Recent searches for electroweak production and 3rd generation SUSY particles with CMS

SUSY 2024

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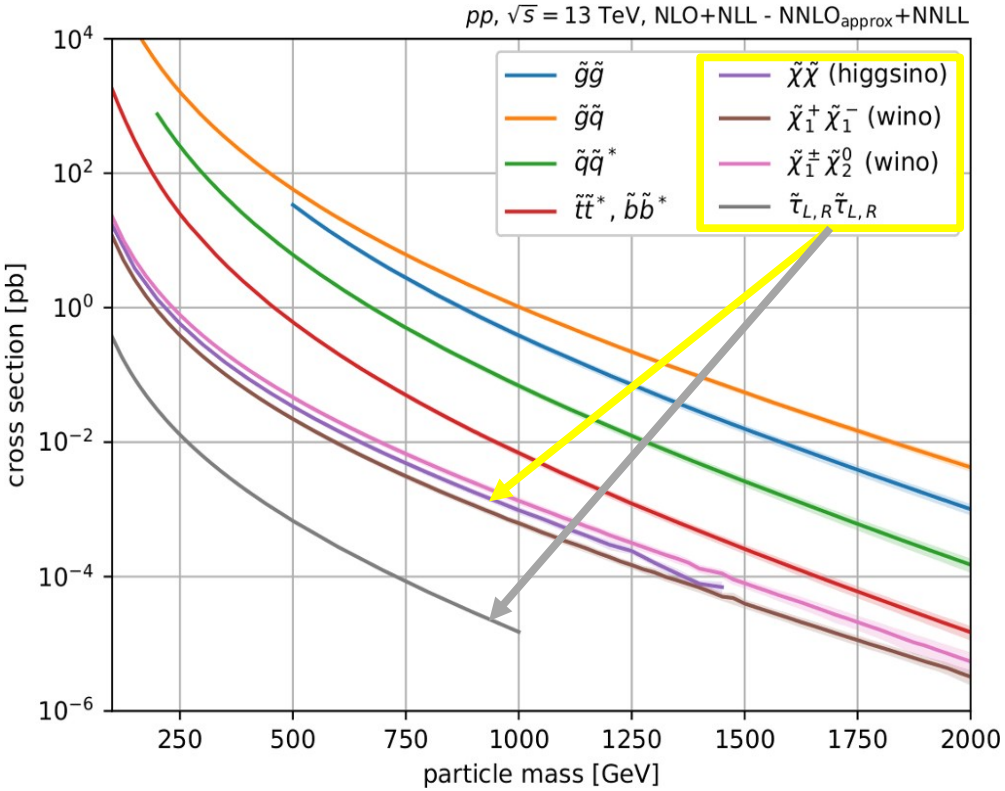
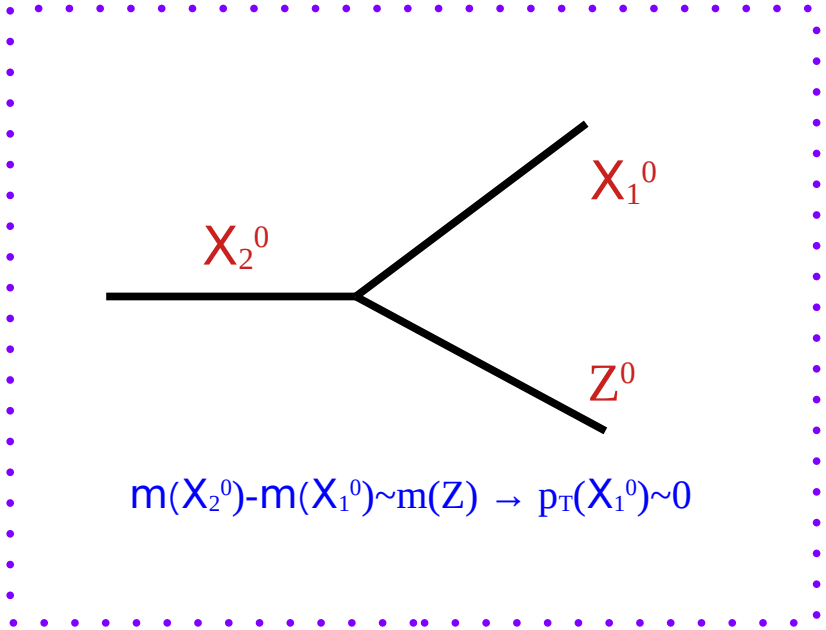
CMS
IFCA Instituto de Física de Cantabria
CSIC Consejo Superior de Investigaciones Científicas
UC Universidad de Cantabria

Electroweak SUSY: a challenging business

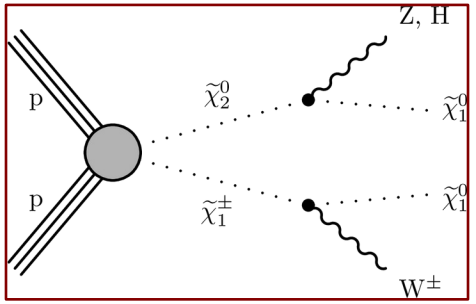
- Direct production of gauginos or sleptons is well motivated theoretically in many models
- However electroweak SUSY is expected to have small cross sections, especially for sleptons
- In addition, there are several SM processes with similar kinematics and large cross-sections
  - Particularly true for compressed scenarios where no transverse missing p_T is produced

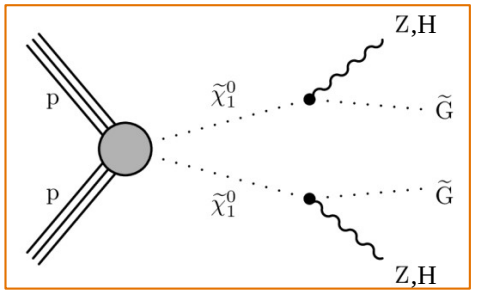




Electroweakino Combination

- Several EWK searches have been combined using the full Run 2 dataset in CMS
  - Wino-like chargino/neutralino decaying via bino-like neutralino
  - Neutralino pair production in GMSB, quasi degenerate Higgsinos
  - Higgsino Chargino/neutralino decaying via bino-like neutralino
  - Slepton pair production
- The combination includes also improvements in some of the analysis
  - Two 2/3 soft lepton analysis has been optimized (see later)





