Search for electroweak SUSY production in multilepton final state at 13 TeV at CMS

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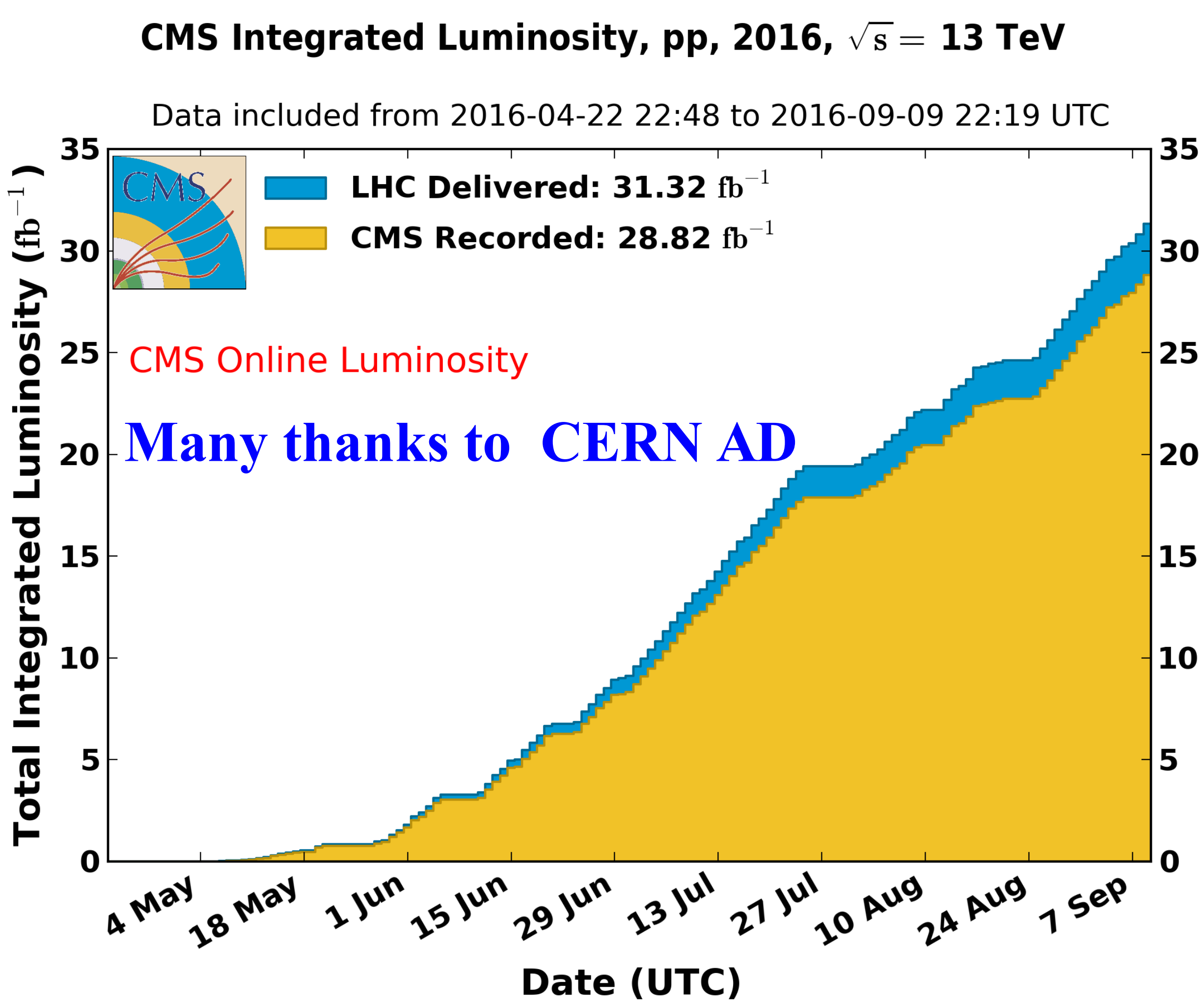
on behalf of the CMS collaboration

CMS dataset

- **today**'s results concern data corresponding to an integrated luminosity of **12.9 fb^{-1}**
- **LHC is working extremely well → much more data to come**



Motivations and context

- **coloured susy particles such as gluinos/squarks subjected to strong interaction have not (yet) been discovered**

- stringent contraints on their mass (> 1-2 TeV)

- EW SUSY searches become even more relevant (and even more so as lumi increases)

- **EW SUSY → production of charginos and neutralinos via EW interactions**

- search (per se) for SUSY partners of EW gauge and scalar sectors of the SM

- production cross sections are lower than for strongly produced SUSY particles (at same mass)

- Run 1 mass constraints on EW gauginos are milder than on gluinos and squarks

- gauginos are expected to be lighter than gluinos and squarks (naturalness, split susy)

- **Leptonic final states**

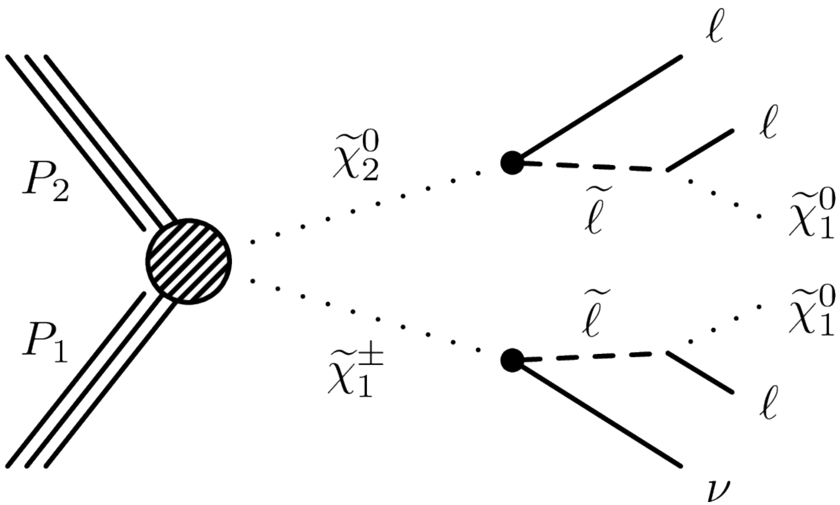
- *R*-parity conservation is assumed

- gauginos may have significant BRs to W, Z or sleptons which can decay to leptons

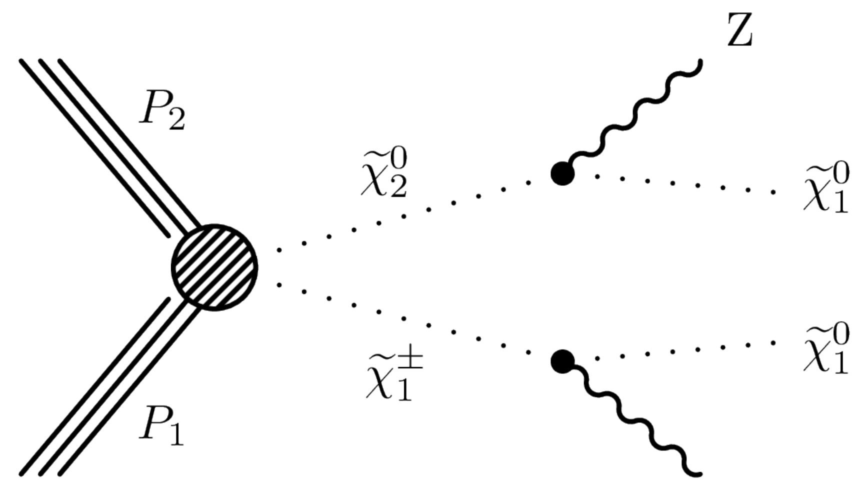
- can have hard and isolated leptons in the final state

- small background from SM (channel formerly known at pre-LHC time as the golden channel)

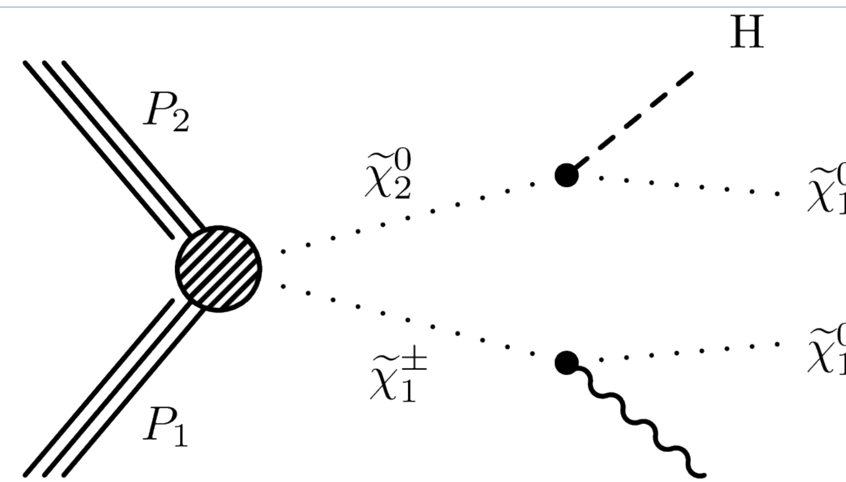
EW SUSY production at CMS



light sleptons
final states with 3 leptons
(or 2 SS leptons if one lepton is missed)



heavy sleptons, direct decay to W/Z
final states with 3 leptons



heavy sleptons, direct decay to WH
final states with 3 leptons ($H \rightarrow WW$)

Multiple final states
→ enhance sensitivity
→ cover as large a phase space as possible

Baseline selection

selection	SS dilepton channel	trilepton channel	4-lepton channel
# leptons	2, same charge	3	> 3
leptons p_T for $e(\mu)$	25 (20) / 15 (10)	25 (20) / 15 (10) / 10	25 (20) / 15 (10) / 10 /10
# taus	0	0, 1, 2	≥ 0
lepton p_T for $\tau_h(e/\mu)$	-	20 (30 / 25)	20
# jets	0, 1	≥ 0	≥ 0
veto evts with OSSF pair with $M_{ll} < 12\,\text{GeV}$	yes	yes	yes
veto evts with on Z M_{3l}	no	yes (in certain category)	no
veto evts with >0 b-tag jet	yes	yes	yes
ME_T	>60	>50	>0
overlap removal	no third lepton	no fourth lepton	no

CEA - Saclay

categorization

CMS-PAS-SUS-16-024

2 lepton

0 tau

- **same-sign**: M_T, ME_T, p_T^{ll} bins

3 lepton final state

0 tau

- **nOSSF=1**: on Z, off Z, M_T bins
- **nOSSF=0**: M_{ll}, M_T bins

1 tau

- **SS τ**: M_{ll}, M_{T2} bins
- **nOSSF=1**: M_{ll}, M_{T2} bins
- **nOSOF=1**: M_{ll}, M_{T2} bins

2 taus

- **l τ τ**: M_{ll}, M_{T2} bins

4 lepton final state

0 tau

- **nOSSF=2**: ME_T bins
- **nOSSF $\leq$1**: ME_T bins

1 tau

- ME_T bins

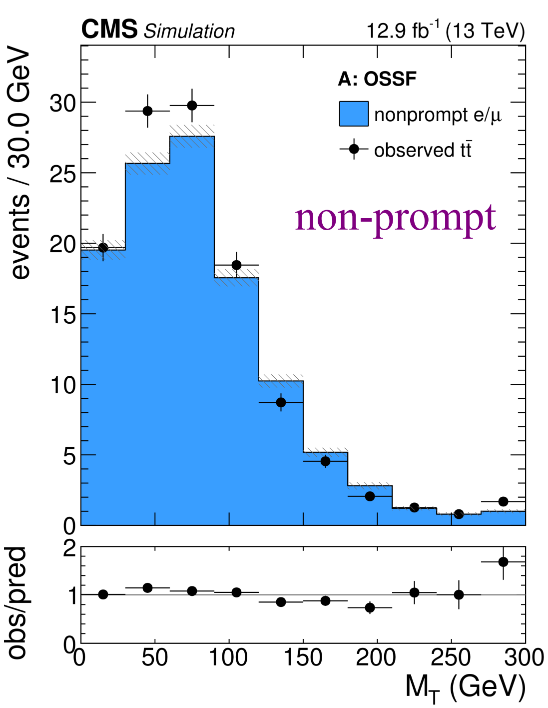
signals

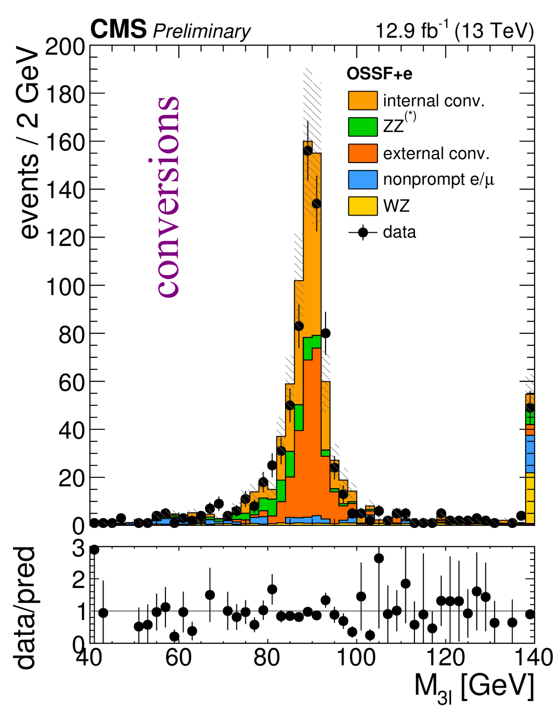
- $\chi^{\pm}\chi^{o} \rightarrow WZ$, $\chi^{\pm}\chi^{o} \rightarrow \tilde{l}\,\tilde{\nu}$ (flavor-demo.)
- $\chi^{\pm}\chi^{o} \rightarrow \tilde{l}\,\tilde{\nu}$ (tau-enriched)
- $\chi^{\pm}\chi^{o} \rightarrow \tilde{l}\,\tilde{\nu}$ (tau dominated)
- $\chi^{o}\chi^{o} \rightarrow ZZ$

