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Searches for SUSY signals at ATLAS

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on behalf of the ATLAS Collaboration

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LHEP
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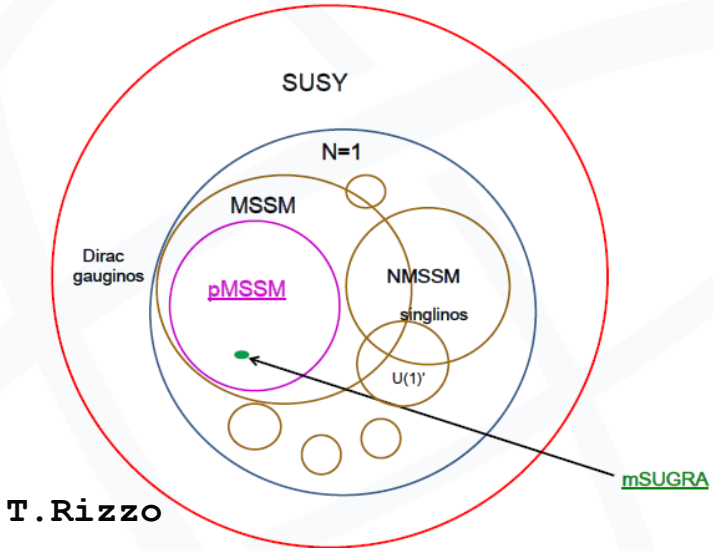
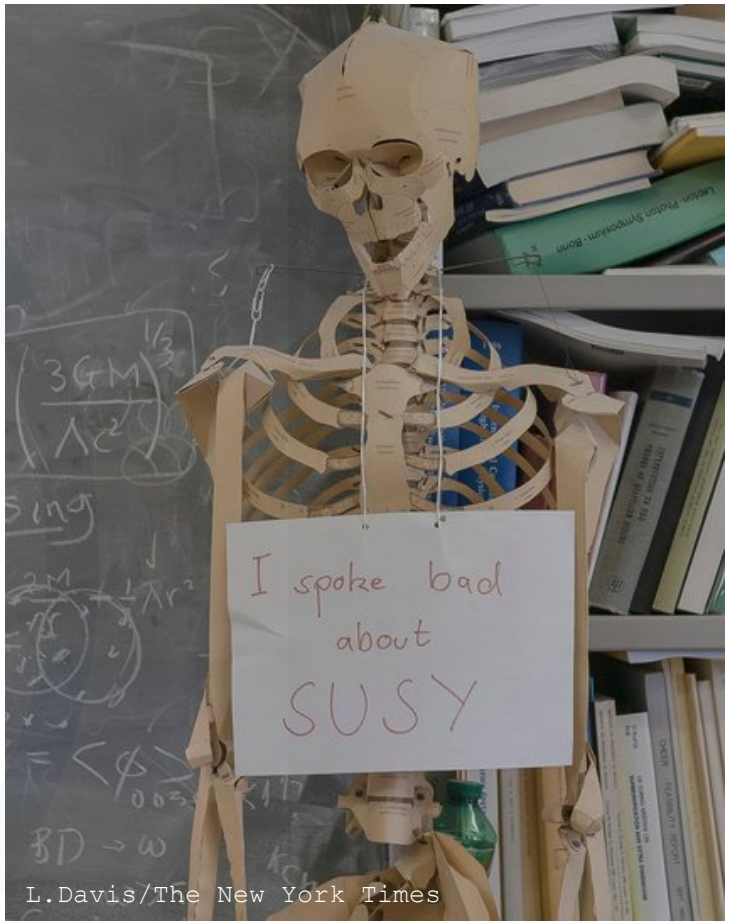
Introduction

At the LHC turn-on, many hoped that SUSY would be just around the corner.

- However, we are still looking for it.





SUSY is not a model but a large theoretical framework.

- **ATLAS is investigating the reach of the HL-LHC** to determine how far can "the corner" be

SUSY prospects strategy

Simple analysis approaches mimicking the Run 1&2 selections

- Parameterised detector response (derived from full simulation)
- Typically consider different pile-up regimes and detector layouts
- Sensitivity evaluated with a significance-like variable, referred to as Z_n

$$Z_n = \sqrt{2}\,\mathrm{erf}^{-1}(1-2p) \qquad p \propto \int_0^\infty db\, G(b; N_b, \delta b) \sum_{i=N_{data}}^{\infty} \frac{e^{-b} b^i}{i!}$$

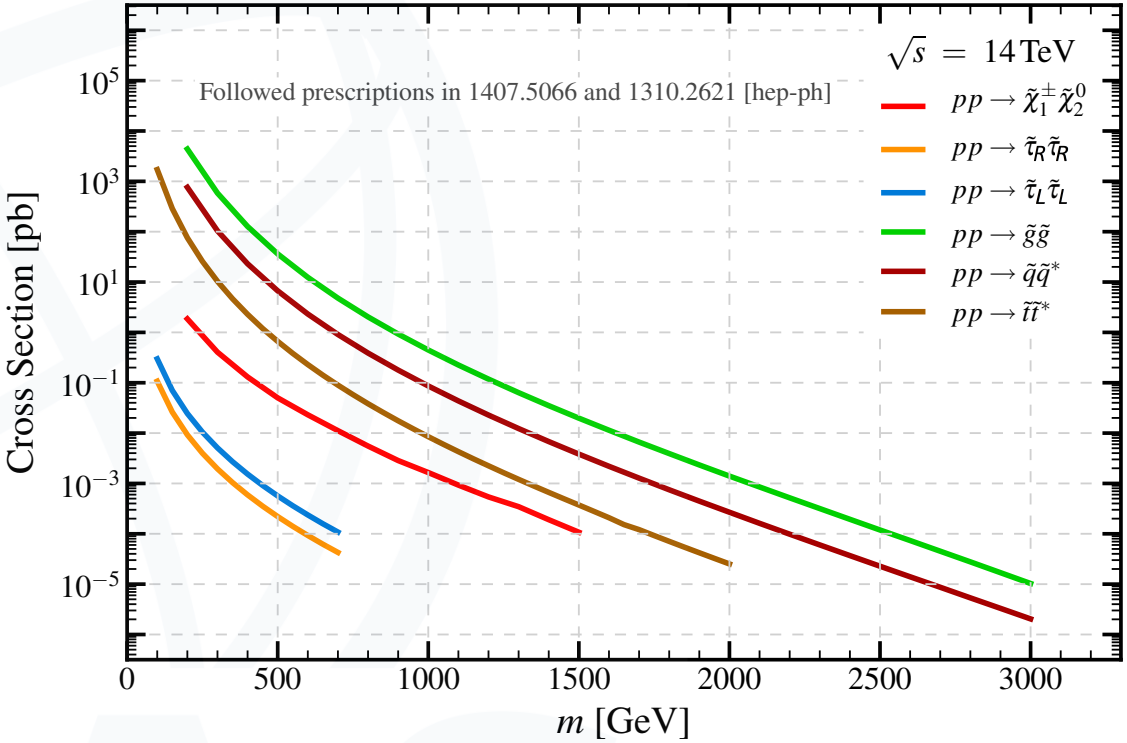
The HL-LHC will provide a much larger dataset, at the cost of additional pile-up interactions.

- Studies are also used to guide detector design and development, to maximise the expected physics results

A comprehensive search programme

The HL-LHC will access both very massive and very rare sparticles.

