Progress Report on Tau Final States of TTTT

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Outline

MVA Stragdy

- Goal
  - Use the smallest set of MVA input variables to get the best performance
- Three methods we are considering
  - Correlation based selection
  - Iterative removal method
  - Combine both

TMVA Setup

- ROOT version
  - Switched to ROOT6.12/07, TMVA version 4.3.0
  - New TMVA version comes with new feature
- Training setup
  - Signal: TTTT_TuneCP5;
  - Background: all bg excerpt H and HH and minor ones
  - 70% goes to training and 30% goes to testing
  - Global weight and event weight same in event yield calculation
  - have added more interesting variables:
    - sphericity, aplanarity
    - added some nonjets variables
  - Dealing with negetive weight events :InverseBoostNegWeights(Boost With inverse boostweight), Boost With inverse boostweight(Pair events with negative and positive weights in traning sample and *annihilate* them)
  - 4 boosting algorithm: BDT(A), BDTG, BDTB, BDTD (all use the default InverseBoostNegWeights)
- Hyperparameters
  - Using the default

Step by Step Correlation Selection

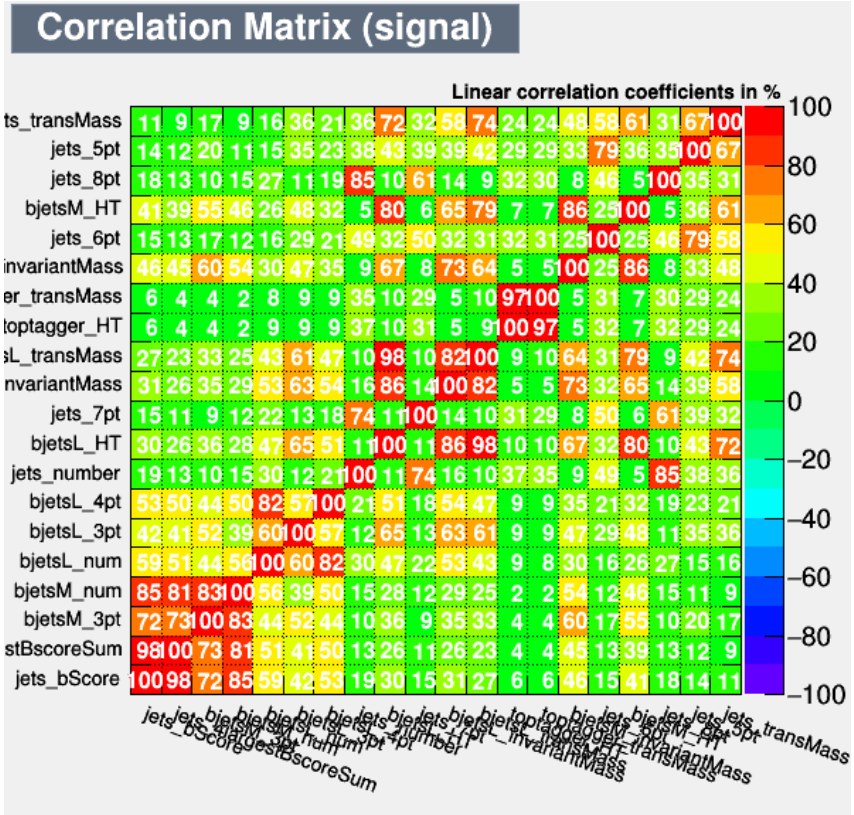
- Step 1: choose the 20 most powerful variables as input to BDT
- Step 2: keep only 1 variable from pairs with correlation>90, see the performance
- Step 3: further remove variables with correlation>80, do the training
- Step 4: add more variables on the basis of step3, repeat step2 ans step3, see if we can gain any AUC(area under ROC curve).

Variables Separation Power Ranking(1Tau1E)

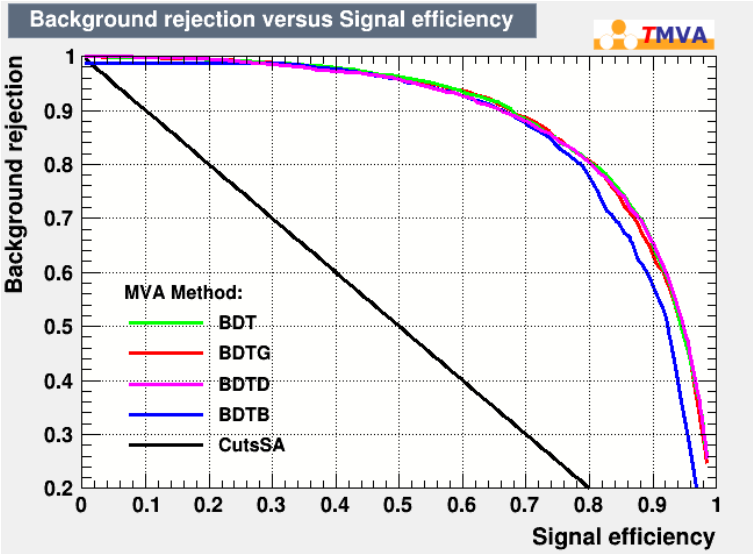
Rank	Variable	Separation
1	jets_bScore	2.686e-01
2	jets_4largestBscoreSum	2.571e-01
3	bjetsM_3pt	2.467e-01
4	bjetsM_num	2.435e-01
5	bjetsM_3eta	2.334e-01
6	bjetsM_3phi	2.334e-01
7	bjetsL_num	2.279e-01
8	bjetsL_3pt	2.279e-01
9	bjetsL_4pt	1.984e-01
10	jets_number	1.968e-01
11	bjetsL_HT	1.941e-01
12	jets_7pt	1.939e-01
13	bjetsL_invariantMass	1.833e-01
14	bjetsL_transMass	1.811e-01
15	toptagger_HT	1.811e-01
16	bjetsL_4eta	1.771e-01
17	bjetsL_4phi	1.765e-01
18	toptagger_transMass	1.730e-01
19	bjetsM_invariantMass	1.696e-01
20	jets_6pt	1.632e-01
21	bjetsM_HT	1.569e-01
22	jets_7eta	1.551e-01
23	jetL_7phi	1.549e-01
24	jets_8pt	1.510e-01
25	bjetsL_3eta	1.489e-01
26	jets_5pt	1.475e-01
27	jets_transMass	1.475e-01
28	bjetsL_3phi	1.458e-01
28	bjetsL_3phi	1.458e-01
29	jets_8phi	1.437e-01
30	jets_8eta	1.436e-01
31	bjetsT_num	1.416e-01
32	toptagger_invariantMass	1.407e-01
33	bjetsT_3pt	1.407e-01
34	jets_HT	1.406e-01
35	bjetsM_transMass	1.394e-01
36	bjetsT_3eta	1.389e-01
37	bjetsT_3phi	1.388e-01
38	toptagger_2pt	1.338e-01
39	toptagger_num	1.328e-01
40	jets_4pt	1.275e-01
41	nonbjetsM_num	1.233e-01
42	bjetsL_2pt	1.181e-01
43	toptagger_minDeltaR_v1	1.157e-01
44	bjetsT_invariantMass	1.106e-01
45	toptagger_2eta	1.084e-01
46	toptagger_2phi	1.082e-01
47	bjetsT_HT	1.068e-01
48	bjetsM_4pt	9.897e-02
49	bjetsM_4eta	9.849e-02
50	bjetsM_4phi	9.828e-02
51	nonbjetsT_num	9.777e-02
52	bjetsT_transMass	9.641e-02
53	bjetsL_minDeltaR	9.494e-02
54	jets_rationHT_4toRest	9.437e-02
55	jets_3pt	9.341e-02
56	bjetsM_2pt	8.773e-02

Step1: Input Variables and Correlation

Rank	Variable	Separation
1	jets_bScore	2.686e-01
2	jets_4largestBscoreSum	2.571e-01
3	bjetsM_3pt	2.467e-01
4	bjetsM_num	2.435e-01
5	bjetsL_num	2.279e-01
6	bjetsL_3pt	2.279e-01
7	bjetsL_4pt	1.984e-01
8	jets_number	1.968e-01
9	bjetsL_HT	1.941e-01
10	jets_7pt	1.939e-01
11	bjetsL_invariantMass	1.833e-01
12	bjetsL_transMass	1.811e-01
13	toptagger_HT	1.811e-01
14	toptagger_transMass	1.730e-01
15	bjetsM_invariantMass	1.696e-01
16	jets_6pt	1.632e-01
17	bjetsM_HT	1.569e-01
18	jets_8pt	1.510e-01
19	jets_5pt	1.475e-01
20	jets_transMass	1.475e-01



Step 1: ROC



DataSet Name:	MVA Method:	ROC-integ
dataset	BDT	: 0.884
dataset	BDTG	: 0.882
dataset	BDTD	: 0.881
dataset	BDTB	: 0.860
dataset	CutsSA	: 0.500

Step 2

- Remove variable with correlation >=90
- jets_bsore, jets_4largestBscoreSum; remove jets_4largestBscoreSum;
- bjetsM_3pt, bjetsM_num, remove bjetsM_num,
- bjetsL_HT, bjetsL_transMass, remove bjetsL_transMass,
- topTagger_HT, toptagger_transMass, remove topTagger_HT,

Rank	Variable	Separation
1	jets_bScore	2.686e-01
2	bjetsM_3pt	2.467e-01
3	bjetsL_num	2.279e-01
4	bjetsL_3pt	2.279e-01
5	bjetsL_4pt	1.984e-01
6	jets_number	1.968e-01
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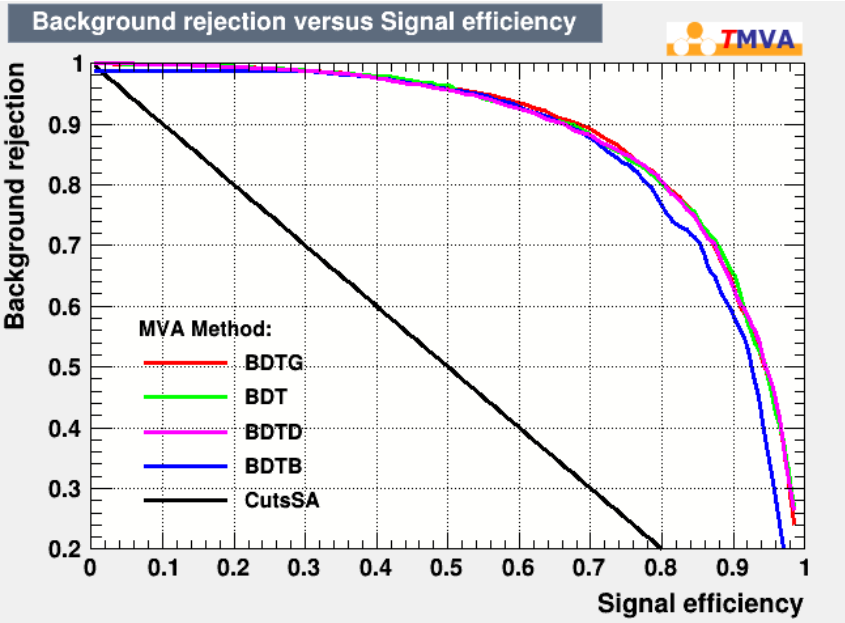
8	jets_7pt	1.939e-01
9	bjetsL_invariantMass	1.833e-01
10	toptagger_transMass	1.730e-01
11	bjetsM_invariantMass	1.696e-01
12	jets_6pt	1.632e-01
13	bjetsM_HT	1.569e-01
14	jets_8pt	1.510e-01
15	jets_5pt	1.475e-01
16	jets_transMass	1.475e-01

