CMS Drift Tubes Readout Phase 1 Upgrade

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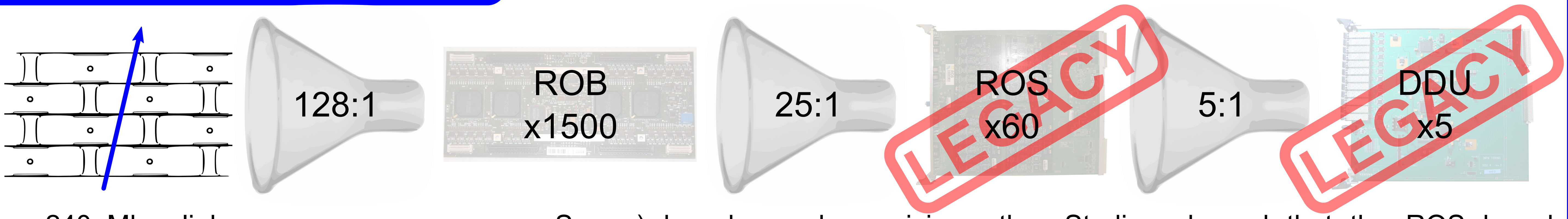
TWEPP-18

Legacy system and motivation

More luminosity, more data...



The CMS Drift Tubes (DT) are responsible for tracking muons in the CMS barrel. The 172200 front-end boards generate an electrical pulse whose timestamp contains spatial information. CERN's **HPTDC** chips in the Read-Out Boards (**ROB**) **digitize** the information from **128 tubes** and carry on window-matching after reception of the Level-1 Accept signal, and deliver this information over a 240 Mbps link.

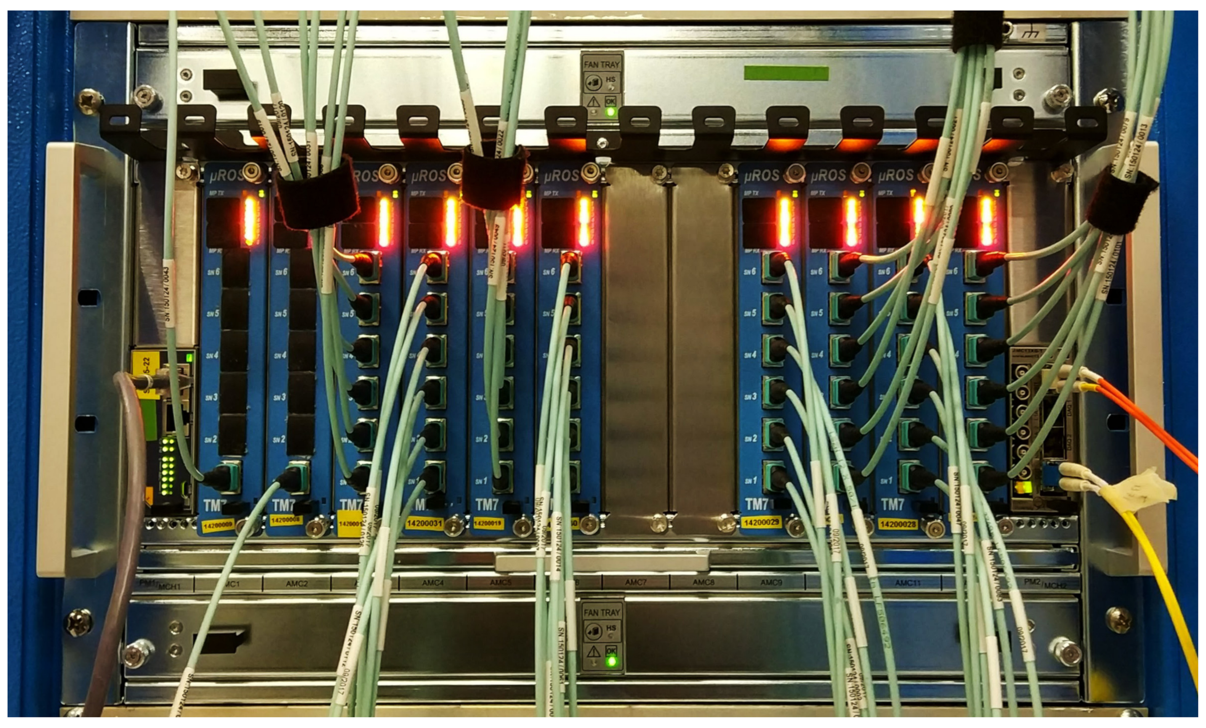
Then data goes through a series of concentration electronics, ultimately reaching the DAQ for storage and later analysis. Originally this chain was composed by **60 ROS** (Read-Out Server) boards, each receiving the information from the 25 ROB board from one sector, and **5 DDU** (Device-Dependent Units), each concentrating the information from the 12 ROS boards in a detector wheel.

