Search for Direct Pair Production of top squark in the 2-tau Leptons Final State with the ATLAS Detector

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Introduction

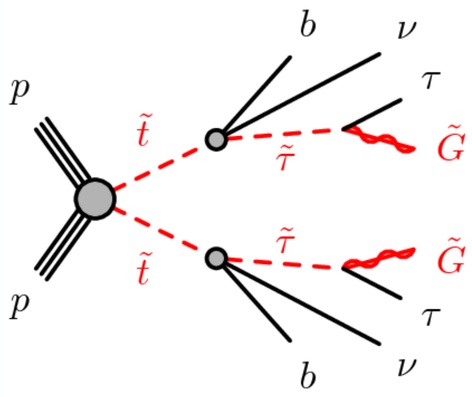
- Supersymmetry (SUSY) can resolve the Standard Model (SM) hierarchy problem [1] if top squark ($\tilde{t}$) is light.
- Expect large rate of top squark pair production in the LHC
- In Gauge-Mediated Supersymmetry Breaking (GMSB) models, gravitino ($\tilde{G}$) is expected to be the lightest supersymmetric particle (LSP)
- Investigating a three body decay $\tilde{t} \rightarrow b\tilde{\tau}\nu$ where, $\tilde{\tau}$ is the super partner of tau lepton and decay into LSP via $\tilde{\tau} \rightarrow \tau\tilde{G}$
- First result from a hadron collider search of this channel
- The results presented use 20.3 fb^{-1} of proton-proton collision data taken with the ATLAS detector at $\sqrt{s}$ = 8 TeV during the 2012 LHC run.

Background Estimation

Background	Had-Had	Lep-Had
$t\bar{t}$ with true τ	MC	CR
$t\bar{t}$ with fake τ	CR	CR
W+jets	CR	CR
Others(small contribution)	MC	MC

Table: Summary of the background estimation methods in hadron-hadron and lepton-hadron channel. MC represents Monte Carlo simulation while CR stands for control region.

Signal Model for stop pair production with 2-tau lepton in the final state

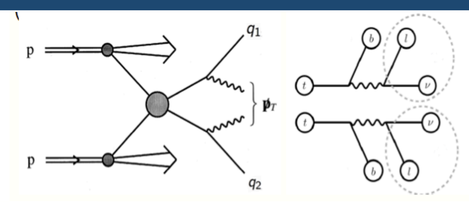


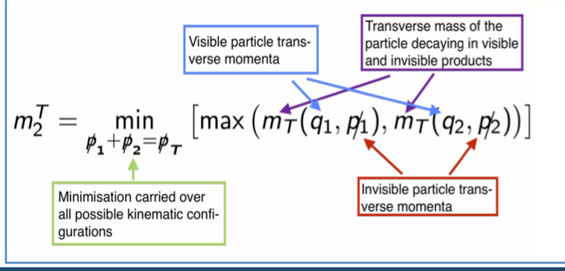
- **Lepton-Hadron (LH) channel**
- **Hadron-Hadron (HH) channel**
- **Lepton-Lepton (LL) channel:** Reinterpretation of the di-lepton analysis [2]

- GMSB Simplified Model
- Branching ratio of the decay chain assumed 100%
- Gravitino LSP

Analysis Strategy

- Cut and count method
- "*Stransverse Mass*"[3] is used to differentiate signal from SM background

