Combination single top $+t\bar{t}$
$tZ \to 1b3\ell$

Lorenzo Basso

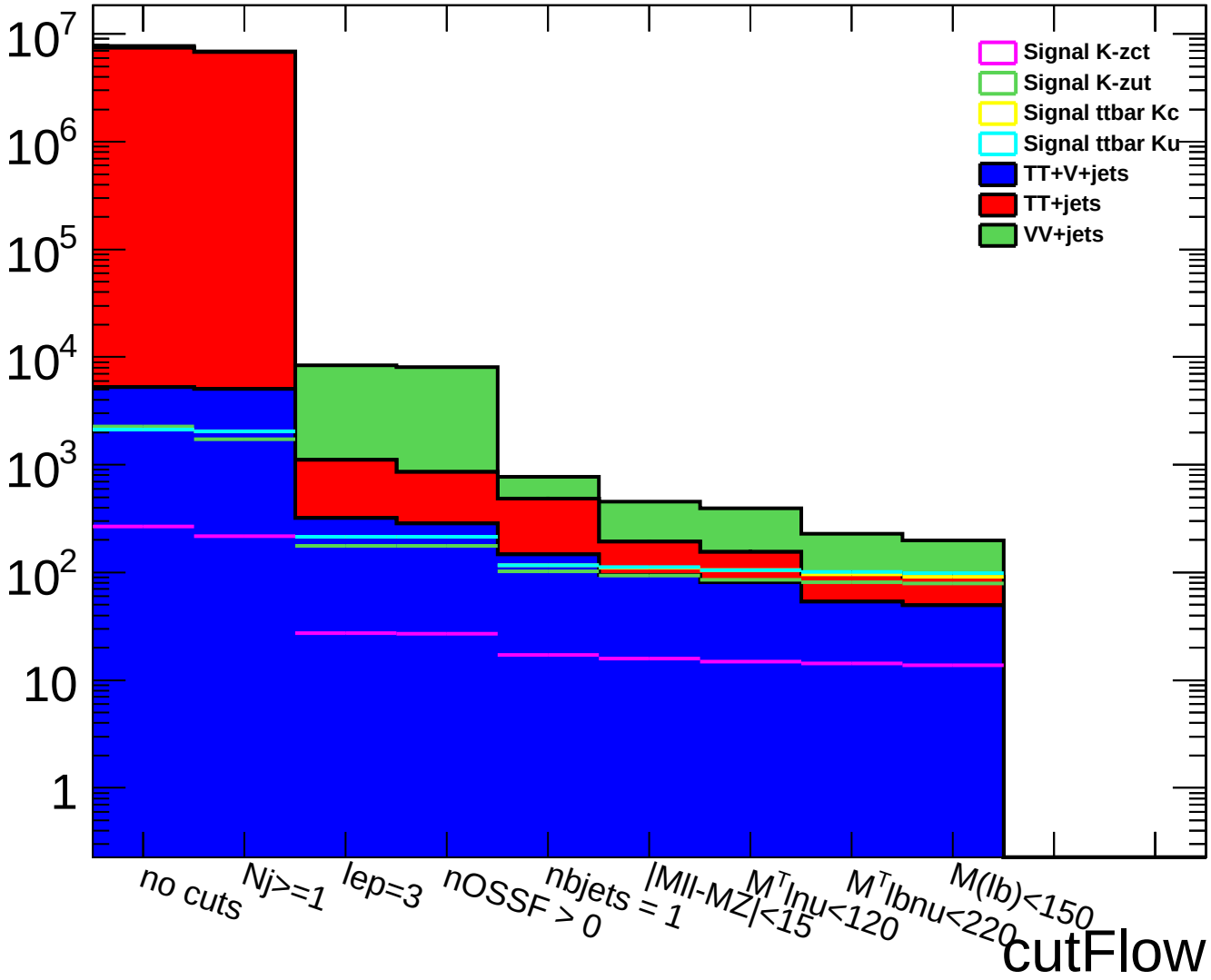
Optimisation - almost matched Isis's

- LEPTONS: $|\eta| < 2.5(2.4)$ for e/μ
  $p_\ell^T > 20$ GeV, ISO: `CONE04`, $I_{rel} < 0.20$ e/μ
- JETS: $p_j^T > 40$ GeV, $|\eta| < 2.4$, $1/$`EEoverHE` > 0.15
  - loose JETS $30 < p_j^T < 40$ GeV, $|\eta| < 2.4$, $1/$`EEoverHE` > 0.15
- Selections:
  1. $N_J \geq 1$ ($J =$ light and b jets); (if $N_J \equiv 1$, then also $N_j^{loose} \equiv 0$)
  2. $N_b \geq 1$ to reduce WZ, $N_b \leq 1$ once WZ is removed $\Rightarrow N_b \equiv 1$
  3. Z candidate as pair of $e^+e^-(\mu^+\mu^-)$ closest to M_Z and $|M_{\ell\ell} - M_Z| < 15$ GeV

  Here, MVA or Cut&Count with
- loose W reco: $10 < M^T(\nu\ell_W)/\text{GeV} < 150$
- loose top reco: $M^T(\nu b\,\ell_W)/\text{GeV} < 215$
- top reco 2: $M(b\,\ell_W)/\text{GeV} < 150$

$$N_j \geq 1$$

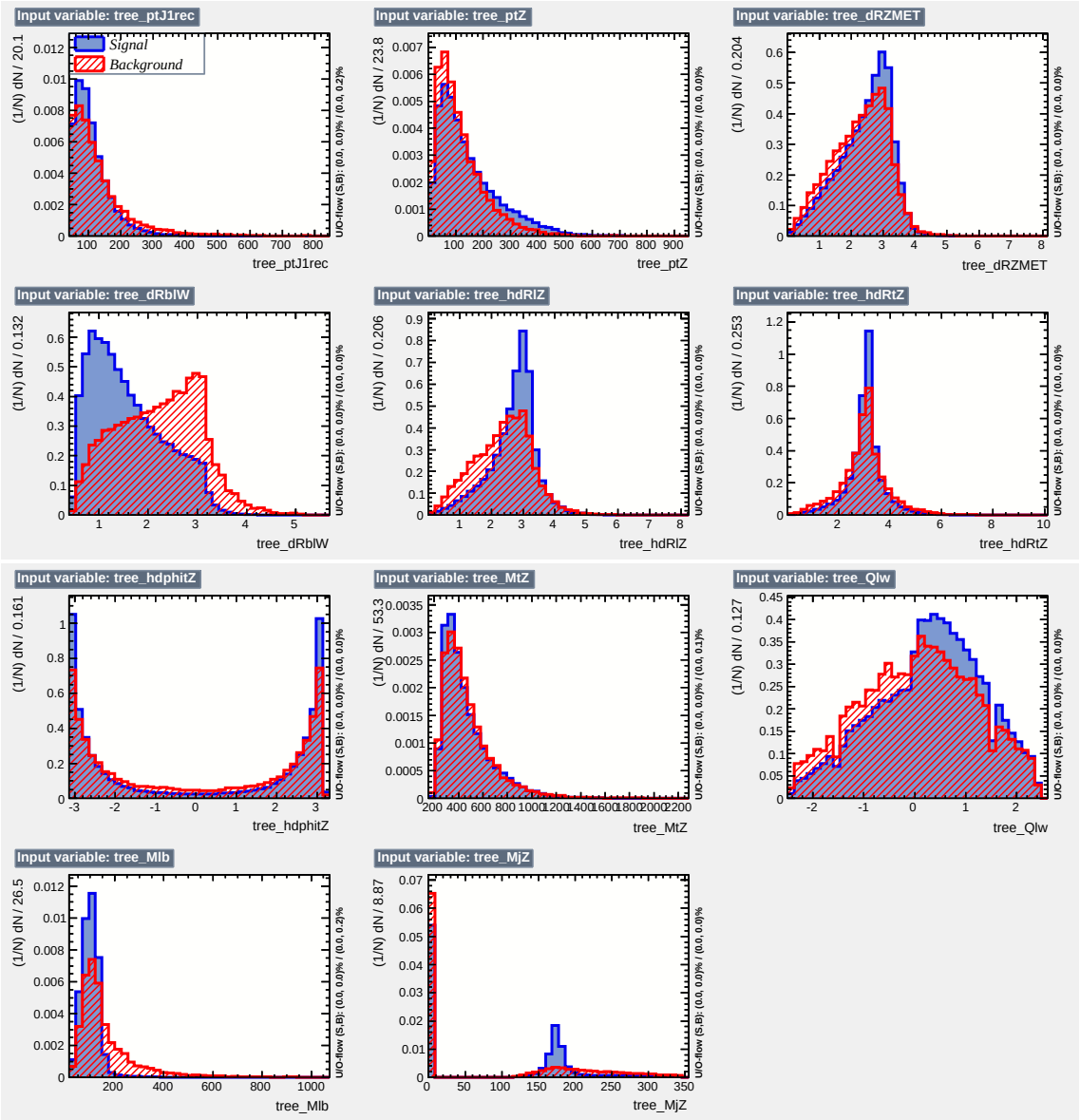
Backgrounds - cutflow



MVA – BDT

- training on sum of signals (naive combination)
- one training each for κ_{zut} and κ_{zct}
- inclusive sample
- training on background without $t\bar{t}$

