Current status of RPV searches at ATLAS

The following super potential is allowed in SUSY

$$W = \frac{1}{2}\lambda_{ijk} L_i L_j \overline{E}_k + \lambda'_{ijk} L_i Q_j \overline{D}_k + \frac{1}{2}\lambda''_{ijk} \overline{U}_i \overline{D}_j \overline{D}_k + \kappa_i L_i H_2$$

λ, λ' terms are lepton flavor violating (LFV).

λ'' terms are baryon number violating.

Lack of proton decay requires products like $|\lambda'^* \lambda''|$ must be extremely small (~10^{-27} in some cases).

R-parity $\equiv (-1)^{3(B-L)+2S}$ = 1 for ordinary particles, -1 for superparticles.

If R-parity is conserved, the superpotential above is zero, proton decay is protected, and the LSP is stable, potentially providing a dark matter candidate.

However, this is not required and we should look for these R-parity violating (RPV) terms.

Recent searches at ATLAS

Sneutrino resonance decaying to $\ell\,\ell'$ ($\lambda\,\lambda'$).

t-channel exchange of a stop (λ').

Muon plus displaced vertex (λ').

Multilepton events (λ).

Multijet events(λ'').

Discussed here

Long-lived R-Hadrons, submitted to Phys. Rev. D, arXiv:1310.6584.

Stable charged particles, ATLAS-CONF-2013-058, cds.cern.ch/record/1557775.

Multijet + E_t^{miss} with a gluino-mediated RPV stop interpretation, JHEP10(2013)130.

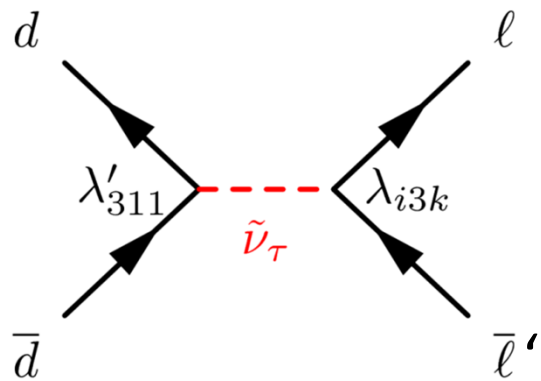
2 same-sign leptons + b-jet + E_t^{miss} with a gluino-mediated RPV stop interpretation, ATLAS-CONF-2013-007, cds.cern.ch/record/1522430.

Some Techniques and Tools

1. Select a scenario that is interesting and potentially yields an event topology distinguishable from backgrounds.
2. Real leptons are modeled well in Monte Carlo.
3. Misidentified leptons, QCD jets, and detector effects are usually studied in data samples, often using control regions with similar kinematics and other properties to the signal region but with small expected signal.
4. The rates in the control regions are usually extrapolated to the signal region using Monte Carlo.
5. For the displaced vertex analysis, sophisticated estimates of hadronic interactions, including with gas molecules, and of randomly associated tracks significantly reduced the backgrounds.
6. For hadronic final states (e.g. UDD, λ''), boosted object techniques can be employed to mitigate backgrounds and aid in data-driven estimates (see, e.g., arXiv:1305.4945 and arXiv:1210.4813).

Sneutrino resonance

Production and decay are RPV



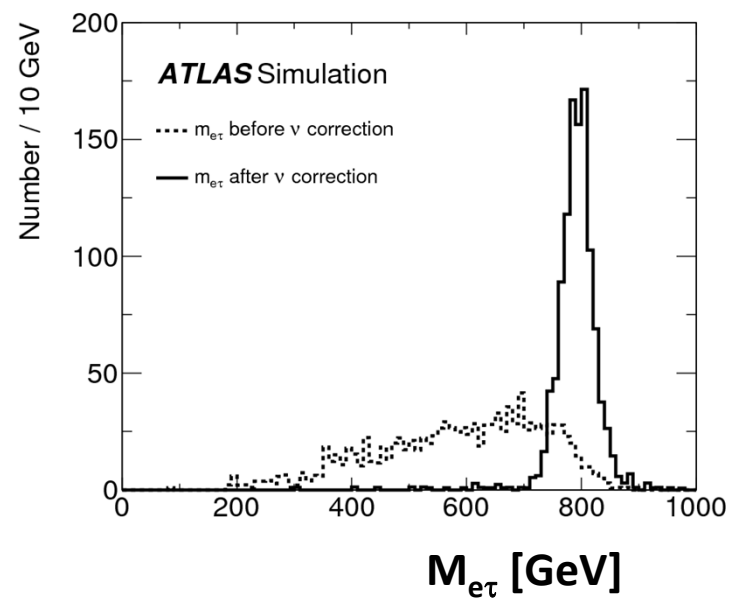
plus complex conjugates

Events with exactly 2, distinct flavor, high Pt, back-to-back leptons (eμ, eτ, μτ).

For τ candidates, use 1-prong hadronic decays and determine momentum of ν from

1. **ν_τ is nearly in direction of τ ($P_\tau >> m_\tau$).**
2. **$\vec{P}^{\nu}_{T} = \vec{E}_t^{miss}$ and $\theta_\nu = \theta_\tau$.**

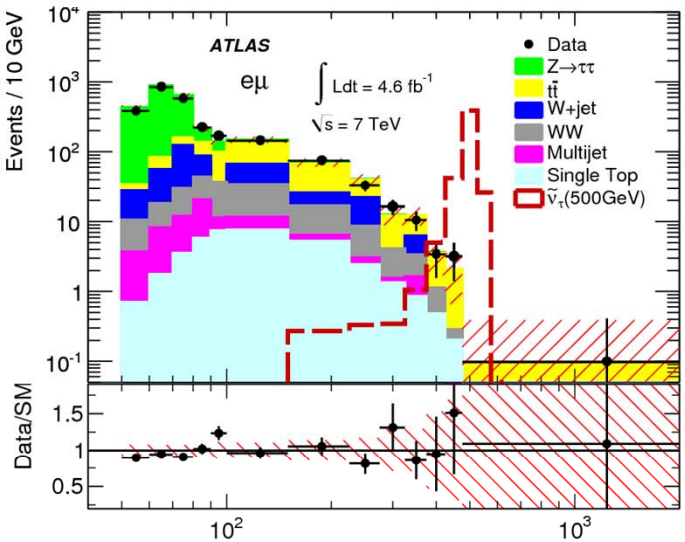
Phys. Lett. B723 (2013) 15-32. 7 TeV, 4.6 fb^{-1}



