# Study of Associated Production of Higgs Boson with Single Top Quark in Leptonic Channels at √s = 13 TeV using CMS detector

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**Annual Meeting of Dept. of High Energy Physics, TIFR Mumbai**

**Motivation of this analysis is to study the Top-Higgs coupling through the measurement of the cross section of the tHq process (as an alternate to the ttH process).**

## Introduction:

➢Standard Model (SM) of Particle Physics: masses of vector bosons, as well as fermions are a consequence of "Electroweak Symmetry Breaking" via the "Higgs Mechanism".

➢Fermions couple to a scalar particle named Higgs boson through "Yukawa interaction" and become massive.

➢The Higgs boson of mass 125 GeV was discovered at the LHC in 2012.

➢The observed particle has SM like coupling to vector boson.

➢However, it remains to be established whether the Fermions indeed get their masses from the Higgs.

## Fermion Coupling to Higgs:

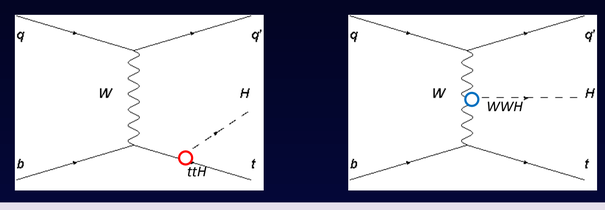
➢Higgs to fermion coupling is proportional to the fermion mass. Yukawa coupling: $y_f \sim m_f / v$, where $m_f$ ~172 GeV and $v$ ~246 GeV.

➢Top-Higgs coupling is largest, $y_f$ ~1.

➢pp→ttH process has been observed, but the cross section measurement has large uncertainties.

➢Top-Higgs coupling can be constrained within large ranges.

➢Hence it is better to have more measurements!

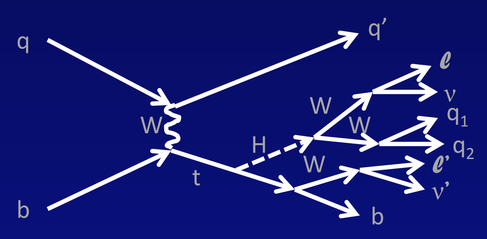



## tHq process:

➢The final state consists of a light quark, a top quark and the Higgs.

➢It has a second contribution from a diagram where the coupling is essentially between two W bosons and a Higgs.

➢According to SM, these two couplings interfere destructively.




Look for two leptons with the same charge in the final state.

## Leptonic Channels:

➢SM prediction for total cross section at 13 TeV is very low: ~71 fb.

➢If there are effects beyond SM, ttH coupling will be different. As a result, cross section will change.

➢To distinguish the signal from the huge amount of background we use leptonic final states.

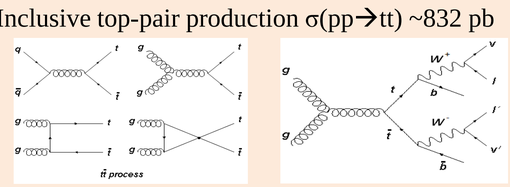
➢Events can be triggered in the experiment with the presence of one or two leptons.

➢After this initial selection, other requirements are put based on the signal topology.

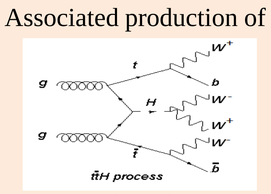
## Backgrounds:

(all cross sections estimated in 13 TeV)

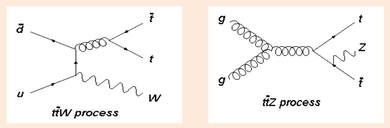
1. Inclusive top-pair production σ(pp→tt) ~832 pb




2. Associated production of Higgs with top σ(pp→ttH) ~0.51 pb

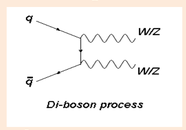



3. Associated production of vector bosons with top



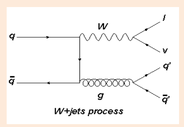

σ(pp→ttW) ~0.20 pb
σ(pp→ttZ) ~0.25 pb
[W, Z decays leptonically]

4. Di-boson processes




σ(pp→WW) ~119 pb
σ(pp→WZ) ~32 pb
σ(pp→ZZ) ~66 pb [inclusive]

5. pp→W+jets process σ(pp→W+jets) > 1000 pb




## Object Selection:

➢Muons: $p_T$ > 10 GeV and |η| < 2.4
Relative isolation after pile-up subtraction < 0.15

