Readout System of the ALICE Fast Interaction Trigger

Dmitry Finogeev on behalf of the ALICE collaboration,
Institute for Nuclear Research of the Russian Academy of Sciences, Moscow, Russia.

The ALICE experiment at the CERN LHC will install the Fast Interaction Trigger detector (FIT) during the ongoing second long shutdown of the LHC (2019-2021). The new FIT detector will serve as the main luminometer and trigger detector. It will also measure the precise collision time, multiplicity, centrality and reaction plane. In order to cope with an increased interaction rate of up to 1 MHz in proton-proton collisions and up to 50 kHz in Pb-Pb collisions, a new readout system for the ALICE FIT detector was designed.

Event time will be measured by using a combined method with 13ps binning TDC THS788 and FPGA-based TDC. The input charge will be integrated and measured with a 12-bit 80Msps ADC. FIT readout system will allow to take data in a continuous (trigger-less) and in a triggered mode (event selection with a trigger). Event readout selection as well as data processing will be done on Xilinx Kintex 7 FPGA. GBT-FPGA based readout will allow to stream data up to 5.5 MHz event rate at a 3.2 Gbps data rate. In this presentation we will discuss the concept, features and performance of the digital readout system.

ALICE needs FIT for:

Luminosity monitoring & feedback to LHC
- **Online trigger latency < 425 ns**
- **Online Vertex determination**
- **Minimum Bias and centrality selection**
- **Rejection of beam/gas events**
- **Veto for Ultra Peripheral Collisions**
- **Collision time for Time-Of-Flight particle ID**
  - **time resolution better than 50 ps.**
- **Multiplicity, Centrality and Event Plane**

Requirements for RUN3

- **Interaction Rates: 50 kHz for Pb-Pb, and up to 1-2 MHz for pp collisions**
- **2 modes of running the detectors: triggered and continuous**