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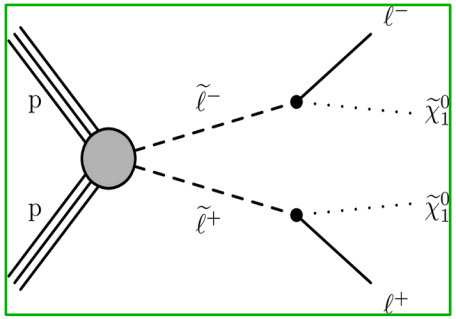
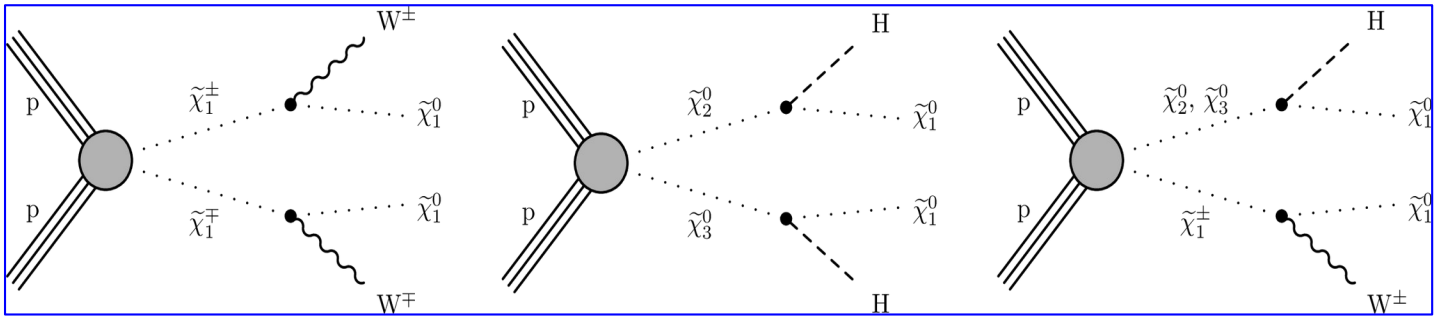




Combination strategy

Leptonic analyses:

- 2/3l soft: JHEP04(2022)091
- 2l on-Z/non res: JHEP04(2021)123
- SSl≥3l: JHEP04(2022)147

Hadronic/Semihadronic analyses:

- 1l 2b: JHEP10(2021)045
- 4b: JHEP05(2022)014
- Hadr.WX: Phys.Lett.B 842(2023)137460

	Wino-bino		GMSB			Higgsino-bino			Sleptons
Search	WZ	WH	ZZ	HZ	HH	WW	HH	WH	$\ell^+\ell^-$
$2/3\ell$ soft [73]	all								2ℓ soft
2ℓ on-Z [71]	EW		EW	EW					
2ℓ nonres. [71]									Slepton
$2SS\ell / \geq 3\ell$ [74]	SS, A(NN)	SS, A–F	all	all	all			SS, A–F	
$1\ell 2b$ [72]		all						all	
4b [75]					all		3-b, 4-b, 2-bb		
Hadr. WX [76]	all	all				ex H		ex H	

Input analyses in a nutshell

- Two-Three lepton soft analysis
  - 2 opposite sign same flavour “2l bin”
  - 1 additional SF (e, mu) → “3l bin”
  - 3.5 (5)<p_T(lep)<30 GeV for 2l (3l) + ISR jet
  - SR regions binned in terms of p_T^{miss} and m_{ll}
- Two lepton on-Z/non resonant
  - 2 Opposite sign same flavour
  - Additional binning in p_T^{miss}
  - On-Z: 86<m_{ll}<96 GeV+ jets (AK4 and AK8)
  - Off-Z: 20 < m_{ll} < 65 GeV and m_{ll} > 120 GeV
- Two Same Sign or Three leptons or more
  - ee/mm or 3/4l with up to 2 hadronic taus
  - P_T^{l1} > 25 GeV, p_T^{l2} > 20 GeV

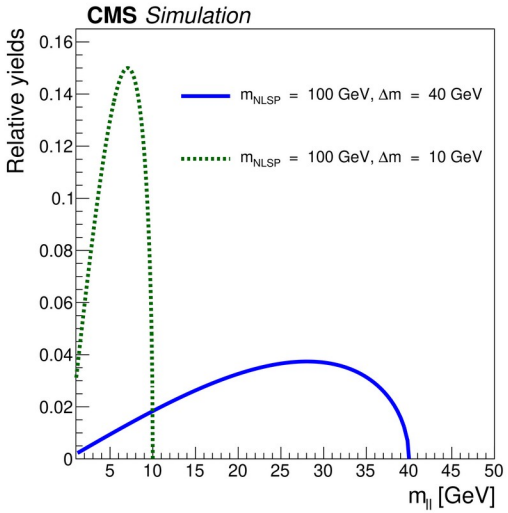
- Single lepton + 2 b
  - P_T^{l1}>30 GeV and large p_T^{miss}
  - 2 b jets consistent with Higgs mass
- Four b
  - No leptons. Two H → bb bosons.
  - Boosted topologies using AK8 jets
  - Signal Regions based on $N_{b\text{-jets}}$
- Hadronic WX:
  - >= 2 AK8 jets compatible with W,Z,H
    - Using DEEPAK8 tagger
  - 2-6 AK4 jets