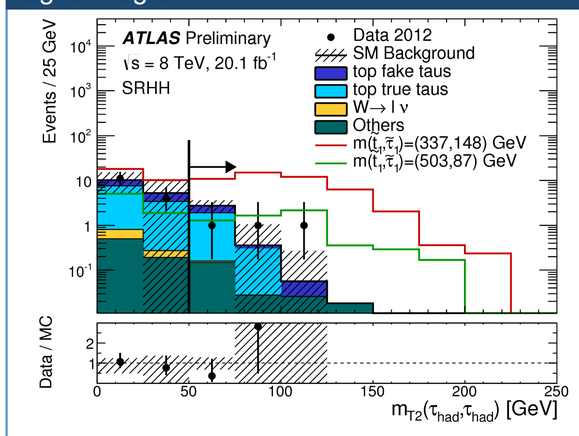


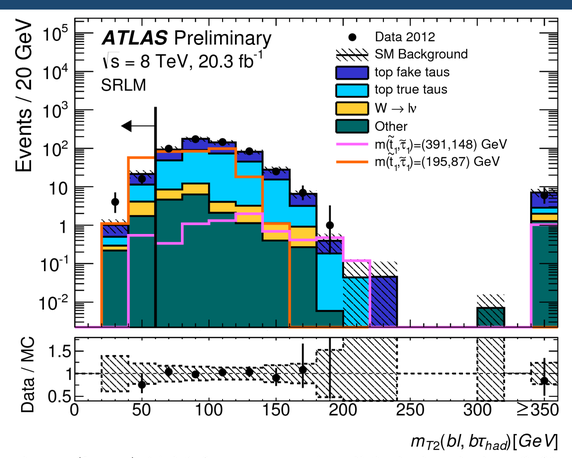


Stransverse Mass:

- Exploits the difference in kinematic endpoint for SM background and signal processes.

Signal Region





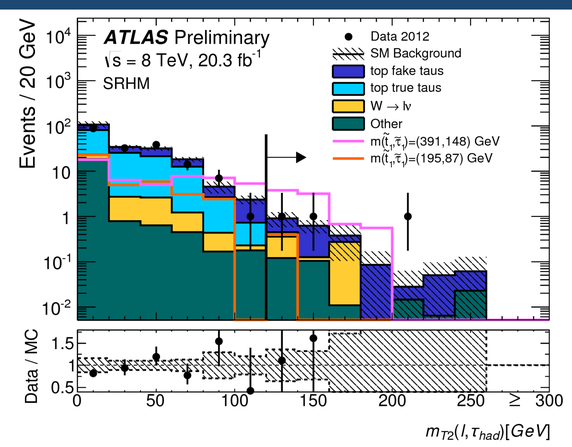


Figure: Distribution of $m_{T2}(\tau_{\mathrm{had}}, \tau_{\mathrm{had}})$ (left), $m_{T2}(bl, b\tau_{\mathrm{had}})$ (middle) and $m_{T2}(l, \tau_{\mathrm{had}})$ (right) for events passing all the hadron-hadron (left) and lepton-hadron (middle, right) signal requirements, except that on m_{T2}. The contribution from all SM backgrounds are shown as a histogram stack; the bands represent the total statistical and systematic uncertainty. The background yields have been rescaled by the post-fit normalization factors. The arrows mark the cut values used to define the signal regions. The distributions expected for two signal models are also shown.

Systematic Uncertainties

- Theoretical and detector uncertainties are considered
- The signal uncertainties: 10% ~ 15%

	Hadron–hadron	Lepton–hadron LM	Lepton–hadron HM
Background events	3.1 ± 1.2	22.1 ± 4.7	2.1 ± 1.5
Uncertainty Breakdown [%]:			
Jet energy scale and resolution	17	13	2
Tau energy scale	9	4	3
Cluster energy scale and resolution	1	2	4
b-tagging	2	4	2
Top-quark theory uncertainty	37	11	64
W+jets theory and normalisation	-	1	19
Simulation statistics	20	6	21
Top normalisation	18	6	20

Table: Summary of the systematic uncertainties on the background estimates. The size of each uncertainty is quoted as a relative uncertainty on the total background. A dash indicates a negligible contribution to the uncertainty. The individual uncertainties can be correlated, and thus do not necessarily sum in quadrature to the total relative uncertainty.

Results

Channel	Hadron–hadron	Lepton–hadron (LM)	Lepton–hadron (HM)
Observed events	3	20	3
Total (constrained) background events	3.1 ± 1.2	22.1 ± 4.7	2.1 ± 1.5
Top with only true tau(s)	2.0 ± 1.1	8.2 ± 3.9	$0.2^{+0.3}_{-0.2}$
Top with at least one fake tau	0.9 ± 0.5	9.8 ± 4.5	$1.2^{+1.4}_{-1.2}$
W+jets	$0.01^{+0.02}_{-0.01}$	2.2 ± 0.6	0.4 ± 0.4
Z/γ^*+jets	$0.04^{+0.15}_{-0.04}$	1.9 ± 1.1	–
$t\bar{t} + V$	0.04 ±0.02	–	0.3 ± 0.1
Diboson	0.14 ± 0.02	–	–

Table: Background fit results for the hadron-hadron SR and the two lepton-hadron SRs. Combined statistical and systematic uncertainties are given. The uncertainties between different background components can be correlated, so they don't necessarily sum to the total background uncertainty. A dash indicates a negligible contribution to the uncertainty.

