Searches for electroweak SUSY with ATLAS at the HL-LHC

FNAL HE/HL-LHC meeting

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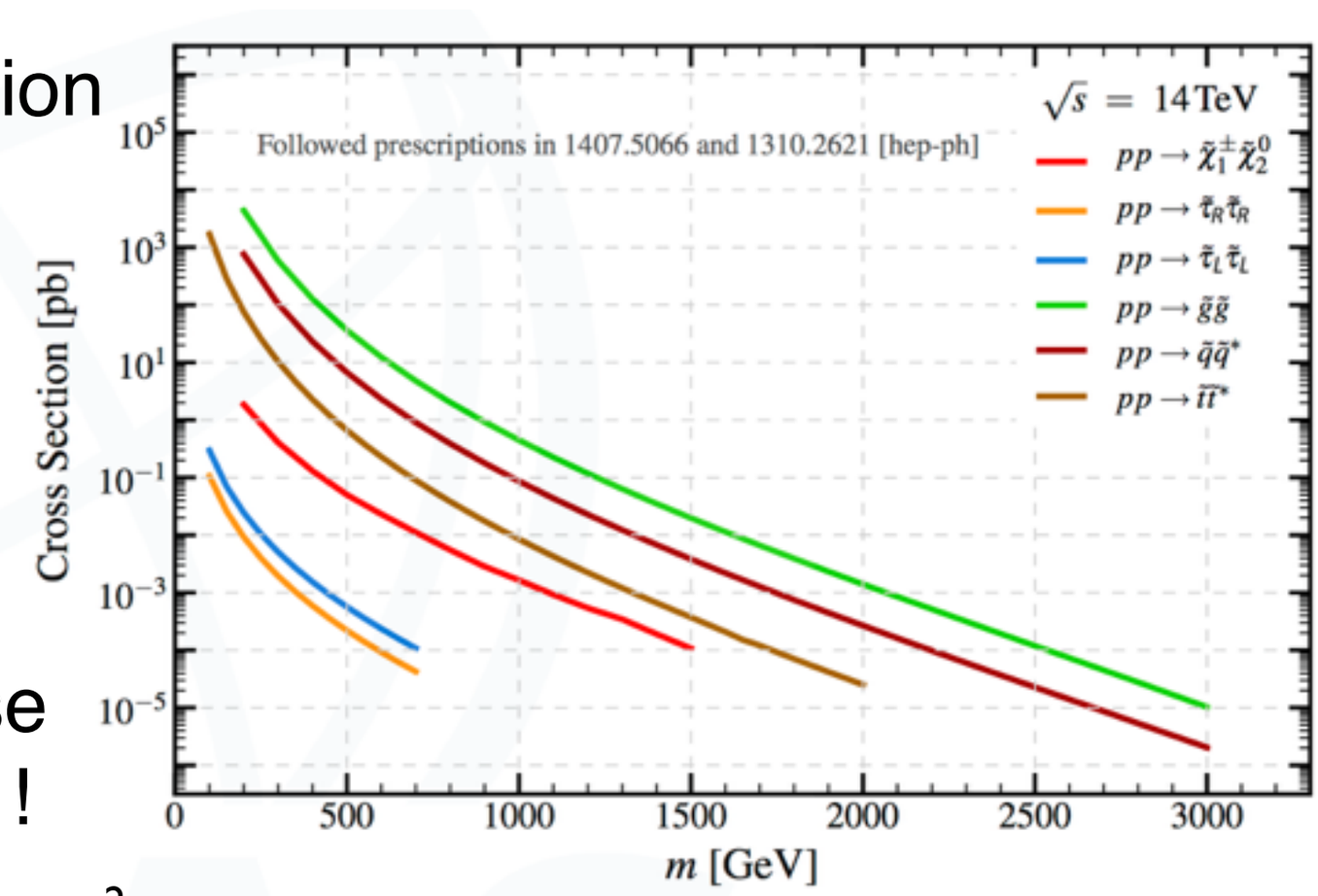
for the

ATLAS Collaboration

EWKinos at High-luminosity

- The LHC Run-1 has excluded a large part of the natural SUSY parameter space
  - Limits for strong production are now well above a TeV
  - Top and bottom squarks also highly constrained

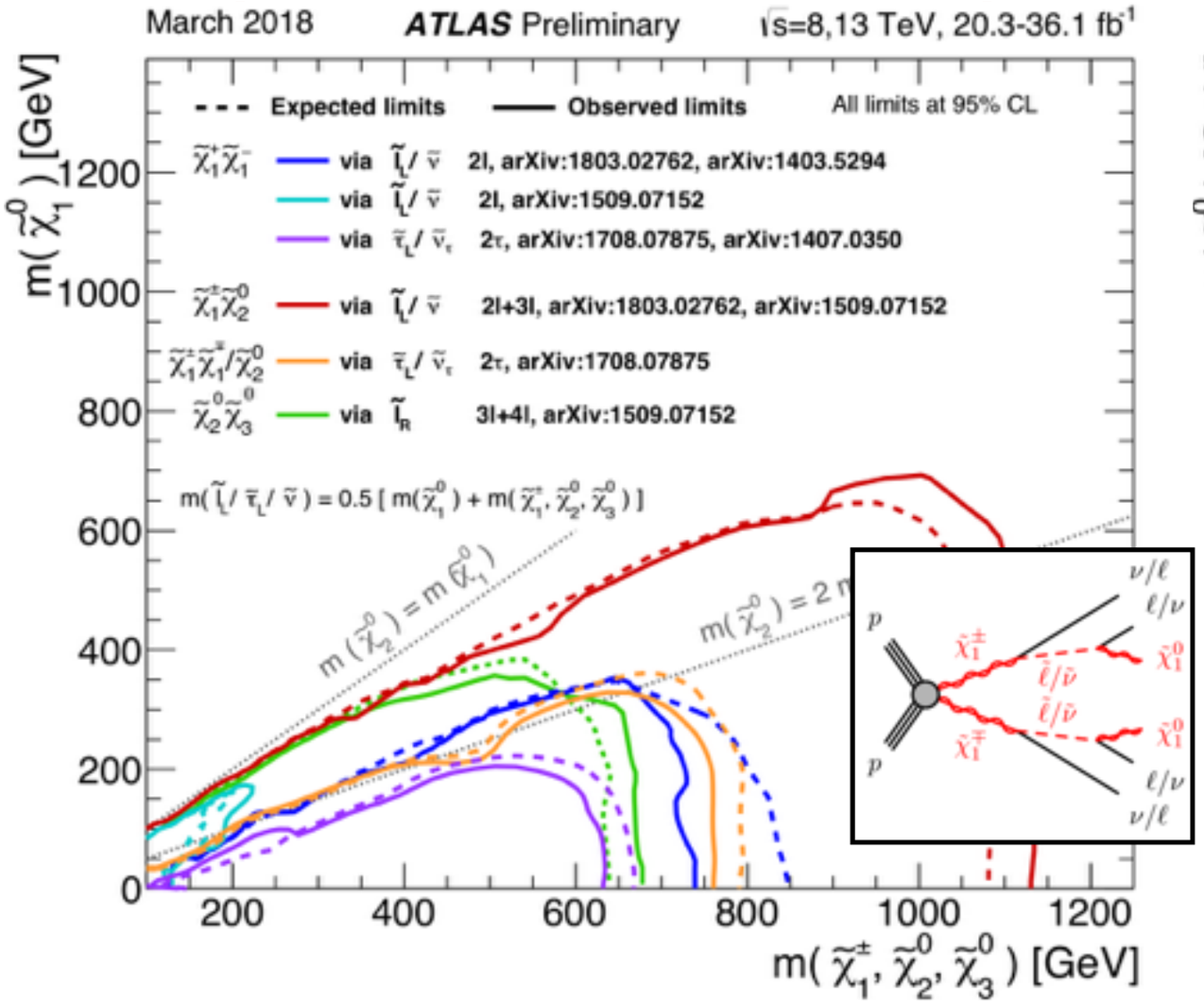
- Lots of opportunities in the electroweak sector
  - Can dominate the production if squarks, gluinos heavy
  - Complex signatures with smaller cross-sections, degenerate spectra
  - LHC limits only starting to probe the interesting phase space -> ***HL-LHC crucial*** !