Step 2: ROC



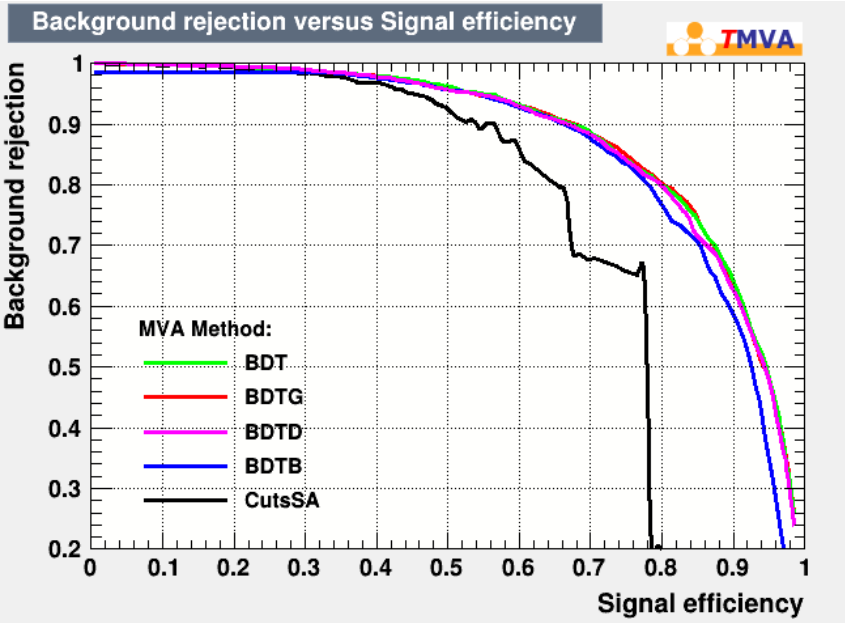

```
: DataSet       MVA
: Name:         Method:          ROC-integ
: dataset       BDTG         : 0.882
: dataset       BDT          : 0.882
: dataset       BDTD         : 0.880
: dataset       BDTB         : 0.863
: dataset       CutsSA       : 0.500
```

step 3

- Remove Correlation > 80
- bjetsL_num and bjetsL_4pt, remove bjetsL_4pt
- jets_number and jets_8pt, remove jets_8pt
- bjetsL_HT, bjetsM_HT(80), bjetsL_invariantMass(86), remove bjetsM_HT and bjetsL_invariantMass,
- bjetsM_invariantMass, bjetsM_HT, already remove bjetsM_HT
- bjetsM_HT and bjetsL_HT(80) and bjetsM_invariantMass(86),

Rank	Variable	Separation
1	jets_bScore	2.686e-01
2	bjetsM_3pt	2.467e-01
3	bjetsL_num	2.279e-01
4	bjetsL_3pt	2.279e-01
5	jets_number	1.968e-01
6	bjetsL_HT	1.941e-01
7	jets_7pt	1.939e-01
8	toptagger_transMass	1.730e-01
9	jets_6pt	1.632e-01
10	jets_5pt	1.475e-01
11	jets_transMass	1.475e-01

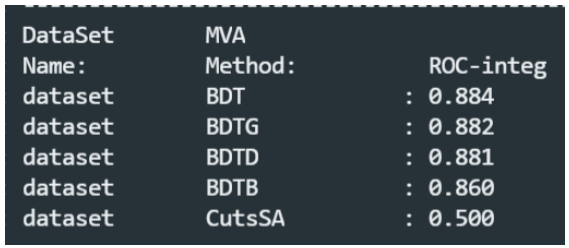
Step3: ROC



DataSet Name:	MVA Method:	ROC-integ
dataset	BDT	: 0.882
dataset	BDTG	: 0.882
dataset	BDTD	: 0.878
dataset	BDTB	: 0.862
dataset	CutsSA	: 0.736

Conclusion for Correlation Removal

Figure: step1



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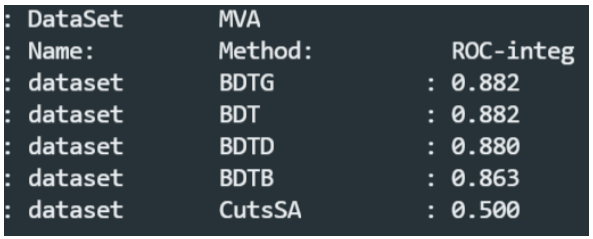
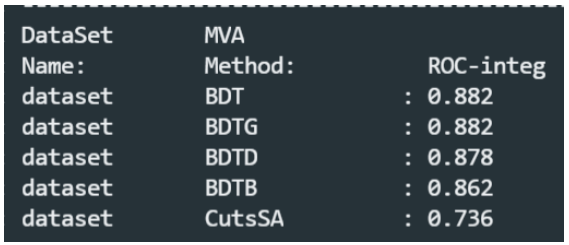
dataset	BDT	: 0.884
dataset	BDTG	: 0.882
dataset	BDTD	: 0.881
dataset	BDTB	: 0.860
dataset	CutsSA	: 0.500

Figure: step2



DataSet Name:	MVA Method:	ROC-integ
dataset	BDTG	: 0.882
dataset	BDT	: 0.882
dataset	BDTD	: 0.880
dataset	BDTB	: 0.863
dataset	CutsSA	: 0.500

Figure: step3



DataSet Name:	MVA Method:	ROC-integ
dataset	BDT	: 0.882
dataset	BDTG	: 0.882
dataset	BDTD	: 0.878
dataset	BDTB	: 0.862
dataset	CutsSA	: 0.736

- We almost lost no AUC performance from step1 to step2 to step3
- The resulting 11 input variables are going to be our starting point for further corelation removal for iterative removal

Iterative Removal

- Procedure
  - Suppose we have 25 input variables for starters
  - For each variable, remove it and use the left 24 as inputs to BDT, see the performance, the variable that has the least impact on the performance is ranked as the least important(25 TMVA training).
  - Now we have a 24 variable set with best performance, repeat previous step (24 TMVA training)
  - plot the AUC value as a function of number of input variables
  - Require to be on the plateu of the curve
- Implementation
  - A bit computation expensive to implement, could take up to 325 times TMVA training for 25 variables
  - Still working on my code to implement it

Iterative Removal Implementation

- trying to implement the vSearch code to our analysis in IHEP cluster https://github.com/sitongan/vSearch
- not sure what a TMVA wrapper is. have written an email to author Sitong about it
- Sitong is not replying to my email. I am afraid I have try to do it myself
- Have some ideas in mind of how to implement it, a bit challenging but want to try them

Combined Variable Optimization

- Do correlation removal for start, keep varible list down to $\approx$25 while still has very good performance
- Use the variable list from correlation removal and go through Iterative Removal.

UL BSM Jobs Preparation

- Legacy ReReco or Legacy, aka Ultra-Legacy (UL)
- What we used before is ReReco
- for 2016, reprocessing is split into 2 parts. Analyzers need to combine them all.
  - With HIP mitigation: Run B (RAW v1, v2), C, D, E, F (most of)
  - Without HIP mitigation: F (7 runs), G, H
  - Run2016B has two sets of RAW data containing disjoint sets of runs. This is reflected in the strings "ver1" and "ver2"
  - UL2016 consists of 9 "eras": Run2016B ver1, Run2016B ver2, Run2016C, Run2016D, Run2016E, Run2016F(HIPM), Run2016F(no HIPM), Run2016G, Run2016H
  - Run2016F is split into two different reconstruction versions
    - "pre-VFP" (aka "HIPM" or "APV"): eras B-F (31 runs) are reconstructed with a reconstruction including HIP mitigation, short "HIPM".Run2016F(HIPM) has 31 runs
    - "post-VFP" (aka "no-HIPM"): eras F(7 runs)-H reconstructed with the default track reconstruction.

- The list of datasets (for example for Nanov8) should look like as follows:
  - /BTagCSV/Run2016B-ver1_HIPM_UL2016_MiniAODv1_NanoAODv2-v1/NANOAOD
  - /BTagCSV/Run2016B-ver2_HIPM_UL2016_MiniAODv1_NanoAODv2-v1/NANOAOD
  - /BTagCSV/Run2016C-UL2016_MiniAODv1_NanoAODv2-v1/NANOAOD
  - /BTagCSV/Run2016D-UL2016_MiniAODv1_NanoAODv2-v1/NANOAOD
  - /BTagCSV/Run2016E-UL2016_MiniAODv1_NanoAODv2-v1/NANOAOD
  - /BTagCSV/Run2016F-HIPM_UL2016_MiniAODv1_NanoAODv2-v1/NANOAOD
  - /BTagCSV/Run2016F-UL2016_MiniAODv1_NanoAODv2-v1/NANOAOD
  - /BTagCSV/Run2016G-UL2016_MiniAODv1_NanoAODv2-v1/NANOAOD
  - /BTagCSV/Run2016H-UL2016_MiniAODv1_NanoAODv2-v1/NANOAOD
- TTTT signal sample is still not available in DAS, maybe I should write to top MC contact asking about it

EventSelection

- MET fillters
- HLT requirements
  - HLT_PFHT450_SixJet40_BTagCSV_p056==1, HLT_PFHT400_SixJet30_DoubleBTagCSV_p056==1
- loose preselection
  - tausL.size()>0, jets.size()>3, bjetsL.size()>1
- Subchannel requirements