Studies showed that the ROS board has inefficiencies both from the increase of luminosity and the way the handling of the input links was done. Therefore, an **upgrade** was considered **necessary**.

System architecture

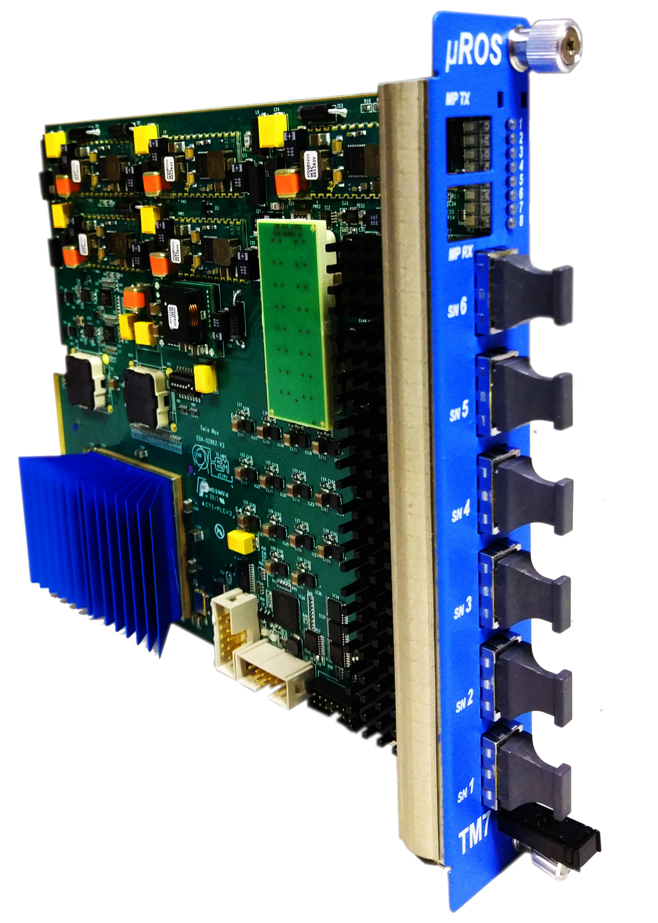
μTCA, AMC13 (gateway for timing&readout), TM7 (data processing)

The architecture adopted in CMS for Phase-1 upgrades consists of a **μTCA crate** in which the redundant MCH is replaced by an **AMC13 board** that acts as an interface to the **TCDS** (Timing and Control Distribution System) and the DAQ.



DT trigger update [1] (TwinMux) and readout's (μROS) use a custom-designed data receiver and processor board (TM7 [1]) whose function is determined by FW. TM7, which occupies μTCA crates' slots, is based on a Xilinx Virtex-7 FPGA and includes optical transceivers for both slow-speed inputs and high speed (<13 Gbps) bidirectional communication.

