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Issues Related to the Separation of the Barrel and Endcap Muon Trigger Track-Finders

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Abstract

Requirements are specified for the barrel and endcap Muon Trigger Track-Finders to ensure efficient coverage of the overlap region between the barrel and endcap muon systems and to avoid duplication of triggers.

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1 Introduction

It has been decided recently that the barrel and endcap muon trigger systems will have separate Muon Trigger Track-Finders (MTTF) for the formation of the Level-1 muon trigger [1]. The task of the MTTF is to find muon tracks originating from the interaction point and to measure the transverse momentum (P_T), pseudo-rapidity (η), and azimuthal angle (ϕ) of each muon. Although this task is the same for the barrel and endcap muon systems, the optimization of the design of the MTTF is significantly different for each muon system because of the different logical partitioning of the trigger primitives and the non-axial magnetic field in the endcap region. Details of these differences are outlined in Sec. 2.

The boundary between the barrel and endcap muon trigger systems must be handled with care to avoid duplication in the trigger system, which otherwise would create secondary ghost tracks. A single muon in the region of overlap between the barrel and endcap muon systems should rarely lead to two muon tracks sent to the Global Muon Trigger, otherwise a di-muon trigger would be difficult to implement. Also, to avoid introducing unnecessary complication to the design and latency of the Global Muon Trigger itself, the issue of duplication should be solved by the MTTF of each system.

Therefore, it is proposed that a line of demarcation in η be drawn between the two muon systems, and each MTTF is allowed to report muons only in its respective trigger region. This boundary in η, however, should be programmable over the region of overlap between the barrel and endcap muon systems: $0.9 < |\eta| < 1.2$.

It is proposed also that each muon system send a subset of the trigger primitive data to the other muon system so as to achieve efficient coverage of the overlap region. As can be seen in Fig. 1, this implies that trigger primitives from MB2/1 and MB2/2 are sent to the endcap MTTF processors, and trigger primitives from ME1/3 and ME2/2 are sent to the barrel MTTF processors. The issues related to this data exchange are addressed in Sec. 3 of this document, as are solutions to achieving a fixed boundary in η between the two muon trigger systems and proper ordering of the muon candidates.

2 Formation of the Level-1 Muon Trigger

2.1 Barrel Primitives

The CMS muon system [2] in the barrel region is partitioned in five **wheels** in the z–direction and in twelve 30 degree **wedges** in the azimuthal direction, resulting in a total of 60 η–ϕ **sectors**. Each sector consists of 4 muon stations in the radial direction. A muon station contains three driftchamber modules (superlayers), consisting of 4 **Drift Tube (DT)** layers. The outer two superlayers (r–ϕ) measure the ϕ–coordinate in the bending plane. The middle superlayer (r–z) measures the z–coordinate, but it is omitted from the outermost station.

For each superlayer the trigger front-end devices, **BTI (Bunch- and Track Identifiers)**, generate a trigger when at least three hits are aligned along a valid track pattern. In the ϕ–view the track stubs eventually found by the BTIs in the inner and outer superlayer, are correlated by the **Track Correlators (TRACO)**. Each TRACO selects up to two **track segments**. A track segment consists of a position, an angle and a quality code (indicating the number of hits used to form the track segment). The position gives the location of the hit in the chamber and the angular value is the angle of the crossing track with respect to the detector radius. Among the track segments found by all TRACOs in a chamber, the **Trigger Server** selects the two best segments and transmits them to the MTTF. The entire system is composed of $12 \times 5 \times 4 = 240$ Trigger Servers. Hence 480 track segments from the ϕ view are delivered to the **barrel Muon Trigger Track-Finder** [3].

2.2 Endcap Primitives

The endcap regions of the CMS muon system are each composed of three stations (ME1–ME3) of **cathode-strip chambers (CSC)** separated in z, although there is a possibility that a fourth station (ME4) could be re-scoped later. A single station is composed of six layers of CSC chambers. A single layer has radial strips and wires aligned in the orthogonal direction.