MC reweighting

- genWeight
- prefireWeight
- PileUp reweighting

Event Yield

```
1Tau0L
Raw entries:
TTTT          = 237389
TT            = 46656
TTX           = 37788
single top    = 3839
TX            = 7785
DYJets        = 0
VV            = 8
VVV           = 98
QCD           = 305
Total BKG     = 7777.06

Weighted:
TTTT          = 1729.23
TT            = 1.30564e+07
TTX           = 55880.3
single top    = 183.319
TX            = 7709.81
DYJets        = 0
VV            = 714.399
VVV           = 10.5086
QCD           = 268.521
Total BKG     = 13936.3

Event yield:
TTTT          = 9.47371
TT            = 6276.17
TTX           = 212.41
single top    = 120.653
TX            = 13.0152
DYJets        = 0
VV            = 0.103319
VVV           = 0.982638
QCD           = 7285.38
Total BKG     = 13936.3
```

```
1Tau1E
Raw entries:
TTTT          = 80344
TT            = 16515
TTX           = 10415
single top    = 3361
TX            = 2598
DYJets        = 0
VV            = 3
VVV           = 20
QCD           = 2
Total BKG     = 93.7667

Weighted:
TTTT          = 623.886
TT            = 2.18092e+06
TTX           = 13611.5
single top    = 147.115
TX            = 2591.97
DYJets        = 0
VV            = 415.464
VVV           = 1.81758
QCD           = 2.17447
Total BKG     = 1178.13

Event yield:
TTTT          = 3.418
TT            = 1092.39
TTX           = 48.6264
single top    = 21.8069
TX            = 3.4963
DYJets        = 0
VV            = 0.0537144
VVV           = 0.249651
QCD           = 2.35911
Total BKG     = 1178.13
```

```
1Tau1Mu
Raw entries:
TTTT          = 99667
TT            = 19225
TTX           = 11729
single top    = 2529
TX            = 3055
DYJets        = 0
VV            = 6
VVV           = 12
QCD           = 0
Total BKG     = 92.2959

Weighted:
TTTT          = 780.561
TT            = 2.46514e+06
TTX           = 15187.2
single top    = 139.593
TX            = 2971.26
DYJets        = 0
VV            = 465.544
VVV           = 0.622918
QCD           = 0
Total BKG     = 1324.63

Event yield:
TTTT          = 4.27635
TT            = 1236.92
TTX           = 54.2688
single top    = 18.7832
TX            = 4.01954
DYJets        = 0
VV            = 0.0786659
VVV           = 0.0812971
QCD           = 0
Total BKG     = 1324.63
```

Event Yield

```
1Tau2OS
Raw entries:
TTTT          = 28250
TT            = 1265
TTX           = 4718
single top    = 3510
TX            = 789
DYJets        = 0
VV            = 1
VVV           = 5
QCD           = 0
Total BKG     = 28.0118

Weighted:
TTTT          = 221.854
TT            = 92102.1
TTX           = 4935.03
single top    = 199.663
TX            = 778.825
DYJets        = 0
VV            = 1.02674
VVV           = 0.650436
QCD           = 0
Total BKG     = 78.0374

Event yield:
TTTT          = 1.21544
TT            = 58.7553
TTX           = 14.9337
single top    = 0.508183
TX            = 0.962345
DYJets        = 0
VV            = 0.0375234
VVV           = 0.0953384
QCD           = 0
Total BKG     = 78.0374
```

```
1Tau2SS
Raw entries:
TTTT          = 14204
TT            = 63
TTX           = 1321
single top    = 520
TX            = 385
DYJets        = 0
VV            = 0
VVV           = 3
QCD           = 0
Total BKG     = 7.59988

Weighted:
TTTT          = 114.525
TT            = 6095.78
TTX           = 1501.54
single top    = 18.4616
TX            = 386.36
DYJets        = 0
VV            = 0
VVV           = 0.421751
QCD           = 0
Total BKG     = 10.1519

Event yield:
TTTT          = 0.627434
TT            = 3.35655
TTX           = 4.78014
single top    = 0.0469887
TX            = 0.498109
DYJets        = 0
VV            = 0
VVV           = 0.0625488
QCD           = 0
Total BKG     = 10.1519
```

```
1Tau3L
Raw entries:
TTTT          = 2848
TT            = 0
TTX           = 355
single top    = 26
TX            = 27
DYJets        = 0
VV            = 0
VVV           = 1
QCD           = 0
Total BKG     = 1.4098

Weighted:
TTTT          = 23.2214
TT            = 0
TTX           = 358.464
single top    = 2.24994
TX            = 25.843
DYJets        = 0
VV            = 0
VVV           = 0.0168772
QCD           = 0
Total BKG     = 1.21668

Event yield:
TTTT          = 0.12722
TT            = 0
TTX           = 1.02004
single top    = 0.00572658
TX            = 0.0294773
DYJets        = 0
VV            = 0
VVV           = 0.00242049
QCD           = 0
Total BKG     = 1.21668
```

Event Yield

```
2Tau0L
Raw entries:
TTTT          = 11422
TT            = 2848
TTX           = 4288
single top    = 2796
TX            = 1575
DYJets        = 0
VV            = 1
VVV           = 4
QCD           = 2
Total BKG     = 37.7907

Weighted:
TTTT          = 92.454
TT            = 500241
TTX           = 4980.38
single top    = 158.423
TX            = 1562.55
DYJets        = 0
VV            = 1.14961
VVV           = 0.414473
QCD           = 1.95001
Total BKG     = 278.15

Event yield:
TTTT          = 0.506514
TT            = 246.776
TTX           = 16.2812
single top    = 6.77039
TX            = 2.56187
DYJets        = 0
VV            = 0.042014
VVV           = 0.0348188
QCD           = 1.41789
Total BKG     = 278.15
```

```
2Tau1E
Raw entries:
TTTT          = 2569
TT            = 180
TTX           = 1007
single top    = 459
TX            = 378
DYJets        = 0
VV            = 0
VVV           = 0
QCD           = 0
Total BKG     = 5.83133

Weighted:
TTTT          = 21.8009
TT            = 22297.4
TTX           = 1020.17
single top    = 29.586
TX            = 372.931
DYJets        = 0
VV            = 0
VVV           = 0
QCD           = 0
Total BKG     = 16.2041

Event yield:
TTTT          = 0.119437
TT            = 11.5052
TTX           = 2.98042
single top    = 0.0753027
TX            = 0.495236
DYJets        = 0
VV            = 0
VVV           = 0
QCD           = 0
Total BKG     = 16.2041
```

```
2Tau1Mu
Raw entries:
TTTT          = 3264
TT            = 190
TTX           = 1021
single top    = 442
TX            = 406
DYJets        = 0
VV            = 0
VVV           = 0
QCD           = 0
Total BKG     = 5.98391

Weighted:
TTTT          = 25.5952
TT            = 21044
TTX           = 1128.94
single top    = 24.0248
TX            = 394.063
DYJets        = 0
VV            = 0
VVV           = 0
QCD           = 0
Total BKG     = 16.4386

Event yield:
TTTT          = 0.140225
TT            = 11.0659
TTX           = 3.52228
single top    = 0.0611482
TX            = 0.530434
DYJets        = 0
VV            = 0
VVV           = 0
QCD           = 0
Total BKG     = 16.4386
```

Event Yield

```
2Tau2OS
Raw entries:
TTTT          = 449
TT            = 1
TTX           = 111
single top    = 8
TX            = 28
DYJets        = 0
VV            = 0
VVV           = 1
QCD           = 0
Total BKG     = 0.59826

Weighted:
TTTT          = 3.23368
TT            = 66.1142
TTX           = 110.585
single top    = 1.52484
TX            = 30.1004
DYJets        = 0
VV            = 0
VVV           = 0.0187778
QCD           = 0
Total BKG     = 0.484251

Event yield:
TTTT          = 0.0177159
TT            = 0.042666
TTX           = 0.31452
single top    = 0.00388105
TX            = 0.031774
DYJets        = 0
VV            = 0
VVV           = 0.00269306
QCD           = 0
Total BKG     = 0.484251
```

```
2Tau2SS
Raw entries:
TTTT          = 190
TT            = 0
TTX           = 13
single top    = 1
TX            = 4
DYJets        = 0
VV            = 0
VVV           = 0
QCD           = 0
Total BKG     = 0.0644176

Weighted:
TTTT          = 1.75733
TT            = 0
TTX           = 11.9666
single top    = -0.00338024
TX            = 2.99069
DYJets        = 0
VV            = 0
VVV           = 0
QCD           = 0
Total BKG     = 0.0578978

Event yield:
TTTT          = 0.00962764
TT            = 0
TTX           = 0.0344717
single top    = -8.60342e-06
TX            = 0.00315698
DYJets        = 0
VV            = 0
VVV           = 0
QCD           = 0
Total BKG     = 0.0578978
```

Backup

back up

1tau0l

TCut mycuts = "tausT_number==1 leptonsMVAT_number==0 jets_number>=8 bjetsM_num>=2" 1tau0l

Variable Importance

- A ranking of the BDT input variables is derived by counting how often the variables are used to split decision tree nodes, and by weighting each split occurrence by the separation gain-squared it has achieved and by the number of events in the node
- This ranking is known to be unstable and sub-optimal, but widely used within the community.
- correlation information is not accounted for in TMVA Ranking.

AUC

- AUC (area under curve),The AUC metric is the area under the signal versus background efficiency Receiver Operating Characteristic (ROC) curve, bounded by 0 and 1, where 1 is equivalent to perfect discrimination between signal and background, and 0.5 represents discrimination no better than random guessing.
- increase the number of input variables to see if we gain extra AUC
- we want to keep as small set of input variables as possible
- importance

Iterative Removal

- A hillclimbing algorithm solves the search problem by always going in the direction with the highest gradient. It can be naive in the sense that it might get stuck in a local maximum instead of a global one, but it is still a valuable and intuitive method
- Among the 21 variable lists produced this way, the one that performs the best indicates which variable, if removed, has the least impact on the performance. This variable is ranked as the least important, and this particular variable list is used to generate a new batch of variable lists by again removing each variable once.
- One potential method to reduce this tendency towards local maxima is to implement a beam search of a certain width W
- We have shown that despite its tendency to get stuck in local maxima, iterative removal performs reasonably well for the problem of variable selection and much better than the standard TMVA Ranking method in most cases.

