Probing the H $\rightarrow b\,\bar{b}\,\gamma$ vertex using MVA at ATLAS/LHC

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In collaboration with Aidan Kelly

Motivation of the project

- The study of the Higgs boson and its couplings with different particles is fundamental not only to test the predictions made by the Standard Model but also to the pursuit of new physics.
- As such, in this project we focused on the $H \rightarrow b\,\bar{b}\,\gamma$ channel in regards to possible anomalous couplings.
- In this case it was used Multivariate Analysis in order to exploit the relations of different variables and optimize the signal/background separation process for this channel.

Signal and Background diagrams

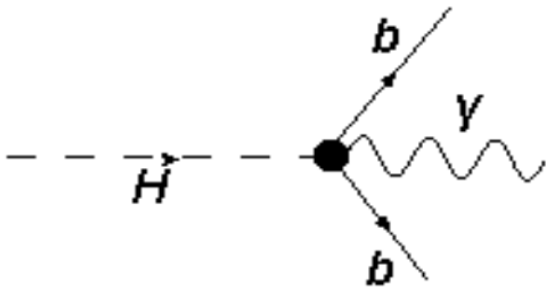


Figure: $H \to b\,\bar{b}\,\gamma$ effective vertex

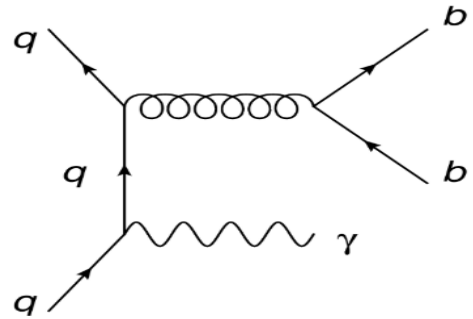


Figure: Background - $bb\gamma$

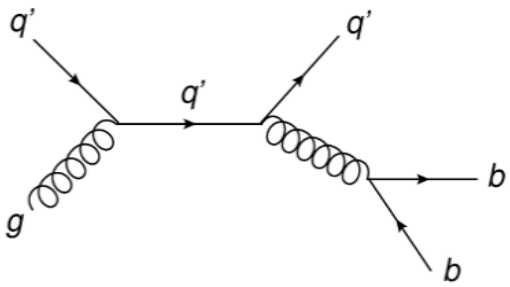


Figure: Background - bbj

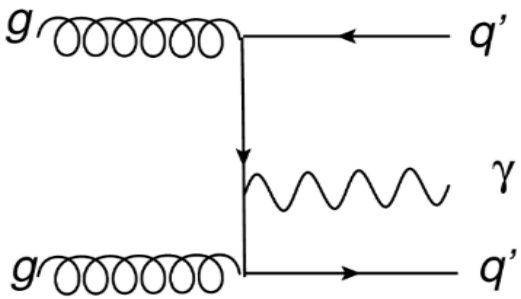


Figure: Background - $jj\gamma$

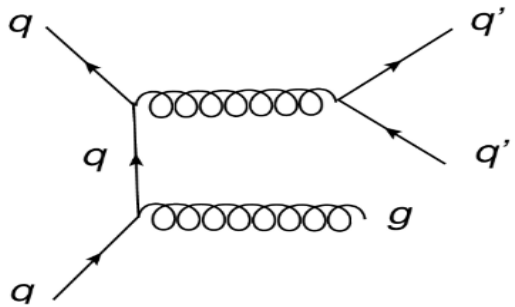
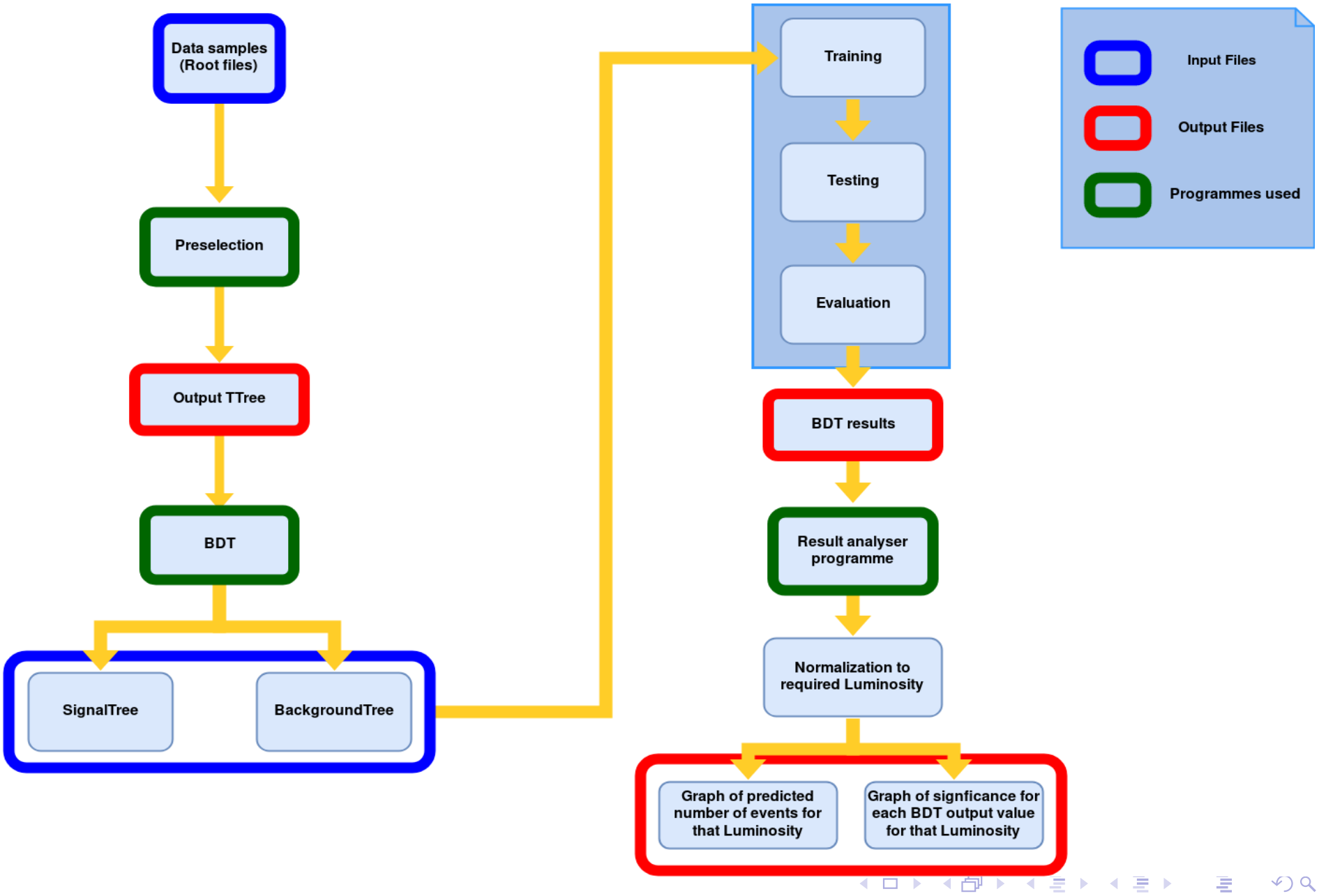


Figure: Background - jjj

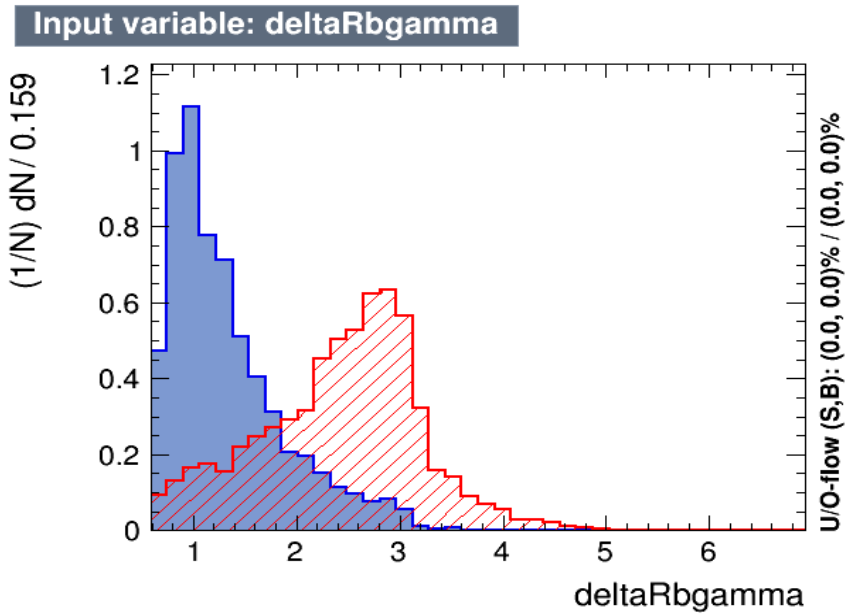
Diagram of the project

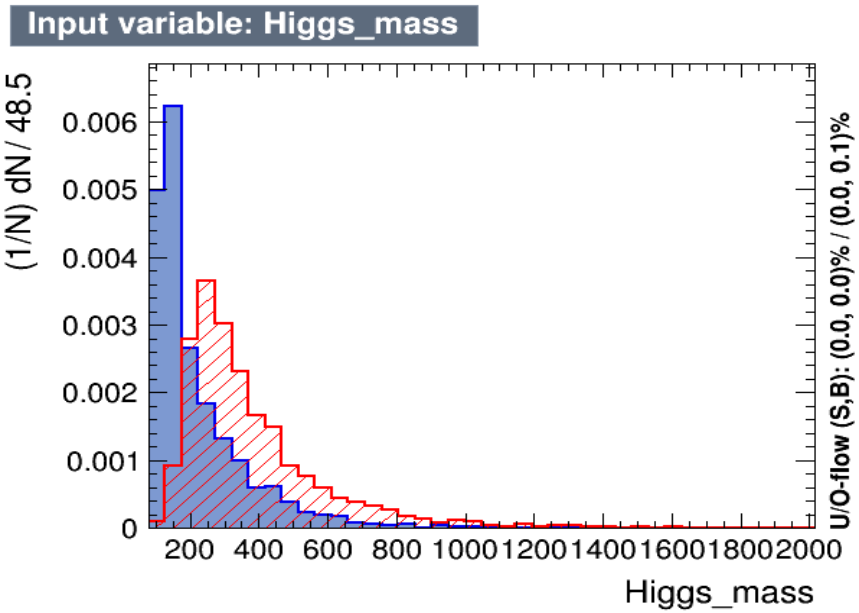


Selected cuts method - cuts used

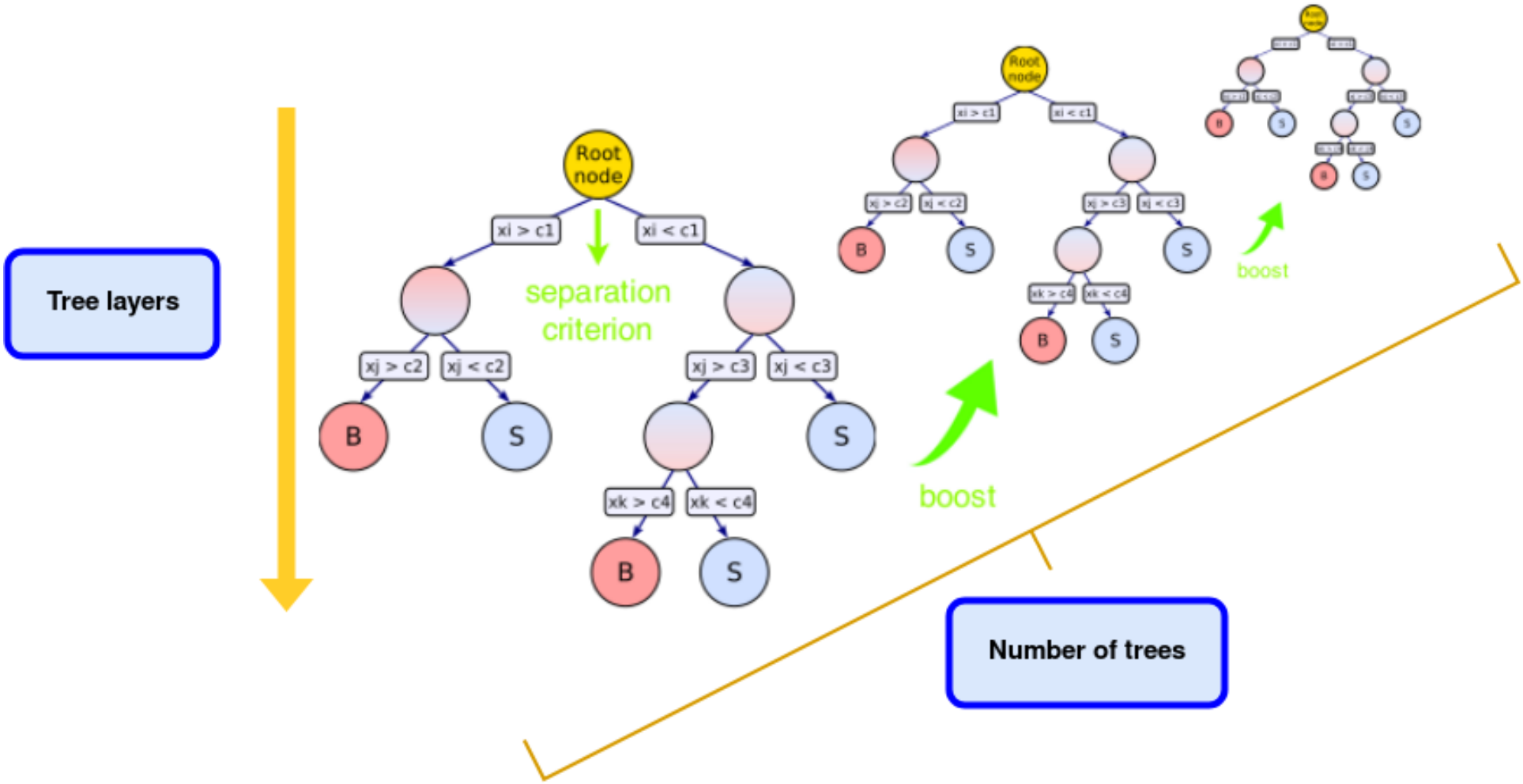
- **At least one photon**
- **Has a photon with a p_T of at least 80 GeV**
- **At least two jets**
- **At least two b-tagged jets**
- **$\Delta R_{b\gamma}$ minimum less than 1.5**
- **Sphericity of at least 0.02**
- **Higgs_mass within 100 and 135 GeV**

Significance			
	$\mathcal{L} = 300\,\text{fb}^{-1}$	$\mathcal{L} = 1000\,\text{fb}^{-1}$	$\mathcal{L} = 3000\,\text{fb}^{-1}$
Selected cuts	0.461	0.842	1.46

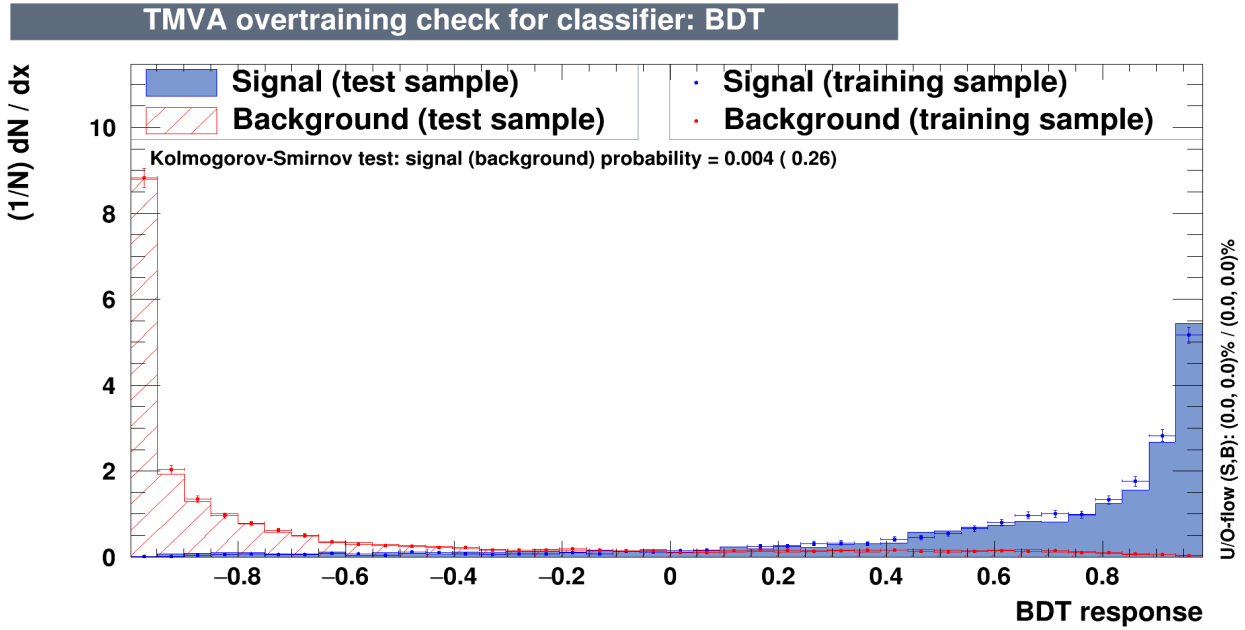


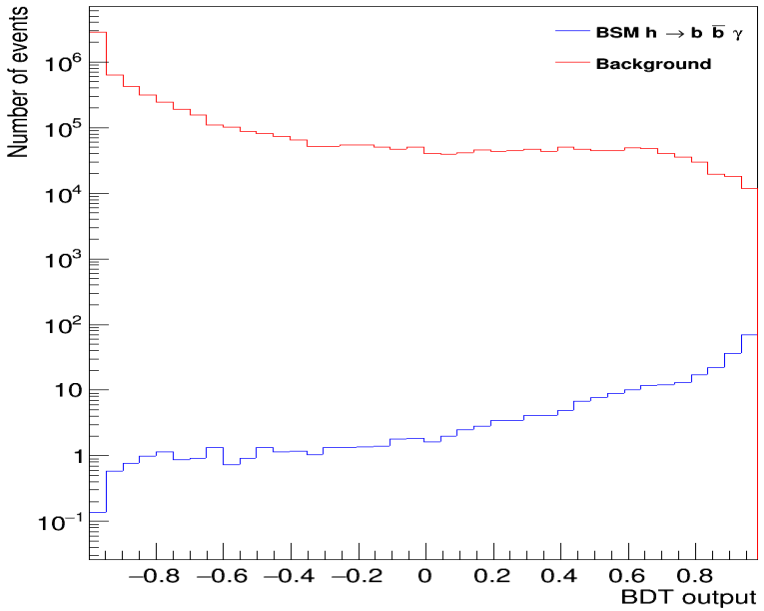


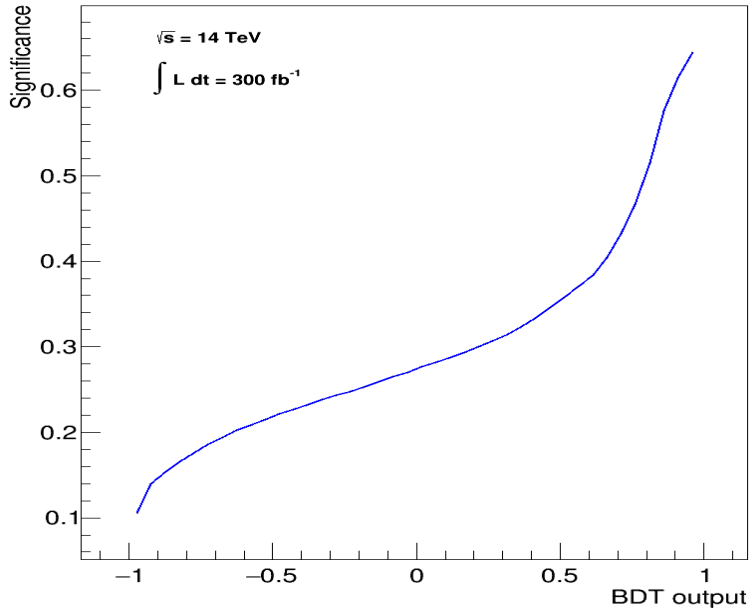
MVA - Method used



MVA - Results


TMVA overtraining check for classifier: BDT
Signal (test sample)
Background (test sample)
Signal (training sample)
Background (training sample)
Kolmogorov-Smirnov test: signal (background) probability = 0.004 (0.26)
(1/N) dN / dx
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%
BDT response


BSM h → b b̄ γ
Background
Number of events
BDT output


√s = 14 TeV
∫ L dt = 300 fb⁻¹
Significance
BDT output

Significance Table for different Luminosities and configurations

BDT Configuration	$\mathcal{L} = 300\,\text{fb}^{-1}$	$\mathcal{L} = 1000\,\text{fb}^{-1}$	$\mathcal{L} = 3000\,\text{fb}^{-1}$
Selected cuts	0.461	0.842	1.46
1500 Trees; Tree depth = 2	0.592	1.08	1.87
1000 Trees; Tree depth = 4	**0.645**	**1.18**	**2.04**
1000 Trees; Tree depth = 2	0.571	1.04	1.81
400 Trees; Tree depth = 2	0.493	0.899	1.56
400 Trees; Tree depth = 4	0.611	1.11	1.93
400 Trees; Tree depth = 6	0.620	1.13	1.96

Table: Max significance values for the selected cuts method and for different BDT configurations across three Luminosities

Conclusion

- We used Boosted Decision Trees in order to optimize the signal and background separation in the $H \to b\,\bar{b}\,\gamma$ process;
- By performing a Multivariate Analysis we managed to get up to an increase of 40 % in significance (for $300\,\text{fb}^{-1}$);
- The best BDT configuration proved to be using 1000 Trees and Tree depth $= 4$;
- Due to such results we can conclude that using this method can be a powerful tool in the search of this type of events in the future.

