Search for SUSY strong production at ATLAS at HL-LHC

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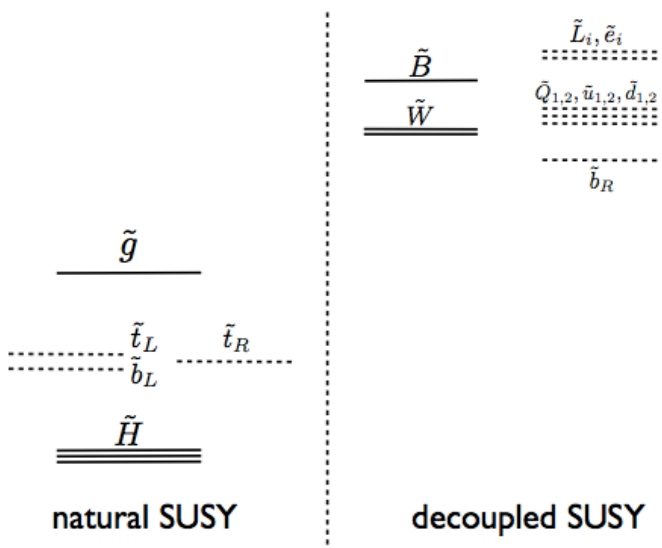
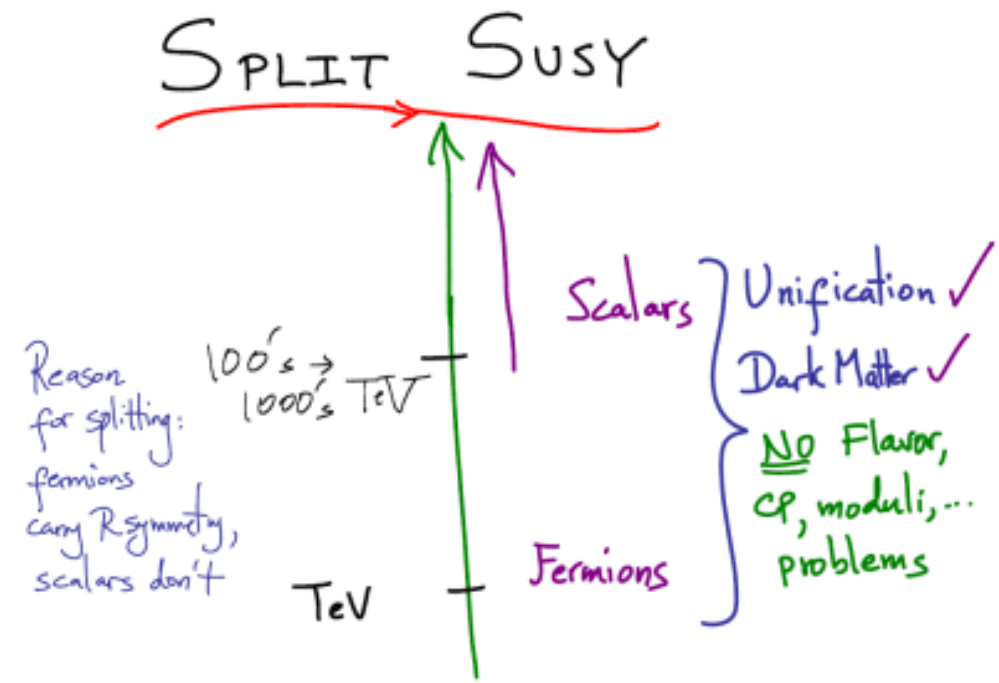
On behalf of the ATLAS Collaboration

Strong production

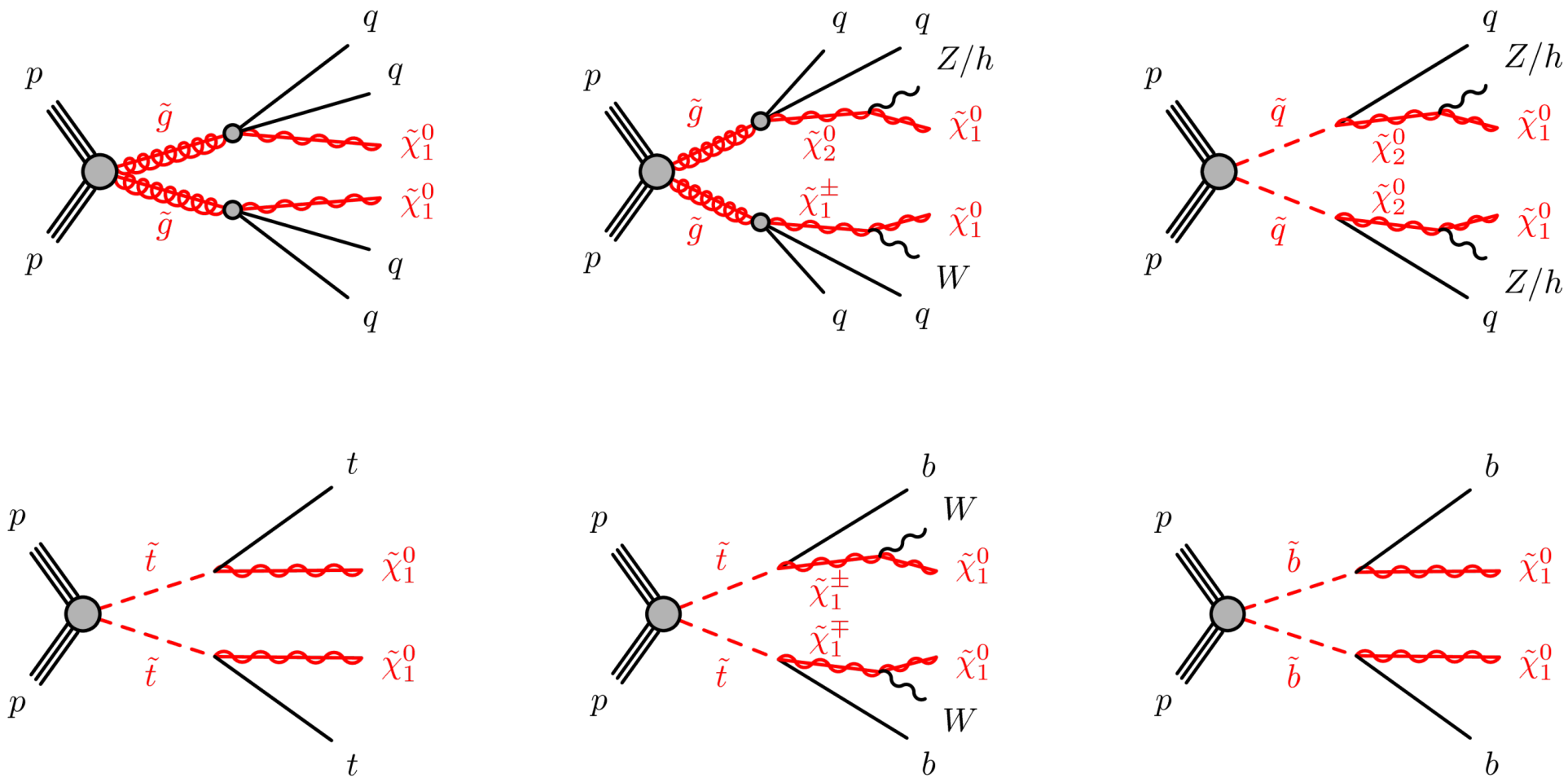
- Generic pre-LHC expectation for sparticles at the TeV scale
  - Refined into expectation of a subset of sparticles with mass at the TeV scale
- Relatively light gluinos expected also in non-natural SUSY models





