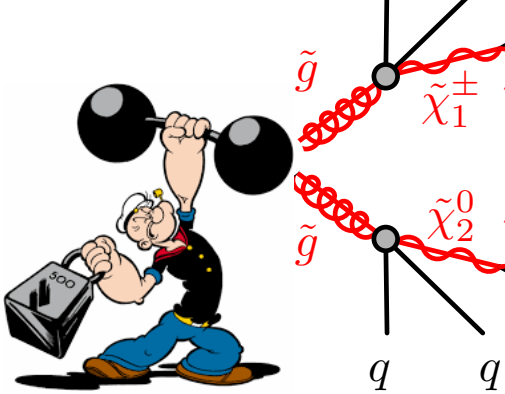


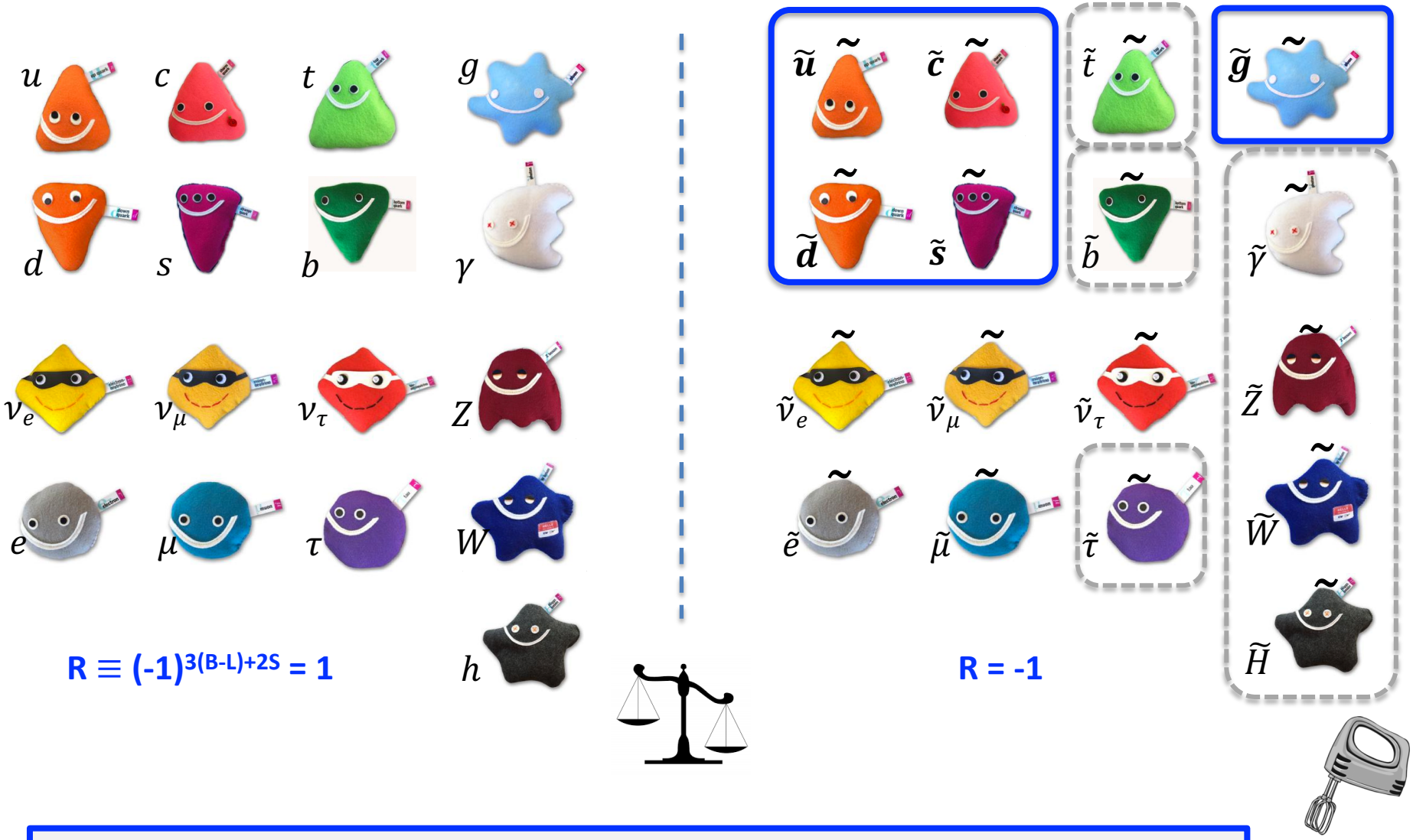
Strong SUSY production

Bertrand Martin dit Latour
University of Bergen

on behalf of **ATLAS** and **CMS** collaborations

LHCP 2019, Puebla

Supersymmetry



$R \equiv (-1)^{3(B-L)+2S} = 1$

$R = -1$

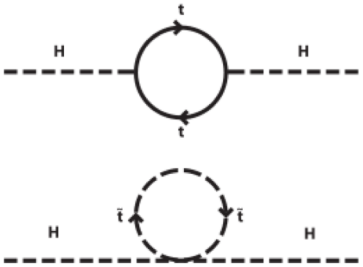
- This talk: searches for **gluinos** and **1st-2nd generation squarks.**
- **R-parity conserved: sparticles pair-produced, LSP stable and DM candidate.**

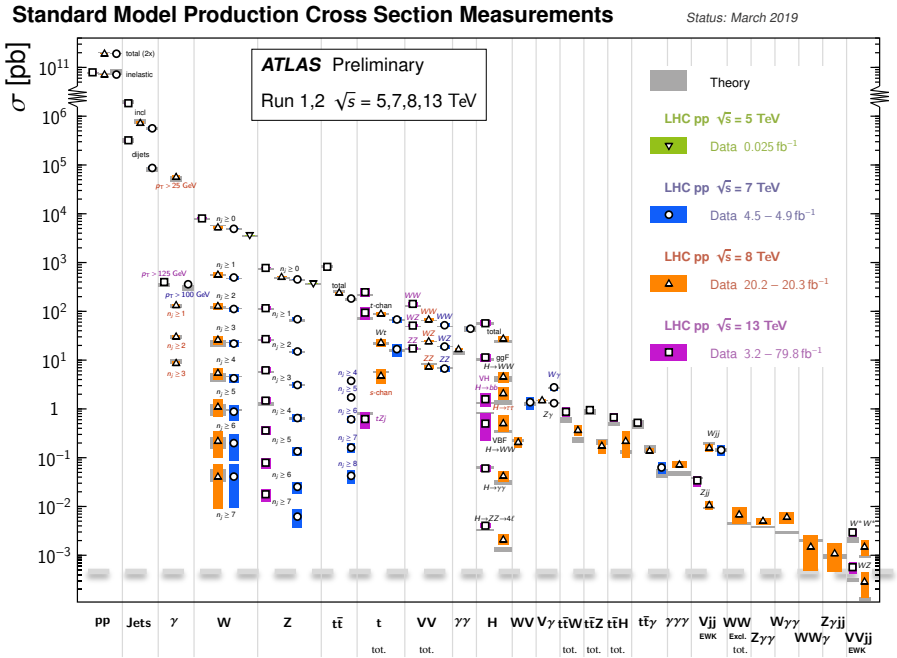
Squarks and gluinos

SUSY partners regulate Higgs mass radiative corrections.

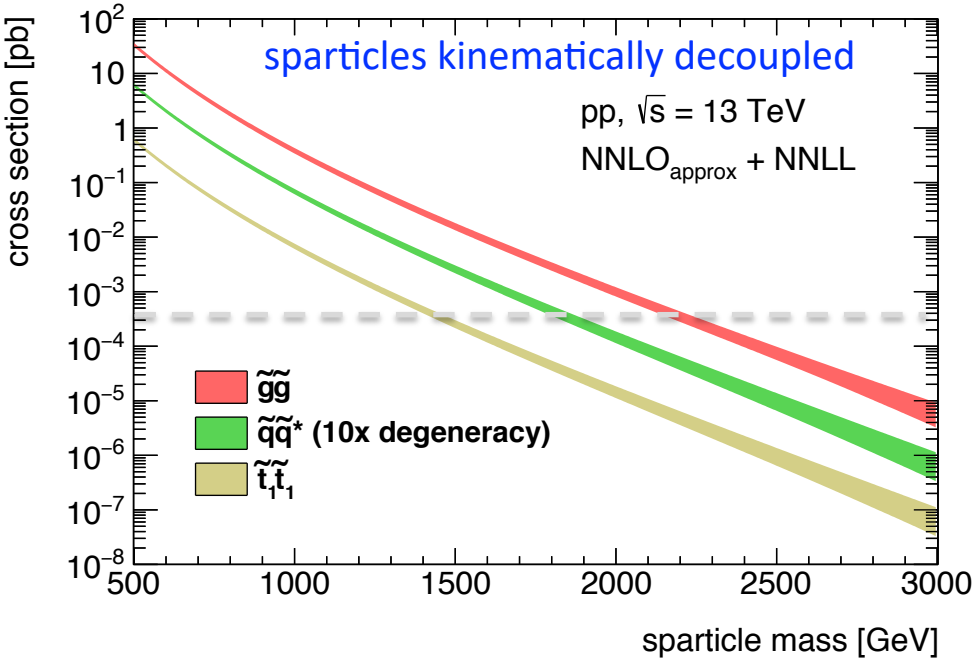
Naturalness favours light stop, gluino and Higgsino.

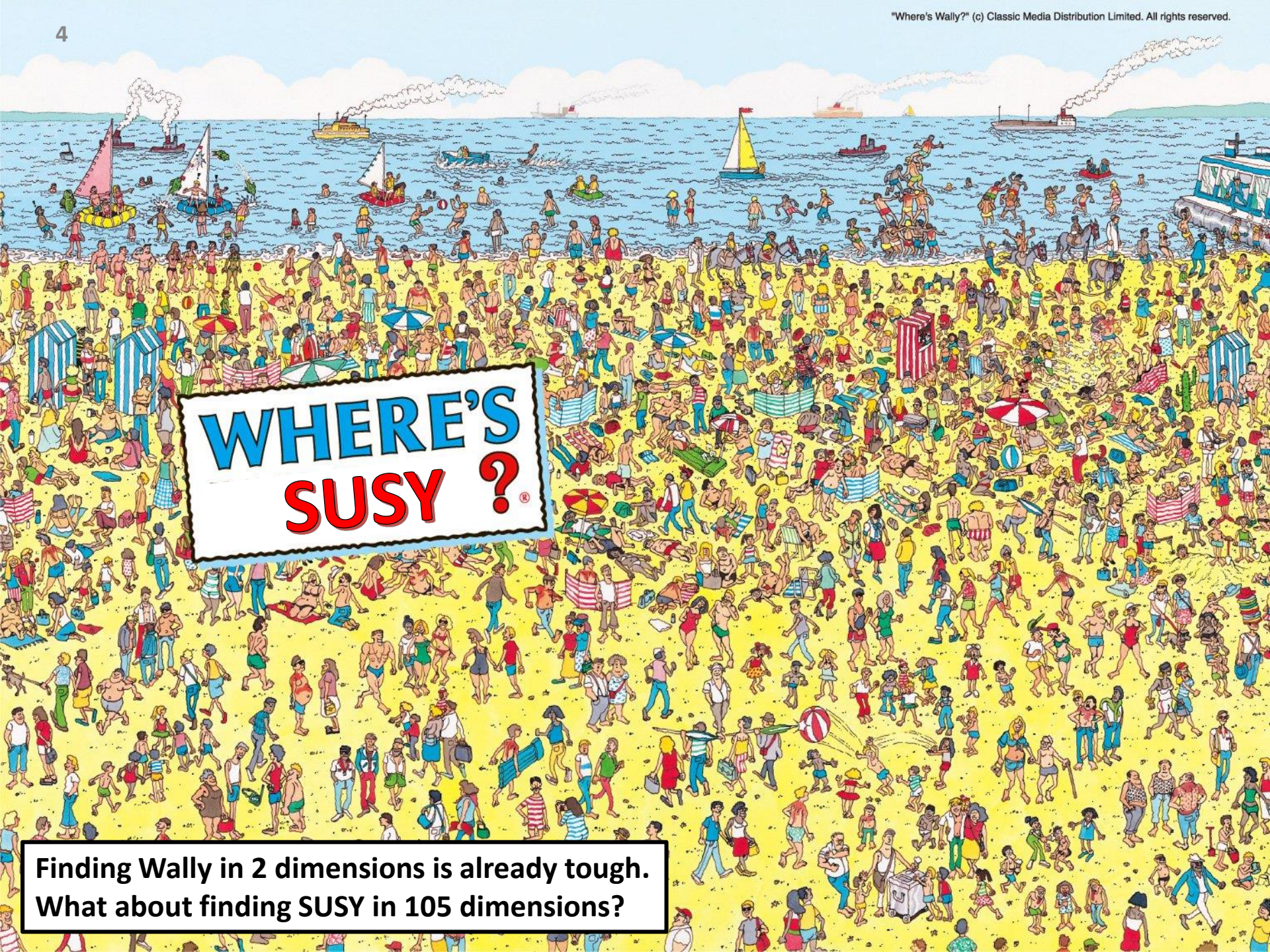
Gluinos and squarks have largest cross sections,
hope they show up at LHC!





