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BEAM TEST RESULTS OF A PRE-SHOWER DETECTOR WITH SILICON STRIPS AS THE ACTIVE MEDIA

(RD36 collaboration)

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Abstract

Silicon strip detectors ($60 \times 60 \times 0.4 \text{ mm}^3$ with 29 strips of 2 mm pitch) used as the active media of the pre-shower detector of an electro-magnetic calorimeter have been designed, manufactured, and tested. The AMPLEX-SICAL signal processor has been used as the read-out system.

Experimental results concerning the shower position accuracy and the energy resolution of the electro-magnetic calorimeter associated with the pre-shower are presented.

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The CMS (Compact Muon Solenoid) project [1] has been designed for searching the SM Higgs boson over a mass range from 90 GeV to 1 TeV, and for the investigation of possible alternative electro-weak symmetry breaking mechanisms. It will work at the Large Hadron Collider (LHC) [2]. One of the detector elements of the CMS is the SHASHLIK-type electro-magnetic calorimeter (Fig. 1).

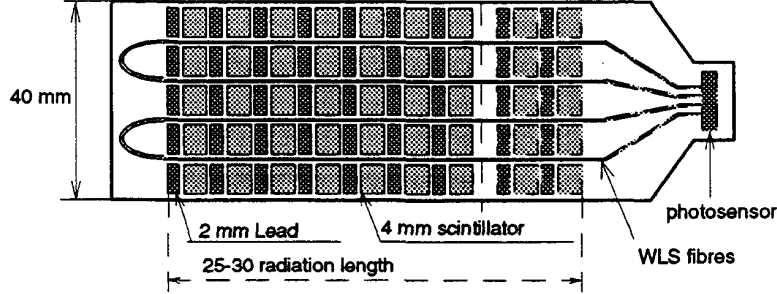


Fig. 1 SHASHLIK-type electro-magnetic calorimeter tower.

This is a lead-scintillator plate sampling calorimeter with wavelength shifter fibres for the light collection. This type of calorimeter should provide the energy measurement accuracy [3]

$$\sigma E / E = (8 - 10)\% / \sqrt{E} \oplus (0.1 - 0.15) / E \oplus (1 - 2)\% ,$$

and allows the shower barycentre measurement with a precision of

$$\sigma = (8 - 10) \text{ mm} / \sqrt{E} ,$$

where E is the energy in GeV.

Unfortunately the space, angular resolution, and two-gamma separation of this kind of calorimeter is not enough to satisfy the requirements of the physics programme of the CMS. One solution is to use an active pre-shower detector in front of the calorimeter. An active pre-shower provides a higher coordinate accuracy with a relatively small decrease in the energy resolution. The active media in this pre-shower could be 2 mm pitch silicon strip detectors. The optimized solution in terms of cost, accuracy, and the number of layers is to have two layers of silicon detectors placed after $2X_0$ and $3X_0$ of absorber. The absorber material may be lead, tungsten, copper, etc. The full area of the silicon strip detectors of the pre-shower in the CMS experiment will be 150–180 m². The silicon layers will be placed at a radius of about 1.3–1.4 m in the barrel region.

The analogue signals from the strip detectors of the pre-shower may be used to find the barycentre of the shower position, and to restore the energy loss in the pre-shower absorber material. In this case, the pre-shower acts as a part of the electromagnetic calorimeter with a different sampling (in comparison with the main part of the SHASHLIK calorimeter).

For the first approximation the shower barycentre coordinate C_i of layer i may be found by using the formula