Orthogonality among analysis ensured

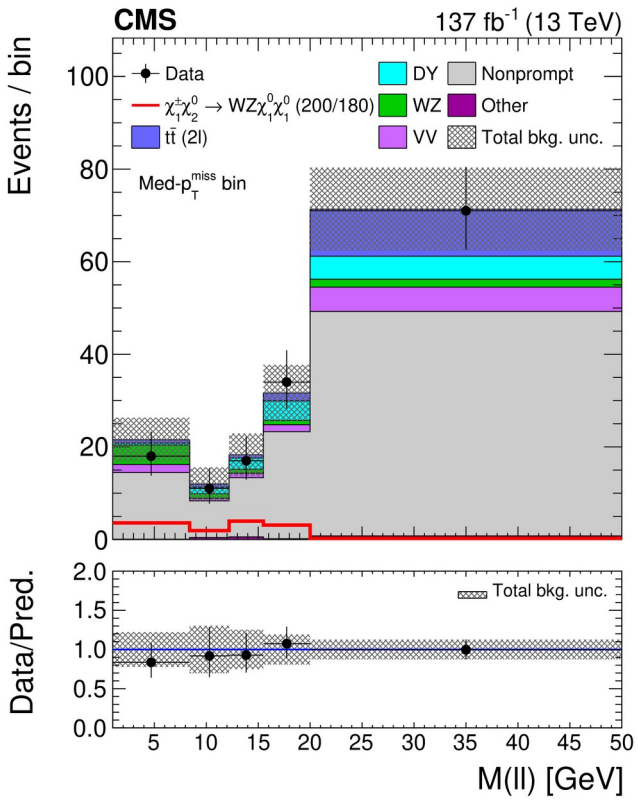
Optimization of 2/3l soft analysis

- Analyses optimized w.r.t. (JHEP04(2022)09) by adjusting the binning for each mass splitting
- Using m_{ll} as discriminating variable for each Δm and signal region, $M_{T2}(ll, X)$ for sleptons
- Expected exclusion of N-LSP improved by 5-25 GeV