10.1007/JHEP12(2016)133

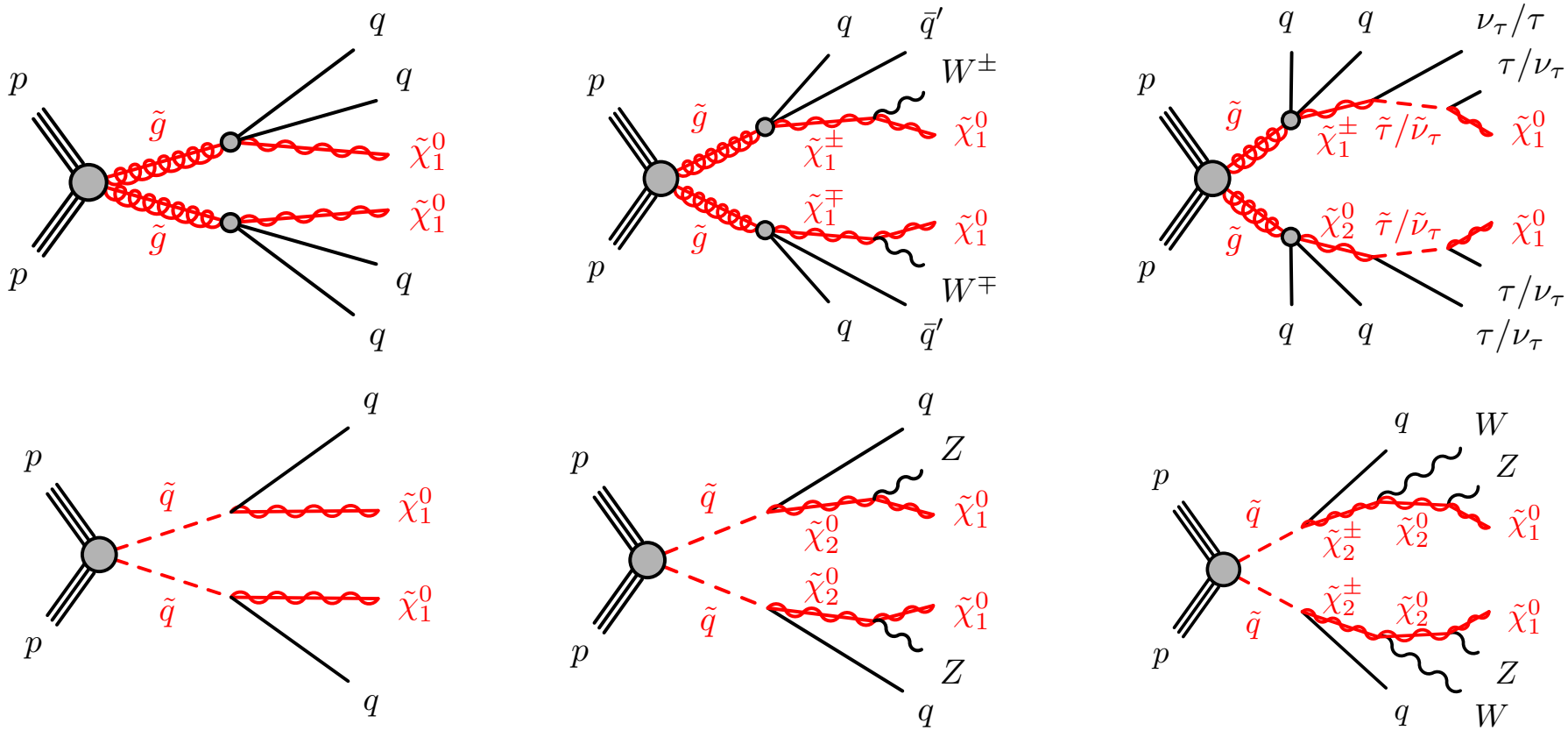




Finding Wally in 2 dimensions is already tough.
What about finding SUSY in 105 dimensions?

Simplified models

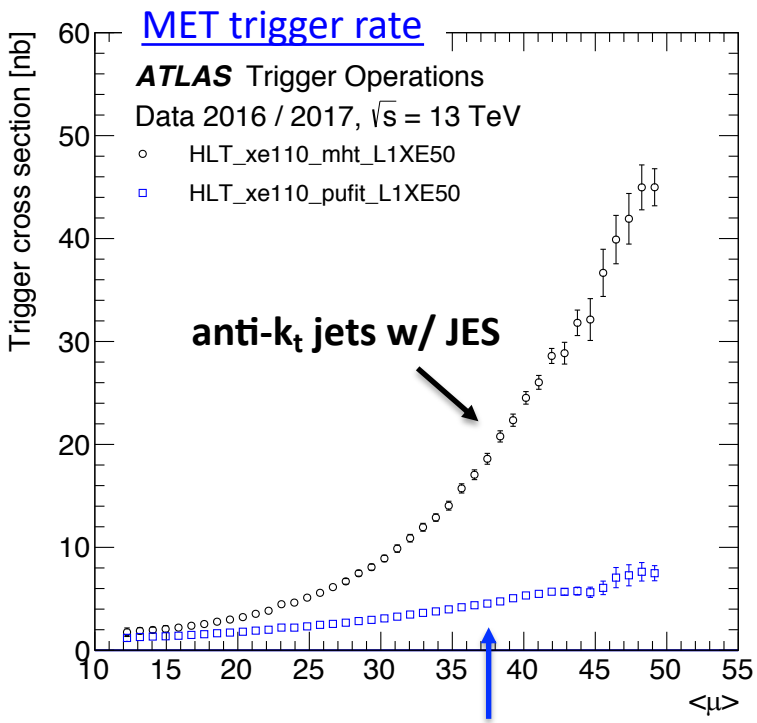
- **Simplified SUSY mass spectrum**, representative of certain parameter space.
- Design **analyses targeting all possible models.**
- **Comprehensive scans (e.g. pMSSM) provide more generic constraints on SUSY.**

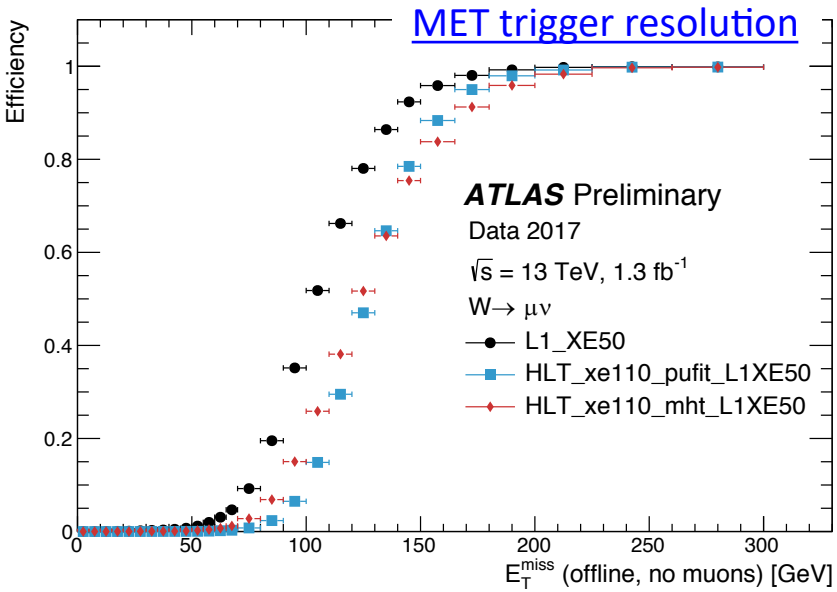


Gluino pairs: $\geq$ 4 jets + MET + X
Squark pairs: $\geq$ 2 jets + MET + X

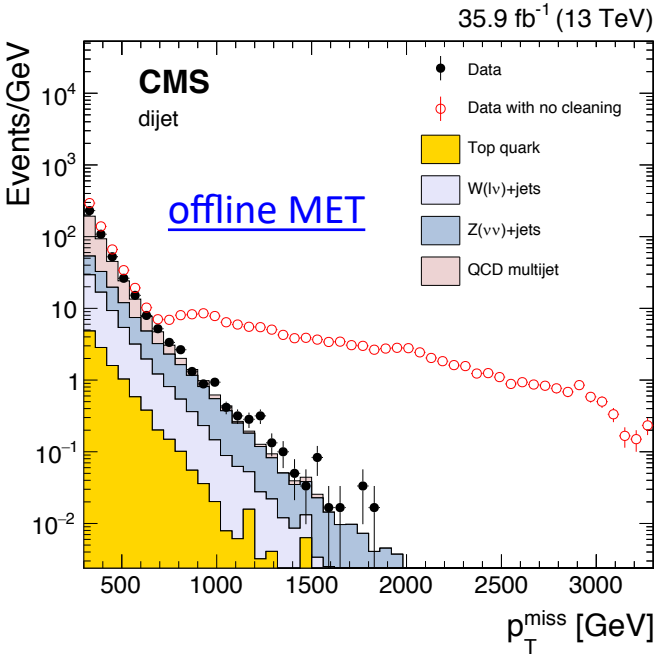
MET in all RPC signatures!

Using MET to find SUSY





pileup E_T density fitted from low-E_T towers assuming $\sum \vec{E_T} = \vec{0}$ within resolution



Lot of care in removing noise:

- calorimeter electronics noise, missing readout
- beam background: structure in ϕ
- poorly measured high-p_T muons

Searches

- **0L** + jets + MET
- **0-1L + b-jets** + MET
- **2L SS / 3L** + jets + MET
- τ + jets + MET
- $\gamma\gamma$ + MET

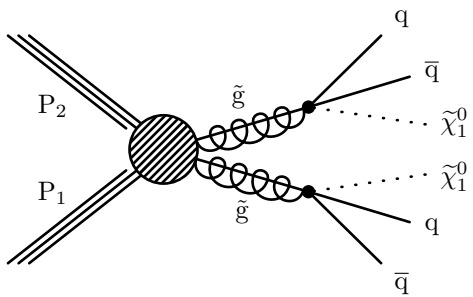
Full Run-2!

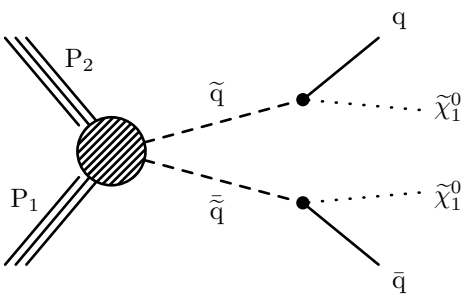
Full Run-2!

