Searches with multilepton final states

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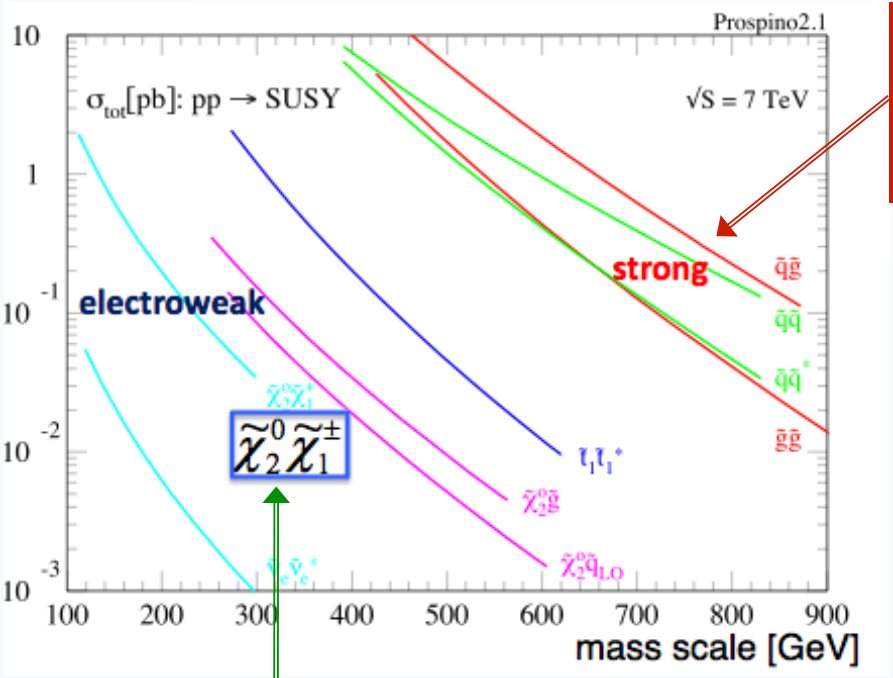
General Strategy



Most SUSY searches have focused on strong production, which has the largest cross-section

Searches look for this strongly interacting particles up to 1.2 TeV. Nothing found!

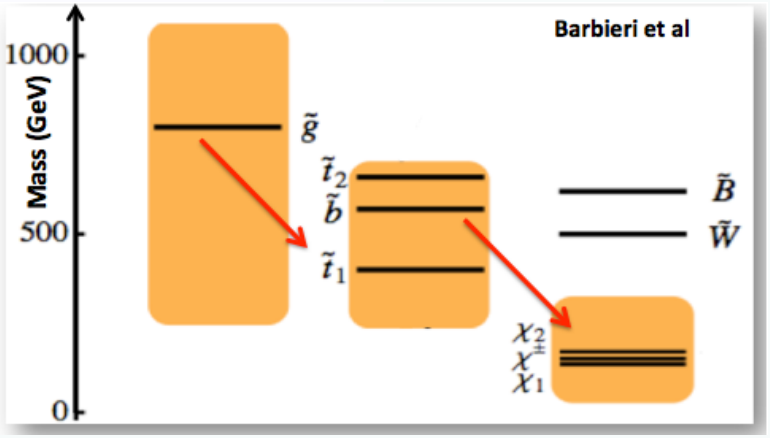
We present here searches with electroweak production of charginos, neutralinos and sleptons:

- small cross section
- Can be done with actual luminosity
- Leptons, moderate missing E_T.

Natural SUSY

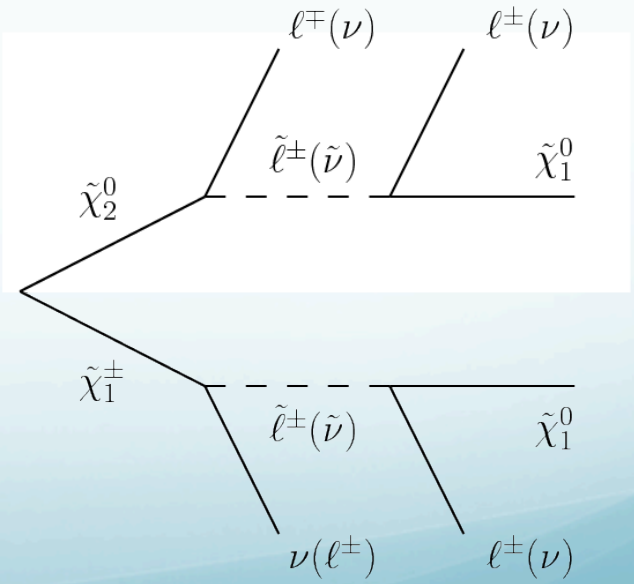
Discovery of new boson at 125 GeV has shifted attention towards pieces relevant for SUSY to solve the hierarchy problem. We could need:

- natural SUSY: search for stop at EW scale
- low cross sections but achievable.
- At reach of LHC.



In several SUSY models renormalization group equations push the lightest stop state to low masses:

- Natural SUSY
- multilepton signatures
- Relative low hadronic activity



Outline

- Look for multilepton SUSY in 3 main scenarios:
  - I. EWkino production (ATLAS: 20.7 fb^{-1}, CMS: 9.2 fb^{-1})
  - II. General multilepton (ATLAS: 20.7 fb^{-1}, CMS: 19.5 fb^{-1})
  - III. RPV with or without stop (ATLAS: 20.7 fb^{-1}, CMS: 19.5 fb^{-1})

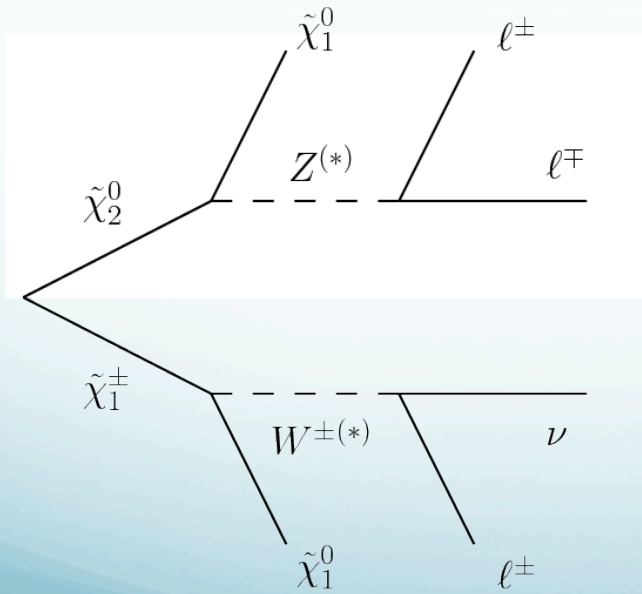
Used CMS-PAS and ATLAS-CONF:
- ATLAS-CONF-2013-049
- ATLAS-CONF-2013-028
- ATLAS-CONF-2013-035
- ATLAS-CONF-2013-036
- CMS-PAS-SUS-13-003
- CMS-PAS-SUS-12-022
- CMS-PAS-SUS-12-026
- CMS-PAS-SUS-13-008
- CMS-PAS-SUS-13-010

EWKino production (I)

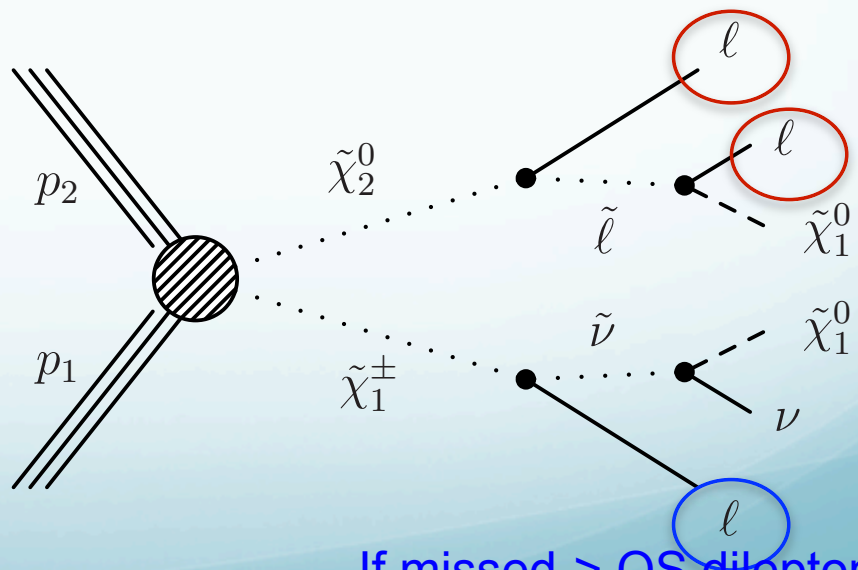
Model gives naturally 2, 3 or 4 leptons searches:

- Chargino and slepton pair production go to 2 leptons.
- Dedicated analysis:
  - Search for charginos and sleptons: ATLAS + CMS @ 8 TeV
  - Missing energy comes from Neutralino LSP's.

- If one lepton out of 3 is lost, one goes to OS/SS analysis



One missed
> SS/OS dileptons



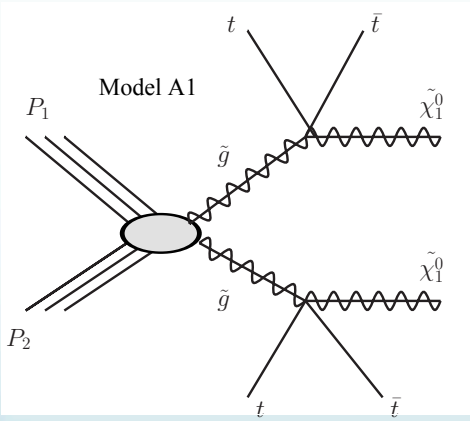
If missed-> OS dileptons

General multilepton (II)

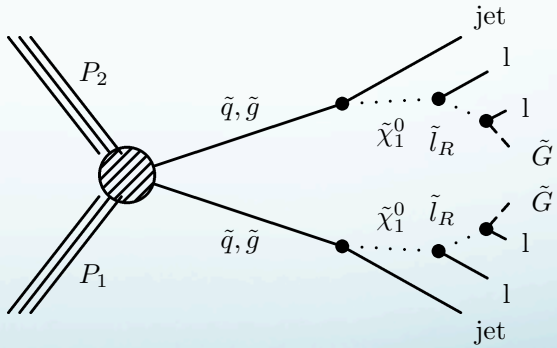
It also can give scenarios with gluinos and squarks to neutralino or gravitino as LSP and RPC:

- In any case 4 leptons can be obtained at the end of the analysis.

Gluinos production



squark/gluino from strong production decaying to sleptons



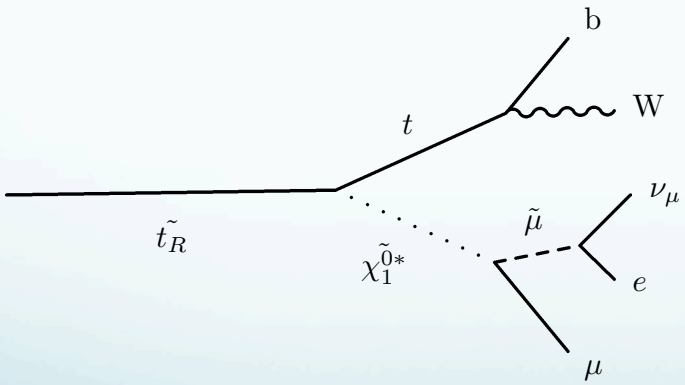
Stop or neutralino with RPV(III)

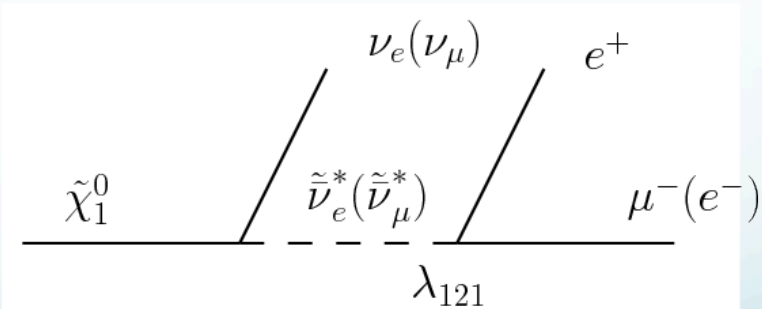
It also can give prompt R-Parity Violation:

$R=(-1)^{(L+3B+2J)}$ where L= leptonic number, B= baryonic number, J=spin

R = -1 for sparticles
R = +1 for SM particles

- Searches for charginos and sleptons in 3 or 4 leptons final states



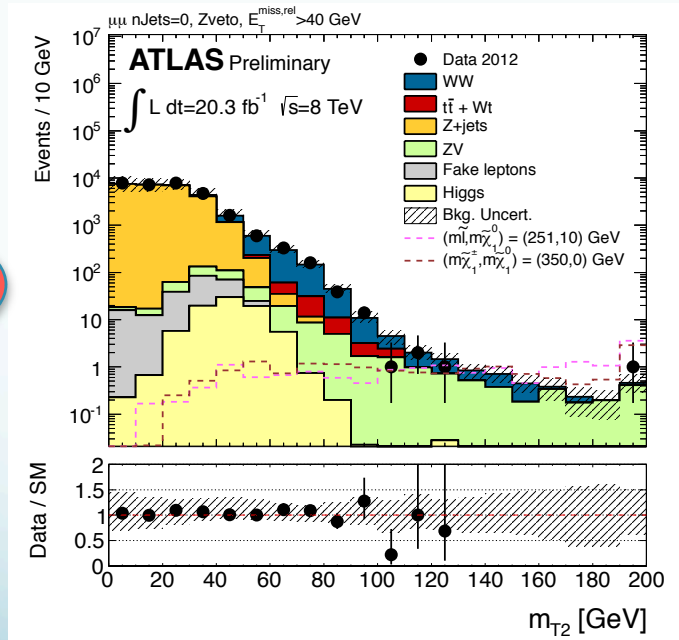


Ewkino production (I)

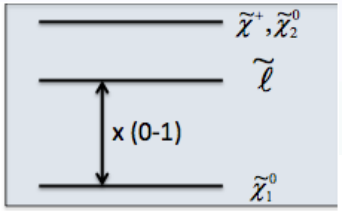
•ATLAS-CONF-2013-049
•CMS-SUS-12-022

- 2 **OS** lepton, Z veto, MET>40 GeV, jet veto
  - •Use m_{T2} variable
  - •Kinematic endpoint for WW, ttbar…

SR-m_{T2}

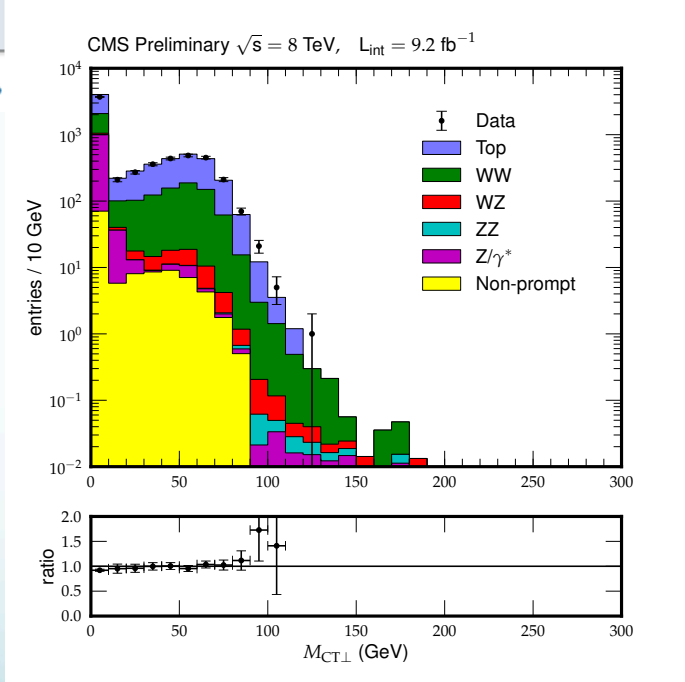


new!



