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A comparison of trigger efficiencies for DT, CSC and RPC triggers using $W \to \mu\nu$ sample

Archana Sharma *, Suman B. Beri

Physics Department, Panjab University, Chandigarh, India

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ABSTRACT

Muons are expected to provide clean signature for a wide range of physics processes. In addition to identify the muons and the precise measurement of their momentum, muons system provides fast information of triggering—a challenging problem at LHC. There are two sets of muon detectors: wire chambers (drift tubes and cathode strip chambers) and resistive plate chambers. At the L1 trigger, two systems are completely independent and can run in standalone mode. This work presents the trigger efficiencies and comparison for all these three types of triggers using the sample $W \to \mu\nu$. The Resistive Plate Chambers (RPC), Drift Tubes (DT) and Cathode Strip Chambers (CSC) geometry version implemented in new CMSSW releases have been used.

1. Introduction

When the LHC collision occurs, large number of events will be produced, from which interesting events should be selected, one of the most difficult task for any experiment at the LHC. The LHC bunch crossing rate of 40 MHz leads to approximately 10^9 interactions per second at design luminosity of $10^{34}\,\mathrm{cm^{-2}\,s^{-1}}$. The task of the Trigger and Data Acquisition System (DAQ) is to analyze the full set of instructions occurring in every bunch crossing, identify the presence of an interesting interaction and write on permanent memories the data related to the bunch crossing for all detectors.

2. Level-1 trigger

The maximum recording rate capability of the Compact Muon Solenoid (CMS) on-line computer farm is 100 Hz, hence the rate reduction that has to be achieved is $40\mathrm{MHz}/100\,\mathrm{Hz} = 4.10^5$. This is done by two steps: Level-1 trigger (L1 trigger) and high level trigger (HLT). The Level-1 triggers involve the calorimetry and muon systems as well as some correlation of information q between these systems. So the major components of L1 trigger system are: the L1 Calorimeter Trigger, the L1 Muon Trigger [1] and the L1 Global Trigger. The Muon system is further organized into subsystems representing the three different muon detector systems, the Drift Tubes (DT) Trigger in the barrel, the Cathode Strip Chambers (CSC) Trigger in the endcap and the Resistive Plate Chambers (RPC) Trigger covering both barrel and endcap up to $\eta = 2.1$. The L1 Muon Trigger is also called Global Muon Trigger (GMT) which combines the trigger information from the DT, CSC and RPC trigger systems and send this to the L1 Global Trigger. The functional relations between the components of the muon trigger systems are shown in the Fig. 1. Some data is exchanged between DT and CSC in the region around $\eta = 1.0$. In this way the Barrel track finder covers $|\eta| < 1.04$ whereas the endcap track finder covers $1.0 < |\eta| < 2.4$. The RPC trigger covers both barrel and endcap but only upto $\eta = 2.1$.

DT and CSC electronics first process the information from each chamber locally. Therefore, they are called Local Triggers. As a result vectors (position and angle) are delivered by each station. Vectors from different stations are collected by track finder which combines them to form a muon track and assign transverse momentum value. Up to four best (highest p_t and quality) muon candidates from each system are selected and sent to the GMT.

In case of RPC there is no local processing apart from synchronization and cluster reduction. Hits from all stations are collected by the so called Pattern Comparator Trigger (PACT) logic [2]. If they are aligned along a possible muon track, a p_t value is assigned and the information is sent to the muon sorter. The RPC muon sorter selects the four highest p_t muons from the barrel and four from the endcap and send them to the GMT. The GMT compares the information from the DT/CSC Track Finder and RPC PACT. The four highest p_t muons in the whole event are then transmitted to the Global Trigger.

2.1. DT trigger

The drift chambers deliver data for track reconstruction and triggering on different data paths. The local trigger is based on two Super Layers (SL) in the ϕ view of the muon station. The trigger

*Corresponding author.
E-mail address: archie.sharma@cern.ch (A. Sharma).

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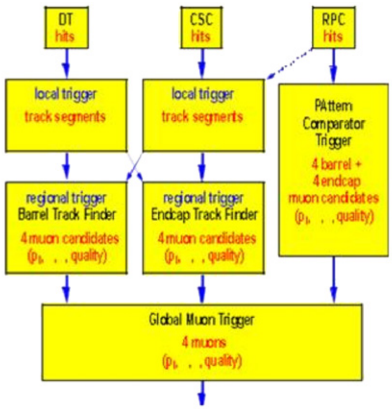

Fig. 1. Muon Trigger data flow.

front-end device, which is directly interfaced to the wire front-end electronics, is called Bunch and Track Identifier (BTI). BTI performs the bunch crossing assignment of every found muon track segment candidate. The algorithm used in the device is a generalization of the mean timer method [3]. Since this method must foresee alignment tolerance and needs to accept alignments of only three hits, the algorithm can generate false triggers. Hence in the bending plane of a system composed by a Track Correlator (TRACO) and a Chamber Trigger Server (TS) is used to filter the information of the two ϕ SLs of a chamber in order to lower the trigger noise. Track segment found in each station are then transmitted to a regional trigger system called DT Track Finder. The track finder connects track segments delivered by the stations into a full track and assign a p_t value to the finally resolved muon track. The system is divided in sectors, each of them covering 30° in the ϕ angle. The sector processors are organised in twelve wedges along the η coordinate. Each sector processor is logically divided in three functional units: the Extrapolator Unit, the Track Assembler and the Assignment Unit.

