

# The ATLAS Forward Proton Real-Time Time-of-Flight Trigger and Trigger Decoder for LHC Run 3

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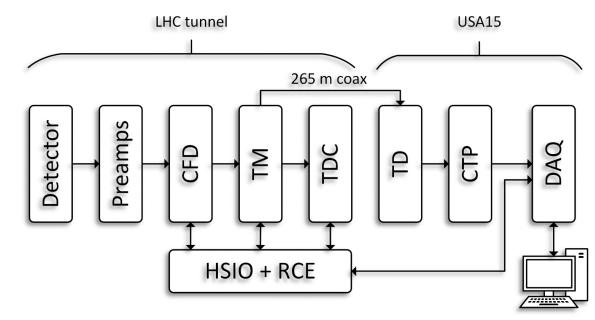
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#### **INTRODUCTION**

This poster describes the in-line real time Digital Trigger Module (DTM) that provides a majority trigger decision for the ATLAS Forward Proton detector (AFP). A forward proton traverses a sequence of four successive Cherenkov radiators (a "Train") connected to a fast multi-anode MCP Photomultiplier (PMT). Four such trains are mounted next to one another and subdivide the AFP acceptance for diffractive protons in "slices" with roughly equal occupancy. Every Train that passes the majority trigger encodes a "bit" in the 5-bit trigger word (the first bit is an "OR" of all trains firing) that is sent over a 265 m foam-core coax cable towards the ATLAS Central Trigger Processor (CTP). The fast real-time DTM is described, including the Trigger Decoder (TD) that interfaces with the CTP.

#### **AFP Time-of-Flight Detector**

The Time-of-Flight (ToF) architecture is shown in the figure below. The Cherenkov detector is composed of 4×4 matrix of quartz bars and multichannel PMT. Each row in the matrix parallel to beam is called train. The protons traversing the quartz bars with velocities higher than the speed of light in the detector material produce the Cherenkov radiation, which is processed by the PMT and then amplified by three-stage amplifiers.

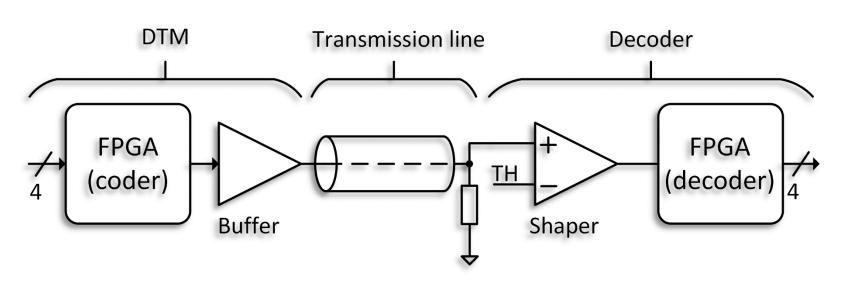


The purpose of the Constant Fraction Discriminator (CFD) module is to code the pulse shape to the pulse width of the digital signal. The DTM is looking for the specific events which are subsequently passed through to the Time-to-Digital Converter (TDC). Another important DTM function is to send the control commands for data storing in the Data AcQuisition (DAQ) system. TDC converts the signal pulse width to the appropriate form for computer processing. High-Speed IOs (HSIO) and Reconfigurable Cluster Element (RCE) modules serve for the data collecting and remote control of the ToF detector.

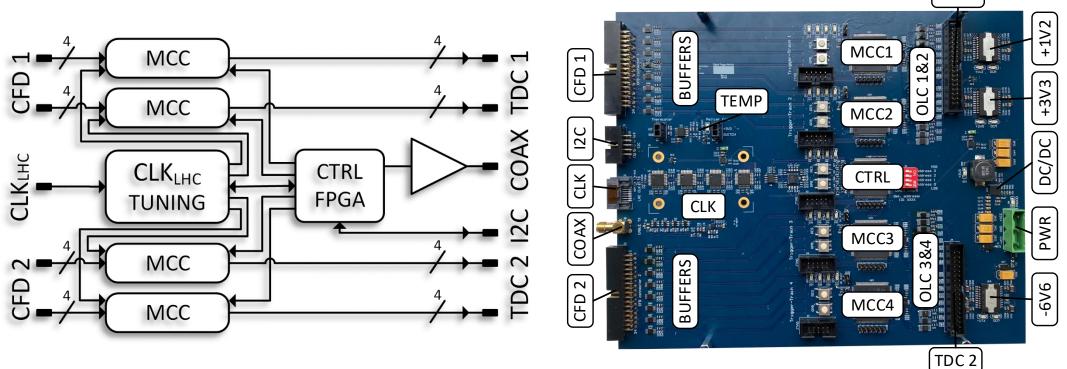
#### **Triggering System**

The AFP Triggering System (TS) as a whole consists of the following three main parts:

