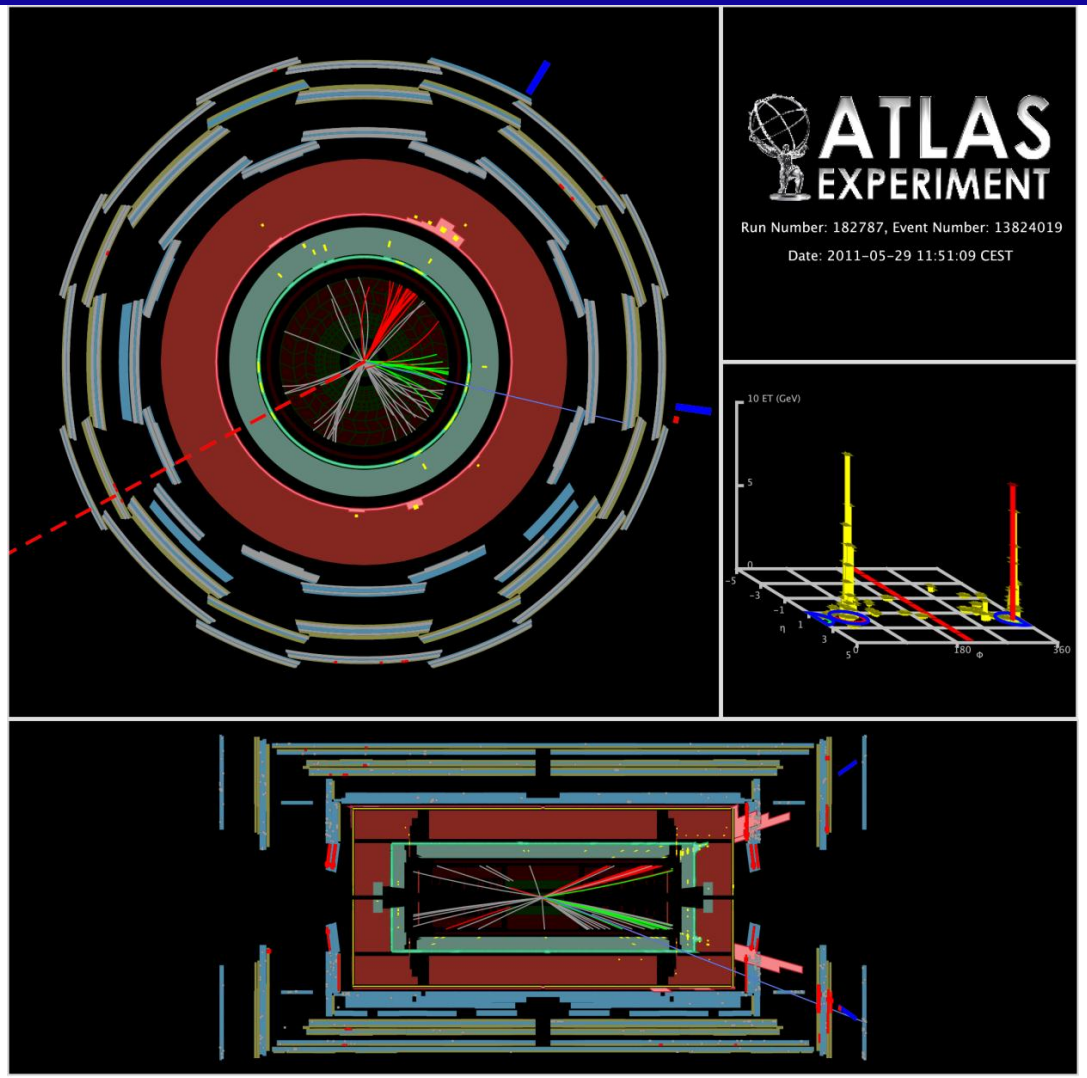
Status of ATLAS+CMS SUSY searches

Renaud Brunelière – Uni. Freiburg

Physikalisches Institut
Albert-Ludwigs-
Universität Freiburg



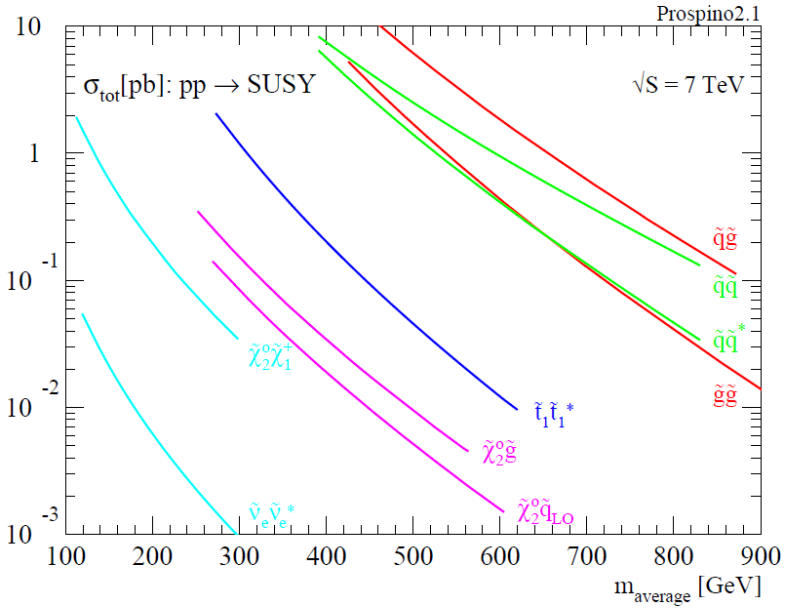
- $pp \to \tilde{b}_1 \tilde{b}_1 + X$ **candidate**
- **2 b-tagged jets pT ~ 152 GeV and 96 GeV**
- **E_T^{miss} ~ 205 GeV, M_{CT}(bb) ~ 201 GeV**

Outline

SUSY Zoo, LHC direct limits on new species:

Constrains

- **Gluino** — **Strongest**
- **Squarks (Stop)**
- **Gauginos**
- **Sleptons, others** — **Weakest**

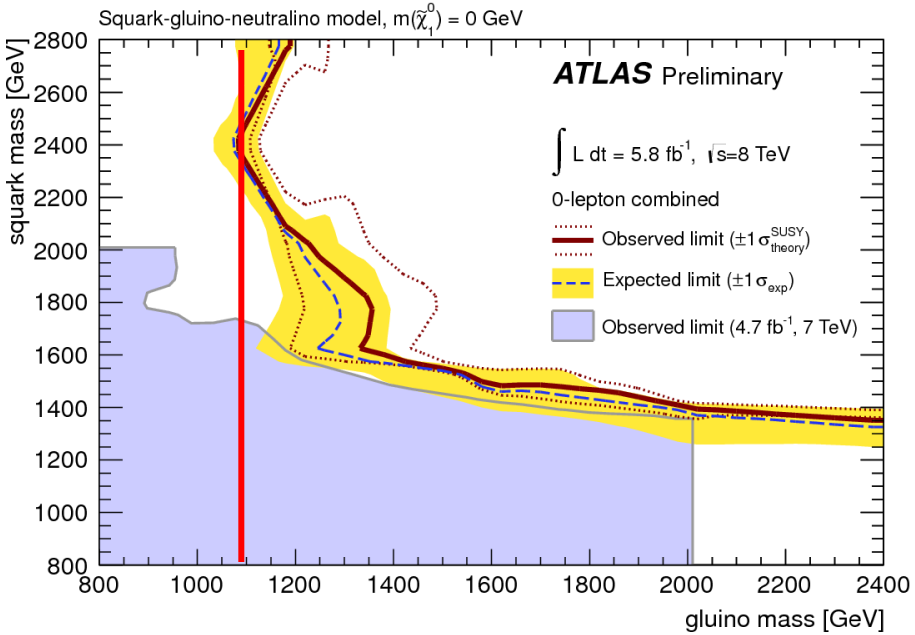


Gluino

Most studied SUSY particle at LHC :

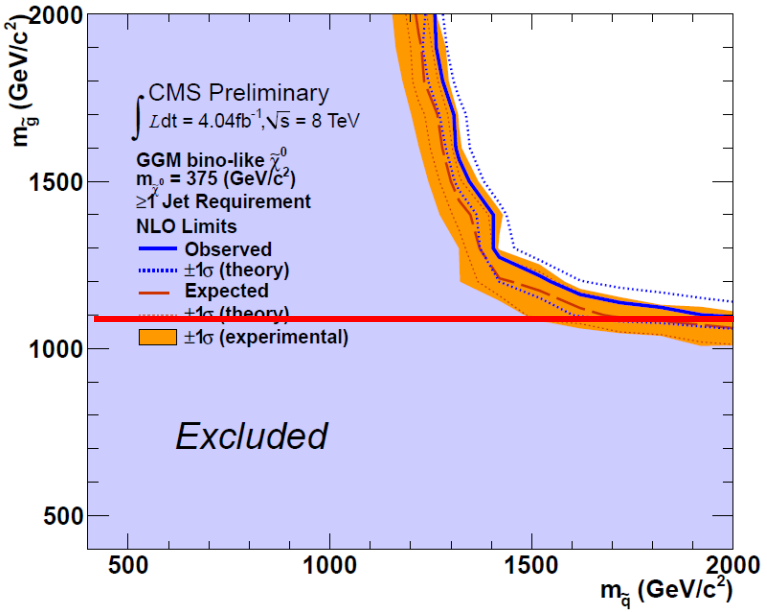
- ✓ **In association with close-by (1st or 2d gen.) squarks (M > 1 TeV)**

