Status Report

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Updates

1. Higgs Reconstruction : Train with <u>matchable events only</u>.

2. **Limitation of Cut-and-count?**

3. Increase Statistics & Irreducible Background, <u>ttW</u>.

4. <u>Shape Method</u> using all DNN scores.

Signal & Backgrounds

Process	Precision	$\sigma \times$ BR $[fb]$	Normalized ($3\ ab^{-1}$)	Generated
Signal				
$t\bar{t}HH$	NLO	0.101	304	13,800,000
Backgrounds				
$t\bar{t}b\bar{b}$	LO	767.1	2,301,269	25,000,000
$t\bar{t}W$	NLO	342.6	1,028,040	10,000,000
$t\bar{t}H$	NLO	332	996,948	20,000,000
$t\bar{t}b\bar{b}b\bar{b}$	LO	201	602,730	8,500,000
$t\bar{t}b\bar{b}V$	LO	14.86	44,569	1,500,000
$t\bar{t}t\bar{t}$	LO	11.81	35,430	4,000,000
$t\bar{t}b\bar{b}H$	LO	8.47	25,412	1,500,000
$t\bar{t}VV$	LO	7.341	22,024	1,500,000
$t\bar{t}ZH$	NLO	0.929	2,785	1,500,000
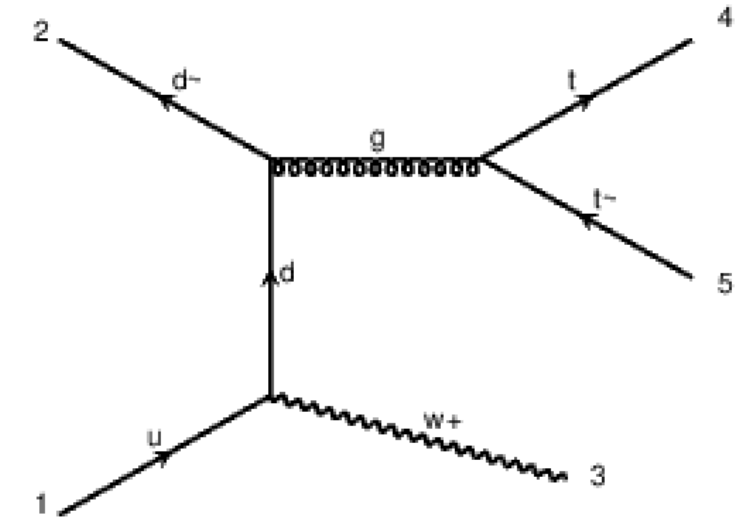
tt -> l+ q q b b

W -> l+

Pass selection if 1 fake b.

Turns out to be First Dominant Irreducible BKG.

- ttH, ttbbH, ttZH, ttVV, ttbbV, ttbb, ttbbbb, ttW -> BR(SL + DL) = 0.543
- tttt -> Inclusive.

(CPU_4 + slurm is so fast.)

Object & Event Selection

Table 2: Definition of physics objects in this analysis.

Object	ID (Efficiency)	p_T (GeV)	$|\eta|$	Isolation (I_{rel}^{PF}, $\Delta R = 0.3$)
Electrons	Medium (0.85)	> 23	< 3.0	< 0.3
Muons	Loose (0.97)	> 17	< 2.8	< 0.3
Jets	AK4, AK8	> 30	< 3.0	-
bjets	DeepJet Loose (0.85)	> 30	< 3.0	-

Event Selection

1. Exact 2 Letpon.
2. Same Sign of the leptons. ➡ **Matchable Event Ratio** = **Matchable** / **Selected**
3. MET > 30 GeV
4. bJet ≥ 3
5. Ht > 300 GeV

Cutflow Result

TTW is the main background.

	None	2Lep	SameSign	MET>30	b≥3	ht>300	DNN_0.99
tthh	304	45	21	18	15	14	3.86
tth	996948	104747	24957	21841	9335	8191	1.2
ttbbh	25412	2625	627	568	445	428	0.1
ttzh	2786	362	86	78	46	45	0.01
ttvv	22024	4118	1405	1301	504	485	0.02
ttbbv	44569	4323	830	737	398	366	0.13
ttbb	2301269	160880	15847	13289	9433	7967	0.46
ttbbbb	602730	41422	3889	3379	2384	2040	0
tttt	35430	4818	1649	1537	1280	1273	0.25
ttw	1028062	146965	50176	44665	12588	10410	0.21
S/sqrt(B)	0.14	0.07	0.07	0.06	0.08	0.08	2.5

