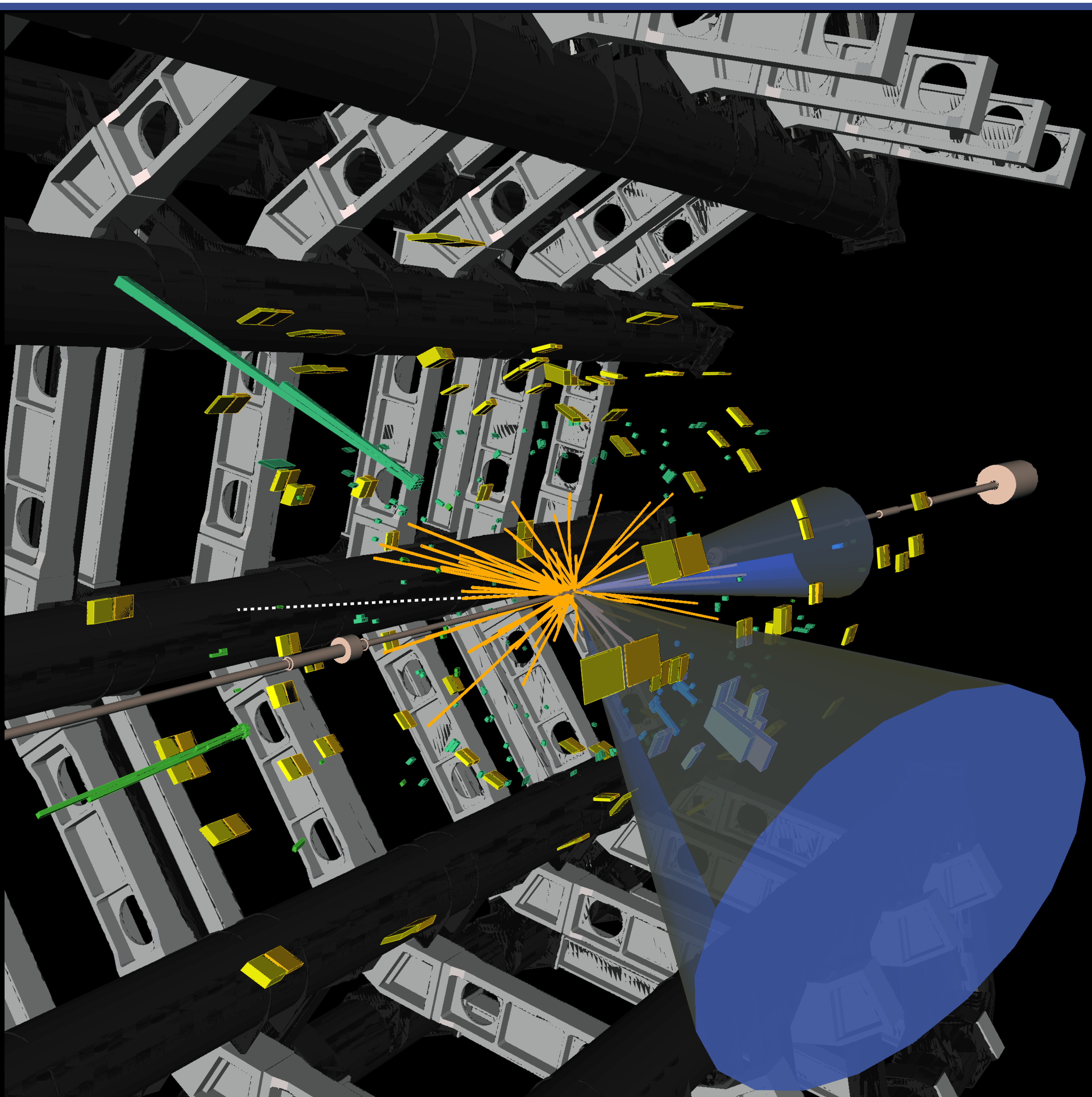
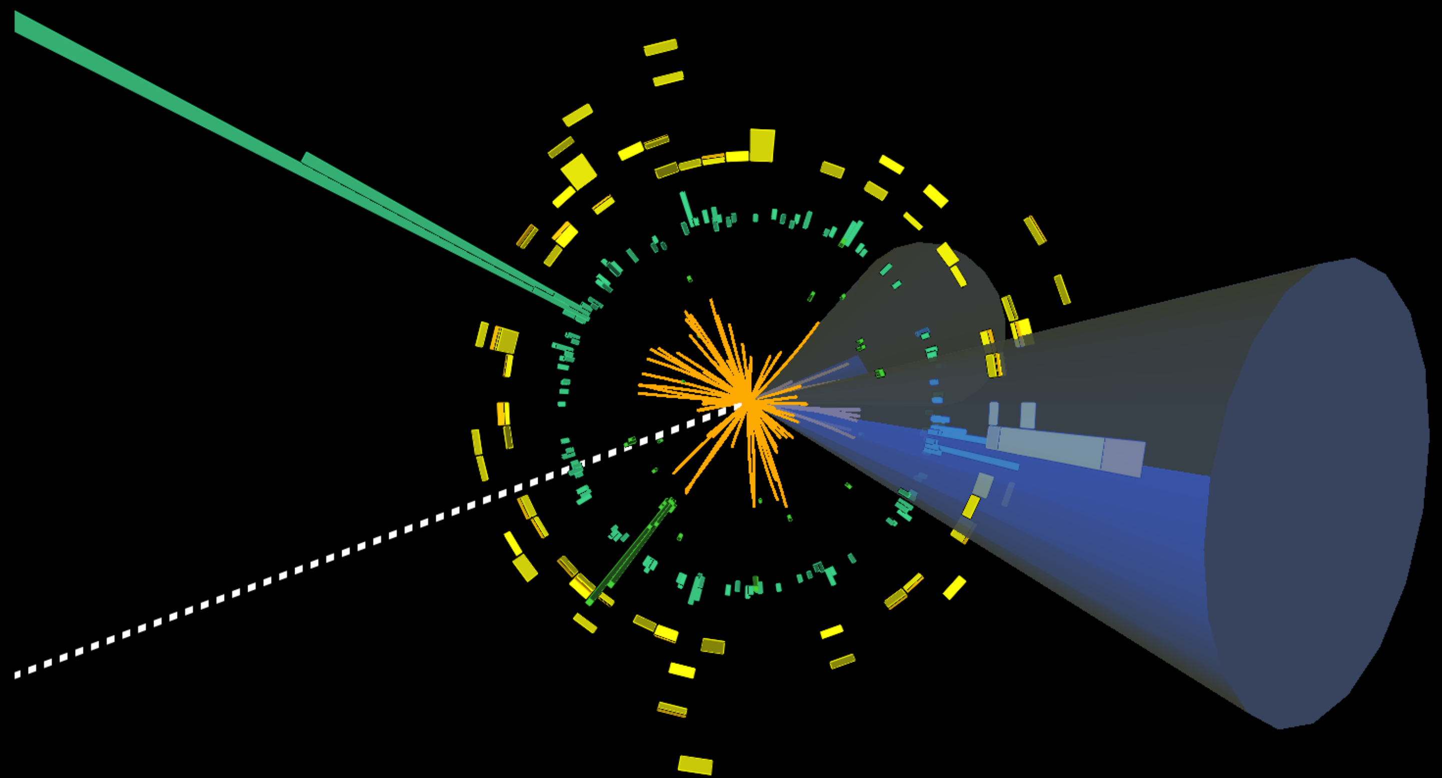
Recent results on SUSY searches in ATLAS





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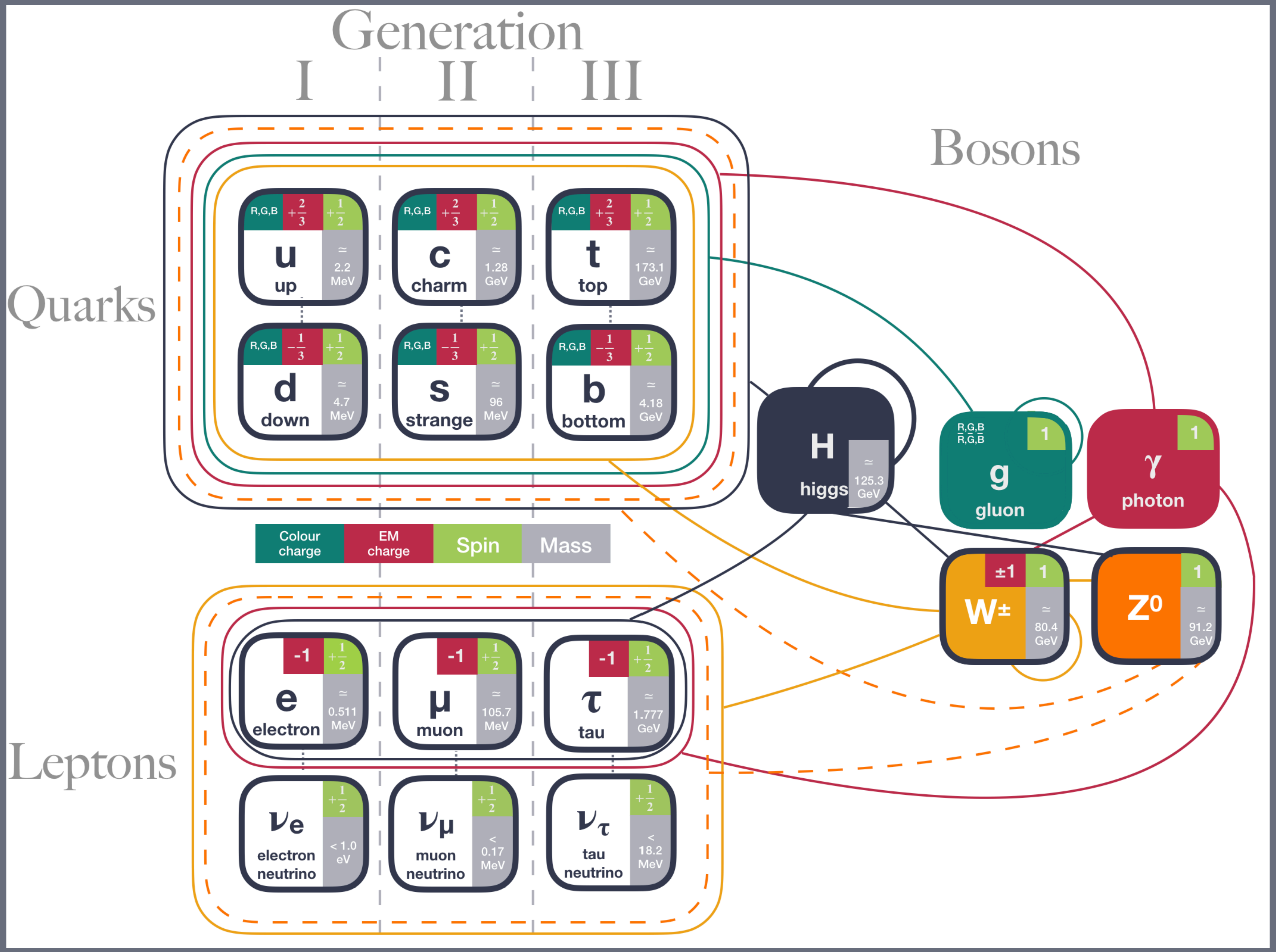
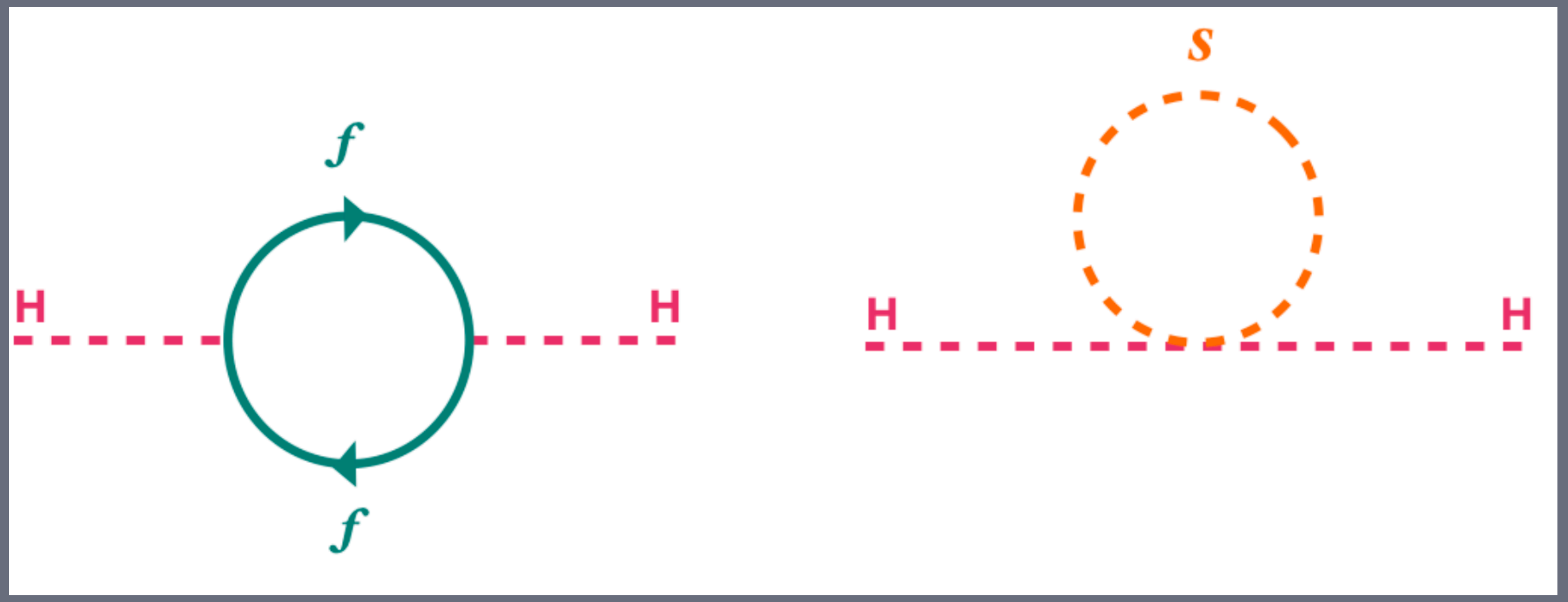
BEACH 2024

Super Symmetry



SUSY

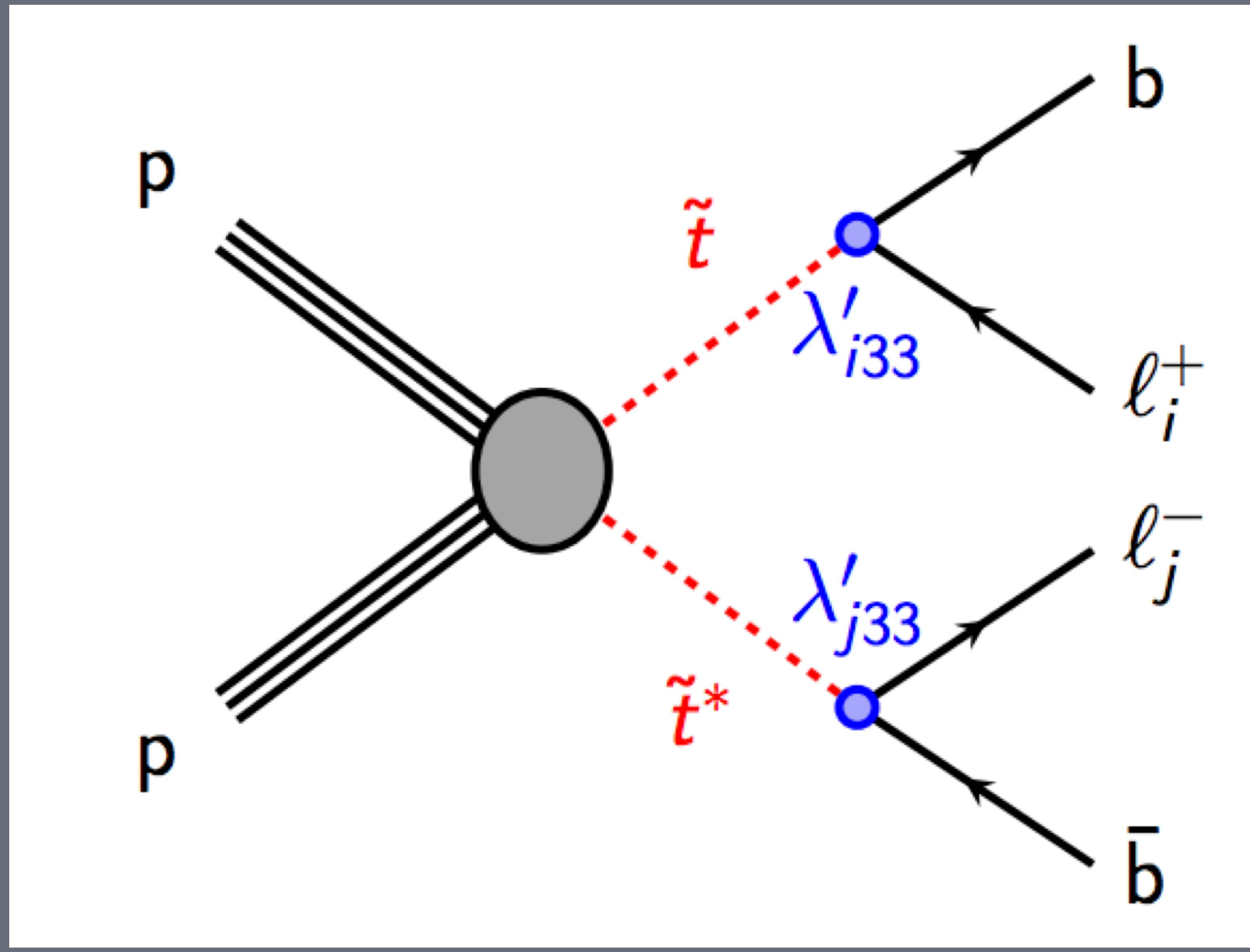
All SM particles have a Supersymmetric particle partner which has spin different by half an integer and a larger mass



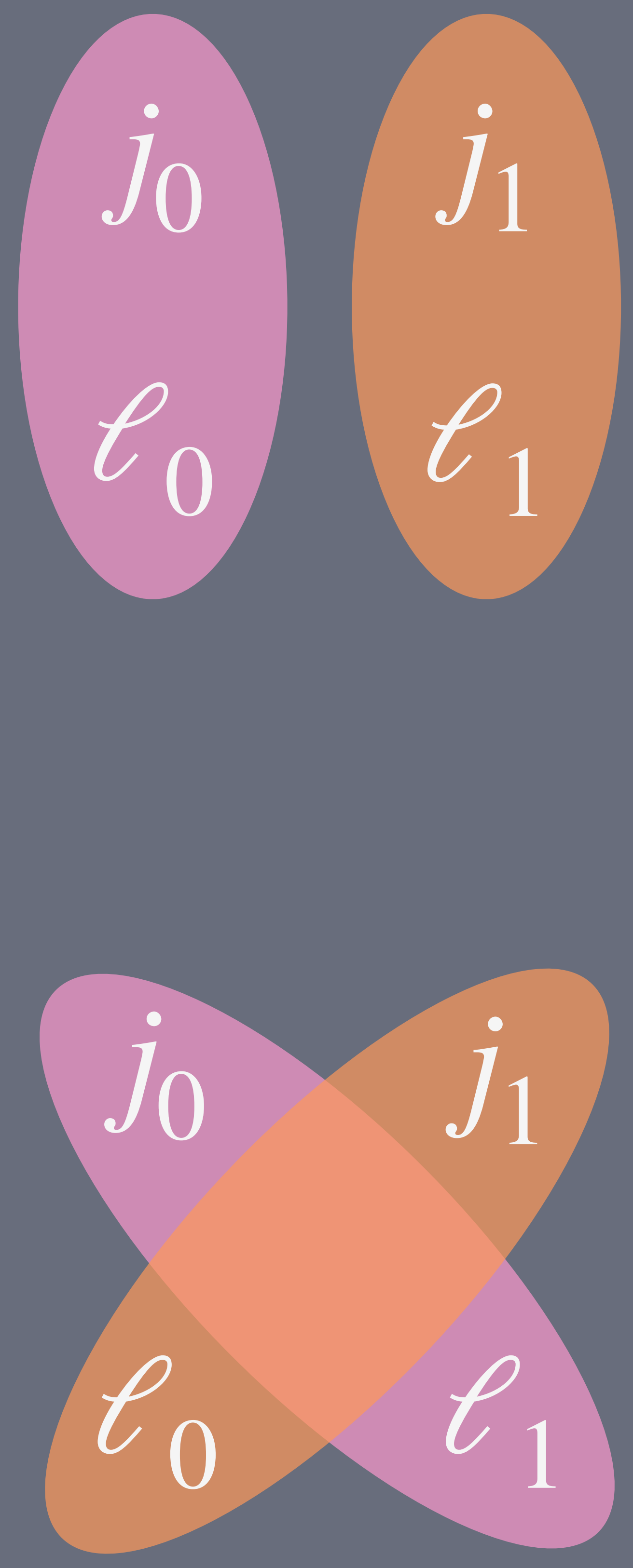
However illusive SUSY insists on being it is an elegant model that could solve many of the unanswered questions in the SM, such as the hierarchy problem and can provide a viable dark matter candidate.

