

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

Lorenzo Basso

# Optimisation - almost matched Isis's

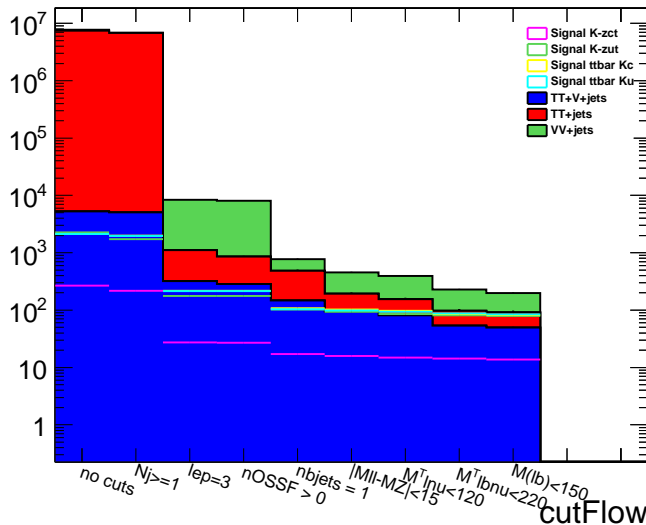
- LEPTONS:  $|\eta| < 2.5(2.4)$  for  $e/\mu$   
 $p_\ell^T > 20$  GeV, ISO: CONE04,  $I_{rel} < 0.20$   $e/\mu$
- JETS:  $p_j^T > 40$  GeV,  $|\eta| < 2.4$ ,  $1/EE_{overHE} > 0.15$ 
  - loose JETS  $30 < p_j^T < 40$  GeV,  $|\eta| < 2.4$ ,  $1/EE_{overHE} > 0.15$
- Selections:
  - 1  $N_J \geq 1$  ( $J = \text{light and b jets}$ ); (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  $\kappa_{zut}$  and  $\kappa_{zct}$
- inclusive sample
- training on background without  $t\bar{t}$

# Variables for $\kappa_{zut}$

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

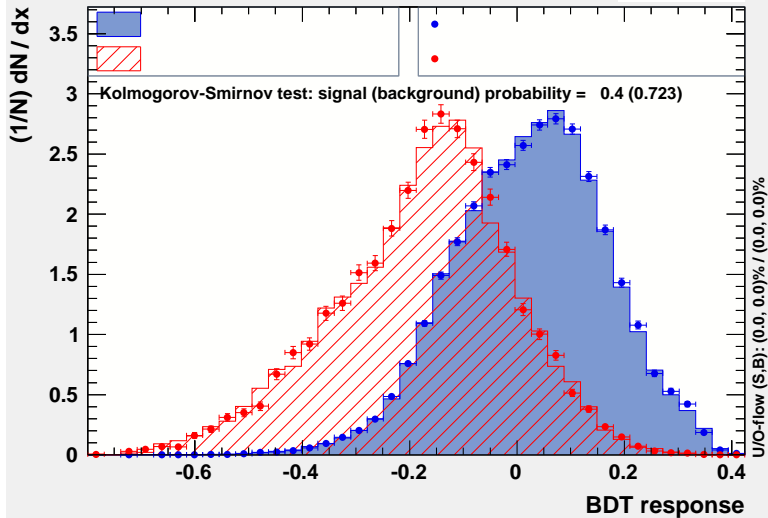
11 Variables with relative importance when trained considering all backgrounds without  $t\bar{t}$ :

Variable	Importance
$M(\ell b)$	$1.99 \cdot 10^{-1}$
$M(jZ)$	$1.47 \cdot 10^{-1}$
$p^T(Z)$	$1.19 \cdot 10^{-1}$
$\Delta R(b, \ell_W)$	$9.58 \cdot 10^{-2}$
$M(tZ)$	$8.30 \cdot 10^{-2}$
$p^T(j_1)$	$7.50 \cdot 10^{-2}$
$Q(\ell_W)$	$7.09 \cdot 10^{-2}$
$\Delta R(Z, \ell_W)$	$7.05 \cdot 10^{-2}$
$\Delta R(t, Z)$	$5.18 \cdot 10^{-2}$
$\Delta R(Z, \text{MET})$	$4.22 \cdot 10^{-2}$
$\Delta\phi(t Z)$	$4.39 \cdot 10^{-2}$

