Search for direct top squark pair production in final states with one electron or muon using 21 fb^{-1} of ATLAS data

based on ATLAS-CONF-2013-037

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Introduction

Naturalness arguments for weak-scale Supersymmetry favour a supersymmetric partner of the top quark (top squark, or "stop") with a mass close to its Standard Model counterpart.
This poster presents a search for pair-produced stops, using the full 2012 dataset with $\sqrt{s} = 8$ TeV and a luminosity of 20.7 fb^{-1}.

Two decay channels are considered separately:

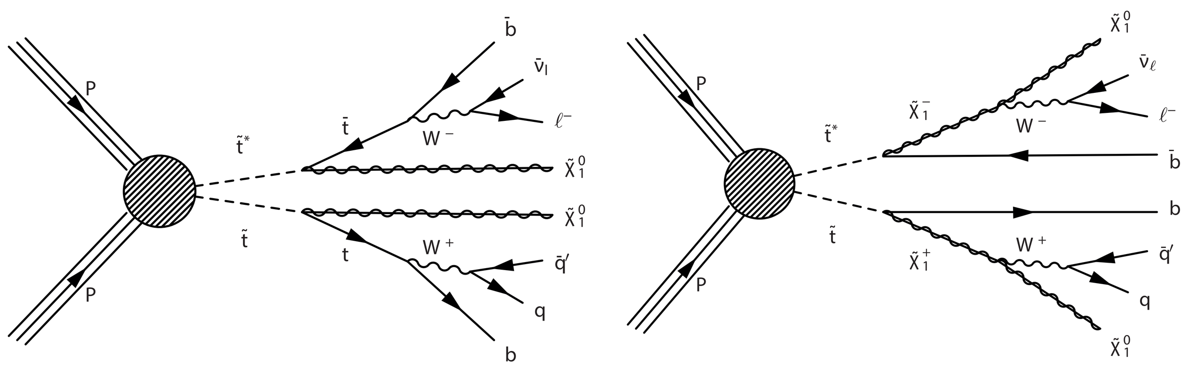


Figure 1: Stop decays targeted by this analysis. ***left:*** *"top+neutralino" (tN)* ***right:*** *"bottom+chargino" (bC). The final state objects are the same as in $t\bar{t}$ production, with additional missing momentum from the 2 neutralinos.*

Event selection

- 1 electron or muon with transverse momentum $p_T > 25$ GeV,
- no other electron or muon with $p_T > 10$ GeV,
- at least 4 jets with $p_T > 80, 60, 40, 25$ GeV,
- at least 1 b-tag in leading 4 jets,
- single lepton OR missing transverse momentum (E_T^{miss}) trigger,
- leading 2 jets not aligned with E_T^{miss}: $\Delta\varphi > 0.8$.

Event kinematic properties differ between the two decay modes and also depend on the masses of the SUSY particles. To maximise the sensitivity, six signal regions (SRs) are defined:

	SRtN1	SRtN2	SRtN3	SRbC1	SRbC2	SRbC3
$E_{\mathrm{T}}^{\text{miss}}$ (GeV)	100	200	275	150	160	160
$E_{\mathrm{T}}^{\text{miss}}/\sqrt{H_{\mathrm{T}}}$ (GeV$^{1/2}$)	5	13	11	7	8	8
m_{T} (GeV)	60	140	200	120	120	120
am_{T2} (GeV)	-	170	175	-	175	200
m_{T2}^{τ} (GeV)	-	-	80	-	-	-
m_{eff} (GeV)	-	-	-	-	550	700
Number of b-jets $\geq$	1	1	1	1	2	2
leading b-jet p_{T} (GeV)	25	25	25	25	100	120
second b-jet p_{T} (GeV)	-	-	-	-	50	90

Table 1: Summary of signal region definitions. The requirements are applied in addition to the preselection defined above.

Background estimation

For each SR, contributions from $t\bar{t}$ and W+jets processes are estimated using control regions (CRs) with a lower m_T requirement. Theoretical/modelling uncertainties affecting the CR→SR extrapolation are dominant and are determined from Monte Carlo (MC) comparisons. Minor backgrounds from $t\bar{t}+V$, VV (diboson) or single top quark events were estimated directly from MC. Contributions from Z+jets and QCD multijet events are negligible.

