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Test beam studies of the LumiCal prototype

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Abstract

The first measurements of the LumiCal prototype performed at DESY electron test beam are reported. The obtained results indicate that full chain of signal flow including silicon sensors, fanout and readout front-end ASIC work correctly and in agreement with expectations. To study the behaviour of the signals from electromagnetic shower development, the measurements with different thickness of tungsten absorber in front of sensor plane were performed The obtained data are compared with the predictions of the Monte Carlo simulation.

1 Introduction

The International Large Detector [1] is one of the two main detectors which are planned for future experiments at International Linear Collider [2]. The precise measurement of the luminosity at ILC will be supply by special detector, LumiCal, placed in very forward region of ILD. The complete Lumical [3] detector contains two electromagnetic calorimeters placed on both side of the interaction point at 5 m from it. The single calorimeter contains 30 layers of tungsten absorber interspersed with silicon sensor planes. The sensor layers are segmented radially and azimuthally into pads of different sizes. A most recent design of the LumiCal internal structure was included in [4]. The readout electronics (FE and ADC ASICs) are placed at the outer radius in the space between the tungsten disks. The concept of front-end electronics for luminosity detector LumiCal was described in [5] and the recent progress in readout electronics together with some results of the the first test measurements can be found in [6]. To match the physics requirement at ILC the accuracy of luminosity measurement should be not worse than 10^{-3}. The mechanical structure with the micrometer precision and special customized front-end (FE) electronics will allow to fulfil such requirement. In this report we present several preliminary results of the LumiCal prototype measurements performed at DESY electron test beam at energy 4.5 GeV. In these measurements the full chain including silicon sensors, kapton fanout and front-end electronics was tested. Figure 1 shows the structure of the LumiCal detector. The yellow colour shows sensors tail which was produced by the Hamamatsu Photonics and those used in test beam measurements.

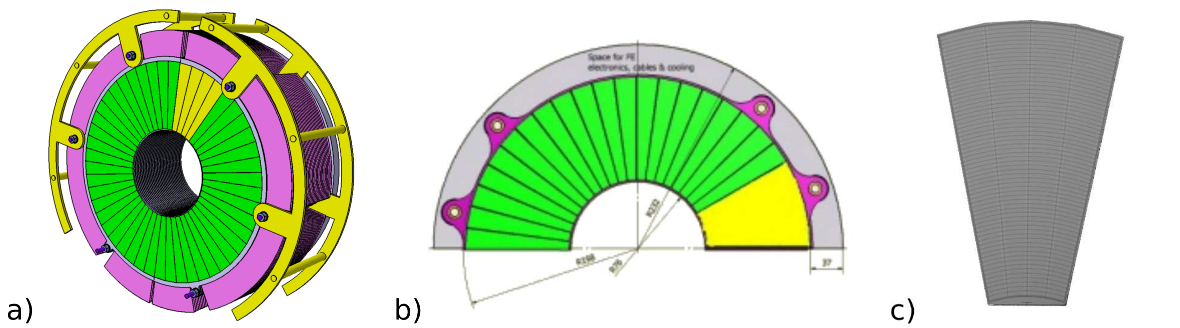

Figure 1: a) LumiCal calorimeter design b) Half plane, silicon sensor tail marked on yellow c) Silicon sensor tail prototype used during test beam measurements together with dedicated front-end electronics.

2 Test beam setup

Figure 2 presents elements of the experimental setup used during beam test measurements. Three ZEUS telescope planes [7] allowed for precision position measurement of the electron beam impact point on the face of the studied sensors (without tungsten absorber).

