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VFCAL Annaul Report 2010

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Abstract

The last deliverable of VFCAL, the VFCAL electronics, has been completed in 2010 with several technological improvements. For the first time several components, most of them developed within EUDET partners, have been combined to form an assembled sensor plane. Using the infrastructure built within EUDET the device has been studied in a test-beam at DESY. Preliminary results are reported here.

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1 Introduction

The objective of VFCAL is the development of the infrastructure to investigate several promising technologies for two special calorimeters, BeamCal and LumiCal, in the very forward region of a future collider detector. These calorimeters must be compact, precisely positioned and readout very fast. The major topic in 2010 was the completion of the readout electronics design, production and test. The test results in the laboratories were successful. In particular a redesigned ADC ASIC with several technological improvements was produced and successfully tested in the laboratory. Essential parameters like integral and differential nonlinearities match the requirements. Sensor prototypes made of silicon for LumiCal and GaAs for BeamCal have been tested in the laboratory and in particle beams in prvious years using the infrastructure supported by EUDET. Then, in spring 2010, these sensors were assembled with front-end ASICs and investigated first in the laboratory and in August 2010 in a particle beam at DESY. Here results from the test of the ADC ASICs and from the investigation of an assembled sensor plane are reported.

2 Read-out Electronics

The block diagram of the LumiCal readout scheme is shown in figure 1. Prototypes of

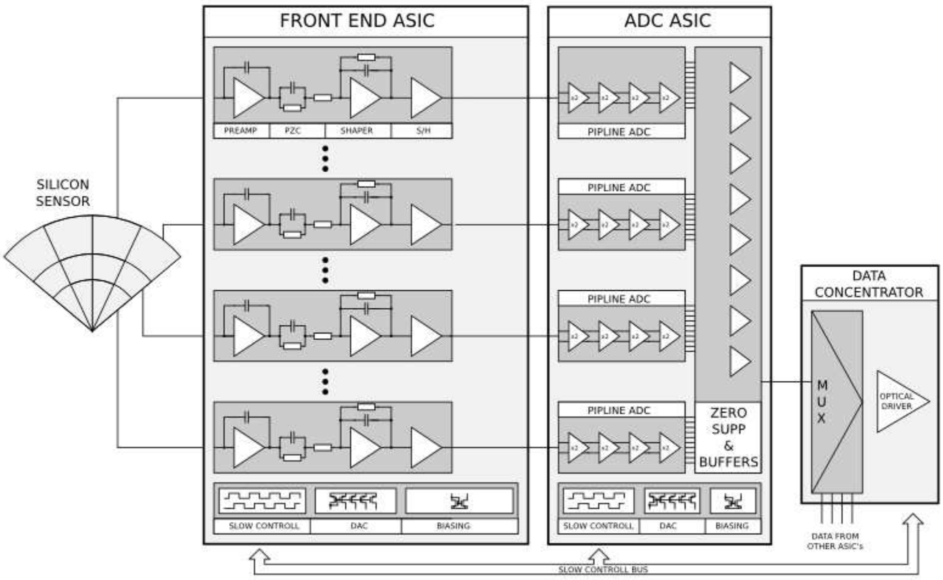

Figure 1: Block diagram of LumiCal readout electronics

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front-end ASICs and single channel version of the ADC were already designed, produced and tested in previous years. The main effort in 2010 was aimed to following issues:

- Complete the characterization of a single channel 10 bit pipeline ADC

- Design and first prototyping of a multichannel 10 bit pipeline ADC

2.1 Characterization of a Single Channel ADC

The prototypes of a single channel 10 bit ADC were produced already in 2009 and partially tested. In 2010 the studies were concentrated on:

- The power consumption as a function of the sampling frequency and the supply voltage.
- Characterization of the static performance, i.e., the measurements of integral (INL) and differential (DNL) nonlinearities.
- Characterization of ADC dynamic performance, i.e., the measurements of signal to noise ratio (SNHR and SINAD) and harmonic distortions (THD)
- Studies of the fast powering on/off feature.

All parameters mentioned above were measured and found to be in agreement with expectations from simulations. The complete discussion of the results can be found in Ref. [1]. The list of the key parameters obtained is shown in table 1. The possibility of switching off the power lowers drastically the average power consumption in applications with long idle times. For standard ILC beam conditions it allows to decrease the average power consumption down to about 15μW.

