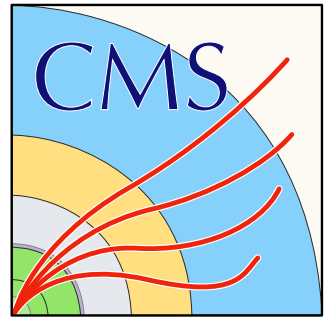
Sensitivity of new Observables.
Part 1: $t\bar{t}$ spin-density-matrix
Part 2: DM single-top variables
(Virtual Talk)

Exotics Weekly Meeting, 16.10.2020

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES



Part 1: $t\bar{t}$ spin-density-matrix (update)

- adding the $b_a^1 \pm b_b^1$ observables
- splitting c_{hel} into its 3 components
- specifying 2 fixed mass points (10 and 500 GeV) for comparison

Signal vs Background Shape: $t\bar{t}$ spin correlation

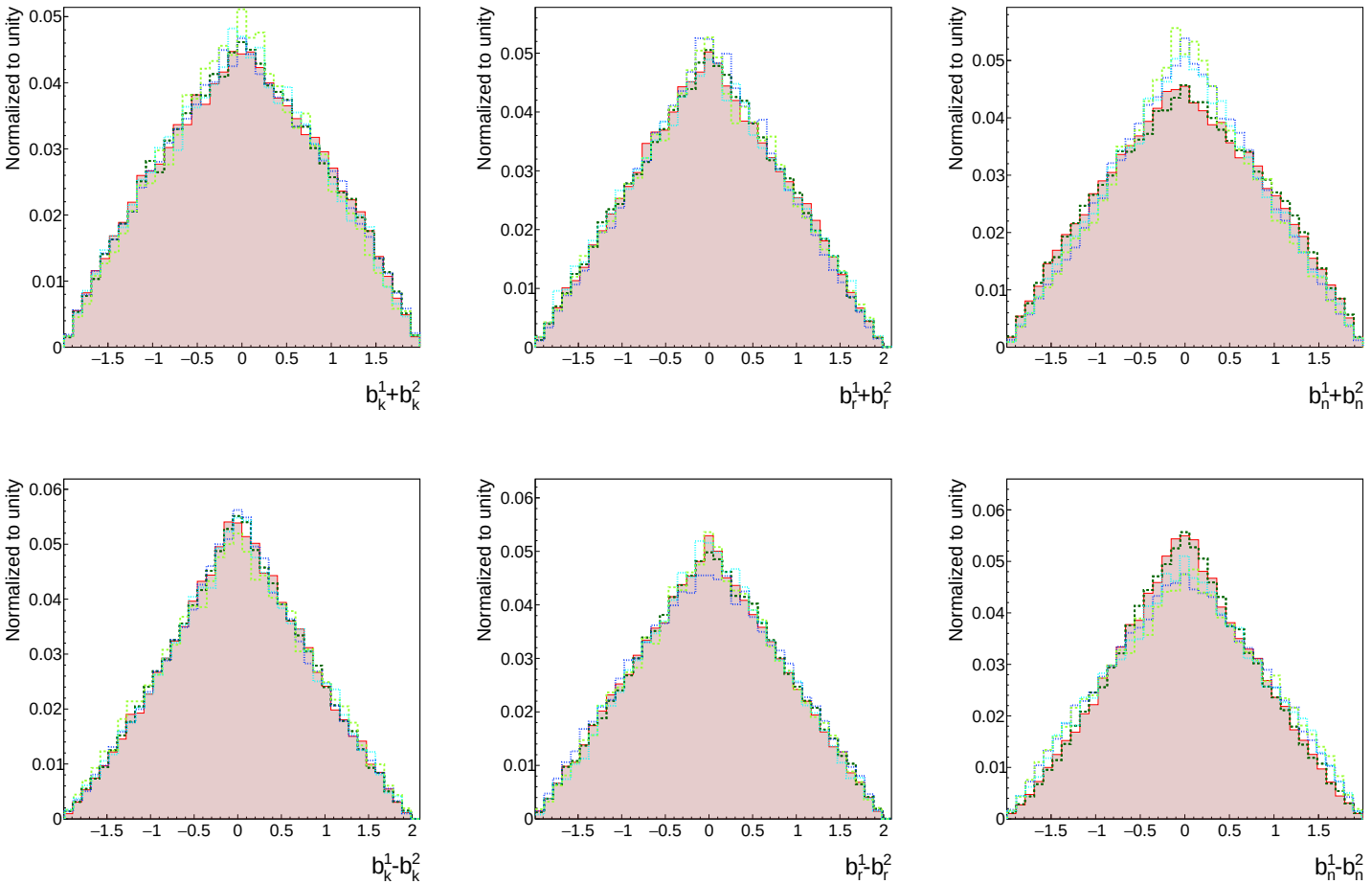
$t\bar{t}\varphi \rightarrow b\bar{l}\nu\bar{b}l\bar{\nu}+\chi\bar{\chi}$ (M=10GeV)

