

# Implementation of the data acquisition system for the Overlap Modular Track Finder in the CMS experiment

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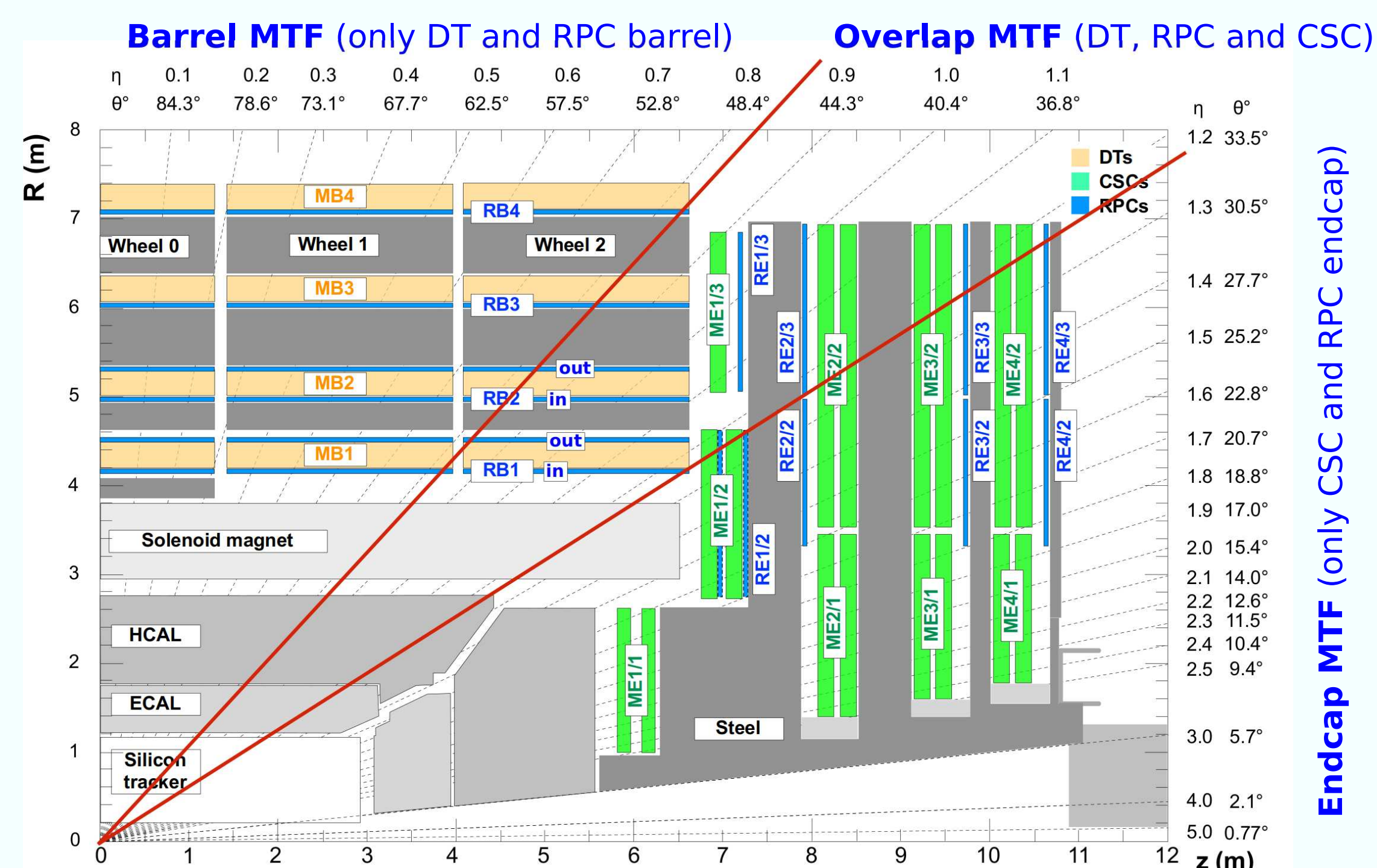
