

Oliver Buchmueller & Paul De Jong

DEALING WITH “SUSY LIMIT INFLATION” FOR THE EXPERIMENTAL PDG REVIEW

The Early SUSY Search Strategy

Complementary set of inclusive topology searches purely defined by experimental signature!

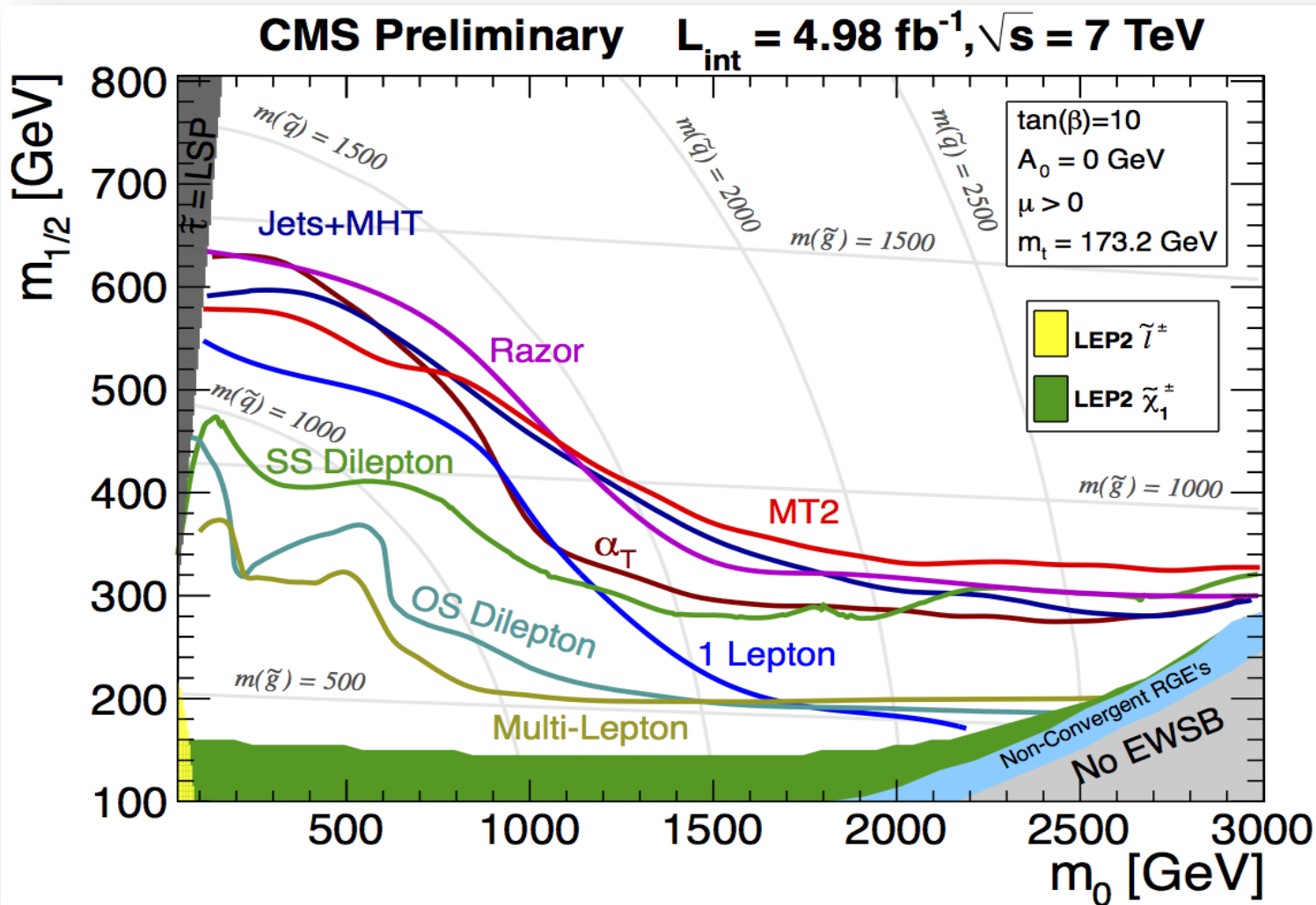
0-leptons	1-lepton	OSDL	SSDL	≥ 3 leptons	2-photons	γ +lepton
Jets + MET	Single lepton + Jets + MET	Opposite-sign di-lepton + jets + MET	Same-sign di-lepton + jets + MET	Multi-lepton	Di-photon + jet + MET	Photon + lepton + MET

Bottom line:

Use the model of SUSY as overall guidance but DO NOT tune the searches according to its details!

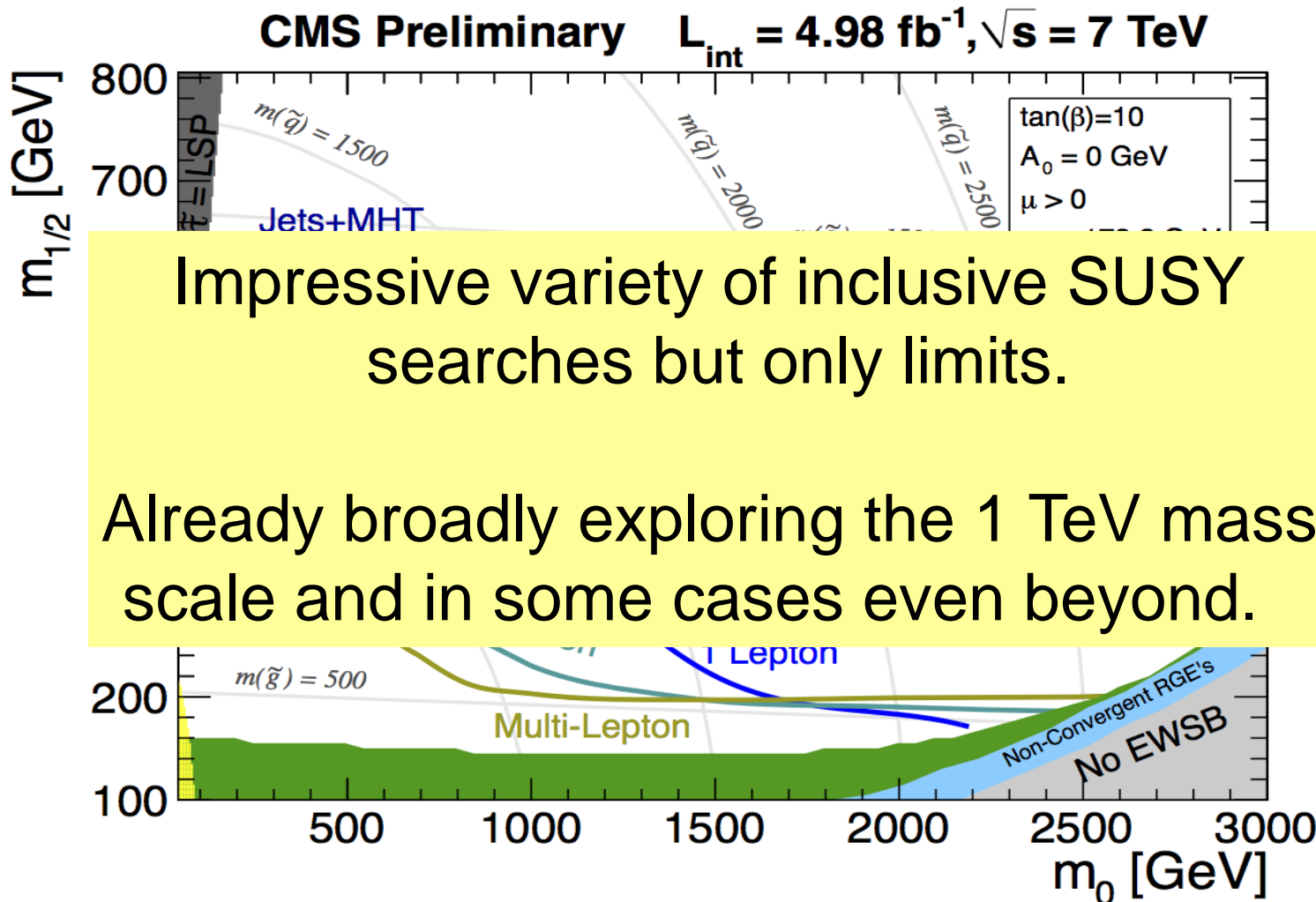
Inclusive SUSY Searches

Landscape in 2011:
Limits in CMSSM; Example CMS (ATLAS similar)

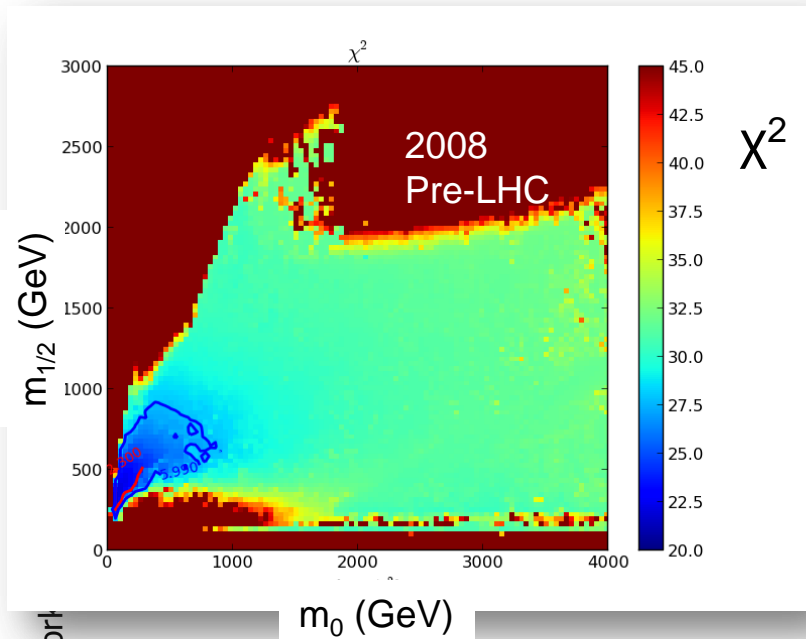


Inclusive SUSY Searches

Landscape in 2011:
Limits in CMSSM; Example CMS (ATLAS similar)



