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Measurements of Some Optical Properties of the Tiles for Module 0

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Abstract

Measurements of the tiles used for the equipment of Module 0 were performed at CERN. We report here on the results obtained.

1 Introduction

The equipment of Module 0 with a new set of tiles has been completed recently. These new tiles were done by IHEP, Protvino. Once at CERN the tiles were wrapped with Tyvek and, on the two lateral sides where the fibers have to be connected, a small piece of aluminized Mylar was put (glued on one side and fixed with scotch tape in the other one) to keep the fibers in. The Tyvek sleeves were produce by the Irrigro Company, in Ontario.
Approximately 160 tiles of each of the 11 sizes (see table 1), were assembled with sleeves. Assembly refers to unpacking tiles, inserting them into Tyvek sleeves and then installing Mylar strips over both ends to couple the tile to the WLS fibers. For this, tiles could be processed at the rate of 20 tiles/hour. Most of this time was spent working with the Mylar strips.
Fifteen tiles of each size were assembled with sleeves but without the Mylar strips, for use the *profile* method developed in Lisbon to connect tile and fibers. The tiles from size # 6 to size # 11 (the biggest ones) were also "masked", namely the Tyvek sleeves were black-painted where the Mylar had to be applied, in order to smooth the light yield near the edges.
Before inserting them in Module 0, tiles were tested as discussed in the following. The main purpose of our measurements was to predict the light budget which will characterize the Module 0 towers.

Tile nr.	length_1 (mm)	length_2 (mm)	Width (mm)	Area (cm^2)	Width/Area (cm^{-1})
1	221	231	97	219.2	0.04425
2	231	241	97	228.9	0.04327
3	241	251	97	238.6	0.04065
4	251	262	128	328.3	0.03899
5	262	274	128	343.0	0.03731
6	274	287	128	359.0	0.03565
7	287	301	147	432.2	0.03401
8	301	316	147	453.5	0.03241
9	316	331	147	475.6	0.03091
10	331	351	188	641.1	0.02933
11	351	367	188	674.9	0.02786

Table 1: *List of the 11 tile sizes used for Module 0 equipment with their dimensions.*

2 Experimental Setup

Measurements were done using the setup shown in figure 1. To excite the scintillating material of the Tiles we used a ^{90}Sr β source (the black point in figure 1). Green WLS Y11 fibers of Kuraray, 2 meters long, were used for these measurements. The fibers had a diameter of 1 mm, and one of the ends was mirrored. After the fibers were inserted at the two sides of the tile, into the Mylar guides, the non-mirrored end was sent to a photomultiplier (PM) connected to an high voltage supply. The PM output was then sent to a multimeter which measured the light yield in mV. All the system was closed in a black box. During the measurements we tried to move as little as possible the connection between the fibers and the photomultiplier. Each time a fiber was cut, the non-aluminized end was polished.

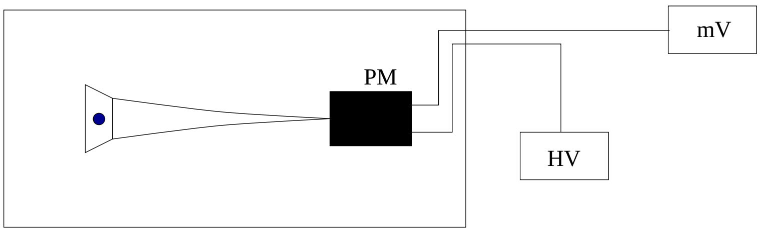

Figure 1: *Setup of the measurements.*

3 Tile Light Yield Comparison

The light yield for different tile sizes was measured by moving the source in the tile length direction in steps of 1 cm each. The results are shown in figure 2, where the upper plot refers to the unmasked tiles, and the lower plot to the masked ones. As can be seen from the figure, the light yield decreases with the tile size, and is pretty much stable when one move the excitation source along the tile length (this is true even for the biggest, masked tiles). The presence of asymmetries can be explained by the fact that no light mixer was used, so that the two fibers were illuminating different photocatode areas.

