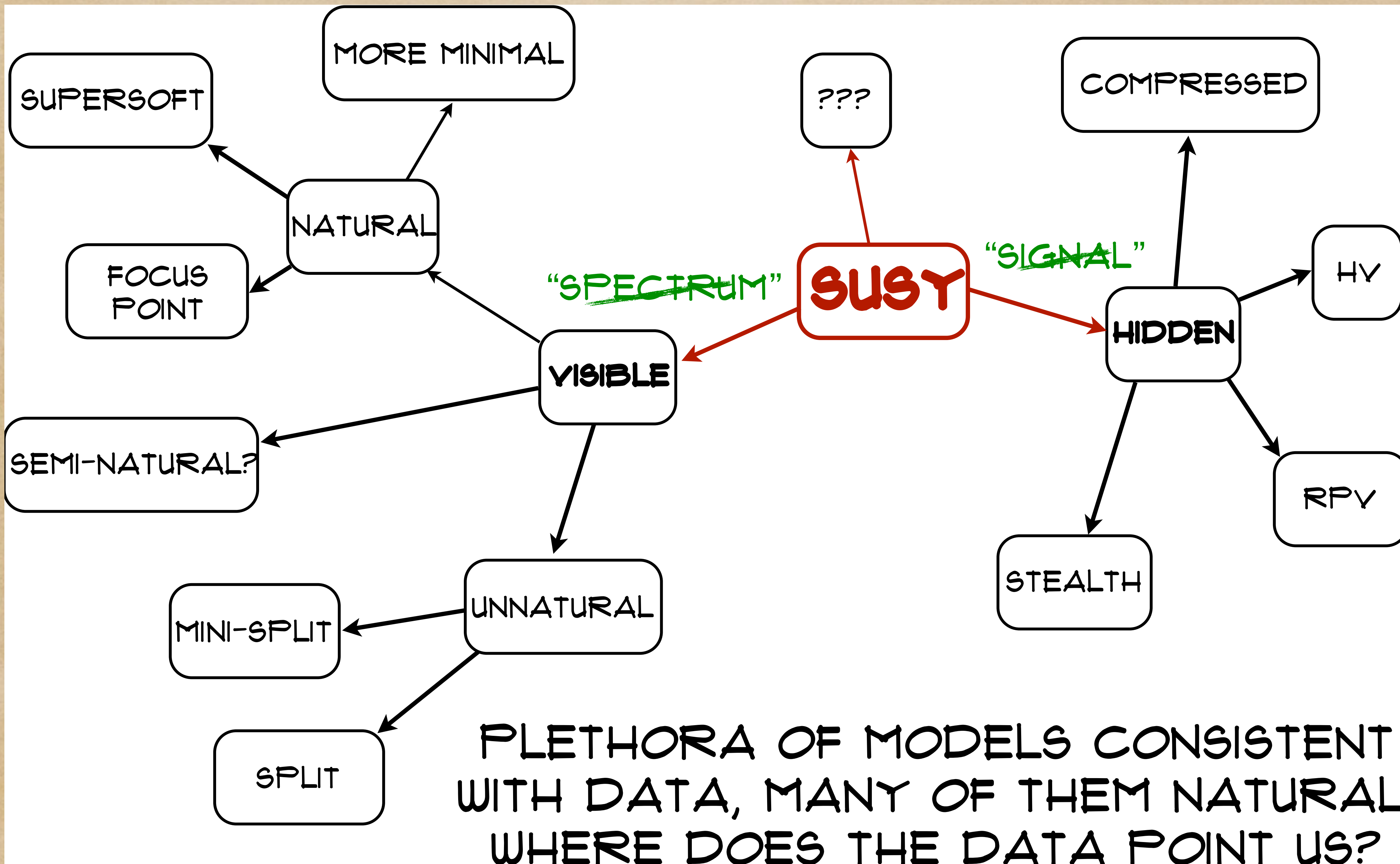
Constraints and prospects of the radiative gluino decay at the LHC

Dipan Sengupta,
LPSC, Grenoble

with Guillaume Chalons - arXiv:1508.06735

Hiding SUSY

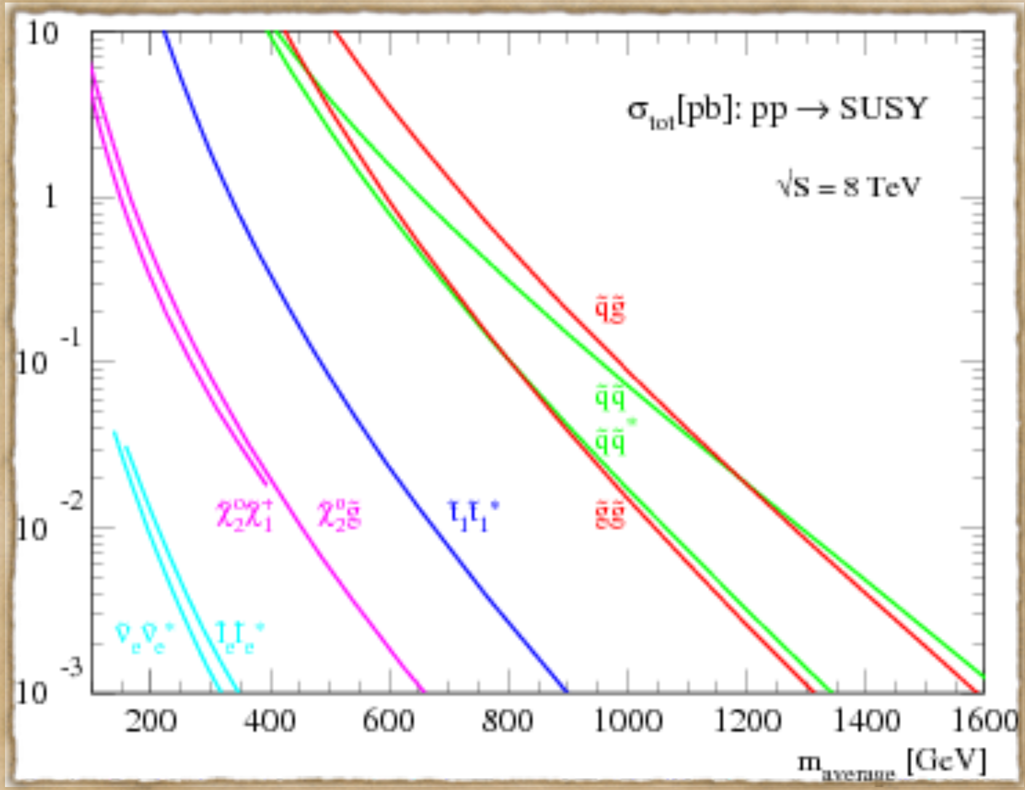


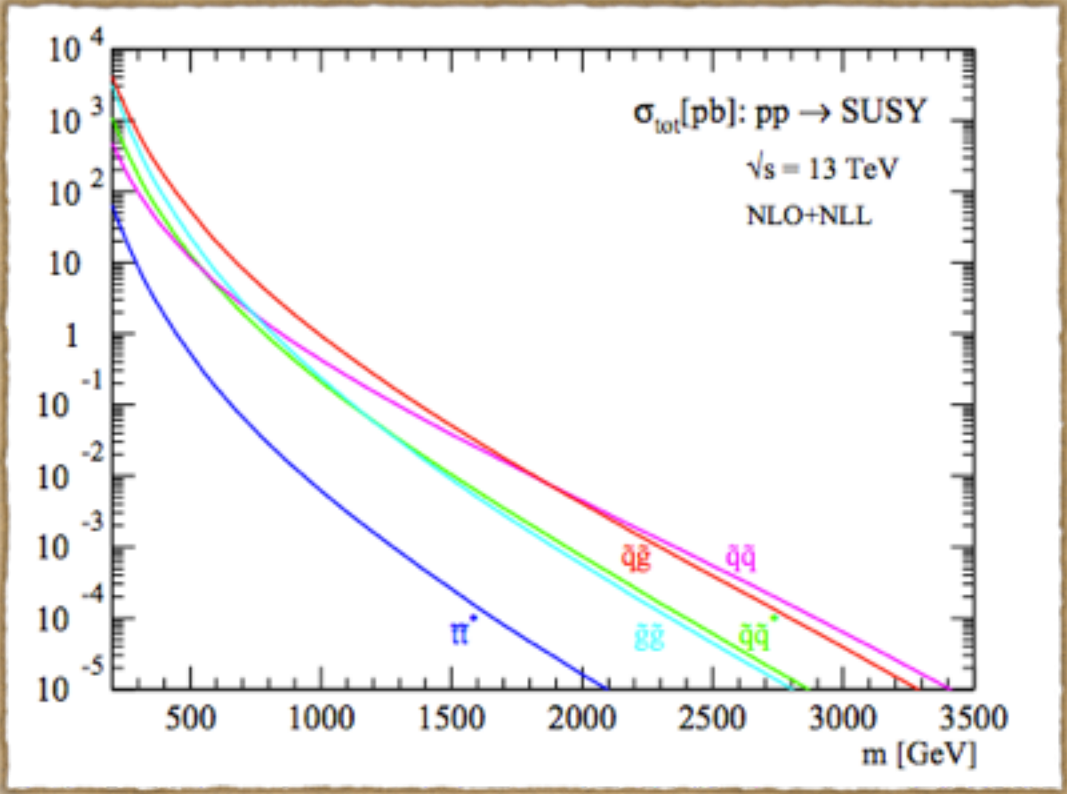
From Craig SUSY 14

Can we have gluinos hiding ?

Motivations: Gluinos at LHC

- Gluinos : Color octet superpartner of the gluon.
- Majorana fermions : Flavor blind coupling to (s)qaurks and gluons
- Largest cross sections at LHC. Easiest to discover, rule out.



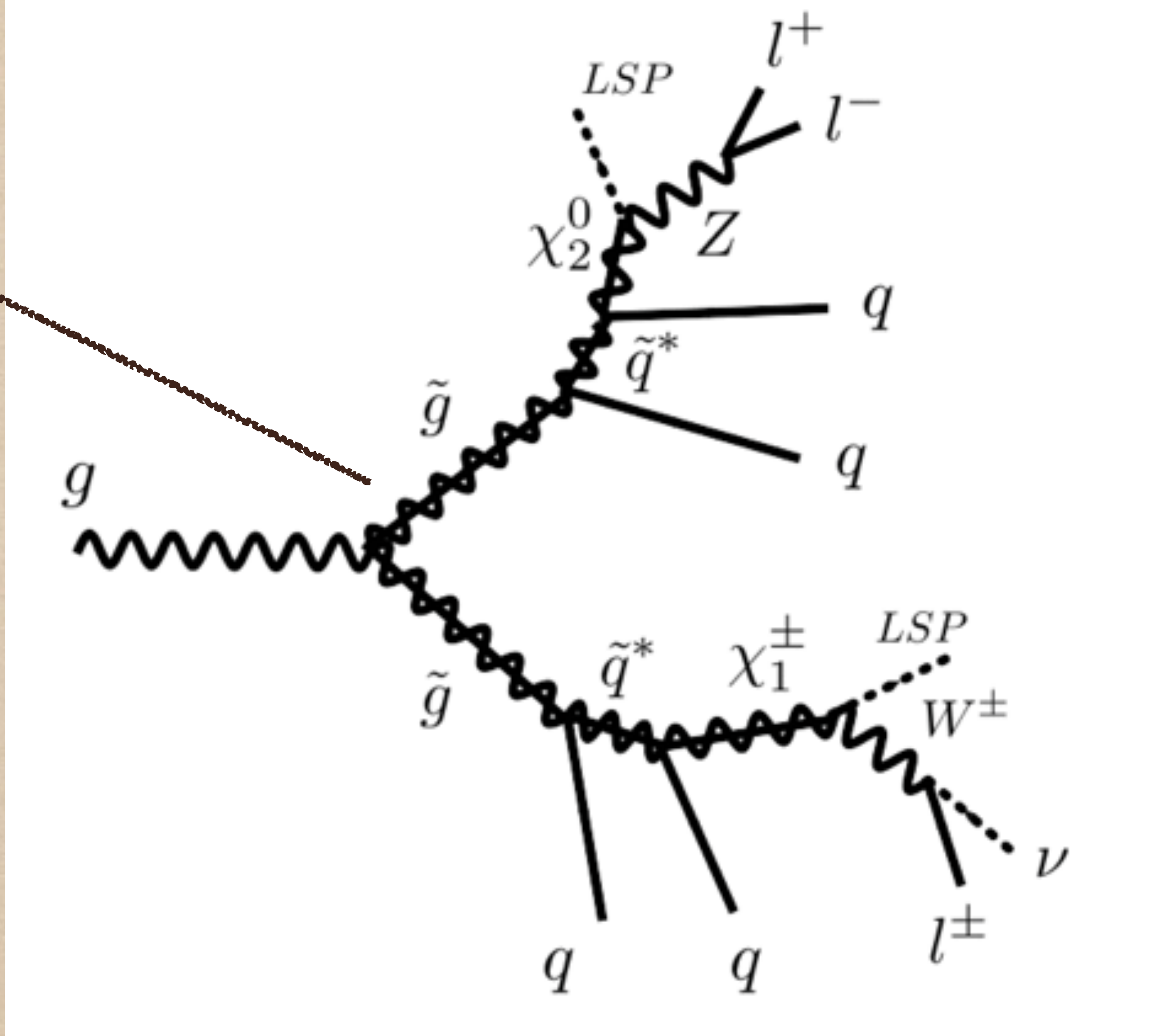


Gluino Searches at LHC.

- Decays typically via long decay chains.

Typical signature :

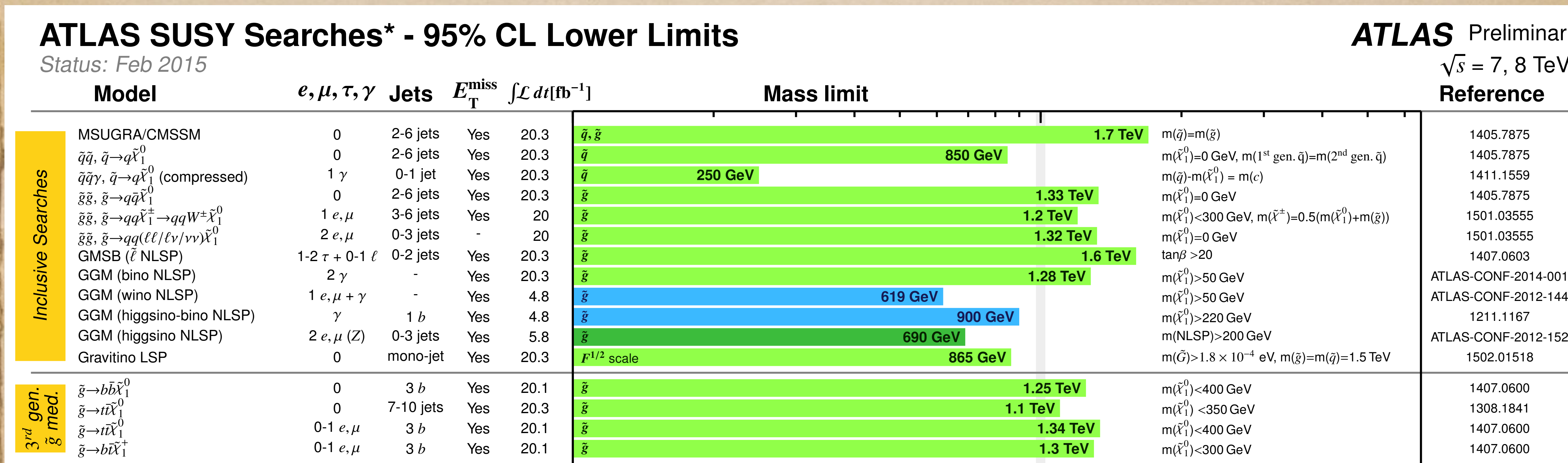
Jets (with b-jets) + leptons+ missing energy



Models interpreted : CMSSM, GMSB,GGM.

Simplified toplogies

LHC constraints



ATLAS SUSY Searches* - 95% CL Lower Limits

Status: Feb 2015

ATLAS Preliminary

$\sqrt{s}$ = 7, 8 TeV

	Model	e, μ, τ, γ	Jets	E_T^{miss}	$\int \mathcal{L}\, dt[\mathrm{fb}^{-1}]$	Mass limit		Reference
Inclusive Searches	MSUGRA/CMSSM	0	2-6 jets	Yes	20.3	$\tilde{q}, \tilde{g}$ 1.7 TeV	m($\tilde{q}$)=m($\tilde{g}$)	1405.7875
	$\tilde{q}\tilde{q}$, $\tilde{q}\to q\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{q}$ 850 GeV	m($\tilde{\chi}_1^0$)=0 GeV, m(1st gen. $\tilde{q}$)=m(2nd gen. $\tilde{q}$)	1405.7875
	$\tilde{q}\tilde{q}\gamma$, $\tilde{q}\to q\tilde{\chi}_1^0$ (compressed)	1 γ	0-1 jet	Yes	20.3	$\tilde{q}$ 250 GeV	m($\tilde{q}$)-m($\tilde{\chi}_1^0$) = m(c)	1411.1559
	$\tilde{g}\tilde{g}$, $\tilde{g}\to q\bar{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{g}$ 1.33 TeV	m($\tilde{\chi}_1^0$)=0 GeV	1405.7875
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	GGM (bino NLSP)	2 γ	-	Yes	20.3	$\tilde{g}$ 1.28 TeV	m($\tilde{\chi}_1^0$)>50 GeV	ATLAS-CONF-2014-001
	GGM (wino NLSP)	1 $e,\mu+\gamma$	-	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
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	Gravitino LSP	0	mono-jet	Yes	20.3	$F^{1/2}$ scale 865 GeV	m($\tilde{G}$)>1.8×10^{-4} eV, m($\tilde{g}$)=m($\tilde{q}$)=1.5 TeV	1502.01518
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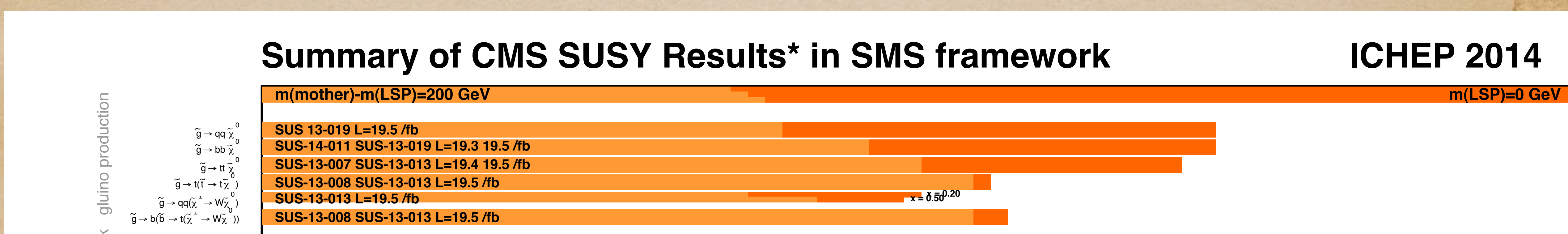

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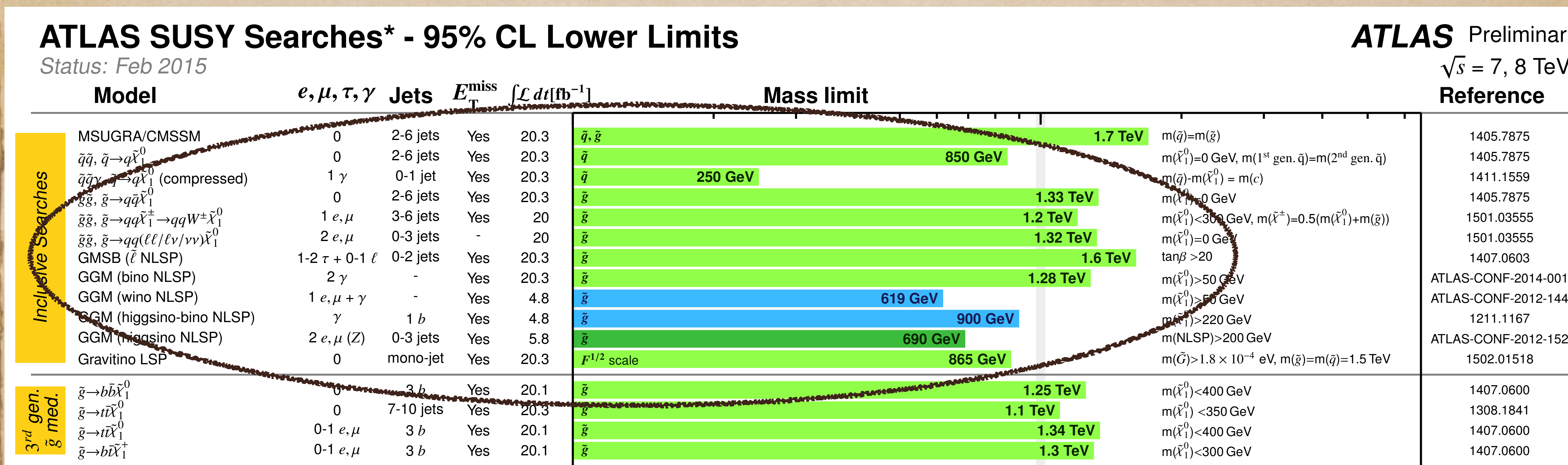

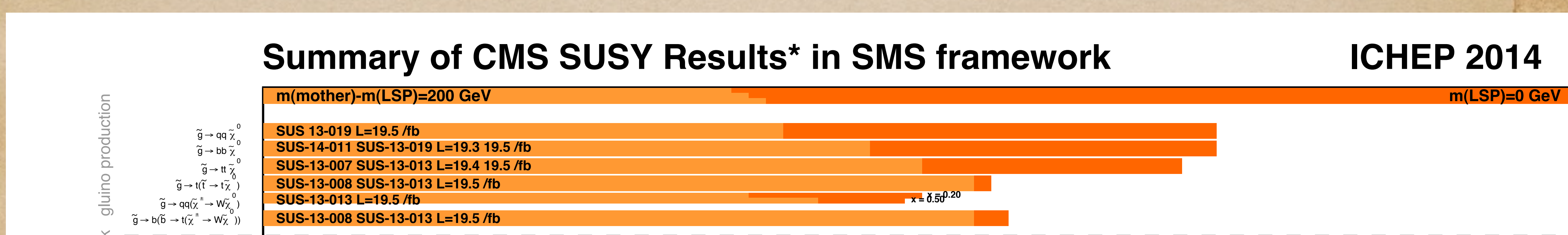

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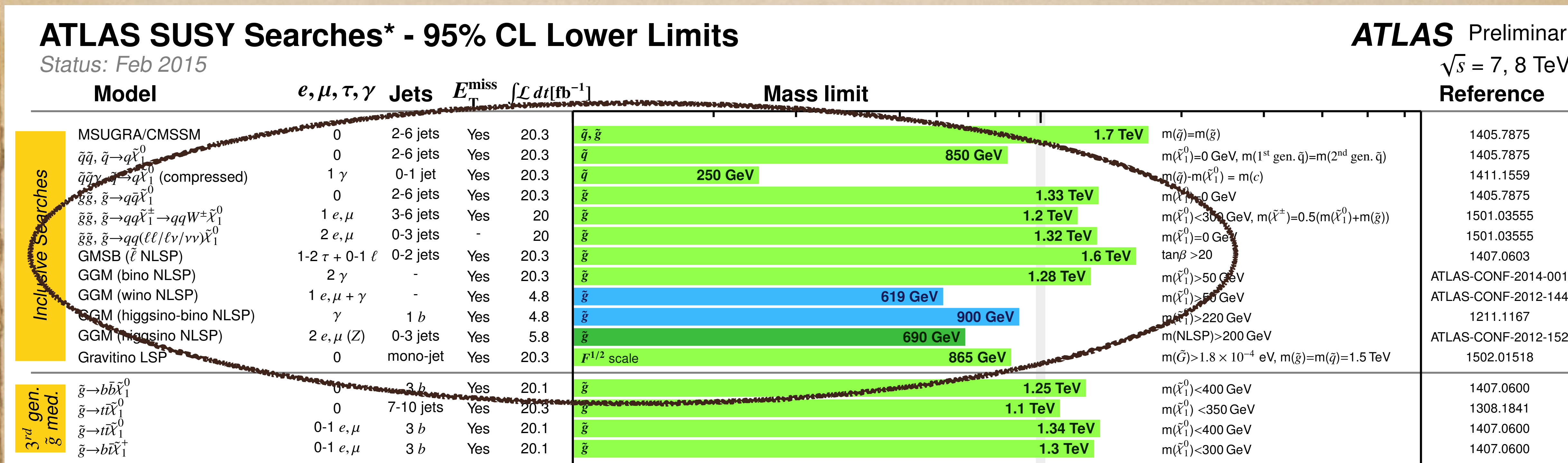

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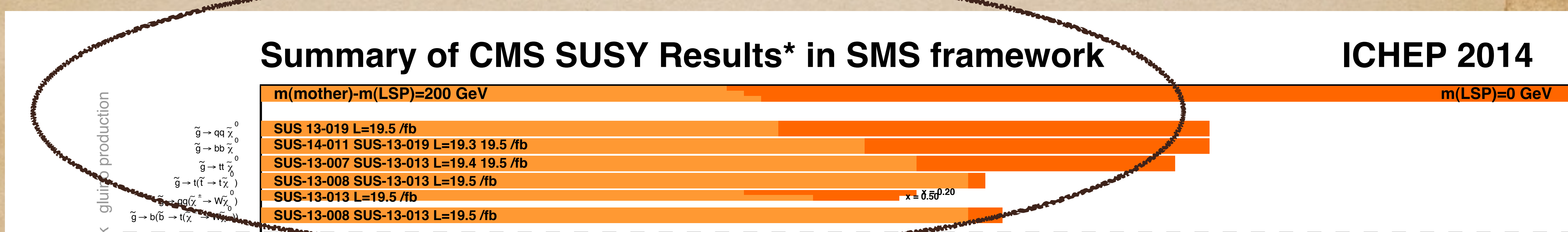