Strong production

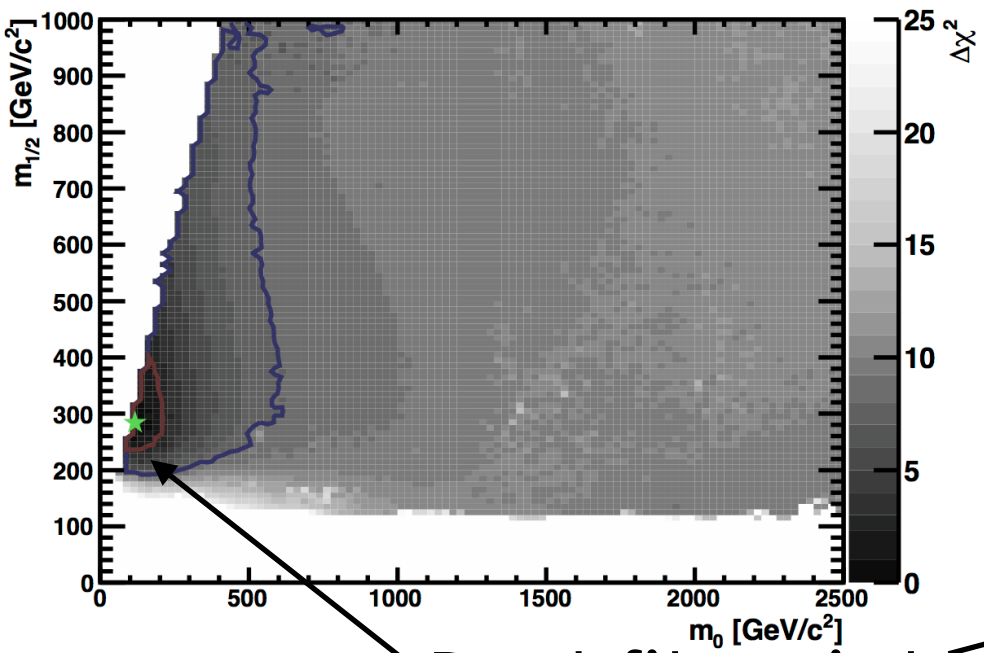
- Some examples



Supersymmetry and the LHC

- LHC has **dramatically** changed the perception that high energy physicists have of **weak scale supersymmetry**