4 Uniformity of Tile Samples

In order to study the tile-to-tile response uniformity, we measured the light output from samples of 10 tiles of each of the 11 sizes. The results are reported in figures 3 and 4 (for unmasked and masked tiles respectively) which show that the tiles examined are uniform in their performances at the level of few percents. Table 2 summarizes the r.m.s measured for the various tile sizes[1].

Tile nr.	r.m.s. (%)
1	2.4
2	1.5
3	2.2
4	1.6
5	2.8
6	3.4
7	3.1
8	3.5
9	4.1
10	1.5
11	2.0

Table 2: *For different tile sizes, r.m.s of the light output.*

The non–uniformity is due to the scintillator quality as well as to the wrapping material.

5 Tile Output vs w/A

We then used the previous measurements, taking the mean value from 10 tiles of each size to verify the light output vs w/A law suggested in note [1], where w is the tile width and A is its area[2]. The results are reported in figure 5. The errors are the deviation of the data from the mean. The parameterization used for the 1995 production (solid line) is not fitting well the data anymore. A new parameterization (-0.49 + 105.2$\cdot w/A$) describe better our results. Using tile # 3 we also measured the light output varying the fiber lengths. We repeated twice the measurements using the same tile but different fibers. Figure 6 which shows the ratio between the first and the second set of measurements is also useful to have an idea of the reproducibility of our measurements as well as of the fiber-to-fiber fluctuation (which includes

[1] A more recent set of measurements shows bigger fluctuations in the light output from the largest tiles, of the order of 5-6%.

[2] We want to point out that this is not the most straightforward way to parametrize the light output as a function of the tile dimensions since in our case w/A is just proportional to the tile length.

the effect of different polishing at one end as well as the different coupling to the PM). The various points are mostly within the $\pm$ 5%.
Figure 7 shows the light output as a function of different fiber lengths. The black points and the triangles refer to two different set of measurements performed with different tiles and fibers. An error of 5% is assigned to each measurement.

6 Light Budget: Simulation of a Hadronic Tower in the ATLAS Detector

Finally, we studied the light budget simulating a tower of the ATLAS detector which corresponds to a rapidity (η) position of η = -0.1.
For this exercise we didn't use any parameterization for the tiles or fibers response, but just the correct tile sizes coupled with the correct fiber lengths. The fiber length for each tile size [2] are listed in Table 3. Fiber lengths are different for left/right (side 1/side 2) tile edges, since the corresponding holes for the PM's are shifted.

Tile nr.	Fiber length (cm) Side 1	Fiber length (cm) Side 2
1	200	195
2	190	186
3	200	195
4	176	181
5	162	167
6	176	181
7	129	132
8	115	118
9	129	132
10	103	108
11	83	88

Table 3: *length of the fibers coupled to the various tile sizes for an ATLAS-like tower at* η *= -0.1.*

For the tiles we measured about 10 of the same size, and then choose for the light budget measurements those who were closer to the value predicted by the parameterization (see figure 5) for each size. The measurements have been therefore performed in an exact Module 0–geometry. The results are reported in Table 4, and compared with the results obtained by the Lisbon group [2] (where a parameterization for both the tile (I_s) and fiber (I_f) responses has been used). All the measurements inside a cell have been normalized to the first measure of that cell, since we are interested in the light budget fluctuation inside a certain cell [3]. In Table 4 are also shown the fluctuations expected in each of the 3 cells as predicted by our results and by the Lisbon parameterization. One can see that the two results are in agreement. The numbers reported are affected by several systematic errors. It is worthwhile to recall that a tile-to-tile fluctuation of the order of at least 2-4% is expected.