Motivations

- Are strongly interacting SUSY particles really in a corner ?
- Strong limits on gluino and squarks of 1st two generations.
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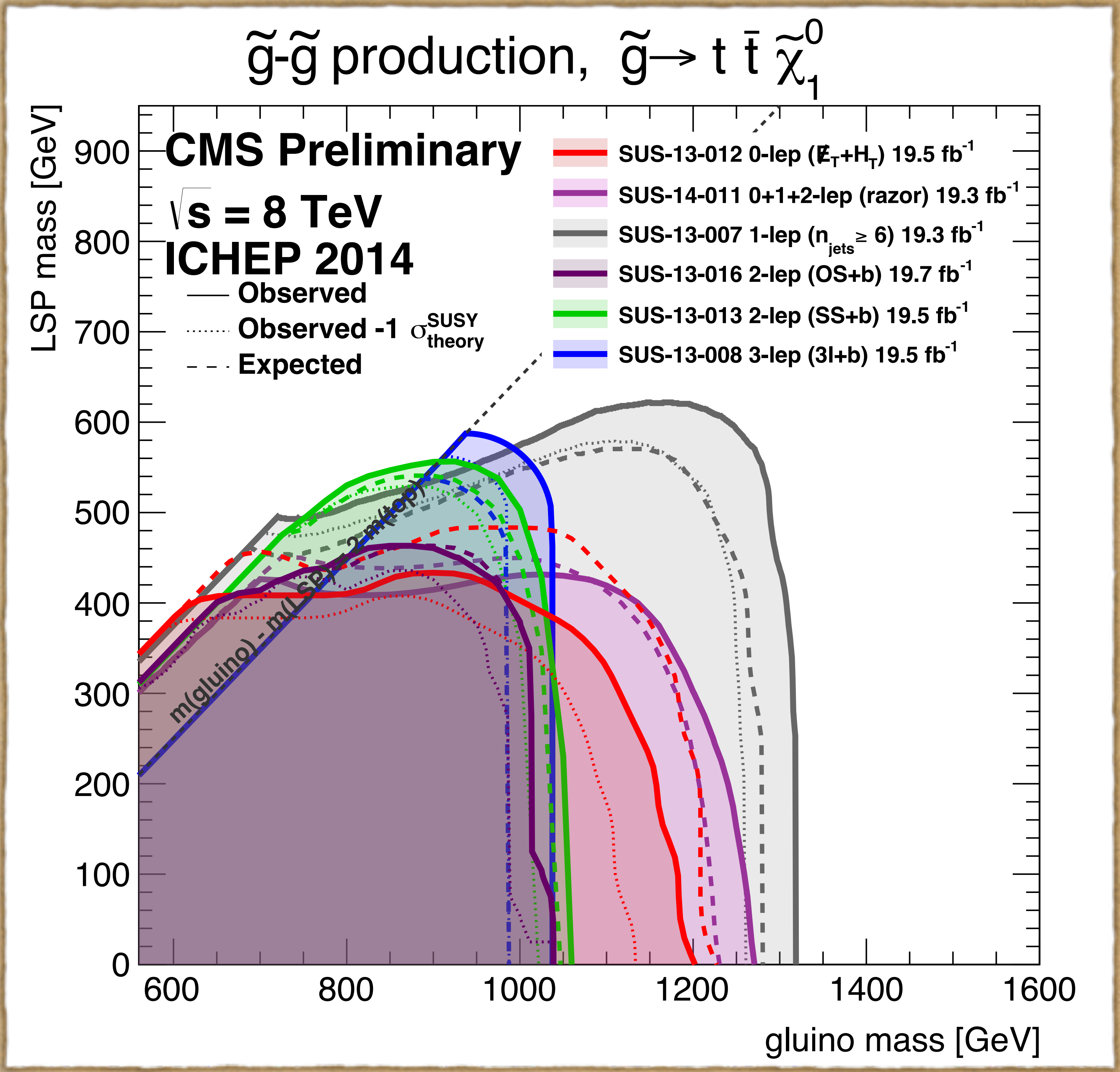

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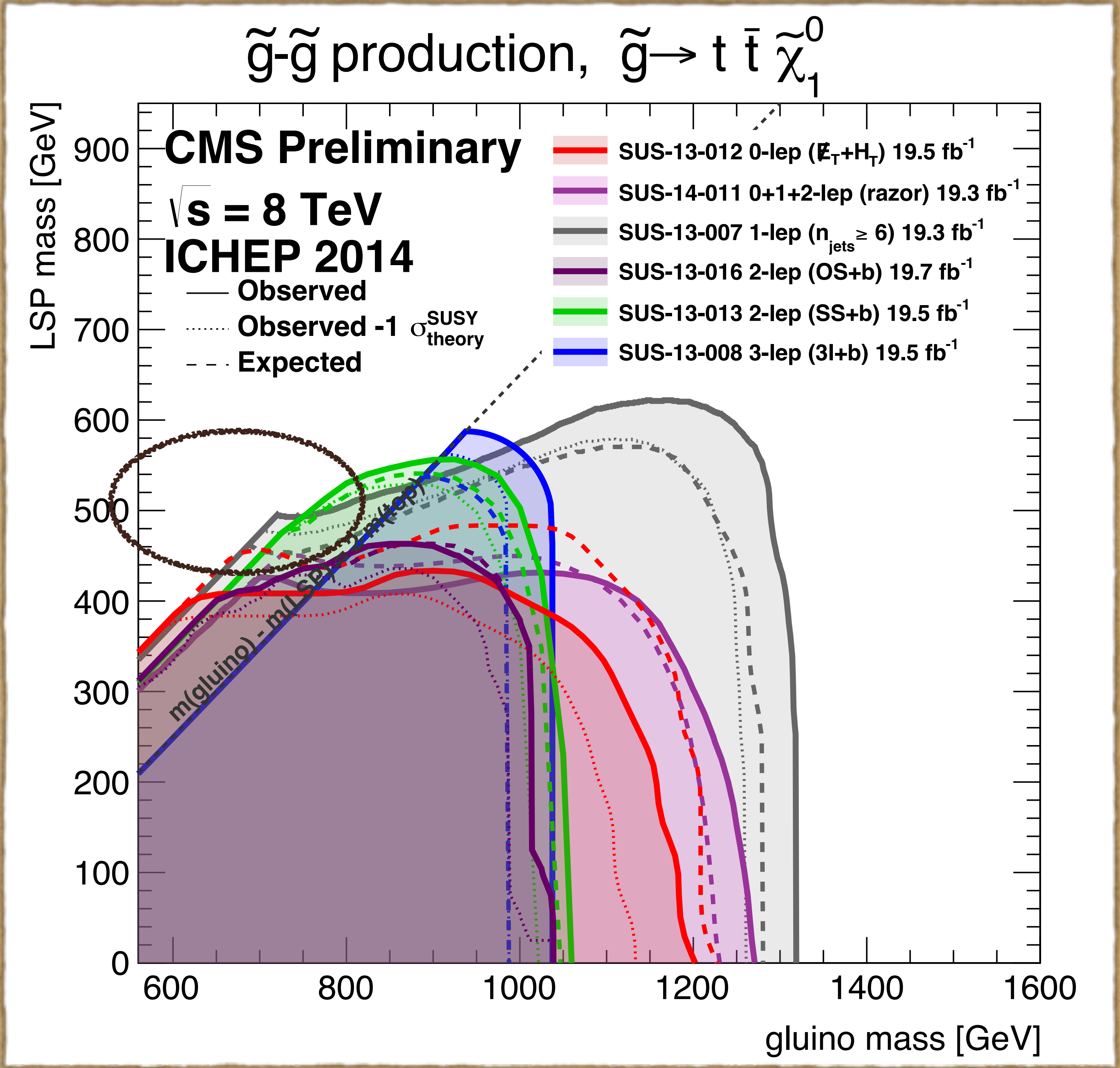

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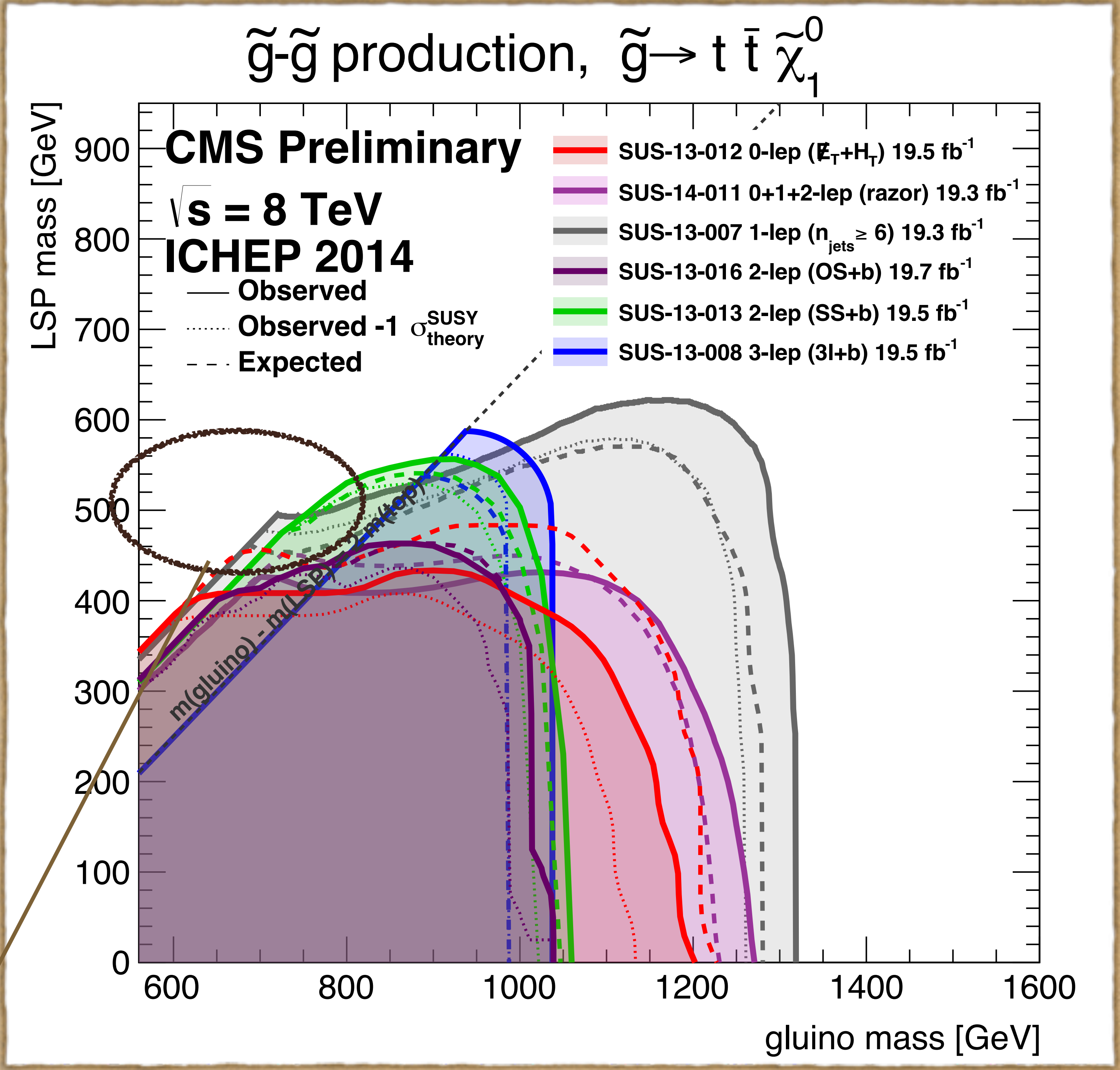

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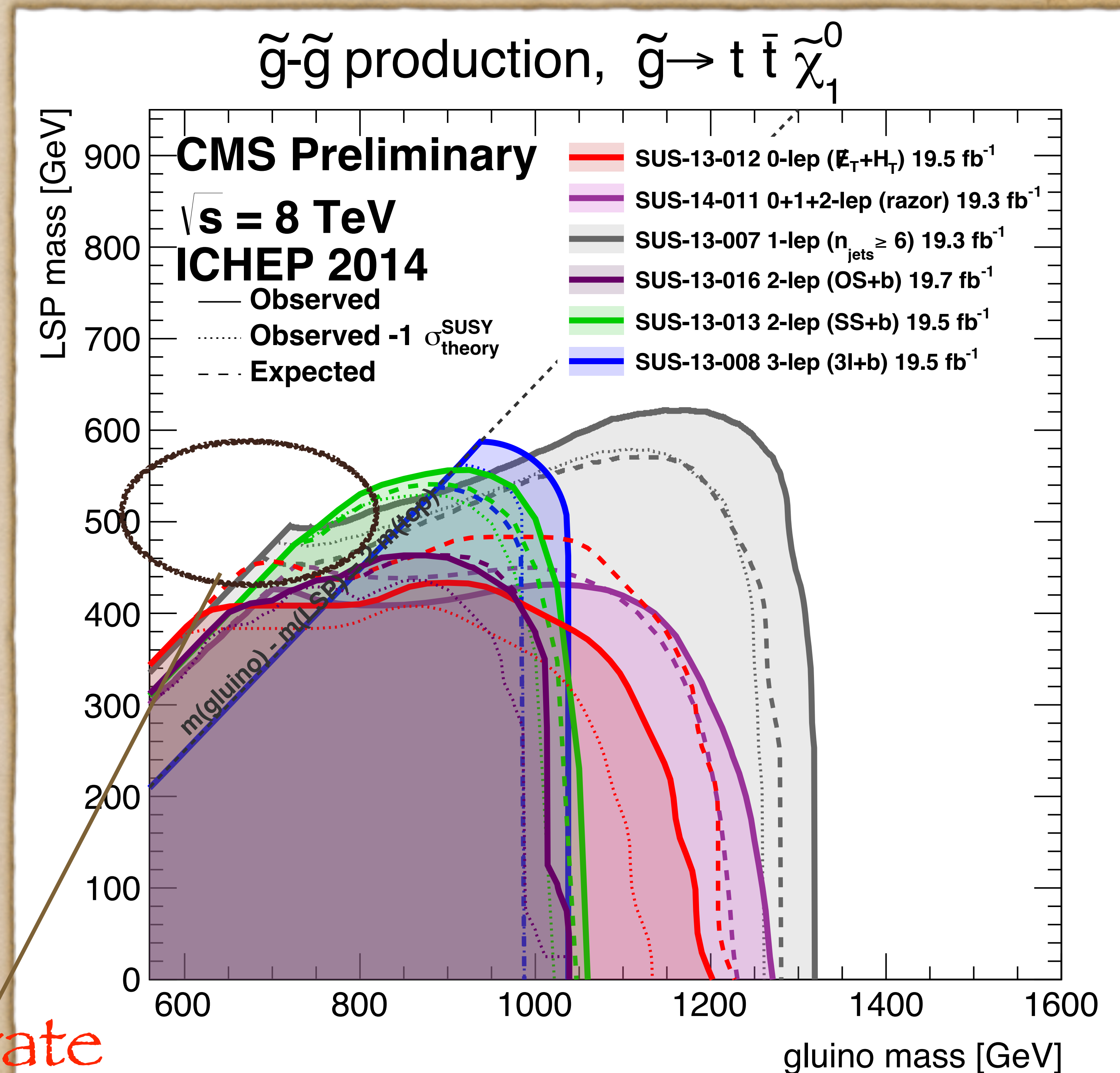

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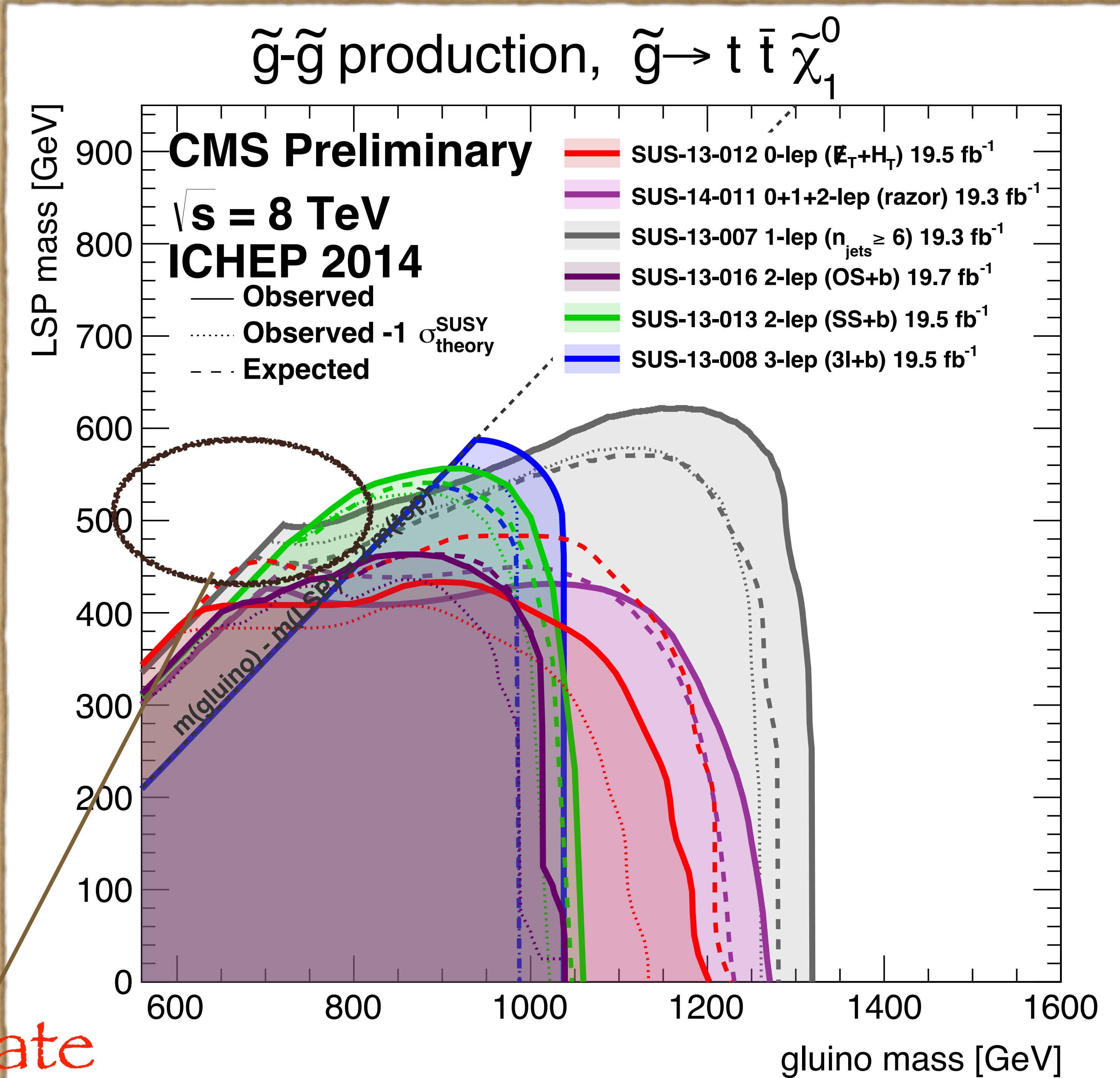

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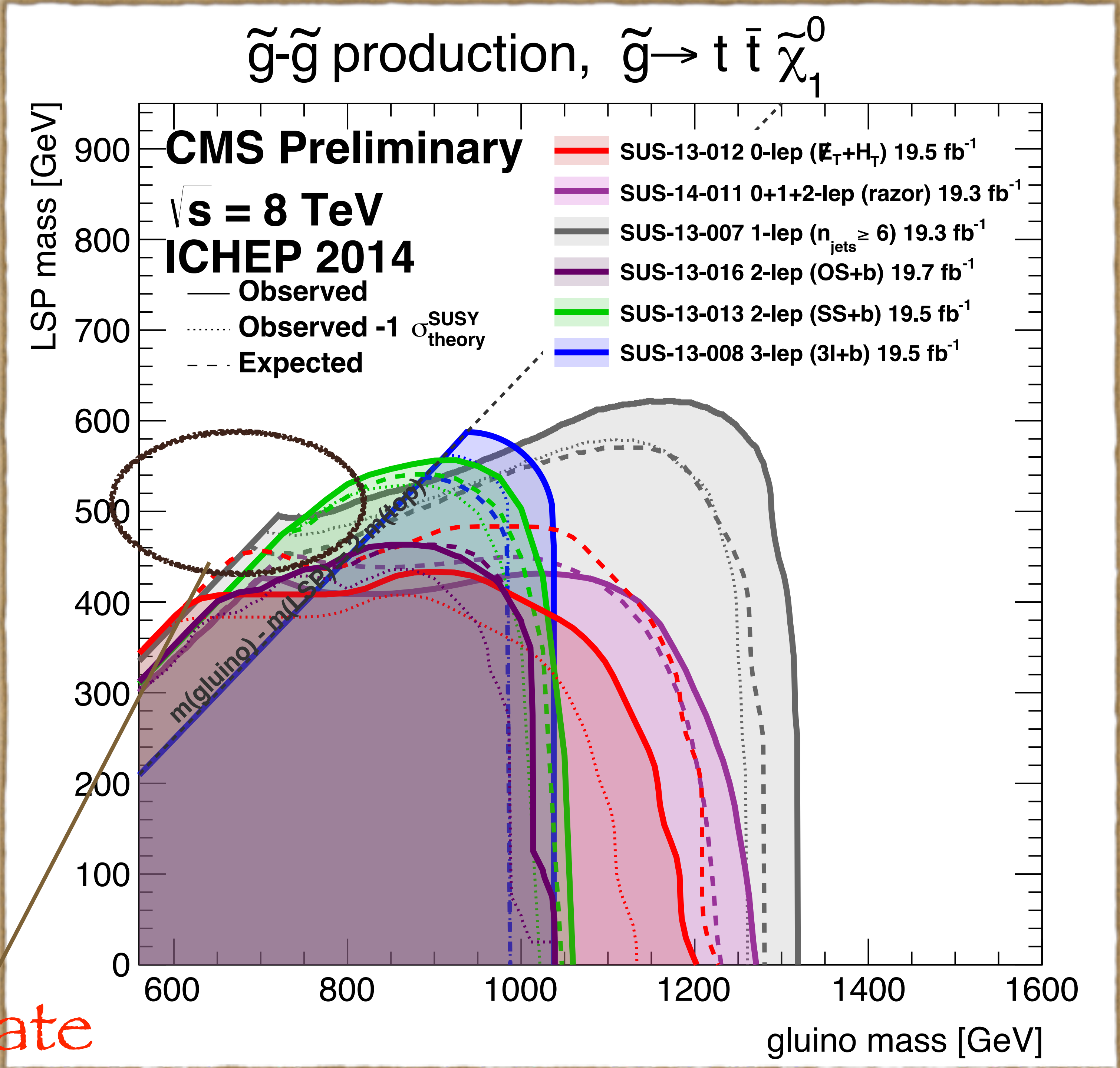

What about degenerate gluino neutrino ?

See De Jong's talk

Radiative Gluino decay: Motivations

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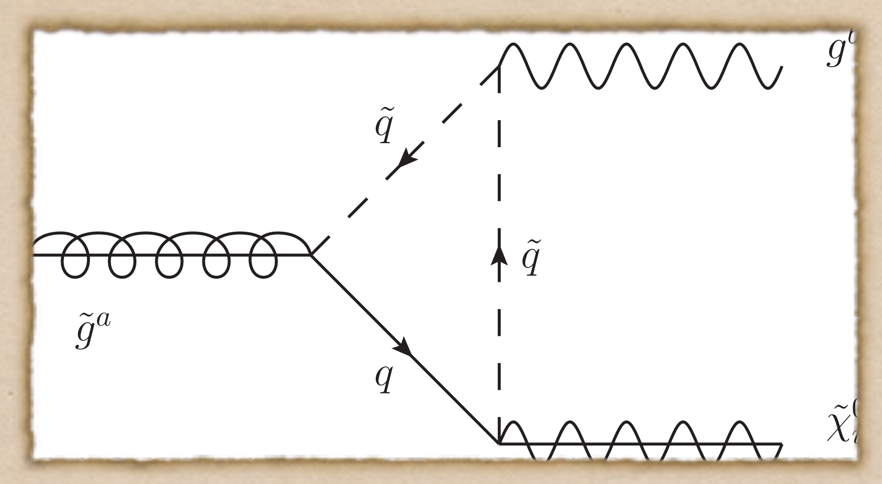

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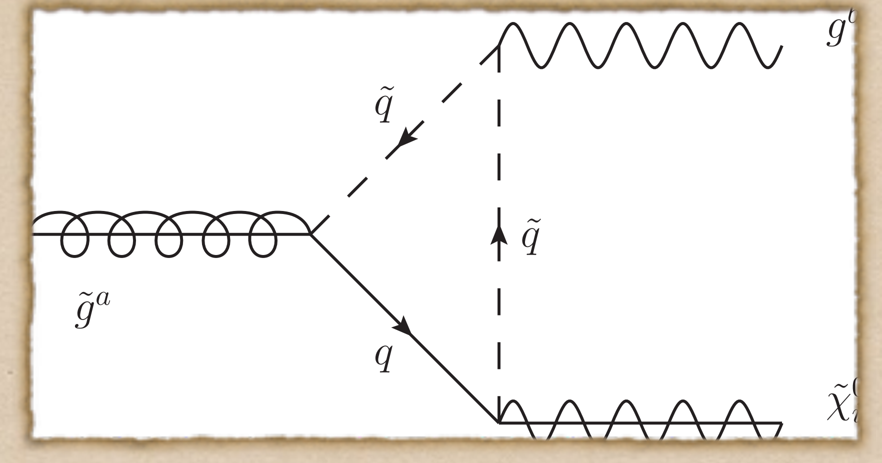

- Possible for a compressed spectrum of gaugino with decoupled sfermions.
- Possible for models like (mini) split SUSY, Spread SUSY, Pure Gravity mediation, NUSUGRA.
- Can account for relic density in GNLSP like scenarios (NUSUGRA models).
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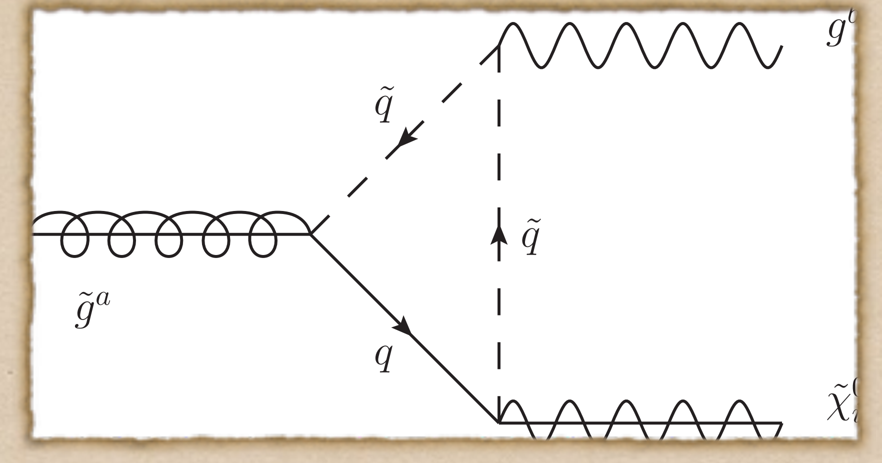

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hep-ph:0411041,0409232,040688, arXiv: 1210.0555,1111.4519,1112.2462,0905.1148 .....