Variables for κ_{zut}



Variables for κ_{zut}

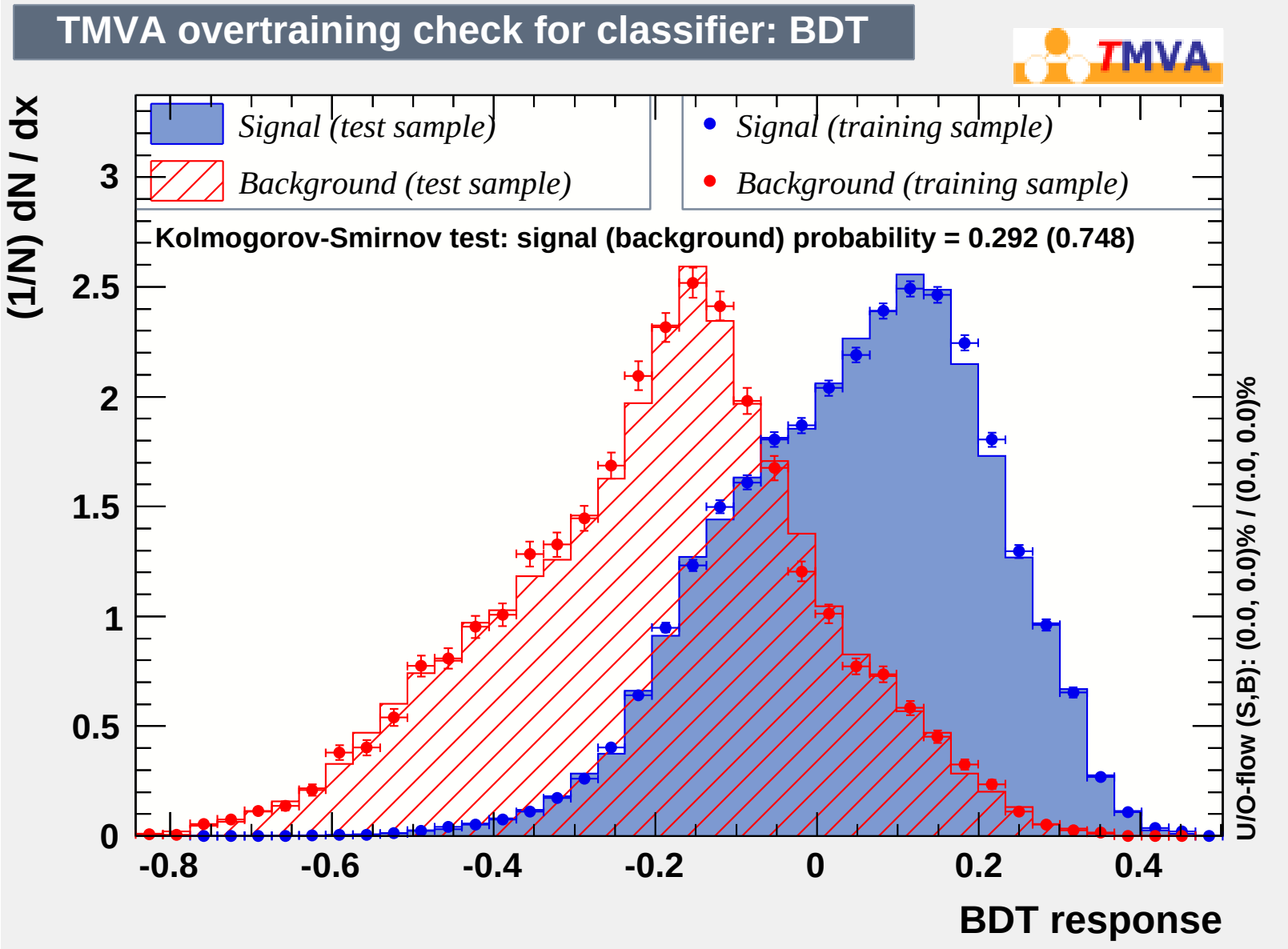
Filled after the $M(\ell^+\ell^-) - M_Z < 15$ GeV cut.

11 Variables with relative importance when trained considering all backgrounds without $t\bar{t}$:

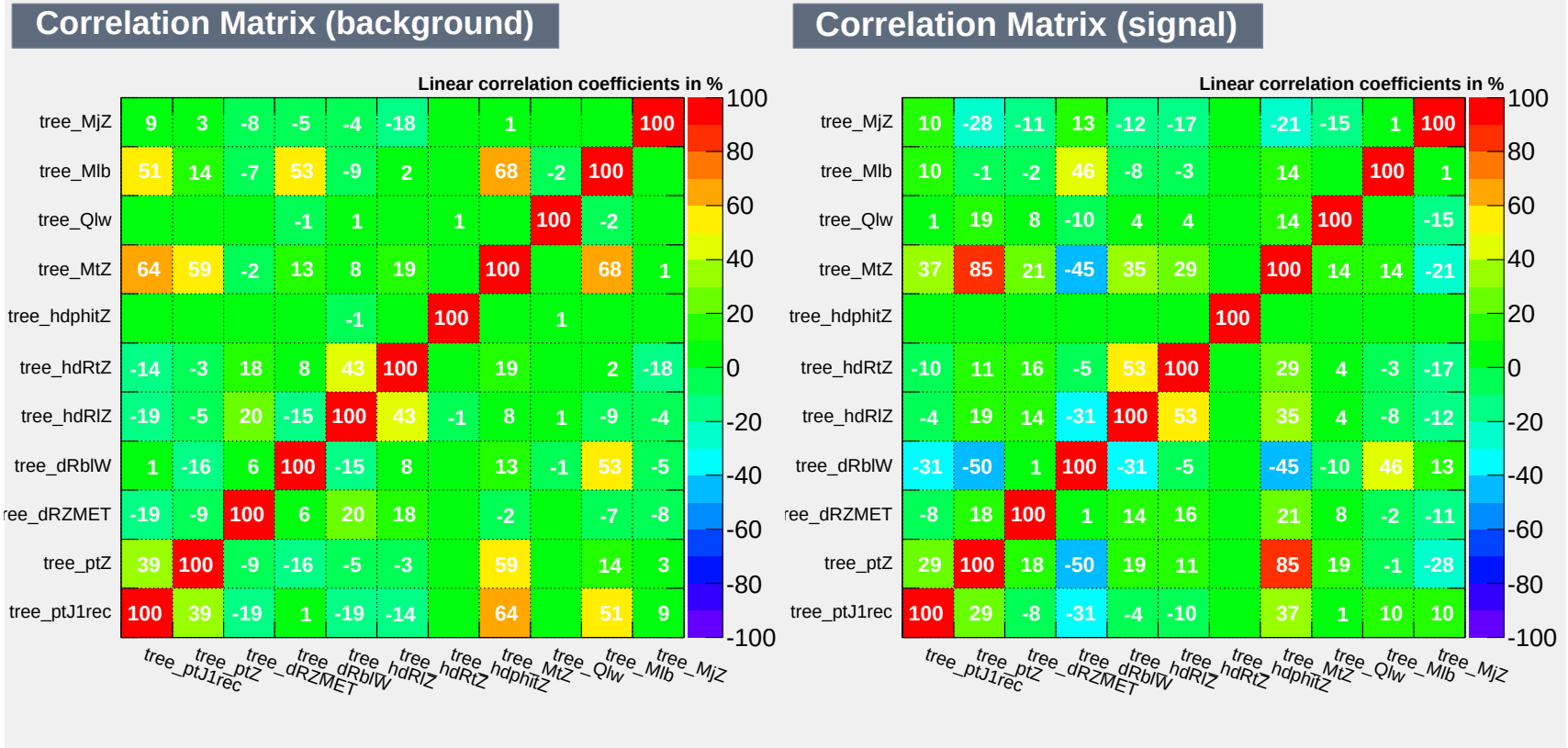
Variable	Importance
$M(\ell b)$	$1.90\,10^{-1}$
$M(jZ)$	$1.50\,10^{-1}$
$p^T(Z)$	$1.24\,10^{-1}$
$p^T(j_1)$	$1.20\,10^{-1}$
$\Delta R(b,\, \ell_W)$	$8.45\,10^{-2}$
$M(tZ)$	$8.09\,10^{-2}$
$Q(\ell_W)$	$7.09\,10^{-2}$
$\Delta R(Z,\, \ell_W)$	$6.11\,10^{-2}$
$\Delta R(t,\, Z)$	$5.36\,10^{-2}$
$\Delta R(Z,\, \texttt{MET})$	$3.99\,10^{-2}$
$\Delta\phi(t\,Z)$	$2.47\,10^{-2}$

where $Q(\ell_W) \equiv Q(\ell_W) \times |eta(\ell_W)|$. Low discriminating variables are kept because work well with $t\bar{t}$.

