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LCCAL A R&D PROJECT FOR THE BARREL ELECTROMAGNETIC CALORIMETER

M. ALEMI, A. BULGHERONI, M. CACCIA
Università dell'Insubria , Como, Italy
S. BERTOLUCCI, M. CORDELLI, S. MISCETTI
I.N.F.N. Laboratori Nazionali di Frascati, Frascati, Italy
M. BETTINI, E. BORSATO, P. CHECCHIA, C. FANIN, M. MARGONI, M. NICOLETTO, R. PEGHIN, L. RAMINA, F. SIMONETTO
I.N.F.N. sezione di Padova, Padova, Italy
B. NADALUT, M. PREST, E. VALLAZZA
I.N.F.N. sezione di Trieste, Trieste, Italy
J. MARCZEWSKI
Institute of Electron Tecnology, Warsaw, Poland

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Corresponding Author: Paolo Checchia paolo.checchia@pd.infn.it

Abstract

The status of the LCcal R&D project for the design and construction of a new Electromagnetic Calorimeter prototype is presented. The progress studies carried out in the last two years and the identified critical items are reported. The status of the collaboration is also addressed.

1 Introduction

The technique used for the LCcal prototype and the reasons for the technological choice are extensively described in the LCcal 2002 and 2003 PRC reports, in LC notes [1] and in several contributions to international workshops [2]. The preliminary results from test-beam runs shown at the 2003 PRC open session have been confirmed by additional analyses. In the following a short review of the results is reported together with the comparison carried out by simulation studies. A discussion of the collaboration status and on the feasibility of further work on this item is also presented.

2 Test beam results

After a test of a segment of the calorimeter (4 layers, 2 X_0) and of a single Si detector in summer 2002 at CERN [1] giving a first indication on the light yield (>5.1 ph.e./m.i.p./scintillator tile), the complete prototype (except for the 3^{rd} Si layer) was exposed twice to the Frascati Beam Test Facility (BTF) [3] in December 2002 and April 2003. A high-energy run with the fully equipped detector (including the third Si layer) was performed as well at the CERN SPS H6 test beam.

In all the tests the prototype region corresponding to the 3×3 central scintillator cells, was equipped with a 4-fold longitudinal segmentation. All the longitudinal sectors of the 16 border cells were grouped into a single bundle since they were used to recover the lateral energy released by particles impinging in the central cells.

2.1 Energy resolution and linearity

The PM response calibration could be obtained by comparing the signals of non-interacting particles (muons or pions) in the four longitudinal segments. The signal amplitude is expected to scale with the number of scintillator layers of each segment. This procedure has shown a fair agreement with the MC expectations in the electromagnetic shower development.

After the calibration, the linearity was assessed below 30 GeV (unfortunately at very high energies the PMs with largest gain were showing clear evidence of saturation) and the energy resolution was measured to be $11.1\%/\sqrt{E}$ with a constant term compatible with the beam momentum spread, according to the expectations (Figure 1).

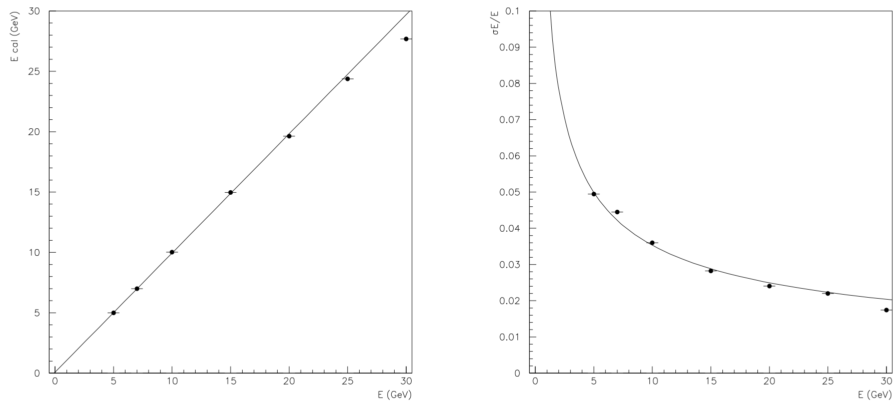

Figure 1: Left: detector energy response to electrons of different energy. Right: energy resolution as a function of the input energy in GeV. The full line corresponds to the fitted function $\sigma_E/E = 11.1\%/\sqrt{E}$. The point at 30 GeV shows clear evidence of PM saturation and thus it was excluded from the fit.

2.2 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 the electron-hadron separation is excellent. Examples of the quantities used for the identification are shown in Figures 2. The evaluation of the overall rejection factor is at the 10^{-3} level, actually limited by the contamination of electrons in the pion beams.