Neutralino LSP
2-6 jets + MET search



ATLAS-CONF-2012-109

Gravitino LSP + Bino-like neutralino NLSP
2-γ + ≥1 jet + MET search



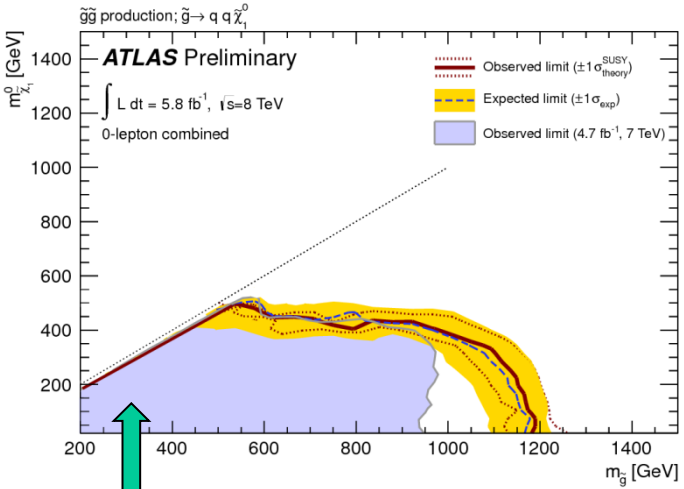
CMS PAS SUS-12-018

Limits are relatively robust wrt compression (ΔM = m(gluino)-m(LSP)) level ~ 700 GeV

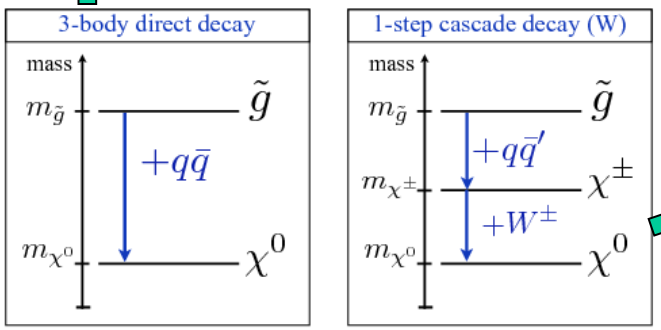
Gluino

- ✓ **Decaying directly to 1st and 2d gen. quarks with/wo intermediate gaugino (M > 0.6 - 1 TeV)**
- ✓ **Squarks are decoupled**

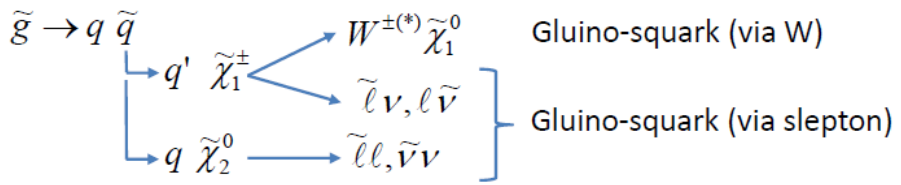
Direct decay to neutralino LSP
0-lepton + 2-6 jets + MET search

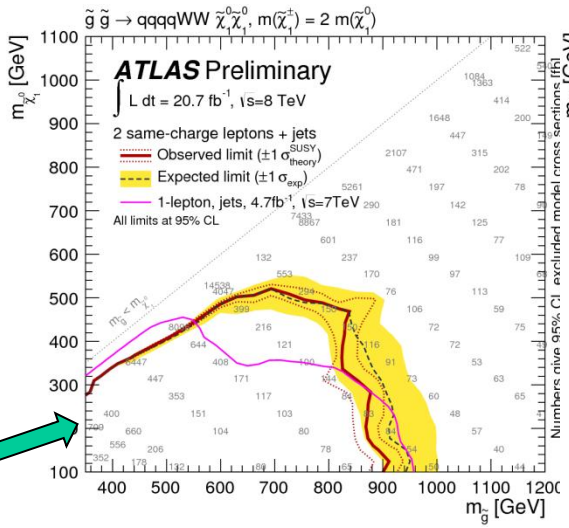


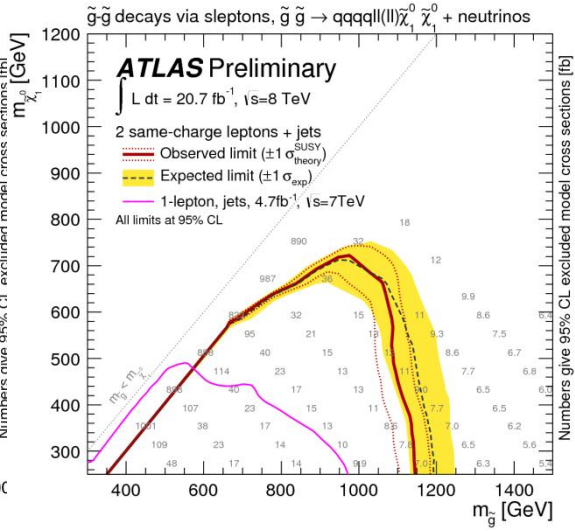
ATLAS-CONF-2012-109



Intermediate chargino/neutralino
2-SS leptons + jets + MET search





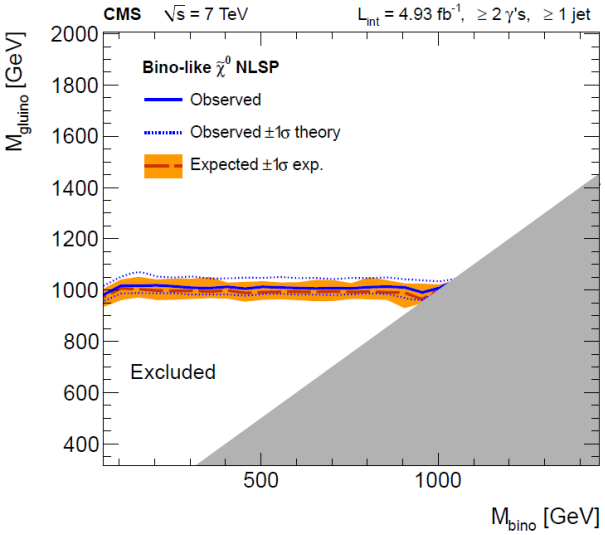


ATLAS-CONF-2013-007

Gluino

- ✓ **Decaying directly to 1st and 2d gen. quarks to a gravitino LSP (M >~ 1 TeV)**
- ✓ **Squarks are decoupled**

Gravitino LSP + Bino-like neutralino NLSP
2-γ + ≥1 jet + MET search

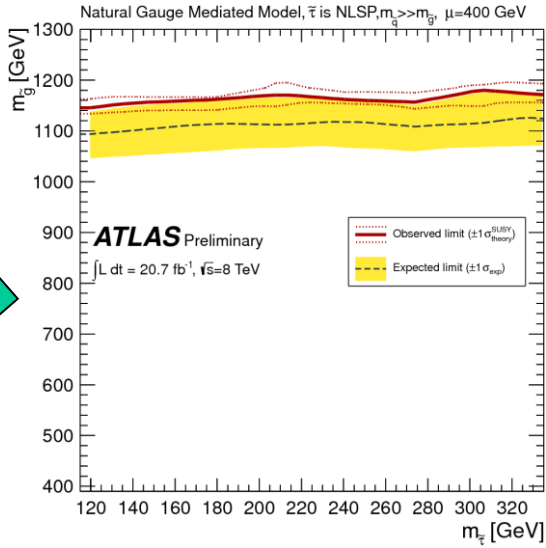


arXiv:1211.4784

1. $\tilde{g} \rightarrow g\tilde{\chi}_i^0 \rightarrow g\tau\,\tilde{\tau} \rightarrow g\tau\tau\tilde{G}$, with $i = 1,2$
2. $\tilde{g} \rightarrow q\bar{q}\tilde{\chi}_i^0 \rightarrow q\bar{q}\tau\,\tilde{\tau} \rightarrow q\bar{q}\tau\tau\tilde{G}$, with $i = 1,2$
3. $\tilde{g} \rightarrow qq'\tilde{\chi}_1^{\pm} \rightarrow qq'\tilde{\nu}_\tau\,\tilde{\tau} \rightarrow qq'\tilde{\nu}_\tau\tau\tilde{G}$

Indirect constrains on light stau

Gravitino LSP + stau NLSP
≥2 τ + ≥4 jets + MET search

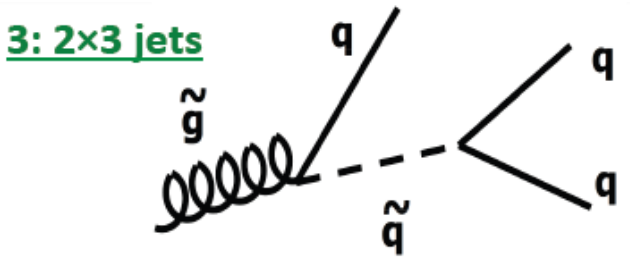


ATLAS-CONF-2013-026

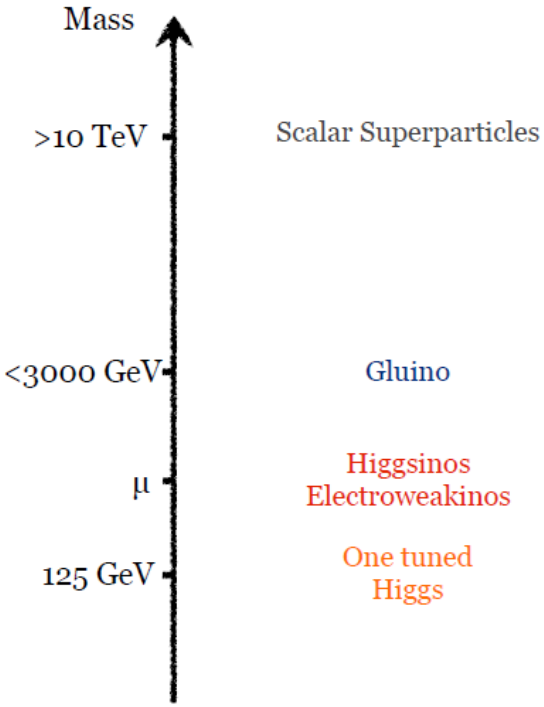
+ other searches with Z+γ, W+γ, b-jet+γ to cover different mixture of the neutralino

