STUDY OF MAGNETIC FIELD INFLUENCE ON HADRON CALORIMETER RESPONSE

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Abstract

The response of 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.

1. 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). Magnetic field changes light yield of scintillator [2] and affects the shower development [3] that in principle can depend on the field orientation. For typical collider geometry the magnetic field is parallel (transverse) to a calorimeter plates for the central part and perpendicular (longitudinal) to the end cap. The primary objective of the study was the calorimeter performance in 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 acceptable resolution for CMS, to test possible candidates of photodetectors capable to work in magnetic field, to tune up various hadronic cascade Monte Carlo programs. In section 2 the prototype calorimeter is described. The experimental set-up is presented in section 3. The results are discussed in section 4.

2. Configuration of the calorimeter

A "reconfigurable-stack calorimeter" with brass plates (59 % Cu, 39 % Zn, 1 % Fe, 1 % Mn) as 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 x 66 cm) are determined by the size of the hole in the magnet RD5. The third box contains photodetectors.

The active medium is 4 mm thick scintillator, produced in Kharkov, with dimensions 22 cm x 22 cm. A WLS fibre is routed through a key-hole shaped groove milled in the tile. One end of the fibre is machined by flying diamond cutter and aluminised. The 3x3 tiles wrapped in reflective material and fixed between aluminium plates 2 and 1 mm thick form a megatile (fig. 2).

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

2.1 Transverse magnetic field

To a 1 mm diameter WLS fibre (doped with K27, produced in Tver, Russia) a 4 m long PMMA clear fibre is glued in tube to transport light to a photodetector. The WLS fibre turned out to be very fragile and cracked along the bending radius in a month time resulting in drop of light yield. The tile with the fibre is wrapped with aluminised mylar. The fibres from each tower are bundled together, glued in a tube and go into separate holes in a photodetector box which contained 25 mm diameter proximity focused Hybrid Photo Diodes [4]. The HPD outputs are directly connected to preamplifiers and than by 60 m cables to amplifiers to equalise the HPD gain. The HPD HV tension is set to 8.08 kV, the preamplifier gain is 0.125 V /10^6 e. The gate length is 150 ns corresponding to the pulse length from preamplifiers. Only 12 HPD 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 consists of 10 4 cm thick plates, the third 5 8 cm thick absorber plates, and the forth - 2 8 cm thick plates (136 cm of brass).

The light tight box with HPD is placed at 110 cm from the centre of the magnet where the magnetic field is about 20 % lower than in its maximum. The HPD axes are aligned along the magnetic field with precision of several degrees. Between the spills the HPD gain is controlled by single LED, the light is fanned out by 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.

2.2 Longitudinal magnetic field

To the WLS fibre 0.83 mm diameter (Y11, produced by Kuraray) a clear fibre is spliced, 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 photo-multiplier (Philips XP 2081 with extended green photocathode) where fibres are rearranged from layer-to-layer cables to tower-to-tower bundles. The photo-multipliers have 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.

3. Experimental set-up

The study of the HCAL performance was carried out on H2 beam at CERN. Beam defining scintillator has dimensions 2 cm x 2 cm. Particle trajectories were measured by 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 $2x10^4$ triggers were collected.

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

In the run with 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 stability of PM operation a LED illuminated all PM through a bundle of fibres. Besides there was a wire radioactive source [5]. To minimise temperature dependence of the LED for each particle type magnetic field was changed separately to make it as quickly as possible.

4. Data analysis and results

With rise of magnetic field from 0 to 3 T the gain variation of different HPD 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 minimisation of energy resolution.

The magnetic field has a high non-uniformity but it is not clear how to correct the shower profile. The value of the magnetic field cited below corresponds to its meaning 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 ionising 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).

The calorimeter, as was mentioned above, was roughly divided in transverse and longitudinal directions. Comparing normalised distributions we conclude that transverse and longitudinal shower development does not depend on 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. 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 dependence on pion energy.

Figs. 6 and 7 show this dependence for longitudinal magnetic field for electrons and muons and pions. In this case the behaviour 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.