Higgs Reconstruction

Training with only matchable ttHH_WWbb_SL signal events only.
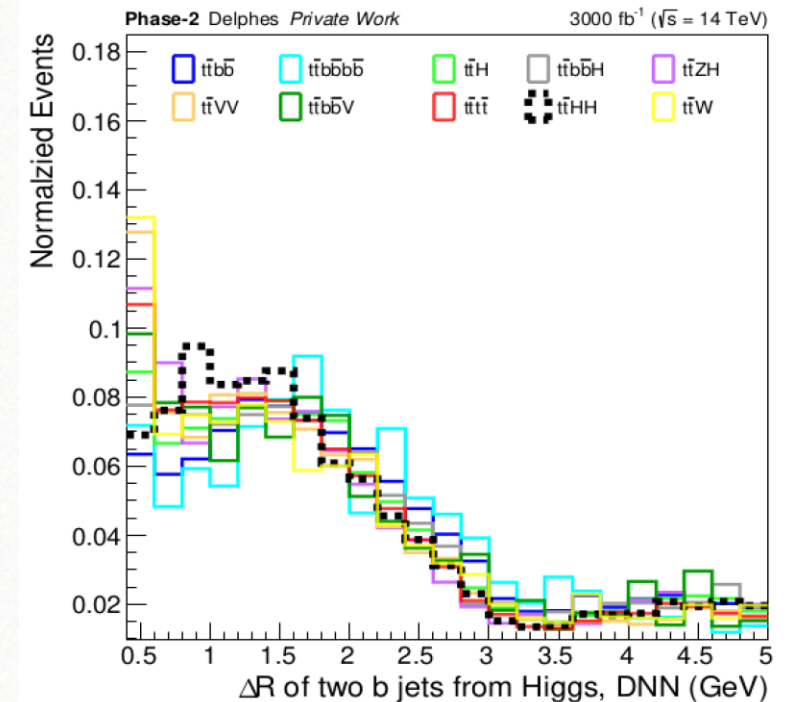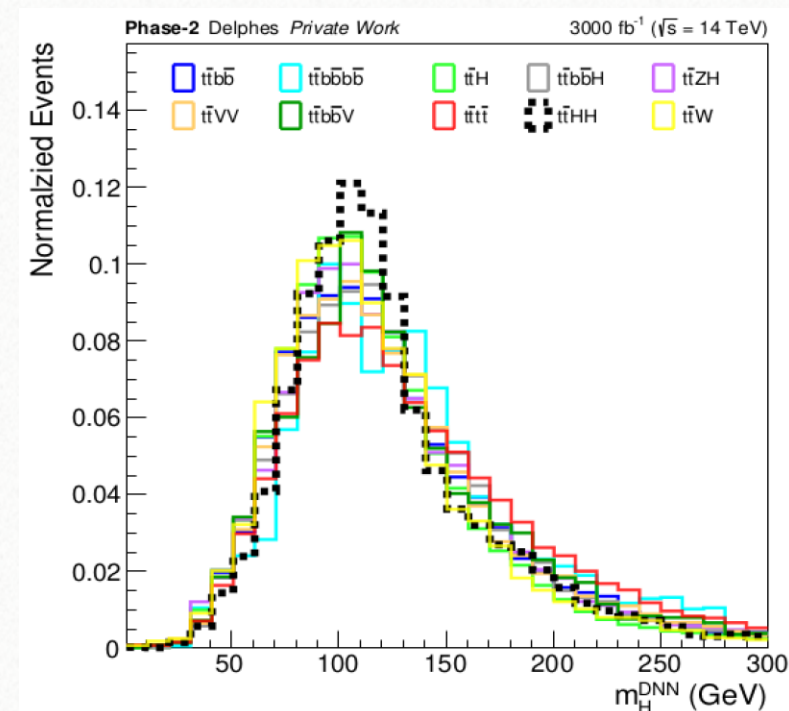
Assign 2b / 5b -> 10 labels.

