

1 Test Beam Studies Of $50\mu\text{m}$ LGAD sensors.

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12 **Abstract**

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

26 *Key words:*

27 Silicon, Timing, LGAD

28 **1. Introduction**

29 **2. Test-beam Setup and Experimental Apparatus**

30 We performed the test-beam measurements at the Fermilab Test-beam Facility (FTBF)
31 which provided a proton beam from the Fermilab Main Injector accelerator at 120 GeV.
32 The Devices Under Test (DUT) were mounted on a remotely operated motorized stage,
33 placed inside the pixel telescope detector [1] which provides better than $10 \mu\text{m}$ 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 ~ 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 introducing 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.

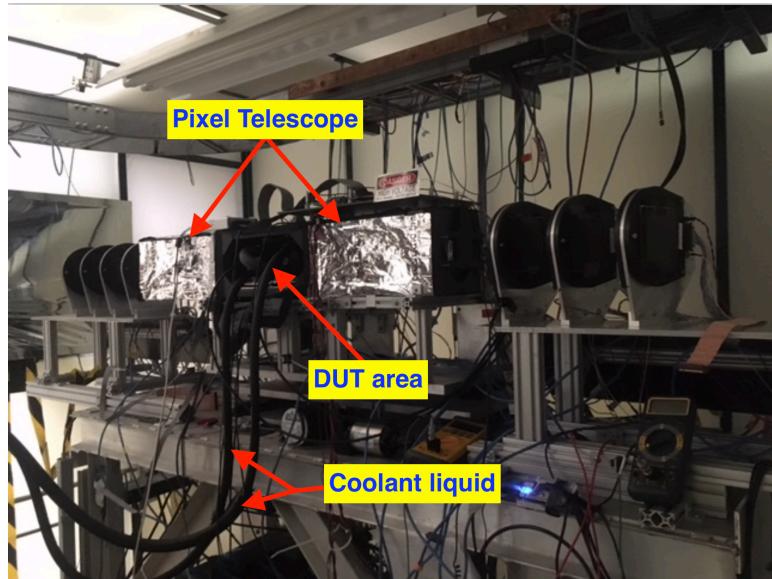


Figure 1: A picture of the experimental area. The pixel telescope detectors are placed inside the ESD shielded boxes on the two sides of the DUT area. Cooling liquid for the Peltier elements inside the DUT area is provided by the two pipes shown in the picture.

58 **3. Properties of the tested LGAD sensors**

59 Sensors manufactured by Hamamatsu (HPK) and CNM were tested during the test
60 beam experiments. All sensors have active thickness of about $50 \mu\text{m}$.

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

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

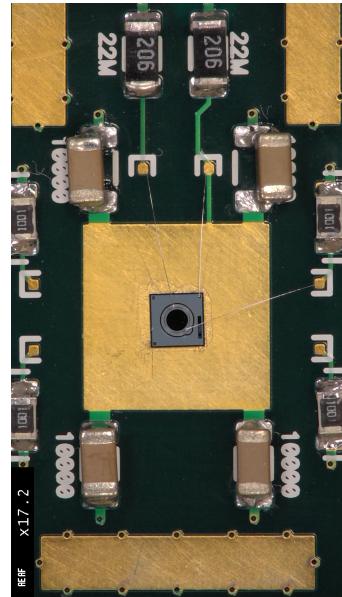


Figure 2: A picture of HPK and CNM sensors.

69 **4. Read-out boards**

70 **5. Study of the uniformity of the LGAD sensors**

71 **6. Comparison of the boards**

72 **7. Comparison of HPK doping profiles**

73 **8. Comparison of HPK 50 μm with 80 μm**

74 **9. Temperature dependence of the LGAD sensors**

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

76 **11. Conclusion**

77 All is good!

78 **References**

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