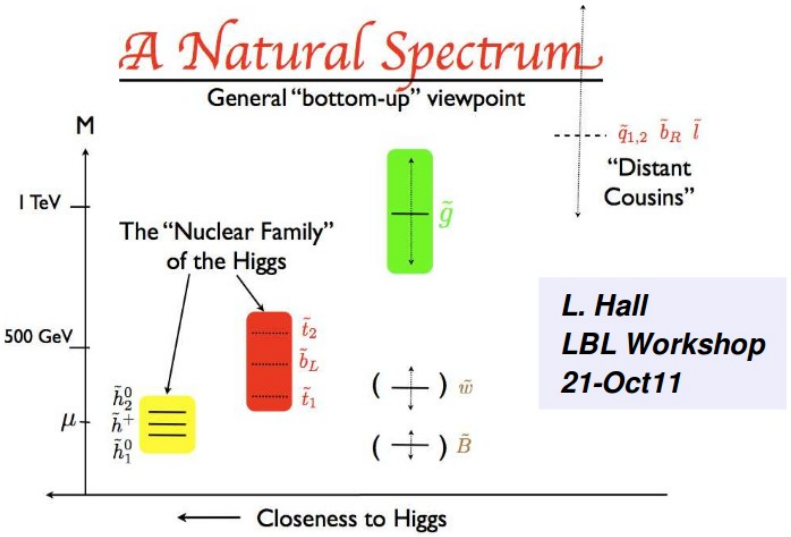
Charginos and sleptons direct production searches with 2 leptons, MET and no jets with ATLAS and CMS

Thomas Serre (CPPM, Marseille)

SUSY cross sections (pMSSM)



- R parity conserved = sparticles produce by pairs
- LSP = neutralino 1

→ Consider a natural spectrum :

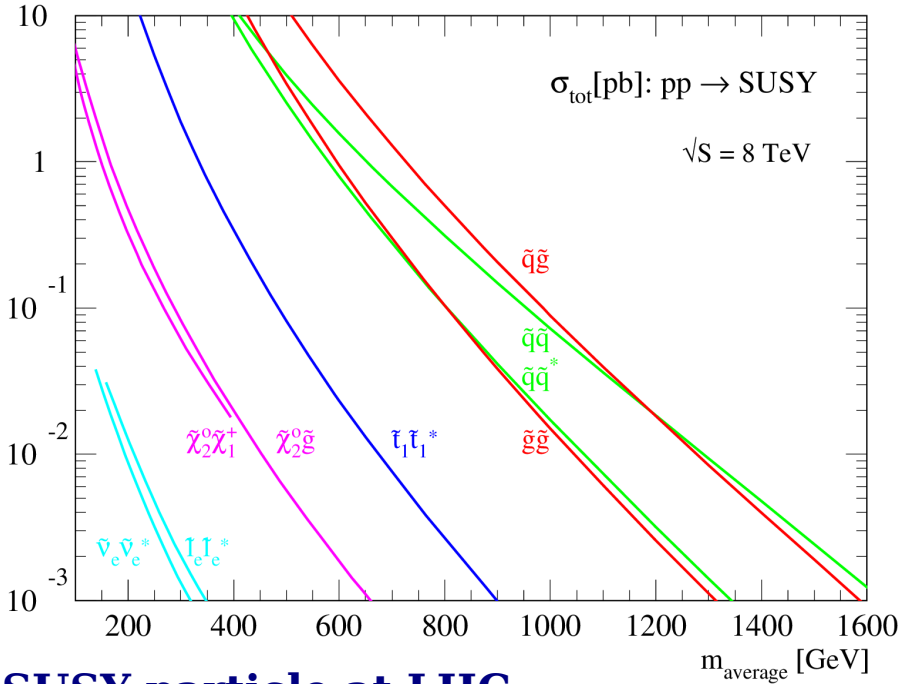
- higgs naturality : M($\tilde{g}$) ~ 1 TeV, M($\tilde{t}$) ~ 400 GeV
- Experimental limits : M($\tilde{g}$) > 1 TeV, M($\tilde{t}$) > 600 GeV

→ Largest XS for charginos/neutralinos

- Light charginos needed in natural scenario
- light sleptons allowed also

- For M($\tilde{\chi}_1^{+/-}$) = 100 GeV & M($\tilde{g}$) = 1 TeV

XS($\tilde{\chi}_1^{+/-}\tilde{\chi}_1^{+/-}$) = 100 * XS($\tilde{g}\tilde{g}$) = (1 – 10) pb



→ **Low mass charginos can be the first visible SUSY particle at LHC**

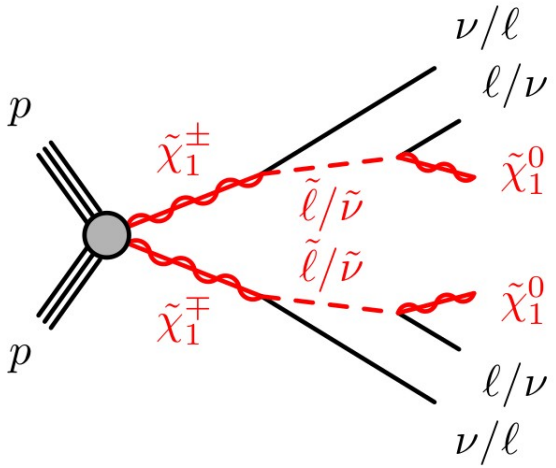
http://arxiv.org/abs/1403.5294

Direct chargino and slepton pair production

→ 3 scenarii considered

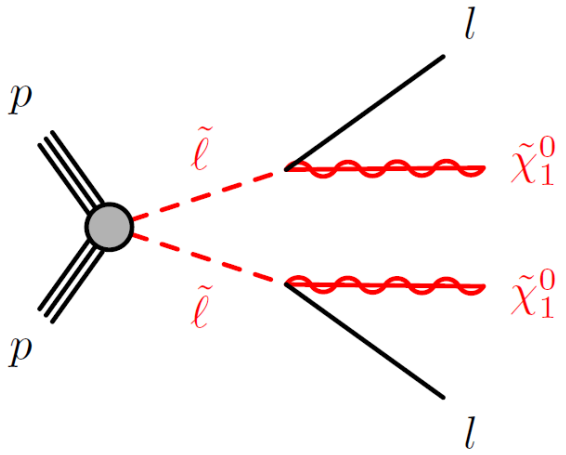
Charginos in sleptons

Optimistic scenario
(no BR cost thanks to the sleptons)



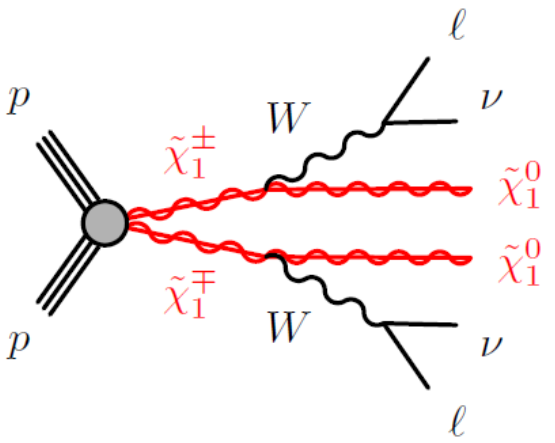
Direct sleptons

Allowed in pMSSM framework
Right and left handed cases



Charginos in W on-shell

Realistic scenario
Harder, leptonic BR
"a *considerable hole in current searches at LHC*" *arXiv:1309.0528*



→ Basic selection : exactly 2 OS leptons , jet - veto , E_t^{miss}

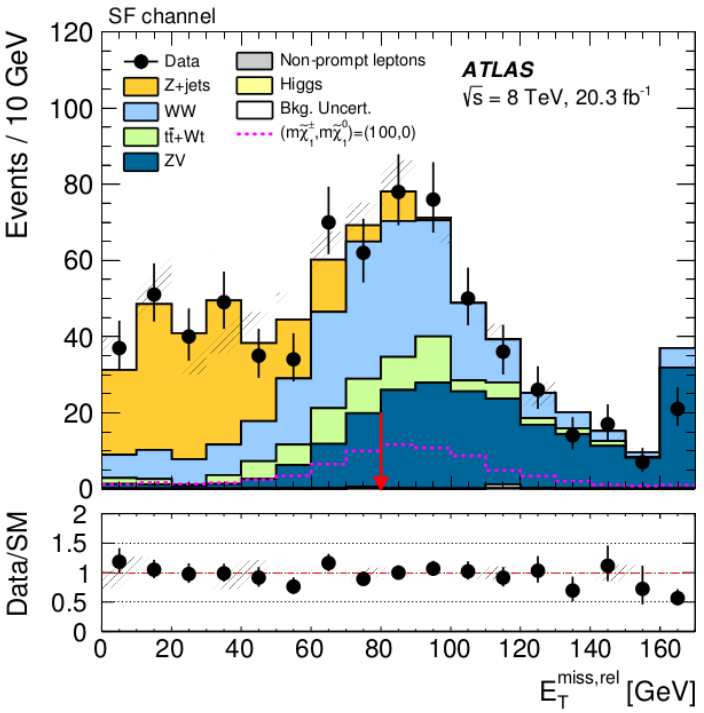
→ Main background Dibosons (mostly WW) and top

