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STUDY OF MAGNETIC FIELD INFLUENCE
ON HADRON CALORIMETER RESPONSE

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Abstract

Abramov V.V. et al Study of Magnetic Field Influence on Hadron Calorimeter Response: IHEP Preprint 96-91. – Protvino, 1996. – p. 6, figs. 7, tables 1, refs.: 6.

The response of a tile/fibre calorimeter to incident muons, electrons and pions in transverse and longitudinal magnetic field up to 3 T has been studied. The light yield increase with magnetic field depends on the field orientation and particle species. Within the errors the energy resolution and transverse and longitudinal shower profiles are not affected by magnetic field.

Аннотация

Абрамов В.В. и др. Изучение влияния магнитного поля на отклик адронного калориметра: Препринт ИФВЭ 96-91. – Протвино, 1996. – 6 с., 7 рис., 1 табл., библиогр.: 6.

Исследован отклик адронного калориметра, в котором свет со сцинтилляторов собирается оптическим волокном с переизлучателем в продольном и поперечном магнитном поле до 3 Т для мюонов, электронов и пионов. Рост световыхода от энергии с увеличением магнитного поля зависит от ориентации поля и сорта частицы. В пределах ошибок энергетическое разрешение и поперечная и продольная формы ливня не зависят от магнитного поля.

Introduction

The CMS hadron calorimeter based on plastic scintillator read out with wavelength-shifting (WLS) fibre embedded in the scintillator plate [1] will operate in strong magnetic field (4 Tesla). The magnetic field changes light yield of scintillator [2] and affects the shower development [3] which, in principle, can depend on the field orientation. For a typical collider geometry the magnetic field is parallel (transverse) to calorimeter plates for the central part and perpendicular (longitudinal) to the end cap. The primary objective of the study was the calorimeter performance dependence on magnetic field direction up to 3 T with muon, electron, and pion beams, to identify practical combinations of thickness and sampling fractions which yield an acceptable resolution for CMS, to test possible candidates of photodetectors capable of work in the magnetic field and to tune up various hadronic cascade Monte Carlo programs. In Section 1 the prototype calorimeter is described. The experimental setup is presented in Section 2. The results are discussed in Section 3.

1. Configuration of the calorimeter

A "reconfigurable-stack calorimeter" with brass plates (59% Cu, 39% Zn, 1% Fe, 1% Mn) as an absorber has been built. It can be reconfigured to vary sampling fractions and longitudinal division and as shown in fig.1, consists of 3 light tight boxes. Two of them contain stainless steel support frame on which the absorber plates and scintillator plates are hanging. The dimensions of the plates (66 cm \times 66 cm) are determined by the size of the hole in the magnet RD5. The third box contained photodetectors.

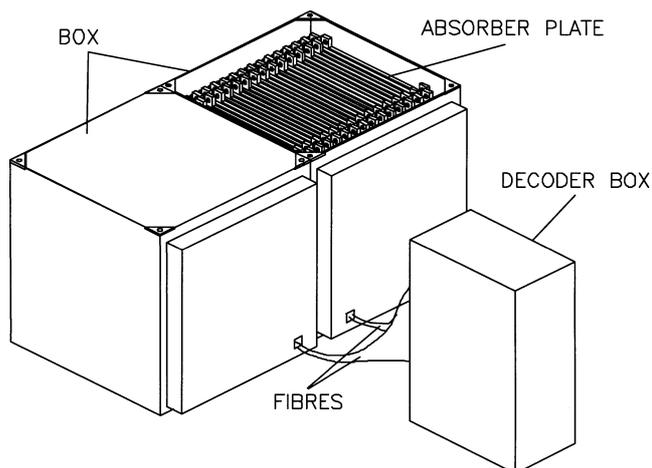


Fig. 1. The schematic view of the "reconfigurable-stack calorimeter".

