

IHEP

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# SUSY Searches with taus at the LHC

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On behalf of ATLAS and CMS Collaboration

The 15<sup>th</sup> International Workshop on Tau Lepton Physics  
Amsterdam, 26/09/2018



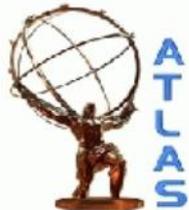


# Motivations



**Final states with taus are of particular interest in SUSY searches:**

- $\tilde{\tau}$  is a superpartner of the third generation fermion  $\tau$  and a colorless scalar, intends to be light in SUSY scenarios, lead to  $\tau$ -riched final states
- Light  $\tilde{\tau}$  could expect a Dark Matter relic density consistent with cosmological observations
- Independent studies of  $\tau$ s channels are necessary to investigate the coupling structure of the new physics may be discovered in leptonic final states, especially with regard to lepton universality



# SUSY searches at LHC



SM processes are backgrounds for SUSY search, need to carefully understand and accurately model the SM backgrounds, finally to determine SUSY signals' exist by observing significant events excess above SM level in LHC real data

## SUSY hunting process

### SM Backgrounds

#### Irreducible backgrounds

**Dominant sources** **Control Regions** in **data** generally used for normalisation, transfer to signal regions using **MC**

**Sub-dominant sources** **MC**

#### Reducible backgrounds

Determined from **data**

Analysis dependent

#### Validation ( essential ! )

Validation **Regions** used for cross-checks

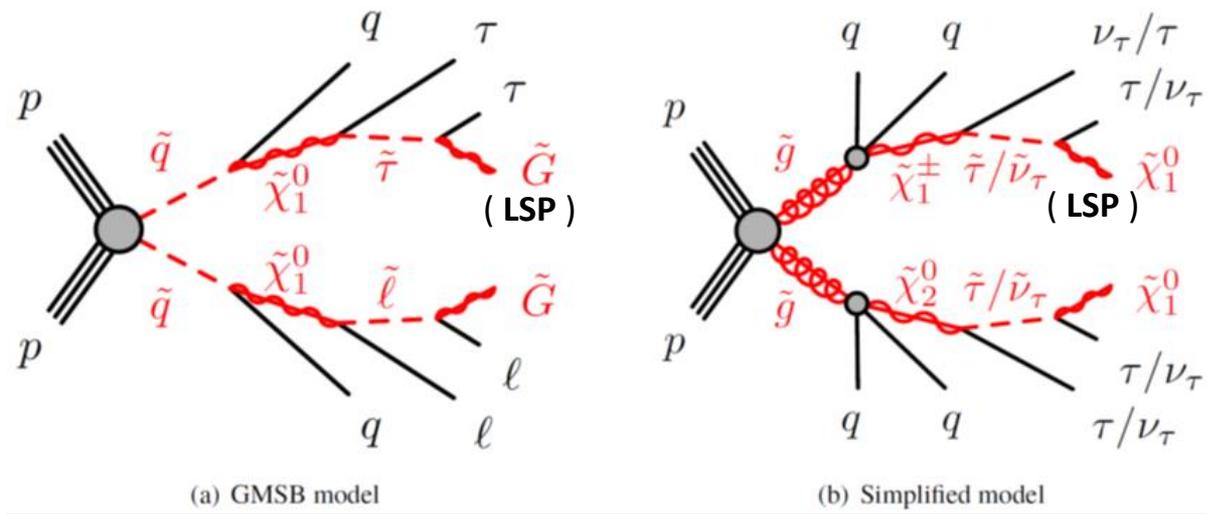
Blinded while developing Background modelling

#### Signal Regions

Blinded until background modelling is verified



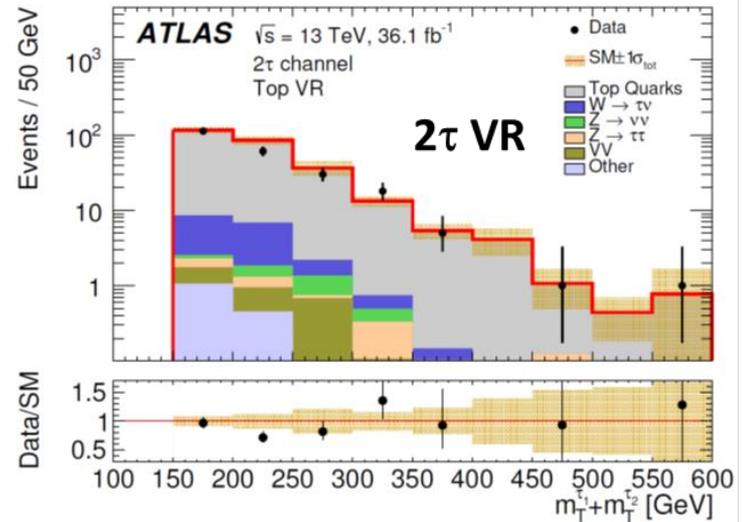
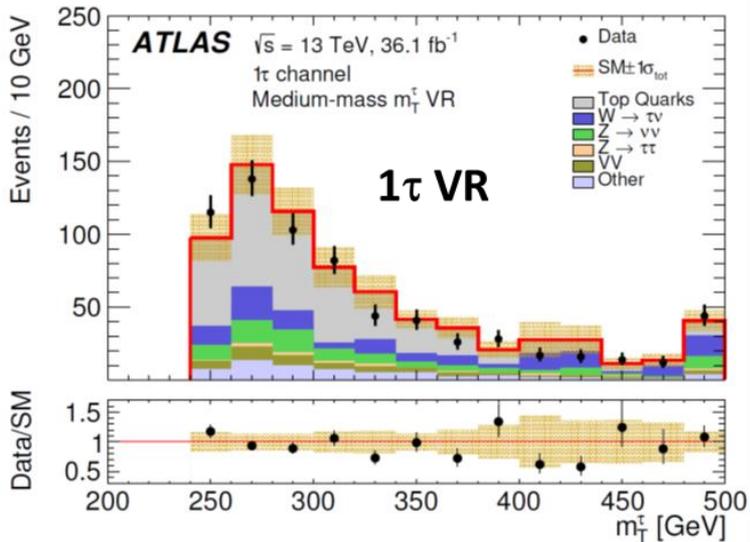
# Strong production: 1<sup>th</sup>/2<sup>th</sup> squark/gluino pair to taus



