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A New Data Concentrator for the CMS Muon Barrel Track Finder

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The CMS muon trigger will undergo considerable enhancements in preparation for the LHC run-2. In order to improve rate reduction and efficiency the full muon trigger chain will be completely redesigned: the plan is to move from a redundant scheme, where the three sub-detectors (CSC, DT, RPC) have a separate track finder, to three geographical track finders (barrel, endcap and overlap) that combine trigger primitives of each sub-detector. In particular, the Muon Barrel Track Finder (MBTF) will host a new algorithm, that aggregating DT and RPC trigger data, will be able to improve the fake rejection and the muon momentum measurement.

This report will focus on the adaptive layer of the MBTF called TwinMux. Its primary role will be to merge, arrange and fan-out the slow optical links from the chambers in faster links (10 Gbps). It will realize a full connectivity matrix between the on-detector electronics and the MBTF allowing for different processing schemes. The TwinMux will be implemented in μTCA form factor compliant with all the CMS standards in terms of clock distribution, slow control and data acquisition. The TwinMux will be centered around a powerful Virtex-7 FPGA able to exchange data on up to 96 optical lanes. The gigabit connectivity on the backplane will guarantee the connection with the central DAQ, allowing the adoption of the TwinMux as a read out board for DT as well.

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1. Introduction

Cathode Strip Chambers (CSC), Drift Tubes (DT) and Resistive Plate Chambers (RPC) are the three sub-detectors that constitute the muon detector of the Compact Muon Solenoid (CMS) experiment. At present the muon trigger preserves the complementarity and redundancy of the three separate muon detection systems until they are combined at the input to the Global Trigger. The upgrade of the muon trigger aims at exploiting the redundancy of the three muon detection systems earlier in the trigger processing chain in order to obtain a high-performance trigger with higher efficiency and better rate reduction [1]. Since every additional hit along a muon trajectory further improves the fake rejection and muon momentum measurement, the upgrade seeks to combine muon hits at the input stage to the Muon Track-Finder layer rather than at its output. All the hits should then contribute to the track irrespectively of the sub-system that detects them. As for the present muon trigger the track processing will still be segmented in sectors of φ and η. The upgrade will introduce a regional segmentation that will treat muon tracks separately depending on η. It will distinguish a barrel region (low η), an endcap region (high η) and a transition region between them ($|\eta| \sim 1$). Such regions will result in different triggering algorithms but also in different deployments of hardware processors. The final sorting and ghost cancellation of muon candidates are also expected to be handled separately for each of the three regions in η.

2. The new DT trigger chain

The first element of the back-end electronics of the new muon barrel trigger chain is called TwinMux. Originally the TwinMux was designed for collecting data from two DT sectors directly from minicrates in the DT chambers or, as backup solution, from two Sector Collector (SC) boards [2]. Since the minicrates transmit data at the rate of 480 Mbps while the SC exploit the GOL chip [3] at 1.6 Gbps, a double input path was designed. Part of the input optical lanes can be routed to standard pins of the FPGA in order to be deserialized by the deserializers embedded in the input hardware block or can be routed to the GTH inputs for a faster deserialization. In the final setup this feature will be used for collecting data from a DT sector plus a RPC sector since RPC

