Universidad de Oviedo
Universidá d'Uviéu
University of Oviedo

Electroweak and strong production of SUSY

S. FOLGUERAS ON BEHALF OF
THE CMS AND ATLAS COLLABORATION

32ND RECONTRES DE PHYSIQUE DE LA VALLÉE DE AOSTE

Outline

This talk will cover a **personal selection** of the latest results (last 3-4 months) from both CMS and ATLAS.

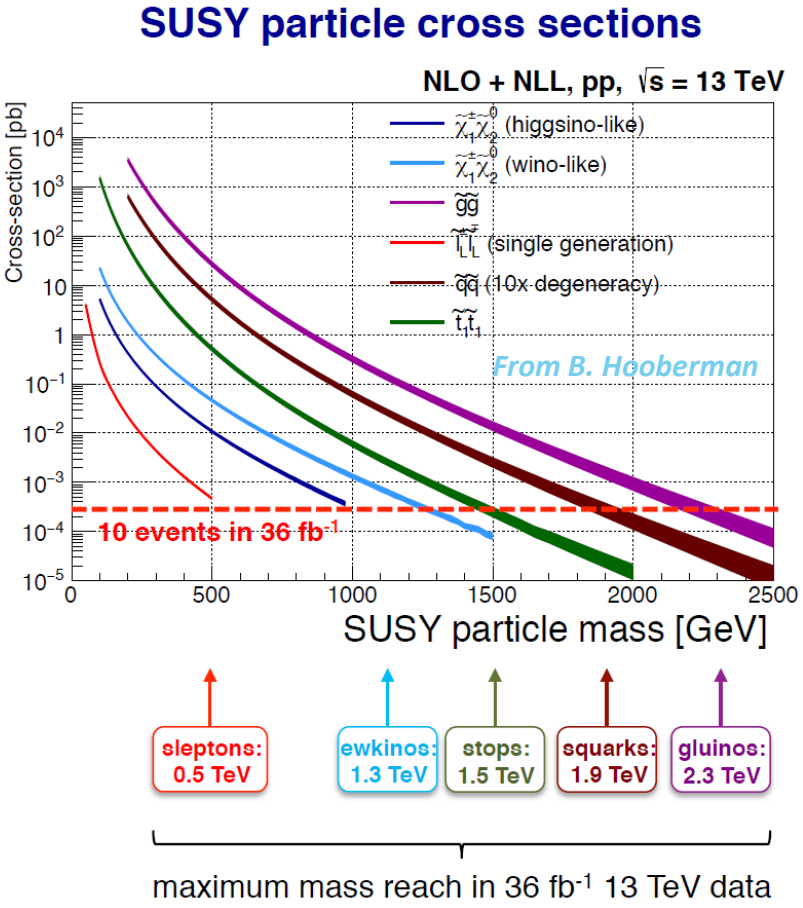
RPC strong production of SUSY:

- Inclusive squark / gluino production
- 3rd generation squarks

RPC electroweak production:

- charginos, neutralinos
- Higgsinos
- Sleptons

R-parity violation searches



Summary of SUSY searches

We **haven't found SUSY (yet)**

- Searches in just about every combination imaginable.
- More ideas to explore.

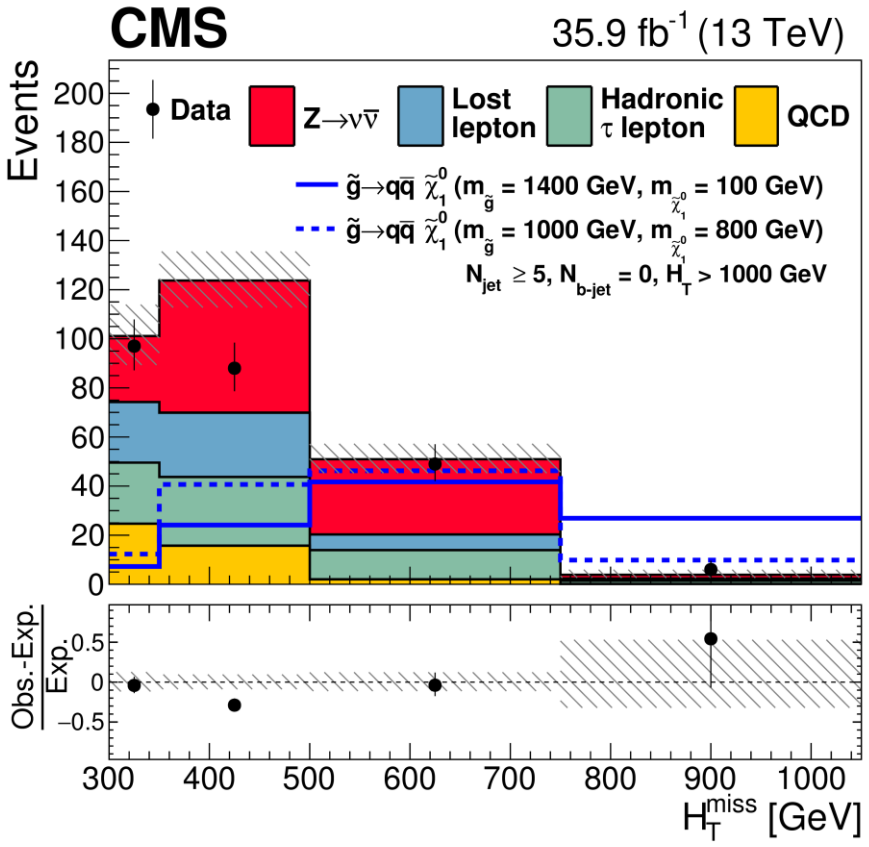
Experimentally SUSY can be thought as a **"signal generator"** for searches.

- Model independent, re-interpretations, BSM signatures…

More details about every search:

- https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS
- https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults

How to…



Look for an excess in the extreme tail of a discriminating variable.

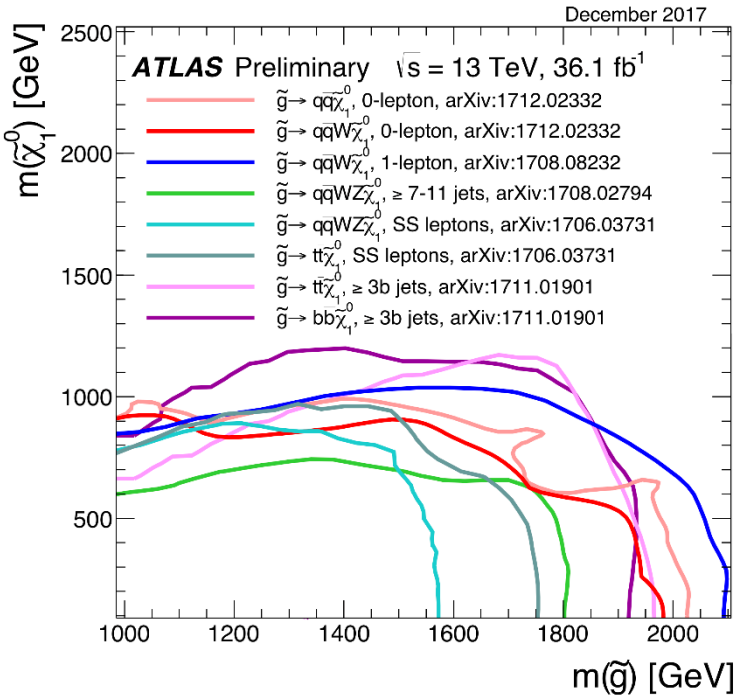
Signal may mimic the background with lower rates.

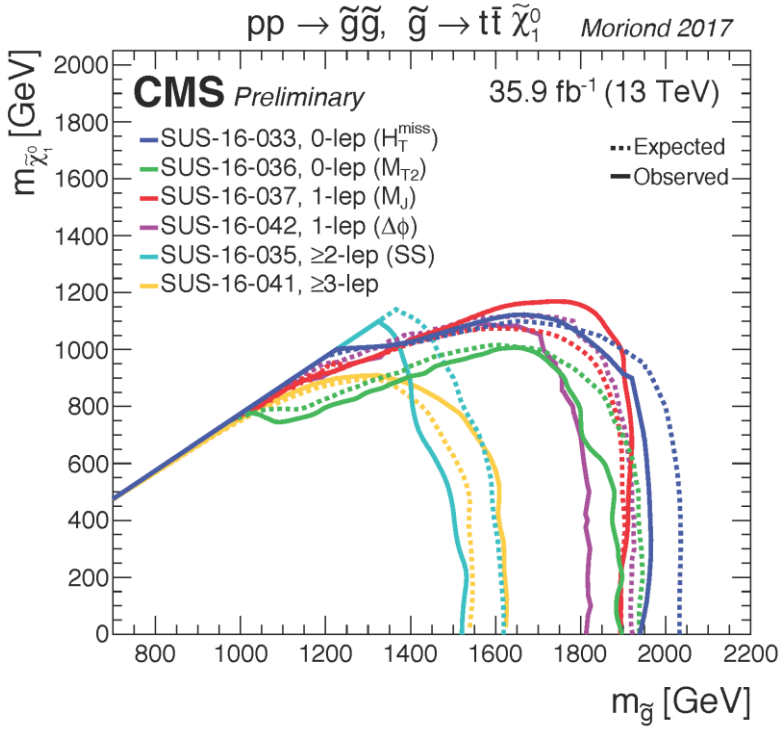
Exploit **unique signatures** or **more sophisticated** discriminants to beat down backgrounds

Strong production:

Inclusive SUSY searches

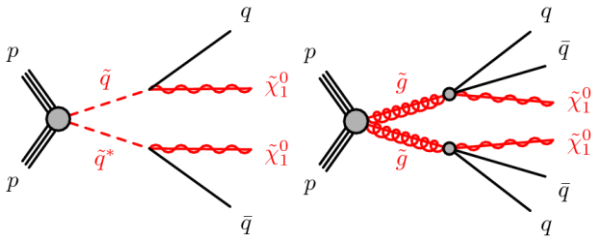
Summary of inclusive searches



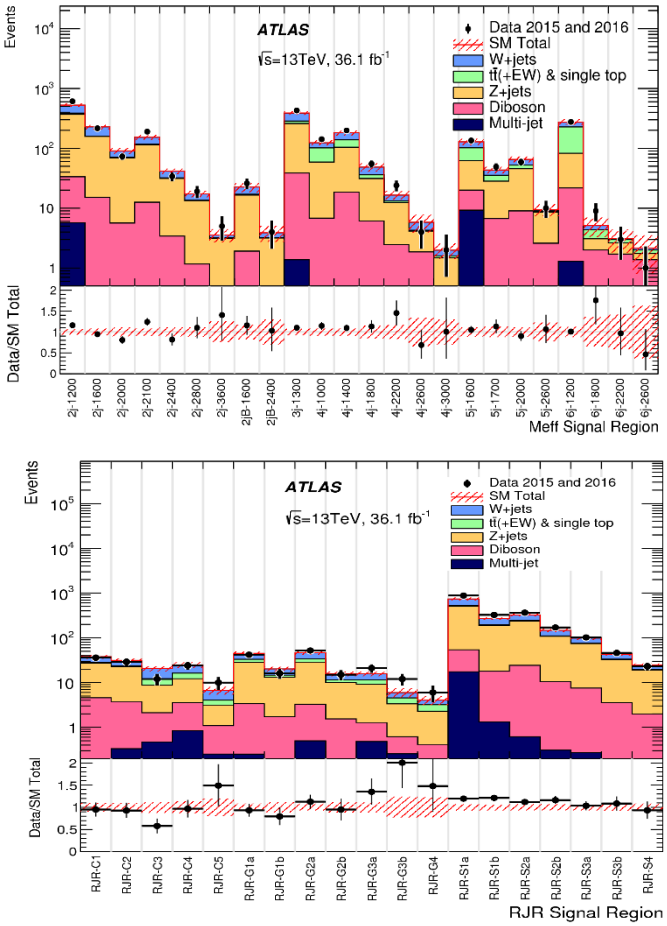


Model-independent: sensitive to a wide-range of model assumptions.

m_{gluino} and m_{squark} probed up to 2 TeV and 1.2 TeV respectively.



0L search for squarks and gluinos

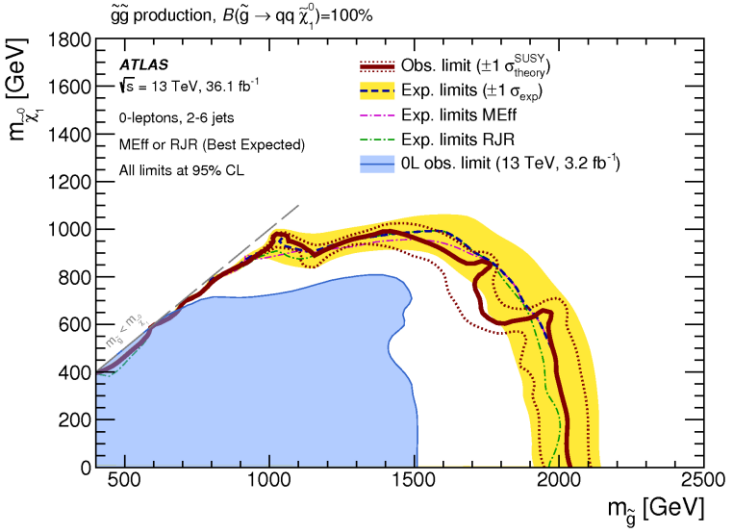


Events with 0-leptons and 2-6 jets. Signal regions defined using:

- $m_{eff} = \sum_{jet} p_T^{jet} + E_T^{miss}$ or the **Recursive Jigsaw Reconstruction** (RJR)

Using the **best** SR of the two approaches.

