ATLAS Internal Note
TILECAL-NO-XXX
February 13th,1998

Light yield of the 1997 Extended Barrels Module 0 from Cs data with nominal PMT settings.

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1. Introduction

One of the first steps in the gain setting of the Tile Calorimeter modules is to take Cs calibration data with the PMTs set to high voltage values corresponding to a nominal gain of 10^5 within a stated precision of ± 5%. These values are determined by lab bench tests at several institutions. These nominal gain data together with tables of PMT gain variation with HV are then used to equalize the Cs responses of all cells in the module. The nominal gain data can also provide useful information on the absolute light yield of the Tile Calorimeter, albeit only to the level of precision to which the nominal PMT gains are known. For example, in the 1997 Extended Barrels Module 0, the nominal gain data should immediately indicate any differences in light yield of the two modules due to differences in fiber routing. In this note we present an analysis of the 1997 EB nominal gain data.

2. Data analysis

The data analyzed were Run 10357 for the ANL module and Run 10360 for the BCN module. These were the first runs at the nominal HVs and with drawer cooling on. The response for each tile row in a cell is calculated as the normalised integral of the corresponding Cs structure (see TILECAL-NO-130 by M. Bosman et al.). Two corrections were applied to the data: one due to the range of photons in the calorimeter structure, and the other to correct for crosstalk effects due to the transparency of the profiles (see presentations by I. Vichou during ATLAS week in September 97 and by S. Bravo in November 97). A weighted average over all PMT signals for a given tile row is calculated, using the number of tiles per cell as the weight. The resulting light yield as a function of tile row is plotted in Figure 1. The light yield units (y-axis) are the corrected integrals in ADC counts.

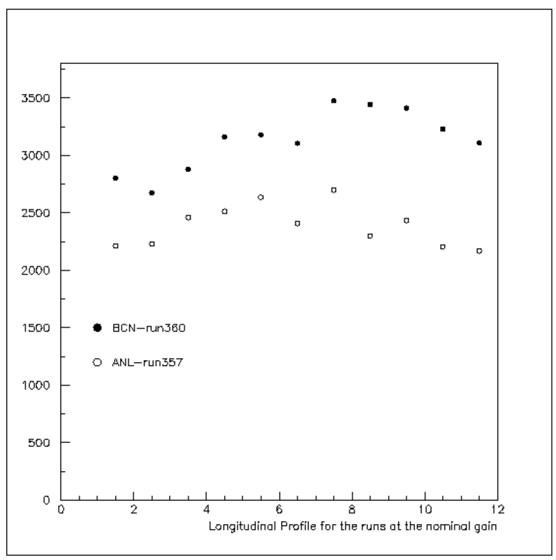

Figure 1

The data clearly show a higher light yield in the BCN module as compared to the ANL module, with a difference of about 20% in the two innermost sampling layers (corresponding to tile rows 1-3 and 4-7) and 30% in the outermost layer (tile rows 8-11). For tile rows 1-7, a difference can be expected, as the fiber routing for the ANL module has longer fiber lengths for these cells, with correspondingly larger light attenuation. The 30% difference for tile rows 8-11 is a surprise, however, as the fiber length is the same for these cells in both modules. This is well beyond the expected uncertainties of the measurements, which are those corresponding to the weighted average over 10, 10 and 4 PMTs, respectively for each sampling, which are nominally set to within 5%.

3. Predictions for the light yield from the Lisbon model.

The Lisbon model [TILECAL-NO-107 by A. Gomes et al.] can be used to predict the differences in light yield between the two modules due to the different fiber routing. The input parameters to the model have been the fiber characteristics used for the 1996 analysis of the Barrel 0 module, the tile characteristics measured for the Extended Barrel prototypes tiles [TILECAL note in preparation by M. Bosman et al.], and the fiber lengths of the prototypes. The prediction of the model can be seen in Figure 2, showing the expected difference of approximately 20% in the innermost layers and equal light yield for the outermost layer of both modules.

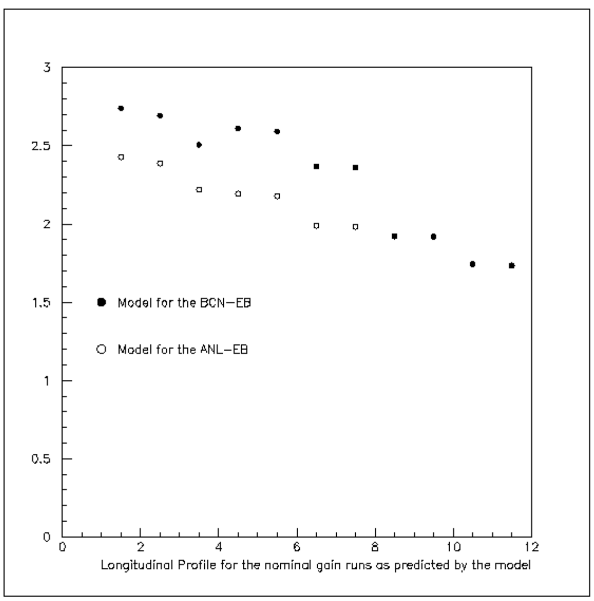

Figure 2

4. Comparison of the Lisbon model with the Extended Barrel prototype data

In order to compare the prediction with the data, and arbitrary normalization has to be introduced. Clearly, no choice of tile row for normalization will make data and model agree. Tile row 9, which is the tile row used for the gain setting of the outermost layer, is chosen for the normalization in Figure 3 (where closed dots are for the Cs data and opened dots for the model). Tile rows 8, 10 and 11 agree quite well with the model, something reported in the analysis of the longitudinal light yield profile. Large discrepancies with respect to the model are seen in the other samples, especially in the BCN module.

