Performance of the Tile-Fiber Hadron Calorimeter

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Abstract. A sandwich type of the tile-fiber hadron calorimeter was constructed and tested at KEK and Fermilab. The energy resolution, linearity and e/π ratio were measured. The results indicate that the detector is quite promising for the calorimeter of the Linear Collider detector.

REQUIREMENTS FOR THE CALORIMETER

The JLC calorimeter design is based on the concept of the hermetic detector in the solenoidal magnetic field. The most important requirement for the calorimeter is the energy resolution in order to resolve W/Z bosons and Higgs scalers at their jet mass reconstruction [1]. We set the target energy resolutions to be ;

$$\sigma/E = \frac{15\%}{\sqrt{E}} \oplus 1\% \; for \; electrons \; and \; \sigma/E = \frac{40\%}{\sqrt{E}} \oplus 2\% \; for \; hadrons, \qquad (1)$$

where $\oplus$ indicates an addition in quadratically and E is the energy in GeV.
The above energy resolutions are very ambitious so that the hardware compensation detector is highly required. We have chosen a sandwich of lead and plastic scintillator, where the scintillation light is read out via optical fiber system. It is expected to have a compensation performance in this type of detector [2].

DETECTOR

In order to contain more than 97% of hadron energy, the physical size is determined to be 1m x 1m in the cross section and more than 6 interaction length in the longitudinal direction of the incident particles [3]. An optical fiber technique was employed to read out the scintillation light. We developed the hadron calorimeter in two steps in the hanging file scheme. In the fist step, we made six straight grooves in the 2mm thick plastic scintillator of 1m long. This is shown in Figure

1-a. By changing the lead plate thickness, we have searched for the compensation condition systematically.

At the second step, the detector has been modified to have a tower structure with the tile-fiber system. Each tower consists of 20 pairs of a plastic scintillator tile (20x20x0.2cm^3) and a lead plate (8mm thick). The scintillation light is fed though a wave-length shifter (WLS) fiber of 1mm-ϕ in a tile and led to a clear fiber which is spliced to the WLS fiber. A photomultiplier is used to read the amount of light from 20 clear fibers which consists of a tower. This is shown in Figure 1-b schematically. The whole detector consists of four sections of the 5x5 tile-fiber towers and a backing calorimeter which composed of the straight grooved scintillators and lead plates. The interaction lengths of the calorimeters are 4.5 λ_I and 1.7 λ_I, respectively.

