Signatures of heavier electroweakinos at LHC

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SUSY17, TIFR

Charginos and Neutralinos

- Charginos : $\widetilde{\chi}_1^{\pm}$, $\widetilde{\chi}_2^{\pm}$
- Neutralinos : $\widetilde{\chi}_1^0$, $\widetilde{\chi}_2^0$, $\widetilde{\chi}_3^0$, $\widetilde{\chi}_4^0$
- $\widetilde{\chi}_1^0$ is the Lightest Supersymmetric Particle (LSP)

Looking for $\widetilde{\chi}_1^{\pm}$ and $\widetilde{\chi}_2^0$ at LHC Run-I through $3l + \not{E}_T$ channel

- Mostly signal of $\widetilde{\chi}_1^{\pm}$ and $\widetilde{\chi}_2^0$ is extensively considered

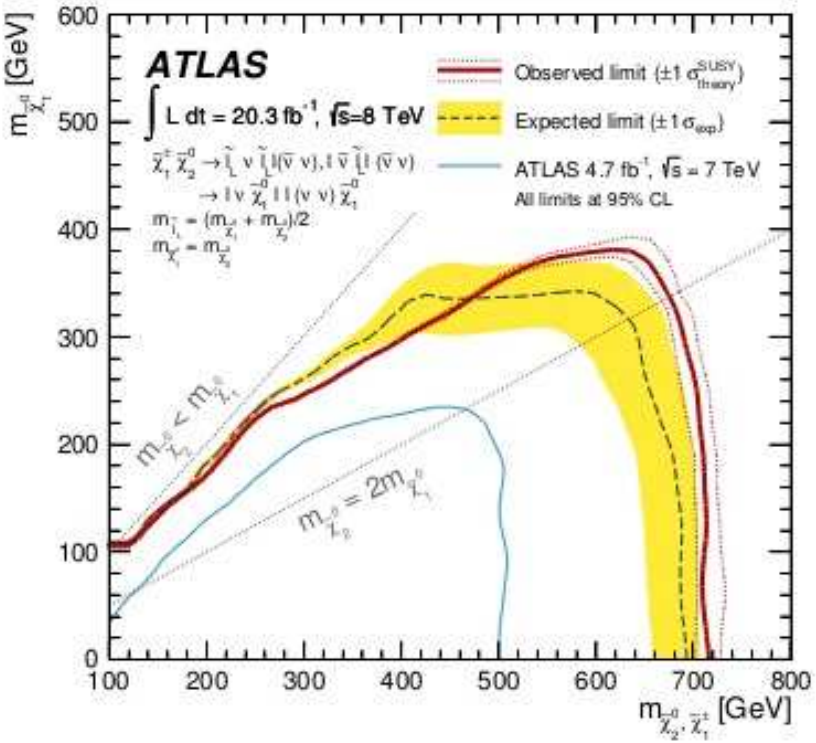
- Larger no. of leptons in final states $\longrightarrow$ reduced SM noise $\longrightarrow$ **BETTER SIGNAL !!**

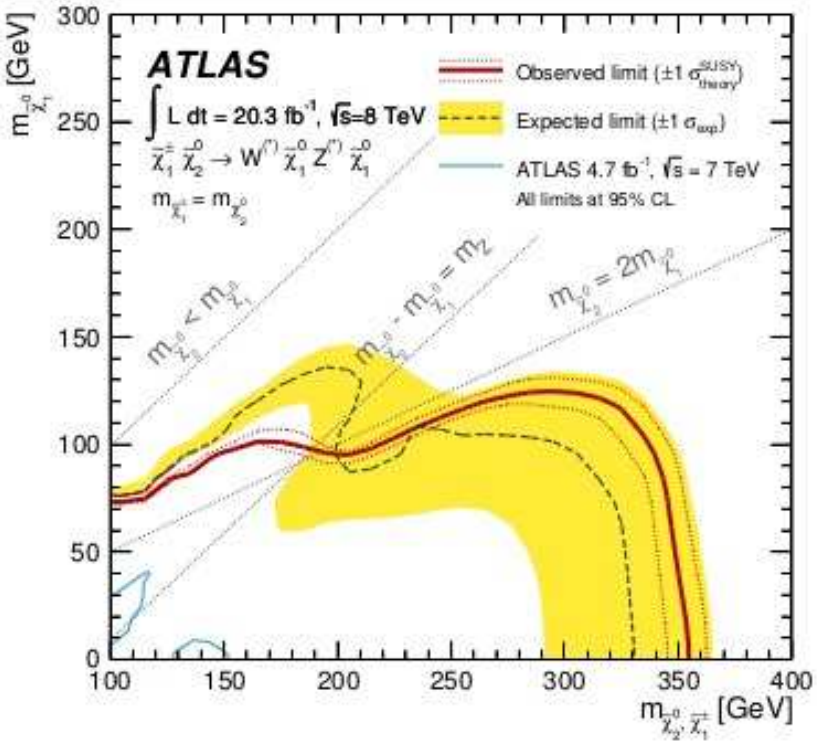
- $\widetilde{\chi}_1^0$ **is the carrier of** $\not{E}_T$

