VBF H->hh->bbtautau (lephad) Status and Plan

Puja Saha
21st November, 2017
on behalf of bbtautau analysis group

Content

- Motivation behind VBF di-Higgs production
- VBF jets kinematics
- Analysis strategy (preliminary):
  - Pre-selection, SR definition
  - VBF jet selection
  - Cut flow: signal and ttbar background
  - ttbar CR region
  - BDT training: signal and background
  - Limit plot (first look)
- MC production status

Why Search for Higgs Pair ?

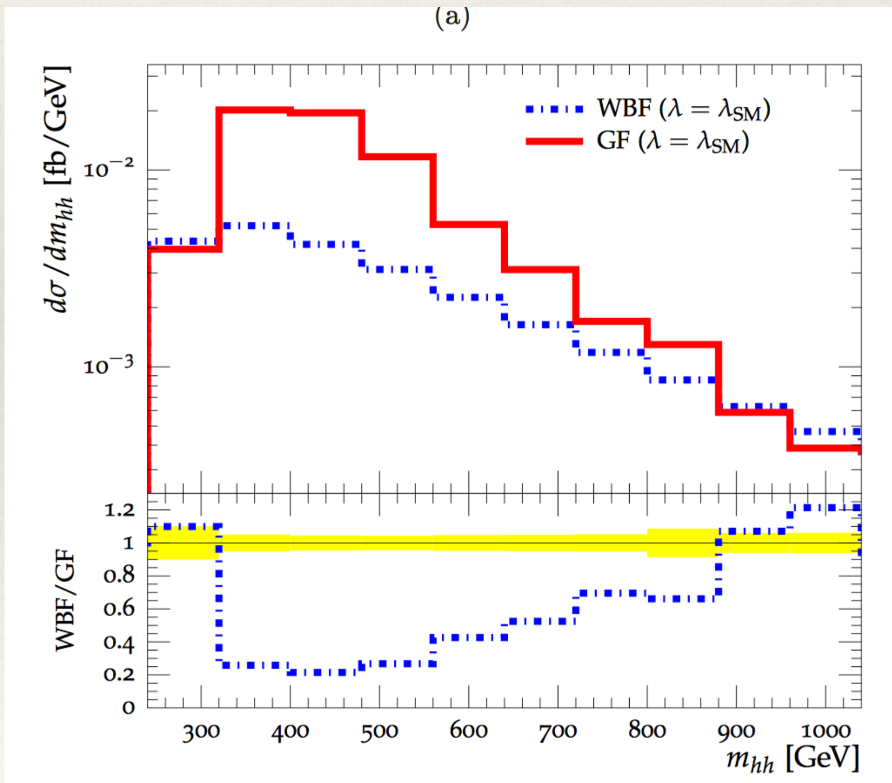
Higgs potential:

$$V(H^\dagger H) = \mu^2 H^\dagger H + \eta\,(H^\dagger H)^2 \sim 1/2\, m_h^2\, h^2 + \sqrt{(\eta/2)}m_h\, h^3 + (\eta/4)h^4$$

by expanding the Higgs doublet around it's vacuum expectation value in unitary guage. Higgs tri-linear coupling $\lambda_{SM} = \sqrt{(\eta/2)}m_h$ is needed to understand the Higgs potential. Search for Di-Higgs production is important measure to the tri-linear coupling.

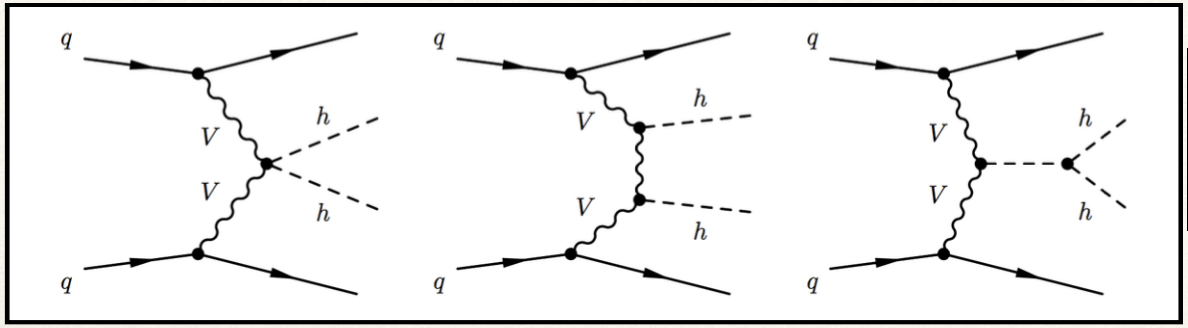
Why hhjj?

- Di-Higgs production in association of two jets has contribution from QCD mediated process and by vector boson fusion (VBF) production.
- VBF di-Higgs production in association of two jets is important:
  - The weak boson fusion component of pp-> hhjj is sensitive to modification of the gauge-Higgs sector, which leads to the large cross-section enhancements.
  - A search for BSM electroweak deviation is not hampered by QCD systematics.
- The ggF contribution is bigger by a factor of 2.5 than VBF , however with increasing invariant di-Higgs mass the WBF contribution is enhanced relative to GF production as consequence of the suppression above $2m_t$ threshold.



arxiv:1506.08008

VBF jets Kinematics



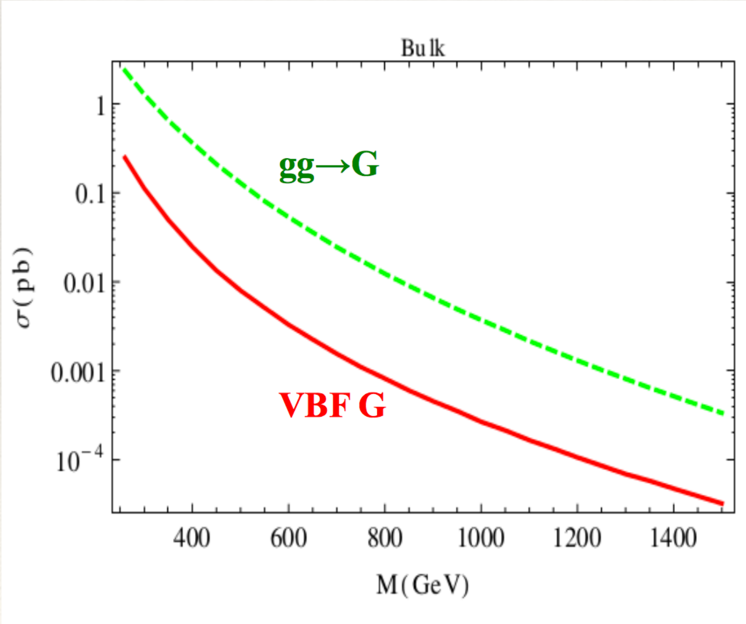
$$|\mathcal{M}_{fi}|^2 \propto \frac{p_1 \cdot p_2 \; p_3 \cdot p_4}{(q_1^2 - M_W^2)^2 (q_2^2 - M_W^2)^2} \,,$$

$$q_1^2 = -2\, p_1 \cdot p_3 = -2 E_1 E_3 (1 - \cos\theta_1) = -\frac{2}{1 + \cos\theta_1} \frac{E_1}{E_3}\, p_{T,3}^2 \,,$$

- The squared matrix element can be maximise, by increasing the numerator or reducing the denominator. $\sqrt{s}=\sqrt{2\, p_1 p_2}$ is constant in the given center of mass energy. $m_{jj} = \sqrt{2\, p_3.p_4}$. Tag jets (VBF) should have high invariant mass.

- Reducing the denominator means, the W/Z boson has low transverse momentum but should have enough energy to produce the heavy scalar.

- Two outgoing quarks carry small portion of the initial momentum but large energies to yield small scattering angle and large pseudo rapidity.



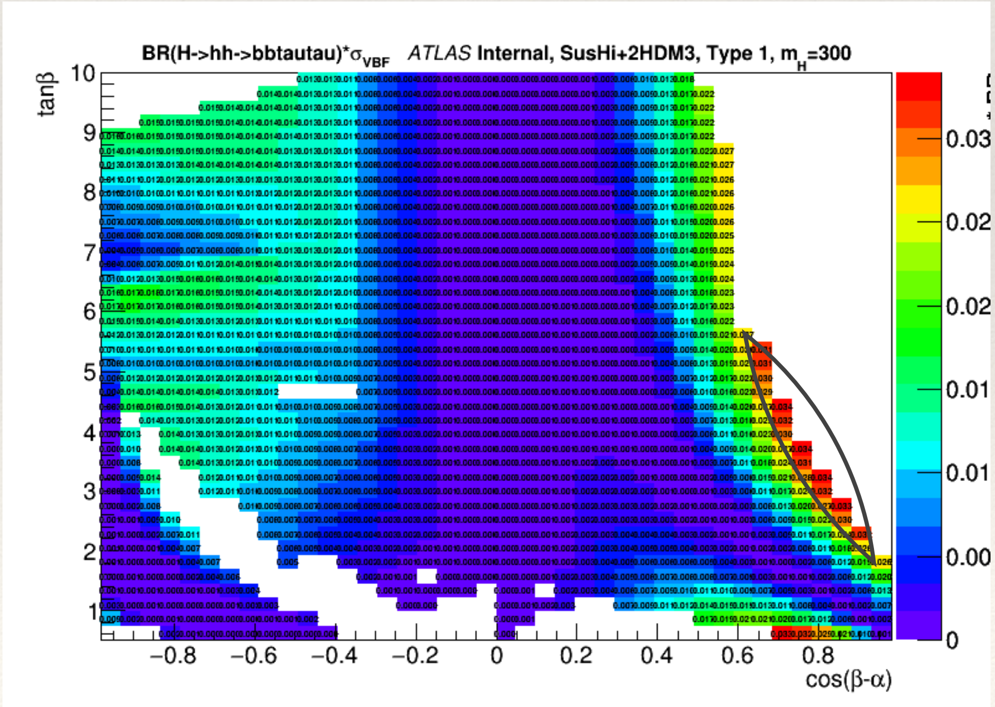
Signal Events in 2015+2016+2017 Data

	bb	WW	ττ	ZZ	γγ
bb	33%				
WW	25%	4.6%			
ττ	7.4%	2.5%	0.39%		
ZZ	3.1%	1.2%	0.34%	0.076%	
γγ	0.26%	0.10%	0.029%	0.013%	0.0053%

- Given the cross sections in VBF hhjj production are very suppressed compared to WBF hjj, we have to rely the dominant Higgs(h) decay modes to be able to observe this final state.
- Among the possible decay modes of the Higgs, we considered h->bb and h->$\tau\tau$ and specifically will focus on the lephad channel of the di-τ decay.

Number of signal events:
82000*.031*(1111/250000)=11.3
including the 2017 data set it will be ~ 11 signal events

Xsection(2HDM, H=300)*BR(H->hh->bbtautau) in the parameter space not excluded by ggF analysis



Pre-selection:

Analysis tool: CxAOD framework
BDT analysis : FastBDT package
k-fold method will be used (later)

- MC event weight < 20.0.
- SLT Trigger matched.
- Exactly one tau , one lepton(e/mu) of opposite sign.
- MMC> 60GeV.
- Two VBF jets.
- At least two signal jets.
- Jet selection is different from bbtautau analysis. VBF jets (tagged jets) are chosen first and then the signal jets. (next slide)

Signal Region (first look):

- DeltaEta of two VBF jets > 3.0.
- Invariant mass of two VBF jets > 700 GeV. (optimisation in 2D plane on slide 8).
- 2-btag category.

Jet Selection

centralJets (eta< 2.5)

forwardJets (eta > 2.5)

pt> 20, eta < 2.5

pt> 30, eta > 2.5

allJets

pair of jets with highest m_jj, eta1*eta2 < 0, non- btagged

VBFJets (size is either 0 or 2)

SelectedCentralJets= centralJets- VBFJets

SelectedForwardJets= forwardJets-VBFJets

2 b-tag region

- Jet1= leading b-tag jet from central jets (eta <2.5)
- Jet2 = sub-leading b-tag jet from cerntral jets(eta <2.5)
- Jet3= If central jet exist then from centraljet otherwise from forward jet

One of them should be pt > 45 GeV, and both pt >20 GeV

Significance in 2D plane for 260 GeV mass point

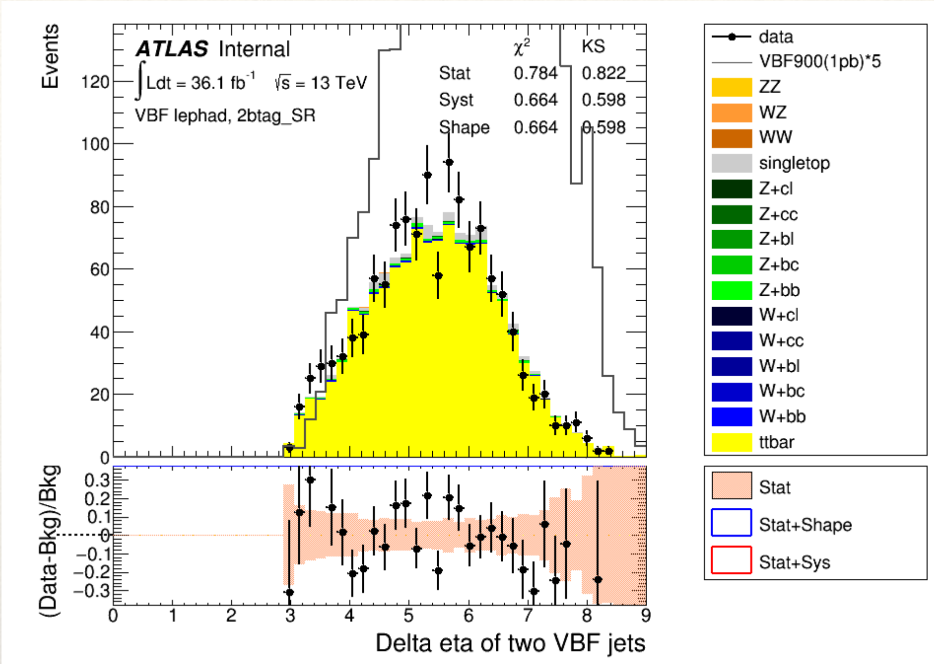
		eta>1	eta>2	eta>3	eta>4	eta>5
mjj>300	sig260	946.418	939.245	911.854	776.755	498.735
	ttbar	8243.47	8040.55	7297.32	5315.53	2555.4
	sigficance	10.2333	10.2799	10.4629	10.4082	9.56866
mjj>400	sig260	860.674	859.366	843.853	745.571	496.742
	ttbar	6063.79	5968.67	5583.98	4456.61	2479.89
	significance	10.8065	10.8713	11.0248	10.8768	9.66708
mjj>500	sig260	779.409	778.103	771.435	700.223	485.449
	ttbar	4549.57	4498.35	4279.94	3602.81	2238.22
	significance	11.2469	11.289	11.4618	11.3156	9.92013
mjj>600	sig260	694.876	694.509	691.16	641.898	467.766
	ttbar	3462.11	3435.88	3310.51	2891.39	1960.43
	significance	11.4444	11.4795	11.6271	10.5322	11.1814
mjj>700	sig260	621.964	621.964	619.914	568.342	440.67
	ttbar	2688.05	2673.43	2600.55	2334.87	1682.97
	significance	11.5733	11.6027	11.7157	11.6733	10.3178
mjj>800	sig260	547.205	547.205	528.205	528.124	413.424
	ttbar	2110.58	2103.28	2064.55	1882.92	1432.27
	significance	11.4451	11.4635	11.5626	11.6596	10.4532

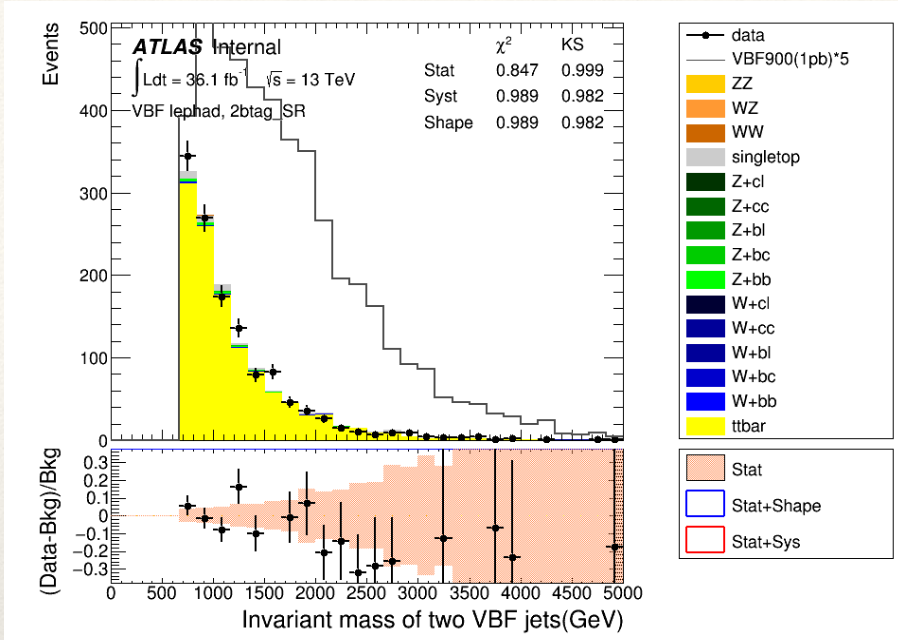
- Significance: s= sqrt(2*((s+b)*Log(1+(s/b)) -s)). The values are the yield after applying all the weights.

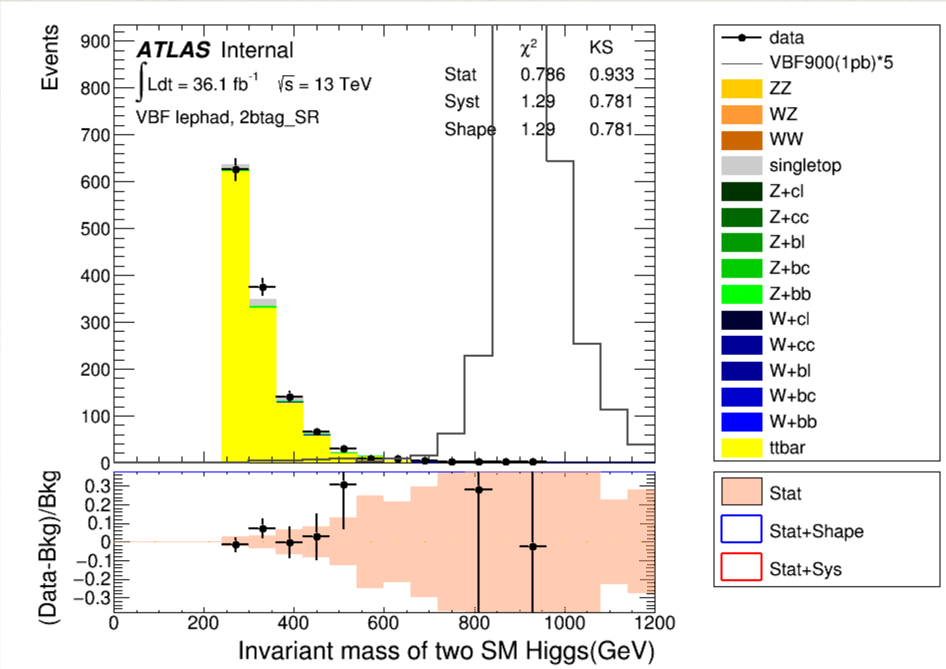
Cut Flow in SR

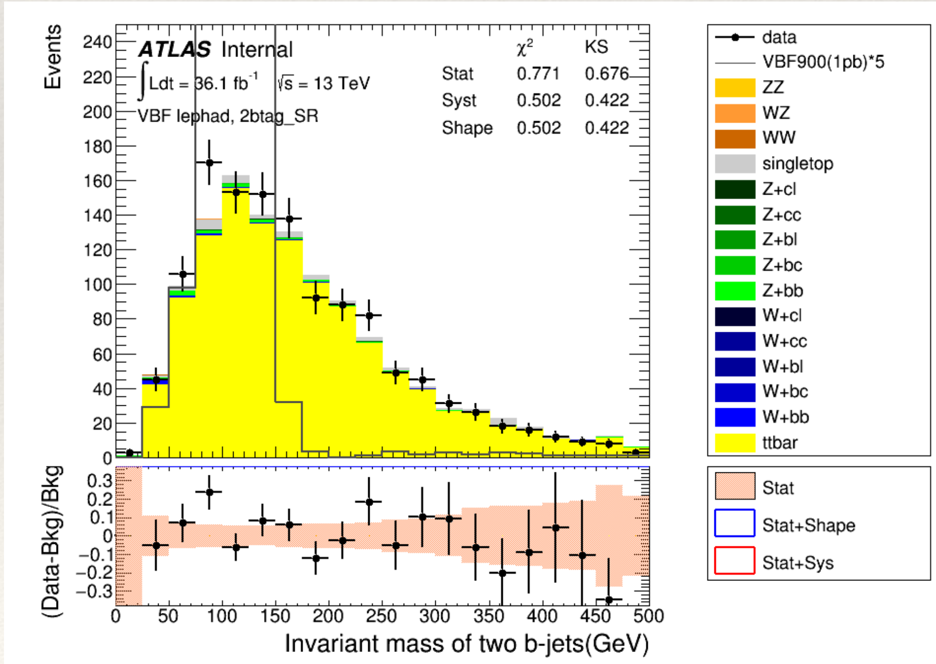
Cuts	mass 260	Signal eff %(260GeV)	w.r.t initial	mass 900	signal eff%(900 Gev)	w.r.t initial number	ttbar	Eff(%)
Total events	17915			35336			519167	
mc weight < 20.0	17697	98.7	98.7	35087	99.2	99.2	513025	98.81
Trigger SLT	11510	65.03	64.24	29331	83.5	83	447404	87.20
remove Elcluster in gap	11497	99.8	64.17	29294	99.8	82.90	446589	87.05
tau=1, remove gap gap/crack	11238	97.74	62.72	29013	99.04	82.10	427403	95.70
opposite sign	10997	97.85	61.38	28711	98.95	81.25	371275	86.86
mmc> 60	10935	99.43	61.03	27788	96.78	78.63	264355	71.20
VBF jet =2	6125	56.01	34.18	15210	54.73	43.04	95348	36.06
signal jet >= 2	5992	97.82	33.44	14791	97.24	41.85	94209	98.80
2btag+pt on signal jets	1925	32.12	10.7	6351	42.93	17.97	26372	27.99
2btag+m_jj >700	1114	57.87	6.2	4840	76.20	13.69	3649	13.83
2btag+Delta_jj> 3.0	1111	99.73	6.2	4819	99.56	13.63	3528	96.68

SR Plots (jet faking taus are estimated from MC)

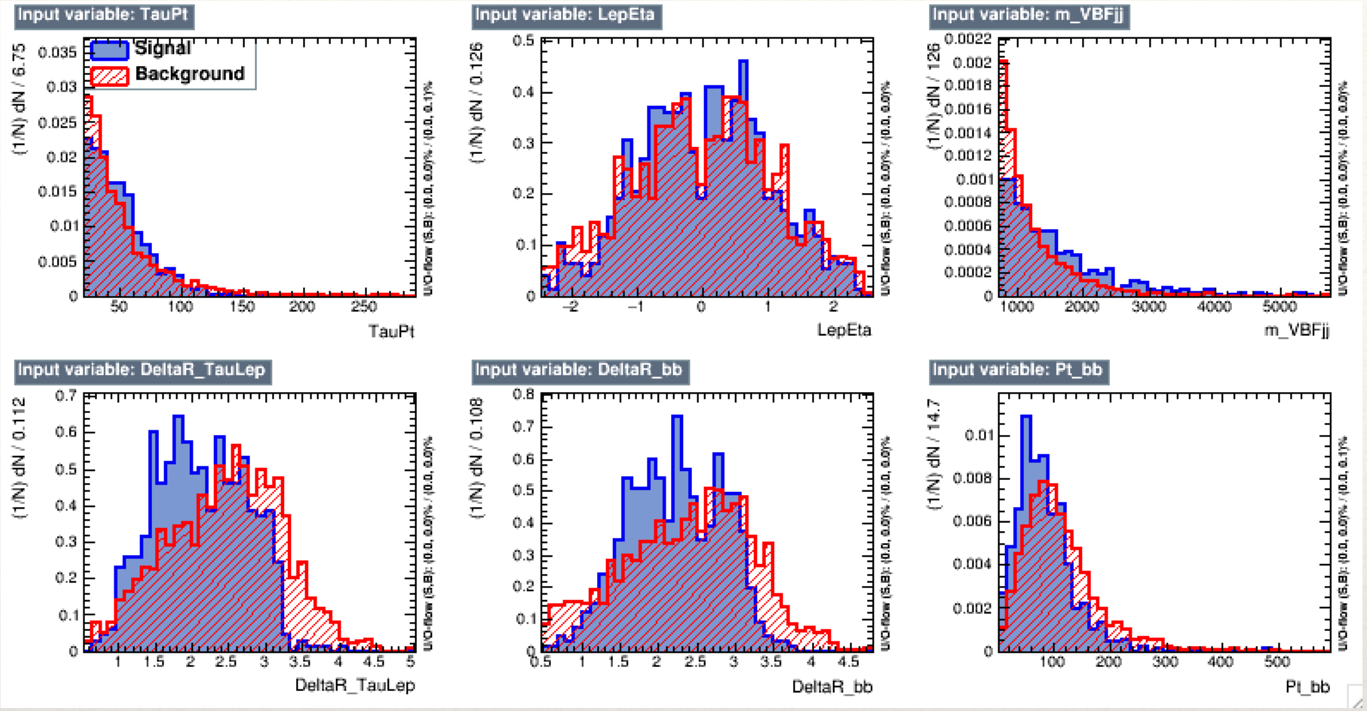






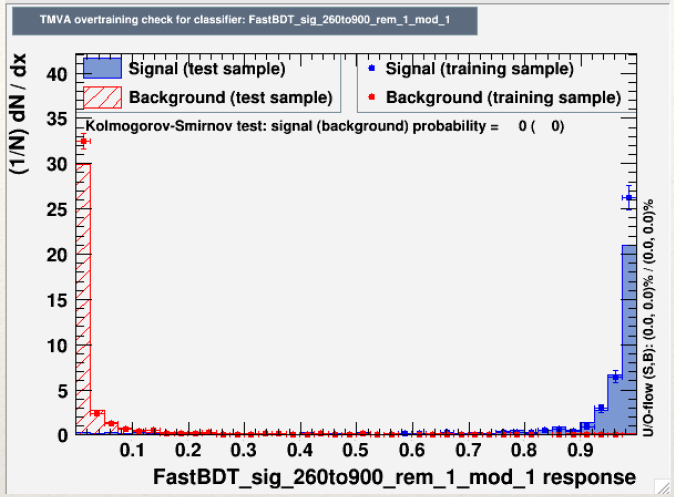


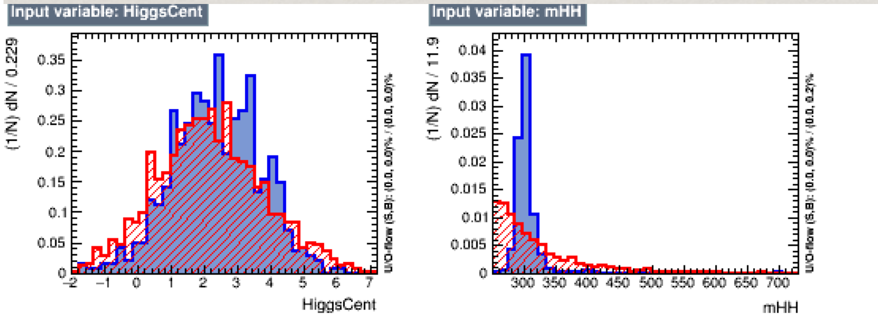
BDT input variable distributions with 300GeV signal

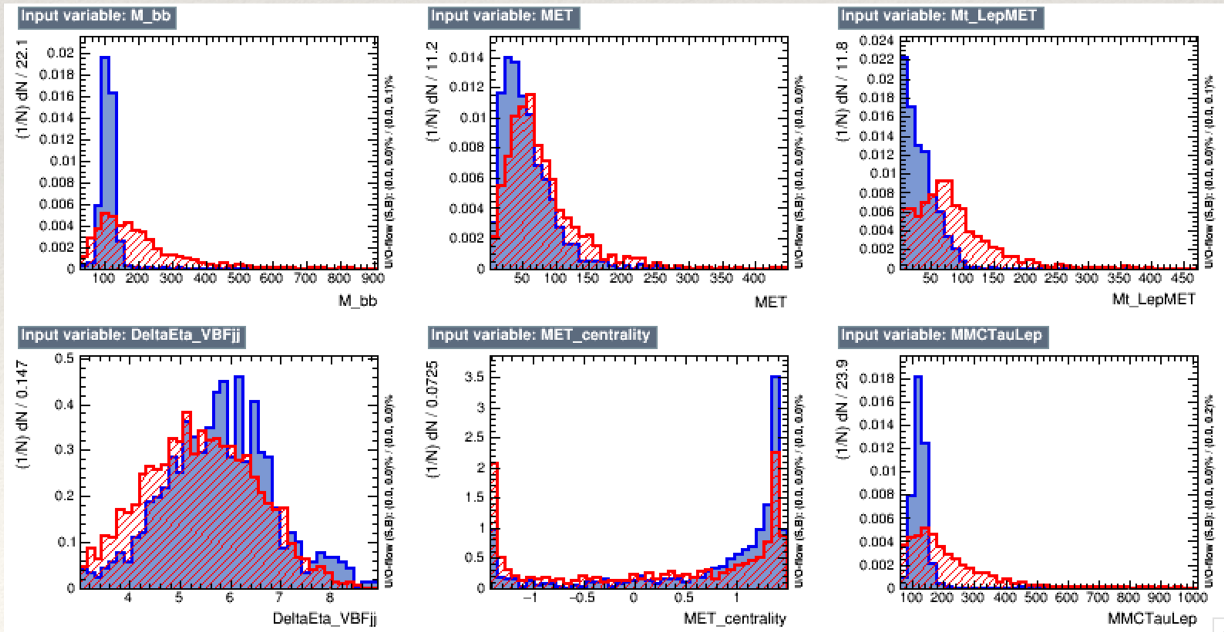


ttbar

signal 300GeV







900 GeV plots are on back up

Variable Ranking in Three Different Mass Points

Rank	Variable	Variable Importance
1	mHH	2.631e-01
2	M_bb	2.430e-01
3	MMCTauLep	2.033e-01
4	Mt_LepMET	1.046e-01
5	m_VBFjj	4.341e-02
6	MET_centrality	2.904e-02
7	TauPt	2.115e-02
8	DeltaR_TauLep	1.783e-02
9	HiggsCent	1.647e-02
10	DeltaEta_VBFjj	1.376e-02
11	Pt_bb	1.343e-02
12	LepEta	1.192e-02
13	MET	1.060e-02
14	DeltaR_bb	8.397e-03

300 GeV

Rank	Variable	Variable Importance
1	mHH	8.612e-01
2	M_bb	3.360e-02
3	MMCTauLep	2.041e-02
4	DeltaR_bb	1.617e-02
5	DeltaR_TauLep	1.548e-02
6	TauPt	1.247e-02
7	Pt_bb	1.125e-02
8	m_VBFjj	5.514e-03
9	Mt_LepMET	5.274e-03
10	MET_centrality	4.579e-03
11	HiggsCent	4.196e-03
12	DeltaEta_VBFjj	3.771e-03
13	MET	3.585e-03
14	LepEta	2.526e-03

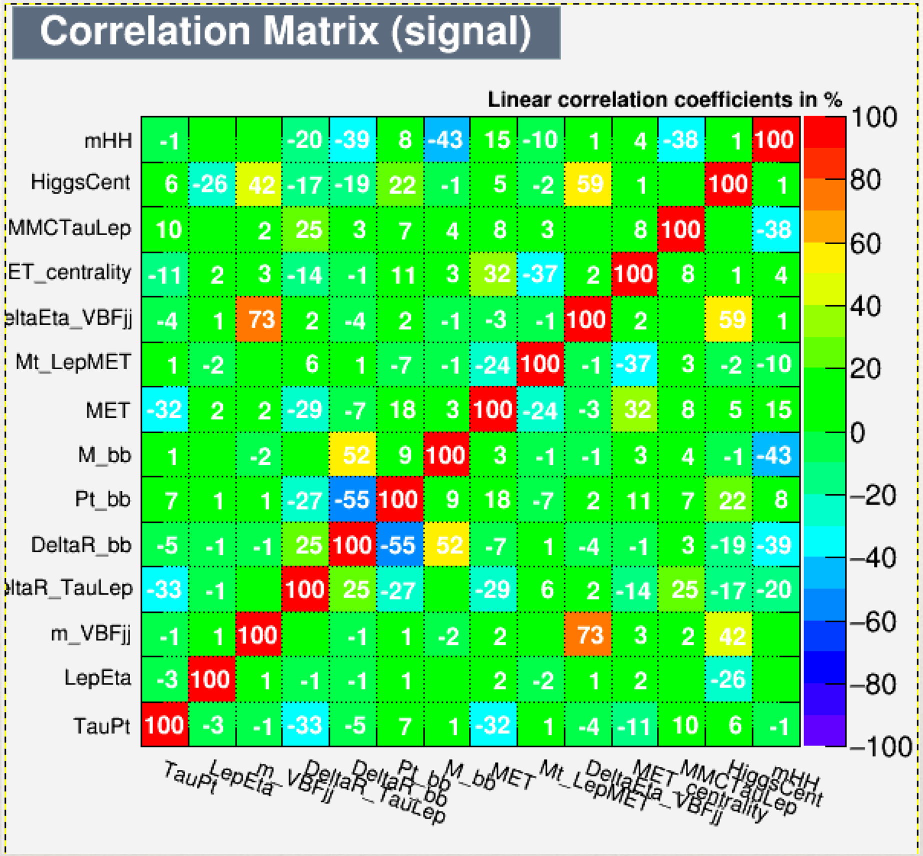
600 GeV

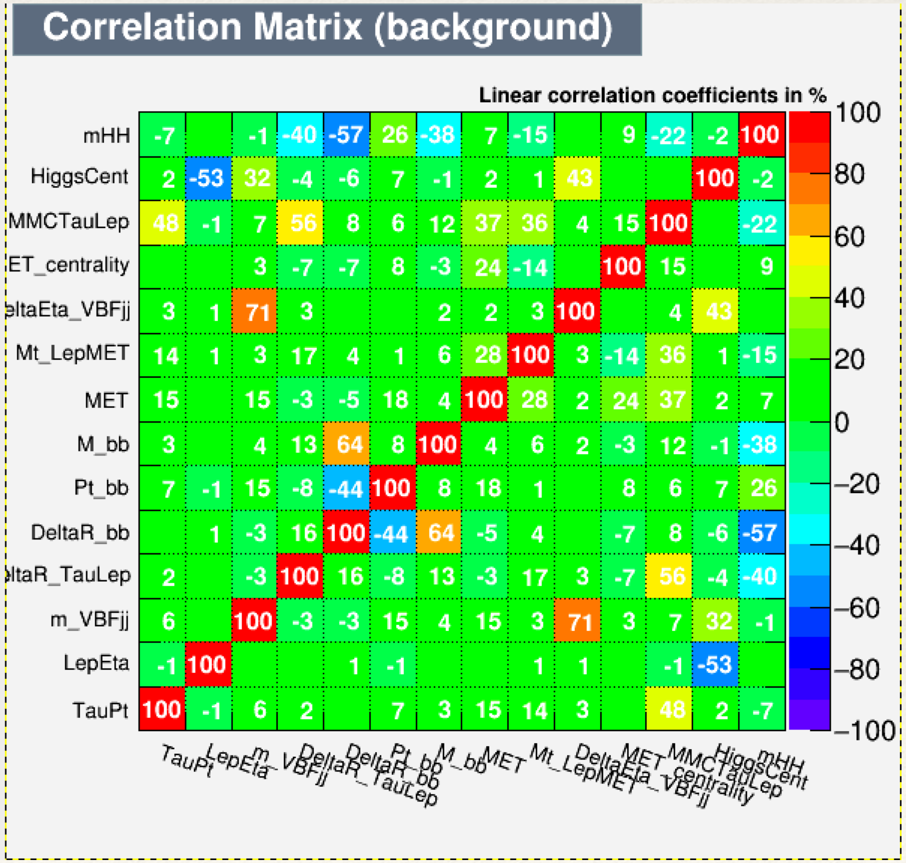
Rank	Variable	Variable Importance
1	mHH	9.427e-01
2	DeltaR_TauLep	1.757e-02
3	M_bb	1.053e-02
4	MMCTauLep	7.156e-03
5	TauPt	5.401e-03
6	Pt_bb	4.597e-03
7	DeltaEta_VBFjj	3.475e-03
8	Mt_LepMET	2.242e-03
9	m_VBFjj	1.643e-03
10	DeltaR_bb	1.515e-03
11	MET_centrality	1.466e-03
12	HiggsCent	1.119e-03
13	MET	4.342e-04
14	LepEta	1.734e-04

900 GeV

Variable ranking varies with the mass points. For 900 GeV, it is enough to do BDT training with mHH.