κ_{zut}: overtraining

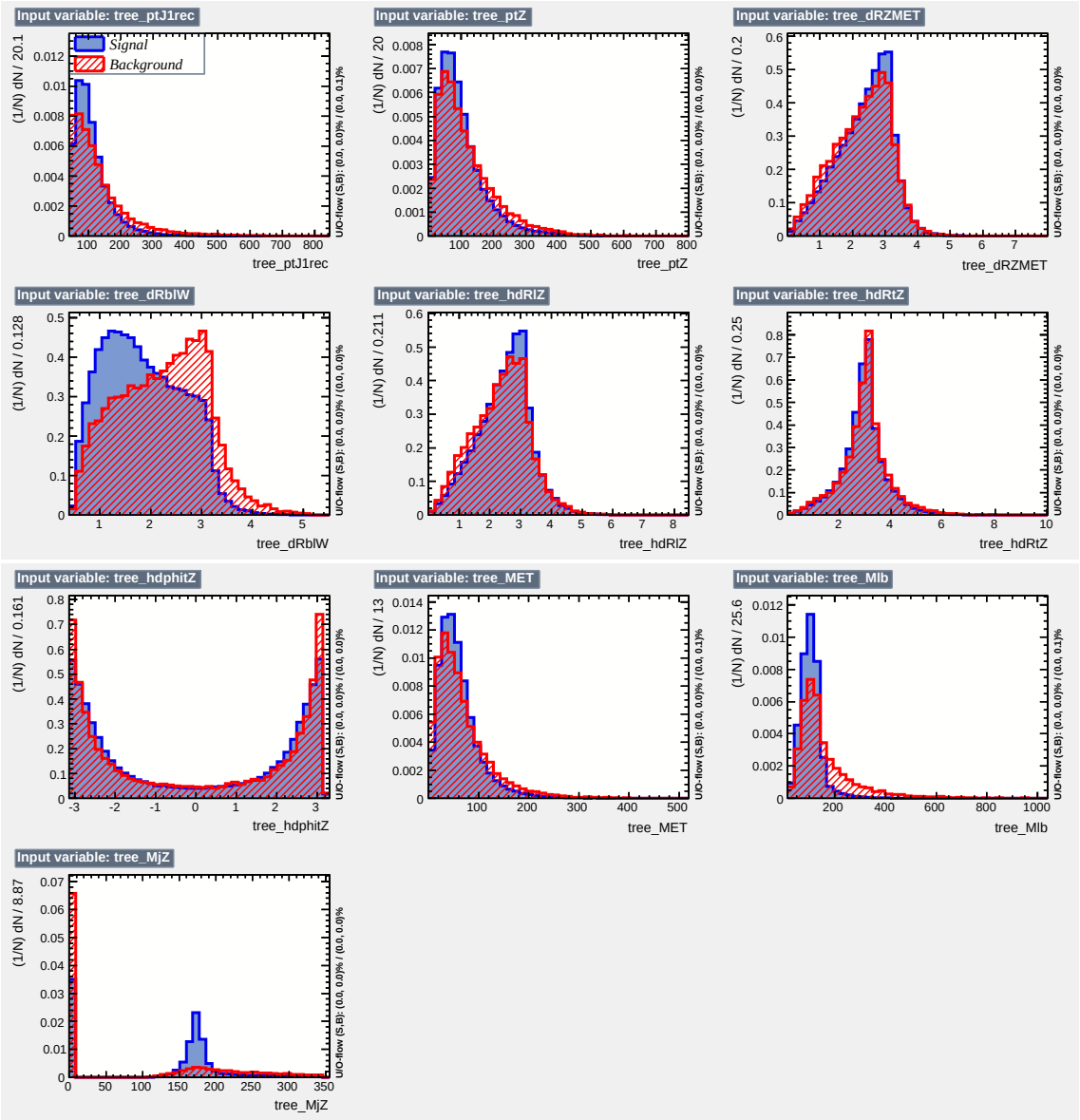


κ_{zut}: correlations



LArge correlations in signal or in background, not both.

Variables for κ_{zct}



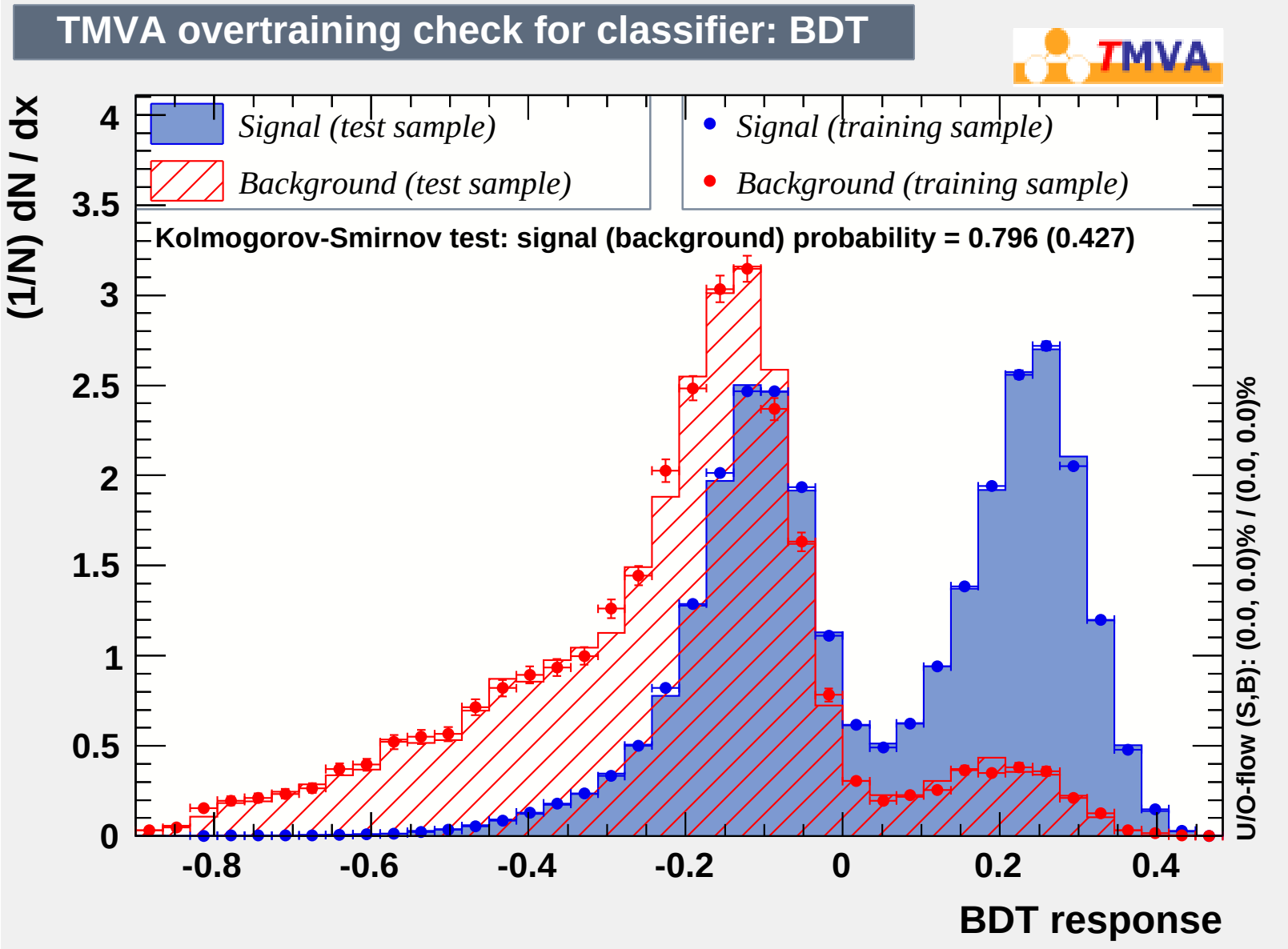
Variables for κ_{zct}

Filled after the $M(\ell^+\ell^-) - M_Z < 15$ GeV cut.