Gluino

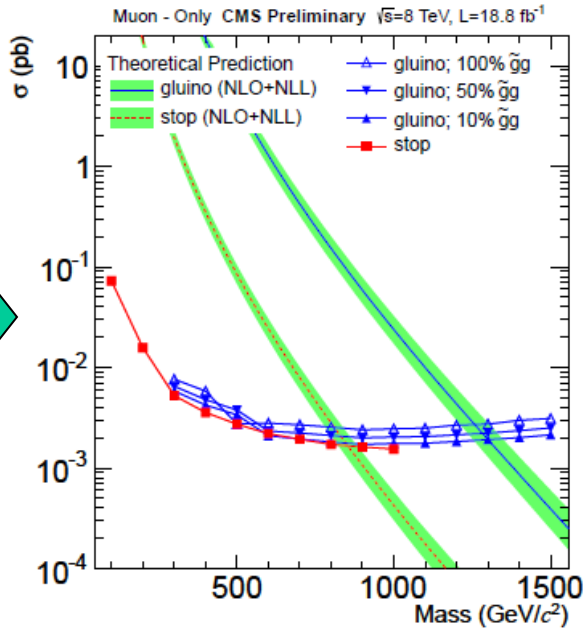
- ✓ Long-lived gluino (M >~ 1.3 TeV)
- ✓ R-parity violating gluino decaying to 3 jets (>~ 300 (unresolved) – 600 GeV (resolved))



Split-SUSY predicts LL gluinos

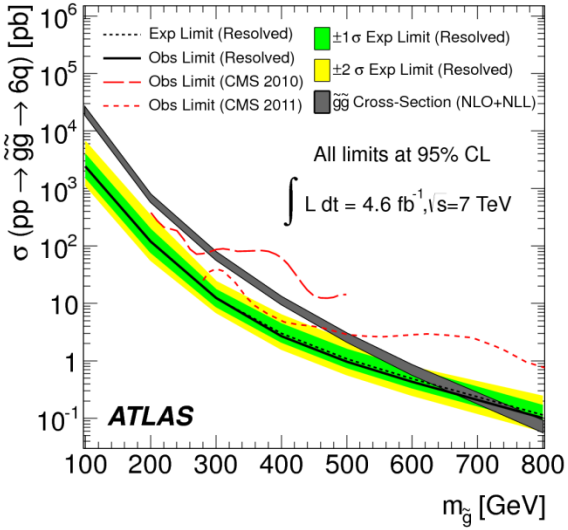


Long-lived gluino constrained with muon detector TOF



CMS-PAS-EXO-12-026

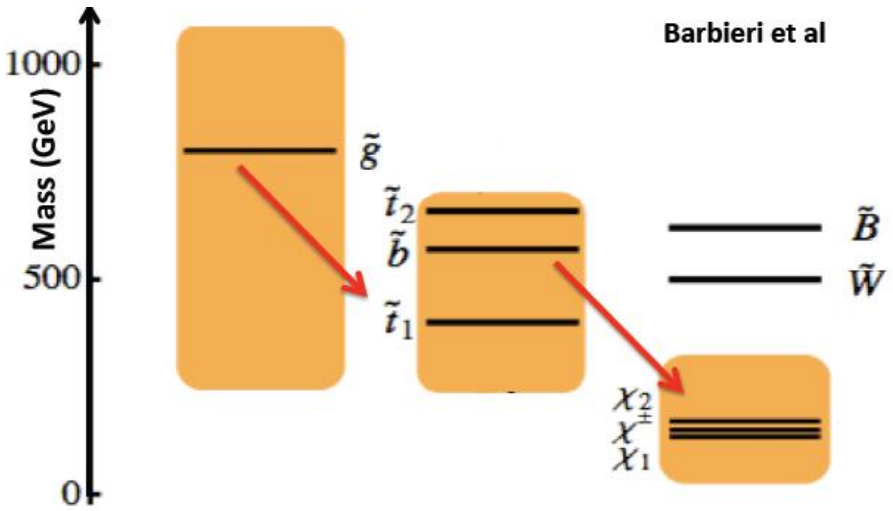
Gluino decaying to a 3-jet resonance

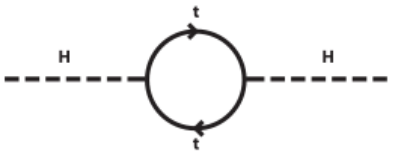


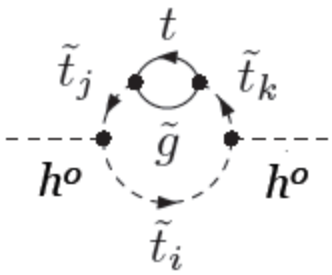
arXiv:1210.4813

Gluino – "Natural" SUSY spectrum

- ✓ Concentrate on minimal content needed to stabilize the Higgs mass
- ⇒ Highlight on 3rd generation squarks
- ⇒ Gluino cannot be too heavy (<~ 1.5 TeV)
- ⇒ Other sparticles can be anywhere



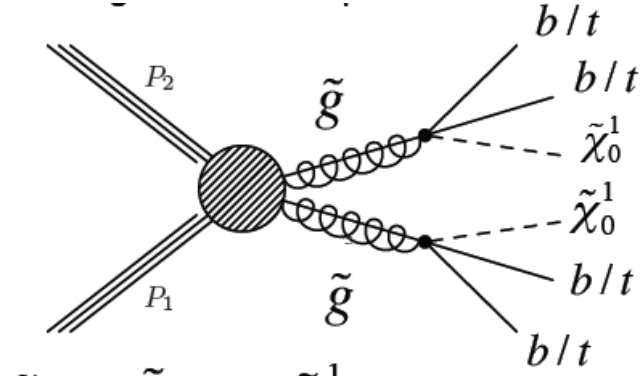




- ✓ **Lot of emphasis put on searches with gluino decaying to:**

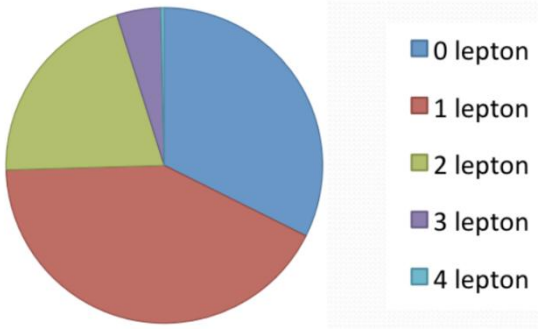
1. **On-shell stop/sbottom**
2. **Directly to top/bottom quarks via off-shell stop/sbottom**

Gluino mediated stop/sbottom search strategy



$$\tilde{g} \rightarrow t\bar{t} \rightarrow tt\tilde{\chi}_0^1$$
$$\tilde{g} \rightarrow b\bar{b} \rightarrow bb\tilde{\chi}_0^1$$

Final states with 4 W (top)
Lepton = e or mu

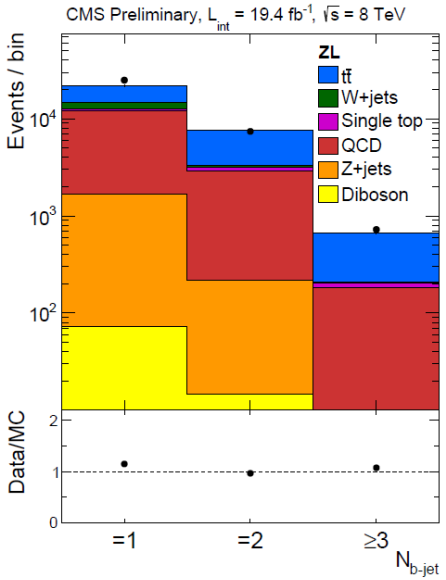


Expect final states with

- ✓ **MET or leptons => reduce QCD multijet background**
- ✓ **Multiple b-tagged jets (≥1-3 b) => reduce W/Z+jets (ttbar) background**
- ✓ **Multiple leptons (possibly SS) => reduce top pairs background**
- ✓ **Multiple jets (≥6 jets) => reduce top pairs background**