CMSSM: Evolution with time



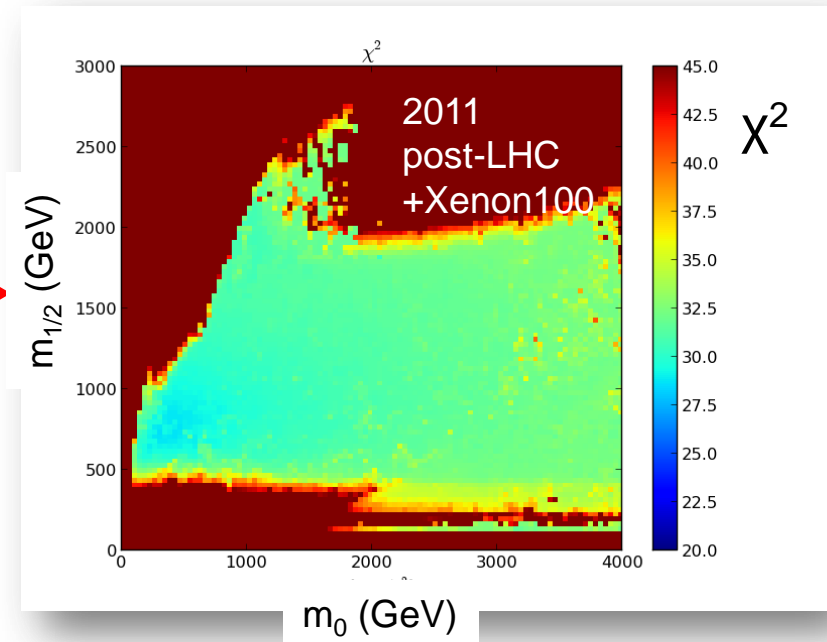
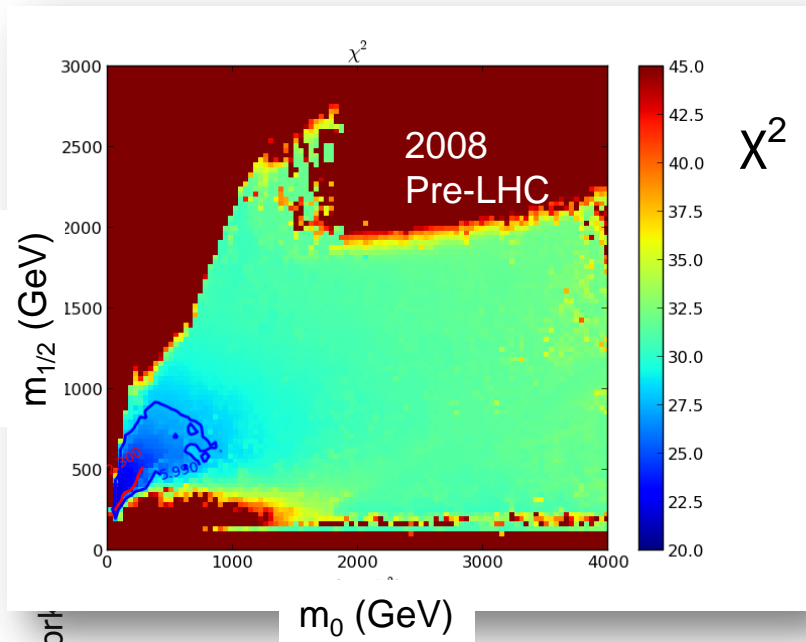
χ^2 increase from
bluish to reddish



Source:

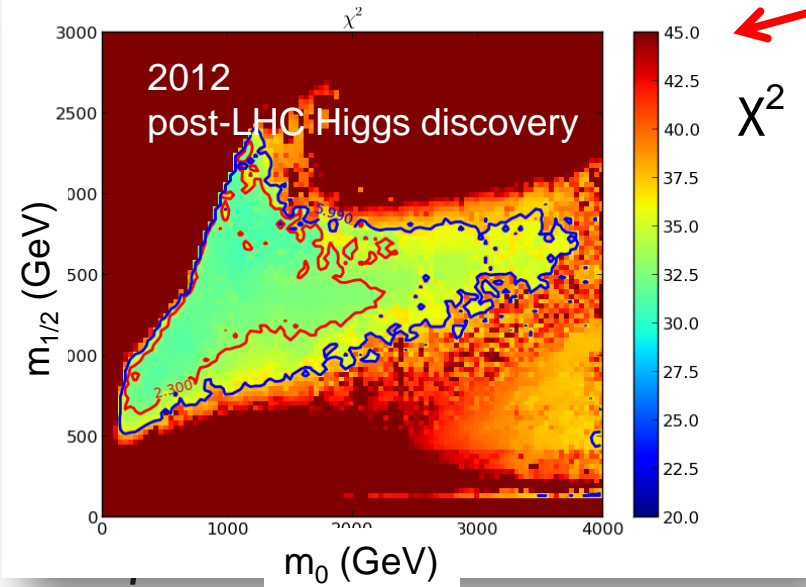
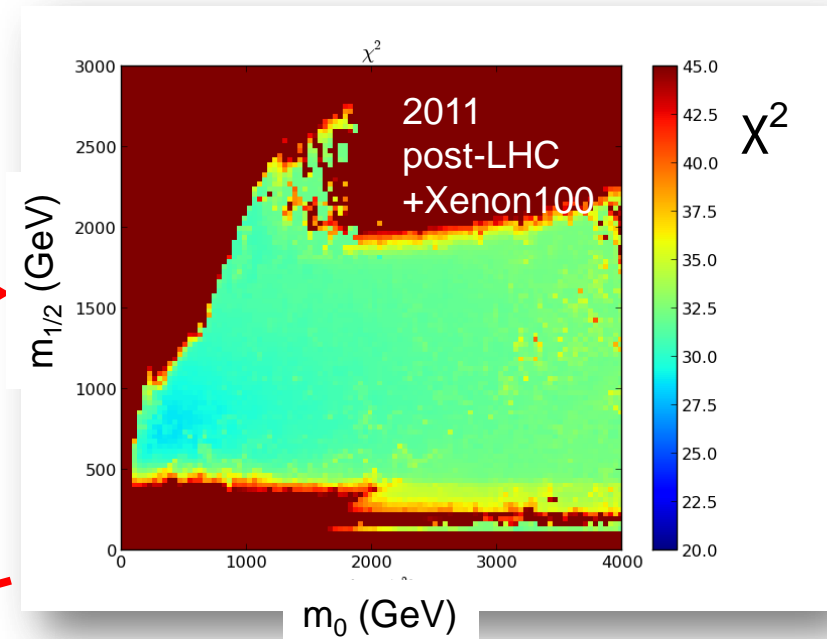
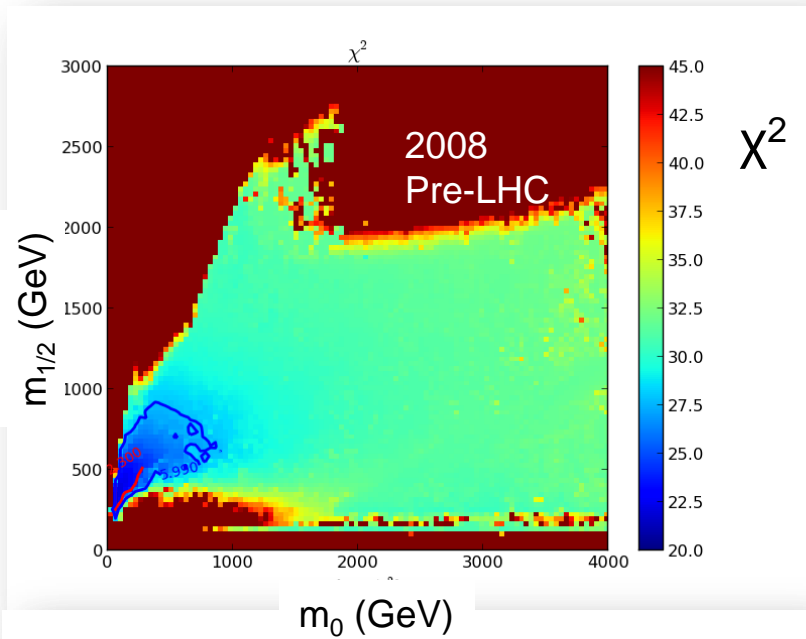
<http://mastercode.web.cern.ch/mastercode/>