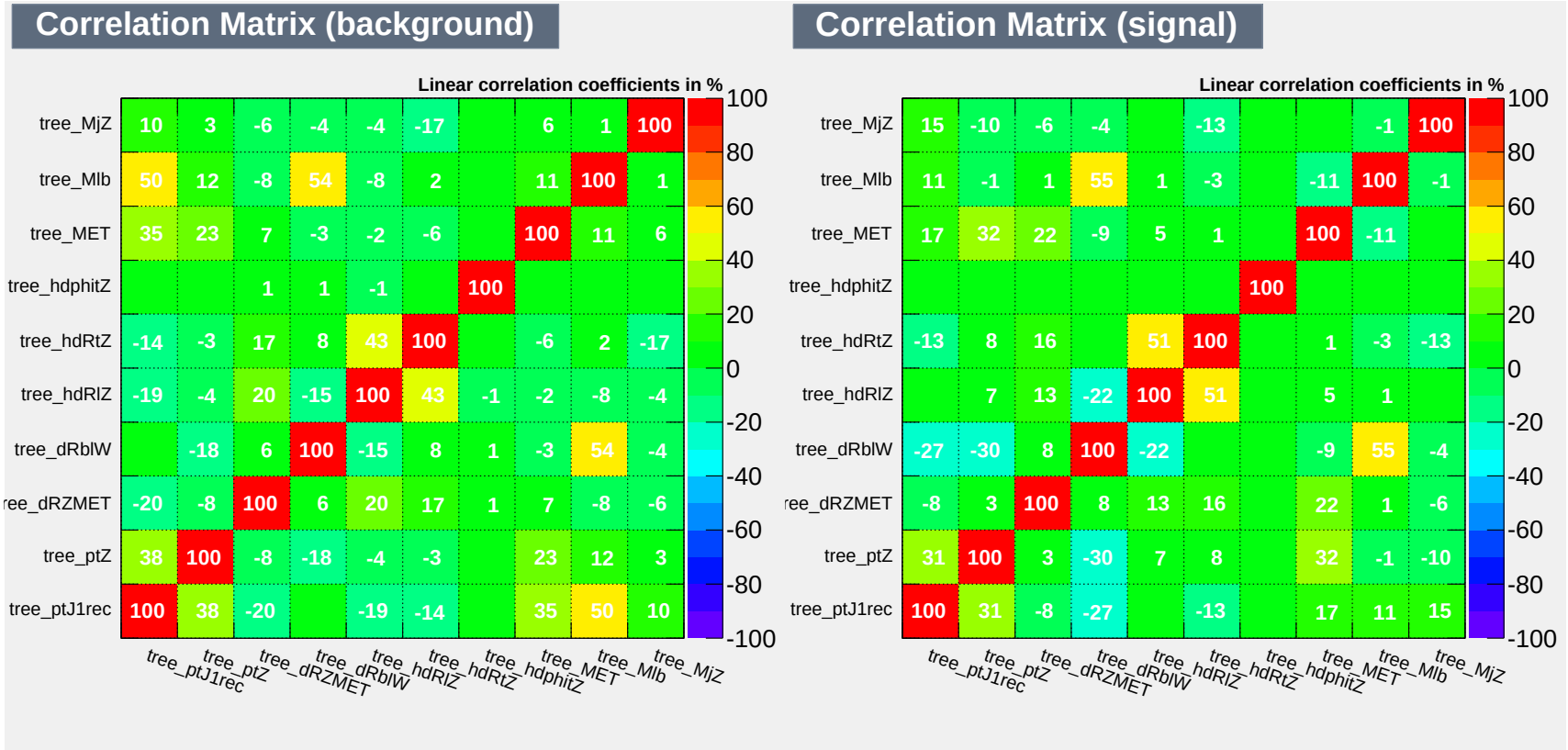
10 Variables with relative importance when trained considering all backgrounds, including $t\bar{t}$:

Variable	Importance
$M(\ell b)$	$2.34\,10^{-1}$
$M(jZ)$	$1.85\,10^{-1}$
$\Delta R(\ell_W,\, Z)$	$9.41\,10^{-2}$
$\Delta R(Z,\, \texttt{MET})$	$8.14\,10^{-2}$
$\Delta R(t,\, Z)$	$7.92\,10^{-2}$
$\texttt{MET}$	$7.59\,10^{-2}$
$p^T(j_1)$	$7.38\,10^{-2}$
$p^T(Z)$	$6.59\,10^{-2}$
$\Delta R(b,\, W)$	$5.79\,10^{-2}$
$\Delta\phi(t,\, Z)$	$5.25\,10^{-2}$