- **DTM** Is used for selecting the interesting events based on the logic conditions set for the individual trains. Each of the activated trains is represented by one bit in a 5-bit data frame. This frame starts with the OR bit signalizing the activity on any train and four train activity bits are following. The output buffer transmits these data frames into the transmission line. The DTM is located in the tunnel next to the LHC accelerator.
- Transmission line The signal going from DTM to TD is transferred via 265 m long low-loss air-core cable connecting the DTM with TD.
- **TD** This module receives the serially transmitted data which are subsequently recovered and sourced to the decoding FPGA for further processing. The FPGA oversamples the input data and resynchronize them with the locally distributed LHC synchronization clock. There are five signal traces between the TD and CTP corresponding to the four trains and one OR.

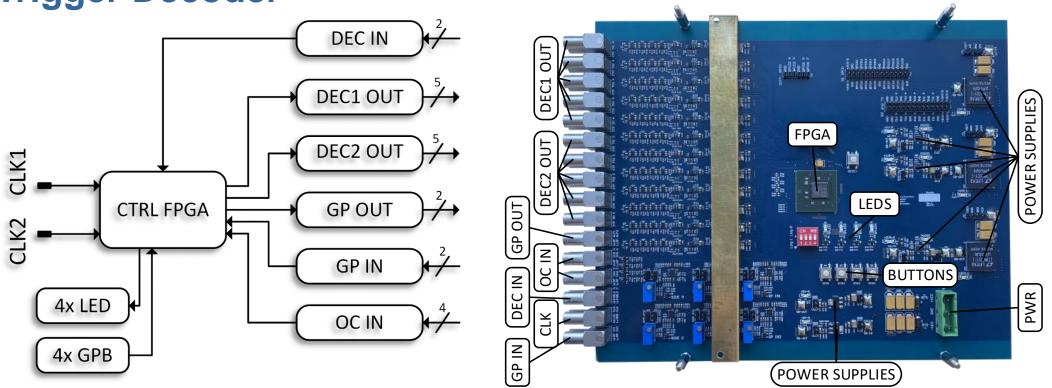


#### **Digital Trigger Module**



The DTM consists of four Multichannel Coincidence Circuits (MCCs) which are selecting the events in the individual trains based on the set logic conditions. The MCCs signalize the train activity to the control FPGA which is producing the above mentioned 5-bit data frames for CTP. Another function of the DTM is to pass through or block the input signals on their way to the TDC. The LHC clock tuning block is useful for qualification of the events with respect to the bunch clock rising edge. This feature enables the DTM to omit the background and wrongly timed incoming events. The PCB is realized with use of radiation hardened or properly tested commercially available components.

### **Trigger Decoder**



The TD module is designed for processing of the CTP control signals produced by two ToF detector chains at once. The decoder input (DEC IN) signals are oversampled when the rising edge on any of the input lines is detected. Then the contained data are identified and resynchronized in accordance with the LHC clock which is also used for timing of the CTP. Two groups of five signals are sourced to the CTP as this system decides whether to store the ToF chain data or not.

#### **Measurement and Results**

The efficiency of the whole Triggering System was precisely tested and the results claim it's 100%. All of the planned features were evaluated with no errors observed. The radiation test proved the lifetime longer than three years in region close to the LHC beam. The TS is currently installed at LHC and the system integration is currently ongoing.

#### **Acknowledgement**

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## SUMMARY

- A completely new Trigger System was designed in order to select the interesting events detected by the AFP ToF detector.
- ► The DTM and TD bring the extensive information concerning the individual train activity to the CTP and therefore to the event data structure itself.
- Performed tests proved 100% efficiency of selecting the events in accordance with the chosen criterions.
- ► The circuitry was designed and tested as a radiation hardened and the expected lifetime in a radiation harsh environment is longer than three years.
- ▶ Ongoing works on the system integration of the TS containing mainly the DTM and TD promise further improvements in research of diffractive p-p collisions.