An extension to the Analytical Method clustering algorithm for BMTL1 benefitting from CMS RPC timing

Ece Asilar[1]*, Javier Fernandez Menendez[2], Raphael Gomes de Souza[3]* on behalf of CMS Collaboration

[1]Hanyang University - South Korea, [2]Universidad de Oviedo - Spain, [3]Rio de Janeiro State University - Brazil. email: raphael.souza@cern.ch

1 Introduction

Trigger primitives (TP) are the first-level processed signals that are generated directly from the raw detector hits in real-time. They are crucial for the Level-1 (L1) trigger system, which is responsible for making rapid decisions (within a few microseconds) about whether to keep or discard an event based on whether it contains interesting physics, providing quick and efficient information about potential muon candidates. In this work, we present improvement of the TP in the so-called super-primitives, with time parameter upgraded using the RPC measurement. The presentation shows the description of the analytical method used to build the Drift Tubes (DT) TP and the impact of the inclusion of the Resistive Plate Chambers (RPCs) in the trigger primitives timing.

CERN, LHC and CMS

CERN is the largest particle physics laboratory in the world, with a big and complex accelerators system. The Large Hadron Collider (LHC) collides beams of protons at center of mass energy that can reach 13.6 TeV. There are four major experiments: LHCb, ALICE, ATLAS and CMS (*Compact Muon Solenoid*). The CMS experiment at CERN is composed of several types of particle detectors, each designed to measure different properties of particles produced in high-energy collisions. The main subdetectors in CMS are: Tracker, Electromagnetic Calorimeter (ECAL), Hadron Calorimeter (HCAL) and Muon System. The muon system in the CMS experiment at CERN is composed primarily of three types of gas-ionization detectors: Drift Tubes (DTs), Cathode Strip Chambers (CSCs) and RPCs. DT chambers are used in the central (or barrel) region characterized by $|\eta| < 1.2$ and they are complemented by a system of RPCs. The barrel chambers are arranged in four muon stations (MB1, MB2, MB3, MB4). Along the beam axis conventionally, DTs and RPCs are divided into 5 slices, called wheels (W-2, W-1, W0, W+1 and, W+2).

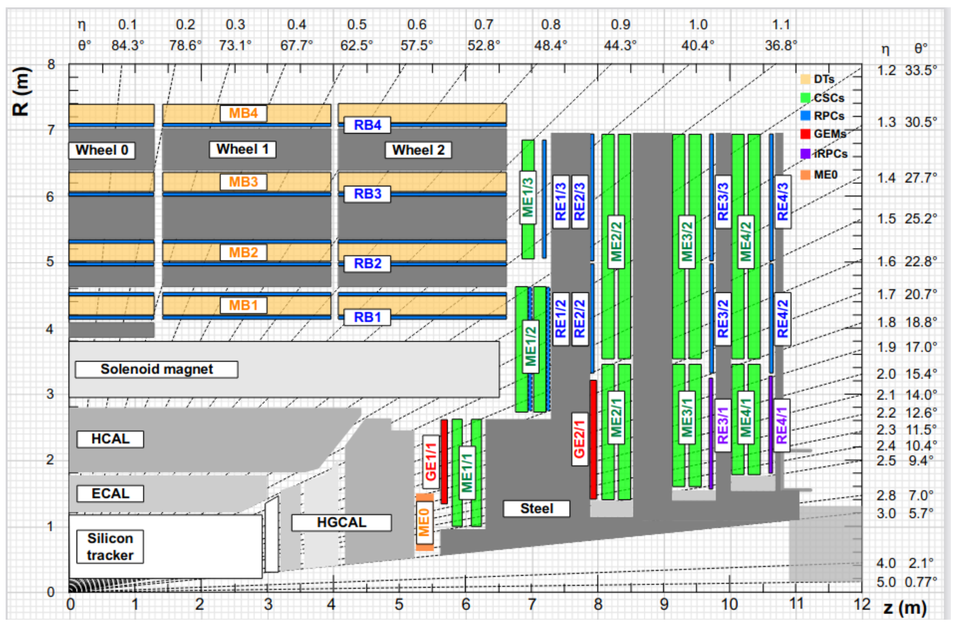
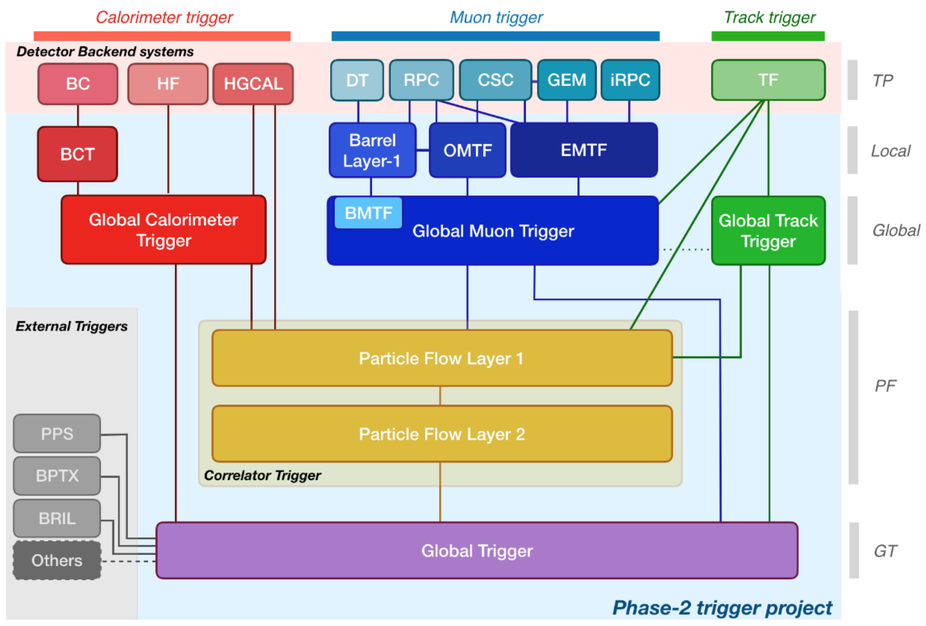


