Searches for direct pair production of third generation squarks with the ATLAS detector

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SUSY19

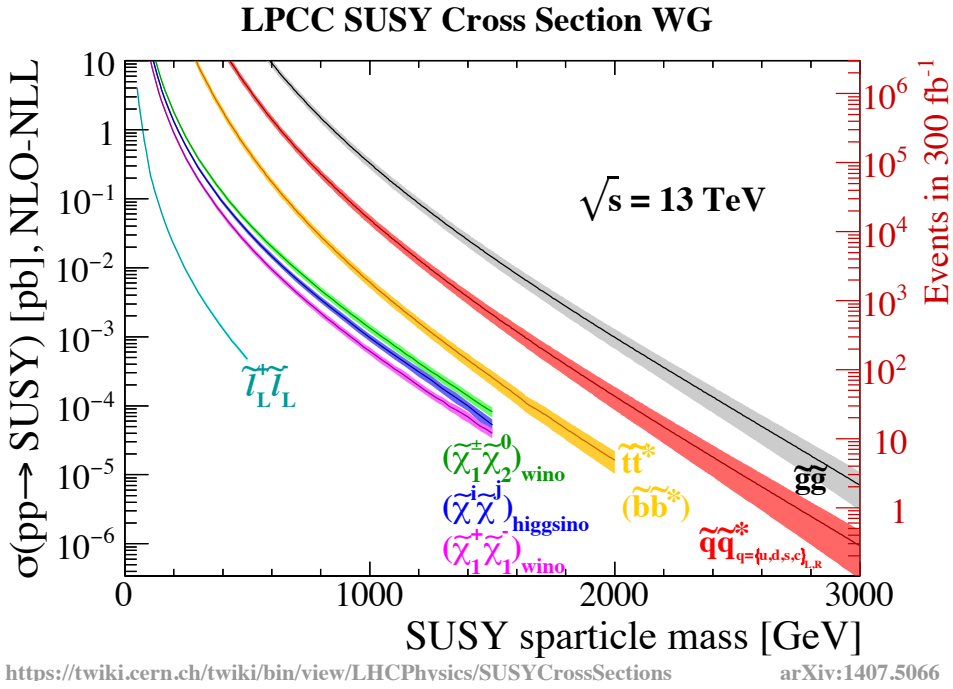
Introduction

3G SUSY motivations

- Introduction of a super partner for each SM particle

- May resolve unanswered questions from the SM:
  - Hierarchy problem
  - Nature of dark matter
  - Unification of fundamental forces at GUT scale

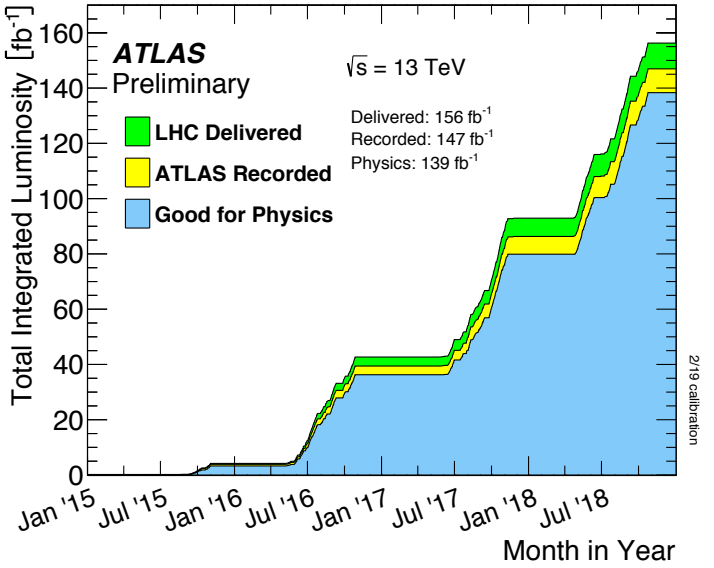
- Due to the role of the top-quark in loop-corrections to the Higgs mass, the superpartners of the 3rd generation quarks (the top-squark and bottom-squark) are of high importance
  - Depending upon the squark masses, they may be produced at an appreciable rate at the LHC

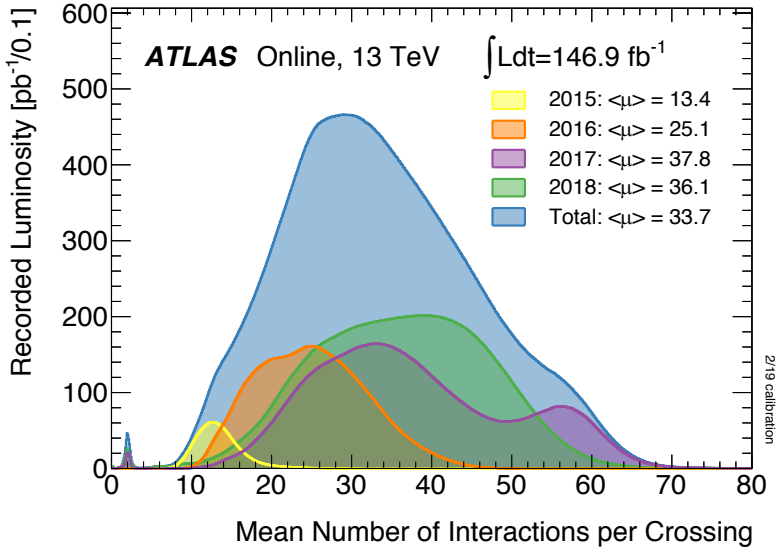


Introduction

The ATLAS detector

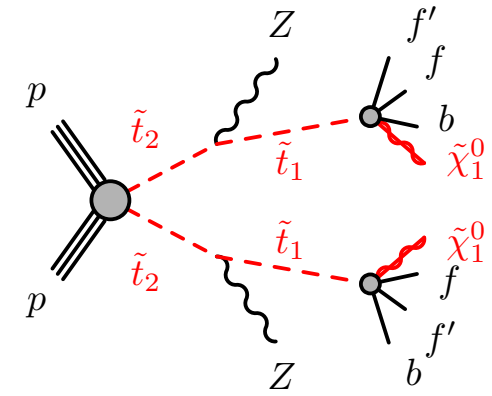
- Fantastic performance of both the LHC and the ATLAS detector for Run 2
- 139 fb^{-1} of data collected, good for physics analysis, with an excellent data taking efficiency of > 95%
- Total average number of interactions per bunch crossing of 33.7

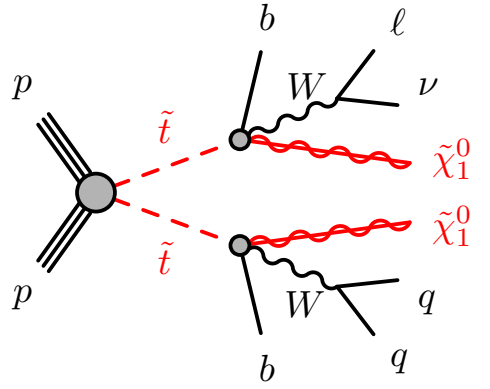


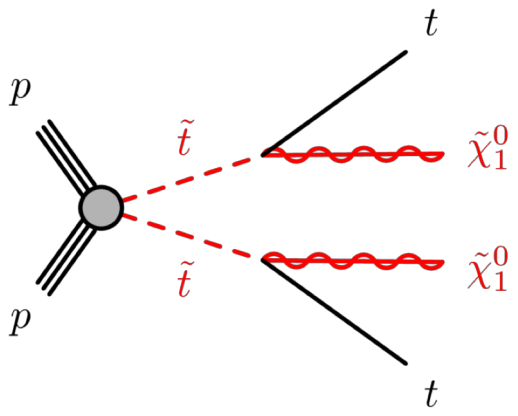


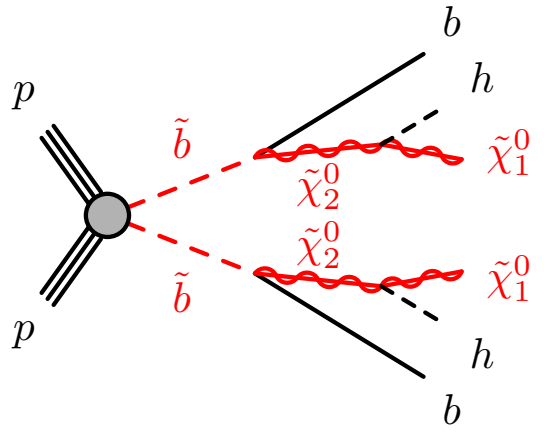
Overview

- Many new results focusing on complex sparticle decays, investigating difficult regions of the SUSY phase space, and reinterpreting SM measurements
- Search for top squarks in events with a Z-boson (139fb^{-1})
- Search for 3-body decays of top squark pairs (139fb^{-1})
- Measurement of top-quark pair spin correlations (36.1fb^{-1})
- Search for bottom squarks in final states containing Higgs bosons (139fb^{-1})









