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The measurements of magnetic field effects on scintillating tiles

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Abstract

We display the effects of the magnetic field on the light yield of the tiles used in the Atlas Hadronic Calorimeter. Covering a large range, from the Earth field to about 1 Tesla, these results are in agreement with other experiments showing that the light yield of polystyrene based scintillator is increased by about 1% below about 100 mT, with a jump of about 0.6% at 1.2 mT and a 1% plateau starting at about 1.5 mT. This effect does not depend upon the field direction. Considering that in Atlas the magnetic field does not exceed 6 ± 2 mT in the tiles (located in the worst Tilecal place), the conclusion is there will not be a sizeable effect on the absolute energy calibration and the cell-to-cell intercalibration.

Introduction

The influence of magnetic fields on the response of plastic scintillators is known and has been measured in several studies [1],[2],[3] and [4]. The effect is an increase in the light yield. Many possibilities could explain this variation [3] : for instance, there could be a saturation effect in the light conversion properties of scintillators. It strongly depends on the nature of the scintillator. This increase for acrylic scintillators is quite large (5 % at 10 mT and 7 % at 100 mT). It also exists for polystyrene based scintillators but is less pronounced (1 % at 10 mT).

The hadronic calorimeter of ATLAS is based on a sampling technics using steel absorber material and scintillating plates (tiles) read out by wavelength shifting (WLS) fibres, the absorber contributing to the return flux of the ATLAS solenoid magnet. Optically transparent polystyrene is used as a base material for the tiles with the addition of two scintillation additives (1.5 % of PTP and 0.04 % of POPOP). Such tiles have been tested in magnetic field between Earth magnetic field and 900 mT although magnetic field simulation [5] have foreseen a magnetic field less than 6 mT for the scintillators located in the worst Tilecal place.

Experimental setup and results

A very realistic setup was laid out, using components from the Tilecal prototype [6]. A large trapezoidal tile, wrapped with white paper was put in magnetic field. It was viewed by a photomultiplier (Philips XP2012) via two 1 mm diameter and 2m long WLS fibres. The shielded PMT was located outside the magnetic field B. It is also known that no effect on WLS fibres has been observed [4]. So, any light variation will come from the scintillator alone. The light output has been measured as a function of B, thanks to a digital multimeter recording a voltage proportionnal to the PMT current. For the range from the Earth field up to 4 mT a Helmholtz coil arrangement has been employed at Clermont-Ferrand and for higher fields up to 900 mT the VENUS magnet situated in the west experimental area at CERN has been used . (see figure 1a) and b) respectively).

- VENUS magnet: (figure 1a)

  A 40 μC Sr source was put at a distance of about 1 mm from the tile. The PMT current produced by the radioactive source was measured while changing the magnetic field value. The ratio signal/noise has first been determined; it was defined by (current-dark current)/(dark current) and found equal to 12, which is very significant. From 10 mT up to 900 mT, every five measurements, the magnetic field was shut off to make a dark current reference (interpolated over these five measurements). The light variation is defined by the signals ratio V/V0 where V and V0 correspond respectively to the field B and the Earth field and is plotted versus B. The uncertainty has been estimated 0.3 % coming mainly from the accuracy of the apparatus. Two series of field arrangement have been performed: one with B perpendicular to the tile ($B_\perp$) and the other with B parallel ($B_{||}$). These results are shown on figure 2, with respectively the black points corresponding to $B_{\perp}$ and the open circles corresponding to $B_{||}$. As already said in the literature [2,3,4], no dependence upon the orientation of B is observed, within the error bars.

- Helmholtz coils: (figure 1b)

  In order to reach lower fields, Helmholtz coils were used only in the case of B perpendicular to the tile since there is no significant field direction dependence. As for the previous measurements, the ratio signal/noise has been calculated and found to be about 6 (because in this case the radioactive source was less active) . Figure 3 shows the light variation results together with higher fields measurements with the same direction. These two kinds of measurements are in goood agreement. A jump of 0.6 % appears at about 1.2 mT and the 1 % plateau starts at about 15mT.

