Search for “Electroweakinos” with the ATLAS Detector at the LHC

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On behalf of the ATLAS Collaboration

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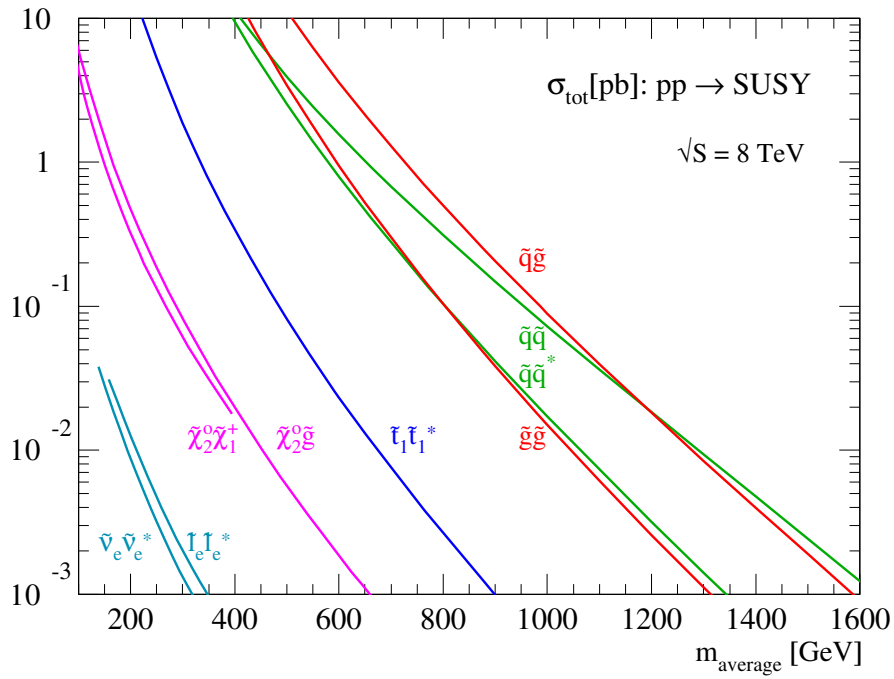
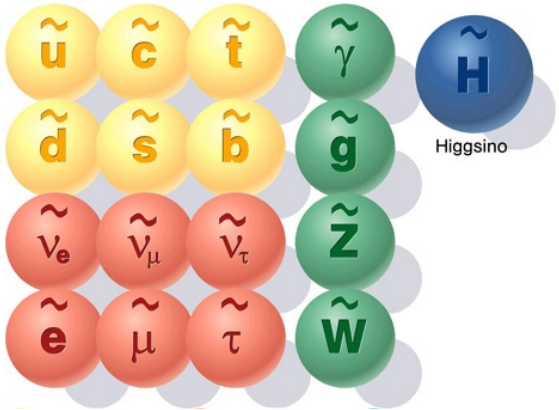
Search for Electroweakinos

- Electroweakinos = charginos $\widetilde{\chi}^{\pm}_{1,2}$ + neutralinos $\widetilde{\chi}^{0}_{1,2,3,4}$ (mixtures of bino, winos, higgsinos)
- Superpartners of $U(1)_Y$ and $SU(2)_L$ gauge bosons and Higgs doublets





Superpartners:
squarks, sleptons, gauginos and higgsinos

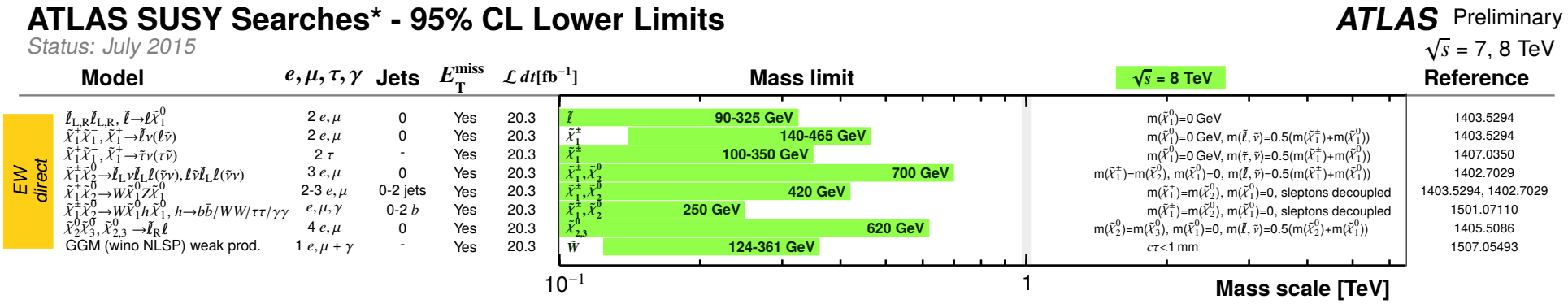
Motivation

- Complementarity: EWK production may dominate at LHC if squarks and gluinos heavy
- Naturalness: masses of lightest charginos and neutralinos accessible at LHC

Status Quo

- Run-2 of LHC has begun, past months: push to finalize remaining Run-1 SUSY analyses
- Not enough Run-2 data yet to produce competitive new results for EWK production

- Here: recent EWK results from ATLAS, 20 fb^{-1} at $\sqrt{s} = 8\ \mathrm{TeV}$ (2012 dataset from Run-1)
- Searches produced null results (no significant excess beyond SM expectation observed)
- $\Rightarrow$ limits on masses of supersymmetric particles



Excerpt from ATLAS mass reach plot

Recent Results from the ATLAS Electroweak Searches

- $h \to \gamma(\gamma) + \not{E}_T$ via $\widetilde{\chi}^0_{1/2}$:
  "Search for exotic Higgs-boson decays in events with at least one photon, missing transverse momentum, and two forward jets produced in $\sqrt{s} = 8\,\mathrm{TeV}$ *pp* collisions with the ATLAS detector"
  (ATLAS-CONF-2015-001, Feb. 2015)
- $\widetilde{\chi}^\pm_1 \widetilde{\chi}^0_2$ via *Wh*:
  "Search for direct pair production of a chargino and a neutralino decaying to the 125 GeV Higgs boson in $\sqrt{s} = 8\,\mathrm{TeV}$ *pp* collisions with the ATLAS detector"
  (Eur. Phys. J. C, 75:208, May 2015)
- **EWK Summary Paper:**
  "Search for the electroweak production of supersymmetric particles in $\sqrt{s} = 8\,\mathrm{TeV}$ *pp* collisions with the ATLAS detector"
  (ATLAS-SUSY-2014-05, to appear)

Scope

- Goal: summarize and extend search for electroweak supersymmetry
- Focus: improvements for compressed scenarios and models with low cross sections

New Analyses

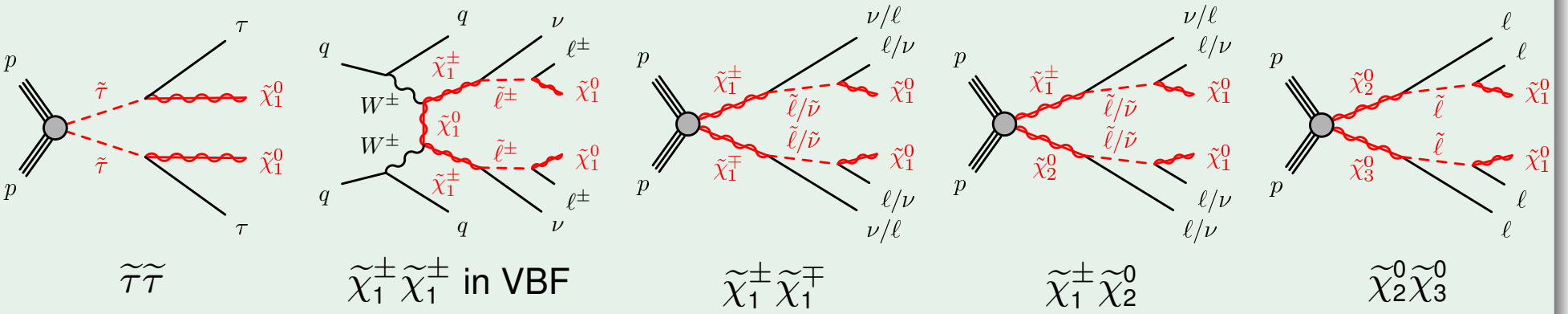
- 2 OS τ (MVA)
- 2 SS ℓ (VBF)
- 2 OS ℓ (ISR)
- 2 SS ℓ (MVA)
- 3ℓ incl. 1 SFOS ℓ pair (ISR)
- Extend reach through lower lepton-p_T thresholds, exploit ISR & VBF, use MVA techniques

New Aspects

- Statistical combinations of new and existing searches
- Impact of mass of intermediate slepton in simplified models on exclusion reach is tested

Interpretations

- Simplified models: (specific production mode, fixed decay chain, BR = 100 %)



- Phenomenological models:
  - "Electroweak" pMSSM (phenomenological Minimal Supersymmetric Standard Model)
    - $\rightarrow$ only direct production of $\tilde{\chi}^{\pm}$ and $\tilde{\chi}^{0}$, relevant parameters: tan β, M_1, M_2, μ
  - NUHM2 (two-parameter Non-Universal Higgs Masses model):
    - $\rightarrow$ CMSSM with 2 additional parameters
  - GMSB (Gauge-Mediated Supersymmetry Breaking)
    - $\rightarrow$ LSP is $\tilde{G}$, electroweak production dominates for large Λ

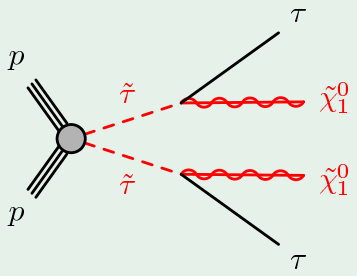
- R-parity assumed to be conserved

Analysis

- Update of simple cut-based analysis published in JHEP 1410 (2014) 96, arXiv:1407.0350

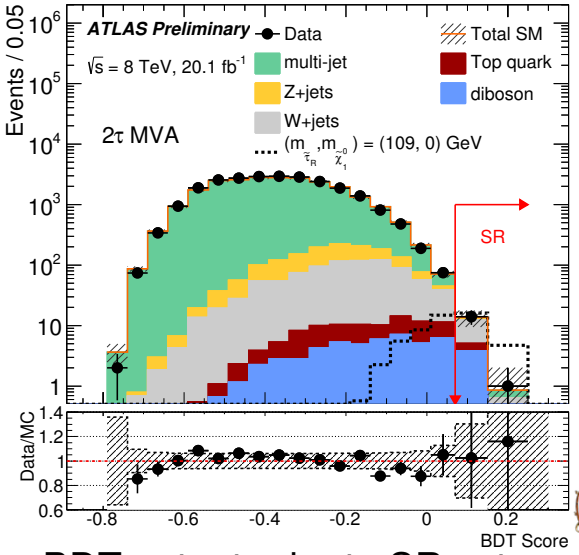
Event Preselection

- Exactly two opposite-sign taus (light lepton veto)
- Veto on *b*-tagged jets and *Z* boson decays



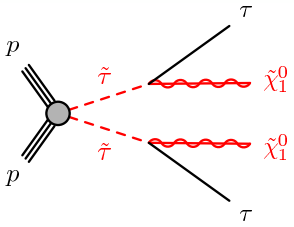
MVA

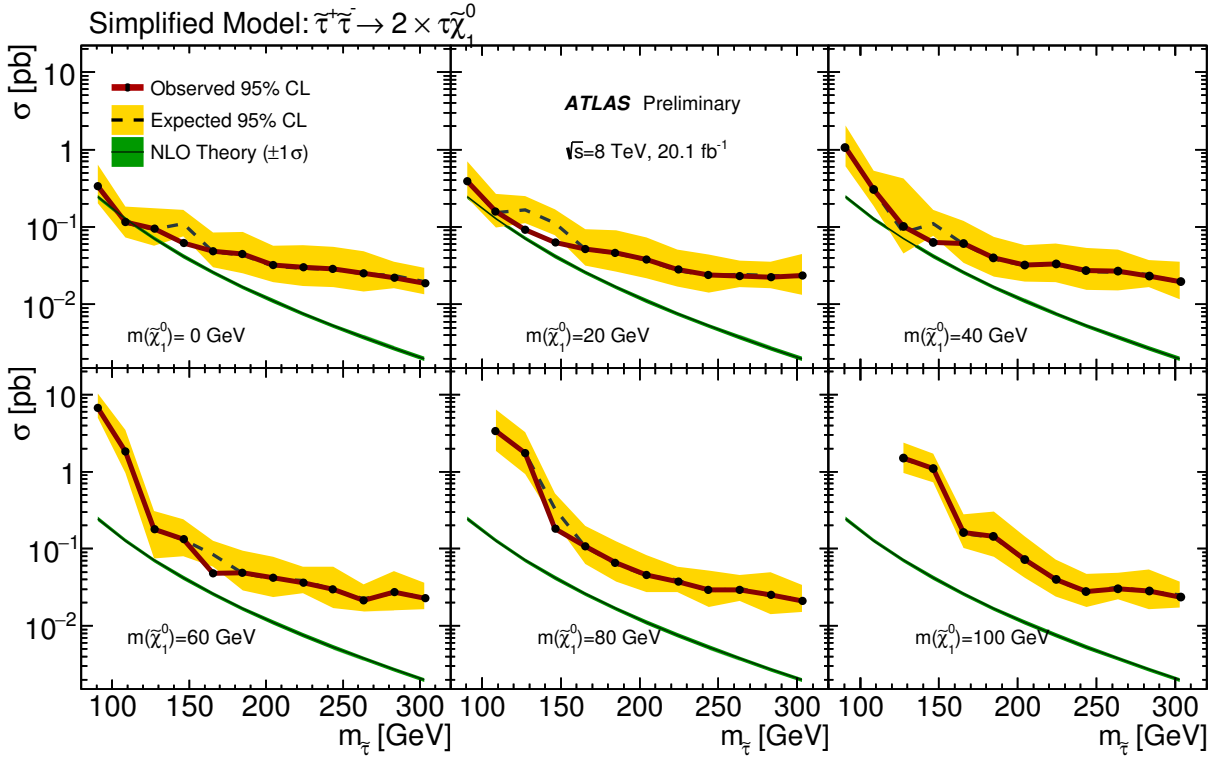
- Train boosted decision trees on 12 input variables with good discriminatory power: $\not{E}_T$, m_{eff}, m_{T2}, $m_{\tau\tau}$, $\Delta\phi(\tau,\tau)$, $\Delta\eta(\tau,\tau)$, $p_T^{\tau 1}$, $p_T^{\tau 2}$, $m_{\text{T}\tau 1}$, $m_{\text{T}\tau 2}$, $\Delta\phi(\not{E}_T,\tau 1)$ and $\Delta\phi(\not{E}_T,\tau 2)$.
- One SR based on BDT output



