FELIX-MROD, FELIX-based readout of the ATLAS Muon Drift Tubes

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Abstract

The ATLAS Muon Drift Tube (MDT) ReadOut Drivers (MROD) have been in operation for more than 15 years and are expected to remain in operation until about 2026. In the event of extensive failures, the number of spare modules may be insufficient. This project proposes using the Front-End LInk eXchange (FELIX) system, a new component of the ATLAS data acquisition (DAQ) infrastructure, to provide an alternative solution for the readout of the MDTs during LHC Run 3.

Legacy MDT readout

- **Muon Drift Tube (MDT) chambers**: main component of the precision tracking system in the ATLAS muon spectrometer.
- **Chamber Service Modules (CSMs)**: multiplexer that serializes the signal coming from up to 18 on-detector chips into a single optical stream. Additionally, it deals with the ATLAS trigger, timing, and control (TTC) system.
- **Muon ReadOut Driver (MROD)**: 9U VME custom module, specifically designed to process the data coming from the CSMs (up to 6) and is interfaced to the TTC.
- **ReadOut System (ROS)**: a set of custom PCIe readout cards hosted by commodity servers, which handle data buffering during the high-level processing performed by the ATLAS high-level trigger (HLT).

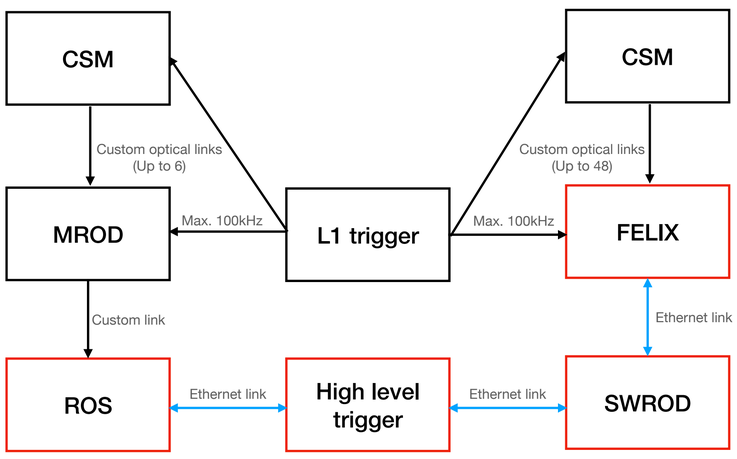


Figure 1. Schematic representation of the FELIX-MROD readout architecture next to the legacy MROD architecture.

FELIX-MROD readout

- **FELIX**: commodity PC hosting a detector-universal FPGA-based PCIe card, a.k.a. FLX-712, equipped with custom firmware to interpret data coming from the CSMs (up to 48).
- **SWROD**: software application running on a commodity server performing data processing. A custom plug-in has been developed in order to implement the MROD functionalities in software.
- FELIX and SWROD are connected through a high bandwidth **Ethernet network**, through which SWROD also interfaces with the HLT and provides it with data information on demand, similarly to what is done by the ROS component of the legacy architecture.

As shown in Figure 1, the only custom component in the FELIX-MROD architecture is in fact the FELIX PCIe card, making it more flexible and easier to maintain (both in terms of hardware and firmware) compared to the legacy one.

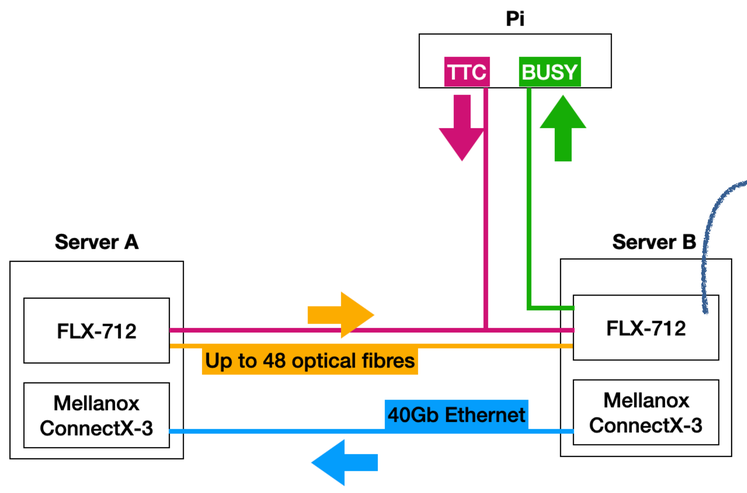


Figure 2. Sketch of the laboratory setup used during the performance tests at Radboud University.

Performance

Performance tests were conducted using the setup shown in Figure 2:

1. A FLX-712 card in Server A, configured with special emulator firmware, acts as a data source;
2. Another FLX-712 card in Server B reads out the data through the optical link, upon reception of L1 accept signals (L1A) generated via the TTC system controlled with an external pulse generator (a RaspberryPi);
3. The FELIX software runs in Server B and is responsible for routing the data from the card to the network;
4. The two servers communicate through a high-speed Ethernet network using a 40Gb Mellanox interface;
5. The SWROD application running in Server A processes the incoming data from the network.

The measured throughput of the card (Figure 3) was found to be in agreement with the theoretical maximum data rate computed for a set of benchmark scenarios (Table 1).

	Nr. CSM links per card	Word rate per card (Mwords/s)	Data rate per card (GB/s)
1 MROD	6	300	1.2
4 MROD	24	1200	4.8
8 MROD	48	2400	9.6

Table 1. FELIX card output rates for three benchmark scenarios. The CSM clock (50 MHz) is taken as input to compute the theoretical limit. Word size is 4 bytes.