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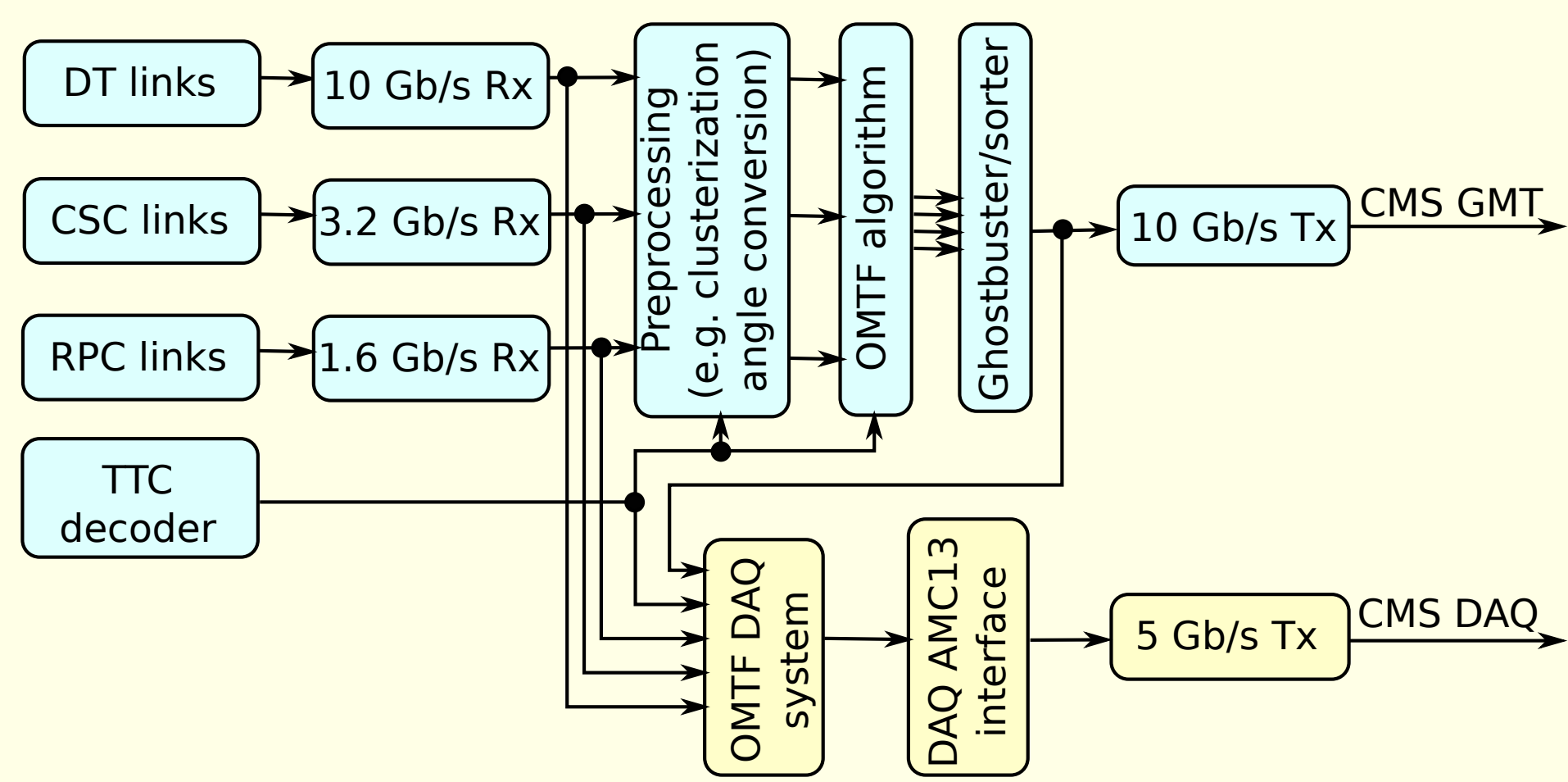
## Introduction

Compact Muon Solenoid (CMS) is one of the experiments at the Large Hadron Collider (LHC) at CERN.