Boosting H->bb at high p_{T_V} with MVA in ATLAS at LHC

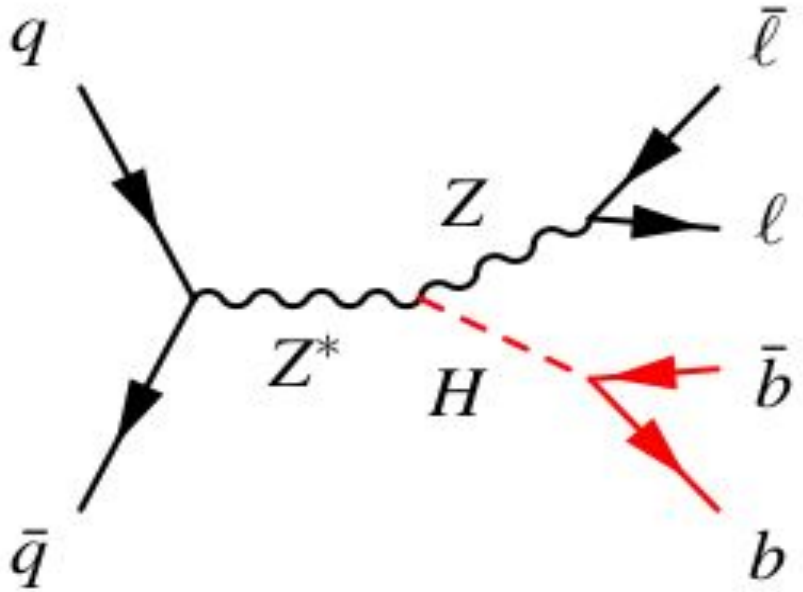
Vânia Nunes

Supervisors:
Rute Pedro
Ricardo Gonçalo

Introduction

- H->bb is the largest branching ratio of the Higgs decay (57.7%), for mHiggs=125GeV
- This decay's measurement is fundamental to determine the Higgs boson decay width and couplings, and to confirm or reject SM hypothesis
- bb decay of Higgs is one of the most challenging searches at the LHC, since the bb background cross-section is orders of magnitude superior to the Higgs production cross-section.
- After years of search, it's measurement was announced in 28 Aug 2018
- Future: study Higgs boson at high pT
    a. Sensitive to new physics

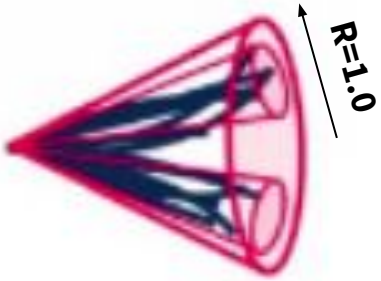
Signal



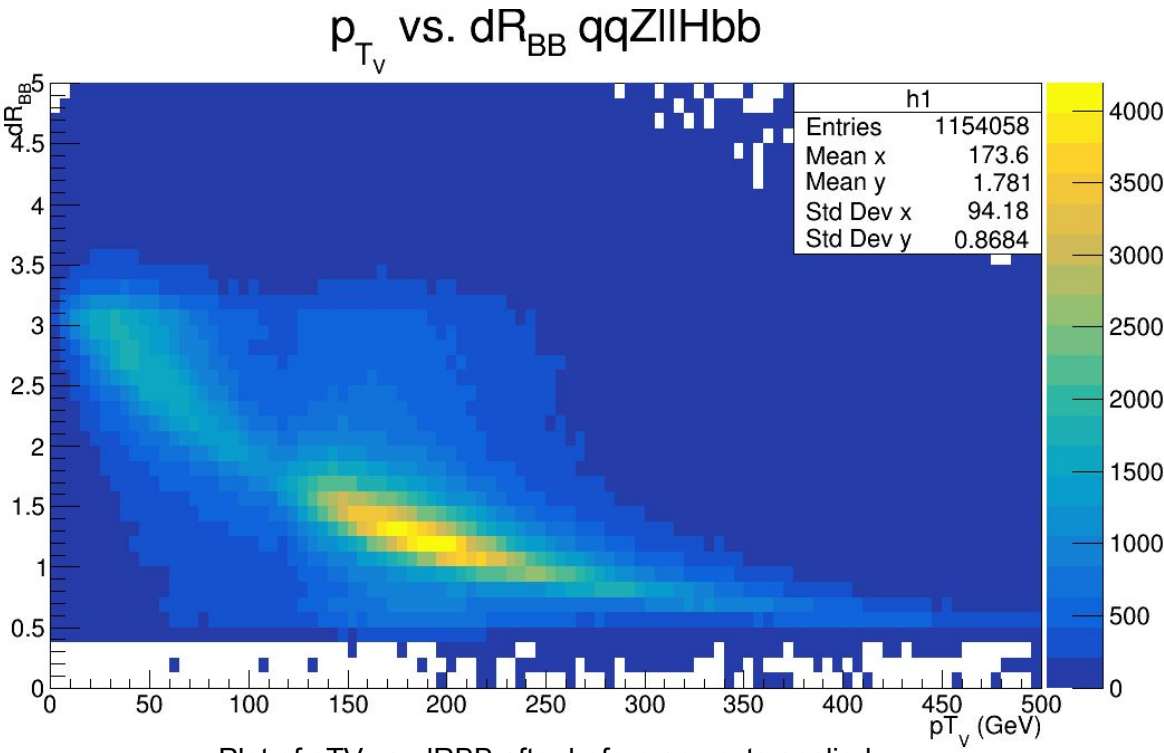
- ➔ 2 isolated leptons
- ➔ Same flavor leptons
- ➔ 2 b-jets

Reconstruction of the H->bb signal

RESOLVED, anti-kt R=0.4 algorithm
algorithm



BOOSTED, anti-kt R=1.0 algorithm



Plot of pTV vs. dRBB after before any cuts applied

Objectives

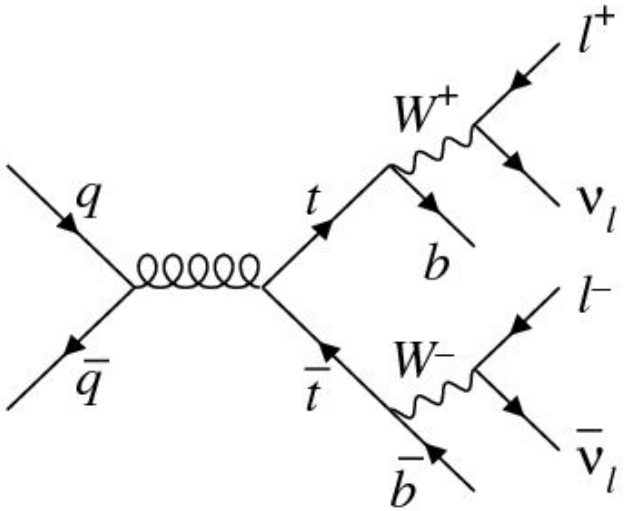
Optimize the Higgs boson selection at high pT, for pTZ>250GeV

-Study significance of events reconstructed in the resolved and boosted regimes;

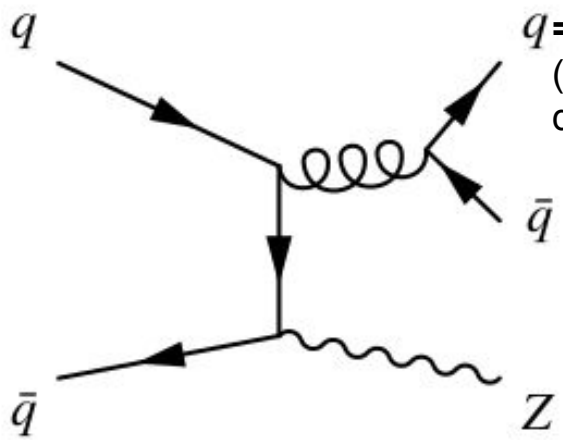
-Compare this methods and try to improve the significance of our results, by applying a multivariate method (BDT) to the simulations.

-Compare MC simulations with data obtained from the ATLAS detector in 2017

Main source of background



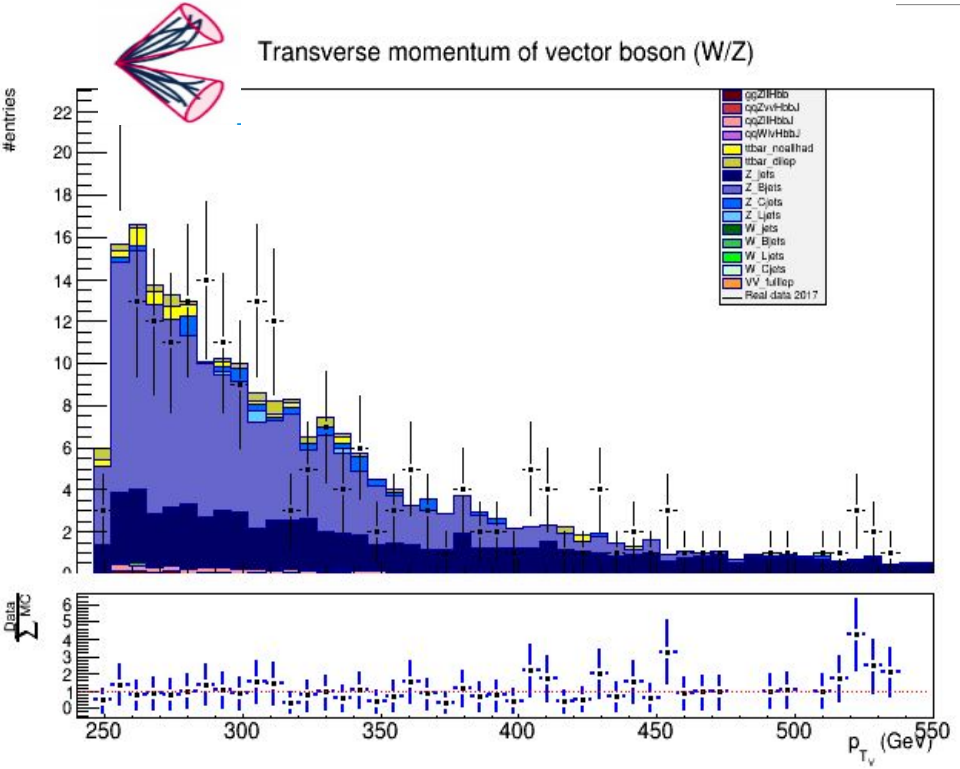
a) ttbar->WW->ll

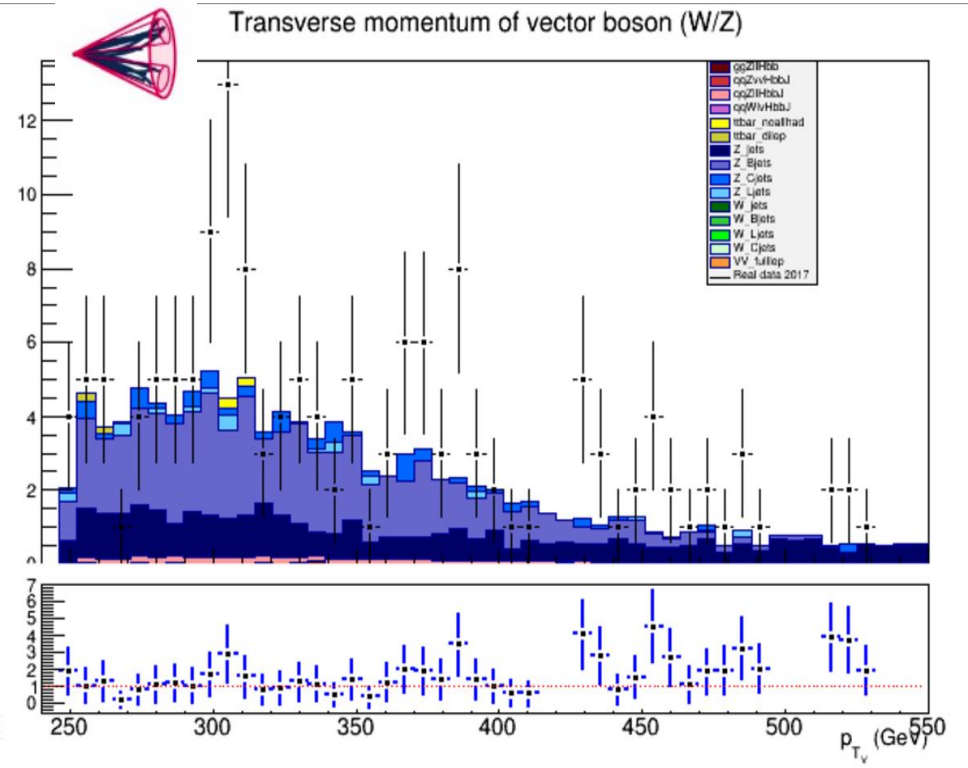


q = **B** (bottom), **C** (charm), **L** (up, down, strange)

b) Z+jets (B, C,L)

Regime RESOLVED and BOOSTED





ttbar

Signal

Z+Bjets

Z+jets

Z+Cjets

Z+Ljets

Multivariate analysis

Applied after requiring Z->ll selection and pTV>250GeV;

BDT trained with 400 trees and depth=4

REGIME RESOLVED

- pTL1 , PTL2
- mLL
- flavL1, flavL2
- chargeL1 , charge L2
- pTV
- nJets
- etaJ3, etaB1, etaB2
- pTB1, pTB2
- dRBB (Radial distance)

REGIME BOOSTED

- nFatJets
- nbTagsInFJ (number of b-subjets inside fat jet)
- fatj1xbbResult (used to identify hadronically decaying boosted bosons)

BDT WITH NOMINAL VARIABLES

- nBJets
- nJets
- MET (missing transverse energy)
- pTB1 and pTB2
- mBB
- dEtaBB (Difference of pseudorapidity)
- dRBB (Radial distance)
- dEtaVBB

BDT WITH NOMINAL AND FAT JET VARIABLES

- nominal variables
  +
- fatj1phi
- fatj1mass
- fatj1Tau21
- fatj1C2
- fatj1D2

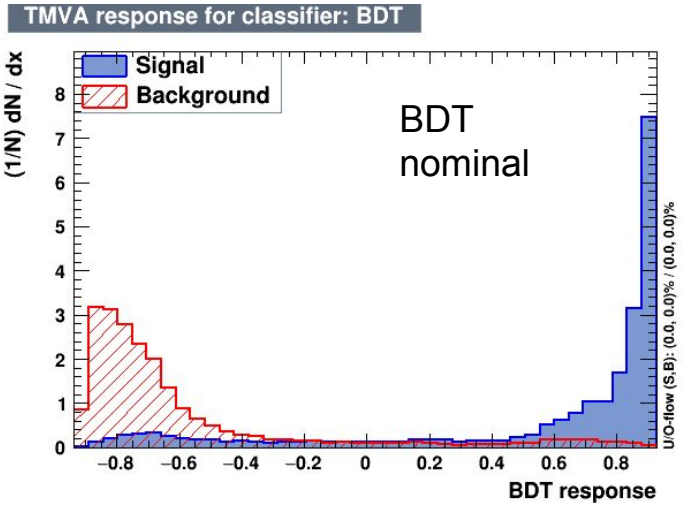
Significance

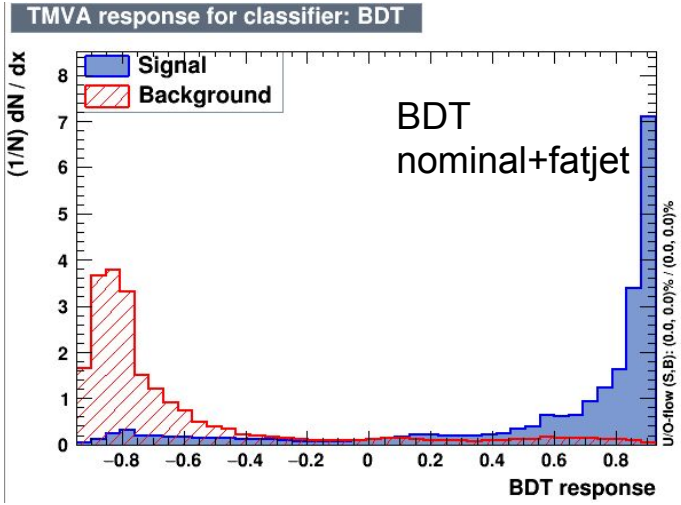
$$Signal/\sqrt{(Background)}$$

	Efficiency (%)	Significance
Initial Cuts $(Z->ll+pTV>250GeV)$	100	0,01
Resolved	19,62	0,31
Boosted	19,14	0,43
BDT with nominal variables	20,00	0,96
BDT with nominal+fatjets variables	20,00	0,95

Table 1: For a signal efficiency of approximately 20%

	Efficiency (%)	Significance
BDT with nominal variables	50	0,59
BDT with nominal+fatjets variables	50	0,59





Conclusion

- Implemented and studied different methods of reconstructing the ZH->ll bb signal at high pT
- Significances obtained from BDT’s are much better that any other obtained from other analysis (RESOLVED or BOOSTED);
- Significances obtained from BDT with nominal variables and BDT with fat jet variables are very similar, for both efficiencies of 20% and 50%

Optimizing double Higgs decay with MVA at FCC luminosities

Filipe Barroso

Supervisores:

Rute Pedro Ricardo Gonçalo

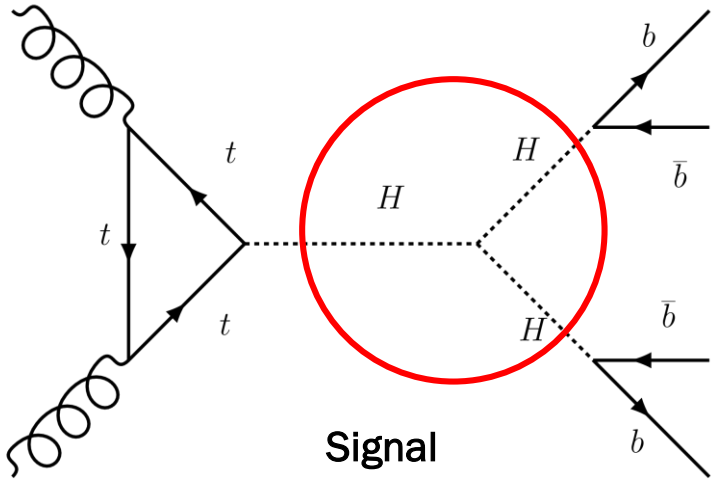
Com apoio de:

Ana Luísa Carvalho

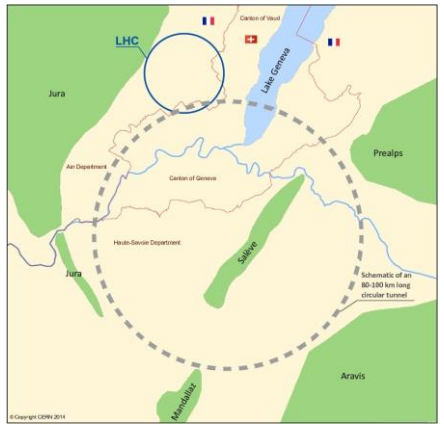
Why study this process?

- It involves a Higgs cubic self-interaction. It's detection allows the measure of cubic coupling constant.

- FCC-hh might be able detect a double Higgs decaying to $b\bar{b}b\bar{b}$, which is a signature of this process.



Signal
(built using https://feynman.aivazis.com/)

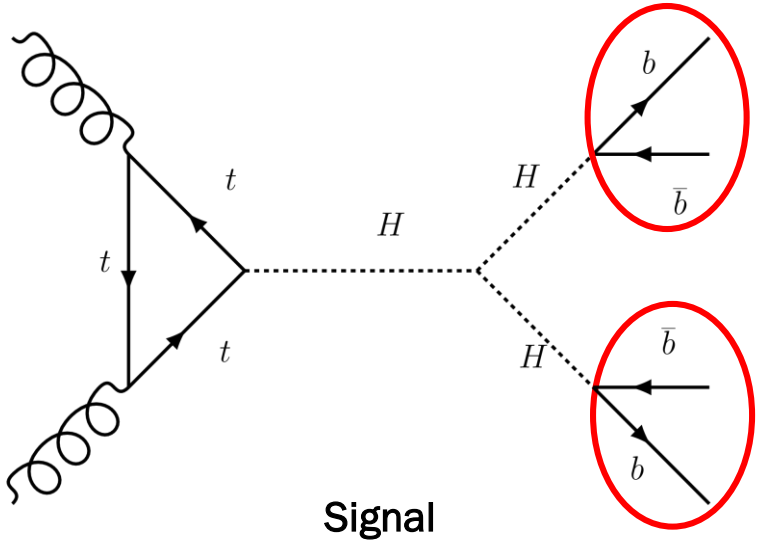


Map of the Future Circular Collider (FCC). It would achieve a CM energy collision of 100 TeV.

Signal and Backgrounds

- $H \rightarrow b\bar{b}$ decay occurs 57,7% of the time.
- B-quark hadronization is well identified.
- Higgs produced with very high Pt.

Pt leading jet > 200 GeV
Pt subleading jet > 200 GeV



Signal
(built using https://feynman.aivazis.com/)

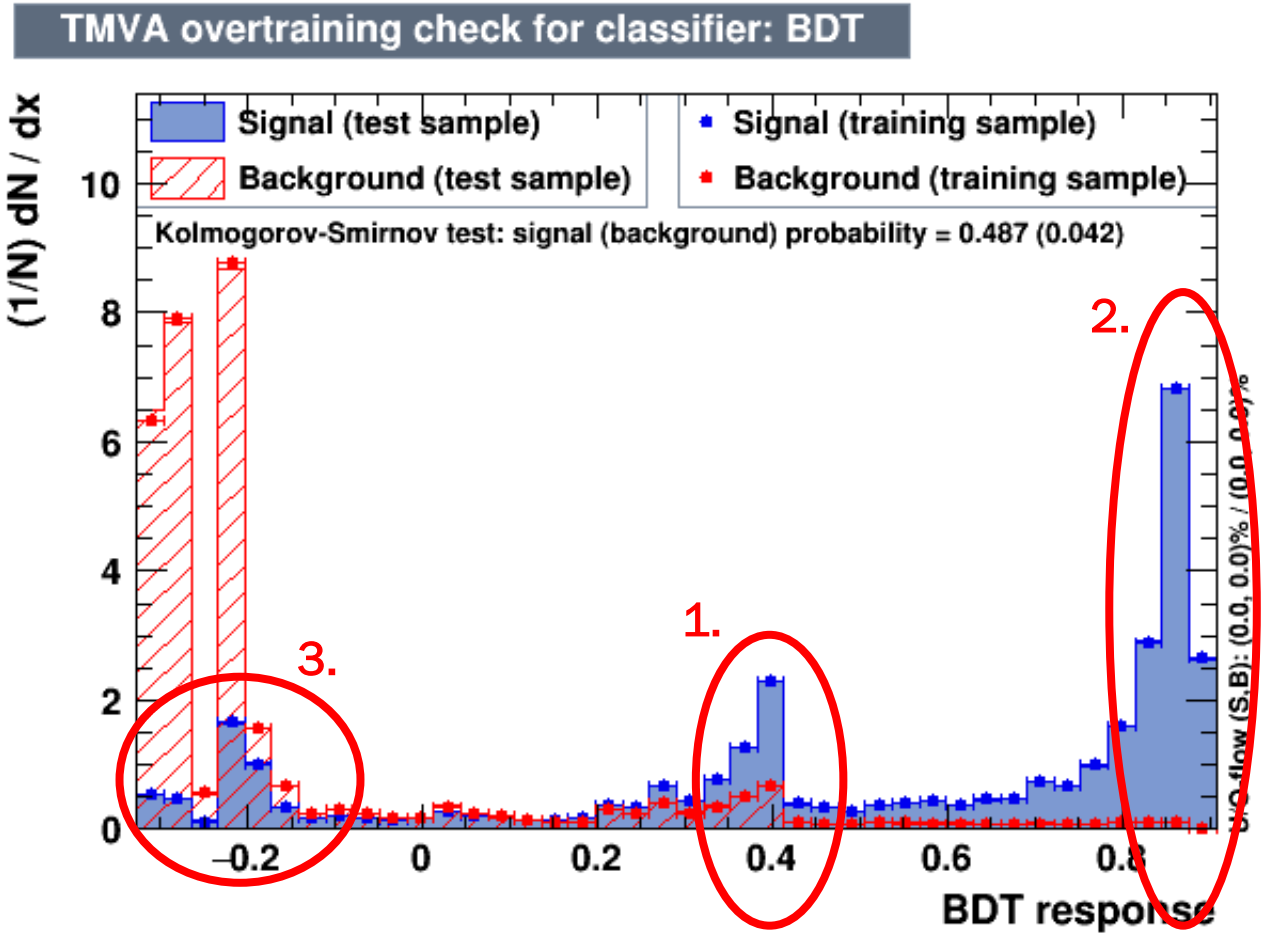
QCD double jets

$b\bar{b}b\bar{b}$ production

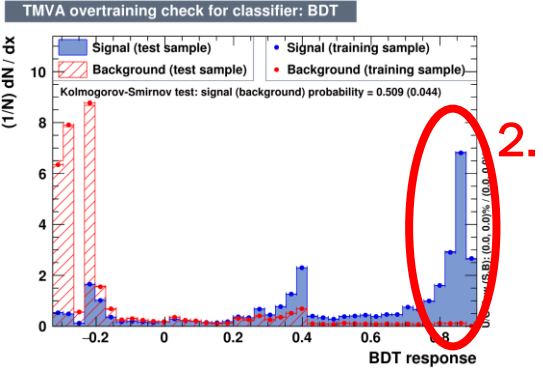
$t\bar{t}$ jets

→ Backgrounds

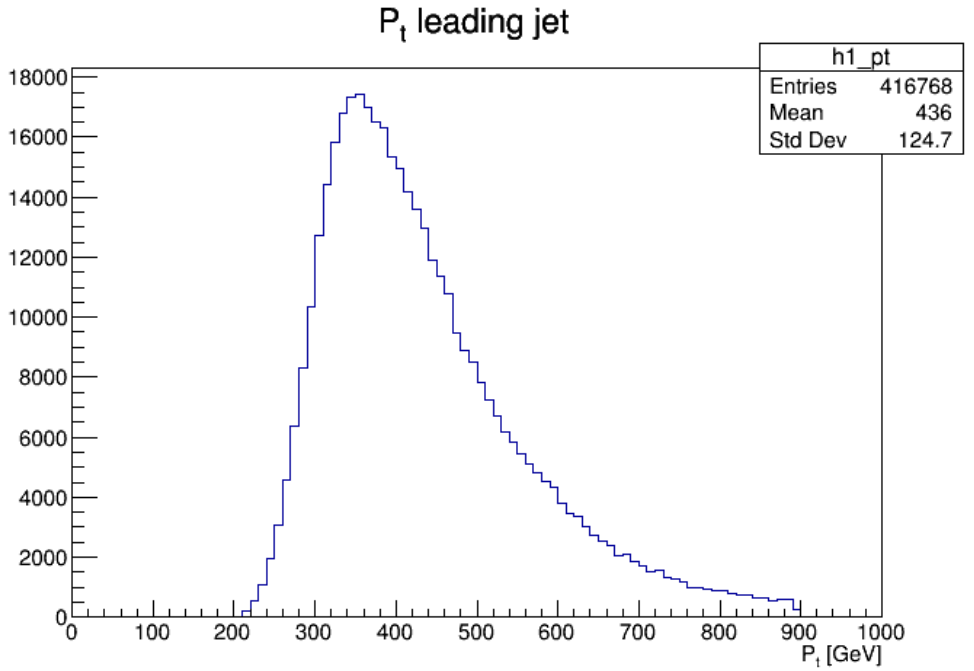
BDT analysis



- Invariant mass of leading e subleading jets;
- Transverse Momentum of leading and subleading jets
- The vector sum of the projection of each jet; momentum in the transverse plane;
- τ_{21} of leading and subleading jets;
- Second Fox-Wolfram momentum of leading and subleading jets.

