Searches for squarks and gluinos with ATLAS

Antonia Strübig

(University of Edinburgh)

on behalf of the ATLAS Collaboration

Windows on the Universe - Vietnam 2018

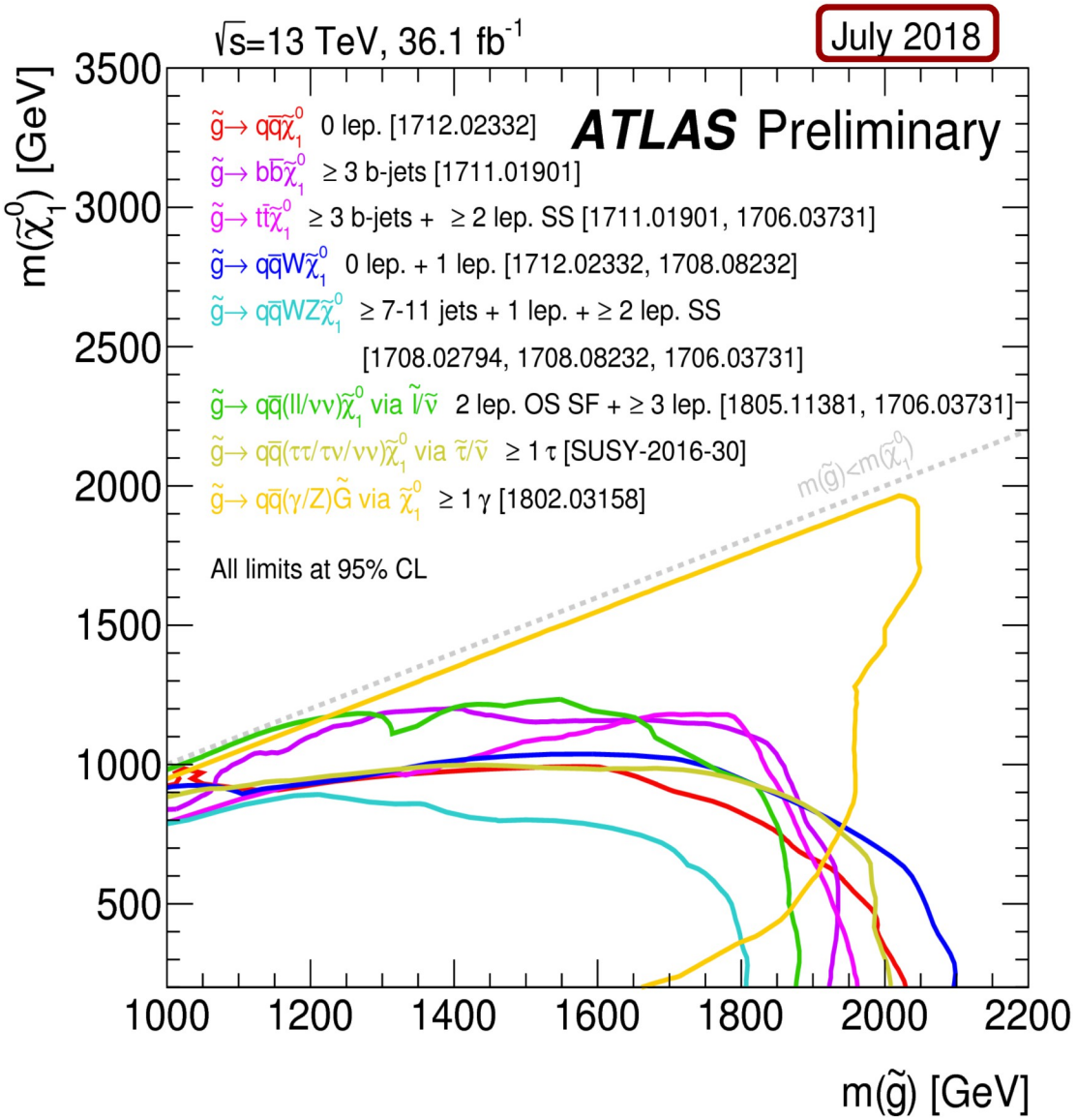
07.08.2018

Supersymmetry

Supersymmetry is still a favoured extension of the Standard Model

- SUSY postulates a superpartner with spin altered by 1/2 for each SM particle
- Offers solutions to open questions of the SM
  - hierarchy problem
  - fine-tuning of the Higgs mass
  - unification of fundamental interactions
- Provides good candidate for dark matter
- General SUSY has more than 100 free parameters

→ large parameter space and many possible signatures to look for



Supersymmetry at the LHC

- many SUSY models assume R-parity is conserved

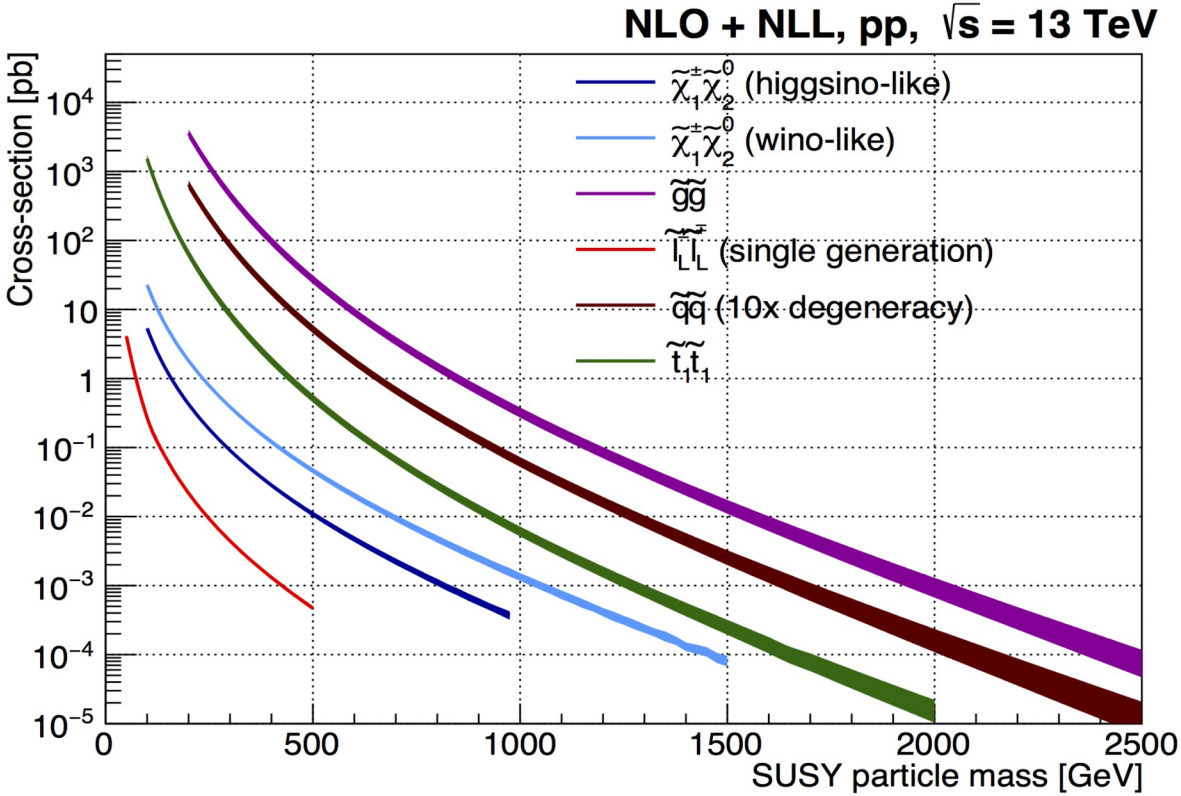
  → SUSY particles are produced in pairs

  → the lightest SUSY particle is stable (LSP)

- The LHC at 13 TeV (Run II) allows to probe for gluino masses > 1 TeV
- Main production mechanisms at the LHC:
  - **strong production** of squarks and gluinos

    → see also Karri Di Petrillo's talk
  - **3rd generation production** of light stop and sbottom squarks
  - **electroweak production** of gauginos (direct production of charginos and neutralinos)

    → see Sarah Wiliam's talk



Strong SUSY searches with ATLAS

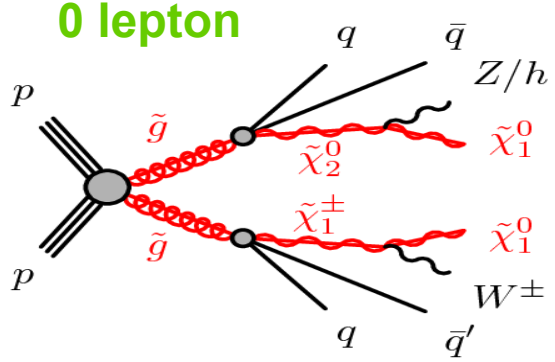
All except one analysis with a **data set of 36.1 fb^{-1} recorded at $\sqrt{s}$ = 13 TeV in 2015/2016**

- 0 lepton + **2-6 jets**: Phys. Rev. D 97 (2018) 112001 (arxiv:1712.02332)
  - targeting the likely dominant direct squark/gluino decay to the LSP
- **Multi b-jets**: ATLAS-CONF-2018-041 **NEW with 80 fb^{-1}**
  - targeting gluino-mediated stop and sbottom production with b-jets in final state
  - 36.1 fb-1 analysis: JHEP 06 (2018) 107 (arxiv:1711.01901)
- **Taus** + jets: SUSY-2016-30 **NEW**
  - Targeting tau-rich final states
- **2 leptons** + jets (*Z+MET/'Edge Analysis'*): arxiv:1805.11381 **NEW**
  - targeting decays via the next-to-lightest neutralino and a *Z*

