EAGLE Internal note :
CAL-NO-006
22 November 1991

AN ECONOMIC CONCEPT FOR A BARREL HADRON CALORIMETER WITH IRON SCINTILLATOR SAMPLING AND WLS-FIBER READOUT

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ABSTRACT

An unconventional concept for a hadron calorimeter with scintillator plates and WLS fiber readout is discussed. It leads to a simple and low-cost design.

1. Introduction

We propose a concept for a barrel hadron calorimeter with scintillator plates positioned - inside the iron absorber structure - in R-Φ planes, instead of the usual Φ-Z orientation. Wavelengthshifting (WLS) fibers coupled to the two radial edges of the scintillator plates can thus be kept straight in radial direction. Outside the absorber structure they are grouped according to the wanted segmentation of the calorimeter and coupled to photomultiplier tubes (PMT).

This configuration can be made very hermetic and has the additional advantage that the absorber can be built up from "self supporting" plates in R-Φ planes.

For close to zero rapidities the plate structure is about parallel to the primary particles. Most of those will have interacted already in the EM-calorimeter in front, to be about one interaction length in depth. To prevent high energy particles from travelling over long distances in the scintillator the individual plates are kept short and are staggered with respect to each other (Fig. 1). (The proposed structure would not be adequate for an EM-calorimeter).

2. GEANT simulations

GEANT simulations have been made to check the effect of this particular geometry on the energy resolution. They used a calorimeter model consisting of a conventional liquid argon EM compartment, 25 X_0 in depth, with 3 mm lead plates and 4 mm gaps, in front of the hadron compartment of Fig. 1, with ℓ = 10 cm, a = 1.4 cm, d = 0.6 cm and a depth of 9.5 interaction lengths. Jets from 25 to 300 GeV were generated at 1.2 m distance from the EM-compartment and at different impact points.

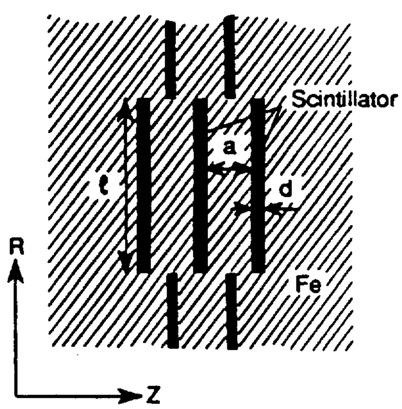

Fig. 1 Basic structure

The results of the energy resolutions lead to a fitted parametrization of

$$\frac{\sigma_E}{E} = \frac{41\%}{\sqrt{E}} + 2\% \text{ (E in GeV)}$$

A higher statistics run with 150 GeV jets (using the parameters ℓ = 10 cm, a = 1.4 cm, d = 0.3 cm) gave

$$\frac{\sigma_E}{E} = (5 \pm 0.2)\%$$

Replacing the hadron compartment by a liquid argon structure (10 cm Pb plates, 4 mm Ar gaps) or by a standard geometry scintillator structure (10 cm Pb plates, 2.5 mm scintillators) results within the statistical errors to similar energy resolutions.

A scan with 50 GeV jets across the calorimeter front face did not show any evidence of non-uniform response beyond a 1% statistical error.

These simulations did not include any instrumental imperfections like light attenuation or fluctuations of the light coupling efficiency.

3. Scintillator plate - WLS fiber coupling

For an efficient optical coupling of 3 mm scintillator plates to 1 mm round or squared read-out fibers the scheme of Fig. 2 has been tested. The fiber is placed into a 1 mm groove cut into the narrow face of the plate, the adjacent edges of which are cut at 45 degrees and polished. A comparative measurement gave 70% light yield with respect to a standard 2 mm WLS plate (as used in the UA2 endcap calorimeter, K-27 doping) coupled to a flat edge of the same scintillator plate.

