Trigger Rate Monitoring Tools for CMS

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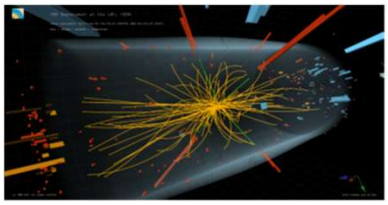
Compact Muon Solenoid (CMS)

- The CMS detector is one of the detectors on the LHC
- It is a general-purpose detector designed to measure the particles that come out of the proton-proton collisions



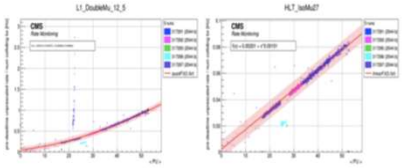
- Bunches of protons cross inside the CMS detector every 25ns or at a rate of 40 MHz
- The trigger system is designed to do a real-time analysis on the data to determine if it is interesting
- The trigger brings the event rate down to ~1 kHz

Trigger System

- The trigger system looks at the data to determine if it should be kept
- This system brings the event rate down to a reasonable 1 kHz allowing us to store data
- The trigger is further divided into subsystems:
  - The level 1 trigger - a hardware-based system that uses FPGAs to do high speed computation, does the first cuts. This brings the event rate 100k kHz
  - The high-level trigger - a software-based system comprised of ~30,000 CPU cores, does the final cuts bringing the event rate to 1 kHz

Trigger Rate Monitoring Tools

- Software is used to monitor the rates at which the different paths in the trigger decide to keep an event
- Abnormal trigger rates are often first signs that something is going wrong
- This software is designed to signal problems while the experiment is running and to validate the data



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**********
* TRIGGER NAME                                                    * ACTUAL [Hz]
COMMENTS
**********
Predictable HLT Triggers (ones we have a flt for)
**********
* HLT_IsoMu27                                                     * 56.25
* HLT_Mu17_TrkIsoVVL_Mu8_TrkIsoVVL_DZ                            * 0.35
* HLT_Mu23_TrkIsoVVL_Ele12_CaloIdL_TrackIdL_IsoVL                * 0.75
* HLT_Mu23_TrkIsoVVL_Ele12_CaloIdL_TrackIdL_IsoVL_DZ             * 0.58
* HLT_Ele23_Ele12_CaloIdL_TrackIdL_IsoVL_DZ                      * 9.29
* HLT_DoublePhoton70                                             * 4.73
* HLT_AK8PFJet200                                                * 1.42
* HLT_PFHT430                                                    * 0.50
* HLT_Photon200                                                  * 6.77
* HLT_CaloJet500_NoJetID                                         * 6.81
* HLT_PFJet450                                                   * 1.48
* HLT_Photon60_R9Id90_CaloIdL_IsoL_DisplacedIdL_PFHT350MinPFJet15 * 4.24
* HLT_DoubleEle33_CaloIdL_MW                                     * 6.46
* HLT_Ele40_WPTight_Gsf                                          * 44.62
**********
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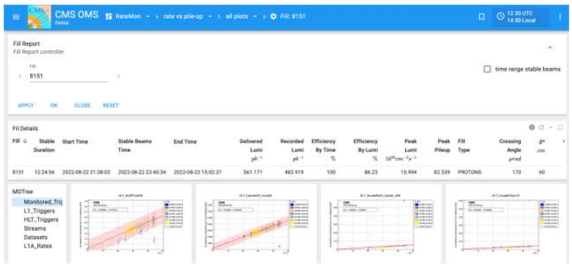
- This software is run 24/7 while the experiment is running and raises alarms if it finds abnormal trigger rates
- It also create rate vs. pile up plots to show if there are problems with runs
- Pile up is a measure of the number of collisions in a bunch crossing

Integration with Online Monitoring System (OMS)

- During the long shutdown, CMS moved to using the Online Monitoring System (OMS)
- Our rate monitoring tools have been migrated to query the OMS database for rate information
- Performed runtime optimization on database queries
- Setup cron job to make plots hourly to display on OMS webpage

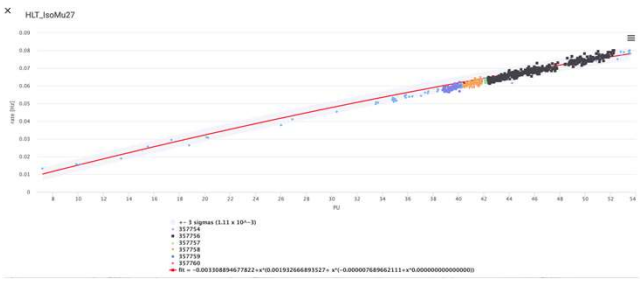


CI/CD Deployment and Automations

- Setup automatic CI/CD deployment to VM in control room network
- Setup systemd to allow 24/7 running of monitoring script on the control room network

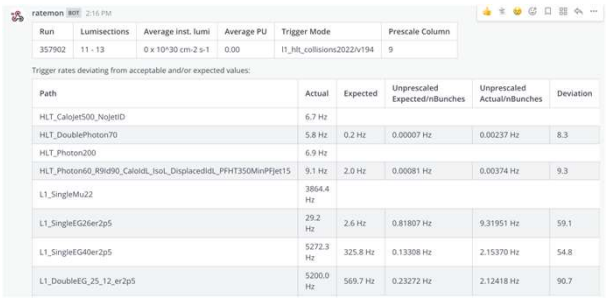
Restful API and Live Plots

- Setup Restful API to produce Rate vs. PU plots upon request
- This allows users to request Rate vs. PU plots live and up-to-date through the OMS webpage
- Produce live plots to allow users to zoom on desired sections



Alerts

- Created statistical fits based on known good data to make a standard on what the rates should be for certain pile-up values
- When deviating from this fit or hit other hard thresholds an alert goes out
- Setup alerts to go to mattermost (CERN chat system) to rapidly notifying on-call experts of the problem.
- These alerts include the threshold crossed and all relevant information on the current run



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Run	Lumisections	Average inst. lumi	Average PU	Trigger Mode	Prescale Column
357902	11 - 13	0 x 10^30 cm-2 s-1	0.00	l1_hlt_collisions2022/v194	9

Trigger rates deviating from acceptable and/or expected values:

Path	Actual	Expected	Unprescaled Expected/nBunches	Unprescaled Actual/nBunches	Deviation
HLT_CaloJet500_NoJetID	6.7 Hz				
HLT_DoublePhoton70	5.8 Hz	0.2 Hz	0.00007 Hz	0.00237 Hz	8.3
HLT_Photon200	6.9 Hz				
HLT_Photon60_R9Id90_CaloIdL_IsoL_DisplacedIdL_PFHT350MinPFJet15	9.1 Hz	2.0 Hz	0.00081 Hz	0.00374 Hz	9.3
L1_SingleMu22	3864.4 Hz				
L1_SingleEG26er2p5	29.2 Hz	2.6 Hz	0.81807 Hz	9.31951 Hz	59.1
L1_SingleEG40er2p5	5272.3 Hz	325.8 Hz	0.13308 Hz	2.15370 Hz	54.8
L1_DoubleEG_25_12_er2p5	5200.0 Hz	569.7 Hz	0.23272 Hz	2.12418 Hz	90.7

Acknowledgements

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