Feasibility Study of Measuring the Higgs Self-coupling Using the Muon Collider

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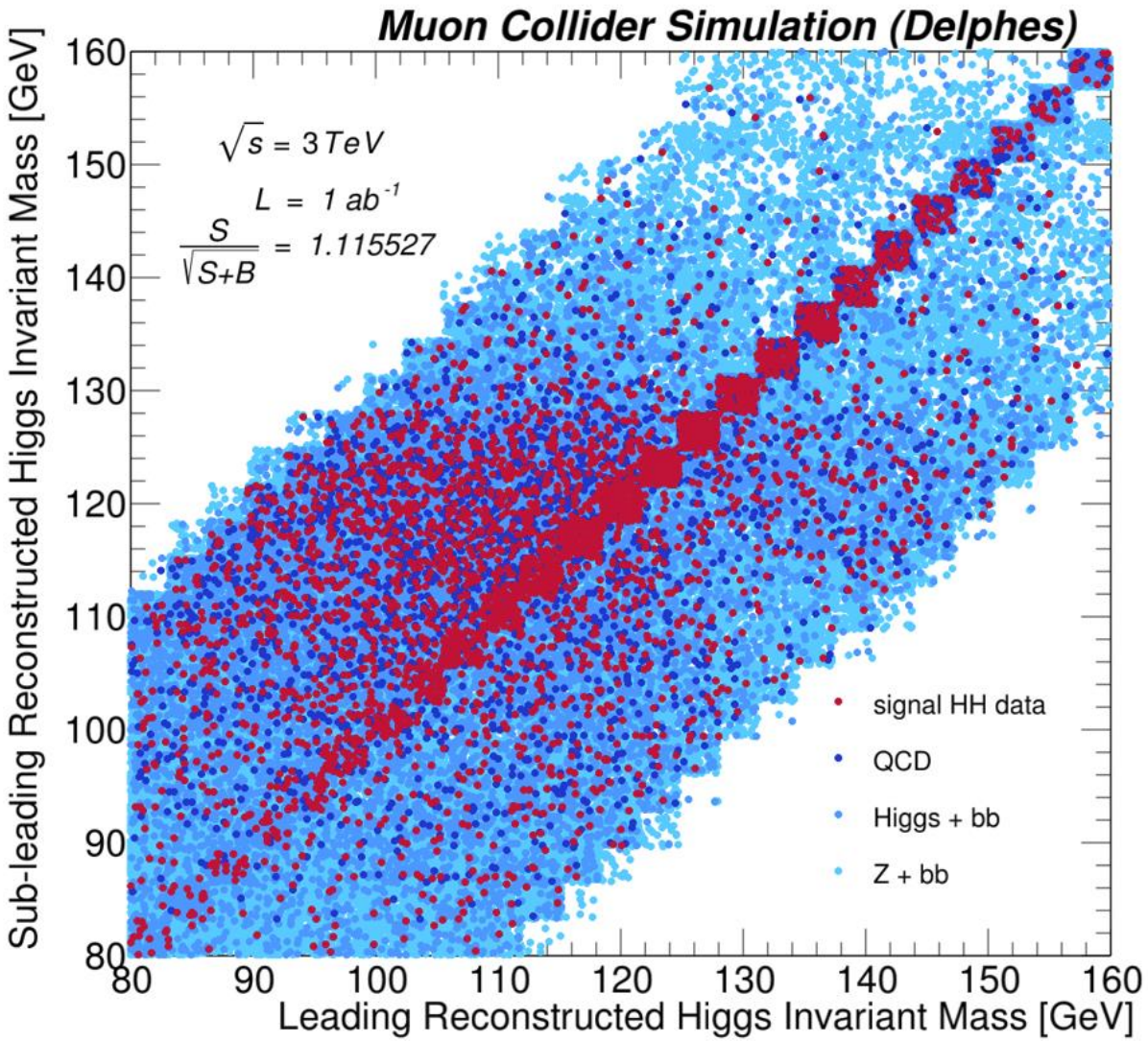
- Signal: $\mu^- + \mu^+ \rightarrow \nu_\mu + \bar{\nu}_\mu + H + H$ $(0.0008182 \pm 6.2\text{e} - 7\ \text{pb})$
- Background:
  - $\mu^- + \mu^+ \rightarrow \nu_\mu + \bar{\nu}_\mu + b + \bar{b} + Z$ $(0.03183 \pm 0.000025\ \text{pb})$
  - $\mu^- + \mu^+ \rightarrow \nu_\mu + \bar{\nu}_\mu + b + \bar{b} + H$ $(0.003771 \pm 3.1\text{e} - 6\ \text{pb})$
  - $\mu^- + \mu^+ \rightarrow \nu_\mu + \bar{\nu}_\mu + b + \bar{b} + b + \bar{b}$ $(0.0009237 \pm 7.2\text{e} - 7\ \text{pb})$