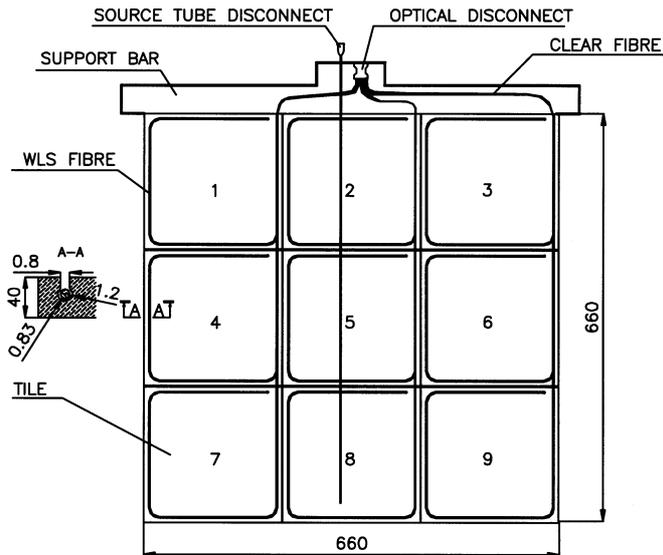


Fig. 2. The plate with scintillating tile/fibre assembly (megatile).

is glued in a tube to transport light to a photodetector. The WLS fibre turned out to be very fragile and cracked along the bending radius in month's time resulting in the light yield drop. The tile with the fibre is wrapped with aluminized mylar. The fibres from each tower are bundled together, glued in a tube and go into separate holes of a photodetector box that contains 25 mm diameter proximity focused Hybrid Photo Diodes [4]. The HPD outputs are directly connected to preamplifiers and then with 60 m cables to amplifiers to equalize the HPD gain. The HPD HV tension is set to be 8.08 kV, the preamplifier gain is $0.125 \text{ V}/10^6 \text{ e}$. The gate length is 150 ns corresponding to the pulse length from preamplifiers. Only 12 HPDs are available (instead of 36: 9 towers x 4 longitudinal divisions), so the horizontal towers are combined into one.

The calorimeter is divided longitudinally into four compartments with the following sampling: the first two consist of 10 plates 4 cm thick, the third of 5 absorber plates 8 cm thick and the fourth one contains 2 plates 8 cm thick (136 cm of brass).

The light tight box with HPD is placed at 110 cm from the center of the magnet, where the magnetic field is about 20% lower than that in its maximum. The HPD axis is aligned along the magnetic field with precision of several degrees. Between the spills the HPD gain is controlled by a single LED, the light is fanned out with fibres. A PIN diode measures the LED signal to study the magnetic field dependence on LED light output. The pedestal position is checked by using random triggers for each measurements.

1.2. Longitudinal magnetic field

A clear fibre is spliced to the WLS fibre 0.83 mm diameter (Y11, produced by Kuraray), the other end of the clear fibre is glued into optical disconnect. The tile with the fibre is wrapped with Tyvek. A 10 m long optical cable with disconnects on both ends connects the megatile to a decoder box containing 18 photomultipliers (Phillips 2081 extended

The active medium is 4 mm thick scintillator, produced in Kharkov, with dimensions $22 \text{ cm} \times 22 \text{ cm}$. A WLS fibre is routed through a key-hole shaped groove milled in the tile. One end of the fibre is machined with a flying diamond cutter and aluminized. The 3×3 tiles wrapped in reflective material and fixed between aluminum plates 2 and 1 mm thick form a megatile (fig.2).

Two configurations of the calorimeter and the active elements were used.

1.1. Transverse magnetic field

To a 1 mm diameter WLS fibre (doped with K27, produced in Tver, Russia) a 4 m long PMMA clear fibre

green photocathode) where fibres were rearranged from layer-to-layer cables to tower-to-tower bundles. The photomultipliers have a magnetic shielding. The calorimeter is divided longitudinally into two read-outs. The sampling is: the first 9 plates 5 cm thick and the last 11 plates — 10 cm thick.