Event Yield

```
1Tau2OS
Raw entries:
TTTT          = 28250
TT            = 1265
TTX           = 4718
single top    = 3510
TX            = 789
DYJets        = 0
VV            = 1
VVV           = 5
QCD           = 0
Total BKG     = 28.0118

Weighted:
TTTT          = 221.854
TT            = 92102.1
TTX           = 4935.03
single top    = 199.663
TX            = 778.825
DYJets        = 0
VV            = 1.02674
VVV           = 0.650436
QCD           = 0
Total BKG     = 78.0374

Event yield:
TTTT          = 1.21544
TT            = 58.7553
TTX           = 14.9337
single top    = 0.508183
TX            = 0.962345
DYJets        = 0
VV            = 0.0375234
VVV           = 0.0953384
QCD           = 0
Total BKG     = 78.0374
```

```
1Tau2SS
Raw entries:
TTTT          = 14204
TT            = 63
TTX           = 1321
single top    = 520
TX            = 385
DYJets        = 0
VV            = 0
VVV           = 3
QCD           = 0
Total BKG     = 7.59988

Weighted:
TTTT          = 114.525
TT            = 6095.78
TTX           = 1501.54
single top    = 18.4616
TX            = 386.36
DYJets        = 0
VV            = 0
VVV           = 0.421751
QCD           = 0
Total BKG     = 10.1519

Event yield:
TTTT          = 0.627434
TT            = 3.35655
TTX           = 4.78014
single top    = 0.0469887
TX            = 0.498109
DYJets        = 0
VV            = 0
VVV           = 0.0625488
QCD           = 0
Total BKG     = 10.1519
```

```
1Tau3L
Raw entries:
TTTT          = 2848
TT            = 0
TTX           = 355
single top    = 26
TX            = 27
DYJets        = 0
VV            = 0
VVV           = 1
QCD           = 0
Total BKG     = 1.4098

Weighted:
TTTT          = 23.2214
TT            = 0
TTX           = 358.464
single top    = 2.24994
TX            = 25.843
DYJets        = 0
VV            = 0
VVV           = 0.0168772
QCD           = 0
Total BKG     = 1.21668

Event yield:
TTTT          = 0.12722
TT            = 0
TTX           = 1.02004
single top    = 0.00572658
TX            = 0.0294773
DYJets        = 0
VV            = 0
VVV           = 0.00242049
QCD           = 0
Total BKG     = 1.21668
```

Event Yield

```
2Tau0L
Raw entries:
TTTT          = 11422
TT            = 2848
TTX           = 4288
single top    = 2796
TX            = 1575
DYJets        = 0
VV            = 1
VVV           = 4
QCD           = 2
Total BKG     = 37.7907

Weighted:
TTTT          = 92.454
TT            = 500241
TTX           = 4980.38
single top    = 158.423
TX            = 1562.55
DYJets        = 0
VV            = 1.14961
VVV           = 0.414473
QCD           = 1.95001
Total BKG     = 278.15

Event yield:
TTTT          = 0.506514
TT            = 246.776
TTX           = 16.2812
single top    = 6.77039
TX            = 2.56187
DYJets        = 0
VV            = 0.042014
VVV           = 0.0348188
QCD           = 1.41789
Total BKG     = 278.15
```

```
2Tau1E
Raw entries:
TTTT          = 2569
TT            = 180
TTX           = 1007
single top    = 459
TX            = 378
DYJets        = 0
VV            = 0
VVV           = 0
QCD           = 0
Total BKG     = 5.83133

Weighted:
TTTT          = 21.8009
TT            = 22297.4
TTX           = 1020.17
single top    = 29.586
TX            = 372.931
DYJets        = 0
VV            = 0
VVV           = 0
QCD           = 0
Total BKG     = 16.2041

Event yield:
TTTT          = 0.119437
TT            = 11.5052
TTX           = 2.98042
single top    = 0.0753027
TX            = 0.495236
DYJets        = 0
VV            = 0
VVV           = 0
QCD           = 0
Total BKG     = 16.2041
```

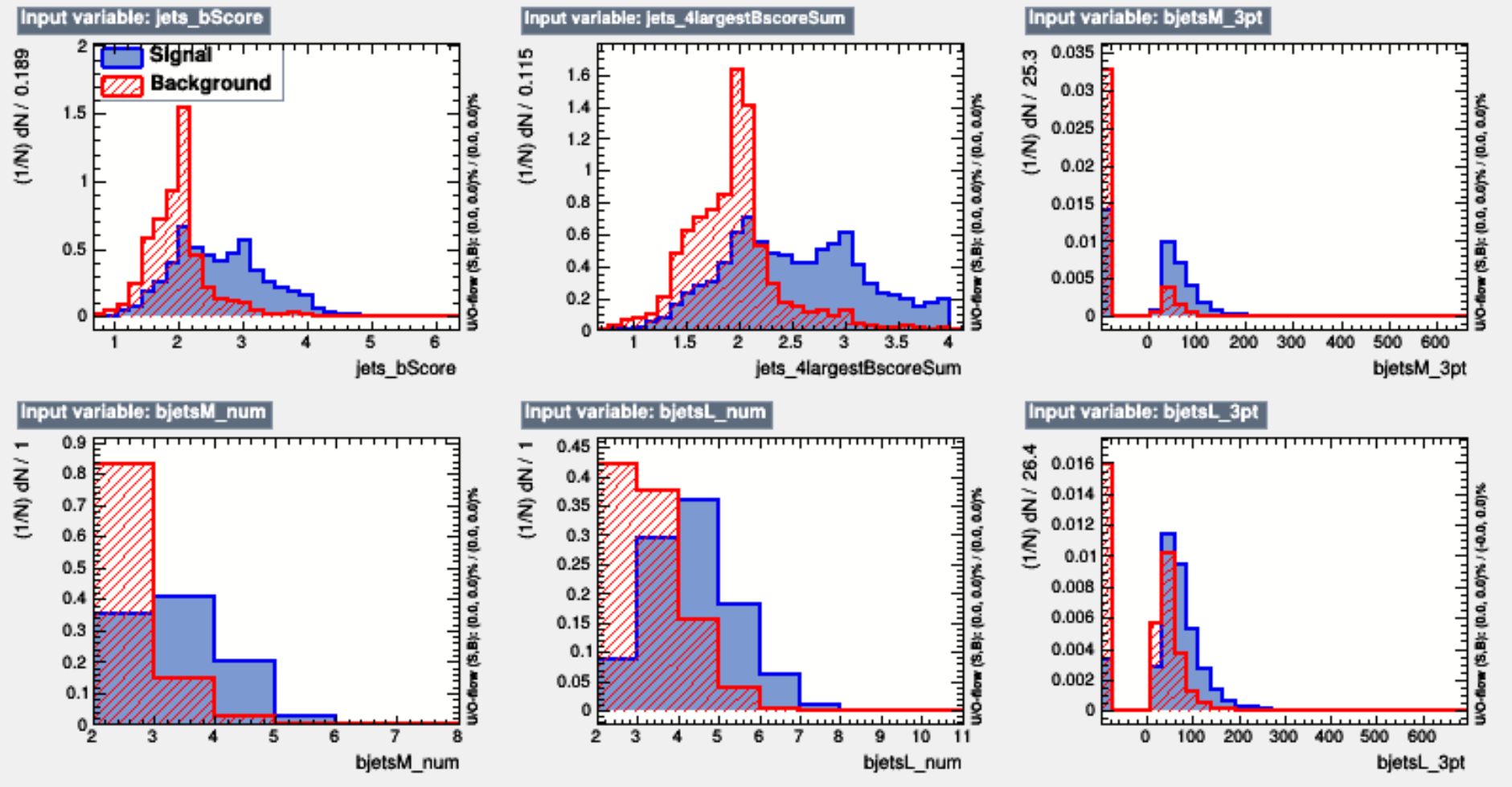
```
2Tau1Mu
Raw entries:
TTTT          = 3264
TT            = 190
TTX           = 1021
single top    = 442
TX            = 406
DYJets        = 0
VV            = 0
VVV           = 0
QCD           = 0
Total BKG     = 5.98391

Weighted:
TTTT          = 25.5952
TT            = 21044
TTX           = 1128.94
single top    = 24.0248
TX            = 394.063
DYJets        = 0
VV            = 0
VVV           = 0
QCD           = 0
Total BKG     = 16.4386

Event yield:
TTTT          = 0.140225
TT            = 11.0659
TTX           = 3.52228
single top    = 0.0611482
TX            = 0.530434
DYJets        = 0
VV            = 0
VVV           = 0
QCD           = 0
Total BKG     = 16.4386
```

Event Yield

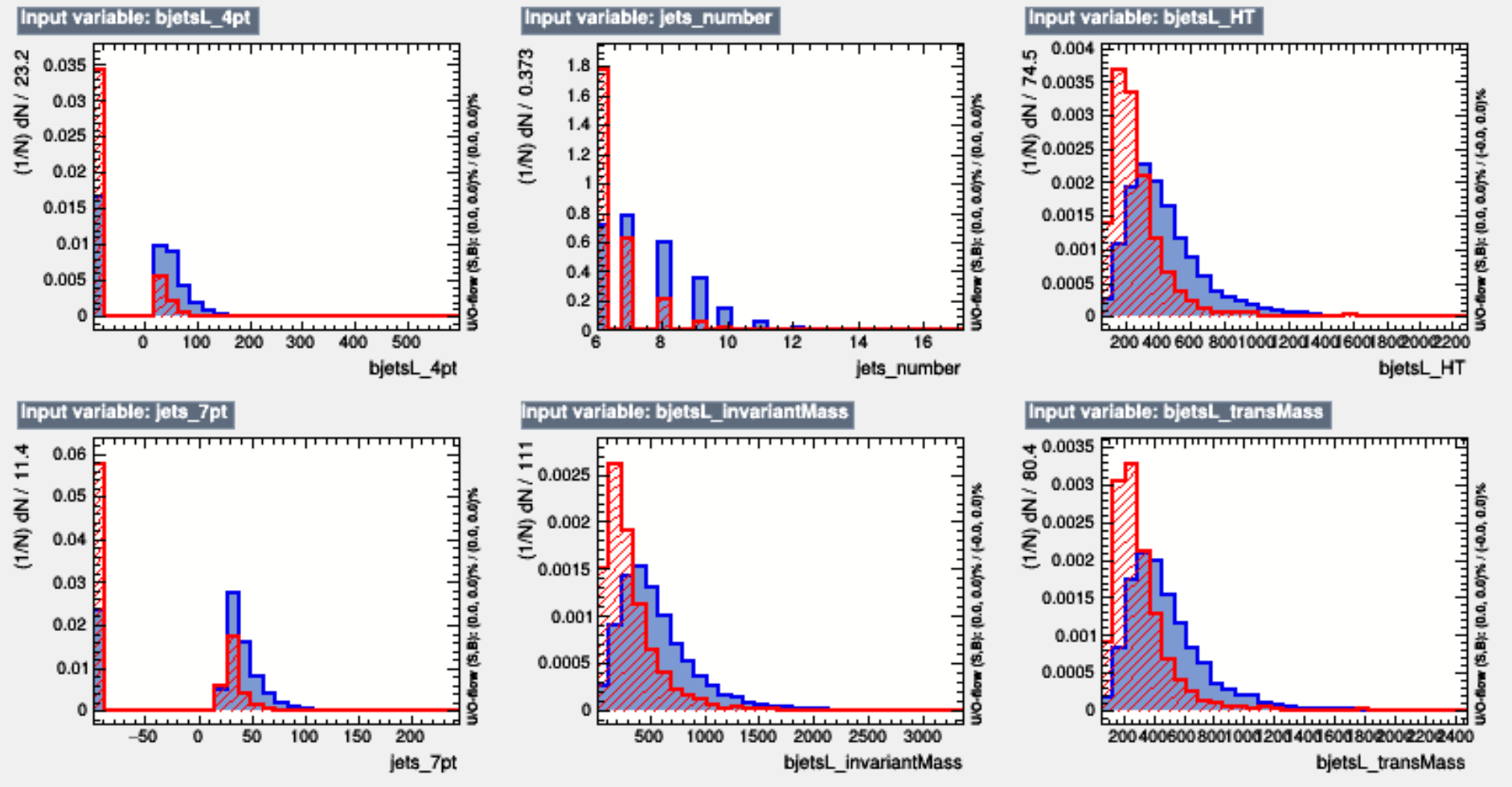
```
2Tau2OS
Raw entries:
TTTT          = 449
TT            = 1
TTX           = 111
single top    = 8
TX            = 28
DYJets        = 0
VV            = 0
VVV           = 1
QCD           = 0
Total BKG     = 0.59826

Weighted:
TTTT          = 3.23368
TT            = 66.1142
TTX           = 110.585
single top    = 1.52484
TX            = 30.1004
DYJets        = 0
VV            = 0
VVV           = 0.0187778
QCD           = 0
Total BKG     = 0.484251

Event yield:
TTTT          = 0.0177159
TT            = 0.042666
TTX           = 0.31452
single top    = 0.00388105
TX            = 0.031774
DYJets        = 0
VV            = 0
VVV           = 0.00269306
QCD           = 0
Total BKG     = 0.484251
```

```
2Tau2SS
Raw entries:
TTTT          = 190
TT            = 0
TTX           = 13
single top    = 1
TX            = 4
DYJets        = 0
VV            = 0
VVV           = 0
QCD           = 0
Total BKG     = 0.0644176

Weighted:
TTTT          = 1.75733
TT            = 0
TTX           = 11.9666
single top    = -0.00338024
TX            = 2.99069
DYJets        = 0
VV            = 0
VVV           = 0
QCD           = 0
Total BKG     = 0.0578978

Event yield:
TTTT          = 0.00962764
TT            = 0
TTX           = 0.0344717
single top    = -8.60342e-06
TX            = 0.00315698
DYJets        = 0
VV            = 0
VVV           = 0
QCD           = 0
Total BKG     = 0.0578978
```