**GMSB:**  
**Gauge-Mediated Supersymmetry**  
**Breaking scenario, LSP = Gravitino**

**Signal: =1 $\tau_h$  or  $\geq 2\tau_h$**

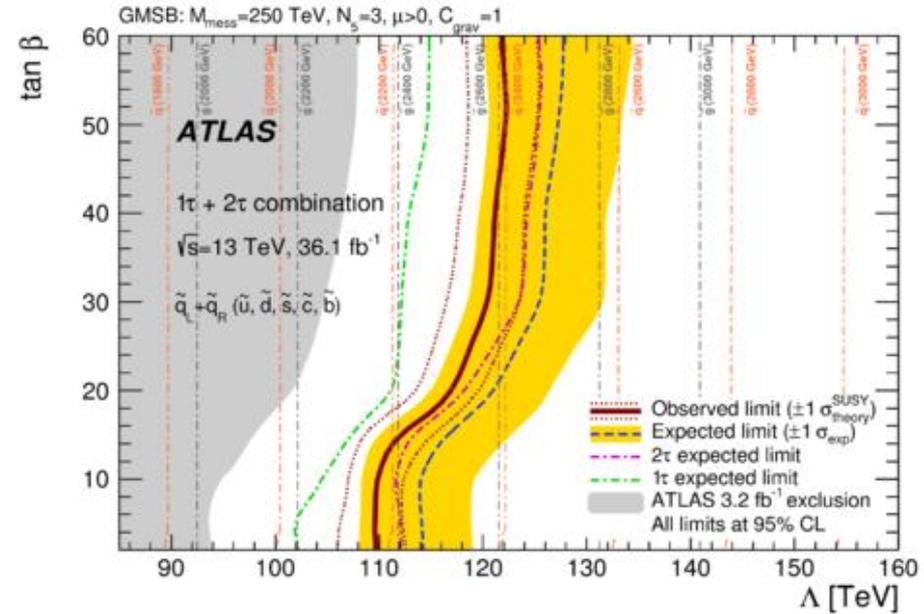
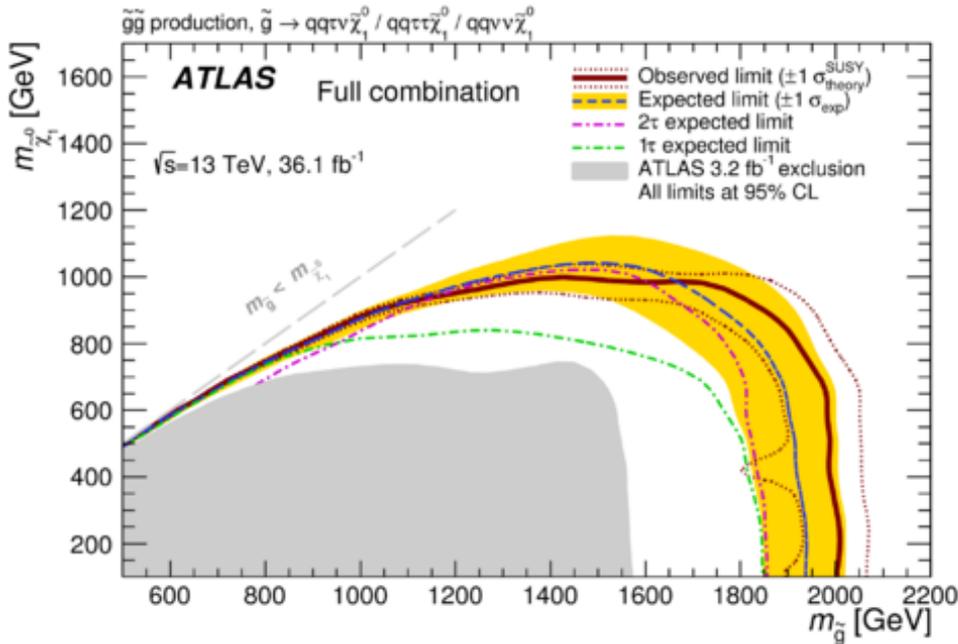
## All CR/VR/SR DATA/MC Comparison: well consistent !



# Strong production: 1<sup>th</sup>/2<sup>th</sup> squark/gluino pair to taus **Result**



arXiv:1808.06358



No significant deviation from SM is observed, 95% CL lower limit is set

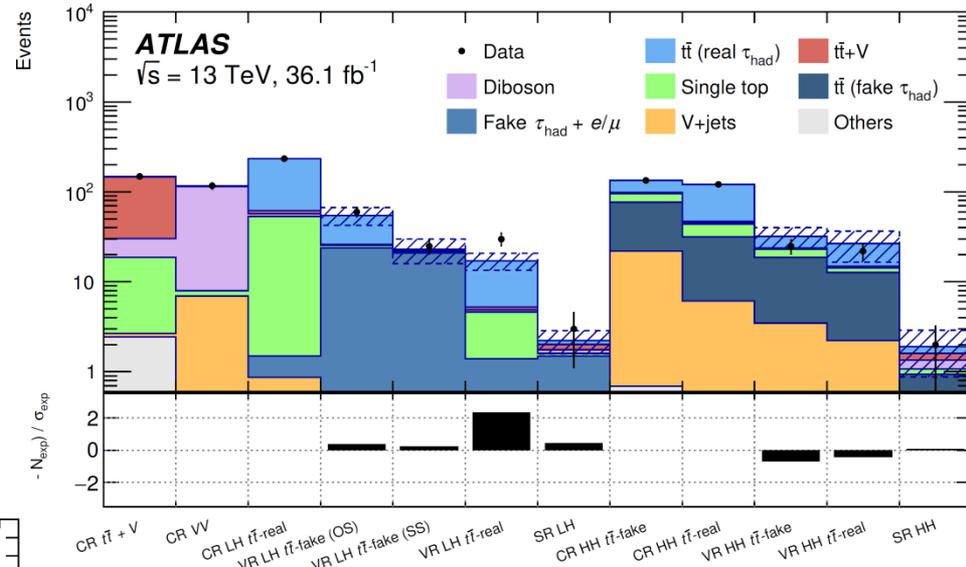
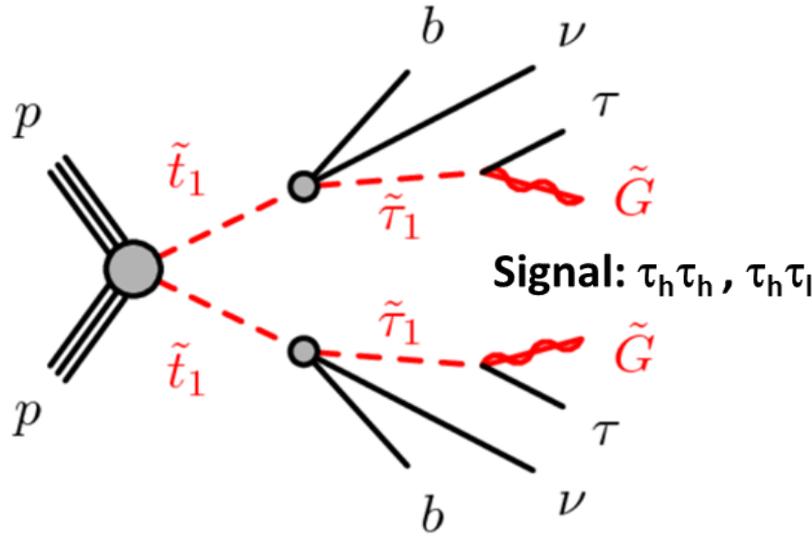
**Exclusion:** Gluino masses up to 2000 GeV for low values of the mass of the Lightest Supersymmetric Particle (LSP); while LSP masses up to 1000 GeV for gluino masses around 1400 GeV in the simplified model

**Exclusion:** Values of the supersymmetry-breaking scale  $\Lambda < 110\text{ TeV}$  for all values of  $\tan\beta$  in the range  $2 \leq \tan\beta \leq 60$ , and  $\Lambda < 120\text{ TeV}$  for  $\tan\beta > 30$  in the GMSB model

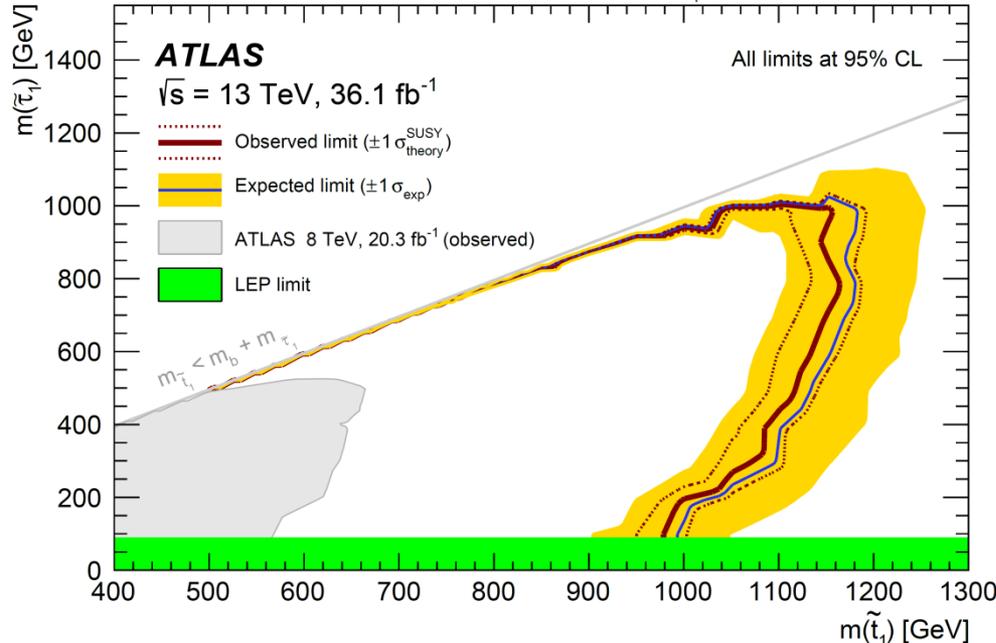
# Strong production: stop pair to taus



PRD 98 (2018) 032008



$\tilde{t}_1 \tilde{t}_1$  production, with branching ratios  $B(\tilde{t}_1 \rightarrow \bar{\tau}_l b \nu) = 1, B(\bar{\tau}_1 \rightarrow \tau \tilde{G}) = 1$