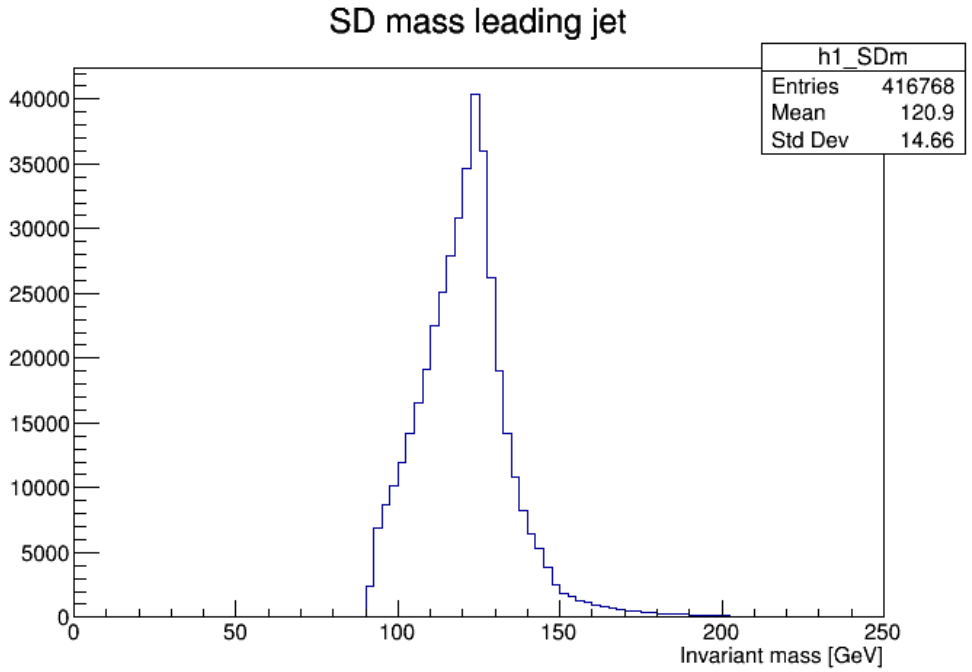


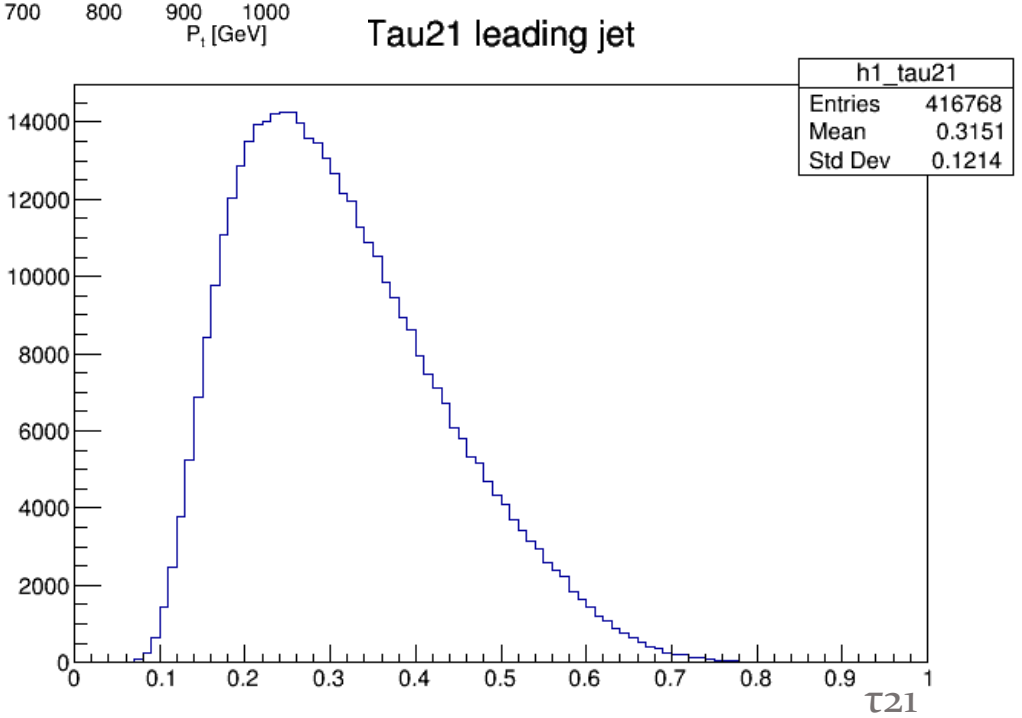
Well classified signal events

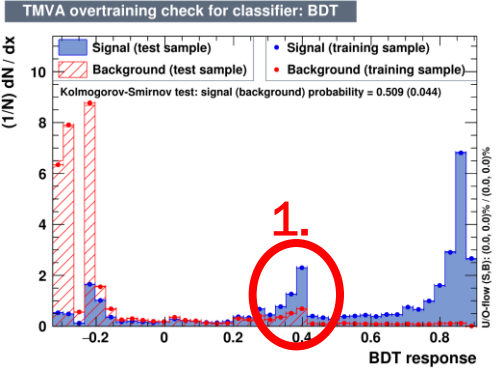


Important BDT cut at 900 GeV.

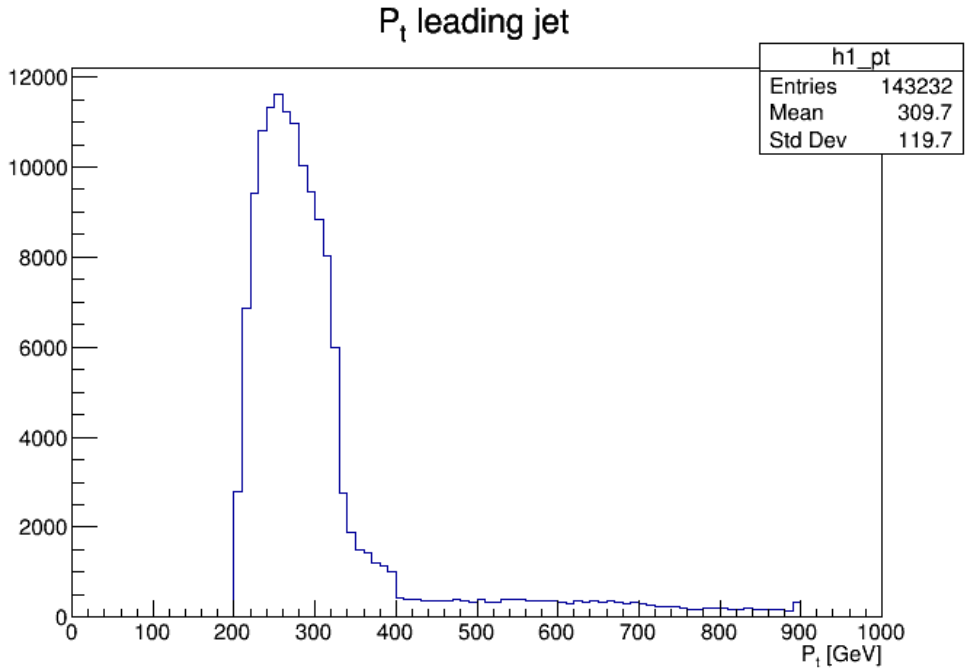
Two subjets jet.





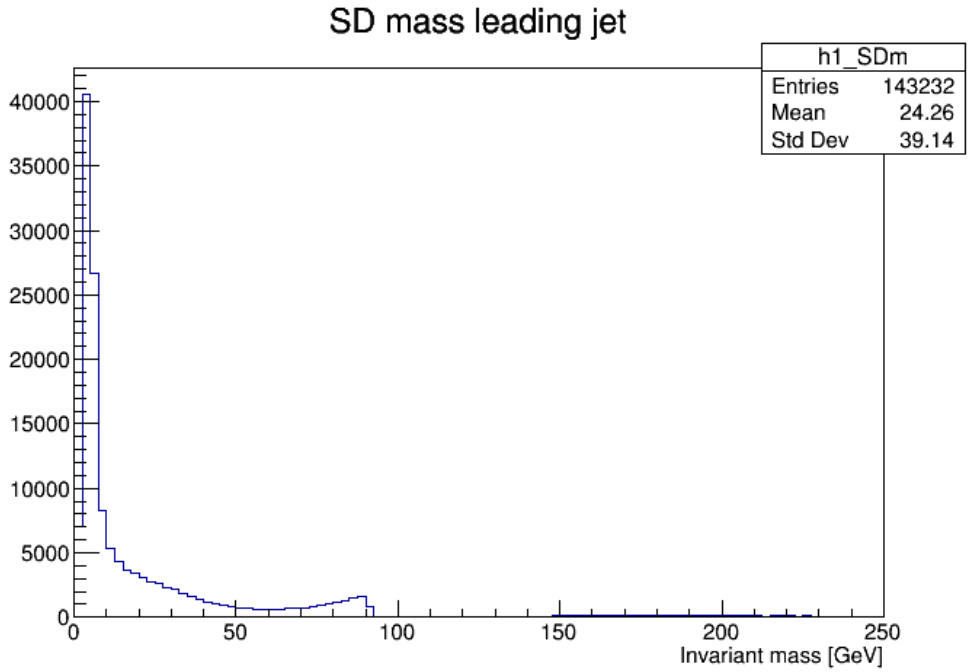


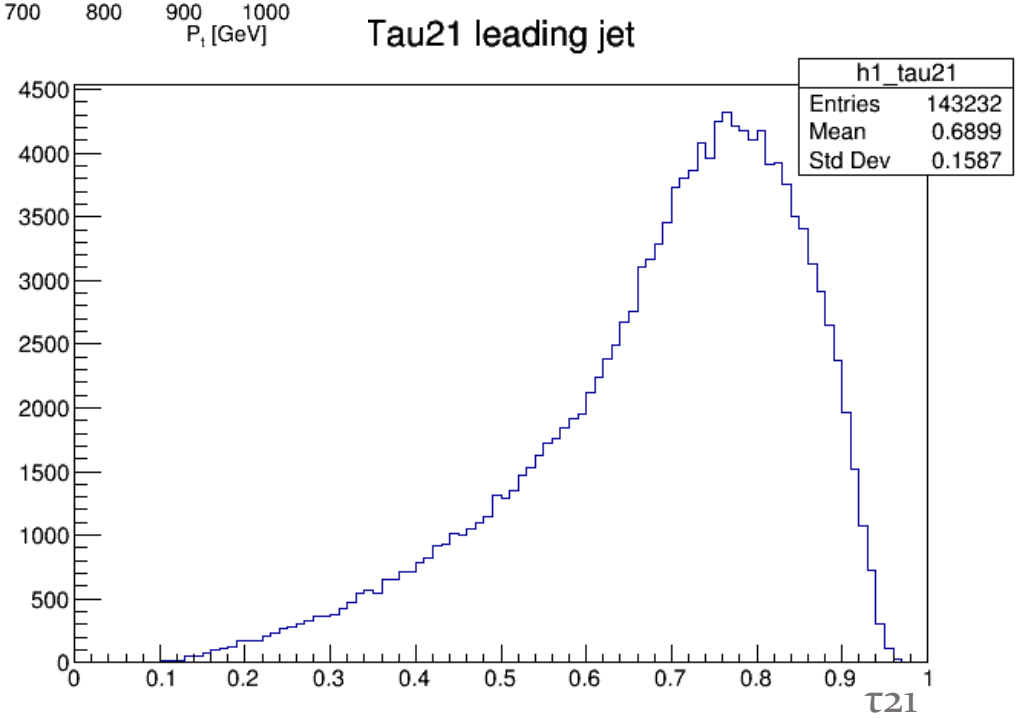
Single light quarks or not fully reconstructed jets.

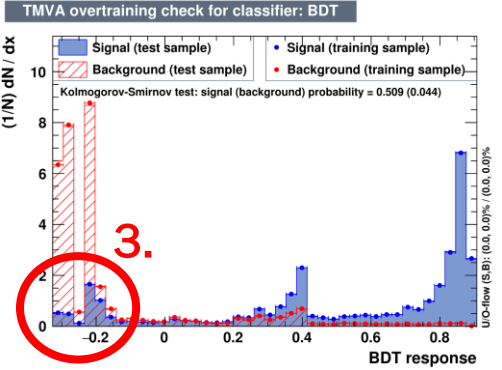


Very low Pt and mass.

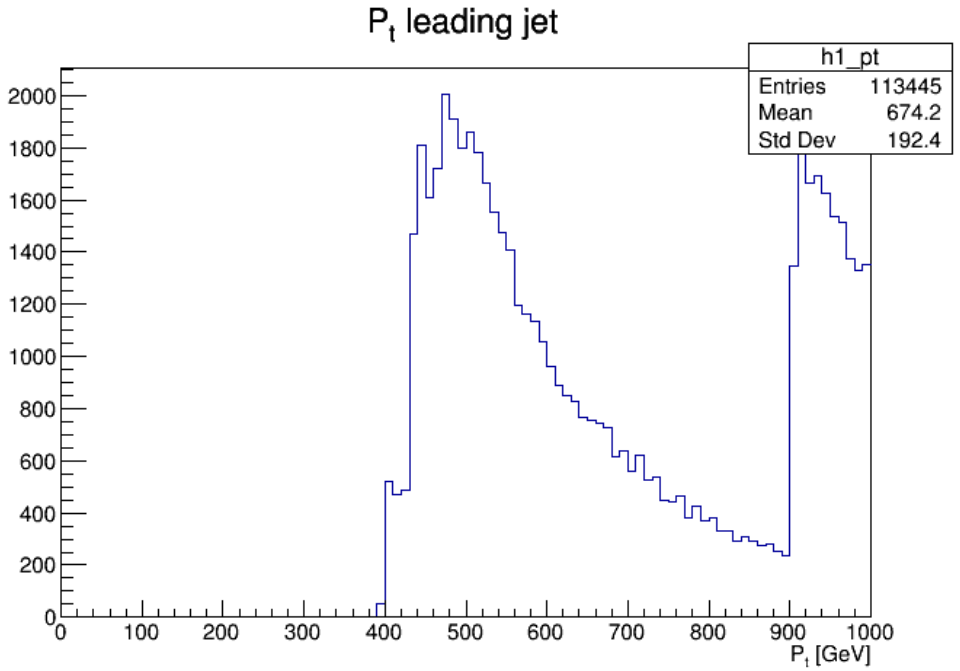
Single subjet jet.



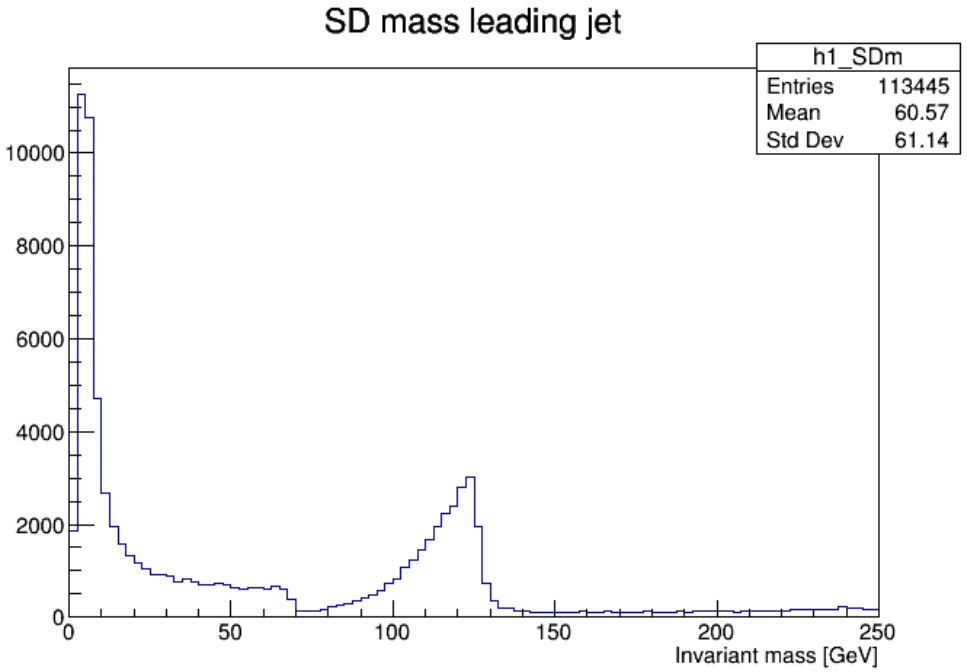


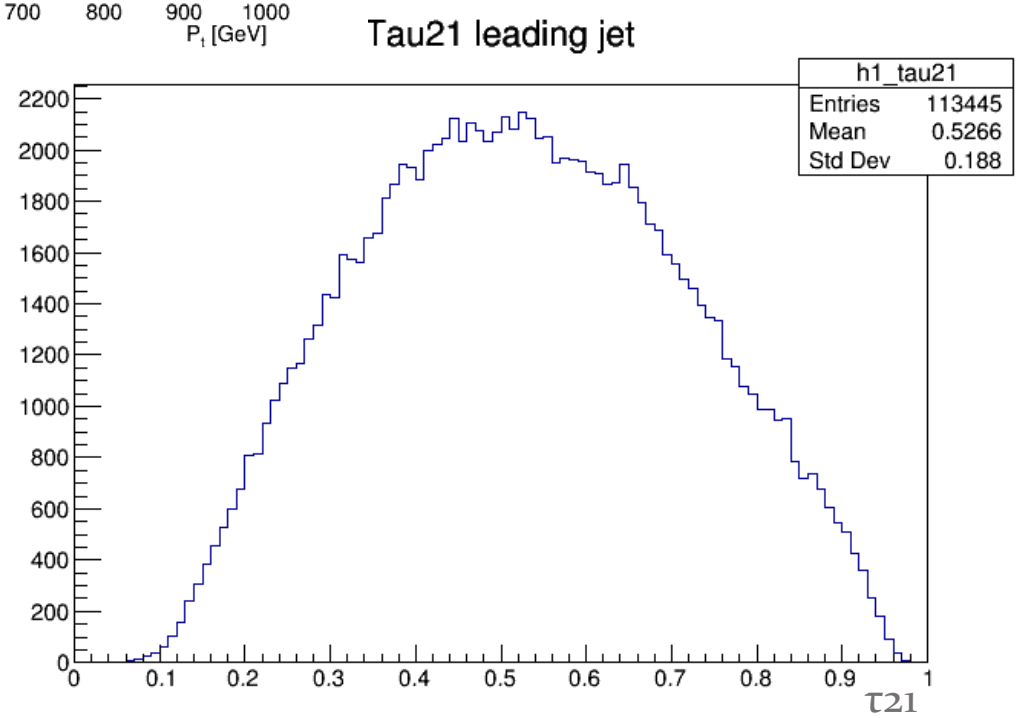


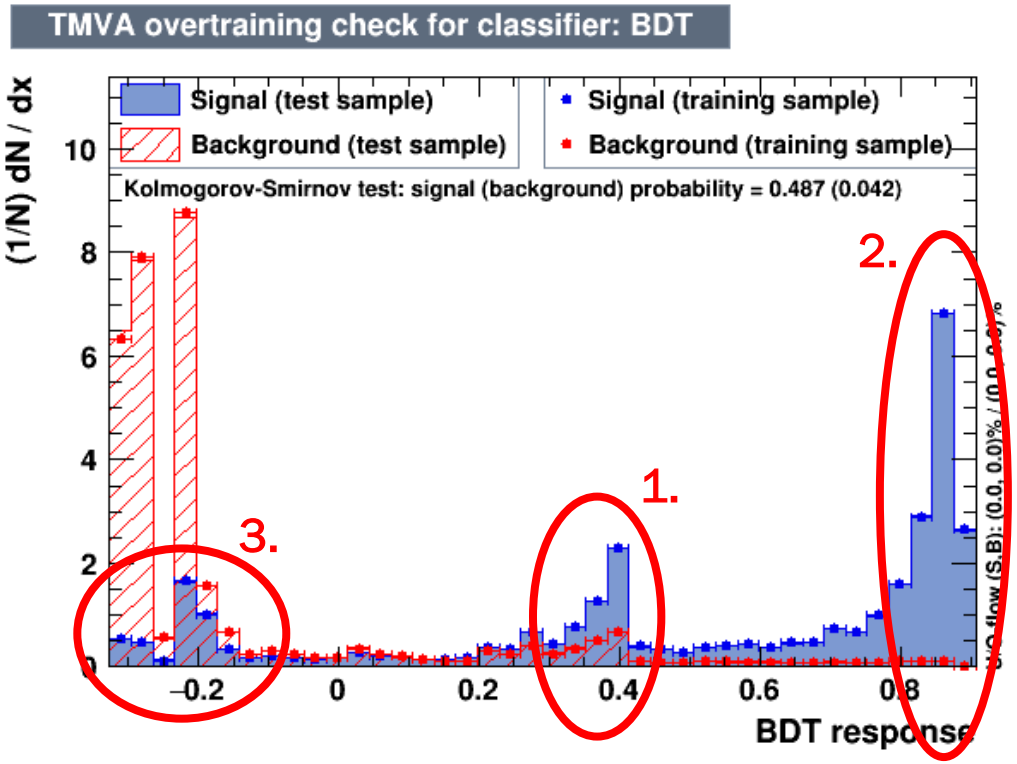
Mixed category of the previous two.

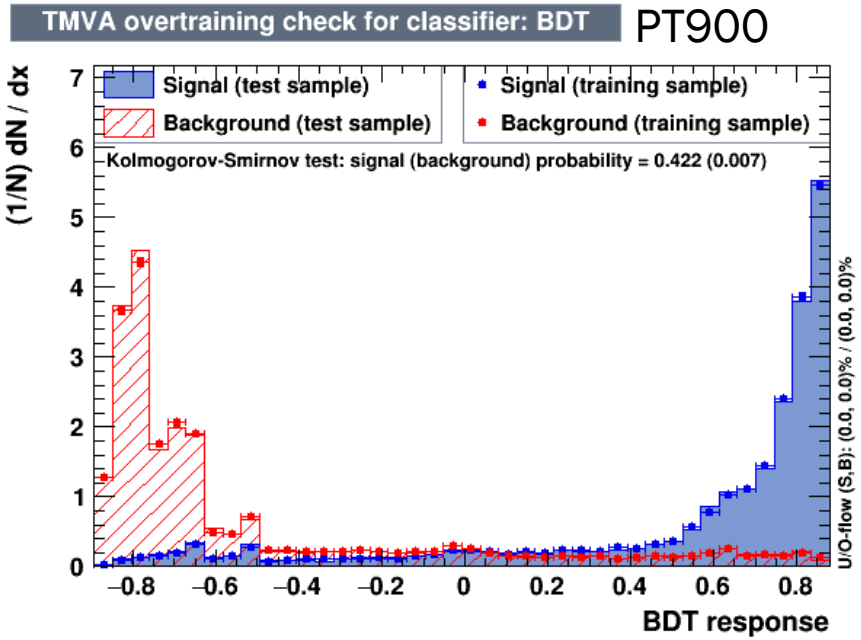


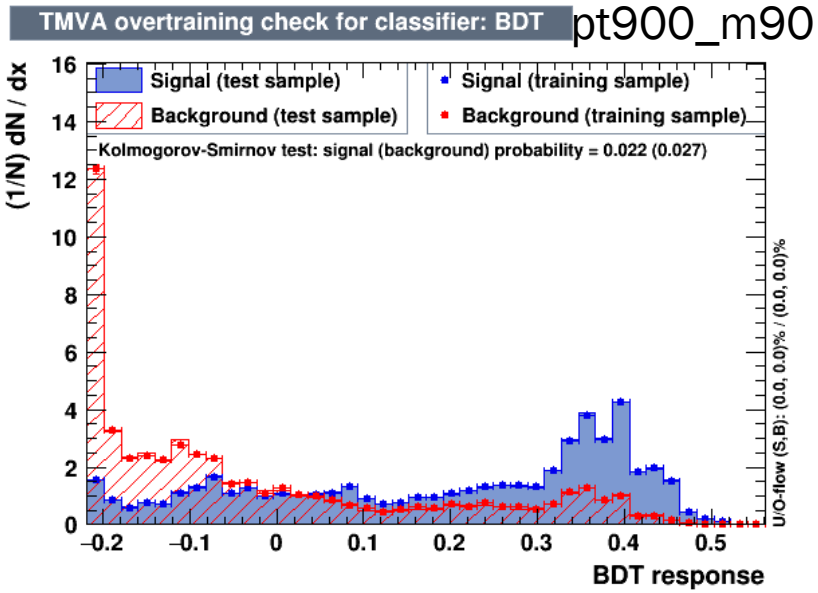
Important BDT cut at 900 GeV.

