

Determination of the Trigger Scale Factors for a search for new light bosons decaying to muon pairs with 2018 Data (AN-19-153).

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1 Introduction

Our 4μ analysis is progressing well and we're at the point where we want to estimate the trigger scale factor. In our analysis we use a number of multi-muon triggers, both di-muon and tri-muon. In the previous iteration where we used a tri-muon trigger we employed the orthogonal method. In the current analysis we use a combination of triggers: HLT_DoubleL2Mu23NoVtx_2Cha, HLT_Mu18_Mu9_SameSign and HLT_TripleMu_12_10_5 and HLT_TrkMu12_DoubleTrkMu5NoFiltersNoVtxv. For the double muon triggers we could try using the tag-and-probe method if the single muon legs were included in the menu. For the two triple-muon triggers we were considering the orthogonal method, where we use data sets other than the DoubleMuon (e.g. MET, SingleElectron,...). Do you know if there are other options for tri-muon triggers? Also, what would be the best procedure is to estimate the overall trigger scale factor?

In your case, it looks too complicated to derive the overall trigger scale factor out of individual scale factors. It might be more realistic to measure the overall efficiency at once instead of breaking it down into individual trigger efficiencies. The reference trigger method [1] is popularly used to measure the efficiency of a mixture of multi-muon triggers, but it seems not applicable to your analysis as there are no shared legs (and also no corresponding control triggers I guess) of the same muon type among your triggers. For now I couldn't think of anything other than just measuring the overall trigger efficiency using the orthogonal method.

2 Methodology

We use several muon signal triggers as described in Sec. ???. The scale factor of the signal triggers will be estimated with the orthogonal method using three-muon events emulating WZ events as done in the previous iteration of this analysis [?]. The orthogonal method assumes that such events are mainly triggered by the substantial MET in the event topology, and therefore independent of muons selection criteria. The efficiency of the triple-muon trigger is determined on events passing a set of selection criteria optimized to select WZ events. This will be done both on data and on MC simulated events. The data are selected using a set of pure MET triggers in the MET dataset. MET triggers with one or more muons in the selection are ignored. MC events are simulated for the processes (1) $pp \rightarrow WZ$ and (2) $pp \rightarrow t\bar{t}Z$. The data and MC samples will be cleaned by selecting high-quality muons to obtain a set of well-reconstructed WZ -like events. The selection criteria are being derived from Ref. [?]. Data vs MC plots in the control region and plot of the efficiency of control region events to pass the signal trigger will be added soon.

3 Datasets

We use the MiniAOD samples shown below in Tab. 1. Additionally, we use WZ Monte Carlo and ttZ Monte Carlo datasets shown in Tab. 2. The cross sections were calculated with the GenXSecAnalyzer ¹.

Tab. 1: MET data samples for the trigger scale factor studies.

Dataset name	Number of events
/MET/Run2018B-17Sep2018-v1/MINIAOD	52,744,621
/MET/Run2018B-17Sep2018-v1/MINIAOD	29,714,277
/MET/Run2018C-17Sep2018-v1/MINIAOD	31,237,456
/MET/Run2018D-PromptReco-v2/MINIAOD	162,272,551
Total	275,968,905

Tab. 2: Monte Carlo samples for the trigger scale factor studies: $WZ \rightarrow 3l\nu$ process and $ttZ \rightarrow ll\nu\nu$ process.

Abbreviation	Dataset name	Events	Cross Section [pb]
WZTo3LNU1	WZTo3LNU_TuneCP5_13TeV-amcatnloFXFX-pythia8 /RunIIAutumn18MiniAOD-102X_upgrade2018_ realistic_v15-v1/MINIAODSIM	10,749,269	5.114 ± 0.075
WZTo3LNU2	/WZTo3LNU_TuneCP5_13TeV-amcatnloFXFX-pythia8 /RunIIAutumn18MiniAOD-102X_upgrade2018_ realistic_v15_ext1-v2/MINIAODSIM	11,248,318	5.120 ± 0.021
WZTo3LNU3	/WZTo3LNU_TuneCP5_13TeV-powheg-pythia8 /RunIIAutumn18MiniAOD-102X_upgrade2018_ realistic_v15_ext1-v2/MINIAODSIM	1,976,600	4.658 ± 0.005
WZTo3LNU4	/WZTo3LNU_mllmin01_NNPdf31_TuneCP5_13TeV _powheg-pythia8/RunIIAutumn18MiniAOD-102X_ upgrade2018_realistic_v15-v1/MINIAODSIM	89,479,400	62.17 ± 0.23
TTZToLLNuNu	/TTZToLLNuNu_M-10_TuneCP5_13TeV-amcatnlo- pythia8/RunIIAutumn18MiniAOD-102X_upgrade2018_ realistic_v15_ext1-v2/MINIAODSIM	13,280,000	0.2432 ± 0.0003

