Vrije Universiteit Brussel

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A search for FCNC in top quark decays with a final state of 1 lepton + 3 b-jets

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Baseline selection

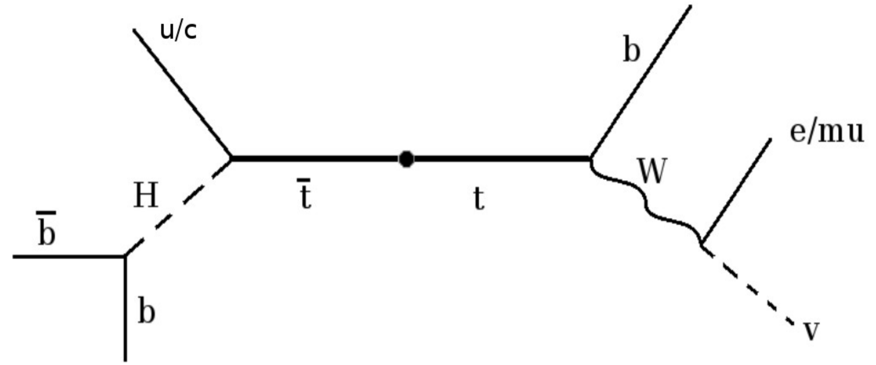
(1) = 1 lepton (e/μ, P_T > 30 GeV, |η| < 2.5 (2.4))

+ veto on loose leptons (10 GeV) < P_T < 30 GeV)

(2) M_T(lep,MET) ≥ 50 GeV

(3) ≥ 4 jets (P_T > 40 GeV, |η| < 2.4)

(4) ≥ 3 CSV Medium(*) b-tagged jets



		Initial	1 lep	M_T(lep,MET) ≥ 50	Nb Jets ≥ 4	Nb B jets ≥ 3 (final)
Bkg	tt + jets	$3.84\ 10^7$	$1.19\ 10^7$	$7.53\ 10^6$	$1.48\ 10^6$	$8.23\ 10^4$
	ttH	$1.44\ 10^4$	$4.77\ 10^3$	$3.03\ 10^3$	$2.13\ 10^3$	$1.11\ 10^3$
	W + jets	$8.18\ 10^7$	$1.94\ 10^7$	$1.34\ 10^7$	$5.57\ 10^5$	462
	tHq	$1.84\ 10^4$	$6.01\ 10^3$	$3.86\ 10^3$	560	327
	t + jets	$2.78\ 10^7$	$3.16\ 10^6$	$2.2\ 10^6$	$3.23\ 10^4$	99
Signal	tcH-ttbar	$4.23\ 10^5$	$8.13\ 10^4$	$4.92\ 10^4$	$1.47\ 10^4$	$5.6\ 10^3$
	tcH-singTop	$2.14\ 10^4$	$2.83\ 10^3$	$1.75\ 10^3$	132	53
	S/√(S+B)	////	////	////	***10.14***	***18.81***
	tuH-ttbar	$4.37\ 10^5$	$8.25\ 10^4$	$5.75\ 10^4$	$1.13\ 10^4$	$3.26\ 10^3$
	tuH-singTop	$1.72\ 10^5$	$2.22\ 10^4$	$1.4\ 10^4$	850	317
	S/√(S+B)	////	////	////	***8.32***	**12.04**

(*) ~1% non-B efficiency and ~70% B efficiency

Systematic uncertainties reduce significance below 1

- Taking 10% of systematic uncertainty into account on $t\bar{t}$ cross section:

$$\frac{S}{\sqrt{S+B+(0.1\times B_{t\bar{t}})^2}} \begin{cases} =0.67 \text{ (tcH)} \\ =0.42 \text{ (tuH)} \end{cases}$$

- Two ways to increase the significance:

    1) Find discriminating variable(s) to perform a template fit

    - Variables related to b-jets coming from H (kinematic resolutions of jets are not so great)
    - Reconstruction mechanisms to select correct b-jets are not so efficient

    2) Revisit selection cuts according to $\frac{S}{\sqrt{S+B+(0.1\times B_{t\bar{t}})^2}}$

Reconstruction mechanism

Reconstruct FCN top-decay and SM b-jet as:

$$\chi^2_{weighted} = \frac{[M(b^1_H b^2_H) - M_H]^2}{16} + \frac{[M(b^1_H b^2_H j_{FCNC}) - M_{top}]^2}{30} + \frac{[M^T(b_{SM}, l, MET) - m_{top}]^2}{30}$$

- b^1_H, b^2_H, b_{SM} taken from b-jet collection
- j_{FCNC} taken from light-jet collection

Reconstruction efficiencies(*):

- $(b^1_H b^2_H \rightarrow H)$	**~ 67%**
- $(b_{SM} \rightarrow t_{SM})$	**~ 22%**
- $(j_{FCNC} \rightarrow u_{FCNC}/c_{FCNC})$	**~ 21%**
- $(b^1_H b^2_H j_{FCNC}$ & $b_{SM} \rightarrow t_{FCNC}$ & $t_{SM})$	**~ 14%**

(*) Denominator = number of events after BL selection
Only measured on ttbar signal samples

Reconstruction mechanism

Reconstruct FCN top-decay and SM b-jet as:

$$\chi^2_{weighted} = \frac{[M(b^1_H b^2_H) - M_H]^2}{16} + \frac{[M(b^1_H b^2_H j_{FCNC}) - M_{top}]^2}{30} + \frac{[M^T(b_{SM}, l, MET) - m_{top}]^2}{30}$$