$t\bar{t}a \rightarrow b\bar{l}\nu\bar{b}l\bar{\nu}+\chi\bar{\chi}$ (M=10GeV)

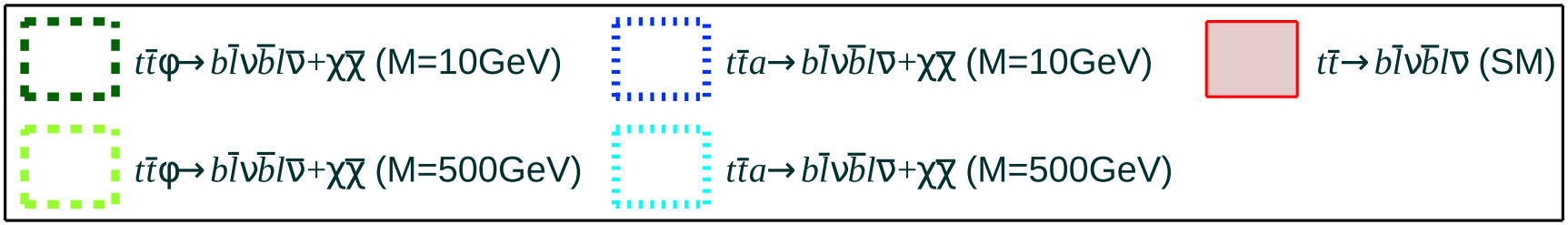
$t\bar{t} \rightarrow b\bar{l}\nu\bar{b}l\bar{\nu}$ (SM)

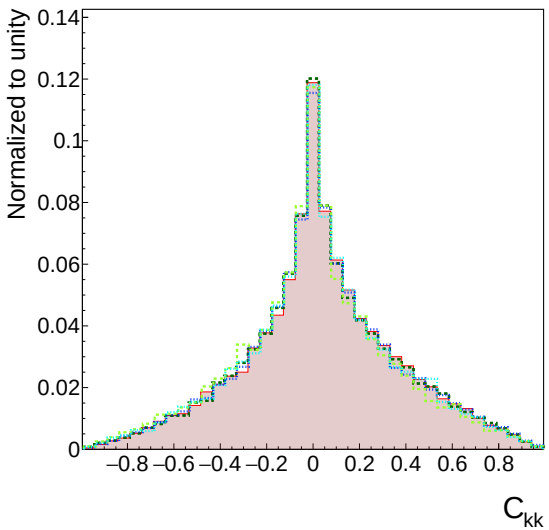
$t\bar{t}\varphi \rightarrow b\bar{l}\nu\bar{b}l\bar{\nu}+\chi\bar{\chi}$ (M=500GeV)

