TEST BEAM RESULTS FROM A VERY FORWARD LIQUID SCINTILLATOR CALORIMETER FOR THE LHC

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ABSTRACT

We report on beam tests performed on a liquid scintillator calorimeter prototype designed to cover the very forward region in an experiment at the LHC. The liquid scintillator technique has known advantages related to high speed, low noise and radiation hardness. The proposed solution is a SPACAL-like calorimeter with liquid scintillator circulating in quartz tubes positioned in a lead matrix. Tests were performed at the CERN SPS with electron and pion beams in the range 20-120 GeV. Results on the energy response and resolution are presented.

1. Introduction

The liquid scintillator technique matches all the requirements for the very forward calorimetry at an LHC experiments i.e. lateral granularity in the range $\Delta\eta \times \Delta\phi \leq 0.2 \times 0.2$, energy resolution better than $100\%/\sqrt{E} \oplus 10\%$, high speed ($\leq 25ns$), radiation hardness and low noise [1] . The proposed solution is a SPACAL-like [2] calorimeter with liquid scintillator circulating in hollow light guides.

An *R&D* study is being carried on as a collaboration between the ITEP group and INFN Naples. In this paper we report on the design, construction and test on electron and pion beams of a four module prototype calorimeter. Results are compared with MC predictions and estrapolated to full containment.

2. Design and construction

The calorimeter has a modular structure [3,4,5]. Each module has a parallelepiped shape with 66×66 mm^2 cross section and 2380 mm length, including a 380 mm long

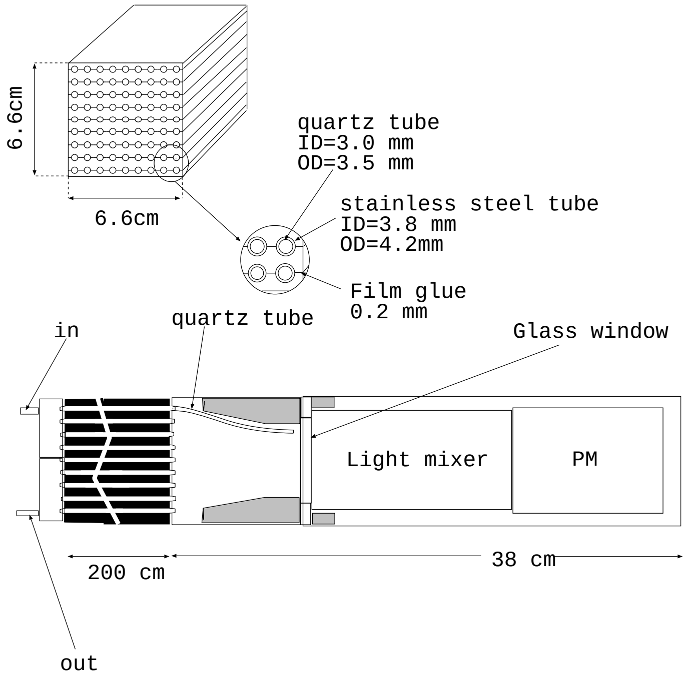

Fig. 1. Calorimeter module design

photodetector housing (see Fig. 1).

It consists of an absorber lead matrix containing 81 quartz tubes with inner diameter of 3 mm and wall thickness of 250 μm. The tubes run parallel to each other along the module to form a square transverse pattern and the modules are aligned parallel to the beam line. The spacing between the tubes (center-to-center) is 7.3 mm, providing a 6:1 ratio between lead and scintillator [3,4].

The modules were constructed from grooved lead plates produced by casting. Then, 2010 mm long stainless steel tubes with inner diameter of 3.8 mm and wall thickness of 200 μm were placed into the grooves. The lead plates were glued together by means of a special 100 μm thick tape placed under and above the tubes and by compression at high temperature. The compression was released after the glue hardening. The tubes coming out at both ends of the module were inserted into the holes drilled in stainless steel manifolds and then tin soldered. The front manifold has inlet and outlet pipes separated by a membrane, the back one is provided with a frame with a glass window to transmit the scintillation light. The module is followed by a 15 cm long plexiglass light mixer and a photomultiplier.