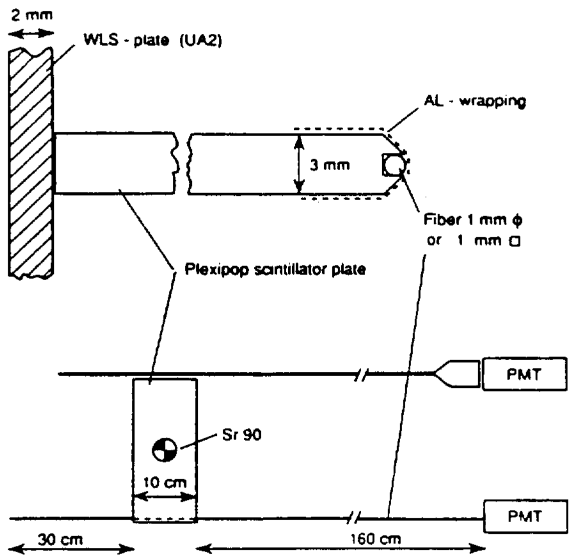

Fig. 2 Test of optical coupling

The distance between scintillator and PMT was 170 cm in both cases. The rear end of the 2 m long fiber was Aluminium plated, while the WLS plate had a white paint on the rear edge.

Another comparative measurement gave 80% light yield with one squared fiber in the groove, with respect to 3 squared fibers coupled side by side to the flat edge of the scintillator.

4. Conceptual design of a barrel hadron calorimeter for LHC

Typically a LHC barrel hadron calorimeter will be about 8 m long with an inner radius of about 2 m. A possible design concept is based on a granularity of $\Delta\Phi \times \Delta\eta = 0.1 \times 0.1$ with a fourfold radial segmentation. The barrel would be subdivided into

64 azimuthal sector modules, each containing 96 cells in R-Z (Fig. 3). The individual cells are not pointing to the vertex, but the centers of the 4 cells forming a tower are pointing.

The whole absorber of a module (Fig. 4) is laminated in the Z-direction into 1.7 mm sheets, which can easily be punched and would not need any machining. The stacked absorber is compressed by a series of rods (~ 8 mm diam.) passing through holes already punched into the sheets and drilled in the centre of each scintillator plate. A beam supporting the PMT's is welded to the outside face of the absorber stack and a 10 mm plate to its entrance face over the whole length of the module.

The 3 mm thick polystyrene scintillator plates are slid into gaps left free in the absorber stacks. WLS fibers are mounted from both sides and fit into radial slots formed by the stack structure, each slot containing - with increasing radius - 1 to 4 fibers.

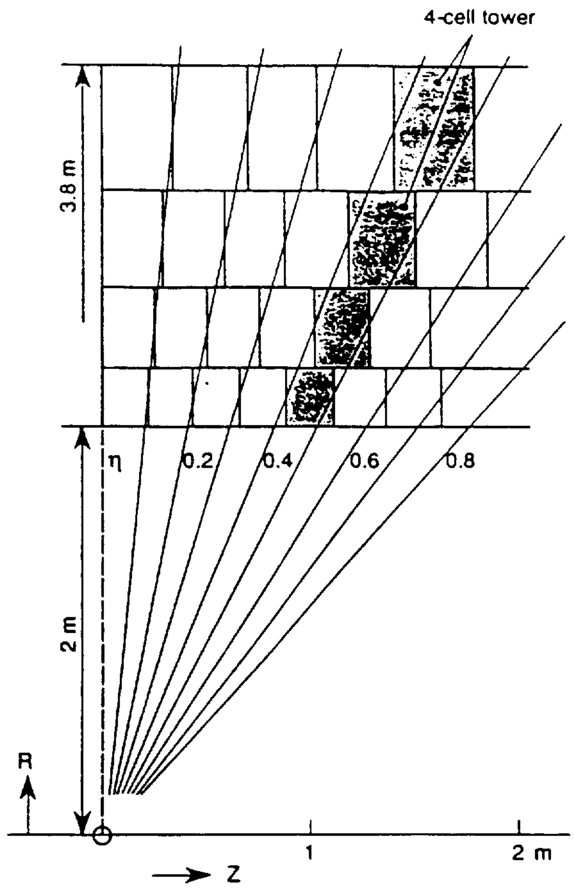

Fig. 3 Cell structure within a module

The absorber thickness between adjacent scintillator plates is $8 \times 1.7 = 13.6$ mm and the pitch between staggered plates is $5 \times 1.7 = 8.5$ mm. The length of a scintillator plate in the radial direction is 10 cm in the most inner cells and might be increased with the radial position of the cells.

