Hi!

Making the most of simplified models results

Suchita Kulkarni (LPSC, Grenoble)

based on:

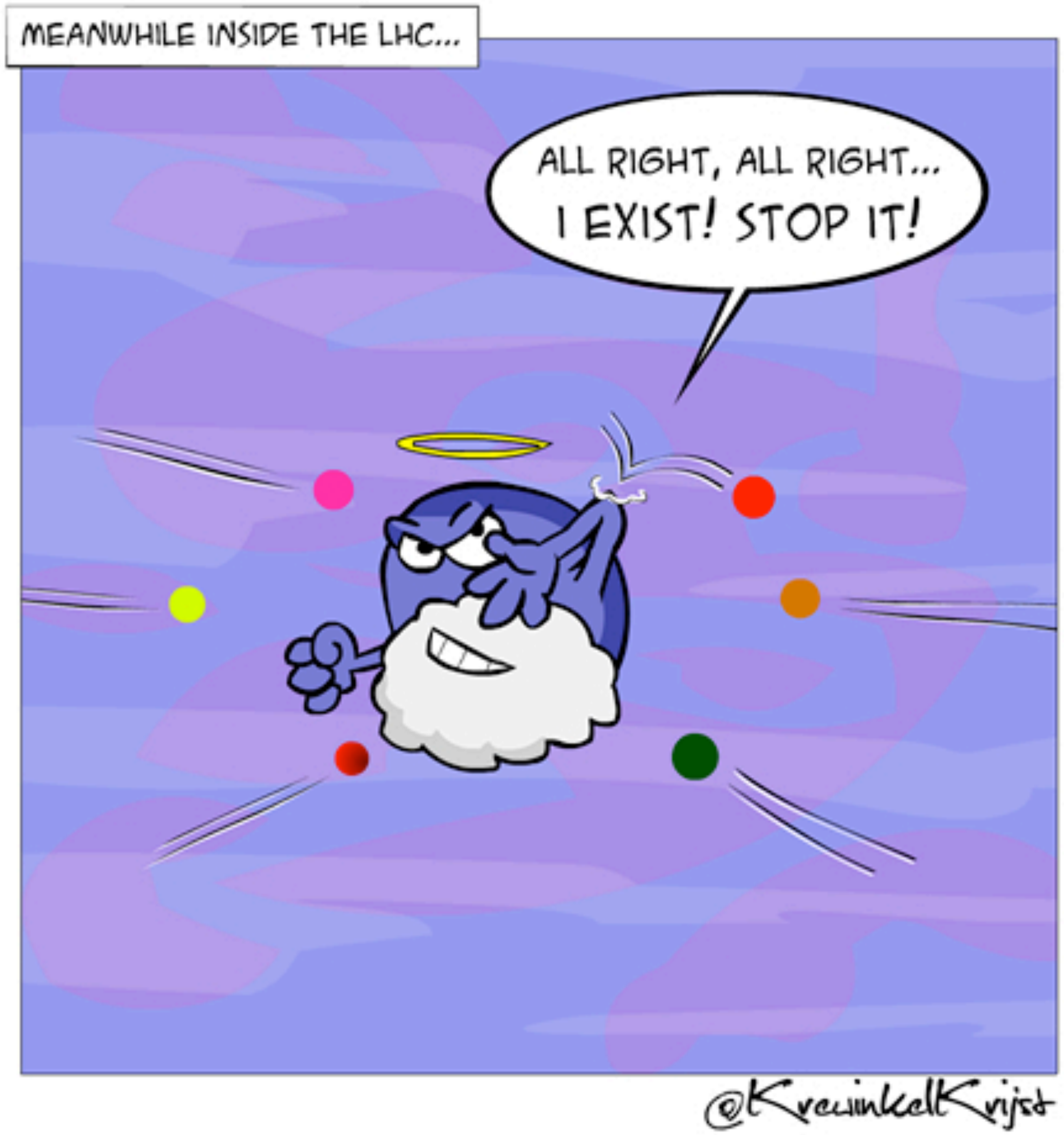
1) S. Kraml, SK, U. Laa, A. Lessa, W. Magerl, D. Proschofsky, W. Waltenberger
   arXiv:1312:4175; EPJ C74 (2014) 2868
2) Work in progress with C. Arina, S. Kraml, U. Laa
3) Work in progress with U. Ellwanger, C. Hugonie, U. Laa