Matchable Event Ratio ~ 0.45

Inputs (53) : nbJet, nJet, nAK8Jet, bJet 4vec, Lepton 4vec,

$\Delta R(b,b)$, $\Delta R(l,l)$, $\Delta R(b,l)$, m(ll), HT(Jet), Higgs mass,

$\Delta R(bb\_DNN)$, HT(bb_DNN), $\Delta\eta(bb\_DNN)$, $\Delta\varphi(bb\_DNN)$

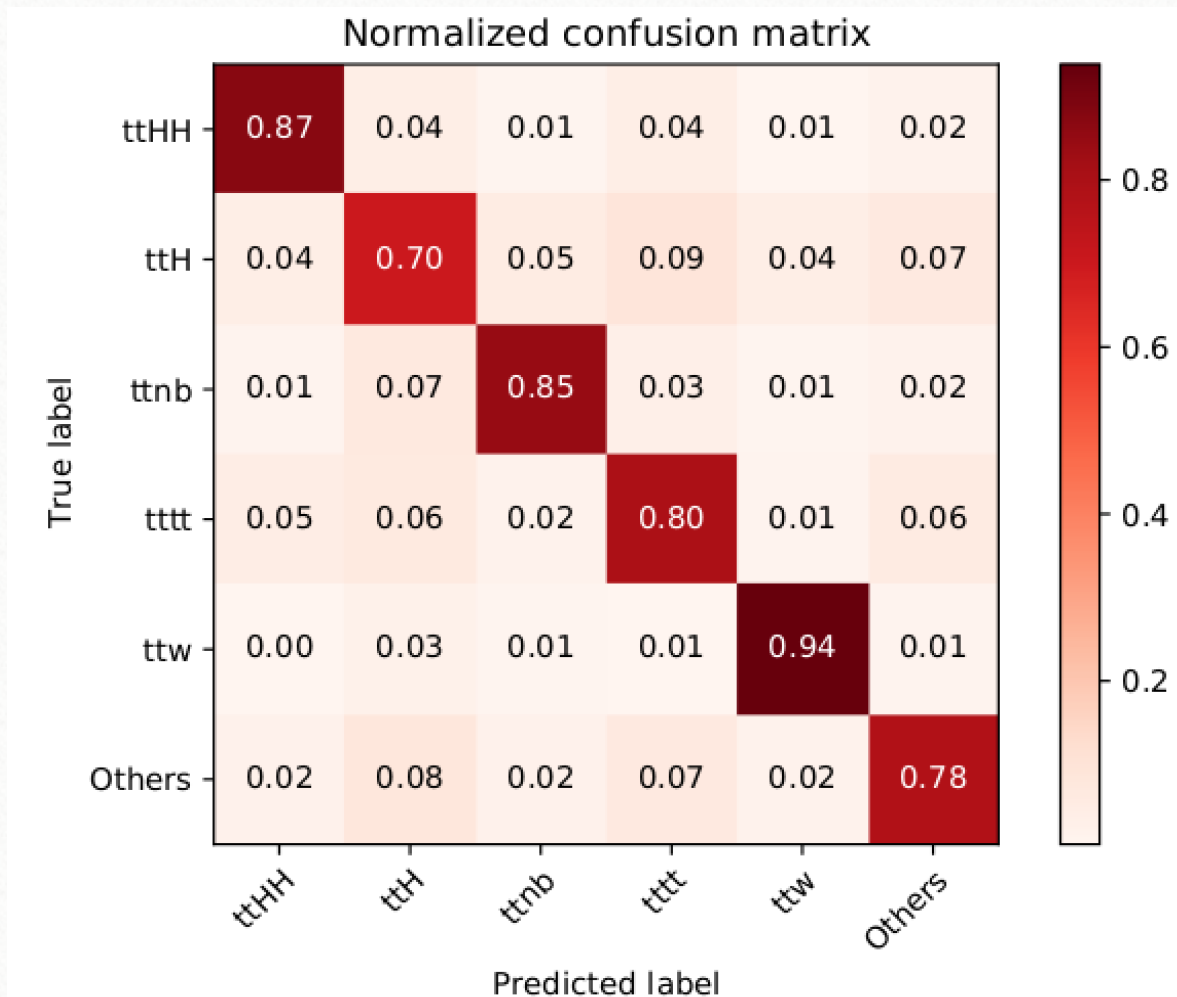Matching Efficiency_DNN = 0.89 > Previous, 0.85

