SUSY: news from Run 2 searches

PLANCK 2017

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on behalf of the ATLAS Collaboration

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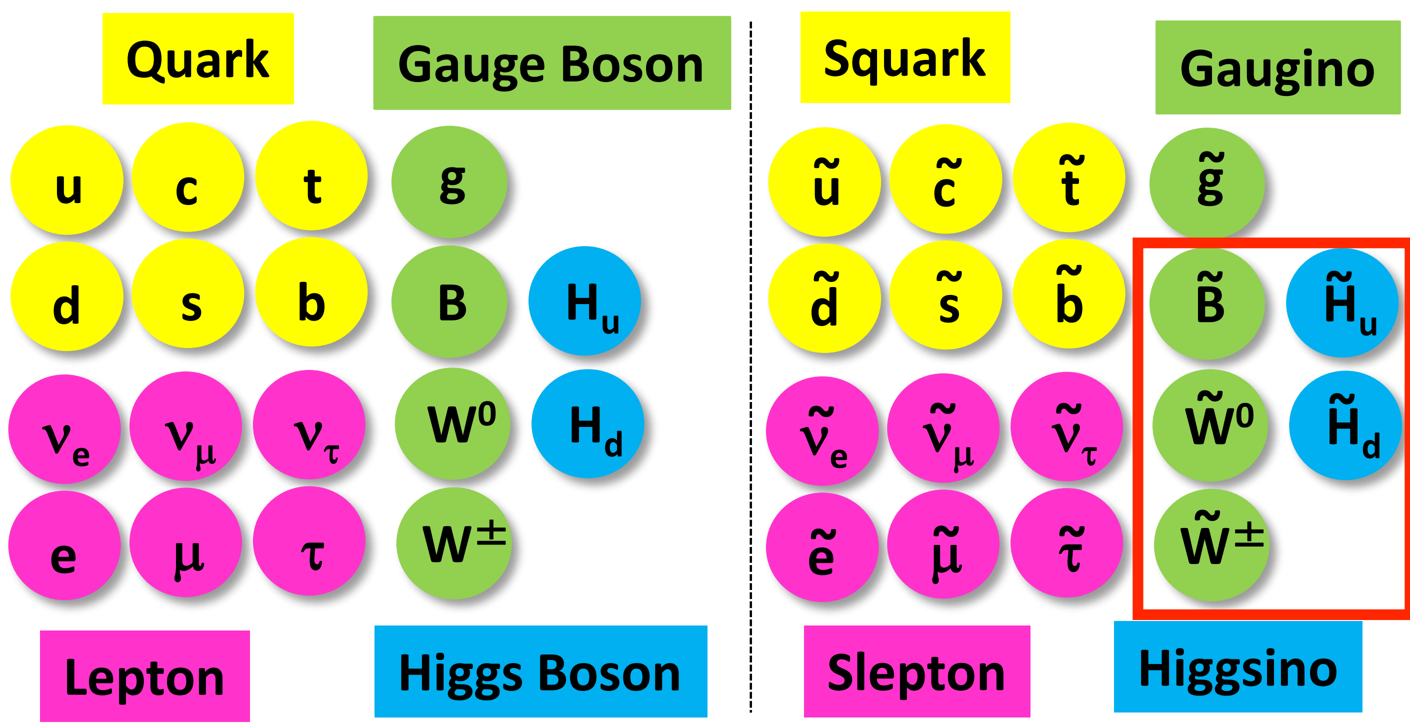
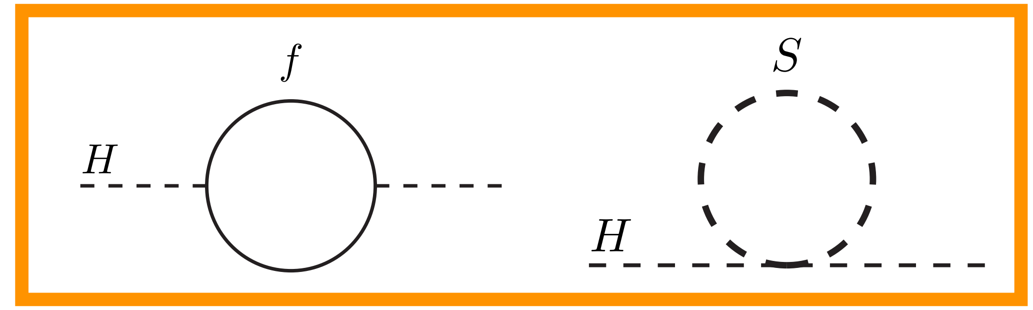
Supersymmetry (SUSY)





bino/winos/higgsinos mix: charginos/neutralinos are mass eigenstates

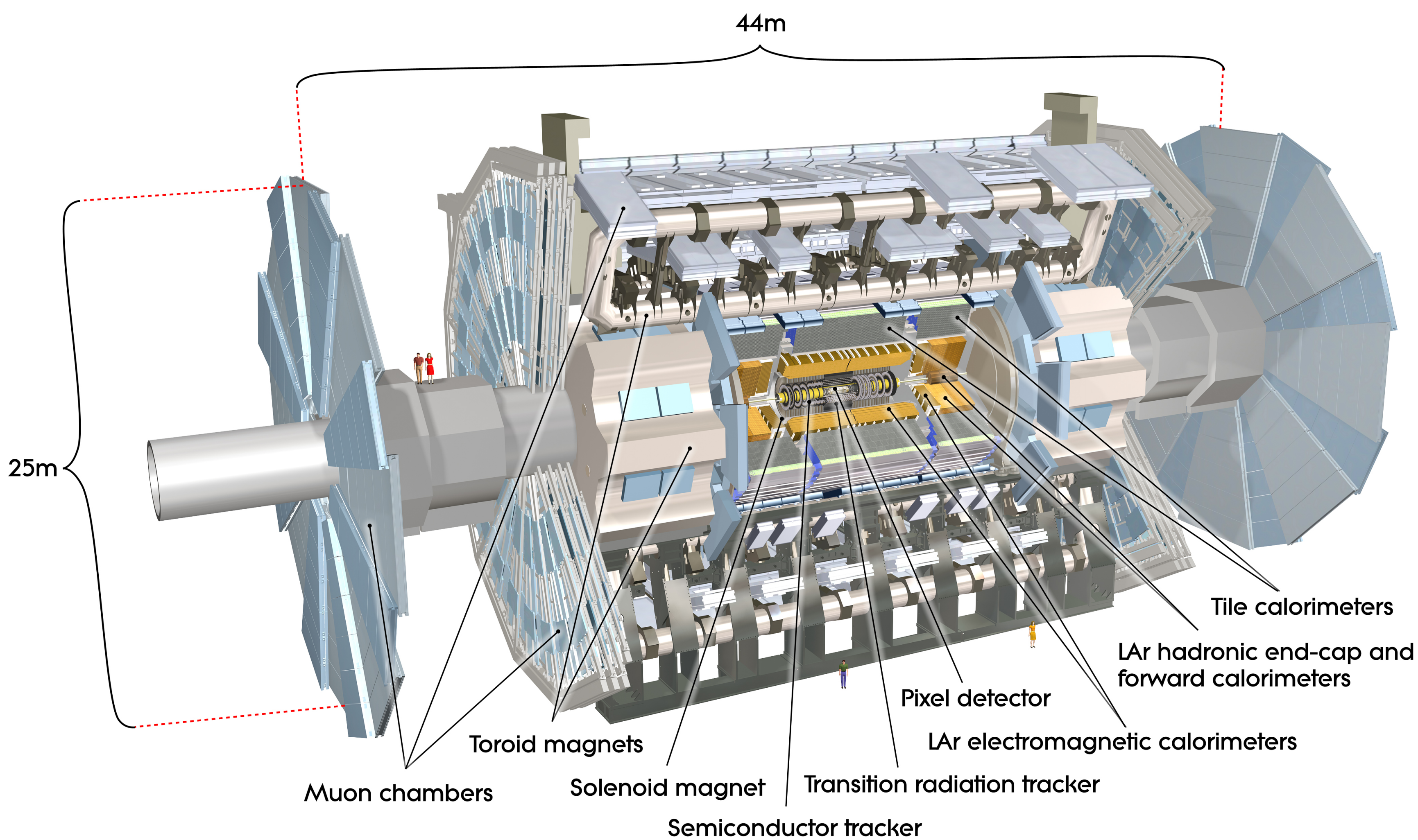
LSP

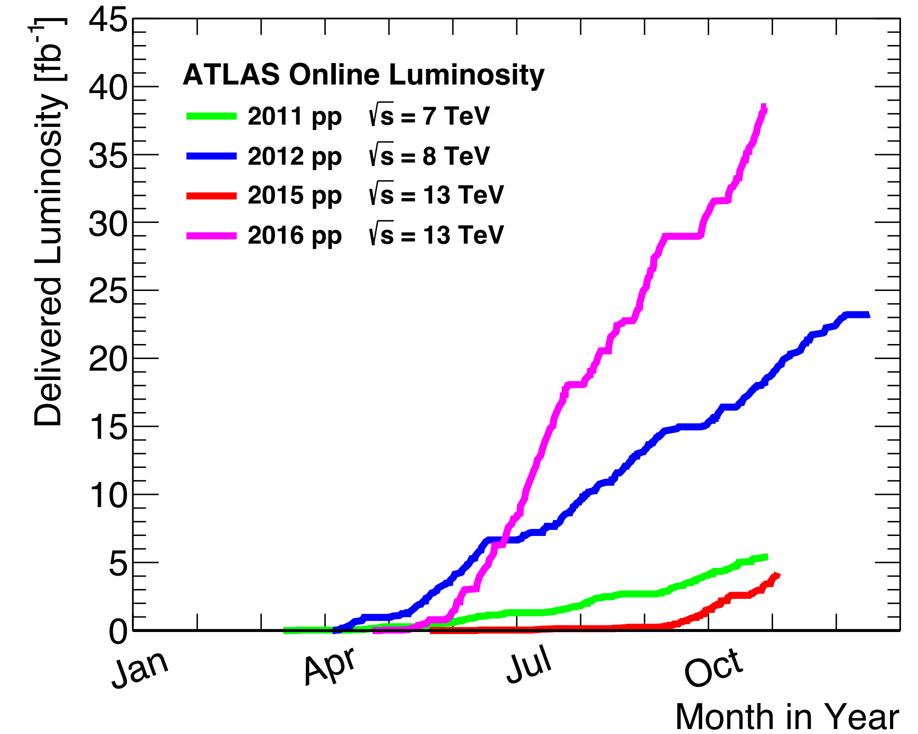
$\tilde{\chi}^0_{1,2,3,4}$

$\tilde{\chi}^{\pm}_{1,2}$

- Fundamental symmetry between **fermions** and **bosons** that presents solutions to some *problems* of the SM:
  - SUSY particles provide opposite-sign loop corrections to the Higgs mass, **canceling out quadratic divergencies**
  - If R-parity = $(-1)^{3(B-L)+2s}$ conserved, Lightest SUSY particle (LSP) is stable and natural **Dark Matter** candidate
  - Achieve **unification** of gauge couplings at $M_{GUT} \approx 10^{16}$ GeV

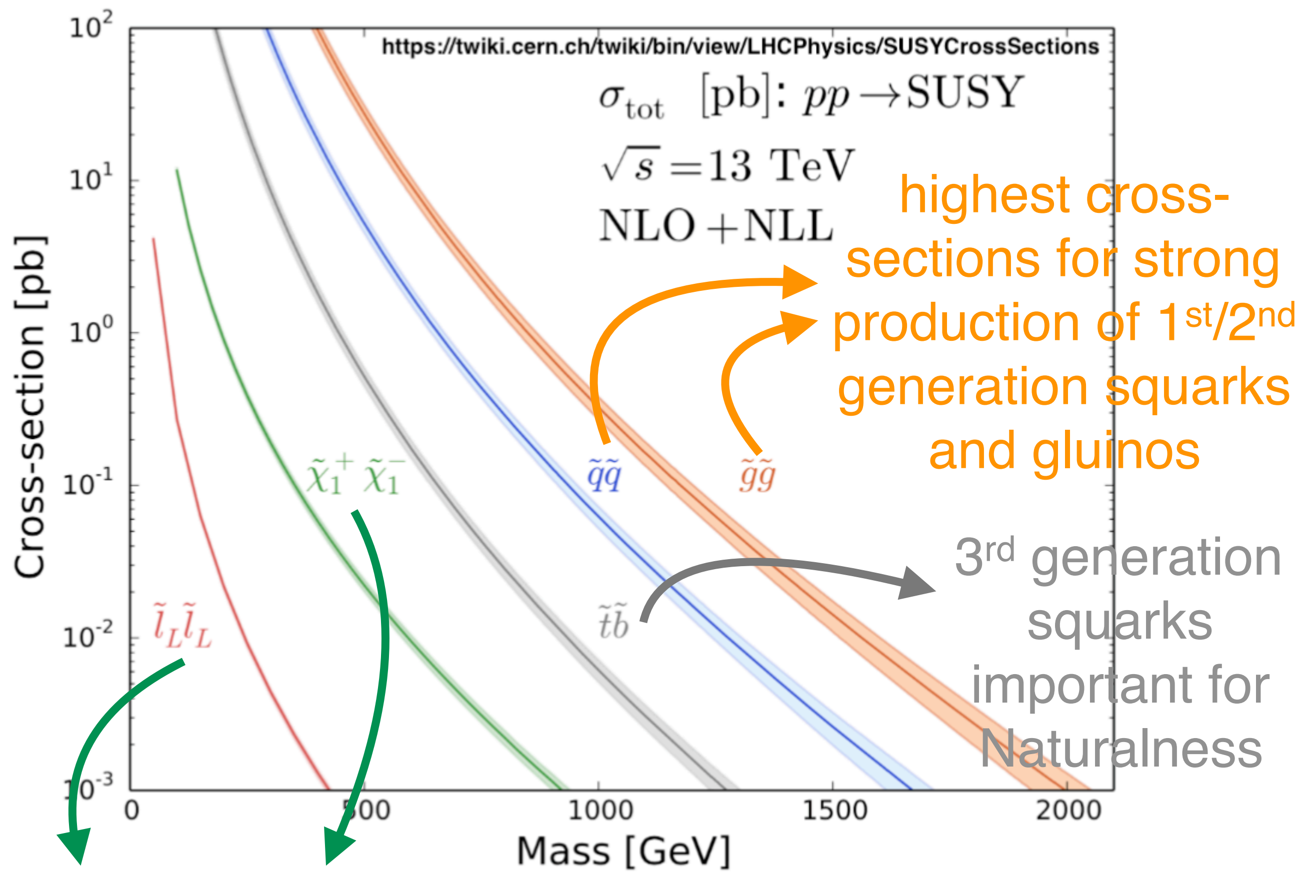
ATLAS: A Toroidal LHC ApparatuS

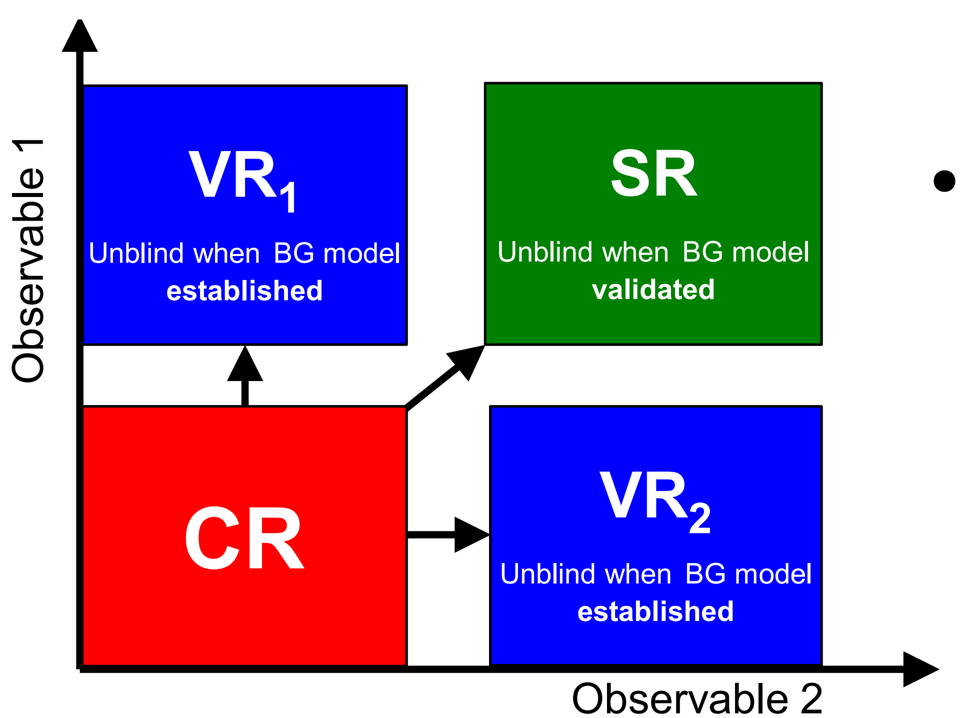




- Major upgrades for Run 2 - detectors, trigger, DAQ, reconstruction
- Excellent performance under challenging LHC conditions
  - peak lumi 1.38×10^{34} cm^{-2} s^{-1}
  - up to 50 interactions per crossing
- **36 fb^{-1} of good 13 TeV *pp* collision data collected in 2015 and 2016**

