Proceedings of the XIX Workshop of the Collaboration on Forward Calorimetry (FCAL) at Future Linear Collider

13 - 15 September 2011
Vinča Institute of Nuclear Sciences
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Editor
Ivanka Božović – Jelisavčić

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Preface

Vinča Institute of Nuclear Sciences from Belgrade, Serbia is proud to host for the second time the Workshop of the Collaboration on Forward Calorimetry (FCAL) at future linear collider. Already the fact that this is the nineteenth meeting in the series of traditional workshops illustrates the continuous effort of the international community not only to instrument the forward region of the future linear collider to meet the requirements from physics, but also to improve the understanding of physics and machine related processes ongoing at the very low polar angles.

From an editor's point of view this Workshop was particularly interesting for bringing up an abundance of the test-beam results on performance of sensors for the forward region calorimeters tested for the first time as an integrated structure with the front-end electronics. In the scope of simulation studies a novel perspective on beam-related effects in the integral luminosity measurement at future linear collider was presented. Overall fifteen contributions are given in the course of the Workshop.

This meeting was supported by the Ministry of Education and Science of the Republic of Serbia as well as through the project OI171012 being realized at the Vinca Institute of Nuclear Sciences.

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REPORT ON FCAL COLLABORATION TESTBEAM

By

Sz. KULIS[1]*, A. MATOGA[1], J. AGUILAR[1,2], I. LEVY[3], L. ZAWIEJSKI[2], E. KIELAR[2], O. NOVGORODOVA[4], H. HENSCHEL[4], I. SMILJANIĆ[5], W. WIERBA[2], J. KOTULA[2], A. MOSZCZYNSKI[2], K. OLIWA[2] AND W. DANILUK[2]

(1) University of Science and Technology, AGH, Cracow, Poland

(2) Institute of Nuclear Physics, PAN, Cracow, Poland

(3) Tel-Aviv University, YAU, Tel-Aviv, Israel

(4) Deutsches Elekronen-Synchrotron, DESY, Zeuthen, Germany

(5) Vinča Institute of Nuclear Sciences, Belgrade, Serbia

A prototype of a LumiCal sensor module was designed and successfully tested on the 4.5 GeV electron beam (DESY II,Hamburg). Full chain is composed of silicon sensor, kapton fan-out, dedicated front-end and ADC ASICs and FPGA based data concentrator. Some very preliminary results, confirming proper system operation, are presented and discussed.

Key words: Detector module, silicon sensor, front-end, ADC, FPGA, DAQ, testbeam.

INTRODUCTION

The precise measurement of the luminosity at future linear colliders will be done by special detector, LumiCal, placed in very forward region[1]. A design studies are being performed for International Linear Collider (ILC) [2] and Compact Linear Collider (CLIC) [3]. The complete Lumical [4] detector contains two electromagnetic calorimeters placed on both side of the interaction point. The single calorimeter contains 30/40 (ILC/CLIC) layers of tungsten absorber interspersed with silicon sensor planes. The sensor layers are segmented radially and azimuthally into pads of different sizes. Signals from sensor are amplified, shaped and digitized in dedicated, fast and low-noise readout electronic. A most recent design of the LumiCal internal structure was included in [5].

The readout concept for each experiment is different, mostly due to different beam structure. In ILC bunch crossing will happen every 330 ns, giving a plenty of time for processing each event separately. Signal from the event is amplified by charge sensitive preamplifier and processed by fast CR-RC shaper (60 ns peaking time) and one ADC conversion is done for pulse maximum. In CLIC period between subsequent bunch crossings is at 0.5 ns level, resulting beam being almost continuous from electronic point of view. An attractive readout scheme for such environments may be to use only one analog processing chain with a relatively fast Analog to Digital Converter (ADC) incorporated in each channel. Taking an advantage of having digital samples, one may think about variety of algorithms to extract information about time and amplitude of events which can not easily be applied using analog technology [6].