CMSSM: Evolution with time

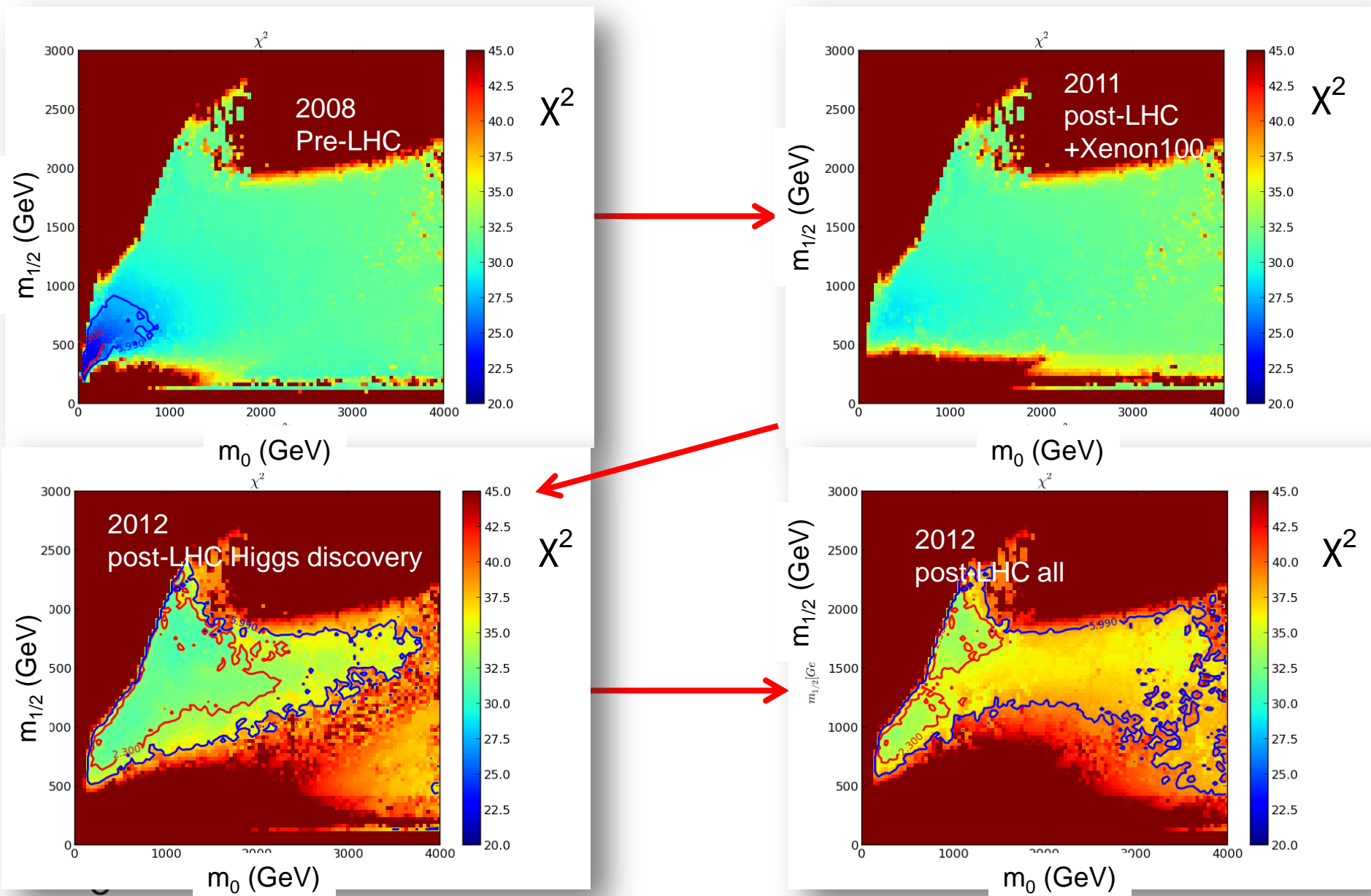


Experimental SUSY, PDG Work

CMSSM: Evolution with time



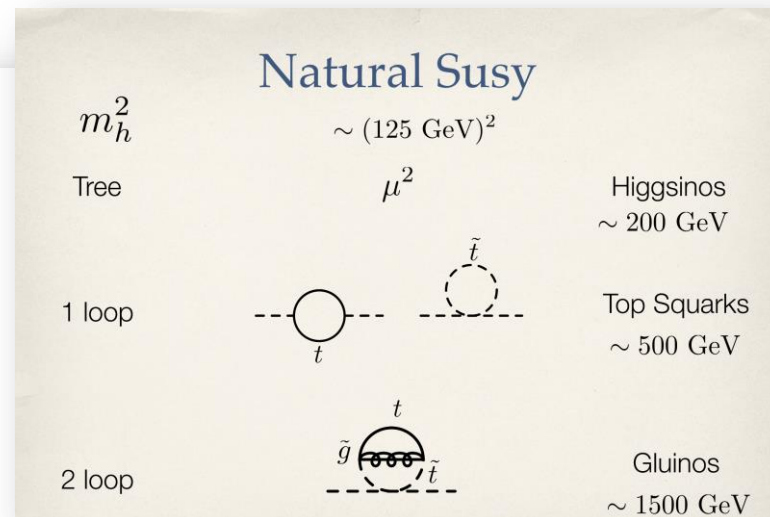
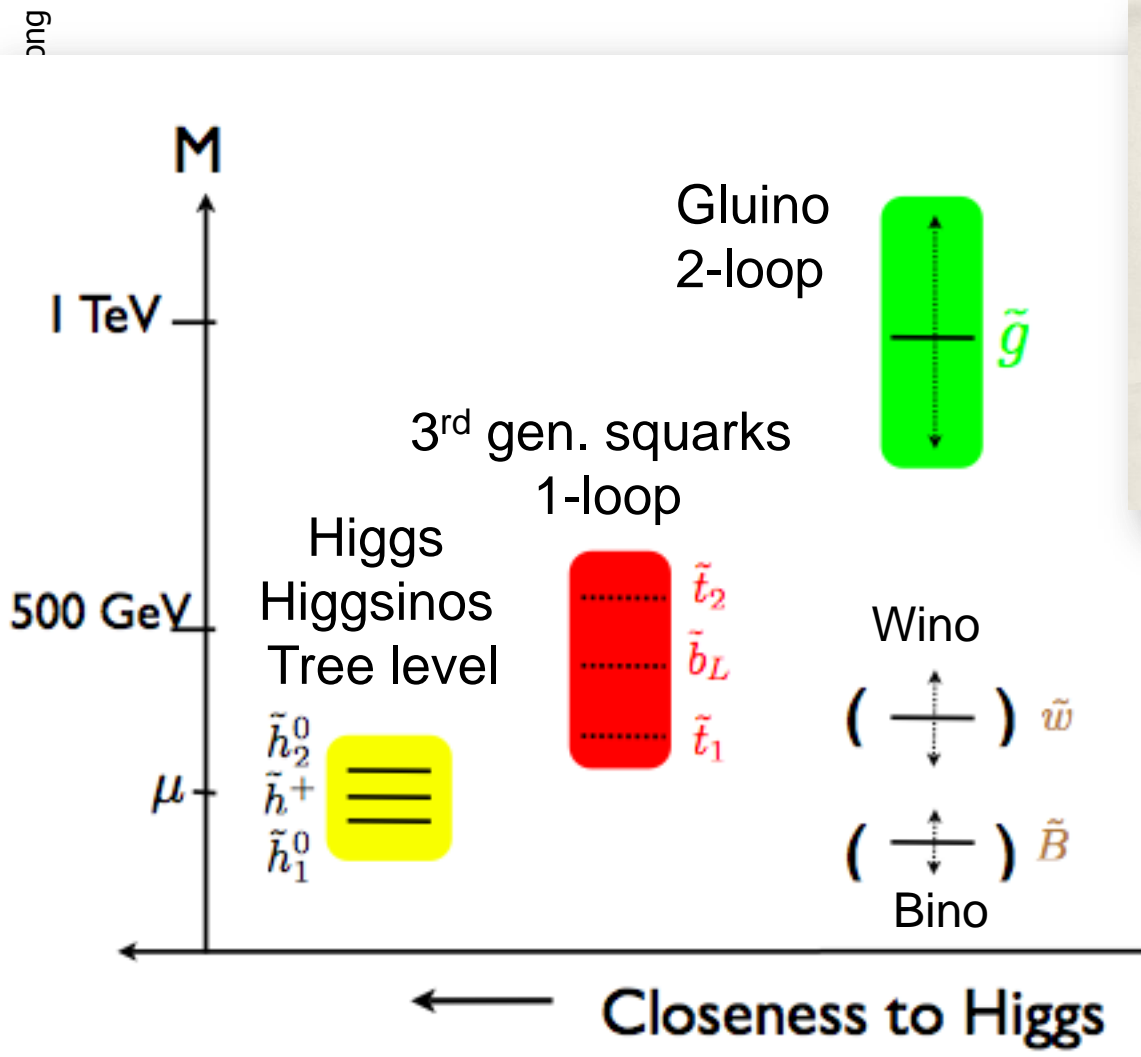
CMSSM: Evolution with time



SUSY Status – post 7 TeV LHC data

- Constrained SUSY models like the CMSSM are severely put under pressure by the LHC limits!
- Experiments define new benchmarks and less complex SUSY models in order to present the interpretation of their searches.
- Aided by the discovery of a Higgs(-like) boson, to focus of the experimental search strategy and corresponding interpretation shifts towards “Natural SUSY”.

(Minimal) Natural SUSY Spectrum

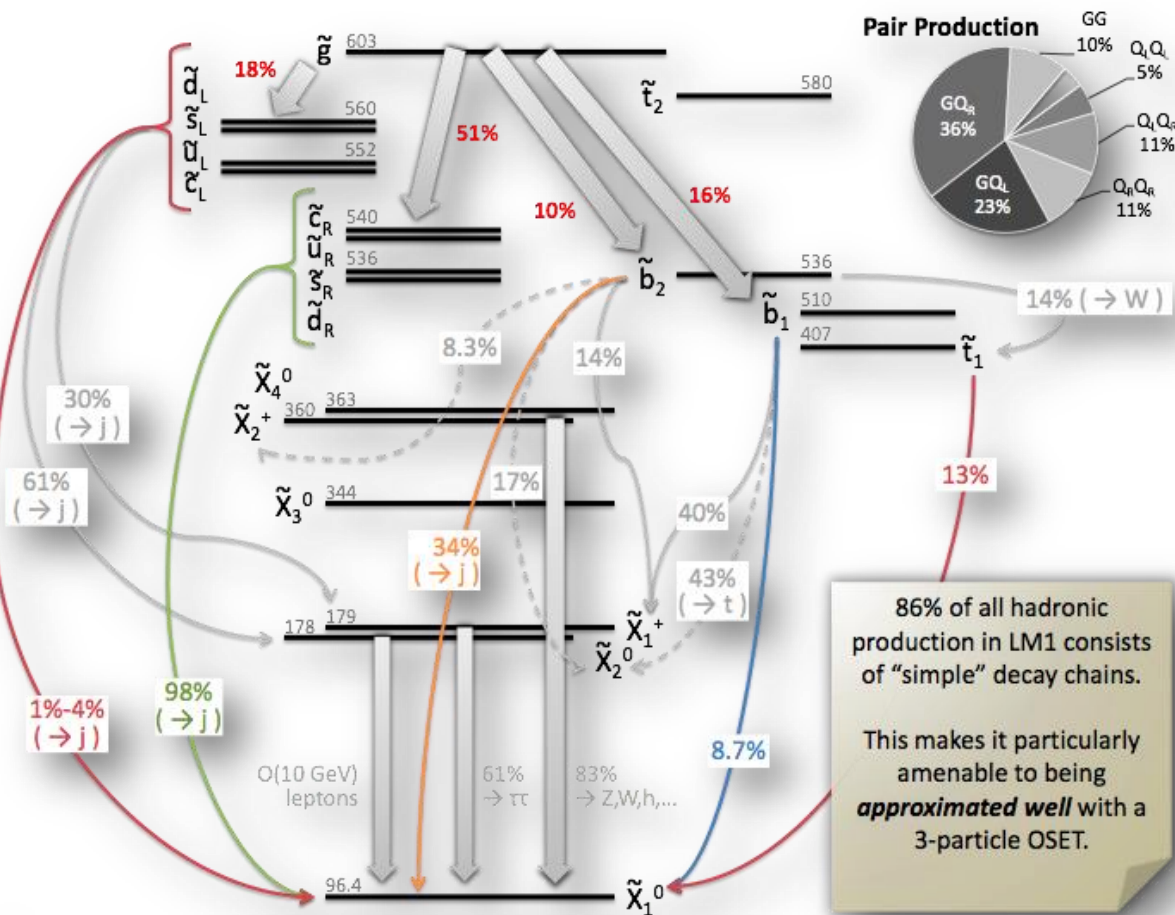


Use the argument of “naturalness” (i.e. fine-tuning) to motivate light **3rd generation squarks** (especially stop) and a rather light **gluino!**

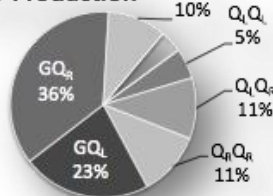
Interpretation in Simplified Models

Experimental SUSY, PDG Workshop 2013 O. Buchmüller & P. de Jong

CMSSM

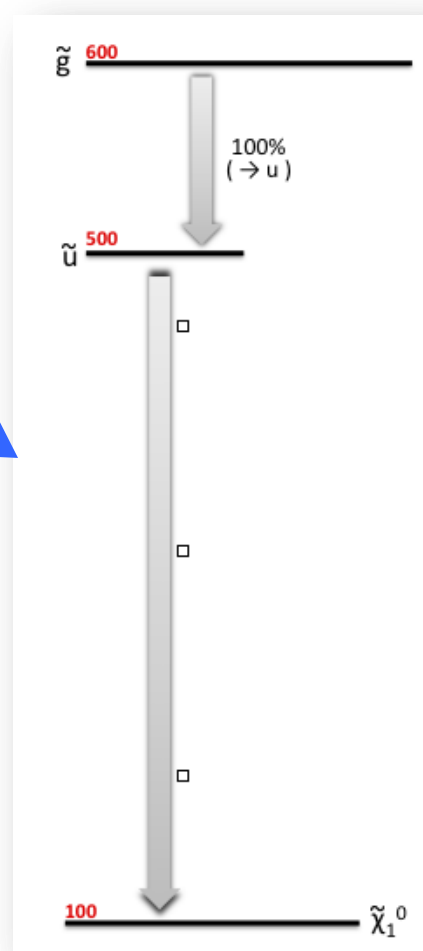


Pair Production



What the individual searches are sensitive to is much more simple...