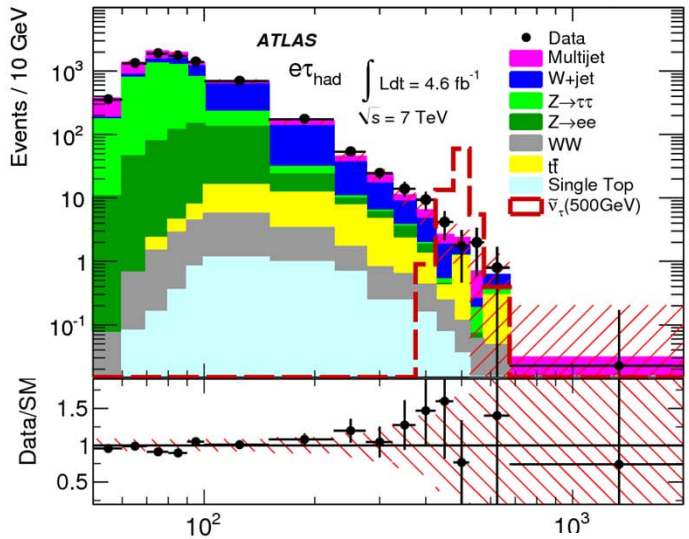
Sneutrino resonance $m_{\ell\ell'}$

Look at dilepton mass.
No excess seen

eμ

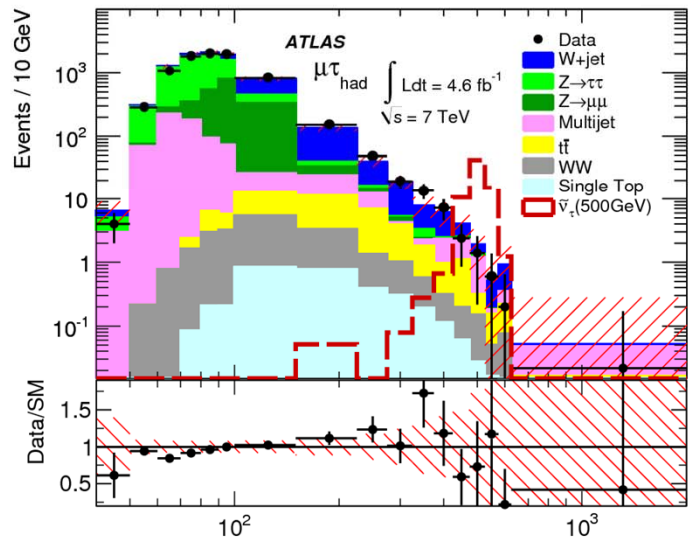


$M_{e\mu}$ [GeV]



eτ

$M_{e\tau}$ [GeV]



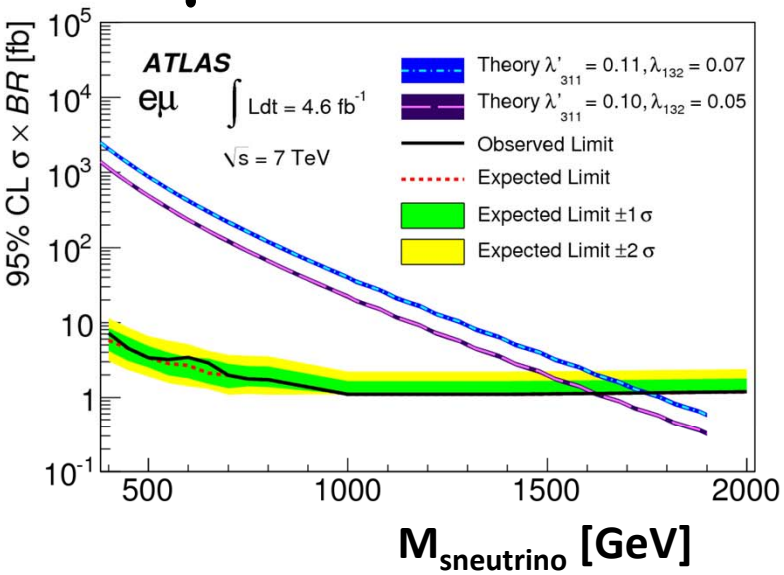
μτ

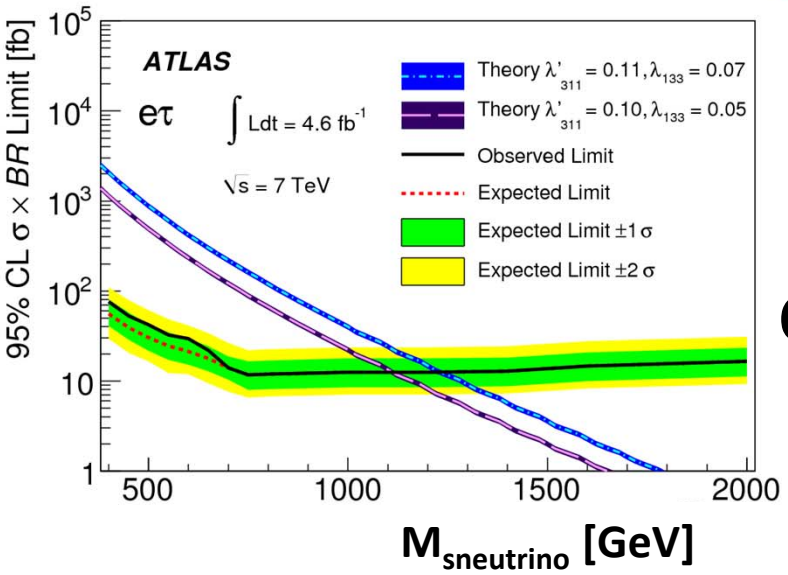
$M_{\mu\tau}$ [GeV]

Sneutrino resonance limits

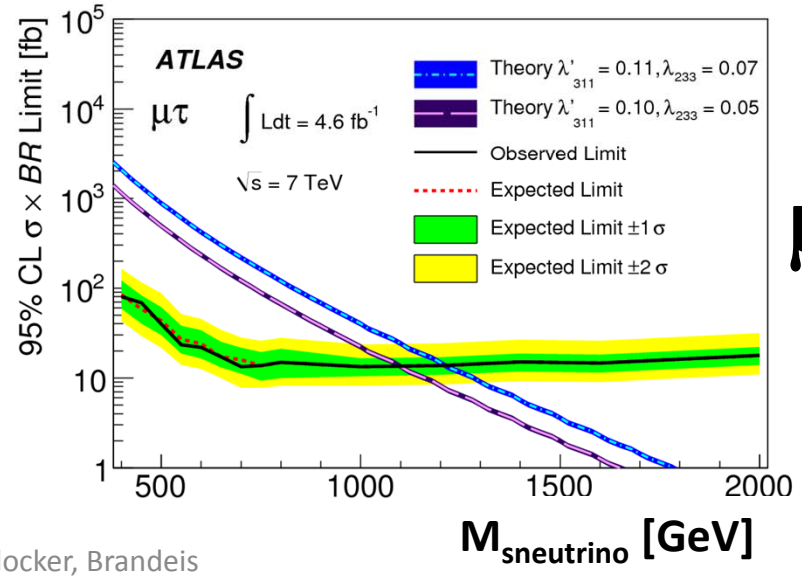
Set limits on cross section times branching ratio.