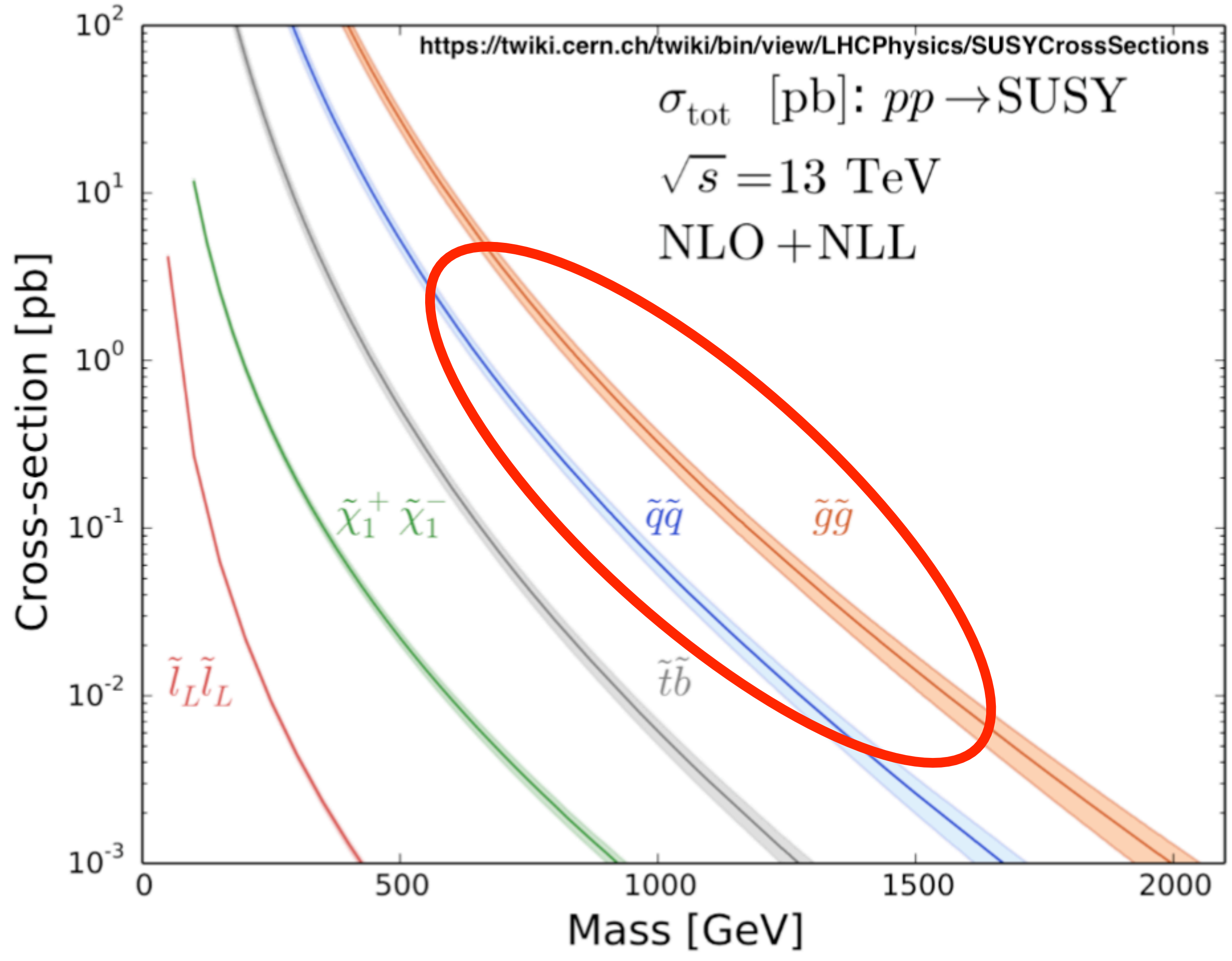
How to search for SUSY





- Make **assumptions** on mass spectra and use **simplified models** to define signatures and guide searches
  - *R-parity conservation - **RPC***: pair-produced SUSY particles decaying to LSP
  - *R-parity violation - **RPV***: LSP decays to SM particles
- **Signal regions** built with high S/B using discriminating variables
- Backgrounds:
  - Irreducible predicted from MC or normalized in **control regions**
  - Reducible estimated from data-driven methods
  - Checked in **validation regions**

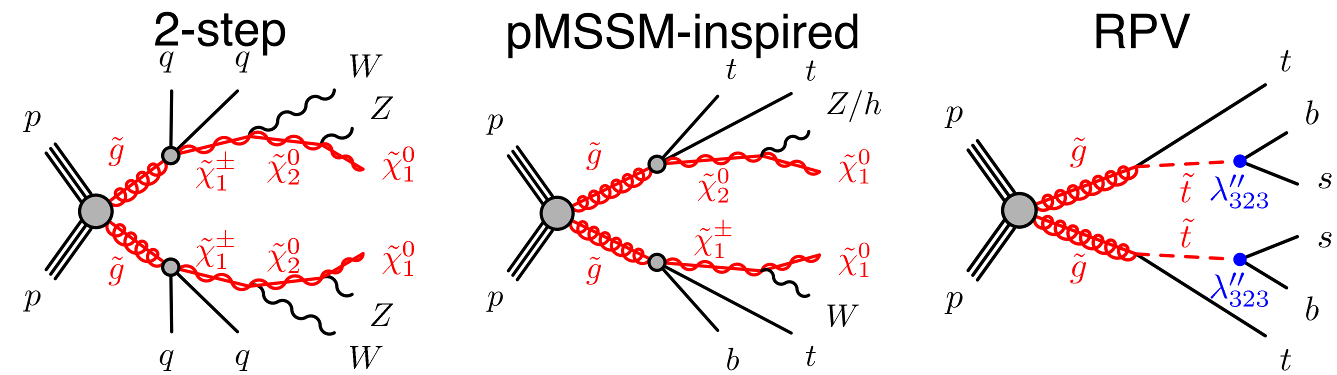
Inclusive searches for squarks and gluinos

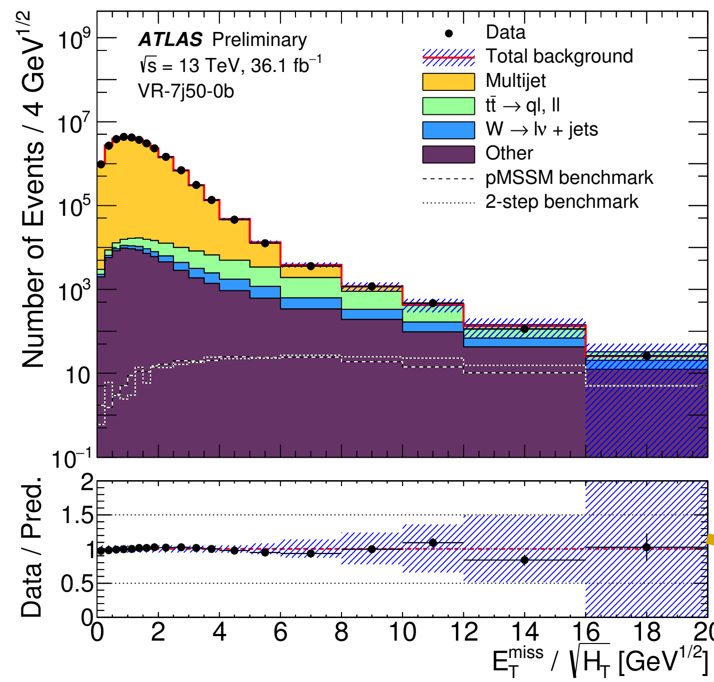


see ATLAS-CONF-2017-033

Multijets

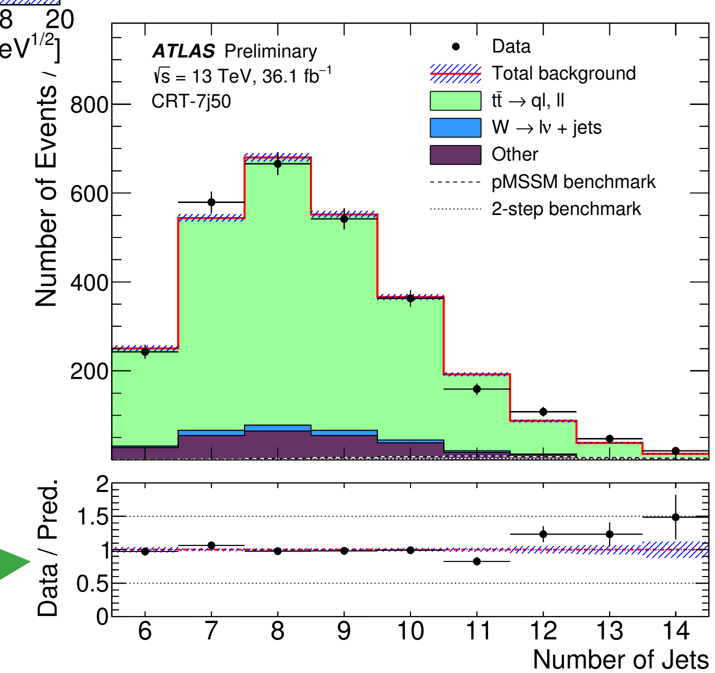
- N_{jets} **≥ 7-11** and leptons vetoed
- Sensitivity to gluino pair production with cascade decays
- Discrimination from **MET/√H_T**
- 27 non-exclusive SRs based on $N_{\text{b-jets}}$ and mass of "fat jets" → **large gluino masses and boosted topologies**
- Template for dominant multijet bkg MET/√H_T distribution extracted from N_{jets} = 6 data
- Leptonic control regions used to normalize W+jets and ttbar





multijet template validated in N_{jets} = 7 VR

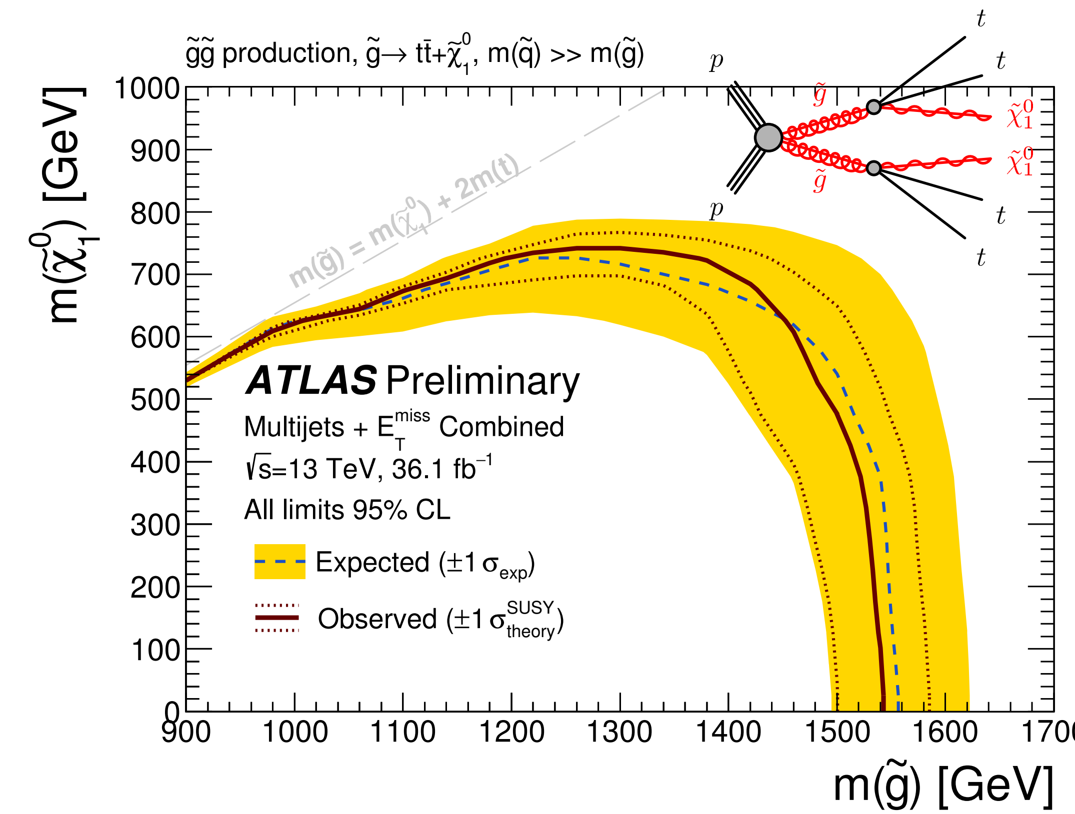
good modelling of N_{jets} in ttbar CR

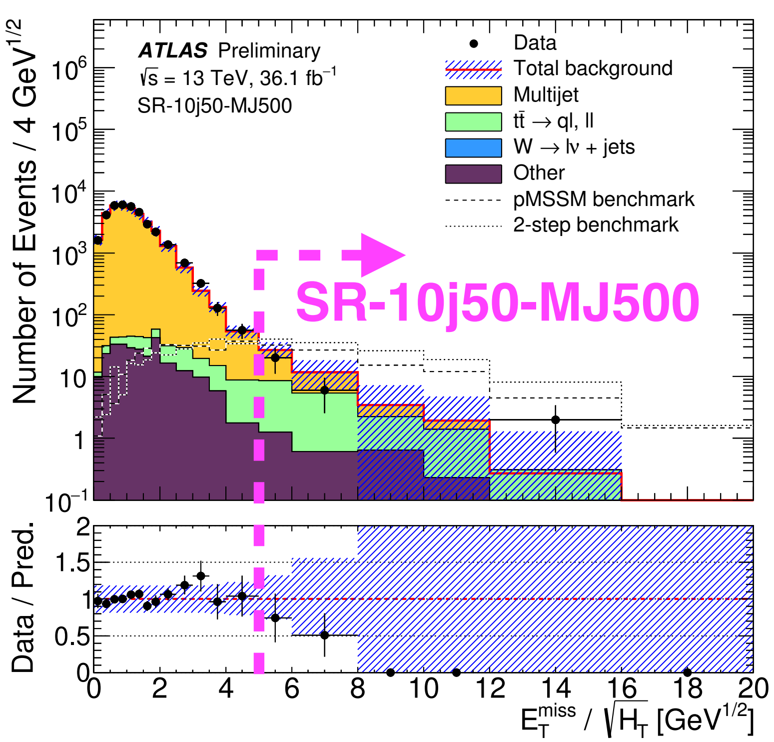


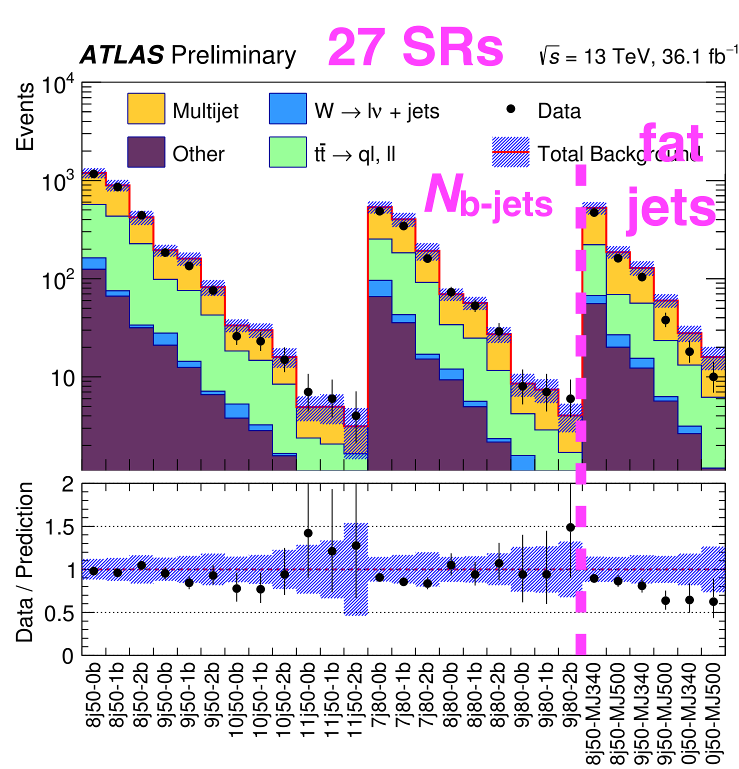
see ATLAS-CONF-2017-033

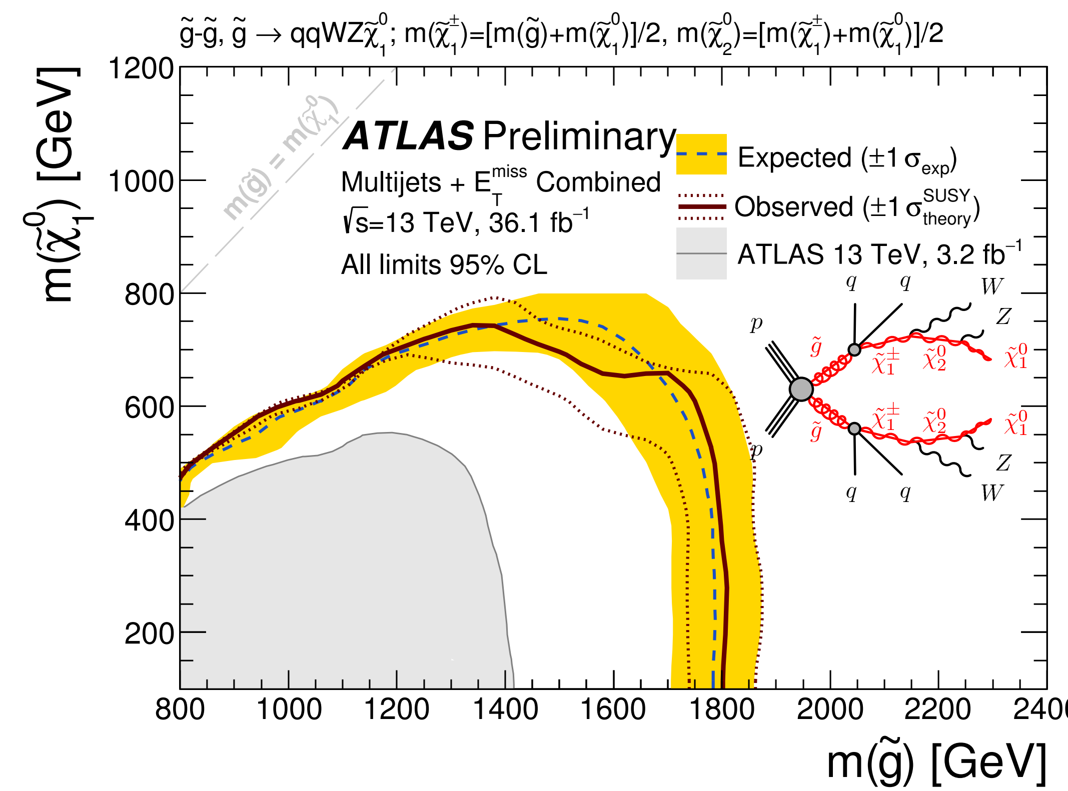
Multijets

- No significant excesses observed over background expectation
- Gluino masses up to 1.8 TeV excluded for light LSPs assuming a two-step cascade decay





