LCCAL A R&D PROJECT FOR THE BARREL ELECTROMAGNETIC CALORIMETER: STATUS REPORT

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The status of the LCcal R&D project for the design and construction of a new Electromagnetic Calorimeter prototype is presented. Preliminary results from test-beam runs are shown.

1 Introduction

The technique used for the LCcal prototype and the reasons for the technological choice are extensively described in the LCcal 2002 PRC report and in a LC note[1]. The prototype is a sampling calorimeter made by absorber and scintillator layers with wavelength shifting fibres and by 3 planes of Si pad detectors to obtain very precise information on the transversal shower profile at different positions in the shower development.

2 The prototype

The proposed prototype has 45 layers of $25\times25\times0.3$ cm^3 lead absorber coupled to 45 layers of scintillator subdivided in 25 cells of $5\times5\times0.3$ cm^3 with a green WLS fiber inserted in circular grooves. The WLS fibres are connected to clean fibres with long attenuation length in order to transport the light signal at large distance. In the region corresponding to the 3×3 central scintillator cells, the fibres of the cells placed at the same lateral position are grouped into 4 bundles each connected to a Photo-Multiplier (P.M.), thus obtaining a 4-fold longitudinal segmentation. All the longitudinal sectors of the 16 border cells are grouped into a single bundle since they are used to recover the lateral energy released by particles impinging in the central cells.

Three planes of 252 silicon diode pads (0.9×0.9 cm^2) are inserted at the depth of 2, 6 and 12 X_0 from the calorimeter front face. The planes consist of 3×2 detectors of 6×7 pads each which are connected through a conductive glue to a pcb where the frontend ASIC VAhdr9c (IDE as) is mounted.

3 The prototype production

The different detector items were produced in in the following way:

- The scintillator tiles (SCSN-61 from Kuraray and BC-408 from Bicron) were machined, with a vacuum plate as a holder, in order to produce circular grooves for the fiber insertion and linear grooves for the cell light separation . The linear grooves were filled by Tyvec paper.

- All the WLS fibres (40 cm in length) were polished and aluminised on one face by sputtering. A middle temperature oven (about 60°) was used to curl the fibres before their insertion into the 2.25 cm radius groove in order to ensure the light yield stability that could not be guaranteed when bending the fibres at room temperature. More than 1100 fibres were bended and glued to clear fibres with optical epoxidic glue and a small supporting tube.

- The Silicon pad production was much slower than foreseen. After one single detector was mounted and fully tested, a set of 20 detectors was delivered in autumn 2002 but many of them had problems due to high leakage current. Only two planes could be fully equipped for the first low energy test beam. More recently (June 2003) a different and simpler production (DC detectors) for additional 12 detectors was successfully accomplished allowing to complete the three planned planes.

The calorimeter prototype was completed in autumn 2002.

4 Test beam results

The first longitudinal segment of the Calorimeter (4 layers, 2 X_0) and the preproduced Si pad detector were exposed to the CERN SPS H4 beam in summer 2002. Electrons of 40 and 50 GeV and pions of 50 and 150 GeV were used.

Useful informations on the light yield (>5.1 ph.e./m.i.p./scintillator tile) and on the uniformity in light collection were obtained by looking at the width and the position of the peak produced by non-interacting particles (m.i.p.).

The completed calorimeter prototype (except for the third Si layer as described before) was exposed twice to the Frascati Beam Test Facility (BTF)[2] in December 2002 and April 2003. BTF is a low energy electron beam (50 to 750 MeV) were the multiplicity of particles arriving almost at the same time can be tuned. A high-energy run with the fully equipped detector was done at the CERN SPS H6 test beam in August 2003.

4.1 Energy resolution and Linearity

In order to calibrate the P.M. response the following procedure was applied:

- defining $C^i = b^i \Sigma_{j=1,4} a_j L^i_j$ as the calibrated sum on the transverse position i of the 4 longitudinal L^i_j signals, 13-1 independent parameters a(4-1) and b(9) had to be determined for the 9 central cells;
- in a 1st step the layer response at the same incoming energy was equalised ($L^i_j = b^k/b^j L^k_j$ when the beam is centred on cell i and k respectively);
- the a_j coefficients were obtained by minimising the width of the total energy obtained by summing over the 9 cells $E_{cal} = \Sigma_{n=1,9} C^n$.