Masses of up to 2 TeV (gluinos) and 1.5 TeV (squarks) are probed.

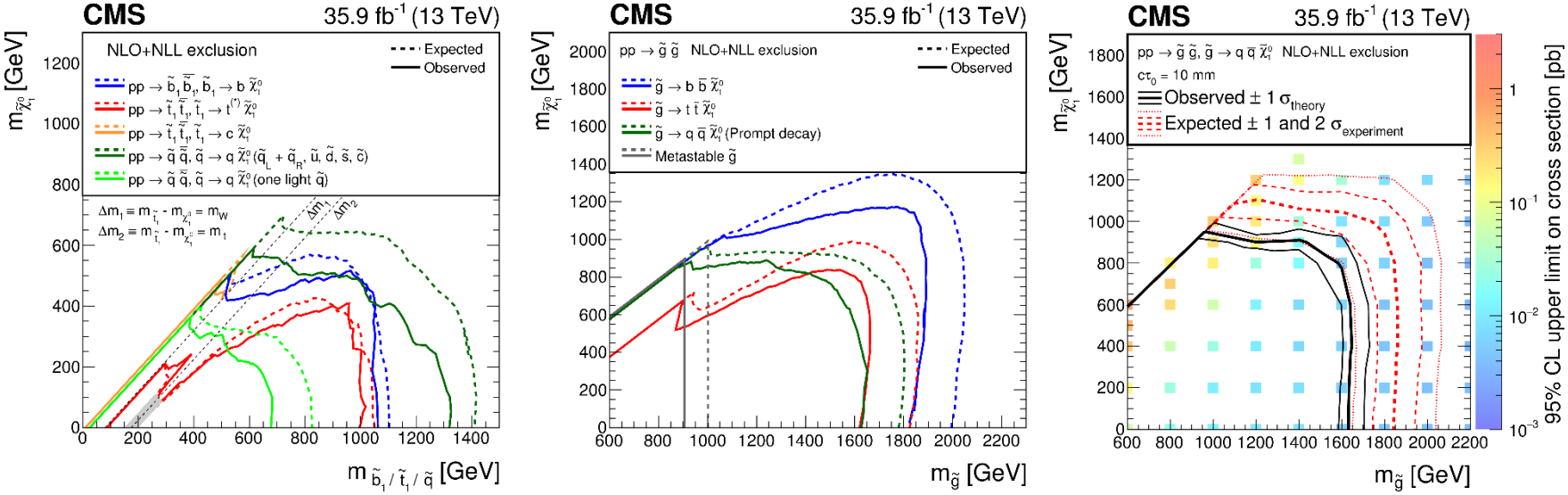


0L search with α_T

Looking for **multiple SUSY-inspired signatures**. Categorization in number of (b) jets and exclusive bins in H_T, H_T^{miss} depending on control region statistics.

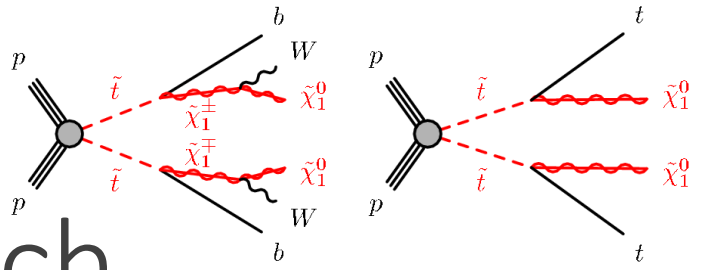
QCD background rejected with kinematic cuts, and remainder estimated using data sidebands, simulation function to compute transfer factors. No sign of new physics.

Masses of up to 1.9 TeV (gluinos) and 1.3 TeV (squarks) are probed. Also sensitive to third generation squarks, long-lived ($10^{-3} < c\tau_0 < 10^5 mm$) gluinos in Split SUSY models.



Is the jar full?

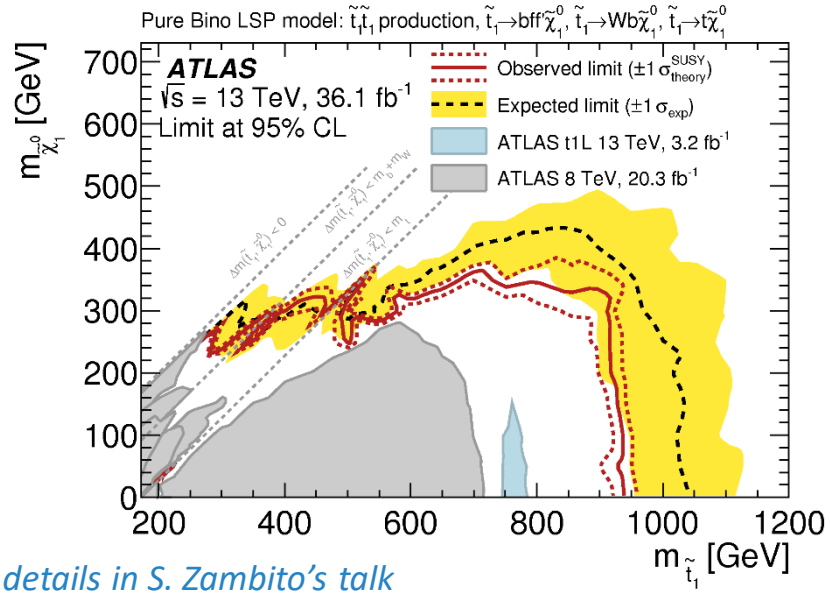
Not yet...

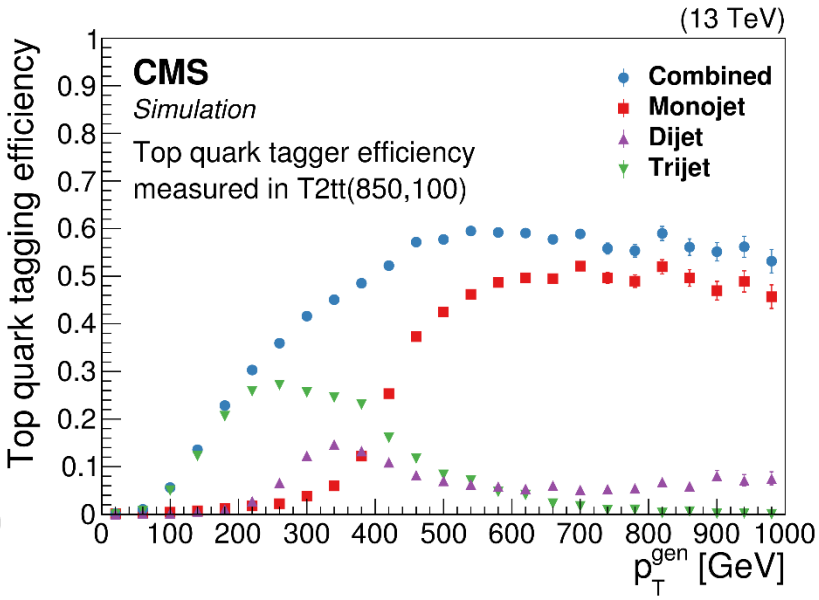


0/1 lepton stop search

Top tagging techniques: 60% efficiency for all possible decays of the top.

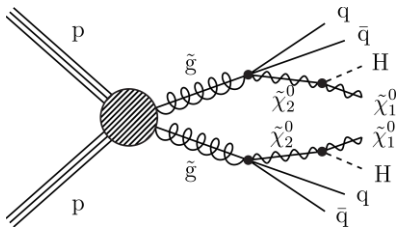
Same final state with **different dedicated signal regions**: a powerful analysis across many different mass splitting and decay modes assumptions.





More details in S. Zambito's talk

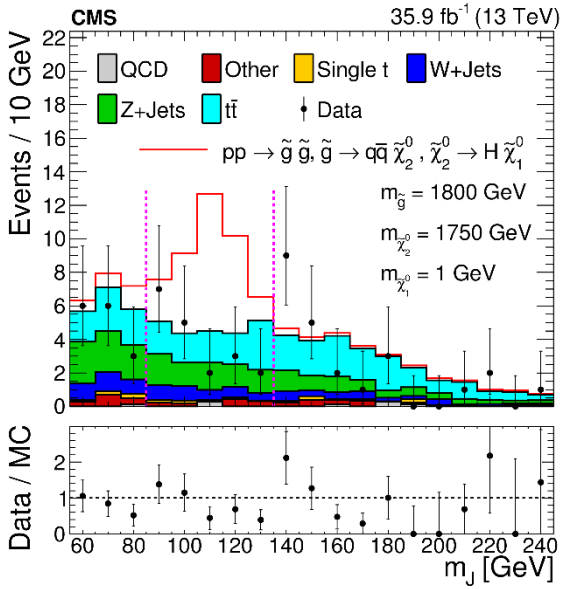
arXiv:1711.11520, arXiv:1710.11188 and arXiv:1707.03316

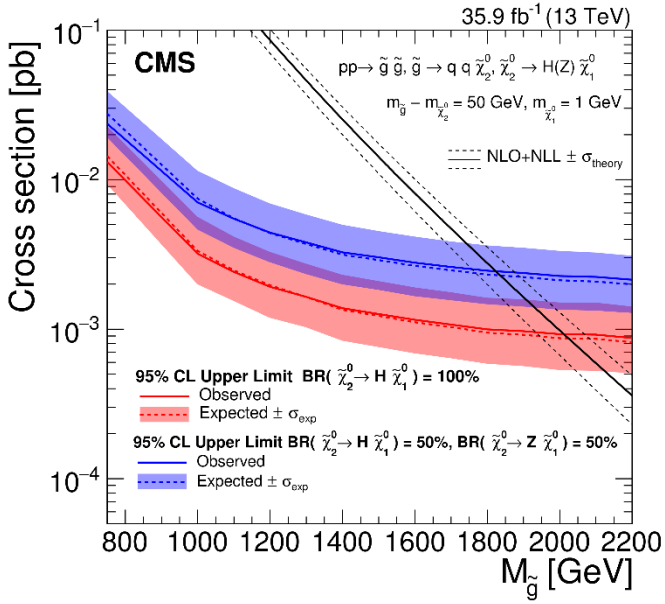


Boosted Higgs search

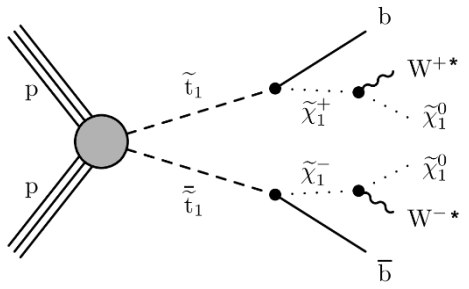
High p_T $H \rightarrow b\bar{b}$ decay with small opening angle. Use large angle jets to capture full Higgs decay. Identify Higgs tags by presence of two displaced sub-jets. **Jet mass shows clear peaking** structure

Select **events with 1 or 2 Higgs tags** and large missing energy. Backgrounds predicted from **mass and bb-tag sidebands** in data.





Compressed stops

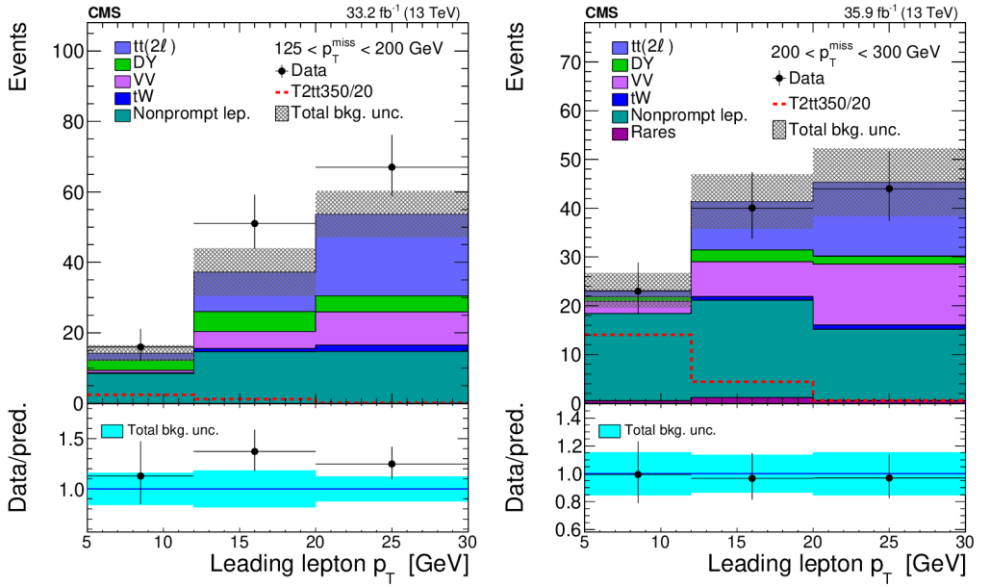


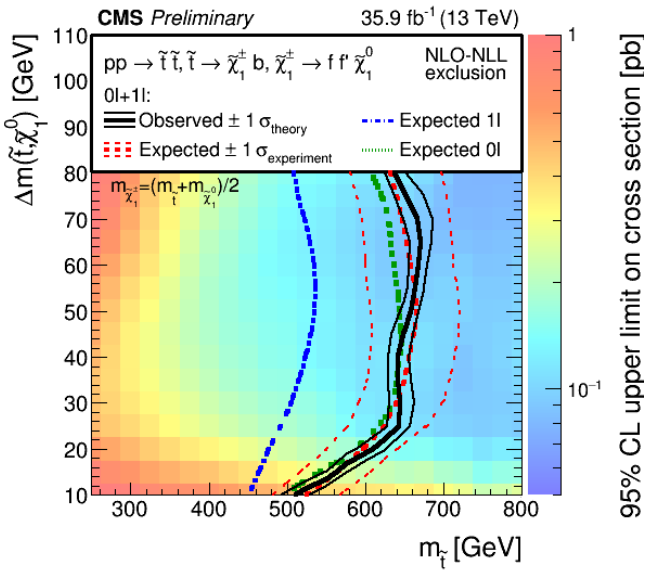
Compressed scenario with small $\Delta m\ (\tilde{t}, LSP)$ proceeds through an off-shell W, resulting in low-p_T decay products.