Tile nr.	Measures (CERN)	fluctuation (%)	$I_s \cdot I_f$ (Lisbon)	fluctuation (%)
1	1		1	
2	0.92		0.98	
3	0.95	3.9	0.92	4.0
4	1		1	
5	0.96		0.98	
6	0.90		0.91	
7	0.95		0.98	
8	1.05		0.96	
9	0.94	7.4	0.89	5.5
10	1.		1	
11	0.99	0.0	1	0.0

Table 4: *Light budget for an ATLAS-like tower at η = -0.1. The second column shows our measurements, normalized to the first tile of a cell, for the 3 cells. In the third one the fluctuation in percentage for each cell is reported. The fourth and fifth columns show the results obtained with the parameterization of the Lisbon group.*

7 1996 Tiles Production Compared with 1995

The performances of tiles produced in Protvino in 1996 were also compared with those of tiles produced in 1995. For these measurements a slightly different setup was used and the output signal was a current instead of a voltage as before. The 96 production tiles are expected to be of a slightly

[3] In this case the fluctutation is defined as the difference between the maximum and minimum ligth output in a cell, divided by two.

worse quality in terms of transparency, since the 95 ones were produced with a better polystyrene and at the beginning there were some problems in the production (the tool for molding was not properly cleaned). This affected especially the large tiles which were the first to be prepared. For the next production, much experience is already gained and it is foreseen to find another good polystyrene.
Tiles of two different sizes for each production year were studied (see table 5: unfortunately the dimensions were not exactly the same for the two production samples).
Tiles were read out by just one fiber, to analyze the attenuation length. A

Tile	$length_1$ (mm)	$length_2$ (mm)	Width (mm)	Area (cm^2)	Height/Area (cm^{-1})
95 small	240	250	97	237.6	0.04082
96 small	231	241	100	236.0	0.04237
95 big	350	360	187	663.8	0.02817
96 big	350	360	100	355.0	0.02817

Table 5: *Characteristics of the 4 tiles used for the 96 and 95 production comparison.*

short dummy fiber was put on the other side. Figure 8 (upper plot) shows that we have a worst attenuation length for the 96 production tiles. To be in line with the results shown previously, obtained by using a two fibers read–out, the data taken at position x from the read–out fiber were added to that at position L -x, being L the tile length. The results are shown in the same figure (lower plot). The flex which characterizes the curves in the upper plot is due to the presence of the holes. At a first sight the data confirm what we expected, that is a better performance of the older tiles especially in the case of the largest dimensions. In addition, one should not forget that the tiles used are of different sizes and this can add an effect too. Using the parameterization from figure 5 to "rescale" the 96 tile dimensions to the 1995 ones, the small 96 tiles signal must be reduced by about a 3%. For the largest tiles, instead, we assume that to an equal w/A corresponds an equal signal so that we do not have to rescale them.

8 Conclusions

We measured some of the optical properties of the tiles which are used for Module 0. The tiles are uniform in their composition, and groups of tiles of the same size present similar characteristics. We also simulated an "ATLAS–like" hadronic tower and identified the presence of fluctuations inside a cell similar to those reported by the Lisbon group. Finally, a comparison between the 95 tile production and the 96 one has been performed, and the results show that the 95 production was of a slightly better quality than the 96 one. These data will need a carefull confirmation from the results of the source scan of Module 0 which is going to be done during the test beam of August '96.

References

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

[2] J. Fatela dos Santos, presentation given at the June 96 Atlas Week (Tilecal meeting).