To verify proposed readout scheme a test beam measurements took a place in July 2011 in Deutsches Elektronen-Synchrotron Research Centre (DESY) Hamburg. Complete multichannel detector module is comprised of silicon sensors, kapton fanout, front-end ASICs (32 channels) multichannel ADC SoC ASICs (32 channels), data concentrator implemented in Field Programmable Gate Array (FPGA) as well as a digitally controlled and monitored biasing and powering circuits.

The paper is organized in two parts. In the first part the experimental setup and design of prototype module are presented. The second part discusses the preliminary results of measurements. Finally, brief conclusions and plans for future work are given.

EXPERIMENTAL SETUP

The beam test measurements took place in the July 2011 at DESY-II area 22 [9]. A bremsstrahlung beam was generated by a carbon fibre in the circulating beam of the electron/positron synchrotron DESY II. The photons were converted to electron/positron pairs with a metal plate (converter). Then the beam was spread out with a dipole magnet. The final electron beam is cut out with a collimator. For presented below measurements, electrons with 4.5 GeV energy were picked up. Schematic diagram of experimental setup is presented in fig. 1.

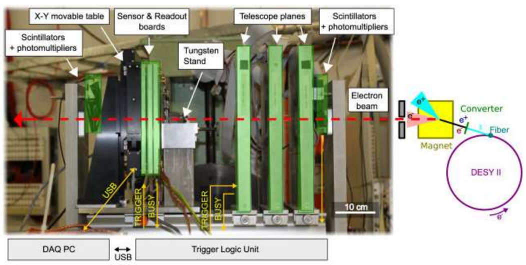


Figure 1. Schematic diagram of experimental setup.

The track of each beam particle was measured by the MVD ZEUS telescope. It consists of three planes. Each plane contains two perpendicular silicon strip detectors. Combining signals from both sensors x, y impact position may be found. Using information form all planes impact position on device under test (DUT) plane may be predicted [10].

The DUT was mounted on remotely controlled, motorized X-Y translation stage. It allowed to change electron impact point on sensor plane.

Trigger signal for all subdetectors (MVD telescope, DUT) was generated by Trigger Logic Unit (TLU) [13] based on signals from three scintillators (two in front of telescope and one after DUT) followed by photomultipliers. The EUDAQ portable DAQ Software framework [12] was used for data taking and event building.

READOUT SYSTEM

The block diagram of developed detector module [8] prototype is presented in fig. 2. The module is composed of two Printed Circuit Boards (PCB), namely sensor and readout boards. Splitting module allows different kinds of sensors to be connected to one readout. Kapton fanout is glued on top of sensor and signal tracks are wire bonded to it. A second end of kapton tracks are wire bonded to PCB and then routed to multiway connector.

Only 32 biggest pads, on top of sensor tail, are read out by front-end electronics, while the rest of pads are grounded. The signal is amplified and shaped using dedicated front-end ASICs [11], and digitized in pipeline ADC chips, working continuously with sampling rate of 20 Msps. The data stream leaving the ADC is continuously written into a buffer inside FPGA.When the trigger occurs, the microcontroller firmware builds event packet and transmits it to PC. Currently Universal Serial Bus (USB) is used as a communication interface. However module is foreseen to support interface to Link Data Agregator (LDA) which suppose to be a common part for all ILC subdetectos [7].

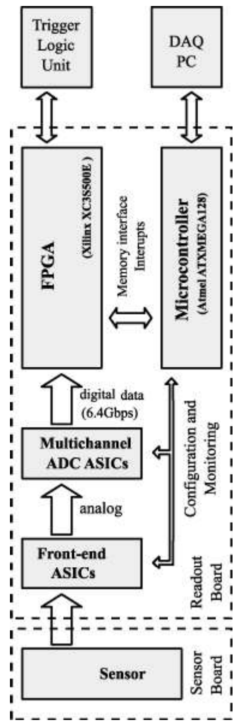


Figure 2. Readout system block diagram.

