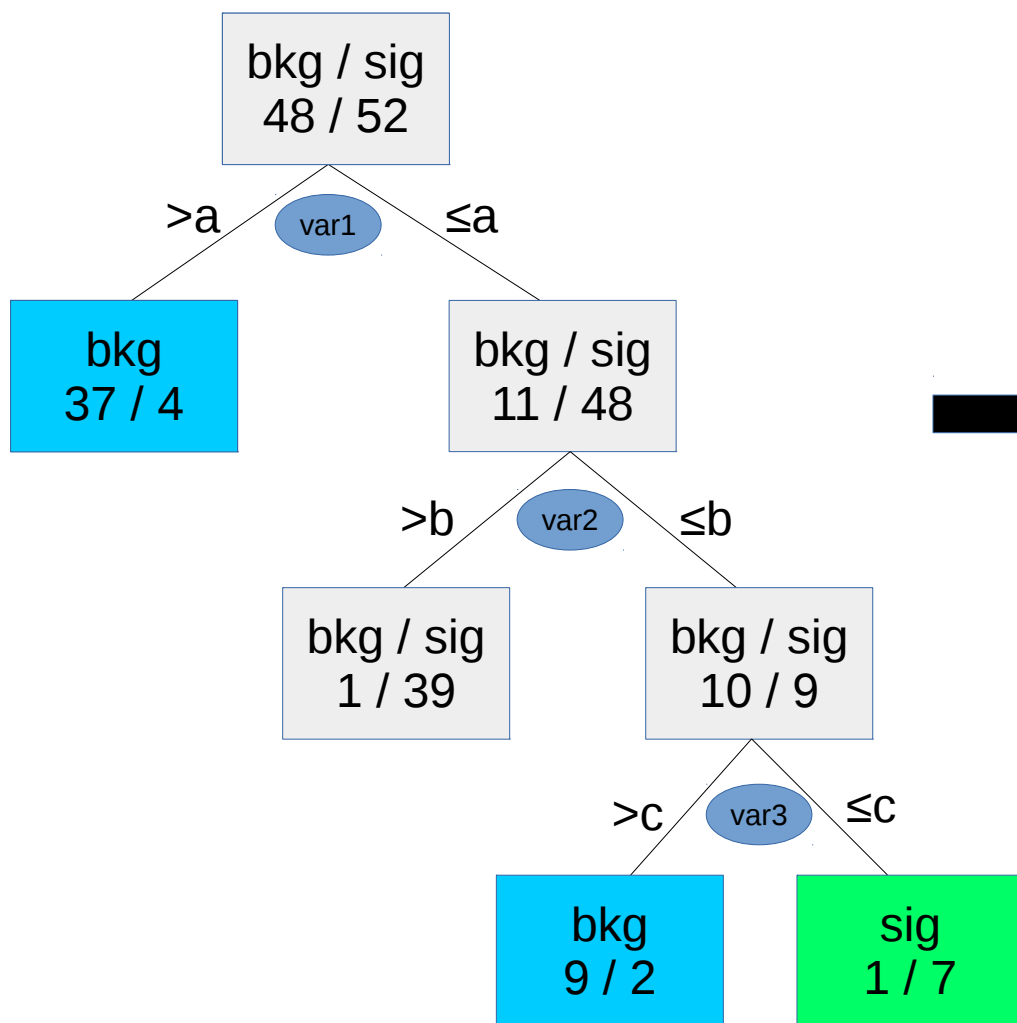


QCD Rejection in fully hadronic ttH with BDT training

DT (Decision Tree) Example

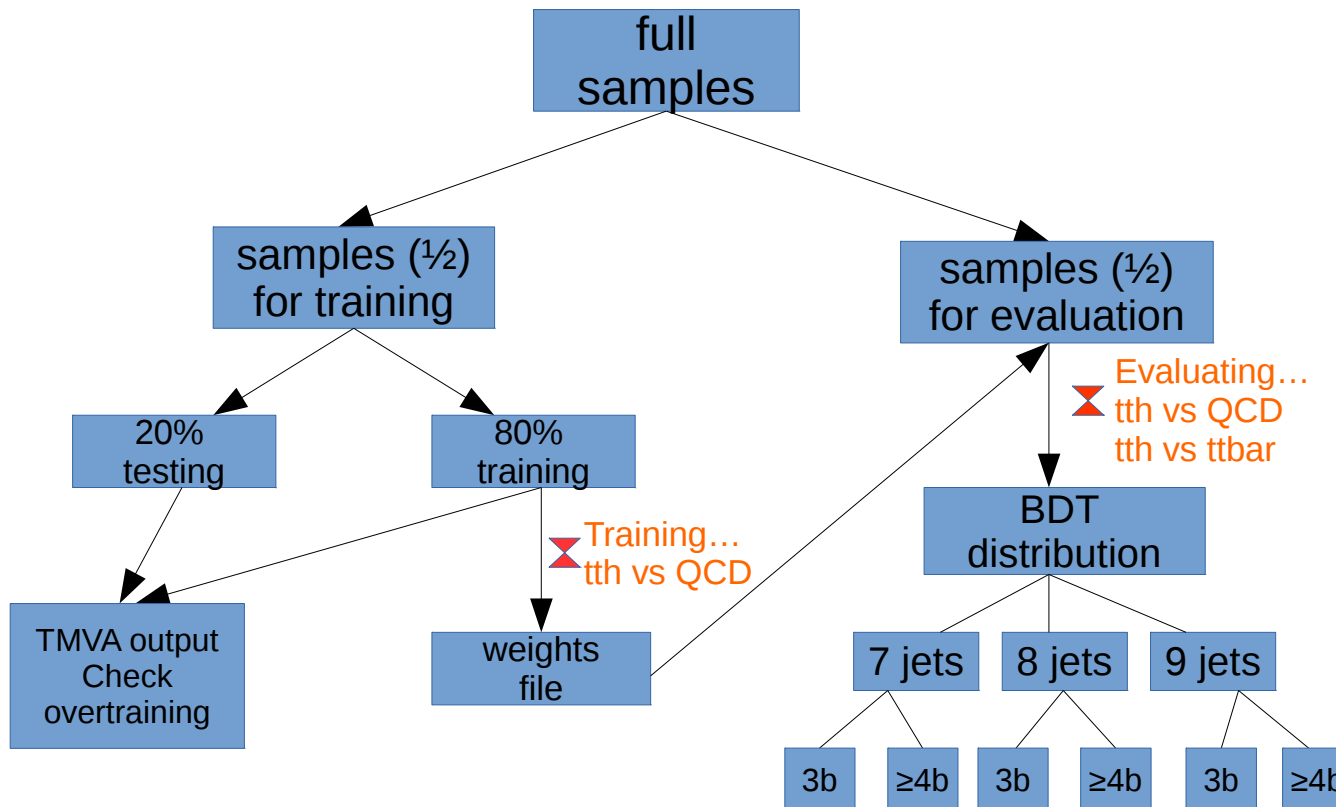


BDT (Boosted Decision Tree)

- build many DTs
 $O(100) \sim O(1000)$,
so that the weighted
average will be insensitive
to fluctuations.
- implement algorithm
AdaBoost
(*adaptive boosting*)

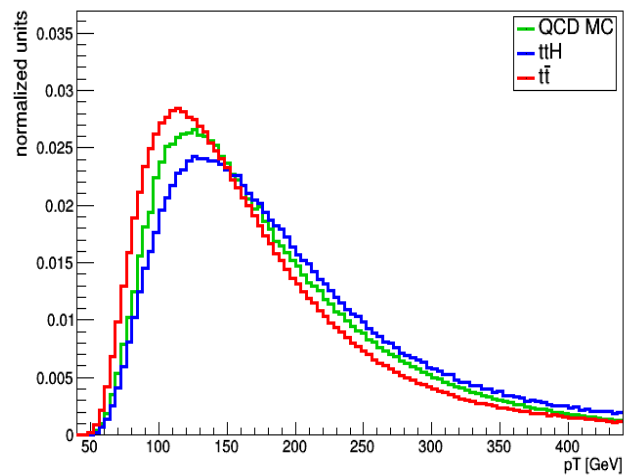
Training samples & procedures

- Signal :
 - ttH : had_V24_4__ttHTobb_M125_13TeV_powheg_pythia8
- Background :
 - ttbar : had_V24_4__TT_TuneCUETP8M1_13TeV-powheg-pythia8
 - QCD Multijets : had_V24_4__QCD_HT300to500_TuneCUETP8M1_13TeV-madgraphMLM-pythia8, ~_HT500to700_~, ... , ~_HT2000toInf_~

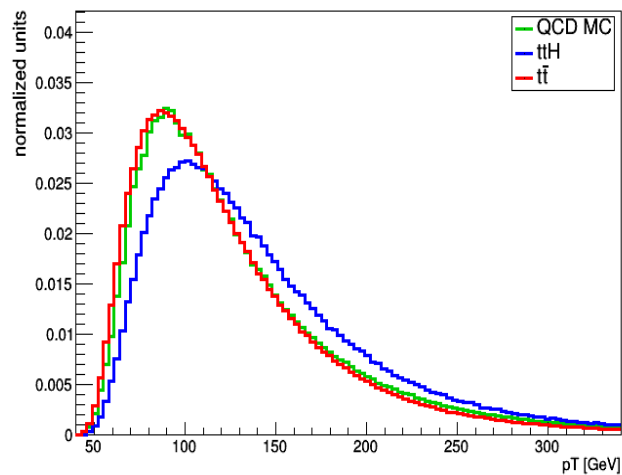


Training Variables: jet_pt[0], jet_pt[1] ... jet_pt[5]