- **Sensitivity investigated with simplified models.**



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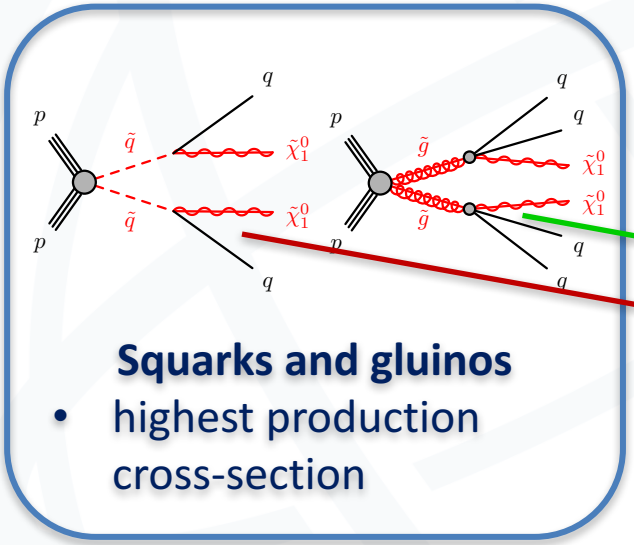
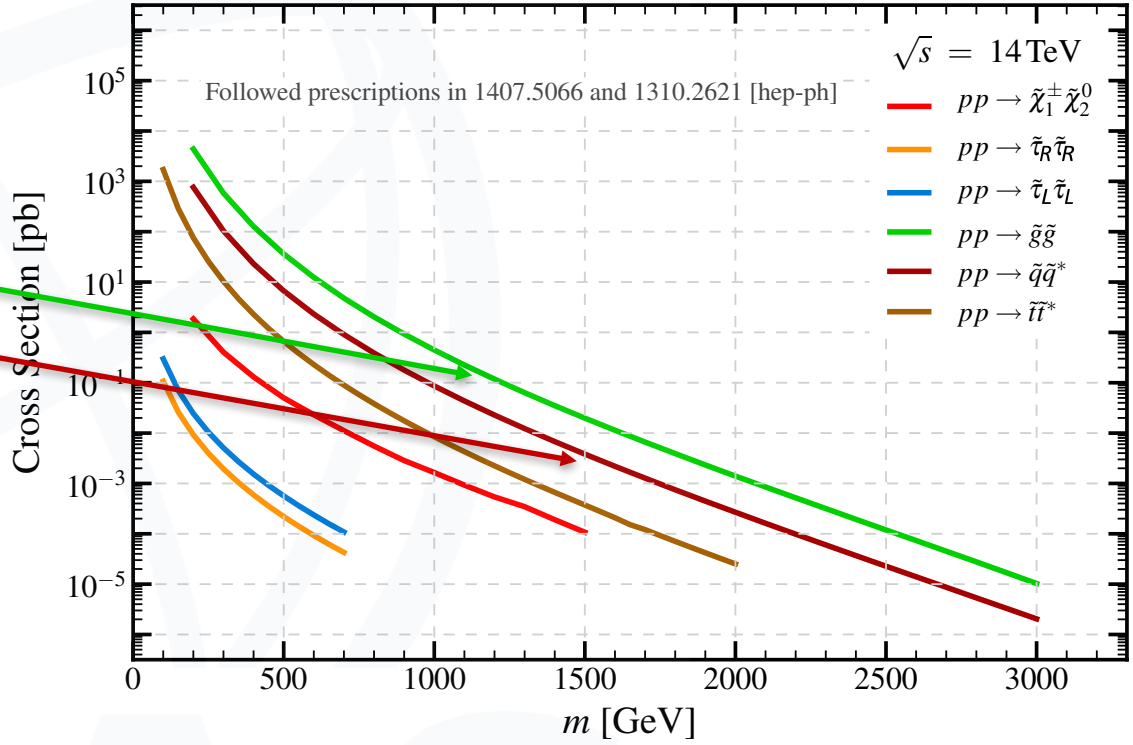


Squarks and gluinos

- highest production cross-section



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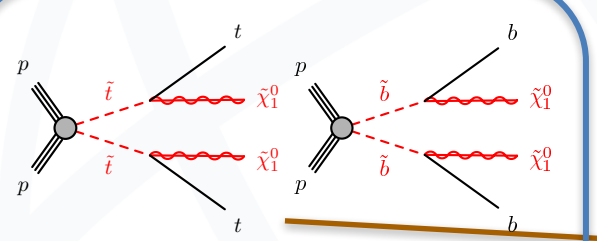
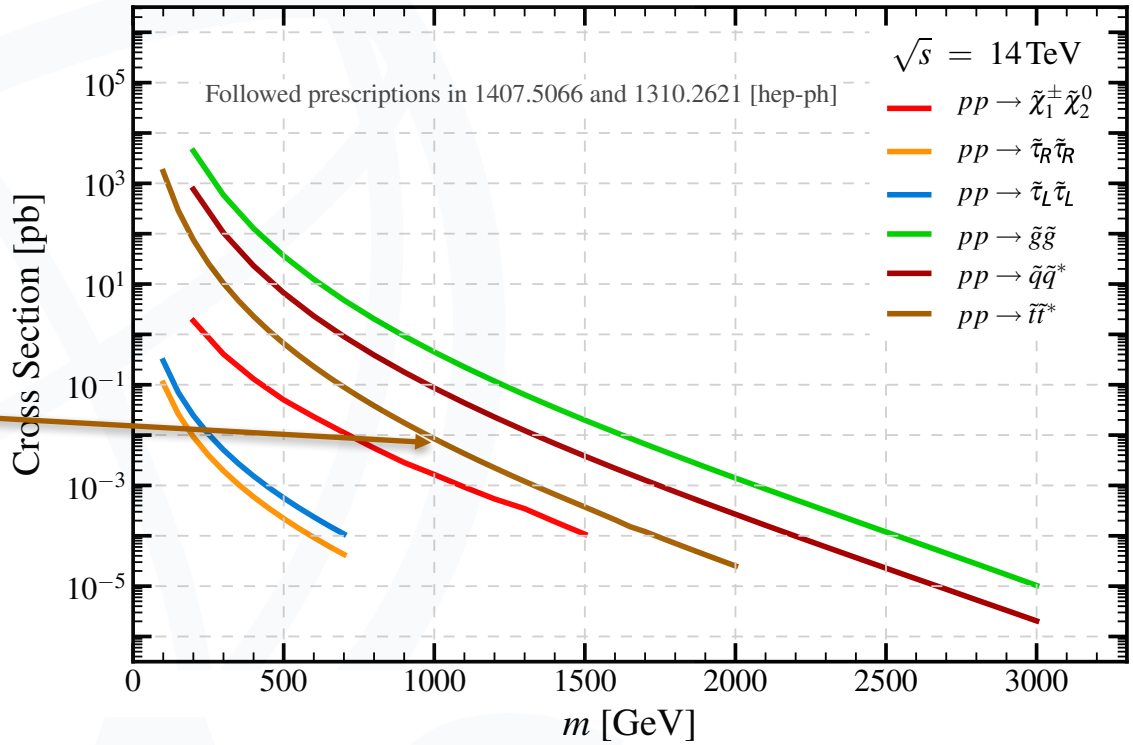


