# Update in VBF H->yy HGTD

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# What's new

New UpgradePerformanceFunction

- Updated the jet efficiency

New config and scenarios

- Cfg1: study the overall significance

  For jets |eta|<3.8, require pT>30GeV with Track Confirmation(TC)

  For jets 3.8<|eta|<4.4, require pT>70GeV, jet efficiency $\epsilon_{jet} = 1$
- Cfg2: focus on HGTD region

  Only remain jet in |eta|<3.8, pT>30GeV, with TC

- Scenarios: ITK(default), HGTD(UseHGTD0=true), remove all PU(based on ITK)

# Event reconstruction and selection(same as before)

MC sample: only VBF vs. ggH (same as before)

- VBF: 14TeV Powheg+Pythia8, AU2CT20, VBFH125 gamgam process,truth sample
- ggH: 14TeV Powheg+Pythia8, CT10, ggH125 gamgam process, truth sample

Event reconstruction: with UpgradePerformanceFunction

- Reconstructed photons, jets, electrons and muons with smearing and efficiency in default layout Step1p6
- Add the pile-up with <mu>=200

Event selection: 2 loose photons, 2 jets, relative pT requirement, mass window [105,160]GeV, $\Delta\eta_{jj} > 2$, $\left|\eta_{\gamma\gamma}^{Zepp}\right| < 5$

# Cut flow config1

| cut flow | ggH | VBF |
|---|---|---|
| 2 photons | 23.082% | 26.877% |
| Rel.pT | 93.240% | 89.157% |
| Mass window | 97.363% | 95.403% |
| 2 jets | 13.354% | 43.231% |
| $\Delta\eta_{jj} > 2$ | 41.459% | 76.512% |
| $\lvert\eta_{\gamma\gamma}^{Zepp}\rvert < 5$ | 99.362% | 99.890% |
| Total | 1.153% | 7.554% |
| Scale to 3 ab-1 | 4291.533 | 2200.596 |

| cut flow | ggH | VBF |
|---|---|---|
| 2 photons | 23.082% | 26.877% |
| Rel.pT | 93.240% | 89.157% |
| Mass window | 97.363% | 95.403% |
| 2 jets | 13.617% | 44.925% |
| $\Delta\eta_{jj} > 2$ | 41.862% | 77.248% |
| $\lvert\eta_{\gamma\gamma}^{Zepp}\rvert < 5$ | 99.347% | 99.888% |
| Total | 1.187% | 7.925% |
| Scale to 3 ab-1 | 4417.744 | 2308.805 |

| cut flow | ggH | VBF |
|---|---|---|
| 2 photons | 23.080% | 26.827% |
| Rel.pT | 93.207% | 89.271% |
| Mass window | 97.407% | 95.430% |
| 2 jets | 10.217% | 39.036% |
| $\Delta\eta_{jj} > 2$ | 39.264% | 80.279% |
| $\lvert\eta_{\gamma\gamma}^{Zepp}\rvert < 5$ | 99.869% | 99.940% |
| Total | 0.840% | 7.158% |
| Scale to 3 ab-1 | 3125.481 | 2085.311 |

↖ ITK
↑ HGTD
← rmPU

# Cut flow config2

| cut flow | ggH | VBF |
|---|---|---|
| 2 photons | 23.082% | 26.877% |
| Rel.pT | 93.240% | 89.157% |
| Mass window | 97.363% | 95.403% |
| 2 jets | 13.059% | 41.212% |
| $\Delta\eta_{jj} > 2$ | 40.177% | 74.984% |
| $\lvert\eta_{\gamma\gamma}^{Zepp}\rvert < 5$ | 99.572% | 99.921% |
| Total | 1.095% | 7.059% |
| Scale to 3 ab-1 | 4075.598 | 2056.553 |

| cut flow | ggH | VBF |
|---|---|---|
| 2 photons | 23.082% | 26.877% |
| Rel.pT | 93.240% | 89.157% |
| Mass window | 97.363% | 95.403% |
| 2 jets | 13.323% | 42.894% |
| $\Delta\eta_{jj} > 2$ | 40.620% | 75.817% |
| $\lvert\eta_{\gamma\gamma}^{Zepp}\rvert < 5$ | 99.550% | 99.917% |
| Total | 1.129% | 7.429% |
| Scale to 3 ab-1 | 4202.925 | 2164.221 |