Comments and conclusion

The effects of the magnetic field on the tiles light yield of have been investigated. Covering a large range, from the Earth field to about 1 Tesla, these results are in agreement with other experiments using polystyrene based scintillators. Firstly there is a confirmation of the insensivity of the light variation with the field direction (figure 2). Second (figure 3), the light is increased by about 1% below about 100 mT, with a jump of about 0.6% at 1.2 mT and the 1% plateau starting at about 15 mT. Considering that in Atlas the magnetic field does not exceed 6 ± 2 mT in the tiles (arranged in the worst Tilecal place)[5], the conclusion is there will not be a sizeable effect on the absolute energy calibration and the cell-to-cell intercalibration of the hadronic Tilecal calorimeter.

Acknowledgements

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References

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3) J.P.Cumalat et al., Nucl. Instr. and Meth. A293 (1990) 606.

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5) S.B.Vorozhtsov et al., ATLAS internal Note TILECAL-NO-7,12,18,22,26 1994.

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Figure Captions

Figure 1. Schematic setup. 1a) Measurement in the VENUS magnet and 1b) in the Helmoltz coils

Figure 2. Effect of the magnetic field on the light output of scintillating tiles for B parallel to the tile (black points) and for B perpendicular to the tile (open circles).

Figure 3. Effect of the magnetic field on the light output of scintillating tiles from Earth field up to about 1 Tesla.

