Status of SUSY searches

FPCP2013, Buzios, Brazil, May 19-25

A. Lipniacka, University of Bergen/CERN
on behalf of
ATLAS & CMS

SUSY searches with ATLAS and CMS

What are we searching for and why?

The Data and Search Techniques

Third Sfamily direct and in gluino decays

Weak Production

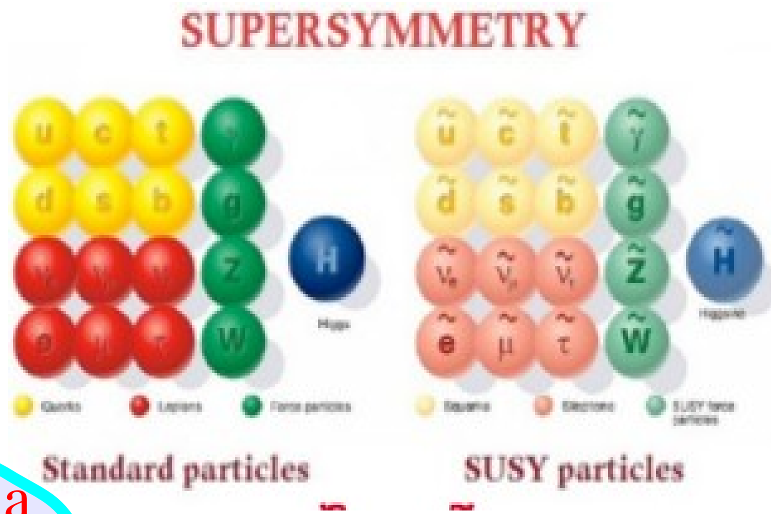
Dark Matter&SUSY
Higgs&SUSY

What could we learn if we find a "SUSY like" process

There are therefore Agents in Nature able to make the Particles of Bodies stick together by very strong Attractions. And it is the business of experimental Philosophy to find them out.

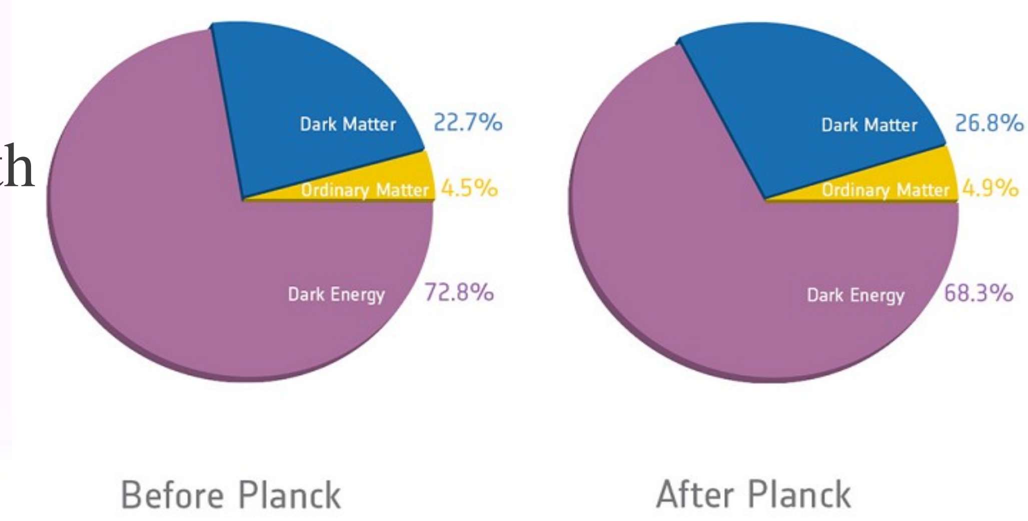
Newton, Principia

Symmetry between "Agents in Nature" and "Particles of Bodies"

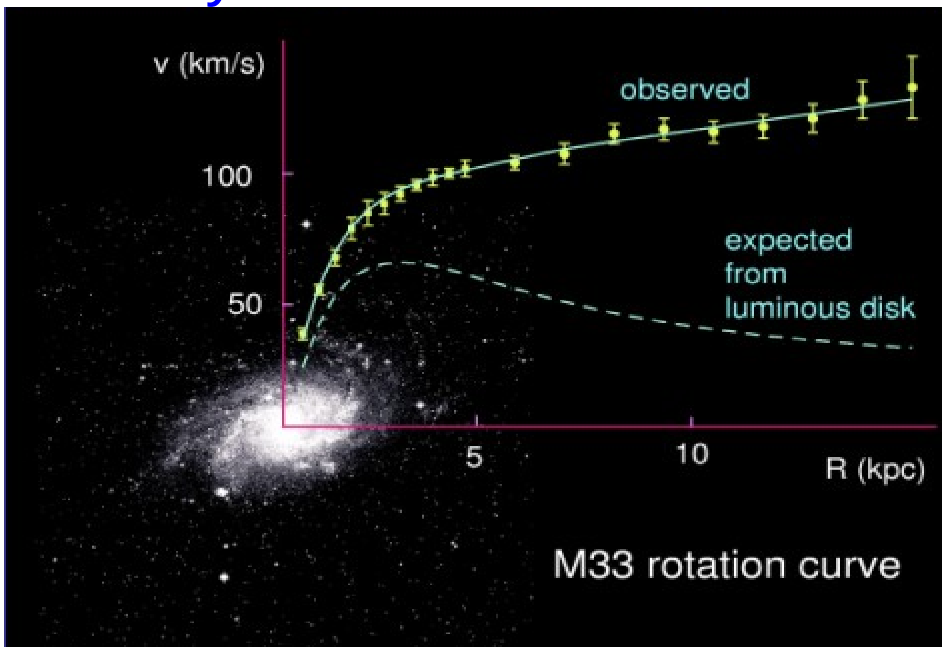


SM “Particles of Bodies” make only 5% of the Universe

Analysis of fluctuations of BB relict: Microwave radiation fluctuations with WMAP and PLANCK



Galaxy rotation curves



If not enough matter, the objects in galaxies would fly apart
F. Zwicky, Astrophys. J. 86 (1937)

First systematic study of rotation of stars in Galaxies by Vera Rubin, 1970. Result:

Most of the matter (90%)is dark: it does not emit light

The MSSM

Particles in Minimal SUSY

One fermionic/bosonic partner to the SM fermions/bosons with SM coupling

particle	spin	sparticle	spin	name
$l = e, \mu, \tau, \nu$	1/2	$\tilde{l}_R, \tilde{l}_L$	0	slepton
$q = u, d, s, c, b, t$	1/2	$\tilde{q}_R, \tilde{q}_L$	0	squark
g	1	$\tilde{g}$	1/2	gluino
γ	1	$\tilde{\gamma}$	1/2	photino
$W^{\pm}$	1	$\tilde{W}^{\pm}$	1/2	wino
Z	1	$\tilde{Z}$	1/2	zino
H_1^0, H_2^0	0	$\tilde{H}_1^0, \tilde{H}_2^0$	1/2	higgsino
$H^{\pm}$	0	$\tilde{H}^{\pm}$	1/2	higgsino

$R \; parity, R = -1^{2J+3B+L}, R = -1 \; for \; Sparticles, R = 1 \; for \; particles$

Gauge Eigenstates		*Mass Eigenstates*	
$\tilde{W}^{\pm}, \tilde{H}^{\pm}$	$\longleftrightarrow$	$\tilde{\chi}^{\pm}_{1,2}$	(Charginos)
$\tilde{B}, \tilde{W}^0, \tilde{H}_1^0, \tilde{H}_2^0$	$\longleftrightarrow$	$\tilde{\chi}^{0}_{1,2,3,4}$	(Neutralinos)

Fermion Eigenstates		*Mass Eigenstates*	
$\tilde{t}_R, \tilde{t}_L$	$\longleftrightarrow$	$\tilde{t}_1, \tilde{t}_2$	(stop)
$\tilde{b}_R, \tilde{b}_L$	$\longleftrightarrow$	$\tilde{b}_1, \tilde{b}_2$	(sbottom)
$\tilde{\tau}_R, \tilde{\tau}_L$	$\longleftrightarrow$	$\tilde{\tau}_1, \tilde{\tau}_2$	(stau)

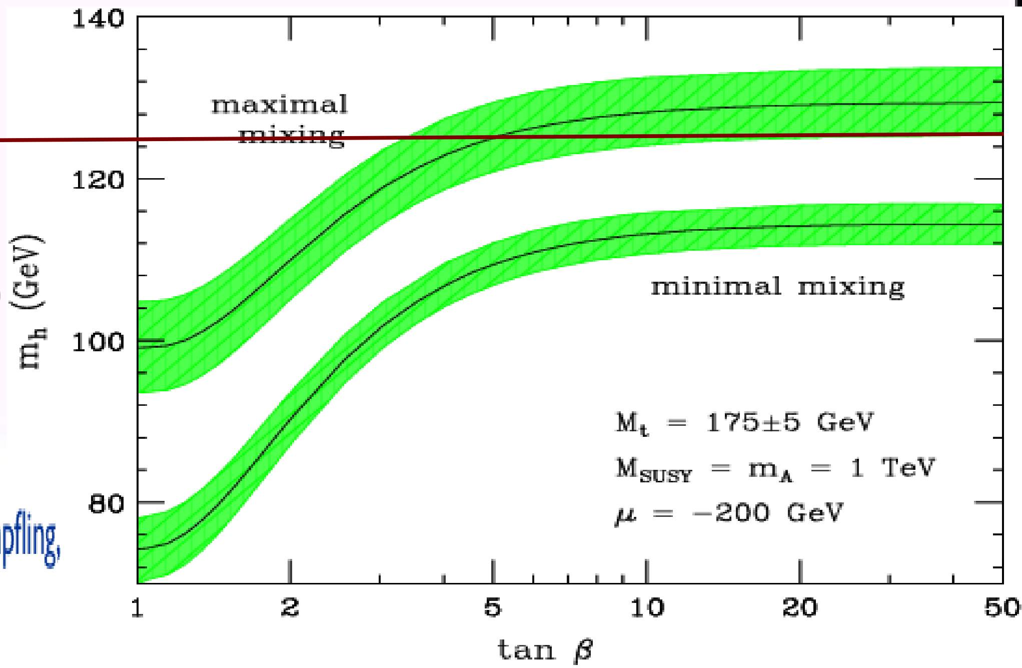
$\tan\beta = v2/v1$

If R-parity conserved, LSP is a Dark Matter candidate. RPC results in this talk

What is the reason for the Higgs boson mass?

$M_h = 125.5 \pm 0.2(stat)^{+0.5}_{-0.6}(syst)\ GeV\ (ATLAS)$

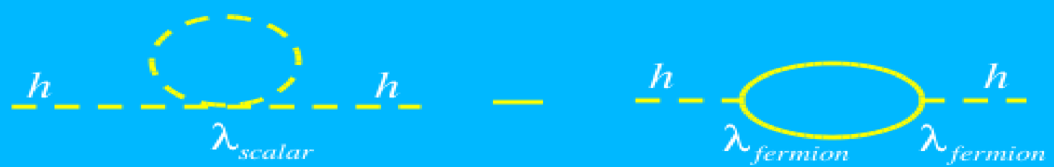
$M_h = 125.7 \pm 0.3(stat) \pm 0.3(syst)\ GeV\ (CMS)$



Long list of two-loop computations: Carena, Degrassi, Ellis, Espinosa, Haber, Harlander, Heinemeyer, Hempfling, Hoang, Hollik, Hahn, Martin, Pilaftsis, Quiros, Ridolfi, Rzehak, Slavich, C.W.Weiglein, Zhang, Zwirner

There are 5 Higgs bosons in the Minimal Supersymmetric SM, the lightest one is lighter than ~130 GeV
Its mass related mostly to stop squark mass (Ml, Mr) and mixing Xt

$$\begin{pmatrix} M_{ll} & X_t M_{top} \\ X_t M_{top} & M_{rr} \end{pmatrix}$$

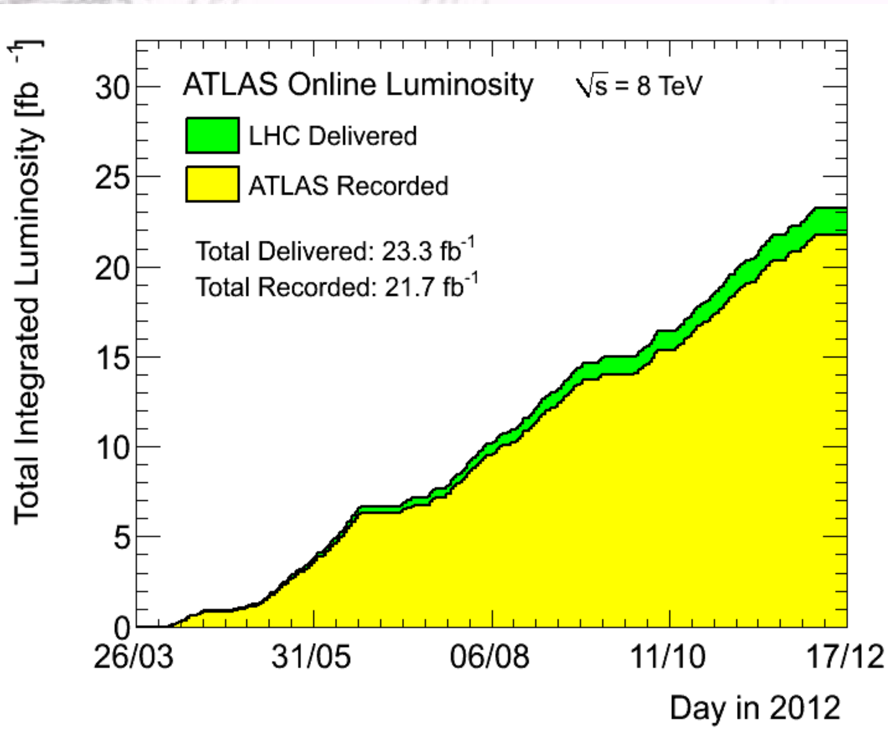


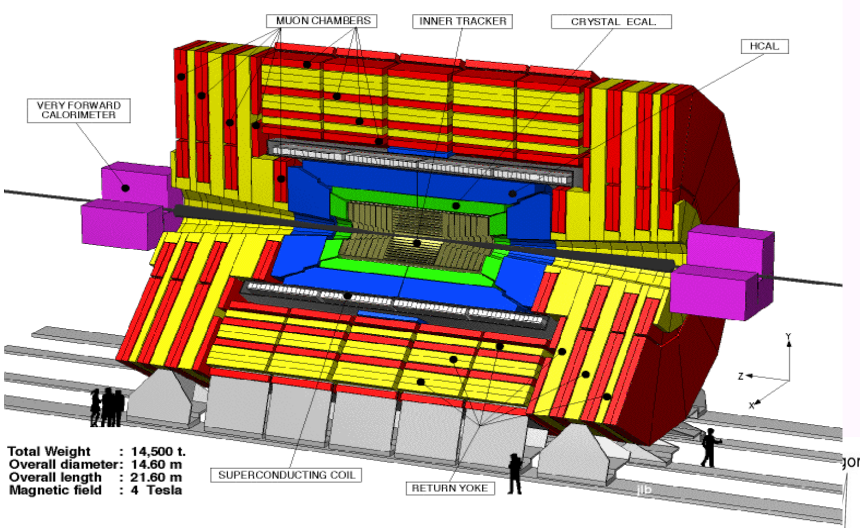
$$\delta m_h^2 = \frac{1}{8\pi^2}\left[\lambda_{scalar}^2 - \lambda_{fermion}^2\right]\Lambda^2 + \ldots$$

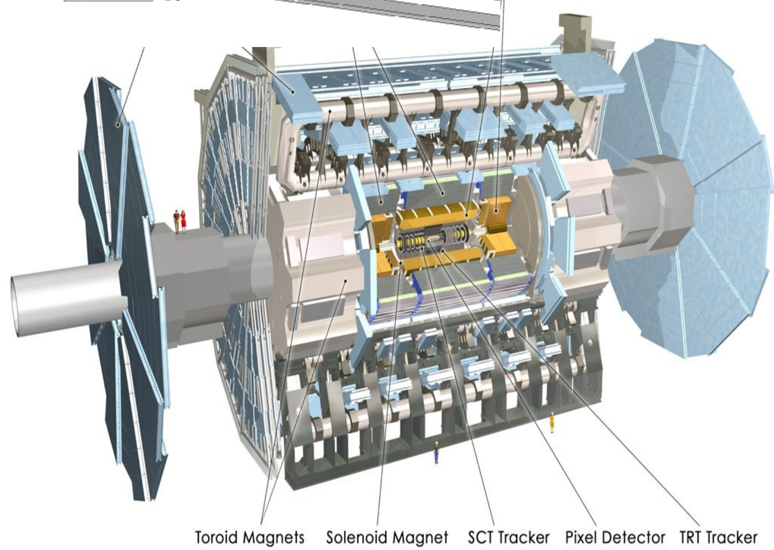
Golfand, Likhtman, JETP Lett. 1971
Volkov, Akulov, Phys.Lett. B, 1973
Wess, Zumino, Nucl. Phys. B, Phys. Lett. B, 1974

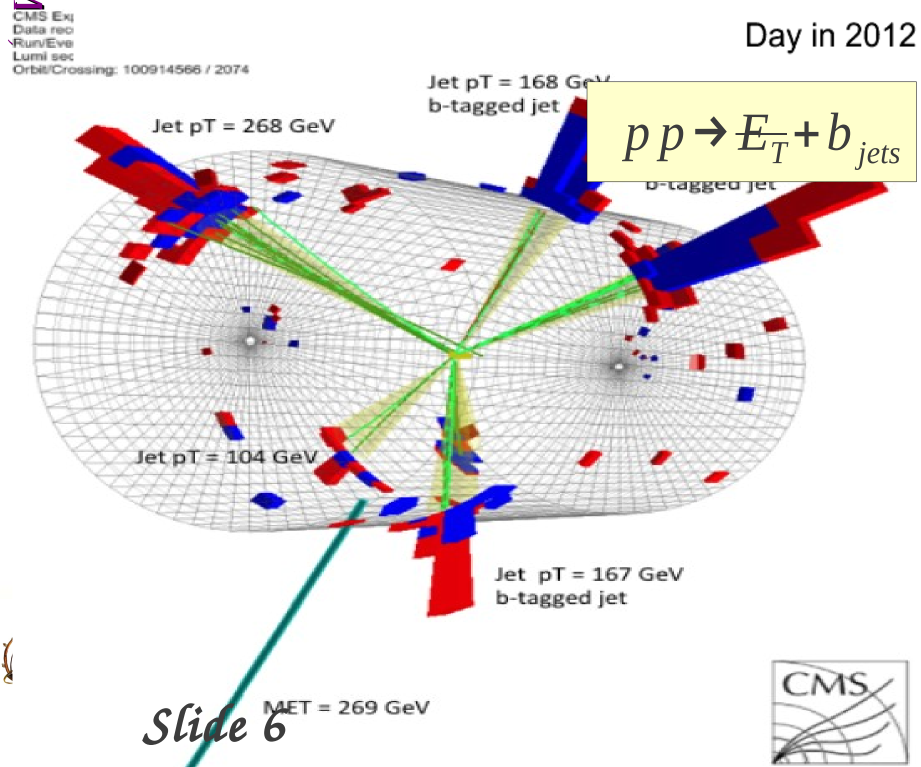
In SUSY, the mass correction proportional to SUSY breaking.

