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The optical links for the trigger upgrade of the Drift Tube in CMS

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Summary. — The first phase of the upgrade of the electronics of Drift Tubes (DT) in the CMS experiment is reported. It consists of the translation of the readout and trigger data from electrical into optical and their transmission from the CMS experimental cavern to the counting room. Collecting the full information of the DT chambers in the counting room allows the development of new trigger hardware and algorithms.

The DT system is a large detector composed of 250 wire chambers arranged in 5 wheels each one divided into 12 sectors, for an overall number of 172 k channels. During the first period of LHC data taking the DT trigger and readout were hierarchically organized in three levels: the first level of DT read out and trigger electronics was in Minicrates, which are mounted directly on the DT chambers, the second level was in the electronic Towers placed nearby the main body of the CMS experiment (Sector Collector electronics) and the last level was in the counting room together with the rest of the CMS global muon electronics.

The DT electronic system has shown high efficiency during the whole data-taking period keeping efficient almost the 99% of operating channels. In order to maintain the high performance for the High Luminosity LHC (HL-LHC) era an upgrade program has started during the LHC Long Shutdown 1 in 2013–2014. The first phase of the DT upgrade project has been to relocate from the CMS cavern to the counting room the complex system of the Sector Collector (SC) electronics. In the counting room the electronics is in fact always accessible also during the LHC run time. The SC relocation implies the translation of the electrical signals that are coming from the DT chambers into optical signals and the transfer of the data with optical fibres to the counting room. A system of Copper to Optical Fibre (CUOF) boards has been developed and a system of 3500 optical links has been installed.

The maximum data rate of around 480 Mbit/s is managed for the signals relative to the trigger path. The CUOF system is composed by 9 U VME Motherboards (fig. 1). Each Motherboard hosts 4 Mezzanines, which accommodates 8 high speed copper to optical channels. The slow control checks environmental temperature and the bias voltage; on each Motherboard the control is managed by two redundant FPGA to minimize Single Event Upset (SEU) issues.

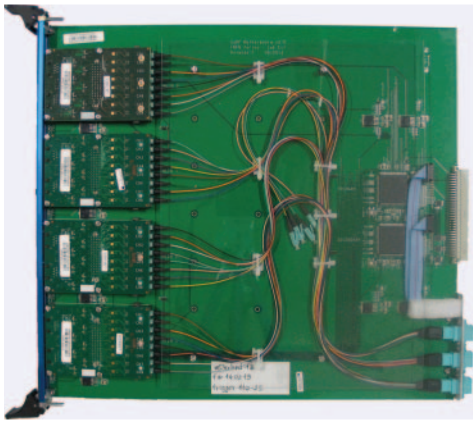

Fig. 1. – The CUOF Motherboard with the Mezzanines and the MTP connectors for the fibres.

Several tests were performed on the CUOF prototypes to evaluate the radiation tolerance of the CUOF system and to assure a good behaviour for 10 years lifetime in the HL-LHC environment. In particular the SEU trend was measured to be of the order of 10 SEU/day for the full CUOF system. The optical link jitter was measured in laboratory to be 0.18 UI for a 622 Mbit/s data rate, well beyond the required 480 Mbit/s; the result was obtained by a Pseudo Random Bit Sequence (PRBS) with a balanced pattern of $2^{23} - 1$ bit. An ageing test was carried out at 70 °C and 70% relative humidity for about 1000 hour without any significant change of the link behaviour.

The total CUOF system counts 700 Mezzanines and 150 Motherboards for a total 3500 optical links. All the links have been accurately measured in laboratory checking their operation efficiency for the translation and the transmission of balanced patterns that are characteristic of the DT read out data and unbalanced patterns that are characteristic of the DT trigger data. The best operation points have been chosen tuning the bias and modulation currents of the laser drivers. A wide interval of bias and modulation currents have been identified for each optical link with a Bit Error Ratio less than 10^{-12} at a Confidence Level of 95%.

The CUOF system have been installed and commissioned in the DT electronic chain in CMS and have been extensively tested during cosmic runs with the magnetic field at nominal value. As expected, the latency of the new links has been incremented of about 3 bunch crossings. The analysed data have shown no changes in the shape of the efficiency and resolution distributions. Therefore the copper to optical signal translation resulted to be completely transparent with respect to the copper links system used during Run 1.

The sector relocation upgrade allowed the development of the upgrade of DT trigger electronics and the production of TwinMux boards. They collect 64 optical links from CUOF system, and merge them together with the signals coming from the RPC muon system in two links of 9.6 Gbit/s. The TwinMux board is based on Xilinx 7 and it is in a μTCA format.

The installation of the CUOF system ended in 2014 and was tested successfully, the integration of the new TwinMux electronics is under way and the first results are very promising. The DT upgrade program is proceeding in time keeping the chambers on one side fully operational for the Run 2 data taking and on the other side developing the full new electronics for the HL-LHC era.