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

# $\kappa_{zut}$ : overtraining

## TMVA overtraining check for classifier: BDT



## Variables for $\kappa_{zct}$

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

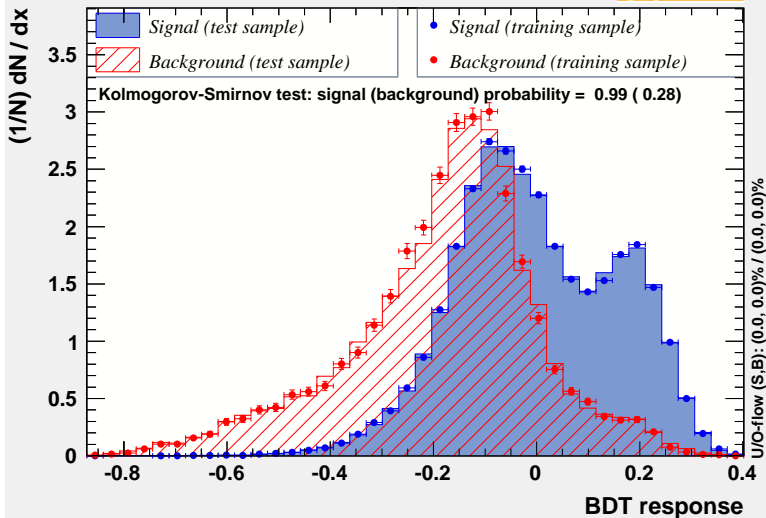
10 Variables with relative importance when trained considering all backgrounds, including  $t\bar{t}$ :

Variable	Importance
$M(\ell b)$	$2.11 \cdot 10^{-1}$
$M(jZ)$	$1.69 \cdot 10^{-1}$
$p^T(j_1)$	$1.20 \cdot 10^{-1}$
$\Delta R(\ell_W, Z)$	$9.64 \cdot 10^{-2}$
<b>MET</b>	$9.24 \cdot 10^{-2}$
$p^T(Z)$	$8.73 \cdot 10^{-2}$
$\Delta R(b, W)$	$7.36 \cdot 10^{-2}$
$\Delta R(Z, \text{MET})$	$6.54 \cdot 10^{-2}$
$\Delta\phi(t, Z)$	$4.45 \cdot 10^{-2}$
$\Delta R(t, Z)$	$4.11 \cdot 10^{-2}$