Correlation Matrix





ttbar CR Region Definition

ttbar CR	SR
Preselection	Preselection
mjj>500, DeltaEta>2.0	mjj>700, DeltaEta>3.0
mTLepMET* > 40 GeV	none
2 b-tag	2 b-tag

sampleName	entries	integral	error	error/integ.
VBF900_lephad_hh_bbtautau	1195	1203.68	43.2189	0.0359057
ZZ	118	0.224658	0.109515	0.487472
WZ	399	0.293297	0.0864701	0.294821
WW	154	0.447863	0.171614	0.383183
stopWt	166	45.9752	4.87928	0.106128
stopt	34	7.94256	1.79347	0.225805
stops	1	0.041344	0.041344	1
Zcl	1567	0.124877	0.0129762	0.103911
Zcc	490	0.25728	0.0221277	0.0860066
Zbl	1313	0.401796	0.0532693	0.132578
Zbc	266	0.586526	0.0984375	0.167831
Zbb	756	9.76348	0.675479	0.0691843
Wcl	1215	0.266793	0.0215017	0.080593
Wcc	288	0.423598	0.0616013	0.145424
Wbl	494	0.43526	0.0376383	0.0864731
Wbc	148	1.29932	0.198537	0.152801
Wbb	226	8.10018	1.16128	0.143365
ttbar	4497	1479.67	25.8958	0.0175011

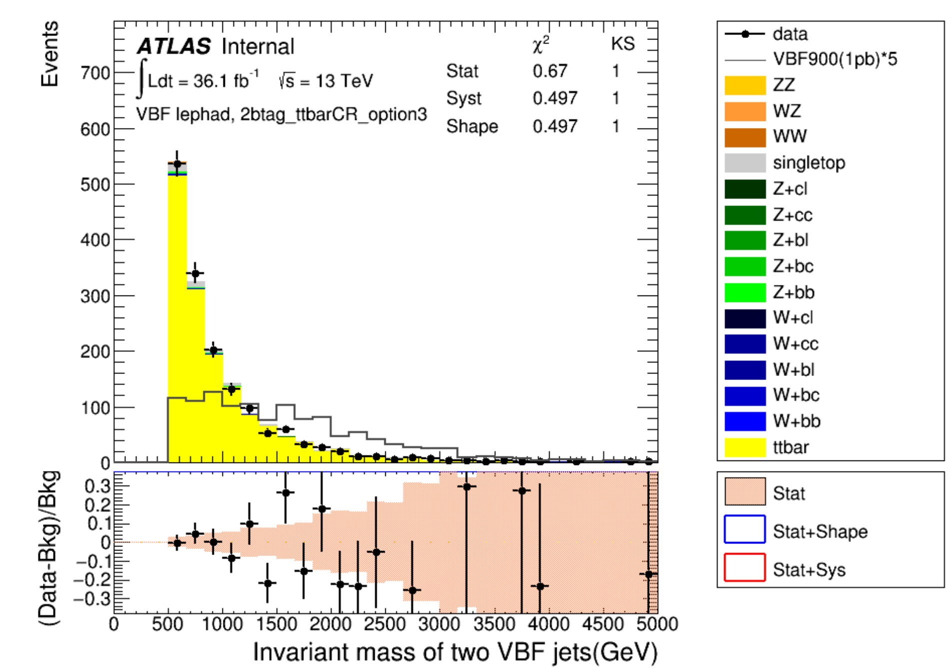
bkg: 1555.89
data 1553

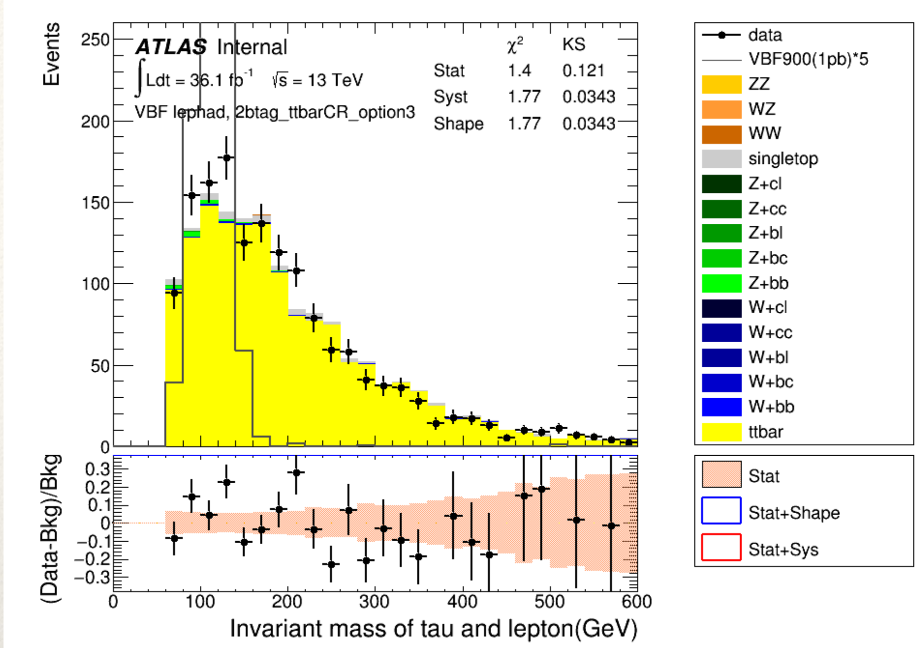
ttbar CR yields

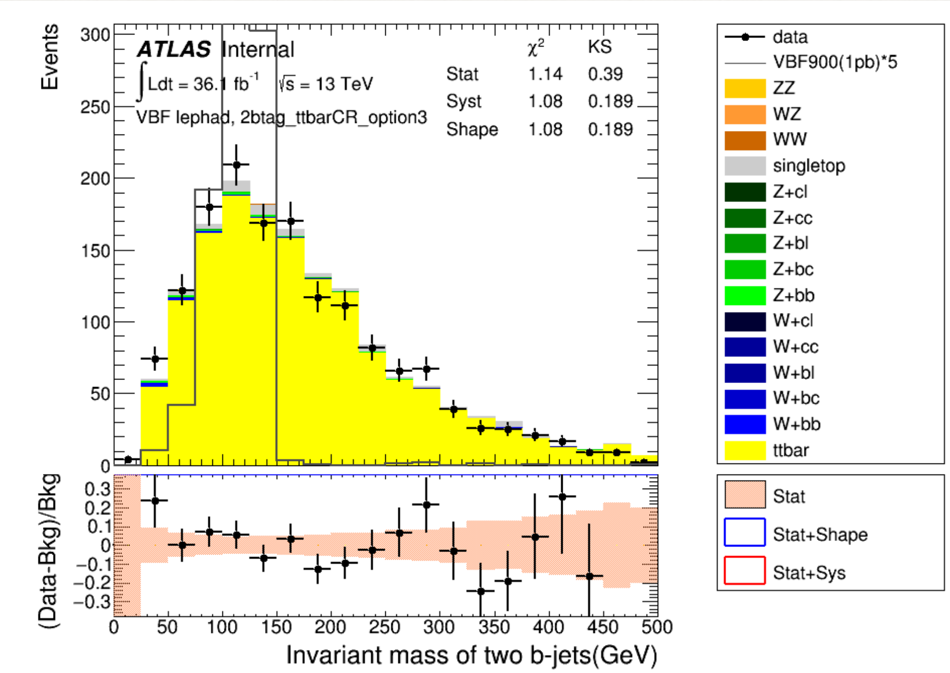
Pre-selection: bbtautau pre selection + different jet selection for VBF

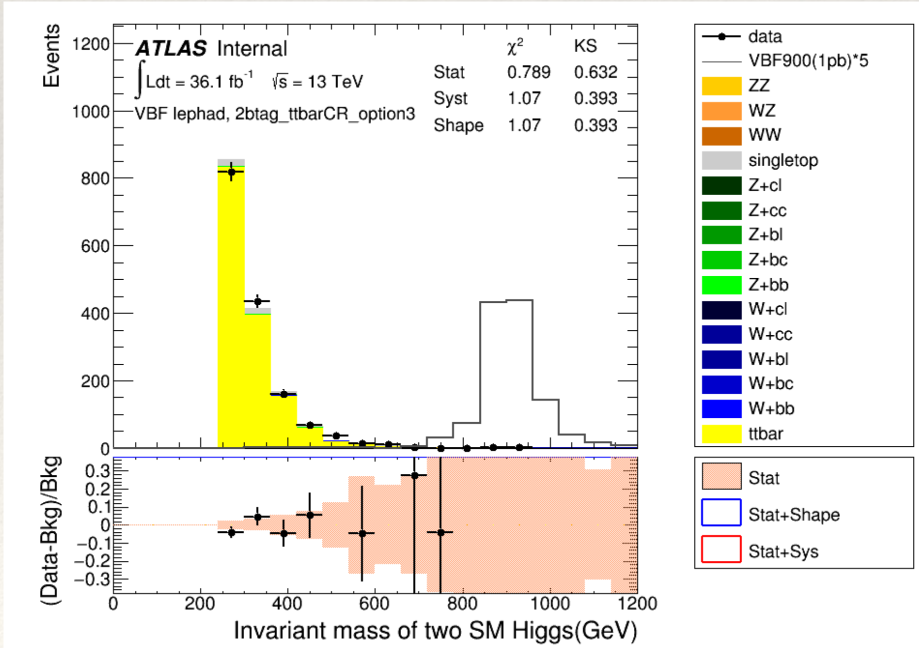
* definition is provided in the backup slide.

CR Plots (jet faking taus are estimated from MC)

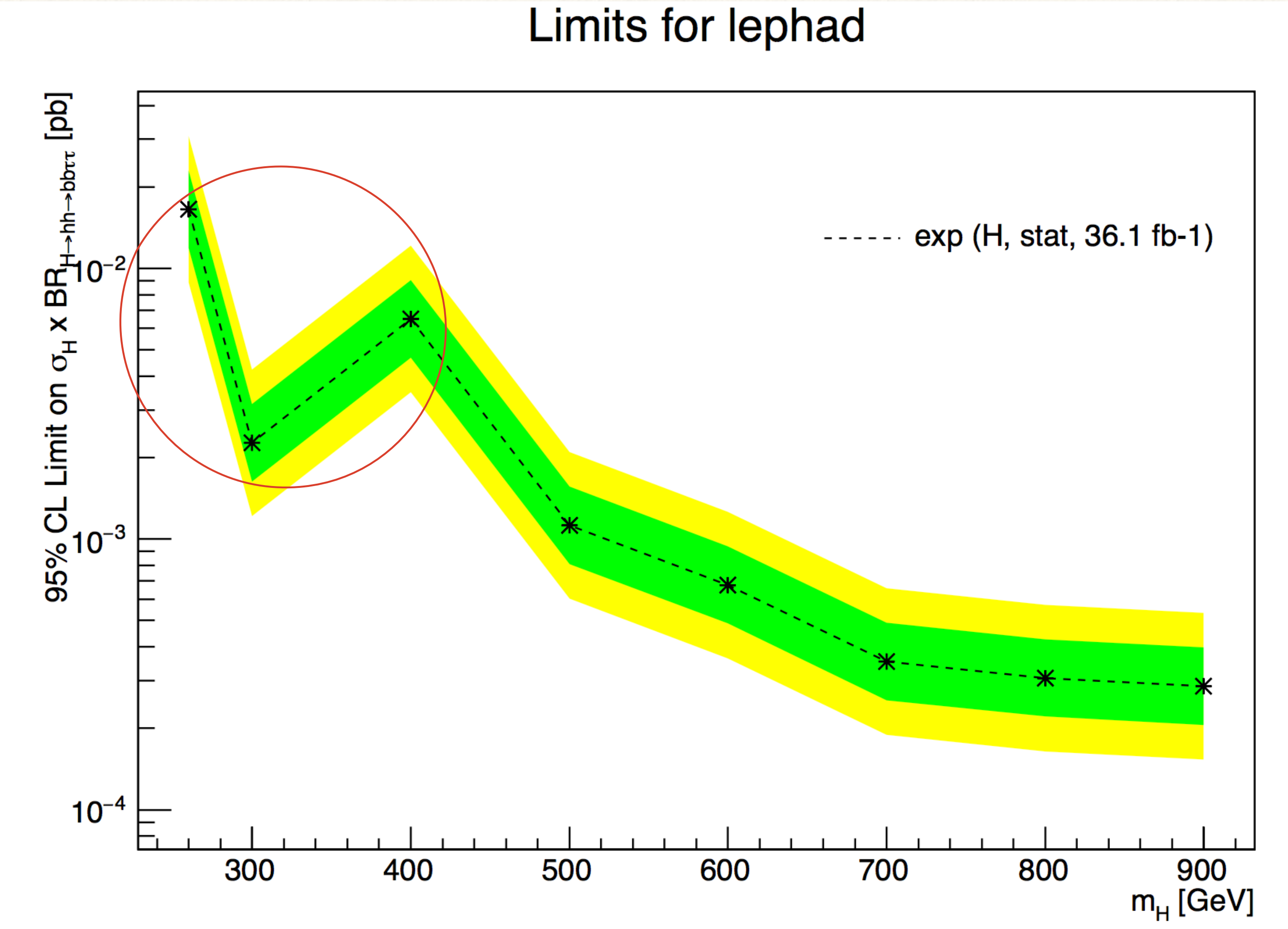








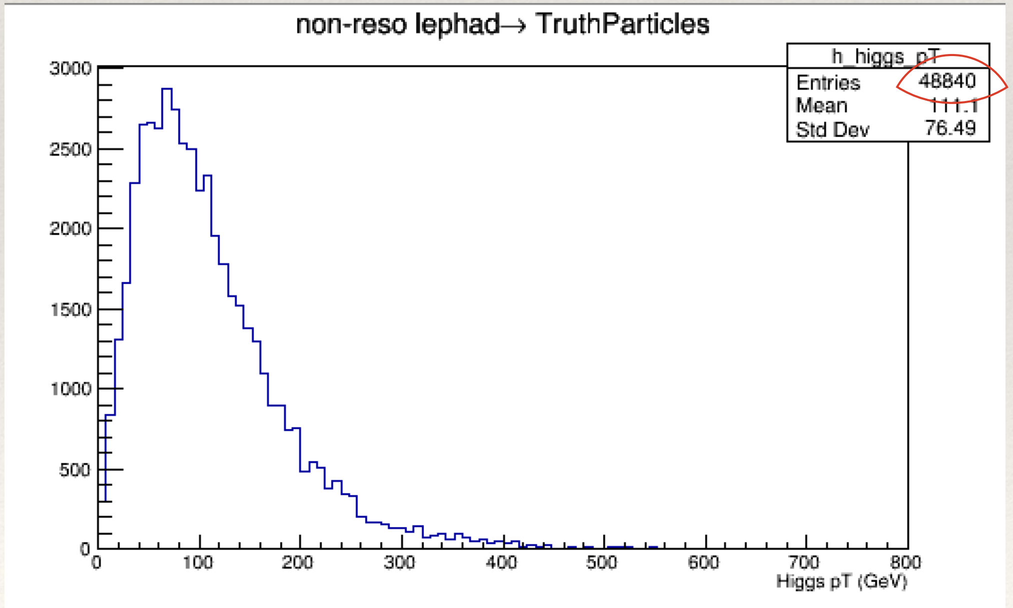
First Look at the Limit plot



- First look at the expected limit using the mHH as final discriminant.
- The big drop at the 300 GeV point, yet not understood. Did not observe anything suspicious in SR plot of mHH(slide 10).
- On slide5 the highest cross section*BR for 2HDM heavy scalar of 300 GeV mass point is ~0.031 and 260 GeV also around 0.031. On the limit plot the limit is set at (.011) which is suspicious. Need to revisit the scale on the Y-axis.

MC Production of VBF Resonant and non-Resonant Sample

- Rel20 resonant sample are already available in lephad and hadhad channel.
- Looking at the cut flow we decided to add pt filter before we request new sample in Rel21, which needs further validation at least few low mass points. No validation needed in EVNT generation part since nothing is changed between two releases in VBF_H.(see back up slide 50)
- Non-resonant sample is generated and validated, which also needs pt filter added. Otherwise validation plots look good except one plot.(plot below).
- Katy and her students will take over the validation of Rel21 sample. Hopefully we can request sample soon.



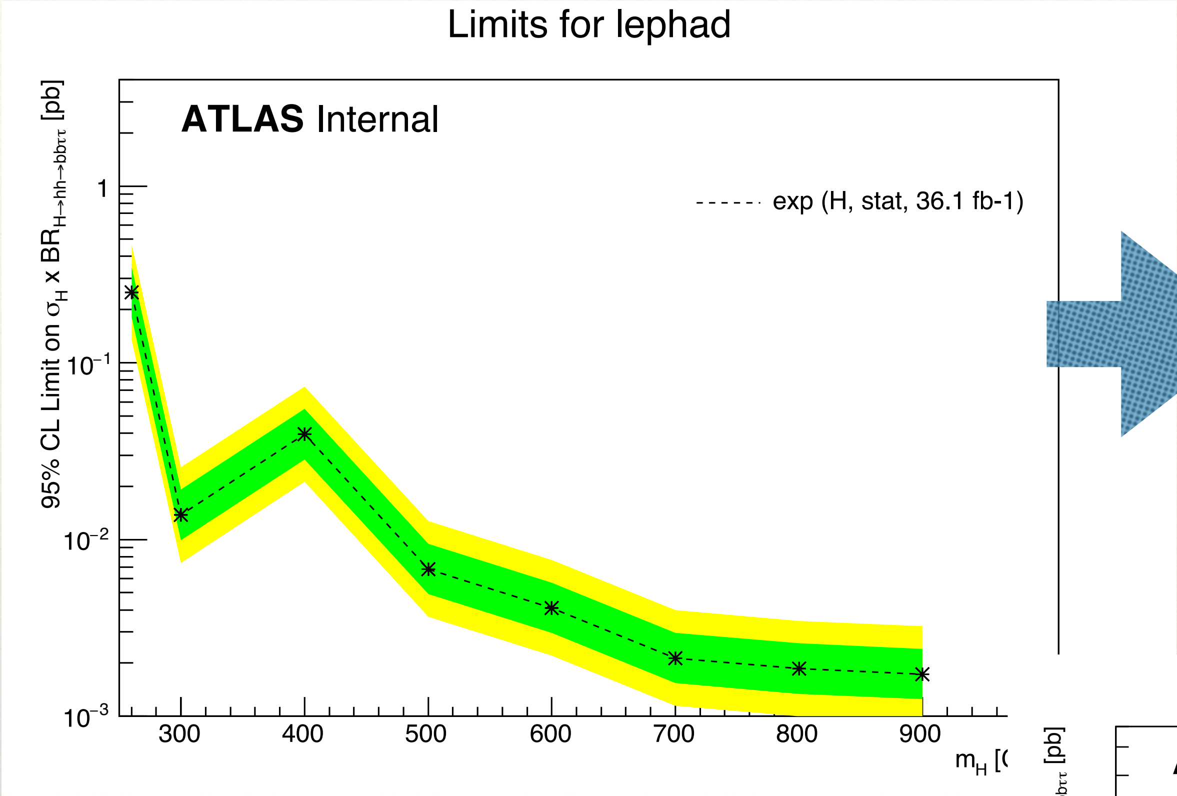
4000 events should have 8000 SM Higgs, but validation plots have much higher

Analysis Plan

- Next thing I will be working on is to define the CR and check the data and MC modelling with the fakes estimated from data driven method.
- Then do the BDT training and choose the variables to train different mass points. More stats are needed to do the BDT training. Can we request more statistics? Situation will improve after adding the pt filter.
- We need to move to the Rel21 framework.
- This analysis will go in my PhD thesis. I am planning to finish this by 2018 December or possibly few more months in 2019, in that case I would like to add 2019 data as well. It would be great if anyone is interested to work on this channel with me and discuss the analysis offline.

Back up

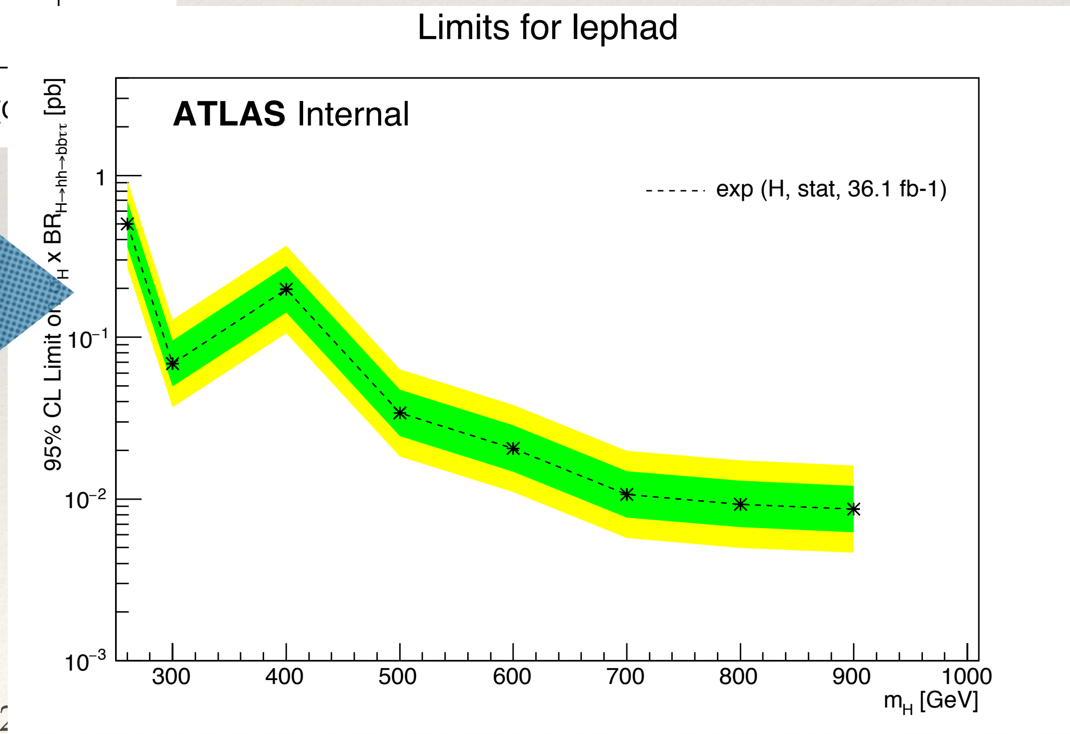
Limit plot on VBF resonant hh-> bbtautau



- This plot is the expected limit and not scale to anything.

- This plot is the expected limit times the cross section used in normalisation.

260 GeV: 2pb , 300-900 : 5 pb



Filter Efficiency

```
14:23:26 EvgenTestSeq          INFO Finalizing EvgenTestSeq...
14:23:26 EvgenFilterSeq        INFO Finalizing EvgenFilterSeq...
14:23:26 scalarFilter          INFO Events passed = 10954  Events failed = 10815
14:23:26 scalarFilter          INFO Statistics of X->VV, V->decay
14:23:26 scalarFilter          INFO   ALL  X->VV  21769
14:23:26 scalarFilter          INFO   Good X->VV  10954
14:23:26 scalarFilter          INFO   Fraction   0.503193
14:23:26 XtoVVDecayFilte...    INFO Events passed = 5000  Events failed = 5954
14:23:26 XtoVVDecayFilte...    INFO Statistics of X->VV, V->decay scanning all ancestors of V in order t
14:23:26 XtoVVDecayFilte...    INFO   ALL  X->VV  10954
14:23:26 XtoVVDecayFilte...    INFO   Good X->VV  5000
14:23:26 XtoVVDecayFilte...    INFO   Fraction   0.456454
14:23:26 Py:EvgenFilterSeq     INFO Filter Expression = scalarFilter and XtoVVDecayFilterExtended
14:23:26 Py:EvgenFilterSeq     INFO Filter Efficiency = 0.229684 [5000 / 21769]
14:23:26 Py:EvgenFilterSeq     INFO Weighted Filter Efficiency = 0.229379 [6036.770040 / 26317.836510]
14:23:26 MetaData:  GenFiltEff = 2.293794e-01
```

- Scalar filter filters bbtautau events from bbbb(25%), bb$\tau\tau$(50%), $\tau\tau\tau\tau$ (25%). so the filter efficiency is 50%.
- XtoVVDecayFilter filters lephad channel: 45%.
- Toltal efficiency ~ 22.50%.

Filter Efficiency

Full List of Available Derivations

DSID (job option link) Panda link	Sim. type	Brief description	Generator versions	AMI Xsec [pb]	Filter eff.	Global K-factor (higher order xsec [pb])	Total xsec sample	Sample Stats (Link to AMI)	Comment	LastUpdated
343439 PANDA link	EVGEN	Gen+PS: Powheg+Pythia8+EvtGen Tune: AZNLO CTEQ6L1 PDF in ME: NULL		1.2086	0.22682	1.0	0.274135	e5383: 250000		
343439 PANDA link	FS (MC15b)	Gen+PS: Powheg+Pythia8+EvtGen Tune: AZNLO CTEQ6L1 PDF in ME: NULL		1.2086	0.22682	1.0	0.274135	e4923_s2726_r7326_r6282: 99000		
343439 PANDA link	FS (MC15c)	Gen+PS: Powheg+Pythia8+EvtGen Tune: AZNLO CTEQ6L1 PDF in ME: NULL		1.2086	0.22682	1.0	0.274135	e5383_s2726_r7772_r7676: 246000		

Last update: 2017-09-01 09:40:03.412676

σ(H300GeV) = 1.2086pb

filter eff= .22682

Model independent cross section

- In the JO Pythia setting is :

BR(h->bb) + BR(h->tautau) = 100%

BR(h->bb)=BR(h->tautau)= 50%

BR(h->bb)*BR(h->tautau) = 50%

```
genSeq.Pythia8.Commands += [
                            'Higgs:useBSM = on',

                            '35:m0 = '+str(H_Mass),
                            '35:mWidth = '+str(H_Width),
                            '35:doForceWidth = on',
                            '35:onMode = off',
                            '35:onIfMatch = 25 25', # H->hh

                            '25:onMode = off',
                            '25:oneChannel = 1 0.5 100 5 -5', #h->bb
                            '25:addChannel = 1 0.5 100 15 -15', #h->tautau
                            '25:m0 125.0', #scalar mass
                            '25:mMin 124.5', #scalar mass
                            '25:mMax 125.5', #scalar mass
                            '25:mWidth 0.01', # narrow width
                            '25:tau0 0', #scalarlife time
                            ]
```

https://twiki.cern.ch/twiki/bin/view/LHCPhysics/CERNYellowReportPageBSMAt13TeV

cross section for production of VBF H(300 GeV) : 1.256 pb

Filter Efficiency (thanks Agni)

σx$\mathcal{B}$r consistency in hh $\rightarrow$ bb$\tau\tau$ - factor of 0.414?

How is this factor of 0.414 derived?

David's talk

In nature:

$\mathcal{B}r(h \rightarrow bb) = 58.09$ % and $\mathcal{B}r(h \rightarrow \tau\tau) = 6.2569$ %

$\mathcal{B}r(h \rightarrow bb)\mathcal{B}r(h \rightarrow \tau\tau) = 3.6346\%$

Whereas inside JobOptions:

Listing 3: JobOptions script (link), only $h \rightarrow bb$ and $h \rightarrow \tau\tau$ are allowed.

```
genSeq.Pythia8.Commands += ["25:onMode=off",
                            "25:onIfAny=5 15"  ]
```

$r = \frac{\mathcal{B}r(h\rightarrow bb)}{\mathcal{B}r(h\rightarrow\tau\tau)} = 9.28415$ is kept within `Pythia`.

$\mathcal{B}r(h \rightarrow bb)_{\texttt{Pythia}} + \mathcal{B}r(h \rightarrow \tau\tau)_{\texttt{Pythia}} = 100\%$

$\mathcal{B}r(h \rightarrow bb)_{\texttt{Pythia}}\mathcal{B}r(h \rightarrow \tau\tau)_{\texttt{Pythia}} = 8.7778\%$

$\frac{3.6346}{8.7778} = 0.414 \implies$ **checks out!**

Conclusion: $\mathcal{B}r(h \rightarrow bb)$ and $\mathcal{B}r(h \rightarrow \tau\tau)$ are accounted for in the `filtereff`.

the multiplicative factor in my case will be : (3.6346/25)= .1454
0.22682*.1454=.03298

Xsection Calculation

Listing 1: XSections_13TeV.txt David's talk

```
# 2HDM H —> hh —> bbtautau (lep had) — Carl Gwilliam — (had had H. Fox)
# From https://twiki.cern.ch/twiki/bin/view/AtlasProtected/MC15BSMHiggsPMG
# Correcting filter efficiency by 0.414 to take into account all Higgs decay channels — Edson Carquin — 23—09

342626    441.86    1.0    2.2683E—02    Hhhbbtautau260    MGPy8EG_A14NNPDF23LO_X260to
342627    634.98    1.0    1.8890E—02    Hhhbbtautau300    MGPy8EG_A14NNPDF23LO_X300hh
...
```

Listing 2: ami query

```
logicalDatasetName   : mc15_13TeV.342627.MadGraphPythia8EvtGen_A14NNPDF23LO_X300tohh_bbtautau_lephad.evgen.EVI
beam_energy          : [6500000.0]
genFilterNames       : MultiElecMuTauFilter, XtoVVDecayFilterExtended
crossSection_mean    : 6.3719E—01
GenFiltEff_mean      : 4.5628E—02
```

4.5628 x 0.414 = 1.8890. The 0.414 multiplicative factor is indeed applied.

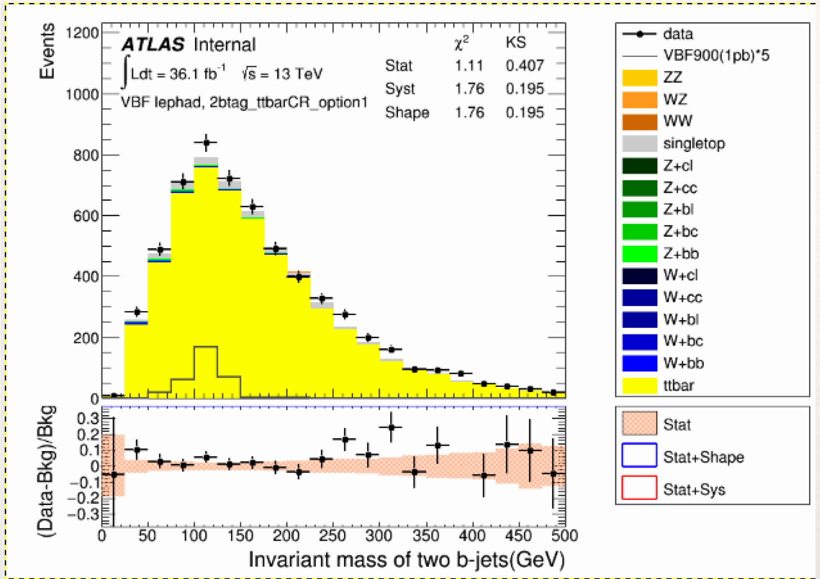
- The 2nd column gives **σ**(H)* BR(H->hh) .
- Then BR(H->hh) is considered ~100%. Not sure why.

Yield for ttbar CR for Different Selections

sampleName	entries	integral	error	error/integ.	
VBF900_lephad_hh_bbtautau	327	326.77	23.791	0.0728064	
ZZ	400	0.972123	0.185599	0.190921	
WZ	1029	1.21566	0.185499	0.152591	
WW	430	0.237789	0.0423243	0.177991	
stopWt	740	188.254	7.93912	0.0421724	
stopt	92	22.703	3.14214	0.138402	
stops	21	1.47242	0.47586	0.323182	
Zcl	3457	0.373655	0.0262233	0.0701804	
Zcc	1037	0.720441	0.313744	0.435489	
Zbl	3663	1.09737	0.154111	0.140436	
Zbc	797	2.41625	0.254501	0.105329	
Zbb	2073	31.5562	1.76111	0.0558087	
Wcl	2753	0.943841	0.0659163	0.0698384	
Wcc	599	1.68115	0.175132	0.104174	
Wbl	1249	1.79387	0.246374	0.137342	
Wbc	364	4.54063	0.502378	0.110641	
Wbb	522	29.2203	2.14632	0.073453	
ttbar	16734	5505.51	50.2615	0.00912931	

bkg: 5710.06
data 5930

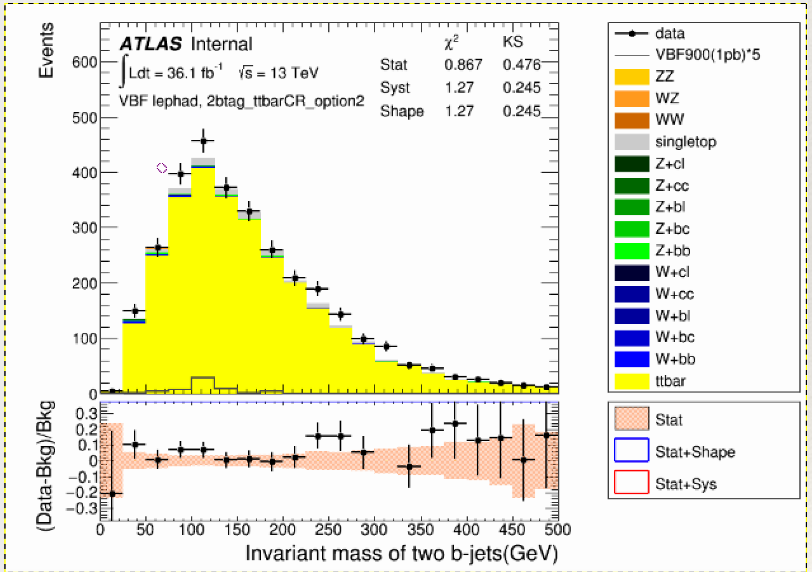
ttbar CR option 1



sampleName	entries	integral	error	error/integ.	
VBF900_lephad_hh_bbtautau	61	56.263	8.42719	0.149782	
ZZ	215	0.589245	0.136631	0.231875	
WZ	556	0.76452	0.144229	0.188653	
WW	221	0.328402	0.136571	0.415865	
stopWt	360	91.9222	5.82659	0.0633861	
stopt	44	10.0792	2.14686	0.212999	
stops	11	0.511505	0.158903	0.310658	
Zcl	2179	0.212366	0.0203169	0.095669	
Zcc	658	0.516782	0.0485384	0.0939243	
Zbl	1987	0.594761	0.0753761	0.126733	
Zbc	457	1.3204	0.144622	0.109528	
Zbb	1163	15.5891	1.08356	0.0695077	
Wcl	1745	0.51603	0.0486522	0.0942817	
Wcc	397	0.888681	0.121031	0.136192	
Wbl	730	0.975232	0.173845	0.17826	
Wbc	227	2.45731	0.331175	0.134771	
Wbb	344	18.3444	1.67515	0.0913166	
ttbar	8783	2884.38	36.3939	0.0126176	

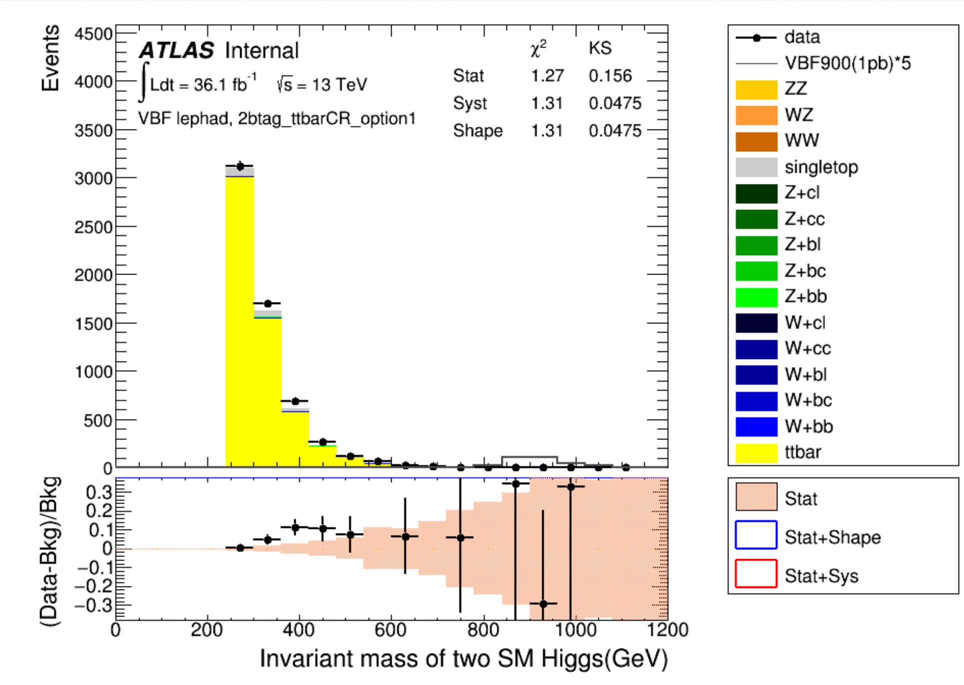
bkg: 2984.6
data 3158

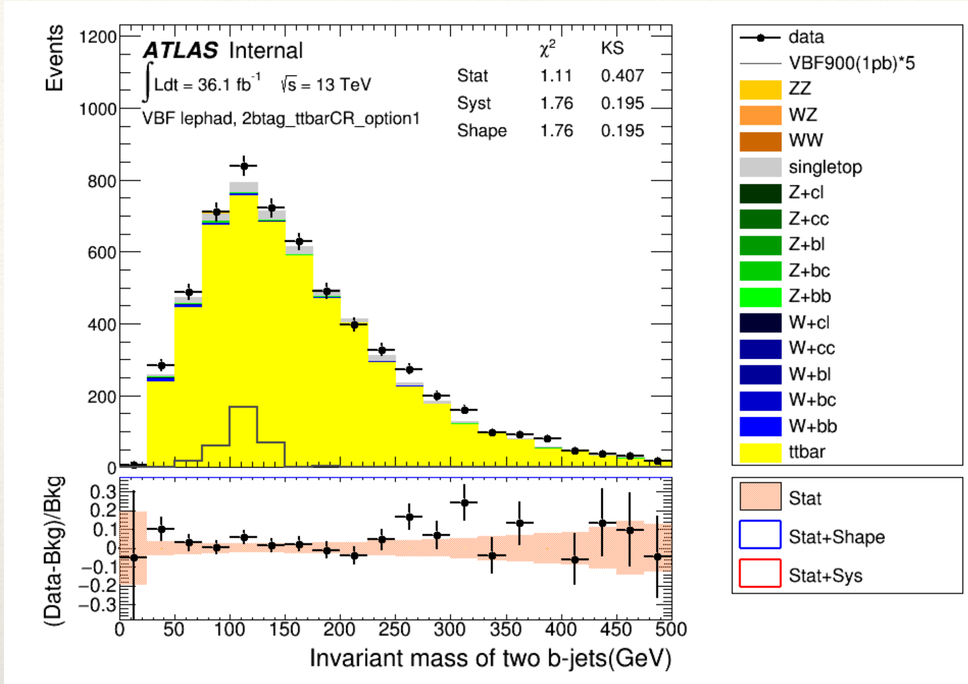
ttbar CR option 2

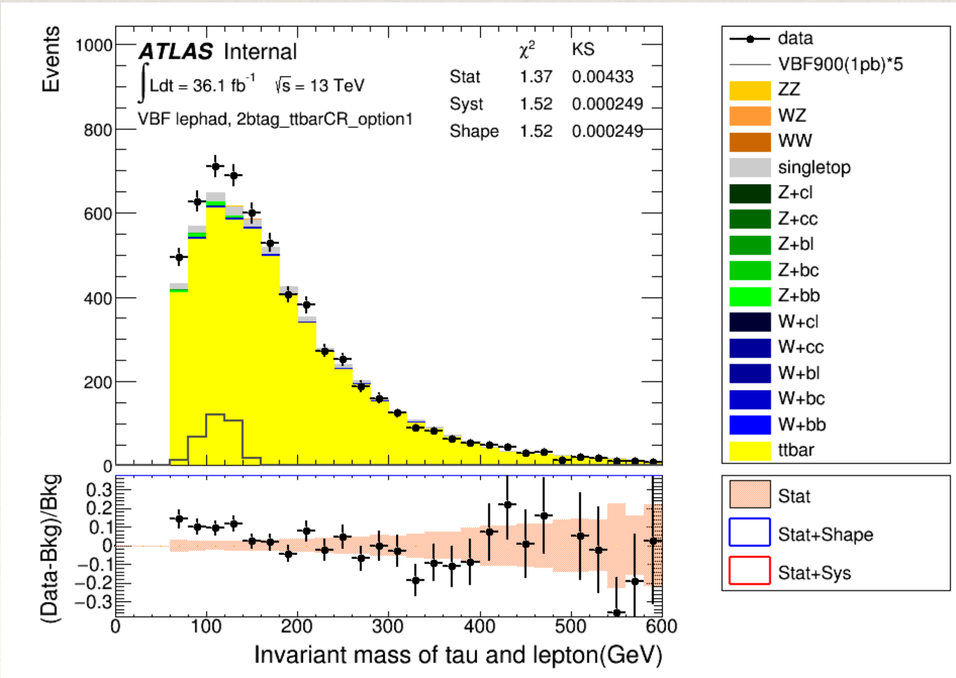


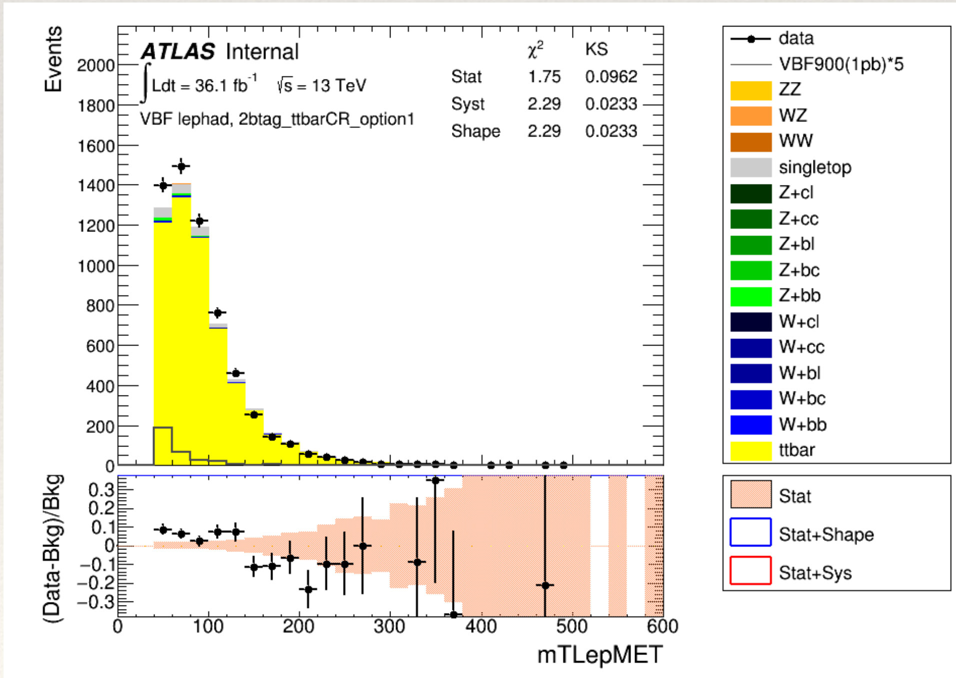
The first option looks better, more statistics, so less stat uncertainty, modelling wise not much difference