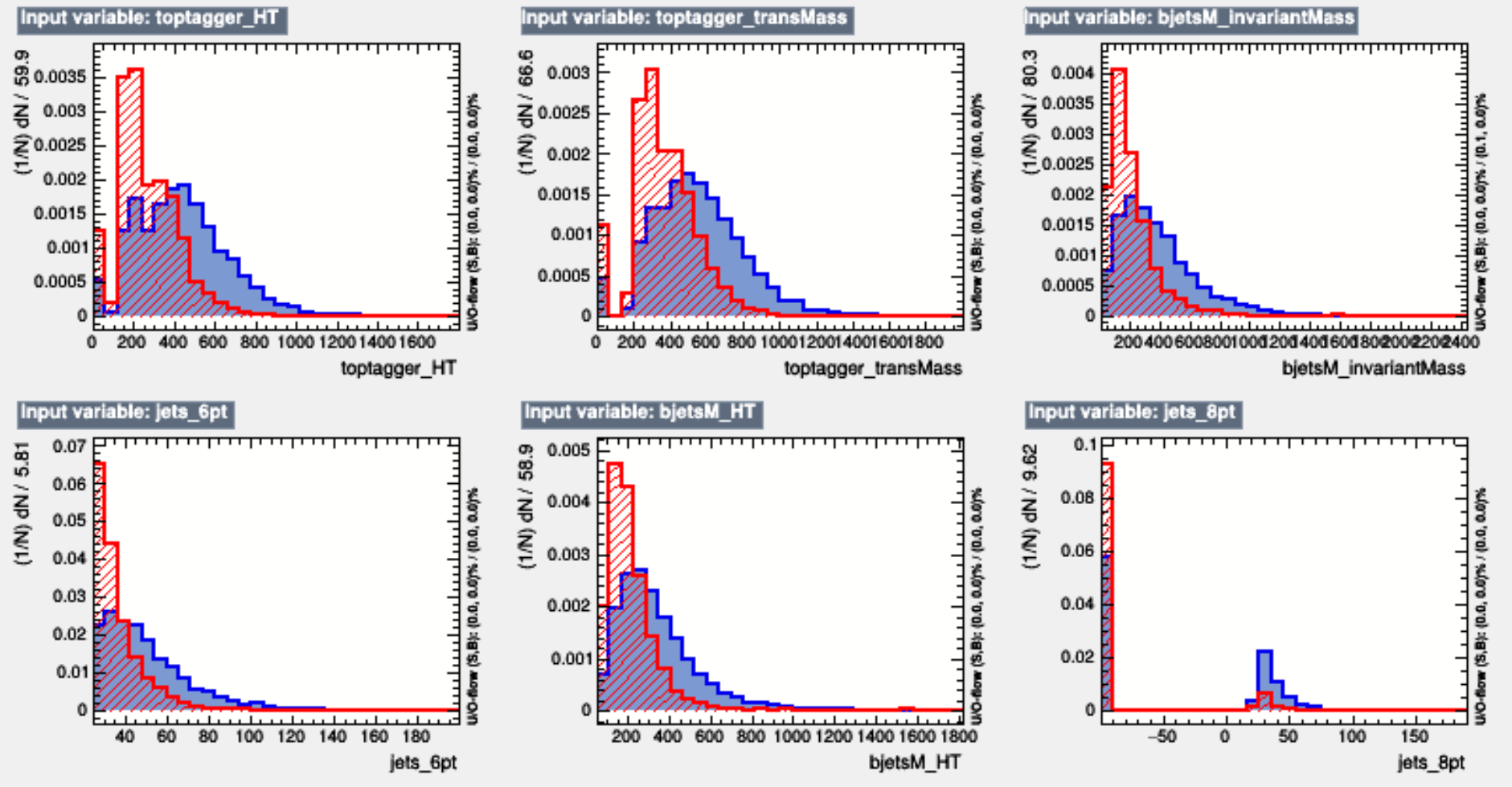
Step1: Input Varible Distribution



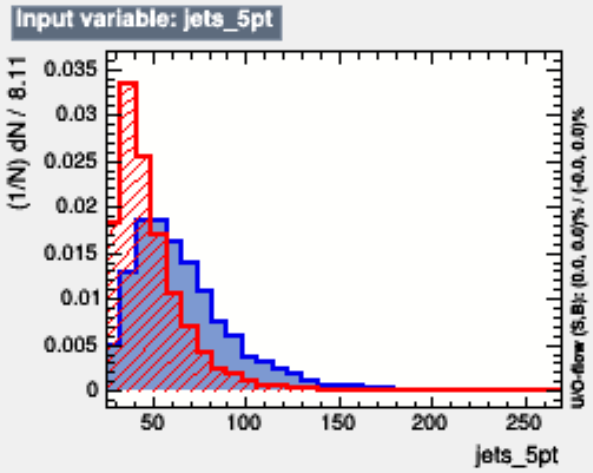
Step1:Input Varible Distribution

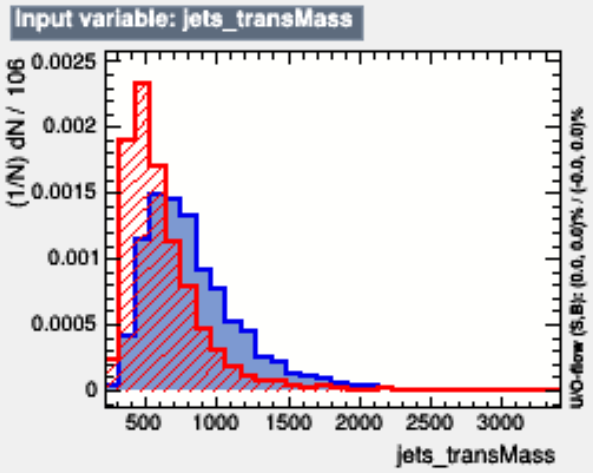


Step1:Input Varible Distribution

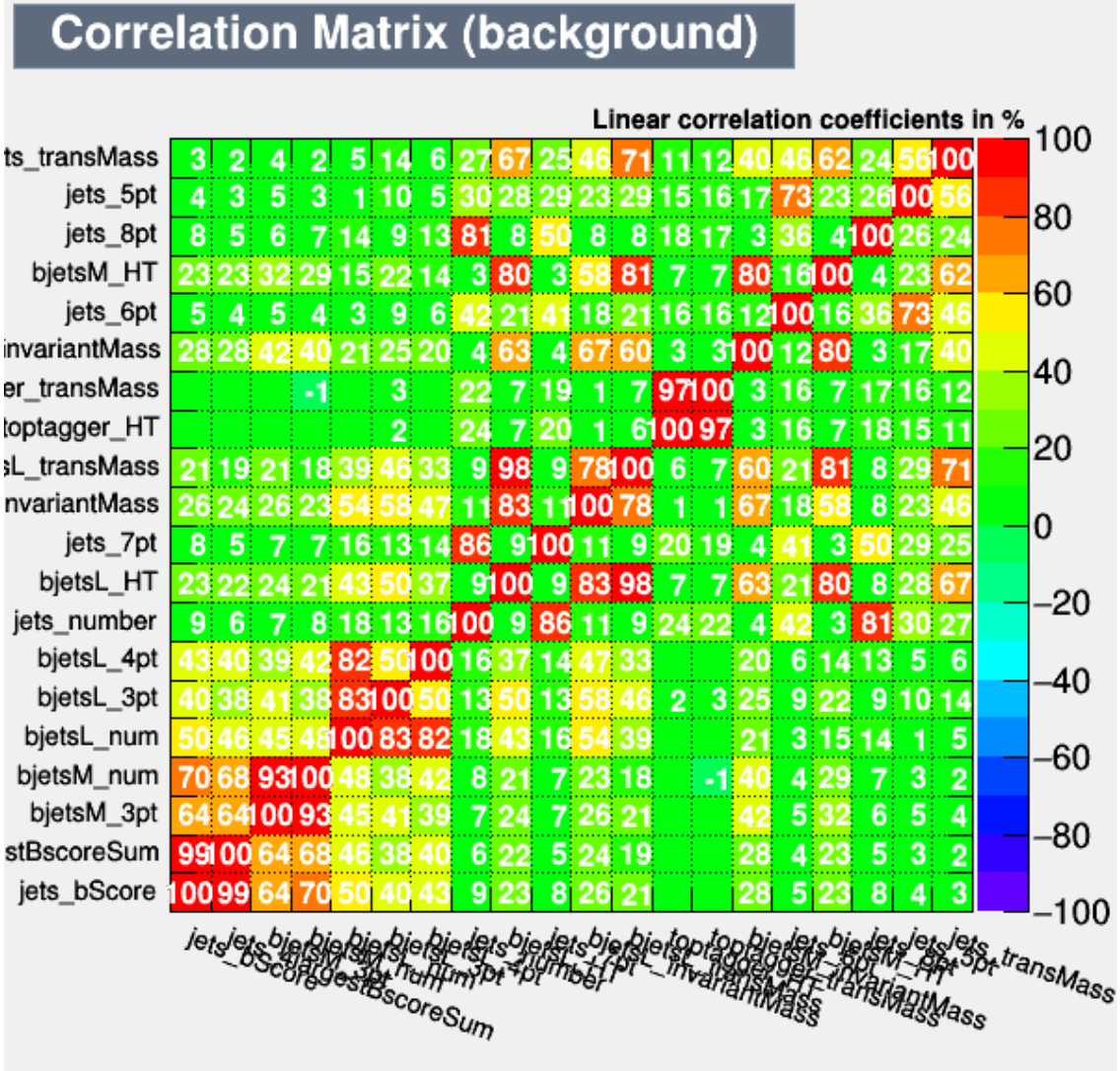


Step1:Input Varible Distribution

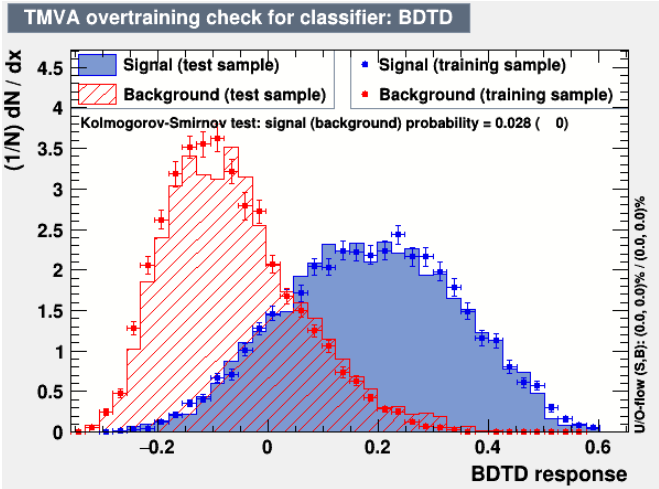