ATLAS&CMS









$$p\,p \rightarrow \not{E}_T + b_{jets}$$

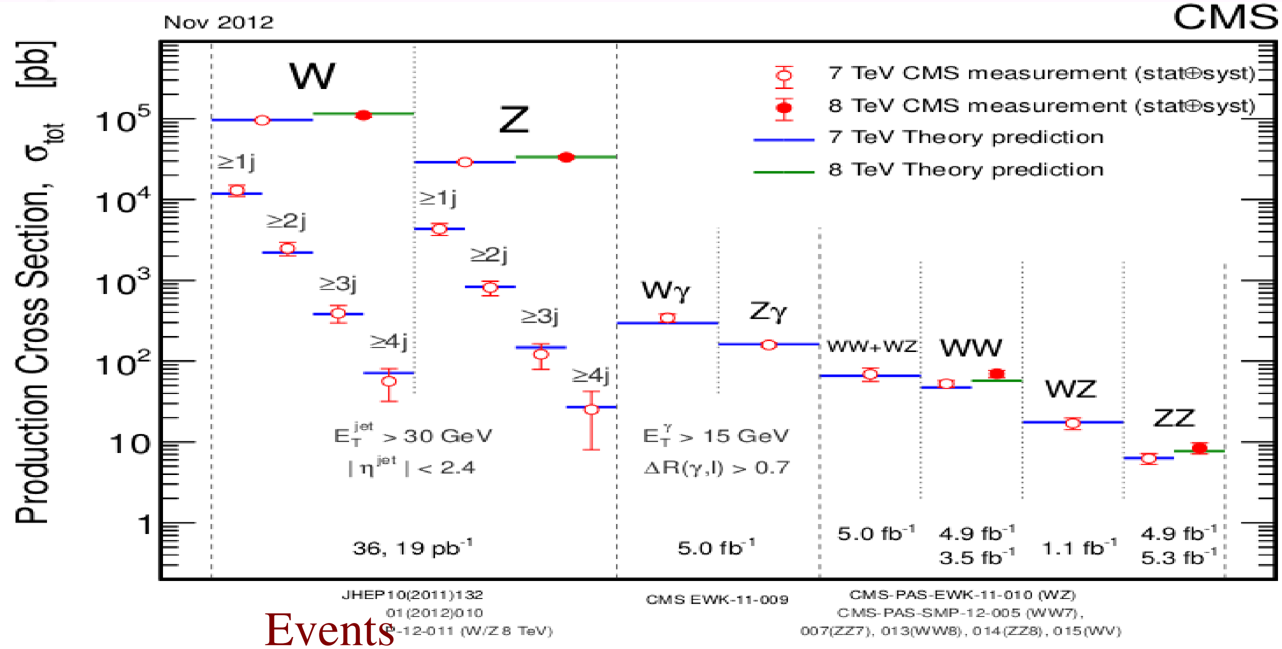
ATLAS and CMS each :
20-22/fb at 8 TeV
4.5-5.5/fb at 7 TeV

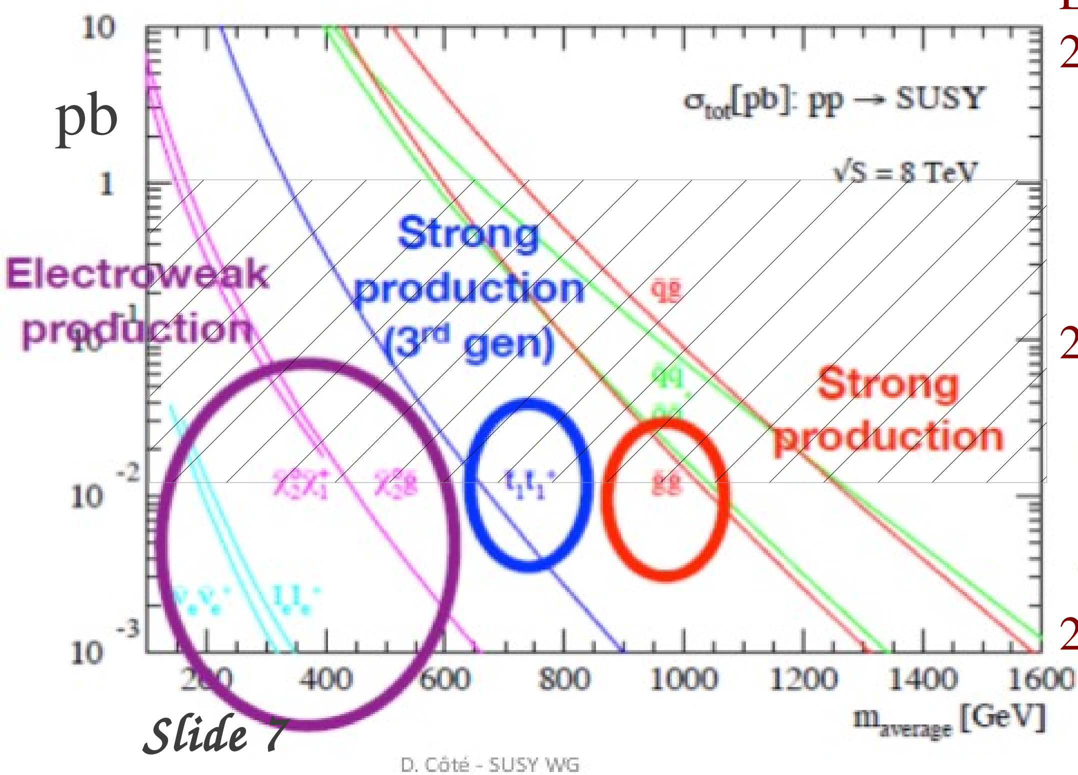
In this talk primarily 8 TeV full luminosity results

SUSY and Standard Model Cross-Sections

Higgs boson prod.

$\sigma(125\,GeV\;H+X)\simeq 20pb$





Events
200 000
2000
20

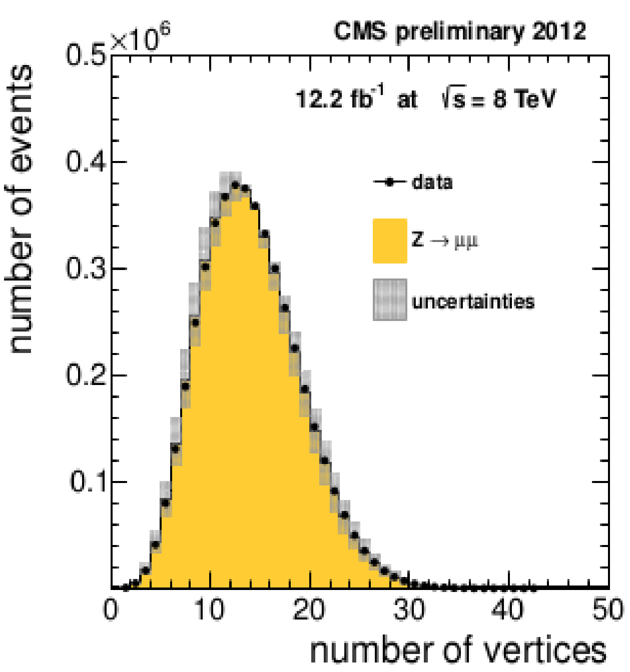
Upper limits on production cross-sections ranging (0.01-1) pb

Resulting in lower limits on sparticles masses.

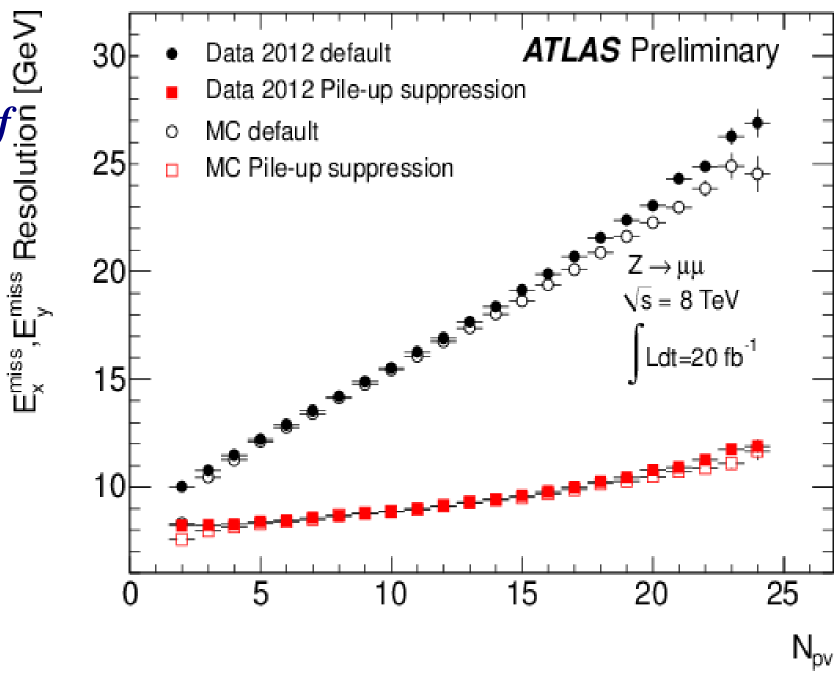
SUSY final states and search techniques

A gallery of topologies with high-medium transverse momentum "objects"; leptons (taus), jets (b-jets), missing transverse energy due to escaping "DM candidate" LSP.

SEARCH STRATEGY ORIENTED TOWARDS FINAL STATE TOPOLOGIES, CHARACTERIZED by "object multiplicity" (ex. 1 lepton, jets, missing transverse energy) Each topology is interpreted in search for SEVERAL SUSY final states.



-Excellent reconstruction of "objects" required, robust against "pile-up" of tens of collisions in the same beam crossing.



Smart and sophisticated kinematic variables aiming at distinguishing between the tails of the SM distributions and candidates for SUSY events.

SUSY searches with ATLAS and CMS, FPCP2013

SUSY search techniques, background control

Excellent control of backgrounds, typically measured in kinematic "Control Regions" (CR) and propagated to the Signal Regions (SR) with simulations.

Standard Model

Top, multijets
V, *VV*, *VVV*, Higgs
& combinations of these

Reducible backgrounds

Determined from data
Backgrounds and methods depend on analyses

Irreducible backgrounds

Dominant sources: normalize MC in data control regions (CR)
Subdominant sources: MC

Validation

Validation regions used to cross check SM predictions with data

blinded

Signal regions (SR)

blinded

Examples

Fake leptons or heavy-flavour jets determined with "matrix method" in different-purity samples using "real" and "fake" probabilities measured in data.

Charge flip rate measured in Z events

Use "ABCD method" (not always applicable)

Example

$$N^{DATA}_{CR1} = SF_{TOP} \times N1^{MC}_{TOP} + SF_{Wjets} \times N1^{MC}_{Wjets} + SF_{Zjets} \times N1^{MC}_{Zjets}$$

$$N^{DATA}_{CR2} = SF_{TOP} \times N2^{MC}_{TOP} + SF_{Wjets} \times N2^{MC}_{Wjets} + SF_{Zjets} \times N2^{MC}_{Zjets}$$

$$N^{DATA}_{CR3} = SF_{TOP} \times N3^{MC}_{TOP} + SF_{Wjets} \times N3^{MC}_{Wjets} + SF_{Zjets} \times N3^{MC}_{Zjets}$$

Solve for DATA/MC Scaling Factors (SF)
Check dependency on selection with MC
Extrapolate to SR

$$N^{signal}_{pred} = \frac{N^{signal}_{MC}}{N^{control}_{MC}} \times N^{control}_{obs}$$

SUSY final states for results interpretation, examples

Direct stop and sbottom production

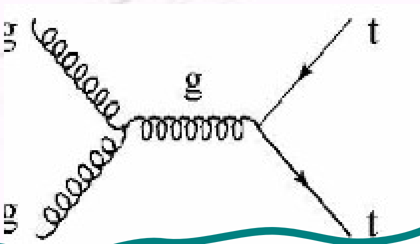
with subsequent decays

$\tilde{t} \to \tilde{\chi}^{+} b \to \tilde{l}\,\nu\, b\,(l\,\tilde{\nu}\, b)(\tilde{\tau}\,\nu\, b)$

$\tilde{t} \to \tilde{\chi}^{0} t$

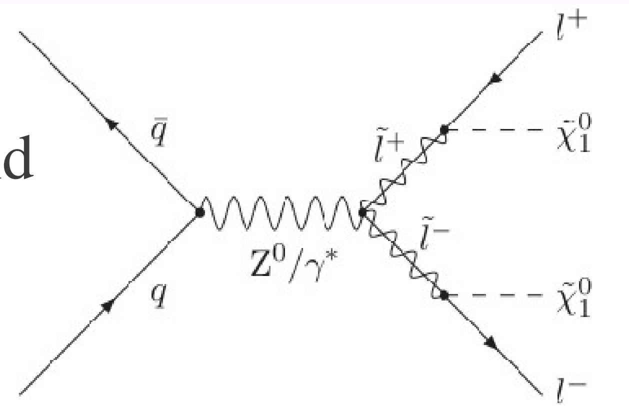
$\tilde{b} \to \tilde{\chi}^{0} b \ldots etc.$

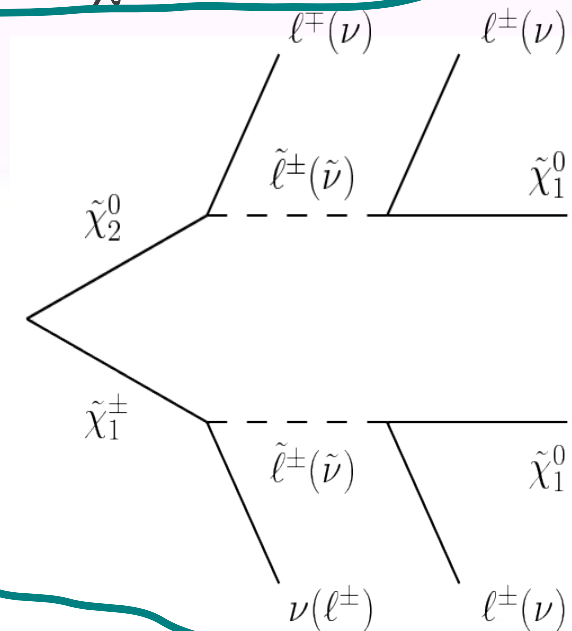
Stops and sbottoms related to Higgs mass.



Electroweak slepton and gaugino productions

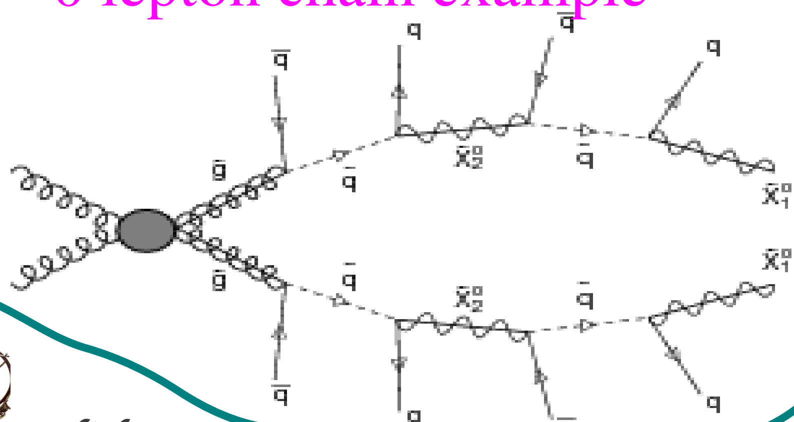
Gluinos and squarks might be beyond reach

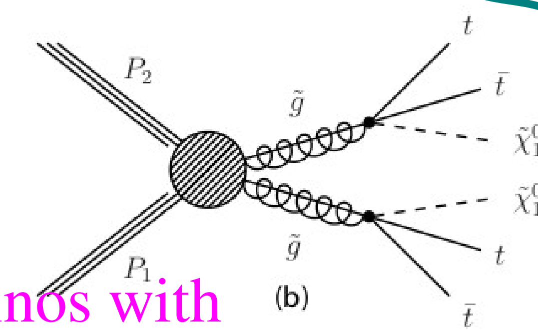




Production of gluinos,

0 lepton chain example

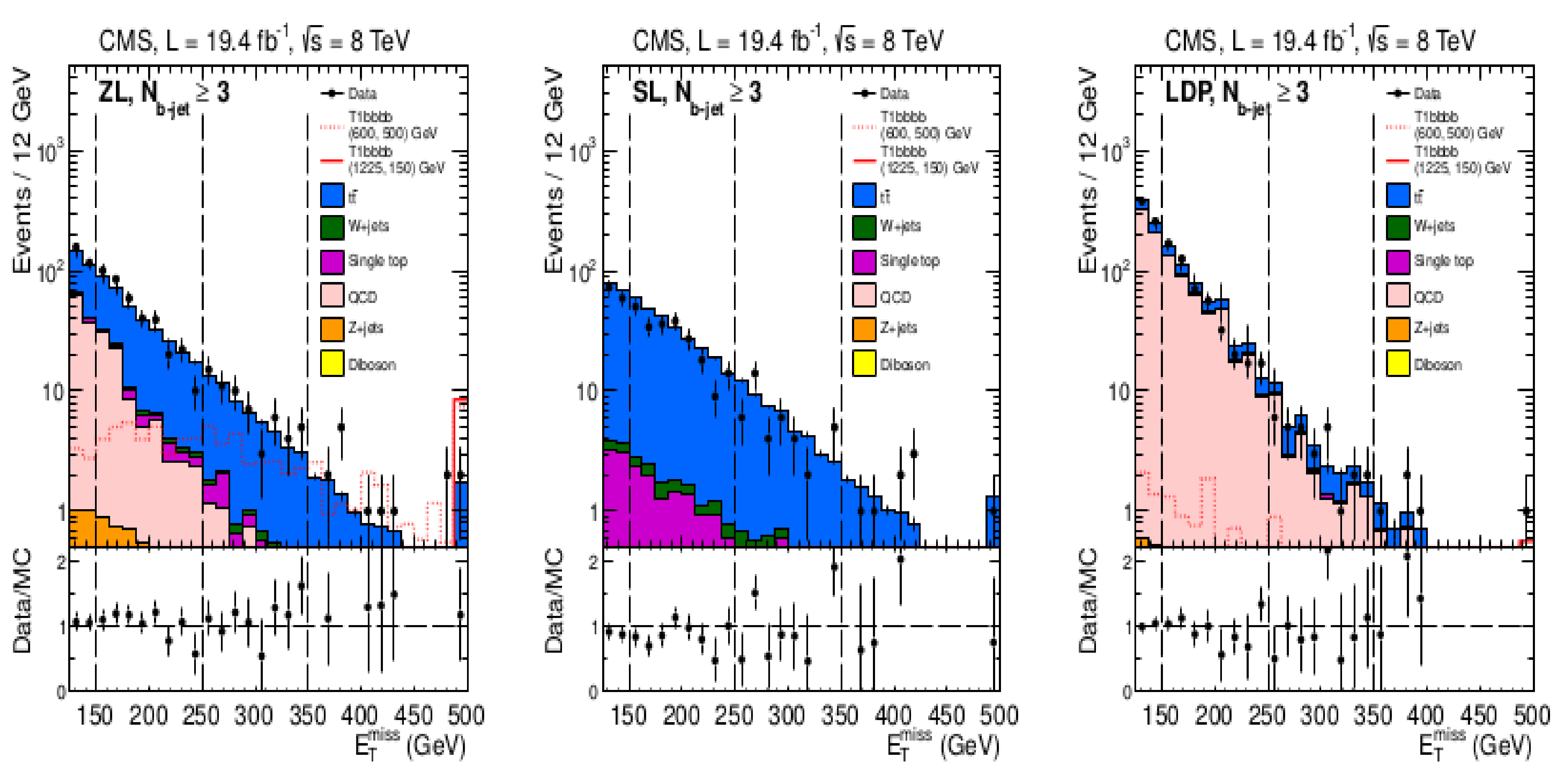




Gluinos with decays to third family

SUSY search techniques, kinematic variables, examples

Missing transverse energy: vector sum of transverse momenta of all visible "objects"