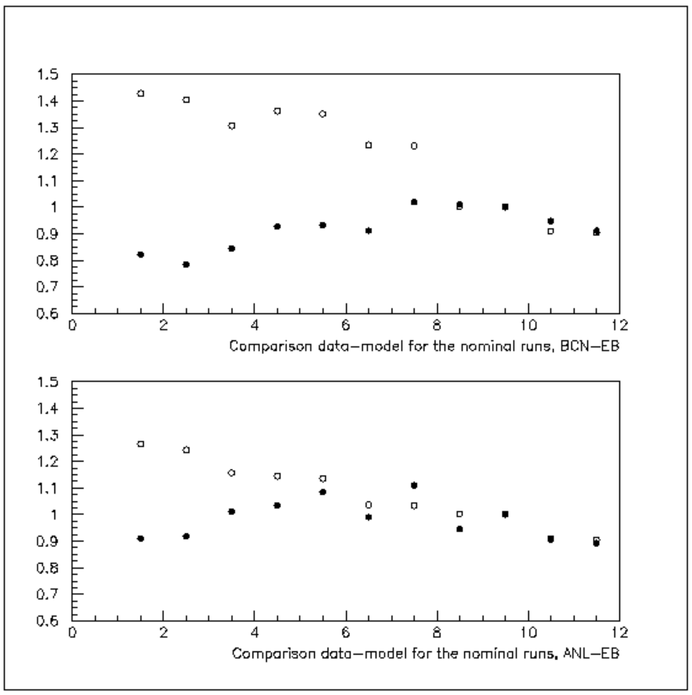

Figure 3. (Closed dots are for the Cs data and opened dots for the model)

Previously, the Lisbon model has only been used to compare the longitudinal light yield profiles, where a layer by layer normalization is used which would hide the discrepancies described above. In order to check the ability of the model to predict the absolute light yield layer by layer, the analysis described above has been repeated using the nominal gain data for the 1996 Barrel Module 0. In this case, the normalization is done with tile row 11, as this was used for the gain setting of the outermost layer. As can be seen in figure 4, for the Barrel Module 0 the model is in agreement with the data at the level of 10%, lending credibility to the analysis methodology.

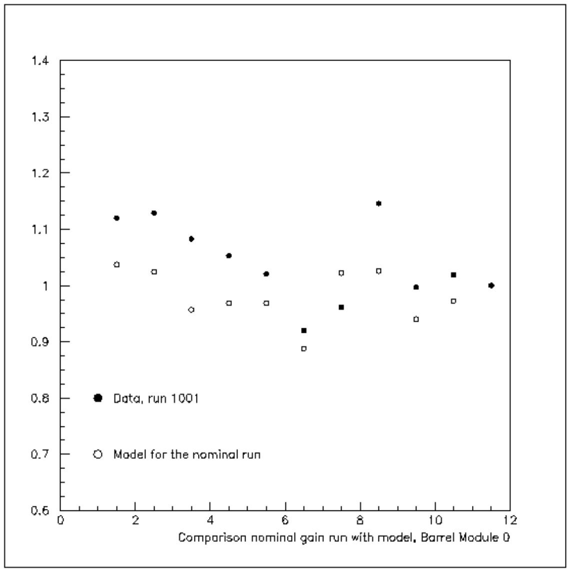

Figure 4

5. Estimation of uncertainties

The design of the Tile Calorimeter is such that the characteristics of tiles and fibers are quite uniform over any give tile row. Under these ideal conditions, the dispersion in the response of different channels of the same tile row would be entirely due to dispersion in the gain of the PMTs and downstream electronics (Cs calibration integrators and ADC in this case). The Cs calibration electronics are checked independently and known to about 1%. Therefore, the observed dispersion of the response over a tile row is an estimator of the dispersion of nominal gains of the PMTs.

The standard deviations of the measurements over a tile row have values between 10 and 20%, higher than expected if the only source of variation is the 5% spread in the nominal setting of the PMTs. A check of the 1996 Barrel Module0 measurements yields similar results. Therefore, as additional effects seem to be contributing to the spread in light yield, the analysis has used the dispersion within a tile row as the estimator of the error. This may be overly pessimistic but assures that the errors are not underestimated. Table 1 shows the difference in absolute light yield between the BCN and ANL modules, tile row by tile row.

