Progress Report on Tau Final States of TTTT

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Outline

Sample List

Process	Sample Name	*CrossSection*[*pb*]	notes
TTTT	TTTT_TuneCUETP8M2T4_13TeV-amcatnlo-pythia8	1.197×10^{-2}	signal
TTJets	TTJets_TuneCUETP8M2T4_13TeV-amcatnloFXFX-pythia8	7.467×10^{2}	major bg
TT	/TT_TuneCUETP8M2T4_13TeV-powheg-pythia8	*usethesameasTTJets*	
TTGJets	TTGJets_TuneCUETP8M1_13TeV-amcatnloFXFX-madspin-pythia8	3.773×10^{0}	
ttZJets	ttZJets_13TeV_madgraphMLM-pythia8	$6.559 \times 10-1$	
ttWJets	ttWJets_13TeV_madgraphMLM	2.014×10^{-1}	
ttH	ttH_4f_ctcvcp_TuneCP5_13TeV_madgraph_pythia8	3.372×10^{-1}	
ttbb	ttbb_4FS_ckm_amcatnlo_madspin_pythia8	1.393×10^{1}	overlap with TTJets,removed
WZ	WZ_TuneCUETP8M1_13TeV-pythia8	2.343×10^{1}	major
WW	WWTo2L2Nu_DoubleScattering_13TeV-pythia8	1.697×10^{-1}	
WpWpJJ	WpWpJJ_EWK-QCD_TuneCUETP8M1_13TeV-madgraph-pythia8	5.390×10^{-2}	
ZZ	ZZ_TuneCUETP8M1_13TeV-pythia8	1.016×10^{1}	
WG	WGJets_MonoPhoton_PtG-40to130_TuneCUETP8M1_13TeV-madgraph	1.269×10^{1}	xsection much smaller than TTH
ZG	ZGJetsToLLG_EW_LO_13TeV-sherpa	1.319×10^{-1}	xsection much smaller than TTH
WWW	WWW_4F_TuneCUETP8M1_13TeV-amcatnlo-pythia8	2.086×10^{-1}	
WWZ	WWZ_TuneCUETP8M1_13TeV-amcatnlo-pythia8	1.651×10^{-1}	
WWG	WWG_TuneCUETP8M1_13TeV-amcatnlo-pythia8	2.147×10^{-1}	
ZZZ	ZZZ_TuneCUETP8M1_13TeV-amcatnlo-pythia8	1.398×10^{-2}	
WZZ	WZZ_TuneCUETP8M1_13TeV-amcatnlo-pythia8	5.565×10^{-2}	

Table: 2016 MC Samples Part1

Sample List

Process	Sample Name	*CrossSection*[*pb*]	notes
WZG	WZG_TuneCUETP8M1_13TeV-amcatnlo-pythia8	4.123×10^{-2}	
WGG	WGG_5f_TuneCUETP8M1_13TeV-amcatnlo-pythia8	1.819×10^{0}	not in tth
ZGG	ZGGJets_ZToHadOrNu_5f_LO_madgraph_pythia8	3.717×10^{-1}	not in ttH
WJets	WJetsToLNu_TuneCUETP8M1_13TeV-madgraphMLM-pythia8	$5.030 \times 10^{+4}$	
DY	DYJetsToTauTau_ForcedMuEleDecay_M-50_TuneCUETP8M1_13TeV-amcatnloFXFX-pythia8_ext1	$1.983 \times 10^{+3}$	
single top	tZq_ll_4f_ckm_NLO_TuneCP5_PSweights_13TeV-amcatnlo-pythia8	7.358×10^{-2}	
	tZq_nunu_4f_13TeV-amcatnlo-pythia8_TuneCUETP8M1	0000	could't get xsection
	ST_tW_antitop_5f_inclusiveDecays_13TeV-powheg-pythia8_TuneCUETP8M2T4	$3.806 \times 10^{+1}$	
	ST_tW_top_5f_inclusiveDecays_13TeV-powheg-pythia8_TuneCUETP8M2T4	$3.809 \times 10^{+1}$	
TG	TGJets_TuneCUETP8M1_13TeV_amcatnlo_madspin_pythia8	$2.967 \times 10^{+0}$	
TH	THW_ctcvcp_HIncl_M125_TuneCP5_13TeV-madgraph-pythia8	1.467×10^{-1}	differ from TTH
	THQ_ctcvcp_Hincl_13TeV-madgraph-pythia8_TuneCUETP8M1	8.816×10^{-1}	differ from TTH
Z/W+H	VHToNonbb_M125_13TeV_amcatnloFXFX_madspin_pythia8	$2.137 \times 10^{+0}$	
	ZHToTauTau_M125_13TeV_powheg_pythia8	7.524×10^{-1}	
	ZH_HToBB_ZToLL_M125_13TeV_powheg_pythia8	7.523×10^{-2}	
ggFH	GluGluHToZZTo4L_M125_13TeV_powheg2_JHUgenV6_pythia8	$2.999 \times 10^{+1}$	
	GluGluHToBB_M125_13TeV_amcatnloFXFX_pythia8	$3.210 \times 10^{+1}$	
	GluGluHToGG_M125_13TeV_amcatnloFXFX_pythia8	$3.198 \times 10^{+1}$	
	GluGluHToMuMu_M-125_TuneCP5_PSweights_13TeV_powheg_pythia8	$2.999 \times 10^{+1}$	
	GluGluHToTauTau_M125_13TeV_powheg_pythia8	$3.052 \times 10^{+1}$	
	GluGluHToWWTo2L2Nu_M125_13TeV_powheg_JHUgen_pythia8	$3.052 \times 10^{+1}$	
	GluGluHToWWToLNuQQ_M125_13TeV_powheg_JHUGenV628_pythia8	$2.999 \times 10^{+1}$	

Table: 2016 MC Samples Part 2

Sample List

Process	Sample Name	*CrossSection*[*pb*]
VBFH	VBFHToWWToLNuQQ_M125_13TeV_powheg_JHUGenV628_pythia8	$3.769 \times 10^{+0}$
	VBFHToWWTo2L2Nu_M125_13TeV_powheg_JHUgenv628_pythia8	$3.769 \times 10^{+0}$
	VBFHToTauTau_M125_13TeV_powheg_pythia8	
	VBFHToMuMu_M-125_TuneCP5_PSweights_13TeV_powheg_pythia8	
	VBFHToGG_M125_13TeV_amcatnlo_pythia8_v2	$3.992 \times 10^{+0}$
	VBFHToBB_M-125_13TeV_powheg_pythia8_weightfix	
	VBF_HToZZTo4L_M125_13TeV_powheg2_JHUgenV6_pythia8	$3.769 \times 10^{+0}$

Table: 2016 MC Samples Part3

Object Definition

- Electron:loose fakeble tight (SS of TTTT)
  - identification
    - MVANoIso94XV2 recommended by SUSY lepton(SS used Spring16_GeneralPurpose_V1 instead)
      ▸ definiton in the backup
    - tight, VLoose, VLooseFO
    - η<|2.5|
  - isolation
    - $I_{mini} < I_1 \wedge (p_T^{ratio} > I_2 \vee p_T^{rel} > I_3)$ (same as SS of TTTT)
    - loose, medium, tight WP(tight WP kill most electrons. not used) ▸ check out backup
  - impact parameter
  - HLT emulation(need to understand this, not implemented yet)
  - charge(not implemented yet)
    - missing inner hits;conversion veto;tight charge not avalible on ntuple

electron	loose	fakeble	tight
ID	Loose	VLoose	Tight
Iso	loose	loose	loose(tight in SS)
HLT emulation	not implemented	not implemented	not implemented
d_0 (cm)	0.05	0.05	0.05
d_z (cm)	0.1	0.1	0.1
SIP_3D	-	<4	<4

Table: electron definition, blue text means different from SS

Object Definition

- Muon: loose, medium(SS of TTTT)
  - ID
    - muon POG Loose ID;muon Medium Id(use POG medium Id instead)
    - $|\eta|$<2.4
    - in my code mounsT is the medium here.
  - loose and medium WP
  - IP(not implemented,code reason)
  - quality of the charge reconstruction (not implemented)

Object Definition

- Tau: loose , fakeble, tight(ttH)
  - kinematic properties: pt>20, $|\eta|$<2.3
  - tau ID:DeepTauv2
    - the tight WP of the discriminant against jets in ttH is channel specific
    - here we adopt tight WP of 1tau1l in ttH, that is medium WP vs jets
  - overlap removal
    - the tau are required not to overlap, within $\triangle R < 0.3$, with any electron or muon passing the loose lepton selection criteria.(updated)

Object Definition

- Jet(ttH)
  - pt>25, $|\eta| < 2.4$
  - loose jet(recommended by JETMET)
  - overlap removal (updated)
    - not to overlap with fakeable electrons/muons or loose tau.
    - within the distance of 0.4 η ϕ space from a jet, the jet is removed from the analysis.
    - add jet jet overlap removal, δR is 0.4, remove the jet with lower pt(not applied)
- Forward Jet(ttH)
  - 2.4<|η|<5
  - pt>25; pt>60(2.7<|η|<3)
  - overlap removal, same as jets (updated)

Object Definition

- B Jet: loose , medium , tight
  - use Deep Flavour B tagging algorithm
  - use the recommended working points
  - overlap removal, same as jets (updated)
- Top
  - use SUSY HOT TopTagger
  - resolved

Event Selection Pre-preselection

- MET filters

filter	*appliedtoMC*	*appliedtodata*
`Flag_goodVertices`	√	√
`Flag_globalSuperTightHalo2016Filter`	√	√
`Flag_HBHENoiseFilter`	√	√
`Flag_HBHENoiseIsoFilter`	√	√
`Flag_EcalDeadCellTriggerPrimitiveFilter`	√	√
`Flag_BadPFMuonFilter`	√	√
`Flag_eeBadScFilter`	×	√

Table: MET Filters

- At least 1 loose tau
- At least 3 loose jet
- At least 1 loose b jet
- Apply no HLT yet

Subchannel Categorization

channel	subchannl	lepton	tau	Ljet	M b jet
1Tau 0L	1Tau 0L	0 tight electrons or muons	1 tight tau	>= 8	>= 2
1Tau1L	1Tau 1E	exact 1 tight electron	1 tight tau	>= 6	>= 2
	1Tau 1Mu	1 tight muon	1 tight tau	>= 6	>= 2
1Tau>=2L	1Tau 2OSL	2 tight leptons of the opposite charge	1 tight tau	>= 4	>=2
	1Tau 2SSL	2 tight leptons of the same charge	1 tight tau	>= 4	>= 2
	1Tau 3L	3 tight letons	1 tight tau	>= 2	>= 2
2Tau+anything	2Tau 0L	0 tight electrons or muons	2 tight tau	>= 6	>= 2
	2Tau 1L	exact 1 tight electron or 1 tighy moun	2 tight tau	>= 4	>= 2
	2Tau 2OSL	2 tight leptons of the opposite charge	2 tight tau	>= 2	>= 2
	2Tau 2SSL	2 tight leptons of the same charge	2 tight tau	>= 2	>= 2

Table: Subchannel difinition

- For tau, we changed the fakeble tau to tight tau for channel categorization.
- B jet is medium b jet.