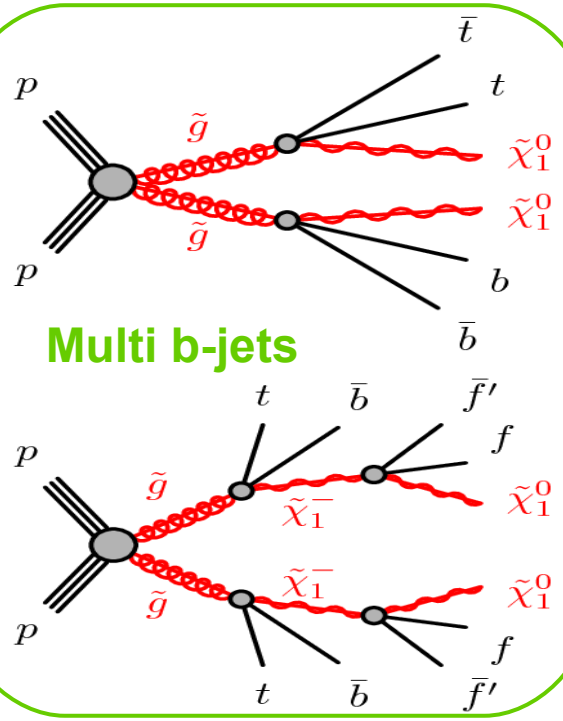
Simplified models

- Optimization of analysis strategy and interpretation of results with **simplified models:**
  - masses of non-relevant SUSY particles at arbitrarily high values
  - BR to final state set to 100%
  - employing more multi-decay models + variable BRs

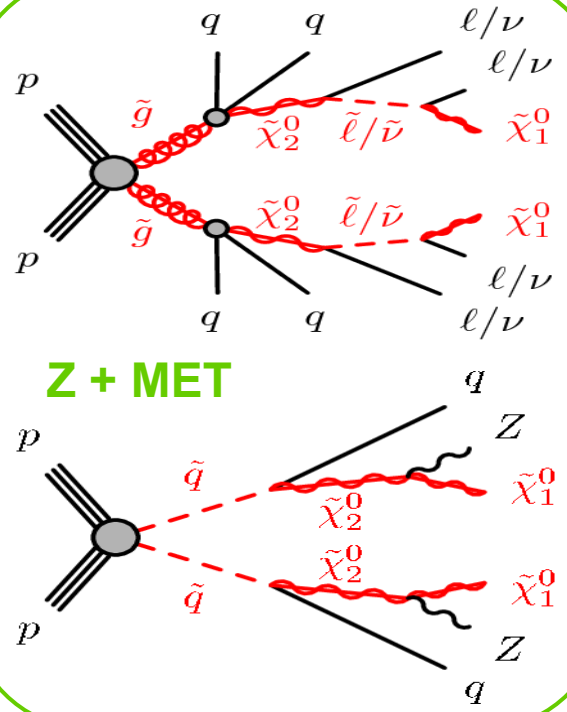
0 lepton



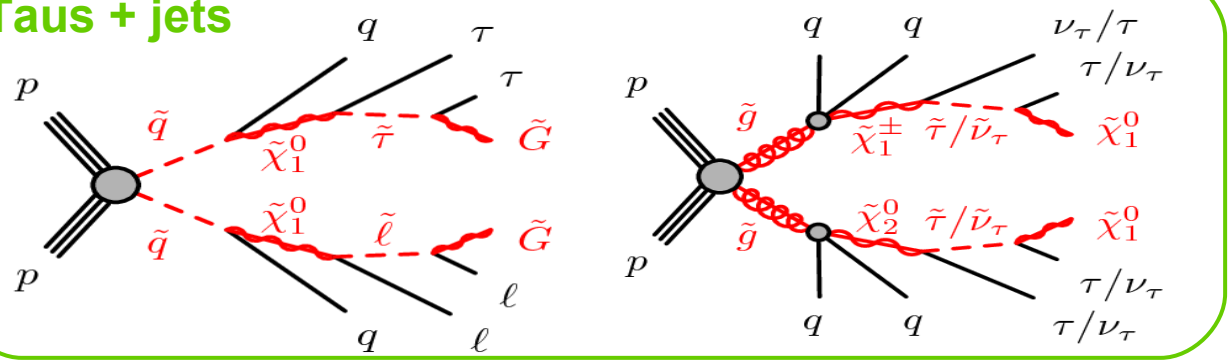
Multi b-jets



Z + MET



Taus + jets



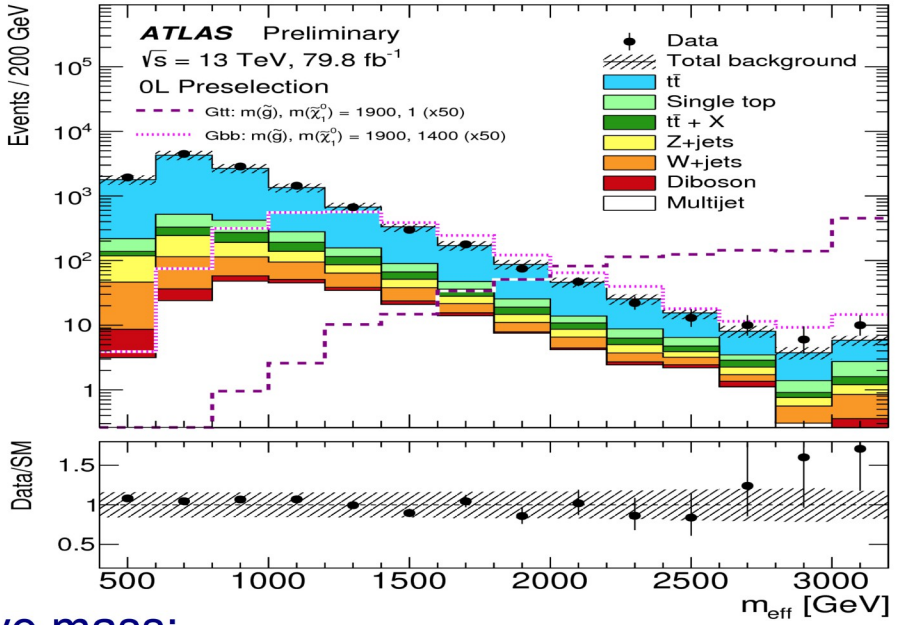
Signal characteristics

- final state characterised by

  → **high p_T jets**

  → the LSP is neutral and escapes the detector,

  leading to large $\mathbf{E_T^{miss}}$



Main discriminating variables

- **2-6 jets and multi b-jets** searches use the effective mass:

$$\mathbf{m_{eff} = E_T^{miss} + \sum p_T^{jet}}$$

  - additional cut on $\Delta\Phi$(jets, E_T^{miss}) and E_T^{miss} / m_{eff} are used to reduce the multijet background
  - for the ttbar-channel in **multi b-jets** a cut on high mass large radius jets and on the m_T^{min}(b-jet,E_T^{miss}) is applied

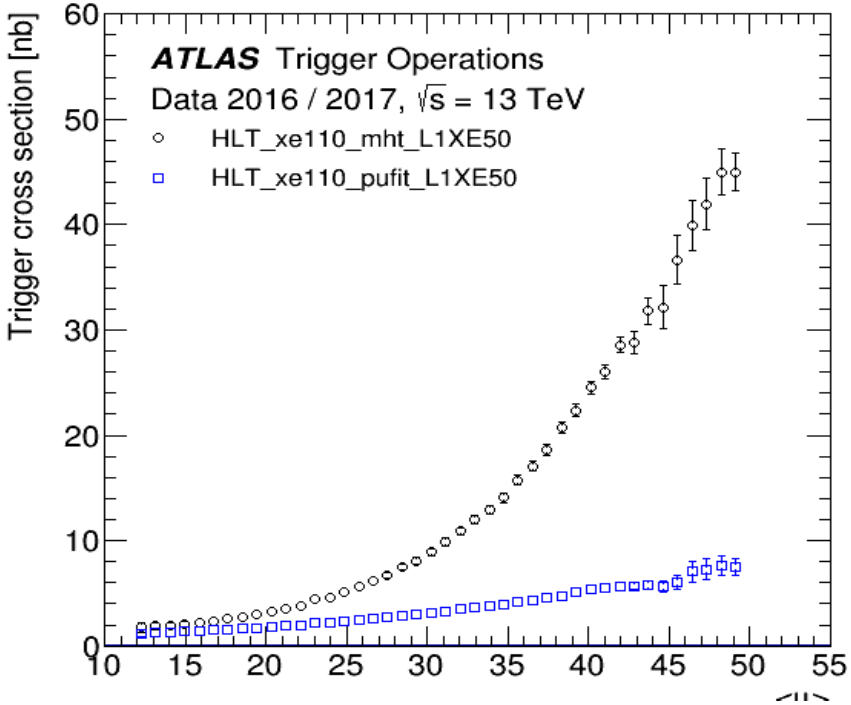
- Others use transverse visible energy $\mathbf{H_T}$, transverse mass $\mathbf{m_T}$, etc.