5. Summary and conclusions

The study of the hadron calorimeter response vs. magnetic field shows that the light yield for muons, electrons, and pions increases up 3 T and for showering particles depends on the field orientation and pion energy. Within the errors there is no appreciable change of transverse and longitudinal shower profile.

There are two effects which lead to 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. Mote Carlo simulation of calorimeter respons.

	K_T=A(4 T)/A(0 T)	K_L = A(4 T)/A(0 T)
100 GeV electrons	1.14	1.06
100 GeV pions	1.05	0.98
225 GeV pions	1.08	0.99

There K_T is the ratio of energy absorption in scintillator for 4 T transverse magnetic field over energy absorption in 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 the calculation.

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 summarise the main results:

- a calorimeter response vs. magnetic field depends on field orientation and particle species and energy (for transverse field);
-the e/h ratio depends on magnetic field and its orientation;
-a 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.

We gratefully acknowlege the support of E.Radermacher.

Figure captions

Fig. 1. Schematic view of the "reconfigurable-stack calorimeter".

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

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

Fig. 4. 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, 200, and 300 GeV pions.

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.

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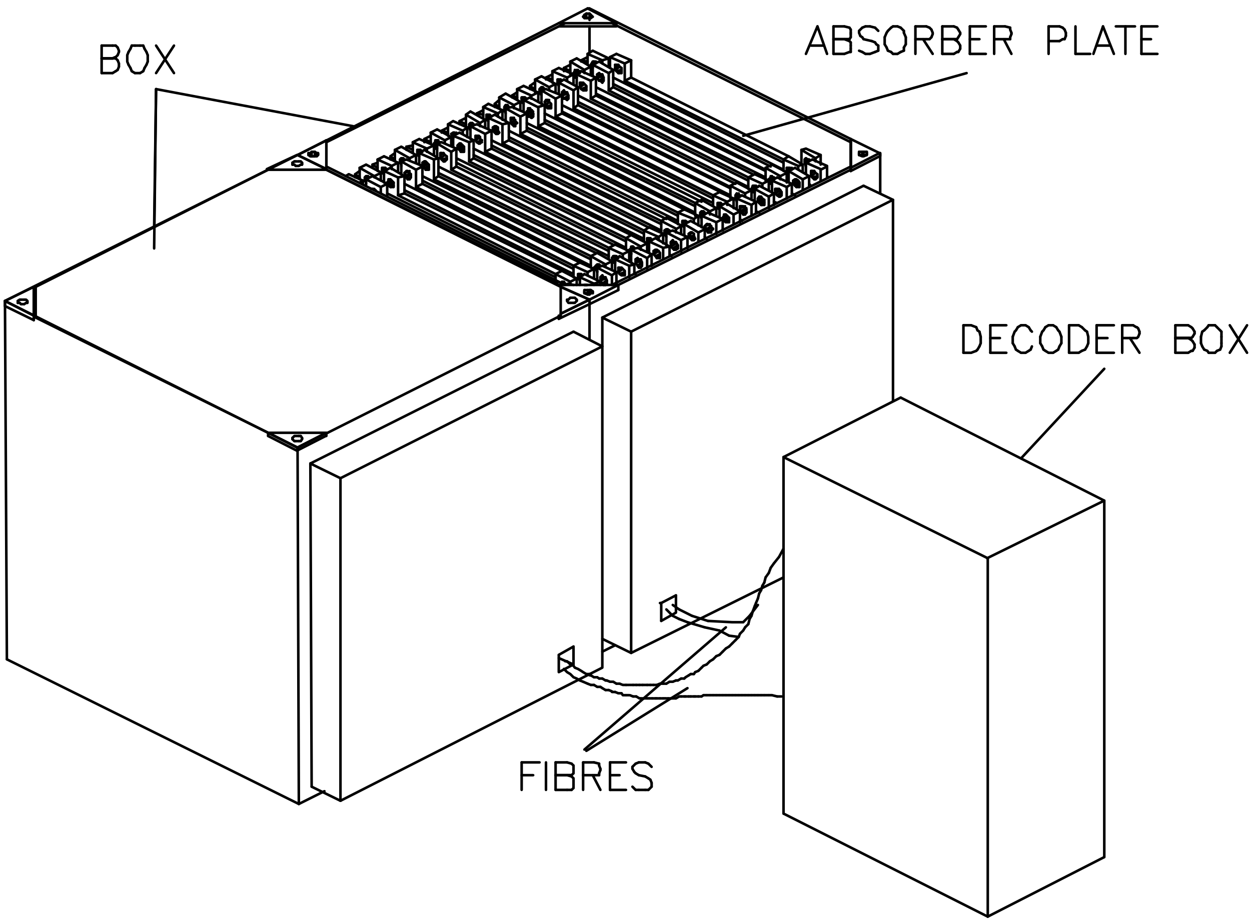
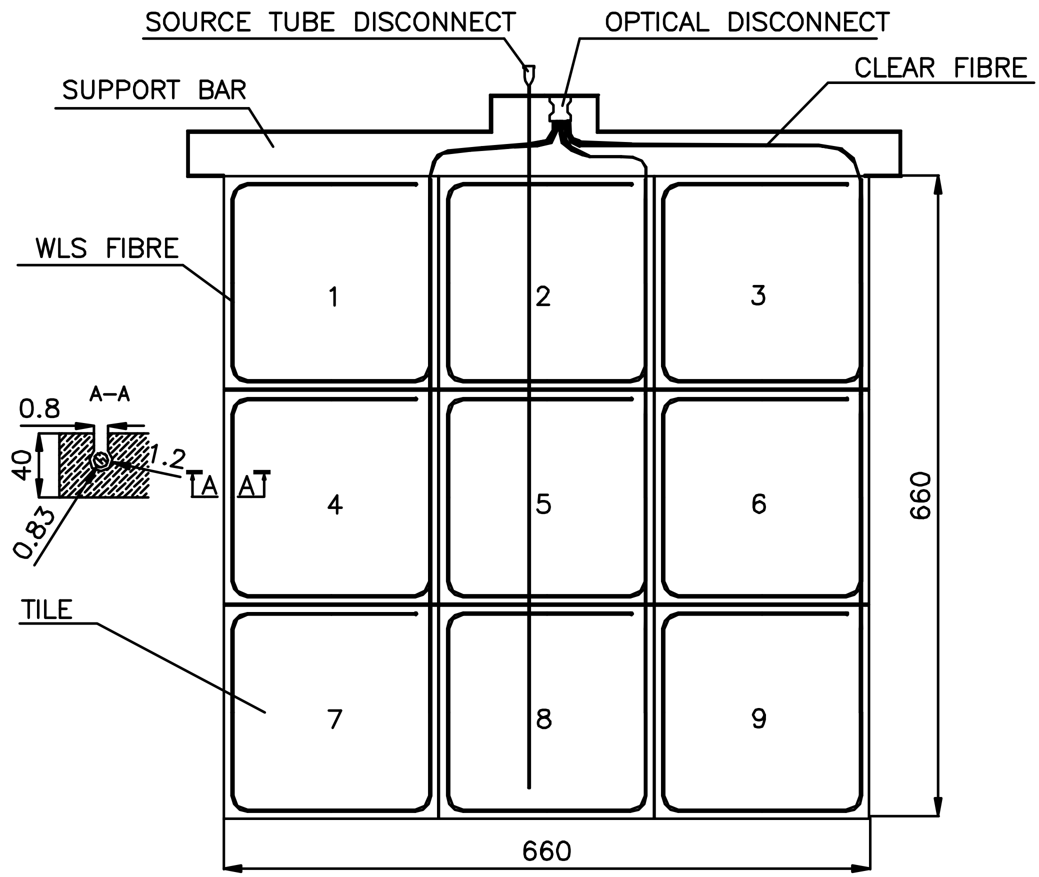