Mostly studied Simplified Models

- $\widetilde{\chi}_1^0$: Bino-like
- $\widetilde{\chi}_1^\pm, \widetilde{\chi}_2^0$: Wino-like
- $\widetilde{\chi}_2^\pm, \widetilde{\chi}_3^0, \widetilde{\chi}_4^0$: Higgsino-like
- $\widetilde{l}_L^\pm$ midway between $\widetilde{\chi}_1^\pm$ and $\widetilde{\chi}_1^0$ or heavier than $\widetilde{\chi}_1^\pm$
- All heavier eweakinos are decoupled

Exclusion limits from ATLAS at RUN-I





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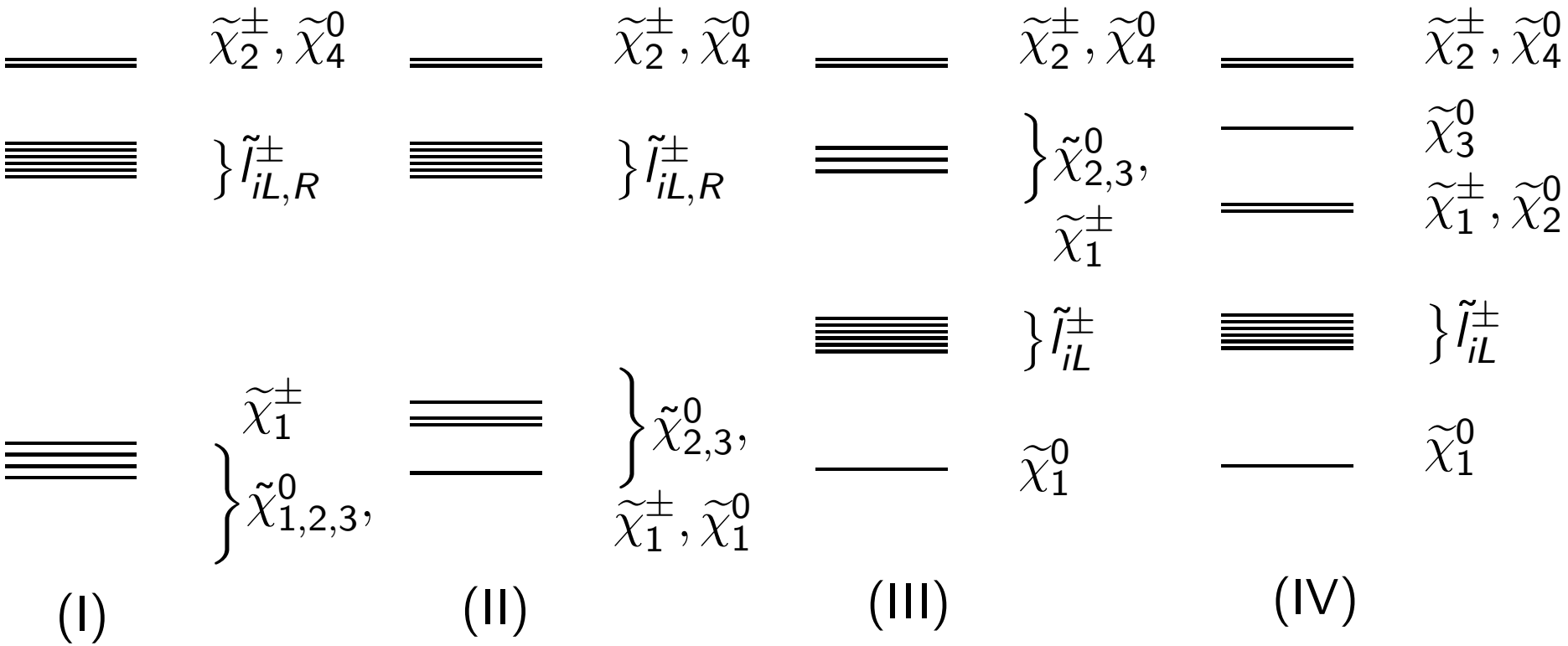
G. Aad *et al.* [ATLAS Collaboration]