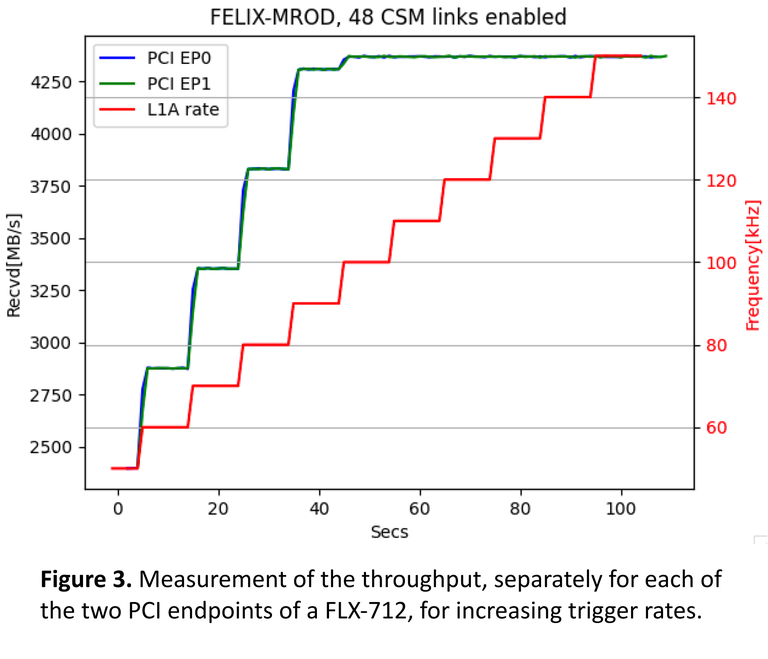
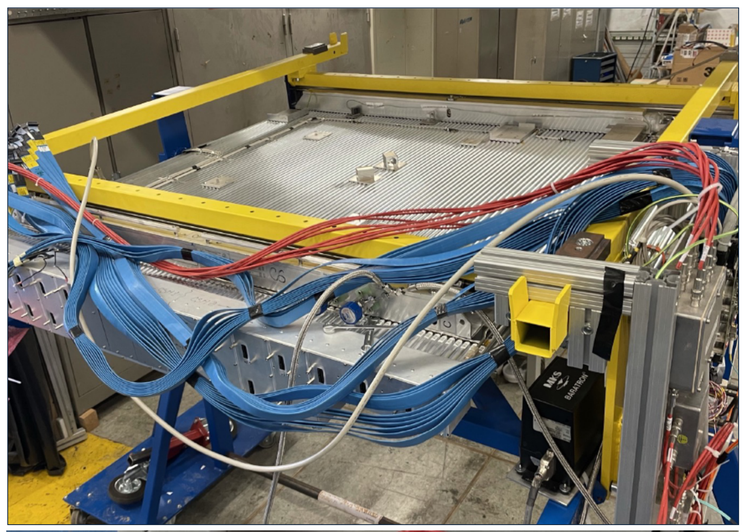


Figure 3. Measurement of the throughput, separately for each of the two PCI endpoints of a FLX-712, for increasing trigger rates.

Tests at CERN

First integration tests were performed at CERN using two MDT chambers, each one equipped with a CSM.

- MDTs were filled with gas and high voltage was applied → source was cosmic rays (and noise).
- Triggers were produced independently by an external TTC system.
- No issues were encountered and stable operation was achieved.



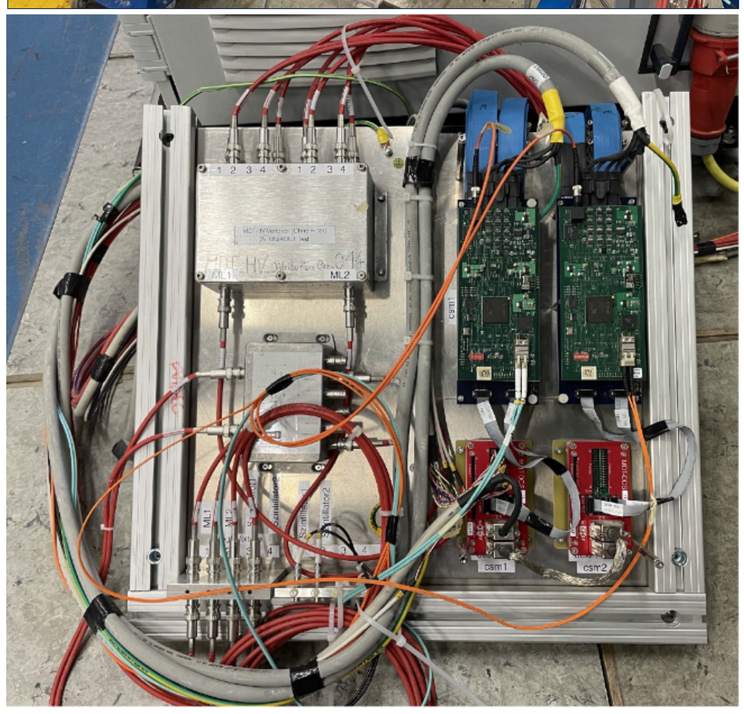


Figure 4. Test MDT chambers and CSM modules at CERN.

Conclusions

The FELIX-MROD project has been developed with the aim of overcoming a possible massive failure of the legacy MROD modules.
Not only it can successfully perform the same functionality of the MROD (and ROS) in the ATLAS MDT readout architecture, but, due to the versatility of the FELIX system, it is also a more efficient solution: the hardware design of an FLX-712 card allows to accommodate up to 48 channels, therefore a single FELIX- MROD unit can potentially replace up to 8 MRODs.
The use of FELIX-MROD for testing of sMDT chambers produced for the Phase-II ATLAS upgrade is considered and integration studies in this direction are currently ongoing.

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