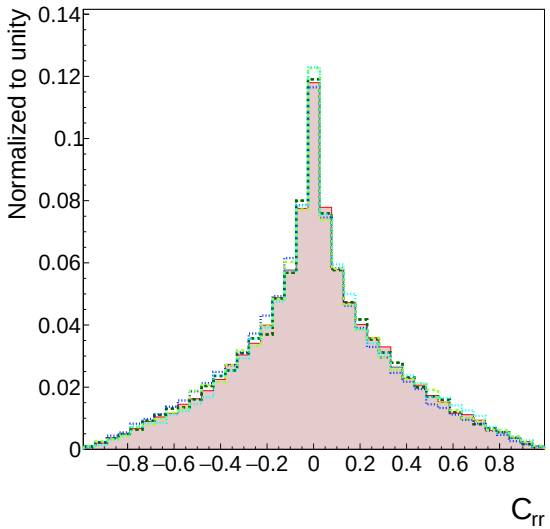
$t\bar{t}a \rightarrow b\bar{l}\nu\bar{b}l\bar{\nu}+\chi\bar{\chi}$ (M=500GeV)

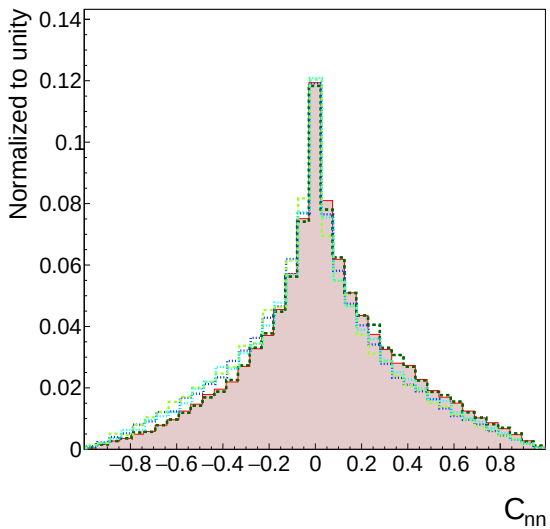


Signal vs Background Shape: $t\bar{t}$ spin correlation

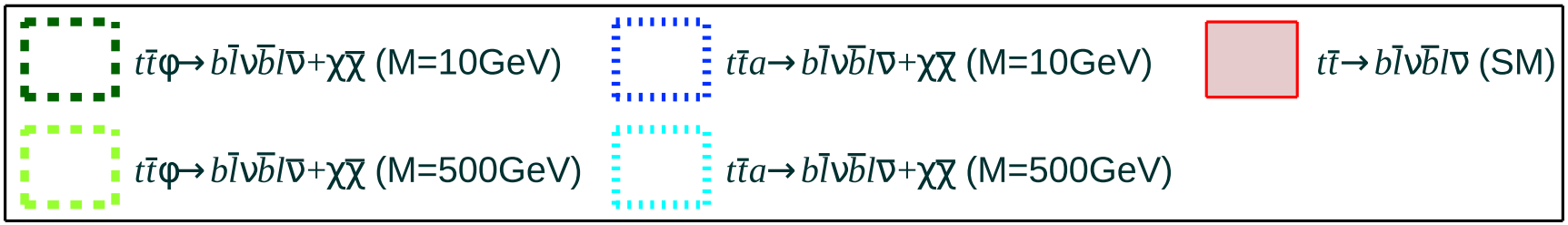


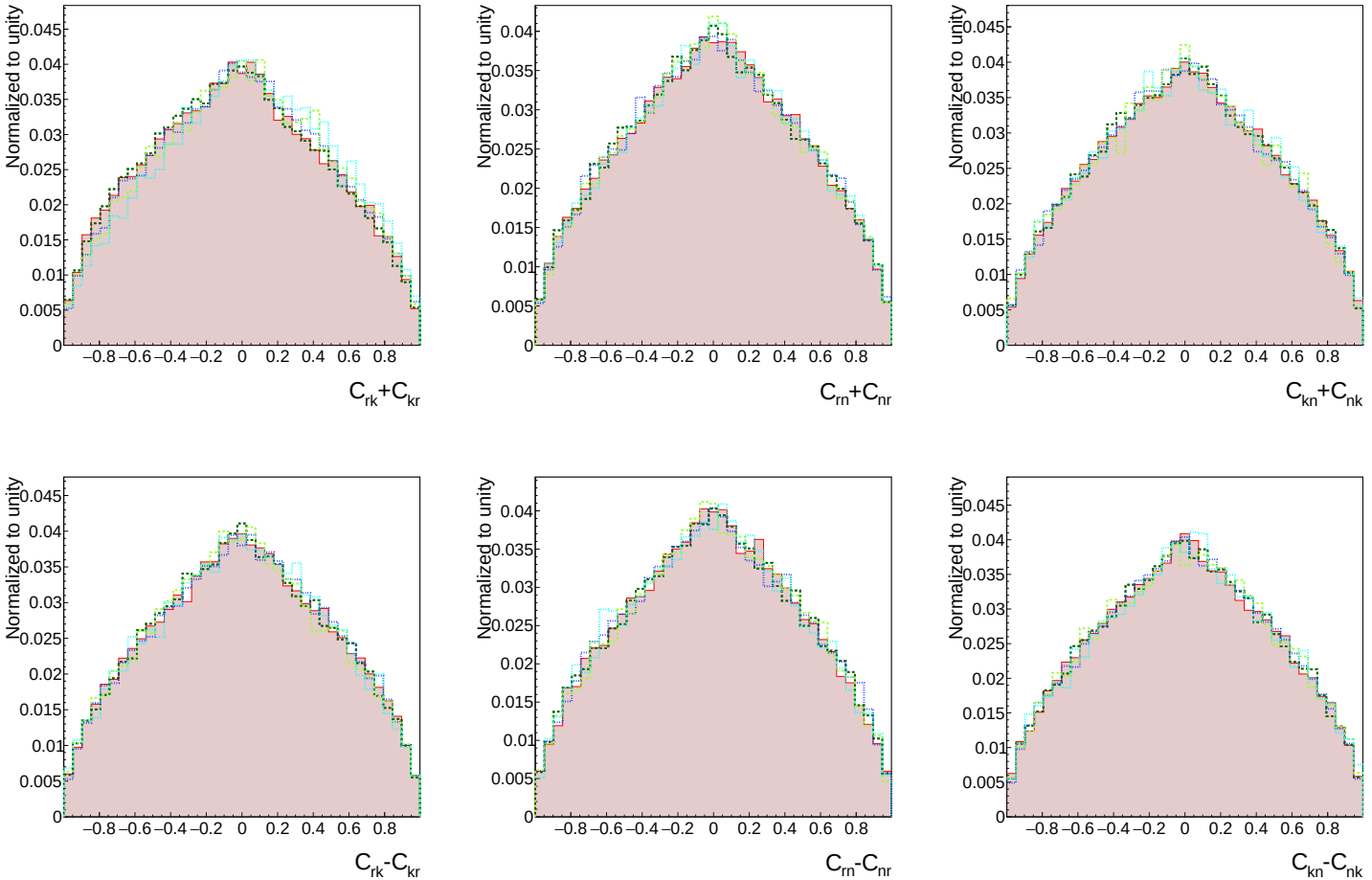






Signal vs Background Shape: $t\bar{t}$ spin correlation





Ranking of variables by separation power

TMVA definition for "separation power" (unspecific)

$$\langle \Delta^2 \rangle = \frac{1}{2} \int \frac{[f_S(x) - f_B(x)]^2}{f_S(x) + f_B(x)} dx$$

Rank	Variable	Separation
1	Ckk	6.020e-04
2	Crn_minus_Cnr	5.403e-04
3	Crr	5.378e-04
4	b1n_minus_b2n	5.136e-04
5	b1r_plus_b2r	4.941e-04
6	Crn_plus_Cnr	4.437e-04
7	Crk_minus_Ckr	4.317e-04
8	b1r_minus_b2r	4.273e-04
9	Ckn_minus_Cnk	4.086e-04
10	Crk_plus_Ckr	3.827e-04
11	b1k_plus_b2k	3.826e-04
12	b1n_plus_b2n	3.754e-04
13	b1k_minus_b2k	3.591e-04
14	Cnn	3.258e-04
15	Ckn_plus_Cnk	2.993e-04