BDT output prior to SR cut

2 OS τ (MVA) — Results





95 % CL upper limits on cross-section for combined production of $\widetilde{\tau}_L\widetilde{\tau}_L$ and $\widetilde{\tau}_R\widetilde{\tau}_R$, $m(\widetilde{\chi}_1^0)$ ranging from 0 GeV to 100 GeV

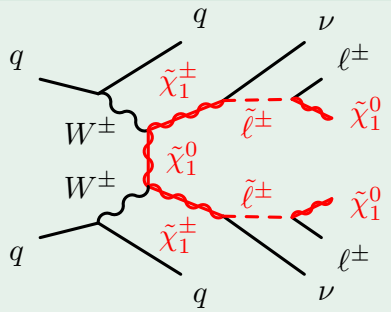
- No excess beyond SM expectation $\Rightarrow$ set limits in simplified model
- MVA improves upon previous expected limits
- Best observed upper limit for $m(\widetilde{\tau}) = 109\,\mathrm{GeV}$ and massless $\widetilde{\chi}_1^0$

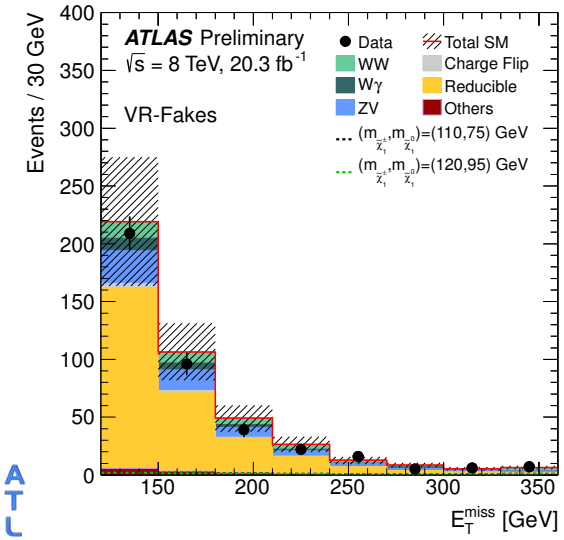
Analysis

- Benefits VBF (lower cross-section):
  - additional jets $\Rightarrow$ means to separate signal from background
  - chargino often boosted $\Rightarrow$ energetic decay products even in compressed spectra

Event Selection

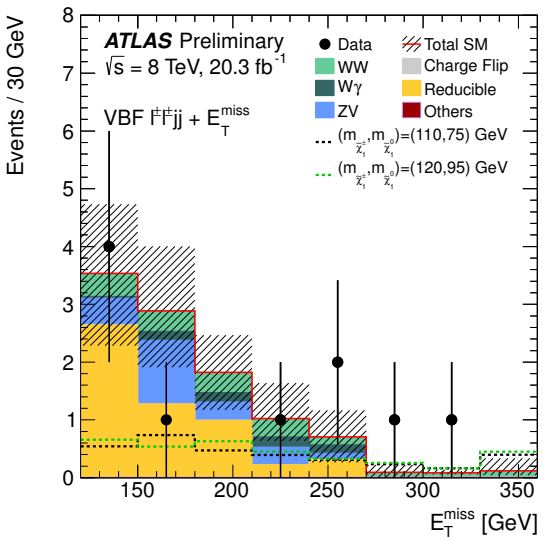
- Exactly 2 SS light leptons + 2 jets + $\not{E}_T > 120\,\mathrm{GeV}$ ($\not{E}_T$ trigger)
- One cut-based SR
  - exploit VBF topology (large m_{jj}, $|\Delta\eta_{jj}|$, $\eta^{j1} \cdot \eta^{j2}$)
  - + cuts to suppress SM backgrounds (mainly diboson + top quark)



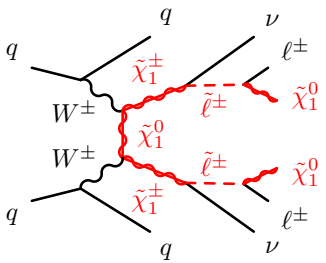


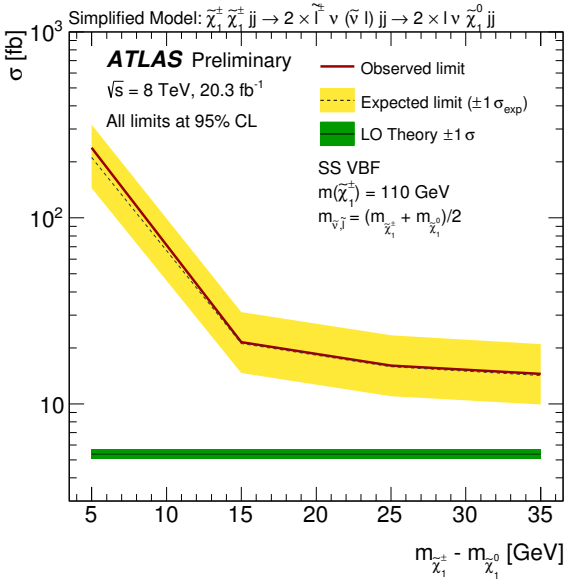
← VR-Fakes:
test prediction of dominant backgrounds from W + jets and $t\bar{t}$ production with fake and non-prompt leptons (fake factor method)

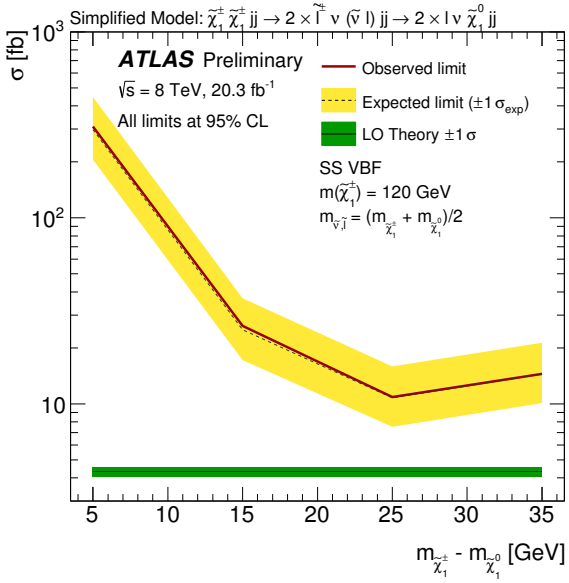
SR →



2 SS ℓ (VBF) — Results







95 % CL upper limits on cross-section for VBF $\tilde{\chi}_1^\pm \tilde{\chi}_1^\pm$ production as function of mass splitting ($m(\tilde{\chi}_1^\pm) = 110$ and $120\,\mathrm{GeV}$)

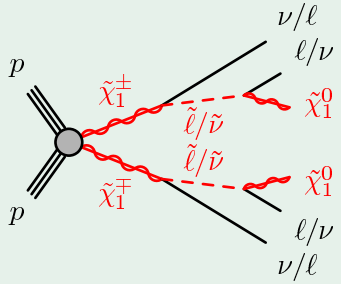
- Best observed upper limit for $m(\tilde{\chi}_1^\pm) = 120\,\mathrm{GeV}$ and $m(\tilde{\chi}_1^\pm) - m(\tilde{\chi}_1^0) = 25\,\mathrm{GeV}$: excluded cross-section $10.9\,\mathrm{fb}$, theoretical LO cross-section $4.33\,\mathrm{fb}$

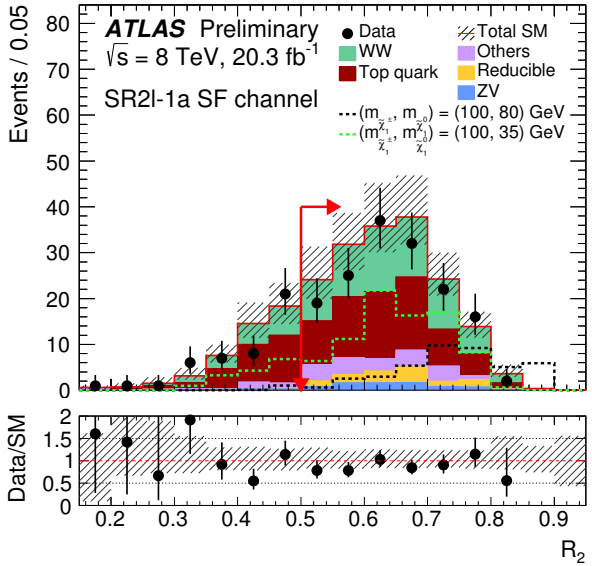
Analysis

- Extends previous analysis to small mass splittings $\Delta m(\tilde{\chi}_1^{\pm}, \tilde{\chi}_1^0)$ by exploiting ISR jets

Event Selection

- Exactly 2 OS light leptons, require high-p_T ISR jet
- Veto on b-tagged / forward jets and Z boson decays
- 2 SR based on "super-razor variables" and R_2





distribution of

$$R_2 = \frac{E_T^{\not{}}}{E_T^{\not{}} + p_T^{\ell 1} + p_T^{\ell 2}}$$

in SR "a"

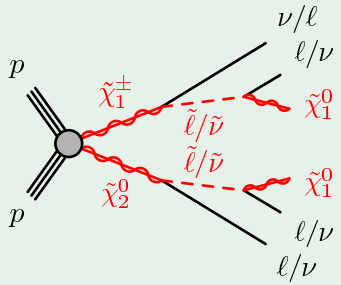
3ℓ incl. 1 SFOS ℓ pair (ISR) — Overview

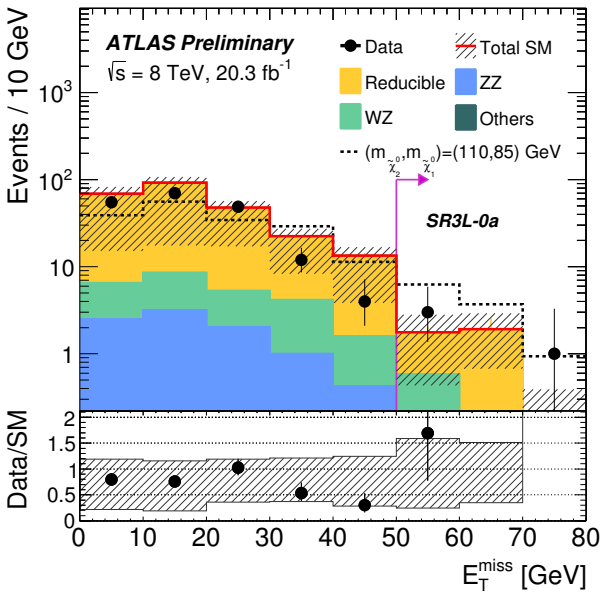
Analysis

- Extends previous analysis to small mass splittings $\Delta m(\tilde{\chi}_2^0, \tilde{\chi}_1^0)$
- New: includes 3ℓ triggers with low-p_T thresholds and also defines SR with ISR jets

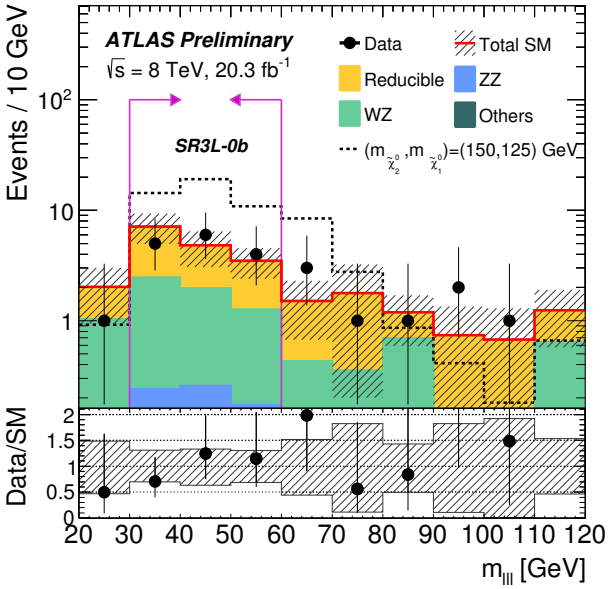
Event Selection

- Exactly 3 light leptons, incl. $\geq$ 1 SFOS ℓ pair
- Veto on b-tagged jets and Υ meson decays
- 2×2 SR: veto or require jet $> 50\,\mathrm{GeV}$, $m_{\mathrm{SFOS}}^{\mathrm{min}}$ between 5 – 15 GeV or 15 – 25 GeV





$\not{E}_T$ and $m_{\ell\ell\ell}$ in 3ℓ SR before cut



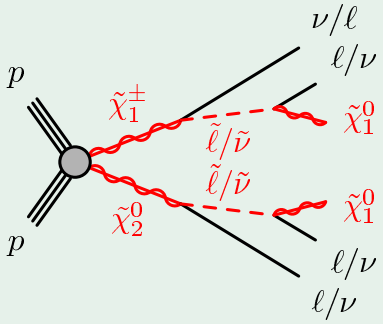
2 SS ℓ (MVA) — Overview

Analysis

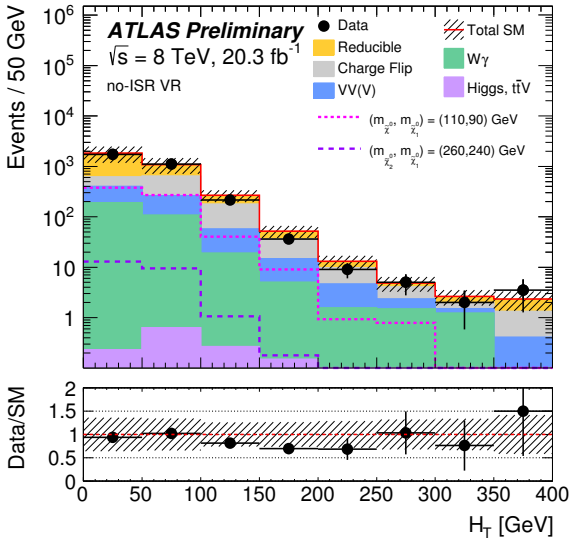
- Complements 3ℓ search in case one lepton not reconstructed
- Extends reach for small mass splittings

Event Selection

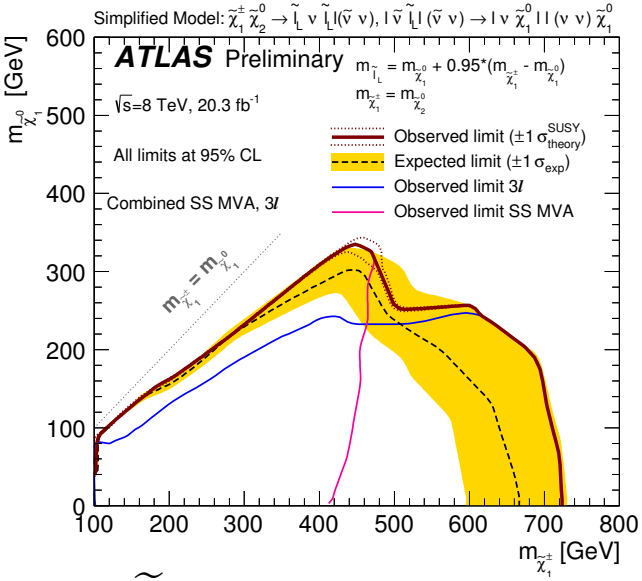
- Exactly 2 SS light leptons
- Veto on b-tagged jets and $m_{\mathrm{SFOS}} < 12\,\mathrm{GeV}$
- Train 8 BDT $\rightarrow$ 8 SR:
  optimized for four mass-splitting scenarios $\Delta m(\tilde{\chi}_2^0, \tilde{\chi}_1^0)$,
  each with and w/o ISR jet