Search for top squarks in events with a Z-boson

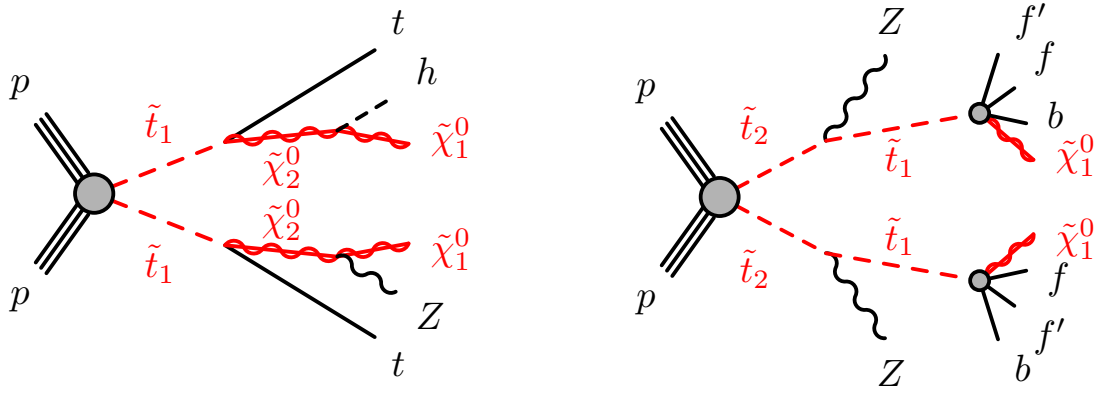
Signal model targeted

ATLAS-CONF-2019-016

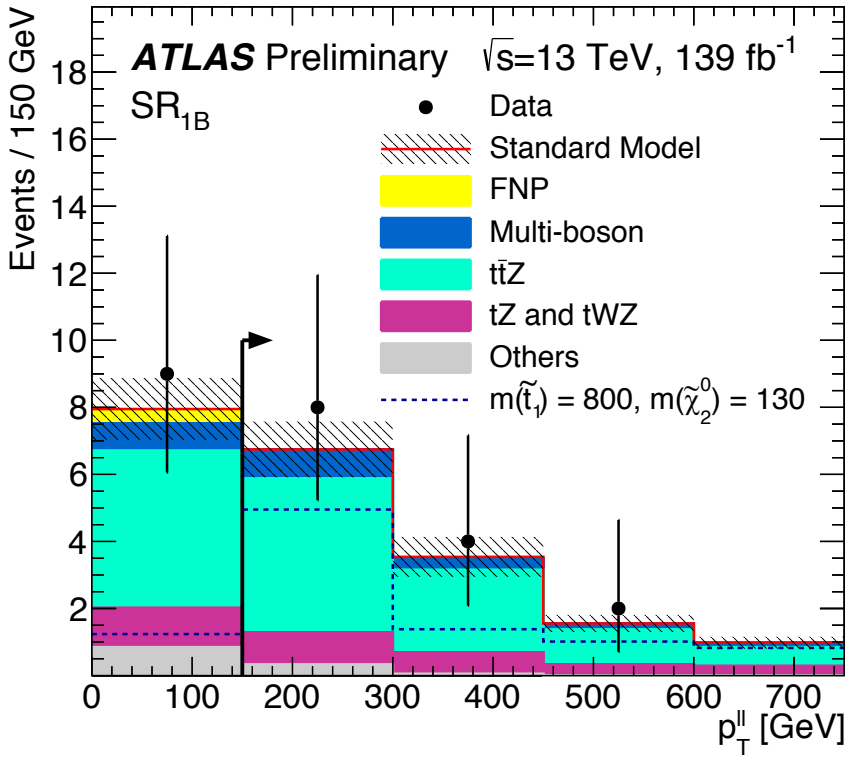
- Search for top squarks in final states containing at least one Z-boson
- Two scenarios considered,

  $\tilde{t}_1 \rightarrow t\tilde{\chi}_2^0$ with, $\tilde{\chi}_2^0 \rightarrow Z/h\tilde{\chi}_1^0$

  $\tilde{t}_2 \rightarrow Z\tilde{t}_1$ with, $\tilde{t}_1 \rightarrow bff'\tilde{\chi}_1^0$, a new signature for ATLAS



- Final states with at least 3 leptons, containing a same-flavour opposite sign (SFOS) lepton pair in the Z-mass window



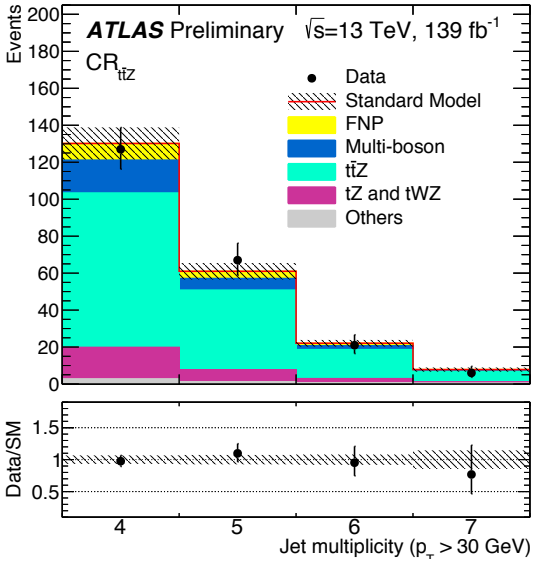
- SR_{1A} & SR_{1B}: $\tilde{t}_1$ model with either large (1A) or small (1B) $\Delta m(\tilde{\chi}_2^0, \tilde{\chi}_1^0)$
  - Requiring many jets, and at least one b-jet
- SR_{2A} & SR_{2B}: $\tilde{t}_2$ model with large (2A) or small (2B) $\Delta m(\tilde{\chi}_2^0, \tilde{\chi}_1^0)$
  - Requiring looser jet and, b-jet requirements, but high E_T^{miss}

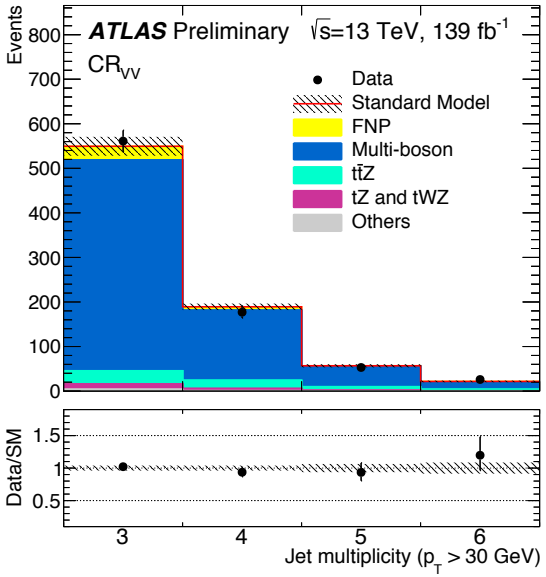
Search for top squarks in events with a Z-boson

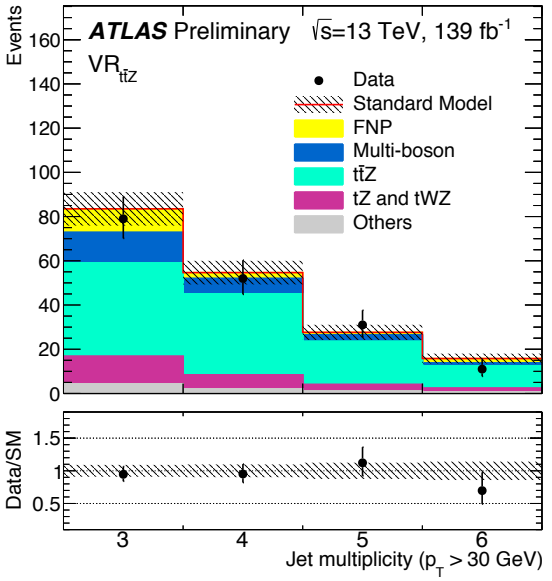
Background estimation

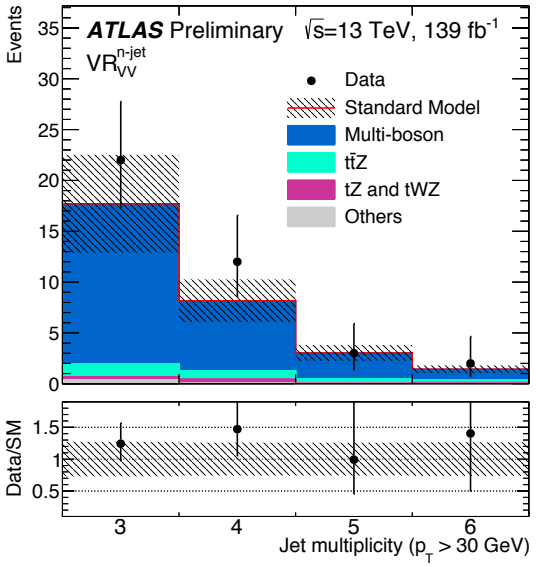
ATLAS-CONF-2019-016

- The dominant backgrounds for all regions of the analysis are $t\bar{t}Z$ and multi-boson production (predominantly WZ) with additional contributions from fake and non-prompt (FNP) leptons
- The dominant backgrounds are estimated in dedicated CRs (orthogonal to the SRs due to either the b-jet multiplicity, E_T^{miss} or lepton p_T requirements) and validated in orthogonal VRs
- The FNP background is estimated using the matrix method, and validated in dedicated VRs.
- The main systematic uncertainties arise from the modelling of the $t\bar{t}Z$ and diboson backgrounds