Search for RPV SUSY - stop to b jet and lepton **NEW!** SUSY-2018-37

Number of b-tagged jets ≥ 1



2 opposite sign leptons e/μ



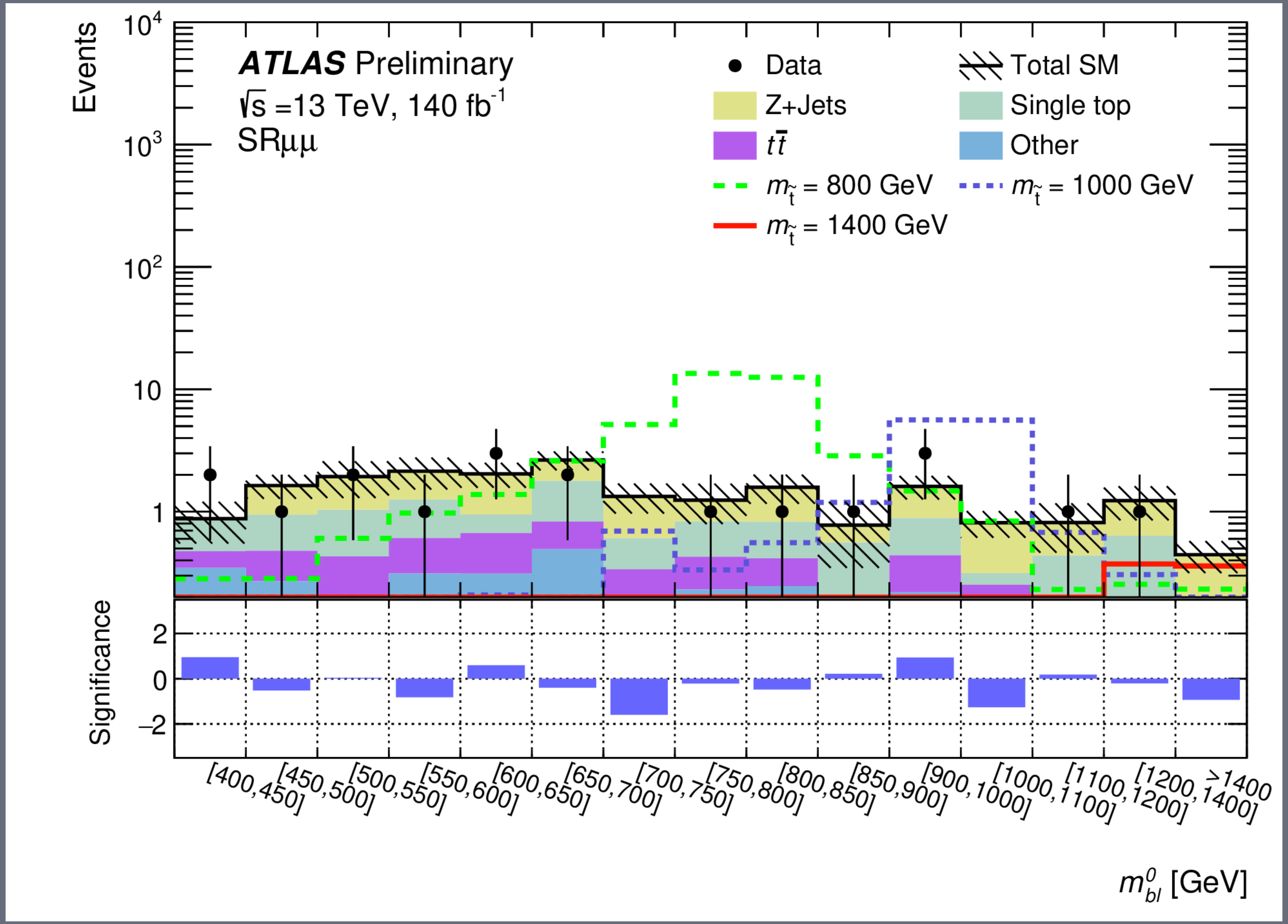
$m_{b\ell}$ asymmetry

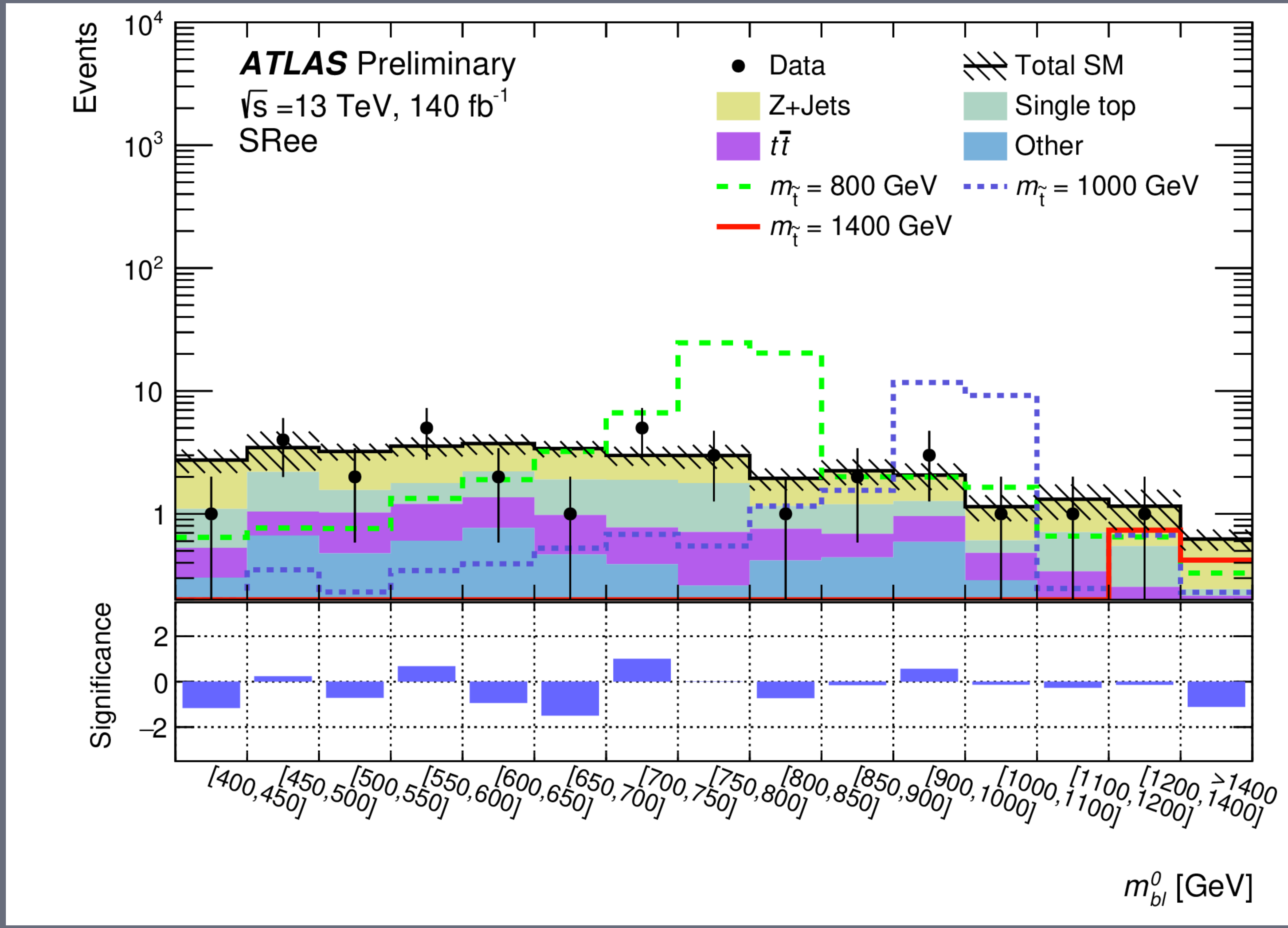
$$\frac{m_{b\ell}^0 - m_{b\ell}^1}{m_{b\ell}^0 + m_{b\ell}^1}$$

Search for RPV SUSY - stop to b jet and lepton

SUSY-2018-37

Dominant backgrounds are: ttbar, single top and Z + jets

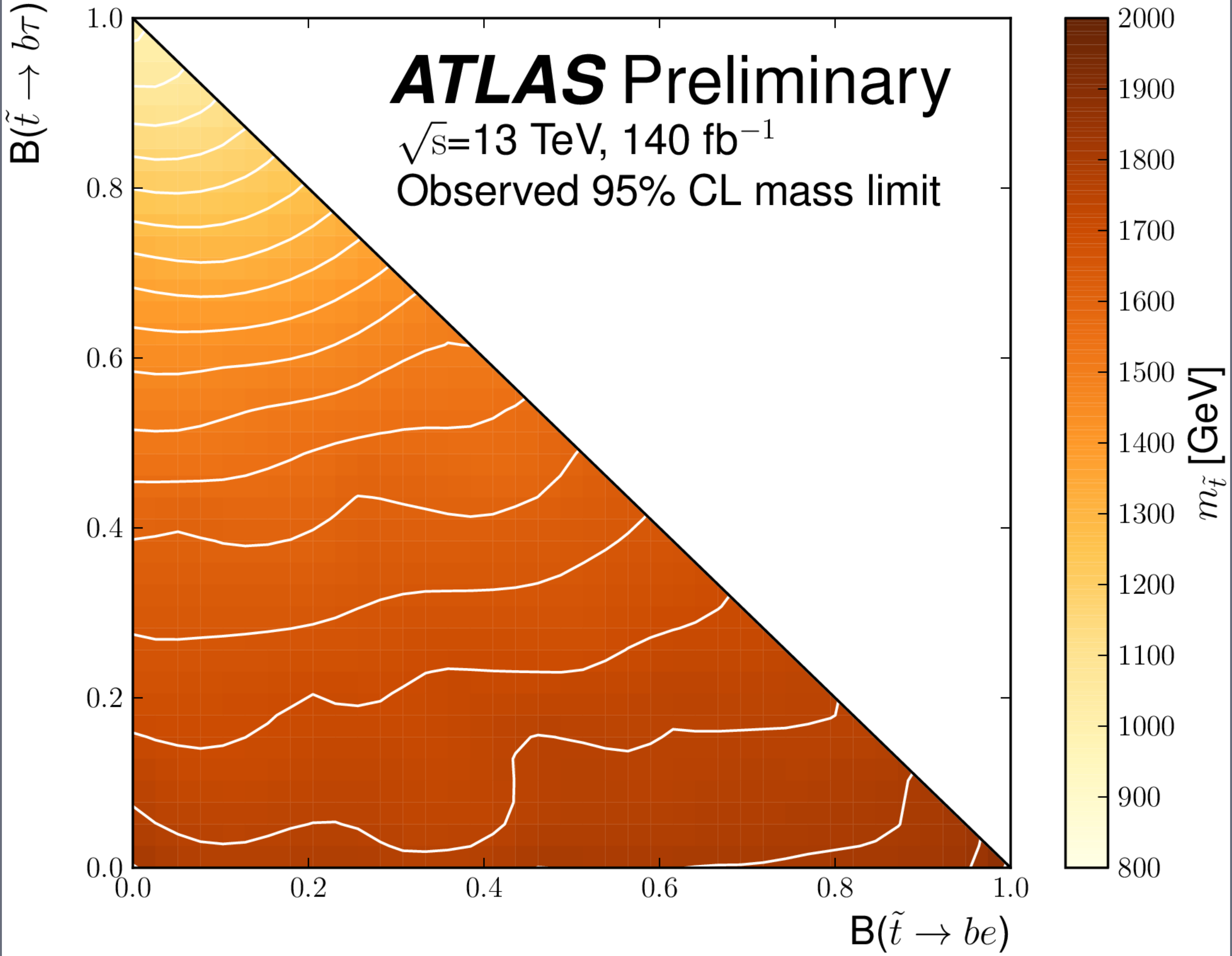


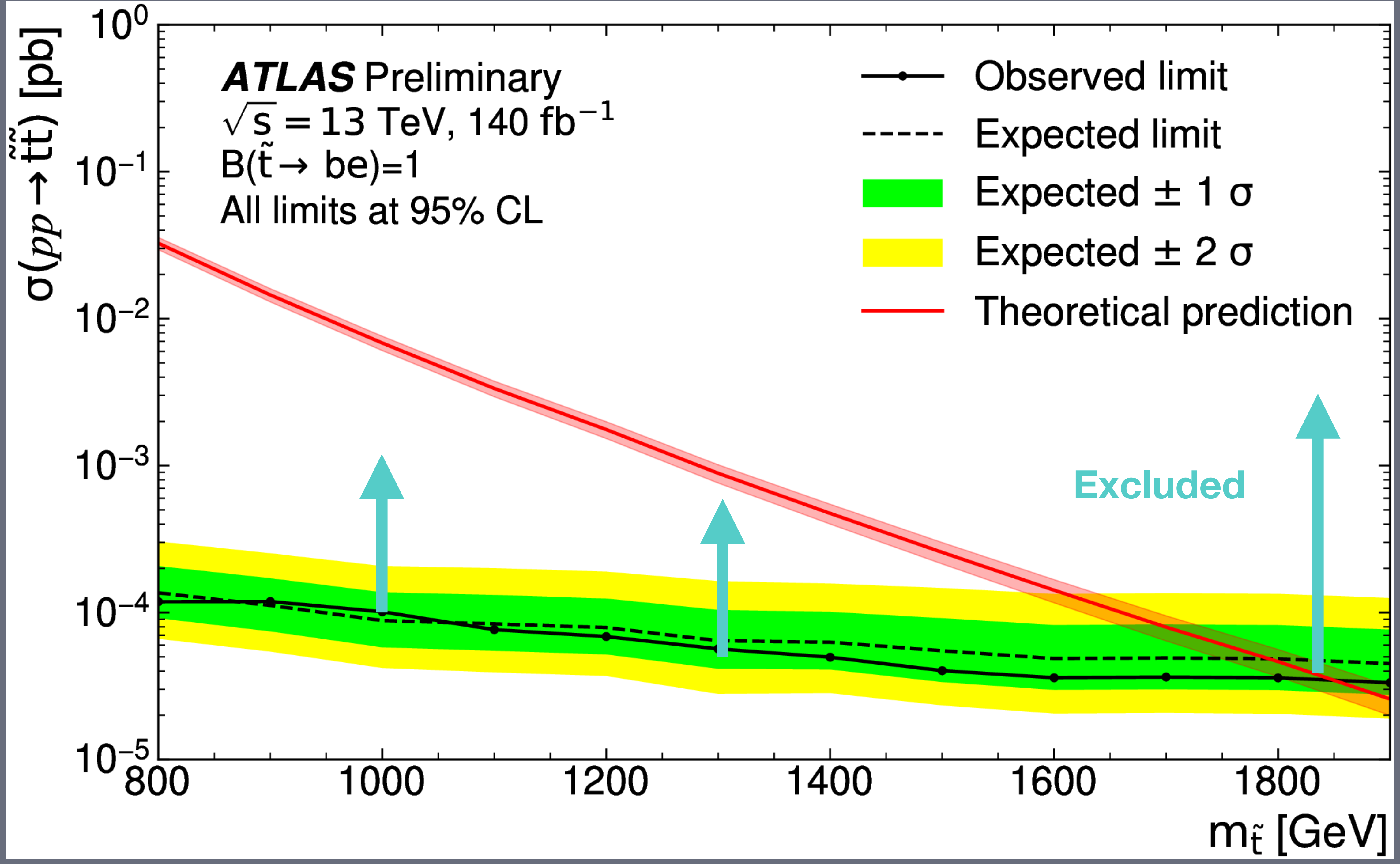


Search for RPV SUSY - stop to b jet and lepton

SUSY-2018-37

Results significantly extend the mass exclusion limits on the “$B - L$ stop” model from previous ATLAS searches





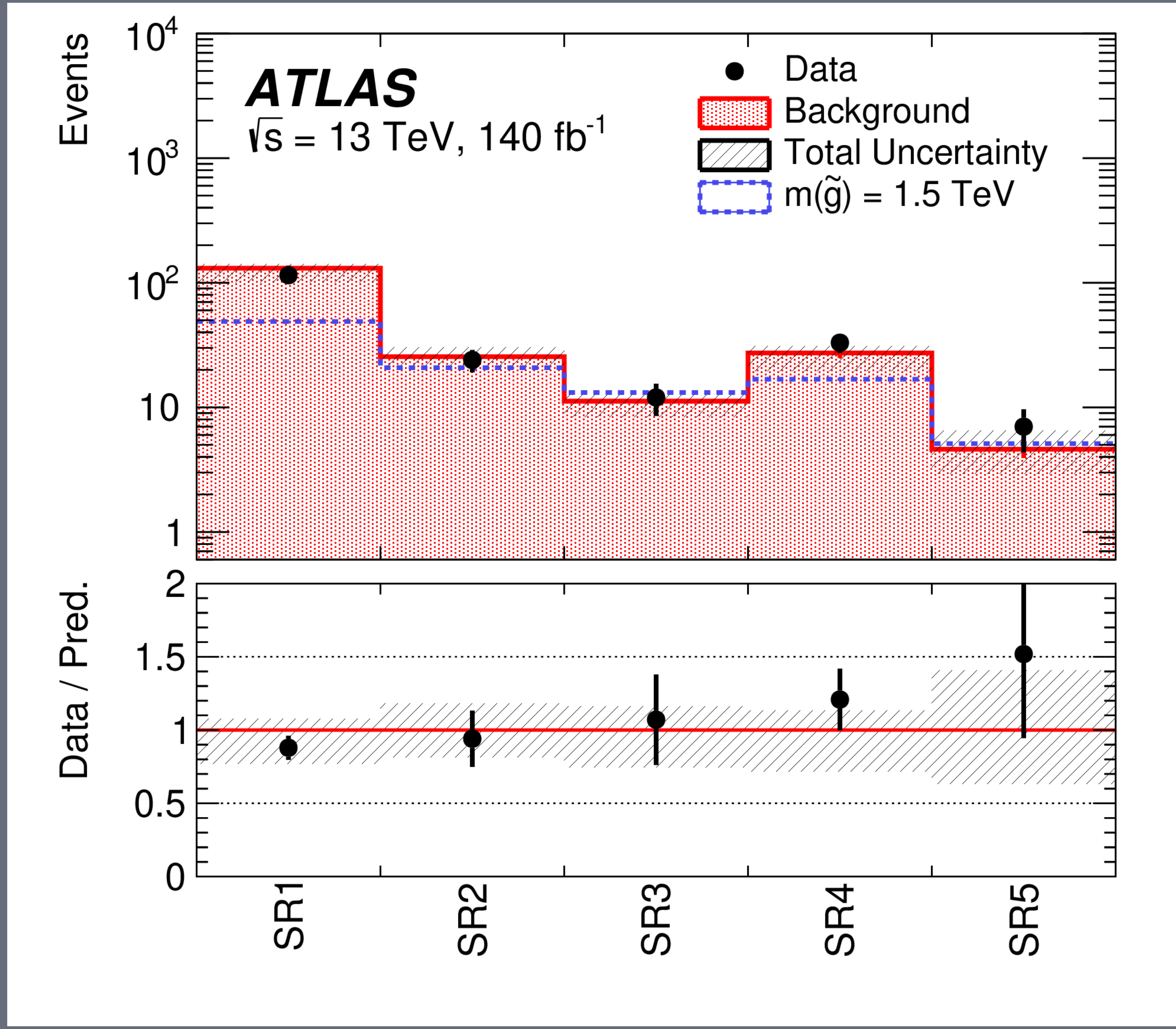
Search for RPV SUSY with 6 - 10 jets

JHEP 05 (2024) 003

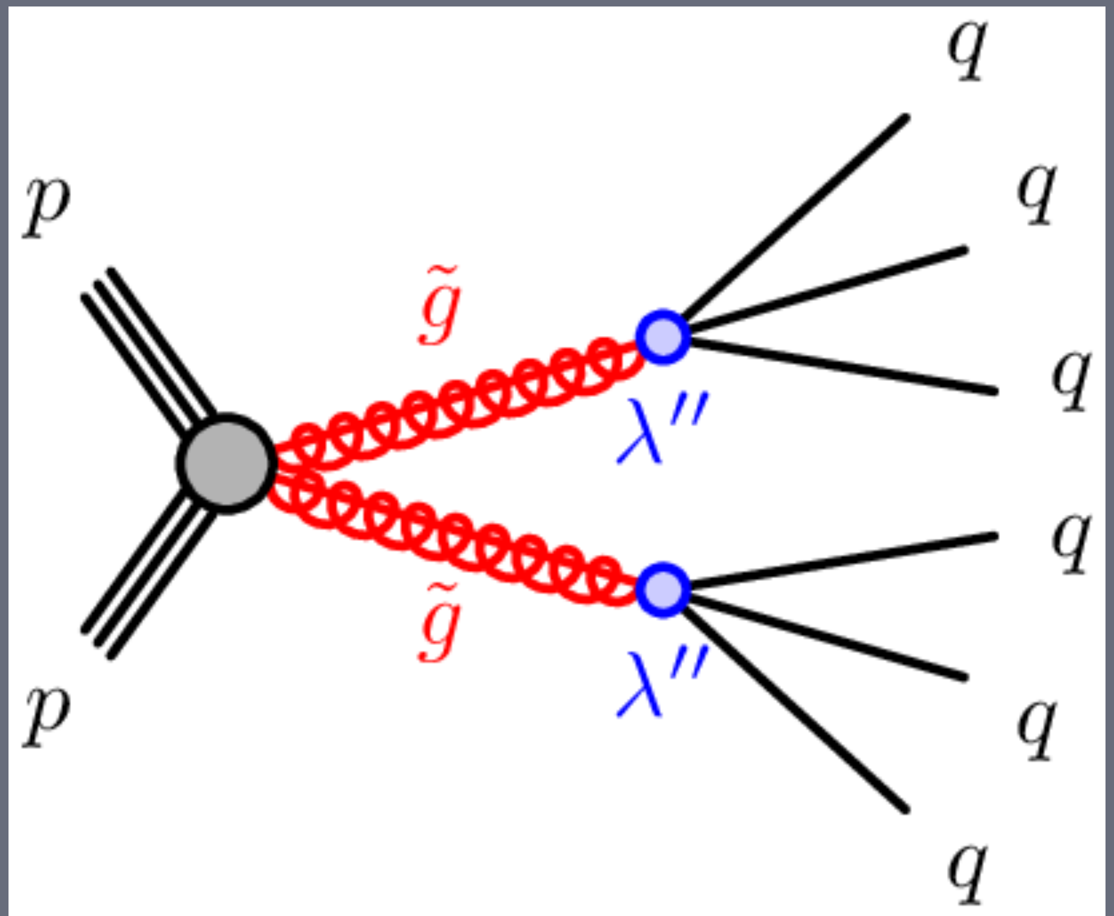
Multijet events are the dominant background