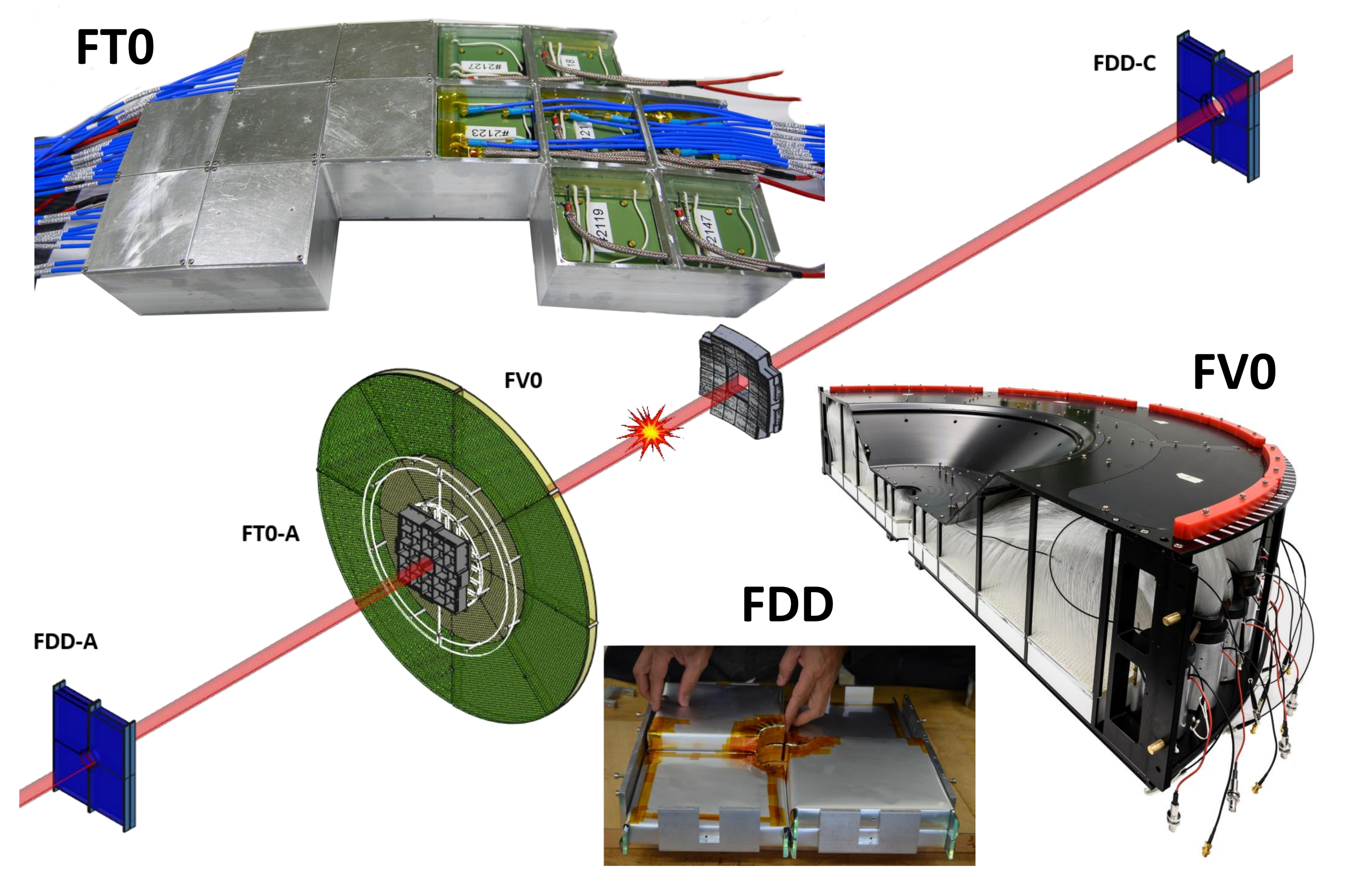
FIT detector description

FT0
- Consists of two arrays of Cherenkov quartz radiators coupled to fast XP85002/FIT-Q MCP-PMT photo-sensors: 24 on the A-side and 28 on the C-side
- The intrinsic time resolution of the modified MCP-PMT is better than 13ps
- The Cherenkov arrays will be placed around the beam pipe at the opposite sides of the interaction point (IP): at 320 cm and –82 cm from the IP
- FT0C has a concave shape with a radius of 82 cm with all sensors facing the IP [1]