Main background: top pairs

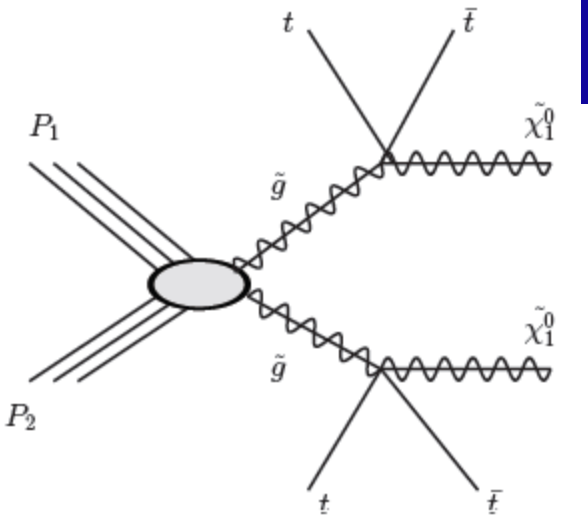
+small irreducible background: ttbar+W/Z, ttbar+bbbar

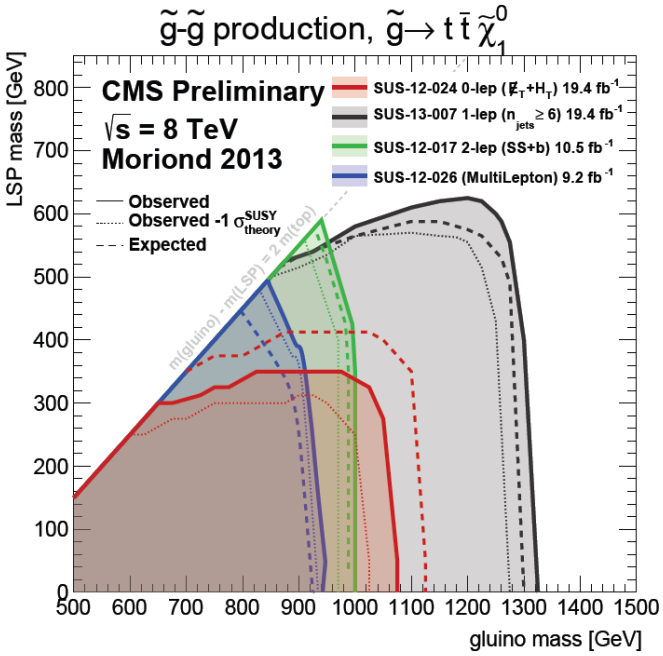


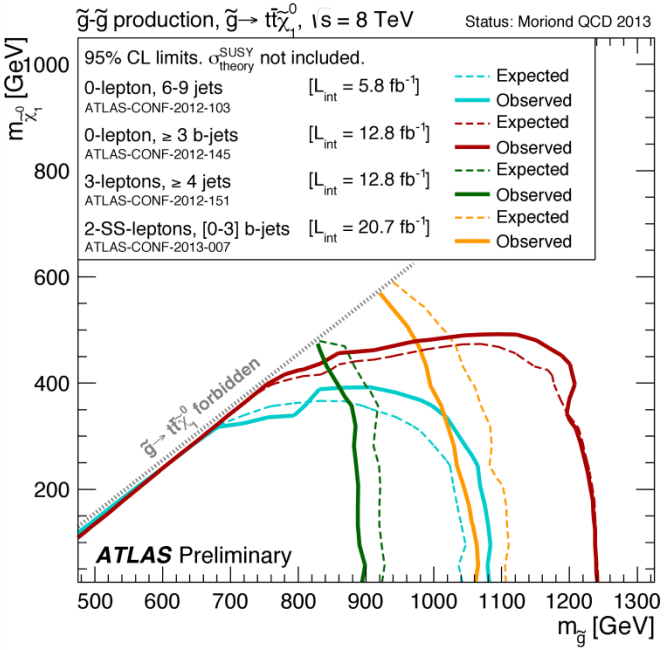
CMS-PAS-SUS-12-024

Gluino

- ✓ **Decaying directly to top quarks and a neutralino LSP (M >~ 1 – 1.3 TeV)**



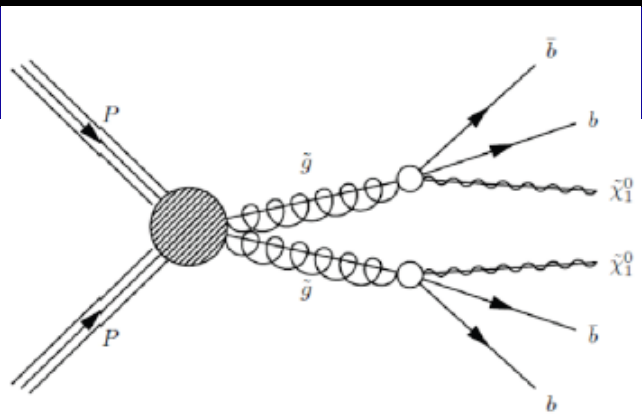


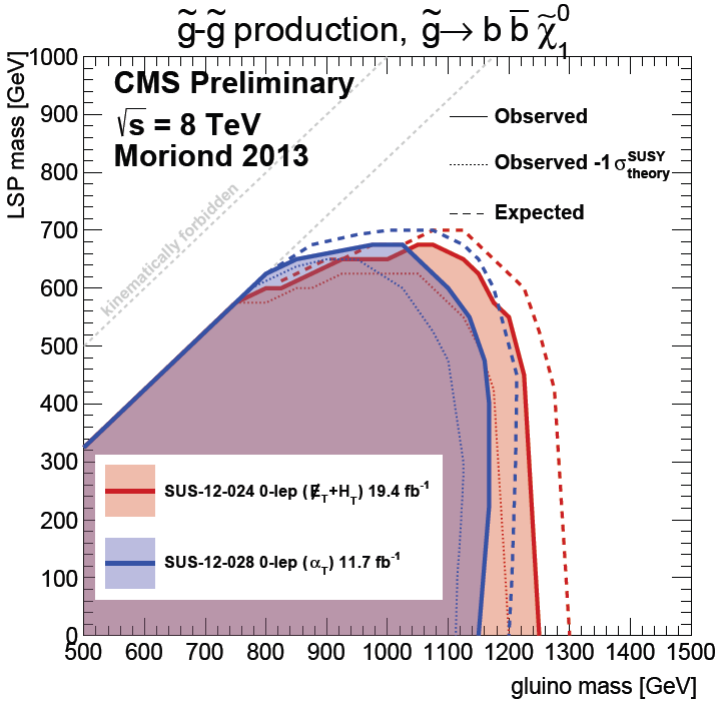


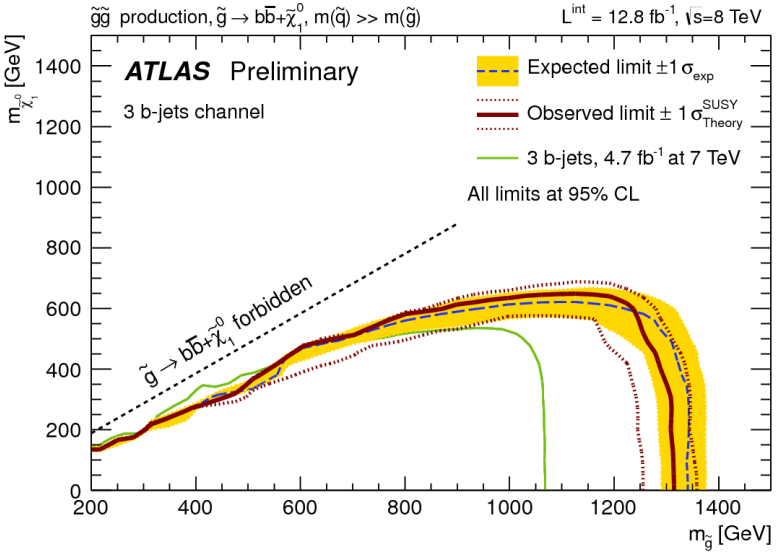
- ✓ **Very strong limits consolidated by multiple channels !**

Gluino

- ✓ **Decaying directly to 4- bottom quarks and a neutralino LSP (M >~ 0.8 – 1.2 TeV)**







ATLAS-CONF-2012-145

Gluino

✓ Decaying to on-shell sbottom and stop (M >~ 1 TeV)

$\tilde{g} \to b\,\tilde{b}_1$

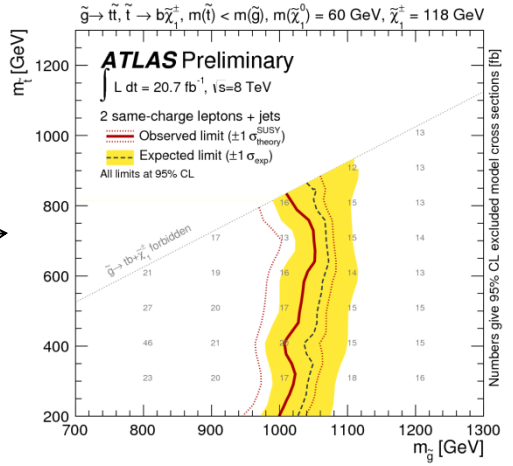
- $t\,\tilde{\chi}_1^{\pm}$ → Gluino-stop ($b\tilde{\chi}_1^{\pm}$) degenerate ($m_{\tilde{\chi}_1^{\pm}}, m_{\tilde{\chi}_1^0}$)