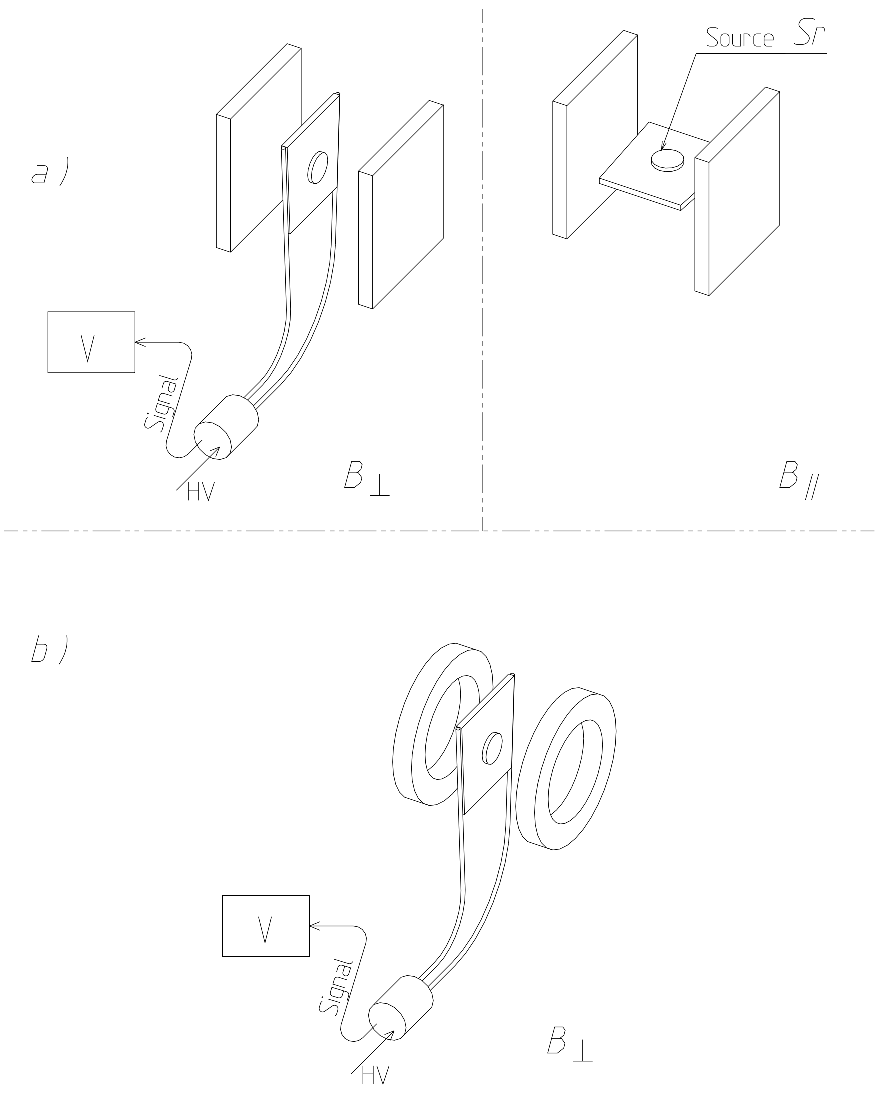

Figure 1

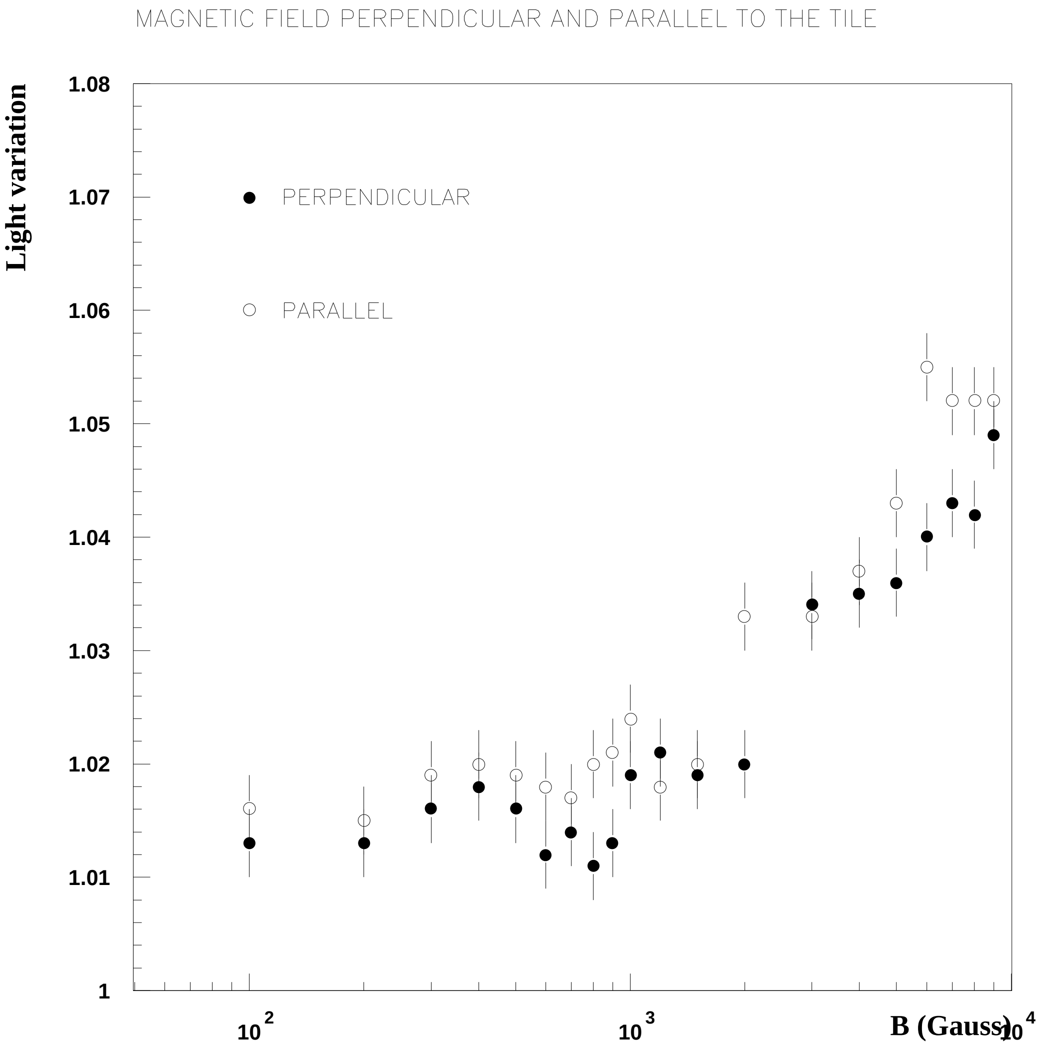
MAGNETIC FIELD PERPENDICULAR AND PARALLEL TO THE TILE
Light variation
1.08
1.07
1.06
1.05
1.04
1.03
1.02
1.01
1
PERPENDICULAR
PARALLEL
10^2
10^3
10^4
B (Gauss)