2. Experimental setup

The study of the HCAL performance was carried out in H2 beam at CERN. The team defining scintillator has $2\text{ cm} \times 2\text{ cm}$ dimensions. Particle trajectories were measured with drift chambers. The following particles were used: electrons (100 GeV), muons (100 and 300 GeV), and pions (50-300 GeV). The magnetic field varied from 0 to 3 T. The deflection of the incident particle by the transverse magnetic field was negligible even for 50 GeV particles. For each measurements about 2×10^4 triggers were collected.

The calorimeter was installed in the center of the superconducting RD5 magnet. The magnetic field has nonuniform distribution shown in fig.3 by the thin line.

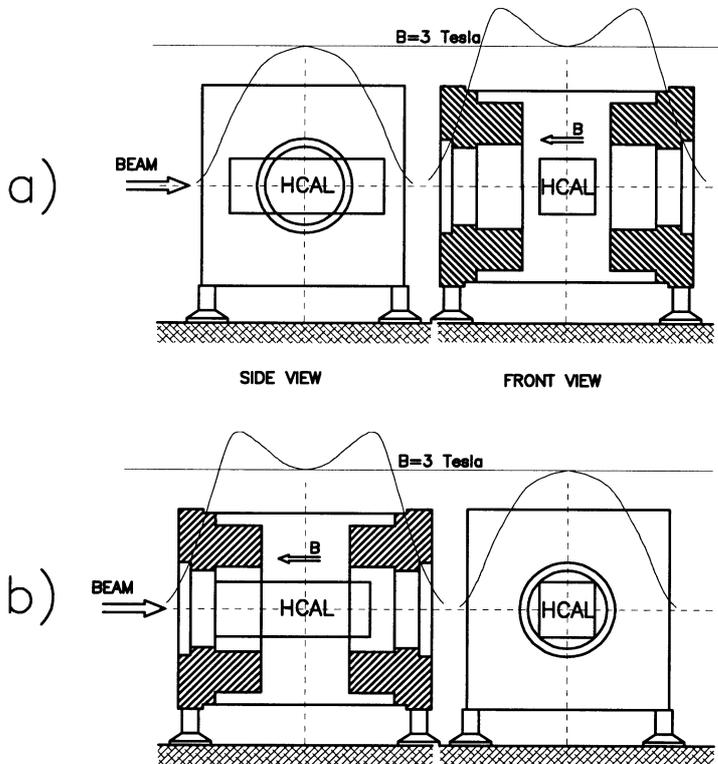


Fig. 3. The set up of measurements with two field orientation and the magnetic field distribution (thin lines).

In the run with the longitudinal magnetic field (see fig.3b) the magnetic field affected the phototube gain though the distance between the decoder box and the magnet was about 7 m. To control the stability of PM operation a LED illuminated all the PMs through a bundle of fibres. In addition a radioactive wire source was utilized to measure

PM gain [5]. To minimize the temperature dependence of the LED for each particle type the magnetic field was changed separately to do it as quickly as possible.

3. Data analysis and results

With the rise of magnetic field from 0 to 3 T the gain variation of different HPDs was in the range 0-3%. This dependence was taken into account during data analysis. Position of the LED amplitude distributions was measured for each spill for each channel and the data were corrected.

Neither the calorimeter nor the beam could be moved in horizontal or vertical directions. Therefore only the central tower was illuminated. The calibration constants for towers and longitudinal sections were determined by minimization of energy resolution.

The magnetic field is nonuniform it but is not clear how to correct the shower profile. The value of the magnetic field cited below corresponds to its value at the center of the magnet.

In transverse magnetic field the light yield per scintillator was too small (about 0.2 p.e. per scintillator for minimum ionizing particle (m.i.p.)) to reliably measure muon pulse height distribution and as a consequence these dependence was not measured. In the longitudinal magnetic field the WLS fibres were replaced and the light yield was about 1 p.e. per tile for m.i.p. Fig.4 shows pulse height distribution for muons obtained for the first compartment (9 tiles).