PASCOS - 2014

The LHC frontier

The LHC frontier

Higgs searches



The LHC frontier

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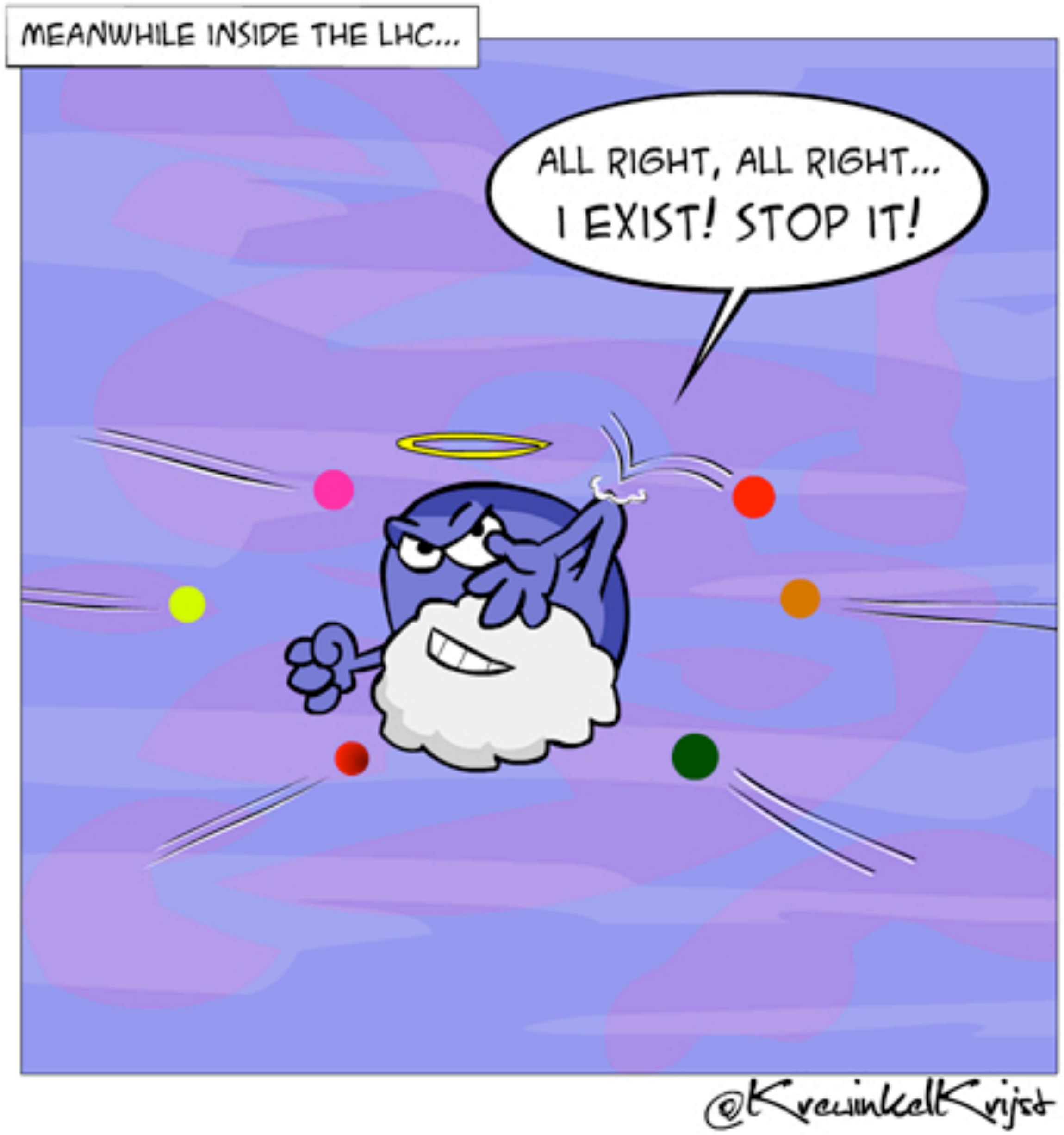
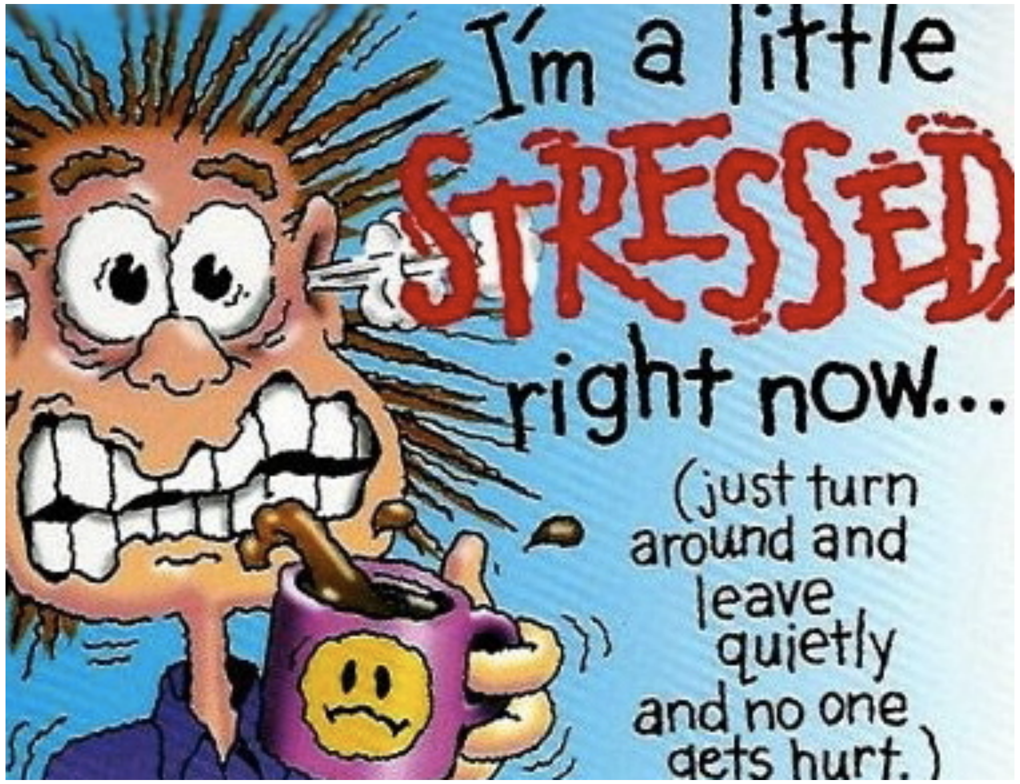


BSM searches



LHC BSM searches

- LHC BSM search interpretation is model dependent
- Re-interpreting LHC BSM searches for various BSM scenarios is necessary to draw sound generic conclusions