0L + jets + MET

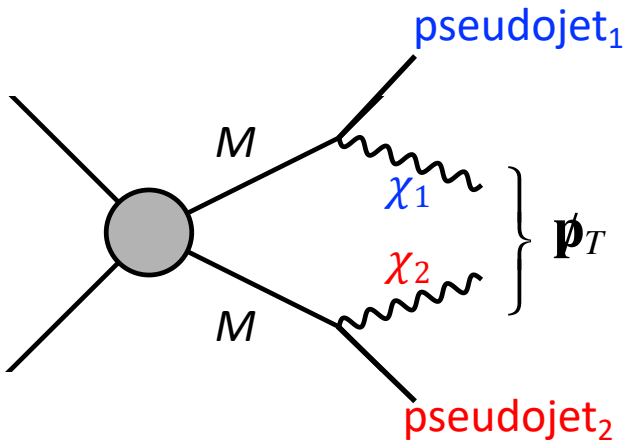
137 fb^{-1}

- no e, μ, charged PF candidate
- large p_T^{miss}, H_T^{miss}, H_T, jet p_T





- **W($\ell\nu$)** and **$t\bar{t}$ with lost ℓ**:
  1ℓ data, 1ℓ → 0ℓ from MC
- **Z($\nu\nu$)+jets**:
  Z($\ell\ell$)+jets data, Z($\ell\ell$) → Z($\nu\nu$) from MC
- **multijet**: from data,
  "rebalance and smear" method

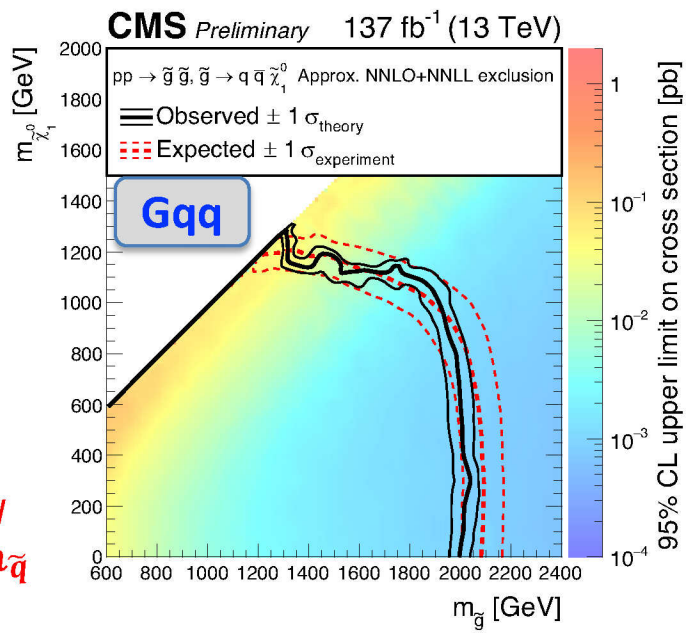


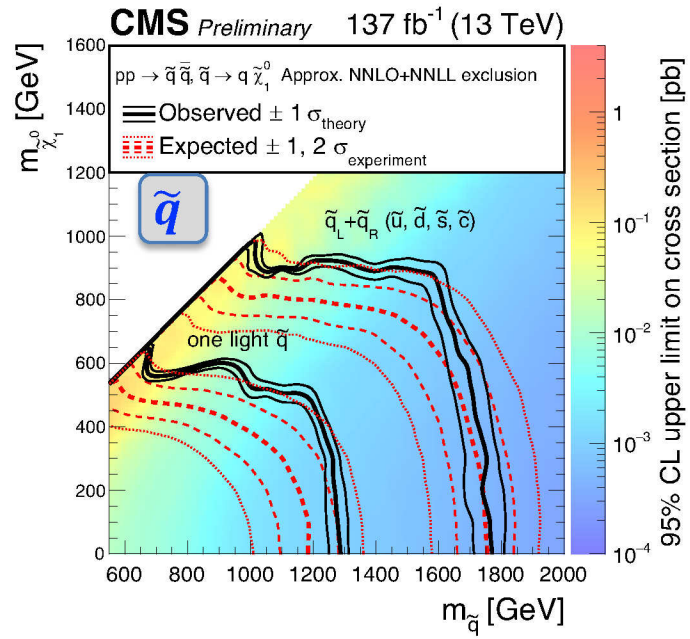
Signal regions binned in N_{jet}, N_{bjet}, H_T,
- M_{T2} when ≥ 2 jets
- jet p_T when 1 jet

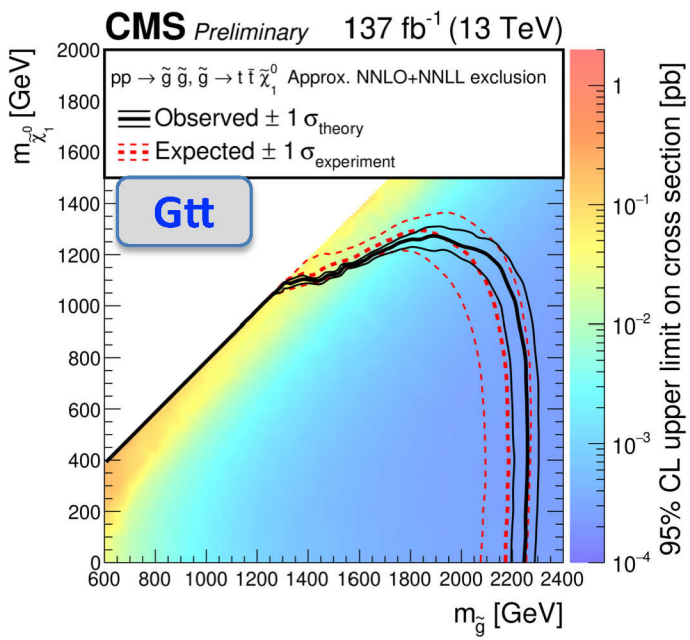
$$M_{T2} = \min_{p_T^{\chi_1} + p_T^{\chi_2} = p_T^{miss}} [\max(m_T^1, m_T^2)] \leq M$$

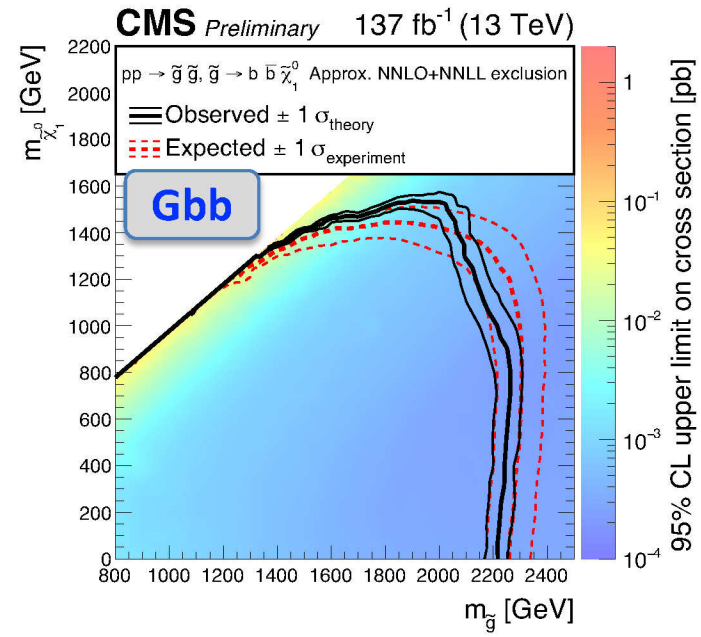
0L + jets + MET: results

36 fb^{-1} limits improved by
- 100-300 GeV on $m_{\tilde{g}}$, $m_{\tilde{q}}$
- 100-250 GeV on $m_{\tilde{\chi}_1^0}$



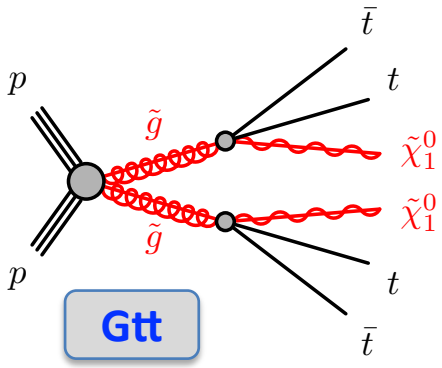


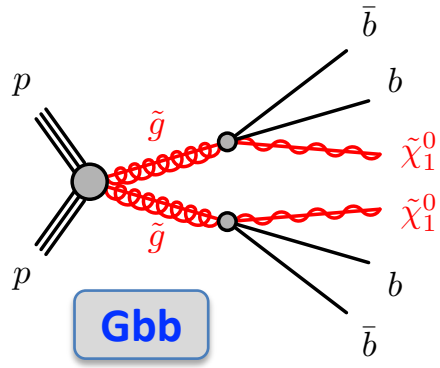


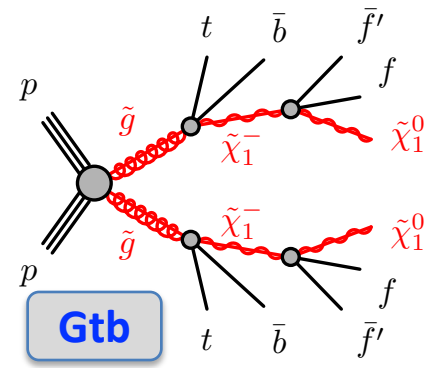


0-1L + b-jets + MET

79.8 fb^{-1}





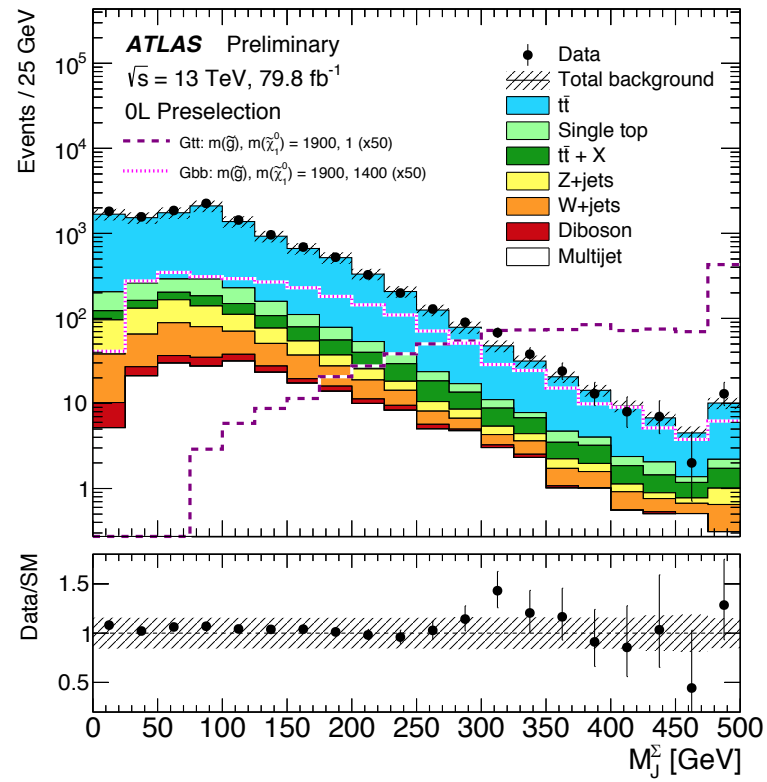


0-1L, ≥4 jets with ≥ 3 b-jets. Main bkg: $t\bar{t}$ **+ jets**.