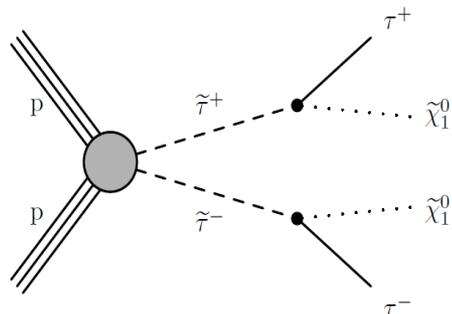
No significant deviation from SM is observed, 95% CL lower limit is set

**Exclusion:  $m(\tilde{t}_1)$  up to 1.16 TeV  
 $m(\tilde{\tau}_1)$  up to 1.00 TeV**

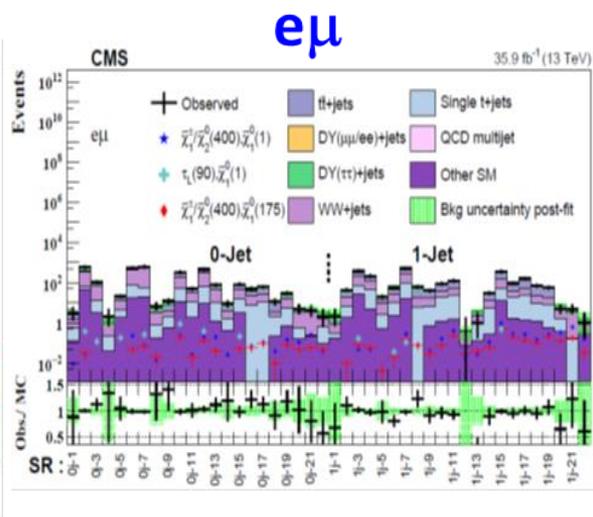
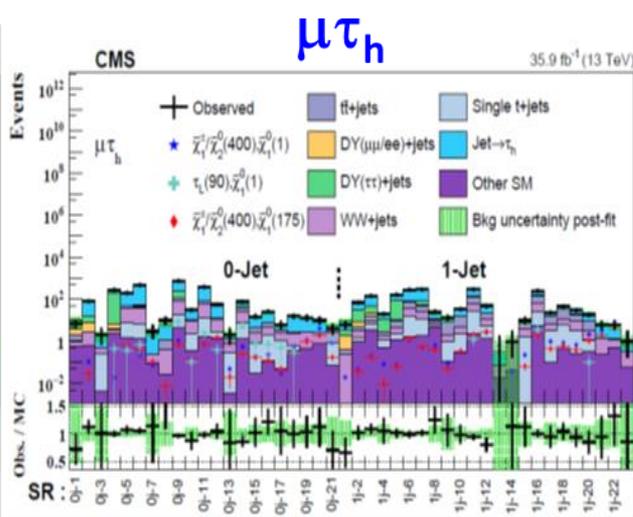
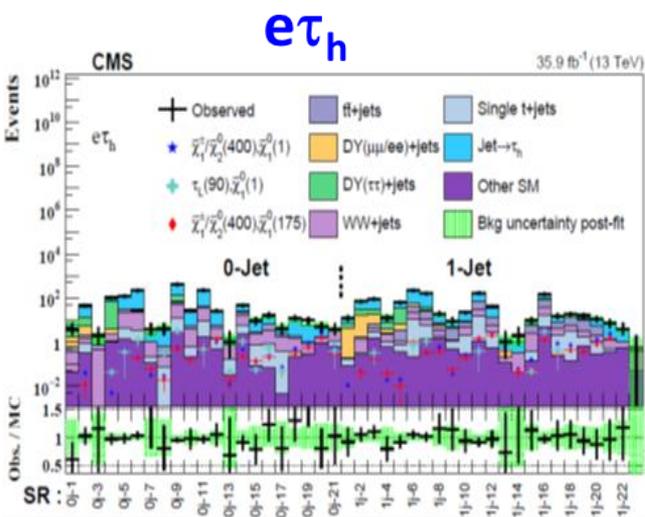
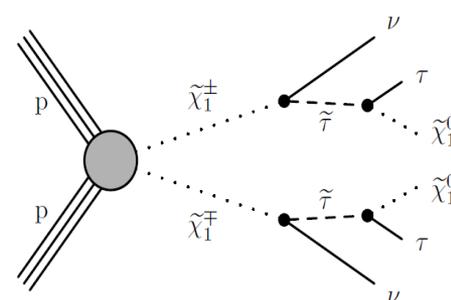
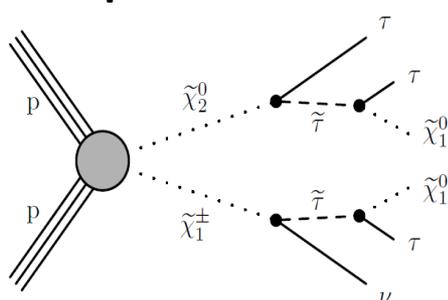
In **simplified model** of supersymmetry with a nearly massless gravitino

# Electroweak: Direct/indirect staus ( up to $2\tau$ )

Signal:  $2\tau$



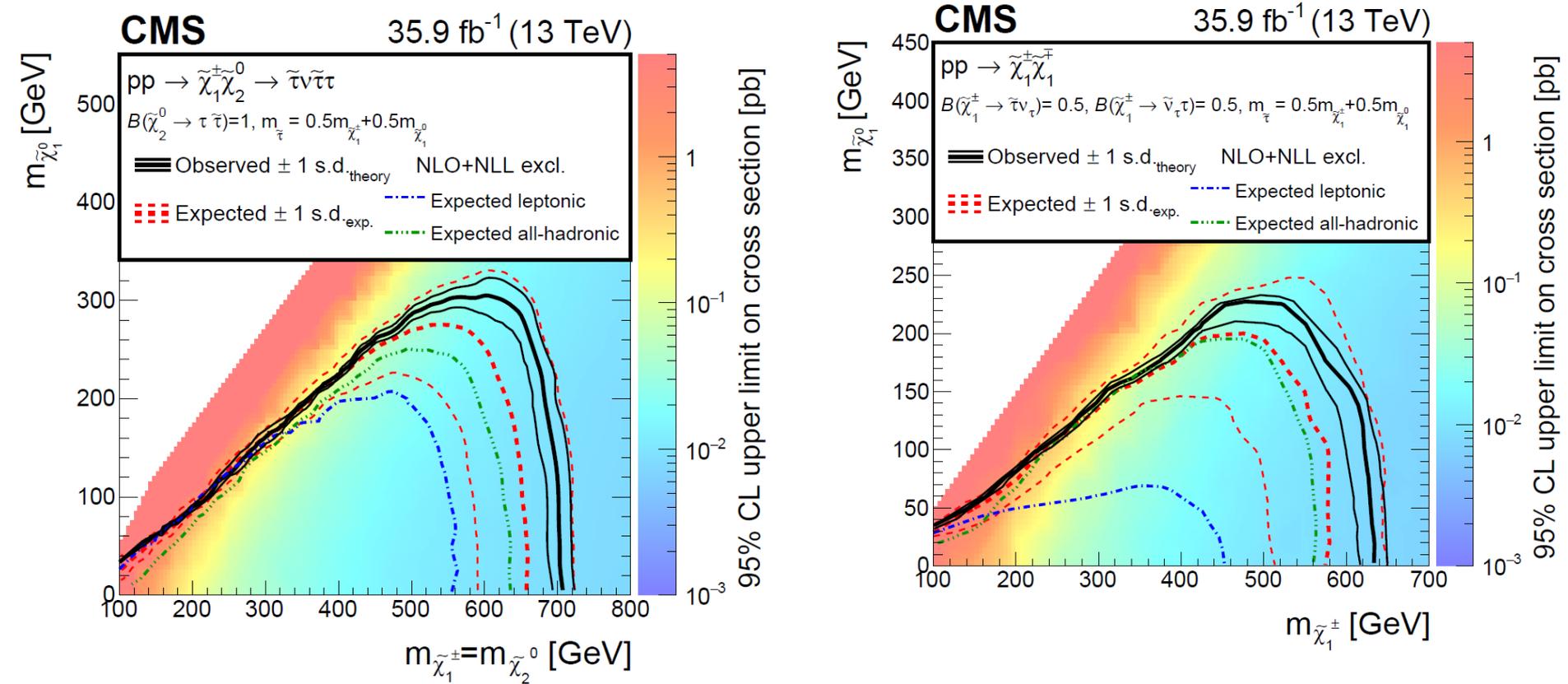
Simplified model



No significant events excess above SM level in all  
**Signal Regions** used for the final signal extraction