Combined Exclusion Limit

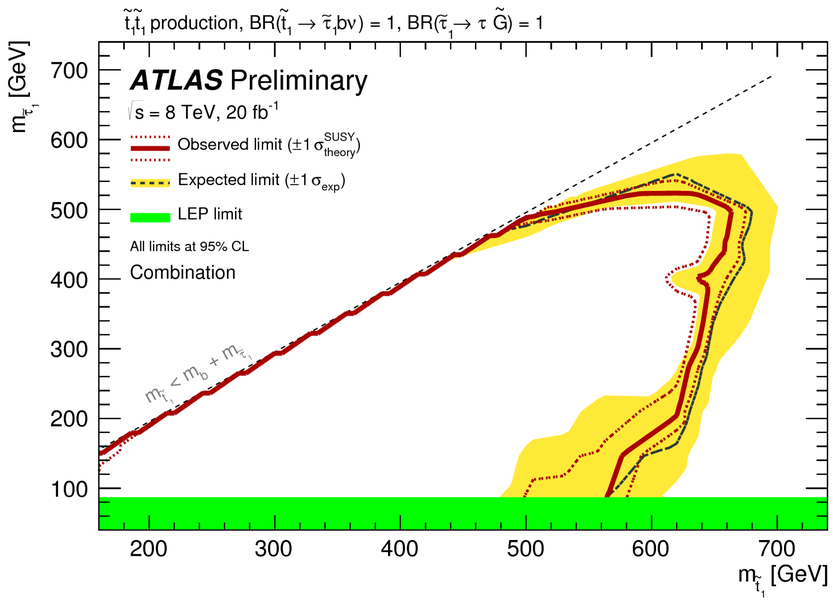
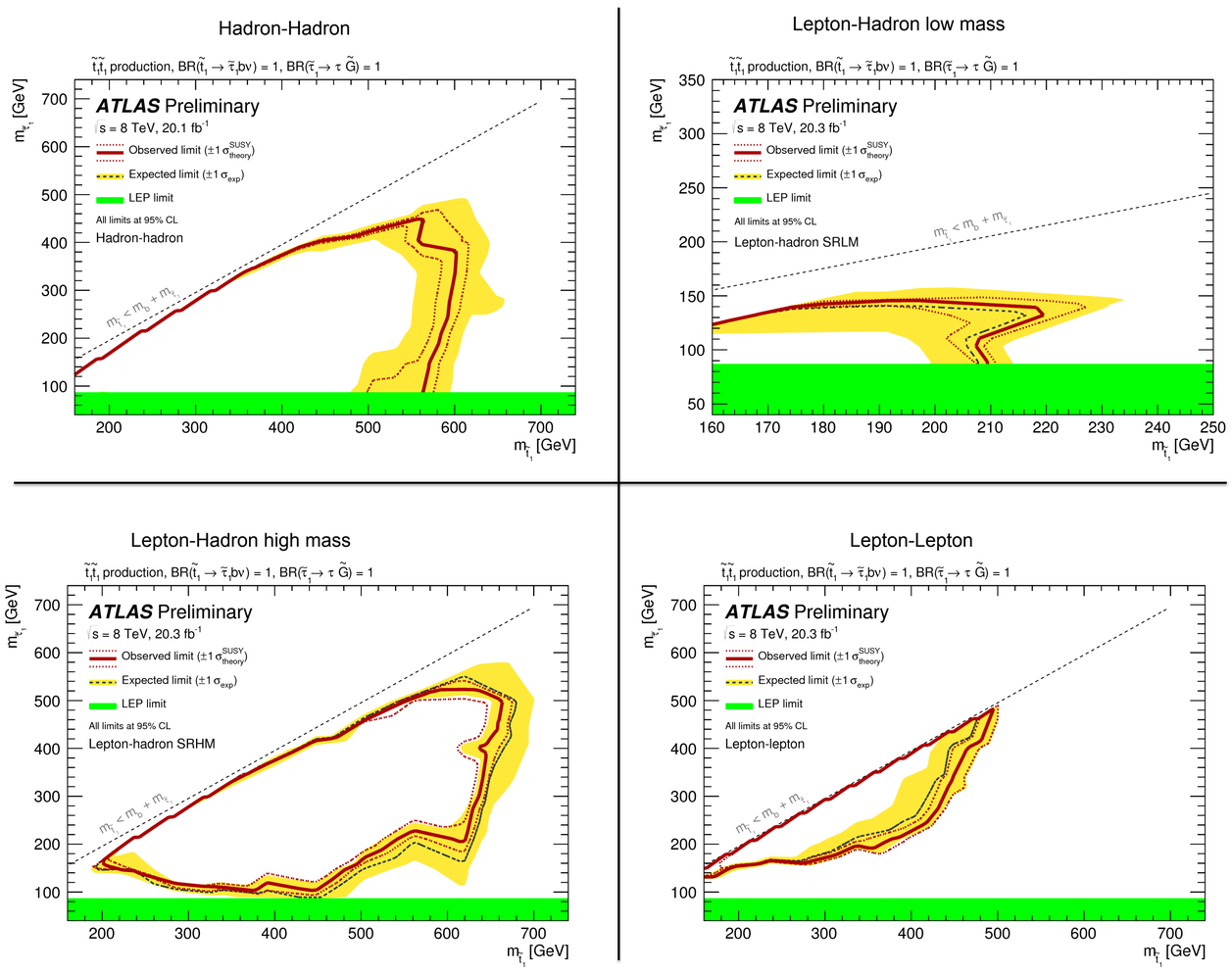