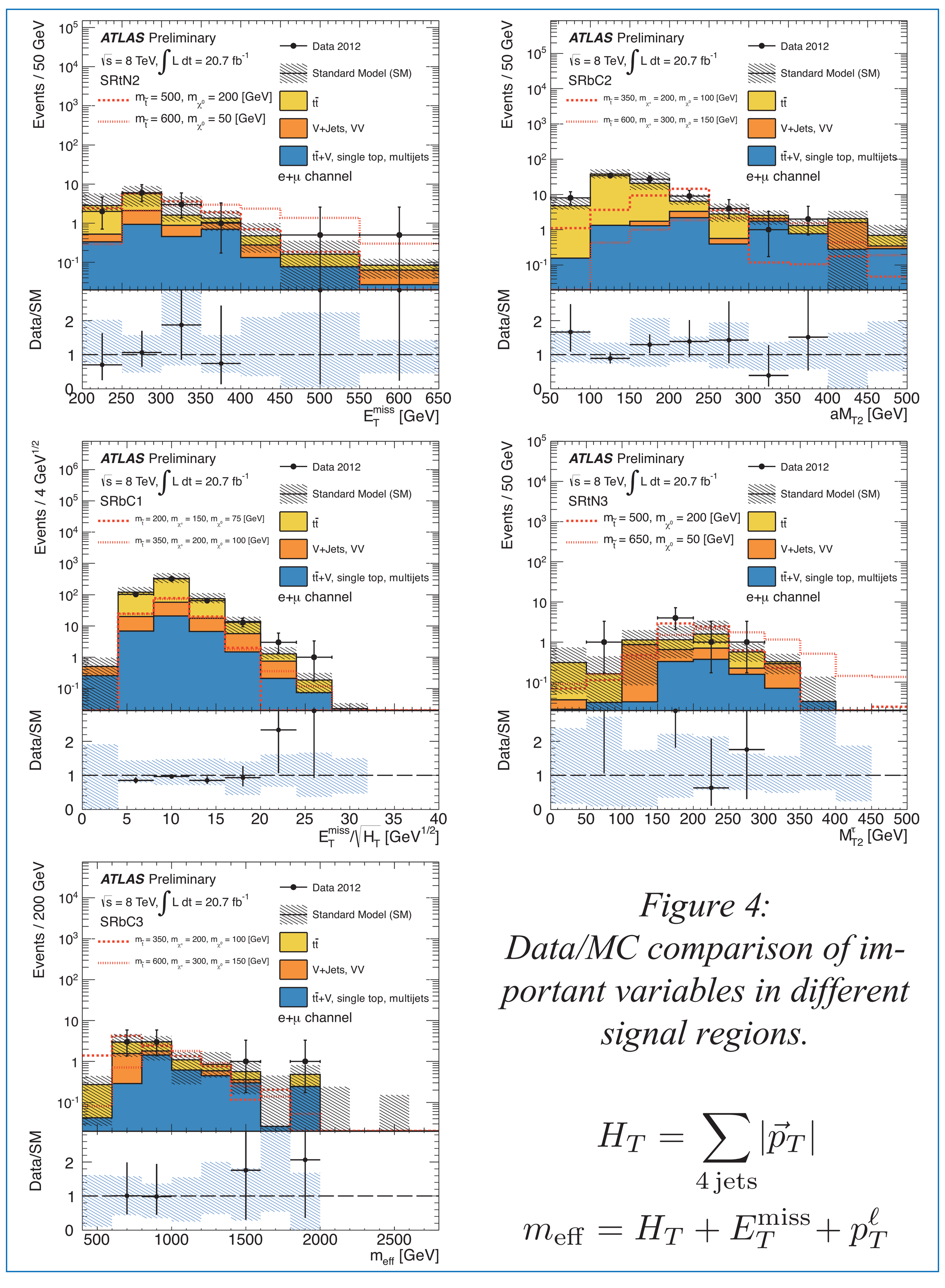


Figure 4: Data/MC comparison of important variables in different signal regions.

