Test Beam Studies Of 50μm LGAD sensors.

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Abstract

The high luminosity upgrade of the Large Hadron Collider (HL-LHC) at CERN is expected to provide instantaneous luminosities of 5×10^{34} cm^{-2} s^{-1}. The high luminosities expected at the HL-LHC will be accompanied by a factor of 5 to 10 more pileup compared with LHC conditions in 2015, further increasing the challenge for particle identification and event reconstruction. Precision timing allows to extend calorimetric measurements into such a high density environment by subtracting the energy deposits from pileup interactions. Calorimeters employing silicon as the active component have recently become a viable choice for the HL-LHC and future collider experiments which face very high radiation environments. In this article, we present studies of basic calorimetric and precision timing measurements using a prototype composed of tungsten absorber and silicon sensor as the active medium. We show that for the bulk of electromagnetic showers induced by electrons in the range of 20 GeV to 30 GeV, we can achieve time resolutions better than 25 ps per single pad sensor.

Key words:
Silicon, Timing, LGAD

1. Introduction

2. Test-beam Setup and Experimental Apparatus

We performed the test-beam measurements at the Fermilab Test-beam Facility (FTBF) which provided a proton beam from the Fermilab Main Injector accelerator at 120 GeV. The Devices Under Test (DUT) were mounted on a remotely operated motorized stage, placed inside the pixel telescope detector [1] which provides better than 10 μm position

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resolution for the particles impinging on the DUT. Finally, a Photek 240 micro-channel plate photomultiplier detector [2–5] is placed furthest downstream, and serves to provide a very precise reference timestamp. Its precision was previously measured to be less than 10 psec [4]. A photograph of the experimental area is shown in Fig. 1.

The DAQ system for the DUTs and the Photek MCP-PMT is based on a CAEN V1742 digitizer board [6], which provides digitized waveforms sampled at 5 GS/s, and one ADC count corresponds to 0.25 mV. The CAEN digitizer is voltage- and time-calibrated using the procedure described in Ref. [7]. The electronic time resolution of the CAEN V1742 digitizer was measured to be $\sim$4 ps, and its impact on the timing measurements presented in this studies can be neglected. The DAQ for the pixel telescope is based on the CAPTAN system developed at Fermilab [1]. The track-reconstruction is performed using the Monicelli software package developed specifically for the testbeam application.

The beam is resonantly extracted in a slow spill for each Main Injector cycle delivering a single 4.2 sec long spill per minute. The primary beam (bunched at 53 MHz) consists of high energy protons (120 GeV) at variable intensities between 1 and 300 kHz. The trigger to both the CAEN V1742 and to the pixel telescope was provided by a scintillator mounted on a photomultiplier tube, placed upstream of the DUTs in the beam-line. Due to the limited buffer depth of the CAEN V1742 board, special care had to be taken in the design of the DAQ system to ensure that both the DUT and telescope DAQs collect exactly the same amount of triggers. This was achieved by limiting the trigger rate by introducting an adjustable dead-time using a custom-designed FPGA board. We found that at a rate of about 1,500 triggers per spill the CAEN V1742 and pixel telescope were maintained fully synchronized. Processed data from the pixel telescope and the DUTs were merged offline by matching the trigger counters recorded by the two systems.