Subchannel Categorization

- channel difinition from ttH

channel	lepton	tau	jet	b jet
1Tau 0L	no difinition			
1Tau1L	1 eleT or 1 muT $\|\eta\|$<2.1, pt>30(25) (within the geometric acceptance of the lepton+tau cross-trigger)	1 tau pass fakeble and medium WP of identification pt>30	>=4 pt>25,$\|\eta\|$<2.4	>= 2 bjetsL or 1 bjetM
1Tau2OSL	2 eleT or 2 muT(opposite charge,leading pt>25,subleading pt > 30(25)) $\|m_{ll} - m_Z\| < 10$	1 tauF and veryT WP of tauID	>=3 jets(pt>25,$\|\eta\|$<2.4)	>=2 bjetL or >=1 bjetM
1Tau2SSL	2 lepT (same charge, highest(lowest)pt >25(14)) (if the second highest pT lepton is a muon, the pT requirement is relaxed to pT>10) (charge of all fakeable electrons and muons to be well measured(supress ttjets)) $\|m_{ll} - m_Z\| < 10$	1 tau pass veryL id (tau chrge opposite to leptons) do not have 2 tauL passing M WP id(not overlap with 2l2tau)	>=3 jets(pt>25,$\|\eta\|$<2.4)	>=2 bjetL or >=1 bjetM
1Tau3L	3 lepT (lep pt > 20, >15, >10;charge sum = 0) $\|m_{ll} - m_Z\| < 10$	1 tau passing veryL WP	>=2 jets requirements on $E_T^{miss}LD > 30$ depending on jet	>=2 L bjets or >=1 M bjets
2Tau0L	0 lepT $\|\eta\|$<2.1, pt>30(25) veto >=1 lepT(overlap 2tau1l and 2tau 2l)	2 tauF and L WP id opposite charge(H decay); both pt>40(ttjets)	>=4 jets	>=2 L WP bjets or >=1 M WP bjets
2Tau1L	1 eleT or 1 muonT $\|\eta\|$<2.1, pt>30(25) (within the geometric acceptance of the lepton+tau cross-trigger) veto >1 leptonT (overlap with 2tau2L)	2 tau of M WP id opposite charge(H decay) higher tau pt>30(ttJets)	>=3 jets pt>25,|eta|<2.4	>=2 bjetsL or 1 bjetsM
2Tau2L	2 leptonsT first pt> 25,2nd pt > 15(10) ele(muon) veto $\|m_{ll} - m_Z\| < 10$ (ttZ)	2 tau M WP id charge sum of the two leptons and the 2 tau = zero	2 jets requirements on $E_T^{miss}LD > 30$ depending on jet	>=2 L bjet or >=1 M bjet

Table: Subchannel difinition

Variable List - - leptons

variables	notes	in ttH DNNs	in ttH BDTs
muonsL_number muonsF_number muonsT_number muonsT_1pt muonsT_1eta muonsT_3phi	loose muon,L for loose F for fakeble T for tight up to 3pt up to 3eta up tp 3phi		
elesMVAL_number elesMVAF_number elesMVAT_number	loose MVA electron		
leptonsMVAT_transMass leptonsMVAT_1pt leptonsMVAT_1eta leptonsMVAT_1phi leptonsMVAT_2pt leptonsMVAT_2eta leptonsMVAT_2phi leptonsMVAT_3pt leptonsMVAT_3eta leptonsMVAT_3phi	also for leptonsMVAF,leptonsMVAL pt of leading lepton η of leading lepton ϕ of leading lepton pt of second largest pt		

Table: variable list

Variable List - - tau

variables	notes	in ttH DNNs	in ttH BDTs
tausL_number	also for F T		
tausL_MHT	also for F T		
tausL_HT	also for F T		
tausL_invariantMass	F T		
tausL_minDeltaR	F and T		
tausF_leptonsT_transMass	tausL and tausL		
tausF_leptonsT_invariantMass	tausL and tausT		
tausF_leptonsT_chargeSum			
tausF_leptonsTMVA_minDeltaR	tausL and tausT		
tauL_1pt	up to 3pt		
tauL_1eta	up to 3eta		
tauL_1phi	up to 3phi		

Table: variable list

Variable List- - jets

variables	notes	in SS	in ttH BDTs
jetsL_number			
jetsL_MHT			
jetsL_HT			
jetsL_invariantMass			
jetsL_transMass	transeverse mass of jets ▸ definiton in the backup		
jetL_minDeltaR			
jetsL_centrality			
jetsL_bScore	b score of all jets		
jetsL_average_deltaR			
jetsL_4largestBscoreSum	sum of 4 largest b score of jets		
jetsL_leading2invariantMass		added	
jetsL_rationHT_4toRest		added	
jetsL_1pt	up to 11pt		
jetsL_1eta	up tp 11eta		
jetsL_1phi	up to 11phi		
jetsL_HTDividedByMet			
MetDividedByHT			
jetsL_MHTDividedByMet			
jetsL_leptonsMVAT_minDeltaR			
jetsL_tausF_minDeltaR			

Table: variable list

Variable List- - Bjets and Forwardjet

variables	notes	in ttH DNNs	in ttH BDTs
bjetsL_num	M and T		
bjetsL_HT	M and T		
bjetsL_MHT	M and T		
bjetsL_invariantMass	M and T		
bjetsL_transMass	M and T		
bjetsL_minDeltaR	M and T		
bjetsL_1pt	up to 4pt, also for M and T		
bjetsL_1eta	up to 4eta,also for M and T		
bjetsL_1phi	up to 4phi,also for M and T		
bjetsL_leptonsMVAT_minDeltaR	bjetsM and bjetsT		
bjetsL_tausF_minDeltaR	bjetsM and bjetsT		
forwardJets_num			
forwardjet_1pt			
forwardjet_1eta			
forwardjet_1phi			
forwardjet1_jetsL_minDeltaEta			

Table: variable list

Variable List - - Met and Top

variables	notes	in ttH DNNs	in ttH BDTs
Met_pt Met_phi			
toptagger_num toptagger_MHT toptagger_HT toptagger_invariantMass toptagger_transMass toptagger_minDeltaR_v1 toptagger_1pt toptagger_1eta toptagger_1phi toptagger_scoreAllTops toptagger_leptonsMVAT_minDeltaR	 up to 3pt up to 3eta up to 3phi		

Table: variable list

1Tau0L

- TTTT event yield in 2016

$$35.9 fb^{-1} \times 0.01197 pb = 35.9 \times 11.97 = 430 \quad (1)$$

- BR for 1Tau0L:

$$\frac{1}{9} \times \frac{2}{3} \times \frac{2}{3} \times \frac{2}{3} \times 4 = \frac{32}{243} = 0.1317 \quad (2)$$

- Event yield in 1Tau0L: 56.6

Outline

MVA Set Up (1Tau0L)

- MVA method: CutsSA, BDTA, BDTG
- 50% go to training and 50% go to test
- Signal:TTTT; background: all the major backgrounds
- Input variables: 29 most high ranking variables

Outline

1Tau0L

Figure: object removal applied

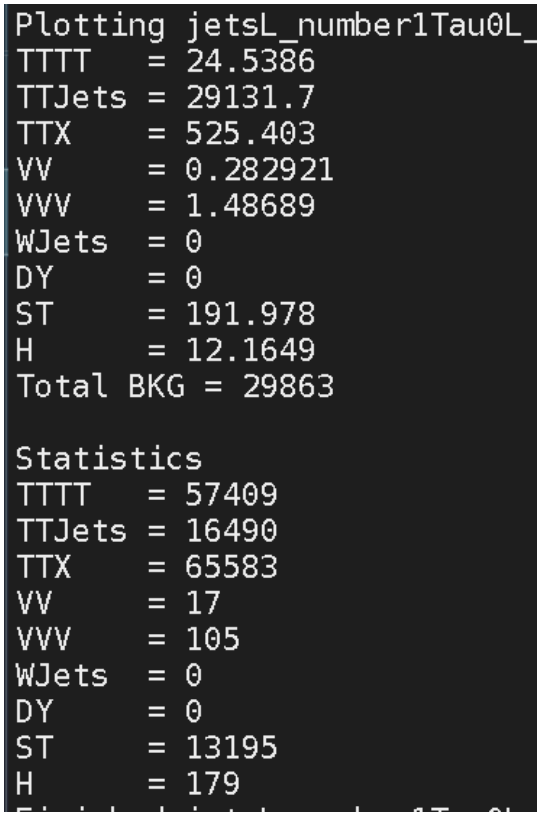
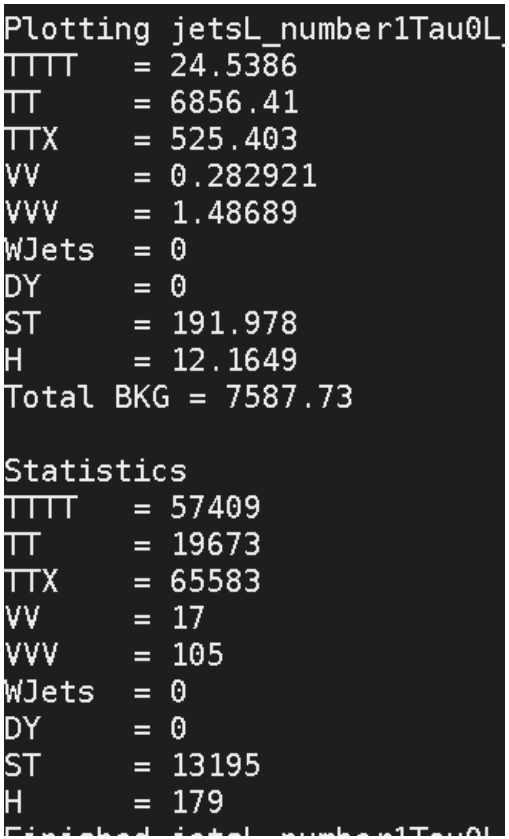


Figure: changed TTJets sample to TT



- actually here we have additional requirement that tausF = 0
- and I performed prefiring reweight here

1Tau0L

Figure: object removal applied

```
Plotting jetsL_number1Tau0L_
TTTT    = 28.6732
TT      = 7790.1
TTX     = 607.64
VV      = 0.320483
VVV     = 1.77492
WJets   = 0
DY      = 0
ST      = 224.303
H       = 13.6994
Total BKG = 8637.84

Statistics
TTTT    = 67082
TT      = 22352
TTX     = 78980
VV      = 19
VVV     = 124
WJets   = 0
DY      = 0
ST      = 16702
H       = 240
```

- remove the additonal tausF=1 requirement, and no reweighting applied.
- it seems that Zhang Yu has done pileup reweighting

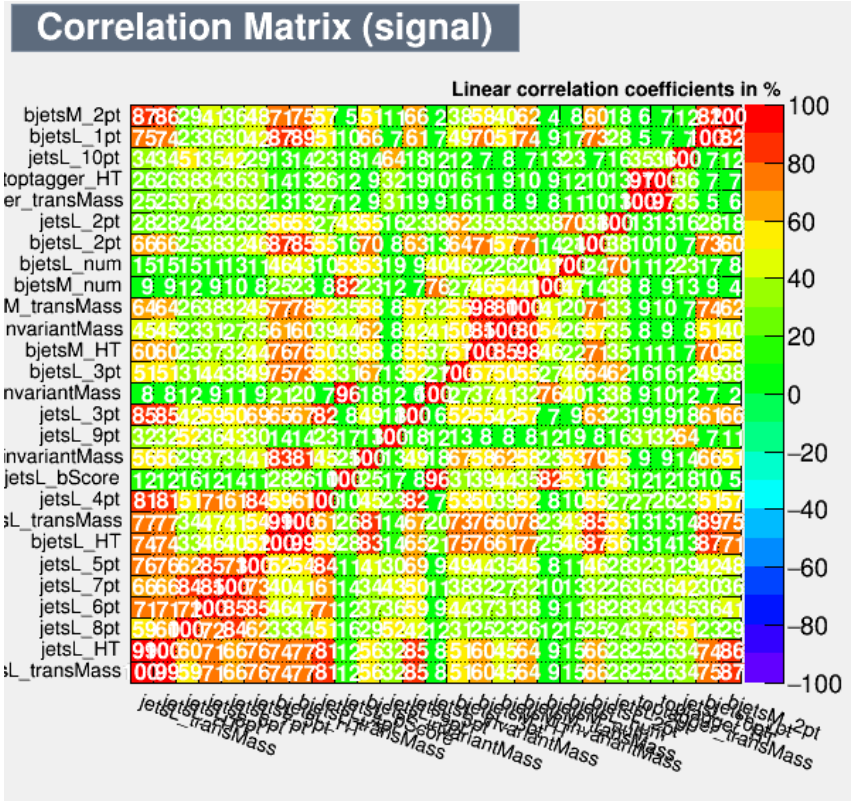
1Tau0L Separation Power

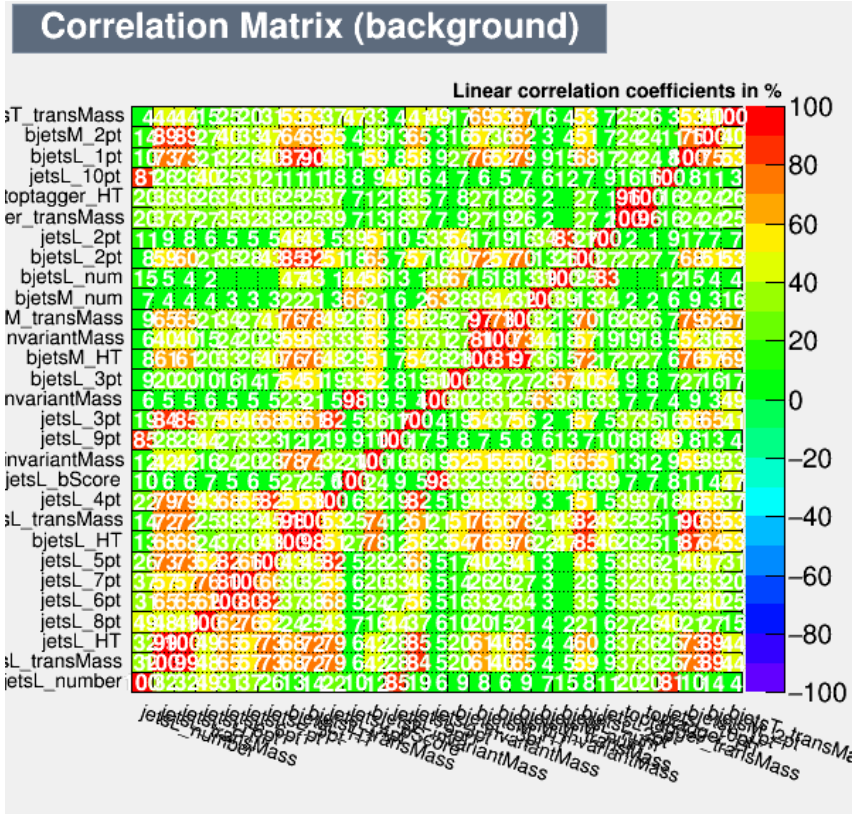
```
channel_1Tau0L_v2==1
jetsL_transMass = 0.238382
jetsL_bScore = 0.233006
jetsL_6pt = 0.231454
jetsL_HT = 0.230838
bjetsL_HT = 0.228024
bjetsL_transMass = 0.221318
jetsL_8pt = 0.22115
jetsL_4largestBscoreSum = 0.221094
jetsL_7pt = 0.217112
bjetsM_num = 0.207168
jetsL_5pt = 0.206755
jetsL_number = 0.205553
jetsL_4pt = 0.188591
bjetsL_invariantMass = 0.187422
bjetsM_invariantMass = 0.186617
bjetsM_HT = 0.183049
bjetsL_3pt = 0.175911
bjetsM_transMass = 0.17333
jetsL_3pt = 0.16676
toptagger_transMass = 0.164988
bjetsL_4pt = 0.1638
bjetsL_num = 0.162844
toptagger_HT = 0.161811
bjetsL_2pt = 0.161587
jetsL_9pt = 0.1517
jetsL_2pt = 0.136109
toptagger_invariantMass = 0.135007
jetsL_invariantMass = 0.132676
toptagger_scoreAllTops = 0.129211
bjetsT_num = 0.127409
bjetsL_1pt = 0.12609
toptagger_num = 0.121638
bjetsT_HT = 0.121194
bjetsT_transMass = 0.117652
bjetsM_2pt = 0.11717
bjetsT_invariantMass = 0.114215
bjetsT_4pt = 0.113286
jetsL_1pt = 0.11207
```