Local Charged Tracks, or **LCTs**, form the trigger primitives of the endcap muon system. Both cathode and anode front-end trigger cards search for valid patterns from six wire and strip planes of the CSC chamber. The anode data provide precise timing information as well as η information, and the cathode data provide precise ϕ information. Comparators on the cathode cards localize a hit cluster to within a half strip. The **Trigger Motherboard** collects this information, associates the wire data to the cathode data, tags the bunch crossing time, and then sends the two best candidates to a **Muon Port Card (MPC)**. For stations ME2 and ME3, each MPC collects trigger primitives from nine chambers, which corresponds to a 60° sector in ϕ. For station ME1, each MPC collects trigger primitives from nine chambers in a 30° sector for $|\eta| < 2.1$, or eight chambers in a 20° sector for $|\eta| < 2.4$ (the exact implementation depends on whether the innermost region of ME1/1 participates in the trigger). The MPC then sends the three best LCTs per sector (two in the case of 20° ME1 sectors) for a total of 144 LCTs to the **endcap Muon Trigger Track-Finder** [4].

2.3 Muon Trigger Track-Finder

Both the barrel and endcap MTTF will be located in the counting house, and the trigger primitives will be sent via optical links from the Trigger Server/Port Card. The input track segments are first received, synchronized reformatted and distributed in a **Sector Receiver (SR)**, then processed by a **Sector Processor (SP)** where the track-finding is done. (These functions are separated into two cards in the endcap system, but may not be physically separated in the barrel system.)

The detailed implementation of the Sector Processor will differ between the barrel and endcap muon systems. The non-projective nature of the DT chambers in η, the staggering of the chambers in ϕ, and the large bending imply that a large number of inputs will need to be sent from neighboring sectors to a Sector Processor. In contrast, the CSC chambers project in ϕ, and the MPC effectively removes the boundary in η between chambers. So a CSC Sector Processor inherently accepts fewer trigger primitives per sector since it is not necessary to include any neighboring sectors. This is offset by the fact that the endcap MTTF must account for the non-axial magnetic field, which implies that the P_T assignment as well as the track extrapolation must use η and ϕ information.

Not more than 2 (3) muon candidates are delivered from each barrel (endcap) Sector Processor. These muon candidates have to be sorted in some way in order to reduce the number of muon candidates transmitted to the Global Muon Trigger [5]. The Global Muon Trigger then associates the barrel and endcap muon candidates with RPC muon candidates, and sends the best 4 muons to the Global Level-1 Trigger.

3 Implications and Responsibilities

3.1 Exchange of Trigger Primitives

The overlap region between the barrel and endcap muon systems ($0.9 < |\eta| < 1.2$) involves the following muon chambers: MB2/1, MB2/2, ME1/3, and ME2/2. Efficient identification of muons in this region requires that the Sector Processor of at least one of the MTTF designs receive these signals. Therefore, we propose that trigger primitive data from MB2/1 and MB2/2 are sent to the endcap MTTF, and data from ME1/3 and ME2/2 are sent to the barrel MTTF. This exchange should take place in the electronics counting house. Thus, the Sector Receivers which correspond to the overlap chambers of one MTTF fan out signals to the corresponding crate of the other MTTF.

The format of the data exchanged should be dictated by the designers of the MTTF which receives the data. A proposal for the bit field corresponding to each muon segment is given in Tab. 1. Note that η is not exchanged, since the barrel MTTF operates only on ϕ information. The total number of bits exchanged per muon is 25 bits. The number of bits sent for Ψ could be reduced since the CSC system has only 6 bits of resolution, not 10 like the DT system. In addition, a 4 bit bunch crossing number (one per Sector Receiver, not one per muon) should be sent to test for synchronization errors.

3.2 Definition of a Sharp Boundary in η

It is important that the two MTTF designs do not report the same muon to the Global Muon Trigger, otherwise the rate for a di-muon trigger will be too high. Extra latency and complication would ensue if this resolution occured in the Global Muon Trigger itself. Thus, each MTTF must have a sharp boundary in η beyond which it does not report any muons. This boundary should be programmable. Here we address solutions to this problem for each MTTF design.

The CSC trigger primitives always have an associated η and ϕ coordinate by design. Thus, a boundary in η can be achieved in one of two ways: either trigger primitives are suppressed in the Sector Receiver or Sector Processor if they belong to the region of the barrel MTTF, or the output of a muon is suppressed by the Sector Processor if the associated η value is not in the allowed region. Since the DT trigger primitives do not have necessarily associated

η information coming from the Trigger Server, the implication is that the endcap MTTF must require at least one matched track segment in the CSC system. Otherwise the η boundary would not be well-defined.