After the successful operation in years 2010-2012, which resulted in the discovery of Higgs boson, it is currently undergoing the upgrade of its trigger, including the Level-1 muon trigger [1]. In the barrel-endcap transition region (see the Figure below) it is possible to combine signals from 3 types of muon detectors - RPC, DT, and CSC. The Overlap Muon Track Finder (OMTF) is a dedicated electronic system analyzing the data received from those detectors and finding trigger muon candidates. The result of the OMTF processing is transferred to the CMS Level-1 Global Muon Trigger.



## OMTF data acquisition system (OMTF DAQ)



The OMTF DAQ is implemented together with the OMTF trigger algorithm [2] in the MTF7 MTCA board [3, 4]. The OMTF DAQ transmits to the CMS data acquisition system (CMS DAQ) the data, that were the source of the trigger decision, to monitor the trigger operation. Data from all detectors are concentrated, subjected to zero-suppression, and transmitted via AMC13 board located in the same MTCA crate.

## Data triggering

The system should record only the data originating from the "triggered" BXes in which the L1A signal was asserted. However, to increase the diagnostic power of the system, it is possible to define how many BXes before the L1A (up to 3) and how many BXes after the L1A (up to 4) should be recorded. Each recorded BX (RBX) in the event receives its "short, relative BX number" (SBXN - between 0 and 7). The BX in which the L1A was asserted has SBXN=3. The trigger rules limit the L1A rate to "no more than 1 trigger in 3 BX's, 2 in 25, 3 in 100, 4 in 240" [5]. That means that two assertions of L1A may occur so near, that a few BXes may belong simultaneously to two events. The example of such situation is shown in the figure below. To handle that, the RBX record contains two fields, describing the association of the recorded BX with one L1A. The consecutive L1As are bound alternately to one of those records. This binding also defines the output FIFO used for the particular event in further processing.

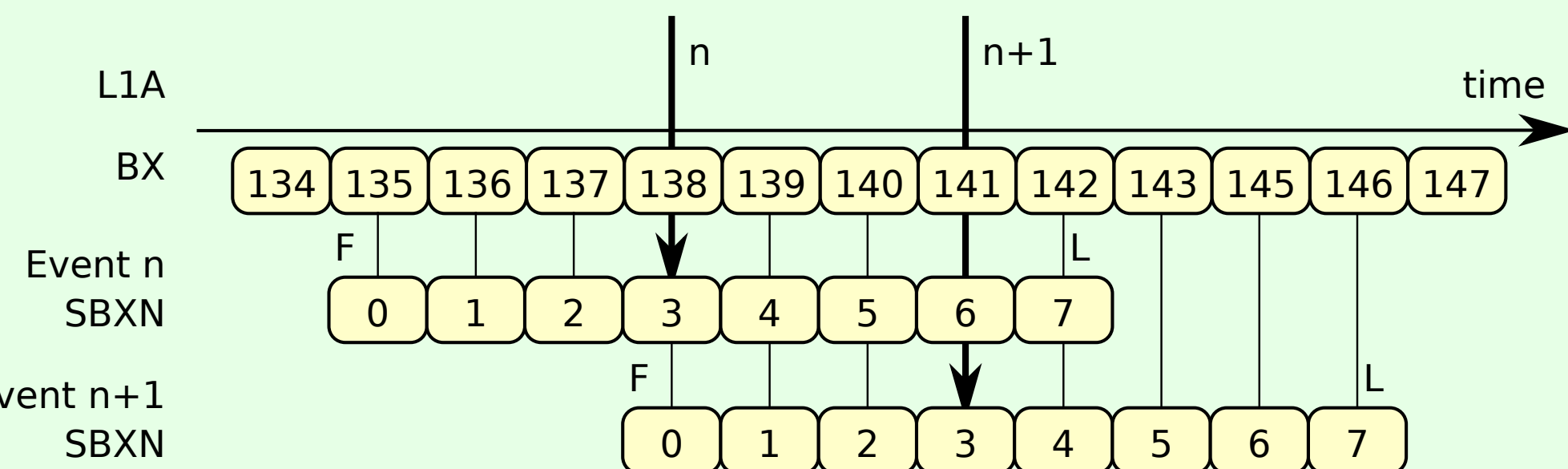


Diagram showing the selection of RBXes. The system is configured to record 3 BXes before the L1A and 4 BXes after the L1A. The case with overlapping events is shown, where certain BXes belong to two events simultaneously. Attributes "F" (first) and "L" (last) are used in the event building process.