| cut flow | ggH | VBF |
|---|---|---|
| 2 photons | 23.080% | 26.827% |
| Rel.pT | 93.207% | 89.271% |
| Mass window | 97.407% | 95.430% |
| 2 jets | 10.124% | 37.152% |
| $\Delta\eta_{jj} > 2$ | 38.621% | 78.868% |
| $\lvert\eta_{\gamma\gamma}^{Zepp}\rvert < 5$ | 99.866% | 99.940% |
| Total | 0.818% | 6.693% |
| Scale to 3 ab-1 | 3046.181 | 1949.759 |

↖ ITK
↑ HGTD
← rmPU

# BDT categorization

BDT training: no re-training, use the previous xml file

VBF vs. QCD background training result.

(QCD is the main background in the analysis, and 2 step BDT helps very little)

Categorization:

- Use $\sigma_{VBF} = \sqrt{2 \times ((N_{VBF} + N_{ggH}) \times \ln\left(1 + \frac{N_{VBF}}{N_{ggH}}\right) - N_{VBF})}$ to split the sample in to 2 categories: tight and loose

# BDT categorization

| Cfg and scenario | Combined significance |
|---|---|
| Cfg1 ITK | 35.59±0.25 |
| Cfg1 HGTD | 36.81±0.26 |
| Cfg1 rmPU | 38.07±0.29 |
| Cfg2 ITK | 34.01±0.25 |
| Cfg2 HGTD | 35.26±0.26 |
| Cfg2 rmPU | 36.00±0.28 |

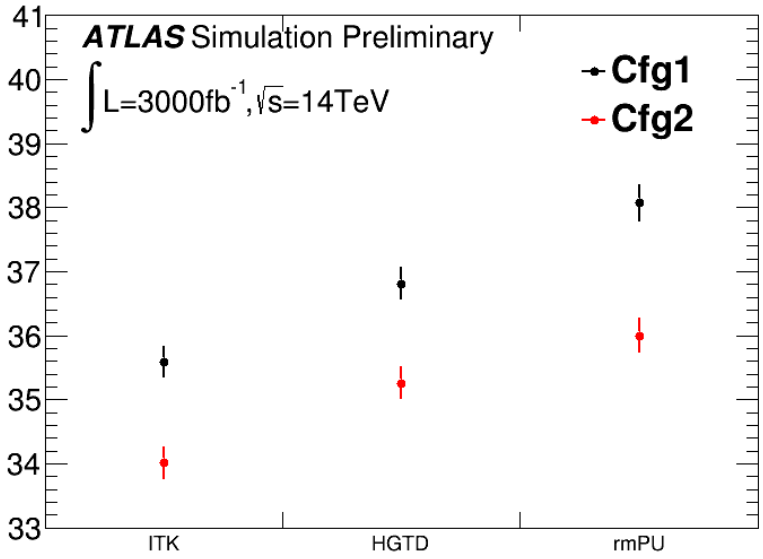



Table and plot: combined significance of 2 categories in different config and scenarios

# Conclusion

Finally a positive result: HGTD could contribute in VBF/ggH distinguishment. With HGTD there could be  less ggH events in VBF categories.

- Globally 3.4% improvement could be achieved with HGTD, while 7% is the maximum(remove all PU).
- 3.7% improvement when focusing on HGTD region.
- Since ggH is not the main background in VBF analysis, these influence might not be visible in final results. (Based on my previous results)

# Back up

# BDT categorization

| | tight | Loose |
|---|---|---|
| VBF | 1432.81±7.722 | 641.697±5.168 |
| ggH | 1409.17±22.91 | 2627.34±31.28 |
| VBF purity | 50.42% | 19.63% |
| Significance | 33.49±0.27 | 12.06±0.115 |
| Combined | 35.59±0.25 | |

Cfg1 ITK

| | tight | Loose |
|---|---|---|
| VBF | 1523.35±7.96 | 653.39±5.21 |
| ggH | 1475.81±23.44 | 2677.60±31.57 |
| VBF purity | 50.79% | 19.62% |
| Significance | 34.74±0.27 | 12.16±0.11 |
| Combined | 36.81±0.26 | |