4 Event Pre-Selection

Events are pre-selected which have at least three muons with $p_T > 5$ GeV and at least one muon with $p_T > 12$ GeV, and are required to be in the run range specified in this JSON file Cert_314472-325175_13TeV_17SeptEarlyReReco2018ABC_PromptEraD_Collisions18_JSON.txt. Events with more than 3 muons with > 5 GeV are rejected. The pre-selection accepts 3.4% of the events in data, as can be seen in Tab. 3. Events in Monte Carlo are not pre-selected.

Tab. 3: 2018 MET Data pre-selection numbers

Sample	Total Events	Pre-selected Events
2018A	52,744,621	1,810,214
2018B	29,714,277	921,467
2018C	31,237,456	1,146,290
2018D	162,272,551	5,403,483
2018	275,968,905	9,281,454

¹ <https://twiki.cern.ch/twiki/bin/view/CMS/HowToGenXSecAnalyzer>

5 Event Selection

Events are required to pass at least one MET trigger (see Tab. 4). Each of these trigger applies a cut of at least 100GeV on the missing transverse energy in the trigger. In addition, events must have exactly three muons with $|\eta| < 2.4$ and with transverse momenta thresholds $40 : 40 : 10\text{ GeV}$. The thresholds have been chosen to reduce the nonprompt contribution. Two muons must have the same charge and one muon have the oppositely charge. Two event categories can thus be identified: $\mu^+\mu^+\mu^-$ and $\mu^+\mu^-\mu^-$. The muons must be prompt, i.e. $dxy < 0.01\text{ cm}$ and $dz < 0.1\text{ cm}$, and must pass the tight ID and tight PF isolation requirement. These selections significantly reduce decays-in-flight. Two muons with opposite charge and with an invariant mass compatible with the Z mass ($|m_{2\mu} - m_Z| < 15\text{ GeV}$) are paired. At least one pair is required in each event. Finally, events with at least one b jet with $p_T > 20\text{GeV}$ are vetoed.

Events in Monte Carlo are weighted according to

$$\text{cross section} \times \text{luminosity} \times \text{relative generator weight} \times \text{pileupweight} \quad (1)$$

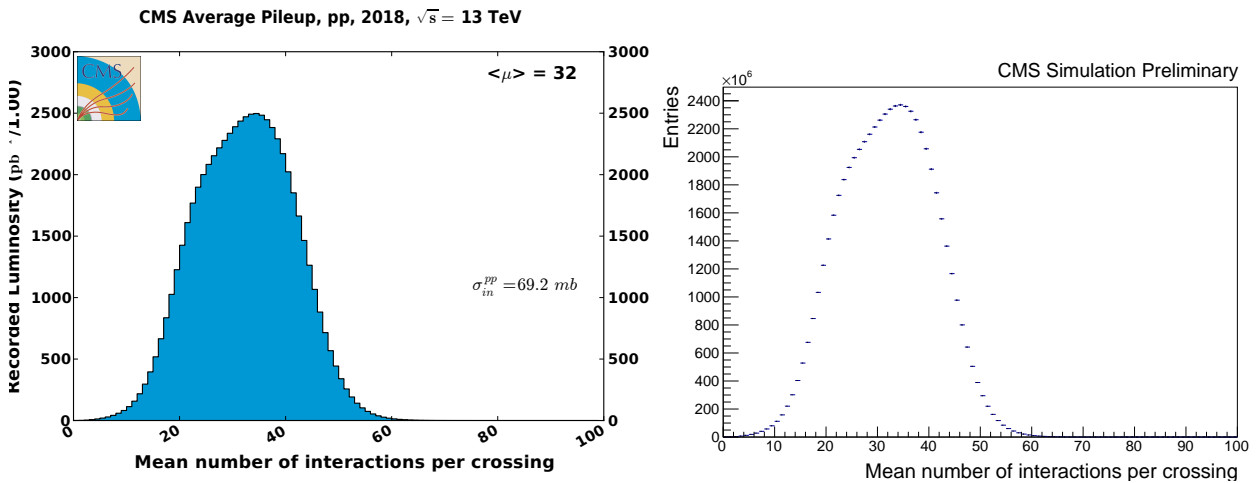


Fig. 1: Left: Average pileup in 2018. Mean number of interactions per bunch crossing for the 2018 pp run at 13 TeV, using the online luminosity values. The plot uses the CMS recommended value of 69.2 mb for the minimum bias cross section, which is determined by finding the best agreement with data and is recommended for CMS analyses. Right: Simulated average pileup in 2018 with the `mix_2018_25ns_JuneProjectionFull18_Poisson00TPU_cfi` configuration.