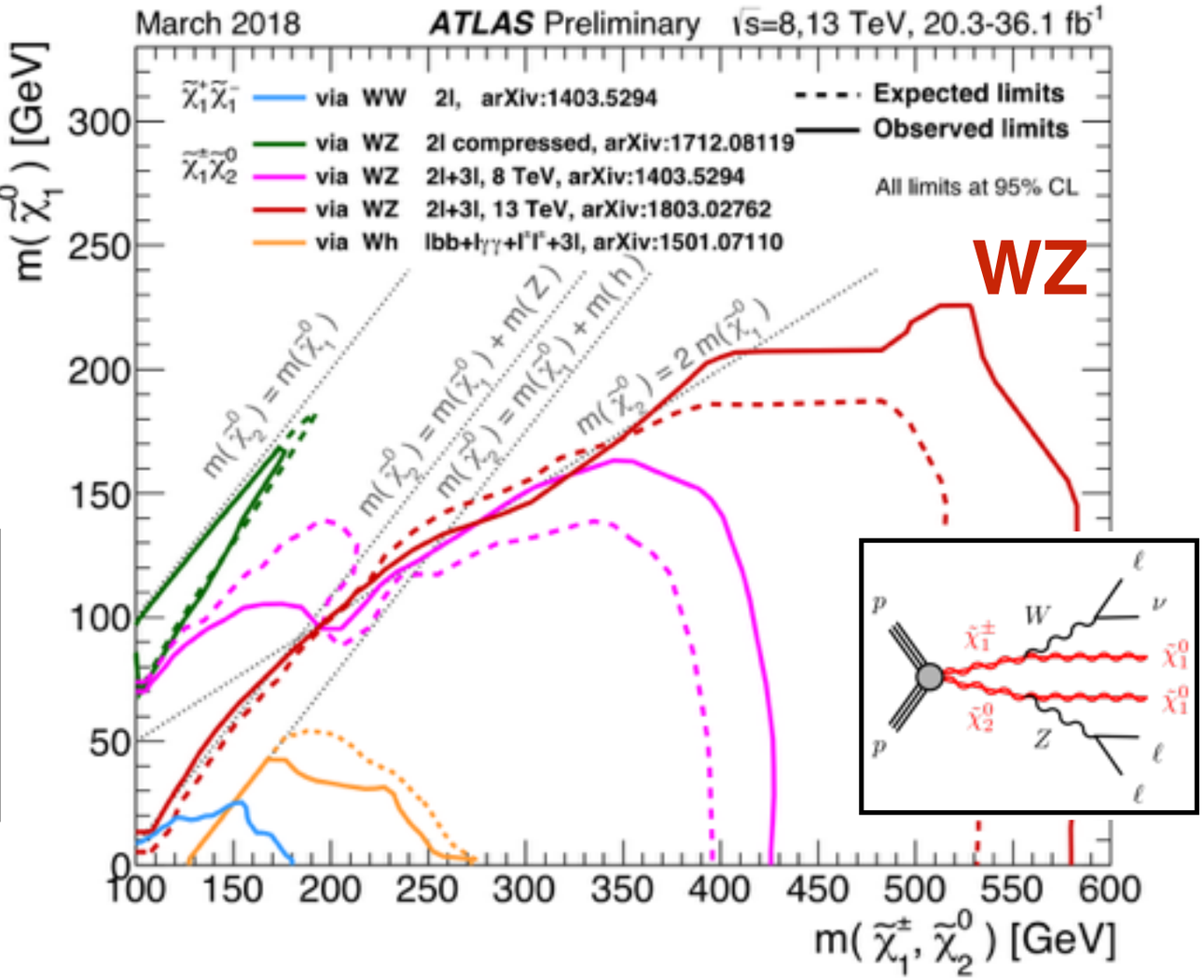
Where are we now?

- Run2 searches have set stringent constraints in simplified models of electroweakinos production
  - Looking both at the production of *charginos* and *neutralinos* and of *sleptons*

slepton mediated decays



SM bosons mediated decays

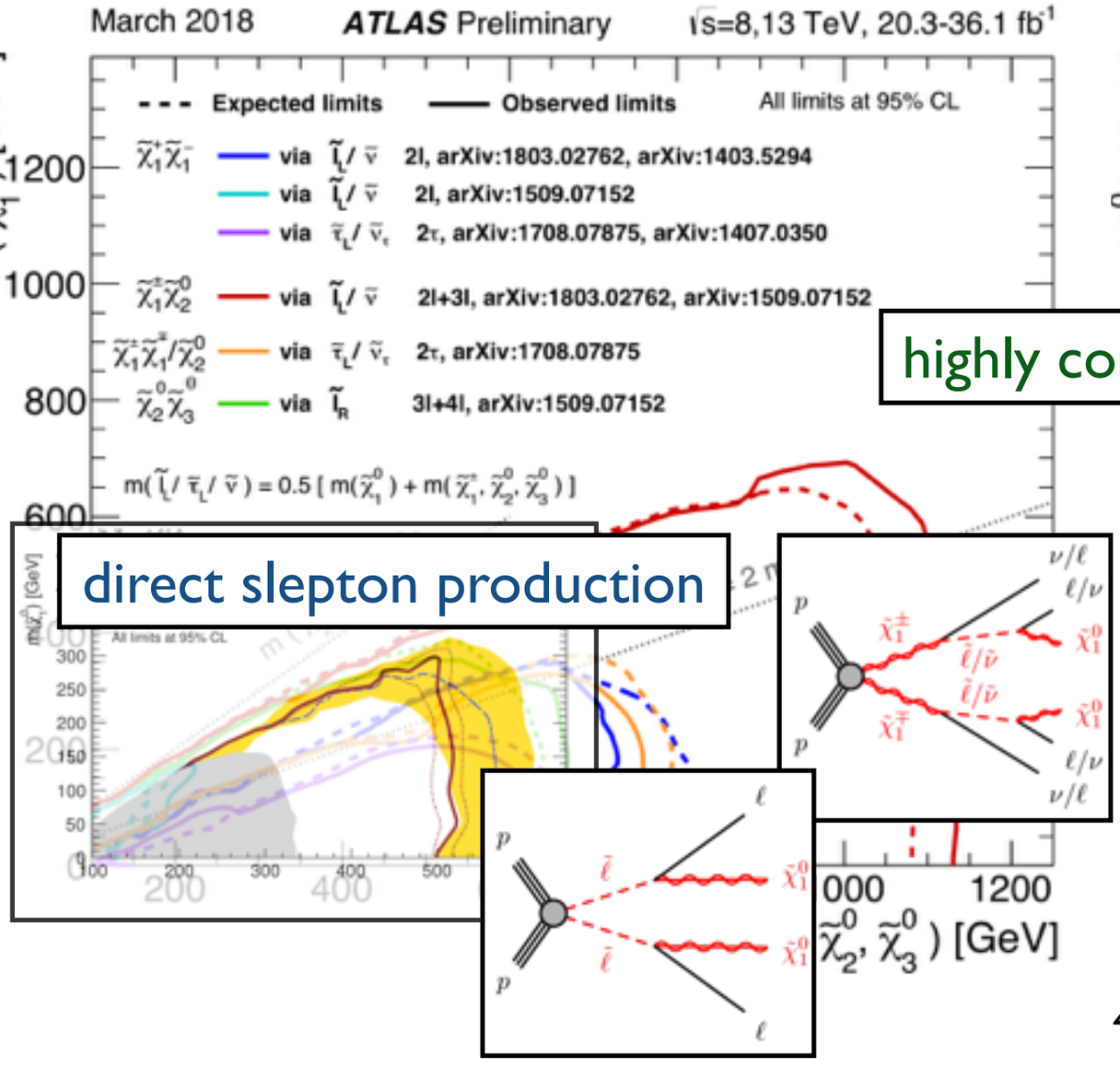


C1C1, N2C1 Wino-like, N2N3 Hino-like cross-sections

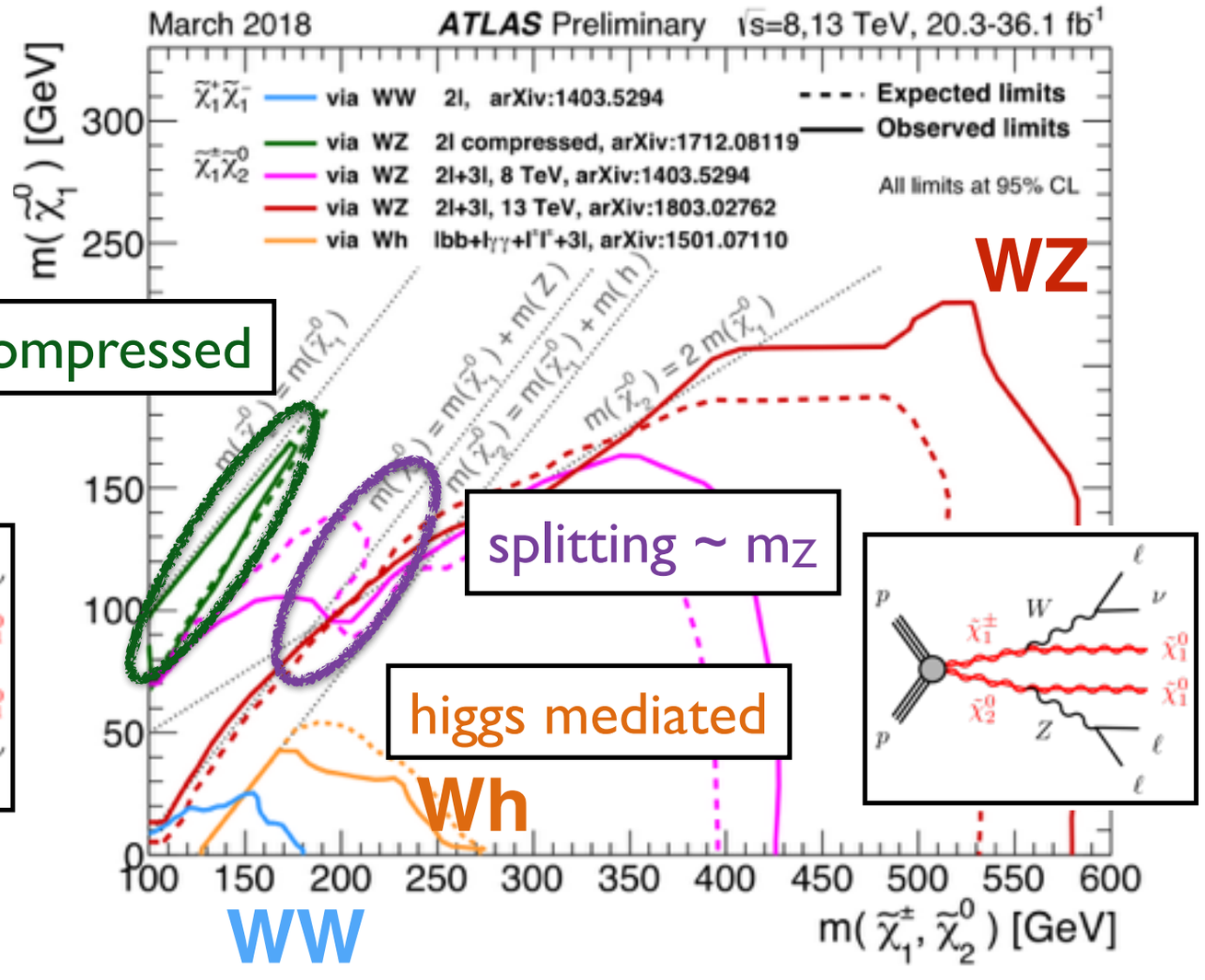
Where are we now?