Only The DT trigger primitives from the ϕ view are delivered to the barrel MTTF. Therefore, η is inferred with a precision which varies from 0.04–0.4 solely from the barrel stations involved. The θ assignment may be improved by a separate processor [6], but the association is not guaranteed. Consequently, a sharp η boundary for the barrel MTTF must be defined implicitly by the barrel chambers associated with the track, or explicitly by the η coordinate of the CSC track segment used in the overlap region. So a criterion for a sharp η boundary from the barrel MTTF manifests itself as requiring that a track reach at least MB2/3 (for an approximate boundary at $\eta = 0.9$ as depicted in Fig. 2), or that the track segment used from the CSC system is in the allowed η region (Figs. 3, 4). The latter should be arranged to be always true for the barrel MTTF by requiring the CSC Sector Receivers to deliver only those track segments which come from the programmed η region of the barrel MTTF. Thus, if the η boundary is set between 0.9 and 1.05, the criterion for the barrel MTTF is that the muon candidate have at least one hit in MB2/3, MB2/4, ME1/3, or ME2/2. If the η boundary is programmed to lie between 1.05 and 1.2, MB2/2 could be allowed to be the terminus of the track without any CSC track segments.

3.3 Separate Ordering of CSC and DT muons

The muons selected by the Sector Processors must be sent to one or more sorters so that only the best 4 muons total of the DT, CSC, and RPC systems combined are delivered to the Global Level-1 Trigger. We propose that the barrel and endcap trigger systems separately sort the muons coming from the respective MTTF before combining the results of the two systems in the Global Muon Trigger. This leaves open the possibility that the each MTTF may have its own sort criterion. Moreover, it allows the design of the barrel muon sorter to include specific features, such ghost cancellation, which may not be applicable to the endcap muon system. However, the information sent from the separate sorters to the Global Muon Trigger should be the same (though not necessarily identical in format). This information is the P_T, η, ϕ, and quality of the muon candidates, and a proposed bit count of these fields is listed in Tab. 2.

References

[1] `http://sungraz.cern.ch/CMS/trigger/muonTrigger/Documents/Presentations/trig_rev_98_claudia.pdf`

[2] CMS, The Muon Project Technical Design Report, CERN/LHCC 97-32

[3] G.M. Dallavalle *et al.*, CMS Note 1998/042; A.Kluge and T.Wildschek, CMS Note 1997/091; A.Kluge and T.Wildschek, CMS Note 1997/092; A.Kluge and T.Wildschek, CMS Note 1997/093

[4] `http://www.phys.ufl.edu/~acosta/cms/trigger.html`

[5] N.Neumeister, P.Porth, and H.Rohringer, CMS-IN 1997/023

[6] `http://home.cern.ch/~mkloim/Present_Lyon.html`

Table 1: Information exchanged between the two Track-Finders.

variable	function	bits / muon
ϕ	Phi Coordinate	12
Ψ	Local Bend Angle	10
quality	Quality	3

Table 2: Information delivered to the Global Muon Trigger.

variable	bits	unit/precision
η	6	0.075 η unit
ϕ	8	$1.4°$
muon sign	1	—
p_T	5	nonlinear scale
quality	2	—