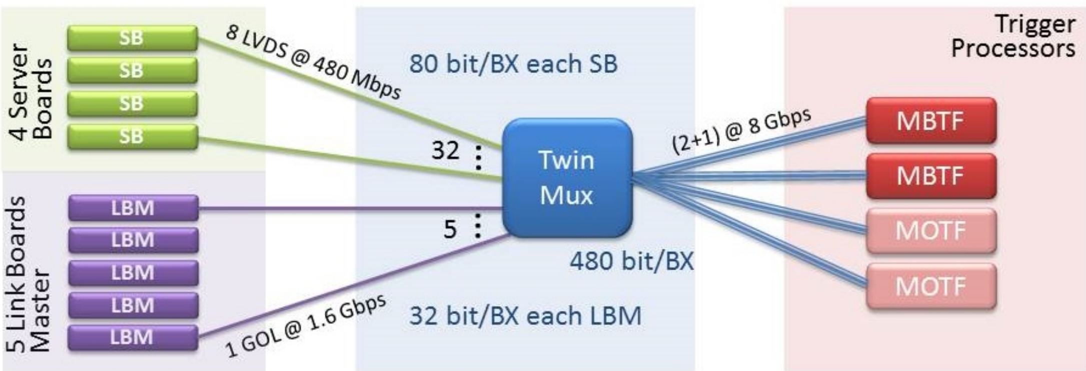

Figure 1: DT and RPC trigger chain. TwinMux collects optical links at different rates and merge and fan-out data to barrel and overlap trigger processors through high speed links.

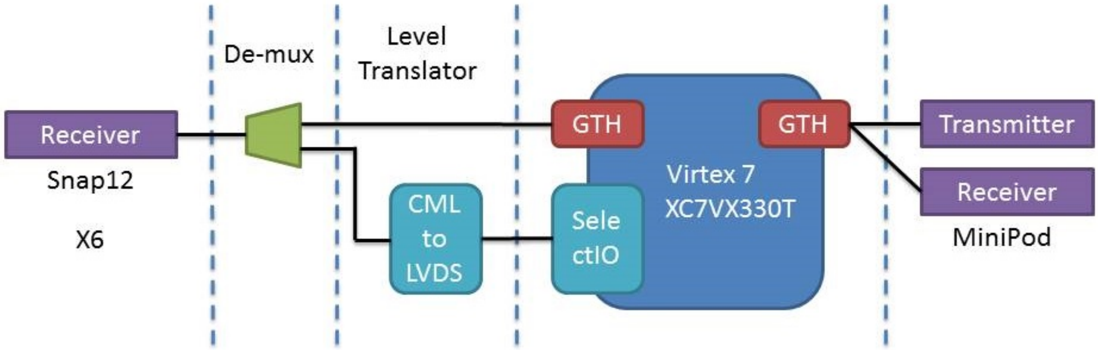

Figure 2: Block diagram of the optical input and output of the TwinMux.

data are transmitted from the Link Boards (LB) with GOL transmitters as well [4]. The computing power of the latest generation of FPGAs embedded in the TwinMux will allow for bringing forward the merging of the DT and RPC trigger primitives, unburdening the trigger processors. The algorithm for achieving this pre-processing is still evolving and is not defined for the time being, however some results showing a significant improvement in efficiency and in Pt assignment are already obtained combining DT and RPC primitives to be used with the legacy track finder.

Fig. 1 shows the trigger chain of the combined DT and RPC trigger data. From each minicrate, the Server Board (SB) transmits the DT trigger primitive over 8 LVDS links (this links are optically converted by CuOF boards, not shown in the figure). For the RPC detector five Link Board Masters (LBMs) compress the trigger hit data relative to one 30° sector and serialize it through the GOL transmitters. As a baseline the TwinMux is charged of forwarding this data to the Muon Barrel Track Finder (MBTF) and to the Muon Overlap Track Finder (MOTF) applying only a scale up in the transmission rate (and hence a reduction in the number of links). TwinMux is also responsible for duplicating (up to four times for the sectors of the outer wheels where data are shared between barrel and overlap track finders) in order to reduce connections between trigger processors increasing the reliability of the system. The minimum bandwidth required for forwarding trigger data of one sector is 16 Gbps for DT data and 8 Gbps for the RPC which needs a total of three high speed links.

The expected latency added by the TwinMux to the trigger chain is around 8 bunch crossing (BX) in total (2 BX for the deserialization, 5 BX for the output serialization and 2 BX to perform local operations, if preprocessing is not needed). Such a latency is compatible with the TSC + OptoRX boards it will replace.

2.1 TwinMux Hardware

TwinMux will be a single slot double-width full-height μTCA board, equipped with 6 front panel SNAP12 receivers and 2 Minipods (one transceiver and one receiver) for high speed data transmission (up to 13 Gb/s). Based around a Xilinx Virex-7 FPGA, the TwinMux must achieve the merging of several 480Mb/s trigger links to higher speed serial links and compensate delays to provide BX alignment of the trigger data coming from the different inputs. Twelve of the 72 TwinMux inputs will be routable to GTH inputs to be able to handle the GOL based 1.6 Gb/s links.