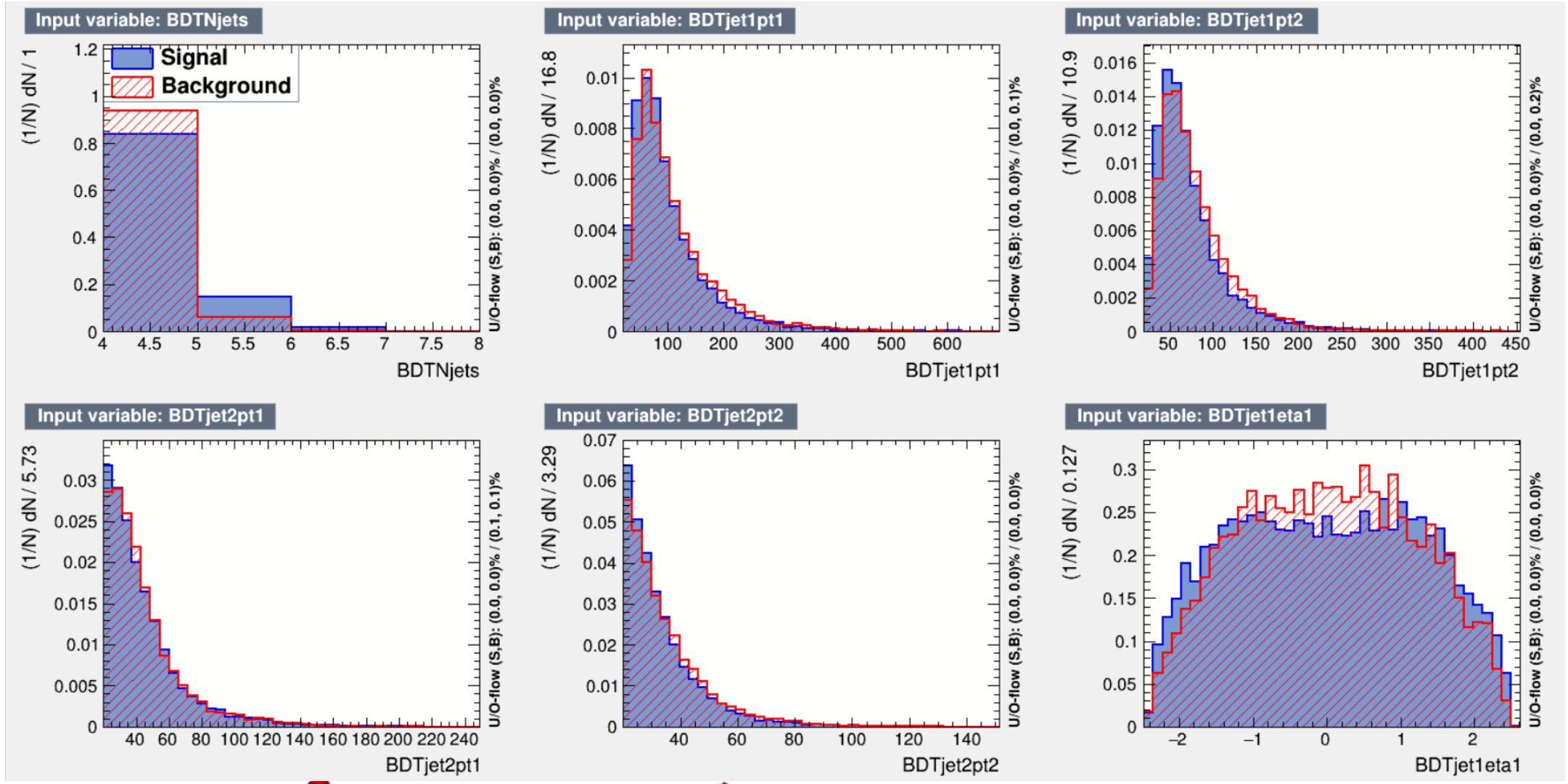
100k for each