Rely on large ISR boost for sizeable E_T^{miss}

Searches with 1l and 2l,

- Backgrounds from MC normalized to data in control regions.





arXiv:1801.01846 and SUS-16-052

Towards lower cross-sections

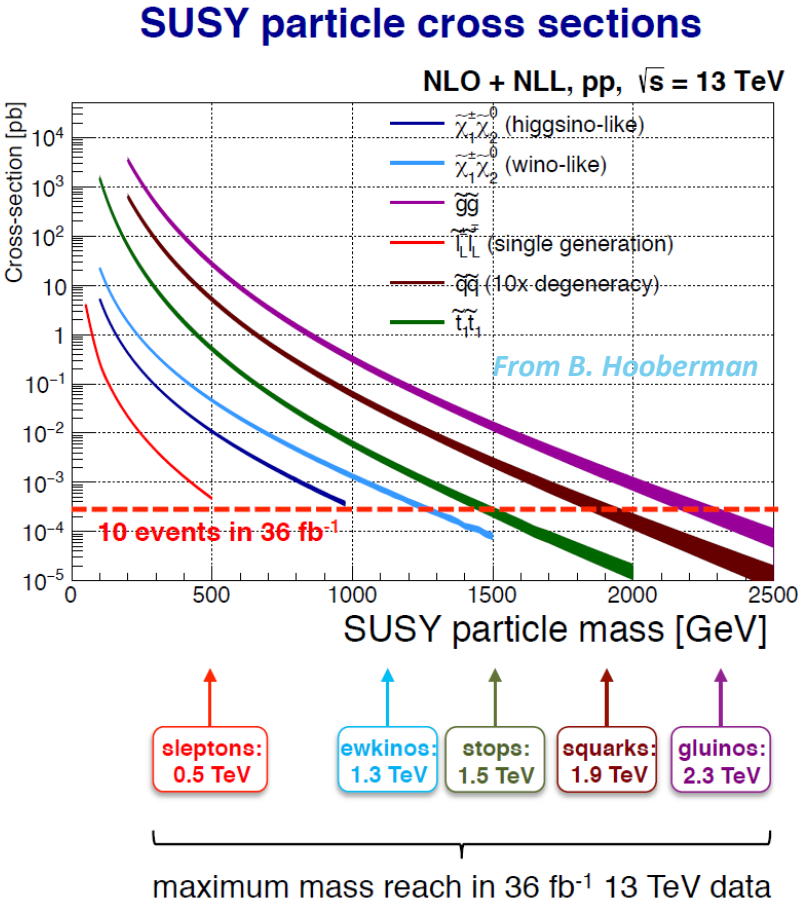
Current dataset allows to target electroweak SUSY production

Most of the LHC SUSY searches focus on **strong production**, with larger cross section.

- Current searches probe masses of squarks and gluinos up to 2 TeV.

Heavy squarks and gluinos may **favour models with direct EWK production of charginos, neutralinos and sleptons** with low hadronic activity associated, and these could be the only accessible SUSY production at the LHC.

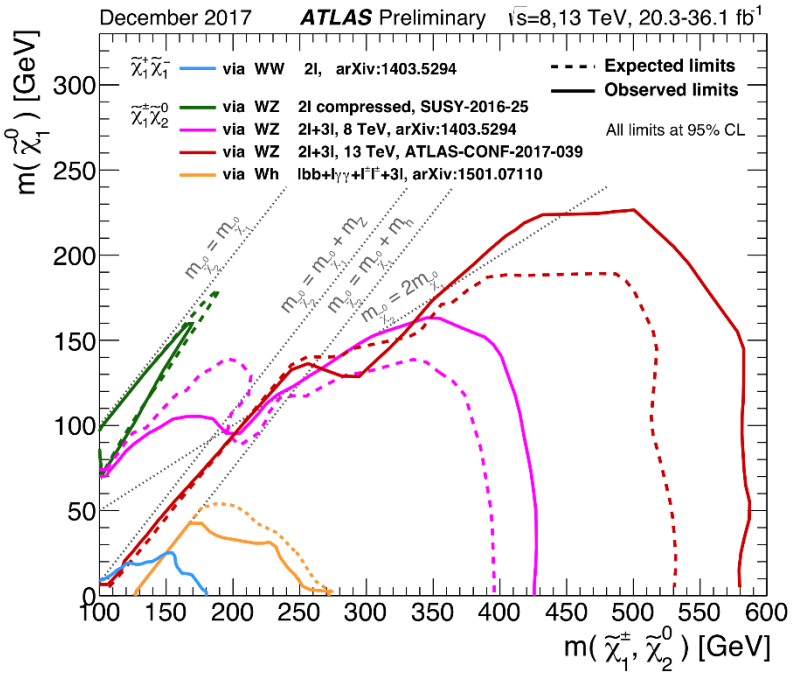
Charginos and neutralinos will decay then to sleptons or W, Z, h bosons

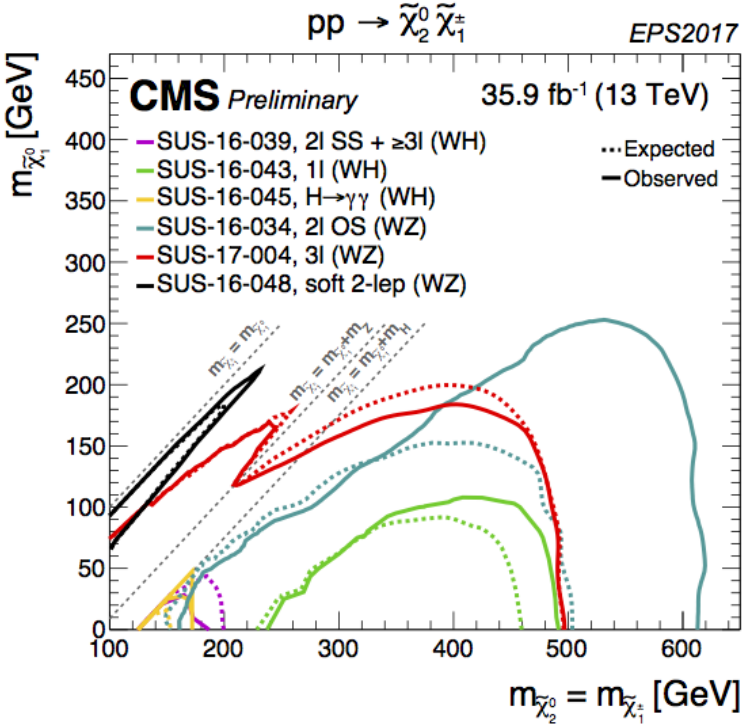


Summary of the searches

Similar reach in both collaborations.

Still quite some open phase space to explore with Run II data.

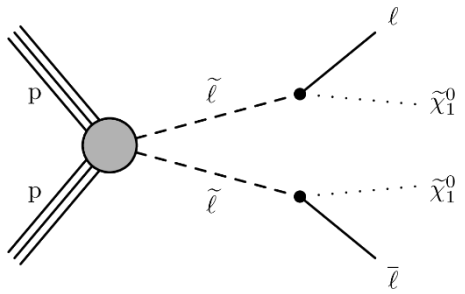




Is the jar full now?

Targeting corners

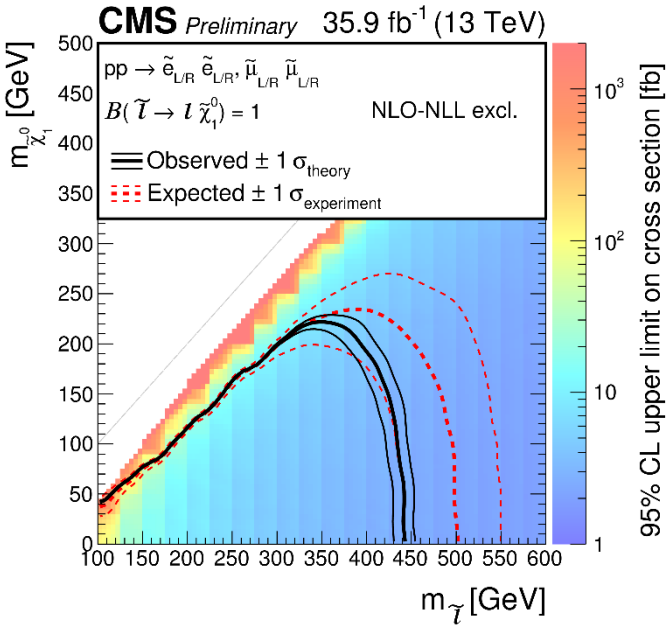
Slepton production

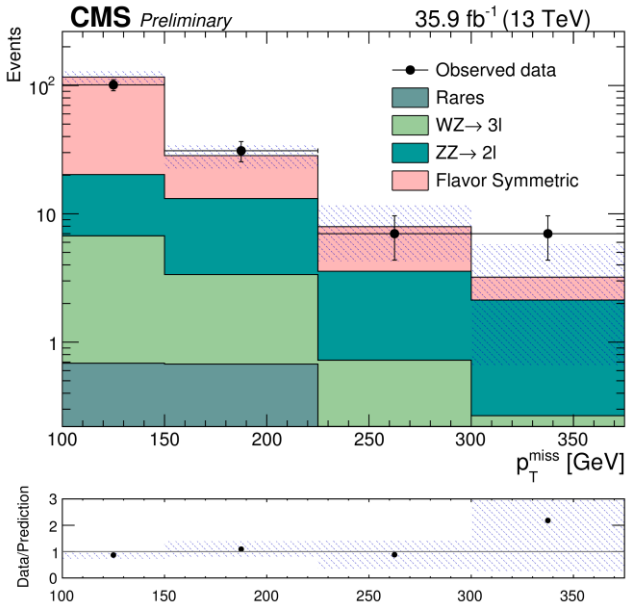


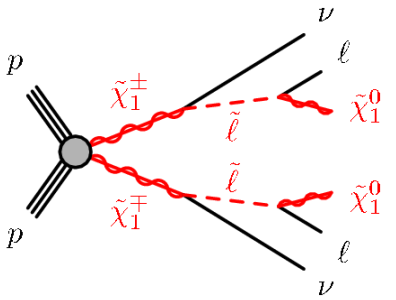
Target direct slepton production, in events with 2OSSF leptons.

The analysis exploits the M_{T2} variable that has an endpoint for SM backgrounds with a W boson.

Results are in agreement with SM expectations. Slepton masses up to 400 GeV are probed.