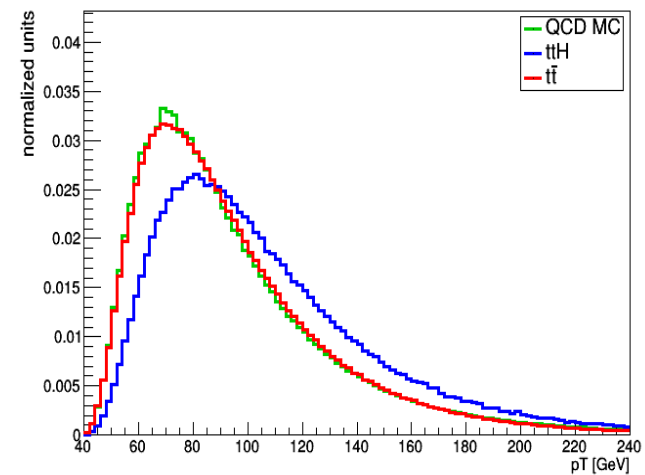
jet_pt[0] Distribution



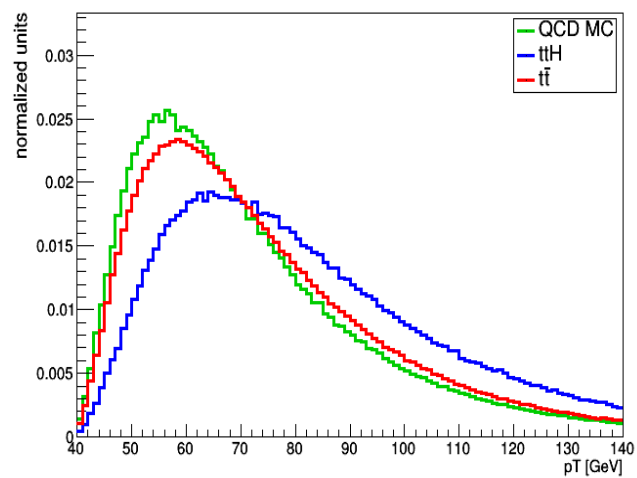
jet_pt[1] Distribution



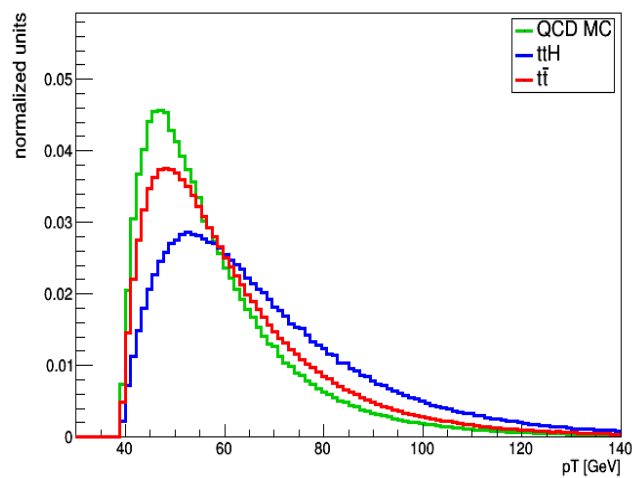
jet_pt[2] Distribution



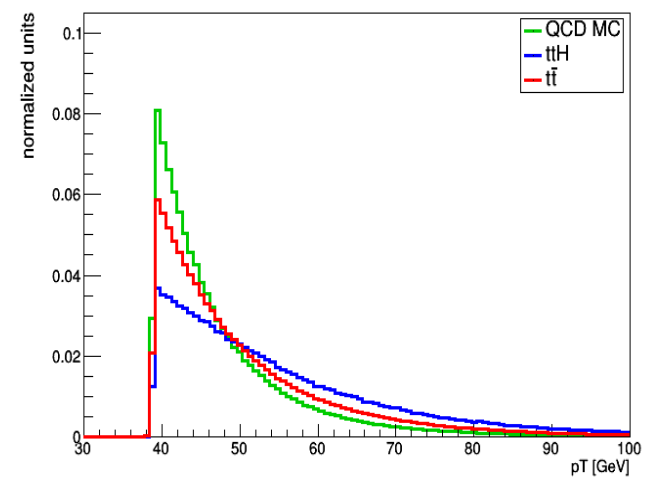
jet_pt[3] Distribution



jet_pt[4] Distribution

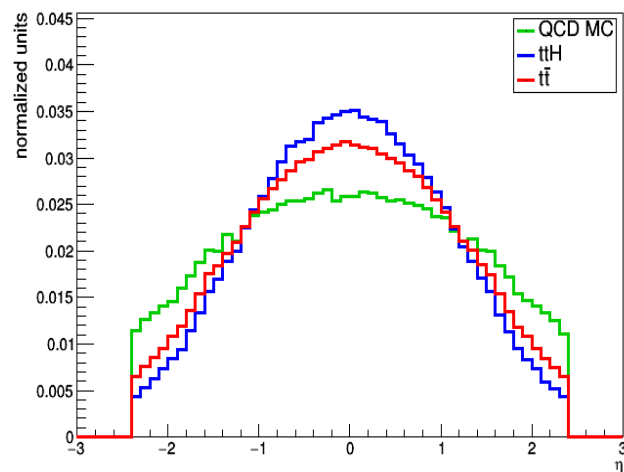


jet_pt[5] Distribution

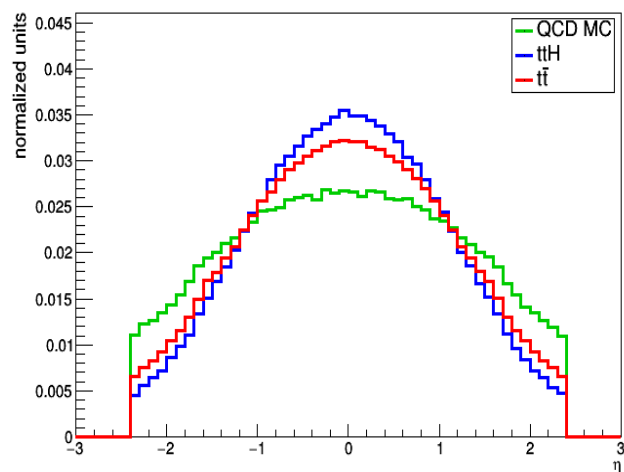


Training Variables: jet_eta[0] ... jet_eta[5]

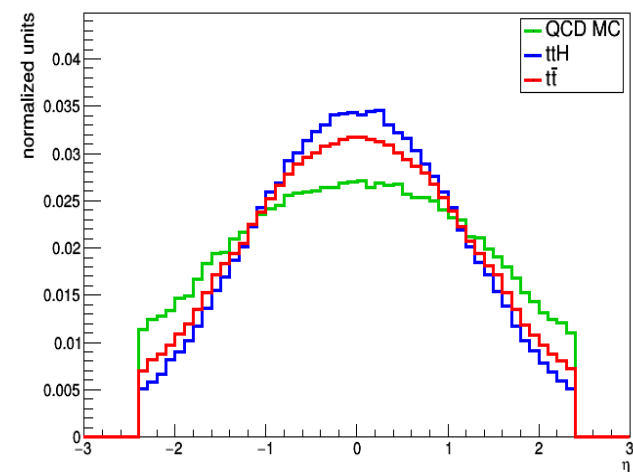
jet_eta[0] Distribution



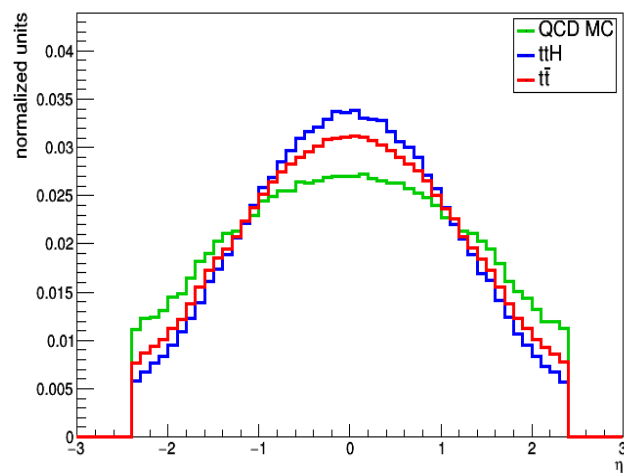
jet_eta[1] Distribution



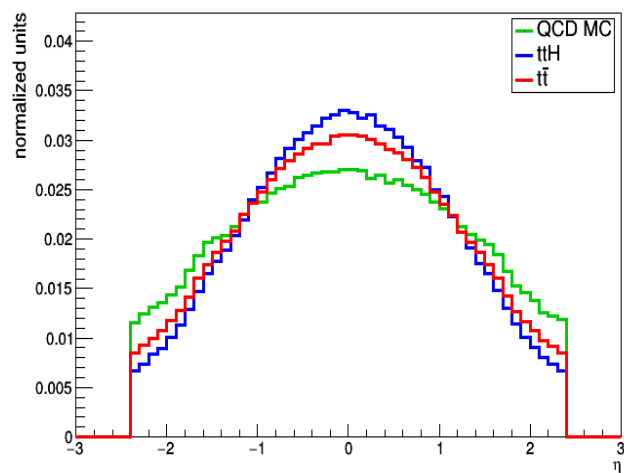
jet_eta[2] Distribution



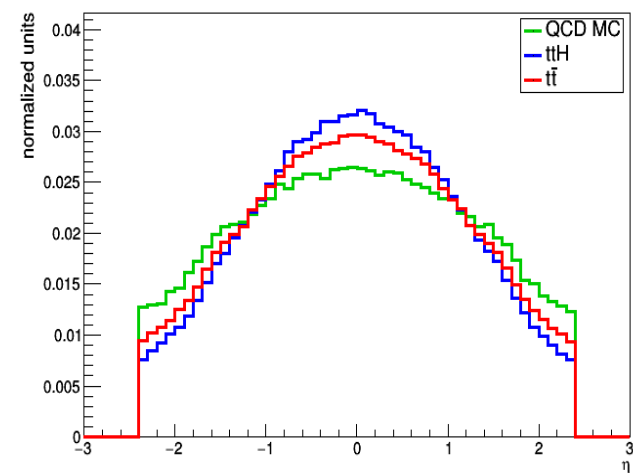
jet_eta[3] Distribution



jet_eta[4] Distribution

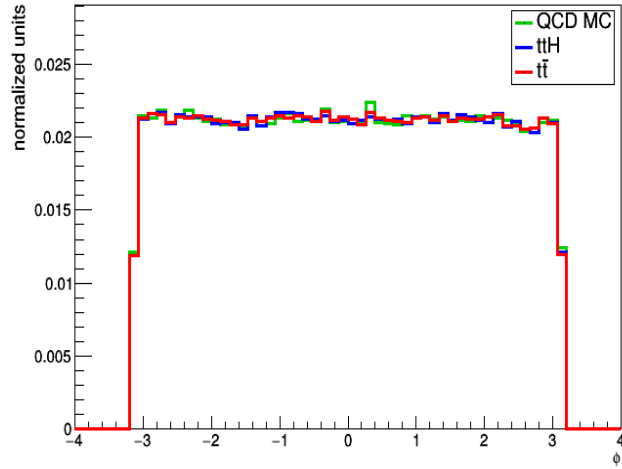


jet_eta[5] Distribution

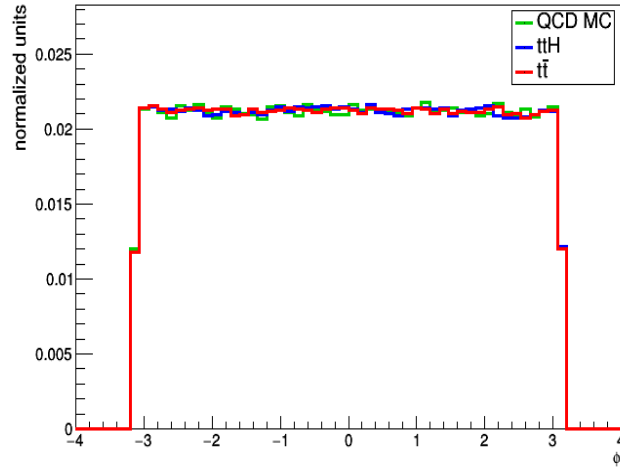


Training Variables: jet_phi[0] ... jet_phi[5]

