SUSY EWK searches

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CoEPP Workshop

University of Adelaide

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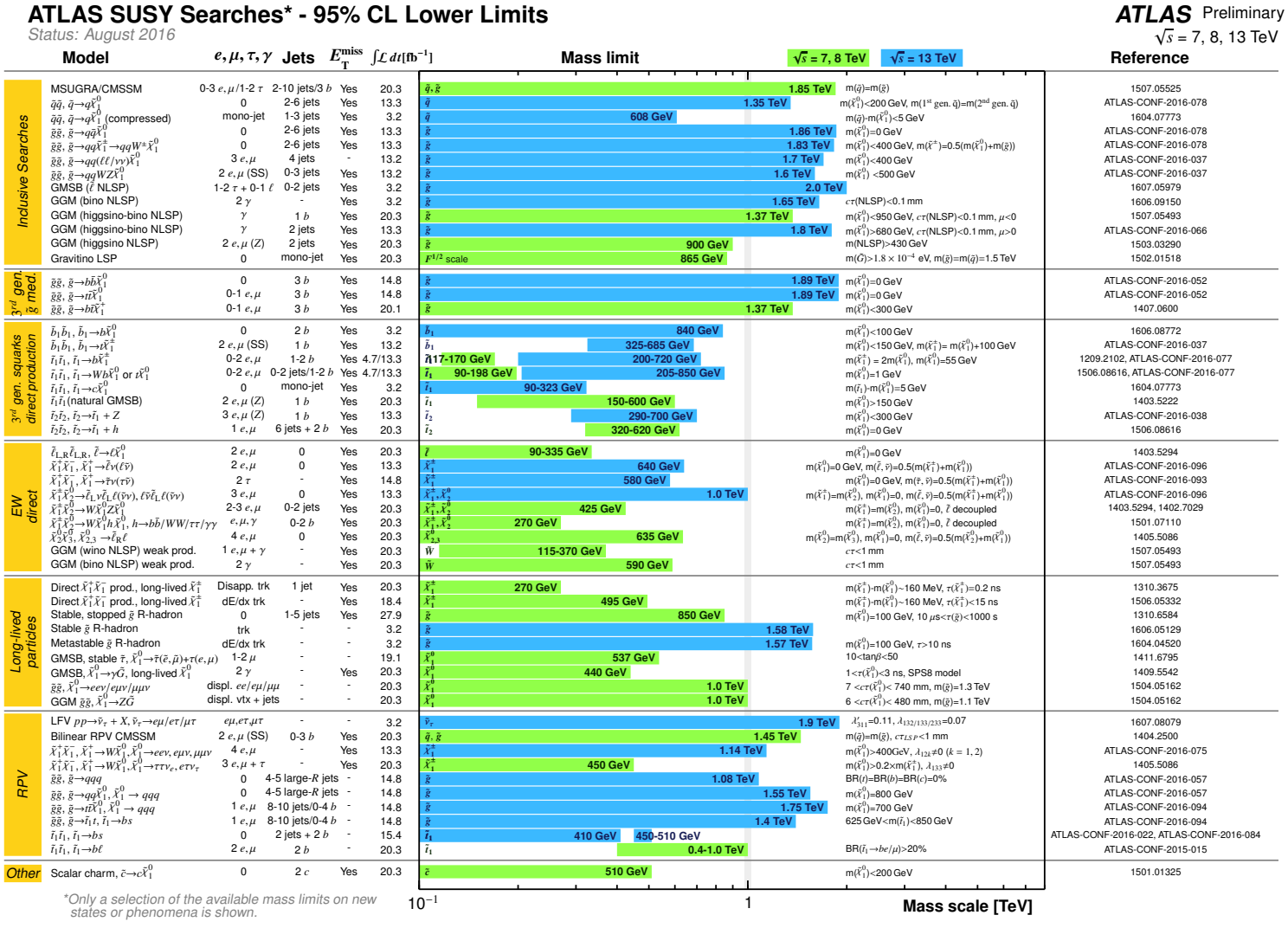
Did we find SUSY?

No

But, there are key regions still unexplored!

Where do we stand?

General picture from ATLAS



Su*persy**mmetric* **E***lectro**weak* *(SUSY EWK) sector:*

Physics motivation:
If gluinos/squarks are heavy ($\mathcal{O}$(TeV)) SUSY EWK production will be the dominant process at the LHC.

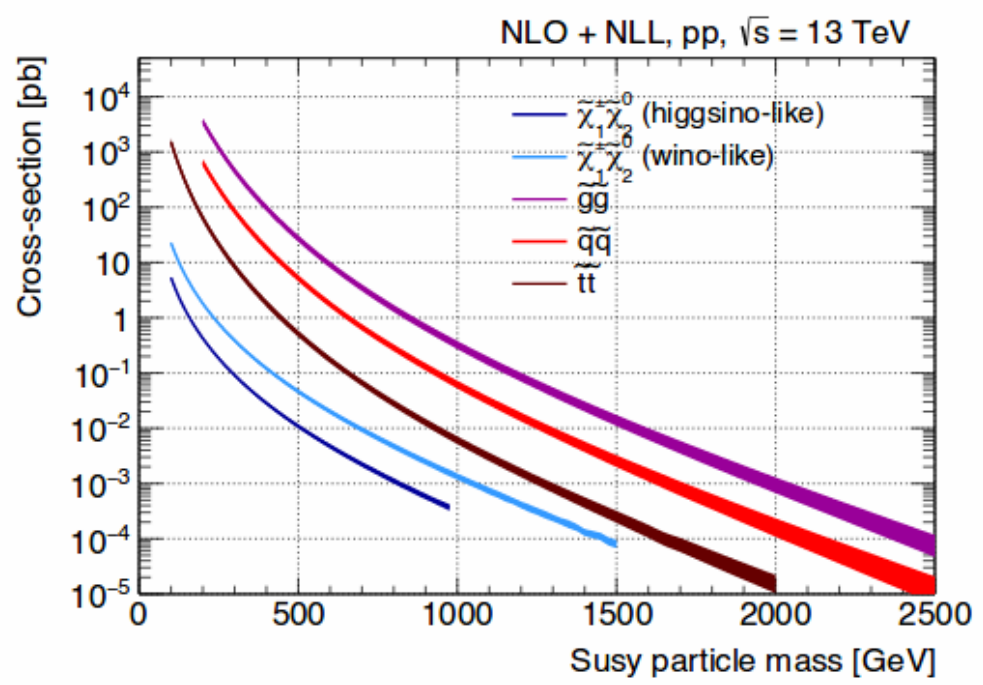
Signatures of direct EWK-ino production:
Multiple leptons, low hadronic activity and missing-energy.