κ_{zct}: overtraining



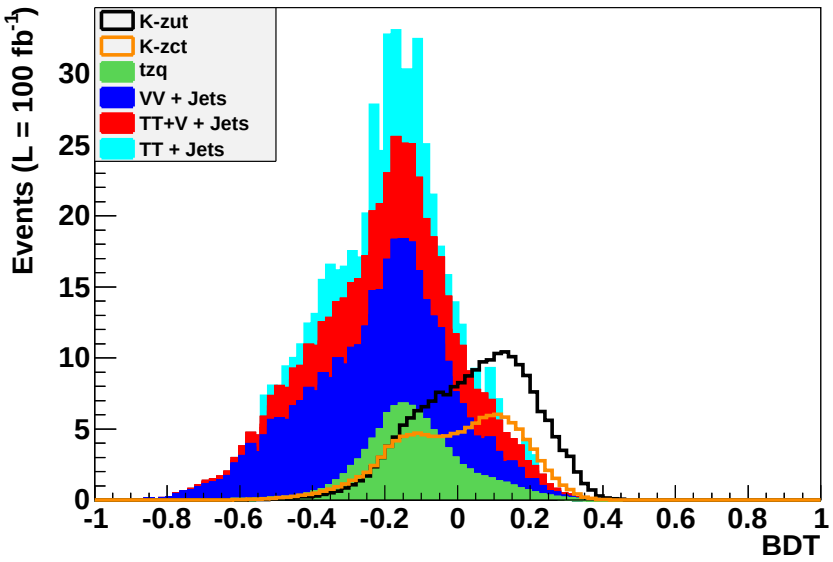
κ_{zct}: correlations



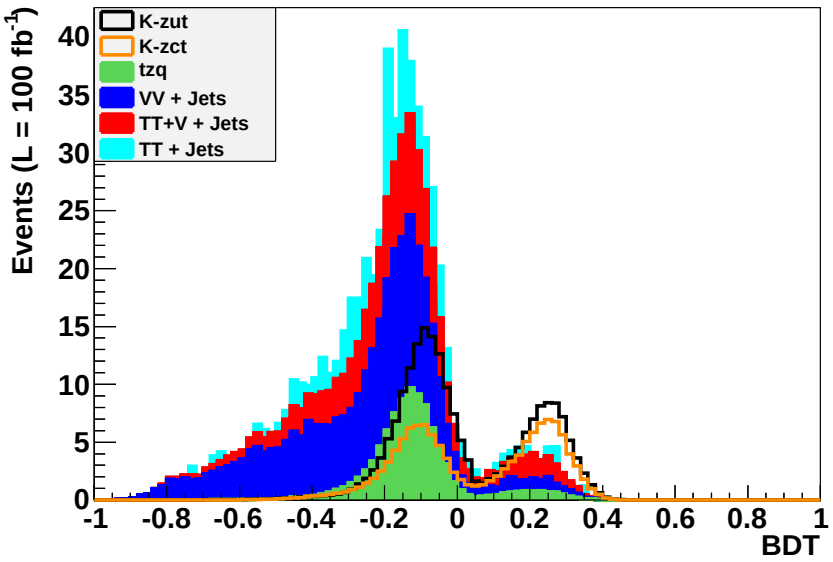
Low correlations

BDT output

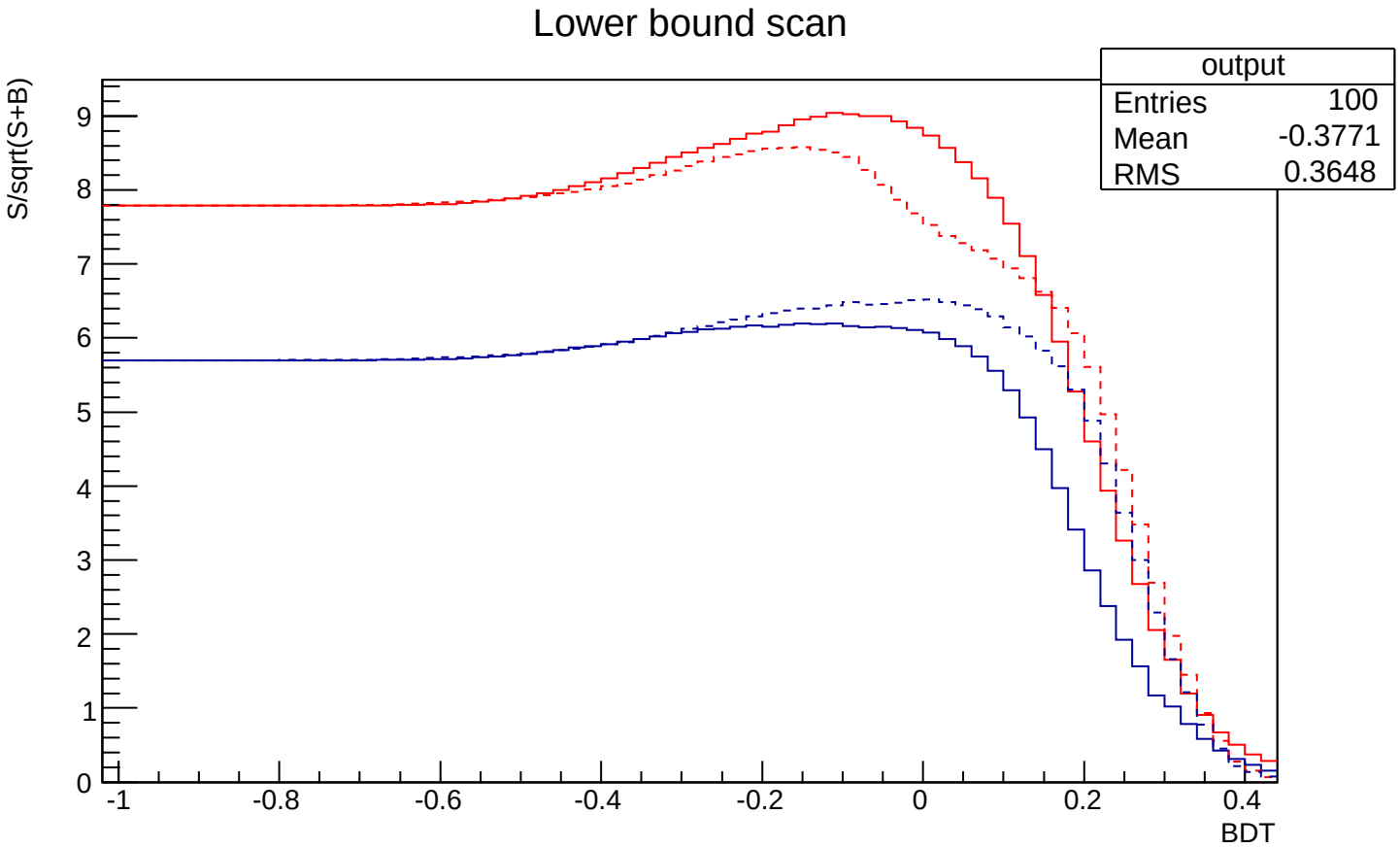
κ_{zut}



κ_{zct}



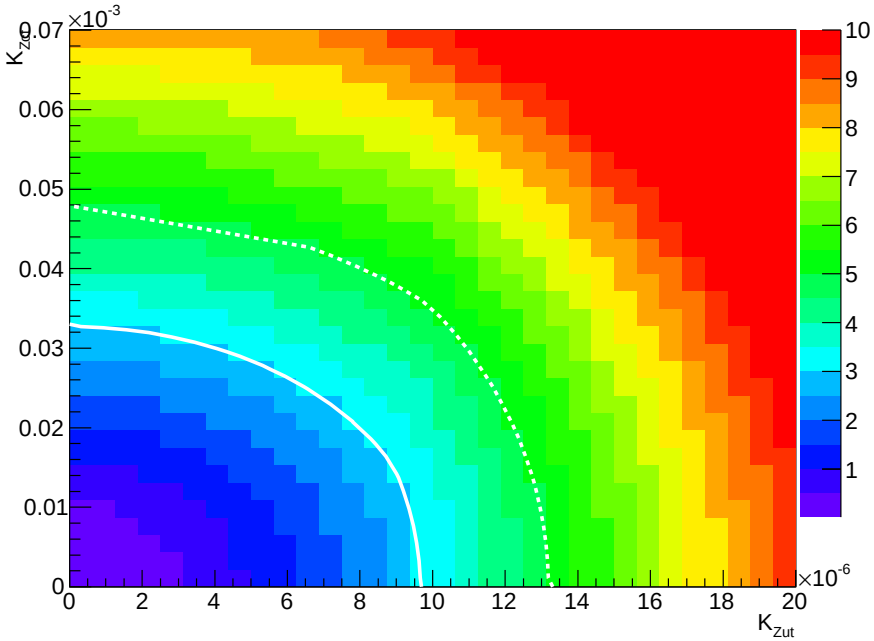
Reading of sum of signals

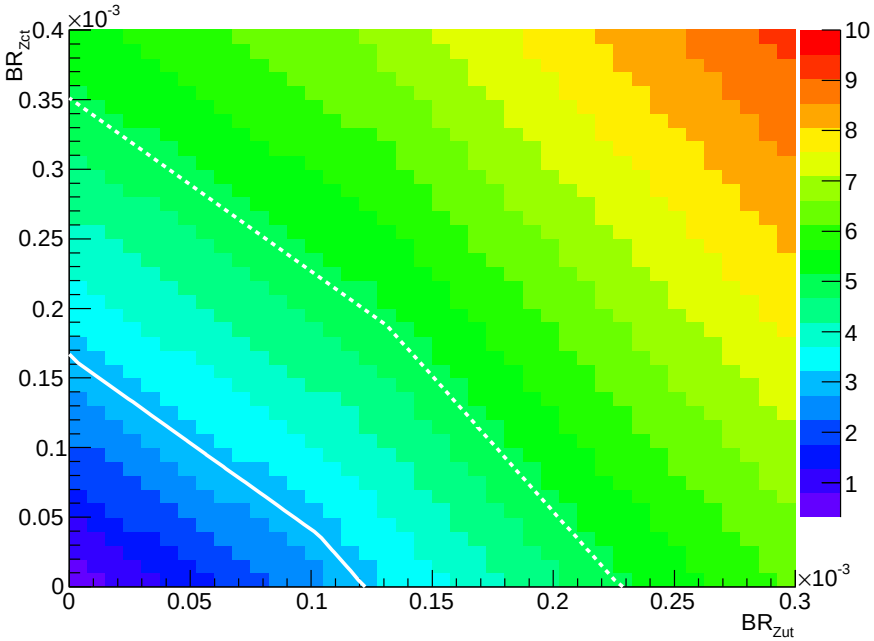


Training: Solid: zut, Dashed: zct

Reading: Red: zut, Blue: zct

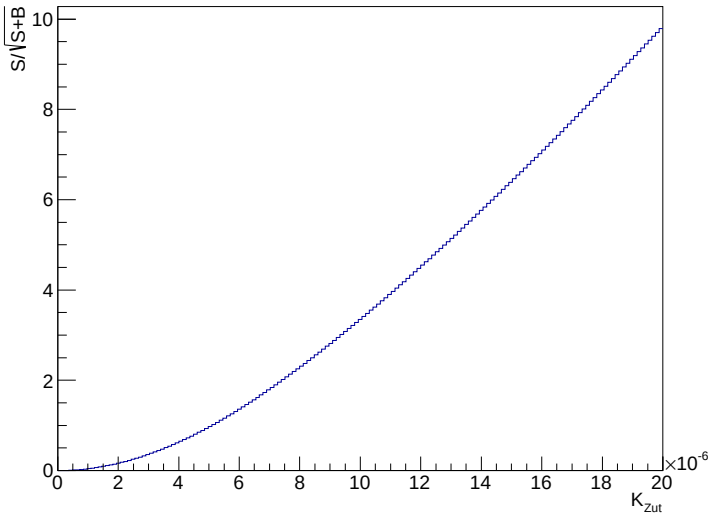
MVA: 2D limits

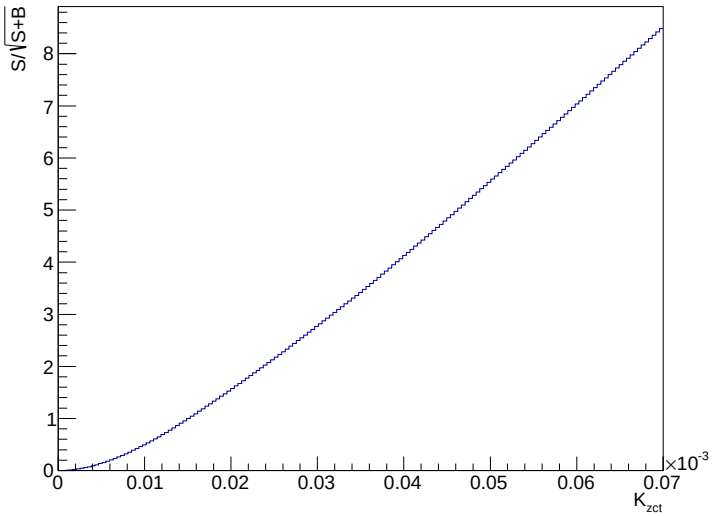


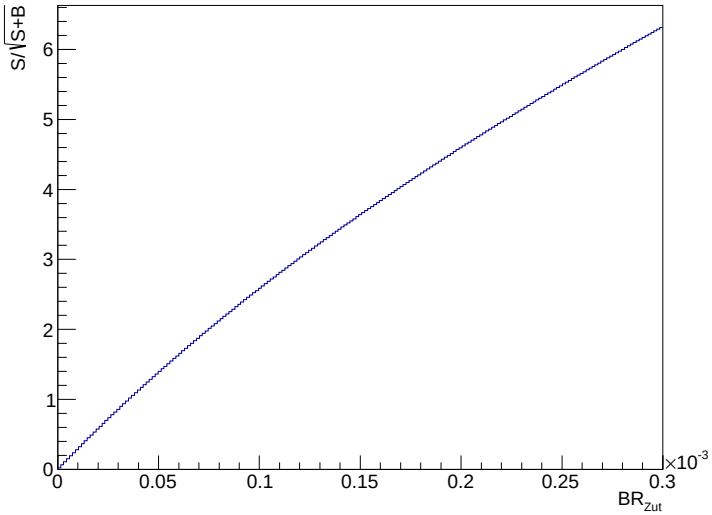


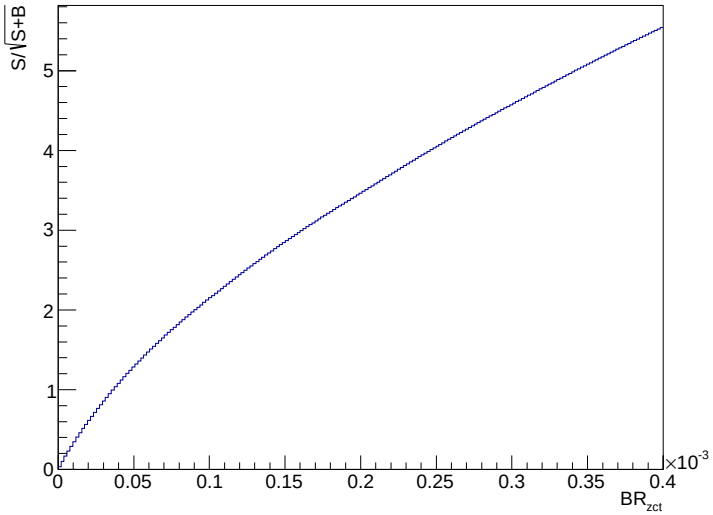
Present limit: BR$(t \to Zq) < 0.05\%$, $K_{Ztq} < 0.2$ TeV^{-1}

MVA: 1D indep limits









Cut-and-count

Cut	Sum Bg	κ_{zct}	κ_{zut}	ttbar κ_{zct}	ttbar κ_{zut}
no cuts	$(662.3 \pm 0.2)\,10^6$	267 ± 0	2263 ± 3	2133 ± 1	2133 ± 1
$N_j \geq 1$	$(133.1 \pm 0.1)\,10^6$	218 ± 0	1730 ± 3	2054 ± 1	2050 ± 1
$\#\ell \equiv 3$	10901 ± 385	27 ± 0	176 ± 1	216 ± 0	215 ± 0
$\#OSSF > 0$	10610 ± 384	27 ± 0	176 ± 1	215 ± 0	214 ± 0
$\#b = 1$	973 ± 16	17 ± 0	103 ± 1	116 ± 0	117 ± 0
$\lvert M(\ell^+\ell^-) - M_Z \rvert < 15$	618 ± 9	16 ± 0	93 ± 1	111 ± 0	112 ± 0
$M^T(\ell\nu) < 120$	535 ± 8	15 ± 0	85 ± 1	105 ± 0	106 ± 0
$M^T(b\ell\nu) < 220$	343 ± 6	14 ± 0	81 ± 1	95 ± 0	101 ± 0
$M(b\ell) < 150$	308 ± 6	14 ± 0	79 ± 1	92 ± 0	$98 \pm$

Table: Signal

Cut	Sum Bg	TT+V+jets	TT+jets	TZq	VV+jets	ZToLL
no cuts	$(662.3 \pm 0.2)\,10^6$	6087 ± 11	$(7439.3 \pm 2.3)\,10^3$	2097 ± 1	286524 ± 87	$(654.6 \pm 0.2)\,10^6$