Search for top squarks in events with a Z-boson

Results

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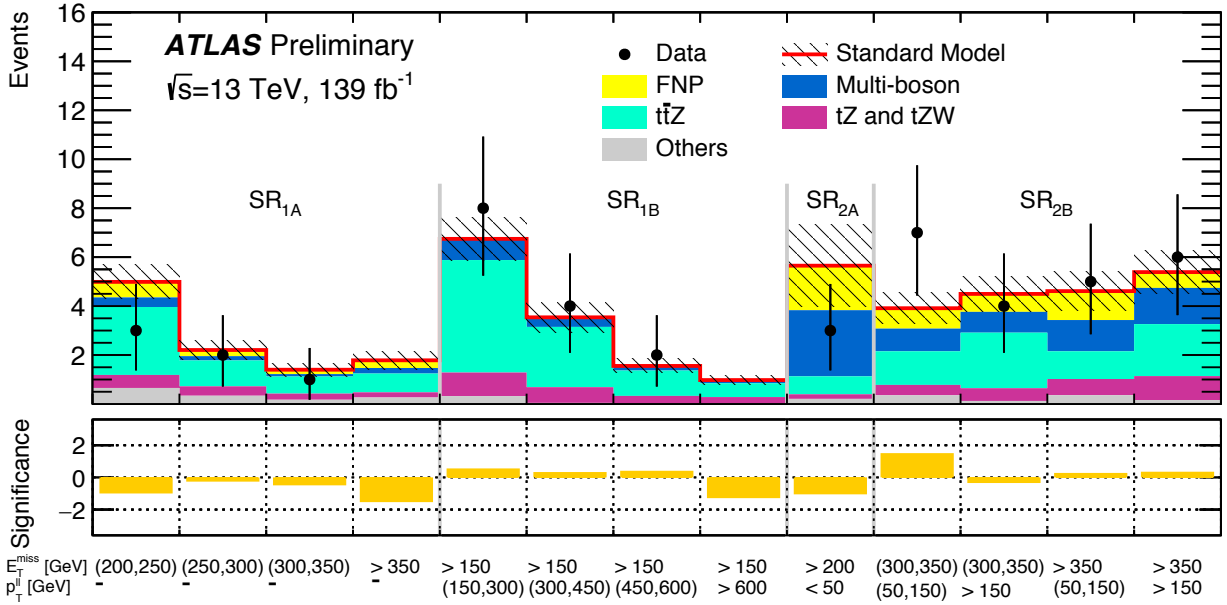
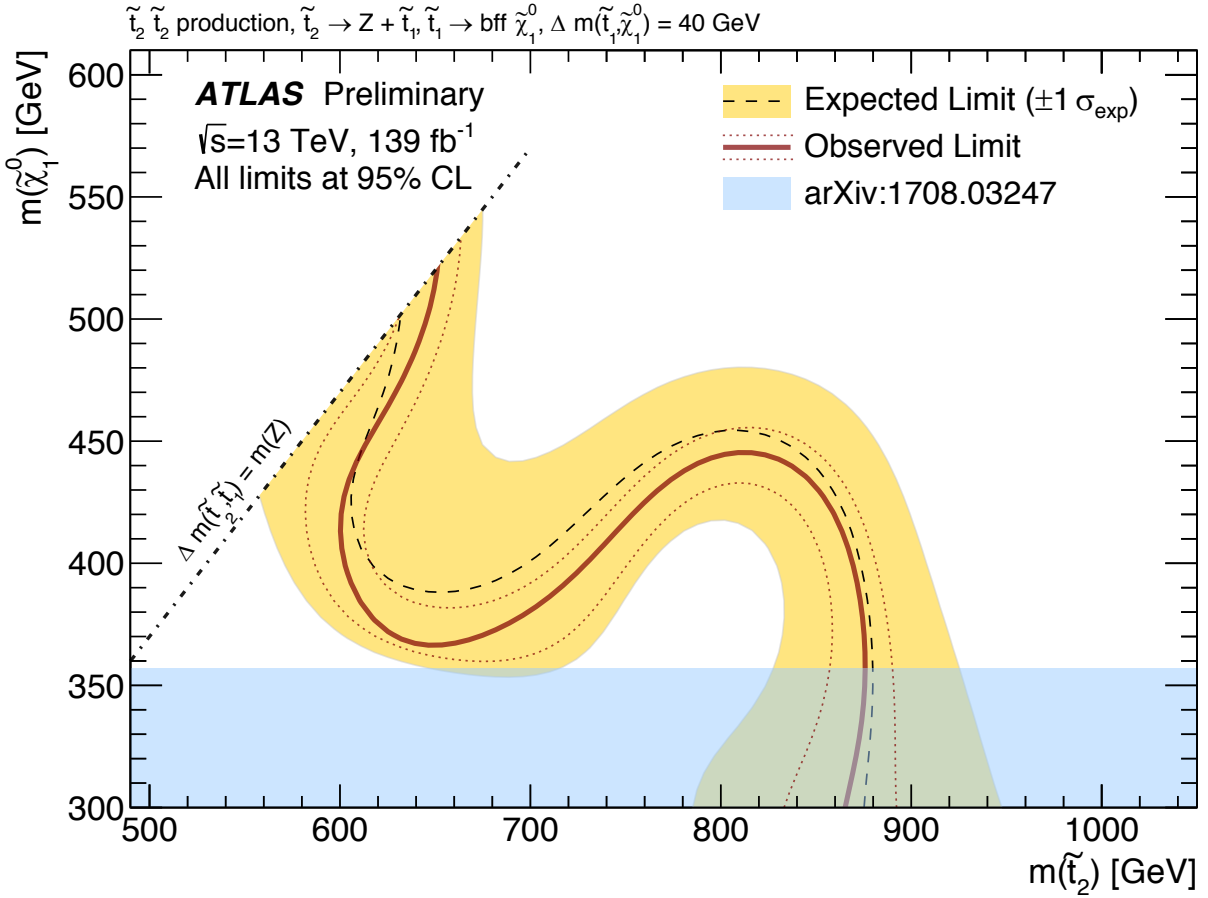
- No significant excesses are found in any of the SRs, and 95% CL limits are placed in both of the signal scenarios considered



- In the $\tilde{t}_1$ scenario the exclusion is up to 1.1TeV depending upon the mass hierarchy considered.