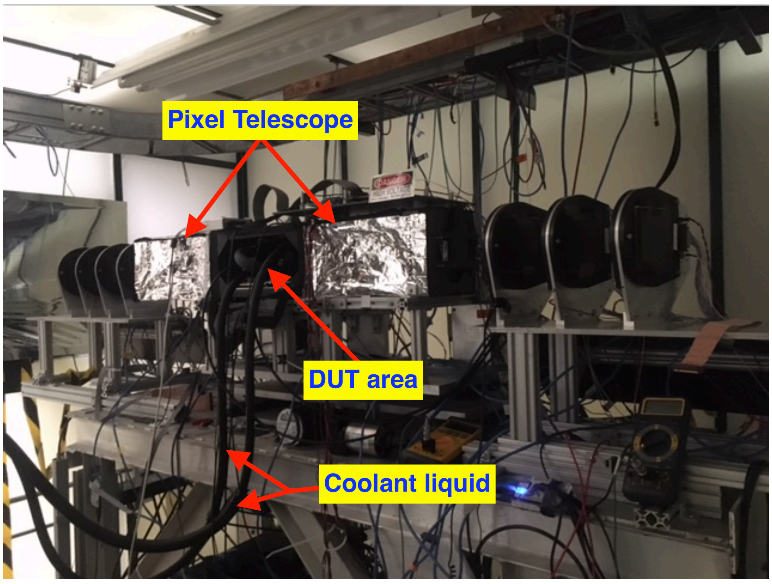

Figure 1: A picture of the experimental area. Thea pixel telescope detectors are placed inside the ESD shielded boxes on the two sides of the DUT area. Cooling liquid for the Peltier elements inside the DUT area is provided by the two pipes shown in the picture.

3. Properties of the tested LGAD sensors

Sensors manufactured by Hamamatsu (HPK) and CNM were tested during the test beam experiments. All sensors have active thickness of about 50 μm.

FIXME NICOLO OR HARTMUT: FILL IN DETAILS OF CNM AND HPK SENSORS, PRODUCTION PROCESS ETC Details on CNM sensors can be found in Ref. [8, 9]. Hamamatsu sensors have the following properties...

Sensors in both single- and four-channel configurations were tested during the measurements. The CNM single-channel sensors had an active area of 1 mm^2 **FIXME: IS THIS CORRECT SIZE OF CNM SINGLE CHANNEL SENSORS?**, and the HPK single-channel sensors had a diameter of 1 mm. The dimensions of the four channel sensors from HPK are shown in Fig. 2

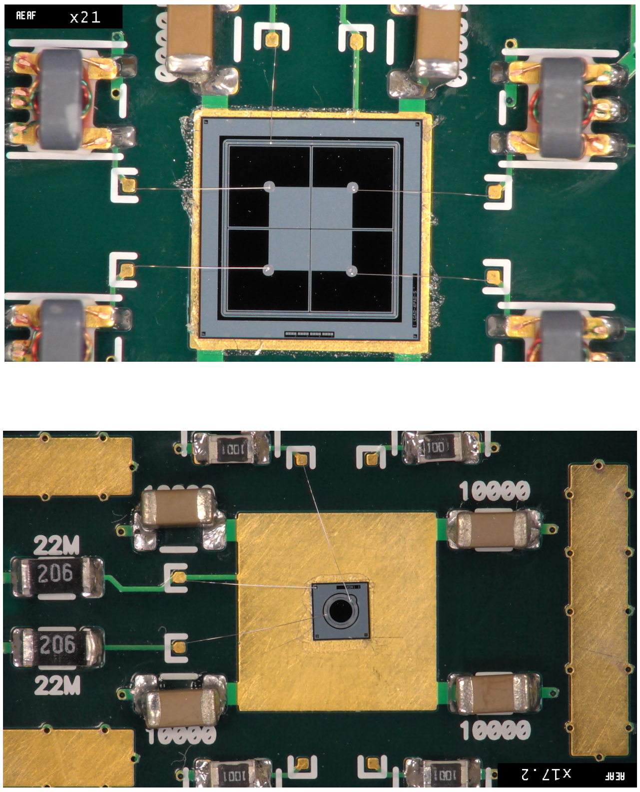

Figure 2: A picture of HPK 50DPix 2x2 array sensor (top), and 50D-GR single sensor (bottom).

4. Read-out boards

Four boards were used in various measurements presented in this paper, which were developed at the University of California Santa Cruz (UCSC), University of Kansas (KU), and at FNAL:

- A single-channel USCS board that was also used in results presented in Ref. [9]
- A four-channel USCS readout board
- A two-channel KU readout board
- A 4-channel FNAL readout board.

and their detailed description is presented below.

5. Study of the uniformity of the LGAD sensors

6. Comparison of the boards

7. Comparison of HPK doping profiles

8. Comparison of HPK 50 μm with 80 μm

9. Temperature dependence of the LGAD sensors

10. Radiation tolerance of the LGADs up to 6×10^{14}

11. Conclusion

All is good!

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