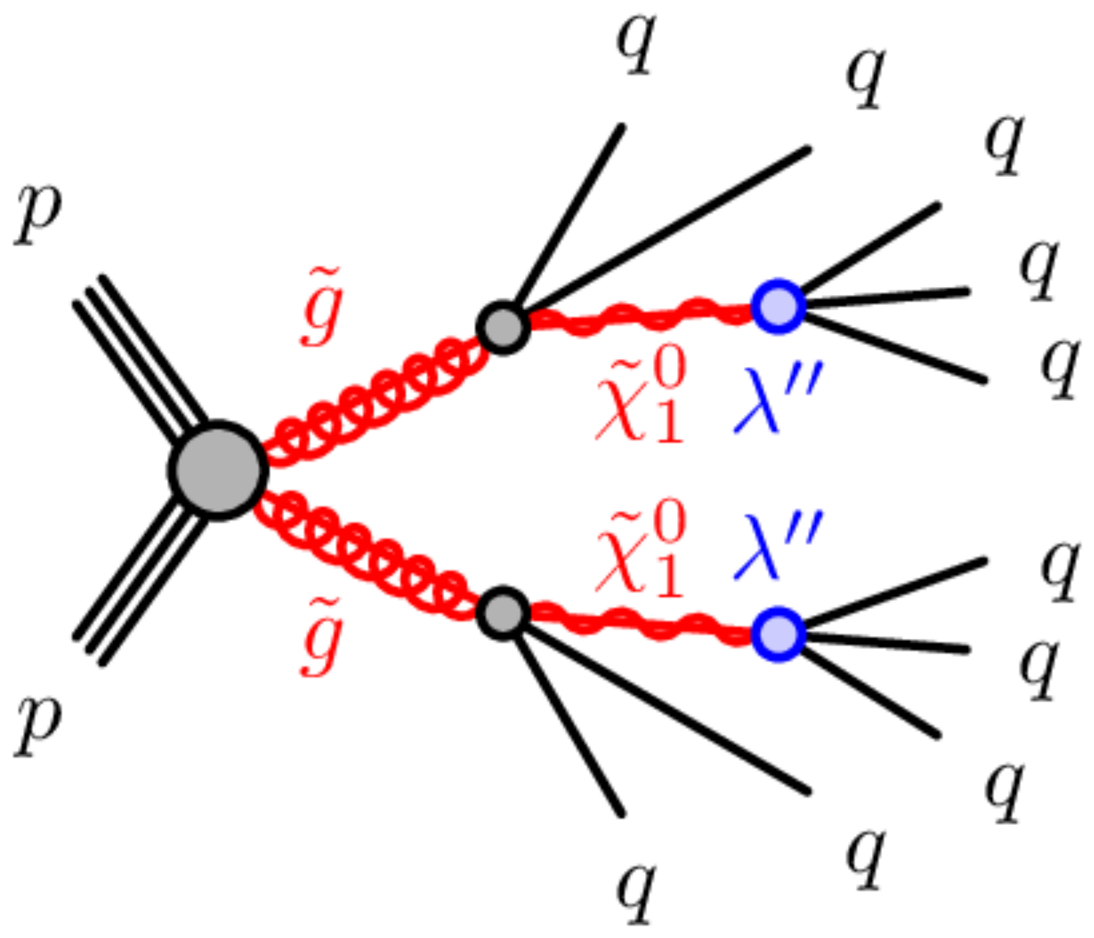
2 complementary analysis methods are used:

- **jet counting** - use jet kinematics and event shapes in a semi data driven method for background extrapolation



- **Mass reconstruction** - use ML to address the combinatorial assignment problem to reconstruct the gluino mass



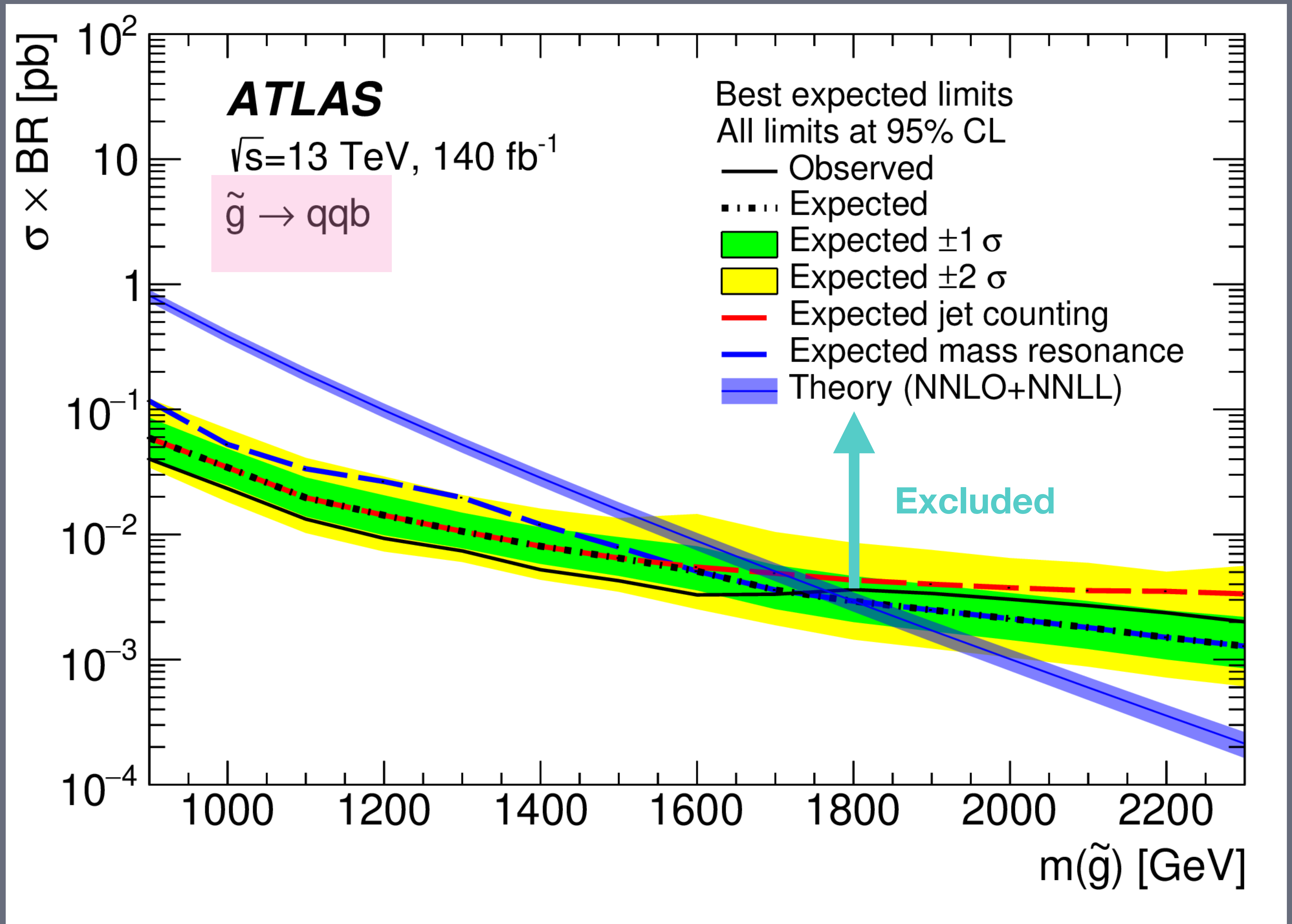


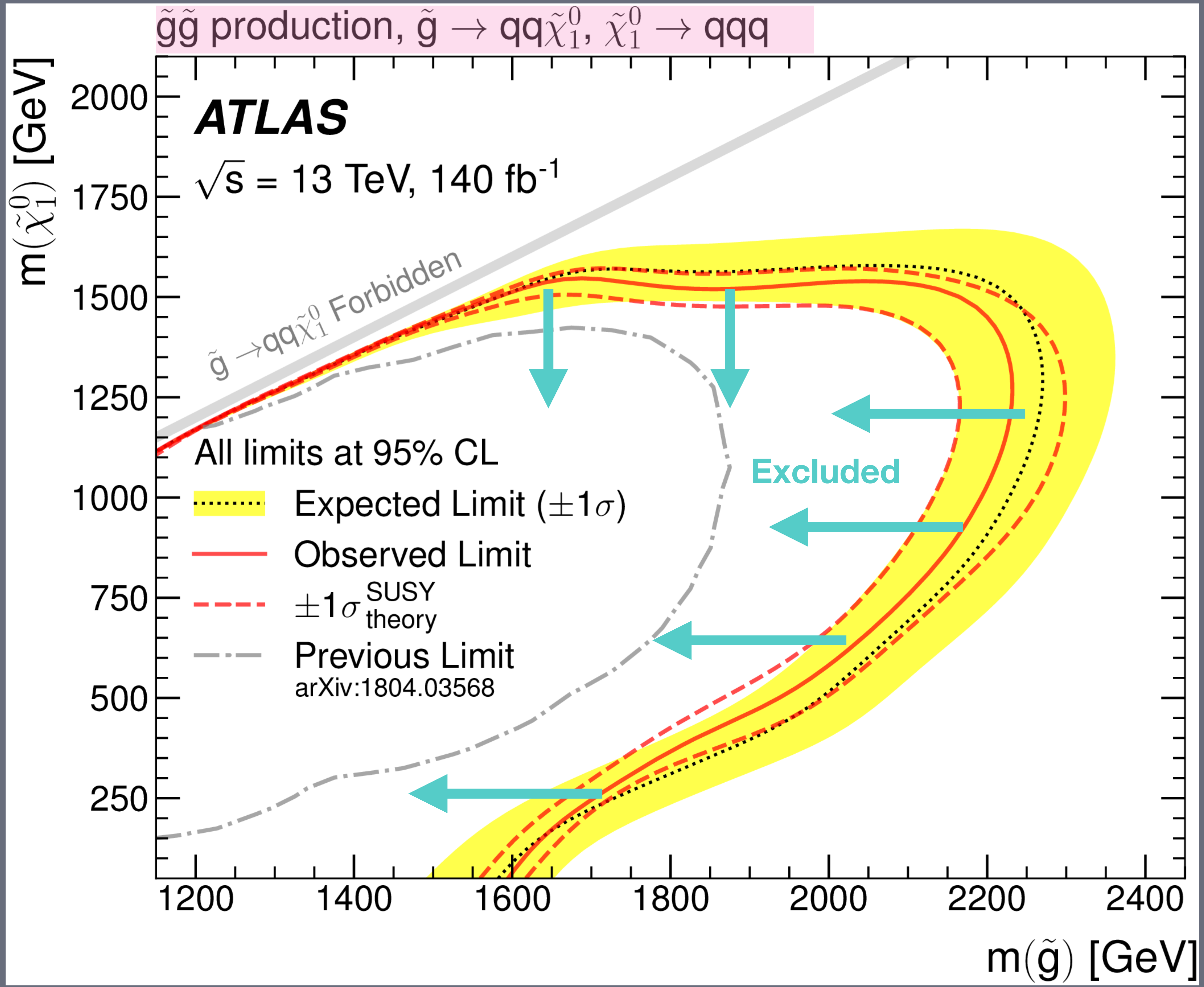
Many jets!

Search for RPV SUSY with 6 - 10 jets

JHEP 05 (2024) 003

Limits set on the production of gluinos in the gluino direct decay and cascade decay models in $U\bar{D}\bar{D}$ scenarios of RPV SUSY





Stop to top or charm Analysis

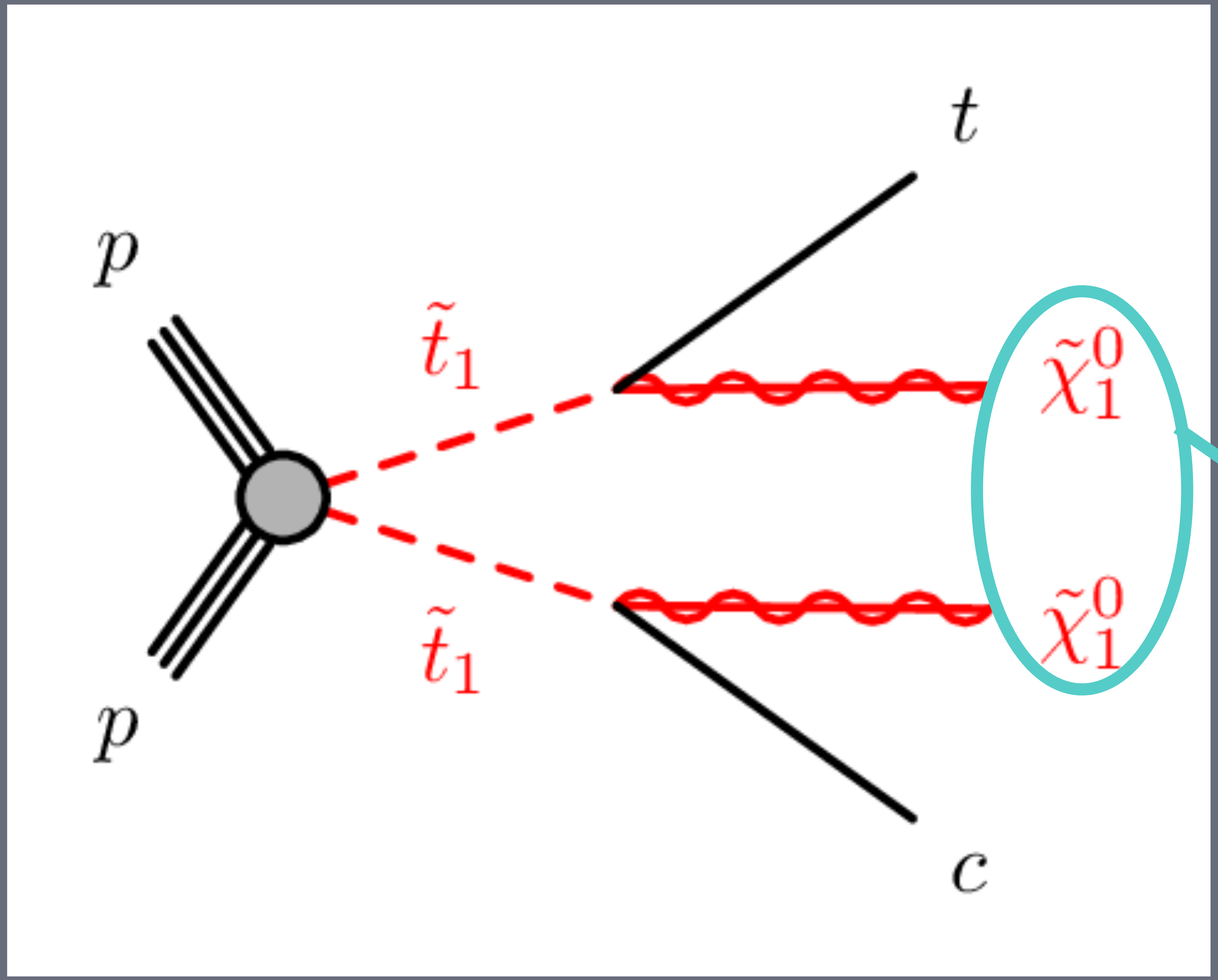
Submitted to JHEP

Target 3 regions of parameter space:

- $\Delta m(\tilde{t}_1, \tilde{\chi}_1^0) \gg m(t)$ - highly boosted c-jets
- $\Delta m(\tilde{t}_1, \tilde{\chi}_1^0) > m(t)$ -moderate p_T c-jets
- $\Delta m(\tilde{t}_1, \tilde{\chi}_1^0) \sim m(t)$ low p_T c-jets, require a high p_T initial state radiation jet to trigger on

Flavour violating model

Number of b-tagged jets ≥ 1



0 leptons

E_T^{miss}

First LHC analysis with this signature!