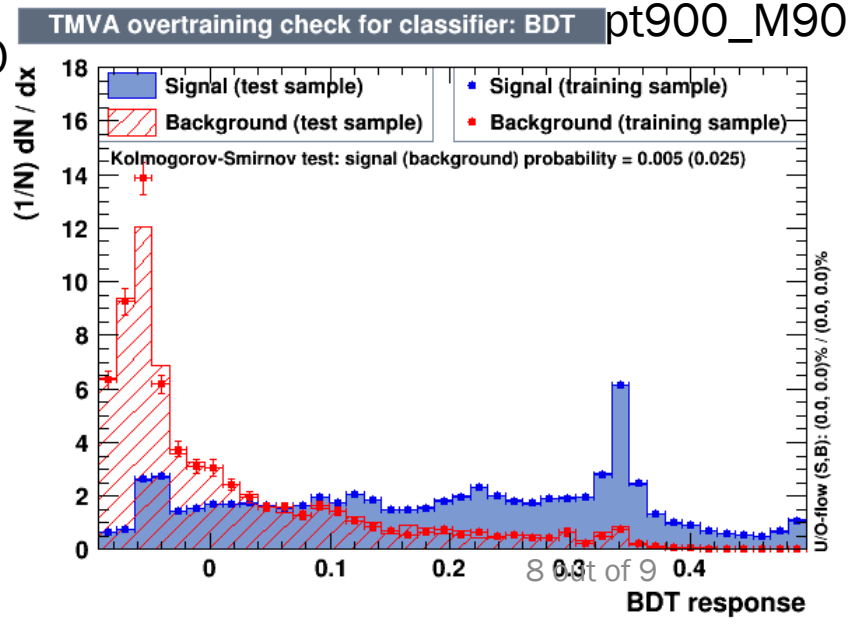


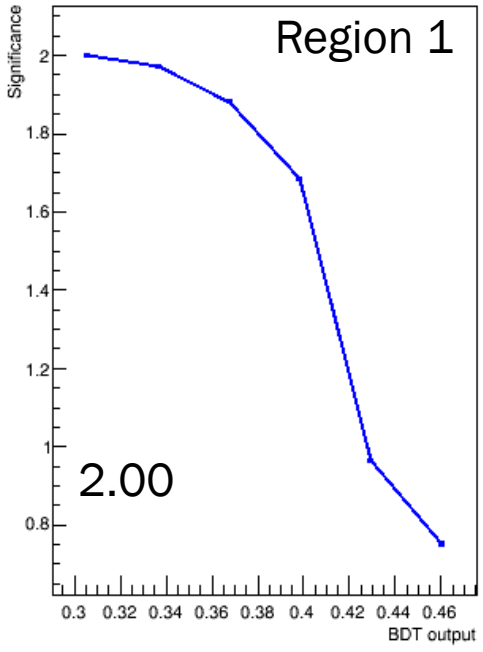


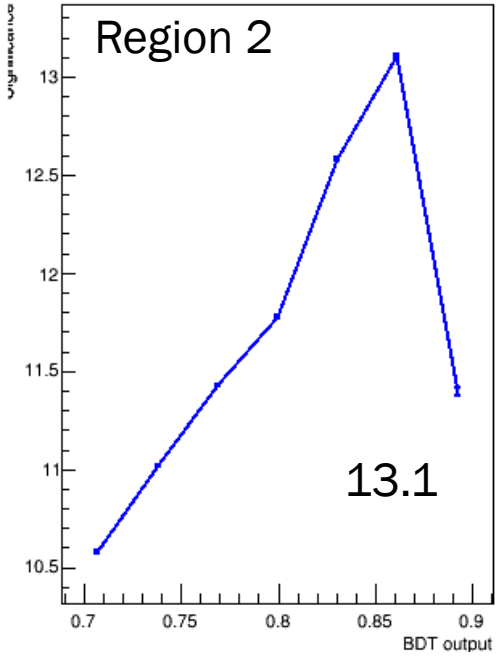

TMVA overtraining check for classifier: BDT
Signal (test sample)
Background (test sample)
Signal (training sample)
Background (training sample)
Kolmogorov-Smirnov test: signal (background) probability = 0.487 (0.042)
(1/N) dN / dx
BDT response
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%
1.
2.
3.

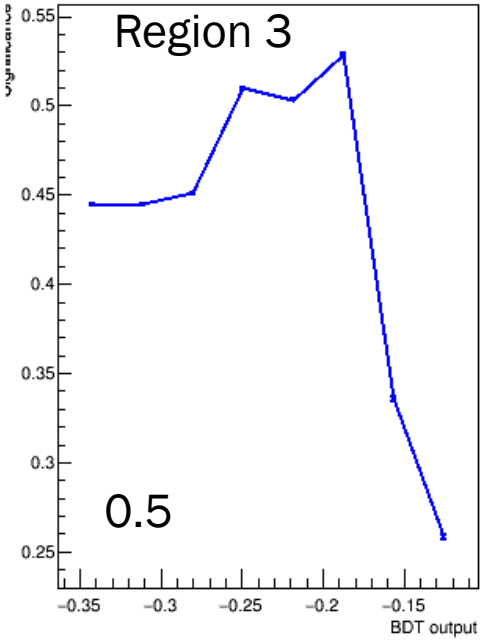

TMVA overtraining check for classifier: BDT
PT900
Signal (test sample)
Background (test sample)
Signal (training sample)
Background (training sample)
Kolmogorov-Smirnov test: signal (background) probability = 0.422 (0.007)
(1/N) dN / dx
BDT response
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%

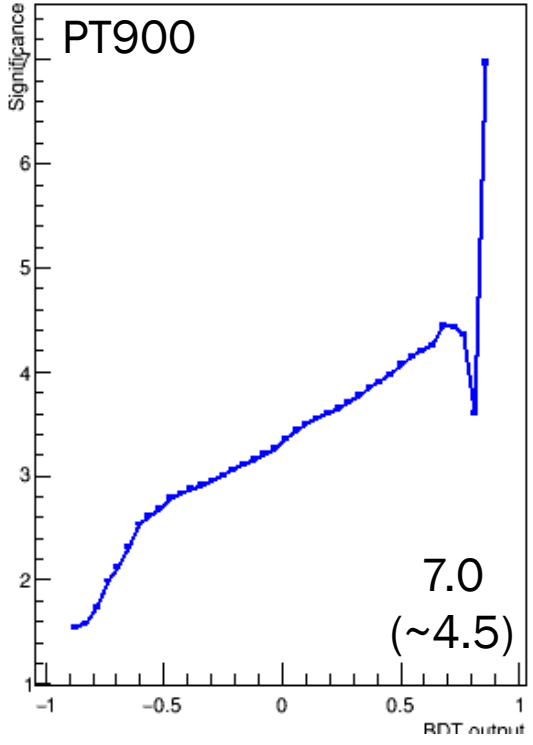

TMVA overtraining check for classifier: BDT
pt900_m90
Signal (test sample)
Background (test sample)
Signal (training sample)
Background (training sample)
Kolmogorov-Smirnov test: signal (background) probability = 0.022 (0.027)
(1/N) dN / dx
BDT response
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%

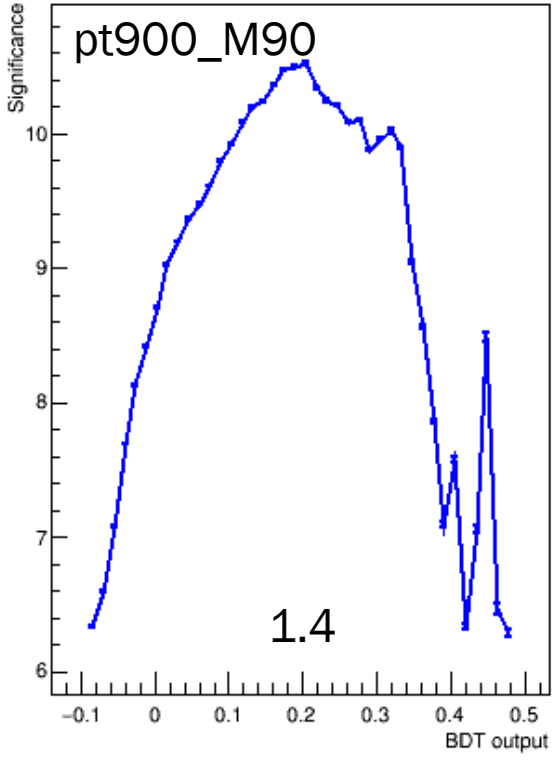

TMVA overtraining check for classifier: BDT
pt900_M90
Signal (test sample)
Background (test sample)
Signal (training sample)
Background (training sample)
Kolmogorov-Smirnov test: signal (background) probability = 0.005 (0.025)
(1/N) dN / dx
BDT response
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%

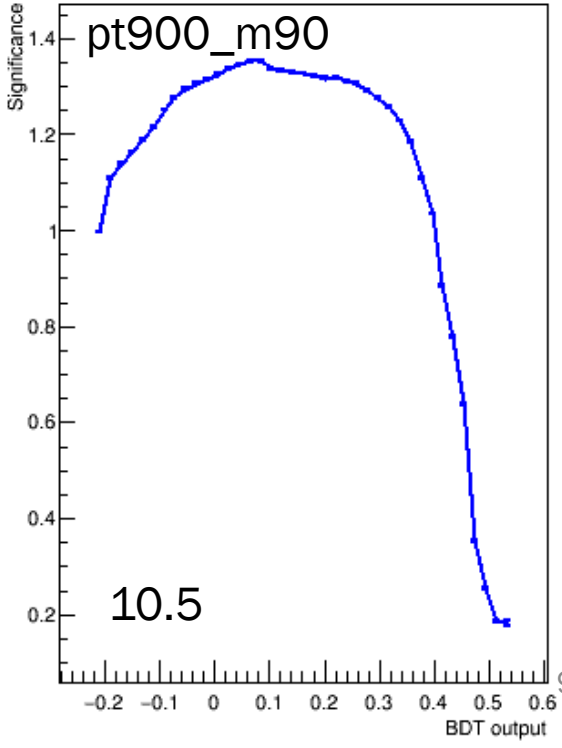

Region 1
Significance
2.00
BDT output


Region 2
13.1
BDT output


Region 3
0.5
BDT output


PT900
Significance
7.0
(~4.5)
BDT output


pt900_M90
Significance
1.4
BDT output


pt900_m90
Significance
10.5
BDT output

Conclusion

- Investigated optimization of (fast simulation) analysis of $HH -> b\bar{b}b\bar{b}$ at FCC using BDT.
- Existence of categories in the signal data and identification with topological and kinematic variables.
- Improvement in the previous significance using the MVA Cuts method (around 7).

Probing the H $\rightarrow b\,\bar{b}\,\gamma$ vertex using MVA at ATLAS/LHC

Alexandre Santos

Supervisors: Rute Pedro, Ricardo Gonçalo

In collaboration with Aidan Kelly

Extra slides

Variables in study

- numbjets;
- numofbjets;
- sphericity;
- jetPT0;
- jetPT1;
- pTb1;
- pTb2;
- bphotonPT;
- PT_All;
- PT_All_else_jet;
- Higgs_mass;
- pTHiggs;
- delR_bjets;
- deltaphiHiggsother;
- deltaetaHiggsother;
- elsejetPT;
- DelPhi_bb;
- DelEta_bb;
- twistangle;
- delRgammamin;

Cut Flow Tables

Cuts	$H \to b\bar{b}\gamma$ ($d_1 = 5$, $d_2 = 5$)	$H \to b\bar{b}\gamma$ ($d_1 = 6$, $d_2 = 0$)	jjj	$jj\gamma$	bbphoton	bbj	SM vertex	$\sum$ Backgrounds
Without Cuts	280225	966875	2199314	4695958	1141671	1036985	600000	9073928
At least one photon	223871	772370	2195393	4609115	829425	1024996	461491	8658929
Has a photon with a p_T of at least 80 GeV	24146	83509	562712	1589123	126269	250497	57110	2528601
At least two jets	20692	71761	561719	1496542	120820	249569	50863	2428650
At least two b-tagged jets	1772	5895	3083	5064	20864	56090	11080	85101
DelRbgamma minimum less than 1.5	1225	4149	369	822	4787	2911	2862	8889
Sphericity of at least 0.02	1192	4055	347	745	4550	2817	2809	8459
Higgs_mass within 100 and 135 GeV	516	1802	15	35	41	34	1131	125

Table: Number of events that pass each cut

Cuts	$H \to b\bar{b}\gamma$ ($d_1 = 5$, $d_2 = 5$)	$H \to b\bar{b}\gamma$ ($d_1 = 6$, $d_2 = 0$)	jjj	$jj\gamma$	bbphoton	bbj	SM vertex
Without Cuts	100 %	100 %	100 %	100 %	100 %	100 %	100 %
At least one photon	79.9 %	79.9 %	99.8 %	98.2 %	72.7 %	98.8 %	76.9 %
Has a photon with a p_T of at least 80 GeV	10.8 %	10.8 %	25.6 %	34.5 %	15.2 %	24.4 %	12.4 %
At least two jets	85.7 %	85.9 %	99.8 %	94.2 %	95.7 %	99.6 %	89.0 %
At least two b-tagged jets	8.56 %	8.21 %	0.549 %	0.34 %	17.3 %	22.5 %	21.8 %
DelRbgamma minimum less than 1.5	69.1 %	70.4 %	12.0 %	16.2 %	22.9 %	5.19 %	25.8 %
Sphericity of at least 0.02	97.3 %	97.7 %	94.0 %	90.6 %	95.0 %	96.8 %	98.2 %
Higgs_mass within 100 and 135 GeV	43.3 %	44.4 %	4.32 %	4.70 %	0.90 %	1.21 %	40.3 %

Table: Percentage of events that pass each cut

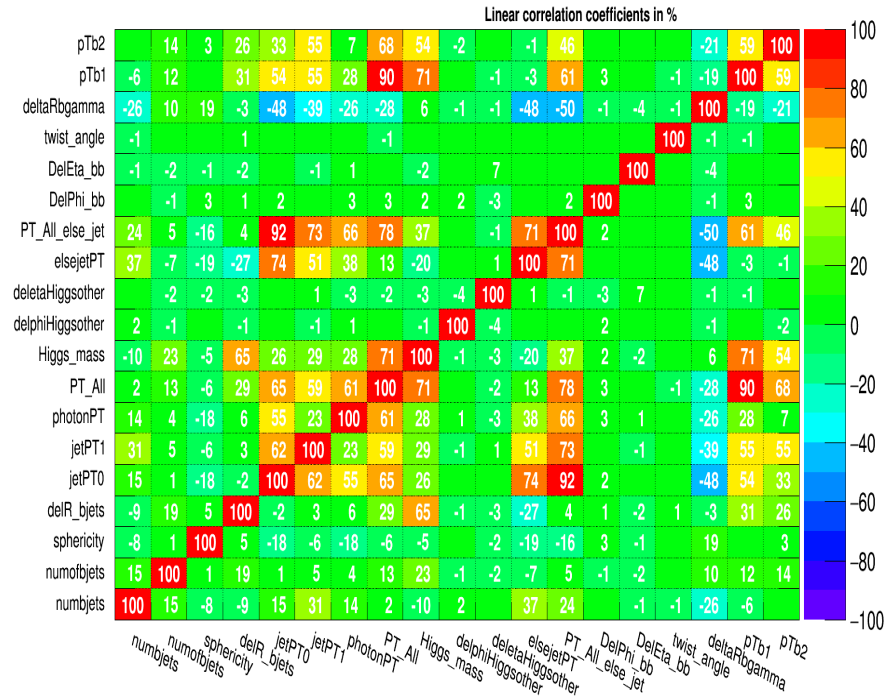
MVA BDT - Parameters used

These were the BDT parameters used:

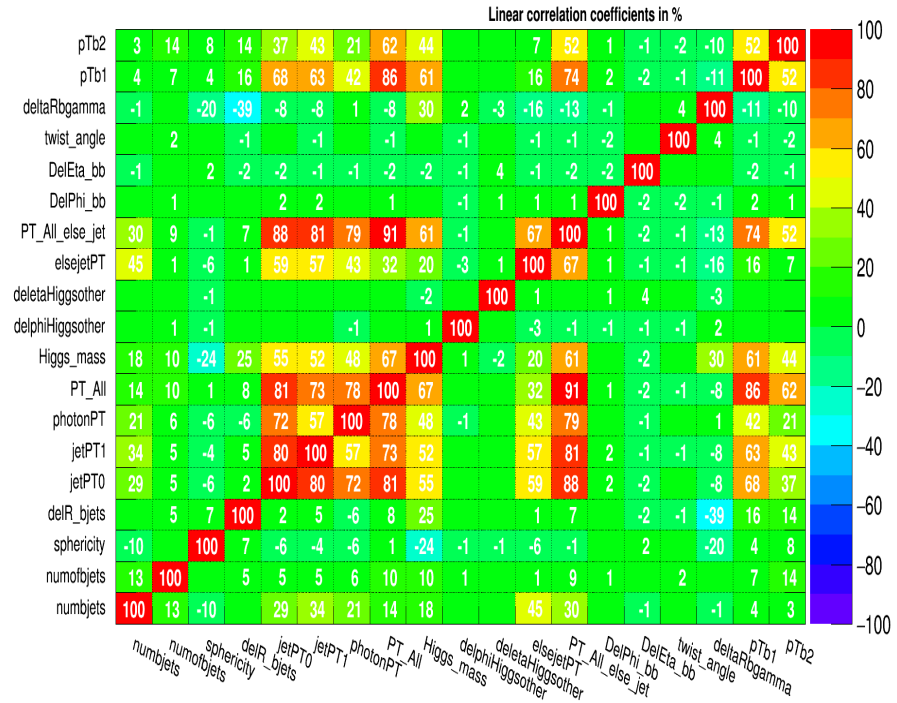
- **NTrees:** 1500/1000/400 (Number of trees used);
- **MinNodeSize:** 2.5 % (Minimum percentage of training events required in a leaf node);
- **BoostType:** Grad (Type of boost applied to the forest, in this case gradient type boost);
- **Shrinkage:** 0.10 (Learning rate for GradBoost algorithm);
- **UseBaggedBoost:** (Use only a random subsample of all events for growing the trees in each iteration);
- **BaggedSampleFraction:** 0.5 (Relative size of bagged event sample to original size of the data sample);
- **nCuts:** 20 (Number of grid points in variable range used in finding optimal cut in node splitting);
- **MaxDepth:** 2/4/6 (Max depth of the decision tree allowed).

Correlation Matrix

Correlation Matrix (signal)



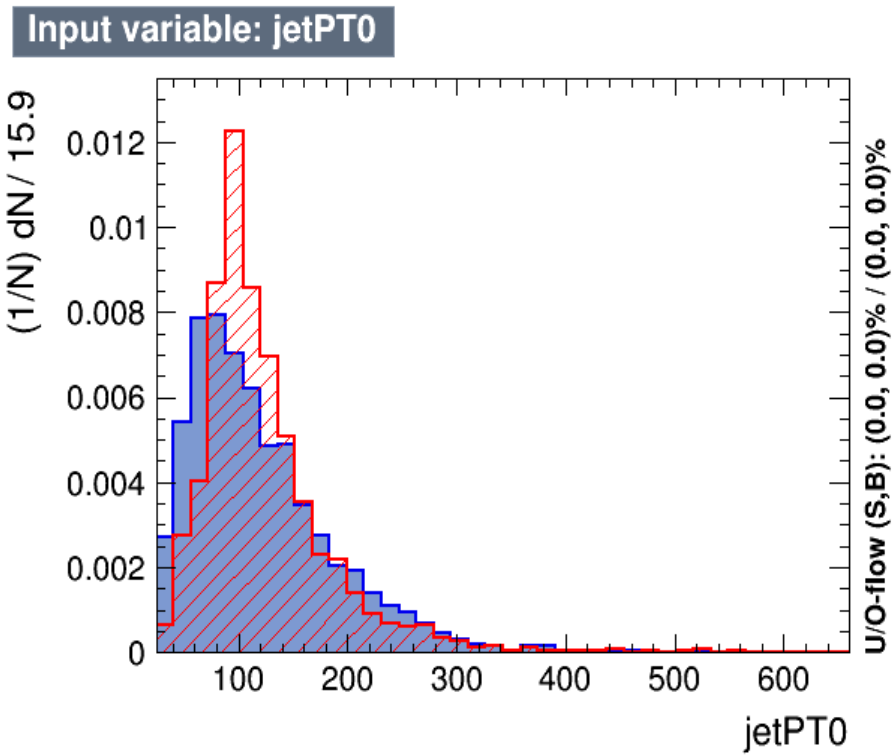
Correlation Matrix (background)

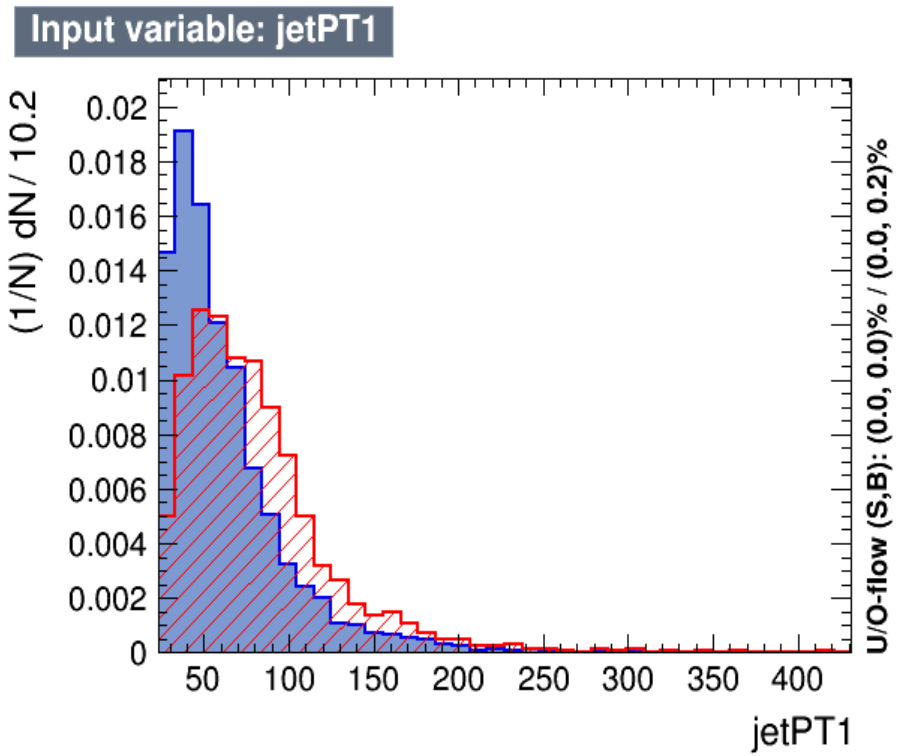


Variable importance Table

Rank	Variable	Variable Importance
1	deltaRbgamma	1.143e-01
2	jetPT1	6.804e-02
3	jetPT0	5.987e-02
4	Higgs_mass	5.938e-02
5	elsejetPT	5.876e-02
6	sphericity	5.540e-02
7	delR_bjets	5.429e-02
8	pTb1	5.311e-02
9	numbjets	5.197e-02
10	numofbjets	5.178e-02
11	DelPhi_bb	5.023e-02
12	PT_All_else_jet	4.721e-02
13	DelEta_bb	4.591e-02
14	pTb2	4.212e-02
15	twist_angle	3.952e-02
16	photonPT	3.890e-02
17	delphiHiggsother	3.888e-02
18	deletaHiggsother	3.856e-02
19	PT_All	3.173e-02

