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Pixel Telescope to test pixel Phase II ROCs and sensors

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[†]A footnote may follow.

1. Introduction

The innermost layer of the CMS Detector at the LHC is the silicon pixel tracker. The current version of the detector has performed well and been critical to the physics program of CMS. The HL-LHC Upgrade of CMS will replace the entire silicon tracking system. As part of this upgrade, a proposed new section of the pixel tracker will be added in the so-called "very-forward" ($\eta \sim 4$) region of the detector. Because the particles in this region are traveling almost parallel to the magnetic field of the detector, enhanced ϕ sensitivity is required to accurately measure track curvature, a critical measurement for finding particle momentum and charge. Therefore, the proposed detector will reshape the standard 100×150μm pixels to be more sensitive in ϕ, sacrificing precision in ρ. A telescope is being developed for the express purpose of characterizing different pixel geometries. The telescope operates by using eight layers of silicon-strip sensors, with the device-under-test placed with four on each side. A beam of mimumum-ionizing charged particles is directed so it passes through both the strip sensors and the the prototype pixel sensors. Measurements from the telescope are taken to reconstruct individual particle tracks. These tracks are then compared to data collected from the pixel sensor to characterize its performance.

2. Projected Performance

The performance of the telescope can be quantified in two ways. First, the precision with which individual particle trajectories can be measured, and second, the rate at which data can be collected.

The measurment precision of particle tracks depends on the number of detector layers and the single hit precision. The telescope consists of eight silicon-strip-sensor layers with strip-widths of 25μm. For strip-sensors with charge sharing the single hit precision can be approximated by the strip-width divided by the signal-to-noise ratio (SNR) of the readout system. The expected SNR of the telescope is 25. This yields a single-hit precision of $\approx$ 1μm. This single-hit precision combined with two measurements in each dimension on each side of the prototype sensor should give sub-micron track localization at the point of impact with the prototype sensor.

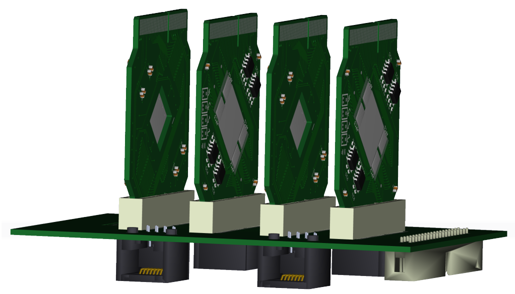
The data collection rate for the telescope is primarily limited by the speed sample data can be transferred from the readout chips to the data acquisition (DAQ) board. This is because many typical test-beam facilities have beam rates on the order of MHz while the telescope can only be triggered at $\approx$ 15kHz. The trigger rate can be improved somewhat by optimizing the readout electronics using well established techniques such as the placement of buffer amplifiers near the readout chips to reduce the RC time constant of the cables running from the readout chips to the DAQ board, as well as making use of differential signaling on these same cables to reduce electromagnetic interference. It is because of this limitation that the decision was made to readout every readout chip in parallel, in contrast with previous incarnations of this telescope which serialized sixteen readout chips.

3. Technical Description

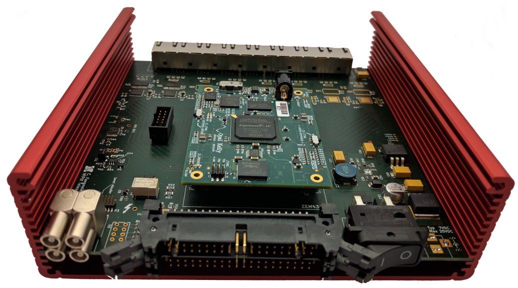
What follows is a a description of the hardware of the telescope and a high-level overview of the readout scheme.