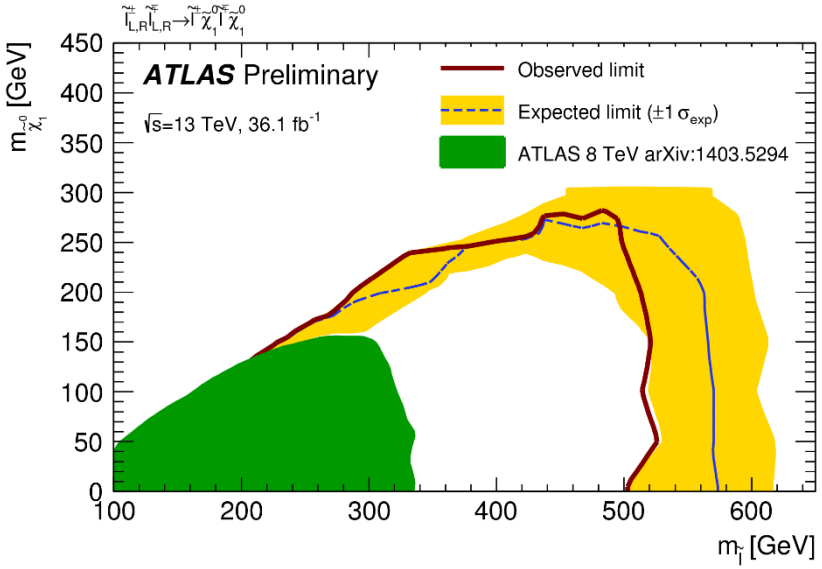


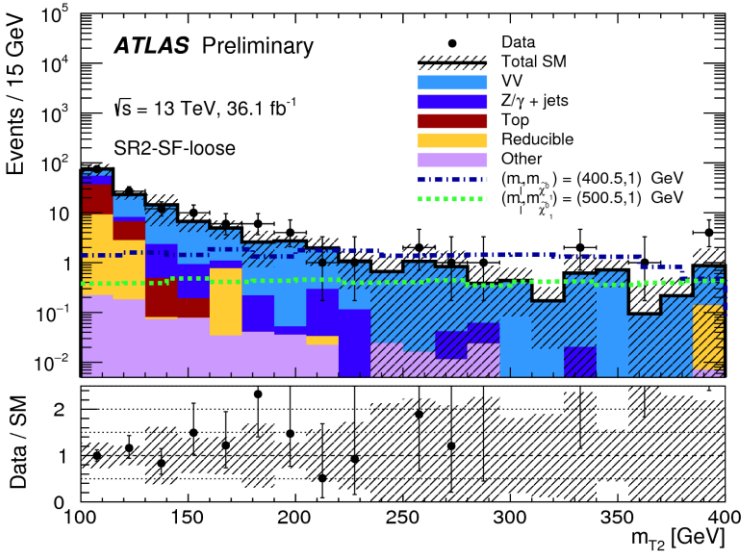
Slepton production

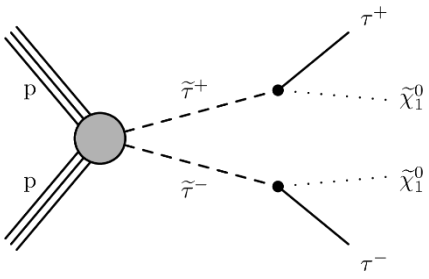
Target direct slepton production, in events with 2 OSSF leptons.

The analysis exploits the M_{T2} variable that has an endpoint for SM backgrounds with a W boson and the invariant mass of the leptons.

Results are in agreement with SM expectations. Slepton masses up to 500 GeV are probed.





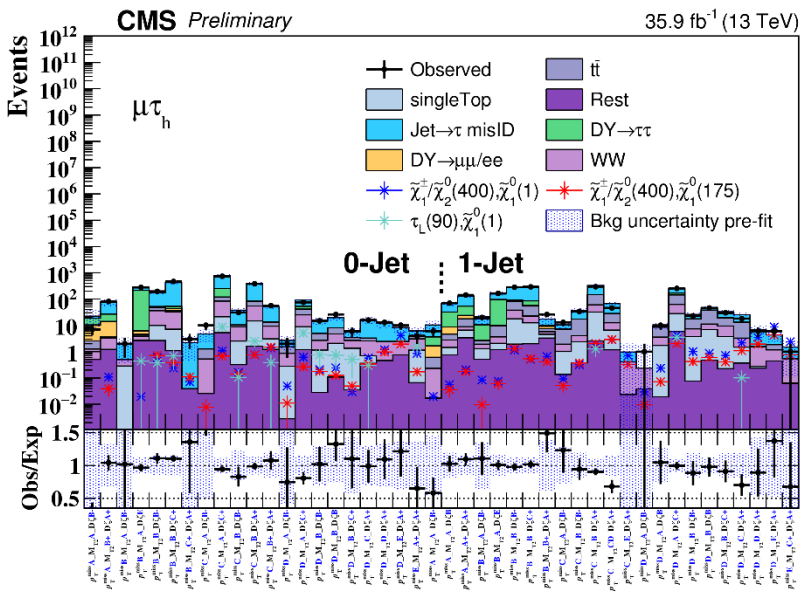


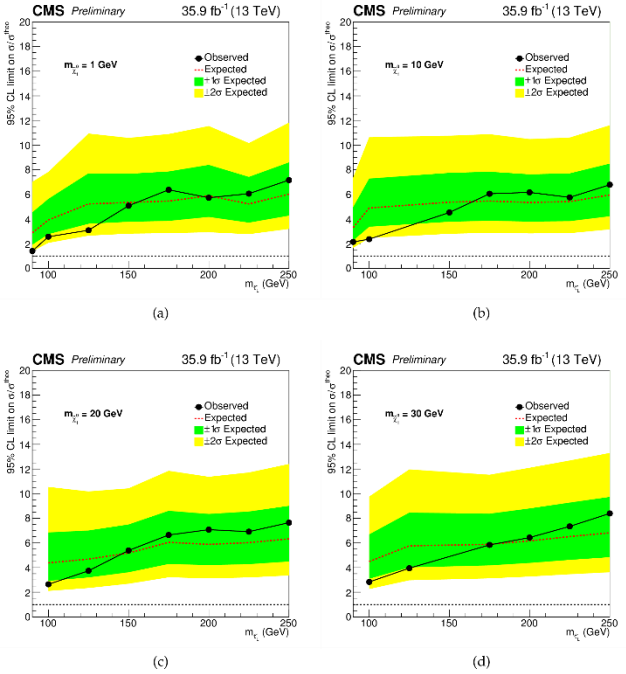
Stau production

Target direct stau production (and chargino-neutralino), in events with e/μ + τ and events with e+μ.

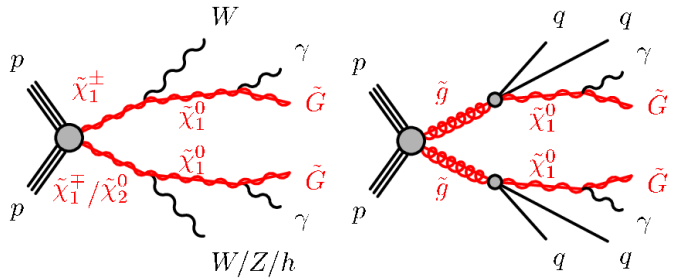
Events are classified by flavour, number of jets, E_T^{miss}, M_{T2} and $D\zeta = \vec{p}_T^{miss} \cdot \vec{\zeta} - \vec{p}_T^{\ell\ell} \cdot \vec{\zeta}$, with $\vec{\zeta}$ the bisector of the two leptons.

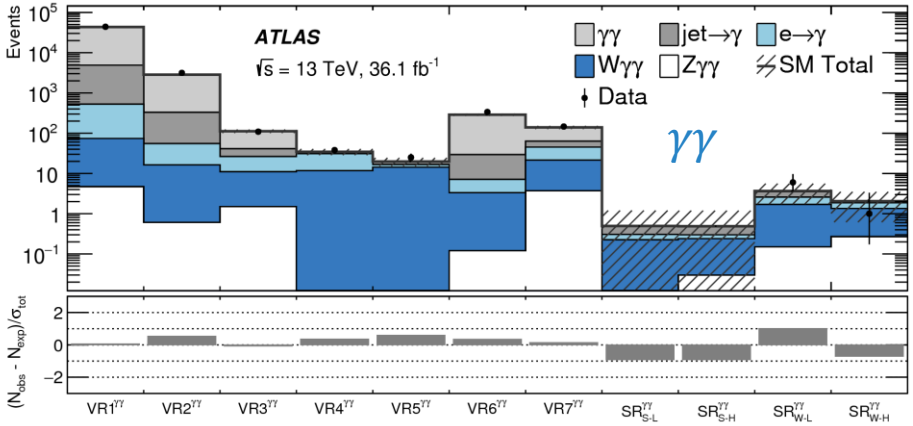
Results in agreement with SM expectations. Limits on chargino-neutralino production (up to 550 GeV) and stau production cross-section.

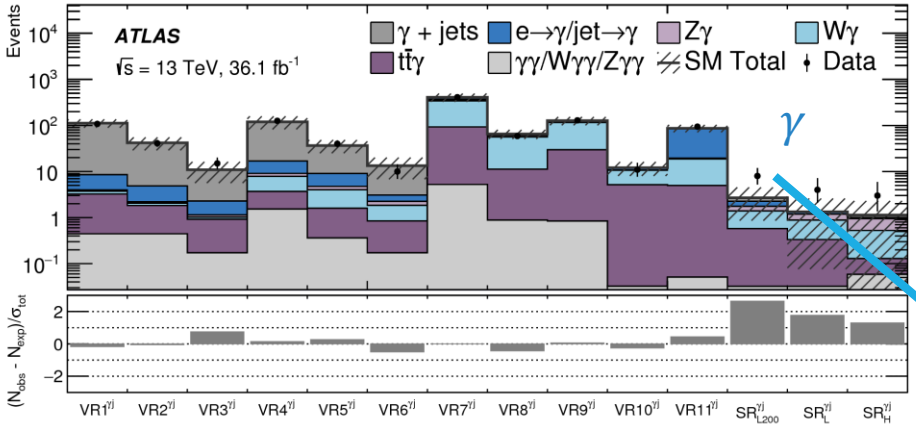




GMSB with photons





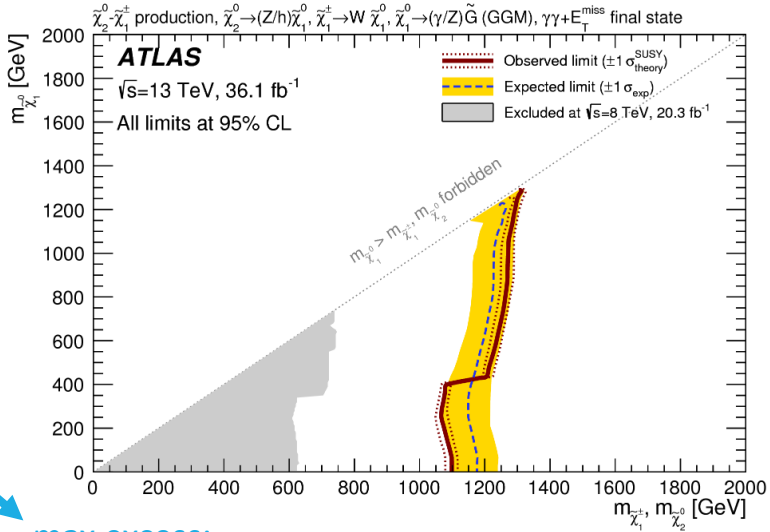


γ / γγ + MET + jets → strong production

- Probe up to 2.2 TeV gluinos / 1.8 TeV squarks

• γ / γγ + MET → electroweak production

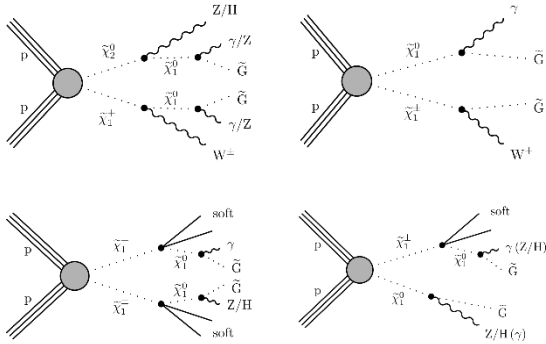
- Probe up to 1.2 TeV charginos/neutralinos

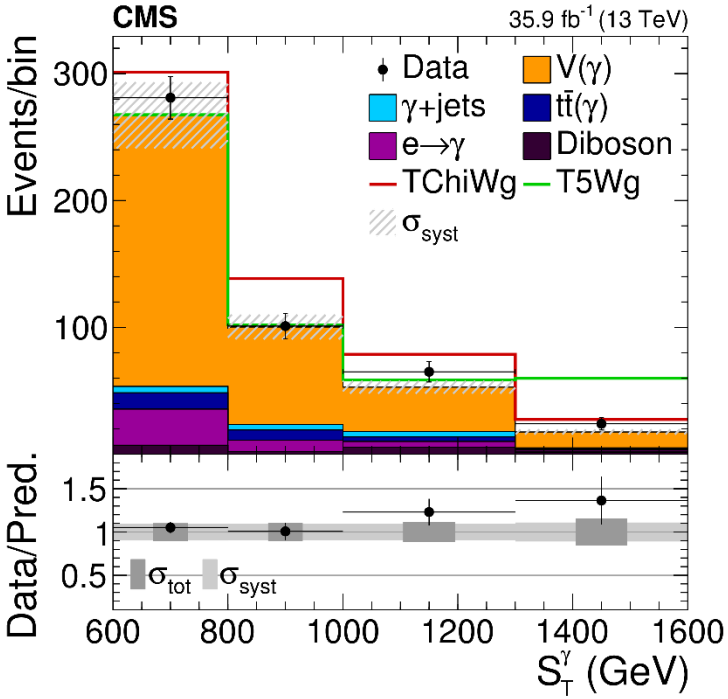


max excess:
8 vs 2.68 ± 0.6

arXiv:1802.03158

GMSB with photons



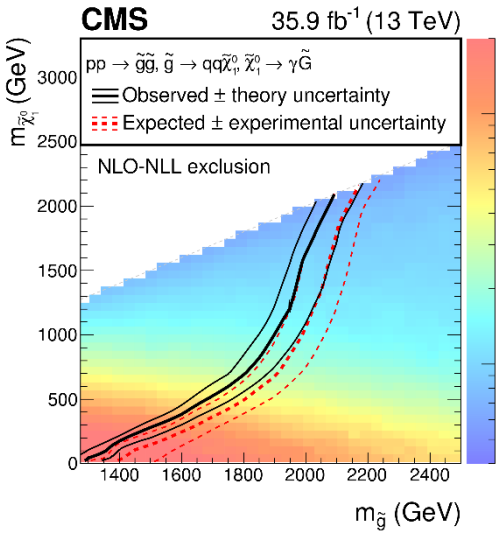


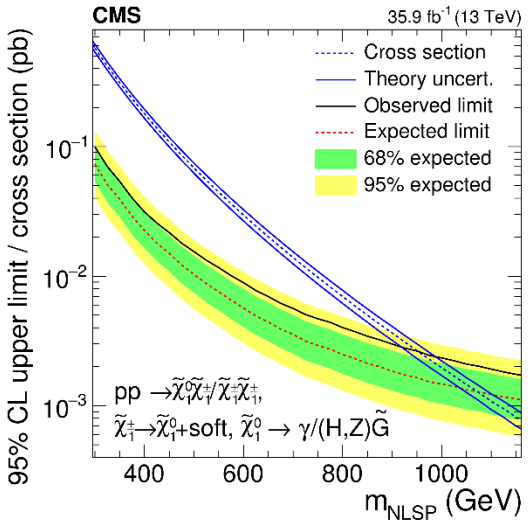
This analysis sets the most stringent limits for the studied models.