eμ



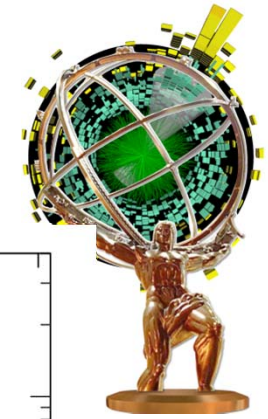


eτ



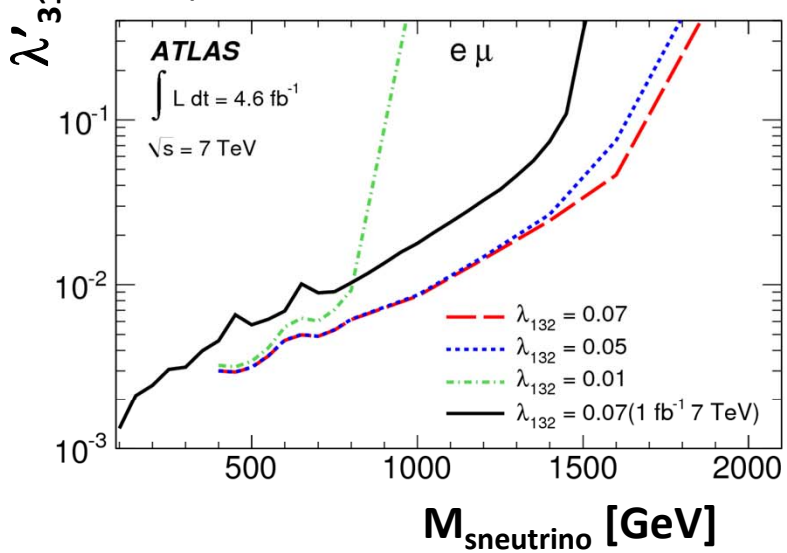
μτ

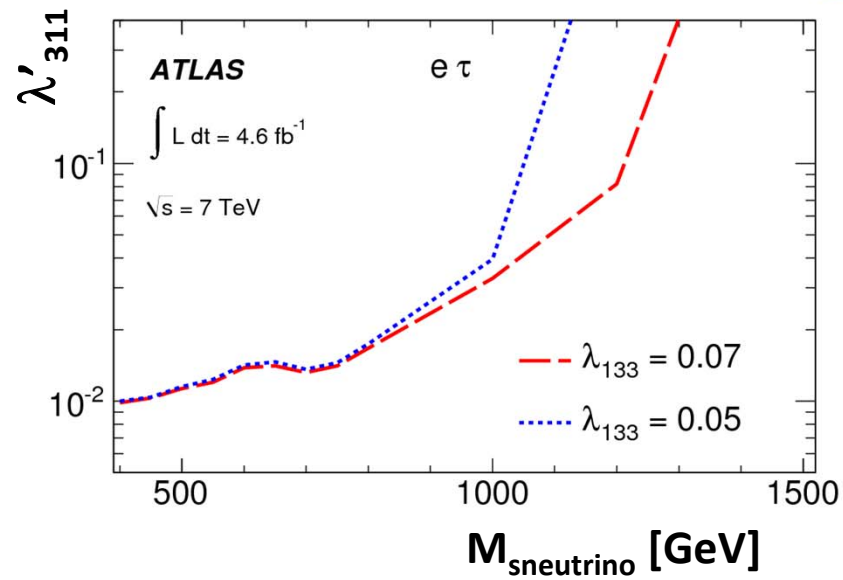
Sneutrino resonance coupling limits



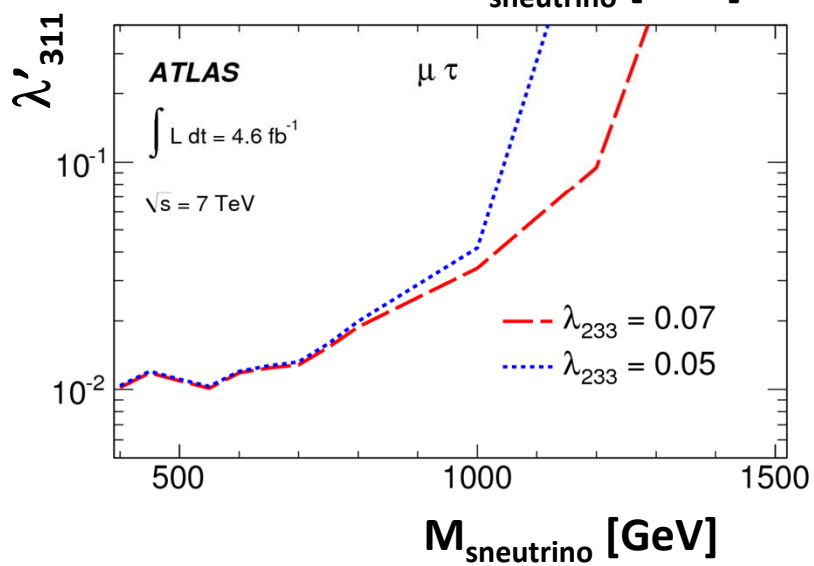
Convert to limits on couplings assuming no other nonzero couplings.

eμ



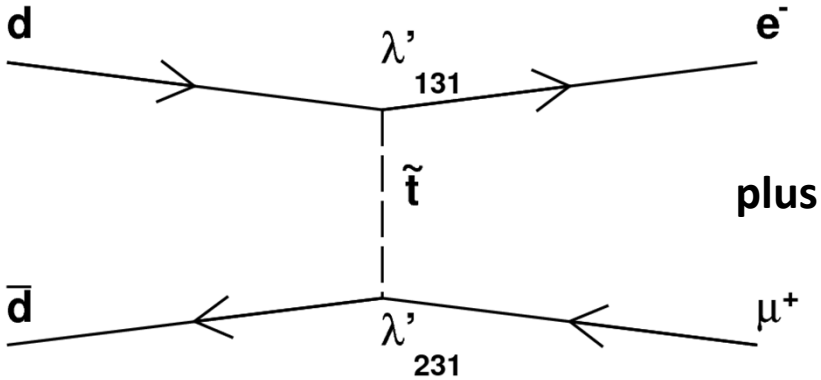


eτ



μτ

t-channel stop exchange (continuum eμ production)



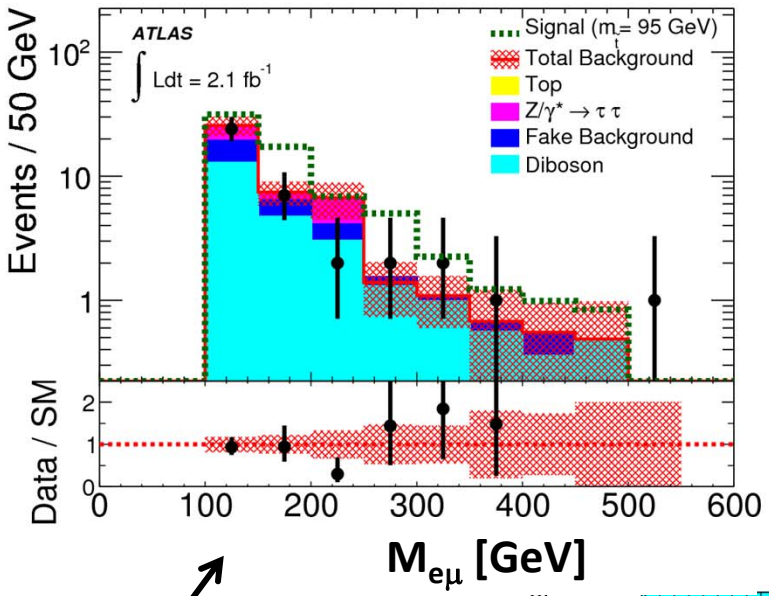
plus complex conjugate

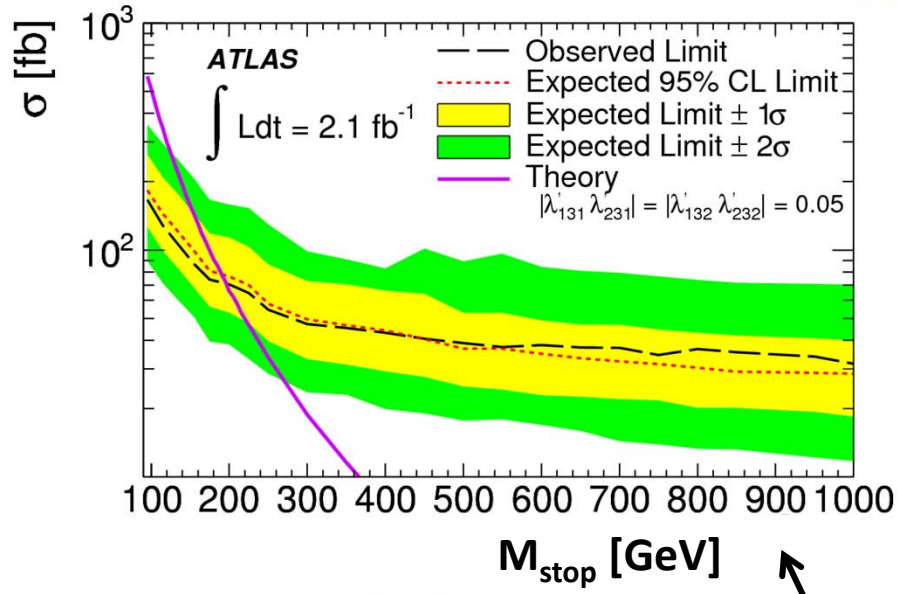
Events with high Pt (> 25 GeV), back-to-back eμ pair.