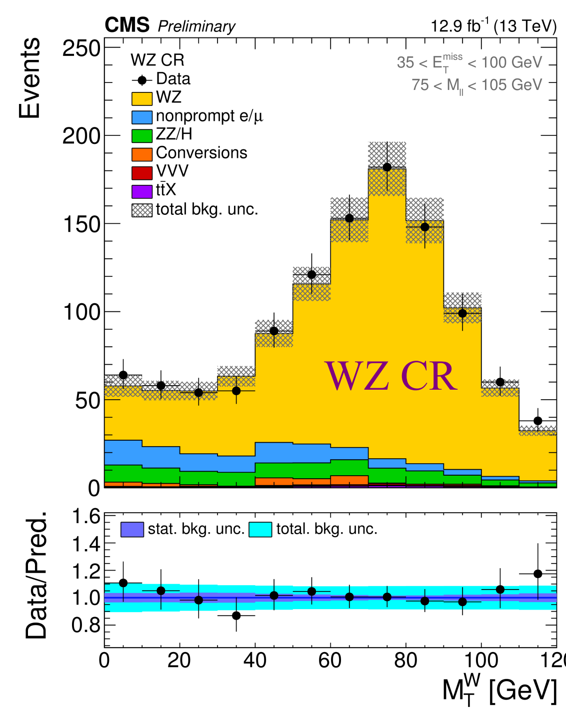
Background estimation

CMS-PAS-SUS-16-024

- **Non-prompt leptons :**
  - Data driven, tight-to-loose ratio
  - probability for a fake lepton (fake ratio) to pass the tight requirements (using dedicated control sample)
  - probability then applied to the sidebands of the signal region
  - validity checked on MC
- **Rare SM processes :** from MC
- **WZ :**
  - estimated from MC
  - normalisation and shape uncertainties driven by Control Region (CR) in data
- **Conversions :**
  - estimated from MC, validated in data
- **Flips** (only for SS):
  - estimated from MC, validated in data







2 lepton same sign results

CMS-PAS-SUS-16-024

N_{jets}	M_{T} (GeV)	$p_{\mathrm{T}}^{\ell\ell}$ (GeV)	$E_{\mathrm{T}}^{\mathrm{miss}} < 100\,\mathrm{GeV}$	$100\,\mathrm{GeV} \leq E_{\mathrm{T}}^{\mathrm{miss}} < 150\,\mathrm{GeV}$	$E_{\mathrm{T}}^{\mathrm{miss}} \geq 150\,\mathrm{GeV}$
0	< 100	< 50	SS 01	SS 02	SS 03
		≥ 50	SS 04	SS 05	SS 06
	≥ 100	< 50 ≥ 50	SS 07	SS 08	SS 09
1	< 100	< 50	SS 10	SS 11	SS 12
		≥ 50	SS 13	SS 14	SS 15
	≥ 100	< 50 ≥ 50	SS 16	SS 17	SS 18

N_{jets}	M_{T} (GeV)	$p_{\mathrm{T}}^{\ell\ell}$ (GeV)	$E_{\mathrm{T}}^{\mathrm{miss}} < 100\,\mathrm{GeV}$		$100 \leq E_{\mathrm{T}}^{\mathrm{miss}} < 150\,\mathrm{GeV}$		$E_{\mathrm{T}}^{\mathrm{miss}} \geq 150\,\mathrm{GeV}$	
			exp	obs	exp	obs	exp	obs
0	< 100	< 50	310 ± 56	294	15 ± 4	16	1.8 ± 0.6	2
		≥ 50	180 ± 32	191	36 ± 8	33	7.9 ± 1.9	4
	≥ 100	-	32 ± 7	29	15 ± 3	9	15 ± 3	9
1	< 100	< 50	120 ± 25	127	33 ± 7	43	7.2 ± 1.5	14
		≥ 50	150 ± 29	146	49 ± 10	59	20 ± 4	39
	≥ 100	-	12 ± 2	13	8.7 ± 1.6	8	4.3 ± 1.0	6

2 lepton same sign results

CMS-PAS-SUS-16-024

2 lepton

0 tau

same-sign

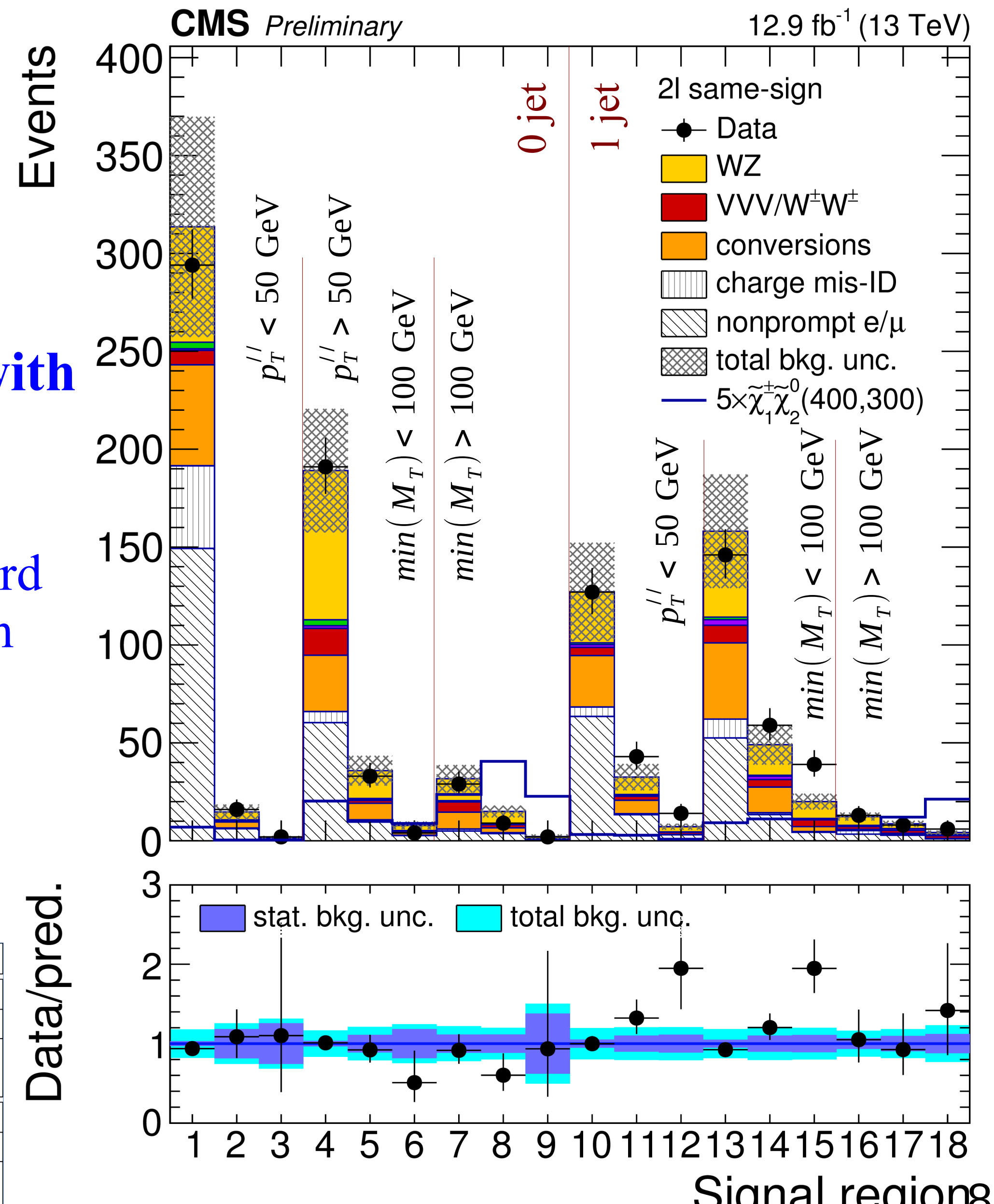
M_T, ME_T, $p_T^{//}$ bins

events further categorized in number of jets (0 or 1 ISR jets)

sensitivity to compressed scenarii

Data in good agreement with SM prediction

2 regions with observed upward fluctuation → compatible with background events



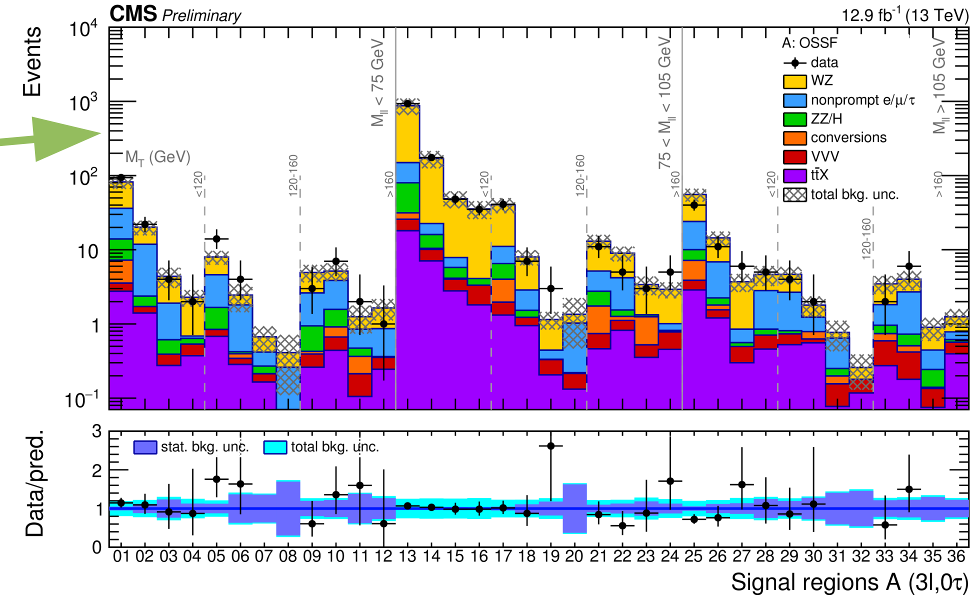
N_{jets}	M_T (GeV)	$p_T^{\ell\ell}$ (GeV)	$E_T^{miss} < 100$ GeV	100 GeV $\leq E_T^{miss} < 150$ GeV	$E_T^{miss} \geq 150$ GeV
0	< 100	< 50	SS 01	SS 02	SS 03
		≥ 50	SS 04	SS 05	SS 06
	≥ 100	< 50 ≥ 50	SS 07	SS 08	SS 09
1	< 100	< 50	SS 10	SS 11	SS 12
		≥ 50	SS 13	SS 14	SS 15
	≥ 100	< 50 ≥ 50	SS 16	SS 17	SS 18

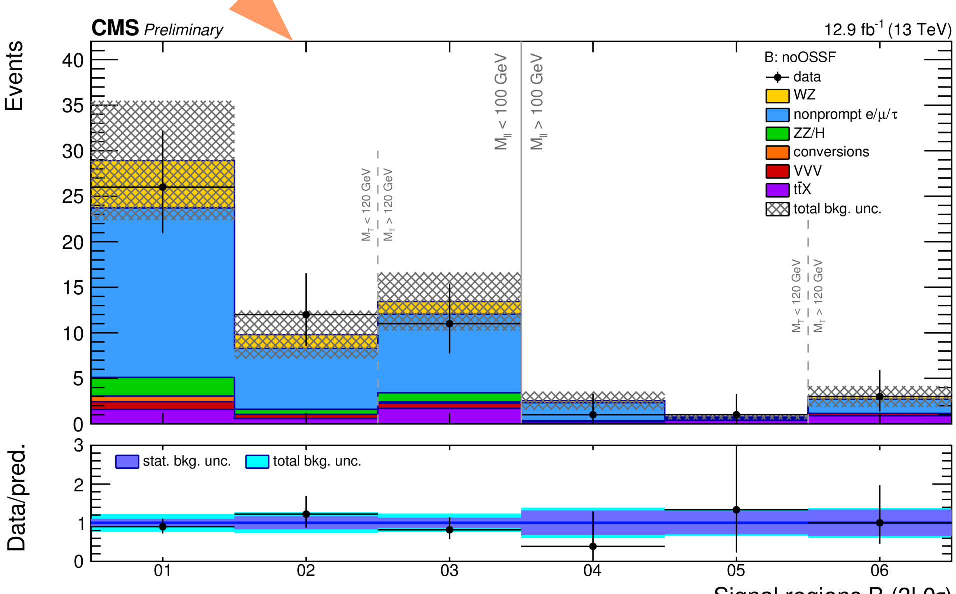
glimpse at 3 lepton channel results

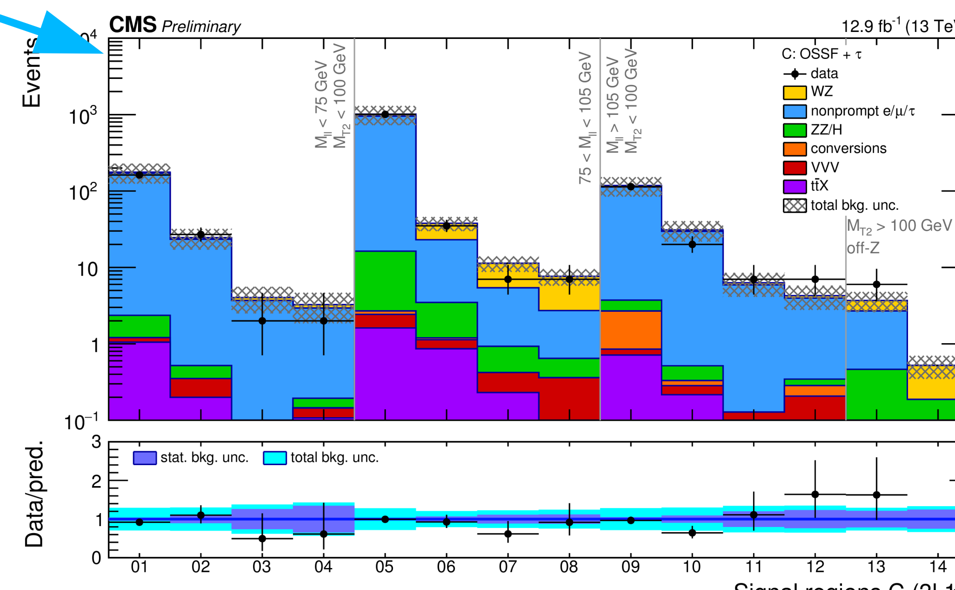
Data in good agreement with SM prediction