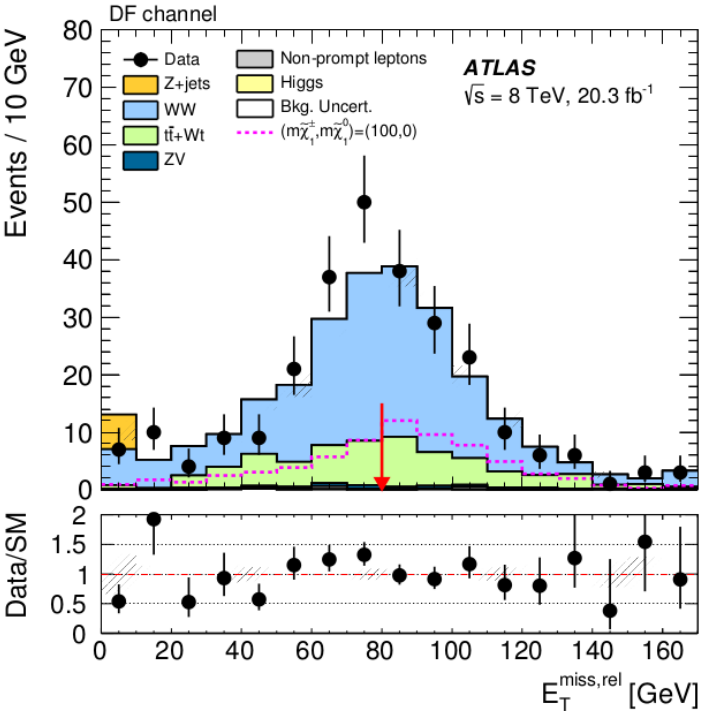
Selection – 'a la Higgs'

- For low mass charginos in W
- Topology close to SM WW and H -> WW
- based on $E_T^{miss,rel}$ and $p_T(ll)$

ΔΦ l,j = min (ΔΦ(MET,l), ΔΦ(MET,j))

$$E_{\mathrm{T}}^{\mathrm{miss,rel}} = \begin{cases} E_{\mathrm{T}}^{\mathrm{miss}} & \text{if } \Delta\phi_{\ell,j} \geq \pi/2 \\ E_{\mathrm{T}}^{\mathrm{miss}} \times \sin\Delta\phi_{\ell,j} & \text{if } \Delta\phi_{\ell,j} < \pi/2 \end{cases}$$





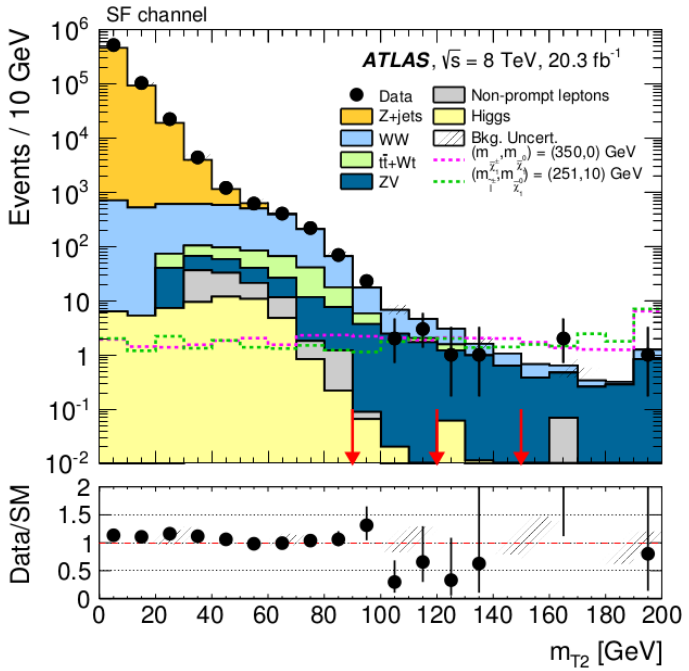
- With these cuts :

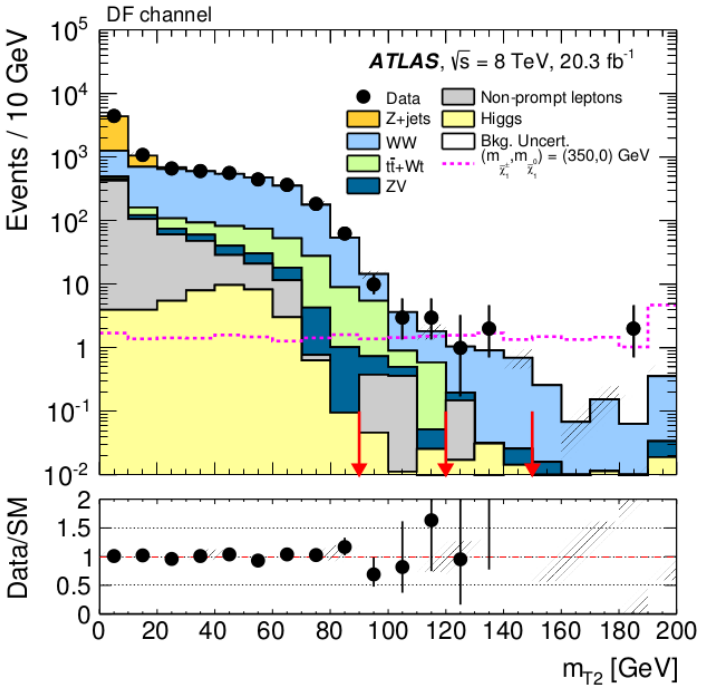
($M(\tilde{X}_1^{+/-})$ = 100 GeV , $M(\tilde{X}_1^{0})$ = 0 GeV) : 42 events, ee/eμ/μμ S / √B = 2.5 with ΔB = 15%

=> $E_T^{miss,rel}$ and $p_T(ll)$ have a good discrimination power for $M(X_1^{+/-})$ < 120 GeV

Selection – M_{T2}

- For high mass charginos in W and in sleptons, direct sleptons
- Using high mass of the SUSY particle
- $$m_{T2} = \min_{\mathbf{q}_T} \left[\max \left(m_T(\mathbf{p}_T^{\ell 1}, \mathbf{q}_T), m_T(\mathbf{p}_T^{\ell 2}, \mathbf{p}_T^{\text{miss}} - \mathbf{q}_T) \right) \right]$$





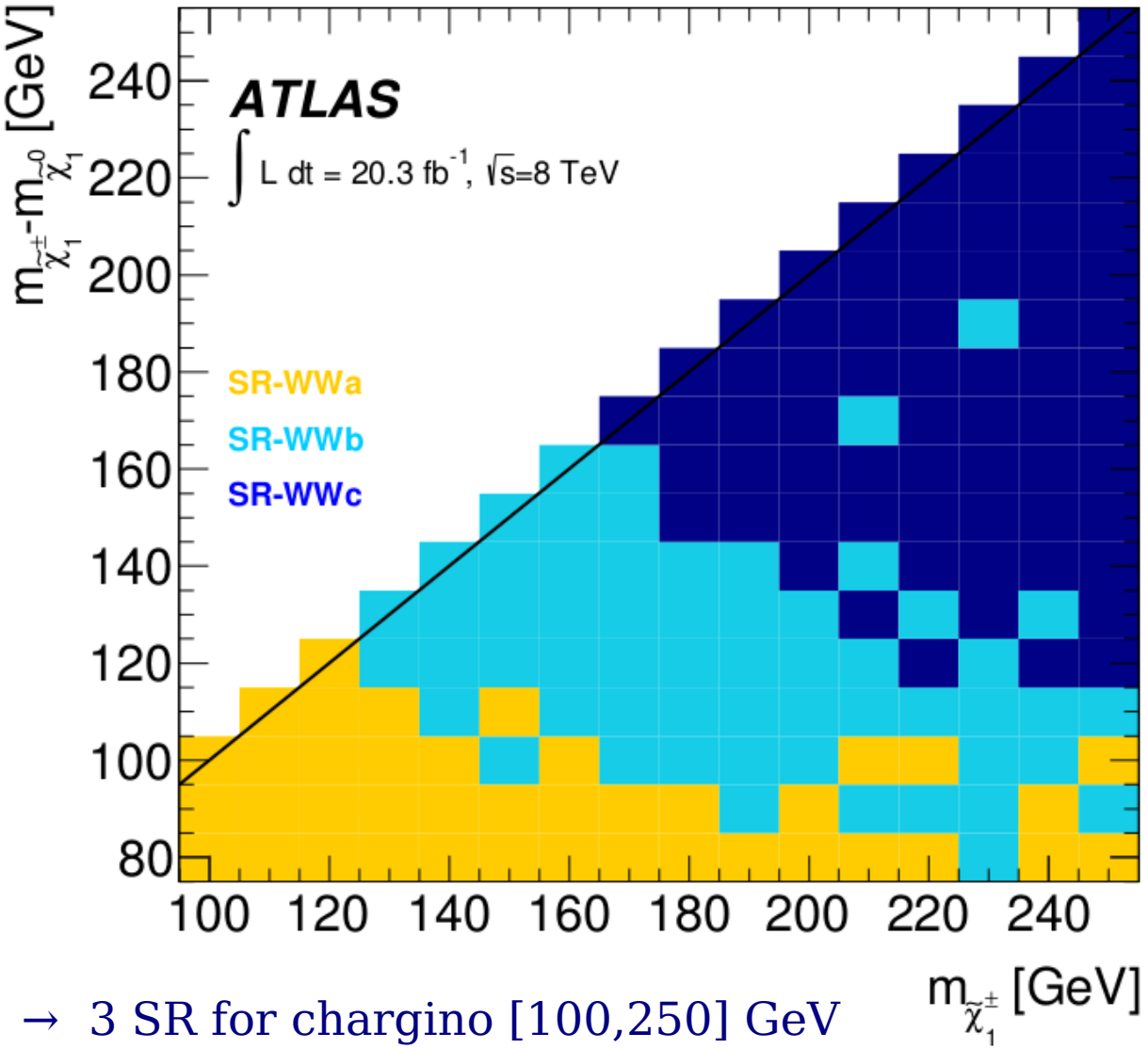
- With M_{T2} > 90 GeV for $\tilde{X}_1^{+/-}$ in W