$$C_i = \frac{\sum_j (E_{ij} * C_{ij})}{\sum_j E_{ij}} , \quad (1)$$

and the corrected energy is

$$E = E_c + K_1 * \sum_j E_{1j} + K_2 * \sum_j E_{2j} , \quad (2)$$

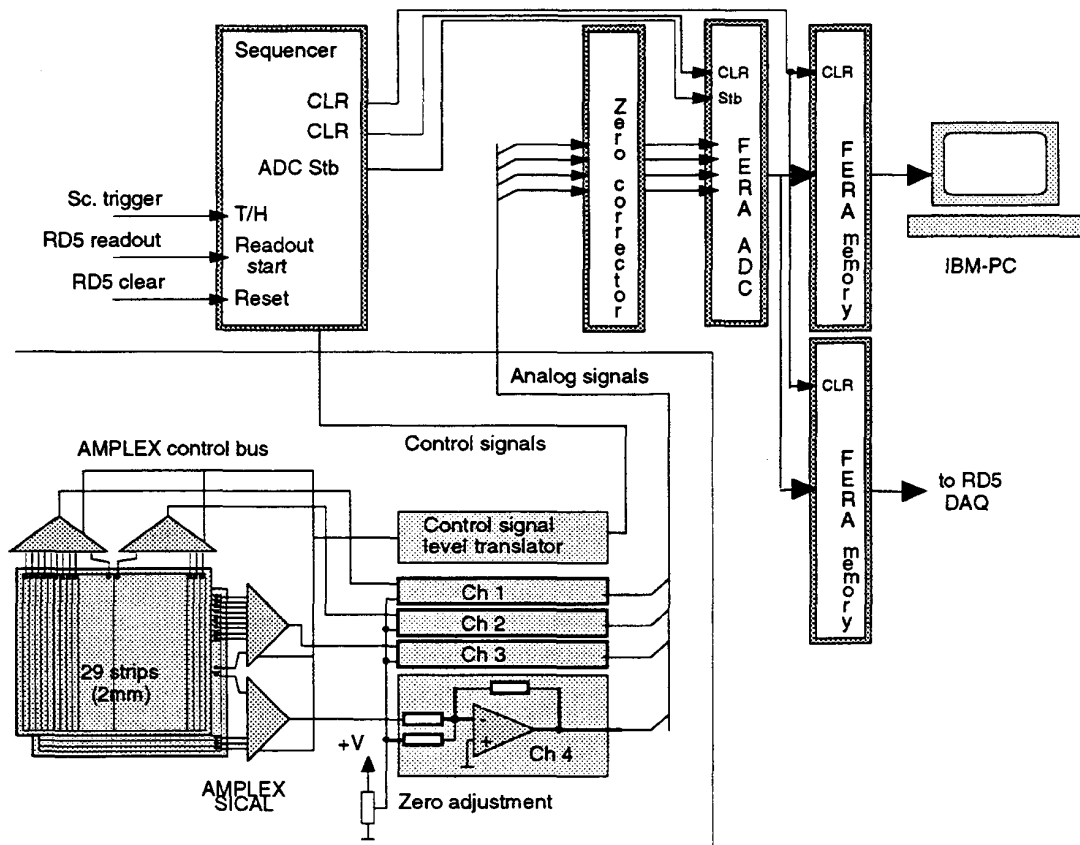


Fig. 4 Pre-shower read-out system

The test and read-out sequences were generated by a specially designed sequencer with a programmable signal sequence. The AMPLEX control signal level translator and output analog signal amplifier were built as a separate module. Every amplifier channel has an analog inverter and DC level shifter to couple the AMPLEX output levels ($-2V$ to $+3V$) to the ADC input (negative polarity signals). The linear fan-in/fan-out LeCroy 428F unit was used for the individual zero level correction of each AMPLEX output.

The output signals were digitized by a LeCroy FERA 4300B charge ADC module and stored in parallel in two FERA 4302 memory modules. One module was placed in the pre-shower control CAMAC crate connected to an IBM/PC computer via a JINR (Dubna) designed CAMAC crate controller KK009. The second FERA 4302 module was installed in the RD-5 data acquisition system (DAQ). This configuration allowed the digitized pre-shower data to be accessed by both DAQ's.

The pre-shower control IBM/PC was used for the downloading of the sequencer memory, for the pre-shower performance control, and for performing measurement and data acquisition independently of the RD-5 data acquisition system. In this case the data were stored on floppy-disks or sent to another computer via the Ethernet link.

The sequencer was built using a LeCroy 4508 programmable lookup unit (PLU) as the main element. Two CAMAC modules with two PLUs per module (Fig. 5) were used.