2.3 Shower position 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 a microstrip telescope with a resolution of 50 μm located in front of the detector. A plot with the difference between the reconstructed and the predicted positions for 10 GeV electrons is shown in Figure 3.

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

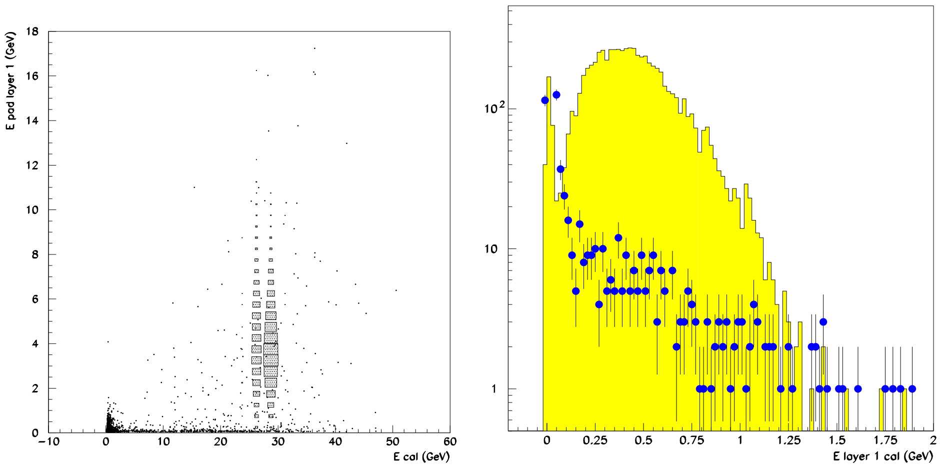

Figure 2: Left: the energy on the first Si pad plane vs. total energy on the calorimeter for electrons of 30 GeV (boxes) and pions of 75 GeV (dots). Right: energy response to 30 GeV electrons (histogram) and 30 GeV pions (dots) on the first longitudinal segmentation of the calorimeter. The peak at low energy on the histogram is due to a contamination of the electron beam.

Figure 3: 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 particle impact.

3 Detector simulation

The shower development in the prototipe was simulated in details with Geant3 Monte Carlo program [4], allowing a careful comparison between test-beam results and expectations of the energy response in scintillator and silicon pad planes. While comparing the lateral signal of the scintillator planes, a much wider spread in data than in Monte Carlo was observed. This was due to a first optimistic approach in the simulation where any light leakage from consecutive lateral cells was excluded. In this way, when simulating an electron beam centered into the central cell, the simulation provided a much smaller signal in the lateral cells than in real test-beam data. An effort was made to calibrate this effect in the simulation. The data-MC discrepancy could be eventually recovered by adding in the simulation ~ 5 % of light cross-talk between consecutive cells. This is probably due to the grooves separating the cells which

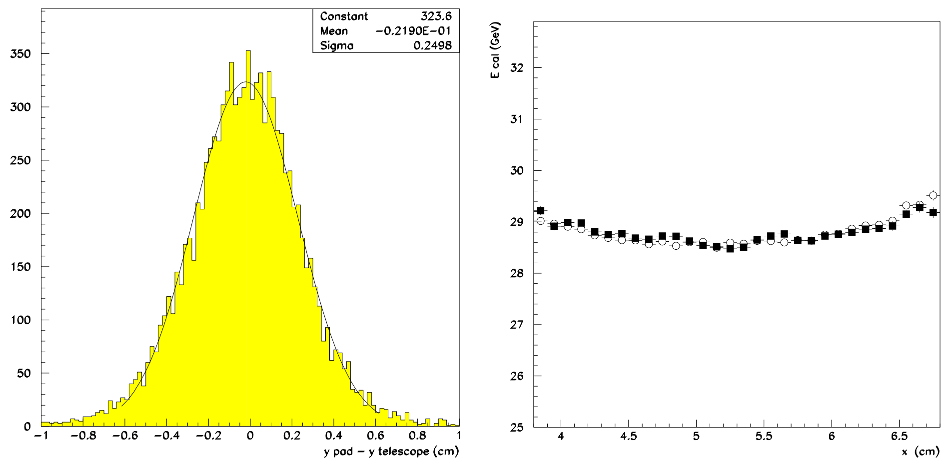

Figure 3: Left: the difference y reconstructed-y telescope for the vertical (y) coordinate on the first Si pad plane for 10 GeV electrons. Right: energy dependence on the horizontal (x) impact coordinate for 30 GeV electrons: predicted by the telescope (open circles), reconstructed by the first plane of Si pads (black dots).

retain a light transmission and to the Tyvec inserted into the grooves which is partially transparent to the light. (Figure 4).