Looking beyond simplified model

- Higgsino model : $M_1 < \mu < M_2$
- Mixed model : $M_1 < \mu \sim M_2$
- Compressed model : $M_1 \sim \mu < M_2$

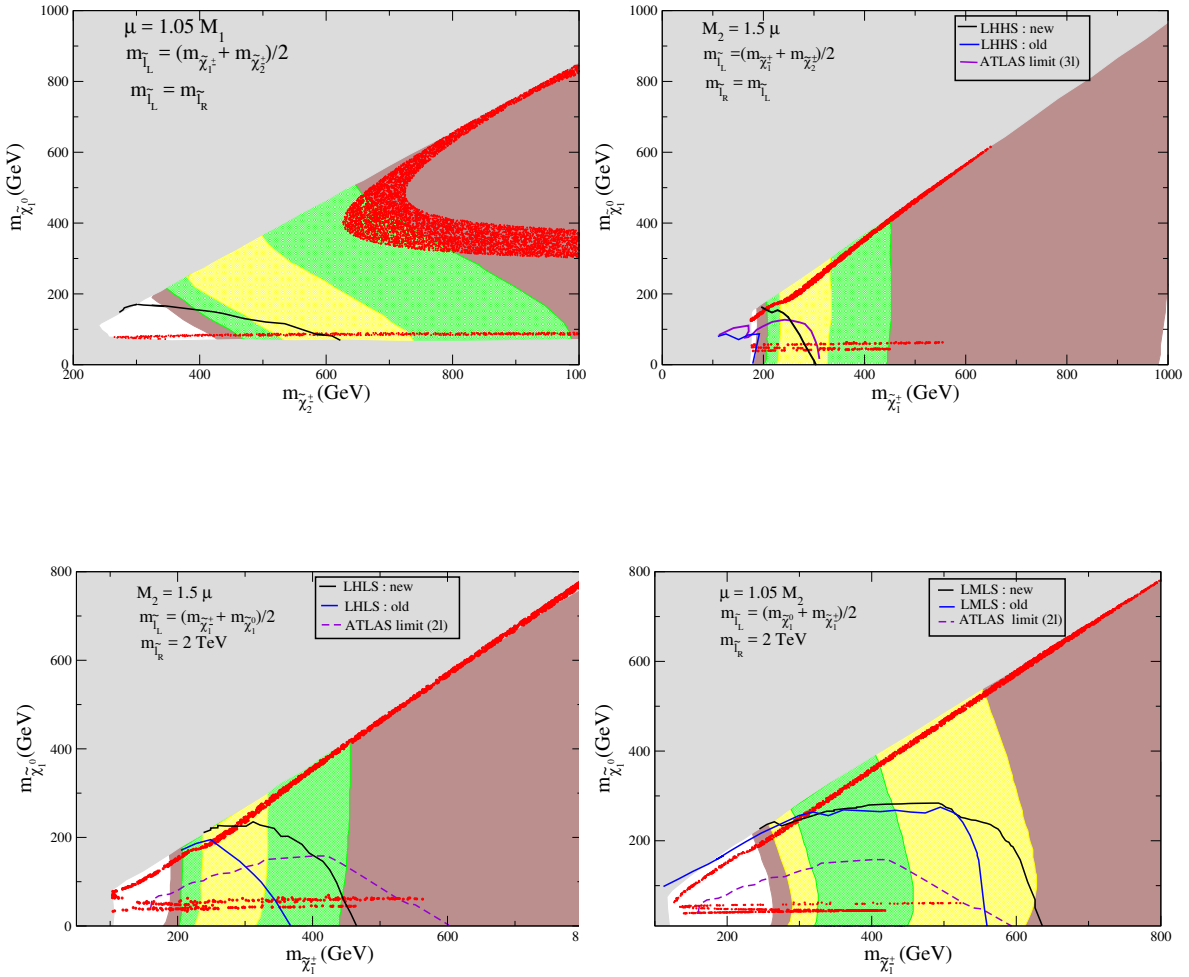
Models - Pictorial representation



What about the heavier eweakinos ??