Signal Region

Control Region
W and top production

Control Region
QCD multijets

Simulations used to account for the shape difference of backgrounds between CR and SR

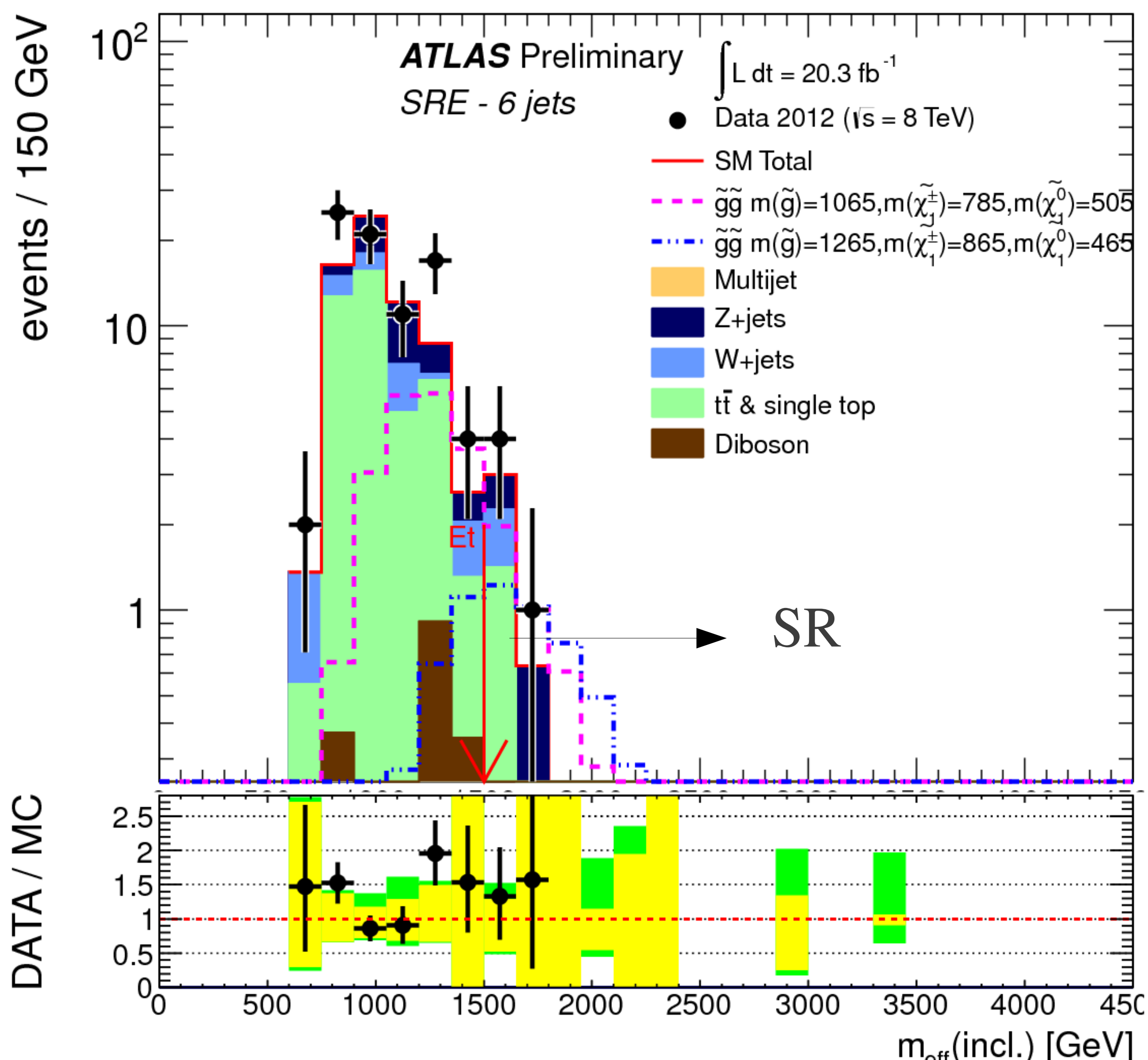
Search for gluino-mediated bottom- and top-squarkproduction in pp collisions at 8 TeV, arXiv:1305.2390

SUSY search techniques, kinematic variables, examples

Effective mass (Meff):

$$m_{\rm eff} = \sum_i (p_{\rm T}^{\rm jet})_i + E_{\rm T}^{\rm miss} + \sum_j (p_{\rm T}^{\rm lep})_j$$

Shown after final cuts, except for Meff selection, indicated by the arrow. 6-jets signal region for high Meff, compared with gluino production and decay via chargino

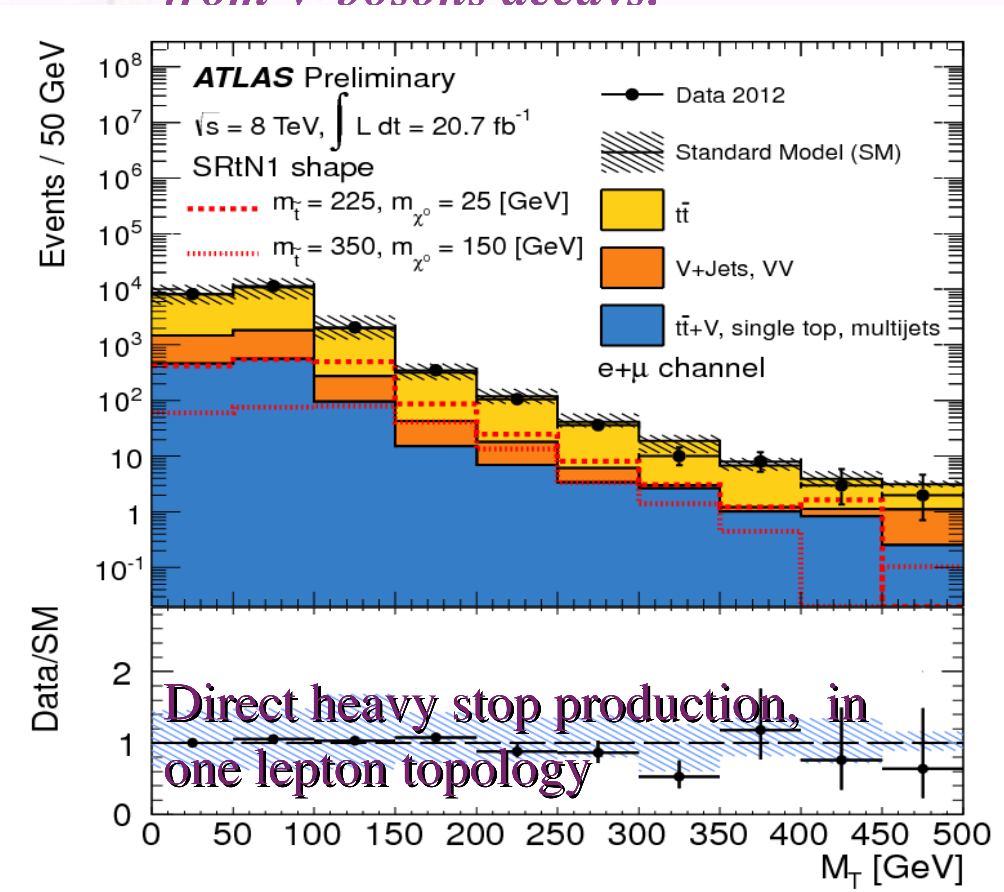


Search for gluino production and decays in final states with no leptons and up to 6 jets.
ATLAS-CONF-2013-035

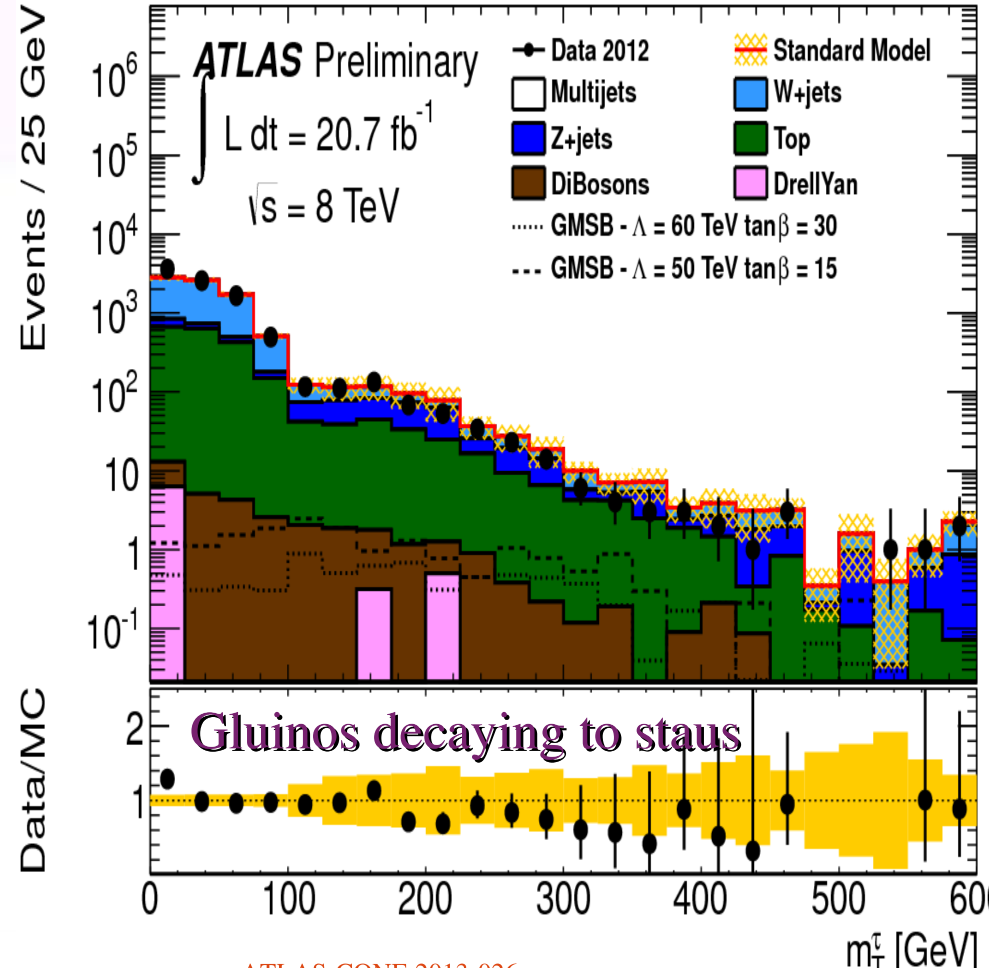
SUSY search techniques, kinematic variables, examples

***Transverse mass** of the lepton and the missing transverse momentum has an "end-point" for leptons and neutrinos from V-bosons decays.*

$$m_T = \sqrt{2\left(|\vec{p}_T^{\,miss}||\vec{p}_T^{\,\ell}| - \vec{p}_T^{\,miss}\cdot\vec{p}_T^{\,\ell}\right)},$$



ATLAS-CONF-2013-037



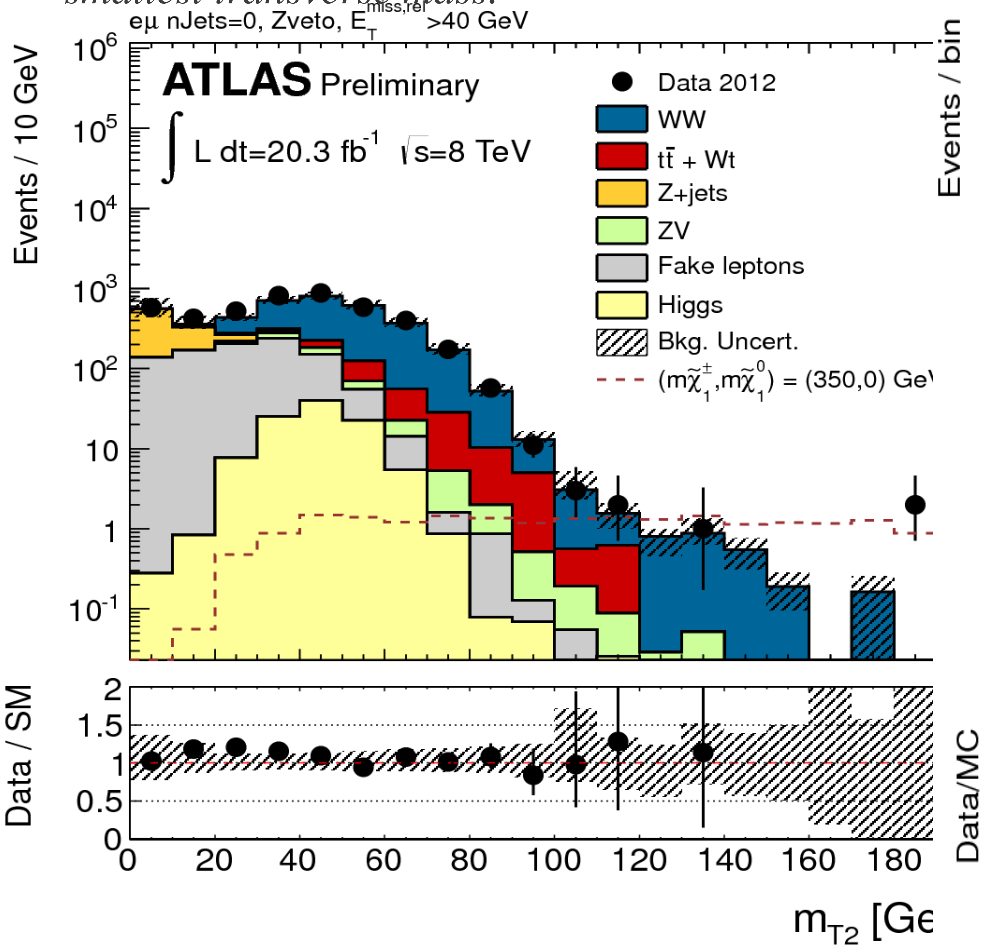
ATLAS-CONF-2013-026

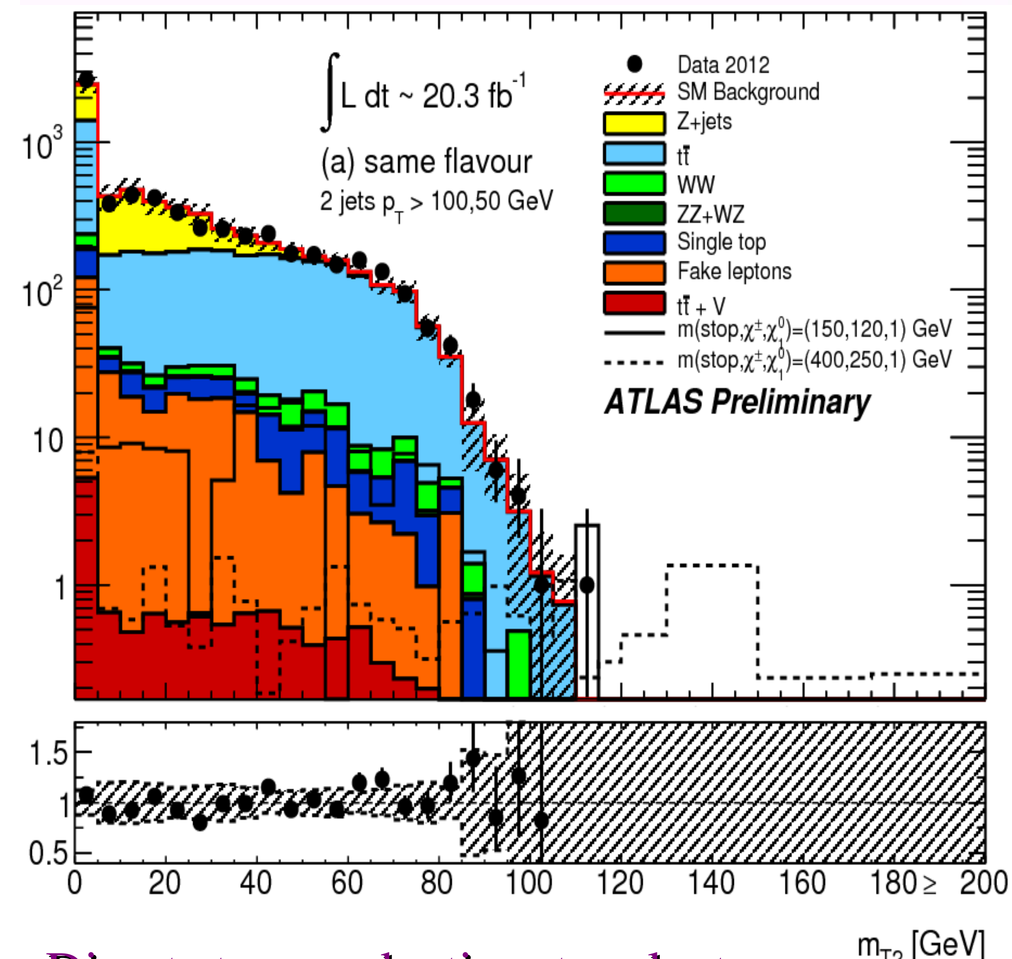
SUSY search techniques, kinematic variables, examples

"Stranverse mass":

$$m_{T2} = \min_{\mathbf{q}_T}\left[\max\left(m_T(\mathbf{p}_T^{\ell 1}, \mathbf{q}_T), m_T(\mathbf{p}_T^{\ell 2}, \mathbf{p}_T^{\text{miss}} - \mathbf{q}_T)\right)\right],$$

Qt is a component of missing transverse momentum maximizing the "lepton, qt" combination giving the smallest transverse mass.