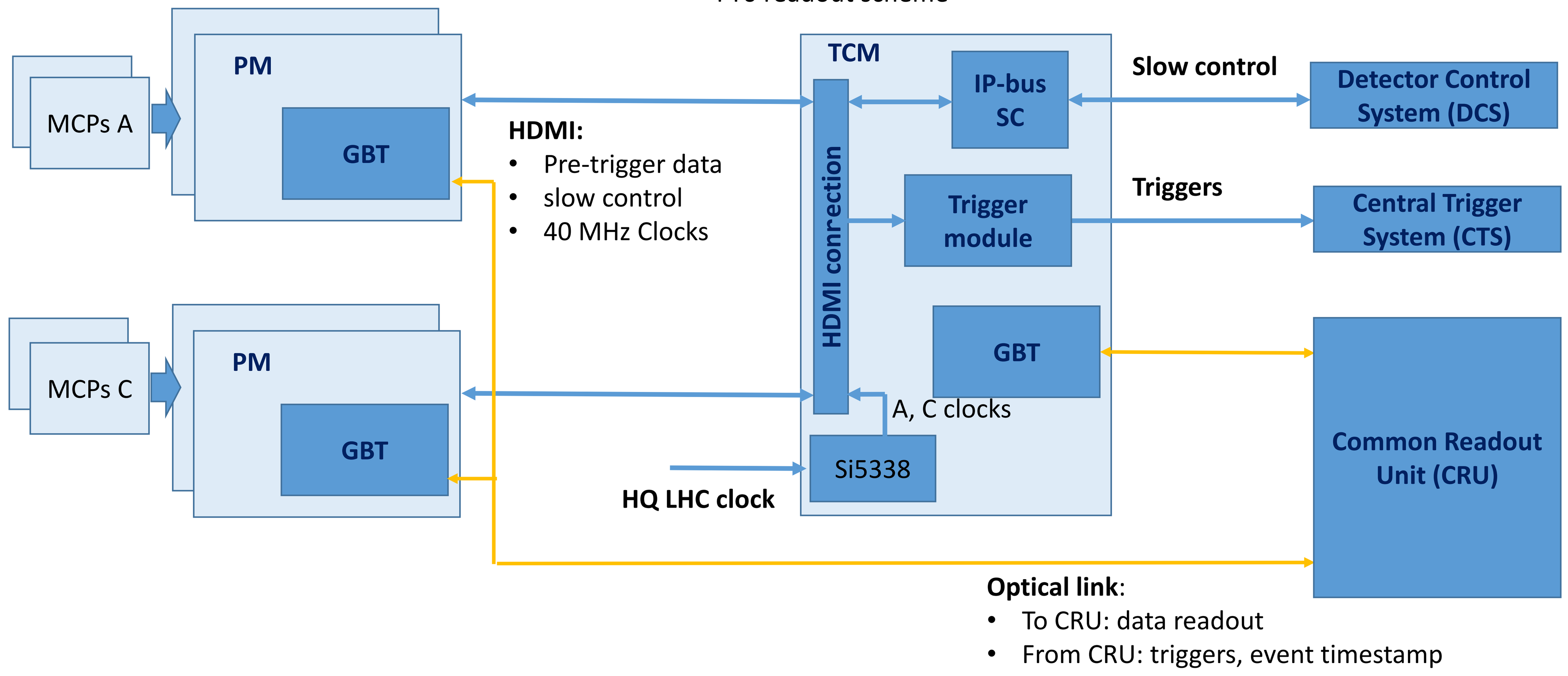
FV0
- The active part of the FV0 detector is a 4 cm thick scintillator disc with an outer diameter of 148 cm and inner diameter of 8 cm
- The scintillator disc is divided into five rings and eight 45-degree sectors
- The most outer ring, because of its large size, is subdivided into two parts
- A dense grid of clear Asahi fibers is coupled to the rear side of the EJ-204 plastic scintillator surface
- The fibers are grouped into equal-length bundles and coupled to a total of 48 Hamamatsu R5924-70 fine-mesh PMTs [1]

FDD
- The FDD detector consists of two stations covering the pseudorapidity ranges of $4.7<\eta<6.3$ and $-6.9<\eta<-4.9$, respectively [2]. This coverage allows FDD to efficiently tag diffractive and ultraperipheral events.