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- 3 available decay modes
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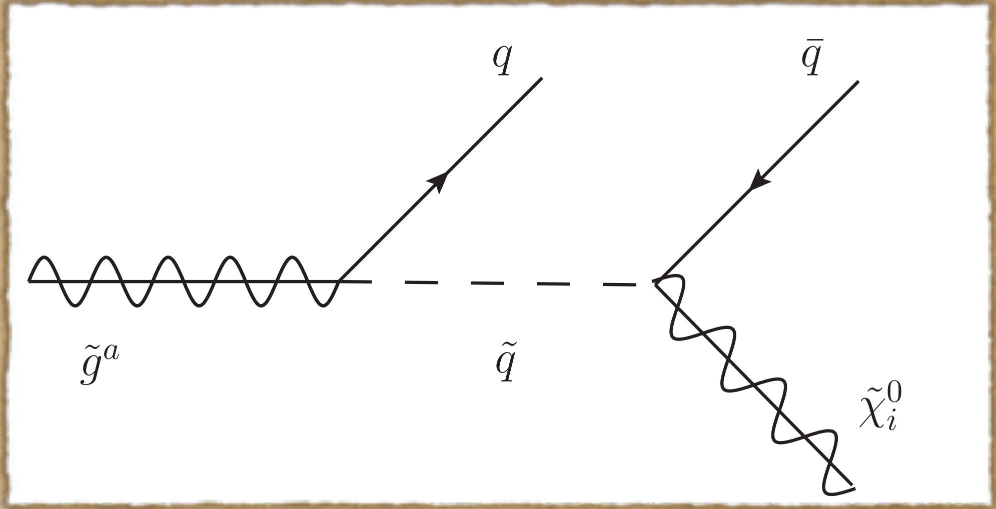

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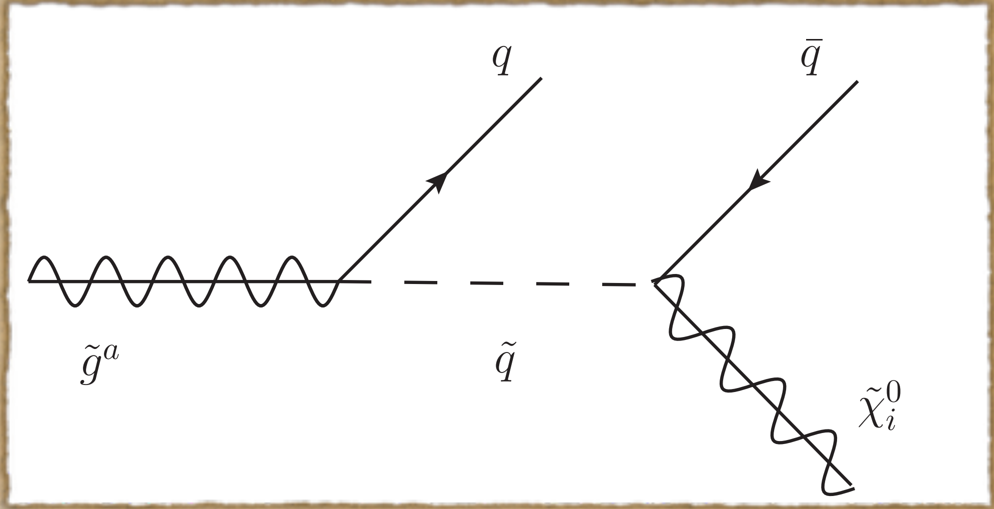

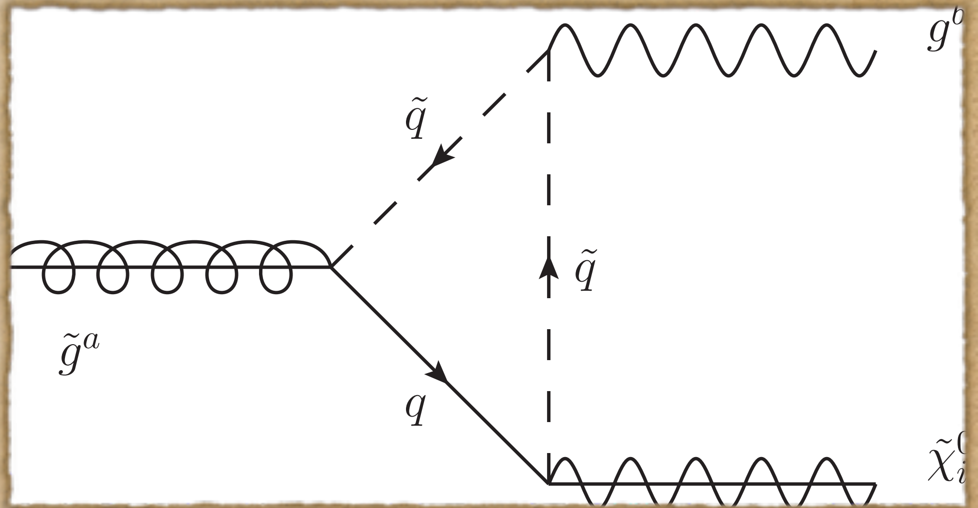

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Decay to bino/higgsino induced by a dimension 5 chromo magnetic operator

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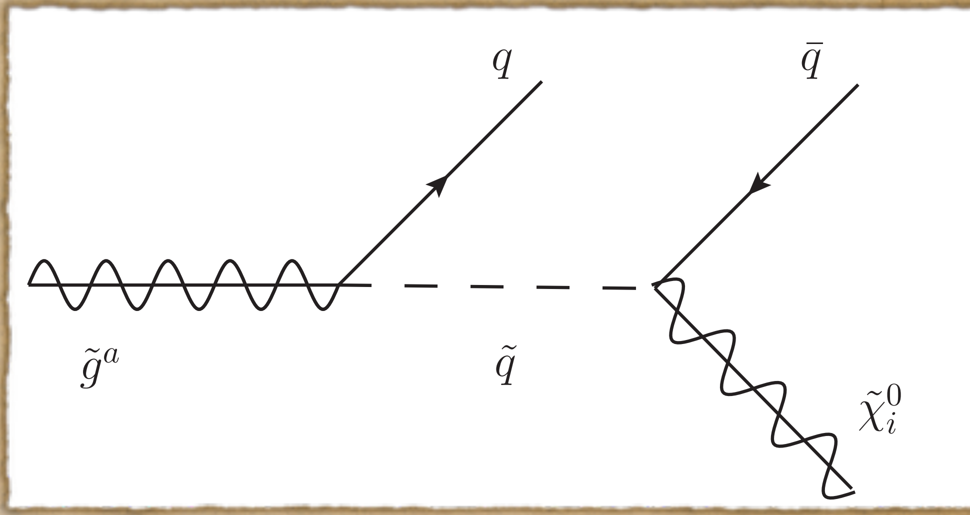

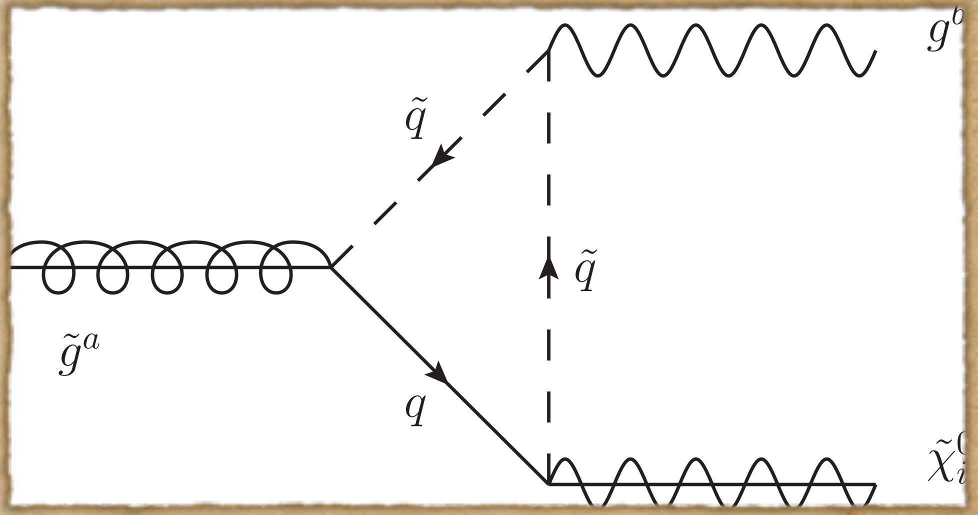

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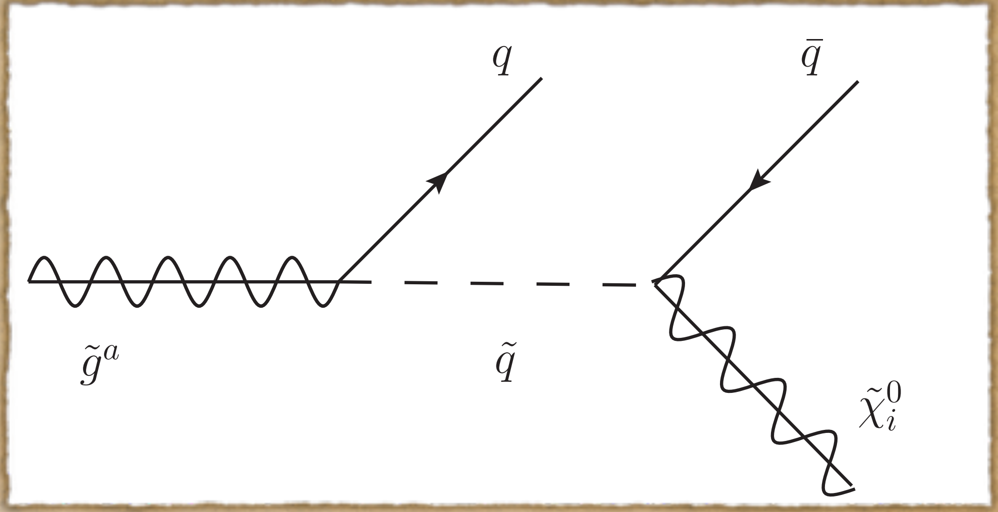
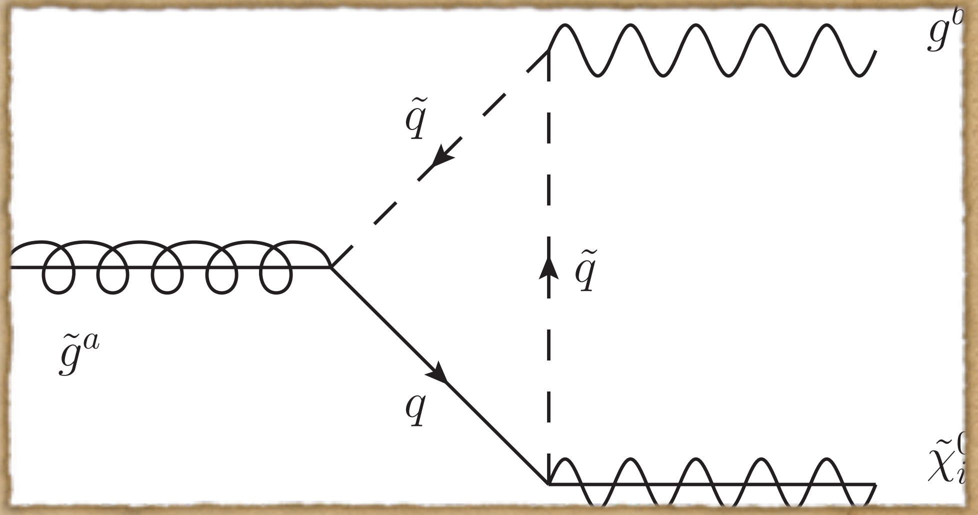


$$\mathcal{L}_{\text{eff.}} = \frac{1}{\tilde{m}} \overline{\tilde{\chi}_i^0} \sigma^{\mu\nu} P_{L,R} \tilde{g}^a G^b_{\mu\nu} \delta_{ab}$$



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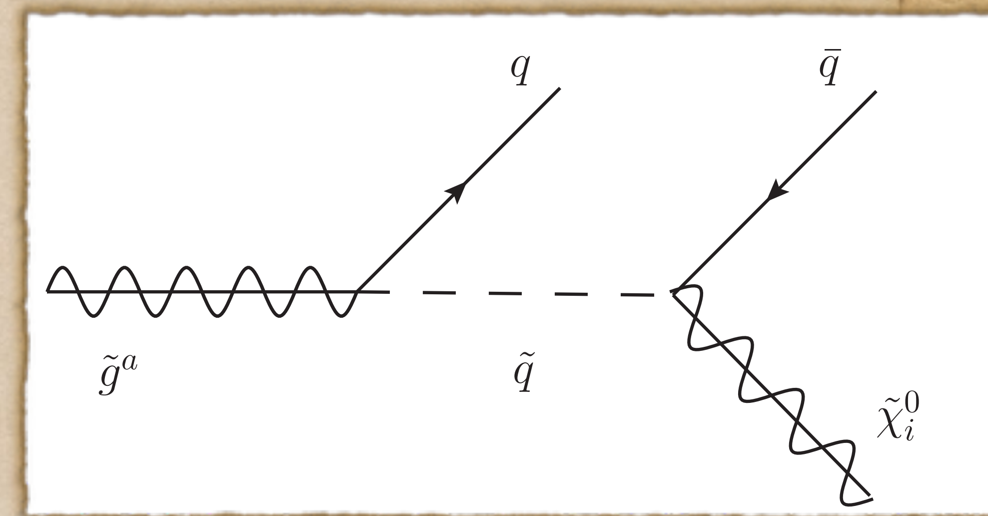
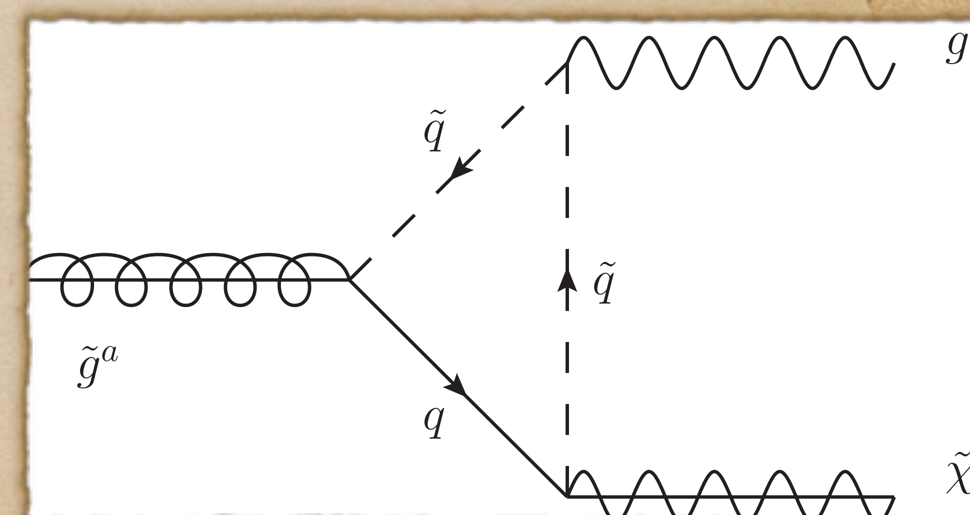
Decay widths : In the heavy squark limit





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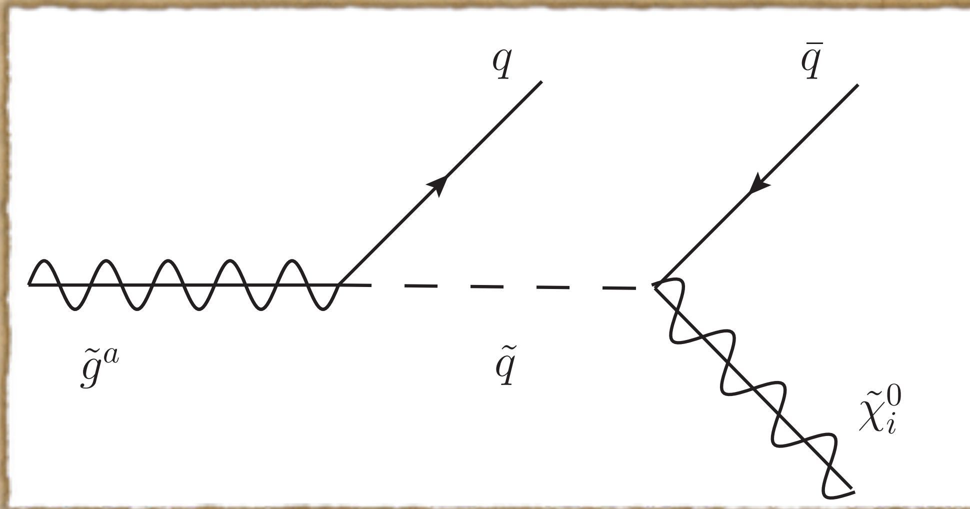

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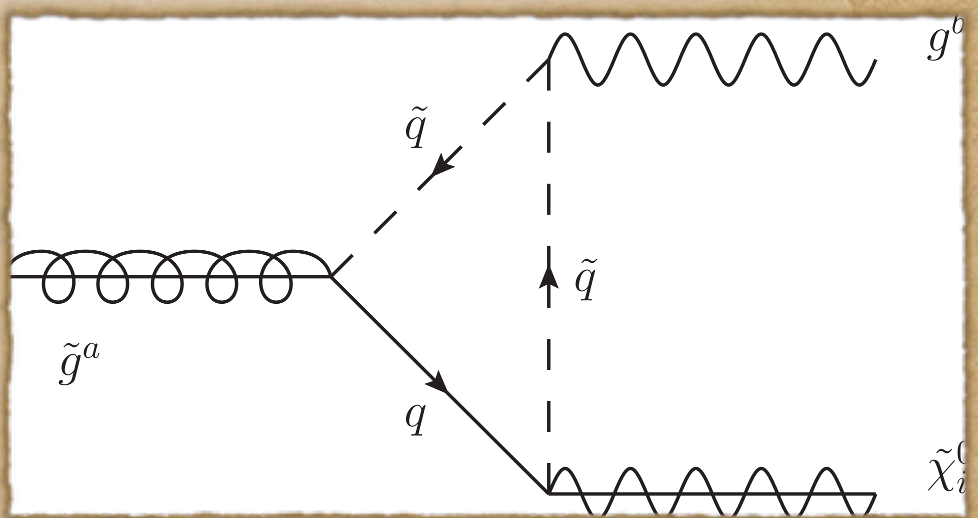
$$\Gamma(\tilde{g} \to g\widetilde{B}) \simeq \frac{\alpha\alpha_s^2}{512\pi^2 c_W^2} \frac{\left(m_{\tilde{g}}^2 - m_{\widetilde{B}}^2\right)^3}{m_{\tilde{g}}^3} \left[\sum_q \frac{Y_{qL}}{m^2_{\tilde{q}_L}} - \frac{Y_{qR}}{m^2_{\tilde{q}_R}}\right]^2 (m_{\tilde{g}} - m_{\widetilde{B}})^2 \quad (6)$$

$$\Gamma(\tilde{g} \to g\widetilde{H}) \simeq \frac{\alpha\alpha_s^2 m_t^2}{128\pi^2 M_W^2 s_W^2 s_\beta^2} \frac{\left(m_{\tilde{g}}^2 - m_{\widetilde{H}}^2\right)^3}{m_{\tilde{g}}^3} \left[\frac{m_t}{m^2_{\tilde{t}_L}}\left(\ln\frac{m^2_{\tilde{t}_L}}{m_t^2} - 1\right) + \frac{m_t}{m^2_{\tilde{t}_R}}\left(\ln\frac{m^2_{\tilde{t}_R}}{m_t} - 1\right)\right]^2 \quad (7)$$



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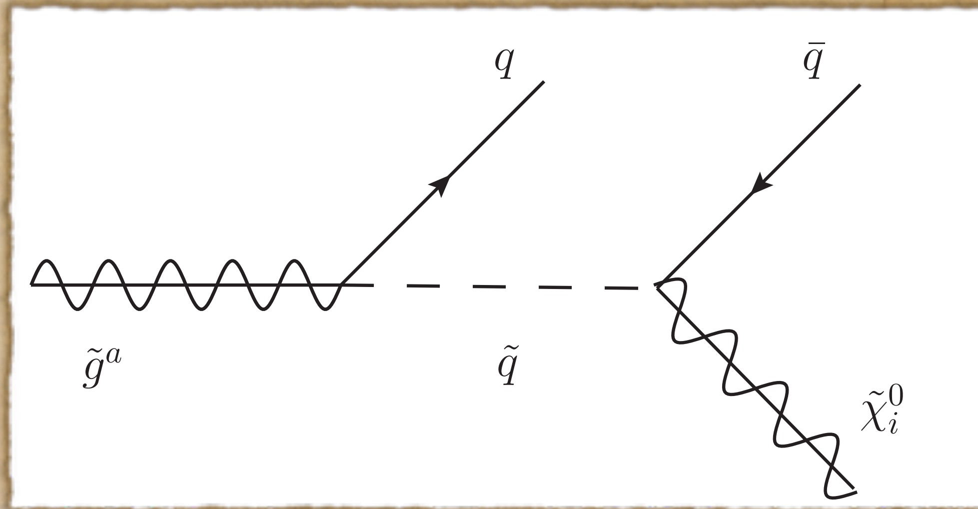
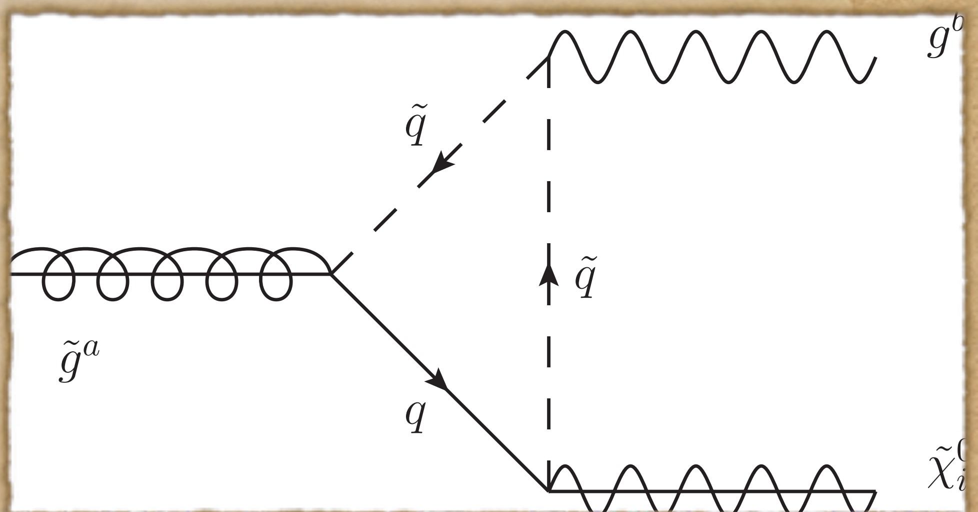


Decay widths : In the heavy squark limit

$$\Gamma(\tilde{g} \to g\widetilde{B}) \simeq \frac{\alpha\alpha_s^2}{512\pi^2 c_W^2} \frac{\left(m_{\tilde{g}}^2 - m_{\widetilde{B}}^2\right)^3}{m_{\tilde{g}}^3} \left[\sum_q \frac{Y_{qL}}{m^2_{\tilde{q}_L}} - \frac{Y_{qR}}{m^2_{\tilde{q}_R}}\right]^2 (m_{\tilde{g}} - m_{\widetilde{B}})^2 \quad (6)$$

$$\Gamma(\tilde{g} \to g\widetilde{H}) \simeq \frac{\alpha\alpha_s^2 m_t^2}{128\pi^2 M_W^2 s_W^2 s_\beta^2} \frac{\left(m_{\tilde{g}}^2 - m_{\widetilde{H}}^2\right)^3}{m_{\tilde{g}}^3} \left[\frac{m_t}{m^2_{\tilde{t}_L}}\left(\ln \frac{m^2_{\tilde{t}_L}}{m_t^2} - 1\right) + \frac{m_t}{m^2_{\tilde{t}_R}}\left(\ln \frac{m^2_{\tilde{t}_R}}{m_t} - 1\right)\right]^2 \quad (7)$$

$$\Gamma(\tilde{g} \to q_L q_R^c \widetilde{B}) = \frac{\alpha\alpha_s Y_{qL}}{96\pi \cos^2\theta_W} \frac{m_{\tilde{g}}^5}{m^4_{\tilde{q}L}} \left[f\left(\frac{m^2_{\widetilde{B}}}{m^2_{\tilde{g}}}\right) + \frac{2m_{\widetilde{B}}}{m_{\tilde{g}}} g\left(\frac{m^2_{\widetilde{B}}}{m^2_{\tilde{g}}}\right)\right]$$



Radiative gluino decay.

- 3 available decay modes
- If m_{squark} >> m_{gluino} , decay to squarks are forbidden

$$\tilde{g} \to q + \bar{q} + \tilde{\chi}_i^0$$
$$\tilde{g} \to q + \bar{q}' + \tilde{\chi}_j^{\pm}$$
$$\tilde{g} \to g + \tilde{\chi}_i^0$$

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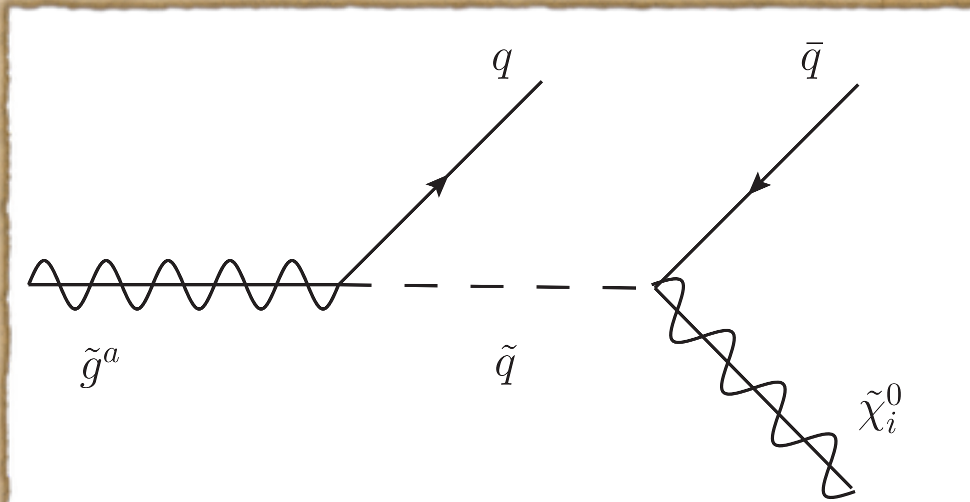

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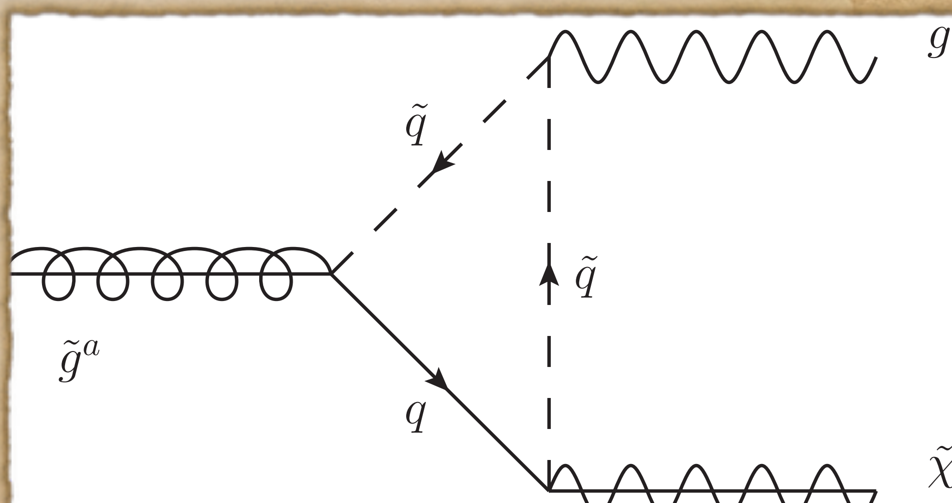

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E.Ma : Mod. Phys. Lett. A3 (1988) 1561,

R. Barbieri et al: Nucl. Phys. B301 (1988) 15.

Radaitive Gluino decay

Ratio of two body to 3 body decay

$$R_{2/3} = \frac{24\alpha_s}{\pi}\left(\frac{\tilde{m}_b}{\tilde{m}_t}\right)^4\left(\frac{m_t^2}{m_{\tilde{g}}m_b\tan\beta}\right)^2\left[\frac{1}{1-x_t}+\frac{\ln x_t}{(1-x_t)^2}\right]^2$$

Two body will dominate over 3 body if :

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Two body will dominate over 3 body if :

- If the tt threshold is closed one needs a somewhat hierarchy between the sbottoms and the stops,
- Decouple all the squarks at very high masses, in this case $R_{2/3} \propto m_t^2/m_{\tilde{g}}^2[1+\ln x_t]^2$.