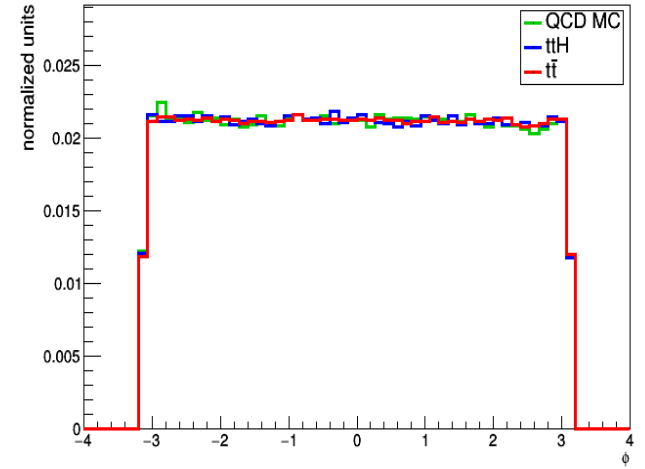
jet_phi[0] Distribution



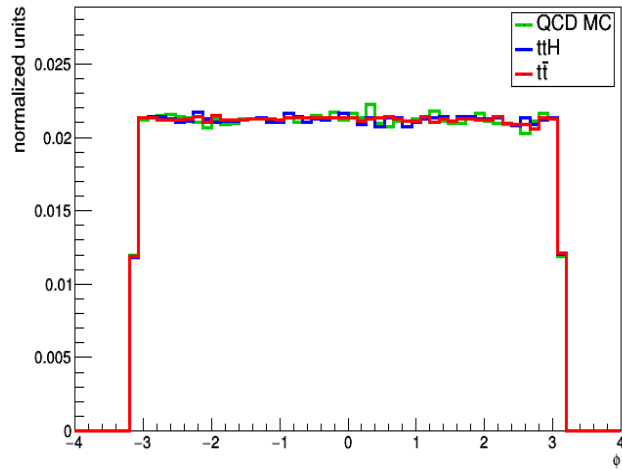
jet_phi[1] Distribution



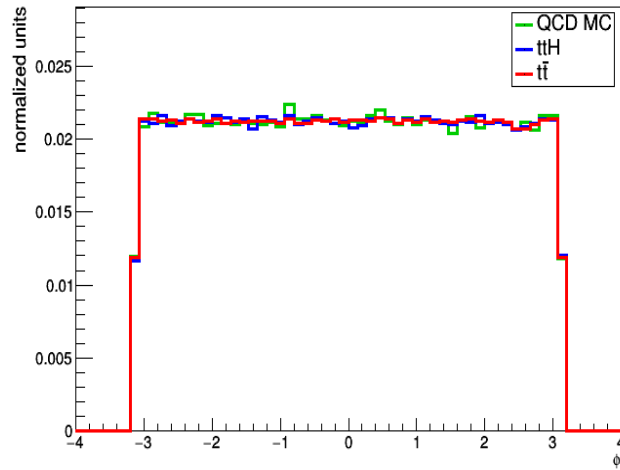
jet_phi[2] Distribution



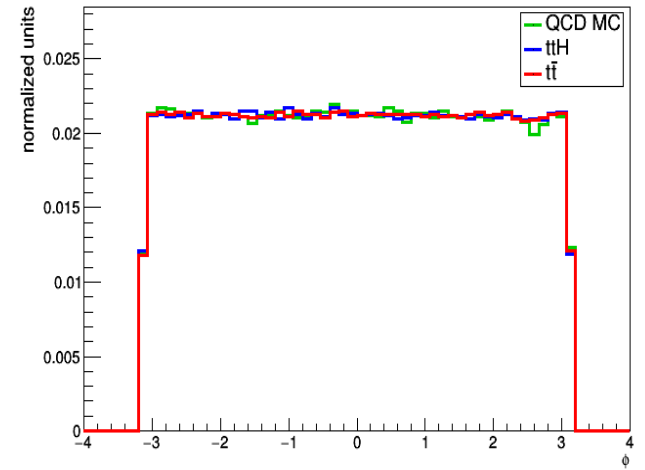
jet_phi[3] Distribution



jet_phi[4] Distribution

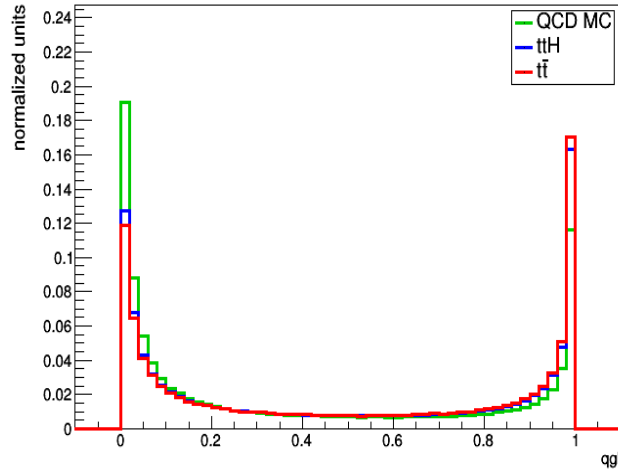


jet_phi[5] Distribution

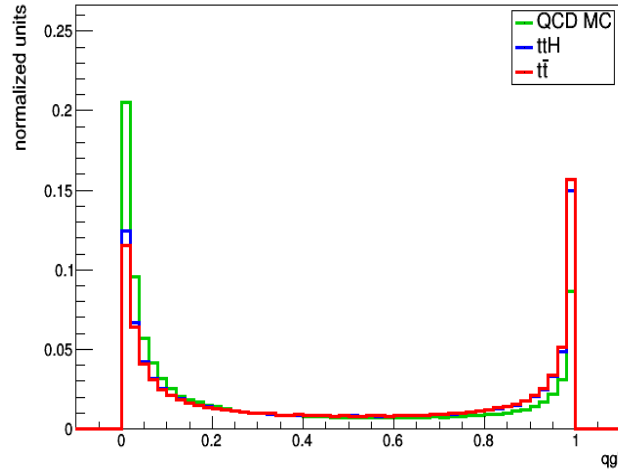


Training Variables: jet_qgl[0] ... jet_qgl[5]

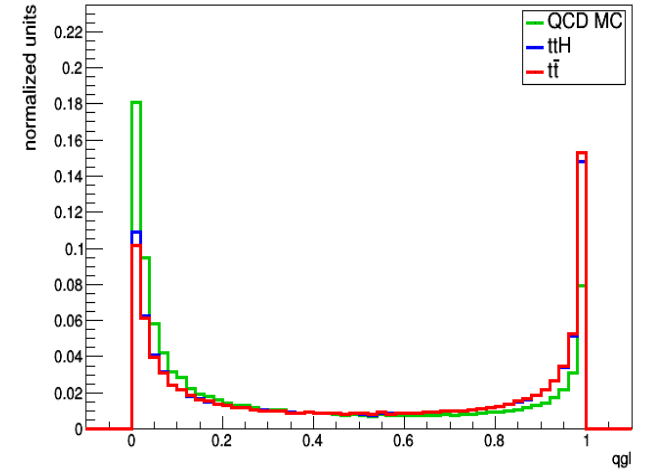
jet_qgl[0] Distribution



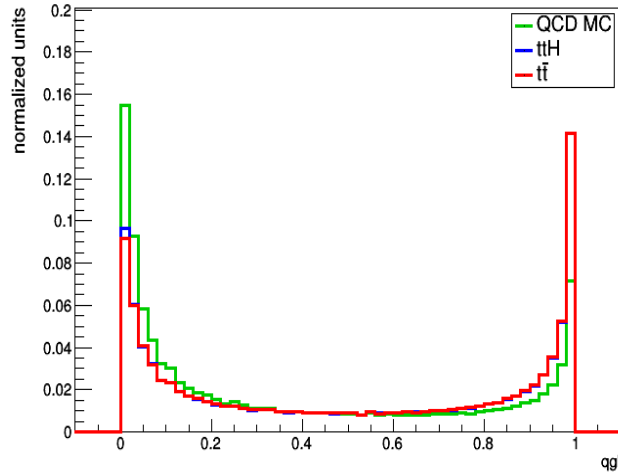
jet_qgl[1] Distribution



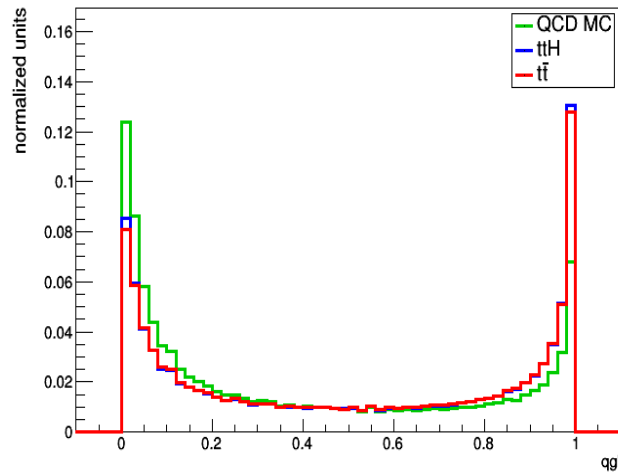
jet_qgl[2] Distribution



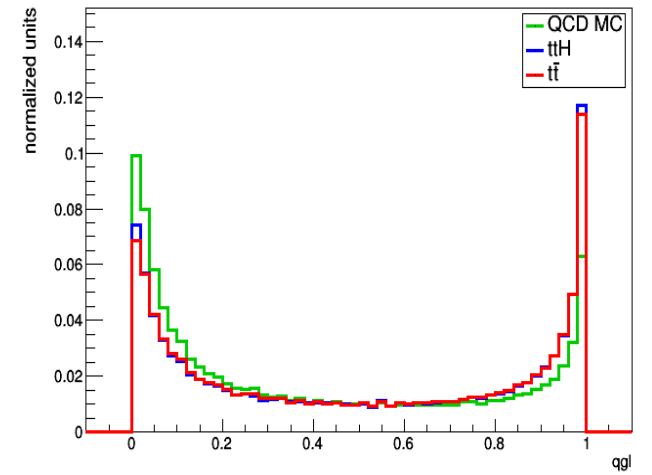
jet_qgl[3] Distribution



jet_qgl[4] Distribution

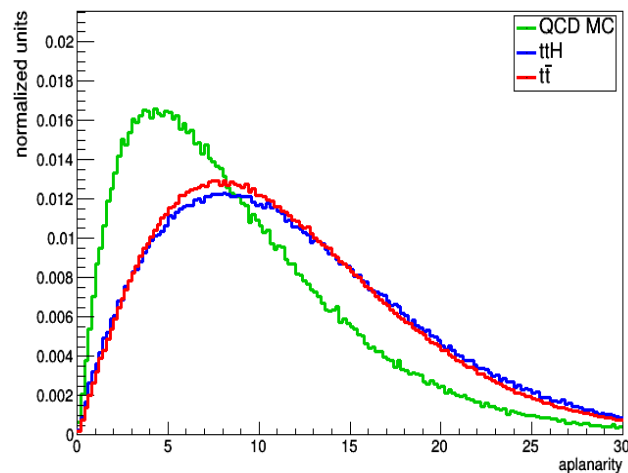


jet_qgl[5] Distribution

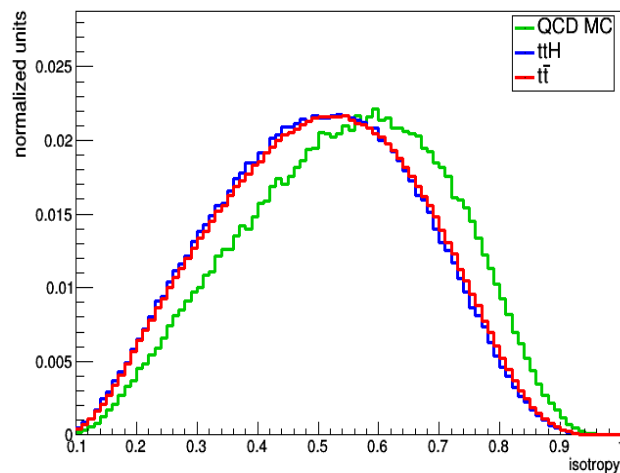


Training Variables: aplanarity, isotropy, min_dr_btag, sphericity, $\log_{10}(C)$, $\log_{10}(D)$