The module parameters are :

inner radius	2 m
outer active radius	3.8 m
length	8 m
active iron weight	25.4 t
scintillator weight	0.72 t
iron volume	80%
scintillator volume	18%
depth at zero rapidity	9 int. lengths
number of cells	96
number of PM channels	192

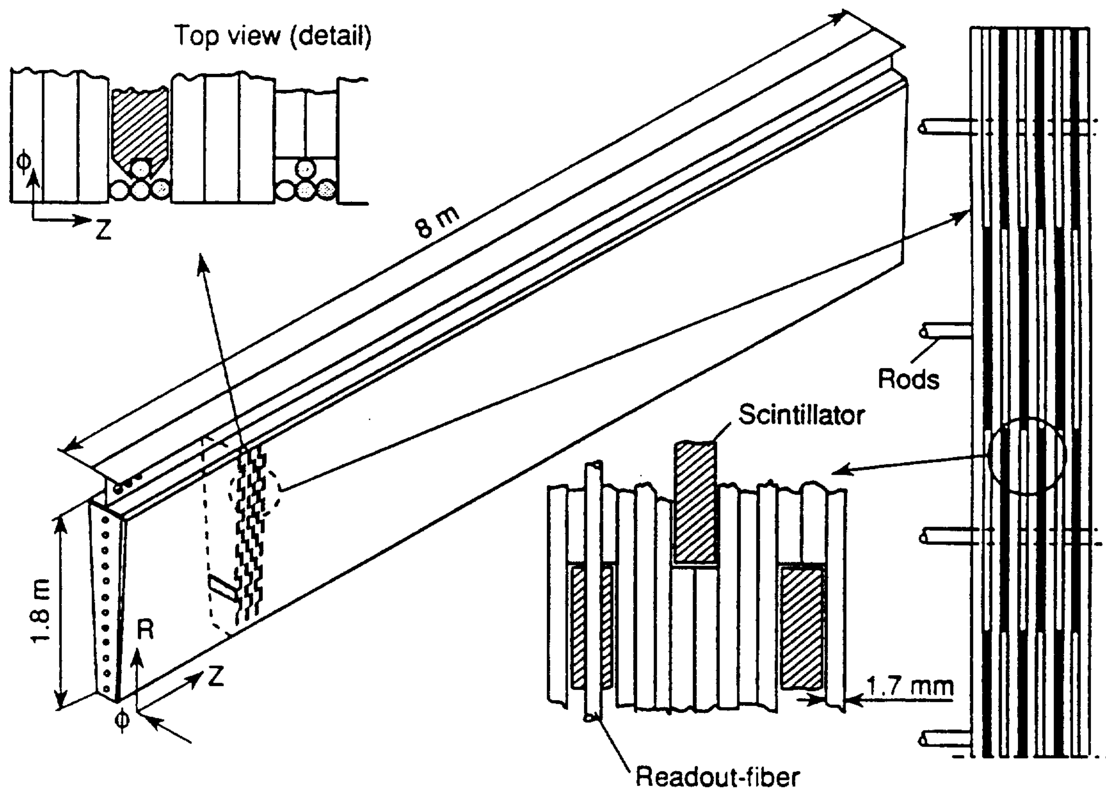

Fig. 4 Conceptual design

Since the absorber structure of the module does not need any machining and is simple and easy to mount this design concept leads to substantial cost savings compared to more conventional constructions.

Acknowledgements

We thank Dr. P. Jenni for many fruitful discussions and suggestions. The company BICRON kindly provided the WLS-fibers for the tests.