Physics processes:

- $\tilde{\ell}\tilde{\ell}$
- $\tilde{\chi}_1^+\tilde{\chi}_1^-$
- $\tilde{\chi}_1^\pm\tilde{\chi}_2^0$

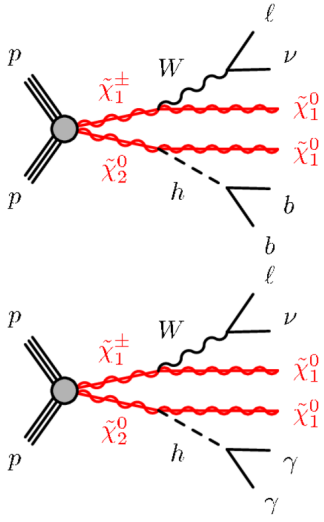
Searches based on simplified models:

- RPC models
  - Wino-Bino, Higgsino LSP
  - GGM (higgsino triplet, $\tilde{\chi}_1^0, \tilde{\chi}_2^0, \tilde{\chi}_1^\pm$)
- RPV (covered in 4ℓ) final states

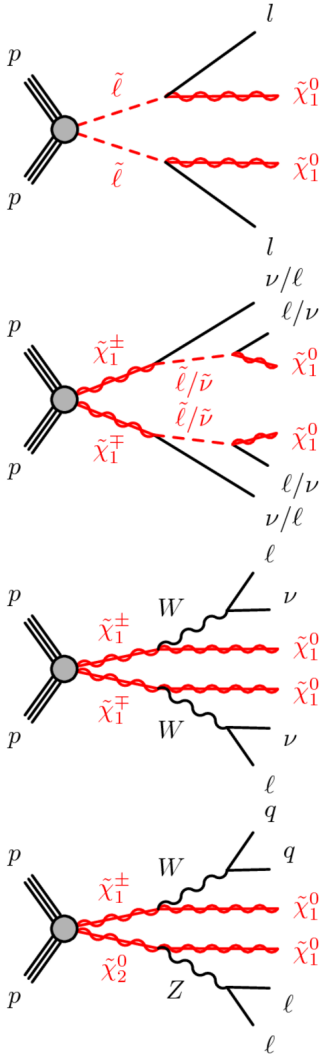


Slicing EWK SUSY searches in lepton multiplicities

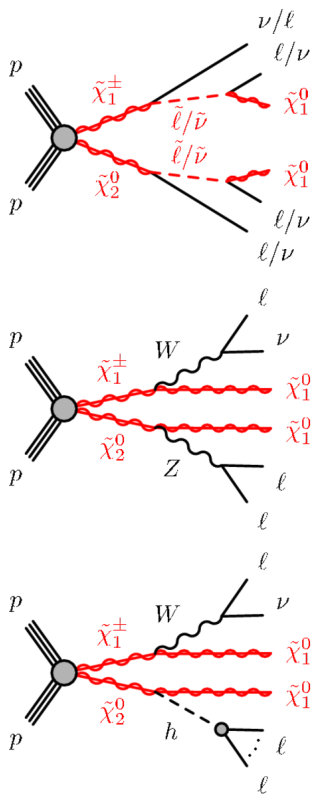
1-lepton



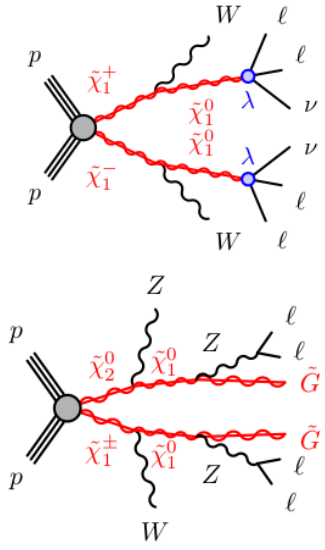
2-lepton



3-lepton



4-lepton

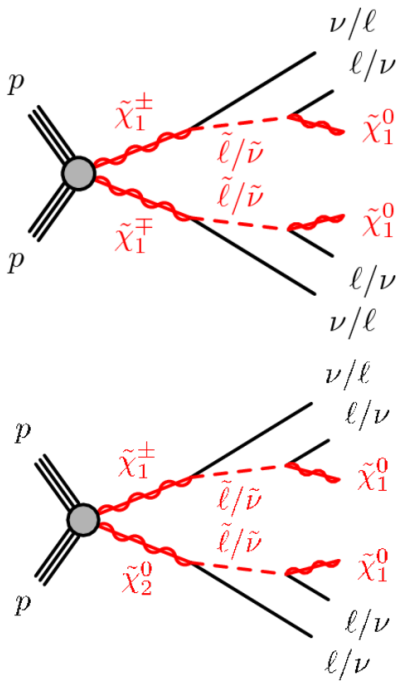


Simplified models based on R-Parity Conservation/Violation;

Results shown during the summer conferences

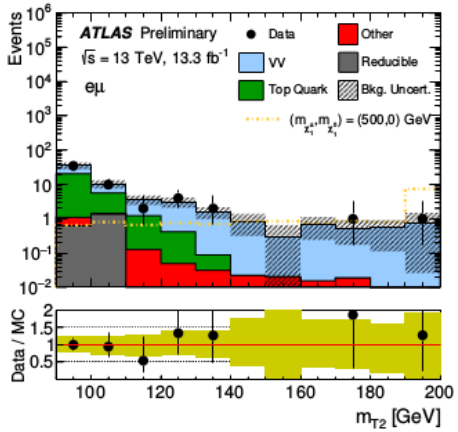
@ $\sqrt{s} = 13\,TeV$

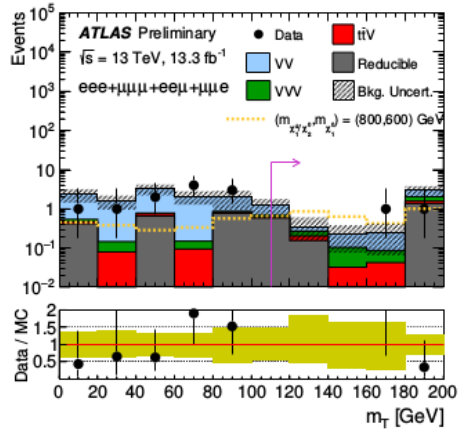
Physics Procecesses with $\tilde{\ell}$ - *ATLAS-CONF-2016-096*



Variable	SR2ℓ	
lepton	$\ell^+\ell^-$	
lepton flavour	SF	DF
central light jets	0_{20}	0_{30}
central b-jets	0_{20}	0_{20}
forward jets	0_{30}	0_{30}
$\lvert m_{\ell\ell} - m_Z \rvert$ [GeV]	> 10	–
m_{T2} [GeV]	$> 90,\ 120,\ 150$	

Variable	SR3ℓ-I	SR3ℓ-H
lepton	$\ell^+\ell^-\ell$	
b-tagged jet	veto	
$m_T >$	110	
m_{SFOS}	$\notin [81.2, 101.2]$	>101.2
$p_T^{3rd\ell} >$	30	80
$E_T^{miss} >$	120	60





