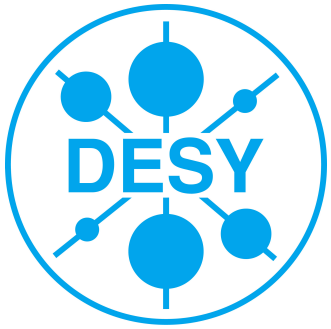


Search for sleptons and charginos at CMS

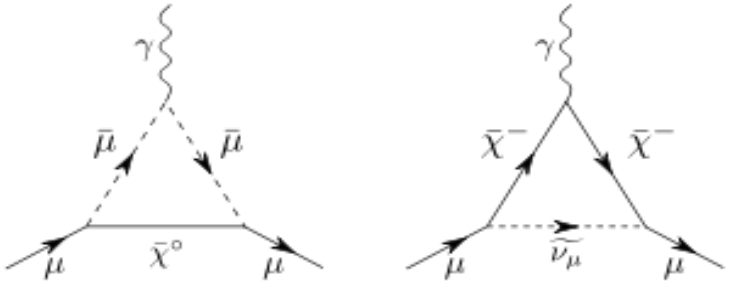
Ilya Bobovnikov on behalf of the CMS collaboration

DESY

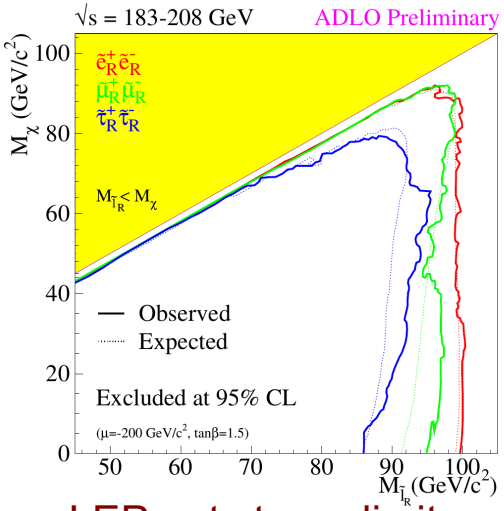
SUSY17, TIFR, Mumbai

Introduction

- LSP co-annihilation with light stau could bring the neutralino relic density to the observed value
- SUSY can explain ~3σ deviation of muon g – 2 from SM prediction → light electroweak sector



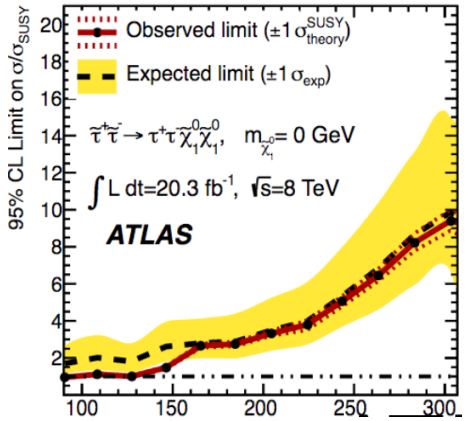
LEP results



LEP put strong limits on slepton masses

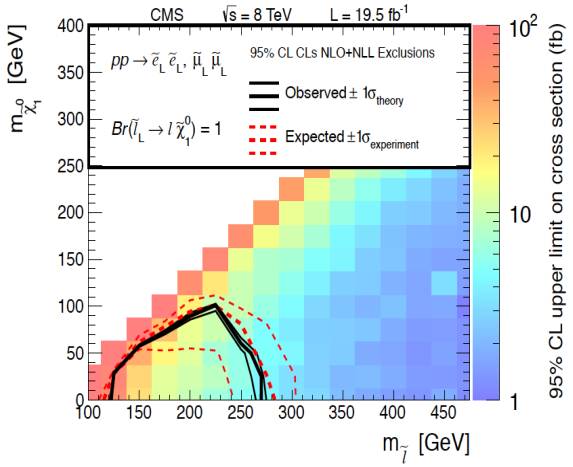
LHC Run1 results

Stau



ATLAS (arxiv:1407.0350)
Only one additional point excluded at 8TeV @ 20 fb^{-1}

Smuon and Selectron

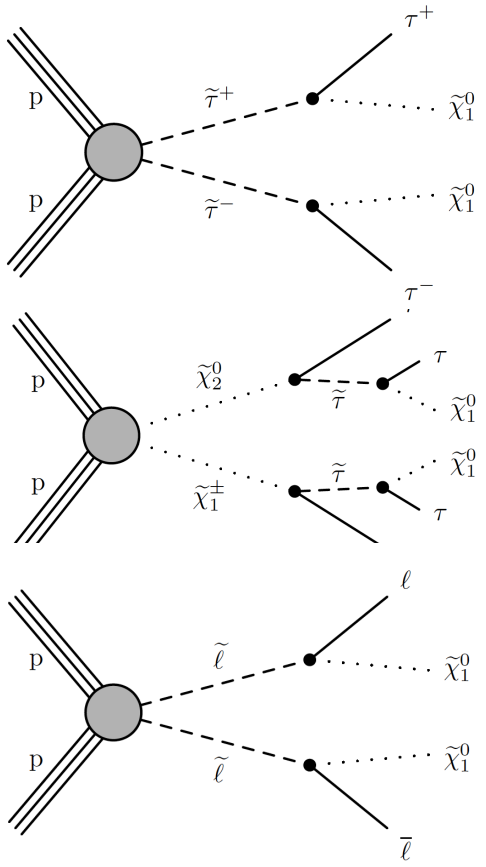


Limits up to 270 GeV for Left-handed scenario

Covered the slepton searches

All results are based on 36 fb^{-1} of data collected at $\sqrt{s}$ = 13 TeV during 2016 at the CMS experiment

- Stau production
  - search in the all-hadronic tau decay final state ($\tau_h\tau_h$) SUS-17-003
  - search in semi-hadronic and leptonic tau decay final state ($\mu\tau_h$, $e\tau_h$, $e\mu$) SUS-17-002 NEW!
- Smuon and selectron production
  - search two opposite-charge, same-flavor (OCSF) leptons ($\mu^{\pm}\mu^{\mp}$, $e^{\pm}e^{\mp}$) SUS-17-009 NEW!