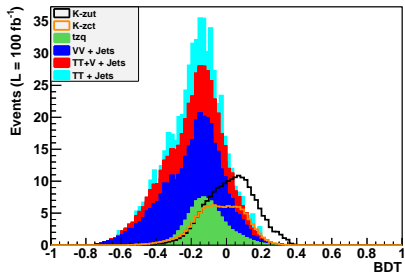
# $\kappa_{zct}$ : overtraining

## TMVA overtraining check for classifier: BDT

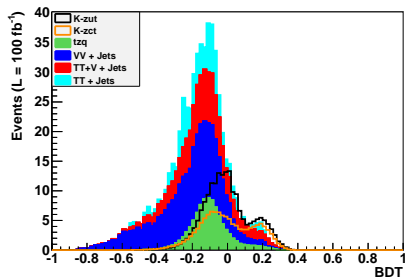


# BDT output

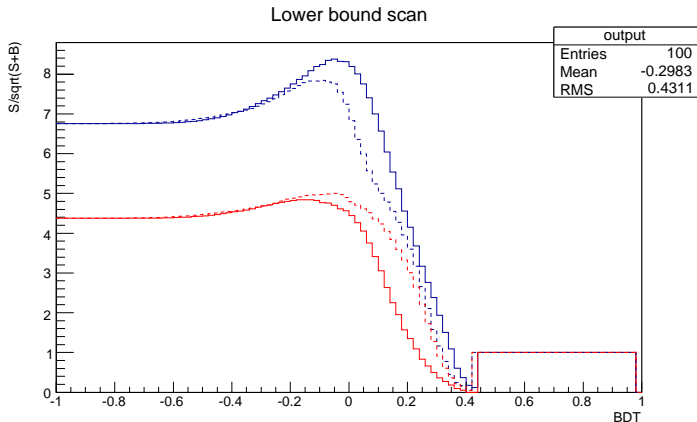
$\kappa_{zut}$



$\kappa_{zct}$



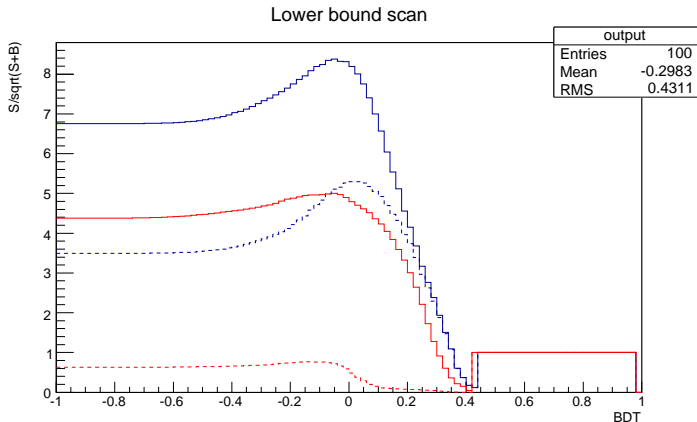
# Reading of sum of signals



Training: Solid: zut,      Dashed: zct

Reading: Blue: zut,      Red: zct

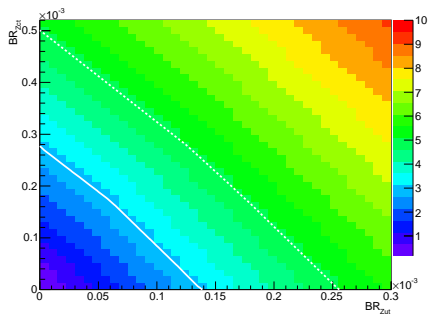
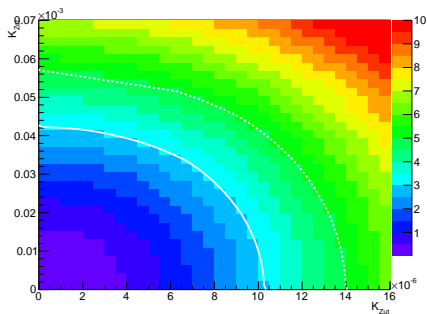
# Reading of sum vs single signals



Reading: Solid: combined,      Dashed: single

Reading: Blue: zut,      Red: zct

# MVA: 2D limits



Present limit:  $BR(t \rightarrow Zq) < 0.05\%$ ,

$K_{Ztq} < 0.2 \text{ TeV}^{-1}$



# Significance

Cut	Signal K-zct	Signal K-zut	Signal ttbar Kc	Signal ttbar Ku	comb (c)	comb (u)
<i>nocuts</i>	0.010	0.088	0.083	0.083	0.093	0.171
$N_j \geq 1$	0.019	0.150	0.172	0.171	0.191	0.321
$lep = 3$	0.260	1.677	2.054	2.035	2.309	3.680
$nOSSF > 0$	0.263	1.691	2.076	2.056	2.334	3.715
$njets = 1$	0.545	3.131	3.290	3.174	3.783	6.022
$ Ml - MZ  < 15$	0.628	3.496	3.835	3.704	4.376	6.760
$M^T lnu < 120$	0.636	3.427	3.861	3.732	4.403	6.697
$M^T lnu < 220$	0.756	3.947	4.156	4.218	4.767	7.462
$M(lb) < 150$	0.771	4.022	4.155	4.260	4.771	7.530
	-nan	-nan	-nan	-nan	-nan	-nan
	-nan	-nan	-nan	-nan	-nan	-nan
	-nan	-nan	-nan	-nan	-nan	-nan
	-nan	-nan	-nan	-nan	-nan	-nan
	-nan	-nan	-nan	-nan	-nan	-nan
	-nan	-nan	-nan	-nan	-nan	-nan
	-nan	-nan	-nan	-nan	-nan	-nan
	-nan	-nan	-nan	-nan	-nan	-nan