Distributions for JetPT0 and JetPT1





Significance Table for different Luminosities and configurations

BDT Configuration	$\mathcal{L} = 300\,\text{fb}^{-1}$	$\mathcal{L} = 1000\,\text{fb}^{-1}$	$\mathcal{L} = 3000\,\text{fb}^{-1}$
Selected cuts	0.461	0.842	1.46
1500 Trees; Tree depth = 2	0.592 / [0.494]	1.08 / [0.902]	1.87 / [1.56]
1000 Trees; Tree depth = 4	**0.645 / [0.576]**	**1.18 / [1.05]**	**2.04 / [1.82]**
1000 Trees; Tree depth = 2	0.571 / [0.499]	1.04 / [0.910]	1.81 / [1.58]
400 Trees; Tree depth = 2	0.493 / [0.426]	0.899 / [0.778]	1.56/ [1.35]
400 Trees; Tree depth = 4	0.611 / [0.490]	1.11 / [0.895]	1.93 / [1.55]
400 Trees; Tree depth = 6	0.620 / [0.570]	1.13 / [1.03]	1.96 / [1.79]

Table: Max significance values / significance for a signal efficiency of 0.5 (in brackets) for the selected cuts method and for different BDT configurations across three Luminosities

Boosting H->bb at high p_{T_V} with MVA in ATLAS at LHC

Vânia Nunes

Supervisors:
Rute Pedro
Ricardo Gonçalo

BACKUP

Cut Flow Table

RESOLVED (normalized)	qqZllHbb	ggZllHbb	qqWlvHbbJ	qqZvvHbbJ	ttbardilep	ttbarnonallhad
Without cuts	1 756	1 154 058	35 476	31	3 310 150	3 822 820
2 leptons with p_T >7Gev, 1 with p_T >27 GeV	582	582	58	0	1 084 060	1 247 720
$81 <= m_{LL} <= 101(GeV)$	505	505	5	0	142 318	158 967
Same lepton Flavour	505	505	2	0	71 304	79 675
Opposite lepton charge	500	500	1	0	70 321	75 093
$\mathrm{pT}_V > 250Gev$	25	25	0	0	120	179
At least two jets	24	24	0	0	120	177
$p_T > 20GeV$ for $\lvert\eta\rvert < 2.5$and $p_T > 30$ for $2.5 < \lvert\eta\rvert < 4.5$	17	17	0	0	108	166
Exactly two b-tagged jets	6	6	0	0	30	35
Leading b-tagged jet with $p_T > 45GeV$	6	6	0	0	29	34
After applying p_{TV} and dR_{BB} conditions	5	5	0	0	6	5

Table: Number of events normalized that pass each cut

Cut Flow Table

RESOLVED (normalized)	Zjets	ZBjets	ZjetsC	ZjetsL	VVfulllep
Without cuts	294 895	3 234 460	5 342 940	16 280 300	104 597
2 leptons with p_T >7Gev, 1 with p_T >27 GeV	98 079	1 065 410	1 757 820	5 355 030	34 336
$81 <= m_{LL} <= 101(GeV)$	80 220	890 098	1 441 270	4 444 080	5 891
Same lepton Flavour	80 181	889 622	1 440 810	4 443 180	3 783
Opposite lepton charge	79 123	882 425	1 428 870	4 405 560	3 742
$\mathrm{pT}_V > 250Gev$	16 425	7 136	11 429	32 235	109
At least two jets	15 955	6 437	10 176	26 379	102
$p_T > 20GeV$ for $\|\eta\| < 2.5$and $p_T > 30$ for $2.5 < \|\eta\| < 4.5$	13 819	4 503	7 033	15 909	67
Exactly two b-tagged jets	255	361	20	1	0
Leading b-tagged jet with $p_T > 45GeV$	243	335	18	1	0
After applying p_{TV} and dR_{BB} conditions	77	125	6	1	0

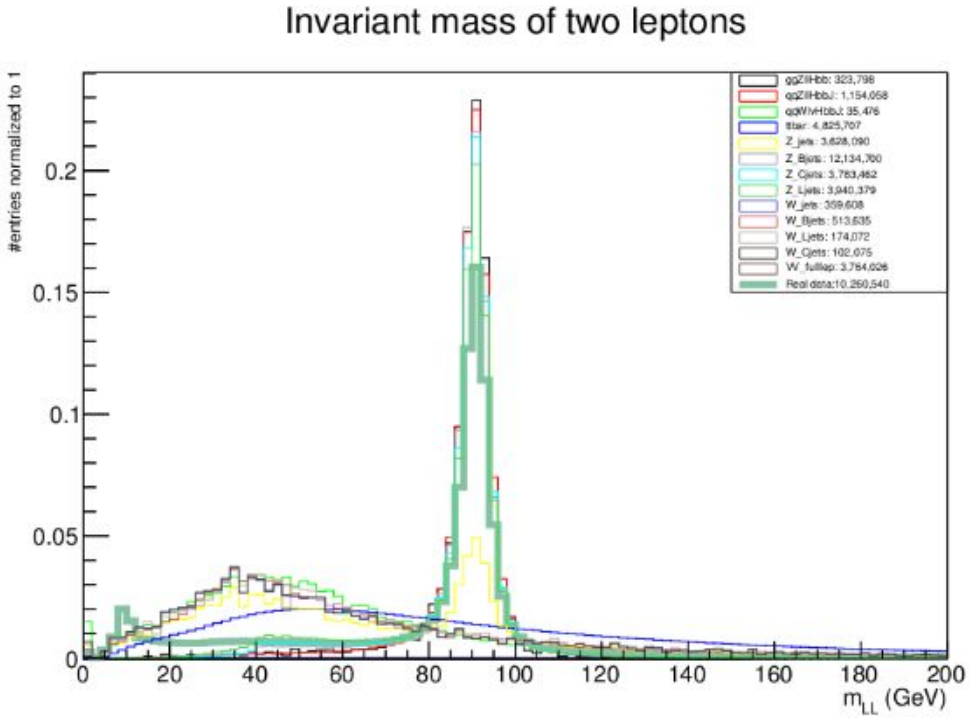
Table: Number of events normalized that pass each cut

Event Selection - RESOLVED

To make the Z boson selection, it was required:

- 2 leptons, both with pT>7GeV, and at least one with pT>27GeV
- Invariant mass of leptons correspondent to Z boson
  81 < mLL <101 (GeV)
- Same lepton flavor
- Opposite lepton charge

Extra cut made for pTV>250 GeV

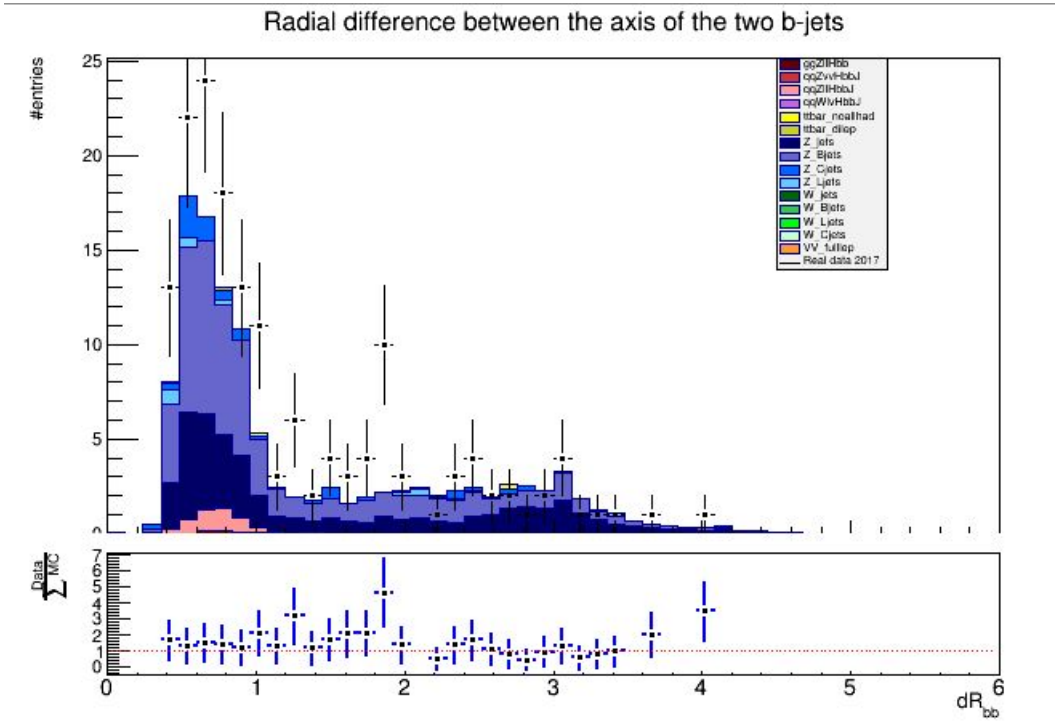


Event Selection - BOOSTED

For this regime, it was required:

- 1 fat jet
- 2 b-tagged jets in fat jet
- Variable xbb_result=1

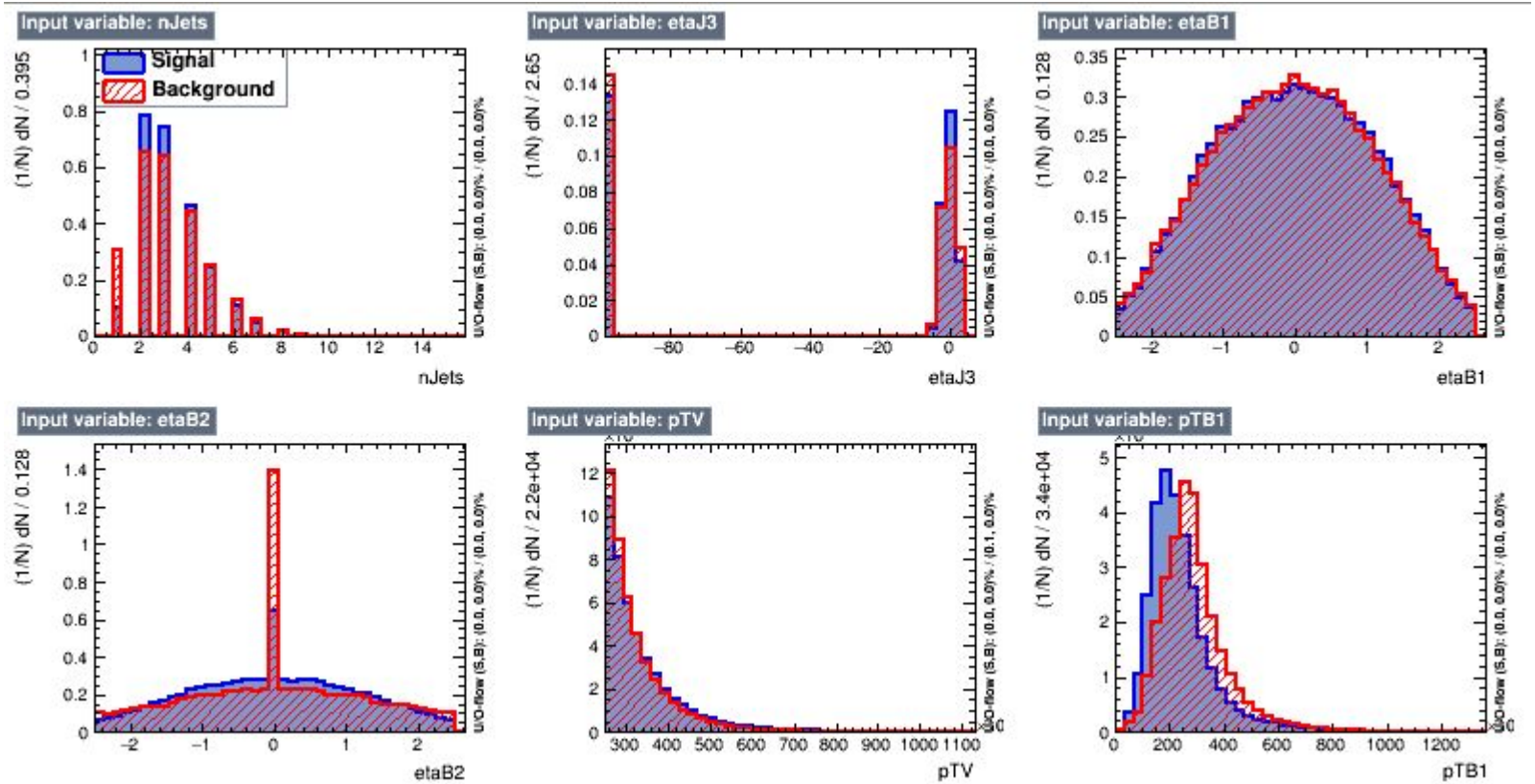
❖ xbb_result is a variable resultant from Xbb Tagger algorithm used to identify hadronically decaying boosted bosons

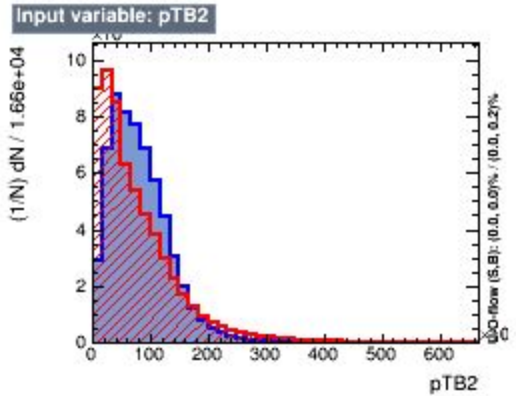


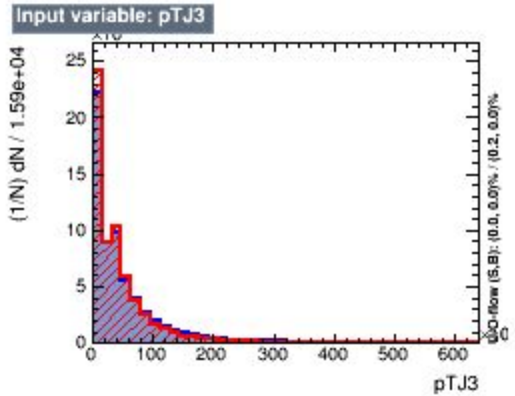
Ranking of the most important variables used in BDT

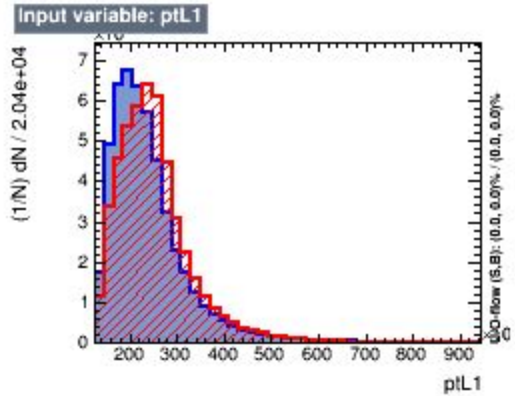
Rank	Variable	Separation
1	nbJets	5.512e-01
2	fatj1xbbResult	3.226e-01
3	mBB	2.537e-01
4	dRBB	1.603e-01
5	fatj1m	1.414e-01
6	fatj1UngroomedTrackWidth1000	1.247e-01
7	fatj1UngroomedTrackWidth500	1.220e-01
8	nbTagsInFJ	1.179e-01
9	dEtaBB	9.055e-02
10	pTB1	7.134e-02
11	pTB1	7.134e-02
12	ptL2	7.119e-02
13	dEtaVBB	6.904e-02
14	fatj1Tau21	6.587e-02
15	pTB2	5.403e-02
16	pTB2	5.403e-02
17	fatj1D2	5.354e-02
18	fatj1NumTrkPt1000PV	5.068e-02
19	fatj1C2	4.574e-02
20	fatj1NumTrkPt500PV	4.483e-02
21	MET	3.269e-02
22	etaB2	2.536e-02
23	nJets	2.448e-02
24	ptL1	1.726e-02
25	pTJ3	6.547e-03
26	nFatJets	5.608e-03
27	fatj1pt	5.118e-03
28	fatj1eta	5.001e-03
29	fatj1phi	4.982e-03

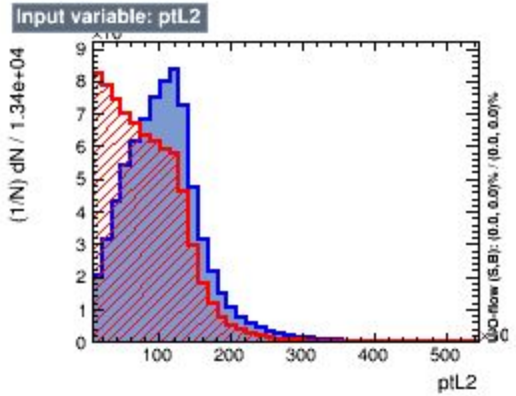
BDT nominal

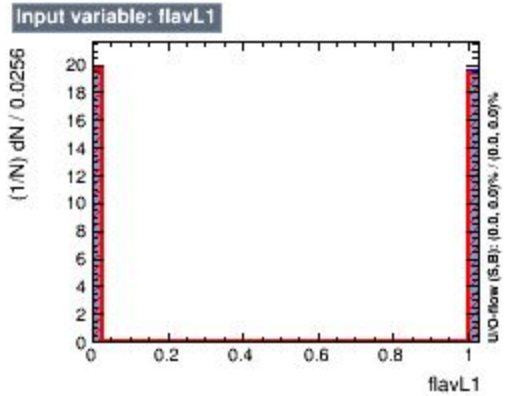

Input variable: nJets
Signal
Background
(1/N) dN / 0.395
nJets
Input variable: etaJ3
(1/N) dN / 2.65
etaJ3
Input variable: etaB1
(1/N) dN / 0.128
etaB1
Input variable: etaB2
(1/N) dN / 0.128
etaB2
Input variable: pTV
(1/N) dN / 2.2e+04
pTV
Input variable: pTB1
(1/N) dN / 3.4e+04
pTB1
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%

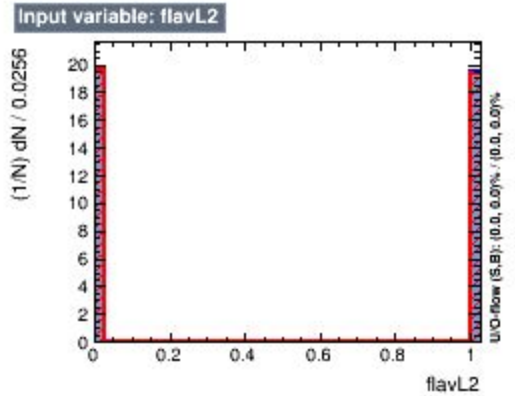

Input variable: pTB2
(1/N) dN / 1.66e+04
pTB2
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.2)%

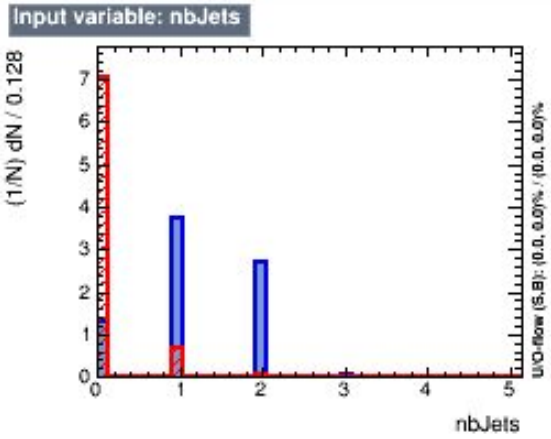

Input variable: pTJ3
(1/N) dN / 1.59e+04
pTJ3
U/O-flow (S,B): (0.0, 0.0)% / (0.2, 0.0)%

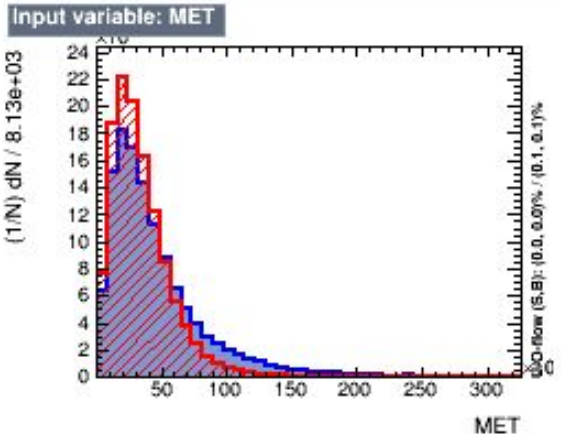

Input variable: ptL1
(1/N) dN / 2.04e+04
ptL1
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%

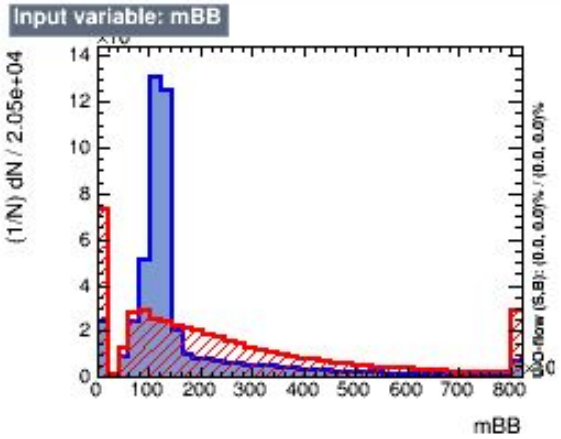

Input variable: ptL2
(1/N) dN / 1.34e+04
ptL2
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%

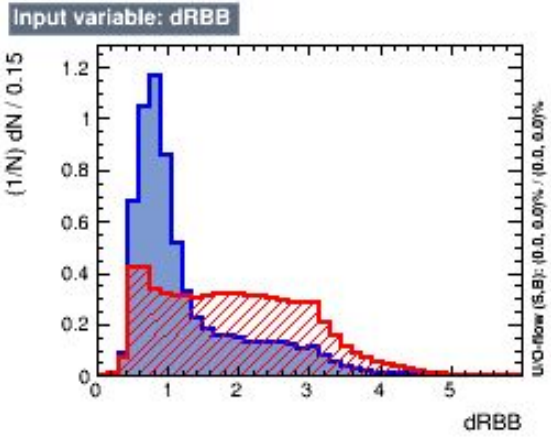

Input variable: flavL1
(1/N) dN / 0.0256
flavL1
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%

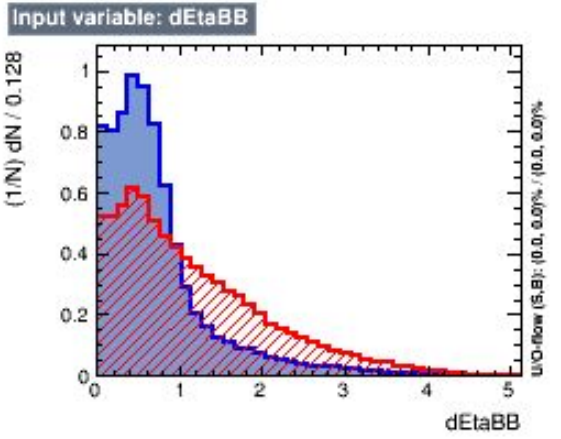

Input variable: flavL2
(1/N) dN / 0.0256
flavL2
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%