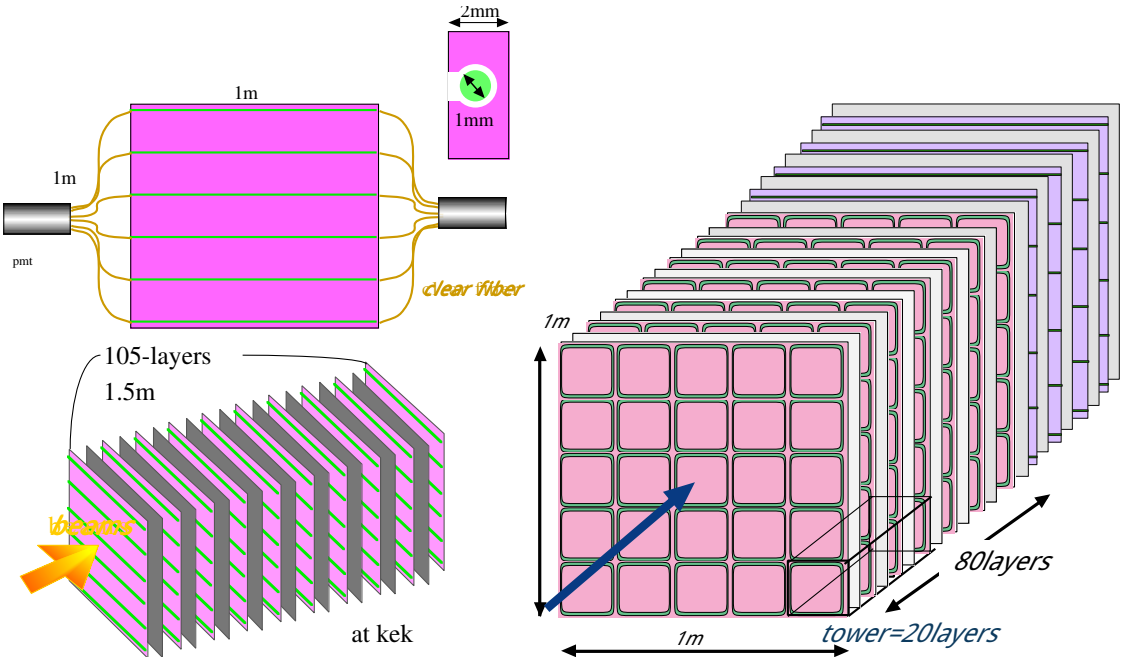

FIGURE 1. Schematic drawings of the straight groove scintillator detector (a, left) and the tile-fiber calorimeter (b, right).

RESULTS OF THE STRAIGHT GROOVE CALORIMETER

The energy measured for electrons divided by that measured for pions at the same energy gives e/π ratio. Discrepancy of this e/π ratio from 1 expresses the detector response difference between the electro-magnetic particles and the hadrons. The compensation condition (e/π ratio=1) is searched for by changing the thickness of the lead plates which act as the absorbers for the shower, where the thickness of

the scintillators has been kept constant to be 2mm. The measurements have been carried out at KEK test beam line from 1 to 4 GeV. The results are shown in Figure 2-a. The expected condition for the hardware compensation is at 8mm of the lead thickness [2], while we found it 9.1 $\pm$ 0.3 mm [4]. We have measured longitudinal shower distribution in this calorimeter which is shown in Figure 2-b, where a 5-pairs of scintillator and lead plate consists of a superlayer in the horizontal axis. In total 21 superlayers in this calorimeter.

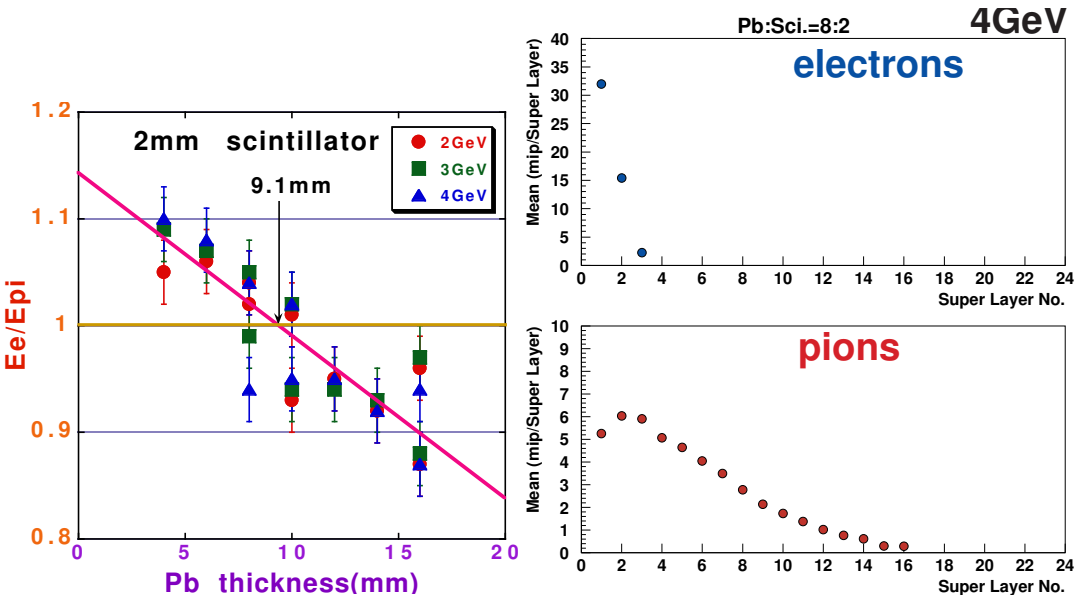

FIGURE 2. Results of the straight groove calorimeter. The e/π energy ratio (a, left) as a function of the lead plate thickness from 4 to 16mm, when the thickness of the scintillators is 2mm. The longitudinal shower energy distribution (b, right) for electrons and pions of 4GeV.