Optimized criteria: $M_{e\mu} > 100$ GeV
No jets
$\Delta\phi_{e\mu} > 3.0$
$E^t_{miss} < 25$ GeV

Eur. Phys. J C72 (2012) 2040. 7 TeV, 2 fb^{-1}

t-channel stop exchange 2

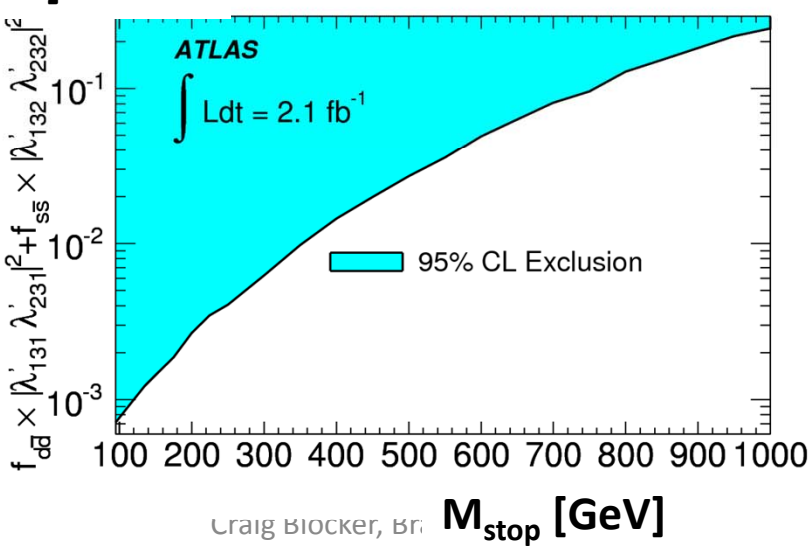




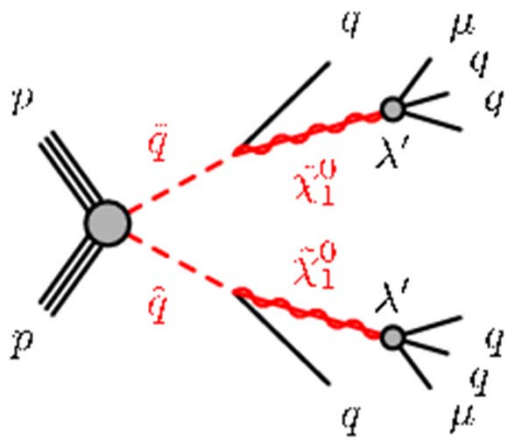
Discriminate using eμ mass.

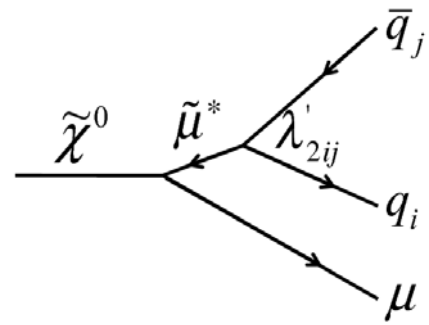
Set limits on cross sections times branching ratio.

Convert to limits on couplings.



Displaced Vertex





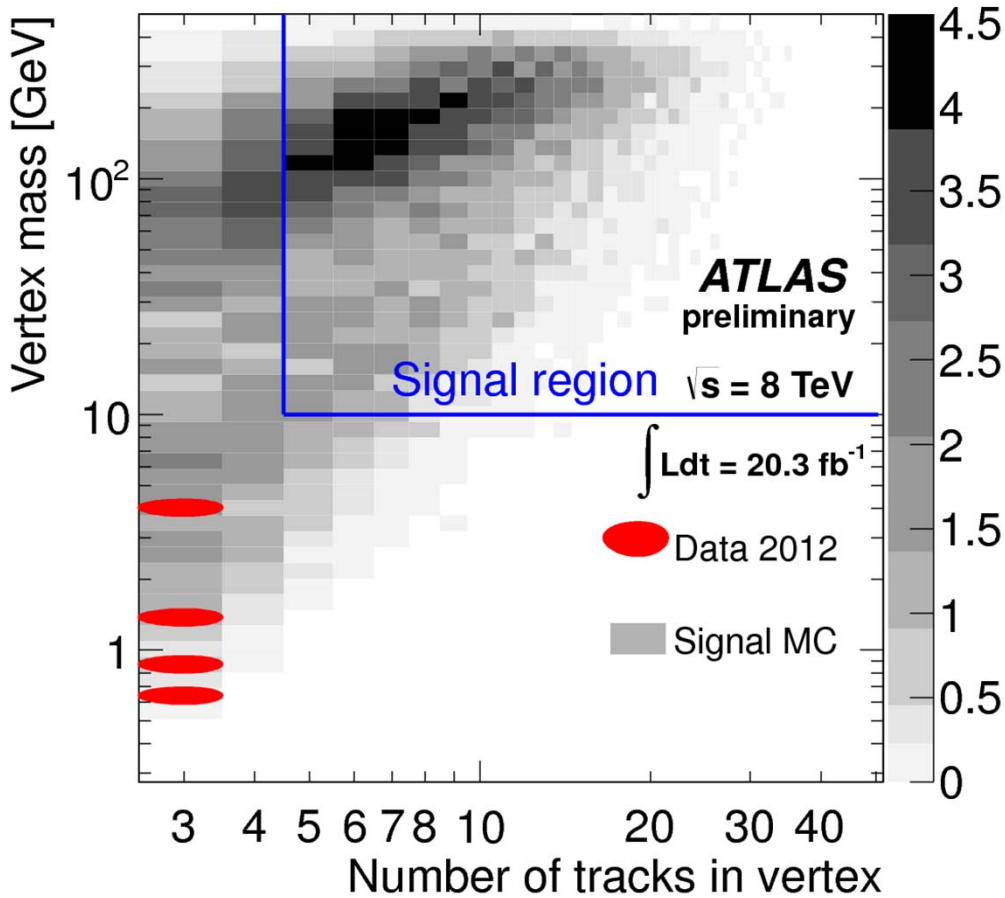
Small RPV couplings could give a long-lived LSP.

This analysis targets models with a displaced vertex from particles in jets from LSP decay plus a high Pt muon.

Use vertex mass and number of tracks in vertex to discriminate from background. Events with a displaced vertex in high material density regions are vetoed.