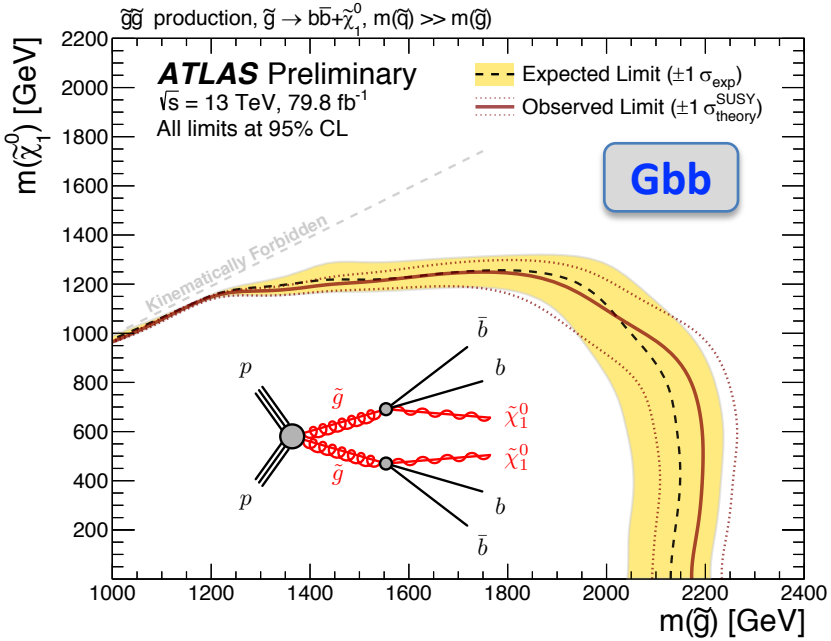
Discriminants:

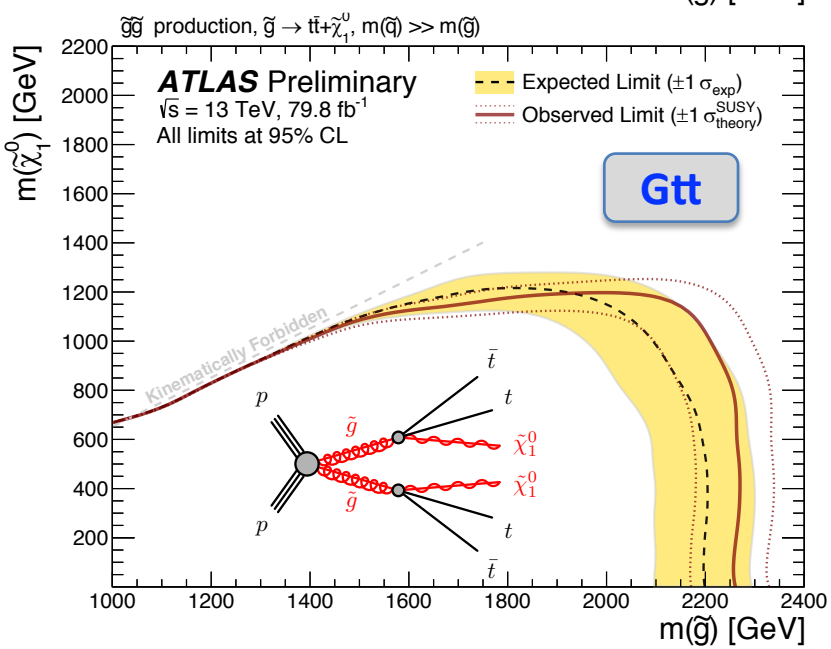
- $m_{\mathrm{eff}} = \sum_i p_{\mathrm{T}}^{\mathrm{jet}_i} + \sum_j p_{\mathrm{T}}^{\ell_j} + E_{\mathrm{T}}^{\mathrm{miss}}$
- $m_{\mathrm{T}}(\ell, \mathrm{MET})$: suppress W($\ell\nu$) and semilep $t\bar{t}$
- $\min_{i \leq 3} m_{\mathrm{T}}(b\text{-jet}_i, \mathrm{MET}) \leq m_t$ for semilep $t\bar{t}$
- M_{J}^{Σ}: sum of masses of ≤4 large-R jets (boosted top)

0L and 1L SRs binned in N_{jet} and m_{eff} .



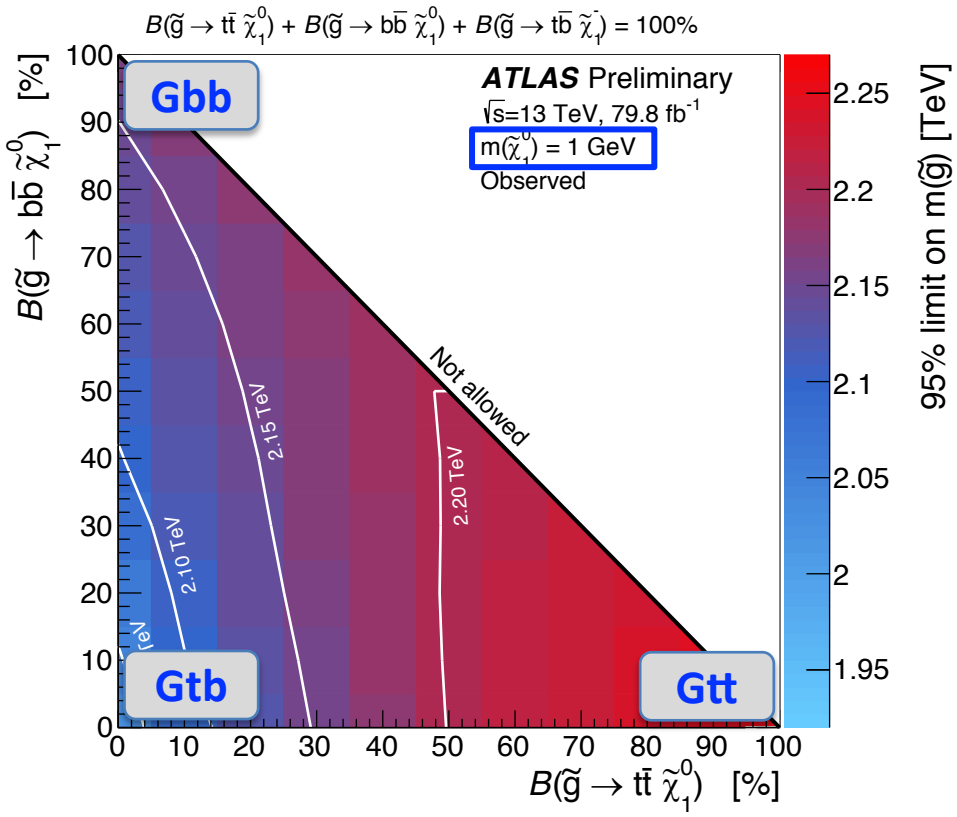
0-1L + b-jets + MET: results





2.3σ excess in 36 fb^{-1} dataset not confirmed ☹

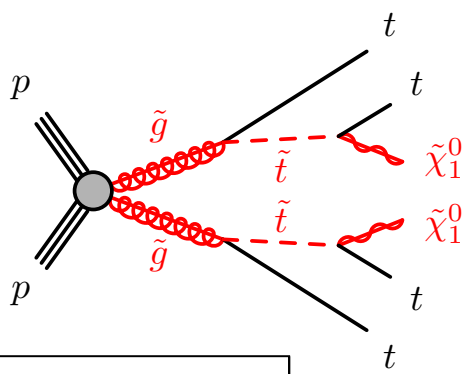
Limits on gluino mass at fixed LSP mass when varying BR($\tilde{g}$)

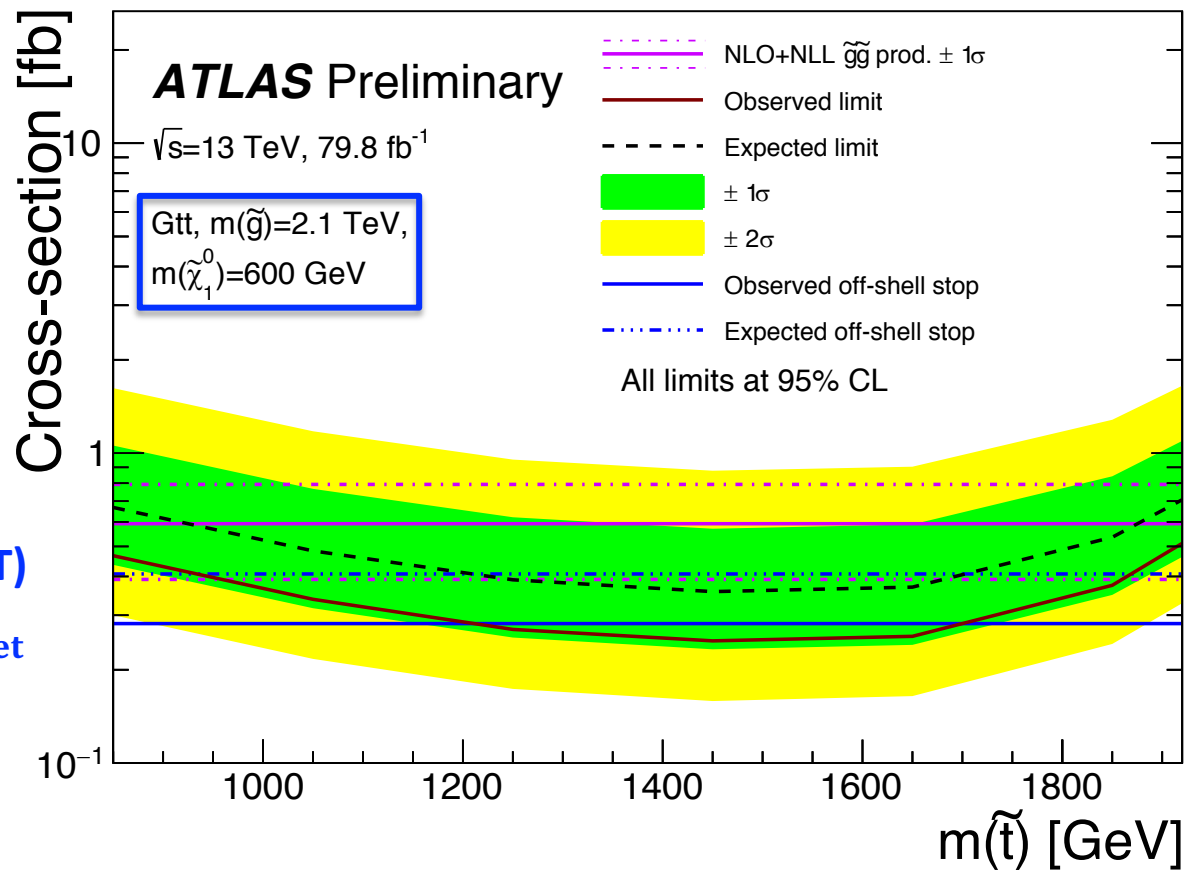


0-1L + b-jets + MET: results

Limits on Gtt model for on-shell $\tilde{t}$.

Limits weakens when $m_{\tilde{t}} \simeq m_{\tilde{g}}$ or $m_{\tilde{t}} \simeq m_{\tilde{\chi}_1^0}$.





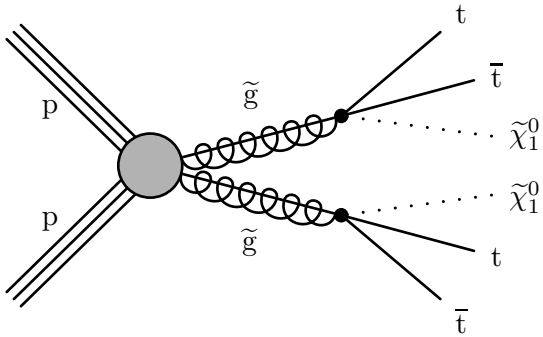
Lower $\Delta\phi$(j,MET)

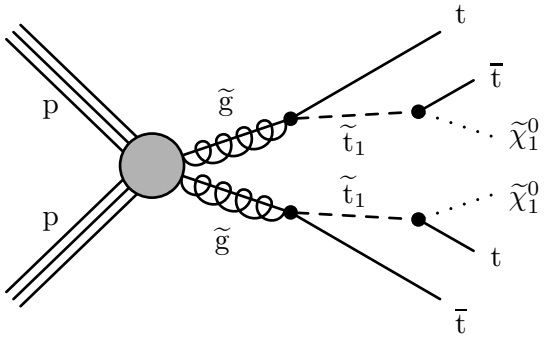
Lower min m_T^{bjet}

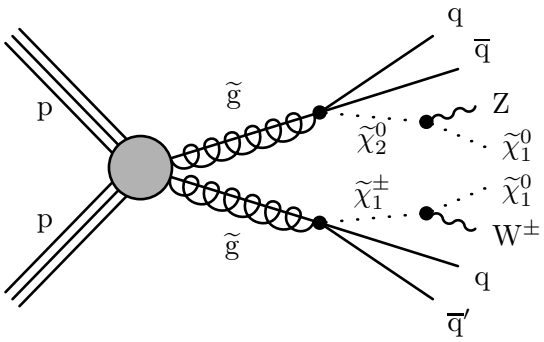
Lower M_J^{Σ}

2L SS / 3L + jets + MET

137 fb^{-1}







≥2 same-sign ℓ, ≥2 jets.
Trigger: $\ell\ell$ or $\ell\ell$ + H_T.