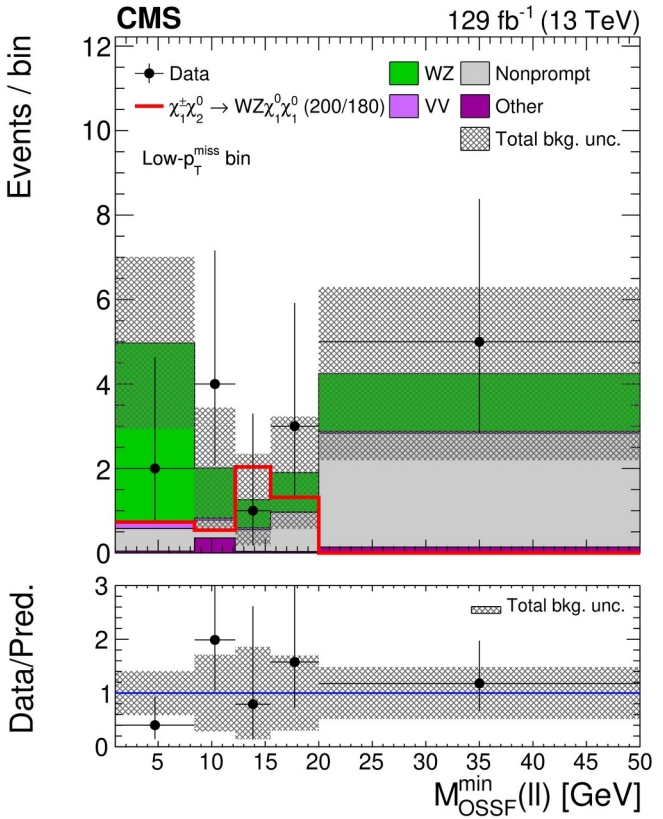
Kinematics dependency on m_{ll}



Medium p_T miss – 2l soft

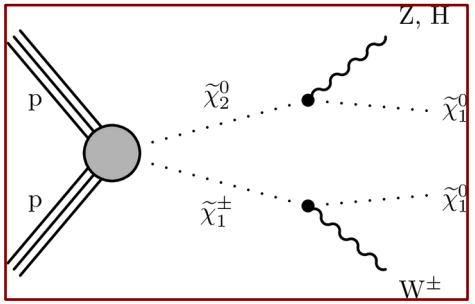


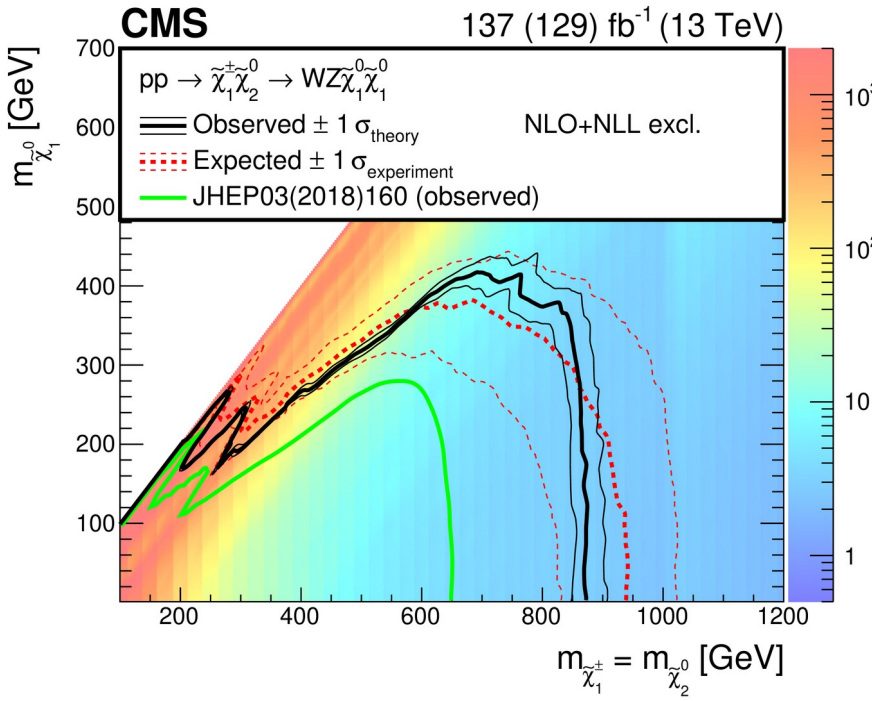
Low p_T miss – 3l soft

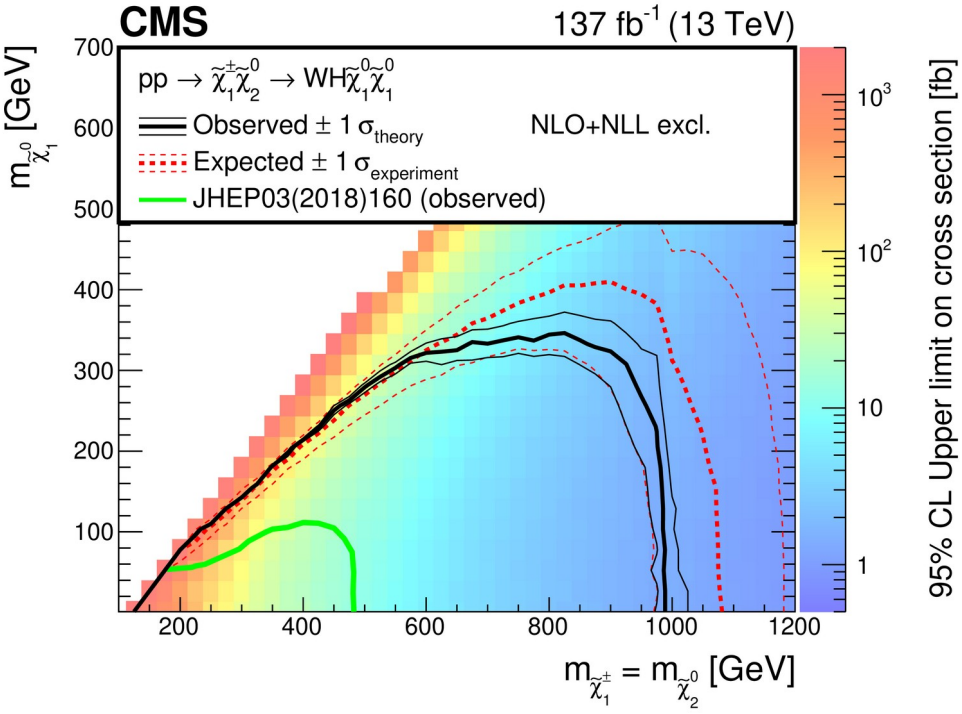


Chargino/neutralino production in WZ/WH

- Uncompressed region dominated by Hadronic WX analysis
- Compressed region: 2/3l soft analysis (>=3l) in the WZ (WH) models
- Large improvement with respect to 2016 combination

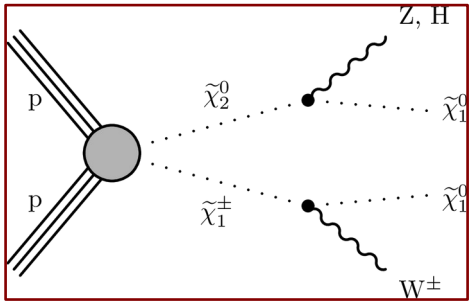


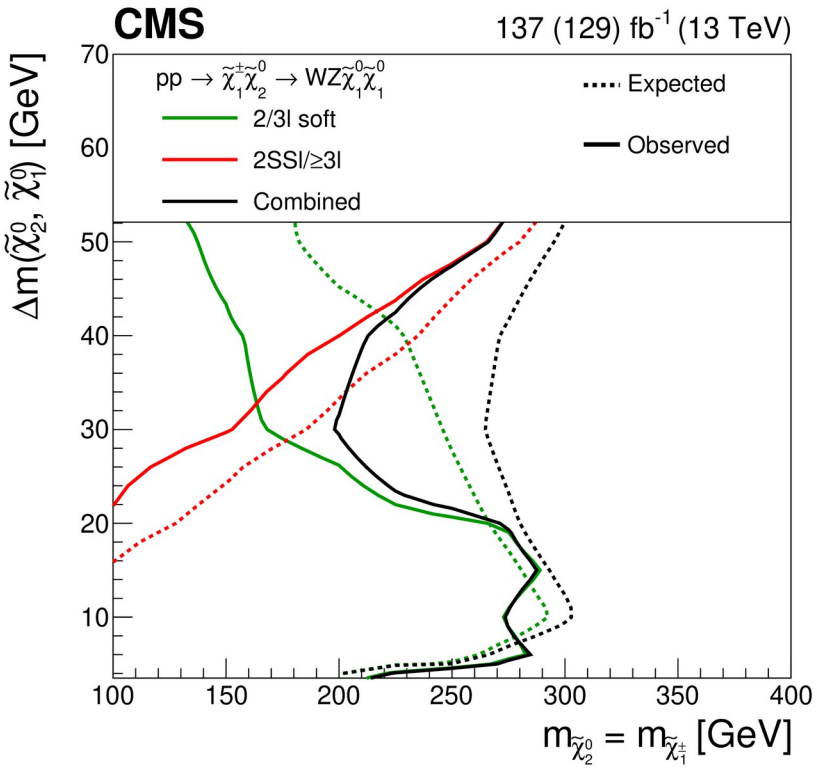


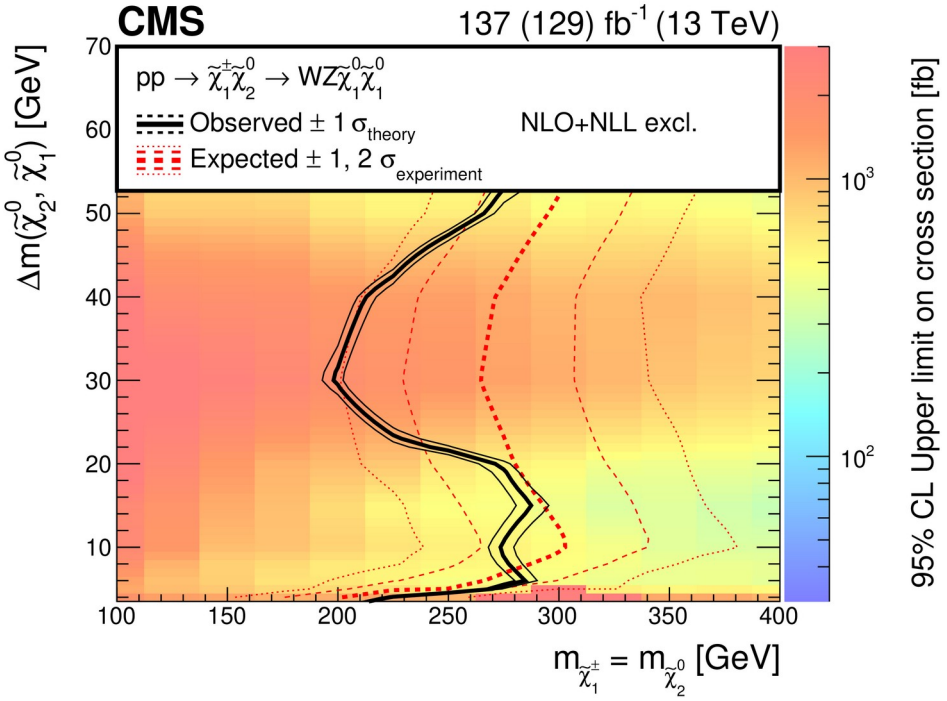


Chargino/neutralino production in WZ (compressed)