$N_j \geq 1$	$(133.1 \pm 0.1)\,10^6$	5842 ± 11	6776868 ± 2212	1747 ± 1	101176 ± 53	$(126.2 \pm 0.1)\,10^6$
$\#\ell \equiv 3$	10901 ± 385	504 ± 3	794 ± 24	181 ± 0	7236 ± 14	2186 ± 384
$\#OSSF > 0$	10610 ± 384	457 ± 3	571 ± 21	181 ± 0	7215 ± 14	2186 ± 384
$\#b = 1$	973 ± 16	240 ± 2	340 ± 16	102 ± 0	291 ± 3	0 ± 0
$\lvert M(\ell^+\ell^-) - M_Z \rvert < 15$	618 ± 9	164 ± 2	98 ± 9	94 ± 0	262 ± 3	0 ± 0
$M^T(\ell\nu) < 120$	535 ± 8	132 ± 1	75 ± 8	89 ± 0	239 ± 3	0 ± 0
$M^T(b\ell\nu) < 220$	343 ± 6	84 ± 1	44 ± 6	84 ± 0	131 ± 2	0 ± 0
$M(b\ell) < 150$	308 ± 6	78 ± 1	42 ± 6	81 ± 0	107 ± 2	0 ± 0

Table: Background

Significance

Cut	κ_{zct}	κ_{zut}	ttbar κ_{zct}	ttbar κ_{zut}	comb κ_{zct}	comb κ_{zut}
no cuts	0.010	0.088	0.083	0.083	0.093	0.171
$N_j \geq 1$	0.019	0.150	0.178	0.178	0.197	0.328
$\#\ell \equiv 3$	0.260	1.677	2.046	2.035	2.301	3.680
$\#OSSF > 0$	0.263	1.691	2.068	2.057	2.325	3.715
$\#b = 1$	0.545	3.131	3.523	3.557	4.012	6.373
$\lvert M(\ell^+\ell^-) - M_Z \rvert < 15$	0.628	3.496	4.114	4.149	4.649	7.157
$M^T(\ell\nu) < 120$	0.636	3.427	4.140	4.181	4.675	7.095
$M^T(b\ell\nu)$	0.756	3.947	4.561	4.796	5.160	7.956
$M(b\ell) < 150$	0.771	4.022	4.583	4.862	5.186	8.041

MVA highest signficances when each signal is trained against itself:

$\kappa_{zut} = 9.10\sigma$, $S = 152.88$, $B = 129.126$,

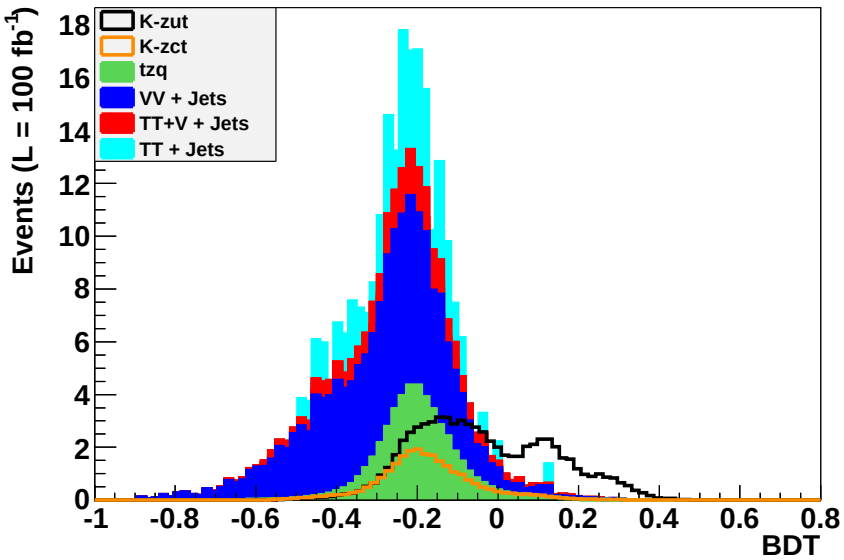
$\kappa_{zct} = 5.90\sigma$, $S = 69.10$, $B = 67.905$

$$N_j \equiv 1$$

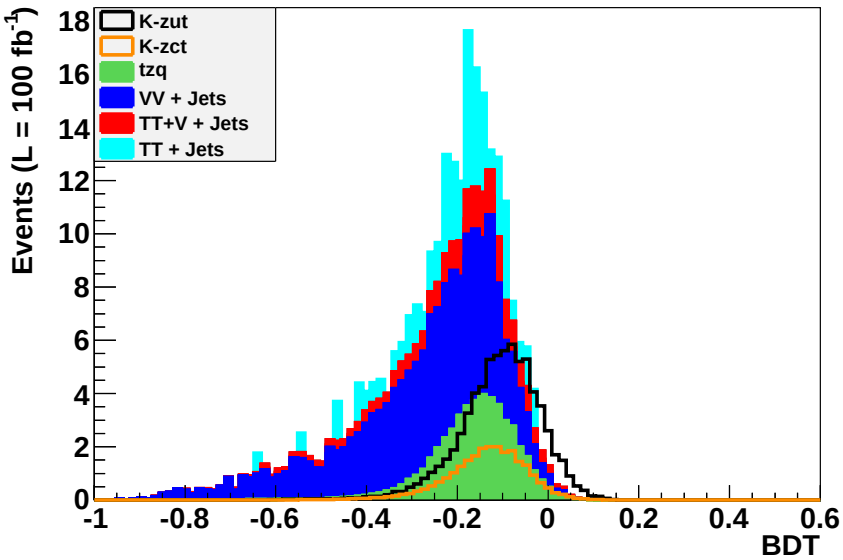
Need to drop $M(jZ)$ as observable because there is no light jet

