CuOF: an electrical to optical interface for the upgrade of the CMS muon Drift Tubes system

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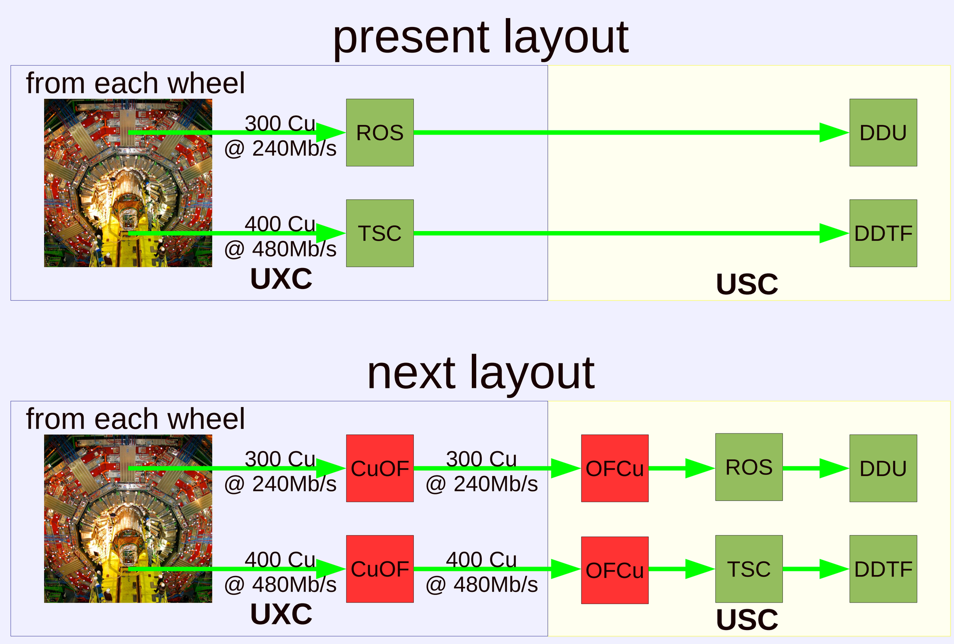
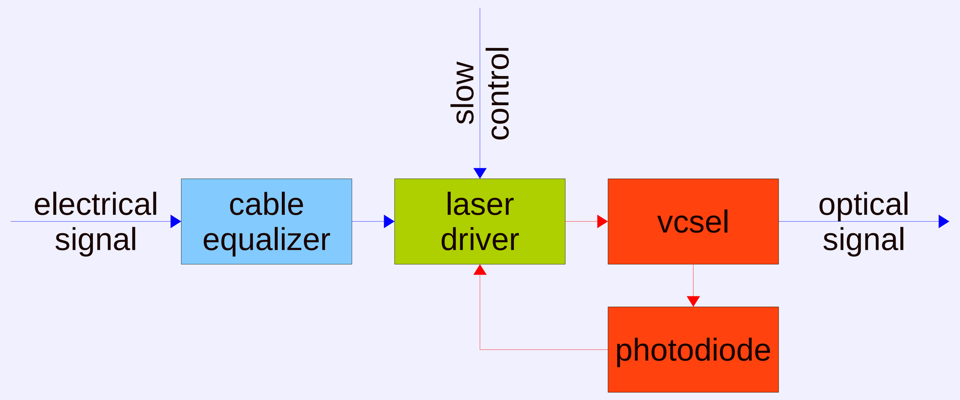
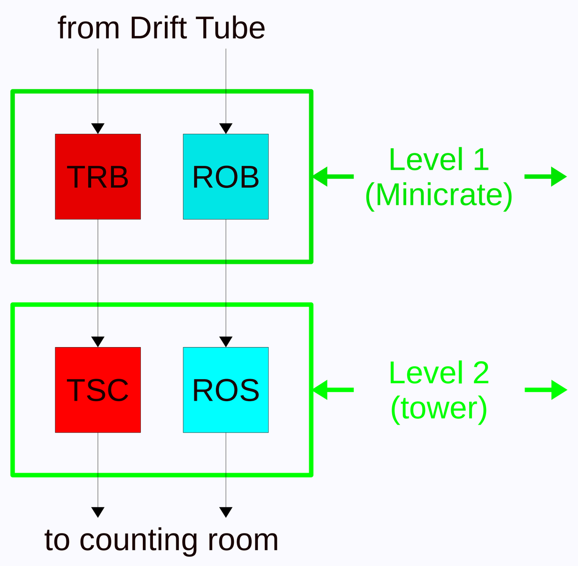
The muons generated inside the CMS experiment are detected by the Drift Tube (DT) system, that is a very large detector composed of 250 chambers arranged in 5 wheels each one split in 12 sectors, for an overall number of 172 k channels. The DT provide the muon identification and a precise momentum measurement, with information for the trigger generation. The trigger and readout for DT is organized in layers: at the Level 1, in the Minicrates, there are on detector electronics such as the TRigger Board (TRB) and the ReadOut Board (ROB); at the Level 2, in the towers, there are the sector electronics such as the Trigger Sector Collector (TSC) and the ReadOut Server (ROS).