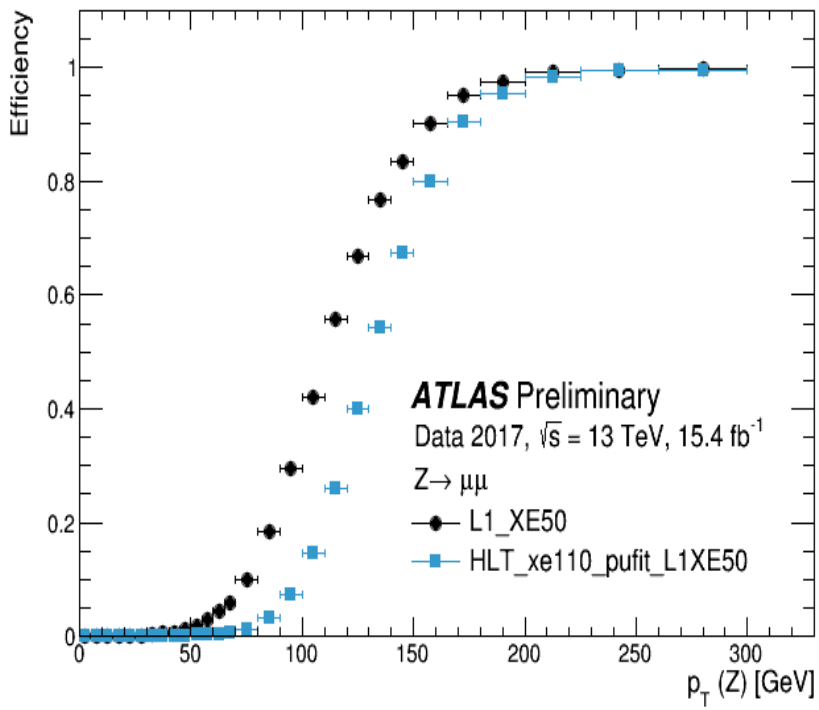
Signal selection

- Characteristic high MET also provides trigger strategy for many SUSY analyses
- MET trigger 100% efficient at 200 GeV

  → lower than MET cut used by analyses
- MET trigger very sensitive to pile-up

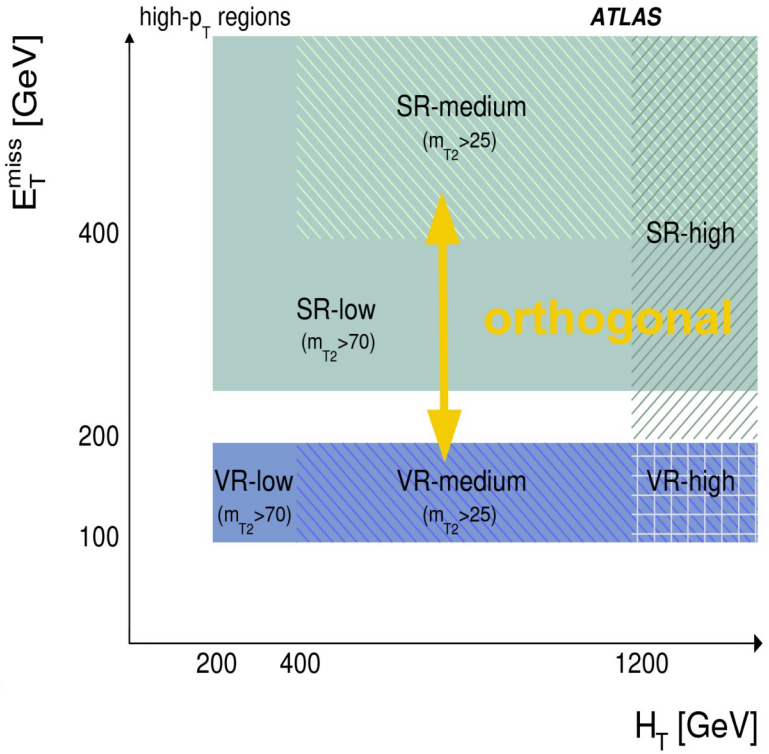
  → mitigated by new pile-up estimation techniques directly online
- Other triggers in use are lepton triggers and b-jet triggers





Analysis strategy

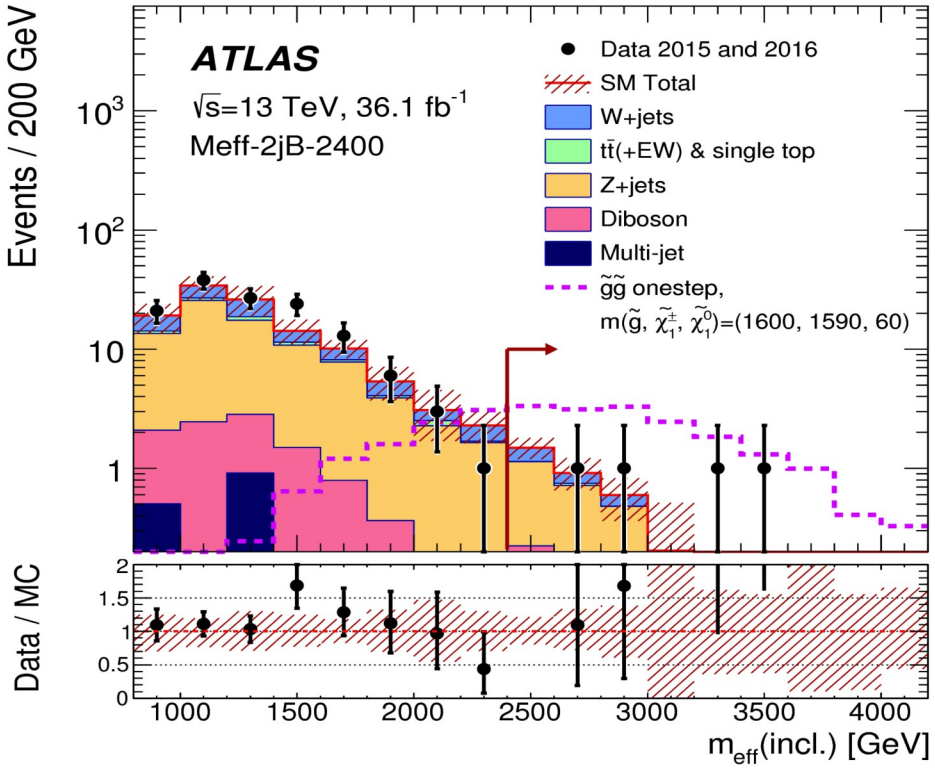
- **Signal region selections** are optimised based on MC samples
- Data in signal regions is blinded until analysis finalized
- MC simulation used to determine acceptance and efficiency of SUSY signal
- Three types of **background estimation**:
  - Simulation normalized to data in control regions orthogonal to the signal regions (e.g. W, Z, ttbar)
  - Data driven techniques like jet smearing (e.g. QCD)
  - Completely relying on MC (rare backgrounds like WW ZZ)
- Background estimation is **checked in validation regions** before unblinding
- After unblinding interpretation of results in selected signal models

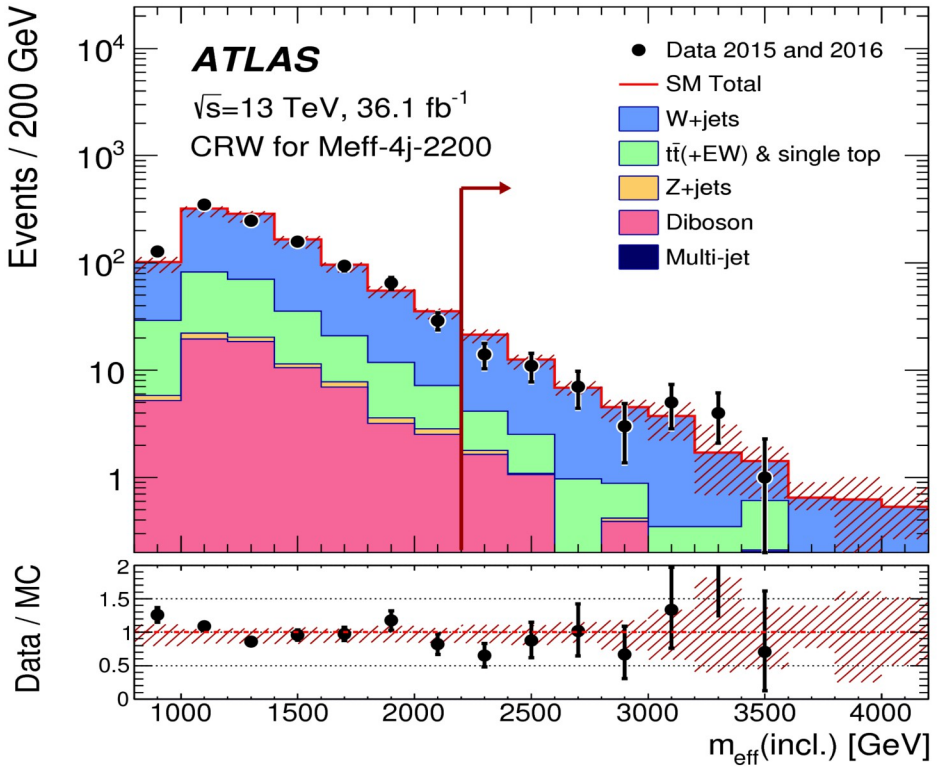


0 lepton + 2-6 jets

- targeting final states with 2-6 jets and large E_T^{miss} from direct and one-step decays of squark and gluino pairs (cut and count and recursive jigsaw reconstruction (RJR) approaches)
- 24 SRs ordered by increasing number of jets, characterised m_{eff} requirements