Matching Efficiency_MinChi2 = 0.13
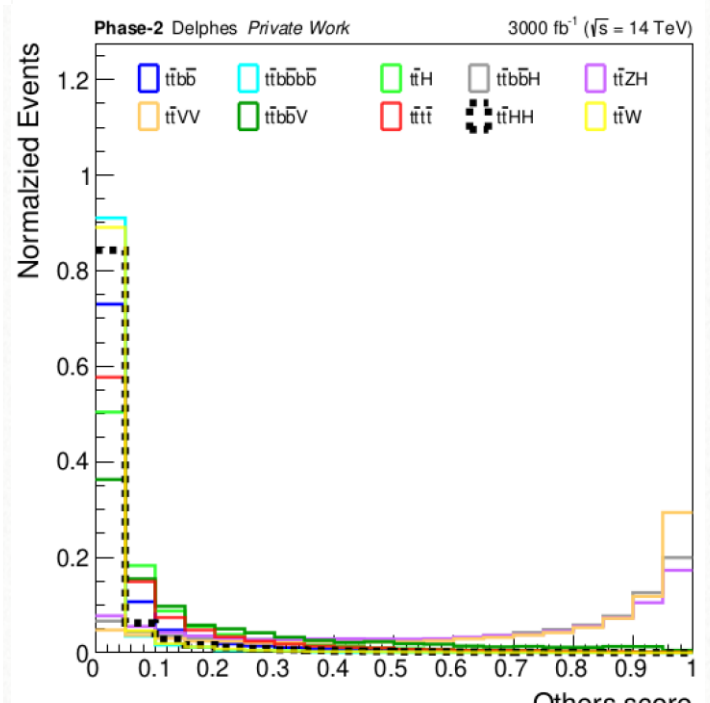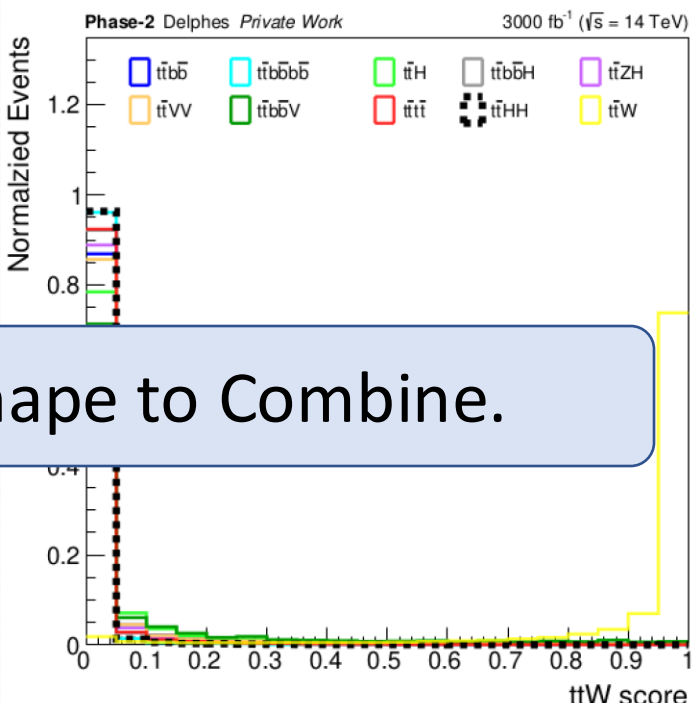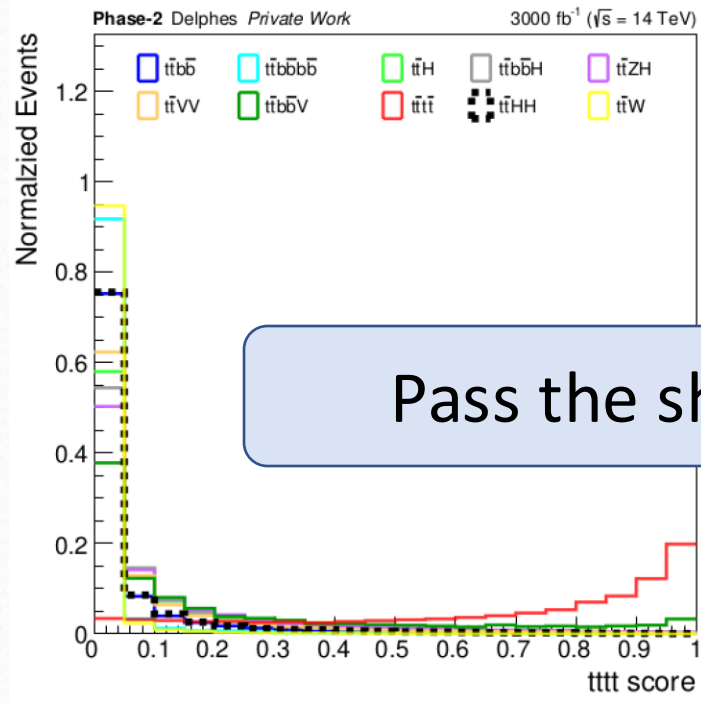
Recap!
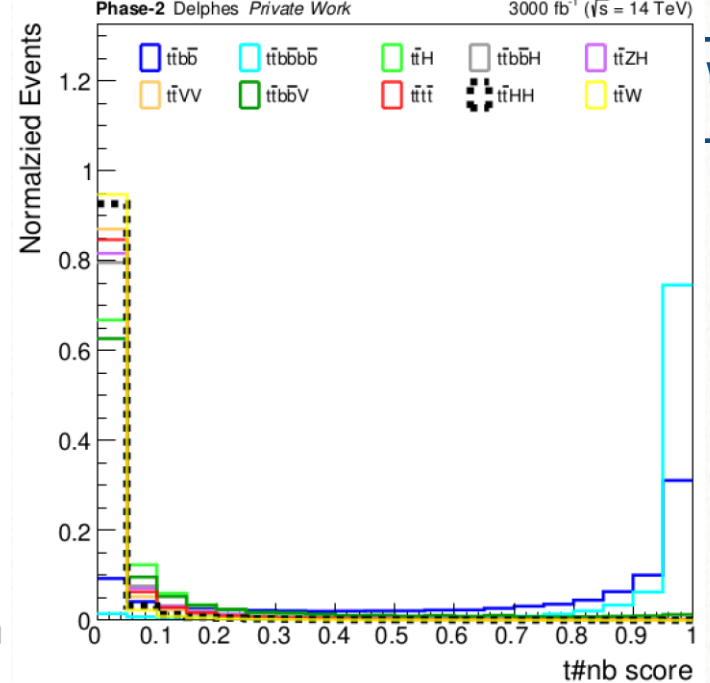Matching Efficiency = Correct / Matchable