Figure 1: Schematic longitudinal view of one quarter of the CMS detector with the different subsystems which compose the Muon Detector for the Phase-II upgrade of LHC [1].

CMS Level-1 trigger

The CMS Level-1 trigger is a crucial component of the CMS experiment at CERN. It is responsible for rapidly selecting and filtering particle collision events of interest from the immense amount of data produced by the LHC. The CMS Level-1 trigger acts as the first stage of the CMS data selection process. It evaluates collision events in real-time, quickly identifying those that potentially contain interesting physics phenomena, such as rare particle decays or high-energy interactions. TP are used immediately in the L1 trigger system to make rapid decisions about event selection. They are formed by combining raw hits in individual muon chambers (like DT, CSC, or RPC) into basic elements that describe a potential muon track.



Functional diagram of the CMS L1 Phase-2 upgraded trigger design [2].

The Analytical Method (AM) algorithm

An algorithm based on analytical solutions for reconstructing the DT trigger primitives, called Analytical Method, has been implemented both as a software C++ emulator and in firmware [3]. The TP have the muon candidates position, direction, and collision timing, and serve as inputs for the Level-1 (L1) CMS trigger system. The algorithm can be logically separated into different steps:

- Grouping step;
- Fitting step;
- Correlation step;
- Confirmation step.

In the final step, data from the RPC can be incorporated to create what are known as super-primitives, with the time parameter enhanced using the RPC measurements.

Results

After the generator matching that were used to make sure that the TP was associate with a generated muon, the time distribution of the TP was plotted.

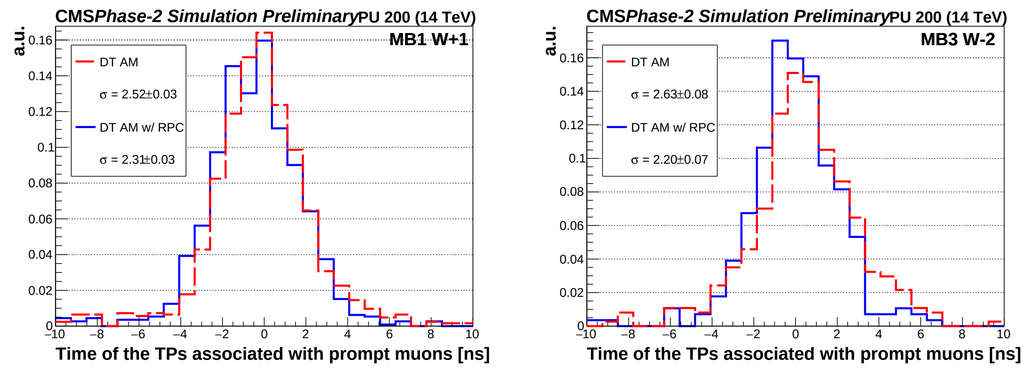


Figure 2: LEFT: The timing distribution of the trigger primitives associated with a generated muon with DT AM (Analytical Method) (Red line) and DT AM + RPC (Blue line) for the station 1 and wheel +1 (MB1 W+1). RIGHT: The timing distribution of the trigger primitives associated with a generated muon with DT AM and DT AM + RPC for the station 3 and wheel -2 (MB3 W-2).

Conclusion

In this work, we have demonstrated an enhancement to the DT trigger primitives by building super-primitives with an upgraded time parameter utilizing the RPC measurement. The timing distribution of the trigger primitives associated with a generated muon with DT AM (Analytical Method) and DT AM + RPC shows that for the DT+RPC super-primitives time distribution has better resolution.

References

[1] CMS Collaboration. CMS RPC background studies and measurements. 2020. DOI:10.1088/1748-0221/16/04/C04005.

[2] CMS Collaboration. The Phase-2 Upgrade of the CMS Level-1 Trigger. 2020.

[3] CMS Muon Group. The Analytical Method algorithm for trigger primitives generation at the LHC Drift Tubes detector. 2023.