- Good coverage in simplified models with specific assumptions on masses, spectra
  - But plenty of holes for highly motivated scenarios

slepton mediated decays



SM bosons mediated decays



C1C1, N2C1 Wino-like, N2N3 Hino-like cross-sections

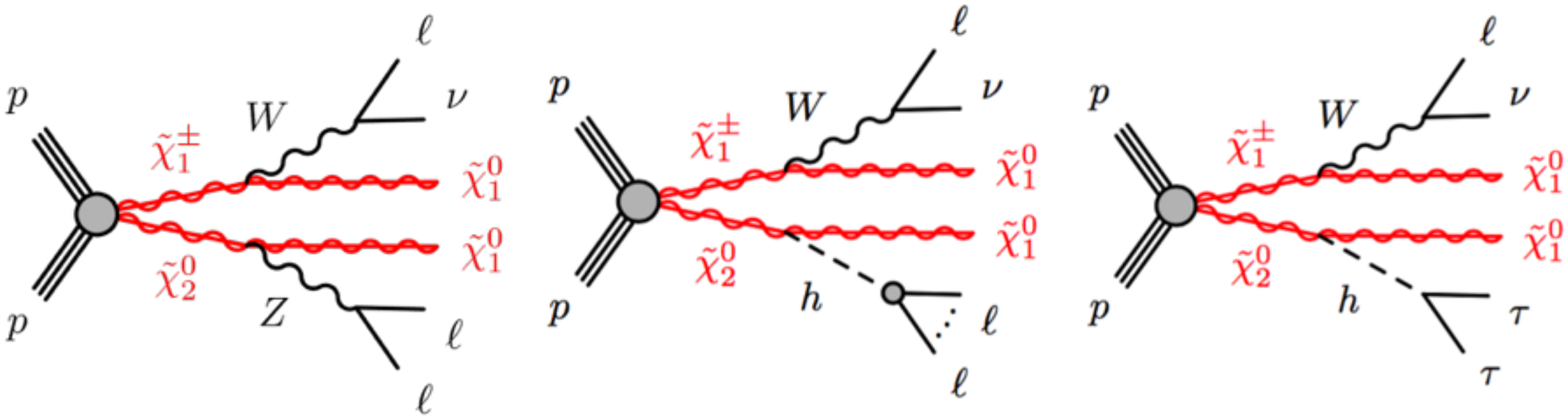
ATLAS UPGRADE STUDIES

- In this talk I will give an overview of the sensitivity projections for electroweak SUSY production using an upgraded ATLAS detector at the HL-LHC
- The studies are mostly covering *benchmark scenarios*, or particularly *challenging models* for the LHC, and where we expect significant gains from the HL/HE-LHC
  - Consider 300 fb^{-1} and 3000 fb^{-1} collected at 14 TeV
  - The detector response is parametrised with *smearings* of the reconstructed objects based on GEANT4 simulation obtained for μ=200
  - Typically projections for different values of bkg. uncertainty
- In addition I will go through new studies which we expect to have ready for the Yellow Report this summer

3-LEPTON SEARCH

ATL-PHYS-PUB-2014-010

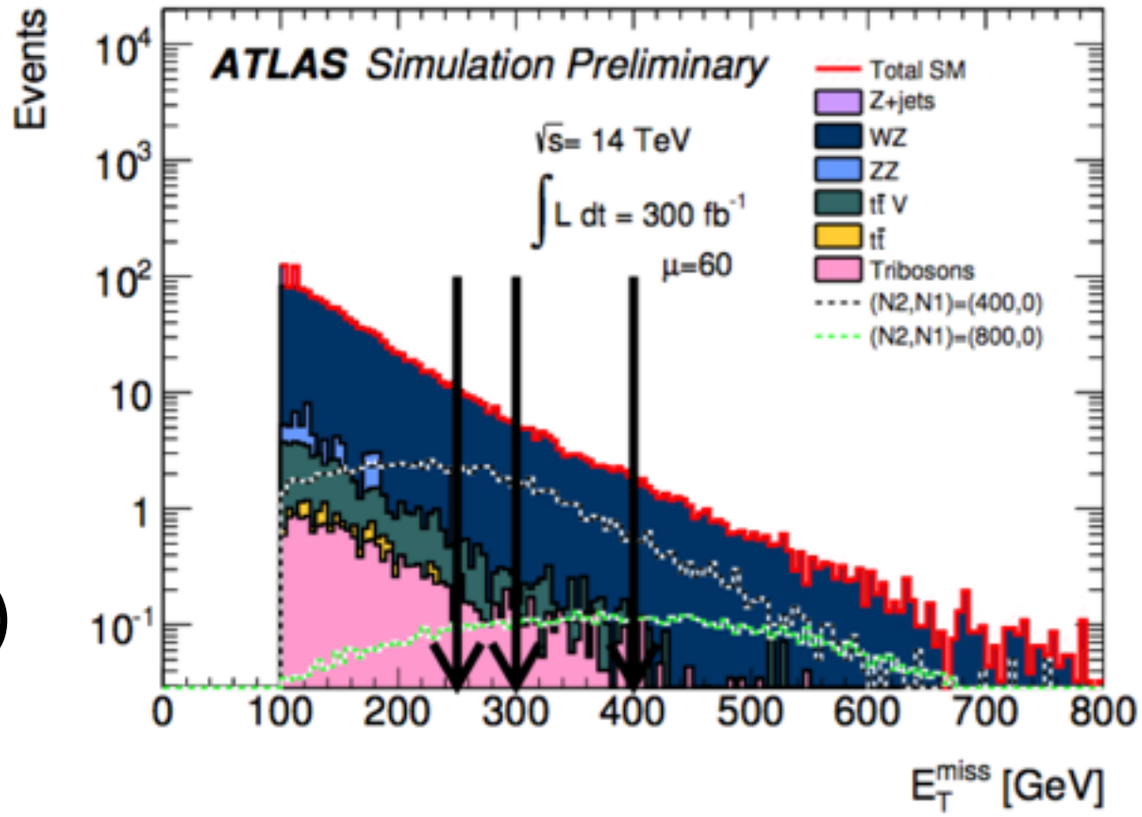
- Targets WZ- and Wh-mediated decays of charginos and neutralinos with wino-like cross-sections



- Two different selections studied for μ=140:
  - Three leptons for both WZ and Wh decays
  - One lepton plus two hadronic taus for the Wh model
- Background dominated by diboson, triboson and tt+V
  - Assuming a 30% uncertainty on the sum of backgrounds inspired by the current searches

3-lepton search (WZ)