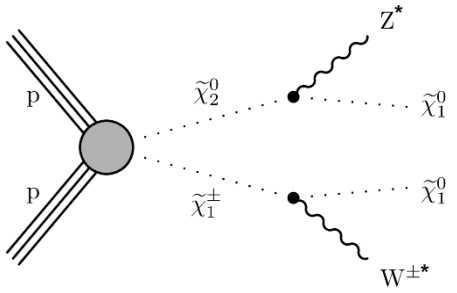
At least one photon and large E_T^{miss}

Signal regions defined in bins of $S_T^{\gamma} = E_T^{miss} + \sum_{\gamma_i} p_T(\gamma_i)$

Gaugino masses up to 950 GeV and gluino masses up to 2100 GeV are probed.







Compressed winos

CMS

2-soft leptons + E_T^{miss} + ISR jet

Search bins: using $M_{\ell\ell}, E_T^{miss}$

Analysis also sensitive to stop production.

Data in agreement with SM.

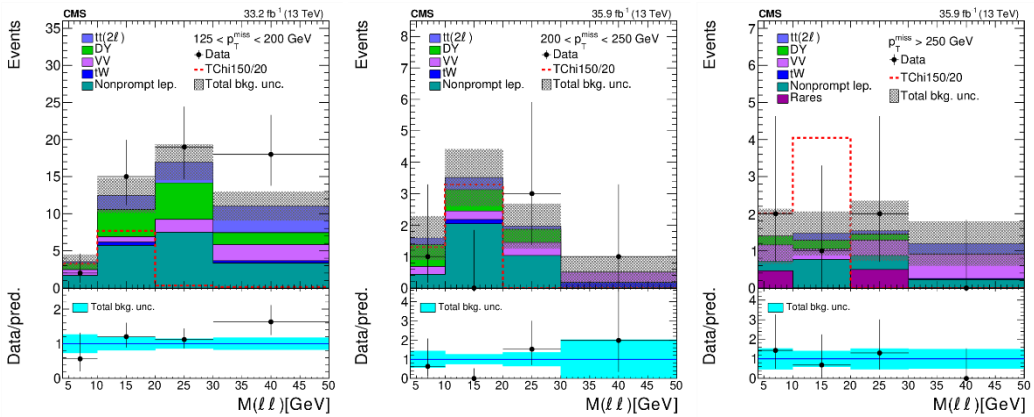
ATLAS

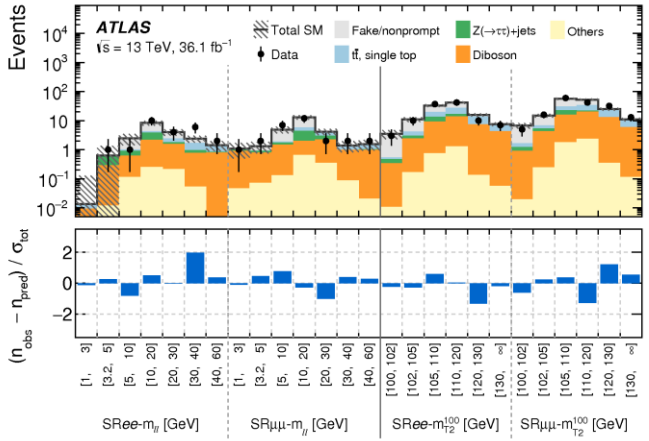
2-soft leptons + E_T^{miss} + ISR jet

Search bins: using $M_{\ell\ell}, M_{T2}$

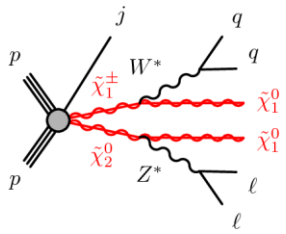
Analysis also sensitive to slepton production.

Data in agreement with SM.





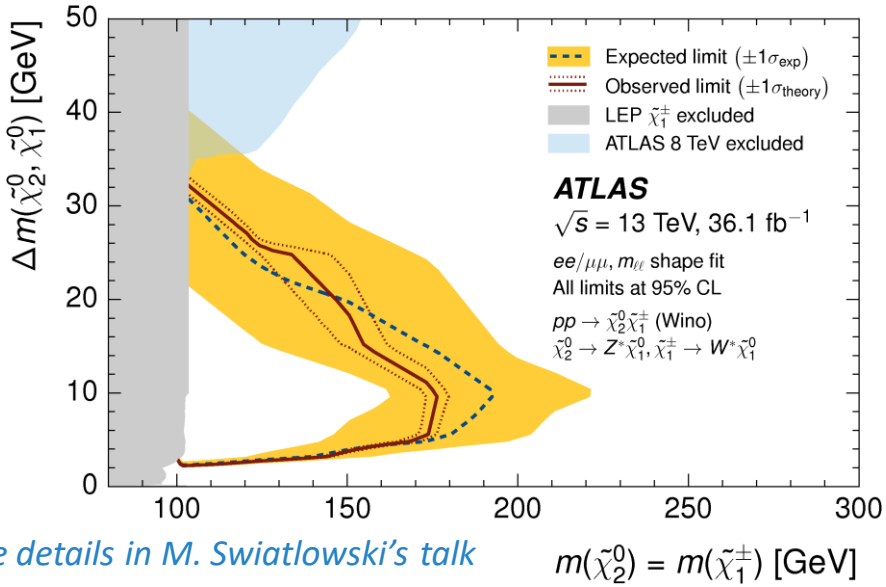
arXiv:1801.01846 (CMS), arXiv:1712.08119 (ATLAS)

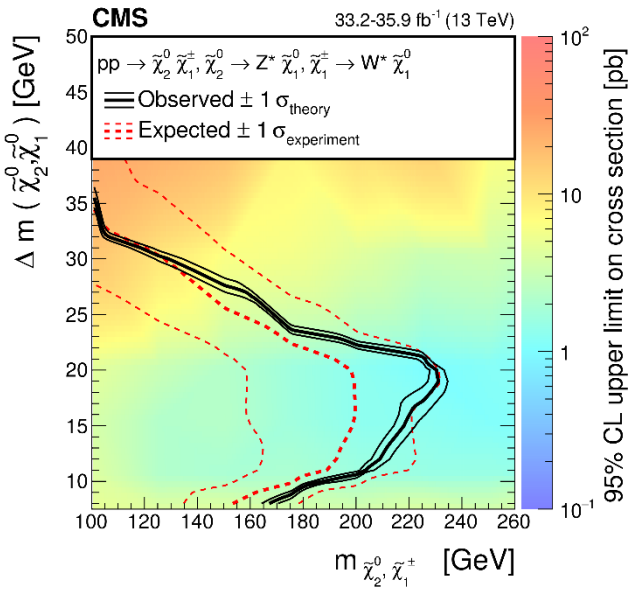


Compressed winos

Both CMS and ATLAS result has similar reach.

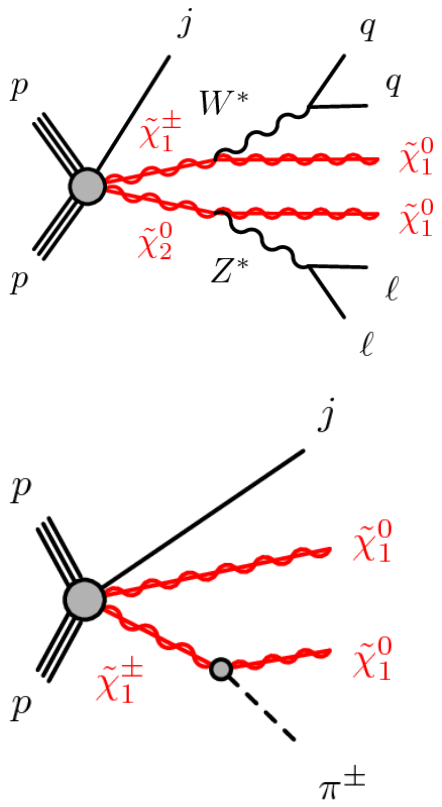
Chargino/neutralino masses are probed up to 220 GeV for a mass diference of 20 GeV.





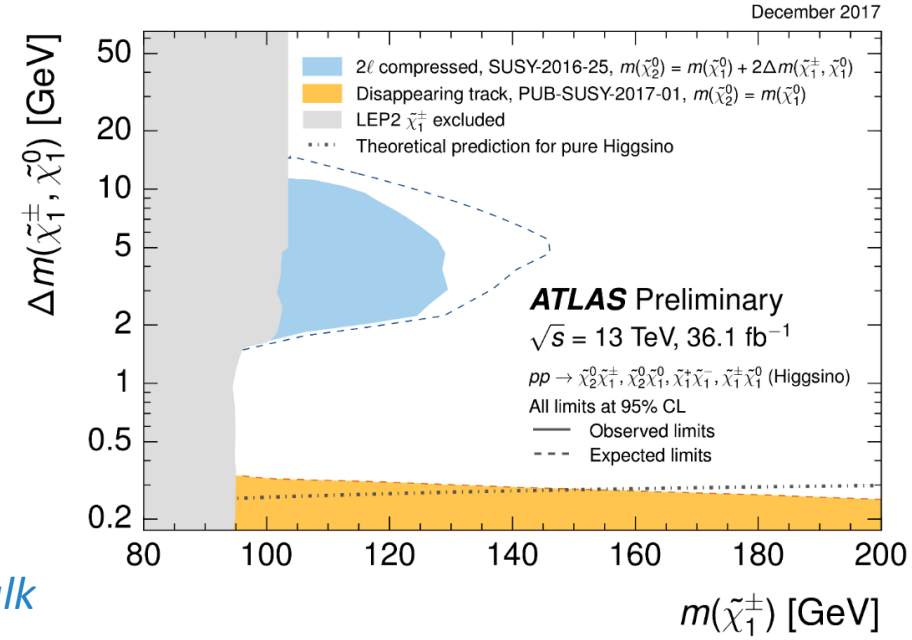
More details in M. Swiatlowski's talk

Compressed higgsinos



Previous search also constrains models with **compressed higgsinos**.

Another **search** for very small mass splitting in which the higgsinos has finite lifetime that gives rise to a **disappearing track**.



Covered in detail in M. Swiatlowski's talk

Is the jar full now?

RPV searches

The presence of significant missing energy is the workhorse of most SUSY searches.

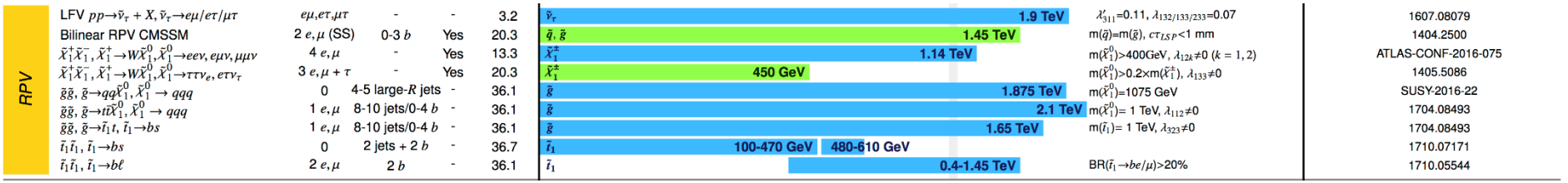
Has served us well, but can potentially blind us to other possibilities

- If R-parity is not conserved, neutralinos are not the end of the SUSY cascade.

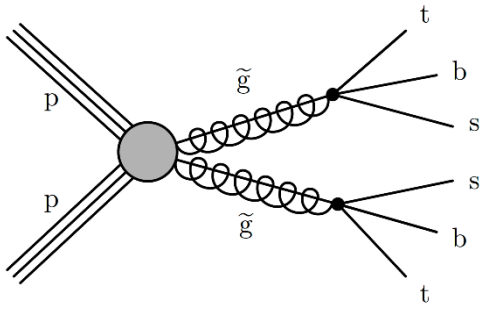
Other possibilities open up.