3 lepton final state

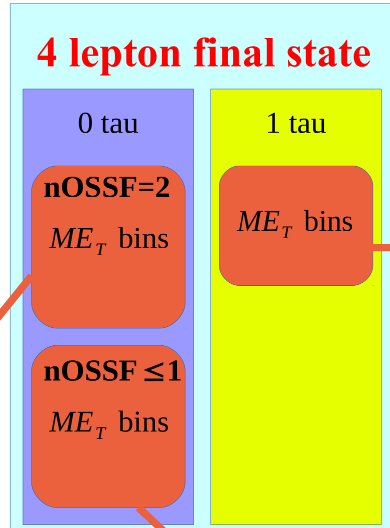
0 tau	1 tau	2 taus
nOSSF=1 on Z, off Z M_T bins	**SS τ** M_{ll}, M_{T2} bins	**l τ τ** M_{ll}, M_{T2} bins
nOSSF=0 M_{ll}, M_T bins	**nOSSF=1** M_{ll}, M_{T2} bins	
	nOSOF=1 M_{ll}, M_{T2} bins	

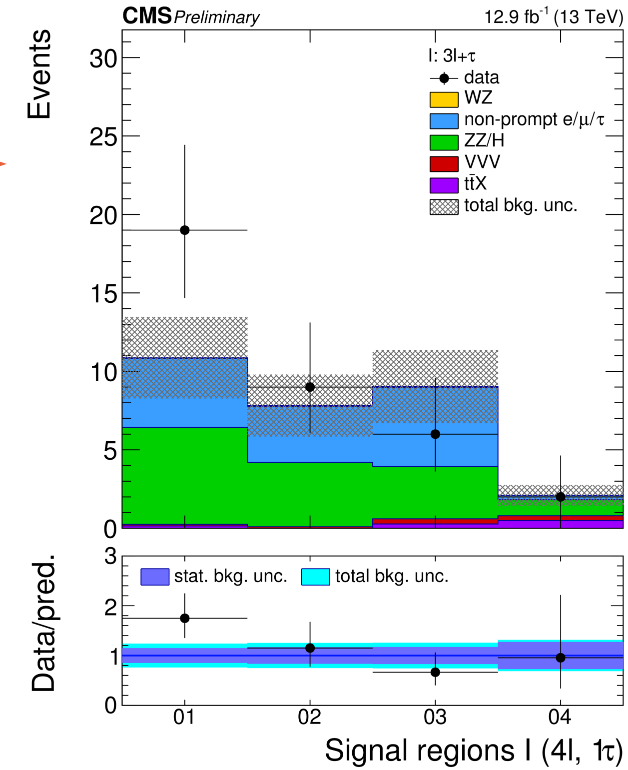


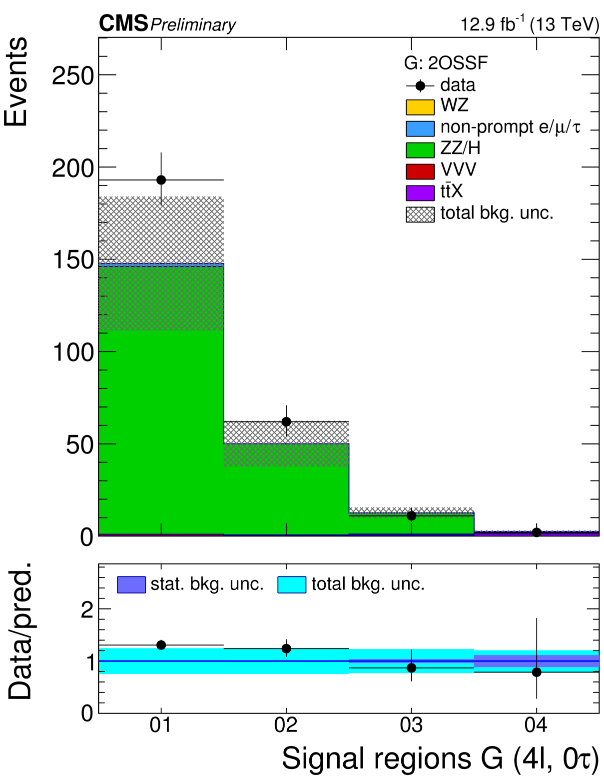


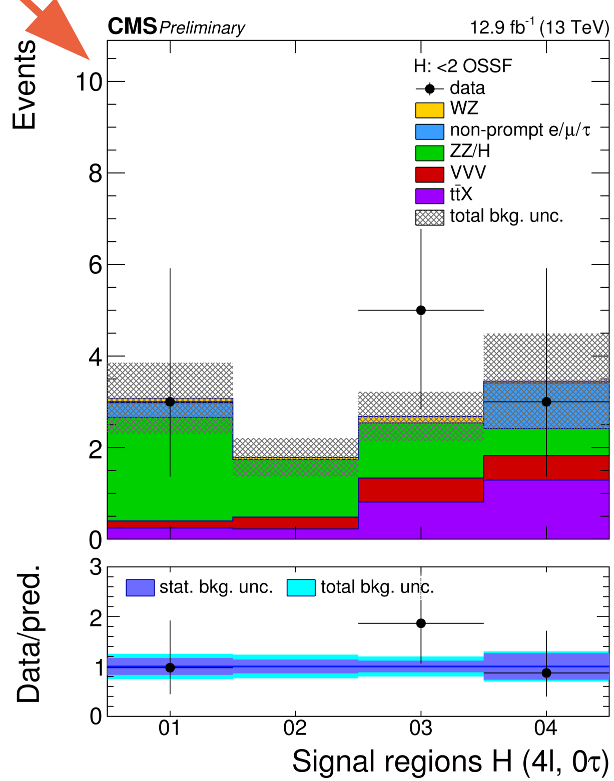


4 lepton channel results









Data in good agreement with SM prediction

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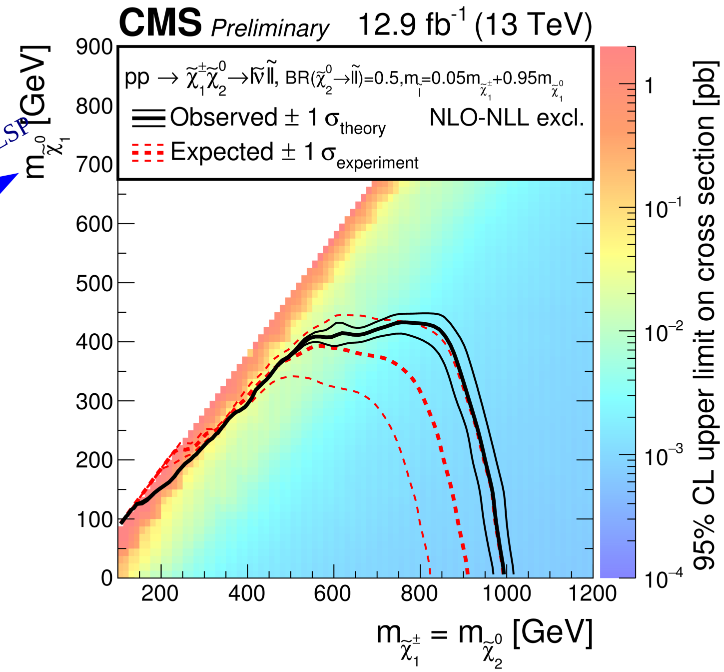
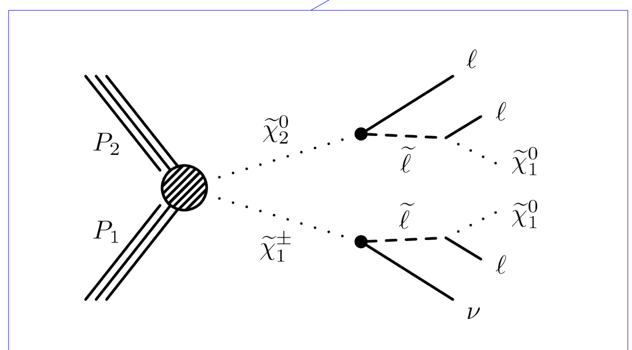
Interpretation I

results can be interpreted in several scenarios and different mass splitting

many assumpations have been made (e.g. branching ratio to leptons is 100%)