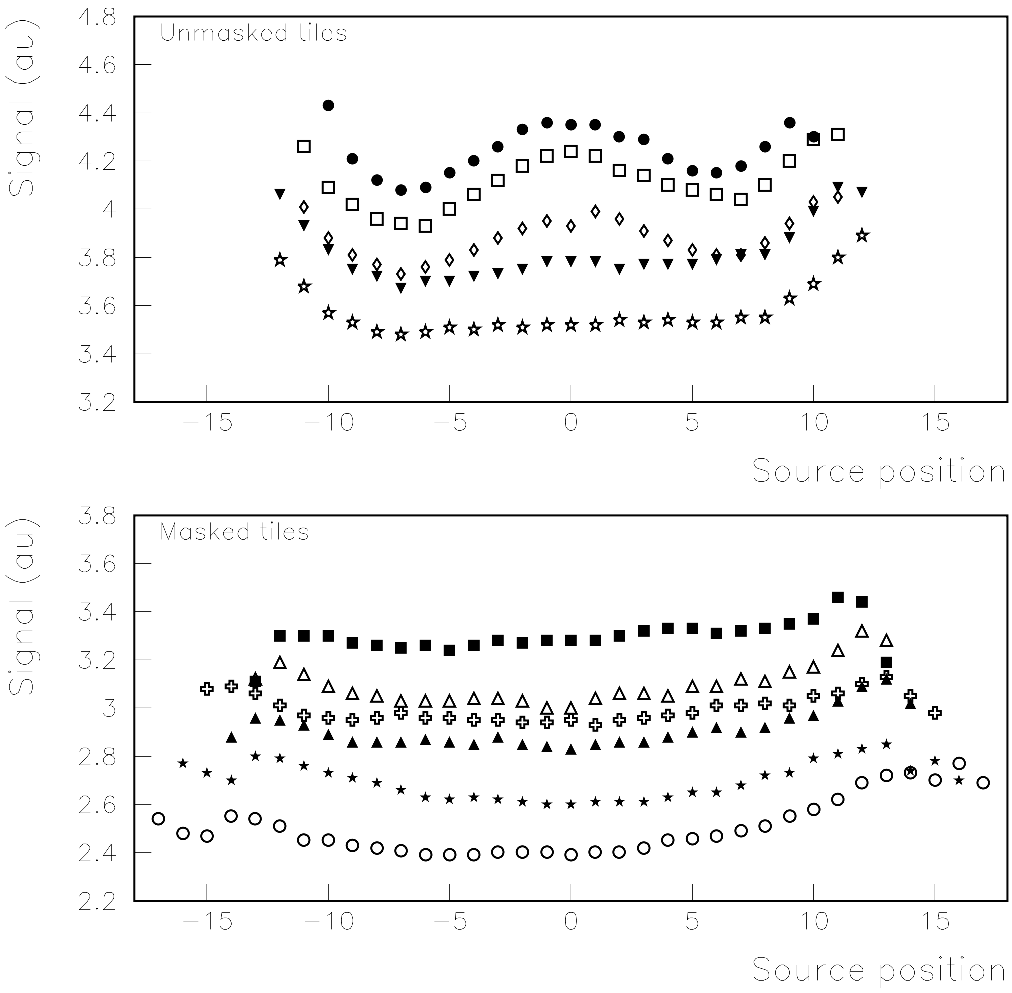

Figure 2: *Light yield for the different 11 tile sizes. In the upper plot the unmasked tiles are shown. In the lower plot the masked ones.*

