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Functional Tests of 2S Modules for the CMS Phase-2 Tracker Upgrade with a MicroTCA-Based Readout System

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First full size 2S module prototypes for the CMS Phase-2 Tracker Upgrade have been assembled. With two sensors with realistic geometries and 16 CBC2 readout chips on two front-end hybrids, the characteristics of these complex objects can be studied.
A microTCA based readout system was developed to test multiple front-end hybrids simultaneously. Therefore the concurrent information of the full module can be used for differential and common-mode noise characterization, as well as for signal tests with radioactive sources or cosmic particles.
This talk will discuss the readout system and test results obtained with the first full size 2S module prototypes.

Summary

To prepare the CMS experiment for the High Luminosity LHC and its planned instantaneous luminosity of up to $7.5 \cdot 10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ the CMS Silicon Tracker will be replaced in the Long Shutdown 3.

A new tracker will be constructed using about 13000 conceptually new modules: Two vertically spaced silicon micro-strip sensors are integrated into a single module and read out by the same front-end chip. The displacement of the hits between both sensors - caused by the bending of charged particle tracks within the 3.8 T magnetic field - can be used to infer a lower bound on the transverse momentum of the track in the modules themselves. Therefore all hits from high transverse momentum tracks can fit in the available bandwidth between module and back-end, where they are used in the first trigger stage of CMS.

First full size module prototypes for the outer radii of the CMS Tracker have been assembled. These so-called 2S modules feature two identical stacked 10x10 cm² micro-strip sensors, each with two rows of 1016 strips. The strip length amounts to 5 cm. One row of each sensor is connected to the same front-end hybrid. This allows to process the hit information from one track –hitting both sensors –in one of the eight CMS Binary Chips (CBC2) of each front-end hybrid.

A microTCA based readout system has been used to test these prototypes, since for the first time it is required to read multiple front-end hybrids simultaneously. Multiple GLIB AMCs are connected to the front-end while the fast control signals (clock, reset, trigger) are distributed within the back-plane of a commercial microTCA crate. The readout data is streamed via the IPBUS protocol through the Ethernet fabric in the back-plane as well.

With this system the two front-end hybrids of one module can be operated synchronously and the concurrent hit data of all 4064 channels is available. It allows to study single channel (differential mode) and coherent noise (common mode) in these complex objects. In this context also the susceptibility of the modules to perturbations on low voltage supply rails and electromagnetic emissions are investigated, since each module will be powered by a DC-DC converter pair, placed on the service hybrid in the direct vicinity of the sensors and the front-end hybrids (below 1mm distance).

Readout chip internal test pulses are used for functional tests and charge calibration, which is then cross-checked with X-rays. Beta sources and cosmic muons provide signals with realistic pulse heights within the sensors. They are used to access quantities which are defined by the sensor like cluster width and signal

height. Due to the binary readout scheme the later one is only measurable on a statistical basis as an integrated charge spectrum. Combining these with the noise measurements, first conclusions on the signal-to-noise characteristics of the 2S prototypes on the scale of a full module can be drawn.

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