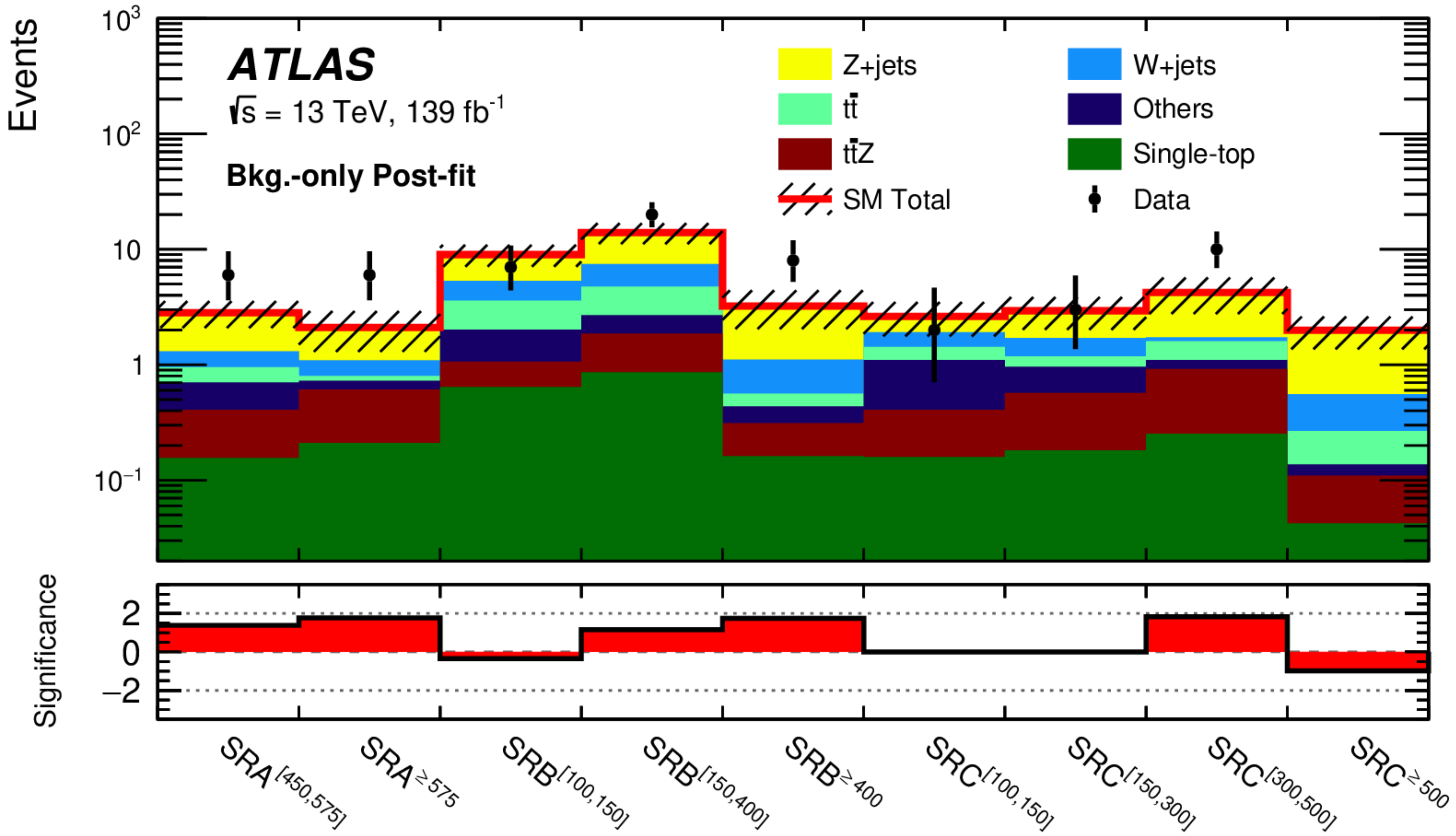
Number of c-tagged jets ≥ 1

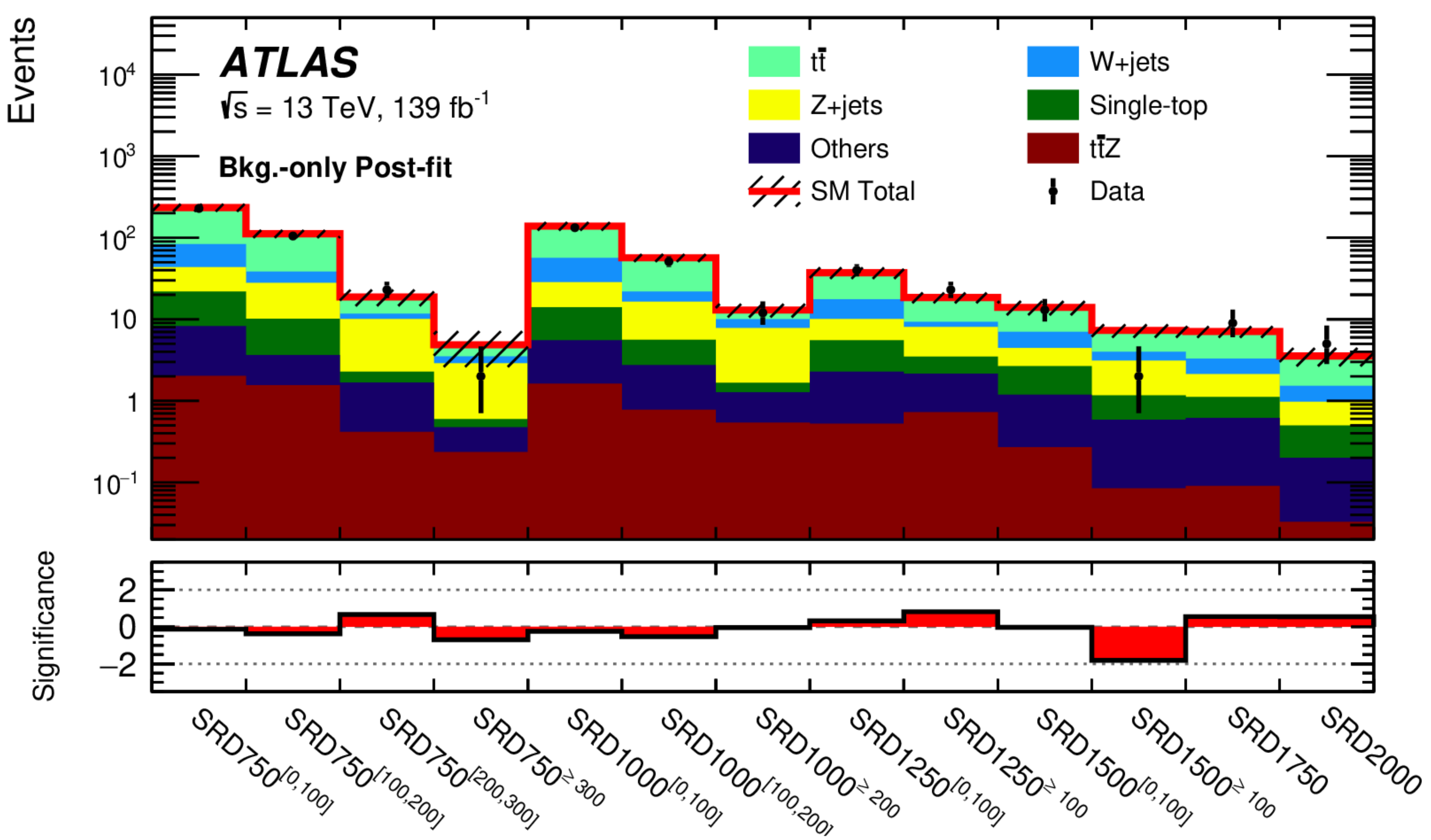
Stop to top or charm Analysis

Submitted to JHEP

For boosted/moderate regions a cut-and-count analysis is used. Large radius top-tagging to distinguish from SM backgrounds

For the compressed region, $\Delta m(\tilde{t}_1, \tilde{\chi}_1^0) \sim m(t)$, use a neural network to distinguish between background and signal

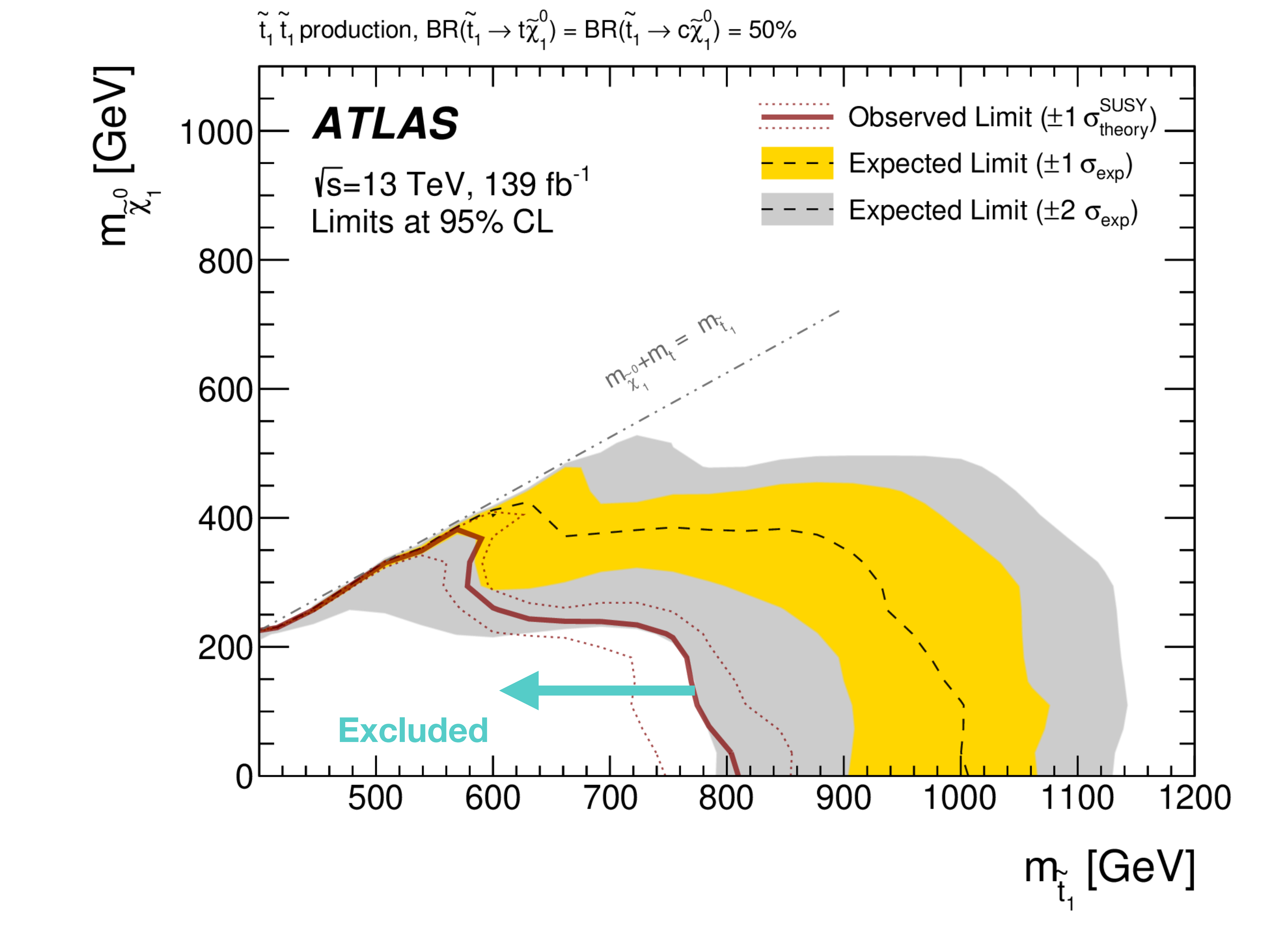


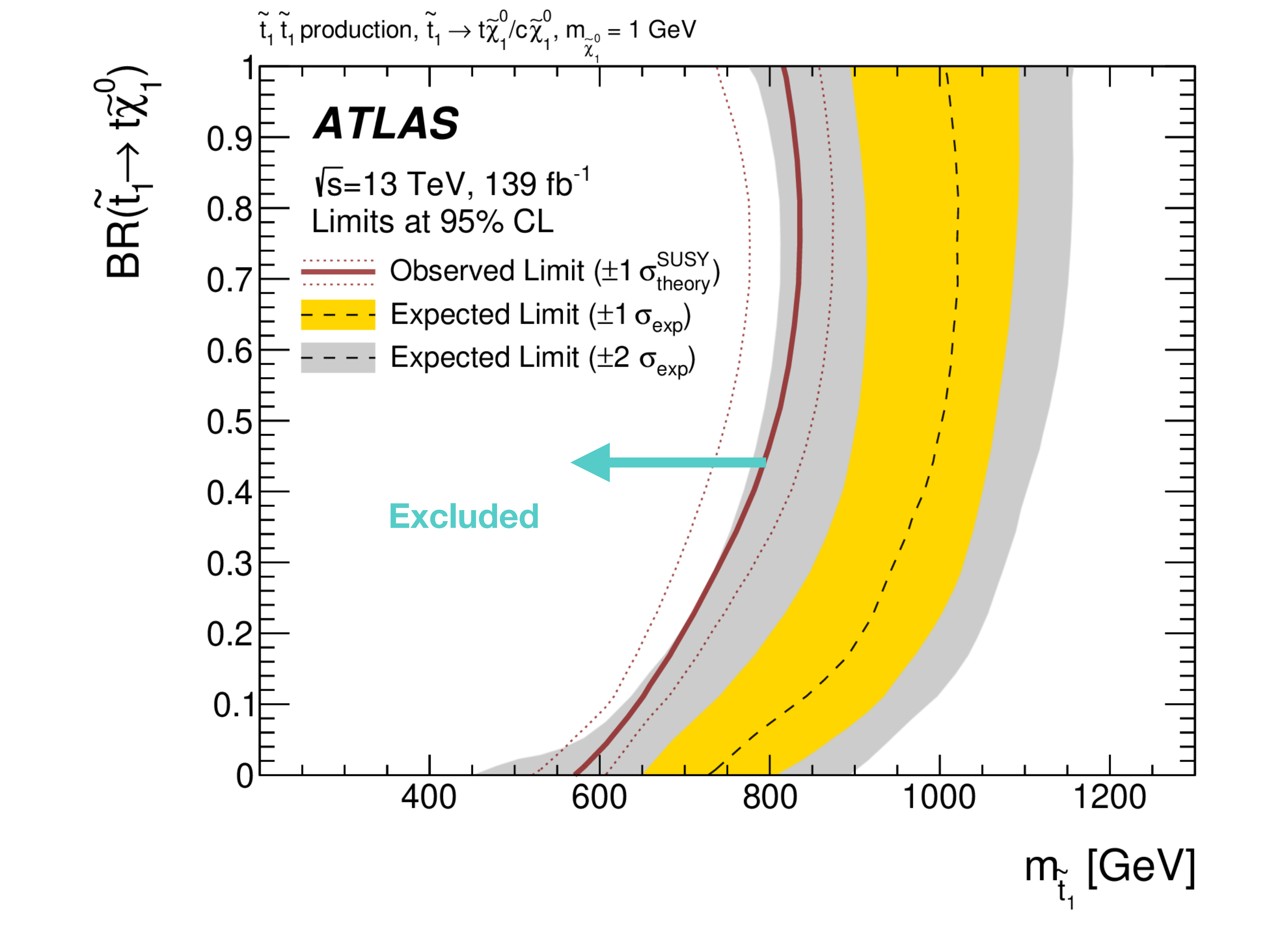


Stop to top or charm Analysis

Submitted to JHEP

The **first** results to date at the LHC on a search for BSM physics in this final-state signature





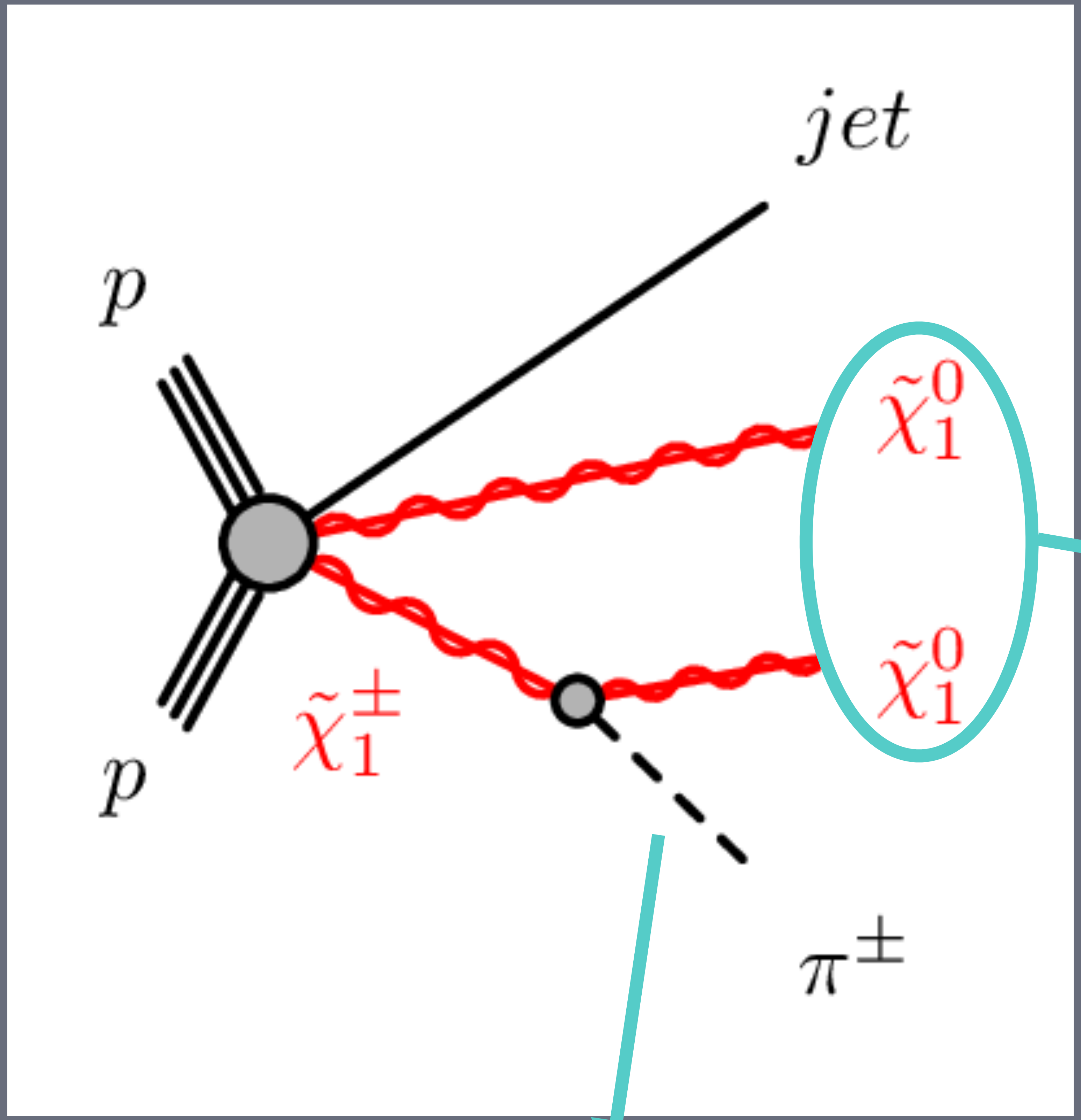
Compressed Displaced Track Analysis

Accepted by PRL

Higgsinos with masses near the electroweak scale can solve the hierarchy problem and provide a dark matter candidate

If the mass splitting of the Higginos is "compressed" $\mathcal{O}(\Delta m(\tilde{\chi}_1^{\pm}, \tilde{\chi}_1^{0})) \sim 1$ GeV the lifetime of the $\tilde{\chi}_1^{\pm}$ is $c\tau \sim \mathcal{O}(1)$ mm

Initial state radiation jet $p_T > 200$ GeV



$E_T^{miss} > 600$ GeV

"Mildly displaced" track with $2 > p_T > 5$ GeV and significance of the tracks transverse impact parameter $S(d_0) > 8$

Compressed Displaced Track Analysis

Accepted by PRL

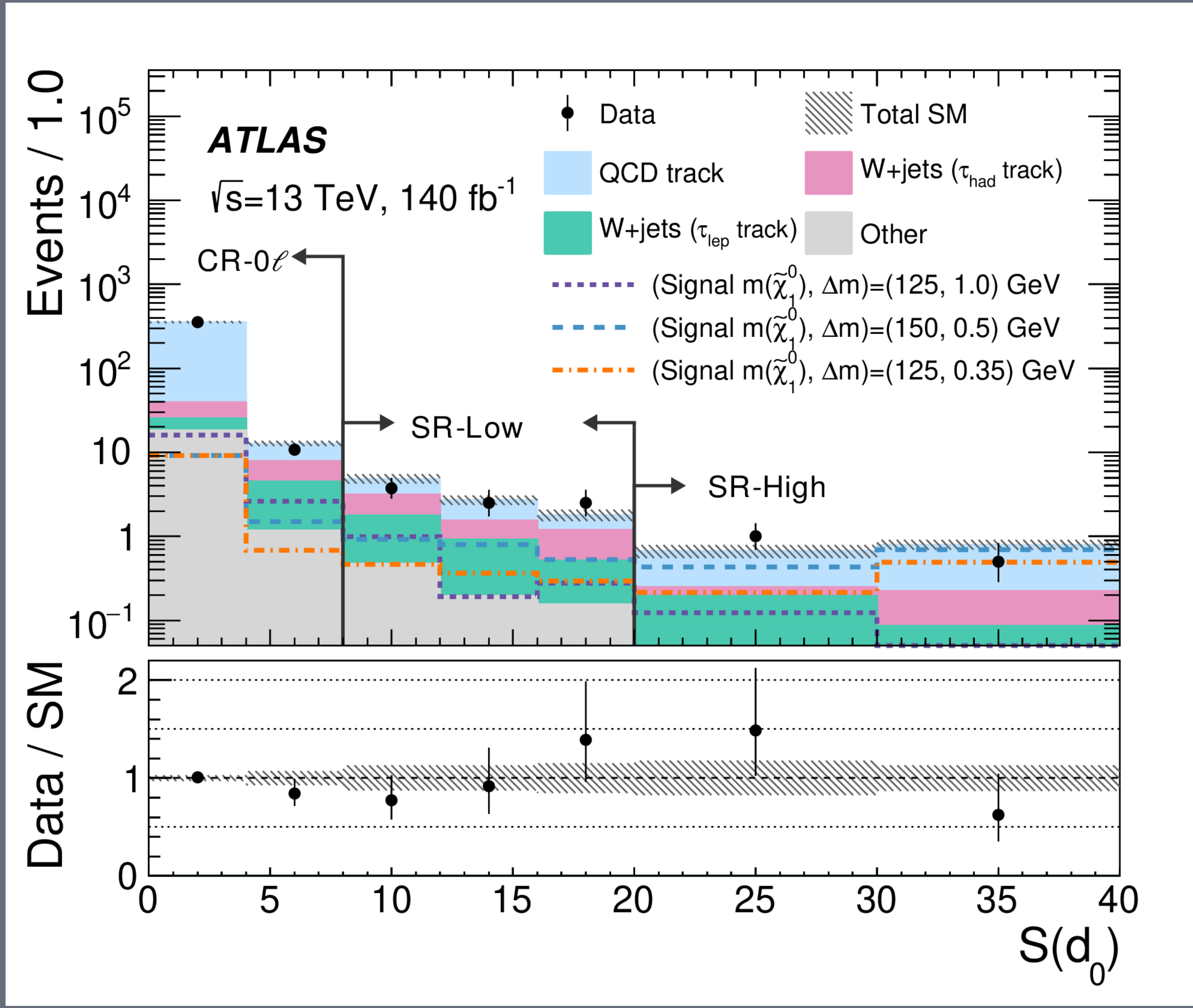
Dominant backgrounds:

- $W \to \tau\nu$, a pion or lepton from a low p_T τ decay

  Estimated using a semi data driven method

- $Z \to \nu\nu(\tau\tau)$ + jets and $W \to \ell\nu$ + jets, $\ell = e, \mu$ - hadrons in the jets with with measurably long lifetimes

  Estimated using fully data driven method, ABCD method

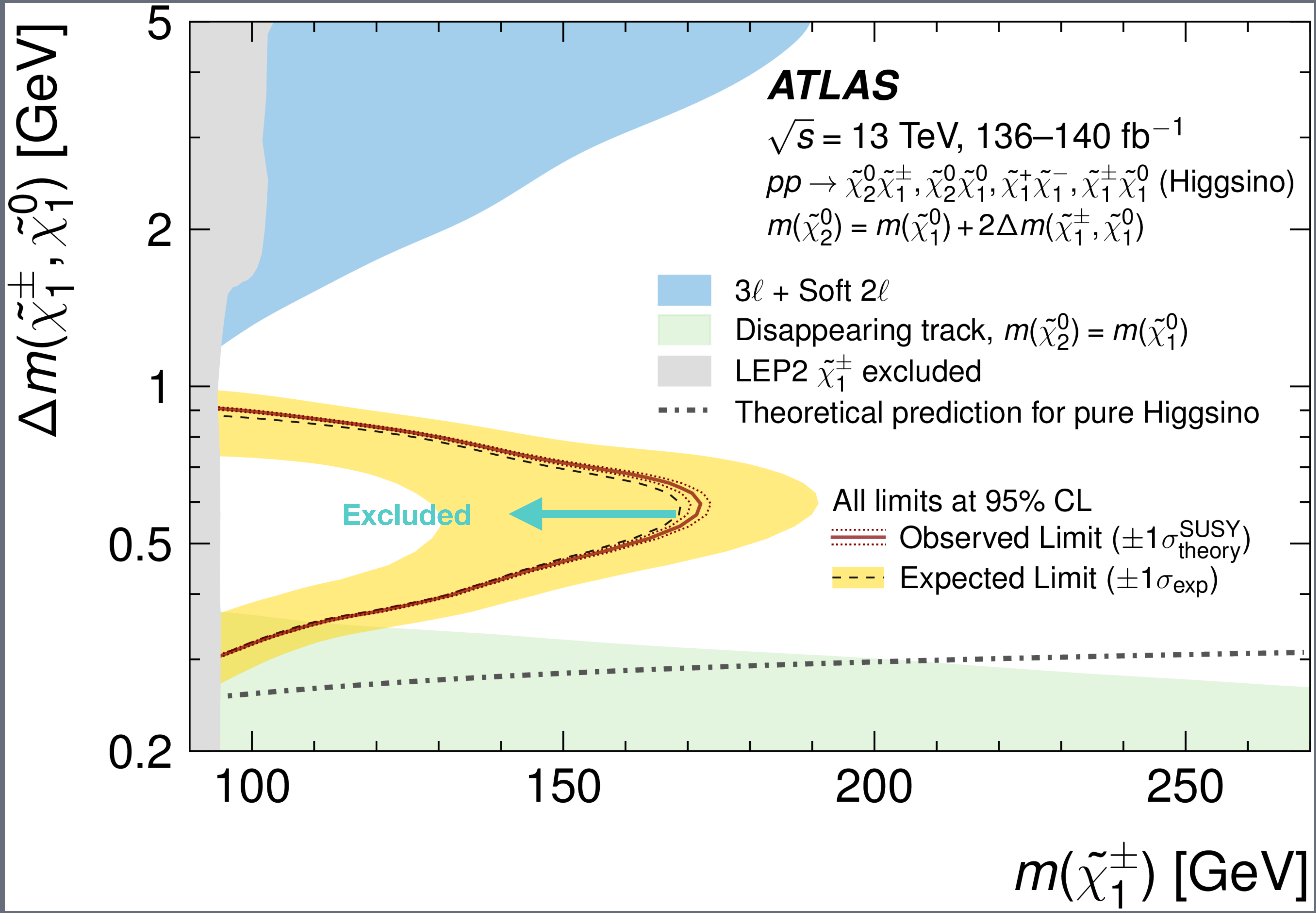


2 signal bins in $S(d_0)$ (sensitive to lower/higher Δm)

Compressed Displaced Track Analysis

Accepted by PRL

Result bridges a long-standing **blind spot** in the sensitivity of Higgsino searches



pMSSM Electroweak Scan

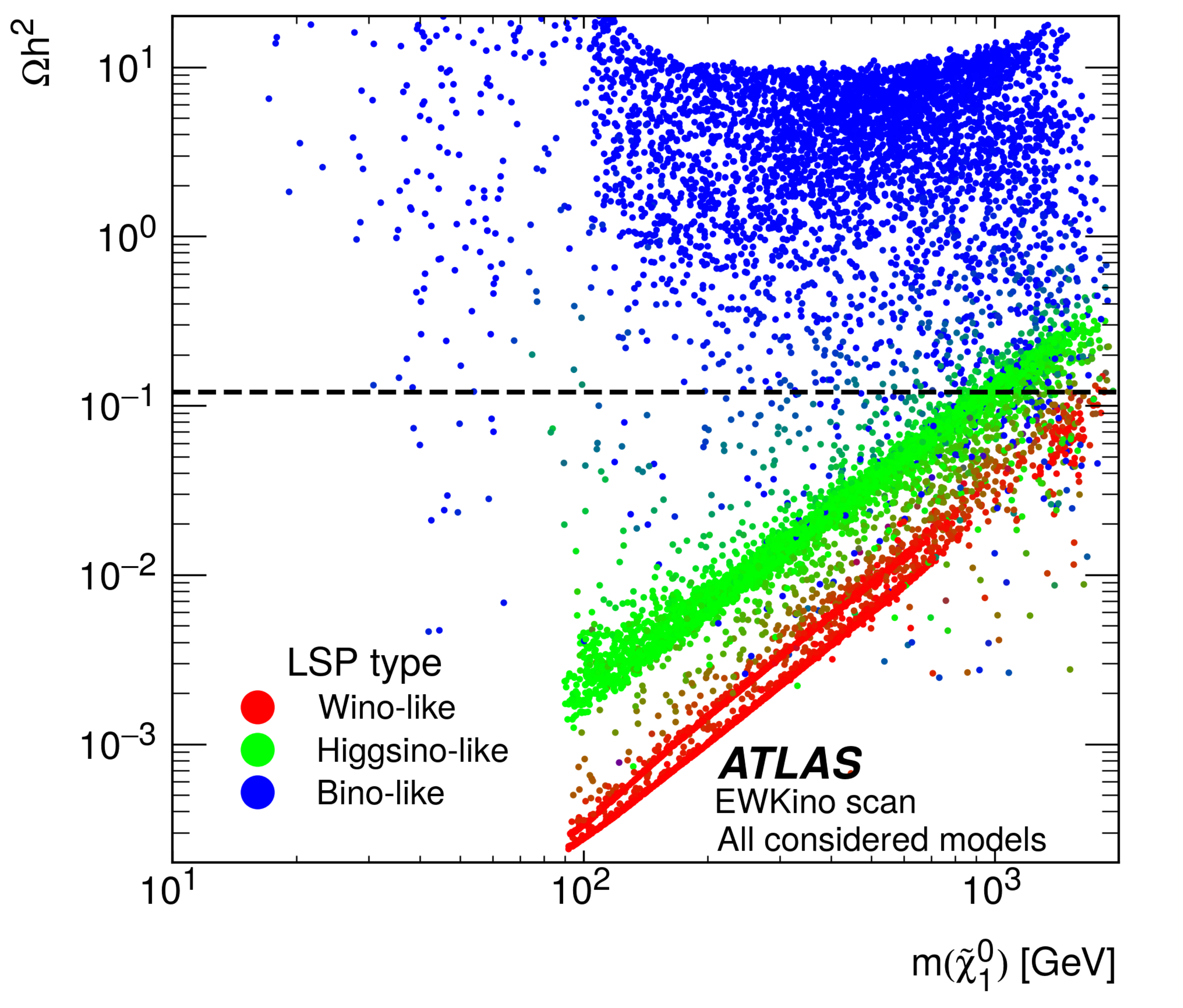
JHEP 2024 (2024) 106

Results from 8 ATLAS SUSY Run 2 searches used in pMSSM scans to set constraints on electroweak production of charginos and neutralinos

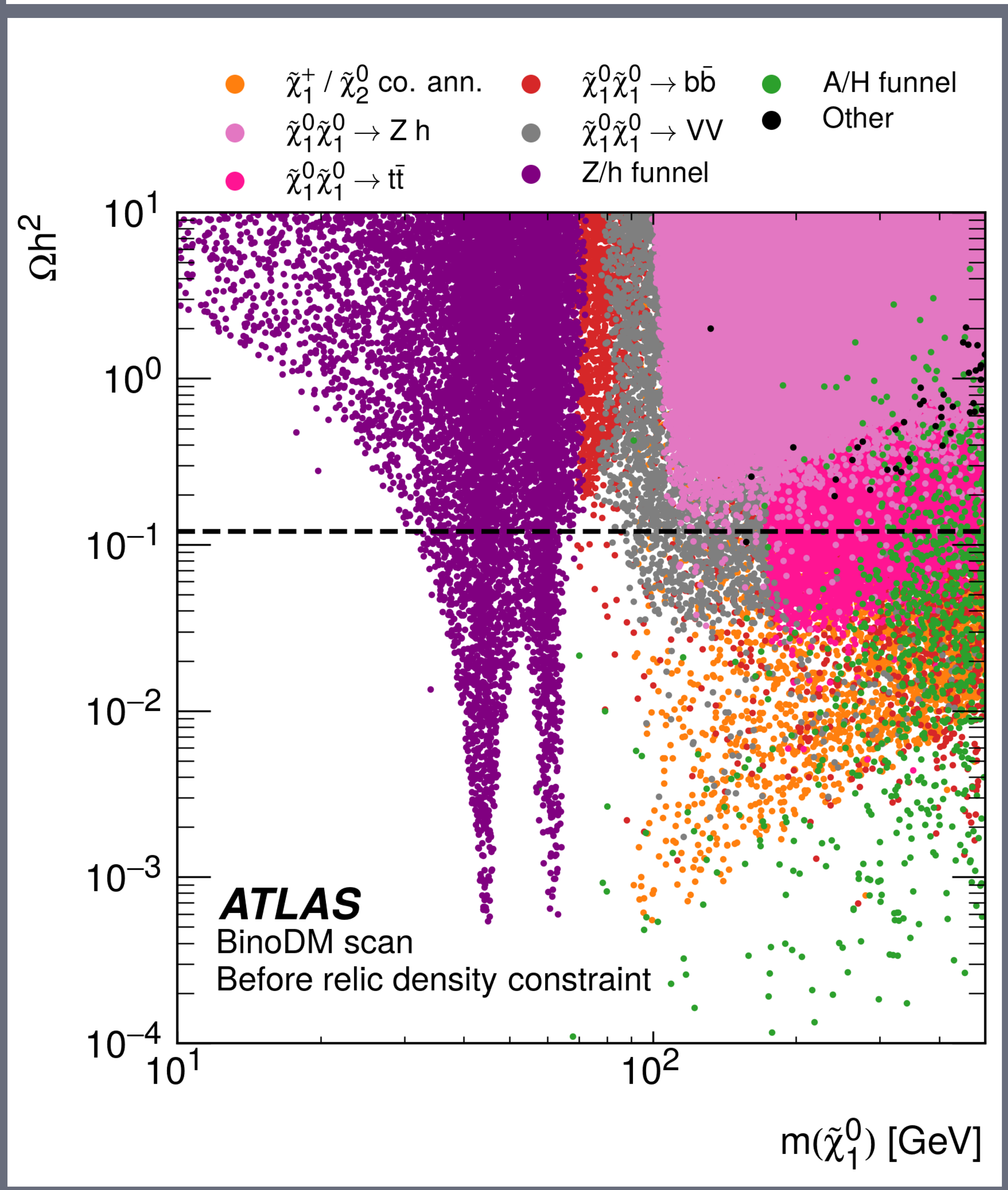
The pMSSM consists of 19 parameters, the scans use 5 parameters relevant for the electroweak production

pMSSM Parameter	Meaning
$\tan\beta$	Ratio of the Higgs vacuum expectation values for the two doublets
M_A	Pseudoscalar (CP-odd) Higgs boson mass parameter
μ	Higgsino mass parameter
M_1, M_2, M_3	Bino, wino and gluino mass parameters
A_t, A_b, A_τ	Third generation trilinear couplings
$M_{\tilde{q}}$, $M_{\tilde{u}_R}$, $M_{\tilde{d}_R}$, $M_{\tilde{l}}$, $M_{\tilde{e}_R}$	First/second generation sfermion mass parameters
$M_{\tilde{Q}}$, $M_{\tilde{t}_R}$, $M_{\tilde{b}_R}$, $M_{\tilde{L}}$, $M_{\tilde{\tau}_R}$	Third generation sfermion mass parameters

2 scans are performed, one with an additional constraint on $|M_1| < 500$ GeV to focus on low-mass bino models



Electroweakino Scan



models that satisfy the DM relic density constraint $\Omega h^2 \leq 0.12$

Bino DM Scan

pMSSM Electroweak Scan

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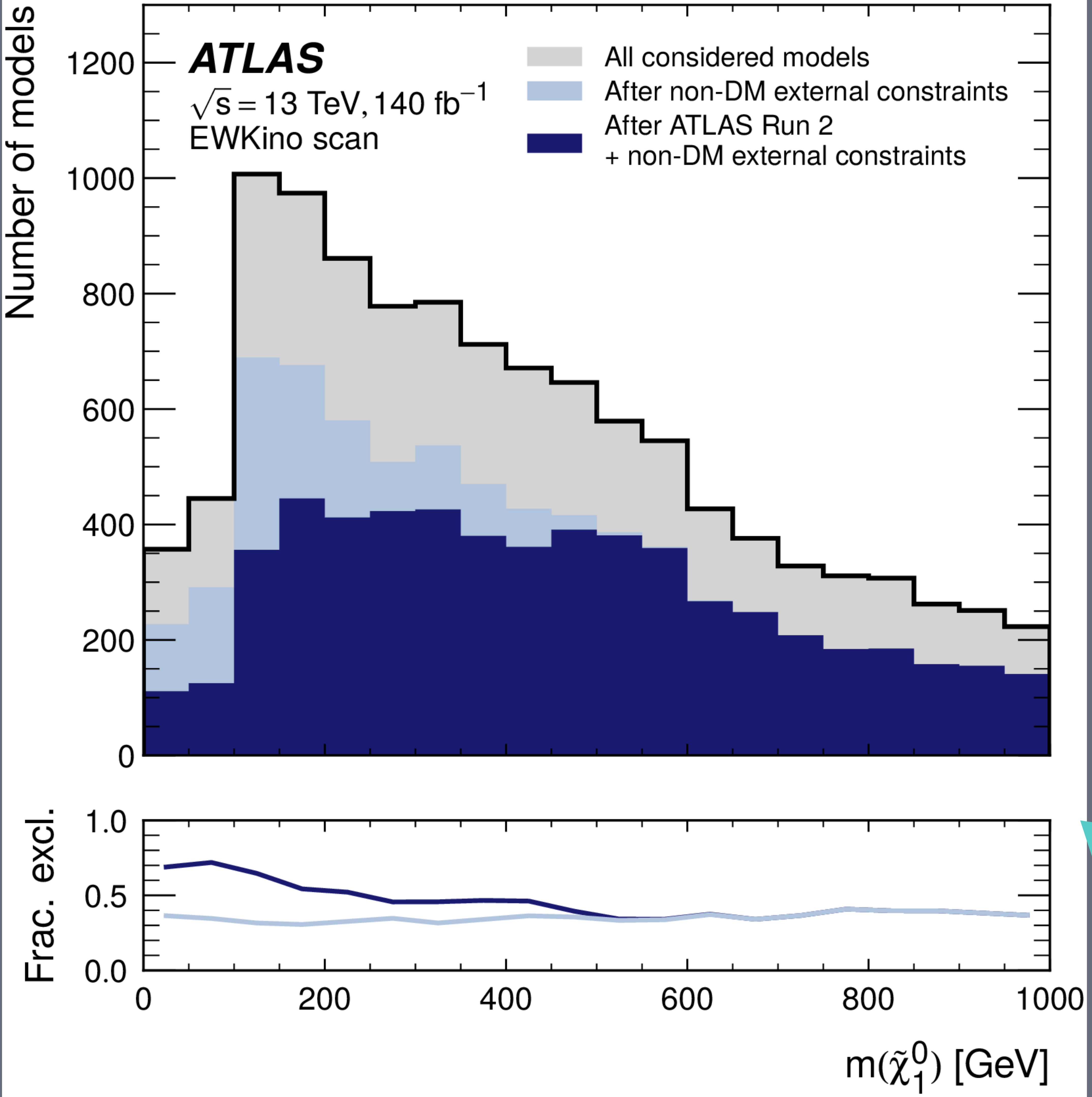
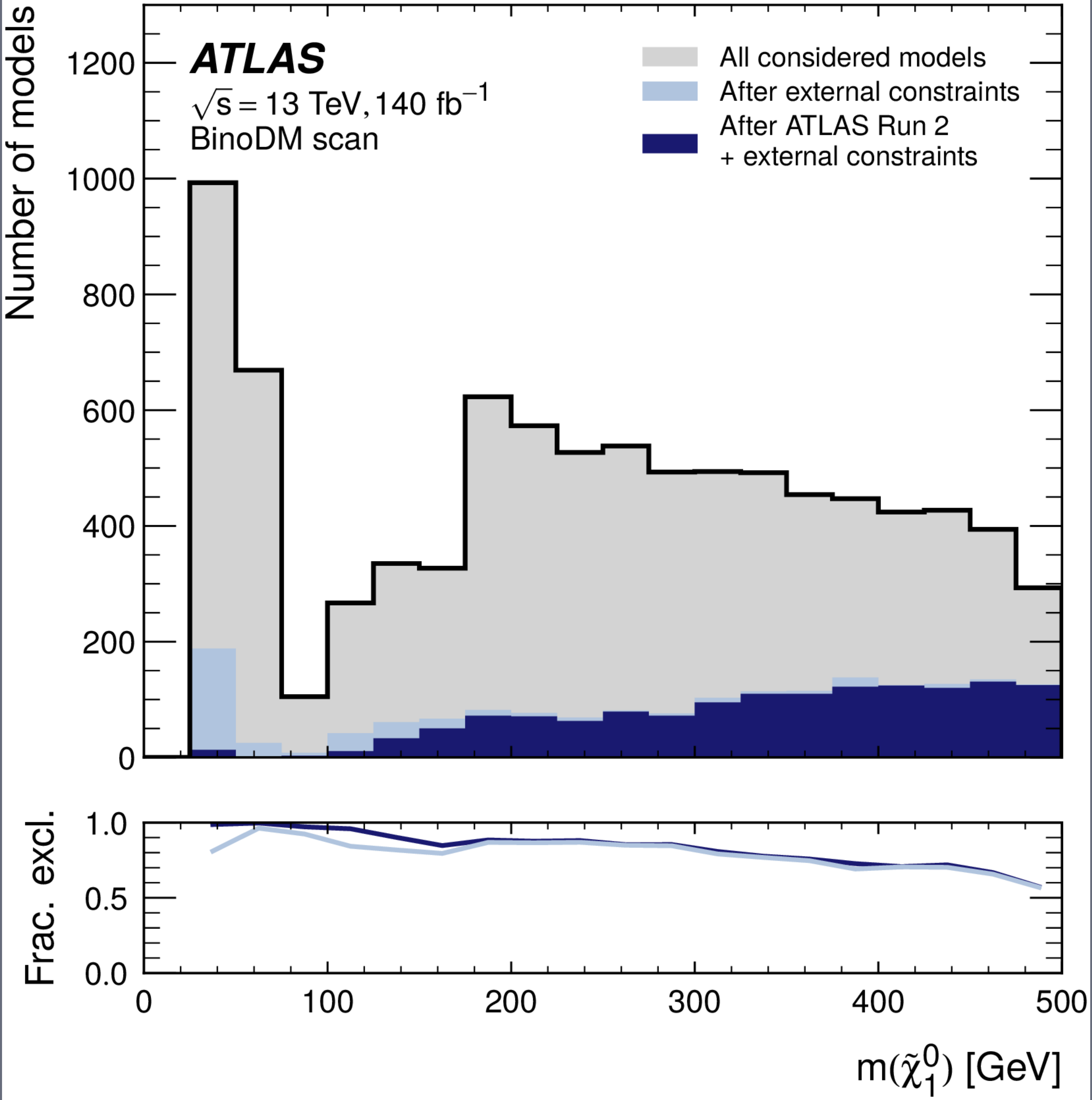
Fraction of models excluded