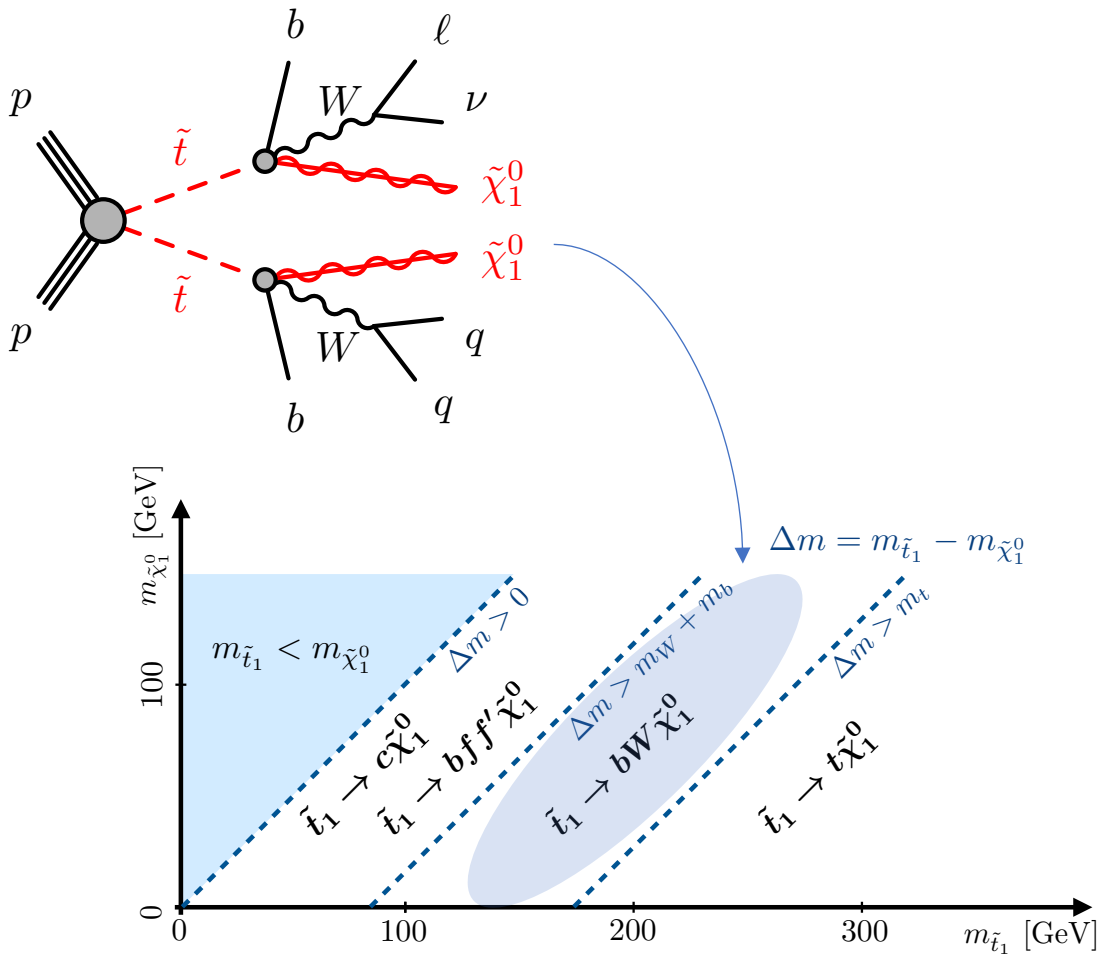


Search for 3-body decays of top squark pairs

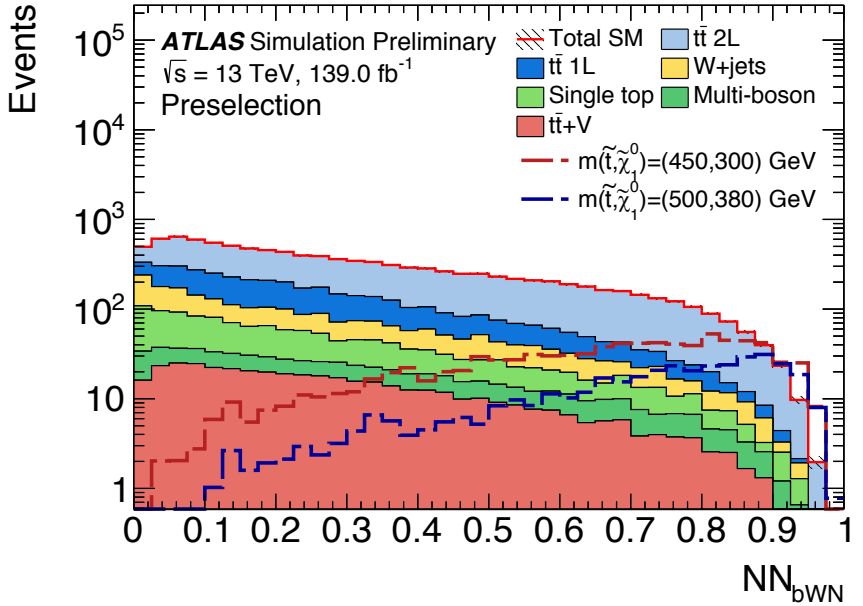
Signal model targeted

ATLAS-CONF-2019-017

- Search for top squarks ($\tilde{t}_1 \rightarrow t\tilde{\chi}_1^0$) in final states with 1 lepton multiple jets and large E_T^{miss}



- A ML technique was developed to distinguish the top squark signal from the $t\bar{t}$ background



- The NN uses 13 inputs (such as: n_{jets}, $n_{b\text{-}jets}$, m_T, m_{bl}^{min}...) to define the discriminator.

- The SR defined as a 1L high E_T^{miss} region, with many (≥ 4) jets, at least 1 b-jet and a selection on the output discriminator

Search for 3-body decays of top squark pairs

Background estimation

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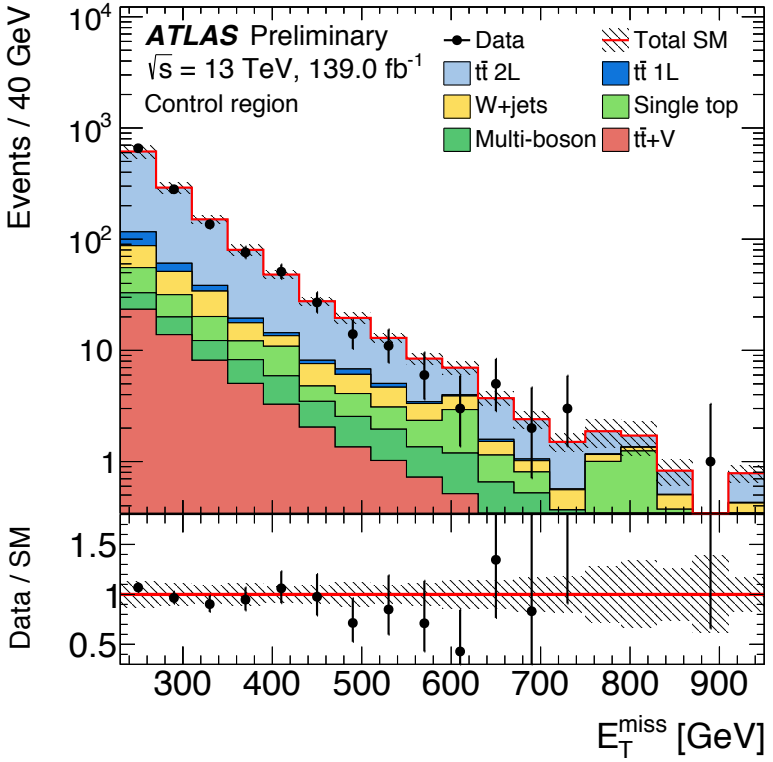

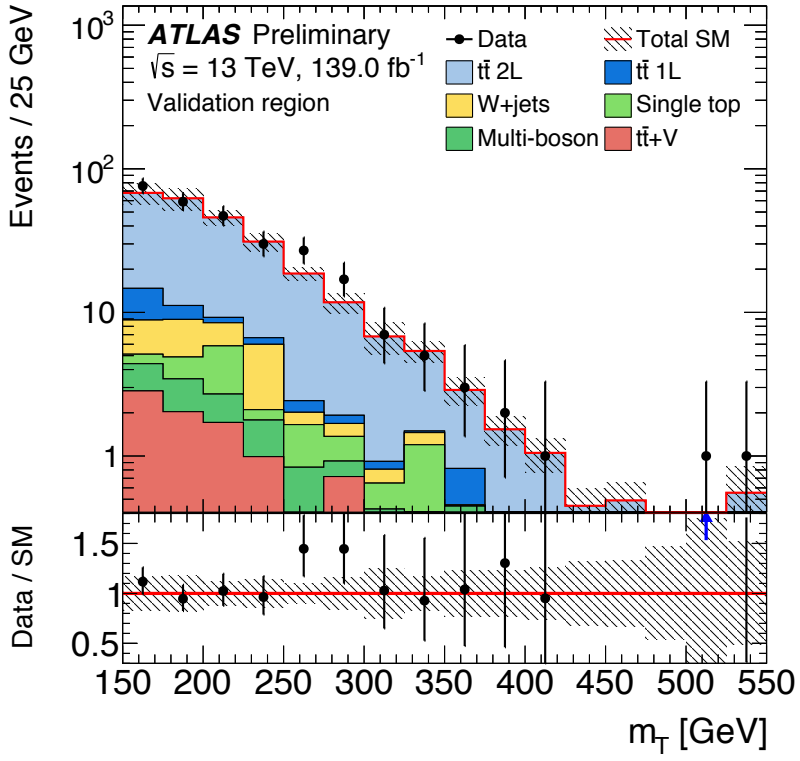

- The main background is di-leptonic $t\bar{t}$ where one lepton is "lost" (not reconstructed/identified) or a tau-lepton is present in one branch of the $t\bar{t}$ decay
- The background is estimated in a 1L CR, orthogonal to the SR due to the selection on the NN discriminator, and the modelling is validated in a VR, which is also orthogonal due to the selection on the discriminator
- The modelling of the $t\bar{t}$ background is the main uncertainty