Plots in ttbar CR region (option 1)





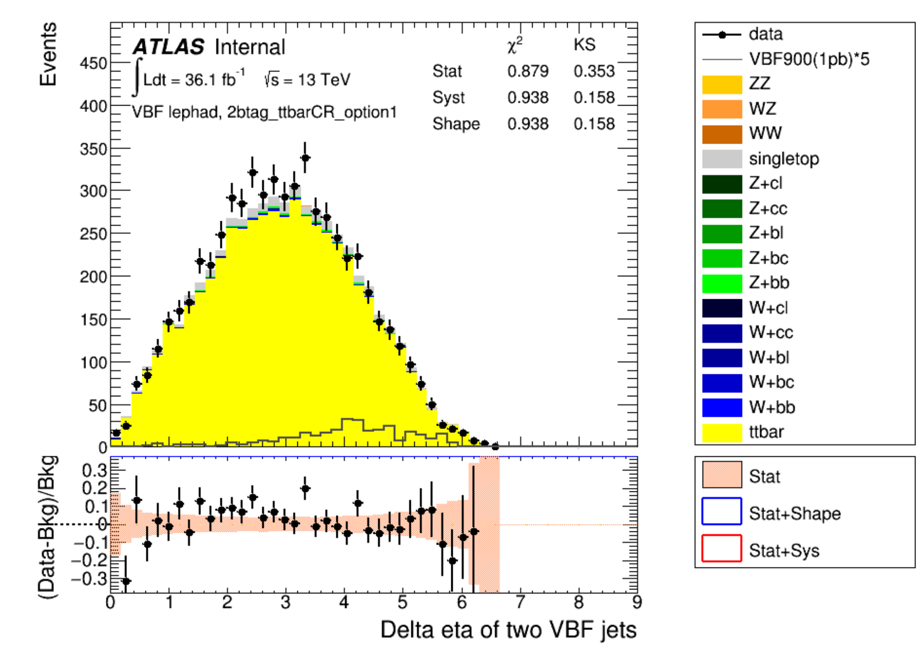


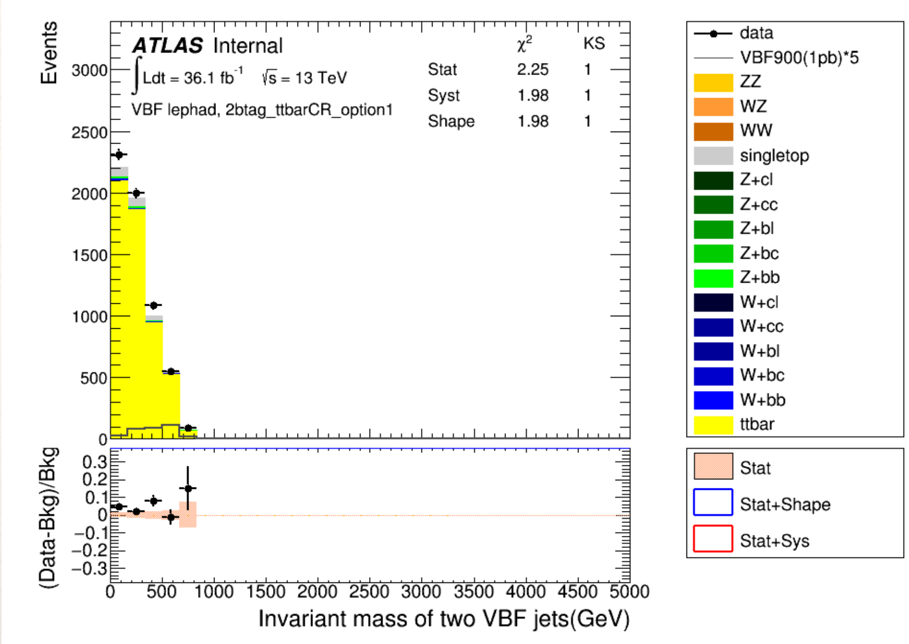


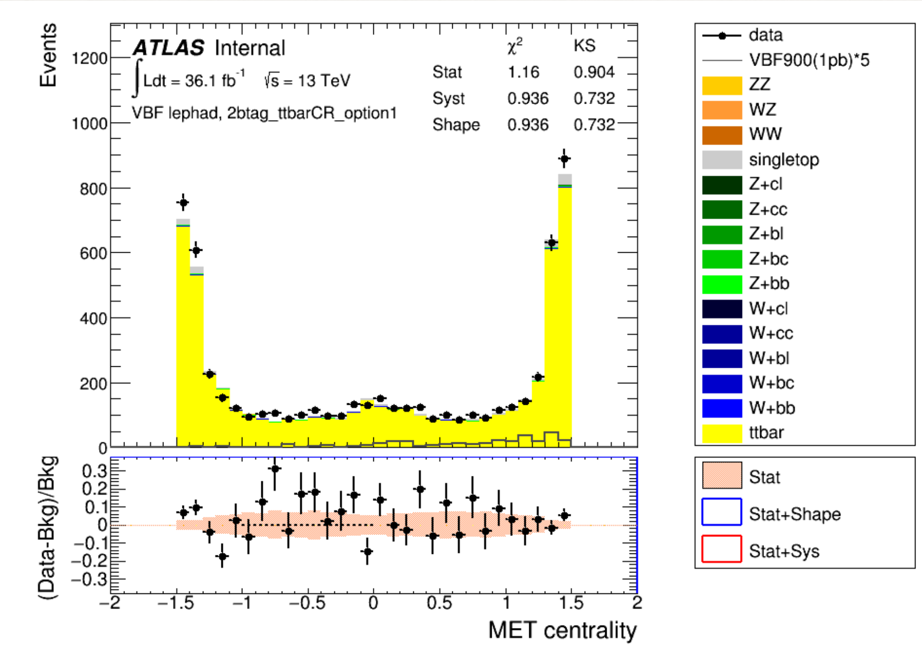
Summary

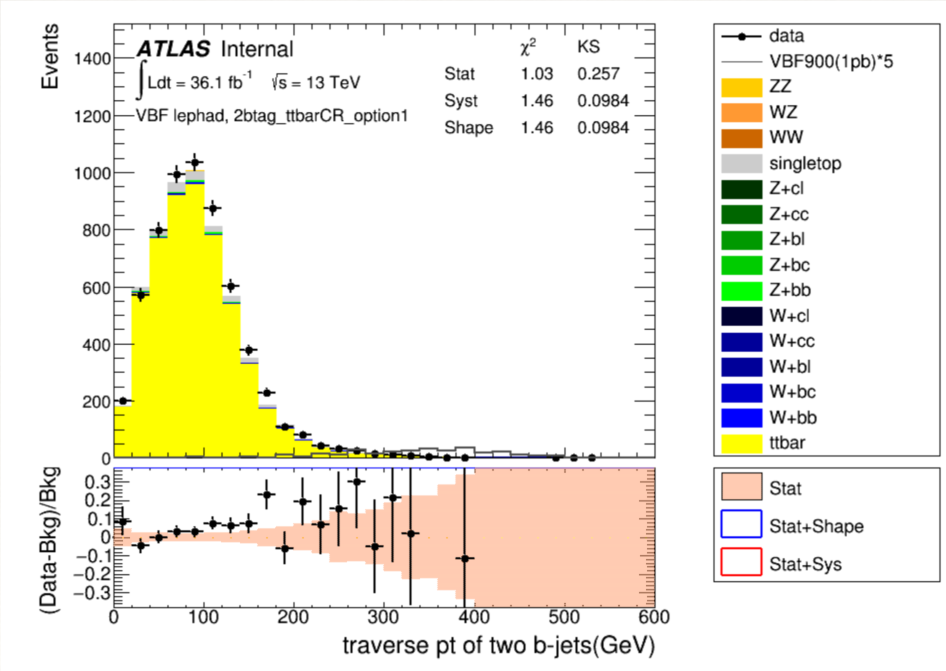
- BDT training in three different mass points, rankings is changes with the signal mass points.
- ttbar CR definition looks better with the first set of selections, more statistics. Please give your opinion.
- Next step: focus on the fake estimation, to get better modelling.

plots in ttbar CR

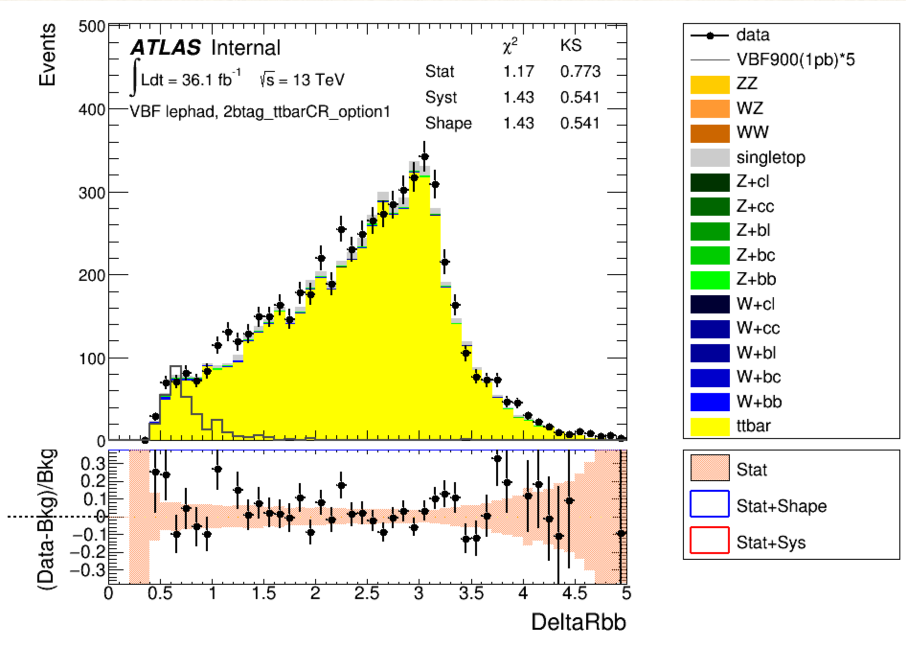


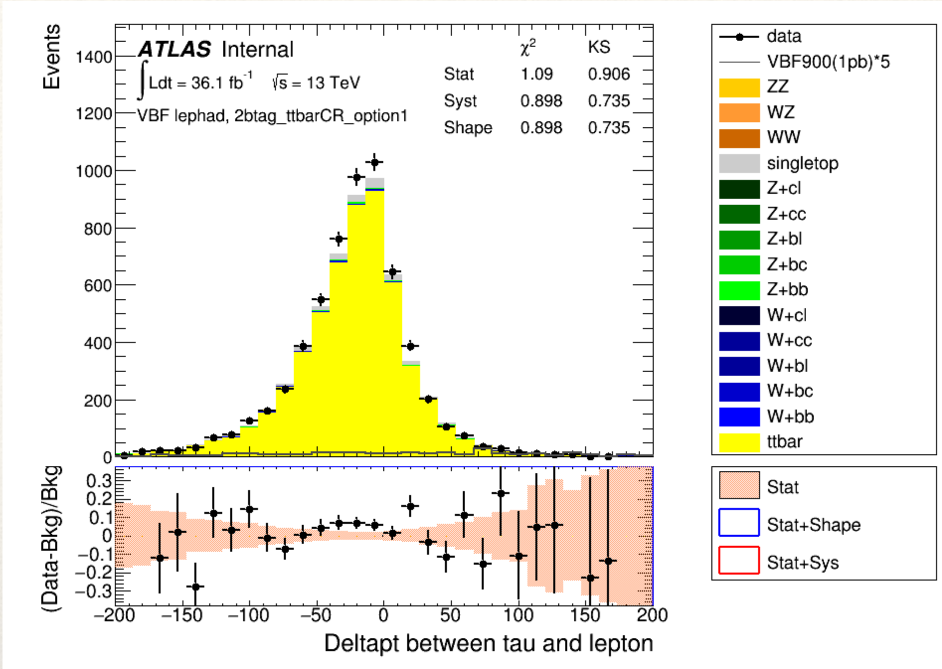


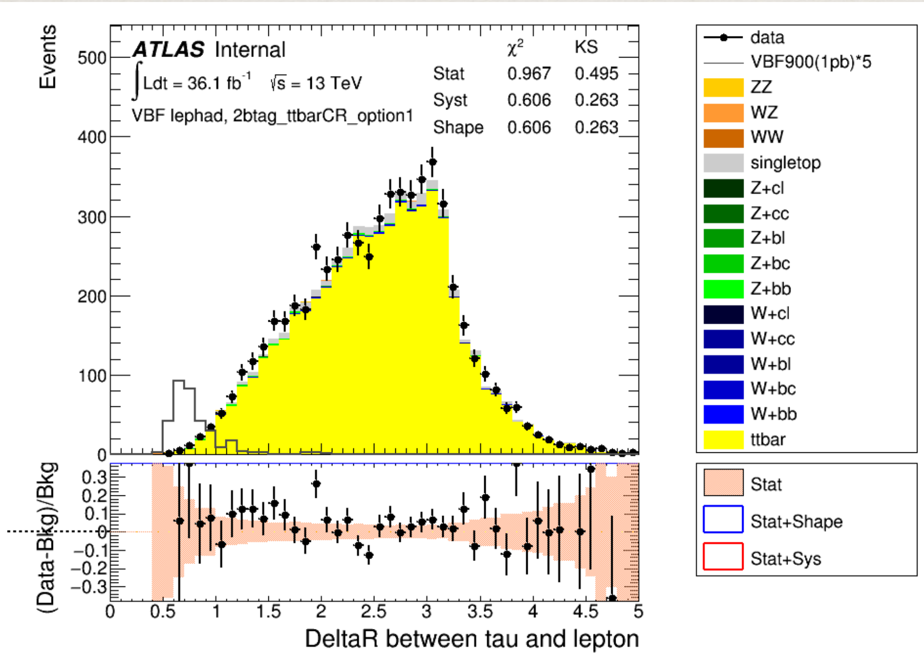




Plots in ttbar CR





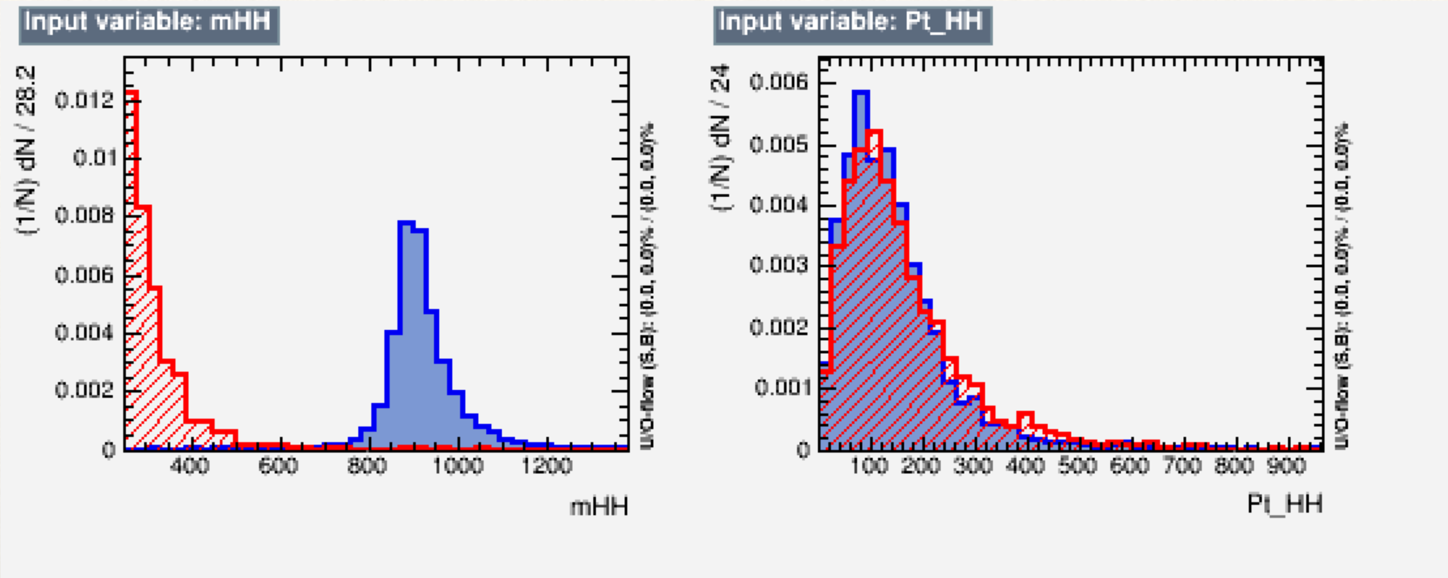


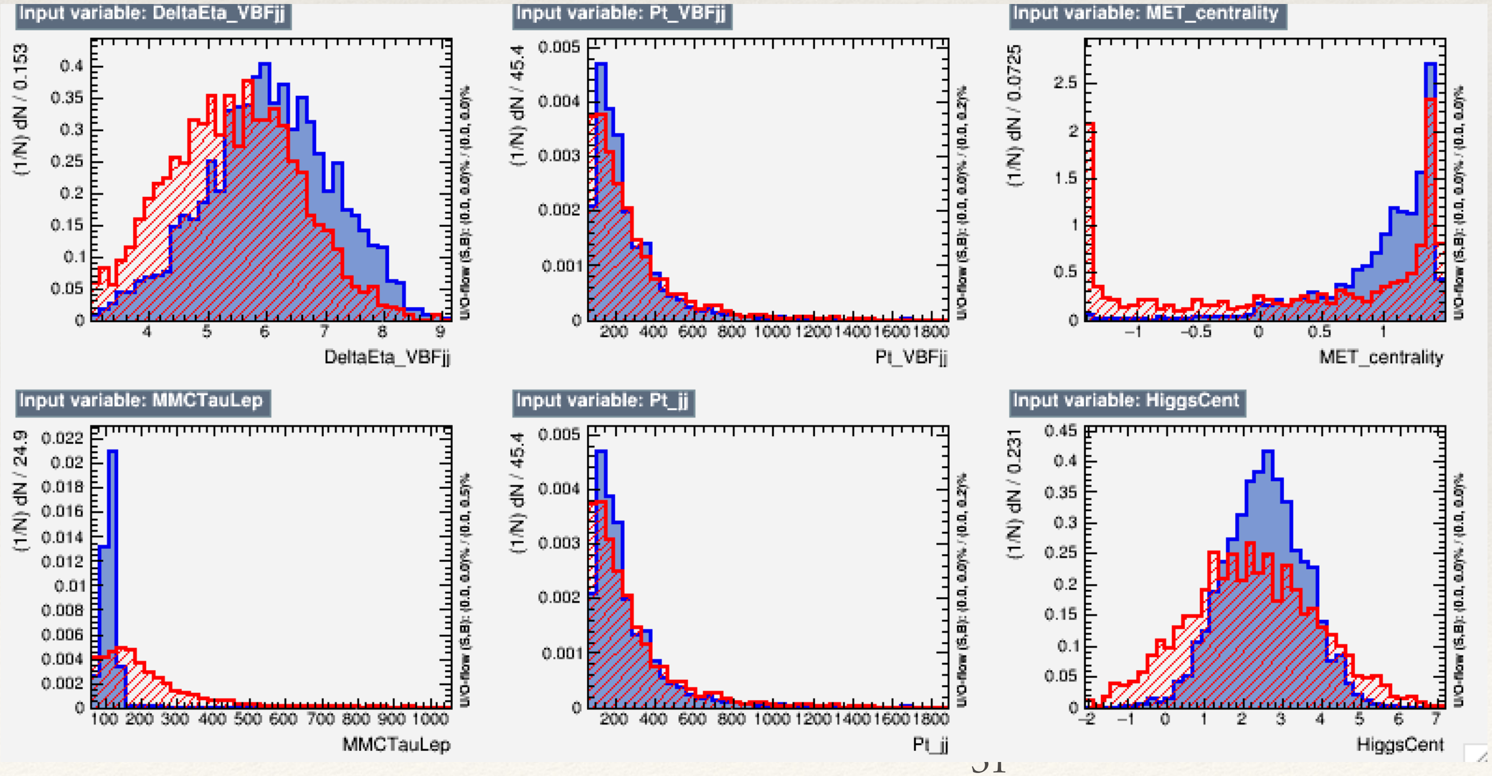
Fake taus from mis-identified jets are estimated from MC

Introduction

- BDT training on the signal (900GeV mass point) and background (ttbar).
- Good discriminating variables.
- BDT training without the the VBF cuts.
- non-resonant validation plots.

Kinematic variables

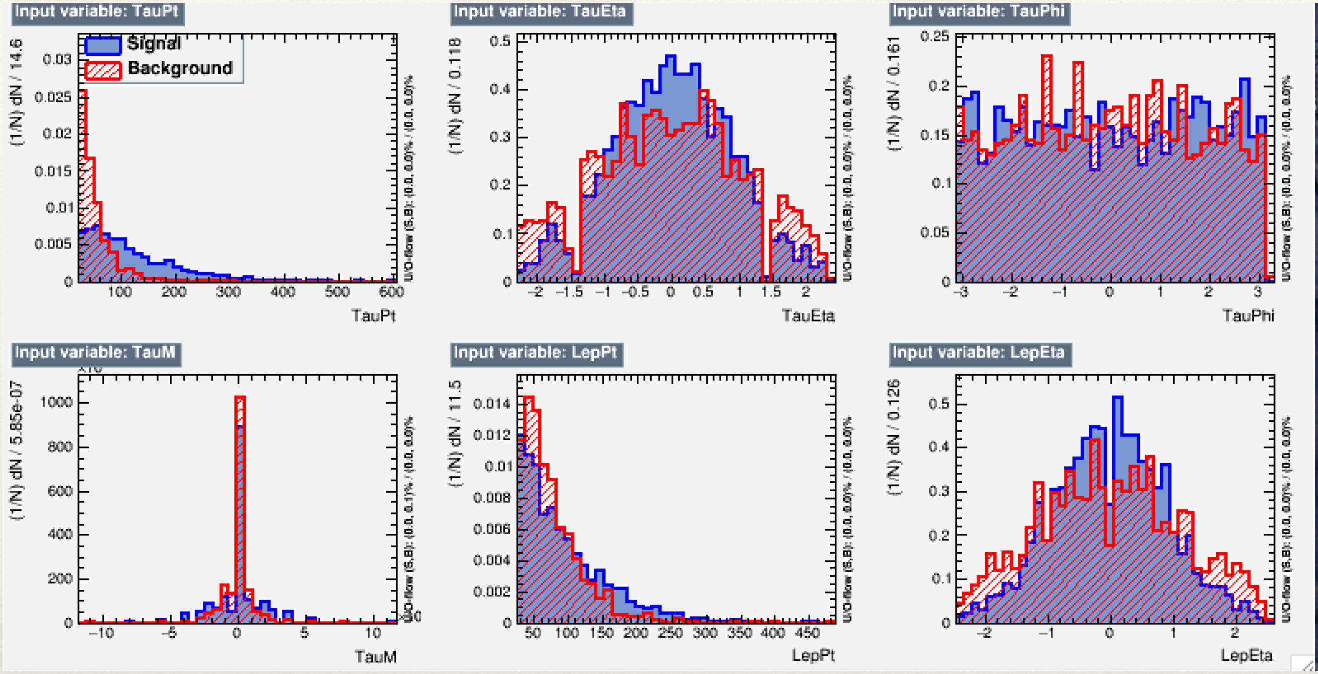




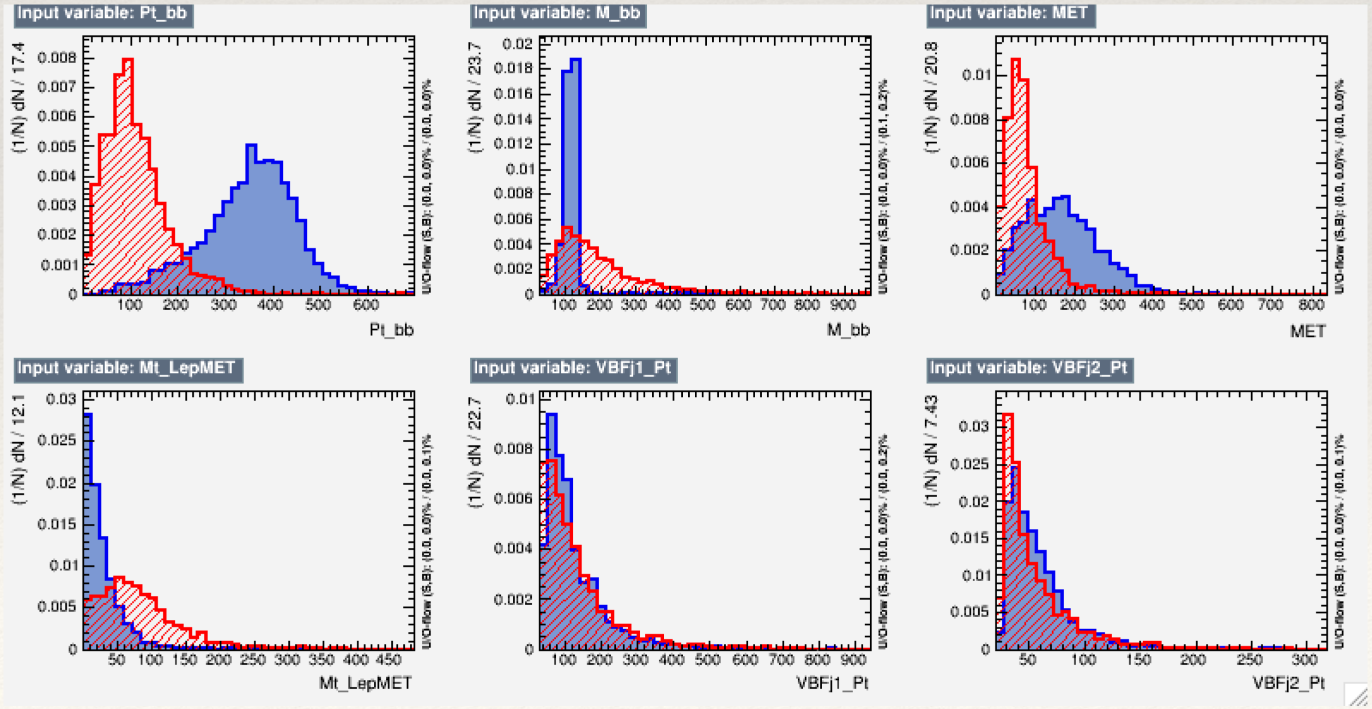
mHH
DeltaEta_VBFjj
MMCTauLep
MET_centrality
HiggsCent!!

ttbar
signal (900GeV)

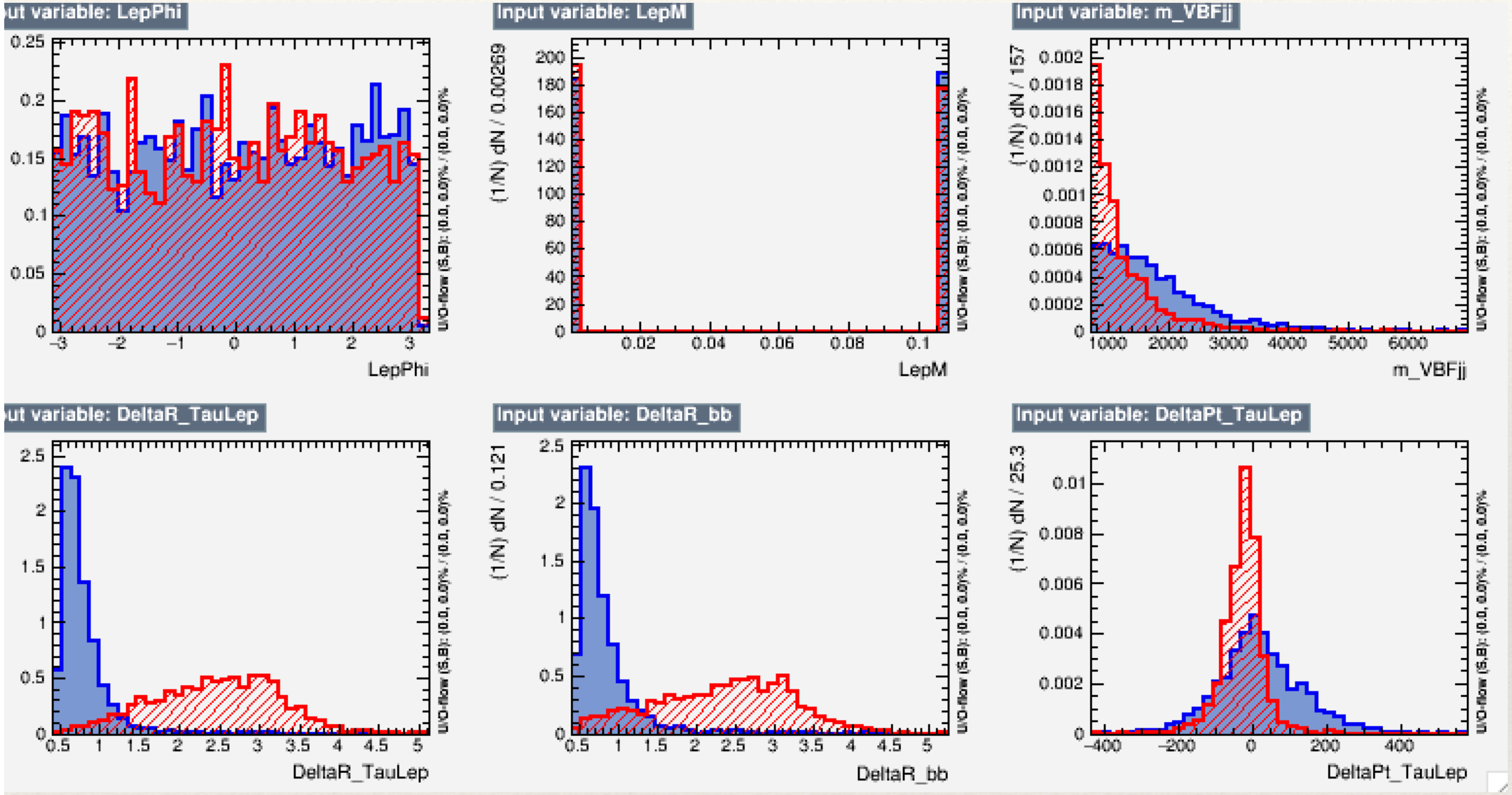
Kinematic variables



Pt_bb
MET

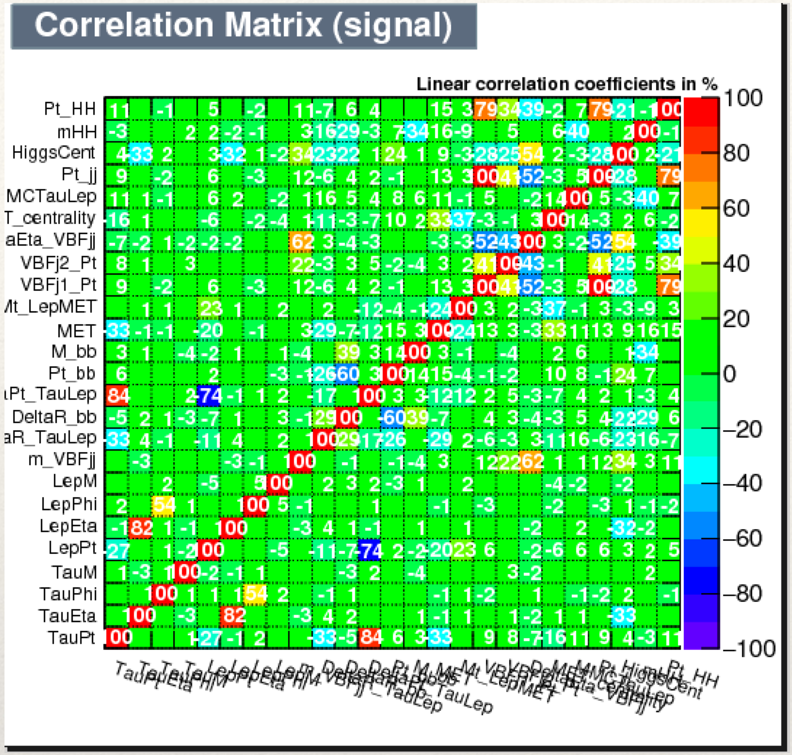


Kinematic variables and Ranking of the variables

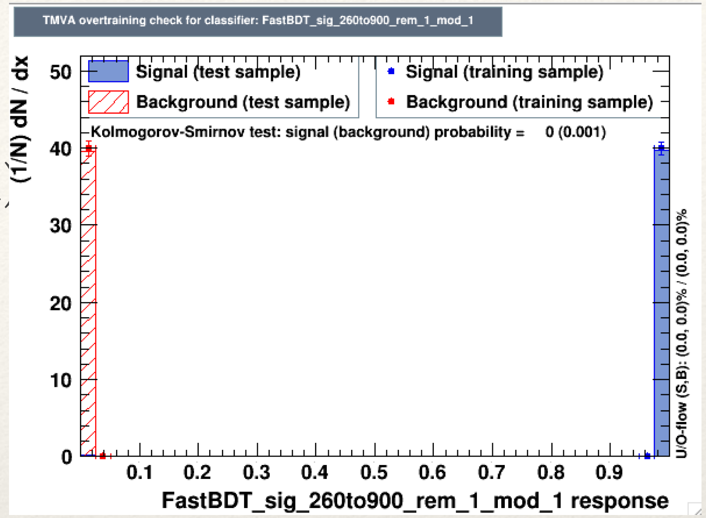


DeltaR_bb
DeltaR_TauLep
DeltaPt_TauLep

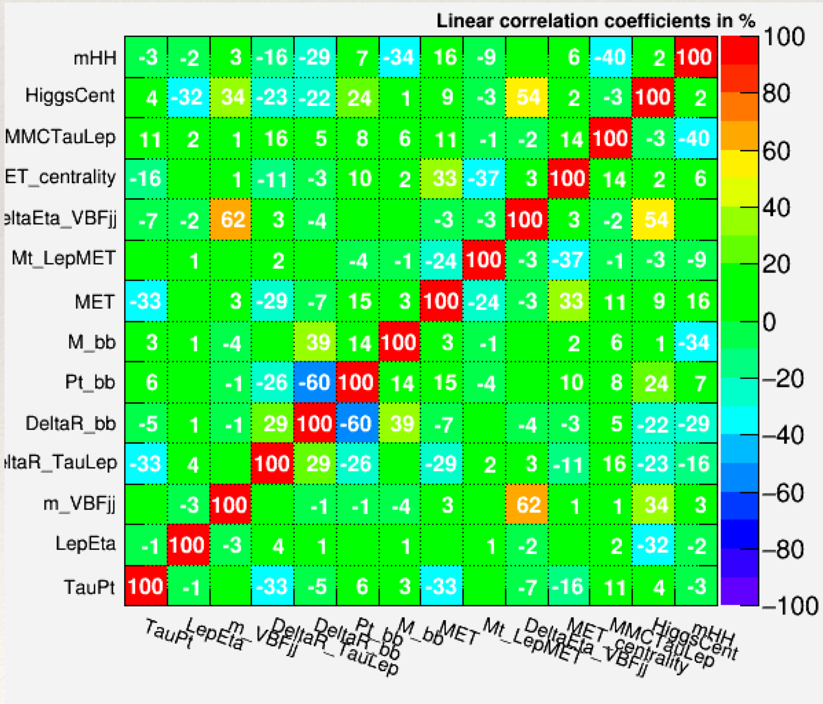
Correlation plot



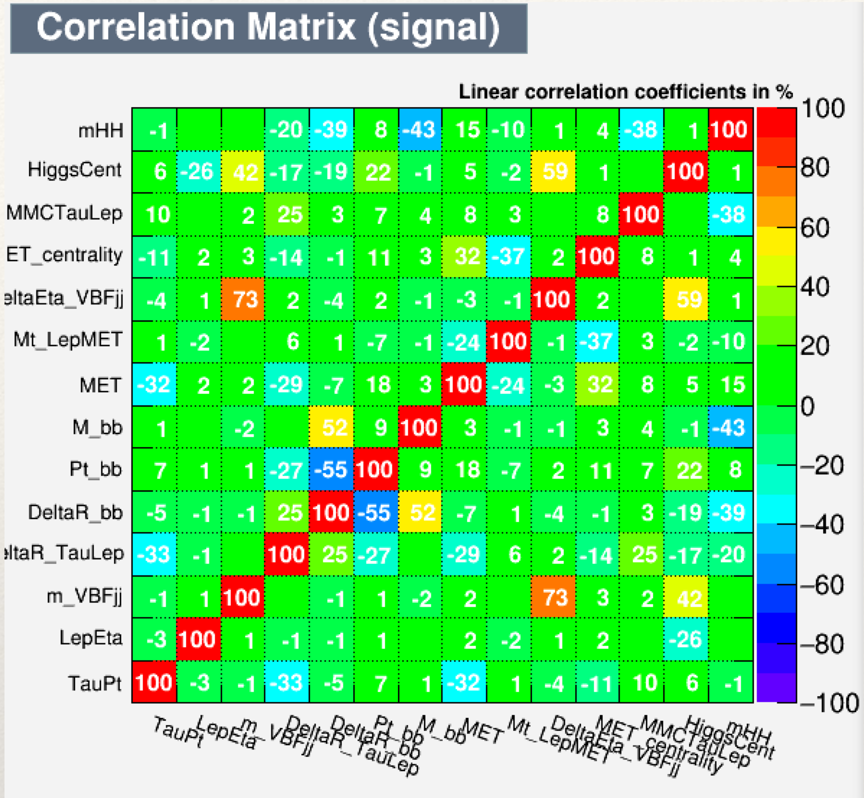
~100% correlated:
TauEta - LepEta
TauPt-DeltaPtTauLep
LepPt-DeltaPtTauLep(anti)
m_VBFjj-DeltaEta_VBFjj
Pt_VBFjj-VBFj1_Pt
Pt_VBFjj-VBFj2_Pt
Pt_VBFjj-DeltaEta_VBFjj(anti)