Cfg1 HGTD

# BDT categorization

| | tight | Loose |
|---|---|---|
| VBF | 1400.93±7.64 | 565.61±4.85 |
| ggH | 1118.40±20.41 | 1834.34±26.13 |
| VBF purity | 55.61% | 23.57% |
| Significance | 35.92±0.3 | 12.60±0.13 |
| Combined | 38.07±0.29 | |

Cfg1 rmPU

| | tight | Loose |
|---|---|---|
| VBF | 1523.35±7.96 | 653.39±5.21 |
| ggH | 1475.81±23.44 | 2677.60±31.57 |
| VBF purity | 50.79% | 19.62% |
| Significance | 34.74±0.27 | 12.16±0.11 |
| Combined | 36.81±0.26 | |

Cfg2 rmPU

# BDT categorization

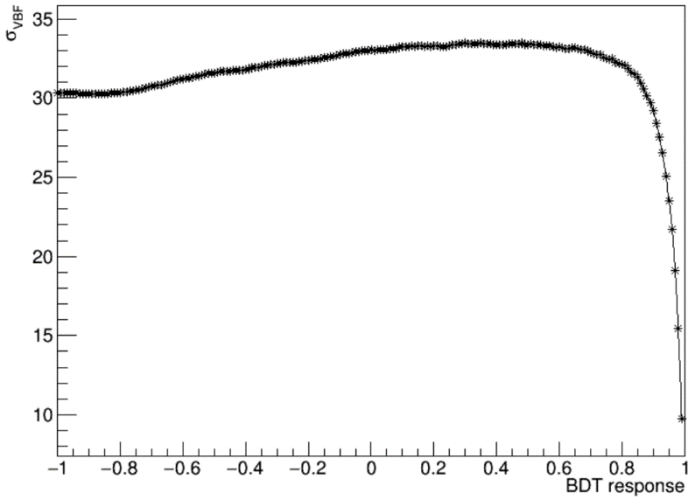
| | tight | Loose |
|---|---|---|
| VBF | 1314.11±7.40 | 625.22±5.10 |
| ggH | 1318.32±22.15 | 2515.65±30.60 |
| VBF purity | 49.92% | 19.91% |
| Significance | 31.82±0.27 | 12.00±0.12 |
| Combined | 34.01±0.25 | |

Cfg2 ITK

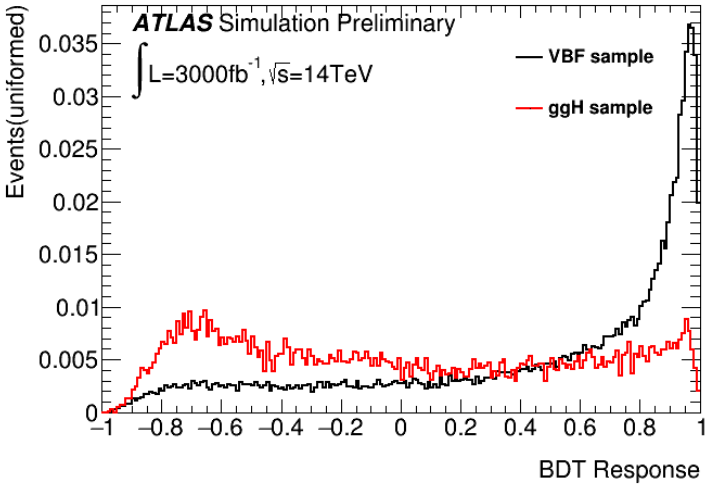
| | tight | Loose |
|---|---|---|
| VBF | 1403.47±7.64 | 637.49±5.15 |
| ggH | 1383.11±22.69 | 2569.26±30.93 |
| VBF purity | 50.37% | 19.88% |
| Significance | 33.12±0.27 | 12.10±0.12 |
| Combined | 35.26±0.26 | |

Cfg2 HGTD

# BDT response cfg1 ITK as example




$\sigma_{VBF}$ with different BDT cut




BDT response distribution in tight cat.