Third generation squarks

- key to natural SUSY



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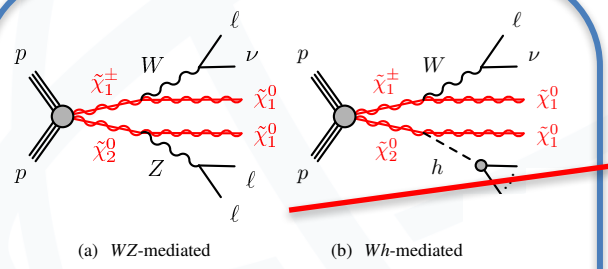
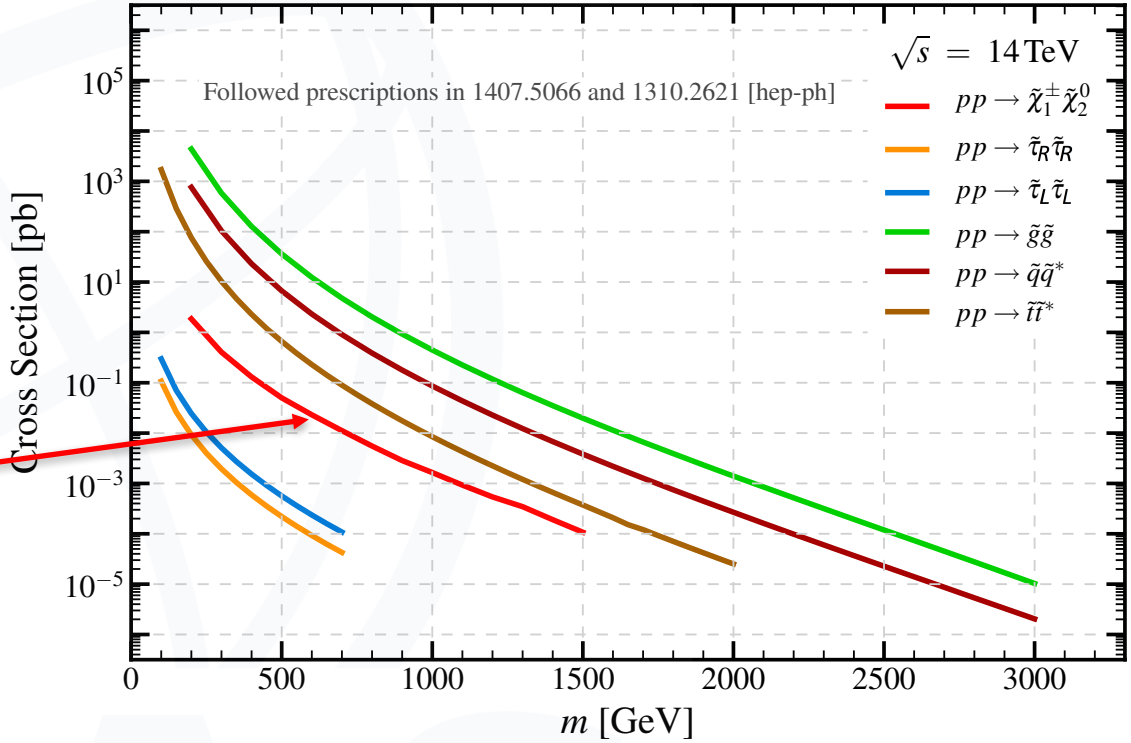


Electroweak-inos

- Can dominate if squarks and gluinos are too heavy



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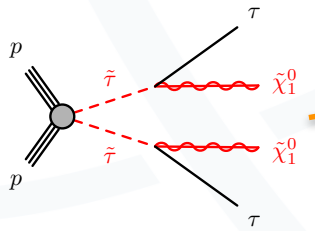
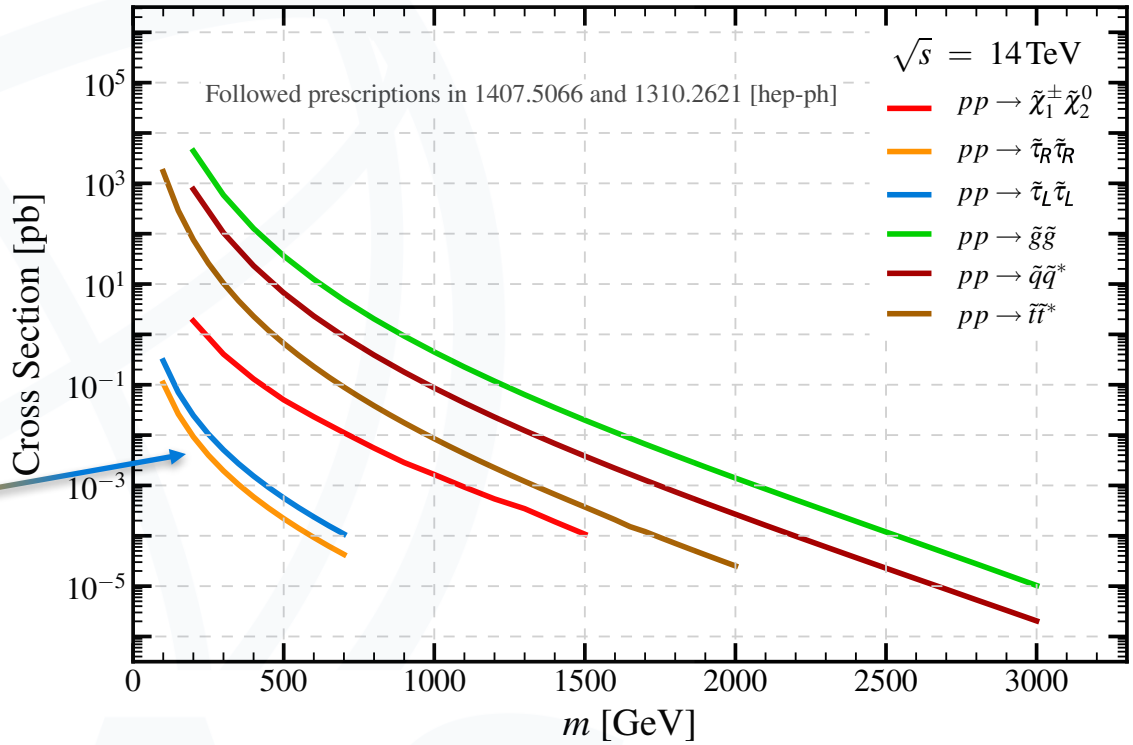
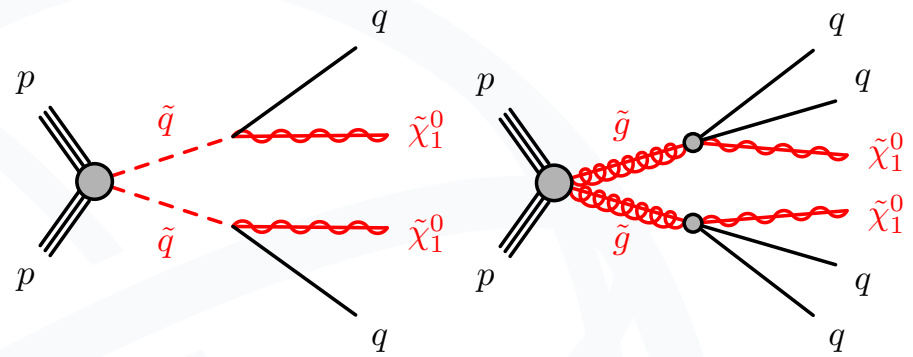


Sleptons (staus)

- Can match the DM observed density
- Can explain the μ g-2



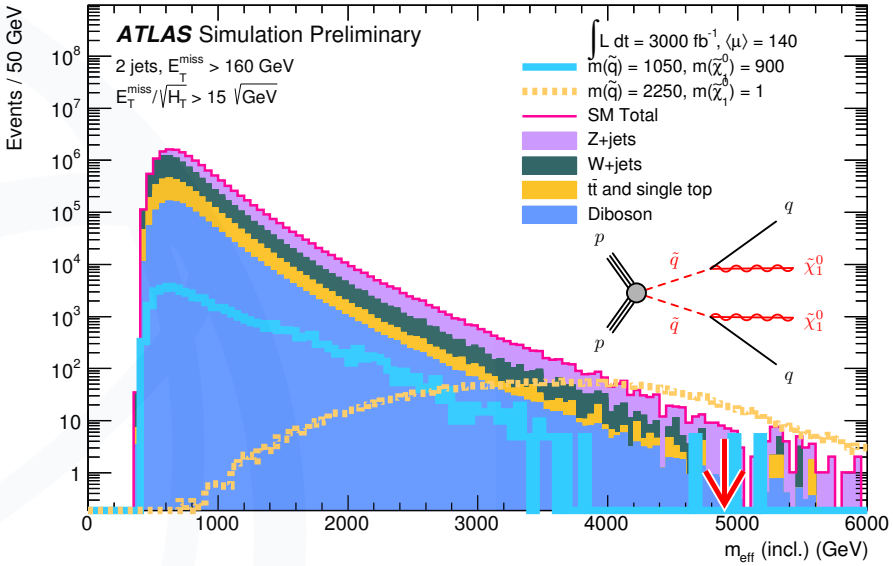


SQUARKS AND GLUINOS

Fully hadronic squarks and gluinos

Selections optimised on E_T^{miss}, m_{eff}, E_T^{miss}/m_{eff} and E_T^{miss}/H_T