($M(\tilde{X}_1^{+/-})$ = 140 GeV , $M(\tilde{X}_1^{0})$ = 20 GeV) : 15 events, S / √B = 2.0 with ΔB = 15%

($M(\tilde{X}_1^{+/-})$ = 200 GeV , $M(\tilde{X}_1^{0})$ = 0 GeV) : 8 events, S / √B = 1.3 with ΔB = 15%

=> mT2 have a good discrimination power for $M(X_1^{+/-})$ > 120 GeV

Signal Regions – Chargino with inter. W



→ 3 SR for chargino [100,250] GeV

- SRWWa 'A la higgs': $E_T^{miss,rel}$, $p_T(ll)$, m(ll) cuts for $\Delta M \sim M(W)$
- SRWW b and c based on m_{T2} cut for higher ΔM

Signal Regions – Summary

Table 10: SR-m_{T2} and SR-WW signal region definitions.

Signal region	SR-m_{T2}(a / b / c)	SR-WW(b / c)	SR-WWa
$p_T^{\ell 1}$ > [GeV]		35	
$p_T^{\ell 1}$ > [GeV]		20	
charge		OS	
flavour		ee,$\mu\mu$,$e\mu$	
$\lvert m_{\ell\ell} - m_Z \rvert$		> 10 for ee and $\mu\mu$	
central light jets		= 0	
signal b-jets		= 0	
signal forward jets		= 0	
$E_T^{\text{miss,rel}}$ [GeV]		–	> 80
$p_{T,ll}$ [GeV]		–	> 80
m_{T2} [GeV]	> 90/120/150	> 90/100	–
$m_{\ell\ell}$[GeV	20 < $m_{\ell\ell}$	20 < $m_{\ell\ell}$ < 170 / no cut	20 < $m_{\ell\ell}$ < 120

3 SR for direct sleptons, charginos with inter. sleptons

3 SR for charginos with inter. W bosons

Background treatment

→ Dominant backgrounds are WW, $t\bar{t}$ and single top, and ZV :

- For them, semi data-driven are performed
- Control regions are built where SF are computed and used to scale MC
- For WW and top, only eμ is used (ee and μμ channels are checked to agree)
- ZV CR with ee and μμ channel

→ Background in SR-WWa :

- Specific variables : $E_T^{miss,rel}$, p_T (ll)
- 3 dedicated control regions for each background

→ Background in SR-WWb/c, SR-M_{T2}a/b/c :

- 3 common CR, one for each background

→ Other backgrounds :

- Fake leptons coming from light/heavy flavor jets (photons also)
- Estimated with a matrix method
- Minor backgrounds, Higgs, VVV, Z+jets estimated by MC only

WW background in SRWWa

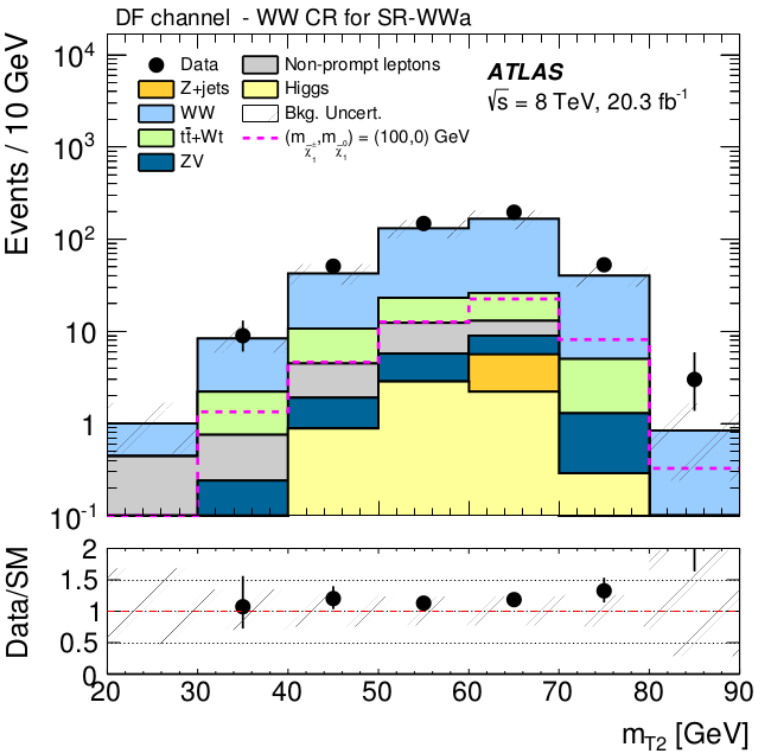
→ WW CR definition

CR	(p_T^{l1}, p_T^{l2}) [GeV]	m_{T2} [GeV]	$E_T^{miss,rel}$ [GeV]	$p_{T,\ell\ell}$ [GeV]	$m_{\ell\ell}$ [GeV]
CRWW-WWa	(>35,>20)	–	[60 – 80] GeV	> 40GeV	< 120 GeV

→ WW CR characteristics

Purity (%)	Signal in CR(%)	TF (%)	SF
85 ± 2	13 ± 0.5	17.1 ± 1.2	1.22 ± 0.07

- SF significantly greater than 1
- High purity and low signal contamination
- SF not applied in this plot



→ Good agreement between Data and MC

ATLAS

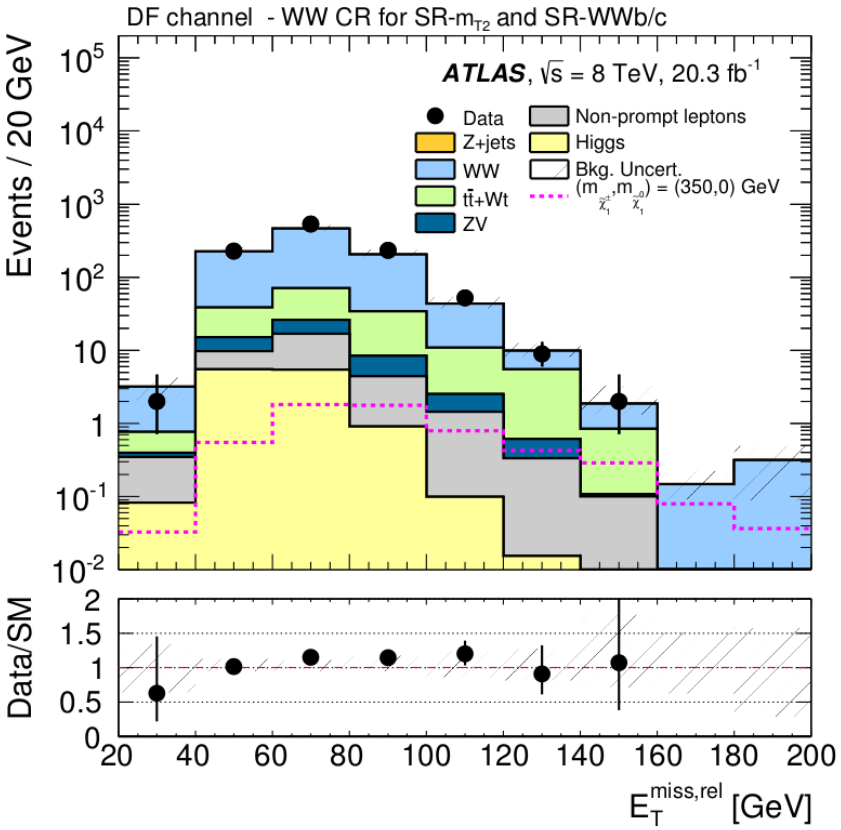
WW background in m_{T2} based region

→ WW CR definition

OS	✔
Lepton Flavor	$e\mu$
$p_T^{\ell 1}$	>35 GeV
$p_T^{\ell 2}$	>20 GeV
$m_{\ell\ell}$	>20 GeV
N_{B20}	=0
N_{L20}	=0
N_{F20}	=0
m_{T2}	>50 GeV, < 90 GeV