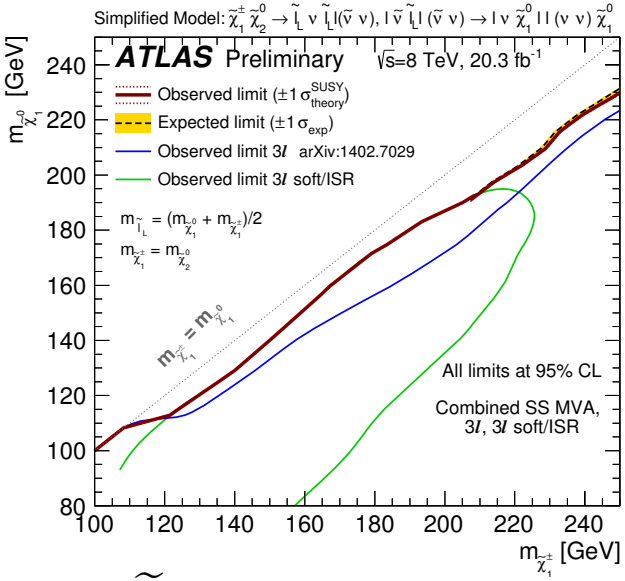
scalar sum of leptons and jet H_T
in the non-ISR VR $\rightarrow$
(VR defined based on BDT output)



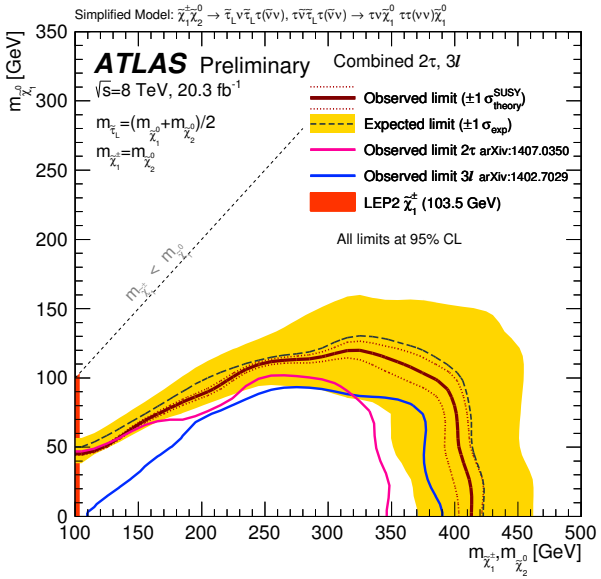
Results — $\widetilde{\chi}_1^{\pm}\widetilde{\chi}_2^0$ Production



$\widetilde{\ell}$-mediated decays,
$m(\widetilde{\ell}) = 0.95m(\widetilde{\chi}_2^0) + 0.05m(\widetilde{\chi}_1^0)$

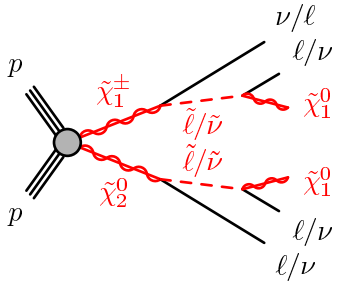


$\widetilde{\ell}$-mediated decays,
$m(\widetilde{\ell}) = \frac{1}{2}(m(\widetilde{\chi}_2^0) + m(\widetilde{\chi}_1^0))$

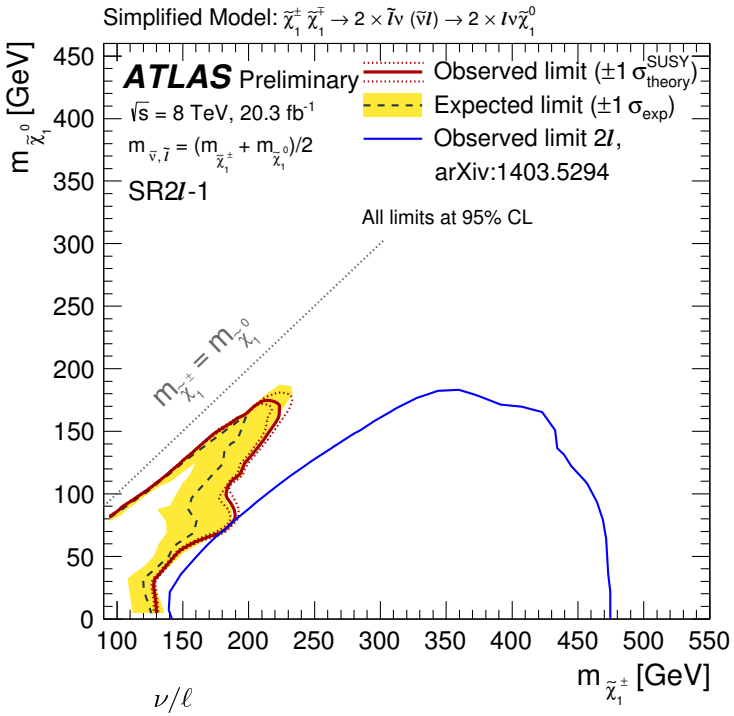


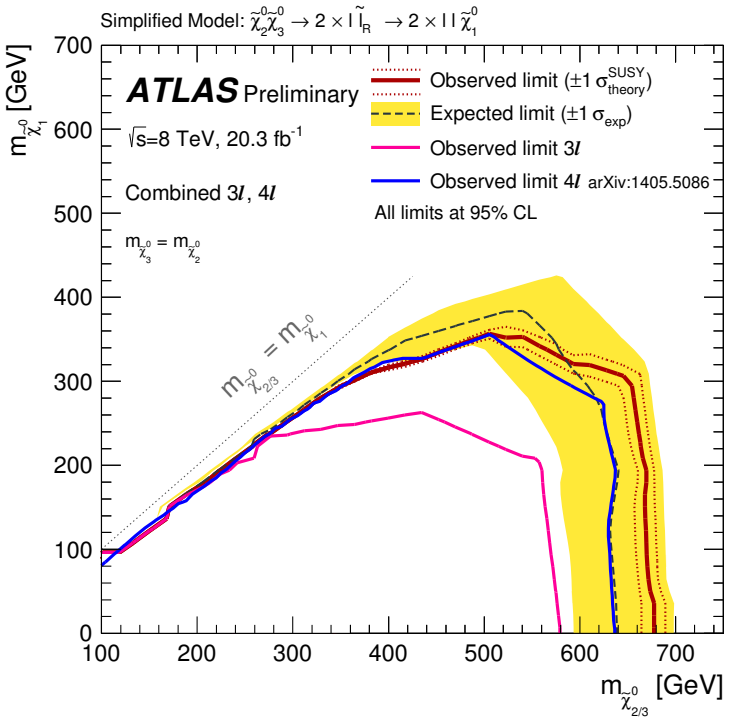
$\widetilde{\tau}$-mediated decays,
$m(\widetilde{\tau}) = \frac{1}{2}(m(\widetilde{\chi}_2^0) + m(\widetilde{\chi}_1^0))$

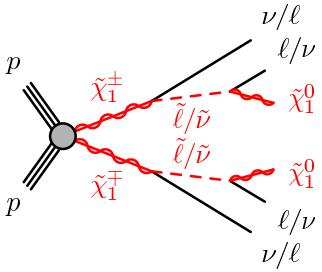
- Left: complementarity of the new 2 SS ℓ (MVA) and the 3ℓ analysis (for sleptons close to $\widetilde{\chi}_2^0$ in mass)
- Middle: improved sensitivity in compressed scenarios from new 3ℓ analysis (for sleptons halfway between $\widetilde{\chi}_2^0$ and $\widetilde{\chi}_1^0$ in mass)
- Right: new combination of 2τ and 3ℓ analyses, improves limits in stau-mediated decays



Results — $\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\mp}$ / $\tilde{\chi}_2^0\tilde{\chi}_3^0$ Production

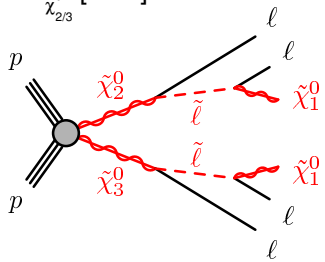






$\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\mp}$ production with slepton-mediated decays

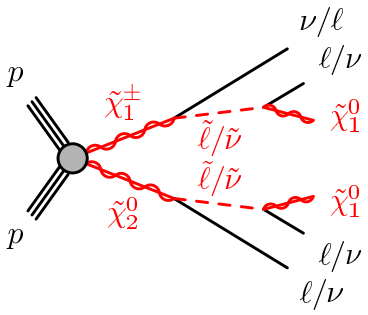
$\tilde{\chi}_2^0\tilde{\chi}_3^0$ production with slepton-mediated decays

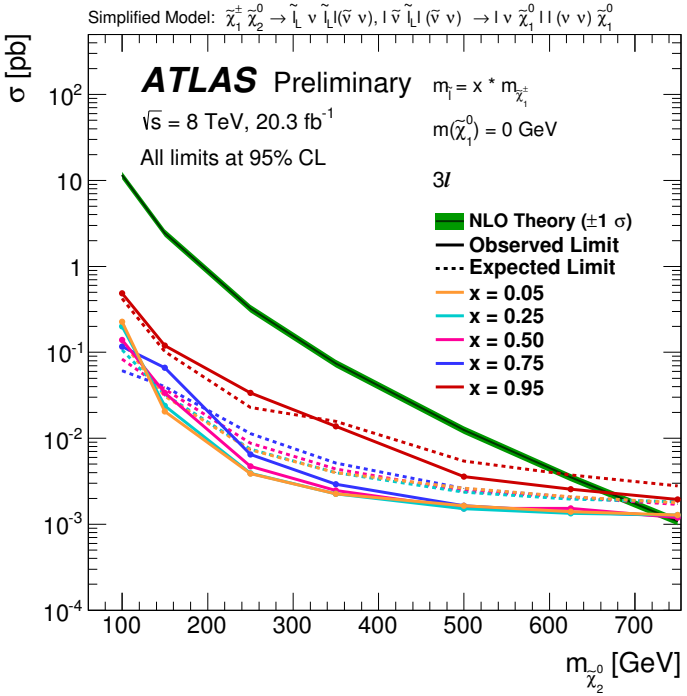


- Left: nice complementarity of new 2 OS ℓ (ISR) analysis at small mass splittings
- Right: new combination of 3ℓ and 4ℓ analyses shows 30 GeV improvement in limits

Impact of Variable Slepton Mass

ATLAS-SUSY-2014-05

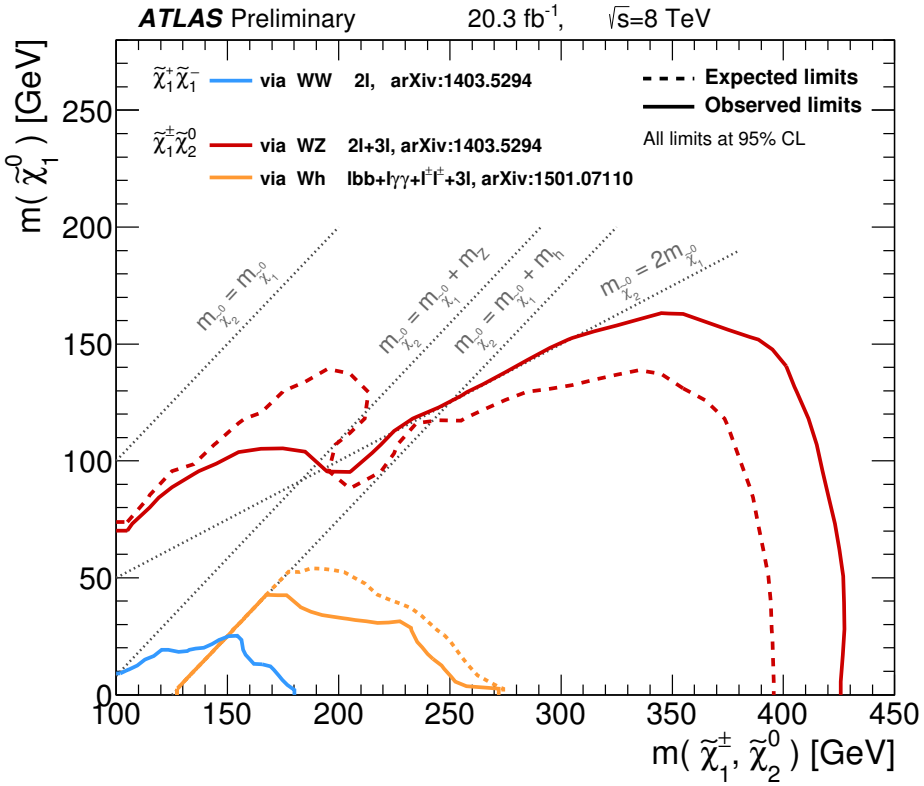




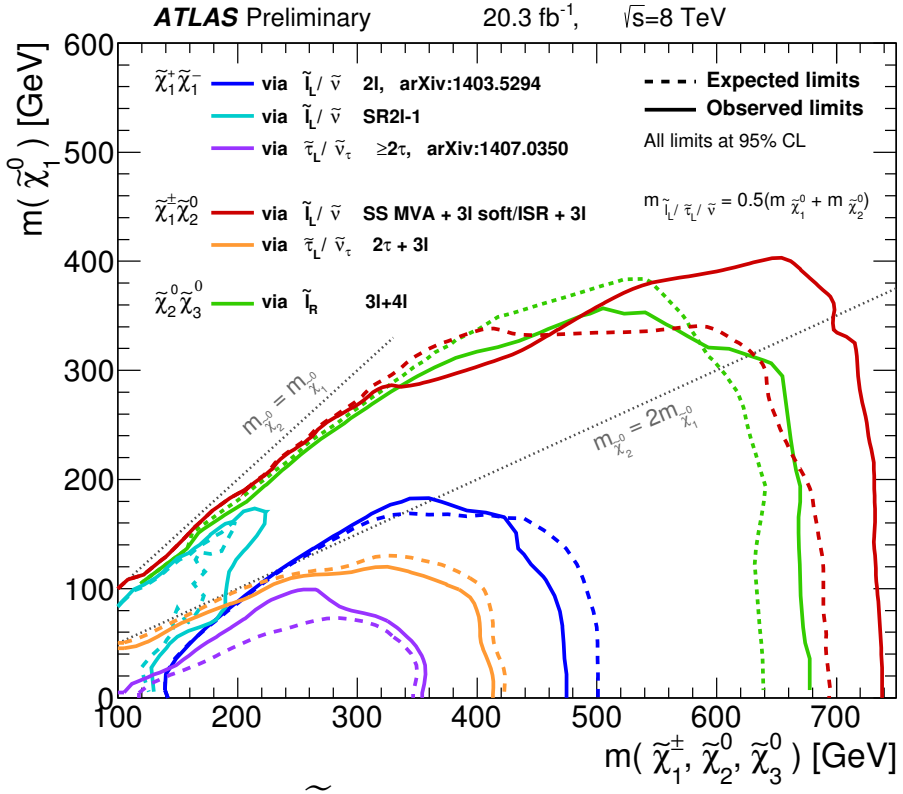
- Comparison of exclusion limits for several different $m(\widetilde{\ell}) = x \cdot m(\mathrm{ISP})$ $\quad (m(\widetilde{\chi}_1^0) = 0\,\mathrm{GeV})$
- $\Rightarrow$ Impact of intermediate slepton mass on limit small
- Same picture for the other models ($\widetilde{\chi}_1^{\pm}\widetilde{\chi}_1^{\mp}$, $\widetilde{\chi}_2^0\widetilde{\chi}_3^0$)