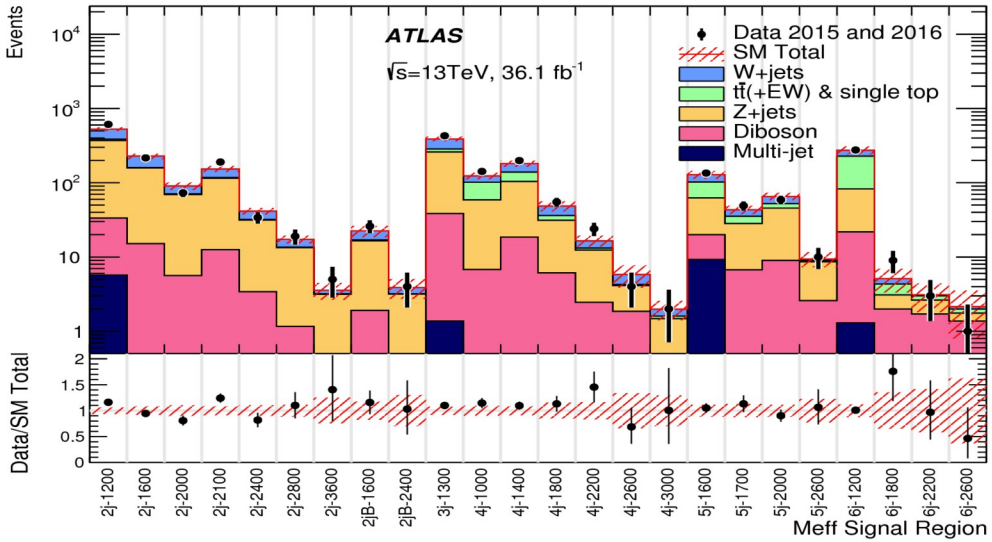
  → includes two new SRs targeting final states with boosted W/Z
- main background W/Z+jets and ttbar estimated via CRs for each SRs

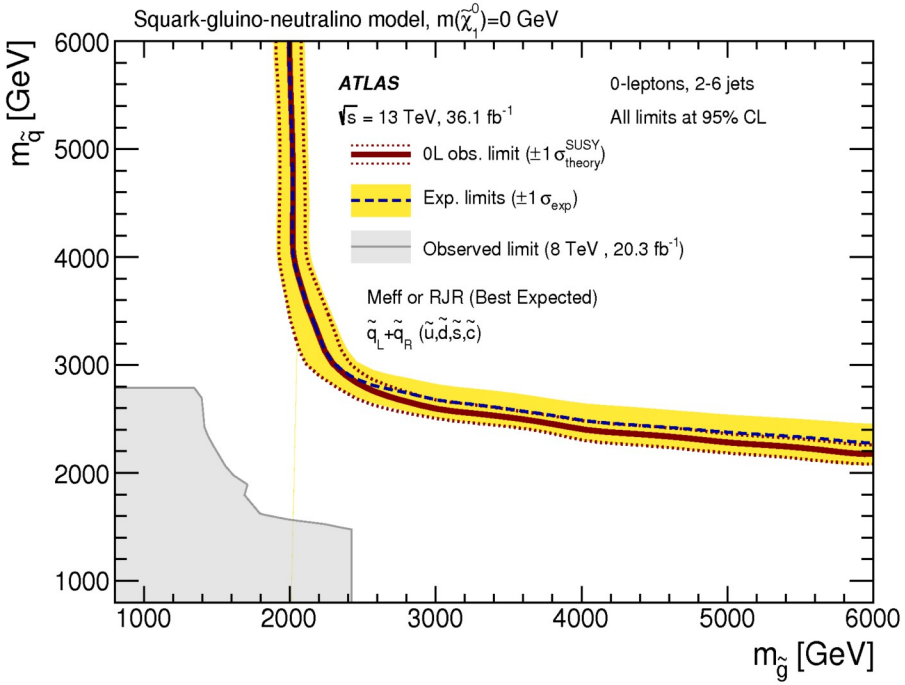


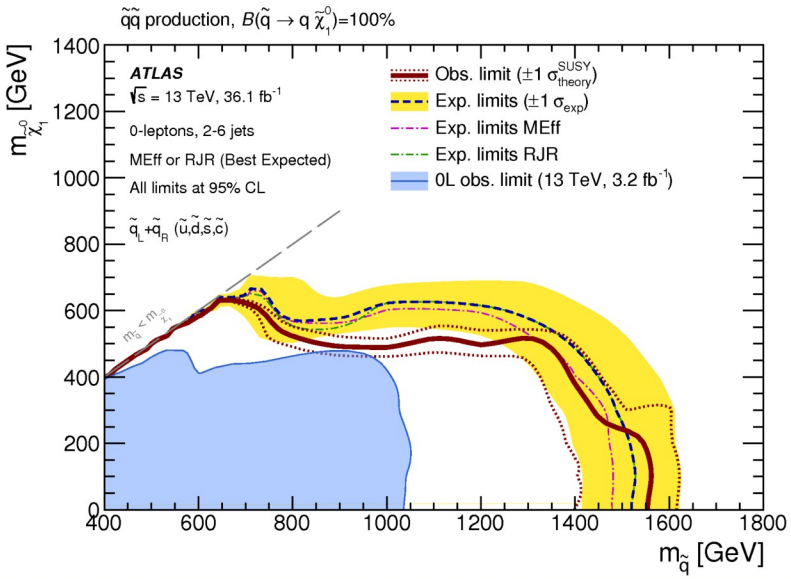


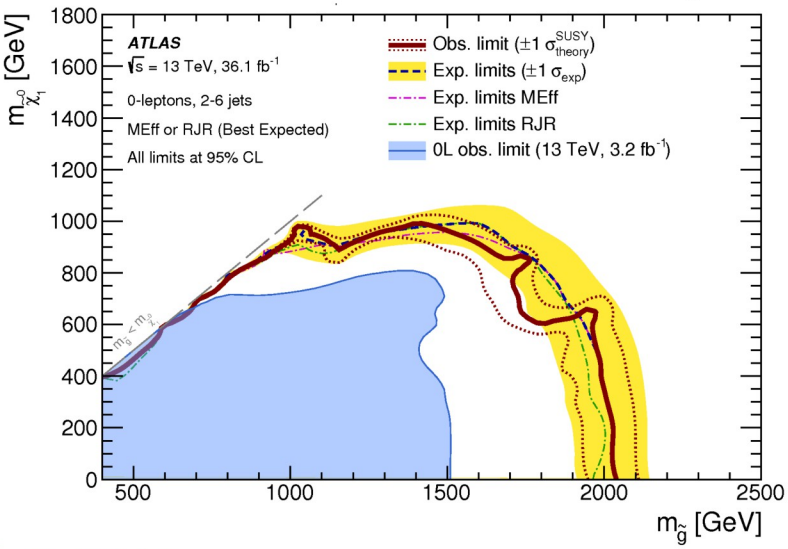
0 lepton + 2-6 jets

- Cut and count combined with RJR for model-dependent limits
  - best signal region chosen for each grid point







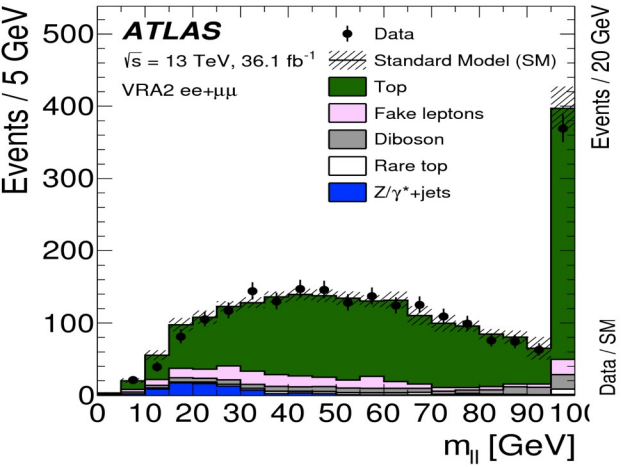


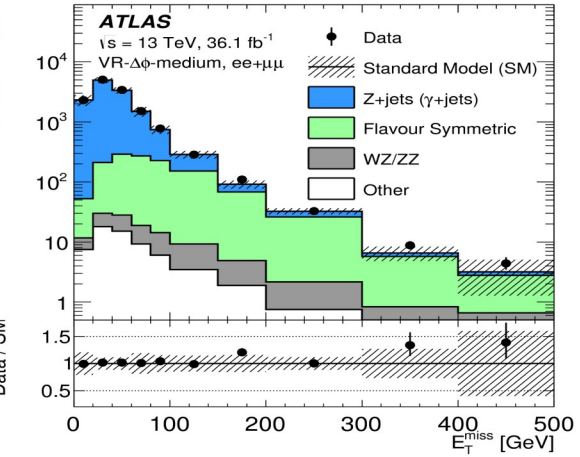
Di-lepton (Z+MET / Edge)