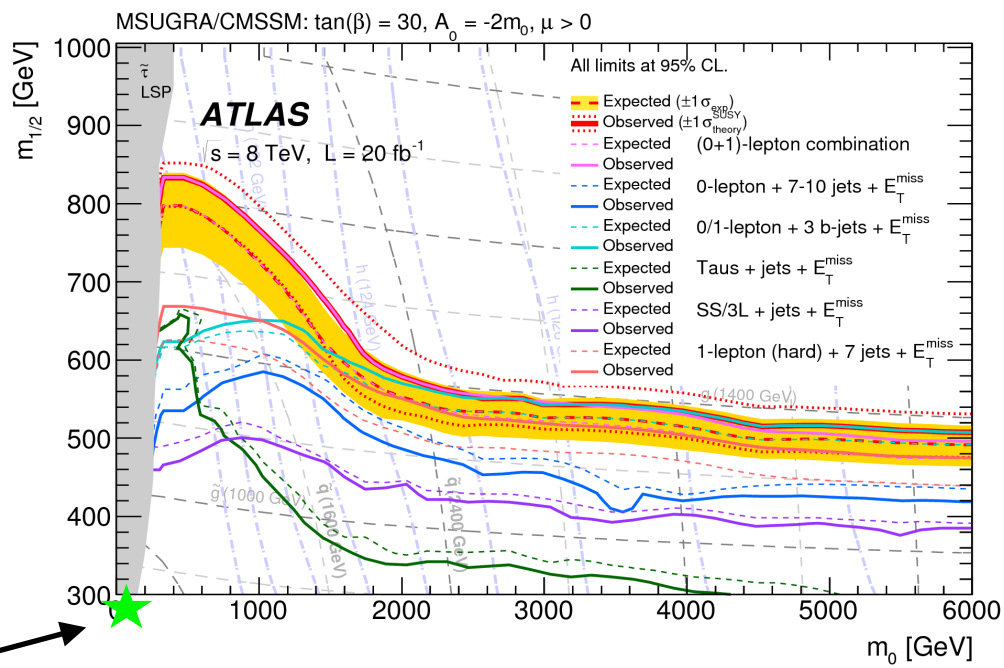
Pre-LHC



arXiv:1011.6118

Best fit point

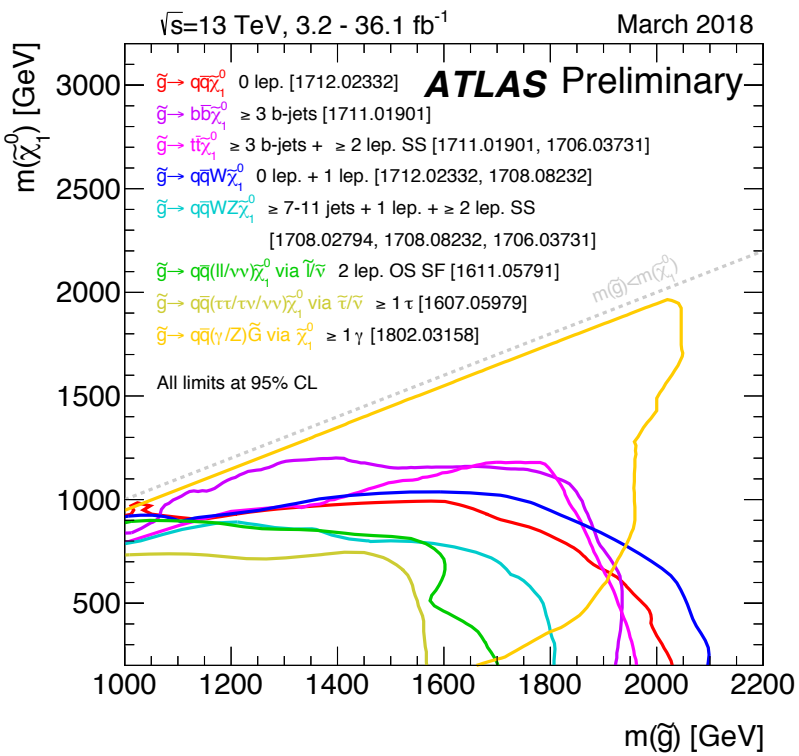
Exclusion limits in 2012



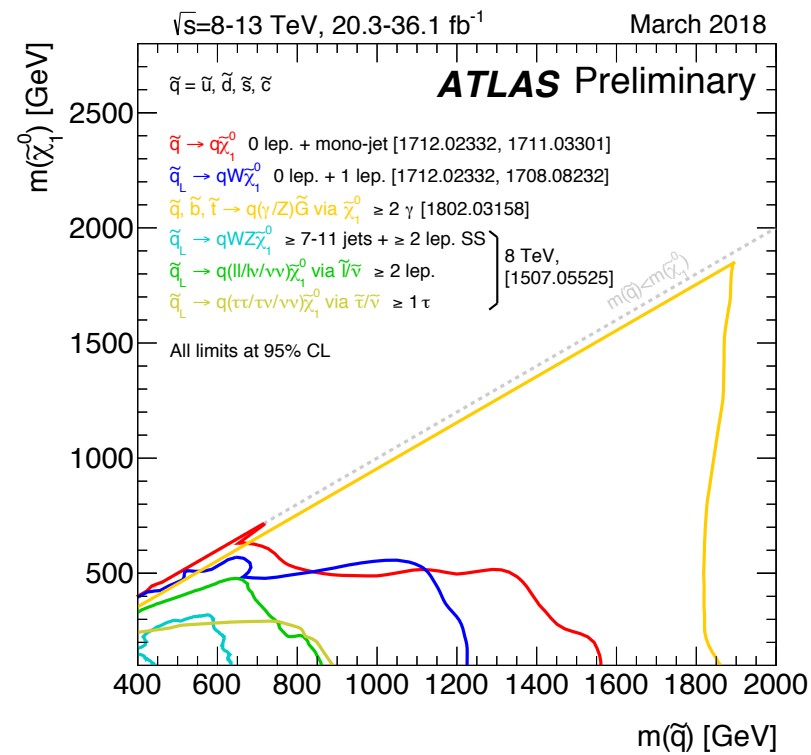
Recent results

- Simplified models recent limits exploiting the 2015-2016 Run 2 dataset
- 1.5-2 TeV exclusion for gluinos at low LSP mass, up to 1.5 TeV for squarks (8-fold degeneracy)

gluinos

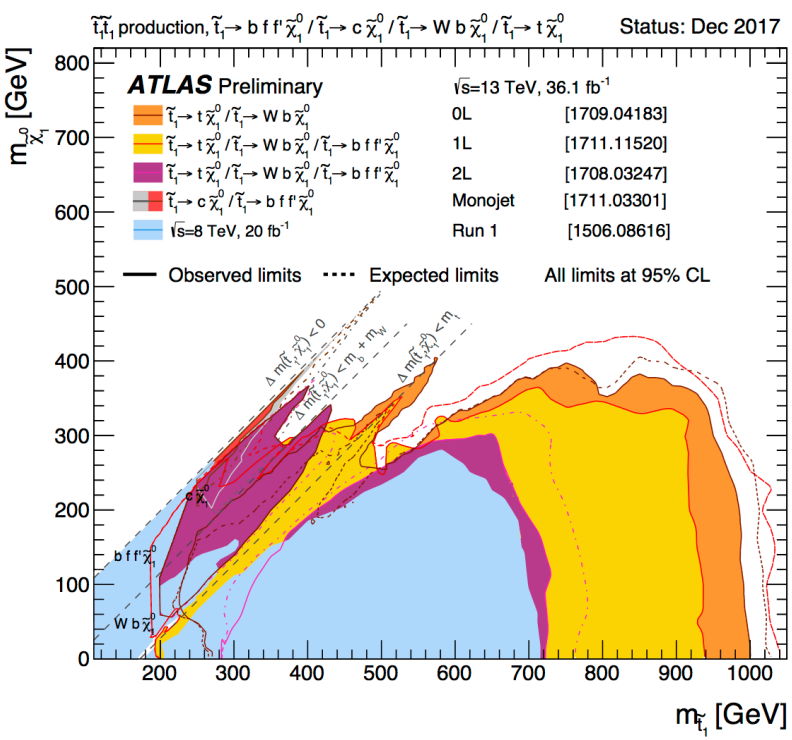


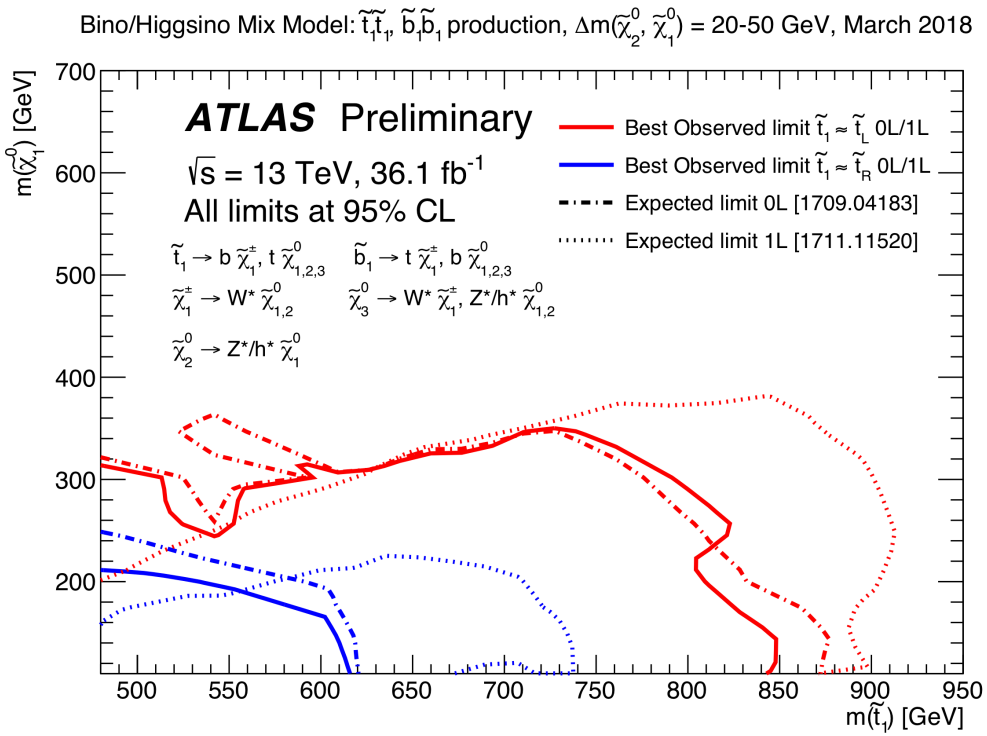
light squarks



Recent results - 3rd generation

- 1 TeV stops excluded in simplified models…
- … but limits can get significantly worse in more complex scenarios ("simplified pMSSM models" studied in Run 2)