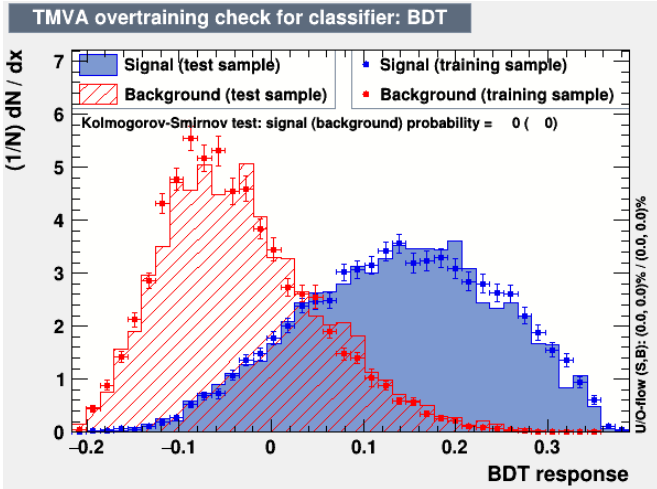


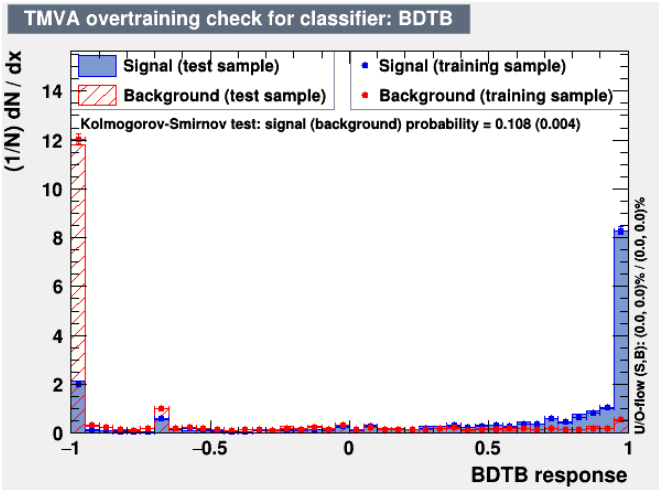
Step1: Correlation

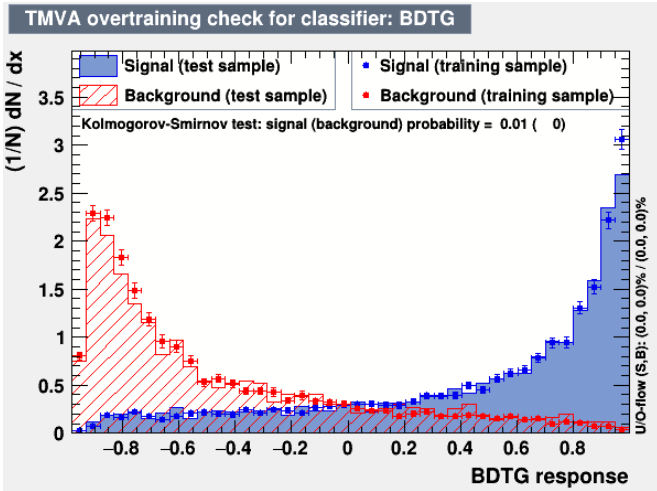


Step 1: OverTrainining

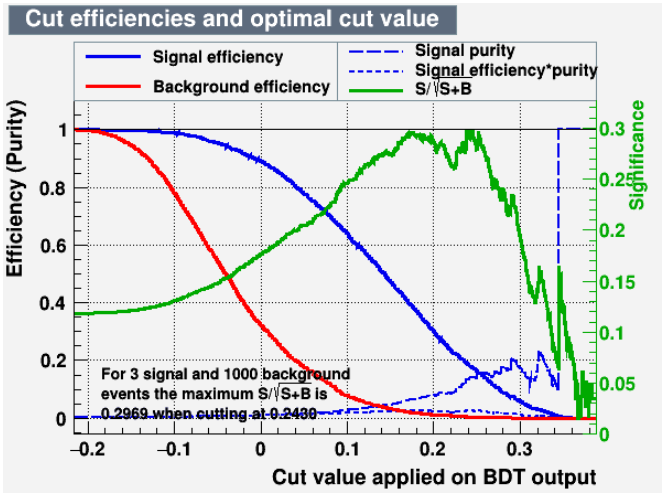


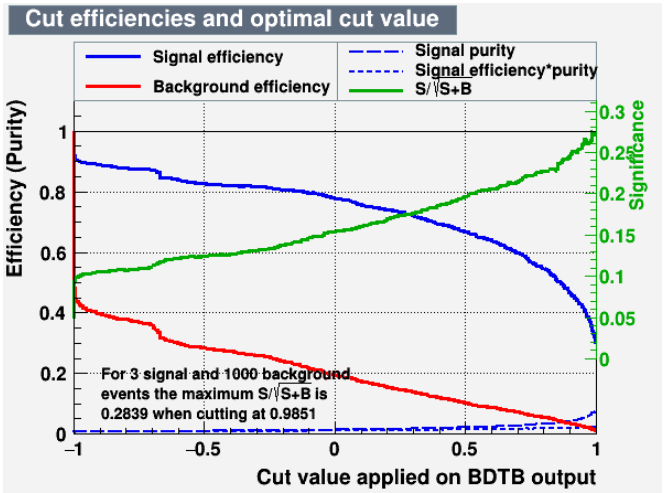


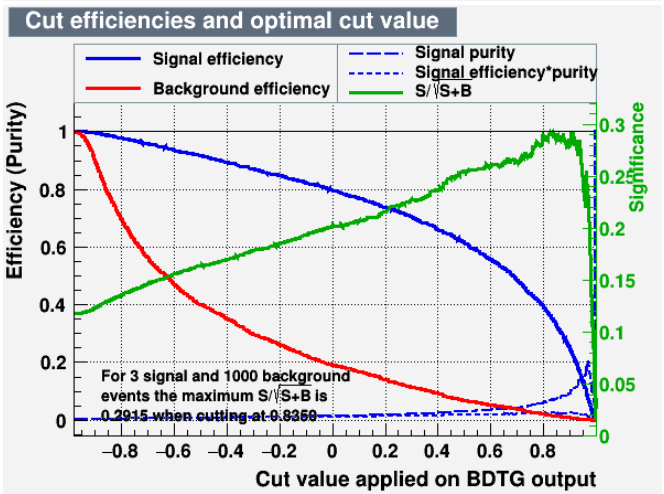