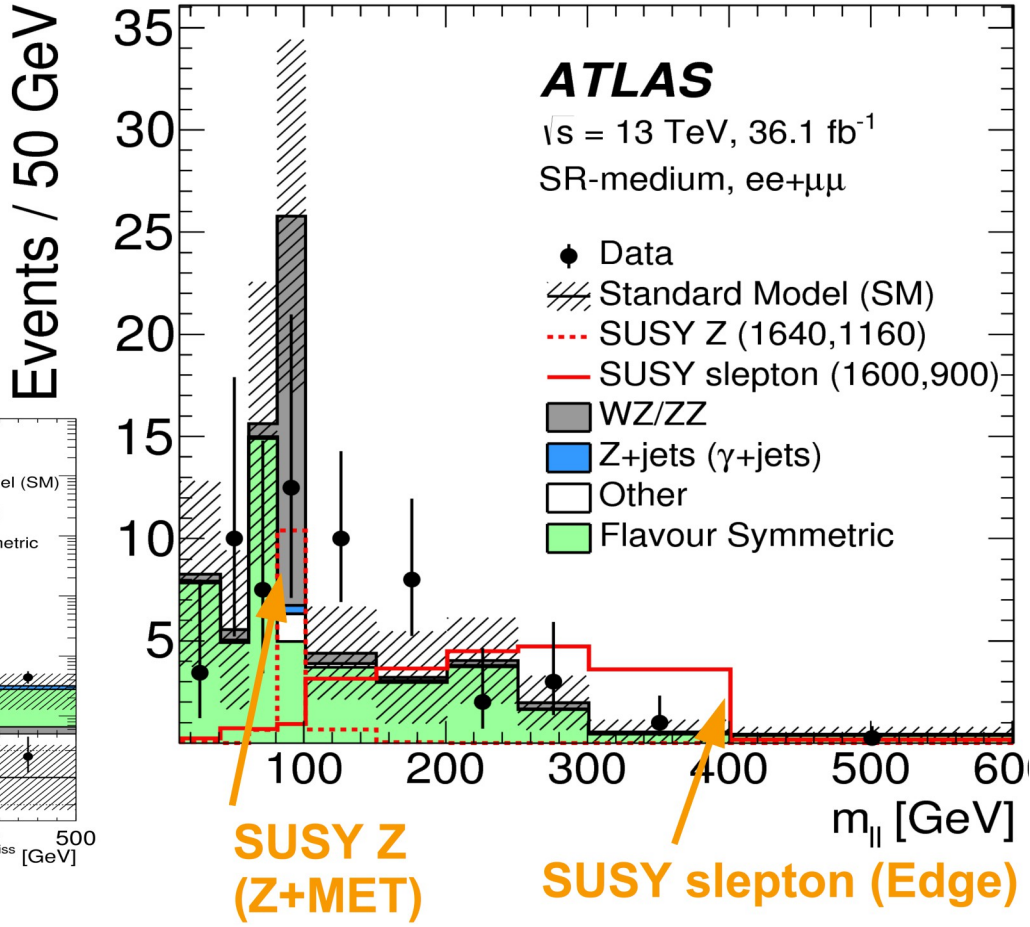
- Final state with two OSSF leptons, after Run I excess follow up now optimised for 13 TeV
  - signal regions with low p_T lepton targeting compressed neutralino spectra
  - signal regions with high p_T lepton targeting kinematic edge near Z-peak
- Main backgrounds ttbar, W/Z + jets and dibosons

→ high p_T estimated via γ+jets + flav. Sym.

→ low p_T with different flavour CR, matrix method for fake est.

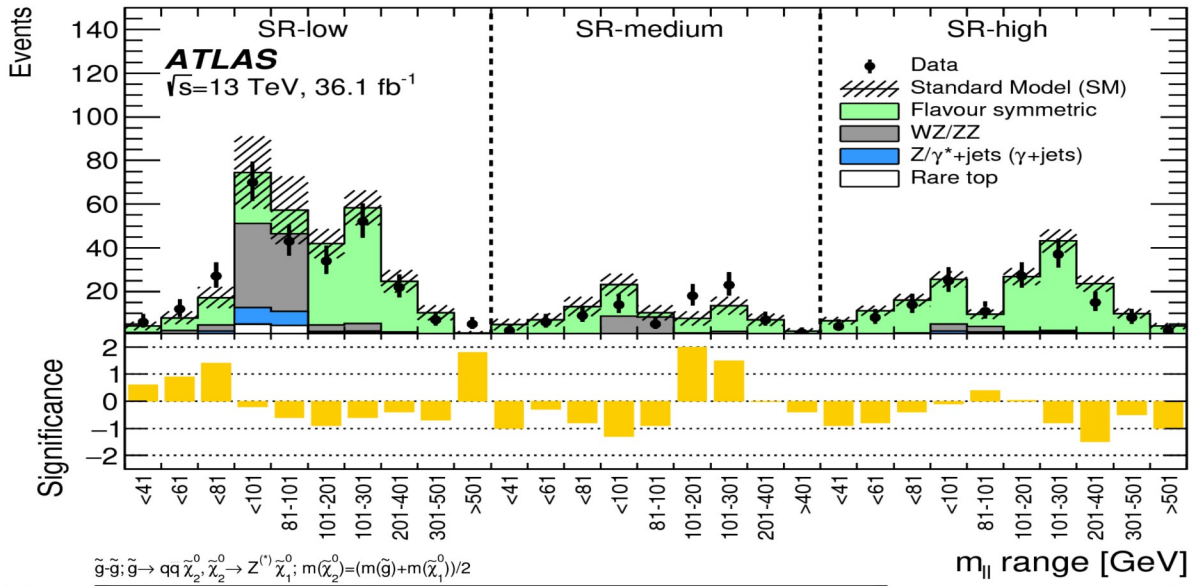


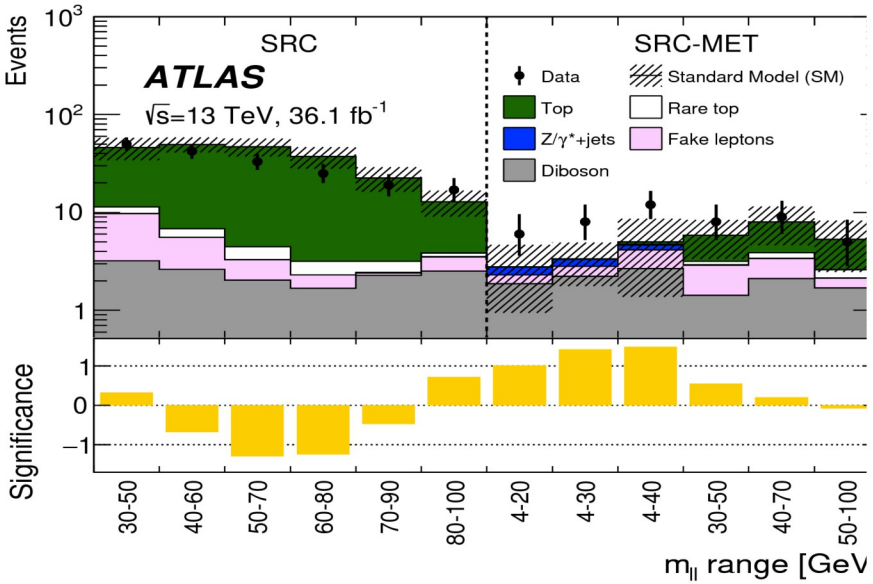


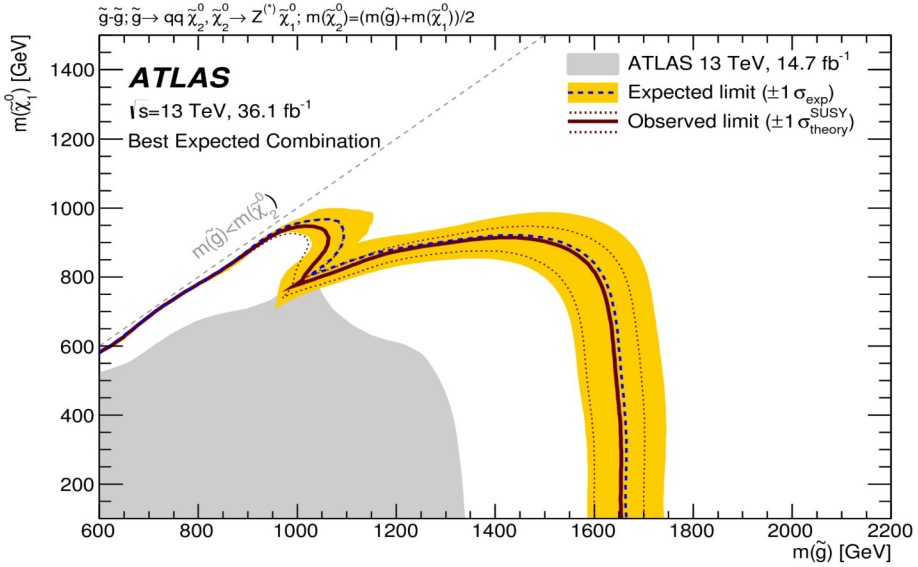


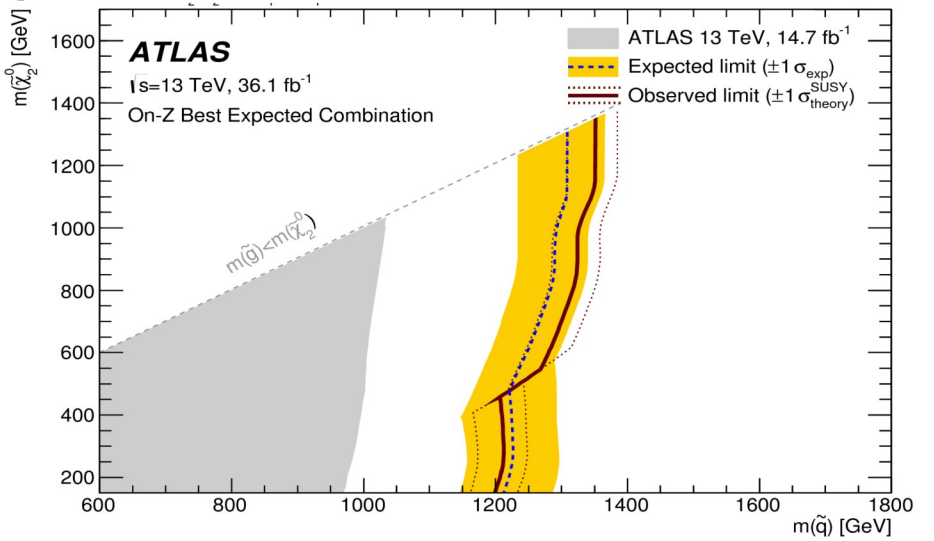
Di-lepton (Z+MET / Edge)