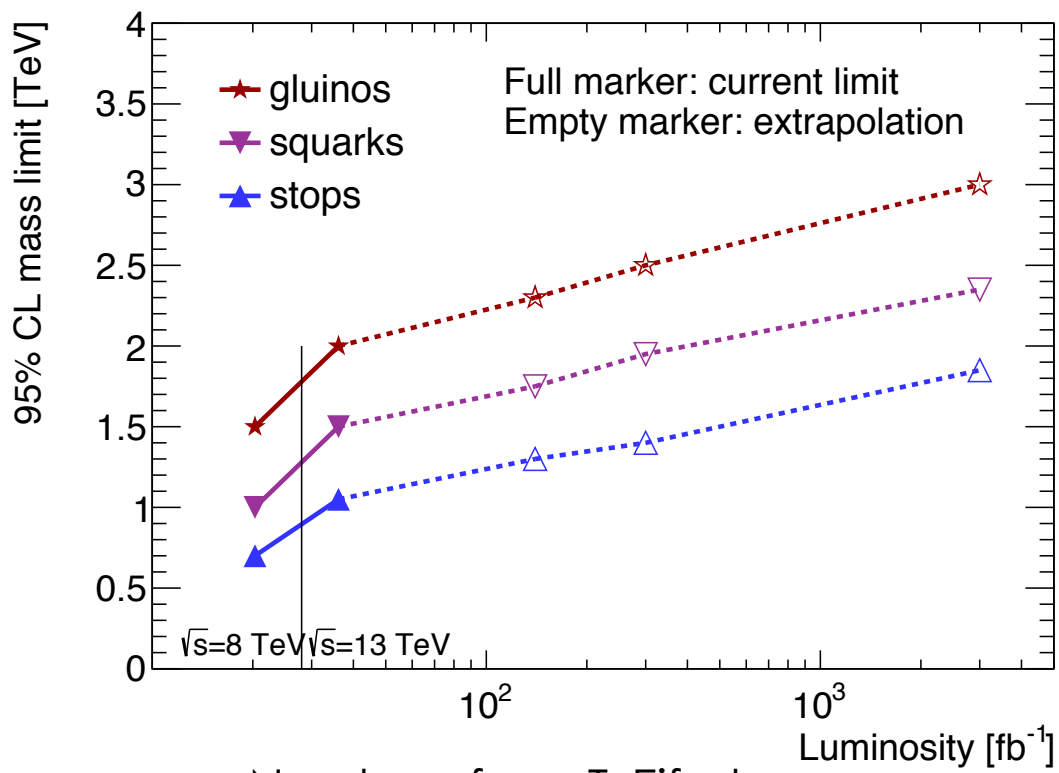
Extrapolation of current results

- Sensitivity extrapolation thumb-rule:
  - Assume upgrade analyses will have same Acc x eff at the exclusion limit
  - Assume the yield needed to exclude for L_{extrap} will be the same as for the current analysis with integrated luminosity L_0, for which we exclude a signal with cross section σ_0

- Then the excluded cross section σ_{extrap} will be

$$\sigma_{\text{extrap}} = \frac{\sigma_0 \mathcal{L}_0}{\mathcal{L}_{\text{extrap}}}$$

- Works pretty well for the simplified model limit - low LSP mass

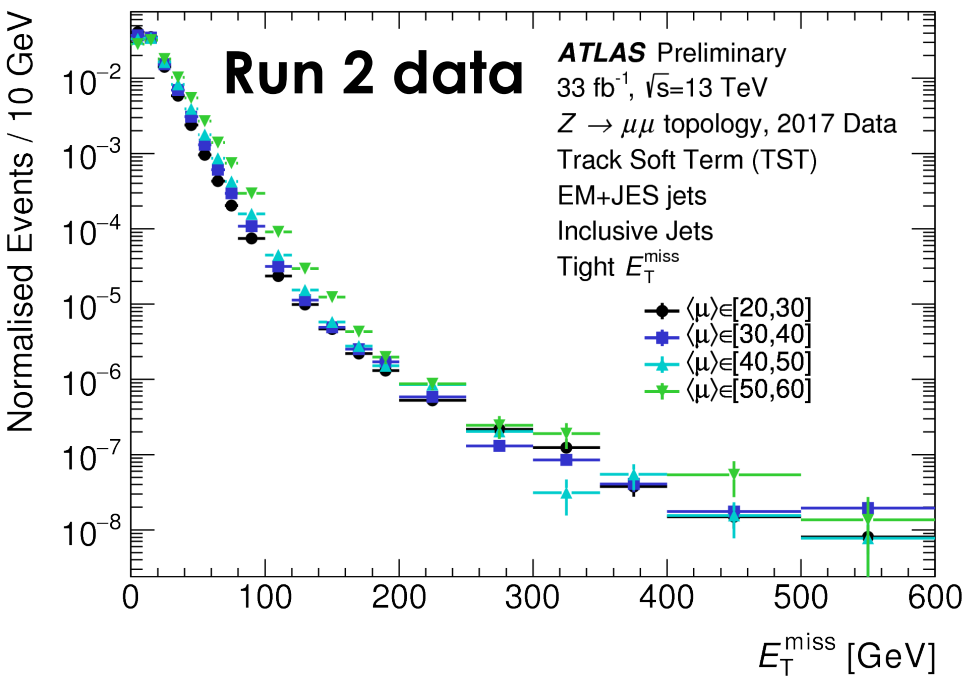


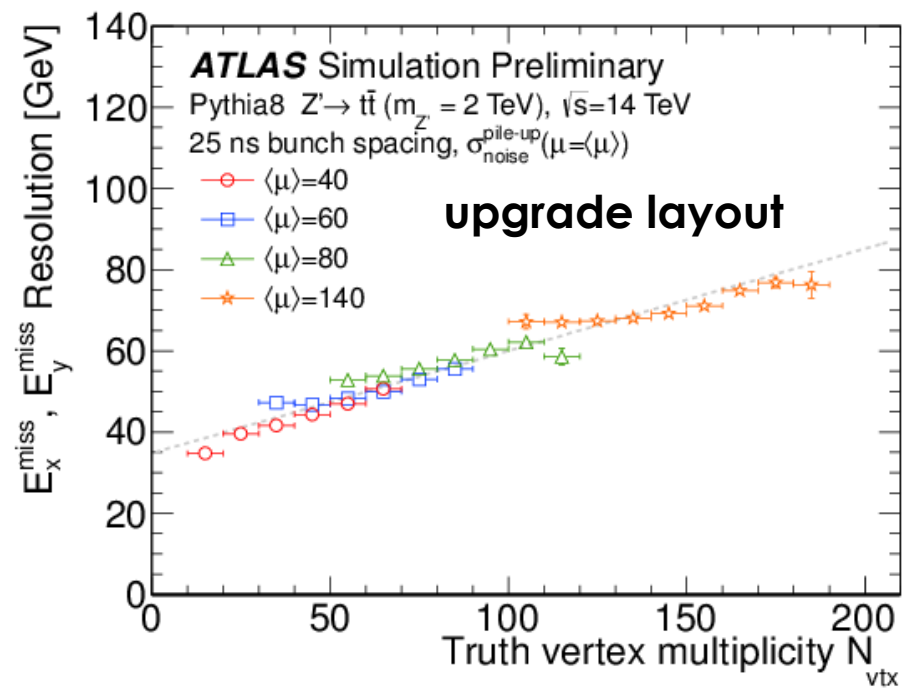
Numbers from T. Eifert

See also L. Shchutska

Improved estimates

- Actual estimates of sensitivity to SUSY go through estimating detector performance
  - Smearing functions acting on stable particles
    - Parametric response coming from full detector simulation
    - Background and signal generated at √s=14 TeV using a setup consistent with current √s=13 official simulation





Gluinos and squarks

- Analysis stemming from final √s=8 TeV analysis
- Phase space binned on N_{jet} and $M_{eff} = E_T^{miss} + \sum p_T^{jet}$
- Final M_{eff} selection optimised depending on the luminosity