An RPC-designed analysis can be potentially sensitive to RPV-signatures.

ATLAS has a broader program on RPV searches.



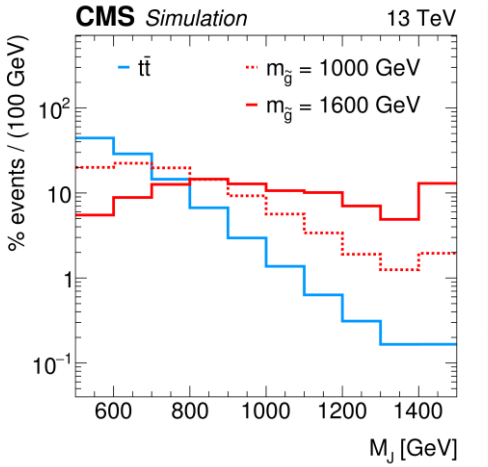
RPV 1lepton+jets

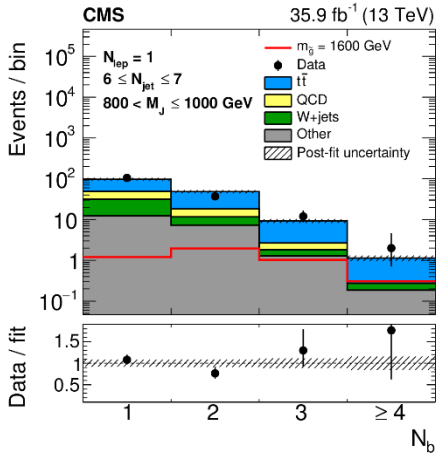


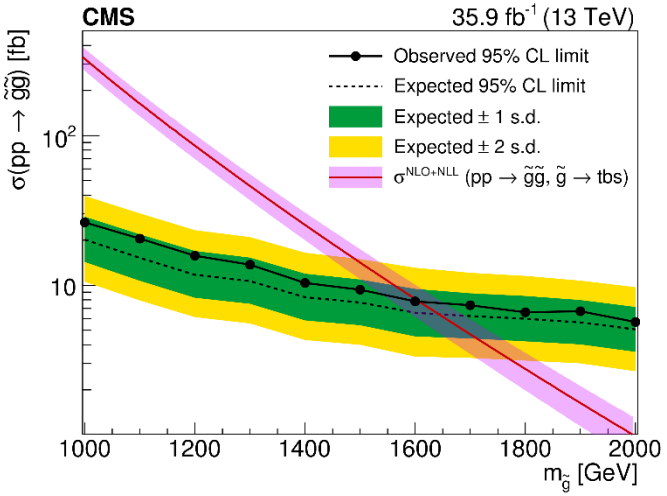
RPV multi-b analysis searching in tails of high N_{jet} and high N_b multiplicity, we select events with one lepton and $H_T > 1200$ GeV, $N_{jet} \geq 4$, $N_b \geq 1$, $M_J > 500$GeV

Signal regions defined in categories of number of (b)jets and jet mass.

Gluino masses probed up to 1.6 TeV.

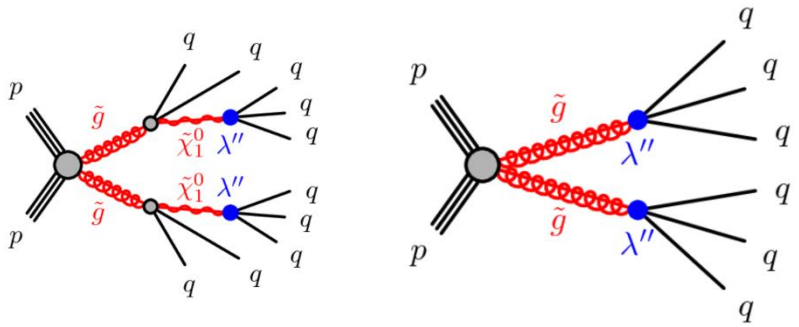






arXiv:1712.08920

RPV multijets

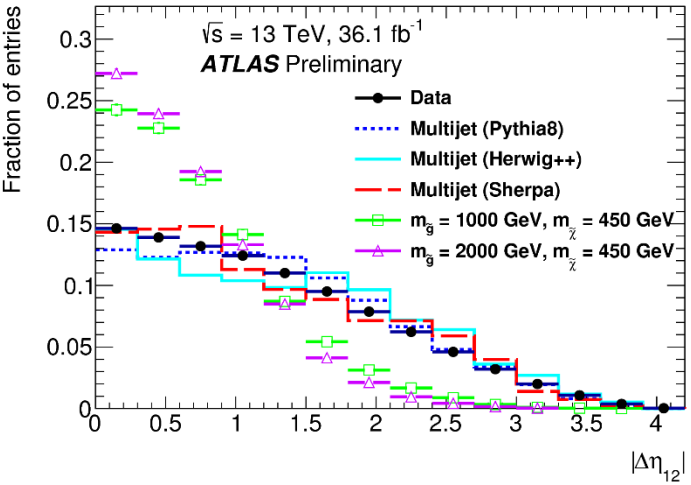


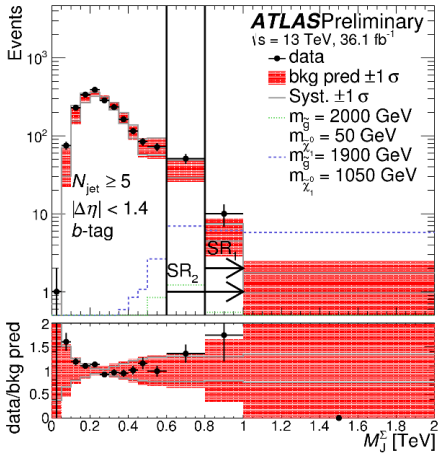
Search in events with 4 or more large jets.

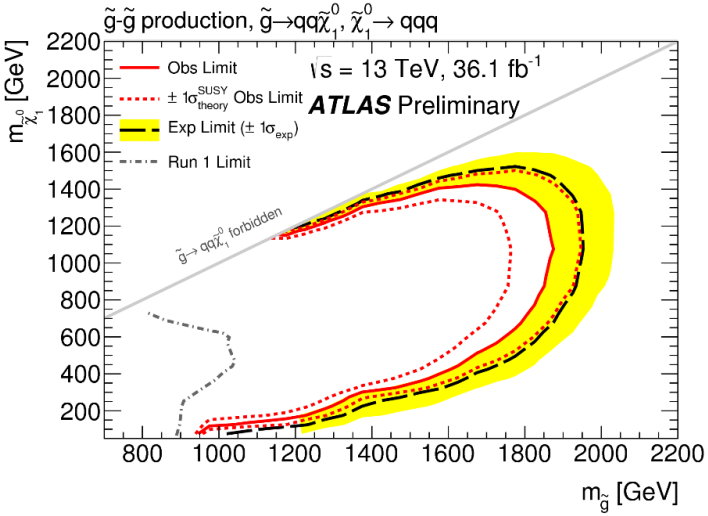
Search regions using bins of the sum of jet masses: $M_J^{\Sigma} = \sum_i m_J$ and $|\Delta\eta_{12}|$

Data-driven backgrounds templates from events with less than 4 jets.

Masses are probed up to 1800 GeV.







Is the jar full now?

We haven't found SUSY (yet).

Exploring new territories and ideas to cover all possible phase space:

- Dedicated variables.
- Object identification, background estimation, systematic uncertainties.
- Compressed spectra, RPV, displaced signatures…

Run II has opened up new territories to explore, a jump in energy but also a huge leap in integrated luminosity.

Exciting years ahead of us, stay tuned!

Back-up slides

Strong production of squarks / gluinos

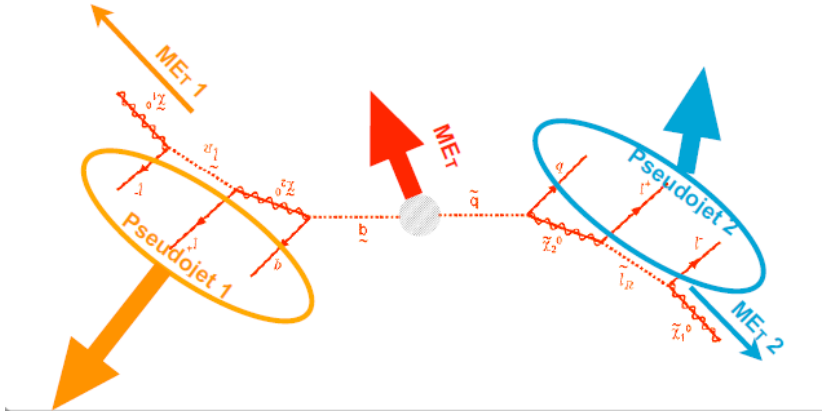
These are the “easy” searches for SUSY:

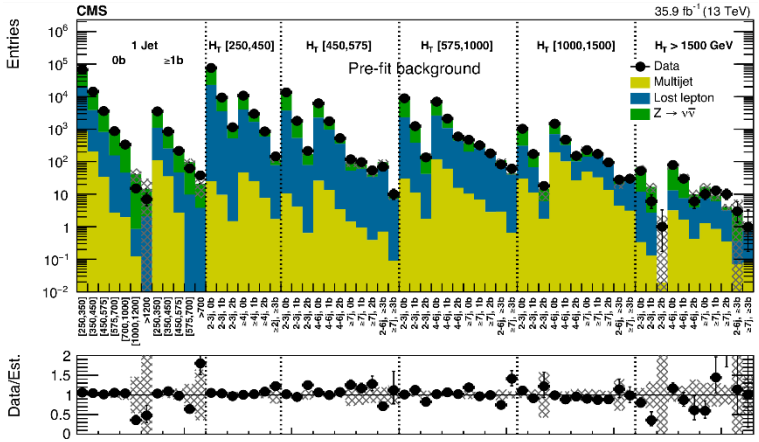
- Looking for pair-produced particle that decay with invisible particle emission (E_T^{miss}).
- Customized variables to reduce background and retain information about SUSY masses.

Searches include 0L, 1L and 2 or more lepton channels.

- Further categorization with discriminating variables.

Avoid model-dependent assumptions.





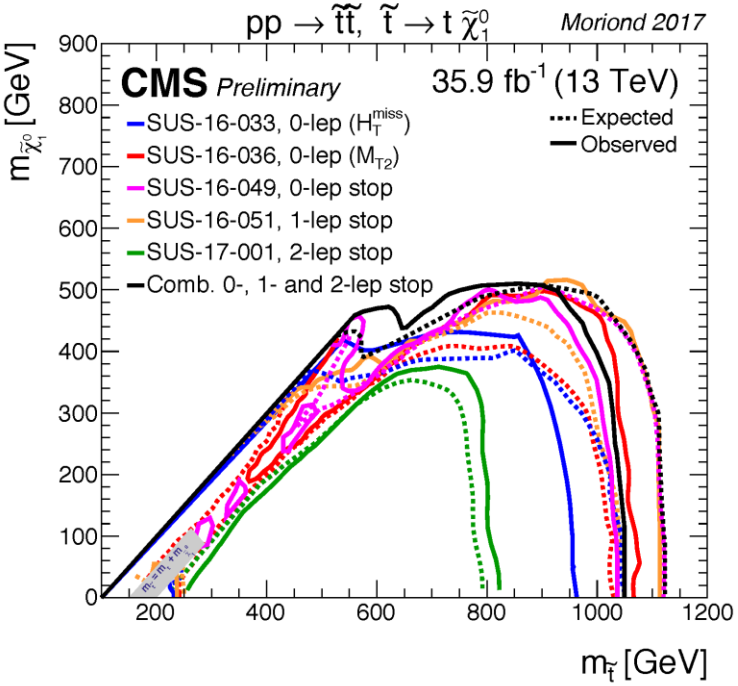
Strong production: stops

Top quarks are very important in SUSY searches, **dedicated stop searches** are performed:

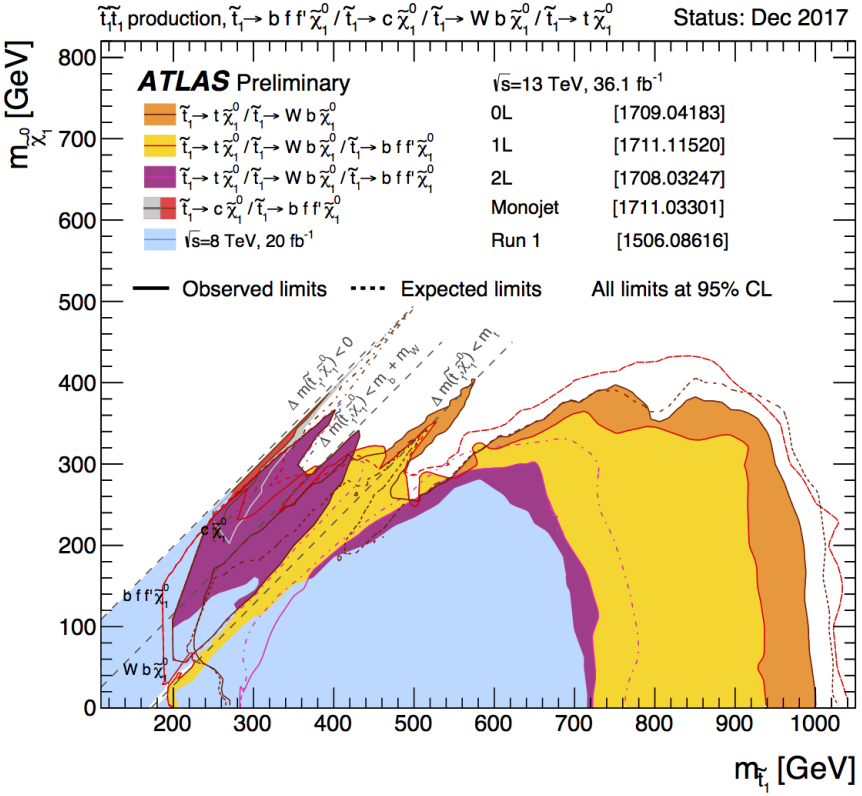
Naively, one would expect “light” stops if we want SUSY to be “natural”.