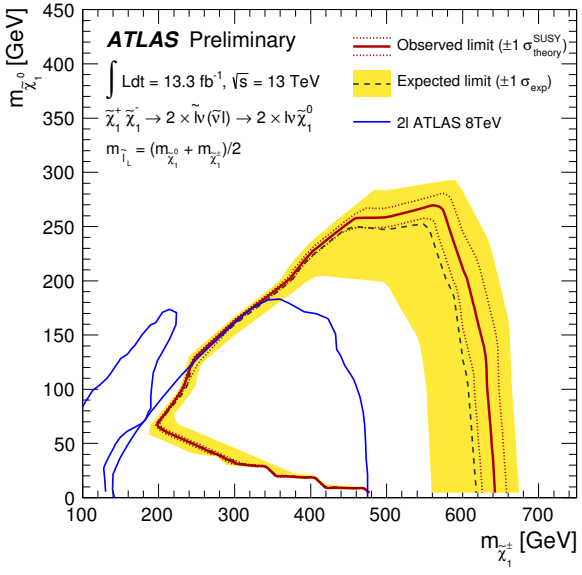
- 2ℓ searches based on the stransverse mass, m_{T2}

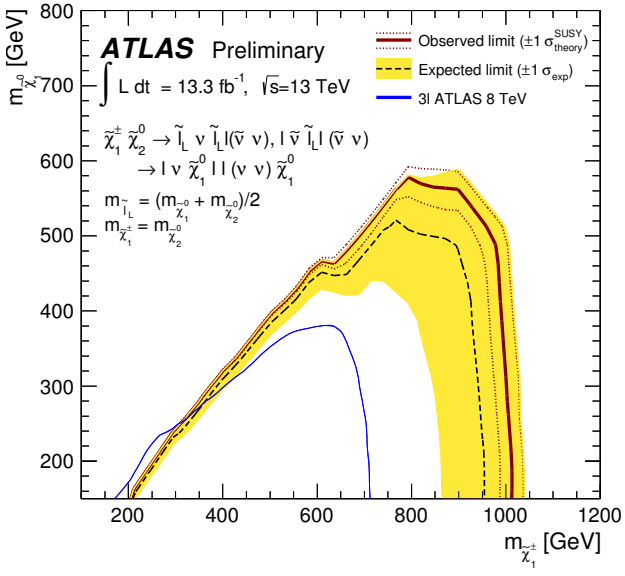
$$m_{T2} = \min_{\mathbf{q}_T} \left[\max \left(m_T(\mathbf{p}_T^{\ell 1}, \mathbf{q}_T), m_T(\mathbf{p}_T^{\ell 2}, \mathbf{p}_T^{miss} - \mathbf{q}_T) \right) \right]$$

- 3ℓ searches based on E_T^{miss} and m_T

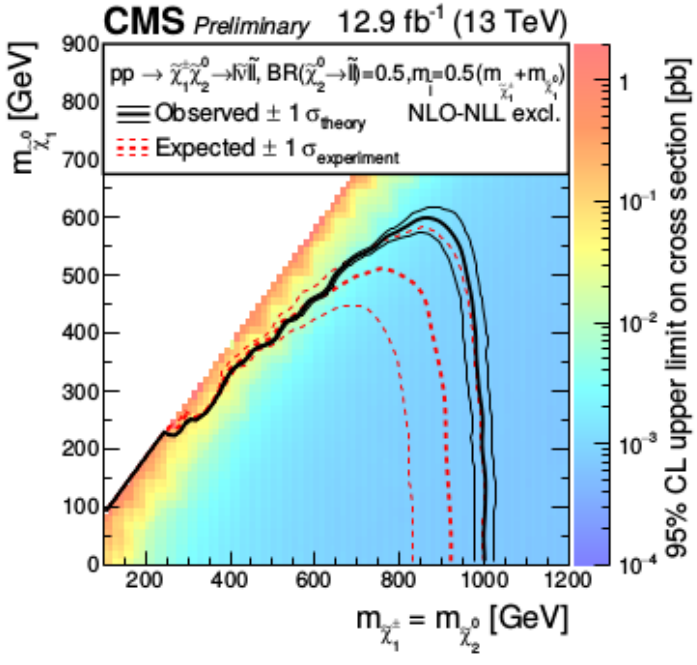
$$m_T(\vec{p}_T^{\ell/\tau}, E_T^{miss}) = \sqrt{2 p_T^{\ell/\tau} E_T^{miss} - 2 \vec{p}_T^{\ell/\tau} \cdot E_T^{miss}}$$

Statistical Interpretation

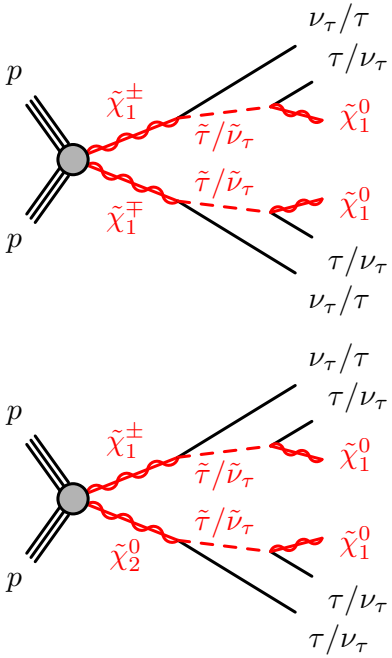




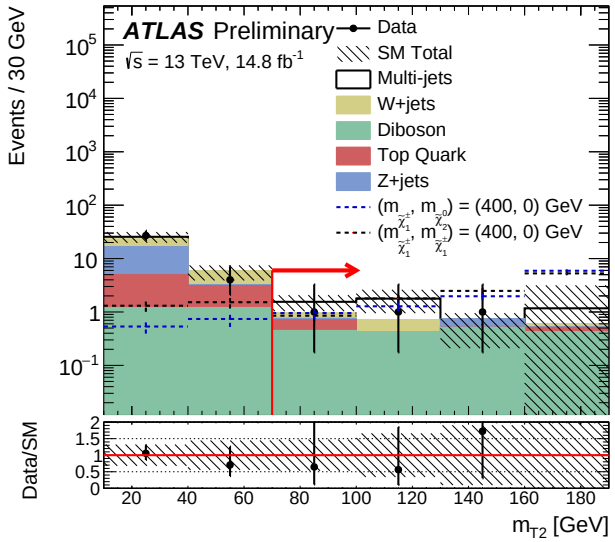
- $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$: Both experiments exclude $m_{\tilde{\chi}_1^{\pm}/\tilde{\chi}_2^0}$ up to 1 TeV for massless LSP;
- $\tilde{\chi}_1^{+}\tilde{\chi}_1^{-}$: Exclude $m_{\tilde{\chi}_1^{\pm}}$ up to 650 GeV for massless LSP;
- *ATLAS-CONF-2016-096*
- CMS-PAS-SUS-16-024