Electroweakino Scan

Bino DM Scan

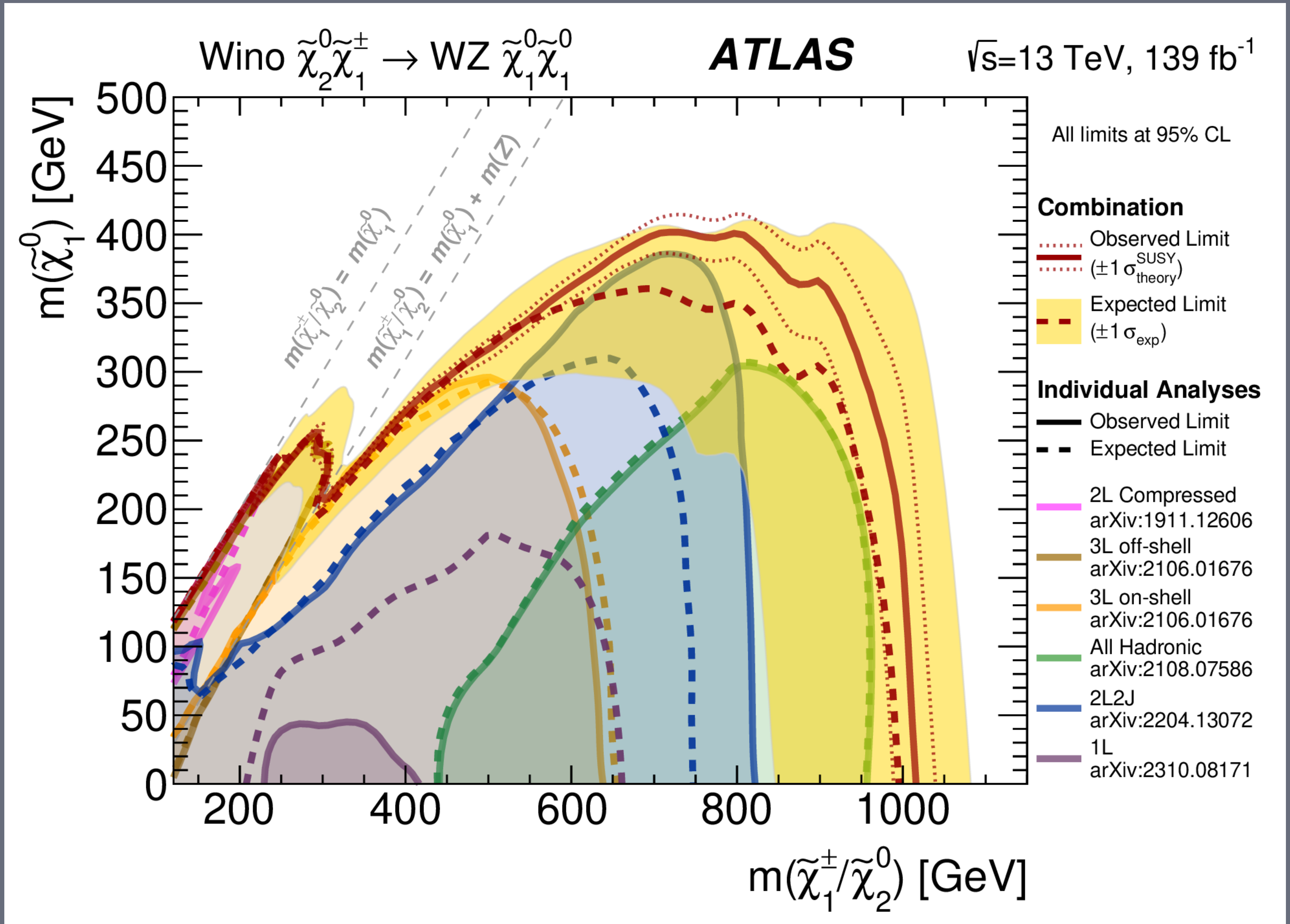
Combinations of electroweakino and slepton searches

Submitted to PRL

Statistical combinations of previous ATLAS searches for charginos and neutralinos using **various decay channels**

In general the combination extends the **mass reach** of the produced SUSY particles by **30–100 GeV**

Sensitivity of the original searches is improved by the combinations: lowering **cross-section upper limits** by **15%–40%**



Summary & Outlook

- No signs of Supersymmetry, however, a lot of phase space has been excluded and results can be **reinterpreted** to other models with similar final states.

- Currently taking data in Run 3, many analyses are developing exciting, new, **novel analysis techniques** to probe difficult to reach regions of phases space. Working on great improvements in **flavour tagging**: LINK.

- Plans are a foot for **HL-LHC**, more collision = access to probe rarer processes!

- Find all our public SUSY results here: LINK and summary plots here: LINK.

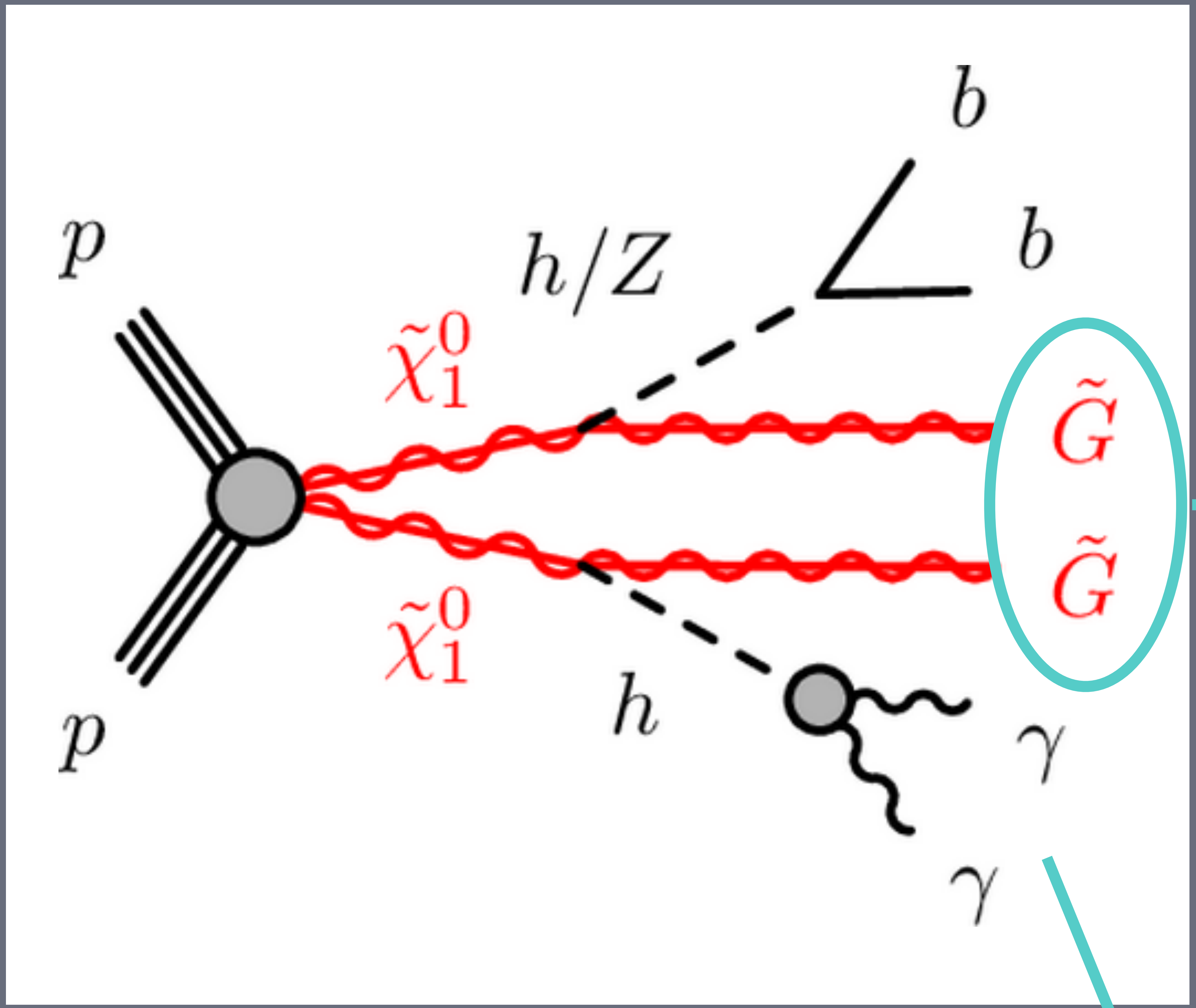
Thank you for listening!

$\gamma\gamma bb + E_T^{miss}$ Analysis

Submitted to PLB

3 Signal Regions:

- $E_T^{miss} \leq 100$ GeV optimised for low $m(\tilde{\chi}_1^0)$
    - $100 < m(bb) < 140$ GeV (bs from h)
    - $60 < m(bb) < 100$ GeV (bs from Z)
- $E_T^{miss} > 100$ GeV optimised for high $m(\tilde{\chi}_1^0)$
    - $35 < m(bb) < 145$ GeV (h & Z)



E_T^{miss}

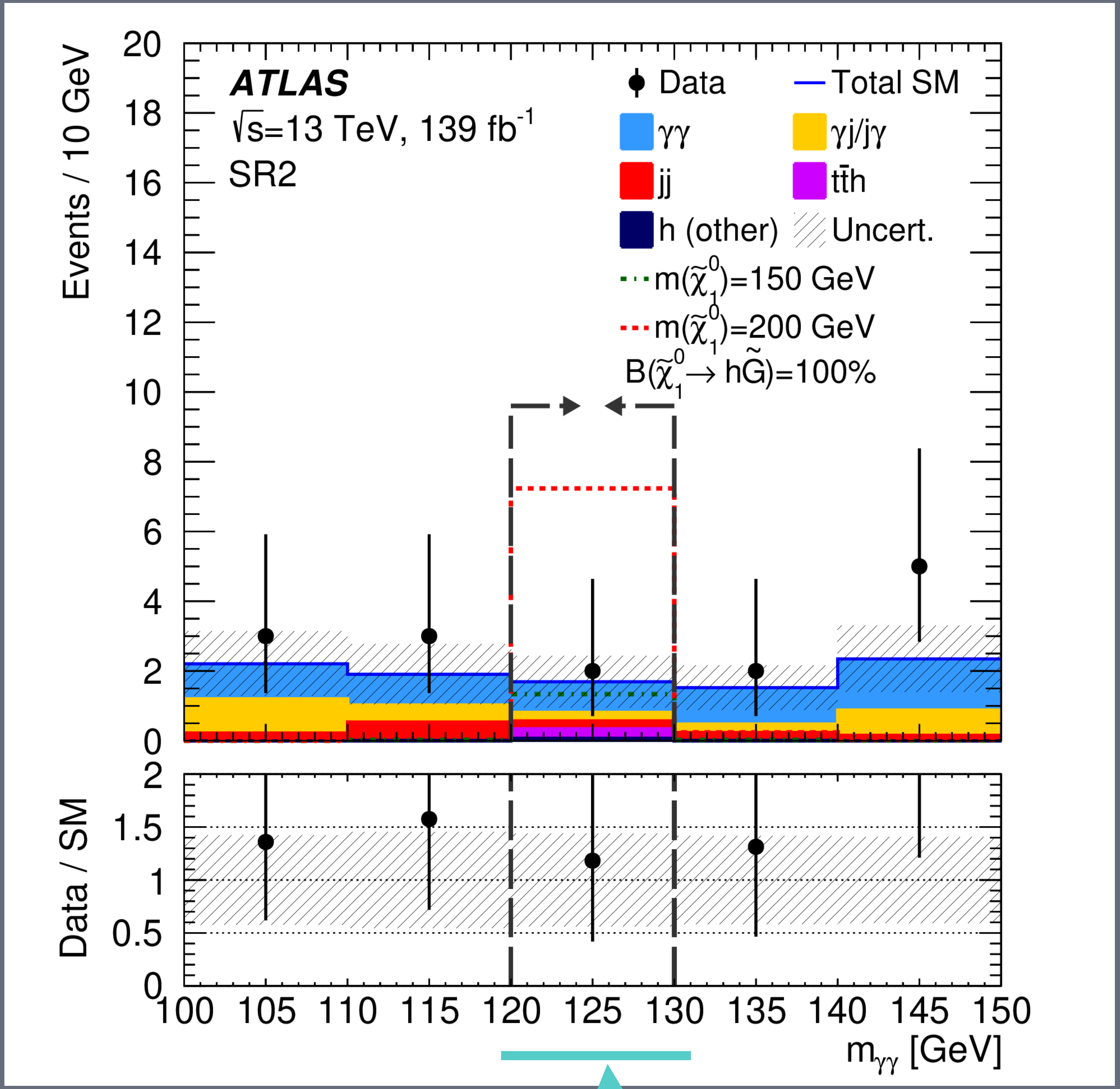
$|m_{\gamma\gamma} - 125| < 5$ GeV

$\gamma\gamma bb + E_T^{miss}$ Analysis

Submitted to PLB

Dominant background from non-resonant events: no peak around $m_{\gamma\gamma} \sim m_h$ GeV ➜ from prompt diphoton events and jets masquerading as photons

Estimate using data driven techniques ('2×2D sideband method')