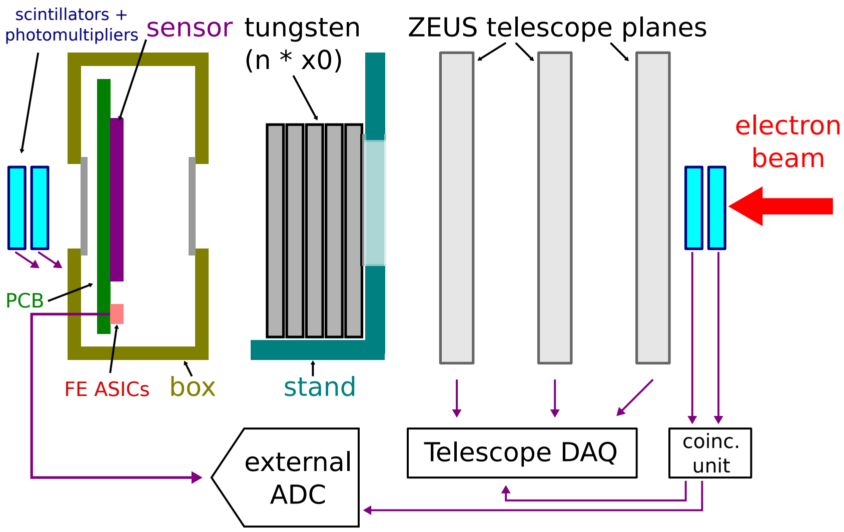

Figure 2: Experimental setup used during beam test measurements.

Dedicated PCB comprising:

- one tail of silicon sensor comprising 256 pads (16 are connected to readout chips),
- kapton fanout providing connection between sensor and front-end electronic,
- front-end ASICs [6],
- power supply and biasing circuits,
- line drivers

was developed, produced and mounted within box. Analogue signals were driven out of the box and sent to an external sampling ADC (v1724, 14 bit, 100 Msps) provided by CAEN. Movable X-Y table was used to precisely position DUT box with respect to the beam line. Three scintillators followed by photomultiplers working in coincidence were providing trigger for both: ZEUS telescope and LumiCal data acquisition systems (DAQ). A veto scheme (through BUSY signal) was used to ensure that both DAQ acquire the same number of events. The event building was done off-line. An additional stand was foreseen to allow adding up to several tungsten layers for studing response of the readout chain to electromagnetic shower. The electron beam energy was set to 4.5 GeV.

Figure 3: Photograph of experimental setup.

3 Results

3.1 Check of the full readout chain

The examples of time response of single front-end channel for different energy depositions are shown in Figure 4 (left). As was expected the shape does not depend on amplitude. The energy distribution in single channel for 4.5 GeV electrons is illustrated in Figure 4 (right). It fits well the Landau distribution for all pads. Set of such spectrum's were used to find readout chain gain (see tab 1). The difference in gain between the first and the last four channels is due to different design of those channels [6]. Spread of gain for the same channel type is below 1 %. The signal to noise ratio is around 18 even for the largest sensor capacitance.

3.2 Crosstalk

In each multi channel design it is very important to ensure a good channel to channel separation. Figure 5 (top) presents the response of 8 channels under test to particle passing through the sensor pad in the centre of instrumented area. In channel four the signal corresponding to approximately 10 MIPs was present. The zoomed baselines of closest neighbours are presented on bottom plot. As one can see there is no visible crosstalk. Detailed studies showed that crosstalk is below 1%.

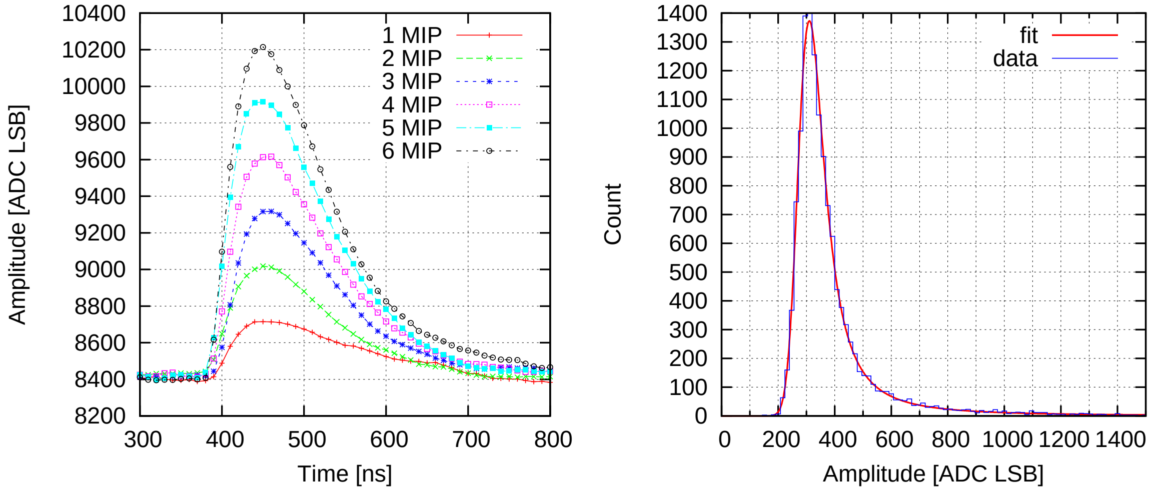

Figure 4: Time response for different energy depositions (left) and energy deposition distribution in single channel (right).