Rank	Variable	Variable Importance
1	mHH	9.427e-01
2	DeltaR_TauLep	1.757e-02
3	M_bb	1.053e-02
4	MMCTauLep	7.156e-03
5	TauPt	5.401e-03
6	Pt_bb	4.597e-03
7	DeltaEta_VBFjj	3.475e-03
8	Mt_LepMET	2.242e-03
9	m_VBFjj	1.643e-03
10	DeltaR_bb	1.515e-03
11	MET_centrality	1.466e-03
12	HiggsCent	1.119e-03
13	MET	4.342e-04
14	LepEta	1.734e-04



Correlation plots



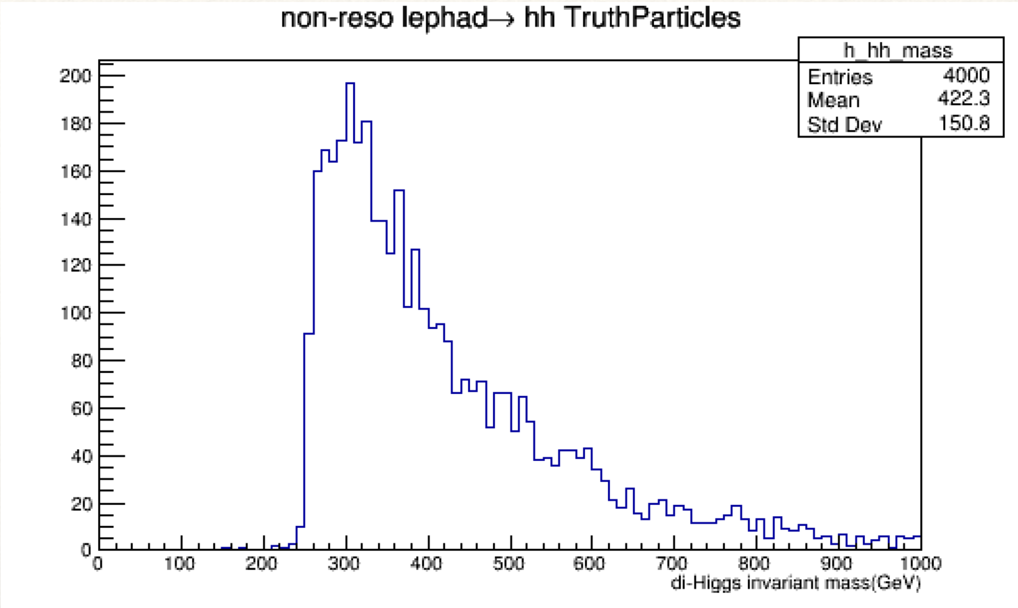
After removing the VBF cuts

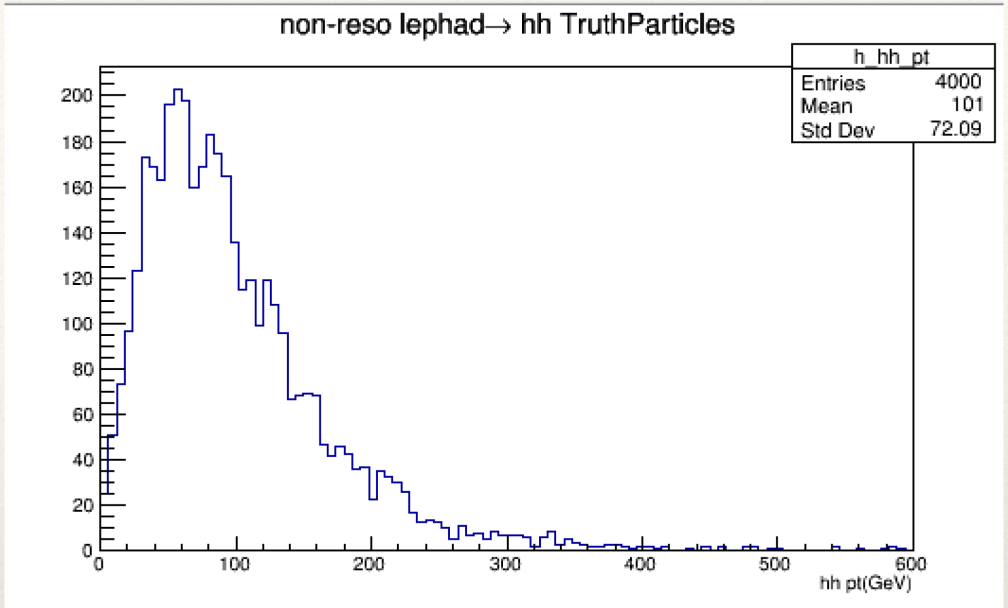
Rank	Variable	Variable Importance
1	mHH	9.384e-01
2	DeltaR_TauLep	1.891e-02
3	M_bb	1.155e-02
4	m_VBFjj	6.380e-03
5	Pt_bb	5.719e-03
6	MMCTauLep	5.228e-03
7	TauPt	3.705e-03
8	DeltaR_bb	2.521e-03
9	HiggsCent	2.342e-03
10	DeltaEta_VBFjj	2.261e-03
11	Mt_LepMET	1.425e-03
12	MET	6.179e-04
13	MET_centrality	5.691e-04
14	LepEta	3.742e-04

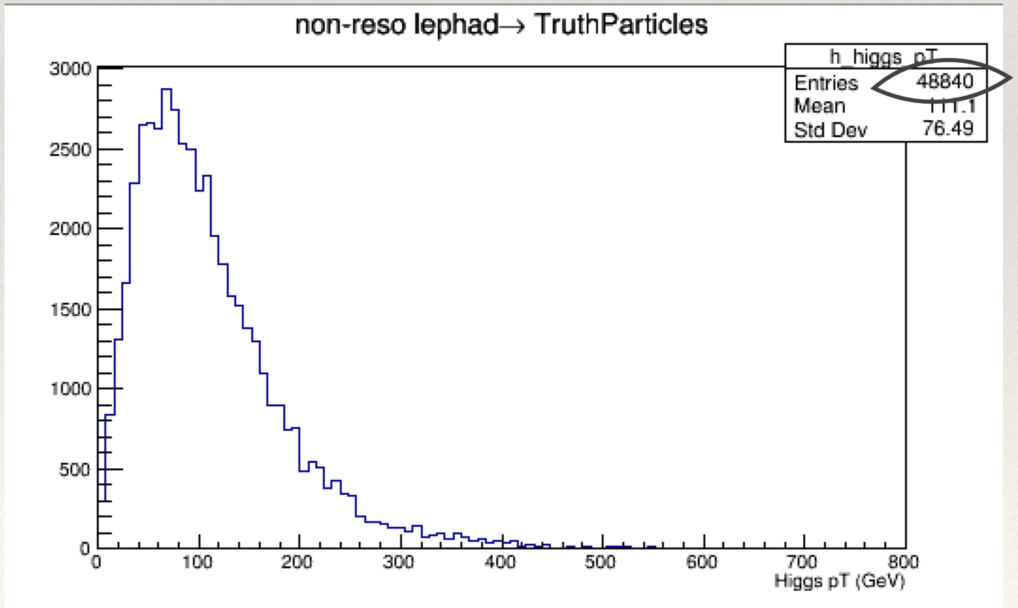
Non resonant VBF production

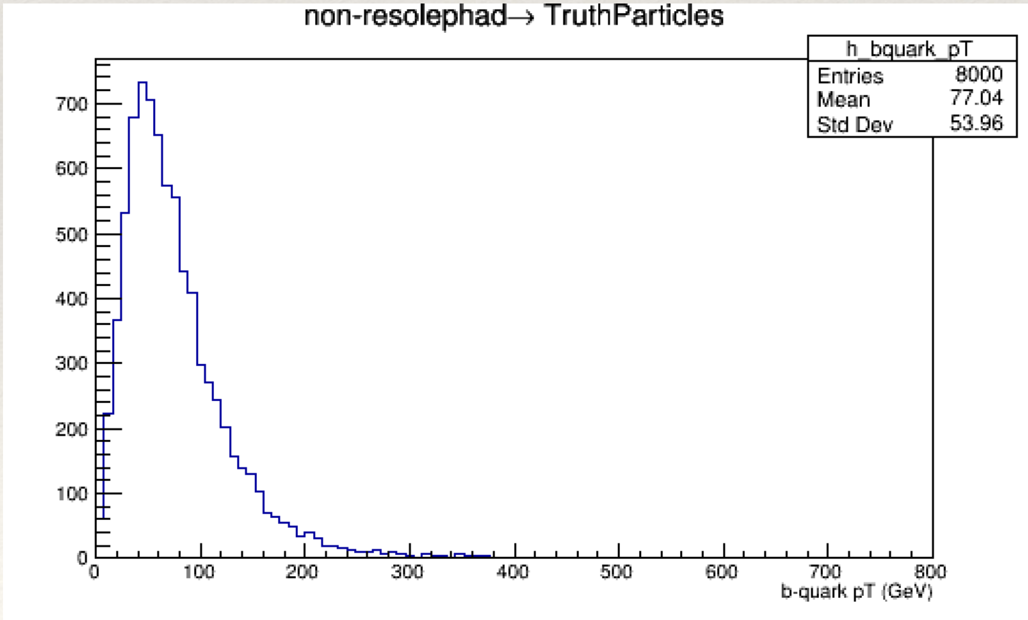
```
#---------------------------------------------------------------------------------------------------------
# Decaying hh to bbyy with Pythia8
#---------------------------------------------------------------------------------------------------------
genSeq.Pythia8.Commands += ["25:oneChannel = on 0.5 100 5 -5 ",  # bb decay
                            "25:addChannel = on 0.5 100 15 -15 "] # tautau decay
#---------------------------------------------------------------------------------------------------------
# Generator Filters
# Use ParentTwoChildren filter to require:
#   Higgs(25) -> b(5)bbar(-5) AND
#   Higgs(25) -> gamma(22)gamma(22)
#---------------------------------------------------------------------------------------------------------
from GeneratorFilters.GeneratorFiltersConf import ParentTwoChildrenFilter
filtSeq += ParentTwoChildrenFilter("HiggsToBBTauTauFilter")
filtSeq.HiggsToBBTauTauFilter.PDGParent = [25]
filtSeq.HiggsToBBTauTauFilter.PDGChild = [5,15]

include("MC15JobOptions/XtoVVDecayFilterExtended.py")
filtSeq.XtoVVDecayFilterExtended.PDGGrandParent = 25
filtSeq.XtoVVDecayFilterExtended.PDGParent = 15
filtSeq.XtoVVDecayFilterExtended.StatusParent = 2
filtSeq.XtoVVDecayFilterExtended.PDGChild1 = [11,13]
filtSeq.XtoVVDecayFilterExtended.PDGChild2 = [24,211,213,215,311,321,323,10232,10323,20213,20232,20323,30213,100213,100323,1000213]
#filtSeq.XtoVVDecayFilterExtended.PDGChild2 = [111,130,211,221,223,310,311,321,323]
filtSeq.Expression = " HiggsToBBTauTauFilter and XtoVVDecayFilterExtended"
```

Validation plot

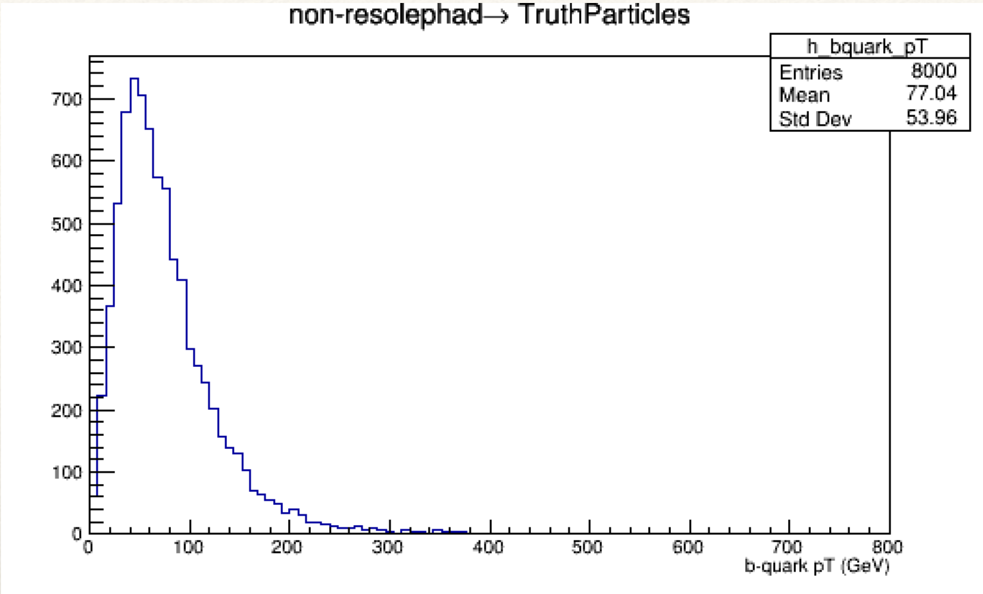


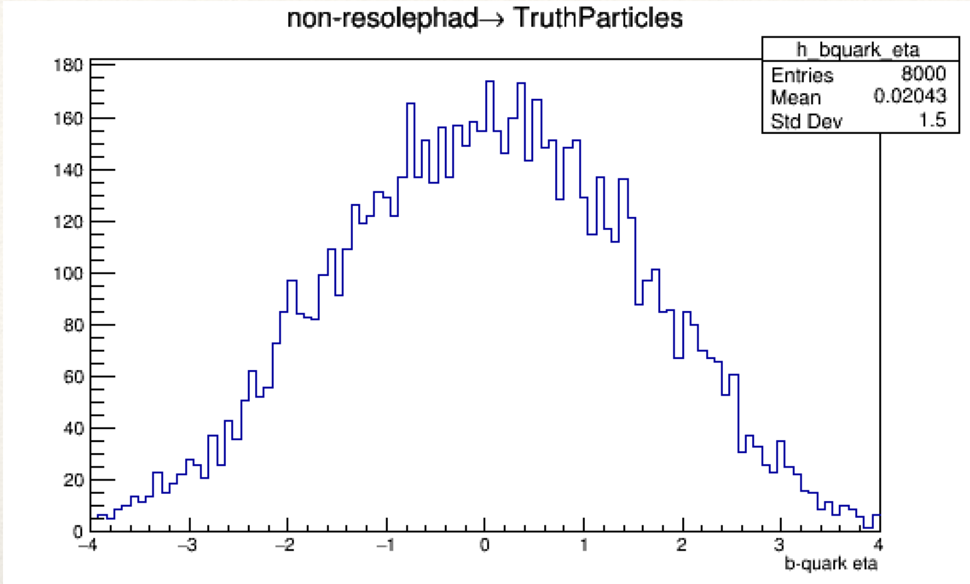


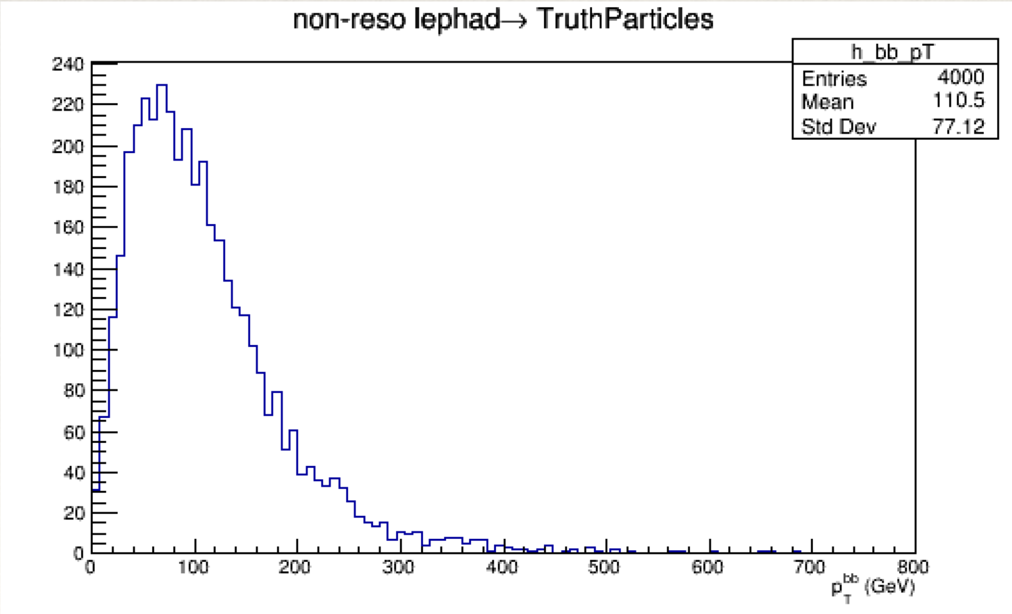


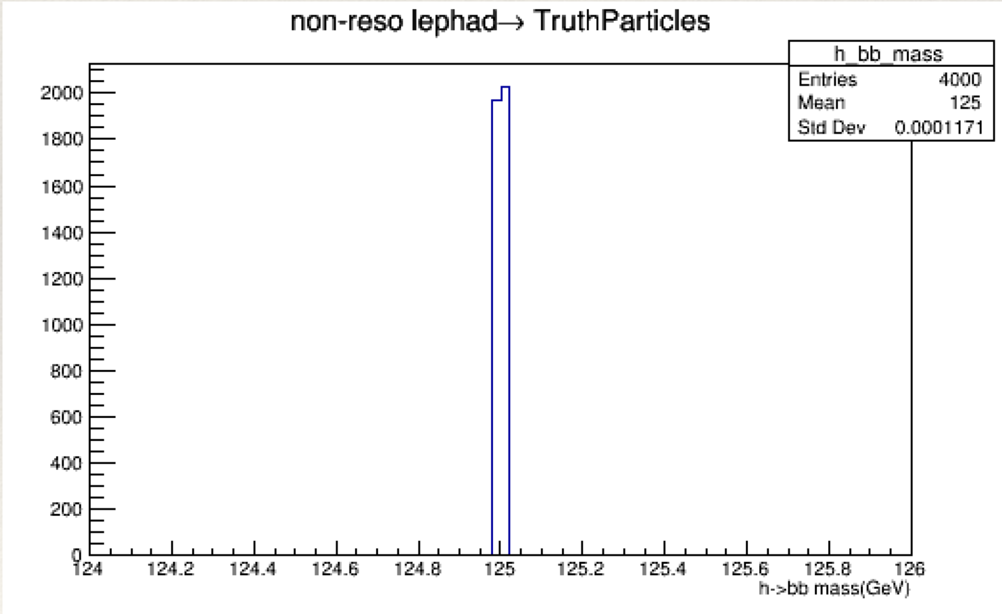


b quark plots

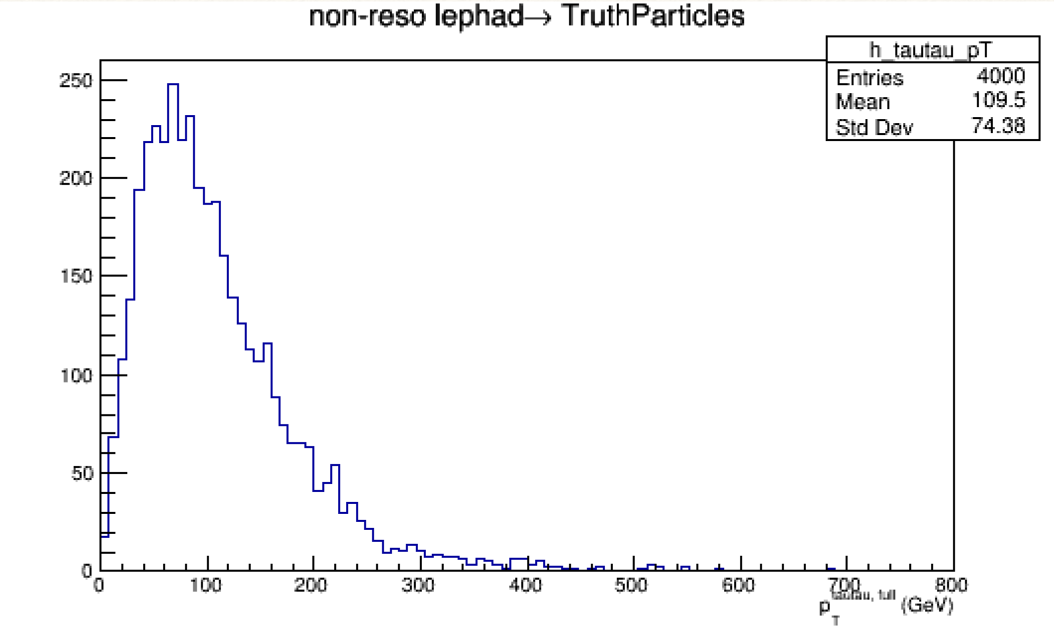


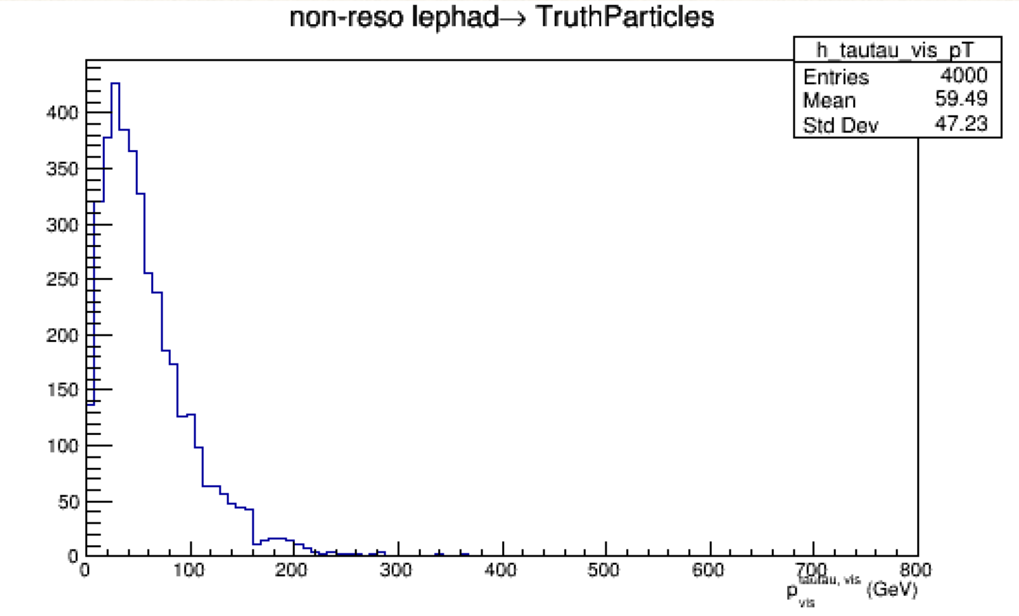


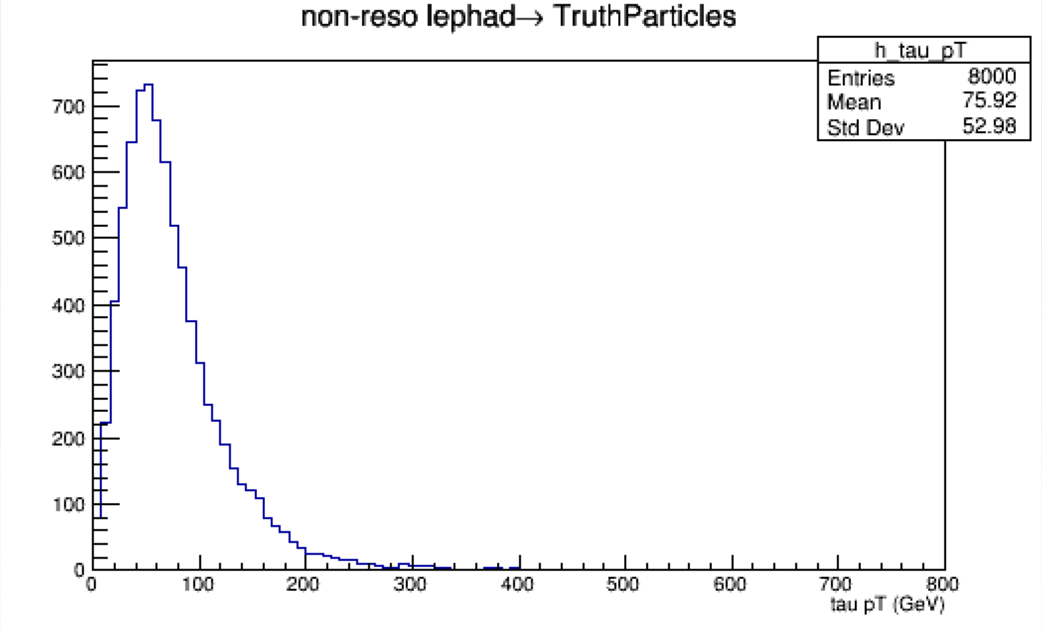


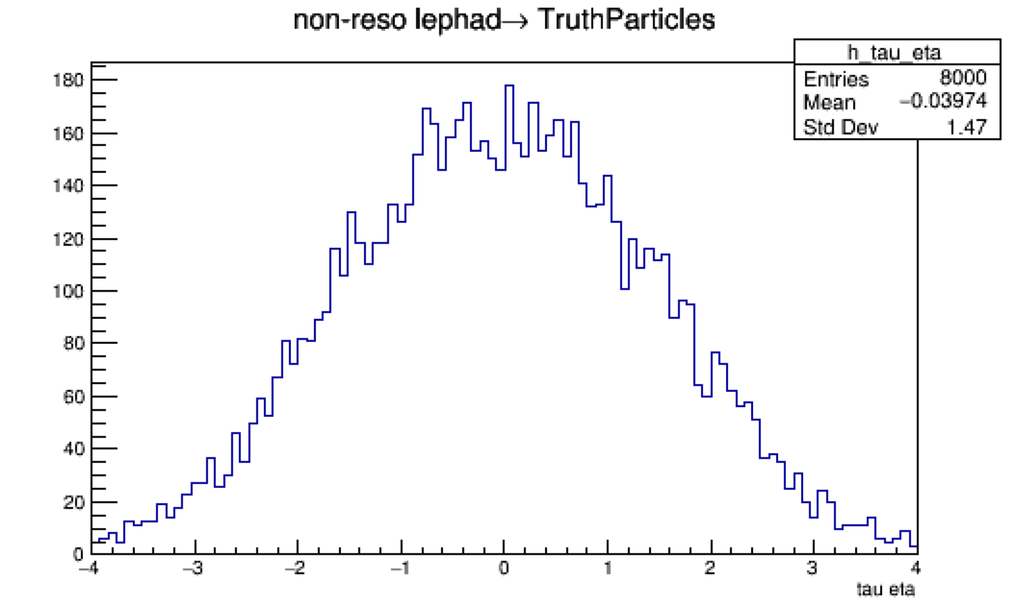


Tau plots

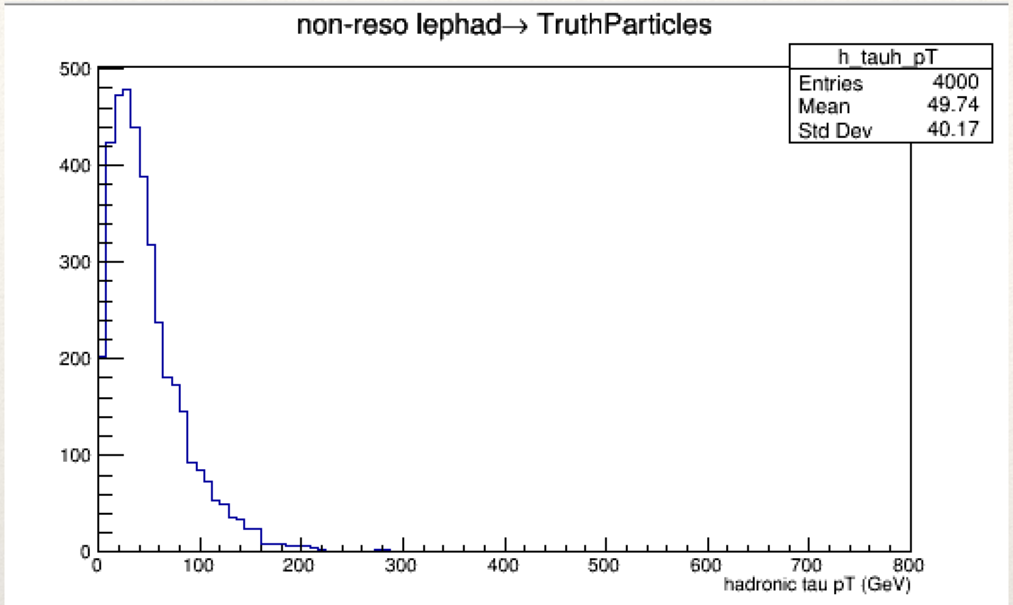

non-reso lephad→ TruthParticles
h_tautau_pT
Entries 4000
Mean 109.5
Std Dev 74.38
(GeV)

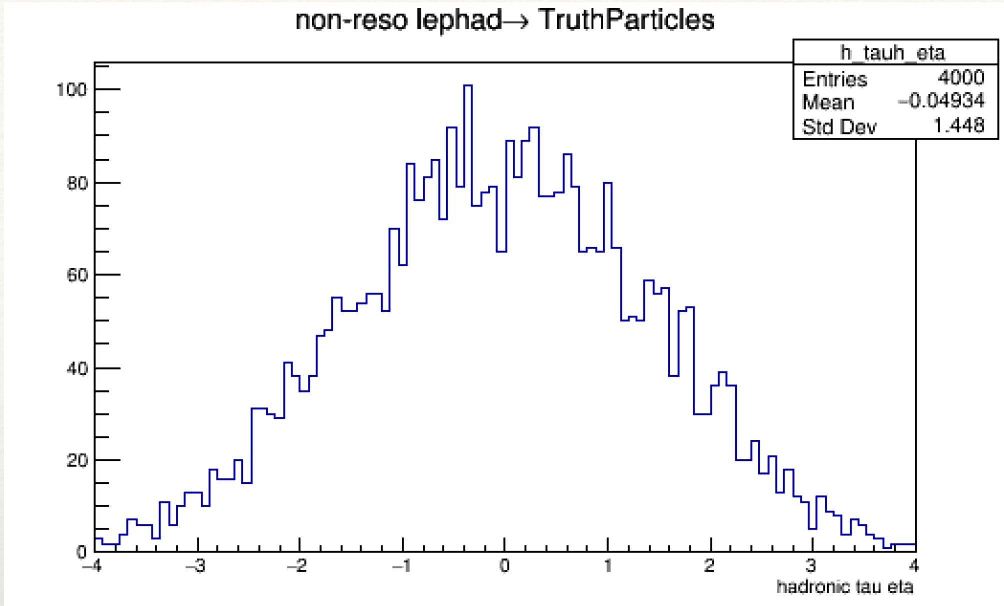

non-reso lephad→ TruthParticles
h_tautau_vis_pT
Entries 4000
Mean 59.49
Std Dev 47.23
(GeV)

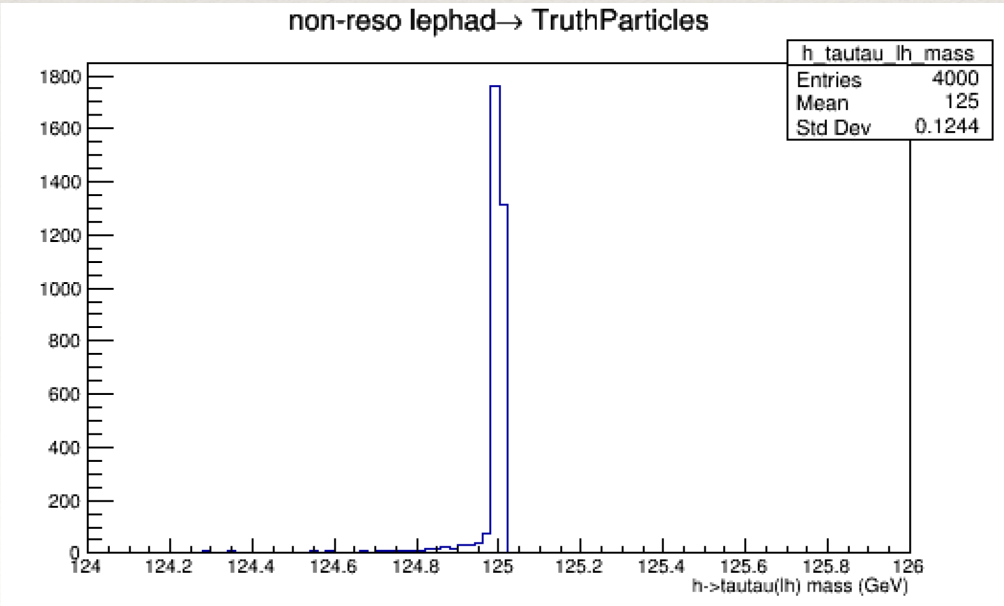

non-reso lephad→ TruthParticles
h_tau_pT
Entries 8000
Mean 75.92
Std Dev 52.98
tau pT (GeV)

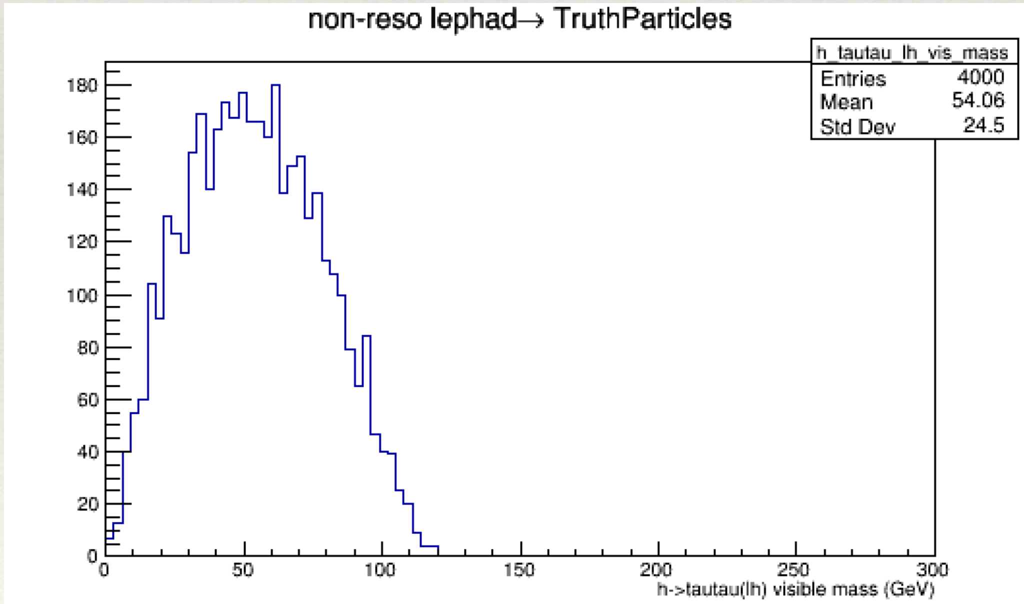

non-reso lephad→ TruthParticles
h_tau_eta
Entries 8000
Mean −0.03974
Std Dev 1.47
tau eta

Tau Plots

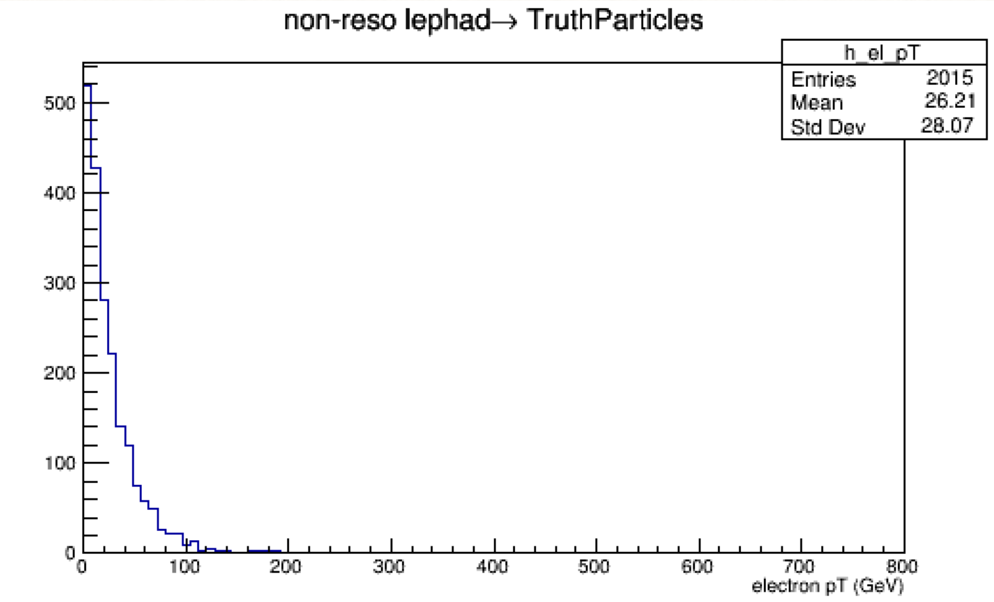

non-reso lephad→ TruthParticles
h_tauh_pT
Entries 4000
Mean 49.74
Std Dev 40.17
0
100
200
300
400
500
600
700
800
hadronic tau pT (GeV)