MVA Input Variable Properties (1Tau0L)

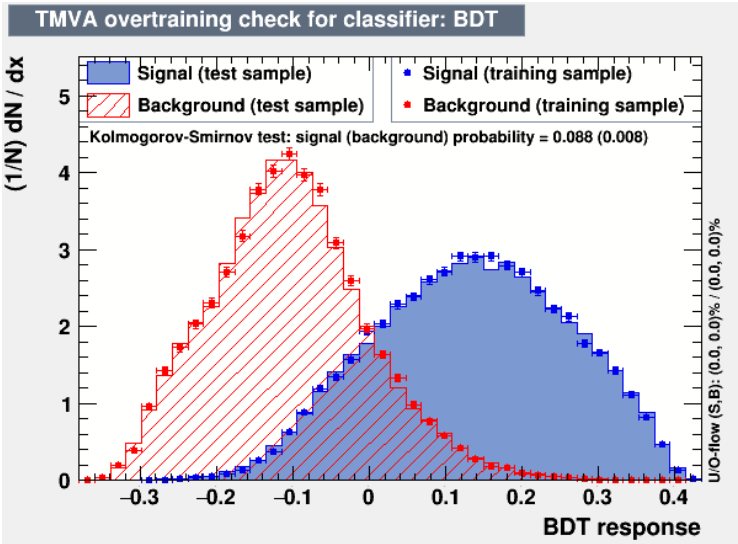
Rank	Variable	Separation
1	jetsL_9pt	3.409e-01
2	jetsL_8pt	3.359e-01
3	jetsL_number	3.334e-01
4	jetsL_7pt	3.324e-01
5	jetsL_transMass	3.267e-01
6	jetsL_HT	3.221e-01
7	jetsL_6pt	3.177e-01
8	jetsL_5pt	2.968e-01
9	jetsL_10pt	2.855e-01
10	bjetsL_HT	2.778e-01
11	bjetsL_transMass	2.719e-01
12	jetsL_4pt	2.659e-01
13	jetsL_bScore	2.617e-01
14	bjetsL_3pt	2.457e-01
15	jetsL_2pt	2.362e-01
16	bjetsL_invariantMass	2.330e-01
17	jetsL_3pt	2.323e-01
18	jetsL_invariantMass	2.296e-01
19	bjetsM_HT	2.151e-01
20	bjetsM_transMass	2.095e-01
21	bjetsM_invariantMass	2.090e-01
22	bjetsM_num	2.087e-01
23	bjetsL_num	2.000e-01
24	bjetsL_2pt	1.952e-01
25	toptagger_transMass	1.717e-01
26	toptagger_HT	1.659e-01
27	bjetsL_1pt	1.583e-01
28	bjetsM_2pt	1.527e-01
29	bjetsT_transMass	1.383e-01

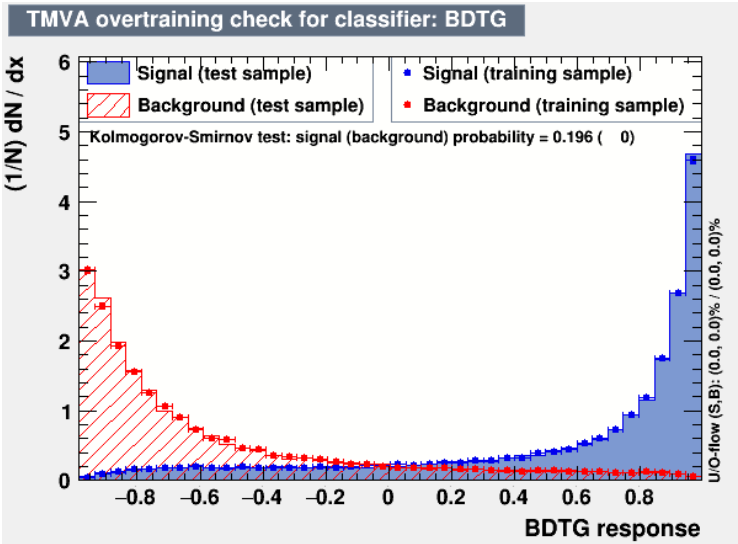
MVA Input Variable Properties (1Tau0L)





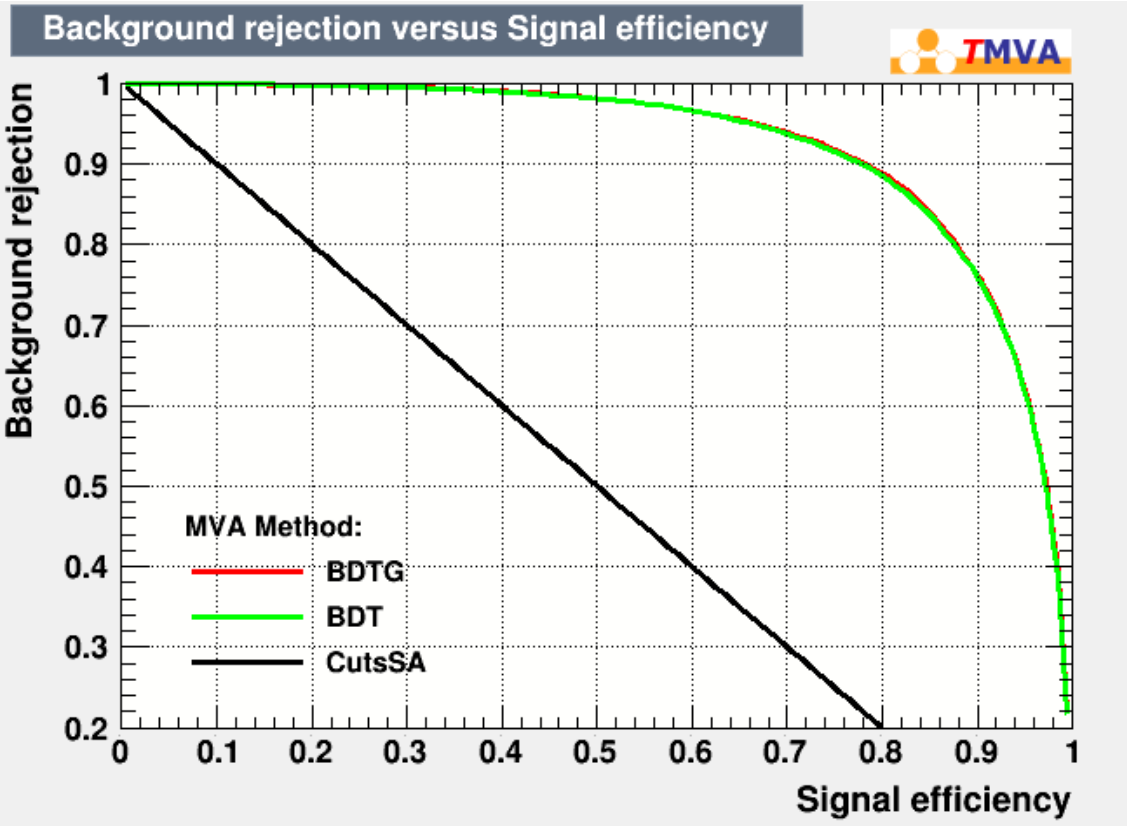
BDT Output (1Tau0L)





- No sign of over training

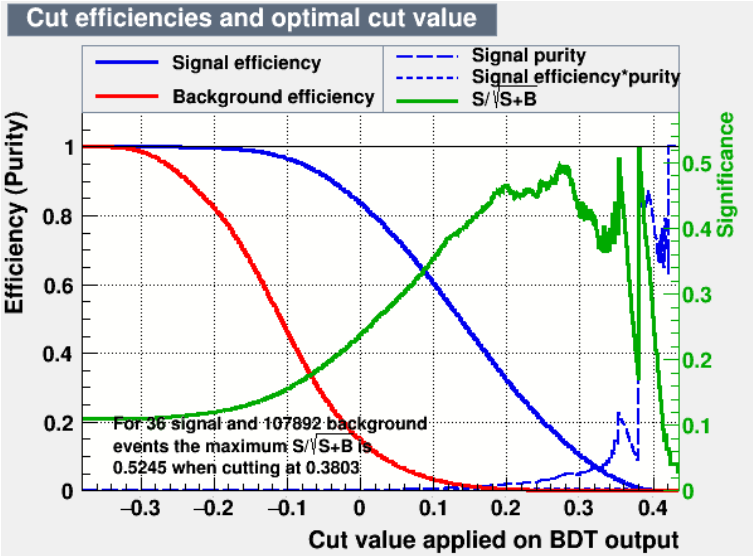
ROC Curve (1Tau0L)

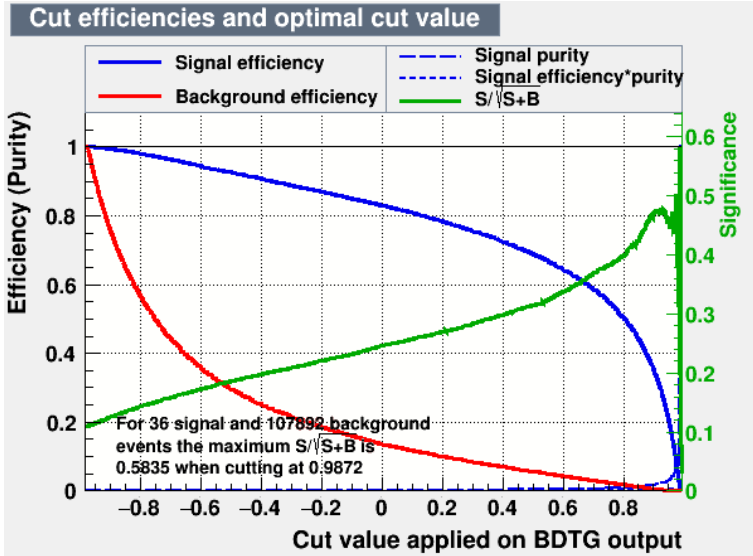


Optimal Cut (1Tau0L)

```
Classifier   (  #signal, #backgr.)  Optimal-cut  S/sqrt(B)      NSig      NBkg   EffSig   EffBkg
--------------------------------------------------------------------------------------------------
    CutsSA:  (       36,    107892)       0.1750   (   0.365  +- 0.146)   6.30574  298.0276   0.1752 0.002762
      BDTG:  (       36,    107892)       0.9872   (    1.58  +-  5.13)  0.3943755  0.06243509  0.01095 5.787e-07
       BDT:  (       36,    107892)       0.3809   (    1.35  +-  5.13)  0.3184028  0.05528086 0.008845 5.124e-07
--------------------------------------------------------------------------------------------------
t [1] --- ================================================================================================
Classifier   (  #signal, #backgr.)  Optimal-cut  S/sqrt(S+B)      NSig      NBkg   EffSig   EffBkg
--------------------------------------------------------------------------------------------------
    CutsSA:  (       36,    107892)       0.1750     0.361461   6.30574  298.0276   0.1752 0.002762
      BDTG:  (       36,    107892)       0.9872     0.583501  0.3943755  0.06243509  0.01095 5.787e-07
       BDT:  (       36,    107892)       0.3803     0.524462  0.3312072  0.06760853   0.0092 6.266e-07
--------------------------------------------------------------------------------------------------
```

Optimal Cut (1Tau0L)