RESULTS OF THE TILE-FIBER HADRON CALORIMTER

The modified detector of 5x5 tower structure has been tested at KEK (1-4 GeV) and FNAL (10 - 200GeV). The combined energy resolution is plotted in Figure 3-a , as a function of $1/\sqrt{E}$ for both pions and electrons. The constant term of the energy resolution for pions is due to the shower leakage at the rear end of the detector. It is reduced from 0.8% to 0.0 % by cutting the leakage events in the sample. The fitted results for pions are ;

$$\sigma/E = \frac{46.7 \pm 0.7\%}{\sqrt{E}} \oplus 0.8 \pm 0.9\% \qquad (2)$$

without leakage cut. Obtained energy resolutions for pions are worse than the design value. Several sources of the systematic errors were studied with MonteCalro

simulations and found to be less than a % level. The non-linearity for pions between 1 and 200 GeV is compatible within ± 1 %. We have measured the resolution for electrons, although the detector is dedicated to the hadrons. The result is $24\%/\sqrt{E}$. This value is worse that the target number of 15%. To achieve such an excellent resolution, an electro-magnetic calorimeter of 1mm thick scintillator tile with much smaller size has to be developed.

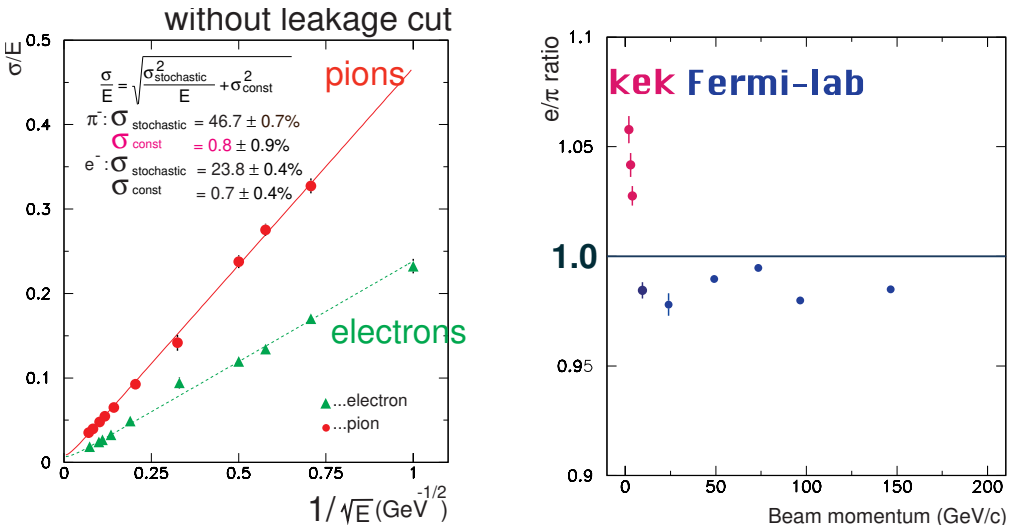

FIGURE 3. Results of tile-fiber calorimeter. The energy resolutions for pions and electrons as a function of $1/\sqrt{E}$ of the incident energy (a, left). The e/π ratio as a function of the energy of the incident particles measured at KEK and FNAL (b, right).

SUMMARY

We have constructed and tested two types of the lead scintillator sandwich hadron calorimeters. One has the straight grooves in 1m plastic scintillator plates. The other has tile fiber modules of 20cm square and 5x5 tower structure in 1m x 1m. The energy resolution measured for pions was $47\%/\sqrt{E}$. This number is a little bit worse than that required. An improvement can be expected with an electromagnetic calorimeter in front of the current hadron detector. The e/π ratio is quite close to one and has almost no energy dependence at high energy.

REFERENCES

1. JLC Group, *KEK Report, 92-16*, (1992).
2. R. Wigmans, *CERN-EP* **86-141**, (1986);
   E. Bernardi et. al., *Nucl. Instr. Meth.* **A262**, (1987) 229-242.
3. D. Acosta et. al., *Nucl. Instr. Meth.* **A308**, (1991) 481-508.
4. T. Suzuki et. al., *Nucl. Instr. Meth.* **A432**, (1999) 48-65.