Electroweak slepton&gaugino production, two leptons (e,mu). ATLAS-CONF-2013-049

Direct stop production, two leptons same flavour ATLAS-CONF-2013-047

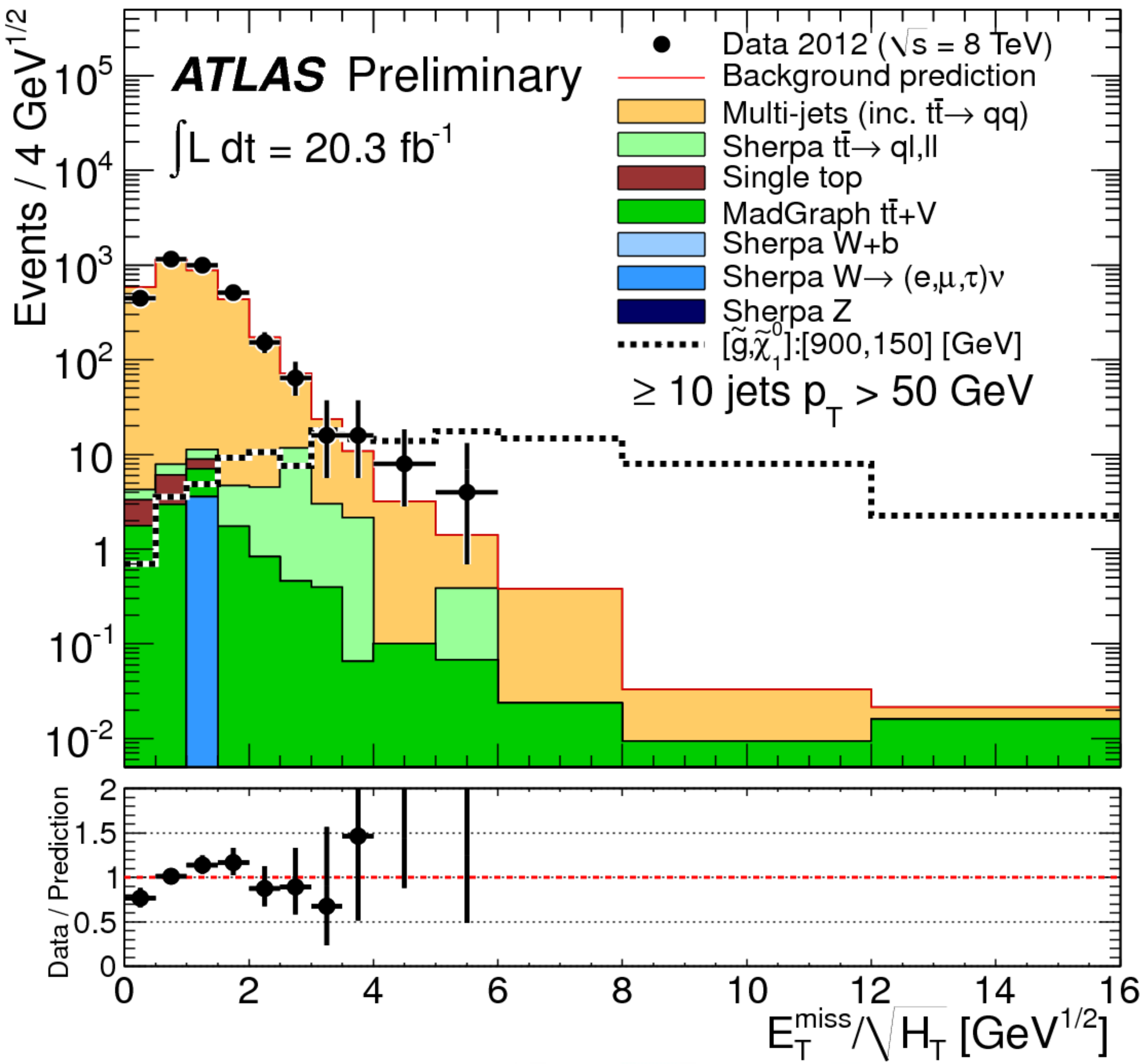
SUSY search techniques, kinematic variables, examples

Multijets with Etmiss , no-lepton
Final selection other than cut on:

$$E_T^{miss}/\sqrt{H_T}$$

Sensitivity less dependent on the number of jets

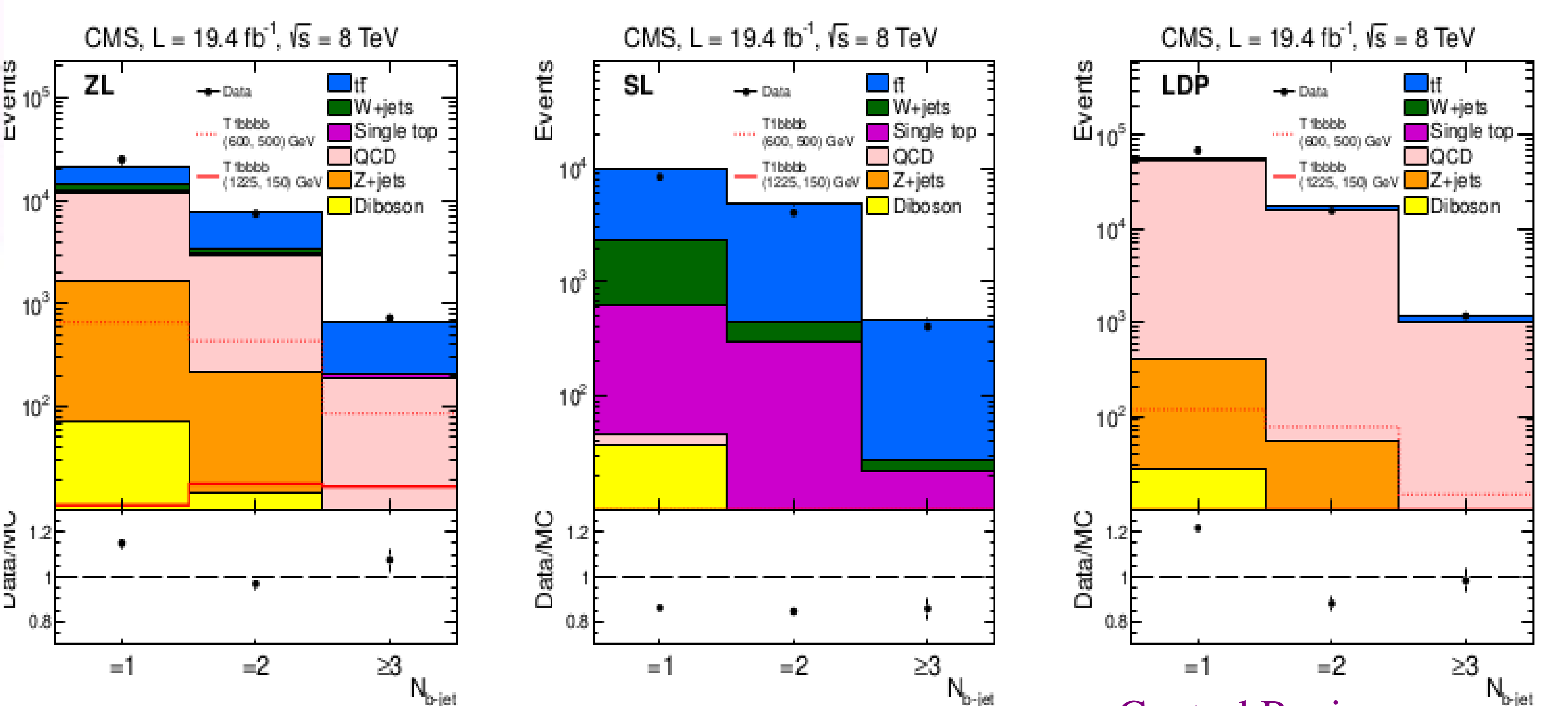
Ht = scalar sum of transverse momenta of selected jets.



ATLAS-CONF-2013-054

SUSY search techniques, kinematic variables, examples

Simultaneous shape analysis of Ht, Etmiss and the number of b-jets.



Signal Region

Control Region
W and top production

Control Region
QCD multijets

Simulations used to account for the shape difference of backgrounds between CR and SR

Search for gluino-mediated bottom- and top-squarkproduction in pp collisions at 8 TeV, arXiv:1305.2390

Results, model exclusions

Excluded regions of SUSY parameter space presented typically in:

1) *Gluino vs LSP mass planes for different intermediate particles and different final state topologies (simplified models with BR and intermediate mass relations fixed)*
   (Constrained Models)

2) *Gluino vs squark mass planes, different final states (simplified models with BR and LSP mass relation fixed)*
   (Constrained Models)

3) *Squark, Slepton, Gaugino vs LSP mass plane, different final states (simplified models with BR and intermediate mass relation fixed)*

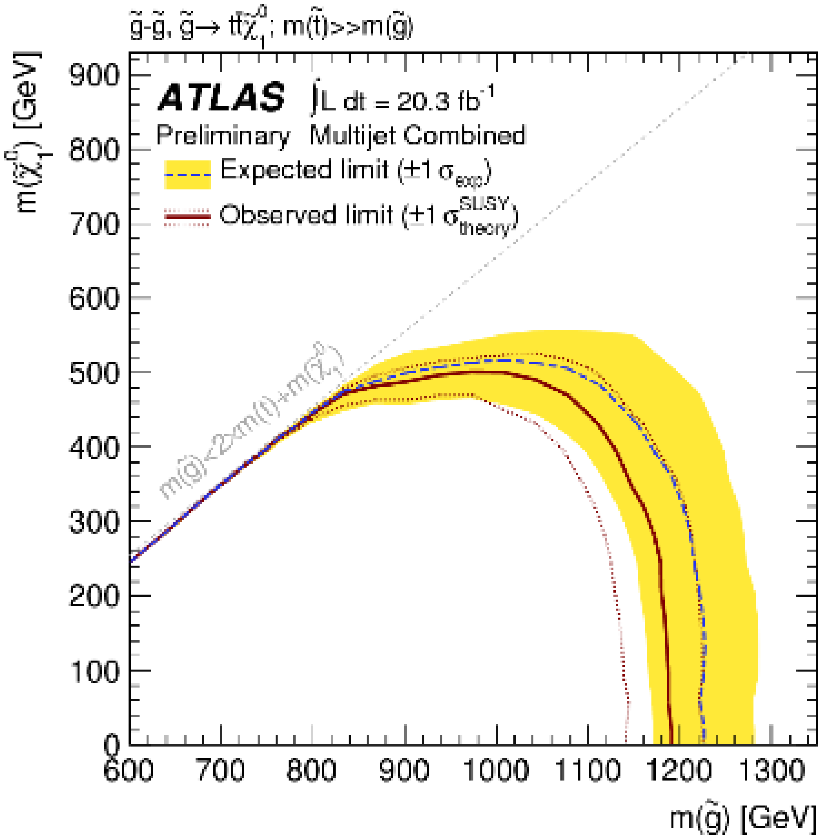
4) *Parameter space of Constrained Models (cMSSM/msugra, cGSMB etc)*

In the following a series of excluded regions...

Results, gluino decays with third family in final states

$\tilde{g} \rightarrow t\bar{t}\,\tilde{\chi}_1^0$ (100%)

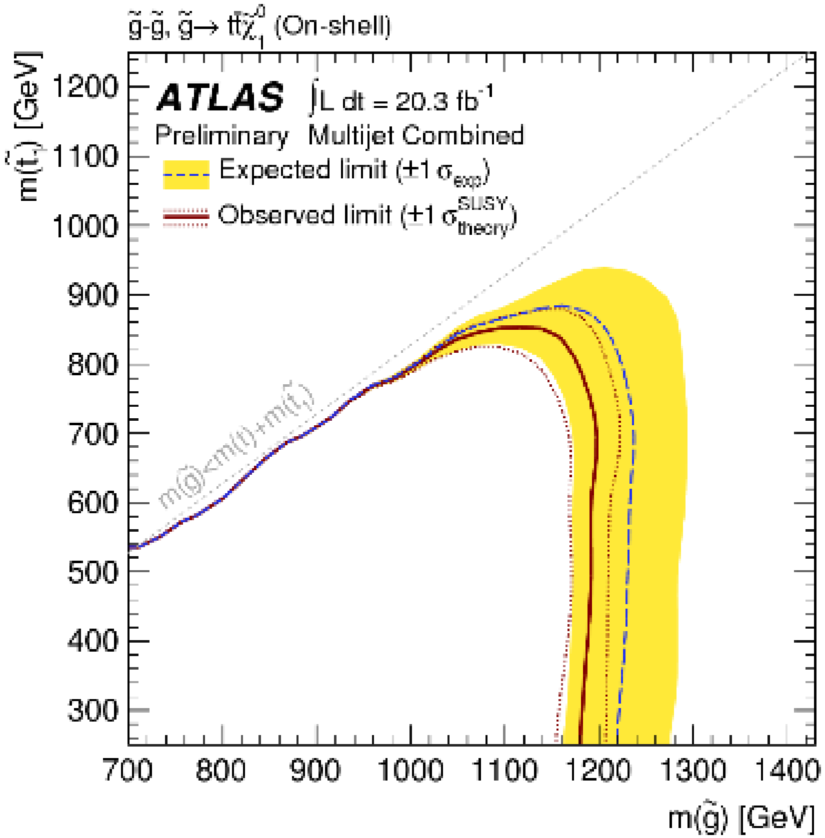
via off-shell stop



→ $m(\tilde{g}) > 1100$ GeV for $m(\tilde{\chi}_1^0) < 350$ GeV

$\tilde{g} \rightarrow t\bar{t}\,\tilde{\chi}_1^0$ (100%)

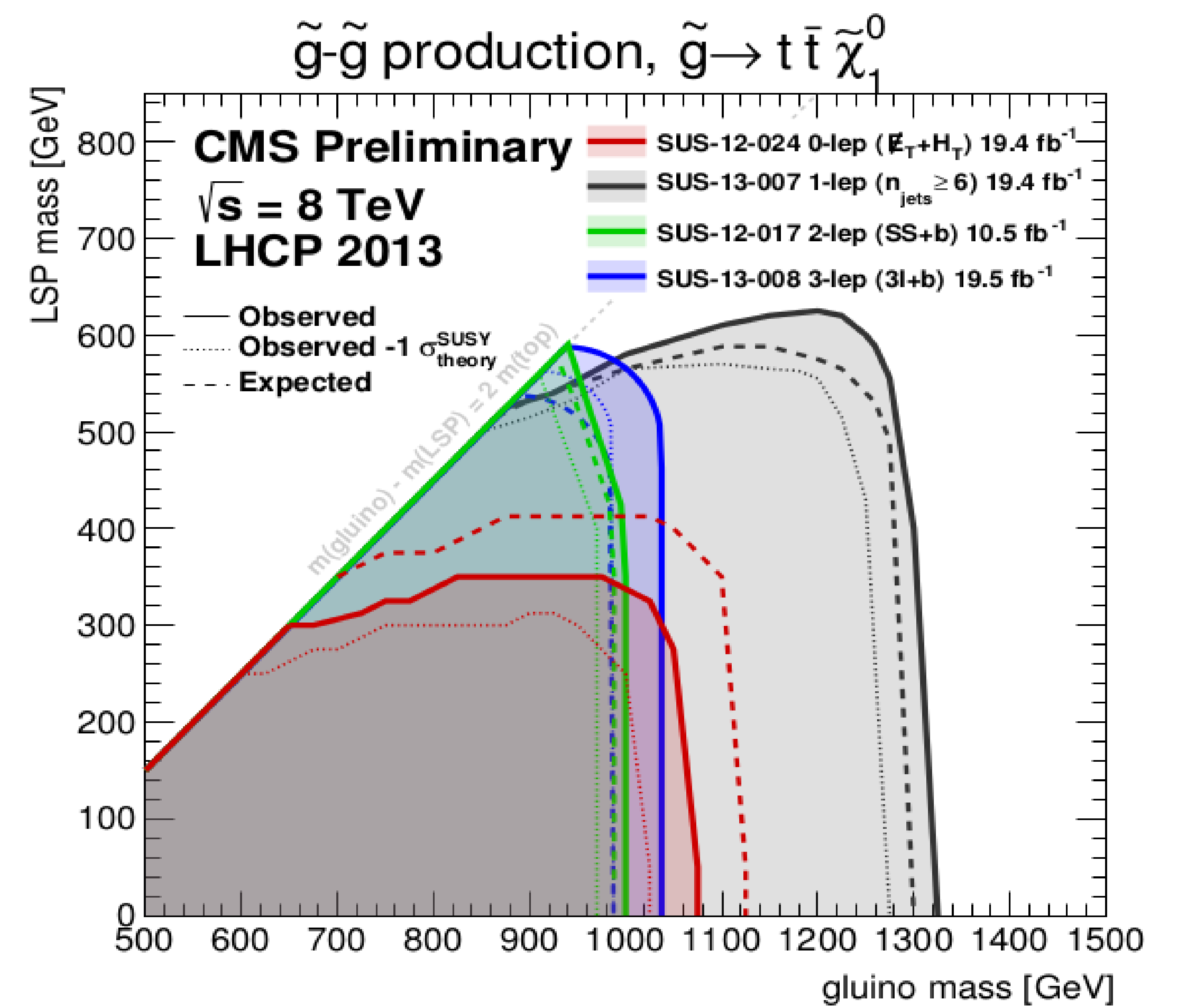
via on-shell stop, $m(\tilde{\chi}_1^0)$=60 GeV



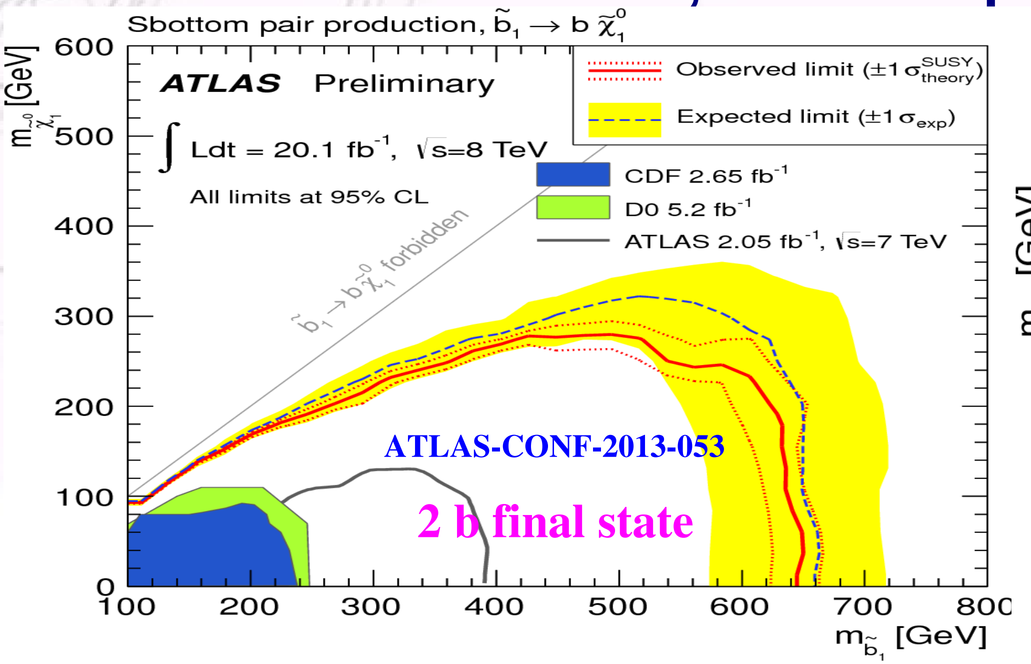
→ $m(\tilde{g}) > 1150$ GeV for $m(\tilde{t}) < 750$ GeV