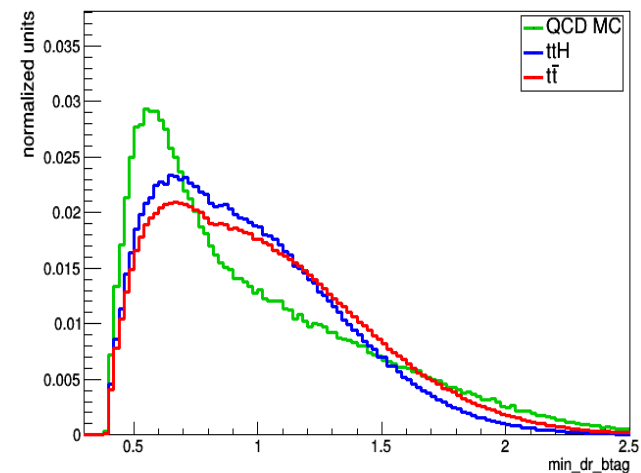
aplanarity Distribution



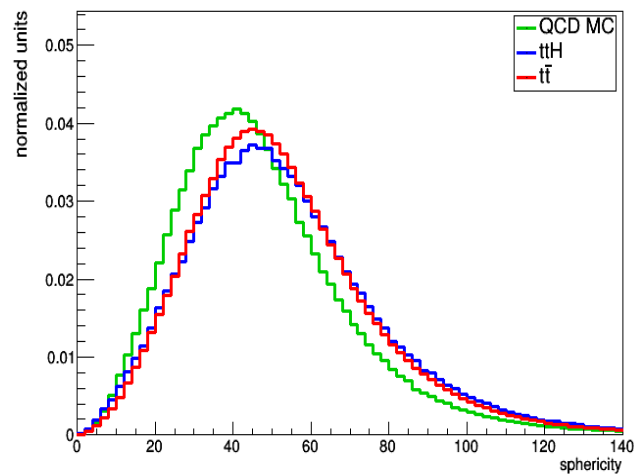
isotropy Distribution



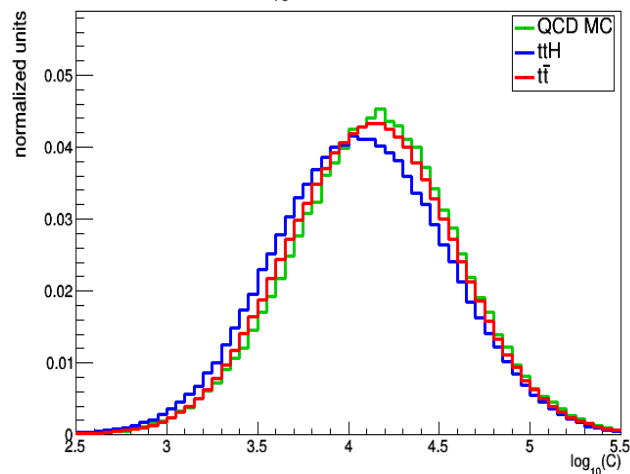
min_dr_btag Distribution



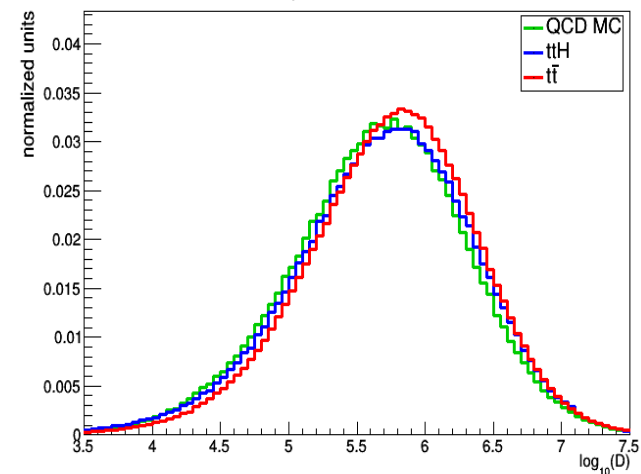
sphericity Distribution



$\log_{10}(C)$ Distribution

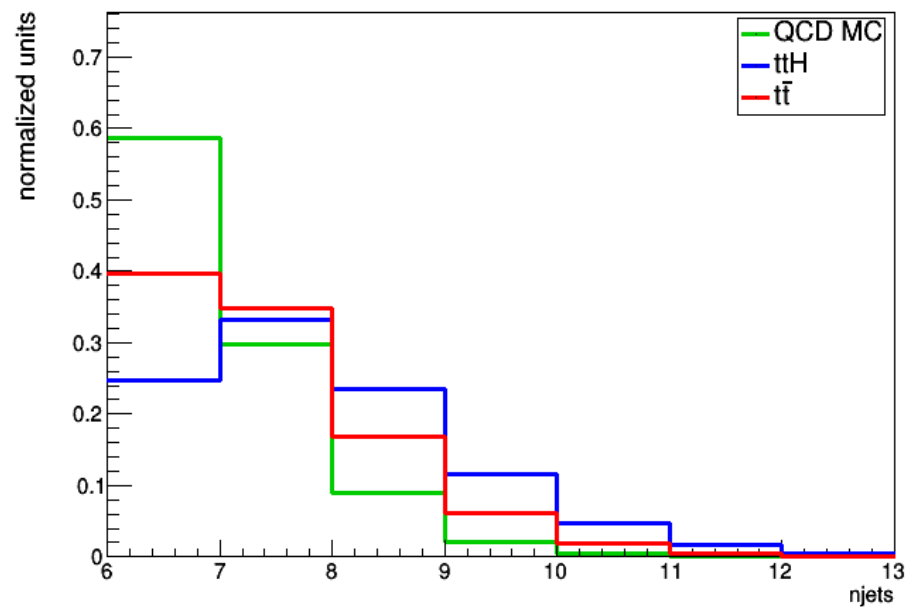


$\log_{10}(D)$ Distribution

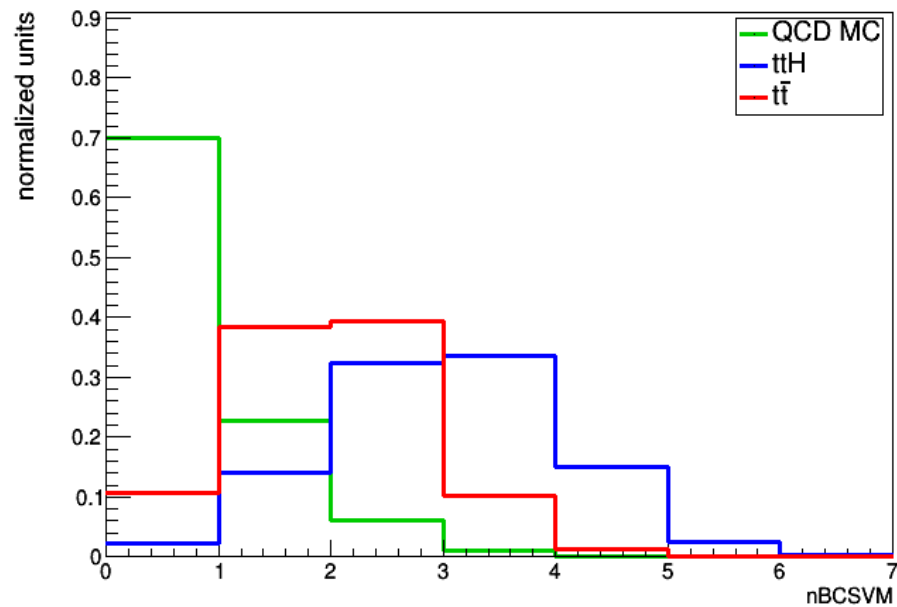


Training Variables: njets, nBCSVM

njets Distribution

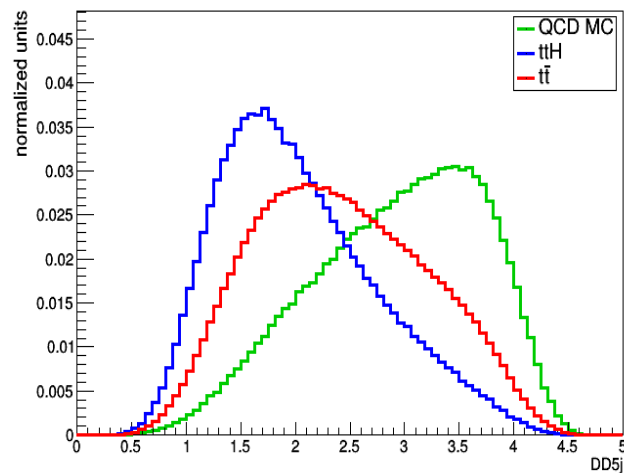


nBCSVM Distribution

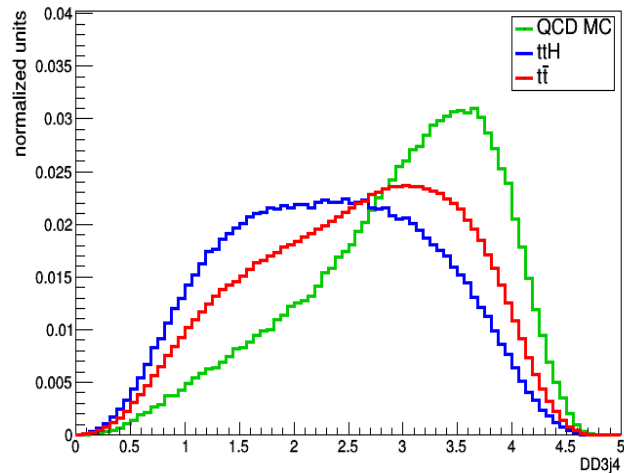


Training Variables: DD5j[12], DD3j4[12], Deta5j, Deta3j4, Dphi5j, Dphi4j5

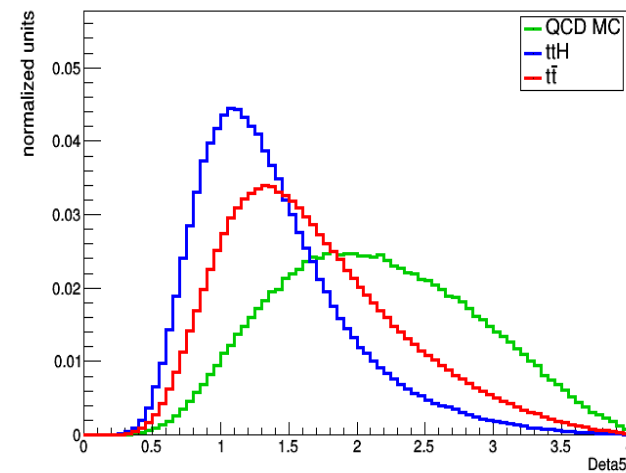
DD5j[12] Distribution



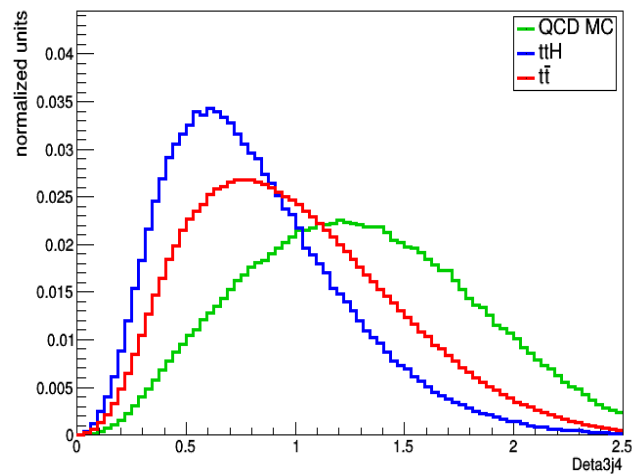
DD3j4[12] Distribution



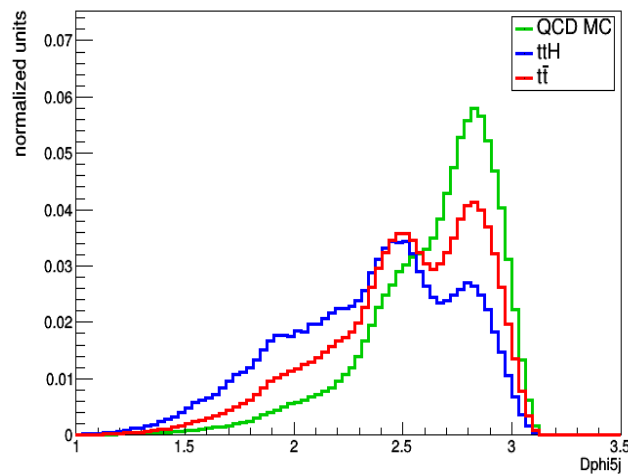
Deta5j Distribution



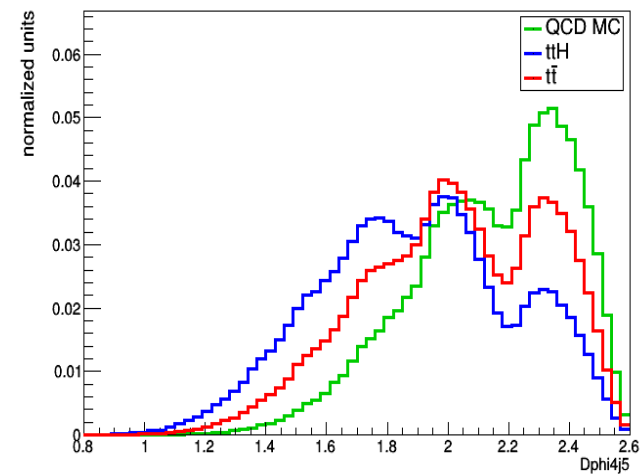
Deta3j4 Distribution



Dphi5j Distribution

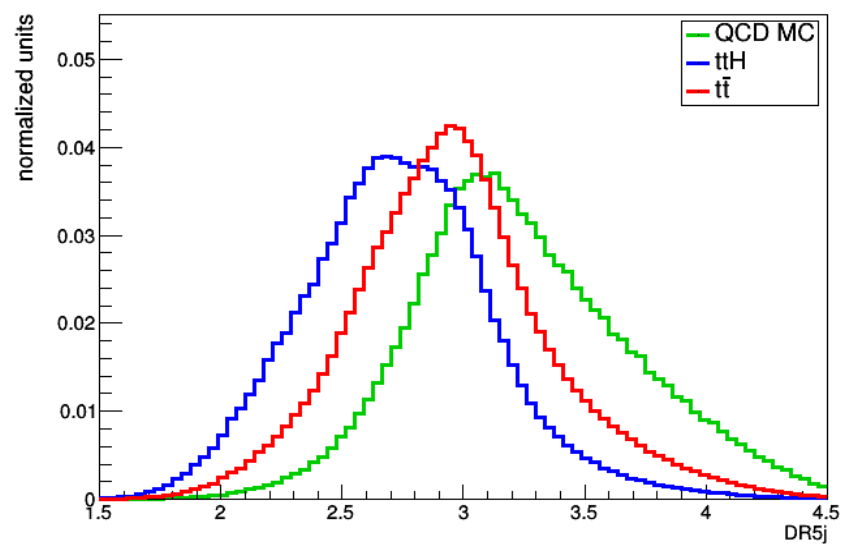


Dphi4j5 Distribution

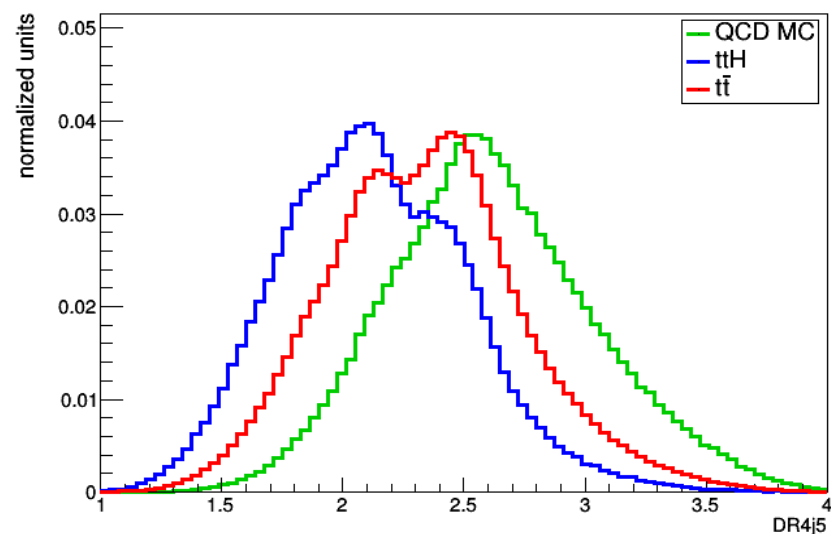


Training Variables: DR5j, DR4j5, DW3j, DW5j6

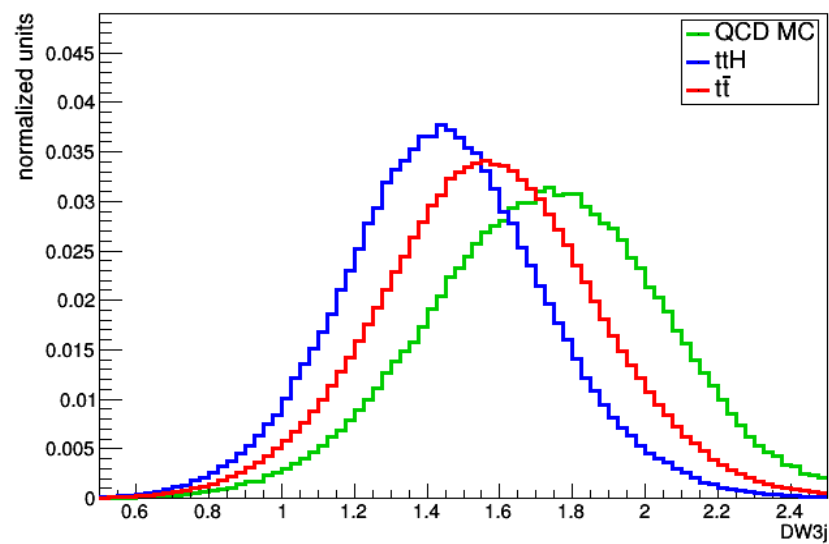
DR5j Distribution