4 Particle-particle separation

The capability of this detector to separate the contributions of two near particles is a complex pattern recognition problem. An example of two particle separation using the first two layers of Silicon pad is shown in Figure 5. As shown in the previous section, we discovered a light cross-talk of 5 % which did not help on carrying out this study. Moreover the Silicon pad signal was saturating at a rather low value (equivalent to about 15 single tracks) because of an erroneous setting of the amplification gain. These two unrelated problems made very difficult to exploit the potential of this kind of detector on particle-particle separation.

5 Progress report and Collaboration situation

In the last two years we could not accomplish the entire scheduled analysis program. However, a detailed simulation allowed us to reach a better understanding of the detector performance essentially limited by light leak and

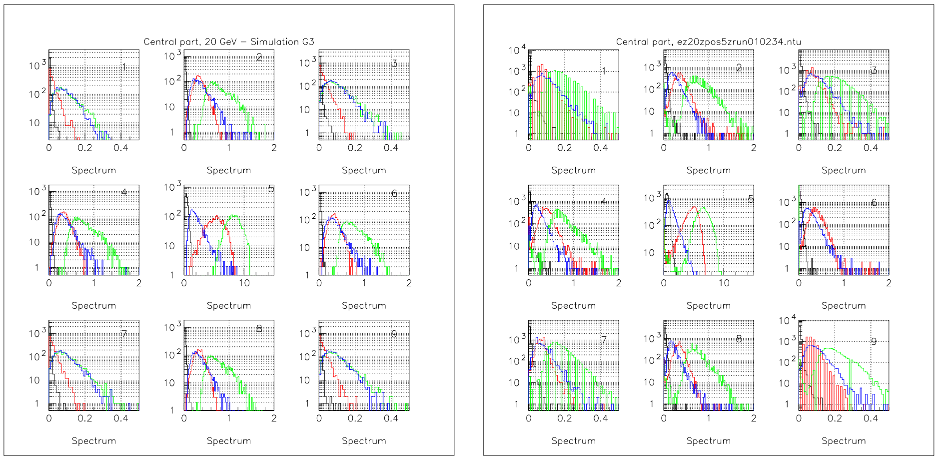

Figure 4: Left: Geant 3 simulation of the 3x3 central cells each subdivided into the 4 longitudinal segments. The simulated spectra correspond to 20 GeV electrons. The black, red, green and blue lines correspond to the 1^{st} to 4^{th} longitudinal segment, respectively. Right: signals on the 3x3 central calorimeter cells for a 20 GeV electron beam. The line colour convention is the same as in the simulation. The 3^{rd} layer was missing in cell 6 due to a PM problem. The fluctuations in the corner cells are due to the integer values in the ADC digitisation.

silicon front-end chip saturation. These items are not considered irreducibly critical. Nevertheless it was not possible to proceed any further, due to the very limited manpower. Moreover, the discovered problematics on the test beam information could not be recovered by additional data taking in 2004. Neither there was the possibility to start an engineering study toward a project of an ILC barrel electromagnetic calorimeter based on the proposed technique. The major causes have to be found in the limited human resources and in the total absence of funds.

6 Conclusions

The 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 reconstruction is ~ 2 mm at 30 GeV and the electron hadron separation is better than permille level. However, in order to exploit all the potentiality of the proposed technique more work (additional beam tests, more refined analyses, general simulation

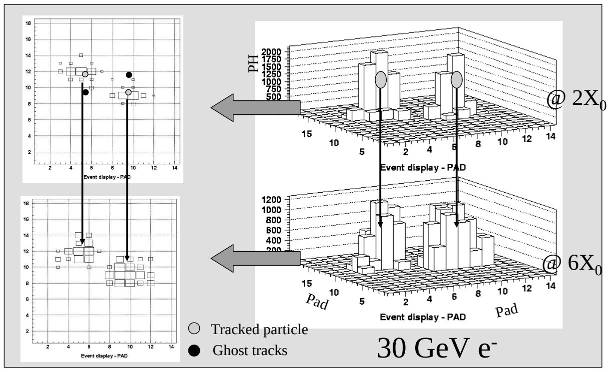

Figure 5: Example of particle separation on the silicon pads. The dots correspond to particle impact prediction using the external telescope. The physical particles are clearly recognised.

work) should be necessary. The lack of human resources due to additional engagements of the involved people imposes, at least on a short time basis, a delay on the expected progress of this project which could be recovered just by fresh injection of new actors in this game.

References

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3. see *www.lnf.infn.it/committee/talks/26mazzitelli.pdf* and references therein.
4. The prototype simulation was accomplished by V. Morgunov during a scientific visit to Padova.