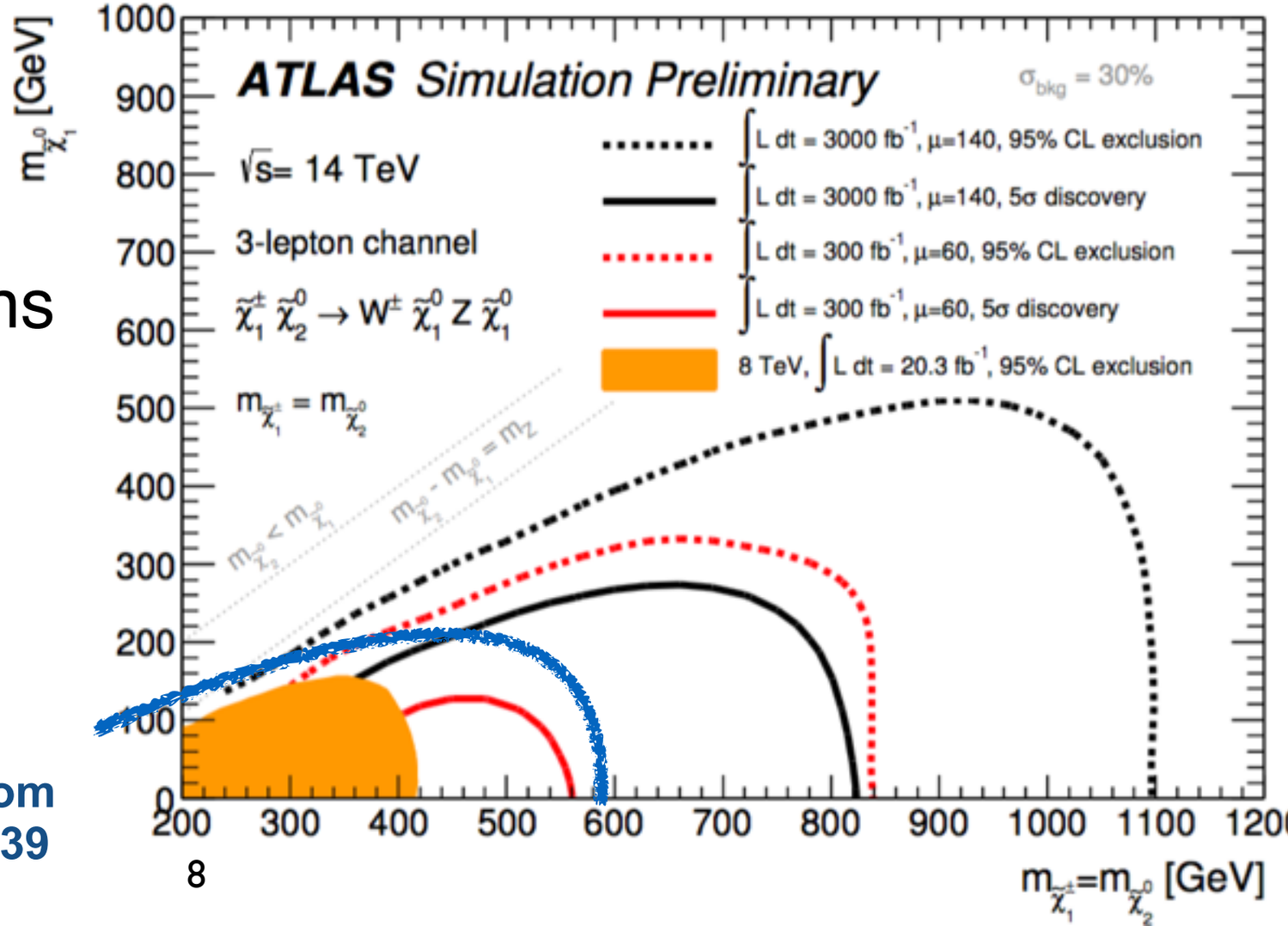
- For the WZ-mediated decays the following preselection is applied:
  - Exactly 3 leptons (p_T>50 GeV)
  - One SFOS lepton pair
  - One Z-boson candidate
  - Veto on b-tag jets (p_T>20 GeV)



- Four signal regions are then defined with varying requirements on E_T^{miss} and m_T
  - m_T constructed with the lepton not forming the SFOS pair
  - They are statistically combined to improve sensitivity

Expected sensitivity (WZ)

- With 3 ab^{-1} roughly doubling the discovery potential over the published 8 TeV searches
  - Exclusion surpassing 1 TeV for a massless LSP
- These projections will be updated for summer
  - Following the Run2 analysis strategy; already better than the 300 fb^{-1} projections
  - Using updated object smearings



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

3-lepton search (WH)

Selection	SRE	SRF	SRG	SRH
SFOS pair		veto		
# b-tagged jets		0		
$E_{\mathrm{T}}^{\mathrm{miss}}$ [GeV]		> 100		
$m_{\mathrm{OS}}^{min\Delta R}$ [GeV]		< 75		
$m_{\mathrm{T}}(\ell_1)$ [GeV]	> 200	> 200	> 300	> 400
$m_{\mathrm{T}}(\ell_2)$ [GeV]	> 100	> 150	> 150	> 150
$m_{\mathrm{T}}(\ell_3)$ [GeV]	> 100	> 100	> 100	> 100
$\langle\mu\rangle = 60$, 300 fb^{-1} scenario	yes	yes	yes	—
$\langle\mu\rangle = 140$, 3000 fb^{-1} scenario	yes	yes	yes	yes

* Four SRs are optimised separately for small and large mass splittings for the 3-lepton search

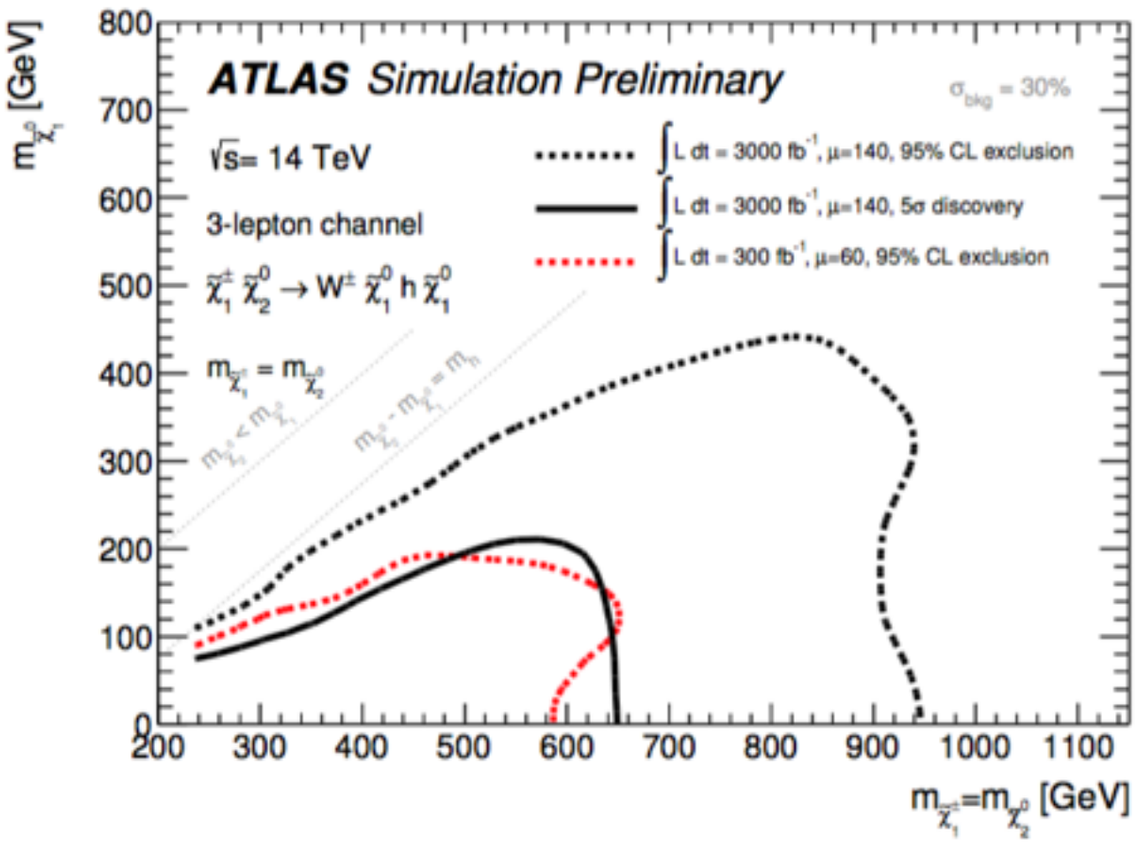
* They are statistically combined to estimate the sensitivity

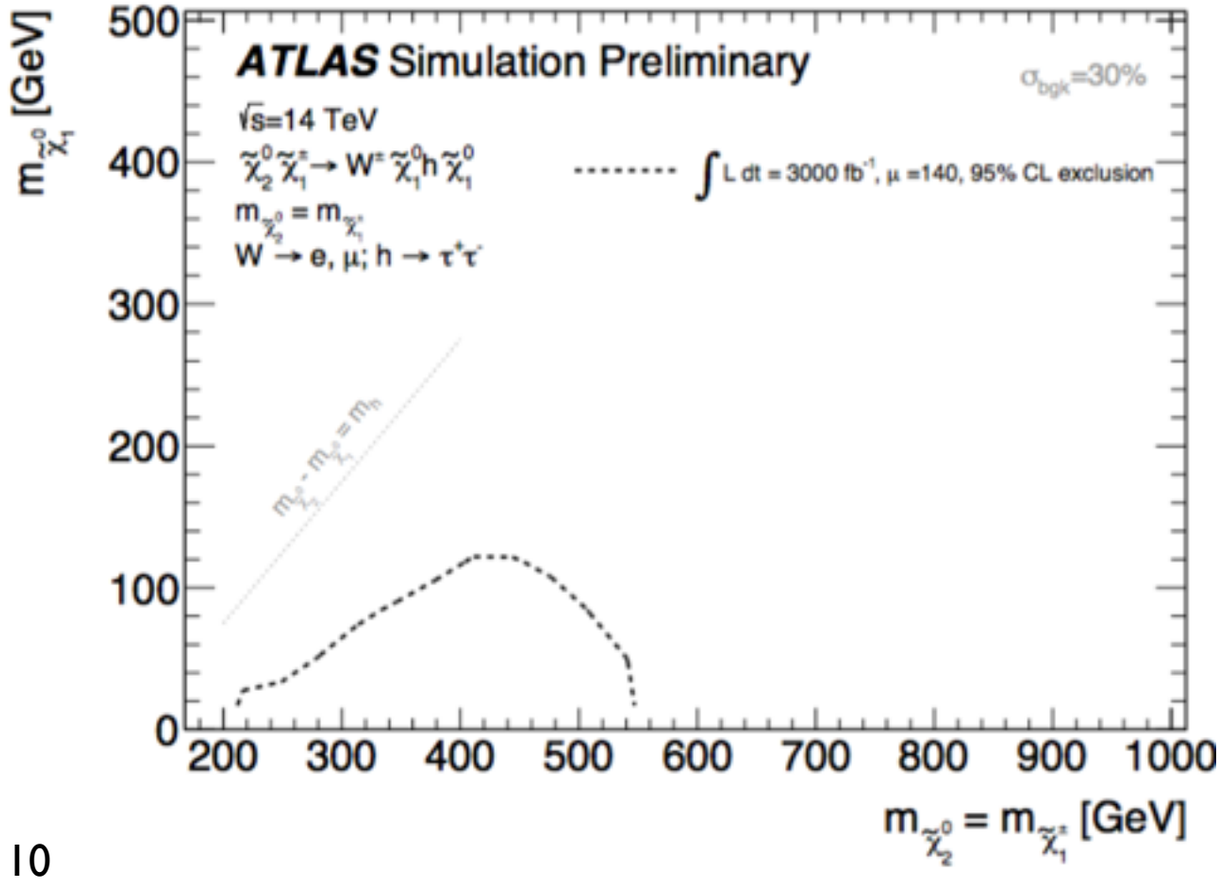
* One SR requiring one lepton in association with two hadronic tau candidates (p_T>20 GeV)