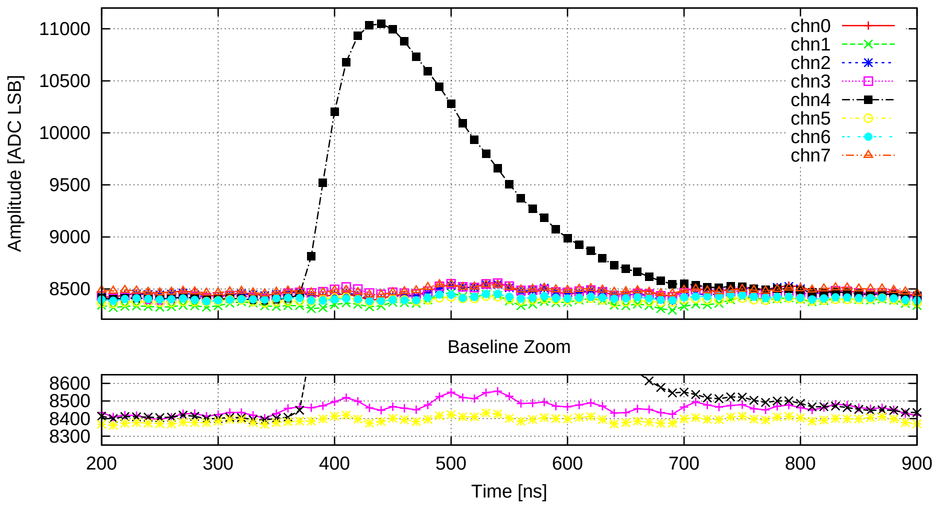

Figure 5: Response of 8 channels under test to particle passing through channel 4 (top) and baseline zoom of neighbours channels (bottom)

Table 1: Gain and SNR for different channels.

pad	Gain [ADC LSB / MIP]	SNR
0	588.7	17.7
1	586.9	18.8
2	588.4	18.7
3	587.5	18.7
4	300.5	18.0
5	303.8	17.8
6	302.4	17.5
7	303.6	17.5

3.3 Position reconstruction

The Zeus telescope was used to obtain information about hit position in the sensor under test. In Figure 6 one can see the combined information from LumiCal DAQ and telescope DAQ. Coloured dot at the position returned by telescope is placed when there is signal present in given electronic channel. As one can see the structure of LumiCal sensor, ploted in black, is reflected in the reconstructed data.

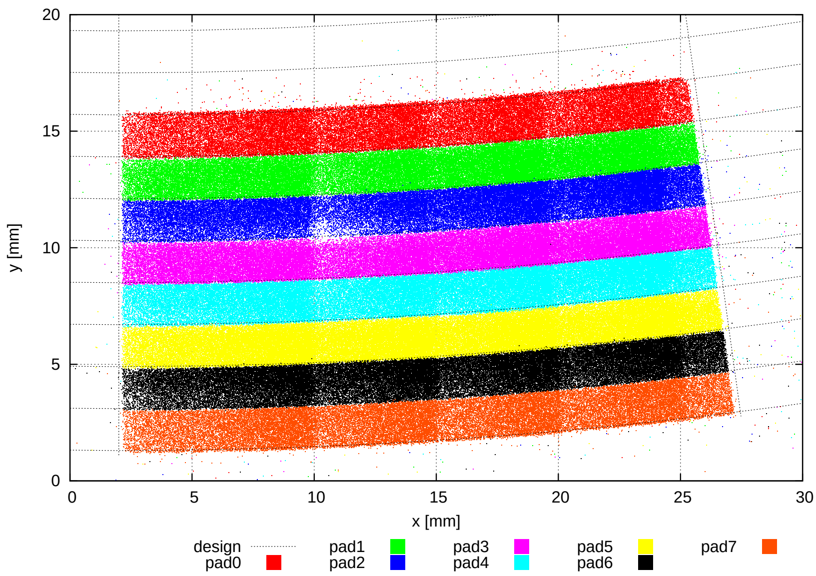

Figure 6: Reconstructed position of beam particle impact point combined with signals registered in LumiCal sensor pads.