Search strategy $\tau_h\tau_h$

SUS-17-003

Selection

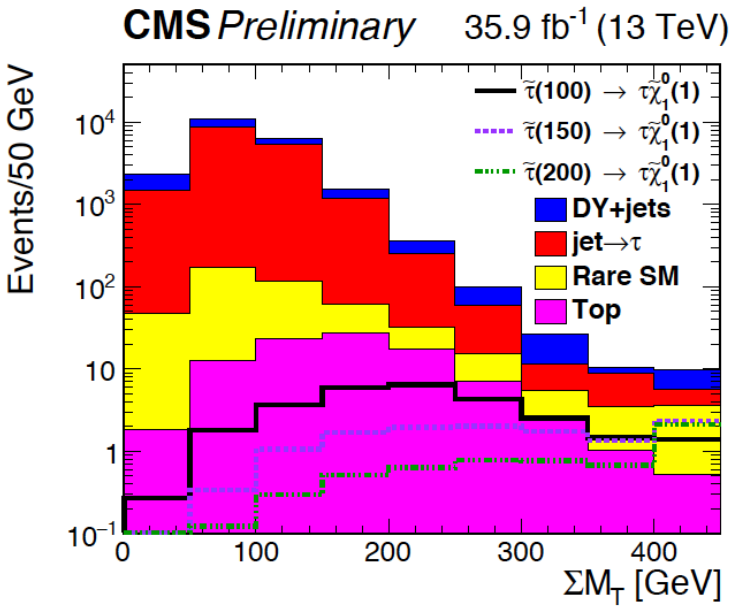
- Opposite charge pair of identified isolated taus
- No additional leptons
- Number of b-tagged jets = 0

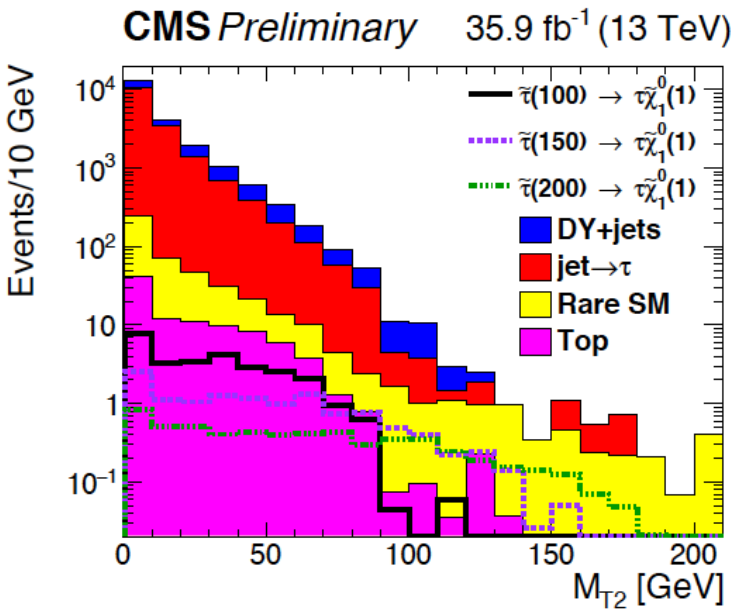
Background estimation

- Z+jets: Check DY mass and pT spectrum in dimuon CR and correct the simulation for any discrepancies
- QCD, W+Jets: Background if jet fakes tau - fake rate derived in same sign data events and parameterized as function of pT and decay mode
- Other rare backgrounds taken from simulation

3 Signal regions

low mass	low mass	high mass
$40\,\text{GeV} < M_{T2} < 90\,\text{GeV}$	$40\,\text{GeV} < M_{T2} < 90\,\text{GeV}$	$M_{T2} > 90\,\text{GeV}$
$\Sigma M_T > 350\,\text{GeV}$	$300\,\text{GeV} < \Sigma M_T < 350\,\text{GeV}$	$\lvert\Delta\phi(l_1, l_2)\rvert > 1.5$
$E_T^{miss} > 50\,\text{GeV}$	$E_T^{miss} > 50\,\text{GeV}$	
$\lvert\Delta\phi(l_1, l_2)\rvert > 1.5$	$\lvert\Delta\phi(l_1, l_2)\rvert > 1.5$	