## Common data format

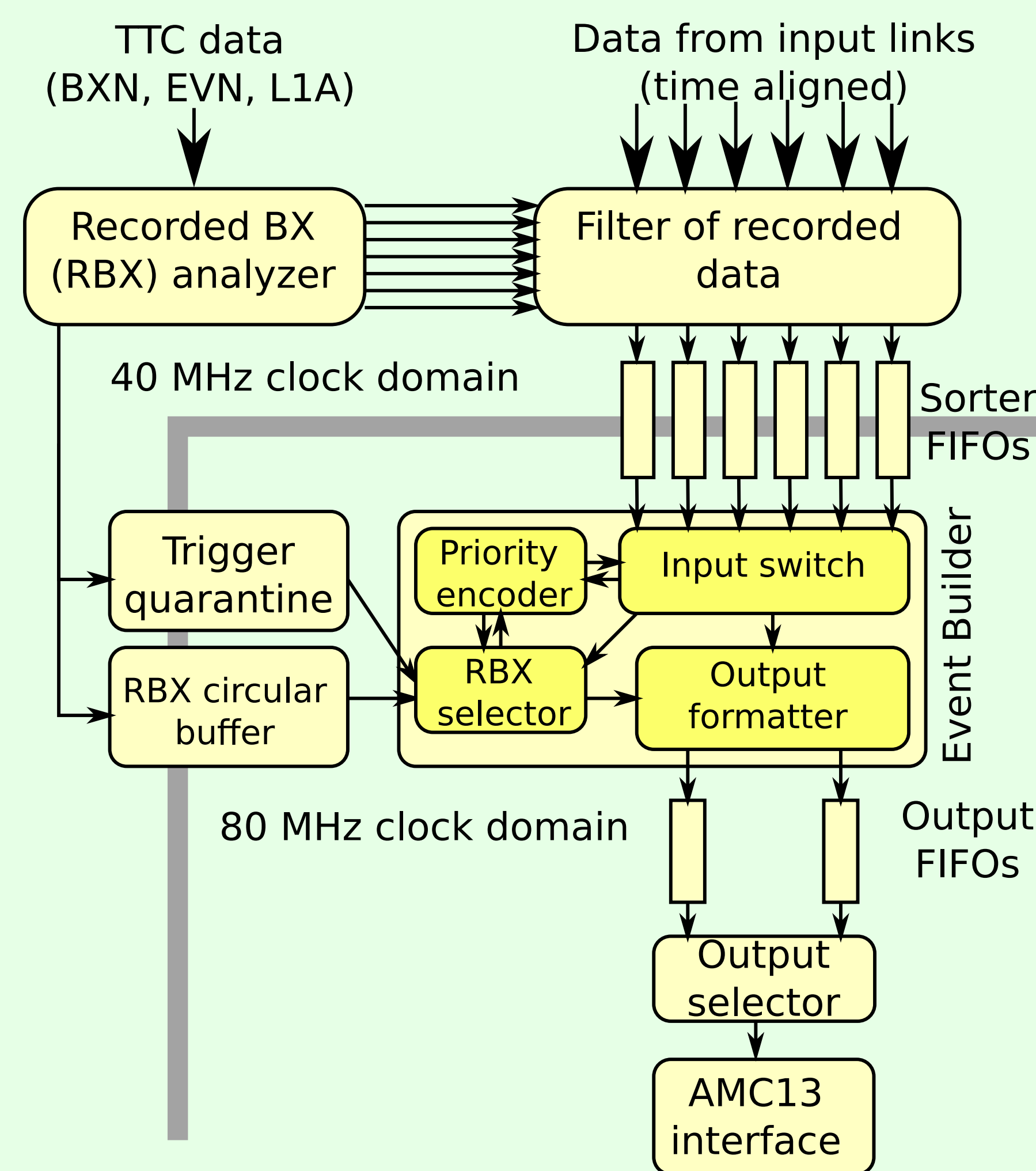
The AMC13 board requires that event data from all sources handled by a single MTF7 board be transmitted in a single event container as a payload consisting of 64-bit words [6]. To simplify analysis of DAQ data, it is assumed that each payload word may be analyzed independently. Therefore each word contains the 4-bit type identifier describing its type and 3-bit SBXN describing its time position (The event header contains the number of BX in which the corresponding L1A occurred). The only