- Both 2/3l soft and 2SSl >= 3l analyses complement each other
  - Orthogonal lepton p_T range for each of them
- Observed limits closing the gap at $\Delta m \sim 30$ GeV
  - Two σ excess found in that region

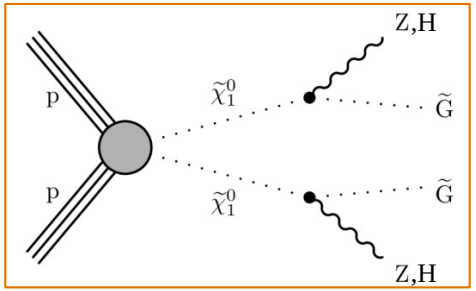


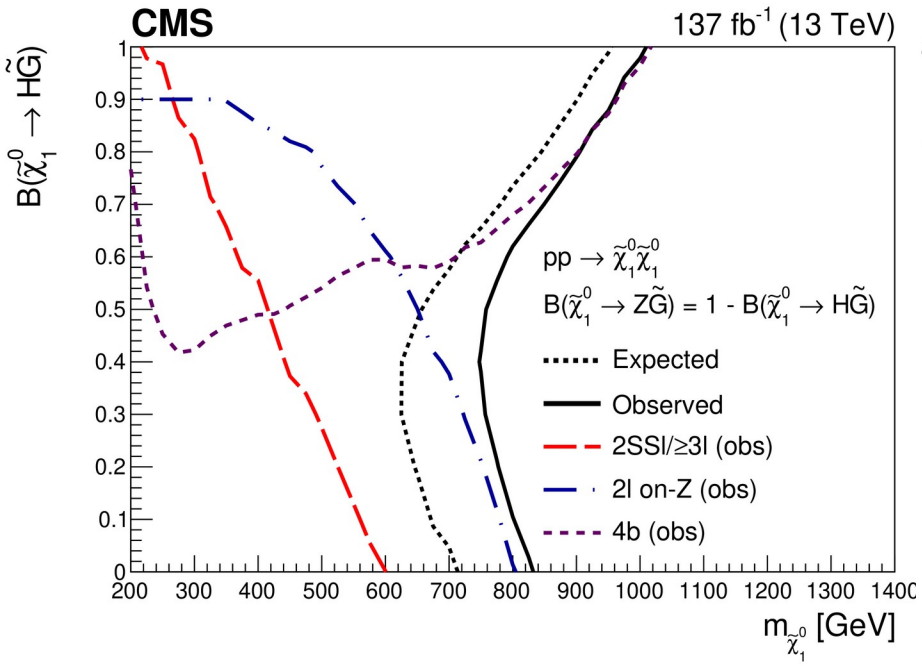


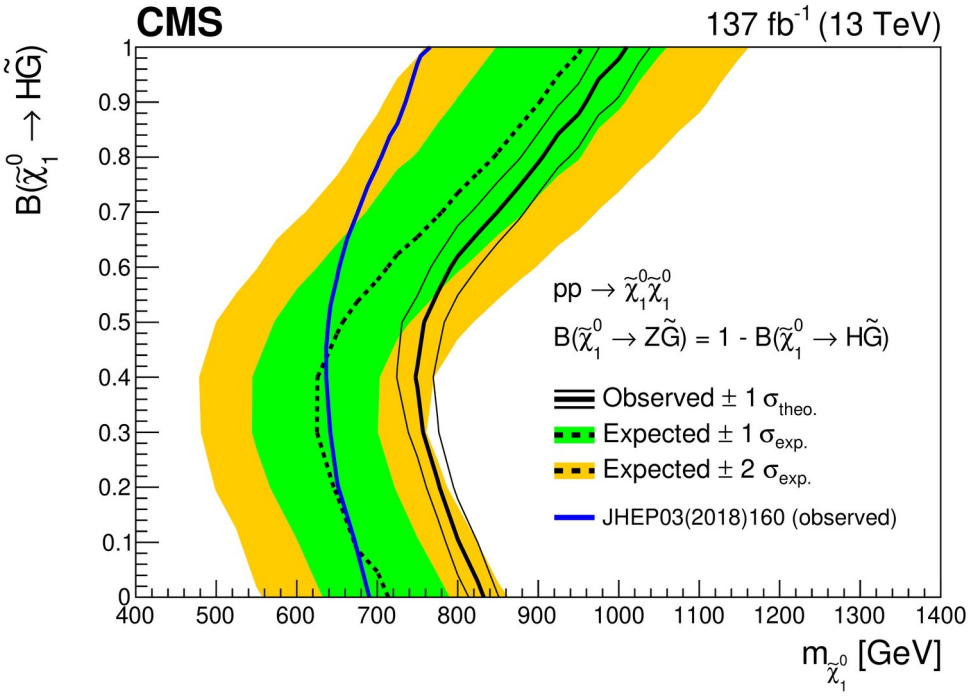


Chargino/neutralino production in GMSB

- In these GMSB models the gravitino mass is fixed to 1 GeV
- Exclusion limits are given in terms of $B(\chi_1^0 \rightarrow H\tilde{G})$
  - At large branching ratio the 4b analysis has larger sensitivity
  - At small branching ratio the 2l on-Z analysis dominates