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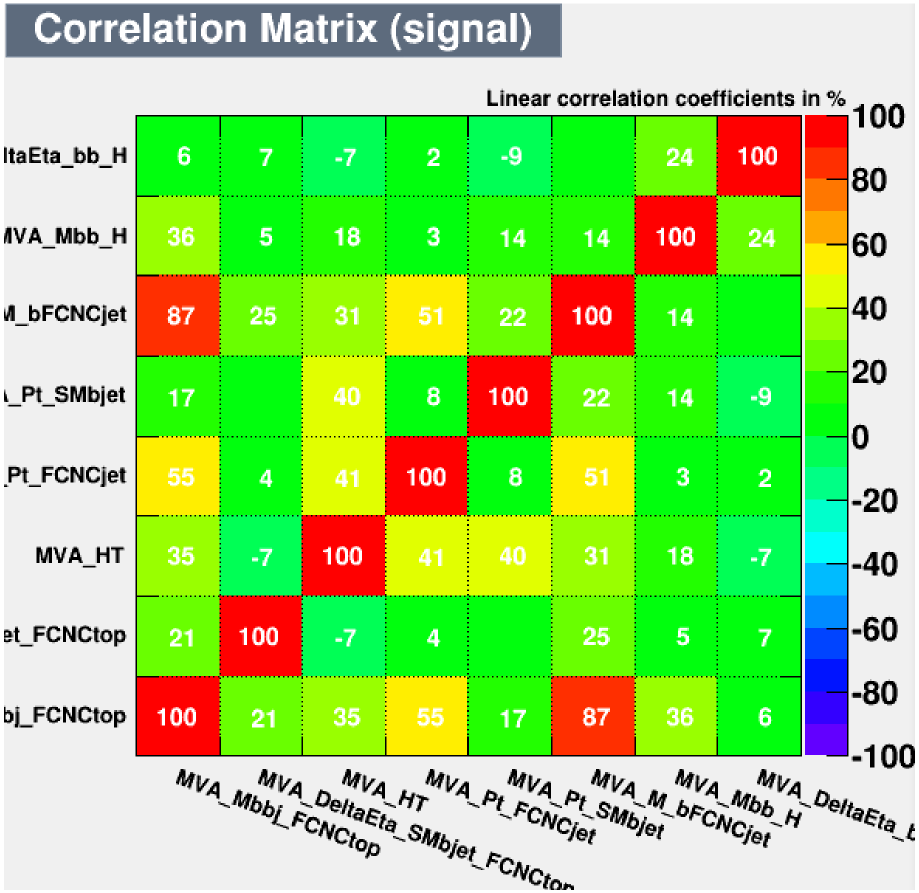
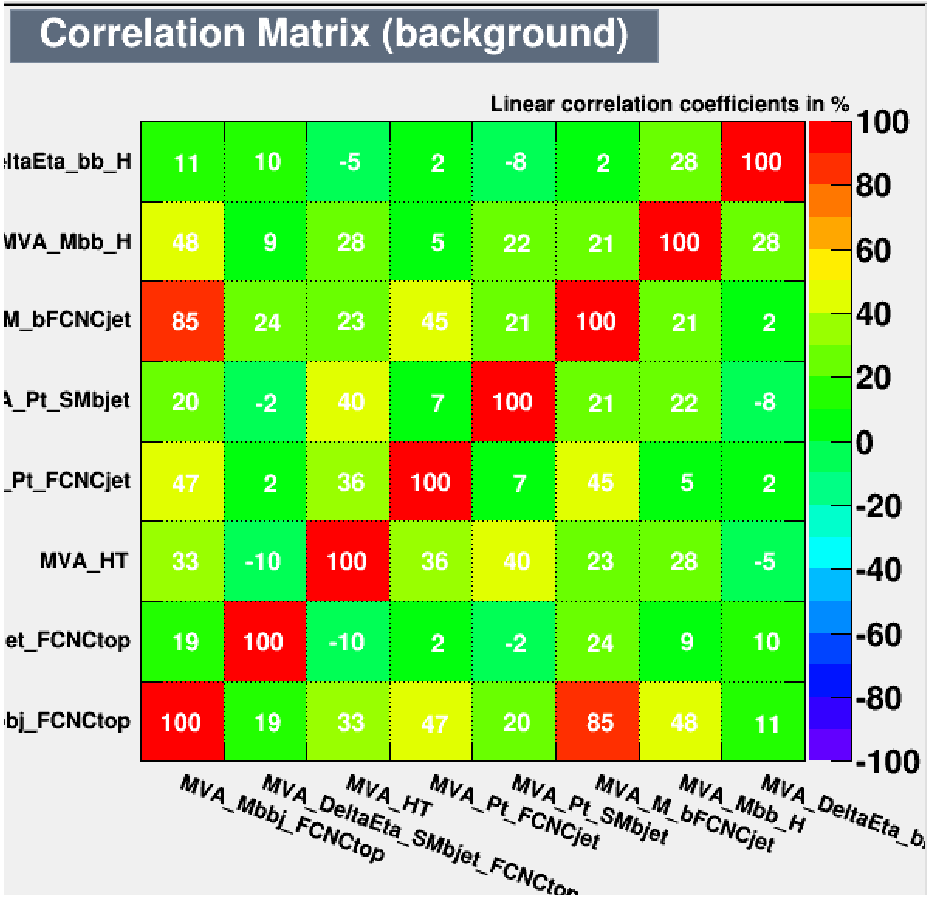
<u>Reconstructed objects for MVA</u>

- $M^T(b_{SM}, l, MET)$
- $M(b^1_H, b^2_H, j_{FCNC})$
- $M(b^1_H, b^2_H)$
- $M(b^1_H, j_{FCNC})$
- $\Delta\Phi(b_{SM}, top_{FCNC})$
- $\Delta\eta(b_{SM}, top_{FCNC})$
- $\Delta\Phi(b^1_H, b^2_H)$
- $\Delta\eta(b^1_H, b^2_H)$
- H_T
- $P_T(b_{SM})$
- $P_T(j_{FCNC})$

(*) Denominator = number of events after BL selection
Only measured on ttbar signal samples