BDT output

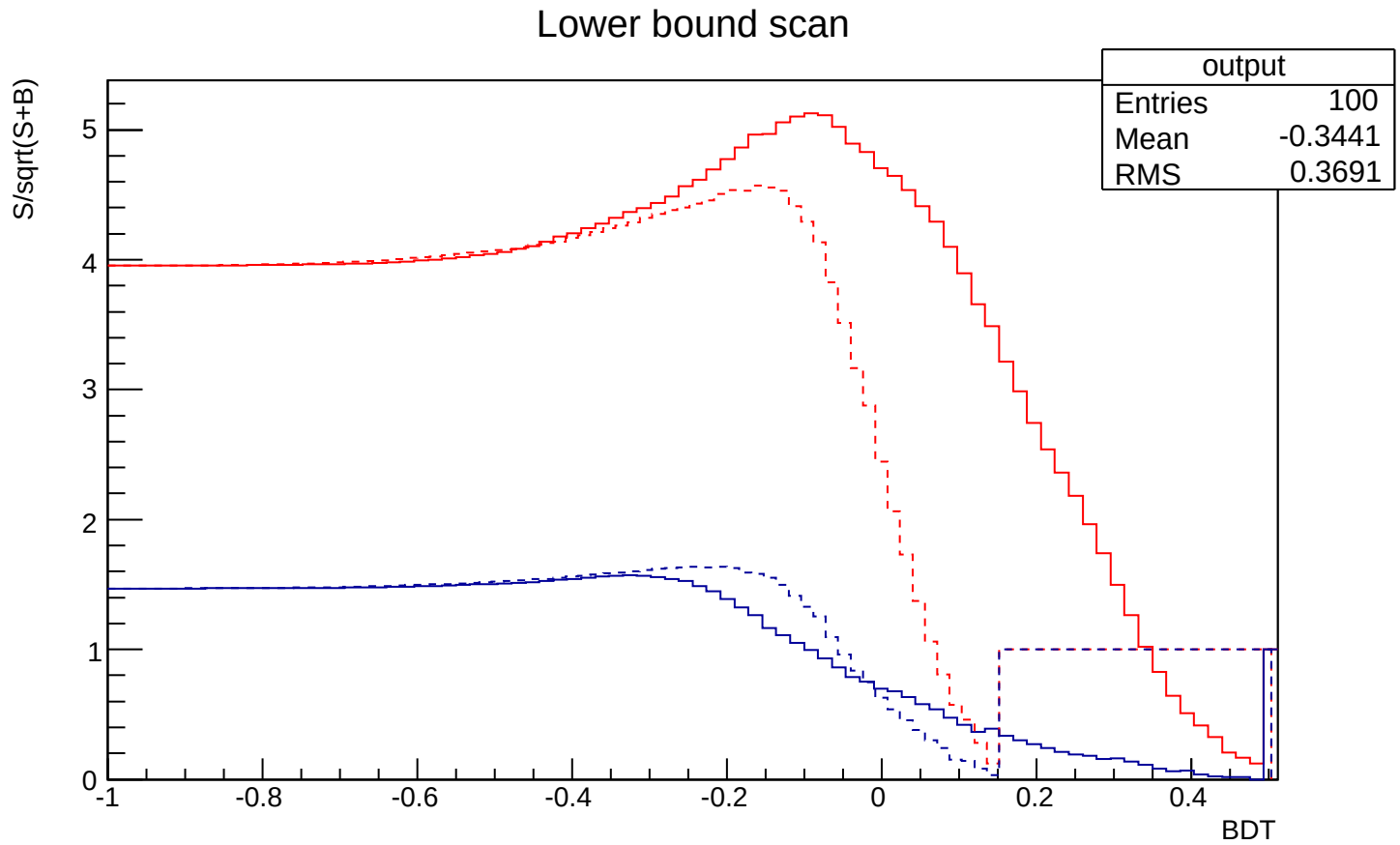
κ_{zut}



κ_{zct}



Reading of sum of signals



Training: Solid: zut, Dashed: zct

Reading: Red: zut, Blue: zct

Cut-and-count

Cut	Sum Bg	ttbar κ_{zct}	ttbar κ_{zut}	κ_{zct}	κ_{zut}
no cuts	$(662.3 \pm 0.2)\,10^6$	2133 ± 1	2133 ± 1	267 ± 0	2263 ± 3
$N_j \equiv 1$	$(9479.4 \pm 8.4)\,10^4$	270 ± 0	285 ± 0	99 ± 0	780 ± 2
$\#\ell \equiv 3$	6628 ± 320	38 ± 0	40 ± 0	17 ± 0	105 ± 1
$\#OSSF > 0$	6507 ± 320	37 ± 0	40 ± 0	17 ± 0	105 ± 1
$\#b = 1$	405 ± 11	16 ± 0	14 ± 0	11 ± 0	62 ± 0
$\lvert M(\ell^+\ell^-) - M_Z\rvert < 15$	259 ± 6	15 ± 0	13 ± 0	10 ± 0	56 ± 0
$M^T(\ell\nu) < 120$	229 ± 6	14 ± 0	13 ± 0	9 ± 0	52 ± 0
$M^T(b\ell\nu) < 220$	153 ± 5	13 ± 0	12 ± 0	9 ± 0	50 ± 0
$M(b\ell) < 150$	136 ± 4	12 ± 0	12 ± 0	9 ± 0	48 ± 0

Table: Signal

Cut	Sum Bg	TT+V+jets	TT+jets	TZq	VV+jets	ZToLL
no cuts	$(662.3 \pm 0.2)\,10^6$	6087 ± 11	$(7439.3 \pm 2.3)\,10^3$	2097 ± 1	286524 ± 87	$(654.6 \pm 0.2)\,10^6$
$N_j \geq 1$	$(9479.4 \pm 8.4)\,10^4$	647 ± 4	1320496 ± 997	717 ± 0	53818 ± 39	$(9341.8 \pm 8.4)\,10^4$
$\#\ell \equiv 3$	6628 ± 320	99 ± 1	342 ± 16	94 ± 0	4469 ± 11	1624 ± 319
$\#OSSF > 0$	6507 ± 320	87 ± 1	245 ± 14	93 ± 0	4458 ± 11	1624 ± 319
$\#b = 1$	405 ± 11	53 ± 1	157 ± 11	50 ± 0	145 ± 2	0 ± 0
$\lvert M(\ell^+\ell^-) - M_Z\rvert < 15$	259 ± 6	32 ± 1	50 ± 6	46 ± 0	130 ± 2	0 ± 0
$M^T(\ell\nu) < 120$	229 ± 6	24 ± 1	41 ± 6	44 ± 0	120 ± 2	0 ± 0
$M^T(b\ell\nu) < 220$	153 ± 5	14 ± 0	26 ± 4	42 ± 0	72 ± 1	0 ± 0
$M(b\ell) < 150$	$308 \pm 136 \pm 4$	13 ± 0	23 ± 4	40 ± 0	59 ± 1	0 ± 0

Table: Background

Significance

Cut	ttbar κ_{zct}	ttbar κ_{zut}	κ_{zct}	κ_{zut}	comb κ_{zct}	comb κ_{zut}
no cuts	0.083	0.083	0.010	0.088	0.093	0.171
$N_j \geq 1$	0.028	0.029	0.010	0.080	0.038	0.109
$\#\ell \equiv 3$	0.460	0.488	0.204	1.279	0.663	1.759
$\#OSSF > 0$	0.462	0.490	0.205	1.286	0.666	1.769
$\#b = 1$	0.762	0.683	0.521	2.868	1.263	3.464
$\lvert M(\ell^+\ell^-) - M_Z \rvert < 15$	0.901	0.810	0.598	3.177	1.467	3.849
$M^T(\ell\nu) < 120$	0.907	0.817	0.604	3.098	1.476	3.771
$M^T(b\ell\nu)$	0.975	0.944	0.703	3.485	1.627	4.213
$M(b\ell) < 150$	0.984	0.970	0.722	3.564	1.650	4.298