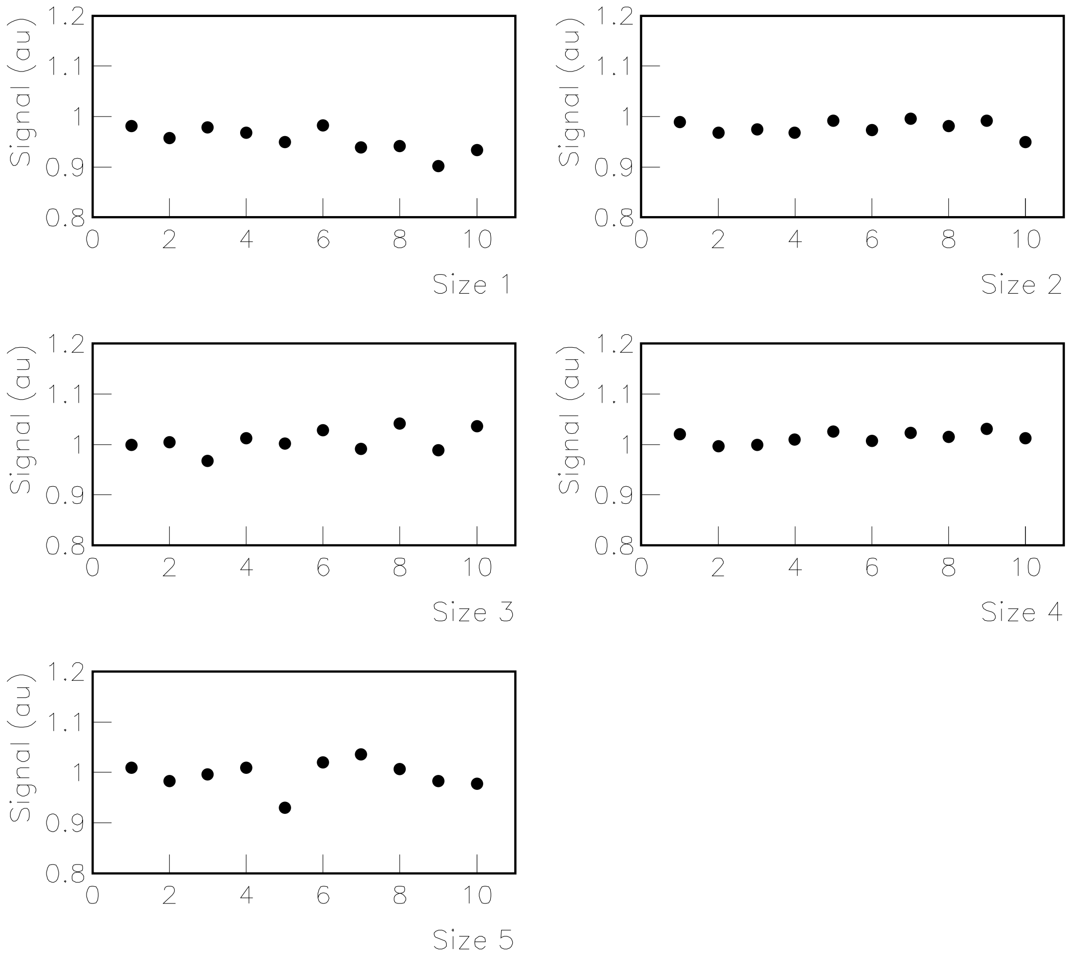

Figure 3: *Uniformity of tile light output for tiles 1-5 (unmasked).*

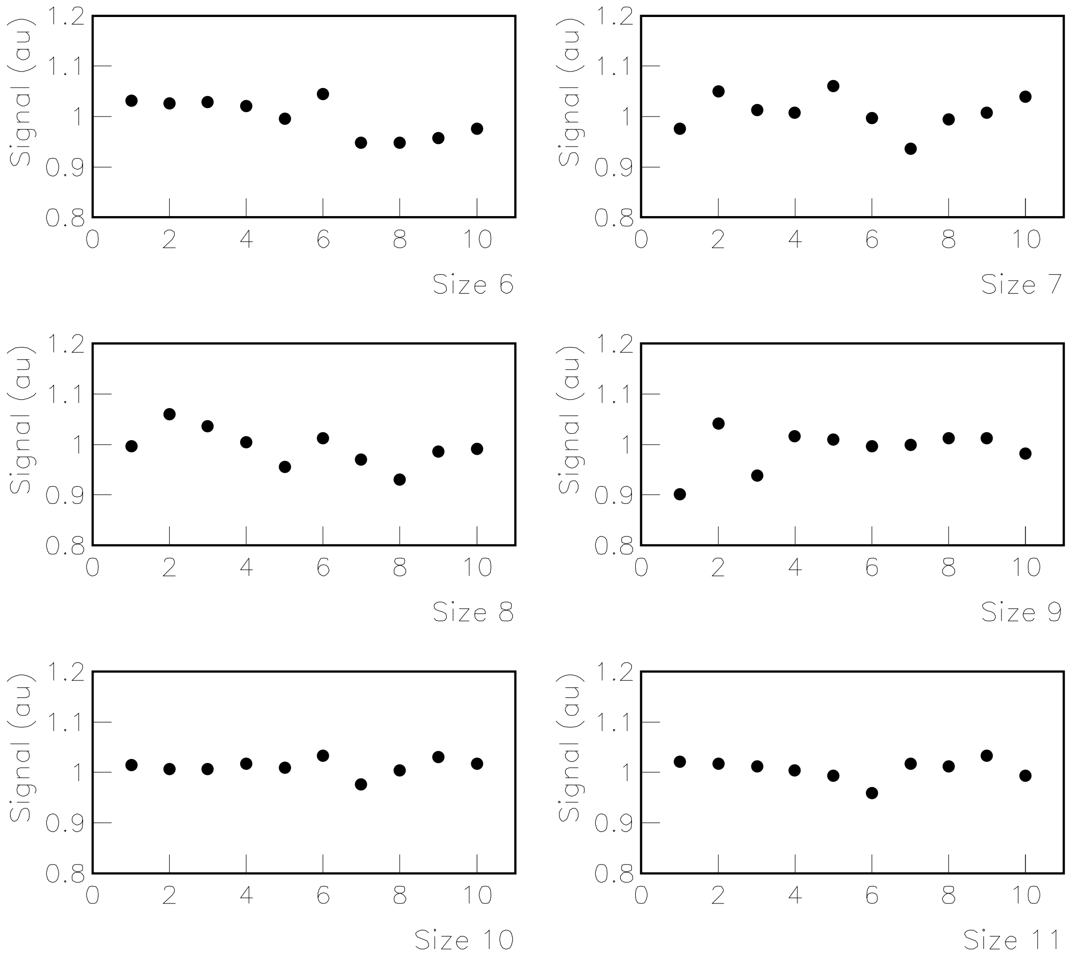

Figure 4: *Uniformity of tile light output for tiles 6-11 (masked).*