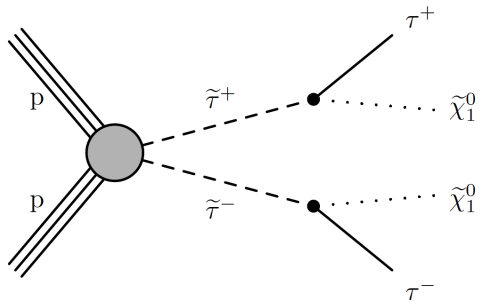


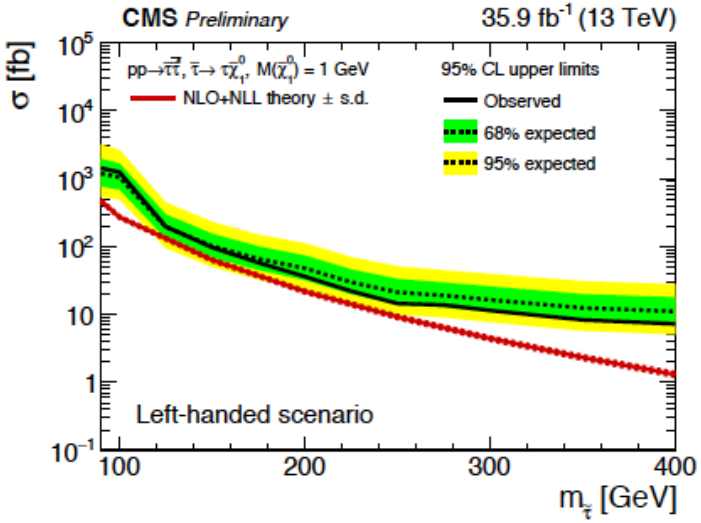


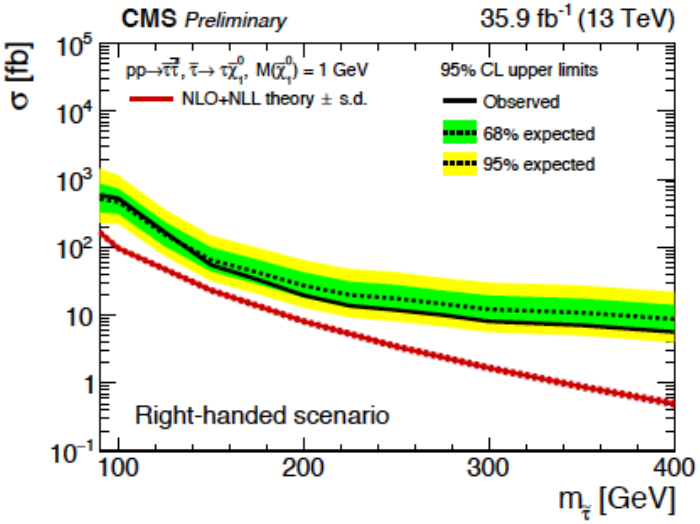
Interpretation $\tau_h\tau_h$

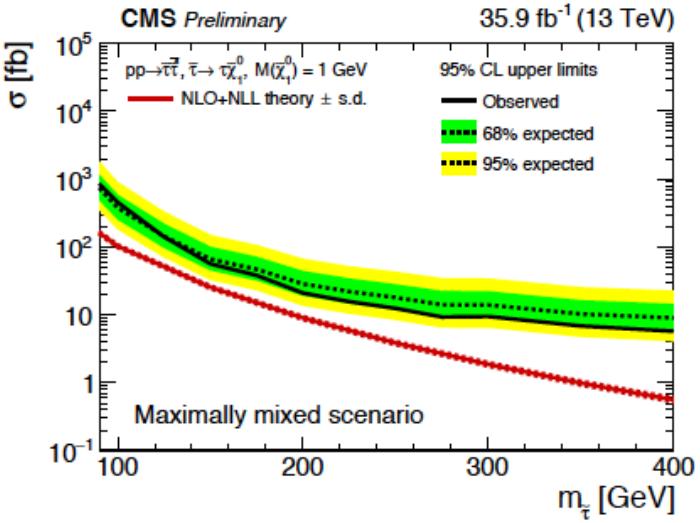
SUS-17-003

Interpretation is done for three different helicity scenarios









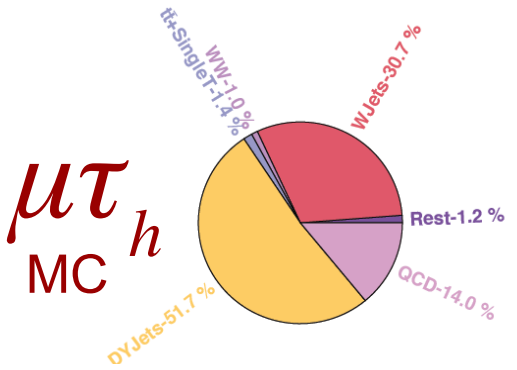
- No significant deviation in any signal region
- Direct stau production not yet excluded due to low cross section
- For left-handed stau of around 125 GeV and a massless LSP we exclude 1.5 times the expected SUSY cross-section.

Search strategy $\mu\tau_h$, $e\tau_h$, $e\mu$

SUS-17-002

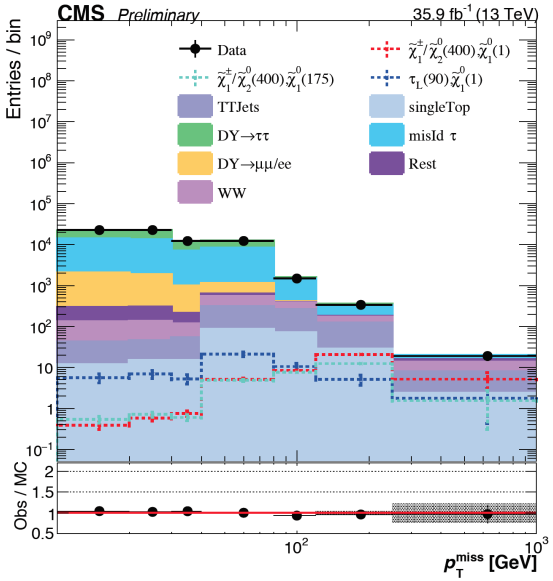
Selection

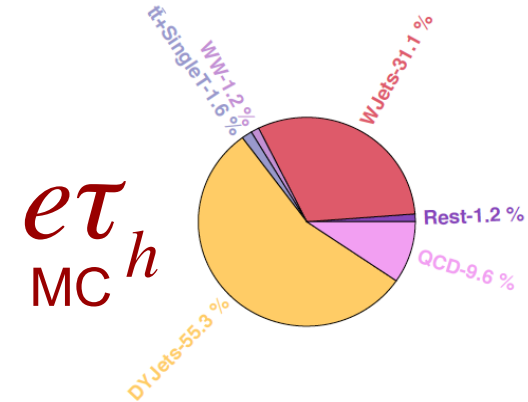
- Opposite charge pair of identified isolated leptons
- No additional leptons
- Number of jets ≤ 1, number of b-tagged jets = 0