$m_{\tilde{l}} = 0.05\ m_{\tilde{\chi}} + 0.95\ m_{LSP}$

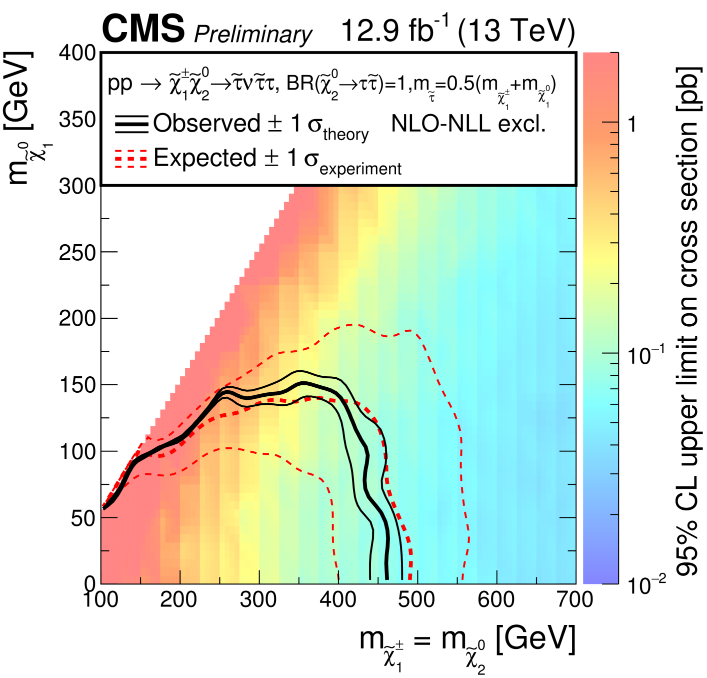


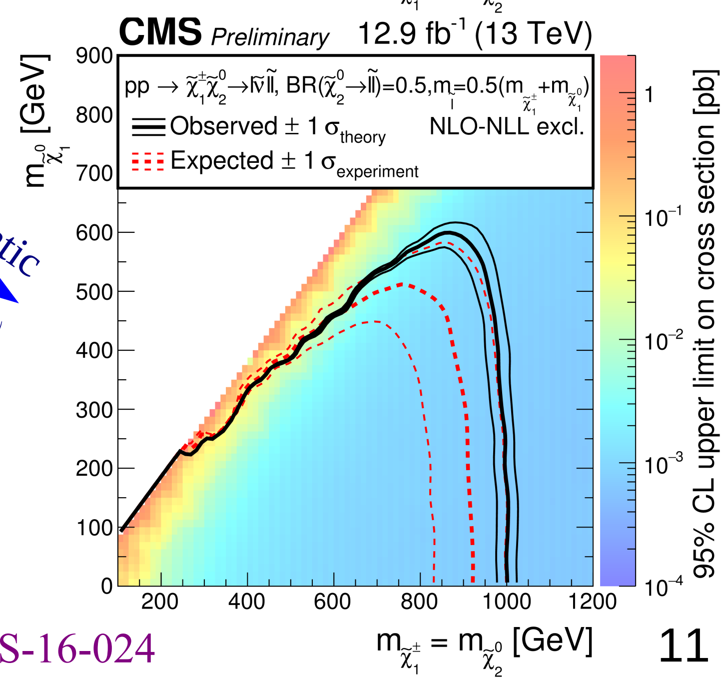


only to τ in final state

flavor democratic

$m_{\tilde{l}} = 0.5 \times (m_{\tilde{\chi}} + m_{LSP})$





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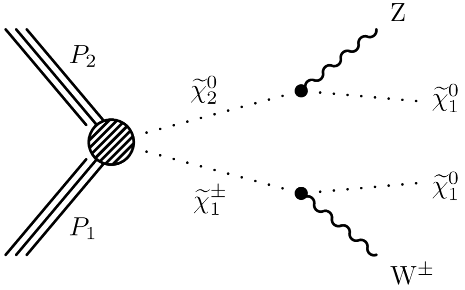
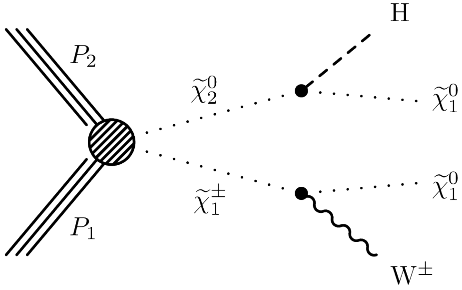
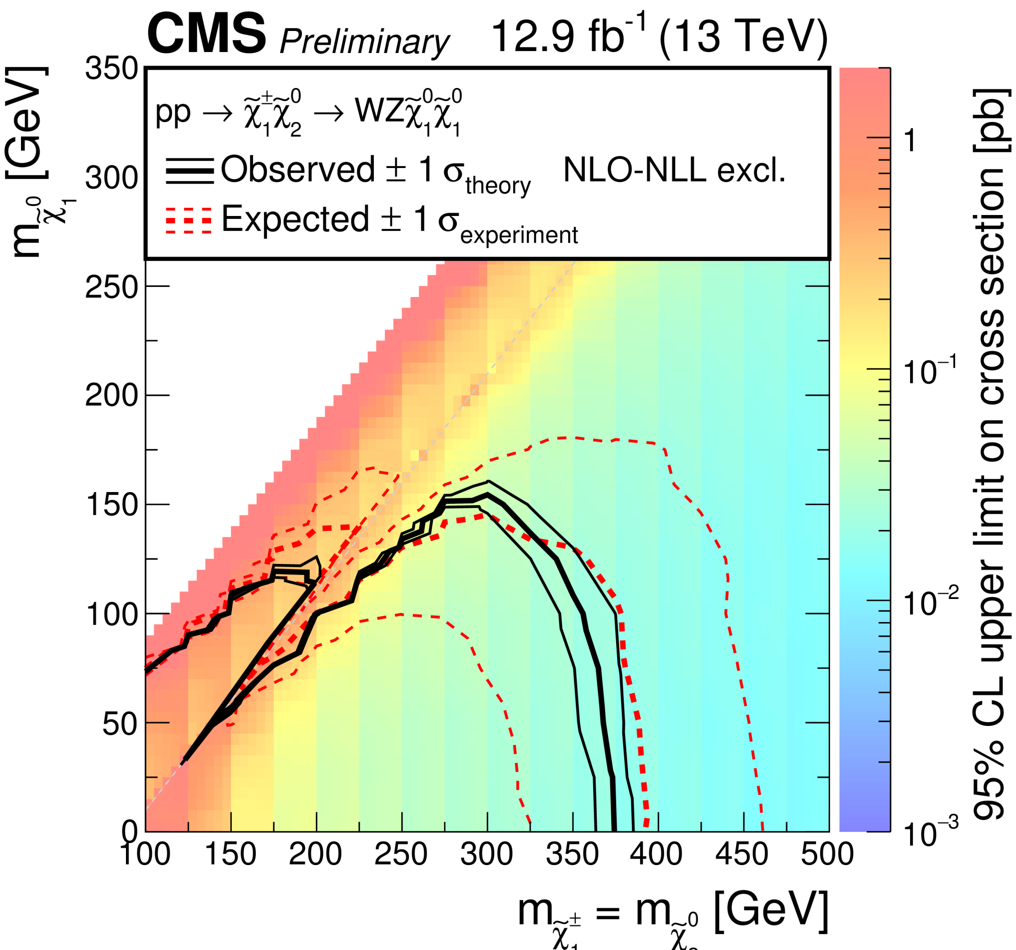
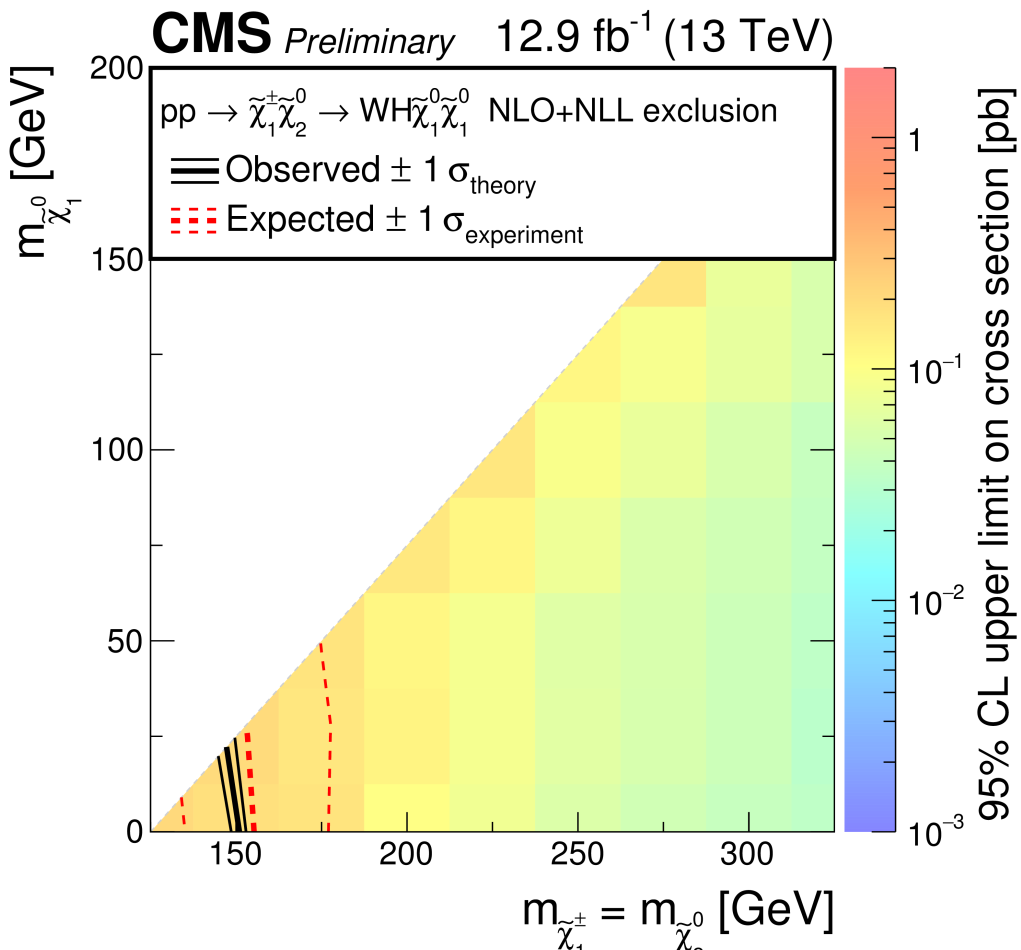
Interpretation II

3 lepton signal region interpreted in terms of chargino-neutralino EW production assuming heavy sleptons and decay into W, Z and h bosons









dilepton searches

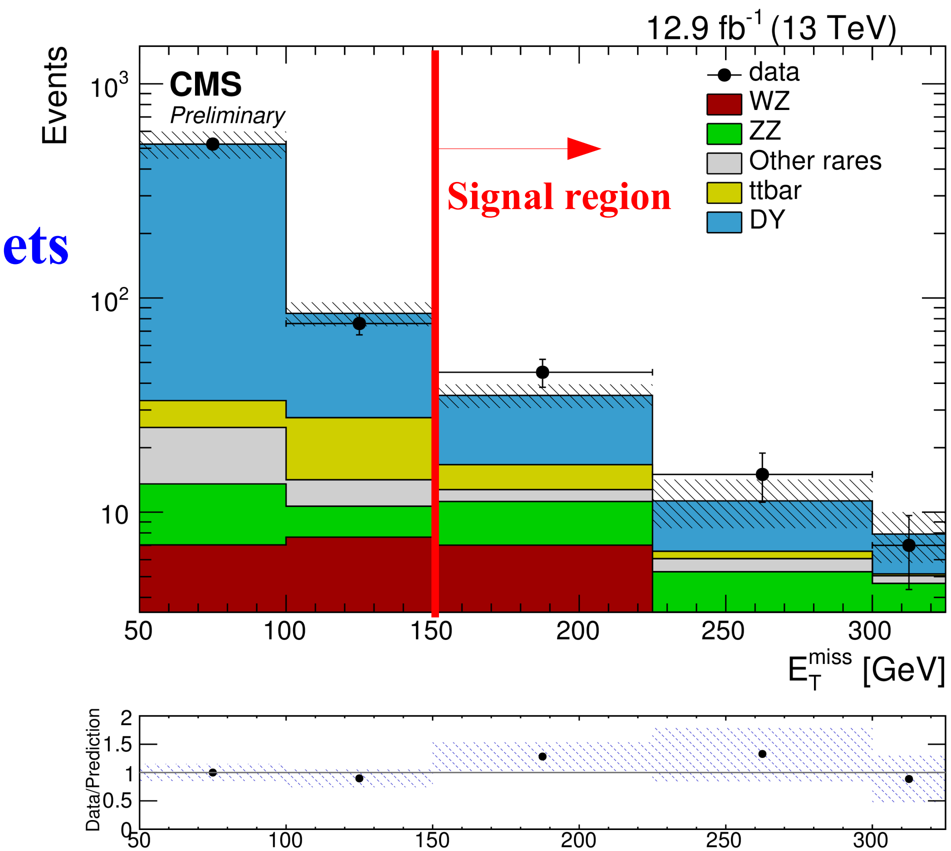
OSSF dilepton search - revisiting the on-Z search

- **select events with 2 OSSF leptons (pT > 25/20 GeV)** and :

  MET > 150 GeV

  at least 2 jets

  dilepton invariant mass in [81-101] GeV



- **binning in number of jets & number of b-jets**

- **signal region in MET bins (+ATLAS SR)**

- **background estimation :**

  - DY from gamma+jets control region

  - emulation of MT2 variable

- **Search strategy :**

  - defined by applying tighter cuts on MT2, MET and angular distance between MET and jet to suppress background from ttbar and fake MET

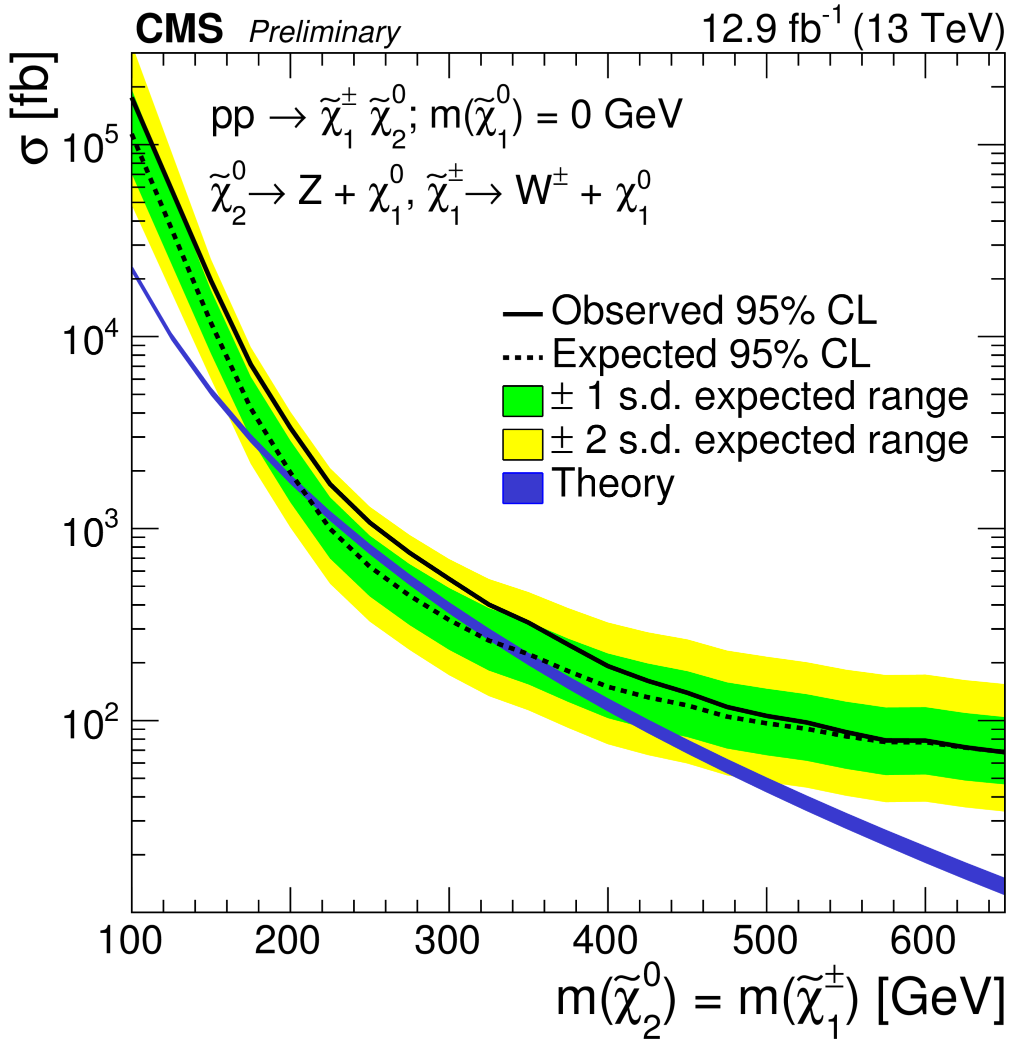
dilepton searches

OSSF dilepton search - revisiting the on-Z search

- no evidence for new phenomena

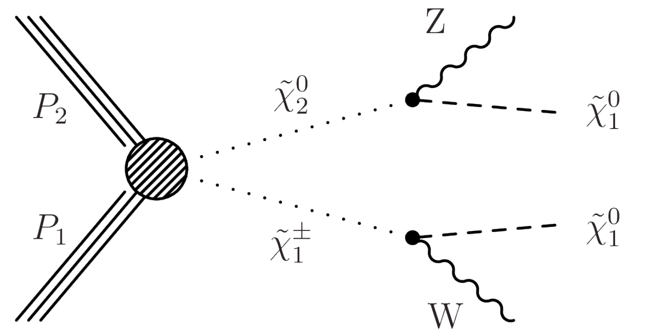
  - put limits on simplified model of chargino-neutralino production assuming heavy sleptons and decay to W/Z bosons