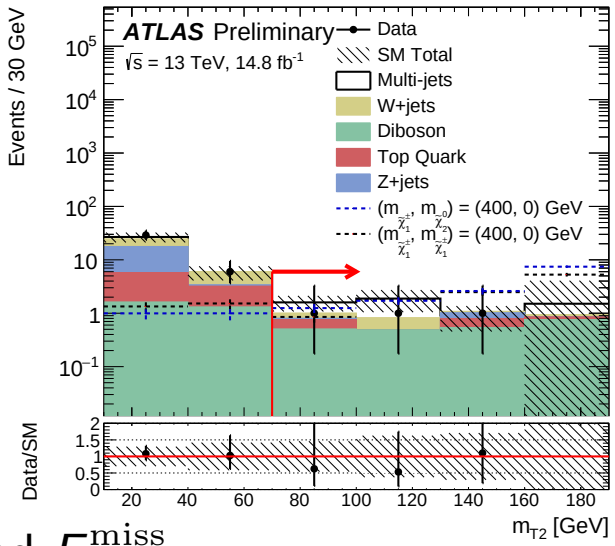


Physics processes w/ $\tilde{\tau}$ - ATLAS-CONF-2016-093



SR-C1C1	SR-C1N2
light lepton veto	-
at least two medium taus	
at least one opposite sign tau pair	
b-jet veto	
Z-veto	
$E_{\mathrm{T}}^{\mathrm{miss}} > 150$ GeV	
$m_{\mathrm{T2}} > 70$ GeV	

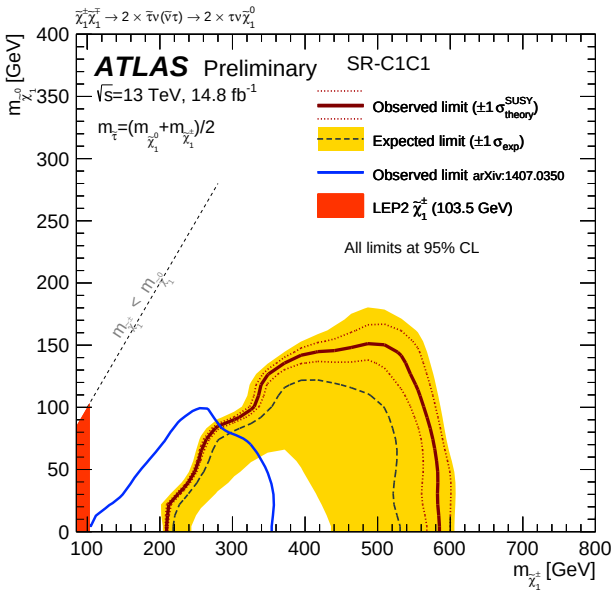


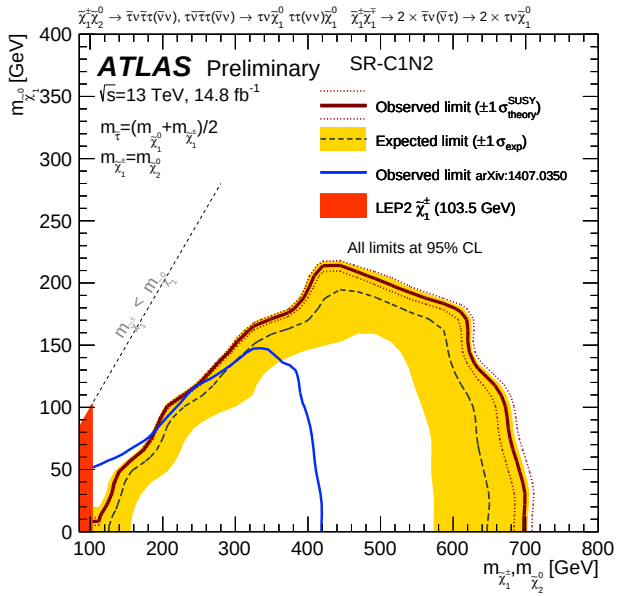


- 2τ searches based on the stransverse mass, m_{T2} and $E_{\mathrm{T}}^{\mathrm{miss}}$

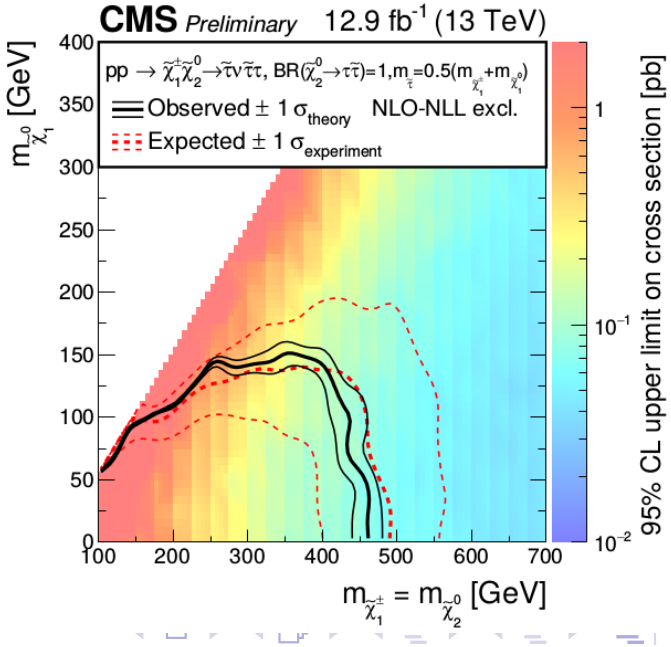
$$m_{\mathrm{T2}} = \min_{\mathbf{q}_\mathrm{T}} \left[\max \left(m_\mathrm{T}(\mathbf{p}_\mathrm{T}^{\ell 1}, \mathbf{q}_\mathrm{T}), m_\mathrm{T}(\mathbf{p}_\mathrm{T}^{\ell 2}, \mathbf{p}_\mathrm{T}^{\mathrm{miss}} - \mathbf{q}_\mathrm{T}) \right) \right]$$

Statistical Interpretation

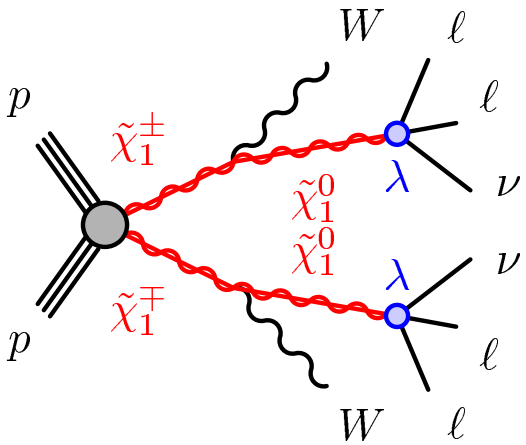




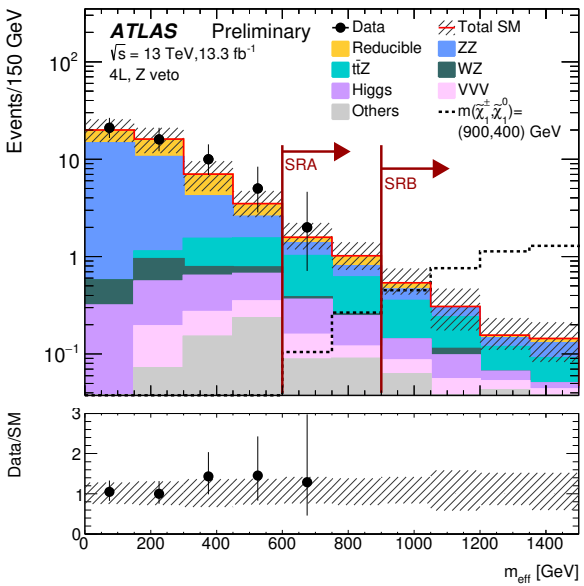
- $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$: Slightly better sensitivity in ATLAS results;
- $\tilde{\chi}_1^{+}\tilde{\chi}_1^{-}$: Exclude $m_{\tilde{\chi}_1^{\pm}}$ up to 600 GeV for massless LSP;
- ATLAS-CONF-2016-093
- CMS-PAS-SUS-16-024