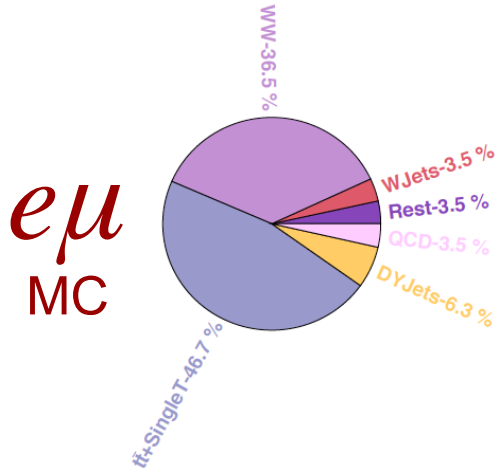


Background estimation

- Z+jets and top pair production: shape from MC is corrected by data in dimuon CR and scaled to normalization from data CR
- Jets misidentified as τ_h (only for $\mu\tau_h$ and $e\tau_h$) and QCD multijet (only for $e\mu$): shape is estimated from data CR and transfer factor is calculated as a ratio of normalizations in from orthogonal CRs
- Other rare backgrounds taken from simulation





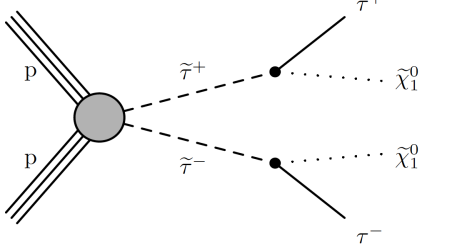


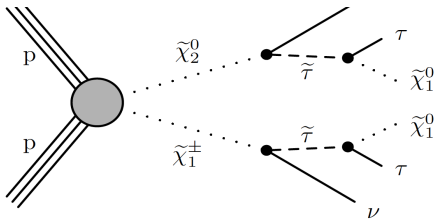
Interpretation $\mu\tau_h$, $e\tau_h$, $e\mu$

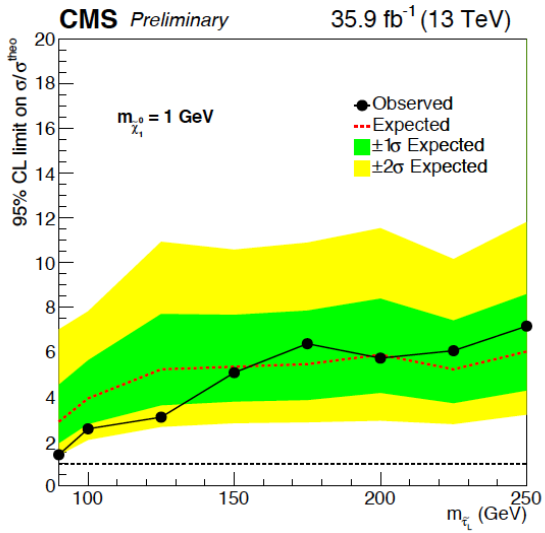
SUS-17-002

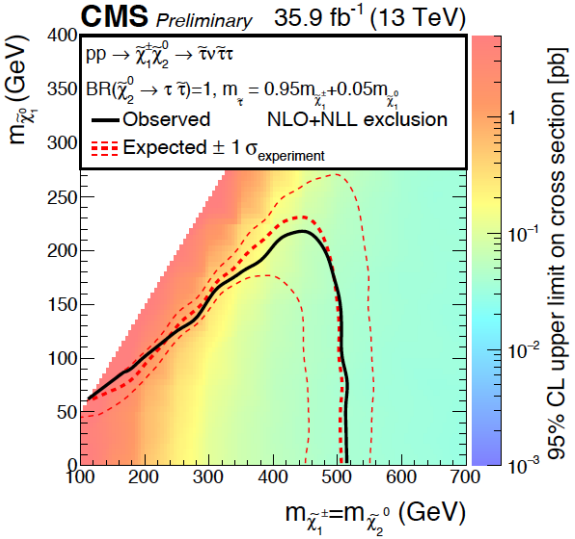
132 search bins are defined with kinematic variables and jet multiplicity

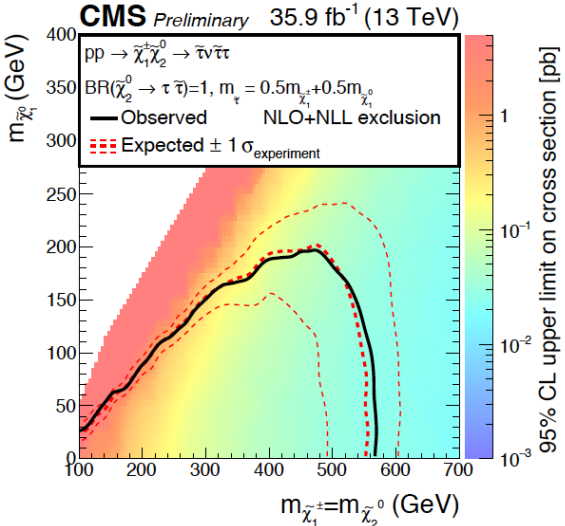
For C1N2 interpretation $m_{\tilde{\tau}} = m_{\tilde{\chi}_1^0} + x(m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0})$