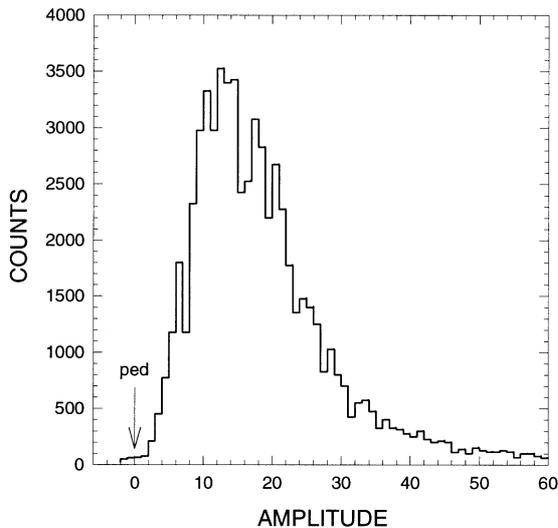


Fig. 4. The muon pulse height distribution, the first compartment (9 scintillators).

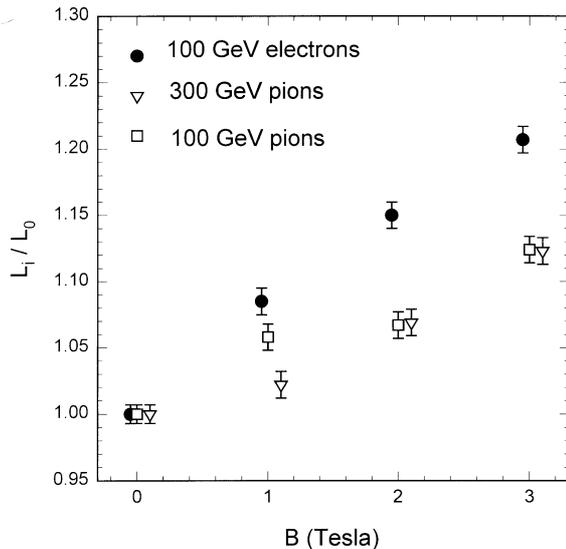


Fig. 5. The relative change of light yield vs. transverse magnetic field for 100 GeV electrons and 100 and 300 GeV pions.

The calorimeter, as mentioned above, was roughly divided in transverse and longitudinal directions. When comparing the normalized distributions we conclude that the

transverse and longitudinal shower development does not depend on the magnetic field for both orientations within the measurement errors and longitudinal division (4 and 2 longitudinal compartments for transverse and longitudinal field correspondingly). The energy resolution also does not depend on magnetic field as well. Fig.5 shows the normalized responses vs. transverse magnetic field for 100 GeV electrons and different energy pions. There is almost linear rise of the calorimeter response on magnetic field and no depends on pion energy.

Figs.6 and 7 show this dependence on longitudinal magnetic field for electrons, muons, and pions. In this case the behavior is very close to the scintillator light yield dependence on magnetic field obtained with radioactive source and does not depend on particle species and pion energy.

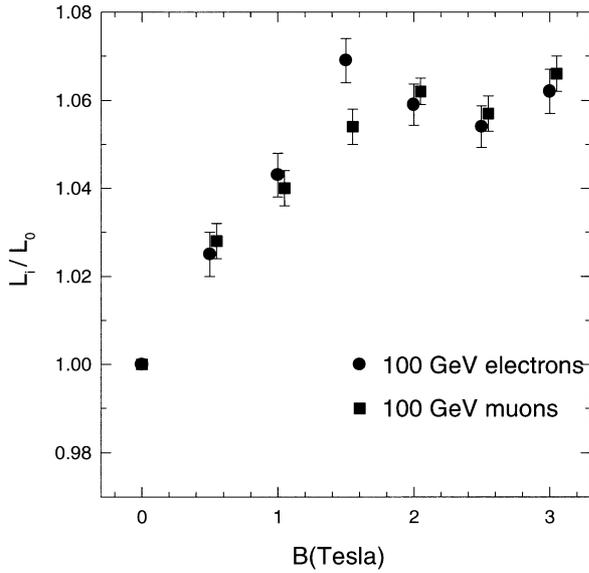


Fig. 6. The relative change of light yield vs. longitudinal magnetic field for electrons and muons.