→ WW CR characteristics

purity in %	83.10 ± 1.13
contamination in %	16.90 ± 1.30
$\mathcal{S}$	1.145 ± 0.044 ± 0.398



- SF > 1 also in this CR
- SF differences with CRWWa agrees in error bars
- Good purity and low signal contamination

→ Good agreement between Data / MC

ATLAS

Background summary

	SR-m_{T2},90		SR-m_{T2},120		SR-m_{T2},150	
	ee/$\mu\mu$	eμ	ee/$\mu\mu$	eμ	ee/$\mu\mu$	eμ
Background						
WW	22.05 ± 4.27	16.18 ± 3.22	3.49 ± 1.29	3.29 ± 1.19	0.98 ± 0.53	0.90 ± 0.46
ZW or *ZZ*	12.85 ± 2.23	0.76 ± 0.22	4.94 ± 1.62	0.15 ± 0.08	2.15 ± 0.49	0.03 ± 0.02
Top	3.04 ± 1.75	5.53 ± 1.88	$0.33^{+0.36}_{-0.33}$	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Others	0.18 ± 0.06	0.78 ± 0.55	0.09 ± 0.03	0.11 ± 0.09	0.07 ± 0.12	0.04 ± 0.03
Total	38.13 ± 5.09	23.26 ± 3.72	8.86 ± 2.08	3.55 ± 1.20	3.19 ± 0.72	0.96 ± 0.46
Observed events	33	21	5	5	3	2
ΔB	14.7 %		28.6 %		35.2 %	

	SR-WWa		SR-WWb		SR-WWc	
	ee/$\mu\mu$	eμ	ee/$\mu\mu$	eμ	ee/$\mu\mu$	eμ
Background						
WW	57.75 ± 5.48	58.21 ± 6.03	16.44 ± 2.54	12.30 ± 2.01	10.38 ± 2.65	7.29 ± 1.93
ZW or *ZZ*	16.31 ± 3.50	1.82 ± 0.48	10.91 ± 1.91	0.56 ± 0.18	9.21 ± 2.12	0.41 ± 0.16
Top	9.17 ± 3.52	11.55 ± 4.32	2.37 ± 1.68	4.31 ± 1.60	$0.62^{+1.15}_{-0.62}$	0.94 ± 0.83
Others	3.3 ± 1.31	2.01 ± 1.1	0.32 ± 0.31	0.91 ± 0.56	0.12 ± 0.04	0.40 ± 0.32
Total	86.53 ± 7.36	73.60 ± 7.91	30.04 ± 3.53	18.07 ± 2.60	20.34 ± 3.54	9.04 ± 2.19
Observed events	73	70	26	17	10	11
ΔB	9.6 %		13.1 %		20.8 %	

→ No excess observed, a slight deficit in SF channel

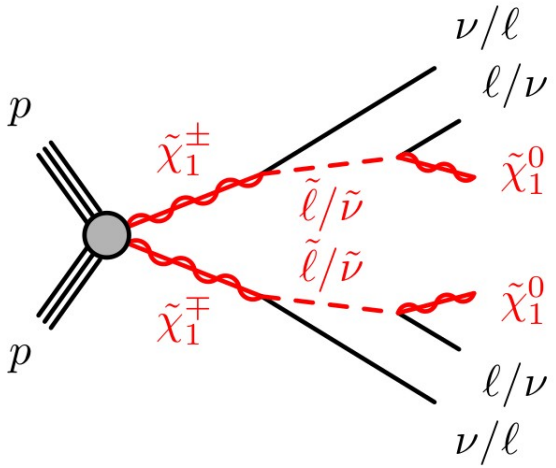
http://arxiv.org/abs/1405.7570

Direct chargino and slepton pair production

→ 2 scenarii considered

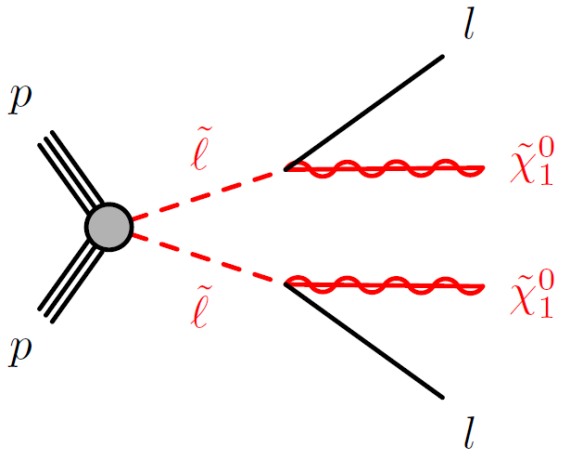
Charginos in sleptons

Allowed in pMSSM framework
Optimistic scenario
(no BR cost thanks to the sleptons)