$m_{slep} = x \cdot m_{\chi^+} + (1-x) \cdot m_{LSP}$

- 2 **OS** lepton, Z veto, MET>60 GeV, b-jet veto
  - •Use $M_{CT,Perp}$ variable
  - •Kinematic endpoint for WW, ttbar…



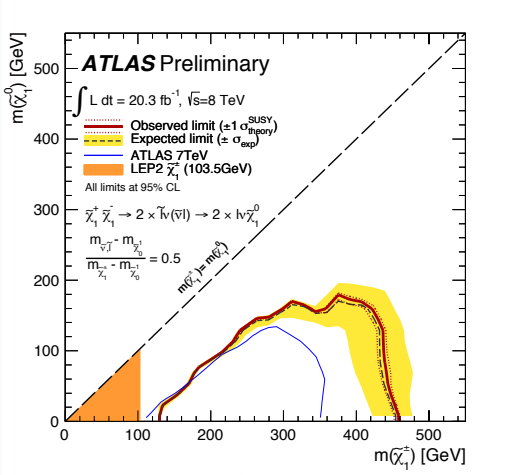
Opposite flavor

- Stransverse m_{T2}: kinematic endpoint at the W mass (ATLAS)
- $M_{CT,Perp}$: same variable showing a kinematic endpoint at W mass (CMS)

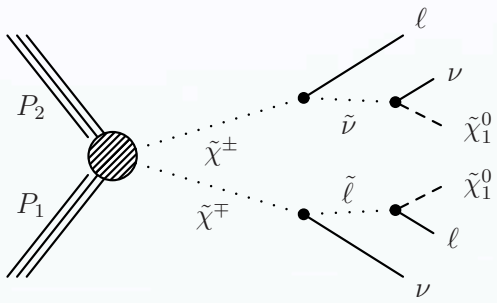
Ewkino production (I)

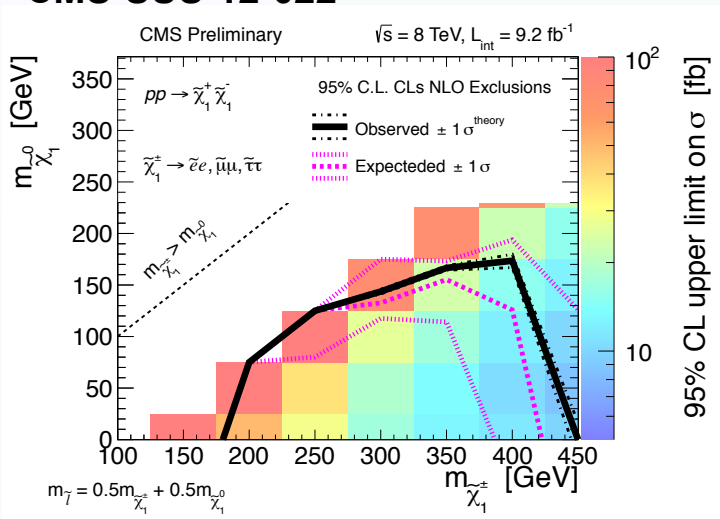
- SUSY particles with **OS** leptons

•**ATLAS-CONF-2013-049**
•**CMS-SUS-12-022**

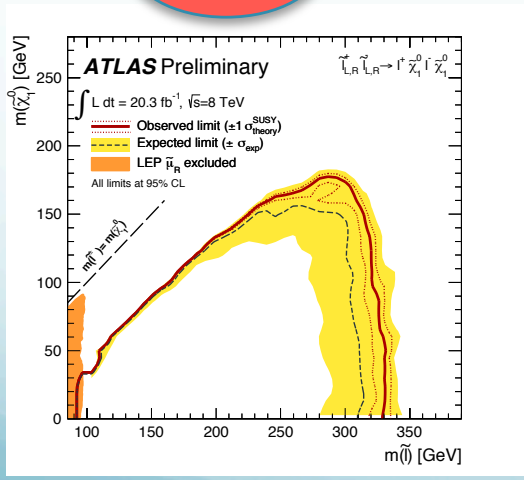


Limits on chargino pair production



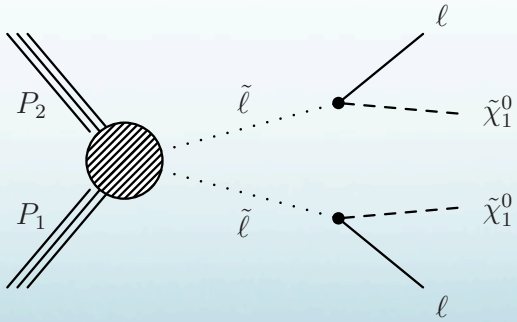


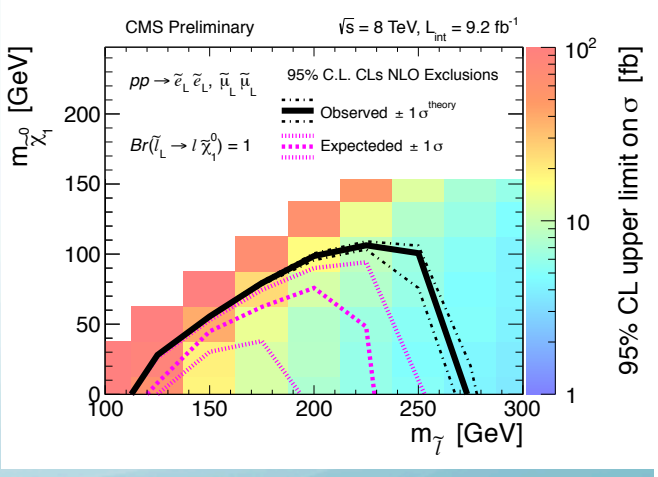
new!



Slepton right and left pair production

Limits on slepton pair production





Slepton left pair production

Ewkino production (I)

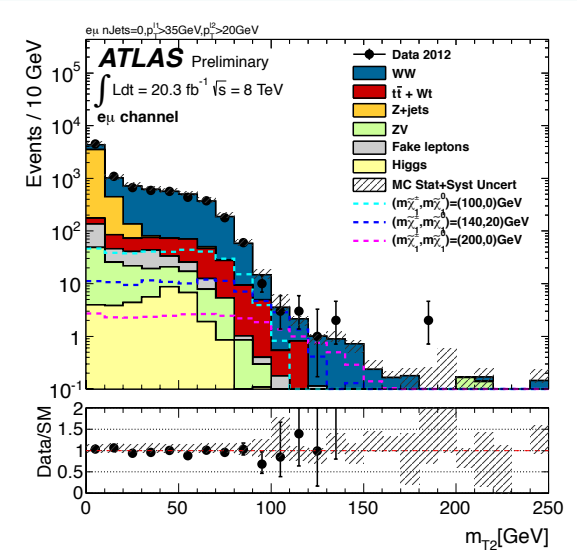
•ATLAS-CONF-2013-049

- 2 **OS** lepton: chargino to W scenario. 100% BR in this channel

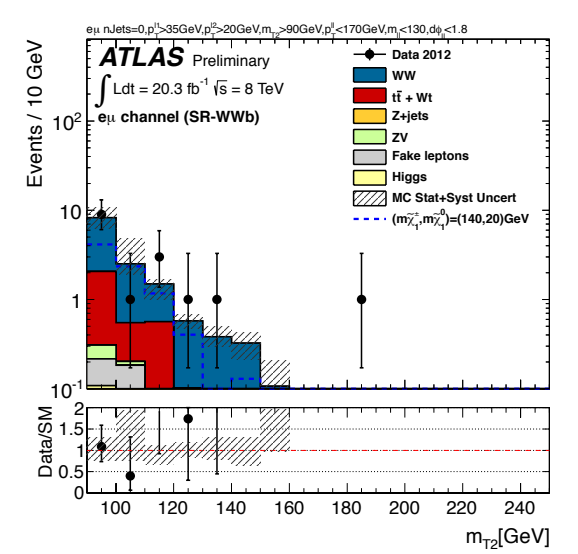
  - "challenging" heavy slepton scenario.
  - Three Signal regions used: SR-WWa, SR-WWb and SR-WWc (0, >90, >100 in m_{T2})
  - Used only in eμ channel!

new!

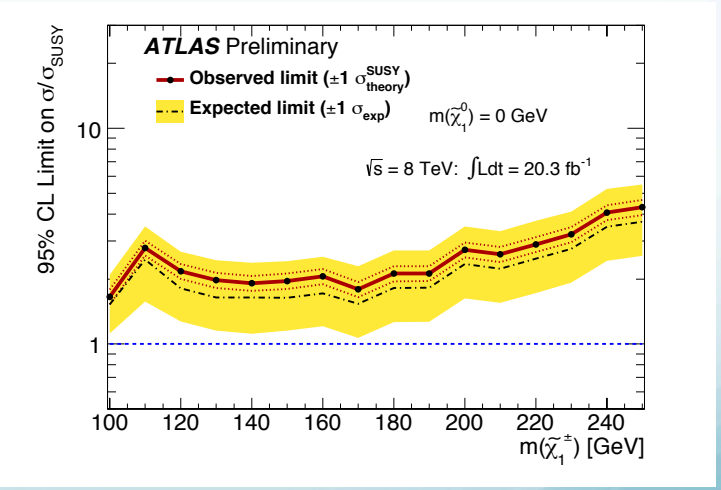
SR-WWa wo cuts



SR-WWb



95% CL upper limit on cross-section

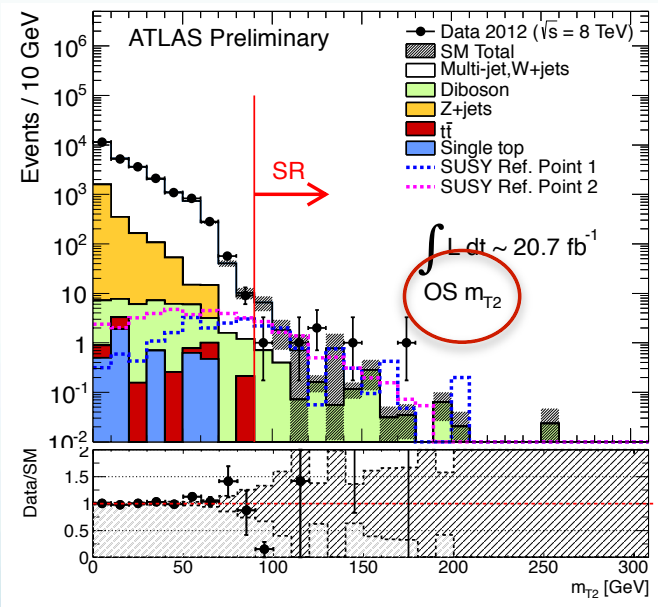


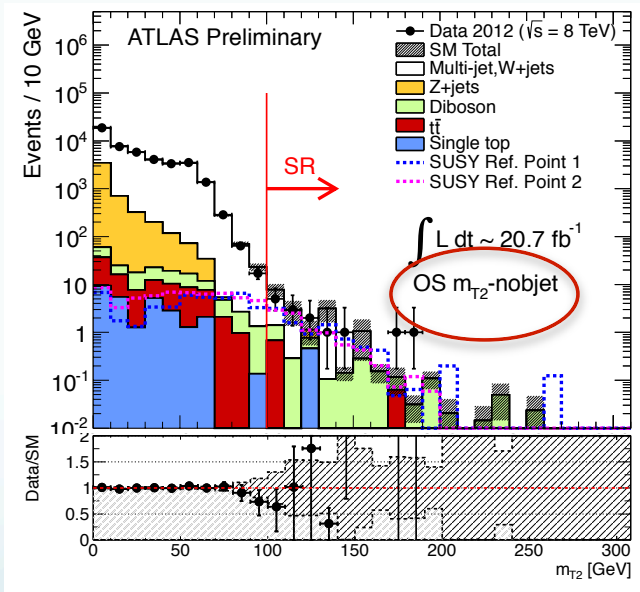
Ewkino production (I)

•**ATLAS-CONF-2013-028**

Intermediate staus: Chargino/neutralino or chargino/chargino pair production through intermediate staus

- SR1:OS hadronic tau, Z-veto, jet-veto, MET>40 GeV, m_{T2}>90 GeV
- SR2:OS hadronic tau, Z-veto, b-jet veto, MET>40 GeV, m_{T2}>100 GeV

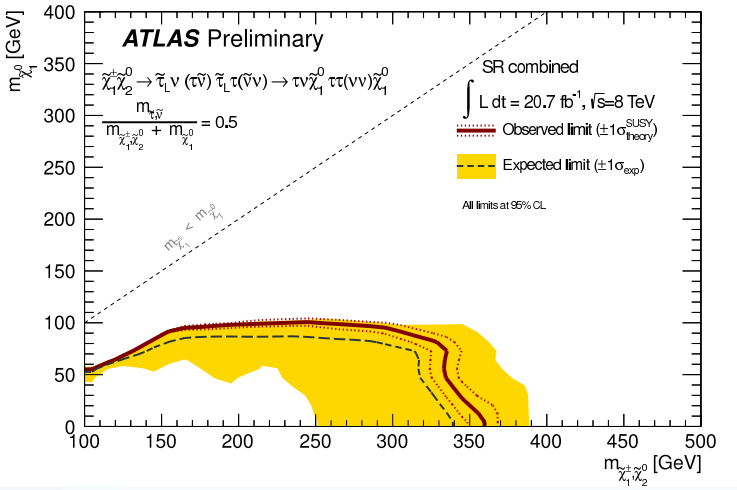




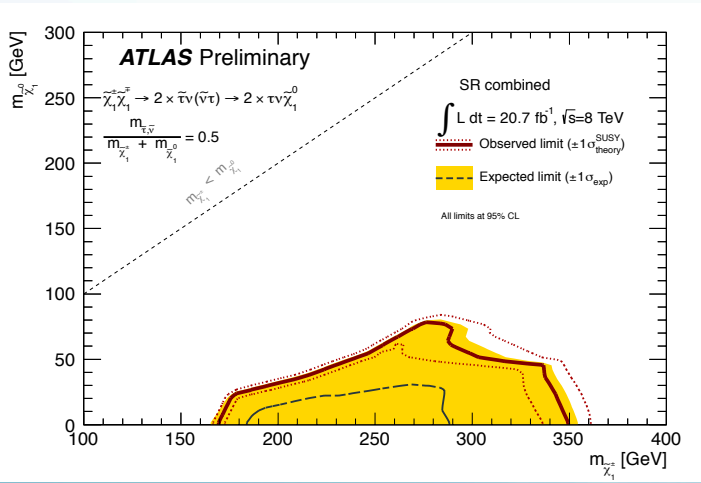
ABCD technique for multi-jet and W+jet backgrounds

Ewkino production (I)

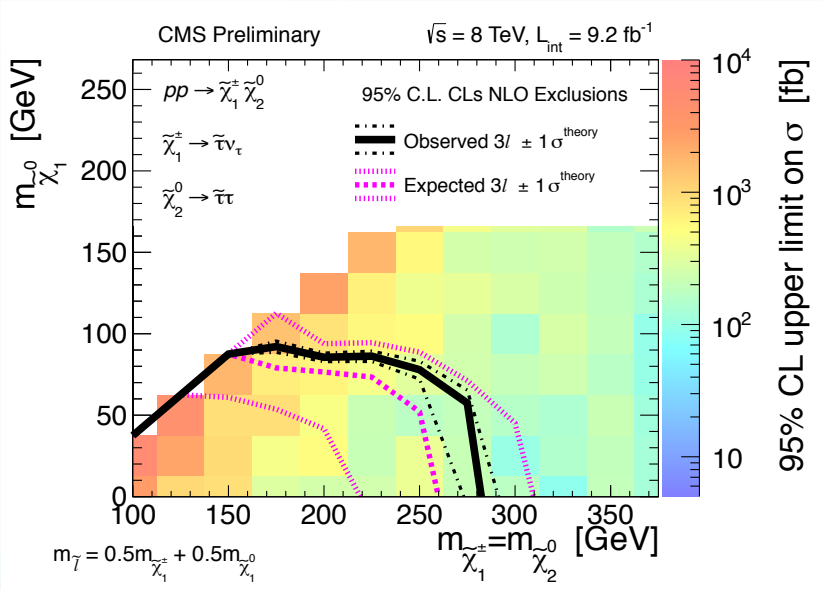
Intermediate staus: Results for chargino/neutralino or chargino/chargino pair production with decays through staus



Chargino-neutralino



Chargino-chargino



- **ATLAS-CONF-2013-028**
- **CMS-SUS-12-022**

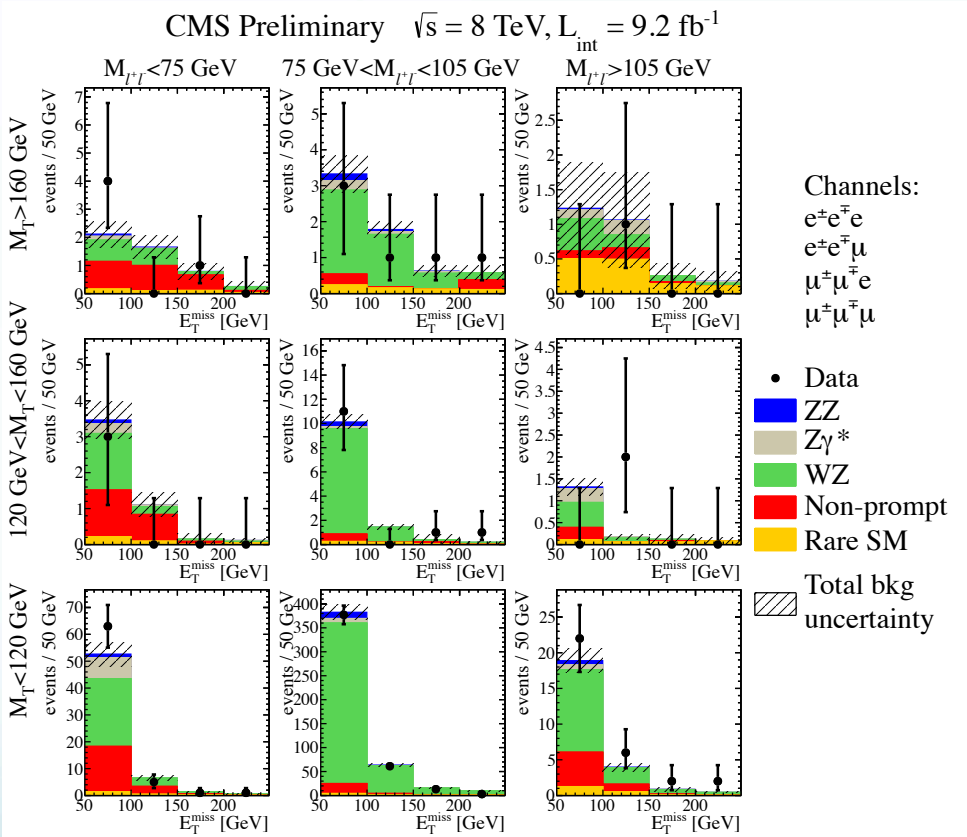
Ewkino production (I)

•CMS-SUS-12-022

•Very low background:
- •Look for 3 isolated leptons

•Use 3D binning: E_T^{miss}, M_T^* and M_{ll}
- • 50 GeV E_T^{miss} bins (E_T^{miss} >50 GeV)

•Background due to:
- •WZ, ZZ real production
  - • correct the MC E_t^{miss} reconstruction to data
- •Fake and non-prompt muons (ttbar, Z+jets and WW+jets)
  - •Use QCD enriched samples to measure the isolation requirement of fake-leptons
  - •Use b-jet veto to supress ttbar (70%b-tag efficiency and misindentification of 1% for CMS, while ATLAS has 85% and 10%)



$M_T^{*2} = 2.\ E_T^{mis} p_T^{l}(1- \cos \Delta\phi_{l,ET}^{miss})$

Ewkino production (I)