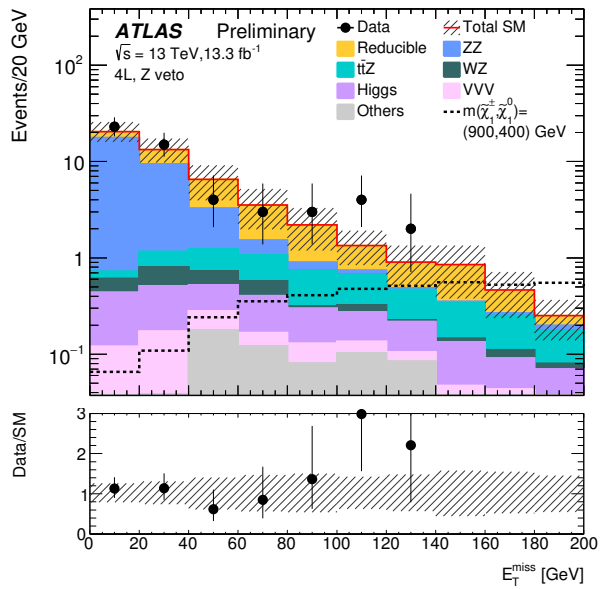


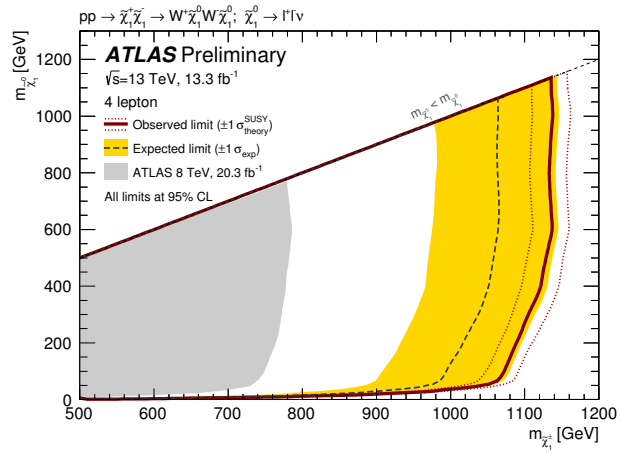
RPV SUSY EWK - ATLAS-CONF-2016-075



Sample	$N(e,\mu)$ signal	$N(e,\mu)$ loose	Z boson	m_{eff} [GeV]
SRA	>= 4	>= 0	veto	> 600
CR-SRA	= 2	>= 2	veto	> 600
SRB	>= 4	>= 0	veto	> 900
CR-SRB	= 2	>= 2	veto	> 900
VR	>= 4	>= 0	veto	< 600
CR-VR	= 2	>= 2	veto	< 600







- Wino-Bino scenario, where the LSP undergoes RPV decay;
- limit set at 1.14 TeV for $LL\bar{E}12k$ models

Upcoming publications

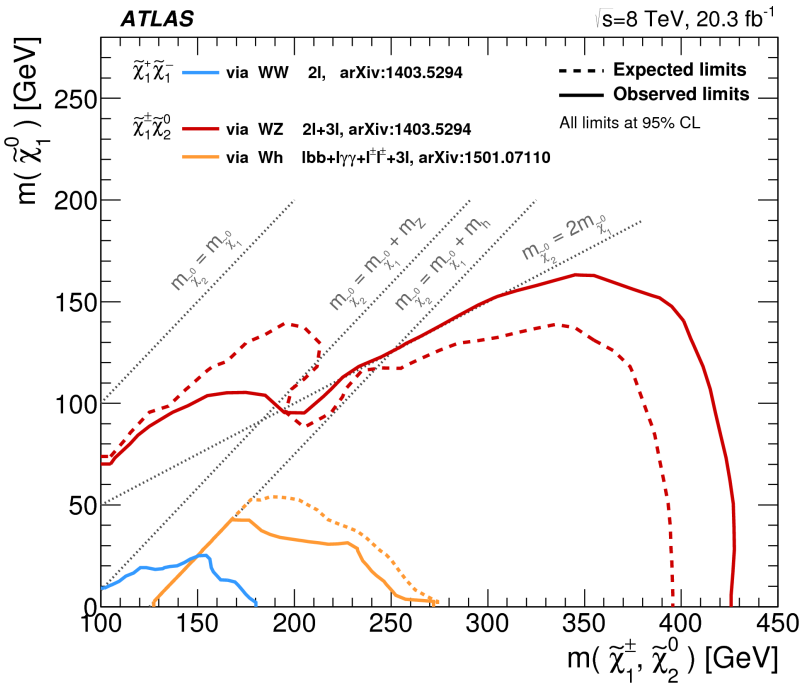
This year's holiday present: Supersymmetry with Dark Matter is still natural

Fine-tuning arguments point to models with a dark matter candidate yielding the correct dark matter relic density: a bino-higgsino particle with a mass of 35-155 GeV...

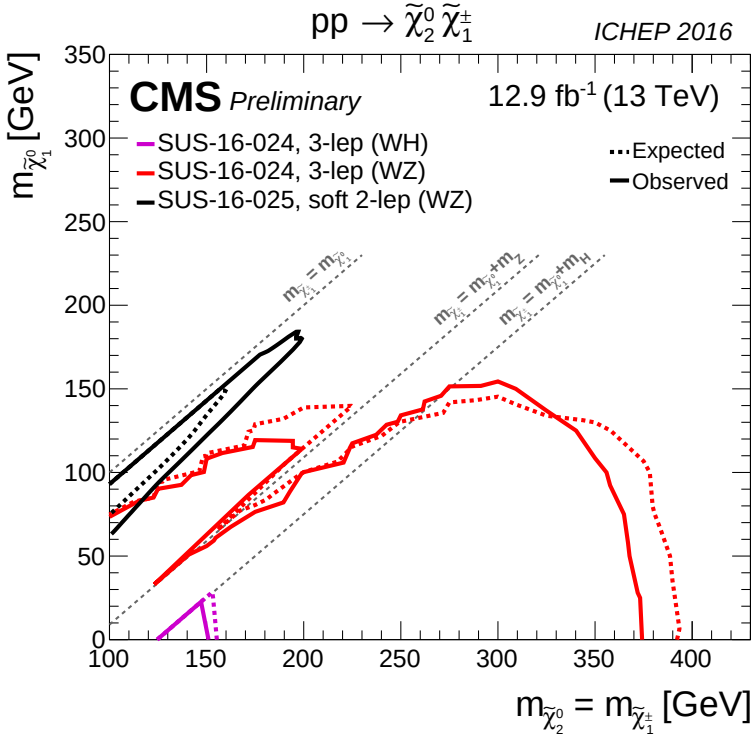
arXiv:1612.06333 [hep-ph]
M. Beekveld, W. Beenakker, S. Caron, R. Peeters, R. R. de Austri