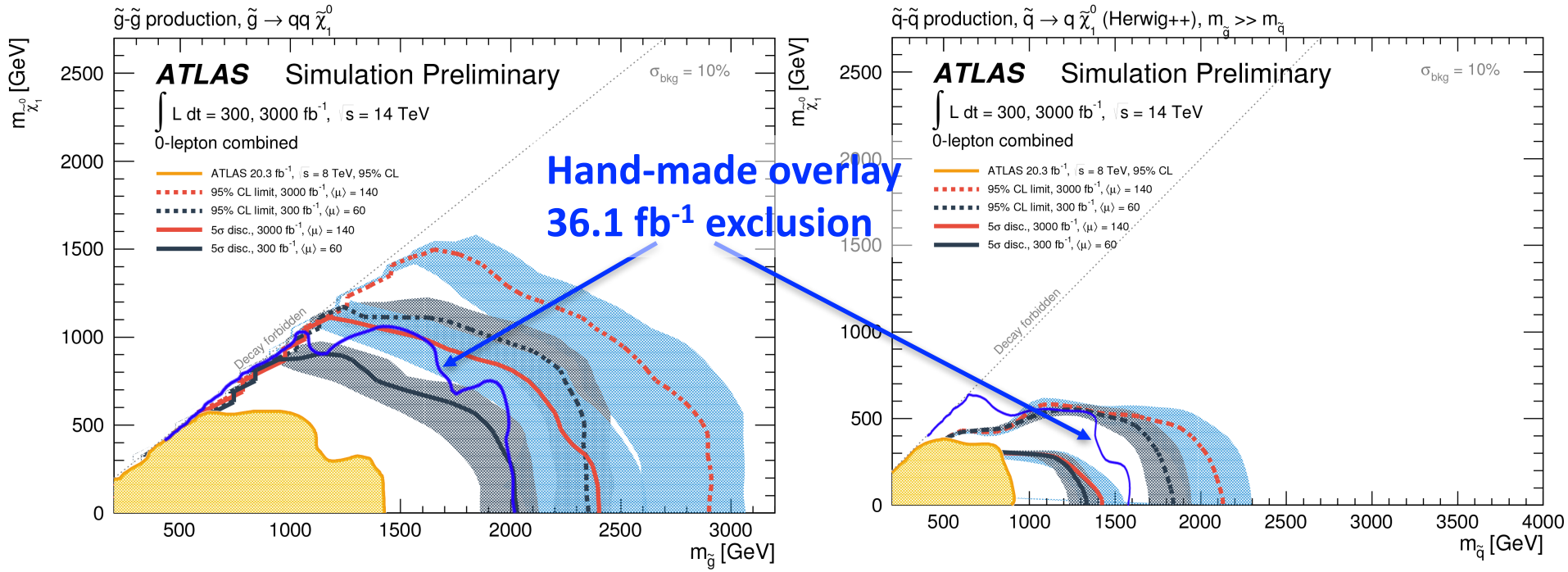
- Events with 2 to 6 jets
- Backgrounds: *Z*(νν)+jets, W+jets, ttbar
- Assumed **μ=140, σ_{bkg}=10%**



- Expected 95% CL limits with the best SR for each model

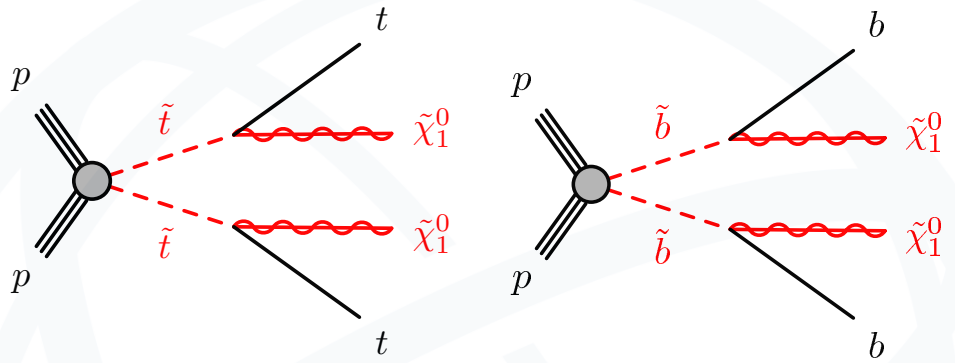
Selection	Channel									
	2jl	2jm	3j	4jl	4jm	4jt	5j	6jl	6jm	6jt
$p_T(j_1)$ [GeV] >	160									
$N_{jets}(p_T > 60$ [GeV]) ≥	2		3	4			5	6		
E_T^{miss} [GeV] >	160									
$\Delta\phi$(jet, E_T^{miss})$_{min}$ [rad] >	0.4 (j_1, j_2, j_3), 0.2 (all p_T > 40 GeV jets)									
E_T^{miss}/m_{eff} >	–	–	0.3	0.35	0.25	–	0.25	0.25	0.35	0.15
$E_T^{miss}/\sqrt{H_T}$ [GeV$^{1/2}$] >	8	15	–	–	–	10	–	–	–	–
m_{eff} [GeV] >	4500, 5000	4500, 4900	4000	4000, 3800	4000	4500	4000	3400	3500	5000

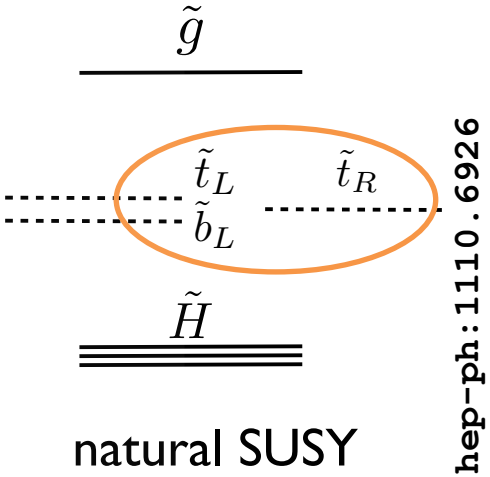
Expected Sensitivity



Discoverable **squark pair production models already excluded** with 36.1 fb^{-1} (ATLAS-CONF-2017-022)

- Gluinos are in similar situation
- **HE-LHC would be needed** to discover these particles





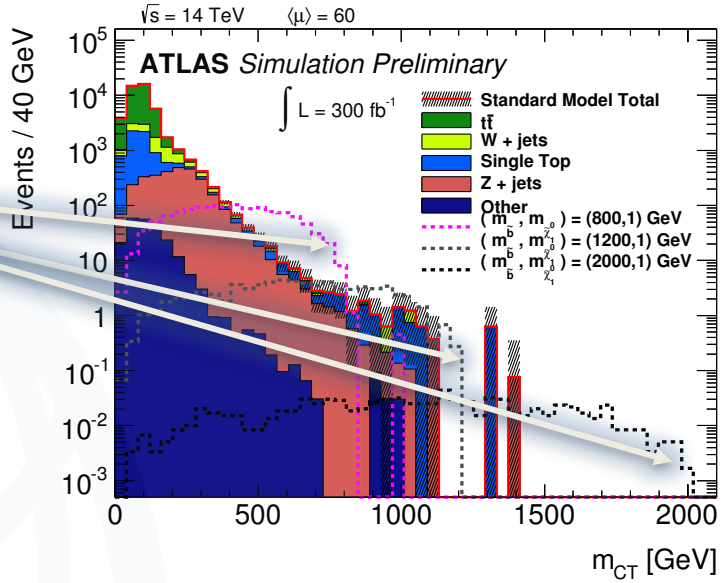
THIRD GENERATION SQUARKS

Bottom squarks

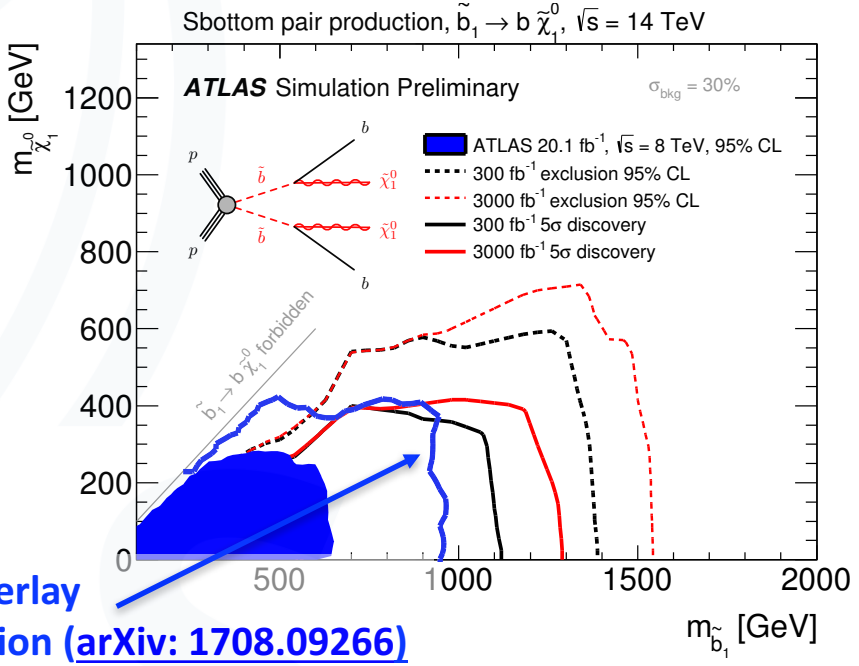
- Exploit m_{CT}**(bb) endpoint** (6 SR)