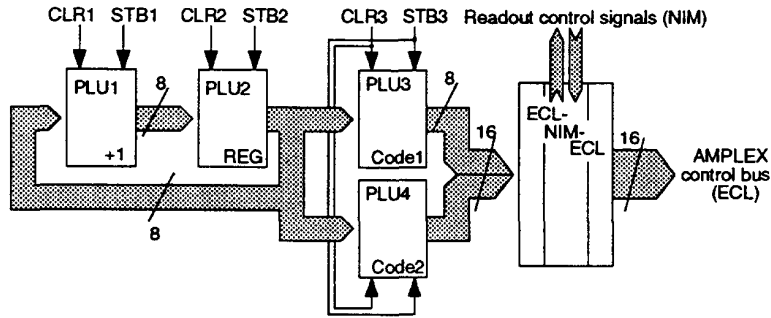


Fig. 5 Sequencer block diagram

PLU2 was programmed as a storage register and PLU1 as an adder. These PLU's together acted as an address counter for PLU3 and PLU4 which contained the read-out and the calibration signal sequences. The timing of the STROBE and CLEAR PLU signals provided the reset of the sequencer when the clock signal generation was stopped. Because of the 8-bit addressing of the PLU3 and PLU4 the sequencer could have 256 steps for 16 signals, enough for our normal use. To access the sequencer signals the ECL-NIM-ECL level converter (LeCroy model 4616) module was used.

The AMPLEX-SICAL signal processor has a peaking time of 350 ns, and the time delay for the RD-5 trigger was about 700 ns. For this reason we had to build our own pre-trigger for the AMPLEX TRACE/HOLD signal generation. This signal was generated using the coincidence of signals from the beam scintillator counters (Fig. 6).

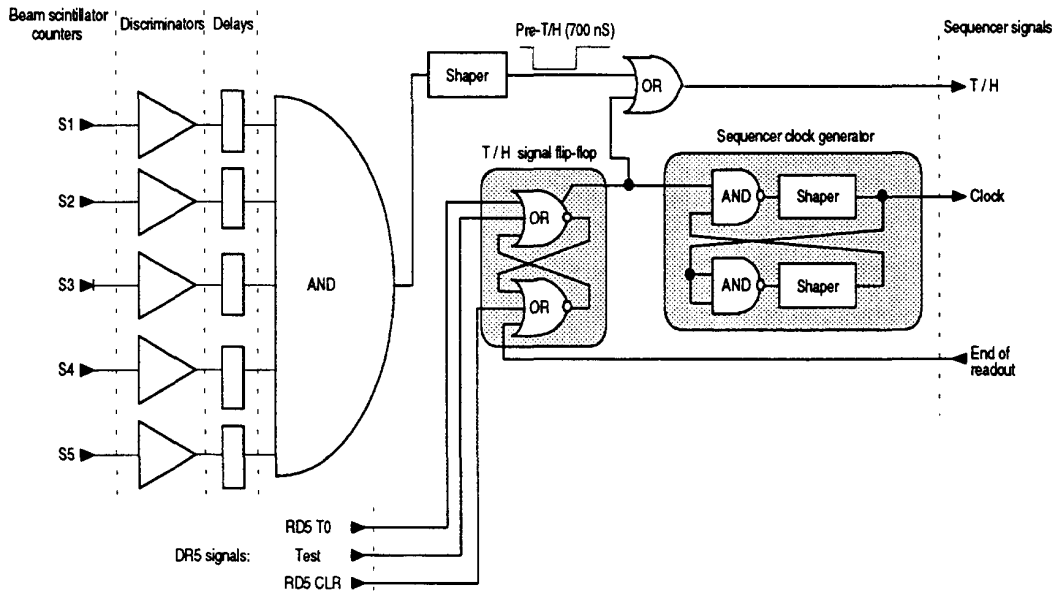


Fig. 6 Trigger block diagram

The read-out signal sequence is shown in Fig. 7. When the pre-trigger (pre-T/H) was confirmed by the signal T_0 from the RD-5 triggering system, the read-out sequence was started. After completion of the read-out, or when the RD-5 CLEAR signal was accepted, the sequencer stopped the signal sequence generation, and after one clock period the DAQ was ready for the new event read-out. The clock period had about 5 μ s duration, sufficiently long to allow the analog-to-digital conversion and the data transfer to the FERA memory to be completed in three clock cycles.