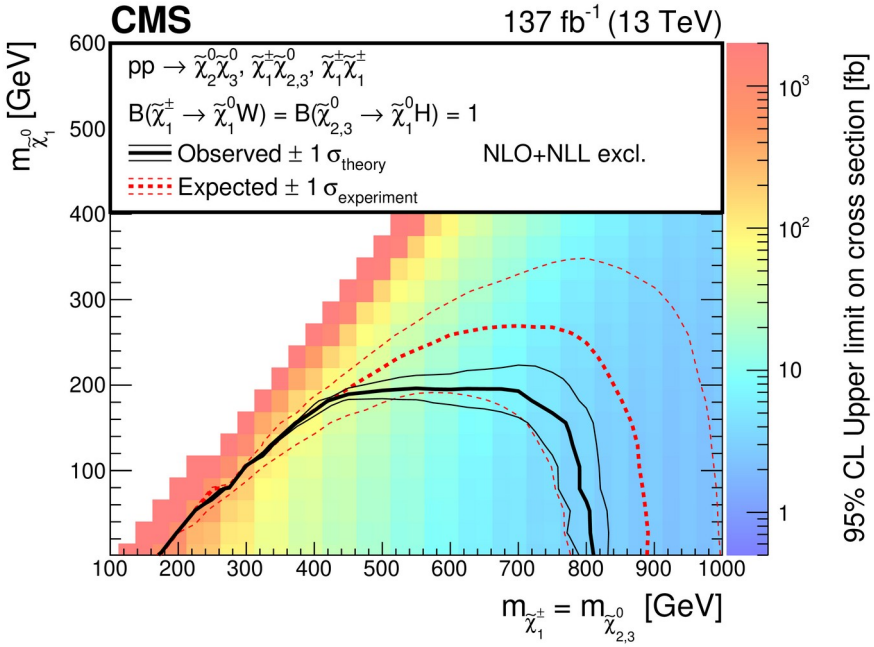


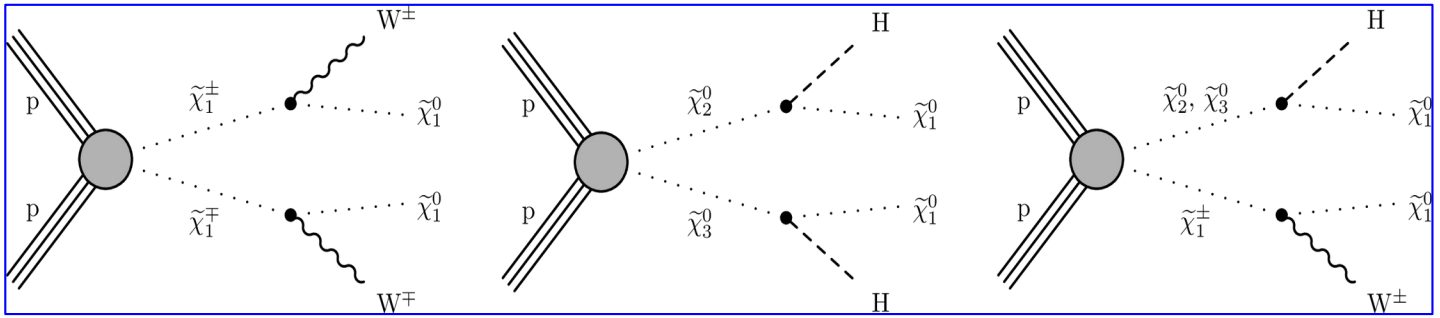




Chargino/neutralino production in Higgsino-bino

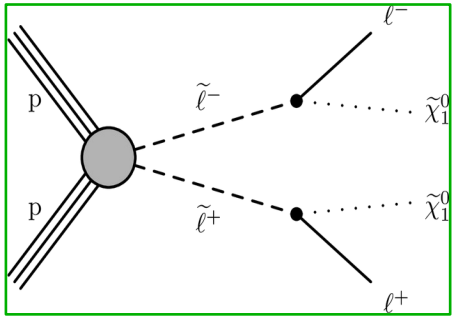
- Targetting WW, HH or WH final states
  - $B(X_1^{+/-} \rightarrow WX_1^0) = 100\%$
  - $B(X_{2,3}^0 \rightarrow HX_1^0) = 100\%$
- Large sensitivity to uncompressed spectra
- WW channel dominated by Hadr. WX analysis
- HH channel dominated by the 4b analysis
- WH channel with large contributions from:
  - Hadr. WX + 4b + 3 leptons