$$m_{\mathrm{CT}}^{\max} = \frac{m^2(\tilde{b}) - m^2(\tilde{\chi}_1^0)}{m(\tilde{b})}$$

- Backgrounds: *Z*(νν)+*bb*, single top, *tt*V (*V*=*W*,*Z*)
- Assumed **μ=140, σ_{bkg}=30%**
- Expected 95% CL limits with the best SR for each model



Selection	SRx
Lepton veto	No e/μ with $p_{\mathrm{T}} > 7(6)$ GeV for $e(\mu)$
$E_{\mathrm{T}}^{\mathrm{miss}}$	> 150 GeV
Leading jet $p_{\mathrm{T}}(j_1)$	> 130 GeV
Third jet $p_{\mathrm{T}}(j_3)$	veto if > 50 GeV
b-tagging	leading 2 jets ($p_{\mathrm{T}} > 50$ GeV, $\lvert\eta\rvert < 2.5$)
$\Delta\phi_{\mathrm{min}}$	> 0.4
$E_{\mathrm{T}}^{\mathrm{miss}}/m_{\mathrm{eff}}(2)$	$E_{\mathrm{T}}^{\mathrm{miss}}/m_{\mathrm{eff}}(2) > 0.25$
m_{CT}	> *x* GeV
m_{bb}	> 200 GeV



Hand-made overlay

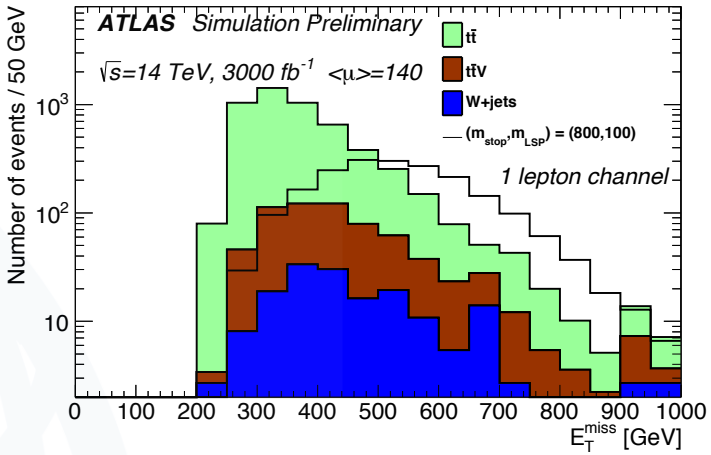
36.1 fb^{-1} exclusion (arXiv: 1708.09266)

Multi-jet and single lepton search

11 fully hadronic SRs (6+ jets)

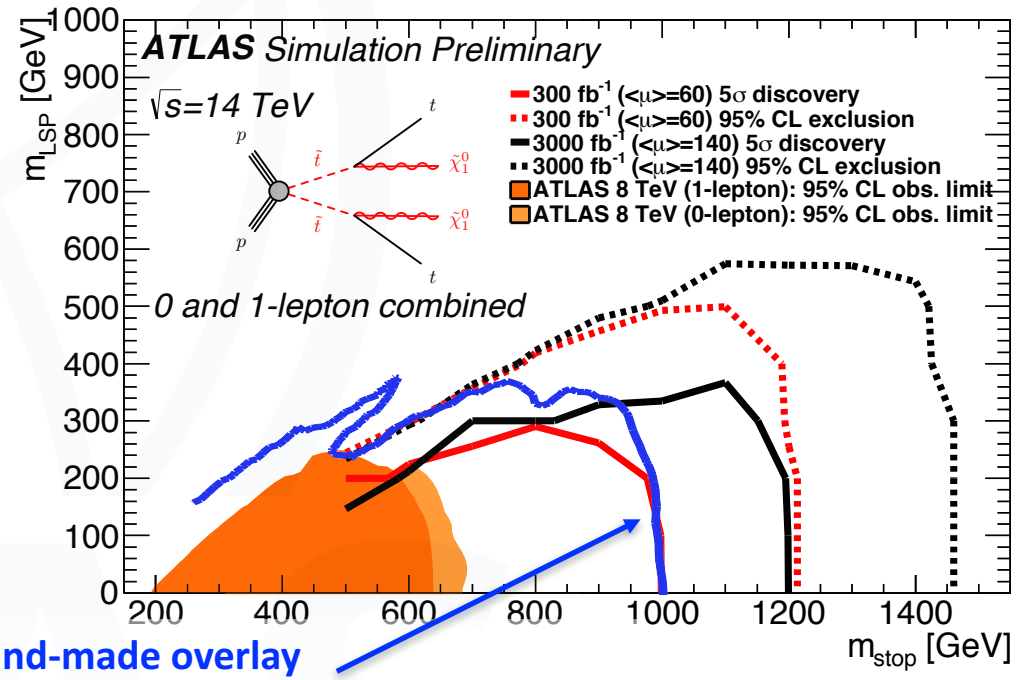
- E_T^{miss} and m_T^b (closest b-jet in ϕ)

$$m_{\mathrm{T}}^{b} = \sqrt{2 \times p_{\mathrm{T,b}} \times E_{\mathrm{T}}^{\mathrm{miss}} \times (1 - \cos(\Delta\phi))}$$



11 single lepton SRs (4+ jets)

- E_T^{miss} and m_T
- Top reconstruction via m_{jjj}
- Backgrounds: ttbar, Z(vv) and *tt*V (*V*=*W*,*Z*)
- Assumed **μ=140, σ_{bkg}=30%**
- 95% CL **limits from the combination** of the best SRs of the two channels



Hand-made overlay

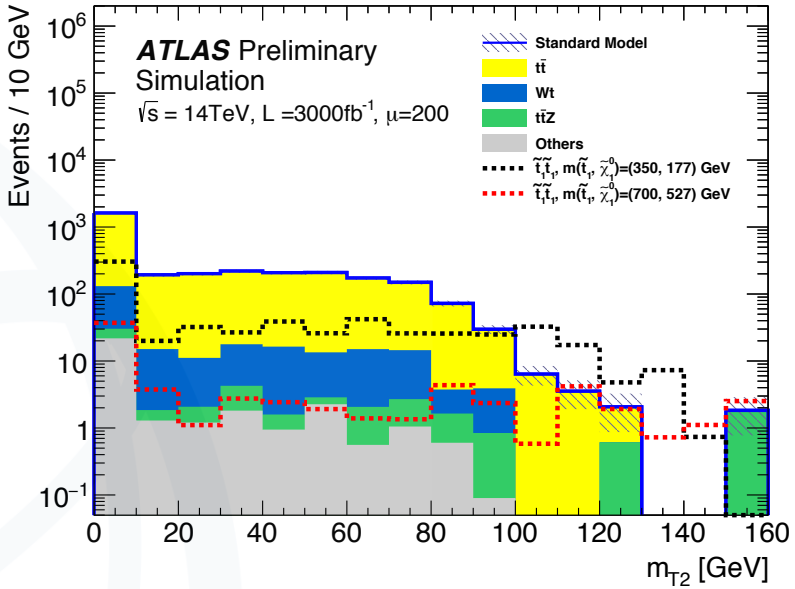
36.1 fb^{-1} exclusion (arXiv:1709.04183)