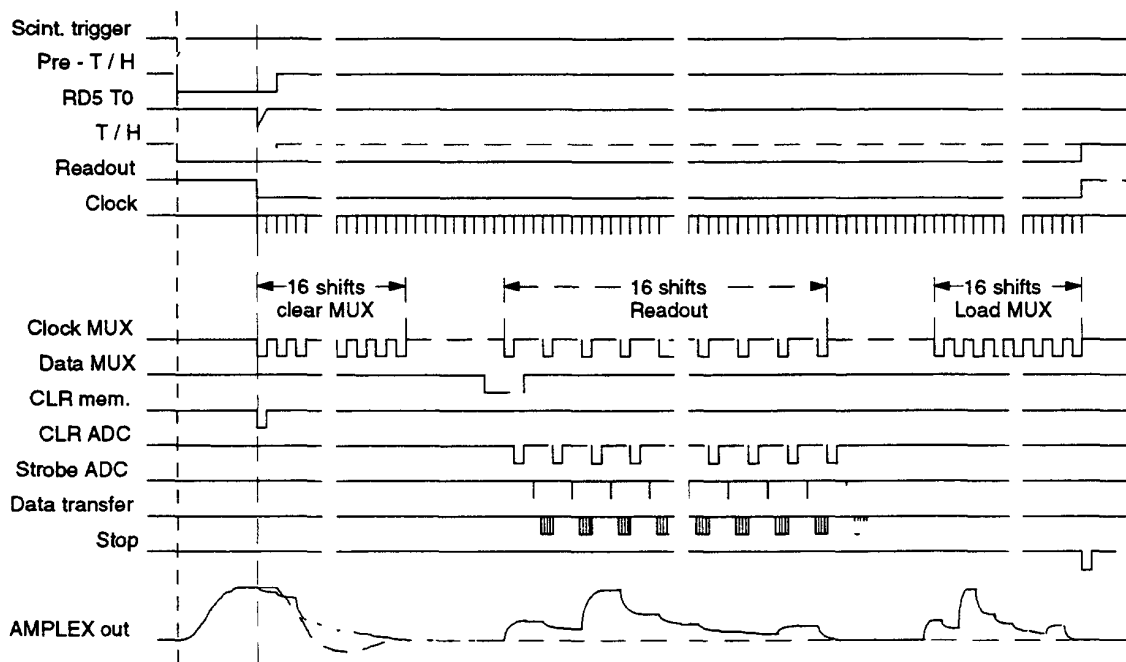


Fig. 7 Read-out timing sequence.

Before every measurement of the AMPLEX output voltage during the read-out sequence, the ADC was cleared by the external CLI pulse generated by the sequencer. The total data read-out time (including the output multiplexer loading) of the system was about 600 μ s.

The detectors were tested using a ^{241}Am (5.5 MeV) alpha-source. The amplitude distribution from the alpha with self-triggering by the 'FAST-OR' signal from a single AMPLEX channel is shown in Fig. 8.

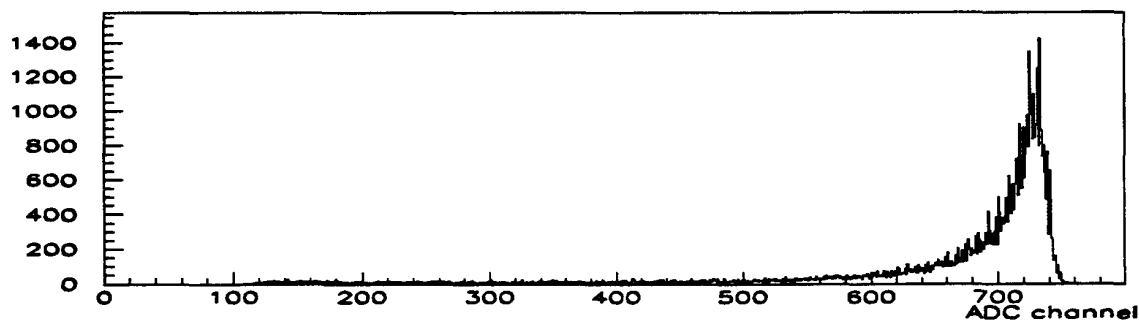


Fig. 8 Alpha-source signal amplitude spectrum.

After installation of the pre-shower in front of the nonet of the Shaslik-type electromagnetic calorimeter towers at the H2 beam, the measurements of the detectors were performed. Figure 9 shows the total energy deposition in the first and second silicon layers for showers from 40 GeV electrons.