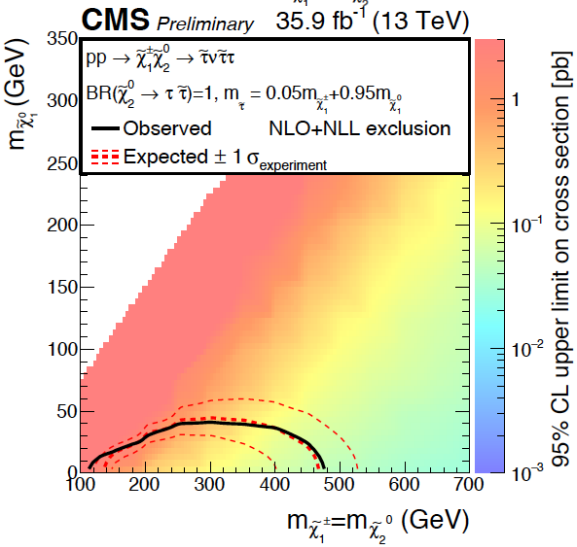












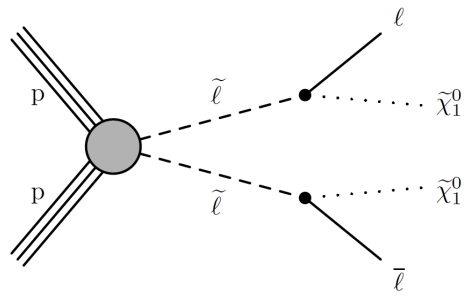
- No significant deviation in any signal region
- Exclude N2 and C1 decaying through staus below 550 GeV
- Direct stau production not yet excluded due to low cross section
- For left-handed stau of around 90 GeV and a massless LSP we exclude 1.5 times the expected SUSY cross-section.

Search strategy $\mu^{\pm}\mu^{\mp}$, $e^{\pm}e^{\mp}$

SUS-17-009

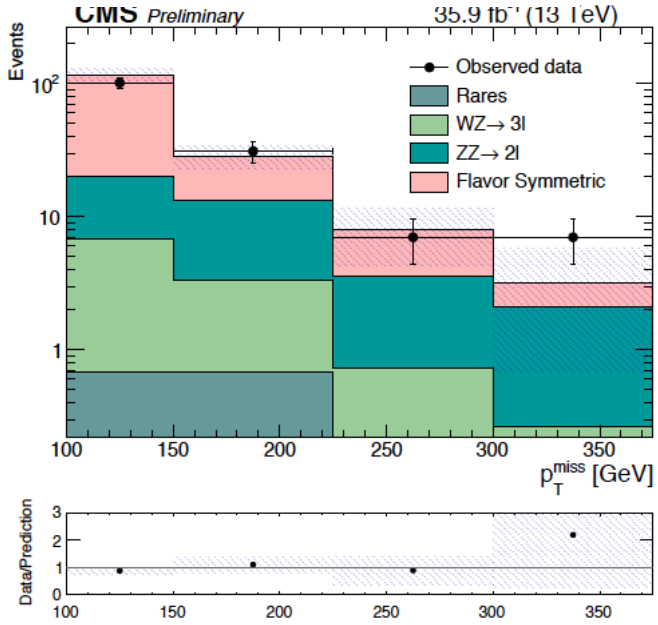
Selection

- Opposite charge pair of identified same flavor muons or electrons
- No additional leptons
- Number of jets = 0



Background estimation

- Top and W pair production (flavor symmetric): Background yields are estimated from opposite flavor CR
- ZZ and WZ: Shape from MC is validated and normalized from data derived from CR



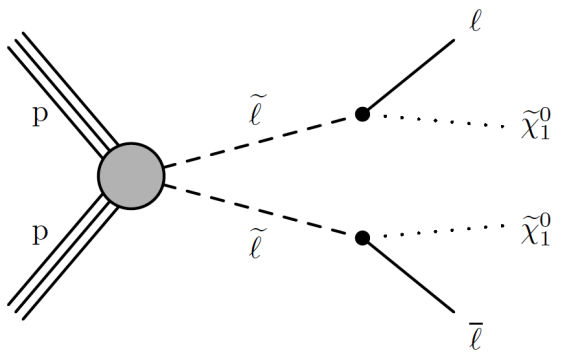
4 Signal regions

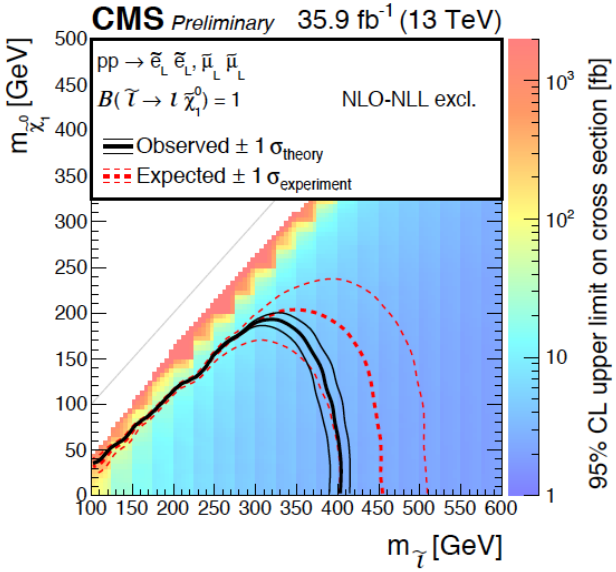
N_{jets}	$m_{\ell\ell}$ [GeV]	$M_{T2}(\ell\ell)$ [GeV]	p_T^{miss} [GeV]
0 (>25 GeV)	>20, <76 or >106	>90	100–150, 150–225, 225–300, 300+

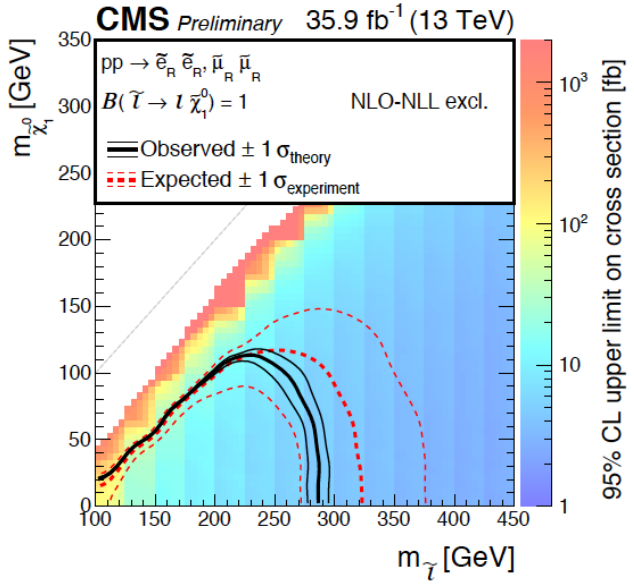
Interpretation $\mu^{\pm}\mu^{\mp}$, $e^{\pm}e^{\mp}$

