

Design and Test of the Off-Detector Electronics for the CMS Barrel Muon Trigger

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Drift Tubes chambers are used in the CMS barrel for tagging the passage of high Pt muons generated in a LHC event and for triggering the CMS data read out. The Sector Collector system synchronizes the track segments built by trigger modules on the chambers and deliver them to reconstruction processors (Track Finder, TF) that assemble full muon tracks. Then, the Muon Sorter has to select the best four candidates in the barrel and to filter fake muons generated by the TF system redundancy. The hardware implementations of the Sector Collector and Muon Sorter systems satisfy radiation, I/O and fast timing constraints using several FPGA technologies. The hardware was tested with custom facilities, integrated with other trigger subsystems, and operated in a beam test. Constraints, design, test and operation of the modules will be presented.

Summary

In CMS barrel, the Drift Tubes (DT) chambers for muon detection were designed to be used in the trigger system. The first stage of DT Muon Trigger is the Local Trigger, i.e. electronics mounted on chambers, that processes DT hits to find track segments. Local trigger data are collected by the Sector Collector (SC) system, located on detector nearby "towers".

Each SC module handles chamber links from one sector of the detector and performs data reduction and synchronization. Spy features allow trigger data to be transmitted to the DT readout modules for inclusion in the readout data. Finally, the SC is able to return a trigger signal to each chamber of the sector, generated as a boolean function of the trigger bits received from the single chambers. In this way a sector-level complete trigger system is implemented.

SC modules are built by several units: a VME 9U motherboard, hosting a board controller device that provides the VME interface, the interconnection with the readout system and the sector trigger generation; four mezzanine cards, receiving data from the four chambers of the sector; and a fifth mezzanine card, hosting serializer (GOL) chips and the optical drivers for the fiber connection to the counting room.

In the counting room, segment data are used by the Track Finder system to build full muon tracks. In the last stage, the Muon Sorter (MS) selects the highest transverse momentum muons in the barrel region. The high redundancy and efficiency, granted by the partitioning of the Track Finder, generates, as a by-product, fake tracks. The MS can run a fake suppression algorithm that can reduce the fake track rate down to 0.5%. After fake suppression, the best four muons are selected among all muon candidates in the barrel (up to 144), according to rules that privilege high reconstruction quality and high transverse momentum.

Muon Sorter algorithms are performed in two stages, with two different hardware modules. The first stage is based on Wedge Sorters (WS). Each WS module collects all muons found in a longitudinal 30° section (wedge) of the barrel detector and sorts up to two muons to ensure dimuon efficiency. Final sorting of the four best candidates in the barrel is performed by a single board, the Barrel Sorter (BS).

The hardware implementation of the systems profits of custom processors implemented on FPGA devices using VHDL programming. The different requirements have been satisfied with several different technology choices. The SC system is based on flash-FPGAs, ensuring high fault immunity in a moderate radiation environment. The MS system located in the underground counting room has no requirements on radiation

tolerance, thus it is based on sram-FPGAs that provide very large I/O and computational power on single devices, simplifying the design of the modules. In order to validate the designs through exhaustive tests, adapter boards were designed to emulate the final operation using custom general purpose I/O modules, Pattern Units (PU). Test setups allow data patterns to be injected at 40 MHz into boards and to read back and check outputs. Custom VME and JTAG software performs bonding checks, dynamic tests, device programming and board parameters configuration.

After stand-alone tests, modules were integrated with other subsystems to validate the interconnection and the synchronization. A full test of the DT Trigger electronics system has been performed at the CERN SpS with a dedicated muon beam pulsed at 25 ns frequency. The trigger electronics chain, comprising prototypes or final parts of the SC and MS systems, could be effectively synchronized and operated.

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