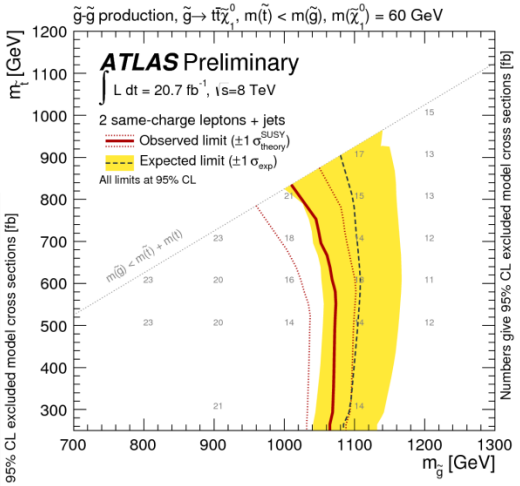
$\tilde{g} \to t\,\tilde{t}_1$

- $b\,\tilde{\chi}_1^{\pm}$ → Gluino-stop ($b\tilde{\chi}_1^{\pm}$) on-shell

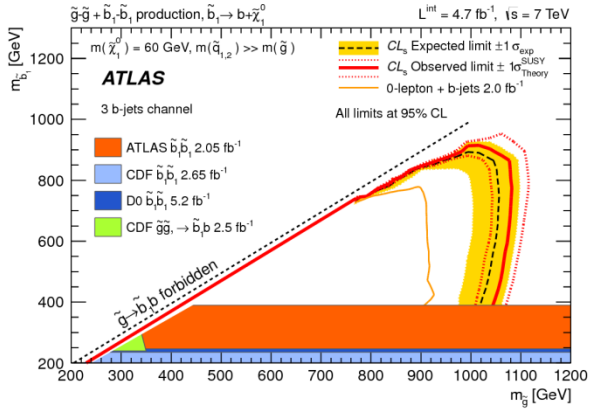
$\tilde{\chi}_1^{\pm} \to W^{\pm(*)}\tilde{\chi}_1^0$

- $t\,\tilde{\chi}_1^0$ → Gluino-stop ($t\tilde{\chi}_1^0$) off-shell ($m_{\tilde{g}} < m_{\tilde{t}} + m_t$)
- $t\,\tilde{\chi}_1^0$ → Gluino-stop ($t\tilde{\chi}_1^0$) on-shell ($m_{\tilde{g}} > m_{\tilde{t}} + m_t$)
- b s → Gluino-stop (bs) RPV

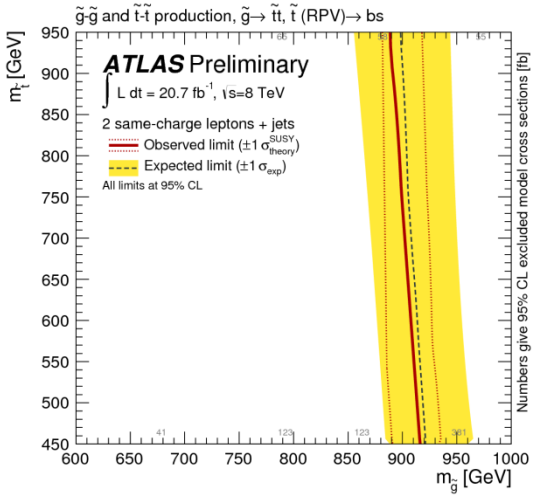




Gluino->sbottom, Sbottom->b neu1



arXiv:1207.4686



Allanach, Gripaios, Gluino hidden because of RPV ? arXiv:1202.6616

2-leptons SS search ATLAS-CONF-2013-007

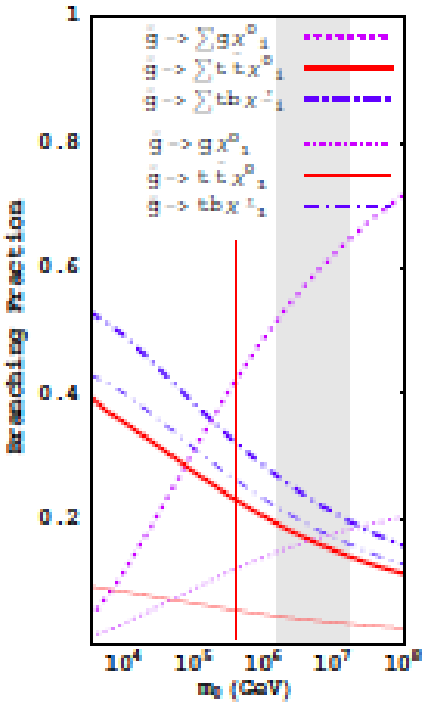
Gluino - Summary

- ✓ **Extensive list of studies on Gluino at LHC7 & 8**
- ✓ **Most of them lead to constrains on gluino mass ~ 1 TeV**

=> If gluino is < 1 TeV, it is well hidden !

- ✓ **Most limits are given for Simplified Model => single decay chain assuming 100% Branching ratio**
- ✓ **What is current best LHC limit for more complex scenario cannot be easily deduced**
- ✓ **Moving toward a more complex description of possible decay chain than in Simplified Models ?**

Decays in Split-SUSY
Toharia, Wells,
arXiv:hep-ph/0503175

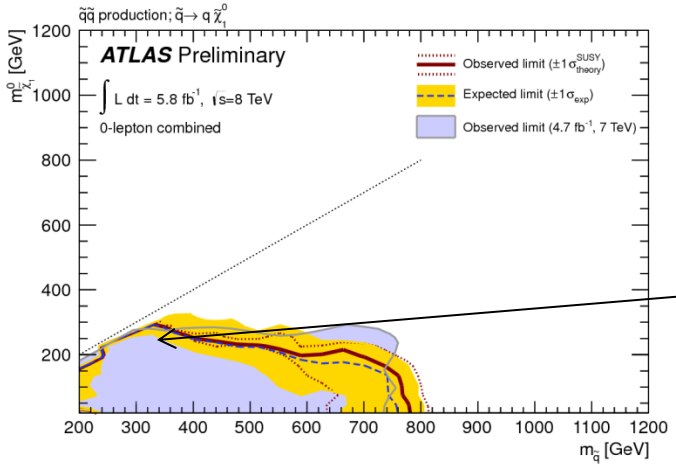


Squarks

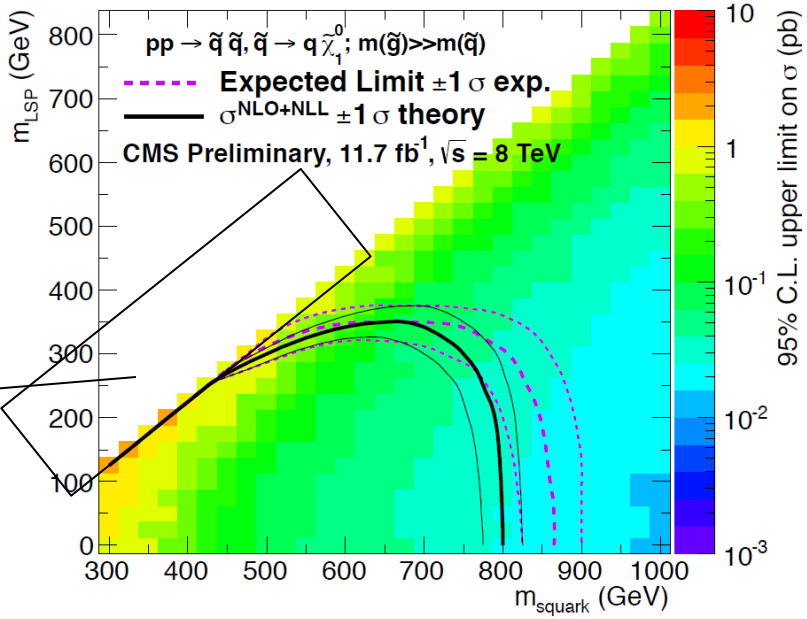
- ✓ **2d most studied SUSY species**
- ✓ **Because of naturalness problem, lot of emphasis put on 3rd gen. squarks**
- ✓ **Remark: provided gluino is heavy, limits on 1st and 2d gen. squarks are weaker than gluino**

Even weaker when

- ✓ **starting to raise 8-fold mass degeneracy**
- ✓ **or multiply possible decay chains**