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For large squark masses, the logaritmic corrections have to be resumed

Parameter space scans

Relevant parameters with decoupled 1st two generations

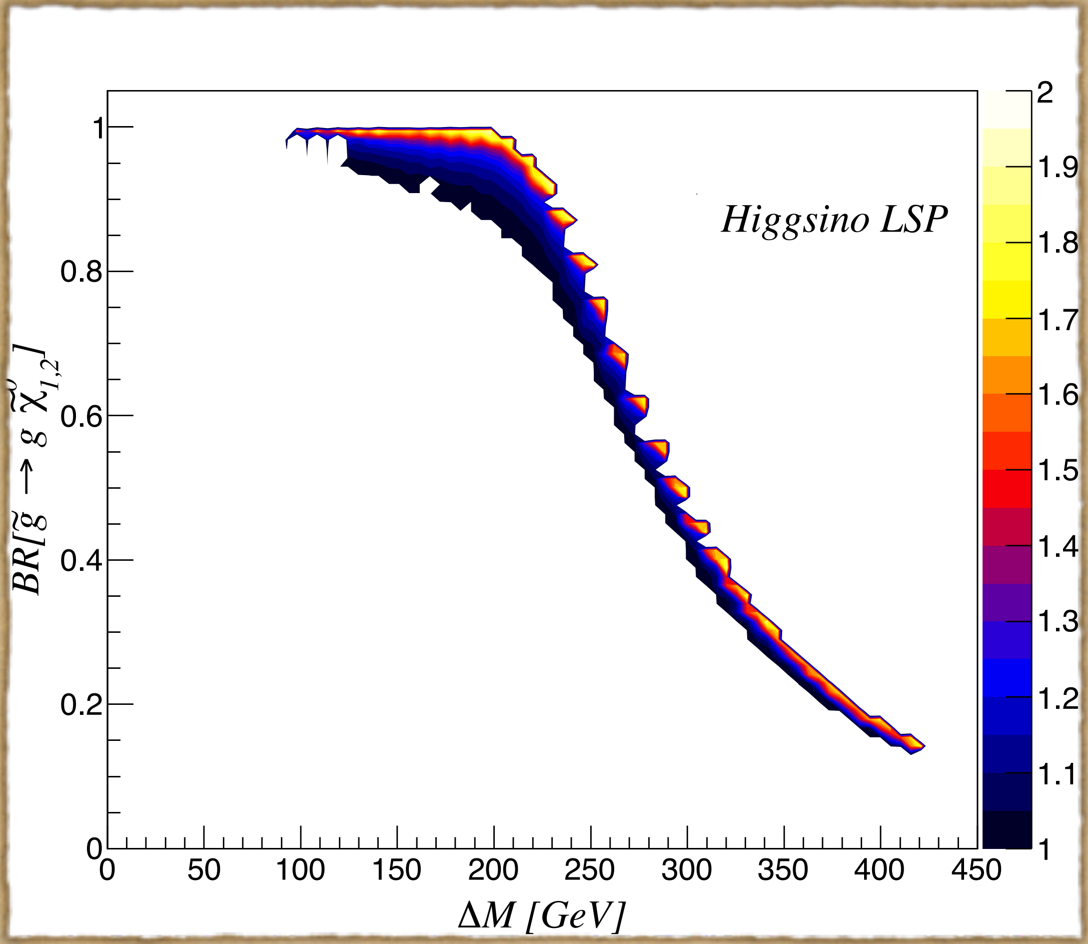
Sfermion sector

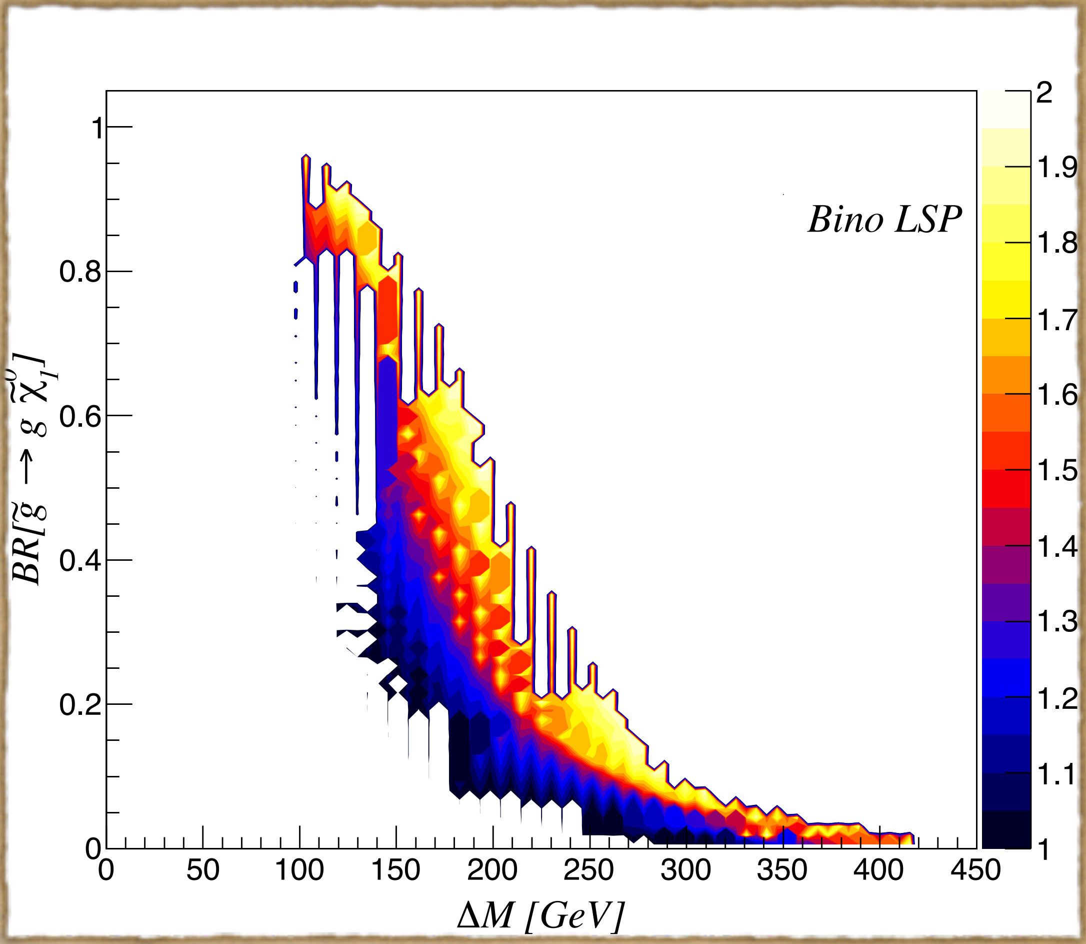
- $M_{\tilde{t}_R} = 1$ TeV, $M_{\tilde{Q}_3} = 2$ TeV, $A_b = 0$
- 1 TeV $< M_{\tilde{b}_R} <$ 2 TeV
- -2 TeV $< A_t <$ 2 TeV

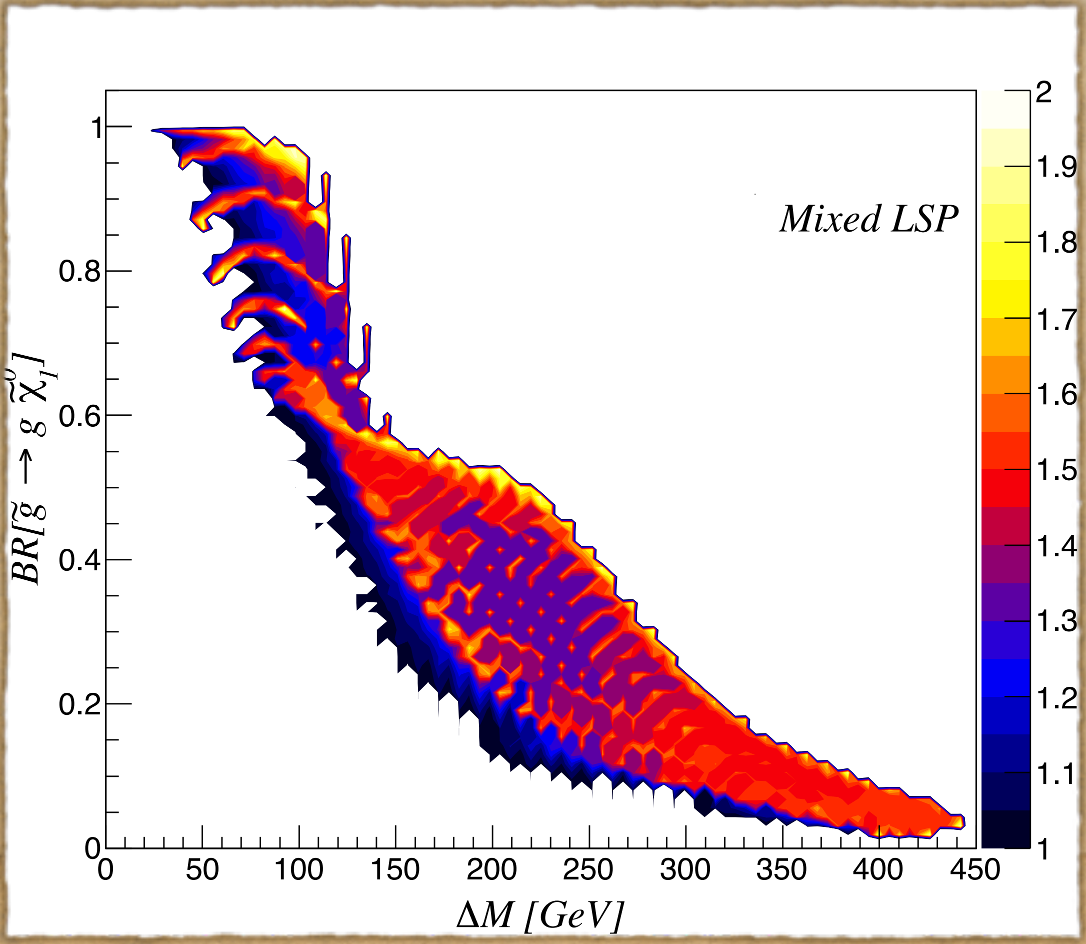
Gaugino sector

- 400 GeV $< M_1, \mu <$ 800 GeV
- $M_2 = 2$ TeV, $M_3 = 600$ GeV, $\tan\beta = 10$

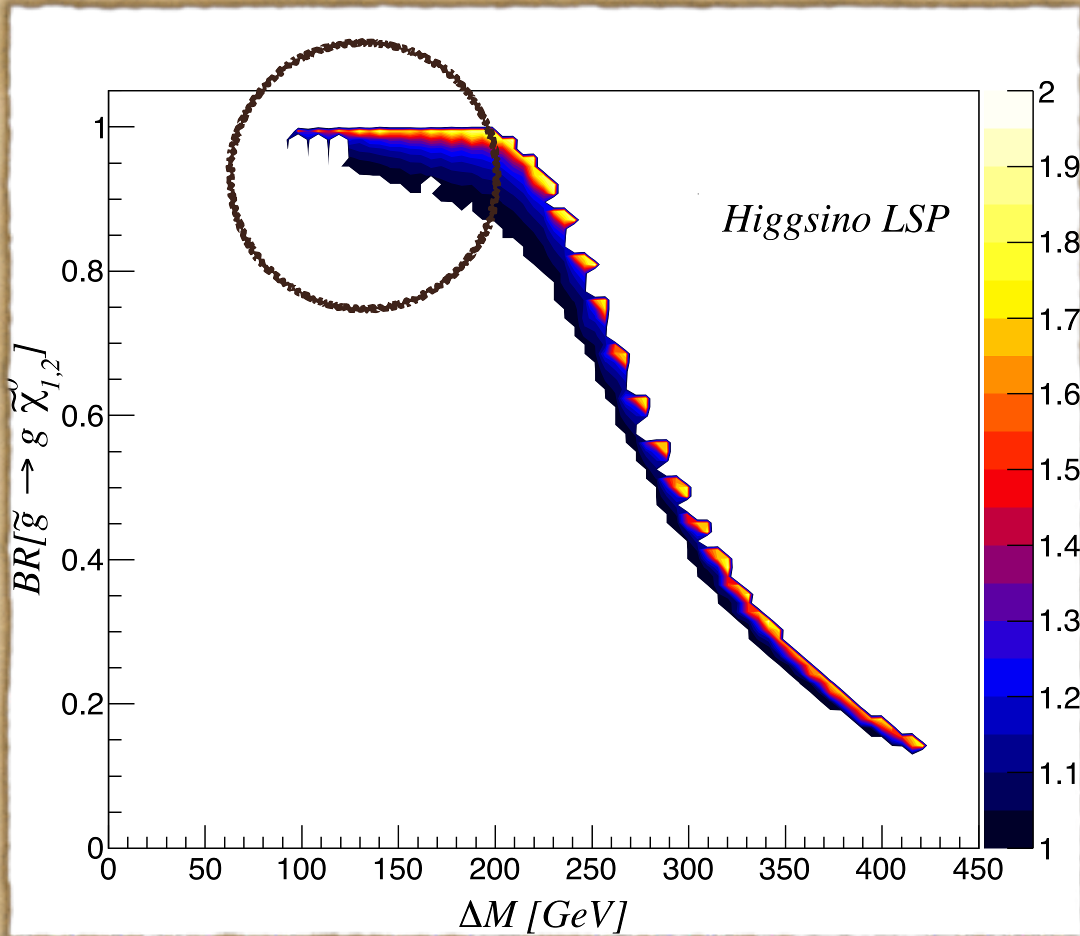
Two Body Decays

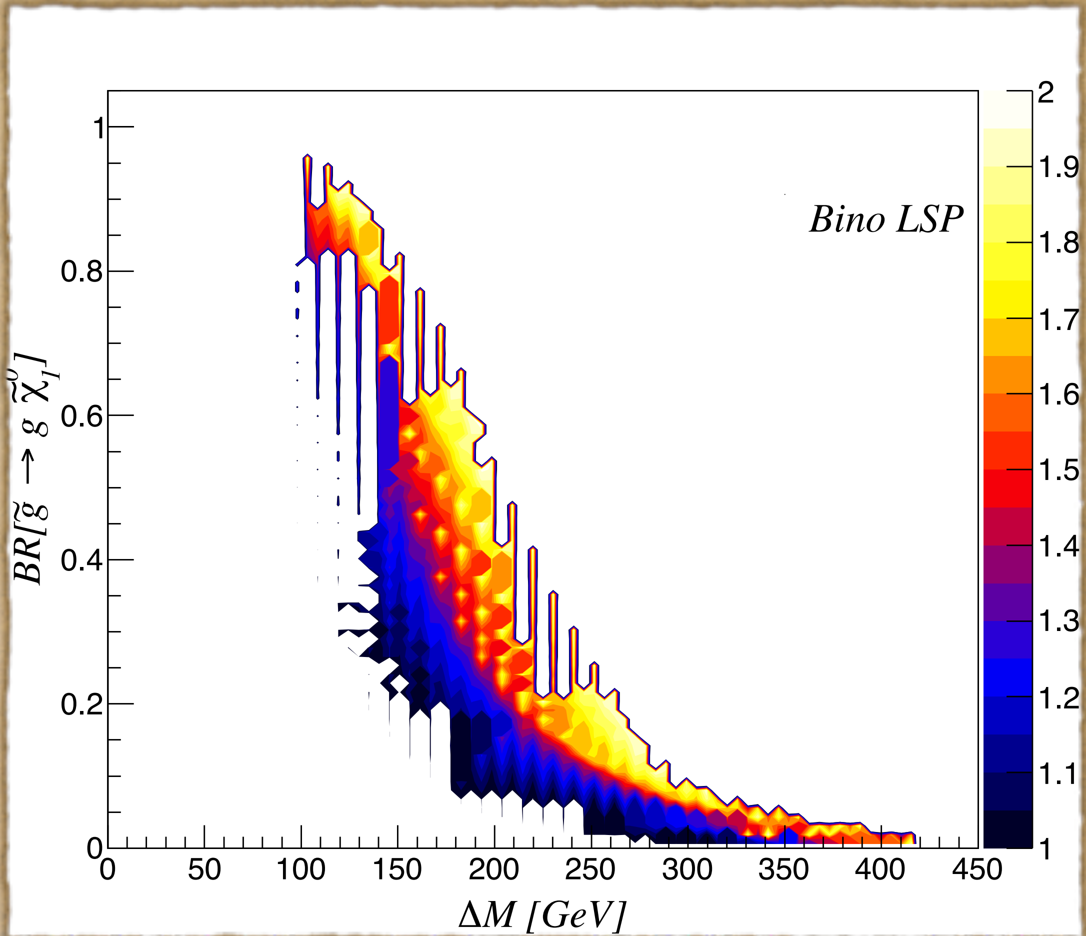


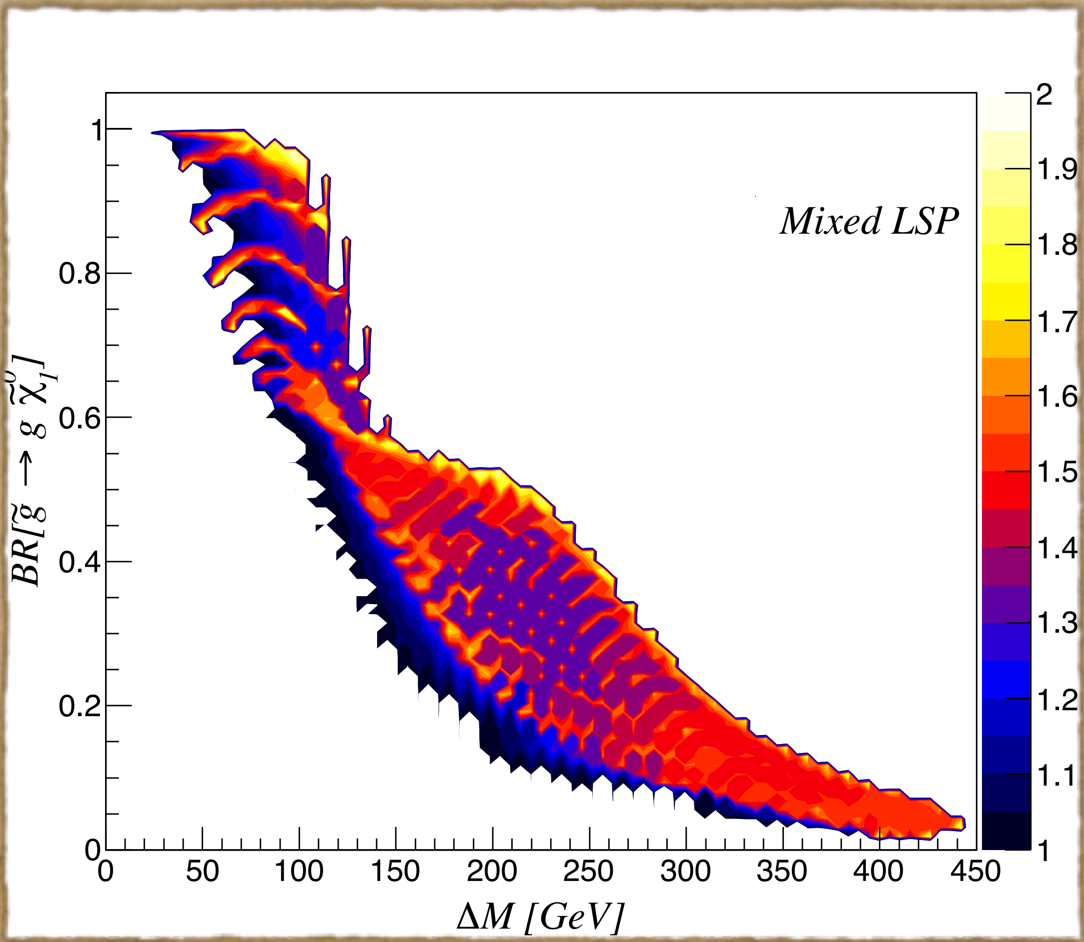




Two Body Decays







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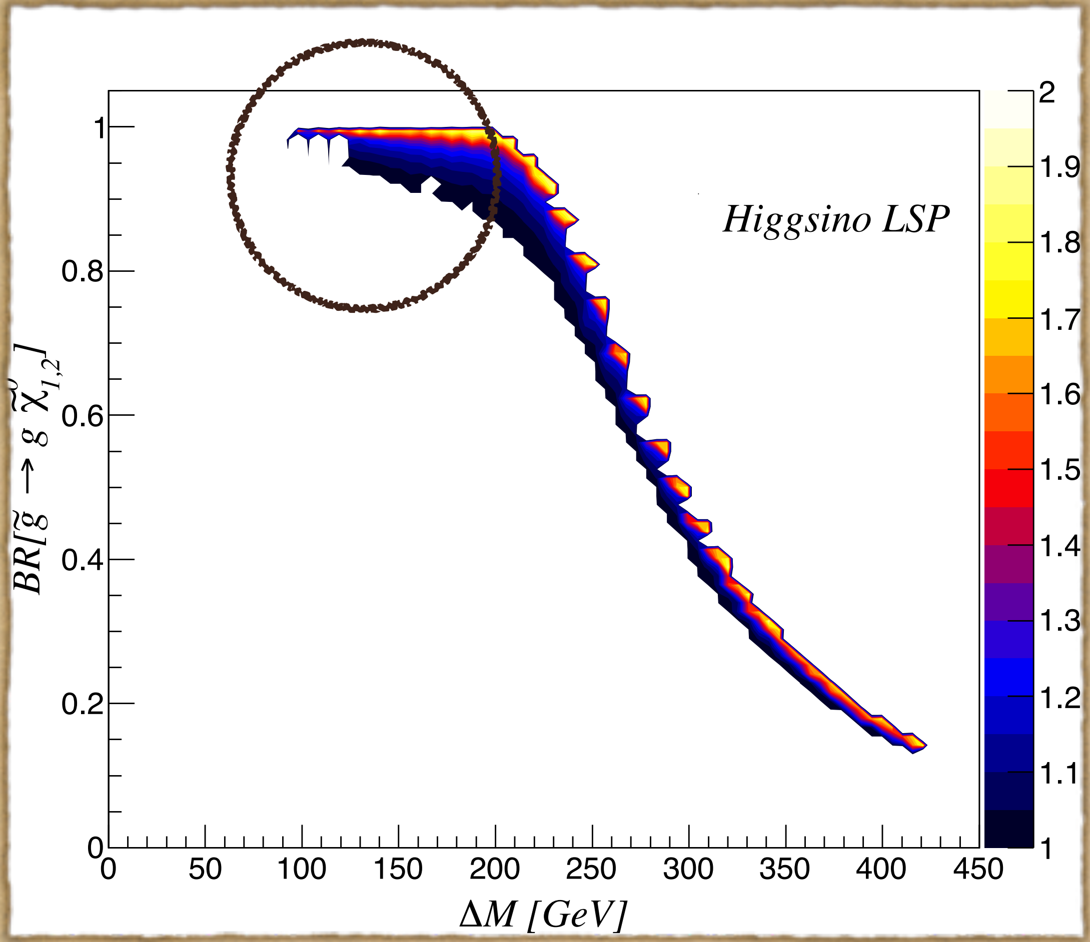

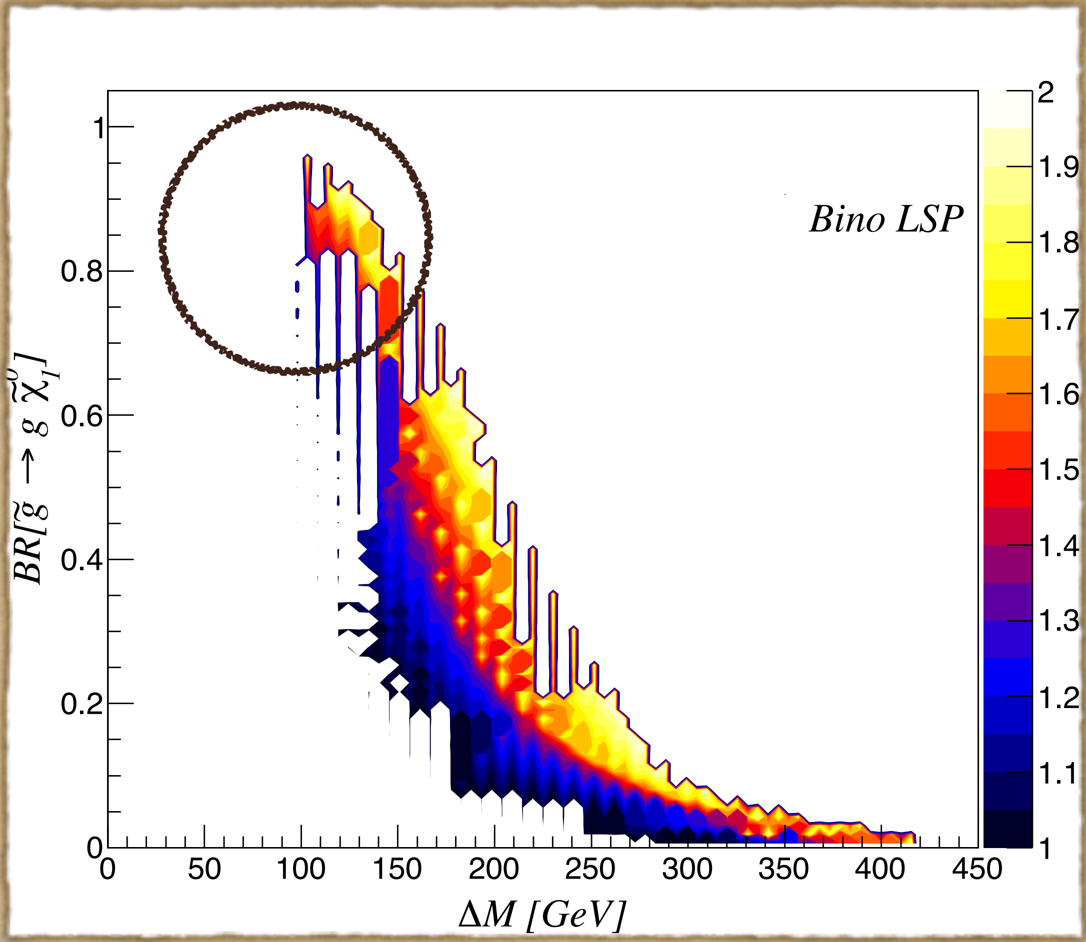

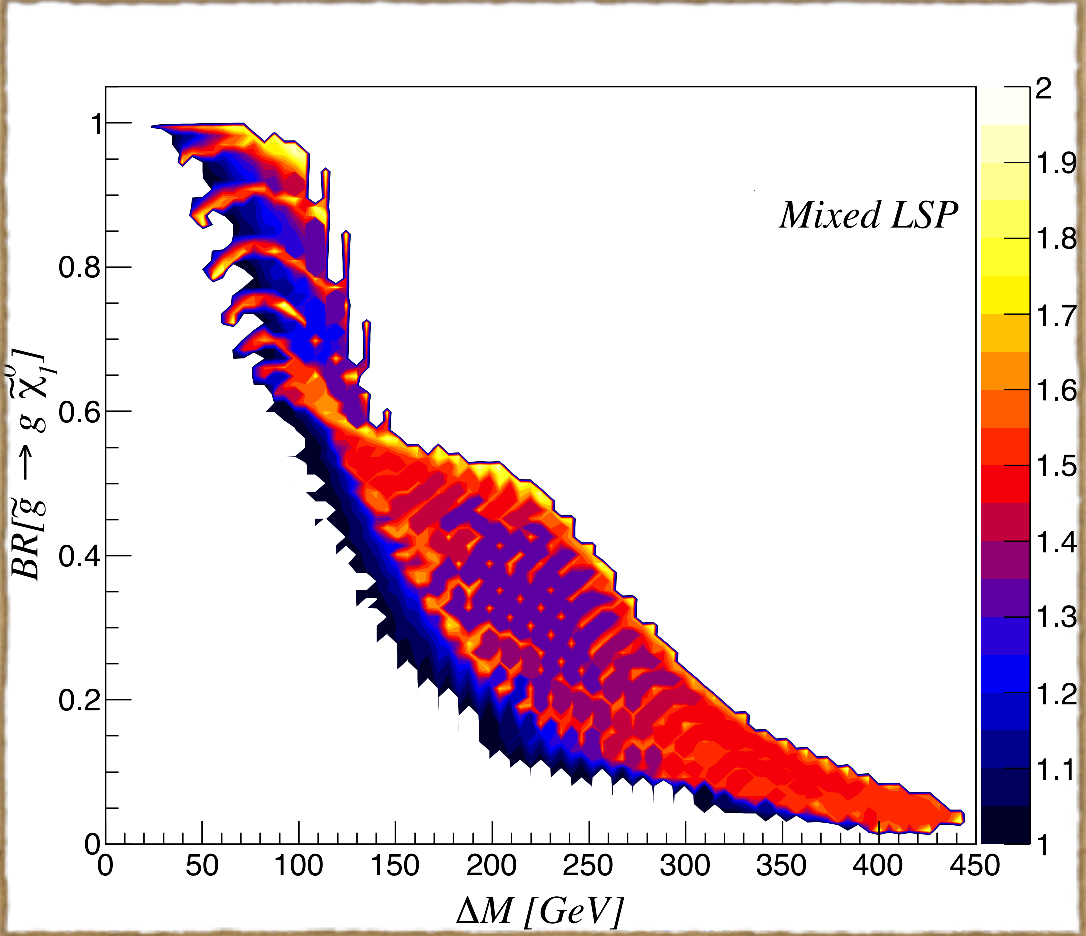

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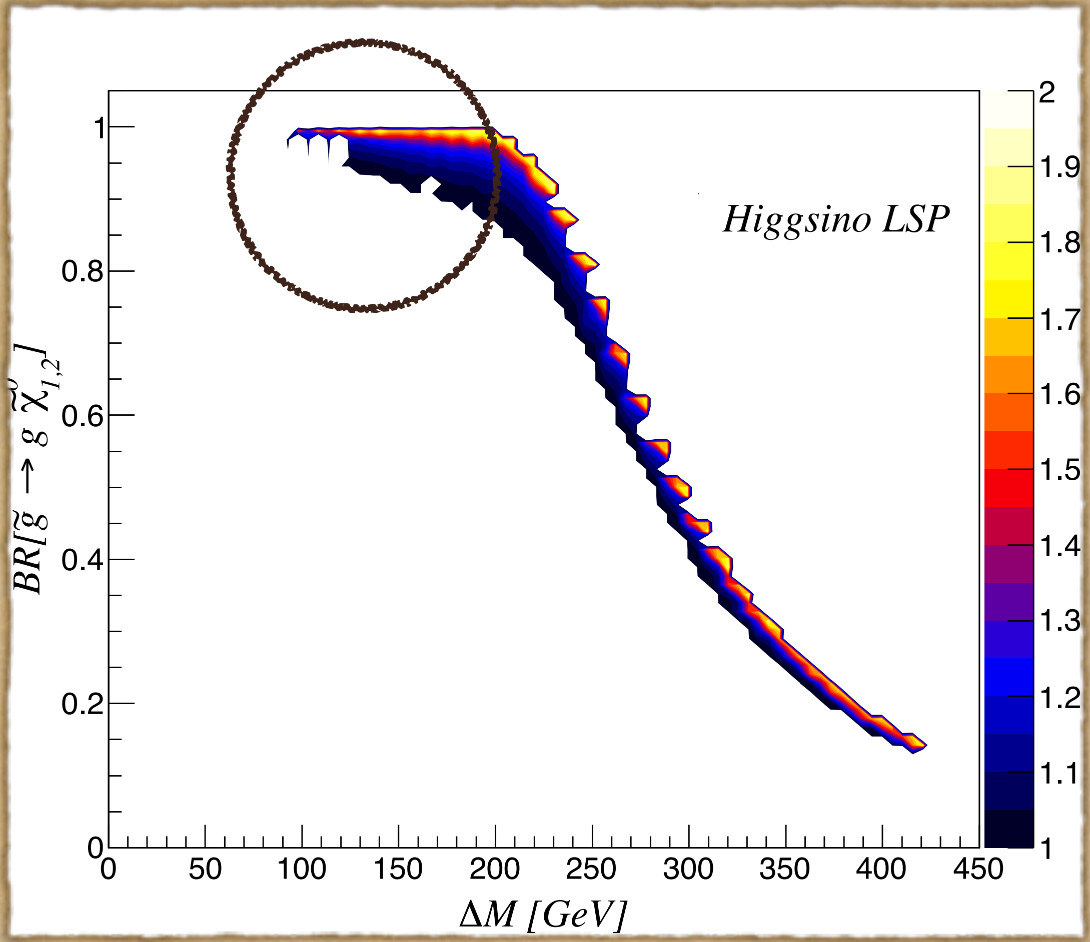