# Direct/indirect stau Result

arXiv:1807.02048 (to JHEP)

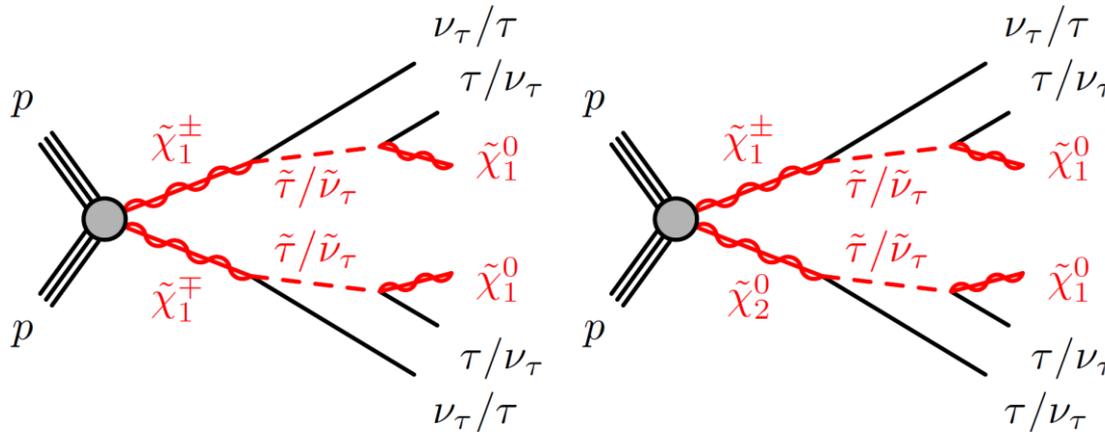


**Exclusion limits in the simplified model are set of indirect stau production to taus, range up to 710 and 630 GeV**

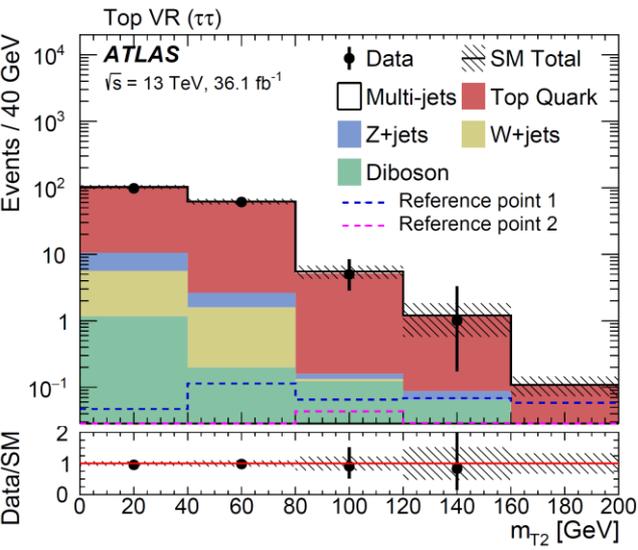
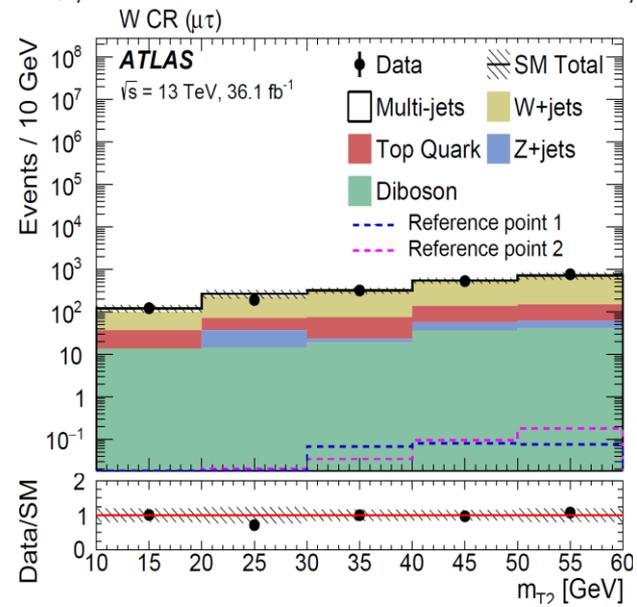
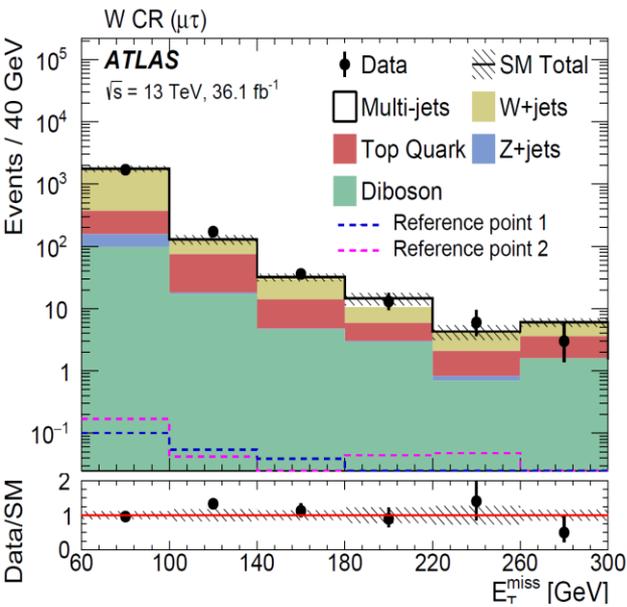
Direct staus gives a purely left-handed 90 GeV  $\tilde{\tau}$  decaying to a  $\sim 0$  GeV neutralino, correspond to 1.26 times expected production cross section in simplified model



# Indirect stau to taus



Signal:  $\geq 2\tau_h$

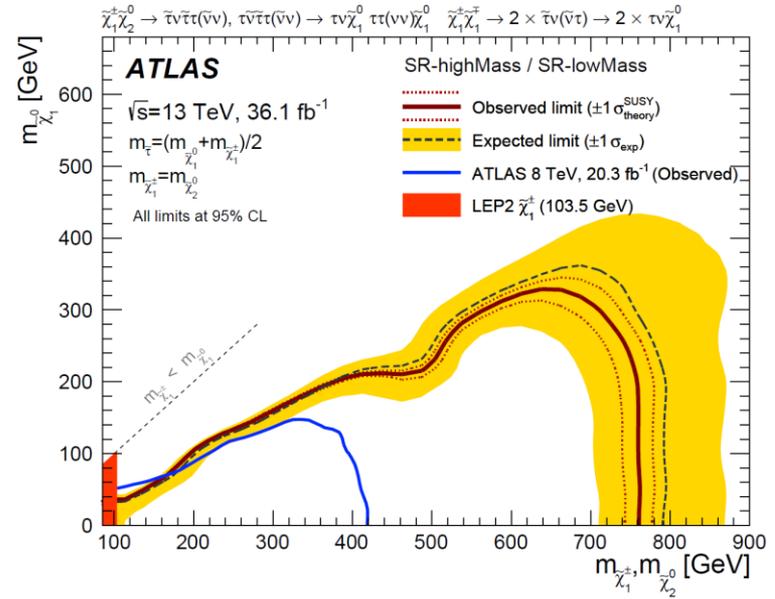
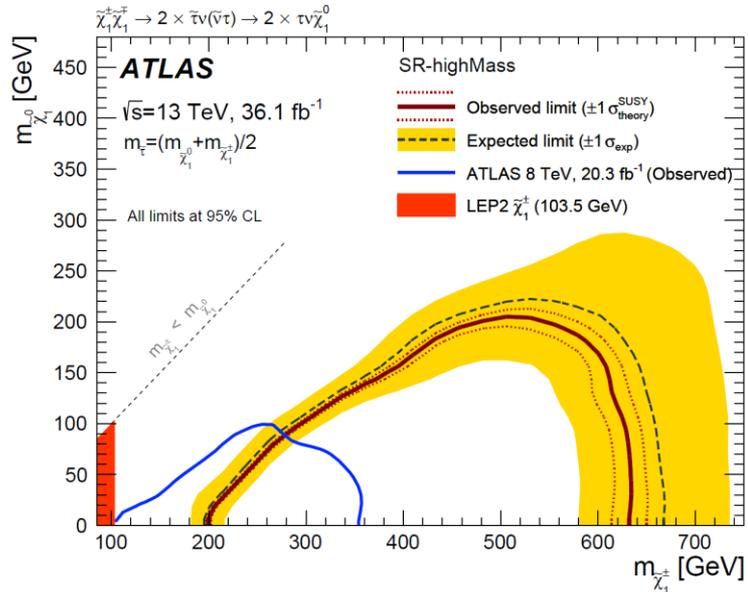
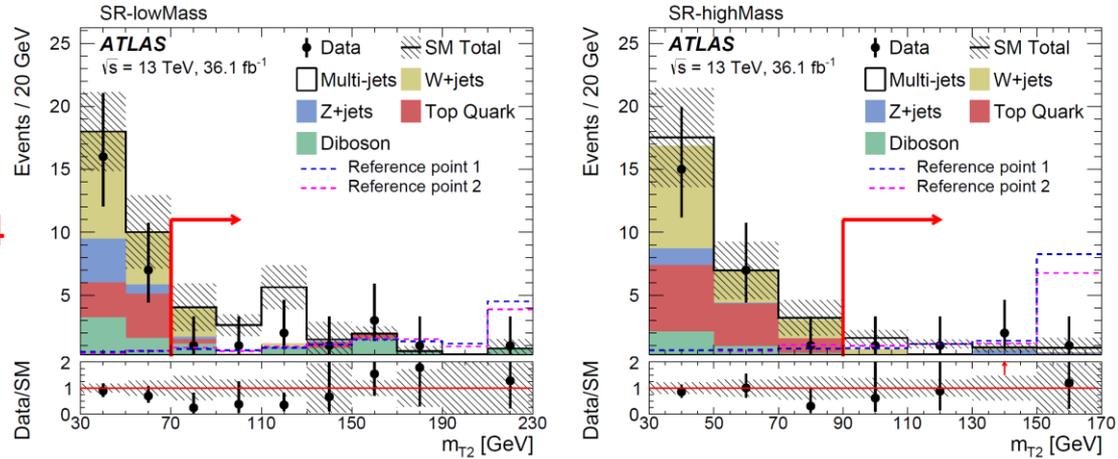