Outline

Step 2

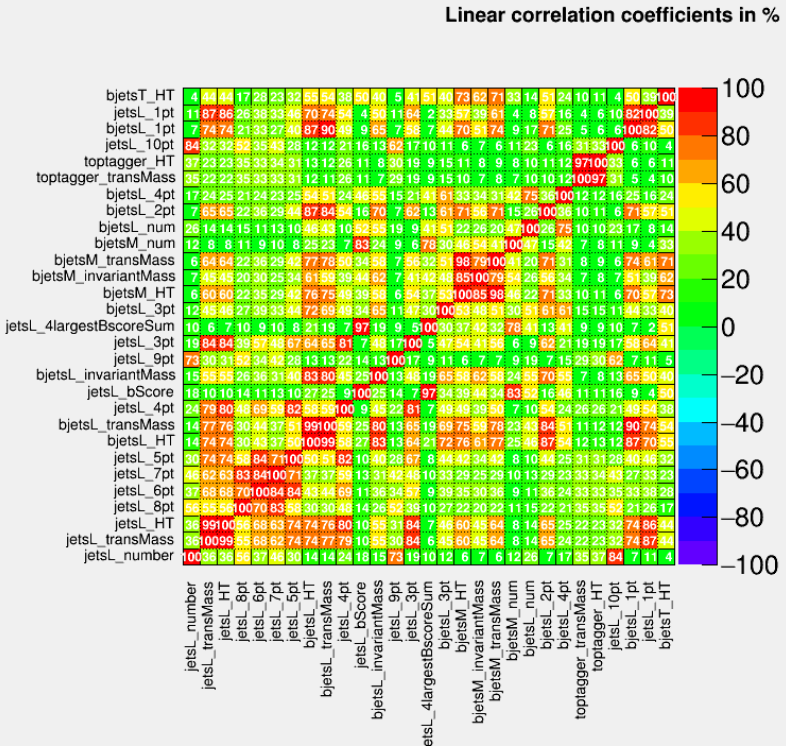
- Add object removal for jet and tau
- Everything else the same

Input Variable Ranking

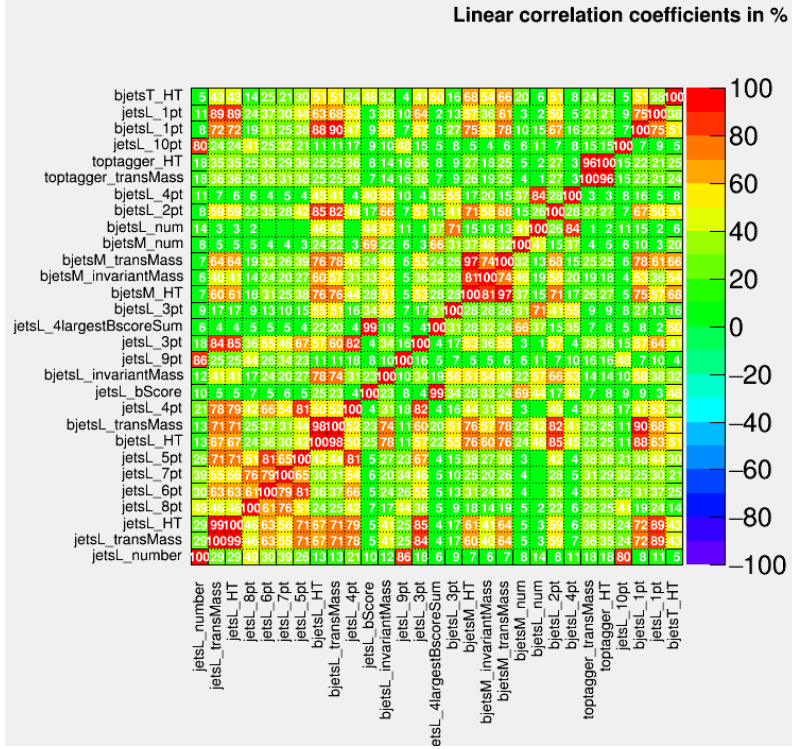
Rank	Variable	Separation
1	jetsL_bScore	2.453e-01
2	jetsL_7pt	2.441e-01
3	jetsL_8pt	2.358e-01
4	jetsL_6pt	2.339e-01
5	jetsL_transMass	2.329e-01
6	jetsL_4largestBscoreSum	2.265e-01
7	bjetsL_HT	2.265e-01
8	jetsL_HT	2.252e-01
9	bjetsL_transMass	2.192e-01
10	jetsL_5pt	2.174e-01
11	bjetsL_3pt	2.138e-01
12	jetsL_9pt	2.112e-01
13	bjetsM_num	2.110e-01
14	jetsL_number	2.052e-01
15	bjetsL_4pt	2.003e-01
16	jetsL_4pt	1.906e-01
17	bjetsM_invariantMass	1.877e-01
18	bjetsL_invariantMass	1.862e-01
19	bjetsM_HT	1.832e-01
20	bjetsM_transMass	1.711e-01
21	jetsL_3pt	1.645e-01
22	bjetsL_num	1.640e-01
23	toptagger_transMass	1.633e-01
24	jetsL_10pt	1.624e-01
25	bjetsL_2pt	1.613e-01
26	toptagger_HT	1.609e-01
27	bjetsL_1pt	1.226e-01
28	bjetsT_HT	1.218e-01
29	jetsL_1pt	1.054e-01

Correlation (1Tau0L)

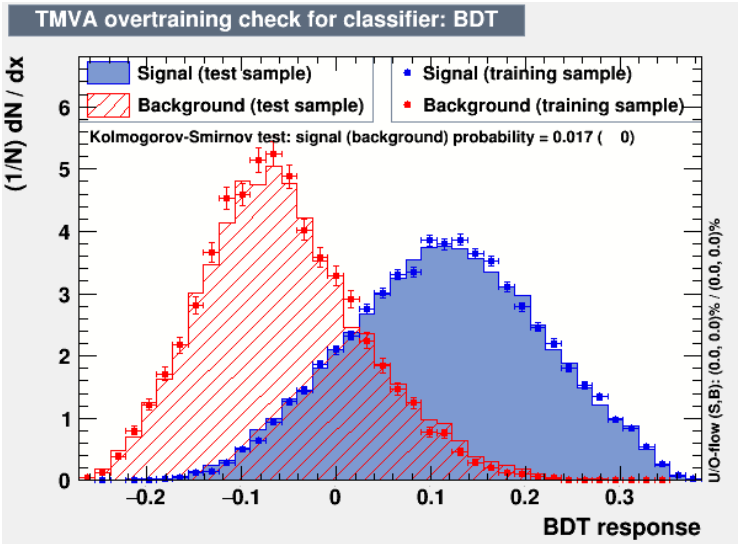
Correlation Matrix (signal)

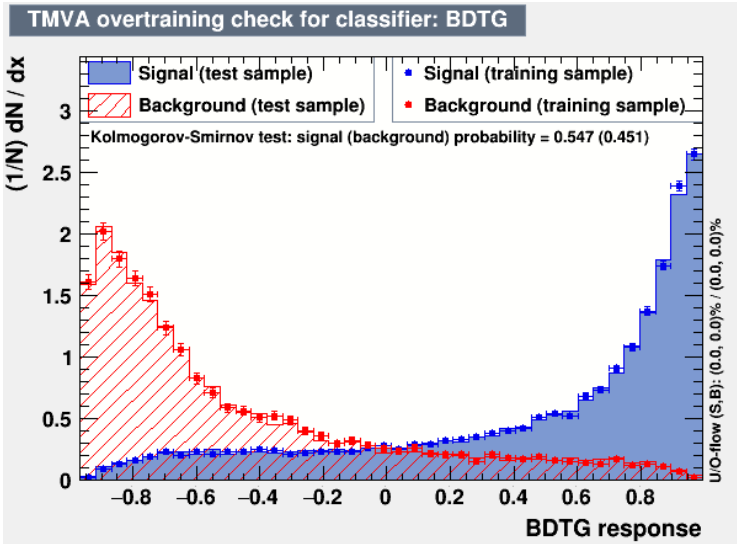


Correlation Matrix (background)



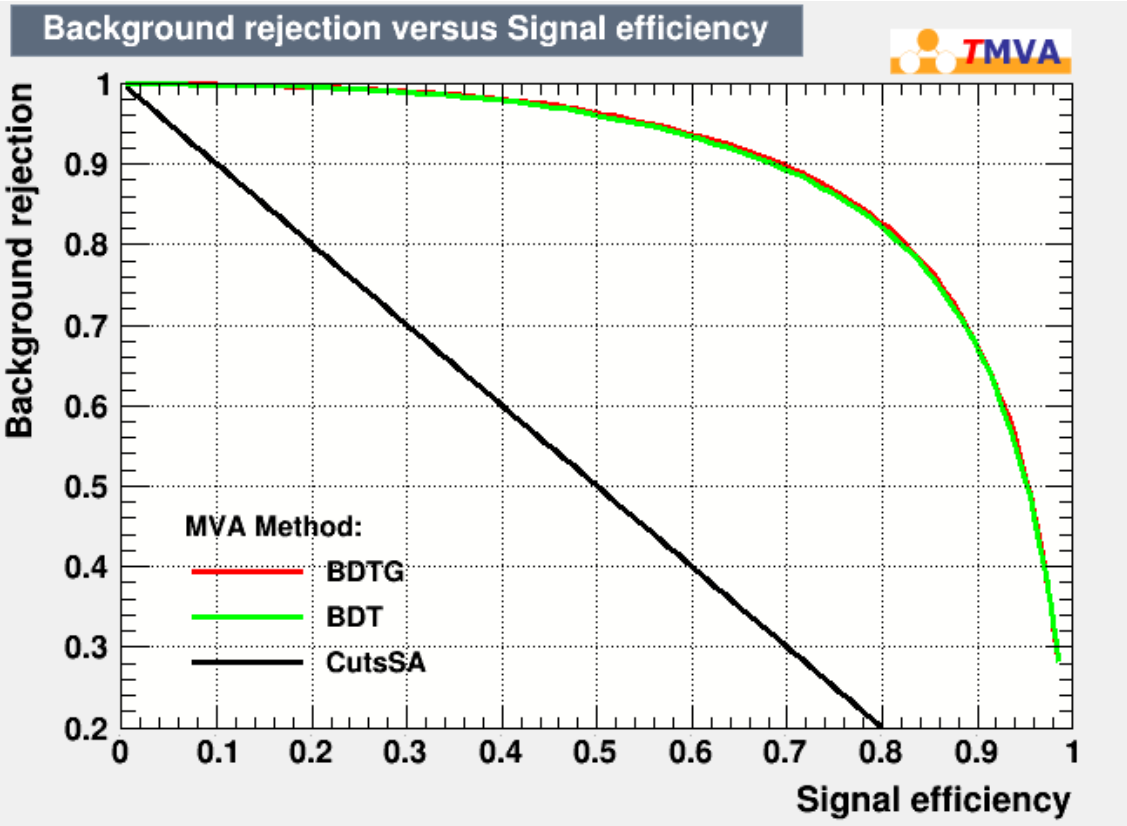
BDT Output (1Tau0L)





- No sign of over training

ROC Curve (1Tau0L)

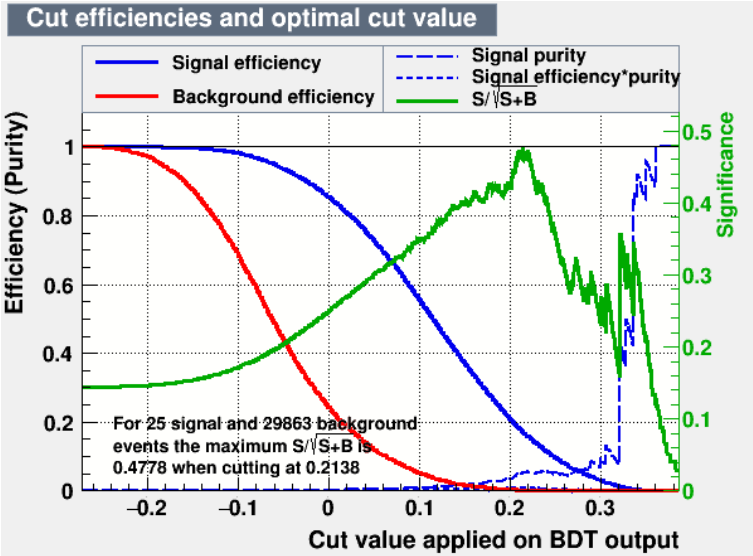


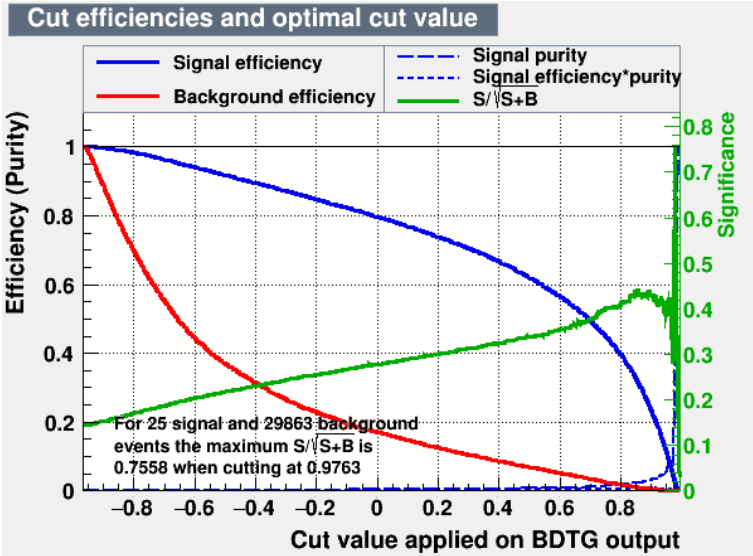
Optimal Cut (1Tau0L)