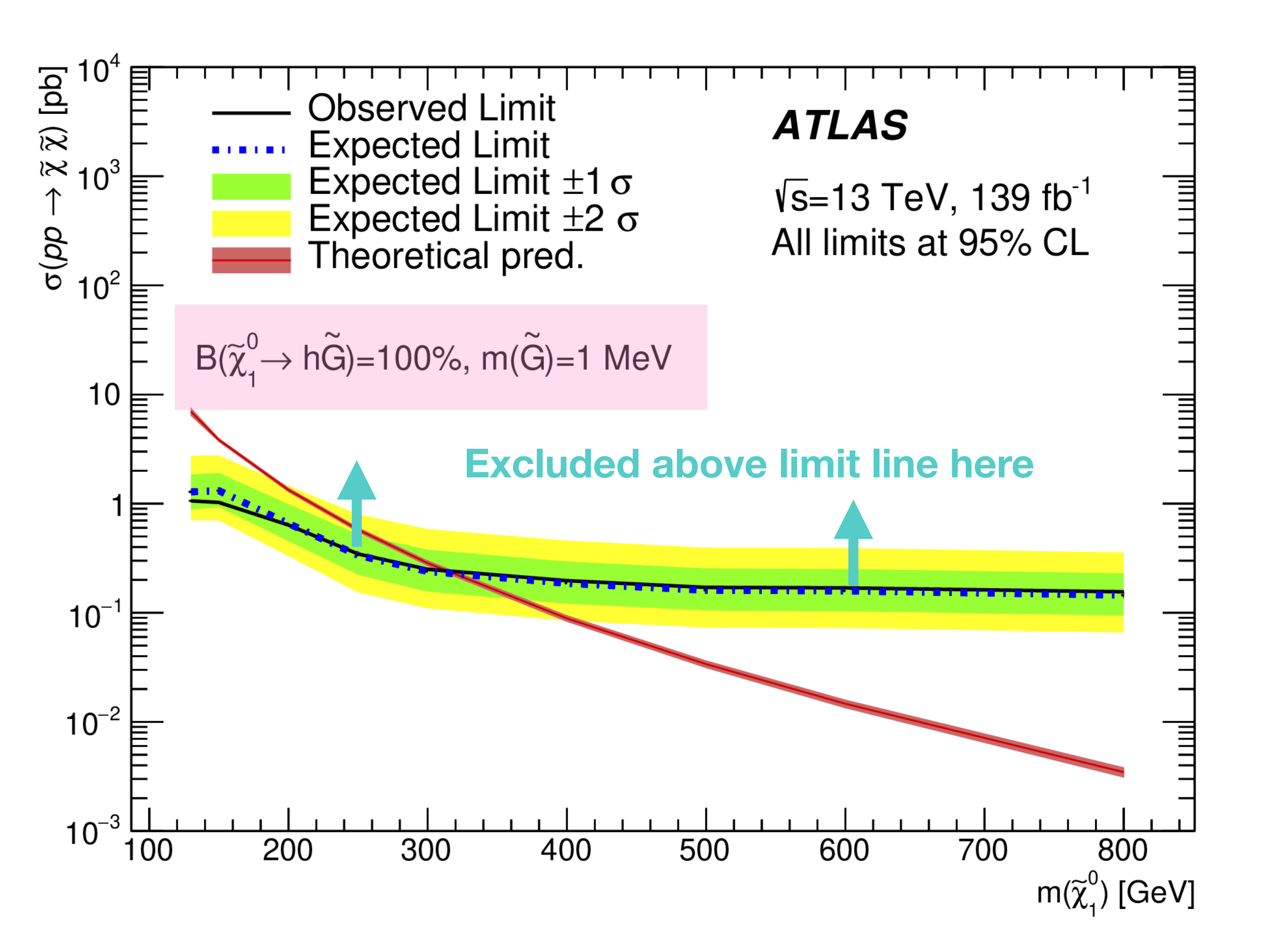
$|m_{\gamma\gamma} - 125| < 5$ GeV

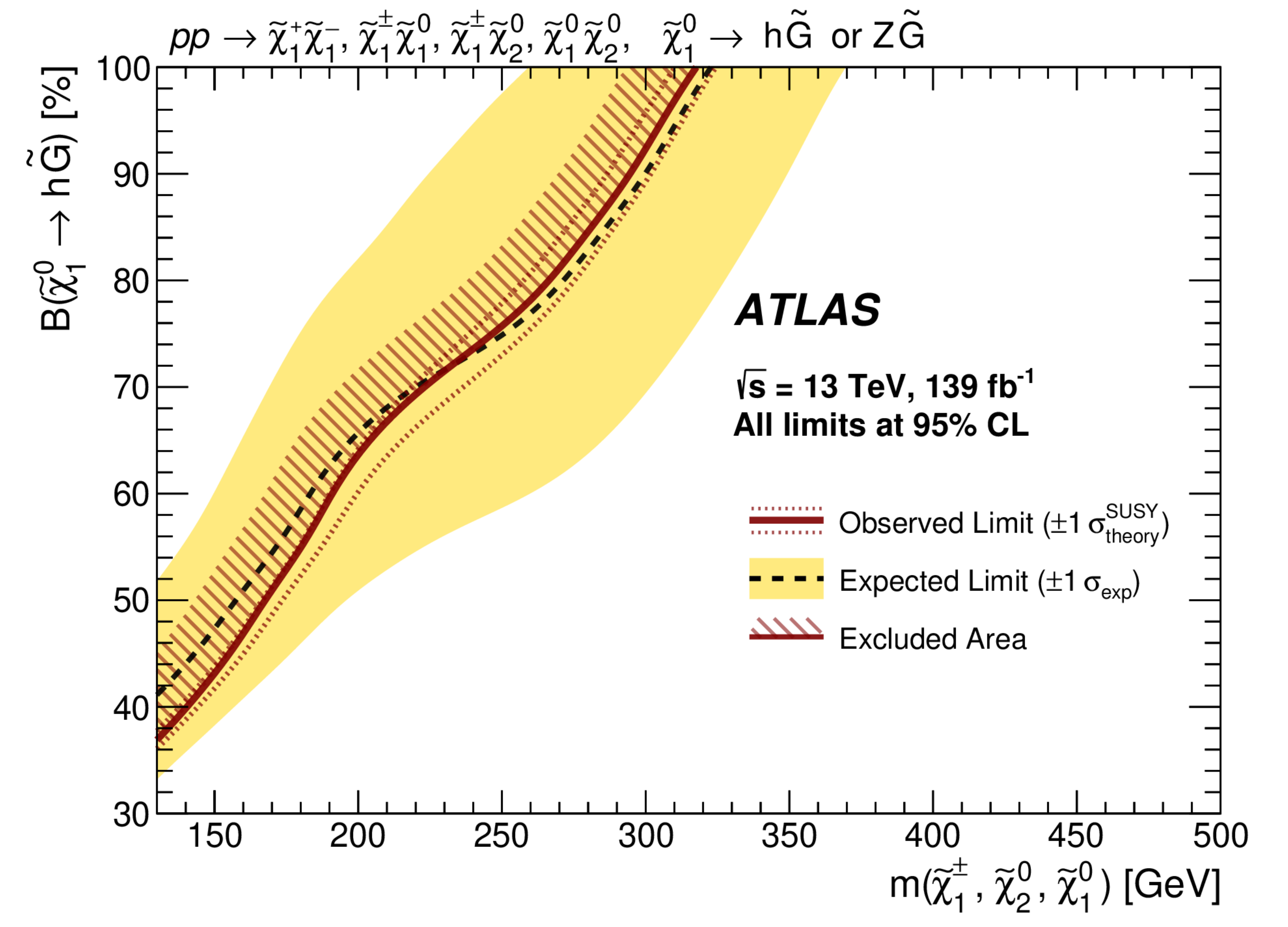
$\gamma\gamma bb + E_T^{miss}$ Analysis

Submitted to PLB

cross-section for higgsino pair-production

pure-higgsino branching fraction to $h\tilde{G}$





Electroweakinos and staus

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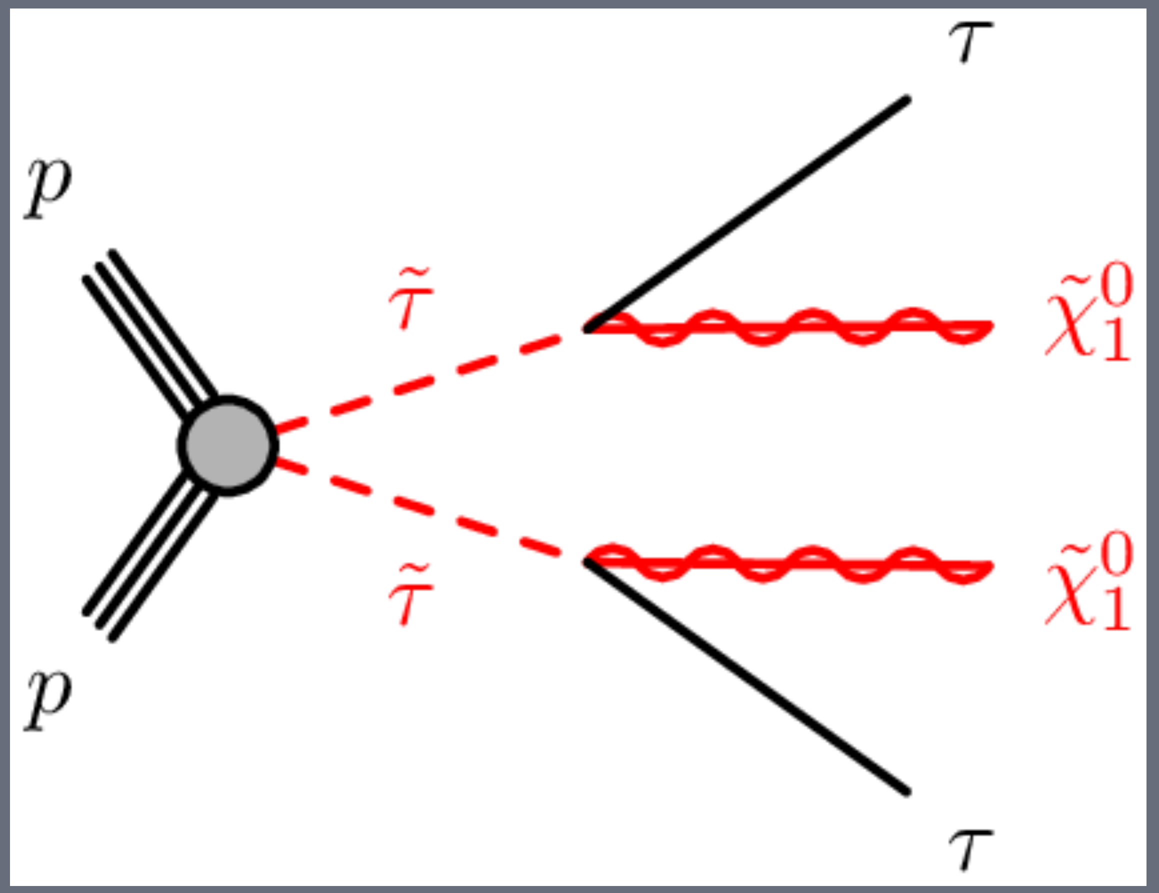
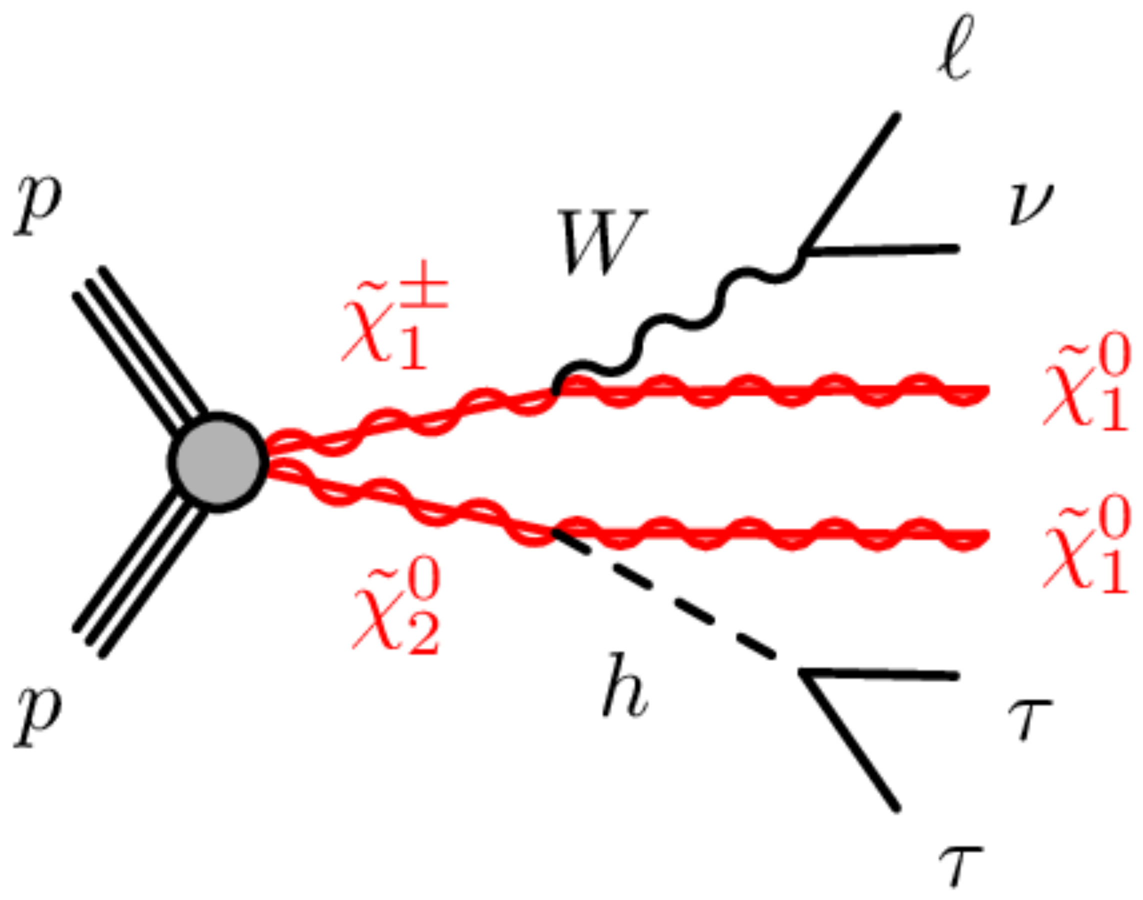
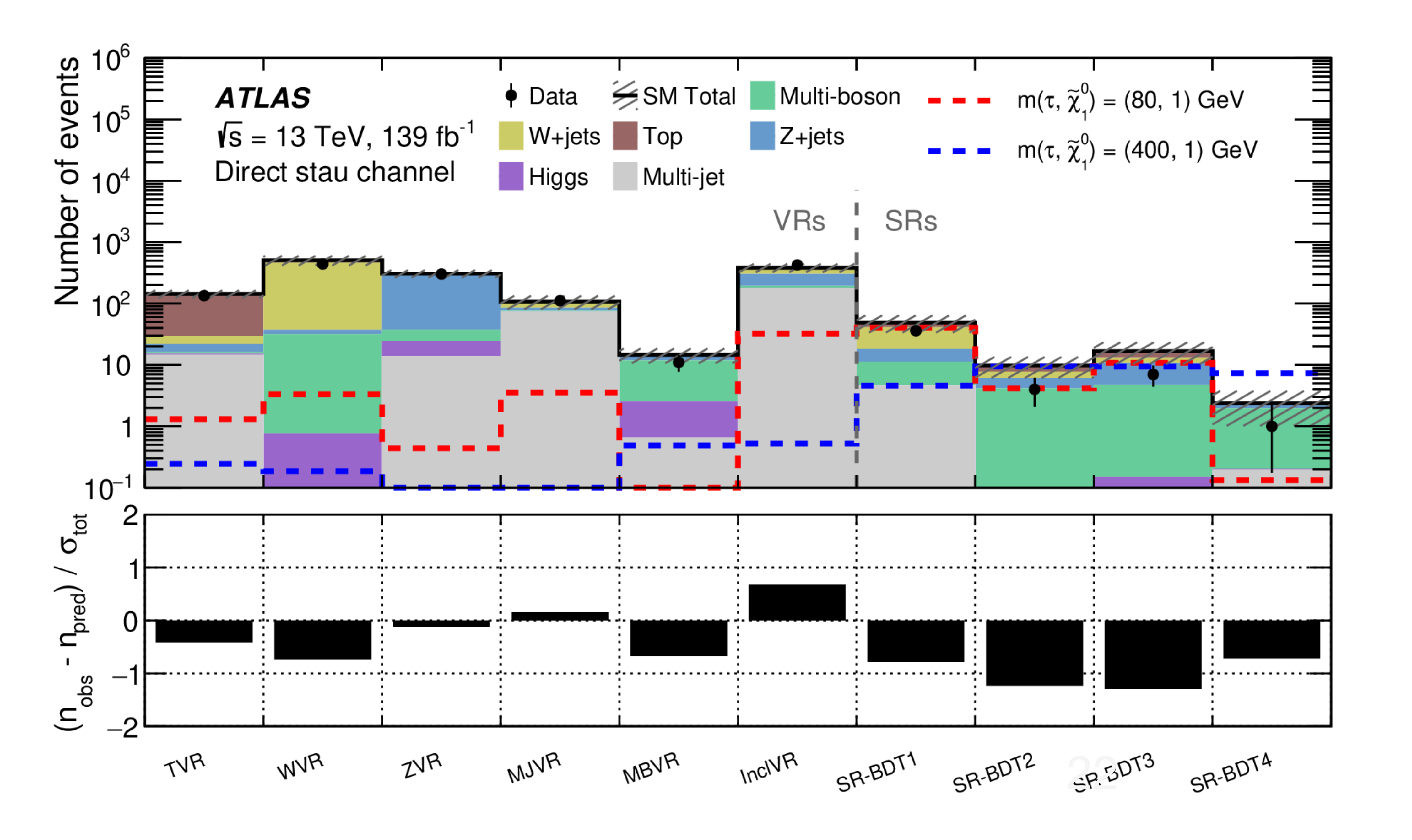


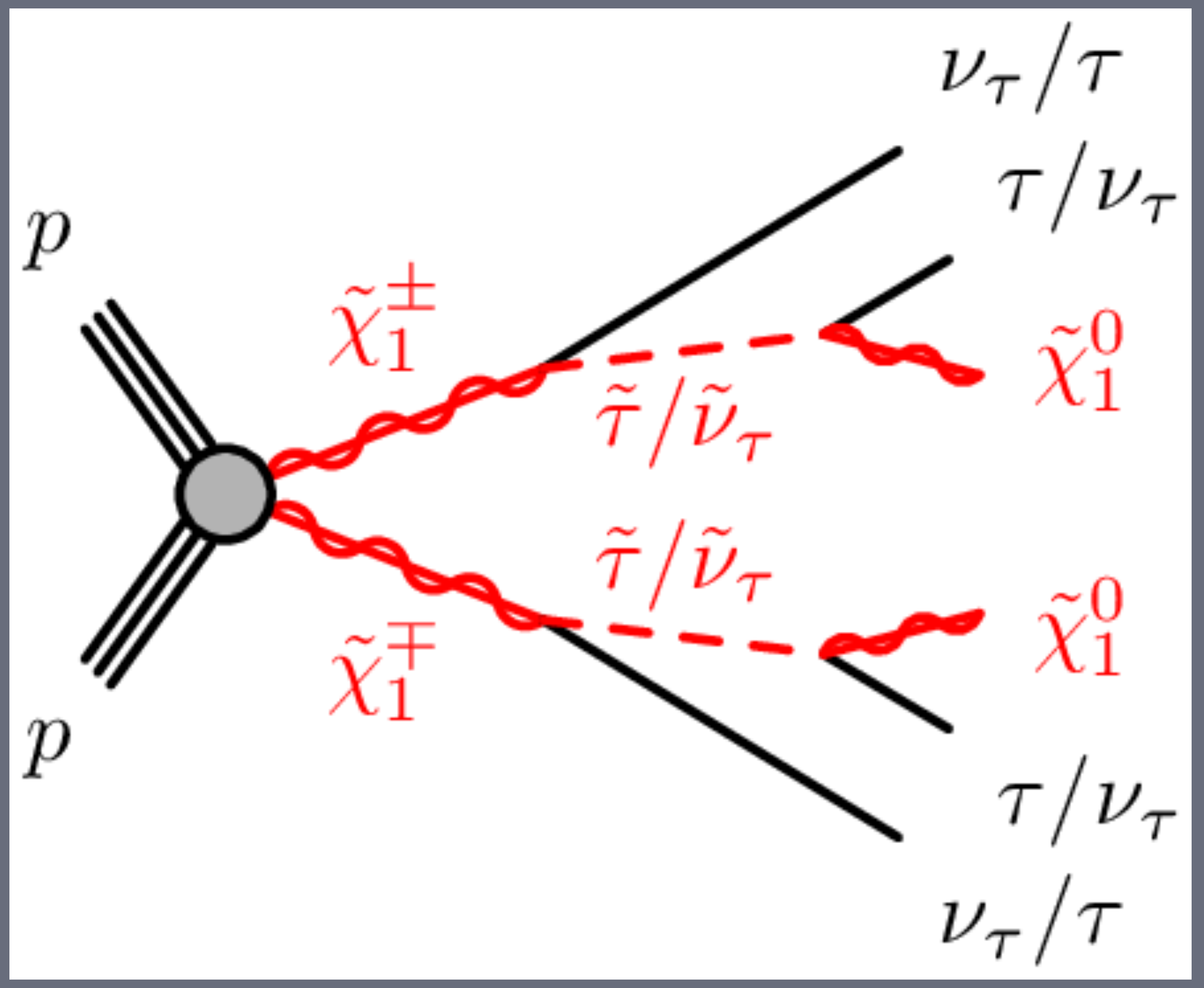
$2 \leq \tau$'s in final state

Increased sensitivity with machine learning for the direct stau production channel

The data driven ABCD method is used to estimate the mulitjet background. Other backgrounds are estimated by normalised MC







Electroweakinos and staus

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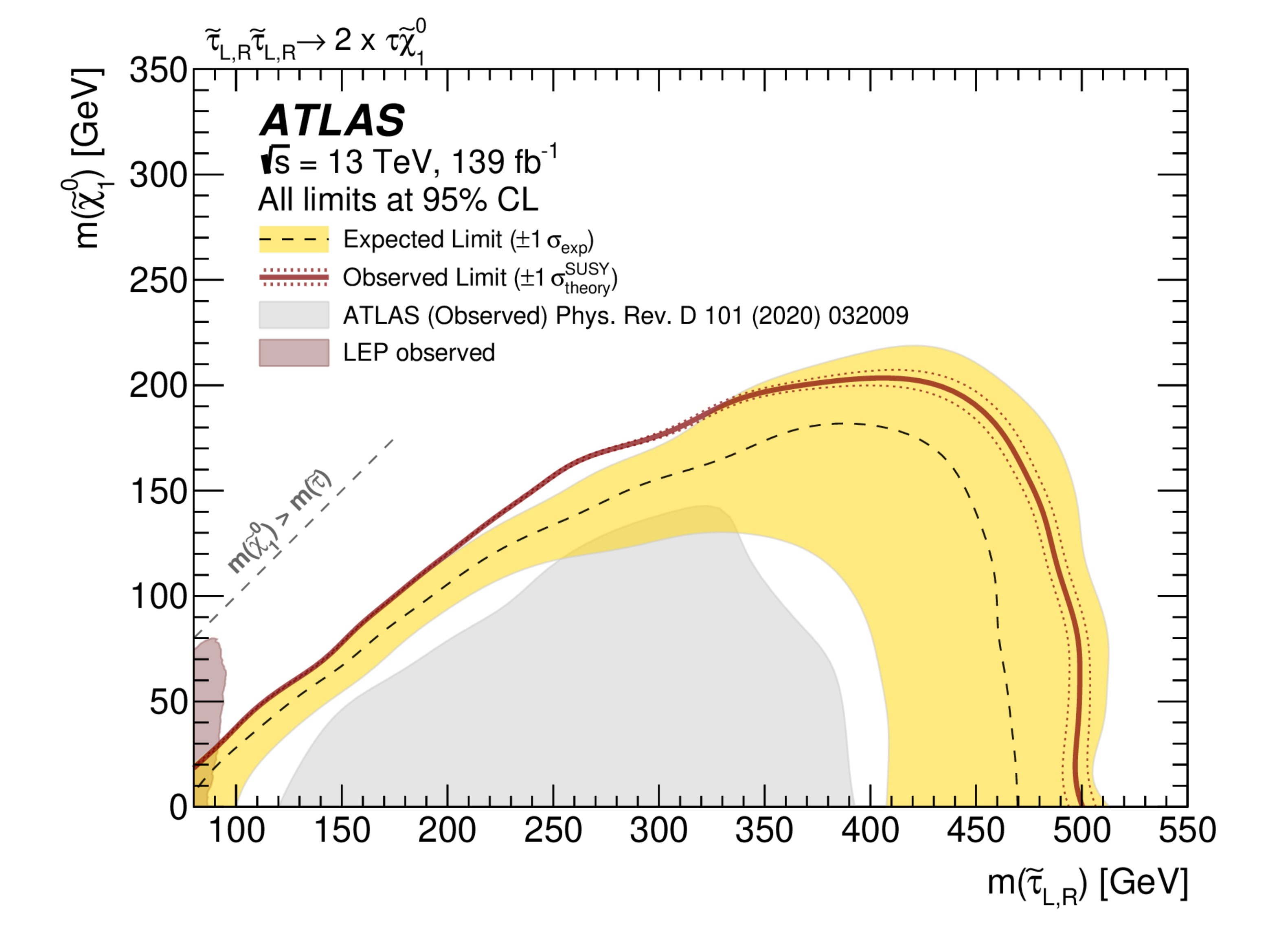