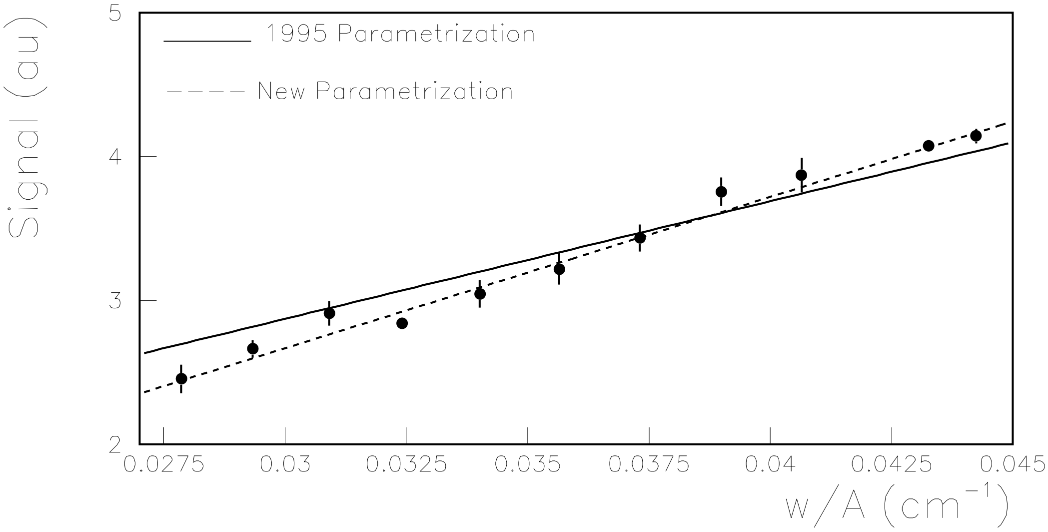

Figure 5: *Tile output vs w/A for the 11 tile sizes. For each size 10 different tiles have been measured, and the mean has been taken.*