General	Type	SBXN	Type specific data
OMTF	0xf	SBXN	OMTF result with $p_T$ , quality etc.
RPC	0xe	SBXN	Link no. Data 0. Data 1. Data 2.
DT	0xd	SBXN	DT data incl. link number
CSC	0xc	SBXN	CSC data incl. link number
Firmware	0x0	Ver.1	[...] Ver.n

exception is the "Firmware" word that contains the least significant bits of versions of different components of the firmware. Currently, only 5 types are used, but to allow further extensions, 4 bits are allocated for type identifier.

## Implementation of the DAQ

The implementation and operation of the DAQ is shown in the figure. The input data and TTC signals are properly aligned in time using the shift registers. The L1A signal marks some BXes as "recorded" (RBX). Data originating from recorded BXes after passing the zero-suppressing input filter are written into sorter FIFOs. The created RBX descriptors are also written into the RBX circular buffer.



The "RBX selector" extracts available RBXes from the circular buffer and processes them. The "Trigger quarantine" block ensures that processing of RBX does not start before the associated data should be available on outputs of sorter FIFOs. The "Priority encoder" selects the first input providing data for requested RBX. If no input offers such data, the encoder requests to process the next RBX. The "Input switch" transfers the payload data from the selected input to the "Output formatter". The "Output formatter" uses the RBX data to build events in the AMC13 format. If the RBX is marked as "first", the Output formatter writes the event header to the appropriate output FIFO before the payload data. If the RBX is marked as "last", the Output formatter writes the event trailer after the payload data. The "Output selector" reads complete events from both output FIFOs alternately (the FIFO used is switched after the event trailer is transferred) and sends them via "AMC13 interface" to the CMS DAQ.

## Flexibility of the design

The presented DAQ system may be easily extended. Currently implemented features provide support both for data sources producing a single word per link in each BX, and for sources producing multiple data words in each BX, and delivering them with a certain delay (like RPC). Adding a new data source requires:

- Implementing the filter deciding whether the particular data word originating from a recorded BX should be transmitted to DAQ (zero-suppression).
- Implementing the formatter, that packs the received data into the sorter queue, and converts the data on the output of the sorter queue into the 64-bit words in common data format, that may be used as payload in the event.

The number of handled RPC, CSC and DT inputs is parametrized and may be easily changed. The design may also be adjusted to possible changes in operating conditions of the experiment. For example, if the trigger rules are changed so that a single RBX may belong to three events simultaneously, the RBX record may be extended to contain three fields associating it with three consecutive L1As. Of course, this modification requires also adding the third output queue. The scalability of the design is limited by the resources available in the FPGA.

## Results

Currently, the OMTF DAQ has been tested in hardware with RPC links and has been found to work correctly at trigger rates up to 120 kHz.

Handlers for CSC and DT links are under development and are tested in simulations.

The full OMTF firmware, containing both OMTF trigger and OMTF DAQ was successfully synthesized for the XC7VX690T chip available in the MTF7 board. The chip occupancy is as follows:

- Slice LUTs: 64.28% (278460 from 433200 available)
- Slice Registers: 29.48% (255458 from 866400 available)
- Block RAM tiles: 64.76% (952 from 1470 available)

## Acknowledgement

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## References

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