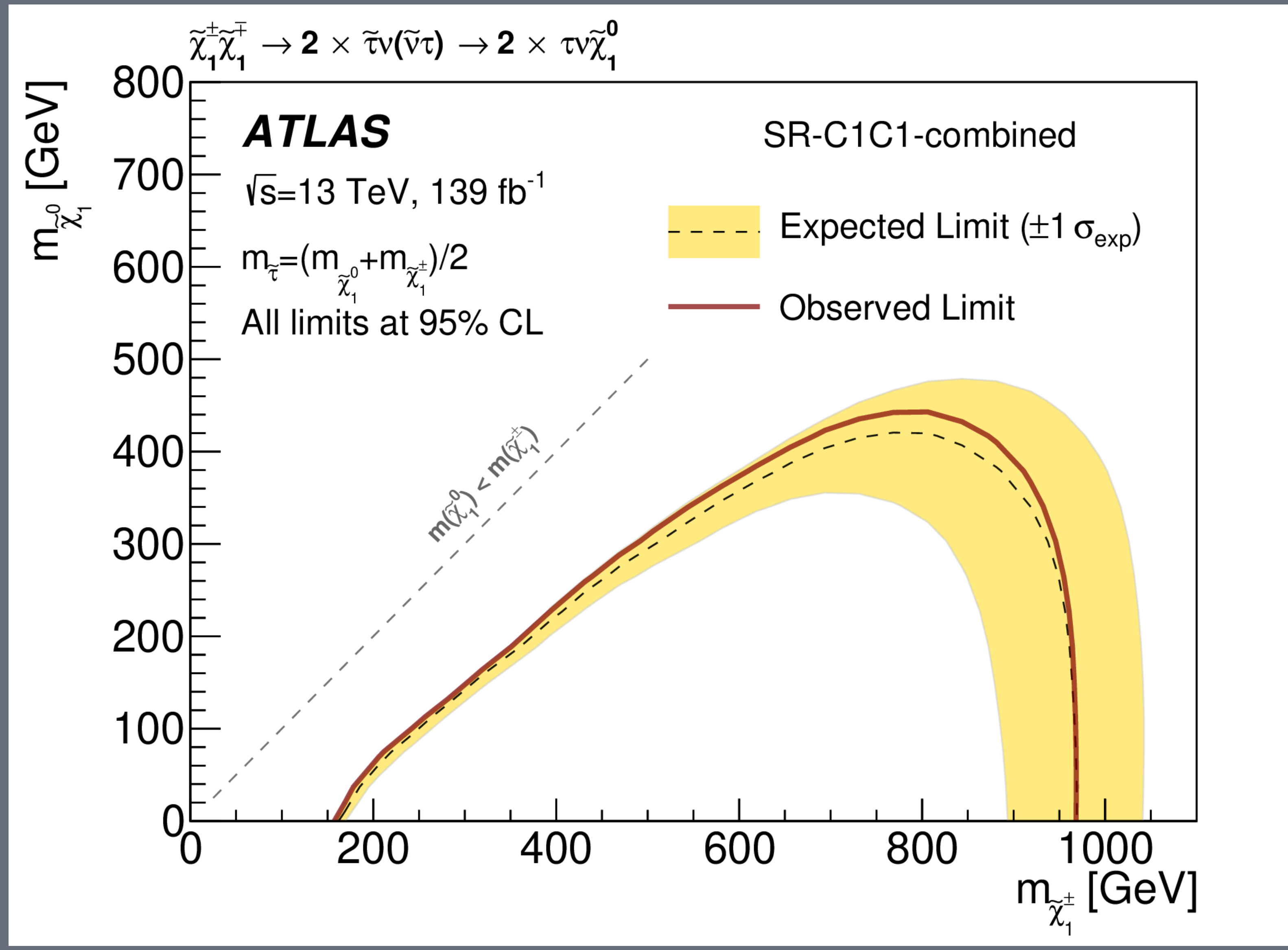

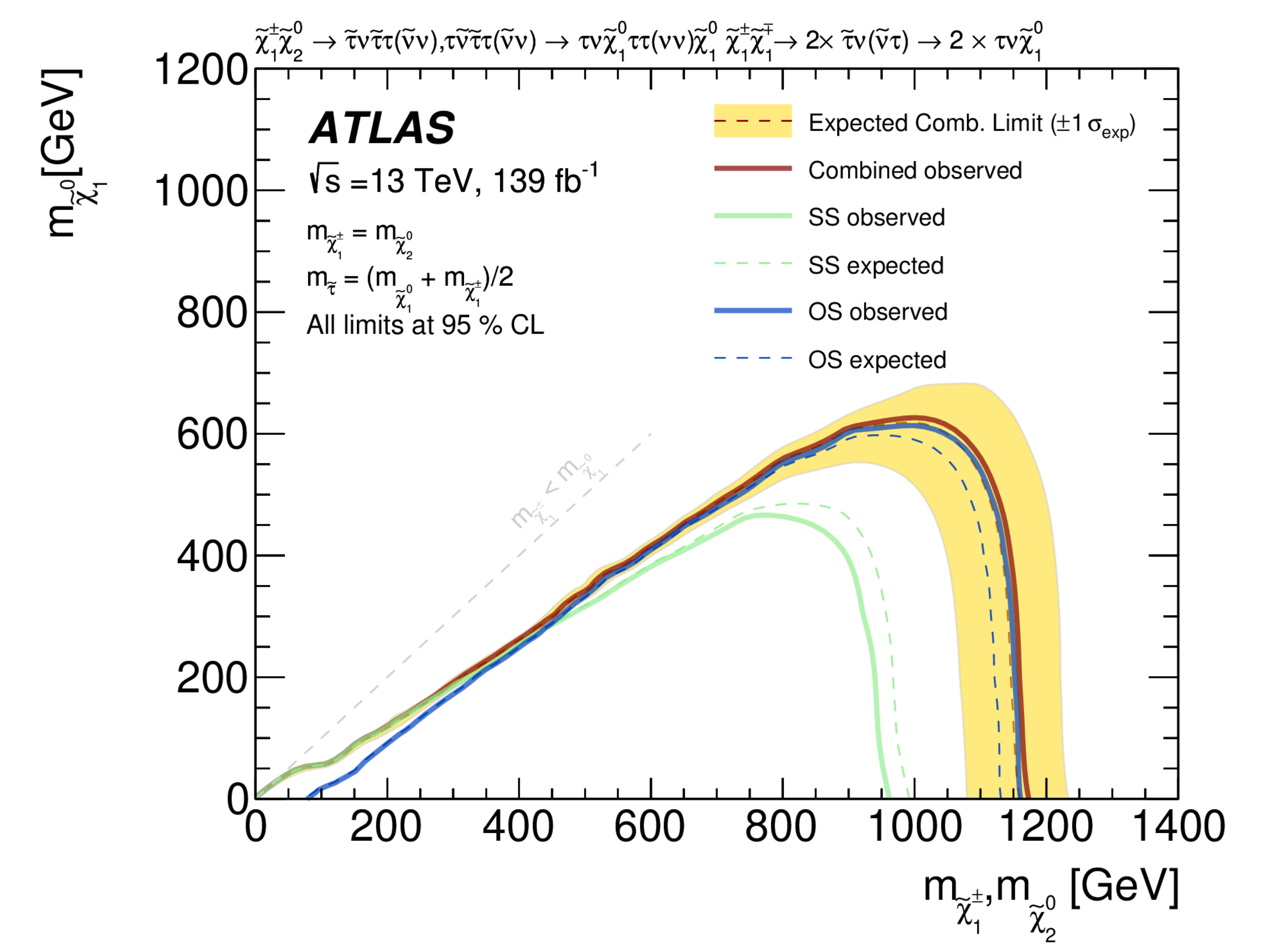

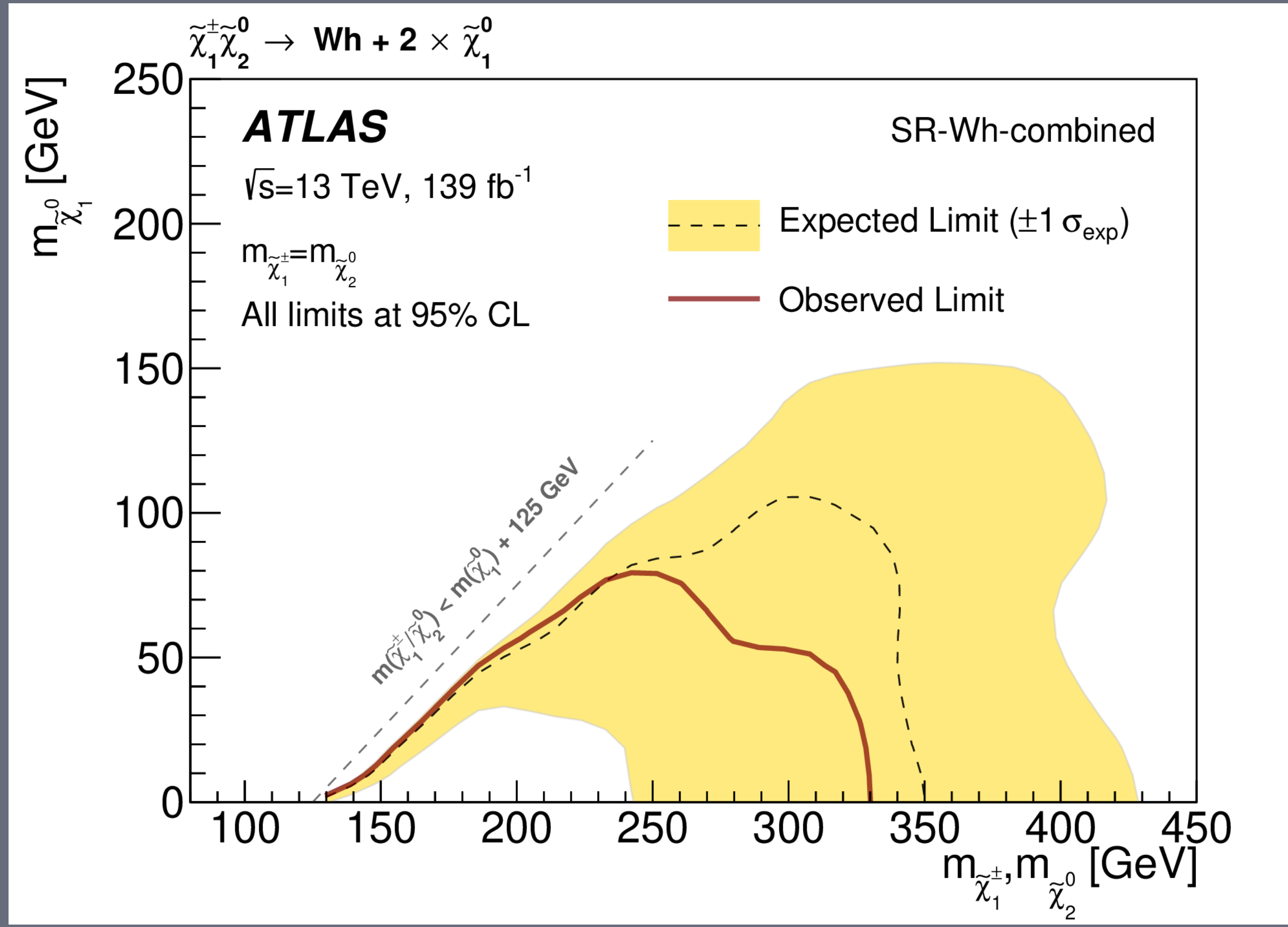

Electroweakinos and staus

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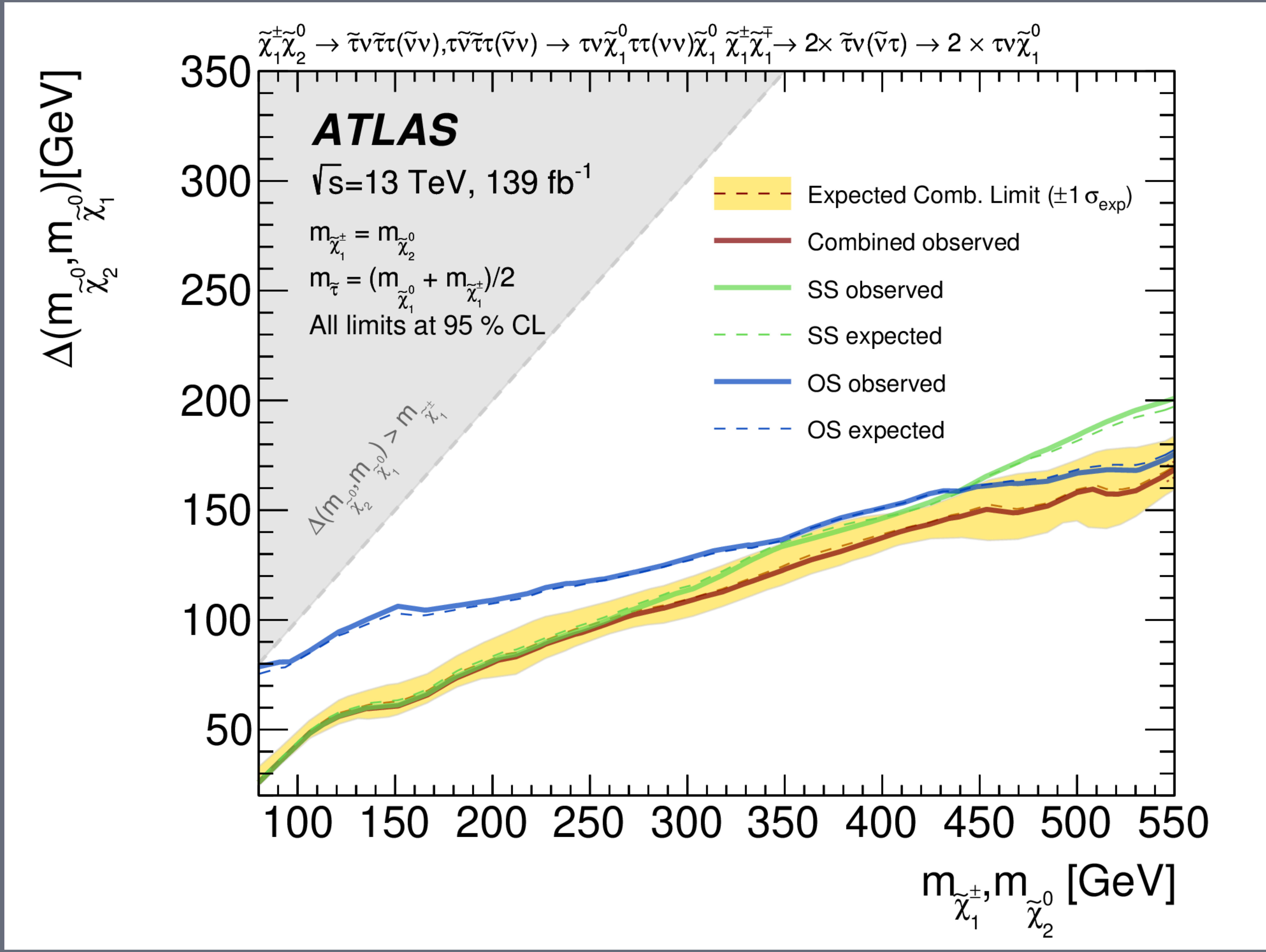
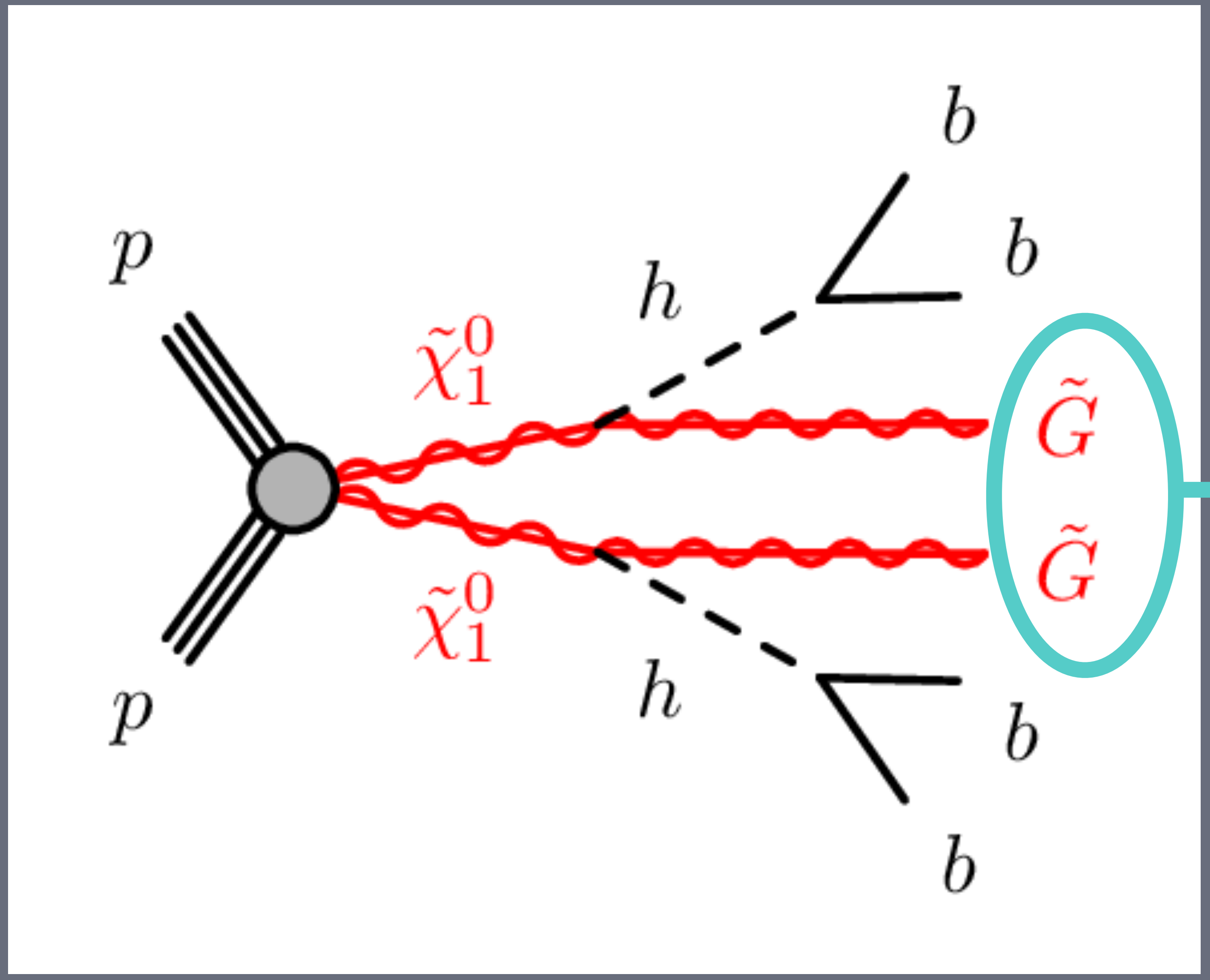


Search for higgsinos in HH(4b) +E_T^{miss}

Accepted by PRD

2 search channels:

- Low-mass Higgsinos using b-jet triggers
    - Multijet background estimate is fully data driven
    - Optimised b-tagger
- High-mass using E_T^{miss} trigger
    - Background estimate via normalised MC
    - Improved signal/background discrimination via multivariate techniques



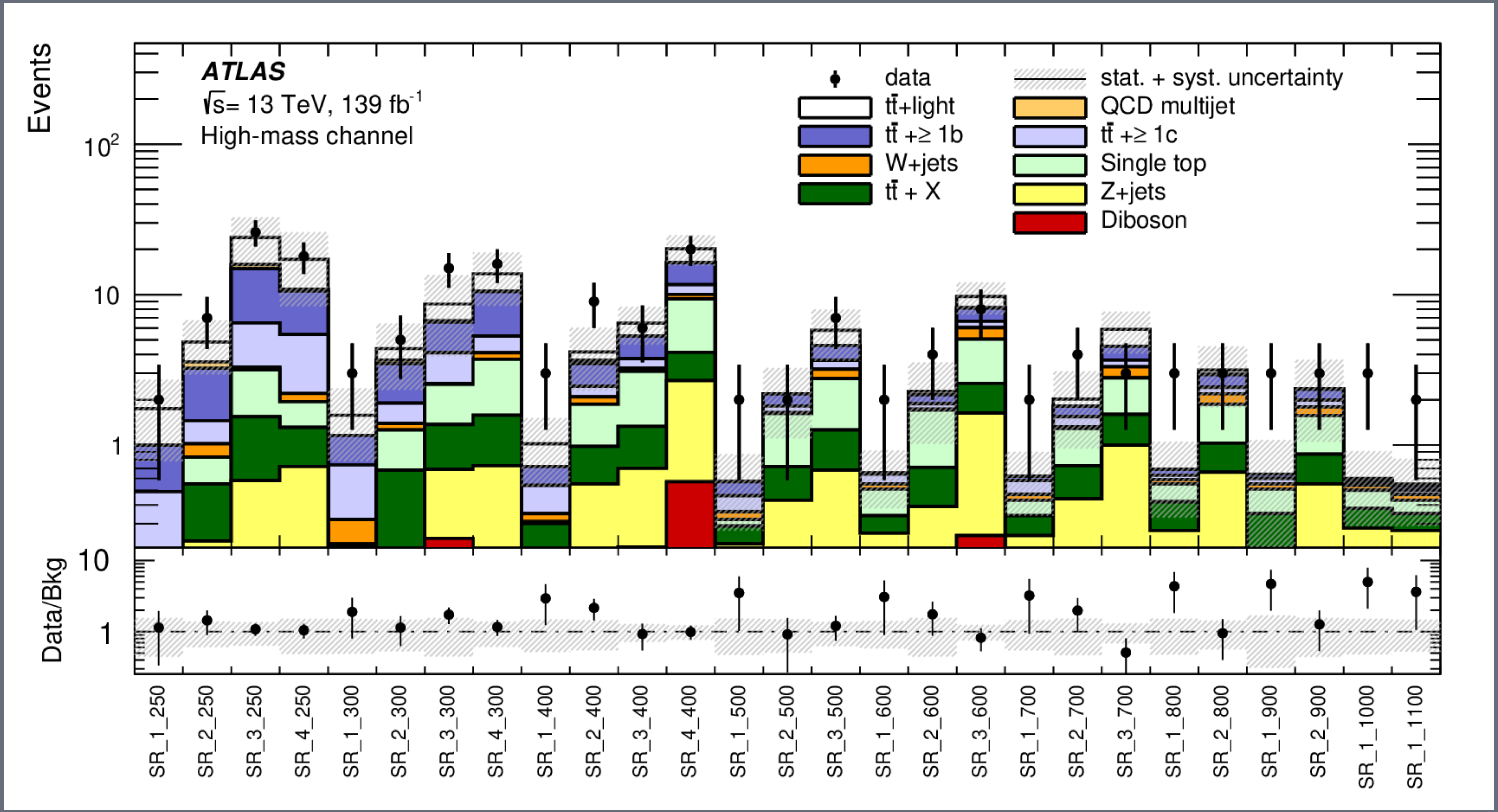
≥3 b-jets

E_T^{miss}

0 leptons

Search for higgsinos in HH(4b) +E_T^{miss}

Accepted by PRD



Search for higgsinos in HH(4b) +E_T^{miss}

Accepted by PRD