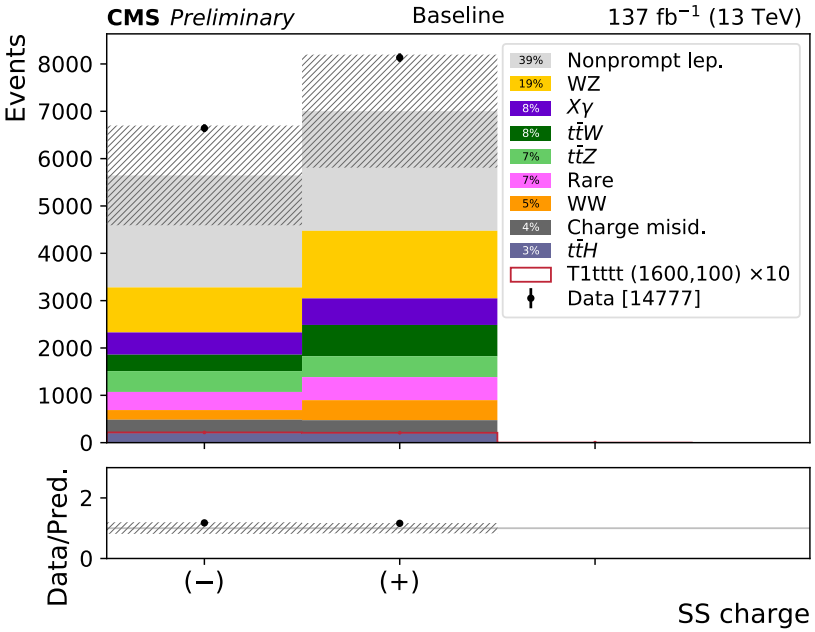
168 SRs binned in p_T^ℓ, p_T^{miss}, N_{jet}, N_{bjet}, H_T, m_T^{min}

Backgrounds:

- **prompt $\ell^\pm\ell^\pm$ from MC**:
  WZ, $W^\pm W^\pm$, $t\bar{t}$+W/Z/h, X+γ

- **non-prompt $\ell^\pm\ell^\pm$ from data**, **"matrix method"**:
  proba. for loose true/fake ℓ to pass tight ID.

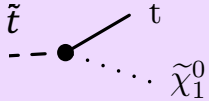
- **$e^\pm$ with misreconstructed charge**:
  OS data + charge flip rate from MC,
  charge-flip SF from **Z(ee) data**.

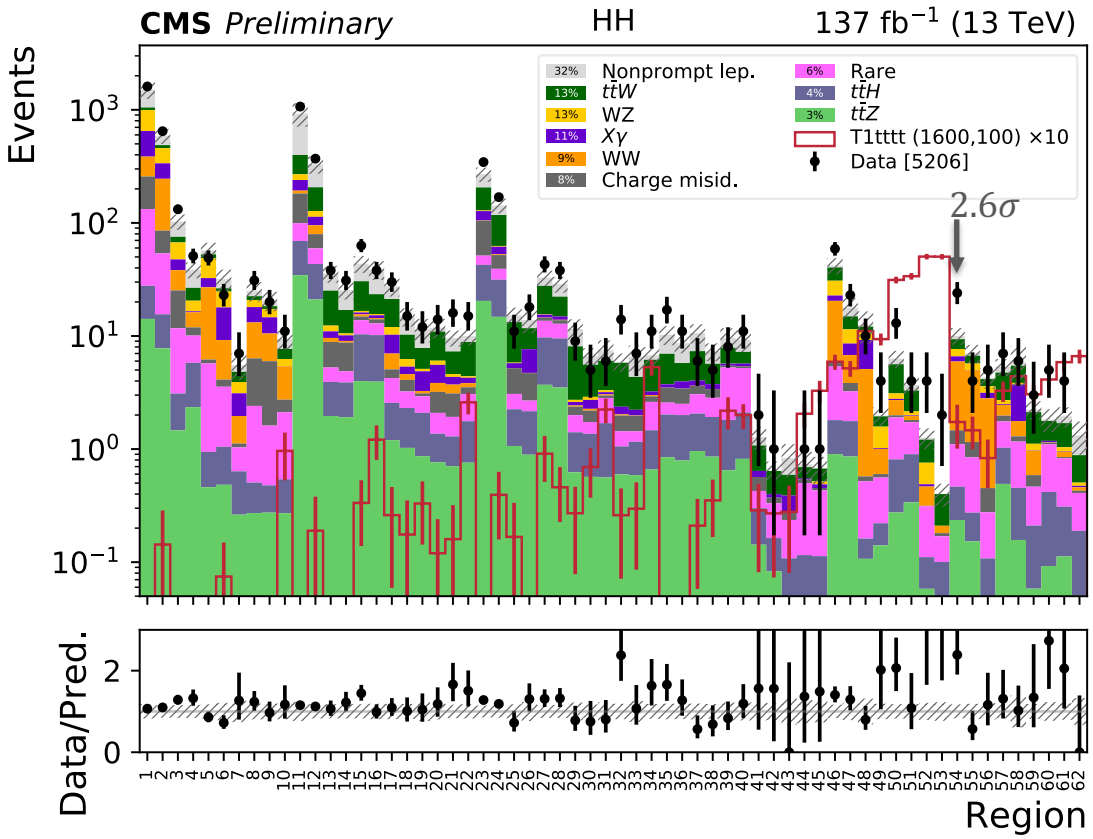


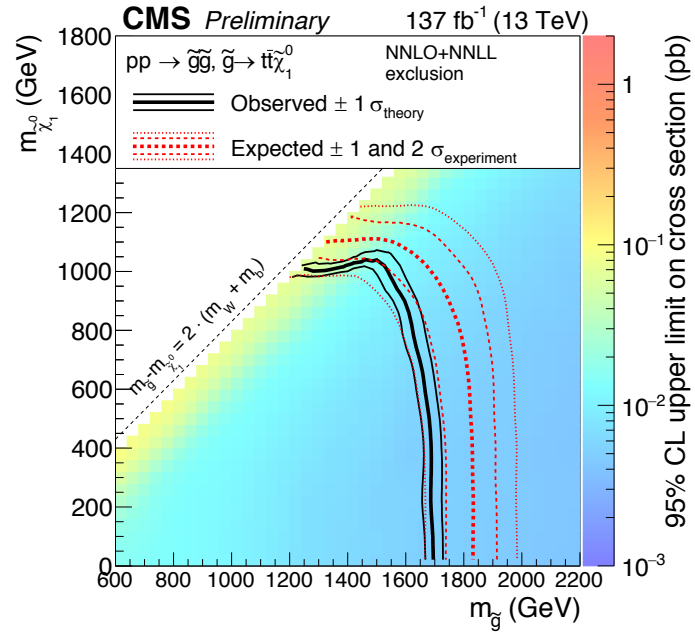
2L SS / 3L + jets + MET

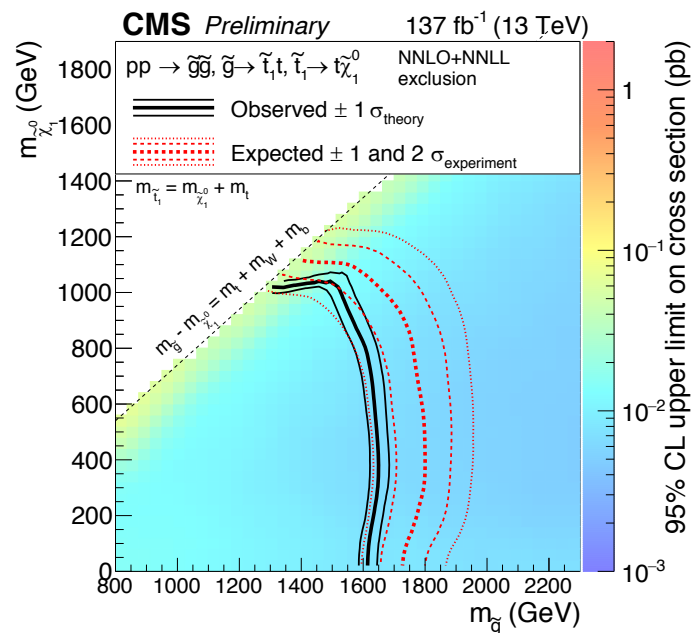
Largest excess: 2.6σ. Set limits on:

- $\tilde{g} \to t\bar{t}\tilde{\chi}_1^0$
- $\tilde{g} \to t\tilde{t} \to t\bar{t}\tilde{\chi}_1^0$ with $\Delta m(\tilde{t}, \tilde{\chi}_1^0) = m_t$