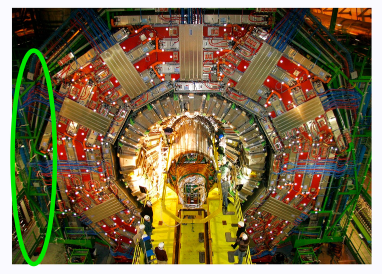


The proposed system is composed by a 9 U VME motherboard, hosting 4 mezzanines. Each mezzanine accommodates 8 high speed conversion channels, where the optical outputs are available on some LC connectors. A set of fibre fanouts are foreseen to adapt the interface to MTP connectors, where each one is able to manage 12 optical signals. Parameters, such as the environmental temperature and supply voltage, are recorded by ADC with Inter Integrated Circuit (I^2C) ports. The slow control is managed by two redundant FPGA interfaced on two independent Can buses controlled from the counting room.

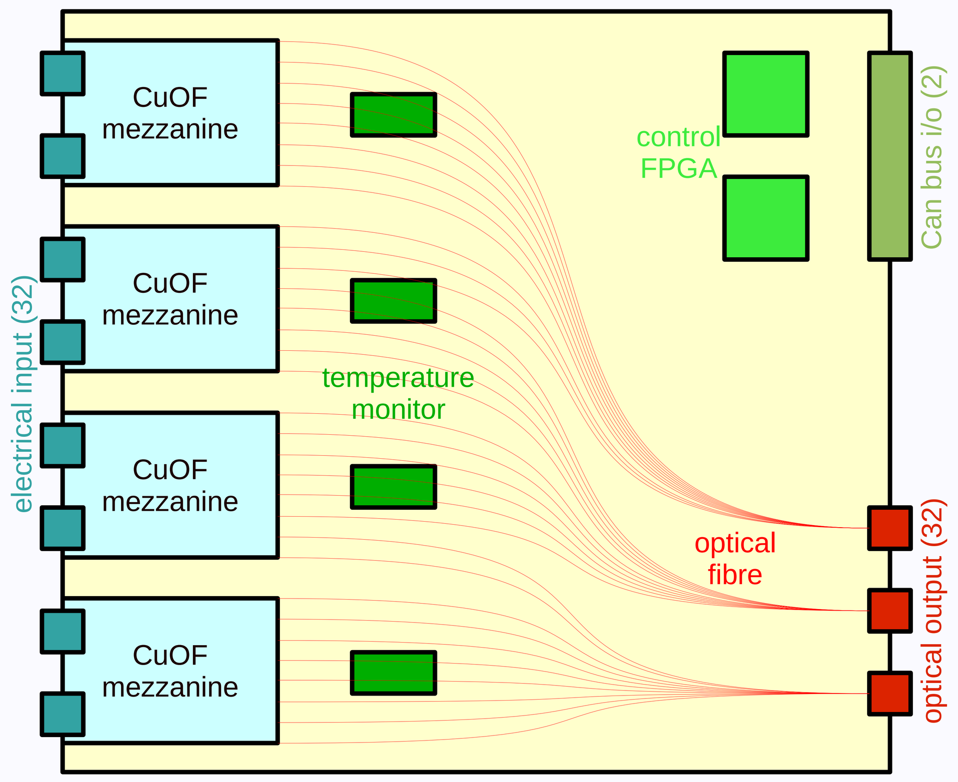


After the production of a test board for the evaluation of the different candidates as cable equalizer and laser driver, a first CuOF prototype was designed and assembled to check its behaviour together with the long input cable and the 60 m long optical fibres on the output. The test board was used in an irradiation test, to validate the hardness of the commercial components. The prototype implements the current solution for the optical conversion channel, that is under test together with the complementary OFCu.