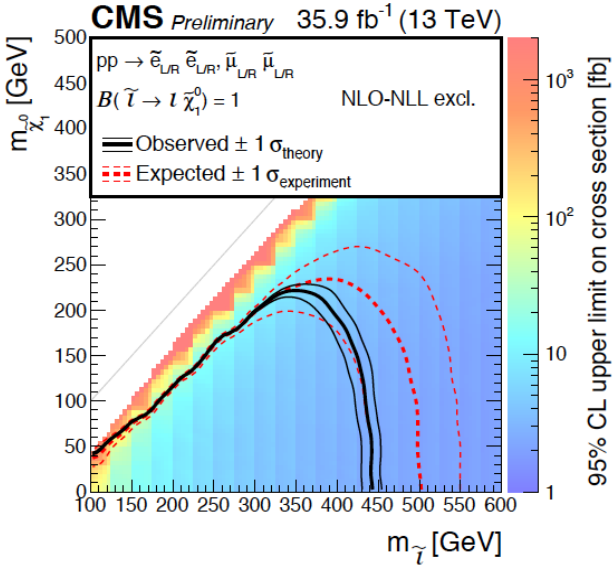
SUS-17-009

Interpretation is done for three different helicity scenarios









- No significant deviation in any signal region
- 8 TeV exclusion is extended by around 100–150 GeV in the slepton mass

Summary

- Search for sleptons and charginos has been presented using 36 fb^{-1} of data collected by CMS
  - Direct stau production ($\tau_h\tau_h$)
    CMS-PAS-SUS-17-003
  - Direct and indirect stau production ($\mu\tau_h$, $e\tau_h$, $e\mu$)
    CMS-PAS-SUS-17-002
  - Smuon and Selectron production ($\mu^{\pm}\mu^{\mp}$, $e^{\pm}e^{\mp}$)
    CMS-PAS-SUS-17-009
- None of the analyses show significant deviation from SM

Backup

Full hadronic stau

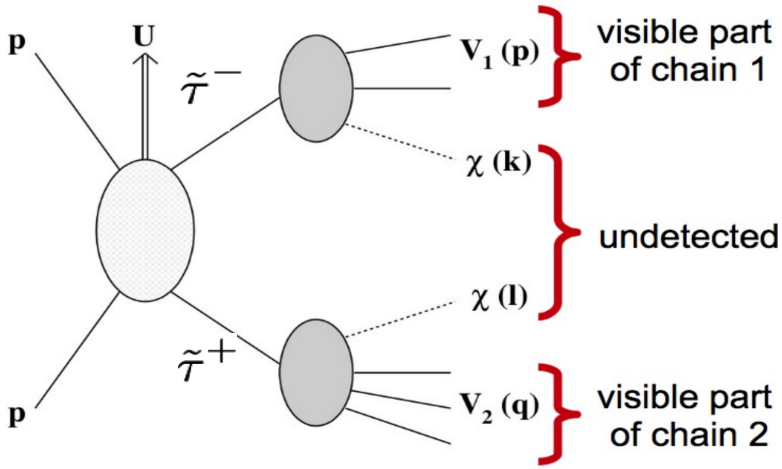
	SR1	SR2	SR3
Non-prompt and misidentified taus	$0.68^{+0.90}_{-0.68}$	2.49 ± 1.83	<1.24
Drell-Yan background	$0.80^{+0.97}_{-0.80}$	< 0.71	< 0.71
Top-quark related background	$0.02^{+0.03}_{-0.02}$	0.73 ± 0.31	1.76 ± 0.68
Rare SM processes	0.72 ± 0.38	0.20 ± 0.15	$0.20 \pm ^{+0.25}_{-0.20}$
Total background	$\mathbf{2.22}^{+1.37}_{-1.12}$	$\mathbf{4.35}^{+1.75}_{-1.53}$	$\mathbf{3.70}^{+1.52}_{-1.08}$
Left (150,1)	1.25 ± 0.40	2.91 ± 0.59	1.53 ± 0.33
Right (150,1)	1.09 ± 0.26	1.27 ± 0.20	0.74 ± 0.17
Mixed (150,1)	1.04 ± 0.22	1.39 ± 0.27	0.92 ± 0.15
Observed	**0**	**5**	**2**

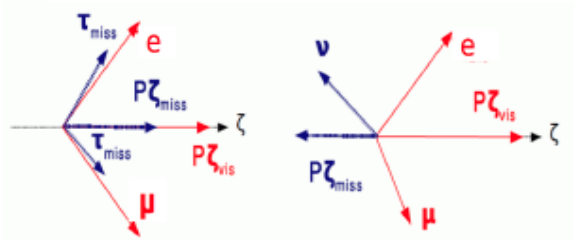
Search variables $\mu\tau_h$, $e\tau_h$, $e\mu$

- E_{Tmiss} – missing transverse energy
- M_{T2} – "stransverse" mass

$$M_{T2}^2 = \min_{\vec{k}_T+\vec{l}_T=\text{tot miss } \vec{p}_T} \left\{ \max\left[M_T^2(\text{chain 1}), M_T^2(\text{chain 2}) \right] \right\} \leq m^2_{\tilde{\tau}}$$