FIT = FT0 + FV0 + FDD



FT0 readout scheme



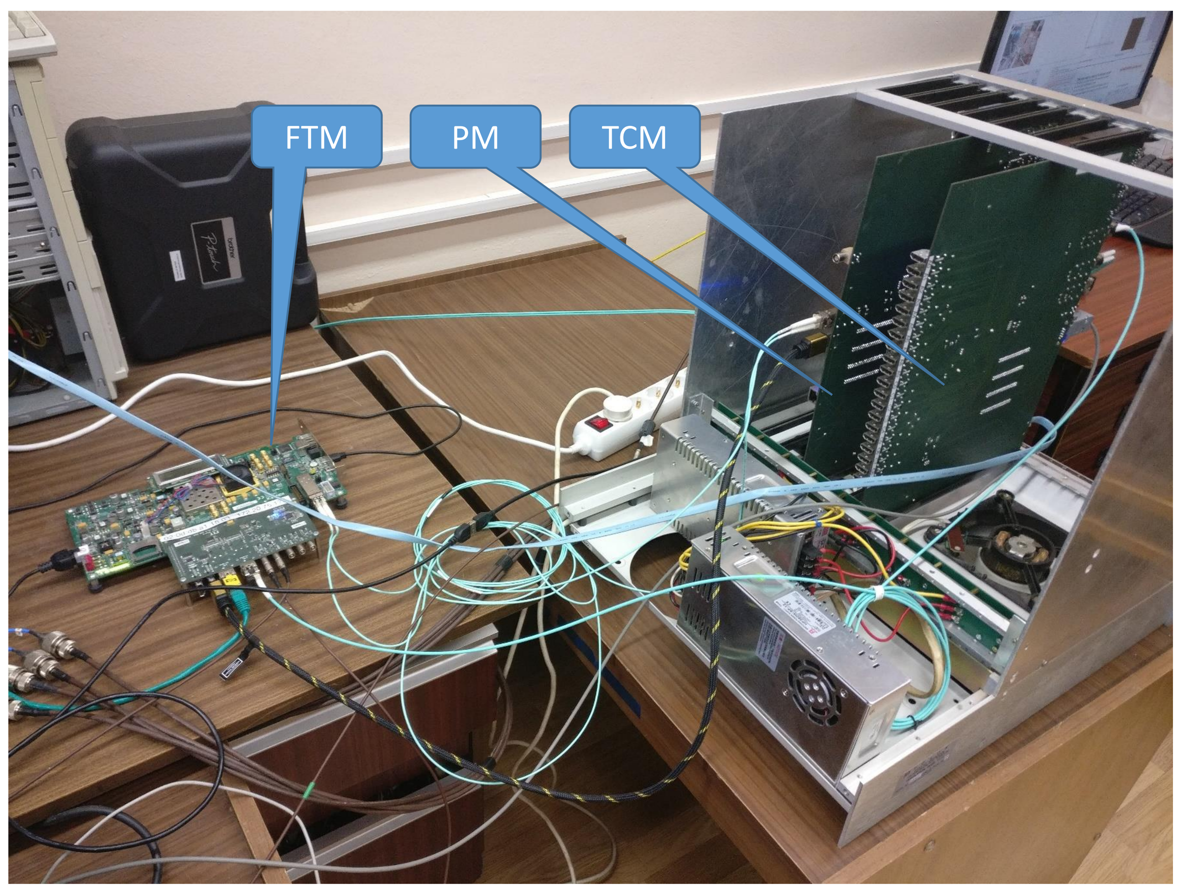
The signals from FT0, FV0 and FDD detectors will be processed with a set of PMs with the outputs connected to one TCM per sub-detector

PM functionality
- **Analog signal digitizing.** Analog signals from the detector comes directly to the Processing Modules (PM), and digitized by the Time to Digital Converters (TDC) and Ampitute to Digital Converters (ADC). [3]
- **"Pre-trigger" Data generation.** All PM modules will provide first "pre-trigger" digital data to TCM for trigger processing. "Pre-trigger" data are sent to TCM via HDMI and contain data for events in predefined time window +-2,5ns: sum of amplitudes, sum of hit times, number of fired channels.

TCM functionality
- **Forms the online trigger signals.** TCM receive "pre-trigger" data from all PMs and form detector trigger decision. Time span from receiving an analog signal at the input of PM to trigger output from TCM is 208 ns [3].
- **Provides synchronous high-quality clock to all PMs.** Si5338 generator used in the TCM module produces two 40MHz clock to A and C sides of FIT with manageable phase shift sourcing high quality LHC clock. A and C clocks distributed to PMs via HDMI cable. "A" side clock is used as source for GBT interface.
- **Electronics configuration.** TCM modules are configured via IPbus (UDP based protocol) through the 1 Gb Ethernet optical link. PMs are configured via HDMI SPI connection with TCM. TCM also transmit important parameters to the Detector Control System.

FIT will send trigger signals to Central Trigger System (CTS), where the Physics trigger decision is generated. Physics trigger decision will be sent back to FIT and other ALICE detectors using GBT downlink. [4]

PM and TCM modules send digitized data to the next processing level (O^2) via the 3.2 Gbps optical link with CERN proprietary protocol GBT [5].