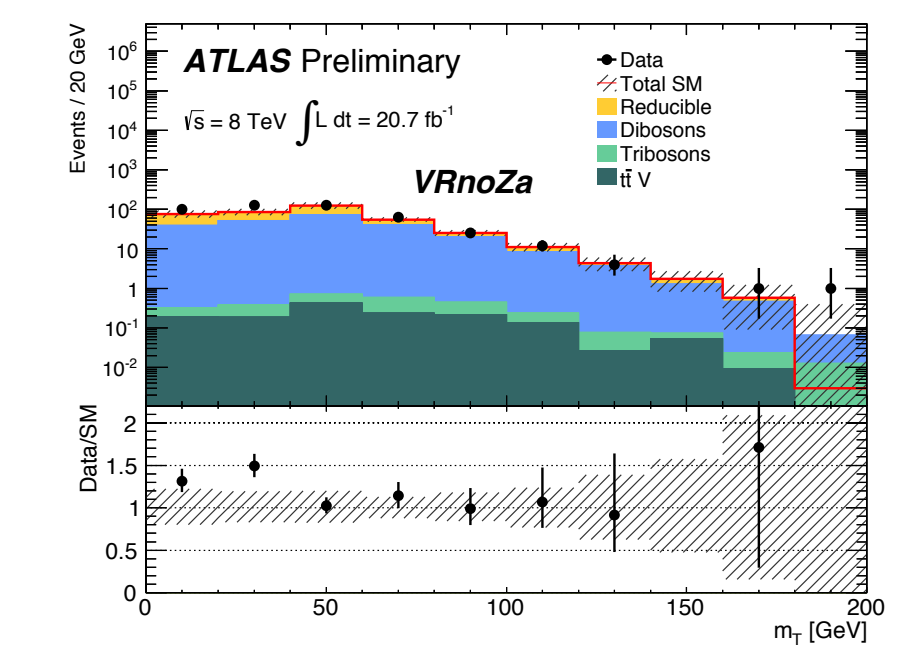
- Look for targeted search regions with different cuts:

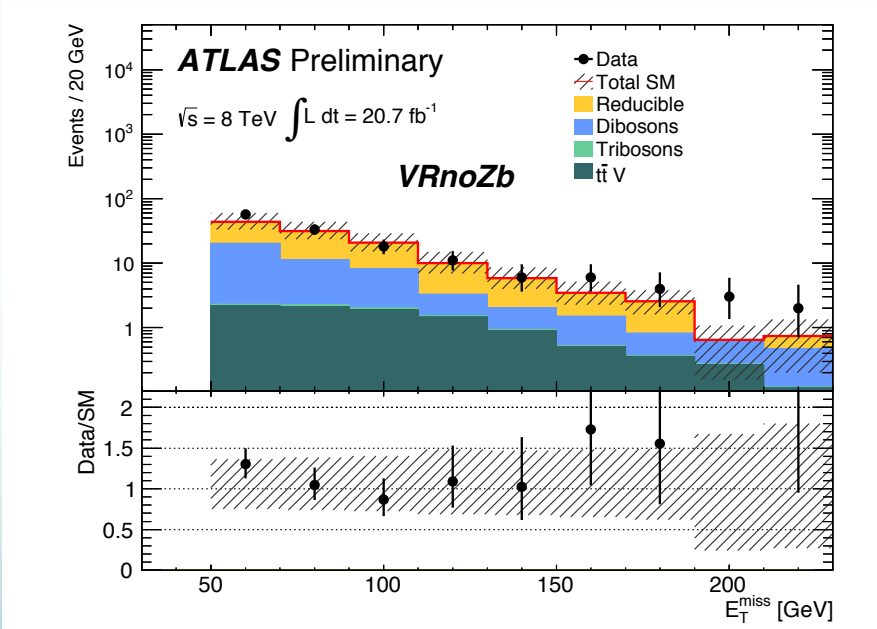
- **ATLAS-CONF-2013-035**

Selection	SRnoZa	SRnoZb	SRnoZc	SRZa	SRZb	SRZc
m_{SFOS} [GeV]	<60	60–81.2	<81.2 or >101.2	81.2–101.2	81.2–101.2	81.2–101.2
E_T^{miss} [GeV]	>50	>75	>75	75–120	75–120	>120
m_T [GeV]	–	–	>110	<110	>110	>110
p_T 3rd ℓ [GeV]	>10	>10	>30	>10	>10	>10
SR veto	SRnoZc	SRnoZc	–	–	–	–

Selection	VRnoZa	VRnoZb	VRZa	VRZb
m_{SFOS} [GeV]	<81.2 or >101.2	<81.2 or >101.2	81.2–101.2	81.2–101.2
b-jet	veto	request	veto	request
E_T^{miss} [GeV]	35–50	>50	30–50	>50
Dominant process	WZ^*, Z^*Z^*, Z^*+jets	$t\bar{t}$	WZ, Z+jets	WZ

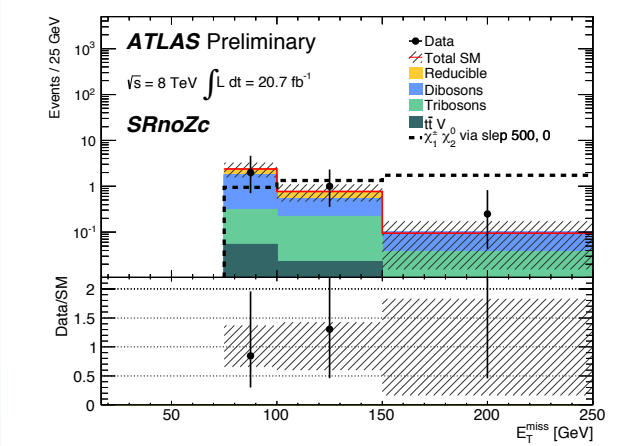
- Represent background on control data:

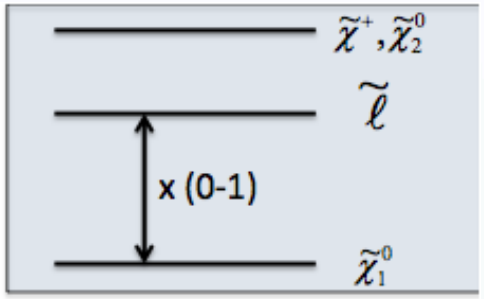




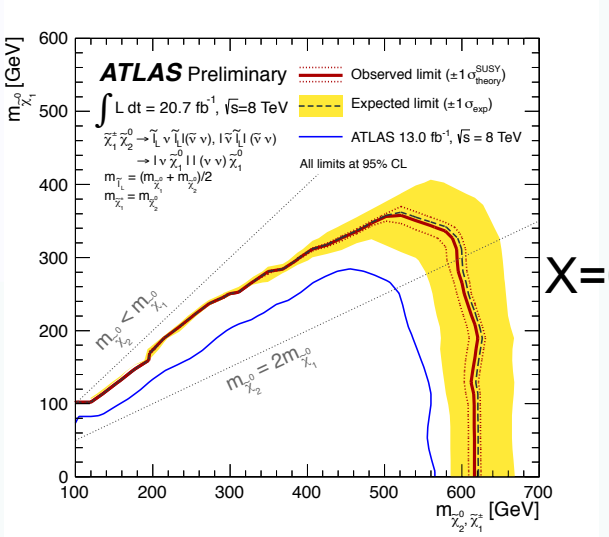
Ewkino production (I)

- Compare with signal and extract exclusion limits:
  - Use Simplified SUSY models
  - Decay via sleptons: limit up to 600 GeV

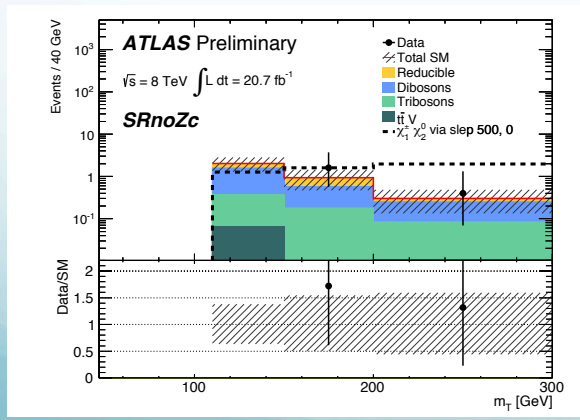


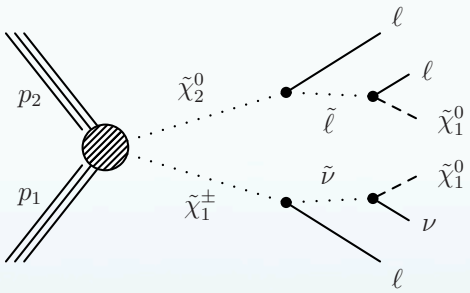


$m_{slep} = x \cdot m_{\chi^+} + (1-x) \cdot m_{LSP}$



X=0.5

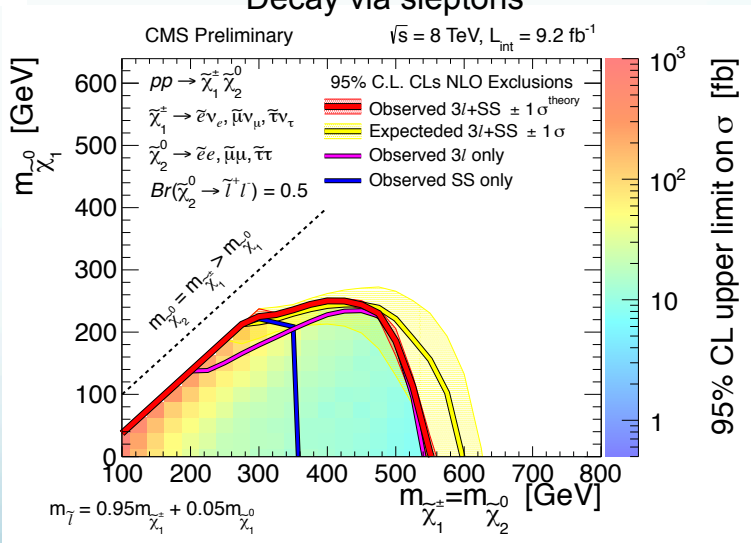




X=0.95

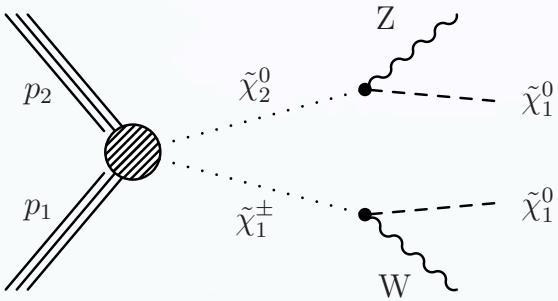
- **ATLAS-CONF-2013-035**
- **CMS-SUS-12-022**

Decay via sleptons

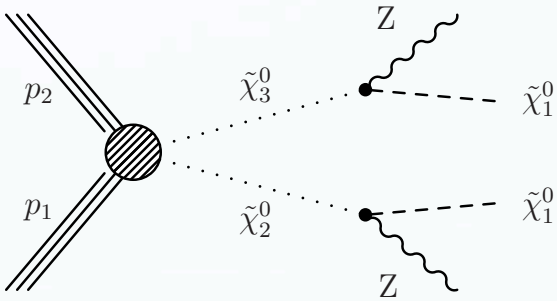


Ewkino production (I)

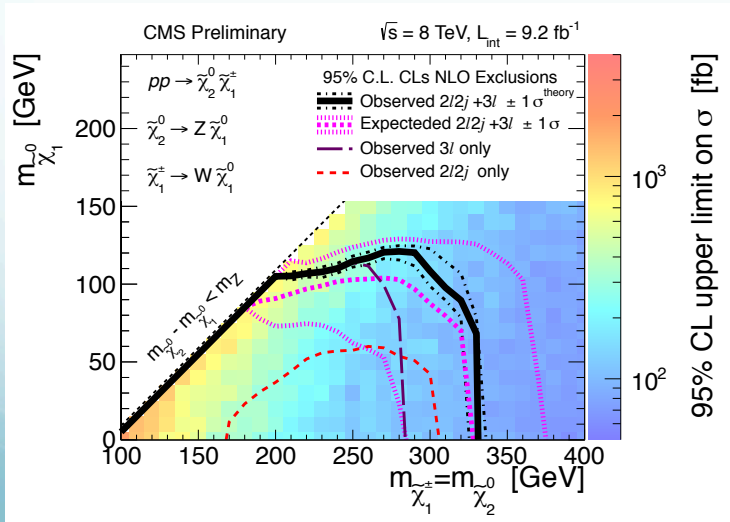
- Compare with signal and extract exclusion limits:
  - If sleptons are heavy, chargino or neutralino can decade through W or Z.
  - Decay via gauge bosons: limit up to 315 GeV

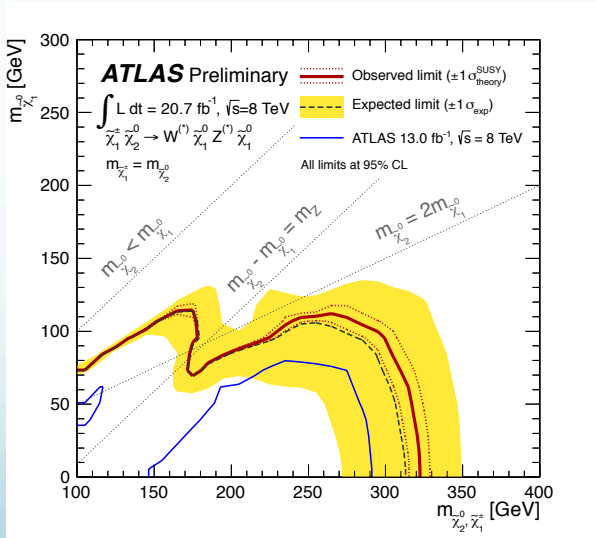


- **ATLAS-CONF-2013-035**
- **CMS-SUS-12-022**



Decay via gauge bosons





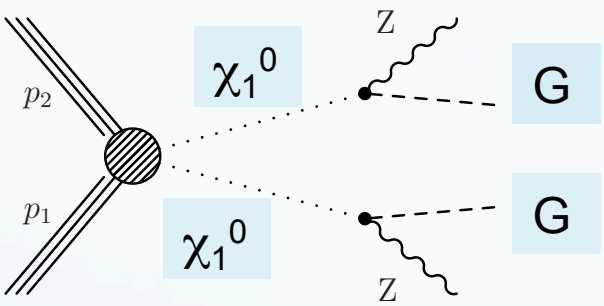
Ewkino production (I)

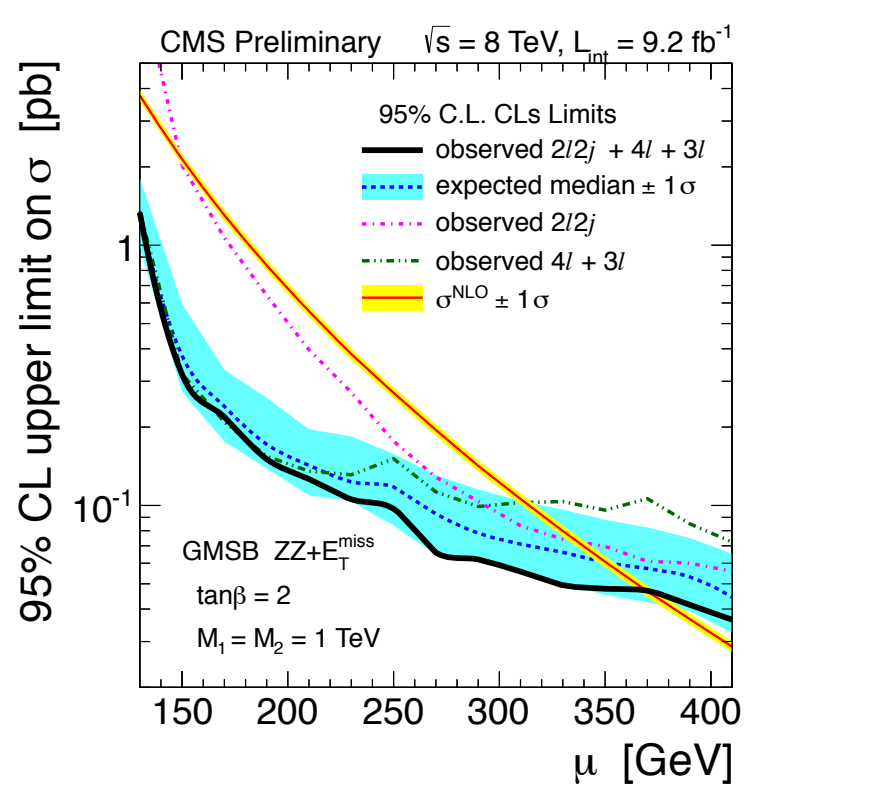
•Gauge mediated symmetry breaking (GMSB) Z-enriched higgsino model

•**CMS-SUS-12-022**

•The LSP is almost a massles gravitino

•nLSP is a Z-enriched higgsino χ_1^0



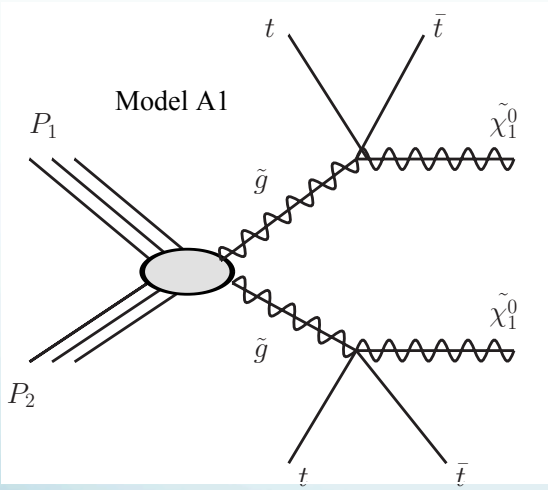


•Setting limits on neutralino-neutralino production in the GMSB scenario

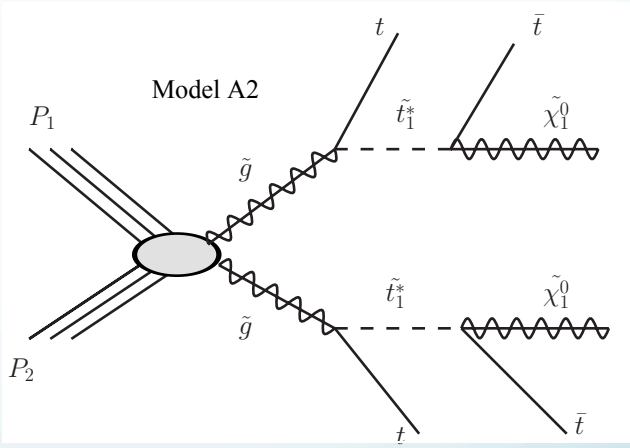
•Exclusion in terms of parameter μ that controls the chargino and LSP masses

General multilepton (II)