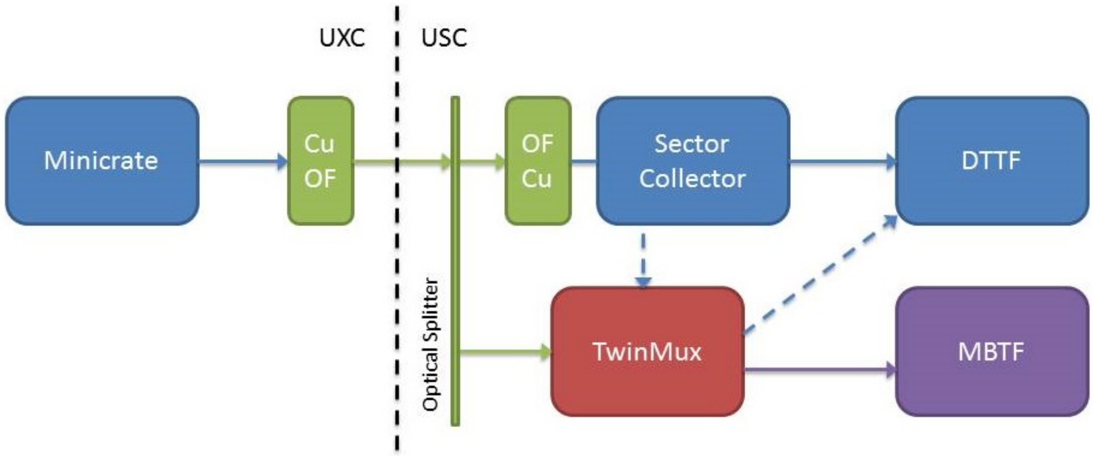

Figure 3: The expected double path of the DT trigger chain for a slice of the full system.

The 72 CML lanes need to be level translated to cope with the LVDS input of the Virtex 7. In Fig. 2 a sketch of the TwinMux input and output connections is shown.

To cover the full barrel, 60 TwinMux will be hosted in 6 μTCA dual star crates, each of which is equipped with an AMC13 [5] for clock and slow control commands distribution and for providing a connection to the central DAQ. Each crate will also be equipped with a commercial μTCA Carrier Hub (MCH), a redundant power module and a JTAG switch used for programming remotely each TwinMux board. Finally, each crate will also host a CPU that will be charged of accessing the PCI Express IP on each TwinMux through a PCI Express switch placed on the commercial MCH.

2.2 A slice test

Since the full upgrade of the Level-1 Trigger is scheduled to happen before the Long Shutdown 2 (LS2) of the LHC, the new muon trigger system should be commissioned in parallel with the operation of the current trigger. For that reason the trigger primitives from the CSC and RPC systems will be fully split into two paths,while, due to cost concerns, the DT system foresees to split only a slice of the system (6 sectors). A portion of the links coming from the minicrates will be equipped with passive optical splitters in order to deploy and validate the TwinMux board. The portion will cover three sectors over two wheels, for a total of 192 split links, so to enclose all possible neighbor correlations that the track finding algorithm has to explore to correlate track segments. Fig. 3 shows the double path towards the legacy DT Track Finder and the new MBTF.

3. Conclusions

In 2016 the muon trigger chain will undergo considerable improvements. In particular the MBTF, through the employment of the TwinMux, will have all the primitives from the chamber minicrates available, which will improve the θ hits information and skip the sorting, providing 4 segments/BX instead of 2. The TwinMux will be the adaptive layer for the MBTF: it will merge, arrange and fan-out the optical links from the chambers in faster links (13 Gbps). Such new hardware, at present in its prototyping phase, will be based on the μTCA standard and will be fully compliant with the CMS requirements in terms of timing distribution and DAQ.

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