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

Expected sensitivity (Wh)

- Discovery reach of 650 GeV in C1/N2 mass for 3 ab^{-1}
  - Significant improvement over the 8 TeV exclusion of ~250 GeV for a massless LSP
- For h->ττ exclusion going up to 550 GeV

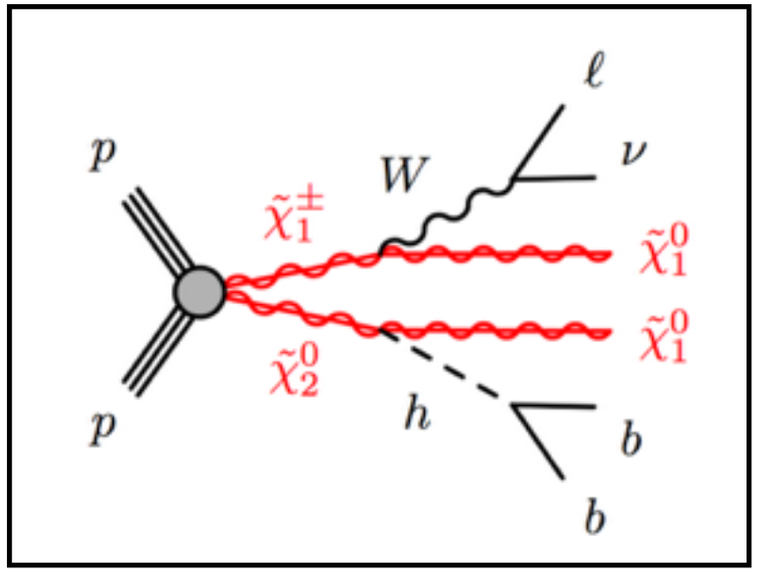




WH(→BB)

ATL-PHYS-PUB-2015-032

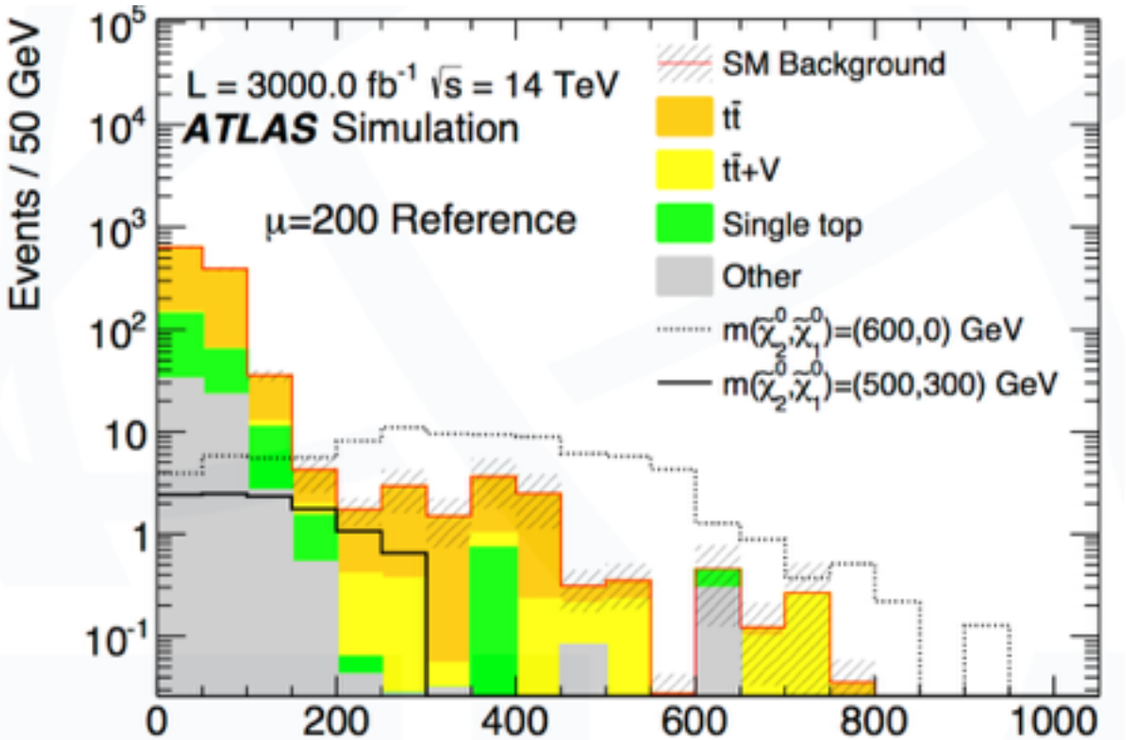
- Also looking at Wh-mediated decays with the higgs decaying into a bbbar pair
  - Requires one lepton and a pair of b-jets consistent with a Higgs mass hypothesis (5% signal efficiency)
  - Vetoes multi jet events to reduce tt, ttV
  - Selections on m_{CT}, m_T, E_T^{miss}



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

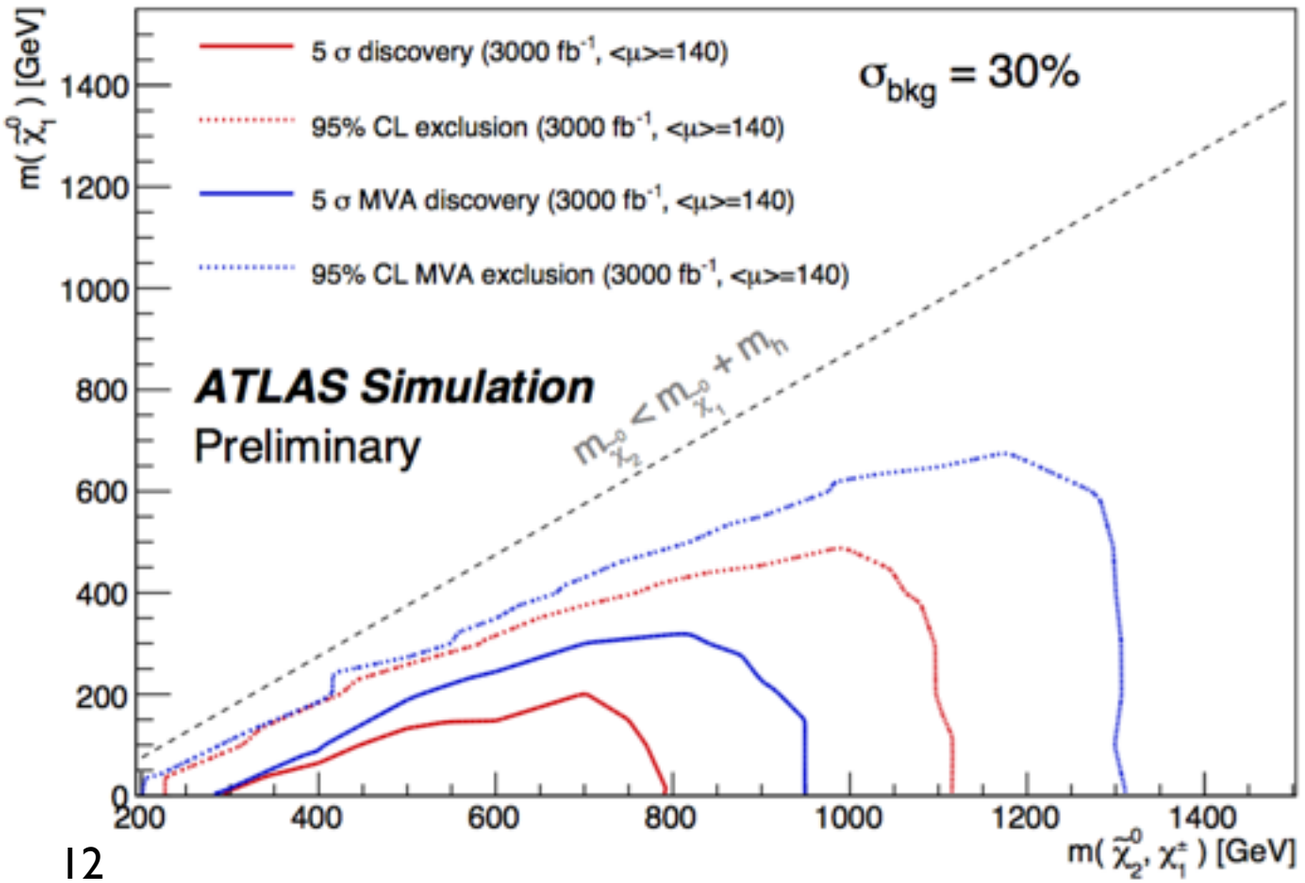
- Four SRs defined maximising the discovery sensitivity
- In addition considered an MVA selection (BDT)