Classifier	(#signal, #backgr.)	Optimal-cut	S/sqrt(B)	NSig	NBkg	EffSig	EffBkg
CutsSA:	(24.530001,29131.699)	0.0150	(0.509 +- 1.16)	0.2828676	0.3087628	0.01153	1.06e-05
BDTG:	(24.530001,29131.699)	0.9763	(1.32 +- 2.08)	0.8280926	0.3929825	0.03376	1.349e-05
BDT:	(24.530001,29131.699)	0.3404	(1.08 +- 2.08)	0.1016956	0.008839019	0.004146	3.034e-07

- Signal efficiency very low for BDTA and BDTG, why? What can we do about it?
  - ~~maybe aplly a tighter cut for this channel? Like b jets number >= 3?~~
  - try make signal and bg events to be same in training stage
- TTJets event yield is 5 times larger than ZhangYu's result

Optimal Cut (1Tau0L)





Outline

Step3

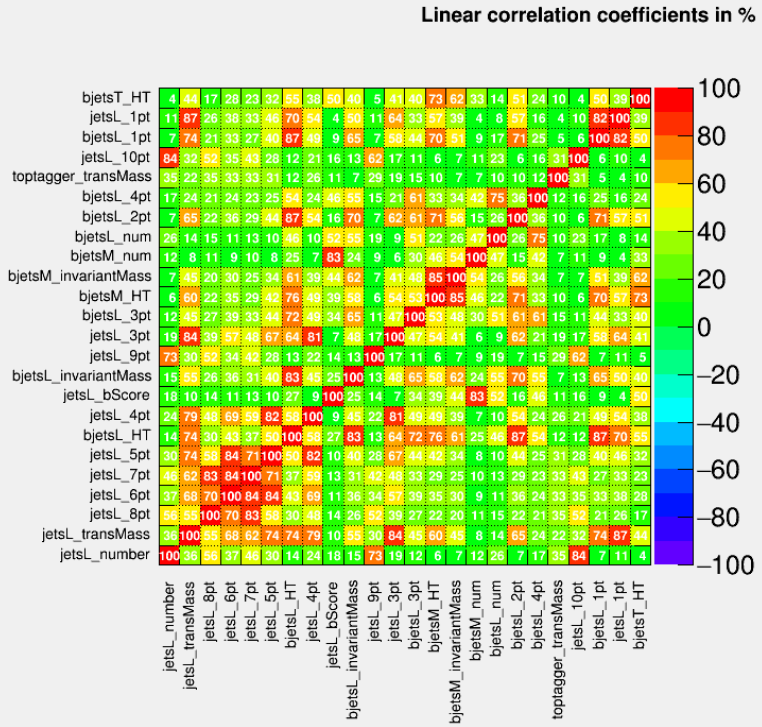
- Object removal
- Removal variables with high correlation, correlation >= 90, only look at signal here
  - jetsL_HT and jets_transMass, remove jetsL_HT
  - bjetsL_transMass and bjetsL_HT , remove bjetsL_transMass
  - jetsL_4largestBscoreSum and jetsL_bscore, remove jetsL_4largestBscoreSum
  - bjetsM_transMass and bjetsM_HT, remove bjetsM_transMass
  - toptagger_HT and toptagger_transMass, remove toptagger_HT

MVA Input Variable Properties (1Tau0L)

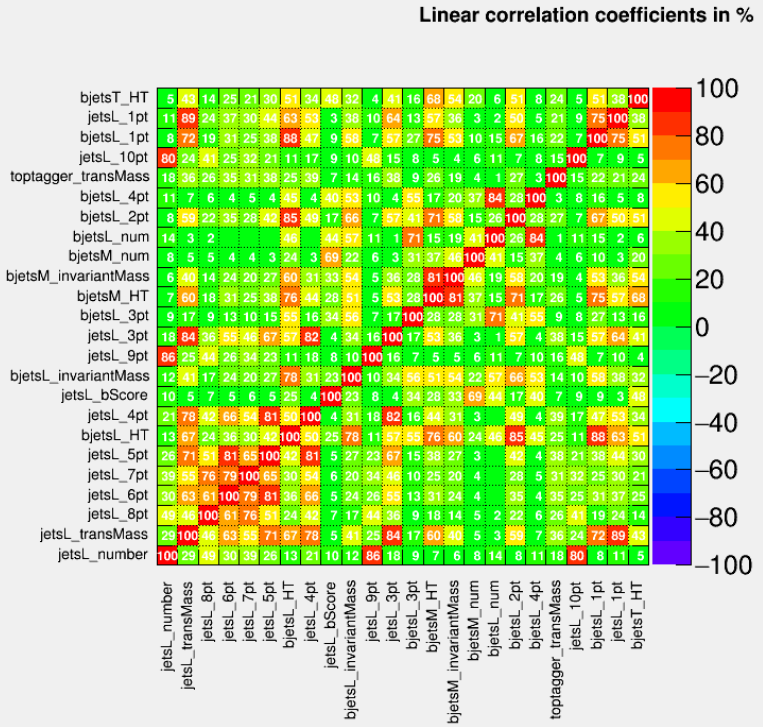
Rank	Variable	Separation
1	jetsL_bScore	2.453e-01
2	jetsL_7pt	2.441e-01
3	jetsL_8pt	2.358e-01
4	jetsL_6pt	2.339e-01
5	jetsL_transMass	2.329e-01
6	bjetsL_HT	2.265e-01
7	jetsL_5pt	2.174e-01
8	bjetsL_3pt	2.138e-01
9	jetsL_9pt	2.112e-01
10	bjetsM_num	2.110e-01
11	jetsL_number	2.052e-01
12	bjetsL_4pt	2.003e-01
13	jetsL_4pt	1.906e-01
14	bjetsM_invariantMass	1.877e-01
15	bjetsL_invariantMass	1.862e-01
16	bjetsM_HT	1.832e-01
17	jetsL_3pt	1.645e-01
18	bjetsL_num	1.640e-01
19	toptagger_transMass	1.633e-01
20	jetsL_10pt	1.624e-01
21	bjetsL_2pt	1.613e-01
22	bjetsL_1pt	1.226e-01
23	bjetsT_HT	1.218e-01
24	jetsL_1pt	1.054e-01

Correlation (1Tau0L)

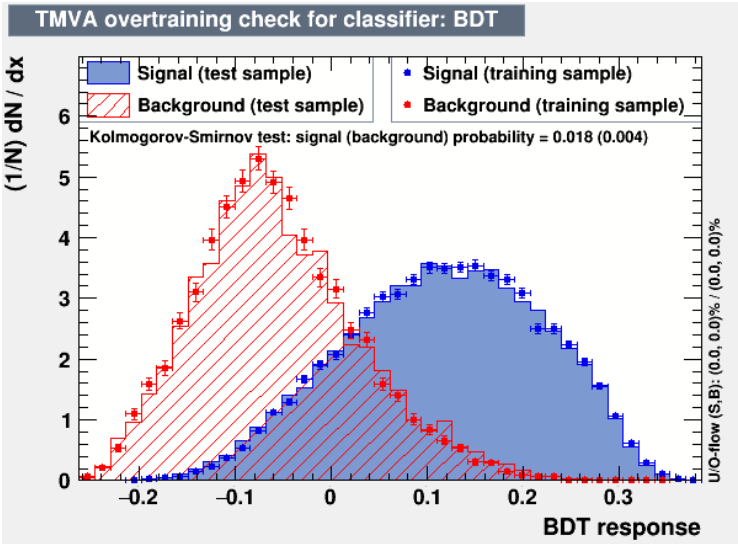
Correlation Matrix (signal)

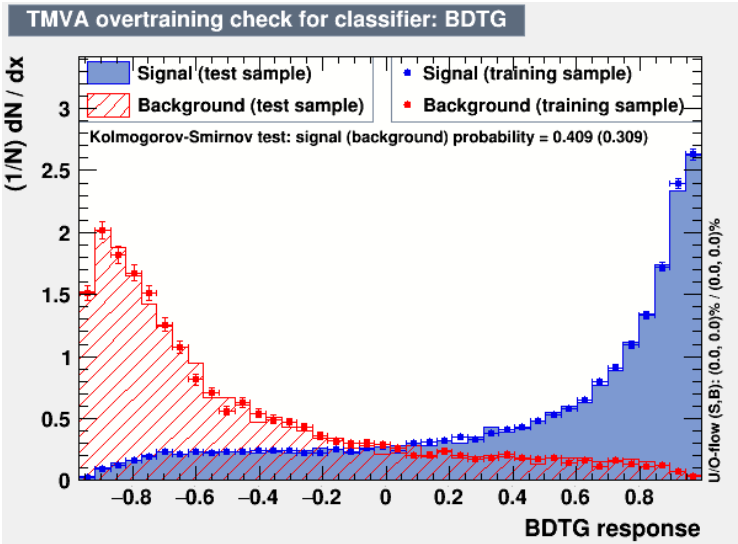


Correlation Matrix (background)



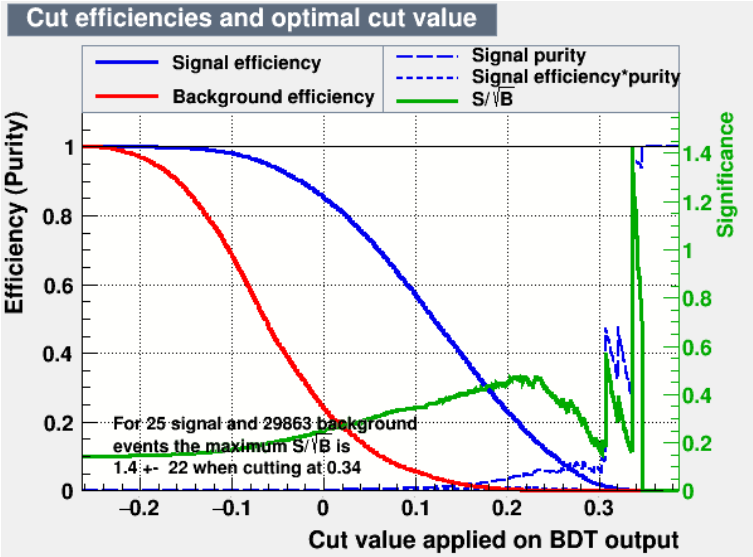
BDT Output (1Tau0L)

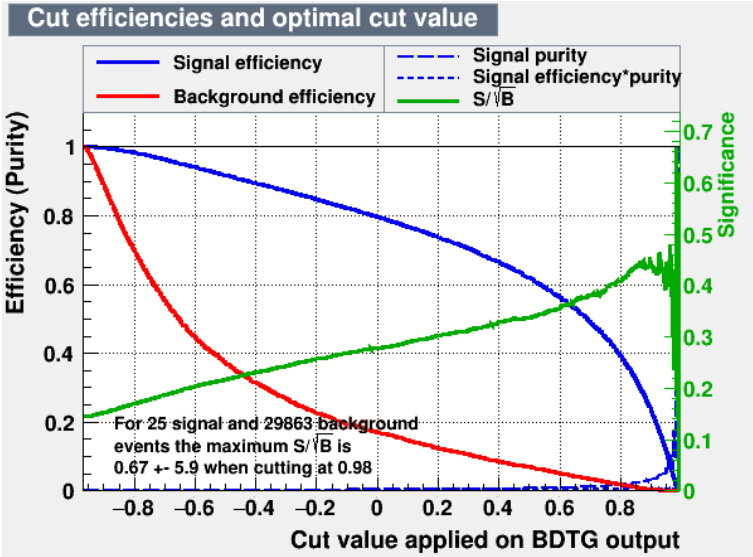




- No sign of over training

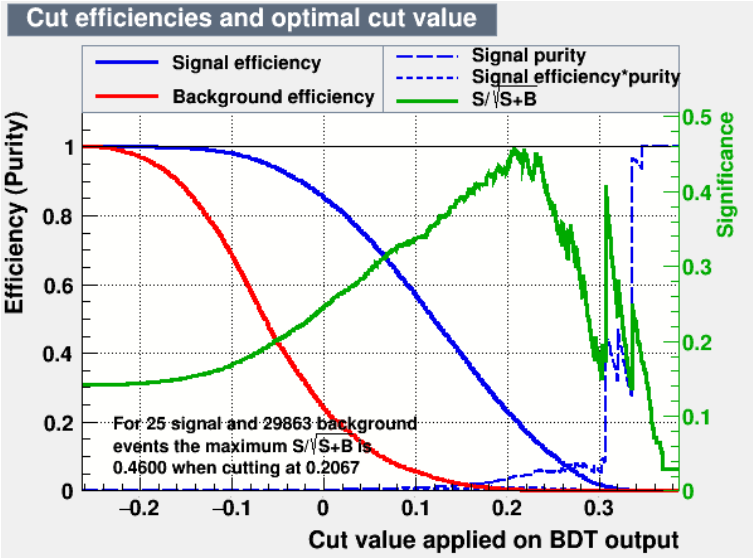
Optimal Cut (1Tau0L)