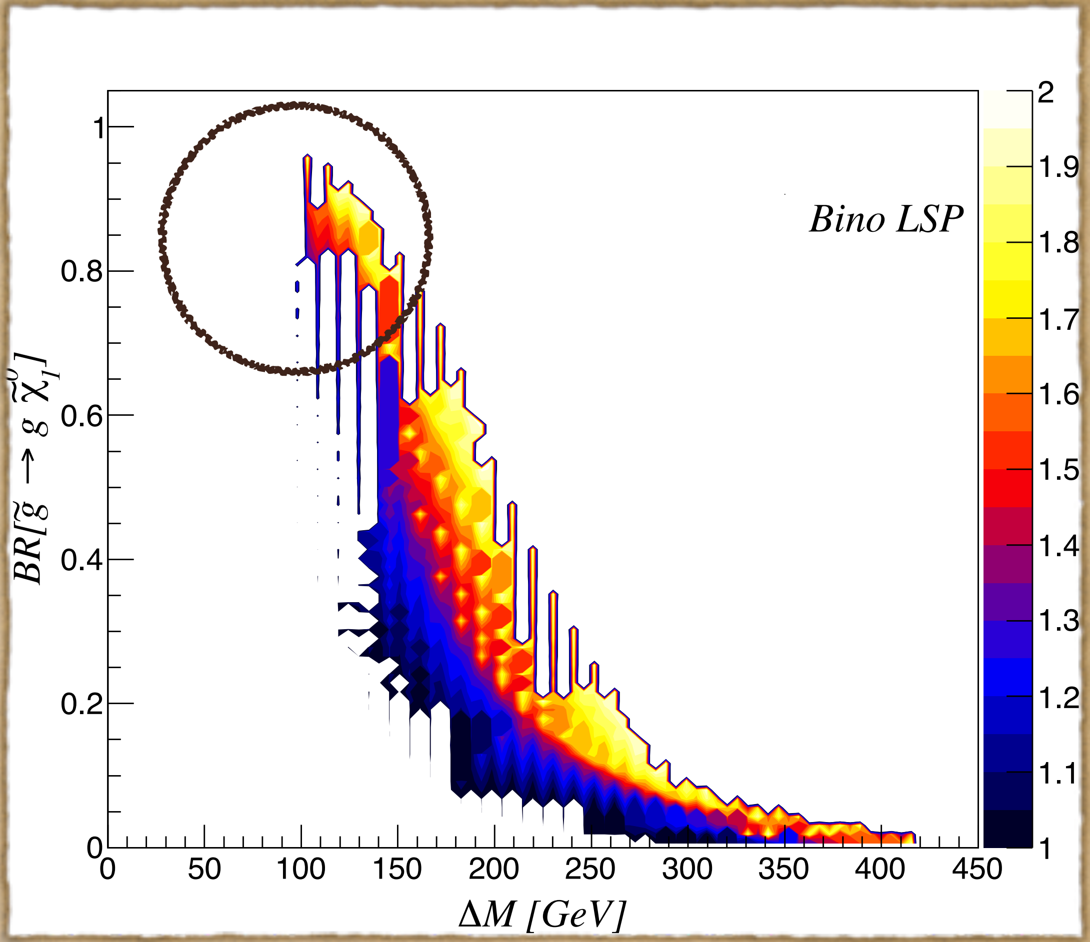

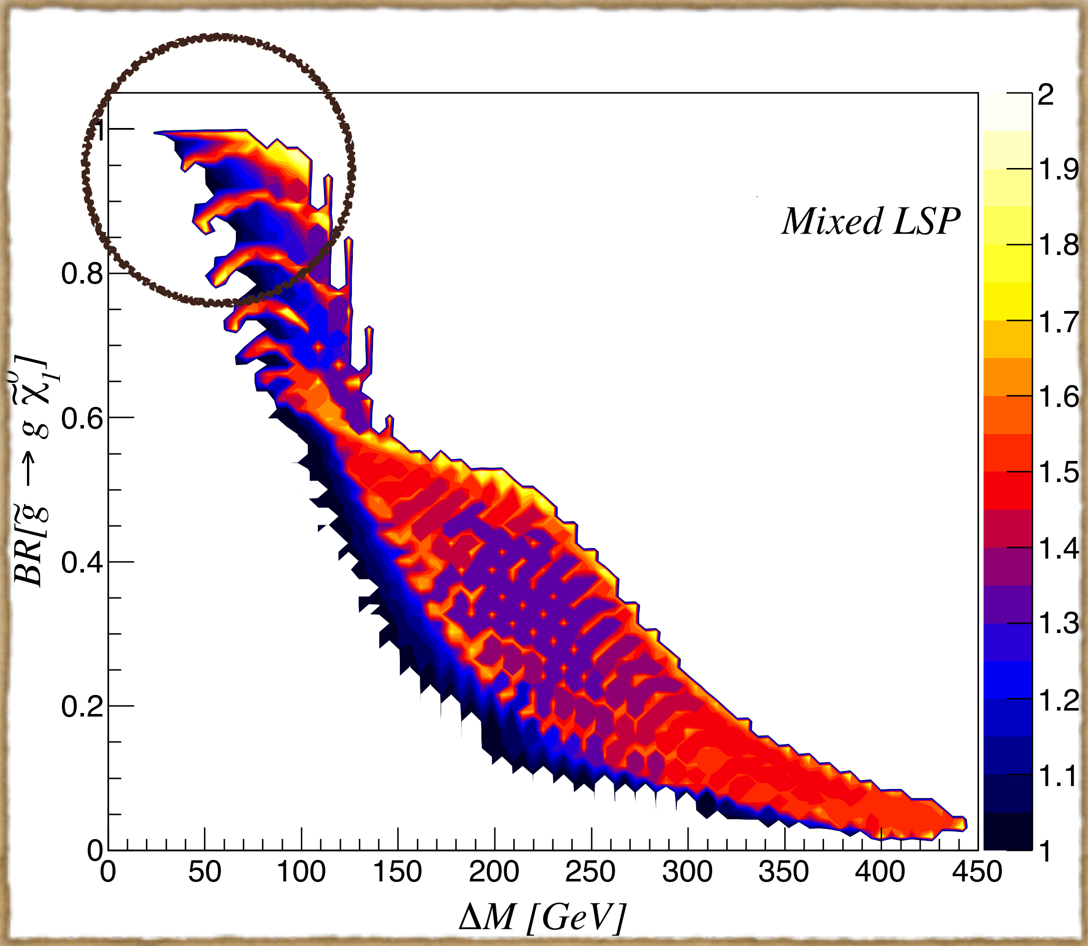

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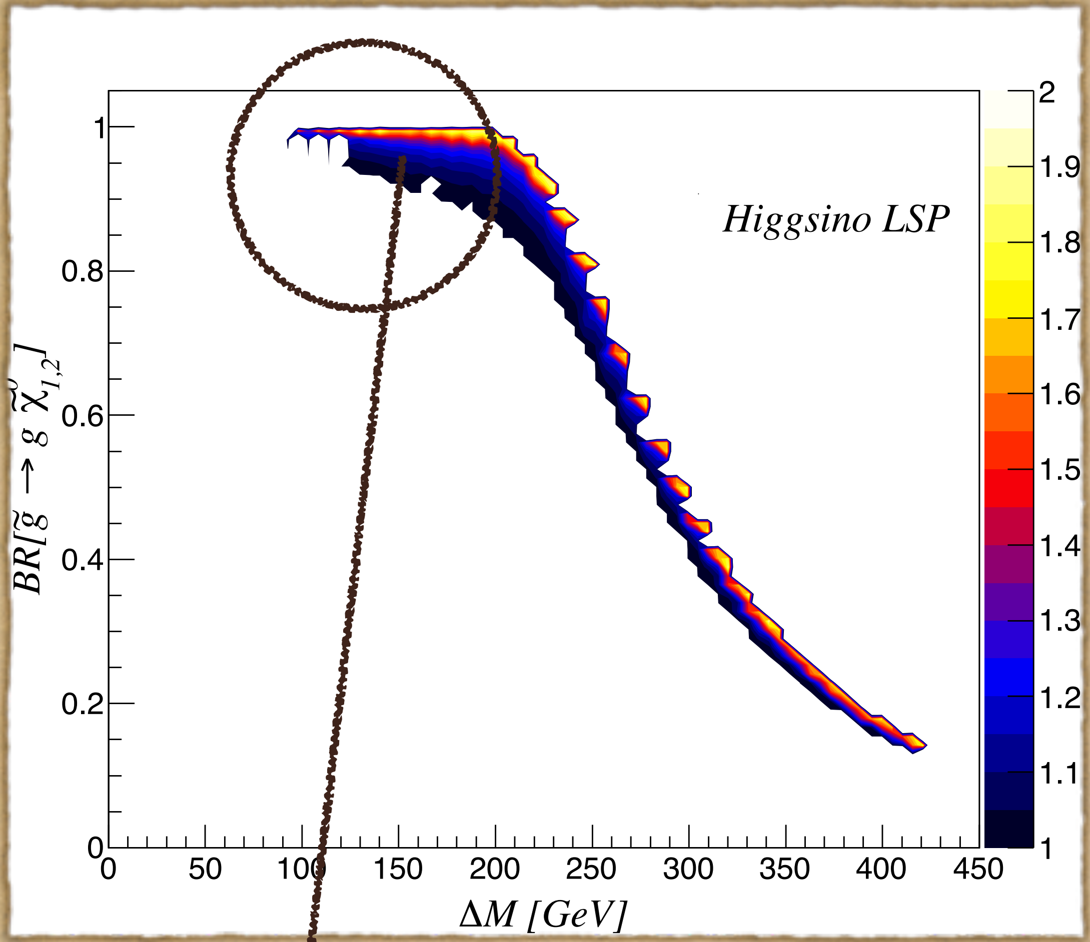

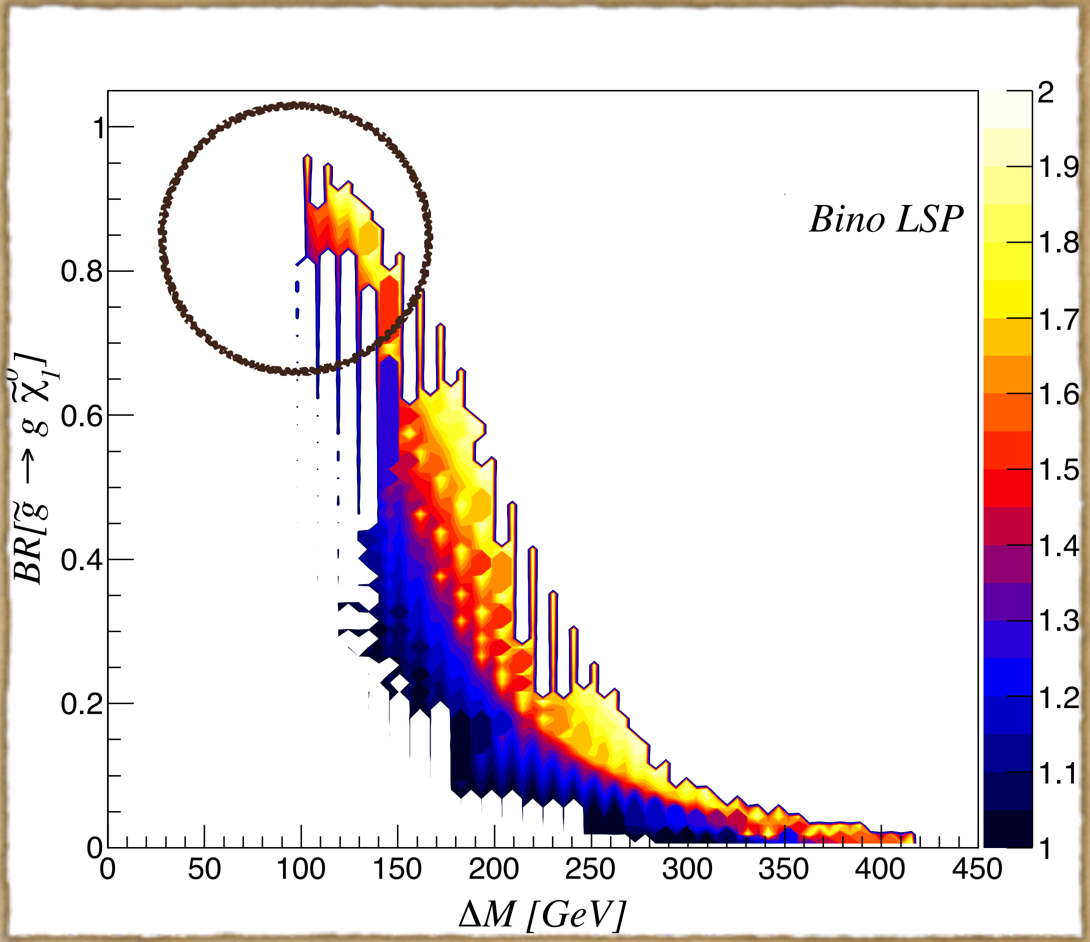

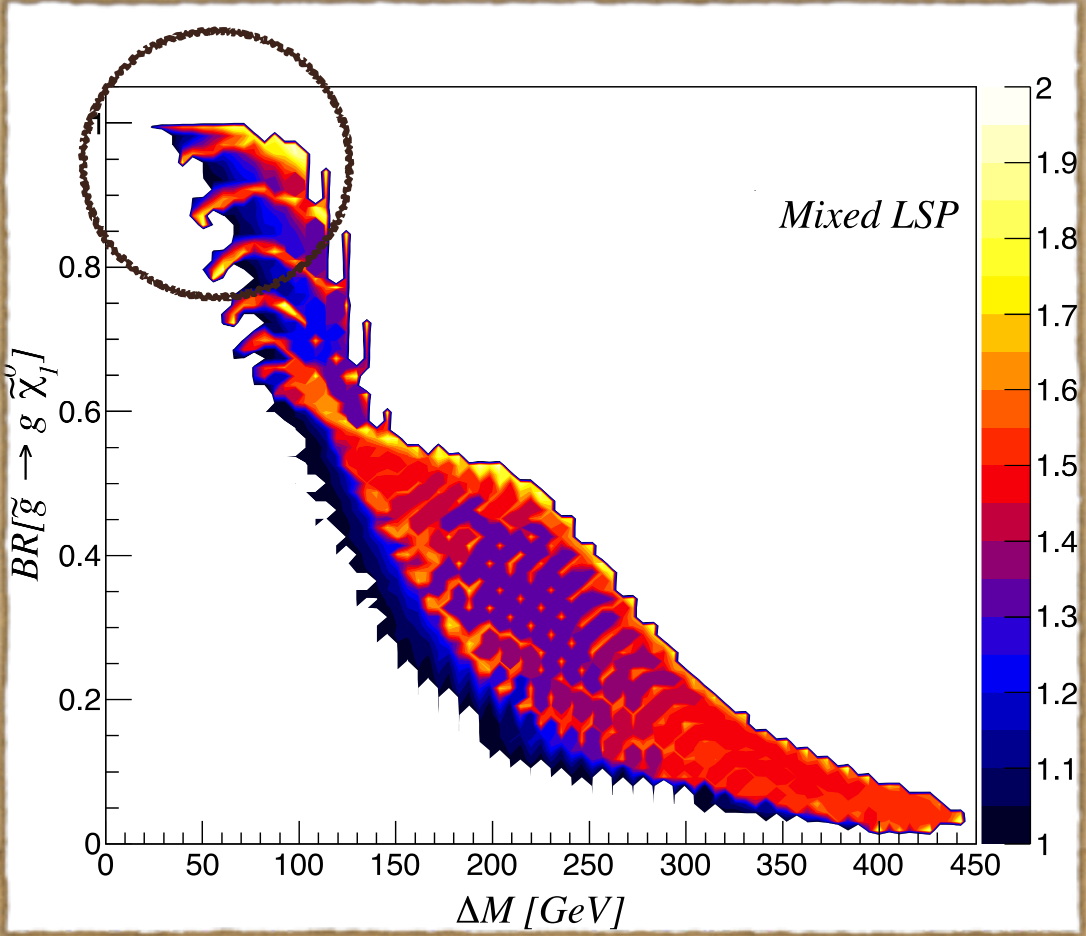

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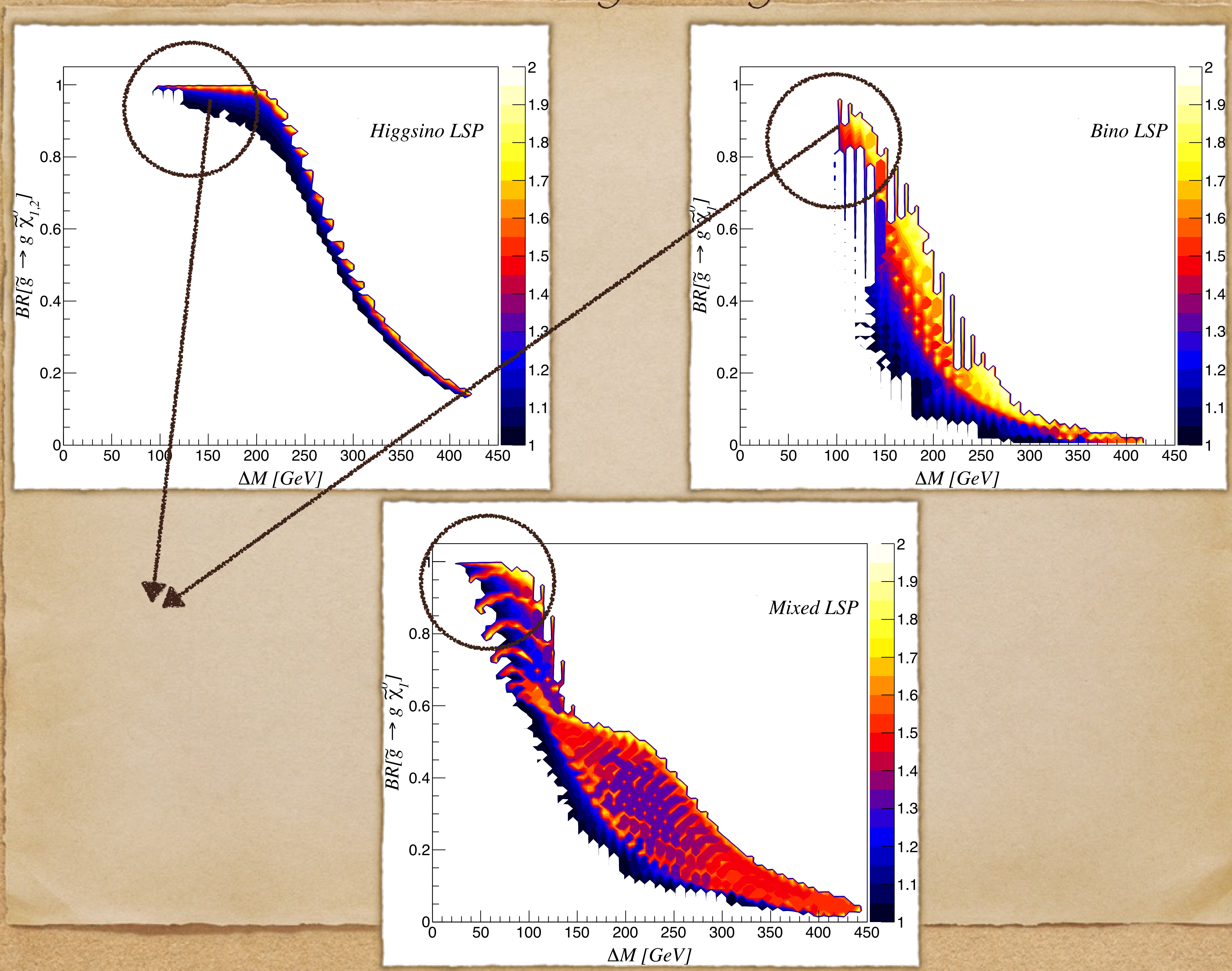

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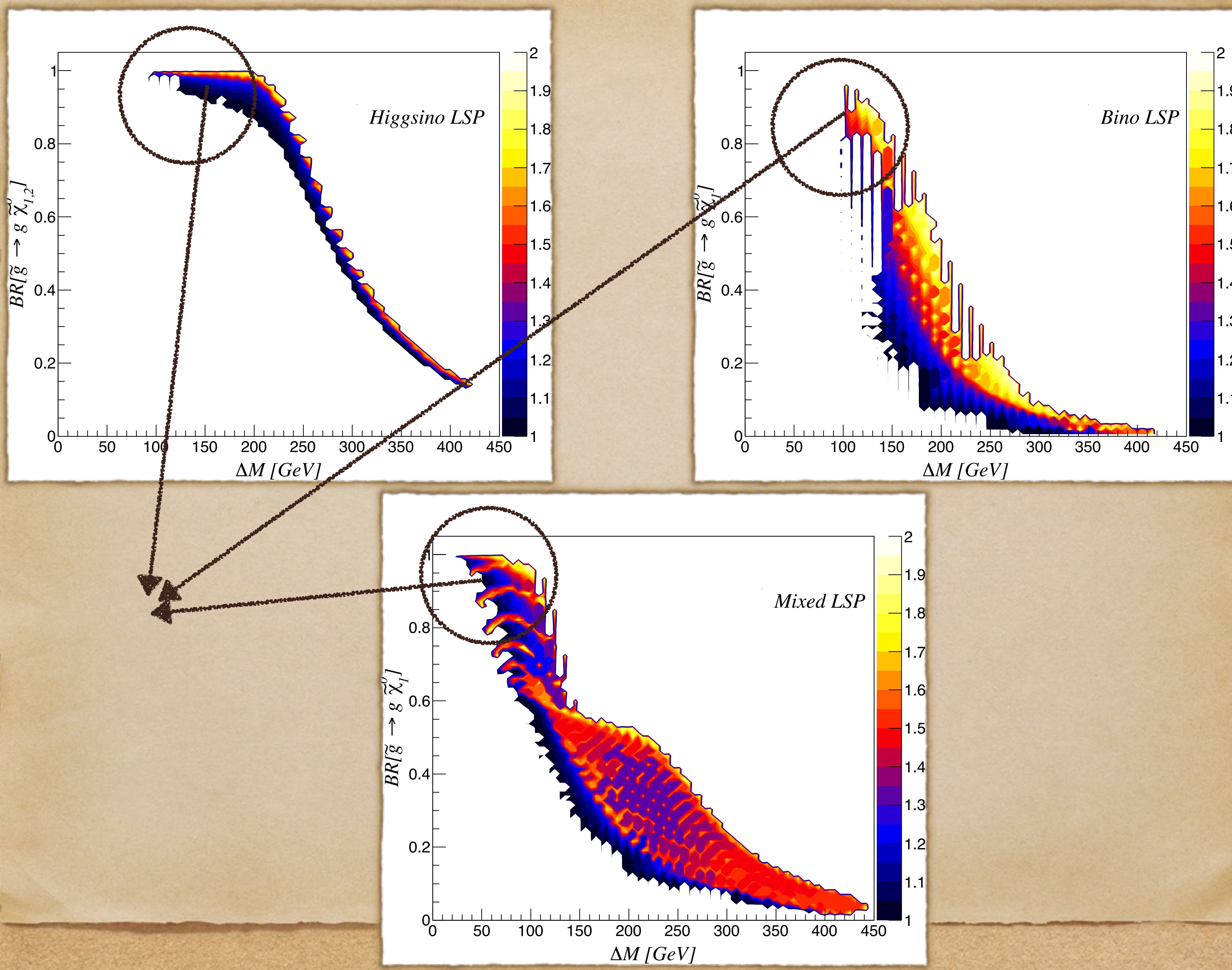