- New shape fit
- No excess found – greatly improved sensitivity









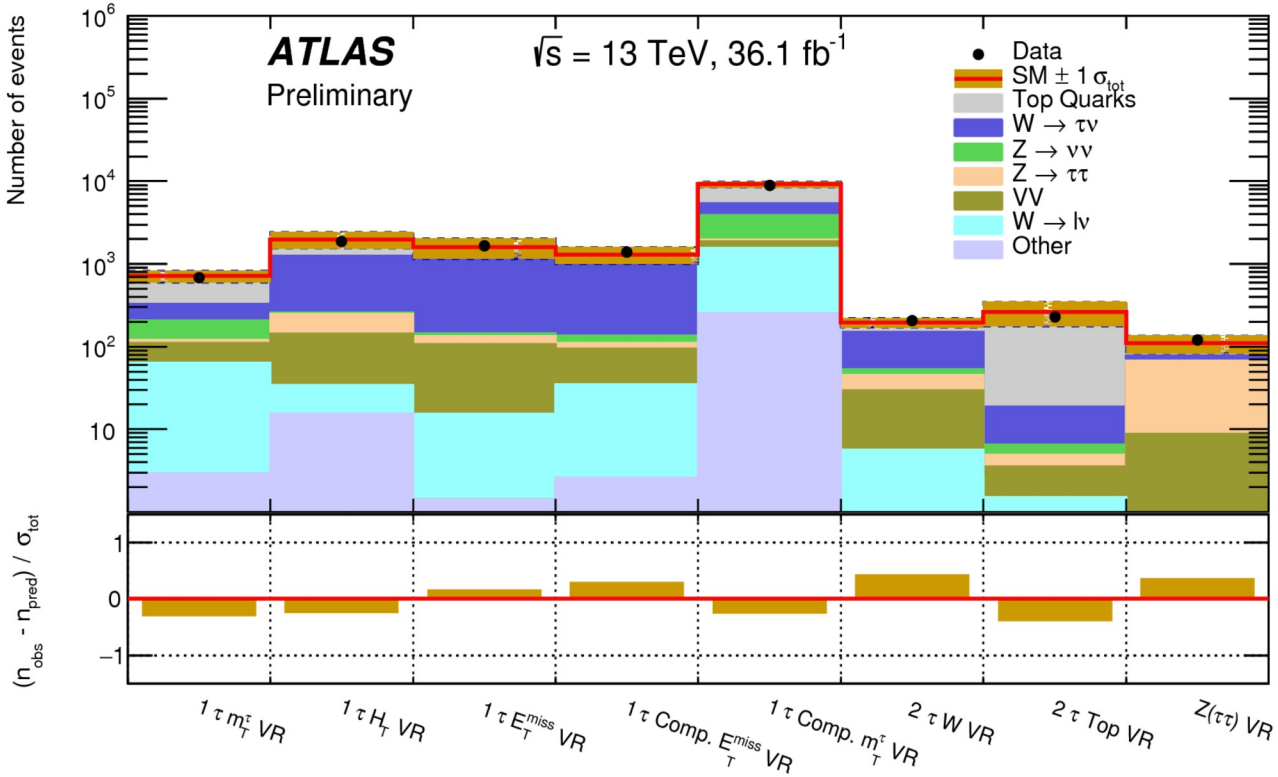
Taus + jets

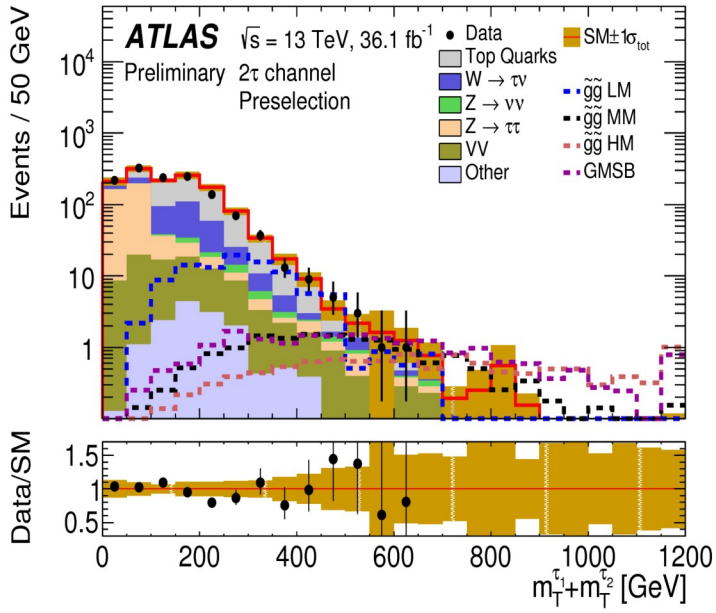
- 2 signal regions targeting final state with one tau, 3 signal regions for di-tau channel

  → including multi-bin and gauge-mediated SUSY breaking channel

  → characterized by H_T cut and tau p_T and m_T requirement

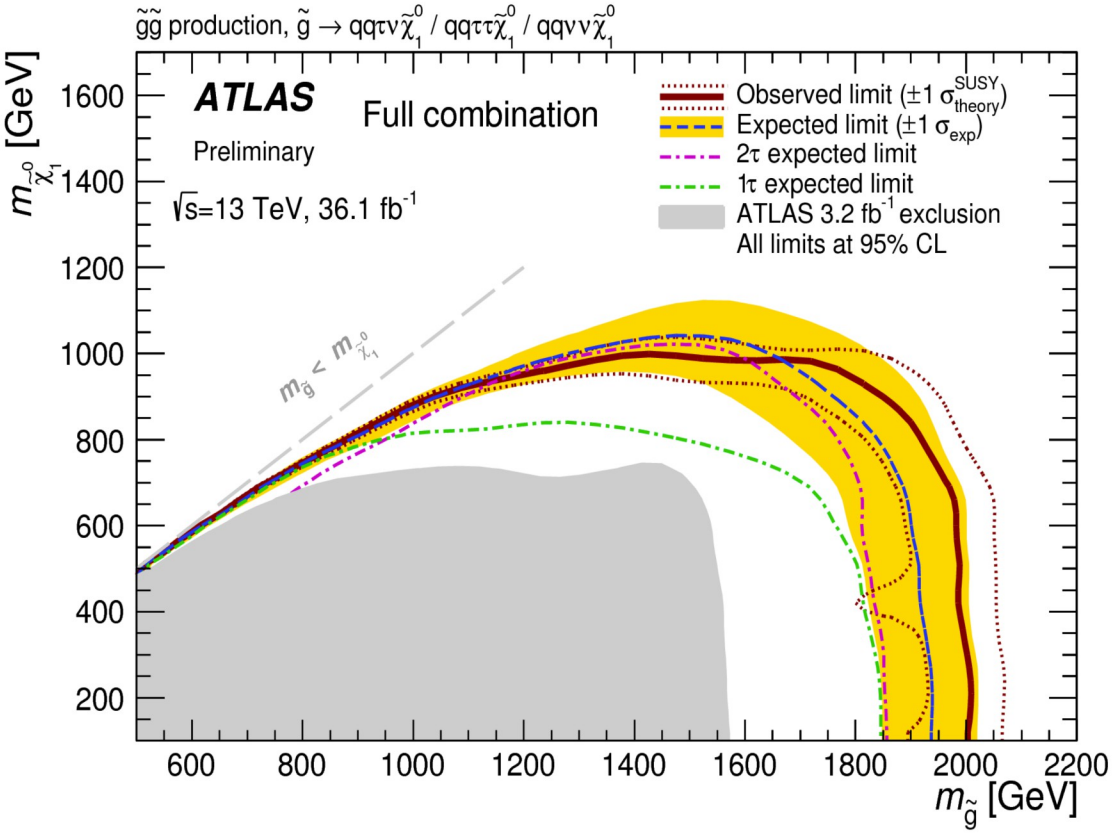
- ttbar, W/Z+jets background estimated via CR, jet smearing technique for QCD background