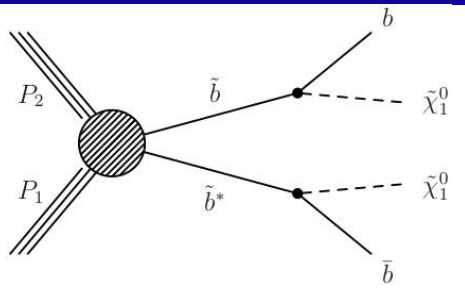


ATLAS-CONF-2012-109

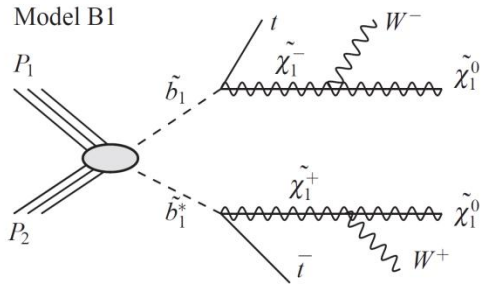


arXiv:1303.2985

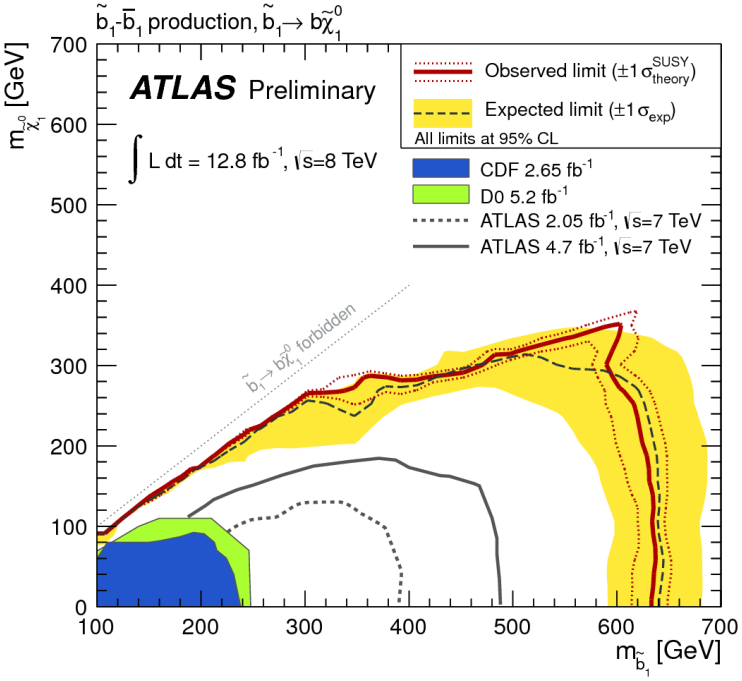
Sbottom



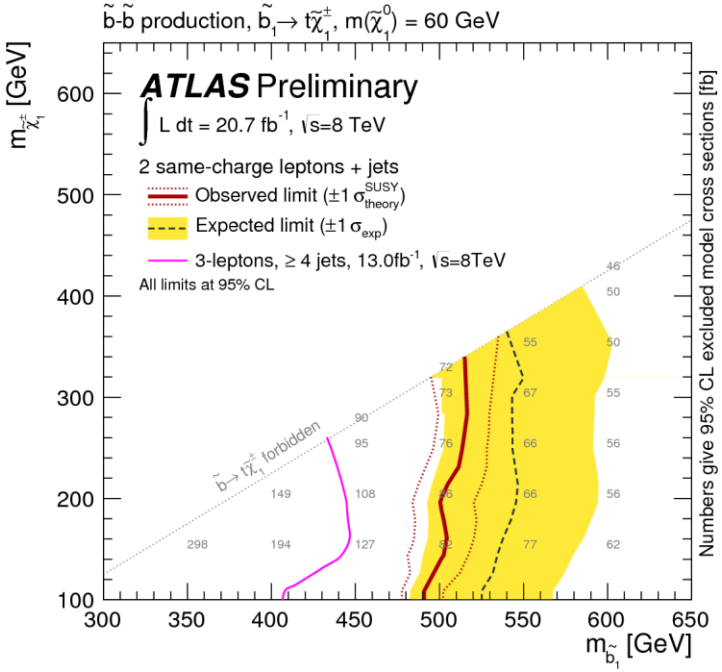
Final state with 0-lepton + 2 b-jets +1 extra ISR jet (when compressed)



Final state with 4 W bosons + 2 b-jets !



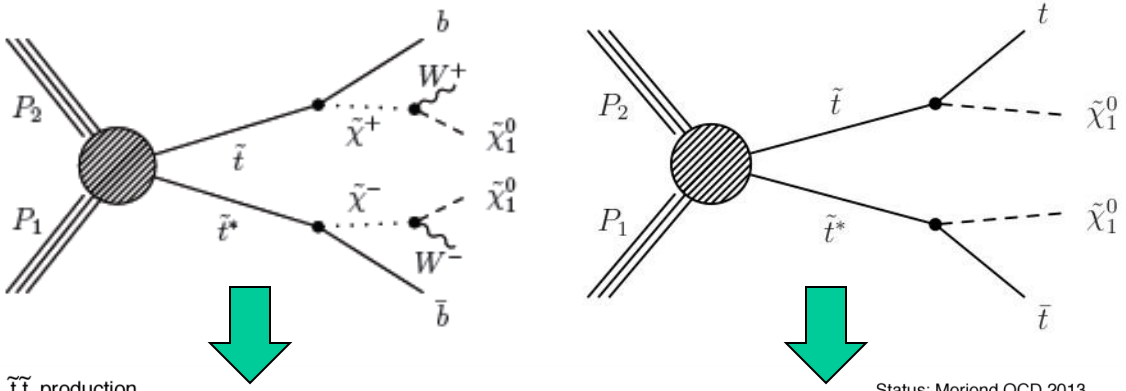
ATLAS-CONF-2012-165

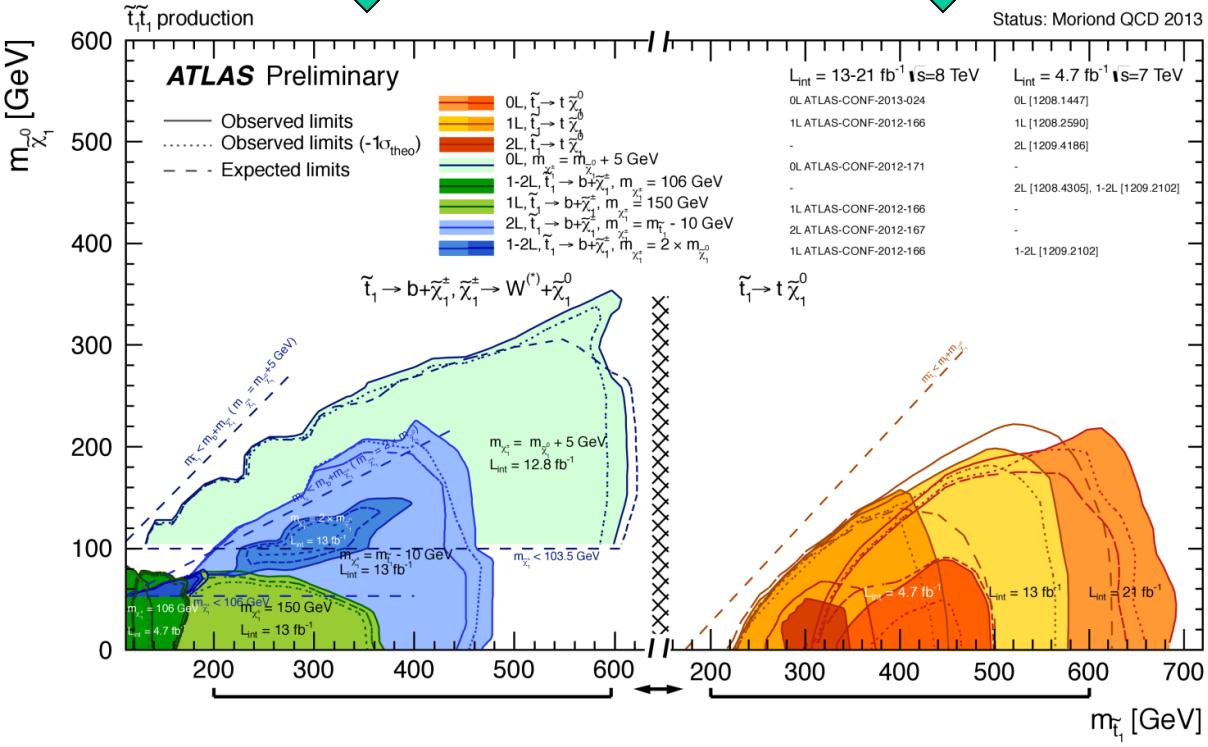


ATLAS-CONF-2013-007

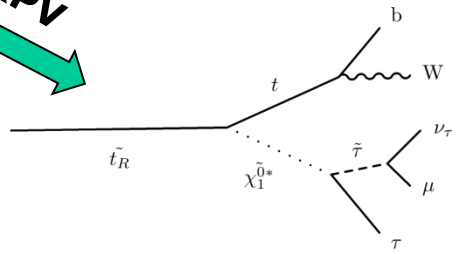
✓ **Limits on bottom squark mass ~ 500 – 600 GeV (assuming BR = 1)**

Stop !