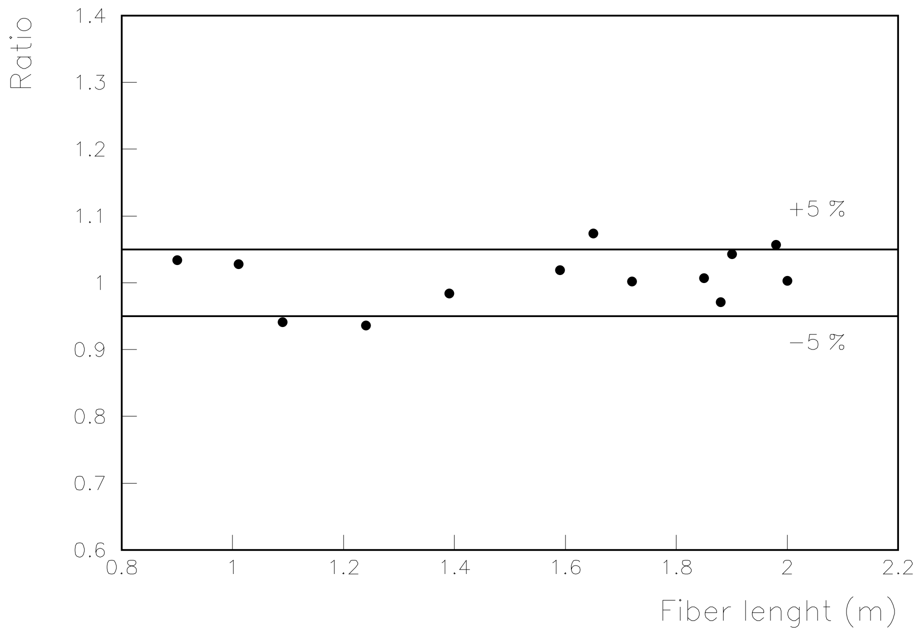

Figure 6: *Ratio between the first and the second set of measurements, for different fiber length. One can see that results are reproducible at the level of 5% almost.*

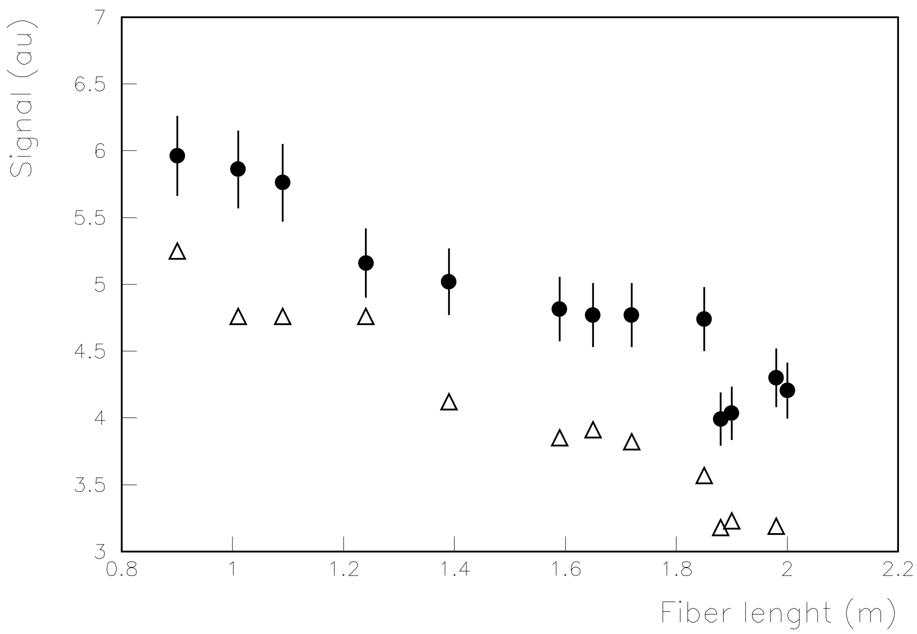

Figure 7: *Light output as a function of different fiber lengths. The black points and the triangles refer to two different set of measurements, done with a different tile and different fibers.*