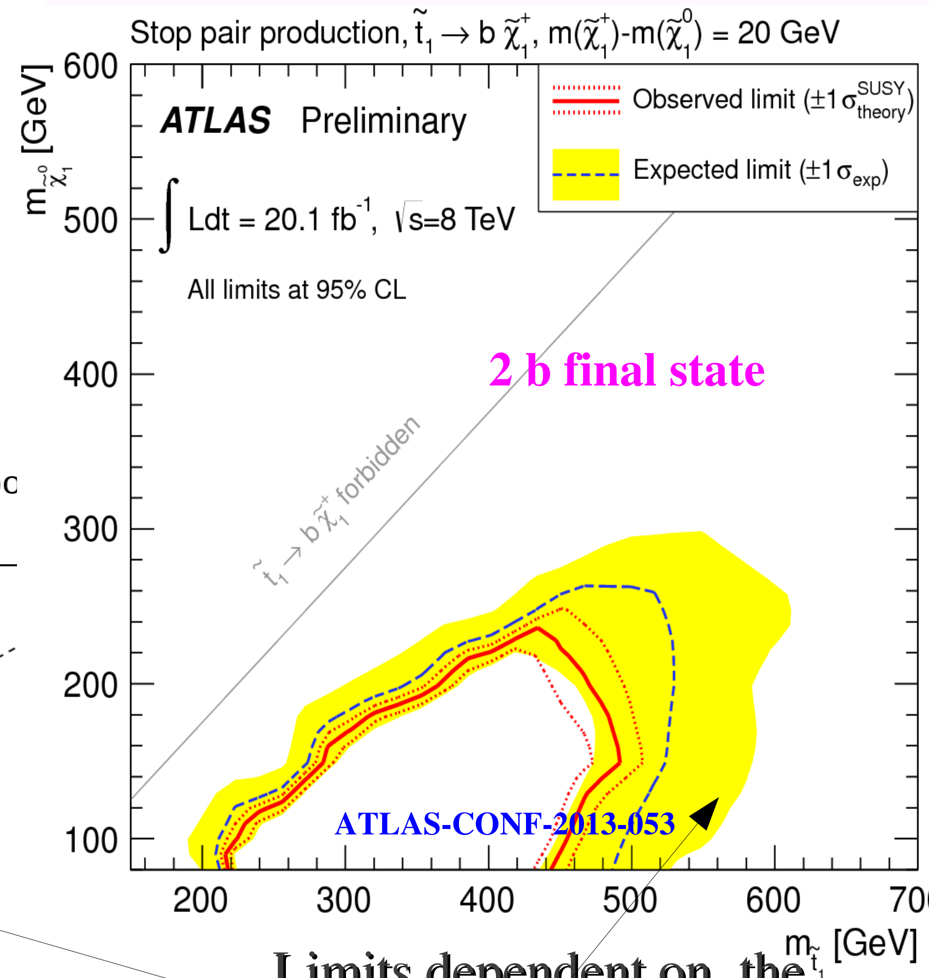
ATLAS-CONF-2013-054

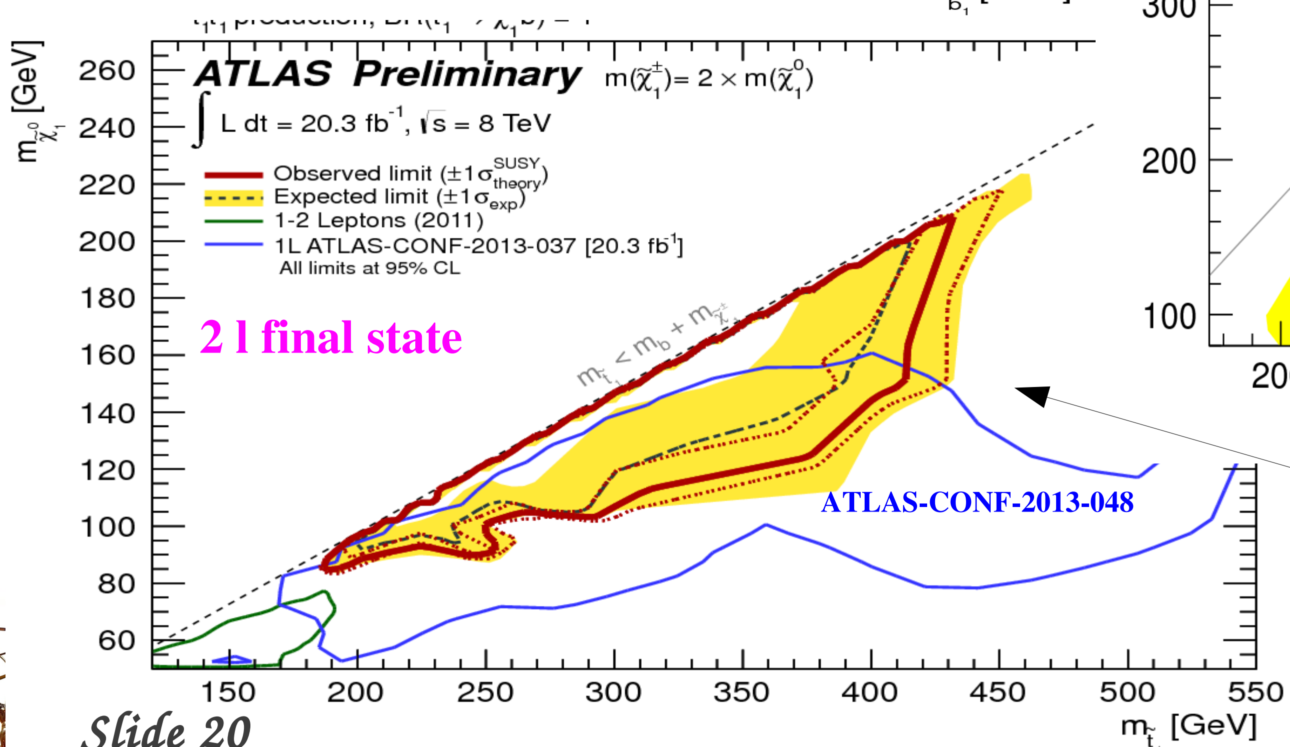
Results, gluino decays with top in final states



Results, direct stops and sbottoms

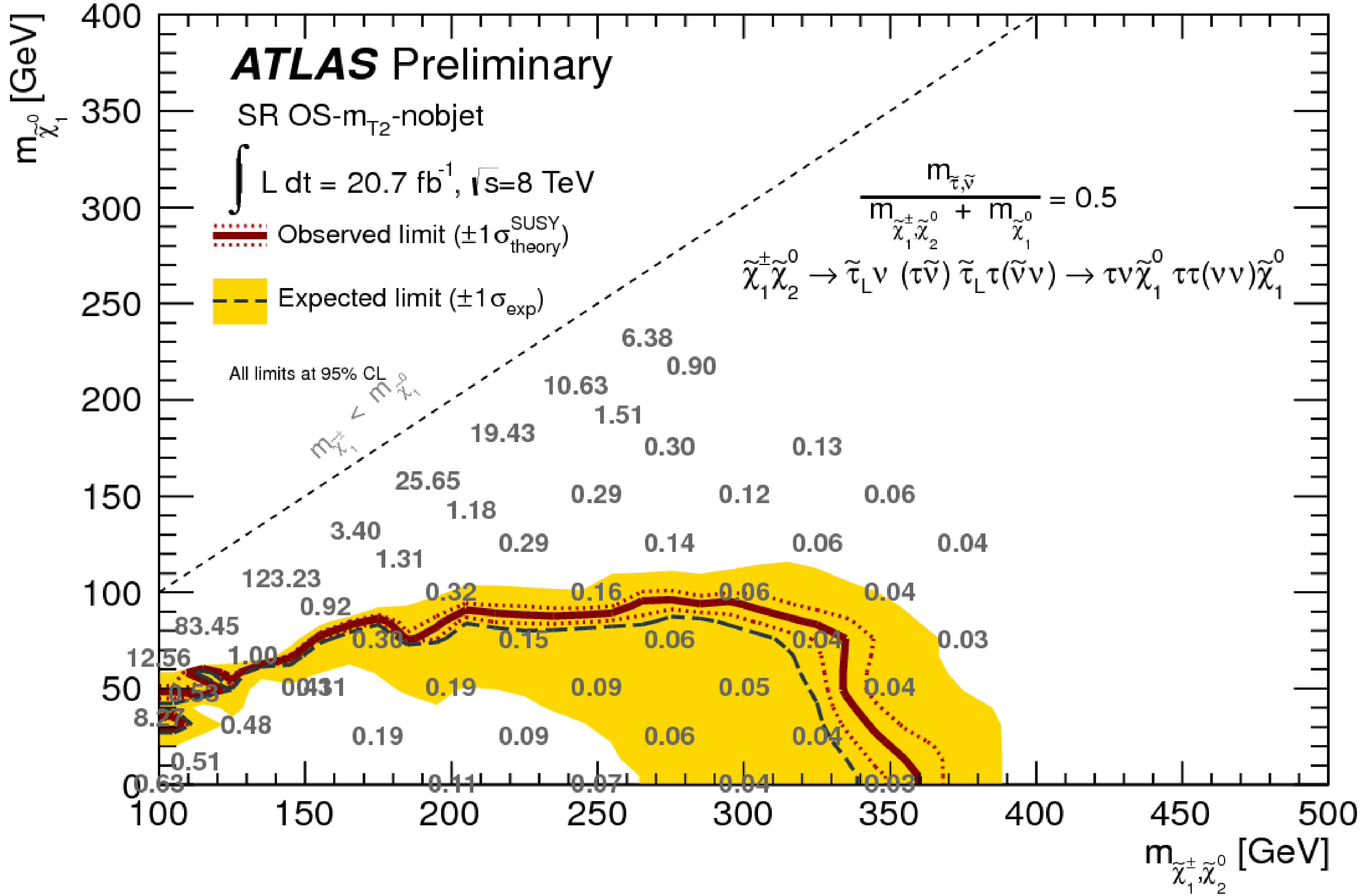






Limits dependent on the chargino-neutralino mass relations

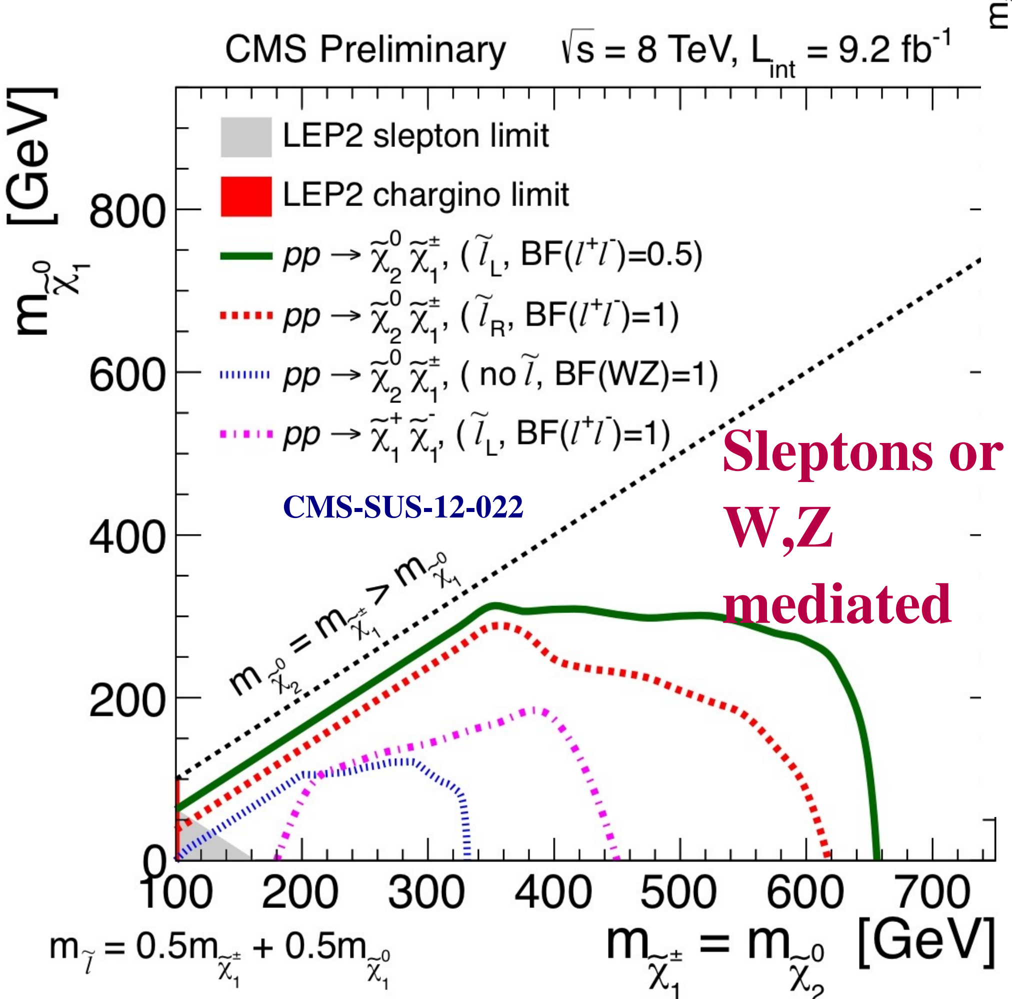
SUSY searches, electroweak production with staus



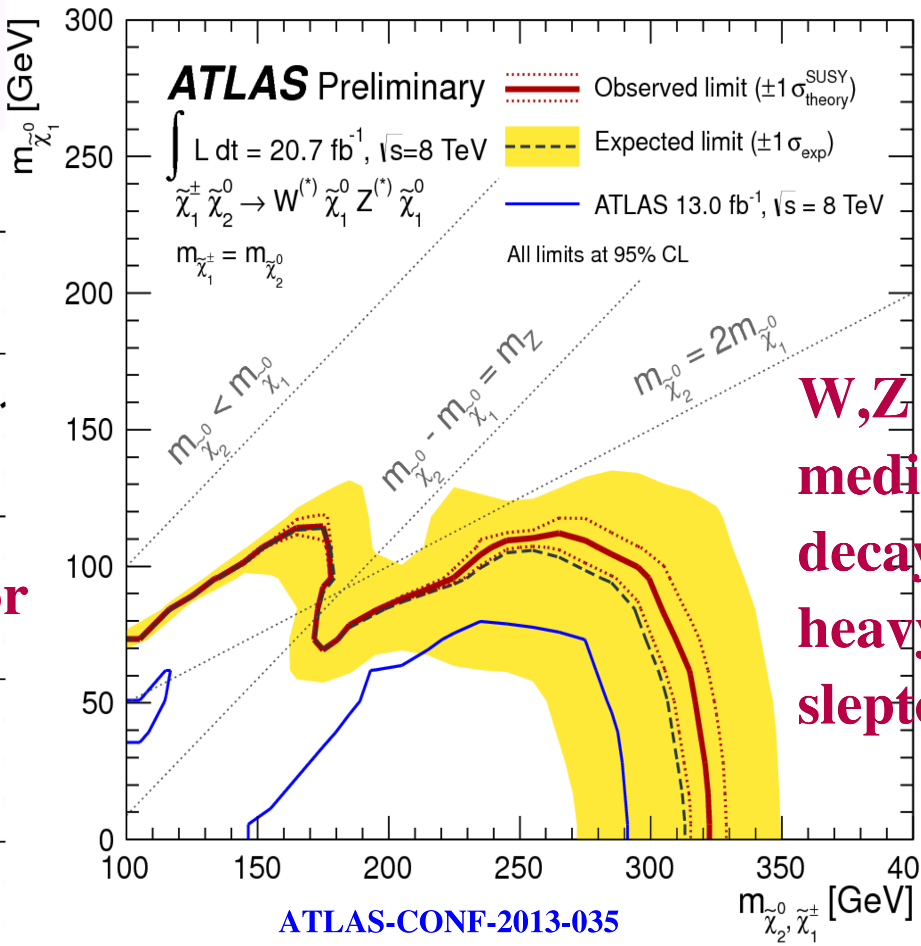
ATLAS-CONF-2013-028

SUSY searches, electroweak gaugino production with 3 leptons

"classical" 3 leptons final state search interpreted for Chargino-Neutralino production