Expected sensitivity (WH)



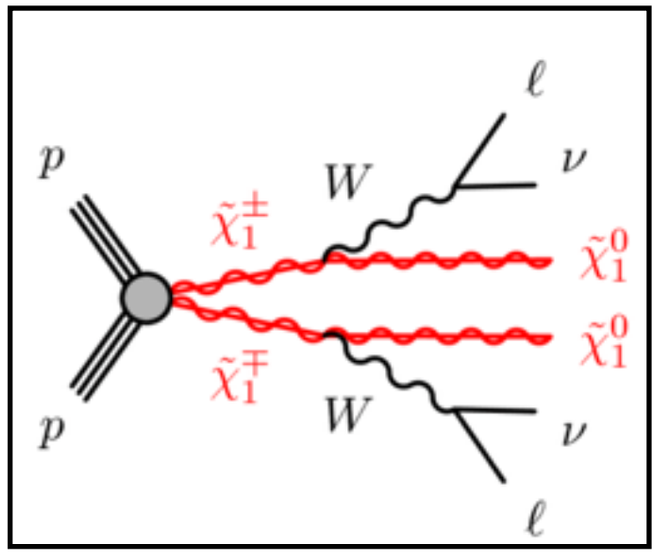
- Discovery sensitivity up to 800 GeV in N2/C1 mass
- Reaching almost 1 TeV of discovery sensitivity
- MVA selection improves the results by about 200 GeV

- Result will be updated for summer with the new detector parametrisation

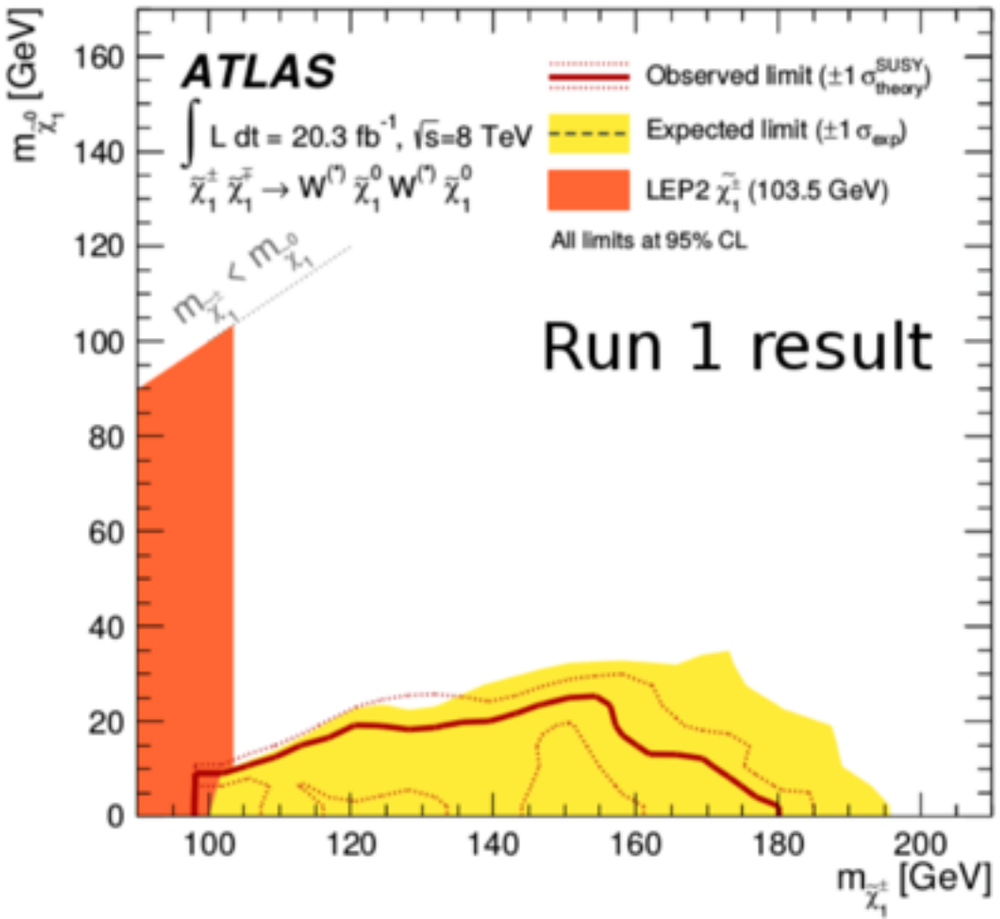


C1C1 TO WW

- Challenging process, with a signature very similar to the Standard Model WW production
  - Run1 results only scraping sensitivity
  - Extremely interesting channel for HL-LHC



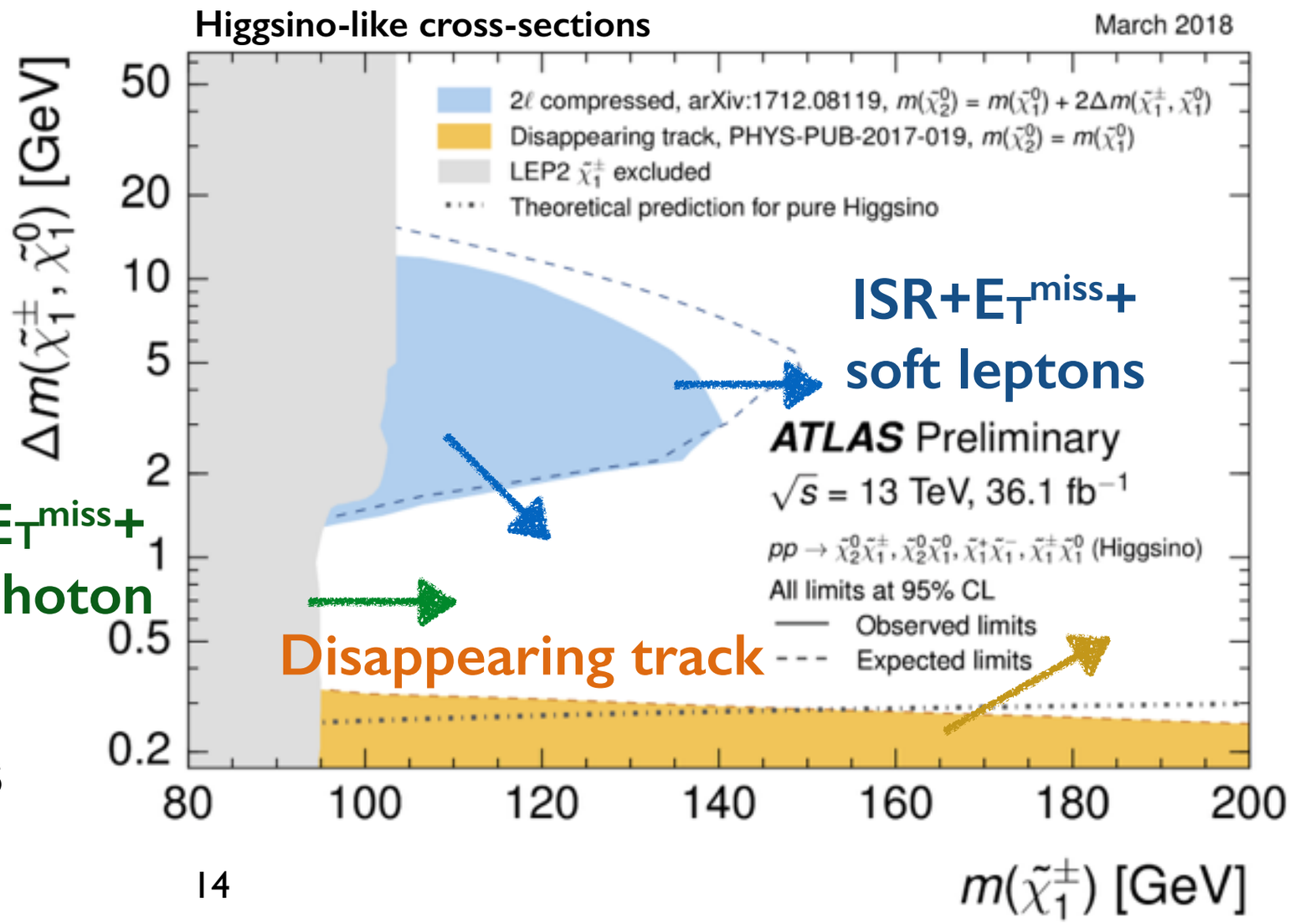
- Plan for a new upgrade study result for the Yellow Report



- Optimising the jet veto and the requirements on E_T^{miss} and M_{T2}
- Evaluating the sensitivity for different assumptions on the WW background uncertainty