The Extrapolator Unit attempts to match track segments pairs of distinct stations. Using the spatial coordinate ϕ and the bending angle of the source segment, an extrapolated hit coordinate may be calculated. The Track Assembler attempts to find at most two tracks in a detector sector with the highest rank, i.e. exhibiting the highest number of matching track segments and the highest extrapolation quality. As a last step, the Address Assignment sub-unit extracts the corresponding track segment data from the data pipeline and forwards them to the Assignment Unit. Once the track segment data is available to the Assignment Unit, memory based look up tables are used to determine the transverse momentum, the ϕ and η coordinates, and a track quality. At least two segments from different stations are required to find a muon. Each Sector Processor forwards the two best ranking candidates to the Wedge Sorter, which selects the two track candidates with the highest p_t. Each of the 12 Wedge Sorters send the muon candidates to the Muon Sorter, which reduces the number of split tracks performing a check over the neighboring wedge candidates. The four highest momentum tracks are selected and then forwarded to the GMT for the final decision.

2.2. CSC trigger

At large rapidities, high backgrounds are expected from pions, primary muons, secondary muons and neutron induced gamma rays. The high rapidity muons also have higher momentum corresponding to a particular p_t and hence radiate more. CSC Local Triggers provides high rejection power against these background by finding muon segments, also referred to as Local Charged Tracks (LCTs), in the 6-layer endcap muon CSC chambers. Muon segments are first found separately by anode and cathode electronics and then time correlated, providing the precision measurement of bend coordinate position and angle. The primary purpose of the CSC anode trigger electronics is to determine the exact muon bunch crossing with high efficiency where as the primary purpose of the CSC cathode trigger electronics is to measure the ϕ coordinate precisely to allow a good muon momentum measurement up to high momentum.

Cathode and anode segments are brought into coincidence and sent to CSC Track Finder electronics which links the segments from the endcap muon stations. Each Track Finder unit finds muon track in a 60° sector. Because of the limited bending in the endcap region, information is not shared across sector boundaries. Each CSC track finder can find up to three muon candidate. The CSC muon sorter module selects the four best CSC muon candidates and send them to the GMT. Quality is assigned according to the number of segments used in the track: three or more segments correspond to quality 3, two segments, one of them coming from ME1, gives quality 2, any two other segments result into quality 1.

2.3. RPC muon trigger

RPC [4,5] has been chosen in both the barrel and endcap as dedicated trigger detectors. Because of their fast response and good time resolution, they guarantee a precise bunch crossing assignment of the muon tracks. The barrel muon stations are equipped with two RPC layers for the innermost stations (RB1 and RB2) and one layer for the outer stations (RB3 and RB4) for a total number of 6 layers per sectors. The endcap are instrumented with one RPC layer per station for a total number four layers. The idea of the RPC based trigger for CMS is illustrated in Fig. 2. The solenoidal fields bends tracks in the rϕ plane. A pattern of hits recorded by the RPCs carries the information about the bending and can be used to determine the p_t of the track. This is done by comparison with a predefined set of patterns corresponding to various p_t^{cut}. The RPC based muon trigger operates on four (logical) trigger planes chosen (direction dependent) out of possible (hardware) RPC chambers from barral and endcaps of the CMS detector. There is one RPC plane in each muon except RB1 and RB2. These stations contains additional planes referred to as RB1′ and RB2′. They are used to trigger on low momentum muons ($p_t < 6\,\text{GeV}$) which cannot reach RB3 and RB4. The RPC system covers the η-range up to $|\eta| = 2.1$. RPCs are read out by strips covering $\Delta\eta = 0.1$ and $\Delta\phi = \frac{5}{16^\circ}$ each. If the signal is shared by more than two strips the cluster size is reduced by removing extreme strips. In the case of low p_t tracks, since the resolution is limited by multiple scattering, the strips are grouped by 2, 4 or 8, depending on the momentum. The baseline algorithm always works on 4 planes. In the case of $p_t > 6\,\text{GeV}$ only one plane per station is used. For muons with $p_t < 6\,\text{GeV}$ in the barral the 4 inner planes are used: RB1, RB1′, RB2, RB2′ [6].

The basic logical unit of PACT, called segment, is handled by single PAC (Pattern Comparator) processor. It is defined by 8 strips

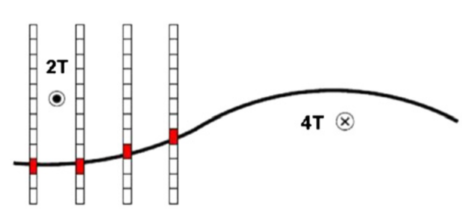

Fig. 2. The basic principle of the RPC muon trigger.