All Constral/Validation Regions DATA/MC Comparison are Consistent !



# Indirect stau to taus Result

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No significant deviation from SM is observed, 95% CL lower limit is set

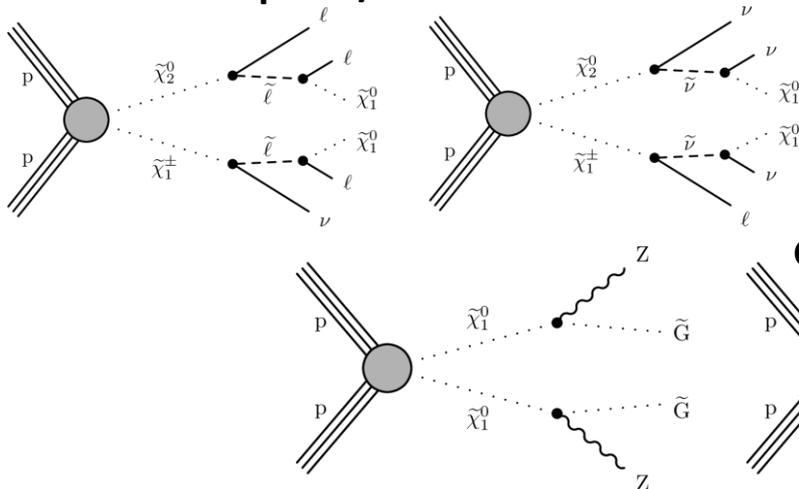
Chargino mass up to 630 GeV, direct production of  $\tilde{\chi}_1^+ \tilde{\chi}_1^-$  for a massless  $\tilde{\chi}_1^0$

Common  $\tilde{\chi}_1^\pm$  and  $\tilde{\chi}_2^0$  masses up to 760 GeV,  $\tilde{\chi}_1^+ \tilde{\chi}_2^0$  and  $\tilde{\chi}_1^+ \tilde{\chi}_1^-$  assuming a massless  $\tilde{\chi}_1^0$

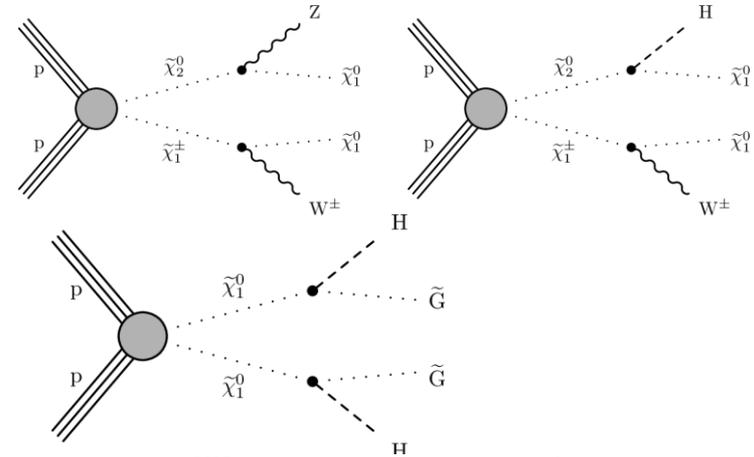


# Gauginos to 3/4 L ( up to $2\tau_h$ )

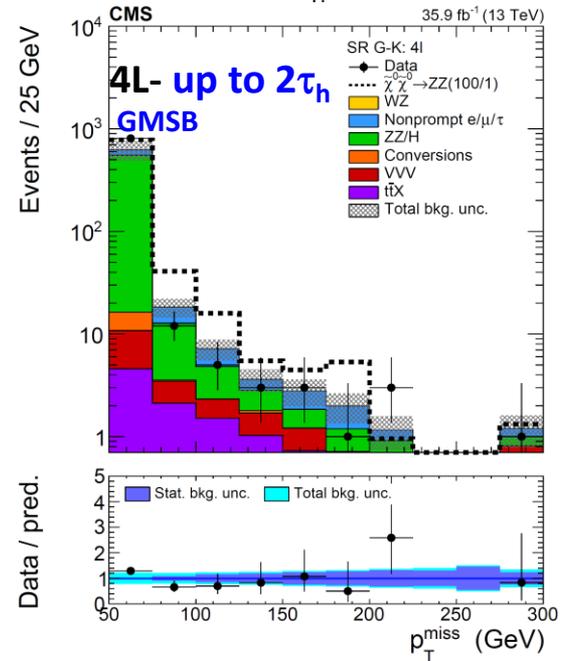
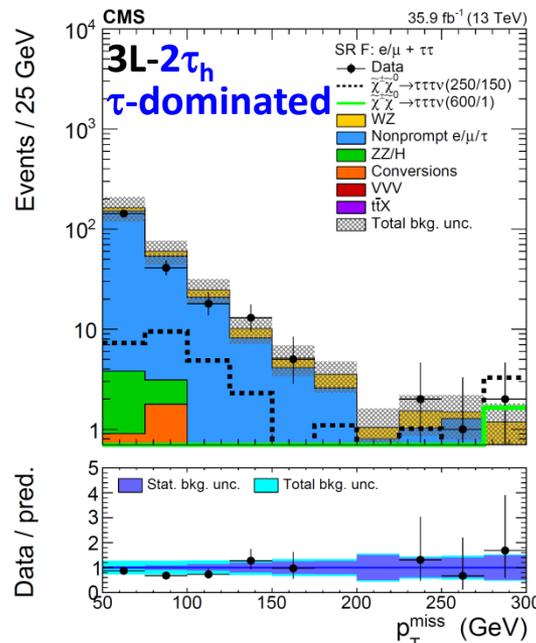
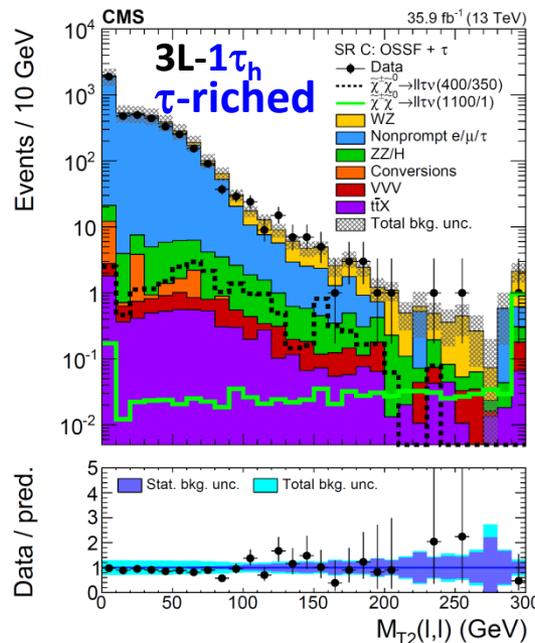
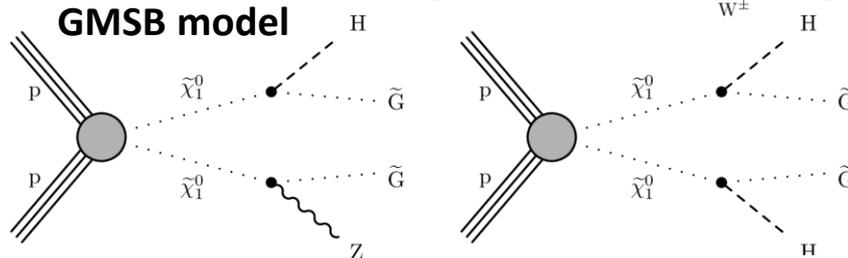
Via sleptons/sneutrinos