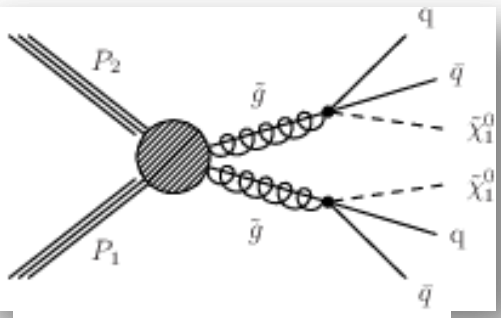
86% of all hadronic production in LM1 consists of "simple" decay chains. This makes it particularly amenable to being *approximated well* with a 3-particle OSET.



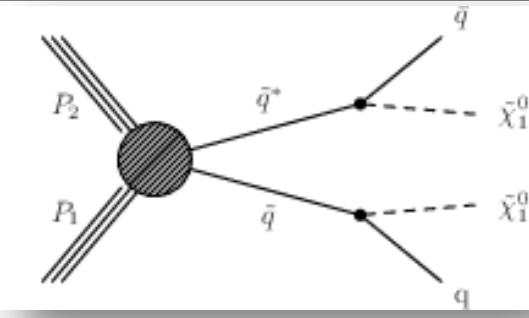
Simplified model spectrum or sms
with 3 particles, 2 decay modes

Simplified Model Spectra (SMS)

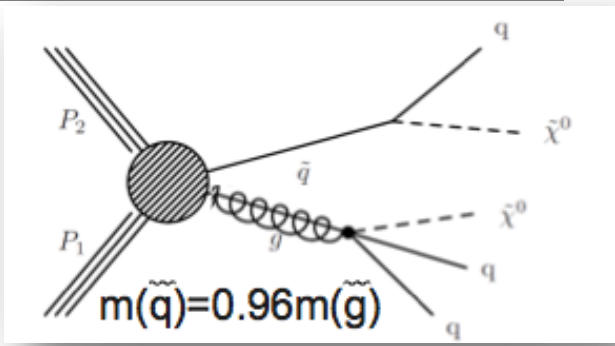
O. Buchmüller & D. de Lorme



$$\tilde{g}\tilde{g} \rightarrow q\bar{q}\tilde{\chi}_1^0 q\bar{q}\tilde{\chi}_1^0$$

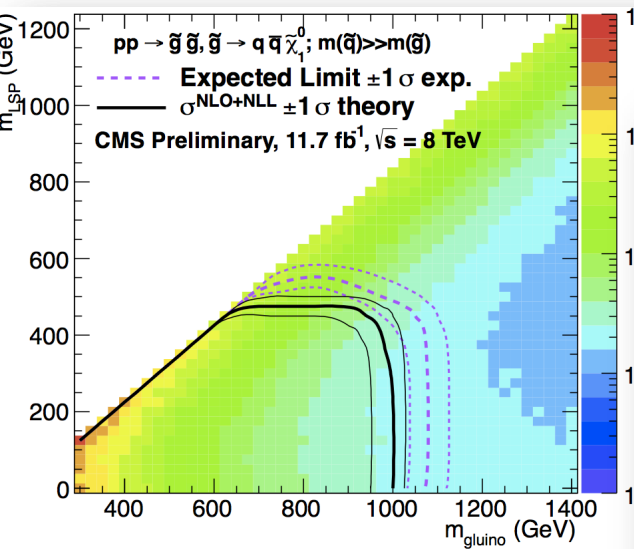


$$\tilde{q}\tilde{q} \rightarrow q\tilde{\chi}_1^0 \bar{q}\tilde{\chi}_1^0$$

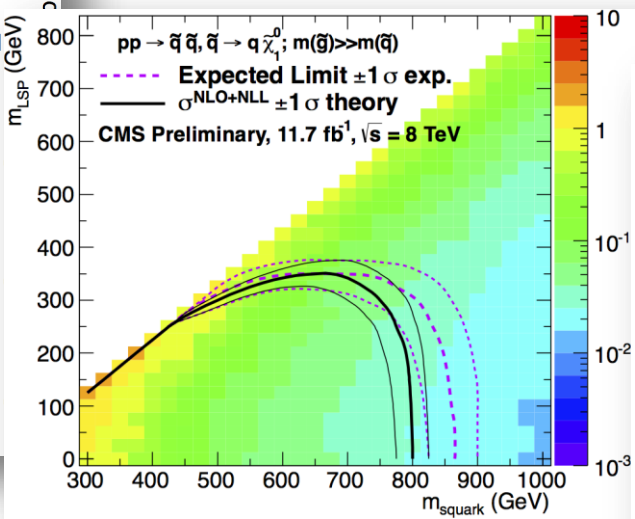


$$m(\tilde{q})=0.96m(\tilde{g})$$

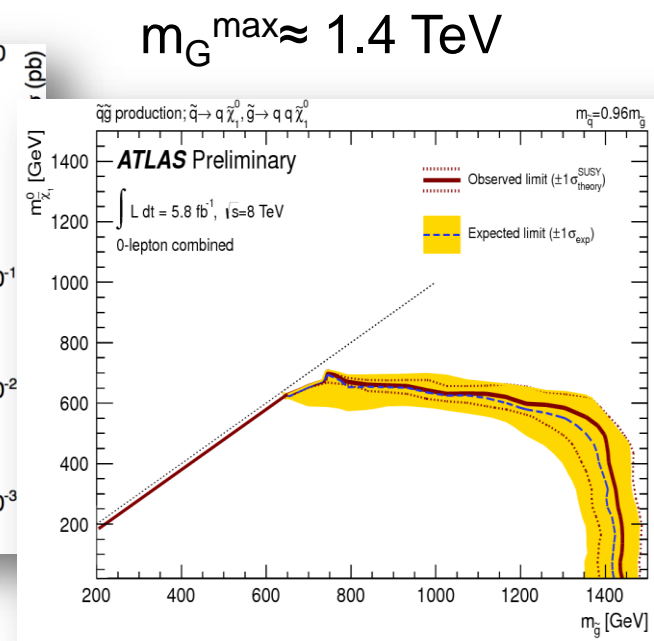
$$\tilde{q} \rightarrow q\tilde{\chi}_1^0, \tilde{g} \rightarrow q q\tilde{\chi}_1^0$$



$m_G^{\max} \approx 1 \text{ TeV}$



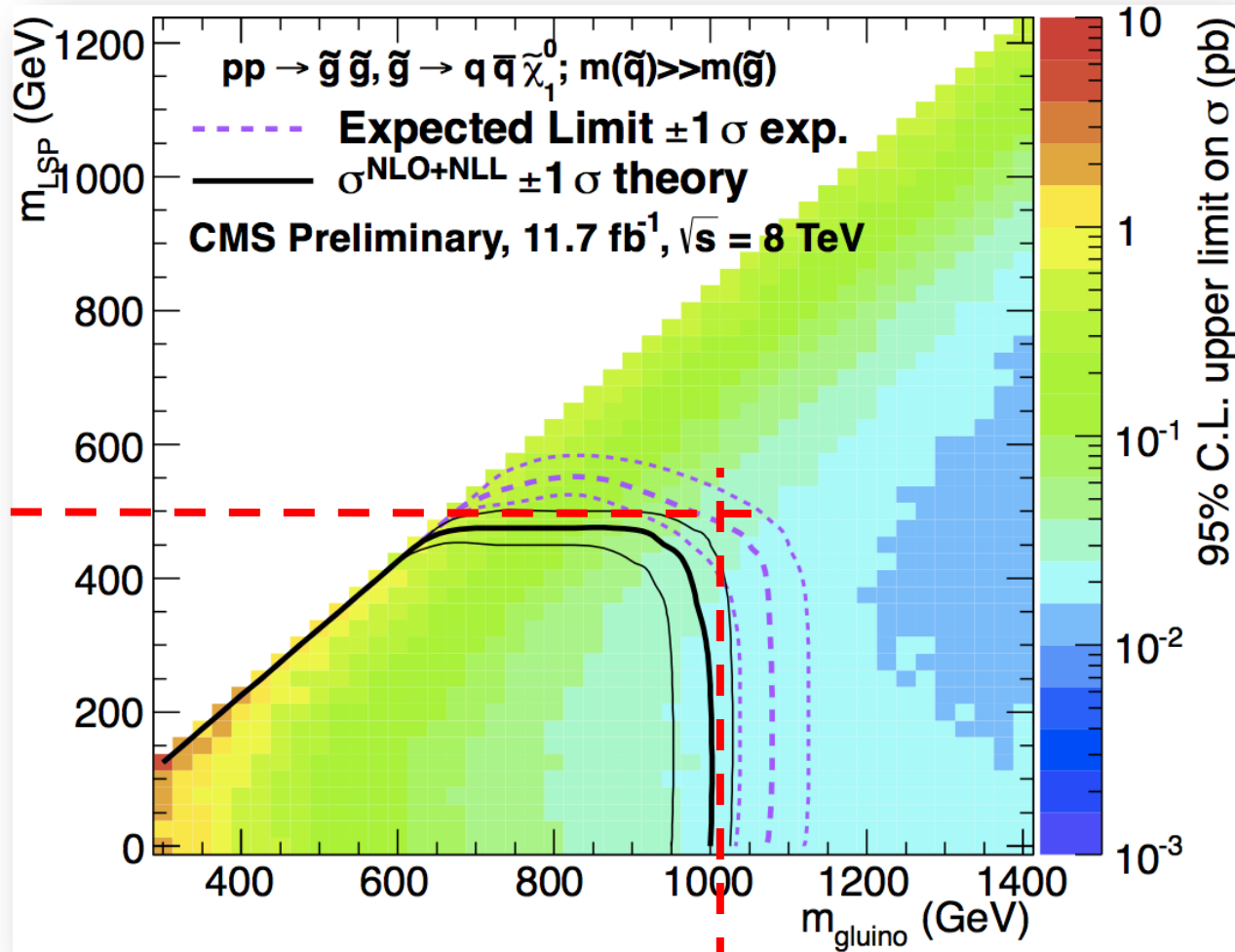
$m_{sq}^{\max} \approx 0.8 \text{ TeV}$



SMS: a few interesting features

Experimental SUSY, PDG Workshop 2013 O. Buchmüller & P. de Jong

$m_{\text{LSP}}^{\text{max}} \approx 0.5 \text{ TeV}$: LSP mass above
which there is NO limit anymore



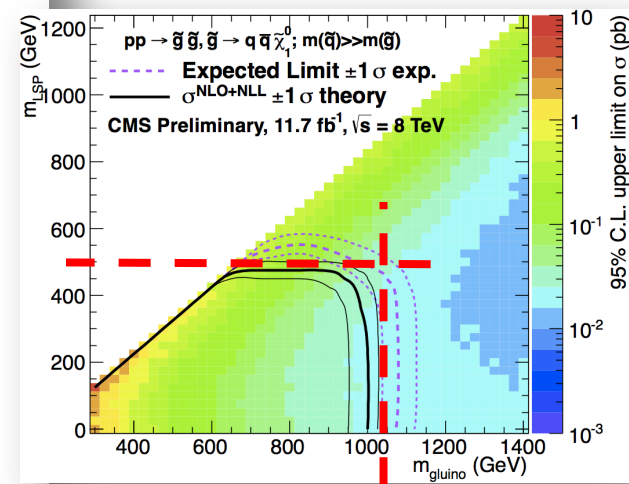
$m_{\text{G}}^{\text{max}} \approx 1 \text{ TeV}$: Best limit in plane

How to summarize SMS limits?