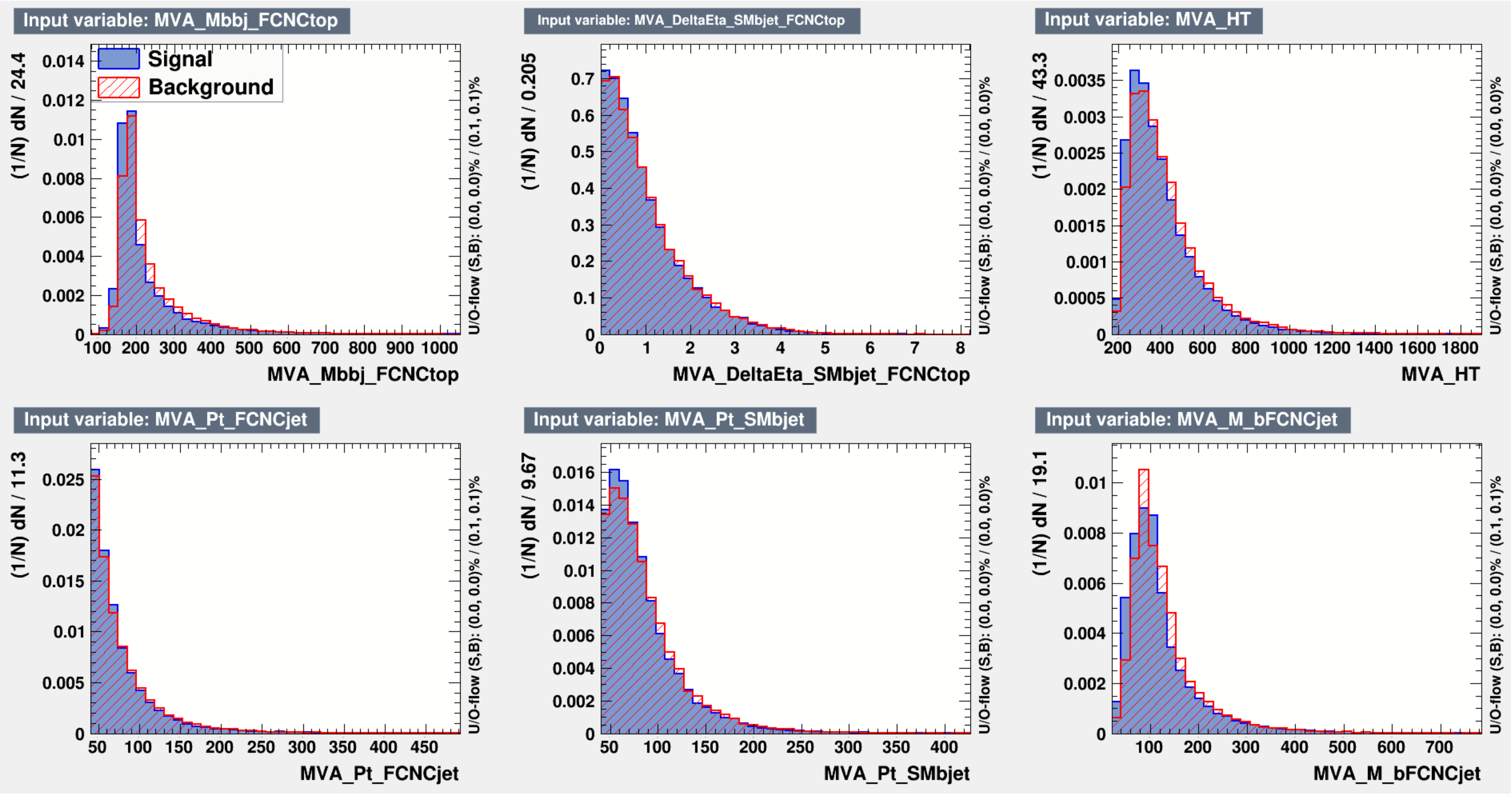
MVA – input variables





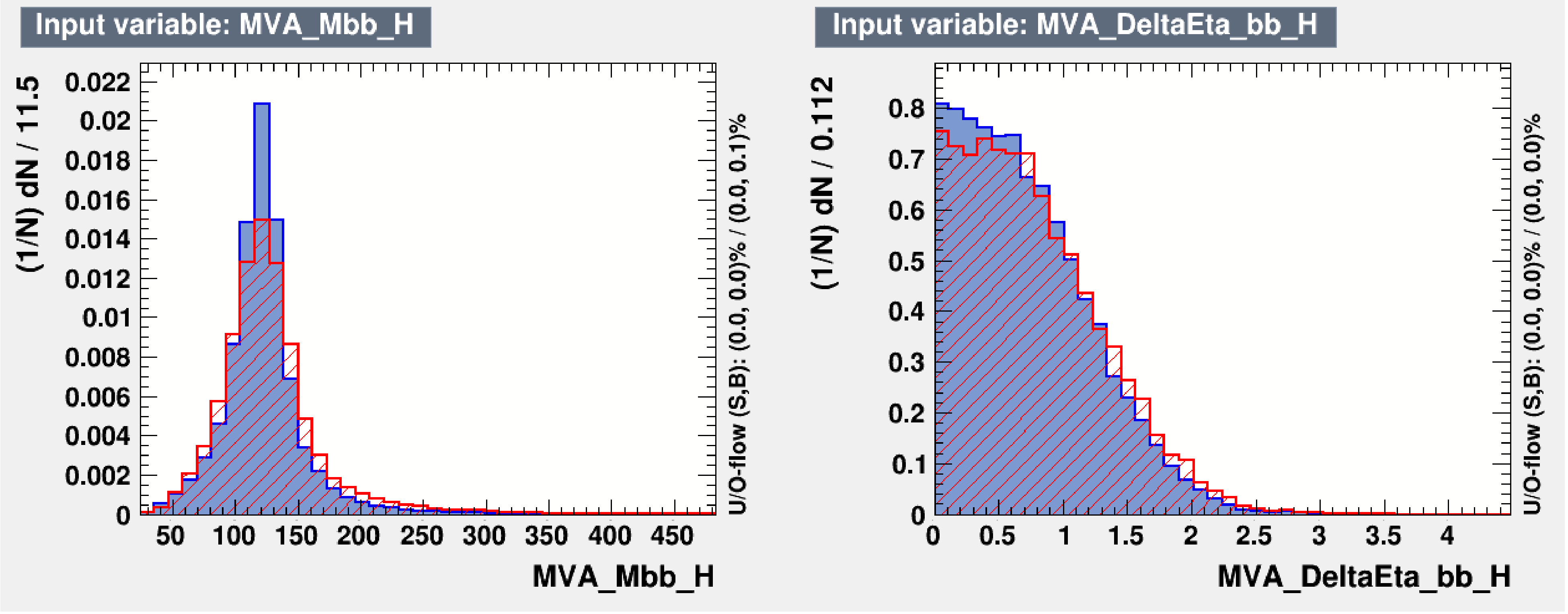
Normalized distributions input variables (1)

(blue: Signal, red: Background)

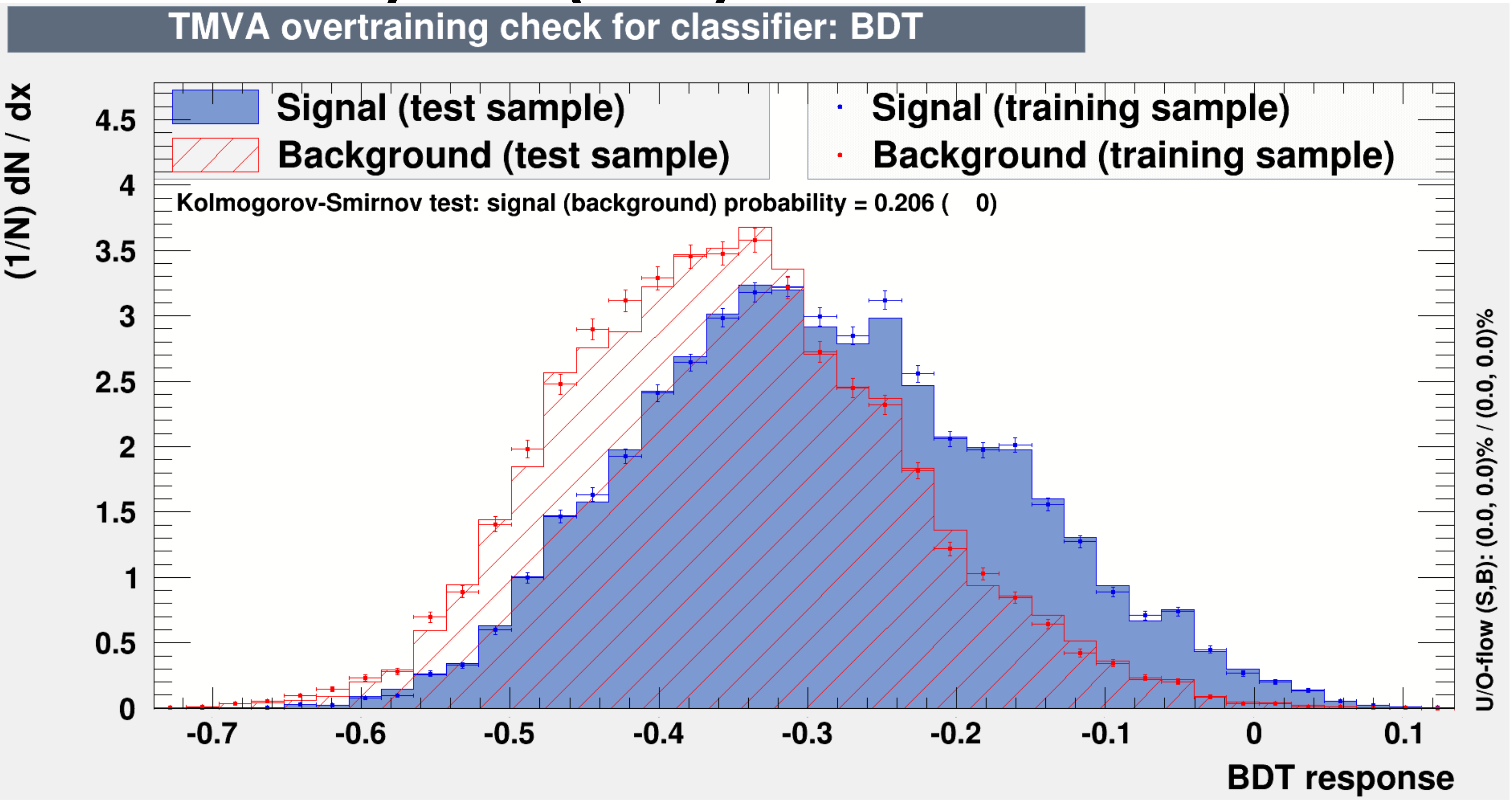


Normalized distributions input variables (2)

(blue: Signal, red: Background)



1) MVA (BDT) not distinctive

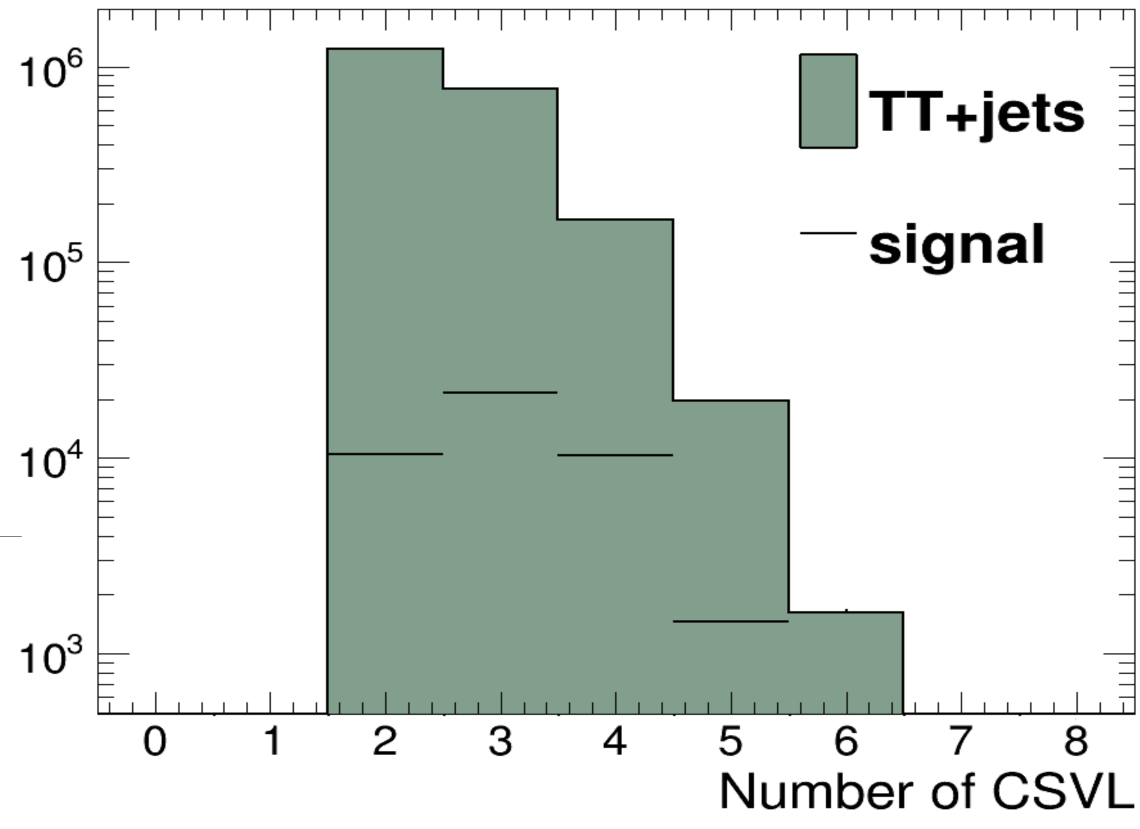


Kinematic information not useful → Discrimination power to be looked for in b-tagging information (# b-tagged jets, ~~b-tag discriminator~~)

Not accessible in our pheno study

1) # b-jets not discriminating enough to perform reasonable template fit

Loosen selection by requiring 2 CSV Medium b-tagged jets (instead of 3)



Template fit on this doesn't render sensible significance (even without syst. unc.)

Conclusion: Performing **template fit** to constrain influence of systematic uncertainties **does not help**

2) Revision of selection cuts gets significance up to 4.96

- Optimize selection according to $$\frac{S}{\sqrt{S + B + (0.1 \times B_{t\bar{t}})^2}}$$
  - = 1 lepton (e/μ, P_T > 30 GeV)
  - M_T(lep,MET) ≥ 50 GeV
  - ≥ 4 jets (P_T > 40 GeV)
    - **≥ 4 CSV Medium b-tagged jets (tcH)**
    - **≥ 3 CSV Tight(*) b-tagged jets (tuH)**

2.70 (tcH)
0.98 (tuH)

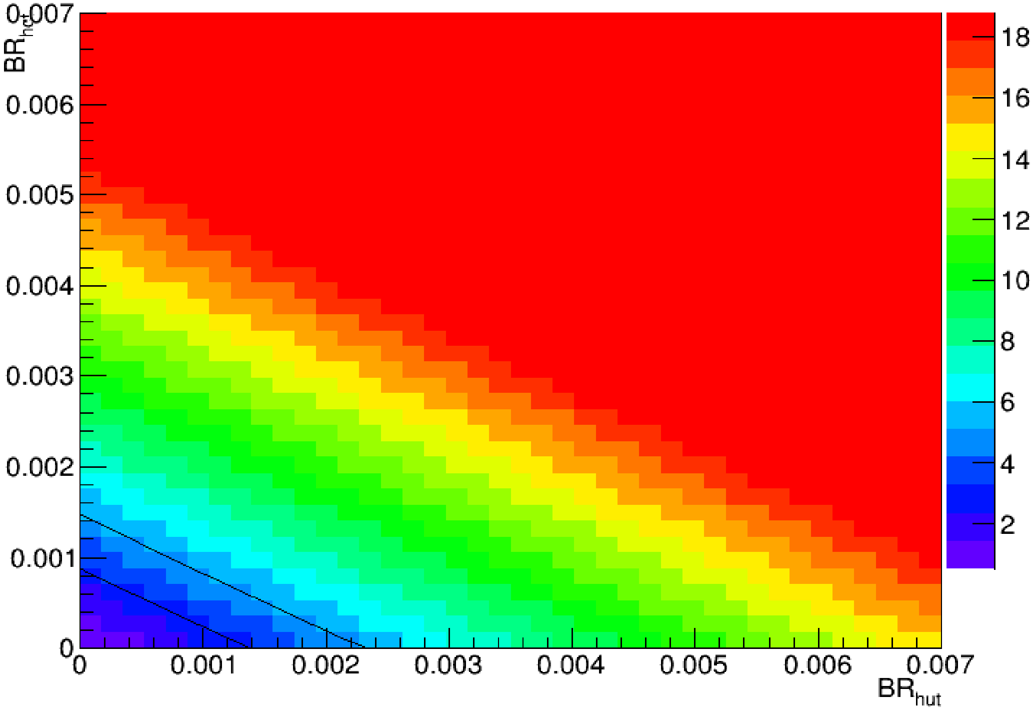
- Conclusion

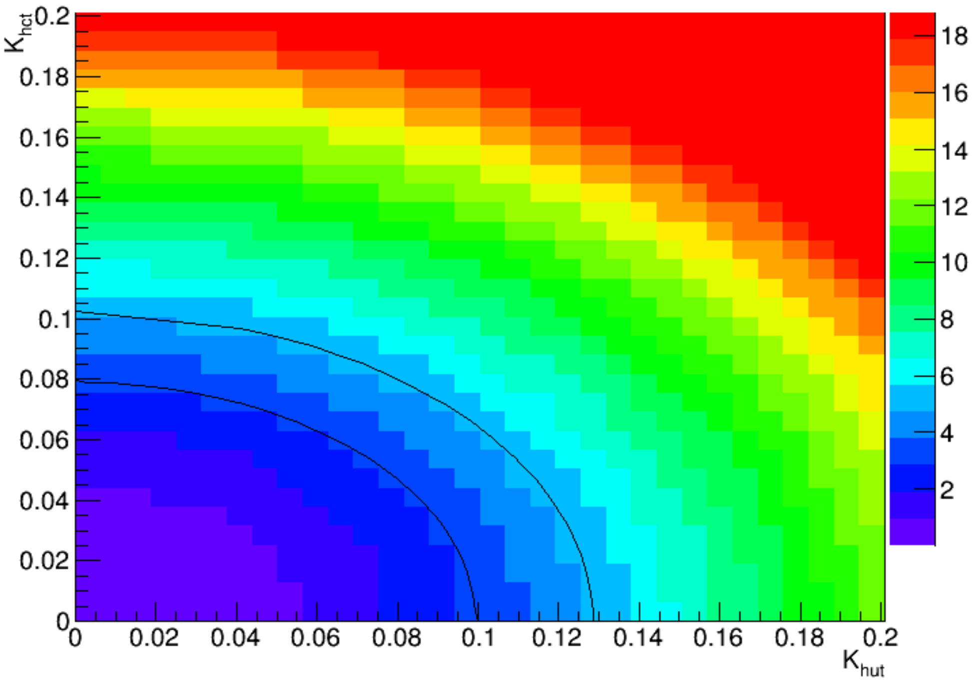
  - A significance of **2.7 (1)** can be reached with simple cut-and-count methods. Depending on the handle on systematic uncertainties, this can even go up to 18 (12)

(*) ~0.1% non-B efficiency and ~50% B efficiency

BR & coupling-scan

~Caroline's tool~





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brhct_sig5 0.0014875

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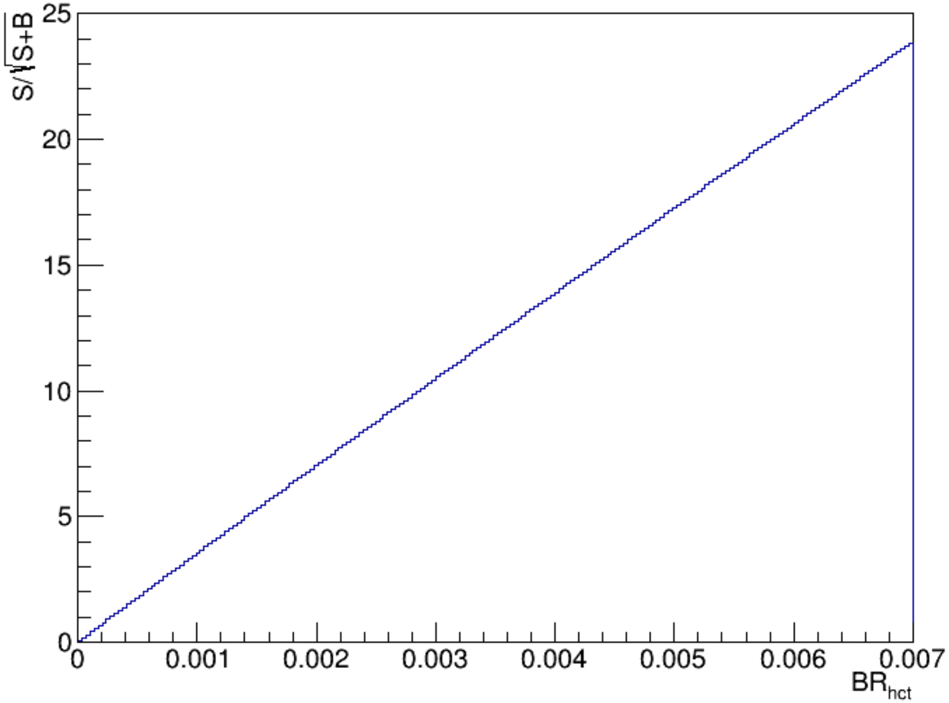
S/√S+B
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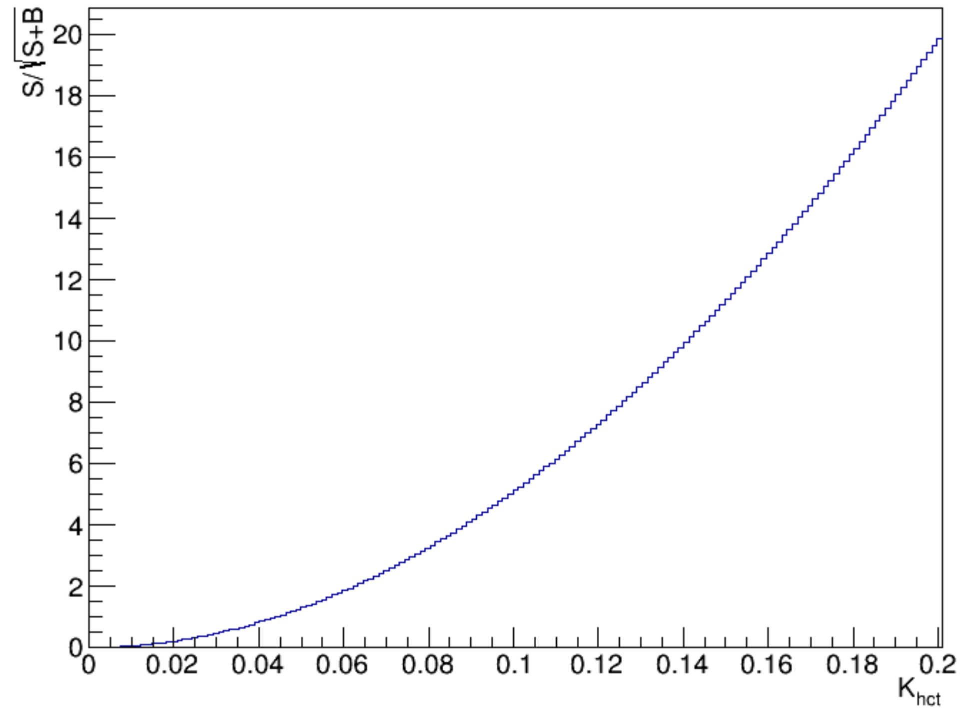
BRhct


S/√S+B
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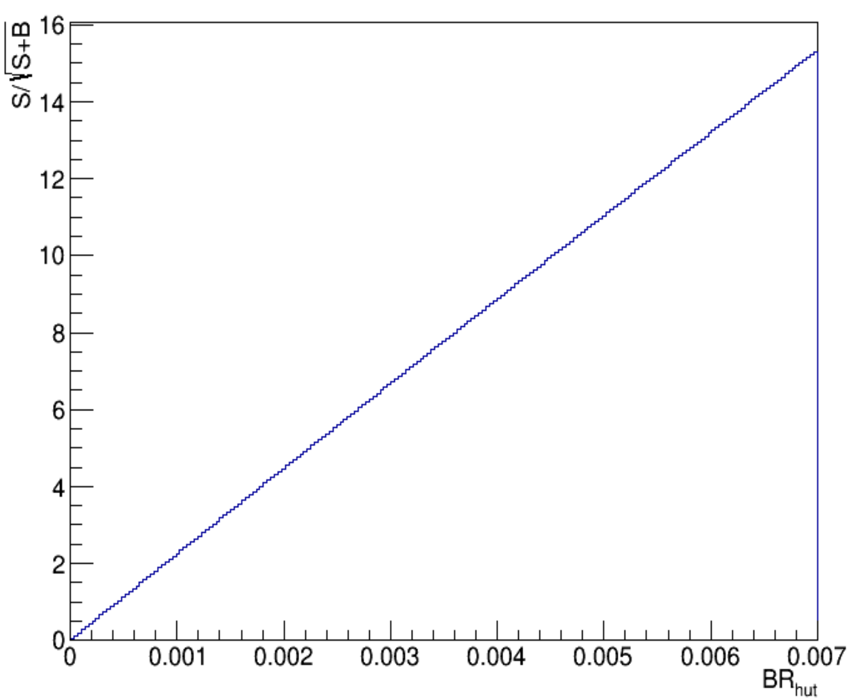
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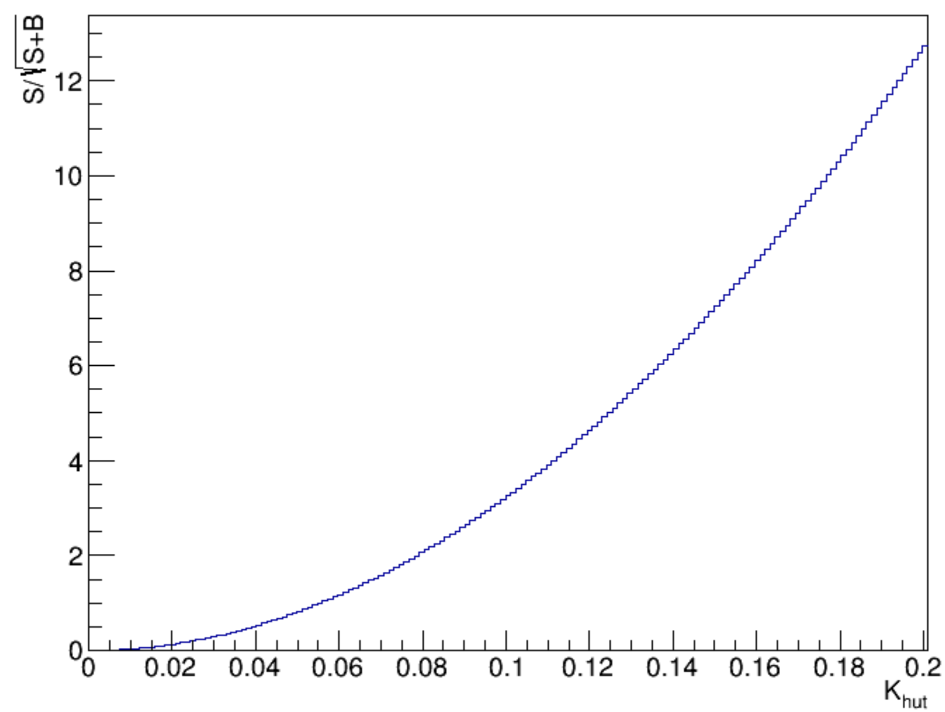
BRhut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Khut

Conclusion

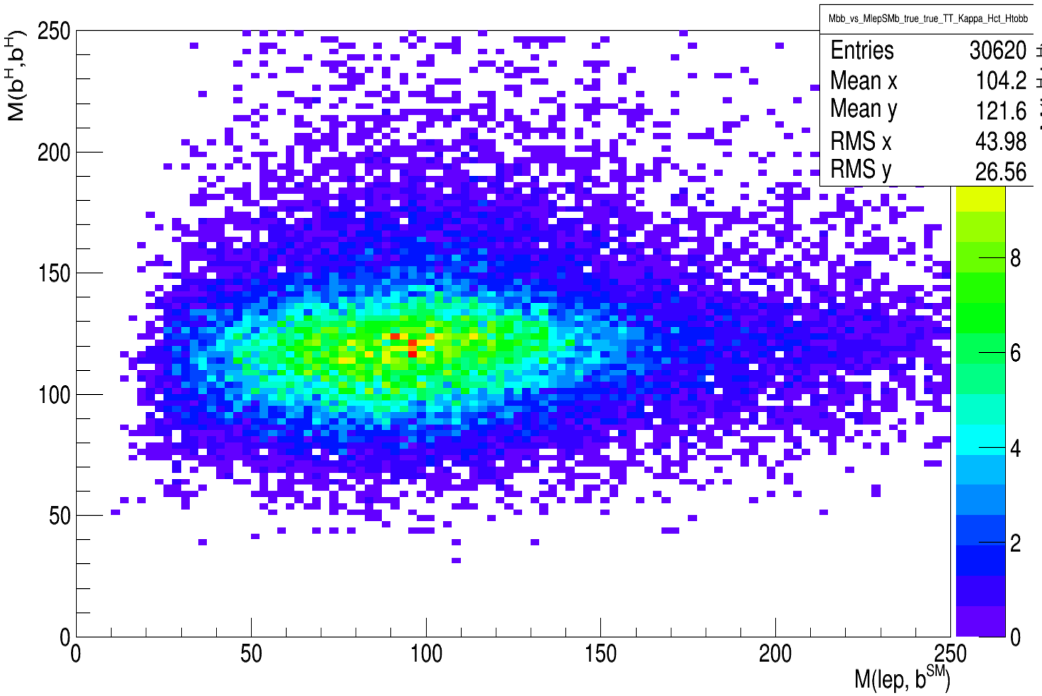
- The 1L3B channel shows promising significances for FCNH top decays applying simple cut-and-count techniques
- MVA and template fitting not useful due to lack of discriminating power in kinematic variables
- Need to turn to heavy flavour tagging information for CMS analysis

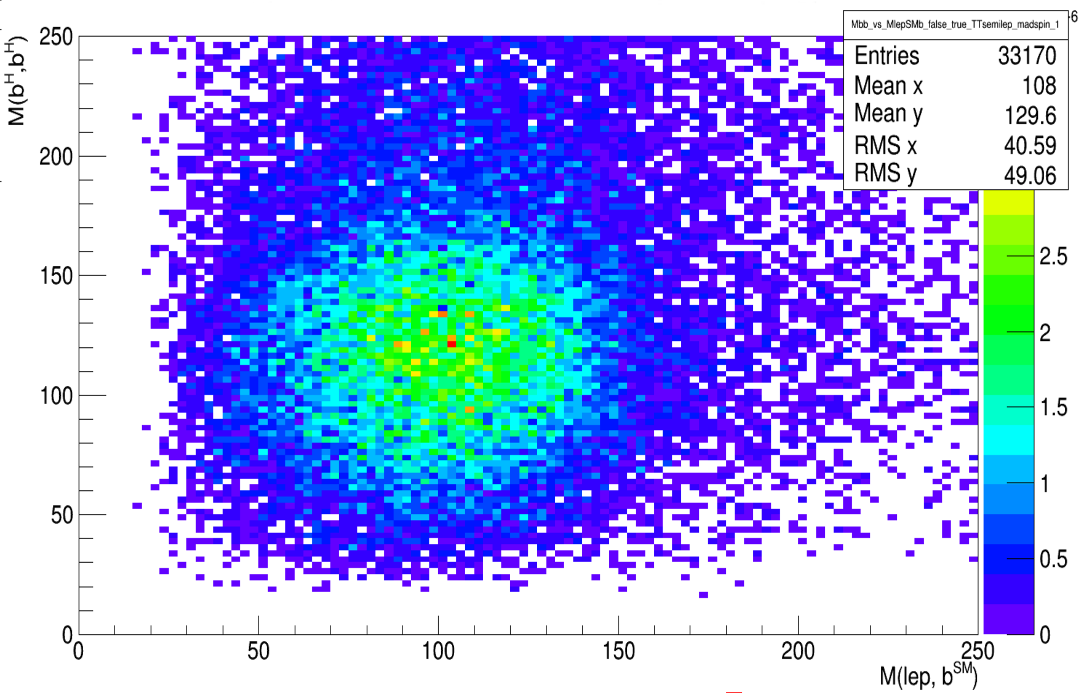
- Pheno study finished → Turn to CMS study (TopTree framework)

Backup

	initial	== 1 lepton	M_T(lep,MET) > 50 GeV	$\geq$ 4 jets	$\geq$ 3 CSVM jets
TT+jets	3.84e+07 $\pm$ 9.82e+03	1.19e+07 $\pm$ 5.59e+03	7.53e+06 $\pm$ 4.43e+03	1.48e+06 $\pm$ 2.02e+03	8.23e+04 $\pm$ 481
TTH	1.44e+04 $\pm$ 13.9	4.77e+03 $\pm$ 7.97	3.03e+03 $\pm$ 6.34	2.13e+03 $\pm$ 5.46	1.11e+03 $\pm$ 3.94
W+jets	8.18e+07 $\pm$ 1.77e+04	1.94e+07 $\pm$ 9.04e+03	1.34e+07 $\pm$ 7.4e+03	5.57e+05 $\pm$ 1.67e+03	462 $\pm$ 48
tHq	1.84e+04 $\pm$ 8.11	6.01e+03 $\pm$ 4.58	3.86e+03 $\pm$ 3.65	560 $\pm$ 1.39	327 $\pm$ 1.06
T+jets	2.78e+07 $\pm$ 2.47e+04	3.16e+06 $\pm$ 7.69e+03	2.2e+06 $\pm$ 6.49e+03	3.23e+04 $\pm$ 331	99.4 $\pm$ 10.6
ZToLL	3.27e+07 $\pm$ 1.5e+04	3.08e+06 $\pm$ 3.46e+03	7.72e+05 $\pm$ 1.39e+03	5.15e+04 $\pm$ 243	76.9 $\pm$ 9.24
TT+V+jets	1.41e+04 $\pm$ 25.7	3.36e+03 $\pm$ 12.3	2.08e+03 $\pm$ 9.78	724 $\pm$ 6.06	39.8 $\pm$ 1.43
VV+jets	9.17e+05 $\pm$ 1.07e+03	1.28e+05 $\pm$ 400	9.08e+04 $\pm$ 338	4.59e+03 $\pm$ 76	27.7 $\pm$ 5.9
κ_{hct} TTbar	4.23e+05 $\pm$ 210	8.13e+04 $\pm$ 90.7	4.92e+04 $\pm$ 70.5	1.47e+04 $\pm$ 38.6	5.6e+03 $\pm$ 23.8
κ_{hct} SingleTop	2.14e+04 $\pm$ 27.6	2.83e+03 $\pm$ 10	1.75e+03 $\pm$ 7.89	132 $\pm$ 2.17	52.5 $\pm$ 1.37
κ_{hut} TTbar	4.37e+05 $\pm$ 637	8.25e+04 $\pm$ 277	5.57e+04 $\pm$ 228	1.13e+04 $\pm$ 103	3.26e+03 $\pm$ 55.1
κ_{hut} SingleTop	1.72e+05 $\pm$ 206	2.22e+04 $\pm$ 74	1.4e+04 $\pm$ 58.8	850 $\pm$ 14.5	317 $\pm$ 8.84

M(bb) vs M(lep,b) at MC truth level





Signal

$M(b^H_{true},b^H_{true})$

vs

$M(lep^{SM}_{true},b^{SM}_{true})$

~ 38.2% of signal

Semileptonic $t\bar{t}$

$M(b_{random},b_{random})$

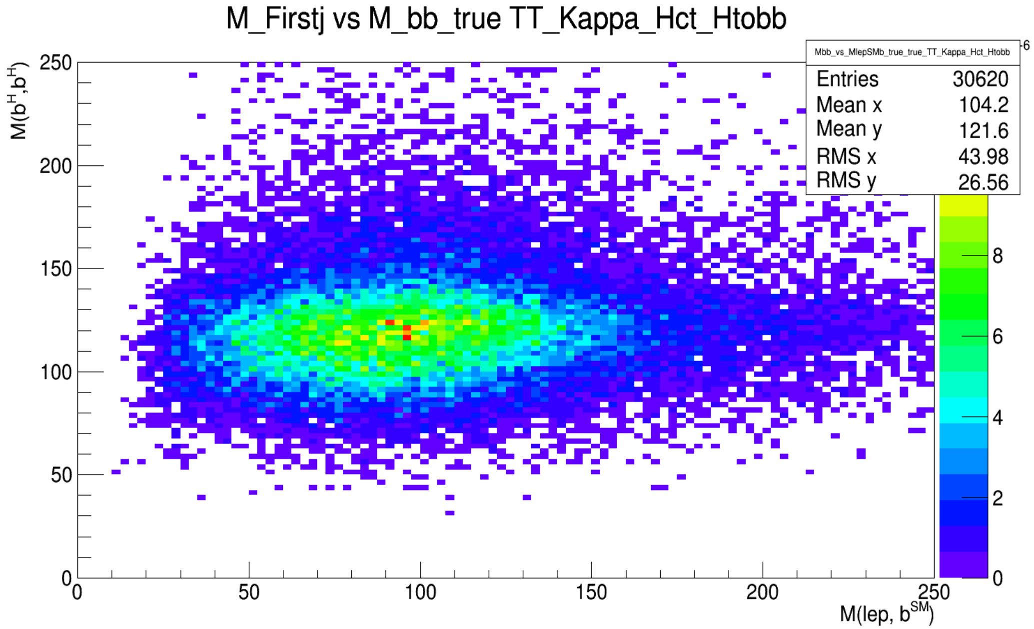
vs

$M(lep^{SM}_{true},b^{SM}_{true})$

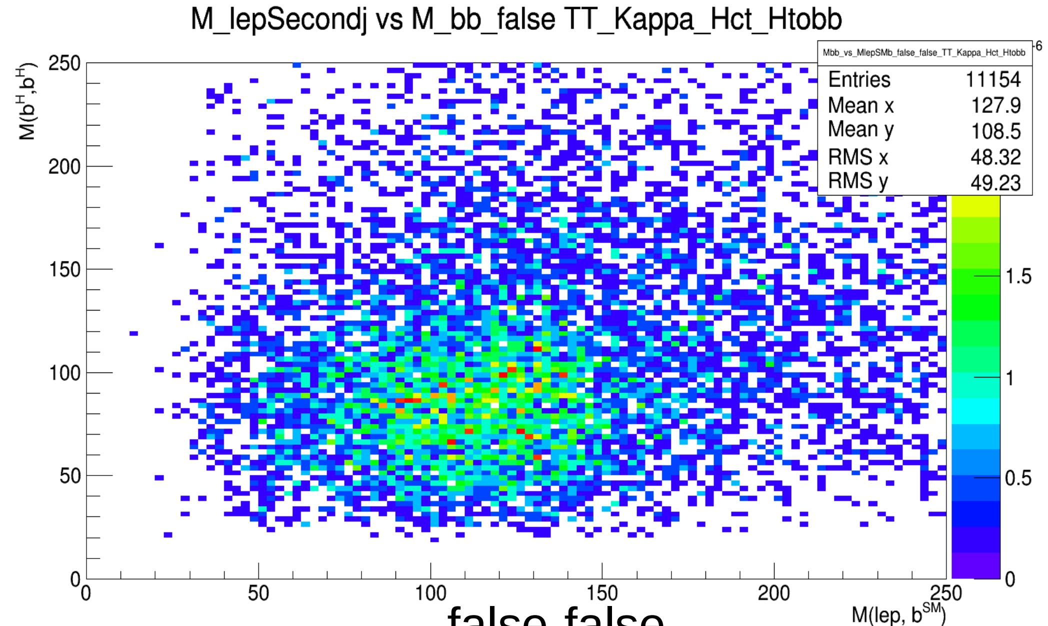
> 90% of sample

Best case scenario: 38% of signal gives distinguishable mass distributions.
Remaining 62% will look like semileptonic $t\bar{t}$

M(bb) vs M(lep,b) - signal

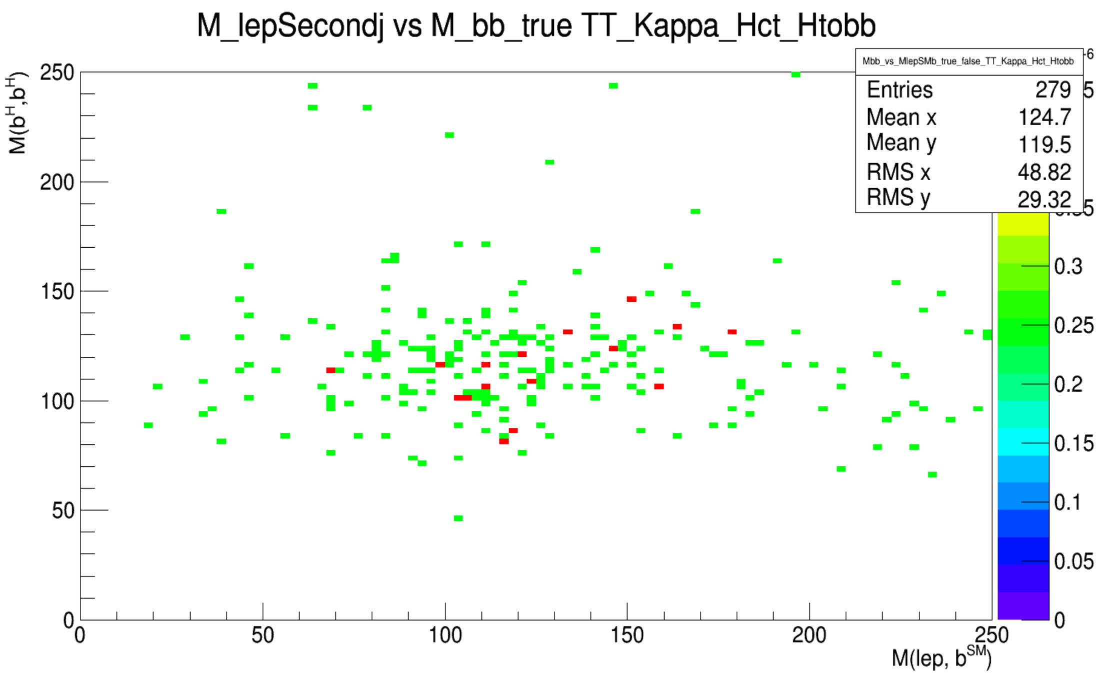


true-true

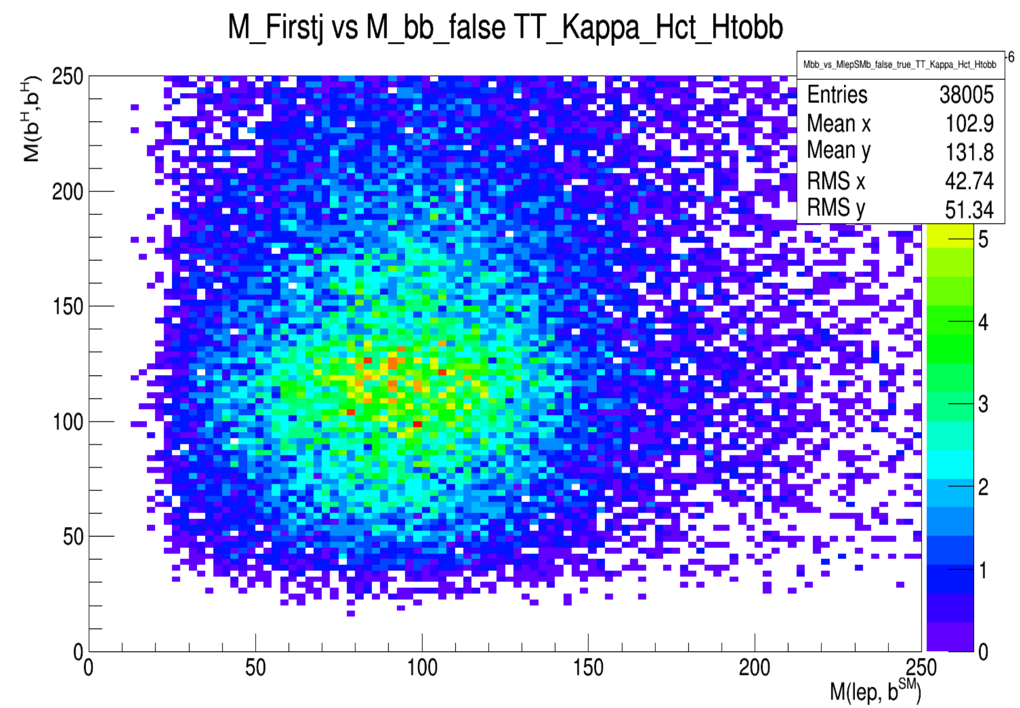


false-false

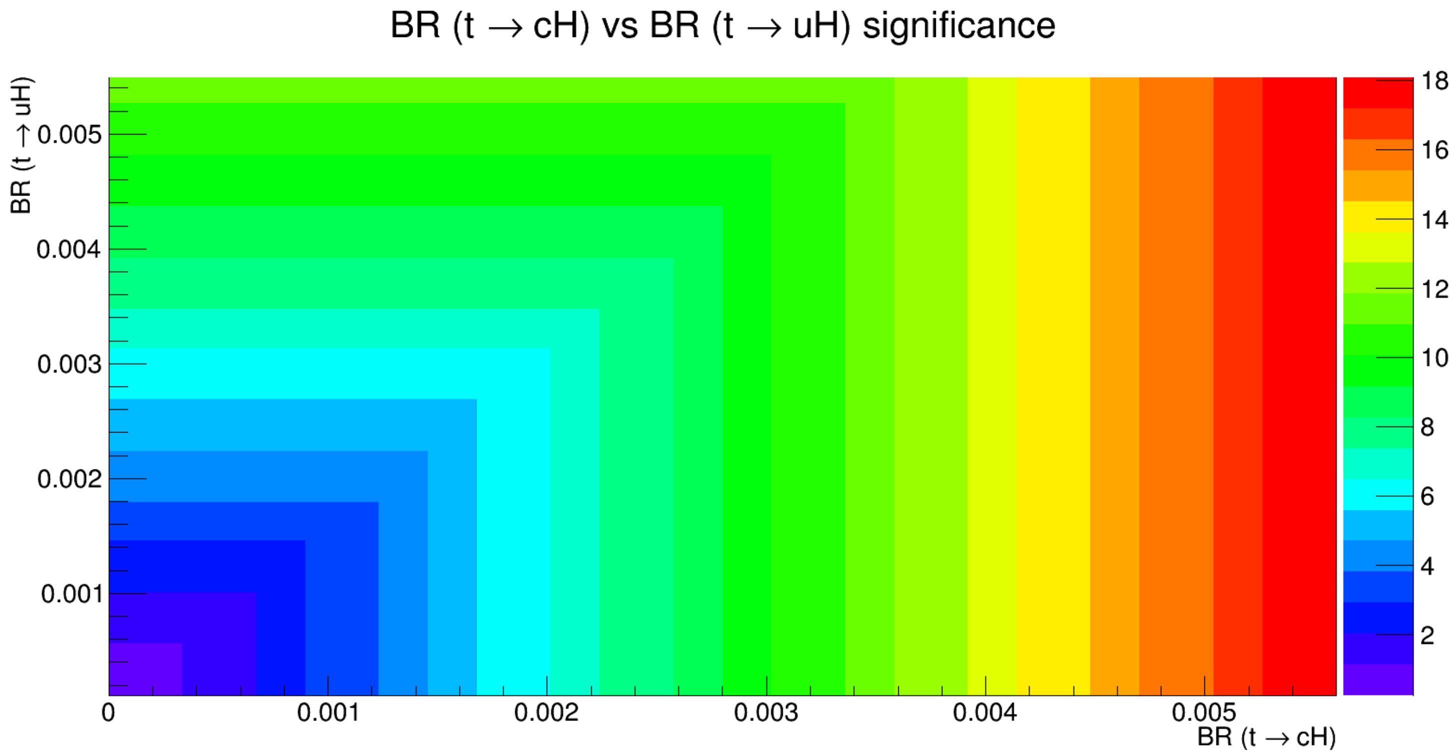
true-false



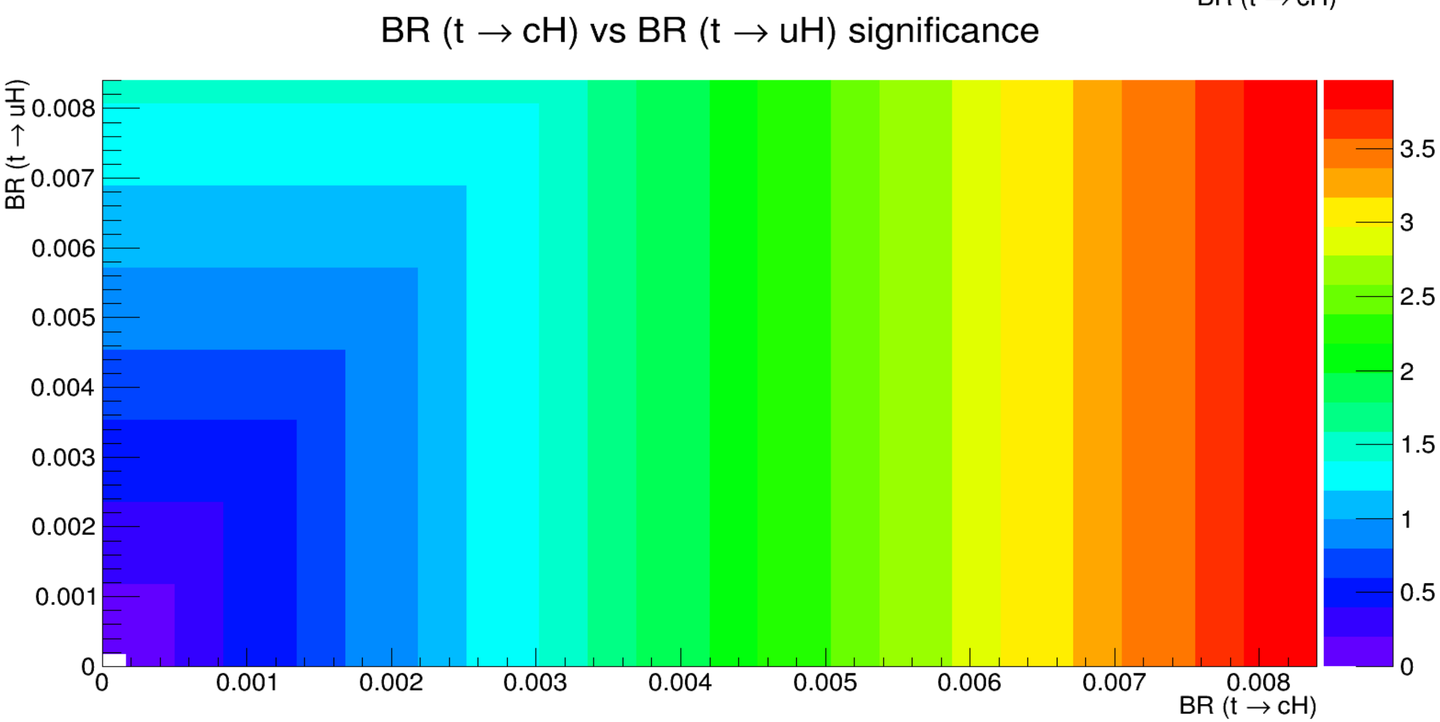
false-true



BR scan



No systematic uncertainty



10% systematic uncertainty on background