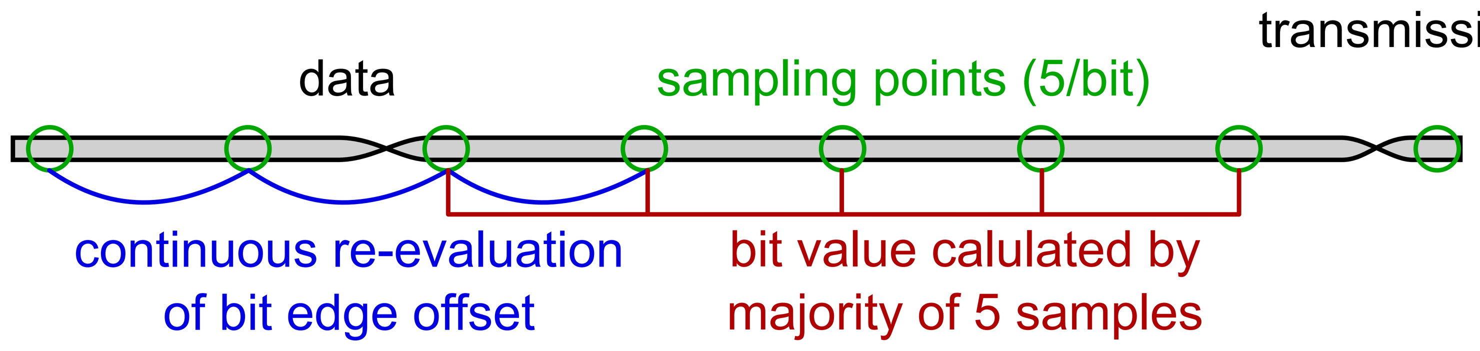
The μROS system has replaced both ROS and DDU systems. Each wheel's data is processed by 5 μROS boards, 4 of them receiving 3 sectors each (24 channels per sector, 72 links), with the 5th receiving the 25th channel for each of the 12 sectors. The **production system** comprises **three μTCA crates** (central, positive and negative wheels, respectively) **and 25 μROS boards**.



FW & Performance

Special care has been placed in designing a firmware for data serialization capable of recovering the input data stream with high quality and minimize any data losses. For improved performance, the main logic of deserialization and bit alignment was implemented in the main FPGA fabric. It **adapts automatically** without data loss **to phase shifts** and can also perform asynchronous reception and some transmission **error correction**.