  - observed limits are weaker than expected



Soft OS dilepton searches

- **motivated by SUSY scenarii with small mass splitting : compressed SUSY**



- **look for final states with :**
  - 2 **soft** OS leptons (ee/mumu) with pT in [5 (3.5) – 30] GeV
  - MET
  - at least 1 jet

- **design a dedicated trigger strategy**
  - 2 low pT muons with MET
  - increase sensitivity by factor 2

Variable	SR selection criteria
N_ℓ	$= 2$ (ee,$\mu\mu$, eμ)
$Q(\ell_1)Q(\ell_2)$	-1
$p_T(\ell_1)$, $p_T(\ell_2)$	$[5, 30]$ GeV
$p_T(\mu_2)$ for high E_T^{miss} $\tilde{t}$-like SR	$[3.5, 30]$ GeV
$\|\eta_\mu\|$	< 2.4
$\|\eta_e\|$	< 2.5
$d_z(\ell_{1,2})$ & $d_{xy}(\ell_{1,2})$	< 0.01 cm
$Iso_{rel}(\ell_{1,2})$ & $Iso_{abs}(\ell_{1,2})$	< 0.5 & < 5 GeV
$p_T(jet1)$	> 25 GeV
$\|\eta\|(jet1)$	< 2.4
N_b (>25 GeV, CSVL)	$= 0$
$M(\ell\ell)$	< 50 GeV
$p_T(\ell\ell)$	> 3 GeV
E_T^{miss}	> 125 GeV
E_T^{miss} (muon subtracted)	> 125 GeV
E_T^{miss} / H_T	$[0.6, 1.4]$
H_T	> 100 GeV
$M(\ell\ell)$	> 4 GeV
$M(\ell\ell)$	veto$[9, 10.5]$ GeV
$M_{\tau\tau}$	veto$[0, 160]$ GeV
$M_T(\ell_x, E_T^{miss}), x = 1, 2$	< 70 GeV (for electroweakino selection only)

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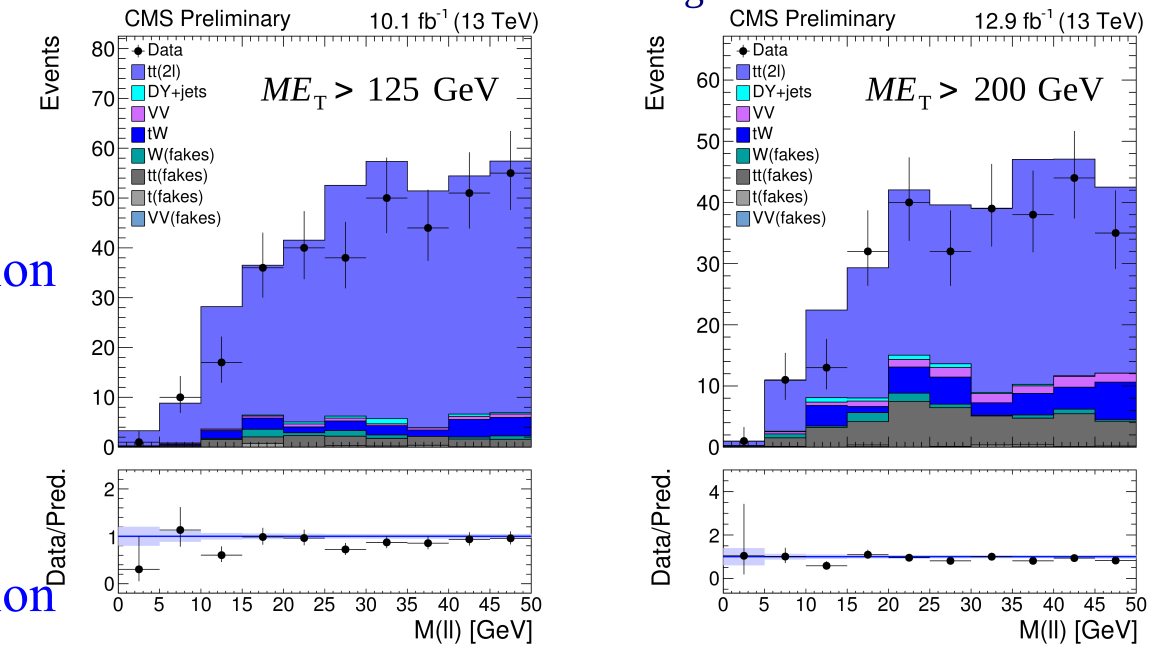
Soft OS dilepton searches

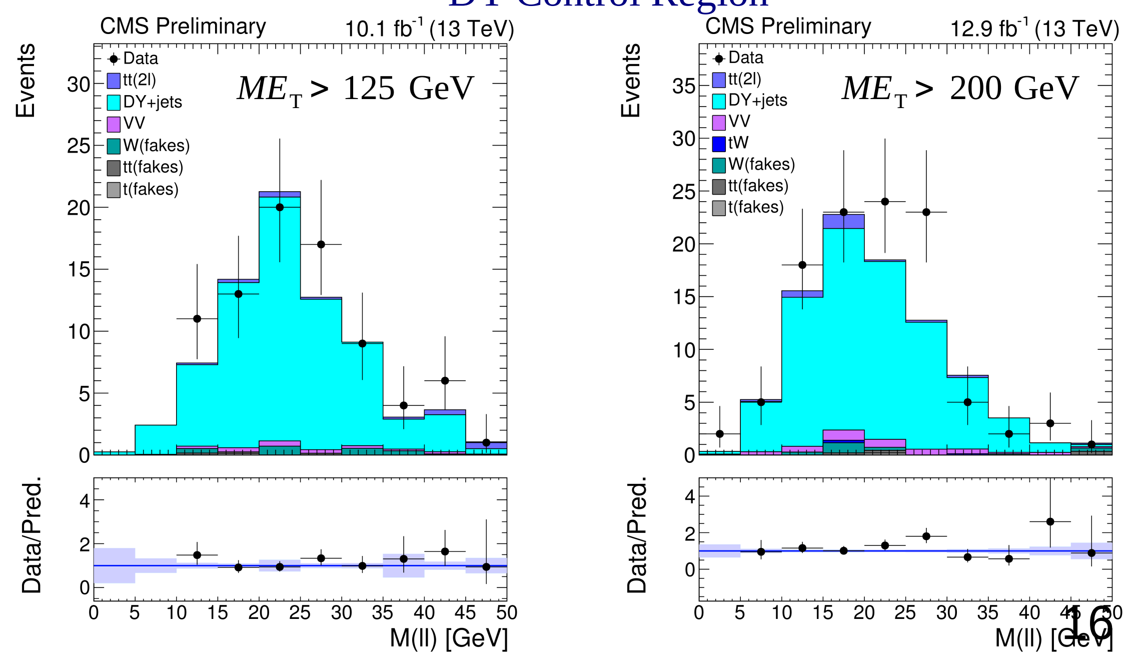
background estimation methods

- **dileptonic ttbar**
  - shape from MC
  - normalised in dedicated data control region
  - extrapolation to signal region from MC
- **Drell-Yan**
  - shape from MC
  - normalised in dedicated data control region
  - extrapolation to signal region from MC
- **VV**
  - from MC, validated in data
- **Non-prompt**
  - from data, using tight-to-loose method
- **Rare SM processes**
  - from MC