- It also can give scenarios with gluinos to top and neutralino plus b-tag jets:
  - 3 or 4 leptons can be obtained at the end of the analysis.
  - Off-Z scenarios
  - 4 W plus b jets
- Or decays trough 4 leptons



gluinos from strong production decay to 4 top and 2 LSP

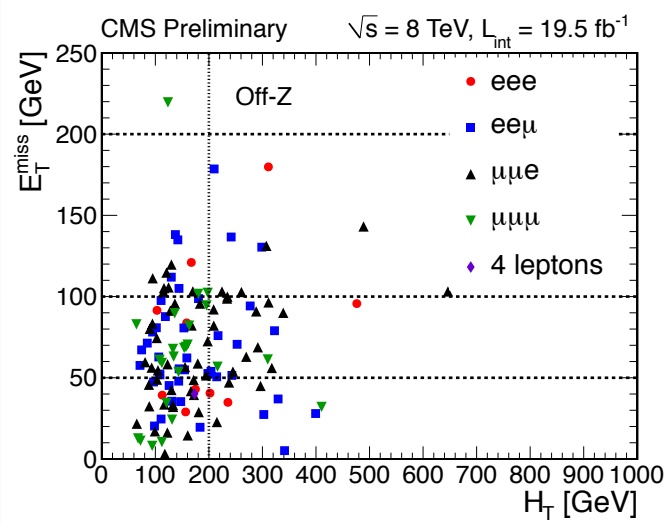


Off-shell stop

On-shell stop

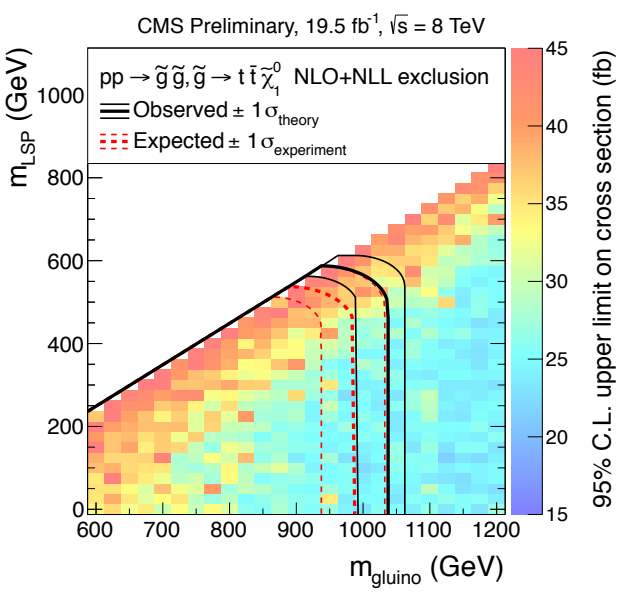
General multilepton (II)

- Use bidimensional H_T vs E_T^{miss} bins for off-shell Z. Use regions with high H_T and high N_{jets}
- Data-driven prediction for non-prompt and misidentified leptons
- Use number of b-tagged jets: $N_{b\text{-}tags}>1$

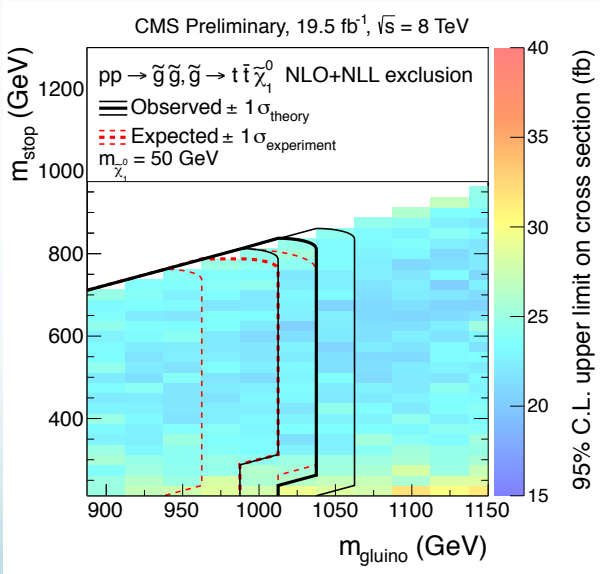


- **CMS-SUS-13-008**

new!



Medium or High E_t^{miss}

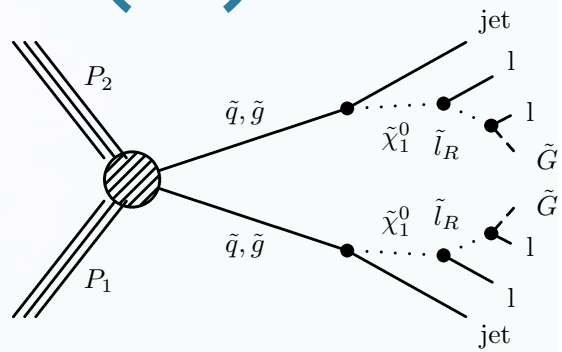


High E_T^{miss} $m\chi_1^0$ = 50 GeV

General multilepton (II)

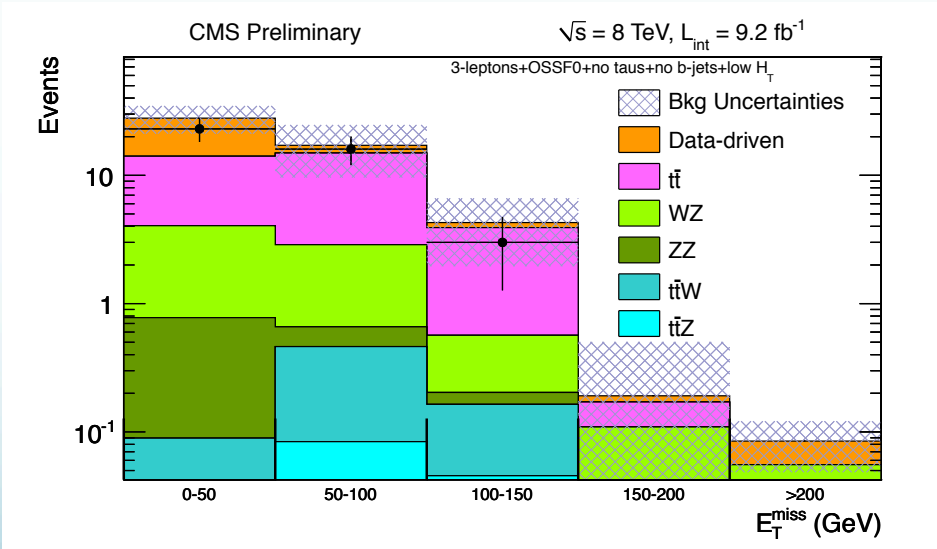
It also can give scenarios with gluinos and squarks to gravitino as LSP:

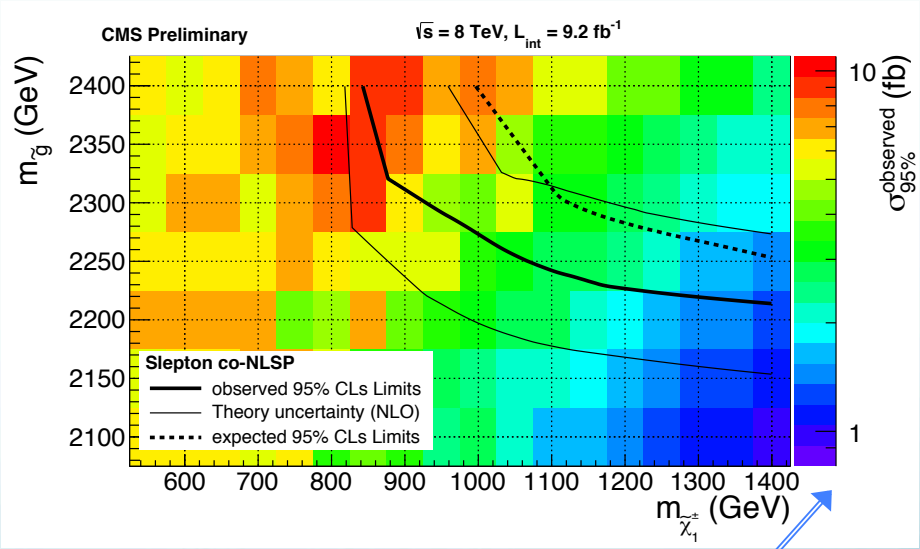
- In any case 3 or 4 leptons can be obtained at the end of the analysis.



•**CMS-SUS-12-026**

squark/gluino from strong production decaying to sleptons





E_t^{miss} distribution

Co-NLSP

Observed 95% CL excluded cross section

General multilepton (II)

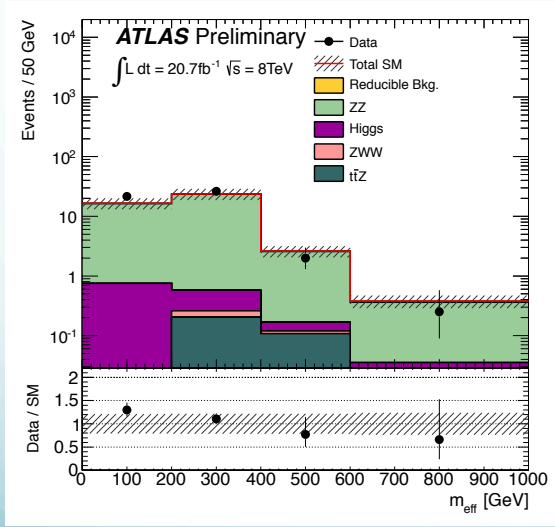
Search 4 leptons looking at E_T^{miss} and m^*_{eff} for signal and background:

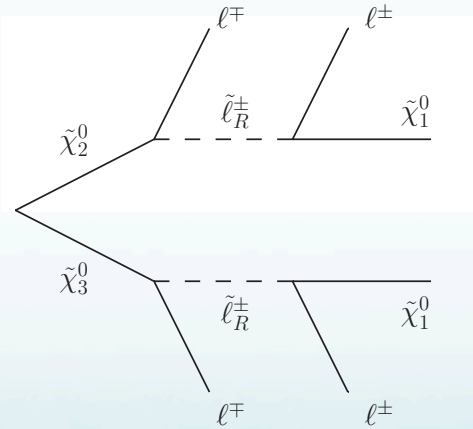
•**ATLAS-CONF-2013-036**

SR	$N(\ell = e,\mu)$	$N(\tau)$	Z Candidate	E_T^{miss}[GeV]		m_{eff}[GeV]	Scenario
SR0noZa	≥4	≥0	extended veto	>50			RPC
SR0noZb	≥4	≥0	extended veto	>75	or	>600	RPV
SR1noZ	=3	≥1	extended veto	>100	or	>400	RPV
SR0Z	≥4	≥0	request	>75			GGM
SR1Z	=3	≥1	request	>100			GGM

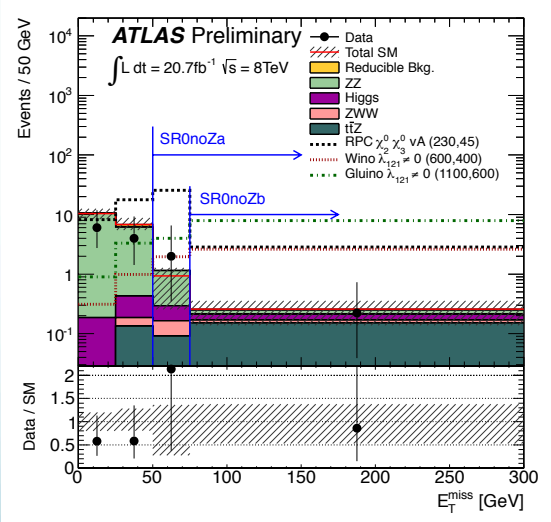
VR	$N(\ell = e,\mu)$	$N(\tau)$	Z Candidate	E_T^{miss}[GeV]		m_{eff}[GeV]	Dominant Background
VR0noZ	≥4	≥0	extended veto	<50	and	<400	Z^*Z^*
VR1noZ	=3	≥1	extended veto	<50	and	<400	Z^*Z^*, WZ^*, Z^*+jets
VR0Z	≥4	≥0	request	<50			ZZ
VR1Z	=3	≥1	request	<50			ZZ, WZ, Z+jets

VR0Z





SR0noZa

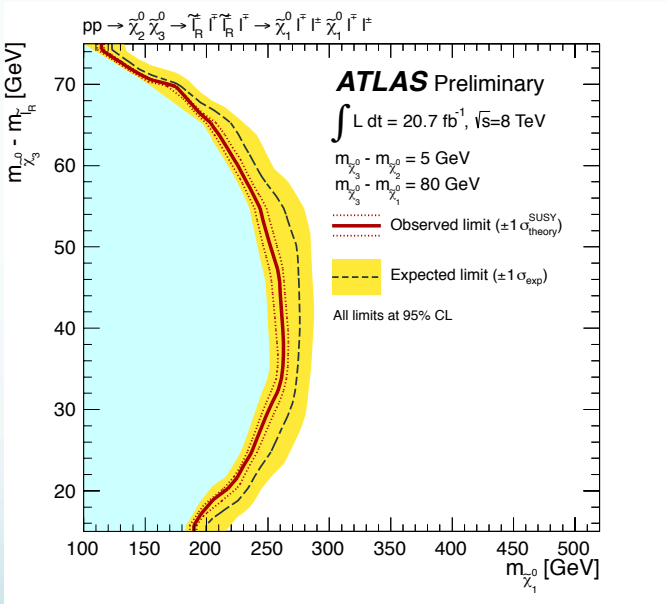


$$(m^*_{eff} = E_T^{miss} + \Sigma p_T^e + \Sigma p_T^\mu + \Sigma p_T^\tau + \Sigma p_T^j)$$

General multilepton (II)

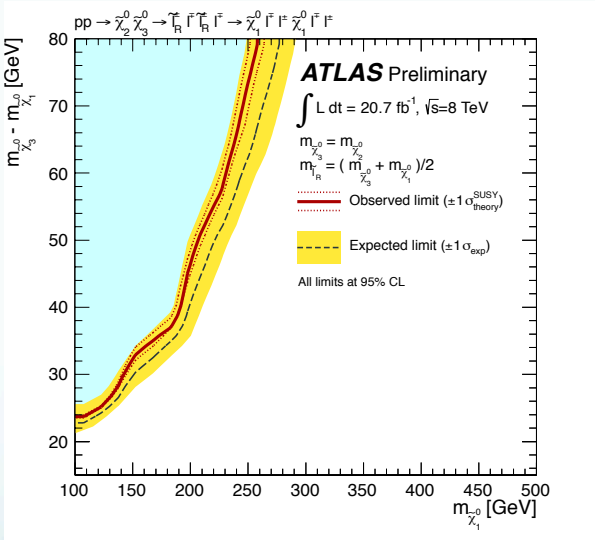
•ATLAS-CONF-2013-036

- vA: $\Delta m(\chi_3^0, \chi_2^0) = 5$ GeV and $\Delta m(\chi_3^0, \chi_1^0) = 80$ GeV
- vB: $\Delta m(\chi_3^0, \chi_2^0) = 0$ GeV and $m(l_R) = 0.5*[m(\chi_3^0) + m(\chi_1^0)]$



$\chi_3^0 \chi_2^0$ production

vA



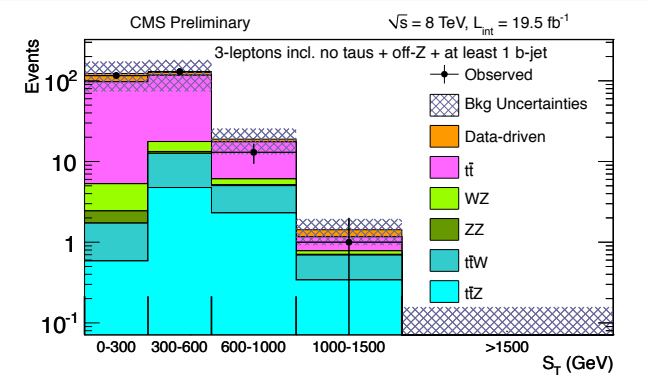
vB

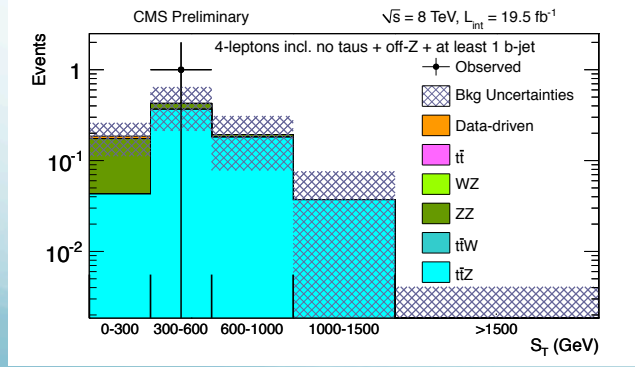
Stop with R-Parity Violation(III)

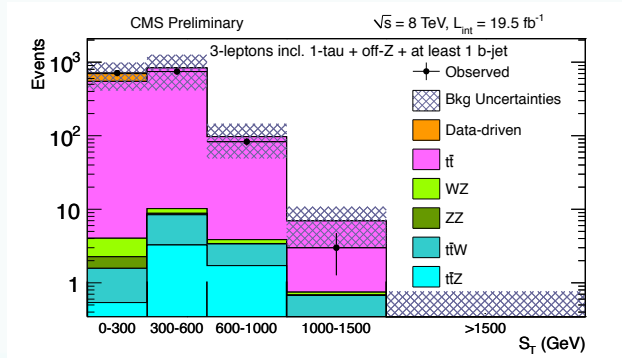
•**CMS-SUS-13-003**

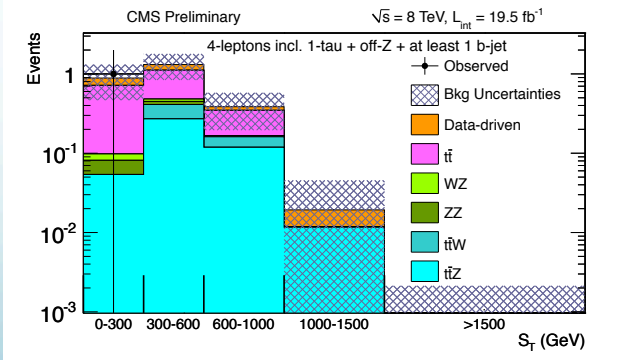
We look for data with three or more isolated leptons and at least one bottom-quark jet:

- use $S_T = E_t^{miss} + H_T + L_T$ (L_T sum of charged lepton p_T)
  - •This takes into account the low E_t^{miss} in the event due to RPV









Stop with R-Parity Violation(III)

RPV renormalizable Superpotential:

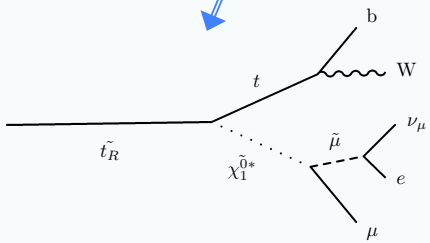
•CMS-SUS-13-003

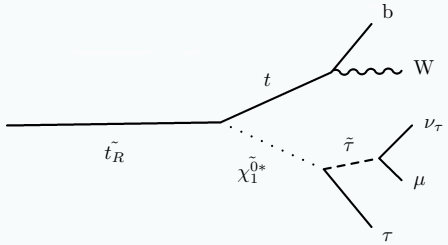
$$W_{RPV} = \lambda_{ijk} L^i L^j E^k + \lambda'_{ijk} L^i Q^j D^k + \lambda''_{ijk} U^i D^j D^k + \varepsilon_i L_i H_2$$

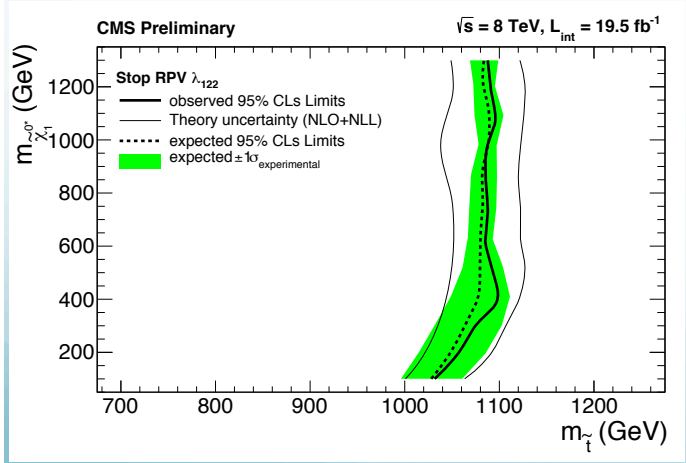
LLE122 coupling non zero

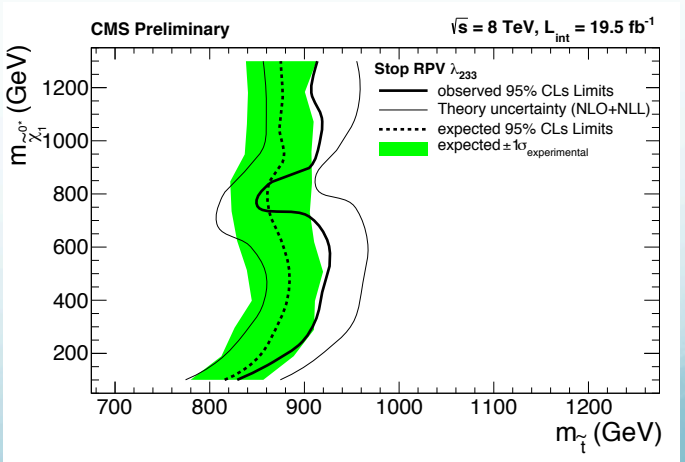
LLE233 coupling non zero

λ-term	neutralino LSP decay mode
$\lambda_{121} = -\lambda_{211}$	$e\mu\nu_e + ee\nu_\mu$
$\lambda_{122} = -\lambda_{212}$	$\mu\mu\nu_e + \mu e\nu_\mu$
$\lambda_{123} = -\lambda_{231}$	$\tau\mu\nu_e + \tau e\nu_\mu$
$\lambda_{131} = -\lambda_{311}$	$e\tau\nu_e + ee\nu_\tau$
$\lambda_{132} = -\lambda_{312}$	$\mu\tau\nu_e + \mu e\nu_\tau$
$\lambda_{133} = -\lambda_{331}$	$\tau\tau\nu_e + \tau e\nu_\tau$
$\lambda_{231} = -\lambda_{321}$	$e\tau\nu_\mu + e\mu\nu_\tau$
$\lambda_{232} = -\lambda_{322}$	$\mu\tau\nu_\mu + \mu\mu\nu_\tau$
$\lambda_{233} = -\lambda_{321}$	$\tau\tau\nu_\mu + \tau\mu\nu_\tau$









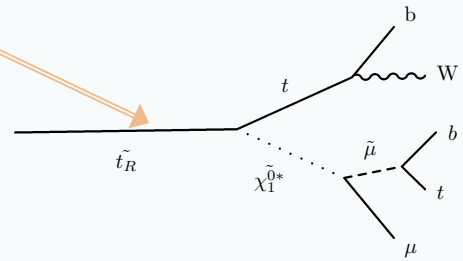
Stop with R-Parity Violation(III)

•CMS-SUS-13-003

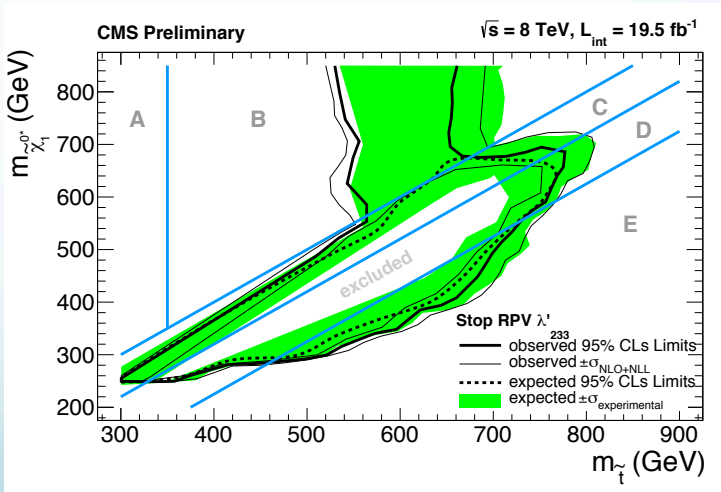
$$W_{RPV} = \lambda_{ijk} L^i L^j E^k + \lambda'_{ijk} L^i Q^j D^k + \lambda''_{ijk} U^i D^j D^k + \varepsilon_i L_i H_2$$

LQD223 coupling non zero

Several kinematic regions
With different acceptance

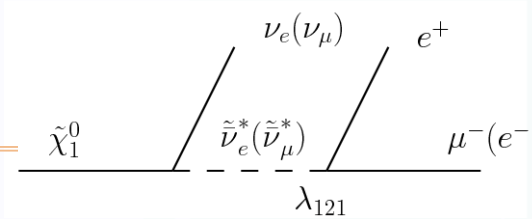


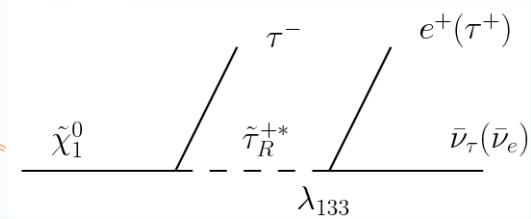
region label	kinematic region	stop decay mode(s)
A	$m_t < m_{\tilde{t}} < 2m_t, m_{\tilde{\chi}_1^0}$	$\tilde{t} \to t\nu b\bar{b}$
B	$2m_t < m_{\tilde{t}} < m_{\tilde{\chi}_1^0}$	$\tilde{t} \to t\mu t\bar{b} + t\nu b\bar{b}$
C	$m_{\tilde{\chi}_1^0} < m_{\tilde{t}} < m_W + m_{\tilde{\chi}_1^0}$	$\tilde{t} \to \ell\nu b\tilde{\chi}_1^0 + jjb\tilde{\chi}_1^0$
D	$m_W + m_{\tilde{\chi}_1^0} < m_{\tilde{t}} < m_t + m_{\tilde{\chi}_1^0}$	$\tilde{t} \to Wb\tilde{\chi}_1^0$
E	$m_t + m_{\tilde{\chi}_1^0} < m_{\tilde{t}}$	$\tilde{t} \to t\tilde{\chi}_1^0$



R-Parity Violation(III)

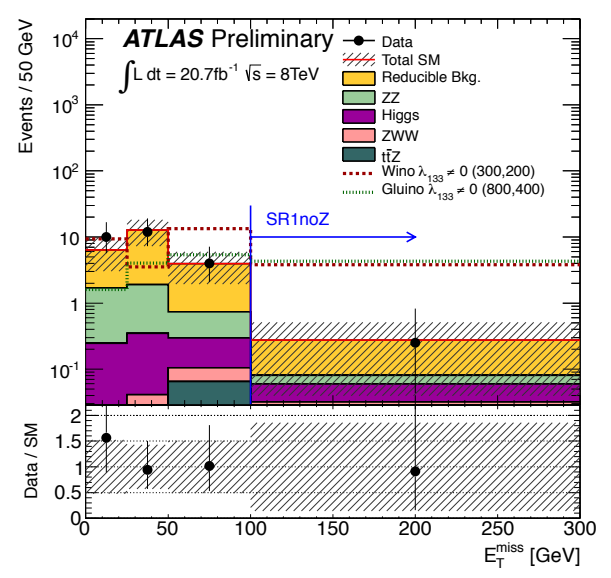
SR	N($\ell = e,\mu$)	N(τ)	Z Candidate	E_T^{miss}[GeV]		m_{eff}[GeV]	Scenario
SR0noZa	≥4	≥0	extended veto	>50			RPC
SR0noZb	≥4	≥0	extended veto	>75	or	>600	RPV
SR1noZ	=3	≥1	extended veto	>100	or	>400	RPV
SR0Z	≥4	≥0	request	>75			GGM
SR1Z	=3	≥1	request	>100			GGM

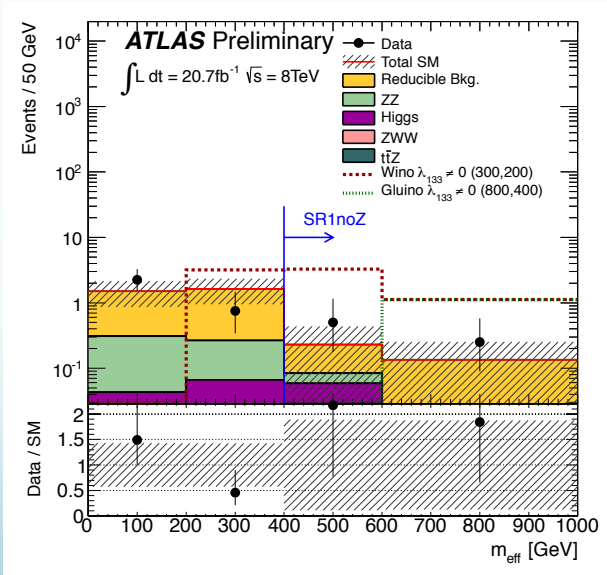




Distribution of E_t^{miss} and m_{eff} in events with 3 leptons and one or more τ

•**ATLAS-CONF-2013-036**



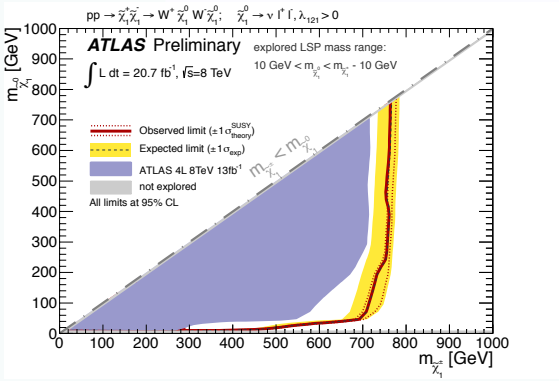


R-Parity Violation(III)

•**ATLAS-CONF-2013-036**

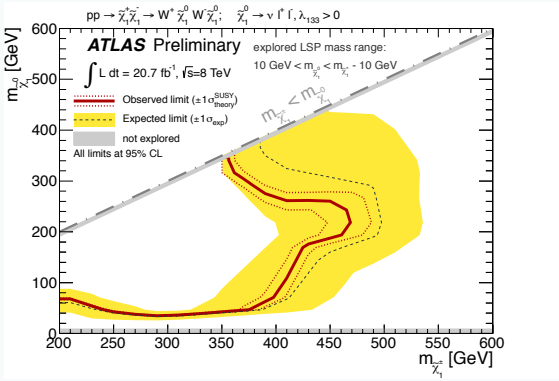
95% CL limit contours for the RPV wino and gluino simplified models where $\lambda_{121} \neq 0$ or $\lambda_{133} \neq 0$.

Wino $\lambda_{121} \neq 0$

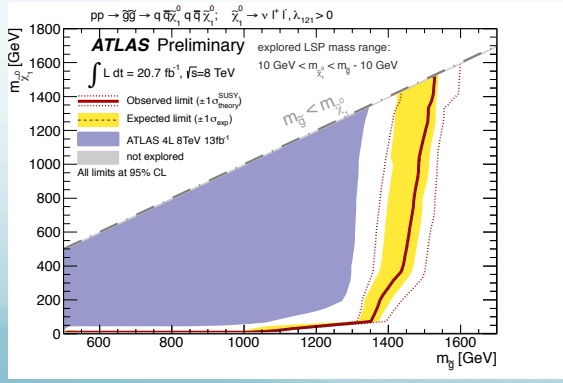


SR0noZb used in $\lambda_{121} \neq 0$

Wino $\lambda_{133} \neq 0$

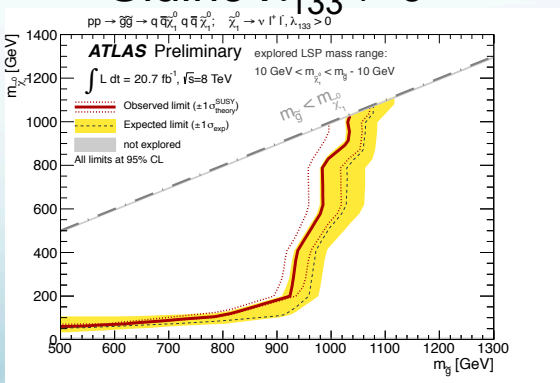


Gluino $\lambda_{121} \neq 0$



SR1noZ used in $\lambda_{133} \neq 0$

Gluino $\lambda_{133} \neq 0$



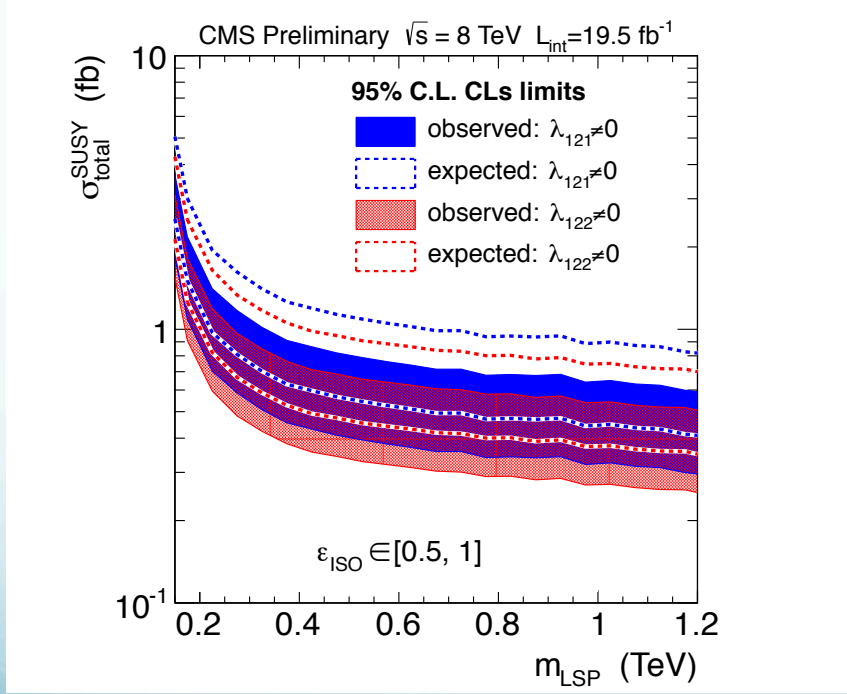
R-Parity Violation(III)

•CMS-SUS-13-010

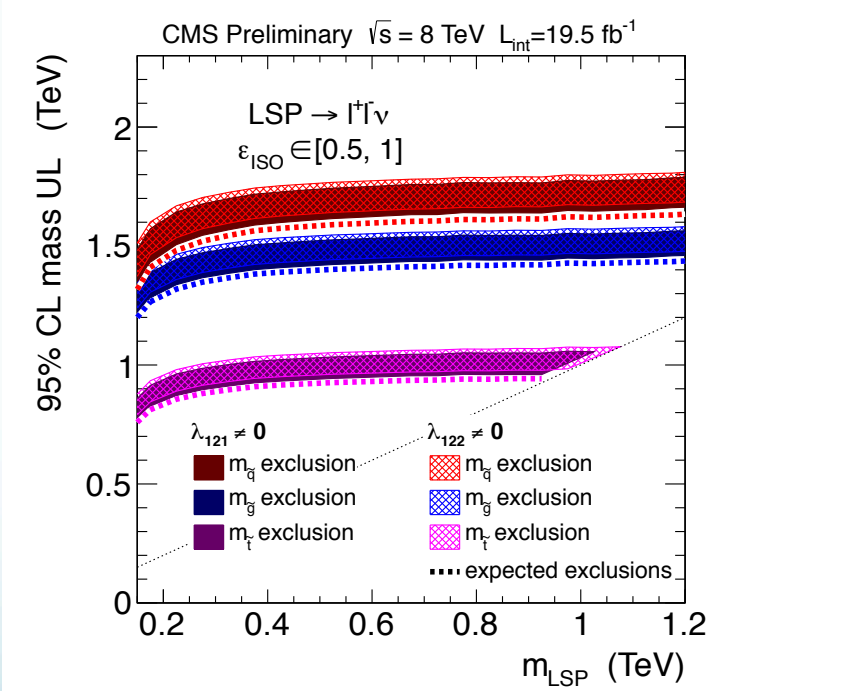
•CMS looks for final events with 4 isolated leptons (electrons/muons) in LRPV neutralino decays containing at least one OSSF lepton pair (only selection applied!)