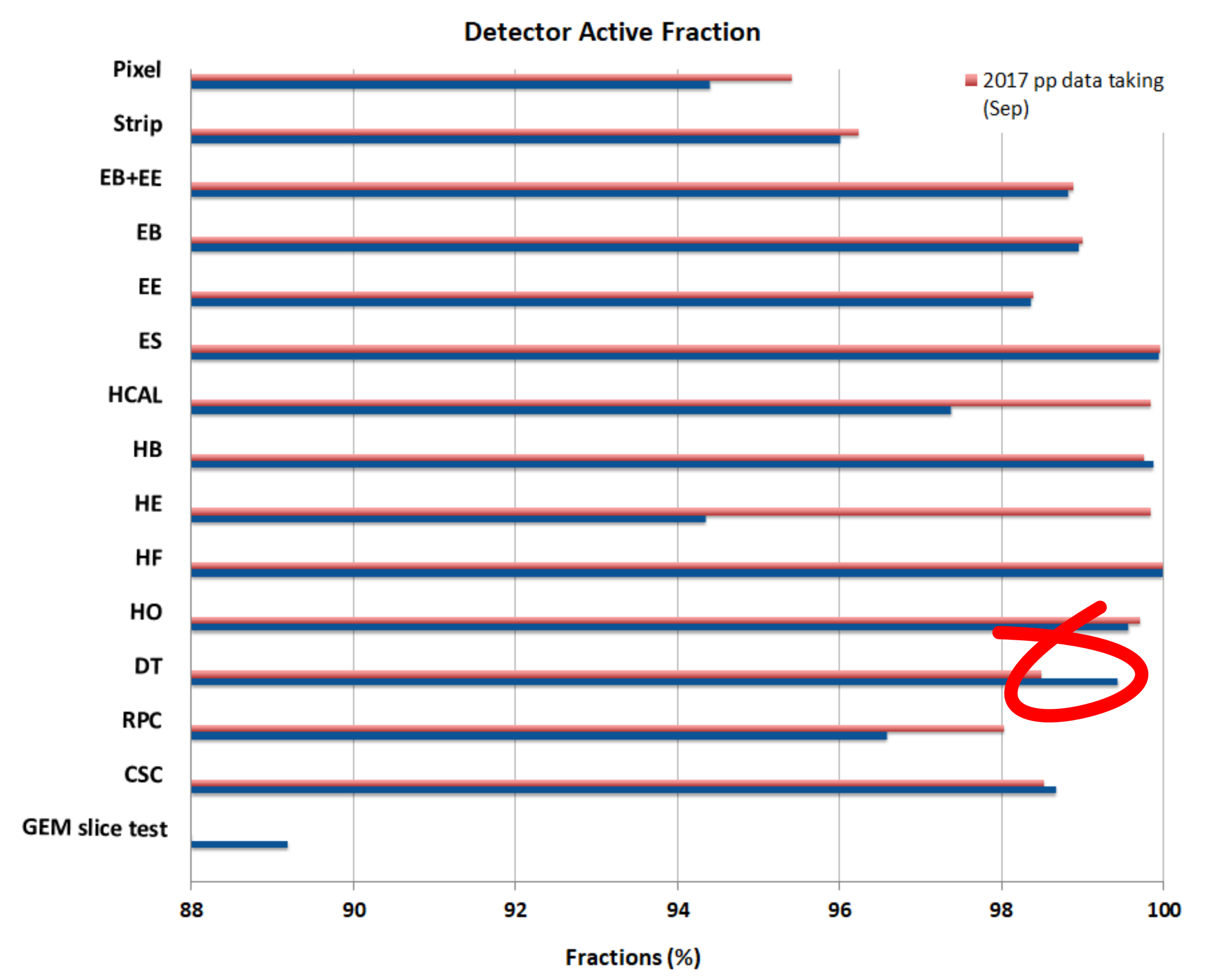
The incoming signal is oversampled by a factor 5 by an ISERDES. The output is continuously monitored to detect bit transitions, so that samples can be grouped together, even during phase shifts (e.g. variations in LHC clock).



The 5 samples from a bit are merged using a majority criterion. The bits whose value is decided by a weak majority (3 vs 2) are marked as candidates for a transmission error. A gearbox prevents missing or duplicated bits during bit edge shifts. If the data frame's parity check fails, the logic corrects the data if exactly one bit is marked as a transmission error candidate.

The FW implements **full verification** of the analysis of the ROB transmission **protocol**, and offers **detailed statistics**, having become a new, very useful tool for diagnosing fault conditions in the ROB.

While the legacy system masked channels on transmission errors, only recovering after a resync, the event builder in the μROS is able to properly recover from all types of errors in data reception automatically. Thanks to this, after installation of the system, **many ROB** problematic channels have been **recovered**. The increase in DT active fraction observed in this year's data taking responds primarily to this.



Online SW

The online SW replicates CMS state transitions into the system and gathers useful monitoring information. Communication with the HW in the CMS μTCA architecture is done via **IP network**. This makes the system more robust with respect to the previous system, in which a failure in the hardware-connected hosts required physical intervention at the service cavern.

The monitoring information is rendered in a way that is **useful for** both **quick**-glance **evaluation** of the system status and **deep** expert **analysis** of failures.

General run information is available, as well as values for all monitoring registers.

Data is graphically presented and color-coded to quickly identify the boards in the system as well as the status of each FW module.

Additionally, the status of each of the 1500 ROB links is given in several color mappings that allow to quickly visualize occupancy, transmission errors, event loss ratio, etc.

The status information is updated every few seconds and stored to the database every 2 minutes. All the historic information can be navigated and visualized.

The system has been running very smoothly with no data losses during 2018 p-p collisions.

[1] The CMS Barrel Muon trigger upgrade, A. Triossi *et al.*, JINST vol12, C03070 (2017)