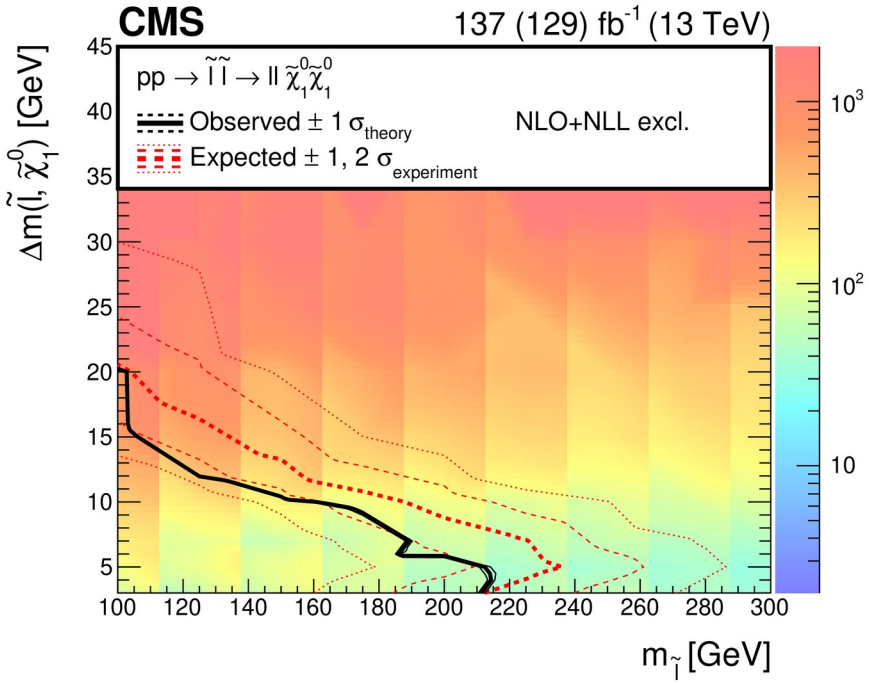


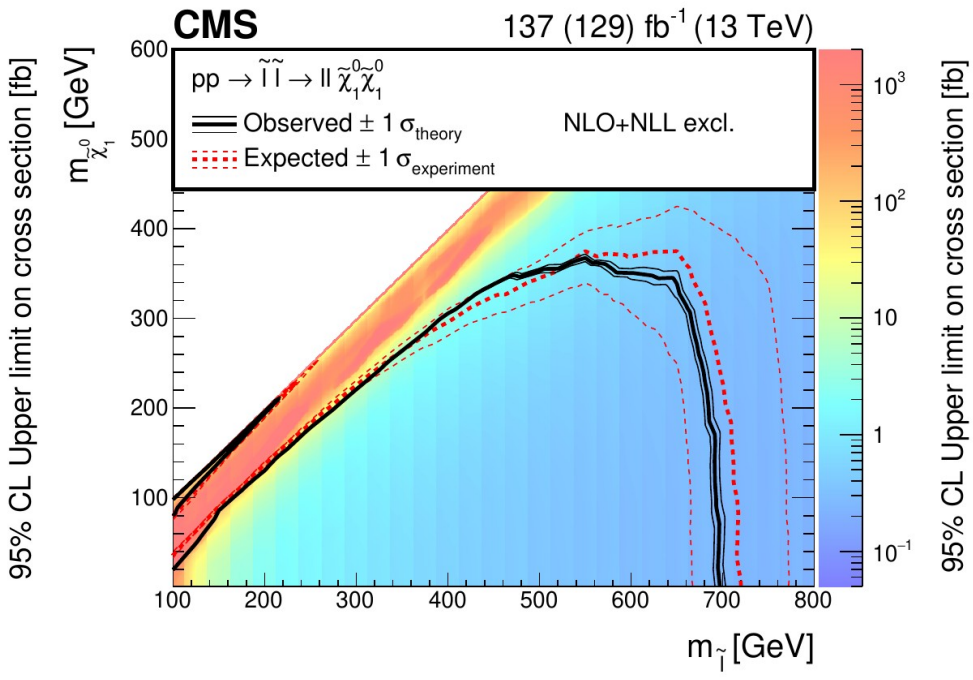


Slepton production

- Slepton production particularly challenging due to small cross sections
  - Only 1st and 2nd generations covered here (see next slides for staus)
- Compressed signatures dominated by 2/3l soft analysis
- Non-compressed scenarios dominated by 2l non-resonant

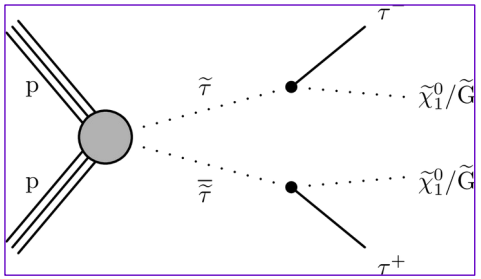






Prompt/Displaced stau production

- A search for direct production of staus prompt and slightly displaced ~ 2.5 mm (full Run2 data)
- Basic selection: 2 hadronically decaying taus + large m_{T2} and Σm_T
- Background dominated by missidentified taus from QCD events



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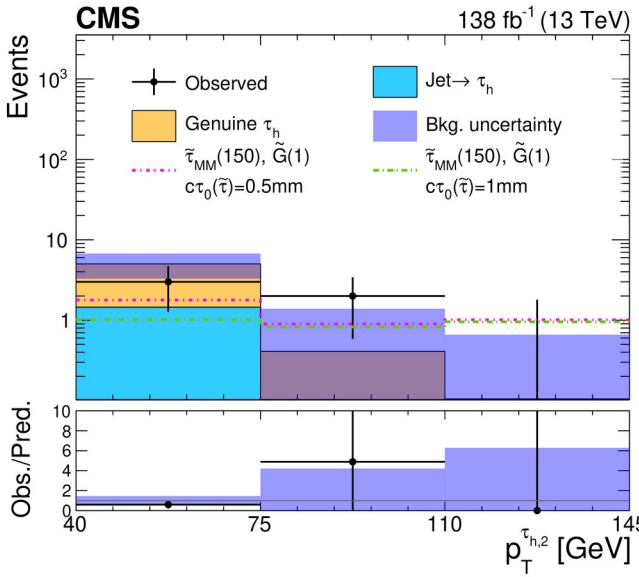
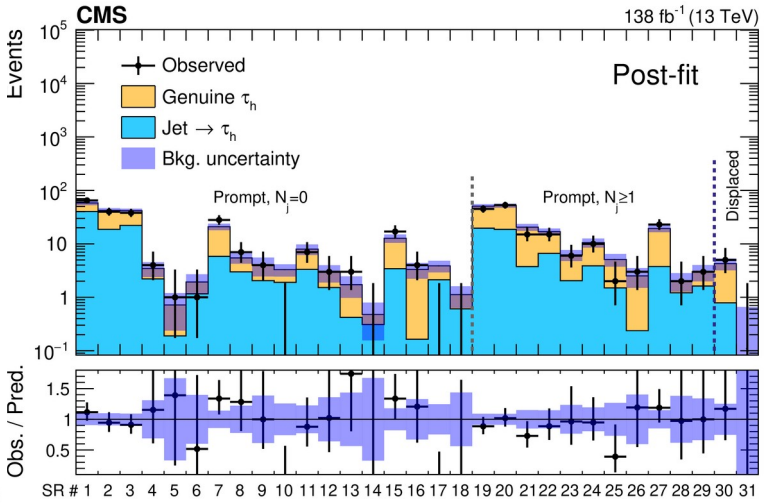
P_T^{tau2} distribution for displaced SR