Di-lepton search

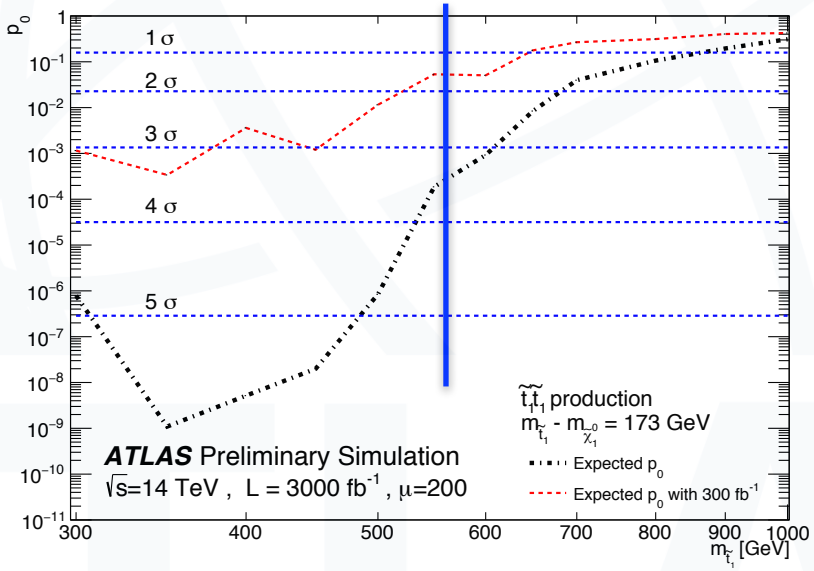
Targets **compressed scenarios with $m(t_1)$-$m(\chi_1)$=m(t)**

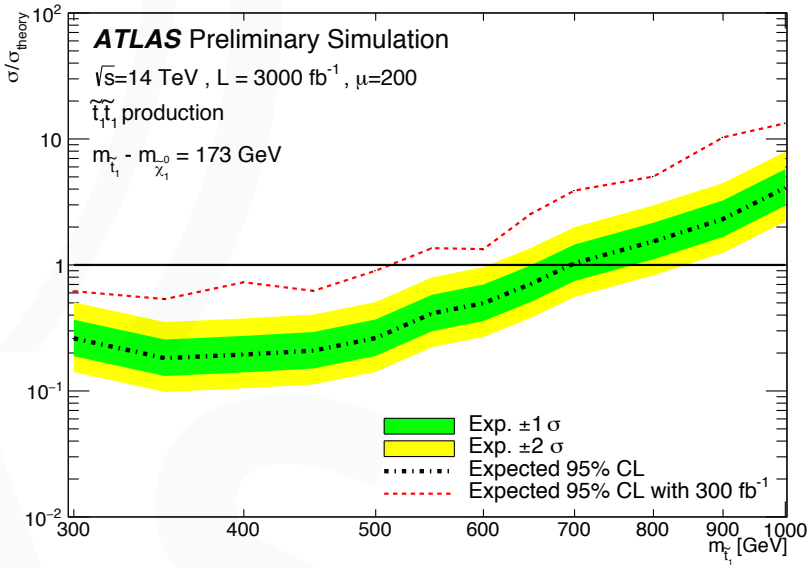
- one ISR jet, E_T^{miss} and m_{T2}
- Backgrounds: ttbar and *ttZ*

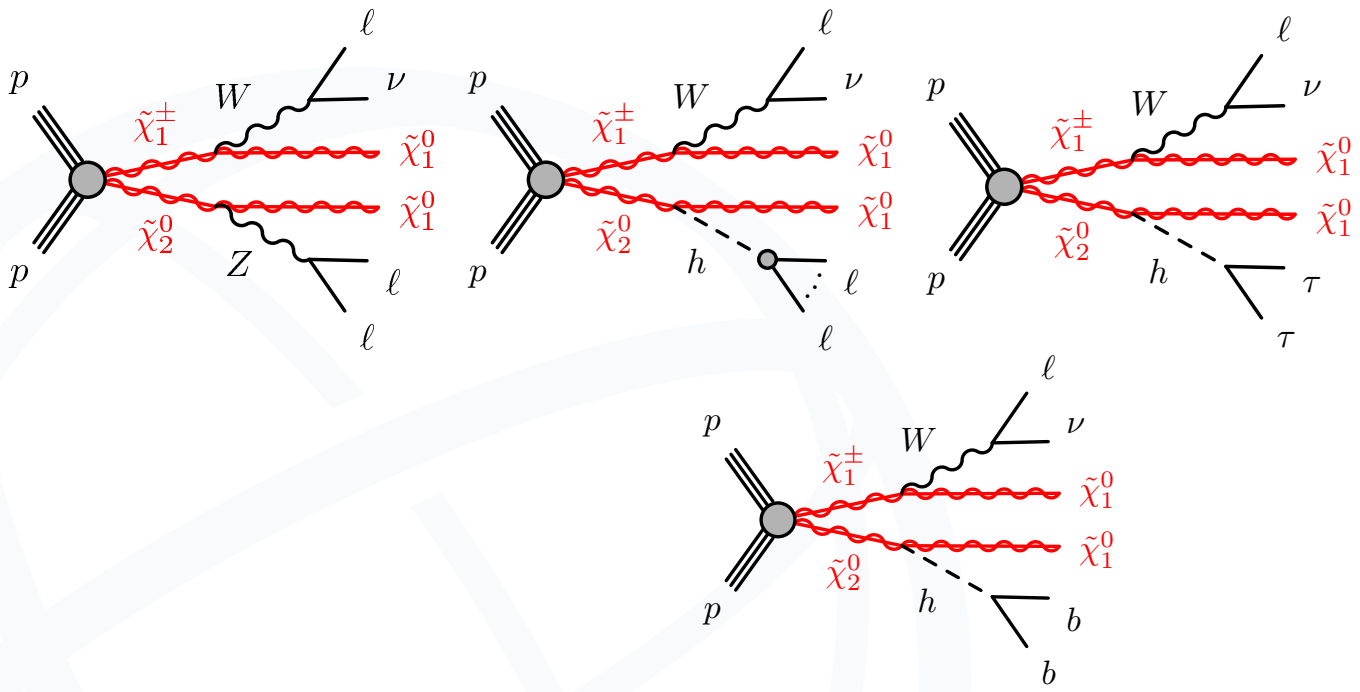
- Assumed **μ=200, σ_{bkg}=30%**



36.1 fb^{-1} exclusion
[1709.04183]