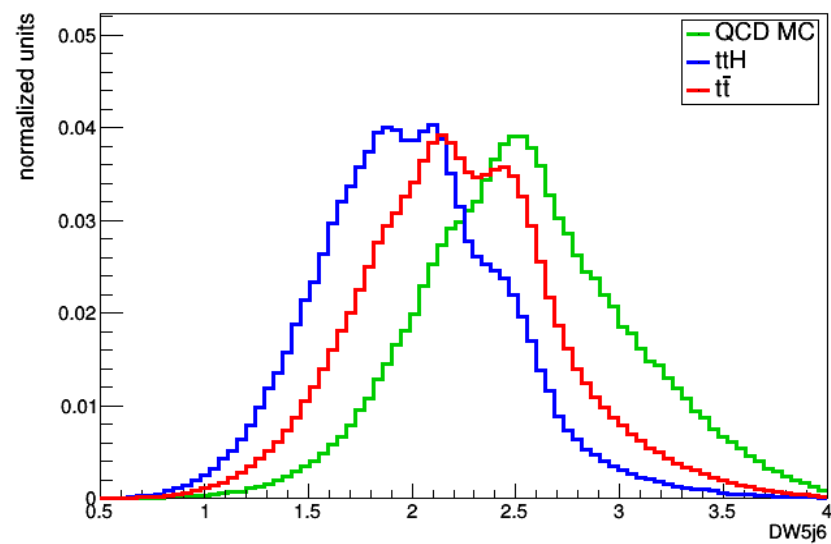
DR4j5 Distribution



DW3j Distribution



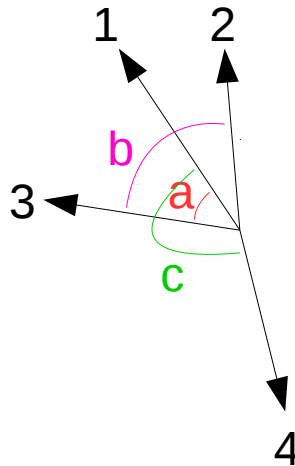
DW5j6 Distribution



Distance variables

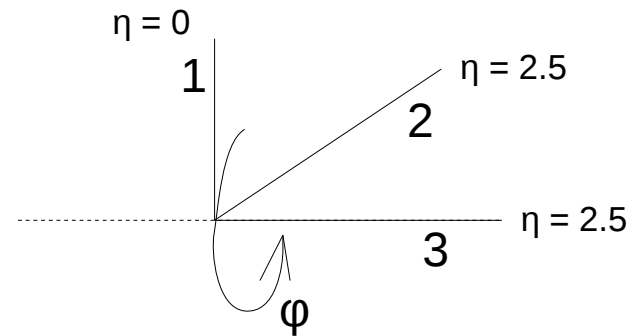
Example 1:

- $D_{\phi 2j}$: the average $\Delta\phi$ of the 2nd closest jet to each jet in an event.
- in this case:
 j1: $\Delta\phi = a$, j2: $\Delta\phi = b$,
 j3: $\Delta\phi = b$, j4: $\Delta\phi = c$
 $D_{\phi 2j} = \frac{1}{4}(a + b + b + c)$
- Therefore, $D_{\phi 4j5}$: the average $\Delta\phi$ of the 4th closest jet to each jet of the first 5 jets in an event.



Example 2:

- $DR = \sqrt{(\Delta\phi)^2 + (\Delta\eta)^2}$
- DD & DW are similar to DR, but are used to penalize $\Delta\phi$ when $\Delta\eta$ is very small



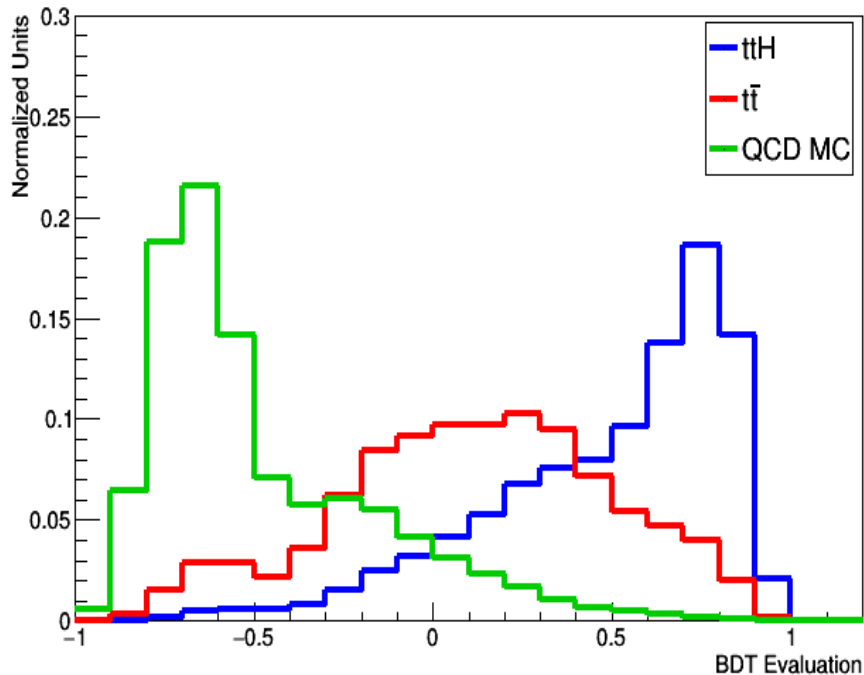
BDT Training & Evaluation (1st attempt)

Input variables(16) :

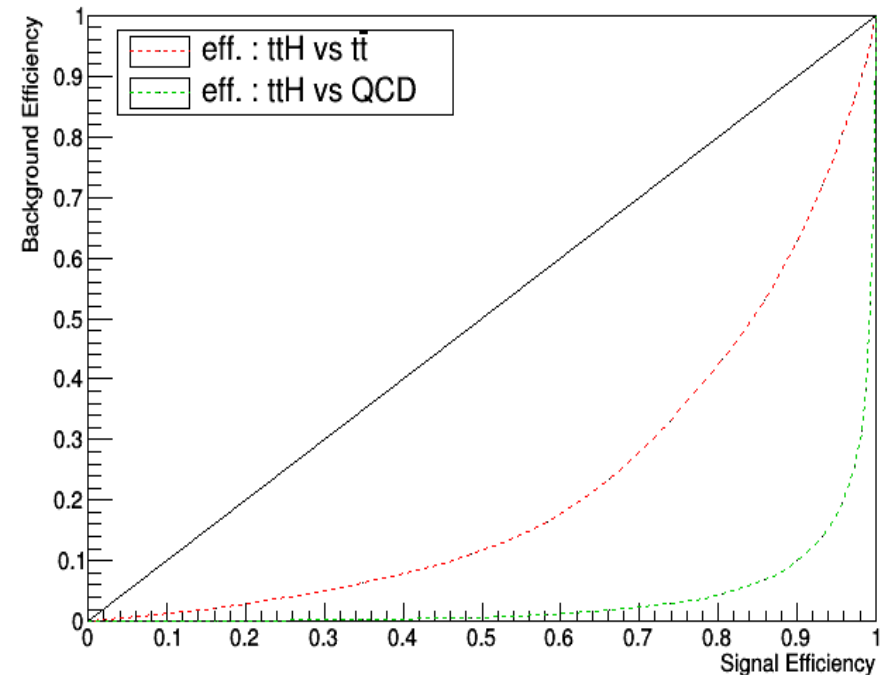
- jet_pt[0] ... jet_pt[3], jet_eta[0] ... jet_eta[3]
- aplanarity, isotropy, sphericity, min_dr_btag, log(C), log(D)
- njets, nBCSVM

However, we can't rely on njets & nBCSVM since later on we will categorize BDT distribution based on these two variables.