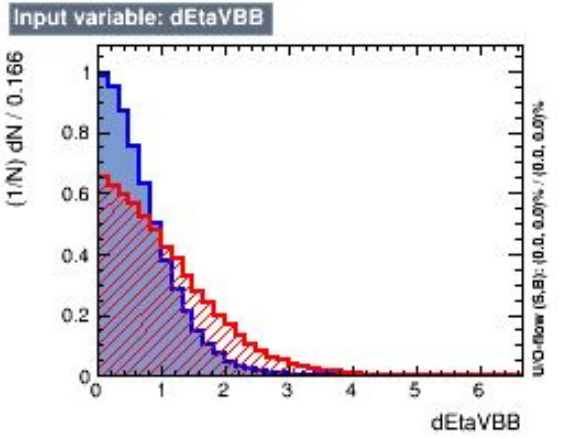

Input variable: nbJets
(1/N) dN / 0.128
nbJets
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%


Input variable: MET
(1/N) dN / 8.13e+03
MET
U/O-flow (S,B): (0.0, 0.0)% / (0.1, 0.1)%

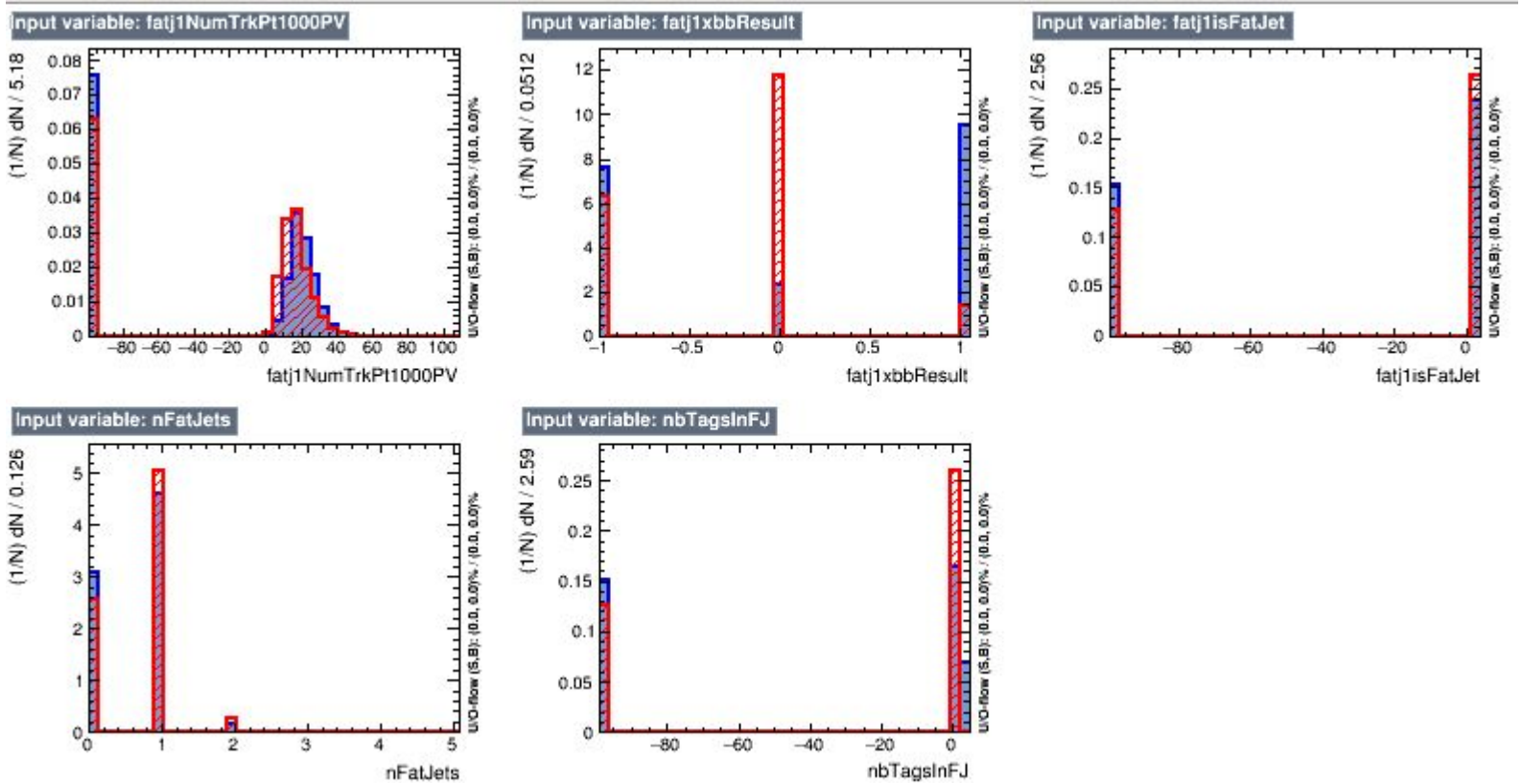

Input variable: mBB
(1/N) dN / 2.05e+04
mBB
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%

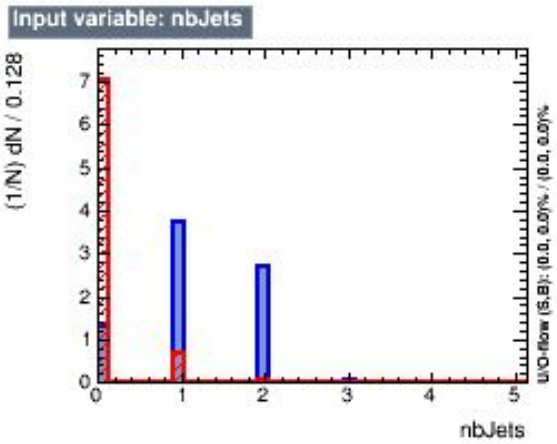

Input variable: dRBB
(1/N) dN / 0.15
dRBB
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%

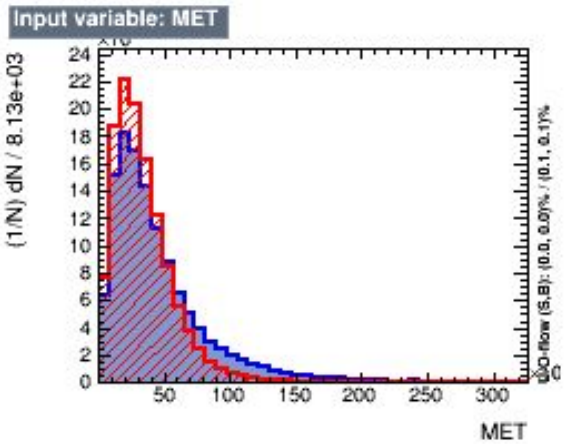

Input variable: dEtaBB
(1/N) dN / 0.128
dEtaBB
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%

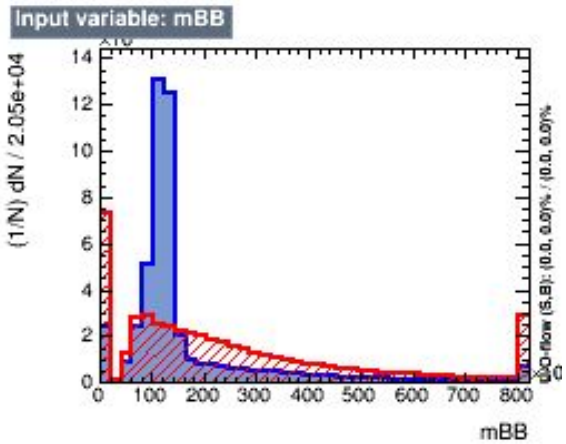

Input variable: dEtaVBB
(1/N) dN / 0.166
dEtaVBB
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%

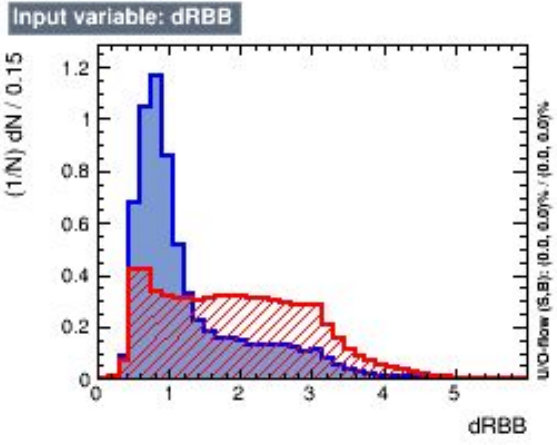
BDT nominal+fatjet variables

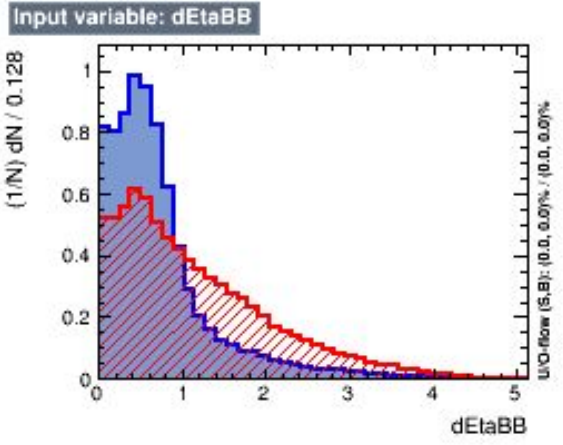


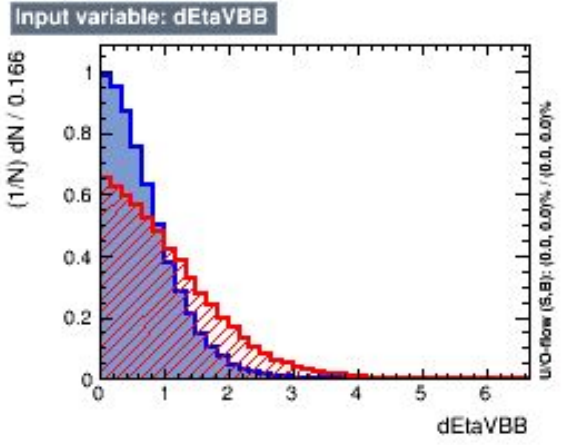

Input variable: nbJets
(1/N) dN / 0.128
nbJets
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%

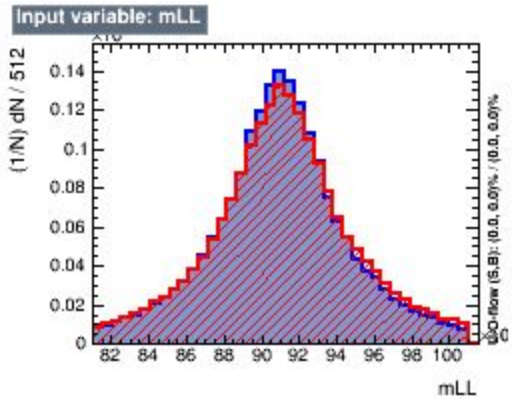

Input variable: MET
(1/N) dN / 8.13e+03
MET
U/O-flow (S,B): (0.0, 0.0)% / (0.1, 0.1)%

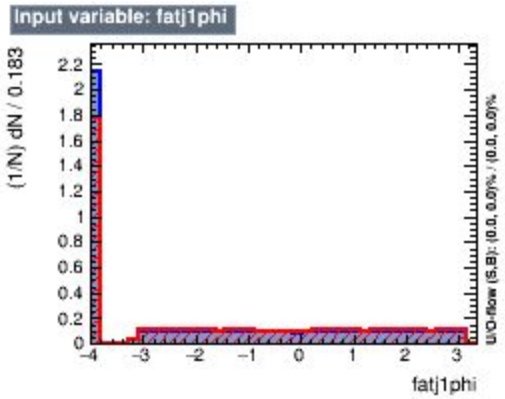

Input variable: mBB
(1/N) dN / 2.05e+04
mBB
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%

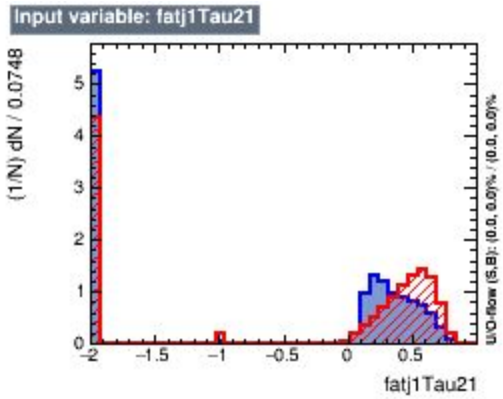

Input variable: dRBB
(1/N) dN / 0.15
dRBB
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%

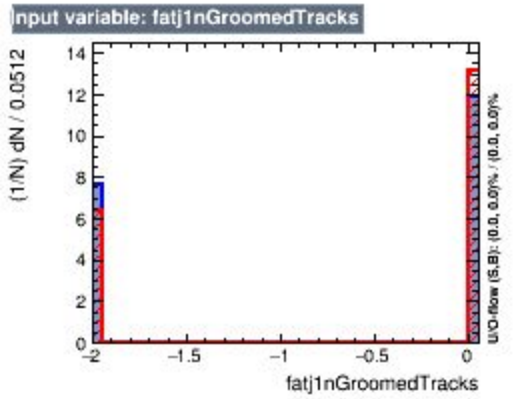

Input variable: dEtaBB
(1/N) dN / 0.128
dEtaBB
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%

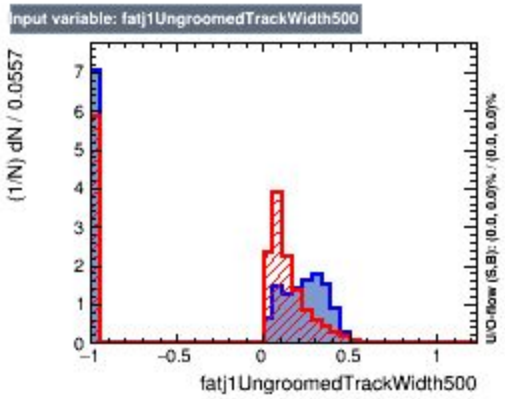

Input variable: dEtaVBB
(1/N) dN / 0.166
dEtaVBB
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%

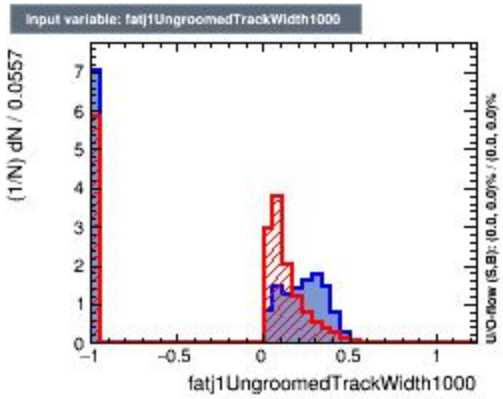

Input variable: mLL
(1/N) dN / 512
mLL
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%

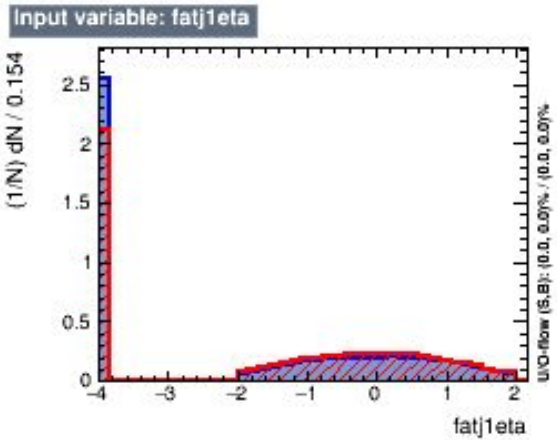

Input variable: fatj1phi
(1/N) dN / 0.183
fatj1phi
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%

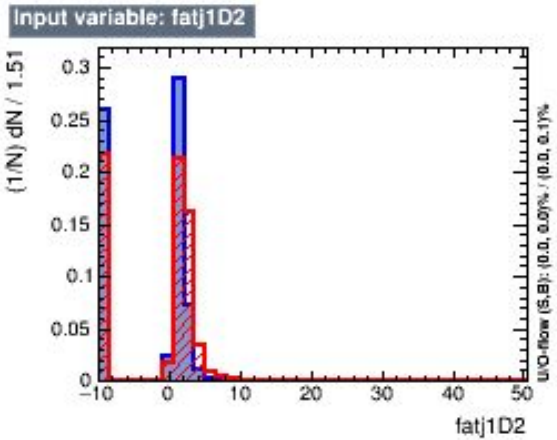

Input variable: fatj1Tau21
(1/N) dN / 0.0748
fatj1Tau21
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%

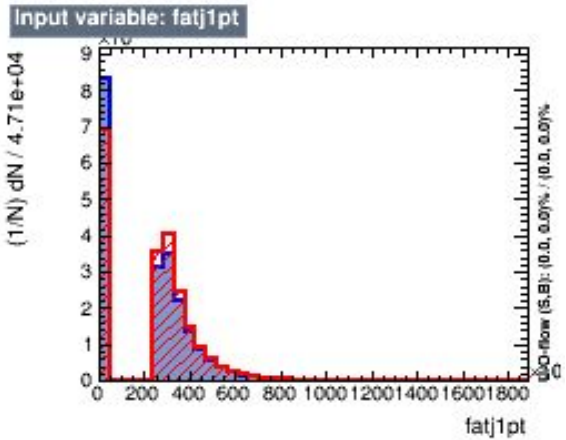

Input variable: fatj1nGroomedTracks
(1/N) dN / 0.0512
fatj1nGroomedTracks
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%

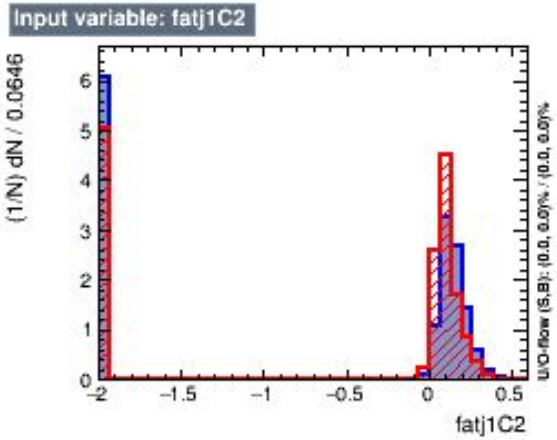

Input variable: fatj1UngroomedTrackWidth500
(1/N) dN / 0.0557
fatj1UngroomedTrackWidth500
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%

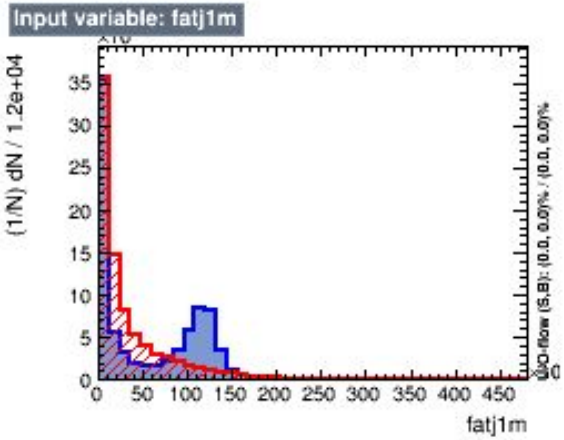

Input variable: fatj1UngroomedTrackWidth1000
(1/N) dN / 0.0557
fatj1UngroomedTrackWidth1000
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%

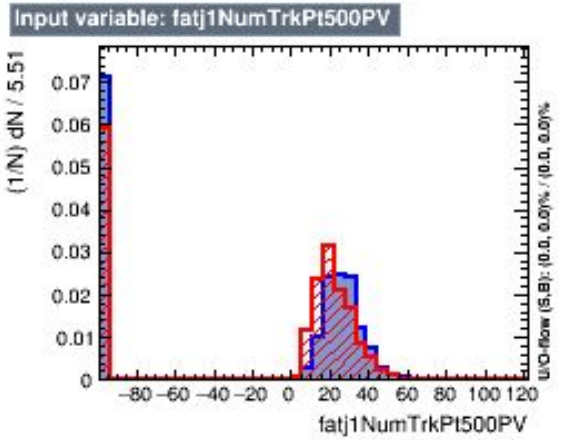

Input variable: fatj1eta
(1/N) dN / 0.154
fatj1eta
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%

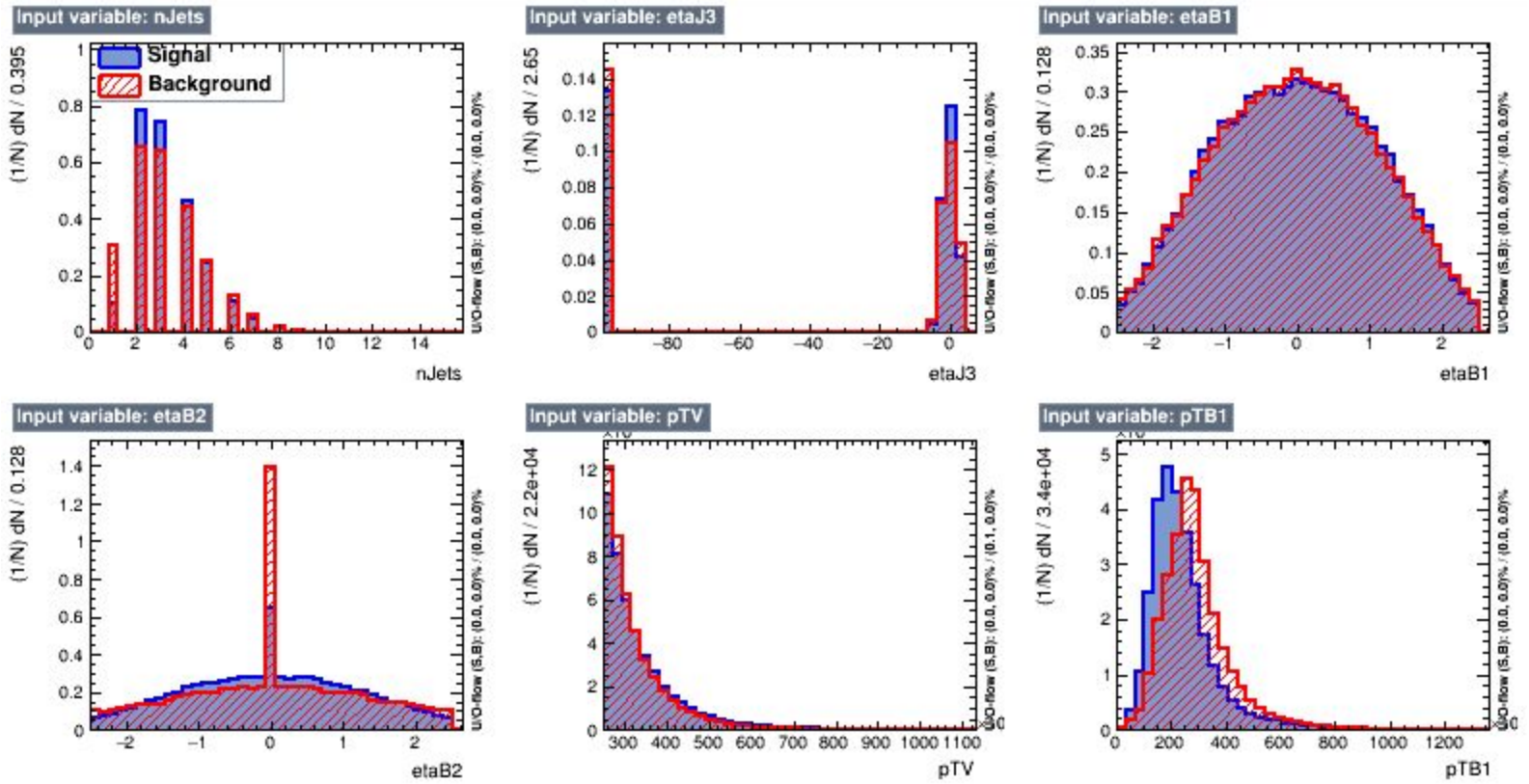

Input variable: fatj1D2
(1/N) dN / 1.51
fatj1D2
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.1)%


Input variable: fatj1pt
(1/N) dN / 4.71e+04
fatj1pt
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%


Input variable: fatj1C2
(1/N) dN / 0.0646
fatj1C2
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%


Input variable: fatj1m
(1/N) dN / 1.2e+04
fatj1m
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%


Input variable: fatj1NumTrkPt500PV
(1/N) dN / 5.51
fatj1NumTrkPt500PV
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%


Input variable: nJets
Signal
Background
(1/N) dN / 0.395
nJets
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%
Input variable: etaJ3
(1/N) dN / 2.65
etaJ3
Input variable: etaB1
(1/N) dN / 0.128
etaB1
Input variable: etaB2
(1/N) dN / 0.128
etaB2
Input variable: pTV
(1/N) dN / 2.2e+04
pTV
U/O-flow (S,B): (0.0, 0.0)% / (0.1, 0.0)%
Input variable: pTB1
(1/N) dN / 3.4e+04
pTB1