*Approach taken in the 2012 Experimental SUSY PDG review
[OB & Paul De Jong]:*

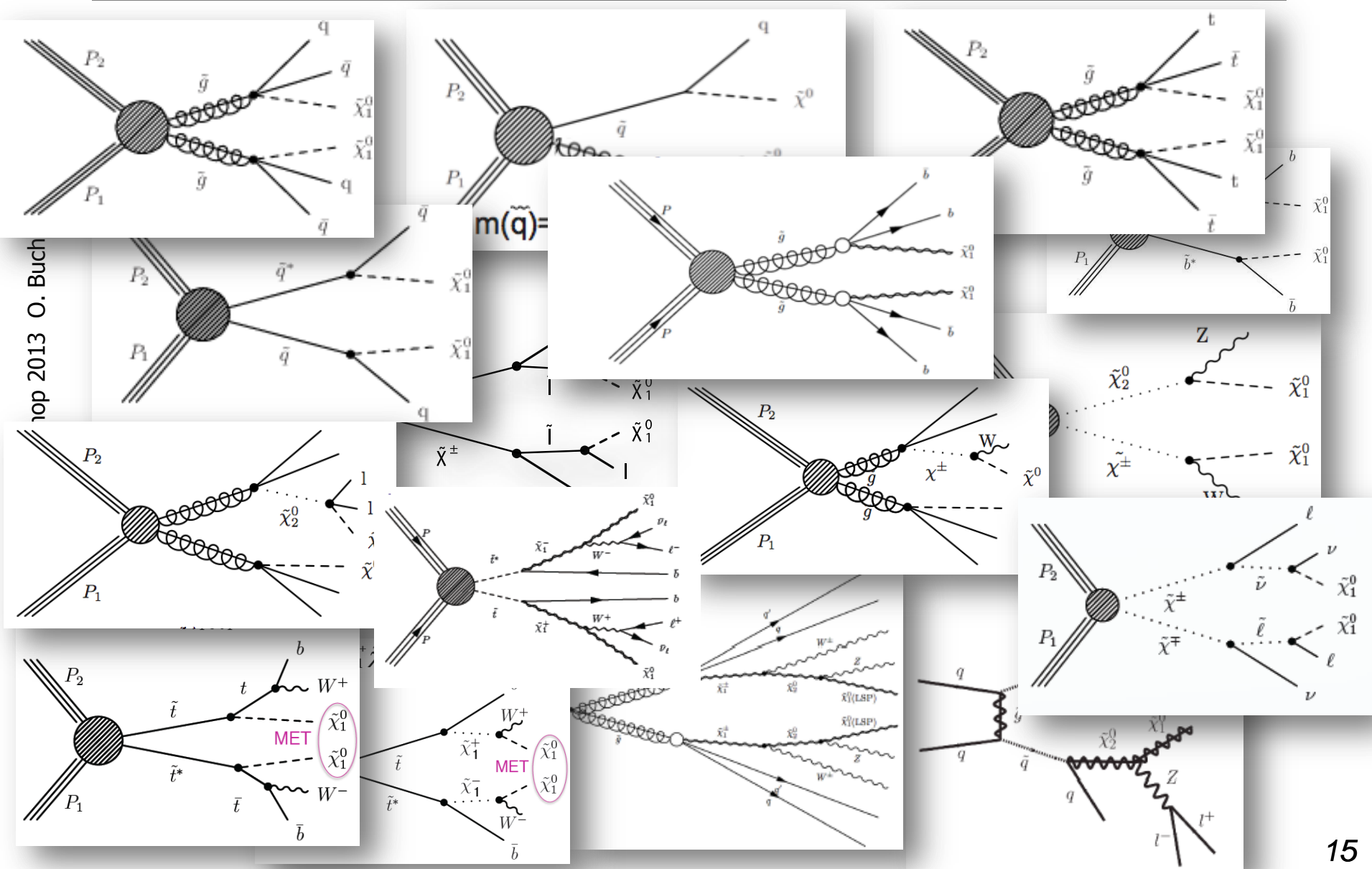
<http://pdg.lbl.gov/2012/reviews/rpp2012-rev-susy-2-experiment.pdf>

Model	Assumption	$m_{\tilde{q}}$	$m_{\tilde{g}}$
CMSSM	$m_{\tilde{q}} \approx m_{\tilde{g}}$	1400	1400
	all $m_{\tilde{q}}$	-	800
	all $m_{\tilde{g}}$	1300	-
Simplified model $\tilde{g}\tilde{g}$	$m_{\tilde{\chi}_1^0} = 0$	-	900
	$m_{\tilde{\chi}_1^0} > 300$	-	no limit
Simplified model $\tilde{q}\tilde{q}$	$m_{\tilde{\chi}_1^0} = 0$	750	-
	$m_{\tilde{\chi}_1^0} > 250$	no limit	-
Simplified model $\tilde{g}\tilde{q}, \tilde{g}\tilde{\bar{q}}$	$m_{\tilde{\chi}_1^0} = 0, m_{\tilde{q}} \approx m_{\tilde{g}}$	1500	1500
	$m_{\tilde{\chi}_1^0} = 0, \text{ all } m_{\tilde{g}}$	1400	-
	$m_{\tilde{\chi}_1^0} = 0, \text{ all } m_{\tilde{q}}$	-	900



This was an appropriate approach for the rather limited amount of inclusive searches and corresponding SMS interpretations available in 2011 (7 TeV).

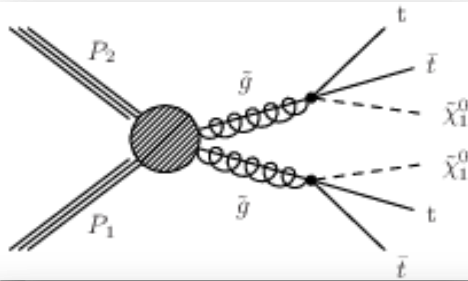
Today: many different SMS are considered



top 2013 O. Buch

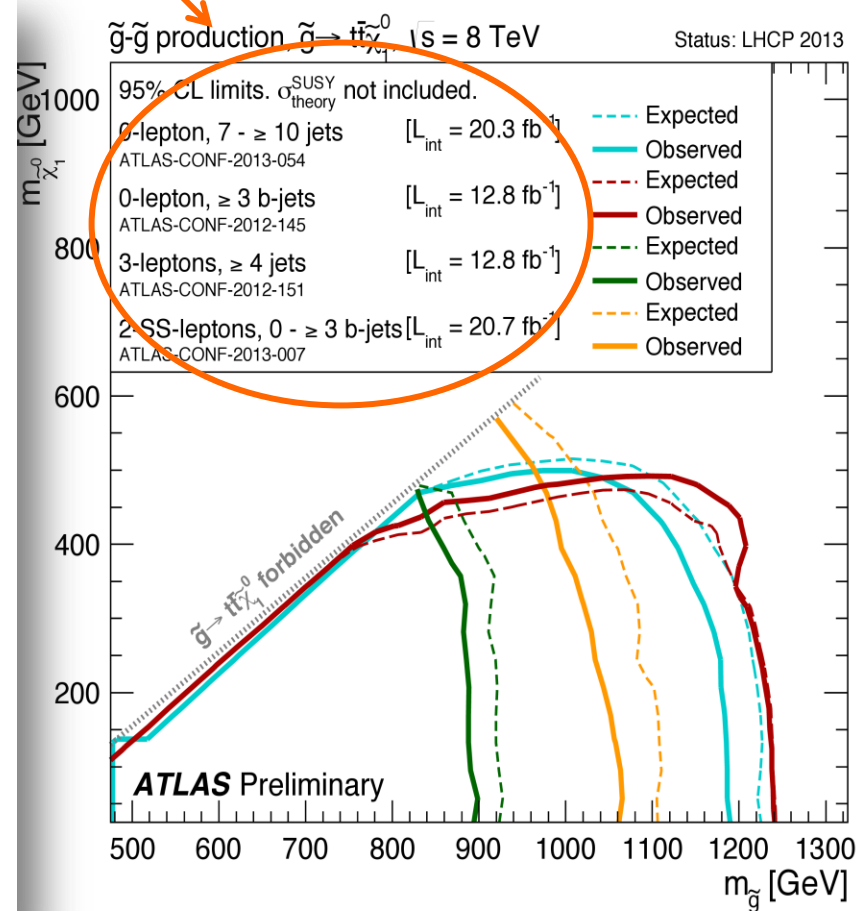
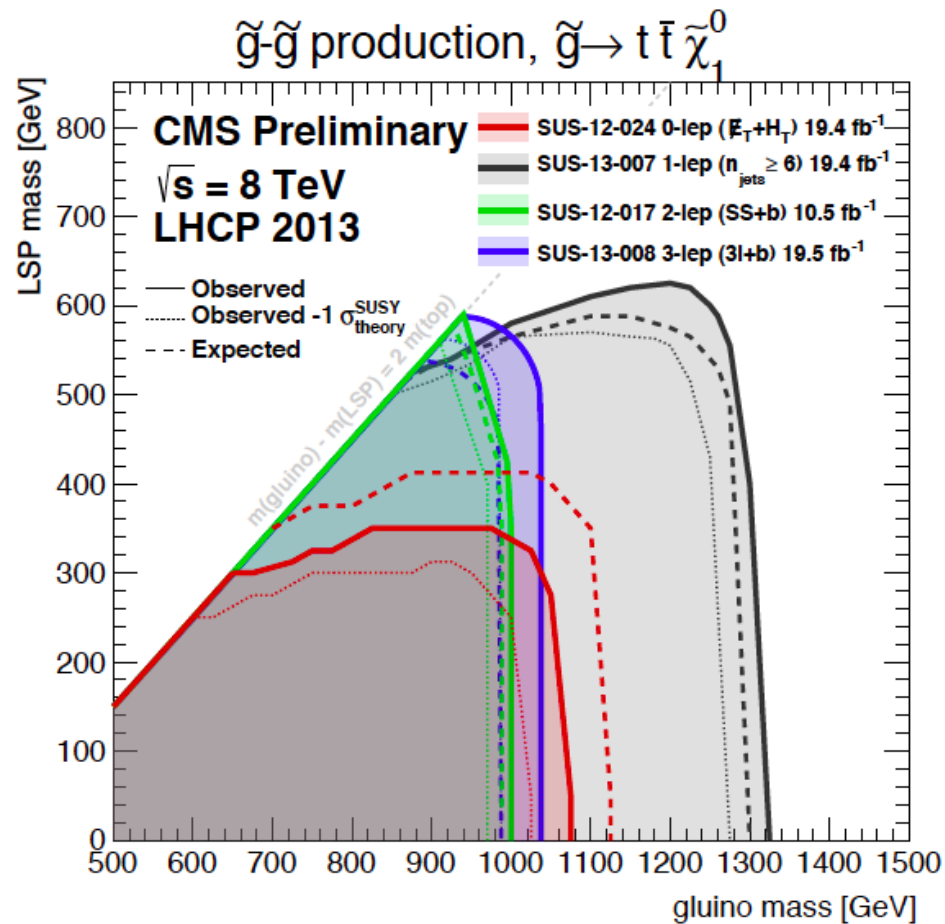
$$m(\tilde{q}) =$$