Search for 3-body decays of top squark pairs

Results

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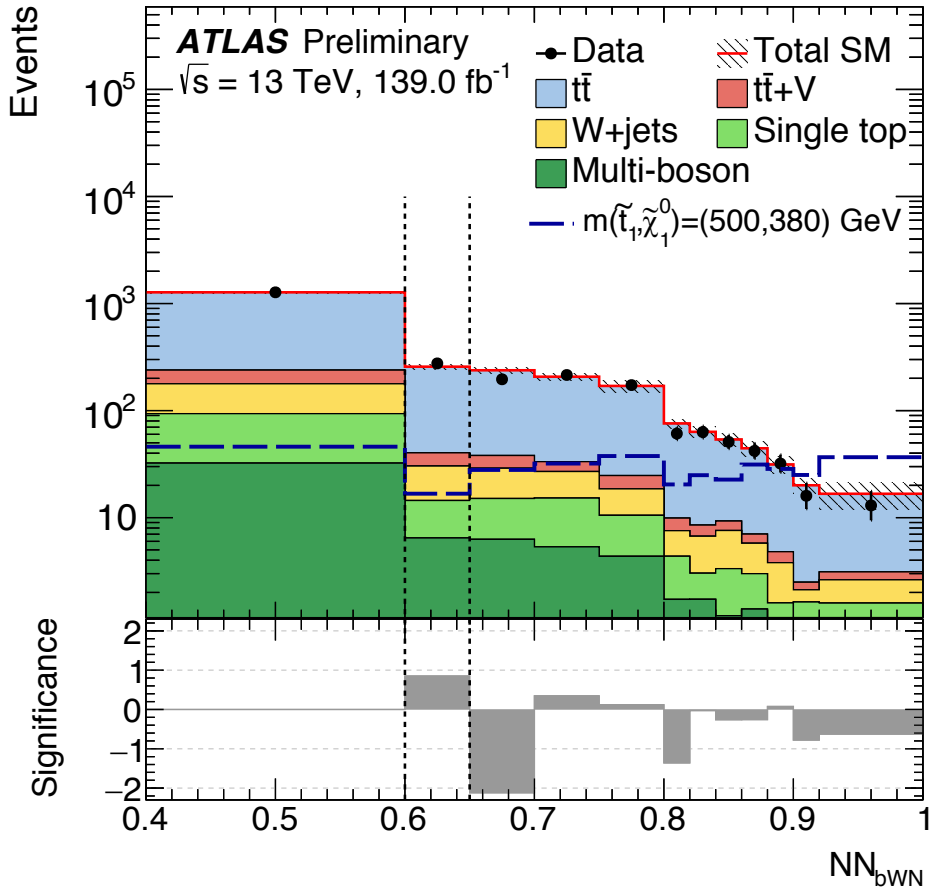
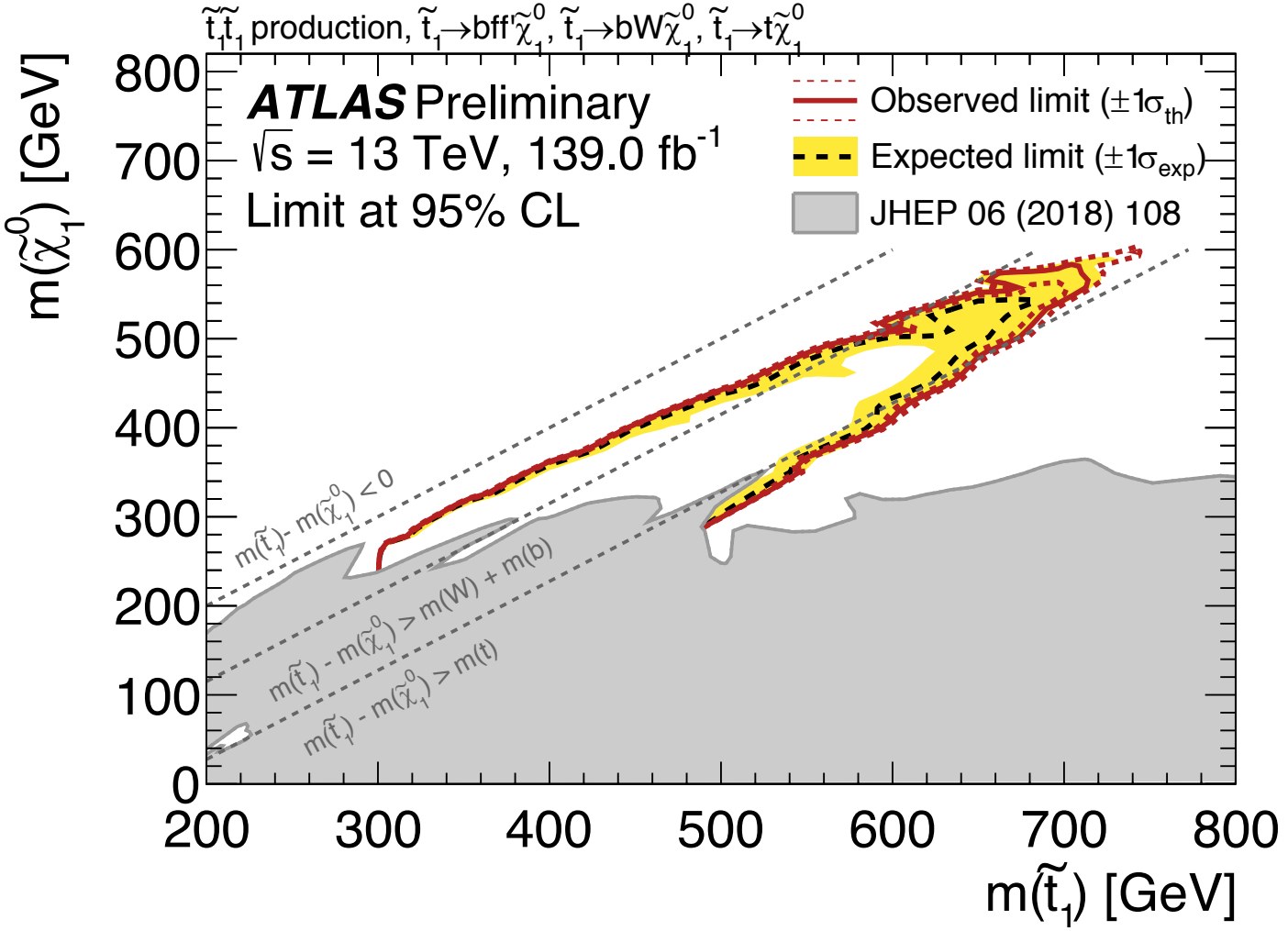
- No excesses above the post-fit background expectation are found. When performing the exclusion fit a multi-bin fit is used, with 10 bins for NN discriminator values between [0.65:1]



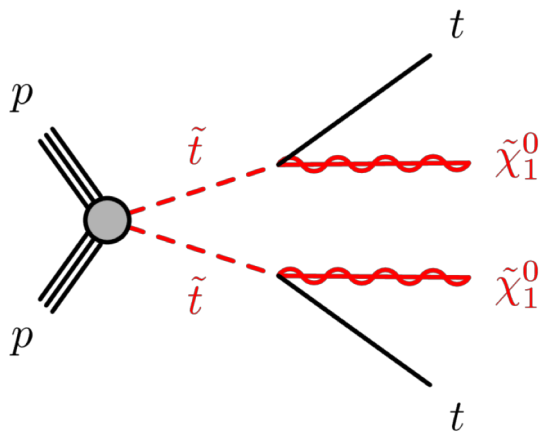


Measurement of top-quark pair spin correlations

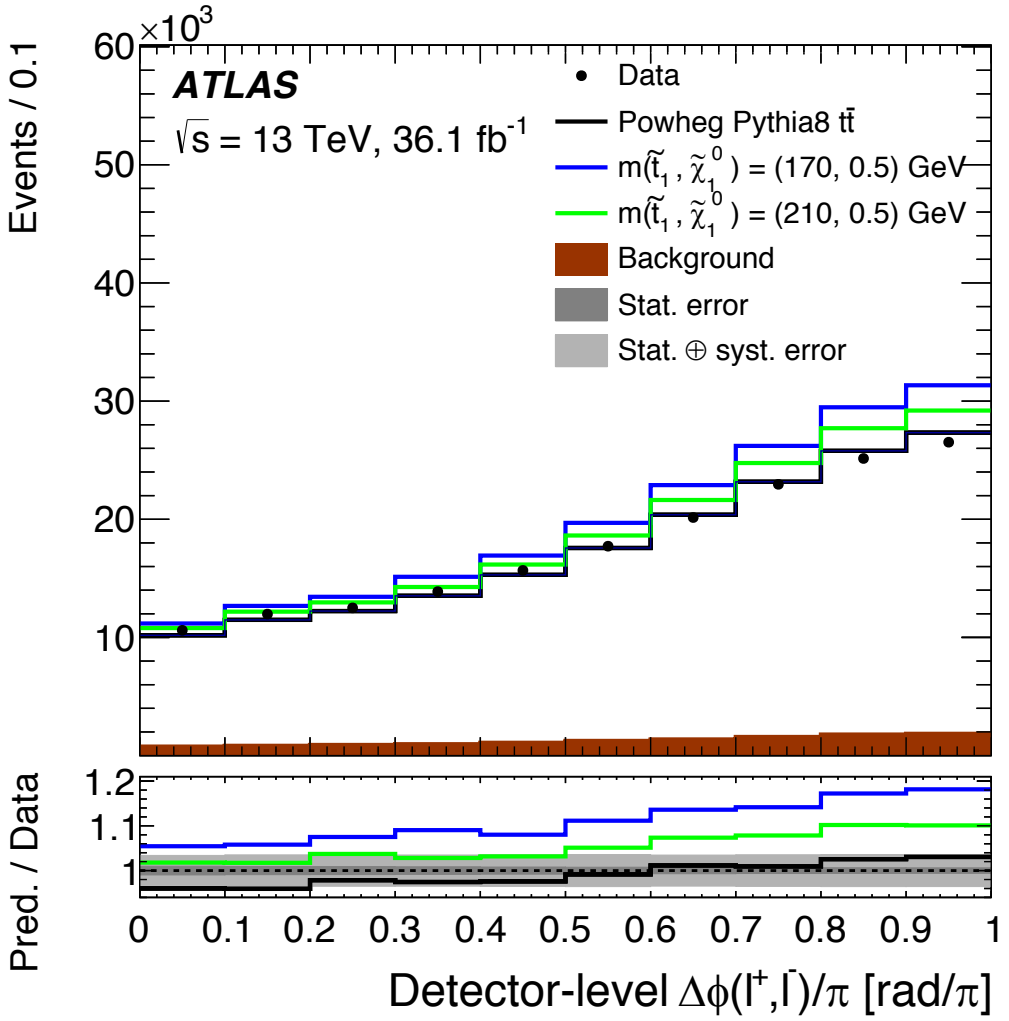
Signal model targeted

arXiv:1903.07570

- Reinterpretation of the SM dileptonic $t\bar{t}$ spin correlation measurement (36.1fb-1) in the context of $\tilde{t}_1 \rightarrow t\tilde{\chi}_1^0$ decays
- Targets the uncovered region of the simplified model phase space, with small $\Delta m(\tilde{t}_1, \tilde{\chi}_1^0)$ and $m(\tilde{t}_1) \sim m(t)$



- For top-pair production, the leptons contain the parent spin information and are correlated
- For top squark pair production there is no correlation between the decay products