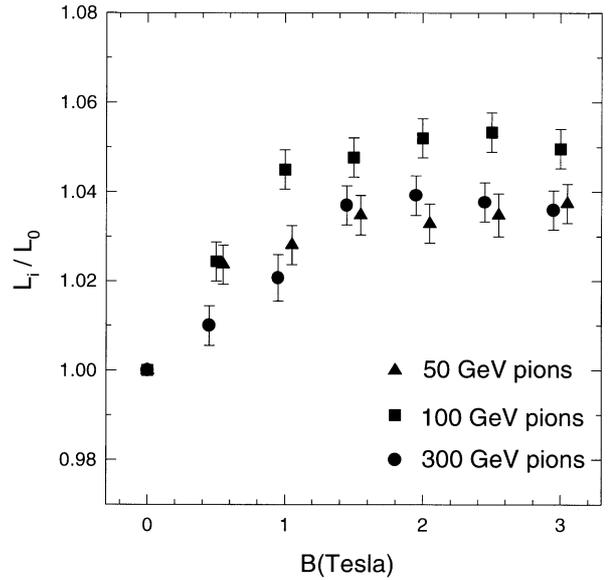


Fig. 7. The relative change of light yield vs. longitudinal magnetic field for 50, 100 and 300 GeV pions.

Summary and conclusions

The study of the hadron calorimeter response vs. magnetic field shows that the light yield for muons, electrons and pions increases with the rise of magnetic field and for showering particles depends on the field orientation. Within the errors there is no appreciable change of transverse and longitudinal shower profile.

There are two effects which lead to the calorimeter light yield dependence on magnetic field: light emission of scintillators and shower energy absorption in scintillator. Simulations of the calorimeter response due to only the second effect give the results presented in the Table.

Table 1. Monte Carlo simulation of calorimeter response.

Particle	$K_T=A(4\text{ T})/A(0\text{ T})$	$K_L=A(4\text{ T})/A(0\text{ T})$
100 GeV electrons	1.13	0.99
100 GeV pions	1.06	0.99
225 GeV pions	1.07	0.99

There K_T is the ratio of energy absorption in the scintillator for the 4 T transverse magnetic field over energy absorption in the scintillator without magnetic field and K_L is the ratio for the longitudinal magnetic field. If the scintillator light yield dependence on magnetic field is added (about 5% independent on magnetic field orientation) there is a qualitative agreement of the experimental results and calculations.

For muons if one neglects the electromagnetic interaction at these energies the light yield dependence is mainly determined by the first effect and must not depend on magnetic field orientation.

In conclusion we summarize the main results:

- calorimeter response vs. magnetic field depends on field orientation and particle species (for transverse field);
- the e/h ratio depends on magnetic field orientation;
- radioactive source calibration to transfer coefficients obtained with extracted beams and calibration with muons will be more complicated at high magnetic field so calibration in situ using physical processes [6] becomes very important.

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References

- [1] 1 The Compact Muon Solenoid. Letter of Intent. CERN/LHCC 92-3, LHCC/I 1, 1 October, 1992.
- [2] S.Bertolucci et al.// Nucl. Instr. and Meth., A254 (1987) 561;
D.Blomker et al., IEEE Transactions on Nuclear Science, 37/2 (1990) 220;
J.P.Cumalat et al.// Nucl.Instr. and Meth., A293 (1990) 606.
- [3] V.Abramov //Nucl. Instr. and Meth., A374 (1996) 34.
- [4] H.Arnauden, P.Benetti, L.Boskma et al. Preprint CERN-LAA/HC/93-16.
- [5] P.de Barbaro et al. Univ. of Rochester preprint UR-1360 (July 1994).
- [6] J.Freeman and W.Wu. Preprint FNAL-TM-1984.

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