Optimizing double Higgs decay with MVA at FCC luminosities

Filipe Barroso

Supervisores:

Rute Pedro Ricardo Gonçalo

Com apoio de:

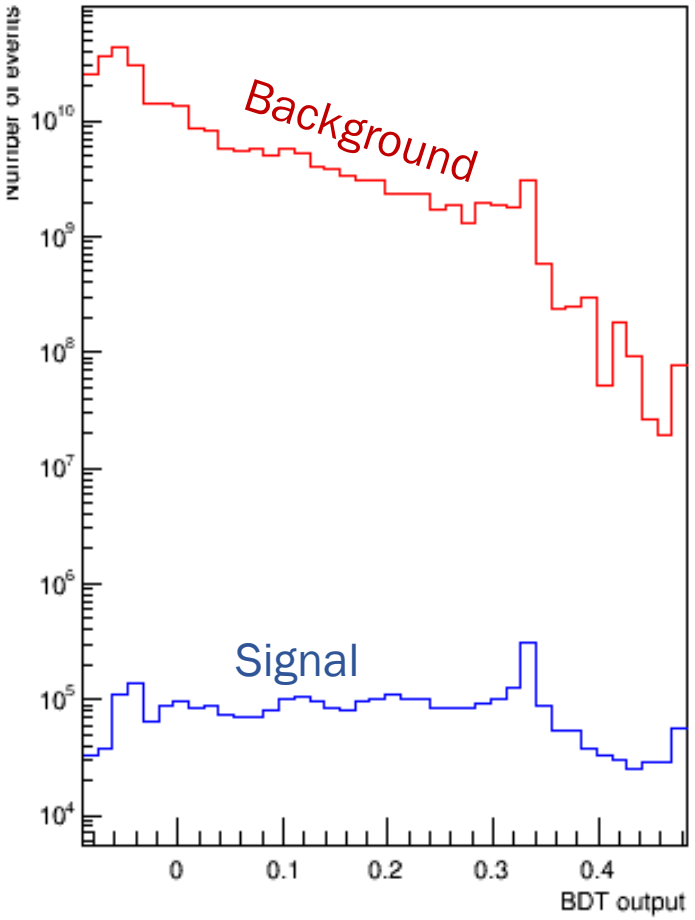
Ana Luísa Carvalho

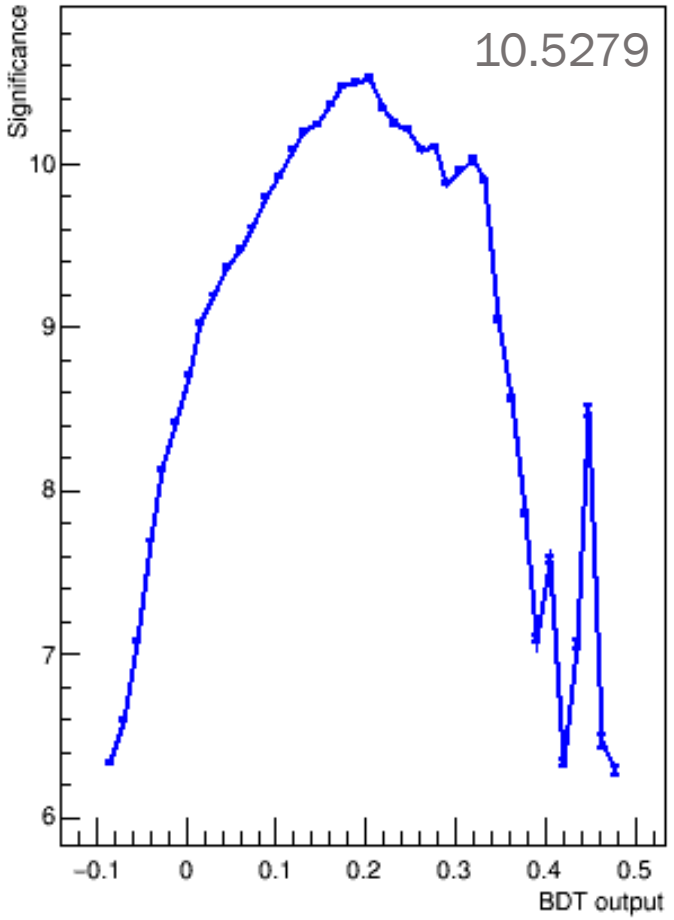
Backup

Significances

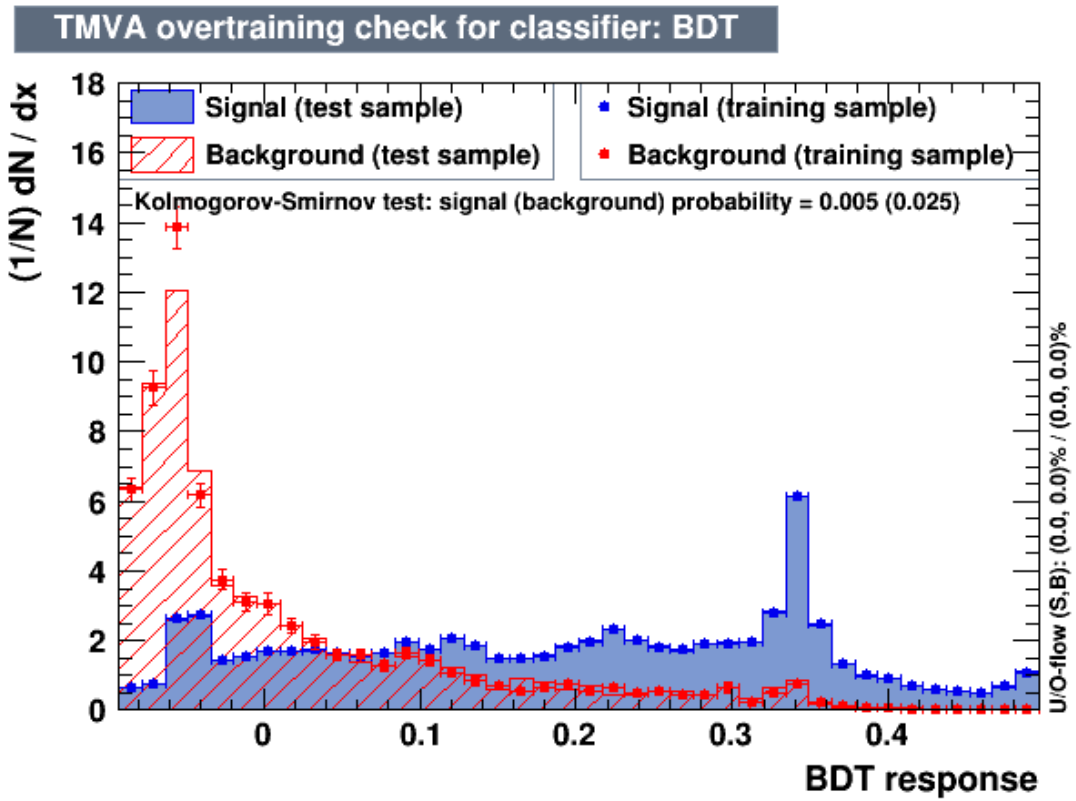
$\mathcal{L} = 30\ ab^{-1}$

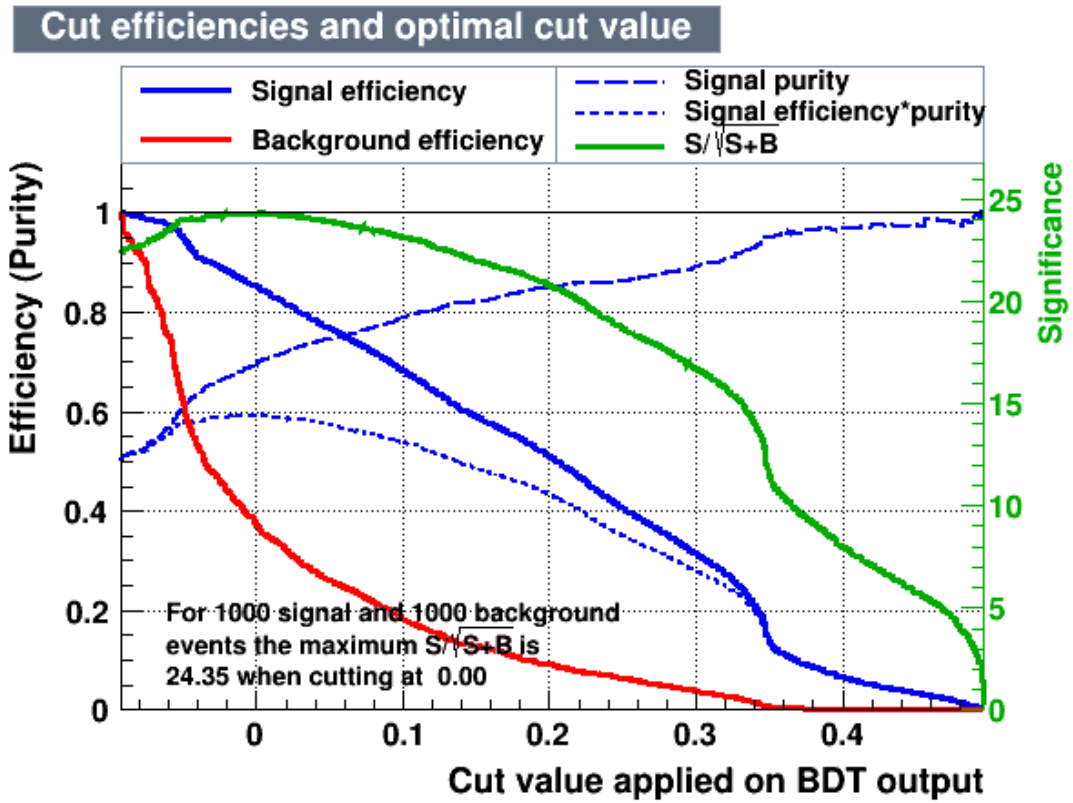
$P_t < 900\ GeV$
$M > 90 GeV$



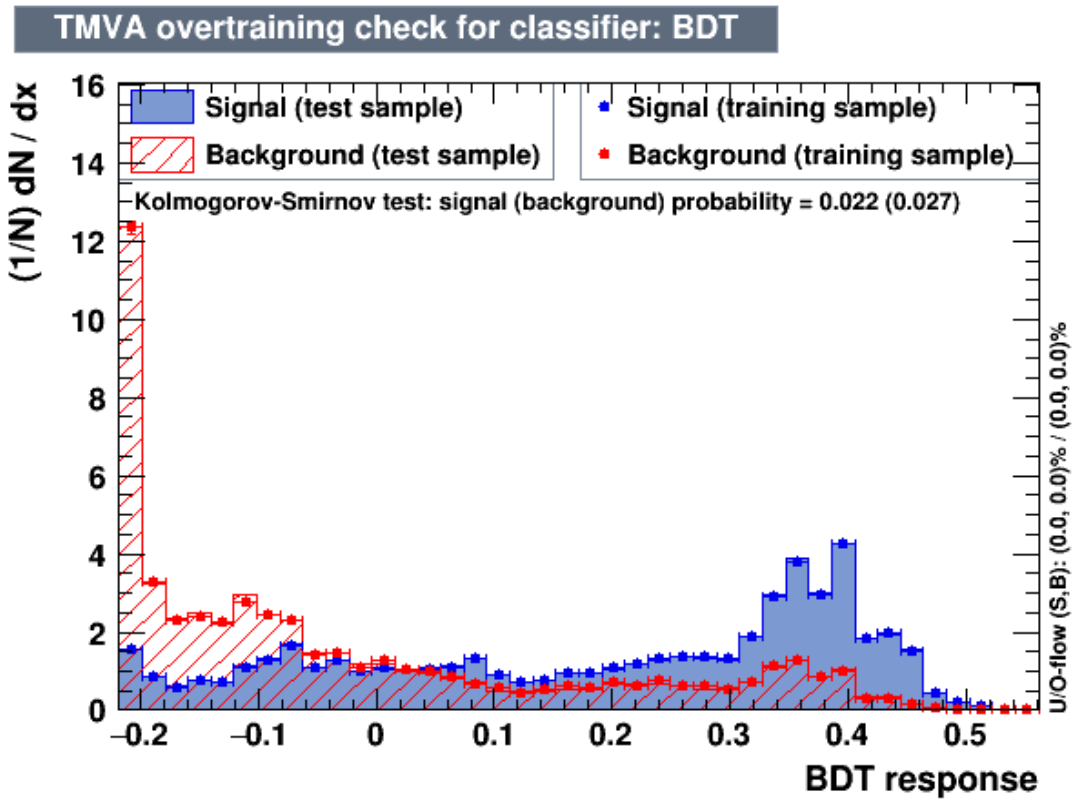


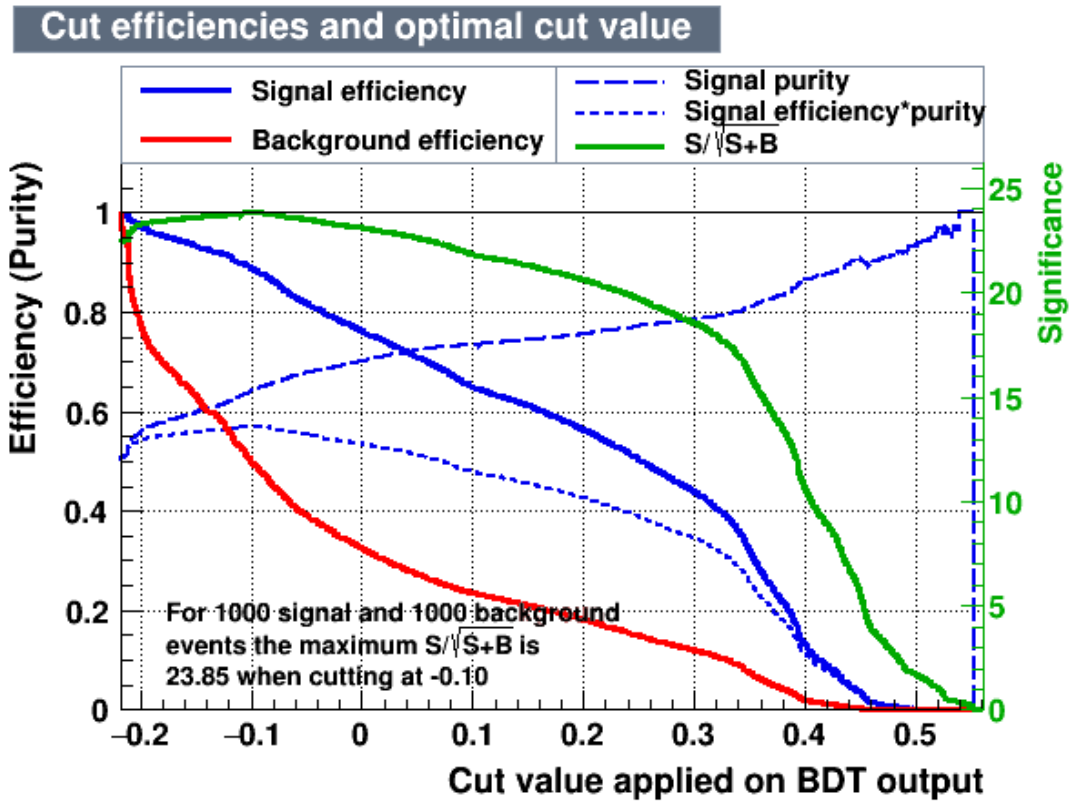
Pt < 900 GeV; SDm > 90 GeV

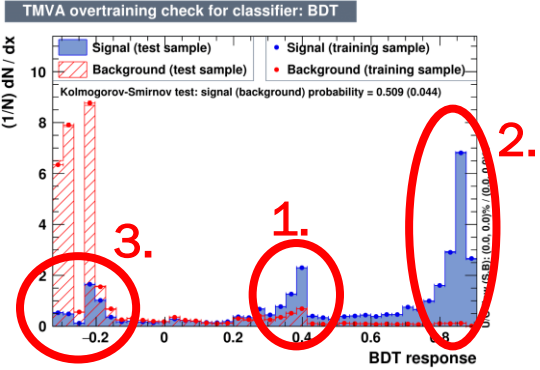




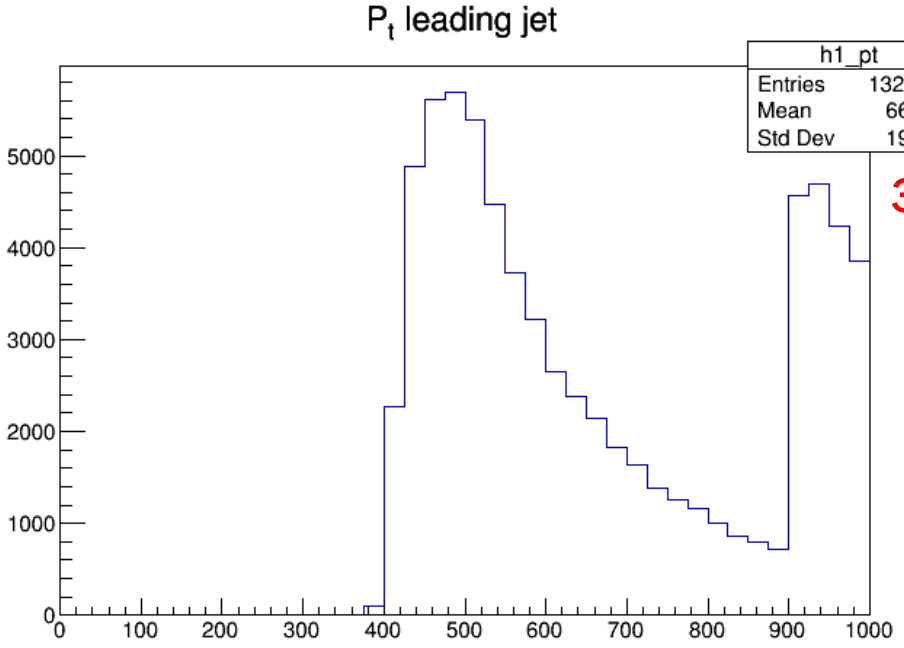
Pt < 900 GeV; SDm < 90 GeV

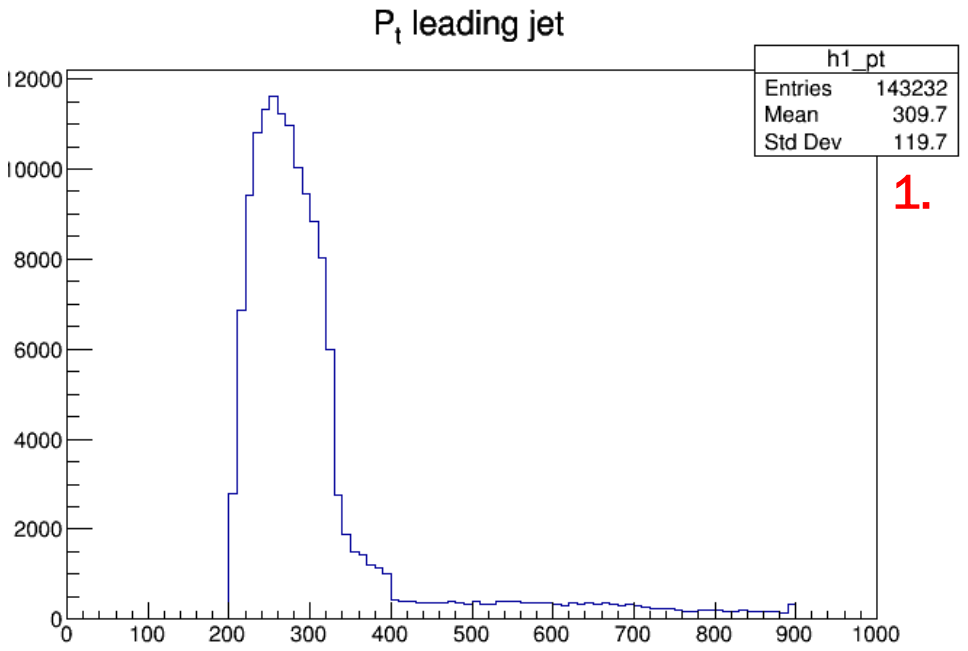


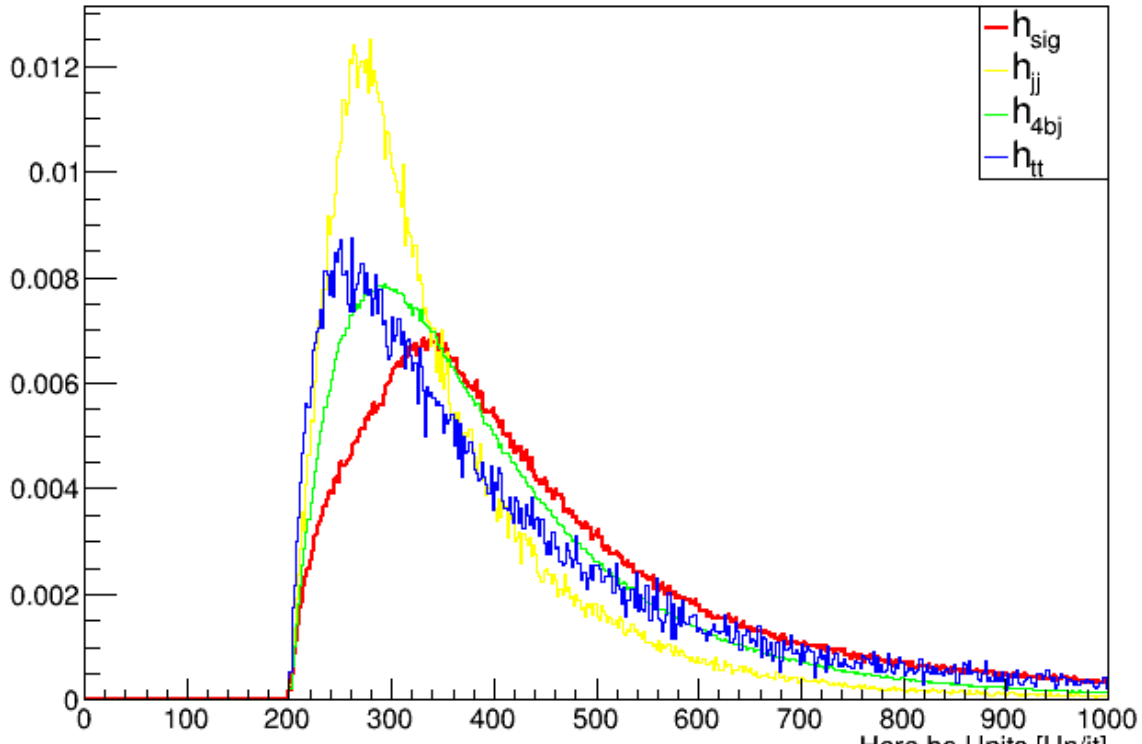


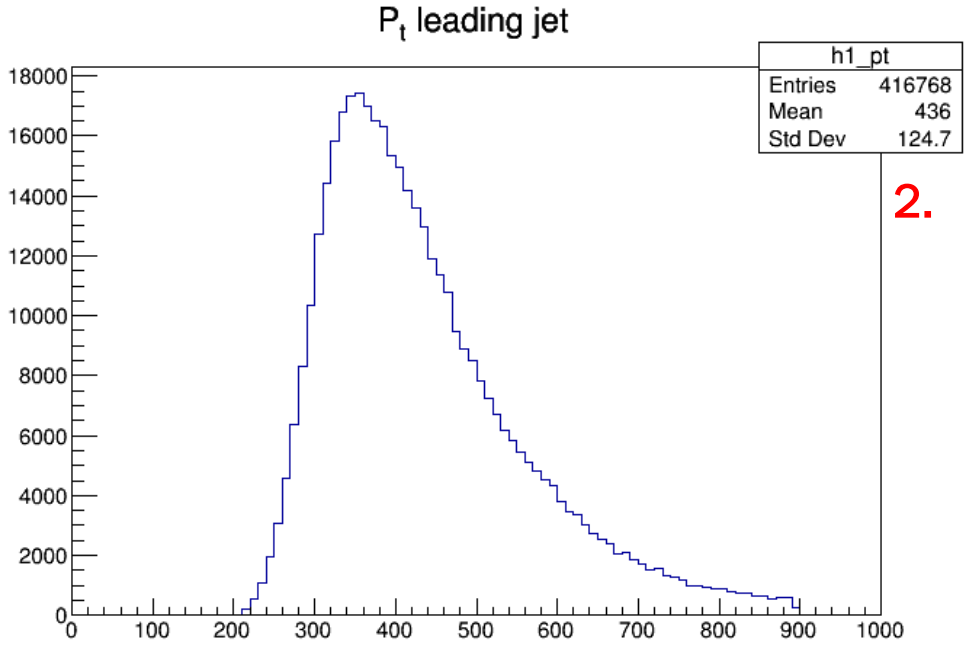


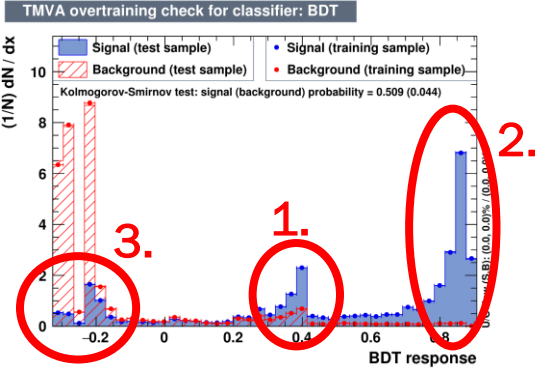
Important BDT cut at 900 GeV.