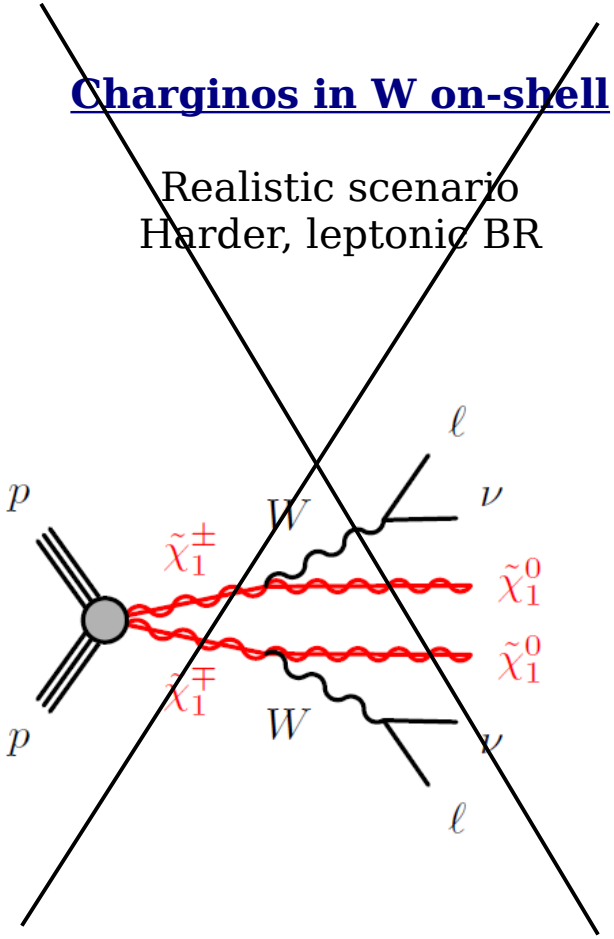
Direct sleptons

Allowed in pMSSM framework
Right and left handed cases



Charginos in W on-shell

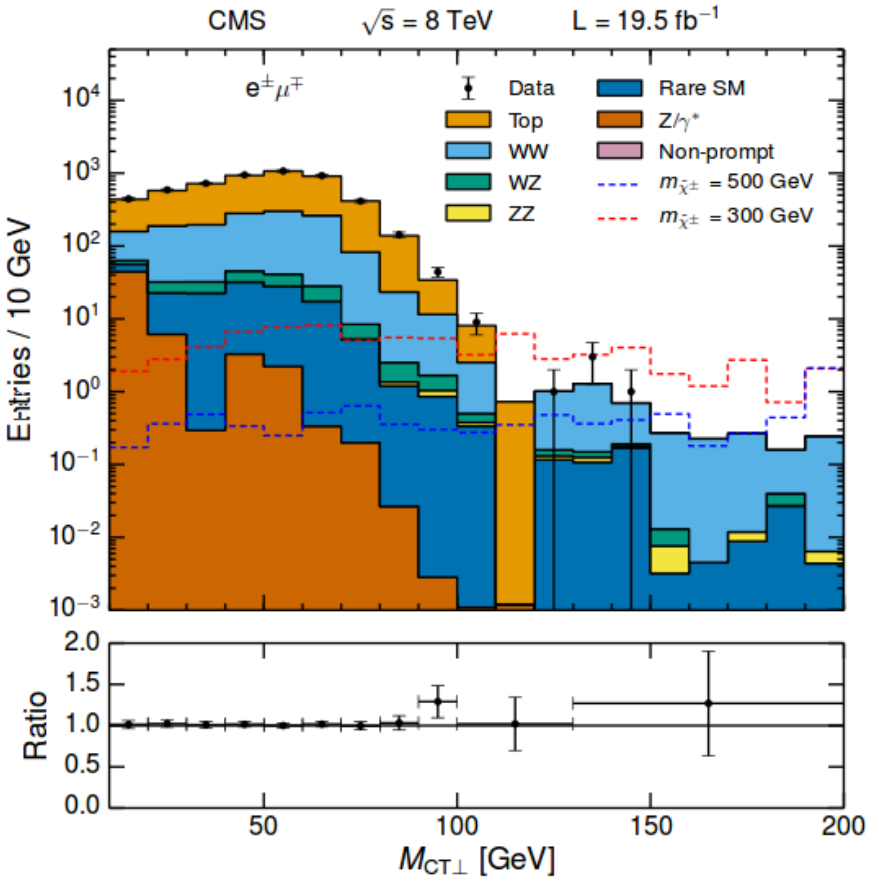
Realistic scenario
Harder, leptonic BR

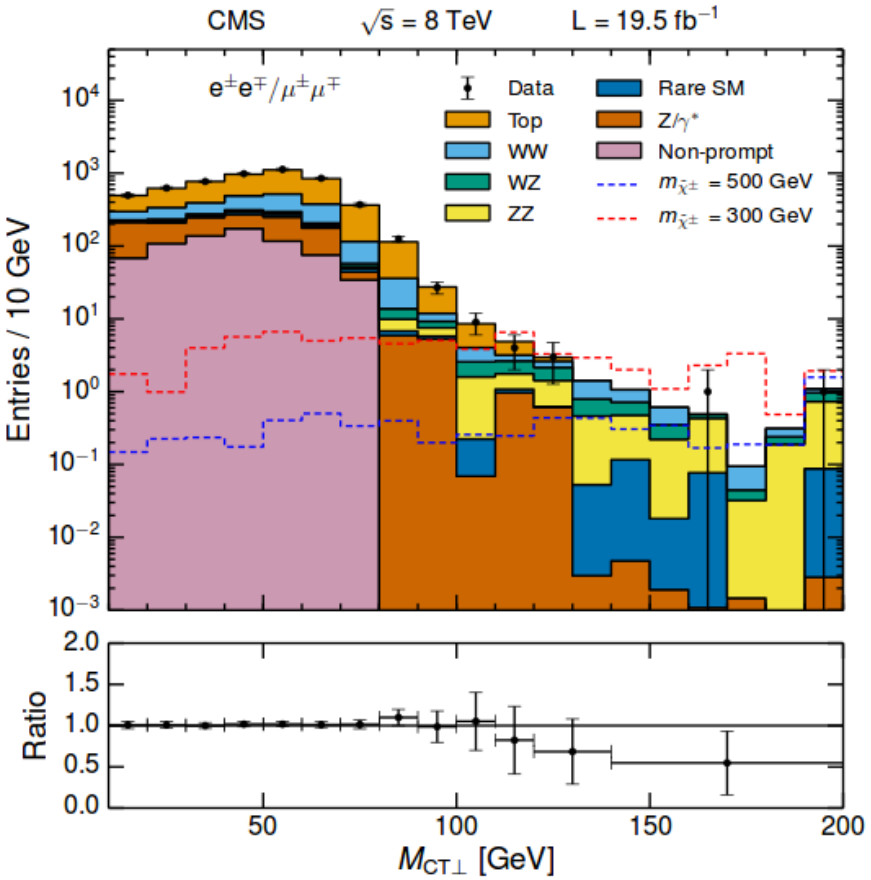


→ Basic selection : exactly 2 leptons , jet - veto , E_T^{miss}

Selection – M_{CT}

- End point at m(W) for SM background, high value tail for SUSY processes
- $M_{\mathrm{CT}}^2 = m^2(\mathrm{v}_a) + m^2(\mathrm{v}_b) + 2\left[E_{\mathrm{T}}(\mathrm{v}_a)E_{\mathrm{T}}(\mathrm{v}_b) + \mathbf{p}_{\mathrm{T}}(\mathrm{v}_a)\cdot\mathbf{p}_{\mathrm{T}}(\mathrm{v}_b)\right]$
- Take components perpendicular to the recoil direction of the system





→ **Typical signal regions with M_{CT} > 120 GeV**

CMS

Background treatment

→ Dominant backgrounds are WW, $t\bar{t}$, single top, and ZV :

- Similar approch as ATLAS
- Template built in control regions then normalized to data with a fit
- For ZV and top, independent control regions

→ WW

- using a 3 lepton control region dominated with WZ
- Four momentum of 1 lepton is added to the MET
- WW simulation validated with this template

→ Background in SR

- Binned fit from 10 to 120 GeV in M_{CT}
- Extrapolated in $M_{CT} > 120$ GeV (signal region)

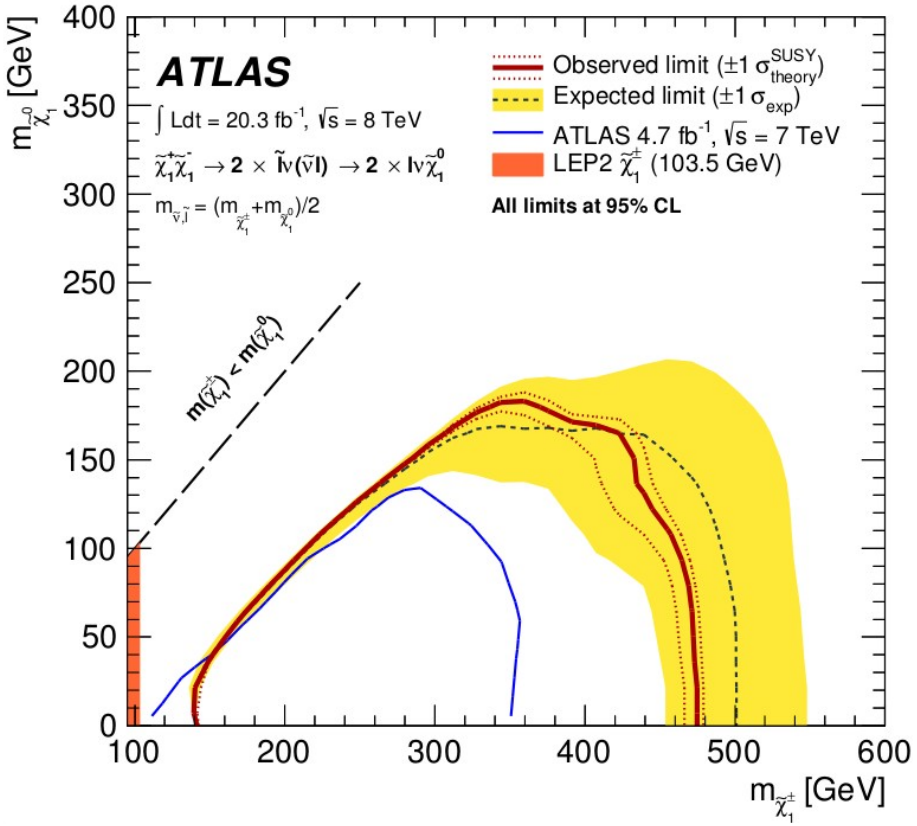
Sample	Opposite flavor		Same flavor	
	$M_{CT\perp}$ 10–120 GeV	$M_{CT\perp} > 120$ GeV	$M_{CT\perp}$ 10–120 GeV	$M_{CT\perp} > 120$ GeV
Top quark	3770 ± 90	< 0.4	2770 ± 110	0.35 ± 0.10
Diboson and rare SM	1430 ± 110	4 ± 3	1240 ± 90	9 ± 3
Z/γ^*	57 ± 25	< 0.01	700 ± 240	0.6 ± 0.3
Non-prompt	< 81	< 0.01	659 ± 77	< 0.5
Total	5260 ± 130	4 ± 3	5370 ± 100	10 ± 3
Data	5309	5	5388	5