ATLAS-CONF-2013-12, cds.cern.ch/record/1595755. 8 TeV, 20.3 fb^{-1}

Displaced Vertex search

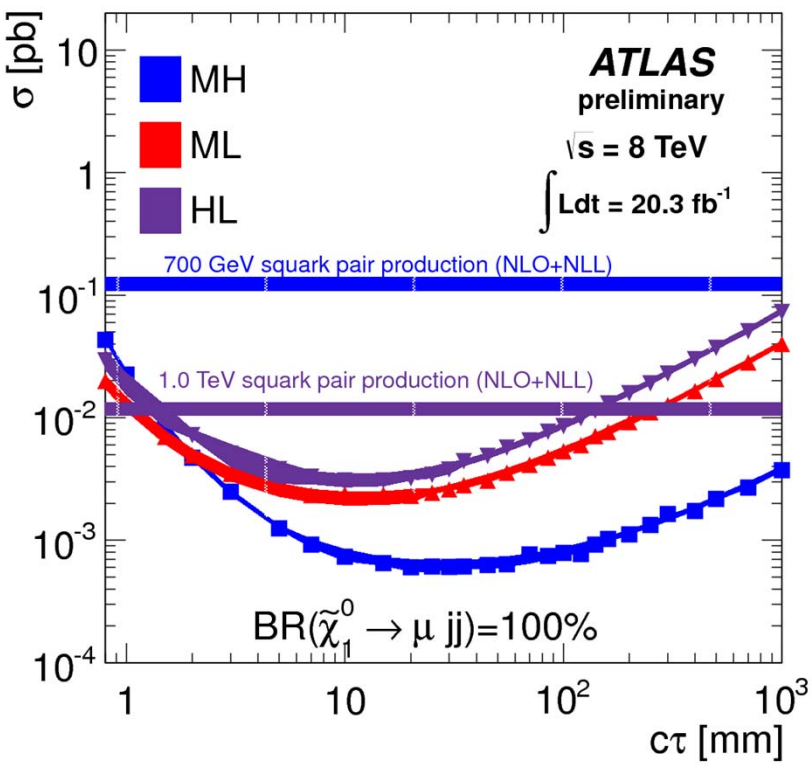


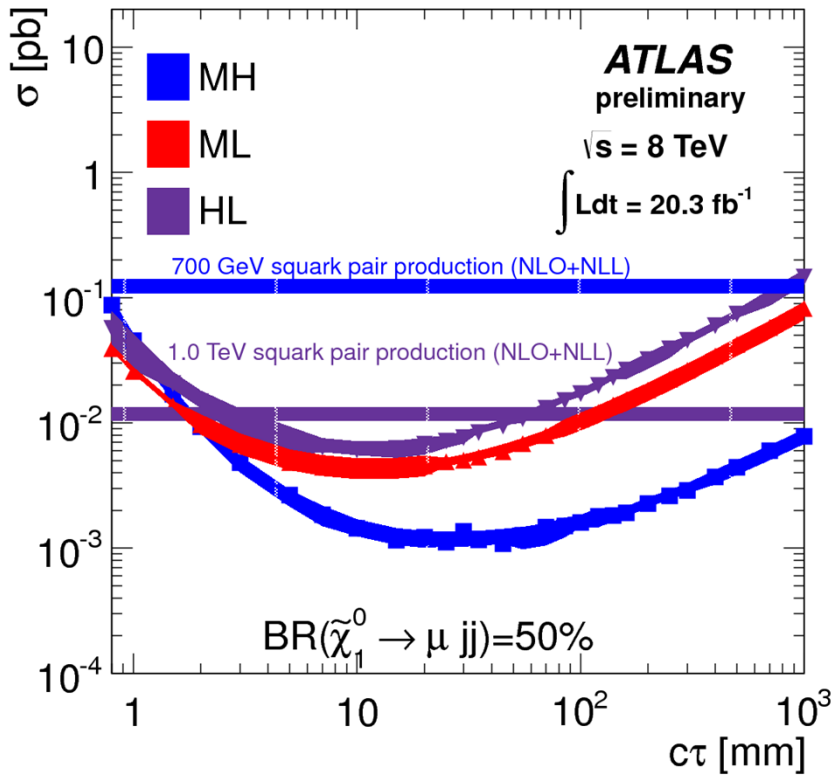
Expected background in signal region is extremely low: 0.02 ± 0.02

No excess seen, so set limits on cross section times branching ratio.

Displaced Vertex limits

MH: m_{squark} = 700 GeV, m_{LSP} = 494 GeV
ML: m_{squark} = 700 GeV, m_{LSP} = 108 GeV
HL: m_{squark} = 1000 GeV, m_{LSP} = 108 GeV





Models are constrained over 2 to 3 orders of lifetime.

Multilepton

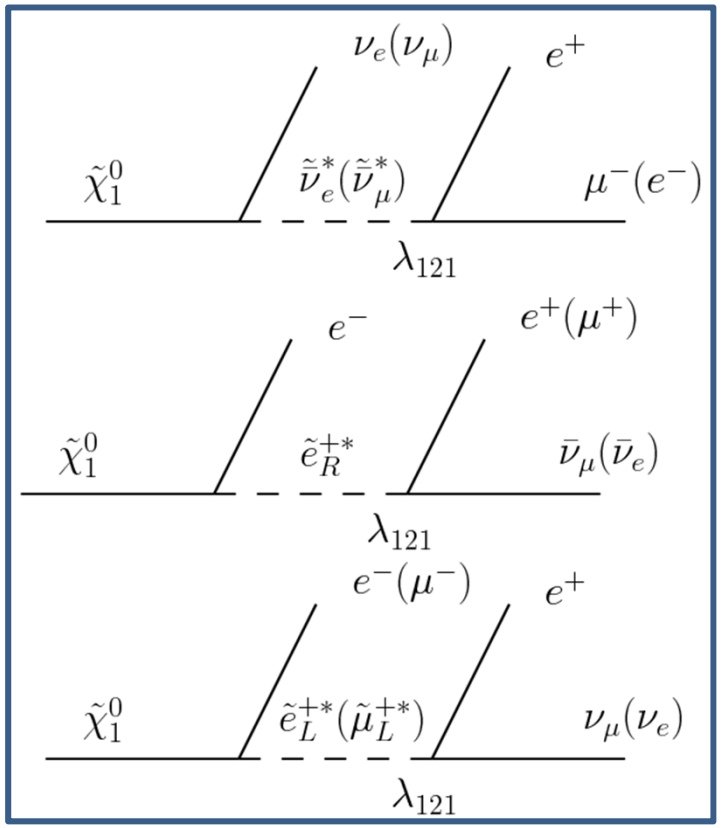
2 modes

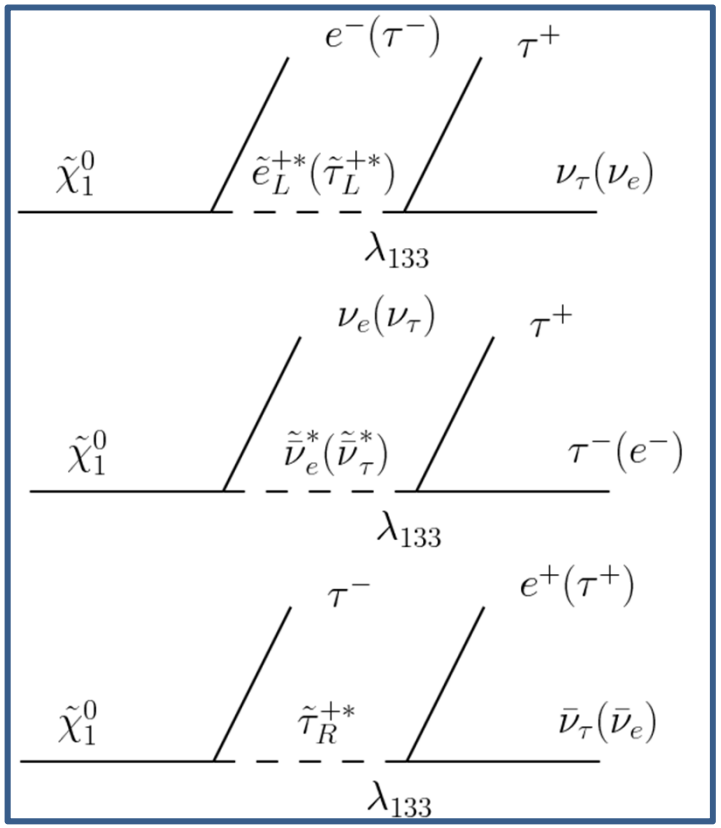
Winos: $p\,p \rightarrow \tilde{\chi}^{+}\,\tilde{\chi}^{-} \rightarrow W^{+}\,\tilde{\chi}^{0}\,W^{-}\,\tilde{\chi}^{0}$

gluinos: $p\,p \rightarrow \tilde{g}\,\tilde{g} \rightarrow q\,\bar{q}\,\tilde{\chi}^{0}\,q\,\bar{q}\,\tilde{\chi}^{0}$

ATLAS-CONF-2013-036, cds.cern.ch/record/1532429. 8 TeV, 20.7 fb^{-1}

Probes λ_{121}





Probes λ_{133}

Multilepton selection

Look for events with ≥ 4 leptons, ≥ 3 are e or μ.
Reject if mass of e's or μ's in Z region.

