New algorithms and performance for the Level 1 Muon Trigger of the CMS experiment targeting the Run 3 era of the LHC

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Abstract

The Level 1 (L1) Trigger system of the CMS experiment at CERN is a collection of FPGA based custom electronics. Its purpose is to provide early information about the results of the collisions inside the CMS apparatus and reduce the experiment output rate to manageable volume of data for further analysis. This talk will be focused on the latest algorithmic developments and their displayed performance for the muon systems during the Run 3 period (2022-2025), by also exploring the differences of the future approaches targeting the Phase 2 era of the LHC (HL-LHC). The L1 muon system consists of 3 main subsystems, the Barrel, the Endcap, and the Overlap Muon Track Finders (BMTF, EMTF, and OMTF respectively). Each one of these are responsible to reconstruct "muon candidates" for their respective part of the detector, the central part (BMTF), the edges (EMTF), and the area where they meet (OMTF). The L1 uses input information from detectors of 4 different technologies, Drift Tube chambers (DTs), Resistive Plate Chambers (RPC), Cathode Strip Chambers (CSC), and the lately added Gas Electron Multipliers (GEMs). Beginning from the end of Run 2 (2016-2018) and during the long shut-down of the LHC (2019-2021) groups in the L1 project improved the existing algorithms and incorporated new ideas in order to enhance the capabilities of the system on identifying new physics already from the L1 stage. Both the BMTF and the EMTF have already implemented algorithms that target also "displaced muons" (particles that don't originate from the center of the detector) and the OMTF is exploring ideas to extend their capabilities also to the displaced region. Moreover, the EMTF introduced several new enhancements in order to incorporate new information from the CSC and GEM detectors and also other ideas to enhance their system performance for the Run 3. Although these algorithms have been illustrated with high efficiency, good resolution, and low background rejection (the CMS experiment is physics generic), they

also serve as proof-of-concept exercises providing extremely useful information for the Phase 2 algorithms. Furthermore, the new capability to identify the so-called “displaced physics” at the L1 is a game changer for the CMS experiment during the Run 3 and afterwards. Existing already at the L1 stage, the displaced information enlarges significantly the available statistical power for the physics analyses that study final states with displaced objects because now the CMS is capable of producing dedicated datasets targeting specific analyses needs. Such analyses are searches for long-lived particles from scenarios beyond the Standard Model like supersymmetry or other exotic models. For these reasons we consider it important to also present the effectiveness of these new methods during the first 2 years of the Run 3. Finally, but equally significant, during Phase 2 the L1 system will be expected to cope with a more complex reconstruction environment. Thus, by taking advantage of this year’s higher luminosity test runs of the LHC, we investigate the limits of the current system by pushing it to slightly higher output rates (>100kHz), and also examine whether it is still capable of performing the triggering task effectively. These stress tests on the current system might be proven significant lessons on configuring the future system.