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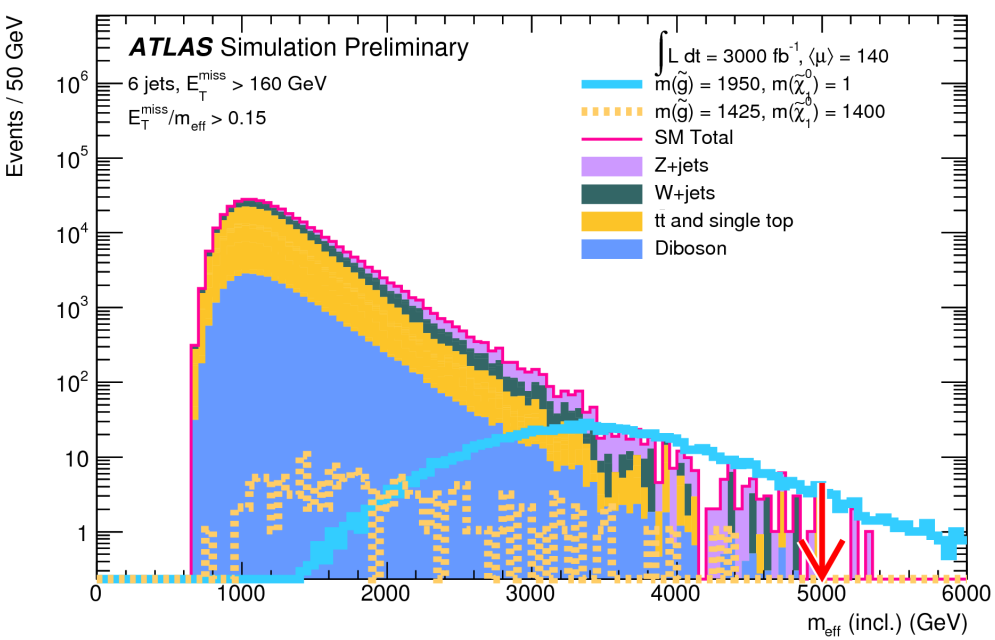
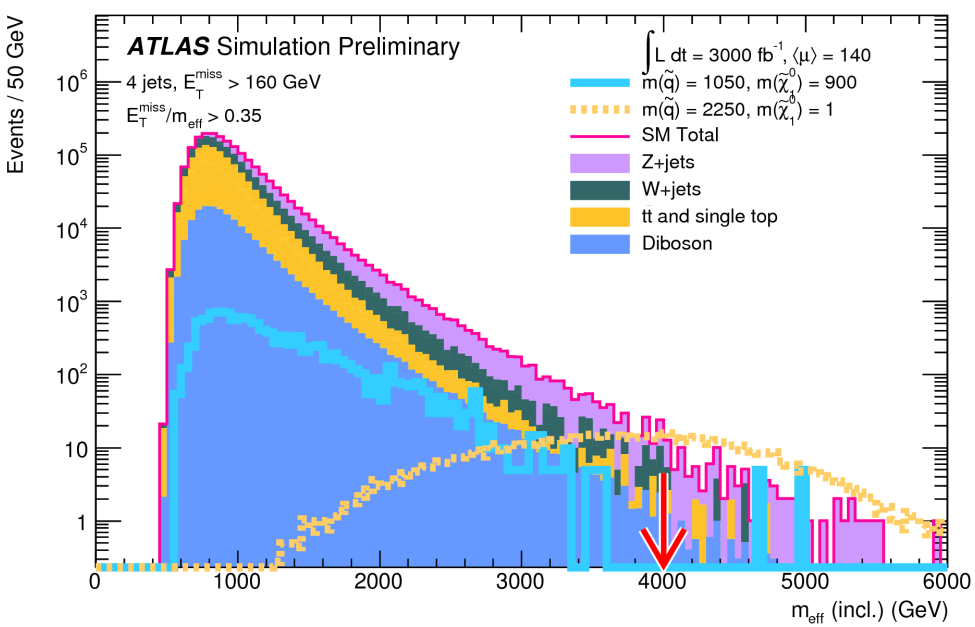
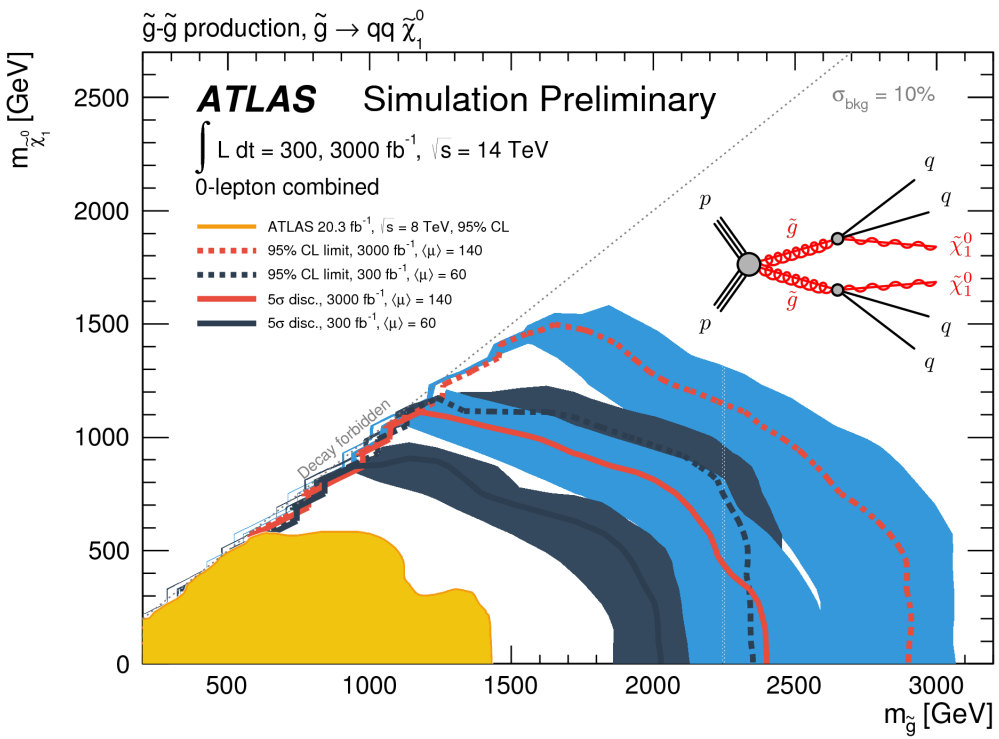
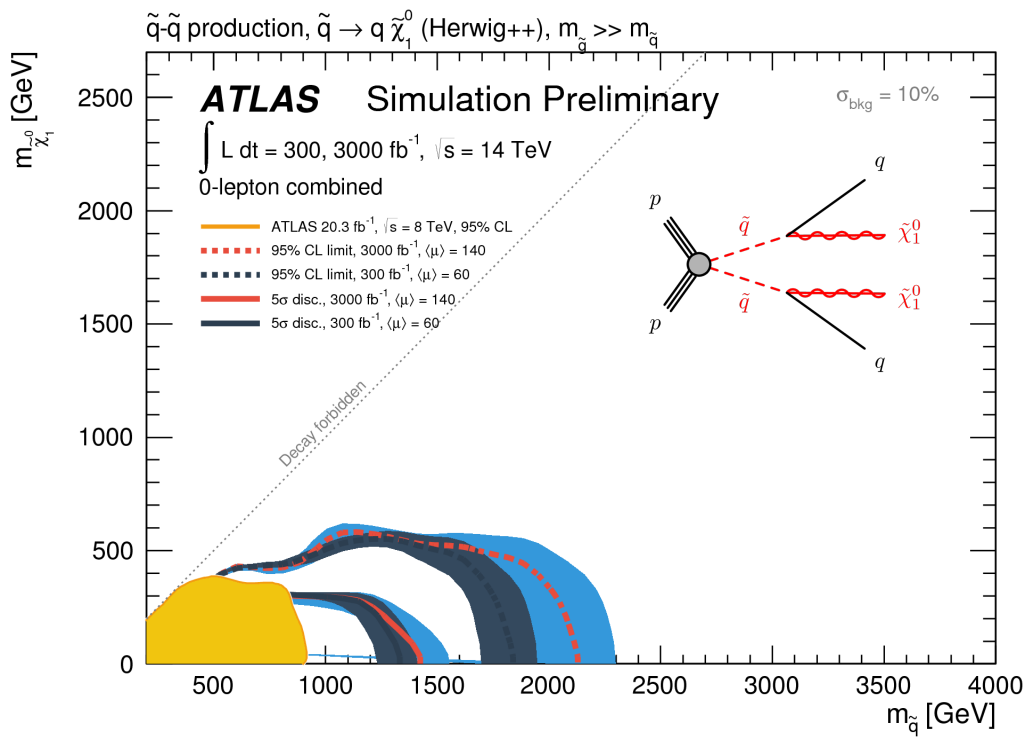