New Summary Plots with Interpretations in Simplified Models

ATLAS-SUSY-2014-05



W/*Z*/*h*-boson mediated decays

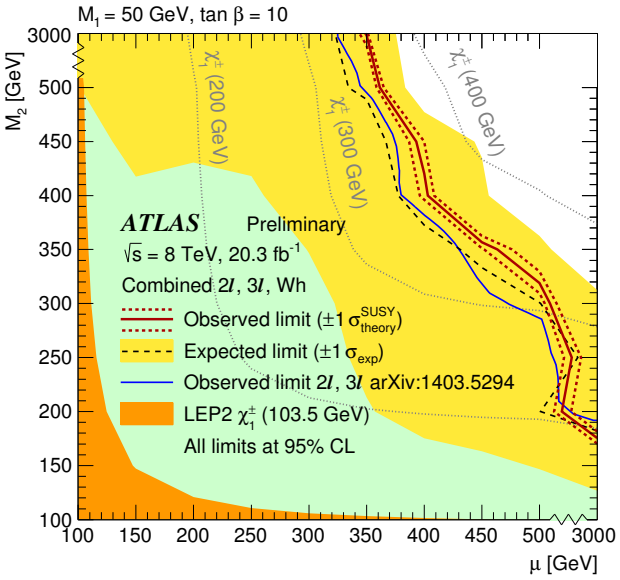


$\widetilde{\ell}$-mediated decays

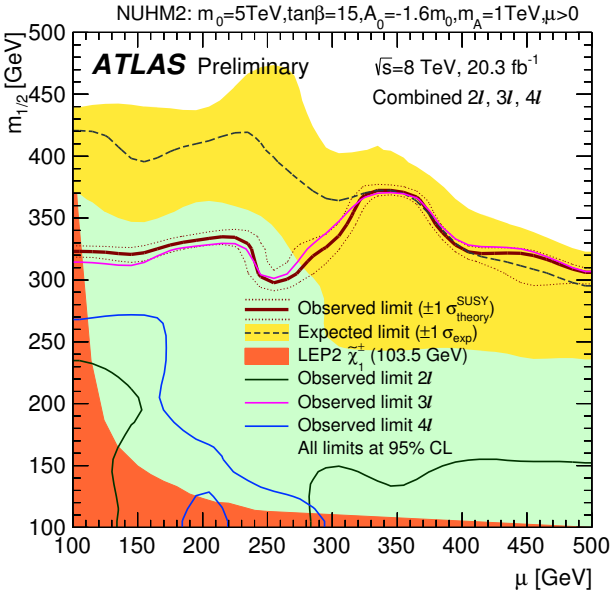
- $\widetilde{\chi}_1^{\pm}\widetilde{\chi}_1^{\mp}$ via *WW*, $\widetilde{\chi}_1^{\pm}\widetilde{\chi}_2^{0}$ via *WZ*/*Wh*
- Small sensitivity from new analyses ($\rightarrow$ no combination)

- $\widetilde{\chi}_1^{\pm}\widetilde{\chi}_1^{\mp}$, $\widetilde{\chi}_1^{\pm}\widetilde{\chi}_2^{0}$, $\widetilde{\chi}_2^{0}\widetilde{\chi}_3^{0}$ production with slepton-mediated decays
- light blue: new analysis
- red: combination with new analyses
- green, orange: new combinations

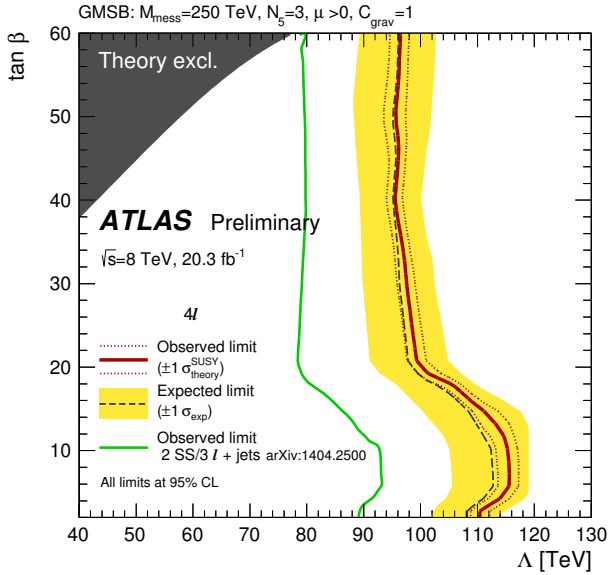
Interpretation in Phenomenological Models



pMSSM



NUHM2



GMSB

- pMSSM (μ-M_2 plane): new combination of 2ℓ, 3ℓ, and *Wh* (added)
- NUHM2 (μ-$m_{1/2}$ plane): new interpretation of 2ℓ, 3ℓ (drives exclusion limit), and 4ℓ
- GMSB (Λ-tan β plane): new reinterpretation of 4ℓ analysis,
  yields improvement by 15 – 20 TeV w. r. t. earlier combination of 2 SS / 3ℓ analyses

Summary & Outlook

End of Run-1

- No strong signs for physics beyond the Standard Model found in Run-1 data
- Large number of SUSY analyses have been made public
- Presented the new EWK summary paper
  - with final $\sqrt{s} = 8\,\mathrm{TeV}$ ATLAS limits for EWK production
  - not only a summary, but also new analyses and new combinations

Onto Run-2

- Run-2 is on-going, new data already flowing in
- First months certainly belong to strong searches
  - stronger benefit from higher center-of-mass energy, quick re-not-discovery of SUSY
- Electroweak searches need more data to become competitive with Run-1 results
  - will be able to build upon lots of experience from Run-1
  - profit on long term from higher integrated luminosity in Run-2

Web Page

- Overview of public results on searches for supersymmetry using ATLAS: https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults

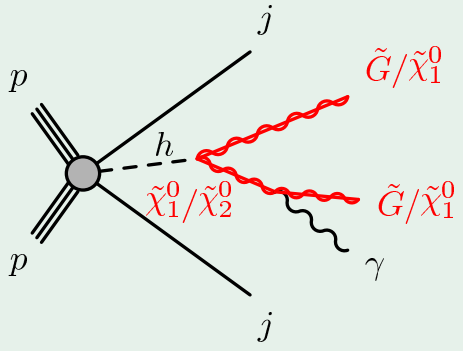
Backup

ATLAS-CONF-2015-001

VBF $H \to \gamma(\gamma) + \not{E}_T$ in GMSB / NMSSM

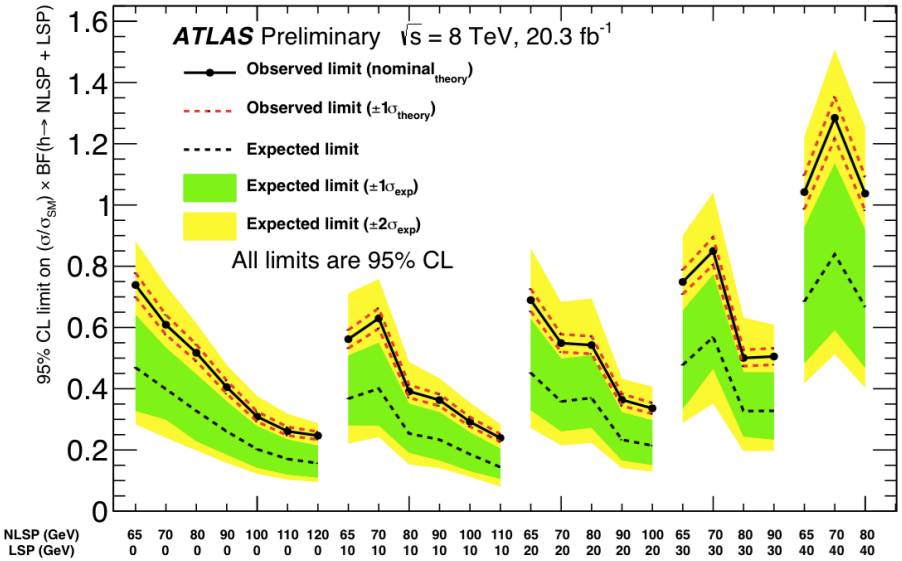
ATLAS-CONF-2015-001 (Feb. 2015)

- Search for exotic Higgs decays, photon + $\not{E}_T$ final state
- Motivation: BR($h \to$ BSM) $\sim \mathcal{O}(50\,\%)$ possible
- VBF Higgs production, $m_h = 125\,\mathrm{GeV}$
- Interpretation:
  - GMSB: $h \to \tilde{G}\tilde{\chi}_1^0$ (or $\tilde{\chi}_1^0\tilde{\chi}_1^0$), $\tilde{\chi}_1^0 \to \tilde{G}\gamma$
  - NMSSM: $h \to \tilde{\chi}_2^0\tilde{\chi}_1^0$ (or $\tilde{\chi}_2^0\tilde{\chi}_2^0$), $\tilde{\chi}_2^0 \to \tilde{\chi}_1^0\gamma$
- Diphoton final states also considered



(for $m_{\tilde{\chi}_{1,2}^0} > m_h/2$)

- Event selection:
  - 1 isolated photon, $\not{E}_T > 50\,\mathrm{GeV}$
  - ≥ 2 separated jets with high inv. mass
  - lepton veto, non-VBF jet veto
- Signal region yields:
  - expected: $38.0 \pm 2.2 \pm 4.5$
    (dominant background: γ+jets, multijet)
  - observed in data: 50



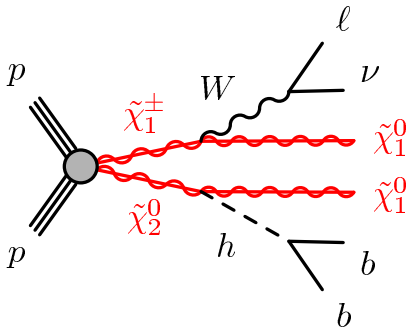
Exclusion limits in mono-photon channel

Eur. Phys. J. C, 75:208 (May 2015)

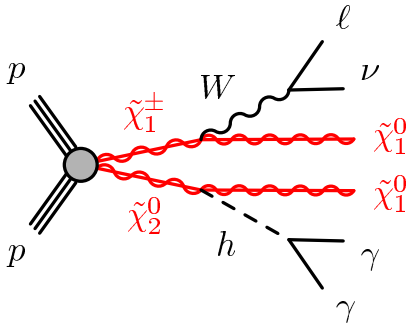
$\widetilde{\chi}_1^{\pm}\widetilde{\chi}_2^0$ via Wh

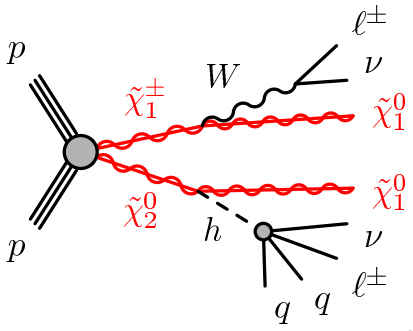
Eur. Phys. J. C, 75:208 (May 2015)

- Search for $pp \to \widetilde{\chi}_1^{\pm}\widetilde{\chi}_2^0$ decaying via Wh
- Focus on scenarios where $\widetilde{\chi}_2^0 \to \widetilde{\chi}_1^0 h$ dominant: $\widetilde{\chi}_1^{\pm}$ and $\widetilde{\chi}_2^0$ wino-like, $m(\widetilde{\chi}_1^{\pm}) \simeq m(\widetilde{\chi}_2^0)$
- Always: $W \to 1\ell + \not{E}_T$
- Combination of 3 signatures: SM-like $h \to bb$ / $\gamma\gamma$ / $\ell\nu qq'$

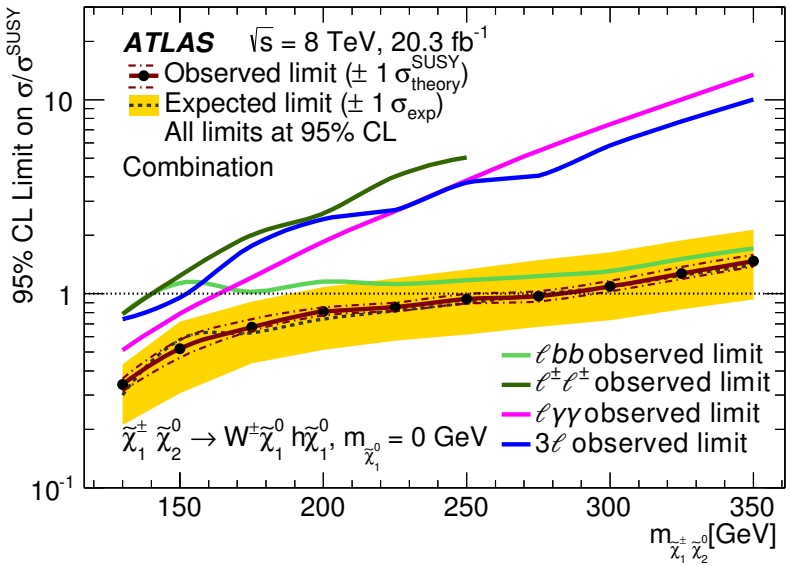


- bb:
  - 2 SR based on transverse mass m_{T}^{W}, cotransv. mass m_{CT}
  - dominant bg.: W and top-quark production
- $\gamma\gamma$:
  - 2 SR based on $m_{\mathrm{T}}^{W_{\gamma 1,2}}$, W and h roughly back-to-back
  - dominant bg.: multijets + $Z\gamma$ (misid. γ from leptons or jets)
- WW:
  - 2 SR for each ee, $e\mu$, $\mu\mu$ based on $\Delta\eta_{ll}$, m_{eff}, $m_{\mathrm{T}}^{\mathrm{max}}$
  - dominant bg.: dibosons (irr.), non-prompt leptons (red.)
- common: Higgs-mass window / sidebands