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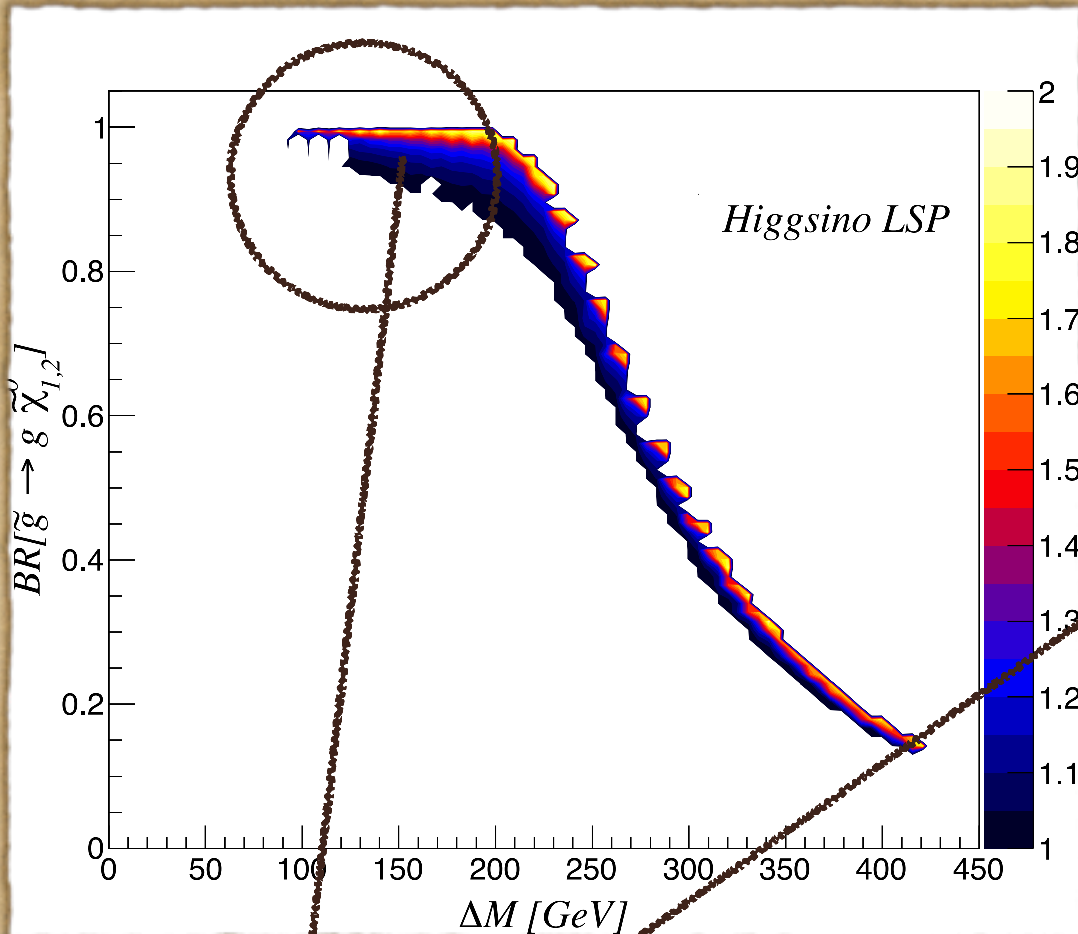
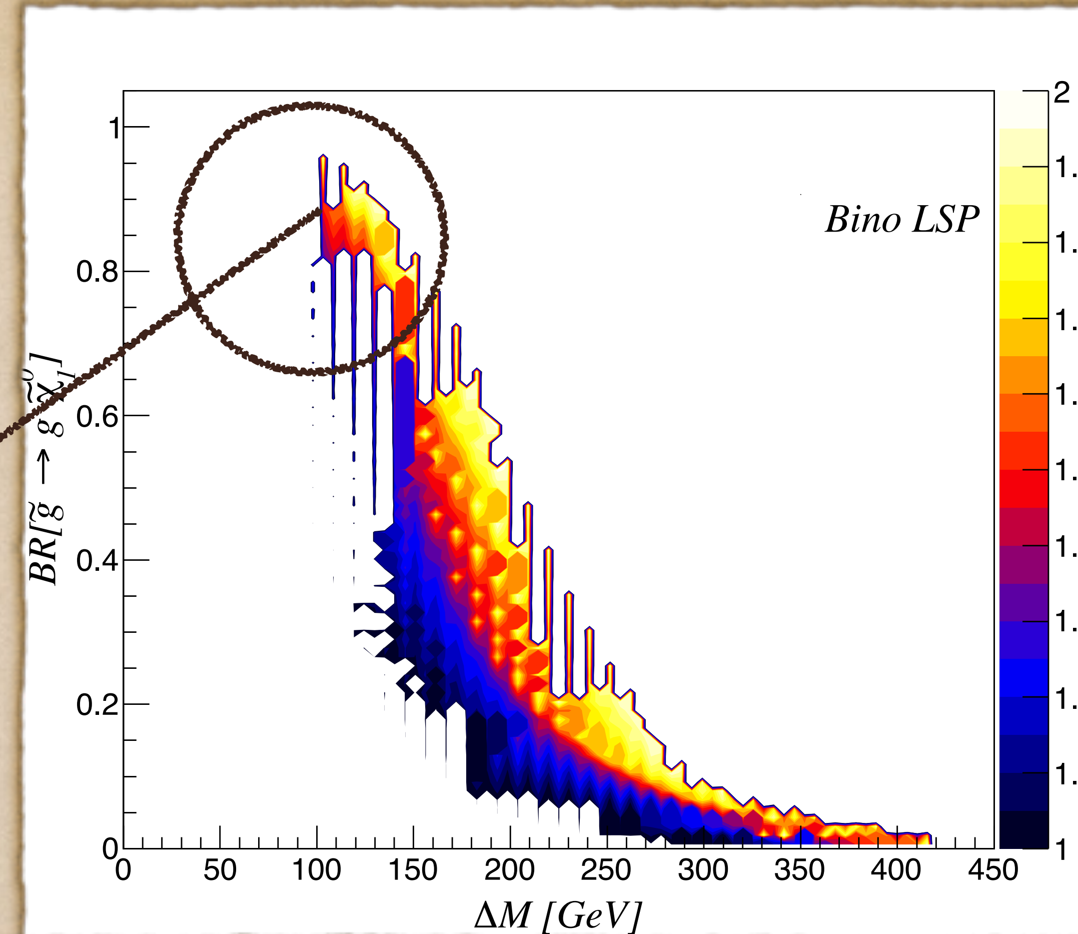
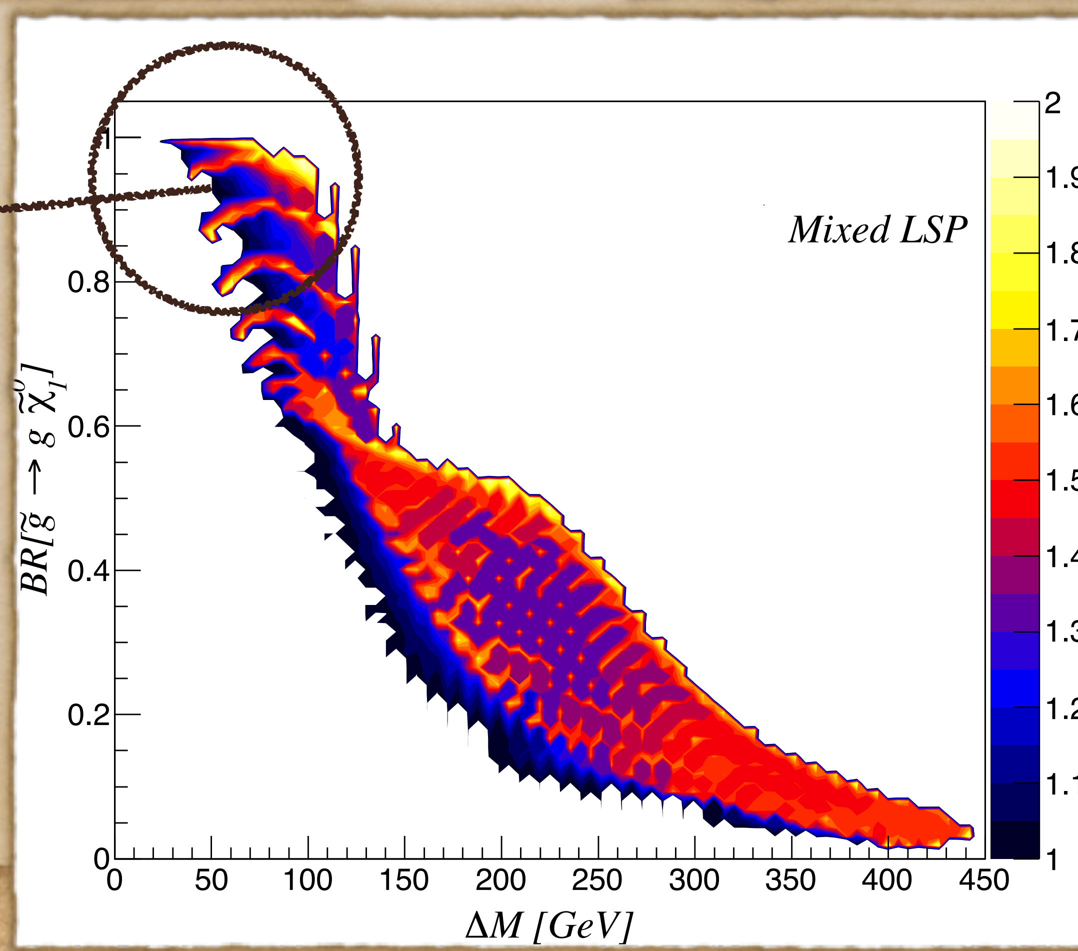






Low mass gaps preferred

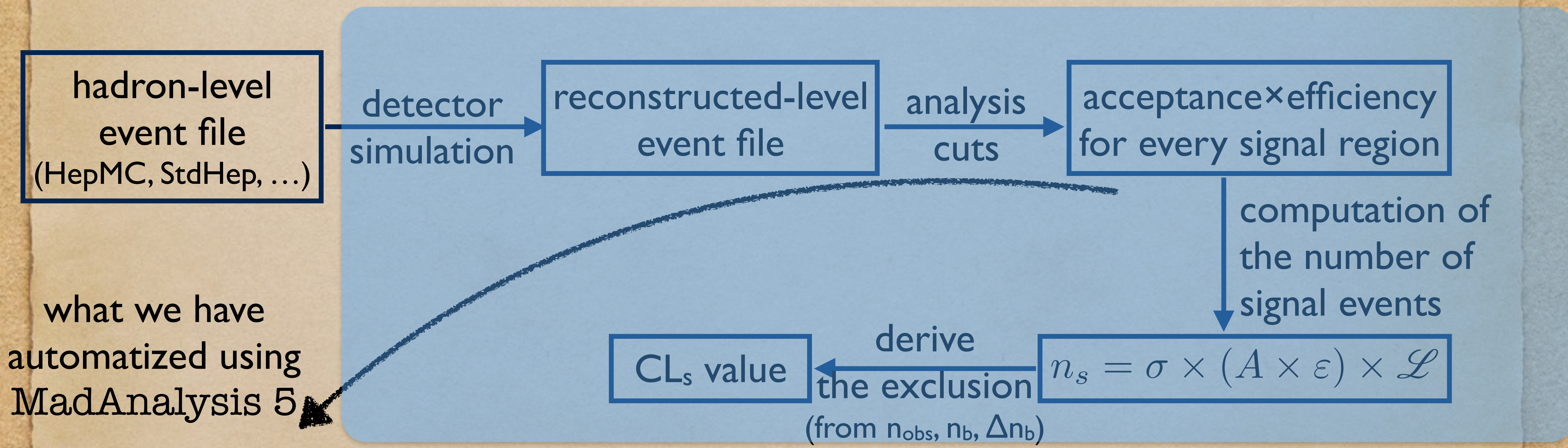
Constraints from the LHC RUN I

Reinterpreting LHC searches

- A large number of BSM models have been left unconstrained by LHC run I.
- However existing LHC searches (although not optimized) can constrain a large class of models.
  → separate implementation using publicly available tools.
- For phenomenological studies, "faithful" recasting of existing LHC searches required.

Generic Working principle:

$$(A \times \varepsilon) = \frac{N_{\text{after cuts}}}{N_{\text{before cuts}}}$$



The MadAnalysis5 framework

- what is MadAnalysis 5?
  - a public framework for phenomenological analyses
  - any level of sophistication: partonic, hadronic, detector reconstructed
  - several input format: StdHep, HepMC, LHE, LHCO, ROOT (from Delphes)
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ATLAS-SUSY-2013-21 (published)	0 leptons + mono-jet/c-jets + MET	G. Chalons, D. Sengupta	Inspire	PDF (source)	done
ATLAS-SUSY-2013-02 (published)	0 leptons + 2-6 jets + MET	G. Chalons, D. Sengupta	Inspire	PDF	done

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CMS-SUS-13-012 (published)	gluino/squark search in jet multiplicity and missing energy	S. Bein, D. Sengupta	Inspire	PDF (source)	done

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CMS-SUS-13-012 (published)	gluino/squark search in jet multiplicity and missing energy	S. Bein, D. Sengupta	Inspire	PDF (source)	done

The Public Analysis Database

Last modified on 08/26/15 11:12:00

MadAnalysis 5 Public Analysis Database for recasting LHC results

This page contains a collection of LHC analyses that have been implemented in the MadAnalysis 5 framework (in the expert mode) described in arXiv:1405.3982 and arXiv:1407.3278. For each analysis, a commented C++ code is available for download provided together with information on the analysis and references to relevant publications. A careful validation of each implementation is also provided.

In order to use these files, you need **MadAnalysis 5 version 1.1.12**, which can be downloaded here (beware, the latest version on Launchpad is 1.1.11 and will not have all the functionality described below). After installation of MadAnalysis 5 v1.1.12, you also need our modified version of Delphes. To install it, type

```
install delphesMA5tune
```

within MadAnalysis 5. If you have an older version of MadAnalysis 5, first update it to the latest one. Also, beware that the standard Delphes and delphesMA5tune cannot be used simultaneously!!

In order to use the code, you first need to create a working directory (that will be called *PAD*). You can also optionally install a couple of python tools that allows for limit and efficiency map extractions. However, in order to have those tools available in the *PAD* directory, they need to be installed prior to the creation of the working directory. You need to start MadAnalysis 5 as

```
./bin/ma5 -R
```

If you want to use our scripts for limit setting and efficiency maps (see below), next type

```
install RecastingTools
```

For creating a working directory that contains all the analyses that are publicly available, then type

```
install PAD
```

New analyses (within the PAD or separately) can be added by running the script newAnalyzer.py (located in Build/SampleAnalyzer), passing as an argument the name of the analysis of interest. For instance,

```
python newAnalyzer.py cms_sus_14_001
```

will create and modify the necessary files for adding the analysis named cms_sus_14_001. In particular, a pair of header and source C++ files cms_sus_14_001.cpp and cms_sus_14_001.h are now available in the subdirectory Build/SampleAnalyzer/User/Analyzer. You can now either implement the analysis yourself or replace the newly created files with those shared by somebody else (or downloaded from the list below in case you do not use the automatic PAD installation from above).

After execution of an analysis, **exclusion under the CLs prescription** can be computed with the Python code exclusion_CLs.py Note that it requires SciPy to be installed. The path to the working directory of interest has to be provided in the variable analysis_path in the beginning of the code. If you have done *install RecastingTools*, then a local copy of exclusion_CLs.py is available in every new working directory. The code is called as

Available Analyses

!! please properly cite all the re-implementation codes you are using (see Inspire citation entry) !!

ATLAS analyses, 8 TeV

Analysis	Short Description	Implemented by	Code	Validation note	Status
ATLAS-SUSY-2013-05 (published)	stop/sbottom search: 0 leptons + 2 b-jets	G. Chalons	Inspire	PDF (figures)	done
ATLAS-SUSY-2013-11 (published)	EWK-inos, 2 leptons + MET	B. Dumont	Inspire	PDF (source)	done
ATLAS-HIGG-2013-03 (published)	ZH->ll+invisible	B. Dumont	Inspire	PDF (source)	done
ATLAS-EXOT-2014-				PDF	

- http://madanalysis.irmp.ucl.ac.be/wiki/PhysicsAnalysisDatabase

Validation of the ATLAS monojet (PRD90(052008))

- Analysis looks for stop >c +LSP SMS with monojet + MET
- Documentation in ATLAS-SUSY-2013-21.
- Data points and validation material available in http://hepdata.cedar.ac.uk/view/ins1304459.
- Monte Carlo configuration, cutflows , validation plots available in the conf. note.

Benchmark $(m_{\tilde{g}}, m_{\tilde{\chi}_1^0})$	(200/125) GeV		(200/195) GeV		(250/245) GeV	
	MA 5	CMS	MA 5	CMS	MA 5	CMS
cut	result	result	result	result	result	result
$E_T^{\rm miss} > 80$ GeV Filter	192812.8	181902.0	104577.6	103191.0	36055.4	48103.0
$E_T^{\rm miss} > 100$ GeV	136257.1	97217.0	82619.0	64652.0	29096.3	23416.0
Event cleaning	-	82131.0	-	57566.0	-	21023.0
Lepton veto	134894.2	81855.0	82493.9	57455.0	29041.8	20986.0
$N_{\rm jets} \leq 3$	101653.7	59315.0	75391.5	52491.0	26295.2	18985.0
$\Delta\phi(E_T^{\rm miss}, {\rm jets}) > 0.4$	95568.8	54295.0	70888.1	49216.0	24676.9	17843.0
$p_T(j_1) > 150$ GeV	17282.8	14220.0	25552.0	20910.0	9652.1	8183.0
$E_T^{\rm miss} > 150$ GeV	10987.8	9468.0	21569.1	18297.0	8363.0	7290.0
M1 Signal Region						
$p_T(j_1) > 280$ GeV	2031.2	1627.0	4922.0	3854.0	2156.1	1748.0
$E_T^{\rm miss} > 220$ GeV	1517.6	1276.0	4628.4	3722.0	2022.9	1694.0
M2 Signal Region						
$p_T(j_1) > 340$ GeV	858.0	721.0	2509.0	1897.0	1107.4	882.0
$E_T^{\rm miss} > 340$ GeV	344.4	282.0	1758.9	1518.0	817.5	736.0
M3 Signal Region						
$p_T(j_1) > 450$ GeV	204.3	169.0	773.3	527.0	376.1	279.0
$E_T^{\rm miss} > 450$ GeV	61.3	64.0	476.8	415.0	268.0	230.0

Validation of the ATLAS monojet (PRD90(052008))

- Analysis looks for stop >c +LSP SMS with monojet + MET
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Benchmark $(m_{\tilde{g}}, m_{\tilde{\chi}_1^0})$	(200/125) GeV		(200/195) GeV		(250/245) GeV	
	MA 5	CMS	MA 5	CMS	MA 5	CMS
cut	result	result	result	result	result	result
$E_T^{miss} > 80$ GeV Filter	192812.8	181902.0	104577.6	103191.0	36055.4	48103.0
$E_T^{miss} > 100$ GeV	136257.1	97217.0	82619.0	64652.0	29096.3	23416.0
Event cleaning	-	82131.0	-	57566.0	-	21023.0
Lepton veto	134894.2	81855.0	82493.9	57455.0	29041.8	20986.0
$N_{jets} \leq 3$	101653.7	59315.0	75391.5	52491.0	26295.2	18985.0
$\Delta\phi(E_T^{miss}, \text{jets}) > 0.4$	95568.8	54295.0	70888.1	49216.0	24676.9	17843.0
$p_T(j_1) > 150$ GeV	17282.8	14220.0	25552.0	20910.0	9652.1	8183.0
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Validation of the ATLAS Multijet (JHEP09(2014)176)

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- Data points and validation material available in http://hepdata.cedar.ac.uk/view/ins1298722.
- Monte Carlo configuration, outflows validation plots available in the conf. note.

Benchmark/SR	2jm ($\tilde{q}\tilde{q}$)		2jt($\tilde{q}\tilde{q}$)		3j($\tilde{g}\tilde{q}$)	
	MA 5	ATLAS	MA 5	ATLAS	MA 5	ATLAS
cut	result	result	result	result	result	result
$E_T^{\text{miss}} > 160$, $p_T(j_1, j_2) > 130{,}60$	1656.1	1781.2	62.1	61.6	18.8	18.6
$p_T(j_3) > 60$	–	–	–	–	15.1	14.8
$\Delta\phi(j_i, E_T^{\text{miss}}) > 0.4$	1295.9	1462.7	56.9	55.7	13.3	12.9
$E_T^{\text{miss}}/\sqrt{H_T}$	449.1	566.1	40.1	38.5	–	–
$E_T^{\text{miss}}/M_{\text{eff}}(N_j)$	–	–	–	–	10.1	9.6
M_{eff}(incl)	122.2	102.4	23.8	21.7	6.2	5.9

Benchmark/SR	4jl-($\tilde{q}\tilde{q}$)		4jl($\tilde{g}\tilde{g}$)		4jt($\tilde{g}\tilde{g}$)	
	ATLAS	MA 5	ATLAS	MA 5	ATLAS	MA 5
cut	result	result	result	result	result	result
$E_T^{\text{miss}} > 160$, $p_T(j_1, j_2) > 130{,}60$	16135.8	15097	634.6	679.0	13.2	12.7
$p_T(j_3, j_4) > 60$	2331	2112	211.4	185.7	12.0	12.0
$\Delta\phi(j_{i\leq 3}, E_T^{\text{miss}}) > 0.4$ $\Delta\phi(j_4, E_T^{\text{miss}}) > 0.2$	1813.7	1723.0	154.6	144.9	8.4	8.9
$E_T^{\text{miss}}/\sqrt{H_T}$	1009	943	98.7	84.4	–	–
$E_T^{\text{miss}}/M_{eff}(N_j)$	–	–	–	–	4.8	5.5
M_{eff}(incl)	884	843	39.5	41.5	2.5	2.9

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Exceptionally good validation

Validation of the ATLAS Multijet (JHEP09(2014)176)

- Analysis looks for gluino > qq' +LSP SMS in 0 leptons + 2-6 jets + MET
- Documentation in ATLAS-SUSY-2013-02.
- Data points and validation material available in http://hepdata.cedar.ac.uk/view/ins1298722.
- Monte Carlo configuration, outflows validation plots available in the conf. note.

Benchmark/SR cut	2jm ($\tilde{q}\tilde{q}$) MA 5 result	2jm ($\tilde{q}\tilde{q}$) ATLAS result	2jt($\tilde{q}\tilde{q}$) MA 5 result	2jt($\tilde{q}\tilde{q}$) ATLAS result	3j($\tilde{g}\tilde{q}$) MA 5 result	3j($\tilde{g}\tilde{q}$) ATLAS result
$E_T^{\rm miss} > 160$, $p_T(j_1, j_2) > 130{,}60$	1656.1	1781.2	62.1	61.6	18.8	18.6
$p_T(j_3) > 60$	–	–	–	–	15.1	14.8
$\Delta\phi(j_i, E_T^{\rm miss}) > 0.4$	1295.9	1462.7	56.9	55.7	13.3	12.9
$E_T^{\rm miss}/\sqrt{H_T}$	449.1	566.1	40.1	38.5	–	–
$E_T^{\rm miss}/M_{\rm eff}(N_j)$	–	–	–	–	10.1	9.6
$M_{\rm eff}$(incl)	122.2	102.4	23.8	21.7	6.2	5.9

Benchmark/SR cut	4jl-($\tilde{q}\tilde{q}$) ATLAS result	4jl-($\tilde{q}\tilde{q}$) MA 5 result	4jl($\tilde{g}\tilde{g}$) ATLAS result	4jl($\tilde{g}\tilde{g}$) MA 5 result	4jt($\tilde{g}\tilde{g}$) ATLAS result	4jt($\tilde{g}\tilde{g}$) MA 5 result
$E_T^{\rm miss} > 160$, $p_T(j_1, j_2) > 130{,}60$	16135.8	15097	634.6	679.0	13.2	12.7
$p_T(j_3, j_4) > 60$	2331	2112	211.4	185.7	12.0	12.0
$\Delta\phi(j_{i\leq 3}, E_T^{\rm miss}) > 0.4$ $\Delta\phi(j_4, E_T^{\rm miss}) > 0.2$	1813.7	1723.0	154.6	144.9	8.4	8.9
$E_T^{\rm miss}/\sqrt{H_T}$	1009	943	98.7	84.4	–	–
$E_T^{\rm miss}/M_{eff}(N_j)$	–	–	–	–	4.8	5.5
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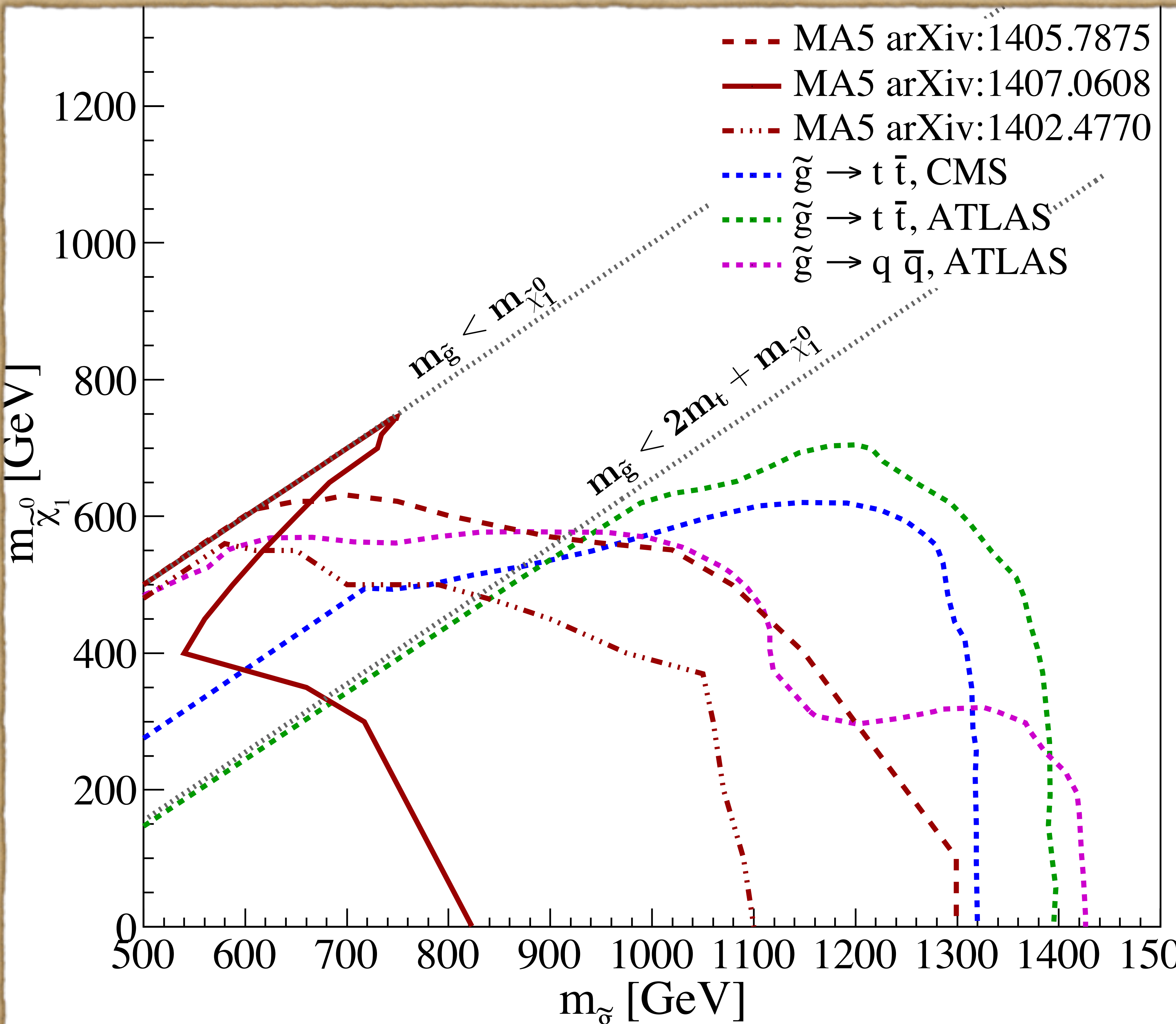
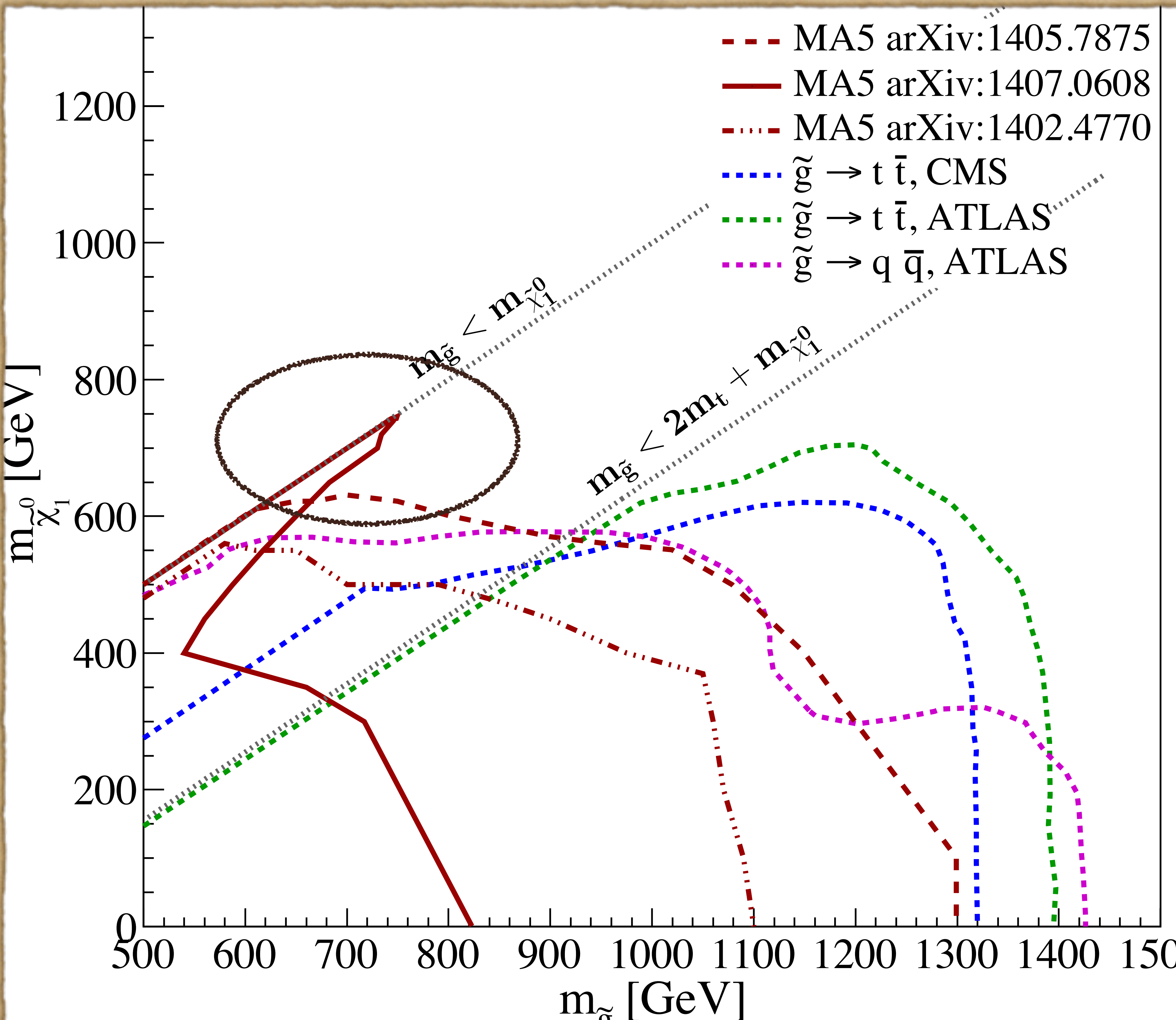
Exceptionally good validation