Today: many different searches per SMS

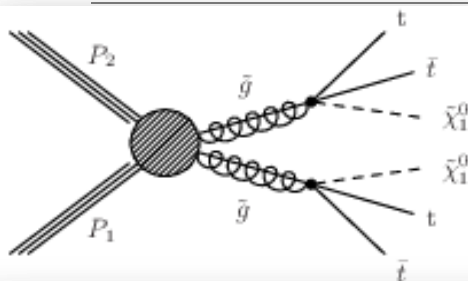


Example: glunio \rightarrow top-top LSP

Several **DEDICATED** searches are interpret in this particular SMS.



Today: many different searches per SMS



Example: gluino \rightarrow top-top LSP

Several **DEDICATED** searches are interpreted in this particular SMS.

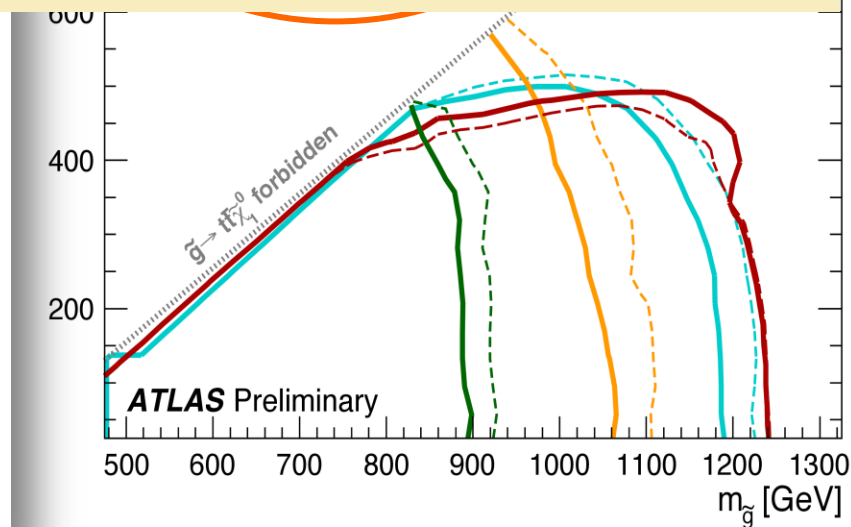
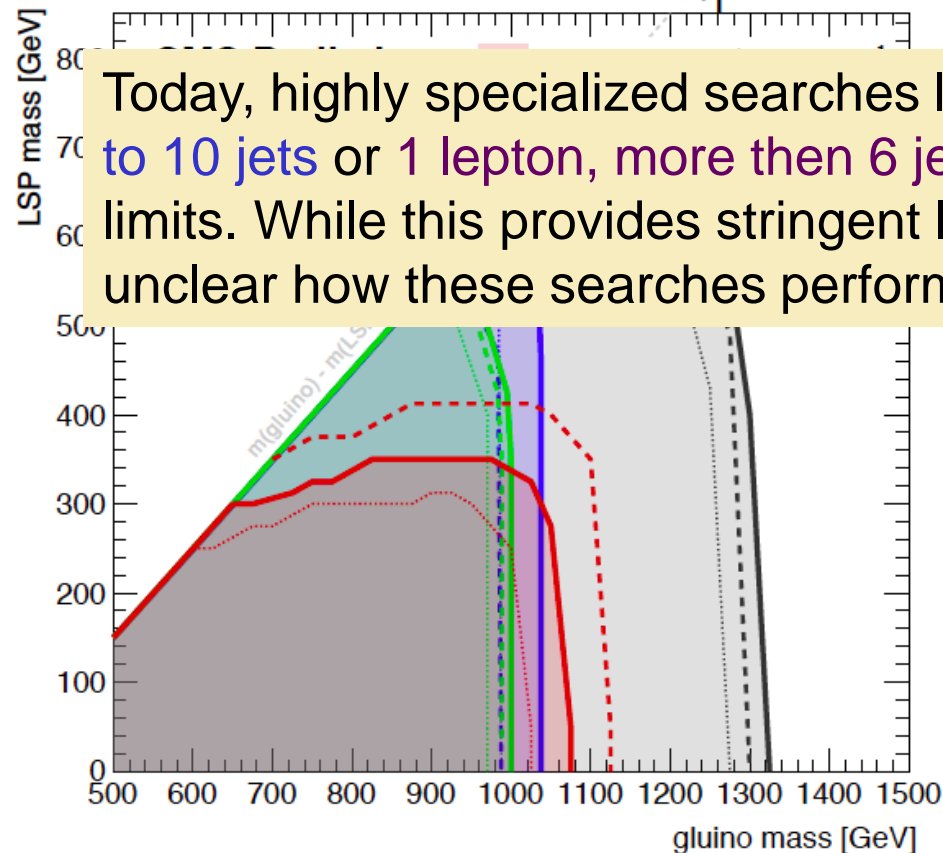
$\tilde{g}\text{-}\tilde{g}$ production, $\tilde{g} \rightarrow t \bar{t} \tilde{\chi}_1^0$

$\tilde{g}\text{-}\tilde{g}$ production $\tilde{g} \rightarrow t \bar{t} \tilde{\chi}_1^0$ | $\sqrt{s} = 8$ TeV

Status: LHCp 2013

95% CL limits. $\sigma_{\text{theory}}^{\text{SUSY}}$ not included. Expected

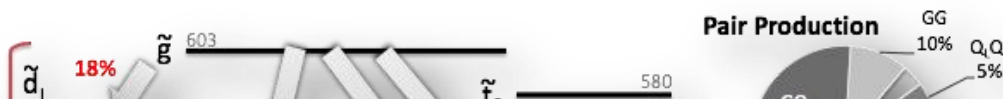
Today, highly specialized searches like in this case e.g. 0 lepton and 7 to 10 jets or 1 lepton, more than 6 jets, and b-tag are used to push the limits. While this provides stringent limits for the target SMS, it is often unclear how these searches perform for other topologies.



Interpretation in Simplified Models

Experimental SUSY, PDG Workshop 2013 O. Buchmüller & P. de Jong

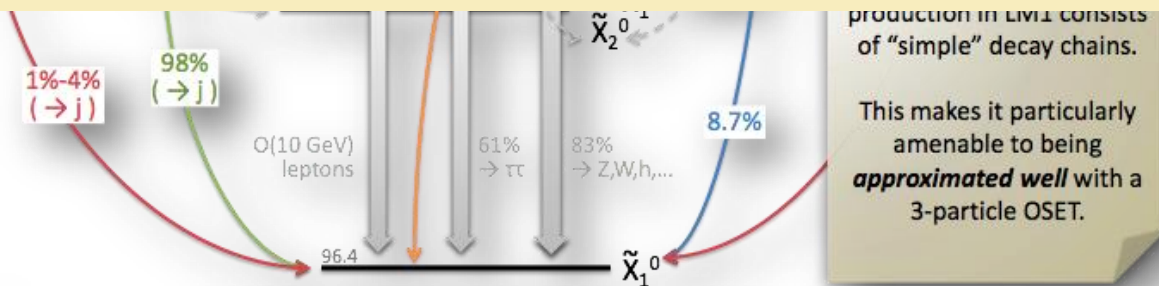
CMSSM



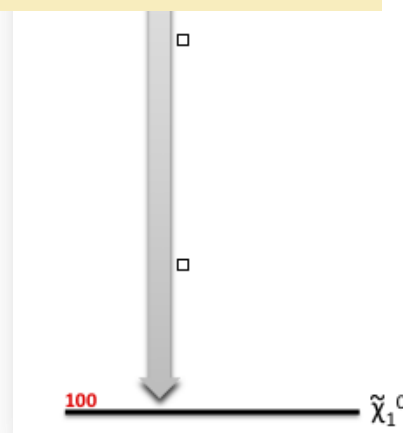
What the individual searches are sensitive to is much more simple...

Going "simplified" after the constraint SUSY models was the next logical step. Yet, experiments have pushed this to a point where, perhaps, this strategy has become too simple and too specialized.

The challenge for the next experimental SUSY review:
How do we establish the big picture from all these individual SMS limits?



Simplified model spectrum or sms
with 3 particles, 2 decay modes



BACKUP

One possibility: Going back to the roots

Focus more on limits from inclusive topology searches:

i.e. complementary set of inclusive topology searches purely defined by experimental signature!