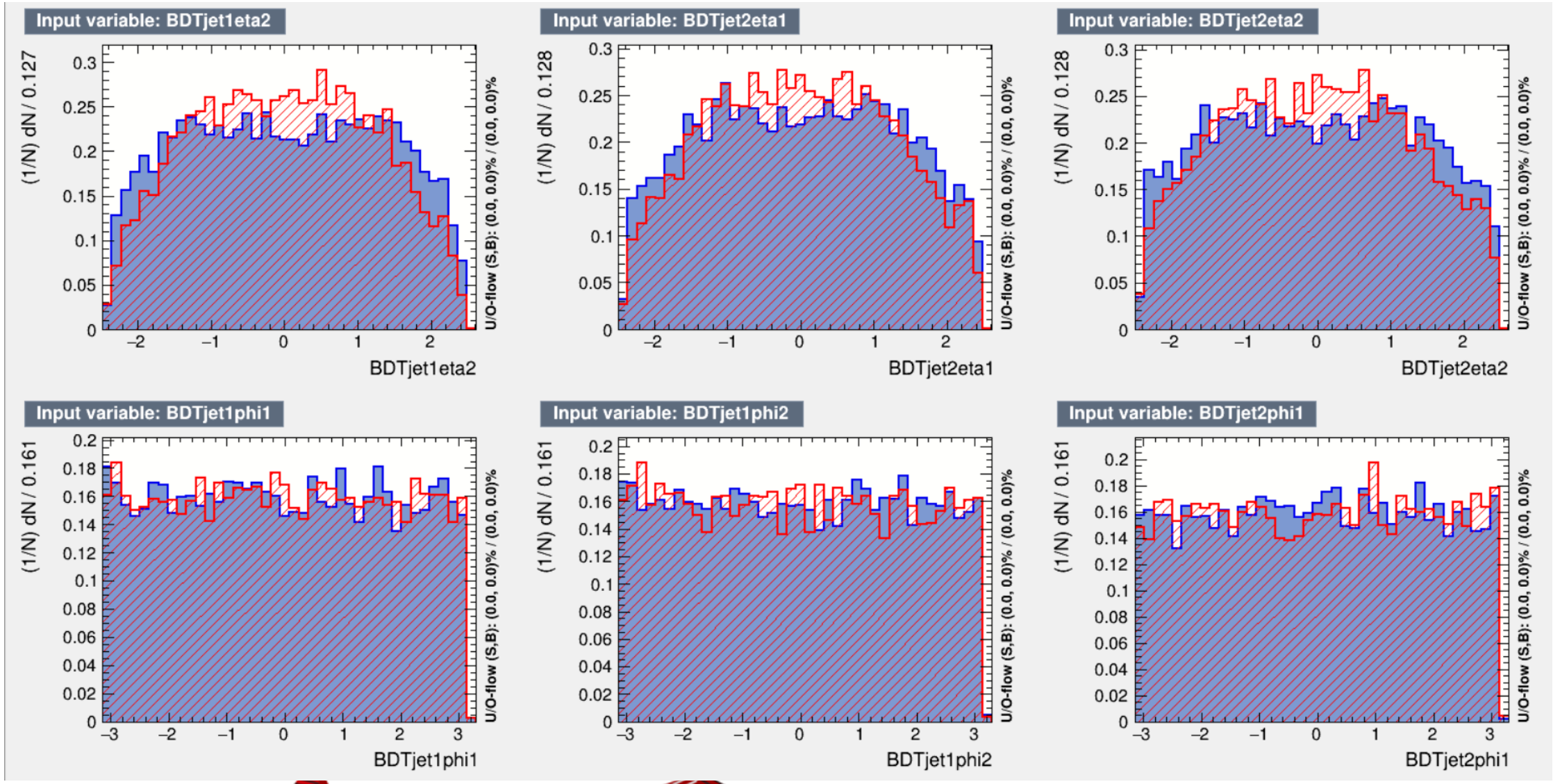
MVA to discriminate vvHH with dominant bkg vvbbZ