$t\bar{t}$ Control Region



DY Control Region



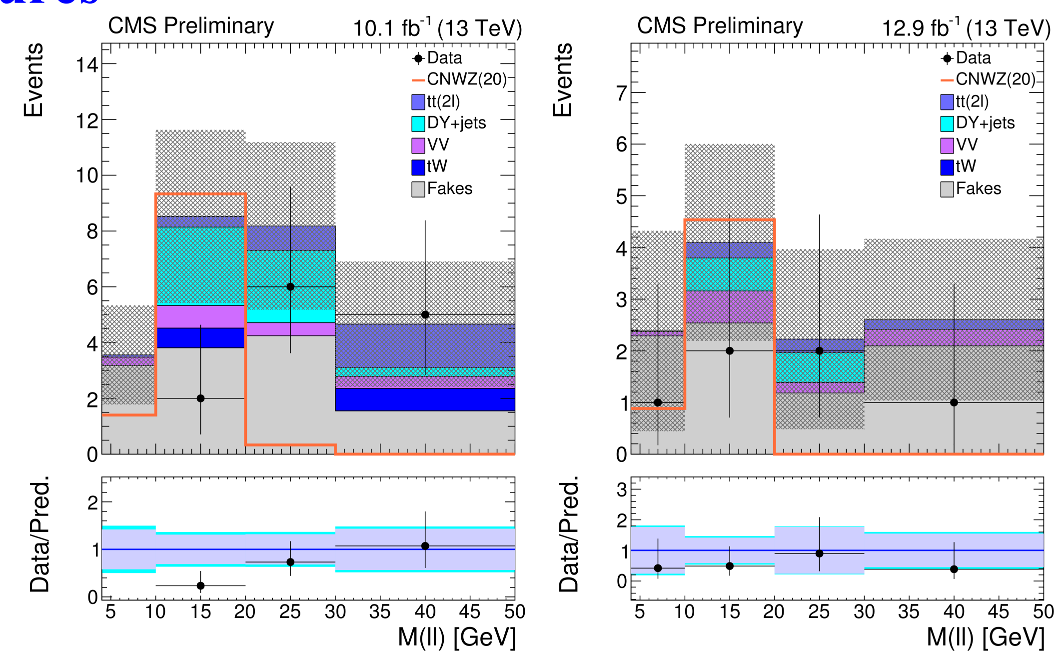
CMS-PAS-SUS-16-025

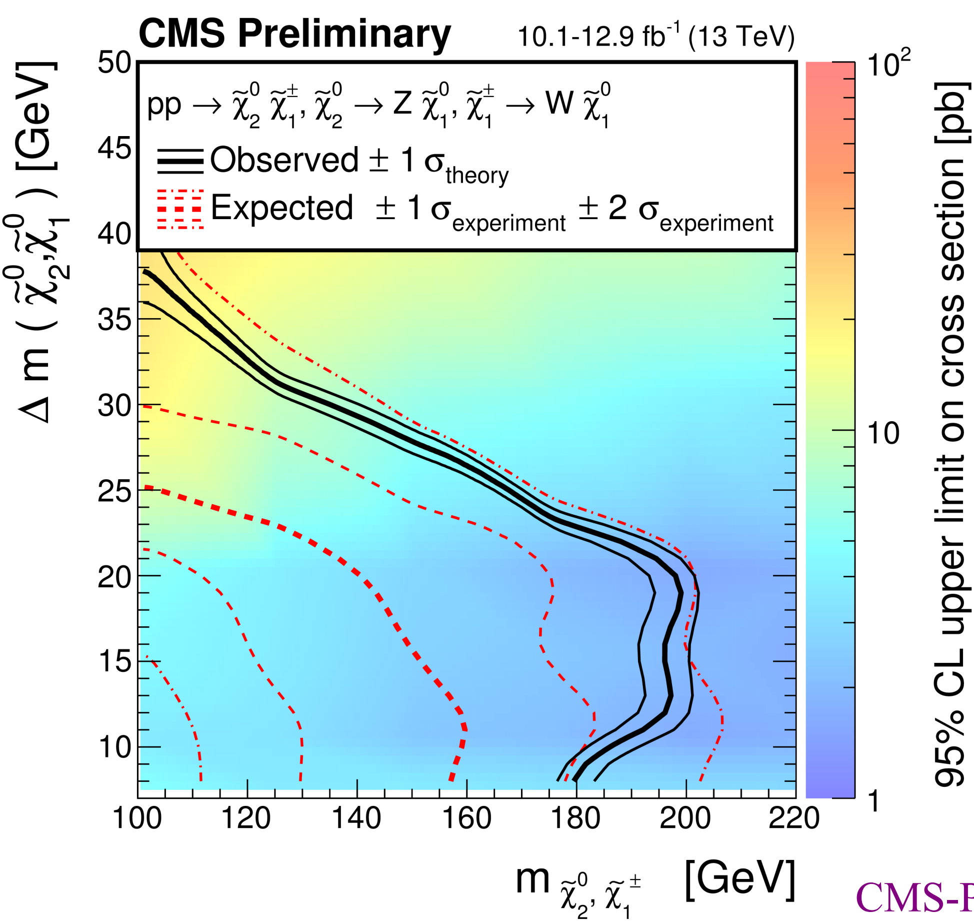
Soft OS dilepton searches

interpretations

- selection **optimized for EWKinos signatures**

  signal regions defined by binning in the invariant mass of the dilepton pair





- **complementary search**

  → probe a much more compressed region of phase

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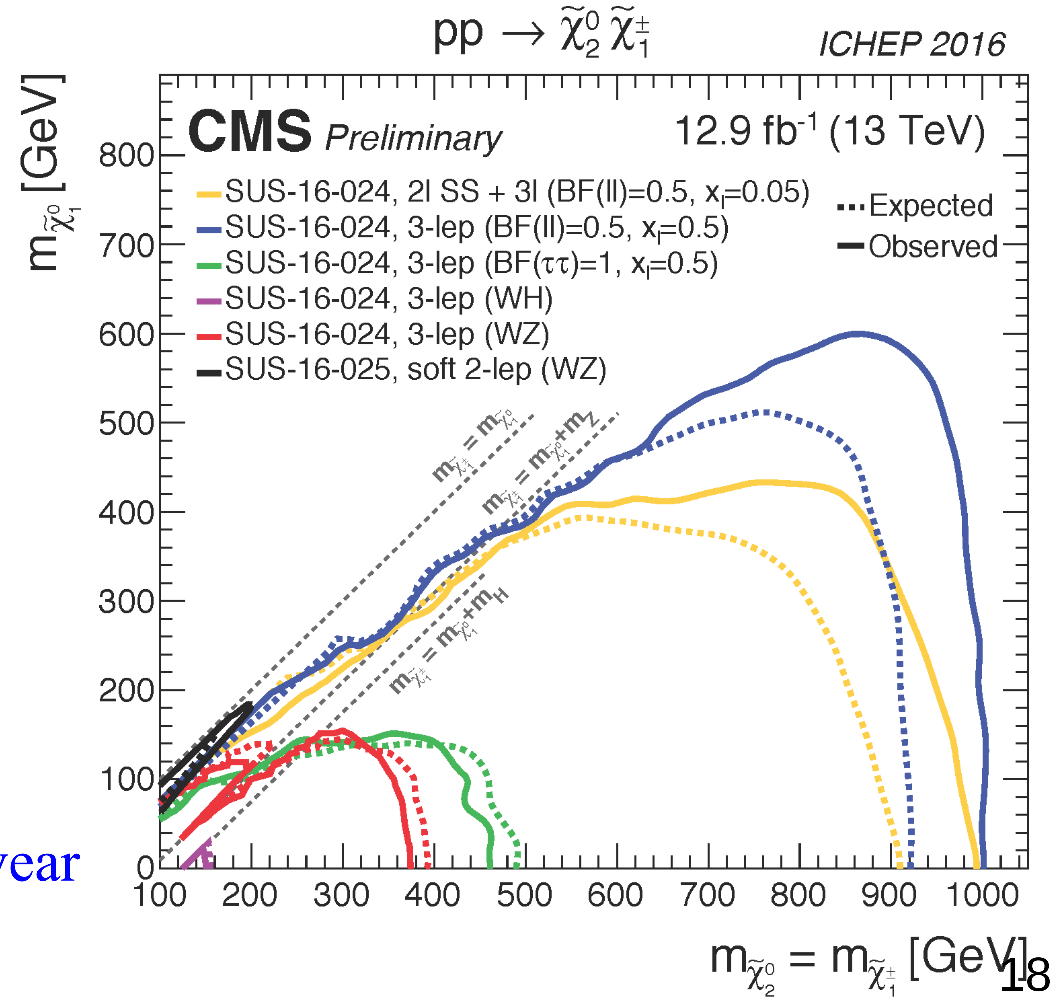
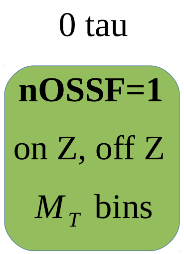
Summary

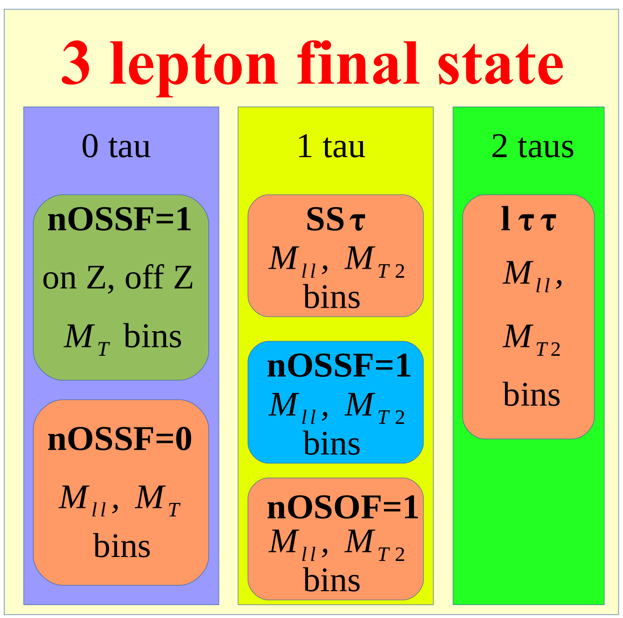
- extended 8 TeV searches, improved search strategy and increase sensitivity almost everywhere
- many final states probing different regions of phase space
- no evidence for new phenomena
- results interpreted in the context of simplified model of chargino-neutralino
- final states were combined to improve sensitivity
- need more data to probe some regions of the phase space
- LHC is performing extremely well
  - more results to come by the end of this year
  - stay tuned !



BACKUP

3 lepton channel results





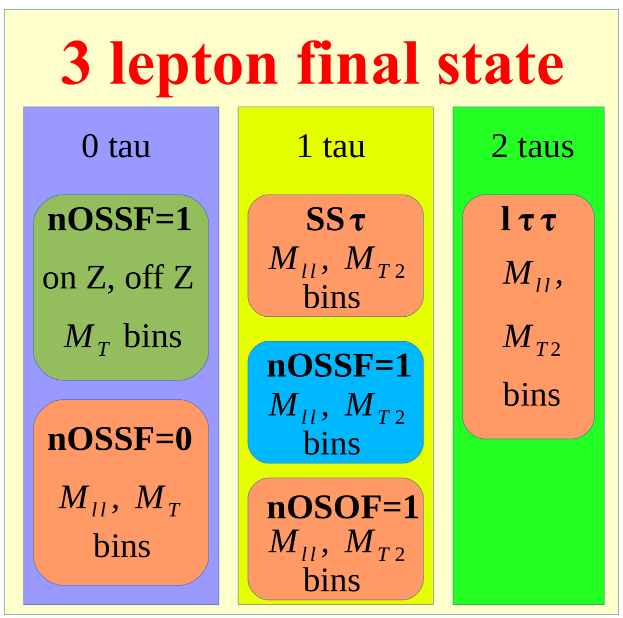
M_T (GeV)	E_T^{miss} (GeV)	$M_{\ell\ell} < 75$ GeV	75 GeV $\leq M_{\ell\ell} <$ 105 GeV	$M_{\ell\ell} \geq 105$ GeV
0 – 120	50 – 100	SR A01	SR A13	SR A25
	100 – 150	SR A02	SR A14	SR A26
	150 – 200	SR A03	SR A15	SR A27
	> 200	SR A04	SR A16	SR A28
120 – 160	50 – 100	SR A05	SR A17	SR A29
	100 – 150	SR A06	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

M_T (GeV)	E_T^{miss} (GeV)	$m_{\ell\ell} < 75$ GeV		$75 \leq m_{\ell\ell} < 105$ GeV		$m_{\ell\ell} \geq 105$ GeV	
0 – 120	50 – 100	82 ± 11	94	900 ± 100	933	56 ± 8	40
	100 – 150	20 ± 4	22	170 ± 33	175	14 ± 3	11
	150 – 200	4.4 ± 1.3	4	49 ± 12	48	3.7 ± 1.0	6
	> 200	2.3 ± 0.6	2	36 ± 10	35	4.6 ± 1.4	5
120 – 160	50 – 100	8.0 ± 2.2	14	40 ± 16	41	4.7 ± 1.5	4
	100 – 150	2.5 ± 1.0	4	8.0 ± 2.9	7	1.8 ± 0.6	2
	150 – 200	0.7 ± 0.3	0	1.2 ± 0.6	3	0.8 ± 0.3	0
	> 200	0.4 ± 0.3	0	1.4 ± 0.9	0	0.3 ± 0.2	0
> 160	50 – 100	5.0 ± 1.5	3	13 ± 4	11	3.5 ± 1.1	2
	100 – 150	5.2 ± 1.4	7	9.0 ± 2.5	5	4.0 ± 1.2	6
	150 – 200	1.3 ± 0.5	2	3.4 ± 1.2	3	0.9 ± 0.3	0
	> 200	1.6 ± 0.6	1	2.9 ± 0.9	5	1.3 ± 0.4	0

3 lepton channel results

0 tau

nOSSF=0
M_{ll}, M_T
bins



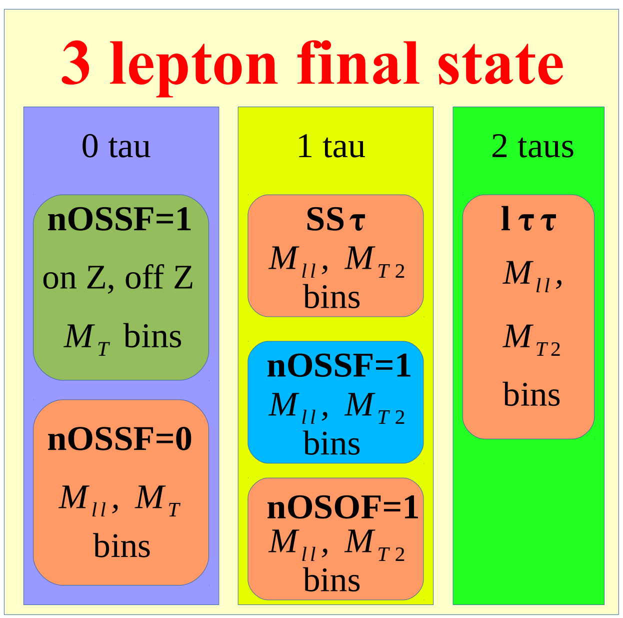
M_T (GeV)	E_T^{miss} (GeV)	$M_{\ell\ell} < 100$ GeV	$M_{\ell\ell} \geq 100$ GeV
$0-120$	$50-100$	SR B01	SR B04
	> 100	SR B02	SR B05
> 120	> 50	SR B03	SR B06

M_T (GeV)	E_T^{miss} (GeV)	$m_{\ell\ell} < 100$ GeV		$m_{\ell\ell} \geq 100$ GeV	
$0-120$	$50-100$	29 ± 7	26	2.6 ± 1.0	1
	> 100	9.8 ± 2.6	12	0.8 ± 0.3	1
> 120	> 50	13 ± 3	11	3.0 ± 1.1	3

3 lepton channel results

1 tau

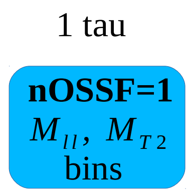
SS τ
M_{ll}, M_{T2}
bins



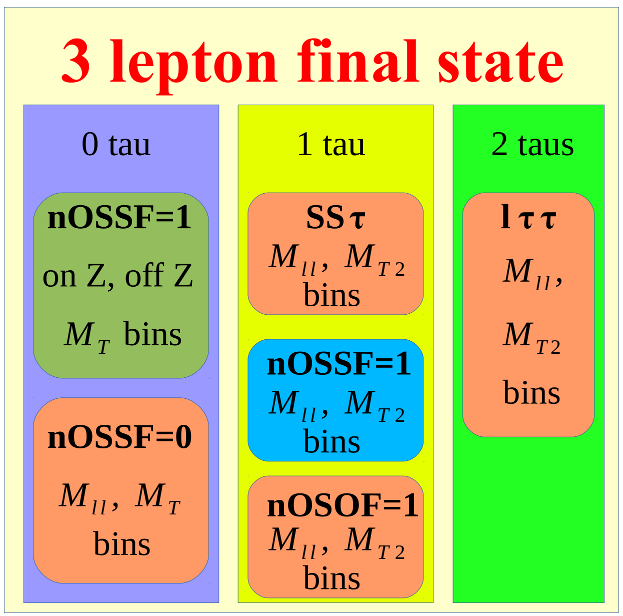
$M_{T2}(\ell_1, \tau)$ (GeV)	E_T^{miss} (GeV)	$M_{\ell\ell} < 60$ GeV	$60 \leq M_{\ell\ell} < 100$ GeV	$M_{\ell\ell} \geq 100$ GeV
< 100	$50 - 100$	SR E01	SR E05	SR E09
	$100 - 150$	SR E02	SR E06	
	$150 - 200$	SR E03	SR E07	
	> 200	SR E04	SR E08	
≥ 100	> 50	SR E10		