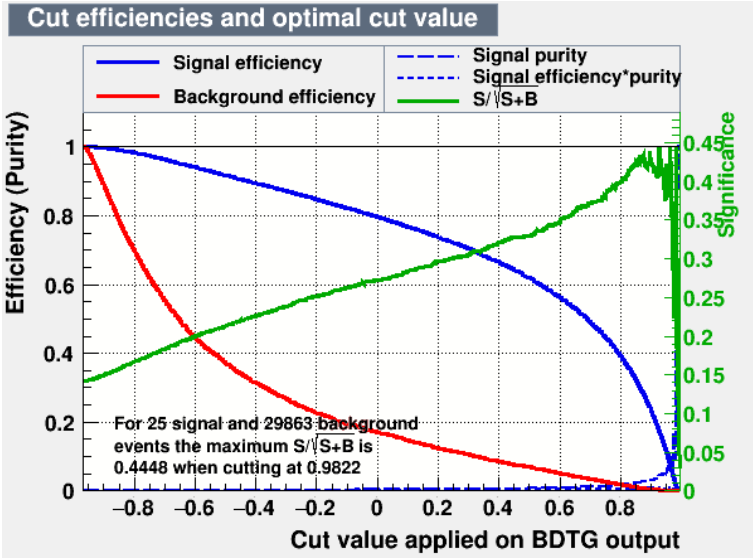




- Try a log of y maybe

Optimal Cut (1Tau0L)





- For BDTA, best is around 0.46.
- For BDTG, best is 0.44

Outline

Step4

- all requirements of step3
- Additonal requirement of jet to not overlap with jet

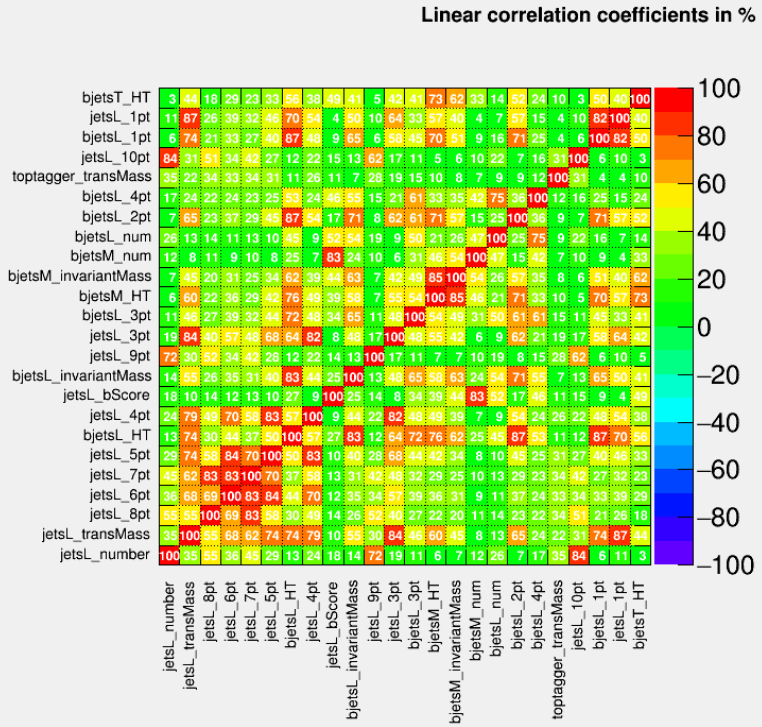
1Tau0L

Figure: jet jet removal applied

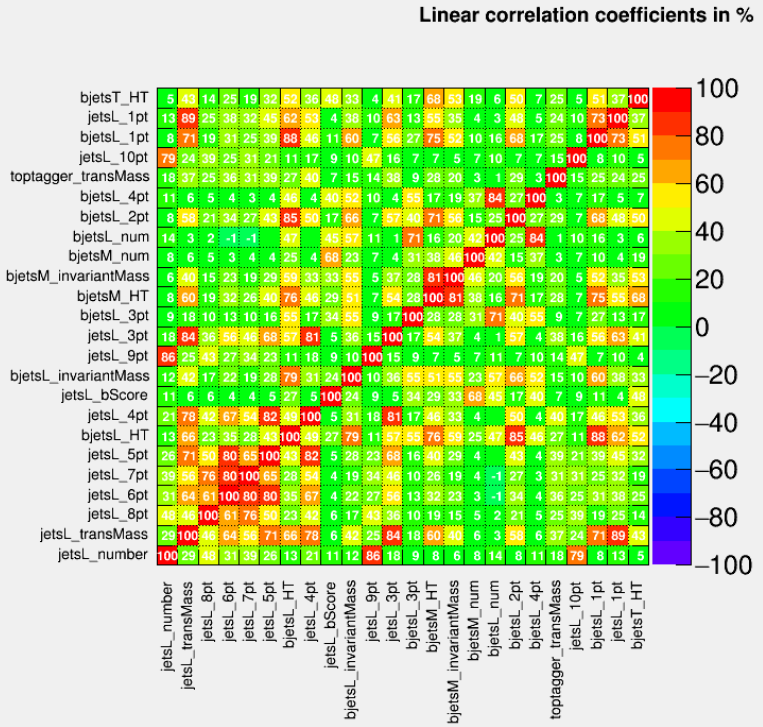
```
Plotting jetsL_number1Tau0L_
TTTT    = 28.6694
TT      = 7785.91
TTX     = 607.435
VV      = 0.320483
VVV     = 1.77492
WJets   = 0
DY      = 0
ST      = 224.296
H       = 13.6994
Total BKG = 8633.44

Statistics
TTTT    = 67073
TT      = 22340
TTX     = 78957
VV      = 19
VVV     = 124
WJets   = 0
DY      = 0
ST      = 16695
H       = 240
```

Correlation (1Tau0L)

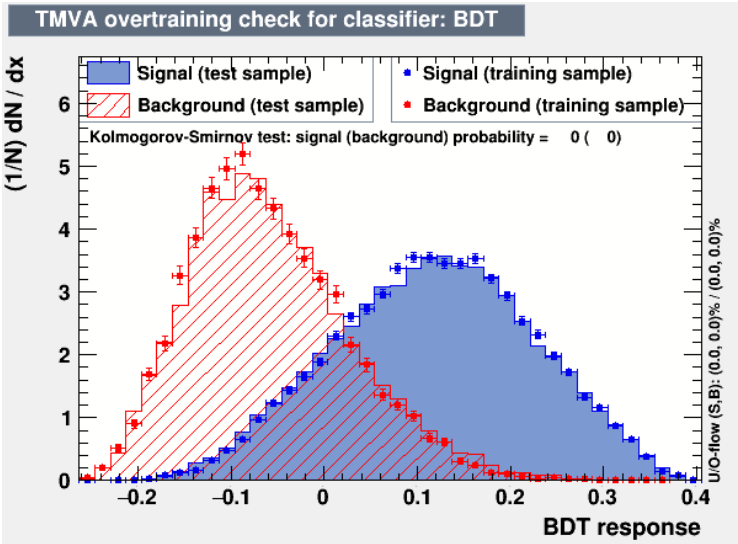
Correlation Matrix (signal)

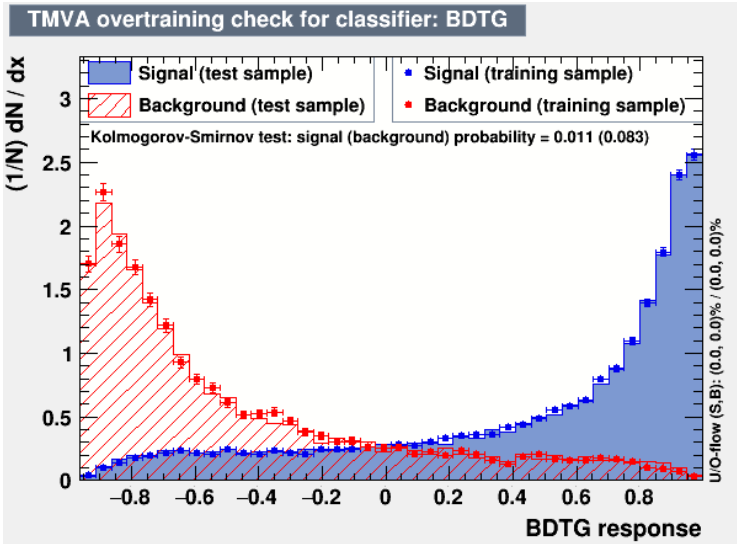


Correlation Matrix (background)



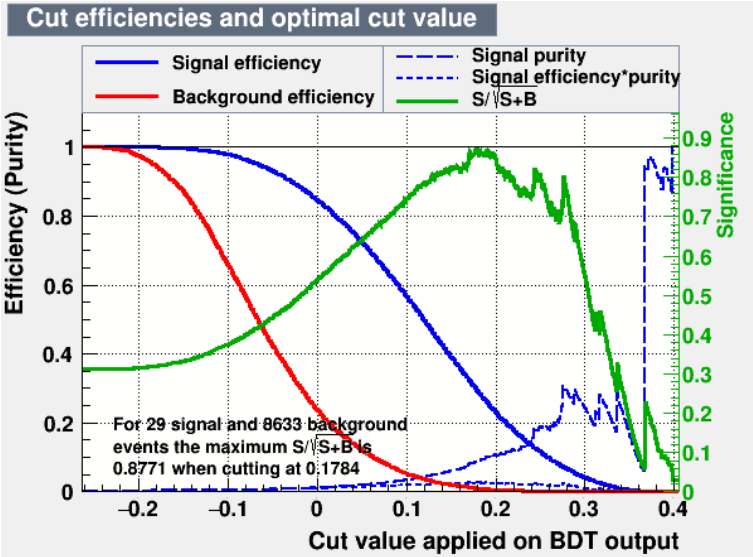
BDT Output (1Tau0L)

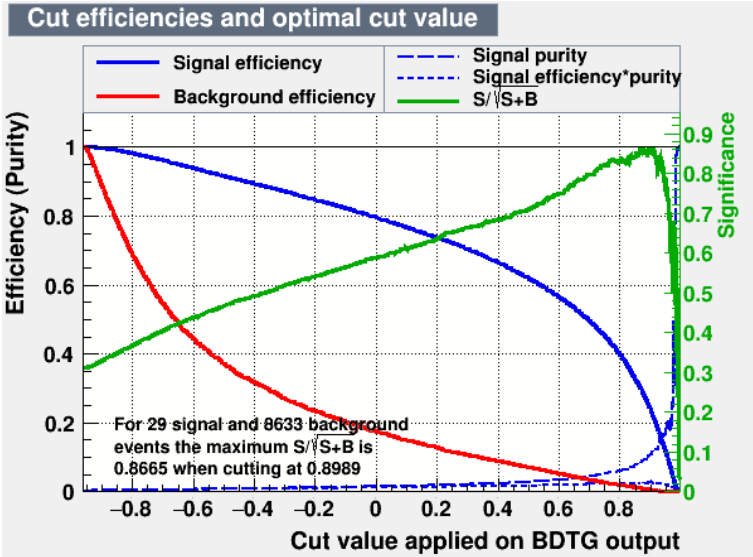




- No sign of over training

Optimal Cut (1Tau0L)





- For BDTA, best is around 0.88.
- For BDTG, best is 0.87
- Just jet jet overlap can show such improvement?
  - improvement due to wrong number of signal and bg as input.
  - here in step 4 we are still traning agaist TTJets MC sample but used event yield of TT MC samples