BDT Distribution (training: ttH vs QCD MC)



ROC Curve for BDT Evaluation

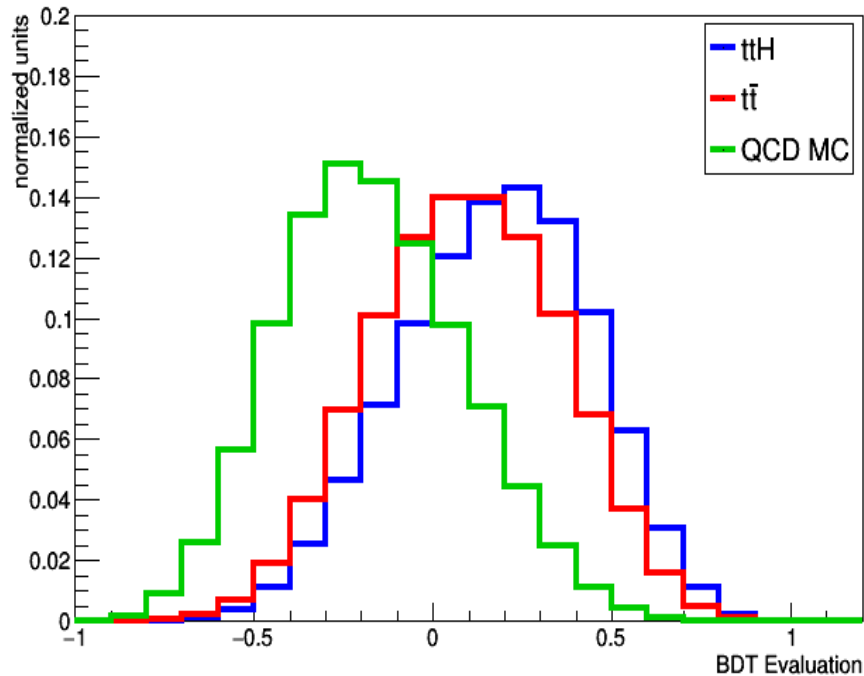


BDT Training & Evaluation (2nd attempt)

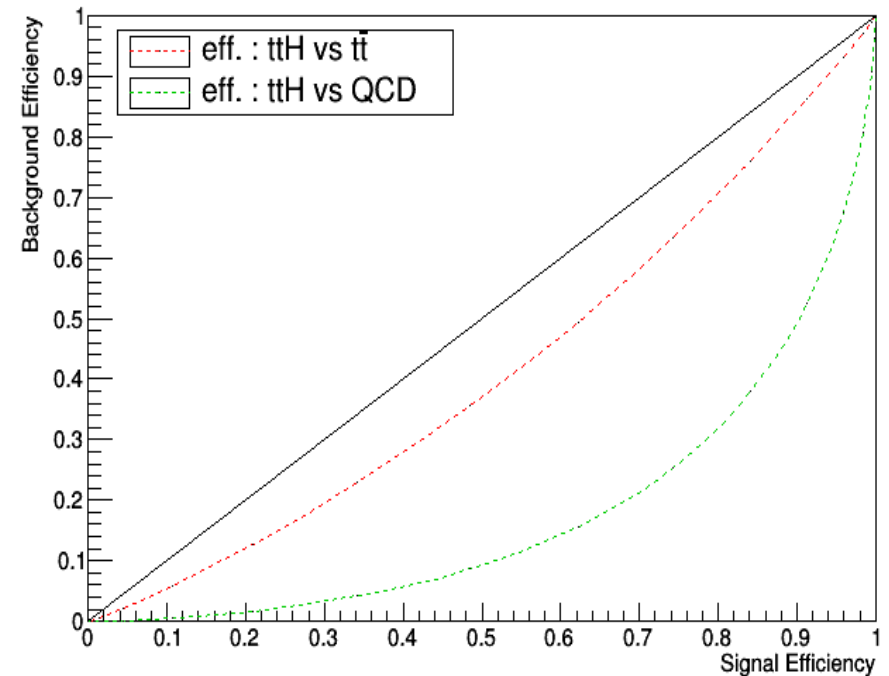
Input variables(30) : \rightarrow n_{jets} & n_{BCSVM} are restricted

- jet_pt[0] ... jet_pt[5], jet_eta[0] ... jet_eta[5]
- jet_phi[0] ... jet_phi[5], jet_qgl[0] ... jet_qgl[5]
- aplanarity, isotropy, sphericity, min_dr_btag, log(C), log(D)

BDT Distribution (training: ttH vs QCD MC)



ROC Curve for BDT Evaluation



BDT Training & Evaluation (3rd attempt)

Input variables(40) :

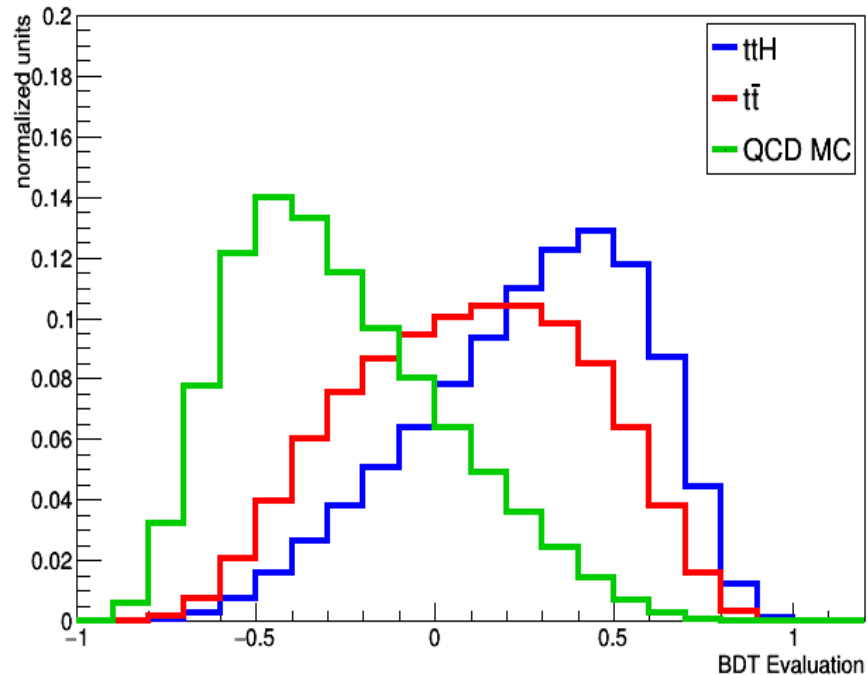
Previous variables(30) :

- jet_pt[0] ... jet_pt[5], jet_eta[0] ... jet_eta[5]
 - jet_phi[0] ... jet_phi[5], jet_qgl[0] ... jet_qgl[5]
 - aplanarity, isotropy, sphericity, min_dr_btag, log(C), log(D)
- +

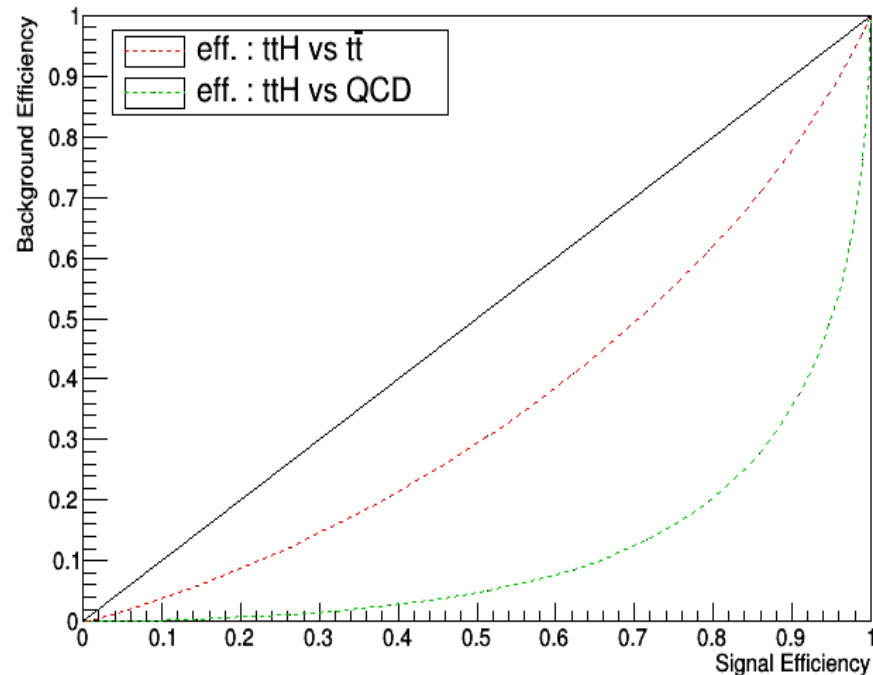
Distance variables(10) :

- DD5j[12], DD3j4[12]
- Deta5j, Deta3j4, Dphi5j, Dphi4j5, DR5j, DR4j5, DW3j, DW5j6

BDT Distribution (training: ttH vs QCD MC)



ROC Curve for BDT Evaluation

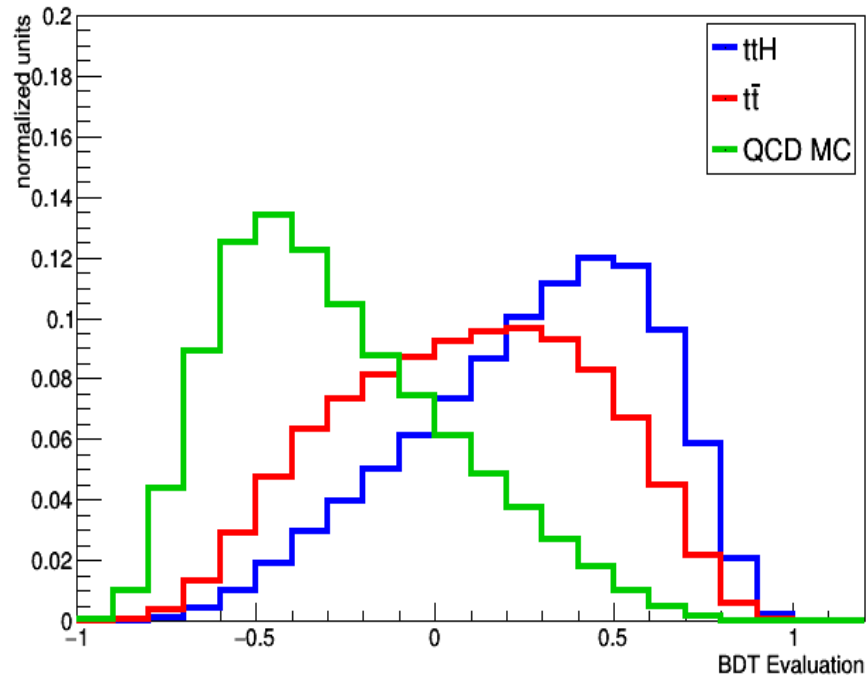


BDT Training & Evaluation (4th attempt)