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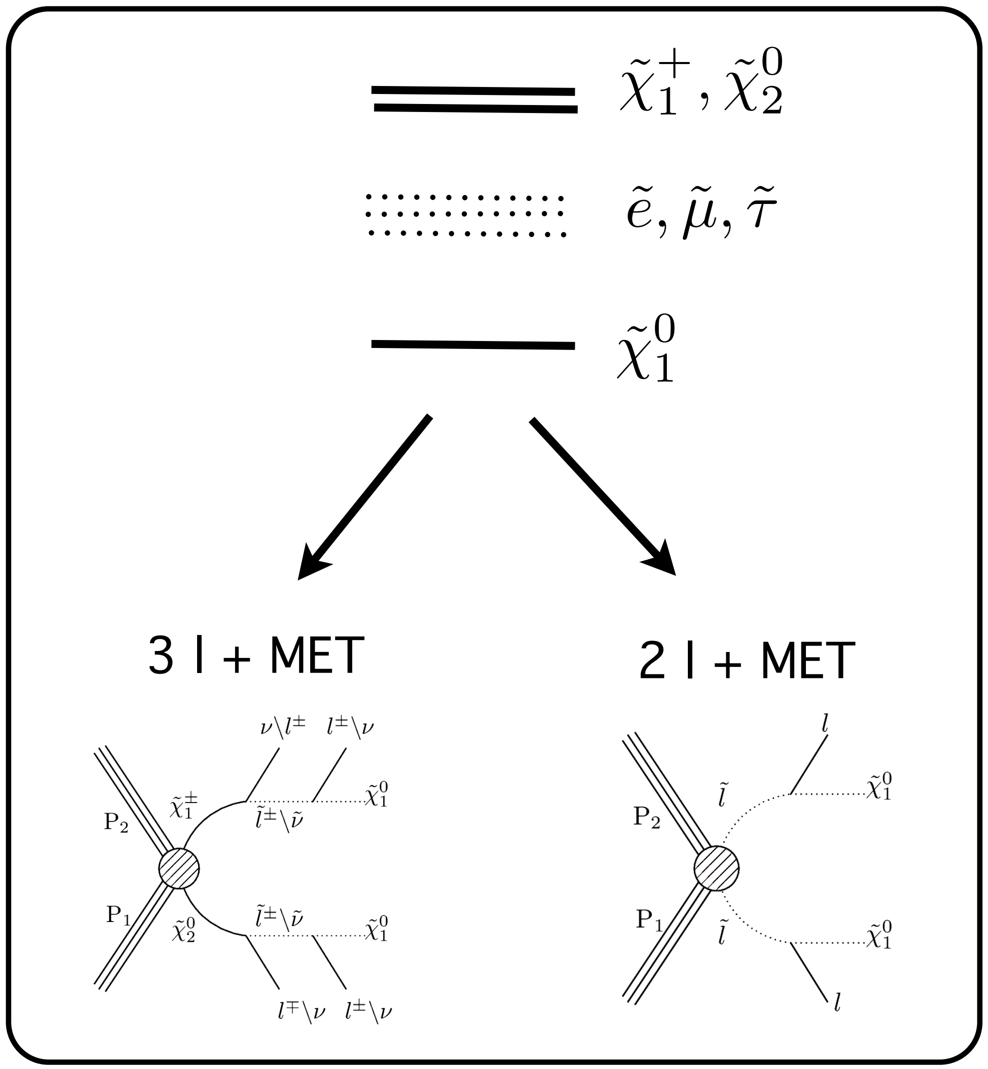

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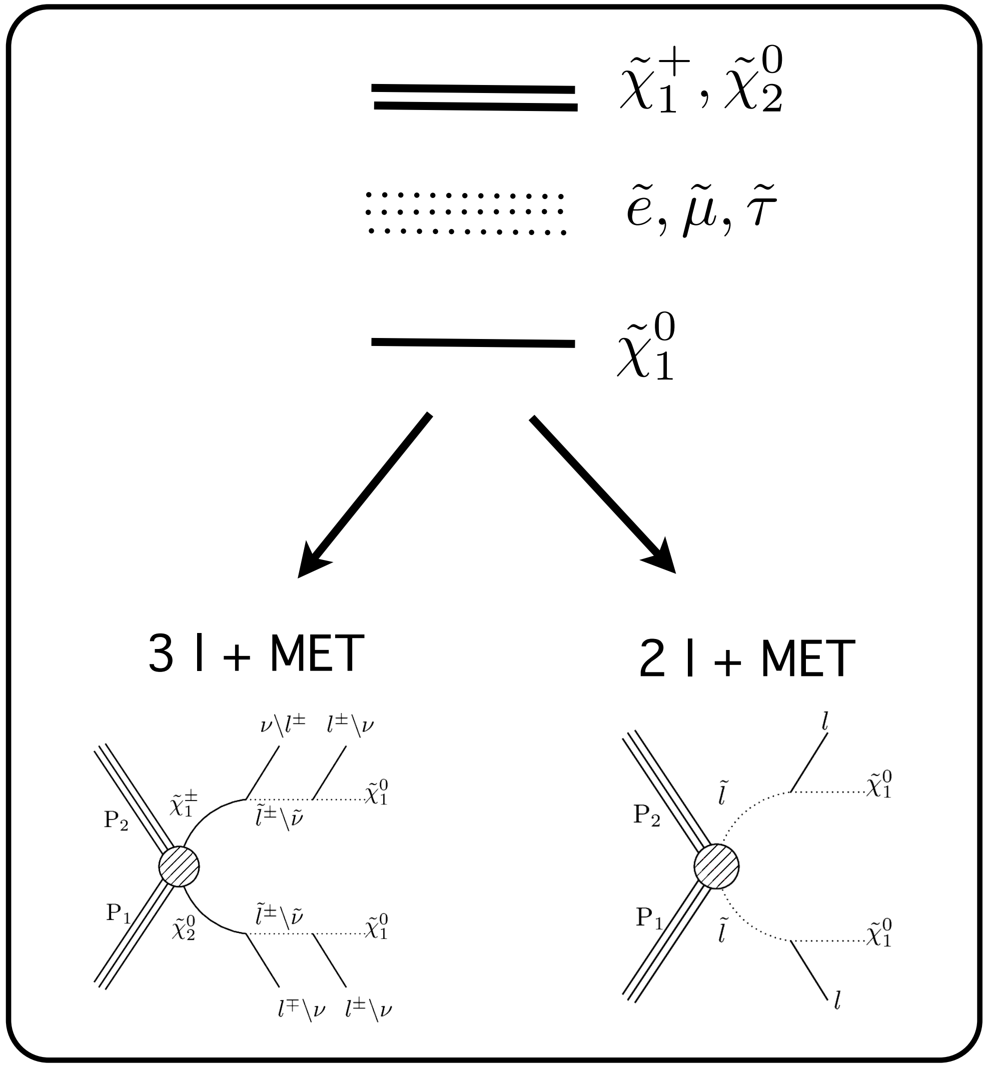

