Contribution ID: **173** Type: **Poster**

LHCb Scintillating Fiber Tracker Front End Electronics Test System

Tuesday, 20 September 2022 16:40 (20 minutes)

LHCb is undergoing a major upgrade to cope with LHC RUN3's increased luminosities and a trigger-less 40 MHz read-out to improve on many world-best physics measurements. A light and homogeneous tracker based on plastic scintillating fibers (SciFi) driven by 524k SiPM channels is being installed downstream of the LHCb dipole magnet. A Test System is in use to ensure the Quality Control of each of the 256 custom-designed and large-scale produced Front-End Boxes used in this new LHCb tracker. Here we describe the design, assembly, and operation of this Test System and its multiple custom-made electronics modules.

Summary (500 words)

LHCb is undergoing a major upgrade to cope with LHC RUN3's increased luminosities and a trigger-less 40 MHz read-out to improve on many world-best physics measurements. A light and homogeneous tracker based on plastic scintillating fibers is being installed downstream of the LHCb dipole magnet. The Scintillating Fiber Tracker (SciFi) covers an area of 340 m2 by using more than 10,000 km of blue-emitting scintillating fiber with 250 µm diameter, enabling a spatial resolution of better than 80 µm for charged particles and a hit efficiency of better than 99%. Six-layer fiber mats of 2.4 m in length are assembled to form individual detector modules (0.5 m x 4.8 m) consisting of eight fiber mats each. Linear arrays of Silicon Photomultipliers (SiPM) cooled to -40 ℃ are placed at the fiber ends.

The read-out of 524k SiPM channels occurs in 256 units of custom-designed front-end electronics with fast 10 ns shaping, dual integrators, and a 3-comparator flash ADC to digitize the signals. An FPGA clusters the signals over the threshold and outputs their barycenters to the 40 MHz DAQ farm with a total bandwidth of over 20 Tbits/sec. These units are called Read-Out Box, each box reading 2048 SiPM channels with a data output rate of 70 Gbps.

As introduced by W.E.W. Vink in TWEPP 2016 presentation "LHCb Scintillating Fiber detector front end electronics design and quality assurance"a Test System has been developed and is being used to ensure the Quality Control of the more than 290 produced Read Out Boxes. The system consists of one LHCb MiniDAQ and one mechanical assembly containing multiple electronic PCBs and has been designed to automate as much as possible the Quality Control procedure.

Eight Injector Modules generate 2048 individually controlled synchronized (+/- 1ns) charge pulse channels under calibrated conditions to emulate the dynamic range of the SiPM signals produced during the detector' s normal operation. One Control Module distributes fast and slow control signals. The MiniDAQ handles the system control and receives the data from the Device Under Test (DUT). By generating well-known specific patterns, the operation of the DUT can be evaluated by comparing the acquired data against the expected data. Other additional tests are also carried out on the DUT.

This Test System required the development of mixed analog and digital FGPA-driven custom-made electronics capable to generate a shaped SiPM-like pulse and ensure the time alignment of the 2048 channels spread over 8 modules, respecting a timing deviation among channels $\sigma<1$ns. The synchronization of the arbitrary injected pattern with respect to the readout integration window required to individually control the on/off state, width, and charge of each channel and deliver this on-time stimulus to test the new LHCb SciFi 40MHz trigger-less readout system. As a testing system, we had also to develop a calibration procedure to ensure the

reliability of the system as a reference.
Here we describe the design, assembly, and operation of this Test System, focusing on its custom-made electronic modules and the challenges faced on the way.

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Session Classification: Tuesday posters session

Track Classification: Production, Testing and Reliability