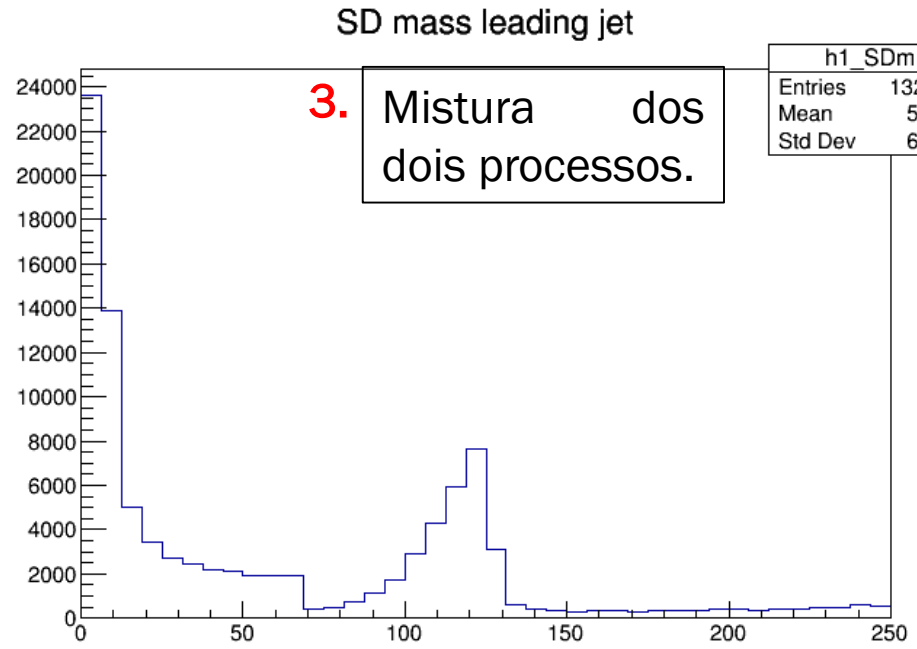




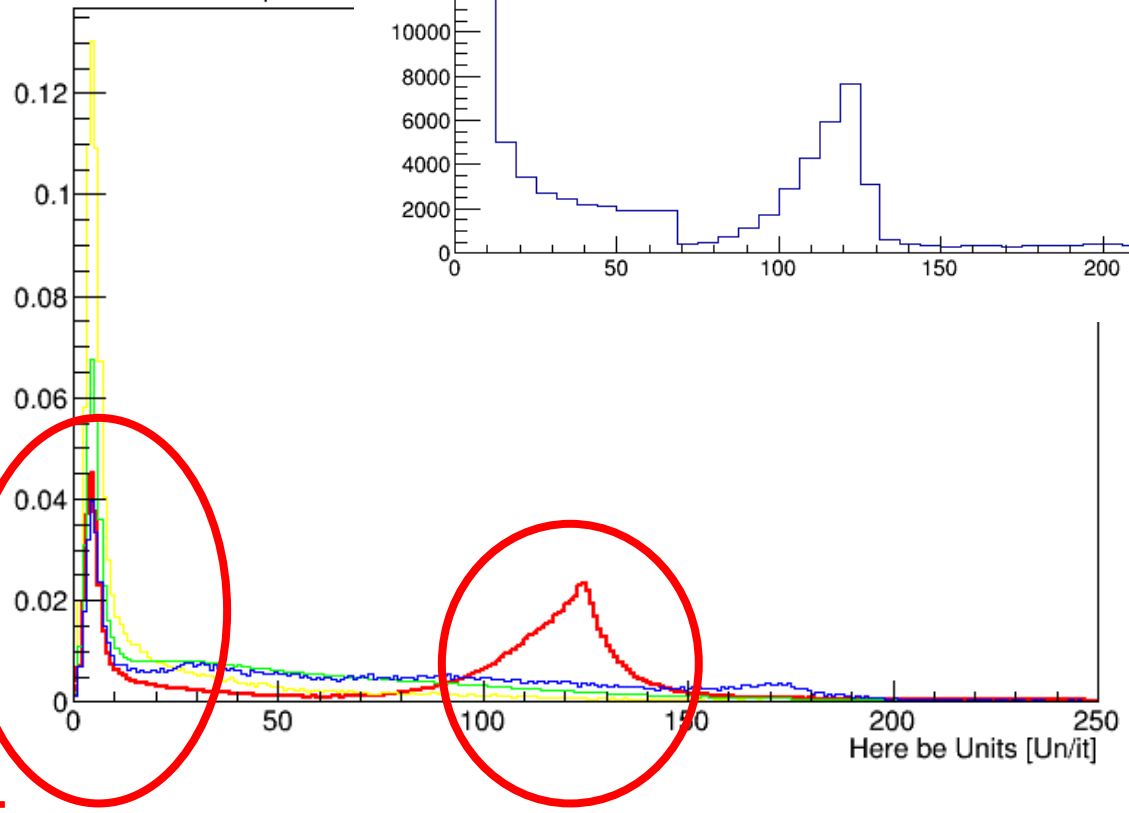








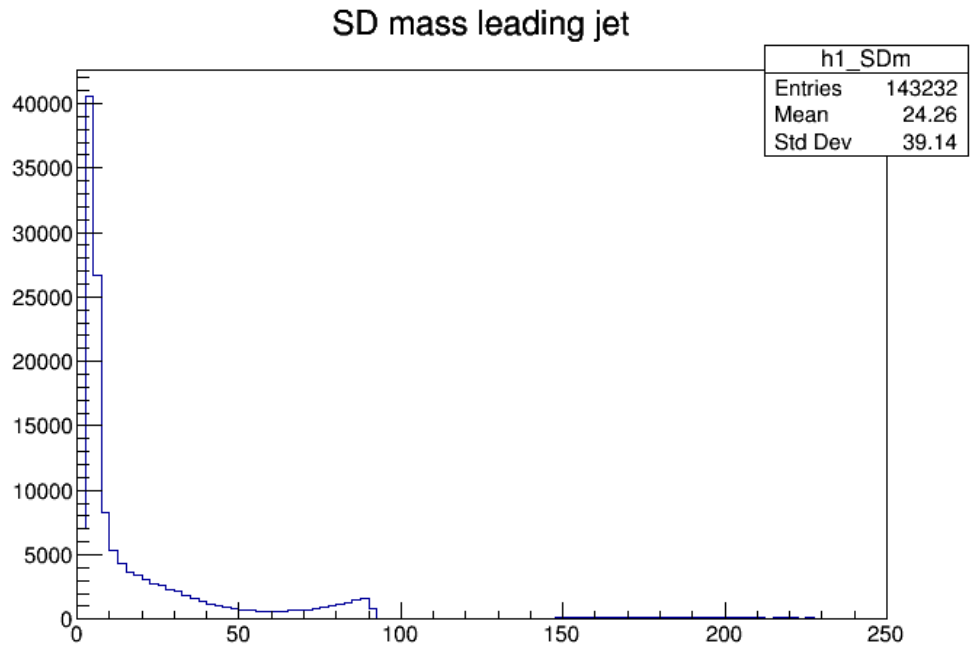
3. Mistura dos dois processos.



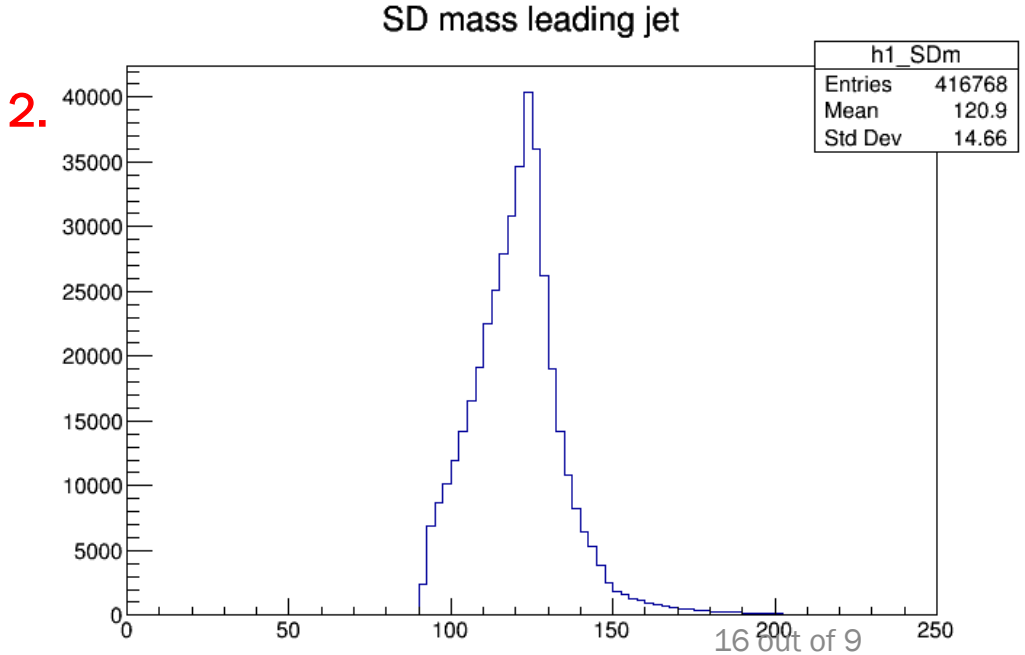
1.

Low mass jets: single b-tagged quarks.

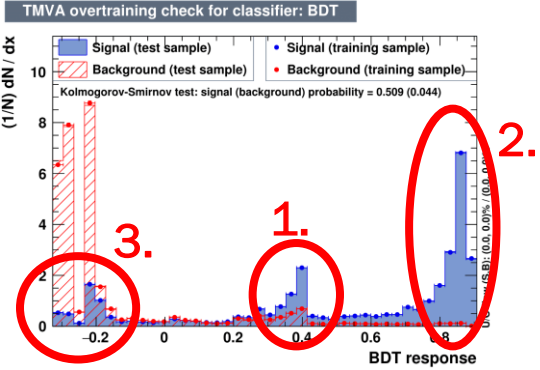
2. Jets whose mass peaks at the Higgs mass.



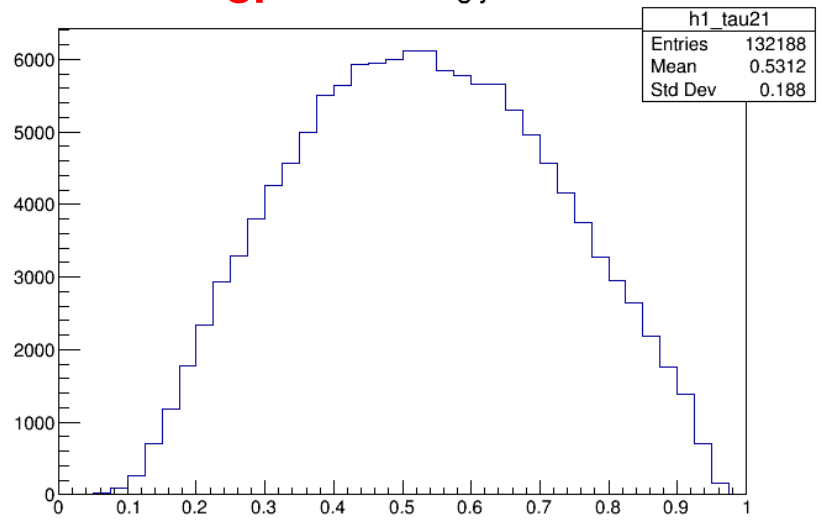
1

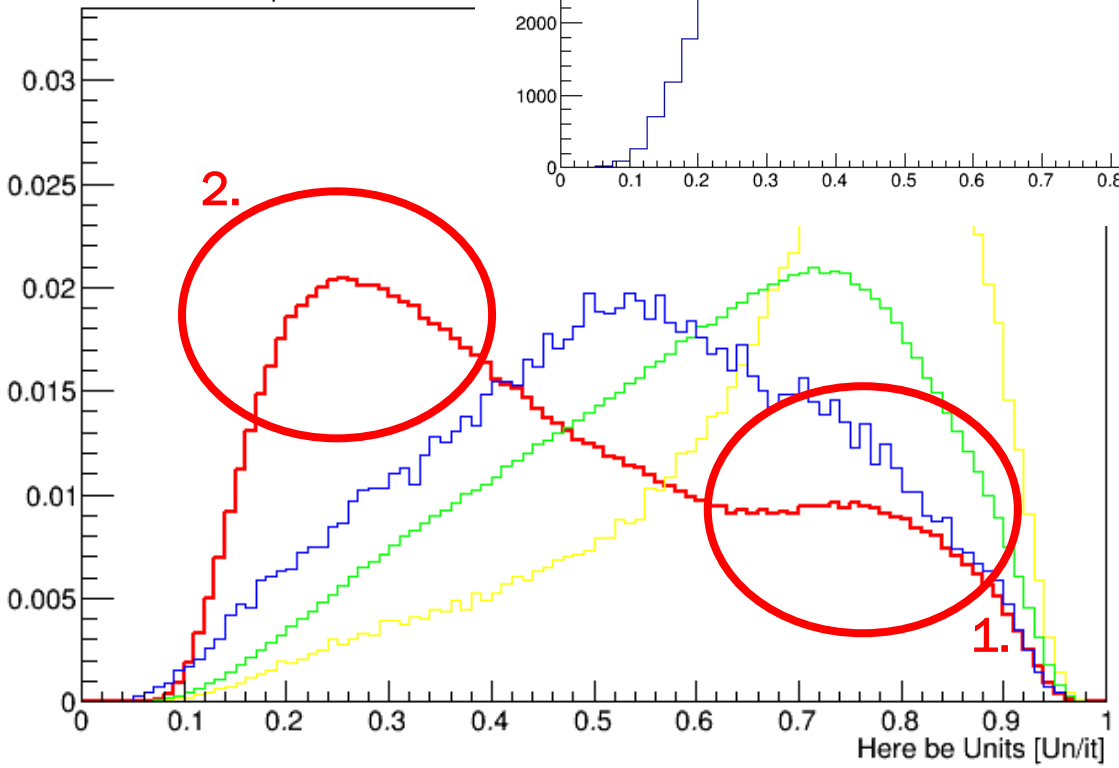


2.



3. Tau21 leading jet



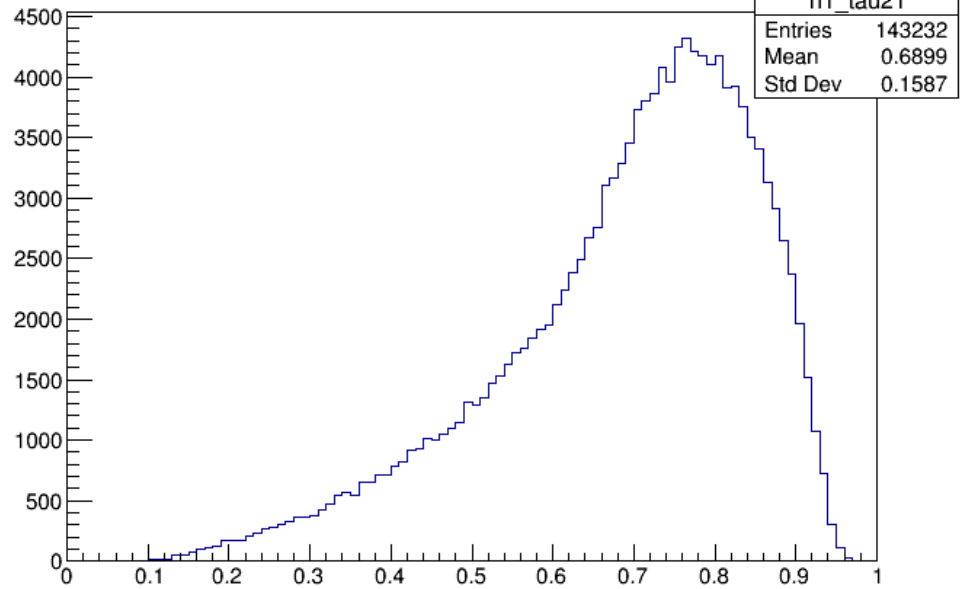


2. Signal jets: near zero as predicted.

1. Jets with a single subjet.

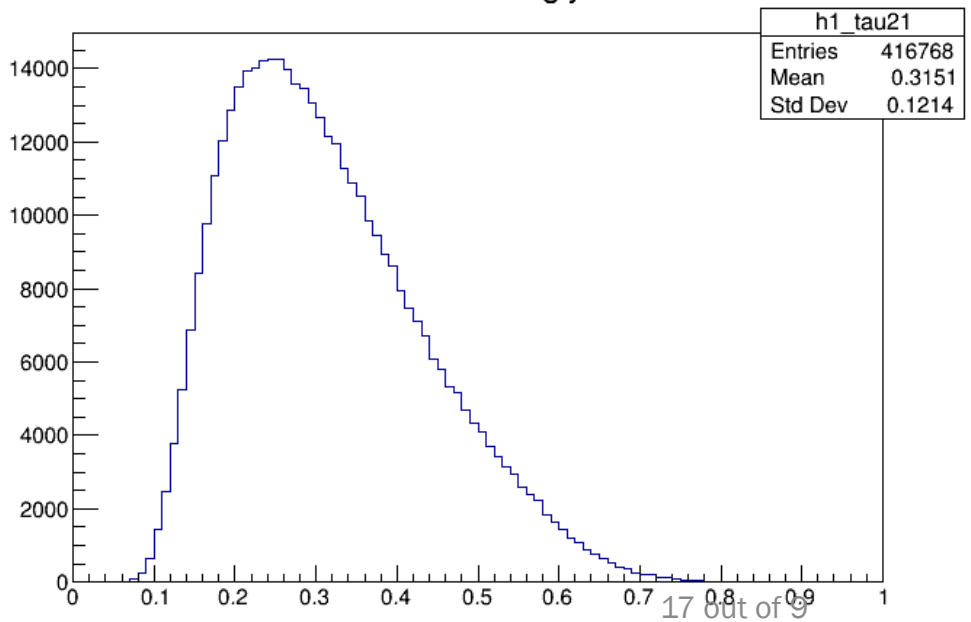
Tau21 leading jet

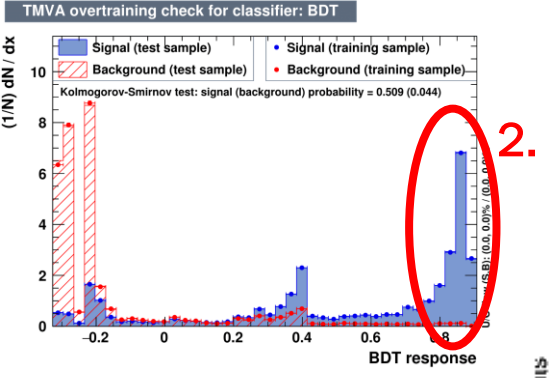
1.



Tau21 leading jet

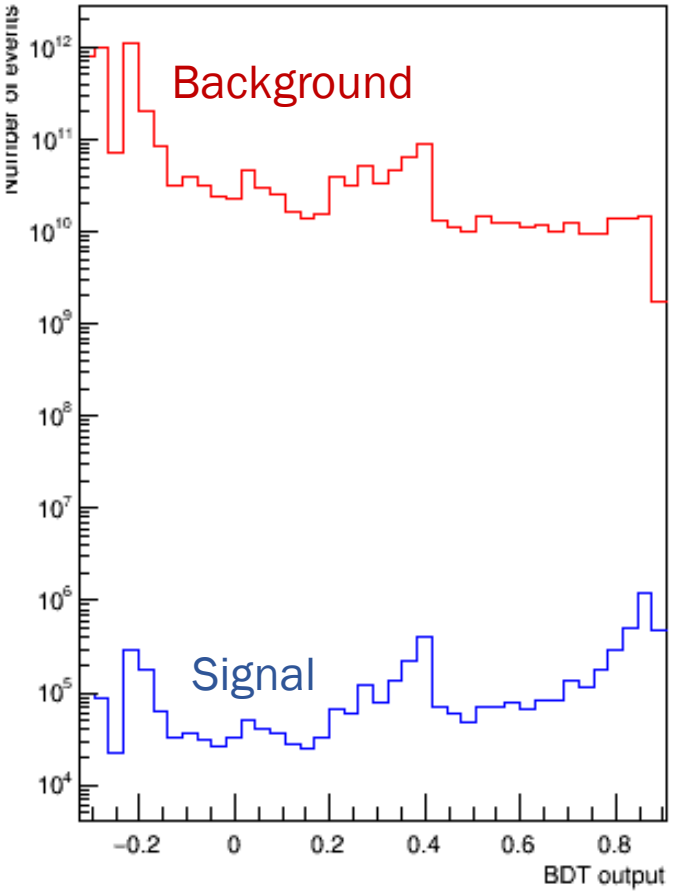
2.

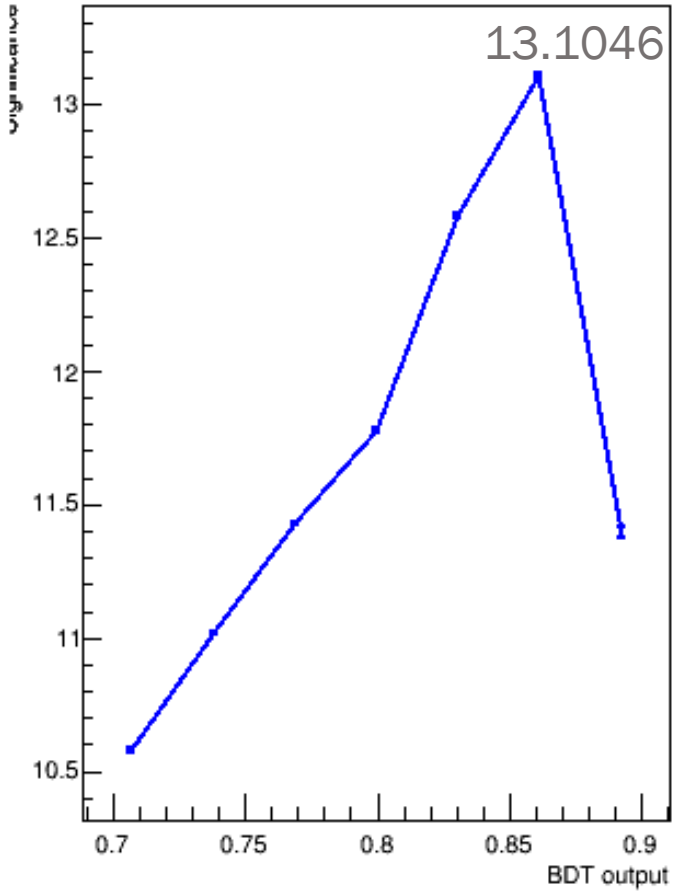




Significances

$\mathcal{L} = 30\ ab^{-1}$





Boosted Decision Trees

- We've used this Multivariate Method to separate the signal from the background and assess which input variables were more relevant in such endeavour.
- Each successive decision tree trains more diligently the events where the separation is harder to evaluate.