Scintillator+MPPC ECAL Testbeam Results

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A scintillator-tungsten ECAL prototype with full MPPC readout was constructed and exposed to positron beams at DESY. We describe the detector and present the results of a preliminary analysis of its performance.

1 Introduction

At the future ILC experiments, the success of the physics program will depend, among other things, on the jet energy resolution. One way to achieve excellent jet energy resolution is by means of a Particle Flow Algorithm, which relies on the accurate separation of calorimeter energy deposits due to charged and neutral particles. The momentum of charged tracks, accurately measured in the tracking detector, are used to estimate the charged jet energy, while the energy deposits in the calorimeter not associated to charged particles are used to estimate the neutral energy. To achieve the separation of charged and neutral energy, a highly granular calorimeter is required. We are studying the design of such a calorimeter, and have produced a prototype electromagnetic calorimeter, whose performance we have tested in a positron beam at DESY.

2 Prototype Design

The calorimeter prototype is a sampling calorimeter, with alternating layers of scintillator and tungsten. Each scintillator layer consists of 18 scintillator strips, arranged in two rows of 9 strips. Each strip has a size of 4.5×1 cm^2, and a thickness of 3 mm. The thickness of the tungsten plates is 3.5 mm. The light produced in each scintillator strip is read out by a Multi Pixel Photon Counter (MPPC), manufactured by Hamamatsu Photonics. The orientation of strips in successive layers is orthogonal, giving an effective overall granularity of 1×1 cm^2.

We tested three types of scintillator layers.

- WLS "megastrip": scintillator plates (of size $90 \times 45 \times 3$ mm) produced by Kuraray. Grooves were machined into the plate and filled with white PET film, giving 9 optically isolated strips, each with width 10mm. A wavelength shifting fibre was inserted into a 1 mm diameter hole drilled along the central axis of each strip. The MPPC was placed at one end of this fibre. The faces of the megastrip were covered in radiant mirror film produced by 3M.

- direct readout "megastrip": as above but without the WLS (or its hole). The MPPC was directly attached to one end of the scintillator strip.

- KNU extruded: extruded scintillator strips, developed by Kyungpook National University, Korea, with a co-extruded coating of TiO_2 and a central WLS.

Three modules, each with 13 scintillator-tungsten layers, were constructed, one for each scintillator type. Two modules were combined to make the detector prototype. Of the various combinations tested, only the results with the two Kuraray megastrip modules, the WLS module placed upstream of the direct readout module, are reported here.

The effective Moliere radius of this detector is around 21 mm, and the effective radiation length 8 mm.

3 DESY testbeam setup

The prototype detector was taken to DESY in February/March 2007, and exposed to secondary positron beams at the DESYII accelerator, in the energy range $1-6$ GeV.

The beamline was instrumented with two scintillator trigger counters, a scintillator veto counter and four drift chambers upstream of the ECAL detector, which was placed on an automated movable stage. One additional trigger counter and one veto counter were placed downstream of the detector. The detector was read out using the readout electronics and DAQ developed for the CALICE Analogue HCAL prototype detector.

In four weeks of running, around 10^8 events were collected.

4 Detector calibration

At several points during the data taking, the detector was calibrated. The tungsten plates were removed, and the detector was exposed to positron beams. The detector was scanned, aiming the beam at the centre of each scintillator strip.

Calibration events were selected by requiring appropriate signals in the trigger and veto counters up- and down-stream of the detector. Each strip in the detector was separately calibrated. To select events in which a positron (considered to be a MIP) passed through a particular strip in the detector, almost all similar strips in the other same polarity layers were required to have recorded a signal inconsistent with being purely pedestal. The other strips in the same layer as the one being considered were required to have measured a signal consistent with the pedestal. This event selection provides a clean sample of events in which a MIP passed through a particular strip.

The distribution of the signals from the selected strip were then used to measure the response of the strip. It was fitted by a Landau distribution convoluted with a Gaussian, and the most probable value of the Landau was used as the calibration constant for that strip.

5 Energy scan

The detector was exposed to positron beams of energy 1, 2, 3, 4, 5 & 6 GeV (with the tungsten plates inserted). For the data analysed here, the beam was directed at the centre of the detector; beam scans across the detector were also performed, but these data have not yet been analysed.

To estimate the energy deposited in the detector, the signal from each strip was converted, by means of the calibration constants, to a number of MIP equivalents. This was then summed over all detector strips to give the total energy, in terms of MIP equivalents, reconstructed in the detector.

These distributions were then used to measure the detector's basic performance. The linearity of the energy response is shown in Fig. 1: the detector is relatively linear, with residual non-linearities on the order of 4%. The cause of this non-linearity is presently under study. The widths of the response curves were used to measure the detector's energy resolution. The evolution of the resolution with beam energy is shown in Fig. 2; this was fitted by the quadratic sum of a statistical and constant term, giving an energy resolution of $\sigma_E/E = 13.45\%/\sqrt{E} \oplus 2.87\%$.

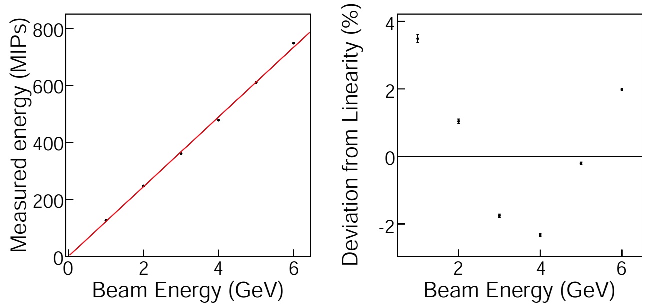

Figure 1: Linearity of the detector energy response.

6 Future refinements

There are several effects which we know we need to correct for, and which are presently being studied. One example is the nonlinear behaviour of the MPPC, which affect the response, particularly at large light yields. Another example is a correction due to temperature variations, which can have a strong effect on the characteristics of the MPPC.

We will also measure the dependence of the performance on the position at which the positron enters the calorimeter, and measure the performance using modules made of different scintillator types. This will help us to choose the best scintillator to use in the ILC detector.

Another area of current work is the development of a more sophisticated simulation of the detector: the simple simulation we have at present does not model the detector sufficiently well.

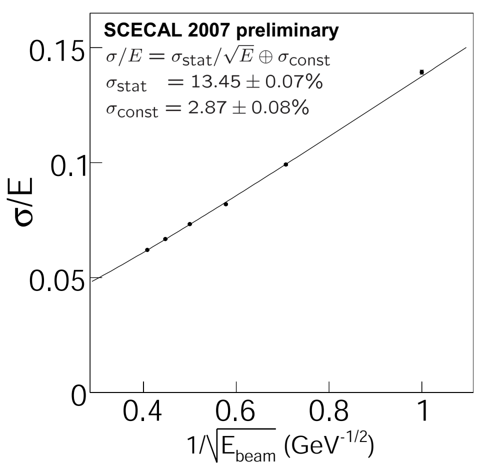

Figure 2: Energy resolution of the detector response.

7 Conclusions

A prototype ECAL was constructed using scintillator strips readout by MPPCs, and exposed to positron beams at DESY. The results of a preliminary analysis of its performance were presented: the detector is linear to within 4% in the energy range considered, and the energy resolution for positrons was measured to be $\sigma/E = 13.5\%/\sqrt{E} \oplus 2.9\%$.