Fig. 1


SOURCE TUBE DISCONNECT
OPTICAL DISCONNECT
CLEAR FIBRE
SUPPORT BAR
WLS FIBRE
A–A
0.8
1.2
40
0.83
A
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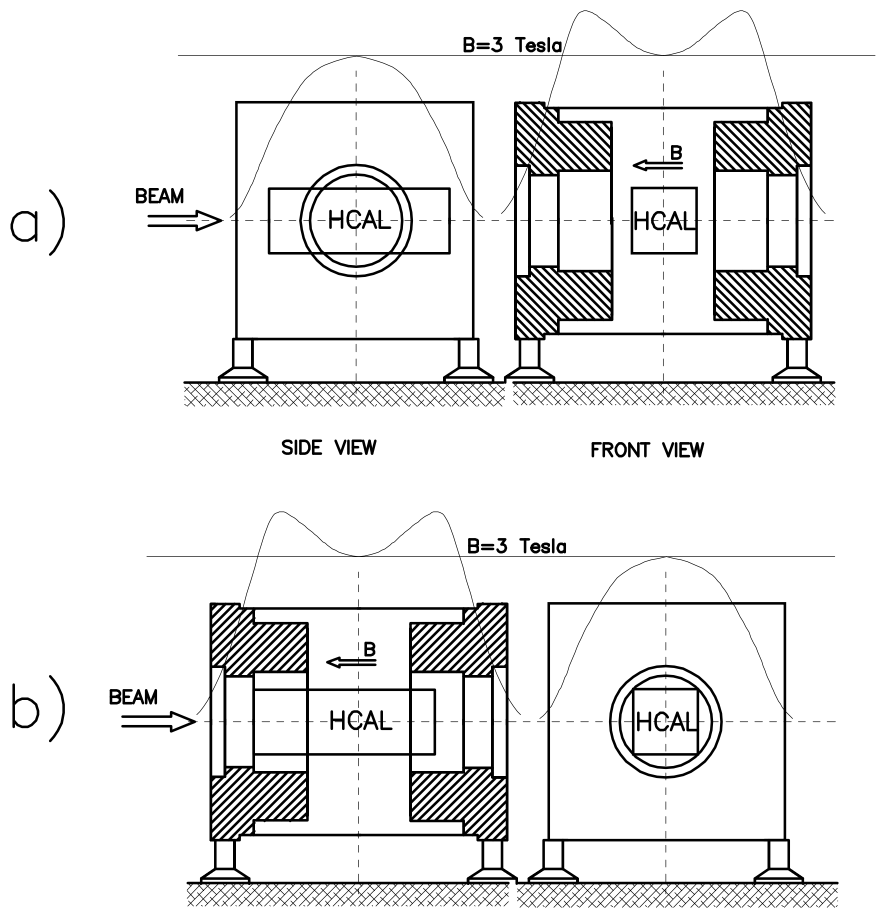
TILE
1
2
3
4
5
6
7
8
9
660
660

Fig. 2


B=3 Tesla
a)
BEAM
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B
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SIDE VIEW
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B=3 Tesla
b)
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B
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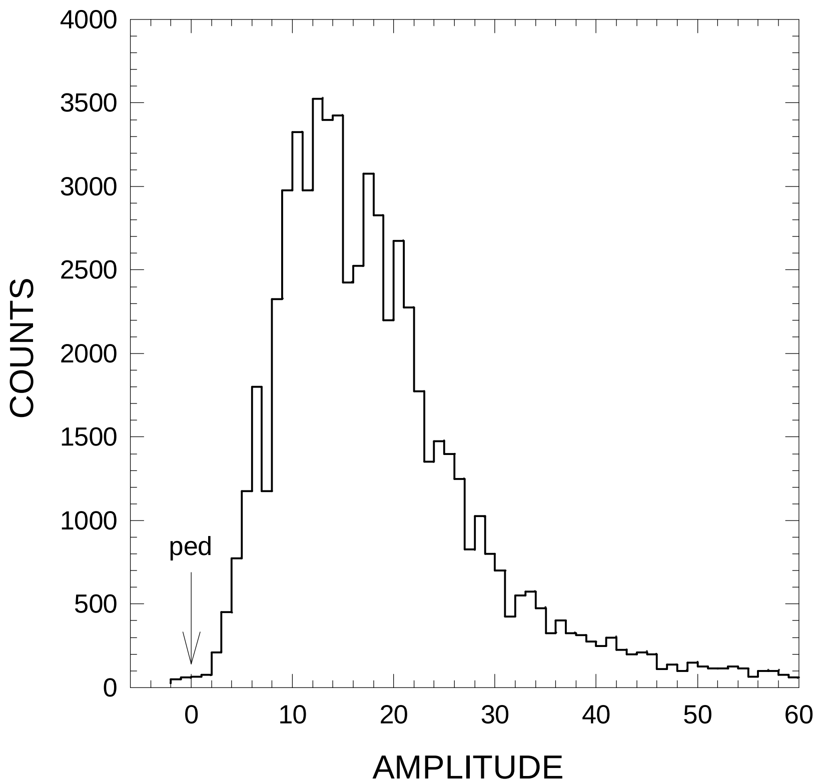
HCAL