BSM searches at the LHC

- ATLAS Exotica - 26 CONF notes (12 full luminosity); 9 papers
- ATLAS SUSY - 37 CONF notes (22 full luminosity); 12 papers
- CMS Exotica - 18 PAS (17 full luminosity); 10 papers
- CMS SUSY - 19 PAS (13 full luminosity); 12 papers

Total number of analysis = 107

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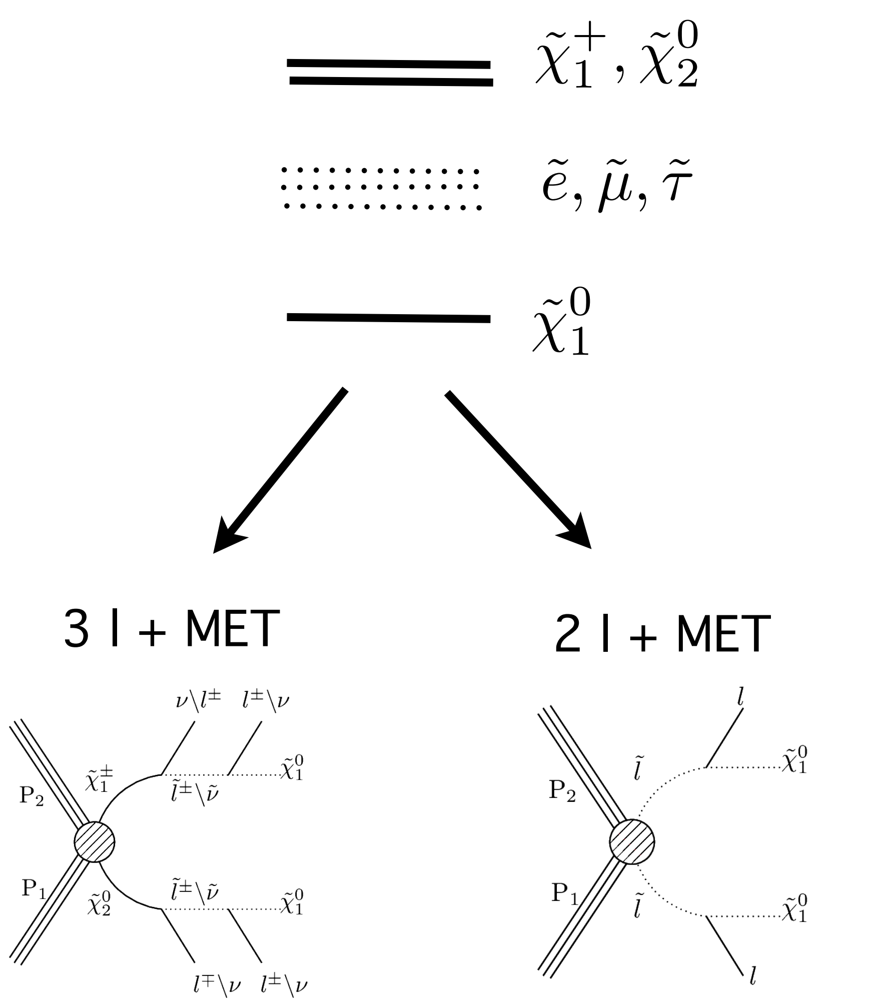
- Re-interpreting LHC BSM searches for various BSM scenarios is necessary to draw sound generic conclusions