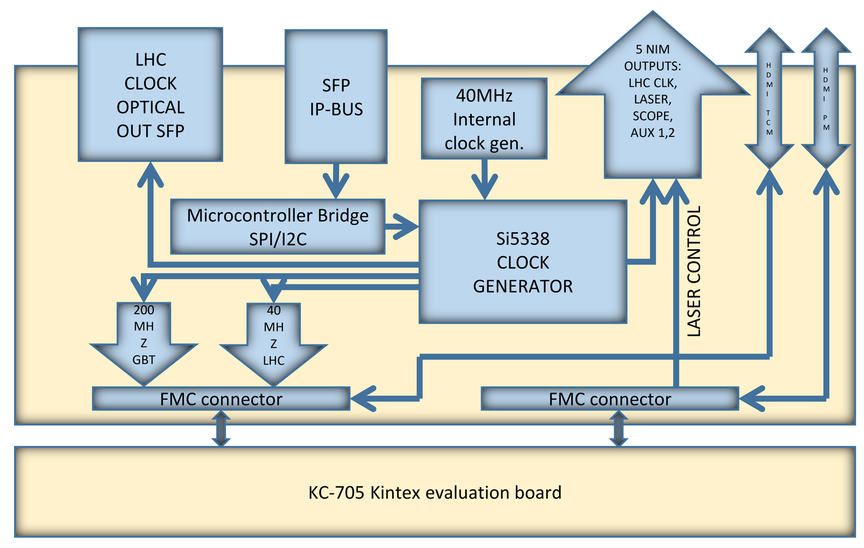


PM and TCM workbench was assembled at INR RAS, Moscow in October 2019. The workbench allows to test full functional behavior of PM and TCM including slow control, readout, data processing and trigger generation.

All tests consist of the following stages:
1. One PM: configuration, readout and data processing test
2. PM + TCM: readout, HDMI data synchronization, TCM readout test, PM and TCM configuration
3. 2 PM + TCM: Vertex and Multiplicity triggers (trigger by predefined time and amplitude thresholds for two sides of FIT detector – two PM needed). EMC (electromagnetic compatibility) test

Custom test board FTM was developed for readout test
- Test board is based on Kintex 7 FPGA evaluation board with FTM addon
- GBT readout via IPbus (UDP based protocol)
- TCM functional simulation: HDMI connection, PM configuration (for PM standalone test)