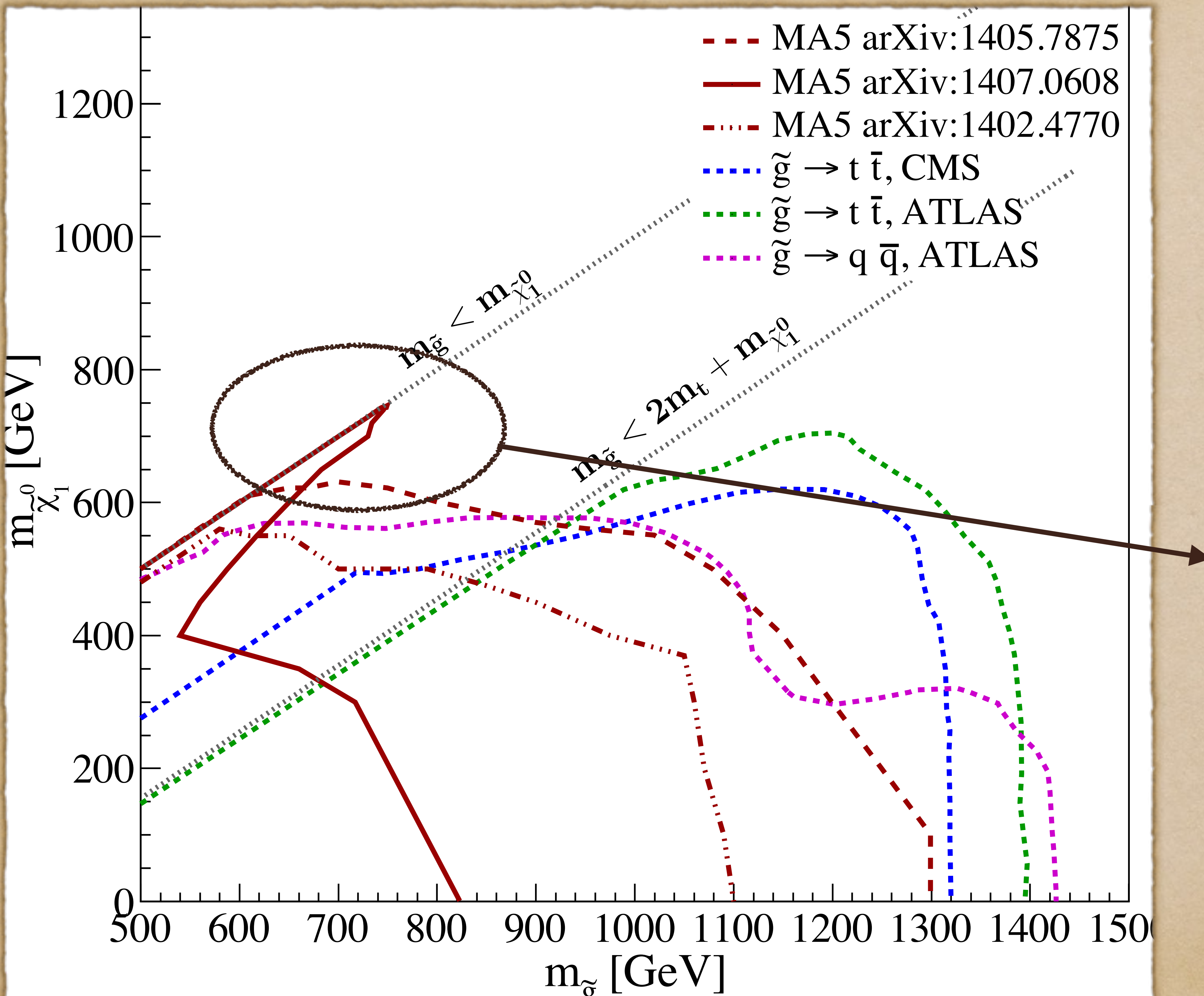
Constraints from RUN I



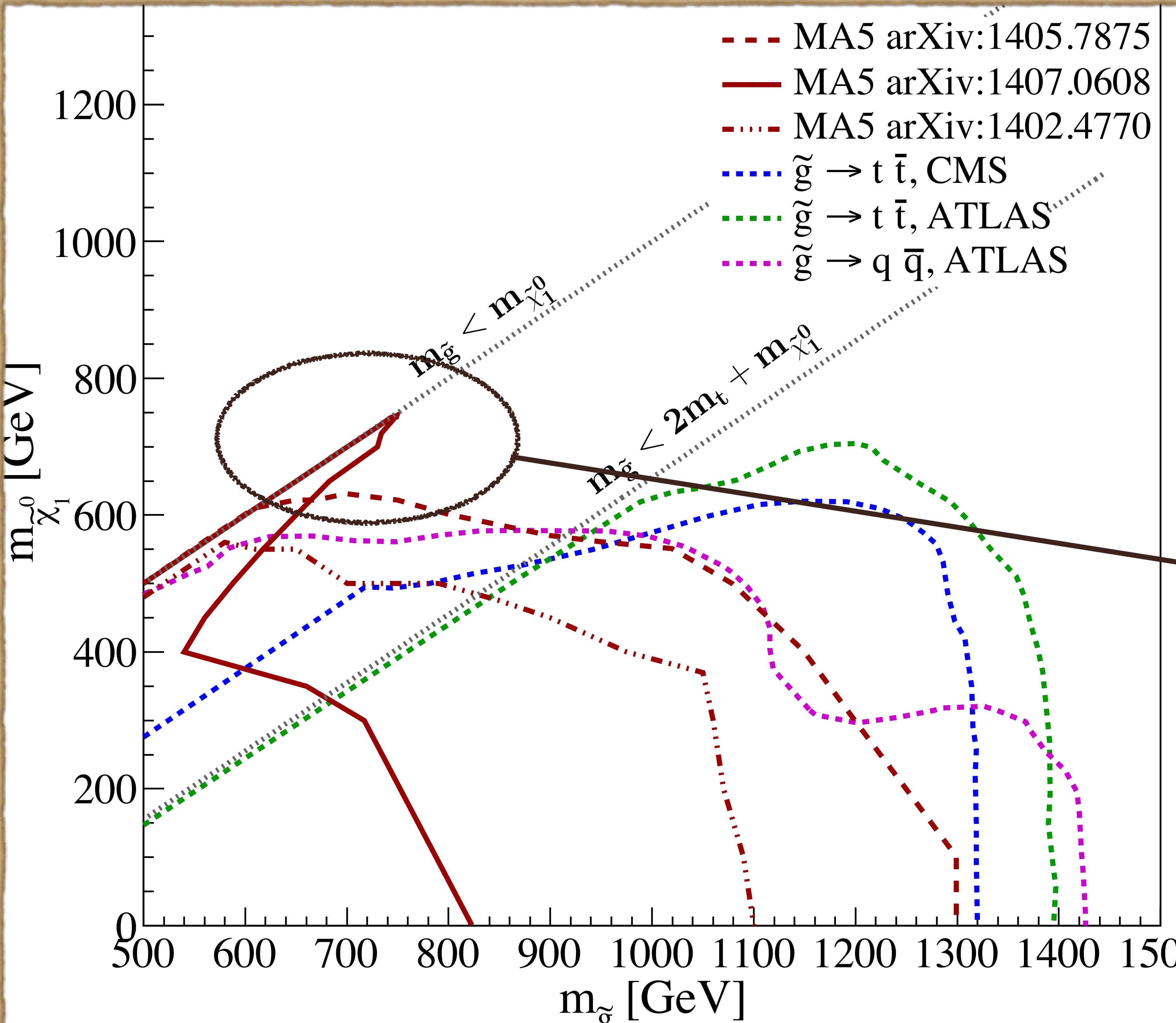
Constraints from RUN I



Constraints from RUN I



Constraints from RUN I



New region constrained

Prospects for RUN II

Designing an analysis for 13 TeV

- Designing an analysis for the low mass gap scenario. (of the order of 10 GeV.)
- Expected more radiation jets at 13 TeV.
- Use a di-jet + missing energy scenario instead of the standard monojet (from ISR).
- Use M_{T2} to suppress the background.

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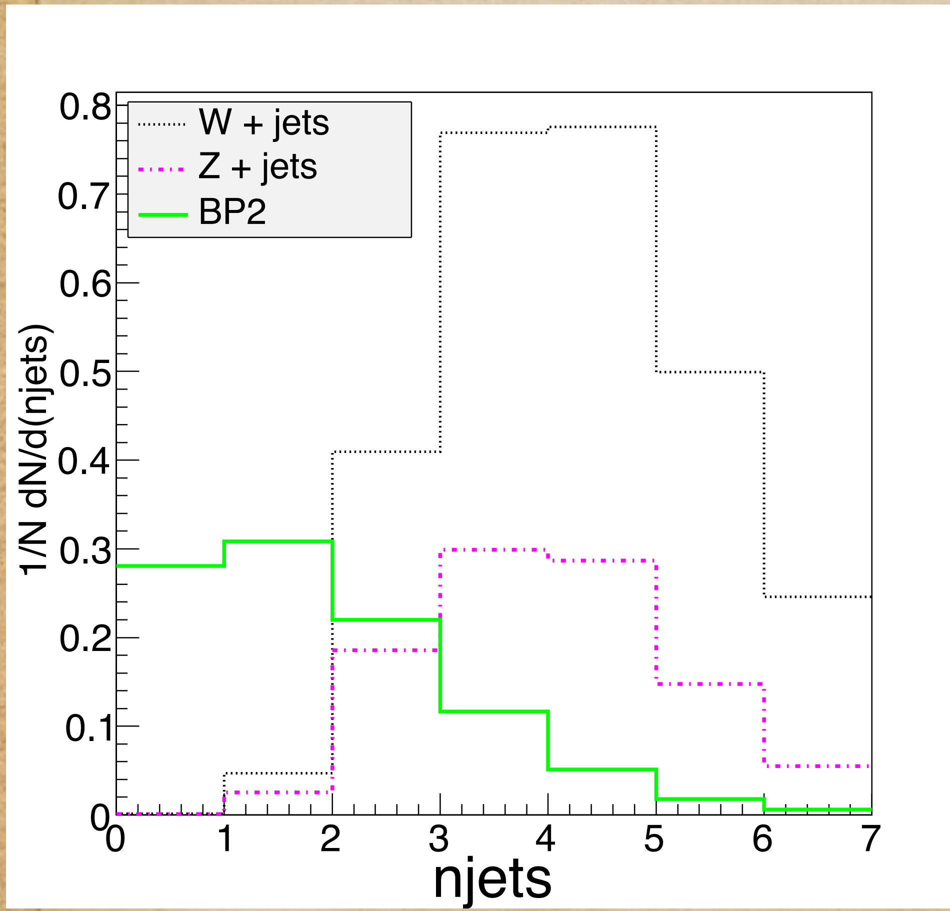

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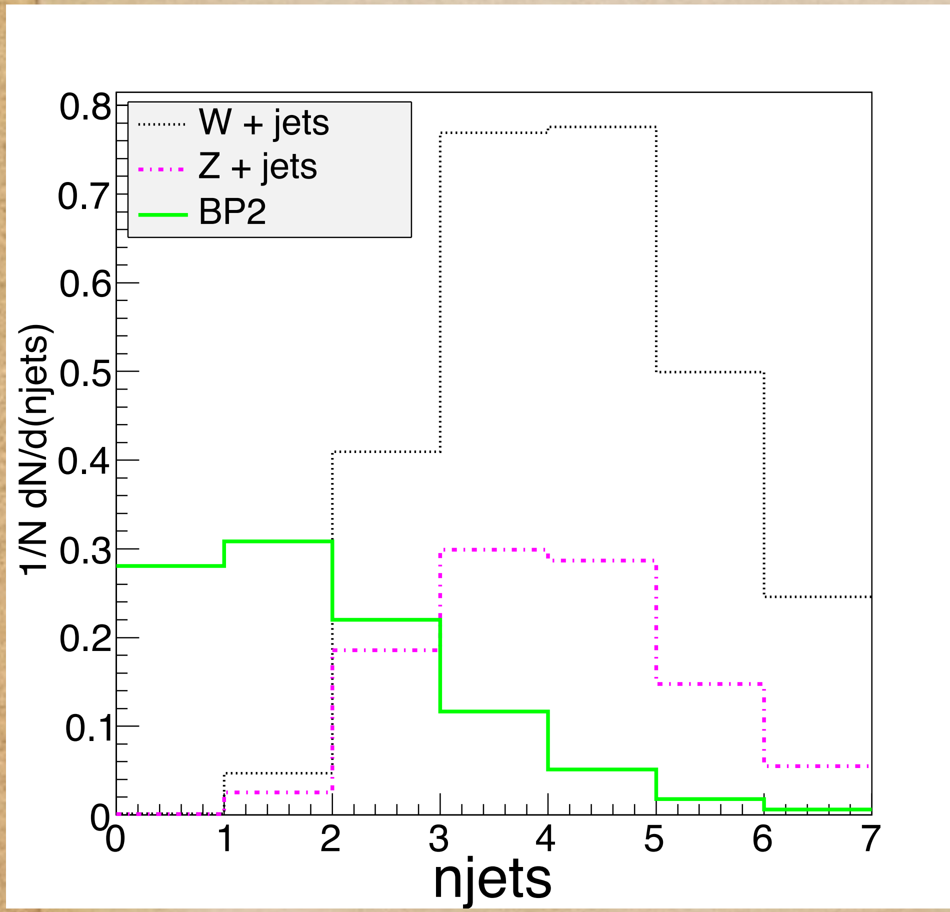
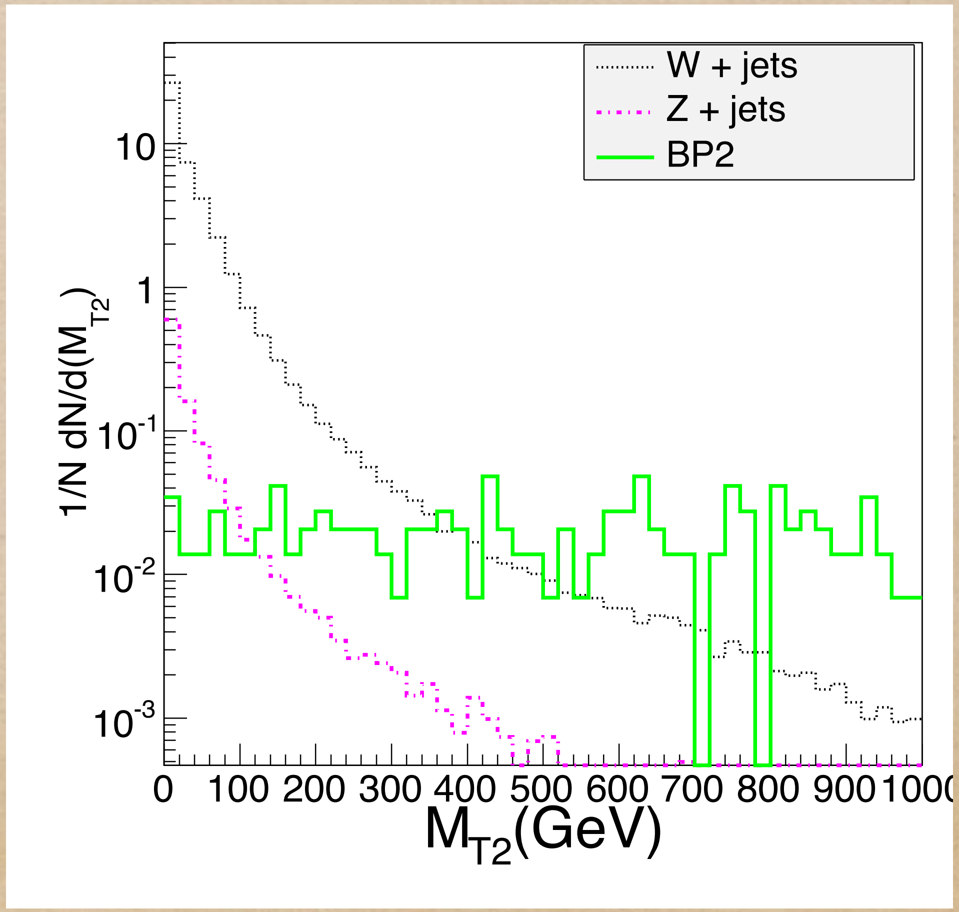




Designing an analysis for 13 TeV

- MadGraph 5 to generate the signal and backgrounds.
- Additional 3 partons generated at the hard matrix element level.
- PYTHIA6 to shower and hadronize, Fastjet for jet reconstruction followed by DELPHES 3 for detector simulation.
- Merging parameter set to 50 GeV.
- Backgrounds generated W/Z+ jets, tt+ jets, ZZ, WZ, WW, QCD.

Desigining an analysis for 13 TeV

- Lepton veto to suppress the weak backgrounds.
- b-jet veto to suppress the tt + jets backgrounds.
- $P_T^{J1} > 600$ GeV, $P_T^{J2} > 200$ GeV.
- $M_{T2} > 800$ GeV.

	P1	P2	P3
$m_{\tilde{g}}, m_{\tilde{\chi}_1^0}$(GeV)	1005,999	1205,1195	1405,1395
$S/\sqrt{B}(30\ \mathrm{fb}^{-1})$	5.3	2.0	0.7
$S/\sqrt{B}(100\ \mathrm{fb}^{-1})$	9.7	3.7	1.27
$S/\sqrt{B}(3000\ \mathrm{fb}^{-1})$	53	20	7

- Expected discovery Reach: 1 TeV with 30 fb^{-1} luminosity.
- Expected discovery reach : 1.4 TeV with 3000 fb^{-1} luminosity.

Conclusions

- We investigated the region of parameter space where the radiative gluino decay is dominant.
- The loop induced decay dominates for a pure higgsino like neutrino till the tb threshold is reached.
- We reinterpreted ATLAS and CMS simplified model searches to constrain this decay mode.
- At Run I a gluino mass of 740 GeV is excluded for mass degenerate scenarios.
- A full simulation to investigate the prospects of this decay at 13 TeV for small mass gap situations was performed.
- A gluino mass of up to 1 TeV can be discovered with 30 fb^{-1} luminosity at LHC and up to 1.5 TeV at HL-LHC.

Backups

3 body decays

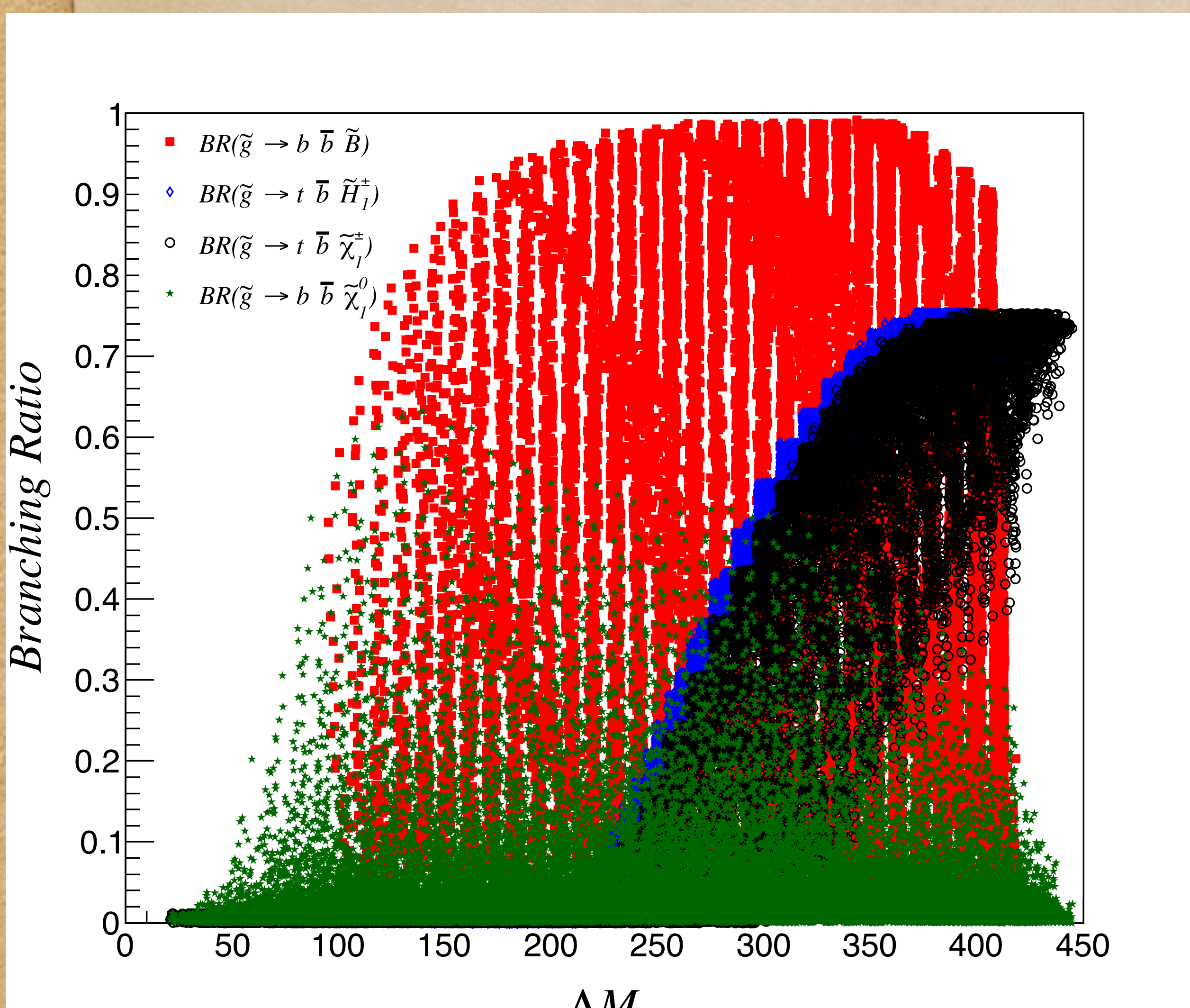
$$\Gamma(\tilde{g} \to q_L q_R^c \widetilde{B}) = \frac{\alpha \alpha_s Y_{q_L}}{96\pi \cos^2\theta_W} \frac{m_{\tilde{g}}^5}{m_{\tilde{q}_L}^4} \left[f\left(\frac{m_{\widetilde{B}}^2}{m_{\tilde{g}}^2}\right) + \frac{2m_{\widetilde{B}}}{m_{\tilde{g}}} g\left(\frac{m_{\widetilde{B}}^2}{m_{\tilde{g}}^2}\right) \right]$$

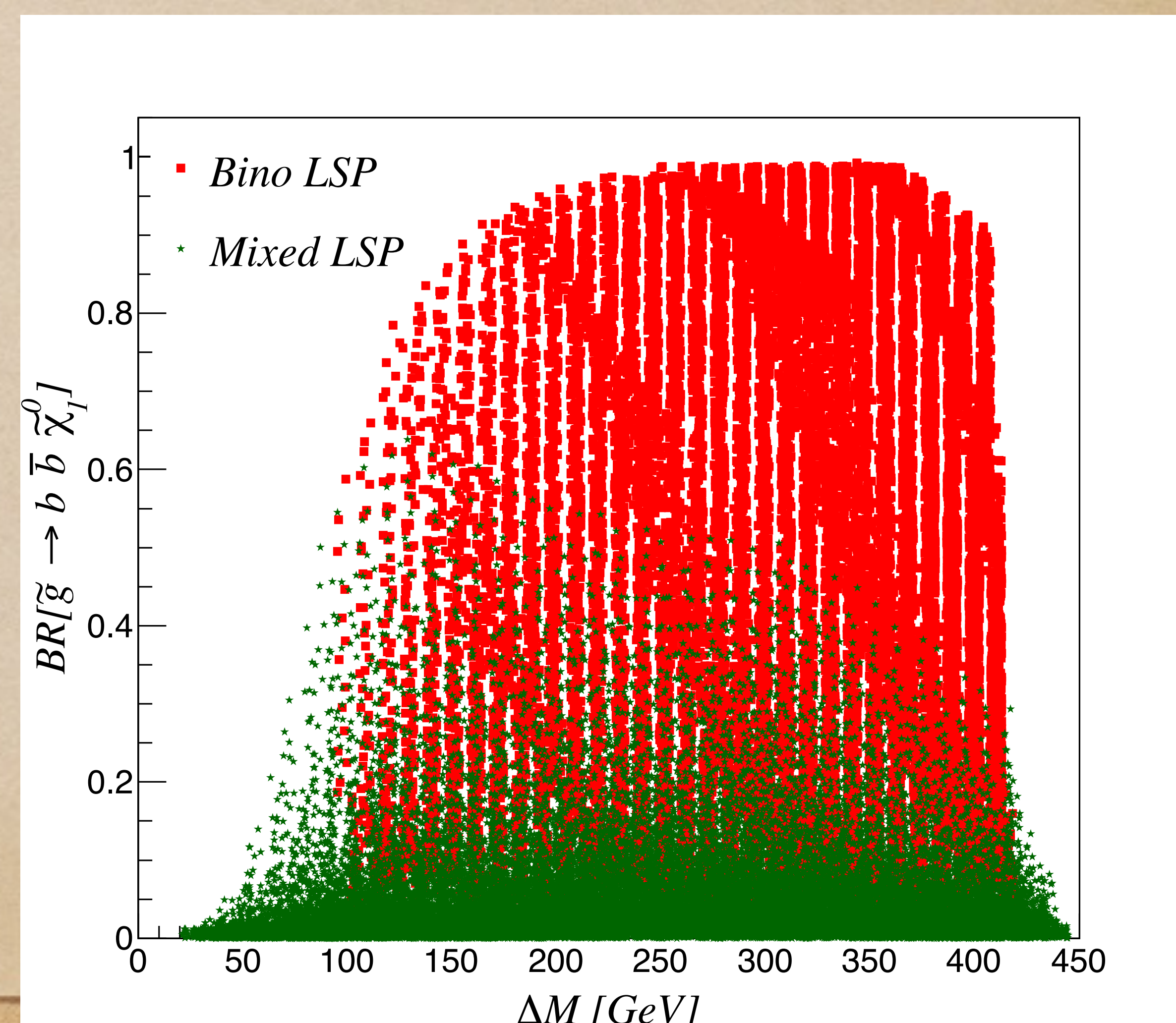
$$\Gamma(\tilde{g} \to q\bar{q}\tilde{\chi}_i^0) \simeq \frac{\alpha_s m_{\tilde{g}}^5}{384\pi^2} \sum_q \left[\frac{|a_q|^2 + |b_{q_L}|^2}{m_{\tilde{q}_L}^4} + \frac{|a_q|^2 + |b_{q_R}|^2}{m_{\tilde{q}_R}^4} \right]$$

e sum is over all quark species allowed by kinematics. The a, b, c coefficients a

$$a_u = \frac{g m_u N_{i4}}{2 M_W \sin\beta}, \quad a_d = \frac{g m_d N_{i3}}{2 M_W \cos\beta},$$

$$b_{q_L} = g\left(\frac{Y_{q_L}}{2} \tan\theta_W N_{i1} + T_3^{q_L} N_{i2}\right), \quad b_{q_R} = g Q_q \tan\theta_W N_{i1}$$