The modules were washed with a purified alcohol flow circulated by a pump during a few hours and then dried with air. The quartz tubes were inserted from the back of the modules. The last 10 cm of the tubes' far end were bent to form a bundle of 42×42 mm^2 cross section.

The modules were blown with Argon, then filled under Argon atmosphere. Finally the liquid was circulated by a pump to remove bubbles. The outlet pipe was then

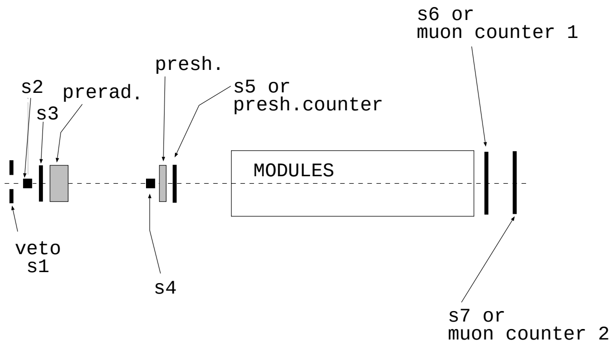

Fig. 2. Position of modules and counters along the beam line

connected to a buffer volume filled up to 1/3 with scintillator and 2/3 with Argon.

3. The beam tests

A prototype calorimeter made of 2×2 full scale modules was tested with pions and electrons beams at the CERN SPS in July 1994. The calorimeter was placed parallel to the beam direction on a movable table allowing displacement in the vertical and horizontal directions and tilt in the horizontal plane.

For three of the modules BC599-13G BICRON scintillator (green emitting) was used, the fourth was filled with methylnaphtalene. All the modules were equipped with filters to enhance the attenuation length of the light, and read by EMI 9839A photomultipliers.

A sketch of the experimental set-up is shown in Fig 2. A veto counter limited the lateral dimensions of the beam, then two scintillation counters (s2 and s3) were placed before a variable amount of material used as a preradiator, to define a beam spot size of 7×7 mm^2. Another 7×7 mm^2 scintillation counter (s5) preceded a $2X_o$ lead preshower and a scintillation counter placed in front of the modules. The modules were followed by two scintillator plates used to detect passing through muons. All counters were read out to allow an off line event selection while the trigger was given by the the coincidence of S2 and S3 only.

4. Experimental results

The calorimeter was exposed to electron and pion beams of 20, 40, 80, 120 GeV; the modules were calibrated by hitting 120 GeV pions on their center and equalizing the response.

Fig. 3 (a) shows the energy distributions for 120 GeV electrons with 1^o tilt angle with and without a $3X_o$ preradiator. In the case of no preradiator a high energy tail is clearly visible, due to channelling effects, The use of preradiator strongly reduces this effect and the RMS of distributions is decreased by 50%.

Fig. 3 (b) shows distributions with the $3X_o$ preradiator for 1^o and 3^o tilt angles.

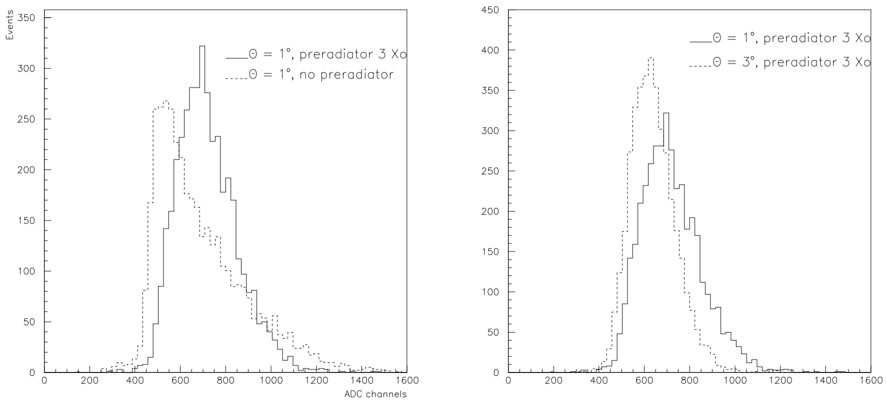

Fig. 3. (a) Energy distribution for 120 GeV electrons with and without preradiator; (b) distribution with preradiator at two different angles