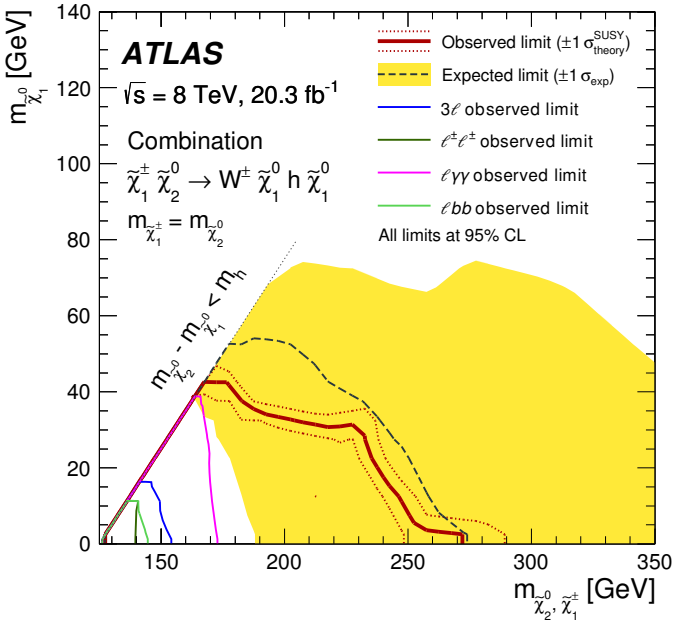




- Event yields: consistent with SM expectations in all signal regions
- Interpretation: upper limits on visible cross section and in simplified models
- Limits: in individual channels and as combination (incl. 3ℓ analysis)
- *bb* channel: strongest limits for massless LSP overall, but actual exclusion from $\gamma\gamma$ stronger at low gaugino masses



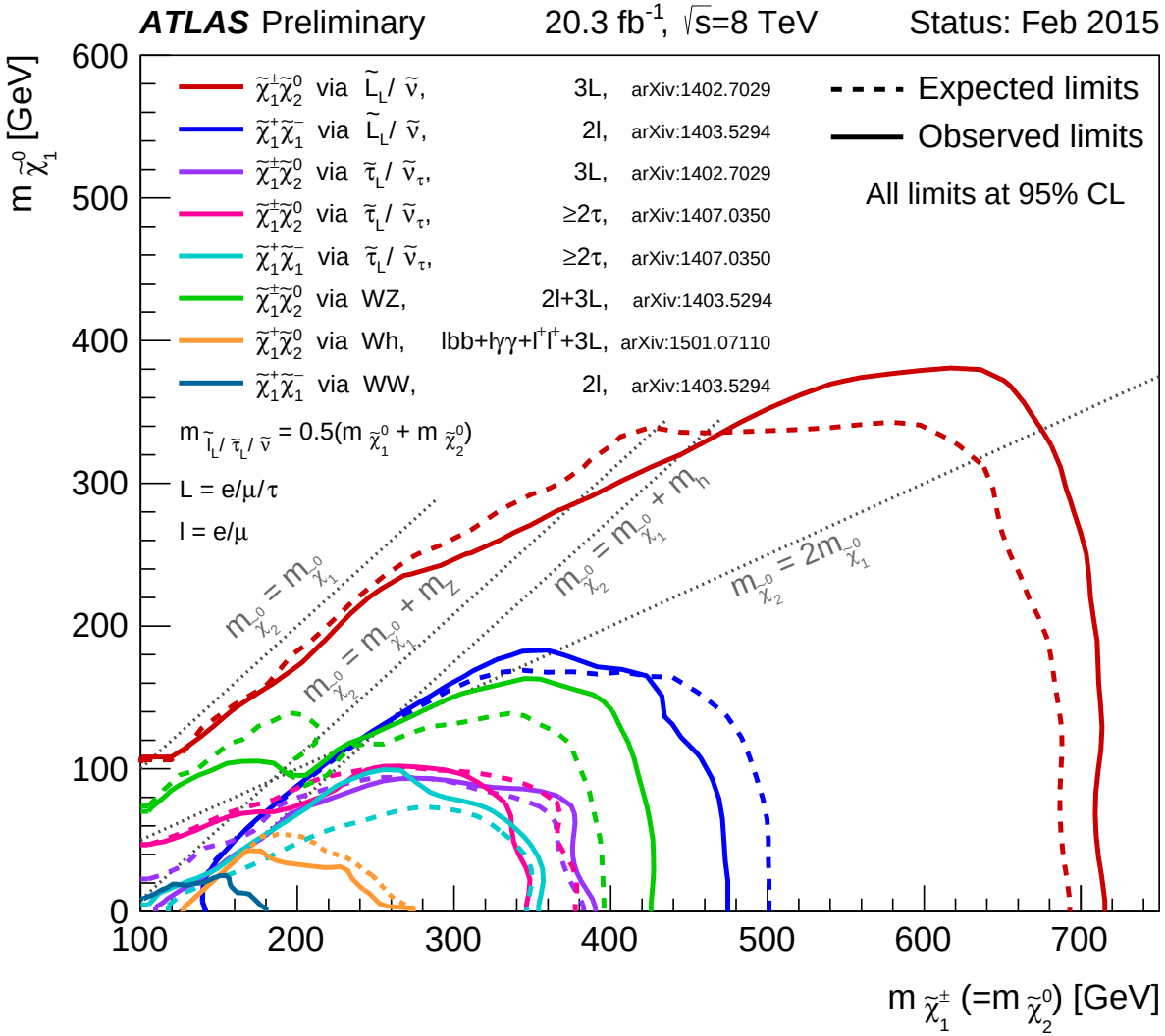
Limits on signal strength for massless $\tilde{\chi}_1^0$



Exclusion limits in mass plane

Additional Material

EWK Summary Plot (Feb. 2015)



Summary of Exclusion Ranges from ATLAS SUSY Searches in Run-1

ATLAS SUSY Searches* - 95% CL Lower Limits

Status: July 2015

ATLAS Preliminary

$\sqrt{s}$ = 7, 8 TeV

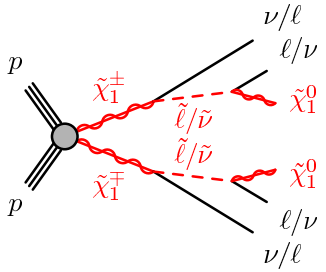
	Model	e, μ, τ, γ	Jets	E_T^{miss}	$\int \mathcal{L}\, dt[\mathrm{fb}^{-1}]$	Mass limit ($\sqrt{s}$ = 7 TeV / $\sqrt{s}$ = 8 TeV)		Reference
Inclusive Searches	MSUGRA/CMSSM	0-3 e,μ/1-2 τ	2-10 jets/3 b	Yes	20.3	$\tilde{q},\tilde{g}$ 1.8 TeV	m($\tilde{q}$)=m($\tilde{g}$)	1507.05525
	$\tilde{q}\tilde{q}, \tilde{q}\to q\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{q}$ 850 GeV	m($\tilde{\chi}_1^0$)=0 GeV, m(1st gen. $\tilde{q}$)=m(2nd gen. $\tilde{q}$)	1405.7875
	$\tilde{q}\tilde{q}, \tilde{q}\to q\tilde{\chi}_1^0$ (compressed)	mono-jet	1-3 jets	Yes	20.3	$\tilde{q}$ 100-440 GeV	m($\tilde{q}$)-m($\tilde{\chi}_1^0$)<10 GeV	1507.05525
	$\tilde{q}\tilde{q}, \tilde{q}\to q(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}_1^0$	2 e,μ (off-Z)	2 jets	Yes	20.3	$\tilde{q}$ 780 GeV	m($\tilde{\chi}_1^0$)=0 GeV	1503.03290
	$\tilde{g}\tilde{g}, \tilde{g}\to q\bar{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{g}$ 1.33 TeV	m($\tilde{\chi}_1^0$)=0 GeV	1405.7875
	$\tilde{g}\tilde{g}, \tilde{g}\to qq\tilde{\chi}_1^\pm\to qqW^\pm\tilde{\chi}_1^0$	0-1 e,μ	2-6 jets	Yes	20	$\tilde{g}$ 1.26 TeV	m($\tilde{\chi}_1^0$)<300 GeV, m($\tilde{\chi}^\pm$)=0.5(m($\tilde{\chi}_1^0$)+m($\tilde{g}$))	1507.05525
	$\tilde{g}\tilde{g}, \tilde{g}\to qq(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}_1^0$	2 e,μ	0-3 jets	-	20	$\tilde{g}$ 1.32 TeV	m($\tilde{\chi}_1^0$)=0 GeV	1501.03555
	GMSB ($\tilde{\ell}$ NLSP)	1-2 τ + 0-1 ℓ	0-2 jets	Yes	20.3	$\tilde{g}$ 1.6 TeV	tanβ >20	1407.0603
	GGM (bino NLSP)	2 γ	-	Yes	20.3	$\tilde{g}$ 1.29 TeV	$c\tau$(NLSP)<0.1 mm	1507.05493
	GGM (higgsino-bino NLSP)	γ	1 b	Yes	20.3	$\tilde{g}$ 1.3 TeV	m($\tilde{\chi}_1^0$)<900 GeV, $c\tau$(NLSP)<0.1 mm, μ<0	1507.05493
	GGM (higgsino-bino NLSP)	γ	2 jets	Yes	20.3	$\tilde{g}$ 1.25 TeV	m($\tilde{\chi}_1^0$)<850 GeV, $c\tau$(NLSP)<0.1 mm, μ>0	1507.05493
	GGM (higgsino NLSP)	2 e,μ (Z)	2 jets	Yes	20.3	$\tilde{g}$ 850 GeV	m(NLSP)>430 GeV	1503.03290
	Gravitino LSP	0	mono-jet	Yes	20.3	$F^{1/2}$ scale 865 GeV	m($\tilde{G}$)>1.8×10^{-4} eV, m($\tilde{g}$)=m($\tilde{q}$)=1.5 TeV	1502.01518
3rd gen. $\tilde{g}$ med.	$\tilde{g}\tilde{g}, \tilde{g}\to b\bar{b}\tilde{\chi}_1^0$	0	3 b	Yes	20.1	$\tilde{g}$ 1.25 TeV	m($\tilde{\chi}_1^0$)<400 GeV	1407.0600
	$\tilde{g}\tilde{g}, \tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0	7-10 jets	Yes	20.3	$\tilde{g}$ 1.1 TeV	m($\tilde{\chi}_1^0$) <350 GeV	1308.1841
	$\tilde{g}\tilde{g}, \tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0-1 e,μ	3 b	Yes	20.1	$\tilde{g}$ 1.34 TeV	m($\tilde{\chi}_1^0$)<400 GeV	1407.0600
	$\tilde{g}\tilde{g}, \tilde{g}\to b\bar{t}\tilde{\chi}_1^+$	0-1 e,μ	3 b	Yes	20.1	$\tilde{g}$ 1.3 TeV	m($\tilde{\chi}_1^0$)<300 GeV	1407.0600
3rd gen. squarks direct production	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\to b\tilde{\chi}_1^0$	0	2 b	Yes	20.1	$\tilde{b}_1$ 100-620 GeV	m($\tilde{\chi}_1^0$)<90 GeV	1308.2631
	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\to t\tilde{\chi}_1^\pm$	2 e,μ (SS)	0-3 b	Yes	20.3	$\tilde{b}_1$ 275-440 GeV	m($\tilde{\chi}_1^\pm$)=2 m($\tilde{\chi}_1^0$)	1404.2500
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to b\tilde{\chi}_1^\pm$	1-2 e,μ	1-2 b	Yes	4.7/20.3	$\tilde{t}_1$ 110-167 GeV, 230-460 GeV	m($\tilde{\chi}_1^\pm$) = 2m($\tilde{\chi}_1^0$), m($\tilde{\chi}_1^0$)=55 GeV	1209.2102, 1407.0583
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to Wb\tilde{\chi}_1^0$ or $t\tilde{\chi}_1^0$	0-2 e,μ	0-2 jets/1-2 b	Yes	20.3	$\tilde{t}_1$ 90-191 GeV, 210-700 GeV	m($\tilde{\chi}_1^0$)=1 GeV	1506.08616
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to c\tilde{\chi}_1^0$	0	mono-jet/c-tag	Yes	20.3	$\tilde{t}_1$ 90-240 GeV	m($\tilde{t}_1$)-m($\tilde{\chi}_1^0$)<85 GeV	1407.0608
	$\tilde{t}_1\tilde{t}_1$(natural GMSB)	2 e,μ (Z)	1 b	Yes	20.3	$\tilde{t}_1$ 150-580 GeV	m($\tilde{\chi}_1^0$)>150 GeV	1403.5222
	$\tilde{t}_2\tilde{t}_2, \tilde{t}_2\to\tilde{t}_1+Z$	3 e,μ (Z)	1 b	Yes	20.3	$\tilde{t}_2$ 290-600 GeV	m($\tilde{\chi}_1^0$)<200 GeV	1403.5222
EW direct	$\tilde{\ell}_{L,R}\tilde{\ell}_{L,R}, \tilde{\ell}\to\ell\tilde{\chi}_1^0$	2 e,μ	0	Yes	20.3	$\tilde{\ell}$ 90-325 GeV	m($\tilde{\chi}_1^0$)=0 GeV	1403.5294
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to\tilde{\ell}\nu(\ell\tilde{\nu})$	2 e,μ	0	Yes	20.3	$\tilde{\chi}_1^\pm$ 140-465 GeV	m($\tilde{\chi}_1^0$)=0 GeV, m($\tilde{\ell},\tilde{\nu}$)=0.5(m($\tilde{\chi}_1^\pm$)+m($\tilde{\chi}_1^0$))	1403.5294
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to\tilde{\tau}\nu(\tau\tilde{\nu})$	2 τ	-	Yes	20.3	$\tilde{\chi}_1^\pm$ 100-350 GeV	m($\tilde{\chi}_1^0$)=0 GeV, m($\tilde{\tau},\tilde{\nu}$)=0.5(m($\tilde{\chi}_1^\pm$)+m($\tilde{\chi}_1^0$))	1407.0350
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to\tilde{\ell}_L\nu\tilde{\ell}_L\ell(\tilde{\nu}\nu), \ell\tilde{\nu}\tilde{\ell}_L\ell(\tilde{\nu}\nu)$	3 e,μ	0	Yes	20.3	$\tilde{\chi}_1^\pm,\tilde{\chi}_2^0$ 700 GeV	m($\tilde{\chi}_1^\pm$)=m($\tilde{\chi}_2^0$), m($\tilde{\chi}_1^0$)=0, m($\tilde{\ell},\tilde{\nu}$)=0.5(m($\tilde{\chi}_1^\pm$)+m($\tilde{\chi}_1^0$))	1402.7029
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to W\tilde{\chi}_1^0 Z\tilde{\chi}_1^0$	2-3 e,μ	0-2 jets	Yes	20.3	$\tilde{\chi}_1^\pm,\tilde{\chi}_2^0$ 420 GeV	m($\tilde{\chi}_1^\pm$)=m($\tilde{\chi}_2^0$), m($\tilde{\chi}_1^0$)=0, sleptons decoupled	1403.5294, 1402.7029
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to W\tilde{\chi}_1^0 h\tilde{\chi}_1^0, h\to b\bar{b}/WW/\tau\tau/\gamma\gamma$	e,μ,γ	0-2 b	Yes	20.3	$\tilde{\chi}_1^\pm,\tilde{\chi}_2^0$ 250 GeV	m($\tilde{\chi}_1^\pm$)=m($\tilde{\chi}_2^0$), m($\tilde{\chi}_1^0$)=0, sleptons decoupled	1501.07110
	$\tilde{\chi}_2^0\tilde{\chi}_3^0, \tilde{\chi}_{2,3}^0\to\tilde{\ell}_R\ell$	4 e,μ	0	Yes	20.3	$\tilde{\chi}_{2,3}^0$ 620 GeV	m($\tilde{\chi}_2^0$)=m($\tilde{\chi}_3^0$), m($\tilde{\chi}_1^0$)=0, m($\tilde{\ell},\tilde{\nu}$)=0.5(m($\tilde{\chi}_2^0$)+m($\tilde{\chi}_1^0$))	1405.5086
	GGM (wino NLSP) weak prod.	1 $e,\mu+\gamma$	-	Yes	20.3	$\tilde{W}$ 124-361 GeV	$c\tau$<1 mm	1507.05493
Long-lived particles	Direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^\pm$	Disapp. trk	1 jet	Yes	20.3	$\tilde{\chi}_1^\pm$ 270 GeV	m($\tilde{\chi}_1^\pm$)-m($\tilde{\chi}_1^0$)~160 MeV, τ($\tilde{\chi}_1^\pm$)=0.2 ns	1310.3675
	Direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^\pm$	dE/dx trk	-	Yes	18.4	$\tilde{\chi}_1^\pm$ 482 GeV	m($\tilde{\chi}_1^\pm$)-m($\tilde{\chi}_1^0$)~160 MeV, τ($\tilde{\chi}_1^\pm$)<15 ns	1506.05332
	Stable, stopped $\tilde{g}$ R-hadron	0	1-5 jets	Yes	27.9	$\tilde{g}$ 832 GeV	m($\tilde{\chi}_1^0$)=100 GeV, 10 μs<τ($\tilde{g}$)<1000 s	1310.6584
	Stable $\tilde{g}$ R-hadron	trk	-	-	19.1	$\tilde{g}$ 1.27 TeV		1411.6795
	GMSB, stable $\tilde{\tau}, \tilde{\chi}_1^0\to\tilde{\tau}(\tilde{e},\tilde{\mu})+\tau(e,\mu)$	1-2 μ	-	-	19.1	$\tilde{\chi}_1^0$ 537 GeV	10<tanβ<50	1411.6795
	GMSB, $\tilde{\chi}_1^0\to\gamma\tilde{G}$, long-lived $\tilde{\chi}_1^0$	2 γ	-	Yes	20.3	$\tilde{\chi}_1^0$ 435 GeV	2<τ($\tilde{\chi}_1^0$)<3 ns, SPS8 model	1409.5542
	$\tilde{g}\tilde{g}, \tilde{\chi}_1^0\to ee\nu/e\mu\nu/\mu\mu\nu$	displ. $ee/e\mu/\mu\mu$	-	-	20.3	$\tilde{\chi}_1^0$ 1.0 TeV	7 <$c\tau$($\tilde{\chi}_1^0$)< 740 mm, m($\tilde{g}$)=1.3 TeV	1504.05162
	GGM $\tilde{g}\tilde{g}, \tilde{\chi}_1^0\to Z\tilde{G}$	displ. vtx + jets	-	-	20.3	$\tilde{\chi}_1^0$ 1.0 TeV	6 <$c\tau$($\tilde{\chi}_1^0$)< 480 mm, m($\tilde{g}$)=1.1 TeV	1504.05162
RPV	LFV $pp\to\tilde{\nu}_\tau+X, \tilde{\nu}_\tau\to e\mu/e\tau/\mu\tau$	$e\mu,e\tau,\mu\tau$	-	-	20.3	$\tilde{\nu}_\tau$ 1.7 TeV	λ'_{311}=0.11, $\lambda_{132/133/233}$=0.07	1503.04430
	Bilinear RPV CMSSM	2 e,μ (SS)	0-3 b	Yes	20.3	$\tilde{q},\tilde{g}$ 1.35 TeV	m($\tilde{q}$)=m($\tilde{g}$), $c\tau_{LSP}$<1 mm	1404.2500
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to W\tilde{\chi}_1^0, \tilde{\chi}_1^0\to ee\tilde{\nu}_\mu, e\mu\tilde{\nu}_e$	4 e,μ	-	Yes	20.3	$\tilde{\chi}_1^\pm$ 750 GeV	m($\tilde{\chi}_1^0$)>0.2×m($\tilde{\chi}_1^\pm$), $\lambda_{121}\neq0$	1405.5086
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to W\tilde{\chi}_1^0, \tilde{\chi}_1^0\to\tau\tau\tilde{\nu}_e, e\tau\tilde{\nu}_\tau$	3 $e,\mu+\tau$	-	Yes	20.3	$\tilde{\chi}_1^\pm$ 450 GeV	m($\tilde{\chi}_1^0$)>0.2×m($\tilde{\chi}_1^\pm$), $\lambda_{133}\neq0$	1405.5086
	$\tilde{g}\tilde{g}, \tilde{g}\to qqq$	0	6-7 jets	-	20.3	$\tilde{g}$ 917 GeV	BR(t)=BR(b)=BR(c)=0%	1502.05686
	$\tilde{g}\tilde{g}, \tilde{g}\to q\bar{q}\tilde{\chi}_1^0, \tilde{\chi}_1^0\to qqq$	0	6-7 jets	-	20.3	$\tilde{g}$ 870 GeV	m($\tilde{\chi}_1^0$)=600 GeV	1502.05686
	$\tilde{g}\tilde{g}, \tilde{g}\to\tilde{t}_1 t, \tilde{t}_1\to bs$	2 e,μ (SS)	0-3 b	Yes	20.3	$\tilde{g}$ 850 GeV		1404.250
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to bs$	0	2 jets + 2 b	-	20.3	$\tilde{t}_1$ 100-308 GeV		ATLAS-CONF-2015-026
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to b\ell$	2 e,μ	2 b	-	20.3	$\tilde{t}_1$ 0.4-1.0 TeV	BR($\tilde{t}_1\to be/\mu$)>20%	ATLAS-CONF-2015-015
Other	Scalar charm, $\tilde{c}\to c\tilde{\chi}_1^0$	0	2 c	Yes	20.3	$\tilde{c}$ 490 GeV	m($\tilde{\chi}_1^0$)<200 GeV	1501.01325