$M_{T2}(l, \tau)$ (GeV)	E_T^{miss} (GeV)	$m_{\ell\ell} < 60$ GeV	$60 \leq m_{\ell\ell} < 100$ GeV	$m_{\ell\ell} \geq 100$ GeV
< 100	$50 - 100$	19 ± 4 20	16 ± 4 26	1.6 ± 0.7 4
	$100 - 150$	4.5 ± 1.5 8	3.4 ± 1.0 5	
	$150 - 200$	1.4 ± 0.6 0	0.7 ± 0.3 1	
	> 200	0.9 ± 0.3 0	0.5 ± 0.2 0	
≥ 100	> 50	1.3 ± 0.5 1		

3 lepton channel results



$M_{T2}(\ell_1,\ell_2)$ (GeV)	E_T^{miss} (GeV)	$M_{\ell\ell} < 75$ GeV	$75\,\text{GeV} \leq M_{\ell\ell} < 105$ GeV	$M_{\ell\ell} \geq 105$ GeV
< 100	$50 - 100$	SR C01	SR C05	SR C09
	$100 - 150$	SR C02	SR C06	SR C10
	$150 - 200$	SR C03	SR C07	SR C11
	> 200	SR C04	SR C08	SR C12
≥ 100	$50 - 200$	SR C13	SR C05 – SR C07	SR C13
	> 200	SR C14	SR C08	SR C14

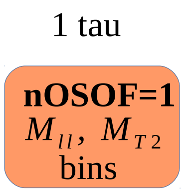


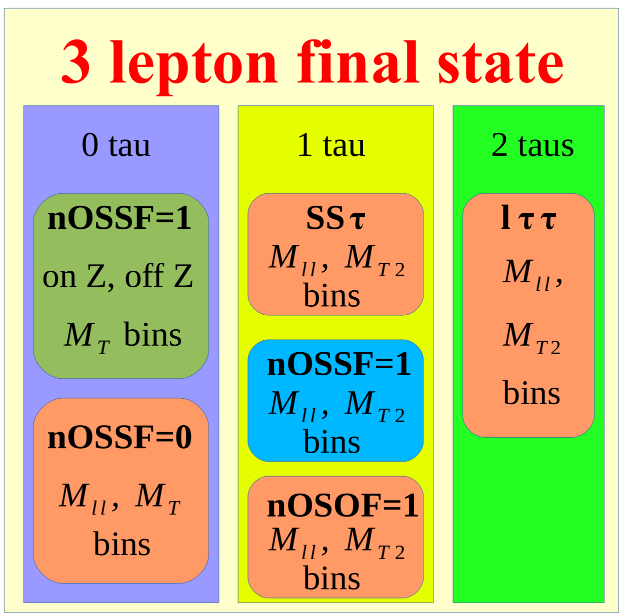
regions where there is a Z candidate are not split in MT2 categories.

$M_{T2}(l,l)$ (GeV)	E_T^{miss} (GeV)	$m_{\ell\ell} < 75$ GeV		$75 \leq m_{\ell\ell} < 105$ GeV		$m_{\ell\ell} \geq 105$ GeV	
< 100	$50 - 100$	200 ± 50	162	1000 ± 300	1007	120 ± 33	114
	$100 - 150$	25 ± 7	27	38 ± 8	35	31 ± 9	20
	$150 - 200$	4.0 ± 1.5	2	11.3 ± 2.6	7	6.3 ± 2.2	7
	> 200	3.3 ± 1.4	2	7.6 ± 1.8	7	4.3 ± 1.5	7

$M_{T2}(l,l)$ (GeV)	E_T^{miss} (GeV)	off-Z	
≥ 100	$50 - 200$	3.7 ± 1.1	6
	> 200	0.5 ± 0.2	0

3 lepton channel results

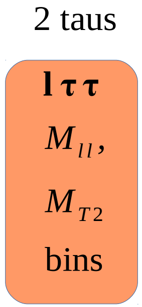




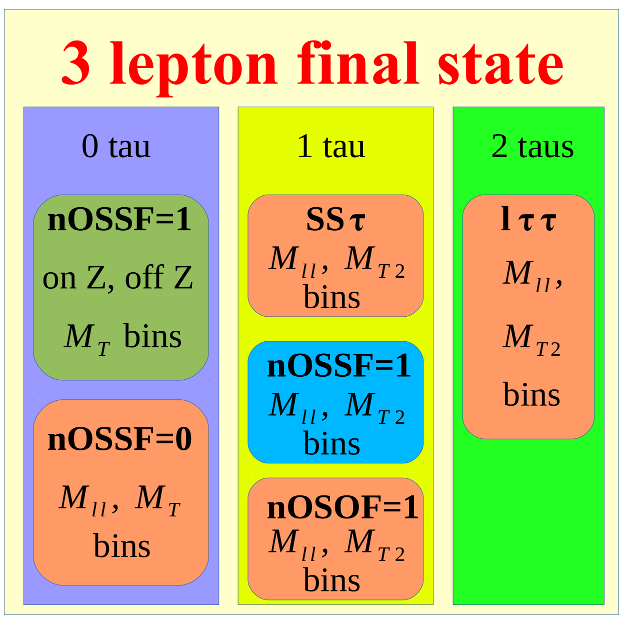
$M_{T2}(\ell_1,\ell_2)$ (GeV)	E_T^{miss} (GeV)	$M_{\ell\ell} < 60$ GeV	$60 \leq M_{\ell\ell} < 100$ GeV	$M_{\ell\ell} \geq 100$ GeV
< 100	$50 - 100$	SR D01	SR D05	SR D09
	$100 - 150$	SR D02	SR D06	SR D10
	$150 - 200$	SR D03	SR D07	SR D11
	> 200	SR D04	SR D08	SR D12
≥ 100	$50 - 200$	SR D13		
	> 200	SR D14		

$M_{T2}(l,l)$ (GeV)	E_T^{miss} (GeV)	$m_{\ell\ell} < 60$ GeV		$60 \leq m_{\ell\ell} < 100$ GeV		$m_{\ell\ell} \geq 100$ GeV	
< 100	$50 - 100$	100 ± 30	82	97 ± 28	83	23 ± 7	25
	$100 - 150$	41 ± 12	27	32 ± 10	26	8.1 ± 2.7	7
	$150 - 200$	8.3 ± 2.5	10	8.5 ± 2.8	6	2.5 ± 1.1	4
	> 200	4.8 ± 1.8	3	2.7 ± 1.1	6	1.4 ± 0.7	2
≥ 100	$50 - 200$	3.5 ± 1.4			1		
	> 200	0.3 ± 0.3			0		

3 lepton channel results



$M_{T2}(\ell,\tau_1)$ (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	



$M_{T2}(l,\tau)$ (GeV)	E_T^{miss} (GeV)	$m_{\ell\ell} < 100$ GeV		$m_{\ell\ell} \geq 100$ GeV	
< 100	$50 - 100$	100 ± 28	82	30 ± 8	20
	$100 - 150$	16 ± 5	17	7.0 ± 2.1	6
	> 150	6.5 ± 2.1	3	2.4 ± 0.9	2
≥ 100	$50 - 200$	2.9 ± 1.2		1	
	> 200	0.5 ± 0.4		1	

4 lepton channel results

4 lepton final state

- 0 tau
  - **nOSSF=2**: ME_T bins
  - **nOSSF ≤1**: ME_T bins
- 1 tau
  - ME_T bins

E_T^{miss} (GeV)	$0\tau_h$		$\geq 1\tau_h$
	nOSSF ≥ 2	nOSSF ≤ 1	nOSSF ≥ 0
$0-30$	SR G01	SR H01	SR I01
$30-50$	SR G02	SR H02	SR I02
$50-100$	SR G03	SR H03	SR I03
>100	SR G04	SR H04	SR I04

E_T^{miss} (GeV)	$0\tau_h$				$\geq 1\tau_h$	
	nOSSF ≥ 2		nOSSF ≤ 1		nOSSF ≥ 0	
$0-30$	148 ± 40	193	3.1 ± 0.8	3	10.9 ± 2.6	19
$30-50$	50 ± 12	62	1.8 ± 0.4	0	7.8 ± 2.0	9
$50-100$	12.7 ± 2.9	11	2.7 ± 0.5	5	9.0 ± 2.3	6
>100	2.5 ± 0.5	2	3.5 ± 1.0	3	2.1 ± 0.7	2

Ewkinos in multileptons systematic uncertainties

Source	estimated uncertainty (%)
e/μ selection	3
τ_h selection	6
Trigger efficiency	1–4
Jet energy scale	2–10
b tag veto	5
Pileup	1–5
Integrated luminosity	6.2
Theoretical ($t\bar{t}Z$ and $t\bar{t}W$)	15
Theoretical (ZZ)	25
Conversions	20-50
Other backgrounds	50
Monte Carlo statistical precision	1–30
Nonprompt leptons	30–36
Charge misidentification	30
WZ normalization	9–11
WZ shape	10–80

CMS-PAS-SUS-16-024

dilepton searches

OSSF dilepton search - revisiting the on-Z search

- **ATLAS Signal Region (SR)**

$$p_T^{\text{leading lepton}} > 50 \text{ GeV} \quad , \quad p_T^{\text{subleading lepton}} > 25 \text{ GeV}$$

$$H_T + p_T^{l1} + P_T^{l2} > 600 \text{ GeV}$$

$$E_T^{\text{miss}} > 225 \text{ GeV}$$

$$\Delta\varphi\left(\text{each of the leading jets, } E_T^{\text{miss}}\right) > 0.4$$

- reminder

$$M_{T2}^2 \equiv \min_{\not{p}_1 + \not{p}_2 = \not{p}_T} \left[\max\left\{ m_T^2(\boldsymbol{p}_{Tl^-}, \not{p}_1), m_T^2(\boldsymbol{p}_{Tl^+}, \not{p}_2) \right\} \right]$$

CMS-PAS-SUS-16-021

dilepton searches

OSSF dilepton search - revisiting the on-Z search

MET region	150 – 225 GeV	225 – 300 GeV	$\geq$ 300 GeV
Other rare	1.53 ± 0.79	0.80 ± 0.45	0.40 ± 0.23
WZ	7.01 ± 2.16	2.67 ± 0.85	2.61 ± 0.84
ZZ	4.20 ± 1.98	2.60 ± 1.36	2.03 ± 1.08
DY prediction	18.28 ± 2.91	4.69 ± 2.32	2.73 ± 1.56
$t\bar{t}$	3.91 ± 1.36	0.50 ± 0.27	0.10 ± 0.11
Total bkg	34.9 ± 4.4	11.3 ± 2.9	7.9 ± 2.1
Observed	45	15	7

CMS-PAS-SUS-16-021

dilepton searches

OSSF dilepton search - revisiting the on-Z search

Source of uncertainty	Uncertainty (%)
Luminosity	6.2
Pileup	0-3
b tag modeling	0-5
Lepton reconstruction and isolation	7
Fast simulation scale factors	4-5
Fast simulation MET uncertainty	1-10
Trigger modeling	5
Jet energy scale	1-5
ISR modeling	0-10
Statistical uncertainty	1-9
Total uncertainty	12-16

CMS-PAS-SUS-16-021

Soft OS dilepton searches

Process	E_T^{miss} = [125-200]			
	$4 < M(\ell\ell) < 10$	$10 < M(\ell\ell) < 20$	$20 < M(\ell\ell) < 30$	$30 < M(\ell\ell) < 50$
$t\bar{t}(2\ell)$	0.1 ± 0.1	0.4 ± 0.2	0.9 ± 0.3	1.6 ± 0.5
DY	$0.0 + 0.05$	2.8 ± 1.4	2.6 ± 1.0	0.3 ± 0.2
VV	0.3 ± 0.2	0.8 ± 0.4	0.5 ± 0.2	0.4 ± 0.2
tW	$0.0 + 0.2$	0.7 ± 0.9	$0.0 + 0.2$	0.8 ± 1.0
Non-prompt leptons	3.2 ± 1.8	3.8 ± 2.6	4.2 ± 2.8	1.6 ± 2.0
Total SM prediction	3.6 ± 1.8	8.5 ± 3.1	8.2 ± 3.0	4.7 ± 2.3
Data	0	2	6	5

Process	E_T^{miss} = [200-inf]			
	$4 < M(\ell\ell) < 10$	$10 < M(\ell\ell) < 20$	$20 < M(\ell\ell) < 30$	$30 < M(\ell\ell) < 50$
$t\bar{t}(2\ell)$	$0.0 + 0.05$	0.3 ± 0.3	0.3 ± 0.2	0.2 ± 0.2
DY	$0.0 + 0.05$	0.6 ± 0.3	0.6 ± 0.4	$0.0 + 0.05$
VV	0.1 ± 0.1	0.6 ± 0.4	0.2 ± 0.1	0.3 ± 0.2
Non-prompt leptons	2.3 ± 1.9	2.5 ± 1.9	1.2 ± 1.7	2.1 ± 1.5
Total SM prediction	2.4 ± 2.1	4.1 ± 2.0	2.2 ± 1.8	2.6 ± 1.6
Data	1	2	2	1