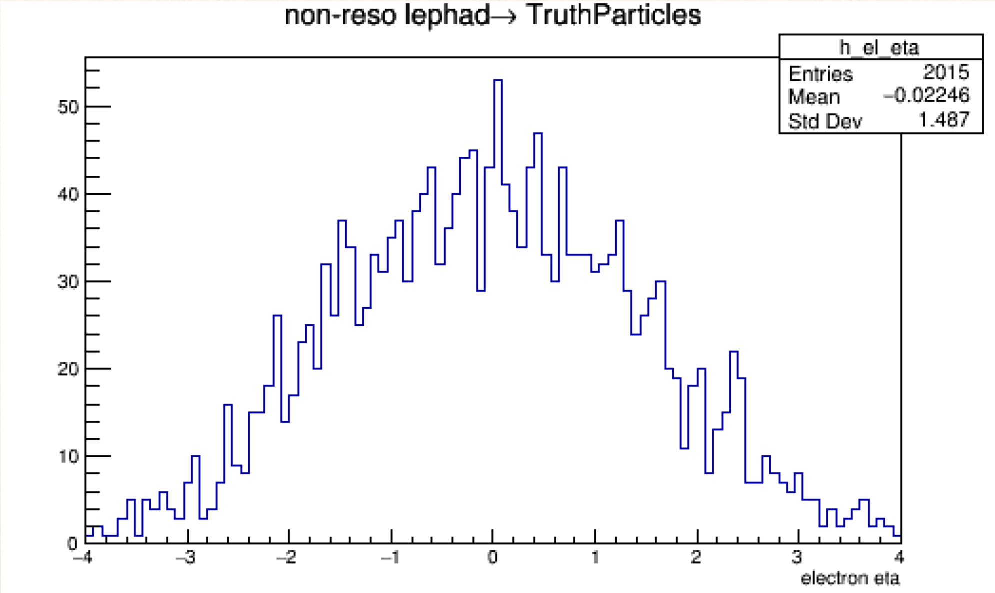

non-reso lephad→ TruthParticles
h_tauh_eta
Entries 4000
Mean −0.04934
Std Dev 1.448
0
20
40
60
80
100
−4
−3
−2
−1
0
1
2
3
4
hadronic tau eta

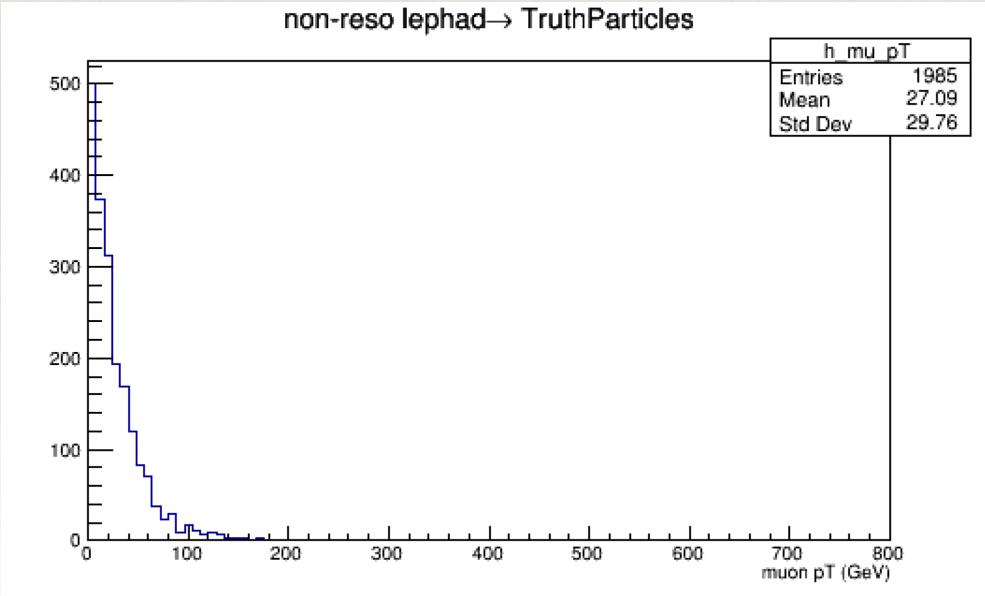

non-reso lephad→ TruthParticles
h_tautau_lh_mass
Entries 4000
Mean 125
Std Dev 0.1244
0
200
400
600
800
1000
1200
1400
1600
1800
124
124.2
124.4
124.6
124.8
125
125.2
125.4
125.6
125.8
126
h->tautau(lh) mass (GeV)

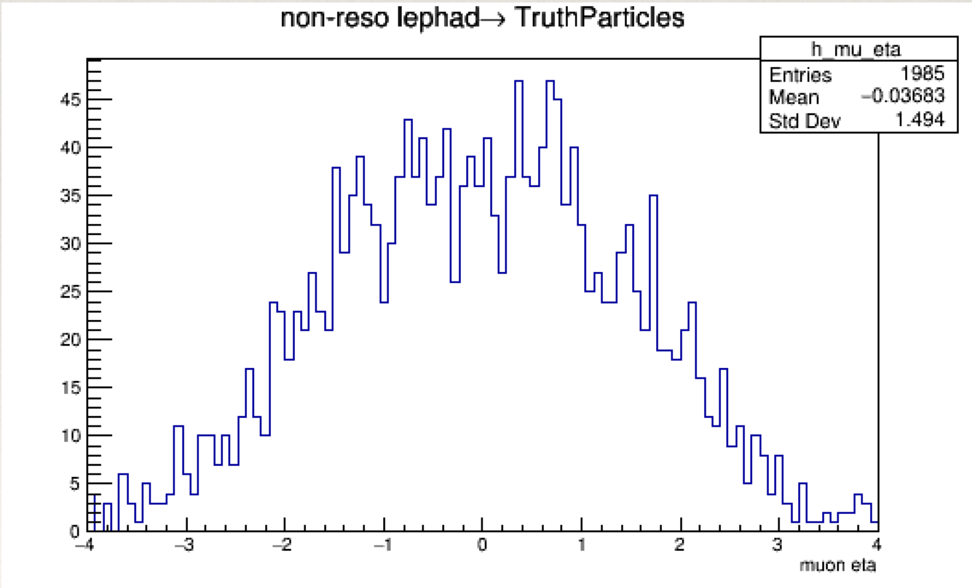

non-reso lephad→ TruthParticles
h_tautau_lh_vis_mass
Entries 4000
Mean 54.06
Std Dev 24.5
0
20
40
60
80
100
120
140
160
180
0
50
100
150
200
250
300
h->tautau(lh) visible mass (GeV)

Lepton plots

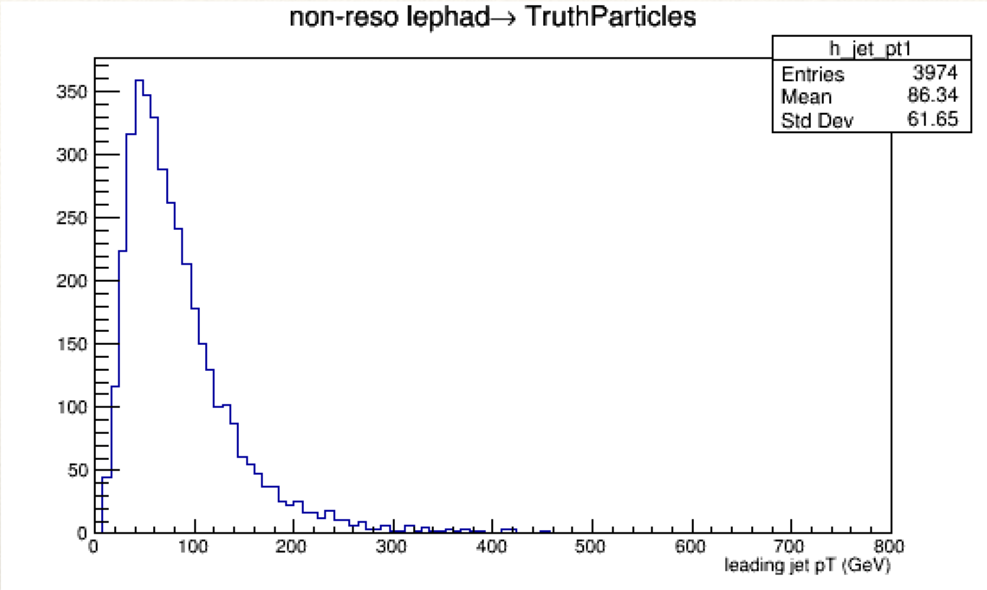




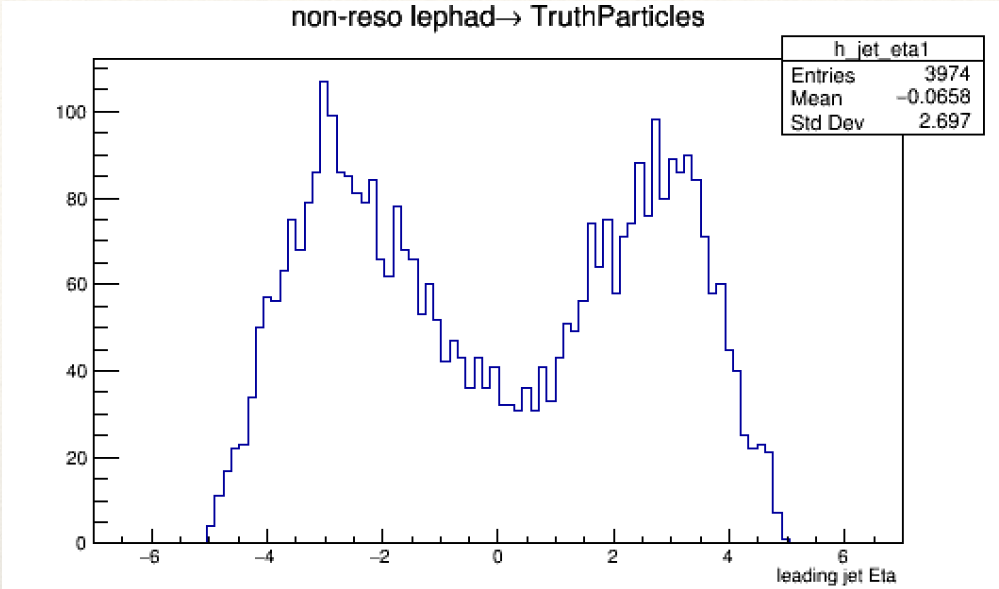




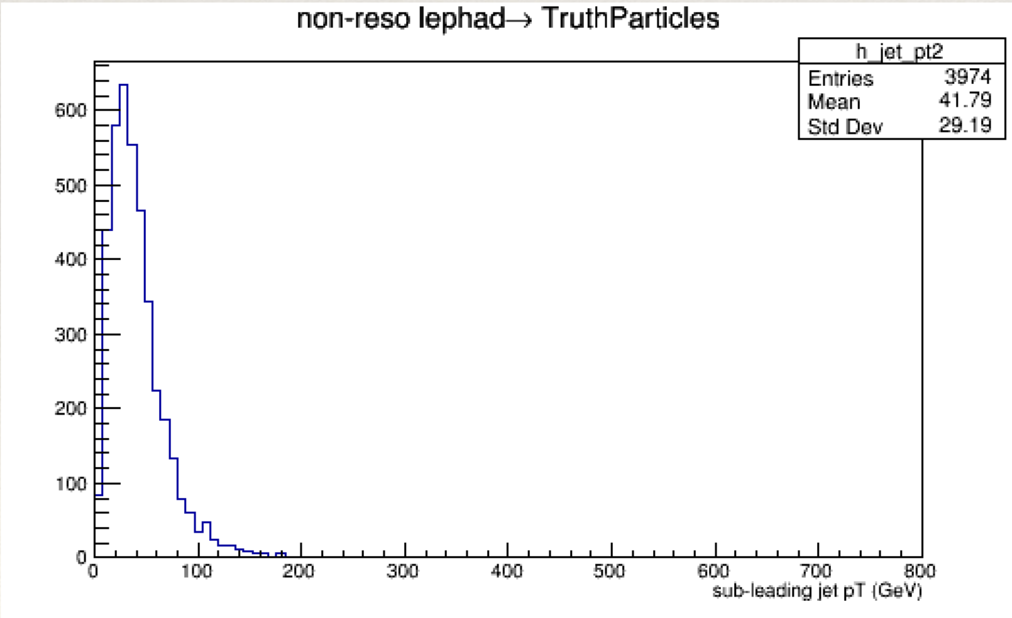
Jet plots



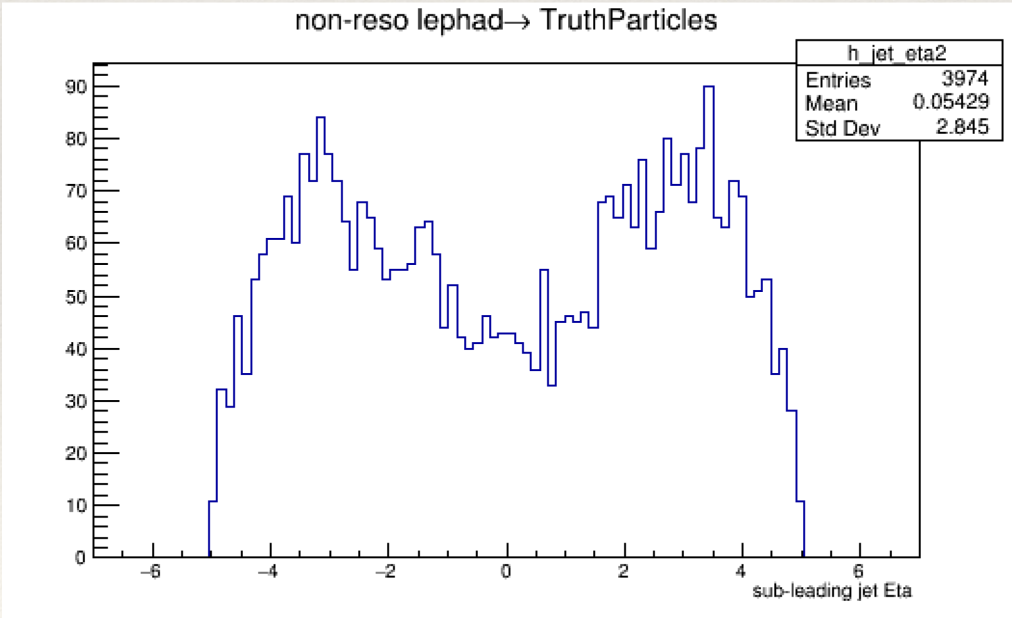
non-reso lephad→ TruthParticles
h_jet_pt1
Entries 3974
Mean 86.34
Std Dev 61.65
leading jet pT (GeV)



non-reso lephad→ TruthParticles
h_jet_eta1
Entries 3974
Mean −0.0658
Std Dev 2.697
leading jet Eta

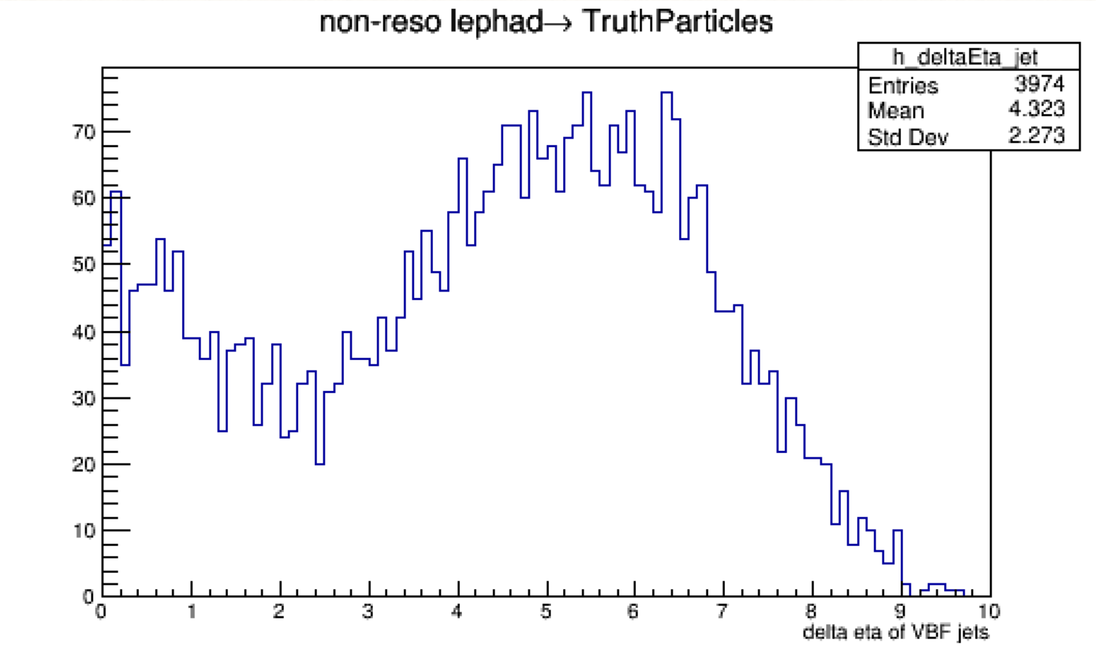


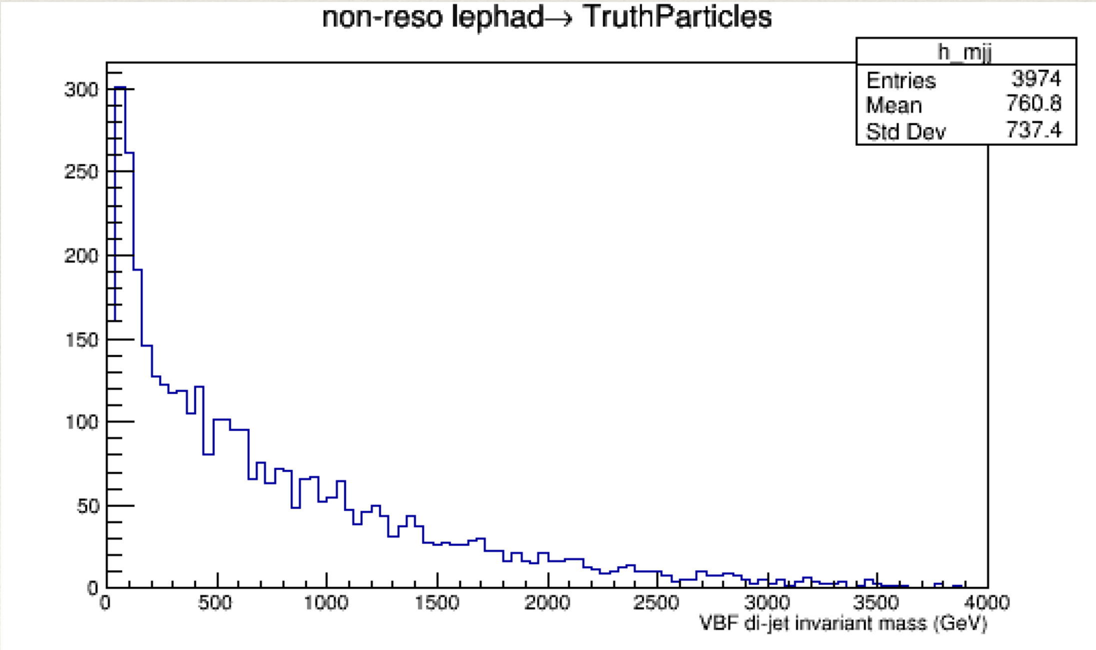
non-reso lephad→ TruthParticles
h_jet_pt2
Entries 3974
Mean 41.79
Std Dev 29.19
sub-leading jet pT (GeV)



non-reso lephad→ TruthParticles
h_jet_eta2
Entries 3974
Mean 0.05429
Std Dev 2.845
sub-leading jet Eta

jet Plots

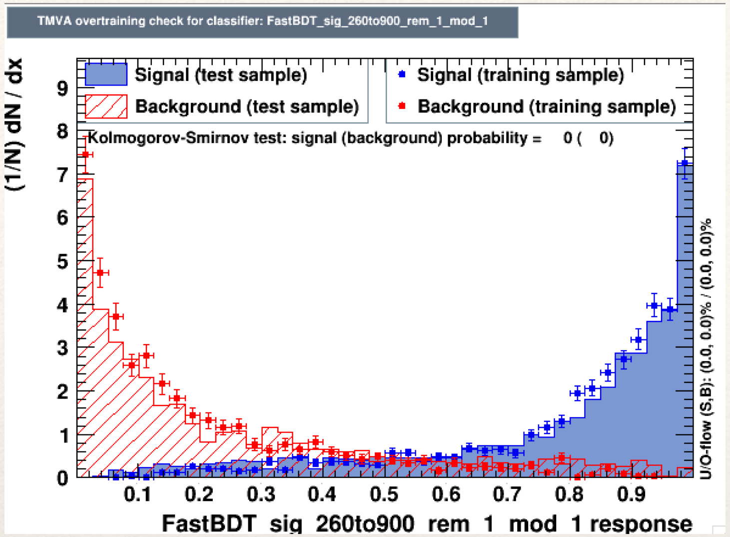

non-reso lephad→ TruthParticles
h_deltaEta_jet
Entries 3974
Mean 4.323
Std Dev 2.273
0 10 20 30 40 50 60 70
0 1 2 3 4 5 6 7 8 9 10
delta eta of VBF jets

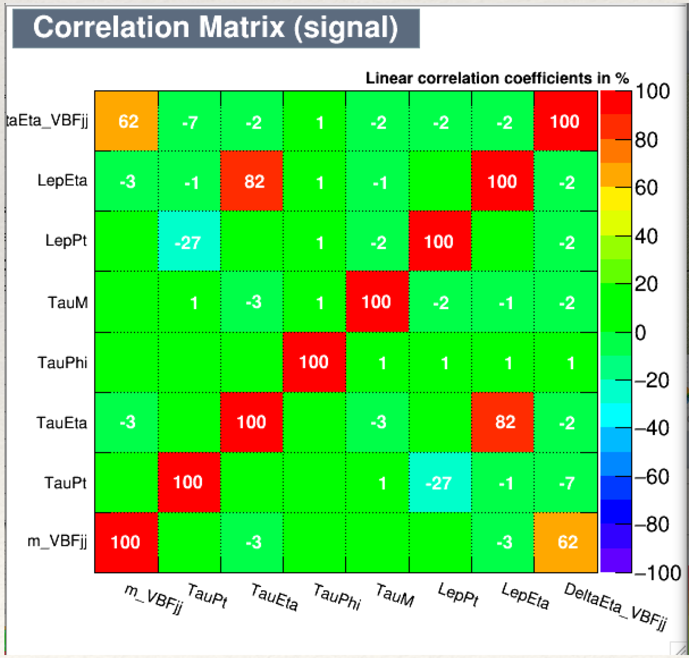

non-reso lephad→ TruthParticles
h_mjj
Entries 3974
Mean 760.8
Std Dev 737.4
0 50 100 150 200 250 300
0 500 1000 1500 2000 2500 3000 3500 4000
VBF di-jet invariant mass (GeV)

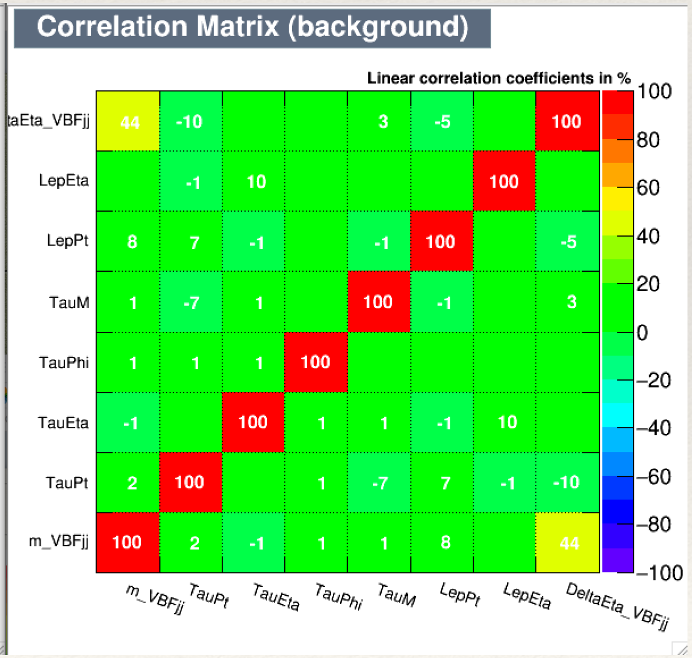
Summary

- Started working on the expected limit, problem found in the variable name “m_HH”, the script could not pick the variable for the “_” . Then new inputs are generated but now the workspace is not getting created.
- For non-resonant sample, the pt filter is not applied yet. For resonant sample pt filter is applied, although it seems filter is applied properly but validation plots do not look right.

Analysis

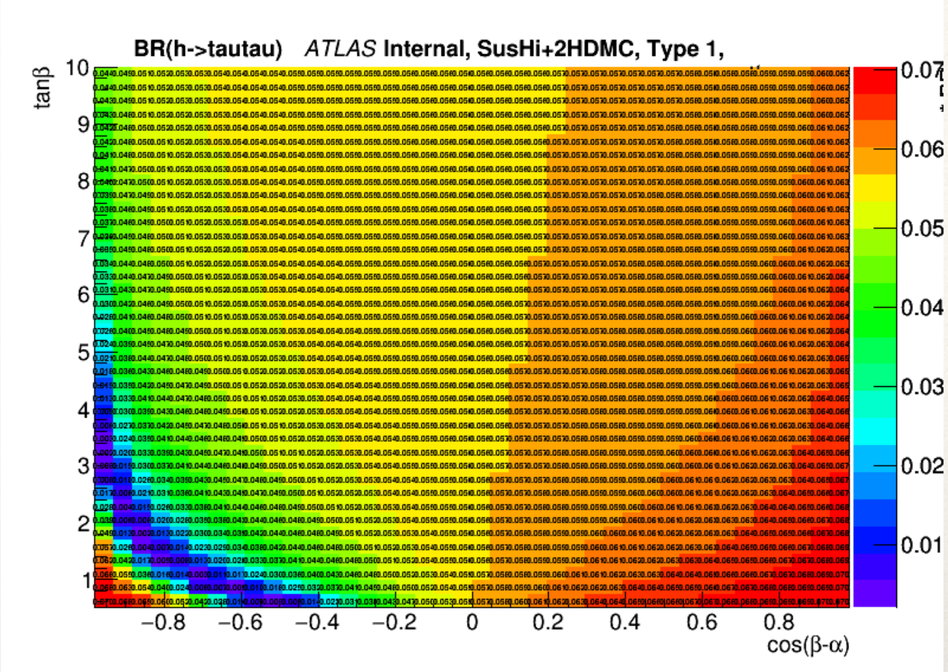


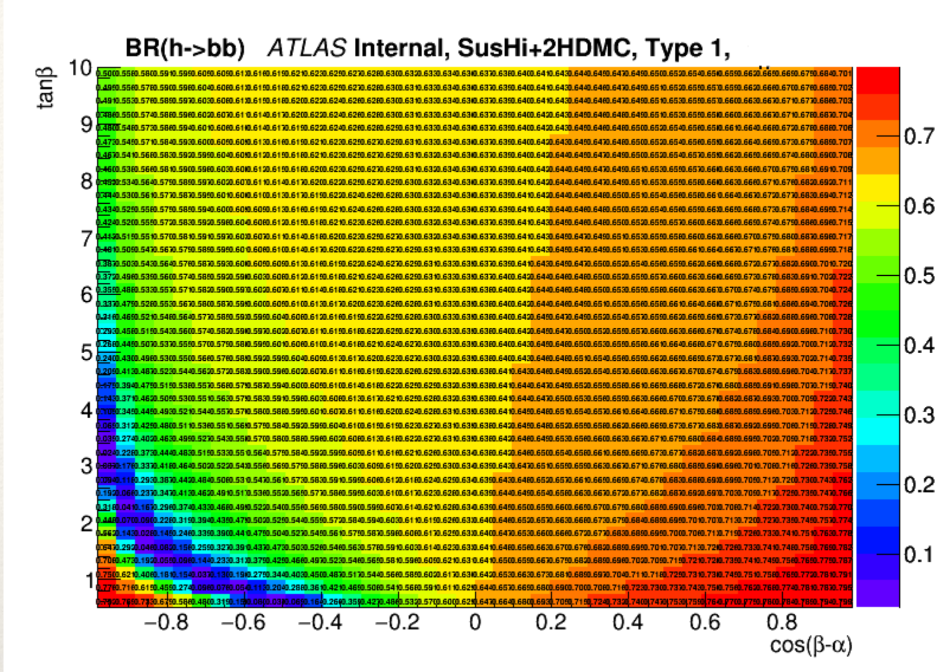


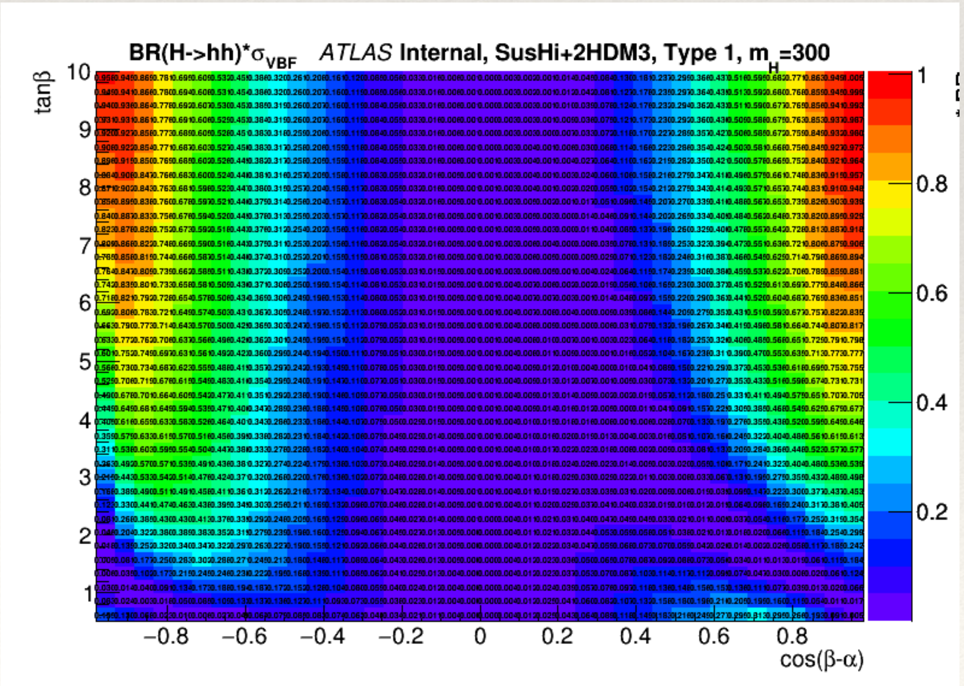


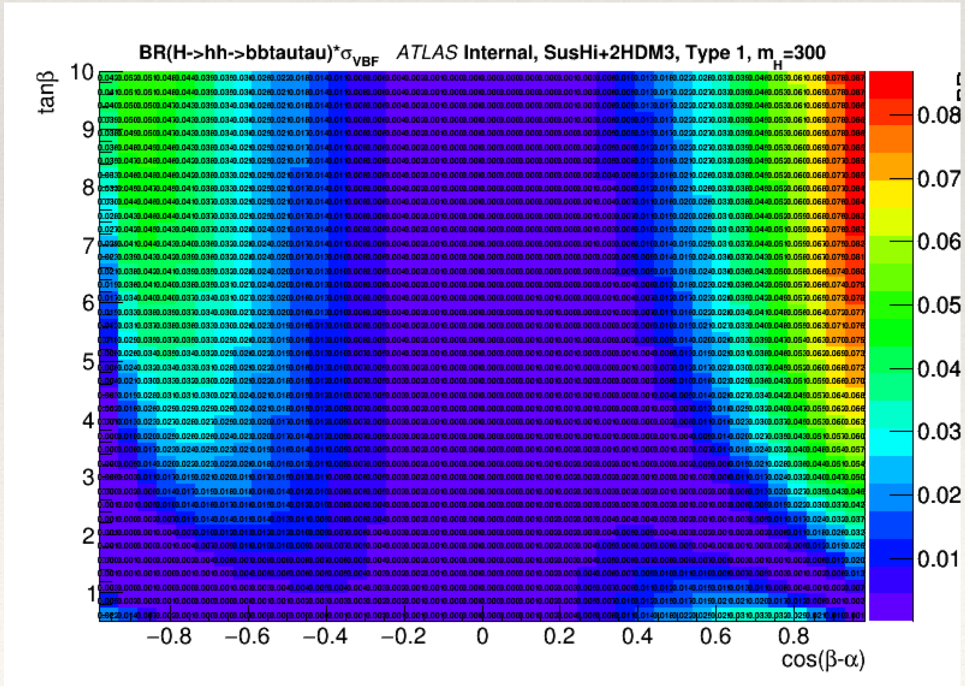
- Made the BDT plots with test and training sample. (next slide). The co-relation plots only have few variables. So the plots are not complete.
- non-resonant sample JO ran successfully this time, problem was in the filter parameters settings. Need to generate the validation plots now.
- Mini-workshop on VBF 25-27th October, organised in SLAC and CERN . https://indico.cern.ch/event/665600/overview

Plots

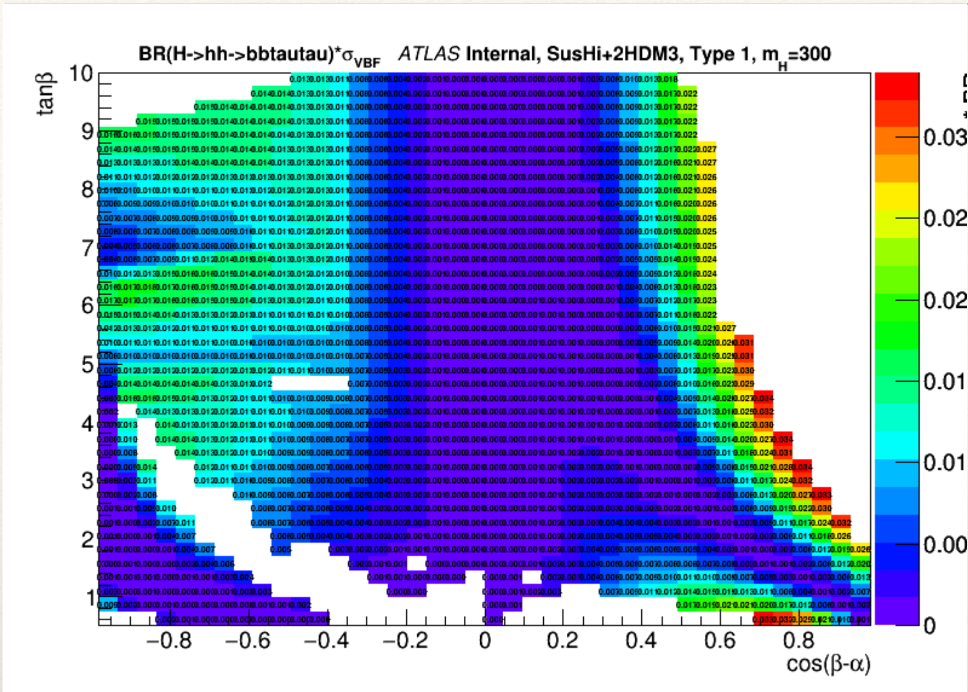

BR(h->tautau) ATLAS Internal, SusHi+2HDMC, Type 1,
tanβ
cos(β-α)
−0.8 −0.6 −0.4 −0.2 0 0.2 0.4 0.6 0.8
0.07 0.06 0.05 0.04 0.03 0.02 0.01


BR(h->bb) ATLAS Internal, SusHi+2HDMC, Type 1,
tanβ
cos(β-α)
−0.8 −0.6 −0.4 −0.2 0 0.2 0.4 0.6 0.8
0.7 0.6 0.5 0.4 0.3 0.2 0.1


BR(H->hh)*σ_VBF ATLAS Internal, SusHi+2HDM3, Type 1, m_H=300
tanβ
cos(β-α)
−0.8 −0.6 −0.4 −0.2 0 0.2 0.4 0.6 0.8
1 0.8 0.6 0.4 0.2

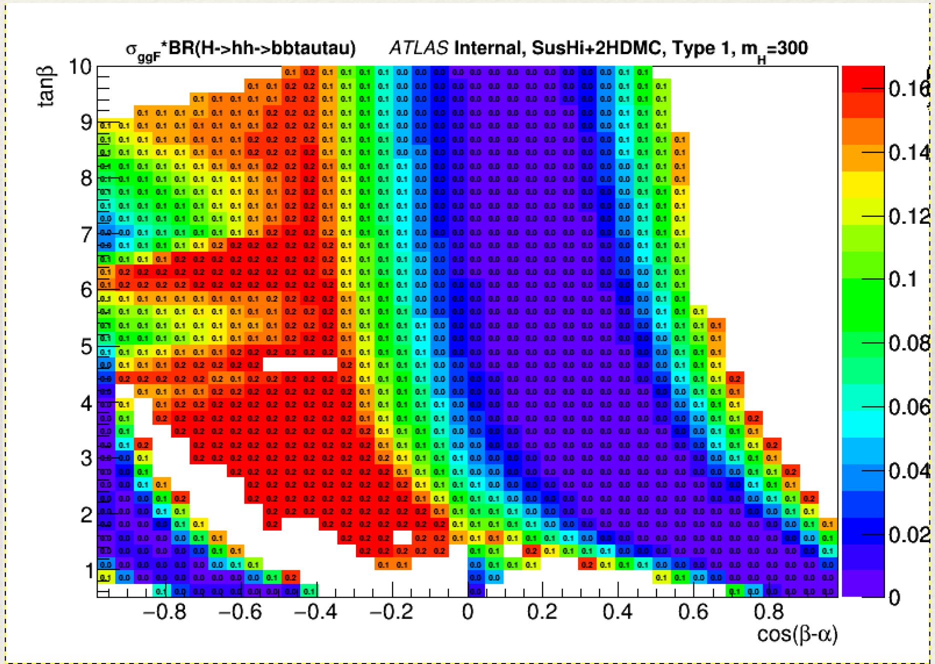

BR(H->hh->bbtautau)*σ_VBF ATLAS Internal, SusHi+2HDM3, Type 1, m_H=300
tanβ
cos(β-α)
−0.8 −0.6 −0.4 −0.2 0 0.2 0.4 0.6 0.8
0.08 0.07 0.06 0.05 0.04 0.03 0.02 0.01