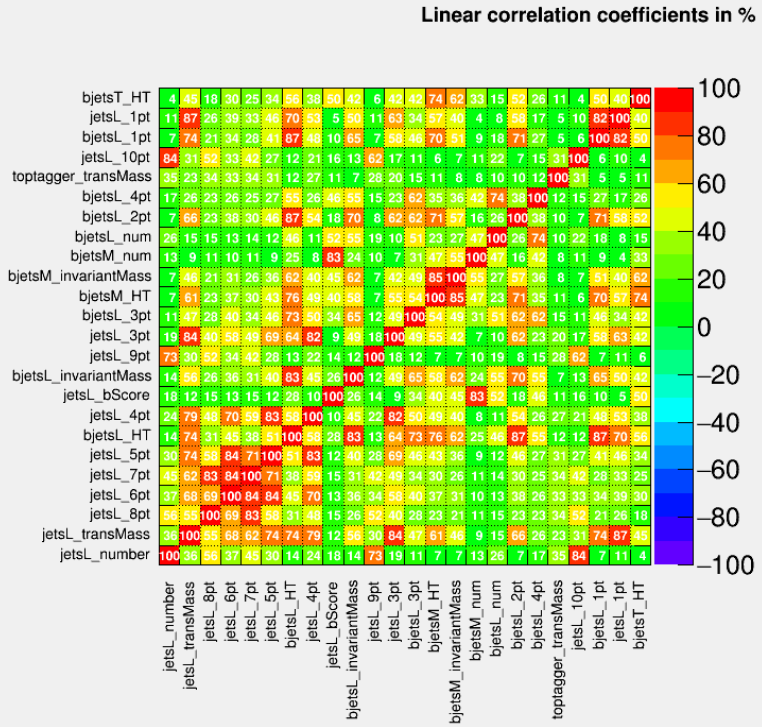
Outline

Step 5

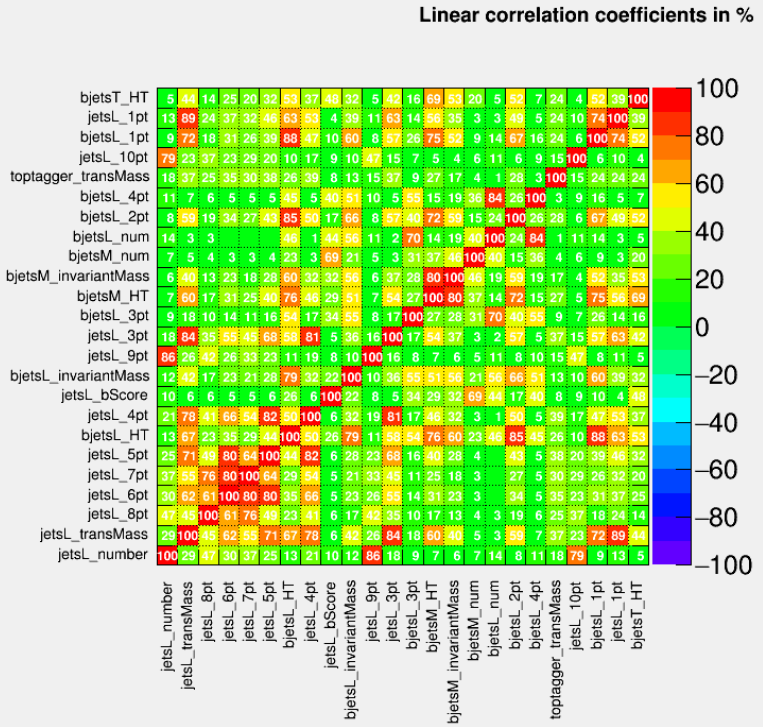
- Change jet removal back to step3, which means no jetjet removal.

Correlation (1Tau0L)

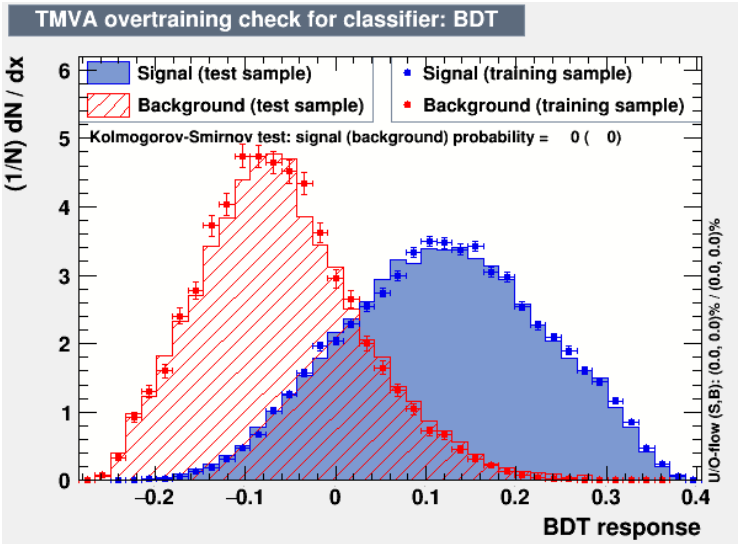
Correlation Matrix (signal)

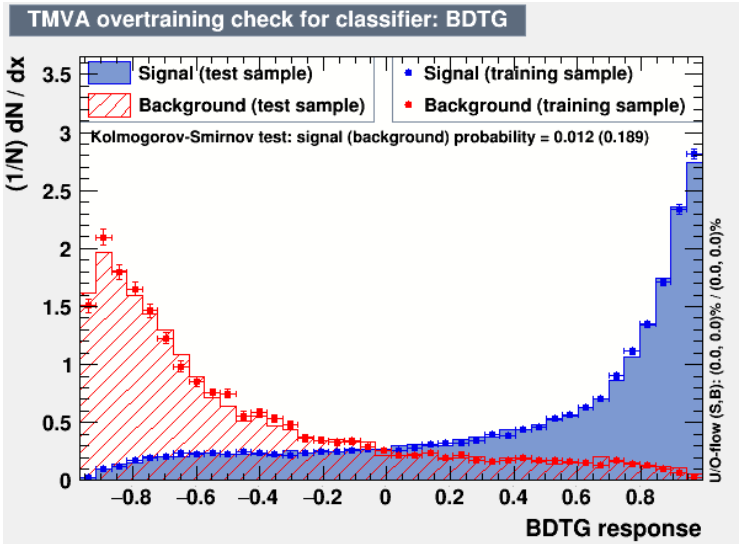


Correlation Matrix (background)



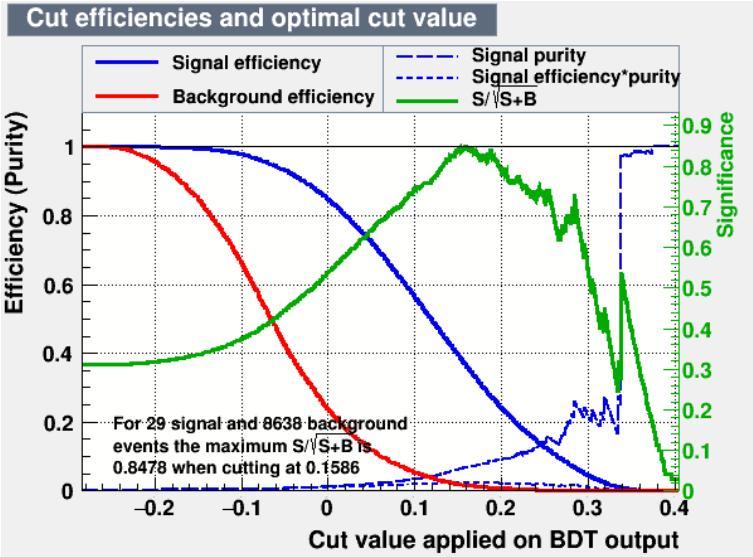
BDT Output (1Tau0L)

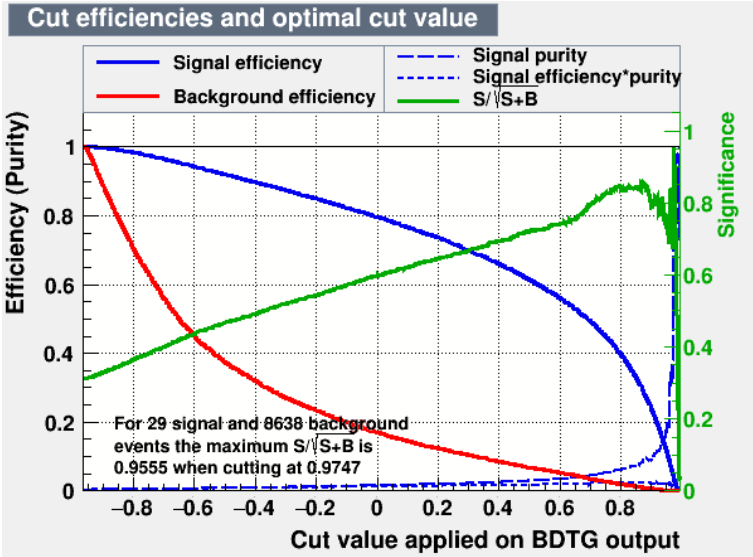




- No sign of over training

Optimal Cut (1Tau0L)





- For BDTA, best is around 0.88.
- For BDTG, best is 0.87
- Just jet jet overlap can show such improvement?

Outline

Step 6

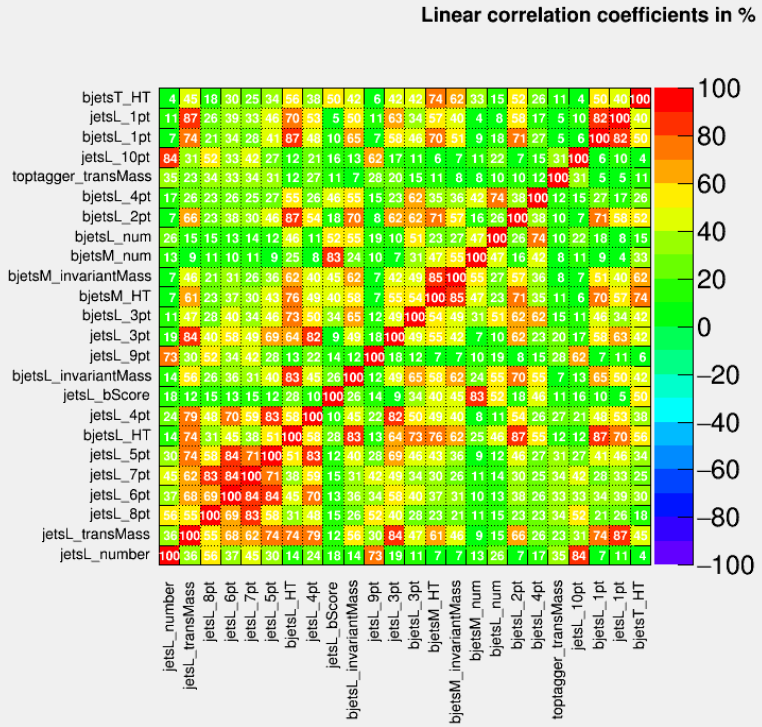
- Traning against tt background instead of TTJets.
- Everything else the same as step 5

Event Yield

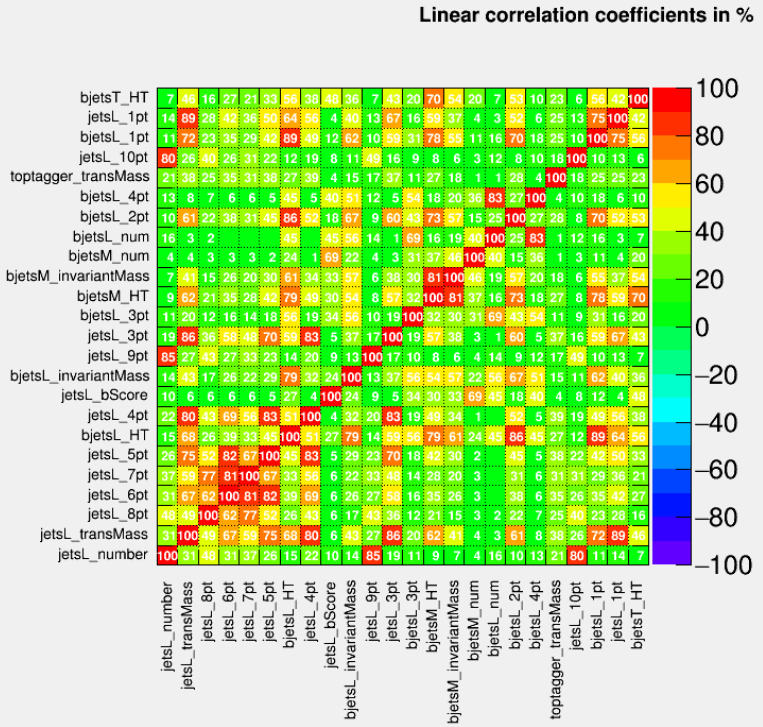
```
Plotting jetsL_number1Tau0L_
TTTT    = 28.6732
TT      = 7790.1
TTX     = 607.64
VV      = 0.320483
VVV     = 1.77492
WJets   = 0
DY      = 0
ST      = 224.303
H       = 13.6994
Total BKG = 8637.84

Statistics
TTTT    = 67082
TT      = 22352
TTX     = 78980
VV      = 19
VVV     = 124
WJets   = 0
DY      = 0
ST      = 16702
H       = 240
```

Correlation (1Tau0L)