3.4 Response of sensors to electromagnetic shower

During the beam test the response of readout chain to electromagnetic shower was studied. Figure 7 shows the histogram of energy deposition in the whole instrumented area (8 sensor pads) under the 2 X_0 (left) and 4 X_0 (right) tungsten absorber. The measurement results (red) were compared with prediction of GEANT4 Monte Carlo simulations (blue) where the experimental setup was implemented. A good agreement was found between them.

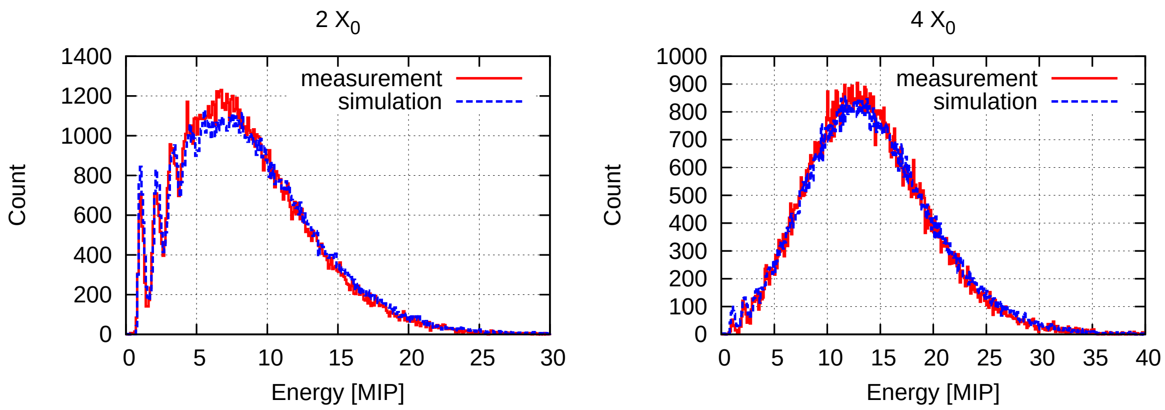

Figure 7: Energy deposition in instrumented area under the 2 X_0 (left) 4 X_0 (right)

The average charge deposited in instrumented area as a function of tungsten thickness is shown in Figure 8. The reasonable agreement with Monte Carlo was found.

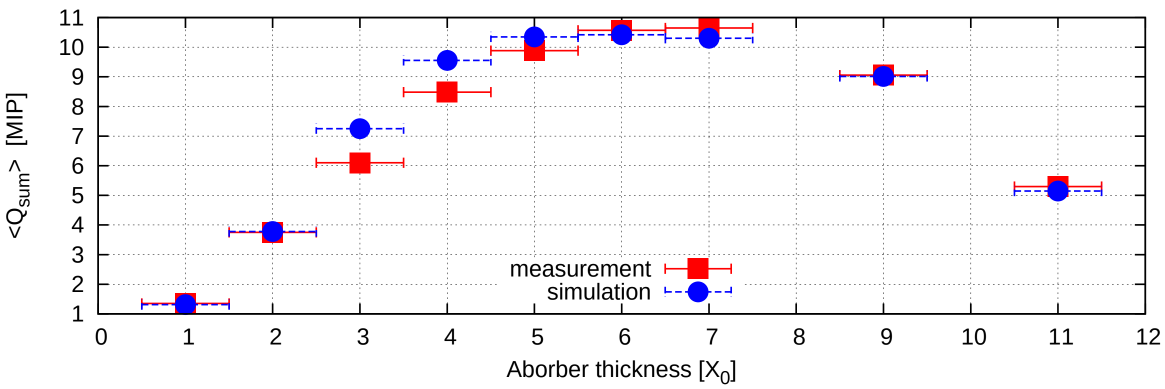

Figure 8: Average charge deposited in instrumented area as a function of tungsten thickness.

4 Conclusions

The first tests performed at 4.5 GeV electron beam at DESY allowed verification of the response of full readout chain to charged particles. The obtained results indicate a good working performance of all components(silicon sensors, kapton fanout and front-end electronics) and match the expectations. Test beam measurements allowed also the studies of shower development studies using tungsten as an absorber. More beam tests with extended readout system will be done in near feature.

Acknowledgements

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