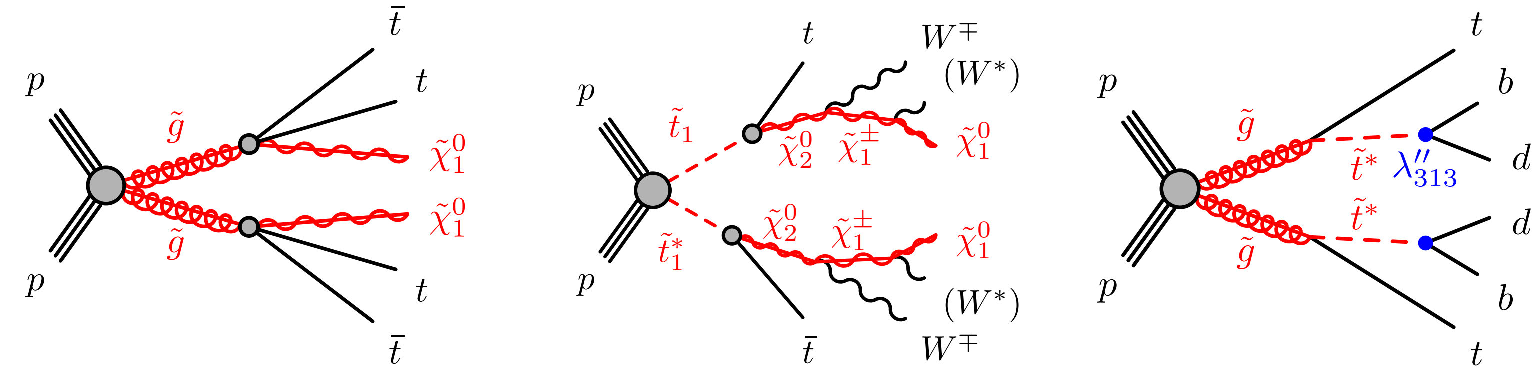


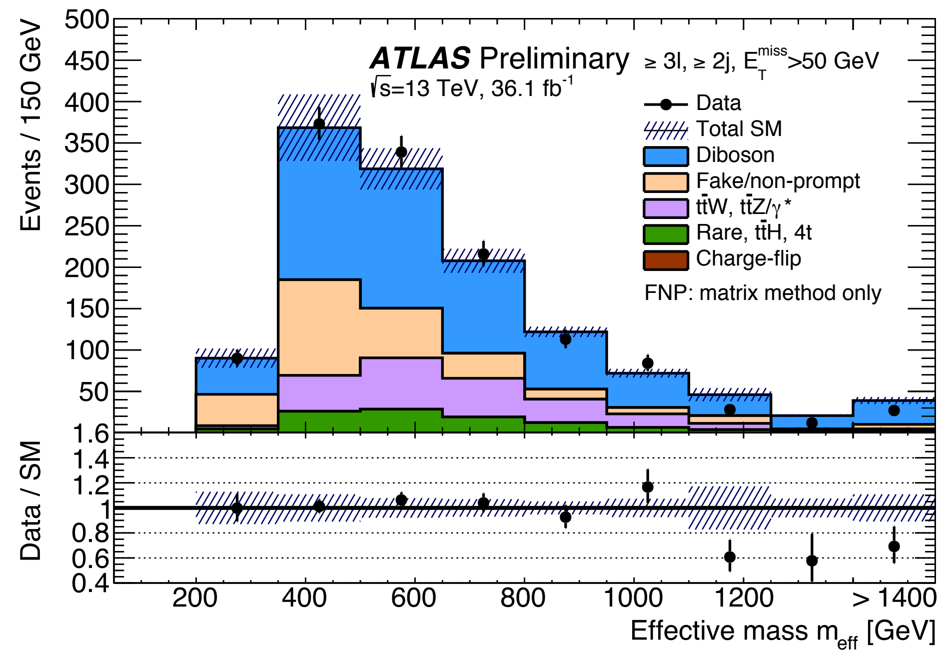


see ATLAS-CONF-2017-030

2ℓ same sign / 3ℓ + (b-)jets

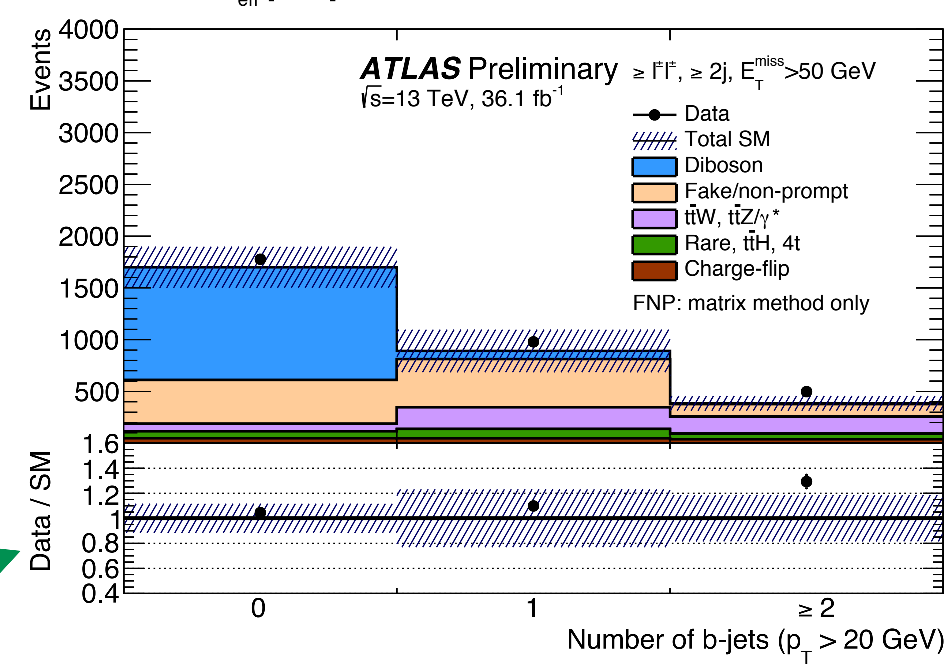
- Sensitivity to 12 different RPC and RPV models
- Low SM backgrounds → looser selections → target **low mass splittings**
- 19 non-exclusive SRs based on N_{jets}, N_{bjets}, MET and $m_{eff} = \sum p_T$ + MET
- Electron charge-flip bkgs estimated from likelihood fit to Z/γ^* → *ee* data
- Fake or non-prompt lepton backgrounds estimated with data-driven methods





good modelling of m_{eff} in events with $\geq 3\ell$, $N_{jets} \geq 2$ and MET>50 GeV

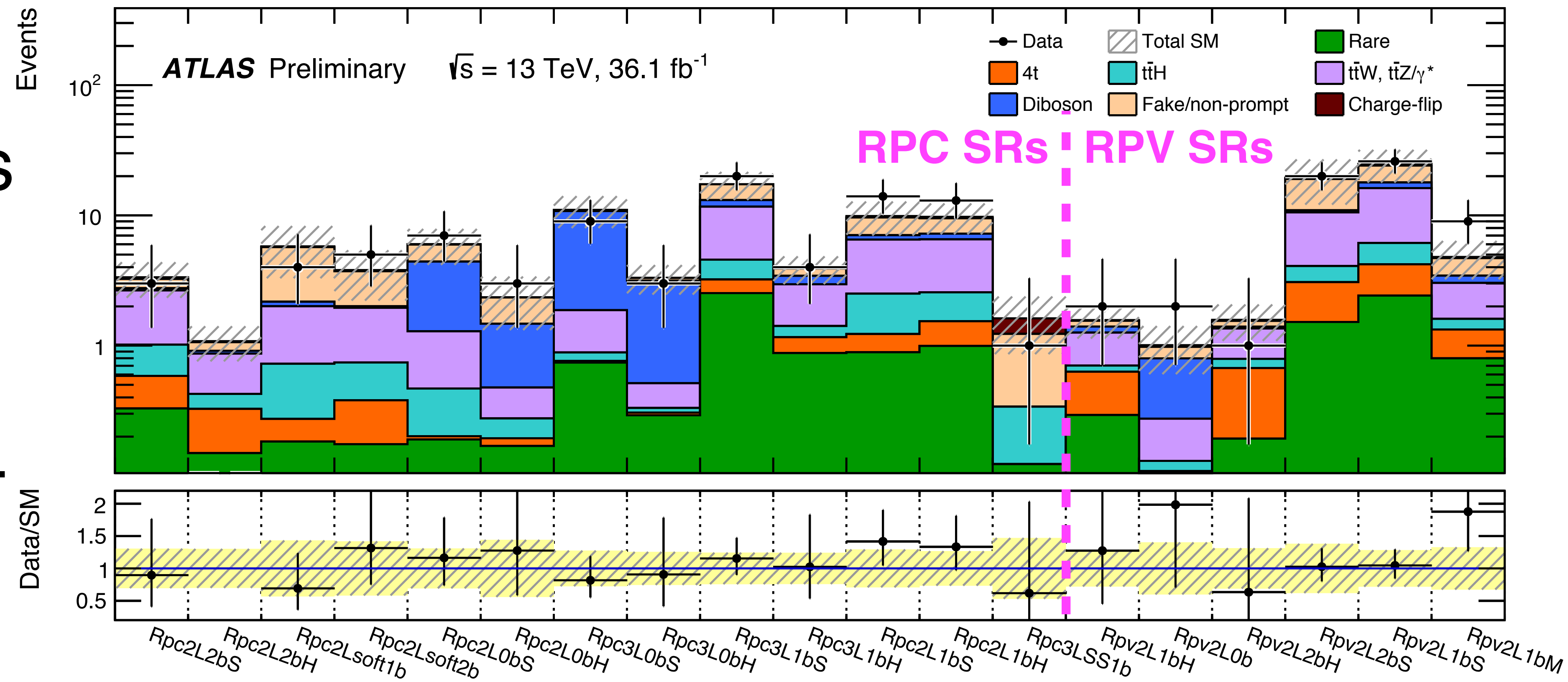
good modelling of $N_{b\text{-}jets}$ in events with 2ℓ SS, $N_{jets} \geq 2$ and MET>50 GeV

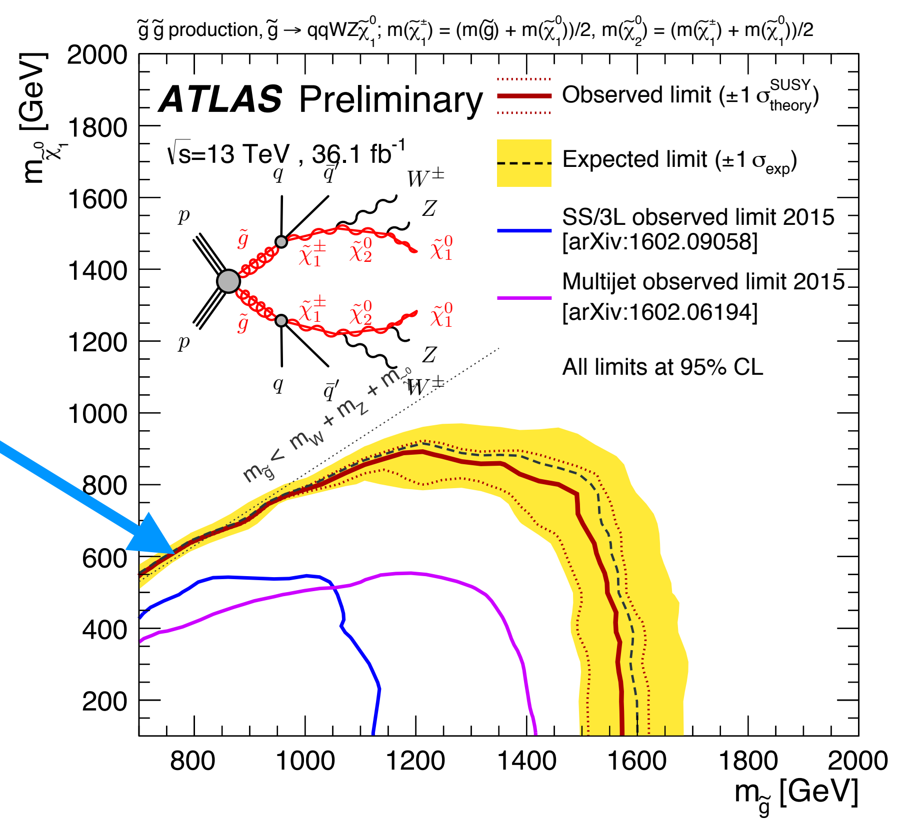


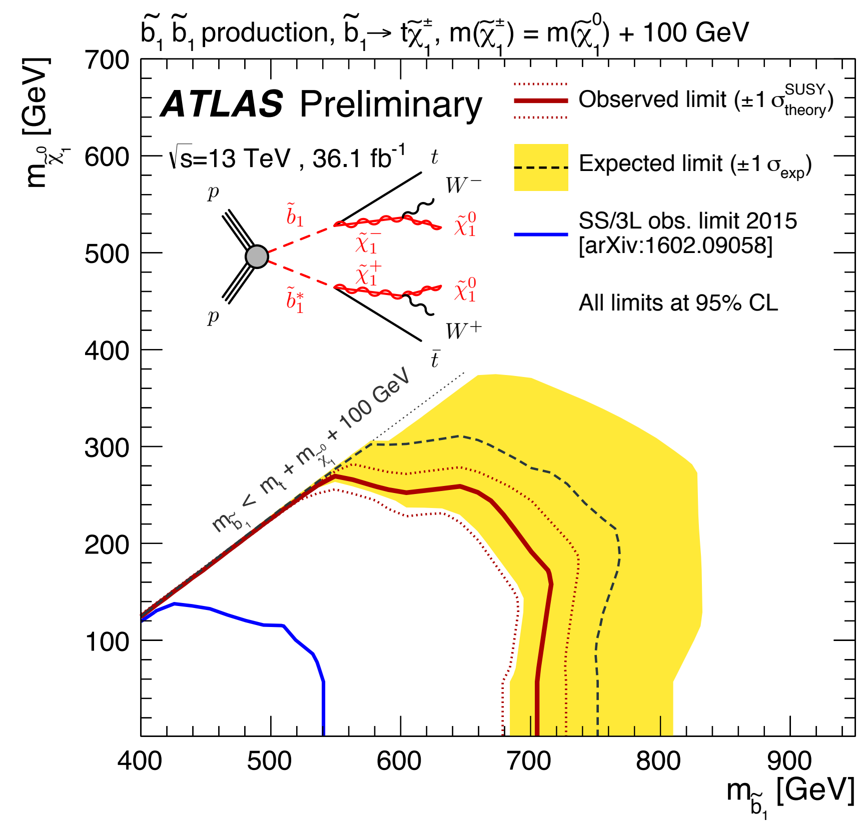
see ATLAS-CONF-2017-030

2ℓ same sign / 3ℓ + (b-)jets

- Observed no significant excess over SM expectation
- Previous 95% CL exclusion limits greatly extended, especially in **compressed regions**
- All models with gluino masses below 1.3 TeV excluded