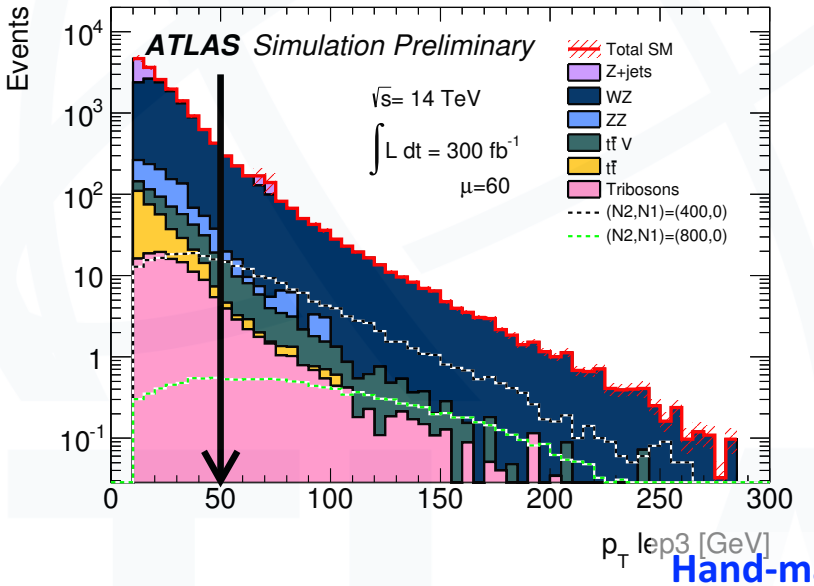
ELECTROWEAK-INOS

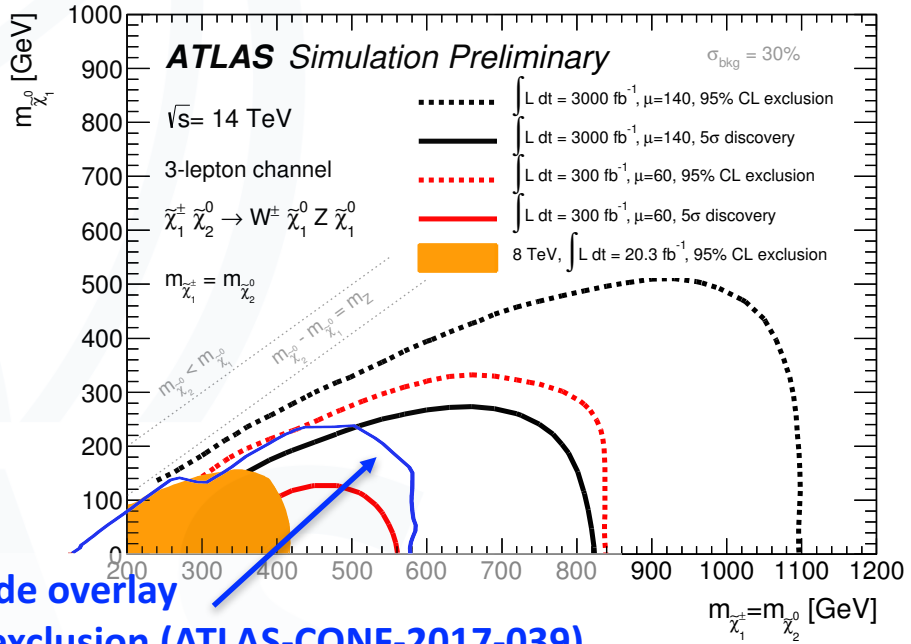
Multi-lepton search

Targets WZ-mediated decays

- Backgrounds: *WZ* and *ttV*
- Assumed **μ=140, σ_{bkg}=30%**
- Expected 95% CL limits from combination of non-overlapping regions

Selection	SRA	SRB	SRC	SRD
m_{SFOS}[GeV]	81.2-101.2			
# *b*-tagged jets	0			
lepton p_T (1,2,3)[GeV]	> 50			
E_T^{miss}[GeV]	> 250	> 300	> 400	> 500
m_T [GeV]	> 150	> 200	> 200	> 200
$\langle\mu\rangle$ = 60, 300 fb^{-1} scenario	yes	yes	yes	–
$\langle\mu\rangle$ = 140, 3000 fb^{-1} scenario	yes	yes	yes	yes





Hand-made overlay

36.1 fb^{-1} exclusion (ATLAS-CONF-2017-039)

Higgs mediated decays (ℓ and $\tau\tau$)

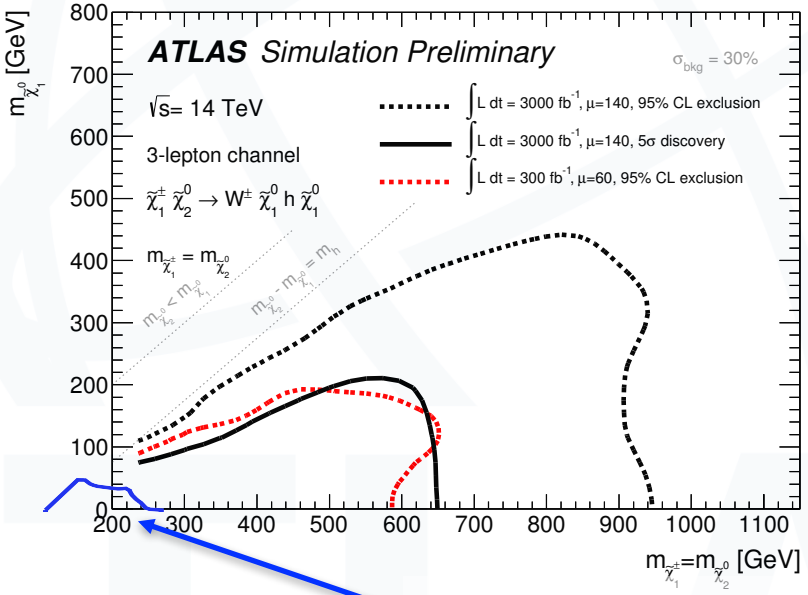
Additional multi-lepton SRs

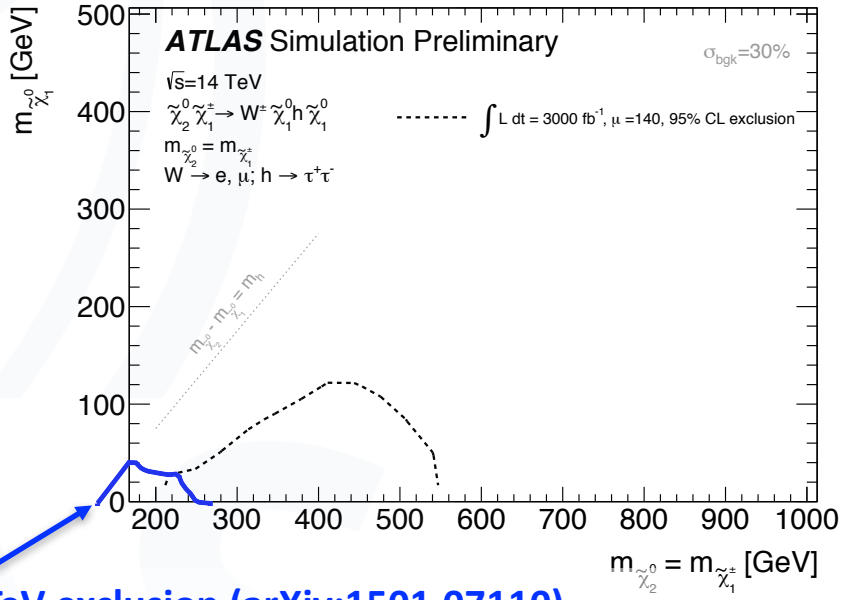
- Z-veto for same flavour lepton pairs

Dedicated hadronic taus selection

- Backgrounds: ttbar and *WW*
- Assumed **μ=140, σ_{bkg}=30%**
- Expected 95% CL limits from combination of non-overlapping regions

Selection	SR1ℓ2τ
# e, μ	1
# τ	2 (OS)
# b-tagged jets	0
$E_{\mathrm{T}}^{\mathrm{miss}}$ [GeV]	> 250
$m_{\tau\tau}$ [GeV]	80-130
$\lvert p_T(\tau_1)\rvert + \lvert p_T(\tau_2)\rvert$ [GeV]	> 190
$m_{\mathrm{T}}(\ell)$ [GeV]	> 130





Hand-made overlay of 8 TeV exclusion (arXiv:1501.07110)

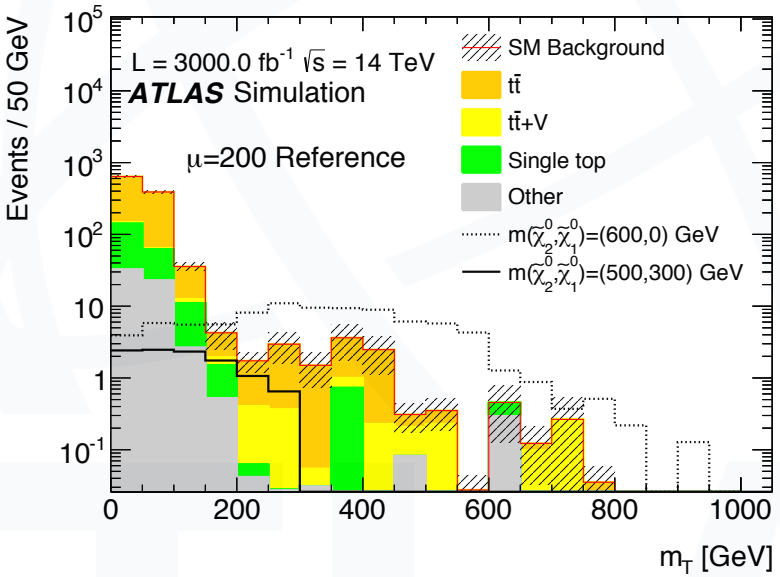
ATL-PHYS-PUB-2015-032
CERN-LHCC-2015-020