•pMSSM covers MSSM spectra! Very generic exclusion SUSY models with LRPV term.

•No tau contribution due to presence of only LRPV terms λ_{121} and λ_{122}



new!

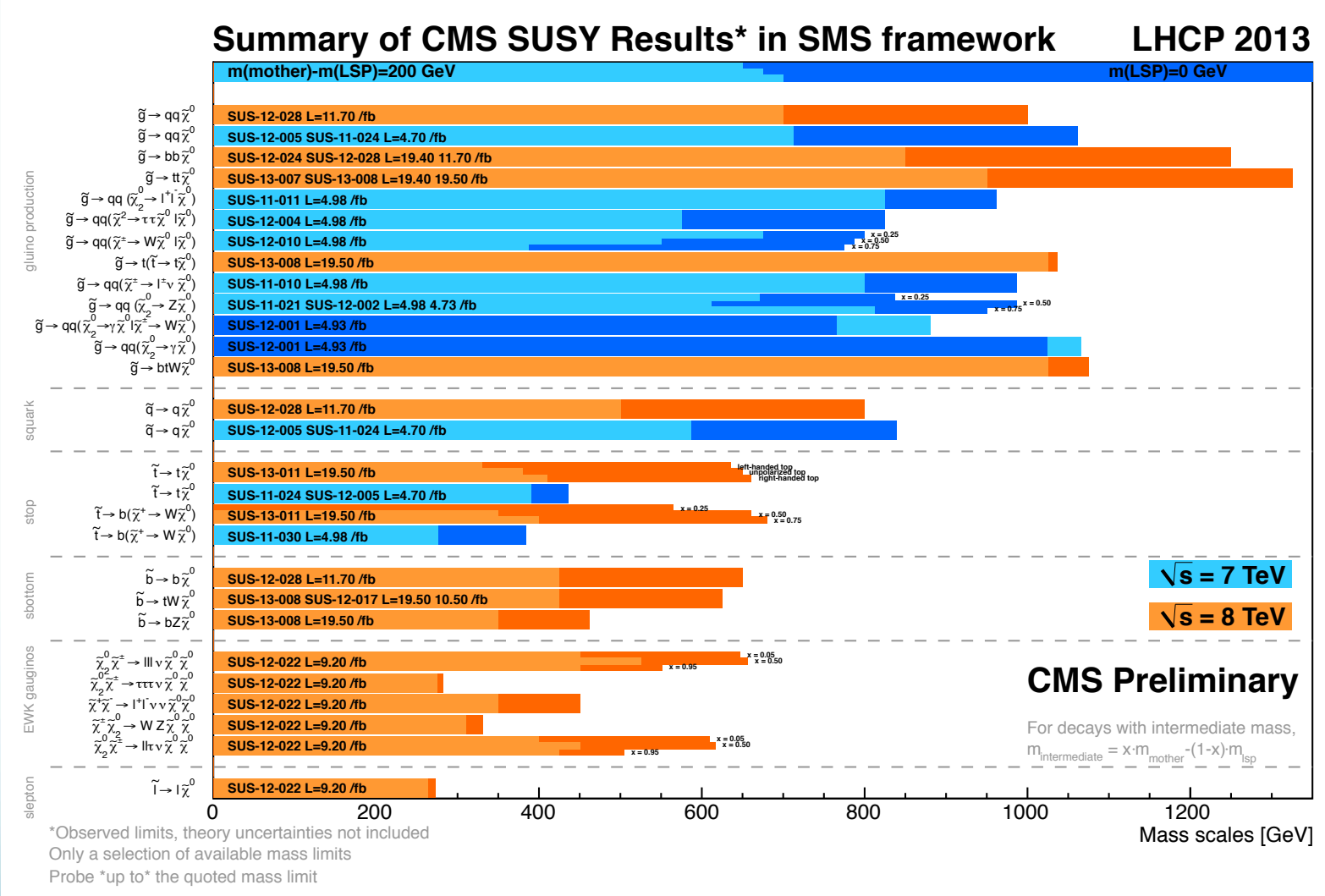


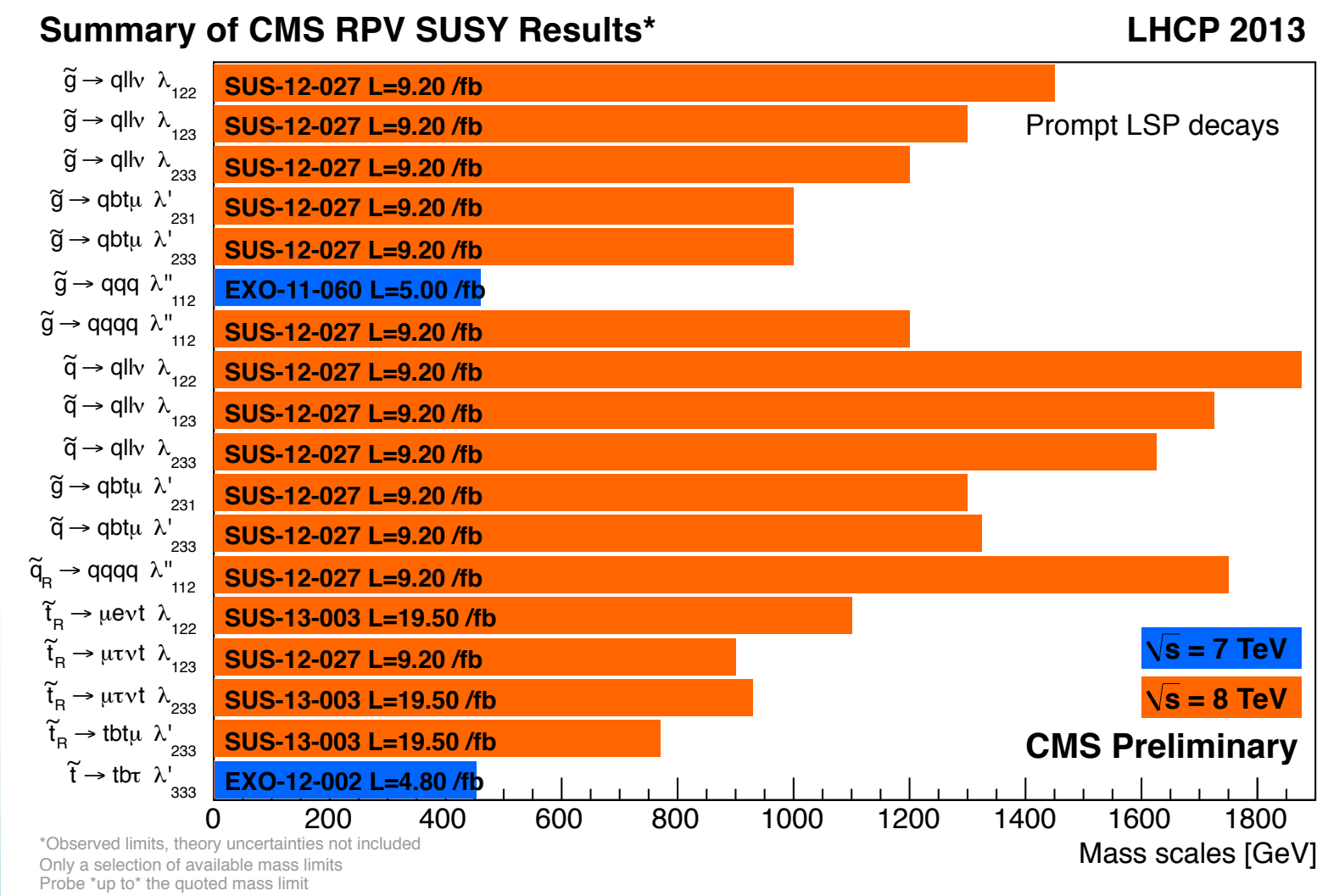
Generic cross section exclusion on inclusive RPV production

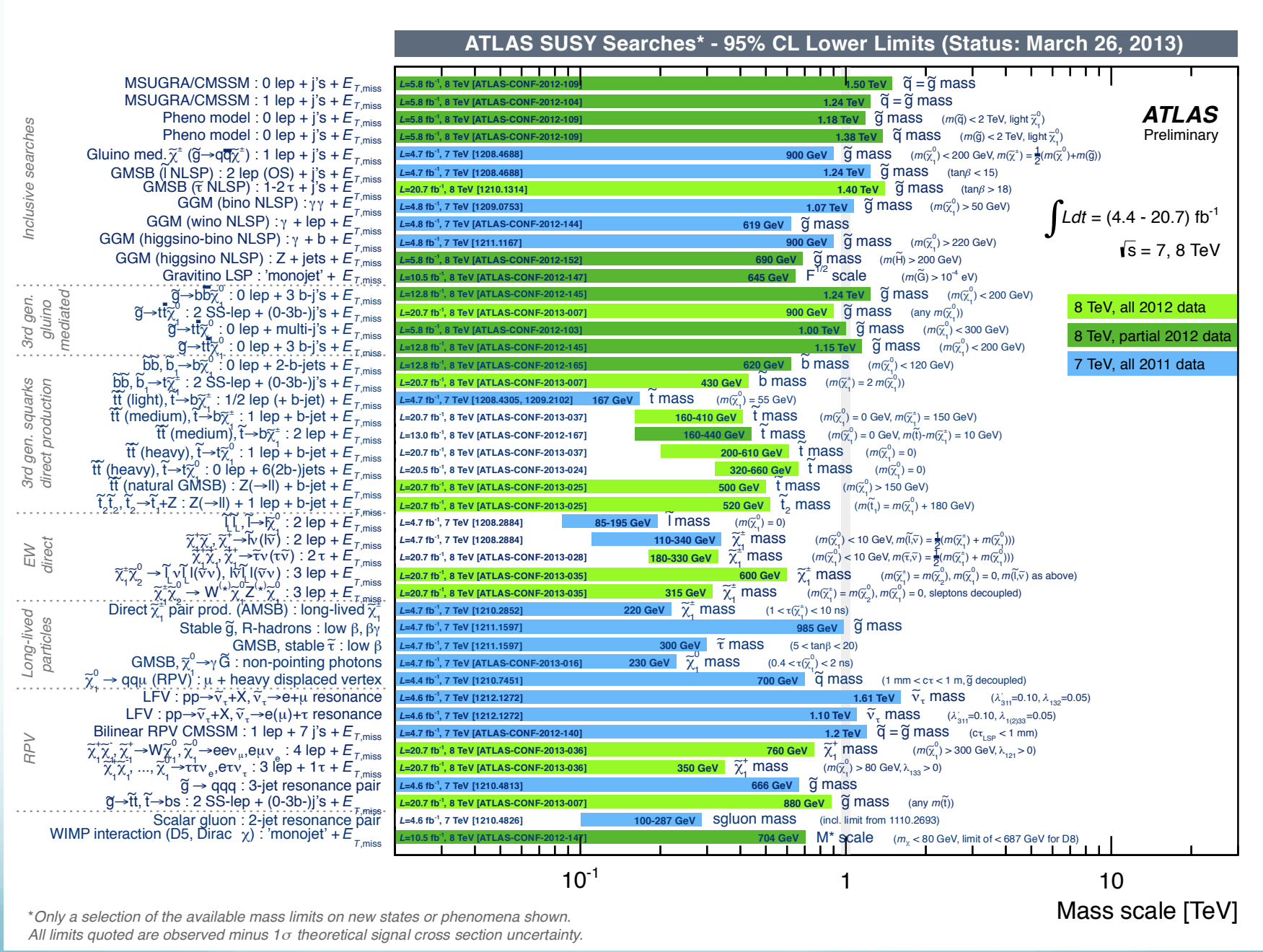
Generic mass exclusion on inclusive RPV production

Conclusions

- Many searches for SUSY in multiplepton final states have been performed at LHC:
  - No excess beyond Standard Model expectation is observed
  - Stringent constraints on masses of charginos, neutralinos and sleptons
  - Stay tuned for more results in the near future.
  - https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS
  - https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults


Summary of CMS SUSY Results* in SMS framework
LHCP 2013
m(mother)-m(LSP)=200 GeV
m(LSP)=0 GeV
gluino production
squark
stop
sbottom
EWK gauginos
slepton
SUS-12-028 L=11.70 /fb
SUS-12-005 SUS-11-024 L=4.70 /fb
SUS-12-024 SUS-12-028 L=19.40 11.70 /fb
SUS-13-007 SUS-13-008 L=19.40 19.50 /fb
SUS-11-011 L=4.98 /fb
SUS-12-004 L=4.98 /fb
SUS-12-010 L=4.98 /fb
SUS-13-008 L=19.50 /fb
SUS-11-010 L=4.98 /fb
SUS-11-021 SUS-12-002 L=4.98 4.73 /fb
SUS-12-001 L=4.93 /fb
SUS-12-001 L=4.93 /fb
SUS-13-008 L=19.50 /fb
SUS-12-028 L=11.70 /fb
SUS-12-005 SUS-11-024 L=4.70 /fb
SUS-13-011 L=19.50 /fb
SUS-11-024 SUS-12-005 L=4.70 /fb
SUS-13-011 L=19.50 /fb
SUS-11-030 L=4.98 /fb
SUS-12-028 L=11.70 /fb
SUS-13-008 SUS-12-017 L=19.50 10.50 /fb
SUS-13-008 L=19.50 /fb
SUS-12-022 L=9.20 /fb
SUS-12-022 L=9.20 /fb
SUS-12-022 L=9.20 /fb
SUS-12-022 L=9.20 /fb
SUS-12-022 L=9.20 /fb
SUS-12-022 L=9.20 /fb
√s = 7 TeV
√s = 8 TeV
CMS Preliminary
For decays with intermediate mass,
m_intermediate = x·m_mother-(1-x)·m_lsp
0
200
400
600
800
1000
1200
Mass scales [GeV]
*Observed limits, theory uncertainties not included
Only a selection of available mass limits
Probe *up to* the quoted mass limit


Summary of CMS RPV SUSY Results*
LHCP 2013
$\tilde{g} \to qll\nu\ \lambda_{122}$
$\tilde{g} \to qll\nu\ \lambda_{123}$
$\tilde{g} \to qll\nu\ \lambda_{233}$
$\tilde{g} \to qbt\mu\ \lambda'_{231}$
$\tilde{g} \to qbt\mu\ \lambda'_{233}$
$\tilde{g} \to qqq\ \lambda''_{112}$
$\tilde{g} \to qqqq\ \lambda''_{112}$
$\tilde{q} \to qll\nu\ \lambda_{122}$
$\tilde{q} \to qll\nu\ \lambda_{123}$
$\tilde{q} \to qll\nu\ \lambda_{233}$
$\tilde{g} \to qbt\mu\ \lambda'_{231}$
$\tilde{q} \to qbt\mu\ \lambda'_{233}$
$\tilde{q}_R \to qqqq\ \lambda''_{112}$
$\tilde{t}_R \to \mu e\nu t\ \lambda_{122}$
$\tilde{t}_R \to \mu\tau\nu t\ \lambda_{123}$
$\tilde{t}_R \to \mu\tau\nu t\ \lambda_{233}$
$\tilde{t}_R \to tbt\mu\ \lambda'_{233}$
$\tilde{t} \to tb\tau\ \lambda'_{333}$
SUS-12-027 L=9.20 /fb
SUS-12-027 L=9.20 /fb
SUS-12-027 L=9.20 /fb
SUS-12-027 L=9.20 /fb
SUS-12-027 L=9.20 /fb
EXO-11-060 L=5.00 /fb
SUS-12-027 L=9.20 /fb
SUS-12-027 L=9.20 /fb
SUS-12-027 L=9.20 /fb
SUS-12-027 L=9.20 /fb
SUS-12-027 L=9.20 /fb
SUS-12-027 L=9.20 /fb
SUS-12-027 L=9.20 /fb
SUS-13-003 L=19.50 /fb
SUS-12-027 L=9.20 /fb
SUS-13-003 L=19.50 /fb
SUS-13-003 L=19.50 /fb
EXO-12-002 L=4.80 /fb
Prompt LSP decays
$\sqrt{s}$ = 7 TeV
$\sqrt{s}$ = 8 TeV
CMS Preliminary
0
200
400
600
800
1000
1200
1400
1600
1800
Mass scales [GeV]
*Observed limits, theory uncertainties not included
Only a selection of available mass limits
Probe *up to* the quoted mass limit