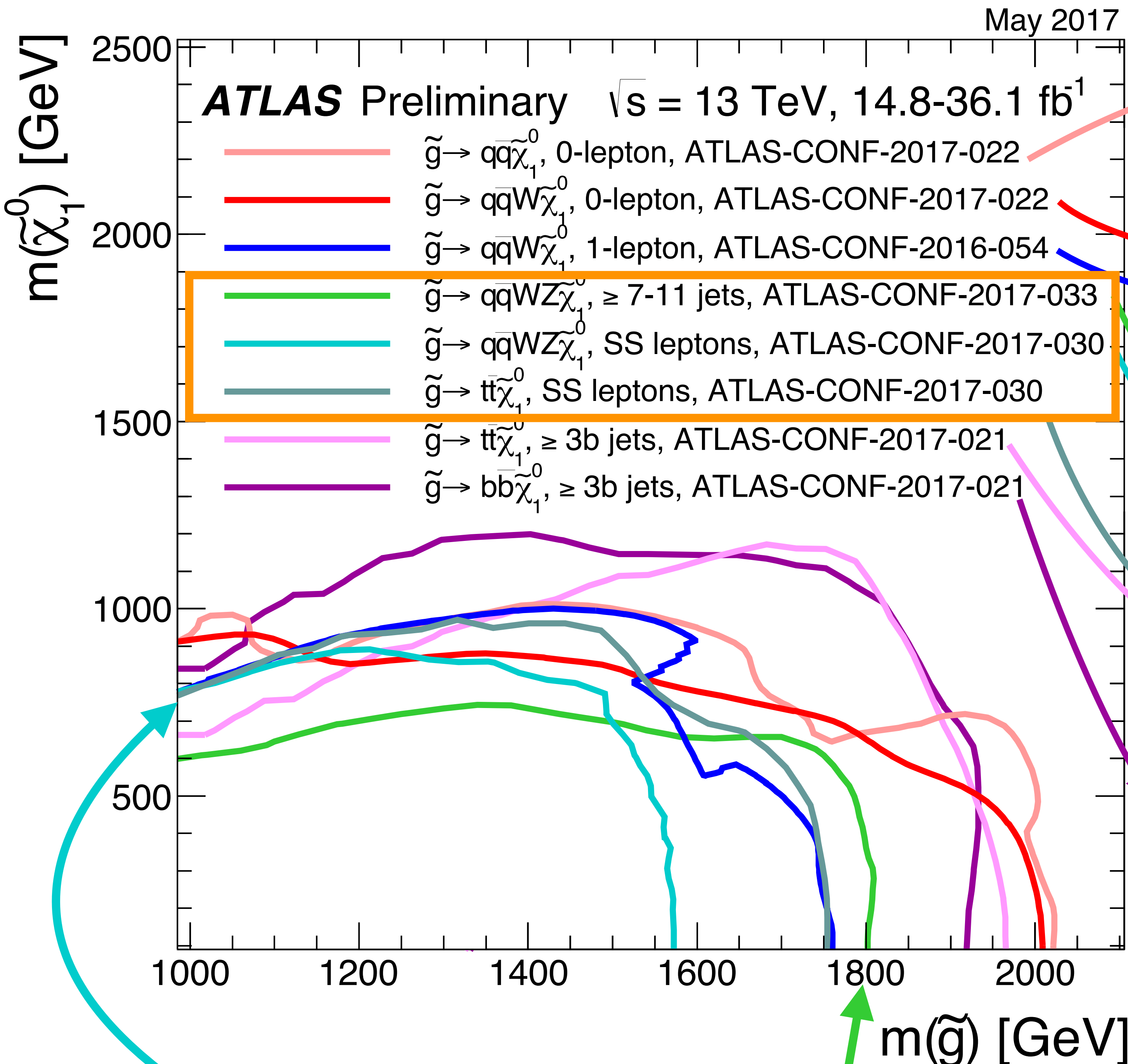


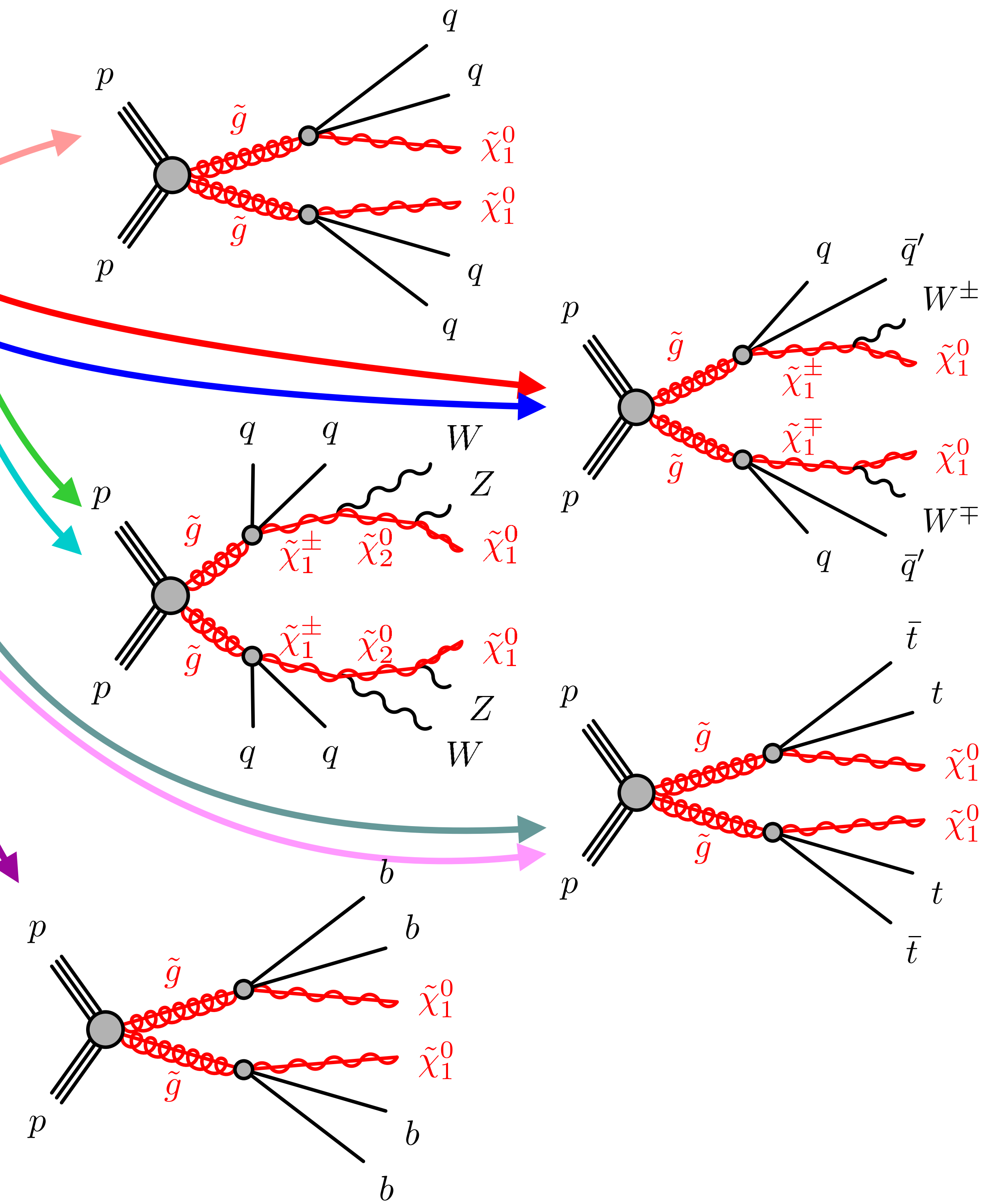




see ATLAS SUSY Public Results

Summary of gluino searches



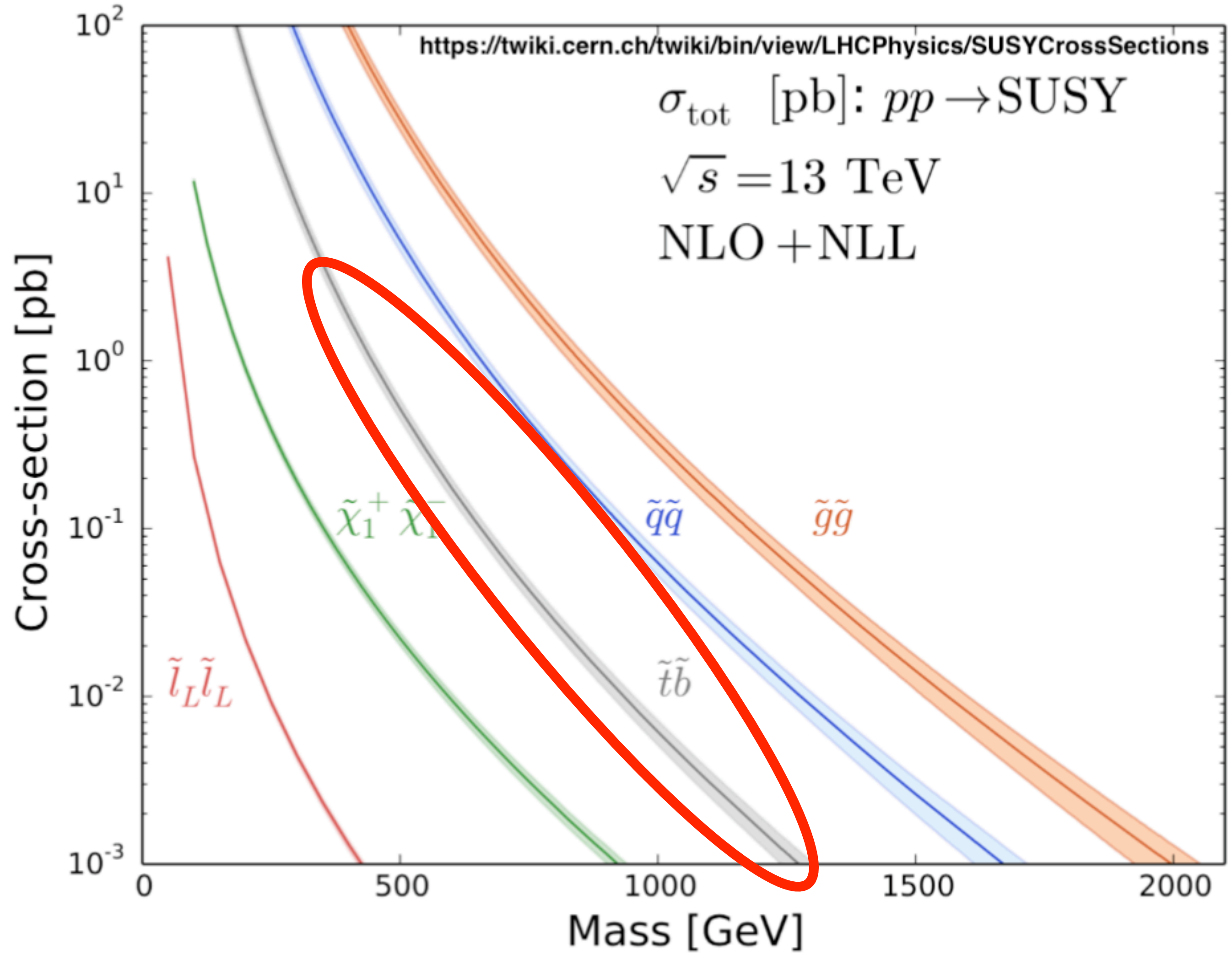


2LSS/3L powerful in compressed region

multijets powerful at high gluino masses

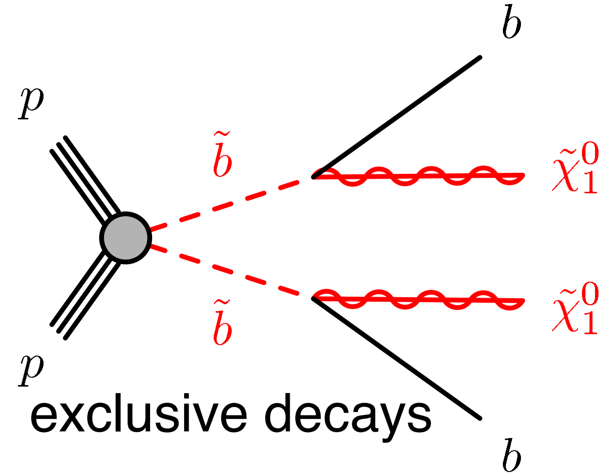
Several analyses searching for up to ~2 TeV gluinos!

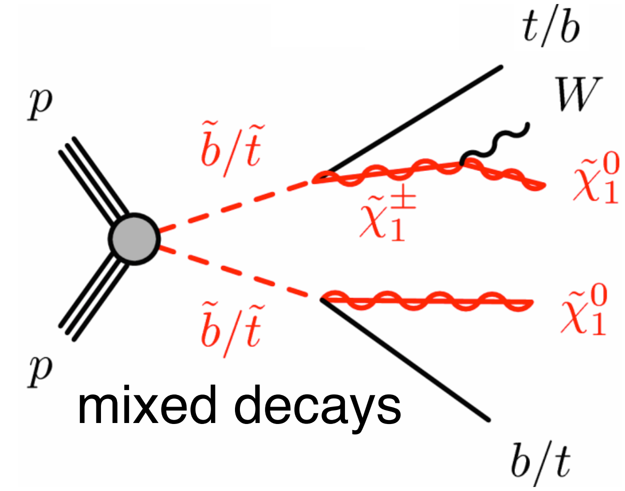
Searches for direct production of 3rd generation squarks



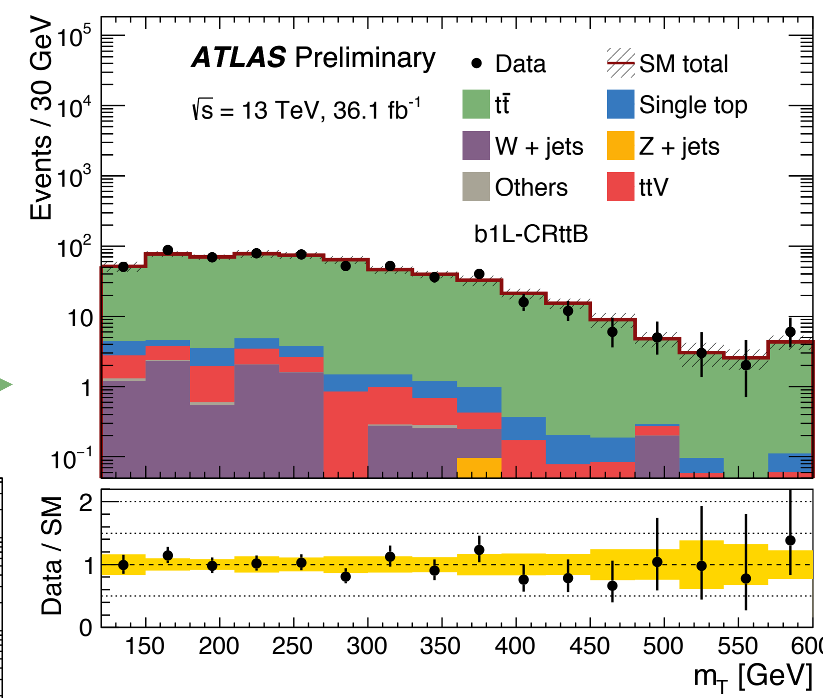
b-jets + MET

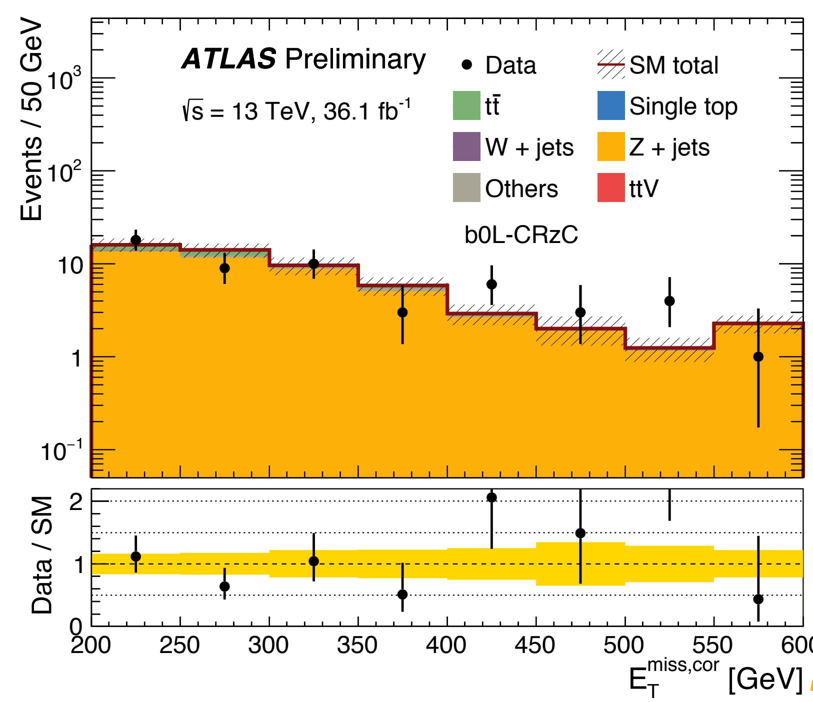
- $N_{\text{jets}} \leq 4$, 2 b-jets and MET
- Target sbottom and stop pair production with exclusive and mixed decays
- SRs A, B and C target **large, intermediate and compressed** mass splittings (m_{sbottom} - m_{LSP})
- **0ℓ** and **1ℓ** SRs defined and combined
- W+jets, ttbar, single top and Z+jets normalized in dedicated CRs





ttbar dominant in 1ℓ SRs
good modelling in ttbar CR

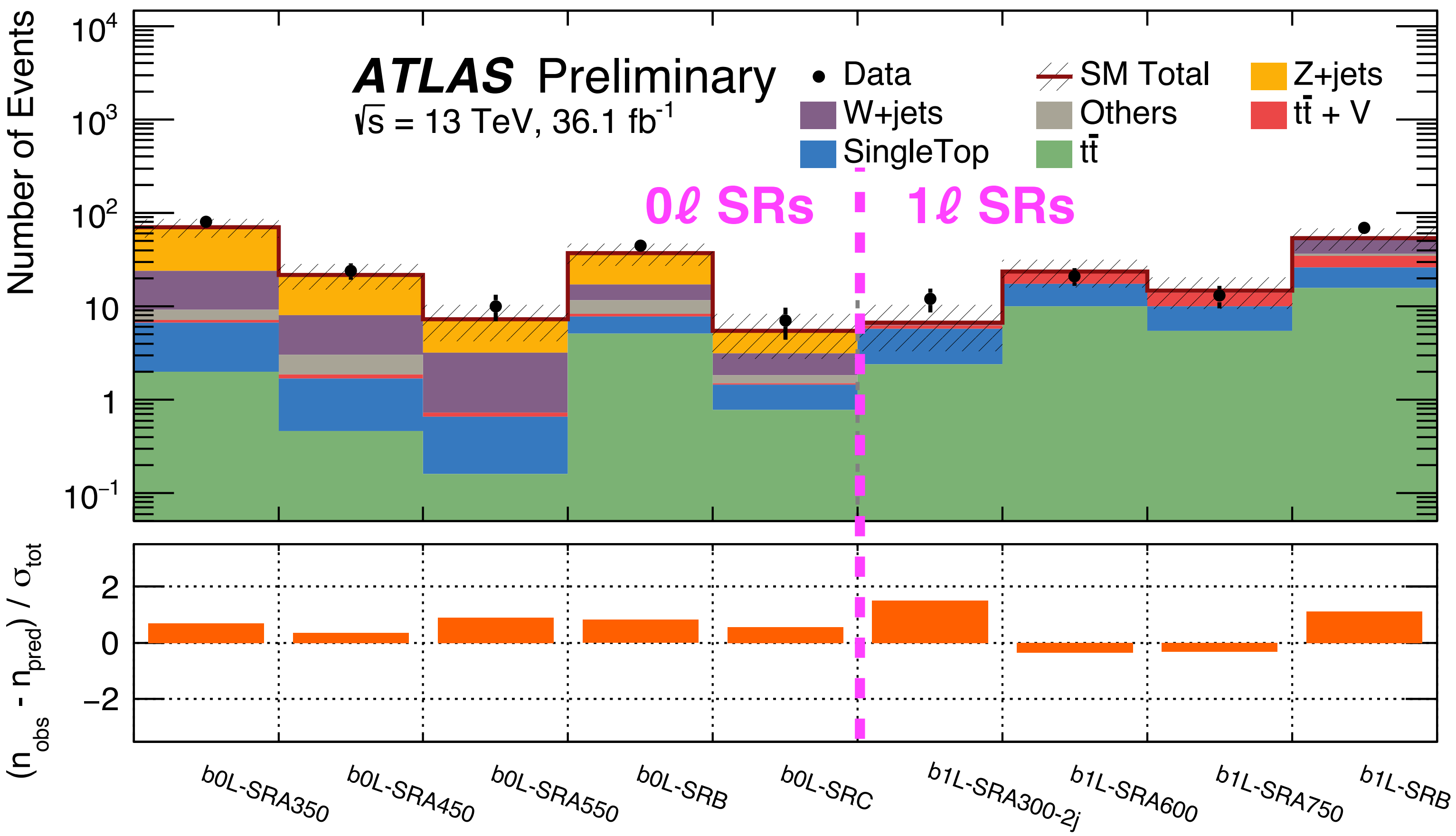


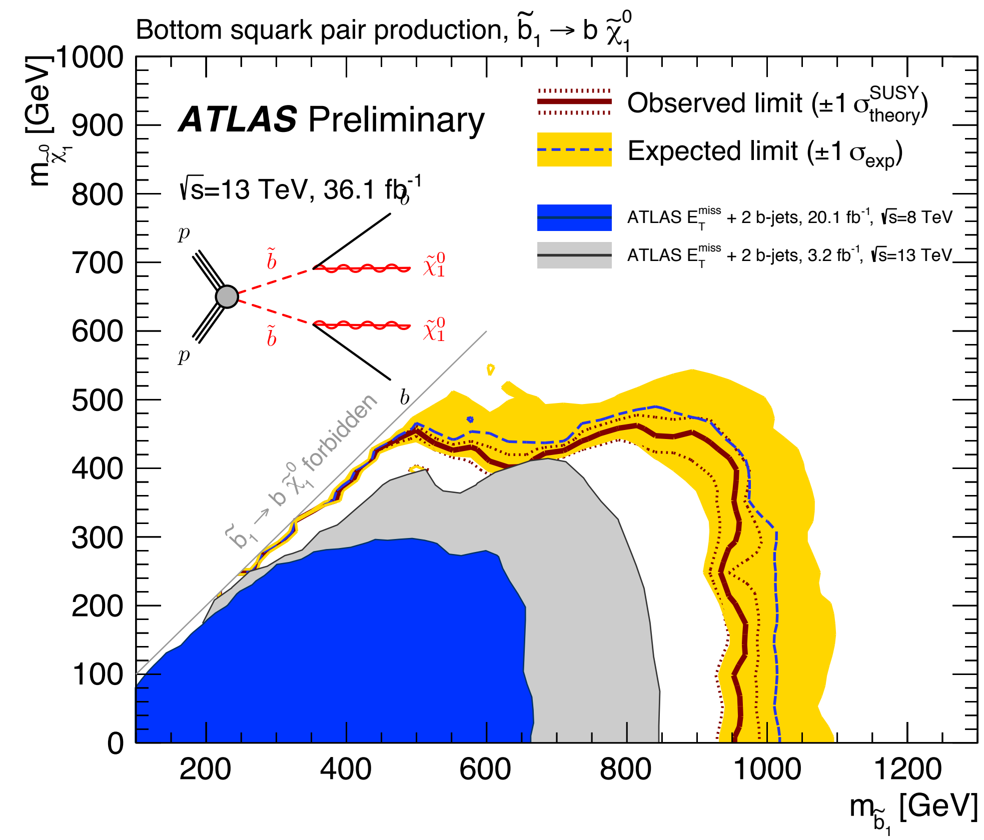


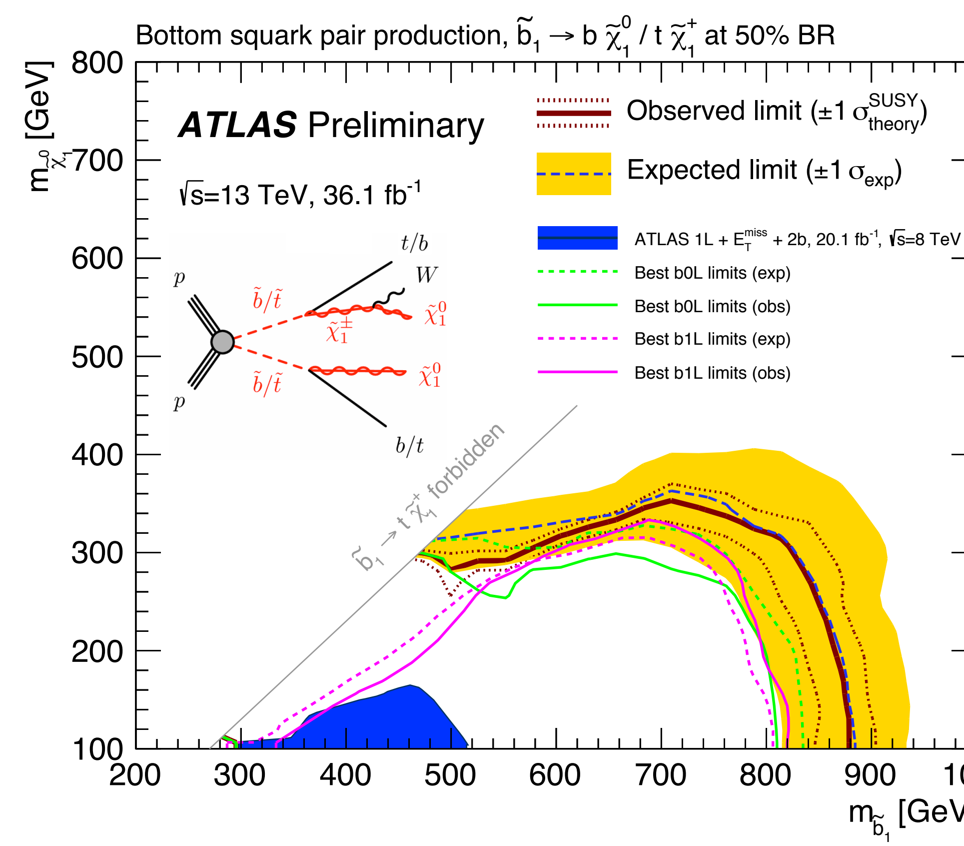
Z→$\nu\nu$ dominant in 0ℓ SRs
normalized in Z→$\ell\ell$ CR
ℓ used to mimic MET from ν