➢Jets: selected based on loose jet id; $E_T$ > 25 GeV and |η| < 4.5

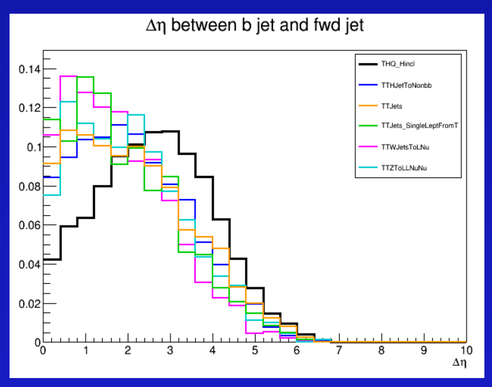
➢b-jets must have $E_T$ > 35 GeV and |η| < 2.4
b-discriminator value > 0.890

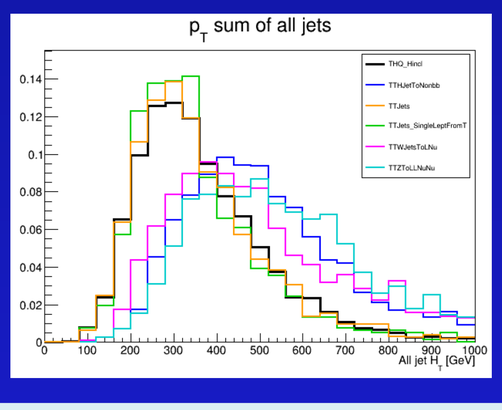
➢Light quark jets must have $E_T$ > 35 GeV, |η| < 4.5
b-discriminator < 0.890

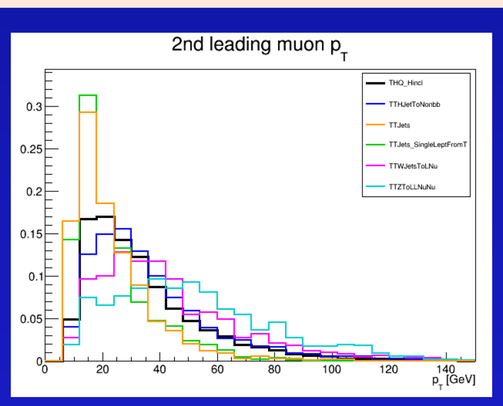
## Event Pre-selection:

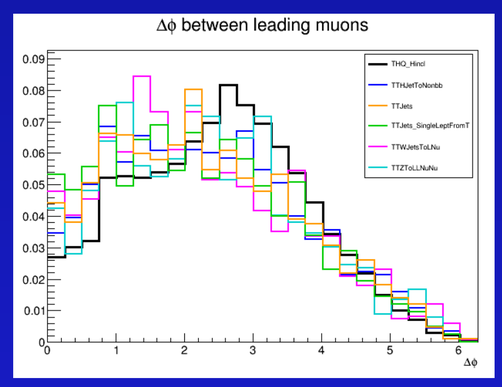
For this study we have only considered muons in the final state. The events are selected in the following four steps:

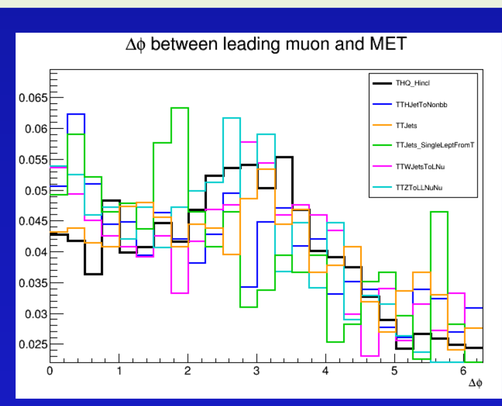
Events are chosen with two same-sign isolated muons
↓
Event should have exactly one b-jet
↓
Event should have at least one light quark jet
↓
The muons must have radial separation > 0.8
↓
Final selection of events is done using Multi-Variate Analysis Method