The procedure was applied independently at the BTF and at the CERN runs since the P.M. gains were lowered at CERN to cope with the signal amplitide. The energy response to one, two and three 450 MeV electrons after the calibration is shown in Figure 1

The energy resolutions at low energy is as expected (around 11.5 $\%/\sqrt{E}$) as shown in Figure 2 and the linearity is good (Figure 3).

The previous results are confirmed by a preliminary analysis of the high-energy 2003 test: the linearity is good below 30 GeV (unfortunately at very high energies the P.M.'s with largest gain were showing clear evidence of saturation) and the energy resolution is compatible with the low-energy one (11.1$\%/\sqrt{E}$ with a constant term compatible with the beam momentum spread) (Figure 4).

4.2 Electron-hadron separation

The detector has a high redundancy in the measurements of the longitudinal and lateral shower development. This is given by the four calorimetric longitudinal samples and by the three planes of high granularity Si pads. Therefore

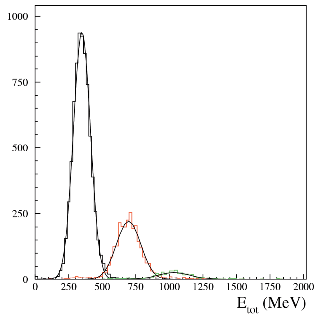

Figure 1: Energy distribution for a 450 MeV electron beam with multiplicity 1, 2 and 3.

the electron-hadron separation is excellent. Examples of the quantities used for the identification are shown in Figures 5 and 6.

The evaluation of the overall rejection factor is limited by the contamination of electrons in the pion beams and is preliminary given to be $< 10^{-3}$.

4.3 Shower reconstruction

The shower position is determined through the centre of gravity of the energy released on the pads. The position resolution is obtained by comparing the reconstructed position with the particle impact point as given by the microstrip telescope with a resolution of 50 μm. A plot with the difference between the reconstructed and the predicted positions for the three Si planes is shown in Figure 7 for 30 GeV electrons and the difference at the first layer for 10 GeV electrons is shown in Figure 8. The results are preliminary and need more study on the pad noise subtraction.

Given the good position resolution, it is possible to compare the energy dependence on the impact point on the calorimeter as determined both by the external telescope and by the internal pad information. This is shown in Figure 9: the dependence is small ($< 2\%$) and there is almost no difference between the two position determinations. It is therefore possible to use the pads to apply a correction to the energy value depending on the reconstructed

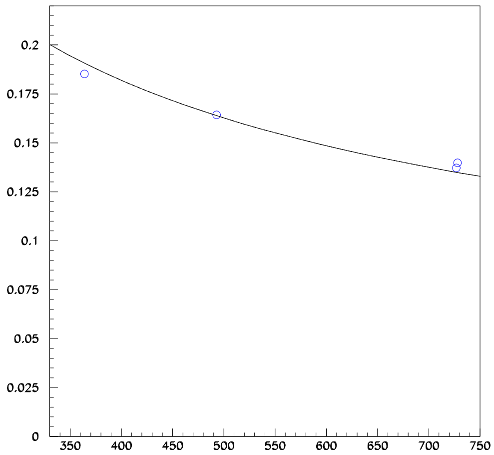

Figure 2: Energy resolution for a single electron beam as a function of the energy (MeV). The full line corresponds to a stochastic term of $11.5\%/\sqrt{E}$.

particle impact.

5 Particle-particle separation

The capability of this detector to separate the contributions of two near particles is a more complex pattern recognition problem which is still under study. At present the indications coming from the impact resolution and the shower width on the first Si pad plane (~ 2.5 cm in average for 50 GeV electrons) are very promising.