see ATLAS-CONF-2017-038

b-jets + MET



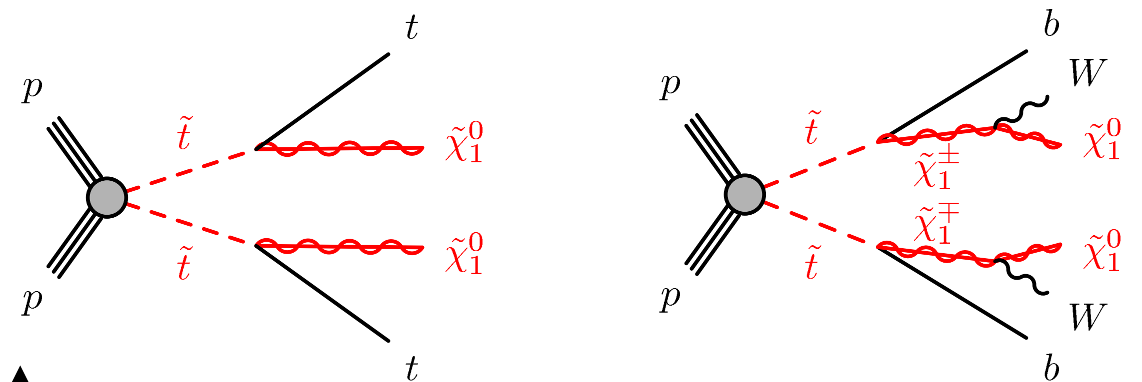


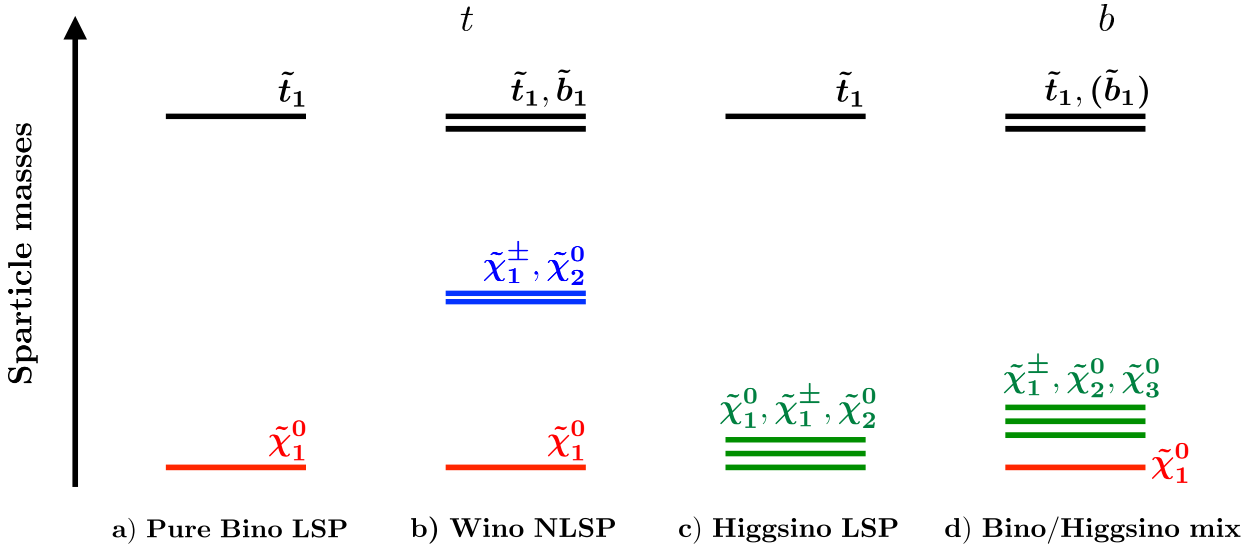


- No significant excesses observed
- Sbottom masses excluded up to 950 GeV for LSP masses below 420 GeV in exclusive decay modes
- Stop and sbottom masses excluded up to 860 GeV for LSP masses below 300 GeV in mixed decay modes

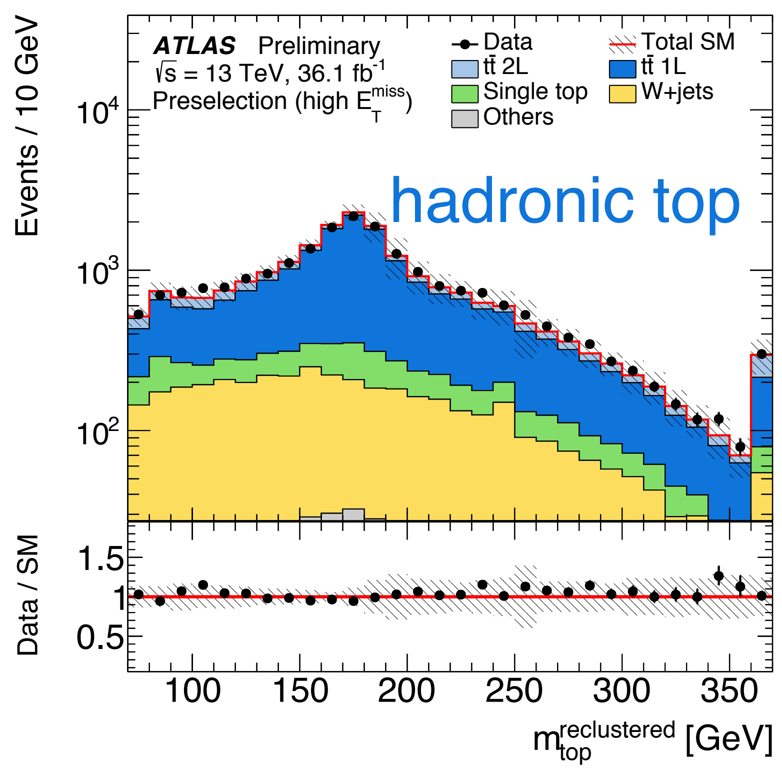
see ATLAS-CONF-2017-037

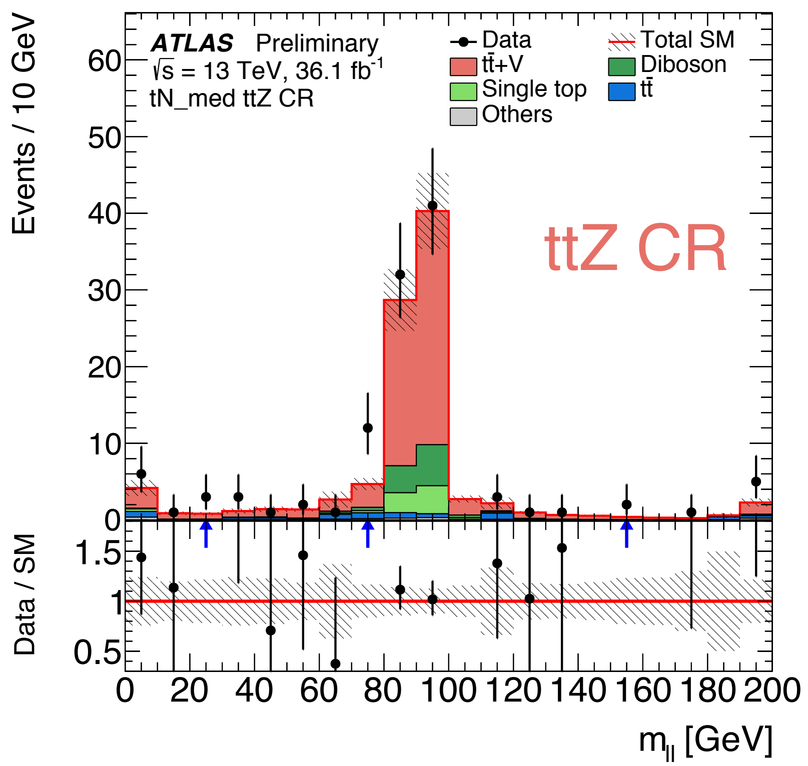
1ℓ





- Stop search in **ttbar + MET with 1ℓ** final states
- Different stop decays and LSP scenarios considered
- 16 SRs optimized
- BDTs and soft leptons for **small mass splittings**
- Hadronic top reconstruction essential for **boosted topologies**
- ttbar, W+jets, single top and ttV normalized in CRs

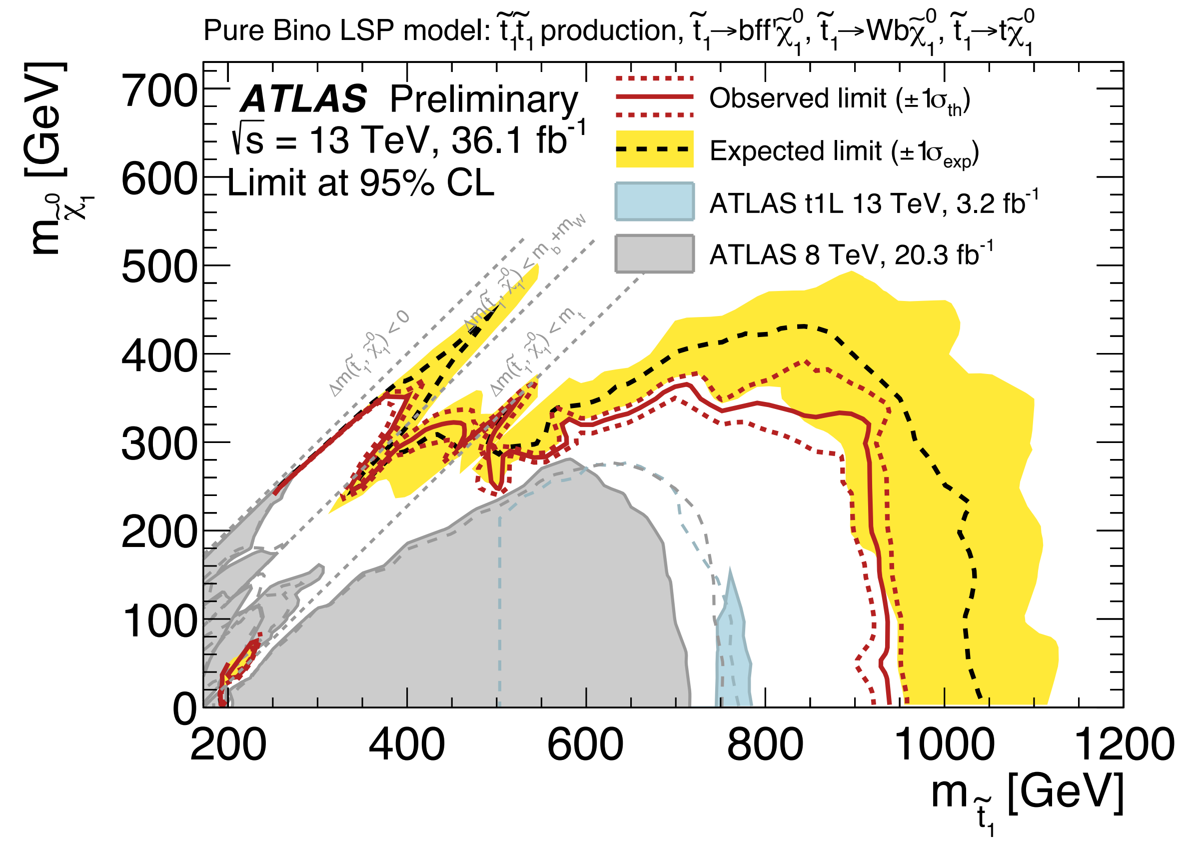




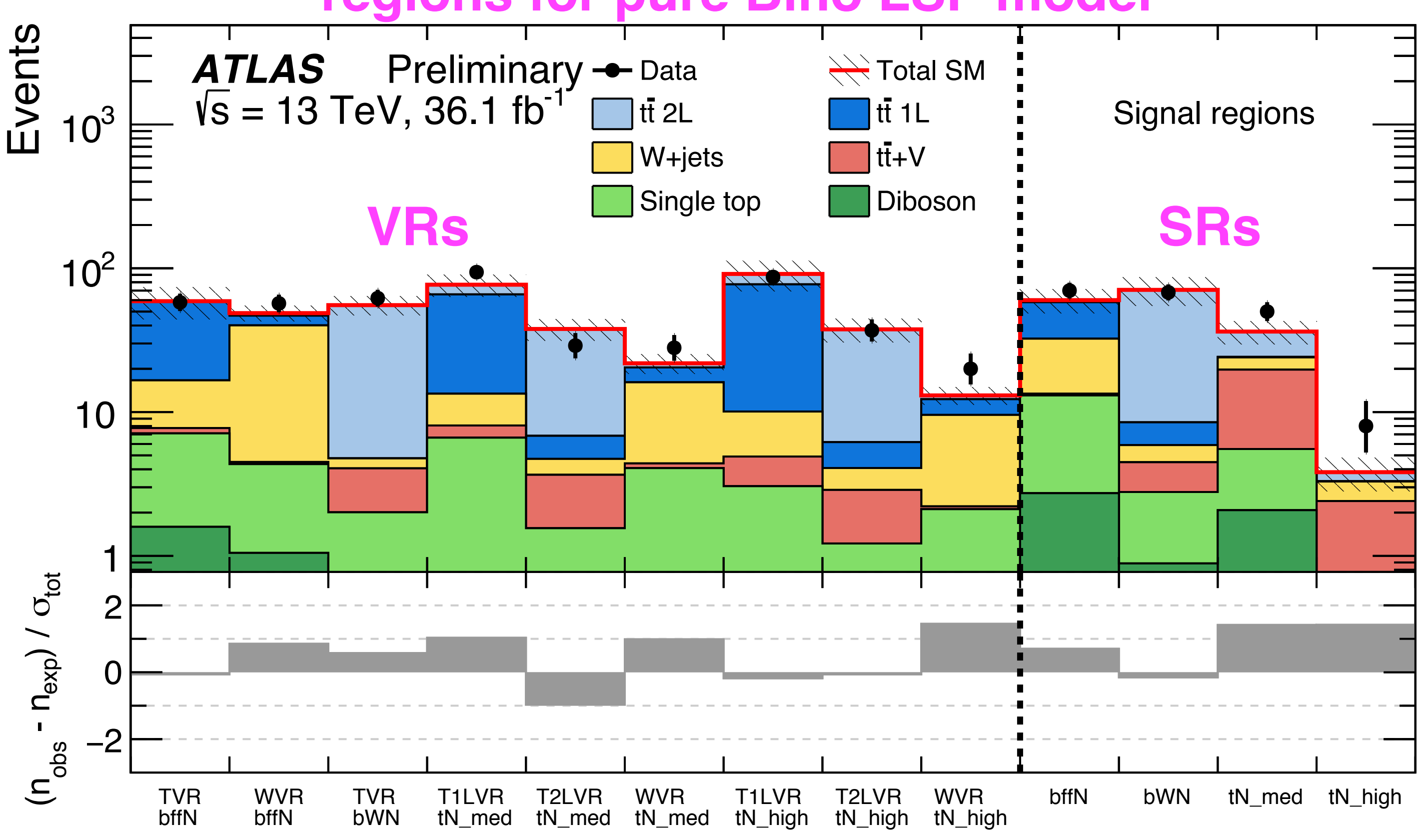
see ATLAS-CONF-2017-037

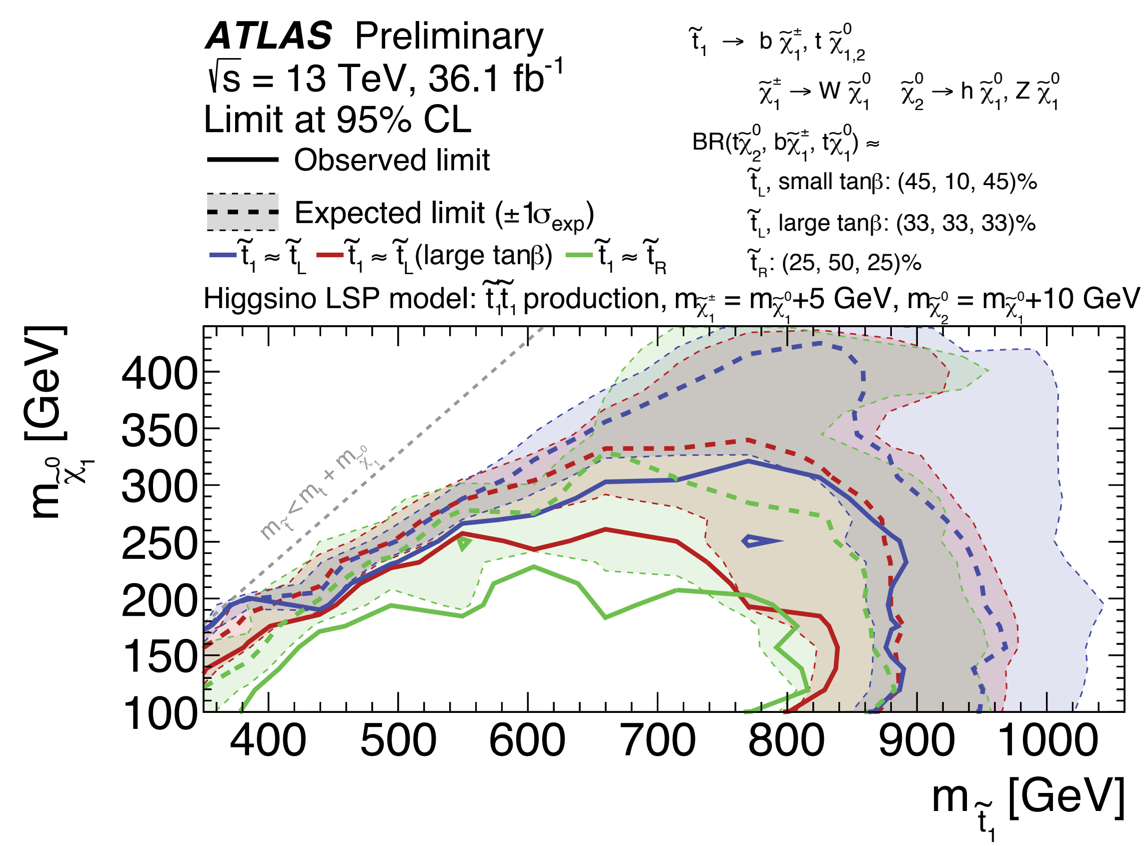
1ℓ

- No significant excesses observed
- Exclusion limits set on different simplified, pMSSM and dark matter models
- Stop masses up to 920 GeV excluded for massless LSPs