Table 1: ADC measured parameters

architecture	10-bit pipeline
technology	0.35 μm CMOS
sampling rate range	1 kS/s–25 MS/s
input range	2 V_{pp}
power consumption	~0.85 mW/MS/s, 3 V_{supp} (~0.6 mW/MS/s, 2.6 V_{supp})
area	0.87 mm^2
linearity	INL $<$ 1 LSB, DNL $<$ 0.5 LSB
SINAD	56–58.5 dB
ENOB	9.3 bit
time of switching OFF/ON	~3 μs

2.2 Development of the multichannel ADC

Since the single channel ADC fulfilled the requirements the design of a multichannel version was done in 2010. In the first version 8 channels of the above described single channel version was layout in the prototype ASIC. Because of various settings and control signals needed, a number of new functionalities and technological improvements have been implemented in the multichannel ADC version. The submitted prototype ASIC contains:

- 8 channels of the core pipeline 10 bit ADC.
- Digital multiplexer/serializer providing different modes of operation. In the Serial mode, which is the ILC baseline mode, one data link is used for output of all ADC channels, allowing a maximum ADC sampling frequency up to about 4 MSps. In the Parallel mode one data link serves per each channel, allowing a maximum sampling frequency of about 25 MSps. In the Test mode a single channel is readout through 10 parallel output lines.
- High speed LVDS drivers (1GHz) with variable power consumption
- Low power DAC control references for various settings of ADC biasing currents and voltages.
- Precise Band-Gap reference source.
- Temperature sensor.

The layout of the prototype ASIC is shown in figure 2.

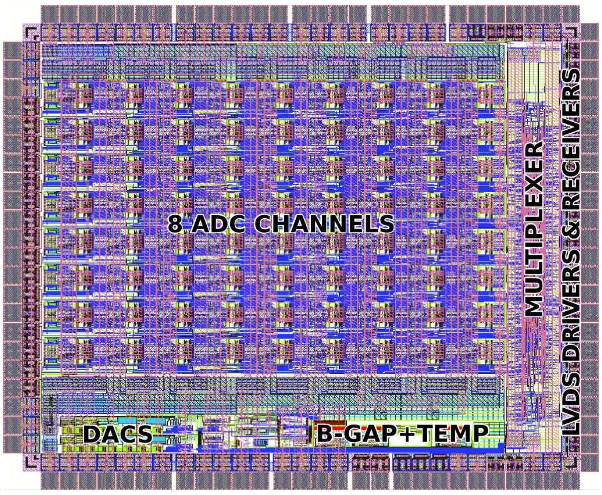

Figure 2: Layout of multichannel ADC.

The tests of the multichannel ADC prototype have been started. Preliminary measurements confirm the expected ASIC functionality. In figure 3 measurements of the FFT spectrum (top) and dynamic parameters (bottom) as a function of the sampling frequency obtained in the test mode are shown. It is seen that the multichannel version works well up to about 45 MHz, which is substantially higher than for previous, single channel version. The measurements are just ongoing and more results will be available soon.