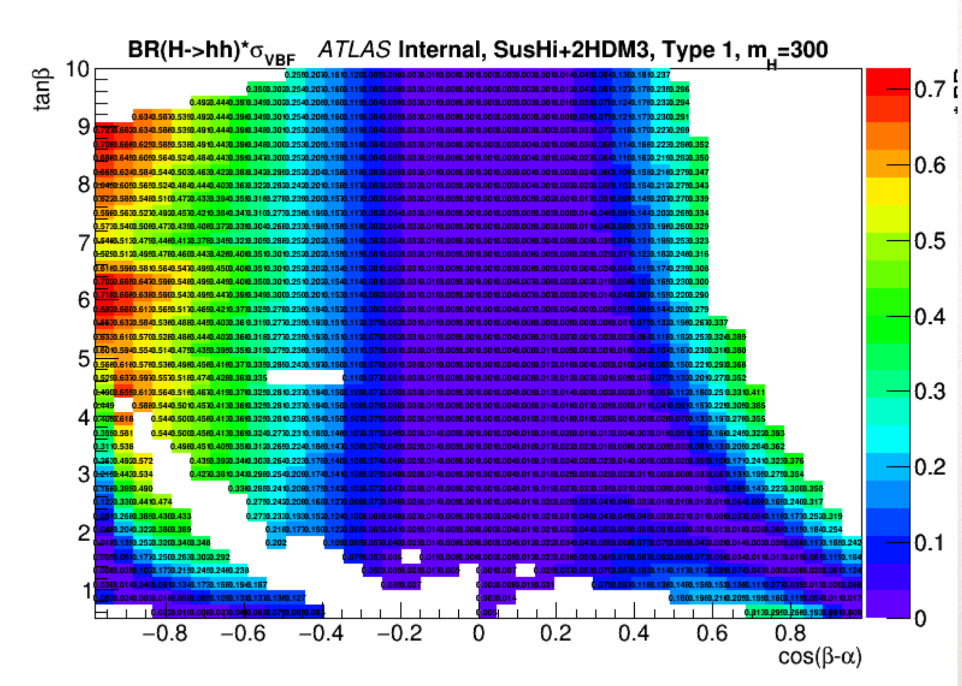
Plots



VBF

ggF



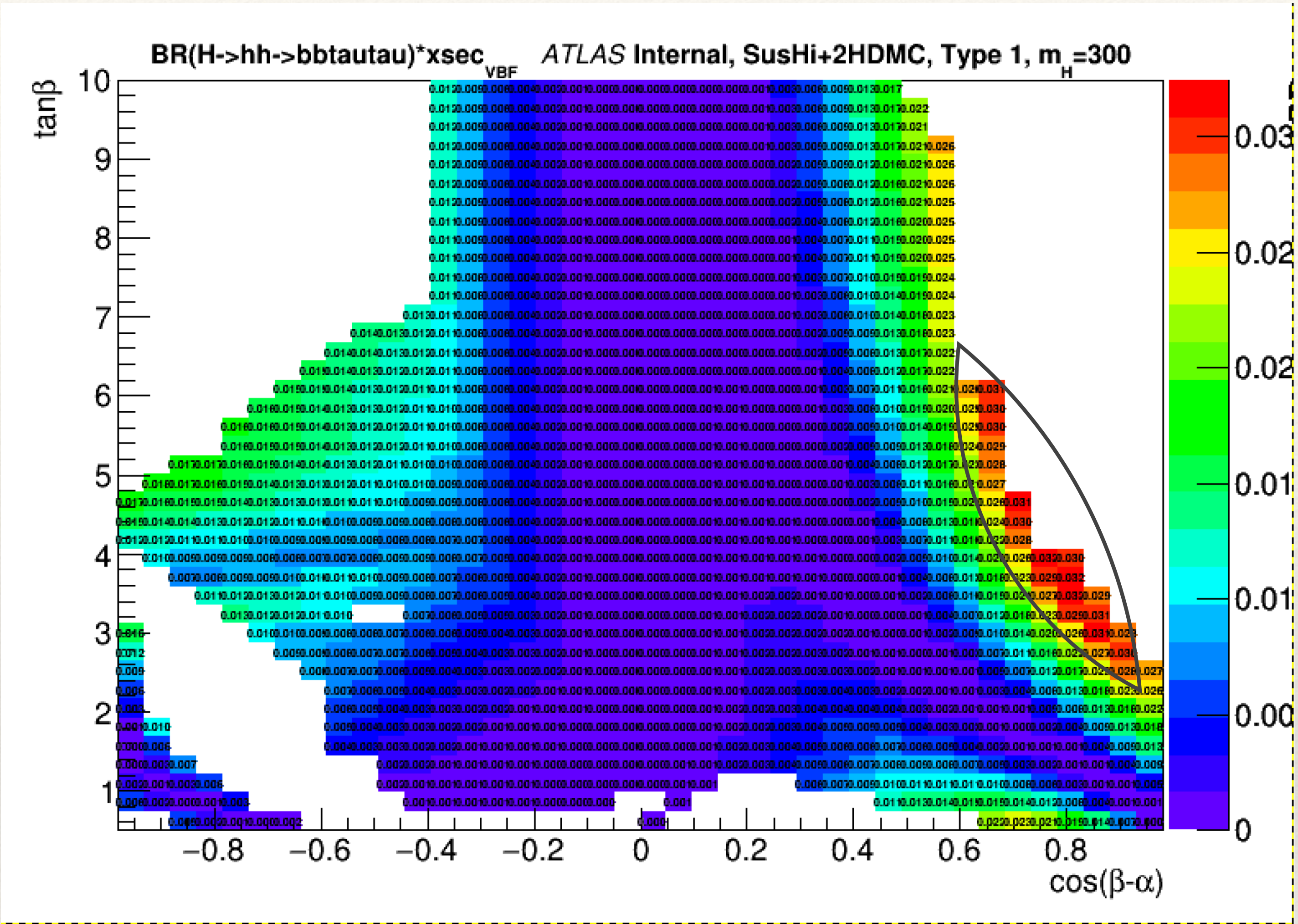


BR(H->hh)*σVBF ATLAS Internal, SusHi+2HDM3, Type 1, mH=300
tanβ
cos(β-α)
10
9
8
7
6
5
4
3
2
1
−0.8
−0.6
−0.4
−0.2
0
0.2
0.4
0.6
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

Script

```
while (t.next()) {

  //std::cout << t.mH << std::endl;
  if (t.type == type  &&
      // mH == mA == mCh
      fabs(t.mA-t.mH) < epsilon &&
      fabs(t.mH-t.mCh) < epsilon &&
      // mass
      fabs(t.mH-m) < epsilon  &&
      // cba/tanb
      fabs(t.cosba()) < 0.99+epsilon     &&
      t.tanb < tb+epsilon && t.tanb > 0.5-epsilon
      // theory constraints status
      // && t.status == 0
      && (t.xsec_H_gg*t.br_H_hh*0.072692)<0.168
      ){

    float br(0);
    float xs(0);
    //float xsref = t.xsec_H_gg;
    if (mode == "VBF") {br = t.br_H_hh*.072692;xs= t.xsec_H_VBF;} //.072692
    else if (mode == "VH") {
      //xs = t.xsec_H_ZH + t.xsec_H_WH;
      //xsref += t.xsec_H_VBF;
      //xsref += t.xsec_H_bb;
    }

    width->SetPoint(ipt++, t.cosba(),t.tanb,(br*xs));
  }
```

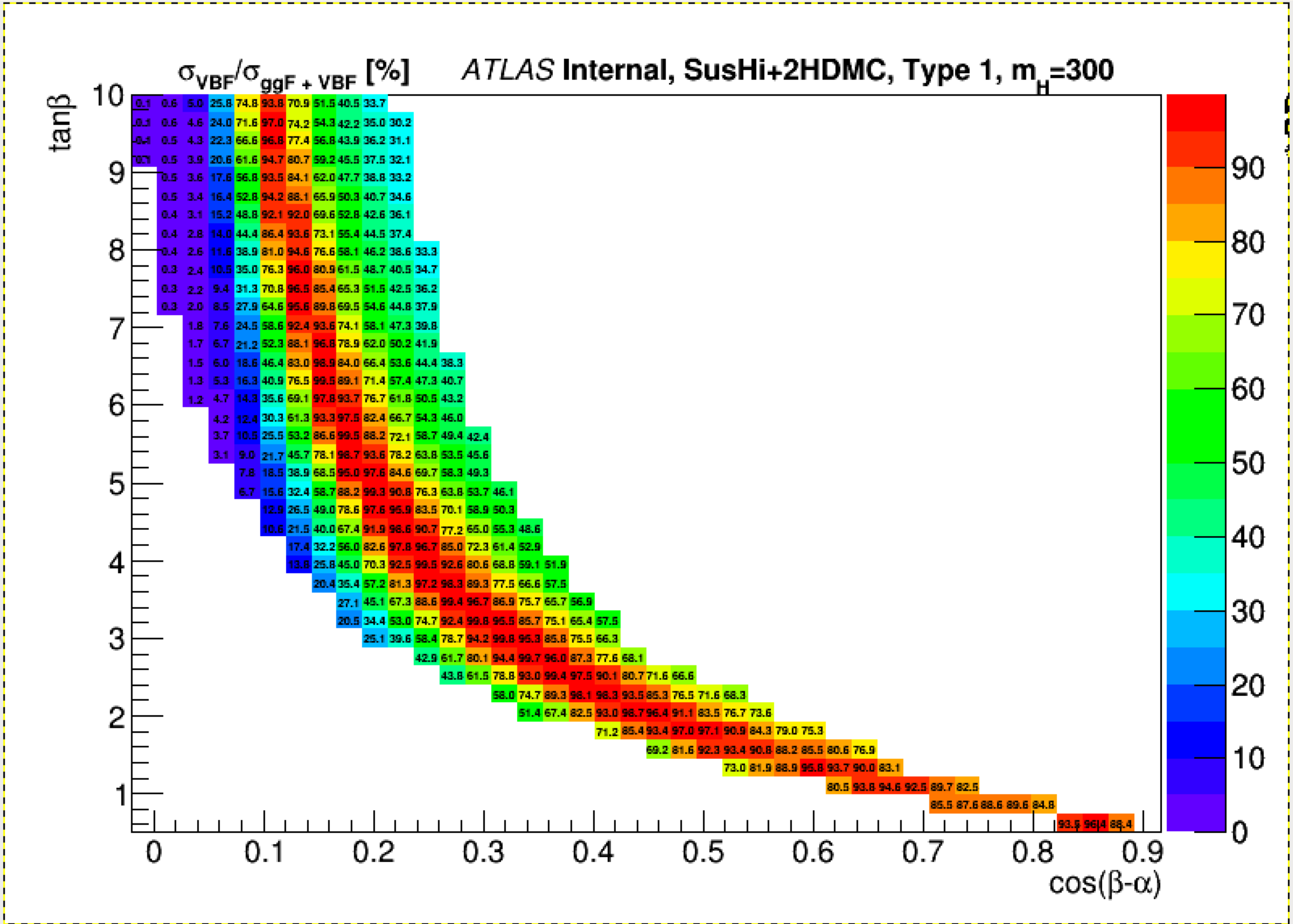
Xsection* BR(H->hh->bbtautau(.072692)) in pb, ggF< excluded limit



Number of signal events:
36000*.031*(844/250000)=3.7
including the 2017 data set it will be ~ 7 signal events

Plots shows the VBF(H)*BR(H->hh)* BR(hh->bbtautau) in the parameter space which is not excluded in ggF

Xsection ratio of ggF and VBF



Rel21 sample (Thanks to James)

- No validation needed to request Rel21 sample. But some validation might needed if we apply the pt filter (nothing related with rel21)
- EVNT part is still MC15 (so rel19 production cache), new cache is 19.2.5.25. The older one I used 19.2.5.5.
- 19.2.5.25: Powheg-00-03-09
- 19.2.5.5:   Powheg-00-03-06
- But the VBF_H has the same release r3052(v2).

https://docs.google.com/spreadsheets/d/16XvI5k2I2On4TkkIWJC9MXr0fMaRU2SvOkgBucRPzs0/edit#gid=0

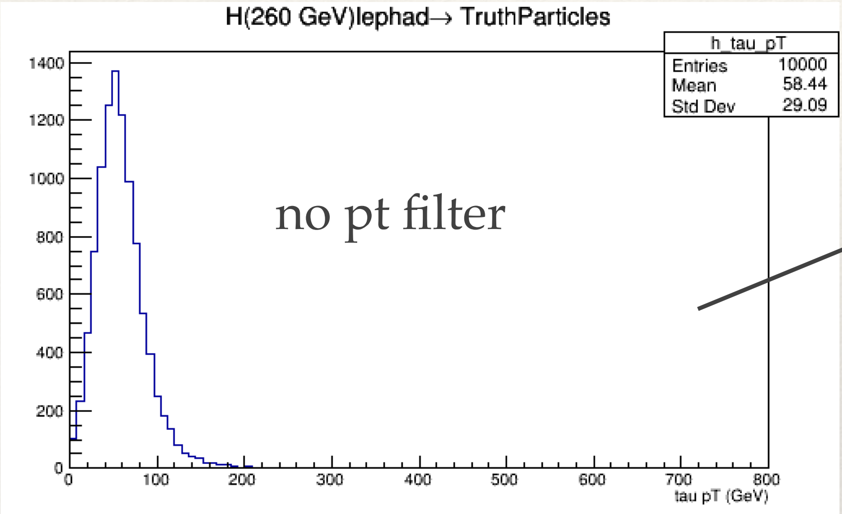
```
[psaha@lxplus001 plots_BR_nocut]$ asetup 19.2.5.25
Using AtlasProduction/19.2.5.25 [cmt] with platform x86_64-slc6-gcc47-opt
        at /cvmfs/atlas.cern.ch/repo/sw/software/x86_64-slc6-gcc47-opt/19.2.5
Test area: /afs/cern.ch/work/p/psaha/private/Xsection_VBFH/plots_BR_nocut
[psaha@lxplus001 plots_BR_nocut]$ cmt show versions External/Powheg
External/Powheg Powheg-00-03-09 /cvmfs/atlas.cern.ch/repo/sw/software/x86_64-slc6-gcc47-opt/19.2.5/AtlasProduction/19.2.5.25
External/Powheg Powheg-00-03-04 /cvmfs/atlas.cern.ch/repo/sw/software/x86_64-slc6-gcc47-opt/19.2.5/AtlasSimulation/19.2.5
[psaha@lxplus001 plots_BR_nocut]$ asetup 19.2.5.5
Using AtlasProduction/19.2.5.5 [cmt] with platform x86_64-slc6-gcc47-opt
        at /cvmfs/atlas.cern.ch/repo/sw/software/x86_64-slc6-gcc47-opt/19.2.5
Test area: /afs/cern.ch/work/p/psaha/private/Xsection_VBFH/plots_BR_nocut
[psaha@lxplus001 plots_BR_nocut]$ cmt show versions External/Powheg
External/Powheg Powheg-00-03-06 /cvmfs/atlas.cern.ch/repo/sw/software/x86_64-slc6-gcc47-opt/19.2.5/AtlasProduction/19.2.5.5
External/Powheg Powheg-00-03-04 /cvmfs/atlas.cern.ch/repo/sw/software/x86_64-slc6-gcc47-opt/19.2.5/AtlasSimulation/19.2.5
```

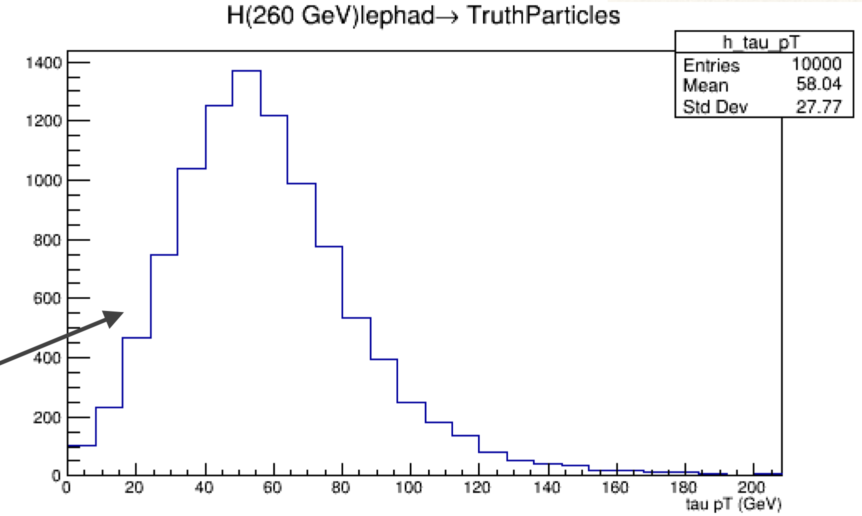
		eta>1	eta>2	eta>3	eta>4	eta>5
mjj>300	sig900	13143	13127	13009.3	12051	9594.33
	ttbar	8243.47	8040.55	7297.32	5315.53	2555.4
	sigficance	120.379	121.347	124.686	130.45	136.735
mjj>400	sig900	12699.2	12686.7	12599.7	11849	9570.5
	ttbar	6063.79	5968.67	5583.98	4456.61	2479.89
	significance	130.343	130.943	133.179	136.392	137.694
mjj>500	sig900	11998.7	11994.9	11936.6	11401.5	9443.86
	ttbar	4549.57	4498.35	4279.94	3602.81	2238.22
	significance	136.808	137.36	139.035	141.45	140.423
mjj>600	sig900	11368.2	11364.5	11328.1	10908.9	9249.77
	ttbar	3462.11	3435.88	3310.51	2891.39	1960.43
	significance	142.877	143.176	144.451	146.016	143.506
mjj>700	sig900	10682.8	10679	10650.8	10325.4	8923.66
	ttbar	2688.05	2673.43	2600.55	2334.87	1682.97
	significance	146.748	146.944	147.834	148.842	145.506
mjj>800	sig900	10019	10017	10002	9763	8579
	ttbar	2110.58	2103.28	2064.55	1882.92	1432.27
	significance	149.611	149.735	150.35	151.381	147.567

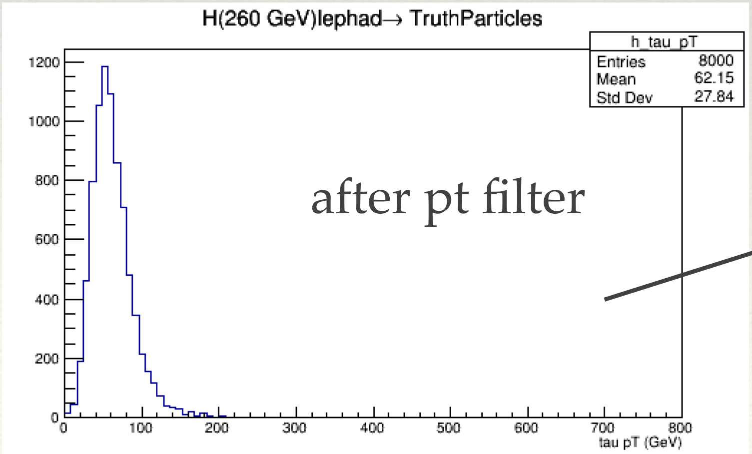
- Significance: s= sqrt(2*((s+b)*Log(1+(s/b)) -s)).

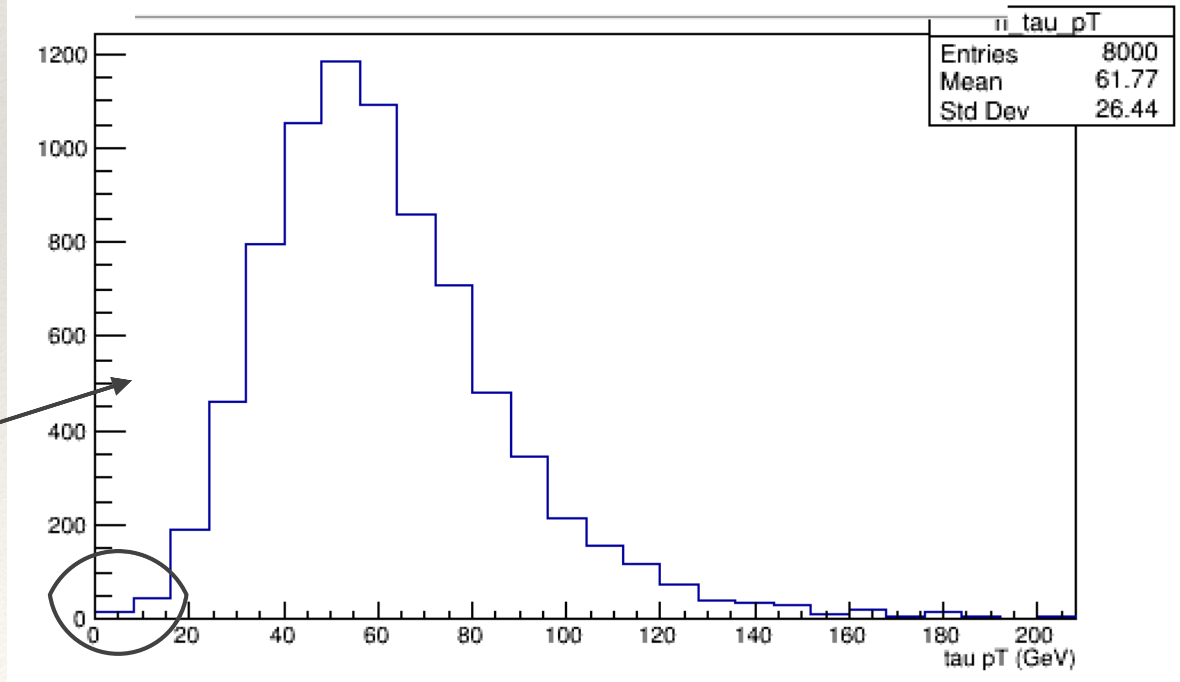
Effect of pt filter

```
#----------------------------------------------------------------------------------------------
# Filter for 2 leptons (inc tau(had)) with pt cuts on e/mu = 13 GeV and tau(had) = 15 GeV
#----------------------------------------------------------------------------------------------
from GeneratorFilters.GeneratorFiltersConf import MultiElecMuTauFilter
filtSeq += MultiElecMuTauFilter("LepTauPtFilter")
filtSeq.LepTauPtFilter.IncludeHadTaus = True
filtSeq.LepTauPtFilter.NLeptons = 2
filtSeq.LepTauPtFilter.MinPt = 13000.
filtSeq.LepTauPtFilter.MinVisPtHadTau = 15000.
filtSeq.LepTauPtFilter.MaxEta = 5.
```

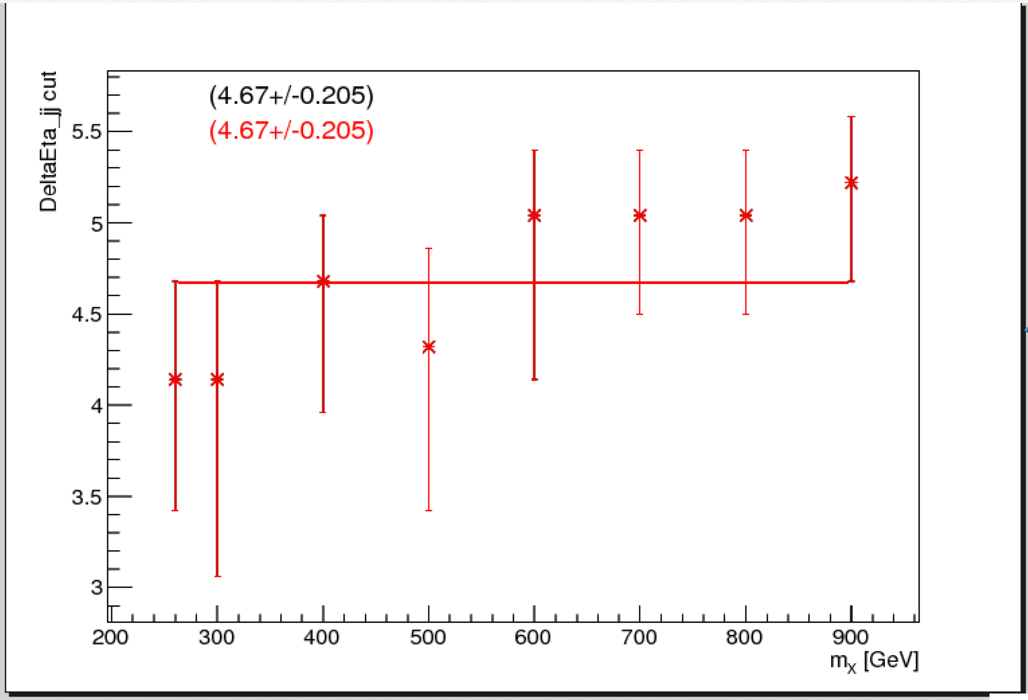






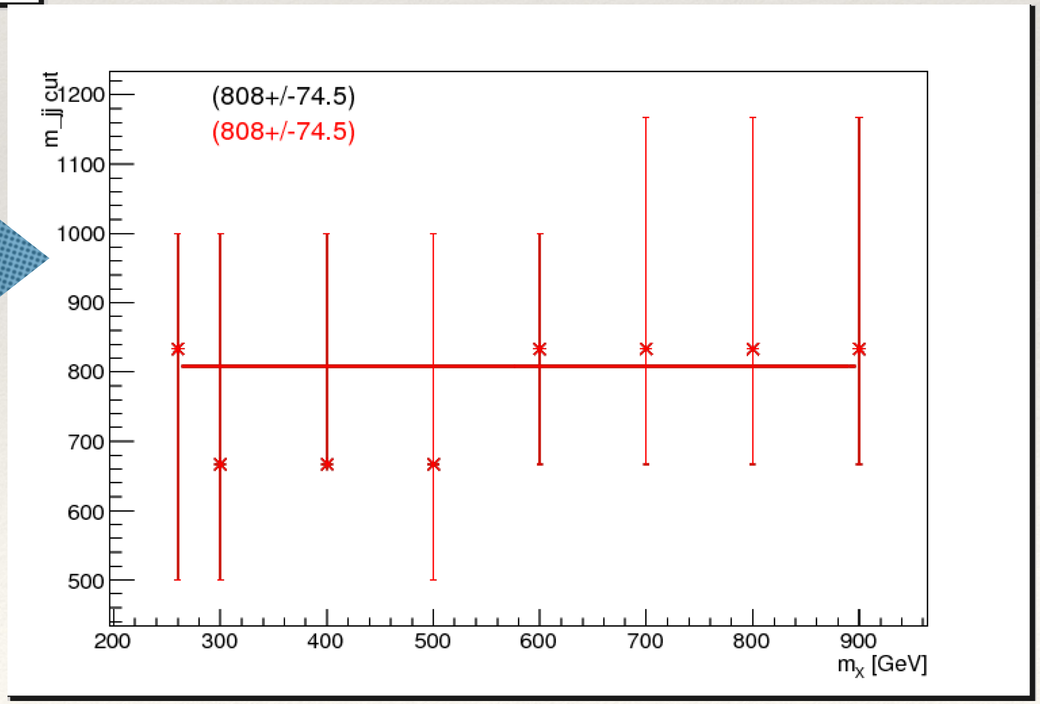


Cut optimisation



Optimised cut DeltaEta_jj > 4.7

Optimised cut m_jj > 800 GeV after optimising DeltaEta_jj



VBF 260 GeV sample

	raw events	weight(100fb-1)	weight(80fb-1)	weight(36fb-1)
preselection	844			
b-tag weight	844	896.30	896.30	896.30
truthtagging	844	896.30	896.30	896.30
tauEff	844	949.93	949.93	949.93
triggerSF	844	890.77	890.77	890.77
lepton SF	844	854.99	854.99	854.99
PU*LU event weight	844	577.99	462.39	208.49

VBF 900 GeV Sample

	raw events	weight(100fb-1)	weight(80 fb-1)	weight(36fb-1)
preselection	4122			
b-tag weight	4122	4064.94	4064.94	4064.94
truthtagging	4122	4064.94	4064.94	4064.94
tauEff	4122	4302.55	4302.55	4302.55
triggerSF	4122	4097.48	4097.48	4097.48
lepton SF	4122	3971.17	3971.17	3971.17
PU*LU event weight	4122	11333.5	9066.82	4088.08

2HDM ntuple

Introduction

All relevant recommendations: HiggsBSM2HDMRecommendations HiggsBSMSingletrecommendations

This is a description on how to access cross sections and BRs for 2HDM benchmark points.

A generic CP-conserving 2HDM with a softly broken Z_2 symmetry ($\Phi_1 \to \Phi_1, \Phi_2 \to -\Phi_2$) has 7 free parameters:

- Higgs bosons: 2 CP-even with masses `mH` and `mh`; 1 CP-odd with mass `mA`; two charged scalars with mass `mCh`
- a mixing angle among the neutral Higgses, α
- the ratio of the vevs of the two Higgs doublets $\tan\beta = u1/u2$
- the m_{12} parameter of the potential, which is the softly breaking term of the Z_2 symmetry of the potential.

To define benchmarks we usually set `mh` = 125 GeV. The rest of the parameters can be assigned in principle arbitrary values. Nevertheless, the mass splitting among the rest of the Higgs bosons cannot be very large (e.g. >200 GeV) due to theoretical considerations. The m_{12} has also to be finely tuned in order to get a valid model.

In the limit $\sin(\beta - \alpha) \to 1$ then the choice $m_{12}^2 = m_A^2 \tan\beta/(1 + \tan^2\beta)$ gives always a valid model. This is the SM-like limit of the 2HDM (which is different from the decoupling limit).

Production mechanisms in the 2HDM for neutral Higgs are b-associated production, g-fusion, VBF and VH.

Ntuple versions 13 TeV

Version 1.6.7 NEW

Bug in 1.6.6: bbA/H xsec was smaller than they should be due to a wrong implementation of Santander matching. Fixed in the following file.

- `/afs/cern.ch/user/x/xiaohu/public/2HDM-THEO-NTUP/thdm_grid_v167.root`

Version 1.6.6 (buggy bbA/H xsec)

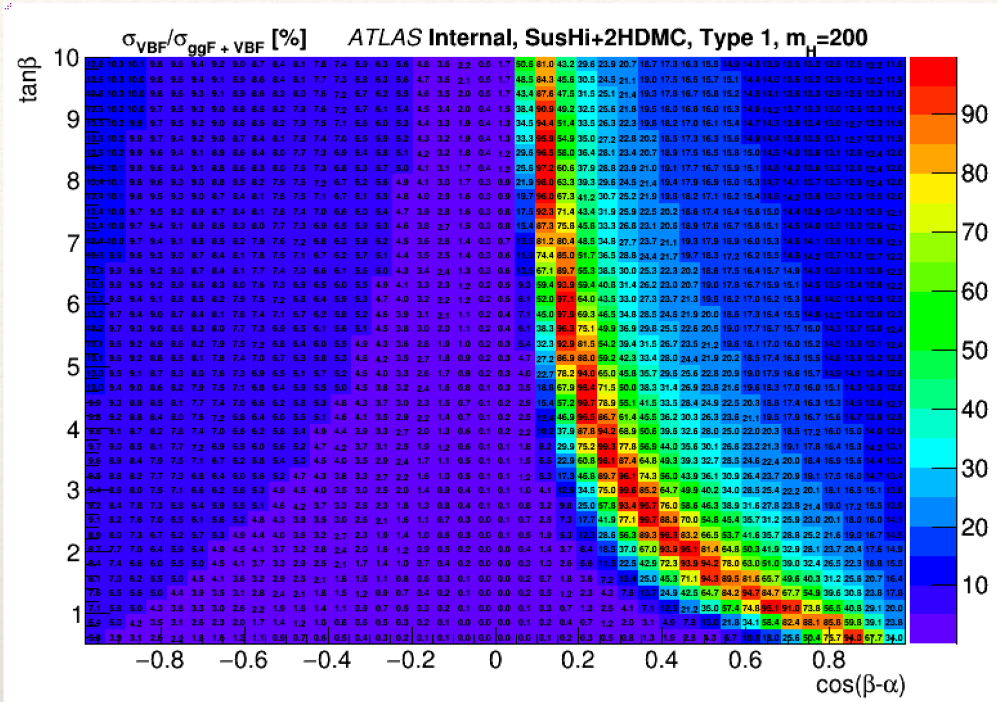
NOTE: the combined bbA/H xsec is wrong in this version due to a wrong implementation of Santander matching. However, the separate 5FS and 4FS bbA/H xs are correct. One can either do a matching on the fly or simply move to version 1.6.7 .

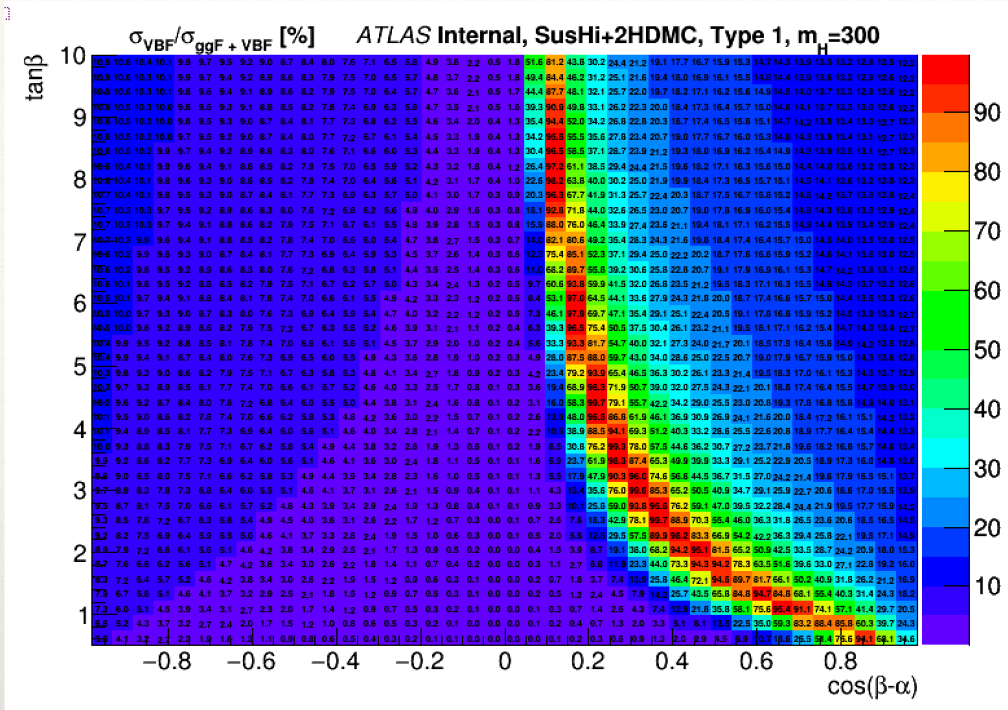
This is a stable version of the 2HDM ntuple for 13TeV

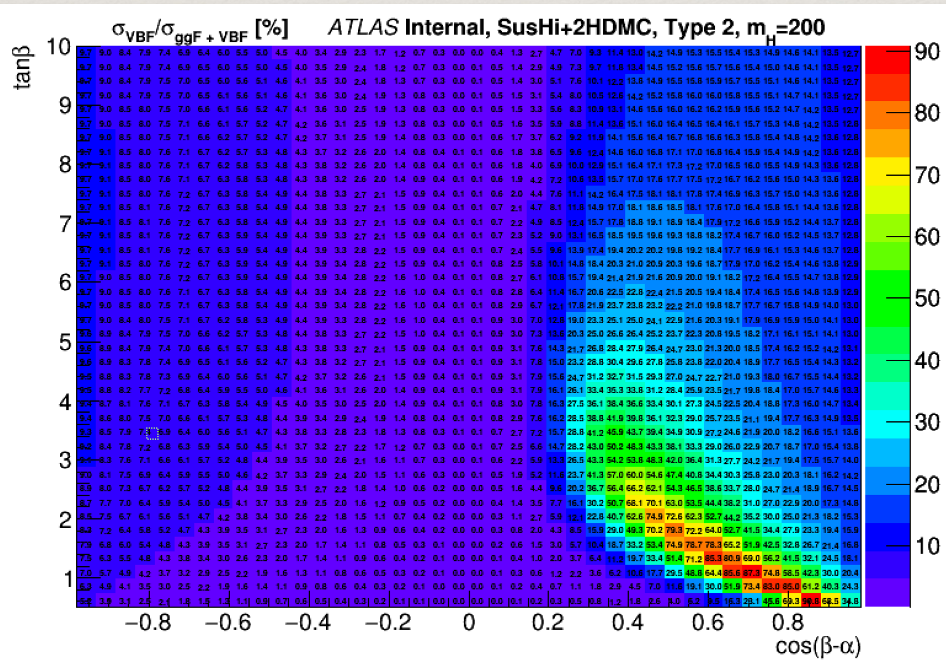
- `/afs/cern.ch/user/x/xiaohu/public/2HDM-THEO-NTUP/thdm_grid_v166.root`

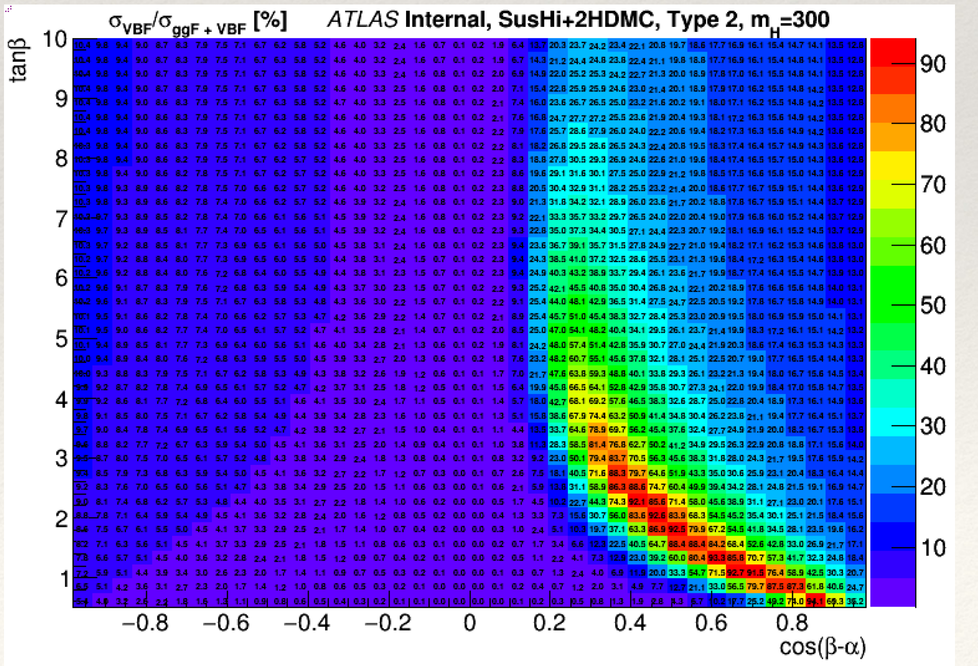
- https://twiki.cern.ch/twiki/bin/viewauth/AtlasProtected/HiggsBSM2HDMRecommendations#Version_1_6_7

Xsection(Thanks Carl for the script)