Direct decay to LSP



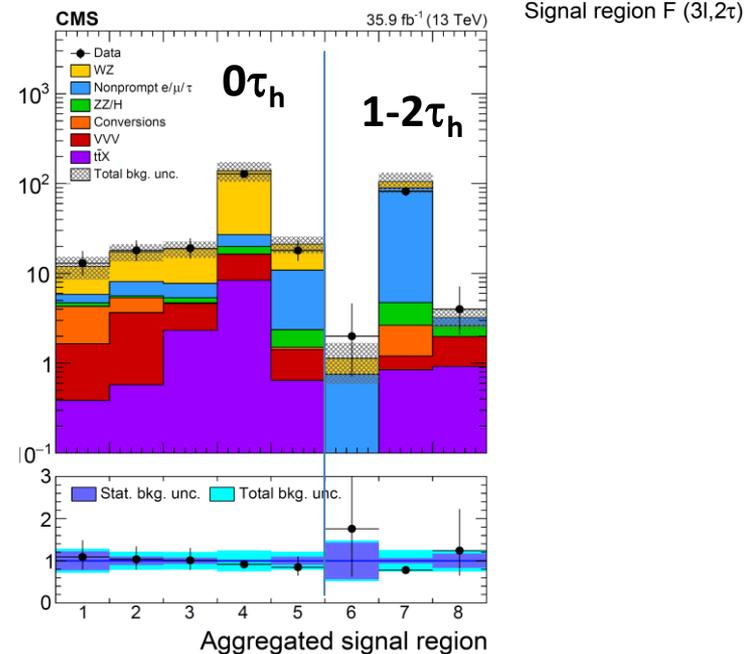
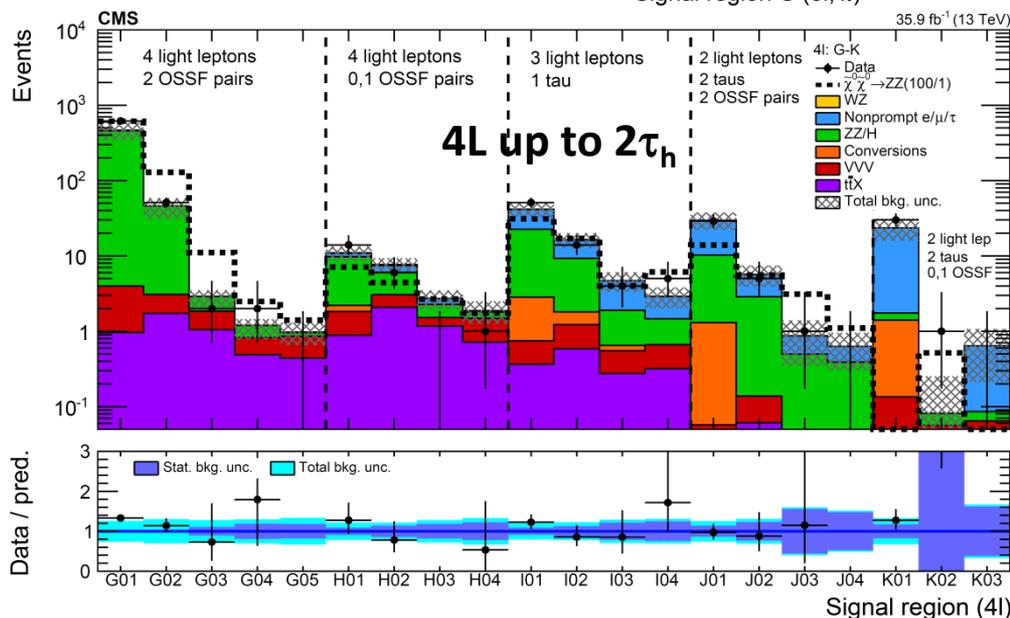
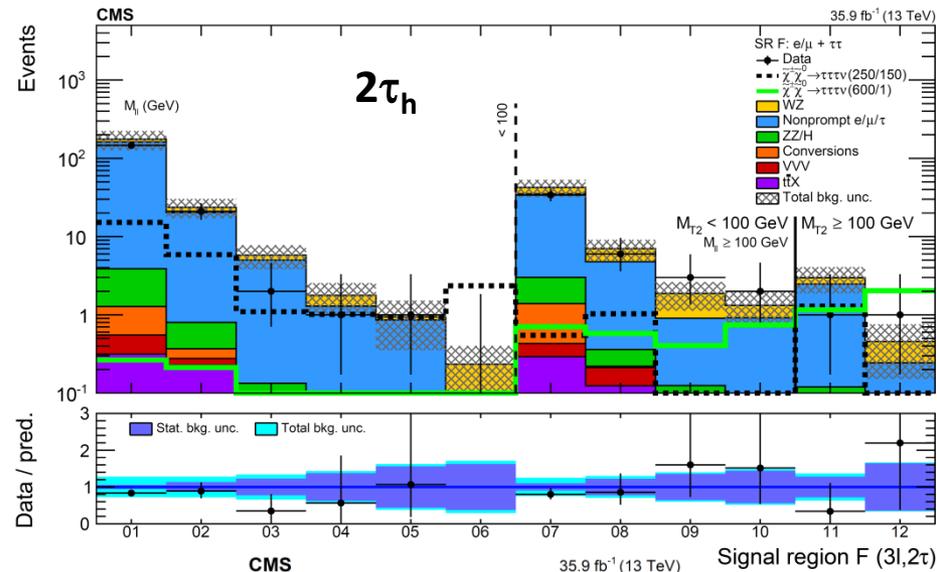
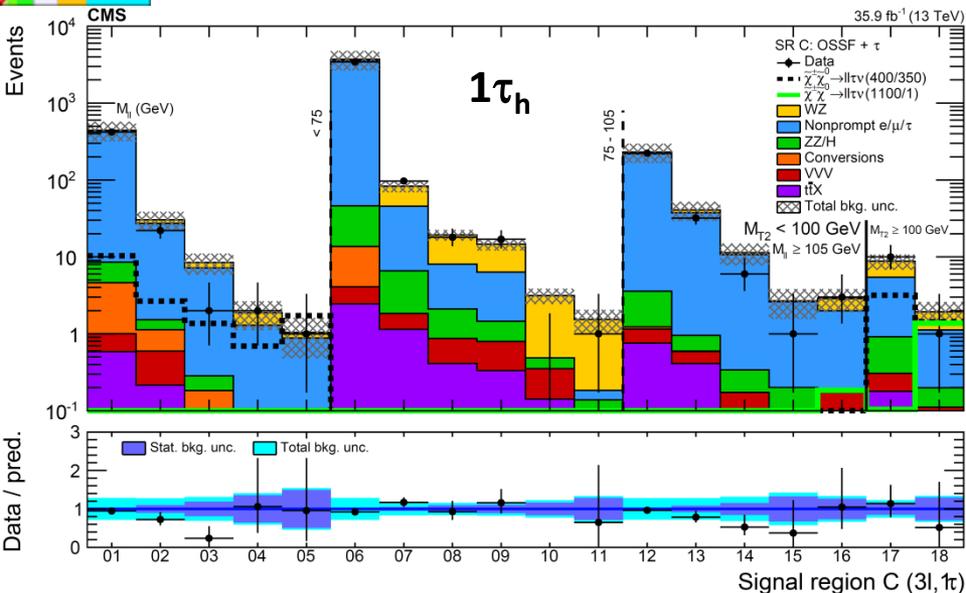
GMSB model