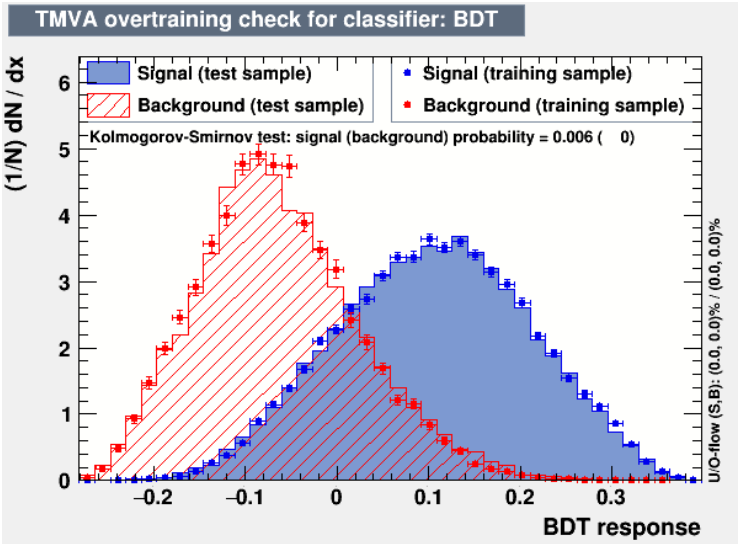
Correlation Matrix (signal)

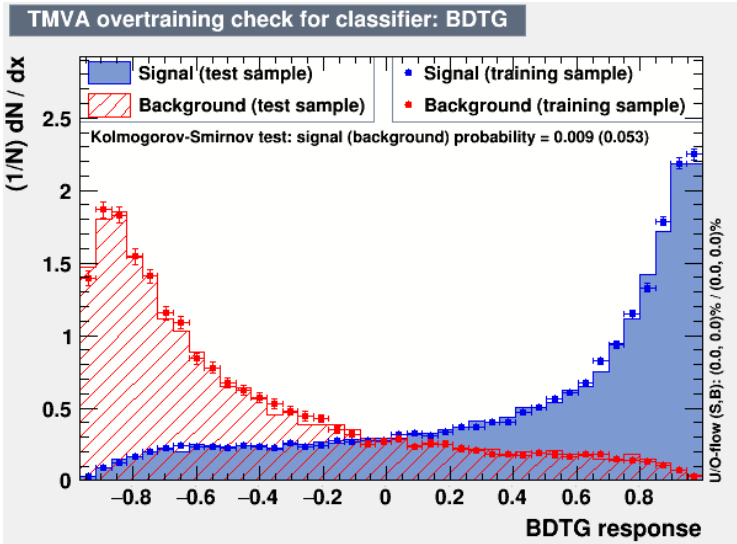


Correlation Matrix (background)



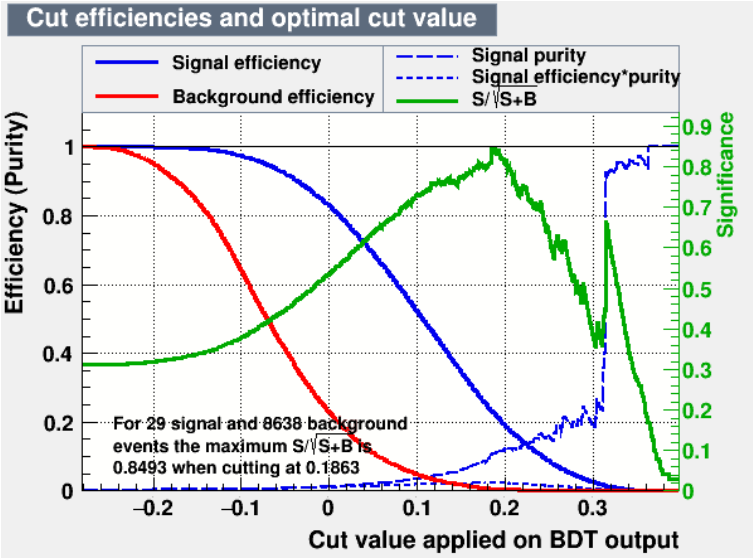
BDT Output (1Tau0L)

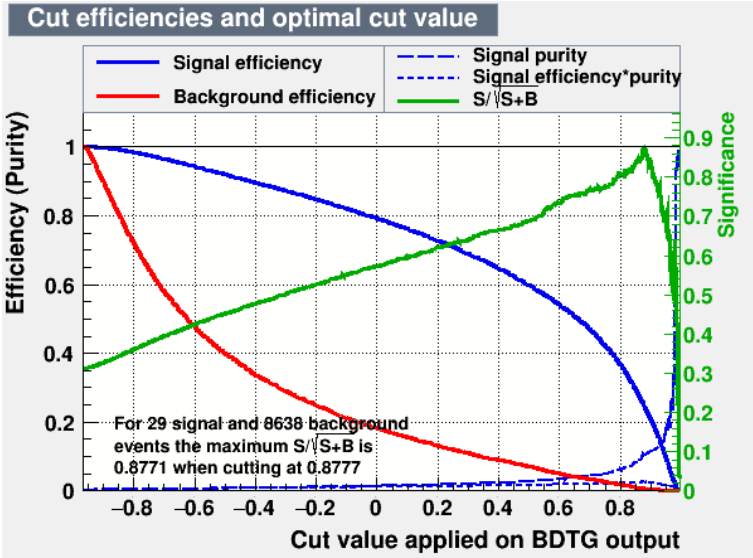




- No sign of over training

Optimal Cut (1Tau0L)





- For BDTA, best is around 0.85.
- For BDTG, best is 0.88

HLT used in TTH

channel	HLT
0L2Taus	double tau trigger
1L	combination of single lepton triggers and lepton+tau cross-triggers
2L	A combination of single and double lepton triggers
3L	a mix of single double and triple lepton triggers

Table: Subchannel difinition

- For some triggers, we use a combination of HLT paths with different pT thresholds or a com bination of paths with and without a dz requirement applied to the leptons
- In the case of the double muon triggers we further use a mix of HLT paths with and without a requirement on the invariant mass of the di-muon pair, namely m > 3.8 GeV
- for >= 2 leptons, drop the 1tau + 0Lepton channel as the pT threshold of the single tau trigger is so high that the efficiency for your tttt signal will be very low

Trigger Effiency

- Review of ZhangYu's previous result
  - Under the preselection condition, he showed that trigger from TTH is not very good for our signal.
  - He suggested trying multi-jet+b-jet triggers for all subchannels instead of using ttH triggers.
- My strategy
  - I think we should measure trigger efficiency of signal MC under the requirements of gen tau and gen leptons.
  - 1tau0l
    - Denominator: events that have 1 gen tau that comes from gen top and 0 gen leptons decaying from W .
    - Numerator : events passing denominator requirement and passing the trigger.
  - The same fashion to caculate efficiency in other channels and compare multi-jet+b-jet triggers with TTH trigger set.

Signal Trigger Efficiency

- trigger menu: /frozen/2016/25ns15e33/v4.0/HLT/V2
- 2 jet and bjet cross triggers are HLT_PFHT450_SixJet40_BTagCSV_p056 and HLT_PFHT400_SixJet30_DoubleBTagCSV_p056

Trgger Efficiency Reweighting

- How to do trigger efficiency reweighting?
- How to get systematics?

Other stuff that I have done

- I copied some samples to /publicfs/cms/data/TopQuark/FourTop_hua/
- Removed some samples in T2: TT_TuneCUETP8M2T4_13TeV-powheg-pythia8
- Submitted more samples to crab job
  - output ntuples are in the new SE now. gfal-ls gsiftp://ccsrm.ihep.ac.cn/dpm/ihep.ac.cn/home/cms/store/user/hhua
  - QCD_HT100to200_TuneCUETP8M1_13TeV-madgraphMLM-pythia8(ongoing)
  - TTJets_TuneCP5_PSweights_13TeV-amcatnloFXFX-pythia8 (ongoing)
  - TTToSemiLeptonic_TuneCP5_PSweights_13TeV-powheg-pythia8 (finished)
  - TTTo2L2Nu_TuneCP5_PSweights_13TeV-powheg-pythia8 (finished)
  - TTToHadronic_TuneCP5_PSweights_13TeV-powheg-pythia8 (finished)

Other Considerations

- We should indeed add a tighter cut at BSM step, otherwise it the outputNtuple is too large and it would slow down analysis
- ~~Might consider moving our file and code to CERN cluster because IHEP is sometimes unstable~~

Next Step

- Trigger study, ongoing.
- MVA in other subchannels.
- Check more kinematics variables and their combinations
- Try a 70% and 30% of training and testing
- Add QCD background
- Check and move of our ntuples in T2

Electron ID

SUSY eletron MVA recommendation

Figure: Cuts/Equations for MVA Ids (94X MVA)

Cuts/Equations for MVA (2016 - MVANoIso94XV2)

6

Different from 2017/2018

Tight

Region	MVA value, 10<ePt<40	MVA value ePt>=40
$\|\eta\| < 0.8$	> 3.447 + 0.063(pt - 25)	> 4.392
$0.8 \le \|\eta\| < 1.479$	> 2.522 + 0.058(pt - 25)	> 3.392
$1.479 \le \|\eta\| < 2.5$	> 1.555 + 0.075(pt - 25)	> 2.680

VLoose

Region	ePt: 5-10	10<ePt<25	ePt>=25
$\|\eta\| < 0.8$	> 1.309	> 0.887 + 0.088(pt - 25)	> 0.887
$0.8 \le \|\eta\| < 1.479$	> 0.373	> 0.112 + 0.099(pt - 25)	> 0.112
$1.479 \le \|\eta\| < 2.5$	> 0.071	> -0.017 + 0.137(pt - 25)	> -0.017

VLooseFO

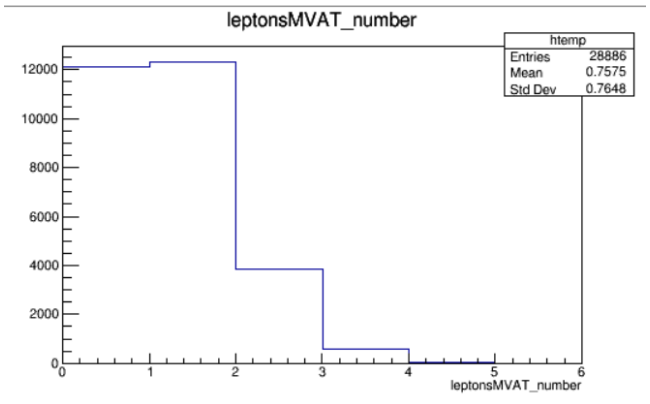
Region	ePt: 5-10	10<ePt<25	ePt>=25
$\|\eta\| < 0.8$	> -0.259	> -0.388 + 0.109(pt - 25)	> -0.388
$0.8 \le \|\eta\| < 1.479$	> -0.256	> -0.696 + 0.106(pt - 25)	> -0.696
$1.479 \le \|\eta\| < 2.5$	> -1.630	> -1.219 + 0.148(pt - 25)	> -1.219

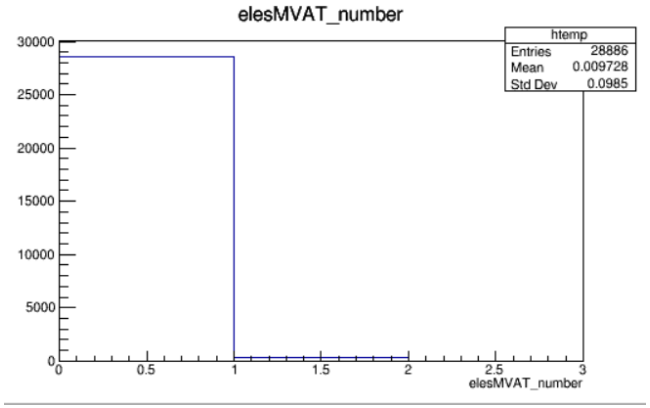
Electron Iso

Figure: electron ISO in SS

Table 7: Isolation working points 2016

isolation value	loose WP (e/μ)	μ (Medium) WP	e (Tight) WP
I_1	0.4	0.16	0.12
I_2	0	0.76	0.80
I_3	0	7.2	7.2





Tau in ttH

Hadronic τ			
Observable	Loose	Fakeable	Tight
p_T	> 20 GeV	> 20 GeV	> 20 GeV
$\|\eta\|$	< 2.3	< 2.3	< 2.3
$\|d_z\|$	< 0.2 cm	< 0.2 cm	< 0.2 cm
Decay mode finding	New	New	New
Decay modes	All	All except 2-prong($+\pi^0$)[1]	All except 2-prong($+\pi^0$)[1]
DeepTau vs. jets	$>$ WP-VVLoose	$>$ WP-VVLoose	Channel-dependent
DeepTau vs. muons	–	$>$ WP-VLoose	$>$ WP-VLoose
DeepTau vs. electrons	–	$>$ WP-VVVLoose	$>$ WP-VVVLoose

Variable definition

- transverse energy

$$E_T^2 = m^2 + (\vec{p_T})^2 \tag{3}$$

- transverse mass

$$M_T^2 = (E_{T1} + E_{T2})^2 - (\vec{p_{T1}} + \vec{p_{T2}})^2 \tag{4}$$