6 Conclusions and future plans

The preliminary results obtained with the calorimeter built with the proposed technique are in agreement with the expectations. In particular the energy resolution is in the range $11 \div 11.5\%/\sqrt{E}$ with a negligible constant term, the energy uniformity is at the level of few %, the position reconstrucion is ~ 2 mm at 30 GeV and the electron hadron separation is better than permille level. All these values are still preliminary. An analysis on the particle-particle

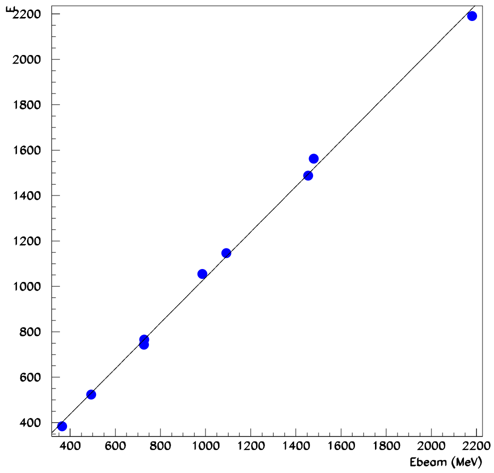

Figure 3: Detector energy response to electrons of different energy and multiplicity as a function of the total input energy (MeV).

separation is ongoing.

References

1. LC note LC-DET-2003-014 .
2. see *www.lnf.infn.it/committee/talks/26mazzitelli.pdf* and references therein.

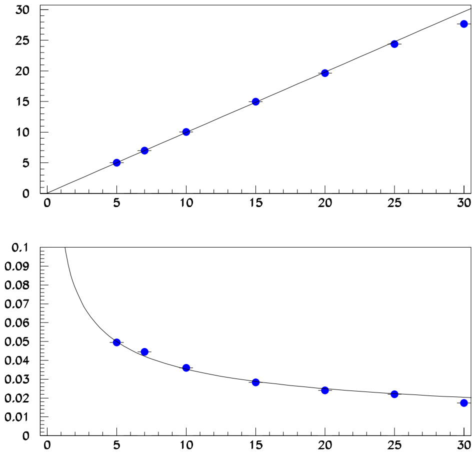

Figure 4: Detector energy response to electrons of different energy (up) and energy resolution as a function of the input energy in GeV (down). The full line corresponds to the fitted function $\sigma_E/E = 11.1\%/\sqrt{E}$.

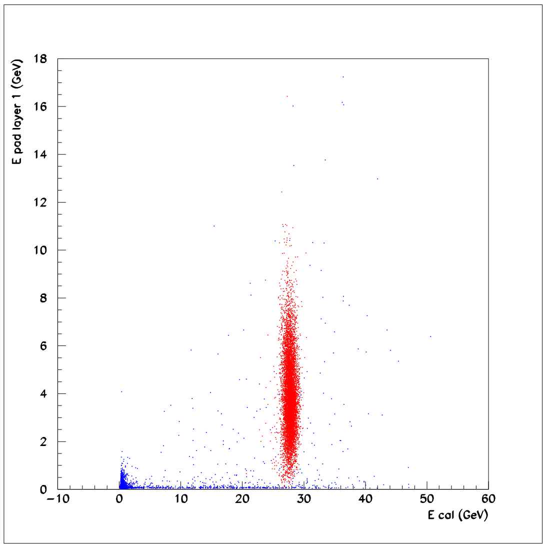

Figure 5: The energy on the first Si pad plane vs total energy on the calorimeter for electrons of 30 GeV (red) and pions of 75 GeV (blue).

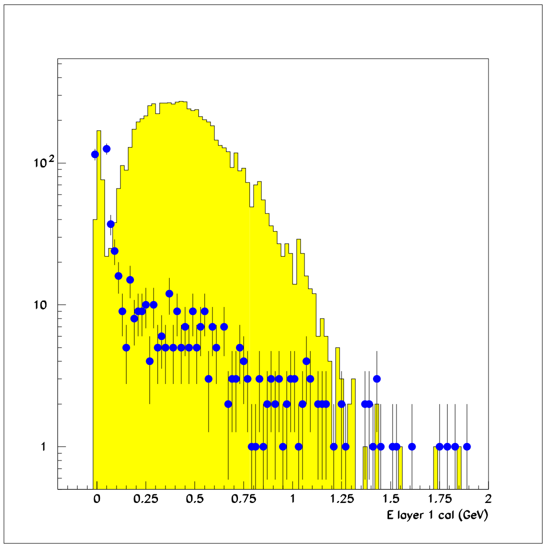

Figure 6: Energy response to 30 GeV electrons (histogram) and 30 GeV pions (dots) on the first longitudinal segmentation of the calorimeter. The peak at low energy on the histogram is due to a contamination on the electron beam.