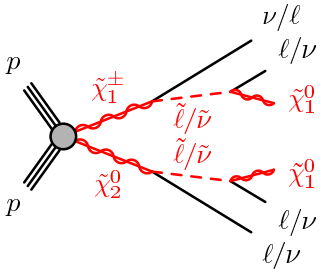
10^{-1} — 1 — Mass scale [TeV]

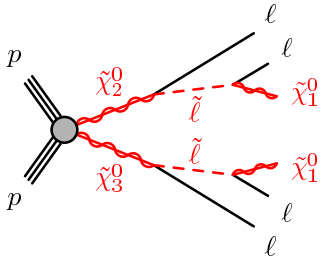
*Only a selection of the available mass limits on new states or phenomena is shown. All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.

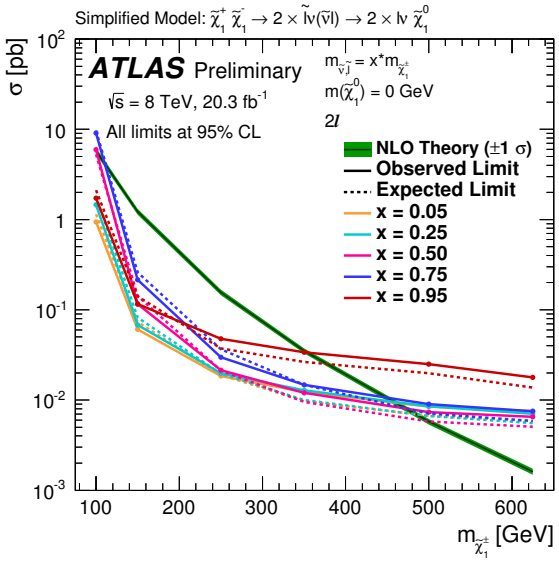
Impact of Variable Slepton Mass

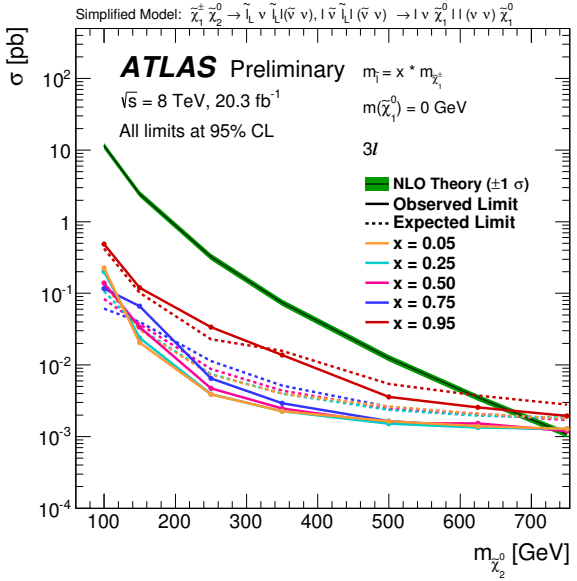
ATLAS-SUSY-2014-05

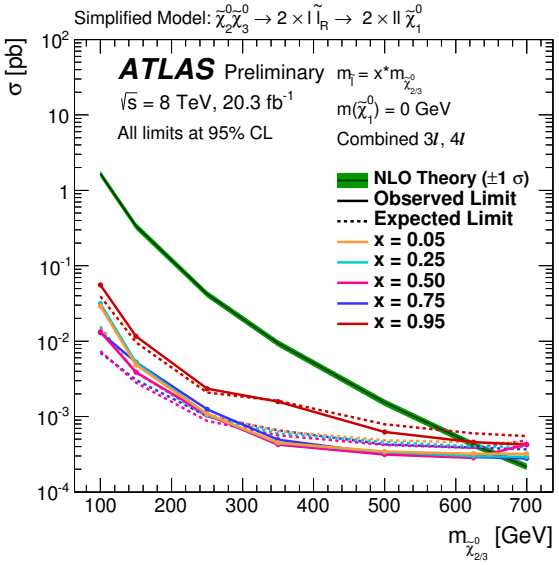








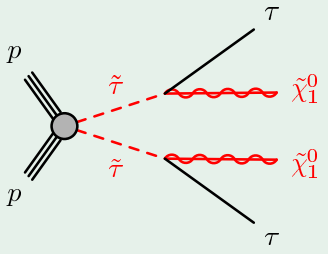




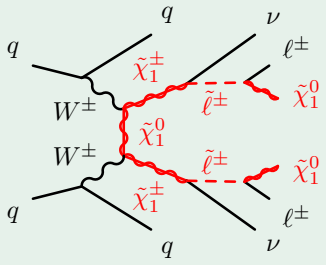
- Comparison of 95 % exclusion limits for $m(\widetilde{\chi}_1^0) = 0\,\mathrm{GeV}$ and $m(\widetilde{\ell}) = x \cdot m(\mathrm{ISP})$
- Impact of intermediate slepton mass very small for all three models (exception: $x = 0.95$)

Interpretations

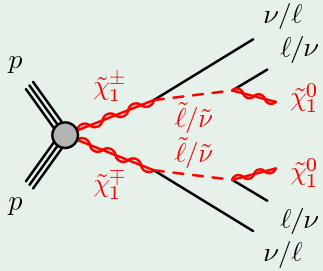
- Simplified models: (specific production mode, fixed decay chain, BR = 100 %)



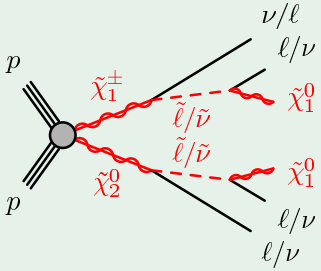
$\widetilde{\tau}\widetilde{\tau}$



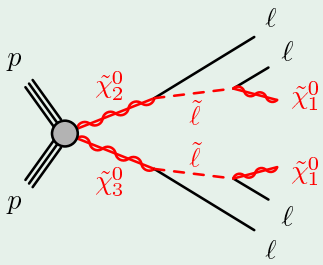
$\widetilde{\chi}_1^\pm\widetilde{\chi}_1^\pm$ in VBF



$\widetilde{\chi}_1^\pm\widetilde{\chi}_1^\mp$



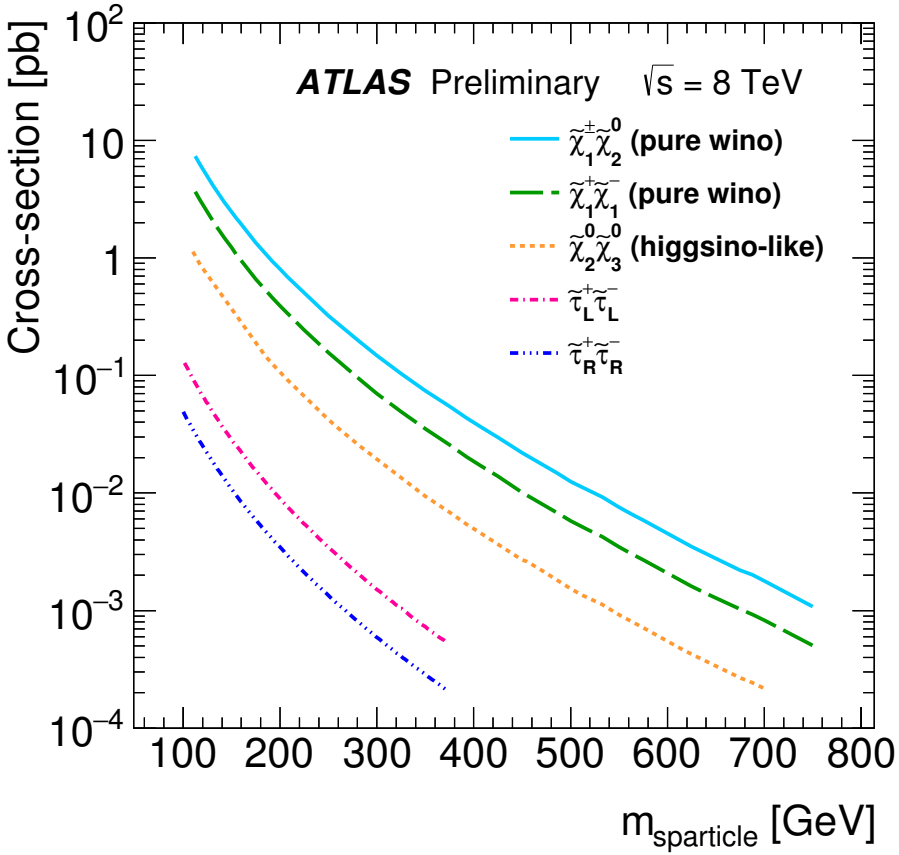
$\widetilde{\chi}_1^\pm\widetilde{\chi}_2^0$



$\widetilde{\chi}_2^0\widetilde{\chi}_3^0$

- Phenomenological models:
  - "Electroweak" pMSSM (phenomenological Minimal Supersymmetric Standard Model)
    - only direct production of $\widetilde{\chi}^\pm$ and $\widetilde{\chi}^0$ (sfermions and others decoupled)
    - reduced set of parameters: tan β, M_1, M_2, μ (instead of 19)
  - NUHM2 (two-parameter Non-Universal Higgs Masses model):
    - CMSSM + 2 additional parameters, μ and m_A
    - little fine-tuning, Higgs mass 125 GeV, squark masses of few TeV
    - electroweak production dominates for heavy gluino masses
  - GMSB (Gauge-Mediated Supersymmetry Breaking)
    - LSP is $\widetilde{G}$, electroweakino decays yield final states with many leptons
    - electroweak production dominates for large Λ

- R-parity assumed to be conserved



Production cross sections for the simplified models of the direct production of $\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\mp}$, $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$, $\tilde{\chi}_2^0\tilde{\chi}_3^0$, and $\tilde{\tau}^+\tilde{\tau}^-$

Table 2: The triggers used in the analyses and the offline p_T threshold used, ensuring that the lepton(s) or E_T^{miss} triggering the event are in the plateau region of the trigger efficiency. Where multiple triggers are listed for an analysis, events are used if any of the triggers is passed. Muons are triggered within a restricted range of $|\eta| < 2.4$.