0-leptons	1-lepton	OSDL	SSDL	≥ 3 leptons	2-photons	γ +lepton
Jets + MET	Single lepton + Jets + MET	Opposite-sign di-lepton + jets + MET	Same-sign di-lepton + jets + MET	Multi-lepton	Di-photon + jet + MET	Photon + lepton + MET

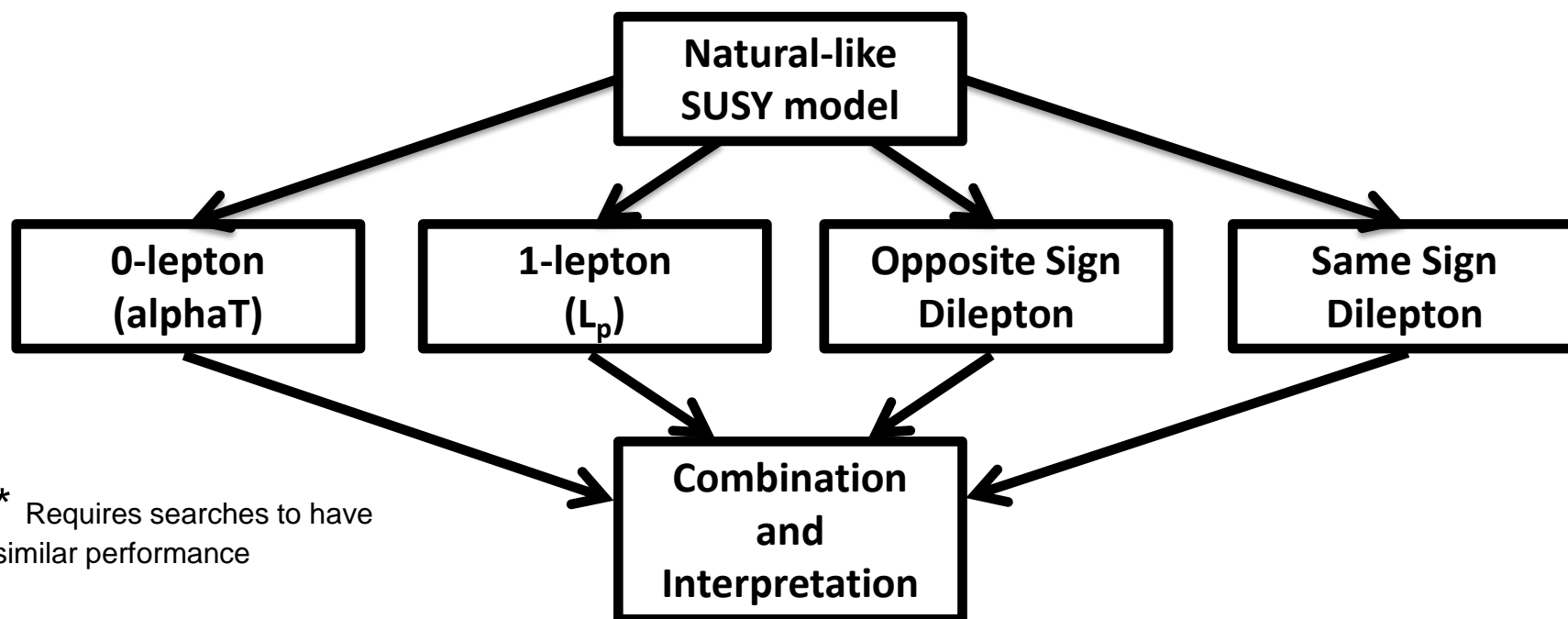
Why?

Combination of inclusive searches

OB, J. Marrouch arXiv:1304.2185

General idea:

The combination of all relevant inclusive topology searches* should provide limits on sparticle masses that are independent on the details and complexity of the underlying SUSY spectrum/model.

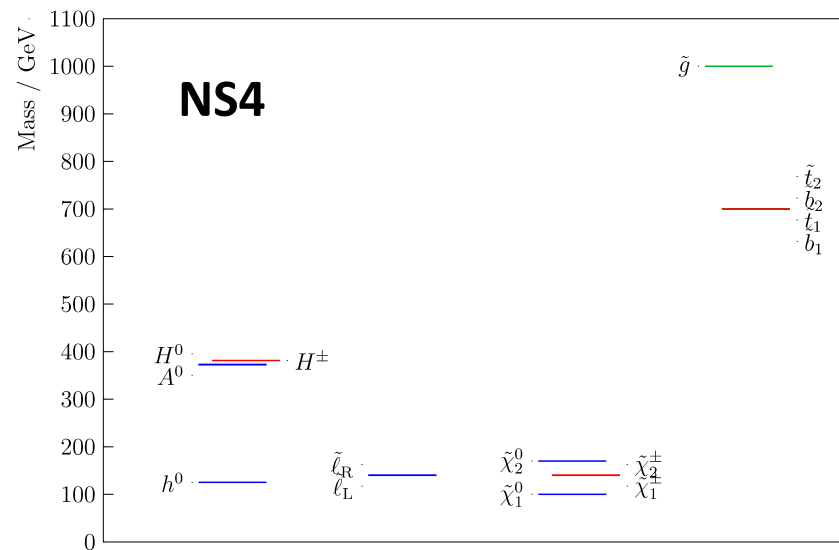
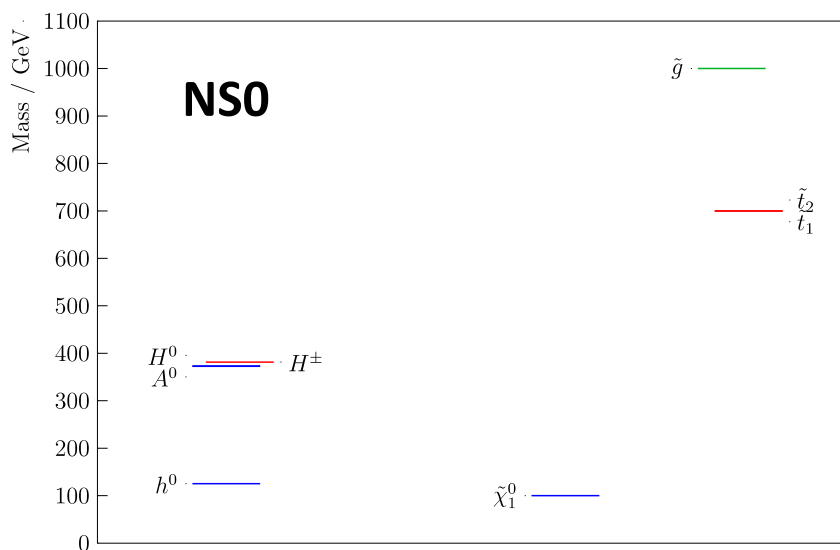


* Requires searches to have similar performance

Example: Natural SUSY spectra

Define (simplified) Natural-like SUSY spectra in terms of increasing complexity.
Three key parameters: gluino mass, average 3G squark mass and LSP mass.

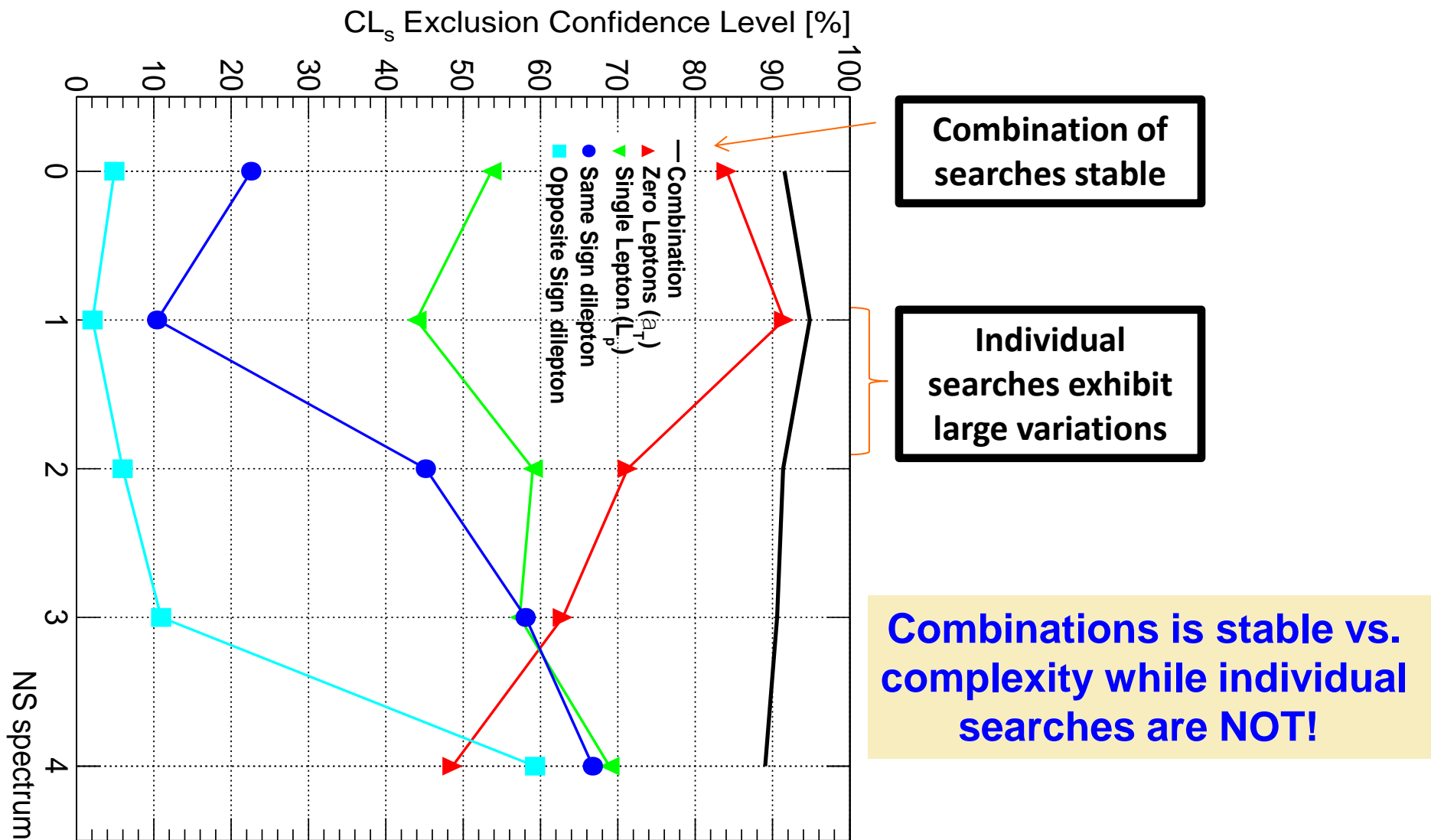
Experimental SUSY, PDG Workshop 2013 O. Buchmüller & P. de Jong



Increasing complexity \rightarrow

Spectra	NS0	NS1	NS2	NS3	NS4
sparticle content	\tilde{g} \tilde{t}_1, \tilde{t}_2 $\tilde{\chi}_1^0$	\tilde{g} $\tilde{t}_1, \tilde{t}_2, \tilde{b}_1$ $\tilde{\chi}_1^0$	\tilde{g} $\tilde{t}_1, \tilde{t}_2, \tilde{b}_1$ $\tilde{\chi}_0^2$ $\tilde{\chi}^\pm$ $\tilde{\chi}_0^1$	\tilde{g} $\tilde{t}_1, \tilde{t}_2, \tilde{b}_1, \tilde{b}_2$ $\tilde{\chi}_0^2$ $\tilde{\chi}^\pm$ $\tilde{\chi}_0^1$	\tilde{g} $\tilde{t}_1, \tilde{t}_2, \tilde{b}_1, \tilde{b}_2$ $\tilde{\chi}_0^2$ $\tilde{\chi}^\pm, \tilde{\ell}_{L,R}$ $\tilde{\chi}_0^1$