Figure: Observed and expected exclusion contours for the combination of the channels at 95% CL in mass (top squark, tau slepton) plane. The dashed solid lines show the 95% CL expected and observed limits, respectively, including all the uncertainties except for the theoretical signal cross section uncertainty (PDF and scale). The band around the expected limit shows the ±1σ expectation. The dotted ±1σ lines around the observed limit represent the results obtained when varying the nominal signal cross section up or down by the theoretical uncertainty. The LEP limit on the mass of the scalar tau is also shown.

Exclusion Limits

- Exclusion contours are evaluated using a likelihood fit
- All systematic uncertainties considered
- The selection giving the best sensitivity is used to calculated the CLs value



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Summary

- A search for direct pair production of $\tilde{t}\tilde{t}^*$ decaying via $\tilde{\tau}$ to nearly massless $\tilde{G}$ has been presented
- Model independent upper limits at 95% CL on the number of beyond-the-SM (BSM) events and the visible cross section are also derived

Signal Region	Background	Observation	$S^{95}_{\mathrm{obs.(exp.)}}$	$\langle \mathcal{A}\epsilon\sigma \rangle^{95}_{\mathrm{obs.(exp.)}}$ [fb]
Hadron–hadron	3.1 ± 1.2	3	$5.5\ (5.5^{+2.1}_{-1.3})$	$0.27\ (0.27^{+0.11}_{-0.06})$
Lepton–hadron LM	22.1 ± 4.7	20	$12.4\ (13.2^{+4.9}_{-3.5})$	$0.61\ (0.65^{+0.24}_{-0.17})$
Lepton–hadron HM	2.1 ± 1.5	3	$6.4\ (5.2^{+2.6}_{-0.9})$	$0.31\ (0.26^{+0.13}_{-0.04})$

Table: Left to right: Expected background, observed events, 95% CL observed (expected) upper limits on the number of BSM events, and the visible cross section

- Good agreement between Standard Model background and data has been observed
- Depending on the tau slepton mass, upper limits up to 650 GeV have been set on the mass of top squark

References

[1] S. Weinberg, Implication of Dynamical Symmetry Breaking, Phys. Rev. D13 (1976), 974
[2] ATLAS Collaboration, Search for direct top squark pair production in the final state with two leptons with ATLAS detector, JHEP 1406(2014)124, arXiv: 1403.4853 [hep-ex]
[3] C.G. Lester, D.J. Summers, Measuring masses of semi-invisibly decaying particles pair produced at hadron colliders, Phys.Lett. B463 (1999) 99-103
Alan Barr, Christopher Lester, Phil Stephens, m(T2): The Truth behind the glamour, J.Phys. G29 (2003) 2343-2363

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