ATLAS SUSY Searches* - 95% CL Lower Limits (Status: March 26, 2013)
Inclusive searches
MSUGRA/CMSSM : 0 lep + j's + $E_{T,miss}$
MSUGRA/CMSSM : 1 lep + j's + $E_{T,miss}$
Pheno model : 0 lep + j's + $E_{T,miss}$
Pheno model : 0 lep + j's + $E_{T,miss}$
Gluino med. $\tilde{\chi}^{\pm}$ ($\tilde{g}\to q\bar{q}\tilde{\chi}^{\pm}$) : 1 lep + j's + $E_{T,miss}$
GMSB ($\tilde{l}$ NLSP) : 2 lep (OS) + j's + $E_{T,miss}$
GMSB ($\tilde{\tau}$ NLSP) : 1-2 τ + j's + $E_{T,miss}$
GGM (bino NLSP) : $\gamma\gamma$ + $E_{T,miss}$
GGM (wino NLSP) : γ + lep + $E_{T,miss}$
GGM (higgsino-bino NLSP) : γ + b + $E_{T,miss}$
GGM (higgsino NLSP) : Z + jets + $E_{T,miss}$
Gravitino LSP : 'monojet' + $E_{T,miss}$
3rd gen. gluino mediated
$\tilde{g}\to b\bar{b}\tilde{\chi}_1^0$: 0 lep + 3 b-j's + $E_{T,miss}$
$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$: 2 SS-lep + (0-3b-)j's + $E_{T,miss}$
$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$: 0 lep + multi-j's + $E_{T,miss}$
$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$: 0 lep + 3 b-j's + $E_{T,miss}$
3rd gen. squarks direct production
$\tilde{b}\tilde{b}$, $\tilde{b}_1\to b\tilde{\chi}_1^0$: 0 lep + 2-b-jets + $E_{T,miss}$
$\tilde{b}\tilde{b}$, $\tilde{b}_1\to t\tilde{\chi}_1^{\pm}$: 2 SS-lep + (0-3b-)j's + $E_{T,miss}$
$\tilde{t}\tilde{t}$ (light), $\tilde{t}\to b\tilde{\chi}_1^{\pm}$: 1/2 lep (+ b-jet) + $E_{T,miss}$
$\tilde{t}\tilde{t}$ (medium), $\tilde{t}\to b\tilde{\chi}_1^{\pm}$: 1 lep + b-jet + $E_{T,miss}$
$\tilde{t}\tilde{t}$ (medium), $\tilde{t}\to b\tilde{\chi}_1^{\pm}$: 2 lep + $E_{T,miss}$
$\tilde{t}\tilde{t}$ (heavy), $\tilde{t}\to t\tilde{\chi}_1^0$: 1 lep + b-jet + $E_{T,miss}$
$\tilde{t}\tilde{t}$ (heavy), $\tilde{t}\to t\tilde{\chi}_1^0$: 0 lep + 6(2b-)jets + $E_{T,miss}$
$\tilde{t}\tilde{t}$ (natural GMSB) : Z(→ll) + b-jet + $E_{T,miss}$
$\tilde{t}_2\tilde{t}_2$, $\tilde{t}_2\to\tilde{t}_1$+Z : Z(→ll) + 1 lep + b-jet + $E_{T,miss}$
EW direct
$\tilde{l}_L\tilde{l}_L$, $\tilde{l}\to l\tilde{\chi}_1^0$: 2 lep + $E_{T,miss}$
$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$, $\tilde{\chi}_1^{\pm}\to\tilde{l}\nu(l\tilde{\nu})$: 2 lep + $E_{T,miss}$
$\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\mp}$, $\tilde{\chi}_1^{\pm}\to\tilde{\tau}\nu(\tau\tilde{\nu})$: 2 τ + $E_{T,miss}$
$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\to\tilde{l}_L\nu\tilde{l}_L l(\tilde{\nu}\nu)$, $l\tilde{\nu}\tilde{l}_L l(\tilde{\nu}\nu)$: 3 lep + $E_{T,miss}$
$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\to W^{(*)}\tilde{\chi}_1^0 Z^{(*)}\tilde{\chi}_1^0$: 3 lep + $E_{T,miss}$
Long-lived particles
Direct $\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\mp}$ pair prod. (AMSB) : long-lived $\tilde{\chi}_1^{\pm}$
Stable $\tilde{g}$, R-hadrons : low β, $\beta\gamma$
GMSB, stable $\tilde{\tau}$: low β
GMSB, $\tilde{\chi}_1^0\to\gamma\tilde{G}$: non-pointing photons
$\tilde{\chi}_1^0\to qq\mu$ (RPV) : μ + heavy displaced vertex
RPV
LFV : $pp\to\tilde{\nu}_\tau$+X, $\tilde{\nu}_\tau\to e+\mu$ resonance
LFV : $pp\to\tilde{\nu}_\tau$+X, $\tilde{\nu}_\tau\to e(\mu)+\tau$ resonance
Bilinear RPV CMSSM : 1 lep + 7 j's + $E_{T,miss}$
$\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\mp}$, $\tilde{\chi}_1^{\pm}\to W\tilde{\chi}_1^0$, $\tilde{\chi}_1^0\to ee\nu_\mu, e\mu\nu_e$: 4 lep + $E_{T,miss}$
$\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\mp}$, ..., $\tilde{\chi}_1^0\to\tau\tau\nu_e, e\tau\nu_\tau$: 3 lep + 1τ + $E_{T,miss}$
$\tilde{g}\to qqq$: 3-jet resonance pair
$\tilde{g}\to\tilde{t}\bar{t}$, $\tilde{t}\to bs$: 2 SS-lep + (0-3b-)j's + $E_{T,miss}$
Scalar gluon : 2-jet resonance pair
WIMP interaction (D5, Dirac χ) : 'monojet' + $E_{T,miss}$
ATLAS
Preliminary
$\int Ldt$ = (4.4 - 20.7) fb^{-1}
$\sqrt{s}$ = 7, 8 TeV
8 TeV, all 2012 data
8 TeV, partial 2012 data
7 TeV, all 2011 data
L=5.8 fb^{-1}, 8 TeV [ATLAS-CONF-2012-109] 1.50 TeV $\tilde{q}=\tilde{g}$ mass
L=5.8 fb^{-1}, 8 TeV [ATLAS-CONF-2012-104] 1.24 TeV $\tilde{q}=\tilde{g}$ mass
L=5.8 fb^{-1}, 8 TeV [ATLAS-CONF-2012-109] 1.18 TeV $\tilde{g}$ mass ($m(\tilde{q})$ < 2 TeV, light $\tilde{\chi}_1^0$)
L=5.8 fb^{-1}, 8 TeV [ATLAS-CONF-2012-109] 1.38 TeV $\tilde{q}$ mass ($m(\tilde{g})$ < 2 TeV, light $\tilde{\chi}_1^0$)
L=4.7 fb^{-1}, 7 TeV [1208.4688] 900 GeV $\tilde{g}$ mass ($m(\tilde{\chi}_1^0)$ < 200 GeV, $m(\tilde{\chi}^{\pm})=\frac{1}{2}(m(\tilde{\chi}^0)+m(\tilde{g}))$)
L=4.7 fb^{-1}, 7 TeV [1208.4688] 1.24 TeV $\tilde{g}$ mass ($\tan\beta$ < 15)
L=20.7 fb^{-1}, 8 TeV [1210.1314] 1.40 TeV $\tilde{g}$ mass ($\tan\beta$ > 18)
L=4.8 fb^{-1}, 7 TeV [1209.0753] 1.07 TeV $\tilde{g}$ mass ($m(\tilde{\chi}_1^0)$ > 50 GeV)
L=4.8 fb^{-1}, 7 TeV [ATLAS-CONF-2012-144] 619 GeV $\tilde{g}$ mass
L=4.8 fb^{-1}, 7 TeV [1211.1167] 900 GeV $\tilde{g}$ mass ($m(\tilde{\chi}_1^0)$ > 220 GeV)
L=5.8 fb^{-1}, 8 TeV [ATLAS-CONF-2012-152] 690 GeV $\tilde{g}$ mass ($m(\tilde{H})$ > 200 GeV)
L=10.5 fb^{-1}, 8 TeV [ATLAS-CONF-2012-147] 645 GeV $F^{1/2}$ scale ($m(\tilde{G})$ > 10^{-4} eV)
L=12.8 fb^{-1}, 8 TeV [ATLAS-CONF-2012-145] 1.24 TeV $\tilde{g}$ mass ($m(\tilde{\chi}_1^0)$ < 200 GeV)
L=20.7 fb^{-1}, 8 TeV [ATLAS-CONF-2013-007] 900 GeV $\tilde{g}$ mass (any $m(\tilde{\chi}_1^0)$)
L=5.8 fb^{-1}, 8 TeV [ATLAS-CONF-2012-103] 1.00 TeV $\tilde{g}$ mass ($m(\tilde{\chi}_1^0)$ < 300 GeV)
L=12.8 fb^{-1}, 8 TeV [ATLAS-CONF-2012-145] 1.15 TeV $\tilde{g}$ mass ($m(\tilde{\chi}_1^0)$ < 200 GeV)
L=12.8 fb^{-1}, 8 TeV [ATLAS-CONF-2012-165] 620 GeV $\tilde{b}$ mass ($m(\tilde{\chi}_1^0)$ < 120 GeV)
L=20.7 fb^{-1}, 8 TeV [ATLAS-CONF-2013-007] 430 GeV $\tilde{b}$ mass ($m(\tilde{\chi}_1^{\pm})=2\,m(\tilde{\chi}_1^0)$)
L=4.7 fb^{-1}, 7 TeV [1208.4305, 1209.2102] 167 GeV $\tilde{t}$ mass ($m(\tilde{\chi}_1^0)$ = 55 GeV)
L=20.7 fb^{-1}, 8 TeV [ATLAS-CONF-2013-037] 160-410 GeV $\tilde{t}$ mass ($m(\tilde{\chi}_1^0)$ = 0 GeV, $m(\tilde{\chi}_1^{\pm})$ = 150 GeV)
L=13.0 fb^{-1}, 8 TeV [ATLAS-CONF-2012-167] 160-440 GeV $\tilde{t}$ mass ($m(\tilde{\chi}_1^0)$ = 0 GeV, $m(\tilde{t})-m(\tilde{\chi}_1^{\pm})$ = 10 GeV)
L=20.7 fb^{-1}, 8 TeV [ATLAS-CONF-2013-037] 200-610 GeV $\tilde{t}$ mass ($m(\tilde{\chi}_1^0)$ = 0)
L=20.5 fb^{-1}, 8 TeV [ATLAS-CONF-2013-024] 320-660 GeV $\tilde{t}$ mass ($m(\tilde{\chi}_1^0)$ = 0)
L=20.7 fb^{-1}, 8 TeV [ATLAS-CONF-2013-025] 500 GeV $\tilde{t}$ mass ($m(\tilde{\chi}_1^0)$ > 150 GeV)
L=20.7 fb^{-1}, 8 TeV [ATLAS-CONF-2013-025] 520 GeV $\tilde{t}_2$ mass ($m(\tilde{t}_1)=m(\tilde{\chi}_1^0)$ + 180 GeV)
L=4.7 fb^{-1}, 7 TeV [1208.2884] 85-195 GeV $\tilde{l}$ mass ($m(\tilde{\chi}_1^0)$ = 0)
L=4.7 fb^{-1}, 7 TeV [1208.2884] 110-340 GeV $\tilde{\chi}_1^{\pm}$ mass ($m(\tilde{\chi}_1^0)$ < 10 GeV, $m(\tilde{l},\tilde{\nu})=\frac{1}{2}(m(\tilde{\chi}_1^{\pm})+m(\tilde{\chi}_1^0))$)
L=20.7 fb^{-1}, 8 TeV [ATLAS-CONF-2013-028] 180-330 GeV $\tilde{\chi}_1^{\pm}$ mass ($m(\tilde{\chi}_1^0)$ < 10 GeV, $m(\tilde{\tau},\tilde{\nu})=\frac{1}{2}(m(\tilde{\chi}_1^{\pm})+m(\tilde{\chi}_1^0))$)
L=20.7 fb^{-1}, 8 TeV [ATLAS-CONF-2013-035] 600 GeV $\tilde{\chi}_1^{\pm}$ mass ($m(\tilde{\chi}_1^{\pm})=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$ = 0, $m(\tilde{l},\tilde{\nu})$ as above)
L=20.7 fb^{-1}, 8 TeV [ATLAS-CONF-2013-035] 315 GeV $\tilde{\chi}_1^{\pm}$ mass ($m(\tilde{\chi}_1^{\pm})=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$ = 0, sleptons decoupled)
L=4.7 fb^{-1}, 7 TeV [1210.2852] 220 GeV $\tilde{\chi}_1^{\pm}$ mass (1 < $\tau(\tilde{\chi}_1^{\pm})$ < 10 ns)
L=4.7 fb^{-1}, 7 TeV [1211.1597] 985 GeV $\tilde{g}$ mass
L=4.7 fb^{-1}, 7 TeV [1211.1597] 300 GeV $\tilde{\tau}$ mass (5 < $\tan\beta$ < 20)
L=4.7 fb^{-1}, 7 TeV [ATLAS-CONF-2013-016] 230 GeV $\tilde{\chi}_1^0$ mass (0.4 < $\tau(\tilde{\chi}_1^0)$ < 2 ns)
L=4.4 fb^{-1}, 7 TeV [1210.7451] 700 GeV $\tilde{q}$ mass (1 mm < $c\tau$ < 1 m, $\tilde{g}$ decoupled)
L=4.6 fb^{-1}, 7 TeV [1212.1272] 1.61 TeV $\tilde{\nu}_\tau$ mass (λ'_{311}=0.10, λ_{132}=0.05)
L=4.6 fb^{-1}, 7 TeV [1212.1272] 1.10 TeV $\tilde{\nu}_\tau$ mass (λ'_{311}=0.10, $\lambda_{1(2)33}$=0.05)
L=4.7 fb^{-1}, 7 TeV [ATLAS-CONF-2012-140] 1.2 TeV $\tilde{q}=\tilde{g}$ mass ($c\tau_{LSP}$ < 1 mm)
L=20.7 fb^{-1}, 8 TeV [ATLAS-CONF-2013-036] 760 GeV $\tilde{\chi}_1^{\pm}$ mass ($m(\tilde{\chi}_1^0)$ > 300 GeV, λ_{121} > 0)
L=20.7 fb^{-1}, 8 TeV [ATLAS-CONF-2013-036] 350 GeV $\tilde{\chi}_1^{\pm}$ mass ($m(\tilde{\chi}_1^0)$ > 80 GeV, λ_{133} > 0)
L=4.6 fb^{-1}, 7 TeV [1210.4813] 666 GeV $\tilde{g}$ mass
L=20.7 fb^{-1}, 8 TeV [ATLAS-CONF-2013-007] 880 GeV $\tilde{g}$ mass (any $m(\tilde{t})$)
L=4.6 fb^{-1}, 7 TeV [1210.4826] 100-287 GeV sgluon mass (incl. limit from 1110.2693)
L=10.5 fb^{-1}, 8 TeV [ATLAS-CONF-2012-147] 704 GeV M* scale (m_χ < 80 GeV, limit of < 687 GeV for D8)
10^{-1}
1
10
Mass scale [TeV]
*Only a selection of the available mass limits on new states or phenomena shown.
All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.

Other SUSY talks at LHCP13

THURSDAY:

10:20 **Searches for squarks and gluinos in events with missing transverse momentum**
Alessandro Gaz (University of Colorado at Boulder (US))

14:45 **Inclusive searches for squarks and gluinos with the ATLAS detector**
Alex Kastanas (University of Bergen (NO))

15:00 **Search for stop pair production at the LHC using the CMS detector**
Verena Ingrid Martinez Outschoorn (Fermi National Accelerator Lab. (US))

15:15 **Searches for gluino-mediated production of third generation squarks with the ATLAS detector**
Mirjam Lena Fehling (Albert-Ludwigs-Universitaet Freiburg (DE))

15:30 **Search for Supersymmetry in the four W and multiple b-quark final state at CMS**
Didar Dobur (University of Florida (US))

15:45 **Searches for direct pair production of third generation squarks with the ATLAS detector**
Claudia Giuliani (Albert-Ludwigs-Universitaet Freiburg (DE))

16:00 **The Higgs: supersymmetric partner of the neutrino**
Francesco Riva (Ecole Polytechnique Federale de Lausanne (CH))

17:15 **Searches for 3rd generation SUSY and heavy top or bottom partners at LHC and Tevatron**
Fabrizio Salvatore (University of Sussex (GB))

Other SUSY talks at LHCP13

FRIDAY:

11:15 **Vector Boson Productions of SUSY Sleptons, Chargino and Neutralinos**
Bhaskar Dutta (Texas A&M University)

11:30 **SUSY searches for EWK production of Gauginos and Sleptons at the LHC by CMS**
Marc Dunser (Eidgenoessische Tech. Hochschule Zuerich (CH))

11:45 **Searches for electroweak production of supersymmetric neutralinos, charginos and sleptons with the ATLAS detector**
Matthew Ryan Relich (Department of Physics-University of California Irvine)

12:00 **Searching for supersymmetry in Z'**
Gennaro Corcella (INFN - Laboratori Nazionali di Frascati (IT))

12:15 **Search for RP violating Supersymmetry at CMS**
Fedor Ratnikov (KIT - Karlsruhe Institute of Technology (DE))

12:30 **Searches for supersymmetry in resonance production, R-parity violating signatures and events with long-lived particles with the ATLAS detector**
Andres Carlos Florez Bustos (York University (CA))

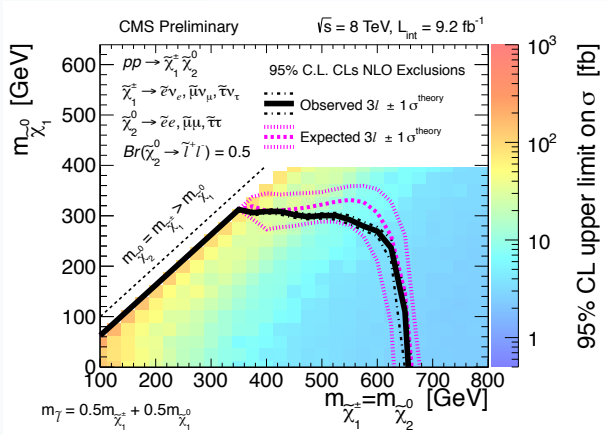
12:45 **Search for Supersymmetry in Gauge Mediated Supersymmetry breaking scenarios at CMS**
Tae Jeong Kim (Korea University (KR))

Thank you !