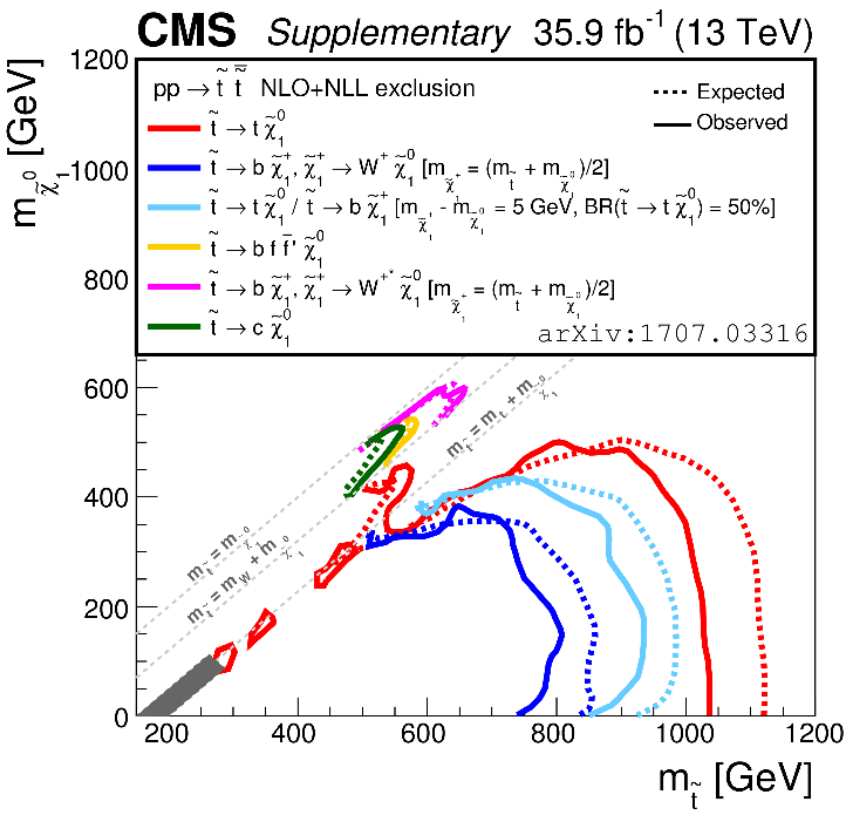
Dedicated searches for stop pair production are designed in every possible final state: 0-lepton, 1-lepton and 2-lepton.

Most recent searches have **incorporated top quark tagging**.

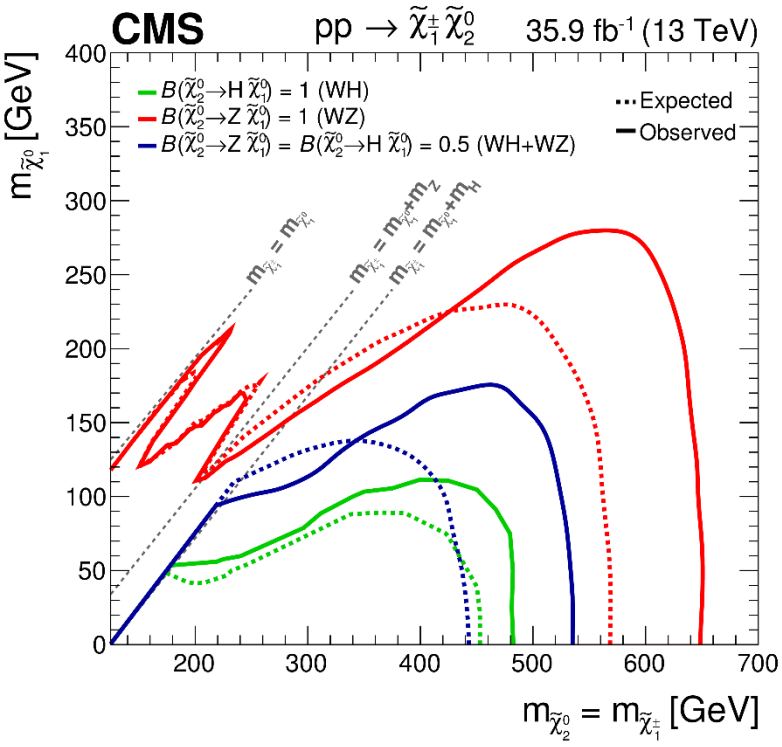


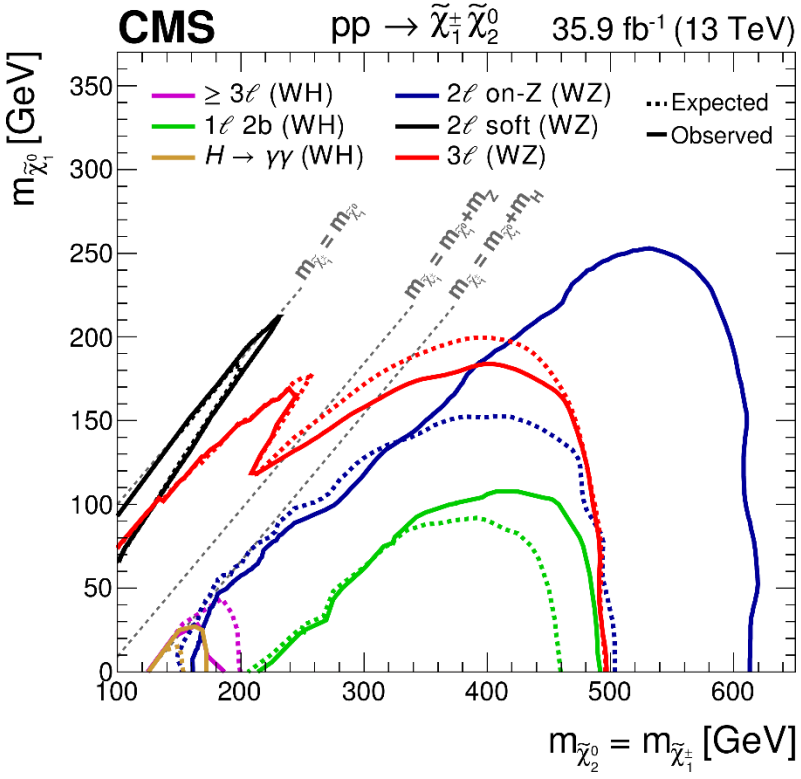
Summary of stop searches



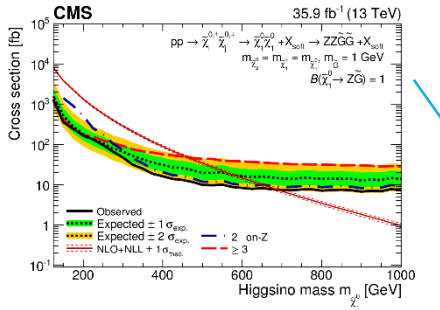


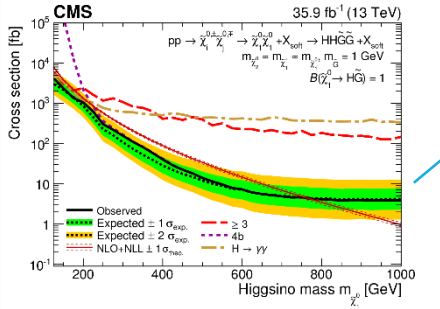
EWKino combination

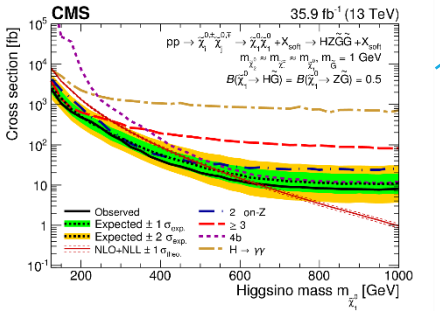


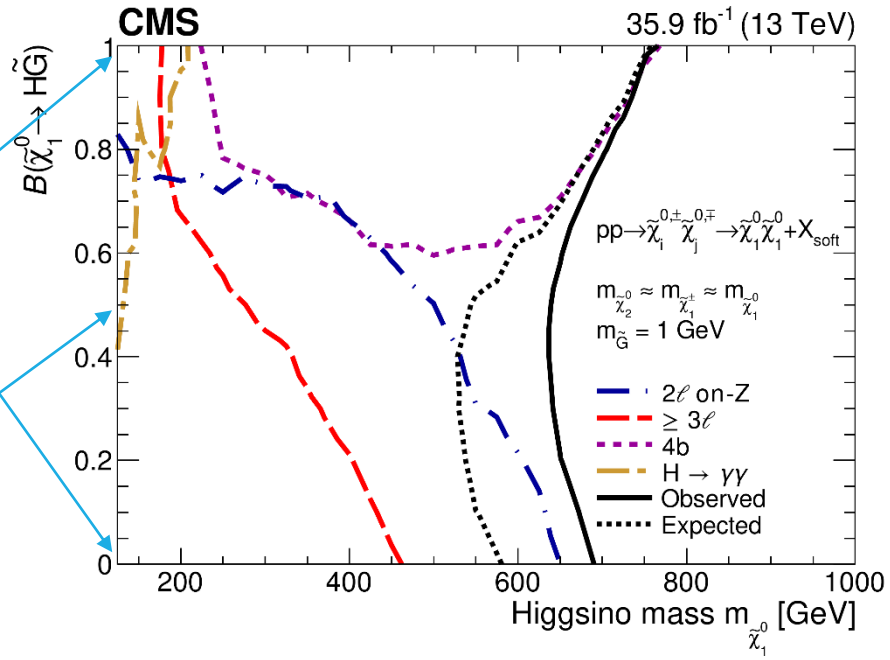


EWKino comb. (higgsinos)

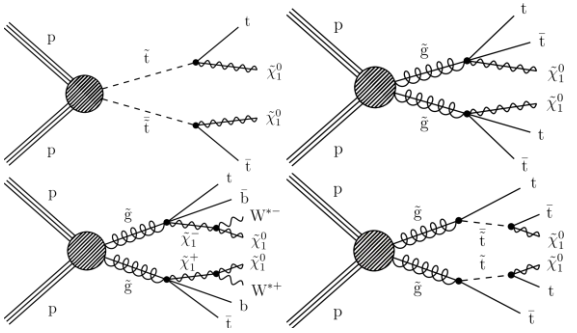








0 lepton search

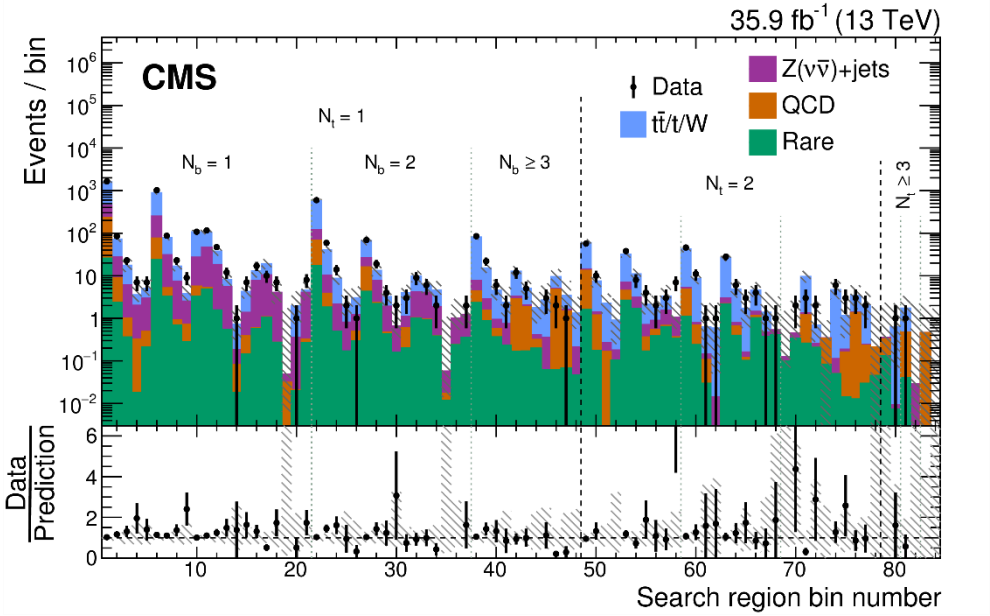


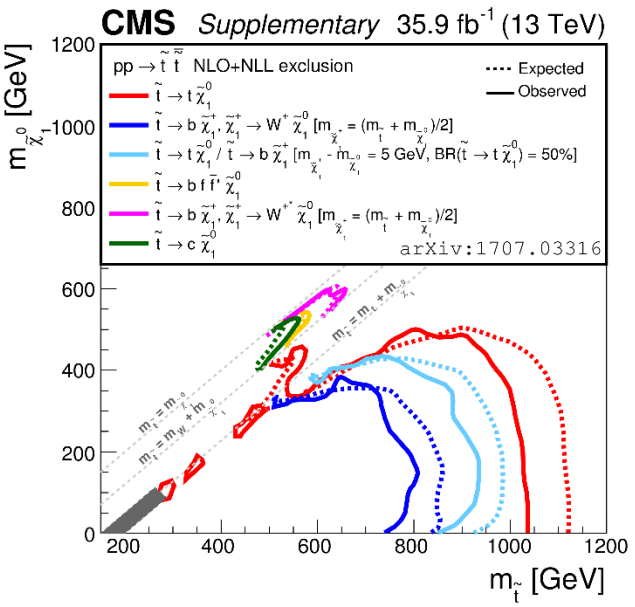
Select events with 0 leptons and significant E_T^{miss}

Search regions defined by the number of bottom and top quark candidates.