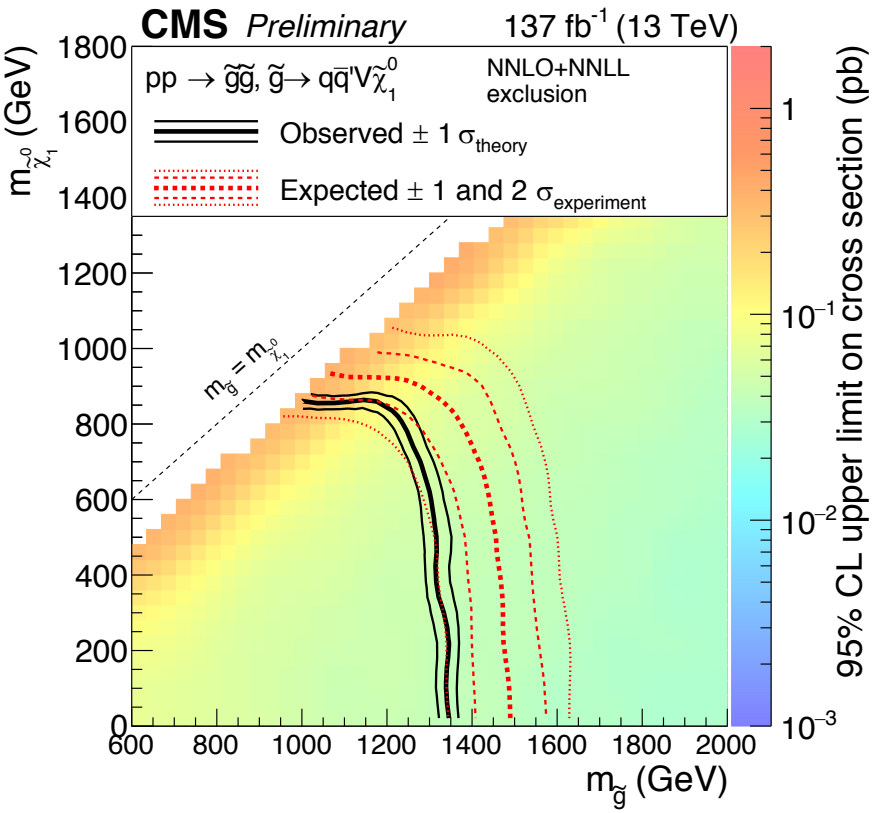


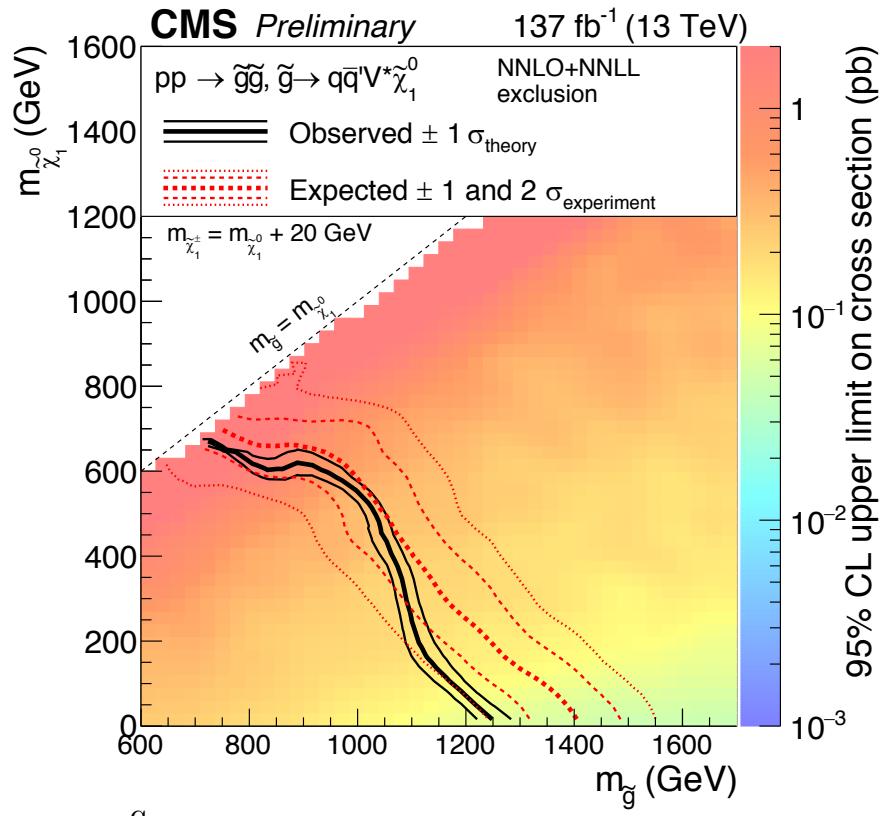




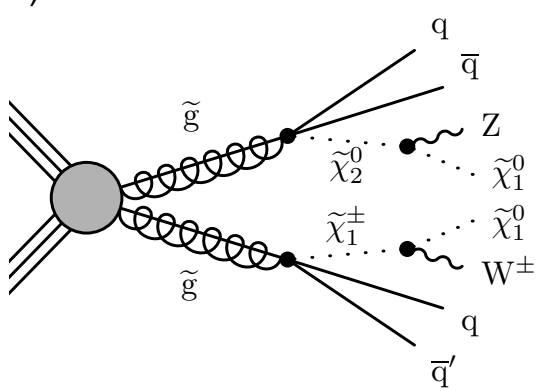


2L SS / 3L + jets + MET





$$m_{\tilde{\chi}_1^\pm} = 0.5(m_{\tilde{g}} + m_{\tilde{\chi}_1^0})$$



$$m_{\tilde{\chi}_1^\pm} = m_{\tilde{\chi}_1^0} + 20\,\mathrm{GeV}$$

2L SS / 3L + jets + MET

139 fb^{-1}

≥2 same-sign ℓ, ≥2 jets.
Trigger: $\ell\ell$ or MET.

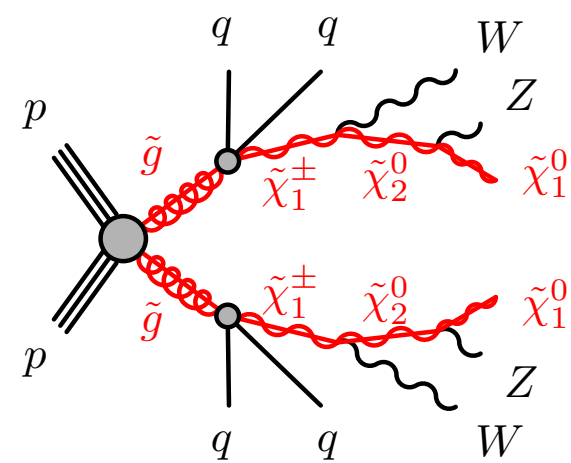
Similar background estimate as CMS:

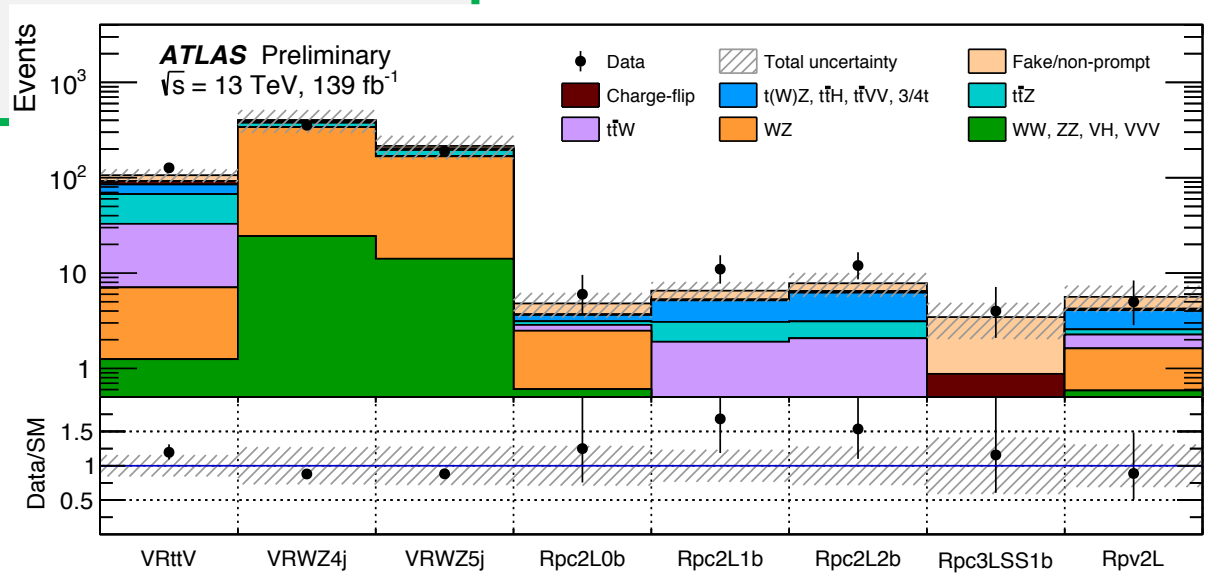
- **prompt $\ell^{\pm}\ell^{\pm}$ from MC**

- **$e^{\pm}$ with charge flip: OS data + charge flip rate.**

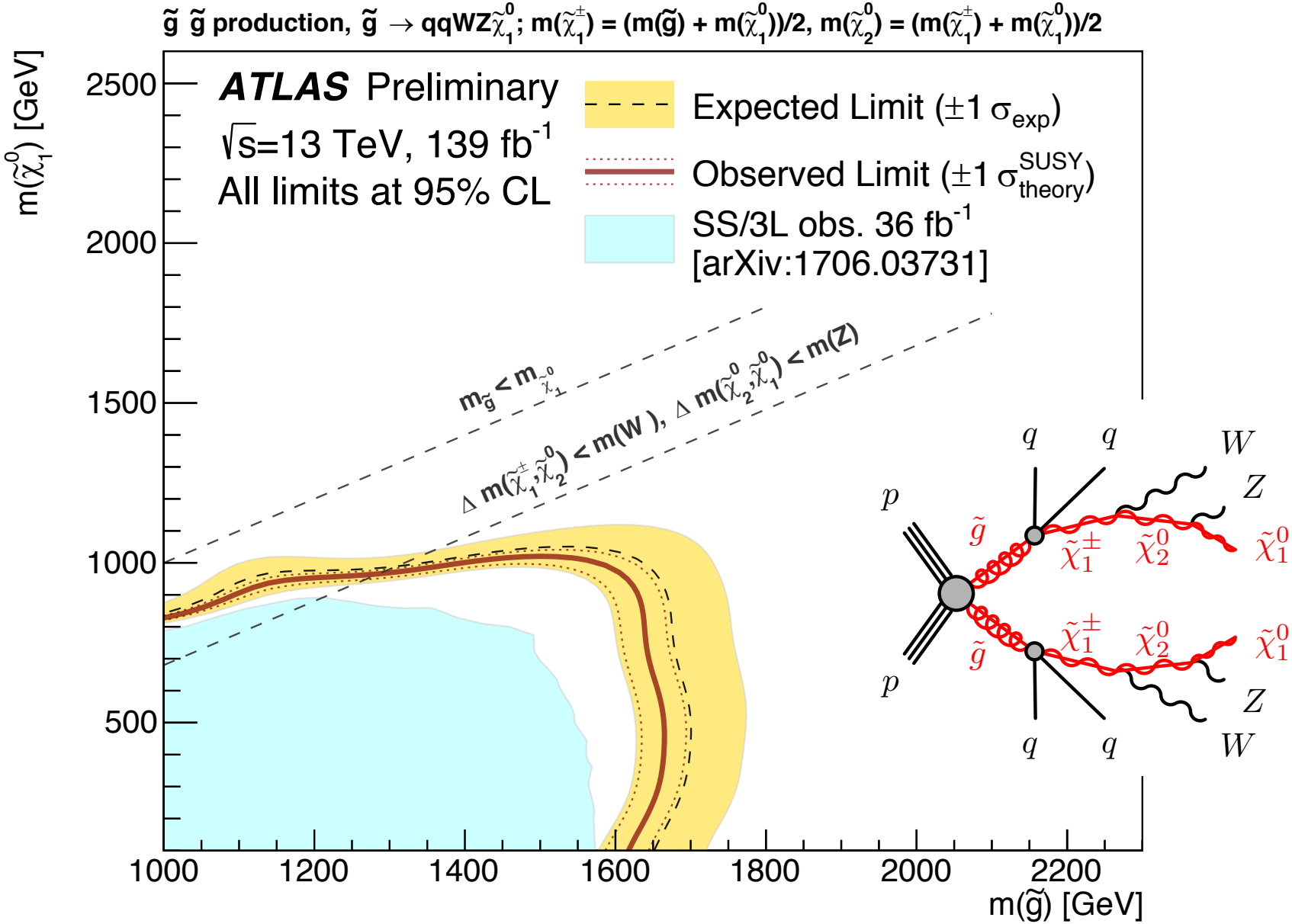
BDT to reject charge-flipped electrons.
$|\eta_e|<2$: *flip rate larger at high $|\eta|$, more material.*

- **non-prompt $\ell^{\pm}\ell^{\pm}$ from data, matrix method.**
Charge-flip background subtracted from data.



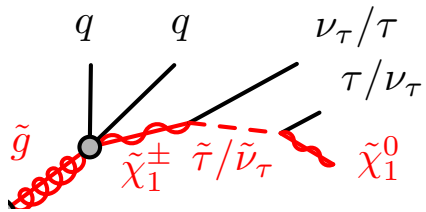


2L SS / 3L + jets + MET



τ + jets + MET

36.1 fb^{-1}



MET trigger.