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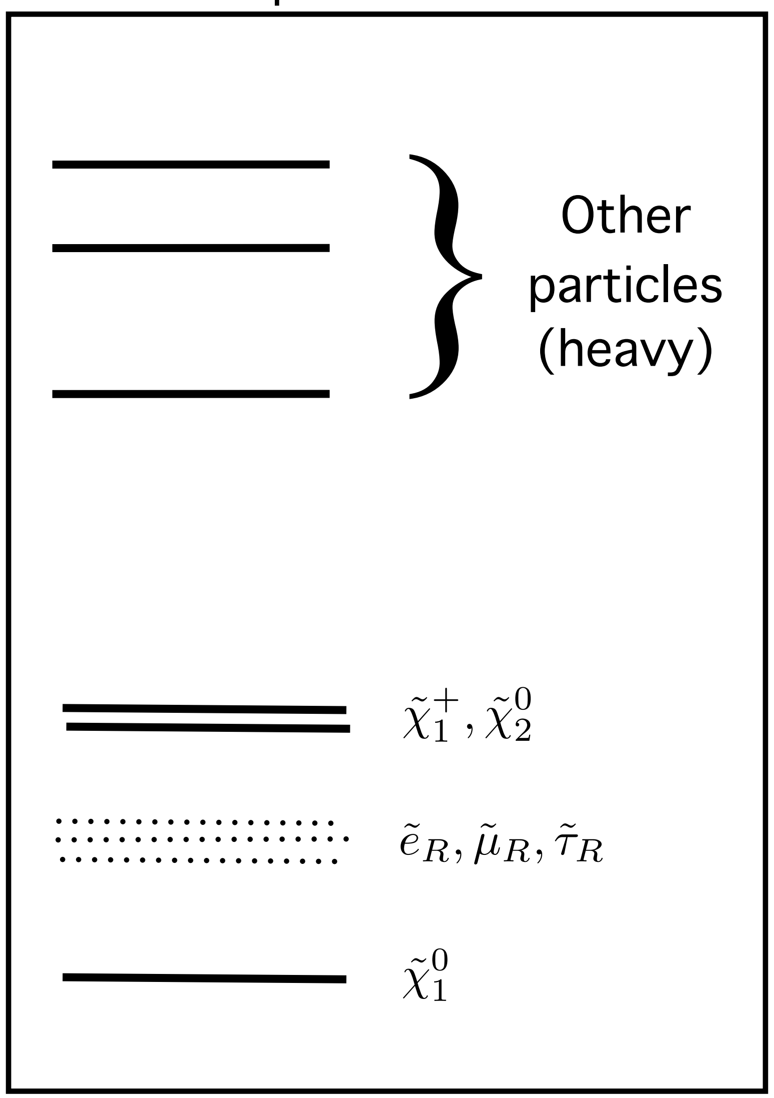
Total number of analysis = 107

- A generic point in theory parameter space can be tested by more than one BSM search and there are > 100 BSM searches

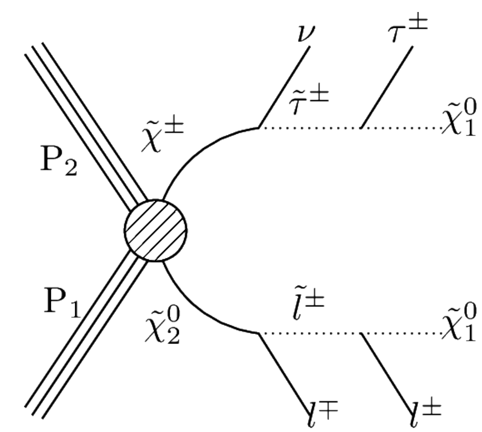
Simplified Model Spectra (SMS)

- SMS are an effective-Lagrangian description of BSM involving a limited set of new particles. Experimentalists interpret their results in SMS framework.