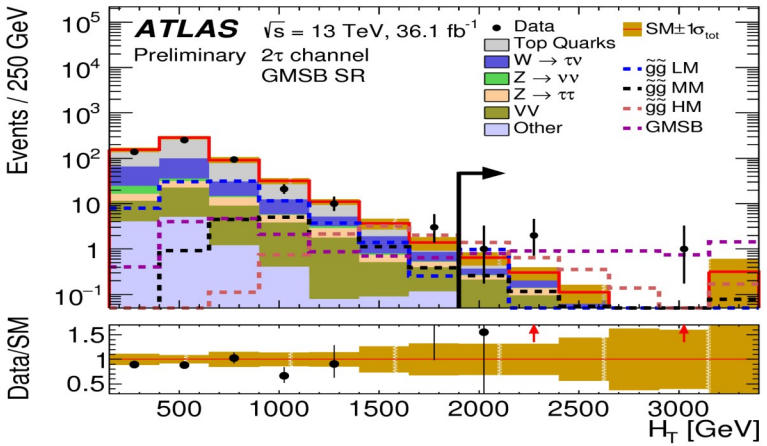


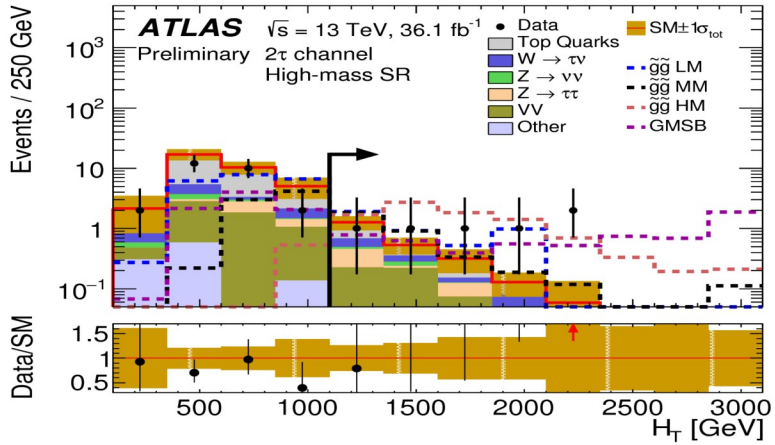


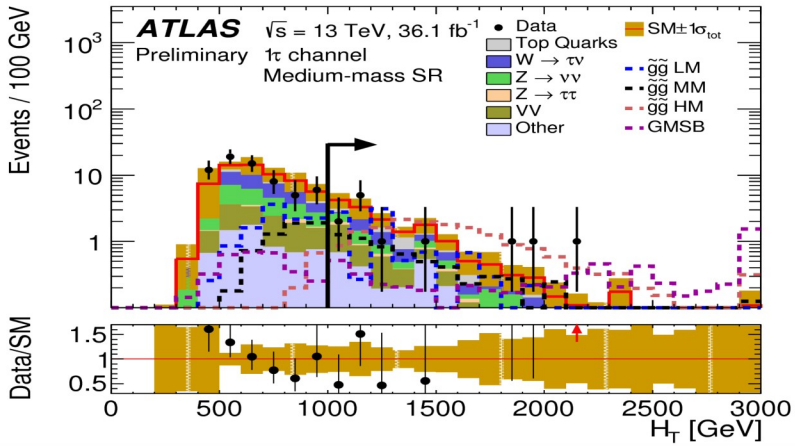
Taus + jets

- Small excesses in 3 SRs, consistent with Standard Model
- Combination of SRs for model dependent limit





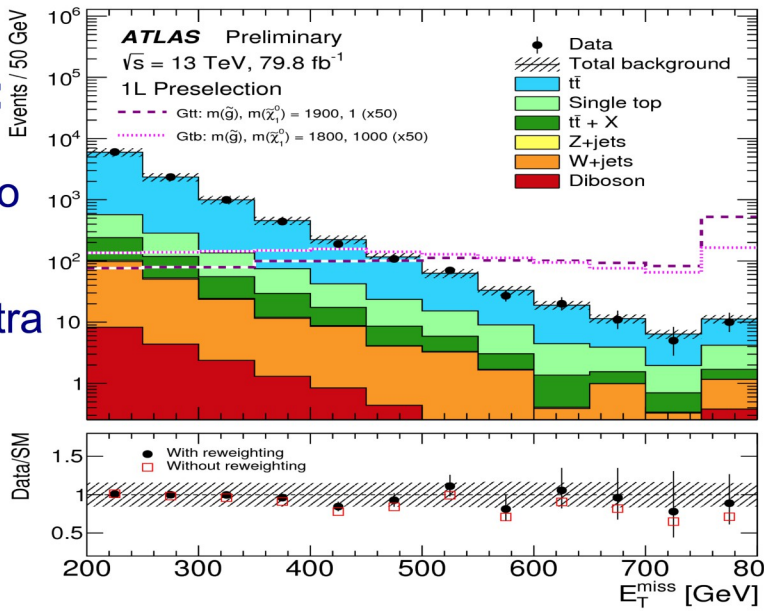




Multi b-jets

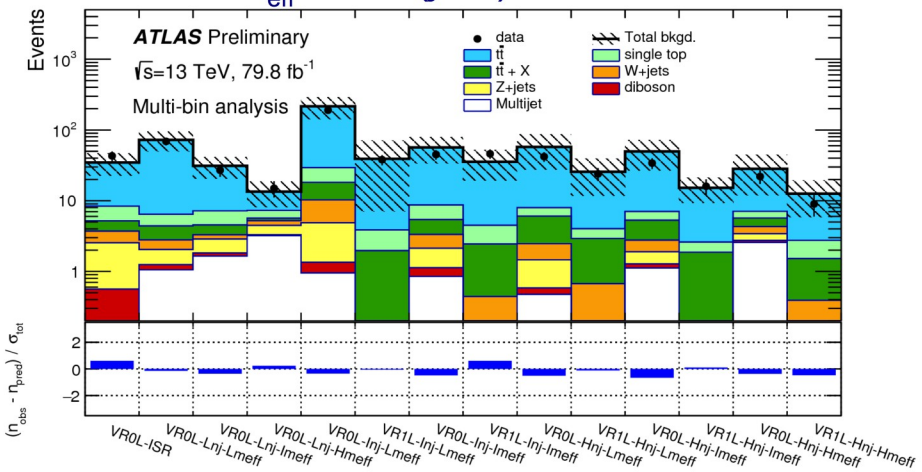
Cut and count approach:

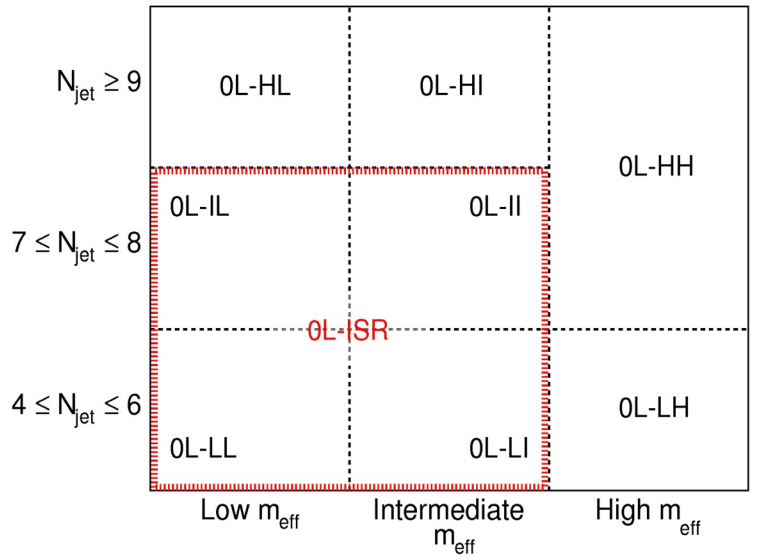
- 10 signal regions with cuts on E_T^{miss} and m_{eff} and **≥ 3 b-jets:**
  - for sbottom: 0 leptons + ≥ 4 jets, 4 scenarios from large Δm to compressed spectra
  - for stop: 1 or 0 lepton + ≥ 5/6/7/8 jets for different mass spectra
- Main background ttbar estimated via CRs for each SR



Multi-bin approach:

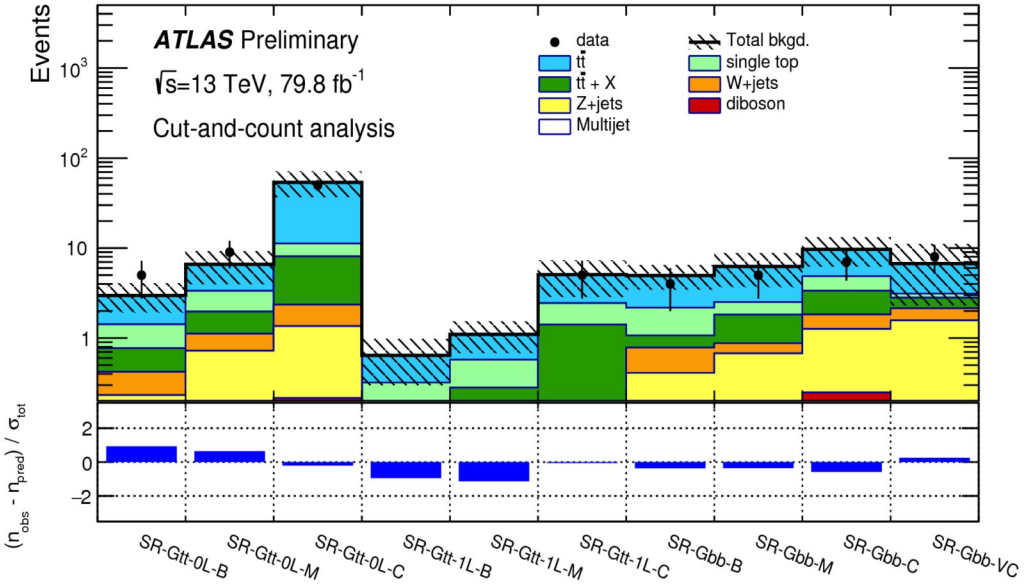
- combination of 0 and 1 lepton regions
- binned in m_{eff} and N(jets)