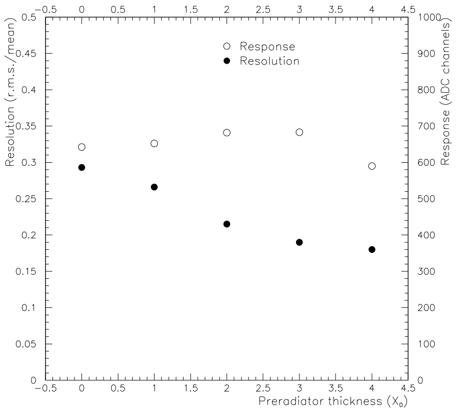

Fig. 4. Energy response and resolution for 120 GeV electrons as a function of the preradiator thickness

As expected, the increase of the tilt angle results in a better energy resolution.

Response and resolutions have been studied for 120 GeV electrons also as a function of the preradiator thickness. Fig. 4 shows that while the response is almost constant for the whole range explored, the resolution improves by the thickness.

The calorimeter was also tested with pions for two different values of the tilt angle (0^o and 1^o).

Fig 5 shows the response distribution for 120 GeV pions. The low energy tail is due to lateral leakage and well explained by a MC simulation. Energy respose and resolution are shown in fig 6. Unlike for the electon events. the resolution for pions is obtained from a gaussian fit of the distributions in a $\pm 2\sigma$ region around the peak.

It turns out to be $\sigma/E = 86\%/\sqrt{E(GeV)}+7\%$ corresponding to a $51\%/\sqrt{E(GeV)}+8\%$ resolution for the full calorimeter, well below the limits imposed by the ATLAS design [1].

Pions seem not to be affected by the material in front of the calorimeter in the thickness range explored above a threshold needed to avoid channeling effects [3].

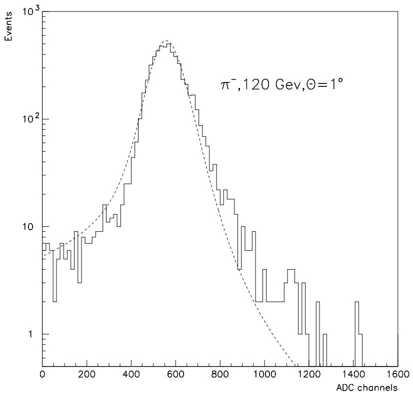

Fig. 5. Energy distribution for 120 GeV pions at 1^o. The dashed line is the result of a MC simulation

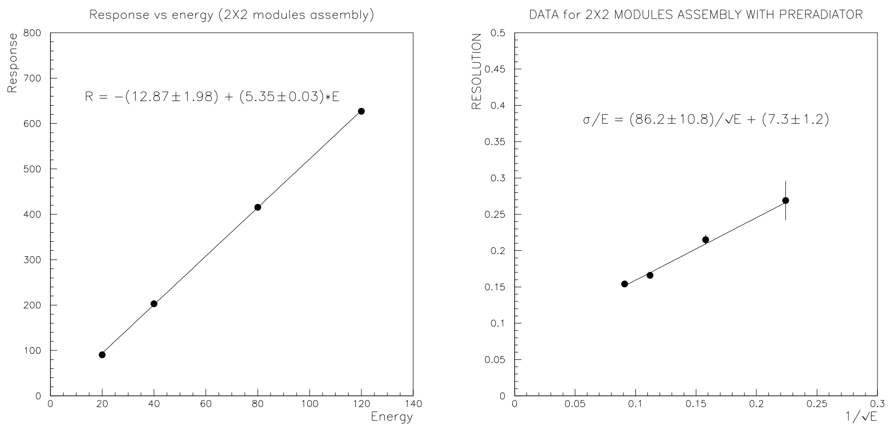

Fig. 6. Pion energy response and resolution as a function of $1/\sqrt{E(GeV)}$

5. Conclusions

We have constructed and tested a prototype lead-liquid scintillator calorimeter to be possibly used as a forward calorimeter in a LHC detector. Good energy resolution for electrons is obtained even at small incidence angles by using a passive preradiator in front of the modules. The response to pions is linear and the energy resolution is $\sigma/E = 86\%/\sqrt{E} + 7\%$ corresponding to $51\%/\sqrt{E} + 8\%$ for the full calorimeter.

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