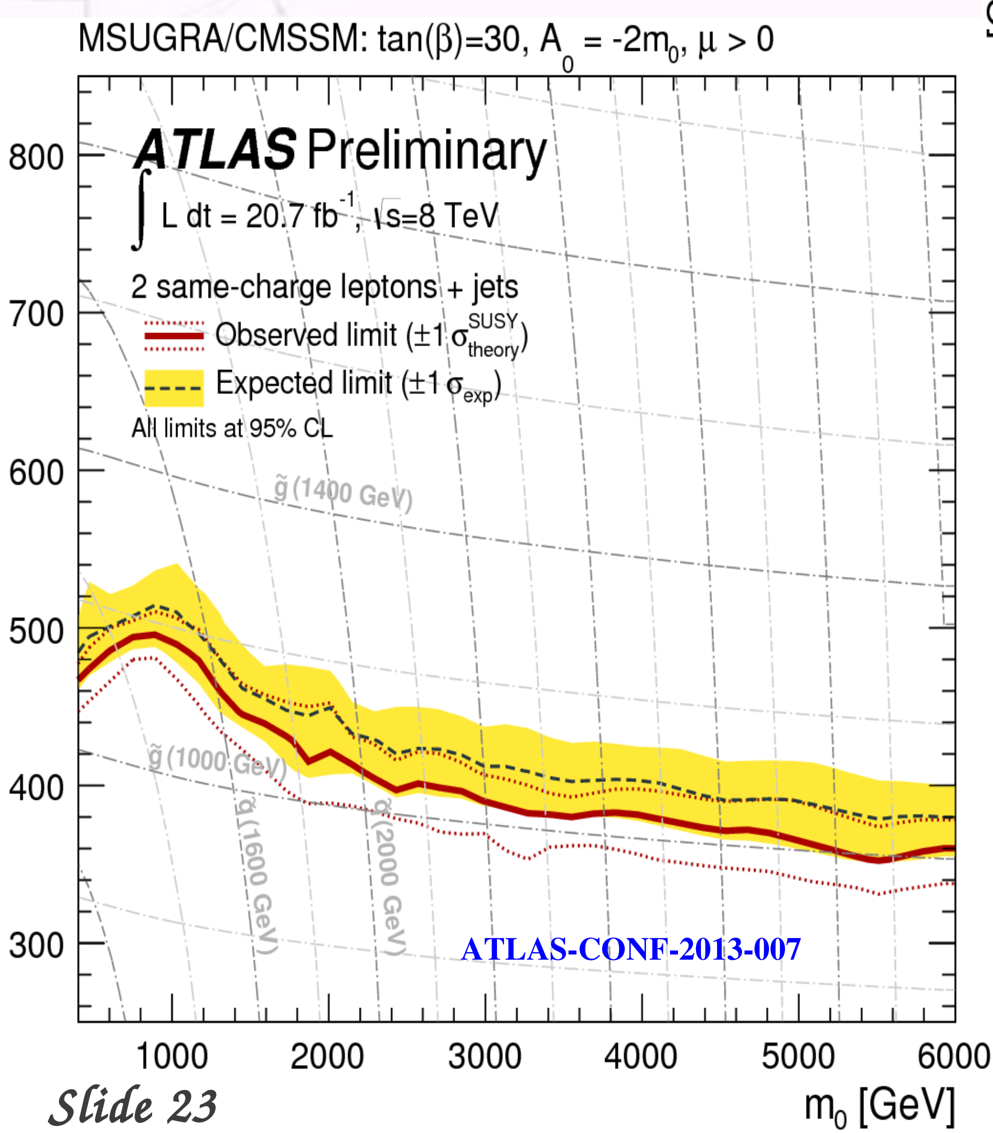
Sleptons or W,Z mediated



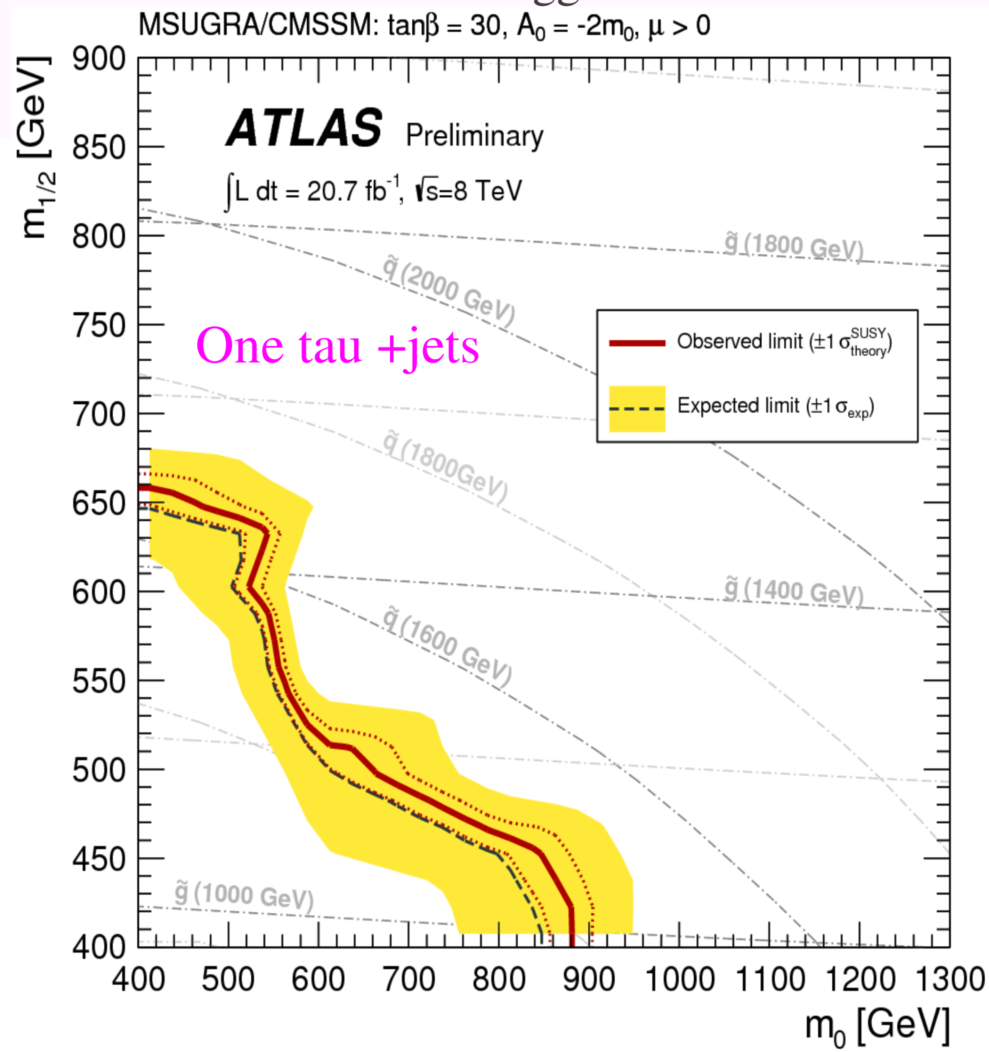
W,Z mediated decays; heavy sleptons

Higgs and SUSY

Constrained models (CMSSM/mSUGRA) allow relating Higgs boson mass to the masses of SUSY particles. Limits in “Higgs aware” slice of cMSSM where the Higgs boson mass is around 125 GeV.



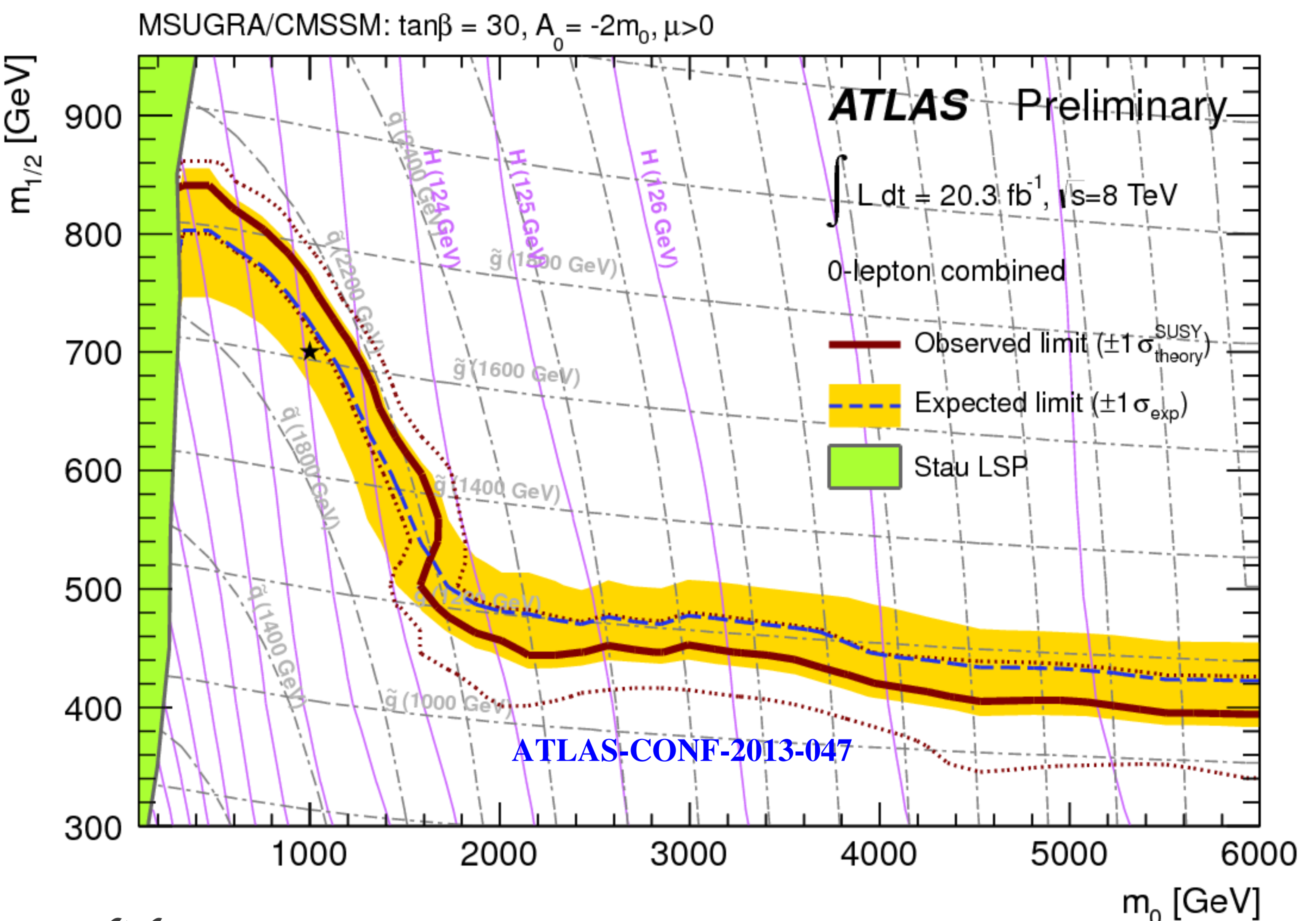
ATLAS-CONF-2013-007

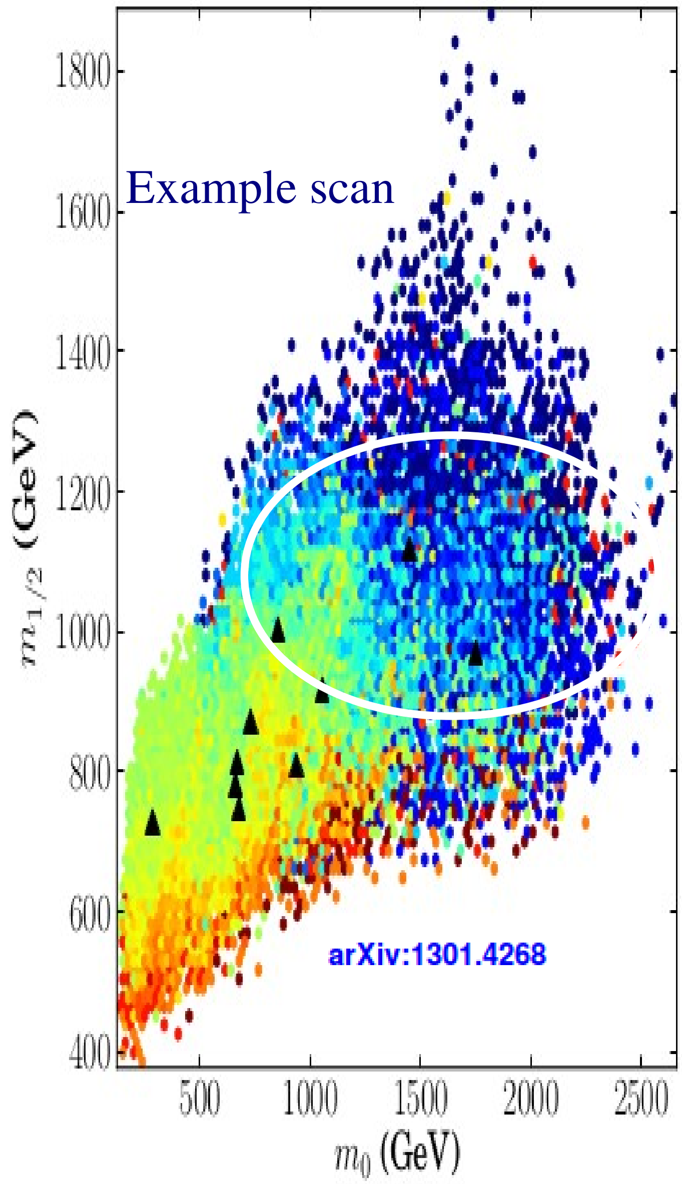


ATLAS-CONF-2013-028

SUSY, Higgs and Dark Matter

Limits in "Higgs aware" slice of cMSSM where the Higgs boson mass is around 125 GeV. Relict Dark Matter density can be calculated in this model. It is plausible in the narrow region where the neutralino mass and the stau mass are close ("nearly stau LSP")



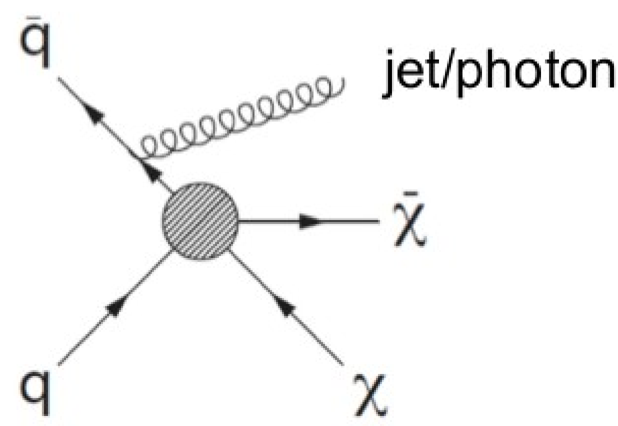


Benchmarks with correct HM and relict density JUST above the present reach

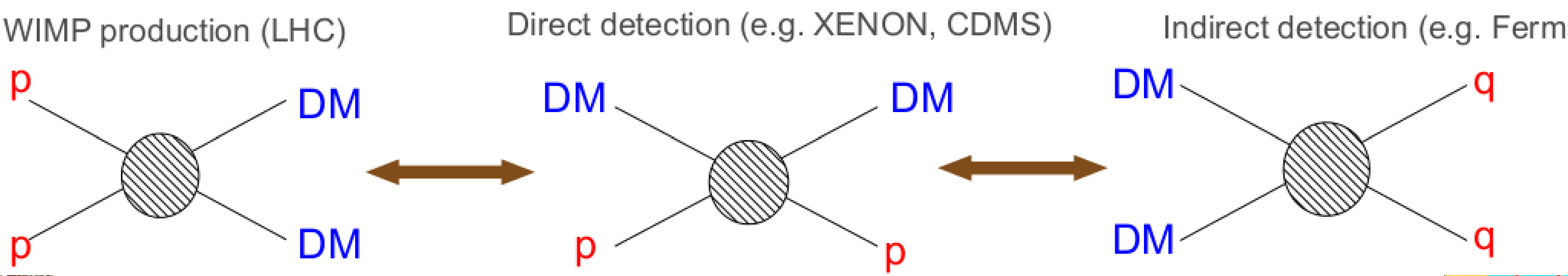
Dark Matter Search in Monojet Events

(Applicable to SUSY if only the LSP is kinematically accessible)

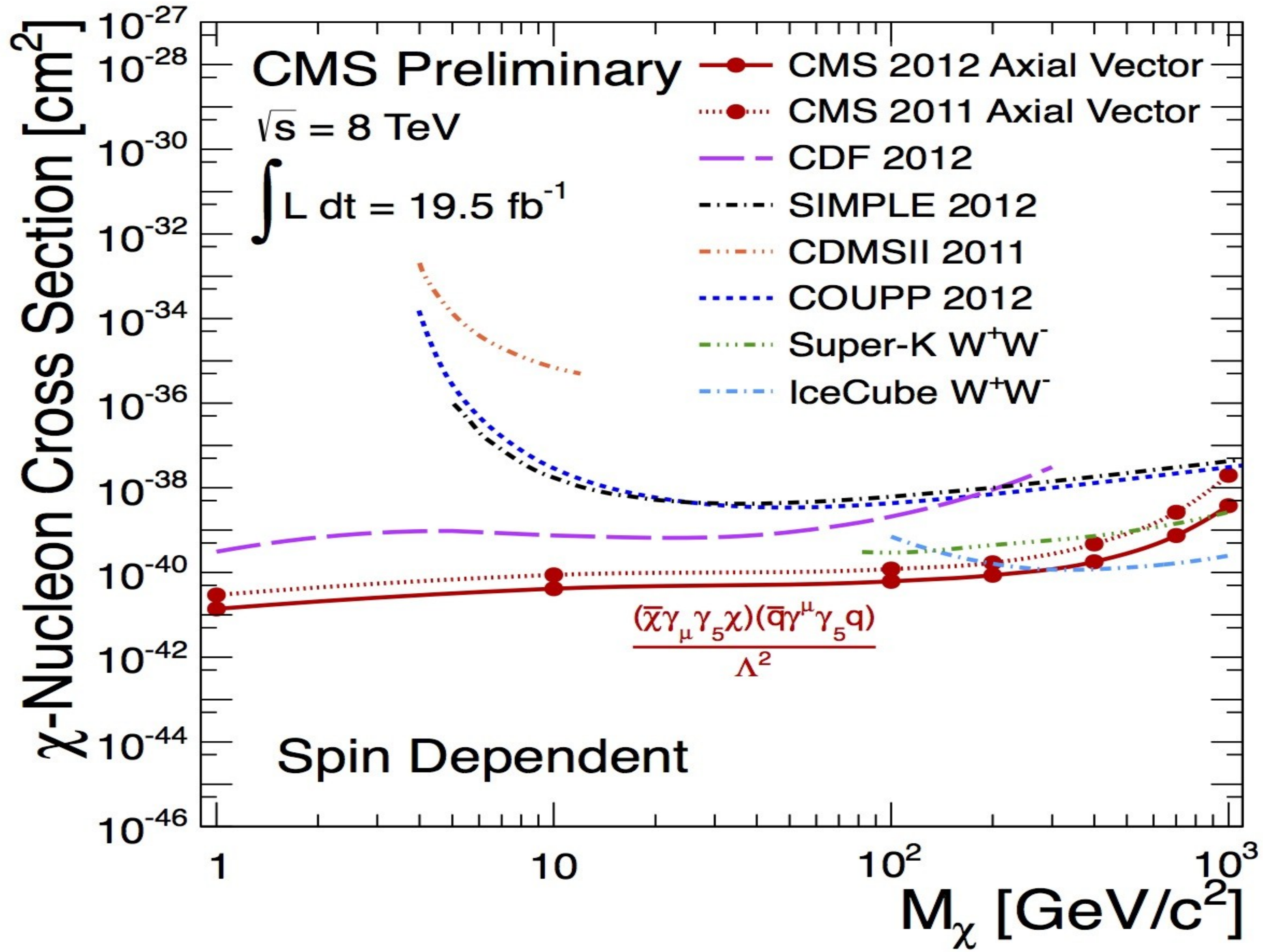
Name	Initial state	Type	Operator
D1	qq	scalar	$\frac{m_q}{M_\star^3}\bar{\chi}\chi\bar{q}q$
D5	qq	vector	$\frac{1}{M_\star^2}\bar{\chi}\gamma^\mu\chi\bar{q}\gamma_\mu q$
D8	qq	axial-vector	$\frac{1}{M_\star^2}\bar{\chi}\gamma^\mu\gamma^5\chi\bar{q}\gamma_\mu\gamma^5 q$
D9	qq	tensor	$\frac{1}{M_\star^2}\bar{\chi}\sigma^{\mu\nu}\chi\bar{q}\sigma_{\mu\nu}q$
D11	gg	scalar	$\frac{1}{4M_\star^3}\bar{\chi}\chi\alpha_s(G^a_{\mu\nu})^2$



DM production at the LHC can be related to DM scattering on protons and to indirect DM detection in an effective theory approach (DM assumed a Dirac Fermion)



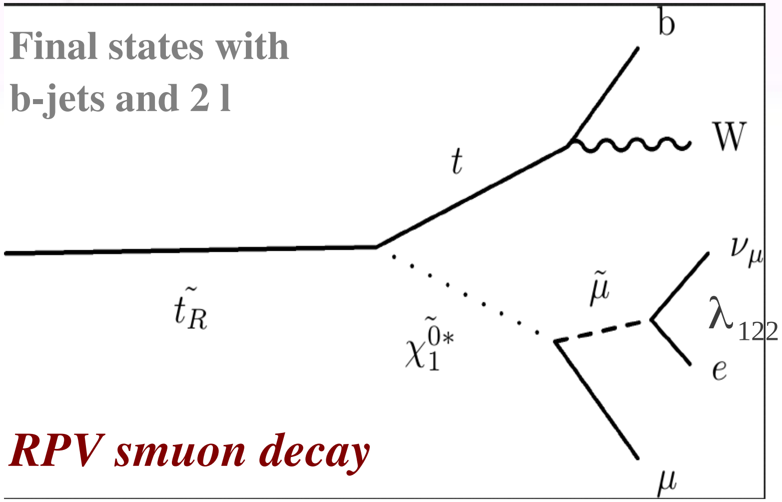
Dark Matter Search in Monojet Events

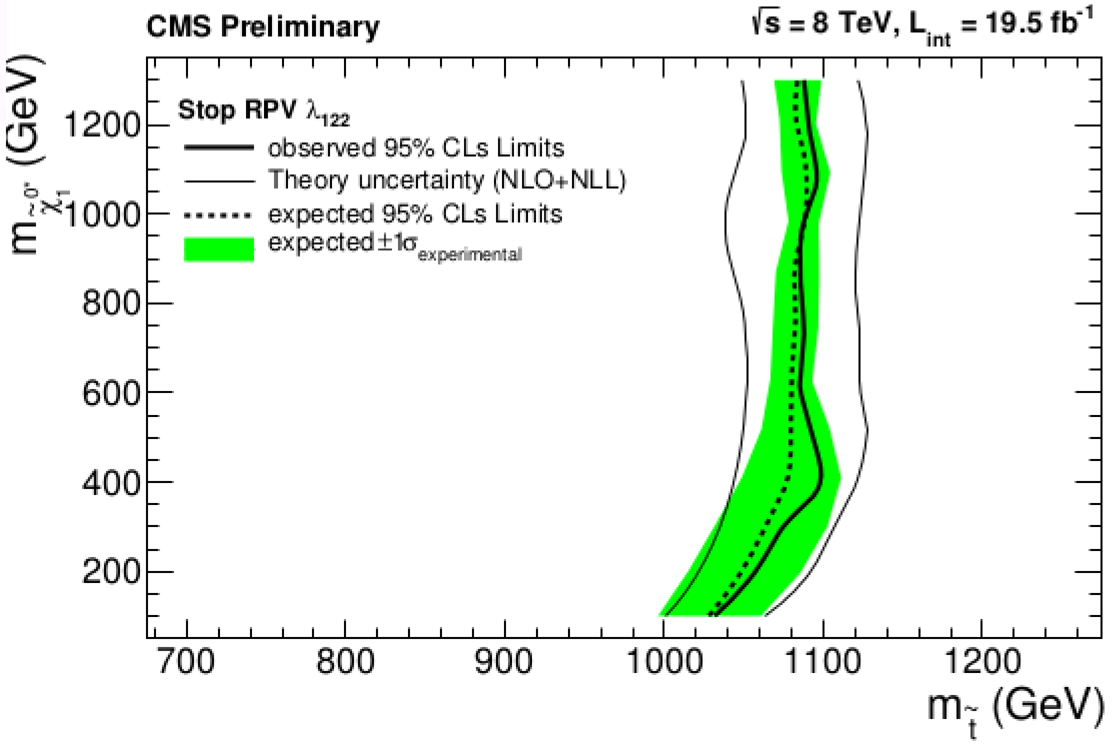


R-parity violation, example search result

-*Proton lifetime can be saved if only one of Lepton of Baryon number violated*
- *neutral LSP can still be a DM candidate if Very Long Lifetime*
-*Limits on B or L violating couplings from rare decays searches (FP)*

$$W_{\not R_p} = \frac{1}{2}\lambda_{ijk}L_iL_j\bar{E}_k + \lambda'_{ijk}L_iQ_j\bar{D}_k + \frac{1}{2}\lambda''_{ijk}\bar{U}_i\bar{D}_j\bar{D}_k,$$





CMS PAS SUS-13-003

Dreams: If we observe a “SUSY-like” particle, what next?

