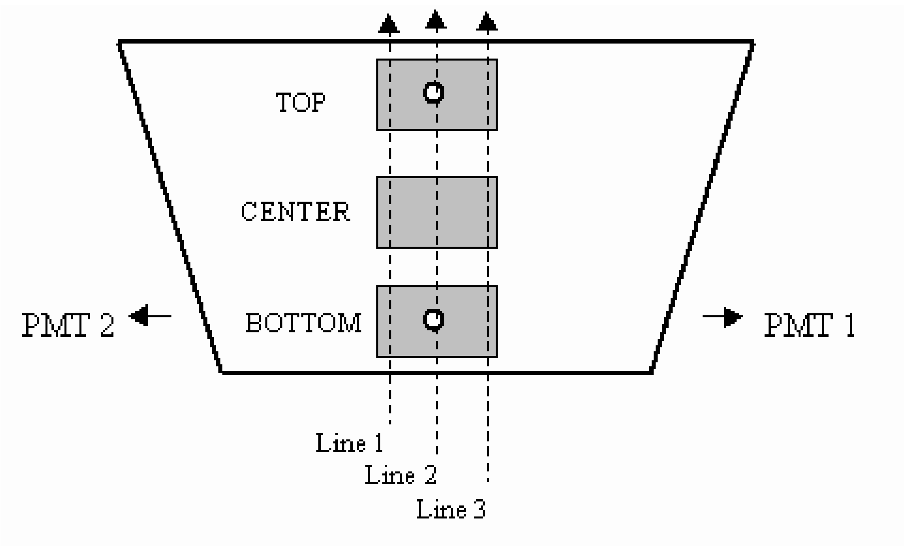

Figure 11: Calibration Zones

Response of different tile zones			
Tile nr.	Bottom	Central	Top
1	.916 ± .035	1. ± .040	.974 ±.040
2	.917 ±.014	1. ±.017	.969 ± .018
3	.923 ±.034	1. ±.037	.969 ±.039
4	.902 ±.049	1. ±.054	1.005 ±.053
5	.913 ±.055	1. ± .067	.984 ±.071
6	.917 ±.016	1. ± .018	.982 ±.018
7	.898 ±.024	1. ± .031	1.003 ±.032
8	.912 ±.053	1. ± .056	.9873 ±.057
9	.903 ±.055	1. ± .054	1.000 ±.053
10	.902 ±.072	1. ± .094	1.042 ±.107
11	.897 ± .024	1. ± .024	1.037 ±.025

Table 5: Cs versus muon calibration zones. The relative responses of the three calibration zones with respect of the central zone (sampled by 90 degrees muons).The errors are the rms value of the distribution for each tile type.

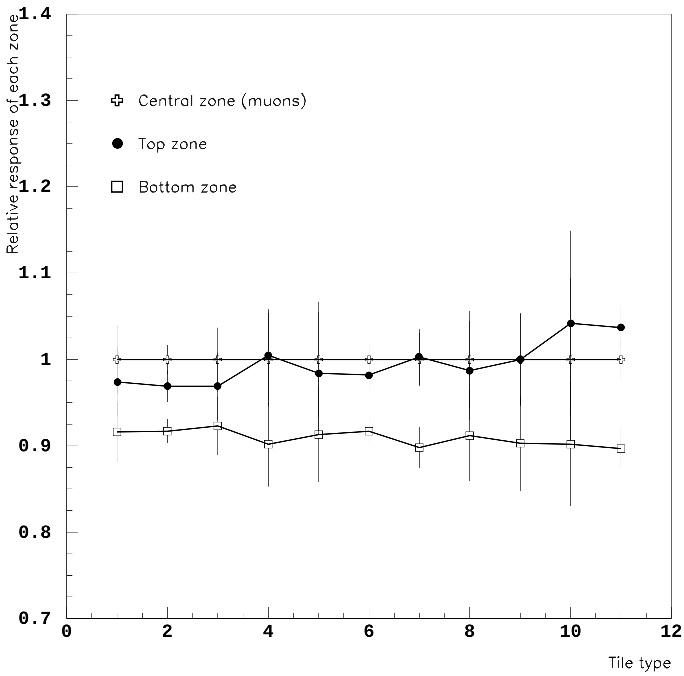

Figure 12: Calibration Zones response comparison

9 Conclusions

The analysis of the tiles produced for the EB0 has shown that groups of tiles of the same size present only a few percent spread in their response. The tile response along the central tile line, when summing the response of both PMT's, is constant within a few percent, showing that the masking is well optimized. The decrease of light yield with the tile size is similar to what was observed in Barrel Module 0. Differences of the tile response around the two holes and in the central zone of the tile are significant and should be taken into account in the calibration process (Cs and Muons).

References

[1] J. Proudfoot and R. Stanek, ATLAS Internal Note, TILECAL-NO-066.

[2] M. Cobal et al., ATLAS Internal Note, CAL-NO-81.

[3] ATLAS Collaboration. *ATLAS Technical Design Report*, Calorimeter Performance, CERN/LHCC/96-40, (15 December 1996), pages 130-136.

[4] Marina Cobal et al., ATLAS Internal Note, TILE-CAL-NO-124 .

[5] Sílvia Bravo, et. al., ATLAS Internal Note, TILE-CAL-NO-124, “Light yield of the 1997 Extended Barrels Module 0 from Cs data with nominal PMT settings” .