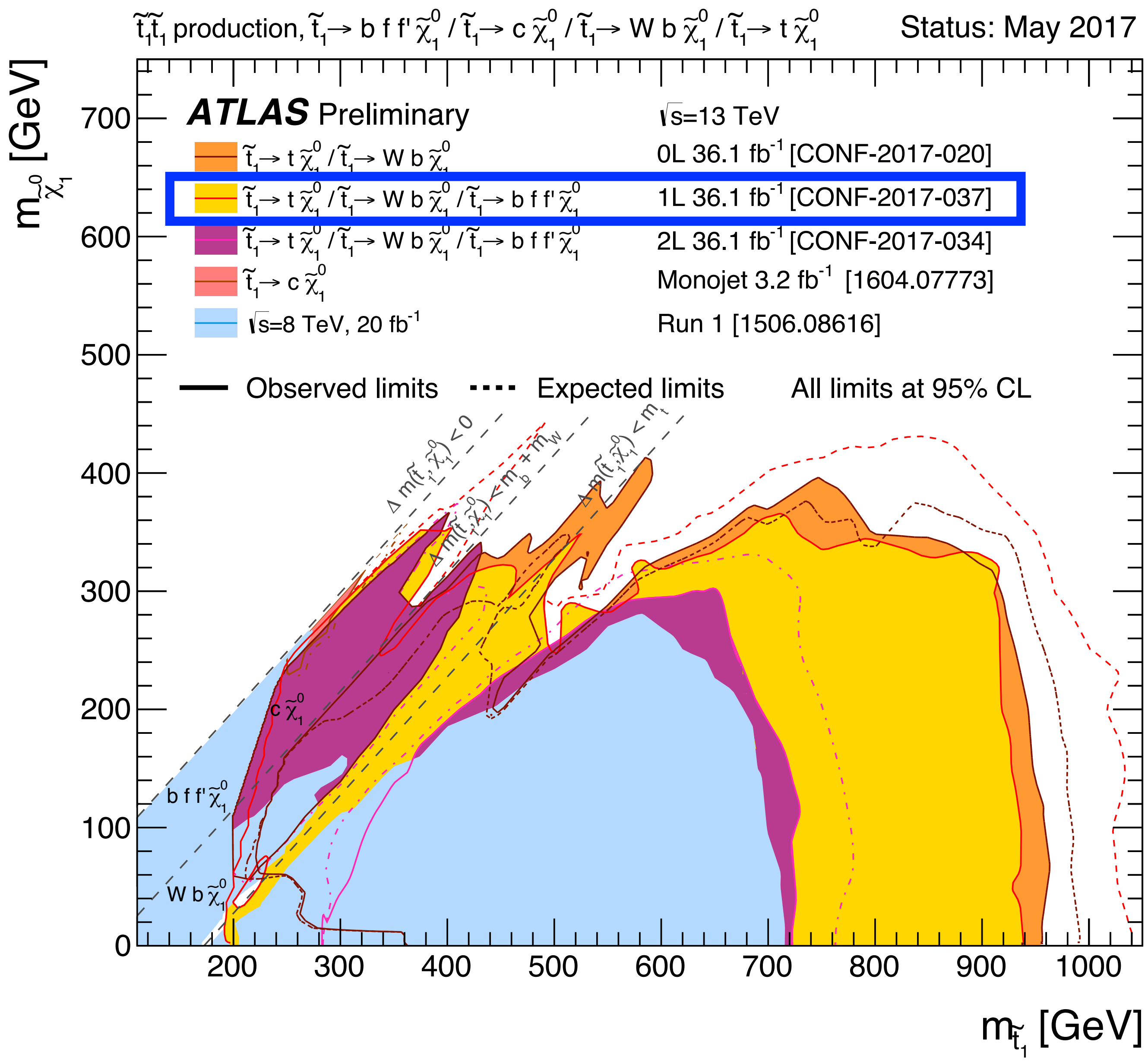
regions for pure Bino LSP model





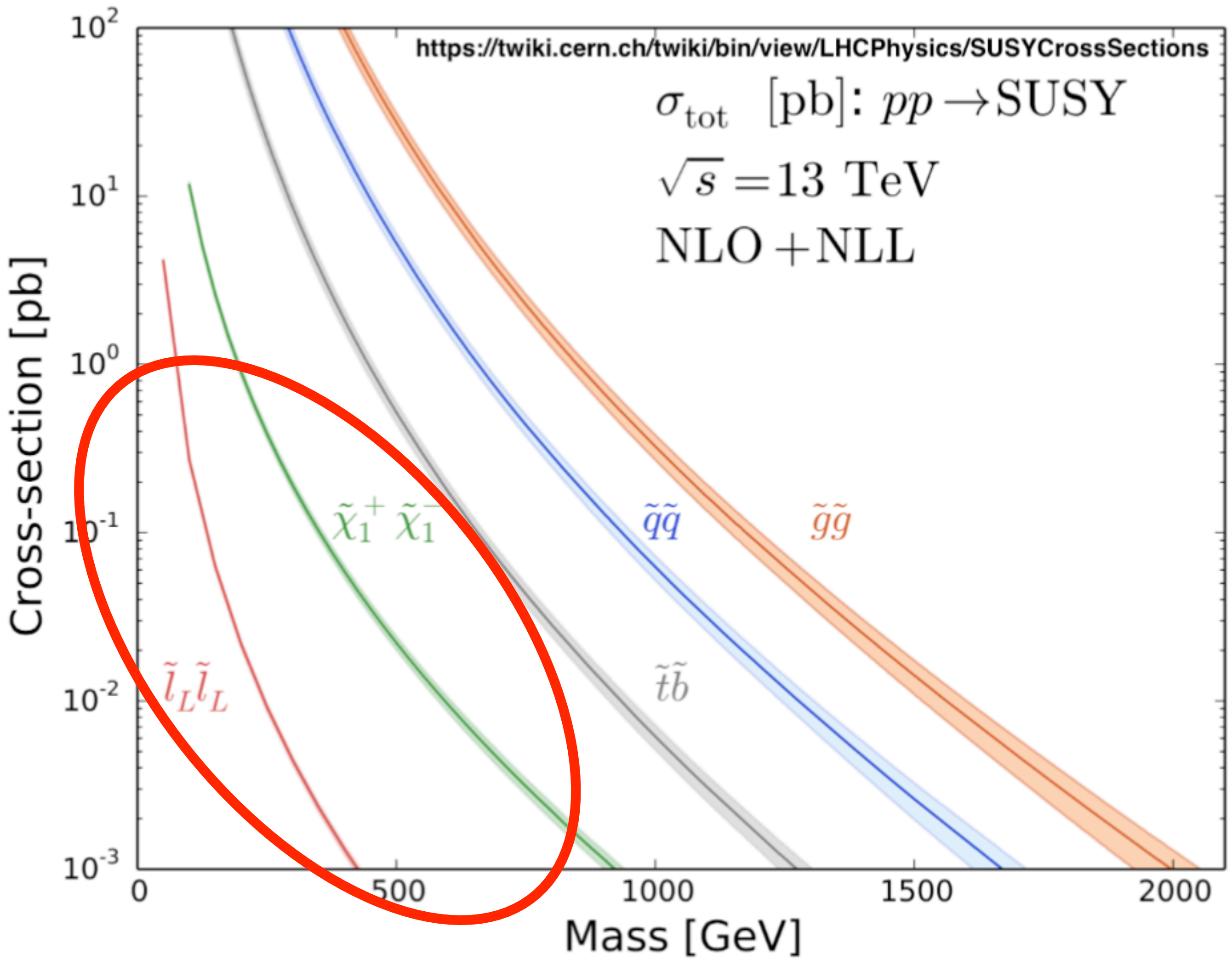
see ATLAS SUSY Public Results

Summary of stop searches



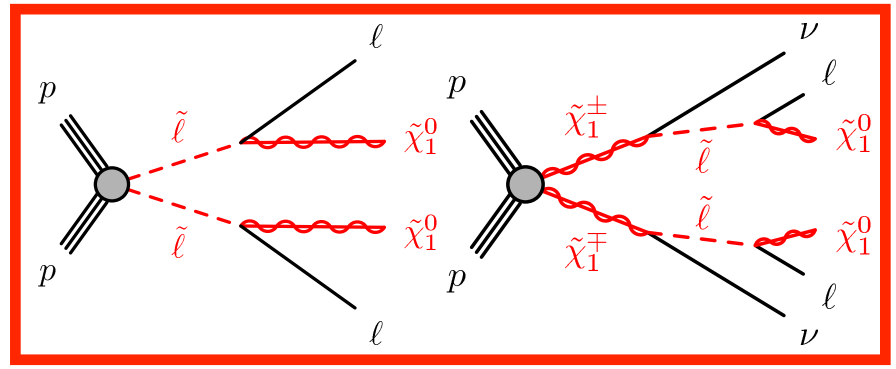
Contours of different analyses (with different assumptions) are overlayed, but overall ATLAS is searching for stops with masses up to 1 TeV!

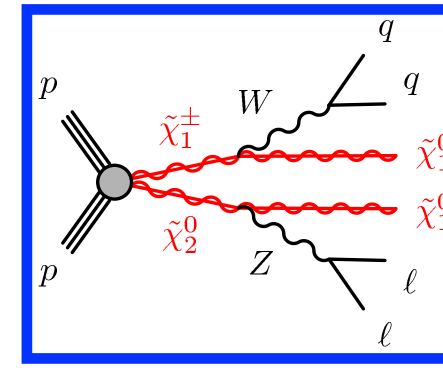
Searches for electroweak production of gauginos and sleptons

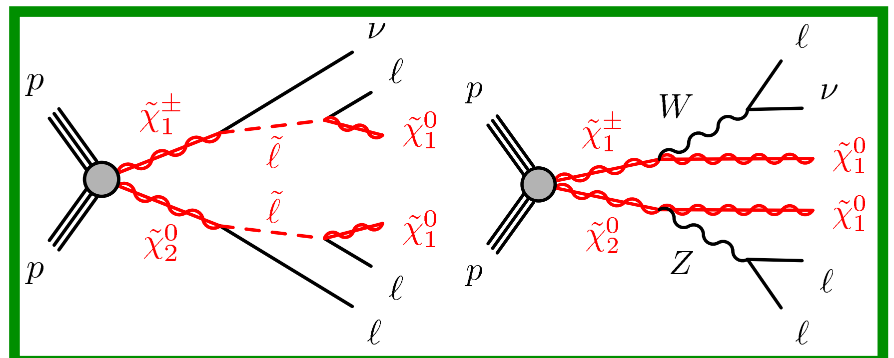


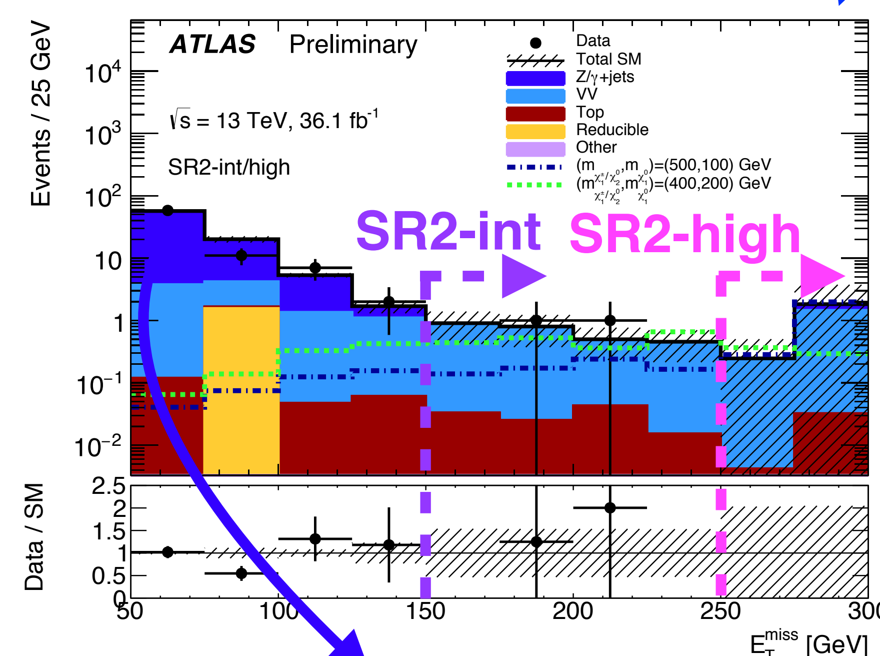
2ℓ / 3ℓ

- Multilepton analyses searching for wino and slepton pair production (bino LSP)
- 17 exclusive 2ℓ+0jet SRs binned in m_{T2} and $m_{\ell\ell}$
- 3 inclusive 2ℓ+2jet SRs targetting low, intermediate and high mass splittings
- 11 exclusive 3ℓ SRs using $m_{\ell\ell}$, m_T, N_{jets} and MET

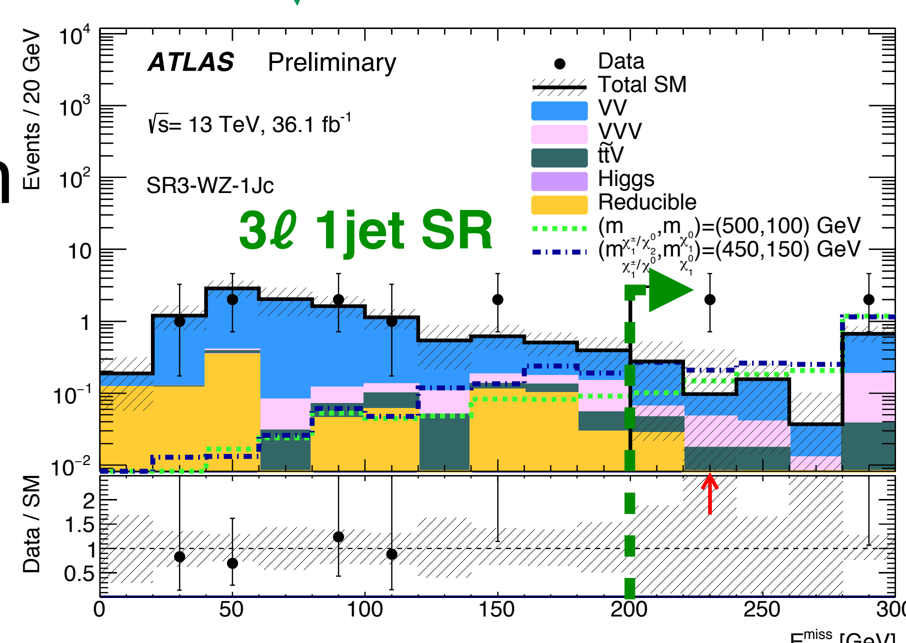








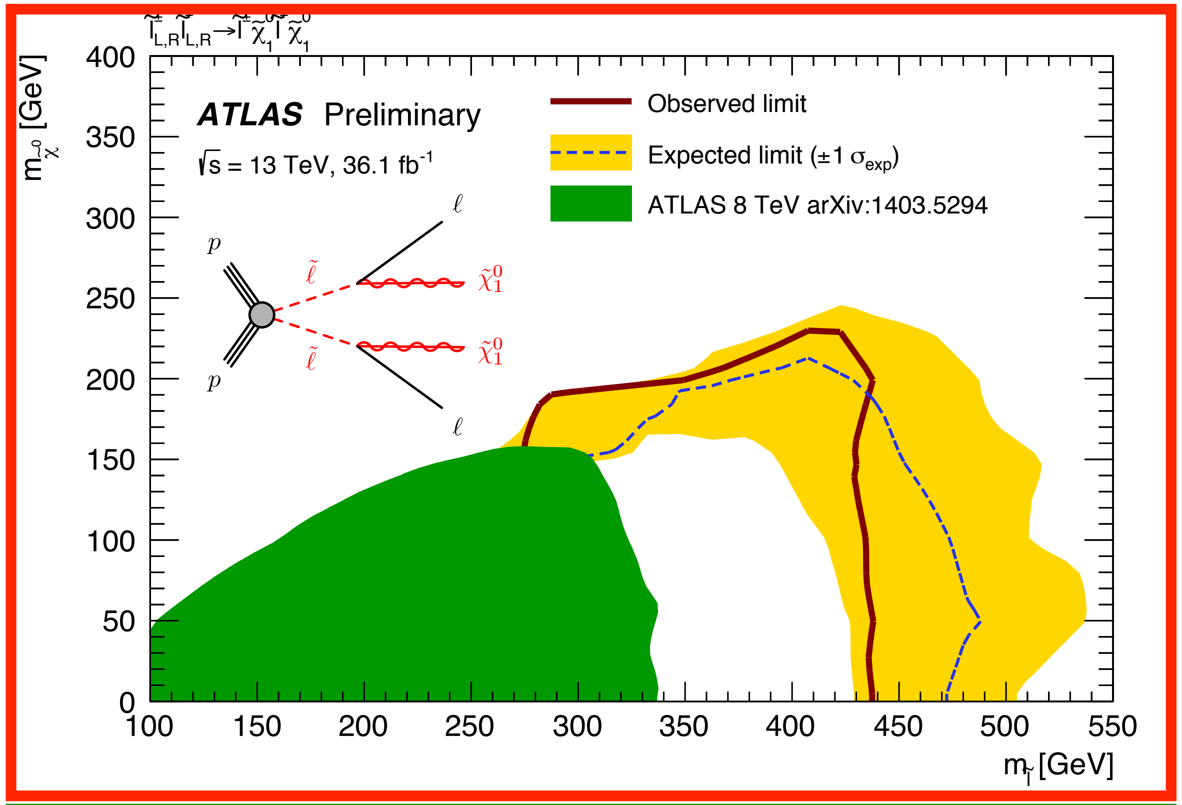
Z+jets in 2ℓ+2jet modelled with γ+jets data