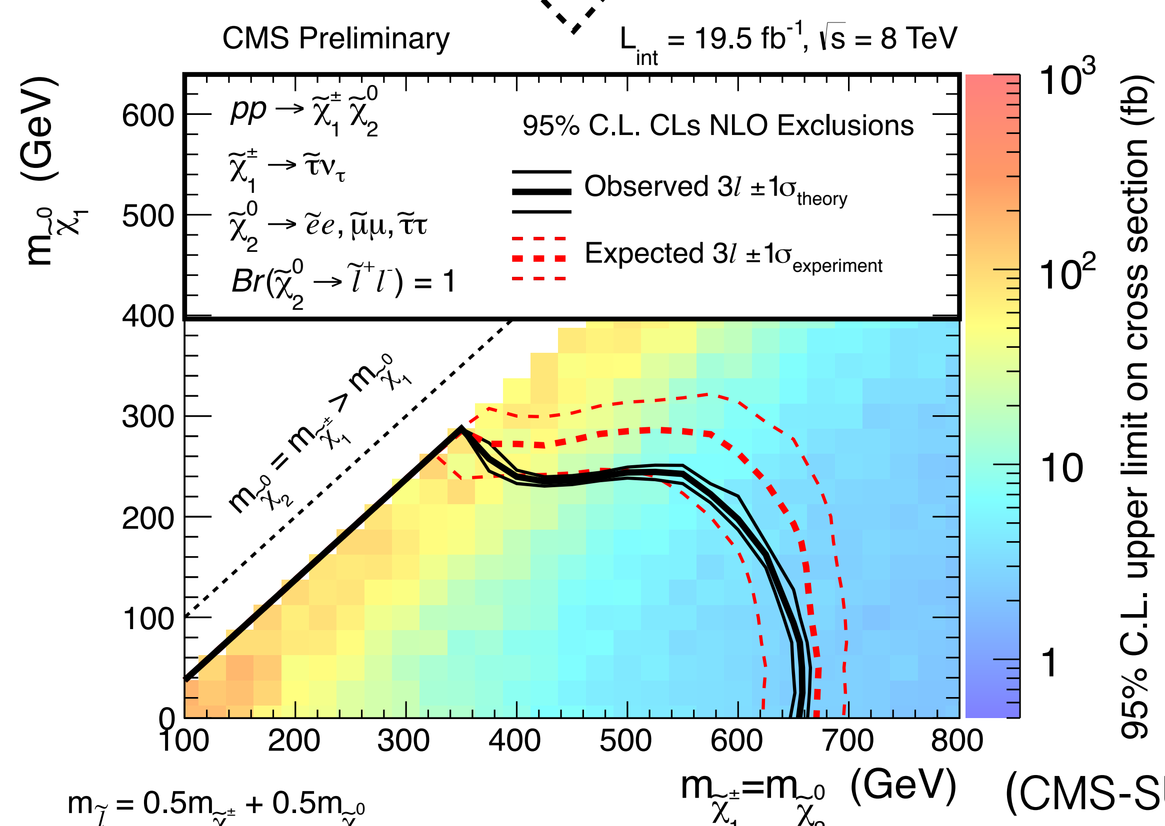
Assumed spectra



Topology

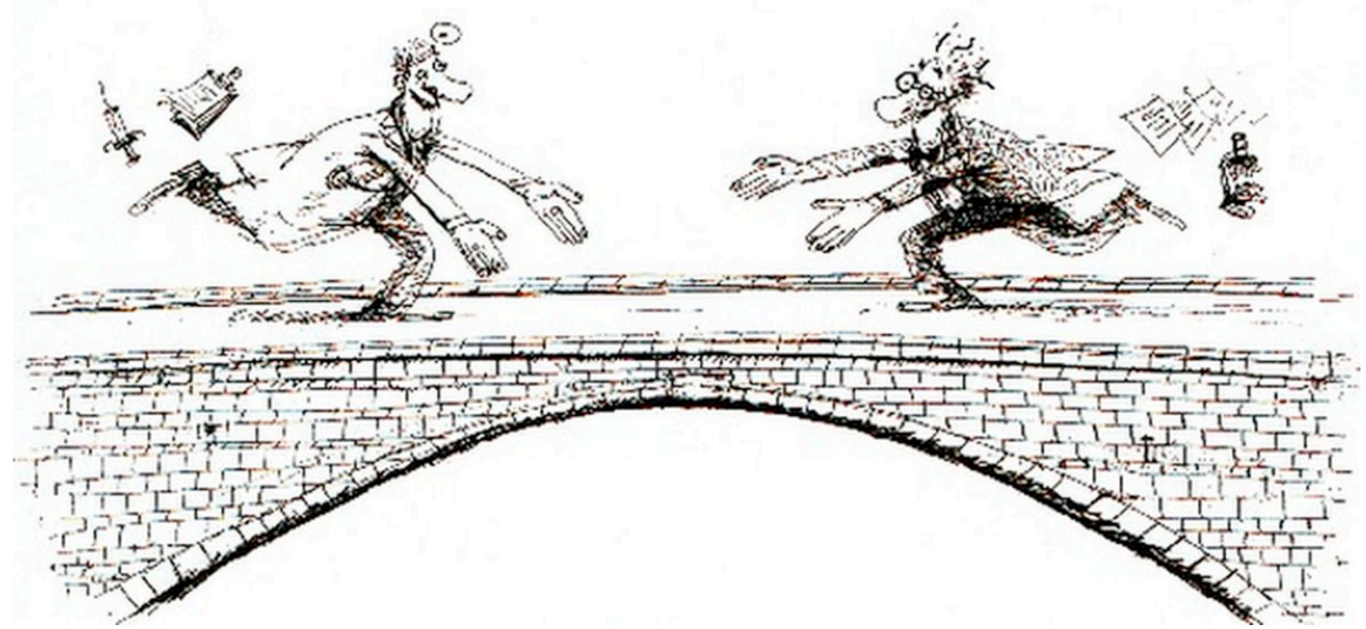


Upper limits on CS



(CMS-SUS-PAS-13-006)

Can the experimental results and theoretical predictions meet half-way?



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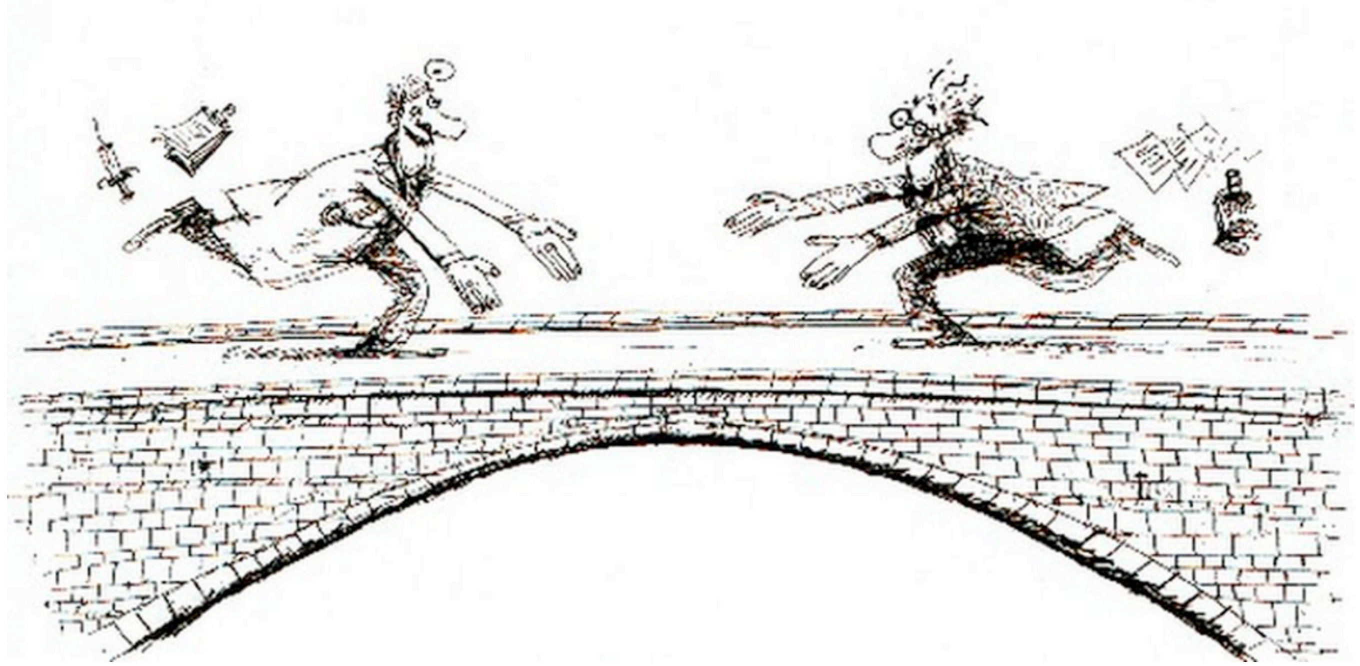
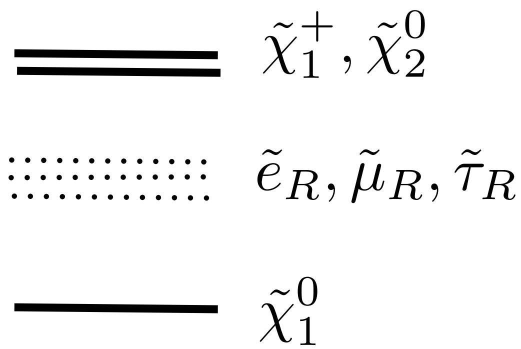