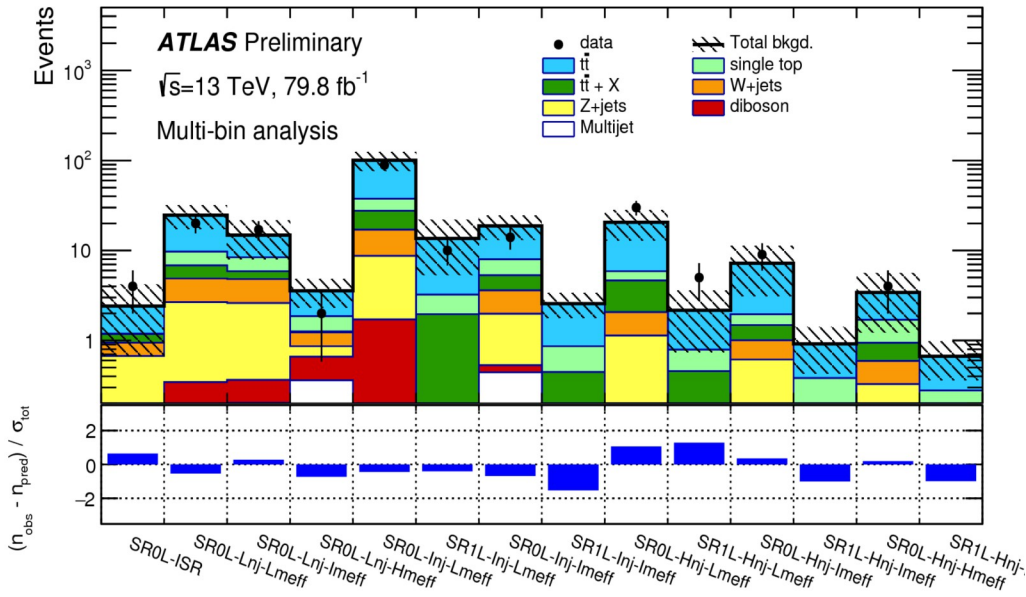


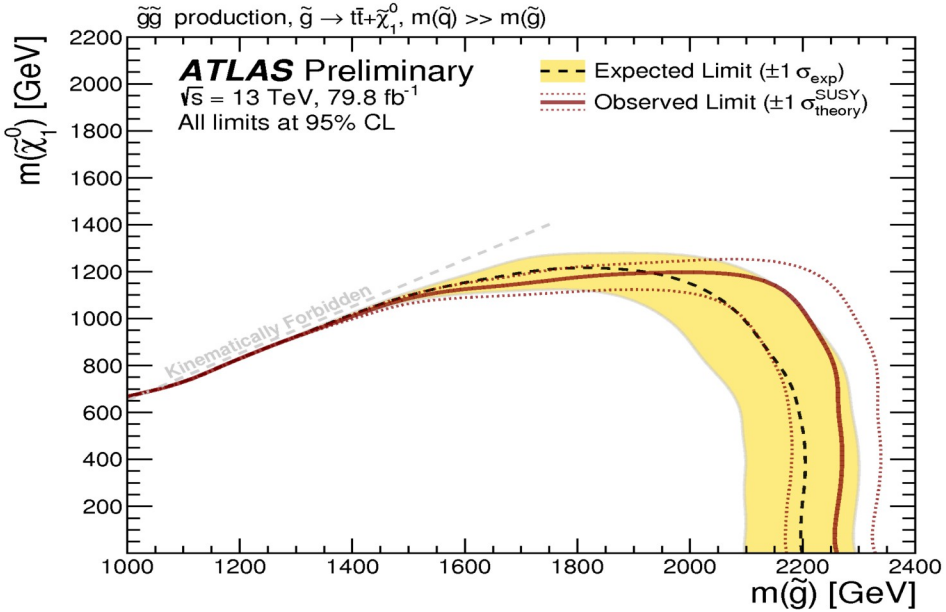


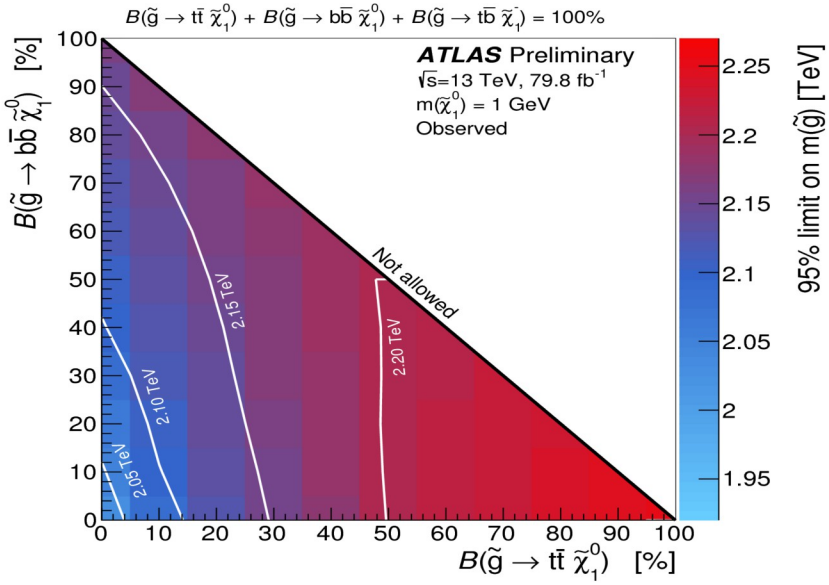
Multi b-jets

- observes good agreement with the Standard Model









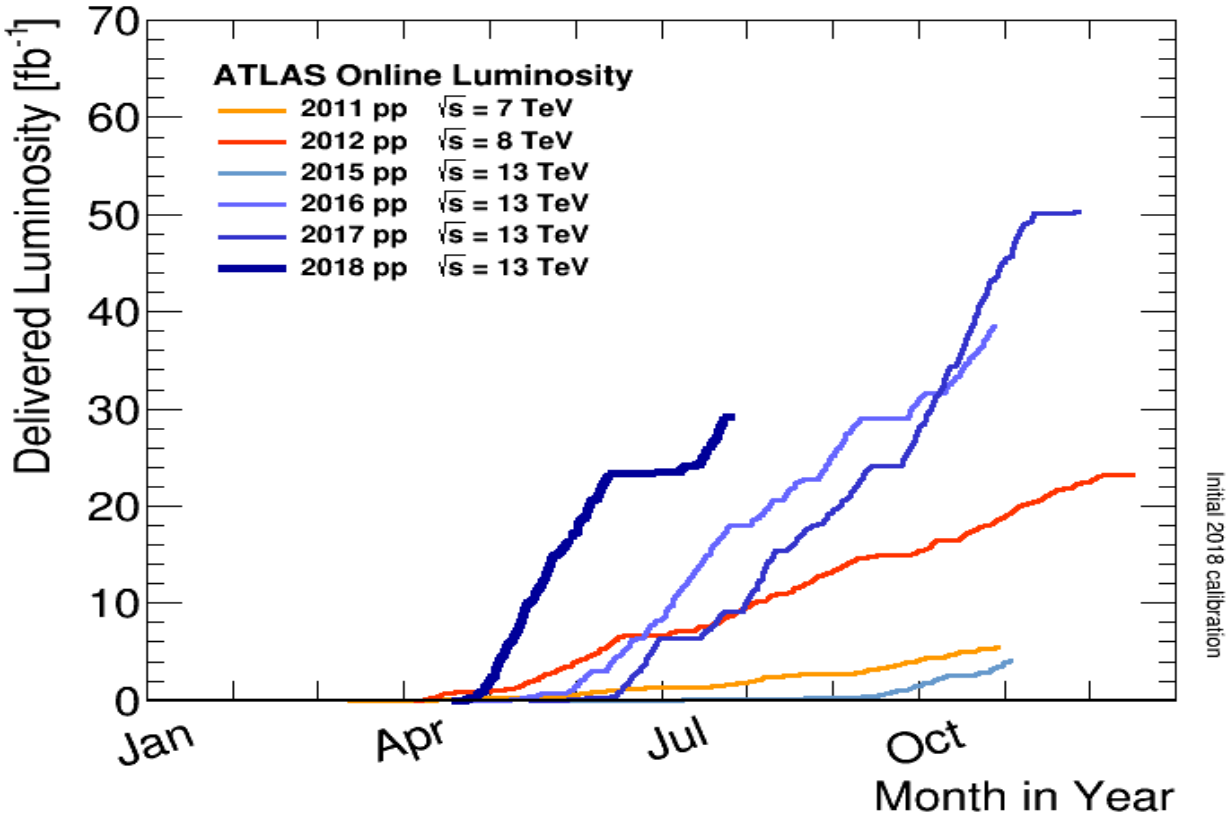
Conclusion

- So far no SUSY discovered in 36.1 fb^{-1} of data from 2015/2016
- Expect around 150 fb^{-1} at end of 2018

→ sensitivity to rarer processes

→ more analyses targeting unconventional and complex signatures

→ focus on maintaining sensitivity with challenging LHC conditions



Stay tuned – many upcoming results with whole Run II data set!