3.1 Hardware

The telescope has been built up around the choice of sensor and accompaning readout chip, both of which were originally developed for the H1 vertex detector at HERA[**?**]. The strip sensor contains 512 strips with 25μm strip-width. The readout chip is the Analog Pipeline Chip - 128 (APC). Each APC can read 128 strips so four are required to read a single strip sensor. The APC operates an integrating pre-amplifier that collects charge from the a sensor strip and keeps a 32 sample history of the output of that pre-amplifier. When a trigger is received from, for example, a scintillation detector, the appropriate sample is chosen from the 32 based on the calibrated trigger latency and the samples from all 128 channels of the APC are serialized to its output.



(a) A rendering of the telescope "motherboard" showing four "sensor-cards" each of which holds a single strip-sensor. The control signals needed by the readout chip are supplied by a 40-pin header (bottom-right). The data readout happens over four RJ-45 connectors, into which CAT-5 cables are plugged to transmit the signals to the DAQ board.



(b) An image of the data acquisition (DAQ) board featuring an 8xRJ-45 connector (back) to receive data from two connected motherboards, a 2×40-pin header (front) for supplying control signals to the motherboards, and an Opal-Kelly FPGA integration module (center) to orchestrate the operation of the telescope.

Figure 1: The main hardware components of the telescope are the motherboard with associated sensor-cards (a) and the data acquisition board (b)

The strip-sensor along with four APC are mounted onto a "sensor-card" along with four buffer amplifiers that compensate for the relativily weak output of the APC and generate a more robust differential signal with the proper output impedance for driving CAT-5 cables (100Ω). Four sensor-cards are plugged into a motherboard which provides structural support for the sensor-cards and routes electrical signals between the sensor cards and the I/O ports.

3.2 Readout Scheme

The readout scheme has been designed to maximize the data throughput in terms of analog strip-sample values per second. This has been done in an effort to minimize downtime since the APC cannot take data during readout so any data from beam that passes through the telescope during readout is lost. Figure 2 illustrates the readout scheme. Roughly speaking, the readout happens in three stages. The first stage is handled by the electronics in and in the immediate vicinity of the beam. It is there that the passage of a charged particle is converted to an electronic pulse by the strip-sensor and the height of that pulse is recorded by the APC. The APC then serializes pulse heights from many channels to the cables exiting the beam region.

The signals from the

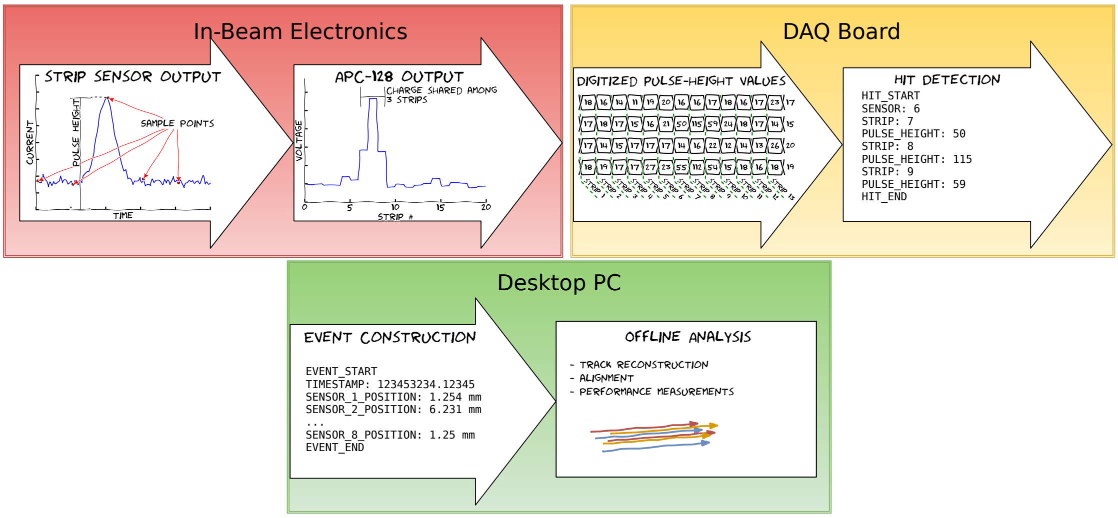


Figure 2: Illustration of the readout scheme of the telescope.

References

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