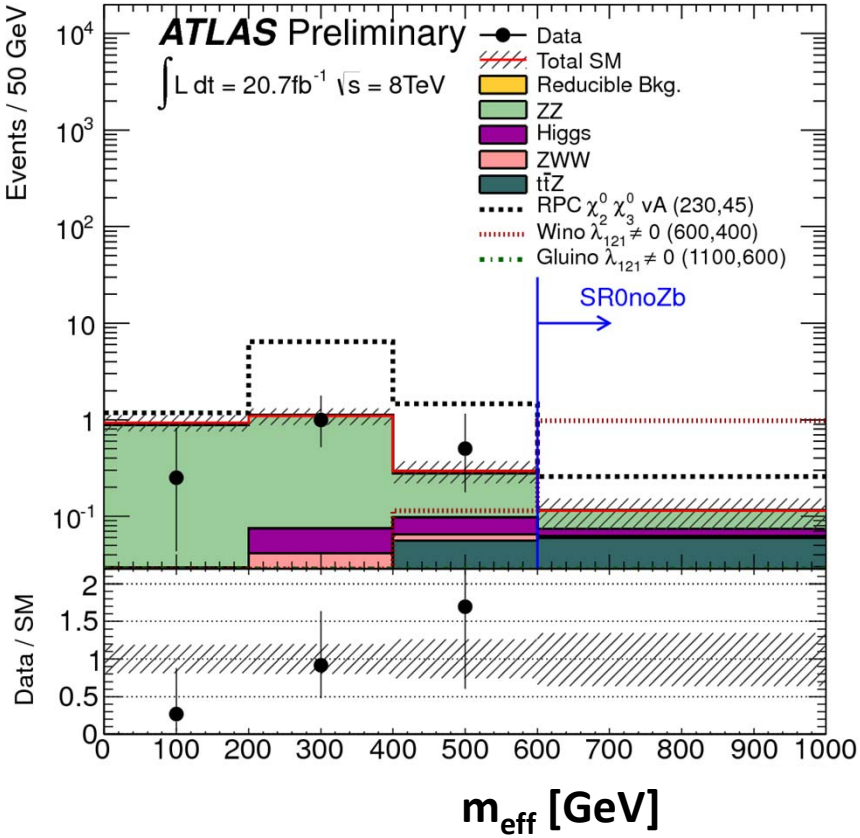
$$m_{eff} = E_t^{miss} + \sum_{\ell=e,\mu,\tau} P_T^{\ell} + \sum_{\substack{j \\ P_T > 40\,GeV}} P_T^{j}$$

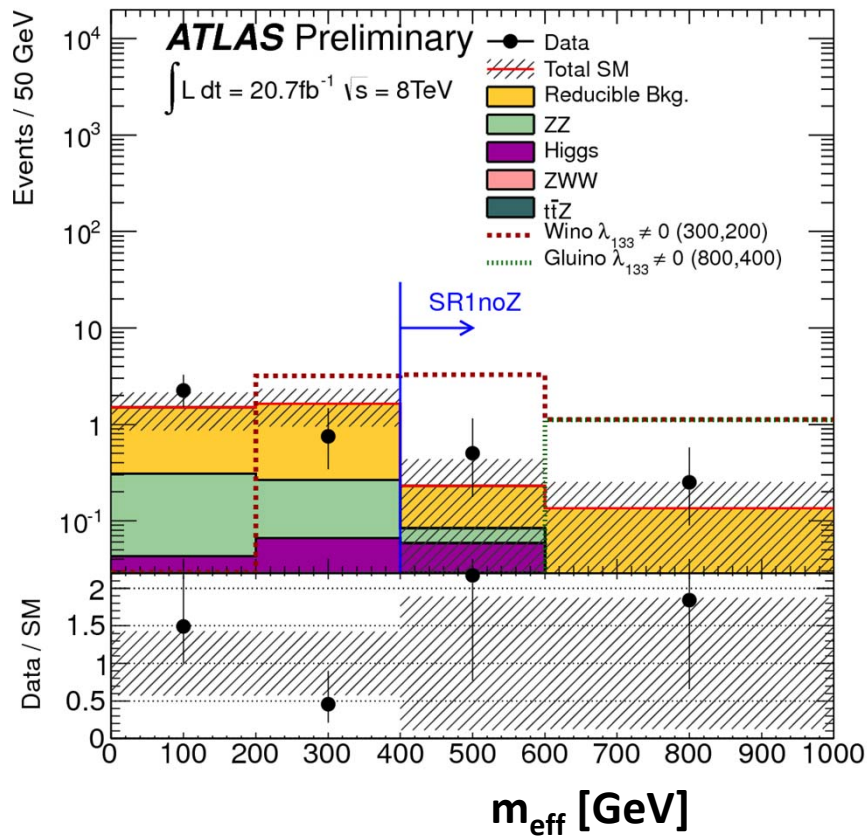
≥ 4 e, μ: $E_t^{miss} > 75$ GeV or $m_{eff} > 600$ GeV

= 3 e, μ; ≥ 1 τ : $E_t^{miss} > 100$ GeV or $m_{eff} > 400$ GeV

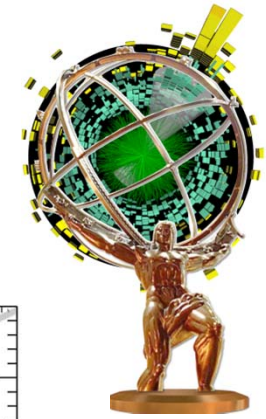
Multilepton m_{eff}

Look at m_{eff} and E_t^{miss} distribtions. No excess seen.