Tab. 4: MET Triggers used in the Analysis

Trigger Path
HLT_PFHT500_PFMET100_PFMHT100_IDTight
HLT_PFHT500_PFMET110_PFMHT110_IDTight
HLT_PFHT700_PFMET85_PFMHT85_IDTight
HLT_PFHT700_PFMET95_PFMHT95_IDTight
HLT_PFHT800_PFMET75_PFMHT75_IDTight
HLT_PFHT800_PFMET85_PFMHT85_IDTight
HLT_PFMET110_PFMHT110_IDTight
HLT_PFMET120_PFMHT120_IDTight
HLT_PFMET130_PFMHT130_IDTight
HLT_PFMET140_PFMHT140_IDTight
HLT_PFMET100_PFMHT100_IDTight_CaloBTagDeepCSV_3p1
HLT_PFMET110_PFMHT110_IDTight_CaloBTagDeepCSV_3p1
HLT_PFMET120_PFMHT120_IDTight_CaloBTagDeepCSV_3p1
HLT_PFMET130_PFMHT130_IDTight_CaloBTagDeepCSV_3p1
HLT_PFMET140_PFMHT140_IDTight_CaloBTagDeepCSV_3p1
HLT_PFMET120_PFMHT120_IDTight_PFHT60
HLT_PFMETNoMu120_PFMHTNoMu120_IDTight_PFHT60
HLT_PFMETTypeOne120_PFMHT120_IDTight_PFHT60
HLT_PFMETTypeOne110_PFMHT110_IDTight
HLT_PFMETTypeOne120_PFMHT120_IDTight
HLT_PFMETTypeOne130_PFMHT130_IDTight
HLT_PFMETTypeOne140_PFMHT140_IDTight
HLT_PFMETNoMu110_PFMHTNoMu110_IDTight
HLT_PFMETNoMu120_PFMHTNoMu120_IDTight
HLT_PFMETNoMu130_PFMHTNoMu130_IDTight
HLT_PFMETNoMu140_PFMHTNoMu140_IDTight
HLT_MonoCentralPFJet80_PFMETNoMu110_PFMHTNoMu110_IDTight
HLT_MonoCentralPFJet80_PFMETNoMu120_PFMHTNoMu120_IDTight
HLT_MonoCentralPFJet80_PFMETNoMu130_PFMHTNoMu130_IDTight
HLT_MonoCentralPFJet80_PFMETNoMu140_PFMHTNoMu140_IDTight
HLT_PFMET200_NotCleaned
HLT_PFMET200_HBHECleaned
HLT_PFMET250_HBHECleaned
HLT_PFMET300_HBHECleaned
HLT_PFMET200_HBHE_BeamHaloCleaned
HLT_PFMETTypeOne200_HBHE_BeamHaloCleaned
HLT_DiJet110_35_Mjj650_PFMET110
HLT_DiJet110_35_Mjj650_PFMET120
HLT_DiJet110_35_Mjj650_PFMET130
HLT_TripleJet110_35_35_Mjj650_PFMET110
HLT_TripleJet110_35_35_Mjj650_PFMET120
HLT_TripleJet110_35_35_Mjj650_PFMET130
HLT_Ele15_IsoVVVL_PFHT450_PFMET50
HLT_Photon50_R9Id90_HE10_IsoM_EBOnly_PFJetsMJJ300DEta3_PFMET50
HLT_PFMET100_PFMHT100_IDTight_PFHT60
HLT_PFMETNoMu100_PFMHTNoMu100_IDTight_PFHT60
HLT_PFMETTypeOne100_PFMHT100_IDTight_PFHT60

6 Results

Add plots and tables here

Tab. 5: Cutflow table for the WZ control region

Selection	WZ	ttZ	Data
No selection			

7 Summary

The overall trigger scale factor is estimated to be $XX\% \pm XX\%$ (stat.).