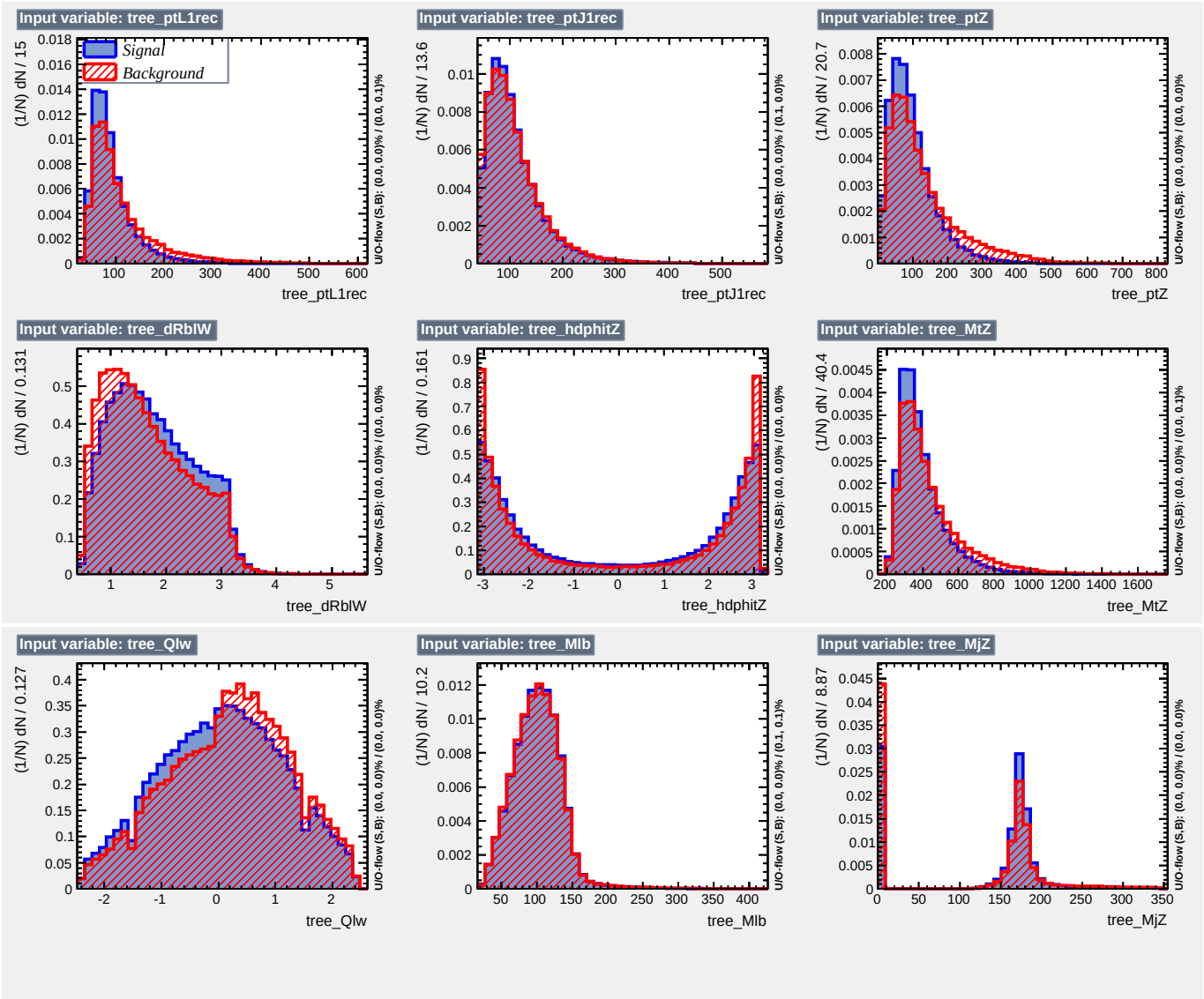
MVA highest signficances when each signal is trained against itself:

$\kappa_{zut} = 5.125\sigma$, $S = 41.467$, $B = 26.192$

$\kappa_{zct} = 1.635\sigma$, $S = 22.153$, $B = 161.398$

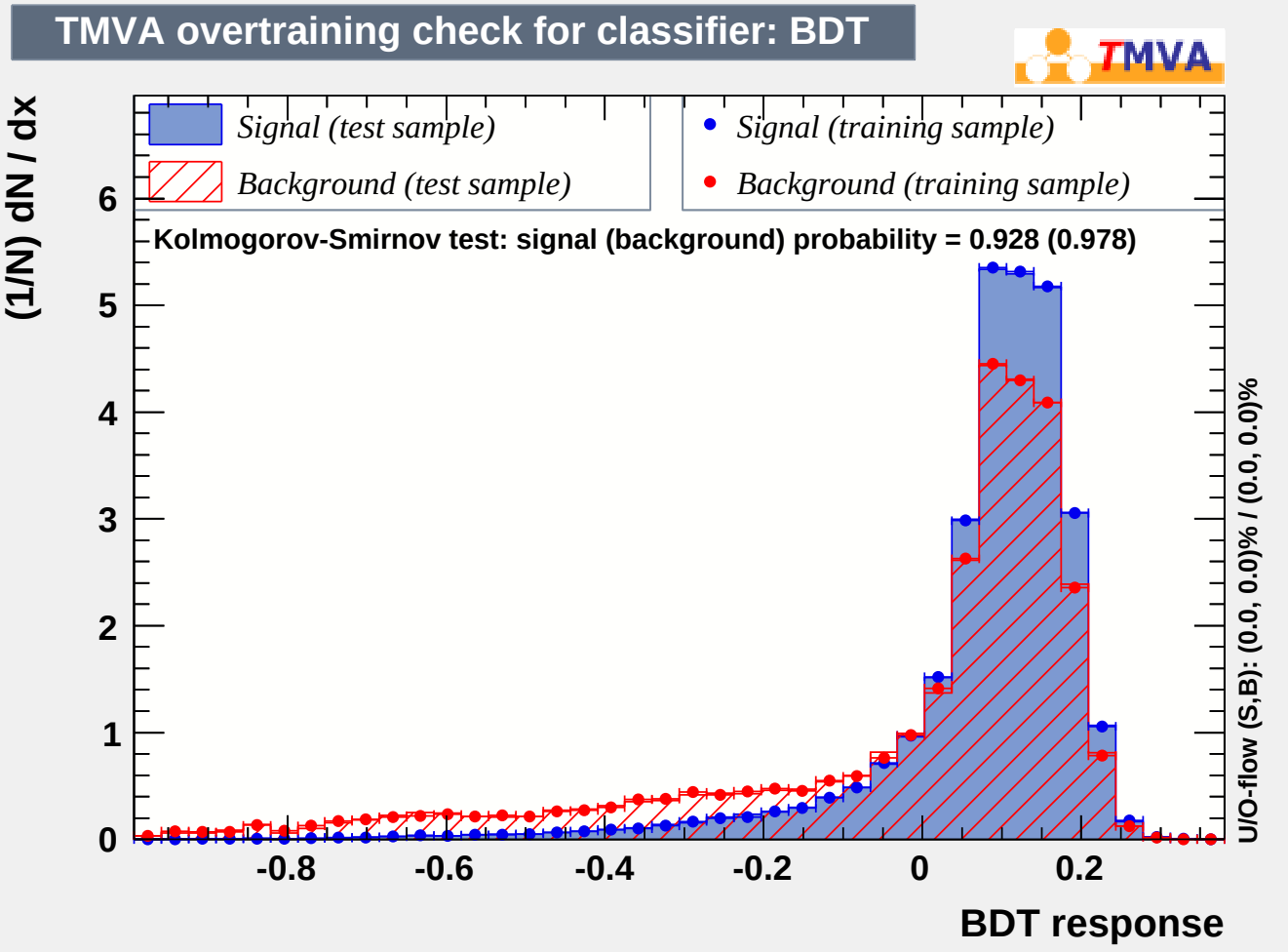
Zeta-couplings?

Comparison of Z_{zut} (signal) vs. K_{zut} (background). 9 variables:



Zeta-couplings?

BDT output:



Hard to separate?

Summary

- separate training for different couplings
- pssibility to isolate a pure single-top sample with MVA
- good improvement with BDT in inclusive sample
- no need for MVA for c-coupling in single-top region
- open question: zeta-couplings (to account for? how to separate them?)