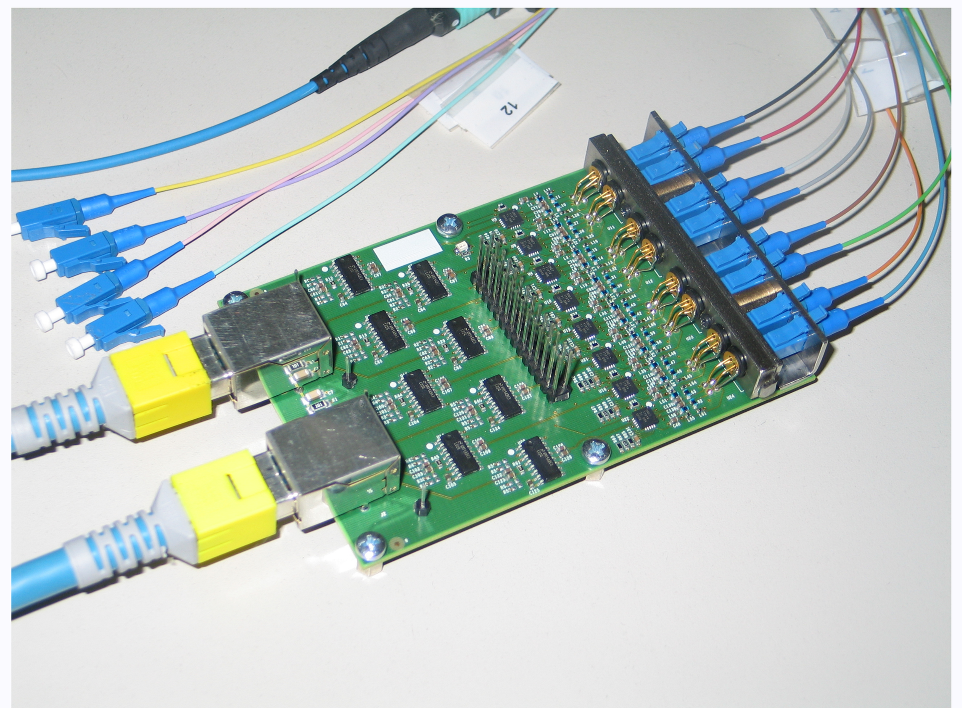




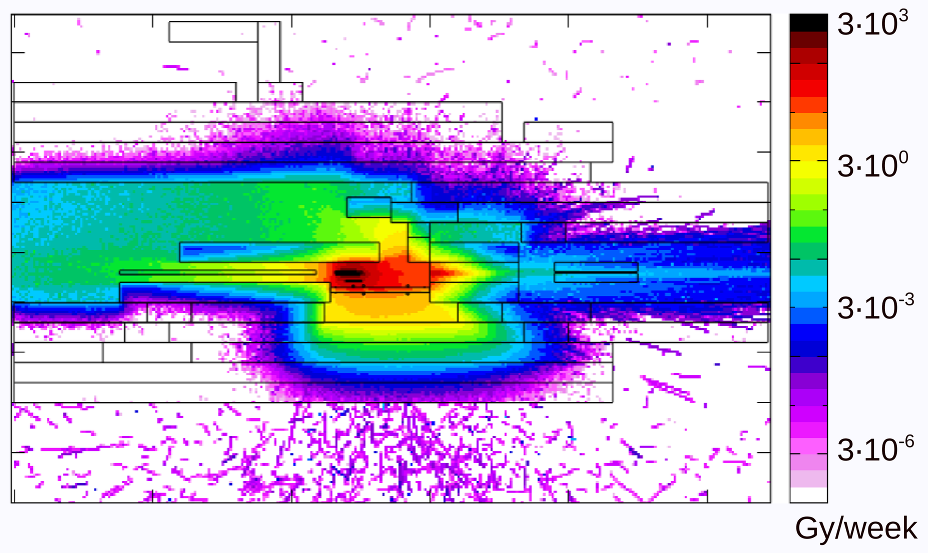
To keep the current high efficiency the complex ROS and TSC boards will be moved from the cavern to a more accessible place, where a possible fault can be handled at any time. So the new architecture foresees the relocation of these crucial cards, from the pit (UXC) to the counting room (USC). Since the data will be transferred by optical signals, a Copper to Optical Fibre (CuOF) board is required in the cavern to manage the large number of 3500 links from the 5 wheels, while on the other side a complementary Optical Fibre to Copper (OFCu) board is planned. A maximum data rate of 480 Mb/s is expected, for the signals relative to the trigger path.