- D_ζ – Discriminant used in legacy Higgs searches



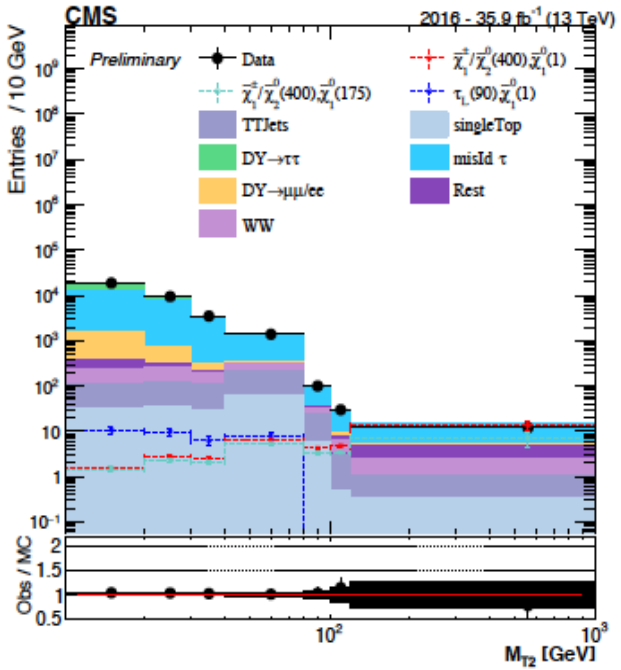


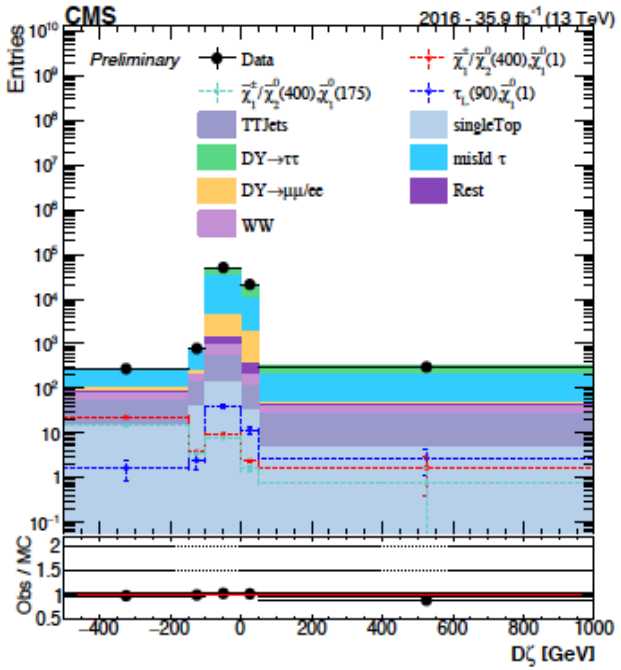
$$D_\zeta = P_{\zeta,\text{mis}} - \alpha \cdot P_{\zeta,\text{vis}}$$

$$P_{\zeta,\text{mis}} = \vec{p}_{T,\text{mis}} \cdot \vec{\zeta}, \quad P_{\zeta,\text{vis}} = (\vec{p}_{T,e} + \vec{p}_{T,\mu}) \cdot \vec{\zeta}$$

ζ – bisector between the direction of the electron and that of the muon

α = 0.85 (optimized value)





Slection $\mu\tau_h$, $e\tau_h$, $e\mu$

Event selection

- Two opposite sign (OS) leptons ($\mu\tau$, eτ, or eμ) with $\Delta R > 0.3$ and no additional leptons
- $n_{\text{jet}} < 2$ and $n_{\text{b-tag}} = 0$
- $M_{\ell_1\ell_2} > 50$ GeV and $M_{\text{Tsum}} > 50$ GeV (low mass-resonances rejection)
- $20 < M_{\text{T}} < 60$ GeV or $M_{\text{T}} > 120$ GeV ($\mu\tau$, eτ channel) (W+jets rejection)
- $90 < M_{\mu e} < 250$ GeV (Z+jets rejection)
- $\text{P}_{\text{T}}(\ell_i) < 200$ GeV (i=e,μ, for the eμ channel only)
- $|d_z(\ell_i)| < 0.2\,\text{cm}, |d_{xy}(\ell_i)| < 0.045\,\text{cm}$ (non-prompt ℓ background rejection)
- $\Delta\eta(J_0, \ell_{1,2}) < 3$ (eτ and $\mu\tau$ channels, 1-jet category only)
- $\Delta R(J_0, \tau) < 4$ (eτ and $\mu\tau$ channels, 1-jet category only)

Search bins

Bin name	p_T^{miss} [GeV]	M_{T2} [GeV]	$D\zeta$ [GeV]	n_{jet}
$p_T^{miss}{}_A M_{T2A} D\zeta_{B-}$	<40	<40	<-100	0
$p_T^{miss}{}_A M_{T2B+} D\zeta_{A+}$		>40	>-500	
$p_T^{miss}{}_B M_{T2A} D\zeta_{B-}$	[40,80]	<40	<-100	
$p_T^{miss}{}_B M_{T2A} D\zeta_{E}$			>50	
$p_T^{miss}{}_B M_{T2B} D\zeta_{B-}$		[40,80]	<-100	
$p_T^{miss}{}_B M_{T2B} D\zeta_{C+}$			>-100	
$p_T^{miss}{}_B M_{T2C+} D\zeta_{A+}$		>80	>-500	
$p_T^{miss}{}_C M_{T2A} D\zeta_{B-}$	[80,120]	<40	<-100	
$p_T^{miss}{}_C M_{T2A} D\zeta_{C+}$			>-100	
$p_T^{miss}{}_C M_{T2B} D\zeta_{B-}$		[40,80]	<-150	
$p_T^{miss}{}_C M_{T2B} D\zeta_{A+}$			>-150	
$p_T^{miss}{}_C M_{T2B+} D\zeta_{A+}$		>80	>-500	
$p_T^{miss}{}_D M_{T2A} D\zeta_{B-}$	[120,250]	<40	<-100	
$p_T^{miss}{}_D M_{T2A} D\zeta_{C+}$			>-100	
$p_T^{miss}{}_D M_{T2B} D\zeta_{B-}$		[40,80]	<-150	
$p_T^{miss}{}_D M_{T2B} D\zeta_{B}$			[-150,-100]	
$p_T^{miss}{}_D M_{T2B} D\zeta_{C+}$			>-100	
$p_T^{miss}{}_D M_{T2C} D\zeta_{A+}$		[80,100]	>-500	
$p_T^{miss}{}_D M_{T2D} D\zeta_{A+}$		[100,120]	>-500	
$p_T^{miss}{}_D M_{T2E} D\zeta_{A+}$		>120	>-500	
$p_T^{miss}{}_E M_{T2A+} D\zeta_{A+}$	>250	>0	>-500	