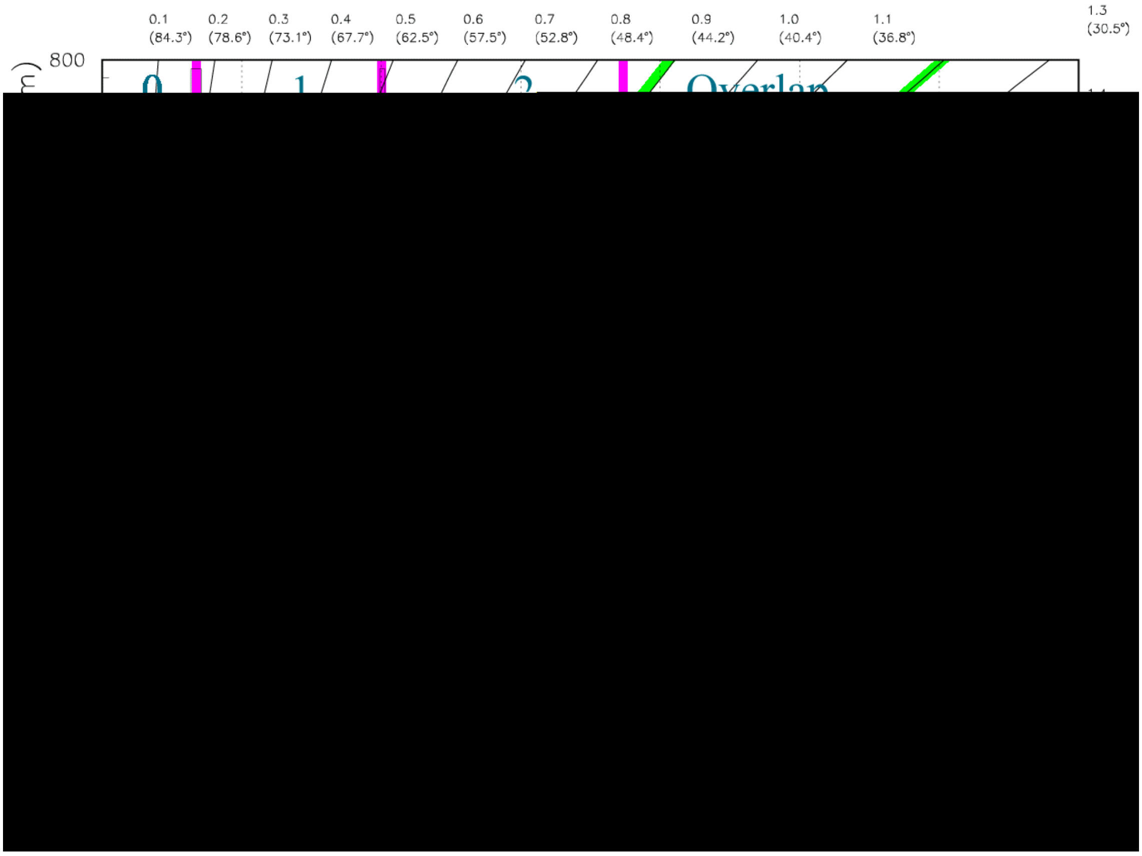

Figure 1: The CMS muon system.

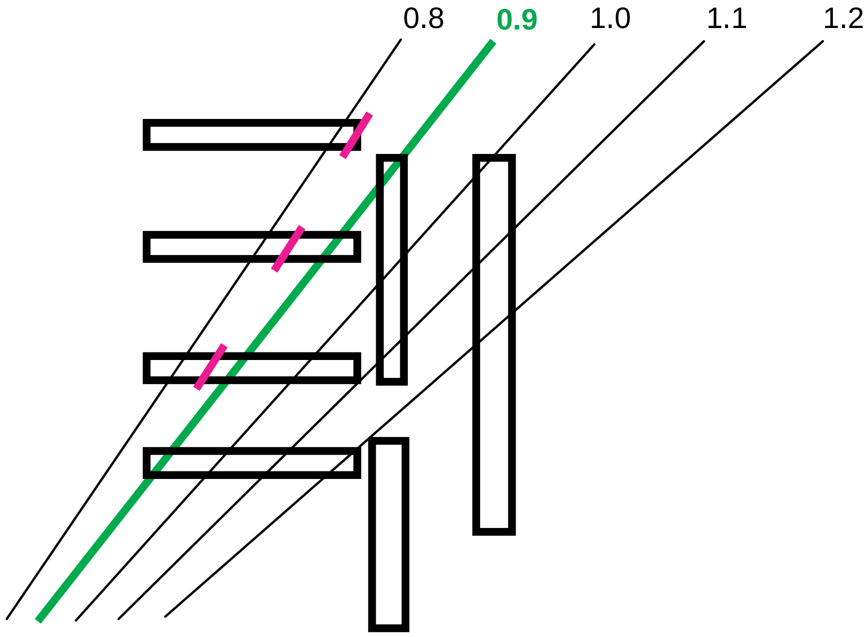

Figure 2: Illustration of the trigger system boundary set to $\eta \approx 0.9$. A track segment in MB2/3 or MB2/4 is required for a valid trigger in the outer wheel of the barrel system. Track segments in MB2/1 and MB2/2 may participate also.