Rank	Variable	Separation
1	Cnn	7.948e-03
2	b1n_minus_b2n	6.325e-03
3	b1n_plus_b2n	5.665e-03
4	Ckk	2.947e-03
5	b1k_plus_b2k	2.402e-03
6	b1k_minus_b2k	2.144e-03
7	Crk_plus_Ckr	1.679e-03
8	b1r_plus_b2r	8.077e-04
9	Ckn_plus_Cnk	7.913e-04
10	Crr	7.235e-04
11	Ckn_minus_Cnk	7.151e-04
12	Crk_minus_Ckr	6.639e-04
13	Crn_minus_Cnr	6.306e-04
14	b1r_minus_b2r	5.661e-04
15	Crn_plus_Cnr	5.054e-04

Rank	Variable	Separation
1	Cnn	6.121e-03
2	b1n_minus_b2n	4.734e-03
3	b1n_plus_b2n	4.408e-03
4	Crr	1.515e-03
5	b1r_minus_b2r	1.405e-03
6	b1r_plus_b2r	1.378e-03
7	Crk_plus_Ckr	9.026e-04
8	Crn_minus_Cnr	6.896e-04
9	Ckk	6.511e-04
10	b1k_minus_b2k	5.621e-04
11	b1k_plus_b2k	5.341e-04
12	Ckn_plus_Cnk	5.119e-04
13	Crn_plus_Cnr	4.846e-04
14	Ckn_minus_Cnk	3.702e-04
15	Crk_minus_Ckr	3.504e-04

Rank	Variable	Separation
1	Cnn	4.218e-03
2	Crk_plus_Ckr	3.917e-03
3	b1n_minus_b2n	3.759e-03
4	b1n_plus_b2n	2.642e-03
5	Ckk	1.109e-03
6	Ckn_minus_Cnk	1.063e-03
7	Crr	1.033e-03
8	b1k_plus_b2k	1.025e-03
9	Crn_minus_Cnr	9.898e-04
10	b1r_minus_b2r	9.457e-04
11	b1r_plus_b2r	9.101e-04
12	b1k_minus_b2k	8.635e-04
13	Crk_minus_Ckr	8.466e-04
14	Ckn_plus_Cnk	7.751e-04
15	Crn_plus_Cnr	4.896e-04

Figure: From Left to Right: Scalar(M=10GeV), Scalar(M=500GeV), Pseudoscalar(M=10GeV), and Pseudoscalar(M=500GeV)

Part 2: DM single-top variables (1 b-Jet cat.)

- study similar to the one performed for $t\bar{t}$
  - dedicated to single-b-Jet category enriched in $tW + DM$
  - generator level observables obtained after some kinematic cuts in η and p_T
- specifying 3 fixed mass points (10, 100, and 500 GeV) for comparison
- variables studied:
  - missing transverse momentum: $P_T(\not{E})$
  - transverse momentum of $l\bar{l}b$ system: $P_T(l\bar{l}b)$
  - difference in azimuthal angle between $l\bar{l}$ system and $\not{E}$: $\Delta\varphi(l\bar{l}, \not{E})$
  - invariant mass of $l\bar{l}b$ system: $M(l\bar{l}b)$
  - transverse momentum of $l\bar{l}b\not{E}$ system: $P_T(l\bar{l}b\not{E})$
  - difference in azimuthal angle between system of "b-Jet and closest lepton" and $\not{E}$: $\Delta\varphi(lb_{closest}, \not{E})$
  - ratio between transverse and total momentum of the $l\bar{l}b$ system (centrality): $\frac{P_T}{P}(l\bar{l}b\not{E})$

Remark: these variables seem to provide very good discrimination between $tW + DM$ and $t\bar{t}$ background for high masses of mediator

Signal vs Background Shape

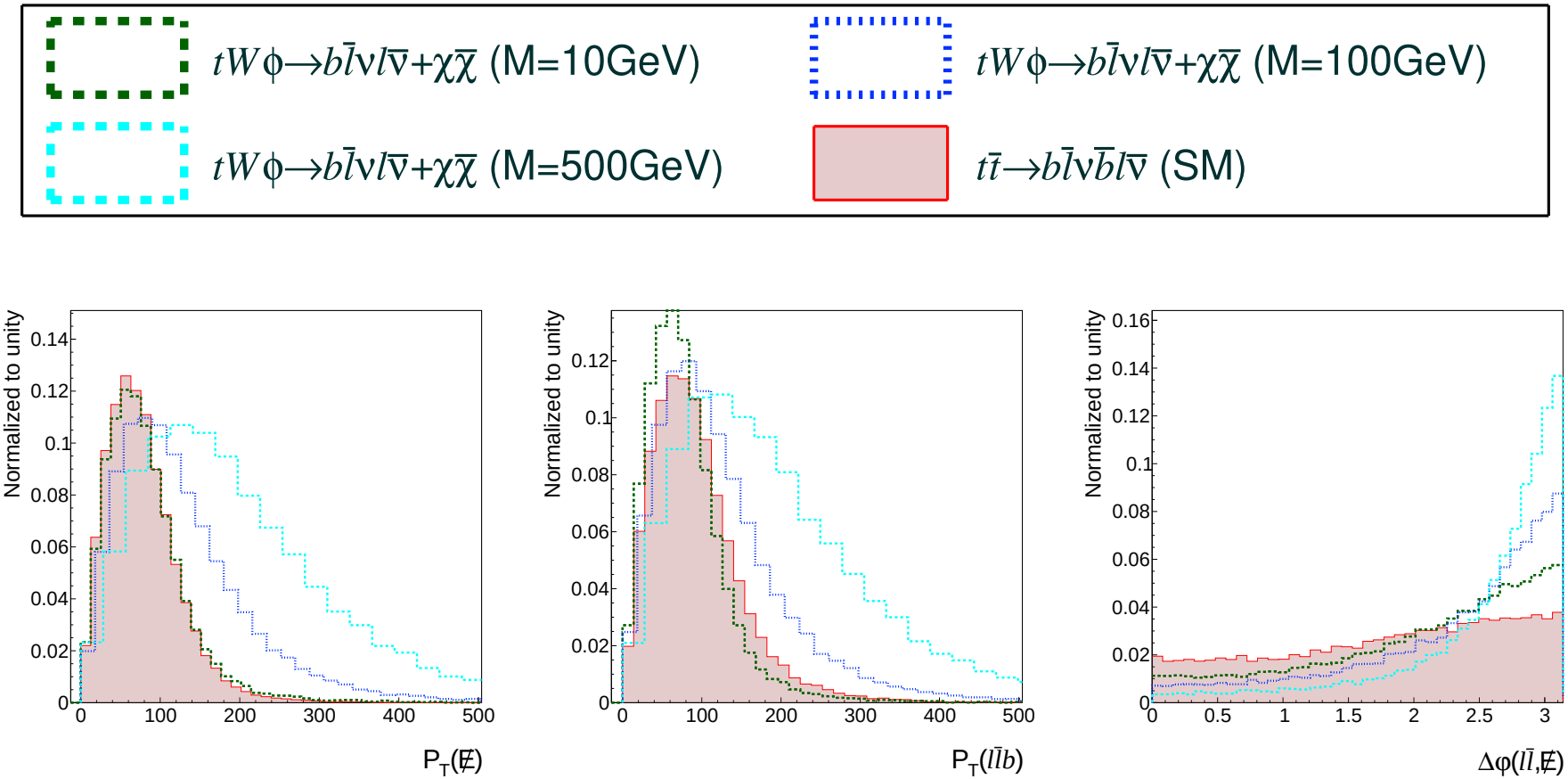


Figure: The first 3 most-discriminating variables (taking as reference M=500 GeV) ordered by ranking from left to right. The correlation observed between all variables is relatively low.

Signal vs Background Shape

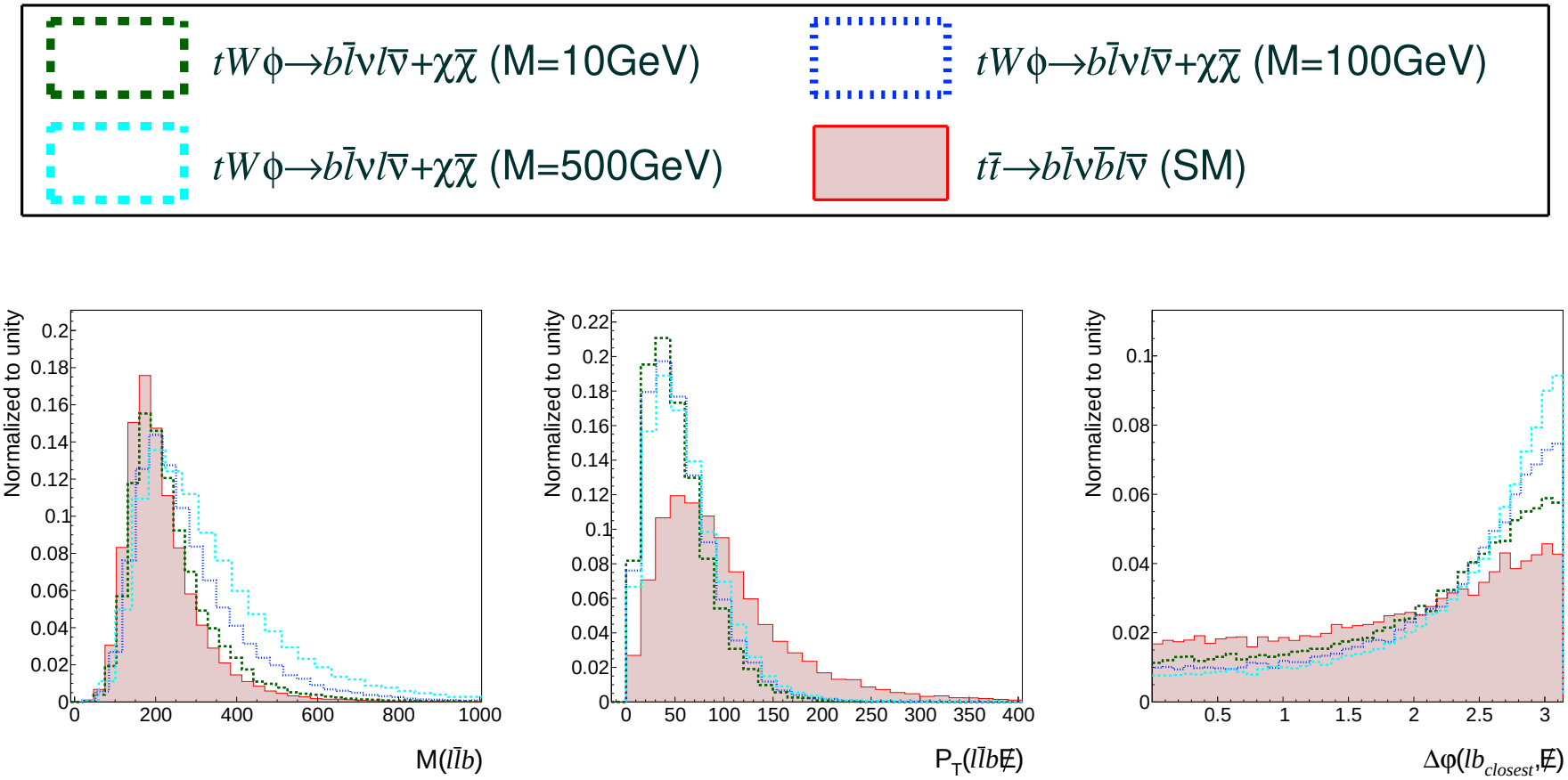
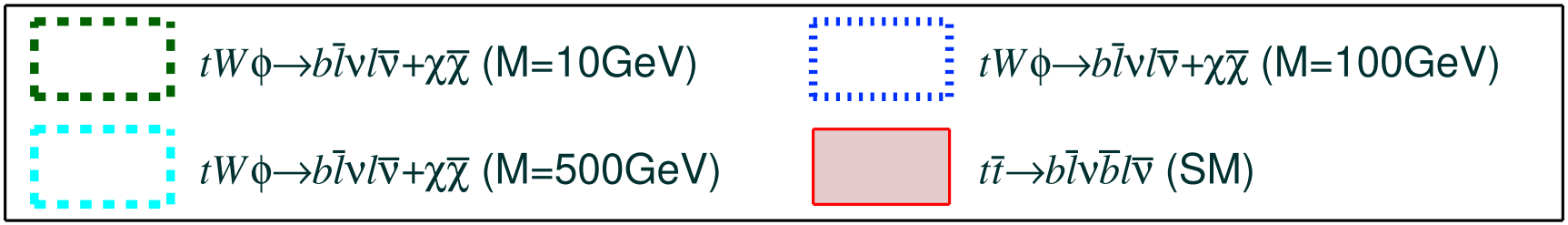


Figure: The second 3 most-discriminating variables (taking as reference M=500 GeV) ordered by ranking from left to right. The correlation observed between all variables is relatively low.

Signal vs Background Shape



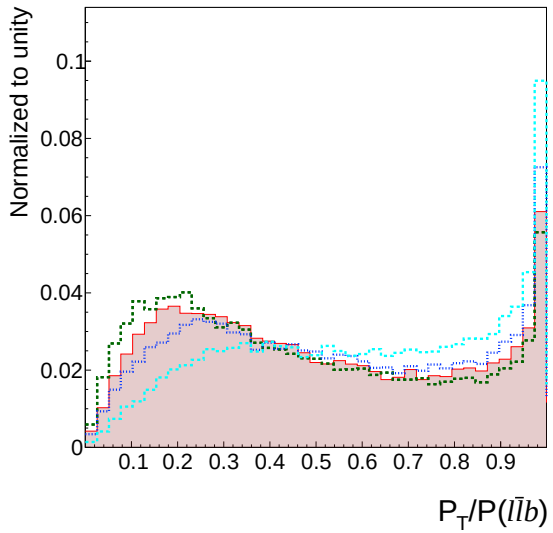


Figure: The 7th most-discriminating variable (taking as reference M=500 GeV). The correlation observed between all variables is relatively low.

Separation power of variables

TMVA definition for "separation power" (unspecific)

$$\langle \Delta^2 \rangle = \frac{1}{2} \int \frac{[f_S(x) - f_B(x)]^2}{f_S(x) + f_B(x)} dx$$

Rank	Variable	Separation
1	LLbarbJetMET_Pt	1.769e-01
2	LLbar_MET_DeltaPhi	2.426e-02
3	LLbarbJet_Pt	1.953e-02
4	LbJetclosest_MET_DeltaPhi	1.483e-02
5	LLbarbJet_Mass	1.439e-02
6	LLbarbJet_PtoverP	4.987e-03
7	MET	3.298e-03

Rank	Variable	Separation
1	LLbarbJetMET_Pt	1.403e-01
2	MET	1.298e-01
3	LLbar_MET_DeltaPhi	7.832e-02
4	LLbarbJet_Mass	7.353e-02
5	LLbarbJet_Pt	4.475e-02
6	LbJetclosest_MET_DeltaPhi	3.861e-02
7	LLbarbJet_PtoverP	4.494e-03

Rank	Variable	Separation
1	MET	3.632e-01
2	LLbarbJet_Pt	2.457e-01
3	LLbar_MET_DeltaPhi	1.960e-01
4	LLbarbJet_Mass	1.555e-01
5	LLbarbJetMET_Pt	1.110e-01
6	LbJetclosest_MET_DeltaPhi	6.511e-02
7	LLbarbJet_PtoverP	3.767e-02

Figure: From Left to Right: Scalar(M=10GeV), Scalar(M=100GeV), and Scalar(M=500GeV)