1) Measure spin and decays BRs.

2) Check how Higgs decay BR are affected (third family, invisible)

3) Recalculate relict DM density
Staus (but also sbottoms and stops) related to keeping relict DM density within observed limits via coaanihilation with the LSP

4) Recalculate rare decays ($B \to \mu\mu$)

5) SUSY mass scale relates to GUT scale,
Gauge couplings unifications!

Summary and Perspective

No discovery yet, but this is “consistent” with the relatively heavy Higgs boson - even in constrained models.

Motivations for SUSY still strong, many analyses in progress to full data sets.

Searches are topology-oriented, very large number of final states analyzed (Presented limits valid within a specific simplified or constrained model)

New window opens in 2015 with 14 TeV collision energy!
Preparation of 14 TeV analyses ongoing!

References:

twiki.cern.ch/twiki/bin/AtlasPublic/SupersymmetryPublicResults

http://cms.web.cern.ch/news/cms-physics-results

Backup

ATLAS SUSY Searches* - 95% CL Lower Limits

Status: LHCP 2013

ATLAS Preliminary

$\int L dt = (4.4 - 20.7)\ \mathrm{fb}^{-1}$ $\sqrt{s}$ = 7, 8 TeV

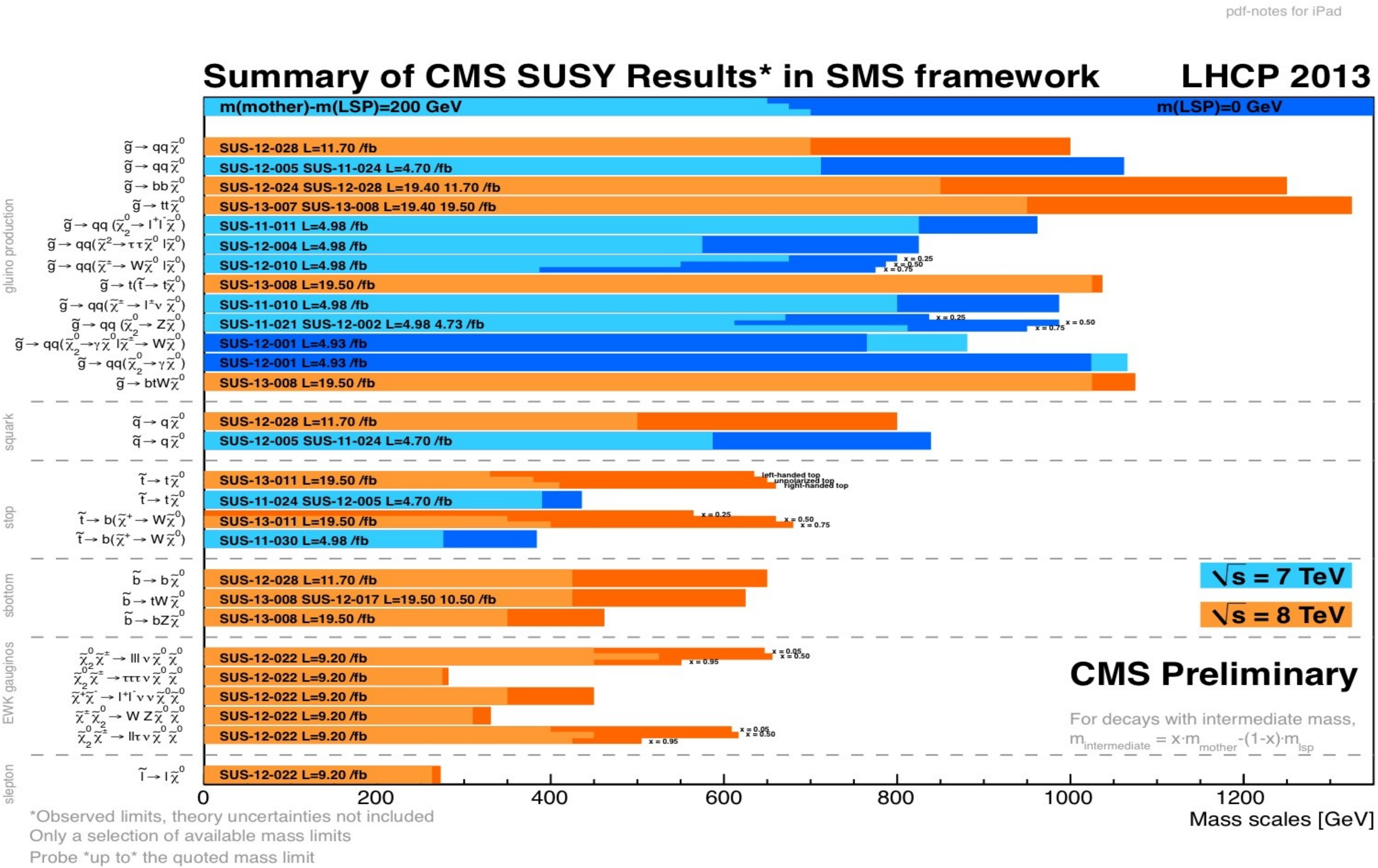
	Model	e, μ, τ, γ	Jets	E_T^{miss}	$\int L dt\ [\mathrm{fb}^{-1}]$	Mass limit			Reference
Inclusive searches	MSUGRA/CMSSM	0	2-6 jets	Yes	20.3	$\tilde{q}, \tilde{g}$	1.8 TeV	$m(\tilde{q})=m(\tilde{g})$	ATLAS-CONF-2013-047
	MSUGRA/CMSSM	1 e, μ	4 jets	Yes	5.8	$\tilde{q}, \tilde{g}$	1.24 TeV	$m(\tilde{q})=m(\tilde{g})$	ATLAS-CONF-2012-104
	MSUGRA/CMSSM	0	7-10 jets	Yes	20.3	$\tilde{g}$	1.1 TeV	any $m(\tilde{q})$	ATLAS-CONF-2013-054
	$\tilde{q}\tilde{q}, \tilde{q}\to q\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{q}$	740 GeV	$m(\tilde{\chi}_1^0)=0$ GeV	ATLAS-CONF-2013-047
	$\tilde{g}\tilde{g}, \tilde{g}\to q\bar{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{g}$	1.3 TeV	$m(\tilde{\chi}_1^0)=0$ GeV	ATLAS-CONF-2013-047
	Gluino med. $\tilde{\chi}^\pm$ ($\tilde{g}\to q\bar{q}\tilde{\chi}^\pm$)	1 e, μ	2-4 jets	Yes	4.7	$\tilde{g}$	900 GeV	$m(\tilde{\chi}_1^0)<200$ GeV, $m(\tilde{\chi}^\pm)=0.5(m(\tilde{\chi}_1^0)+m(\tilde{g}))$	1208.4688
	$\tilde{g}\tilde{g}\to qqqql\nu l\nu\tilde{\chi}_1^0\tilde{\chi}_1^0$	2 e, μ (SS)	3 jets	Yes	20.7	$\tilde{g}$	1.1 TeV	$m(\tilde{\chi}_1^0)<650$ GeV	ATLAS-CONF-2013-007
	GMSB ($\tilde{l}$ NLSP)	2 e, μ	2-4 jets	Yes	4.7	$\tilde{g}$	1.24 TeV	$\tan\beta<15$	1208.4688
	GMSB ($\tilde{\tau}$ NLSP)	1-2 τ	0-2 jets	Yes	20.7	$\tilde{g}$	1.4 TeV	$\tan\beta>18$	ATLAS-CONF-2013-026
	GGM (bino NLSP)	2 γ	0	Yes	4.8	$\tilde{g}$	1.07 TeV	$m(\tilde{\chi}_1^0)>50$ GeV	1209.0753
	GGM (wino NLSP)	1 e, μ + γ	0	Yes	4.8	$\tilde{g}$	619 GeV	$m(\tilde{\chi}_1^0)>50$ GeV	ATLAS-CONF-2012-144
	GGM (higgsino-bino NLSP)	γ	1 b	Yes	4.8	$\tilde{g}$	900 GeV	$m(\tilde{\chi}_1^0)>220$ GeV	1211.1167
	GGM (higgsino NLSP)	2 e, μ (Z)	0-3 jets	Yes	5.8	$\tilde{g}$	690 GeV	$m(\tilde{H})>200$ GeV	ATLAS-CONF-2012-152
	Gravitino LSP	0	mono-jet	Yes	10.5	$F^{1/2}$ scale	645 GeV	$m(\tilde{G})>10^{-4}$ eV	ATLAS-CONF-2012-147
3^{rd} gen. $\tilde{g}$ med.	$\tilde{g}\to b\bar{b}\tilde{\chi}_1^0$	0	3 b	Yes	12.8	$\tilde{g}$	1.24 TeV	$m(\tilde{\chi}_1^0)<200$ GeV	ATLAS-CONF-2012-145
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	2 e, μ (SS)	0-3 b	No	20.7	$\tilde{g}$	900 GeV	$m(\tilde{\chi}_1^0)<500$ GeV	ATLAS-CONF-2013-007
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0	7-10 jets	Yes	20.3	$\tilde{g}$	1.14 TeV	$m(\tilde{\chi}_1^0)<200$ GeV	ATLAS-CONF-2013-054
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0	3 b	Yes	12.8	$\tilde{g}$	1.15 TeV	$m(\tilde{\chi}_1^0)<200$ GeV	ATLAS-CONF-2012-145
3^{rd} gen. squarks direct production	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\to b\tilde{\chi}_1^0$	0	2 b	Yes	20.1	$\tilde{b}_1$	100-630 GeV	$m(\tilde{\chi}_1^0)<100$ GeV	ATLAS-CONF-2013-053
	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\to t\tilde{\chi}_1^\pm$	2 e, μ (SS)	0-3 b	Yes	20.7	$\tilde{b}_1$	430 GeV	$m(\tilde{\chi}_1^\pm)=2\,m(\tilde{\chi}_1^0)$	ATLAS-CONF-2013-007
	$\tilde{t}_1\tilde{t}_1$ (light), $\tilde{t}_1\to b\tilde{\chi}_1^\pm$	1-2 e, μ	1-2 b	Yes	4.7	$\tilde{t}_1$	167 GeV	$m(\tilde{\chi}_1^0)=55$ GeV	1208.4305, 1209.2102
	$\tilde{t}_1\tilde{t}_1$ (light), $\tilde{t}_1\to Wb\tilde{\chi}_1^0$	2 e, μ	0-2 jets	Yes	20.3	$\tilde{t}_1$	220 GeV	$m(\tilde{\chi}_1^0)=m(\tilde{t}_1)-m(W)-50$ GeV, $m(\tilde{t}_1)<<m(\tilde{\chi}_1^\pm)$	ATLAS-CONF-2013-048
	$\tilde{t}_1\tilde{t}_1$ (medium), $\tilde{t}_1\to b\tilde{\chi}_1^\pm$	2 e, μ	0-2 jets	Yes	20.3	$\tilde{t}_1$	150-440 GeV	$m(\tilde{\chi}_1^0)=0$ GeV, $m(\tilde{t}_1)-m(\tilde{\chi}_1^\pm)=10$ GeV	ATLAS-CONF-2013-048
	$\tilde{t}_1\tilde{t}_1$ (medium), $\tilde{t}_1\to b\tilde{\chi}_1^\pm$	0	2 b	Yes	20.1	$\tilde{t}_1$	150-580 GeV	$m(\tilde{\chi}_1^0)<200$ GeV, $m(\tilde{\chi}_1^\pm)-m(\tilde{\chi}_1^0)=5$ GeV	ATLAS-CONF-2013-053
	$\tilde{t}_1\tilde{t}_1$ (heavy), $\tilde{t}_1\to t\tilde{\chi}_1^0$	1 e, μ	1 b	Yes	20.7	$\tilde{t}_1$	200-610 GeV	$m(\tilde{\chi}_1^0)=0$ GeV	ATLAS-CONF-2013-037
	$\tilde{t}_1\tilde{t}_1$ (heavy), $\tilde{t}_1\to t\tilde{\chi}_1^0$	0	2 b	Yes	20.5	$\tilde{t}_1$	320-660 GeV	$m(\tilde{\chi}_1^0)=0$ GeV	ATLAS-CONF-2013-024
	$\tilde{t}_1\tilde{t}_1$ (natural GMSB)	2 e, μ (Z)	1 b	Yes	20.7	$\tilde{t}_1$	500 GeV	$m(\tilde{\chi}_1^0)>150$ GeV	ATLAS-CONF-2013-025
	$\tilde{t}_2\tilde{t}_2, \tilde{t}_2\to\tilde{t}_1+Z$	3 e, μ (Z)	1 b	Yes	20.7	$\tilde{t}_2$	520 GeV	$m(\tilde{t}_1)=m(\tilde{\chi}_1^0)+180$ GeV	ATLAS-CONF-2013-025
EW direct	$\tilde{l}_{L,R}\tilde{l}_{L,R}, \tilde{l}\to l\tilde{\chi}_1^0$	2 e, μ	0	Yes	20.3	$\tilde{l}$	85-315 GeV	$m(\tilde{\chi}_1^0)=0$ GeV	ATLAS-CONF-2013-049
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to\tilde{l}\nu(l\tilde{\nu})$	2 e, μ	0	Yes	20.3	$\tilde{\chi}_1^\pm$	125-450 GeV	$m(\tilde{\chi}_1^0)=0$ GeV, $m(\tilde{l},\tilde{\nu})=0.5(m(\tilde{\chi}_1^\pm)+m(\tilde{\chi}_1^0))$	ATLAS-CONF-2013-049
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to\tilde{\tau}\nu(\tau\tilde{\nu})$	2 τ	0	Yes	20.7	$\tilde{\chi}_1^\pm$	180-330 GeV	$m(\tilde{\chi}_1^0)=0$ GeV, $m(\tilde{\tau},\tilde{\nu})=0.5(m(\tilde{\chi}_1^\pm)+m(\tilde{\chi}_1^0))$	ATLAS-CONF-2013-028
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to\tilde{l}_L\nu\tilde{l}_L l(\tilde{\nu}\nu), l\tilde{\nu}\tilde{l}_L l(\tilde{\nu}\nu)$	3 e, μ	0	Yes	20.7	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$	600 GeV	$m(\tilde{\chi}_1^\pm)=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)=0$, $m(\tilde{l},\tilde{\nu})=0.5(m(\tilde{\chi}_1^\pm)+m(\tilde{\chi}_1^0))$	ATLAS-CONF-2013-035
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to W^{(*)}\tilde{\chi}_1^0 Z^{(*)}\tilde{\chi}_1^0$	3 e, μ	0	Yes	20.7	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$	315 GeV	$m(\tilde{\chi}_1^\pm)=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)=0$, sleptons decoupled	ATLAS-CONF-2013-035
Long-lived particles	Direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^\pm$	0	1 jet	Yes	4.7	$\tilde{\chi}_1^\pm$	220 GeV	$1<\tau(\tilde{\chi}_1^\pm)<10$ ns	1210.2852
	Stable $\tilde{g}$, R-hadrons	0-2 e, μ	0	Yes	4.7	$\tilde{g}$	985 GeV		1211.1597
	GMSB, stable $\tilde{\tau}$, low β	2 e, μ	0	Yes	4.7	$\tilde{\tau}$	300 GeV	$5<\tan\beta<20$	1211.1597
	GMSB, $\tilde{\chi}_1^0\to\gamma\tilde{G}$, long-lived $\tilde{\chi}_1^0$	2 γ	0	Yes	4.7	$\tilde{\chi}_1^0$	230 GeV	$0.4<\tau(\tilde{\chi}_1^0)<2$ ns	1304.6310
	$\tilde{\chi}_1^0\to qq\mu$ (RPV)	1 e, μ	0	Yes	4.4	$\tilde{q}$	700 GeV	1 mm < cτ < 1 m, $\tilde{g}$ decoupled	1210.7451
RPV	LFV $pp\to\tilde{\nu}_\tau+X, \tilde{\nu}_\tau\to e+\mu$	2 e, μ	0	-	4.6	$\tilde{\nu}_\tau$	1.61 TeV	$\lambda'_{311}=0.10$, $\lambda_{132}=0.05$	1212.1272
	LFV $pp\to\tilde{\nu}_\tau+X, \tilde{\nu}_\tau\to e(\mu)+\tau$	1 e, μ + τ	0	-	4.6	$\tilde{\nu}_\tau$	1.1 TeV	$\lambda'_{311}=0.10$, $\lambda_{1(2)33}=0.05$	1212.1272
	Bilinear RPV CMSSM	1 e, μ	7 jets	Yes	4.7	$\tilde{q}, \tilde{g}$	1.2 TeV	$m(\tilde{q})=m(\tilde{g})$, $c\tau_{LSP}<1$ mm	ATLAS-CONF-2012-140
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to W\tilde{\chi}_1^0, \tilde{\chi}_1^0\to ee\tilde{\nu}_\mu, e\mu\tilde{\nu}_e$	4 e, μ	0	Yes	20.7	$\tilde{\chi}_1^\pm$	760 GeV	$m(\tilde{\chi}_1^0)>300$ GeV, $\lambda_{121}>0$	ATLAS-CONF-2013-036
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to W\tilde{\chi}_1^0, \tilde{\chi}_1^0\to\tau\tau\tilde{\nu}_e, e\tau\tilde{\nu}_\tau$	3 e, μ + τ	0	Yes	20.7	$\tilde{\chi}_1^\pm$	350 GeV	$m(\tilde{\chi}_1^0)>80$ GeV, $\lambda_{133}>0$	ATLAS-CONF-2013-036
	$\tilde{g}\to qqq$	0	6 jets	-	4.6	$\tilde{g}$	666 GeV		1210.4813
	$\tilde{g}\to\tilde{t}_1 t, \tilde{t}_1\to bs$	2 e, μ (SS)	0-3 b	Yes	20.7	$\tilde{g}$	880 GeV		ATLAS-CONF-2013-007
Other	Scalar gluon	0	4 jets	-	4.6	sgluon	100-287 GeV	incl. limit from 1110.2693	1210.4826
	WIMP interaction (D5, Dirac χ)	0	mono-jet	Yes	10.5	M* scale	704 GeV	$m(\chi)<80$ GeV, limit of < 687 GeV for D8	ATLAS-CONF-2012-147