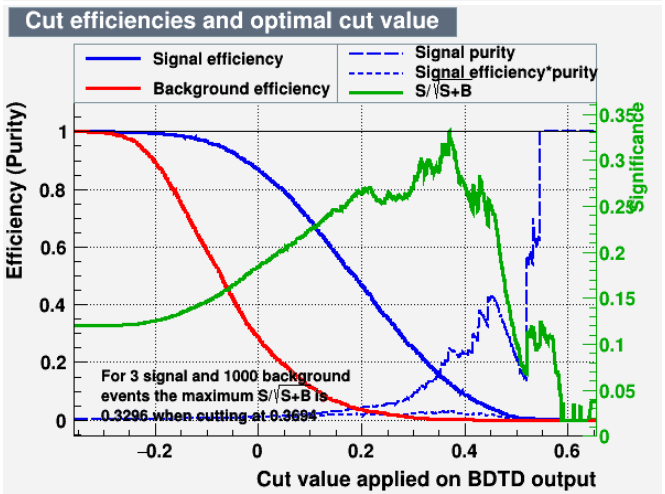


Step1: Significance

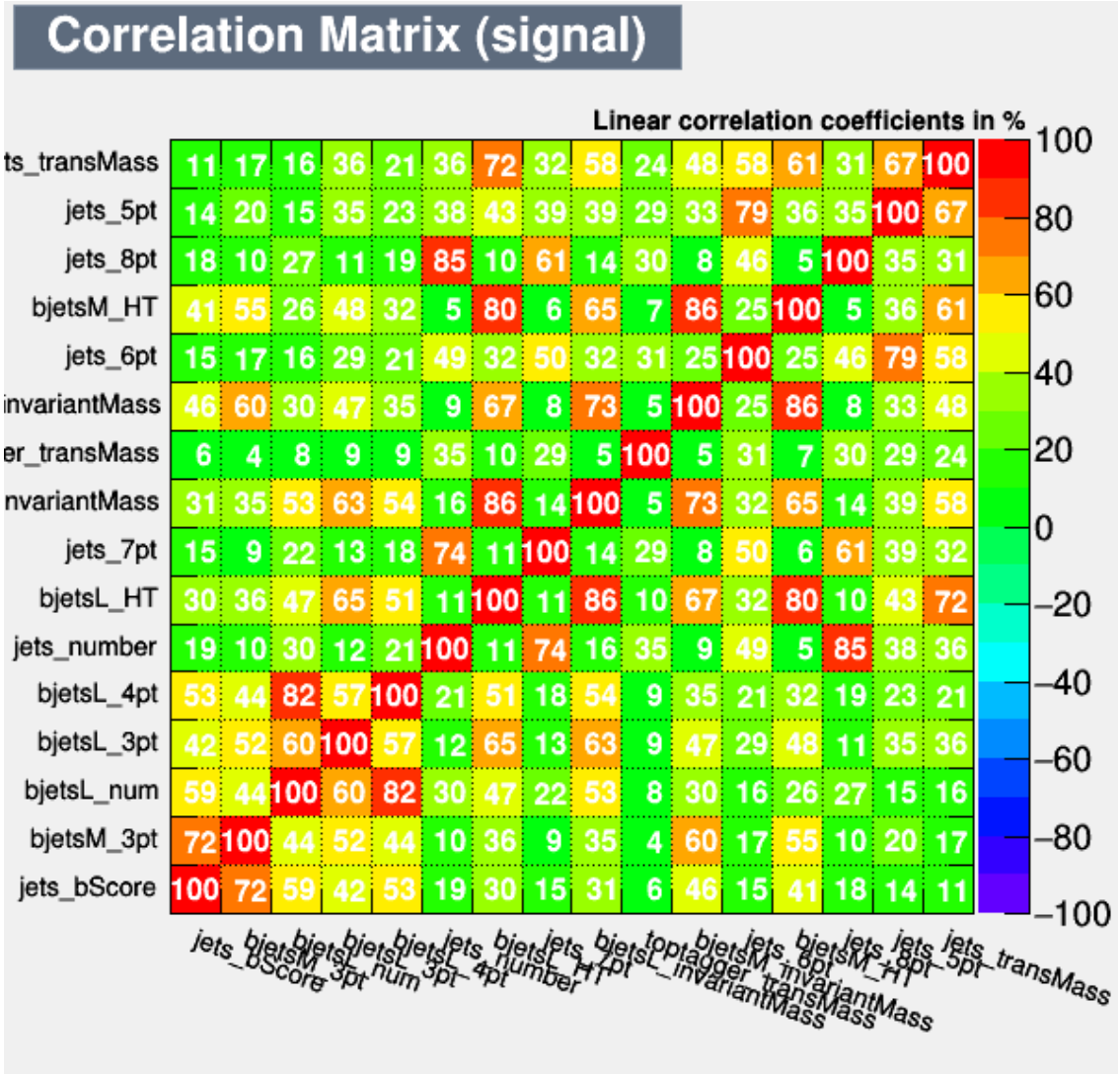




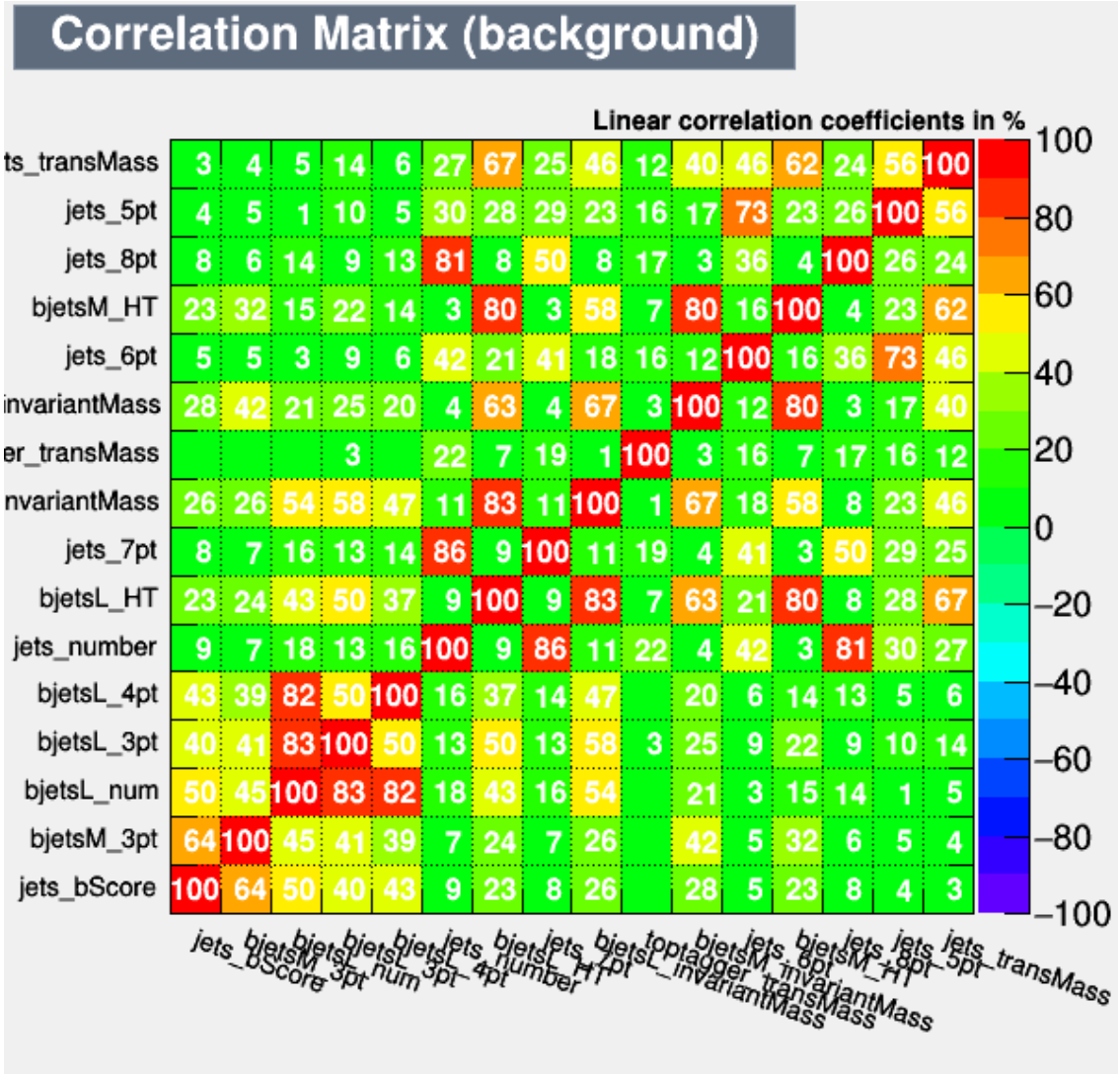




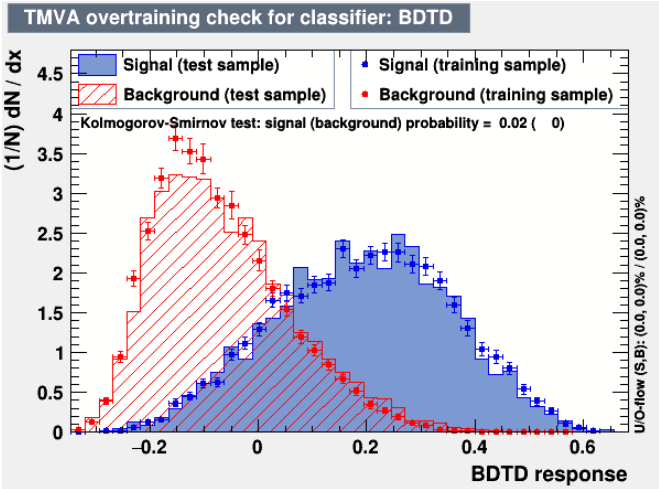
Step 2: Correlation

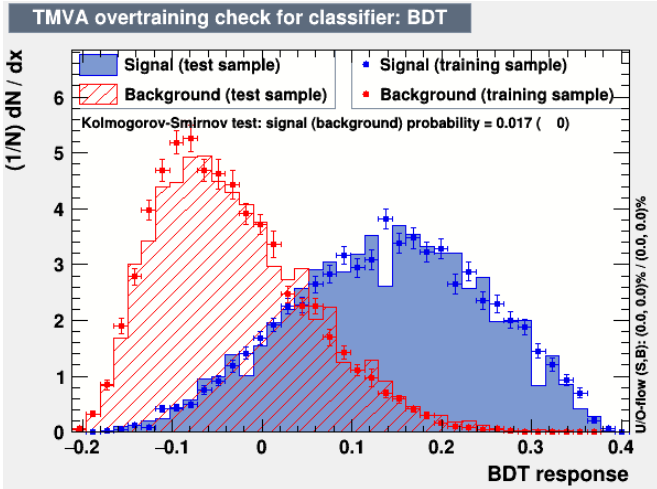


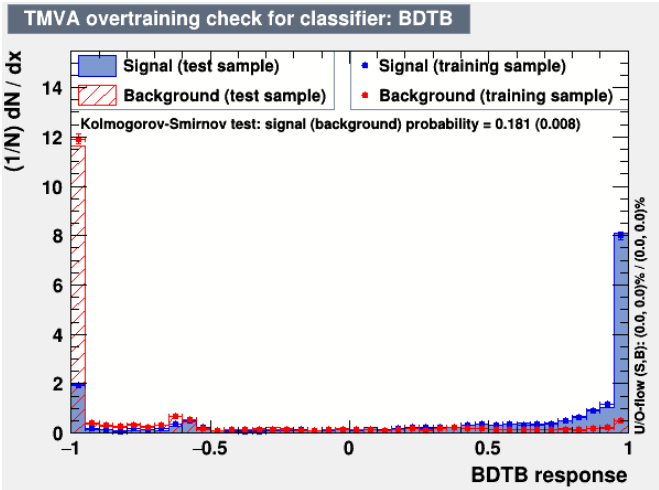
Step 2: Correlation

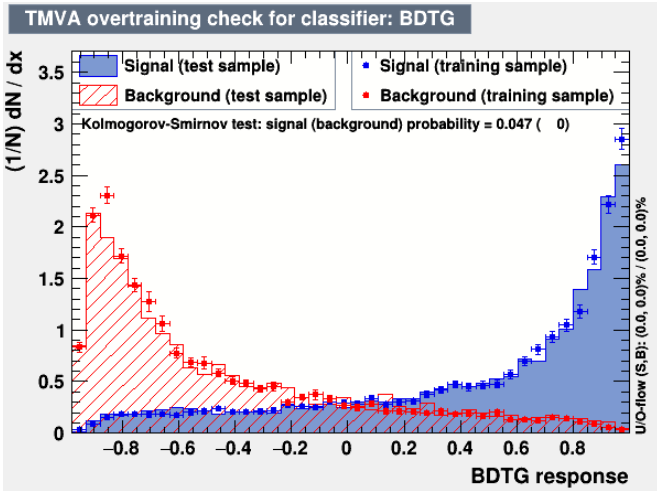