Figure 2

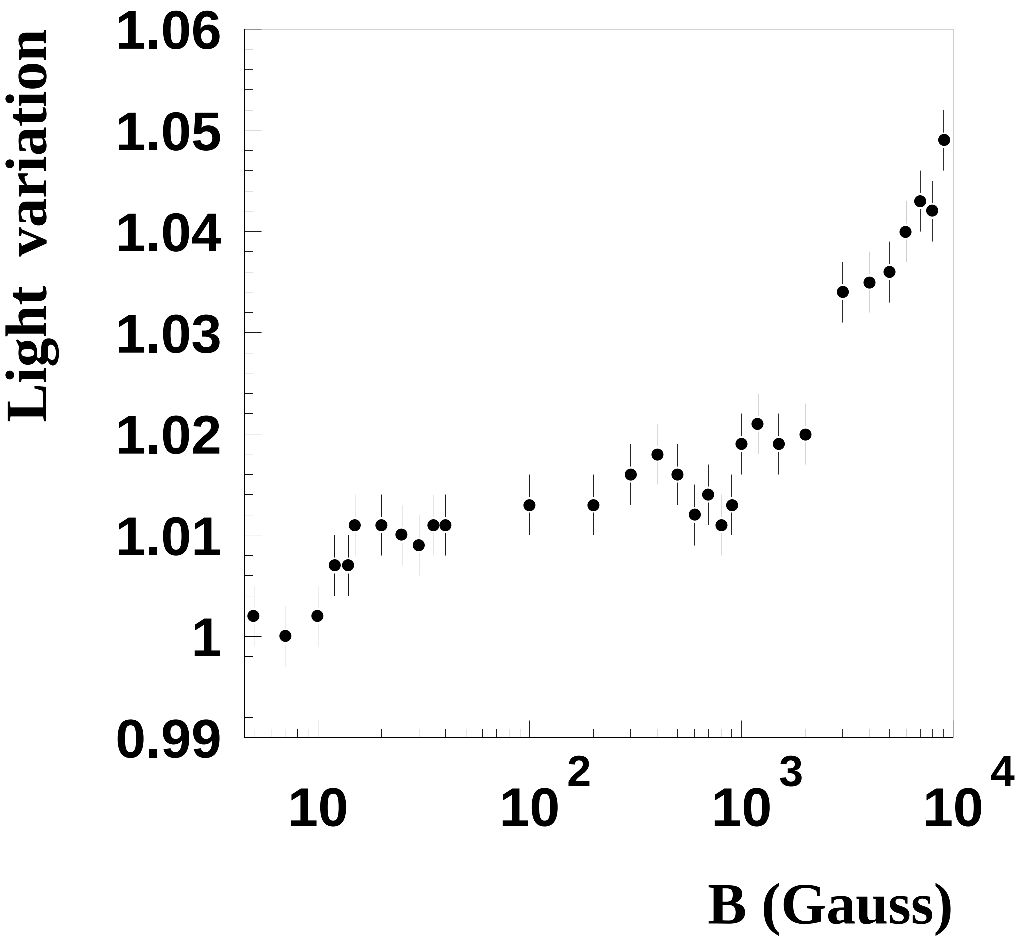
Light variation
1.06
1.05
1.04
1.03
1.02
1.01
1
0.99
10
10 2
10 3
10 4
B (Gauss)

Figure 3