MVA highest significances when each signal is trained against itself:

$$\kappa_{zut} = 8.38\sigma, S = 139.727, B = 138.566,$$

$$\kappa_{zct} = 5.01\sigma, S = 72.925, B = 139.291$$

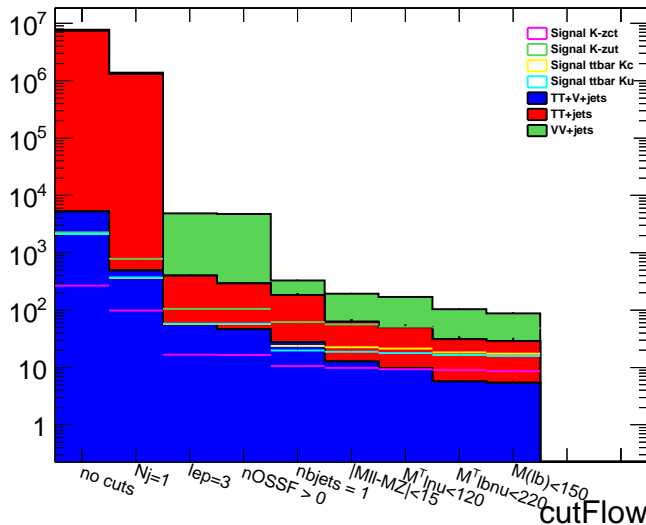
$$N_j \equiv 1$$

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

For zct training, drop also  $MET$



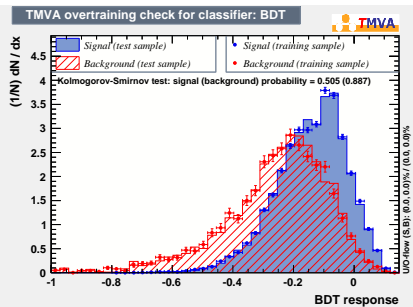
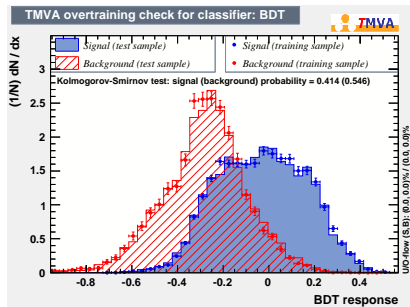
# Backgrounds - cutflow



# $\kappa_{zut}$ : overtraining

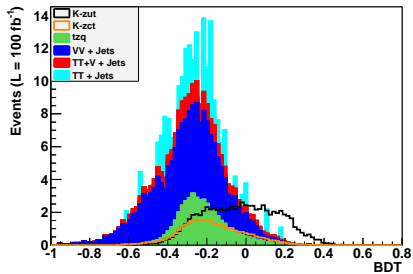
$zut$  training

$zct$  training

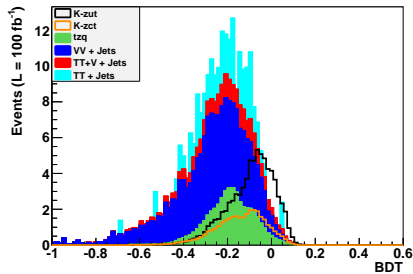


# BDT output

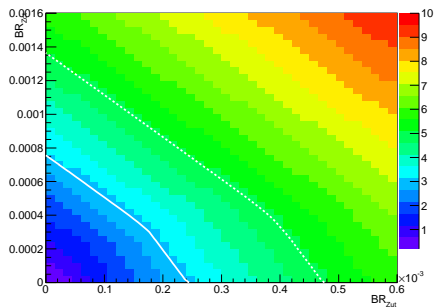
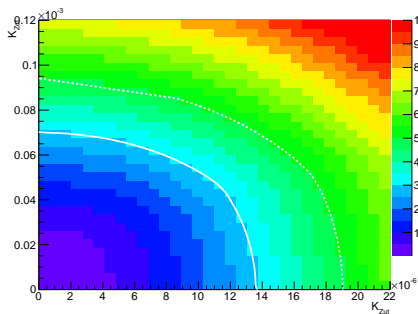
$\kappa_{zut}$