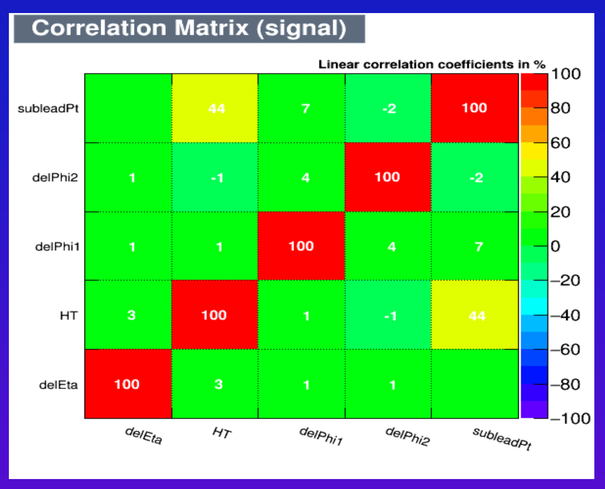



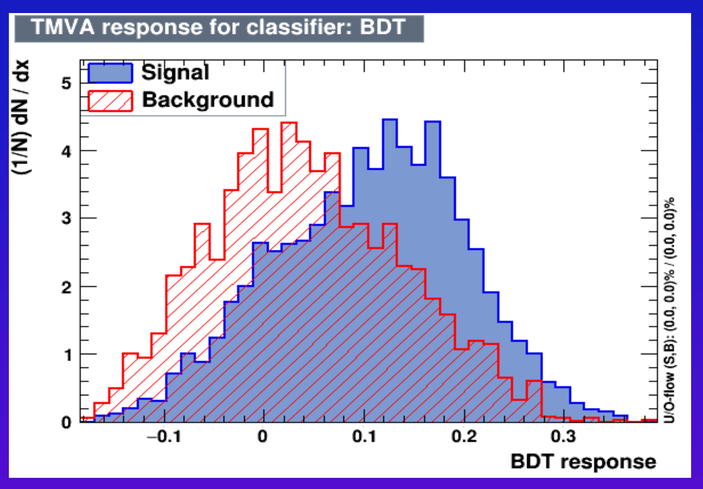

## Multi-Variate Analysis:

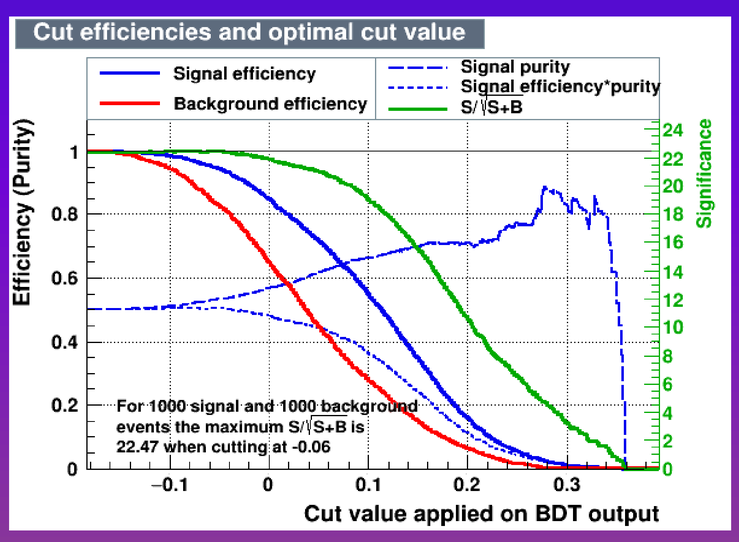
The input variables for the TMVA (Toolkit for Multi-Variate Analysis in ROOT) are:

1. **Difference in pseudorapidities between the b-jet and forward jet with highest pseudorapidity**
2. **Sum $p_T$ of all jets above $E_T$=25 GeV**
3. **Sub-leading muon $p_T$**
4. **Difference in azimuthal angles between two leading muons**
5. **Difference in azimuthal angles between leading muon and MET**

➢Using these variables as input to the MVA, we use the BDT classifier to choose an optimum cut for better selection of signal over background..




| | tHq (incl.) | ttH (H → bb) | ttjet (incl.) | ttjet (single lepton) | ttW (W → lν) | ttZ (Z → llνν) |
|---|---|---|---|---|---|---|
| x-sec (pb) | 0.07096 | 0.21509 | 831.76 | 182.17540 | 0.2043 | 0.2529 |
| $N_{exp}(100fb^{-1})$ | 7096 | 21509 | 83176000 | 18217540 | 20430 | 25290 |
| $N_{gen}$ | 3498596 | 1561760 | 42730273 | 11327907 | 252908 | 398000 |
| 2lss | 20715 | 9783 | 7642 | 3758 | 4528 | 2816 |
| $N_{bjet}$=1 | 9405 | 4724 | 3475 | 1700 | 2126 | 1344 |
| $N_{fjet}$>0 | 7231 | 3249 | 2442 | 1049 | 1431 | 967 |
| $\Delta R_{ll}$>0.8 | 6739 | 2941 | 1920 | 826 | 1340 | 894 |
| BDT>0.06 | 4644 | 1624 | 788 | 300 | 762 | 569 |
| $N_{final}(100fb^{-1})$ | 9 | 22 | 1534 | 482 | 61 | 36 |

## Future Plan:

➢This study is under progress.

➢Signal to background significance needs to be improved for better results.

➢More study of MVA classifiers needed.

➢Need to find more number of discriminating variables.

➢Study of fake rate and charge misidentification required.

➢Measurement of cross section, hence constraint on coupling, to be performed on real data.