

Optimizing Trigger Selection for Detection of Doubly Charged Higgs Bosons at the LHC

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Abstract

In this project, we aim to programmatically find the most efficient triggers for selecting H++ events for application in the Compact Muon Solenoid experiment. Highly efficient triggers are defined as those with high signal efficiency and low background efficiency to give as much signal and as little background as possible. The types of events analyzed were H++, Drell-Yan, and QCD. The initial process started with finding the most efficient triggers on the three sets of events independently, then pairwise comparing the differences, and then finally creating a new figure of merit which was the harmonic mean of all the differences.

Signal

The signal interaction we are searching for is activity of the double charged Higgs boson:

- H++: The doubly charged Higgs boson is our signal and is a hypothetical particle that we believe exists and are therefore trying to prove its existence within Monte Carlo events.

Background

Background interactions include the following:

- Quantum Chromodynamics (QCD). QCD interactions are a strong interaction between quarks that are done through gluons.
- Drell-Yan (DY). DY interactions occur when a quark and an antiquark of distinct hadrons annihilate, form a Z-boson, then decay into oppositely charged leptons.

Process

We start by running Monte Carlo data through a trigger simulation, enabling all triggers individually.

- H++
 - Higgs900.txt
 - m of at least 900 GeV
- QCD
 - QCD500-700.txt
 - H_T between 500-700 GeV
- Drell-Yan
 - DY50.txt
 - m of at least 50 GeV

Preliminary Results

The tables below show the results for the top 5 triggers (highest efficiencies) for each of the three types of events.

Table 1:Trigger Results for H++

Trigger Name	Efficiency
HLT_AK8PFJet40	0.999155
HLT_HcalPhiSym	0.999
HLT_AK4PFJet30	0.99879
HLT_AK4CaloJet30	0.993445
HLT_DiPFJetAve40	0.991245

Best Electron Trigger: HLT_Ele8_CaloldL_TrackIdL_IsoVL_PFJet30 | 0.83359

Best Muon Trigger: HLT_Mu8_TrkIsoVVL | 0.78888

Preliminary Results (cont.)

Table 2:Trigger Results for QCD

Trigger Name	Efficiency
HLT_HcalPhiSym	0.862971
HLT_AK8PFJet40	0.688192
HLT_AK4CaloJet30	0.619257
HLT_AK4PFJet30	0.598404
HLT_PFJet40	0.465758

Best Electron Trigger: HLT_Ele8_CaloldM_TrackIdM_PFJet30 | 0.0633013

Best Muon Trigger: HLT_Mu3_PFJet40 | 0.277873

Table 3:Trigger Results for DY

Trigger Name	Efficiency
HLT_HcalPhiSym	0.884871
HLT_AK8PFJet200	0.882028
HLT_HT425	0.872316
HLT_PFJet200	0.773207
HLT_DiPFJetAve200	0.546264

Best Electron Trigger: HLT_Ele20_WPLoose_Gsf | 0.217682

Best Muon Trigger: HLT_L1SingleMu18 | 0.277113

Redefining Efficiency

To account for comparing multiple efficiencies, we redefine the efficiency as follows:

$$Eff = Eff_{Signal} - Eff_{Background}$$

Intermediary Results

The tables below show the results for the top 5 triggers for the pairwise comparisons

Table 4:Trigger Results for H++ vs. QCD

Trigger Name	Efficiency
HLT_DiPFJetAve320	0.81028139
HLT_PFJet320	0.8088902
HLT_PFMETNoMu110_PFMHTNoMu110_IDTight	0.8054678
HLT_Photon75	0.8039625
HLT_Photon90	0.8035066

Best Electron Trigger: HLT_Ele12_CaloldL_TrackIdL_IsoVL_PFJet30 | 0.7971663

Best Muon Trigger: HLT_IsoMu20 | 0.75249405

Table 5:Trigger Results for H++ vs. DY

Trigger Name	Efficiency
HLT_AK8PFJet140	0.94992018
HLT_DiPFJetAve80	0.9497367
HLT_PFJet140	0.94761912
HLT_PFHT250	0.94691313
HLT_DiPFJetAve140	0.94661373

Best Electron Trigger: HLT_Ele50_CaloldVT_GsfTrkIdT_PFJet165 | 0.79523

Best Muon Trigger: HLT_Mu15_IsoVVVL_PFHT600 | 0.742399778

Redefining Efficiency (pt. 2)

To compare values in the two tables above, we need to redefine efficiency again. This time, we will use the following equation:

$$Eff = Eff_{H++vs.QCD} + Eff_{H++vs.DY}$$

Final Results

The tables below shows the sum of pairwise compared efficiencies.

Table 6:Trigger Results for H++ vs. DY & QCD

Trigger Name	Efficiency
HLT_PFJet320	1.6658838
HLT_Photon75	1.6451807
HLT_AK8PFJet320	1.6429796
HLT_Photon90	1.64207
HLT_DiPFJetAve260	1.632191

Best Electron Trigger: HLT_Ele50_CaloldVT_GsfTrkIdT_PFJet165 | 1.58410567

Best Muon Trigger: HLT_Mu15_IsoVVVL_PFHT600 | 1.4755256380000001

Questions

- Why do photon triggers perform so well?
- How do we optimize using multiple triggers at once?
- How can we account for the fact that we are using Monte Carlo events instead of real data?
- How can we account for high energy collisions that wrongly set off triggers?

Next Steps

- Optimize for multiple triggers.
- Use these triggers on real data instead of just Monte Carlo events.

Conclusions

By the process of comparing various triggers against each other and on different types of Monte Carlo events, we have narrowed down our selection of triggers to a few of the most efficient, which can be found in the "Final Results" section.

