Validation of the MadAnalysis 5 implementation of CMS-EXO-16-012

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1 Setup

In this document, the MadAnalysis 5 implementation of search for associated production of dark matter with a Higgs boson decaying to $b\bar{b}$ or $\gamma\gamma$ at $\sqrt{s} = 13$ TeV (2.3 fb^{-1}), (see also arXiv:1703.05236) is validated.

For this purpose, model UFO, MG5 cards, and a pythia8 card for Monte Carlo production were provided by CMS to generate events with MadGraph MG5_aMC, showered with Pythia 8

This paper is written in the context of Z'-two-Higgs-doublet model, where a high-mass resonance Z' decays into a pseudoscalar boson A and a CP-even scalar Higgs boson, and the A decays to a pair of dark matter particles.

To generate signal sample, model UFO files is provided by CMS. From the CMS genproduction gitbub repository one can retrieve the cards used for MadGraph MG5_aMC event generation for each mass point of Z'. The run card used in MadGraph MG5_aMC and proc card were retrieved from there. Also we applied some custom settings according to the mass of Z'

Since MadGraph MG5_aMC cannot handle the decay of standard model higgs properly, higgs decay and parton shower was handled by Pythia 8. For example, specific Pythia 8 card is used in this process. The pythia settings are then retrieved from the CMS software github repository:

- Pythia8CUEP8M1Settings and
- Pythia8CommonSettings. Also:
- The genfragment file is used.

Models studied are shown in 1. For further theoretical aspects of this model, see the paper arXiv:1402.7074

For detector simulation, we used Delphes 3 with latest version of delphes card used CMS EXO-16-037 recasting. The difference between custom card and default card is presented in appendix A.

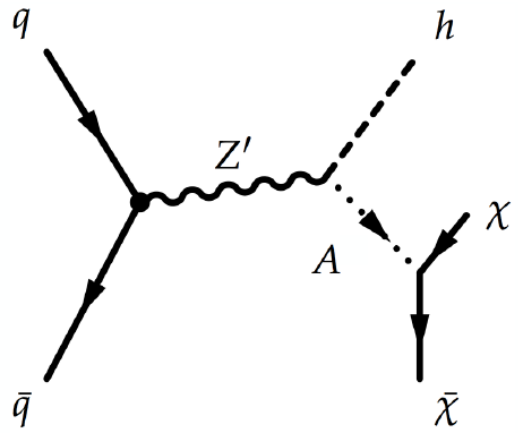

Figure 1: The Z' 2HDM model with pseudoscalar A

2 Cut flow

This analysis is a multijet, missing transverse momentum and zero lepton analysis. The cut flows for the simplified model working points are given in

3 Distributions of observables

Appendices

A Delphes card settings

```
#####################
# MC truth jet finder
#####################

module FastJetFinder GenJetFinder {
  set InputArray NeutrinoFilter/filteredParticles

  set OutputArray jets

  # algorithm: 1 CDFJetClu, 2 MidPoint, 3 SIScone, 4 kt, 5 Cambridge/Aachen, 6
      antikt
  set JetAlgorithm 6
  set ParameterR 0.4

  set JetPTMin 20.0
}

#############
# Jet finder
#############

module FastJetFinder FastJetFinder {
#  set InputArray Calorimeter/towers
  set InputArray EFlowMerger/eflow

  set OutputArray jets

  # algorithm: 1 CDFJetClu, 2 MidPoint, 3 SIScone, 4 kt, 5 Cambridge/Aachen, 6
      antikt
  set JetAlgorithm 6
  set ParameterR 0.4

  set JetPTMin 20.0
}

############
# b-tagging
############

module BTagging BTagging {
  set JetInputArray JetEnergyScale/jets

  set BitNumber 0

  # add EfficiencyFormula {abs(PDG code)} {efficiency formula as a function of
      eta and pt}
```

```
  # PDG code = the highest PDG code of a quark or gluon inside DeltaR cone
      around jet axis
  # gluon's PDG code has the lowest priority

  add EfficiencyFormula {0} { (pt >= 30.0 && pt < 130.0) * (0.124 - 1.0*10^-3*pt
      + 1.06*10^-5*pt^2 - 3.18*10^-8*pt^3 + 3.13*10^-11*pt^4) +
                              (pt >= 130.0) * (0.055 + 4.53*10^-4*pt -
                                 1.60*10^-7*pt^2) }

  add EfficiencyFormula {4} { (pt >= 30.0 && pt <205.0) * (0.40 + 1.23*10^-3*pt
     - 4.60*10^-6*pt^2 + 5.71*10^-9*pt^3) +
                              (pt >= 205.0) * (0.478 + 1.573*10^-4*pt)}

  add EfficiencyFormula {5} { (pt >= 30.0 && pt < 150.0) * (0.707 + 5.6*10^-3*pt
      - 6.27*10^-5*pt^2 + 3.10*10^-7*pt^3 - 5.63*10^-10*pt^4) +
                              (pt >= 150.0) * (0.906 - 6.39*10^-5*pt +
                                 4.11*10^-8*pt^2) }
}
```