Fig. 3


4000
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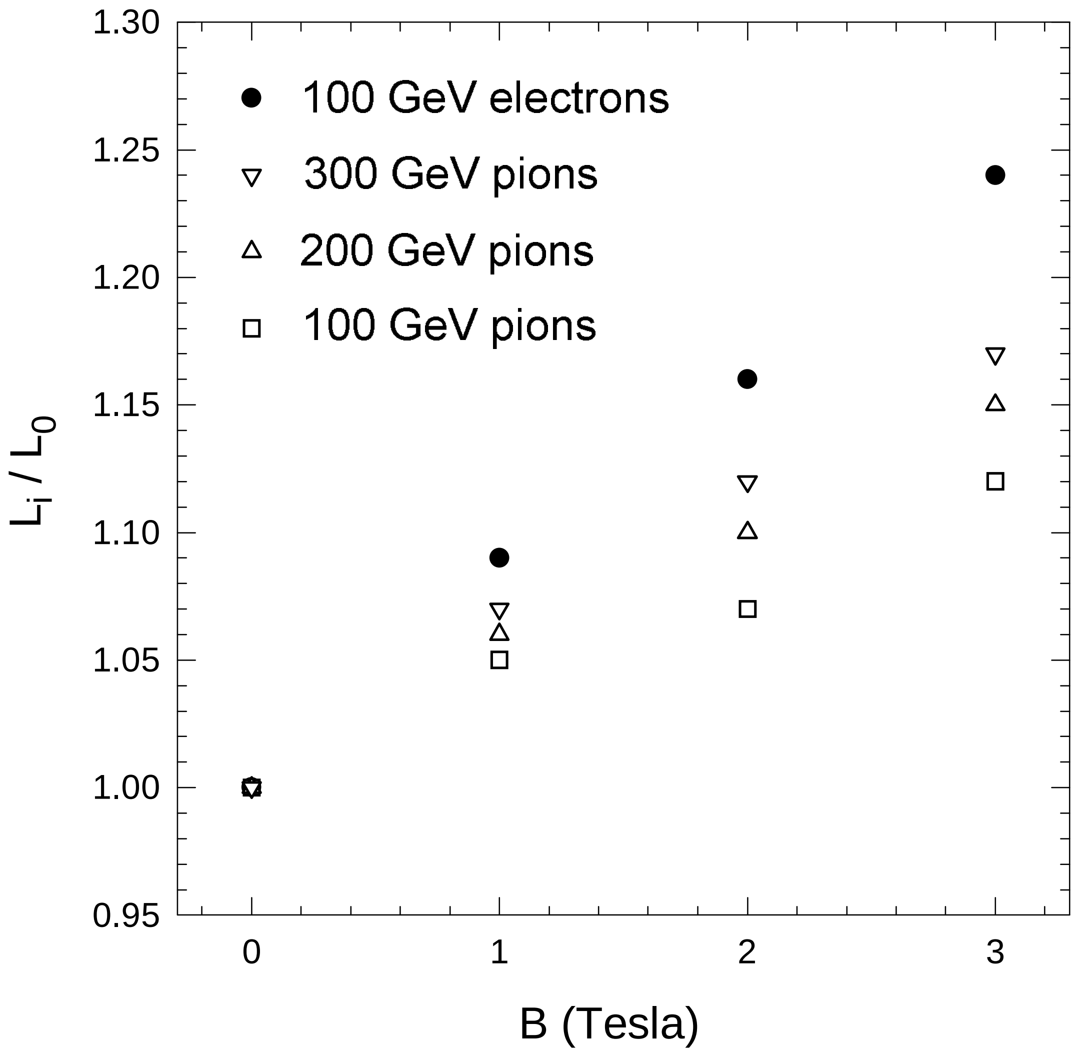
AMPLITUDE