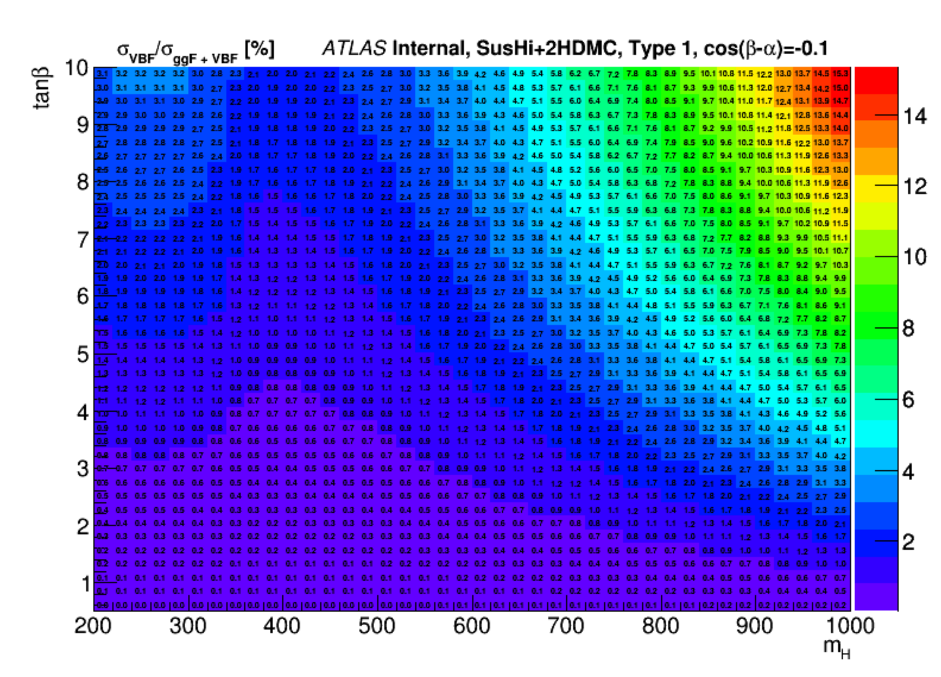


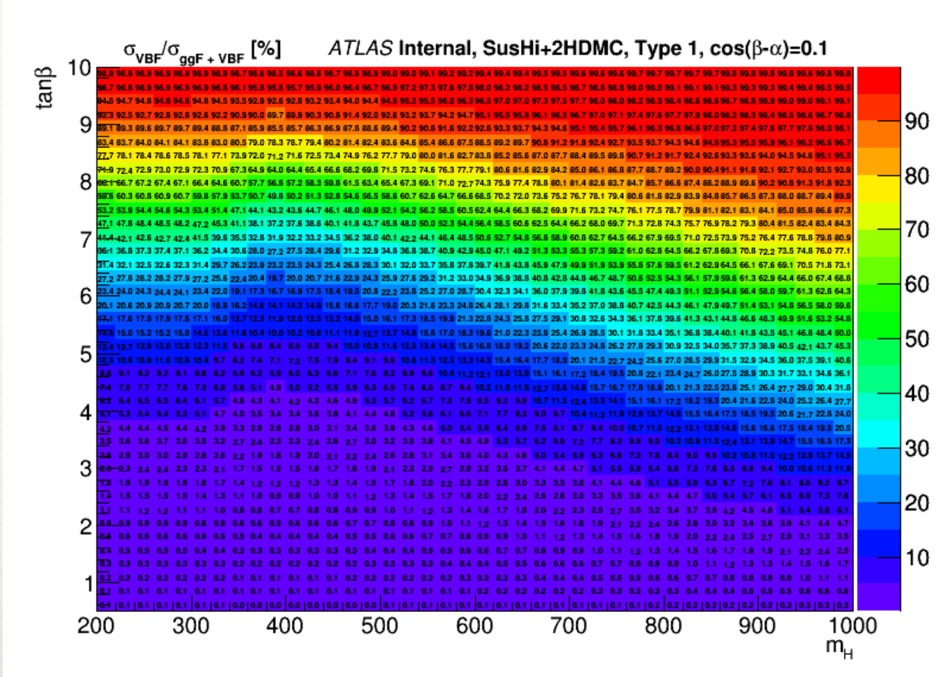


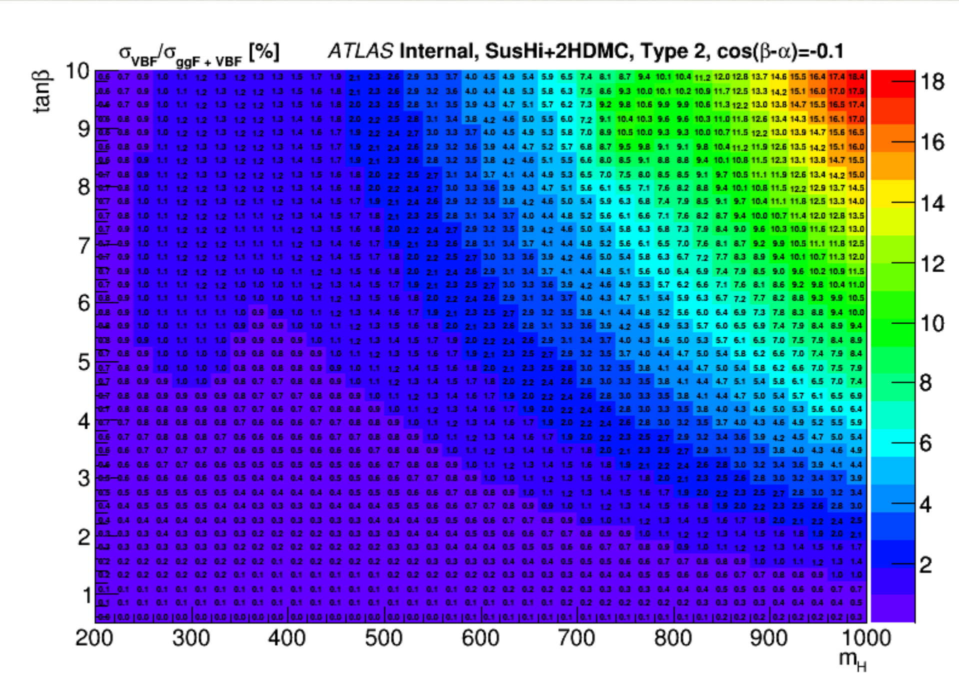


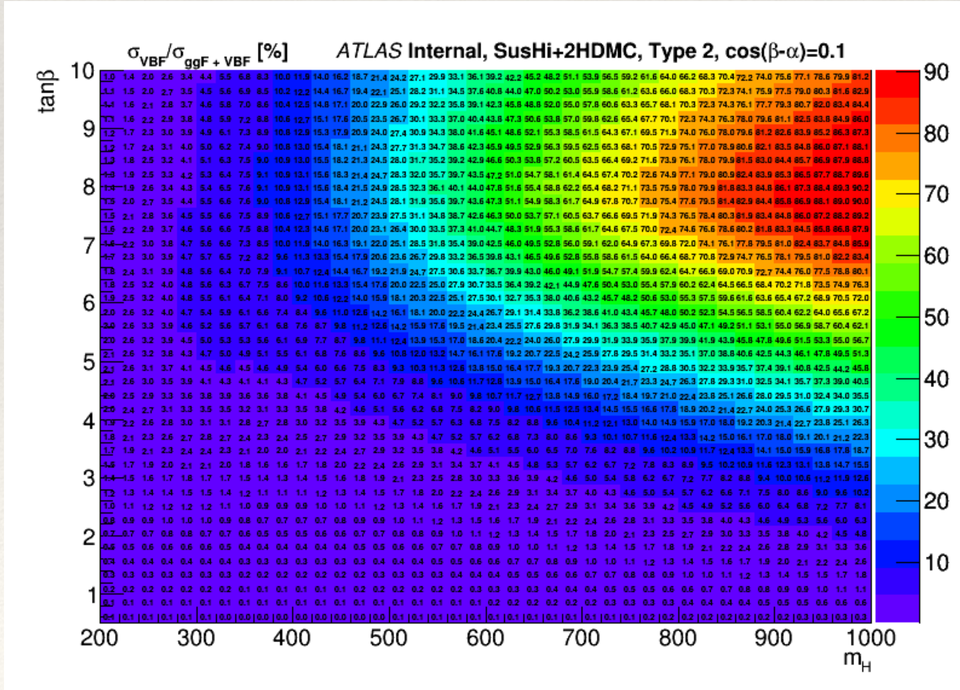


Xsection

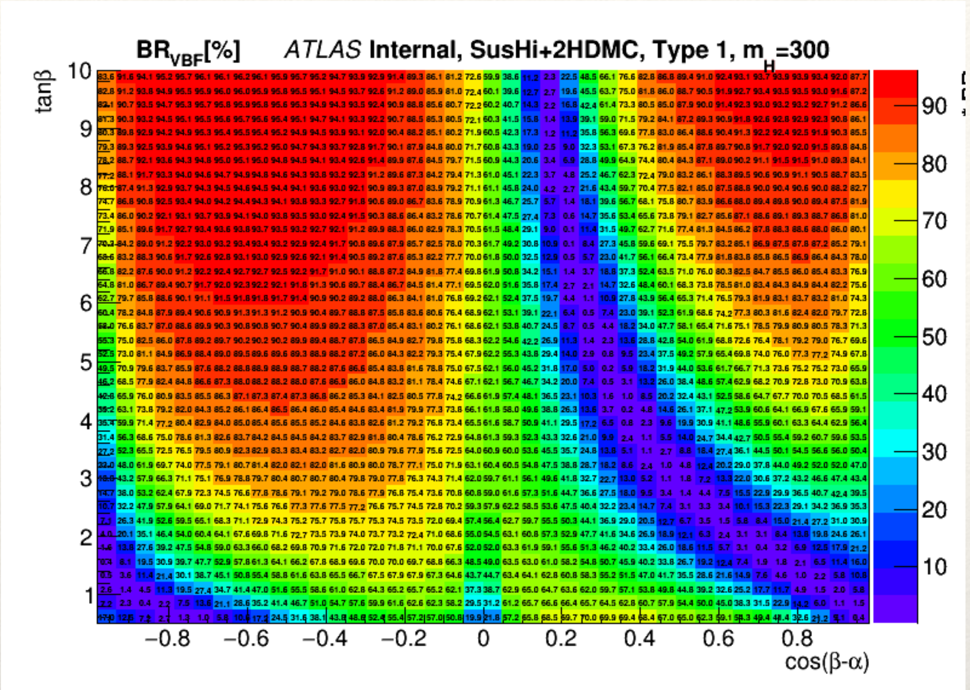

σVBF/σggF + VBF [%]
ATLAS Internal, SusHi+2HDMC, Type 1, cos(β-α)=-0.1
tanβ
mH


σVBF/σggF + VBF [%]
ATLAS Internal, SusHi+2HDMC, Type 1, cos(β-α)=0.1
tanβ
mH

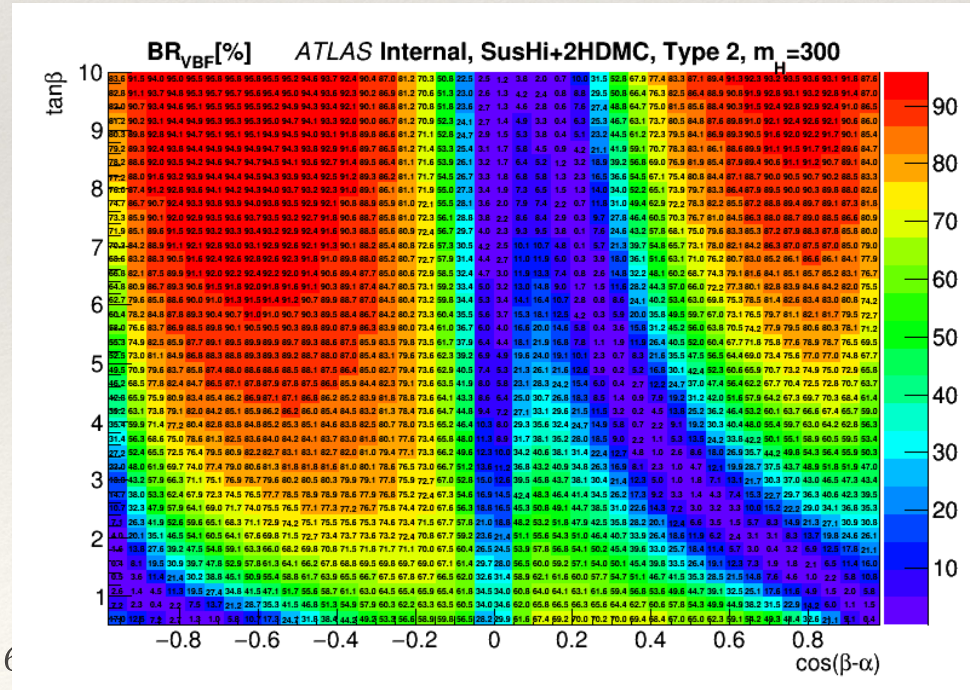

σVBF/σggF + VBF [%]
ATLAS Internal, SusHi+2HDMC, Type 2, cos(β-α)=-0.1
tanβ
mH


σVBF/σggF + VBF [%]
ATLAS Internal, SusHi+2HDMC, Type 2, cos(β-α)=0.1
tanβ
mH

BR of H->hh

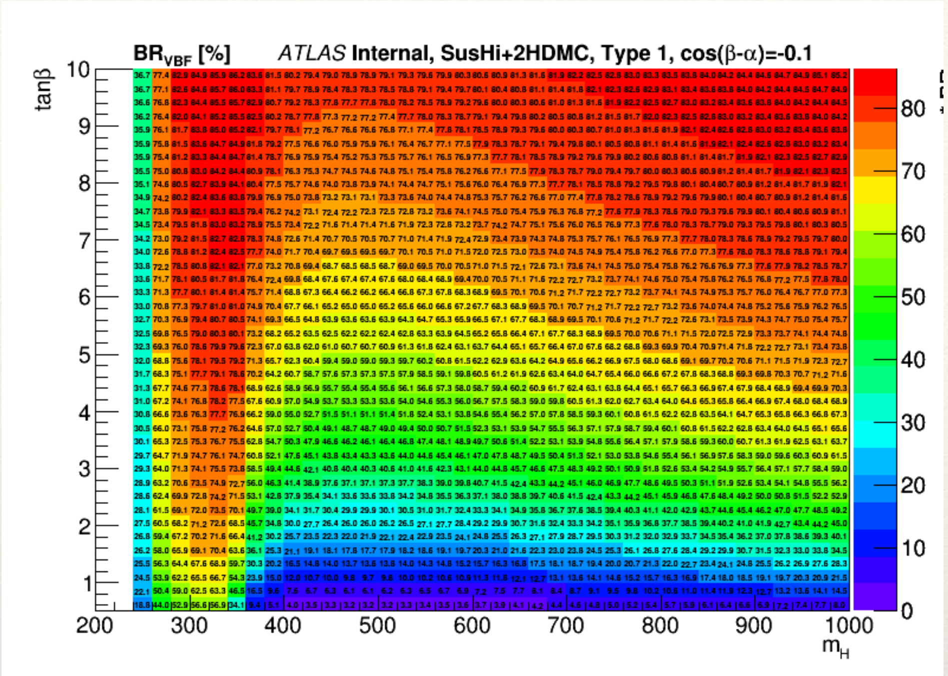


BR$_{VBF}$[%] ATLAS Internal, SusHi+2HDMC, Type 1, m$_H$=300
tanβ
cos(β-α)
−0.8 −0.6 −0.4 −0.2 0 0.2 0.4 0.6 0.8
1 2 3 4 5 6 7 8 9 10
10 20 30 40 50 60 70 80 90

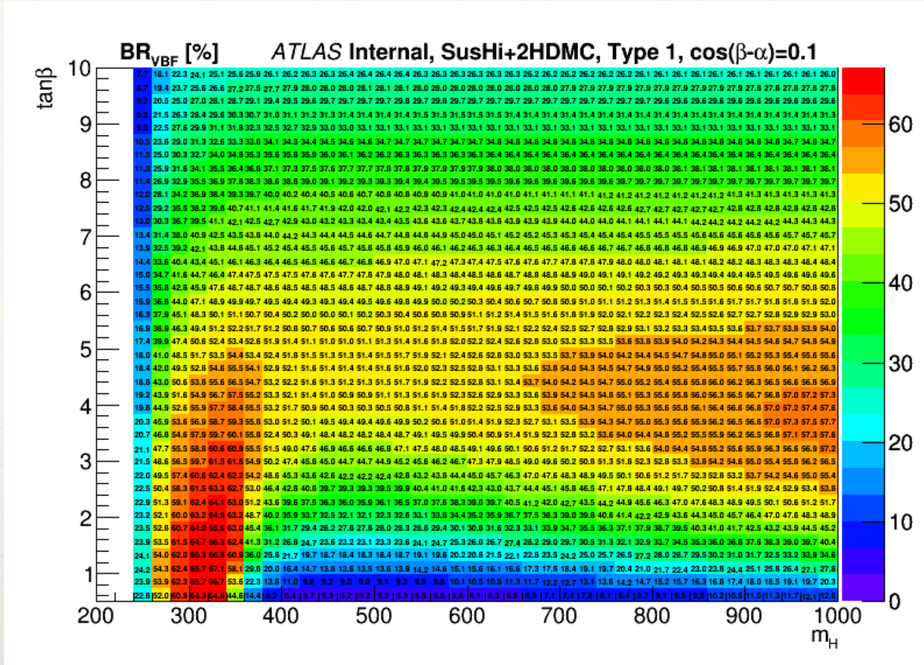


BR$_{VBF}$[%] ATLAS Internal, SusHi+2HDMC, Type 2, m$_H$=300
tanβ
cos(β-α)
−0.8 −0.6 −0.4 −0.2 0 0.2 0.4 0.6 0.8
1 2 3 4 5 6 7 8 9 10
10 20 30 40 50 60 70 80 90

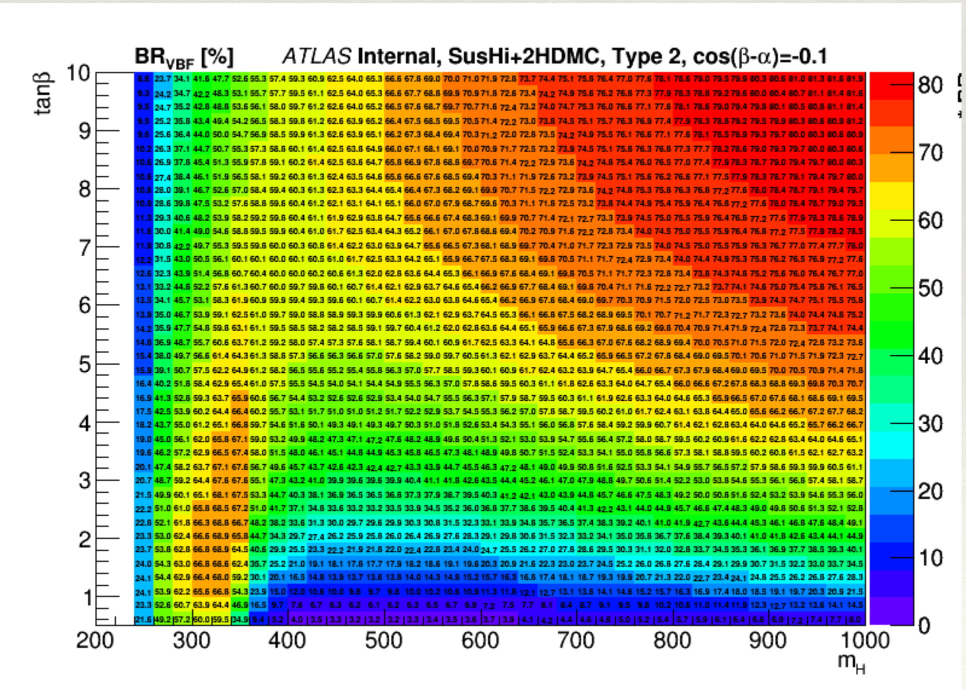
BR of H->hh



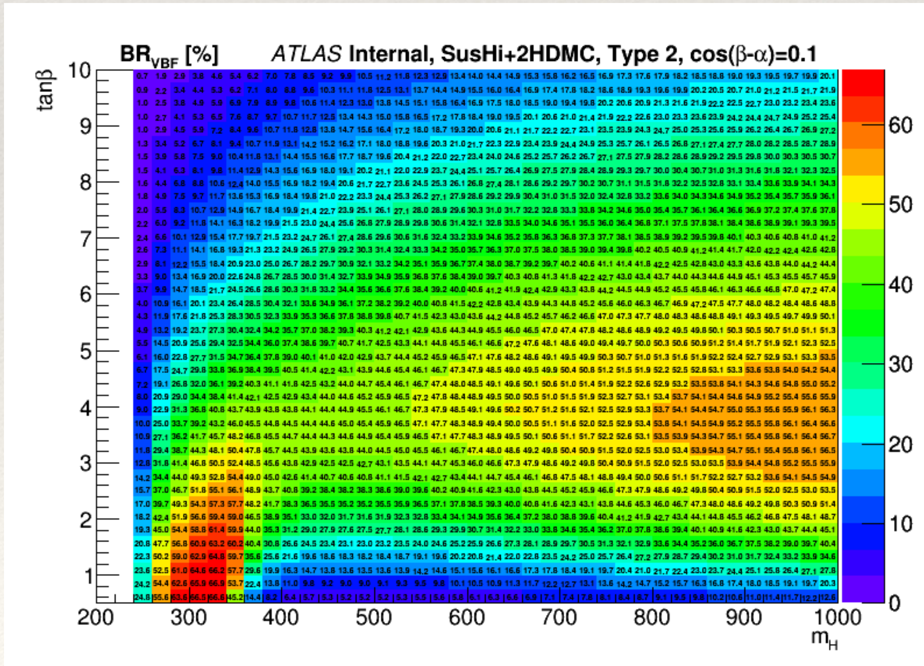
BR_{VBF} [%]
ATLAS Internal, SusHi+2HDMC, Type 1, cos(β-α)=-0.1
tanβ
m_H



BR_{VBF} [%]
ATLAS Internal, SusHi+2HDMC, Type 1, cos(β-α)=0.1
tanβ
m_H

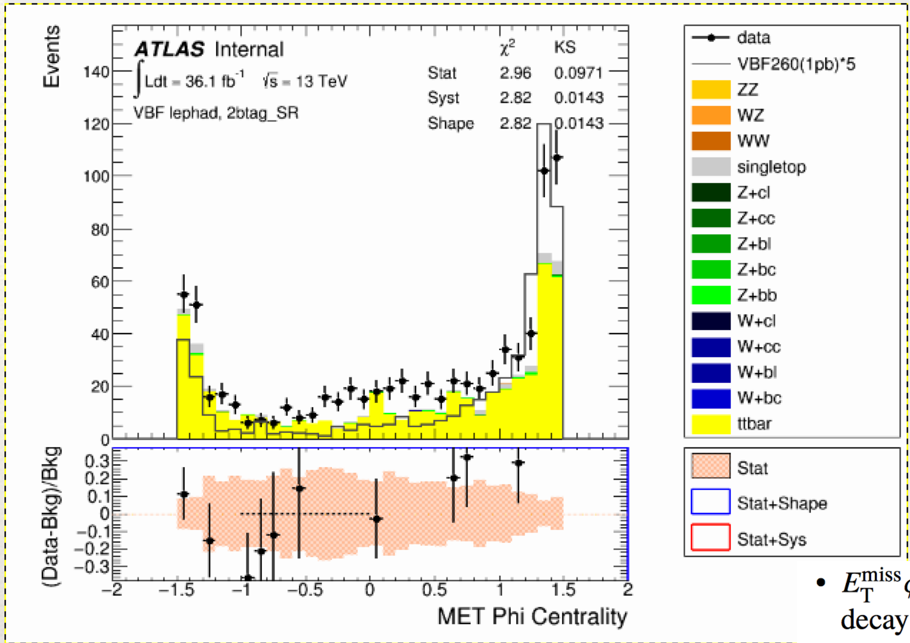


BR_{VBF} [%]
ATLAS Internal, SusHi+2HDMC, Type 2, cos(β-α)=-0.1
tanβ
m_H



BR_{VBF} [%]
ATLAS Internal, SusHi+2HDMC, Type 2, cos(β-α)=0.1
tanβ
m_H

Plots



- $E_T^{\text{miss}}\phi$ centrality: This variable quantifies the position in ϕ of the E_T^{miss} with respect to the visible decay products of the two taus. It is defined as:

$$E_T^{\text{miss}}\phi \text{ centrality} = \frac{A+B}{\sqrt{A^2+B^2}}, \tag{1}$$

where A and B are given by:

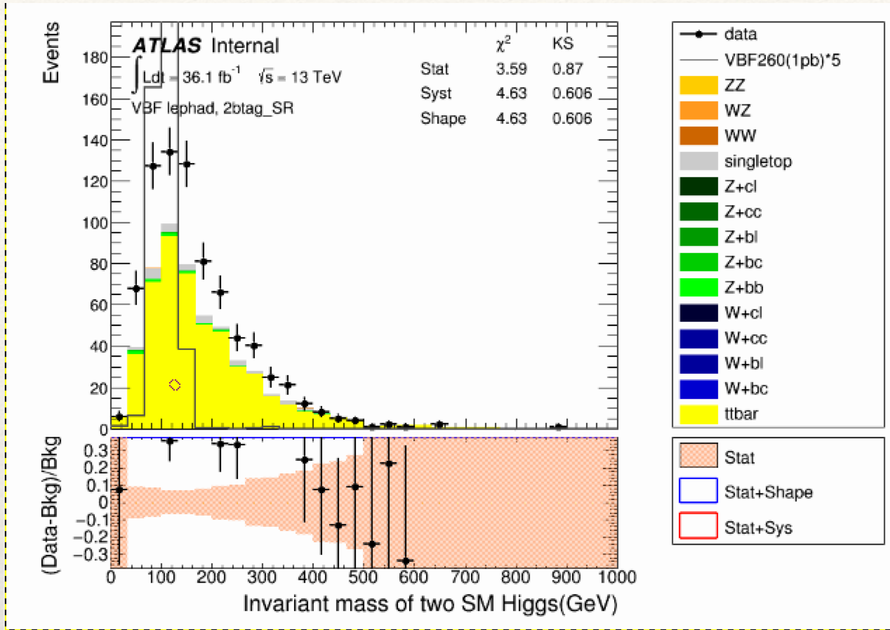
$$A = \frac{\sin(\phi_{E_T^{\text{miss}}} - \phi_{\tau_2})}{\sin(\phi_{\tau_1} - \phi_{\tau_2})}, \quad B = \frac{\sin(\phi_{\tau_1} - \phi_{E_T^{\text{miss}}})}{\sin(\phi_{\tau_1} - \phi_{\tau_2})}. \tag{2}$$

The $E_T^{\text{miss}}\phi$ centrality is equal to:

- $\sqrt{2}$ when the E_T^{miss} lies exactly between the two taus; or
- 1 if the E_T^{miss} is perfectly aligned with either of the taus; or
- < 1 if the E_T^{miss} lies outside of the ϕ anglur region defined by the two taus.

Signal events tend to have larger values of the E_T^{miss} centrality as in these cases the two taus are produced from the decay of a Higgs boson and the reconstructed E_T^{miss} ϕ angle generally falls inbetween the two visible tau decay products.

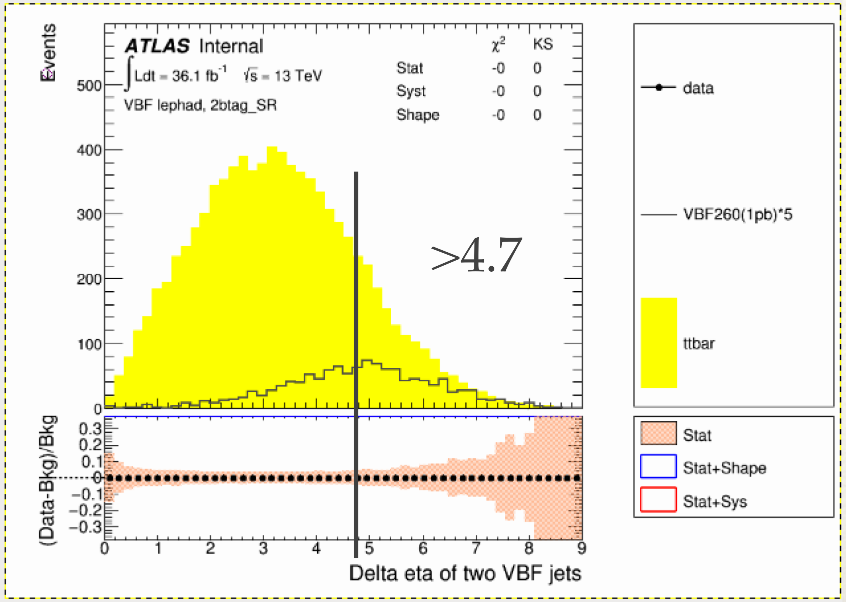
Plots

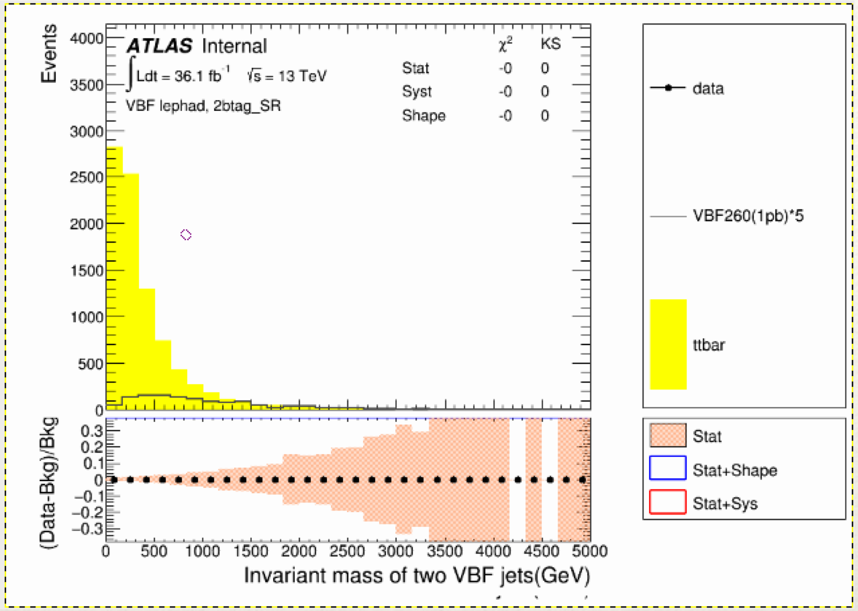


Invariant mass of two SM Higgs not at 260 GeV and it is due to m_bb which is not at 125GeV

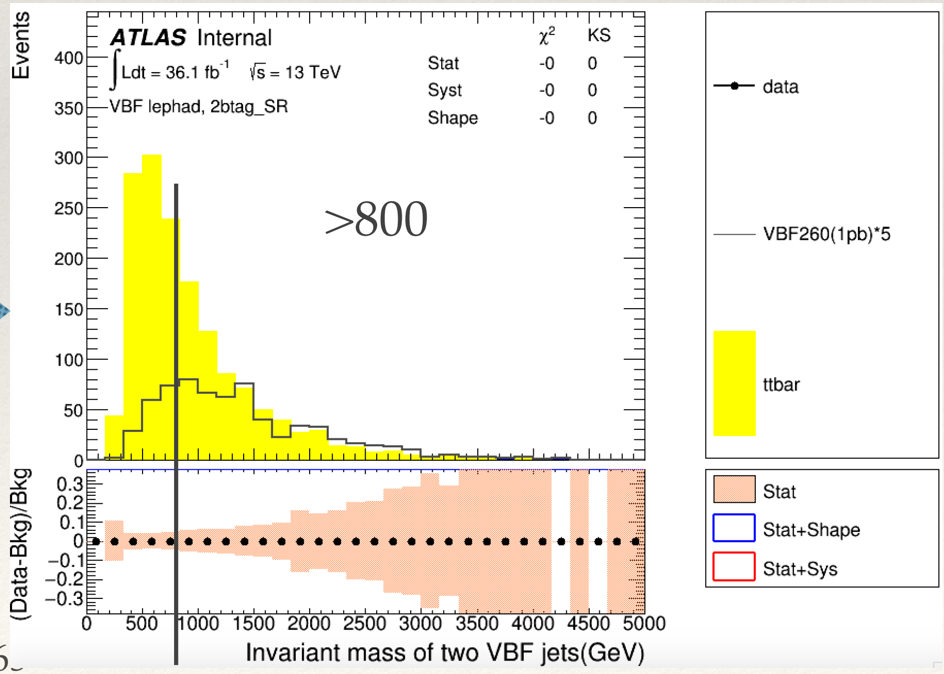
- The four momentum of the closest muon in DeltaR with in the jet is added to the calorimeter based jet energy after removing the energy deposited by the muon in the calorimeter.
- In addition, the jet 4-Vector is multiplied by the pT-dependent correction to account for the biases in the response.
- This correction takes into account the effect of the momentum of the neutrinos produced in b-hadron semi-leptonic decays.
- After applying such correction m_bb peak moved from 109 GeV to 110 GeV. Need to check again.

plots





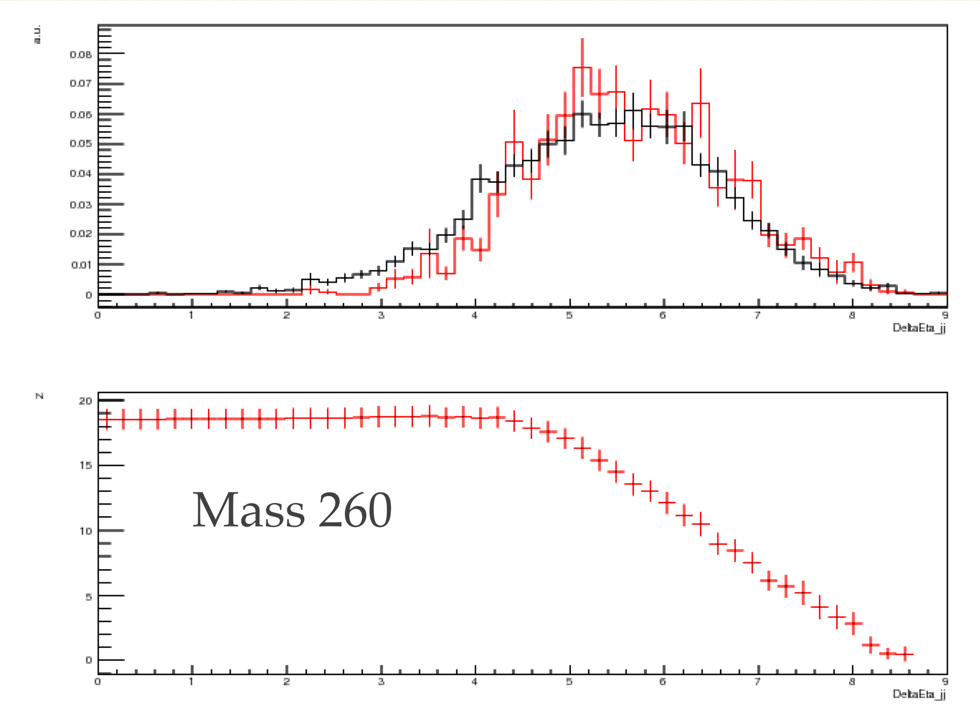
After DeltaEta_jj > 4.7



Introduction

- Brief overview on how I have selected the jets, VBF and h->bb jets.
- Cut optimisation.
- Make a table for signal efficiency for 260 GeV and 900 GeV mass points and for each cut. 1000 GeV is missing in the CxAOD production!!
- Plots for Higgs centrality, combine fake factor.

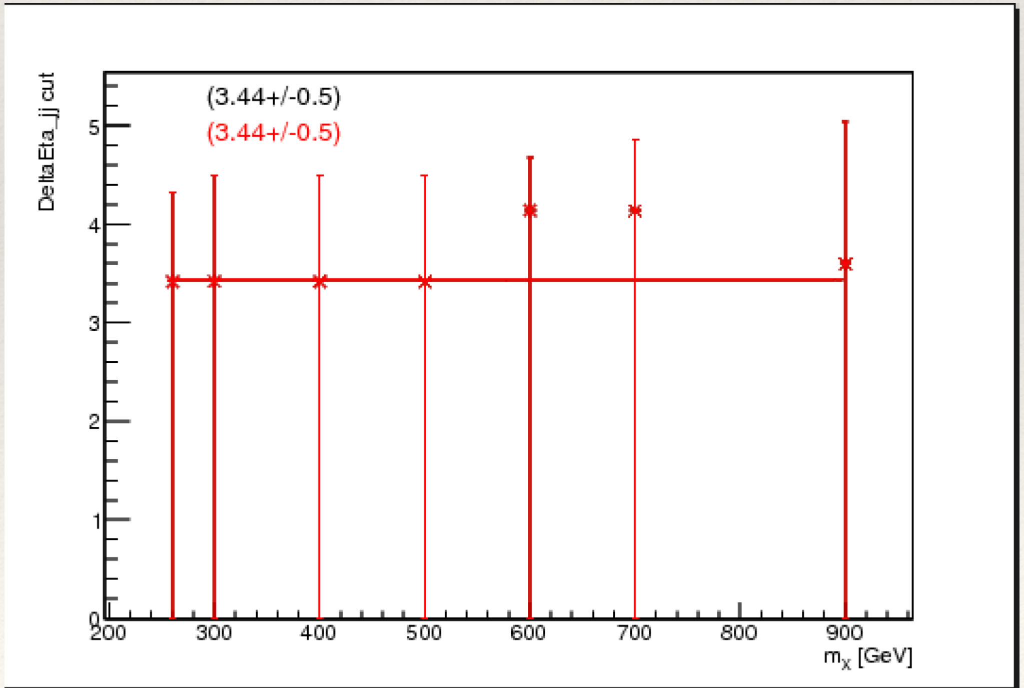
Optimisation of DeltaEta_jj cut



signal

ttbar

Optimisation of DeltaEta_jj after m_jj> 700 GeV



Optimised cut DeltaEta_jj > 3.4

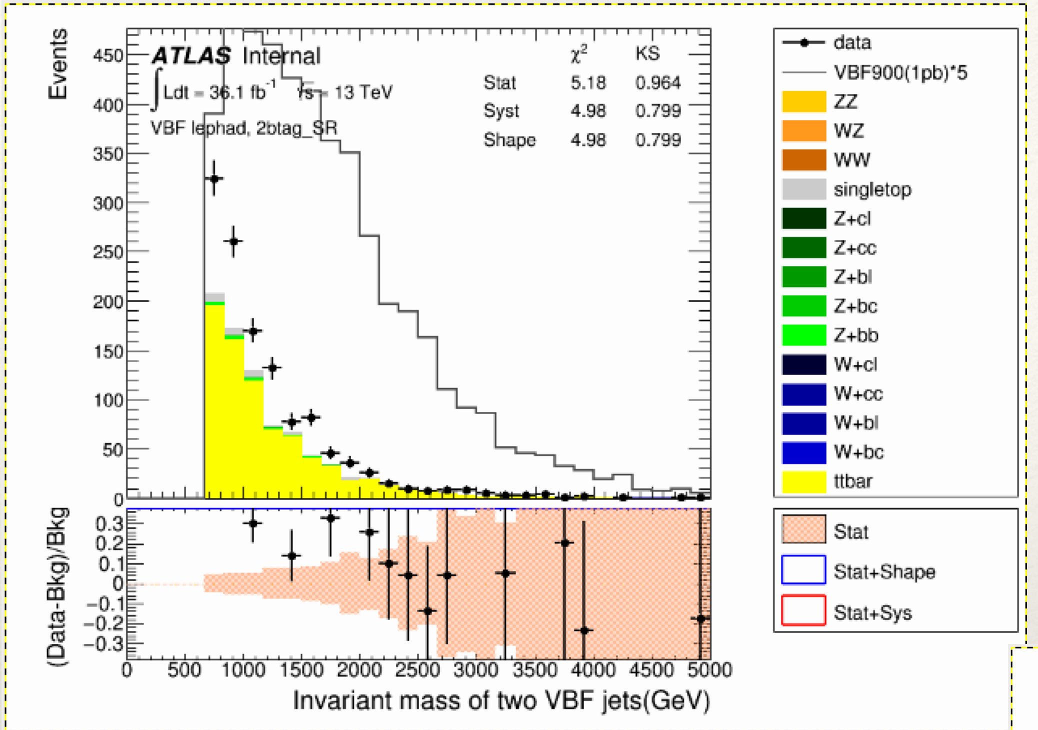
Signal Efficiency (2b -tag region)(optimised m_jj then DeltaEta_jj)

Cuts	mass260	Signal eff %(260 GeV)	w.r.t initial number	mass 900	signal eff%(900 Gev)	w.r.t initial number
Total events	17915			35336		
mc weight < 20.0	17697	98.7	98.7	35087	99.2	99.2
Trigger SLT	11510	65.03	64.24	29331	83.5	83
remove Elcluster in gap	11497	99.8	64.17	29294	99.8	82.90
tau=1, remove gap/crack	11238	97.74	62.72	29013	99.04	82.10
opposite sign	10997	97.85	61.38	28711	98.95	81.25
mmc> 60	10935	99.43	61.03	27788	96.78	78.63
VBF jet =2	7851	71.79	43.82	18564	66.80	52.53
signal jet >= 2	5992	76.31	33.44	14791	79.75	41.85
m_jj >700	3220	76.32	17.97	11461	77.48	32.43
Delta_jj> 3.4	3220	100	17.97	11210	97.80	31.72
pt on signal jets	1099	34.13	6.1	4801	42.28	13.58

Summary

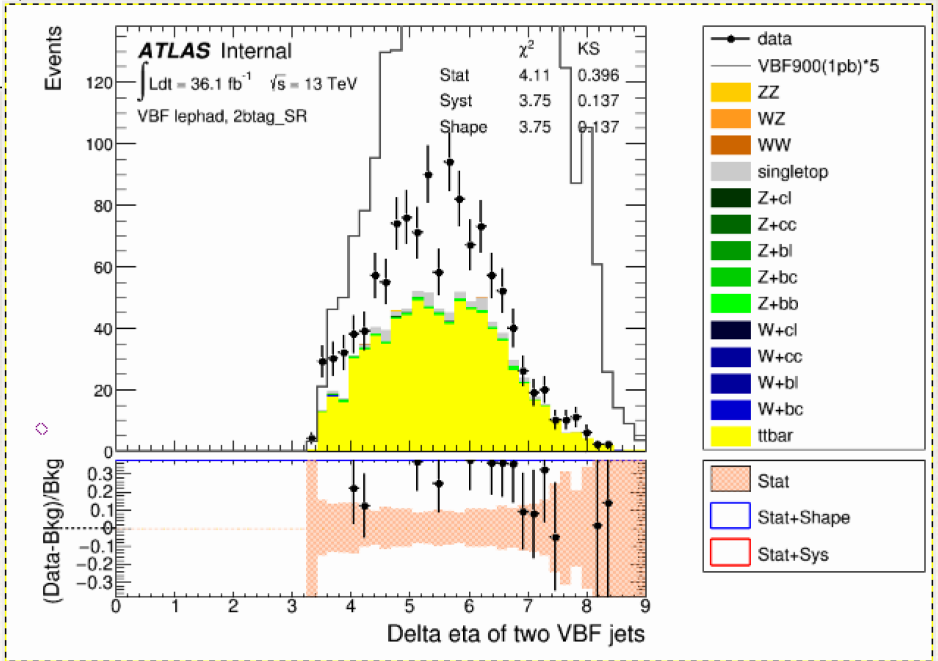
- The main motivation for these table was to see how tight the m_jj and DeltaEta_jj cuts are. m_jj has ~ 76% signal efficiency however DeltaEta_jj has no effect (~100 %) for the low mass points specially.
- We are left with 6.1% - 13 % of initial events, so I tried to remove the pt > 45 GeV constraints on the signal jets, since signal jets are less boosted than VBF jets. But it did not help anything. I checked only 900 GeV mass point. Is there any VBF analysis specific trigger available?
- The reduction of events between last two cuts are mainly due to the 2b-tag selection.