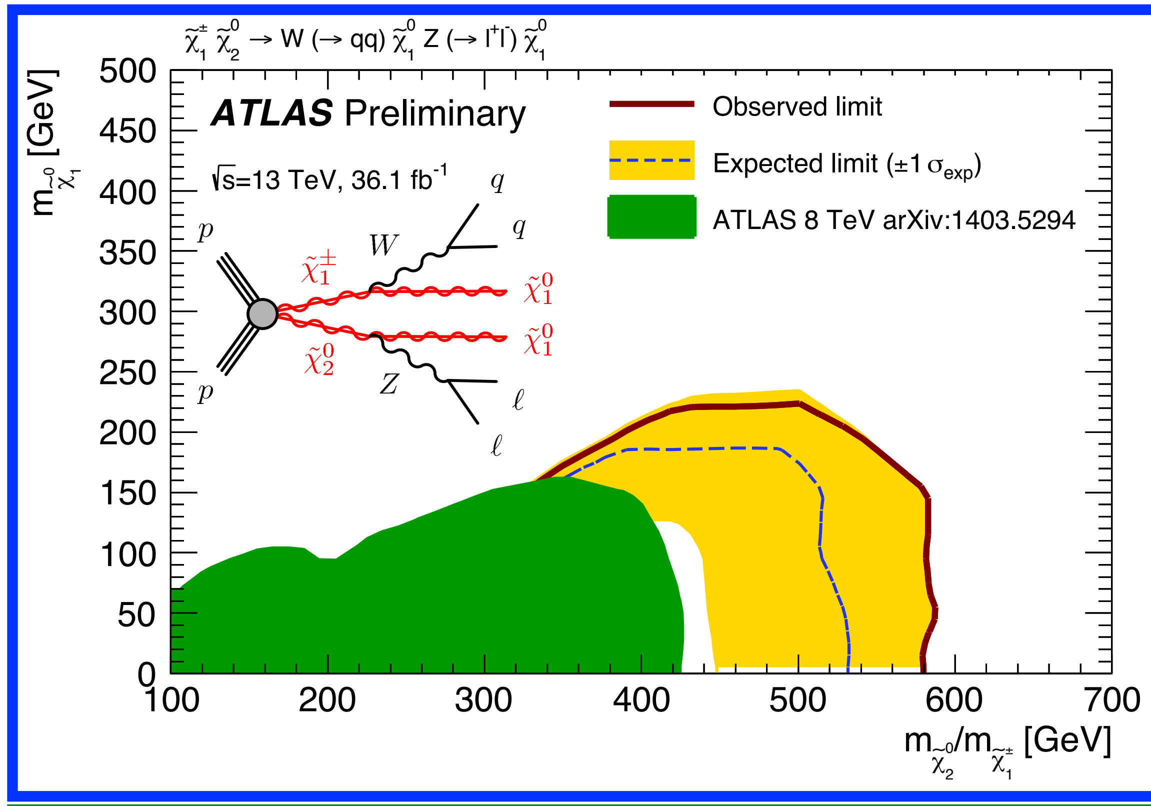


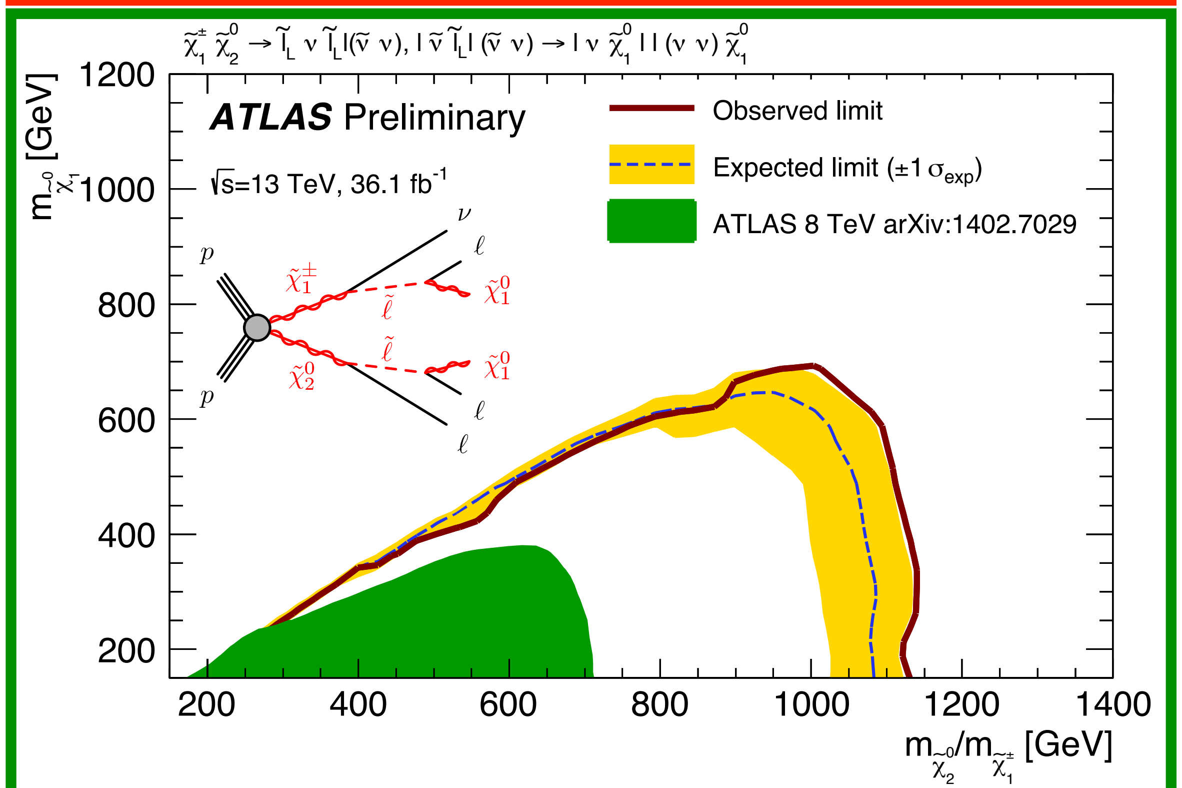
signal at high MET dominant WZ background normalized in CR

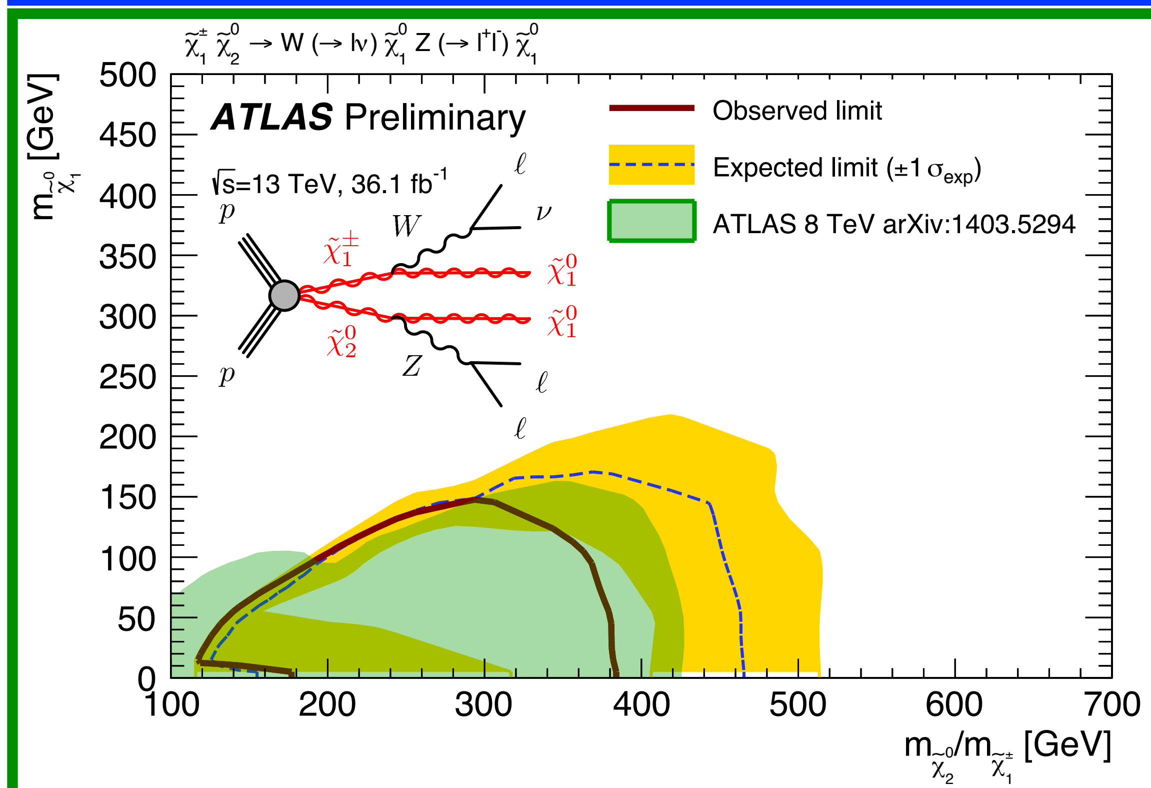
see ATLAS-CONF-2017-039

2ℓ/3ℓ



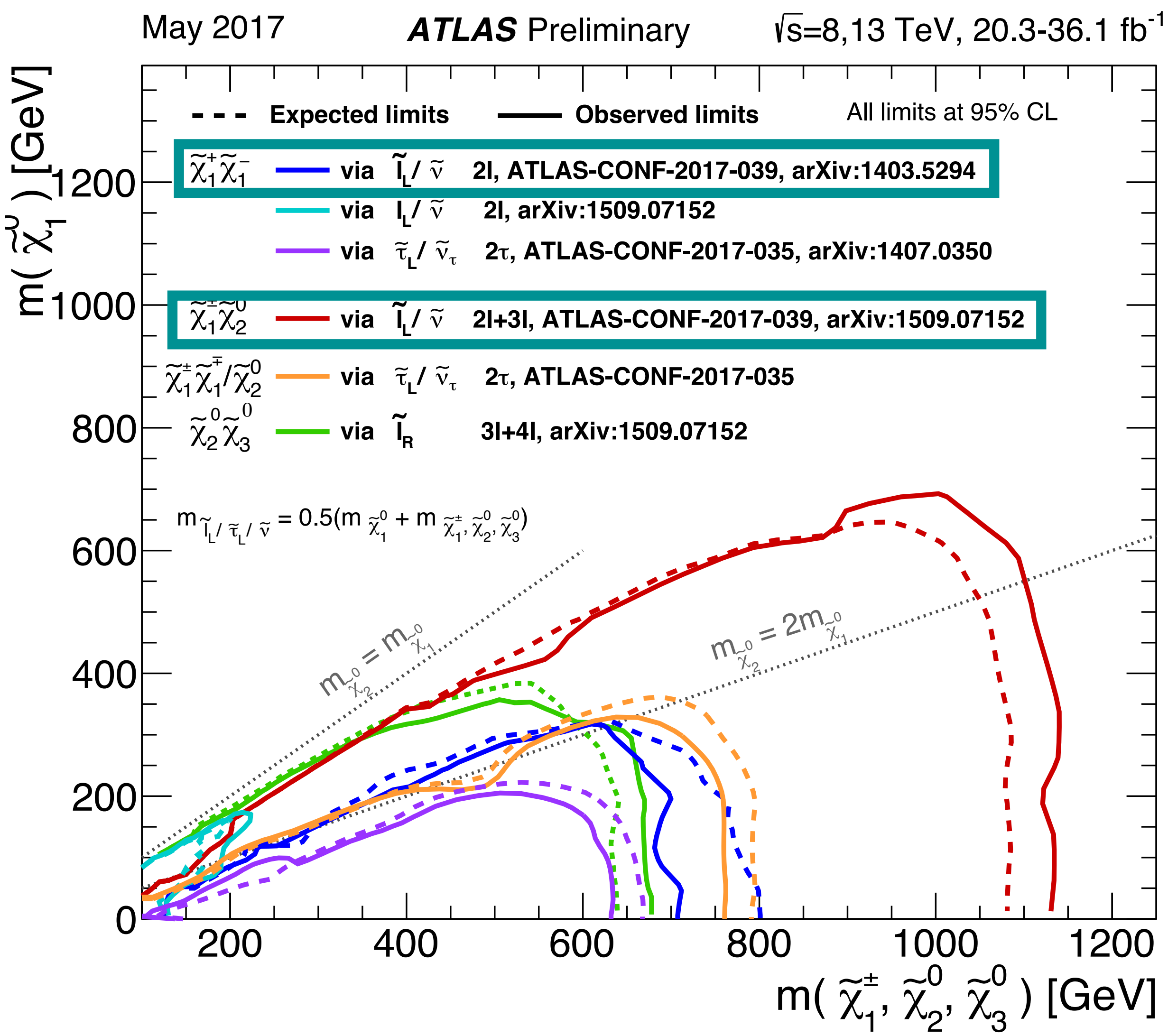


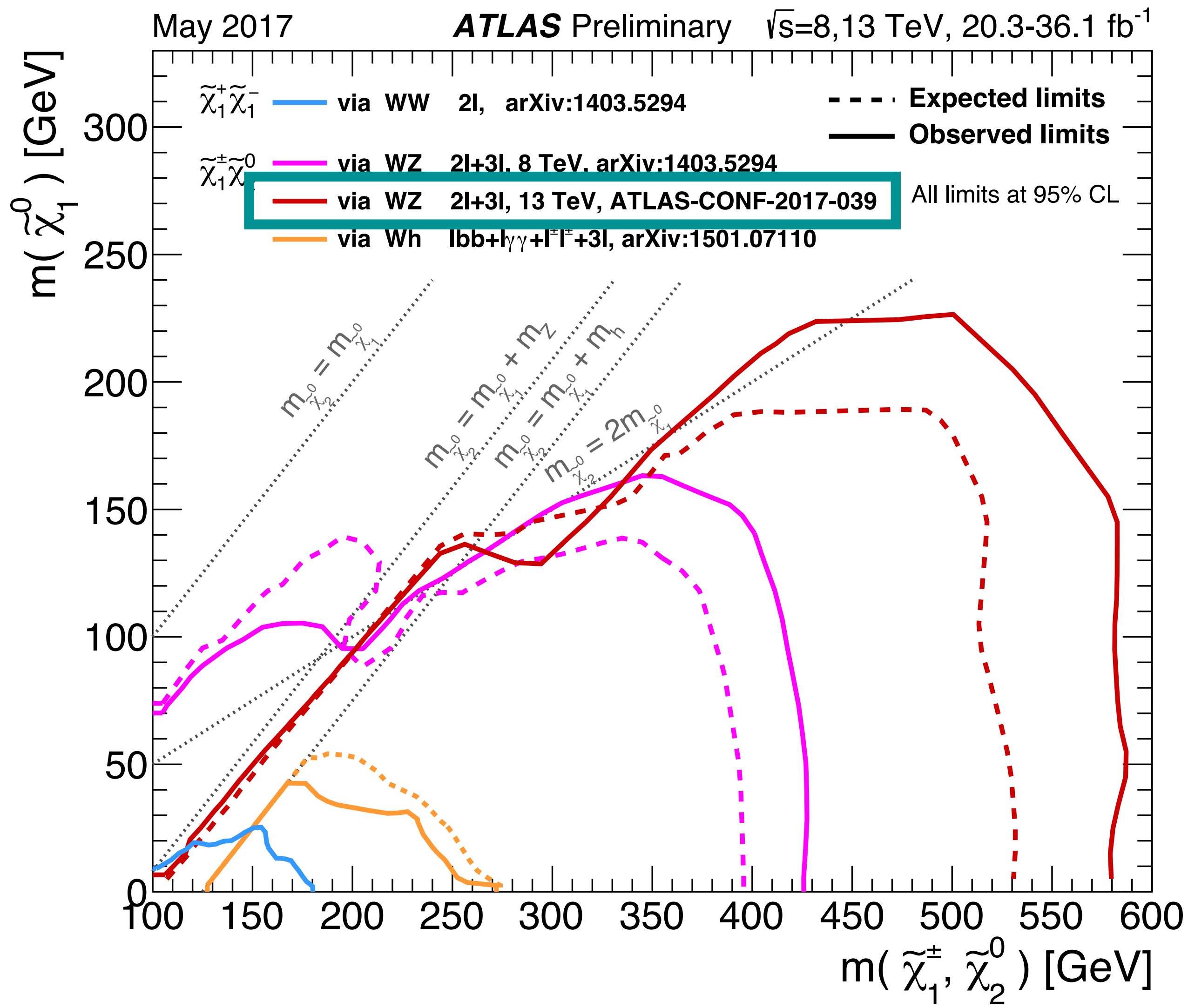




No significant excesses, limits extended compared to Run 1

Summary of EWK searches



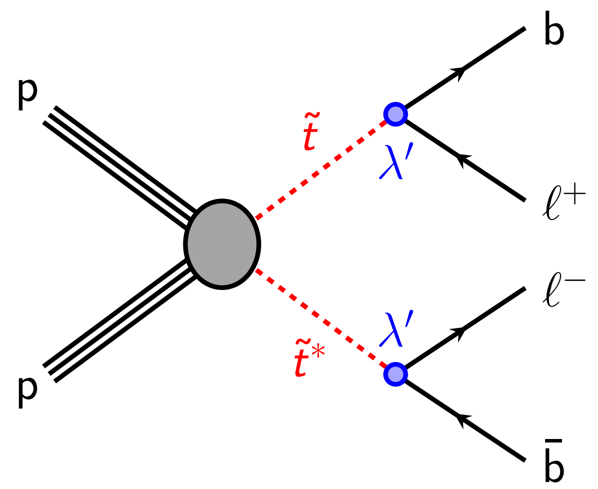


- Probing production of winos with masses up to 1.2 TeV decaying via intermediate sleptons to a bino-like LSP
- Probing production of winos with masses up to 580 GeV decaying via intermediate gauge bosons to a bino-like LSP (sleptons decoupled)