In all Signal Regions: no significant events excess observed above SM level



# Gauginos to 3/4 L, up to $2\tau_h$

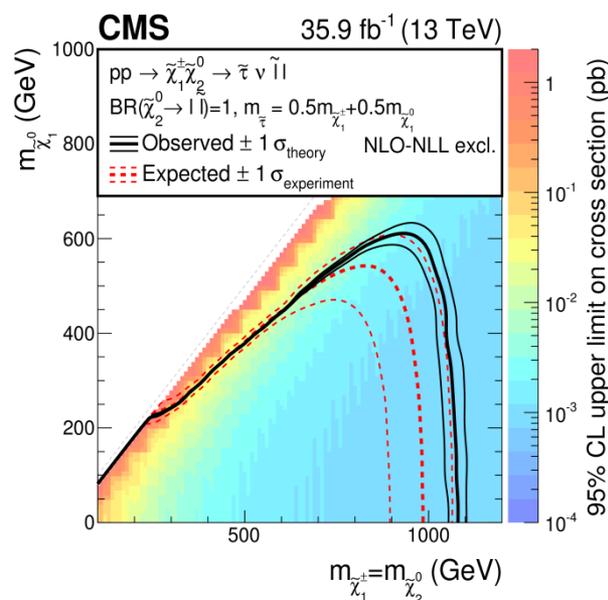


**In all Signal Regions: no significant events excess observed above SM level**

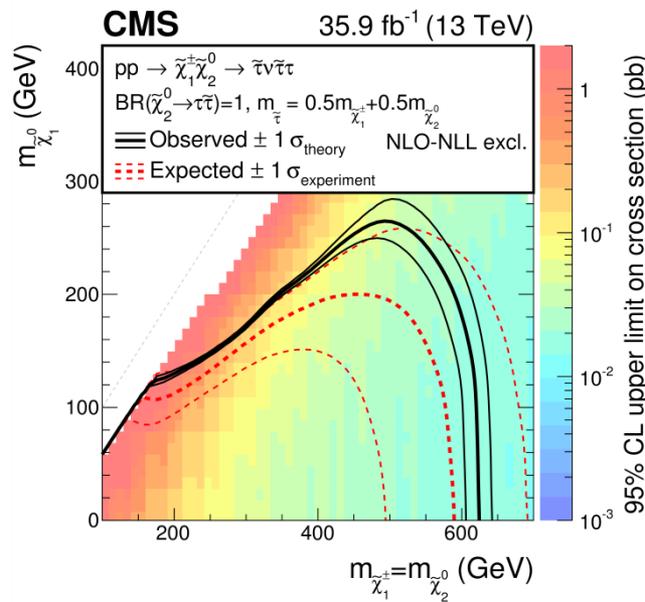


# Gauginos to 3/4 L, up to $2\tau_h$ Result

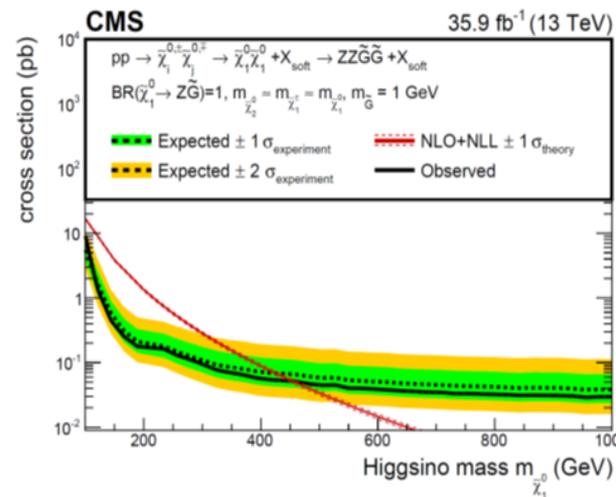
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**$\tau$ -enriched:**  
 exclude charginos and neutralinos up to 1050 GeV



**$\tau$ -dominated:**  
 exclude chargino and neutralino masses up to 625 GeV

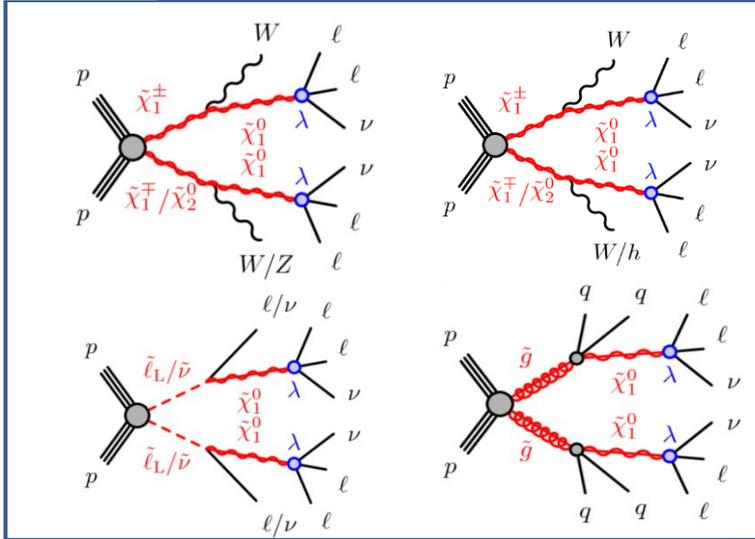


**GSMB model :**  
 exclude higgsino masses up to 450 GeV

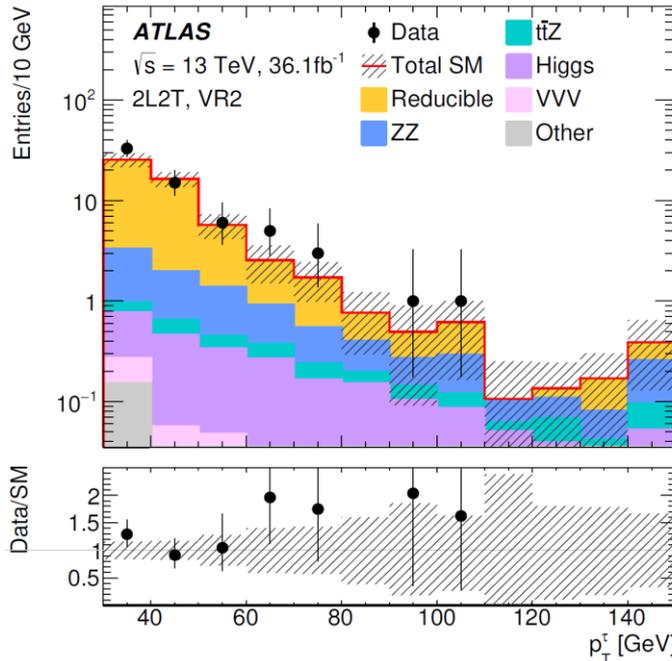
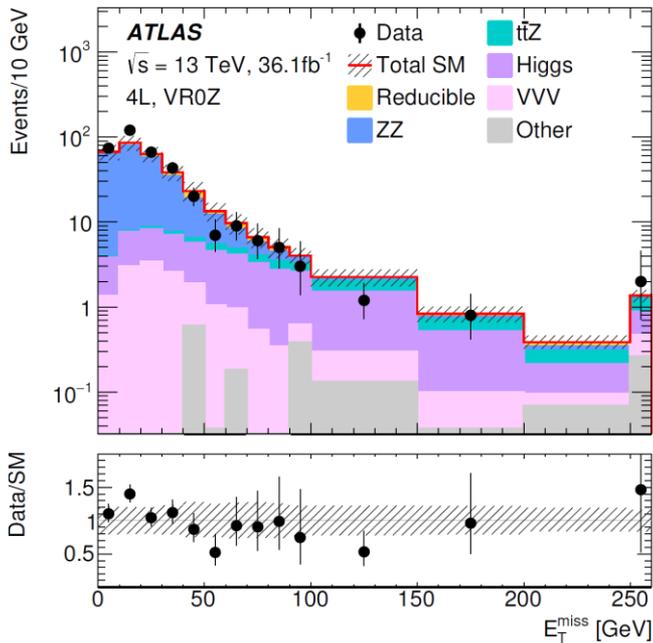
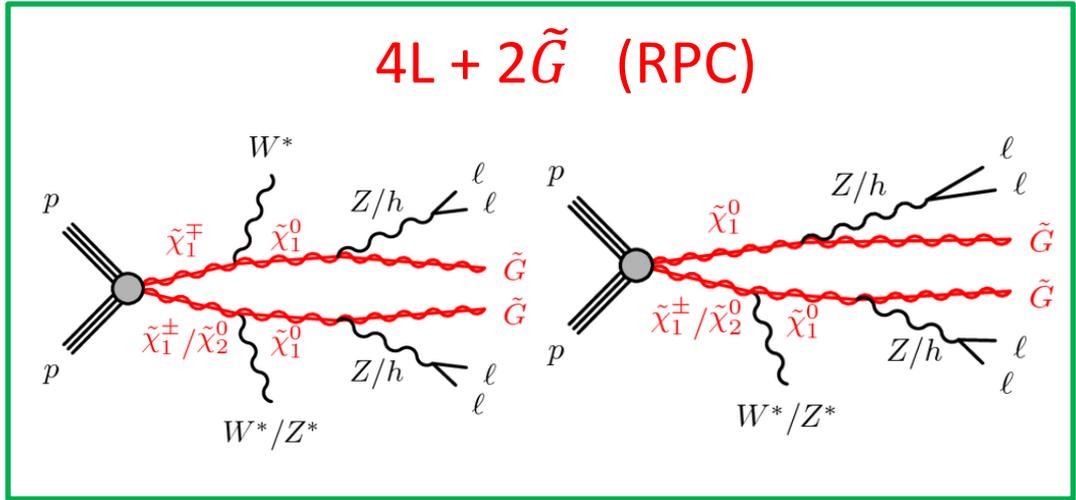