Trigger	p_T threshold [GeV]	Analysis
Single τ Double τ	150 40,25	Direct stau production
Single Isolated e Single Isolated μ	25 25	Compressed spectra $\ell^+\ell^-$, 3ℓ
Double e	14,14 25,10	Compressed spectra $\ell^+\ell^-$, $\ell^\pm\ell^\pm$, 3ℓ
Double μ	14,14 18,10	Compressed spectra $\ell^+\ell^-$, $\ell^\pm\ell^\pm$, 3ℓ
Triple e	20,9,9	Compressed spectra 3ℓ
Triple μ	7,7,7 19,5,5	Compressed spectra 3ℓ
Combined $e\mu$	14(e),10(μ) 18(μ),10(e) 9(e),9(e),7(μ) 9(e),7(μ),7(μ)	Compressed spectra 3ℓ
E_T^{miss}	120	Chargino production via VBF

Compressed Spectra

- For small mass splittings between sparticles and LSP
  $\Rightarrow$ low-momentum decay products $\Rightarrow$ experimentally challenging
- Motivation: naturalness $\Rightarrow$ light higgsino
  $\Rightarrow \tilde{\chi}_1^0, \tilde{\chi}_2^0, \tilde{\chi}_1^\pm$ usually higgsino-dominated $\Rightarrow$ small $m(\tilde{\chi}_1^0) \lesssim m(\tilde{\chi}_2^0), m(\tilde{\chi}_1^\pm)$

- Exclusion limits are calculated by statistically combining results from disjoint SRs
- Where SRs overlap, the best expected SR is used for each grid point

Table 23: Searches used to probe each of the models described in Section 2.

Model	Wh [23]	$2\ell^{\dagger}$ [19]	$2\tau^{*}$ [22]	$3\ell^{\diamond}$ [20]	4ℓ [21]	2τ MVA*	SR2ℓ-1†	SS MVA§	SR3ℓ-0/1$^{\diamond}$	SR2ℓ-2§
$\tilde{\tau}\,\tilde{\tau}$			✓			✓				
$\tilde{\chi}_1^+\tilde{\chi}_1^-$ via $\tilde{\ell}_L$ with $x = 0.5$		✓					✓			
$\tilde{\chi}_1^+\tilde{\chi}_1^-$ via $\tilde{\ell}_L$ with variable x		✓								
$\tilde{\chi}_1^+\tilde{\chi}_1^-$ via WW		✓								
$\tilde{\chi}_1^\pm\tilde{\chi}_1^\pm$ via VBF										✓
$\tilde{\chi}_1^\pm\tilde{\chi}_2^0$ via $\tilde{\tau}_L$			✓	✓						
$\tilde{\chi}_1^\pm\tilde{\chi}_2^0$ via $\tilde{\ell}_L$ with $x = 0.5$				✓				✓	✓	
$\tilde{\chi}_1^\pm\tilde{\chi}_2^0$ via $\tilde{\ell}_L$ with variable x				✓						
$\tilde{\chi}_1^\pm\tilde{\chi}_2^0$ via WZ		✓		✓						
$\tilde{\chi}_1^\pm\tilde{\chi}_2^0$ via Wh	✓	✓		✓						
$\tilde{\chi}_2^0\tilde{\chi}_3^0$ via $\tilde{\ell}_L$ with $x = 0.5$				✓	✓					
$\tilde{\chi}_2^0\tilde{\chi}_3^0$ via $\tilde{\ell}_L$ with variable x				✓	✓					
pMSSM	✓	✓		✓						
NUHM2		✓		✓	✓					
GMSB					✓					

† The opposite-sign, two-lepton signal regions in Ref. [19] and Section 8.1 overlap.

∗ The two-tau signal regions in Ref. [22] and Section 7 overlap.

◇ The three-lepton signal regions in Ref. . [20] and Section 8.3 overlap.

§ The same-sign, two-lepton signal regions in Section 8.2 and Section 9 overlap.

$\boldsymbol{m_{\mathrm{T2}}}$ The "stransverse mass" is calculated as

$$m_{\mathrm{T2}} = \min_{\vec{q}_{\mathrm{T}}} \left[\max \left(m_{\mathrm{T}}(\vec{p_{\mathrm{T}}}^{\ell 1/\tau 1}, \vec{q}_{\mathrm{T}}), m_{\mathrm{T}}(\vec{p_{\mathrm{T}}}^{\ell 2/\tau 2}, E_{\mathrm{T}}^{\mathrm{miss}} - \vec{q}_{\mathrm{T}}) \right) \right],$$

where $\ell 1/\tau 1$ and $\ell 2/\tau 2$ denote the highest- and second-highest-p_{T} leptons or taus in the event, respectively, and $\vec{q}_{\mathrm{T}}$ is a test transverse vector that minimizes the larger of the two transverse masses m_{T}. The m_{T2} distribution has a kinematic endpoint for events where two massive pair-produced particles each decay to two objects, one of which is detected and the other escapes undetected [108, 109].

$\boldsymbol{m_{\mathrm{eff}}}$ The scalar sum of the transverse momenta of the signal leptons, taus, jets and $E_{\mathrm{T}}^{\mathrm{miss}}$ in the event:

$$m_{\mathrm{eff}} = E_{\mathrm{T}}^{\mathrm{miss}} + \Sigma p_{\mathrm{T}}^{\mathrm{leptons}} + \Sigma p_{\mathrm{T}}^{\mathrm{taus}} + \Sigma p_{\mathrm{T}}^{\mathrm{jets}}.$$

In the case of the two-tau analysis, only the sum of the $E_{\mathrm{T}}^{\mathrm{miss}}$ and two taus is used.

$\boldsymbol{R_2}$ The quantity R_2 is defined as

$$R_2 = \frac{E_{\mathrm{T}}^{\mathrm{miss}}}{E_{\mathrm{T}}^{\mathrm{miss}} + p_{\mathrm{T}}^{\ell 1} + p_{\mathrm{T}}^{\ell 2}}.$$

The R_2 distribution is shifted towards unity for signal events compared to the background, due to the existence of the LSPs that results in a larger $E_{\mathrm{T}}^{\mathrm{miss}}$ fraction.

$\boldsymbol{M_\Delta^R, \Delta\phi_R^\beta}$ The super-razor quantities M_Δ^R and $\Delta\phi_R^\beta$ are defined in Ref. [110]. These variables are motivated by the generic process of the pair production of two massive particles, each decaying into a set of visible and invisible particles (i.e. $\tilde{\chi}_1^\pm \rightarrow \ell\nu_\ell\tilde{\chi}_1^0$). Similar to m_{T2}, M_Δ^R is sensitive to the squared mass difference of the pair-produced massive particle and the invisible particle, via a kinematic endpoint. These two variables are expected to have a similar performance. For systems where the invisible particle has mass that is comparable to the pair-produced massive particle (i.e. compressed spectra), the variable $\Delta\phi_R^\beta$ has a pronounced peak near π. The effect is magnified as the spectrum becomes more and more compressed, making this variable a good discriminator for compressed spectra searches.

Signal MC

- $\widetilde{\tau}\widetilde{\tau}$, $\widetilde{\chi}_1^{\pm}\widetilde{\chi}_1^{\mp}$, $\widetilde{\chi}_1^{\pm}\widetilde{\chi}_2^0$: Herwig++ (2.5.2)
- $\widetilde{\chi}_2^0\widetilde{\chi}_3^0$, VBF $\widetilde{\chi}_1^{\pm}\widetilde{\chi}_1^{\pm}$: MadGraph5 (-1.5.12 / _aMC@NLO-2.1.1) + Pythia (6.426)

Signal Grids: EWKino Composition

- $\widetilde{\chi}_1^{\pm}\widetilde{\chi}_1^{\mp}$, $\widetilde{\chi}_1^{\pm}\widetilde{\chi}_2^0$: both $\widetilde{\chi}_1^{\pm}$ and $\widetilde{\chi}_2^0$ pure wino and mass-degenerate, $\widetilde{\chi}_1^0$ pure bino, slepton-mediated decays: BR$= 1/6$ for all 3 $\widetilde{\ell}_L$ / $\widetilde{\nu}$, stau-mediated: BR$= 1/2$ for $\widetilde{\tau}_L$ / $\widetilde{\nu}_\tau$
- $\widetilde{\chi}_2^0\widetilde{\chi}_3^0$: $\widetilde{\chi}_2^0$ and $\widetilde{\chi}_3^0$ pure higgsino and mass-degenerate, $\widetilde{\chi}_1^0$ pure bino, BR=$1/2$ for $\widetilde{e}_R$, $\widetilde{\mu}_R$
- SS $\widetilde{\chi}^{\pm}$-pair production in VBF: $\widetilde{\chi}_1^{\pm}$ pure wino, $\widetilde{\chi}_1^0$ pure bino, BR$= 1/6$ for all 3 $\widetilde{\ell}_L$ / $\widetilde{\nu}$

Interpretation: GMSB Bump

- For most of the parameter space: co-NLSP (stau and slepton)
- Low tan β: just slepton as NLSP $\rightarrow$ BR to light leptons larger
- Since light-lepton analyses usually better reach $\rightarrow$ better sensitivity there

Dominating Backgrounds

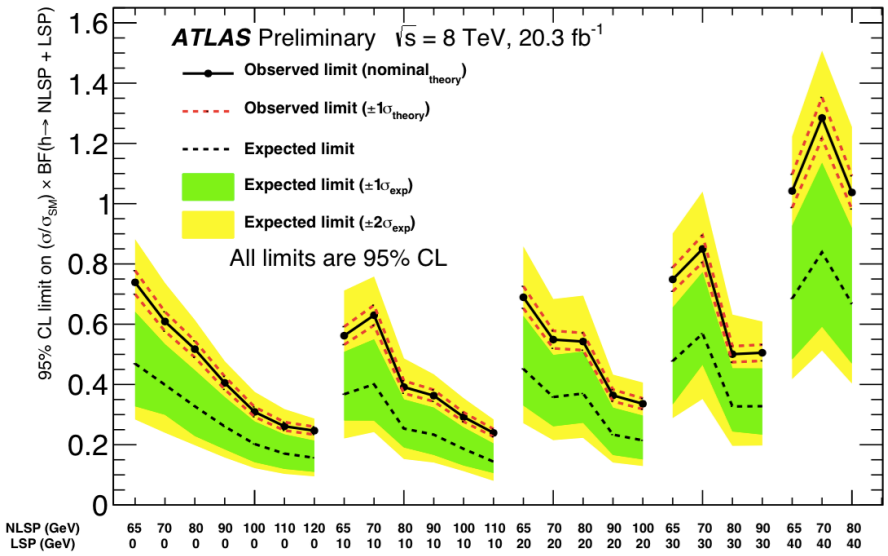
- 2 OS τ (MVA):
  - reducible ($\geq$ 1 fake taus): W + jets (multi-jet)
  - irreducible (2 prompt taus): diboson ($t\bar{t}$, Z + jets)
- 2 OS ℓ (ISR)
  - irreducible (2 prompt leptons): WW, top, (ZV, Higgs, Z + jets)
  - reducible ($\geq$ 1 fake leptons, e. g. e conversions): small
- 2 SS ℓ (MVA)
  - irreducible (2 prompt SS leptons): diboson (triboson, $t\bar{t}V$, tZ, higgs)
  - reducible ($\geq$ 1 fake leptons): $W\gamma$
  - charge flip ($\geq$ 1 lepton with mismeasured charge)
- 3ℓ incl. 1 SFOS ℓ pair (ISR)
  - reducible ($\geq$ 1 fake leptons): $t\bar{t}$, Z + jets (W + jets, WW, top)
  - irreducible (3 prompt leptons): WZ/ZZ (triboson, $t\bar{t}V$, tZ, higgs)
- 2 SS ℓ (VBF)
  - reducible ($\geq$ 1 fake leptons): W + jets ($t\bar{t}$, $W\gamma$)
  - irreducible (2 prompt leptons): WZ, WW
  - charge flip ($\geq$ 1 lepton with mismeasured charge)