- $\widetilde{\chi}_2^{\pm}$, $\widetilde{\chi}_4^0$ can contribute significantly to $3l + \not{E}_T$ signal
- Lead to stronger bounds on lighter eweakino masses
- New bounds on masses of $\widetilde{\chi}_2^{\pm}, \widetilde{\chi}_4^0$
- Can lead to novel multilepton signals before next long shutdown

Exclusion contours



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M. Chakraborti, A. Datta, S. Poddar, NG

New Mass Bounds

Parameters/ Masses	Benchmark Points			
	BP1 (Comp)	BP2 (LHHS)	BP3 (LHLS)	BP4 (LMLS)
M_1	191	105	175	296
μ	$\simeq M_1$	-	-	$1.05M_2$
M_2	-	1.5μ	1.5μ	566
$m_{\tilde{\chi}_1^0}$	152	100	170	250
$m_{\tilde{\chi}_1^\pm}$	178	> 250	> 400	> 590
		(-)	(> 270)	(> 520)
$m_{\tilde{\chi}_2^\pm}$	> 370	-	-	-

Collider Search at $\sqrt{S} = 13$ TeV

- We focus on different multilepton signals associated with $\not{E}_T$ at LHC RUN-II :
  - 3 leptons
  - 4 leptons
  - 3 Same Sign and 1 Opposite Sign leptons (SS3OS1)
  - 5 leptons

- We consider all possible production of electroweakinos :

$$pp \longrightarrow \widetilde{\chi}_i^0 \widetilde{\chi}_j^0, \widetilde{\chi}_i^+ \widetilde{\chi}_j^- , \widetilde{\chi}_i^0 \widetilde{\chi}_j^\pm$$

- Event generation,showering and hadronisation performed using PYTHIA

Standard Model Background

- Backgrounds coming from SM considered in the analysis :
  - ⋆ ZZ
  - ⋆ WZZ
  - ⋆ WWZ
  - ⋆ ZZZ
  - ⋆ $t\bar{t}Z$

Basic selection cuts

Primary selection cuts on final state particles for both signal and background :

- Leptons (e and μ) with $P_T > 10$ GeV and $|\eta| < 2.5$
- Jets with $P_T > 20$ GeV and $|\eta| < 2.5$
- Isolation cuts on leptons following ATLAS

3 Leptons + $\not{E}_T$ analysis

- C1: Events with 3 isolated leptons are selected
- C2: Events with 81.2 GeV $< m_{SFOS} <$ 101.2 GeV are rejected
- C3: $\not{E}_T > 200$ GeV

4 Leptons + $\not{E}_T$ analysis

- C1: Events with 4 isolated leptons are selected
- C2: Events with 81.2 GeV $< m_{SFOS} <$ 101.2 GeV are rejected
- C3: $\not{E}_T > 80$ GeV

SS3OS1 Leptons + $\not{E}_T$ analysis

- C1: Events with 4 isolated leptons are selected
- C2: Total charge of final state leptons are non-zero
- C3: $\not{E}_T > 80$ GeV

5 Leptons + $\not{E}_T$ analysis

- C1: Events with 5 isolated leptons are selected

- C2: $\not{E}_T > 80$ GeV

Sample Benchmark points

Parameters/ Masses	Benchmark Points		
	BP1 (Comp)	BP4 (LHHS)	BP6 (LHLS)
M_1	186	105	249
μ	190	270	300
M_2	350	405	450
$m_{\widetilde{\chi}_1^0}$	150	100	230
$m_{\widetilde{\chi}_1^\pm}$	180	260	290
$m_{\widetilde{\chi}_2^\pm}$	390	450	490

Sample Benchmark points

Parameters/ Masses	Benchmark Points		
	BP3-DM (Comp)	BP1-DM (LHHS)	BP1-DM (LHLS)
M_1	116	200	277
μ	121.8	266	328
M_2	666	399	492
$m_{\widetilde{\chi}_1^0}$	87	186	258
$m_{\widetilde{\chi}_1^\pm}$	123	255	320
$m_{\widetilde{\chi}_2^\pm}$	700	440	530