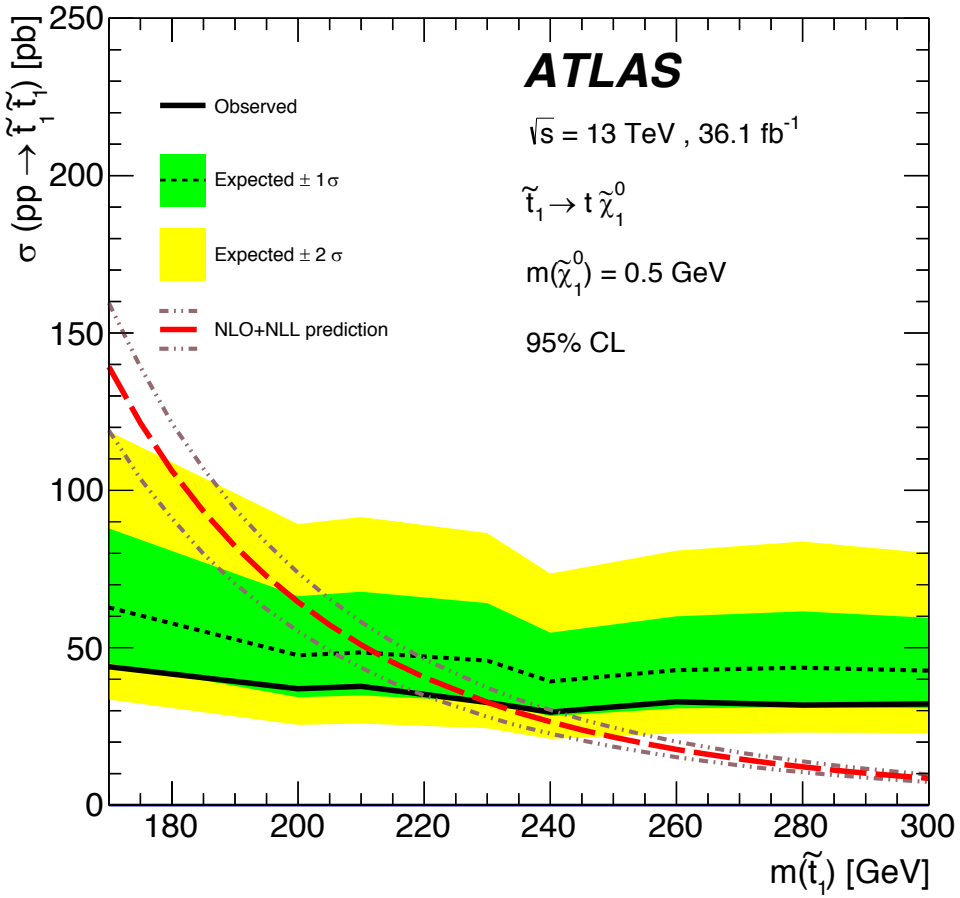


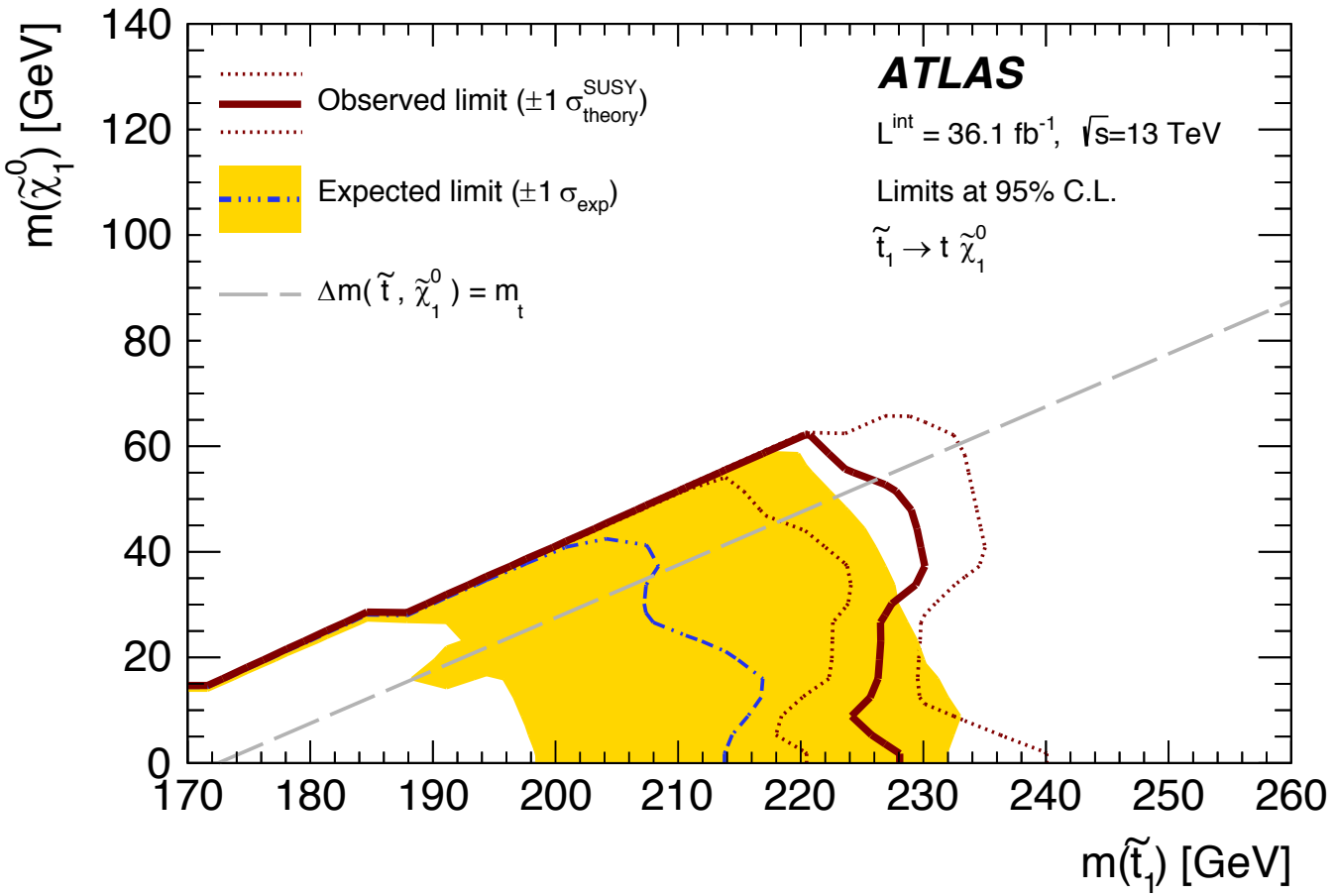
Measurement of top-quark pair spin correlations

Results

arXiv:1903.07570

- A 2D fit is performed in $\Delta\phi$ and $\Delta\eta$, allowing both the SM $t\bar{t}$ prediction and the SUSY signal strength parameters to vary to fit the observed data



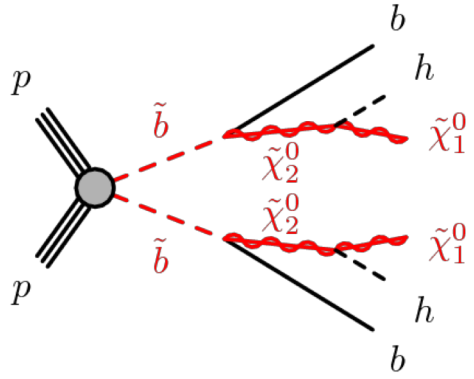


Search for bottom squarks in final states containing Higgs bosons

Signal model targeted

ATLAS-CONF-2019-011

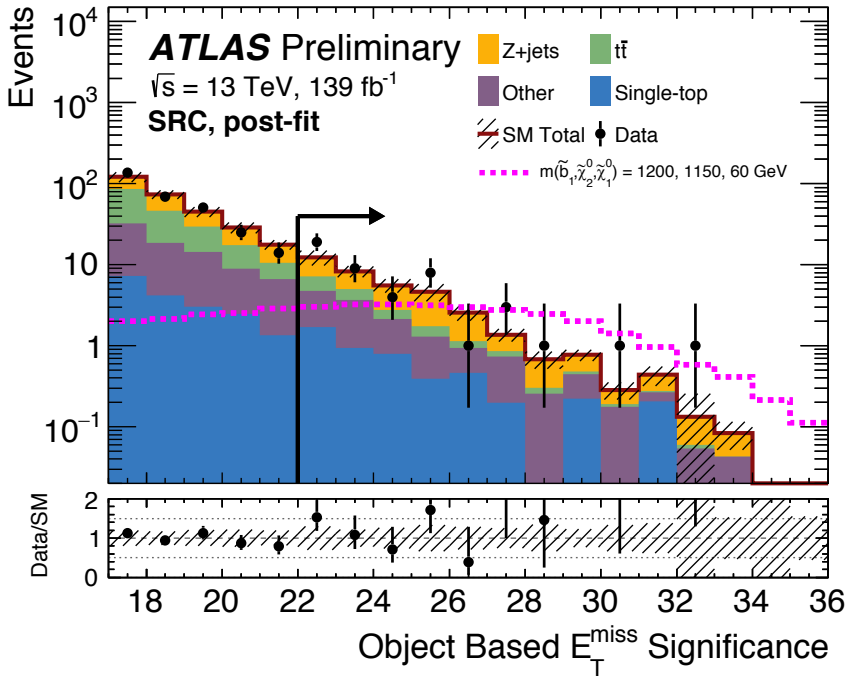
- Search for bottom squark production with Higgs bosons in the final states, $\tilde{b}_1 \rightarrow b\tilde{\chi}_2^0$ with $\tilde{\chi}_2^0 \rightarrow h\tilde{\chi}_1^0$



- Two mass hierarchy assumptions are considered, either: $\Delta m(\tilde{\chi}_2^0, \tilde{\chi}_1^0)$=130GeV or $m(\tilde{\chi}_1^0)$=60GeV

- Final states containing 0L, large E_T^{miss}, high jet and high b-jet multiplicity are considered

- SRA – large $\Delta m(\tilde{b}_1, \tilde{\chi}_2^0)$ in both mass scenarios.
- SRB – small $\Delta m(\tilde{b}_1, \tilde{\chi}_2^0)$ in the $\Delta m(\tilde{\chi}_2^0, \tilde{\chi}_1^0)$=130GeV scenario
- SRC – small $\Delta m(\tilde{b}_1, \tilde{\chi}_2^0)$ in the $m(\tilde{\chi}_1^0)$=60GeV scenario
- Depending upon the SR, either higgs reconstruction algorithms, m_{eff}, or the Object-based E_T^{miss} significance are used.