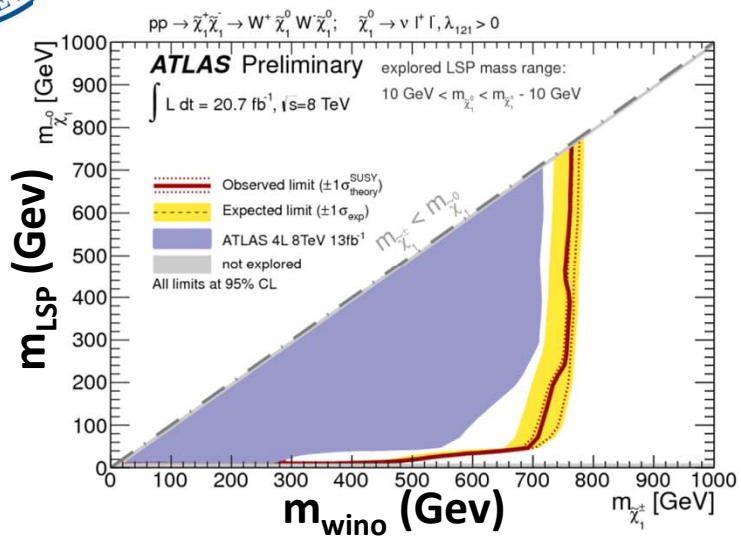
Multilepton Limits

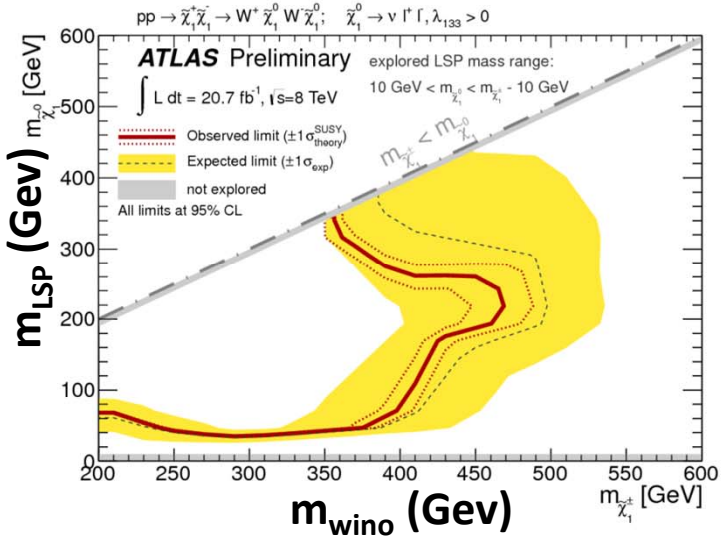


$\lambda_{121} > 0$

$\lambda_{133} > 0$

Wino





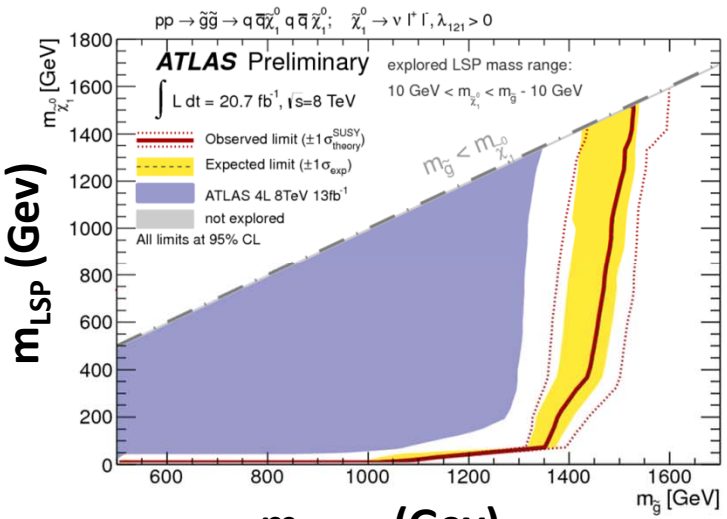
m_{LSP} (Gev)

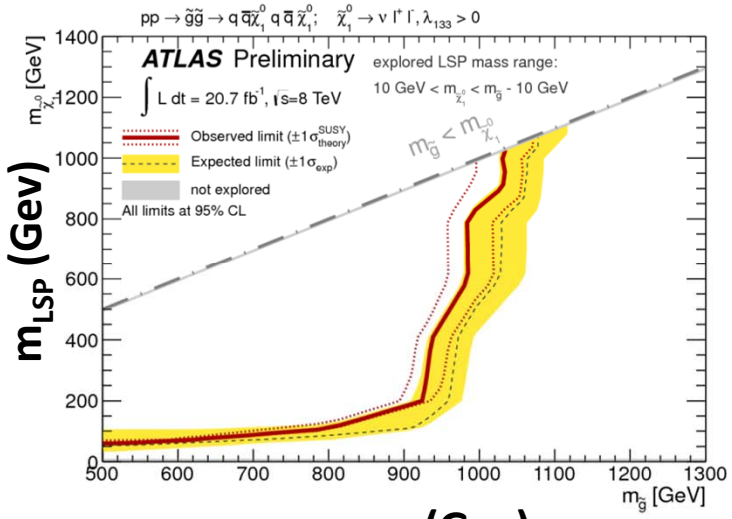
m_{wino} (Gev)

m_{LSP} (Gev)

m_{wino} (Gev)

gluino





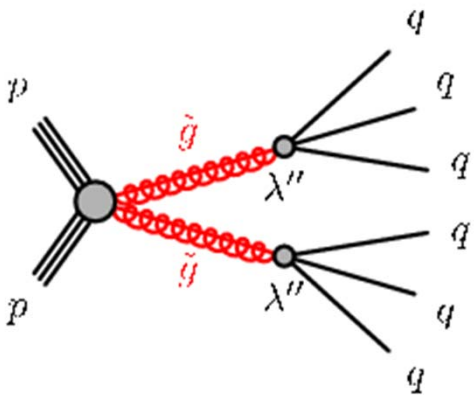
m_{LSP} (Gev)

m_{gluino} (Gev)

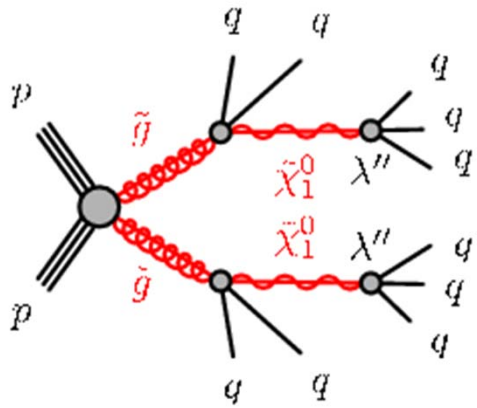
m_{LSP} (Gev)

m_{gluino} (Gev)

Multijet



6 quark



10 quark

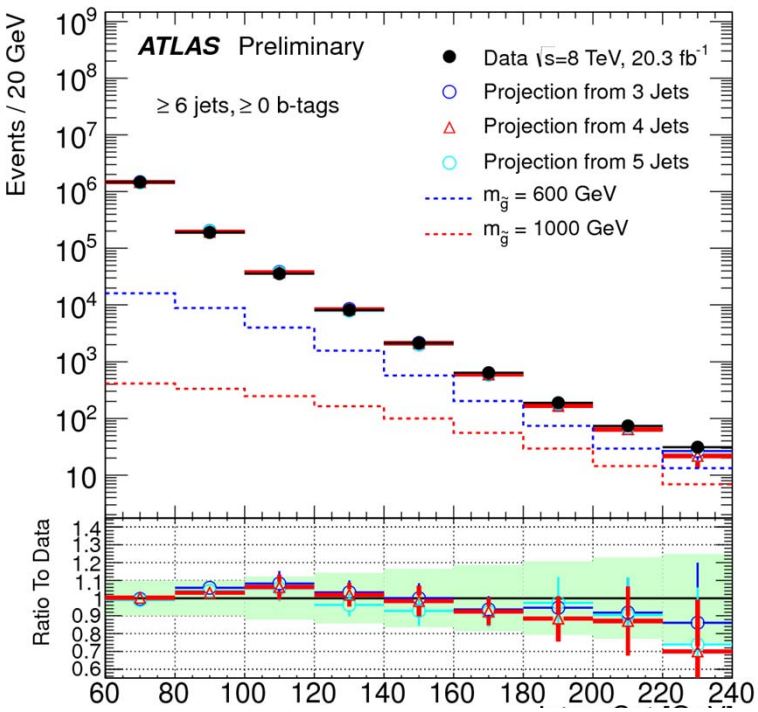
Sensitive to λ'', that is, to baryon number violation.

Look for events with ≥ 6 or ≥ 7 high P_t (> 80 GeV) jets with various number of b-tags (to determine heavy quark contributions).