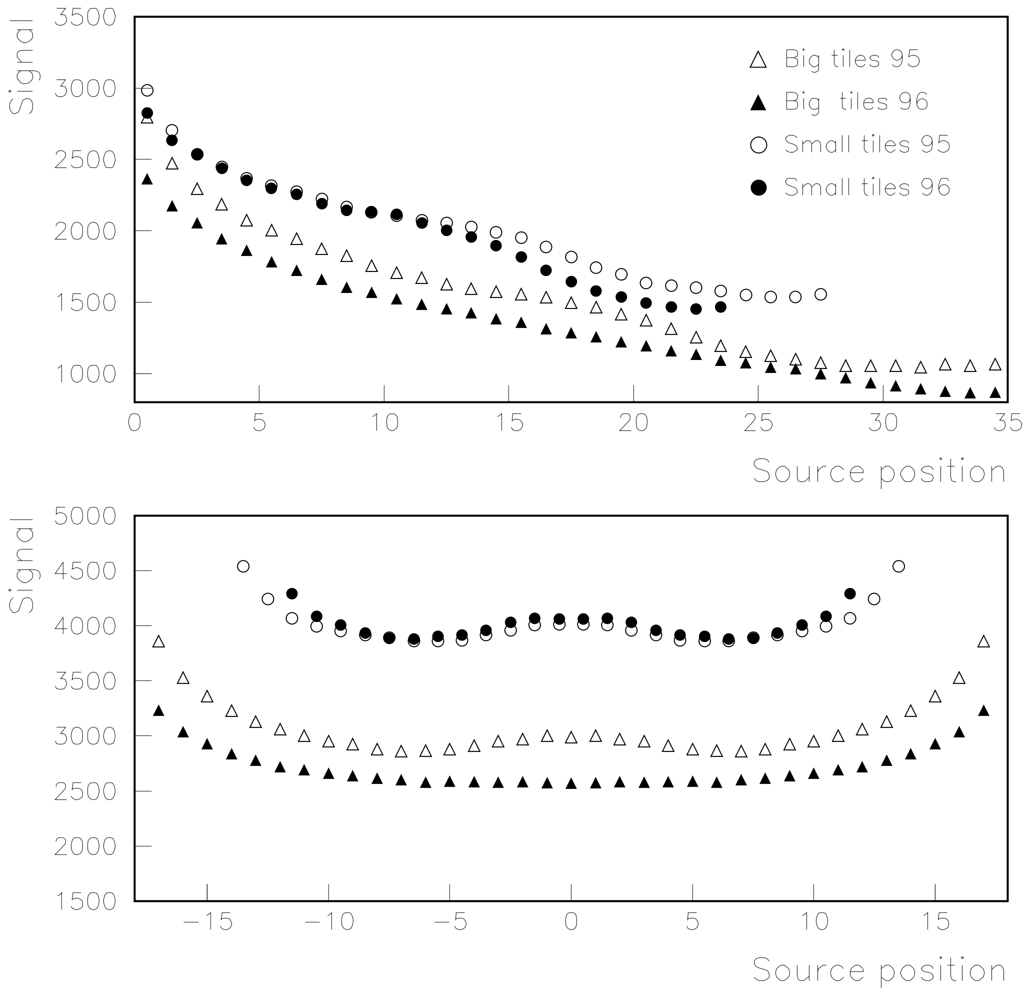

Figure 8: *Signal as read by one (upper plot) or two fibers (lower plot) for old and new production tiles of different sizes.*