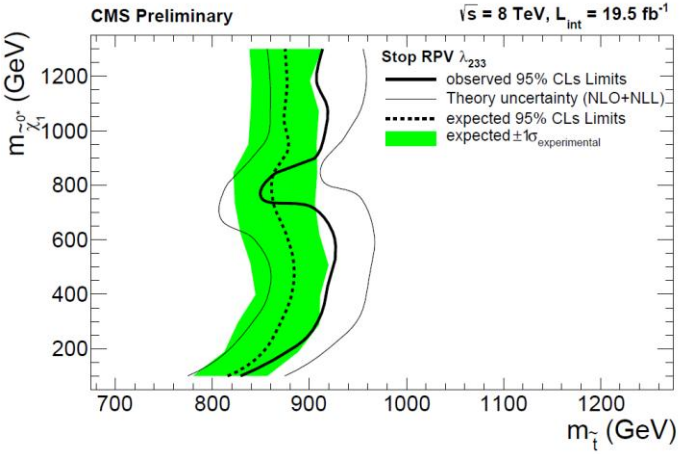




RPV



Final state with 3 leptons + ≥1 b-jets

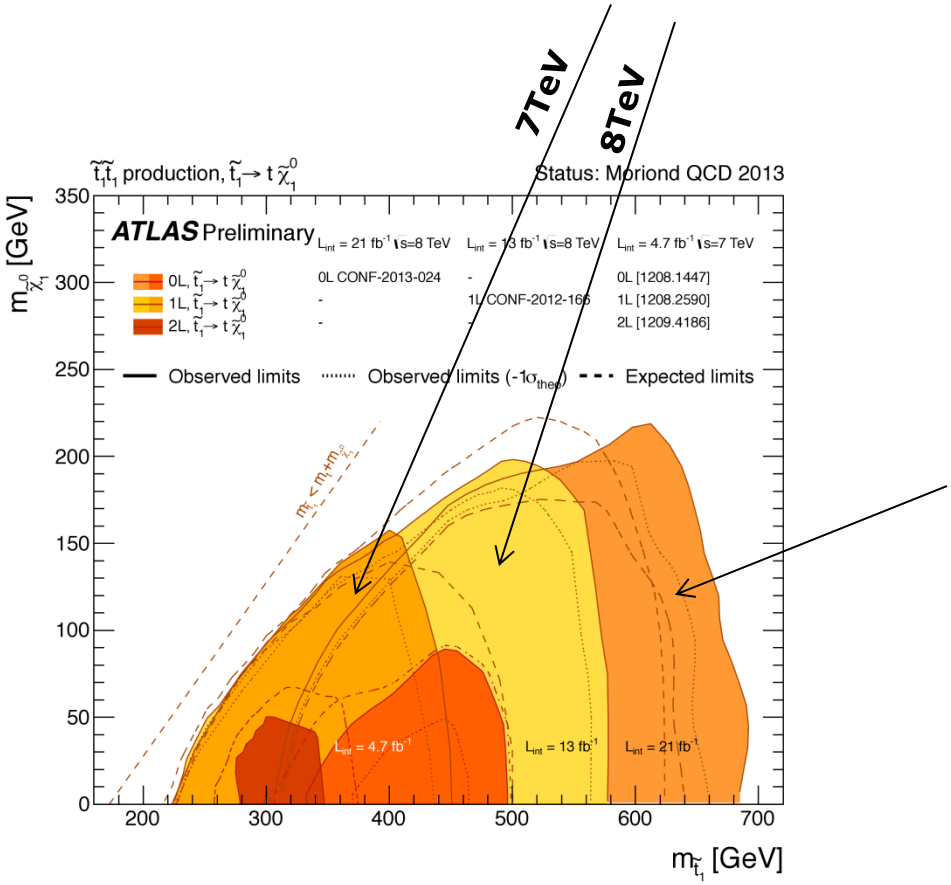


CMS-PAS-SUS-13-003

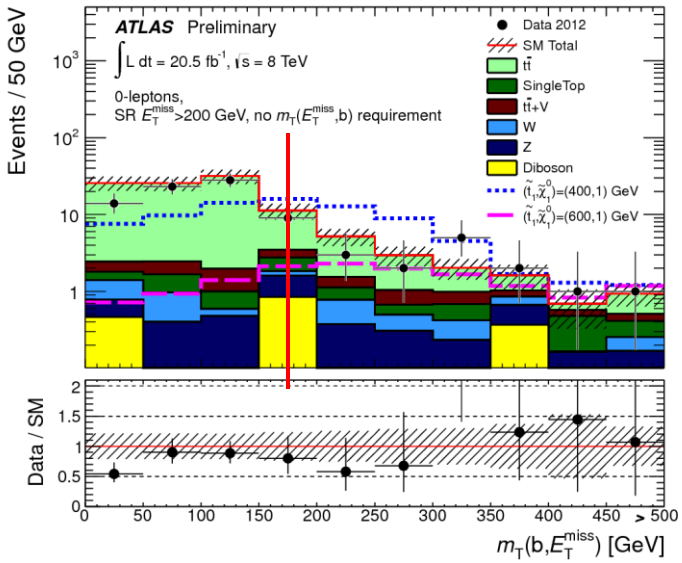
Stop -> charm + neutralino1 ? Not ready yet…

Stop -> top + neutralino

- **Final state with ==1-lepton + MET + ≥4 jets + ≥1 b-jets**
- **Main bkg: top pairs, ttbar+V, W+HF**



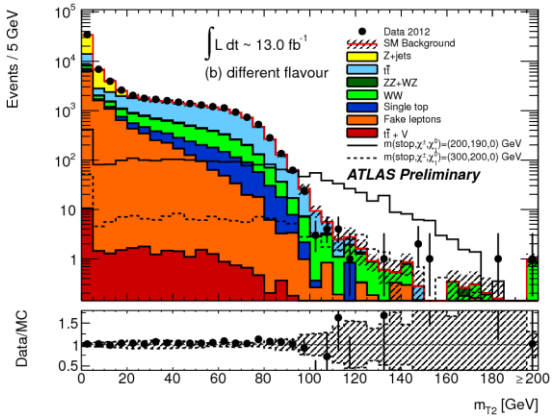
- **Final state with 0-lepton + MET + ≥6 jets + ≥2 b-jets**
- **Main bkg: top pairs, ttbar+Z(→νν), Z →νν+jets**



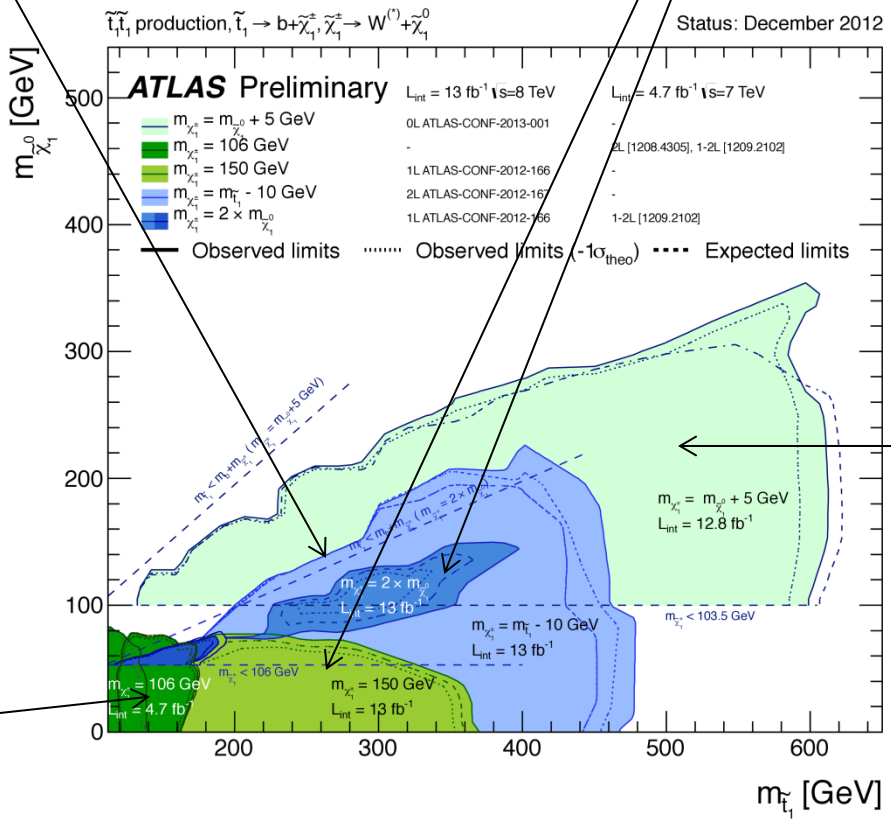
✓ **Top squark mass excluded up to ~ 650 for m(LSP)<200 GeV (BR = 1)**

Stop -> b + chargino

- **Small mass splitting between stop and chargino**
- **Final state with ==2 OS leptons + MET**
- **Discriminating variable: mT2**



- **m(stop) < m(top), m(chargino) = 106 GeV**
- **Final state with 1 or 2 OS leptons ≥2 b-jets + MET**
- **Discriminating variable: "Florida" variable shat_min**

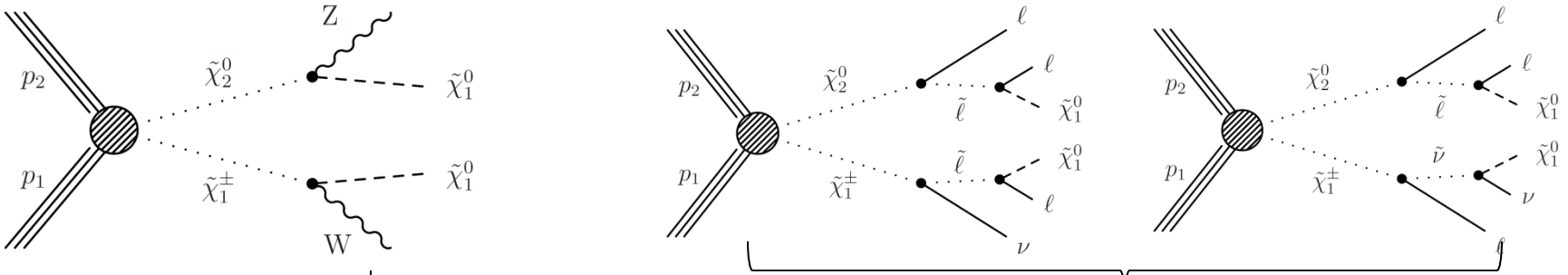


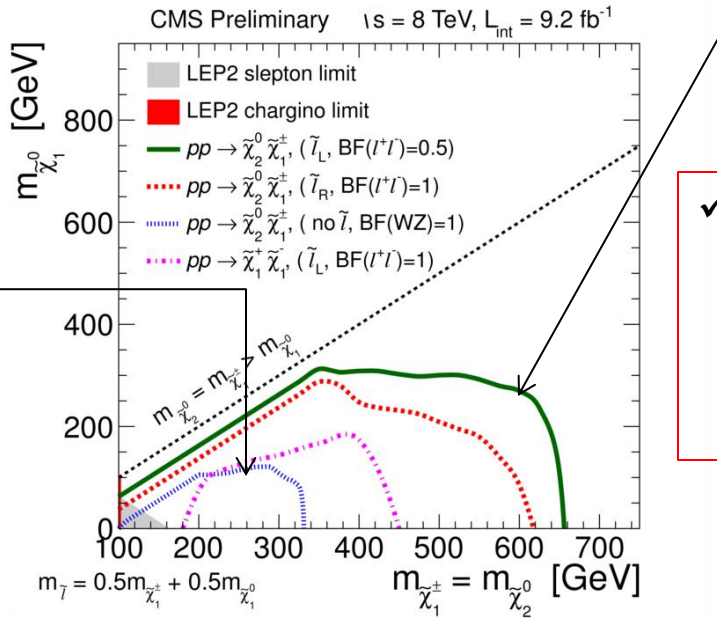
- **Same analysis than 1-lepton stop->top+LSP but different SR**
- **Final state with ==1-lepton + MET + ≥4 jets + ≥1 b-jets**