Dominating Systematic Uncertainties

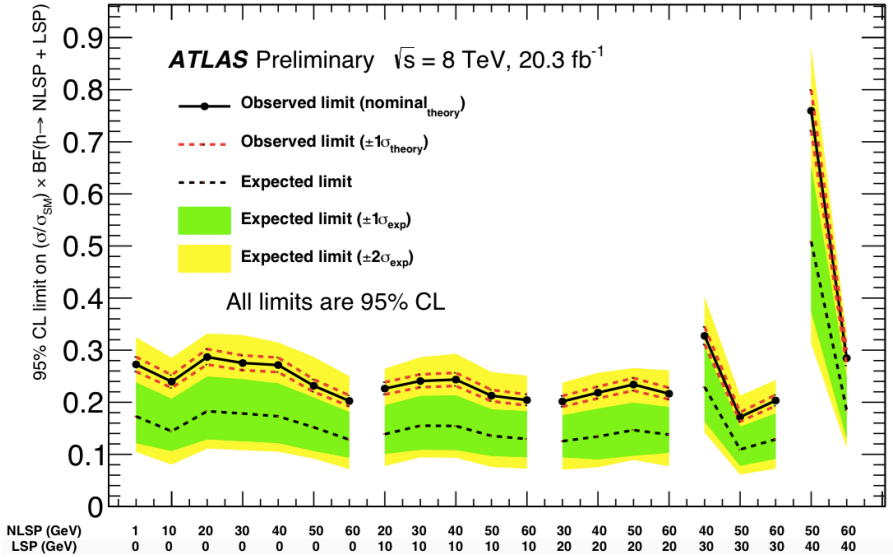
- 2 OS τ (MVA): stat. unc. on MC samples (20 %), $\not{E}_T$ soft-term resolution (20 %); total: 35 %
- 2 OS ℓ (ISR): theory & modeling (generator modeling, parton shower, . . . , 22 – 24 %); total: 23 – 28 %
- 2 SS ℓ (MVA): stat. unc. on MC samples (7 – 74 %), real lepton subtraction 8 – 33 %), jet-energy resolution (1 – 35 %); total: 18 – 81 %
- 3ℓ incl. 1 SFOS ℓ pair (ISR): stat. unc. on reducible bg. estimate (11 – 34 %), muon misidentification probability (red. bg. est., $<$ 1 – 27 %), total: 25 – 59 %
- 2 SS ℓ (VBF): fake-factor closure test (13 %), stat. unc. on the red. bg. (11 %), total: 21 %

VBF $H \to \gamma(\gamma) + \not{E}_T$ in GMSB / NMSSM

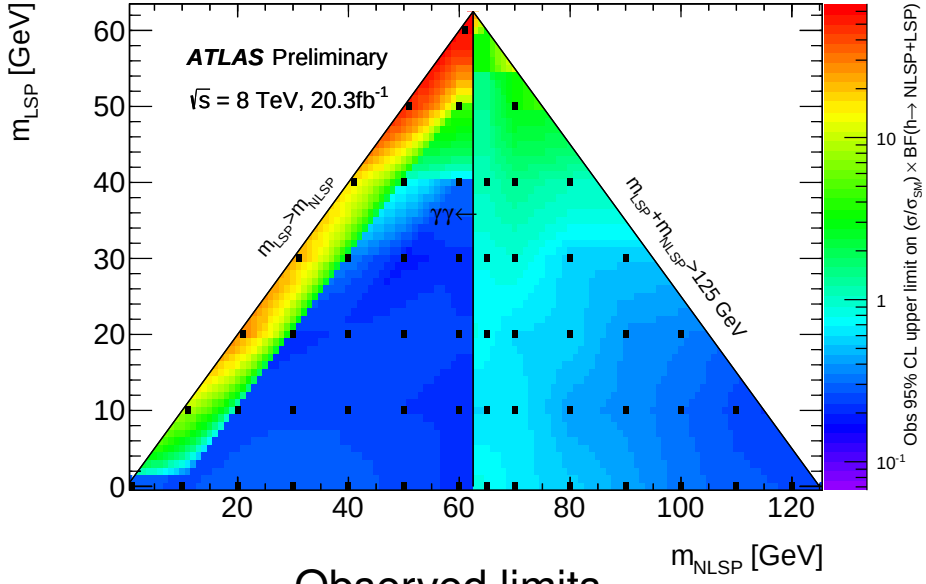
ATLAS-CONF-2015-001 (Feb. 2015)



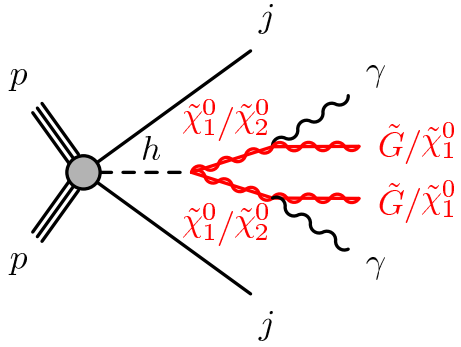
Monophoton signals



Diphoton signals

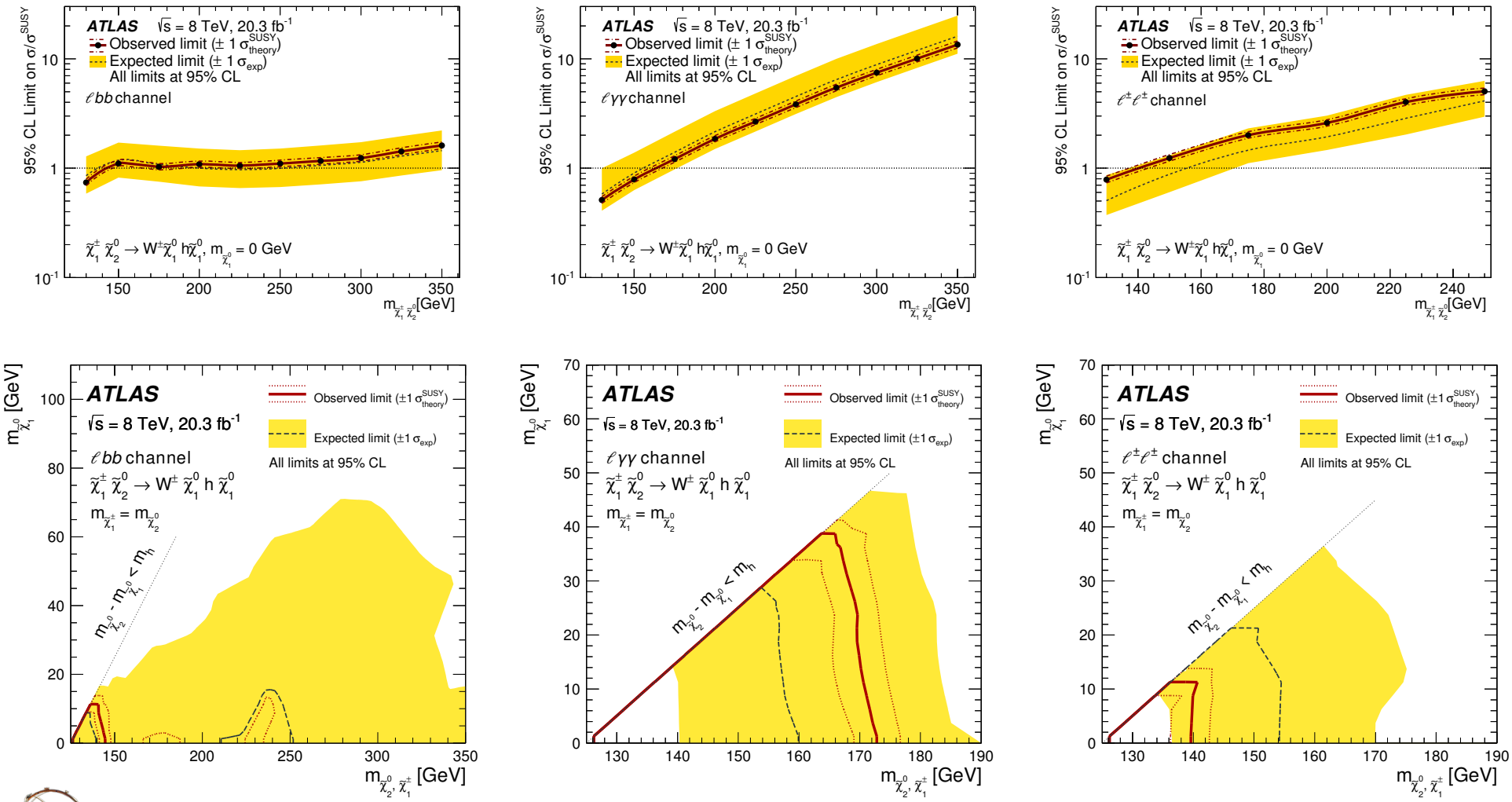


Observed limits



Diphoton production

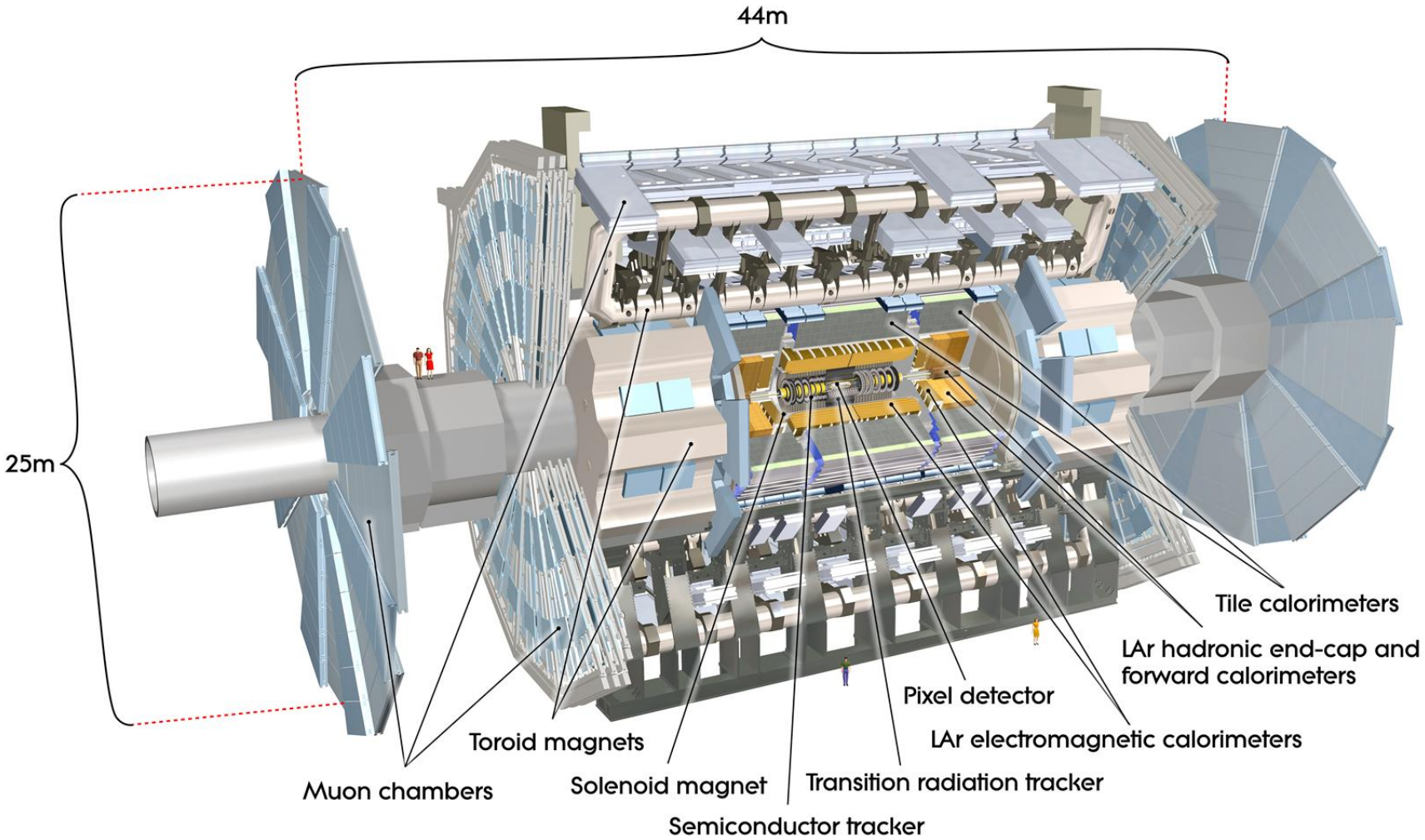
Individual limits in 3 channels (ℓbb, $\ell\gamma\gamma$, $\ell\ell^+\ell^-$):



Discriminating Variables

- Cotransverse mass $m_{\mathrm{CT}} = \sqrt{(E_T^{b_1} + E_T^{b_2})^2 - |\vec{p}_T^{\,b_1} - \vec{p}_T^{\,b_2}|^2}$
  $t\bar{t}$: upper endpoint at approximately top mass
- Transverse mass $m_{\mathrm{T}}^W = \sqrt{2E_T^{\ell}E_T^{\mathrm{miss}} - 2\vec{p}_T^{\,\ell} \cdot \vec{p}_T^{\,\mathrm{miss}}}$
  $W +$ jets: at low values
- $m_{\mathrm{T}}^{W_{\gamma 1,2}} = \sqrt{(m_{\mathrm{T}}^W)^2 + 2E_T^W E_T^{\gamma_i} - 2\vec{p}_T^{\,W} \cdot \vec{p}_T^{\,\gamma_i}}$
  including photon in transverse mass allows to identify lept. W decays with photon FSR
- $\Delta\phi(W, h)$: $W \to \ell\nu$ and $h\gamma\gamma$ back-to-back
- $m_{\mathrm{T}}^{\mathrm{max}} = \max\{m_{\mathrm{T}}(\ell_1), m_{\mathrm{T}}(\ell_2)\}$ (against W)
- m_{eff} = sum of p_T of leptons, jets and $\not{E}_T$ (against diboson)
- $E_{\mathrm{T}}^{\mathrm{miss,rel}}$ = $\not{E}_T$ reduced by component along direction of nearest lepton or jet (against Z, non-prompt leptons, reduced impact from mismeasurements)
- small $\Delta\eta_{ll}$ against WZ, ZZ

The ATLAS Detector



SUSY Models

mSUGRA / CMSSM Parameters

- $\rightarrow$ gravity-mediated SUSY breaking
- m_0: mass of scalar particles
- $m_{1/2}$: gaugino masses
- A_0: trilinear Higgs-sfermion-sfermion coupling parameter
- $\tan\beta = \nu_u/\nu_d$: ratio of the vacuum expectation values of the two Higgs doublets
- sign of the Higgsino mass parameter μ
- NUHM2: adds m_{H_u}, m_{H_d}, trade for μ, m_A

GMSB Parameters

- $\rightarrow$ gauge-mediated SUSY breaking
- Λ: SUSY breaking mass scale felt by the low-energy sector
- M_{mes}: mass scale of the messenger fields
- N_5: number of SU(5) messenger fields
- C_{grav}: scale factor of the gravitino coupling
- $\tan\beta = \nu_u/\nu_d$: ratio of the vacuum expectation values of the two Higgs doublets
- sign of the Higgsino mass parameter μ

NGM

- starts from General Gauge Mediation
- GGM: no specific SUSY mass hierarchy is predicted for colored and uncolored states
  $\Rightarrow$ gluinos and squarks can be below the TeV scale = within reach of LHC
- NGM: decouple all sparticles not related to fine-tuning of Higgs sector
  $\Rightarrow$ light stop and light gluino as only light (relevant) coloured sparticle
- some additional mechanism needed (as in GMSB) to produce “correct” Higgs mass