Fig. 4


1.30
1.25
1.20
1.15
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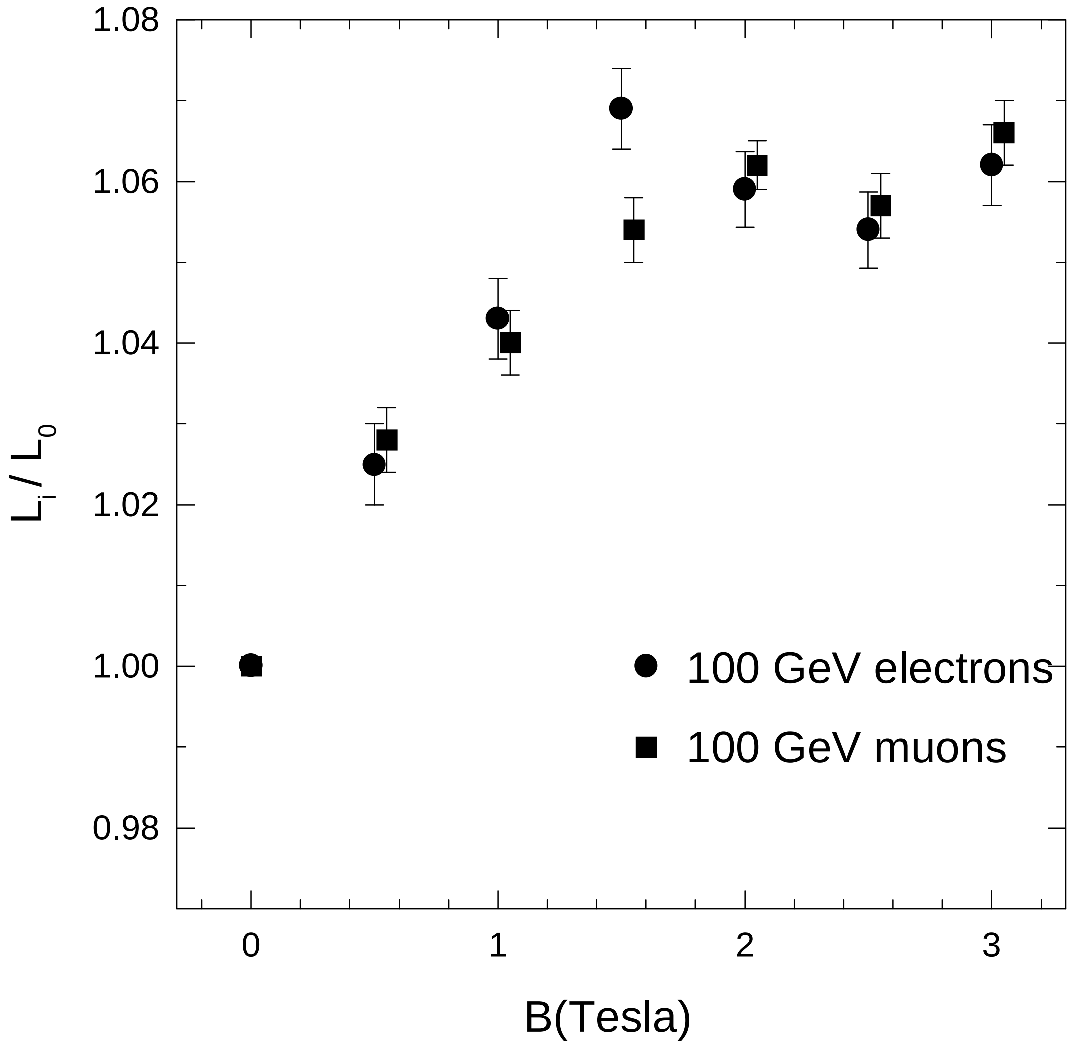
1.05
1.00
0.95
L_i / L_0
100 GeV electrons
300 GeV pions
200 GeV pions
100 GeV pions
0
1
2
3
B (Tesla)