$\kappa_{zct}$



# MVA: 2D limits



Present limit:  $BR(t \rightarrow Zq) < 0.05\%$ ,

$$K_{Ztq} < 0.2 \text{ TeV}^{-1}$$

# Cut-and-count

Cut	Sum Bg	Signal K-zet	Signal K-zut	Signal ttbar Kc	Signal ttbar Ku
<i>nocuts</i>	662298806 ± 223501	267 ± 0	2263 ± 3	2133 ± 1	2128 ± 1
$N_j = 1$	94794063 ± 84224	99 ± 0	780 ± 2	364 ± 0	372 ± 0
$lep = 3$	6628 ± 320	17 ± 0	105 ± 1	57 ± 0	58 ± 0
$nOSSF > 0$	6507 ± 320	17 ± 0	105 ± 1	57 ± 0	58 ± 0
$nbjets = 1$	405 ± 11	11 ± 0	62 ± 0	24 ± 0	20 ± 0
$ Ml - MZ  < 15$	259 ± 6	10 ± 0	56 ± 0	23 ± 0	19 ± 0
$M^T lnu < 120$	229 ± 6	9 ± 0	52 ± 0	21 ± 0	18 ± 0
$M^T lbnu < 220$	153 ± 5	9 ± 0	50 ± 0	18 ± 0	16 ± 0
$M(lb) < 150$	136 ± 4	9 ± 0	48 ± 0	17 ± 0	16 ± 0
	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0

Cut	TT+V+jets	TT+jets	TZq	VV+jets	ZToLL
<i>nocuts</i>	6087 ± 11	7439298 ± 2305	2097 ± 1	286524 ± 87	654564800 ± 2234
$N_j = 1$	647 ± 4	1320496 ± 997	717 ± 0	53818 ± 39	93418384 ± 8421
$lep = 3$	99 ± 1	342 ± 16	94 ± 0	4469 ± 11	1624 ± 319
$nOSSF > 0$	87 ± 1	245 ± 14	93 ± 0	4458 ± 11	1624 ± 319
$nbjets = 1$	53 ± 1	157 ± 11	50 ± 0	145 ± 2	0 ± 0
$ Ml - MZ  < 15$	32 ± 1	50 ± 6	46 ± 0	130 ± 2	0 ± 0
$M^T lnu < 120$	24 ± 1	41 ± 6	44 ± 0	120 ± 2	0 ± 0
$M^T lbnu < 220$	14 ± 0	26 ± 4	42 ± 0	72 ± 1	0 ± 0
$M(lb) < 150$	13 ± 0	23 ± 4	40 ± 0	59 ± 1	0 ± 0
	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0

# Significance

Cut	Signal K-zct	Signal K-zut	Signal ttbar Kc	Signal ttbar Ku	comb (c)	comb (u)
<i>nocuts</i>	0.010	0.088	0.083	0.083	0.093	0.171
$N_j = 1$	0.010	0.080	0.037	0.038	0.048	0.118
$lep = 3$	0.204	1.279	0.699	0.708	0.902	1.976
$nOSSF > 0$	0.205	1.286	0.704	0.712	0.907	1.986
$njets = 1$	0.521	2.868	1.147	0.964	1.639	3.710
$ Mll - MZ  < 15$	0.598	3.177	1.342	1.129	1.894	4.116
$M^T l\nu < 120$	0.604	3.098	1.351	1.138	1.904	4.038
$M^T l\nu < 220$	0.703	3.485	1.398	1.266	2.029	4.465
$M^T (tb) < 150$	0.722	3.564	1.398	1.288	2.042	4.542
	-nan	-nan	-nan	-nan	-nan	-nan
	-nan	-nan	-nan	-nan	-nan	-nan
	-nan	-nan	-nan	-nan	-nan	-nan
	-nan	-nan	-nan	-nan	-nan	-nan
	-nan	-nan	-nan	-nan	-nan	-nan
	-nan	-nan	-nan	-nan	-nan	-nan
	-nan	-nan	-nan	-nan	-nan	-nan
	-nan	-nan	-nan	-nan	-nan	-nan
	-nan	-nan	-nan	-nan	-nan	-nan

MVA highest significances when each signal is trained against itself:

$$\kappa_{zut} = 5.197\sigma, S = 46.678, B = 33.987$$

$$\kappa_{zct} = 2.058\sigma, S = 27.588, B = 152.086$$

# Summary

- separate training for different couplings
- possibility to isolate a pure single-top sample with MVA
- good improvement with BDT in inclusive sample