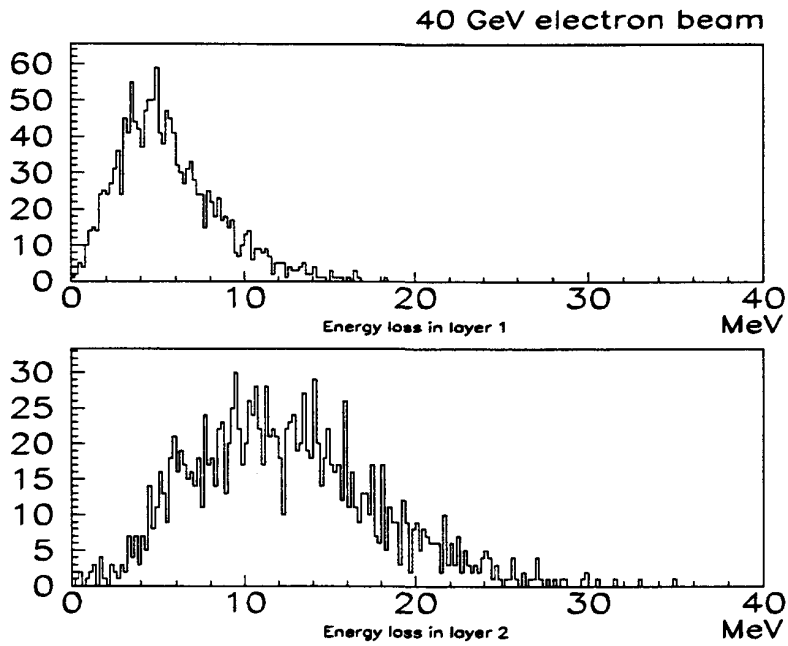


Fig. 9 Shower energy loss in silicon planes 1 and 2.

The main results of the beam test are shown in Fig. 10. Because of the pre-shower absorber in front of the electro-magnetic calorimeter the energy resolution of the calorimeter becomes worse than if no absorbers were present. The silicon strip signals allow a correction to be made, thus compensating for the energy loss in the absorbers. The coefficients K1 and K2 in (2) do not significantly depend on particle energy in a wide energy range (from 10 to 120 GeV).

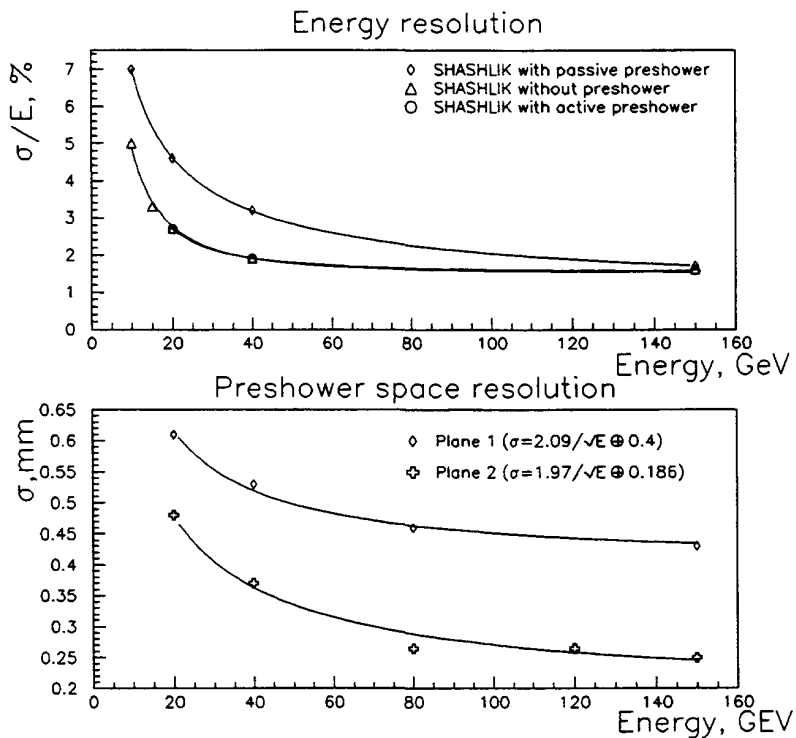


Fig. 10 Energy and spatial resolution.

The coordinate accuracy of the pre-shower depends on the strip width and might be better if narrower strips were used. In our case the angular resolution of the pre-shower together with the electro-magnetic calorimeter, is limited by the coordinate accuracy of the calorimeter, and we do not need higher precision in the pre-shower.

Using linear sum (1) for the calculation of the coordinate does not give the best result. As described in Refs. [5], [6] and [7] it is preferable to use the formula

$$\text{Coord} = \text{Coord}_m + K * \ln(A_{m+1}/A_{m-1}) \quad (3)$$

where Coord_m is the coordinate of the strip with the maximum deposited charge, and A_{m+1} and A_{m-1} are the charge deposited in the left and right strips next to the strip with maximum charge.

Acknowledgments

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