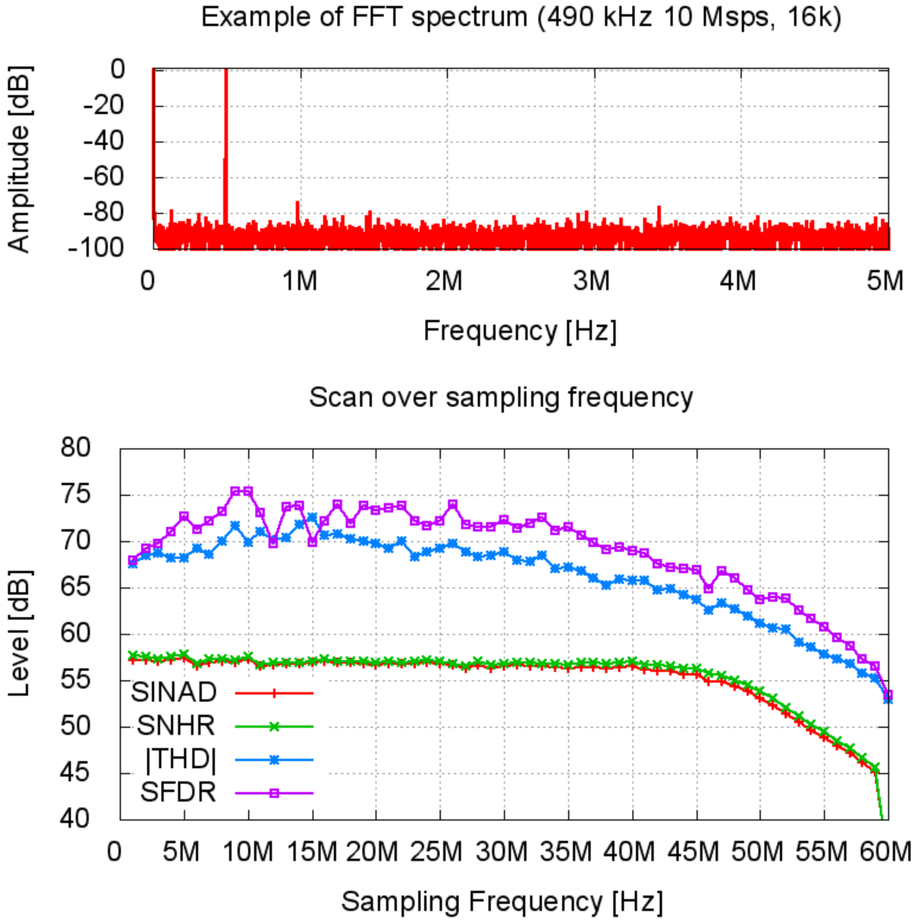

Figure 3: Example of dynamic ADC measurements: FFT spectrum (top), dynamic parameters vs sampling frequency (bottom)

3 Assembled Sensor Plane Tests

Using sensor prototypes made of silicon and GaAs, as shown in figure 4 for LumiCal and BeamCal, respectively, sensor plane prototypes have been assembled with front-end ASICs. These sensors were supported by a PCB. Groups of 8 strips and pads of several areas of the sensor were interconnected via wire-bonds to 8-channel front-end ASICs. After amplification and shaping signals were driven to V1724 (14 bit, 100 Ms/s) and V1721 (8 bit, 500 Ms/s) Flash-ADCs in a VME Crate. The sensors were positioned in a 4.5 GeV electron beam using a movable x-y table. Beam particles were triggered by three scintillator counters and precisely measured by three planes of silicon strip detectors, two upstream and one downstream of the sensor under test, as shown in figure 5. The sensor planes were moved in several positions to record data from particles crossing different pads and in particular also from particles crossing the areas between the pads and the edges of the planes. Within a few days several million trigger have been collected. In a few runs tungsten absorber plates of different thickness were positioned in front of the

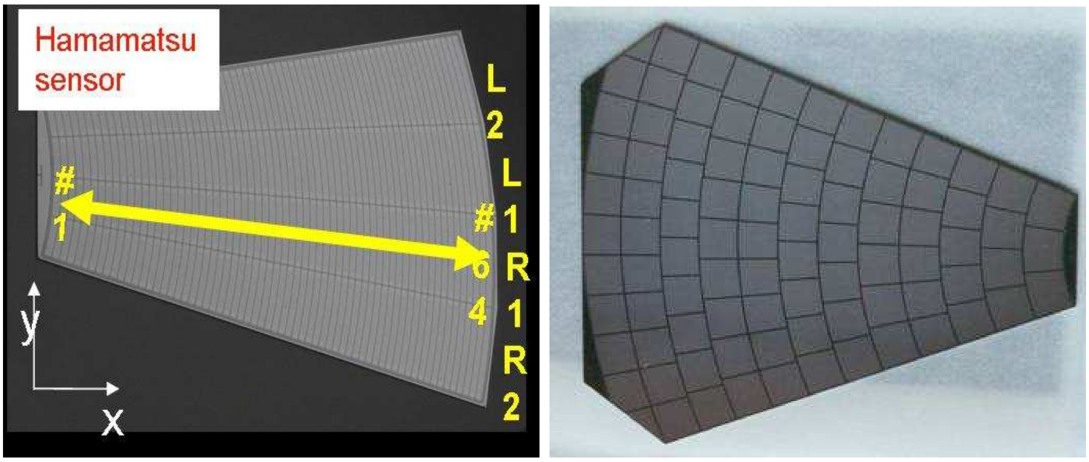

Figure 4: Prototype of silicon sensor (left) and a GaAs sensor (right)

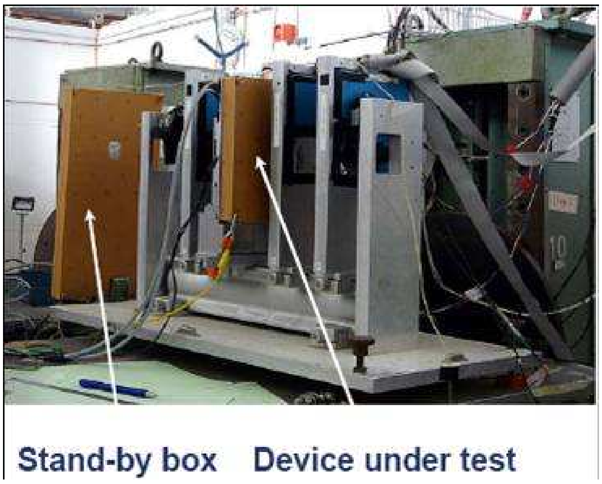

Figure 5: The setup used for the beam-test. The three planes of silicon strip detectors are inside the aluminum frames. The sensor plane under test is mounted inside the copper-colored PCB box between the second and third aluminum frame.

silicon sensor plane in order to measure particle showers.