1τ channel

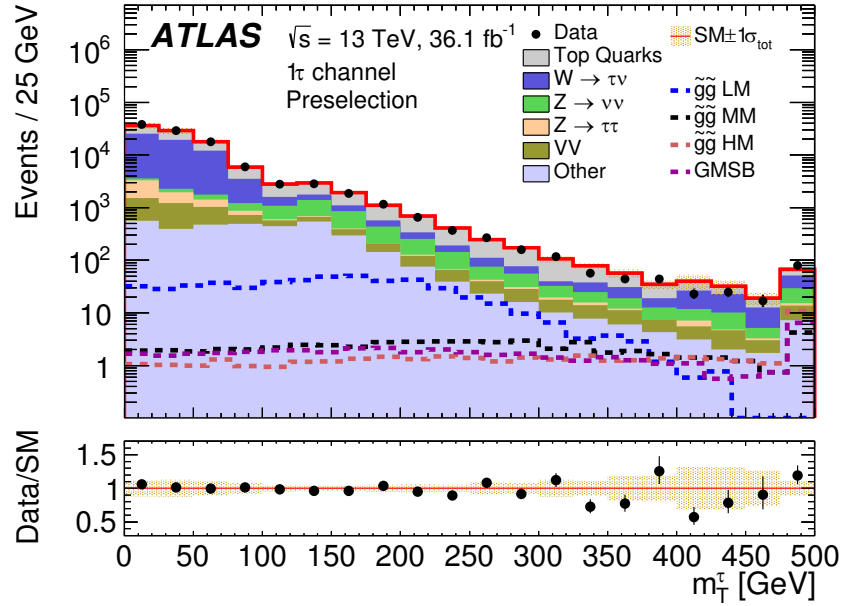
- $\boldsymbol{m_T^\tau}$: suppress $W(\tau\nu)$ and $t\bar{t}$
- **MET**

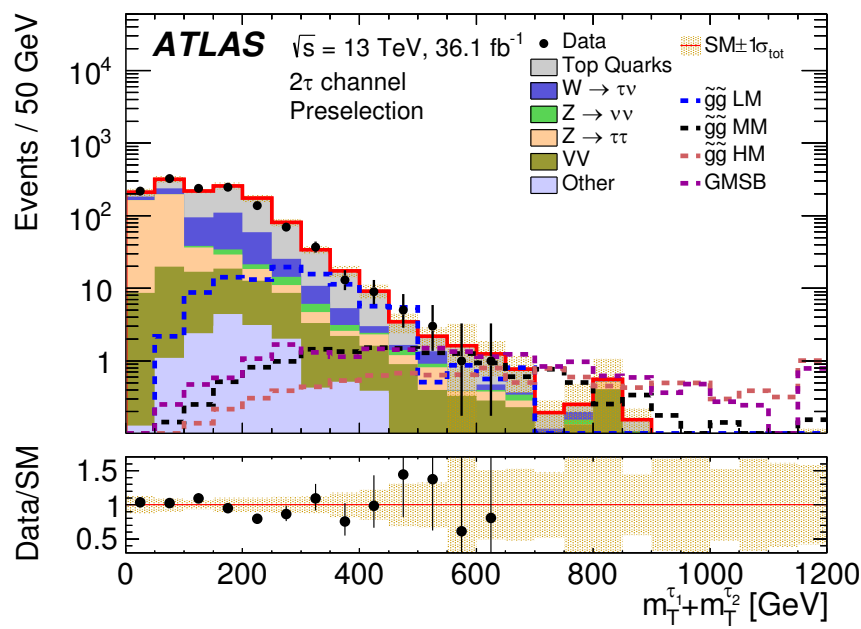
2τ channel

- **H_T**
- $\boldsymbol{m_T^{\tau_1}} + \boldsymbol{m_T^{\tau_2}}$: suppress high-p_T $Z(\tau\tau)$

NEW: used in multi-bin SR

W, $t\bar{t}$, Z($\tau\tau$), Z($\nu\nu$) fitted to data in CRs.

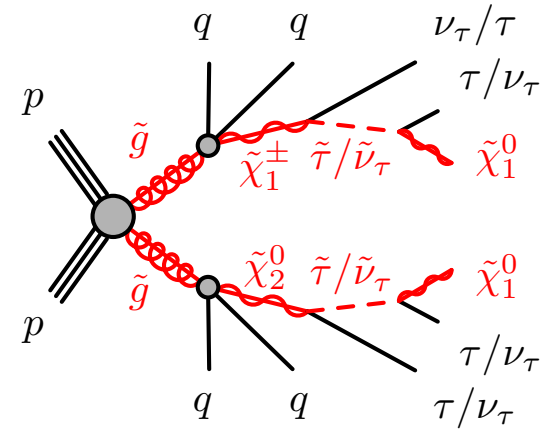


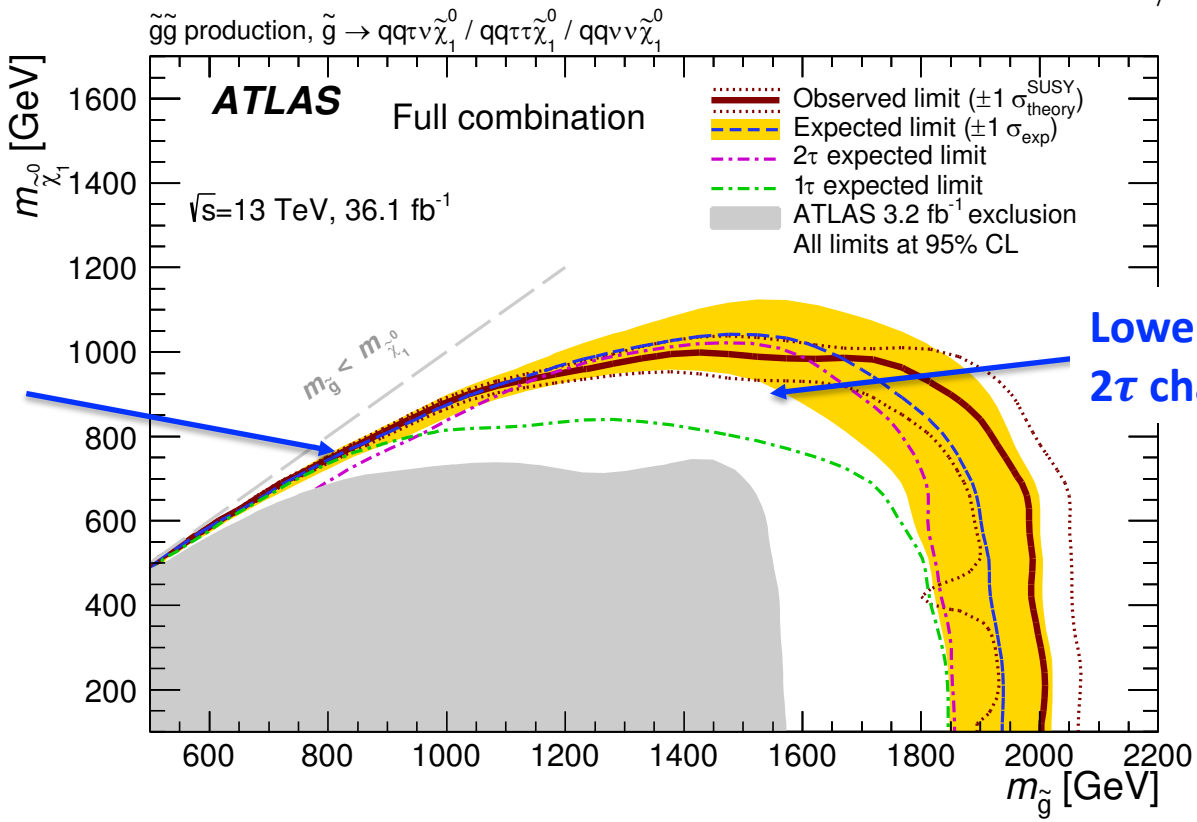


τ + jets + MET: results

Gluino pairs decaying via $\tilde{\tau}$.

Light $\tilde{\tau}$ could help regulate Ω_{DM} (coannihilation).





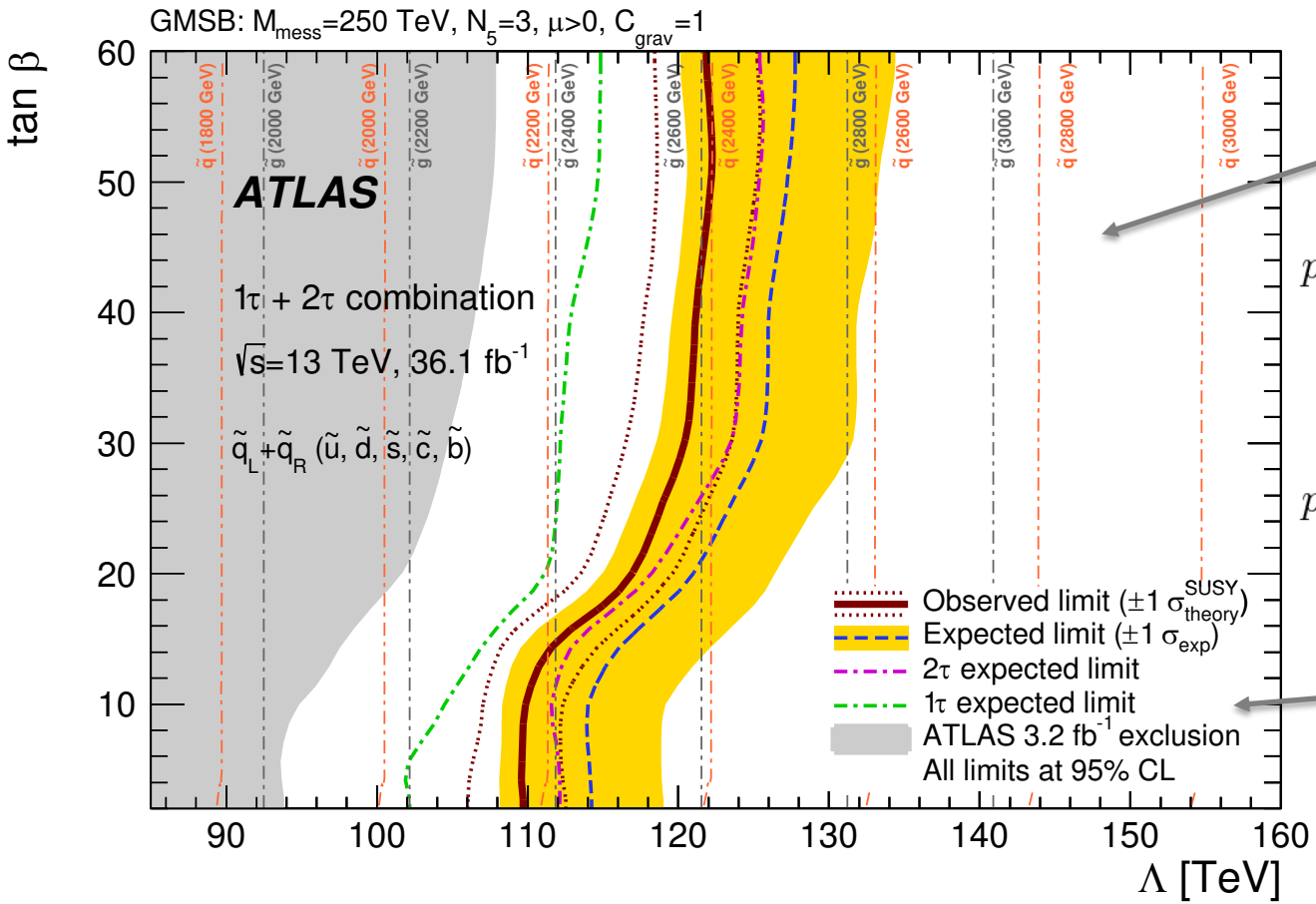
1τ channel good in compressed region

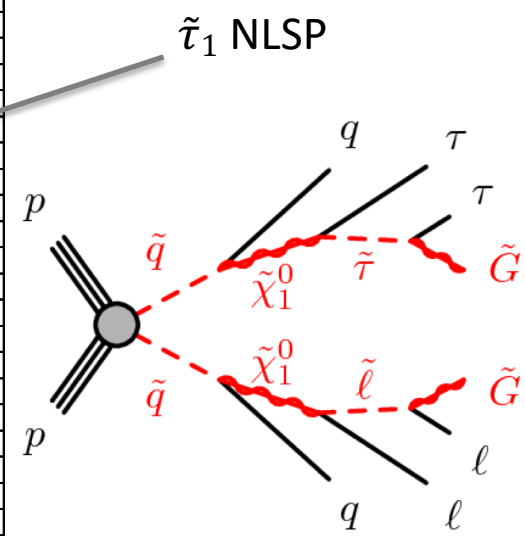
Lower MET, 2τ channel better

τ + jets + MET: results

Gauge-Mediated SUSY Breaking model.