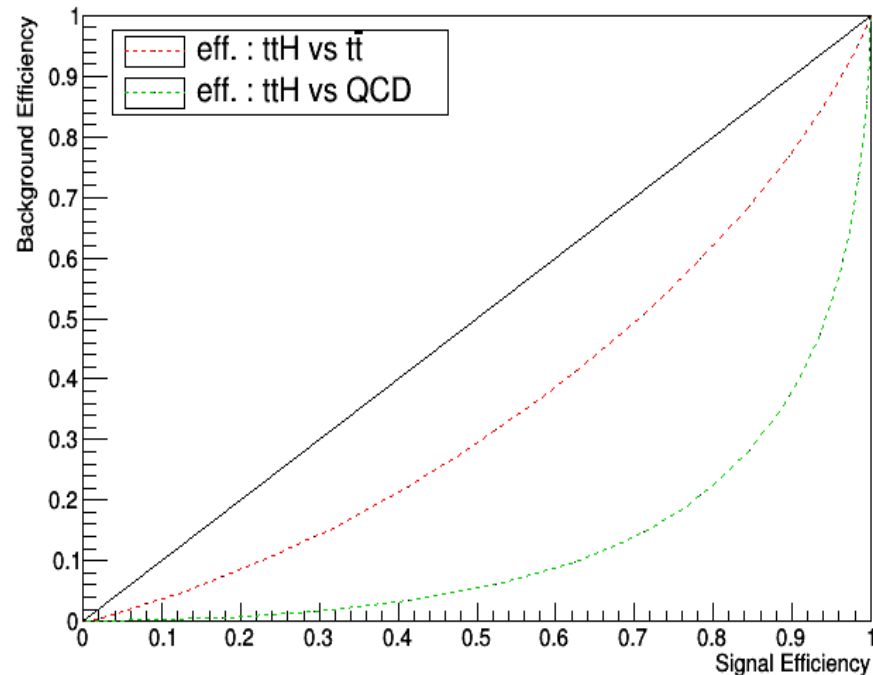
Input variables(28) : → variables that don't show too much discrimination are restricted

- jet_pt[0] ... jet_pt[3], jet_eta[0] ... jet_eta[3]
- jet_qgl[0] ... jet_qgl[3]
- aplanarity, isotropy, sphericity, min_dr_btag, log(C), log(D)
- DD5j[12], DD3j4[12]
- Deta5j, Deta3j4, Dphi5j, Dphi4j5, DR5j, DR4j5, DW3j, DW5j6

BDT Distribution (training: ttH vs QCD MC)

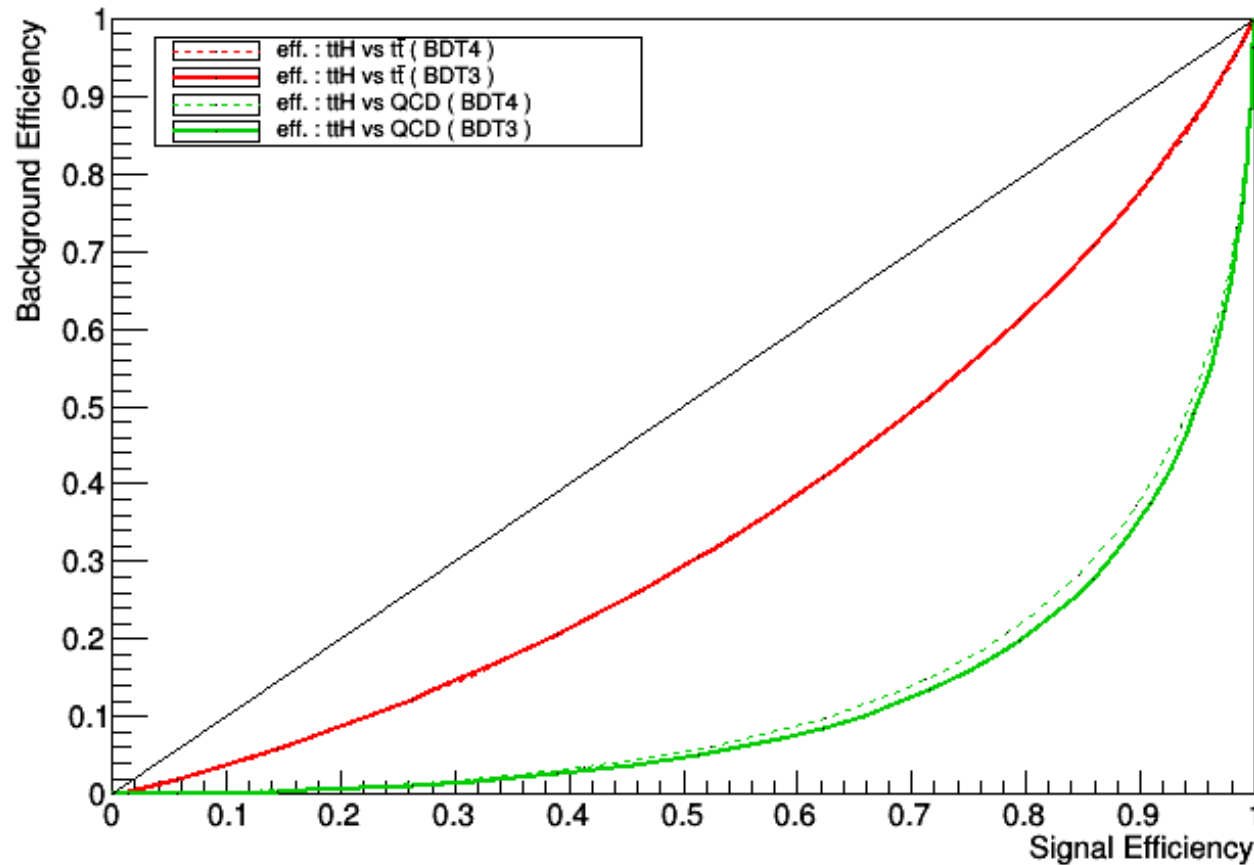


ROC Curve for BDT Evaluation



Comparison between the 3rd & the 4th attempts

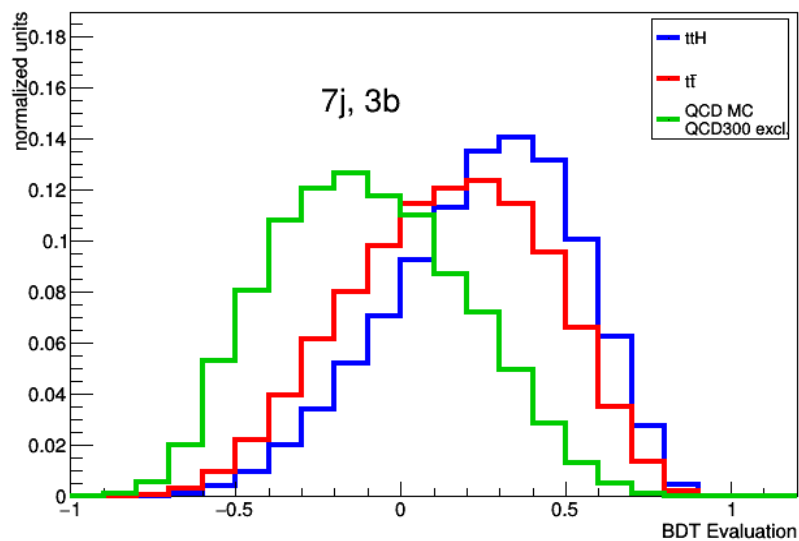
ROC Curve for BDT Evaluation



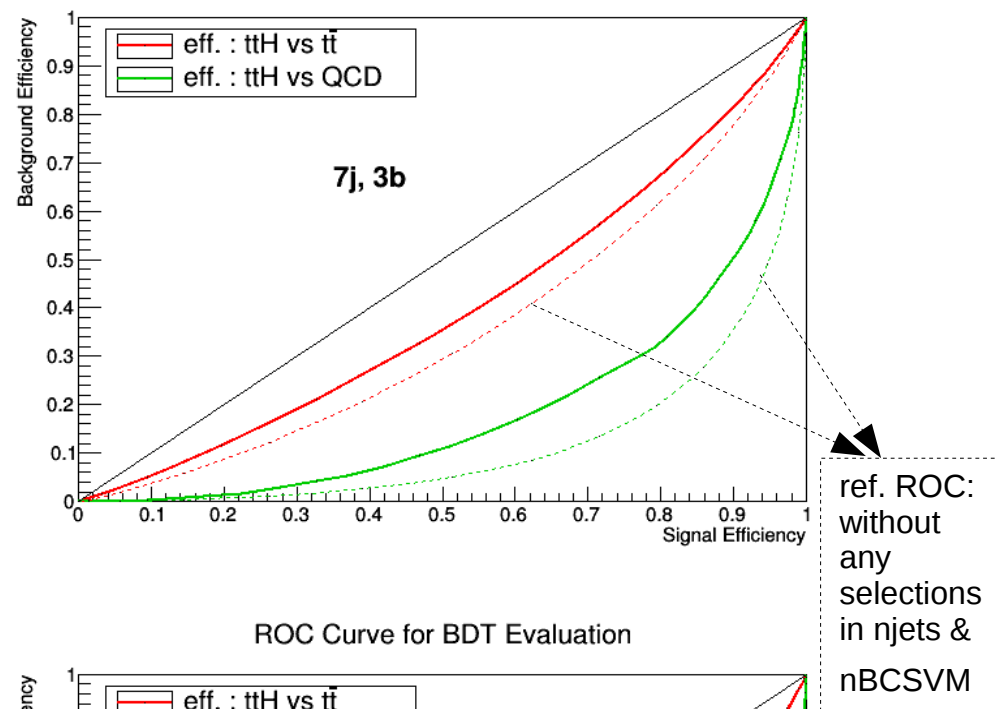
The full training provides the best performance

Categorization for the full training BDT distribution when njets = 7

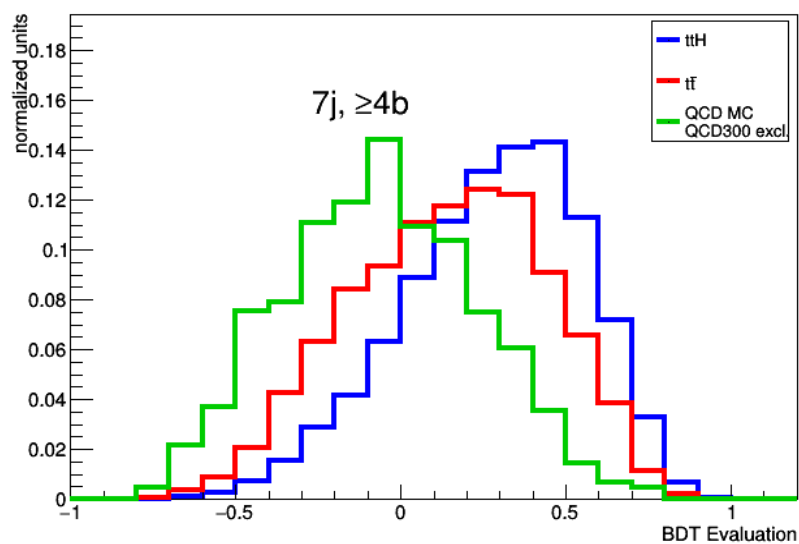
BDT Distribution (training: ttH vs QCD MC)