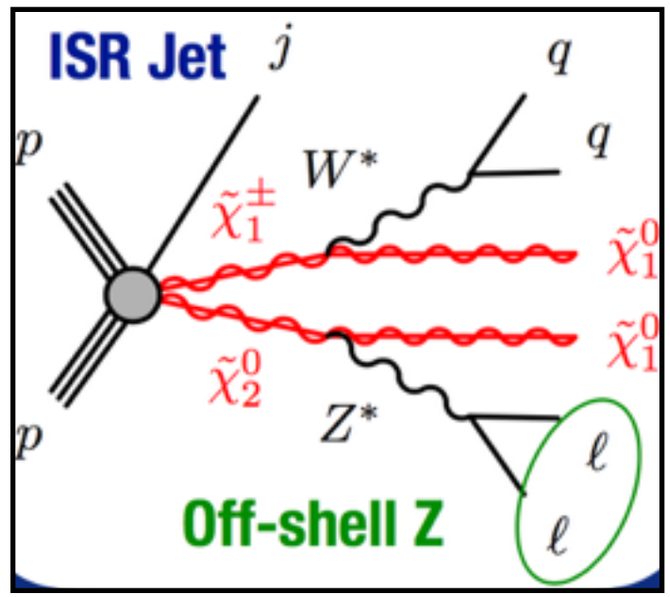
Compressed EWKinos

- In the limit of low-μ the two lightest neutralino and lightest chargino are ***higgsino-like***, and nearly mass degenerate (from hundreds of MeV to few GeVs)
  - Very hard scenario for the LHC, small cross-sections and *soft decay products* of the ewkinos
  - The charginos acquires a lifetime and can give a *disappearing track* signature (L. Jeanty talk)
  - Plan to explore this naturalness inspired scenario with several HL projections for the Yellow Report



ISR + E_T^{miss} + SOFT LEPTONS

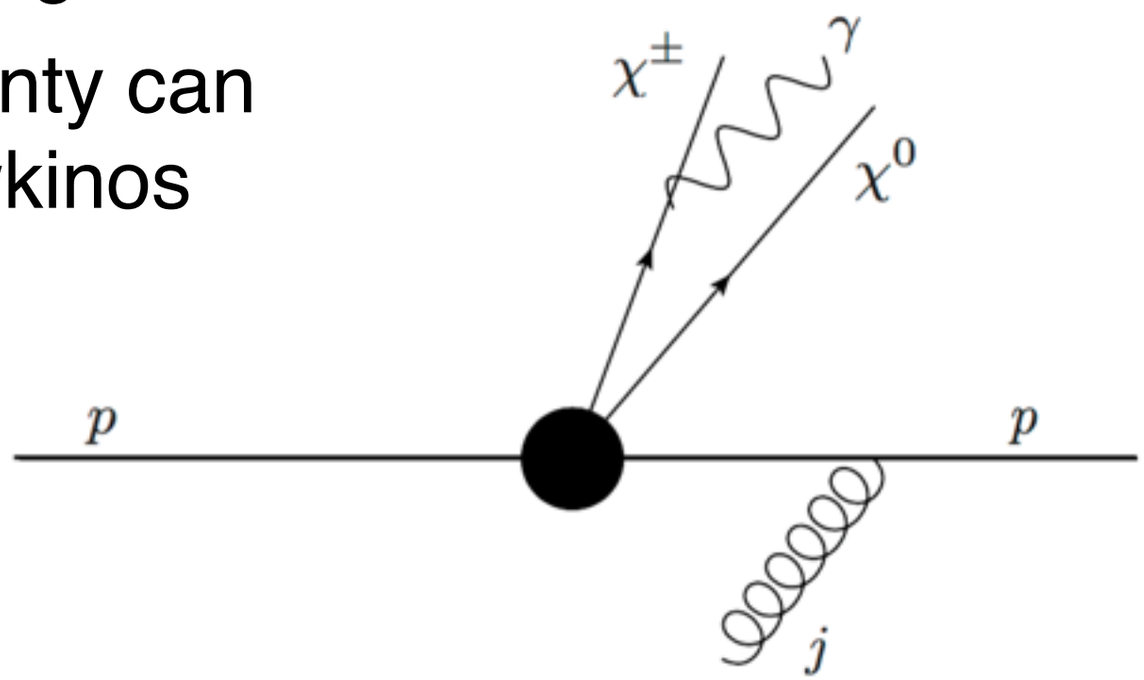
- For splittings greater than a GeV one can try to explicitly reconstruct the soft leptons
  - Recent Run2 result extending the LEP exclusion for the first time
  - Low-p_T lepton reconstruction crucial



- Upgrade study based on the Run2 13 TeV result
  - Require large E_T^{miss} recoiling against a high p_T ISR jet
  - Consider only muons and down to p_T of 3 GeV (4 GeV Run2)
  - Additional requirements on the maximum lepton p_T, $m_{\tau\tau}$, E_T^{miss}/H_T, ΔR_{ll}
  - A fit to the m_{ll} distribution is used to extract the signal
- Projections for 14 TeV and 27 TeV will be provided

ISR + E_T^{miss} + FSR PHOTON

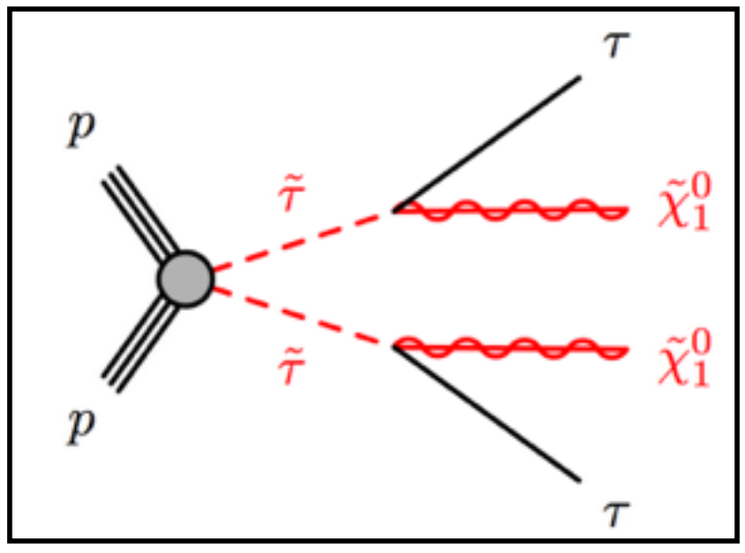
- For mass splittings between ~200 MeV and few GeVs the ewkinos decay products are too soft to be reconstructed
  - And too short decay length for disappearing track searches
- A different strategy proposed in *1605.00658*
- Require an *soft photon from FSR* of the charginos, collinear with the E_T^{miss} direction
  - Reduce the dominant Z→νν bkg
  - For a 2% background uncertainty can get sensitivity to ~150 GeV ewkinos
- Ongoing validation of those projections within an ATLAS upgrade study (for summer)



Direct stau production

ATL-PHYS-PUB-2016-021

- If charginos and NLSP neutralinos are heavy the direct production of stau pairs can become the dominant ewk. production in the pMSSM
- Run1 result excludes Stau_R only up to 109 GeV for a massless LSP
  - Barely improving over the exclusion from LEP



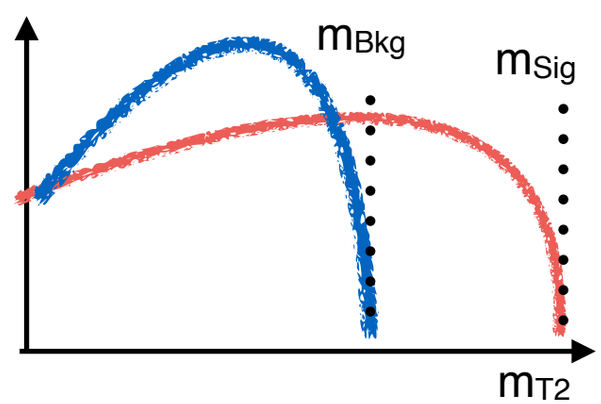
- Study considers production of stau_L or stau_R with a 100% BR into a tau-lepton and the LSP
  - Event selection largely based on the 8 TeV analysis
  - Detector simulation using parameterised smearing for μ=200