Dominant strong processes **at high Λ** (SUSY breaking scale): **squark pairs, squark-gluino**.



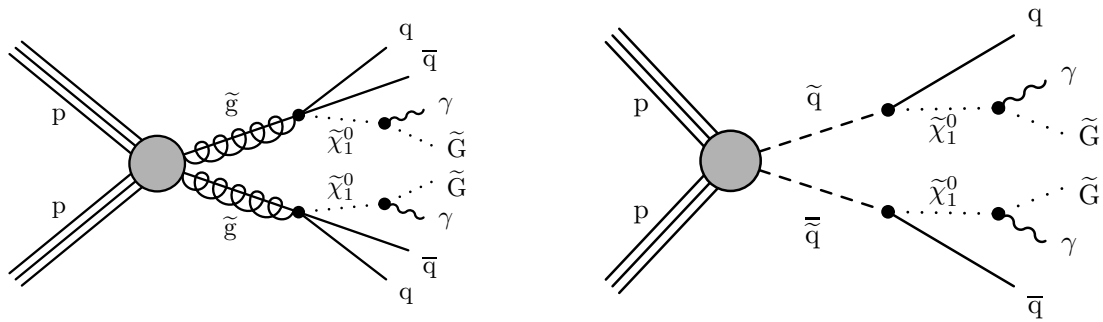


Good sensitivity from EW searches!

$\gamma\gamma$ + MET

35.9 fb^{-1}

General Gauge Mediated SUSY breaking model.

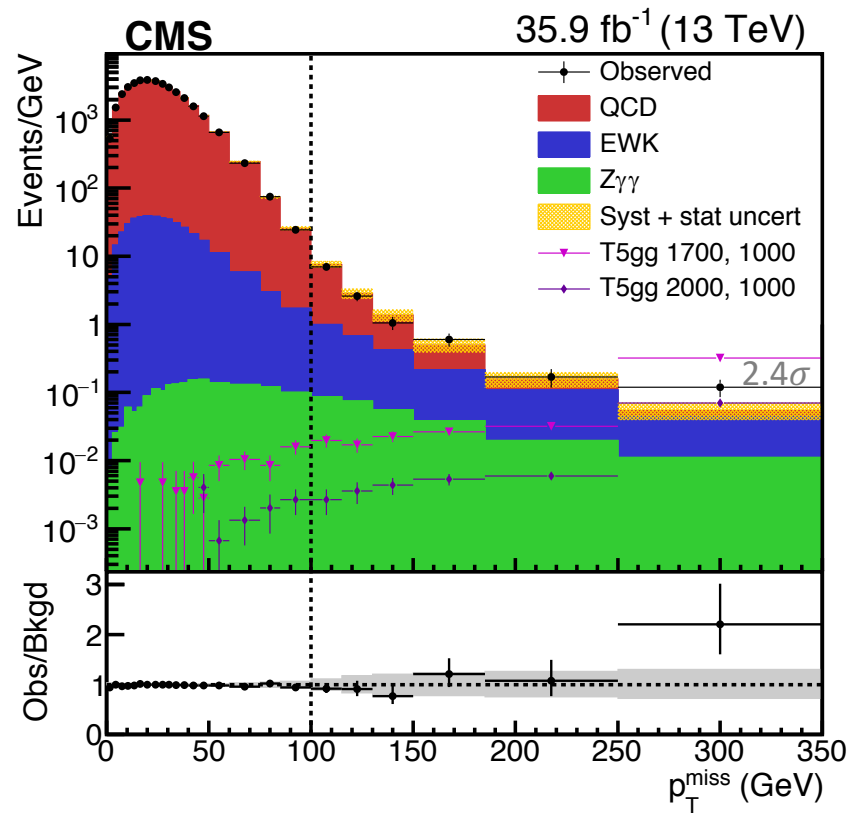


Diphoton trigger + $m_{\gamma\gamma}$.

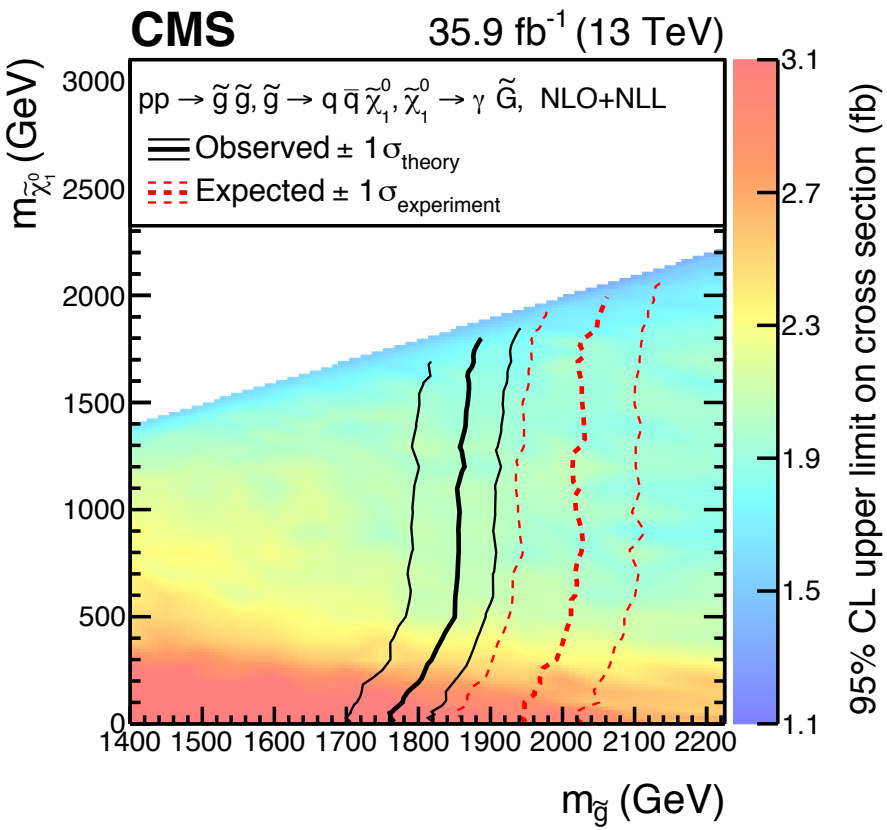
CR: MET < 100 GeV.
SR: MET > 100 GeV, 6 bins.

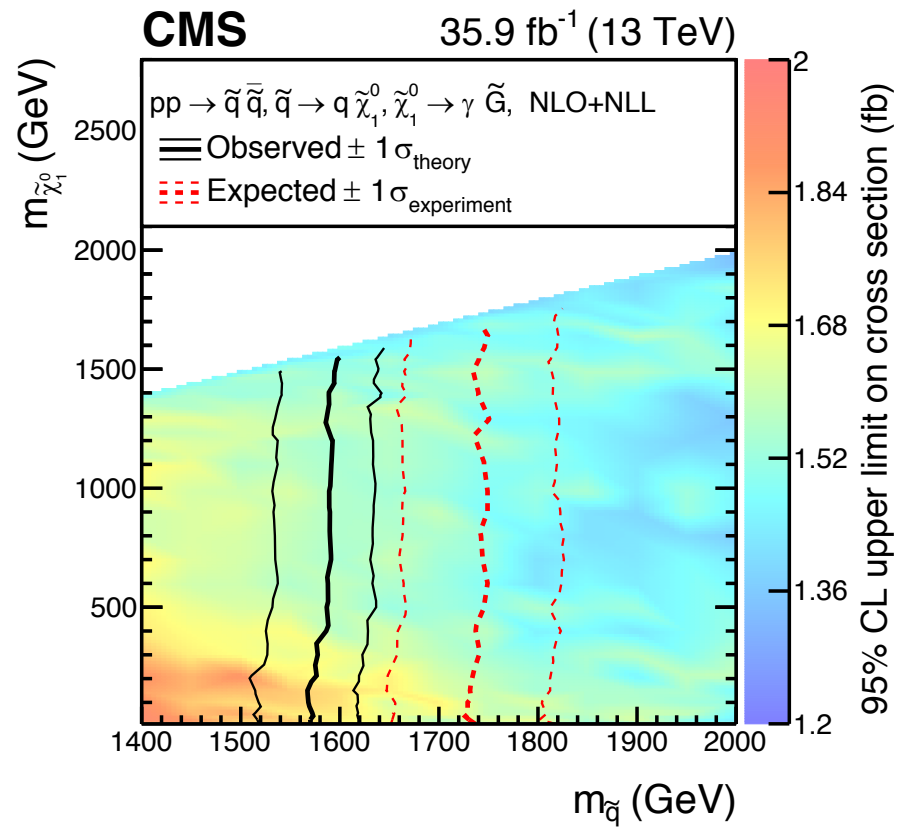
Backgrounds:

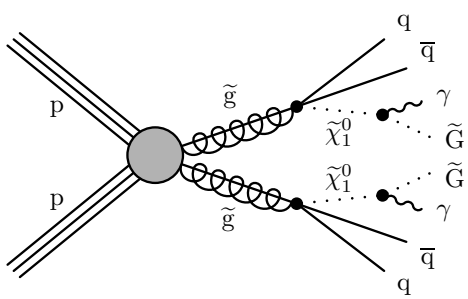
- **Multijet**: **data with fake photons (f)** failing isolation or shower shape criteria; $N_{\gamma\gamma}/N_{ff}$ fitted in CR, extrapolated to SR
- **$W(e\nu)\gamma$** with **e faking γ: from eγ data** $f_{e\to\gamma}$ from m_{ee} and $m_{e\gamma}$ peaks in data
- **$Z(\nu\nu)\gamma\gamma$** from MC

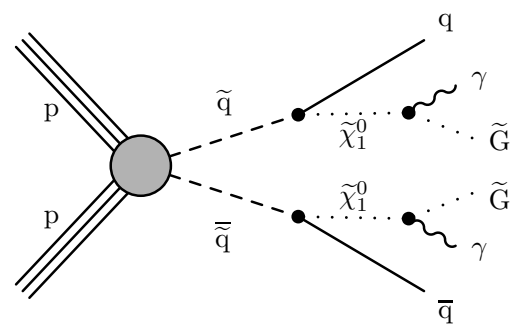


$\gamma\gamma$ + MET: results









Summary

Presented **latest searches for $\tilde{g}$ and $\tilde{q}$ at ATLAS and CMS**.

First results with **full Run-2 dataset (137-139 fb^{-1})**!

No evidence for SUSY signal yet.

Limits on $m_{\tilde{g}}$, $m_{\tilde{q}}$, $m_{\tilde{\chi}_1^0}$ improved by 100-300 GeV w.r.t. 2016 results.

Stay tuned for more SUSY results!

ATLAS: https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults

CMS: https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS

THANKS!

Coming next:
EW (S. Zambito), 3rd gen $\tilde{q}$ (I. Suarez) and **RPV (K. Mei) SUSY searches**.

Backup

0L + jets + MET: multijet bkg

Use **data events from H_T triggers**.

1. **"Rebalance" hard-scattering jets such that $p_{\mathrm{T,reb}}^{\mathrm{miss}} \simeq 0$**

$$L = \prod_{i=1}^{n} \mathrm{P}(p_{\mathrm{T},i}^{\mathrm{reco}} | p_{\mathrm{T},i}^{\mathrm{reb}}) \times G\left(\frac{p_{\mathrm{T,reb,x}}^{\mathrm{miss}}}{\sigma_{\mathrm{T}}^{\mathrm{soft}}}\right) \times G\left(\frac{p_{\mathrm{T,reb,y}}^{\mathrm{miss}}}{\sigma_{\mathrm{T}}^{\mathrm{soft}}}\right)$$

Jet response

MET resolution
$\simeq$20 GeV (min bias)

2. **Smear rebalanced jets according to jet resolution**

Multijet-enriched CRs