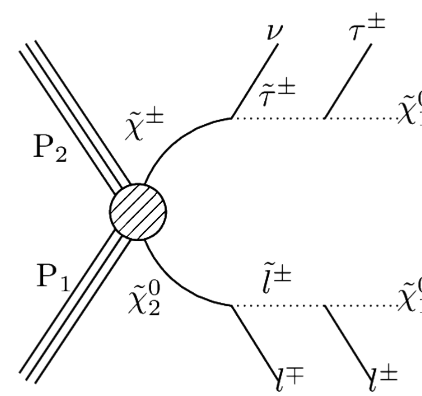
SModelS

SModelS framework



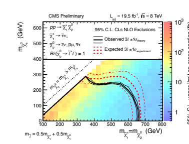
Decompose

Element



description
masses
sigma X BR

Constraint



[[[nu],[tau]],[[L],[L]]]

[[300,200,100],[320,220,100]]

Sigma X BR

Look up upper limit if

Condition

[[[nu],[tau]],[[L],[L]]] >
3* [[[nu],[tau]],[[tau],[tau]]]

- Can be applied to decompose any arbitrary BSM spectrum
- Limit setting assumes that (A×ϵ)'s do not depend too much on model characteristics e.g spin of particles

SModelS language

MSSM scan - weak sector

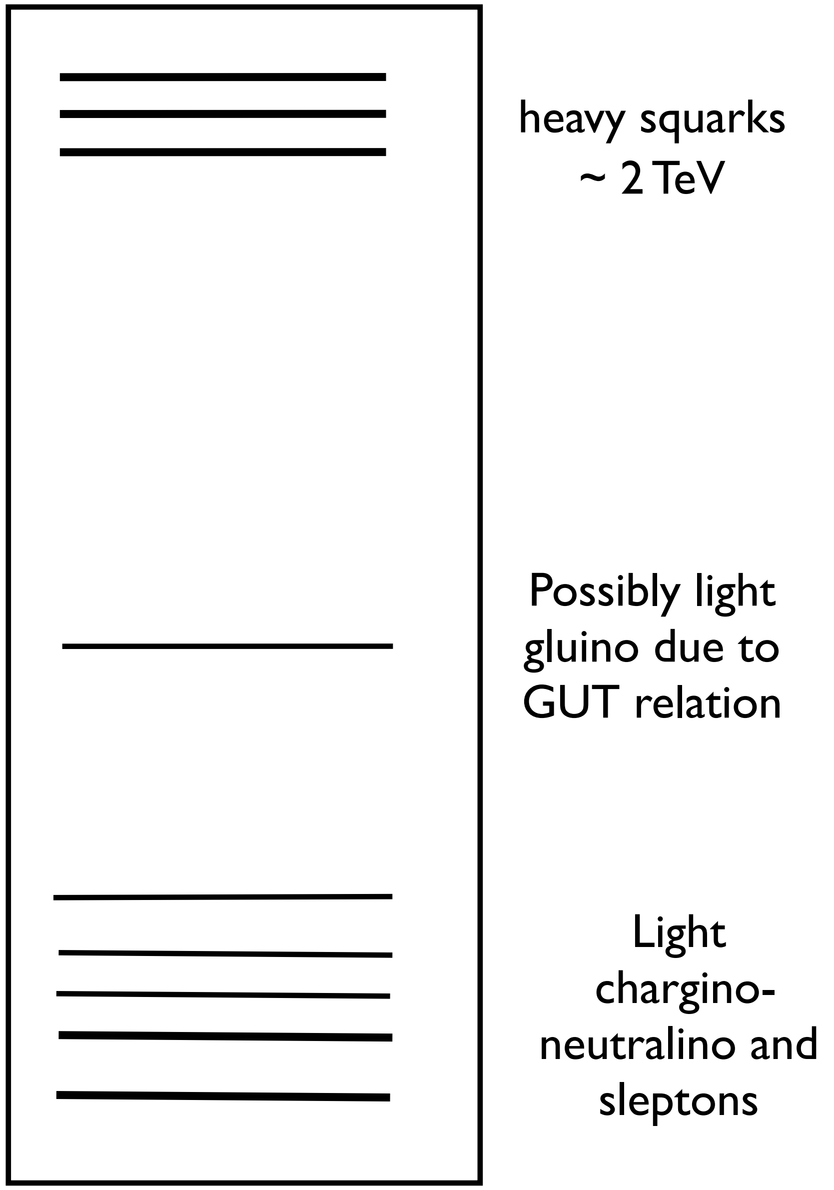
Based on EPJ C74 (2014) 2868

- Weak scale MSSM scan over 6 parameters

M_2	μ	$\tan\beta$	$M_{\tilde{L}}$	$M_{\tilde{E}}$	A_τ
0.1–1	0.1–1	3–60	0.1–1	0.1–1	± 1