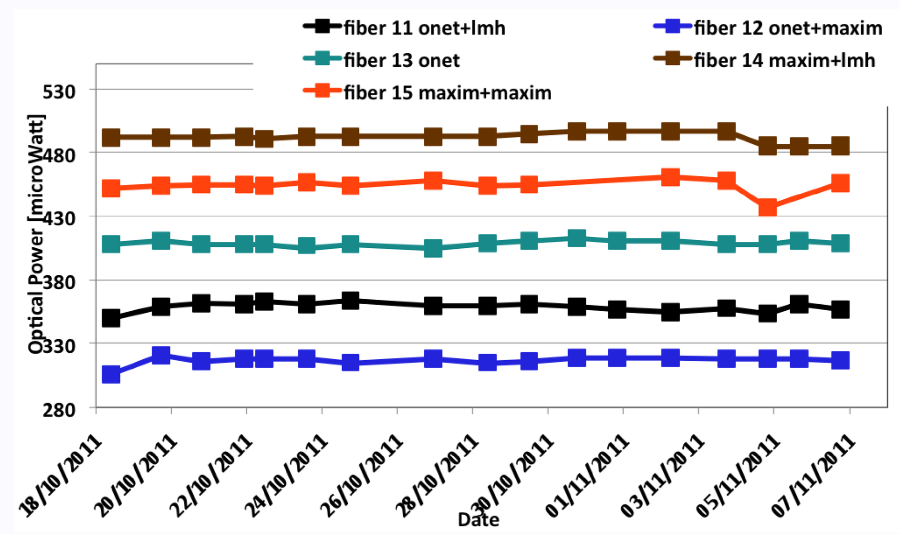
The first stage in the CuOF circuit is the line equalizer lmh0024 that acts to restore the data quality and the DC balance, for signals that have run across a 50 m long cable. That equalizer, from Texas Instruments, can be driven by a differential signal, and operates with data rates ranging up to 540 Mb/s. The next stage is composed of the laser driver that sets the modulation signal for the Vertical Cavity Surface Emitting Laser (VCSEL). In the same package, a photodiode measures the light for implementing a feedback loop to compensate the laser ageing.



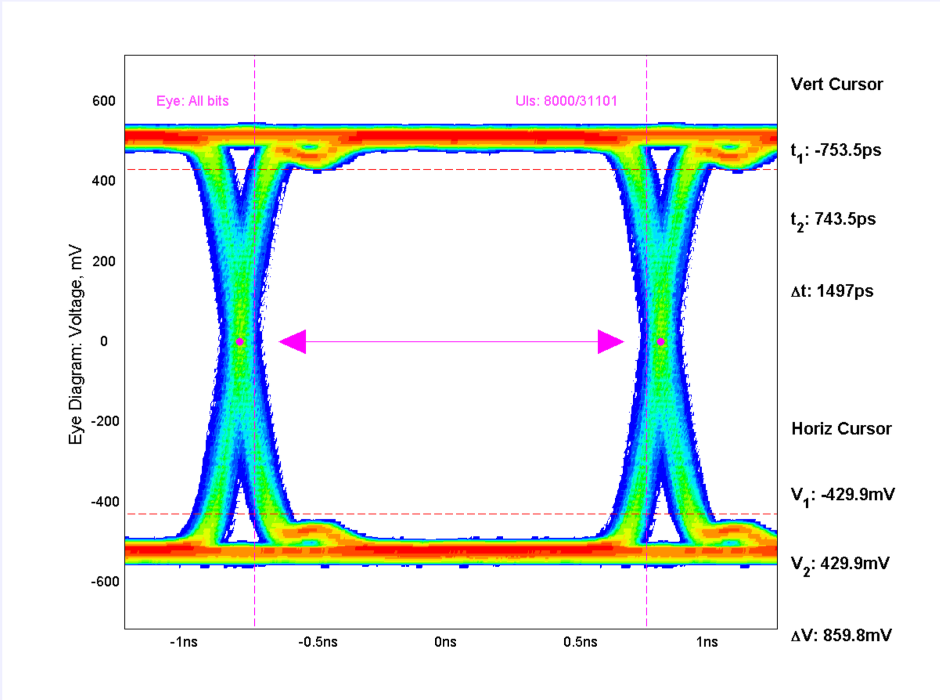
A measurement has been performed for the evaluation of the jitter, with the mezzanine prototype followed by a 50 m long optical fibre. The eye diagram shows a good image with a total jitter of 0.179 UI or 288 ps for a 622 Mb/s data rate, well beyond the required 480 Mb/s data rate. The result was obtained by means of a Pseudo Random Bit Sequence (PRBS), with a pattern of 2^{23}-1 bit. Moreover the circuit was tested both in open loop mode, and in automatic power control mode.