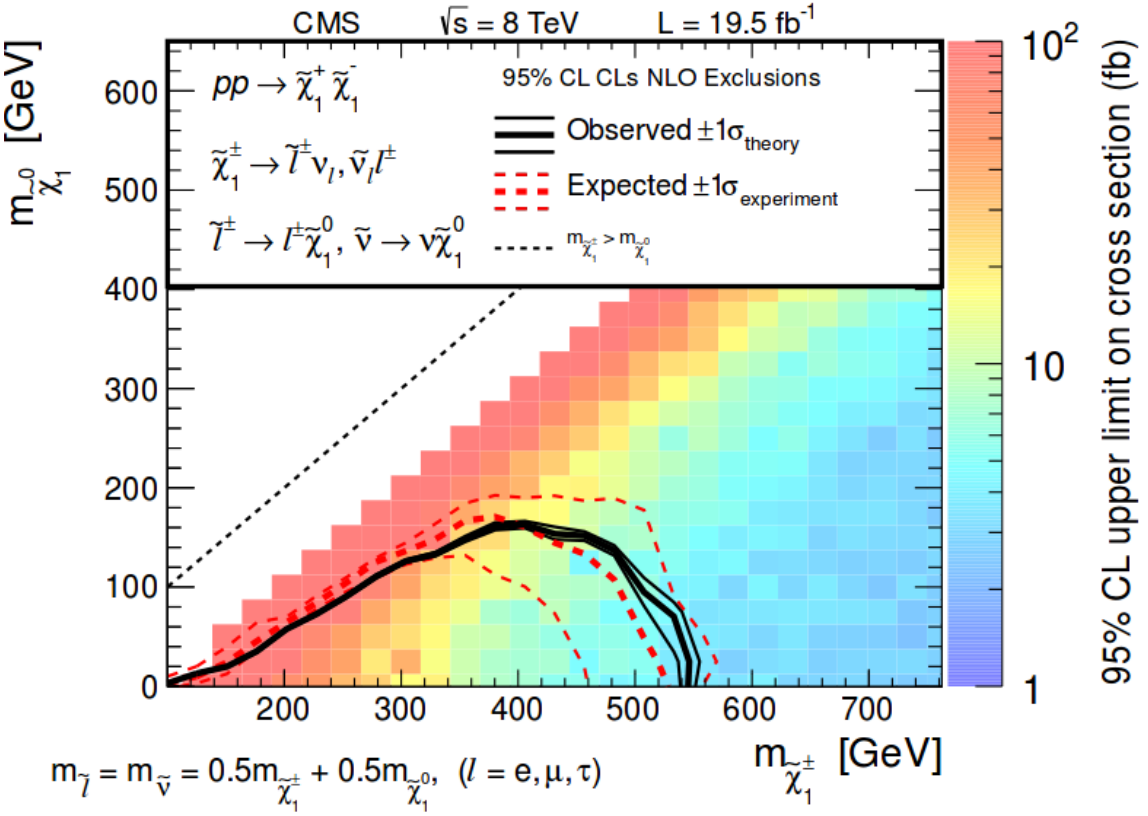
ATLAS & CMS

Limits on direct $\chi_1^{+/-}$ with inter. sleptons

→ Interpretation in simplified models

- All SUSY particles decoupled except charginos and sleptons
- BR of 100 % for chargino in slepton



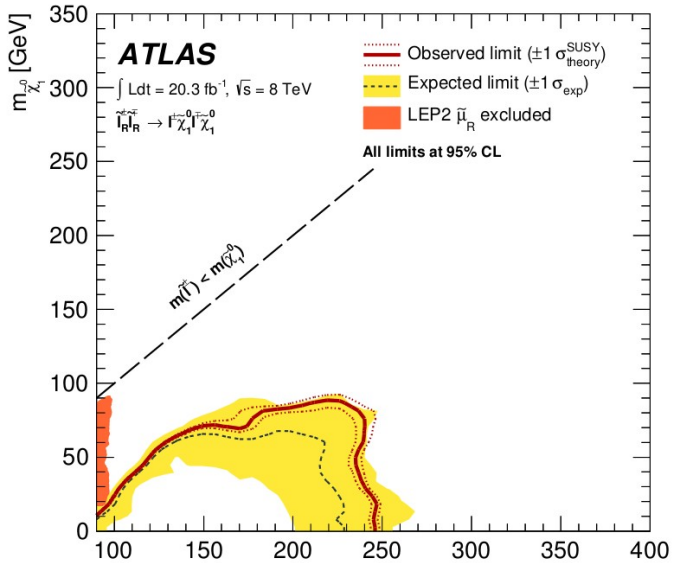


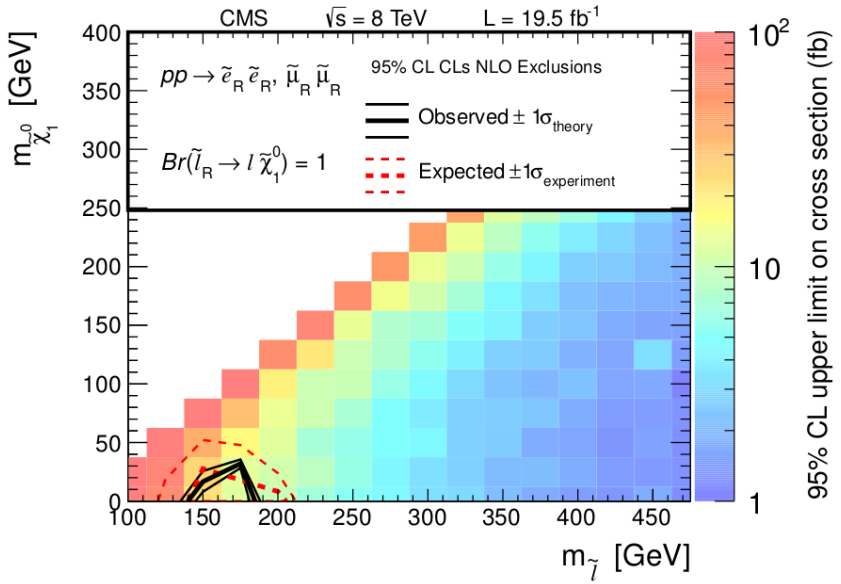
→ Exclusion of chargino in sleptons up to M(χ) > 550 GeV

Limits on direct sleptons

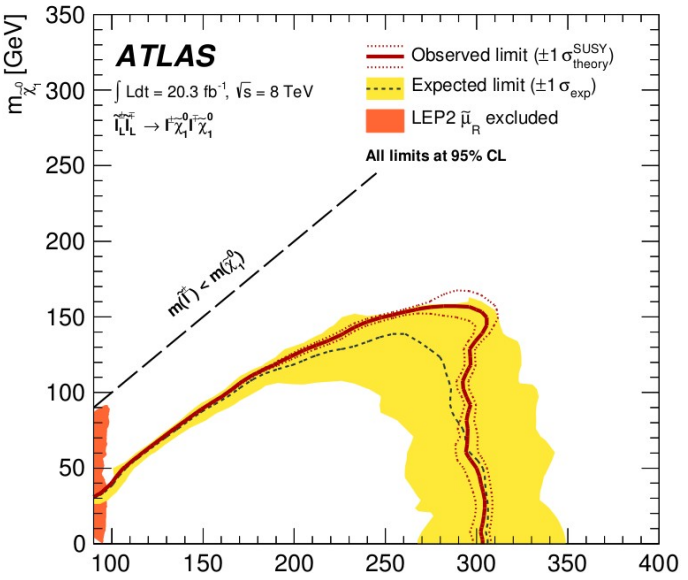
ATLAS & CMS

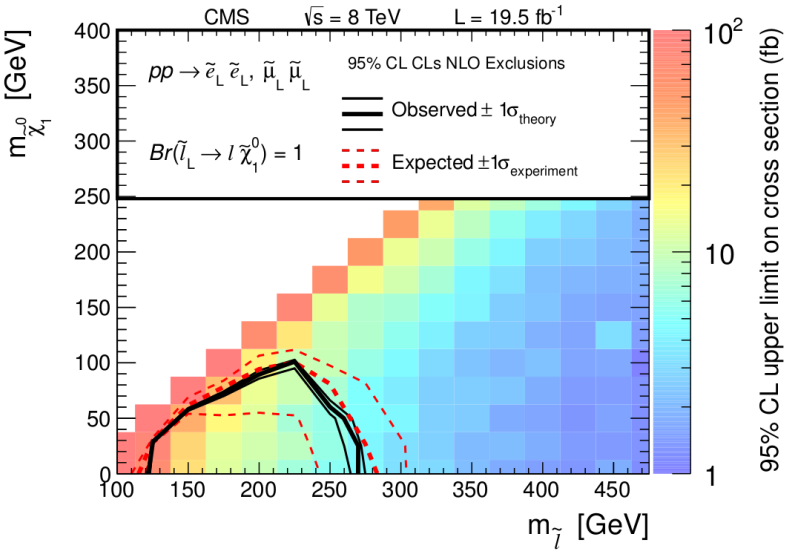
Right handed sleptons





Left handed sleptons



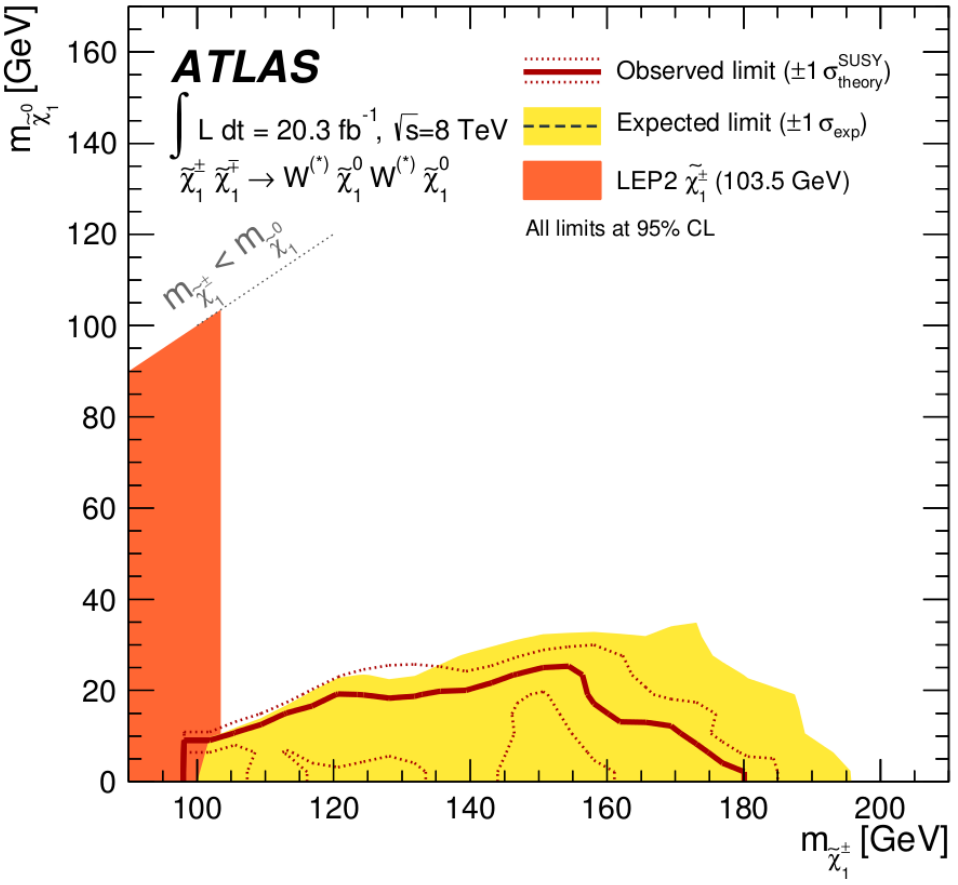


→ Sleptons excluded up to 250 GeV (left handed) and 300 GeV (right handed)