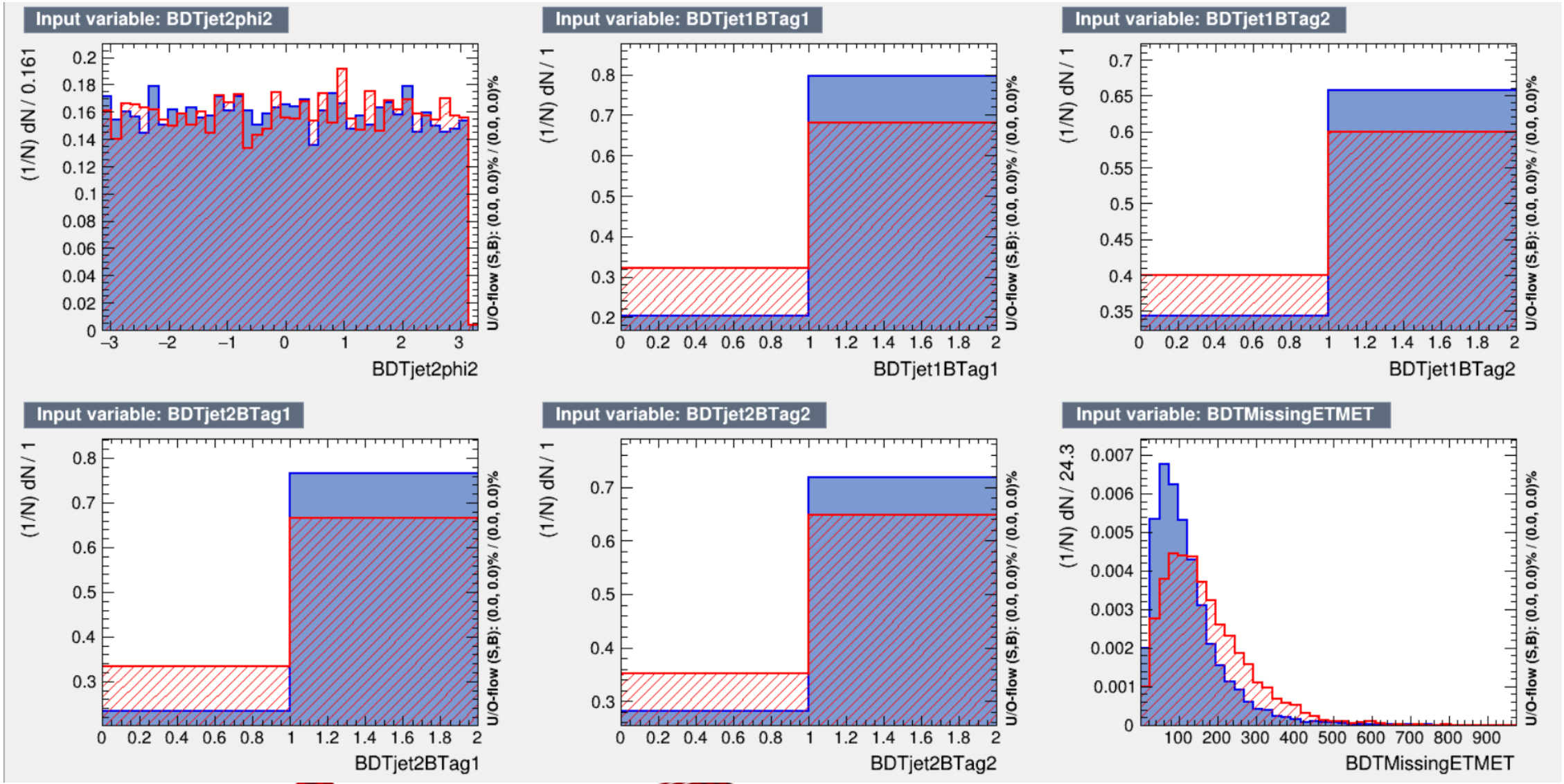
- With TMVA, a built-in package in ROOT
  - Support different ML approach:
    - Boosting Decision Tree
    - Multilayer perceptron
    - Deep Neural Network

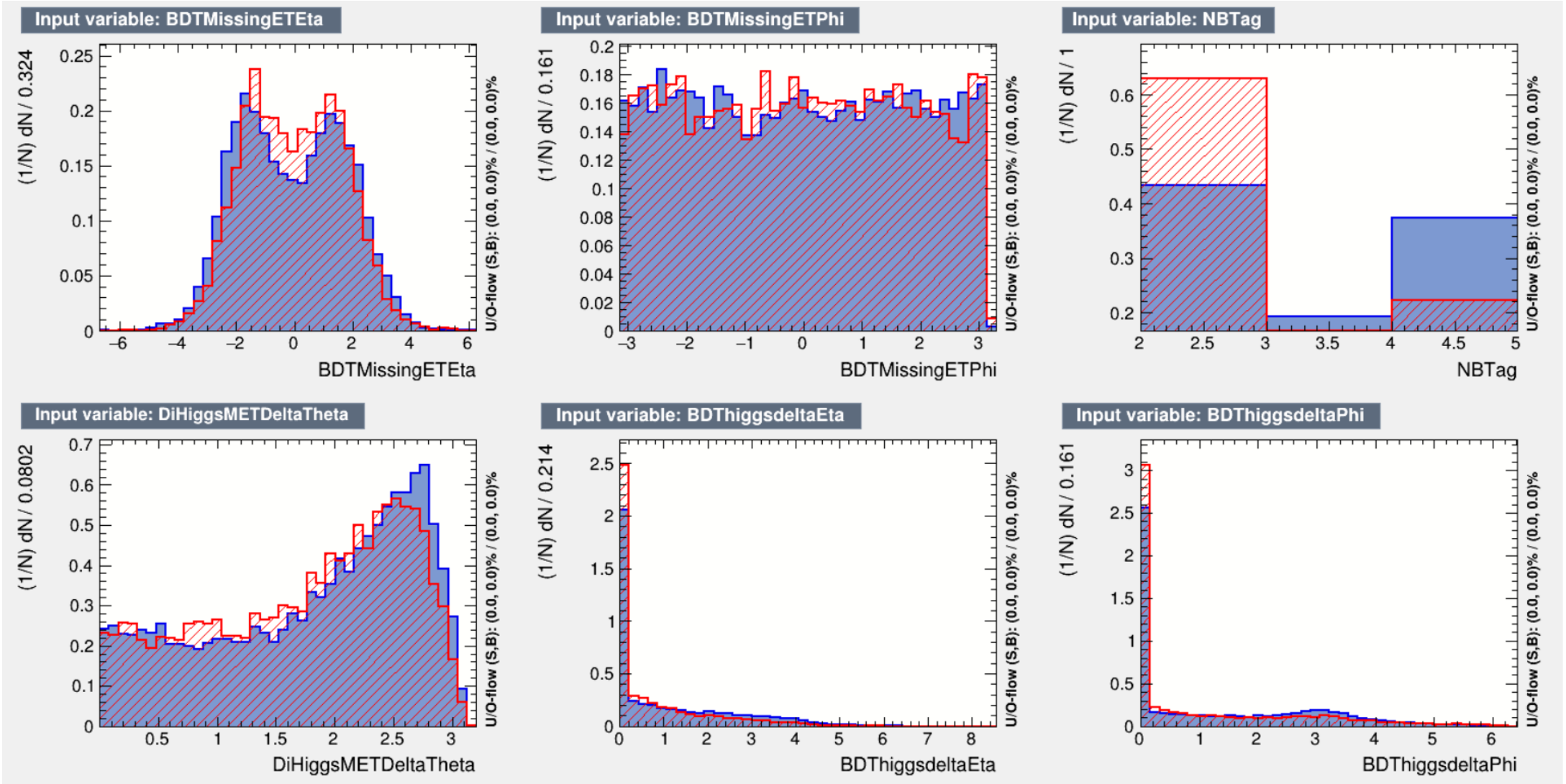
- Require only two tight b-tag rather than four
- Adding all angle variables
- Still writing the code for two tight b-tag with two loose b-tag and the angle between two higgs

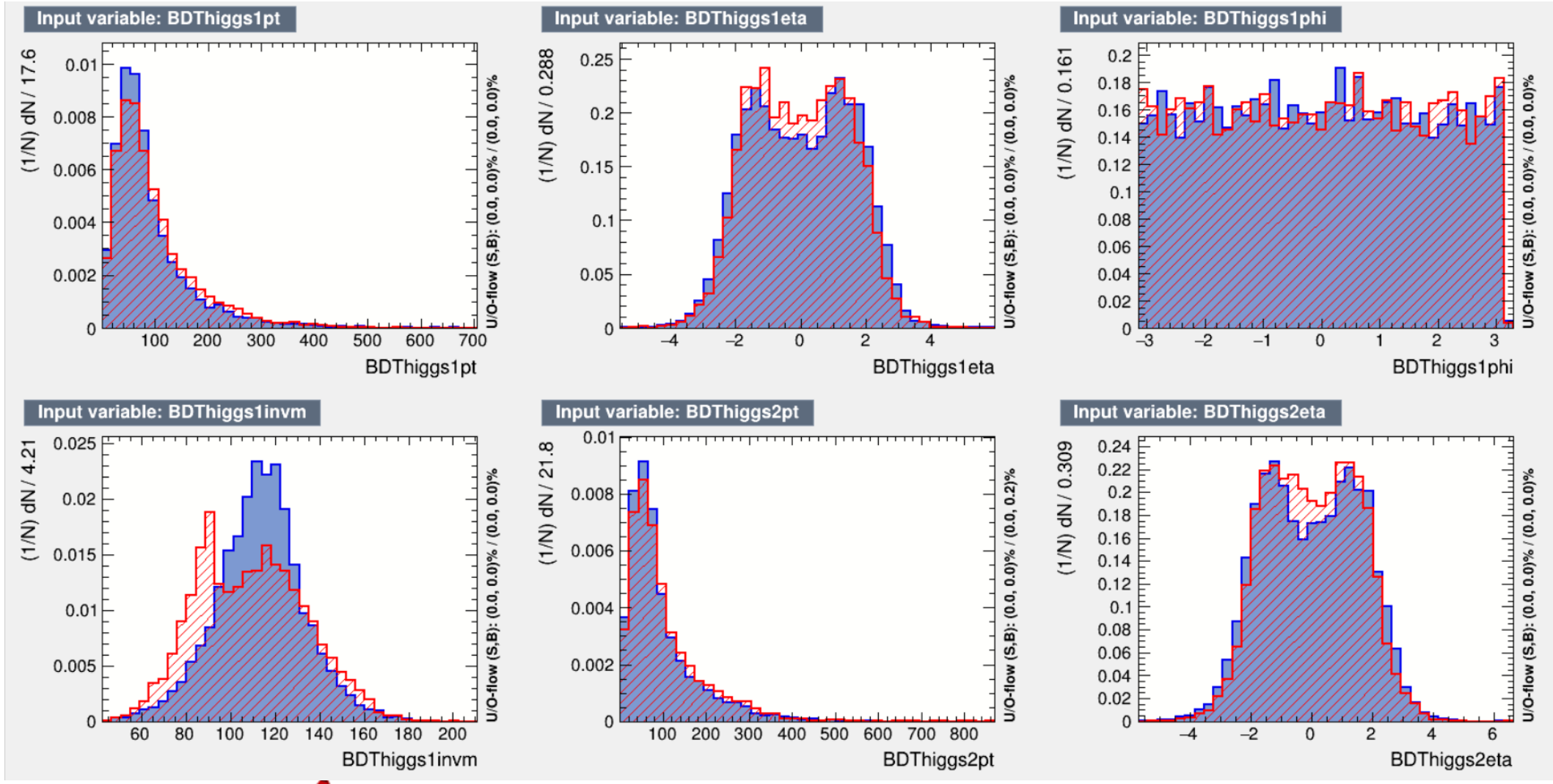

Muon Collider Simulation (Delphes)
$\sqrt{s} = 3\,TeV$
$L = 1\ ab^{-1}$
$\frac{S}{\sqrt{S+B}} = 1.115527$
signal HH data
QCD
Higgs + bb
Z + bb
Sub-leading Reconstructed Higgs Invariant Mass [GeV]
Leading Reconstructed Higgs Invariant Mass [GeV]
80
90
100
110
120
130
140
150
160

