A Shashlik e.m. Calorimeter with Longitudinal Segmentation for a Linear Collider experiment

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Abstract. Two techniques for longitudinal segmentation of Shashlik calorimeters are proposed and tested in order to prove the feasibility of an ElectroMagnetic calorimeter based on the Shashlik technology for a detector at a future Linear Collider. Results concerning energy resolution and e/π separation are reported and the basic concepts of a Linear Collider calorimeter are given.

INTRODUCTION

Shashlik calorimeters are good candidates for barrel electromagnetic calorimetry at future linear e^+e^- colliders [1] because they satisfy the requirements of very high granularity with a transversal segmentation of the order of $0.9^o \times 0.9^o$ ($\sim 3 \times 3$ cm^2), fairly good energy resolution and compactness. They can furthermore be operated inside a high 4 T magnetic field. A longitudinal segmentation however is essential for a good e/π separation, and needs to be studied and implemented.

The CALEIDO collaboration [2] has proposed and tested two solutions for longitudinal segmentation: 1) the insertion of thin vacuum photodiodes (5 mm) between adjacent towers in the front part of the calorimeter (CALEIDO1); 2) the use of a slow ($\tau \simeq 250$ ns) scintillator as sampling medium in the front part of the calorimeter, combined with a fast scintillator in the rest of the detector (CALEIDO2).

CALEIDO RESULTS

CALEIDO1. A prototype detector was exposed to a beam with the aim of measuring the sampling capability and demonstrating that the insertion of diodes neither deteriorates critically the energy response nor produces significant cracks in the tower structure.

A very good e/π separation ($< 5 \times 10^{-4}$ at 50 GeV) was achieved and an energy resolution

$$\frac{\sigma(E)}{E} = \sqrt{\left(\frac{9.6\%}{\sqrt{E}} + 0.5\%\right)^2 + \left(\frac{0.130}{E}\right)^2} \tag{1}$$

where E is expressed in GeV was obtained. The position resolution of the prototype at the cell center was 1.6 mm with 50 GeV electrons. The prototype description and a detailed discussion of the results can be found in [3].

In order to study the feasibility of a calorimeter with higher granularity (3×3 cm^2 lateral cell size), a smaller vacuum photodiode ($5 \times 3 \times 0.5$ cm^3 Hamamatsu protptype PPTXC00052) was tested. The energy response to the early shower development of 30 and 50 GeV electron beam and 30 GeV pions is shown in fig. 1.

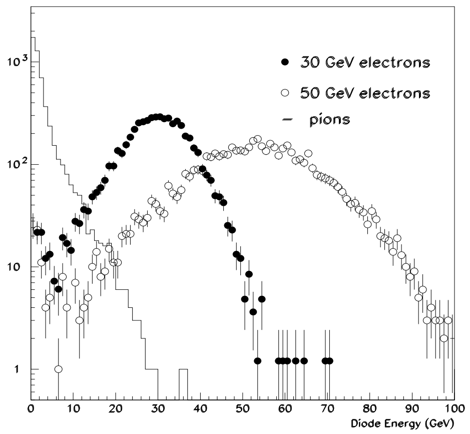

FIGURE 1. Energy response for 30 and 50 GeV electrons and for 30 GeV pions for the $5\times3\times0.5$ cm^3 Hamamatsu photodiode.

CALEIDO2. The second prototype had 9 Pb/scintillator towers ($5 \times 5 \times 28$ cm^3) assembled in a 3×3 matrix. In each tower, the scintillator Bicron BC-444, characterized by a decay time of about 250 ns, was used in the first 29 layers (corresponding to the first 5 X_0). Its decay time is much longer than the the decay time of the CALEIDO1 scintillator which is faster than 10 ns, and which was used in the residual 100 layers of CALEIDO2. The light produced in each tower by both the fast and the slow scintillator was carried to the same photodetector by means of KY11 fibers from Kuraray. The time distribution for both scintillators is shown in Fig. 2.

The prototype was tested using electrons ranging from 5 to 75 GeV and pions of 20, 30 and 50 GeV. Preliminary results from the test beam data analysis show that the proposed technique works. The signal extracted from the slow component versus the total energy is shown in Fig. 3 for electrons and pions. The discriminating power of the E_{slow} information improves the separation capability by a factor ~ 2

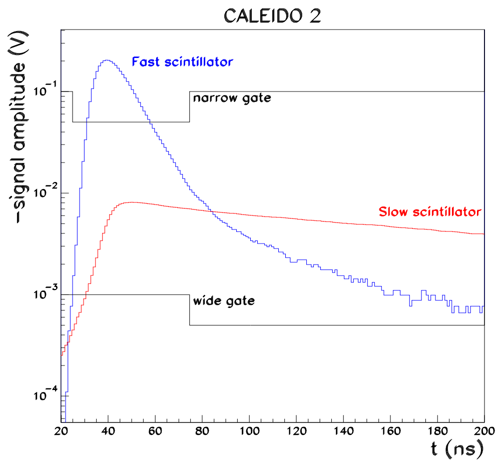

FIGURE 2. Signal time distribution for fast and slow scintillators

w.r.t. the use of E/p ratio alone and it is $\epsilon_\pi < 5.6 \times 10^{-4}$ (95% $C.L.$) for $\epsilon_e = 95\%$ at 50 GeV.

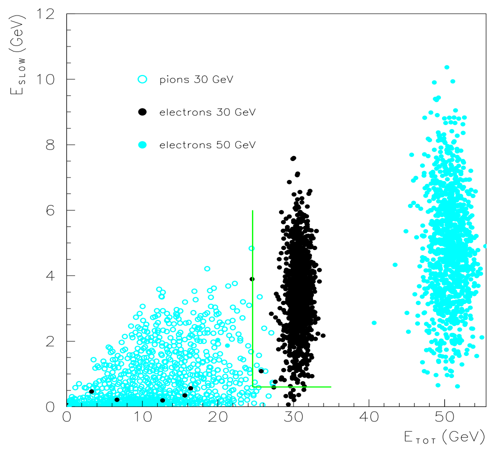

FIGURE 3. CALEIDO2: slow scintillator energy versus total energy for e at 30 and 50 GeV and π at 30 GeV.

The energy resolution can be parametrized as a function of the beam energy by:

$$\frac{\sigma(E)}{E} = \frac{14.2\%}{\sqrt{E}} + 0.6\% \tag{2}$$

.

A more detailed description of the second prototype results can be found in [4].

A DETECTOR FOR A LINEAR COLLIDER

Since both the proposed techniques work, the Shashlik technology can be used for the electromagnetic calorimeter of the detector at a future Linear Collider. The second technique proposed here, despite of the worse energy resolution, offers mechanical advantages. In particular a lateral granularity of $\sim 3 \times 3$ cm^2 can be obtained in a simple way by using large (i.e. $\sim 20 \times 10$ cm^2) absorber plates and confining the scintillation light inside the defined granularity region. This scheme substitutes the small tower structure which is unavoidable if the lateral diode has to be inserted. In the TESLA TDR [5] a Shashlik solution is proposed for a barrel electromagnetic calorimeter based on 19.2×10 cm^2 lateral size modules each with 18 channels having two decay-time scintillators.

CONCLUSIONS

Beam tests have demonstrated the technical feasibility of longitudinally segmented Shashlik calorimeters in which longitudinal sampling is performed by lateral vacuum photodiodes or by using two scintillator types with different decay times. Performance in terms of energy resolution, impact point reconstruction and e/π separation are adequate for applications at future e^+e^- collider experiments.

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