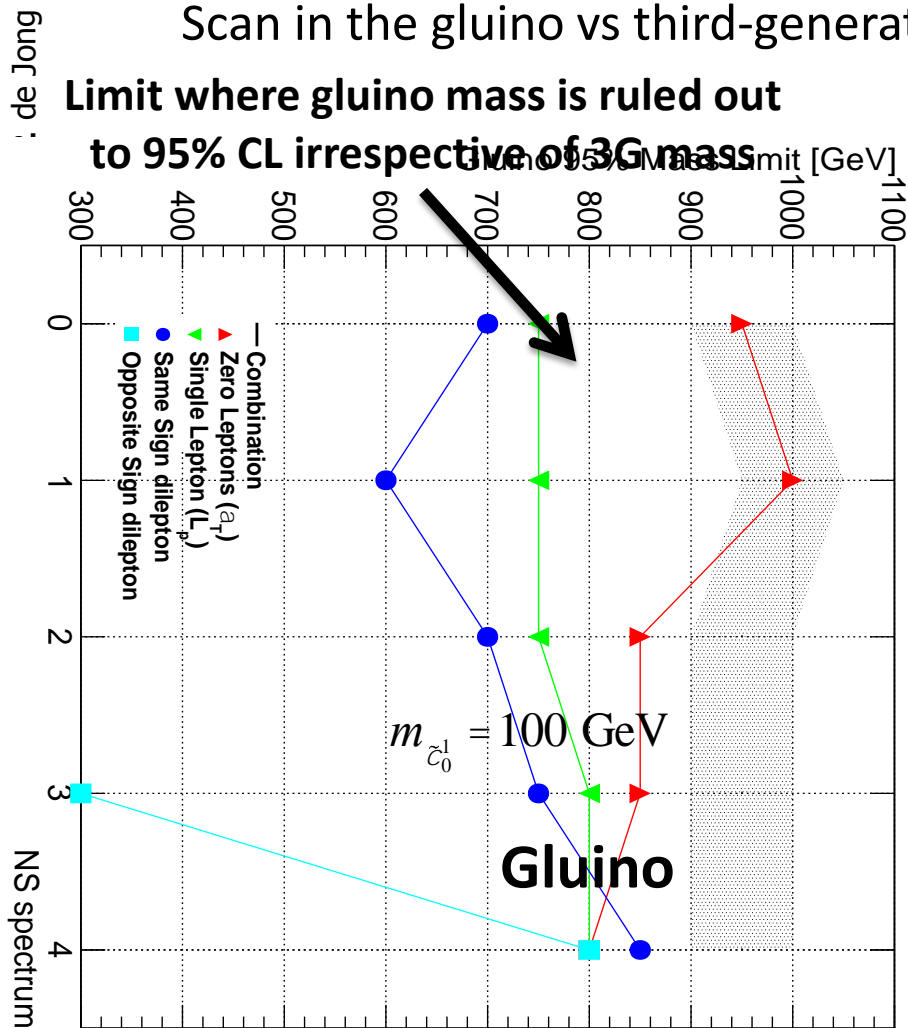
Combination vs individual search



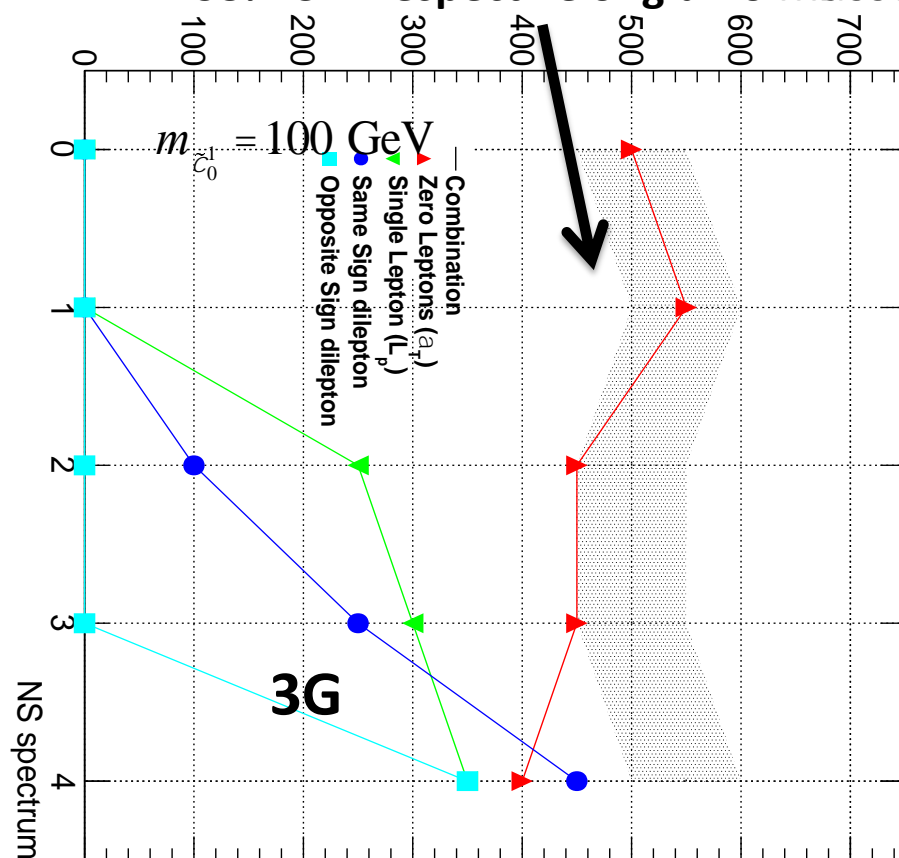
Combination provides universal limits

Scan in the gluino vs third-generation squark mass plane

Limit where gluino mass is ruled out
to 95% CL irrespective of 3G mass

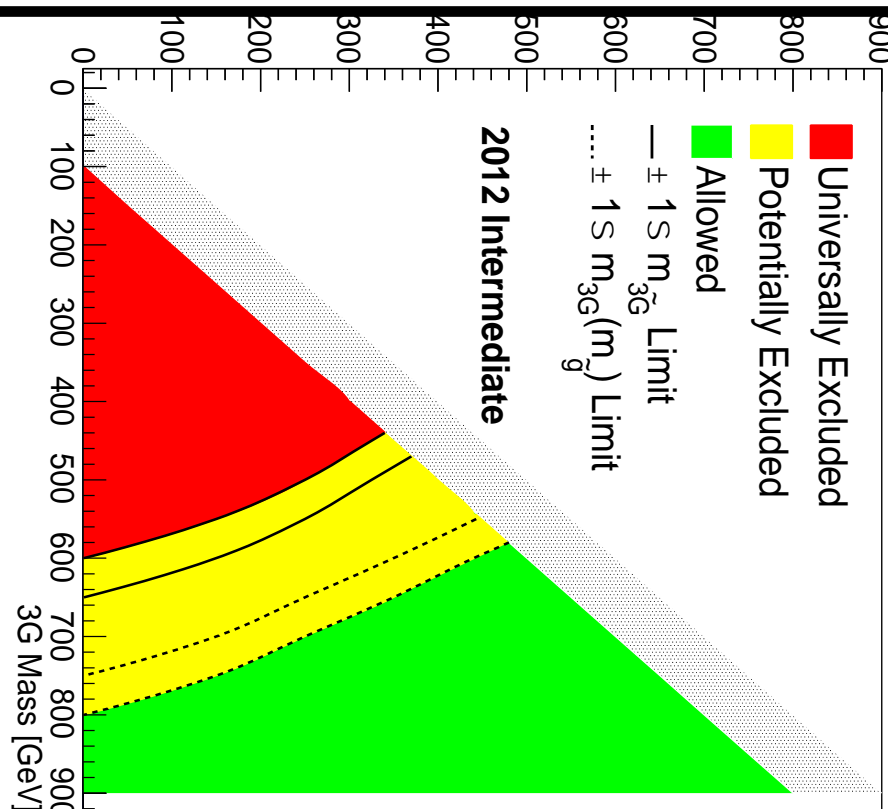
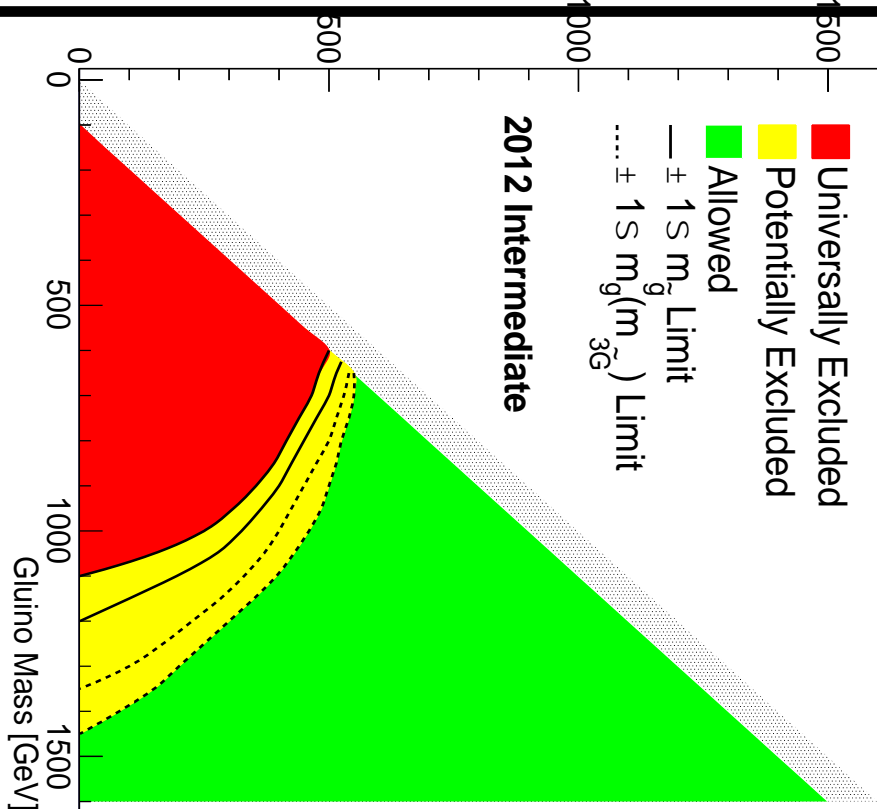


Limit where 3G mass is ruled out to
95% CL irrespective of gluino mass



Natural SUSY: universal limits

If the gluino mass OR 3G mass lies in the red band, the point is excluded.
 If the gluino mass AND 3G mass lie in the yellow band the point may or may not be excluded. Otherwise the point is not excluded.



Combining with the latest published 8 TeV results: