Combination single top + $t\bar{t}$

$tH \rightarrow 1\ell 3b$

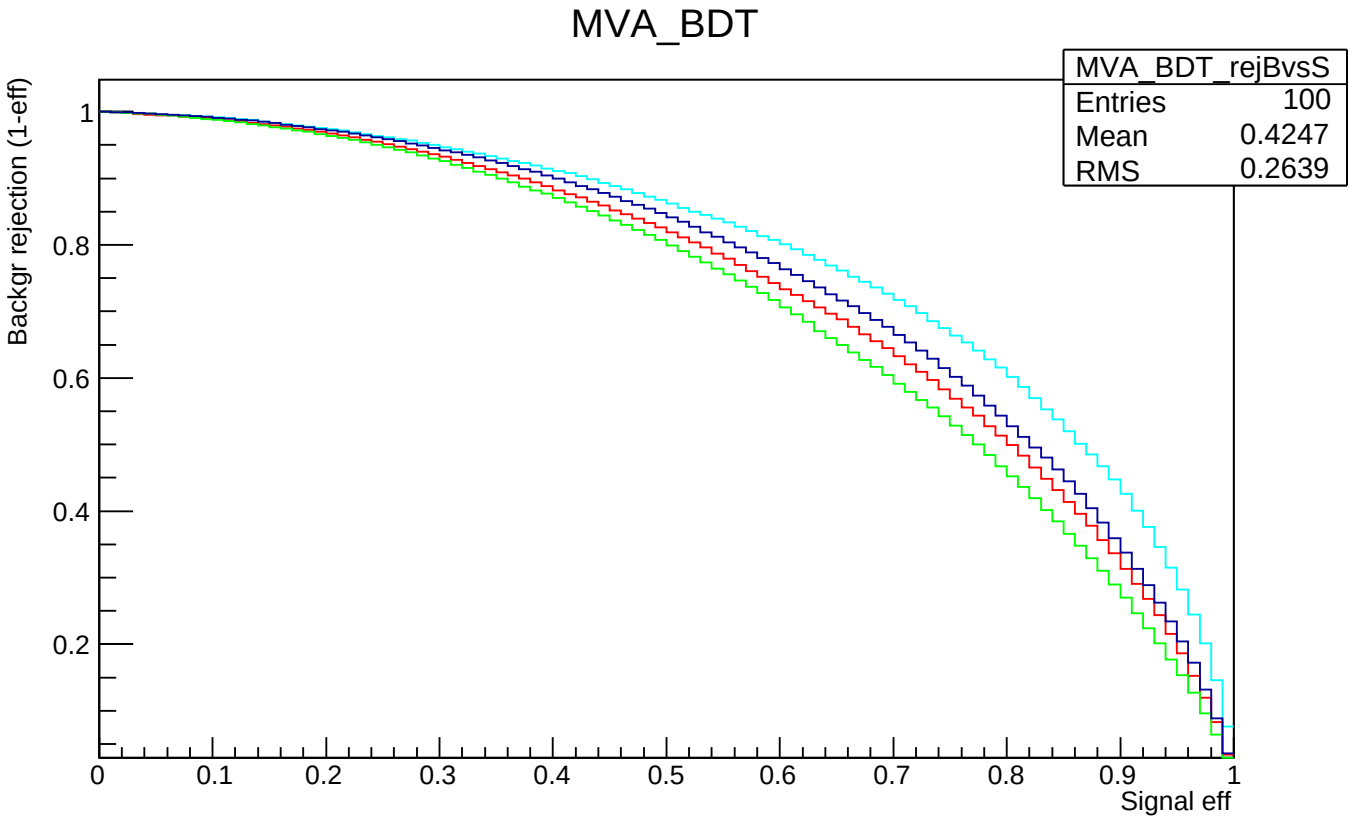
Lorenzo Basso

Optimisation

- LEPTONS: $|\eta| < 2.5(2.4)$ for e/μ, then:
  - Tight: $p_\ell^T > 30$ GeV, ISO: `CONE04`, $I_{rel} < 0.12(0.10)$ e/μ
  - Loose: $10 < p_\ell^T < 30$ GeV, ISO: `CONE04`, $I_{rel} < 0.20$
- JETS: $p_j^T > 40$ GeV, $|\eta| < 2.4$, $1/$`EEoverHE` > 0.15
- Selections:
  1. $N_\ell^{tight} \equiv 1, \qquad N_\ell^{loose} \equiv 0$
  2. $M^T(\ell\nu) > 50$ GeV
  3. $N_J \geq 3$ ($J =$ light and b jets)
  4. $N_b \equiv 3$ (CSVM)

  Here, MVA or Cut&Count with
- 80 GeV $< |M(bb) - M_H| < 205$ GeV
- loose top reco: $M^T(b\,\ell\nu) < 230$ GeV

Higgs and top reco: MVA

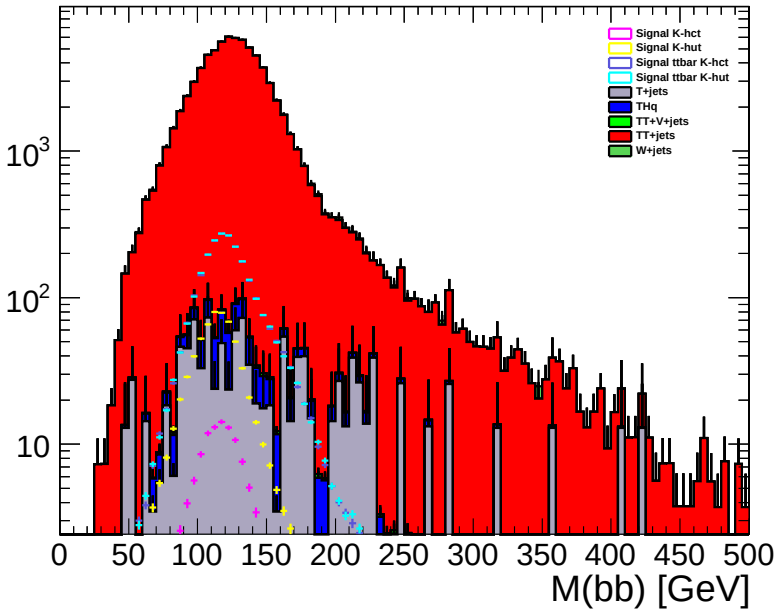


Red: H reco only, Green: t reco only, Blue: simultaneously

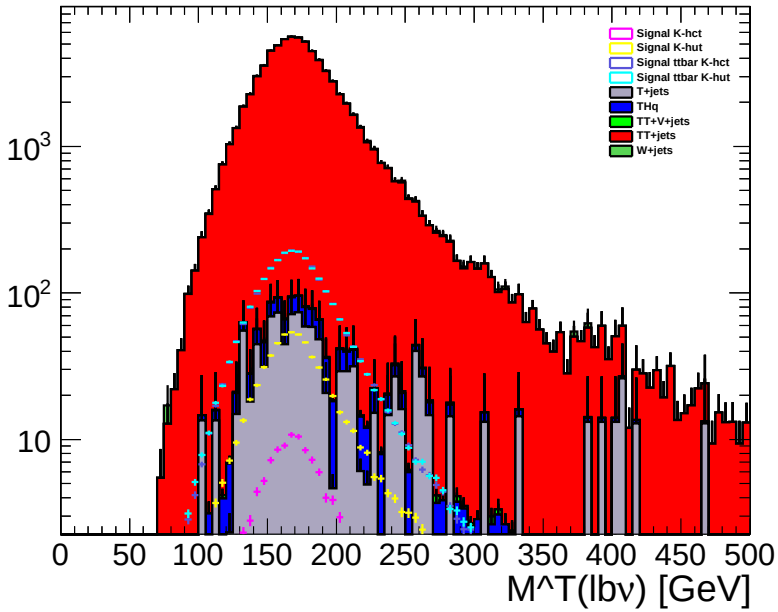
Cyan: chi-squared: minimise $\left(\frac{|M(b_i b_j)-125|^2}{16} + \frac{|M^T(b_k \ell\nu)-173|^2}{30}\right.$ wrt $i, j, k = 1..3$

$M_H - M_{TOP}$

M_H



M_{TOP}



Cut-and-count

Cut	Sum Bg	κ_{hct}	κ_{hut}	ttbar κ_{hct}	ttbar κ_{hut}
no cuts	$(18.62 \pm 0.03)\,10^9$	21261 ± 21	164242 ± 57	133579 ± 46	133528 ± 45
$\#\ell \equiv 1$, 0 loose	$(5858 \pm 1)\,10^6$	2763 ± 8	21995 ± 20	61009 ± 31	60975 ± 30
$M^T(\ell\nu) > 50$	$(5573 \pm 1)\,10^6$	1832 ± 6	14434 ± 16	41456 ± 25	41432 ± 25
$\#j \geq 3$	$(5262 \pm 7)\,10^3$	575 ± 4	3610 ± 8	20553 ± 17	20575 ± 17
$\#b \equiv 3$	77688 ± 389	112 ± 2	628 ± 3	2414 ± 6	2422 ± 6
$80 < M(bb) < 205$	70581 ± 368	109 ± 2	601 ± 3	2341 ± 6	2348 ± 6
$80 < M^T(b\ell\nu) < 230$	64942 ± 352	103 ± 1	560 ± 3	2225 ± 6	2231 ± 6

Table: Signal (ttbar to be rescaled by $2/3$).

Cut	Sum Bg	T+jets	THq	TT+jets	W+jets
no cuts	$(18622 \pm 0.03)\,10^6$	$(28.11 \pm 0.02)\,10^6$	17526 ± 6	$(32322 \pm 7)\,10^3$	$(18562 \pm 3)\,10^6$
$\#\ell \equiv 1$, 0 loose	$(5858 \pm 1)\,10^6$	$(3162 \pm 5.2)\,10^3$	6074 ± 3	$(9245 \pm 4)\,10^3$	$(5845 \pm 1)\,10^6$
$M^T(\ell\nu) > 50$	$(5573 \pm 1)\,10^6$	$(2225 \pm 4)\,10^3$	4043 ± 3	$(5966 \pm 3)\,10^3$	$(5565 \pm 1)\,10^6$
$\#j \geq 3$	$(5262 \pm 7)\,10^3$	$(255 \pm 1)\,10^3$	1664 ± 2	$(3256 \pm 2)\,10^3$	$(1749 \pm 7)\,10^3$
$\#b \equiv 3$	77688 ± 389	1138 ± 113	401 ± 1	75883 ± 371	266 ± 34
$80 < M(bb) < 205$	70581 ± 368	802 ± 93	337 ± 1	69231 ± 355	210 ± 30
$80 < M^T(b\ell\nu) < 230$	64942 ± 352	651 ± 84	270 ± 1	63866 ± 341	154 ± 26

Table: Background

Significance

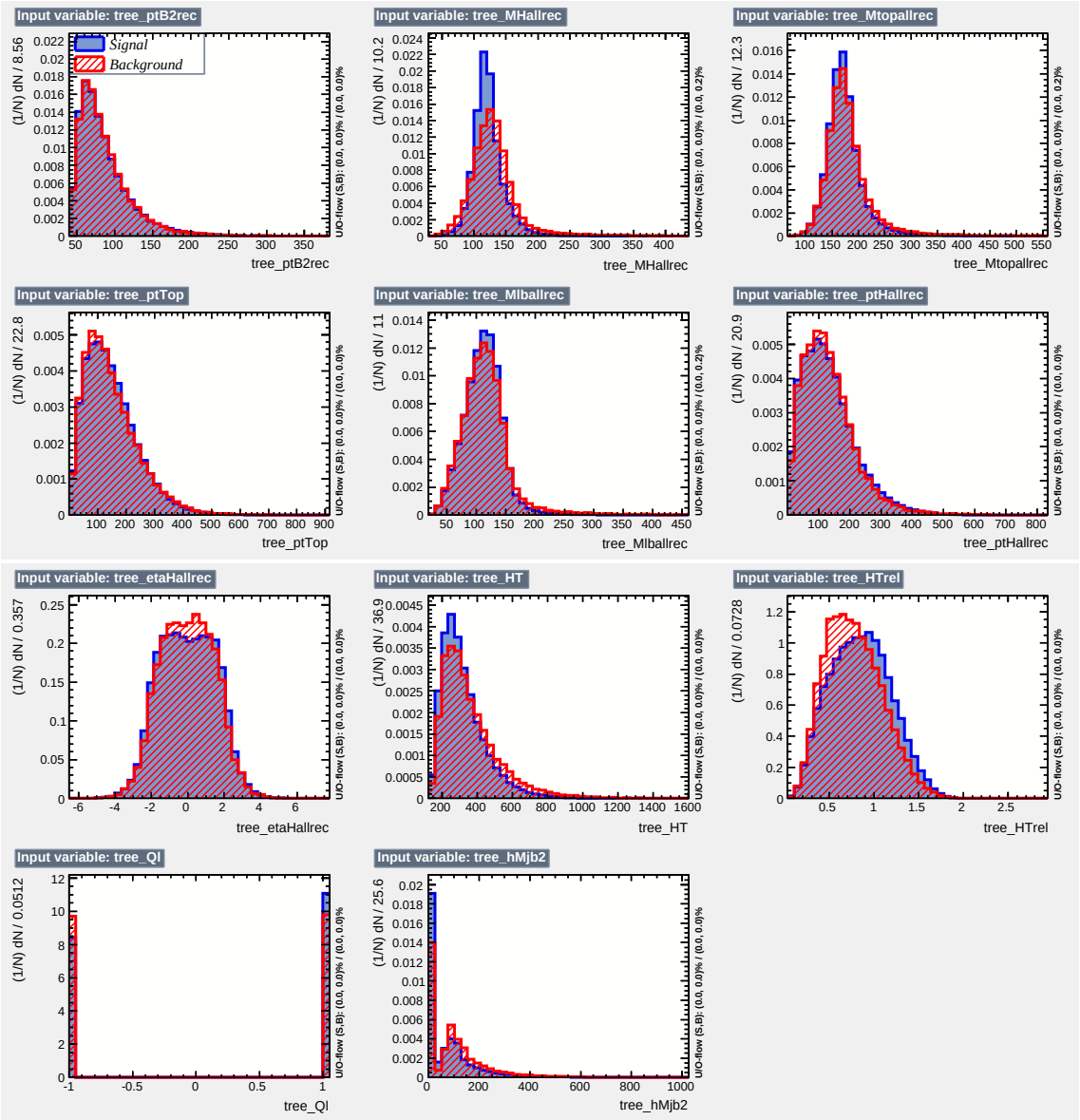
Cut	κ_{hct}	κ_{hut}	ttbar κ_{hct}	ttbar κ_{hut}	comb κ_{hct}	comb κ_{hut}
no cuts	0.156	1.204	0.979	0.978	1.135	2.182
$\#\ell \equiv 1$	0.036	0.287	0.797	0.797	0.833	1.084
$M^T(\ell\nu) > 50$	0.025	0.193	0.555	0.555	0.580	0.748
$\#j \geq 3$	0.251	1.573	8.942	8.952	9.192	10.519
$\#b \equiv 3$	0.402	2.246	8.528	8.556	8.918	10.734
$80 < M(bb) < 205$	0.408	2.254	8.670	8.696	9.065	10.878
$80 < M^T(b\ell\nu) < 230$	0.403	2.188	8.584	8.606	8.973	10.722

$t\bar{t}h$-background still missing: $\mathcal{O}(1\%)$

MVA – BDT

- training on sum of signals (naive combination)
- one training each for κ_{hut} and κ_{hct}
- compare κ_{hut} vs. κ_{hct} training by applying reader on sum of signals
- rescaled $t\bar{t}$-signals by $2/3$ waiting for new signal “with taus”
- tried various asymmetry variables: Q_ℓ, $Q_\ell \times p_\ell^T$, $Q_\ell \times |\eta_\ell|$: no difference

Variables for κ_{hut}



Variables for κ_{hut}

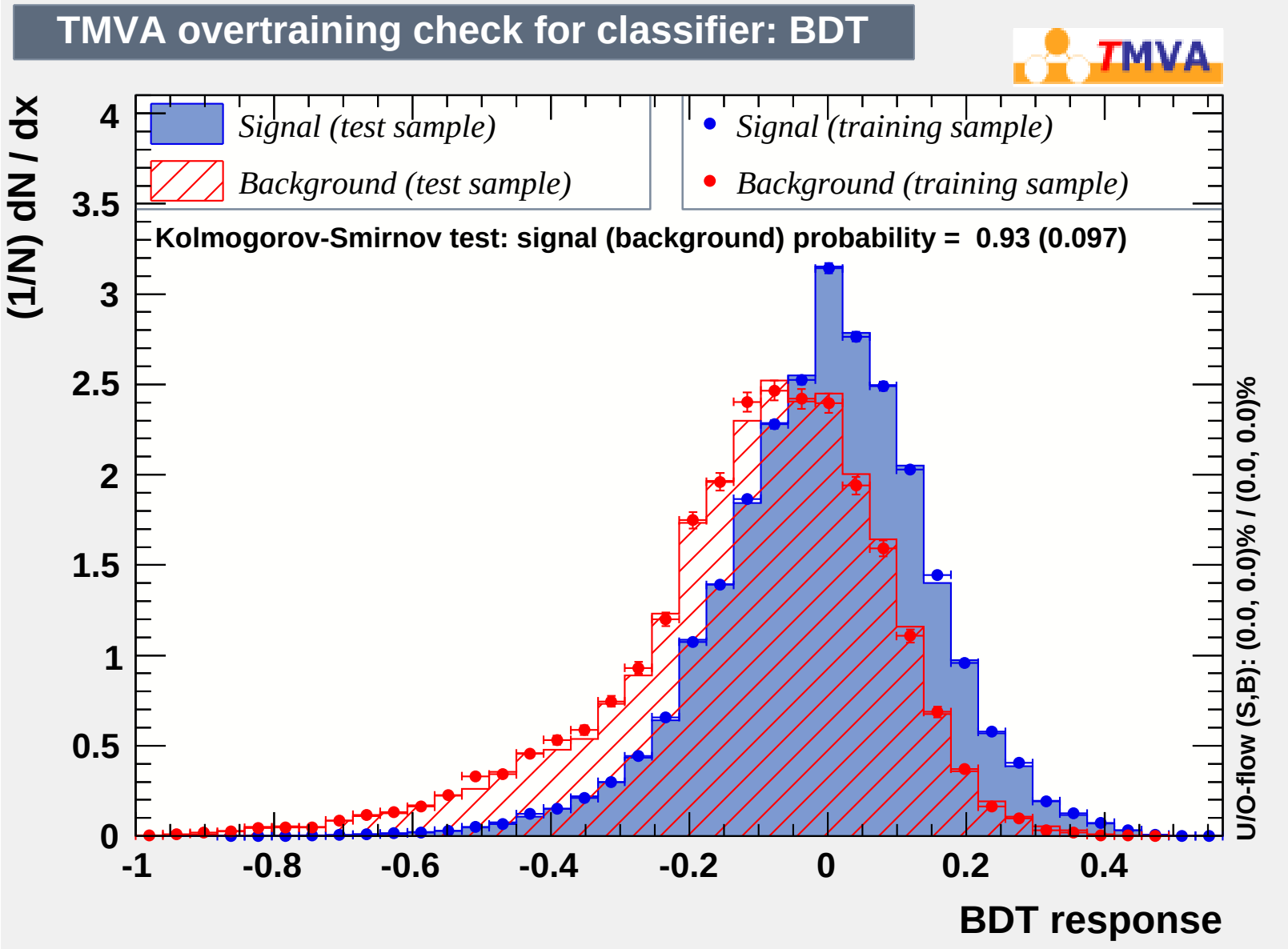
Filled after the $\#b \equiv 3$ cut.

11 Variables with relative importance:

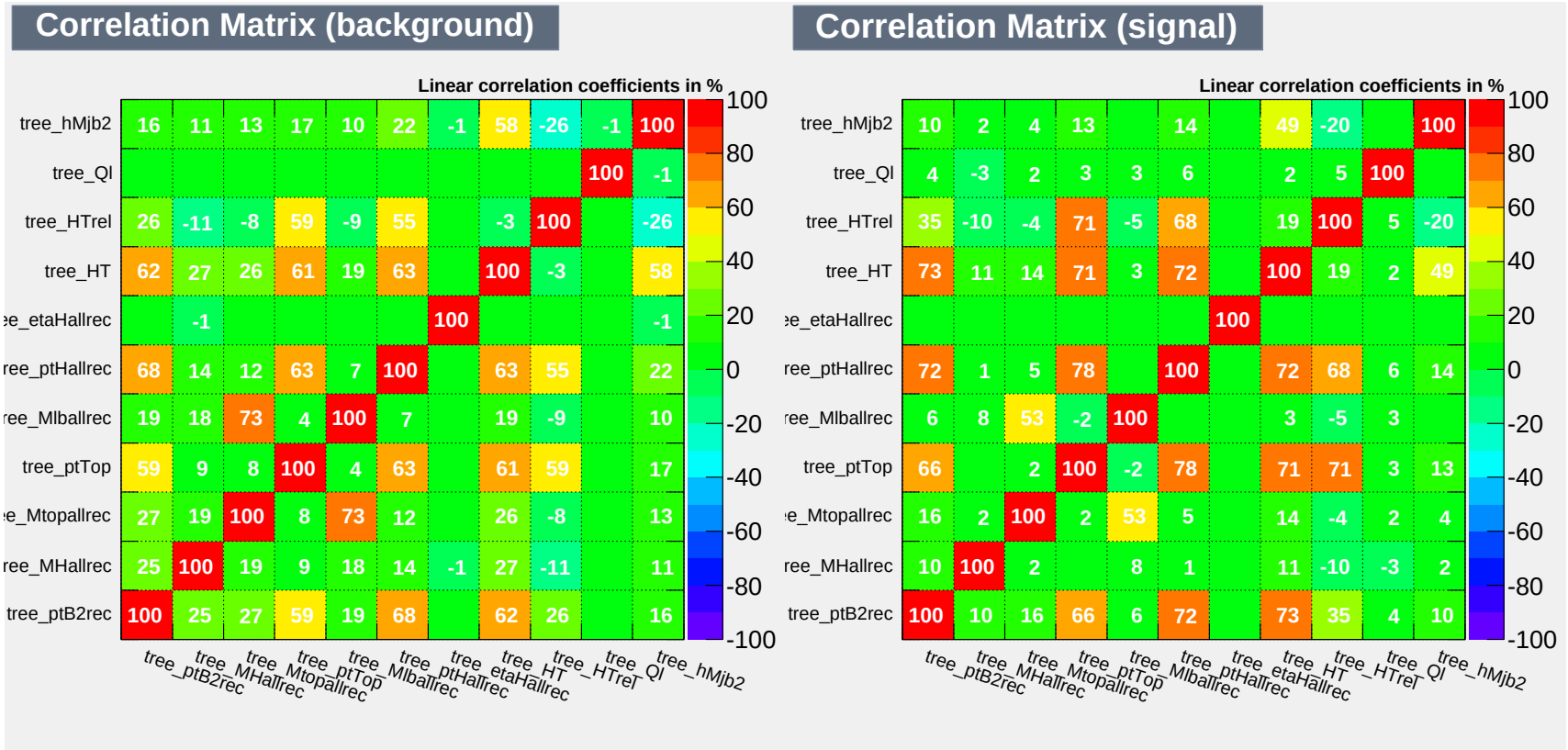
Variable	Importance
H_T	$1.94\,10^{-1}$
$M(H)$	$1.48\,10^{-1}$
$p^T(H)$	$1.13\,10^{-1}$
$p^T(top)$	$1.13\,10^{-1}$
Q_ℓ	$1.06\,10^{-1}$
H_T^{rel}	$7.21\,10^{-2}$
$p^T(b_2)$	$5.90\,10^{-2}$
$M(\ell b)$	$5.76\,10^{-2}$
$M(jb_2)$	$5.73\,10^{-2}$
$\eta(H)$	$4.76\,10^{-2}$
$M(top)$	$3.43\,10^{-2}$

where $H_T^{rel} \equiv (p^T(H) + p^T(top))/H_T$

κ_{hut}: overtraining

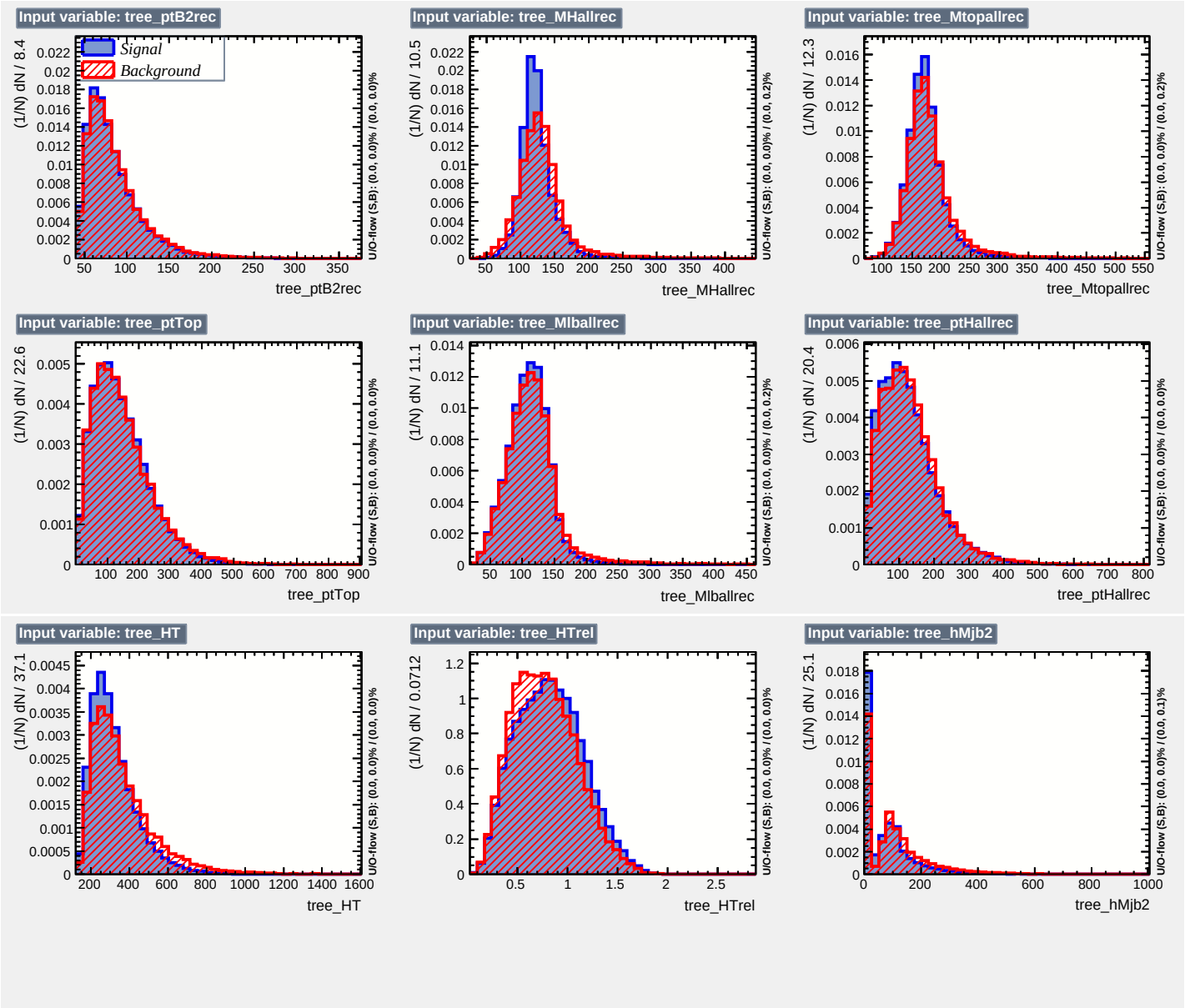


κ_{hut}: correlations



Some large correlations, but if removed BDT loses discriminating power

Variables for κ_{hct}



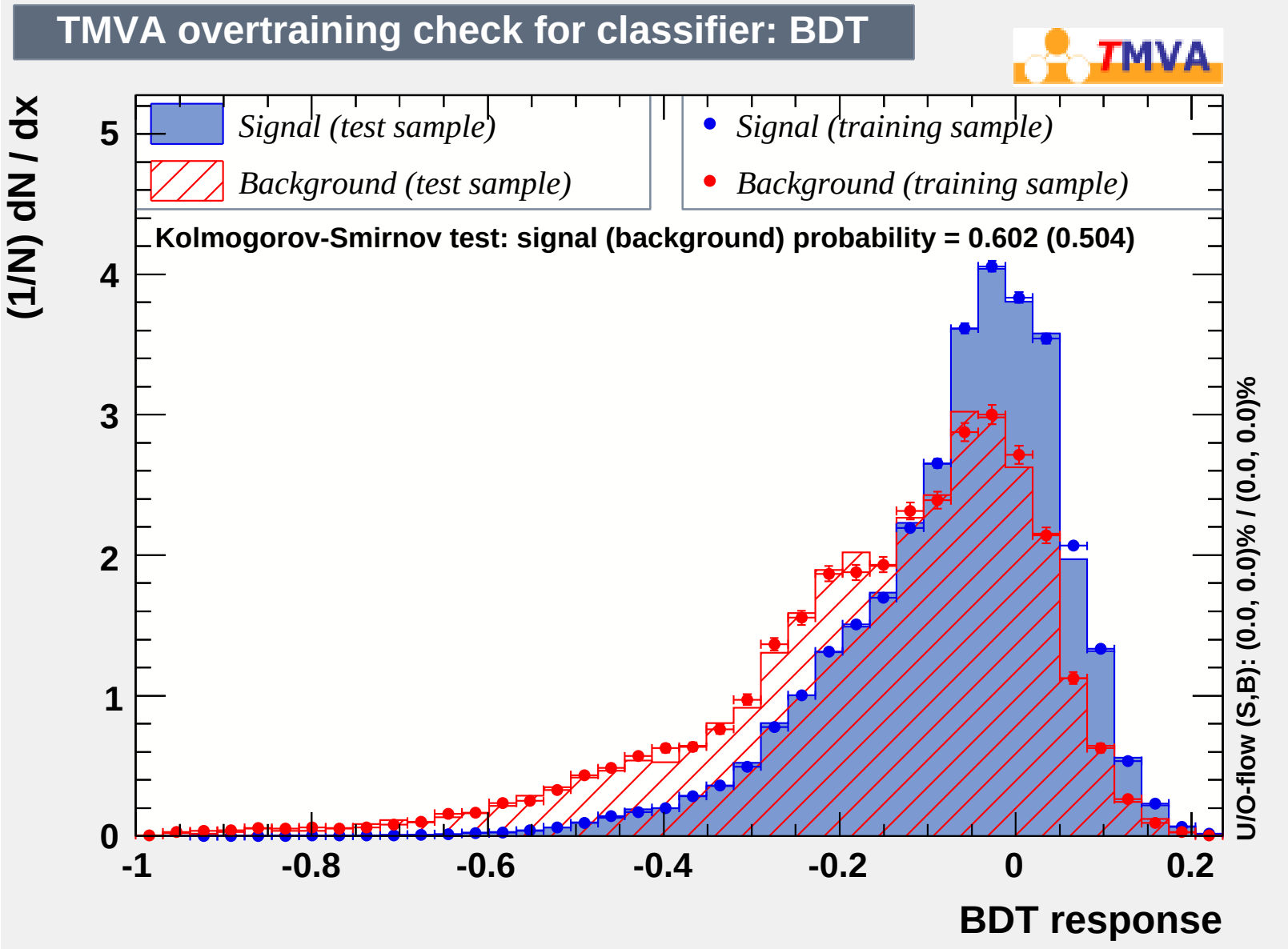
Variables for κ_{hct}

Filled after the $\#b \equiv 3$ cut.

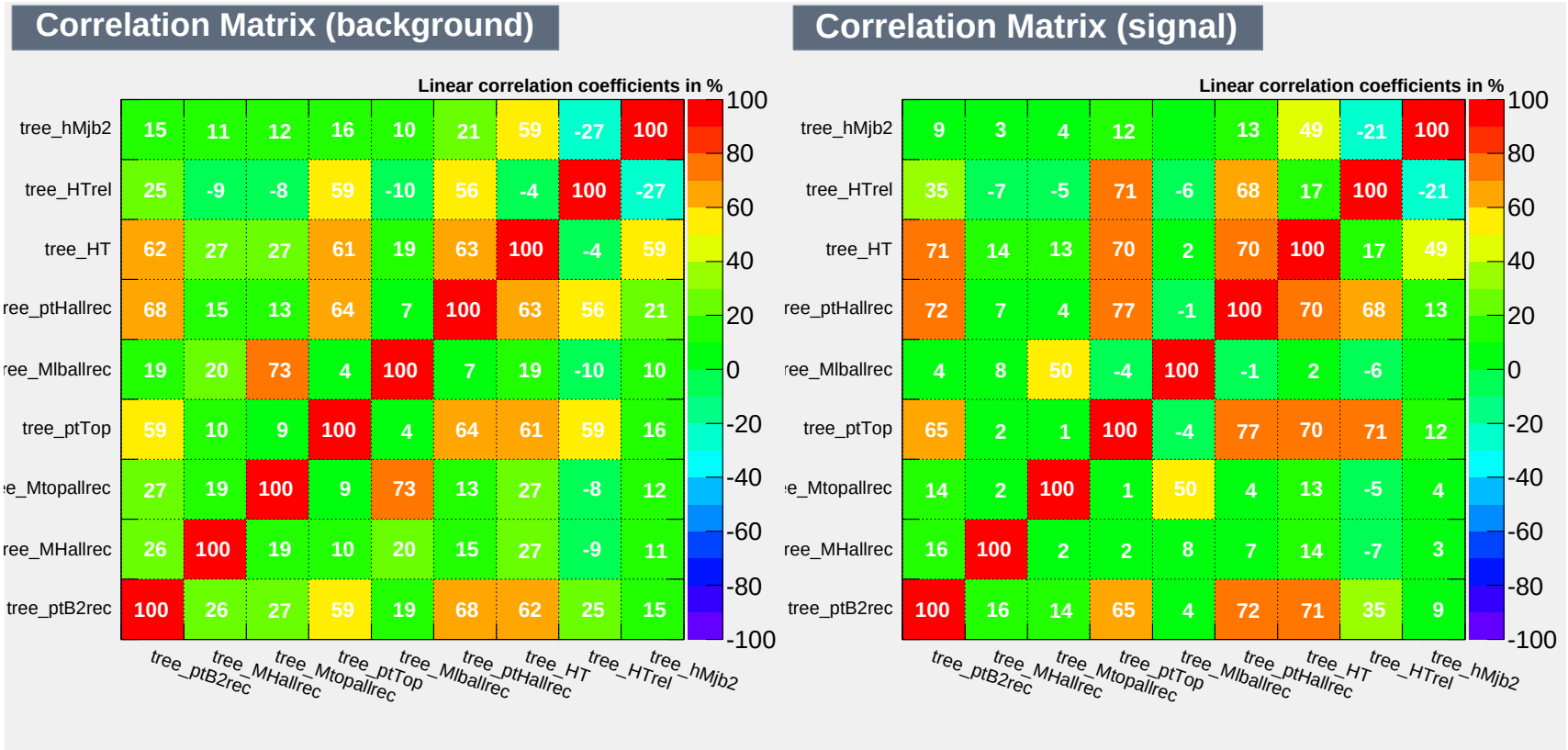
9 Variables with relative importance:

Variable	Importance
H_T	$2.42\,10^{-1}$
$M(H)$	$1.82\,10^{-1}$
$p^T(top)$	$1.35\,10^{-1}$
$p^T(H)$	$1.04\,10^{-1}$
$M(\ell b)$	$8.63\,10^{-2}$
$M(jb_2)$	$8.60\,10^{-2}$
H_T^{rel}	$6.05\,10^{-2}$
$p^T(b_2)$	$4.94\,10^{-2}$
$M(top)$	$4.47\,10^{-2}$

κ_{hct}: overtraining



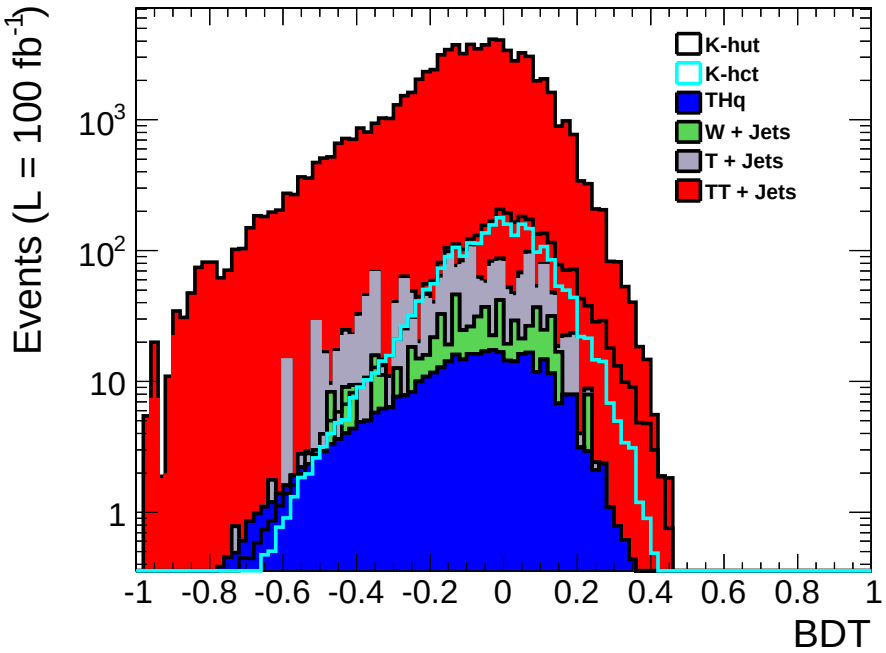
κ_{hct}: correlations



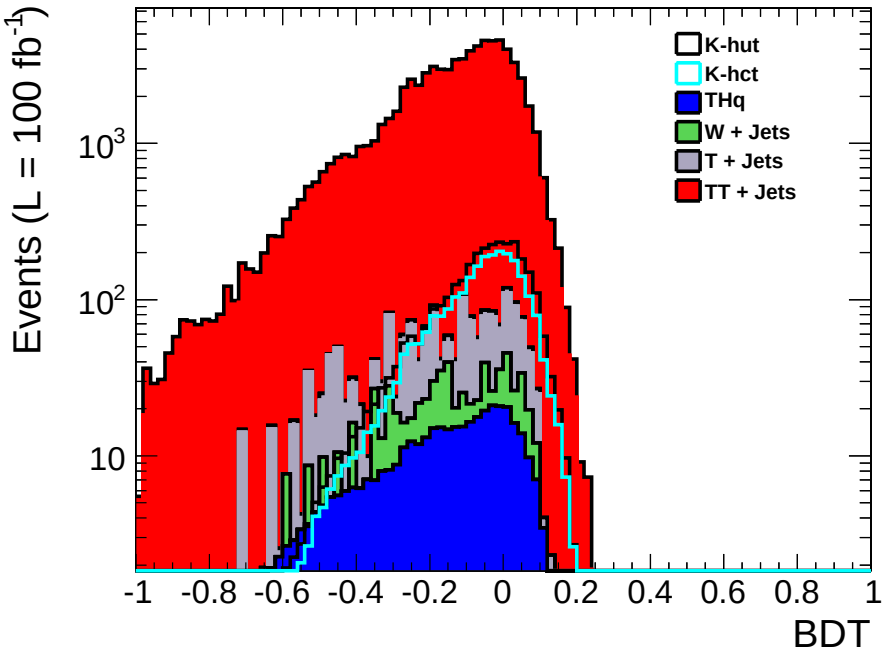
Some large correlations, but if removed BDT loses all discriminating power

BDT output

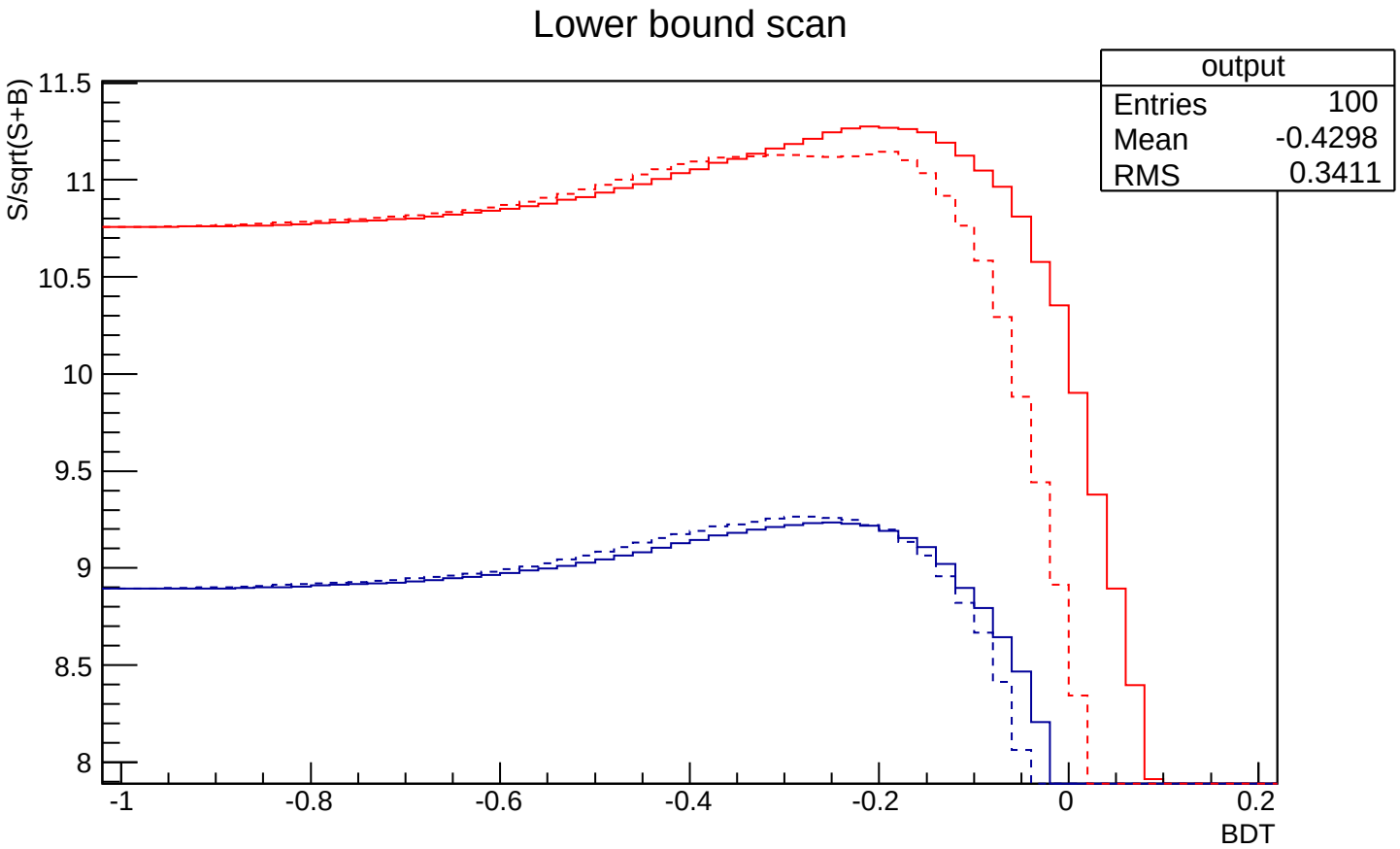
κ_{hut}



κ_{hct}



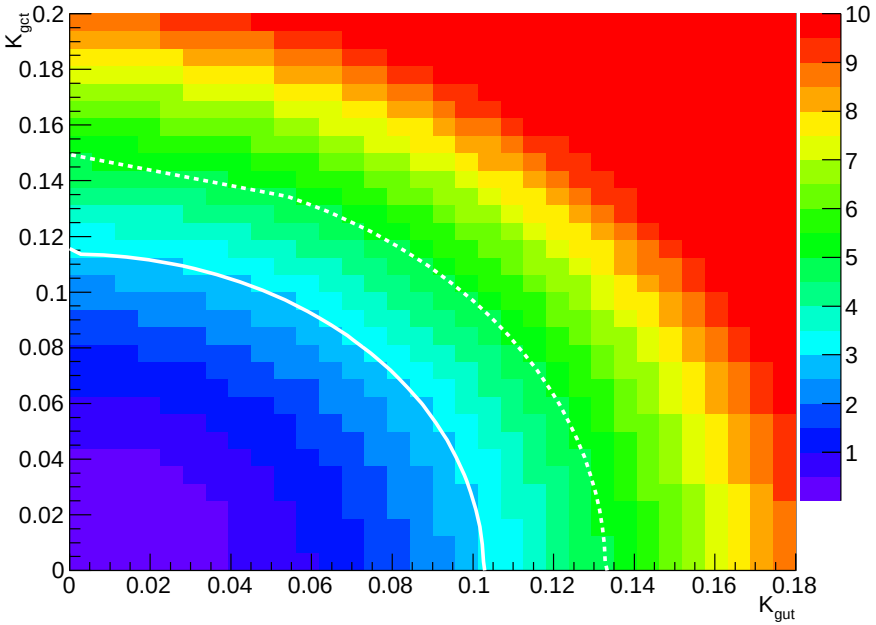
MVA: reading of sum of signals

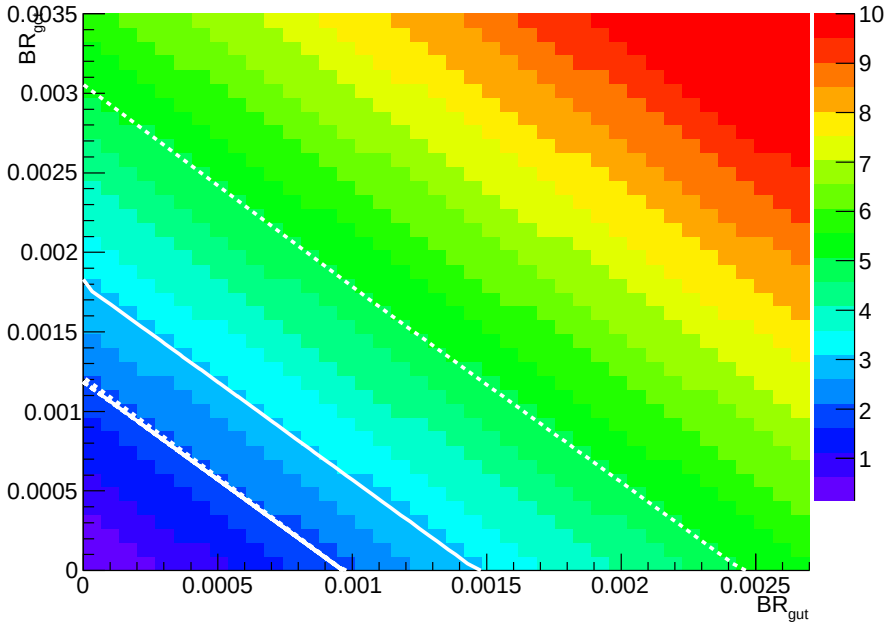


Reading onto: Red- κ_{hut} Blue- κ_{hct}

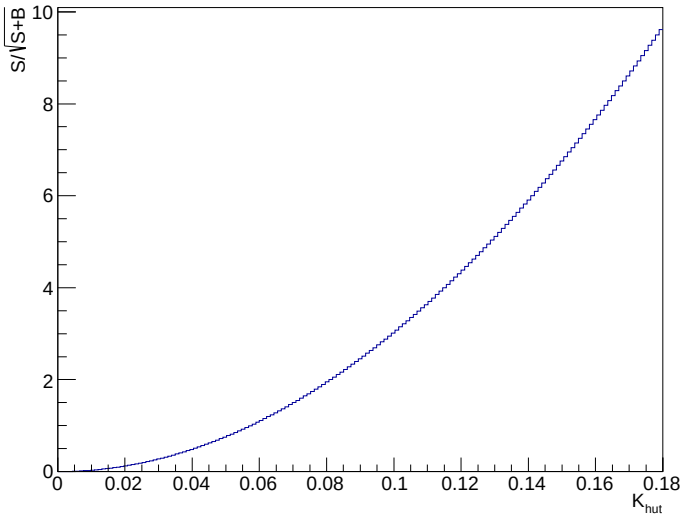
Training onto Solid- κ_{hut} Dashed- κ_{hct}

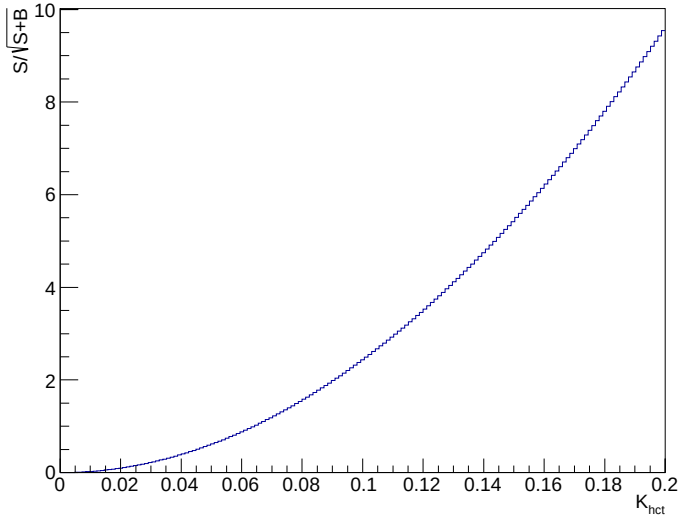
MVA: 2D limits

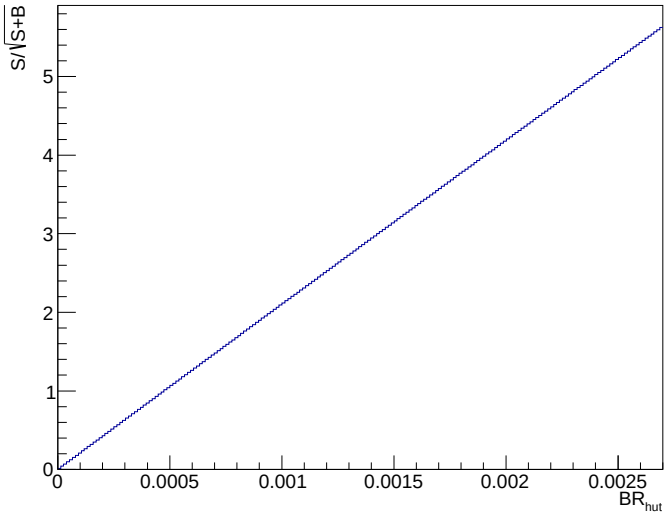


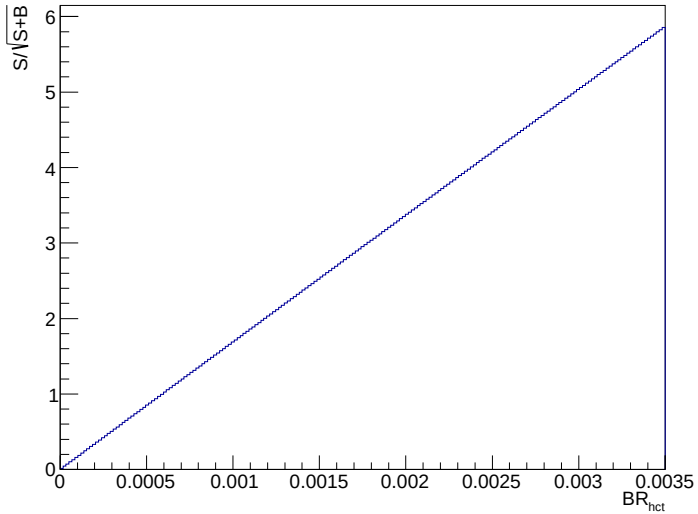


MVA: 1D indep limits









sinlge-top-enriched selection: $\#j \equiv 3$

Cut	Sum Bg	κ_{hct}	κ_{hut}	ttbar κ_{hct}	ttbar κ_{hut}
no cuts	$(18.62 \pm 0.03)\,10^9$	21261 ± 21	164242 ± 57	133579 ± 46	133528 ± 45
$\#\ell \equiv 1$, 0 loose	$(5858 \pm 1)\,10^6$	2763 ± 8	21995 ± 20	61009 ± 31	60975 ± 30
$M^T(\ell\nu) > 50$	$(5573 \pm 1)\,10^6$	1832 ± 6	14434 ± 16	41456 ± 25	41432 ± 25
$\#j \equiv 3$	$(382 \pm 7)\,10^3$	434 ± 3	2728 ± 7	12873 ± 14	12887 ± 14
$\#b \equiv 3$	28423 ± 245	78 ± 1	429 ± 3	1060 ± 4	1065 ± 4
$80 < M(bb) < 205$	26605 ± 234	76 ± 1	414 ± 3	1031 ± 4	1038 ± 4
$80 < M^T(b\ell\nu) < 230$	24943 ± 224	73 ± 1	389 ± 3	981 ± 4	989 ± 4

Table: Signal (ttbar to be rescaled by $2/3$).

Cut	Sum Bg	T+jets	THq	TT+jets	W+jets
no cuts	$(18622 \pm 0.03)\,10^6$	$(28.11 \pm 0.02)\,10^6$	17526 ± 6	$(32322 \pm 7)\,10^3$	$(18562 \pm 3)\,10^6$
$\#\ell \equiv 1$, 0 loose	$(5858 \pm 1)\,10^6$	$(3162 \pm 5.2)\,10^3$	6074 ± 3	$(9245 \pm 4)\,10^3$	$(5845 \pm 1)\,10^6$
$M^T(\ell\nu) > 50$	$(5573 \pm 1)\,10^6$	$(2225 \pm 4)\,10^3$	4043 ± 3	$(5966 \pm 3)\,10^3$	$(5565 \pm 1)\,10^6$
$\#j \equiv 3$	$(382 \pm 7)\,10^3$	$(205 \pm 1)\,10^3$	1046 ± 1	$(1868 \pm 2)\,10^3$	$(1744 \pm 7)\,10^3$
$\#b \equiv 3$	28423 ± 245	813 ± 97	211 ± 1	27103 ± 222	296 ± 36
$80 < M(bb) < 205$	26605 ± 234	44 ± 87	180 ± 1	25558 ± 215	223 ± 31
$80 < M^T(b\ell\nu) < 230$	24943 ± 224	491 ± 75	148 ± 1	24107 ± 209	197 ± 29

Table: Background

Significance

Cut	κ_{hct}	κ_{hut}	ttbar κ_{hct}	ttbar κ_{hut}	comb κ_{hct}	comb κ_{hut}
no cuts	0.156	1.204	0.979	0.978	1.135	2.182
$\#\ell \equiv 1$	0.036	0.287	0.797	0.797	0.833	1.084
$M^T(\ell\nu) > 50$	0.025	0.193	0.555	0.555	0.580	0.748
$\#j \equiv 3$	0.222	1.396	6.576	6.583	6.798	7.974
$\#b \equiv 3$	0.460	2.523	6.175	6.205	6.619	8.638
$80 < M(bb) < 205$	0.465	2.516	6.204	6.246	6.652	8.669
$80 < M^T(b\ell\nu) < 230$	0.459	2.443	6.092	6.142	6.534	8.493

MVA: no improvement. For combination use only cut-and-count.

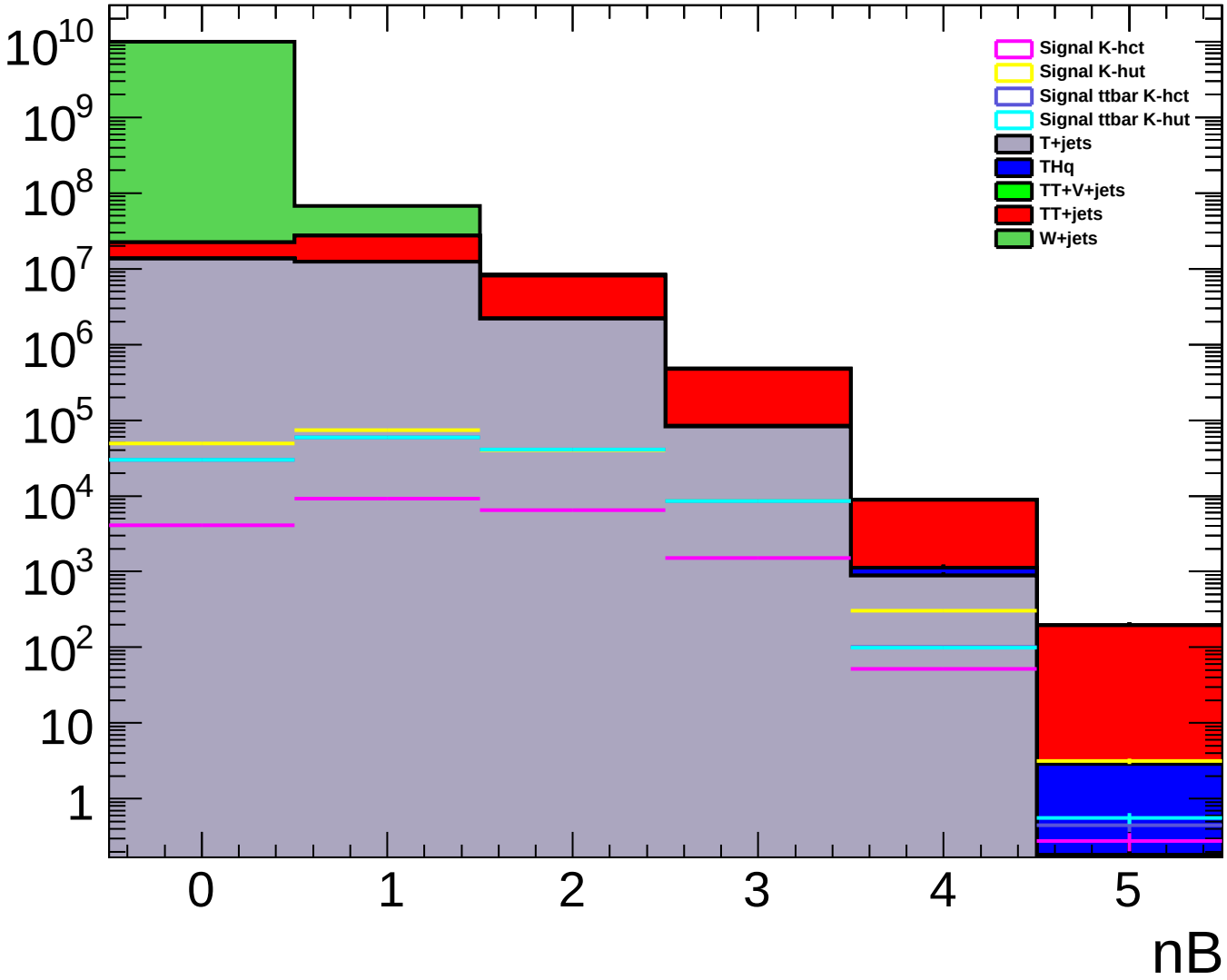
To compare with inclusive analysis

Summary

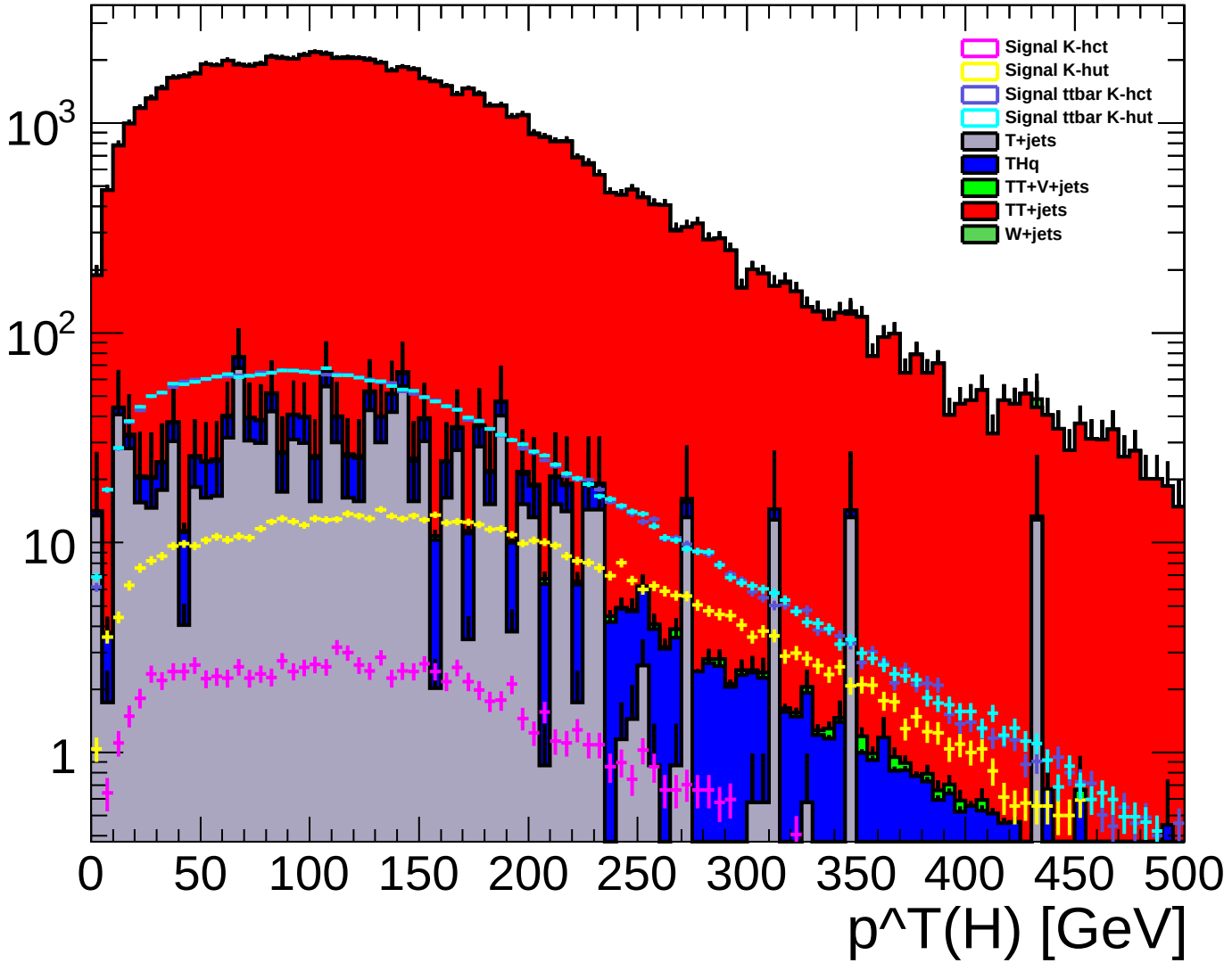
- no need for separate training for different couplings
- tiny improvement with BDT for inclusive sample
- NO improvement with BDT for single-top enriched sample
- ...final numbers awaiting for new TT-signal (almost there!)

Backup slides

Number of b-jets



PT of Higgs


Signal K-hct
Signal K-hut
Signal ttbar K-hct
Signal ttbar K-hut
T+jets
THq
TT+V+jets
TT+jets
W+jets
10^3
10^2
10
1
0
50
100
150
200
250
300
350
400
450
500
p^T(H) [GeV]