$\langle T_1\rangle_{BCN} - \langle T_1\rangle_{ANL}$	=	588.51 ± 155.58
$\langle T_2\rangle_{BCN} - \langle T_2\rangle_{ANL}$	=	478.02 ± 155.85
$\langle T_3\rangle_{BCN} - \langle T_3\rangle_{ANL}$	=	330.01 ± 147.09
$\langle T_4\rangle_{BCN} - \langle T_4\rangle_{ANL}$	=	682.69 ± 217.92
$\langle T_5\rangle_{BCN} - \langle T_5\rangle_{ANL}$	=	634.93 ± 211.12
$\langle T_6\rangle_{BCN} - \langle T_6\rangle_{ANL}$	=	738.83 ± 210.17
$\langle T_7\rangle_{BCN} - \langle T_7\rangle_{ANL}$	=	678.45 ± 200.87
$\langle T_8\rangle_{BCN} - \langle T_8\rangle_{ANL}$	=	879.73 ± 187.72
$\langle T_9\rangle_{BCN} - \langle T_9\rangle_{ANL}$	=	966.56 ± 197.76
$\langle T_{10}\rangle_{BCN} - \langle T_{10}\rangle_{ANL}$	=	1014.64 ± 184.03
$\langle T_{11}\rangle_{BCN} - \langle T_{11}\rangle_{ANL}$	=	938.43 ± 192.82

Table 1.

6. Possible systematic effects.

The following possible sources of systematic effects have been considered:

- Sorting of the PMTs by gain during installation: The PMTs have been assigned to cells randomly [G. Montarou, private communication].
- Fiber bending effects: The model only takes into account fiber lengths, so additional effects due to the different fiber bending of the two routing schemes used could be unaccounted for. However, there is no way to add bending effects and simultaneously explain the differences within a module and between the two modules [A. Gomes, private communication].
- Reduced light yield due to sliced profiles in tile rows 1 and 2: The drop in light yield in going from tile row 3 to rows 1 and 2 could be due to optical differences as the end of the profiles has been sliced for mechanical installation reasons. A quantitative measurement is needed to verify this hypothesis.

7. Comparison with the photoelectrons results.

The photoelectron (pe) yield for both modules has been estimated using testbeam data [TILECAL-NO 133 by J. Proudfoot.)]. The measured number of pe/Gev using electrons at 90 degrees also seems to be anomalous. The comparison of these results with the nominal gain runs can be seen in figure 5 where the ratio between the two EBs for three tiles is plotted. The results for Cs are the ratios of the averages for the given tile row, as plotted in figure 1. The results for the electrons come from table 1 and 2 of Proudfoot's note. The Cs and the electrons results, both show a large difference in the response of sample three between the BCN and ANL modules.

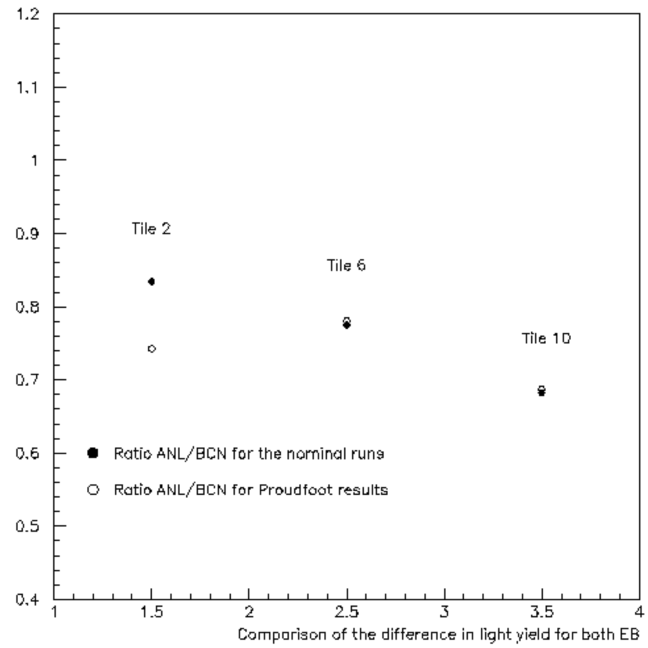

Figure 5

8. Conclusions

Anomalies in the absolute light yield of the Tile Calorimeter Extended Barrel module 0 may be present, as observed from Cs calibration runs with the PMTs set to nominal gains of 10^5. Two discrepancies have been found. First, the unexpected difference between the two modules in the light yield of the outermost layer, expected to be identical as the fiber lengths are the same. Second, the discrepancies between the model predictions and the actual response in the tile row by tile row behaviour of the light yield. This effect is more pronounced in the BCN module, where an anomaly of almost a factor of two seems to be present. The experimental setup cannot distinguish if the innermost layers have anomalously low light yield or the outermost ones have anomalously high yield. This analysis has also been performed for the 1996 Barrel Module 0 where much better agreement with the model is found.

The present measurement critically depends on the accuracy with which the absolute gains of the PMTs have been set. An upper limit on the gain spread of 10 to 20%, depending on tile row, is obtained from the data itself, which may account for additional optical effects above the nominally quoted accuracy of the PMT gain of 5%. Using this upper limit, the significance of the discrepancies is always larger than two standard deviations. The results presented here agree to a large extent with the 30% differences previously reported in the photoelectron yield of sample 3 between the two modules.