Fig. 5


1.08
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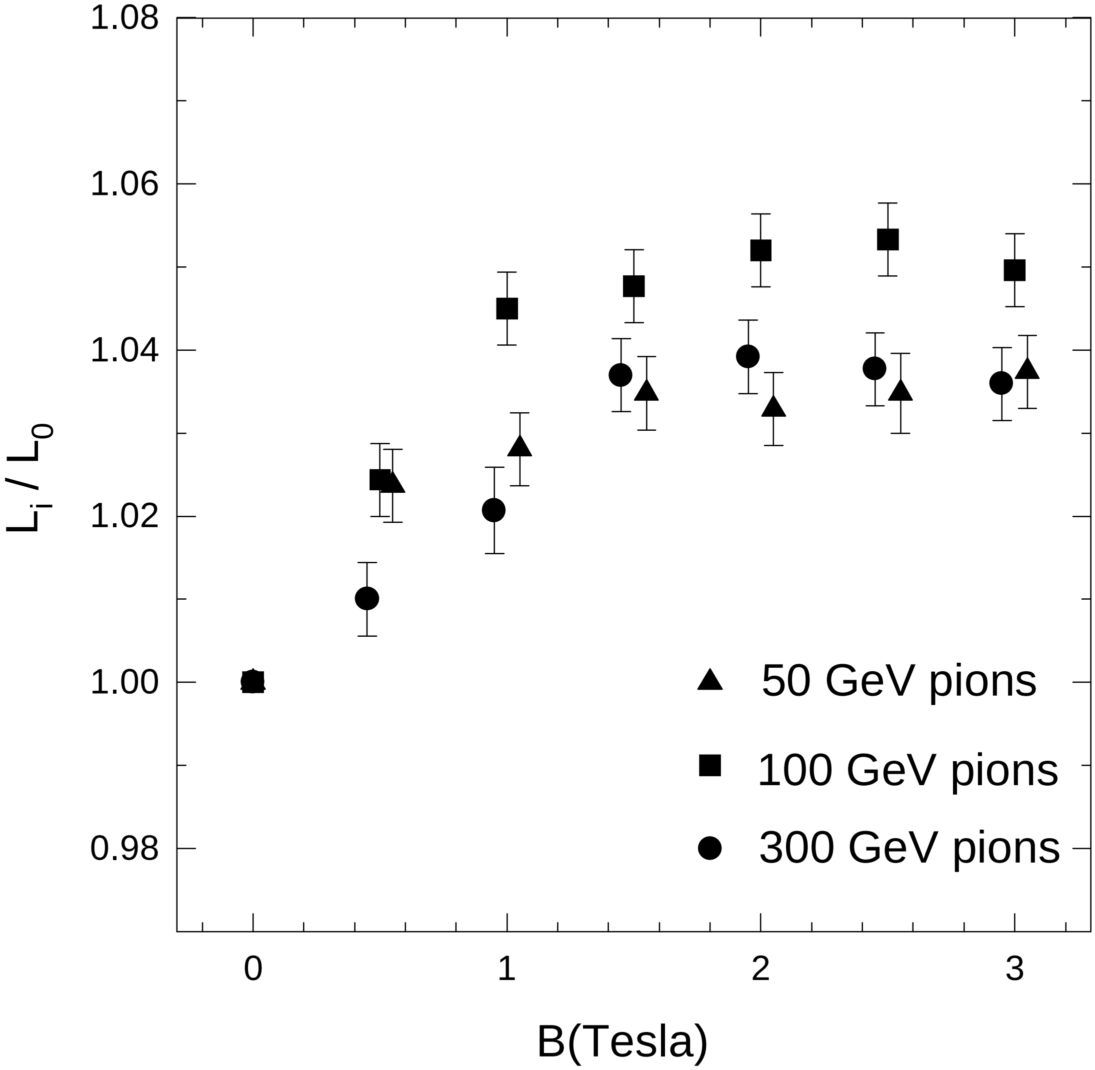
B(Tesla)
100 GeV electrons
100 GeV muons

Fig. 6



1.08
1.06
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L_i / L_0
0
1
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B(Tesla)
50 GeV pions
100 GeV pions
300 GeV pions

Fig. 7