Where we are with $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ w/ *WZ*

ATLAS



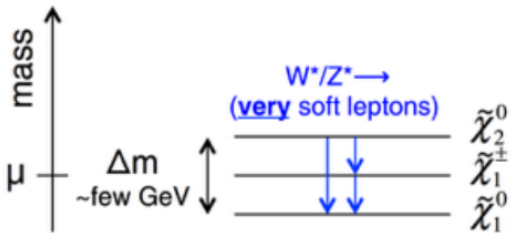
CMS



- Challenging process due to the low cross-section ($\sigma \times BR$)
- Dedicated searches from both ATLAS and CMS (exploring all high/intermediate/compressed mass regions)
- ATLAS high priority physics process (Check Damir Duvnjak's poster for more details!);
- $\tilde{\chi}_1^{+}\tilde{\chi}_1^{-} \rightarrow WW$ will also be considered;

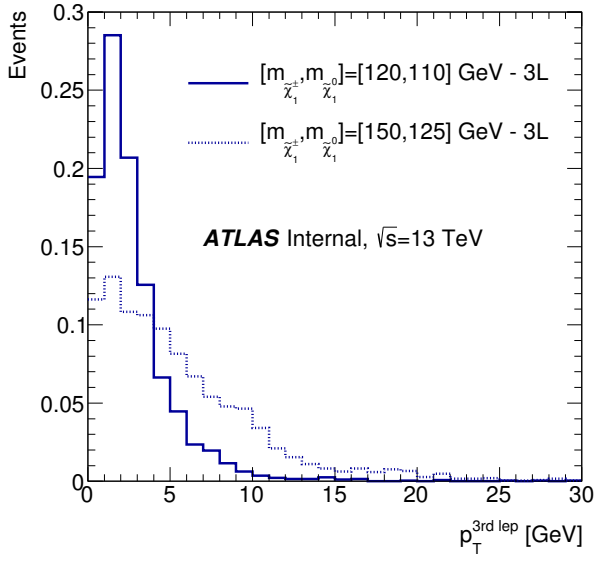
Compressed EWK SUSY searches

ATLAS: Higgsino LSP

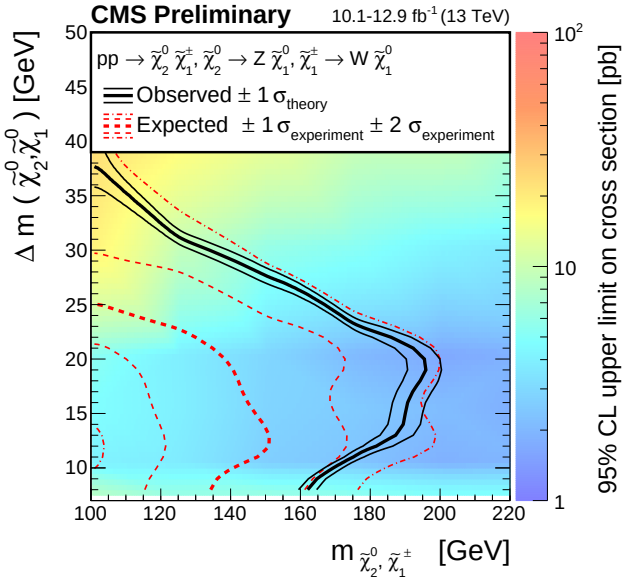


Produced leptons can be very soft!

Generator level studies

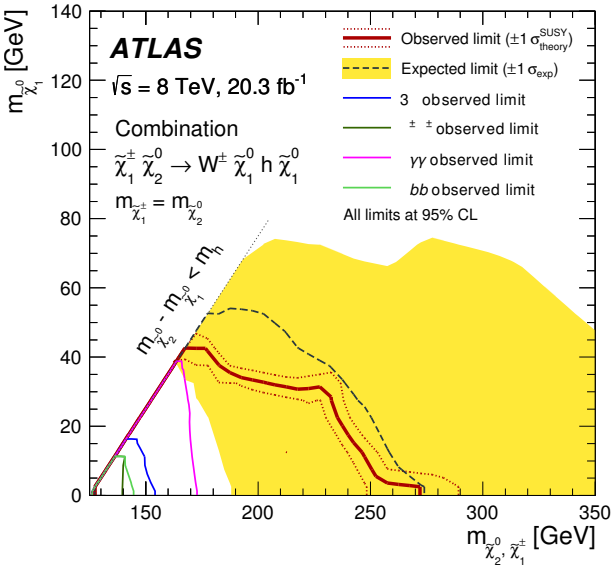


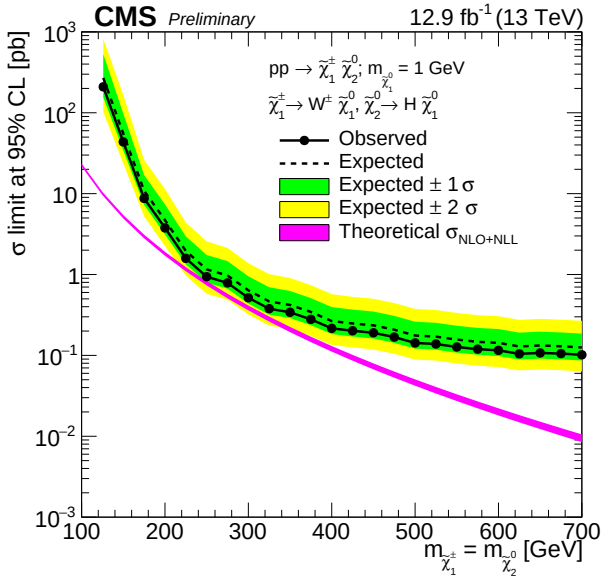
CMS results based on a Wino scenario



- *For the first time in ATLAS we measured electron efficiencies down to 4.5 GeV* (Check Abhishek Sharma poster!)
- ATLAS: Working on improving electron reconstruction and identification;
- Improved trigger strategy;
- ATLAS: Provide results on both Higgsino LSP and Bino LSP scenarios
- CMS: CMS-PAS-SUS-16-025 (Sensitive up to mass-splits of 7.5 GeV for $m_{\tilde{\chi}_1^\pm/\tilde{\chi}_2^0} = 160$ GeV)