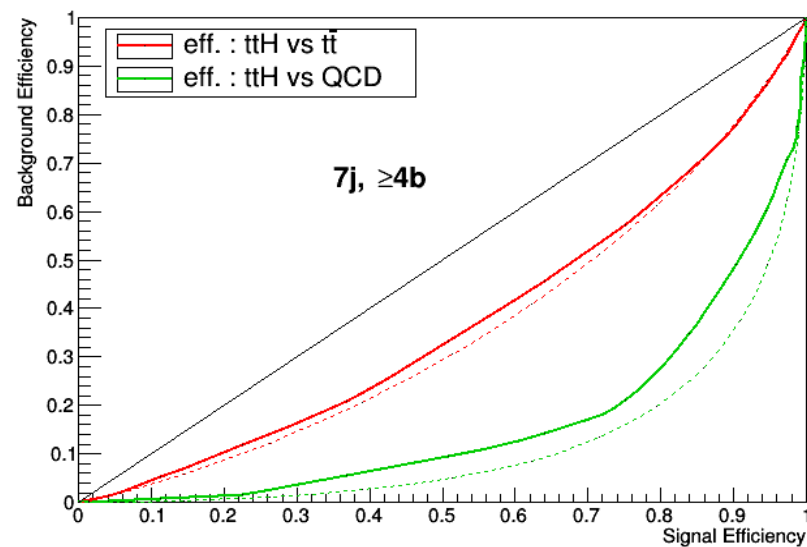
ROC Curve for BDT Evaluation



BDT Distribution (training: ttH vs QCD MC)

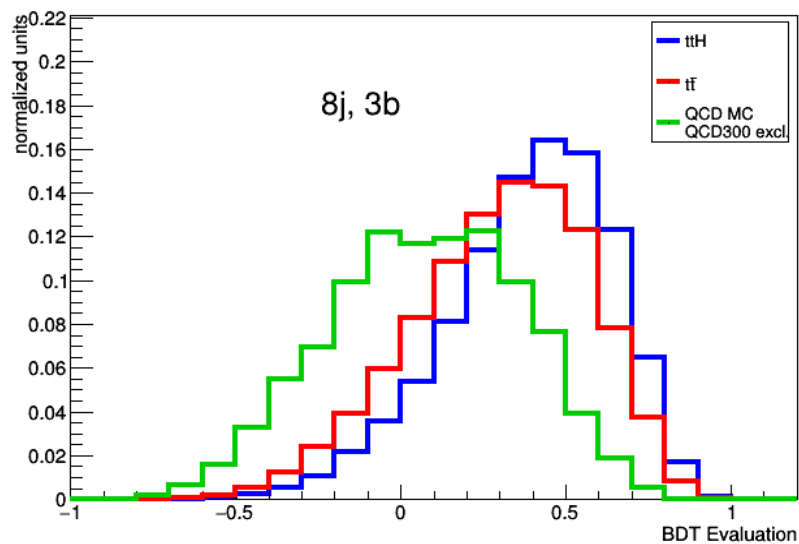


ROC Curve for BDT Evaluation

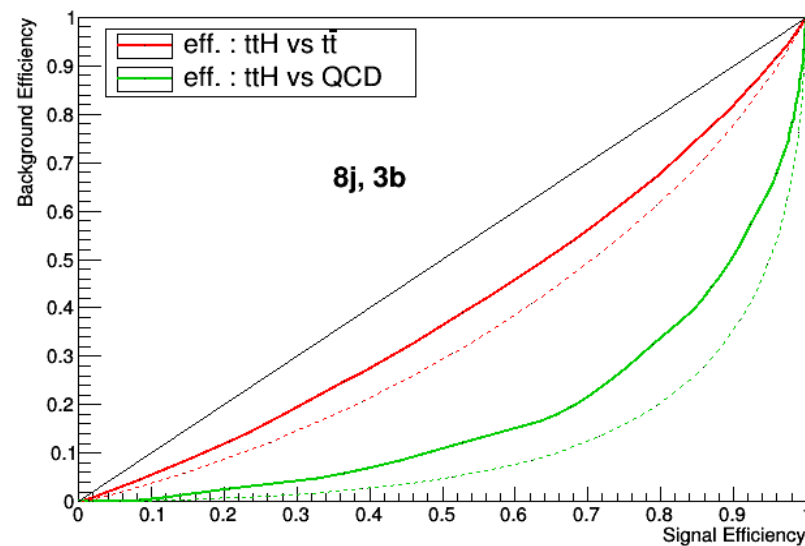


Categorization for the full training BDT distribution when njets = 8

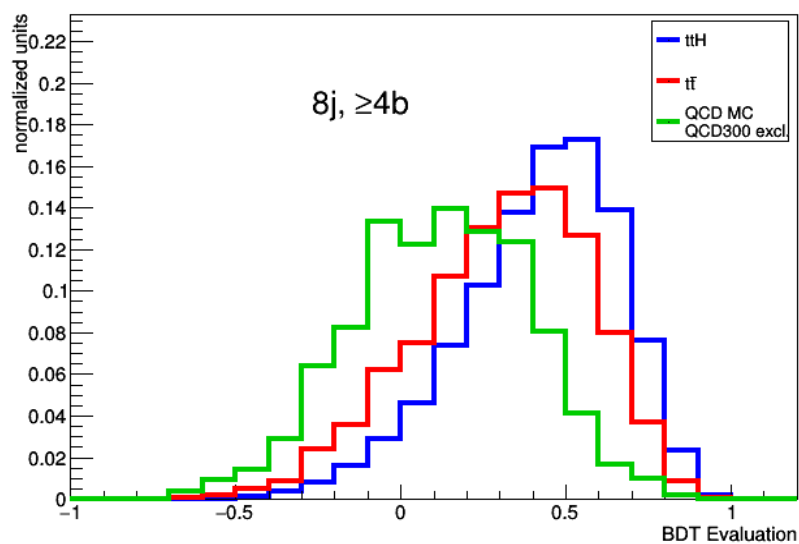
BDT Distribution (training: ttH vs QCD MC)



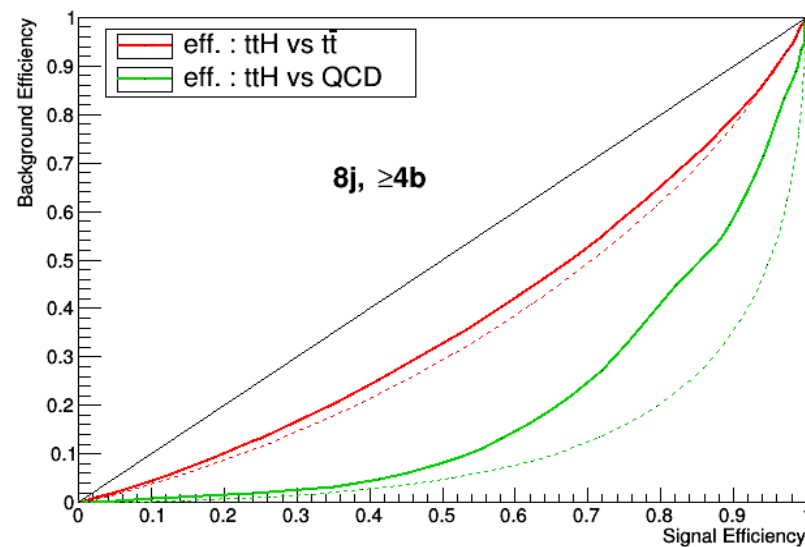
ROC Curve for BDT Evaluation



BDT Distribution (training: ttH vs QCD MC)

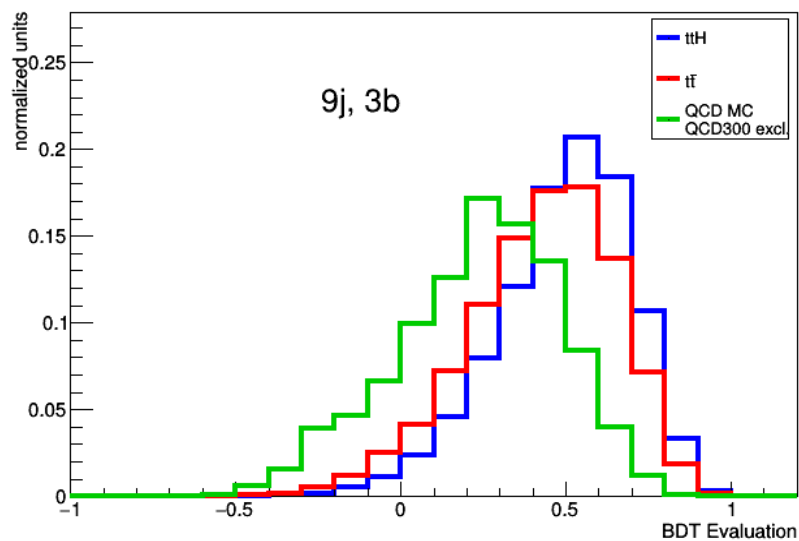


ROC Curve for BDT Evaluation

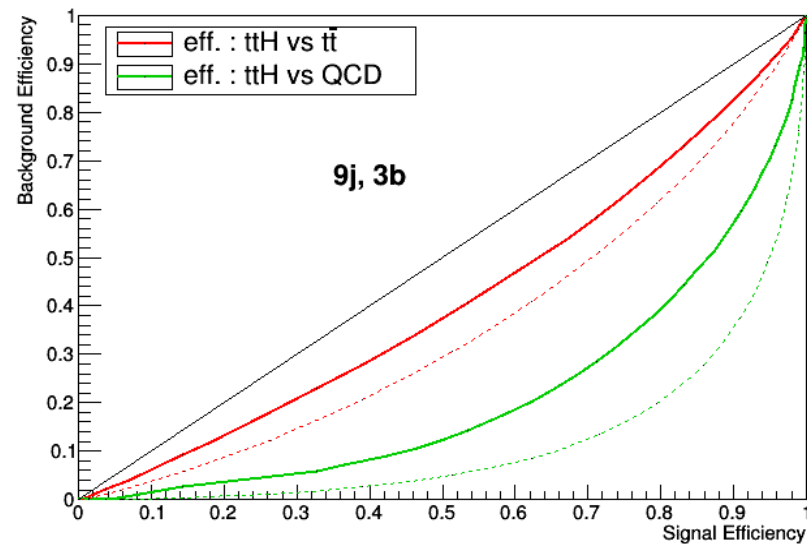


Categorization for the full training BDT distribution when njets = 9

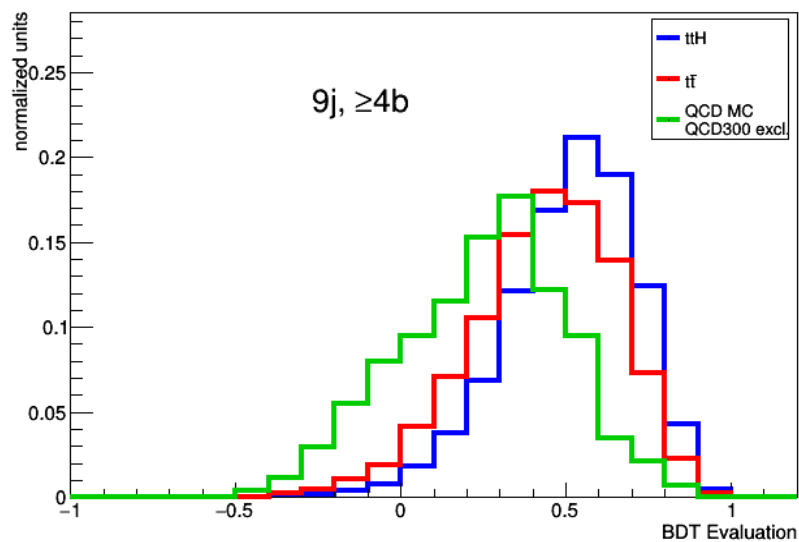
BDT Distribution (training: ttH vs QCD MC)



ROC Curve for BDT Evaluation



BDT Distribution (training: ttH vs QCD MC)



ROC Curve for BDT Evaluation