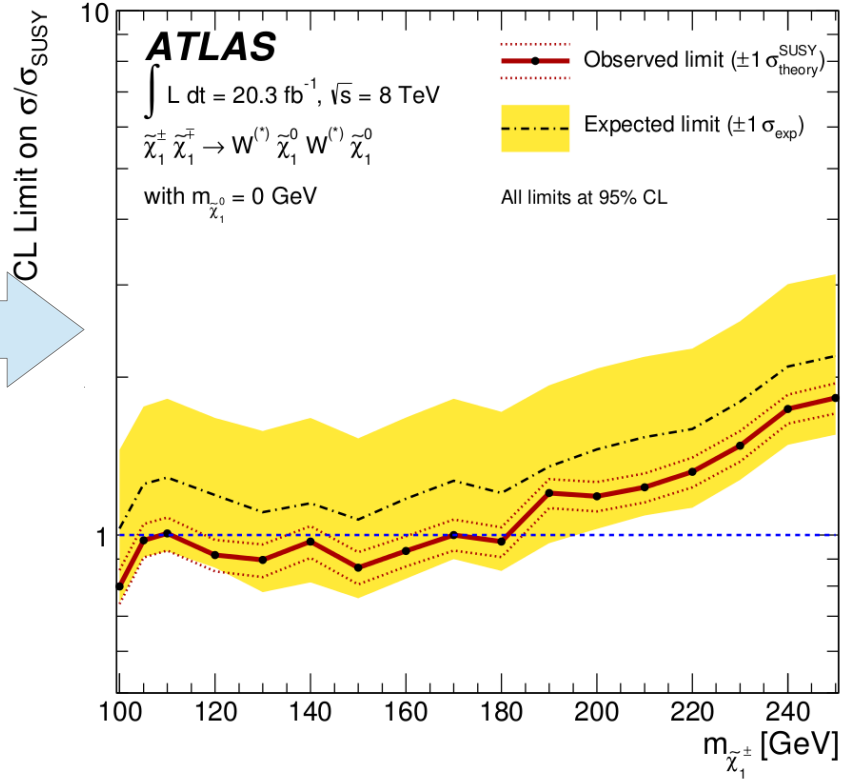
ATLAS

Limits on direct chargino with inter. W

→ Interpretation in simplified models



1D



→ Excluding chargino up to 180 GeV with massless neutralinos

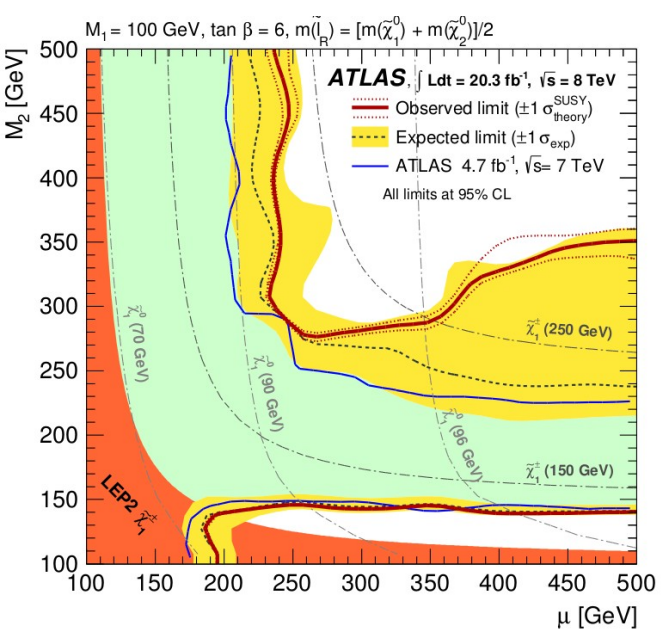
→ Several points excluding with massive neutralinos