Sensitivity

- Gluino discovery reach with 3000 fb^{-1} close to 2.5 TeV for m_{LSP}=0. Sensitivity (2σ) up to about 3 TeV.
- Squark discovery reach up to about 1.8 TeV for 3000 fb^{-1}, with the 2σ sensitivity exceeding 2 TeV

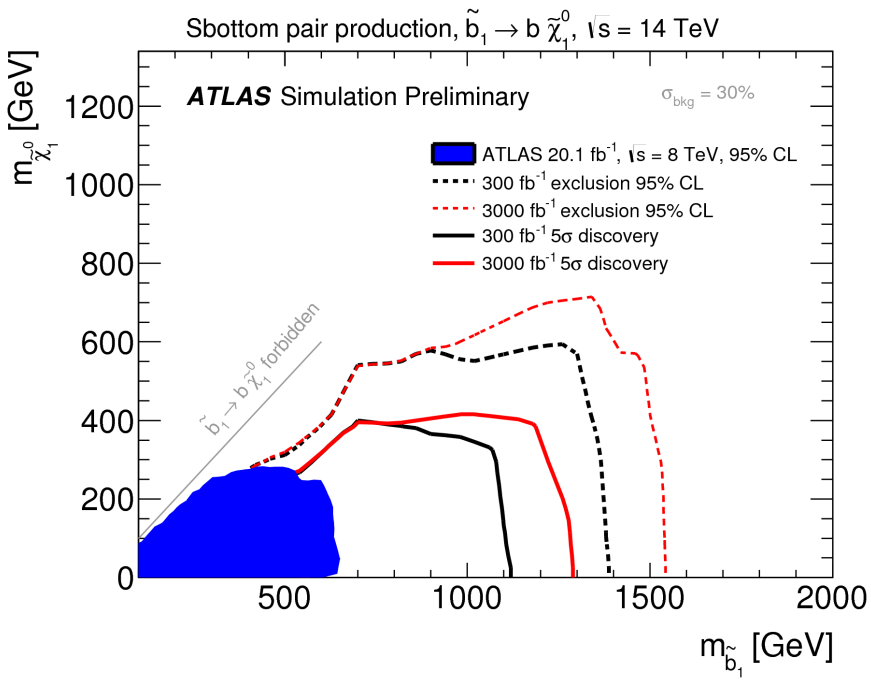




Third generation squarks

- Sensitivity estimates still based on the √s=8 TeV version of the analysis
  - Discovery contour at 1.2-1.3 TeV, while the 2σ sensitivity is 1.4-1.5 TeV.
  - Beware the different colour coding in the plots.

ATL-PHYS-PUB-2014-10



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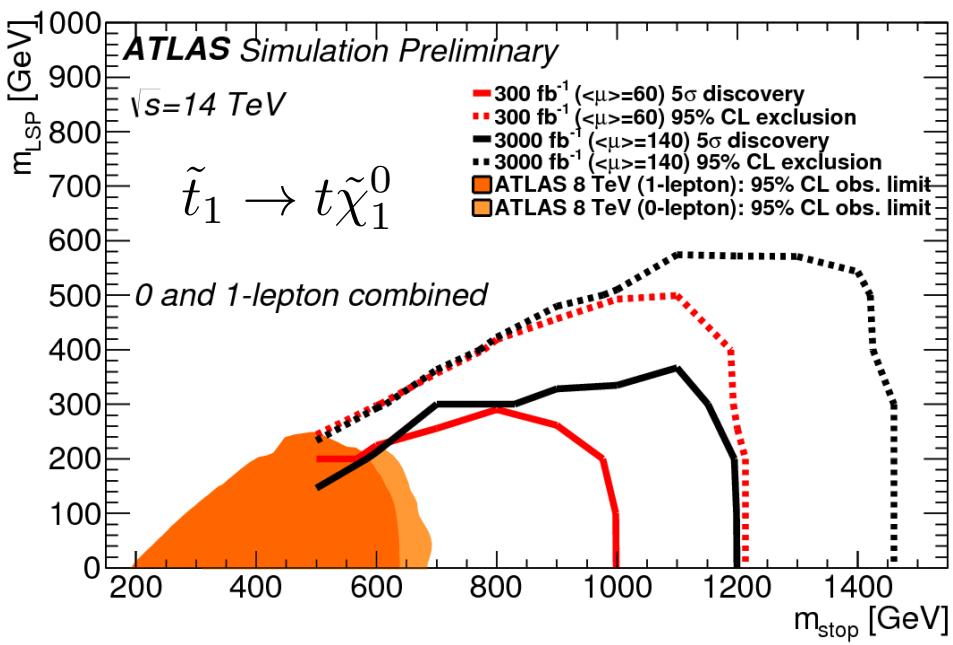
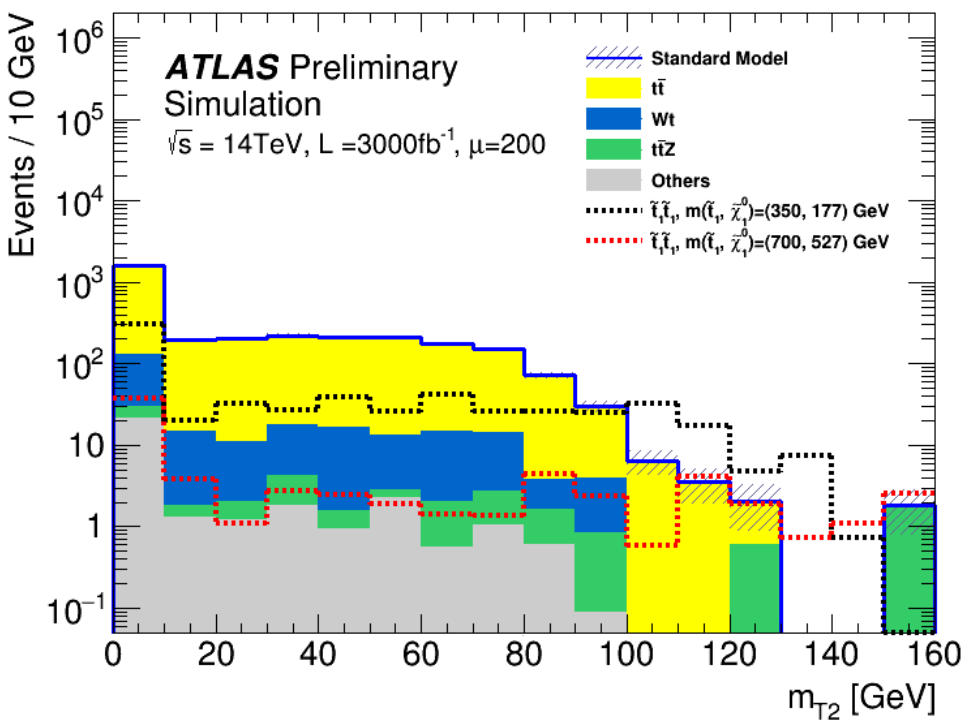
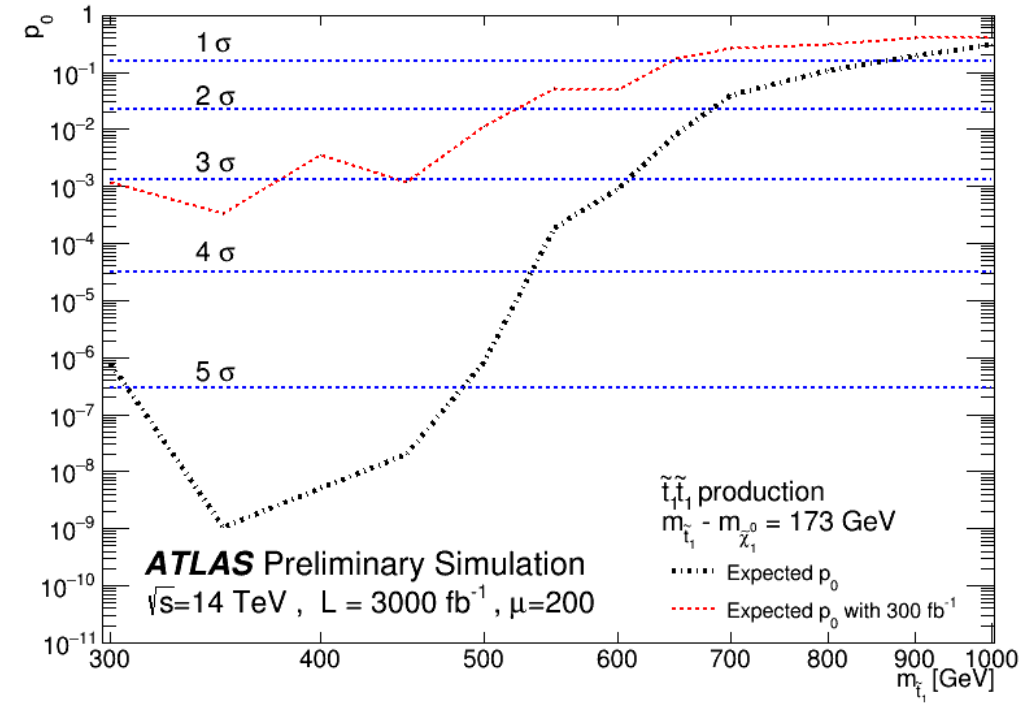