Post-fit distribution for all regions



Prompt SRs

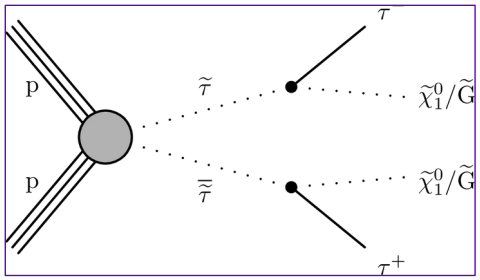
SR bin	Σm_T [GeV]	m_{T2} [GeV]	$p_T^{\tau_{h,1}}$ [GeV]
	$N_j = 0$		
1	200 – 250	25 – 50	<90
2	200 – 250	25 – 50	>90
3	200 – 250	50 – 75	<90
4	200 – 250	50 – 75	>90
5	200 – 250	>75	—
6	250 – 300	25 – 50	<90
7	250 – 300	25 – 50	>90
8	250 – 300	50 – 75	<90
9	250 – 300	50 – 75	>90
10	250 – 300	>75	—
11	300 – 350	25 – 50	—
12	300 – 350	50 – 75	—
13	300 – 350	75 – 100	—
14	300 – 350	>100	—
15	>350	25 – 50	—
16	>350	50 – 75	—
17	>350	75 – 100	—
18	>350	>100	—
	$N_j \geq 1$		
19	200 – 250	25 – 50	—
20	200 – 250	>50	—
21	250 – 300	25 – 50	—
22	250 – 300	50 – 75	—
23	250 – 300	>75	—
24	300 – 350	25 – 50	—
25	300 – 350	50 – 75	—
26	300 – 350	>75	—
27	>350	25 – 75	—
28	>350	75 – 100	—
29	>350	>100	—

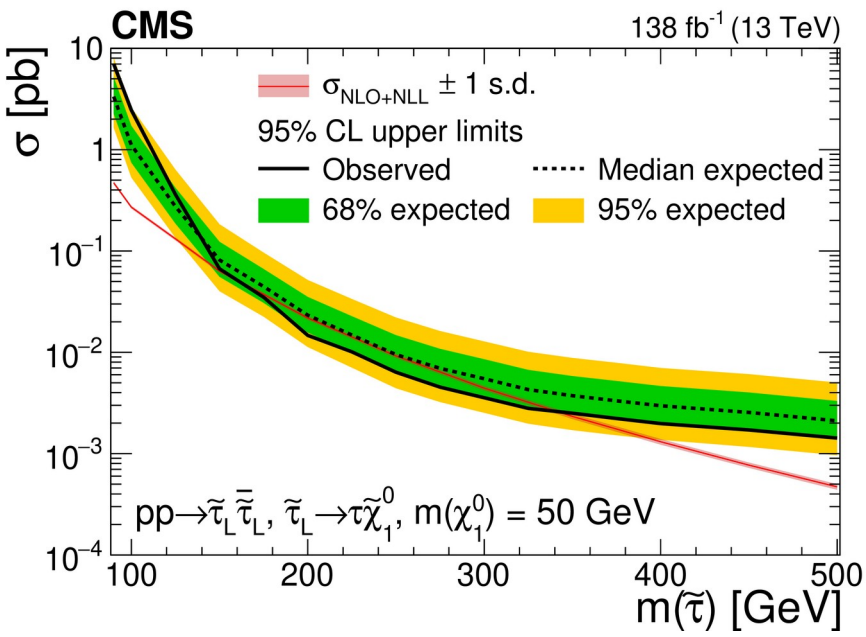
Displaced SRs

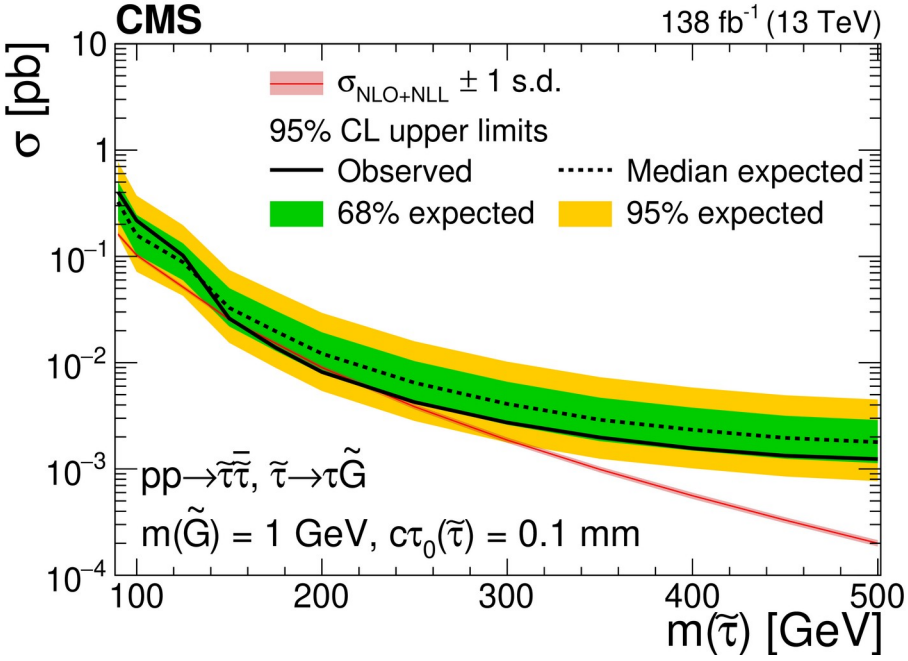
SR bin	$p_T^{\tau_{h,2}}$ [GeV]
30	<110
31	>110

Prompt/Displaced stau production: interpretation

- Analysis interpreted in terms of degenerate stau scenarios and purely left/right handed scenarios
- Exclusion for pure left-handed staus in the range m(stau) ~ 115-340 GeV
- Exclusion for degenerate staus up to m(stau) ~ 400 GeV
- The most stringent observed limits for direct prompt staus
- Staus with cτ=0.1mm excluded in the range m(stau) ~ 150-220 GeV







Conclusions

- Electroweak production has been extensively searched for with the Run 2 dataset in CMS
- Large gains coming from the combination of different signatures and analyses
  - And large effort to design Signal Regions without overlaping
  - Many lessons learned in this process
- Focus is now on Run 3 data → **Please stay tuned!**