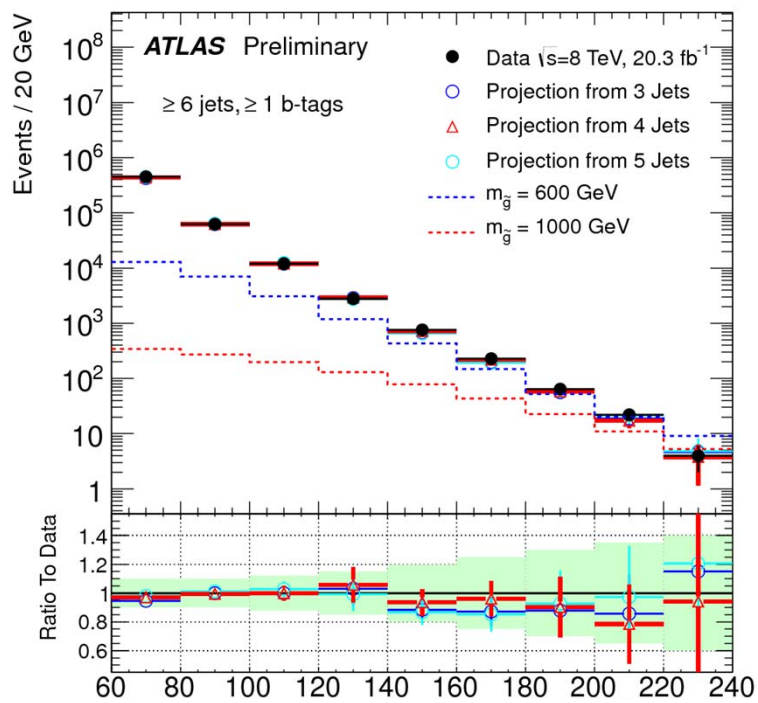
ATLAS-CONF-2013-091, cds.cern.ch/record/1595753, 8 TeV, 20.3 fb^{-1}

Multijet P_T cut

Use jet P_t cut to discriminate potential signal.
Below are two examples



P_T Cut [GeV]

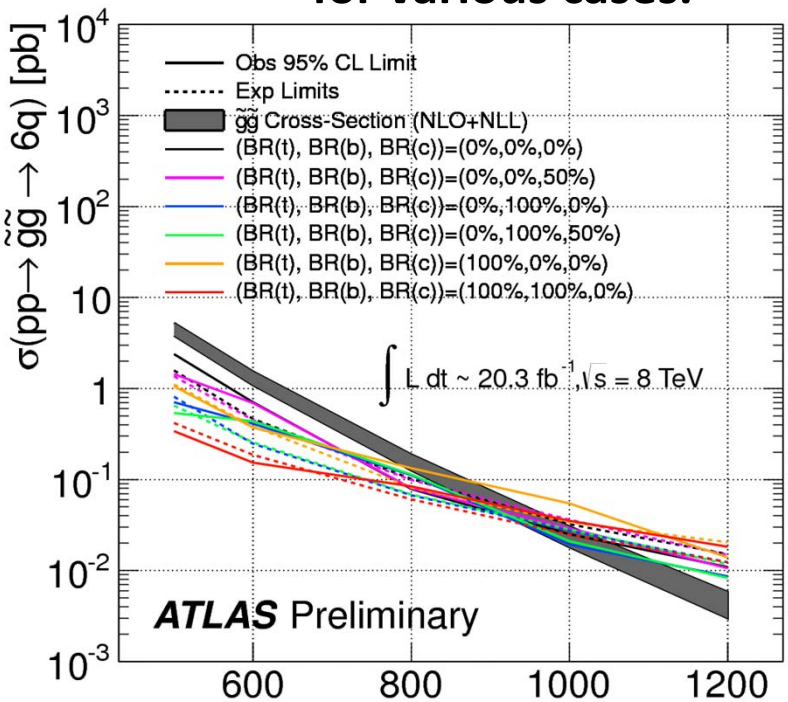


P_T Cut [GeV]

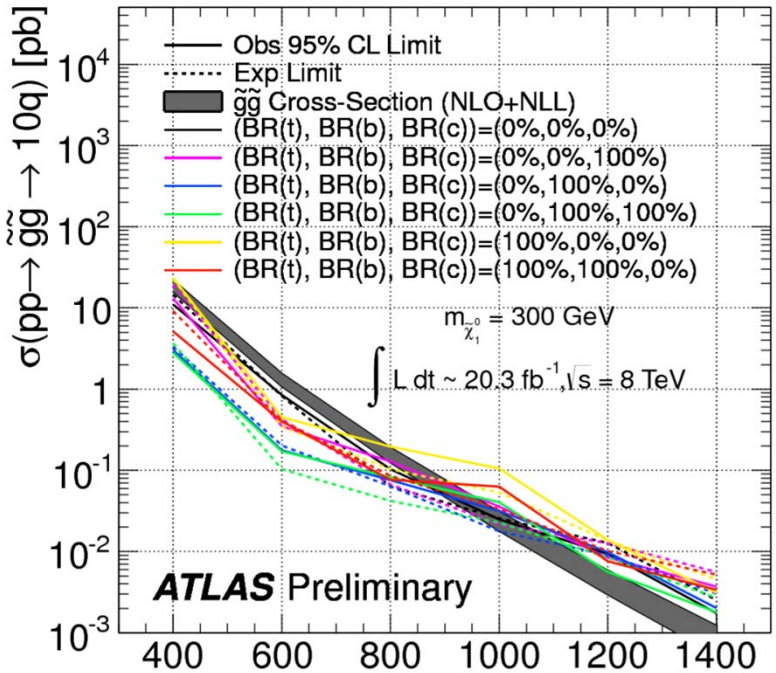
Background determinations are exclusively data driven.

Multijet limits

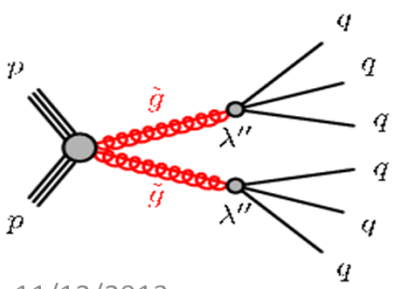
See no evidence for excess due to signal, so set limits on cross section vs mass of gluino for various cases.



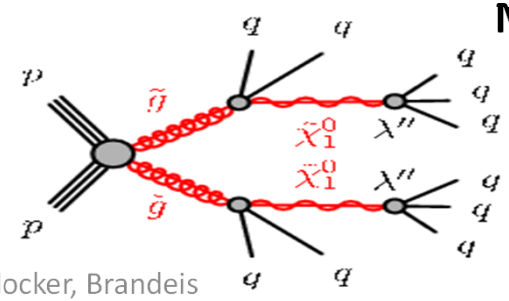
M_{gluino} [GeV]



M_{gluino} [GeV]



6 quark



10 quark

Summary

ATLAS has searched for evidence of RPV SUSY couplings and found none in the following modes

1. **Production and LFV decay of a sneutrino.**
2. **LFV continuum production e-μ due to t-channel stop exchange.**
3. **Decay of an LSP to a muon and jets giving a displaced vertex.**
4. **Decay of an LSPs to final states with ≥ 4 leptons.**
5. **Decay of an LSPs to final states with ≥ 6 jets.**
6. **Long-lived R-hadrons.**
7. **Stable charged particles.**
8. **Multijets + E_t^{miss}, with a gluino-mediated RPV stop interpretation.**
9. **2 same-sign leptons + b-jet + E_t^{miss}, with a gluino-mediated RPV stop interpretation.**

The increased energy and integrated luminosity of the next run will Improve the sensitivity in all these and other searches.