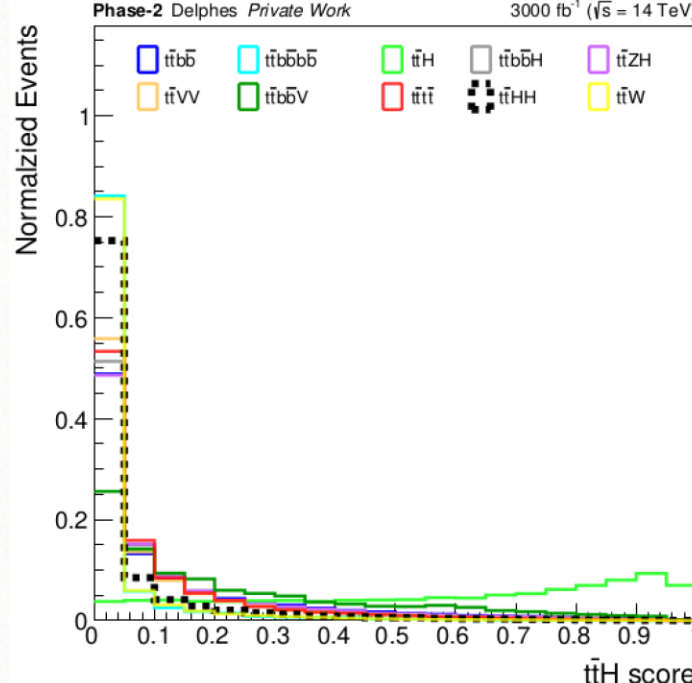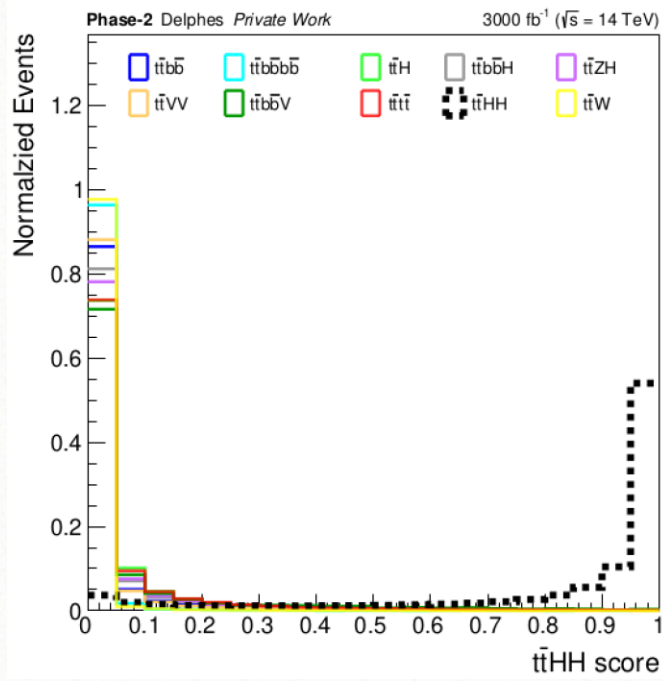# Signal Extraction