# Gauginos RPV & RPC 4L ( $\tau_h$ up to 2)

4L+ 2 $\nu$  (RPV)



4L + 2 $\tilde{G}$  (RPC)



All Validation Regions Data/MC Consistent !



# RPV & RPC 4L Result

PRD 98 (2018)032009

$\lambda_{12k} (k \in 1,2) \neq 0$ :  
LSP  $\rightarrow ee(1/4) + e\mu(1/2) + \mu\mu(1/4)$

$\lambda_{i33} (i \in 1,2) \neq 0$ :  
LSP  $\rightarrow e\tau (1/4) + \tau\tau(1/2) + \mu\tau(1/4)$

Masses exclusion:

wino up to 1.46 TeV,

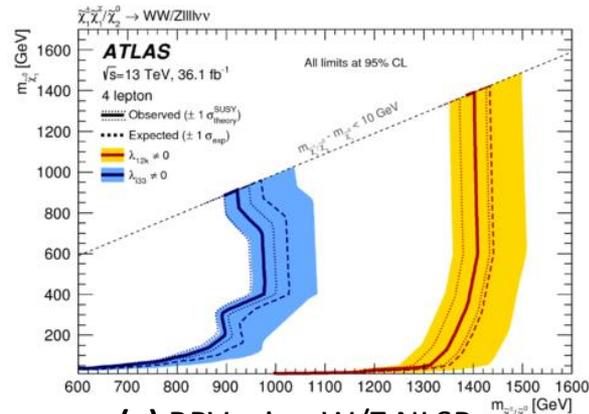
Slepton up to 1.06 TeV,

Gluino up to 2.25 TeV

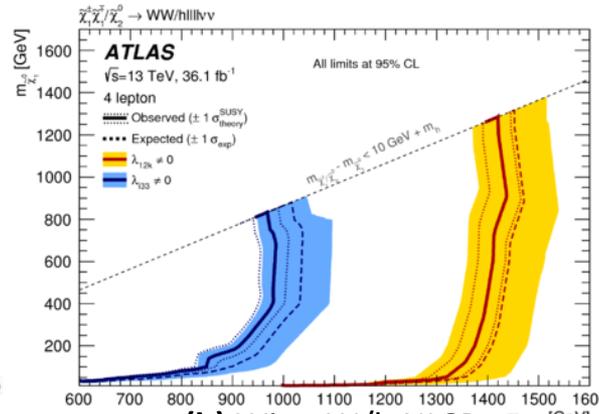
In RPV simplified models with LSP decays to charged leptons

Exclusion:  $m(\text{Higgsino})$  up to 295 GeV

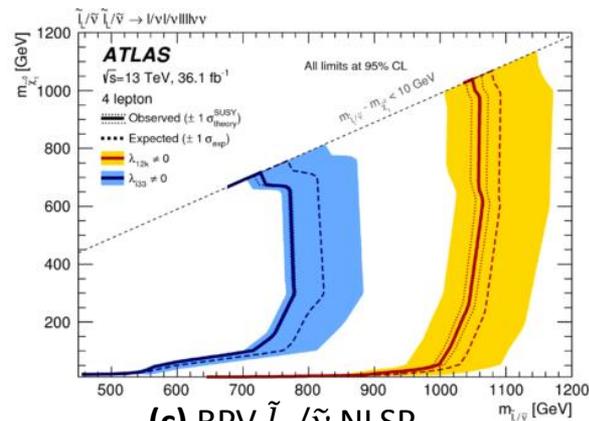
In RPC simplified models of **General Gauge Mediated supersymmetry**



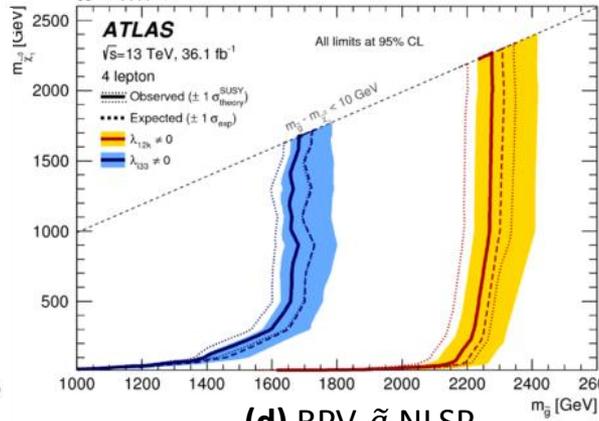
(a) RPV wino W/Z NLSP



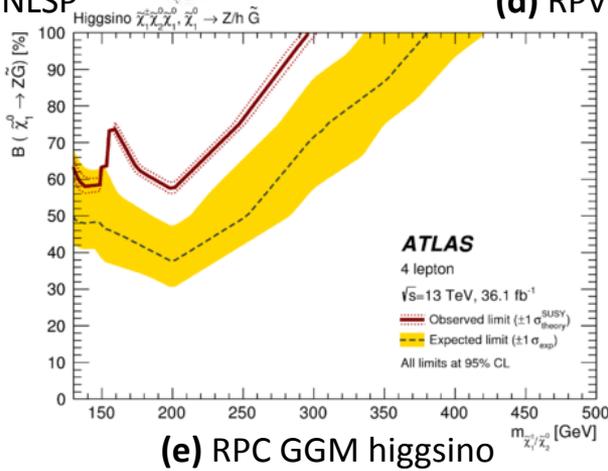
(b) Wino W/h NLSP



(c) RPV  $\tilde{L}_L/\tilde{\nu}$  NLSP



(d) RPV  $\tilde{g}$  NLSP



(e) RPC GGM higgsino



# Summary

- ❑ Six results from ATLAS and CMS with LHC 13TeV ~36 fb are included
- ❑ No significant deviation from SM is observed, 95% CL limits are set
- ❑ Model-independent upper limits on the SUSY-tau cross section are set
- ❑ SUSY masses exclusion limits are set for the various signal scenarios by two kinds of SUSY productions (strong & Electroweak), which remarkably extend the exclusion space of SUSY search

**All these results are just based upon 1.2% of LHC planned total luminosity. 140/300/3000 fb @13/14TeV LHC results will come later ! SUSY still energetic, and it still has a lot of space left for search! Keep efforts for SUSY discovery !**

**Thanks for your attention!**