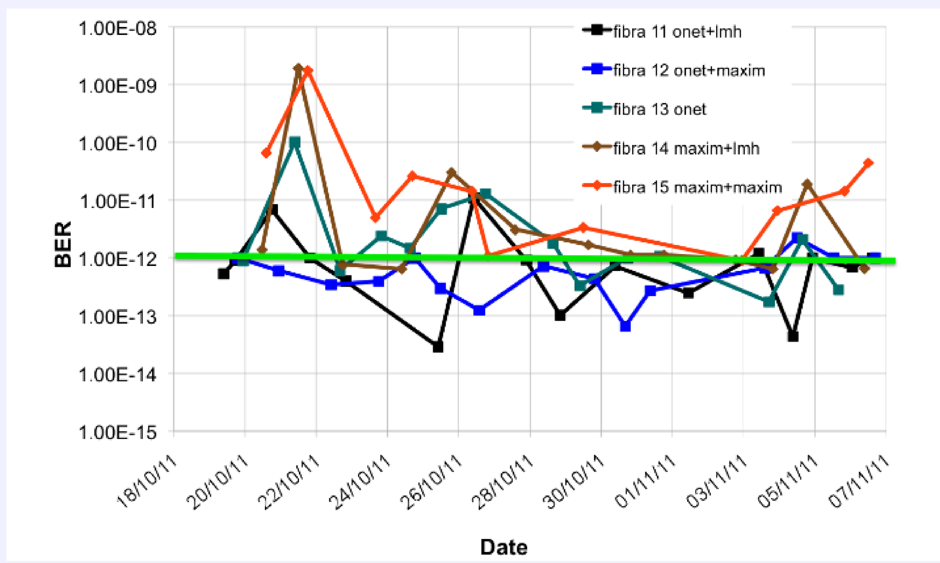
Each run lasted about 20 days, and for the whole time the system was constantly under monitoring. The plot shows that all the channels are still working at the end of the test, and that there is not a clear dependence between the error rate and the total fluence. The best results are obtained with the onet1101 laser driver, from Texas Instruments, that is also remotely configurable via the I^2C protocol by means of the slow control FPGA.



With the last run an evaluation of the Single Event Upset (SEU) has been accomplished for the selected a3p250l FPGA, from Microsemi. An 8 b word has been written in a register, and continuously monitored searching for a bit flipping. When such an event appears it is registered, and the word is restored. The SEU trend matches quite precisely with the beam integrated luminosity, and a 10 SEU/day rate for the full system has been calculated.



The irradiation tests were performed at the H4Irrad facility at CERN to expose the CuOF daughterboard to a radiation level similar to that obtained in 10 years with the High Luminosity Large Hadron Collider (HL-LHC) to select the components and to measure the errors during the transmission. In the last run a Total Integrated Dose (TID) of roughly 40 Gy was collected, and the samples withstood a neutron fluence of about 10^{12} n_{eq}/cm^2.



The optical power emitted by the tp85lcp1f laser diode, from Optowell, turned out to be almost independent from the dose and neutron fluence. The data was collected with a power meter, operating at the wavelength of 850 nm. Even tough no significant variation has been observed, in the final circuit the optical signal will be evaluated with the integrated photodiode and automatically adjusted by the closed loop control.