More challenging scenarios

- Let's assume we find a stop with $m_{stop} \sim m_{top} + m_{LSP}$. Signal characterisation might require sensitivity in the 2L channel.
  - Check sensitivity reach of the 2L channel
- Strategy: look for a high p_T jet recoiling against the stop pair system
  - Heavily rely on $m_{T2}(\mathbf{p}_{T,1}, \mathbf{p}_{T,2}, \mathbf{q}_T) = \min_{\mathbf{q}_{T,1}+\mathbf{q}_{T,2}=\mathbf{q}_T} \{\max[\, m_T(\mathbf{p}_{T,1}, \mathbf{q}_{T,1}), m_T(\mathbf{p}_{T,2}, \mathbf{q}_{T,2})\,]\}$

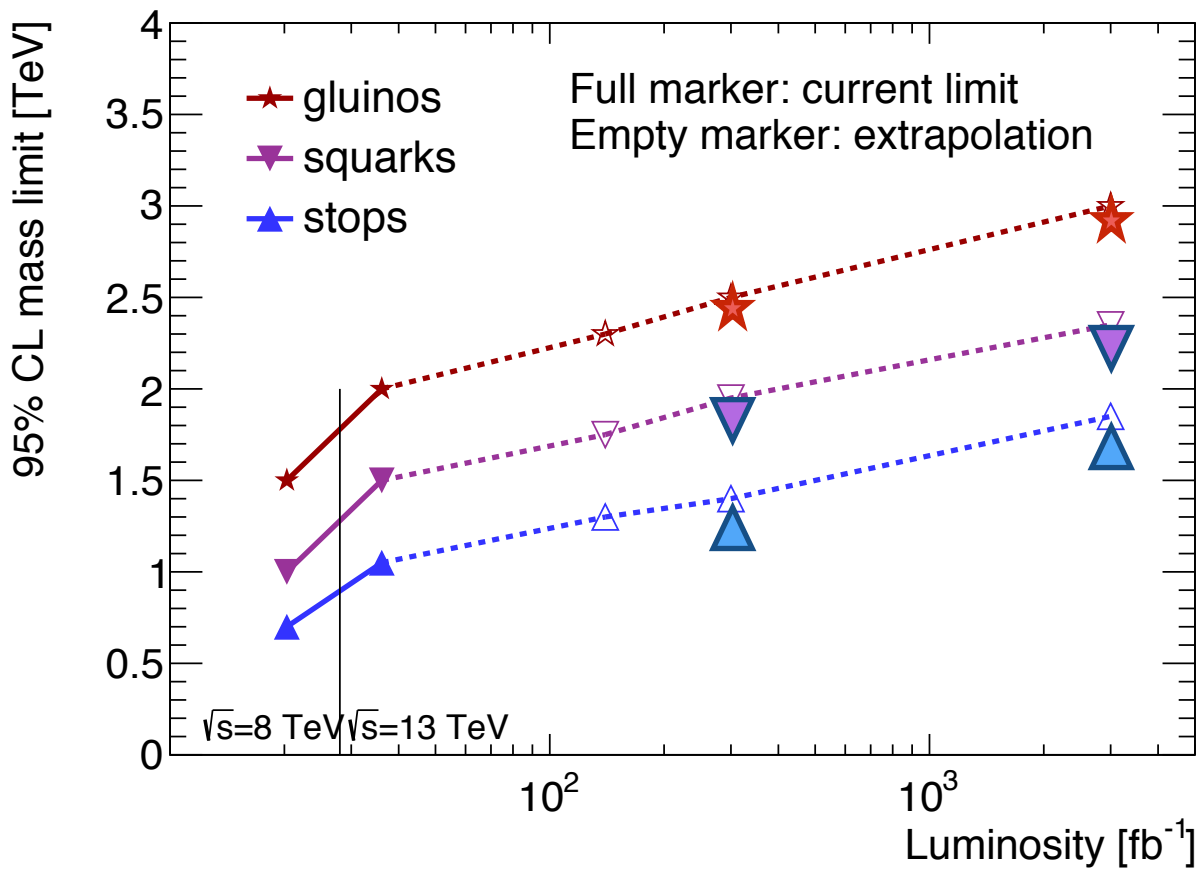




ATL-PHYS-PUB-2016-022

How good was the guess?