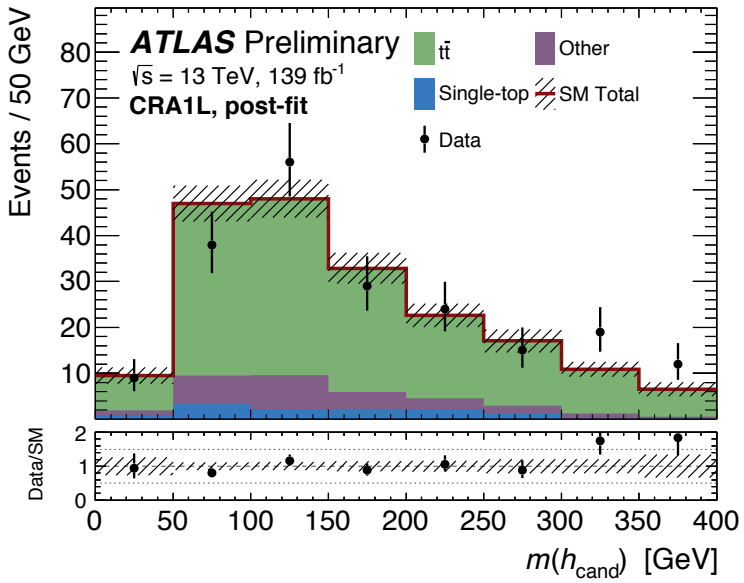


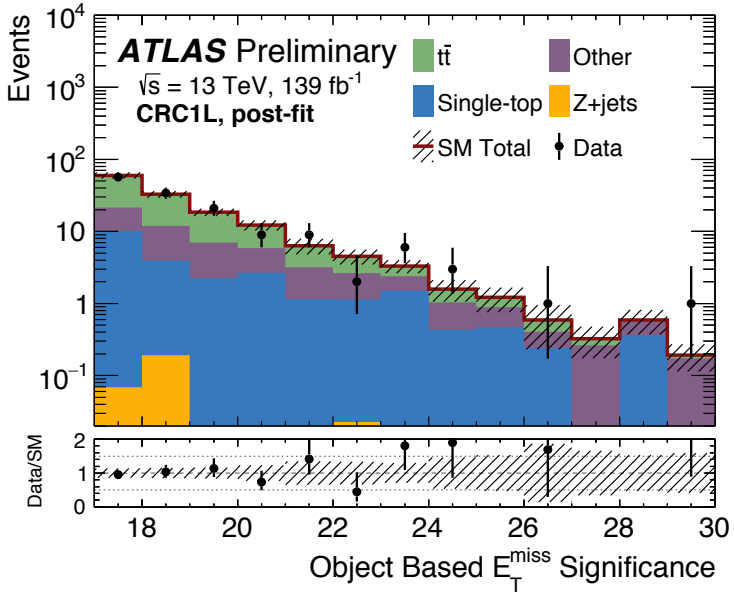
Search for bottom squarks in final states containing Higgs bosons

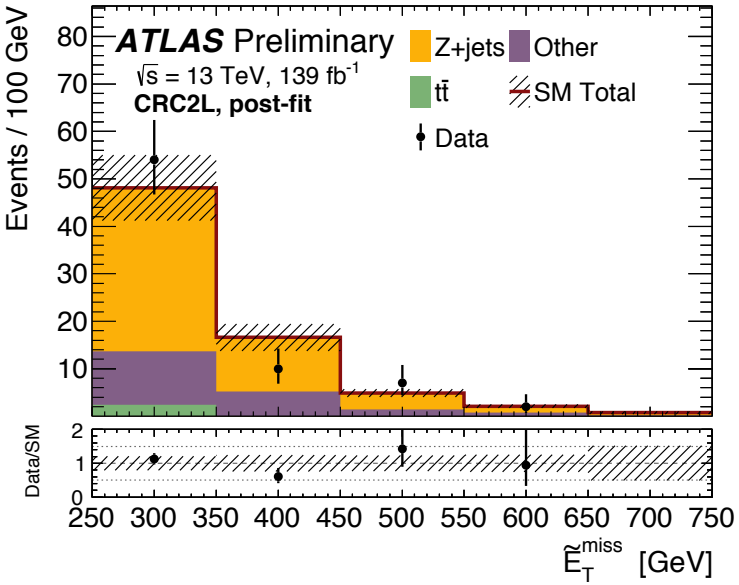
Background estimation

ATLAS-CONF-2019-011

- The main background in the SRA and B regions is $t\bar{t}$ pair production, whilst in the SRC the main background is Z+jets with a sub-dominant contribution from $t\bar{t}$







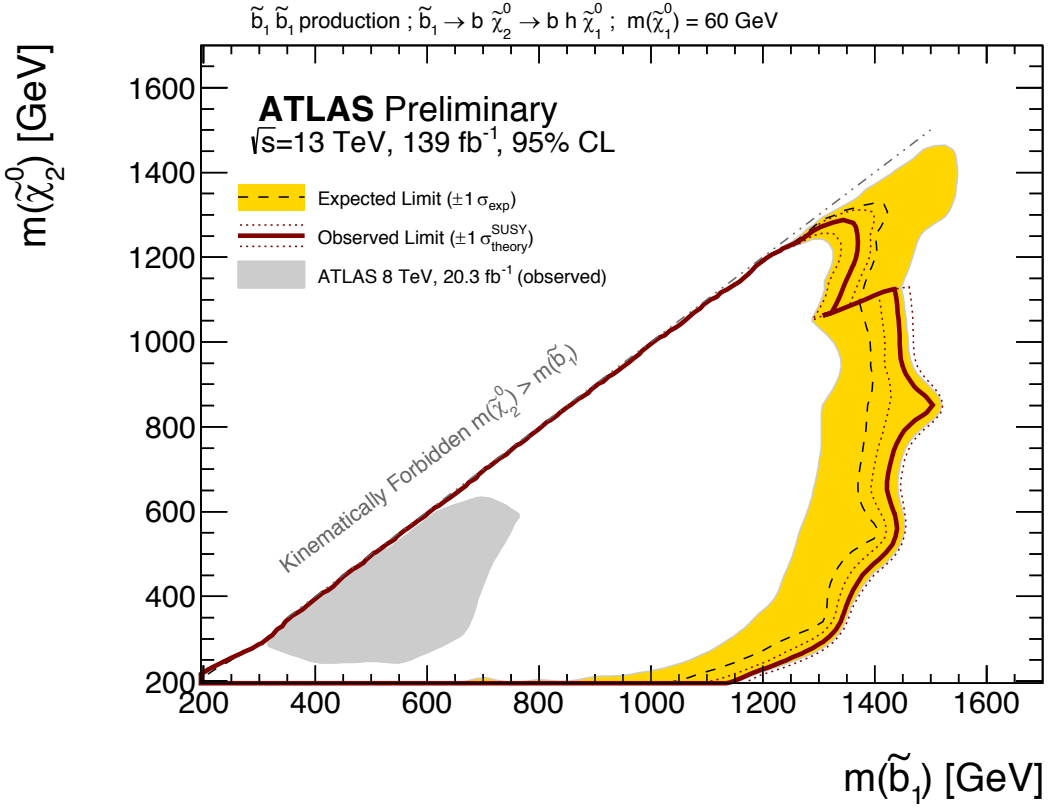
- Three $t\bar{t}$ CRs are defined, orthogonal to the SRs due to the lepton multiplicity selection
- One Z+jets CR is defined, again orthogonal to the SRs due to the 2-lepton selection used
- The background modelling is subsequently validated in 0L VRs.

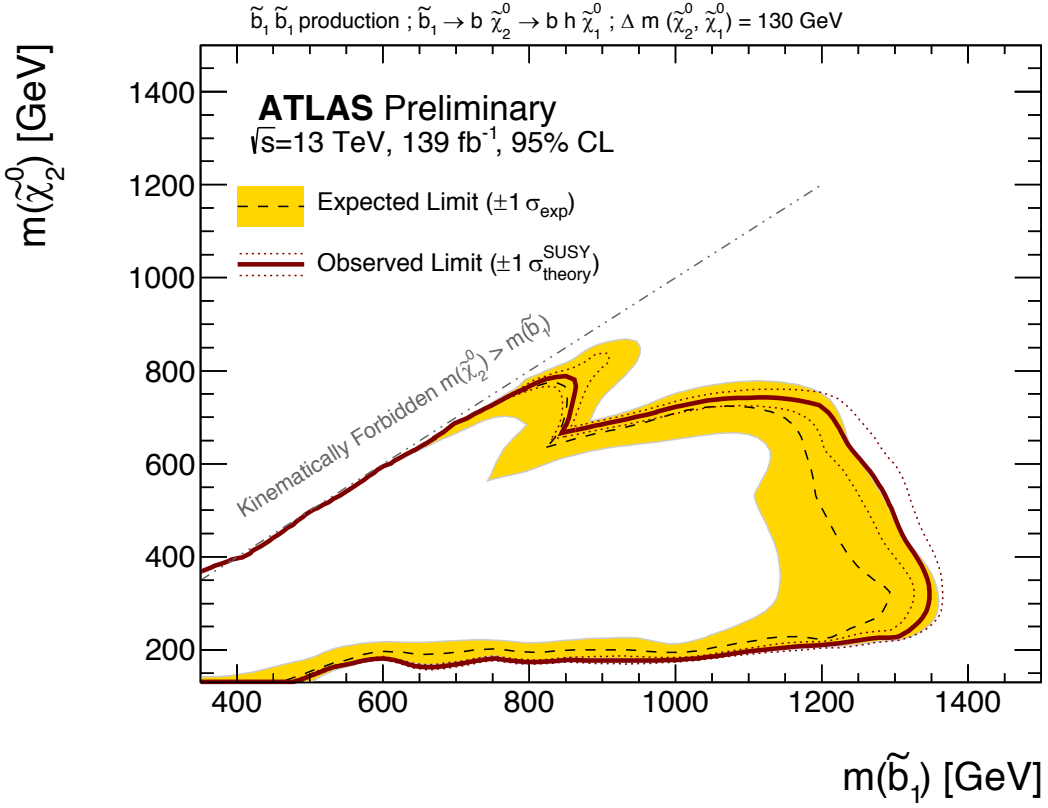
Search for bottom squarks in final states containing Higgs bosons