MEASUREMENTS RESULTS

To evaluate system performance a set of measurements was taken. During testbeam system was working asynchronously with beam. To recover information about event's amplitude a deconvolution method was applied [6]. Example spectrum of energy deposited in one pad is presented in fig. 3. Measured data points (in red) fit very well to Landau convoluted with Gauss distribution (blue). Signal to noise ratio (SNR), calculated as mean probable value (MPV) of Landau distribution to RMS of baseline, was find to be grater than 20 for each channel.

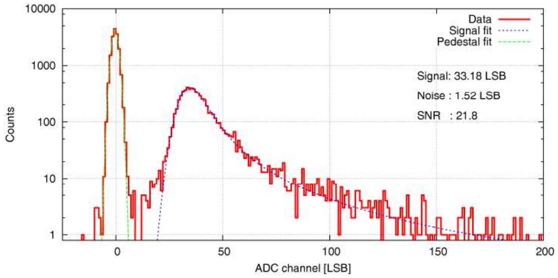


Figure 3. Energy deposition spectrum for single electron events collected from one channel.

In the next step response of detector to electromagnetic shower was studied. Figure 4 shows the histogram of energy deposited in the whole instrumented area (signal integrated over 32 pads) after passing through one 3.5 mm thick tungsten plate, what corresponds to one radiation length.

In zoomed part of beginning of the spectrum signal corresponding to 1 or 2 electrons can be observed.

Same analyzes were performed for different thickness of tungsten absorber. An average charge deposited in whole instrumented area as a function of tungsten absorber thickness is presented in Figure 5a. Electromagnetic cascade for 4.5 GeV electrons has its maximum after 5 radiation lengths. More detail charge deposition distribution, as a function of lateral shower width and absorber thickness is shown in fig. 5b. More detailed analyzes as well as Monte Carlo simulations of described system are being performed right now.

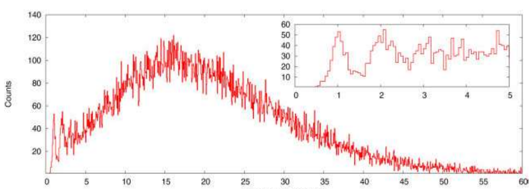
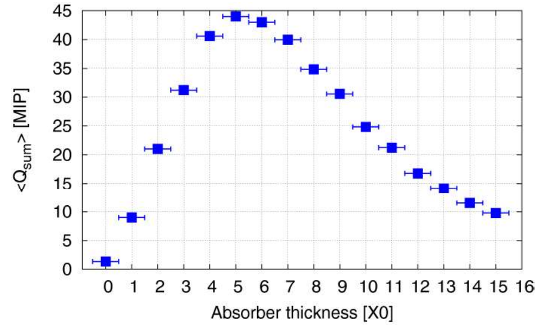


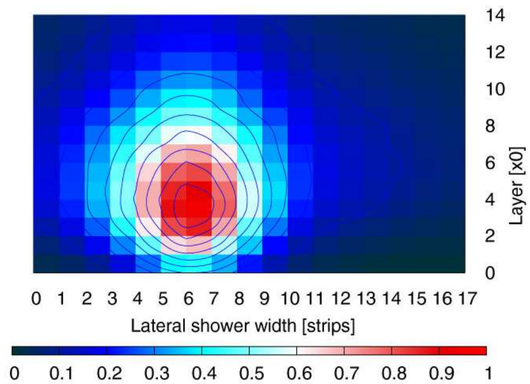
Figure 4. Integrated energy depositied on whole instrumented area with one tungsten plate in front of sensor plane.

SUMMARY & FUTURE WORK

The set of measurements, performed at electron beam at DESY, confirmed proper operation of fully assembled detector module. The obtained results indicate a good working performance of all components, namely: silicon sensors, kapton fanout and front-end, analog to digital converter as well as data concentrator unit. Test beam measurements allowed also the studies of shower development using tungsten as an absorber. The developed multichannel readout system will be extensively used in test beams and laboratory studies of ILC/CLIC readout schemes. It should be integrated to Common DAQ.



(a)



(b)

Figure 5. (a) Average charge deposited in whole instrumented area as a function of tungsten absorber thickness; (b) Energy deposited in one sensor strip for different tungsten absorber thickness normalized to maximum deposition .

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