- Estimate with parametrised detector response in rough agreement (although somewhat lower) with rough guess
  - Recall: markers are the limit for direct sparticle decay to a massless LSP

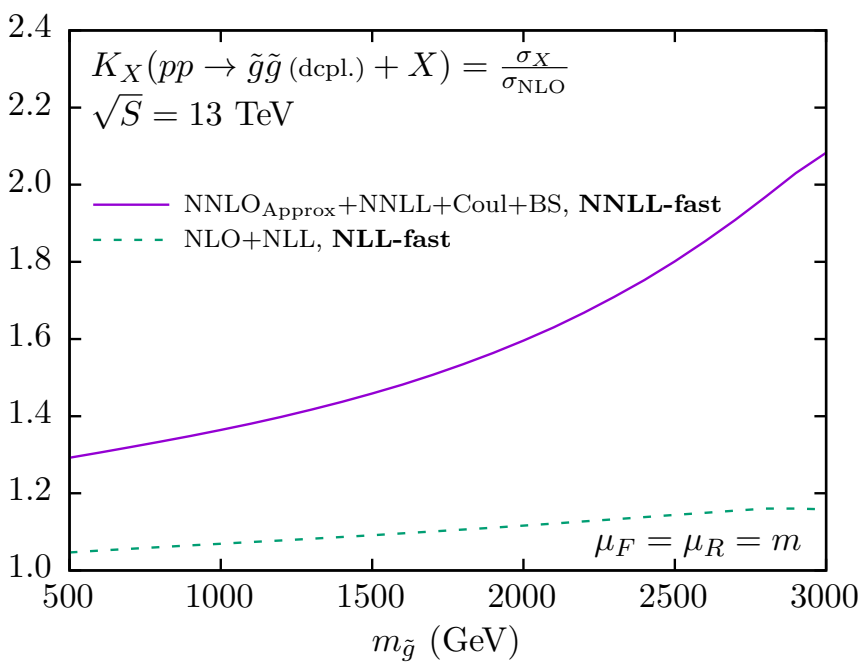


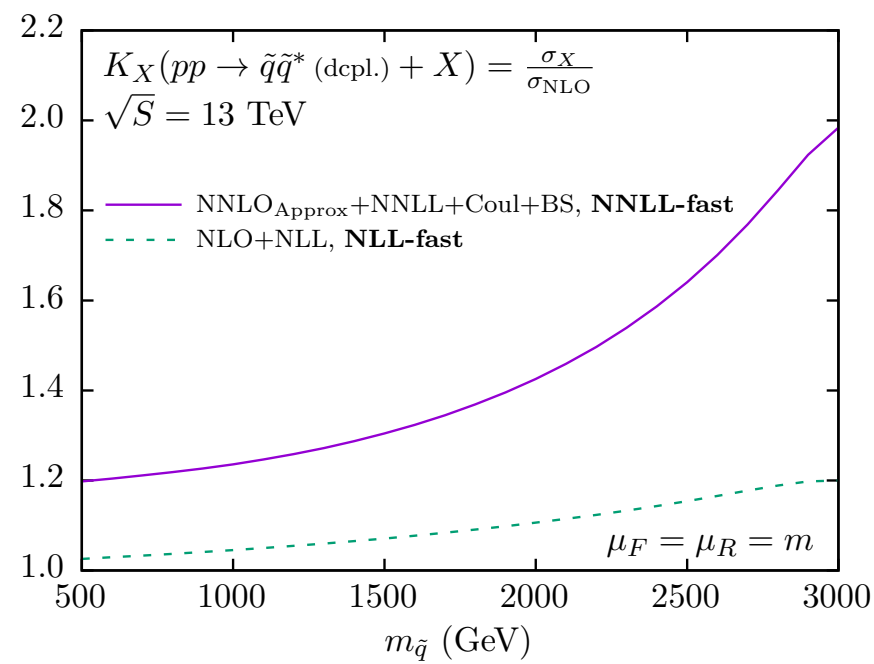
Toward the yellow report

- SUSY strong production plans are mainly aiming at upgrading, improving and extending the existing estimates:
  - Rebase the analyses to the $\sqrt{s}$=13 TeV version - improved selection.
  - Improved systematic uncertainties:
    - Conservative assumptions both on the experimental and theoretical uncertainties assumed
    - Re-evaluate by modelling the evolution of the systematics with the luminosity somehow
  - $<\mu>$ = 200 parametrisation instead of $<\mu>$ = 140

Toward the yellow report

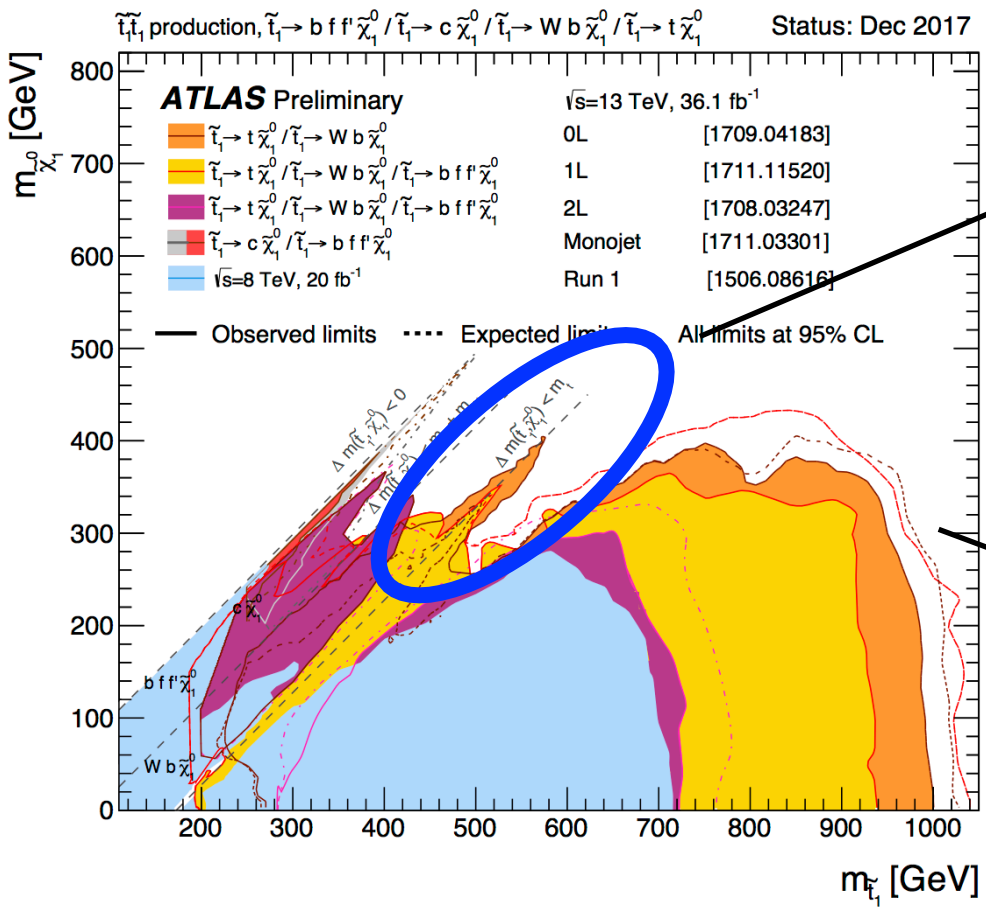
- Few more ideas for discussion:
  - NNLL SUSY cross sections are on the market (https://arxiv.org/abs/1607.07741)
  - Potential significant increase of the signal cross section (and more important for high gluino/squark masses)





Toward the yellow report

- Extend the studies to other interesting regions of the parameter space



diagonal region explored in 2L, review the 0L sensitivity there

High Δm region addressed by previous studies

Prospects for the future

- In the pipeline (strong production only - toward 2018 yellow report):
  - 0L inclusive squark/gluino (2-6 jet MET/Meff analysis)
  - Stop/sbottom (high stop/sbottom mass and compressed scenarios)
- Connected to strong production (and discussed elsewhere)
  - DM+HF (similar analysis techniques than 3rd gen)
  - Displaces Vertices (high sensitivity to LL gluinos)
- No dedicated plans so far for:
  - gtt scenarios
  - More generic scenarios (in particular simplified pMSSM)
    - Not sure it is worth the effort.

Summary

- The LHC has changed the way we think about SUSY
- Strong production SUSY search programme well advanced in Run 2.
- Thin gap for possible discoveries in HL-LHC - a relatively large gap in sensitivity to be covered still.
- Extensive upgrade studies already existing:
  - Plans for updating and improving results discussed