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





CMS SR

Cut	Signal Region
N(leptons)	$= 1$
Isolated track veto	✓
Tau candidate veto	✓
N(b-tags)	$= 2$
$M_{b\bar{b}}$	$\in [90,150]$ GeV
E_T^{miss}	> 100 GeV
M_T	> 150 GeV
M_{CT}	> 150 GeV

- CMS: Results based on $1\ell + b\bar{b} + E_T^{miss}$ final state; Use of contransvarse mass:

$$M_{CT}^2 = 2p_T^{b1}\, p_T^{b2}(1 + \cos\Delta\phi_{bb})$$

- CMS-PAS-SUS-16-026
- ATLAS: Provide results in the near future; Similar strategy by looking in many final states

Summary

- Rich SUSY EWK program from both ATLAS and CMS experiments;
  - Last year's resuts, based on a subset of the total integrated luminosity excluded $m_{\tilde{\chi}_1^\pm/\tilde{\chi}_2^0}$ up to 1 TeV for massless LSP;
  - Similar sensitivities from both experiments, binned SRs or dedicated inclusive SRs;
- More dedicated searches are currently in ATLAS plans and hope to release them soon!
- Stay tuned and you never know what the data might be hiding!

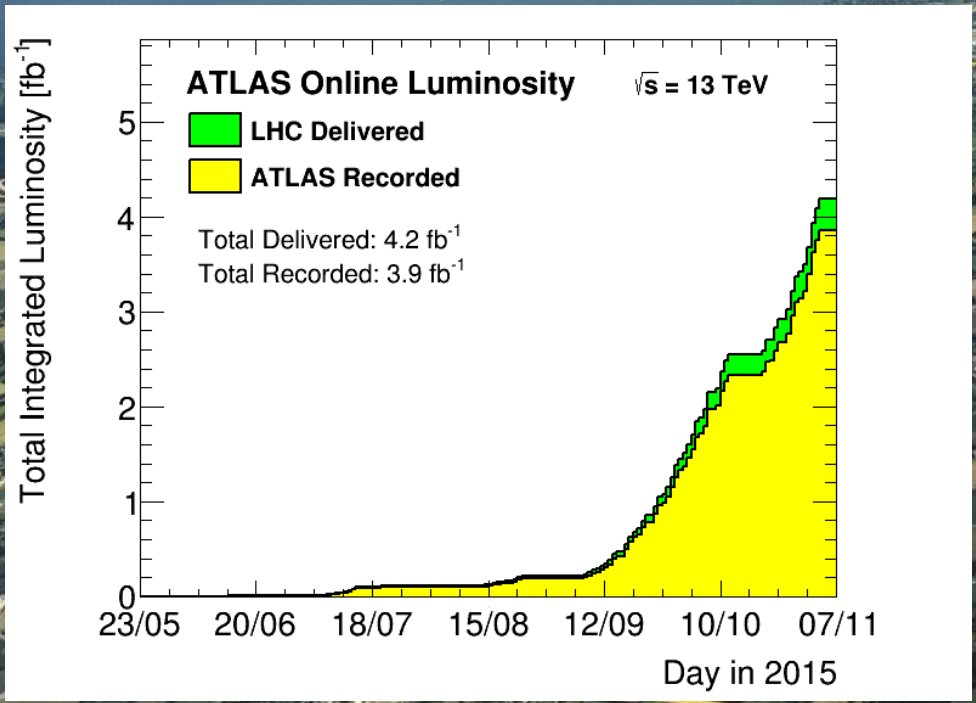
Thank you

Back-up

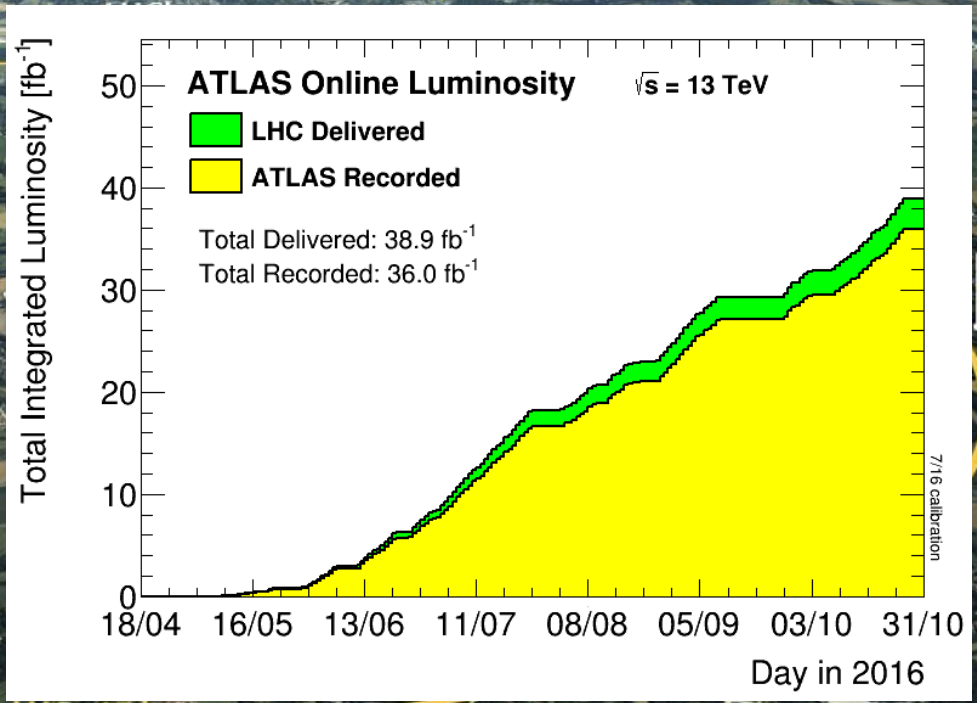
Integrated Luminosity

$$\underbrace{N}_{\#\ \text{of events}} = \underbrace{\sigma}_{\text{cross section of the process (fb)}} \cdot \underbrace{\int L dt}_{\text{integrated luminosity } (fb^{-1})}$$