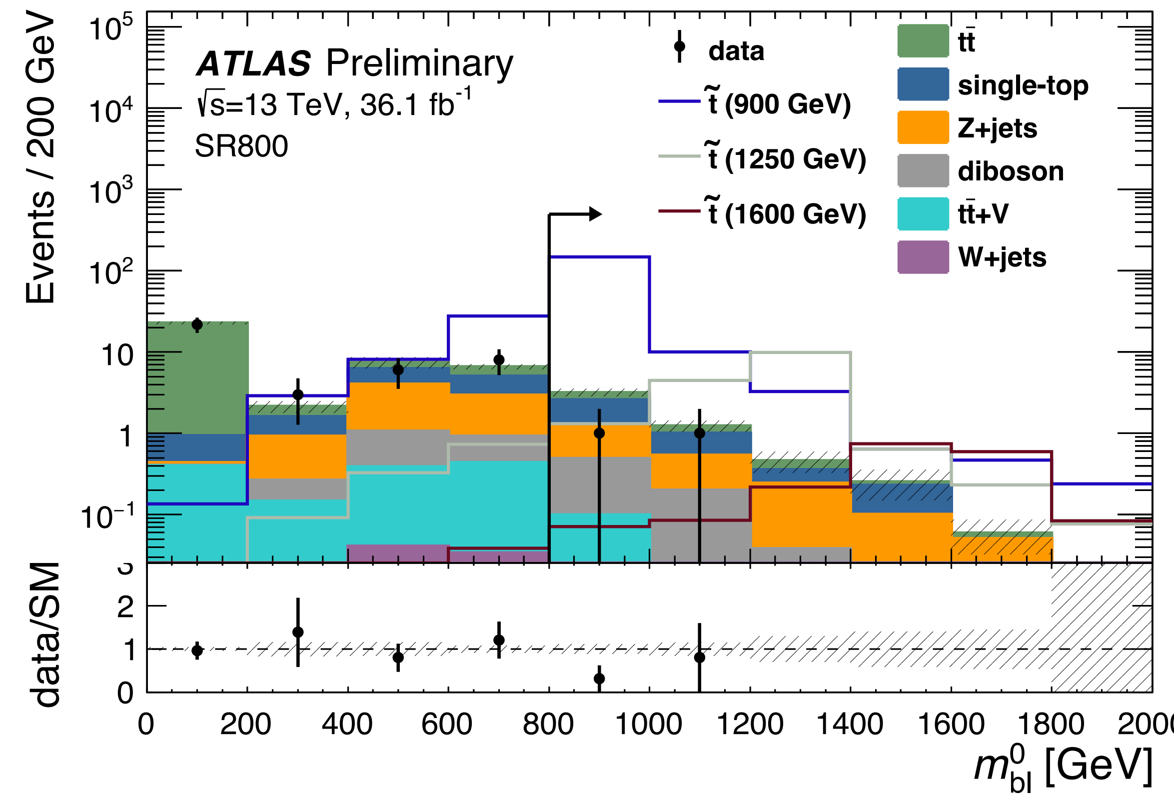
Dedicated searches for RPV SUSY

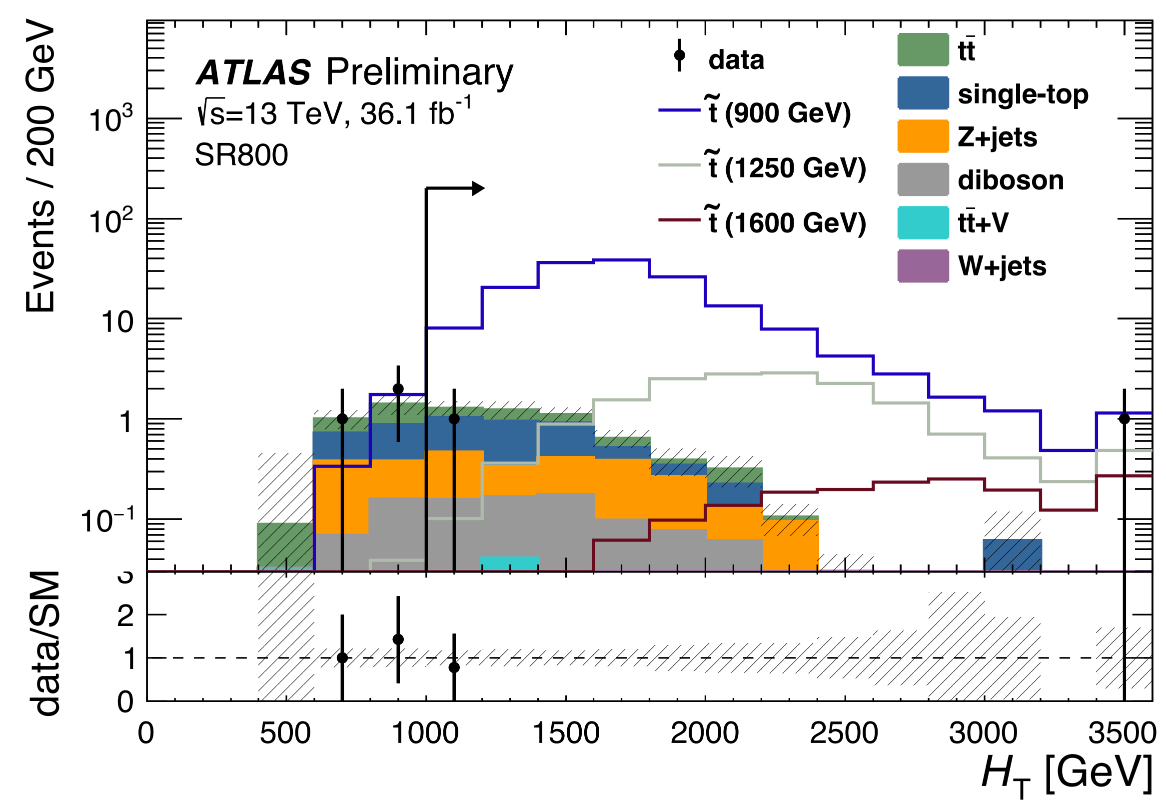
see ATLAS-CONF-2017-036

B-L



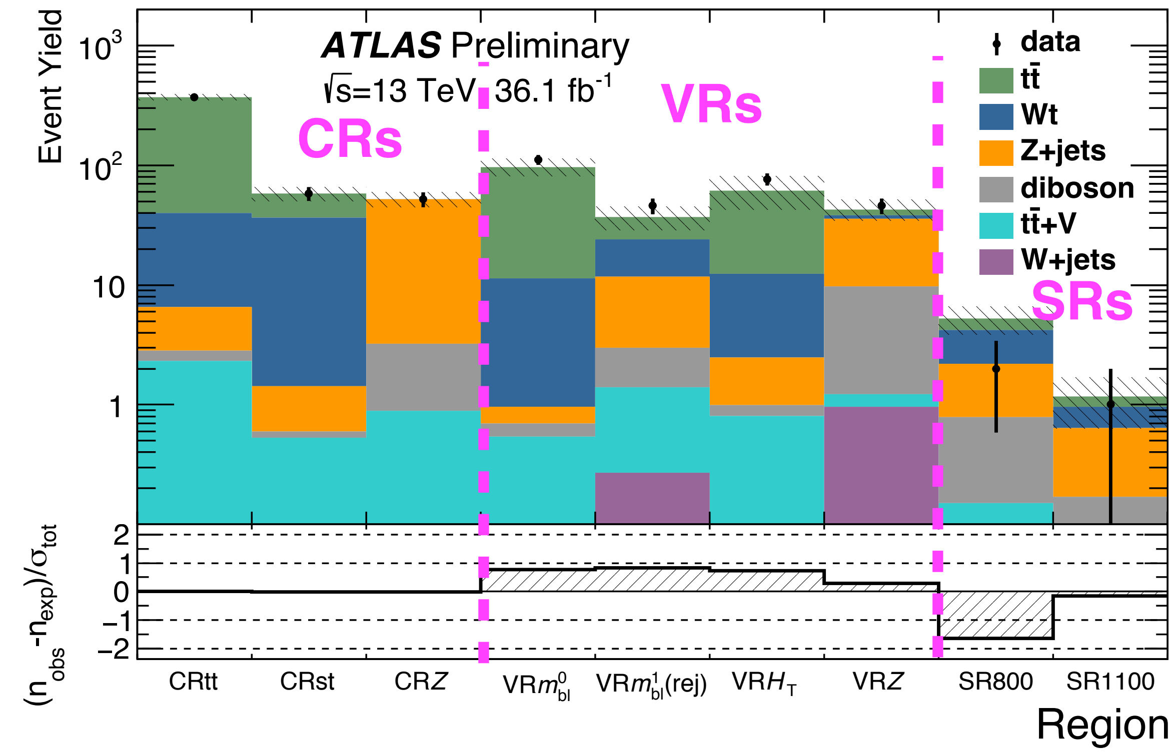
- 2ℓ, $N_{\text{jets}} = 2$, $N_{b\text{-jets}} \geq 1$
- Sensitivity to stop pair production with **RPV decay under minimal B-L** model violating lepton number but not baryon number
- 2 inclusive SRs defined using H_T, $m_{b\ell}$ and $m_{\ell\ell}$
- ttbar, Z+jets and single top normalized in dedicated CRs



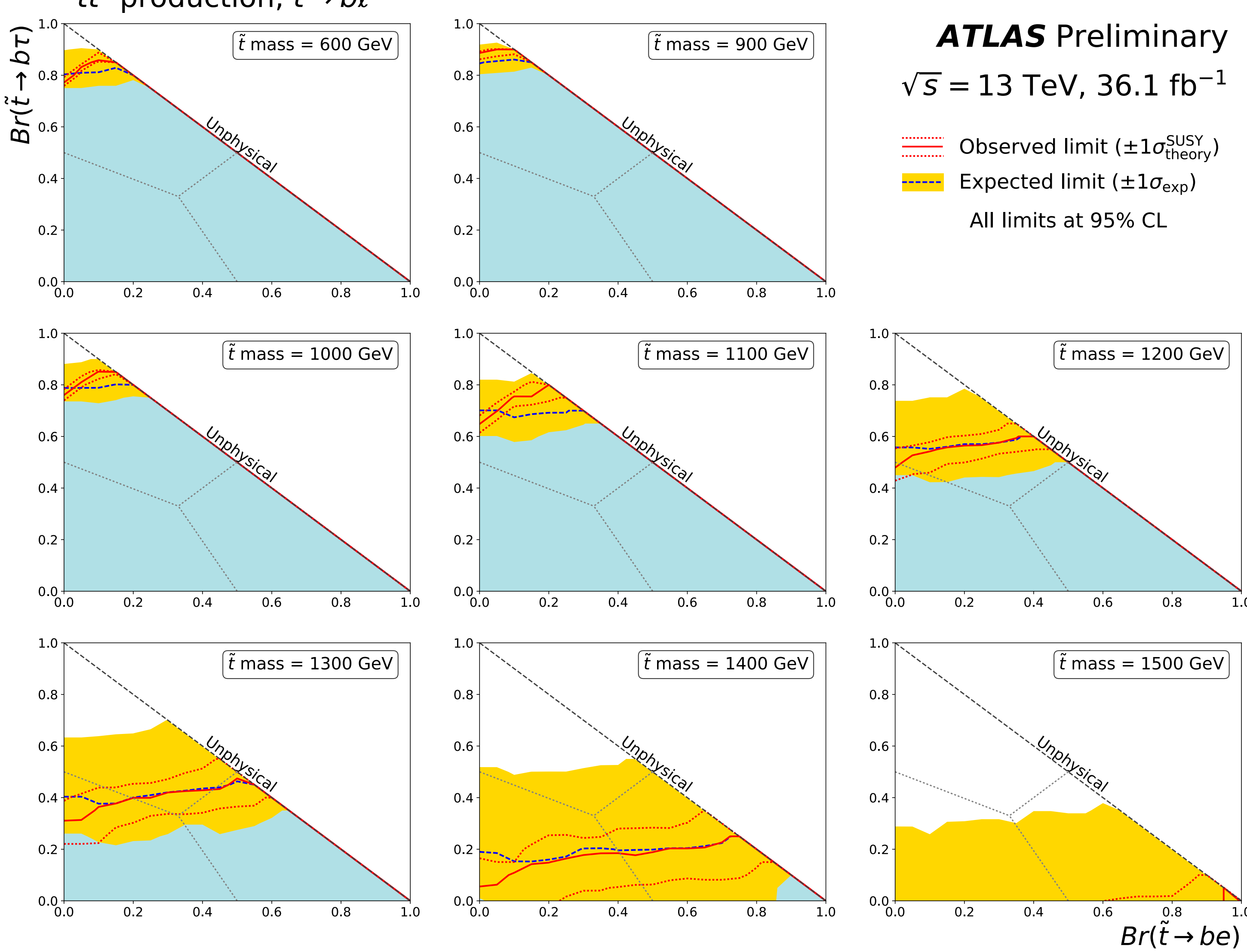


B-L

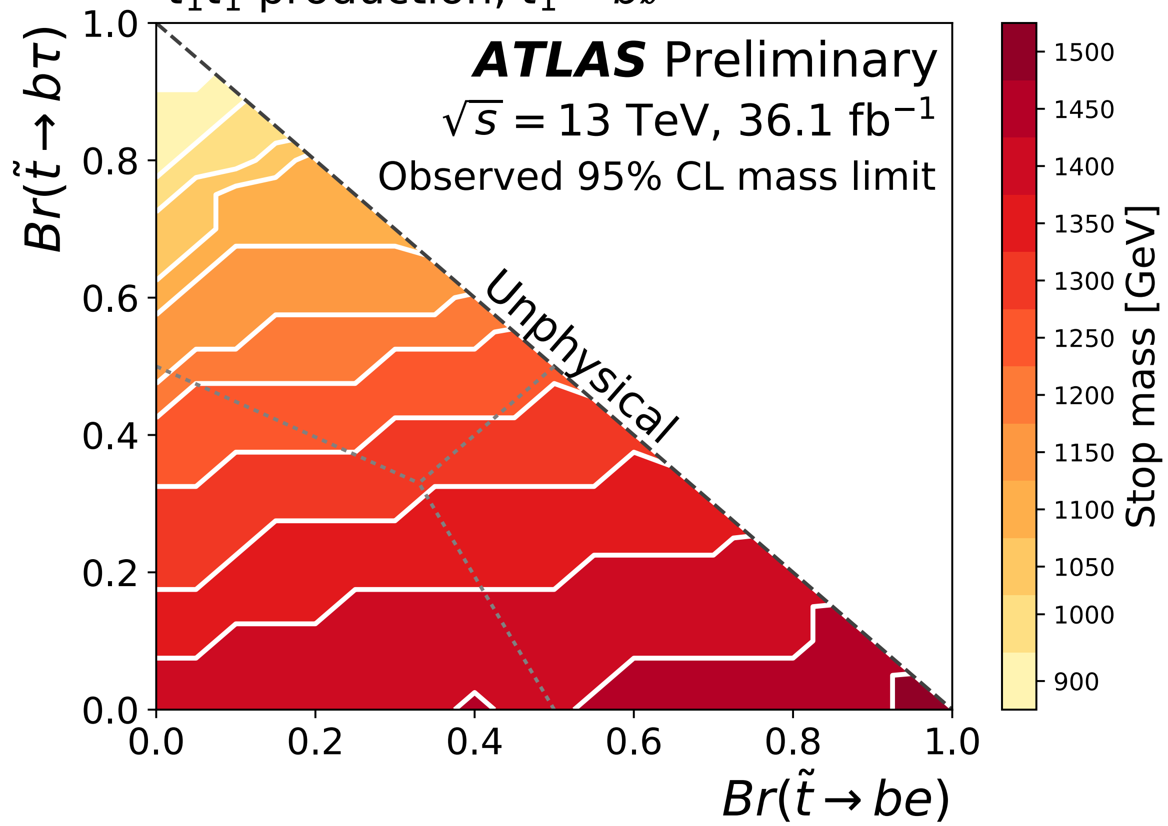
- No significant excesses observed
- BR-dependent limits set on stop masses
- Stop with masses up to 1.55 TeV excluded assuming 100% BR to electron + b-quark



$\tilde{t}\tilde{t}^*$ production, $\tilde{t} \to b\ell$



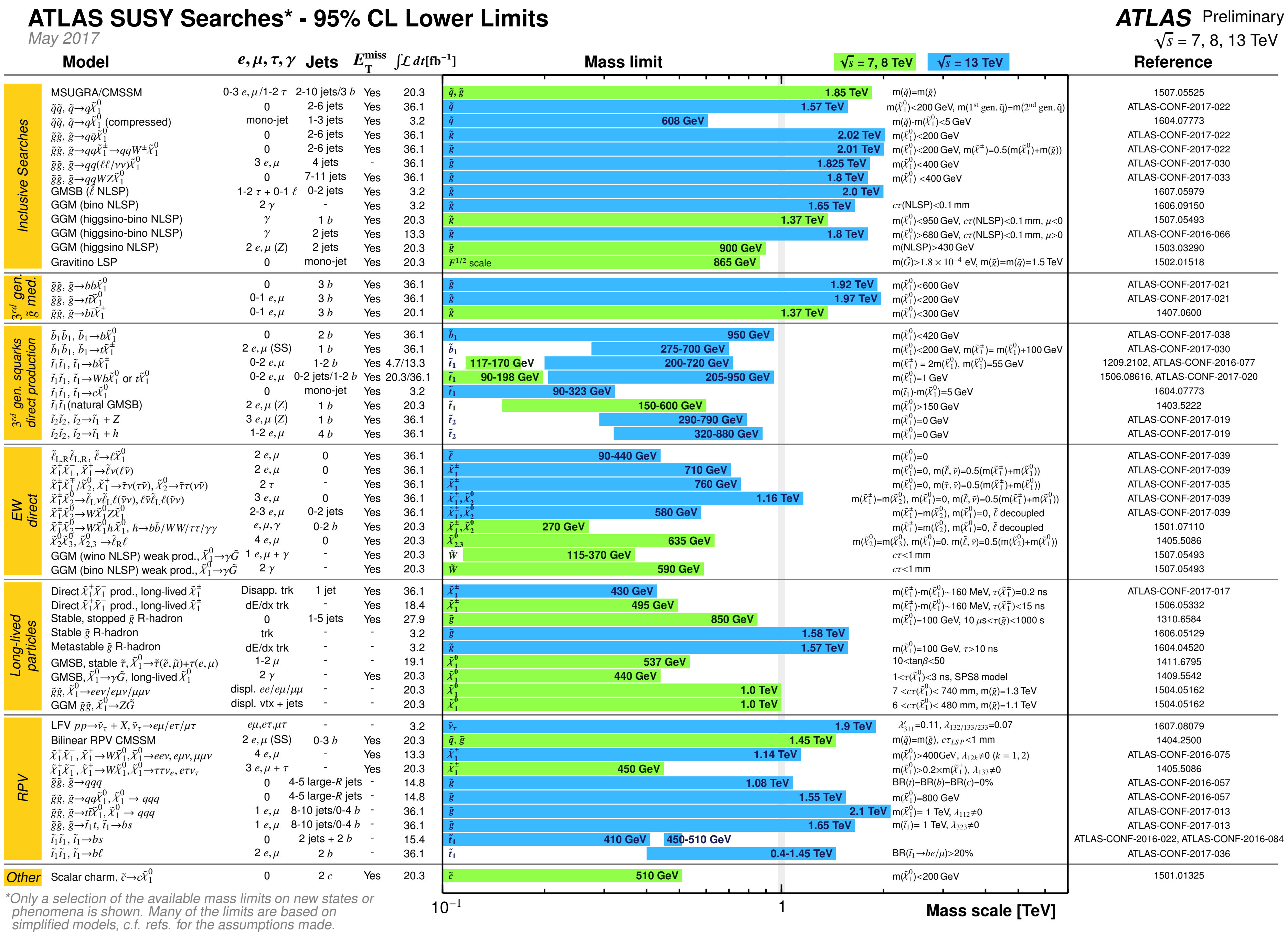
$\tilde{t}_1\tilde{t}_1$ production, $\tilde{t}_1 \to b\ell$



Summary and conclusions

see ATLAS SUSY Public Results

SUSY ATLAS summary



- ATLAS has produced plenty of new searches for SUSY particles using the full 2015 + 2016 dataset
- Only presented a small selection of new results but many more available!
- Sadly no significant deviations from the SM have been observed

- Stronger limits are putting SUSY under more and more stress
- But many corners of phase space are still being explored and a lot more data is on the way so stay tuned!

Back-up