Multi-Lepton Signals

Types of Signal	Benchmark Points		
	BP1 (Comp)	BP4 (LHHS)	BP6 (LHLS)
$(S/\sqrt{B})_{3l}$	14.3	13.6	26.9
	(3.4)	(3.1)	(4.2)
4 leptons	61.5	16.4	19.6
	(0.69)	(0.62)	(2.1)
SS3OS1 leptons	29.9	7.2	5.1
	(0.69)	(-)	(0.17)
5 leptons	8.46	6.1	4.14
	(-)	(-)	(-)

$$L = 100 fb^{-1}$$

Multi-Lepton Signals

Types of Signal	Benchmark Points		
	BP3-DM (Comp)	BP1-DM (LHHS)	BP1-DM (LHLS)
$(S/\sqrt{B})_{3l}$	6.4	6.7	18.6
4 leptons	14.1	18.5	13.8
SS3OS1 leptons	5.63	3.34	2.88
5 leptons	2.81	4.1	3.64

$$L = 100 fb^{-1}$$

Sample Exclusion Contours at RUN-II

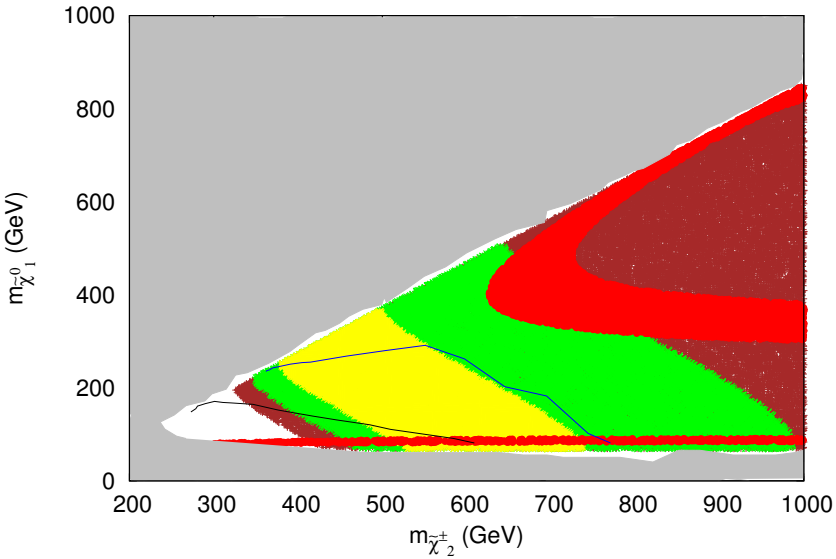

Figure: Compressed

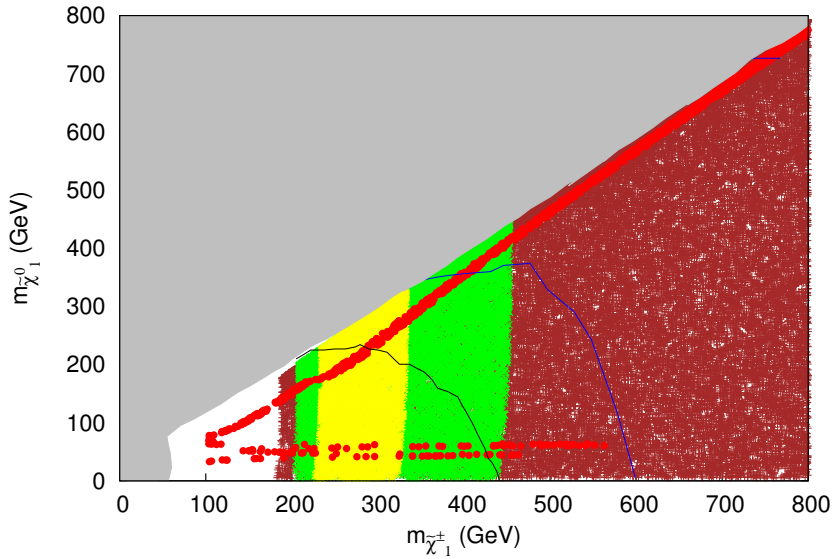

Figure: LHLS

Conclusion

- Various SUSY scenarios in MSSM framework are considered with non-decoupled heavier eweakinos
- New bounds on $m_{\widetilde{\chi}_2^{\pm}}, m_{\widetilde{\chi}_4^0}$ are obtained
- Stronger bounds on masses of lighter eweakinos are calculated for non-decoupled $\widetilde{\chi}_2^{\pm}, \widetilde{\chi}_4^0$
- Inclusion of heavier eweakinos gives better multilepton signal strength

The work is done in collaboration with A. Datta, S. Poddar and M. Chakraborti :

- Phys. Lett. B763, 213-217 (2016)
- JHEP 1711 (2017) 117

THANK YOU!