Input (53) : nbJet, nJet, nAK8Jet, bJet 4vec, Lepton 4vec, ΔR(b,b), ΔR(l,l), ΔR(b,l),

m(ll), HT(Jet), Higgs mass, ΔR(bb_DNN), HT(bb_DNN), Δη(bb_DNN), Δφ(bb_DNN)

Normalized confusion matrix

ttnb   : ttbb + tt4b
Others : ttZH, ttbbH, ttVV, ttbbV

Pass the shape to Combine.

Cut and Count & S/sqrt(B) (One bin)

Limitation of current interpretation.

- Cut-and-count considers only one bin.

- Too small events.. -> S/sqrt(B) Gaussian approximation breaks & Result is too sens

Only 5 Events..

DNN_0.99
3.86
1.2
0.1
0.01
0.02
0.13
0.46
0
0.25
0.21
2.5

```
best_th, best_sig = 0.96 1.937226528204358
best_th, best_sig = 0.97 2.0406851236331414
best_th, best_sig = 0.98 2.3415168016937735
best_th, best_sig = 0.99 2.5015280878707093
cutflow/opt_cutflow_ss2l_withb.py:292: RuntimeWarning: invalid value encountered in double_scalars
  tmp_sig = acc["tthh"]/np.sqrt(acc["tth"]+acc["ttbbh"]+acc["ttzh"]+acc["ttvv"]+acc["ttbbv"]+acc["ttbb"]+acc["ttbbbb"]+ac
best_th, best_sig = 0.99 2.5015280878707093
cutflow/opt_cutflow_ss2l_withb.py:292: RuntimeWarning: invalid value encountered in double_scalars
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best_th, best_sig = 0.99 2.5015280878707093
cutflow/opt_cutflow_ss2l_withb.py:292: RuntimeWarning: invalid value encountered in double_scalars
```

Shape Method (All bins)

1. Get DNN Histogram normalized to cross section weights.
2. Binning the score (10, 0, 10).
3. Analyze the shape (all bins) to get the result. -> Higgs Combine.

Higgs Combine v10.1.0 (Latest) / CMSSW_14_1_0_pre4

datacard.txt :
```
imax 1              number of channels
jmax 9              number of backgrounds (signal + 9 backgrounds)
kmax *              number of nuisance parameters
-----------------------------------------------------
shapes data_obs ch1 myShapes.root data_obs
shapes *            ch1 myShapes.root hist_$PROCESS
-----------------------------------------------------
bin             ch1
observation     -1
-----------------------------------------------------
bin             ch1     ch1     ch1     ch1     ch1     ch1     ch1     ch1     ch1     ch1
process         tthh    tth     ttbbh   ttzh    ttvv    ttbbv   ttbb    ttbbbb  tttt    ttw
process         0       1       2       3       4       5       6       7       8       9
rate            14.24   8191.12 427.77  45.05   484.86  365.51  7966.99 2040.24 1272.93 10410.36
-----------------------------------------------------
lumi    lnN     1.025   1.025   1.025   1.025   1.025   1.025   1.025   1.025   1.025   1.025
```

Shape Method (All bins)

$text2workspace.py datacard.txt -o datacard.root

$combine -M Significance -t -1 --expectSignal=1 datacard.root

$combine -M AsymptoticLimits -t -1 --expectSignal=1 datacard.root

Results

Significance = 1.30447

```
-- AsymptoticLimits ( CLs ) --
Observed Limit: r < 2.4808
Expected  2.5%: r < 0.8342
Expected 16.0%: r < 1.1250
Expected 50.0%: r < 1.5938
Expected 84.0%: r < 2.2926
Expected 97.5%: r < 3.1604
```

Interpretation :
This analysis can observe ttHH signal if the signal is produced more than 2.4 times of SM expectation.

Expected Improvements to go :
- Optimizing Binning Strategy.