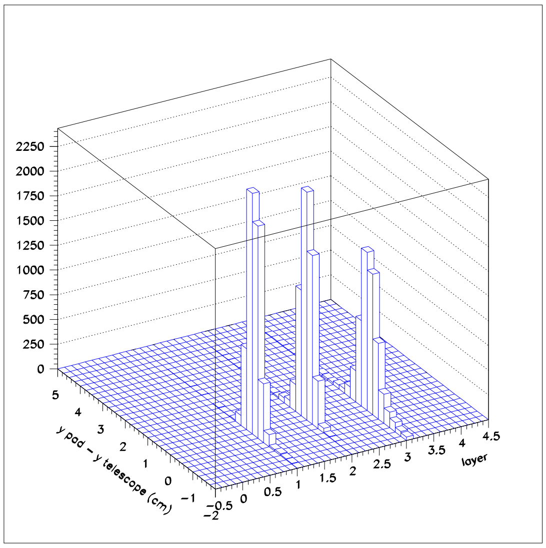

Figure 7: The difference y reconstructed-y telescope for the vertical (y) coordinate on the three Si pad planes for 30 GeV electrons; the obtained resolutions are 2.16, 2.45 and 3.27 mm respectively.

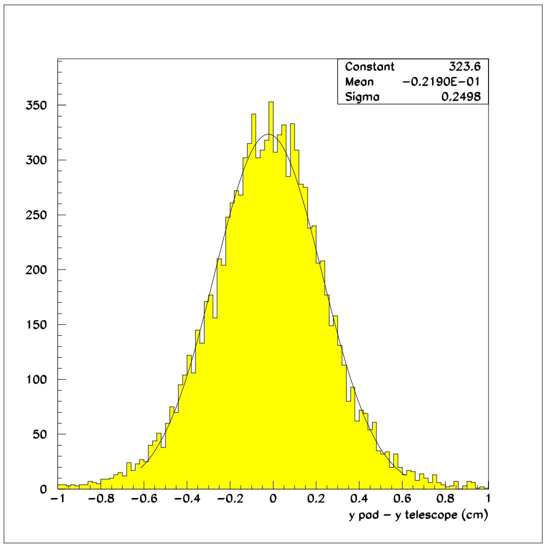

Figure 8: The difference y reconstructed-y telescope for the vertical (y) coordinate on the first Si pad plane for 10 GeV electrons.

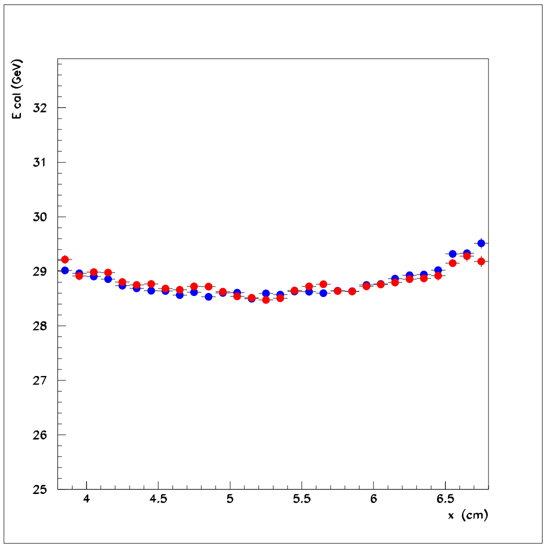

Figure 9: Energy dependence on the horizontal (x) impact coordinate for 30 GeV electrons: predicted by the telescope (blue), reconstructed by the first plane of Si pads (red).