Step 2: OverTrainining

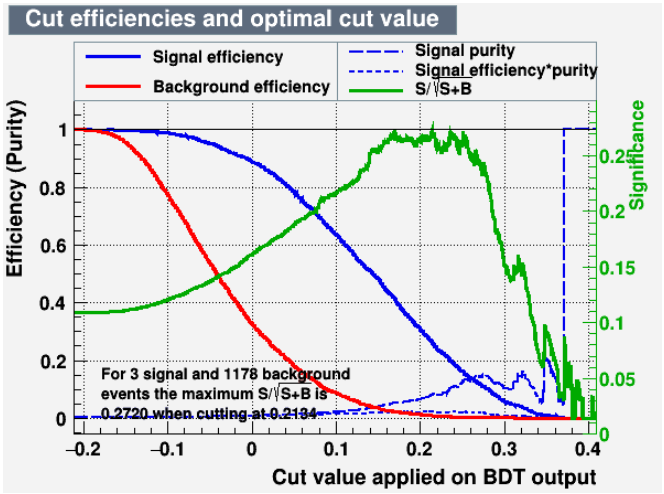


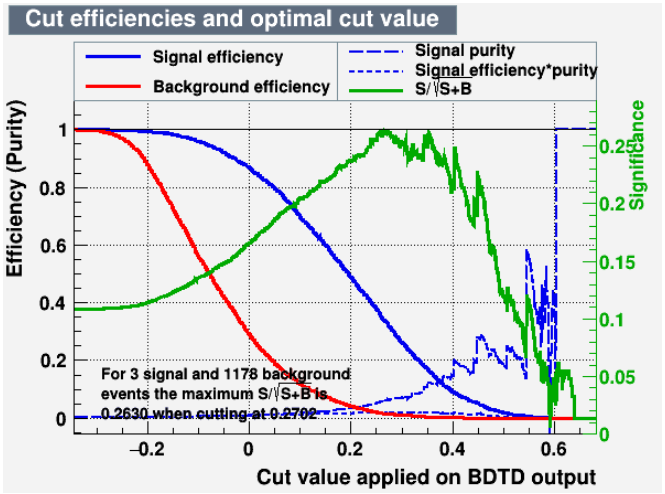


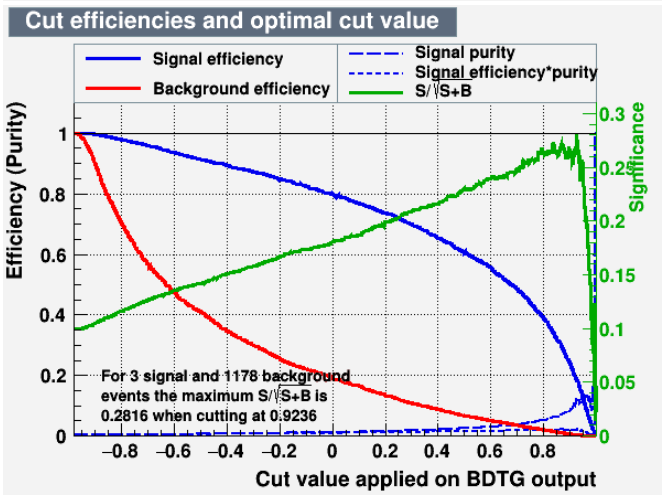




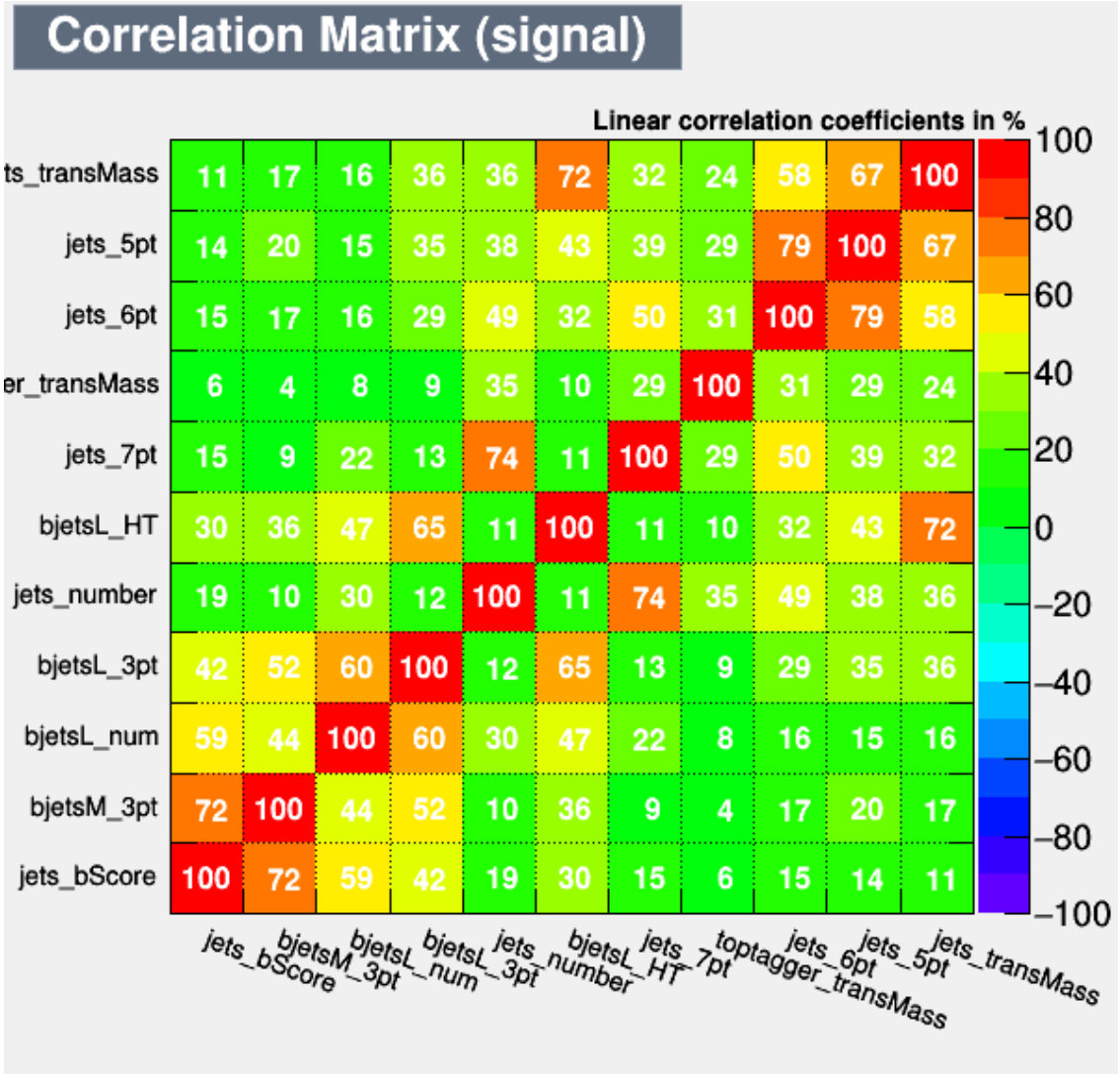
Step 2: Significance



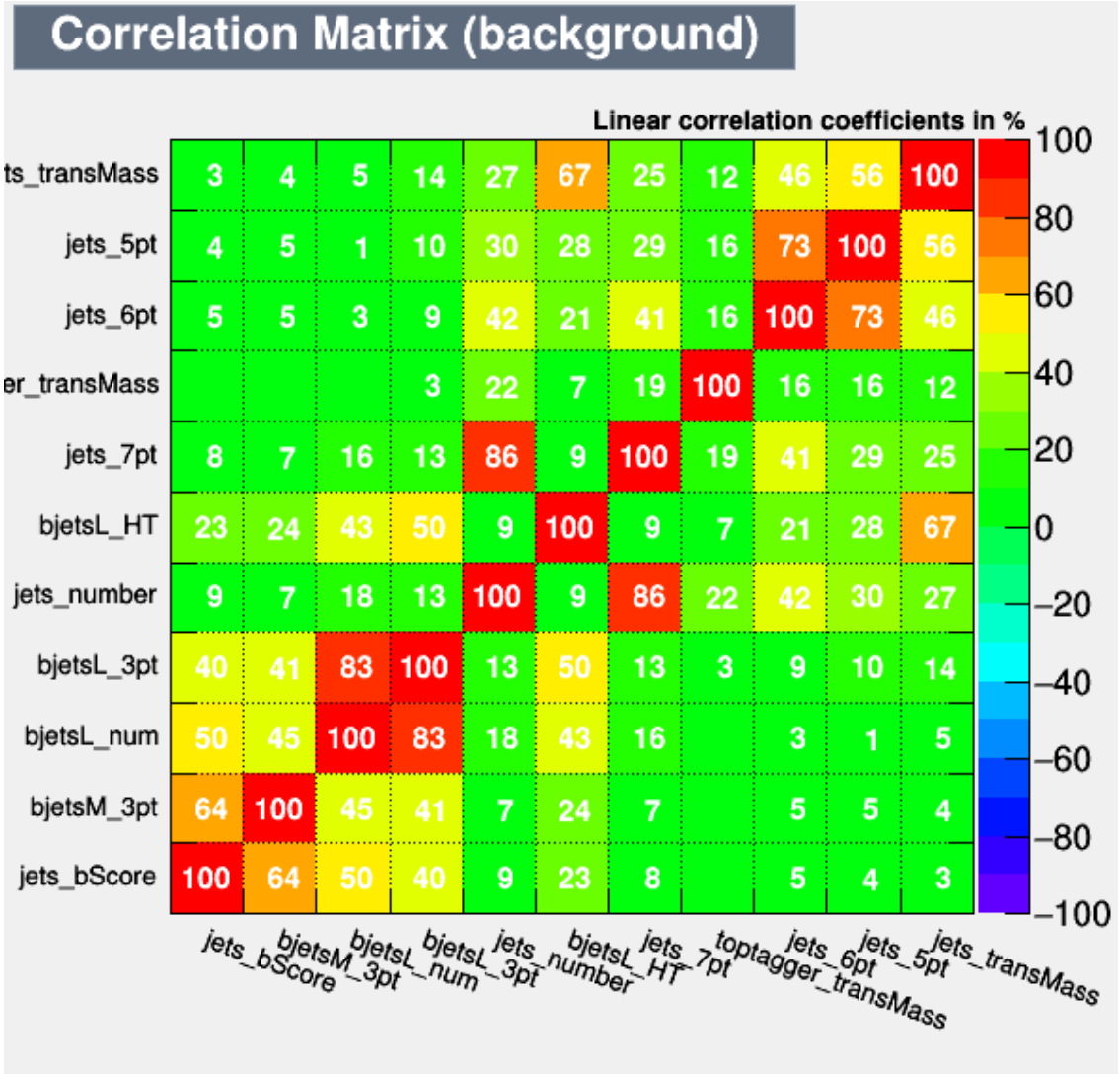




Step3: Correlation



Step3: Correlation



Step3: Significance