Plots

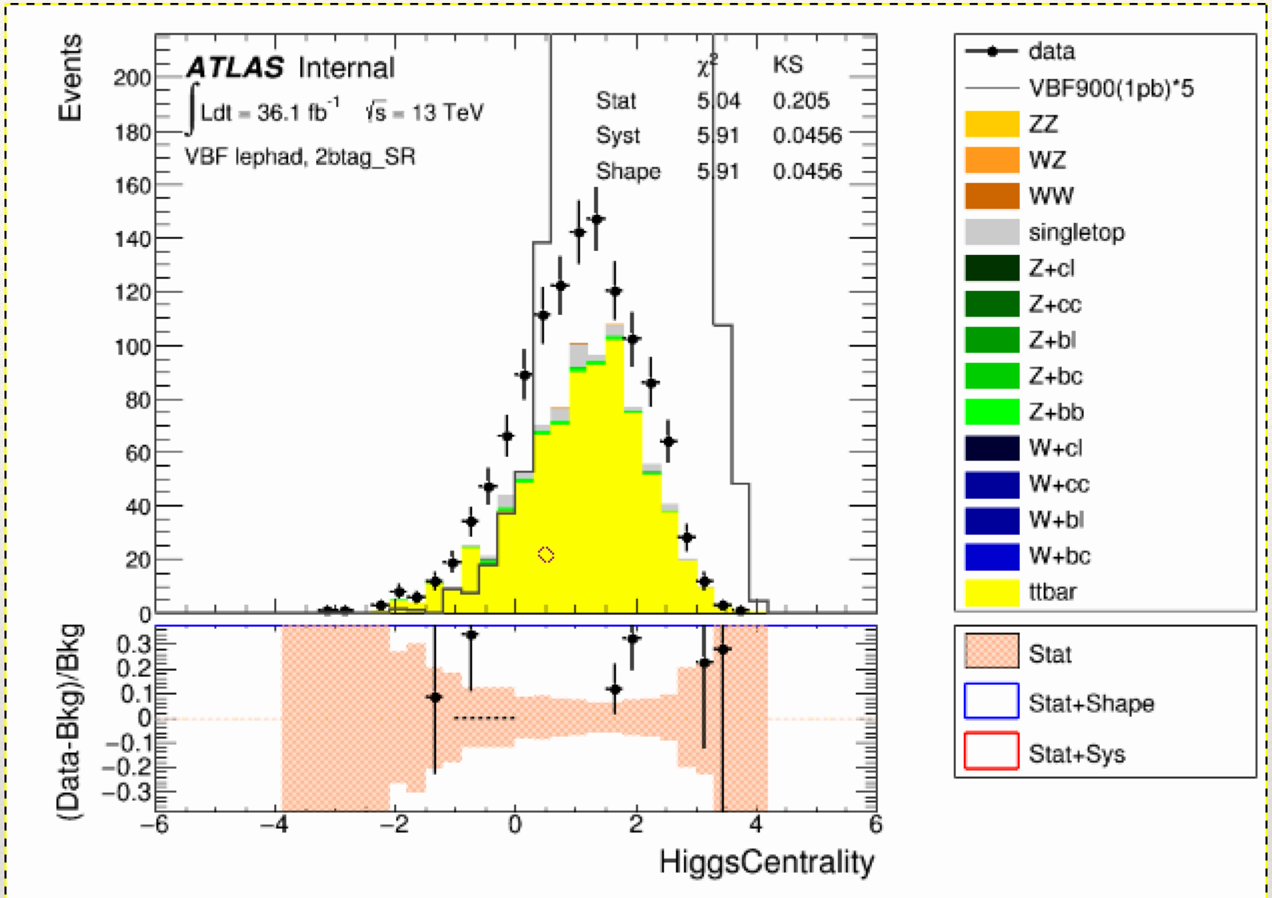


Plots after the m_jj > 700 GeV and DeltaEta_jj > 3.4

ttbar / W+jets are plotted with only true taus , fakes are separated out for the FF calculation



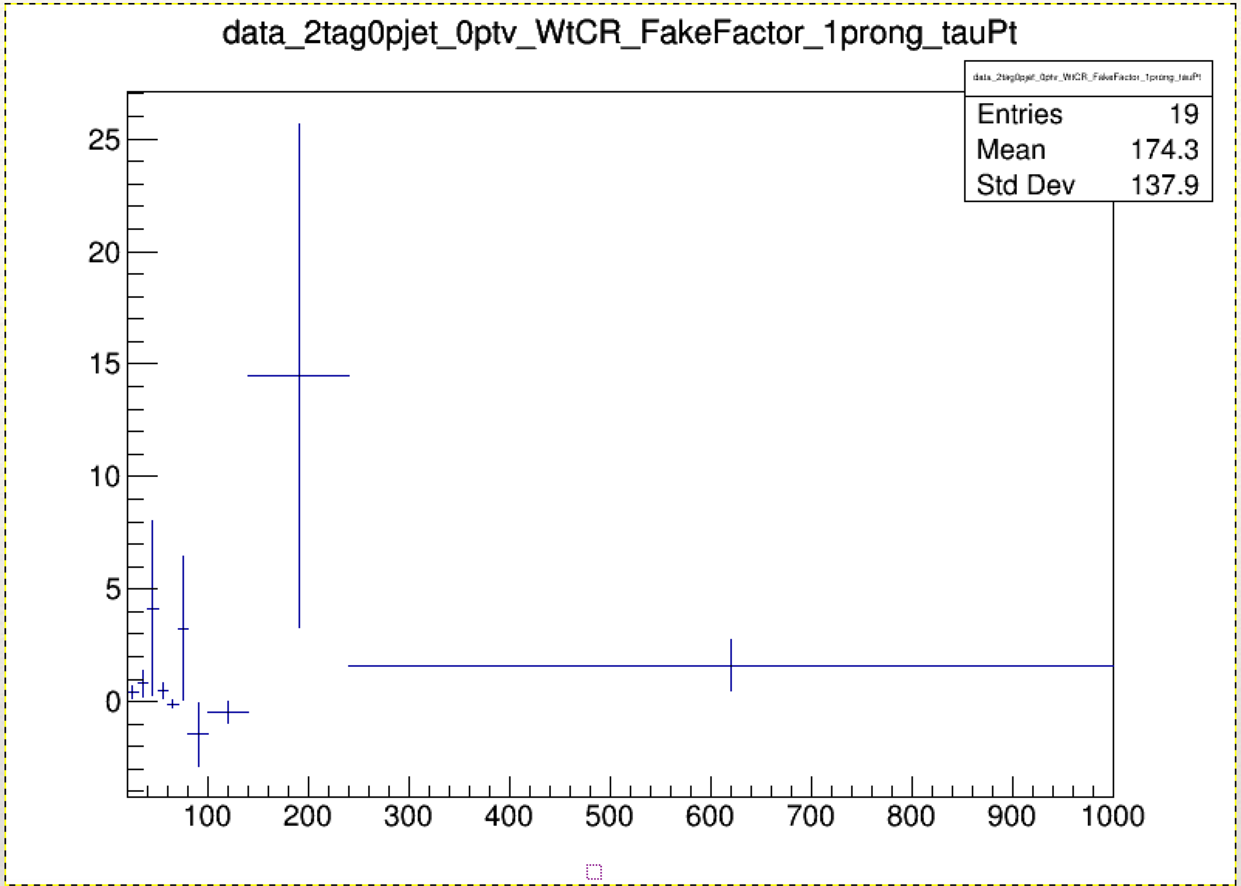
Plots



- VBF jets are ordered as , $\eta_1^{jet} \leq \eta_2^{jet}$ and SM Higgs are ordered as $\eta_1^h \leq \eta_2^h$.
- Higgs centrality : $\alpha = \min\{ \eta_1^h - \eta_1^{jet} , \eta_2^{jet} - \eta_2^h \}$

Combine Fake Factor

Combine FF
one prong



Tau pt (GeV)

Need to rebin as (20, 25, 30, 35, 40, 50, 60, 70, 120, 200). Running out of statistics in the high Pt range.

Plan and Suggestions

- Working on fake estimation. Still need few things to fix.
- Significance is calculated by:

Significance = sqrt(2 * ((Signal + Background) * log(1 + (Signal/Background)) - Signal))

Not sure if this is invariant with the scale I used for the shape comparison. Also tried to calculate the p-value using :

p-value = 1 - R.RooStats.NumberCountingUtils.BinomialExpP(-Signal, Signal+Background, 0.2*Background/(Signal+Background));

This formula needs the total Systematics uncertainty. Assuming 20% uncertainty, did not came out right, problem with the normalisation.

CUTFLOW

SAMPLE	Puja	Carl
Data	28612	28612
ttbar	57830(19495.5)	57830(19461.3)
WW	3820(1.423248)	3820(1.4128)
WZ	12655	12655
ZZ	10141	10141
Singlet_t	654(141.168)	654(141.017)
Singlet_s	153(9.68735)	153(9.67901)
Singlet_Wt	3674(968.234)	3674(967.075)
Ztautaubc	5239	5239
Wtaunubb	16	16
VBF 260	3197	
RSG260	5977	

bbtautau selection + at least two forward jets

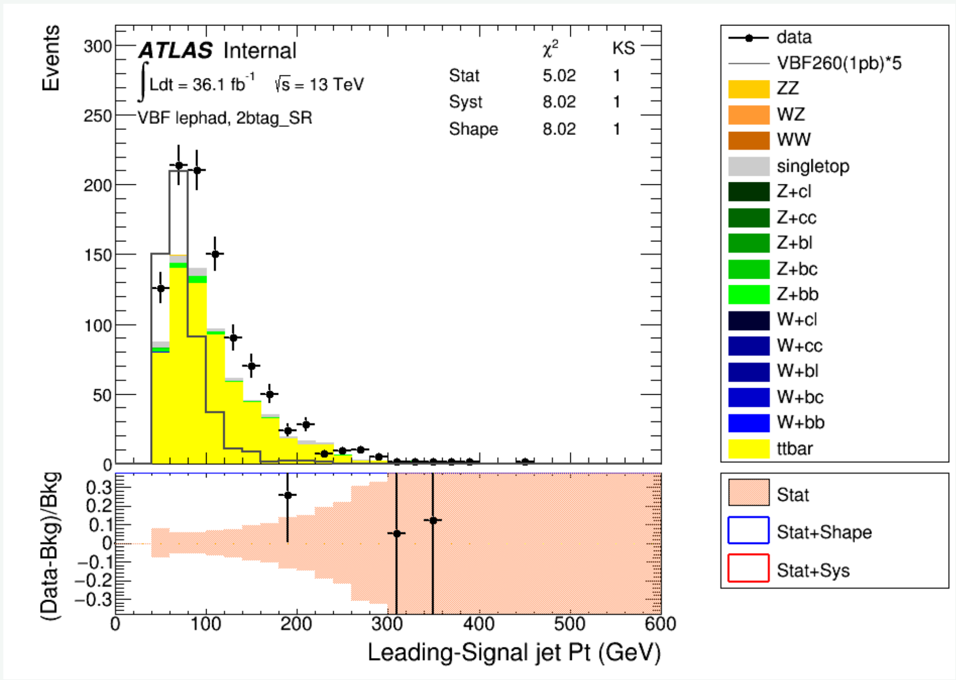
- Event with MCweight < 20.0.
- SLT trigger matched.
- Exclude 1.37 < ElCluster< 1.52, Elcluster> 2.47.
- One medium tau, pt > 20 GeV, exclude 1.37 < tauEta< 1.52.
- Rejecting jet->tau for ttbar, W+jets, QCD. (estimated from data).
- MMC(lepton+tau) > 60GeV.
- Tau and lepton opposite charge.
- jet pt > 45(20) GeV. At least two signal jets
- New: at least two forward jets. Plan is to plot VBF variables (taken from :

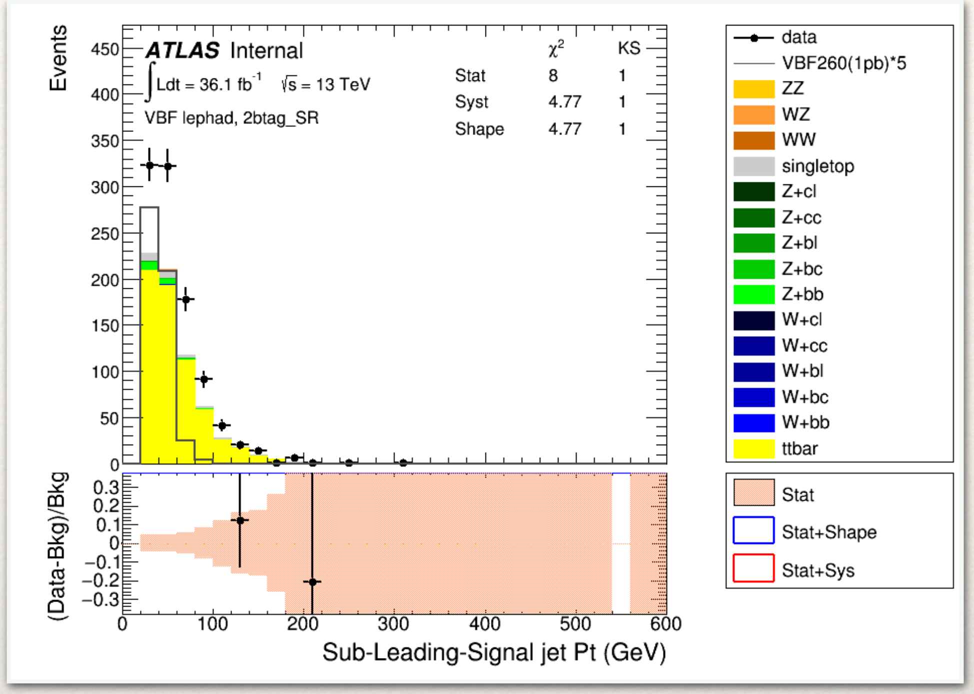
https://cds.cern.ch/record/2206135/files/ATLAS-CONF-2016-053.pdf) and decide cut on it.

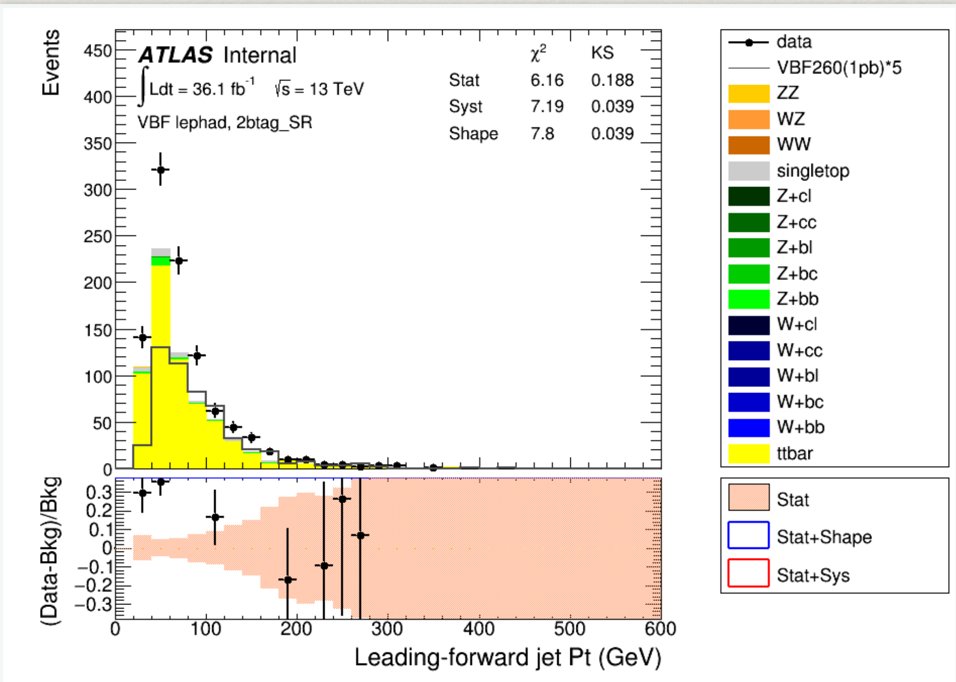
Cuts applied in VBF WW->lνlν paper

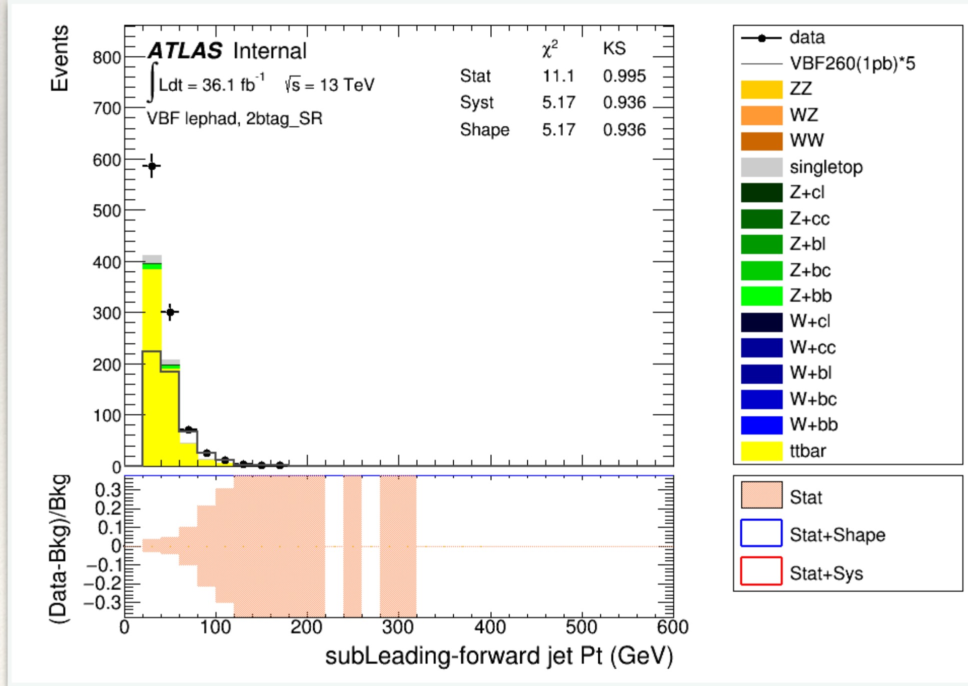
#	Selection criteria
1	event preselection requirements, see text
2	exactly two leptons with $p_{\mathrm{T}} > 25$ GeV
3	pass single lepton trigger and trigger matching
4	third lepton veto
5	dilepton mass $m_{\ell\ell} > 40$ GeV
6	$q_{\ell_1} \times q_{\ell_2} < 0$
7	$\lvert m_{\ell\ell} - m_Z \rvert > 25$ GeV in the ee and $\mu\mu$ channels
8	at least two selected jets with $p_T > 30$ (50) GeV and $\lvert\eta\rvert < 2.5$ ($2.5 < \lvert\eta\rvert < 4.5$)
9	b-jet veto
10	$E_{\mathrm{T}}^{\mathrm{miss}} > 35$ GeV
11	$m_{jj} > 500$ GeV
12	$\lvert\Delta\eta_{jj}\rvert > 2.4$
13	$\eta_{j_1} \times \eta_{j_2} < 0$
14	lepton centrality $\zeta > -0.5$
15	$f_{\mathrm{recoil}} < 2.0$

Plots with bbtautau selection + at least two forward jets in 2 b-tag category

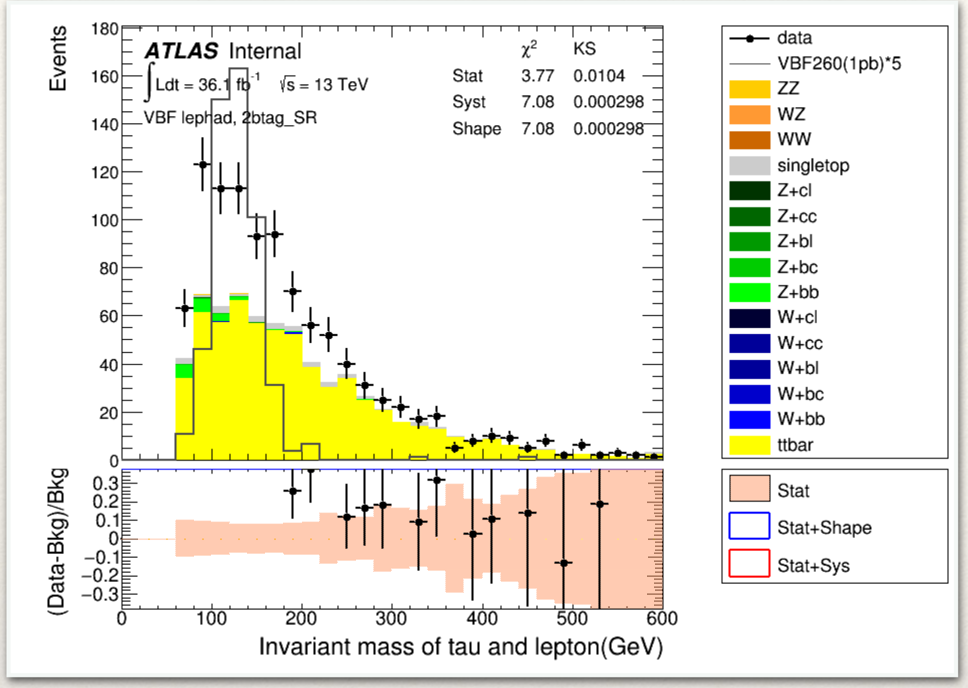


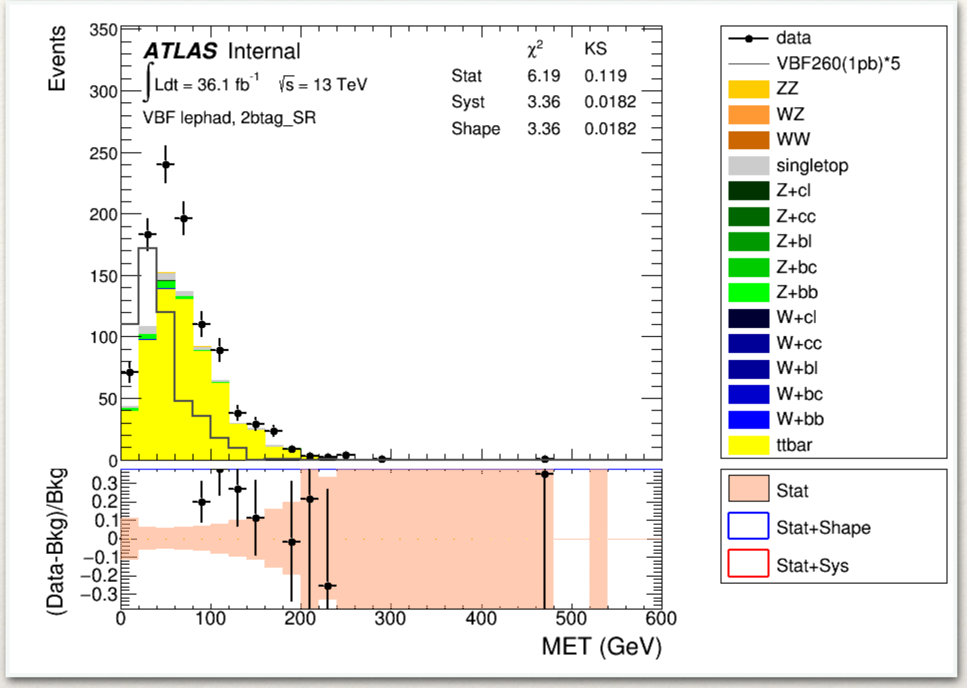


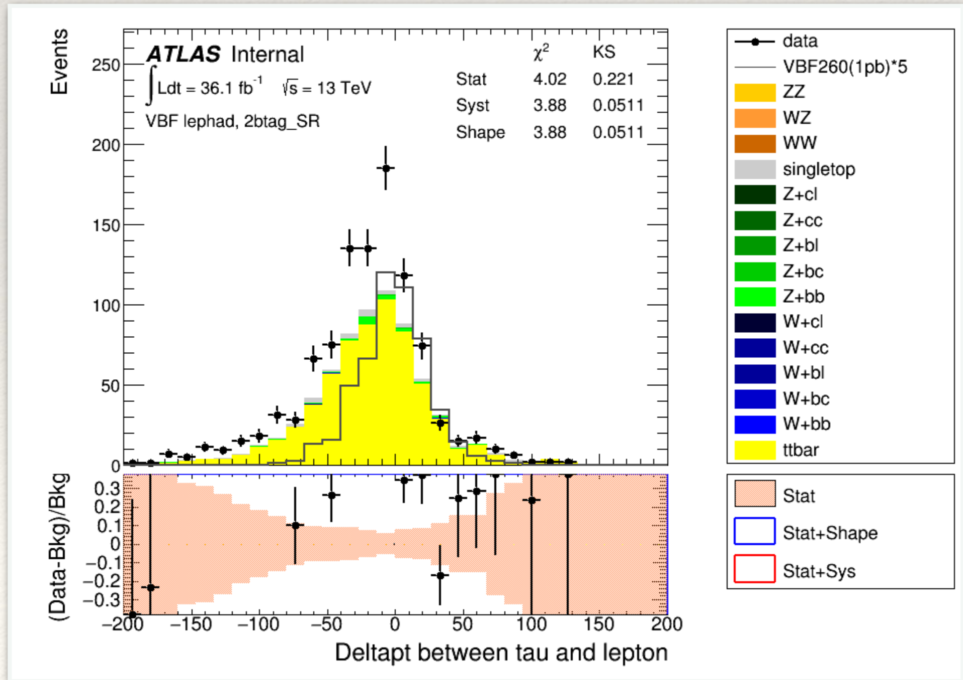


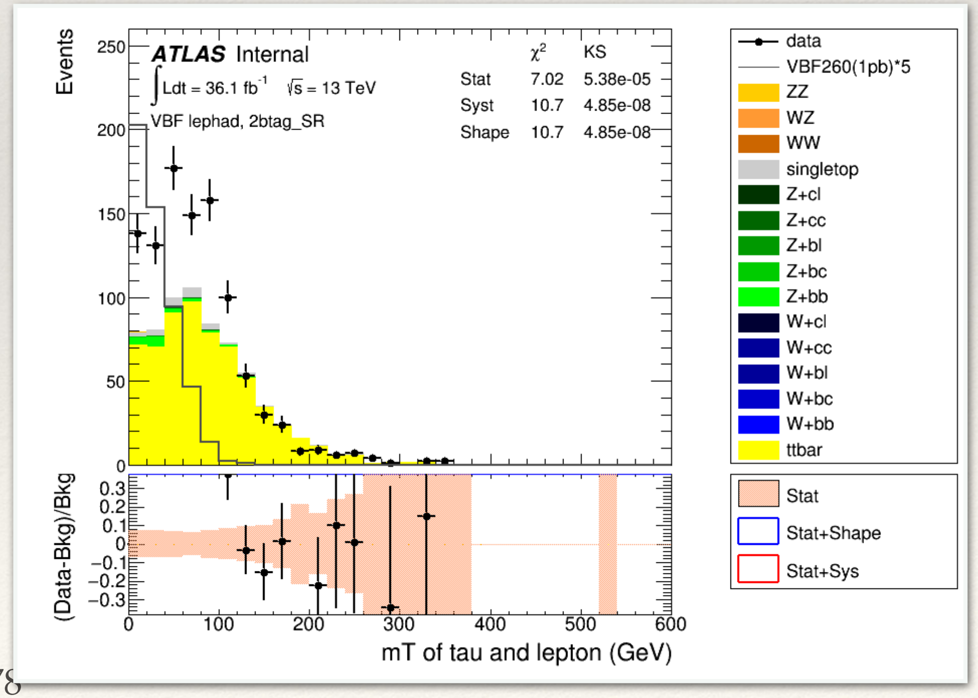


Plots with bbtautau selection + at least two forward jets in 2 b-tag category

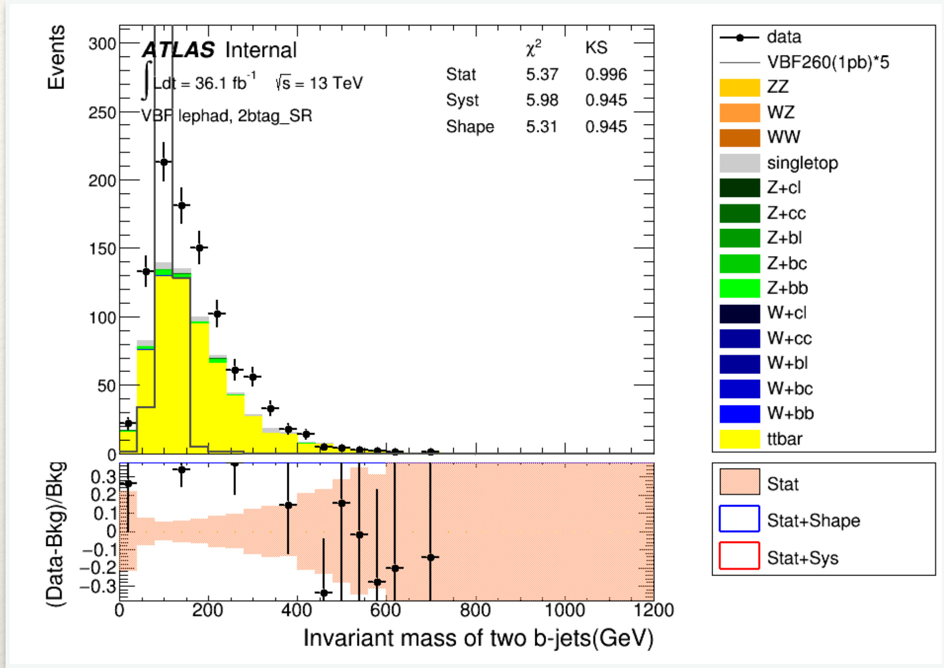


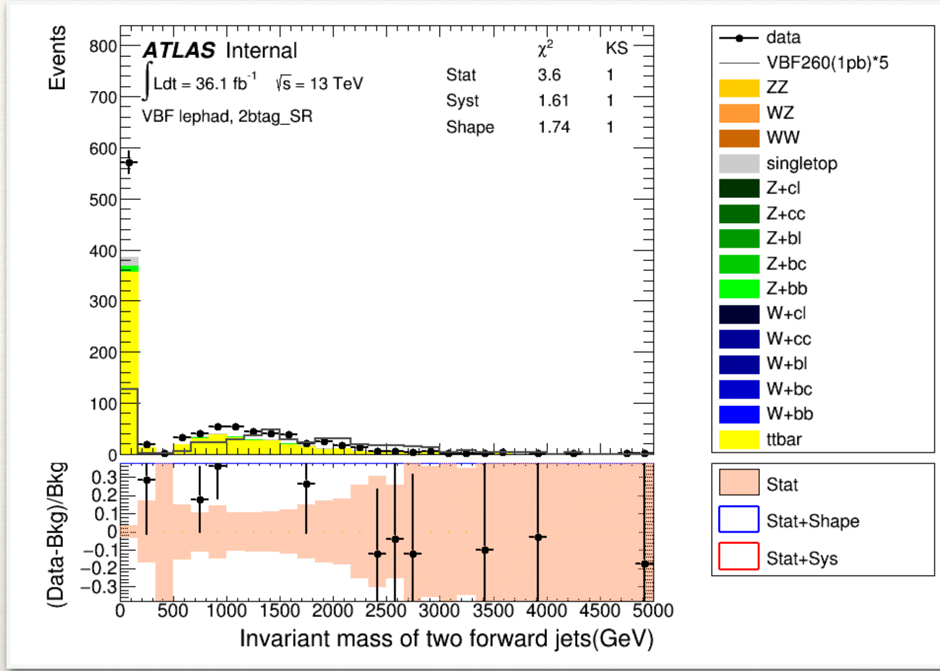


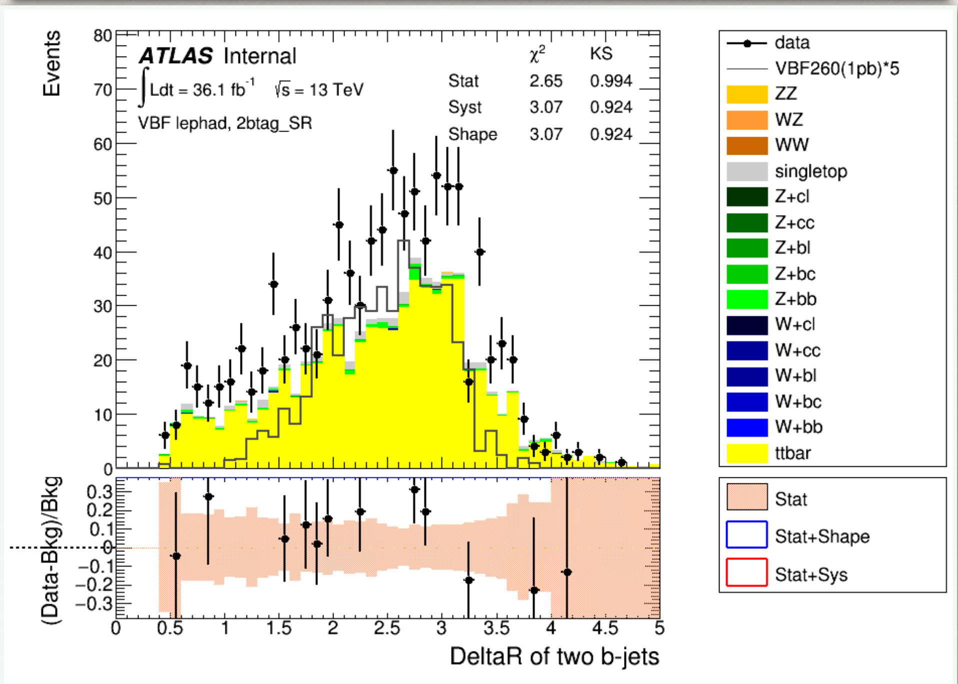


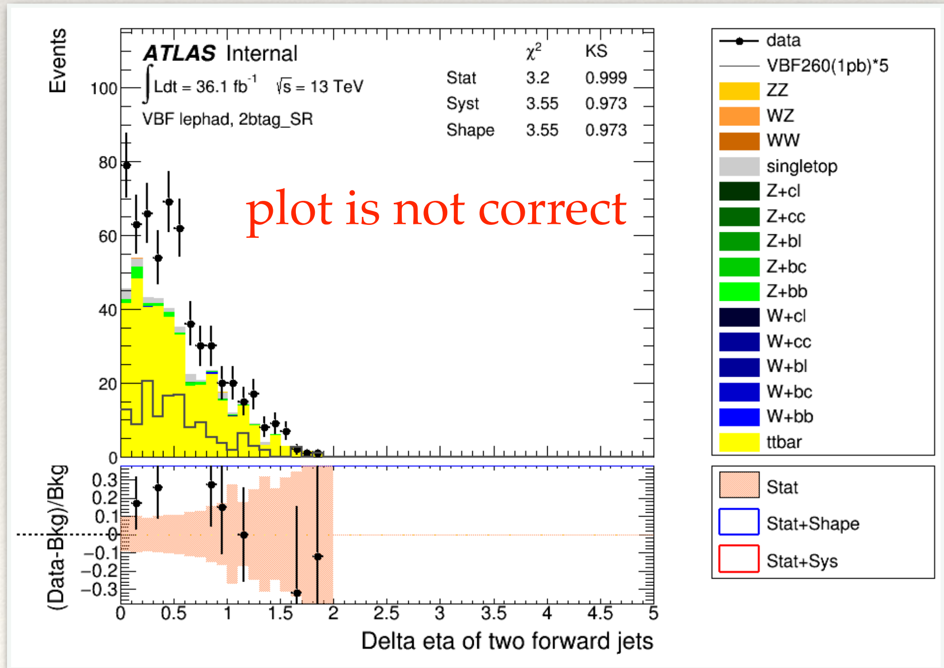


Plots with bbtautau selection + at least two forward jets in 2 b-tag category









plot is not correct