Event selection

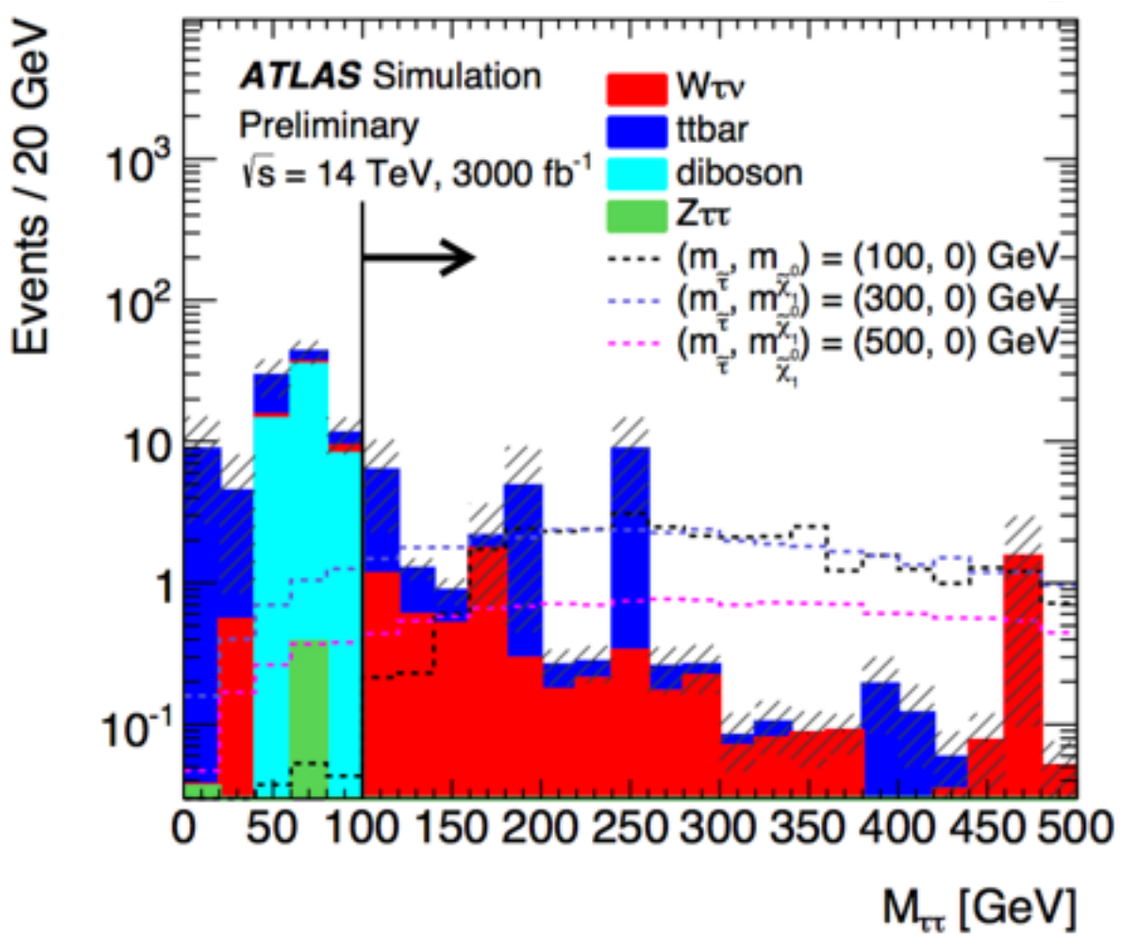
- Require two hadronic tau candidates with $p_T > 50, 40$ GeV
  - Jet veto and Z-veto to reduce backgrounds
  - m_{T2} and the transverse masses of the two tau and the E_T^{miss} are used as sensitive variables

SR Definition
≥ 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

The transverse mass m_{T2} has a kinematic endpoint for events where two massive pair-produced particles each decay into a visible and an invisible particle

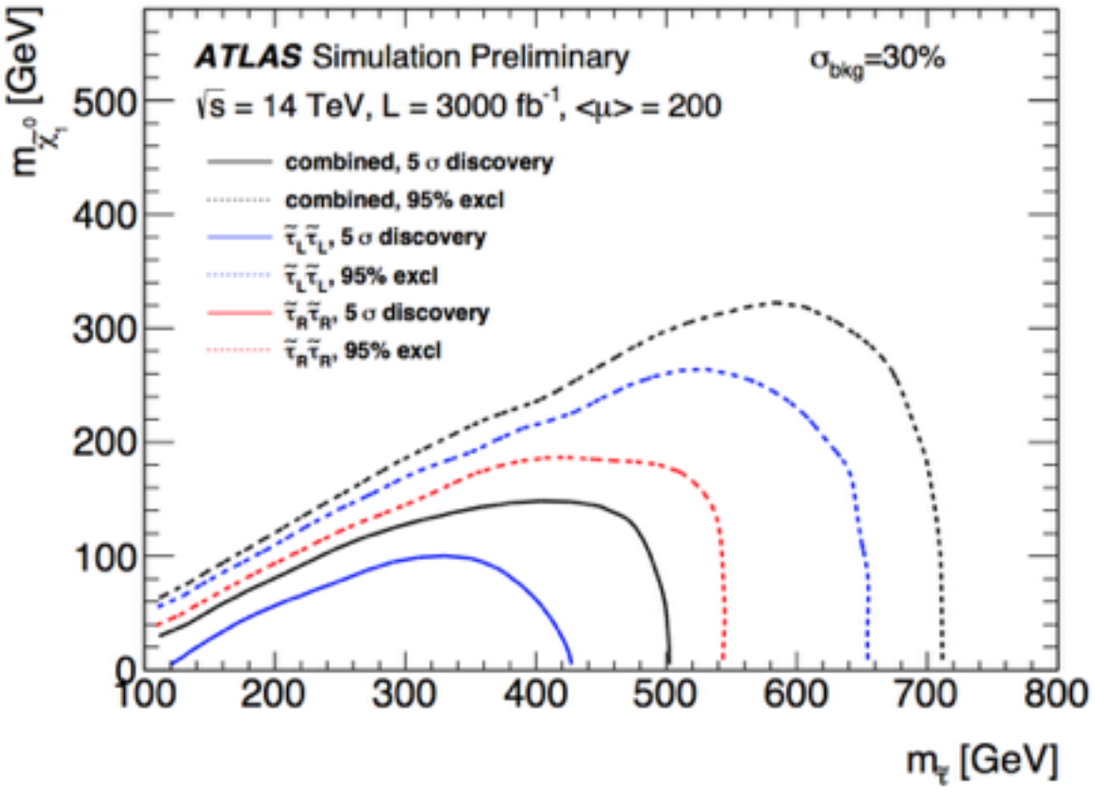


- SM backgrounds dominated by W+jets and ttbar production
- A 30% bkg. uncertainty assumed, inspired by Run1 numbers

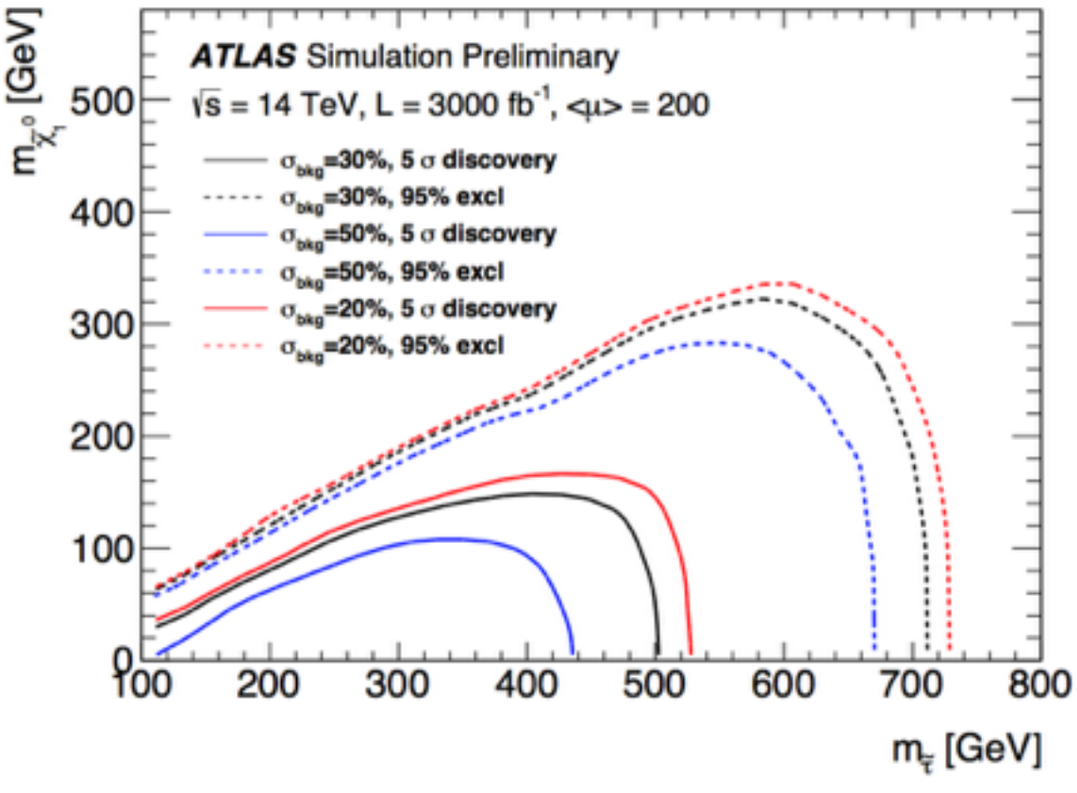


Sensitivity

- Discovery and exclusion sensitivities are computed for both $\tilde{\tau}_L$, $\tilde{\tau}_R$ and their combined production
  - Reaching a discovery sensitivity above 400 GeV for $\tilde{\tau}_L$
  - No discovery sensitivity for pure $\tilde{\tau}_R$ production due to its small cross-section
- Result *to be updated* for summer
  - Expect differences due to new (better) tau smearing
  - Aim to improve sensitivity for $\tilde{\tau}_R$



$\tilde{\tau}_R + \tilde{\tau}_L$ combined



Summary

- Searches for electroweak SUSY partners will benefit the most of the energy and luminosity increase of the LHC
  - Important to asses the reach for benchmark models
- Several projections have been produced in the past years
  - chargino/neutralino pairs with decays to WZ
  - chargino/neutralino pairs with decays to Wh (decays to ττ, bb)
  - Direct production of stau pairs
- They will be updated with the most recent parametrisation of the upgraded detector and improved analysis strategy (with the Run2 experience)
- And new studies are being performed for the Yellow Report
  - Compressed electroweakino with soft leptons
  - Disappearing track (higgsino interpretation)
  - Chargino pair production with decays into WW