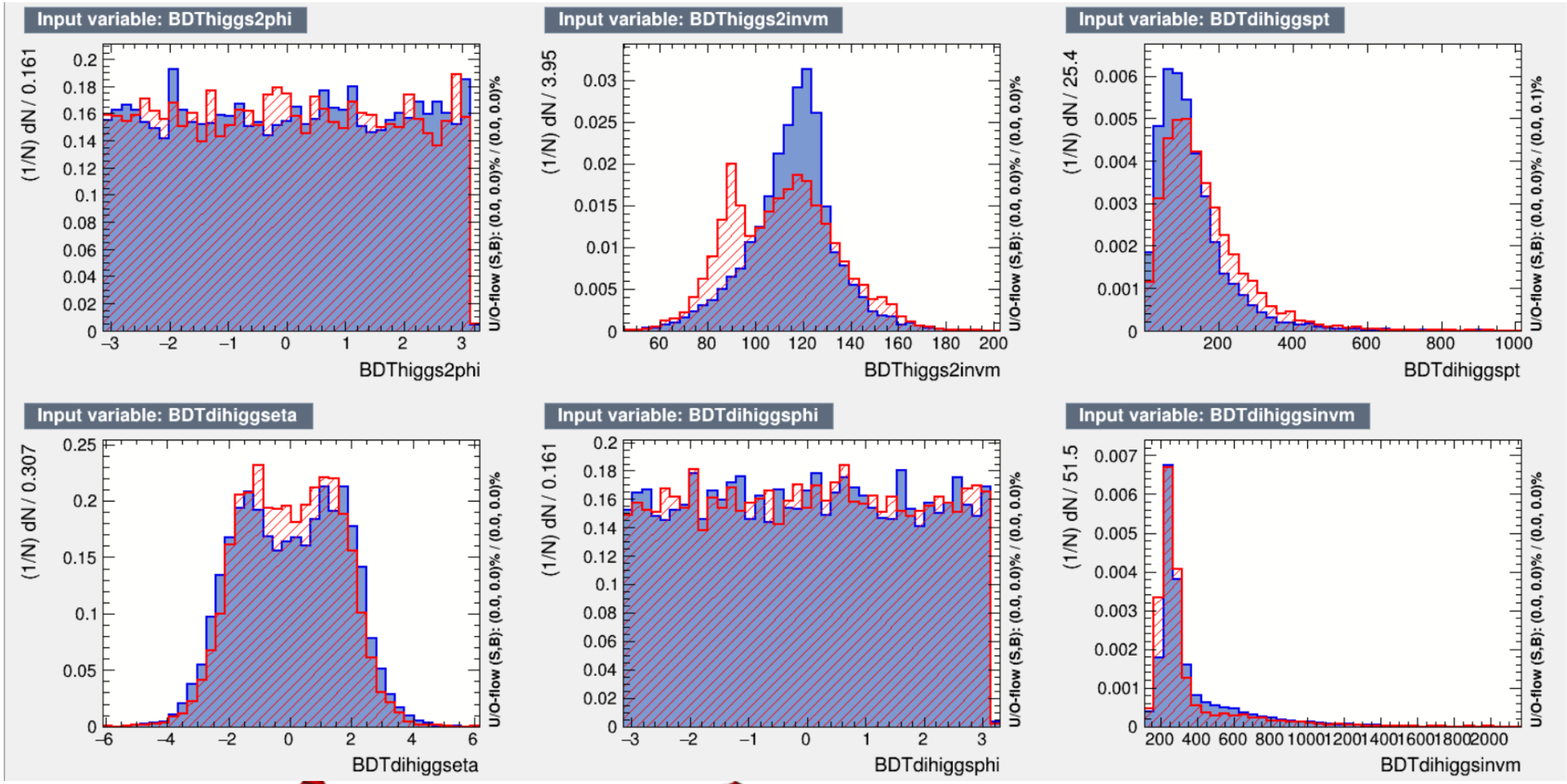

Input variable: BDTNjets
Signal
Background
(1/N) dN / 1
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%
BDTNjets
Input variable: BDTjet1pt1
(1/N) dN / 16.8
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.1)%
BDTjet1pt1
Input variable: BDTjet1pt2
(1/N) dN / 10.9
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.2)%
BDTjet1pt2
Input variable: BDTjet2pt1
(1/N) dN / 5.73
U/O-flow (S,B): (0.0, 0.0)% / (0.1, 0.1)%
BDTjet2pt1
Input variable: BDTjet2pt2
(1/N) dN / 3.29
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%
BDTjet2pt2
Input variable: BDTjet1eta1
(1/N) dN / 0.127
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%
BDTjet1eta1