Results

ATLAS-CONF-2019-011

- No significant excesses over the post-fit SM expectations are found
- A multi-bin fit is performed in bins of the m_{eff} variable for the SRA region, and in bins of the E_T^{miss} significance variable for the SRC region
- The main uncertainty arises from the modelling of the $t\bar{t}$, and Z+jets backgrounds

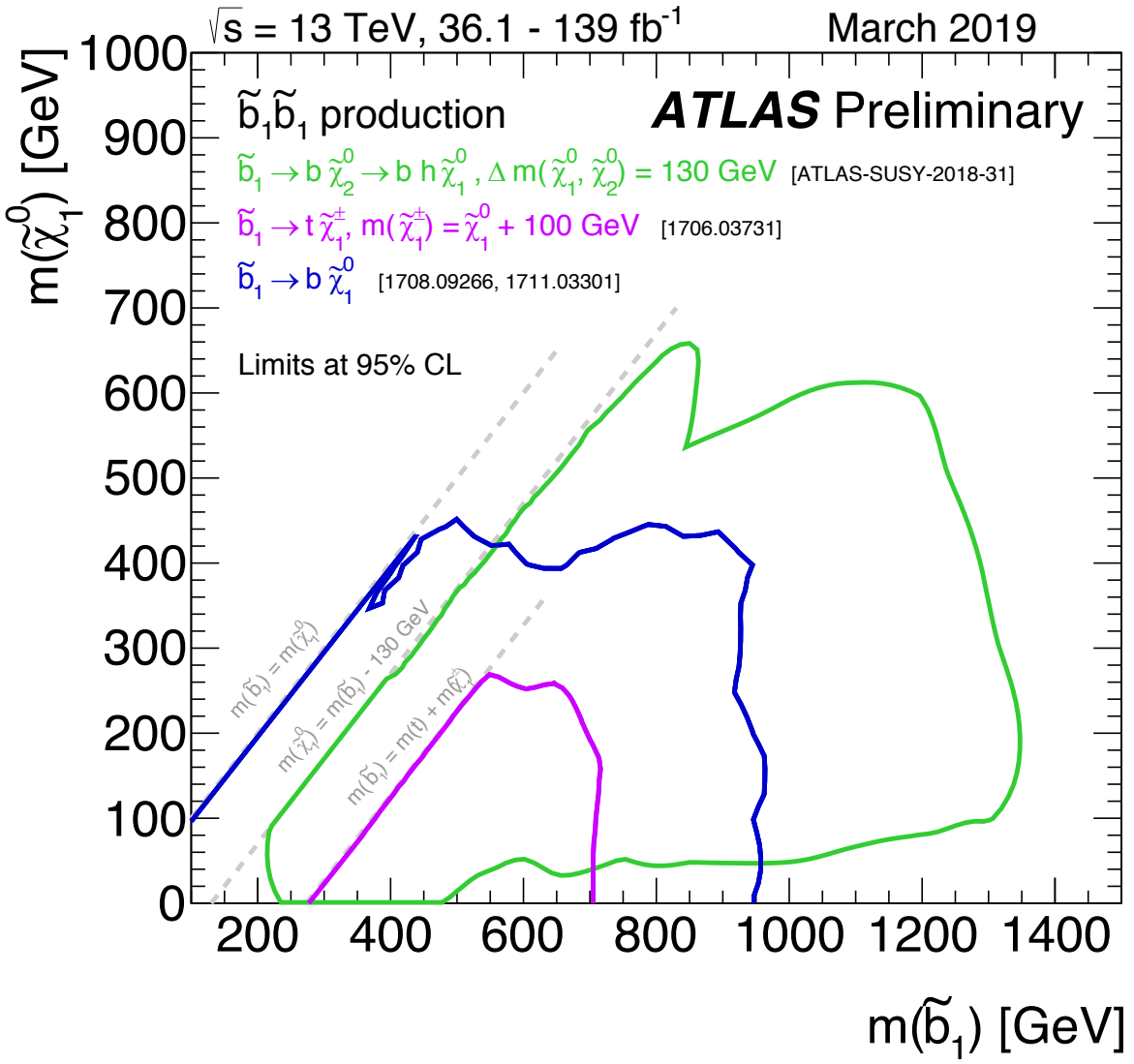




Conclusion

Summary

- Presented a first look at the most recent full Run 2 3G SUSY results from ATLAS
- Unfortunately, no significant excesses above the SM yet!
- However many other searches are currently in progress and are approaching completion
- Stay tuned!



Appendix

Search for top squarks in events with a Z-boson

Results

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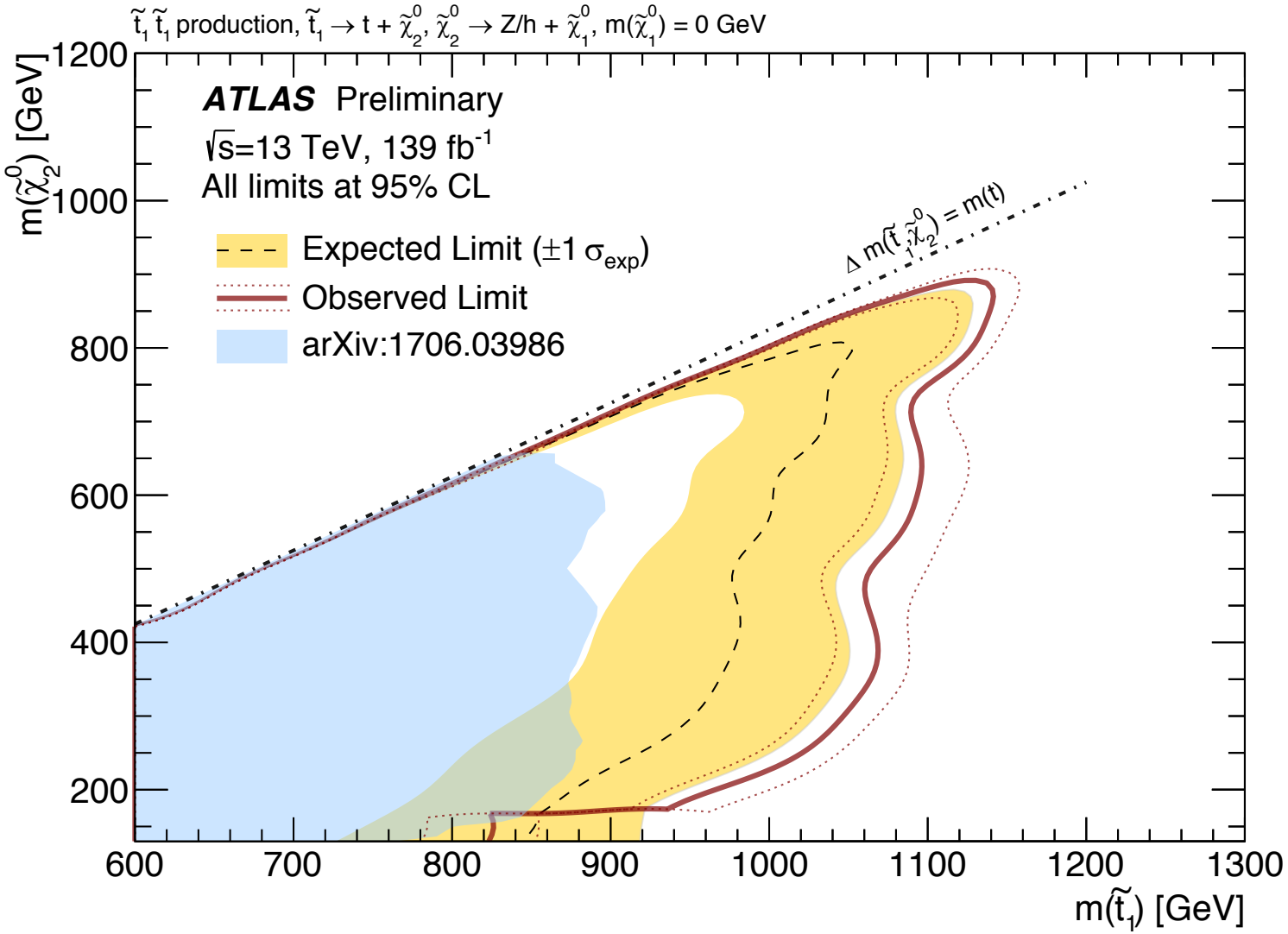

Measurement of top-quark pair spin correlations

SM-Only Fit

arXiv:1903.07570