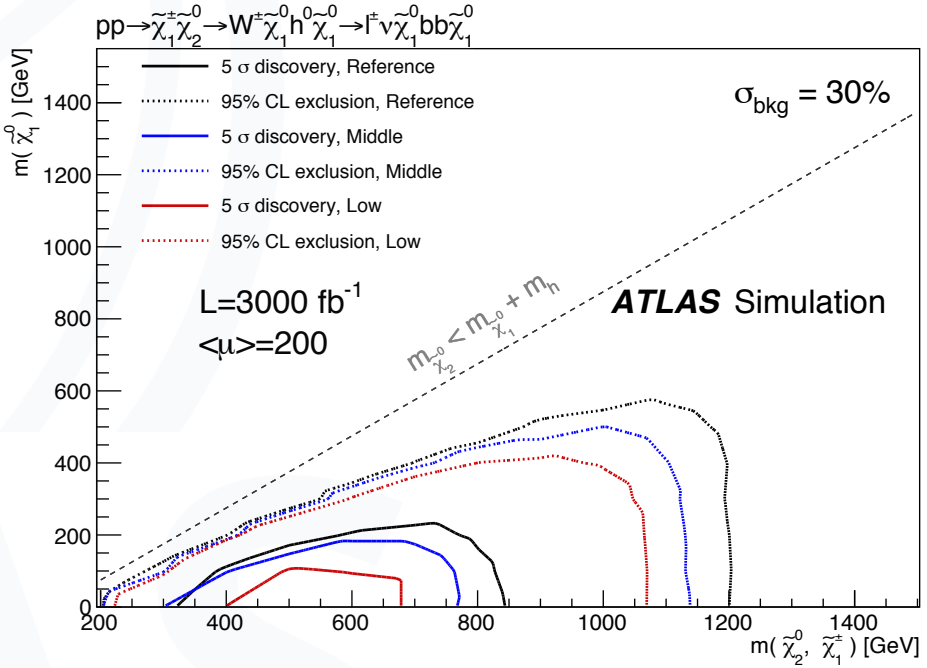
Higgs mediated decays (bb)

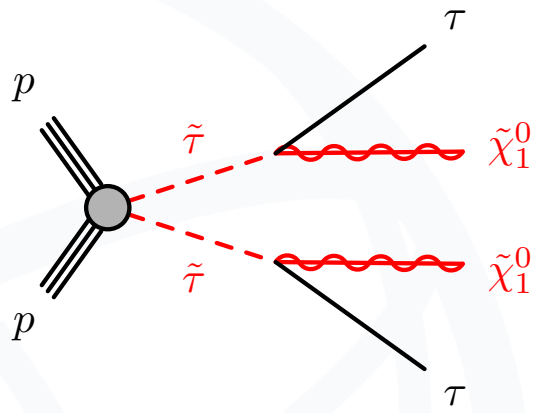
Reconstruct m_{bb} from Higgs

- Backgrounds: tt and *tt*V
- Assumed μ=200, σ_{bkg}=30%
- **Available for different detector designs**
- MVA techniques also explored

Selection	SRA	SRB	SRC	SRD
# of leptons (e, μ)	1			
# b-tagged jets	2			
m_{bb} [GeV]	$105 < m_{bb} < 135$			
# jets	2 or 3			
m_{CT} [GeV]	> 200	> 200	> 300	> 300
m_T [GeV]	> 200	> 250	> 200	> 250
E_T^{miss} [GeV]	> 300	> 350	> 400	> 450
$\langle\mu\rangle$ = 60, 300 fb^{-1} scenario	yes	yes	–	–
$\langle\mu\rangle$ = 140, 3000 fb^{-1} scenario	–	–	yes	yes





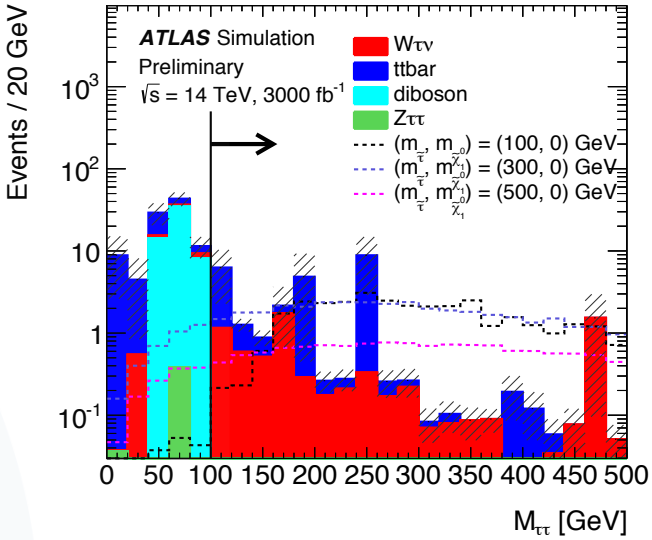


SLEPTONS (STAUS)

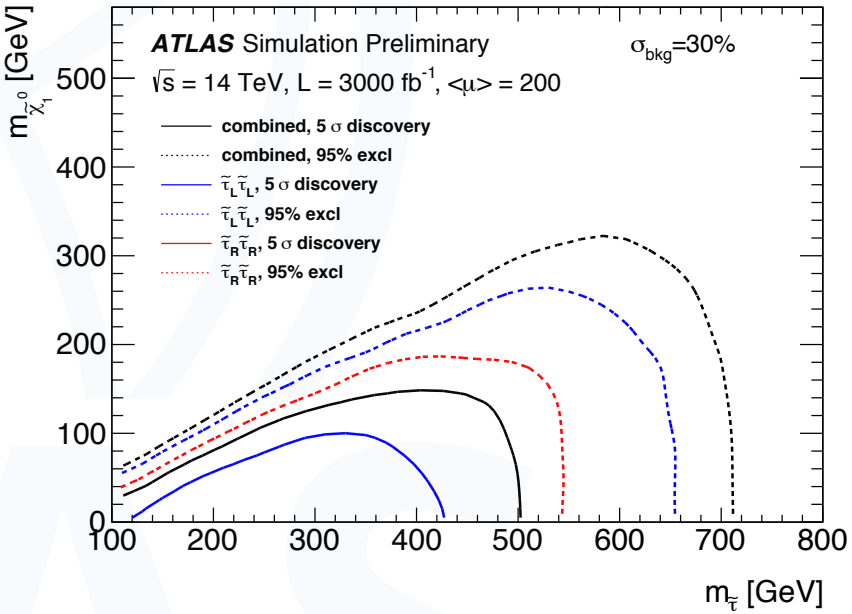
Hadronic tau search

Targets events with two hadron taus and no other hadronic activity

- Backgrounds: W+jets and ttbar
- Assumed μ=200, σ_{bkg}=20,30,50%
- No discovery sensitivity is found for pure τ_R production due to the small cross section



SR Definition
$\geq$ 2 OS taus
loose jet-veto
Z-veto
$\Delta R(\tau 1, \tau 2) < 3.5$
$E_{\mathrm{T}}^{\mathrm{miss}} > 280$ GeV
$m_{\mathrm{T2}} > 40$ GeV
$m_{\mathrm{T}\tau 1} + m_{\mathrm{T}\tau 2} > 480$ GeV



Summary

The reach of simplified SUSY searches at the HL-LHC has been explored.

- A comprehensive programme spanning from strong to electroweakly produced sparticles
- In some cases, higher center of mass energies will be needed to make a discovery

The search for SUSY continues!

- **Many interesting prospects in preparation**
- We'll keep looking into corners (e.g. R-parity violating and long-lived SUSY)

Stay tuned!

Thanks for your attention