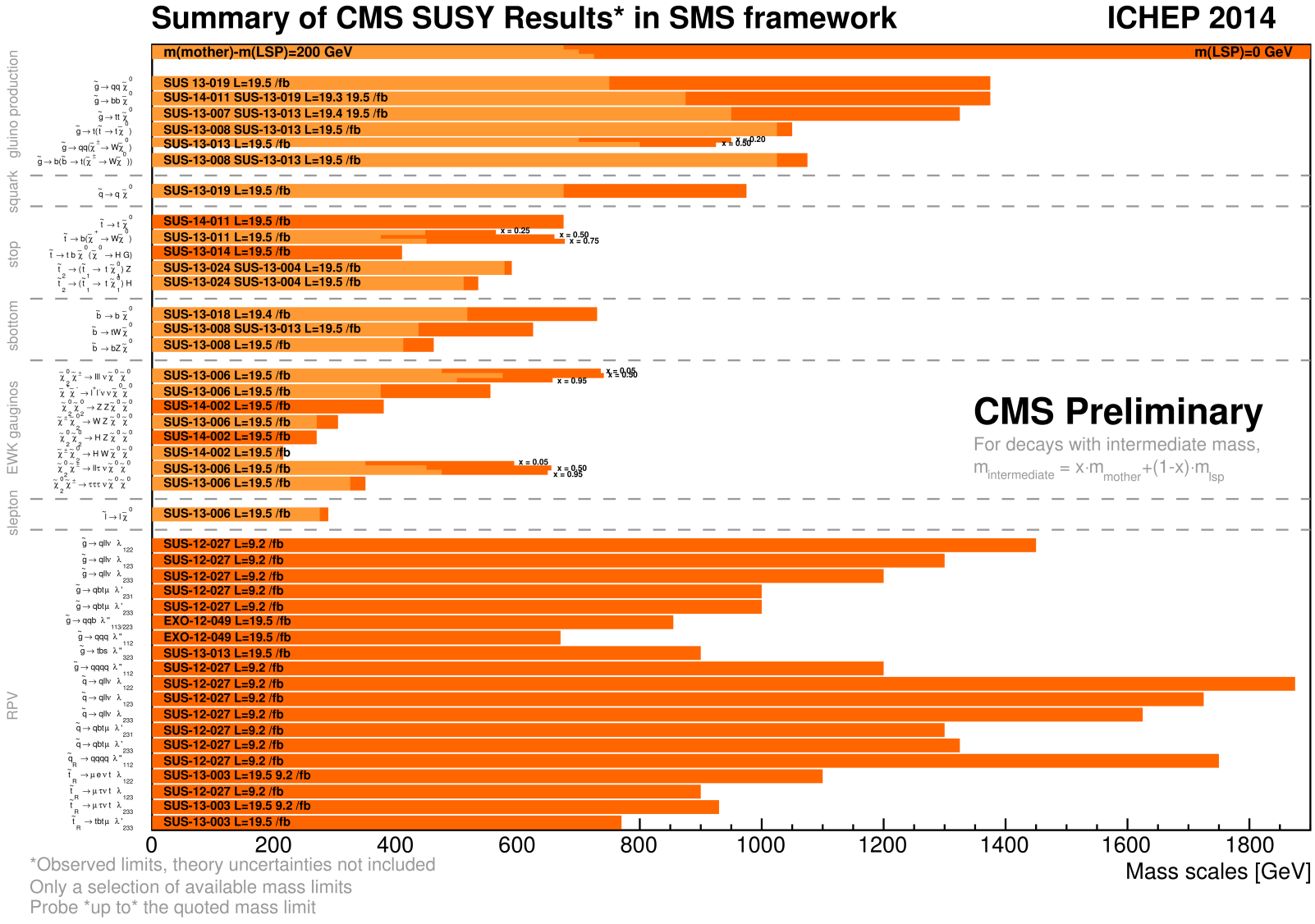
2015 @ $\sqrt{s} = 13$ TeV



2016 @ $\sqrt{s} = 13$ TeV

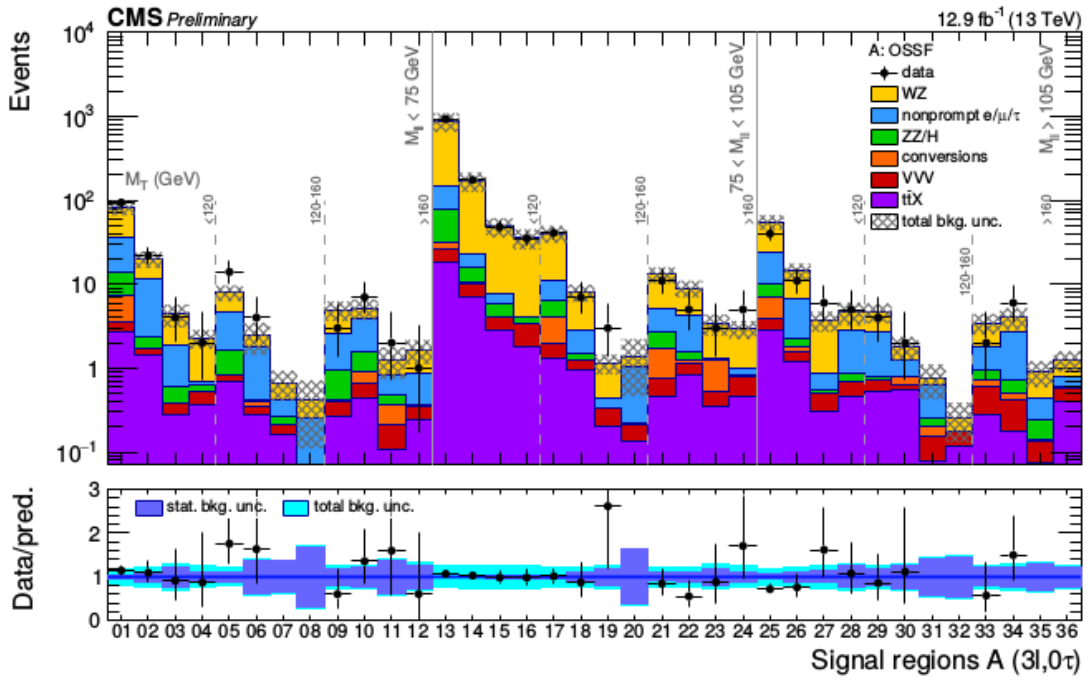


General picture from CMS



First stop: Physics Procecesses with $\tilde{\ell}$ - CMS

M_T (GeV)	E_T^{miss} (GeV)	$M_{\ell\ell} < 75$ GeV	75 GeV $\leq M_{\ell\ell} <$ 105 GeV	$M_{\ell\ell} \geq 105$ GeV
$0-120$	$50-100$	SR A01	SR A13	SR A25
	$100-150$	SR A02	SR A14	SR A26
	$150-200$	SR A03	SR A15	SR A27
	>200	SR A04	SR A16	SR A28
$120-160$	$50-100$	SR A05	SR A17	SR A29
	$100-150$	SR A06	SR A18	SR A30
	$150-200$	SR A07	SR A19	SR A31
	>200	SR A08	SR A20	SR A32
>160	$50-100$	SR A09	SR A21	SR A33
	$100-150$	SR A10	SR A22	SR A34
	$150-200$	SR A11	SR A23	SR A35
	>200	SR A12	SR A24	SR A36



CMS Binned SRs with e or μ and 2 hadronic τ

Table 6: Search region definition for events with one electron or muon and 2 τ_h.

$M_{T2}(\ell, \tau_1)$ (GeV)	E_T^{miss} (GeV)	$M_{\ell\ell} < 100\,GeV$	$M_{\ell\ell} \geq 100\,GeV$
< 100	$50 - 100$	SR F01	SR F04
	$100 - 150$	SR F02	SR F05
	> 150	SR F03	SR F06
≥ 100	$50 - 200$	SR F07	
	> 200	SR F08	

]