Mass limit axis: 10^{-1}, 1 — Mass scale [TeV]

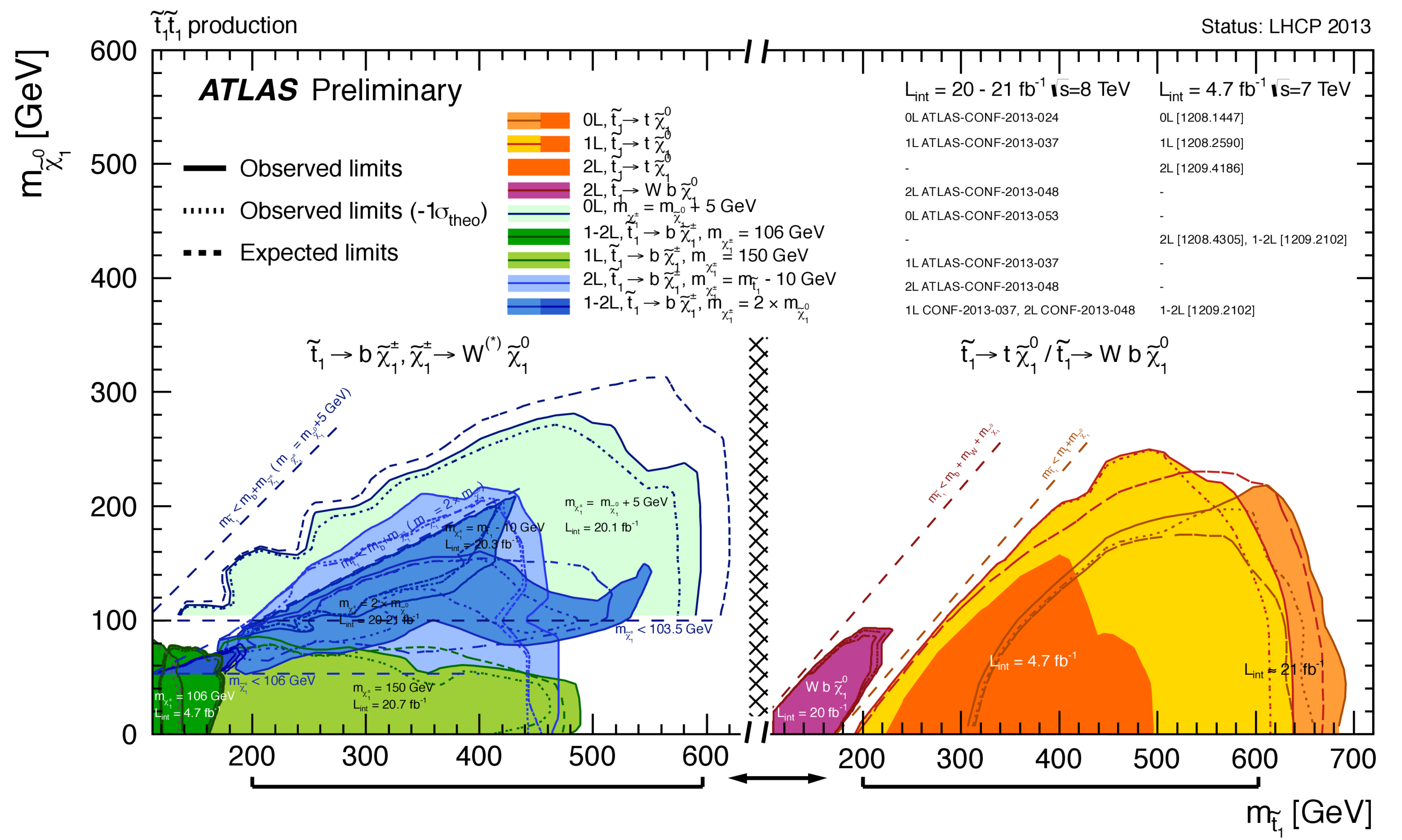
Legend: $\sqrt{s}$ = 7 TeV full data; $\sqrt{s}$ = 8 TeV partial data; $\sqrt{s}$ = 8 TeV full data

*Only a selection of the available mass limits on new states or phenomena is shown. All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.

Backup

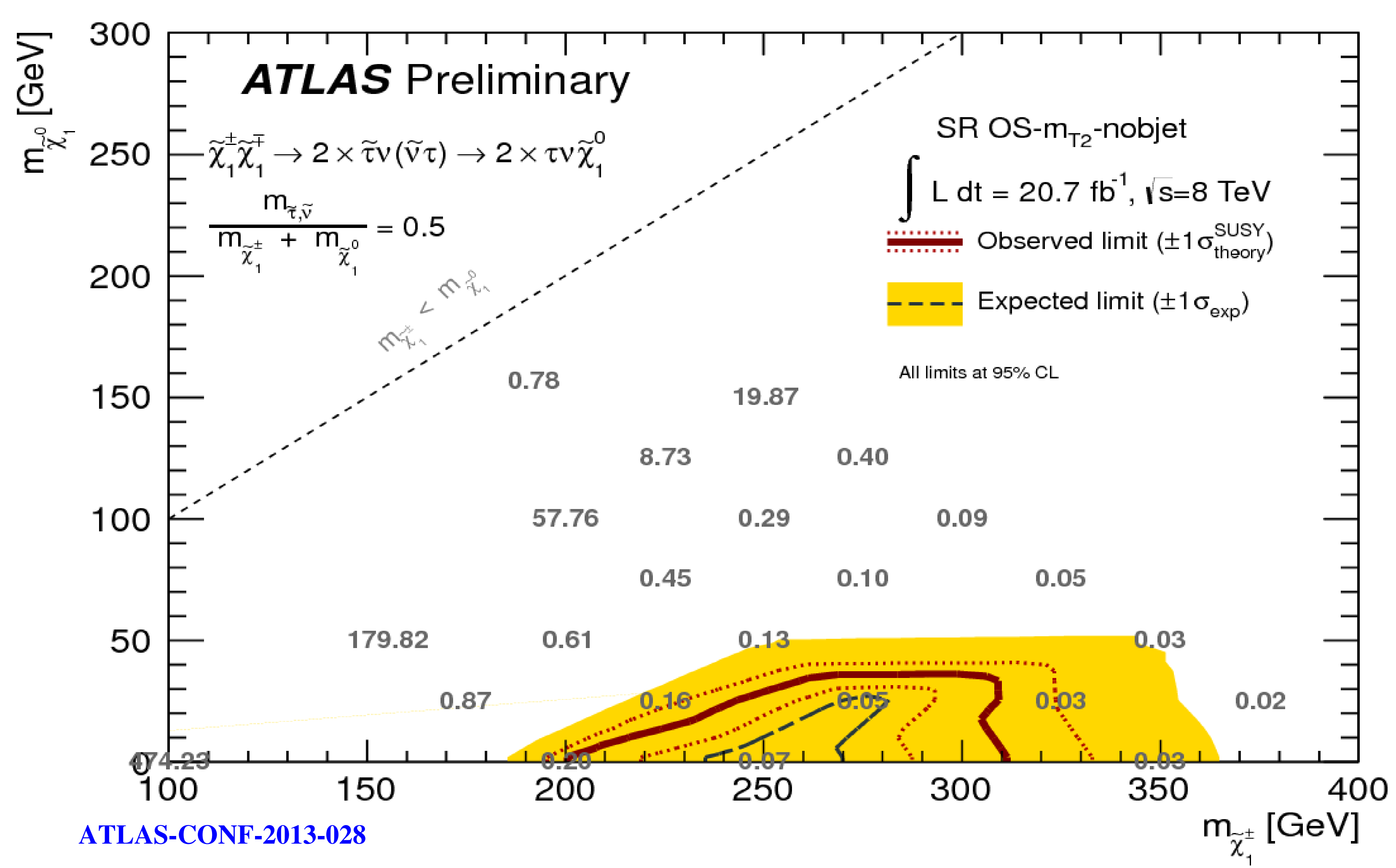

pdf-notes for iPad
Summary of CMS SUSY Results* in SMS framework
LHCP 2013
m(mother)-m(LSP)=200 GeV
m(LSP)=0 GeV
gluino production
SUS-12-028 L=11.70 /fb
SUS-12-005 SUS-11-024 L=4.70 /fb
SUS-12-024 SUS-12-028 L=19.40 11.70 /fb
SUS-13-007 SUS-13-008 L=19.40 19.50 /fb
SUS-11-011 L=4.98 /fb
SUS-12-004 L=4.98 /fb
SUS-12-010 L=4.98 /fb
x = 0.25
x = 0.50
x = 0.75
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
squark
SUS-12-028 L=11.70 /fb
SUS-12-005 SUS-11-024 L=4.70 /fb
stop
SUS-13-011 L=19.50 /fb
left-handed top
unpolarized top
right-handed top
SUS-11-024 SUS-12-005 L=4.70 /fb
SUS-13-011 L=19.50 /fb
SUS-11-030 L=4.98 /fb
sbottom
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
EWK gauginos
SUS-12-022 L=9.20 /fb
x = 0.05
x = 0.50
x = 0.95
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
slepton
SUS-12-022 L=9.20 /fb
√s = 7 TeV
√s = 8 TeV
CMS Preliminary
For decays with intermediate mass,
$m_{intermediate} = x \cdot m_{mother} - (1-x) \cdot m_{lsp}$
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

Results, direct stops and sbottoms, ATLAS summary



SUSY searches, electroweak production with staus

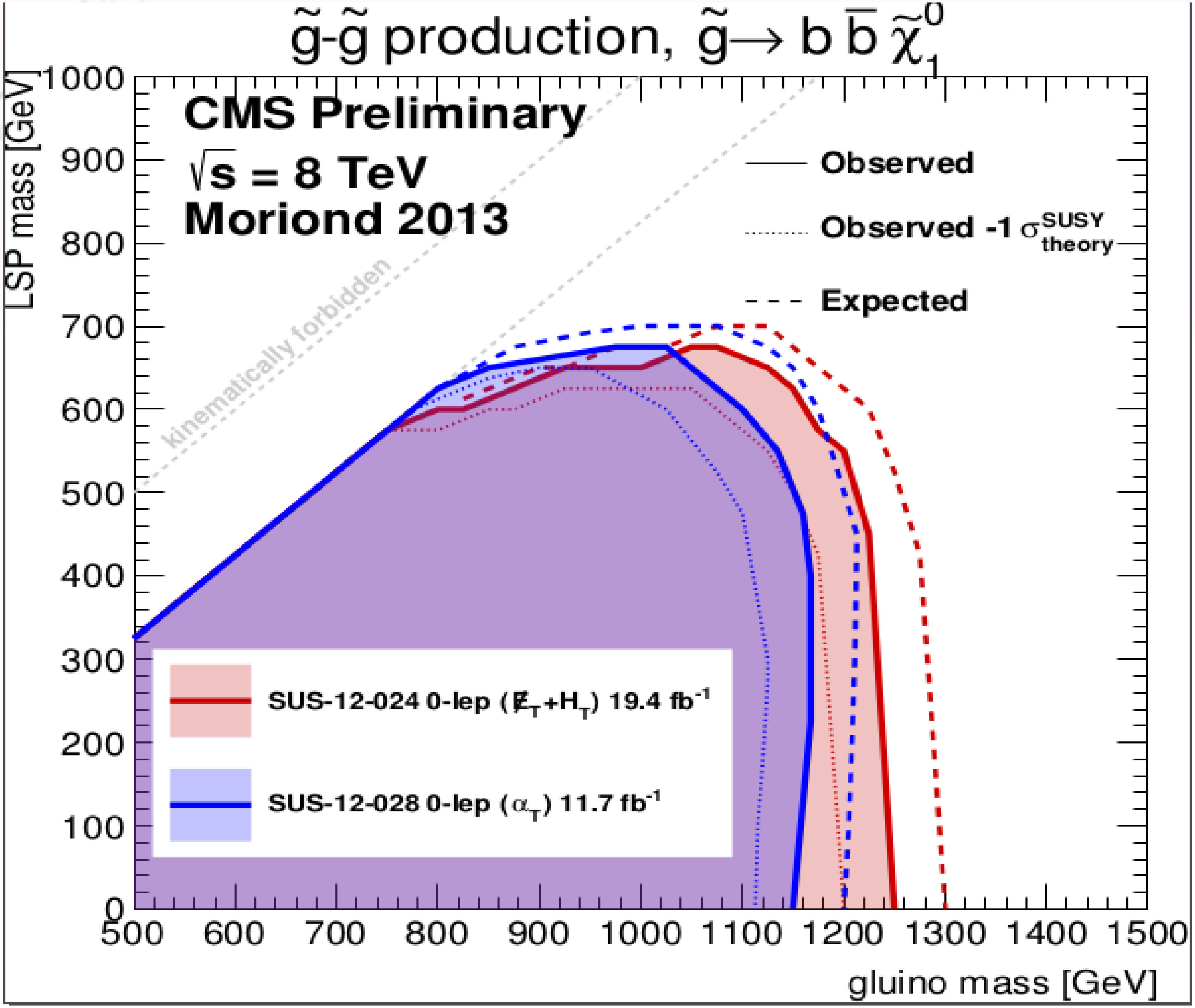
Chargino-Chargino production-> two taus and missing Et, difficult final state for the LHC.



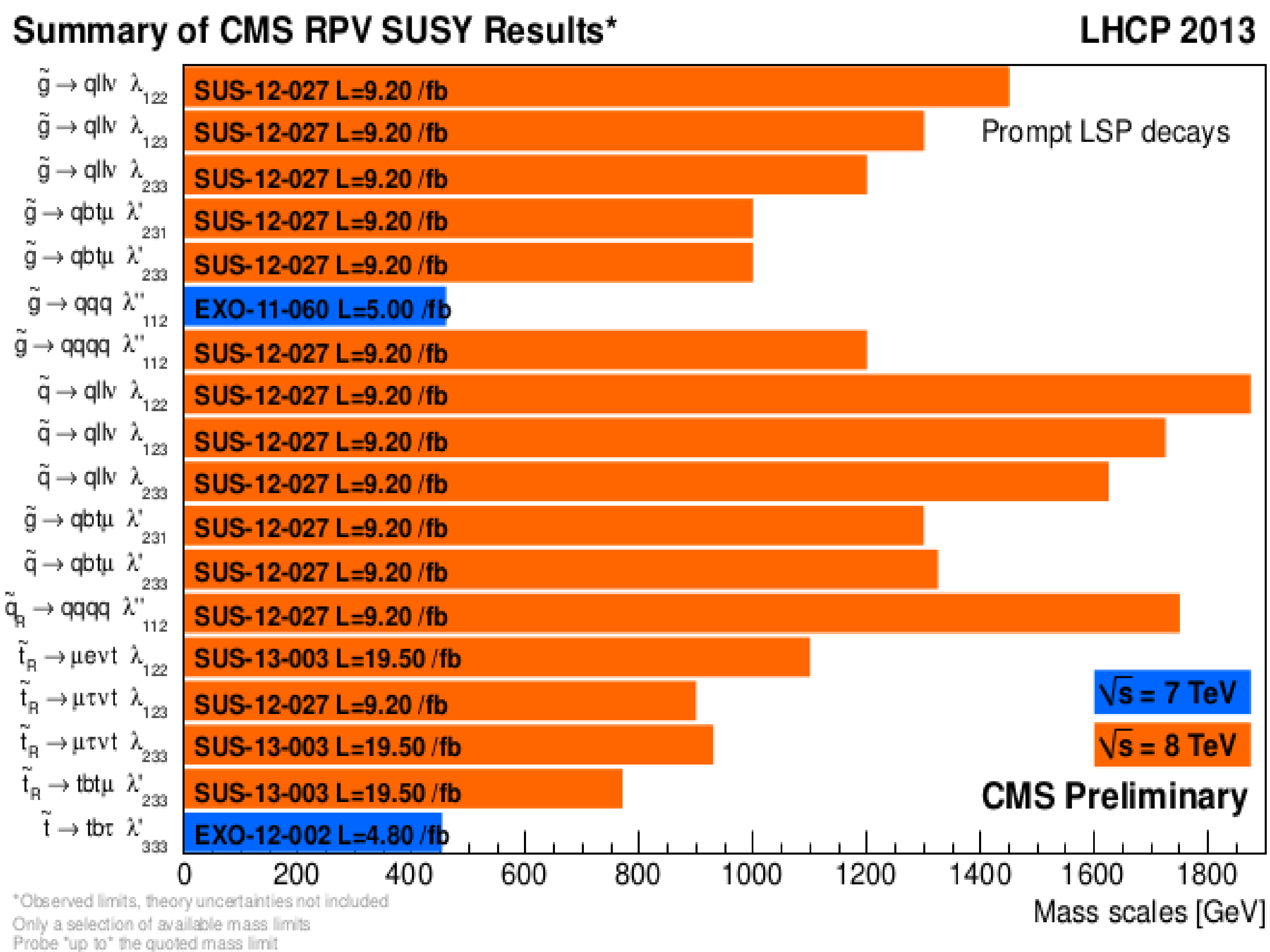
ATLAS-CONF-2013-028

LSP mass limit from LEP around 45 GeV...

Results, gluino decays with bottom in final states



Backup


Summary of CMS RPV SUSY Results*
LHCP 2013
Prompt LSP decays
SUS-12-027 L=9.20 /fb
SUS-13-003 L=19.50 /fb
EXO-11-060 L=5.00 /fb
EXO-12-002 L=4.80 /fb
√s = 7 TeV
√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

Mass relations in MSSM+

$M_{\tilde{g}} \simeq 3\ M_2$

$M_{\tilde{\chi}_1^\pm} \simeq M_2$ (gaugino region)

$M_{\tilde{\chi}_1^0} \simeq 0.5\ M_2$ (gaugino region)

Gauge unification

and .....

$M_{\tilde{\nu}}^2 = m_0^2 + 0.77 M_2^2 + 0.5 M_Z^2 cos(2\beta)$

$M_{\tilde{e}_L}^2 = m_0^2 + 0.77 M_2^2 - 0.27 M_Z^2 cos(2\beta)$

$M_{\tilde{e}_R}^2 = m_0^2 + 0.22 M_2^2 - 0.23 M_Z^2 cos(2\beta)$

${M_{\tilde{q}}}^2 \sim m_0^2 + 10 M_2^2 + O(M_Z^2 cos(2\beta))$

$\pm$ (splitting term)

Sfermion unification

Gauginos and squarks are related
Can use charginos to set
a limit on squarks and sleptons,
and sleptons to set limits on charginos

Mixing -> mass splitting for
stop and , sbottom and stau
$A_t - \mu/\tan\beta$, $A_b - \mu \tan\beta$ $A_\tau - \mu \tan\beta$