$$H_T = \sum_{4\text{ jets}} |\vec{p}_T|$$

$$m_{\text{eff}} = H_T + E_T^{\text{miss}} + p_T^{\ell}$$

Results and statistical interpretation

	SRtN1	SRtN2	SRtN3	SRbC1	SRbC2	SRbC3
Data observed	11733	14	7	456	25	6
SM expectation	11833±378	13± 3	5± 2	482± 76	18± 5	7± 3
$m(\tilde{t}, \text{LSP}) = 225, 25$	1075± 26	2.2±1.0	0.9±0.6	-	-	-
$m(\tilde{t}, \text{LSP}) = 350, 150$	201± 5	2.0±0.5	0.5±0.3	-	-	-
$m(\tilde{t}, \text{LSP}) = 500, 200$	71.9± 1.4	14.9±0.6	6.8±0.4	-	-	-
$m(\tilde{t}, \text{LSP}) = 600, 50$	30.2± 0.5	13.9±0.4	11.6±0.3	-	-	-
$m(\tilde{t}, \chi_1^{\pm}, \chi_1^0) = 200, 150, 75$	-	-	-	233± 18	8± 4	3.1±3.1
$m(\tilde{t}, \chi_1^{\pm}, \chi_1^0) = 350, 200, 100$	-	-	-	166± 5	38.3±2.5	11.1±1.4
$m(\tilde{t}, \chi_1^{\pm}, \chi_1^0) = 600, 300, 150$	-	-	-	26.3±0.6	12.5±0.4	9.0±0.4

Table 2: Event yields in all signal regions, with expectations for SM and several signal points.

For the shape fit region tN1, the sum of all bins with b-requirement is shown.

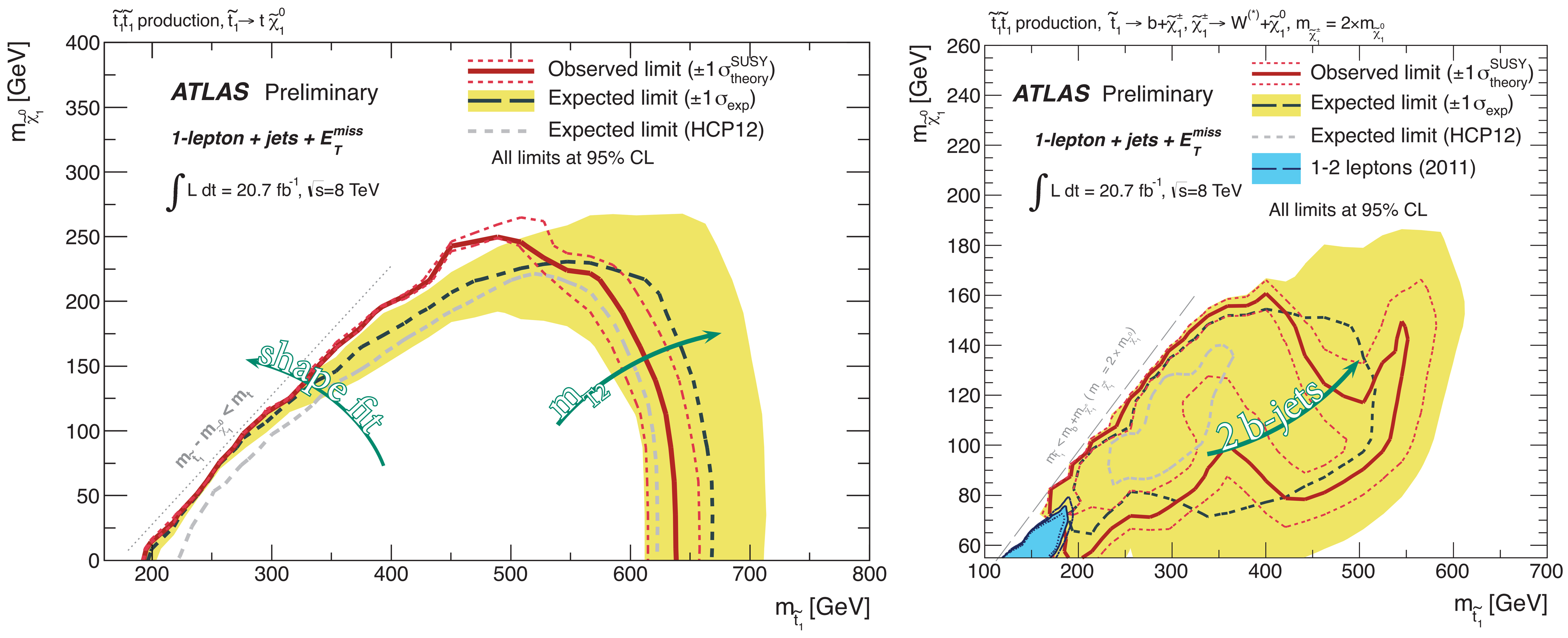
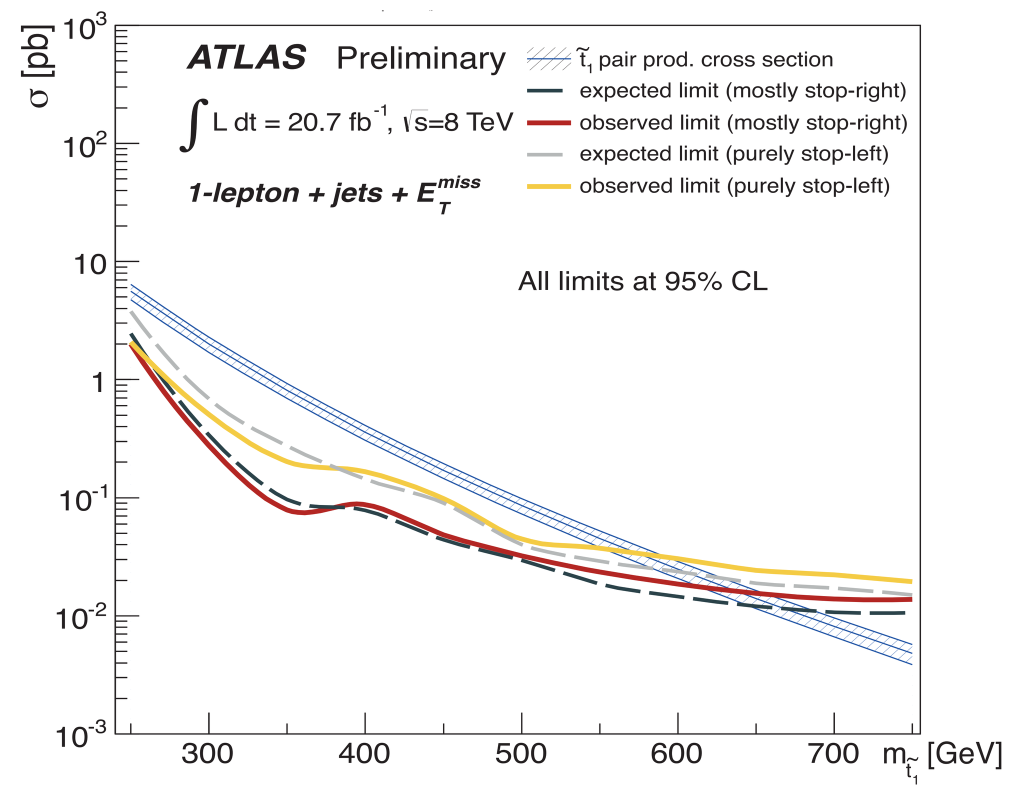