Bin name	p_T^{miss} [GeV]	M_{T2} [GeV]	$D\zeta$ [GeV]	n_{jet}
$p_T^{miss}{}_A M_{T2A} D\zeta_{B-}$	<40	<40	<-150	1
$p_T^{miss}{}_A M_{T2A} D\zeta_{B}$			[-150,100]	
$p_T^{miss}{}_A M_{T2A} D\zeta_{D+}$			>0	
$p_T^{miss}{}_A M_{T2A+} D\zeta_{A+}$		>40	>-500	
$p_T^{miss}{}_B M_{T2A} D\zeta_{B-}$	[40,80]		<-100	
$p_T^{miss}{}_B M_{T2A} D\zeta_{E}$		<40	>50	
$p_T^{miss}{}_B M_{T2B} D\zeta_{B-}$		[40,80]	<-100	
$p_T^{miss}{}_B M_{T2B} D\zeta_{C+}$			>-100	
$p_T^{miss}{}_B M_{T2B+} D\zeta_{A+}$		>80	>-500	
$p_T^{miss}{}_C M_{T2A} D\zeta_{B-}$	[80,120]	<40	<-100	
$p_T^{miss}{}_C M_{T2B} D\zeta_{B-}$		[40,80]	<-150	
$p_T^{miss}{}_C M_{T2B} D\zeta_{A+}$			>-150	
$p_T^{miss}{}_C M_{T2CD} D\zeta_{A+}$		[80,120]	>-500	
$p_T^{miss}{}_C M_{T2E} D\zeta_{A+}$		>120	>-500	
$p_T^{miss}{}_D M_{T2A} D\zeta_{B-}$	[120,250]	<40	<-150	
$p_T^{miss}{}_D M_{T2A} D\zeta_{B}$			[-150,-100]	
$p_T^{miss}{}_D M_{T2A} D\zeta_{C+}$			>-100	
$p_T^{miss}{}_D M_{T2B} D\zeta_{B-}$		[40,80]	<-150	
$p_T^{miss}{}_D M_{T2B} D\zeta_{B}$			[-150,-100]	
$p_T^{miss}{}_D M_{T2B} D\zeta_{C+}$			>-100	
$p_T^{miss}{}_D M_{T2C} D\zeta_{A+}$		[80,100]	>-500	
$p_T^{miss}{}_D M_{T2D} D\zeta_{A+}$		[80,120]	>-500	
$p_T^{miss}{}_D M_{T2E} D\zeta_{A+}$		>120	>-500	
$p_T^{miss}{}_E M_{T2C+} D\zeta_{A+}$	>250	>80	>-500	

Table 9: Definition of combined search bins to be used for easier reinterpretation of the results.

n_{jet}	p_T^{miss}	M_{T2}	Bkg ($e\tau_h$)	Obs. ($e\tau_h$)	Bkg ($\mu\tau_h$)	Obs ($\mu\tau_h$)	Bkg ($e\mu$)	Obs ($e\mu$)
0	> 120 GeV	> 120 GeV	$4.9 \pm 1.5 \pm 1.9$	4	$5.8 \pm 1.8 \pm 2.7$	7.0	$6.8 \pm 2.2 \pm 2.7$	6
1	> 120 GeV	> 100 GeV	$10.8 \pm 2.1 \pm 2.5$	9	$14.4 \pm 2.5 \pm 3.1$	14	$9.7 \pm 2.4 \pm 3.0$	6
1	> 250 GeV	> 80 GeV	$1.6 \pm 0.9 \pm 1.2$	0	$1.5 \pm 0.9 \pm 1.1$	1	$3.3 \pm 2.0 \pm 2.3$	1

Event yields smuon and selectrons

p_T^{miss} [GeV]	100-150	150-225	225-300	300+
FS bkg.	96^{+13}_{-12}	$15.3^{+5.6}_{-4.5}$	$4.4^{+3.6}_{-2.3}$	$1.1^{+2.5}_{-1.0}$
ZZ	13.5± 1.5	9.78±1.19	2.84±0.56	1.86± 0.12
WZ	6.04± 1.19	2.69±0.88	0.86±0.45	0.21± 0.20
Rare processes	0.69±0.44	0.68±0.47	$0.00^{+0.20}_{-0.00}$	$0.05^{+0.12}_{-0.05}$
Total prediction	116^{+13}_{-12}	$28.4^{+5.9}_{-4.8}$	$7.9^{+3.7}_{-2.4}$	$3.2^{+2.6}_{-1.1}$
Data	101	31	7	7
$m_{\tilde{\ell}} = 450\,\text{GeV}, m_{\tilde{\chi}_1^0} = 40\,\text{GeV}$	0.73±0.08	1.81±0.12	2.39±0.14	6.17±0.23
$m_{\tilde{\ell}} = 375\,\text{GeV}, m_{\tilde{\chi}_1^0} = 160\,\text{GeV}$	2.91±0.19	6.86±0.29	6.06±0.27	5.25±0.26
$m_{\tilde{\ell}} = 250\,\text{GeV}, m_{\tilde{\chi}_1^0} = 180\,\text{GeV}$	14.04±1.02	8.59±0.80	0.91±0.26	0.10±0.10
$m_{\tilde{\ell}} = 100\,\text{GeV}, m_{\tilde{\chi}_1^0} = 1\,\text{GeV}$	159.07±16.50	30.41±7.26	12.95±5.00	0.00±0.00