Soft OS dilepton searches

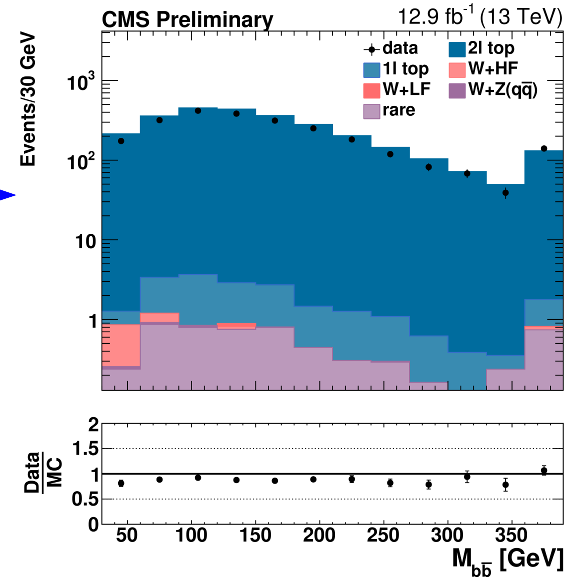
Systematic uncertainty source	typical uncertainty
$t\bar{t}$ and DY+jets stat. unc. from MC	5-20%
$t\bar{t}$ modeling	$\lesssim 5$ %
"Tight to loose ratio" closure in MC	5-25%
DY+jets closure in data	$\lesssim 5$ %
VV cross section	5-10%
tW cross section	5-10 %
Lepton/Trigger/b-tag SF	1-6 %
Jet energy scale	1-5 %

Single lepton + 2 b quarks

Chargino-neutralino production & decay to WH with $H \rightarrow 2b$

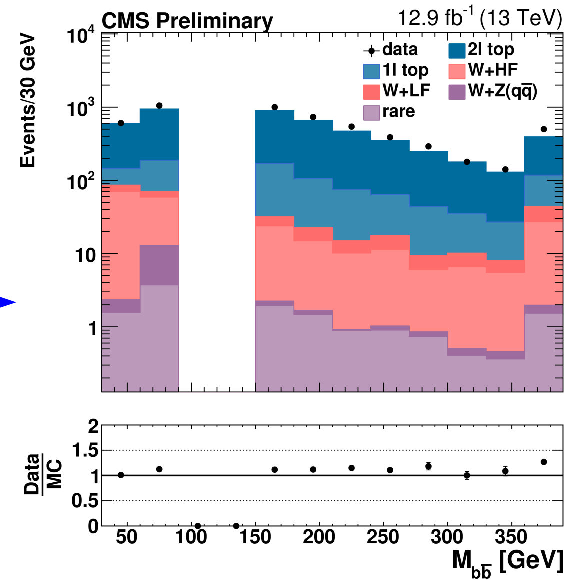
CMS-PAS-SUS-16-026

- **select events with one lepton (pT > 30/25 GeV)** and :
  - 2 b-jets
  - MET > 100 GeV
  - MT and MCT > 150 GeV (to suppress semileptonic ttbar)



- **Signal region :**
  - defined by asking Mbb to be compatible with Higgs mass
  - look for resonance in the Mbb spectrum

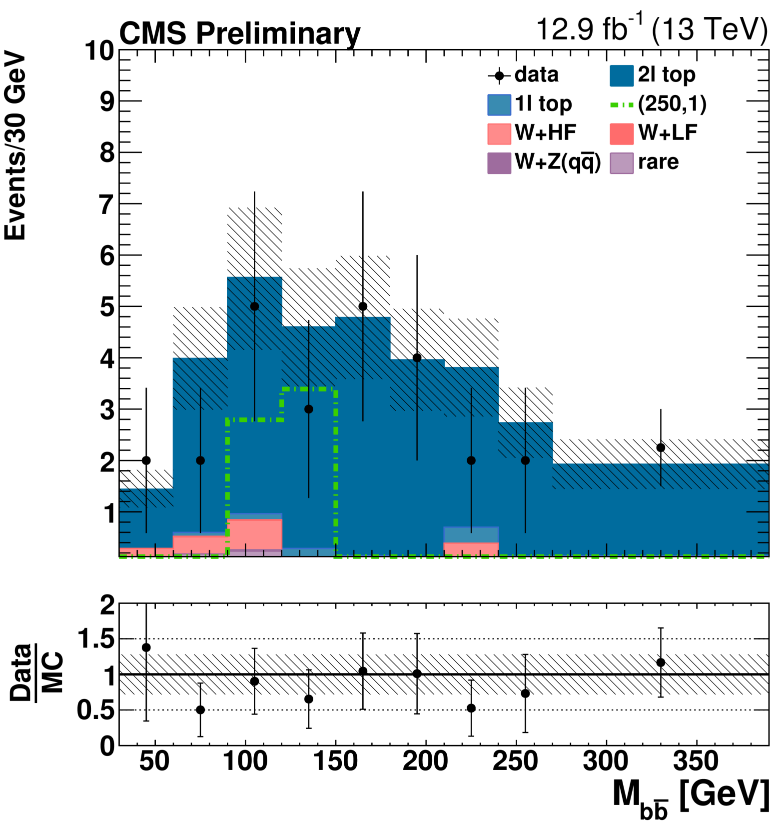
- **Background**
  - from MC with dedicated control region to assess the modeling of most relevant background (dil. ttbar and W+jets)
  - Mbb modelled checked in dilepton control region
  - MET, MT and MCT in orthogonal sample built by inverting the Mbb requirement
  - a b-jet veto control region is used to assess the modelling of the W+jets background

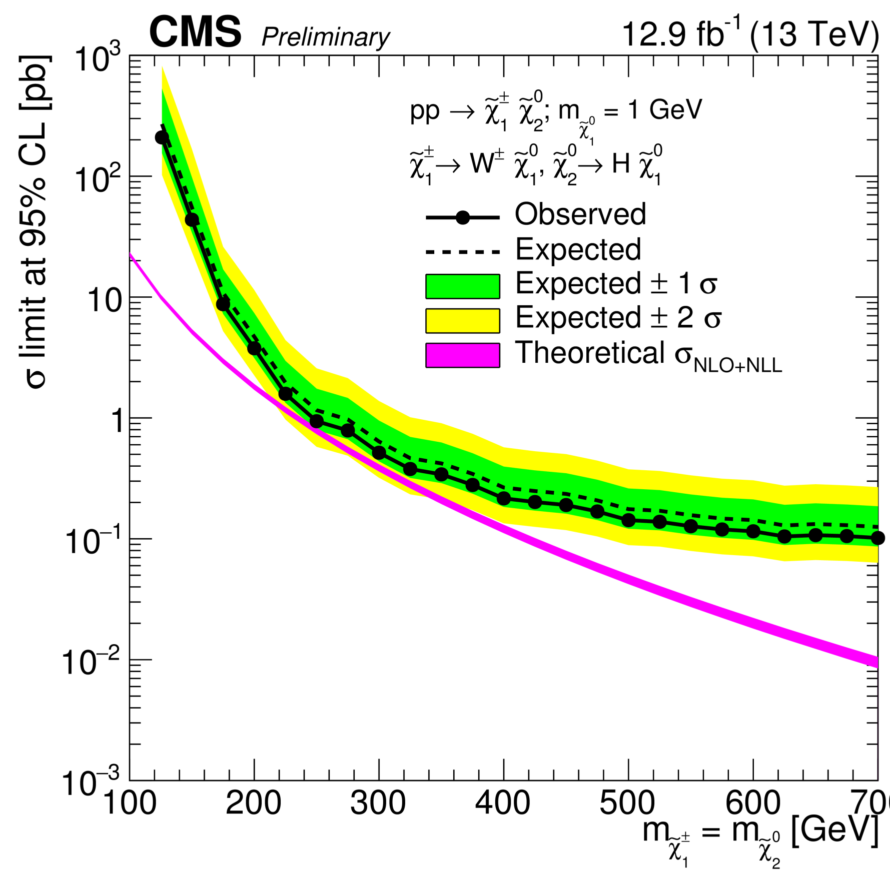


Single lepton + 2 b quarks

Chargino-neutralino production & decay to WH with H → 2b

- **No significant deviation w.r.t. SM prediction**
- Set limits on chargino-neutralino production decaying into WH

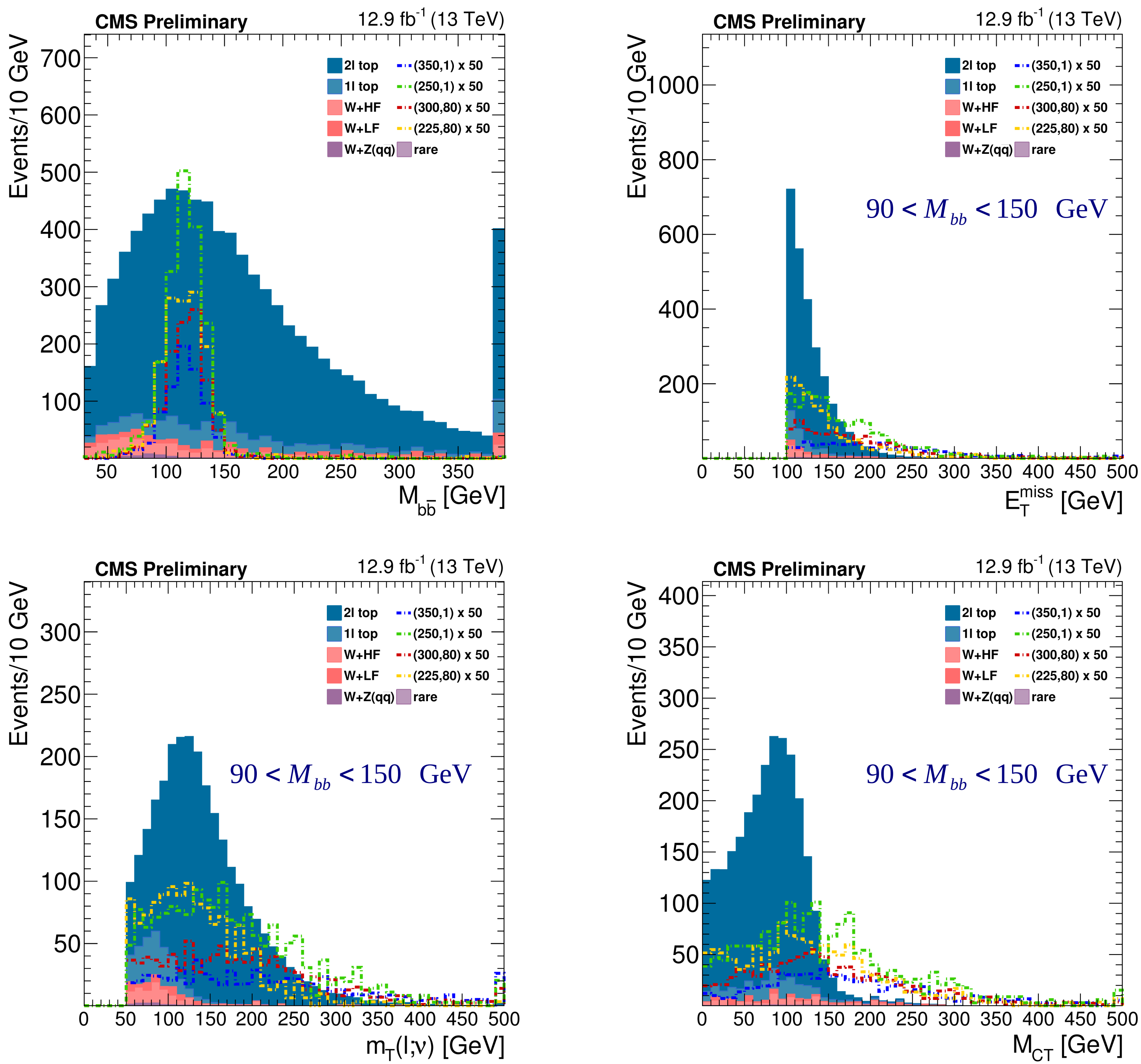




current dataset is at the edge of the sensitivity
more data is needed to probe this phase-space

CMS-PAS-SUS-16-026

Single lepton + 2 b quarks



$$M_T = \sqrt{2\ p_T^l\ E_T^{\text{miss}}\left(1 - \cos\left(\Delta\varphi\right)\right)}$$

$$M_{CT} = \sqrt{2\ p_T^{b1}\ p_T^{b2}\left(1 + \cos\left(\Delta\varphi_{bb}\right)\right)}$$

CMS-PAS-SUS-16-026

Single lepton + 2 b quarks

Chargino-neutralino production & decay to WH with H → 2b

data	8
Dilepton top quark	8.9 ± 2.0
W + light jets	0.01 ± 0.01
W + HF	0.7 ± 0.5
$WZ \rightarrow \ell\nu b\bar{b}$	0.03 ± 0.03
Single lepton top quark	0.3 ± 0.3
Rare	0.3 ± 0.2
Total bkg	10.3 ± 2.1
$(m_{\tilde{\chi}_1^\pm}, m_{\tilde{\chi}_1^0})$ (225,75)	1.7 ± 0.3
$(m_{\tilde{\chi}_1^\pm}, m_{\tilde{\chi}_1^0})$ (250,1)	5.6 ± 0.8
$(m_{\tilde{\chi}_1^\pm}, m_{\tilde{\chi}_1^0})$ (300,75)	4.1 ± 0.5
$(m_{\tilde{\chi}_1^\pm}, m_{\tilde{\chi}_1^0})$ (350,1)	4.1 ± 0.4

Source	Typical Values
Integrated luminosity	6.2%
MC statistics	3–40%
Renormalization and factorization scales	1–3%
B-tagging efficiency	2–3%
Lepton efficiency	2–5%
Trigger efficiency	1–5%
Jet energy scale	1–27%
Fastsim E_T^{miss} resolution	5–50%

CMS-PAS-SUS-16-026