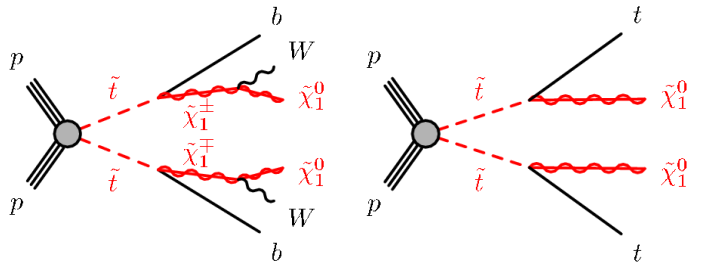
- further binning in M_{T2}, E_T^{miss}, H_T adding a total of 82 signal regions.

Search sensitivity to many models with top / stop decays: stop masses are probed up to 1 TeV





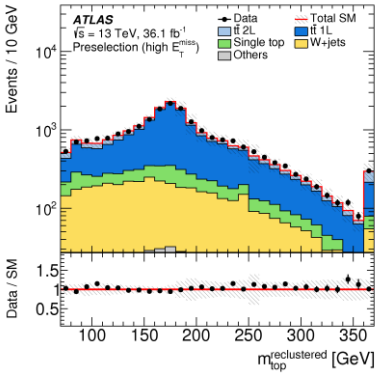
1 lepton search

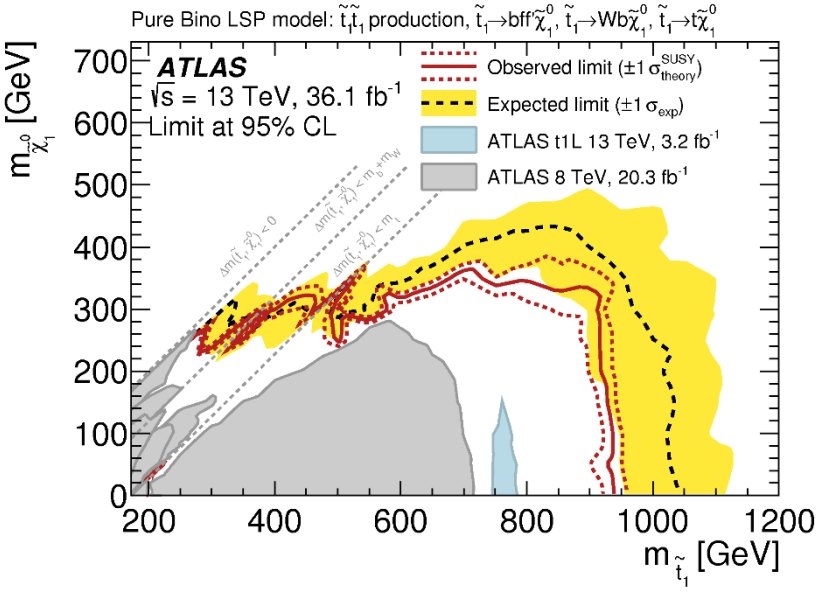


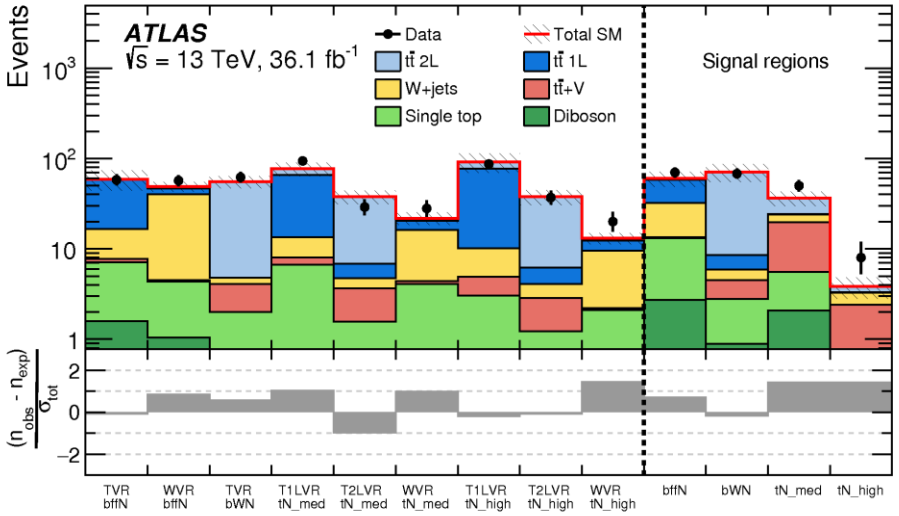
16 dedicated analyses to cover all the phase space, for various model assumptions.

Stop quark masses are probed up to 940 GeV.

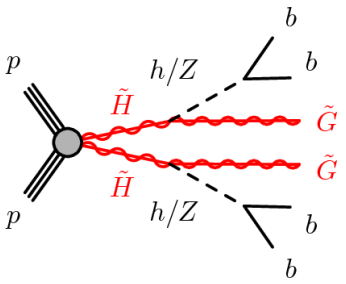
The analysis also targets DM production.







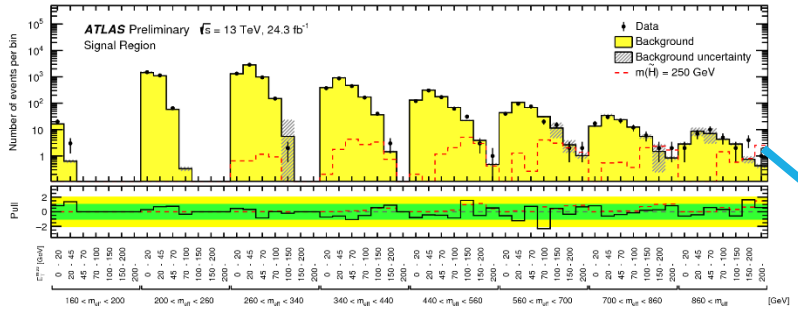
GMSB higgsino NLSP

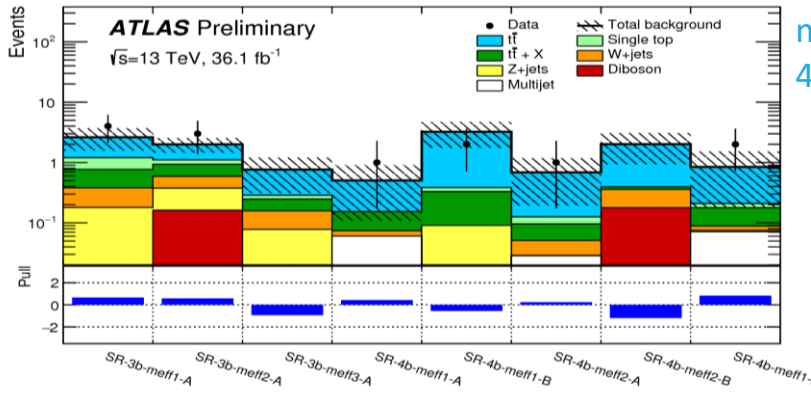


Select events with ≥ 4 jets (≥ 3 b-tag) + E_T^{miss}

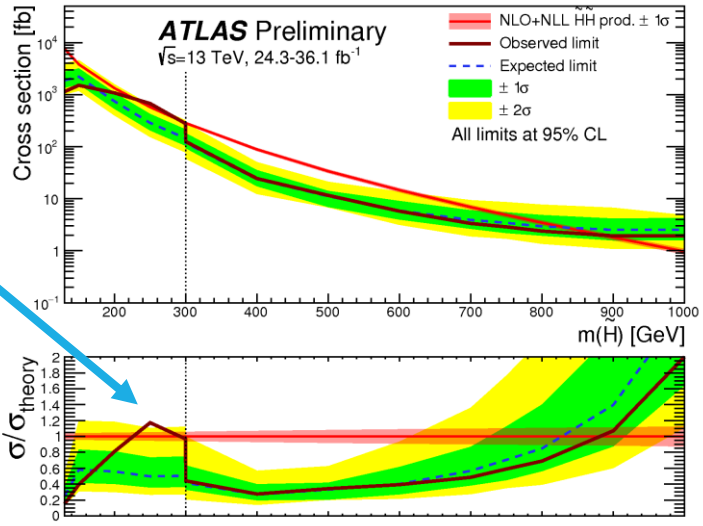
High-mass search ($\mu > 300$ GeV): trigger on large E_T^{miss}, background from MC.

Low-mass search ($\mu < 300$ GeV): Use b-jets triggers to probe low E_T^{miss}, extrapolate from 2b data.



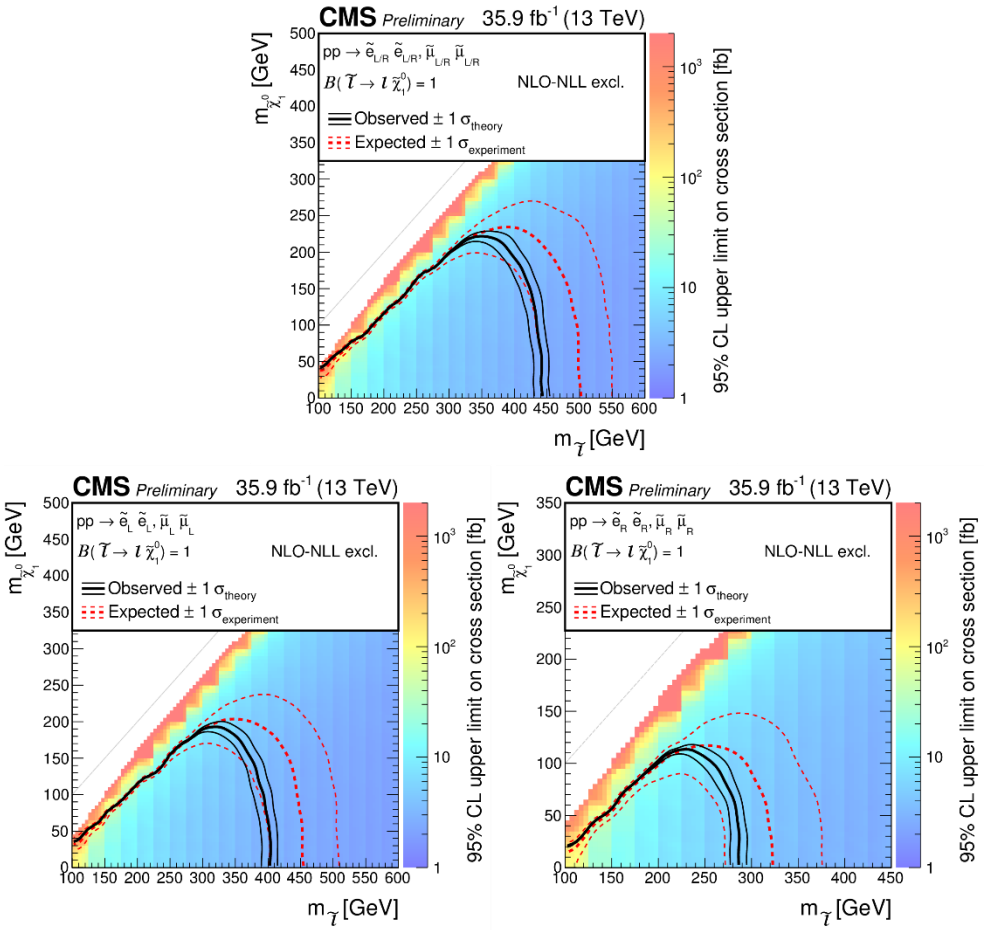


max excess:
4 vs 1.0 ± 0.2



Covered in detail in M. Swiatlowski's talk

Slepton production



Stau production