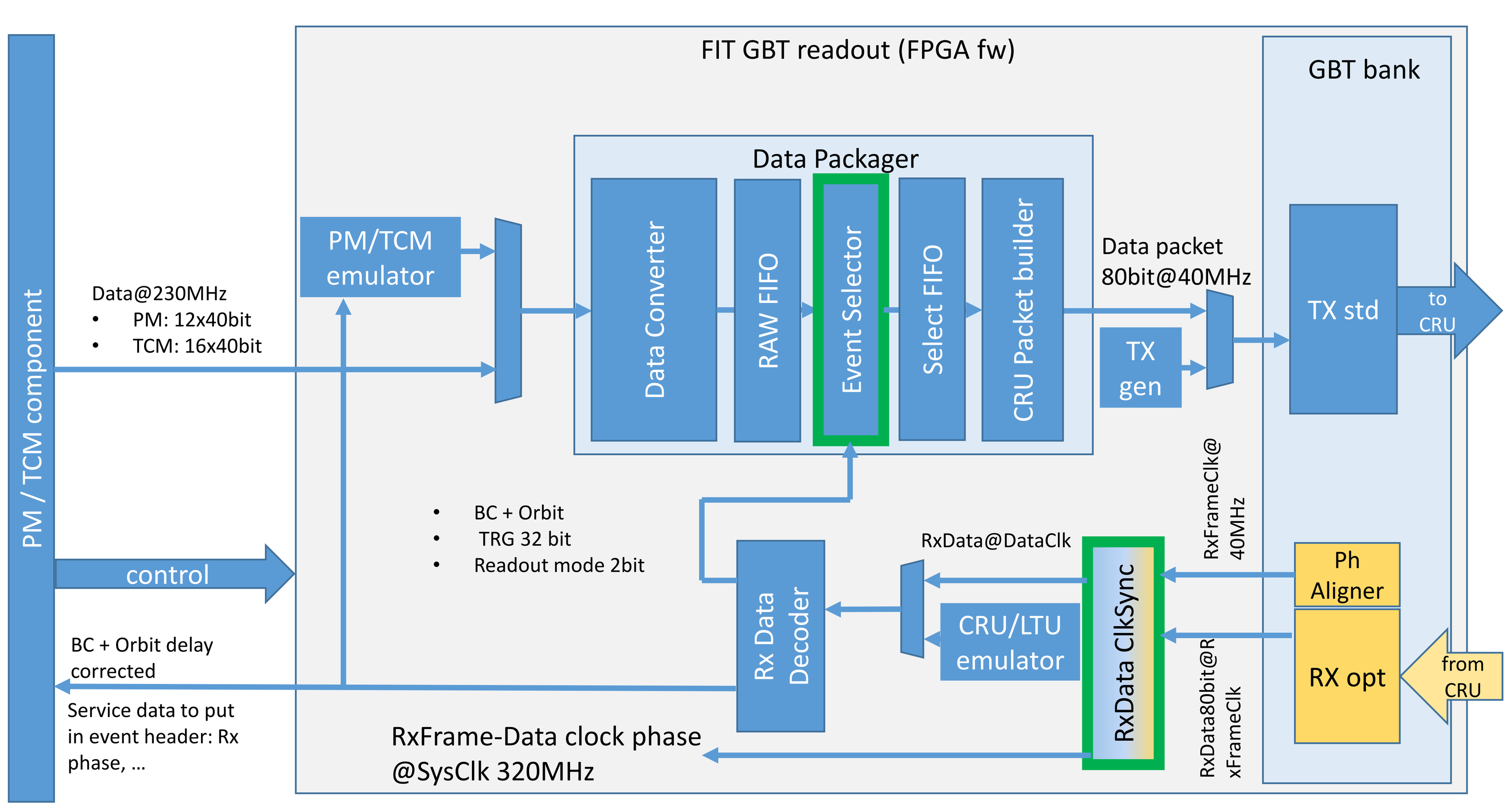
FTM addon scheme



- **Si5338** - I2C-PROGRAMMABLE QUAD CLOCK GENERATOR
  Input clocks:
- 40 MHz internal
- **Output clocks:**
- phase-controlled "LHC clock"
- phase-controlled Laser clock
- 200 MHz clock for GBT

- **"LHC Clock" Optical output**
- **IP-Bus** SFP connector

- **Microcontroller** for
- Si5338 power-up configuring
- SPI/I2C bridge to control Si5338
- Clock status monitoring



- Readout component is part of PM and TCM firmware, it receives data from core firmware PM/TCM component to send it via GBT.
- Readout component function:
  - **Data selection according to trigger decision from CTS**. Two readout modes are maintained at ALICE: triggered and continuous mode. In triggered mode data are sent only in coincident with physics trigger. In continuous mode all measured data should be sent to CRU.
  - **HB trigger response.** Each LHC orbit HB (Heartbeat) trigger sent to all detector subsystems. All data are collected while the orbit should be sent in the same packet initialized by HB trigger.
  - **Data packetizing.** Data should be wrapped with RDH (Raw Data Header), each packet should not exceed 8K.
  - **Data test generators.** CTP trigger messages as well as PM, TCM data could be generated by internal emulators for stand-alone tests.

[1] Fast Interaction Trigger for the upgrade of the ALICE experiment at CERN: design and performance. EPJ Web of Conferences 204, (2019) Published in **EPJ Web Conf. 204 (2019) 11003** DOI: 10.1051/epjconf/201920411003
[2] AD Upgrade for LHC Run 3 The ALICE Forward Diffraction Detector (FDD)
[3] Fully integrated digital readout for the new Fast Interaction Trigger for the ALICE upgrade https://doi.org/10.1016/j.nima.2019.02.047
[4] ALICE Trigger System Design Review https://wiki.to.infn.it/lib/exe/fetch.php?media=elettronica:projects:alice:ctpreview.pdf
[5] GBTX manual http://cern.ch/proj-gbt