- **Degenerated neutralino-chargino case**
- **Same analysis as sbottom->b+LSP**
- **Final state with 0-lepton + MET + 2 b-jets**

Electroweakinos

- ✓ R-parity conserving search mainly through 3-leptons (including hadronic tau) + MET channel
- ✓ BR to leptons can be enhanced via intermediate sleptons
- ✓ Assume bino-like neutralino1 and wino-like neutralino2 and chargino1





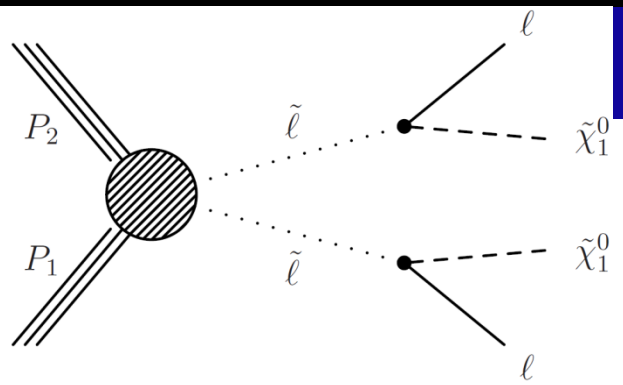
CMS-PAS-SUS-12-022

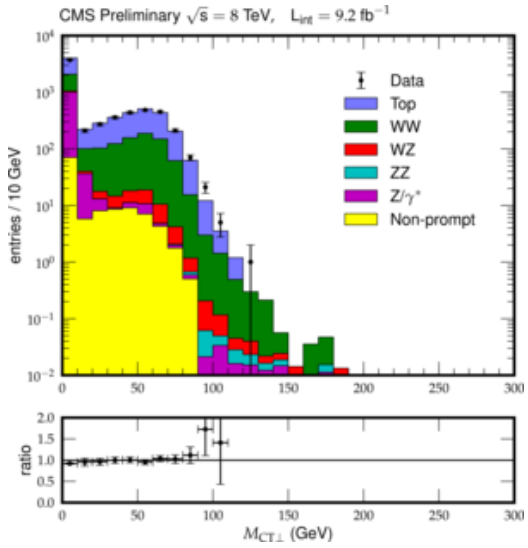
- **Background dominated by WZ and fake-lepton (from ttbar, WW, Z->ll)**

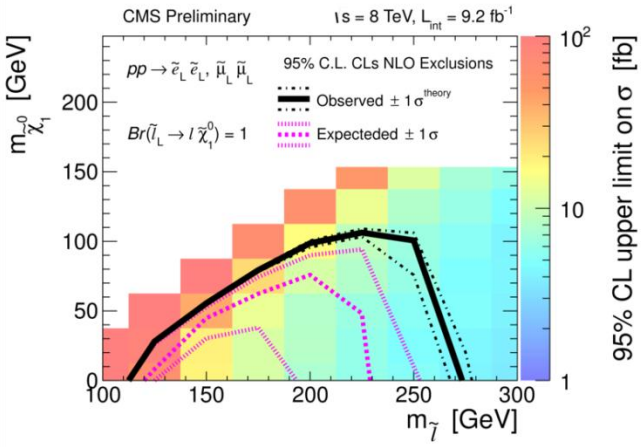
✓ **In absence of intermediate sleptons, limits on EWinos are relatively modest ~ 330 GeV for a massless LSP**

Sleptons (staus)

- ✓ Search for two opposite sign same flavor leptons or hadronic taus
- ✓ Discriminating variables like mCT, mT2

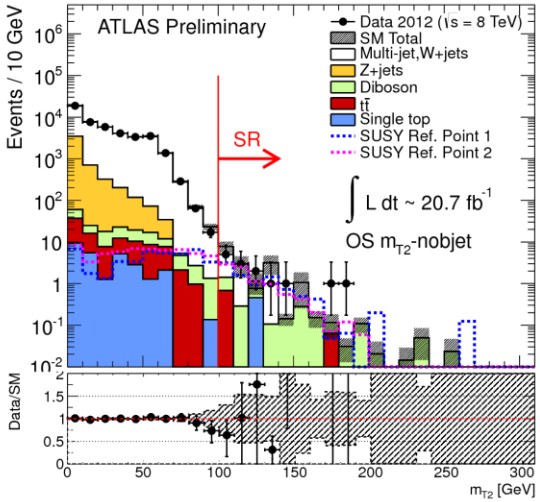


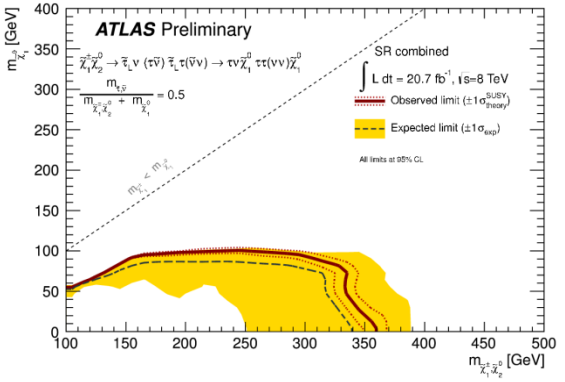




CMS-PAS-SUS-12-022

2 hadronic tau + MET search
Interpretation in term of chargino/neutralino2 decaying to on-shell stau/sneutrino_tau





ATLAS-CONF-2013-028

- ✓ **No constrains yet on direct light stau production**

=> Still a viable scenario

Summary

- **Gluino is most constrained SUSY particle at LHC**
  - **Except for specific scenarios, limits are often ~ 1 TeV**
  - **A complete picture is still lacking, but models builders should be careful about LHC direct gluino limits**
  - **LHC13 will radically improve limits**

- **Sbottoms and stops can be excluded up to 500-650 GeV**
  - **As for gluino, a complete picture, in particular in term of decay chains, is still lacking**

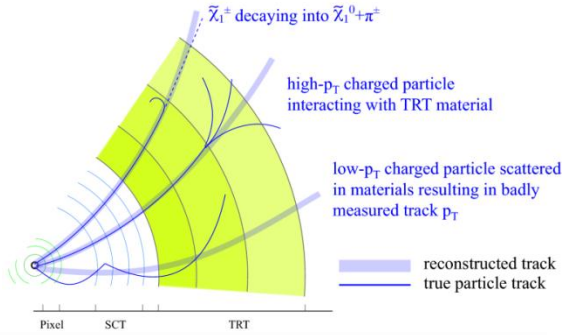
- **Other susy particles are still very weakly (un)constrained**
  - **Gives freedom for theorists to play with indirect constrains (DM, Higgs couplings,…)**
  - **Provided masses of these particles are not directly related to the gluino**

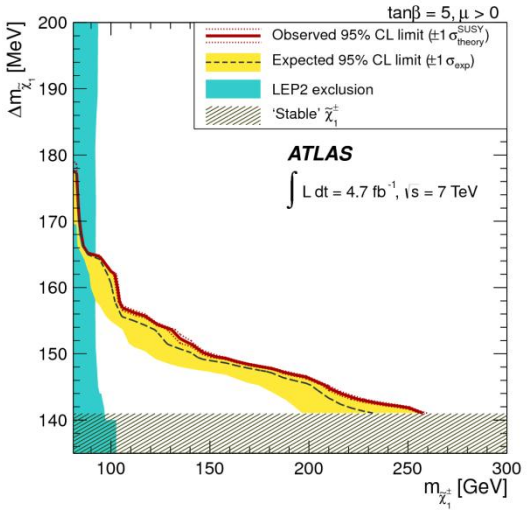
Long-lived gauginos

Wino-like long-lived chargino (AMSB)

- **High pT jet + MET**
- **High pT disappearing track**

$$pp \to \tilde{\chi}_1^{\pm}\tilde{\chi}_1^0 j, \quad pp \to \tilde{\chi}_1^+\tilde{\chi}_1^- j$$
$$\tilde{\chi}_1^{\pm} \to \tilde{\chi}_1^0\pi^{\pm} \quad \text{branching ratio set to 100\%}$$





arXiv:1210.2852

Bino-like long-lived neutralino (GMSB)

- **Non-pointing photons**
- **TOF and shower shape in electromagnetic calorimeter**