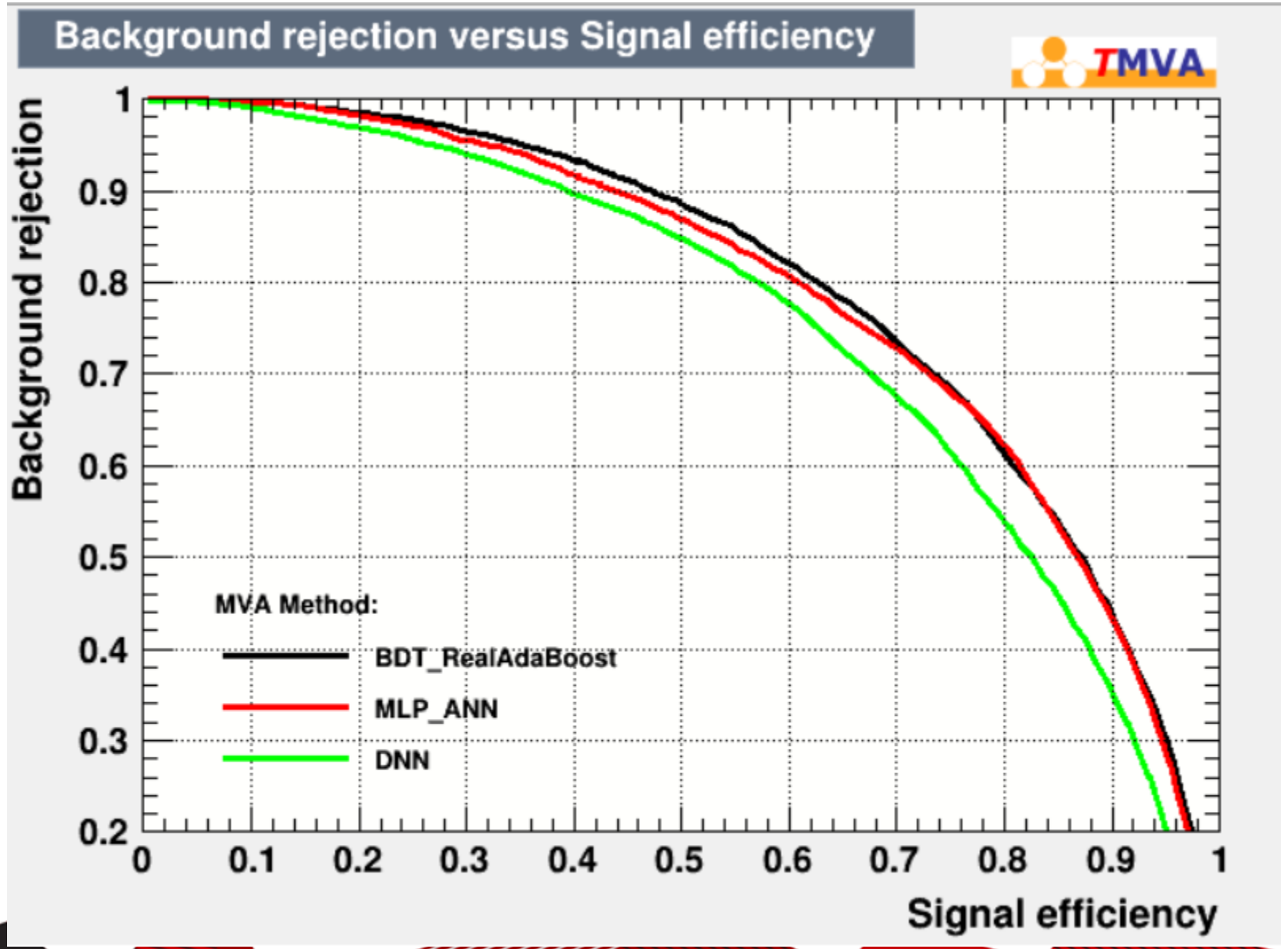

Input variable: BDTjet1eta2
(1/N) dN / 0.127
BDTjet1eta2
Input variable: BDTjet2eta1
(1/N) dN / 0.128
BDTjet2eta1
Input variable: BDTjet2eta2
(1/N) dN / 0.128
BDTjet2eta2
Input variable: BDTjet1phi1
(1/N) dN / 0.161
BDTjet1phi1
Input variable: BDTjet1phi2
(1/N) dN / 0.161
BDTjet1phi2
Input variable: BDTjet2phi1
(1/N) dN / 0.161
BDTjet2phi1
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%


Input variable: BDTjet2phi2
(1/N) dN / 0.161
BDTjet2phi2
Input variable: BDTjet1BTag1
(1/N) dN / 1
BDTjet1BTag1
Input variable: BDTjet1BTag2
(1/N) dN / 1
BDTjet1BTag2
Input variable: BDTjet2BTag1
(1/N) dN / 1
BDTjet2BTag1
Input variable: BDTjet2BTag2
(1/N) dN / 1
BDTjet2BTag2
Input variable: BDTMissingETMET
(1/N) dN / 24.3
BDTMissingETMET
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%


Input variable: BDTMissingETEta
(1/N) dN / 0.324
BDTMissingETEta
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%
Input variable: BDTMissingETPhi
(1/N) dN / 0.161
BDTMissingETPhi
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%
Input variable: NBTag
(1/N) dN / 1
NBTag
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%
Input variable: DiHiggsMETDeltaTheta
(1/N) dN / 0.0802
DiHiggsMETDeltaTheta
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%
Input variable: BDThiggsdeltaEta
(1/N) dN / 0.214
BDThiggsdeltaEta
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%
Input variable: BDThiggsdeltaPhi
(1/N) dN / 0.161
BDThiggsdeltaPhi
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%


Input variable: BDThiggs1pt
(1/N) dN / 17.6
BDThiggs1pt
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%
Input variable: BDThiggs1eta
(1/N) dN / 0.288
BDThiggs1eta
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%
Input variable: BDThiggs1phi
(1/N) dN / 0.161
BDThiggs1phi
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%
Input variable: BDThiggs1invm
(1/N) dN / 4.21
BDThiggs1invm
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%
Input variable: BDThiggs2pt
(1/N) dN / 21.8
BDThiggs2pt
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.2)%
Input variable: BDThiggs2eta
(1/N) dN / 0.309
BDThiggs2eta
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%


Input variable: BDThiggs2phi
(1/N) dN / 0.161
BDThiggs2phi
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%
Input variable: BDThiggs2invm
(1/N) dN / 3.95
BDThiggs2invm
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%
Input variable: BDTdihiggspt
(1/N) dN / 25.4
BDTdihiggspt
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.1)%
Input variable: BDTdihiggseta
(1/N) dN / 0.307
BDTdihiggseta
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%
Input variable: BDTdihiggsphi
(1/N) dN / 0.161
BDTdihiggsphi
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%
Input variable: BDTdihiggsinvm
(1/N) dN / 51.5
BDTdihiggsinvm
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%


Background rejection versus Signal efficiency
TMVA
Background rejection
Signal efficiency
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
MVA Method:
BDT_RealAdaBoost
MLP_ANN
DNN