

CONSTRUCTION AND TEST OF A PROTOTYPE ELECTROMAGNETIC CALORIMETER USING PLASTIC SCINTILLATING FIBERS IMMERSSED IN A BISMUTH LEAD ALLOY

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## I. INTRODUCTION

A group at Saclay has conceived of a new approach to the design of an electromagnetic shower calorimeter using plastic scintillating fibers immersed in a low melting point high density alloy with the fibers pointing along the general direction of the showering particles.

## II. CONSTRUCTION

Approximately 4 km of clad scintillating fibers 1 mm diameter (0.8-1.1 mm) were drawn in Saclay. The characteristics of the fibers are as follows: a polystyrene core with a refractive index  $n = 1.59$ , a cladding about  $10 \mu$  thick with  $n = 1.46$ , a light emission centered at  $\lambda = 430 \text{ nm}$  and an attenuation length going from 30 to 300 cm depending on the distance from the excitation. The fibers were disposed continuously in sheets of 80 fibers covering a metal screen 0.5 mm thick and 80 such sheets were piled on top of each other to give an useful cross section inside the mold of  $80 \times 120 \text{ mm}$  and a length (inside the mold) of 265 mm. An alloy melting at  $71^\circ\text{C}$  (AFBAT: Bi 49.5%, Pb 27.5%, Sn 13.2%, Cd 10%) was then poured at  $80^\circ\text{C}$  to fill completely the allotted volume.

The overall density of the block came out to be  $D = 5.3 \text{ g/cm}^3$  with a radiation length  $X_0 = 14.5 \text{ mm}$  and a filling factor for the fibers of 0.51.

At first we left 20 cm of fibers protruding at one end, tied in a bundle of 110 mm diameter, impregnated with epoxy resin on the extreme 2 cm and polished for good optical contact with a photomultiplier tube (P.M.). For later tests we cut the protruding fibers flush and placed the P.M. tube directly on the polished exit face. The other side (beam entrance) was polished and we applied a reflecting "Scotch" tape to it.

## III. TEST RESULTS WITH BEAM

The block was tested at CERN with electron beams from 5 to 25 GeV. For most tests described here a parallel test was performed with a CEREN 32 lead glass block.

### III.1 - Spatial Scan

We scanned the fiber block in an electron beam about 1 cm in diameter, performing a horizontal and vertical scan at  $0^\circ$  and  $10^\circ$  to check the uniformity of response. The block was always positioned with the wide dimension as the base and the rotation being around a vertical axis. We observed a plateau of about 5 cm, uniform to  $\pm 10\%$ . We also performed a scan of the block turned at  $90^\circ$  with respect to a 25 GeV pion beam. The response to this test indicates that the structure of the block is homogeneous and that the attenuation length of the fibers in the block does not differ appreciably from that of the bare fibers.

### III.2 - Energy Scan

We performed an energy scan with a 5 inch P.M. (RTC XP 2050). The response is linear with energy within the measurement errors and the straight line fit passes close to zero. From the calibration we determine that we collect approximately 4600 photoelectrons per GeV, (with the P.M. placed directly against the exit face). The reflective tape contributes about 25% to this number. The signal was 2.1 times larger than with the lead glass block used with the same P.M.

We also determined, by using a  $\pi^-$  beam, that  $11 \pm 2\%$  of the shower energy is dissipated in the fibers. This has an important bearing on the resistance to radiation damage.

We tested that one has a sufficient amount of light to use a photodiode or phototriode tube allowing an operation in a magnetic field of the order of 1 Tesla.

### III.3 - Energy Resolution

The energy resolution  $\sigma/\sqrt{E}$  varies from 9 to 13% in  $\text{GeV}^{1/2}$  (r.m.s.) for an energy going from 5 to 25 GeV and an incident angle between 5 and 25 degrees. Only at zero degree is the energy resolution appreciably deteriorated.

### III.4 - Reduction in Surface

The fibers fill one half the volume of the block. It becomes therefore possible to group the fibers emerging from the block thus reducing by a corresponding factor the active light sensitive reading area (P.M. or phototriode).

Another important gain in area can be obtained using the fact that the light in the fibers is transmitted in a cone of half opening angle of 24 degrees. Using a plastic "semi-adiabatic" light guide we obtained reduction in light of 23% for an area reduction of a factor of 3.

### III.5 - Shower Localization

We carried out a preliminary attempt to measure the transverse position of the shower. The error we found on this position is of the order of  $\pm 2 \text{ mm}$  with a 20 GeV electron beam.

## IV. RADIATION RESISTANCE

We have observed that it takes a dose of  $3 \times 10^6$  rad. to reduce the attenuation length of the bare fibers by a factor of two. Since only about 10% of the shower energy is deposited in the fibers one can extrapolate that it should be possible to subject the alloy-fiber block to doses of  $3 \times 10^7$  rad.

## V. FUTURE DEVELOPMENTS

V-1. We are testing methods for a more efficient production of the fiber blocks. In particular we have successfully tested industrial weaving techniques which greatly facilitate the ranging of the fibers.

V-2. A company by the name of OPTPECTRON (zone industrielle de Courtaboeuf, 91 - ORSAY, France) has been established near Saclay to carry out the industrial production of plastic optical fibers.