Signatures of heavier electroweakinos at LHC

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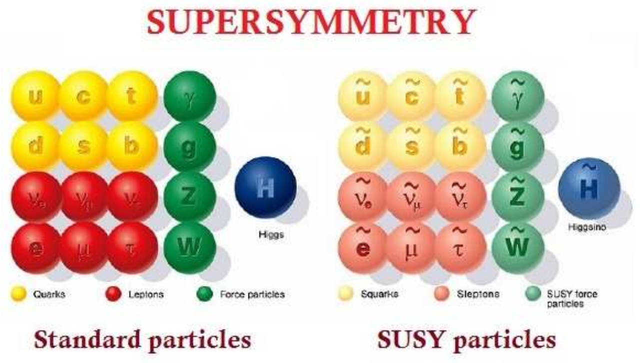
MSSM at a glance



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)

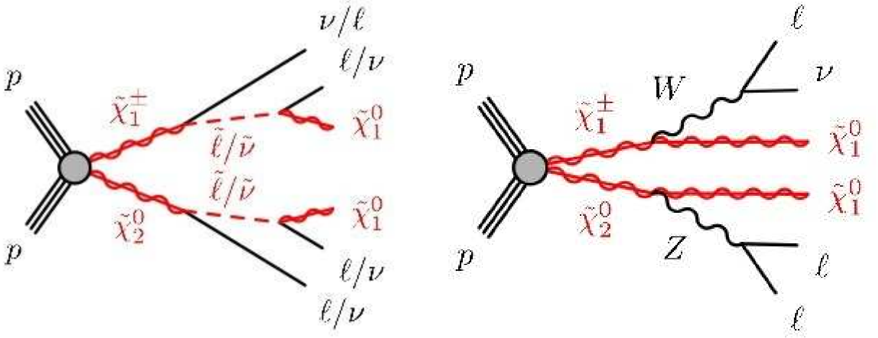
Search for SUSY

- Extensively searched at LHC - but so far there is no signal
- Stringent bounds on strongly interacting sparticles
- Electroweak sparticles may be the only way to probe SUSY in near future

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

- Production of $\widetilde{\chi}_1^{\pm}$ and $\widetilde{\chi}_2^0$ is considered
- Larger no. of leptons in final states $\longrightarrow$ reduced SM noise $\longrightarrow$ **BETTER SIGNAL !!**
- $\widetilde{\chi}_1^0$ **is the carrier of** $\not{E}_T$

$3l + \not{E}_T$ signal

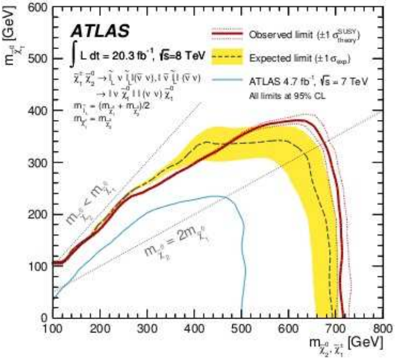


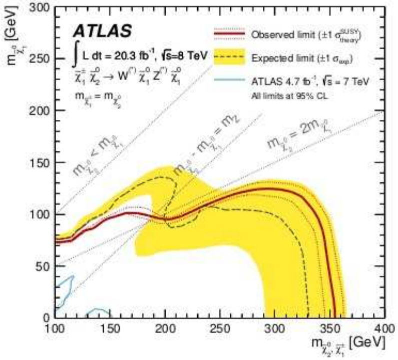
JHEP 1404 (2014) 169
G. Aad *et al.* [ATLAS Collaboration]

Simplified Models considered by ATLAS

- $\widetilde{\chi}_1^0$: 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
- Observation is so far in agreement with SM expectation

Exclusion limits from ATLAS





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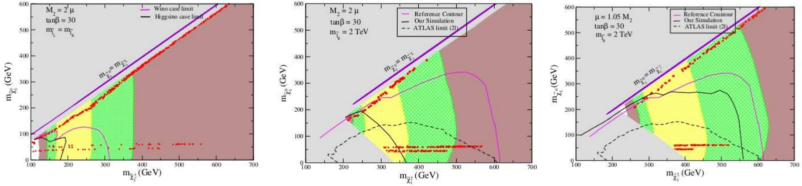
Looking beyond simplified model

- Higgsino model : $M_1 < \mu < M_2$

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

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

Looking beyond simplified model



JHEP 1511 (2015) 050

M. Chakraborti, U. Chattopadhyay, A. Choudhury, A. Datta and S. Poddar

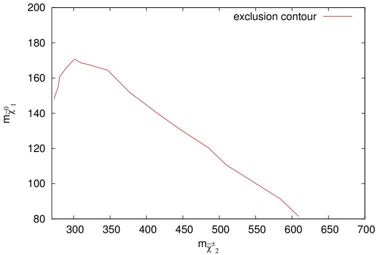
What about the heavier eweakinos ??

- There is no compelling reason for assuming them to be decoupled
- Can contribute to signal significantly
- Leading to stronger bounds on lighter eweakino masses
- New bounds on masses of $\widetilde{\chi}_2^{\pm}, \widetilde{\chi}_4^0$

New Mass Bounds

Parameters/ Masses	Benchmark Points			
	BP1 (Comp)	BP2 (LHHS)	BP3 (LHLS)	BP4 (LMLS)
M_1	191	105	175	296
μ	$\simeq M_1$	-	-	$1.05 M_2$
M_2	-	1.5μ	1.5μ	566
$m_{\tilde{\chi}_1^0}$	152	100	170	290
$m_{\tilde{\chi}_1^\pm}$	178	> 250	> 400	> 540
$m_{\tilde{\chi}_2^\pm}$	> 370	-	-	-

Exclusion contour in Compressed scenario



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: 81.2 GeV $< m_{SFOS} <$ 101.2 GeV

- C3: $\not{E}_T > 200$ GeV

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

- C1: Events with 4 isolated leptons are selected
- C2: 81.2 GeV $< m_{SFOS} <$ 101.2 GeV
- 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)	BP7 (LMLS)
M_1	186	105	249	321
μ	190	270	300	401
M_2	350	405	450	382
$m_{\widetilde{\chi}_1^0}$	150	100	230	305
$m_{\widetilde{\chi}_1^\pm}$	180	260	290	350
$m_{\widetilde{\chi}_2^\pm}$	390	450	490	465

Multi-Lepton Signals

Types of Signal	Benchmark Points			
	BP1 (Comp)	BP4 (LHHS)	BP6 (LHLS)	BP7 (LMLS)
$S/\sqrt{B}$	14.3	13.6	26.9	11.3
	(3.4)	(3.1)	(4.2)	(5.9)
4 leptons	61.5	16.4	19.6	10.2
	(0.69)	(0.62)	(2.1)	(-)
SS3OS1 leptons	29.9	7.2	5.1	1.6
	(0.69)	(-)	(0.17)	(-)
5 leptons	8.46	6.1	4.14	0.78
	(-)	(-)	(-)	(-)

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

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 signal strength

The work is done in collaboration with A. Datta and S. Poddar

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THANK YOU!