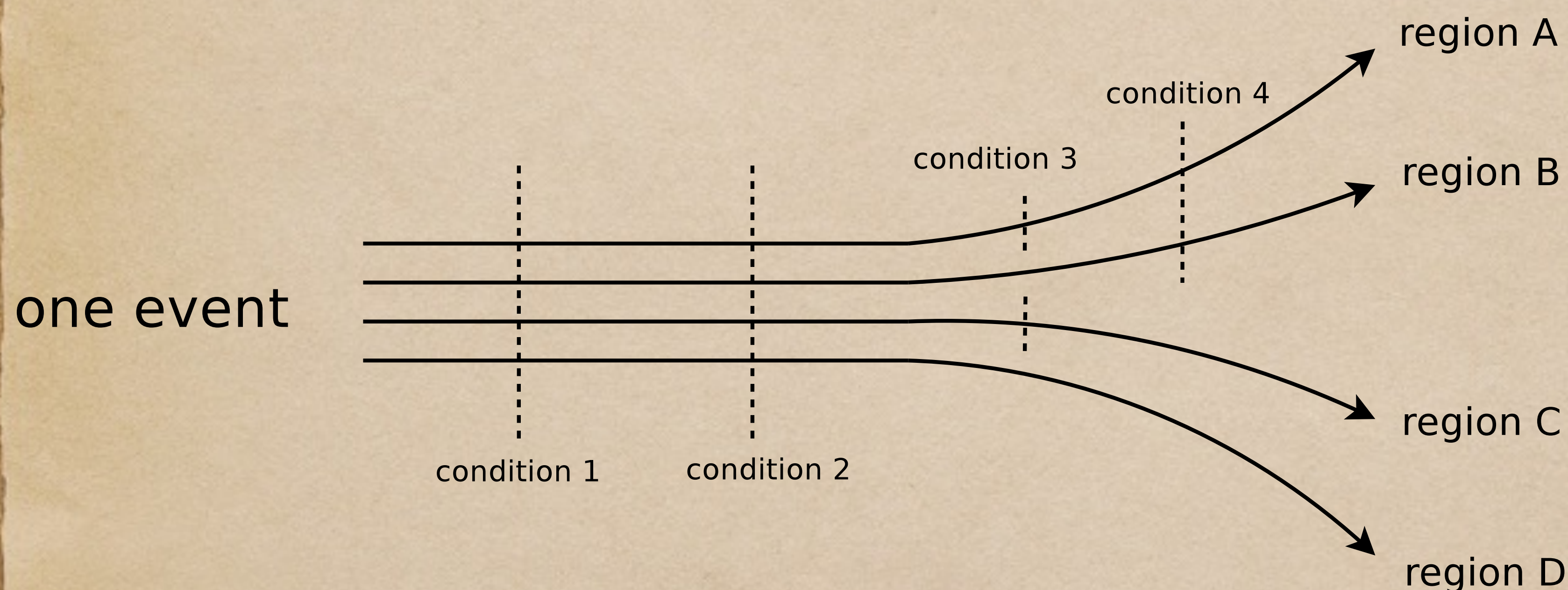




MadAnalysis5

recent extensions of the expert mode:

- support for several sub-analyses
- new ready-to-use observables (M_{T2}, M^W_{T2})
- new optimized handling of cuts and histograms




```
if (condition 3)
{
  count the event in region C
  if (condition 4)
  {
    count the event in region A
  }
}
if (condition 4)
{
  count the event in region B
}
```

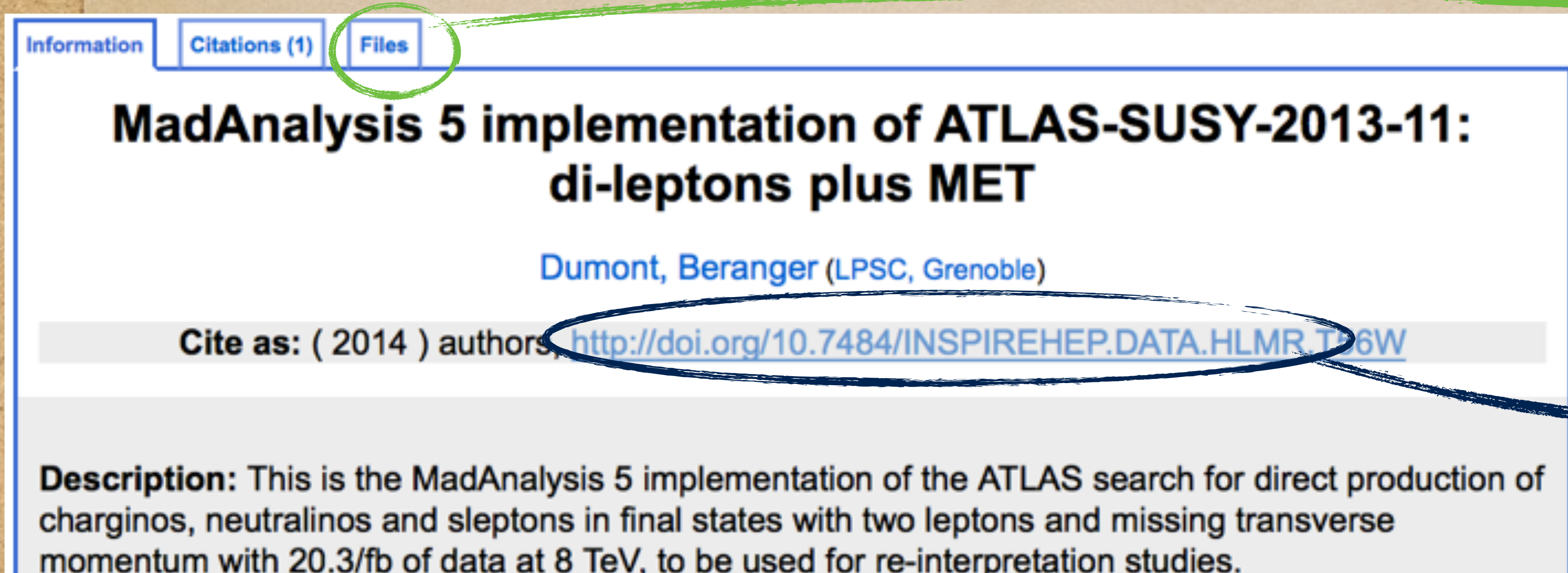
- a more efficient algorithm has been implemented
  - each cut condition is only evaluated once
  - it is applied to all "surviving" regions simultaneously
- similar treatment for histograms

Public analysis database

- we started to build a public database of LHC analyses in the MadAnalysis 5 framework can easily be used to constrain generic new physics scenarios

- instructions on how to install and run MadAnalysis 5 on event files using LHC analyses as well as available analyses and corresponding validation notes are listed at: http://madanalysis.irmp.ucl.ac.be/wiki/PhysicsAnalysisDatabase

- analyses are submitted to INSPIRE and are given a DOI, hence are searchable and citable example:


Information | Citations (1) | Files

MadAnalysis 5 implementation of ATLAS-SUSY-2013-11: di-leptons plus MET

Dumont, Beranger (LPSC, Grenoble)

Cite as: (2014) authors, http://doi.org/10.7484/INSPIREHEP.DATA.HLMR.T56W

Description: This is the MadAnalysis 5 implementation of the ATLAS search for direct production of charginos, neutralinos and sleptons in final states with two leptons and missing transverse momentum with 20.3/fb of data at 8 TeV, to be used for re-interpretation studies.

analysis code in C++

DOI

Deriving limits

- we also provide a statistical tool for deriving limits: exclusion_CLs.py
- it derives exclusion under the CL_s prescription based on n_s, n_{obs}, n_b, and Δn_b
  (can also return the upper limit on the model cross section at 95% CL)
- in case of multiple signal regions: the best expected signal region is selected for the exclusion

XML .info file
(provided on INSPIRE
along with the analysis code)

```xml
<analysis id="atlas_susy_2013_11">
  <lumi>20.3</lumi> <!-- in fb^-1 -->

  <region type="signal" id="MT2-90 emu">
    <nobs>21</nobs>
    <nb>23.3</nb>
    <deltanb>3.7</deltanb>
  </region>

  ... ... ...

</analysis>
```

execution of exclusion_CLs.py
(reads the .info file,
the acceptance×efficiency from MA5 output,
and the signal cross section)

```
[dumont@lpsc4008x pad]$ ./exclusion_CLs.py \
> atlas_susy_2013_11 C1C1_noslep_100.0_0.0.list 0 0.606
The best expected signal region is "WWa emu".
It has: nobs = 70, nb = 73.6 \pm 7.9, nsignal = 28.79.

This signal is excluded at the 98.9% CL (CLs=0.011).
```

More of ATLAS MULTIJET validation

Benchmark/SR cut	2jm ($\tilde{q}\tilde{q}$) MA 5 result	ATLAS result	2jt ($\tilde{q}\tilde{q}$) MA 5 result	ATLAS result	3j ($\tilde{g}\tilde{q}$) MA 5 result	ATLAS result
$E_T^{miss} > 160$, $p_T(j_1, j_2) > 130{,}60$	1656.1	1781.2	62.1	61.6	18.8	18.6
$p_T(j_3) > 60$	–	–	–	–	15.1	14.8
$\Delta\phi(j_i, E_T^{miss}) > 0.4$	1295.9	1462.7	56.9	55.7	13.3	12.9
$E_T^{miss}/\sqrt{H_T}$	449.1	566.1	40.1	38.5	–	–
$E_T^{miss}/M_{\text{eff}}(N_j)$	–	–	–	–	10.1	9.6
M_{eff}(incl)	122.2	102.4	23.8	21.7	6.2	5.9

Table 7: *Cutflows for signal regions 2jm,2jt and 3j, compared to the official ATLAS results documented in [86]. All energy units are in GeV.*

Benchmark/SR cut	4jl-($\tilde{q}\tilde{q}$) ATLAS result	MA 5 result	4jl($\tilde{g}\tilde{g}$) ATLAS result	MA 5 result	4jt($\tilde{g}\tilde{g}$) ATLAS result	MA 5 result
$E_T^{miss} > 160$, $p_T(j_1, j_2) > 130{,}60$	16135.8	15097	634.6	679.0	13.2	12.7
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$E_T^{miss}/\sqrt{H_T}$	1009	943	98.7	84.4	–	–
$E_T^{miss}/M_{eff}(N_j)$	–	–	–	–	4.8	5.5
M_{eff}(incl)	884	843	39.5	41.5	2.5	2.9

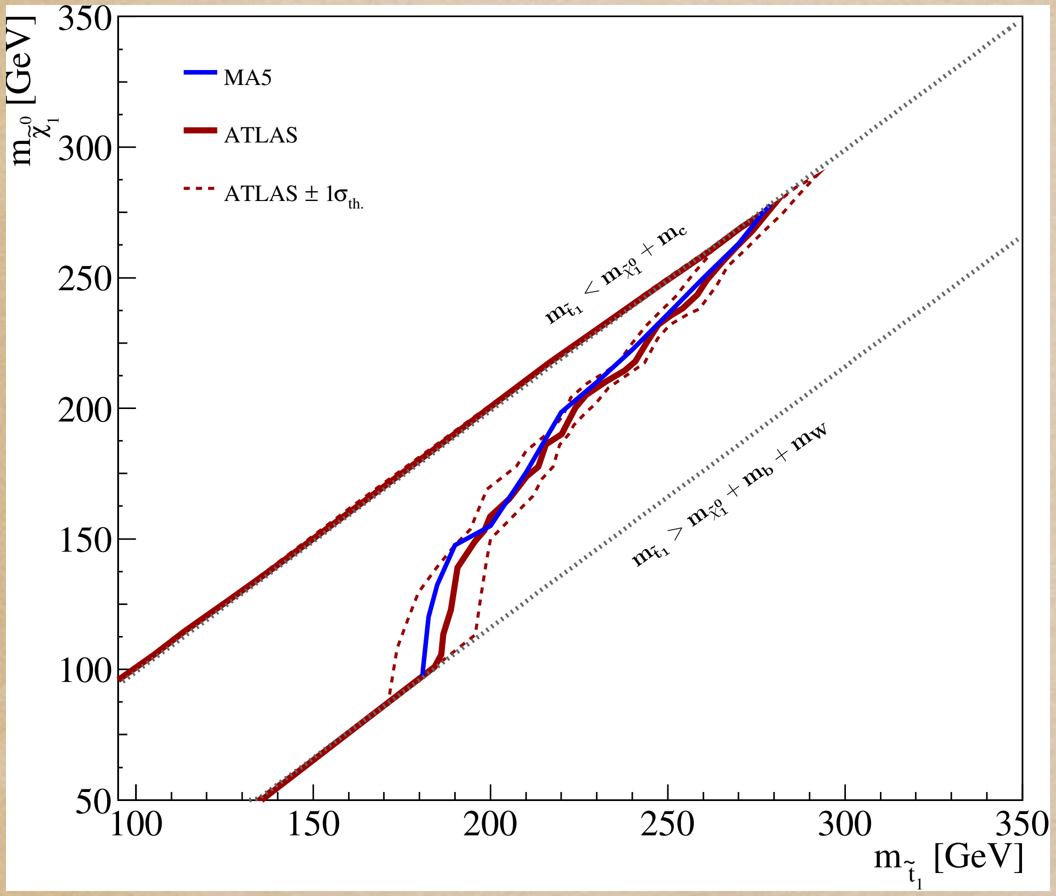
Table 8: *Cutflows for signal regions 4jl-,4jl and 4jt, compared to the official ATLAS results documented in [86].*

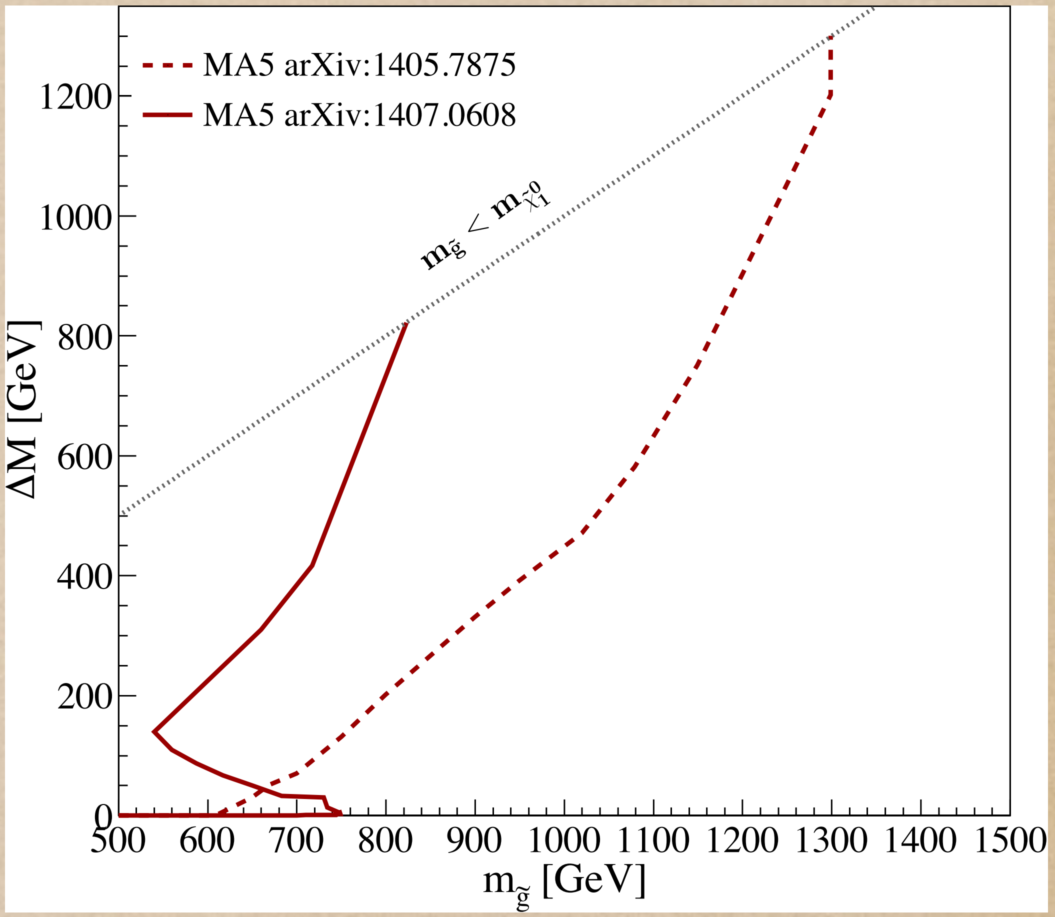
	4jl-($\tilde{q}\tilde{q}$)		4jl($\tilde{g}\tilde{g}$)		4jt($\tilde{g}\tilde{g}$)	
cut	ATLAS	MA 5	ATLAS	MA 5	ATLAS	MA 5
$E_T^{miss} > 160$, $p_T^{j1,j2} > 130{,}60$	16135.8	15097	634.6	679.0	13.2	12.7
$+\ p_T^{j3,j4} > 60$	2331	2112	211.4	185.7	12.0	12.0
$+\ \Delta\phi(j_{i\leq 3}, E_T^{miss}) > 0.4$ $\Delta\phi(j4, E_T^{miss}) > 0.2$	1813.7	1723.0	154.6	144.9	8.4	8.9
$+\ E_T^{miss}/\sqrt{H_T}$	1009	943	98.7	84.4	–	–
$+\ E_T^{miss}/M_{eff}(N_j)$	–	–	–	–	4.8	5.5
$+$ M$_{\text{eff}}$(incl)	884	843	39.5	41.5	2.5	2.9

Table 4: Cutflows for signal regions 4jl-,4jl and 4jt, compared to the official ATLAS results documented in [1].

	5j1($\tilde{q}\tilde{q}$)		5j2($\tilde{g}\tilde{g}$)		6jl($\tilde{g}\tilde{g}$)		6jt($\tilde{g}\tilde{g}$)	
cut	ATLAS	MA 5	ATLAS	MA 5	ATLAS	MA 5	ATLAS	MA 5
$E_T^{miss} > 160$, $p_T^{j1,j2} > 130{,}60$	317.3	262.2	190.4	190.4	451.3	913.6	27.9	28.8
$+\ p_T^{j_i} > 60$	141.8	138.1	60.7	60.7	43.5	29	13.9	12.1
$+\ \Delta\phi(j_{i\leq 3}, E_T^{miss}) > 0.4$ $\Delta\phi(j_i > 3, E_T^{miss}) > 0.2$	103.9	107.1	44.5	45.8	23.7	19.0	9.5	9.0
$+\ E_T^{miss}/\sqrt{H_T}$	–	–	–	–	–	–	–	–
$+\ E_T^{miss}/M_{eff}(N_j)$	85.6	91.9	38	39.2	20	17.4	5.7	5.7
$+\ M_{eff}(incl)$	20.5	24.2	23.8	27.5	20	15.4	2.2	2.8

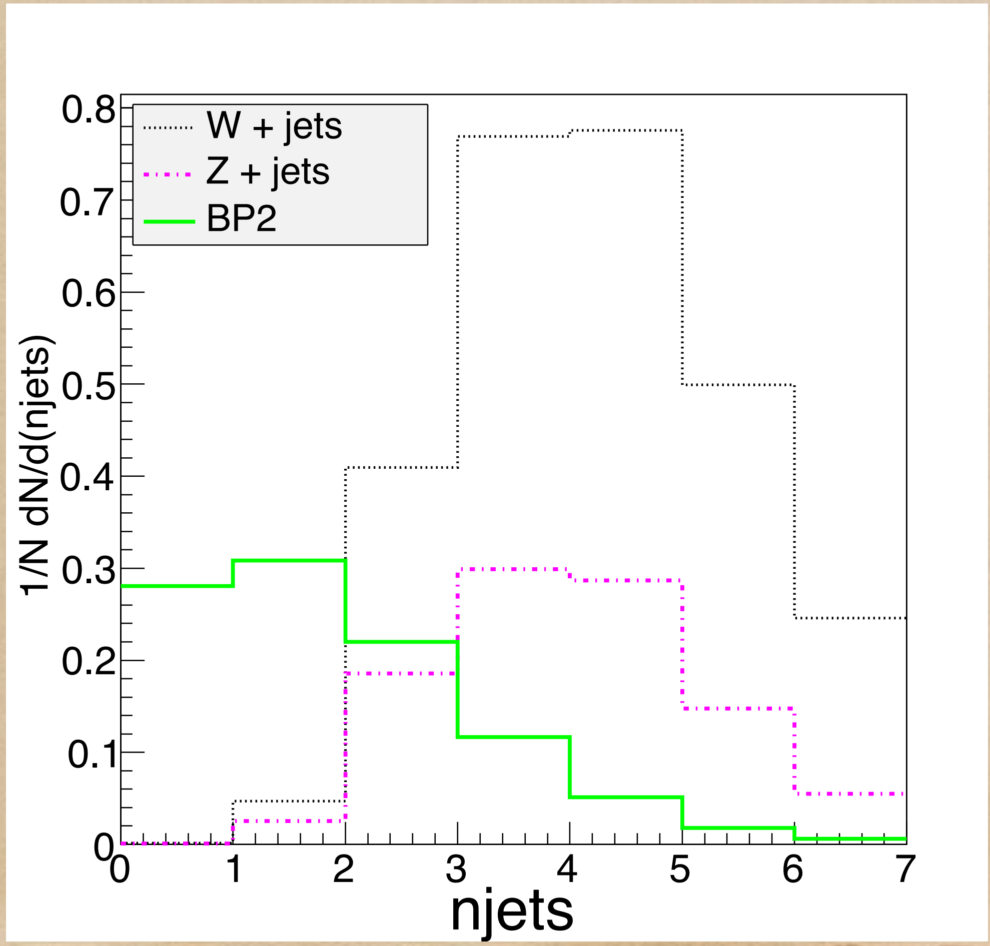
Exclusion plot for ATLAS monojet

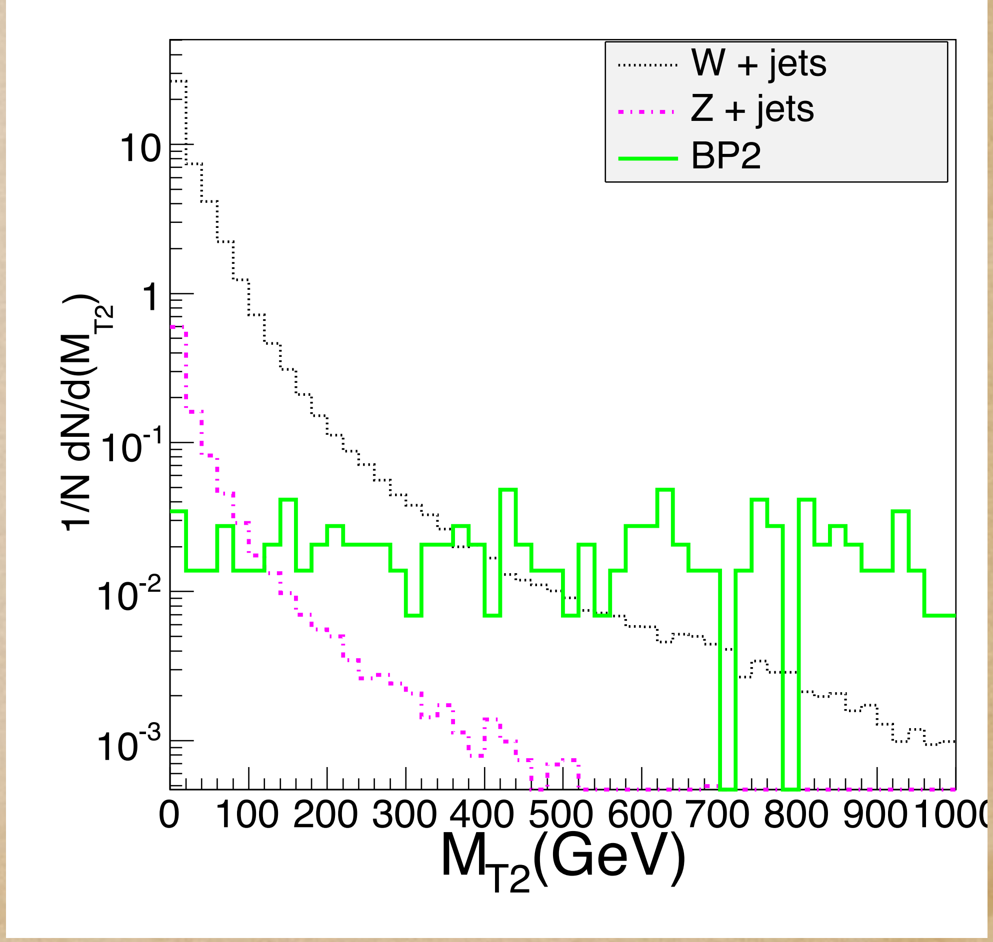




Details of the 13 TeV simulation : Benchmark points and Plots

	BP1	BP2	BP3
M_3	730	820	1100
μ	985	1180	1370
$\mathrm{m}_{\tilde{\mathrm{g}}}$	1005	1205	1405
$\mathrm{m}_{\tilde{\chi}_1^0}$	995	1195	1395
$\mathrm{m}_{\tilde{\chi}_2^0}$	1004	1201	1398
$\mathrm{BR}(\tilde{\mathrm{g}} \to \mathrm{g}\,\tilde{\chi}_1^0)(\%)$	99	53	47
$\mathrm{BR}(\tilde{\mathrm{g}} \to \mathrm{g}\,\tilde{\chi}_2^0)(\%)$	1	45	47





Cutflows for 13 TeV

	$m_{\tilde{g}_1}, m_{\tilde{\chi}_1^0}$	C.S	N	C1+C2+C3	C4	C5
	(GeV)	fb				
BP1	1005,999	314	100K	134	4.2	1.6
BP2	1205,1195	83	100K	46	2.3	0.6
BP3	1405,1395	24	100K	12	0.7	0.21
Z + jets		1.7×10^8	5M	783250	12395	1.7
W+ jets		5.8×10^8	5M	31921.1	7793.1	1.0