Figure 2: Excluded stop and neutralino masses for different signal models (left: tN, right: bC). The green arrows highlight important improvements since HCP 2012.



A likelihood ratio test based on simultaneous fits is run in several variations to test the SM-only hypothesis and to compute exclusion limits for the signal processes (figure 2).

Upper limits for a generic BSM model are also derived to allow simple exclusion estimates for alternative models.

Figure 3 (left): Impact of stop mixing / handedness for a fixed neutralino mass of 50 GeV. A mostly (~70%) stop-right model is used throughout the analysis (red line). A purely stop-left model assumption reduces the exclusion reach by about 75 GeV (yellow line).

Shape fit

When the mass difference between stop and its decay products is small, signal events have similar kinematics properties to $t\bar{t}$ background events.

Region tN1 was optimized for this challenging part of the mass plane: instead of defining signal and control regions, tN1 is subdivided into 3 x 5 bins of E_T^{miss} and m_T; some more signal-like, others more background-like, as seen in figure 5.

While the statistical treatment is more complex than for the remaining, single-bin regions, the additional shape information greatly improves the sensitivity.

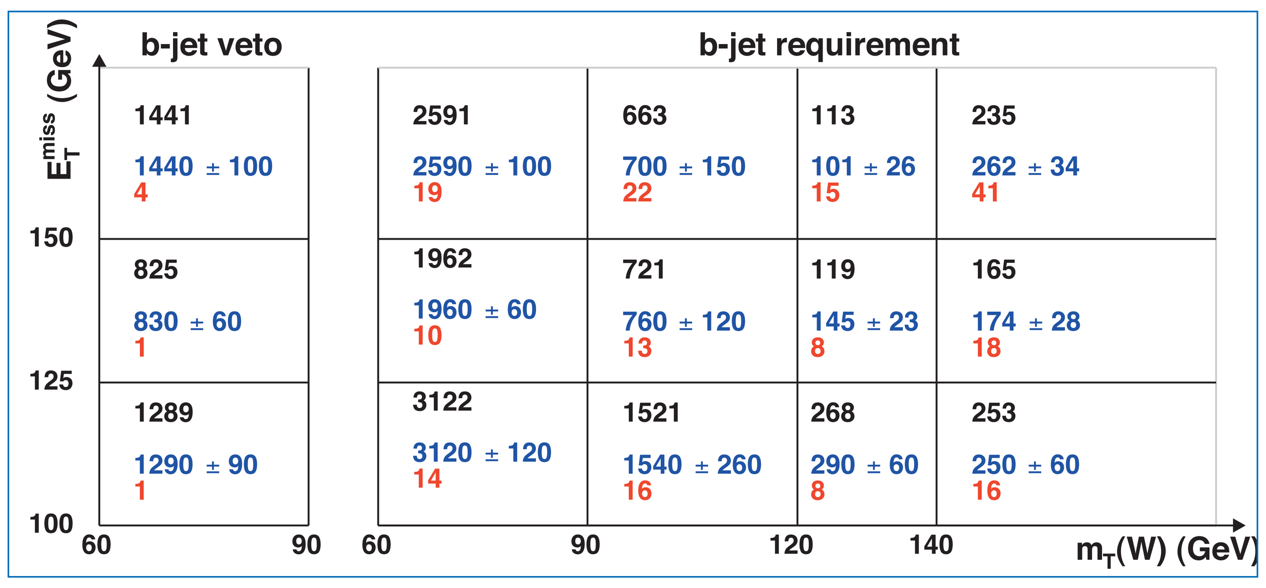


Figure 5: The shape fit uses bins of E_T^{miss} and m_T with different b-jet requirements. Observed counts are shown in black, SM expectations in blue, and signal $m_{\tilde{t}} = 350$ GeV, $m_{\chi_1^0} = 150$ GeV in red.

Variables in event selection

The transverse W mass m_T combines E_T^{miss} and lepton p_T and hints at the presence of a W boson.

am_{T2} and m_{T2}^{τ} are two specialized extensions of the m_T variable for events with two invisible particles, as illustrated in figure 6. They are related to the minimal invisible transverse mass compatible with observed kinematics.

Two variables suppress dileptonic $t\bar{t}$ events: a hadronic top mass cut, based on the invariant mass of 3 jets; and a veto against isolated tracks not assigned to the reconstructed lepton (events with unidentified lepton or 1-prong τ decay).

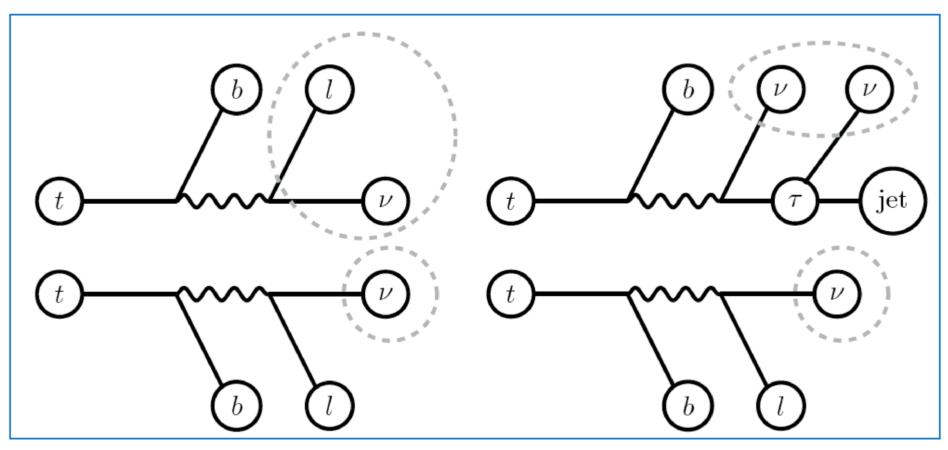


Figure 6: Purpose of m_{T2} variations. ***left:*** *incomplete dileptonic $t\bar{t}$ event – am_{T2} combines visible objects and invisible masses of m_W and 0 to reconstruct 2 tops,* ***right:*** *$t\bar{t}$ event with hadronic τ decay – m_{T2}^{τ} uses two invisible masses of 0 GeV.*

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