3.1 Preliminary Results

Two examples of signal spectra from single beam particles are shown in figure 6. The spectra follow nicely the Landau distribution of energy loss. The signal-to-noise values are around 18 for LumiCal and around 15 for BeamCal. The channel-by-channel differences in the amplification are below 1%. Also the cross-talk between channels is less than 1%.
Using the telescope the impact point of the beam-particle on the sensor is predicted. The signal of the pad hit by the particle is measured, and if it was found above the

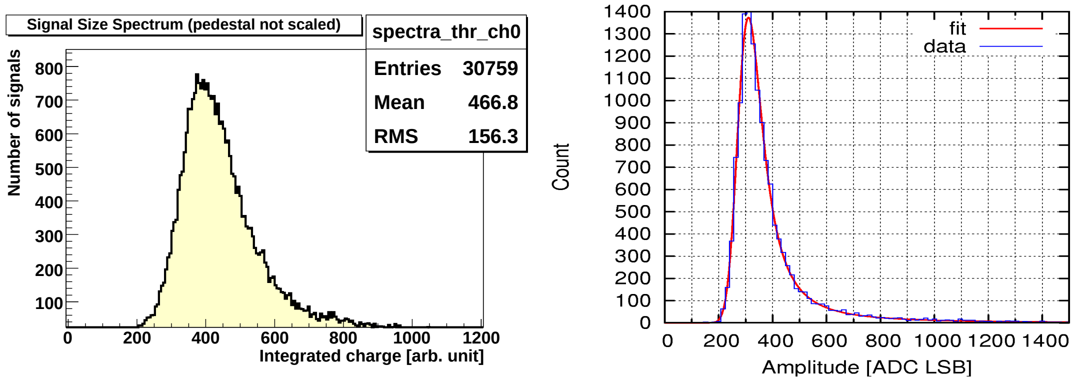

Figure 6: Examples for signal spectra obtained from the sensor plane prototypes of BeamCal (left) and LumiCal (right)

pedestal, the impact point coordinates are fed into two-dimensional histograms, as shown in figure 7. The structure of the pads on the sensors, indicated by different colors, becomes clearly visible.

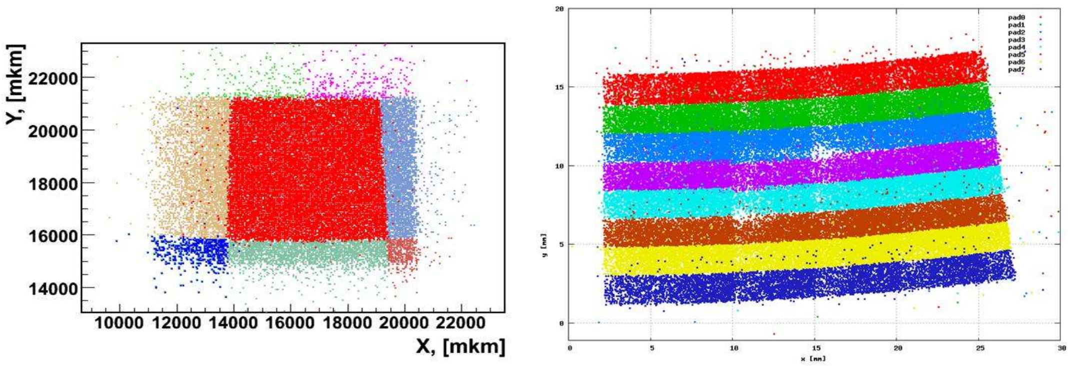

Figure 7: The distribution of impact point of beam particles on the sensors for BeamCal (left) and LumiCal (right). Colors are assigned when the signal on the pad hit is above the pedestal.

Data were also taken with a few radiation length of tungsten in front of the LumiCal sensor plane to record shower particles. Both the distribution of the measured deposited energies and the average deposited energy as a function of the tungsten thickness are well reproduced by GEANT4 simulations of the set-up.
Just now the test-beam data analysis is still ongoing. More refined results will be available soon.

4 Publications

Eudet memos have been published in 2010 on the new mechanics design of LumiCal [2], an improved design of the laser alignment system for LumiCal [3], and on preliminary test-beam results [4]. Talks have been given in several instrumentation conferences and collider workshops, e.g. Ref. [5]. In addition, a summary of the R&D results has been published in JINST [6].

5 Conclusion

The last deliverable of the VFCAL topic, the multichannel ADC ASIC, was successfully produced in 2010 with several technological improvements. Tests performed in the laboratory have shown that it matches the necessary performance parameters. In parallel, the front-end ASICs produced in 2009 were interconnected to sensor prototypes and the system was studied in a particle beam. Preliminary results from test-beam data are very satisfactory.

Acknowledgment

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