ATLAS

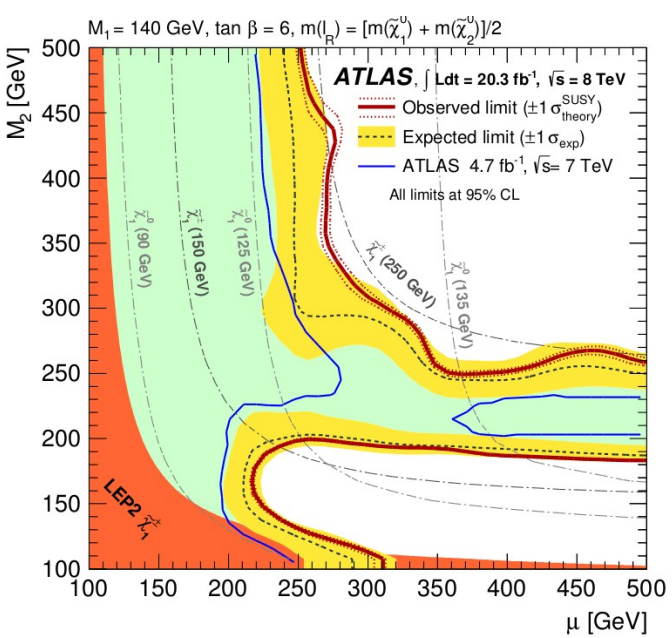
pMSSM Limits with light sleptons

- Reinterpretation in pMSSM models

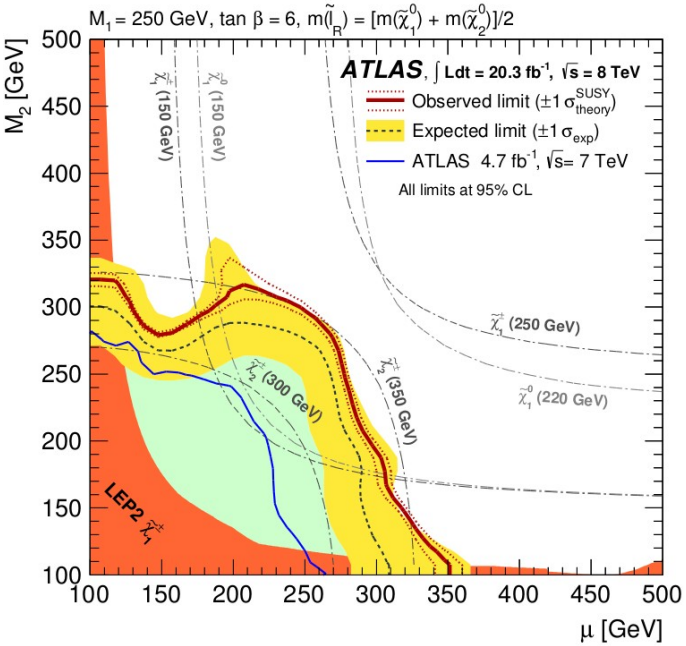
M1 = 100 GeV, tanβ = 6



M1 = 140 GeV, tanβ = 6



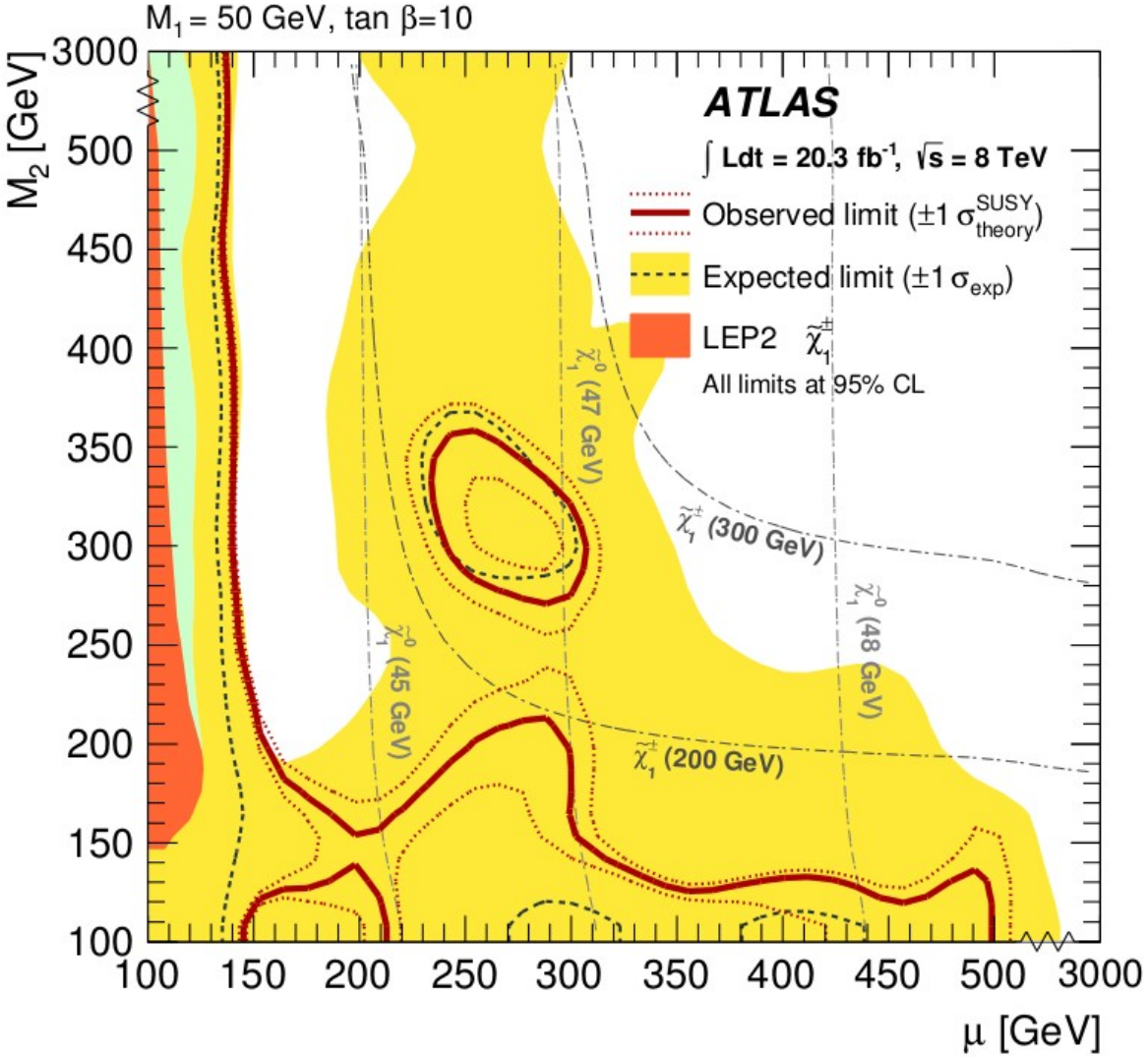
M1 = 250 GeV. tanß = 6



→ Large improvements compared to LEP results

pMSSM Limits with light charginos

- Reinterpretation in pMSSM models



→ Large improvments compared to LEP results

Conclusion

→ Search for direct production of charginos and sleptons in 2 l + mET states

→ Overview of the analysis done at ATLAS and CMS

→ Final exclusion with 8 TeV data set

→ No excess has been found compared to SM prediction

→ Interpretation in several models

→ Exclusion settled for chargino and sleptons production

→ First LHC exclusion of chargino with intermediate W !

→ Simplified model and pMSSM

→ Perspectives

→ Goal is now to setup analysis for 14 TeV

BACK UP

ZV background in SRWWa

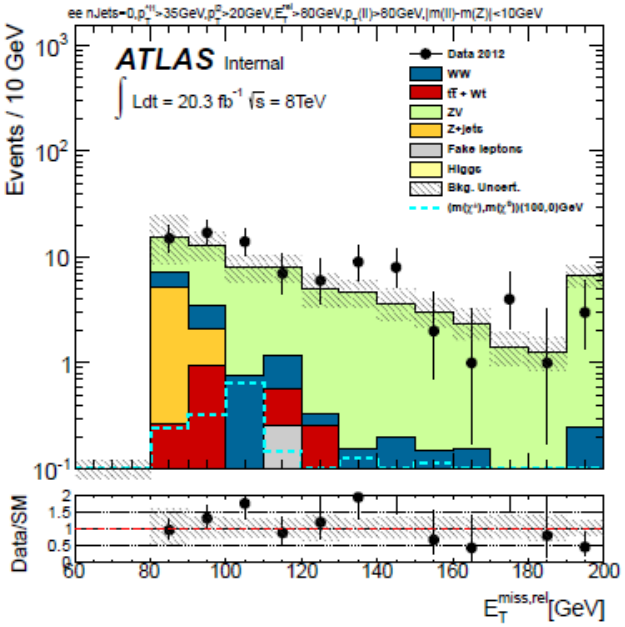
→ ZV CR definition

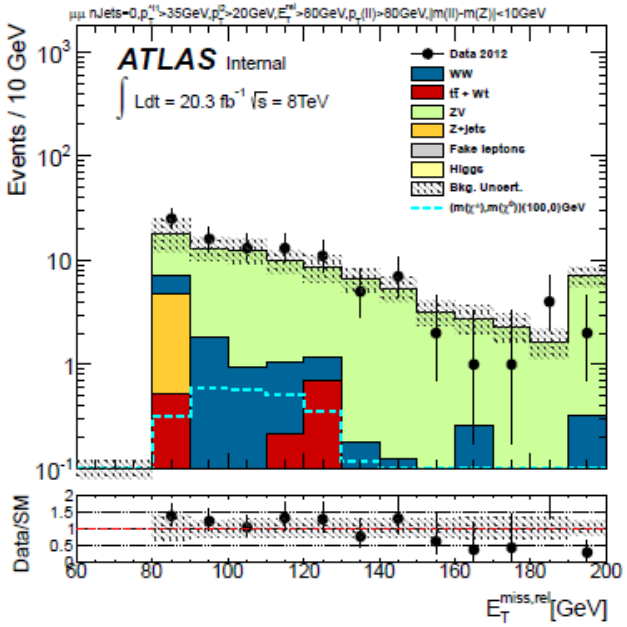
CR	(p_T^{l1}, p_T^{l2}) [GeV]	m_{T2} [GeV]	$E_T^{miss,rel}$ [GeV]	$p_{T,\ell\ell}$ [GeV]	$m_{\ell\ell}$ [GeV]
CRZV-WWa	(>35,>20)	–	>80	>80	$\lvert m_{\ell\ell} - m(Z)\rvert < 10$

→ ZV CR characteristics

CR	Purity (%)	Signal in CR(%)	TF (%)	SF
CRZV-WWa, *ee*	81 ± 4	2 ± 0.4	12.0 ± 1.5	1.14 ± 0.16
CRZV-WWa, *μμ*	85 ± 2	4 ± 0.6	13.9 ± 1.7	1.12 ± 0.13

- New CR to handle this background for ee and μμ final state
- Good agreement of SF in both channels, combined in the fit
- Low signal contamination and good purity





→ Good agreement between Data and MC

Event Selection

→ Trigger :

Use dilepton triggers

trigger	L1	Offline p_T Threshold
EF_2e12Tvh_loose1	L1_2EM10VH	$p_T(e_1) > 14$ GeV, $p_T(e_2) > 14$ GeV
EF_e24vh_medium1_e7_medium1	L1_EM18VH	$p_T(e_1) > 25$ GeV, $p_T(e_2) > 8$ GeV
EF_2mu13	L1_2MU10	$p_T(\mu_1) > 14$ GeV, $p_T(\mu_2) > 14$ GeV
EF_mu18_tight_mu8_EFFS	L1_MU15	$p_T(\mu_1) > 18$ GeV, $p_T(\mu_2) > 8$ GeV
EF_e12Tvh_medium1_mu8	L1_EM10VH_MU6	$p_T(e) > 14$ GeV, $p_T(\mu) > 8$ GeV
EF_mu18_tight_e7_medium1	L1_MU15	$p_T(e) > 8$ GeV, $p_T(\mu) > 18$ GeV

→ Object definition :

Baseline electrons

$p_T > 10$ GeV, $|\eta| < 2.47$, medium++

Baseline muons

$p_T > 10$ GeV, $|\eta| < 2.4$, STACO

Signal electrons

tight++, $d_0 < 5\sigma$, $|z_0|\sin\theta < 0.4$ mm, $p_T^{cone30}/pT < 0.16$, $E_T^{cone30}/pT < 0.18$ (pile-up corrected)

Signal muons

$d_0 < 3\sigma$, $|z_0|\sin\theta < 1$ mm, $p_T^{cone30}/pT < 0.12$ (pile-up corrected)

cuts	Central light jets L20	Central b-jets B20	Forward jets F30
p_T [GeV]	>20	>20	>30
$\|\eta_{det}\|$	<2.4	<2.4	[2.4,4.5]
b-tag MV1	≤0.3511	>0.3511	-
JVF	$\|JVF\| > 0$ if $p_T < 50$ GeV	-	-

- SUSY Tools 03.04, (version 03.07 tested, no impact on results)

→ No change since CONF