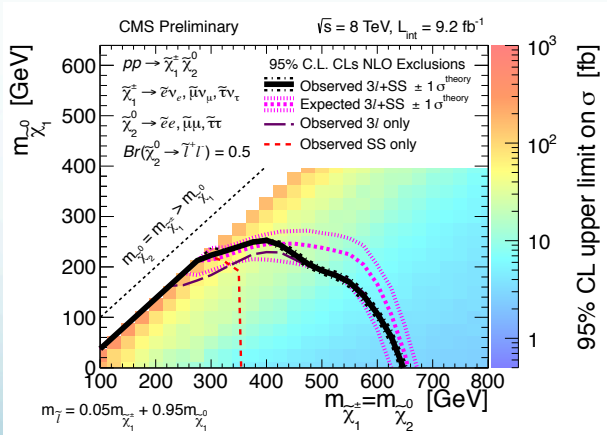
Ewkino production (I)

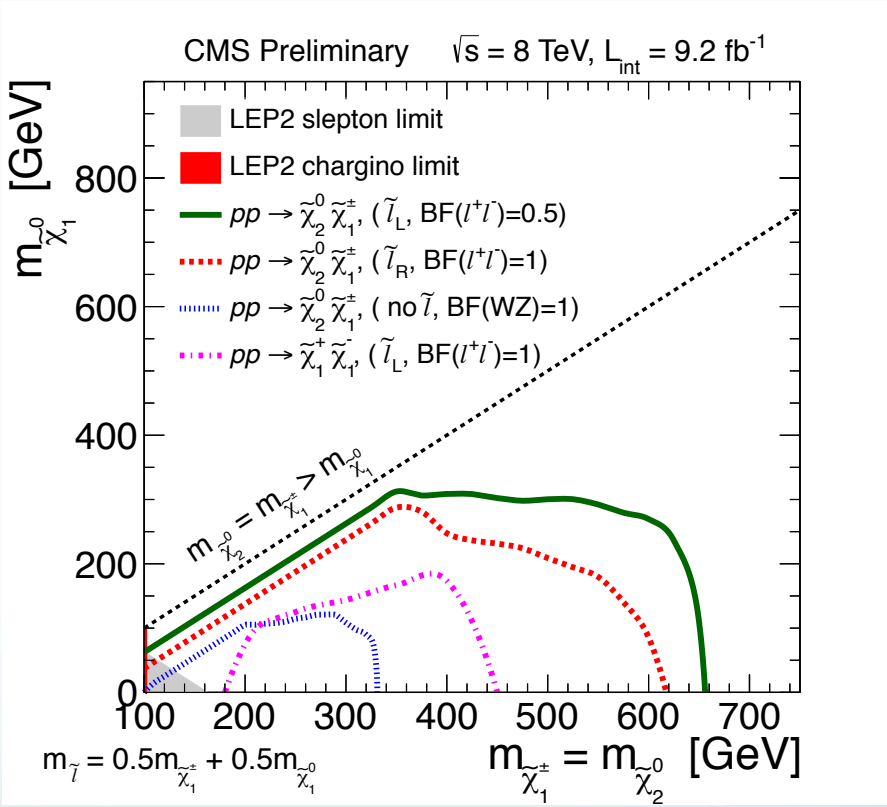
Chargino neutralino production in 3 leptons

X=0.5



X=0.05



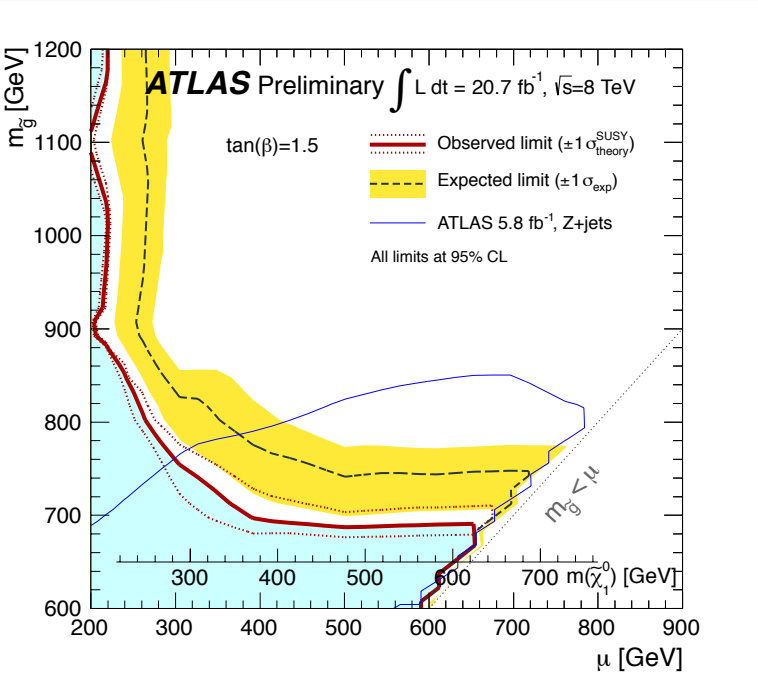


X=0.5

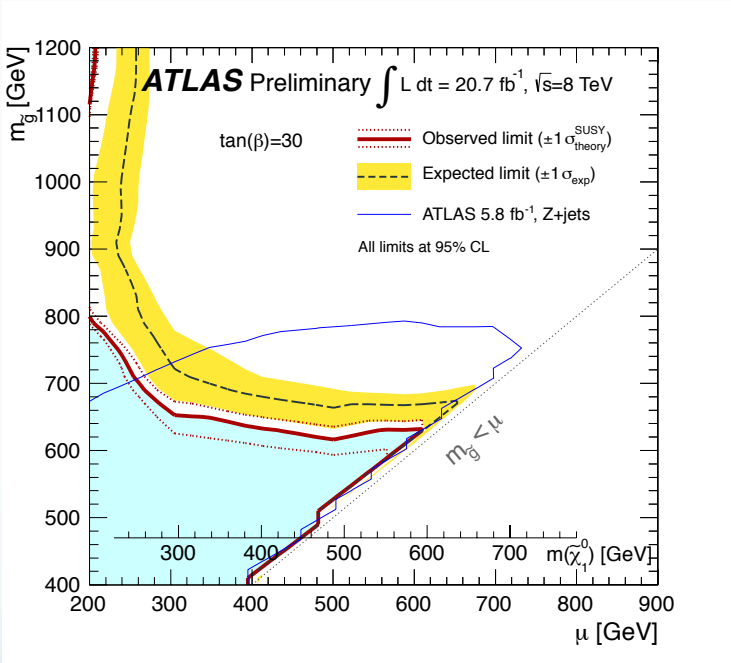
Ewkino production (I)

95% CL limit contours to set limits in the GGM scenarios.

- Two Z-rich GGM models where values of $\mu \approx 200$ GeV are excluded for high gluino masses.



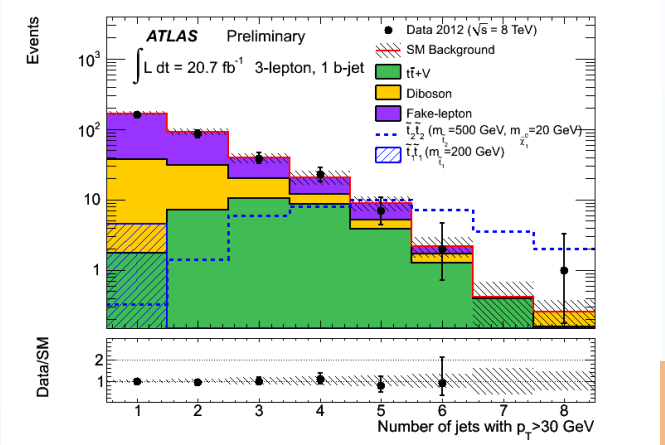
GGM tan β=1.5

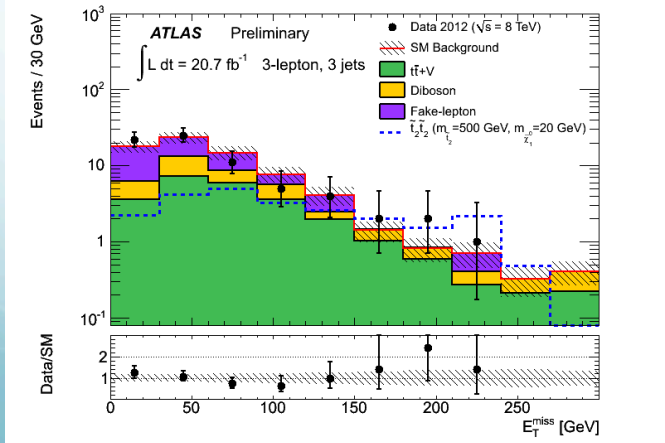


GGM tan β=30

General multilepton (II)

•Looking for direct stop pair production. Look for data with three or more isolated leptons and at least one bottom-quark jet and OSSF close to Z boson

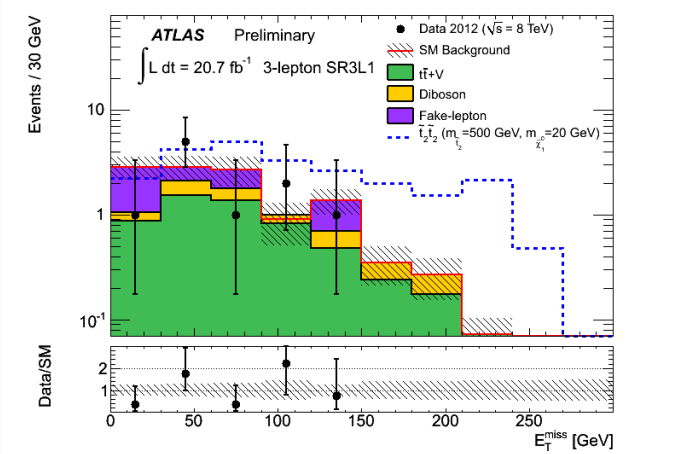


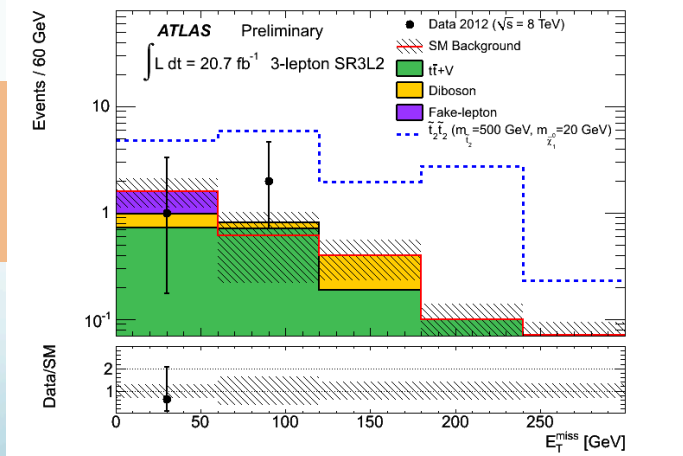


	SR3L1	SR3L2
N^{lepton}	≥ 3	
$\lvert m_{\ell\ell} - m_Z \rvert$	< 10 GeV	
$N^{b\text{-jets}}$	≥ 1	
N^{jets}	≥ 5	
$p_T(\text{jet}_1)$	> 50 GeV	> 40 GeV
$p_T(\text{jet}_N)$	> 30 GeV	> 40 GeV
E_T^{miss}	> 60 GeV	
$p_T(\ell\ell)$	-	> 75 GeV
$\Delta\phi^{\ell\ell}$	-	
$p_T(\ell_1)$	> 40 GeV	> 60 GeV

Validation

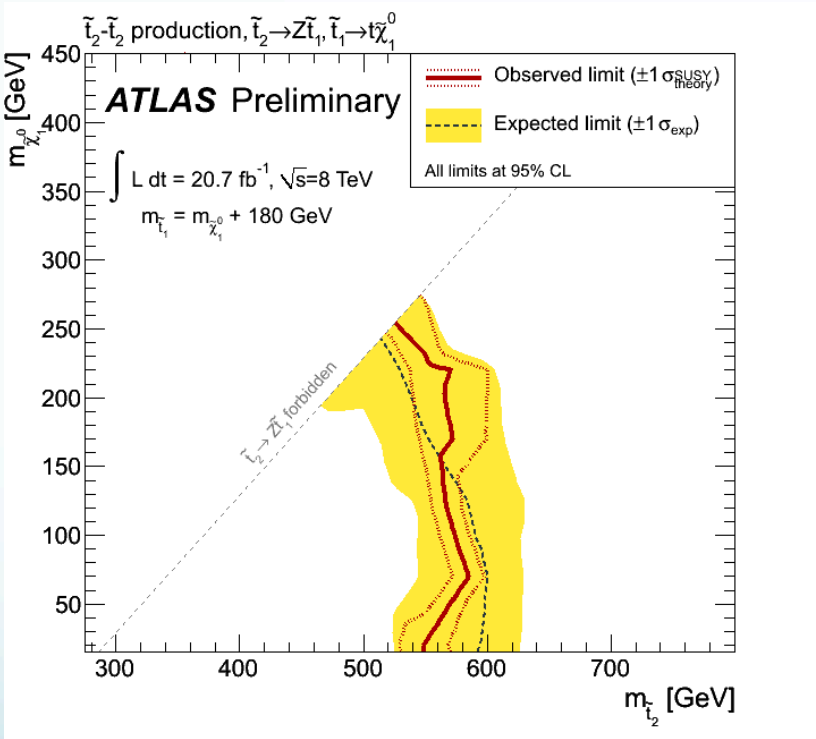
Signal region

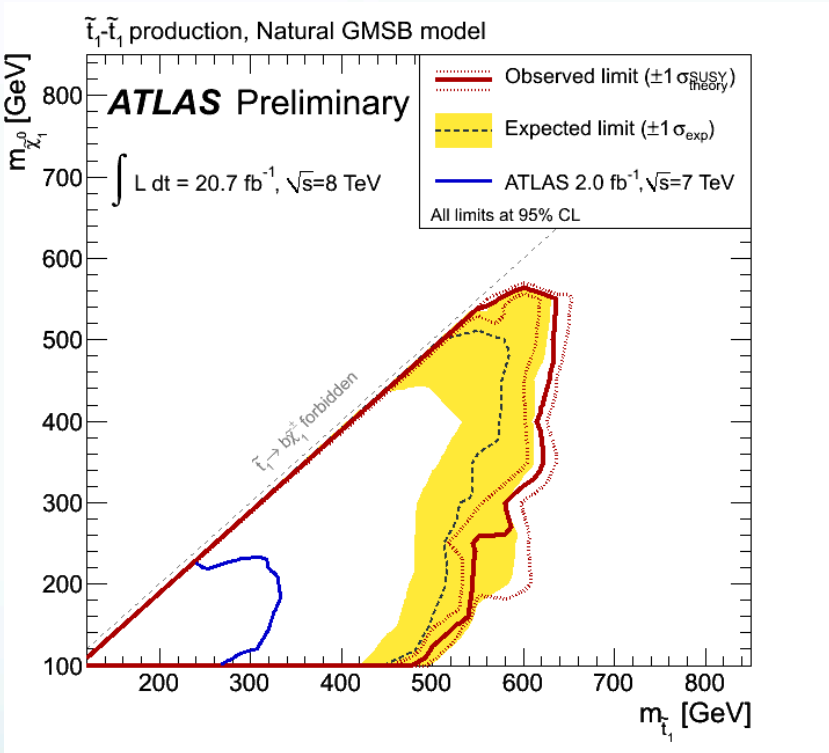




General multilepton (II)

95% CL limits using the CLs calculation:



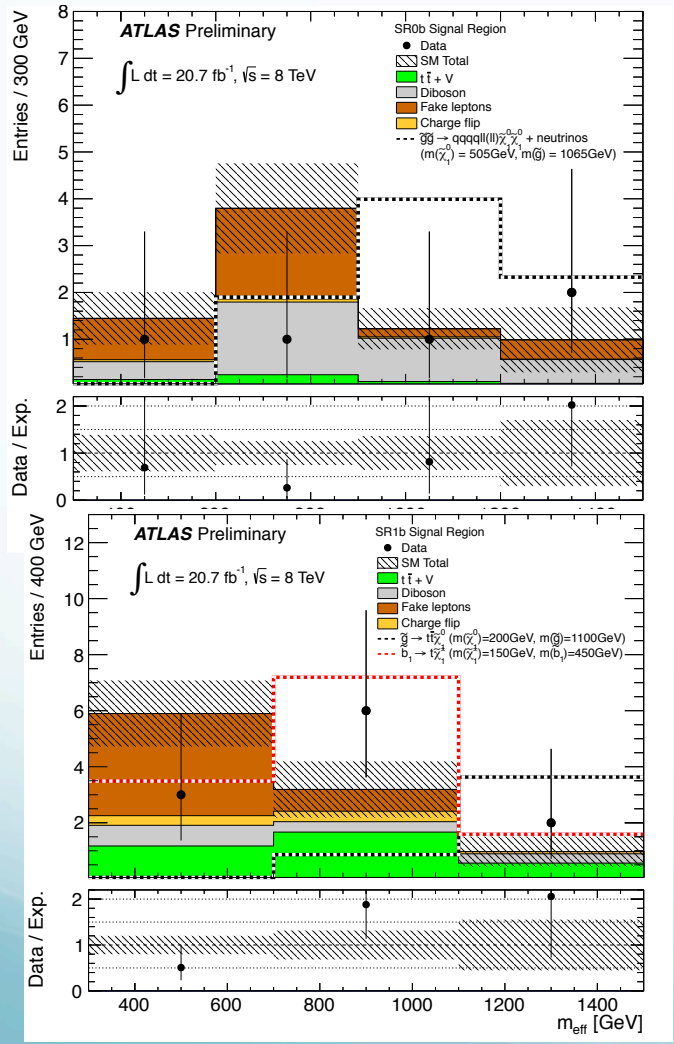


t_2 t_2 simplified model. m_{t_2}<530 GeV for m < 245 GeV

Gauge Mediated SUSY Breaking scenario exclusion limits on t_1, χ_1^0 mass plane

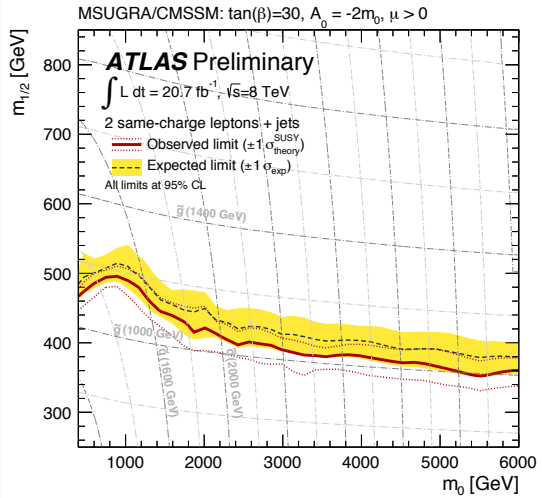
General multilepton (II)

- Strongly produced SUSY particles with **SS** leptons and jets:
  - different signal regions (SR0b, SR1b, SR3b) are created

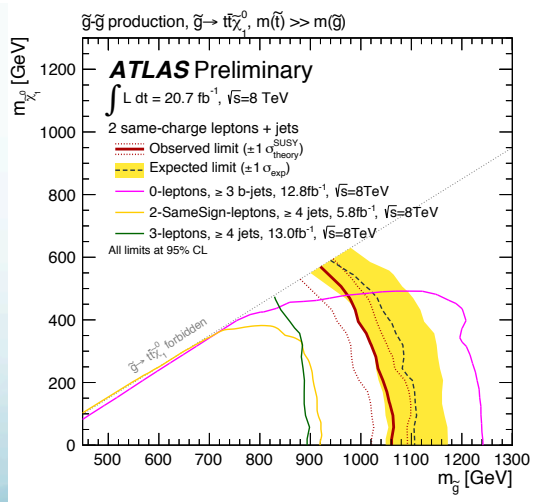


Effective mass distribution in SR0b and SR1b

Observed limits for mSUGRA/CMSSM



Observed limits for gluinos-stop all channels



$(m_{eff} = p_T^{l1} + p_T^{l2})$