  - Gaugino masses obey GUT relation

  - Flavor constraints, invisible Z width, Higgs mass, LEP limits imposed

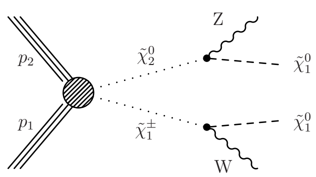


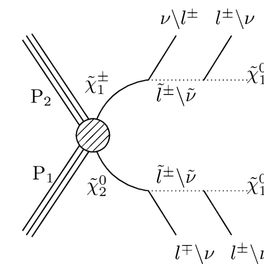
MSSM scan - weak sector

- Topologies being tested:
  - Chargino - neutralino production; decays via sleptons or WZ
  - Gluino production; three body decays via squarks (all three generations)
  - Direct slepton production; decays to leptons

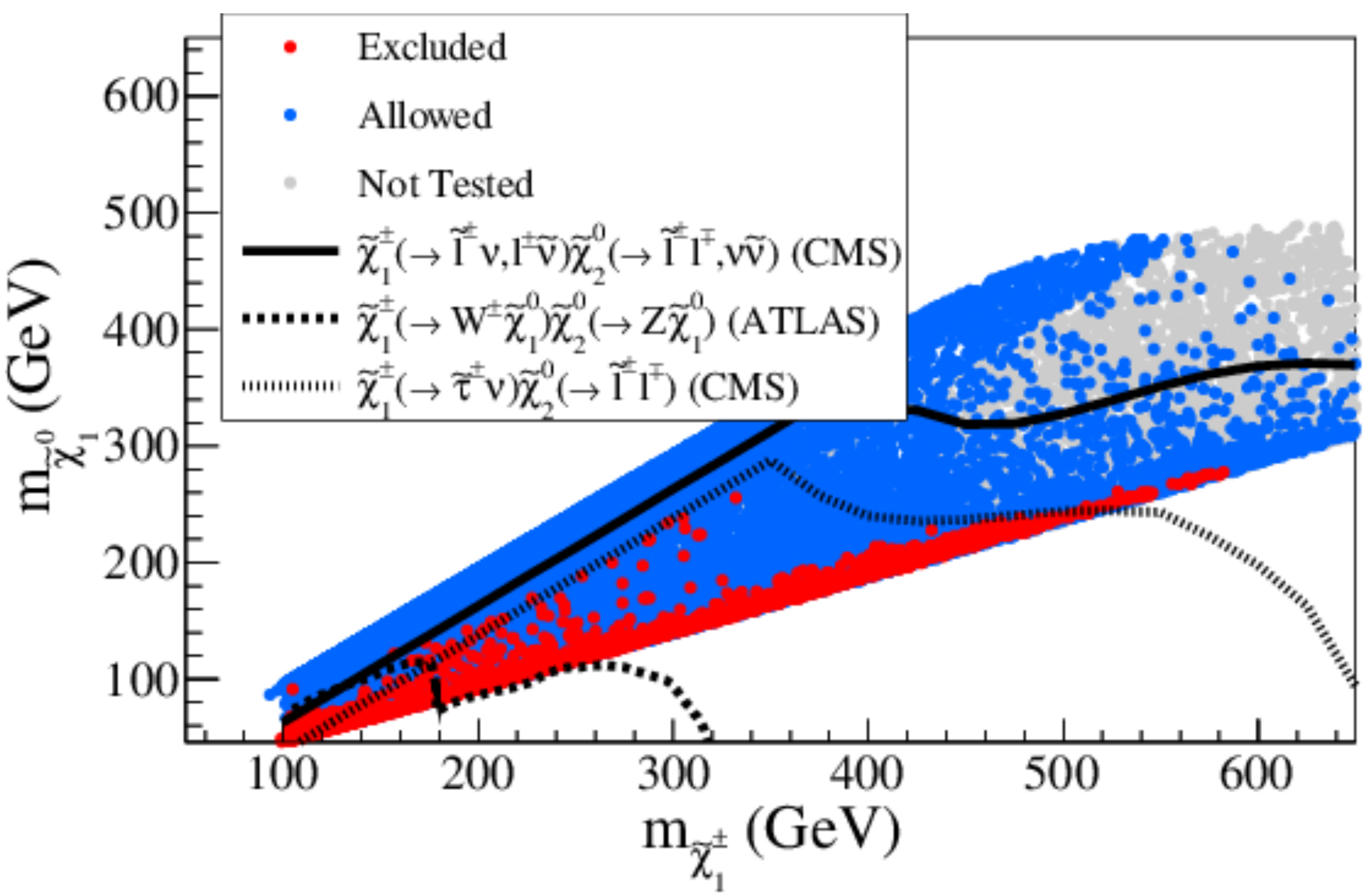
MSSM scan - weak sector

- We are dealing with multi-dimensional parameter space
- Available SMS electroweak -ino topologies: Chargino - neutralino production decay to WZ, decay via sleptons





Excluded points



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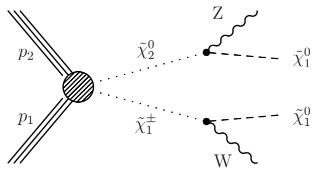

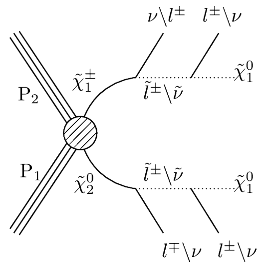

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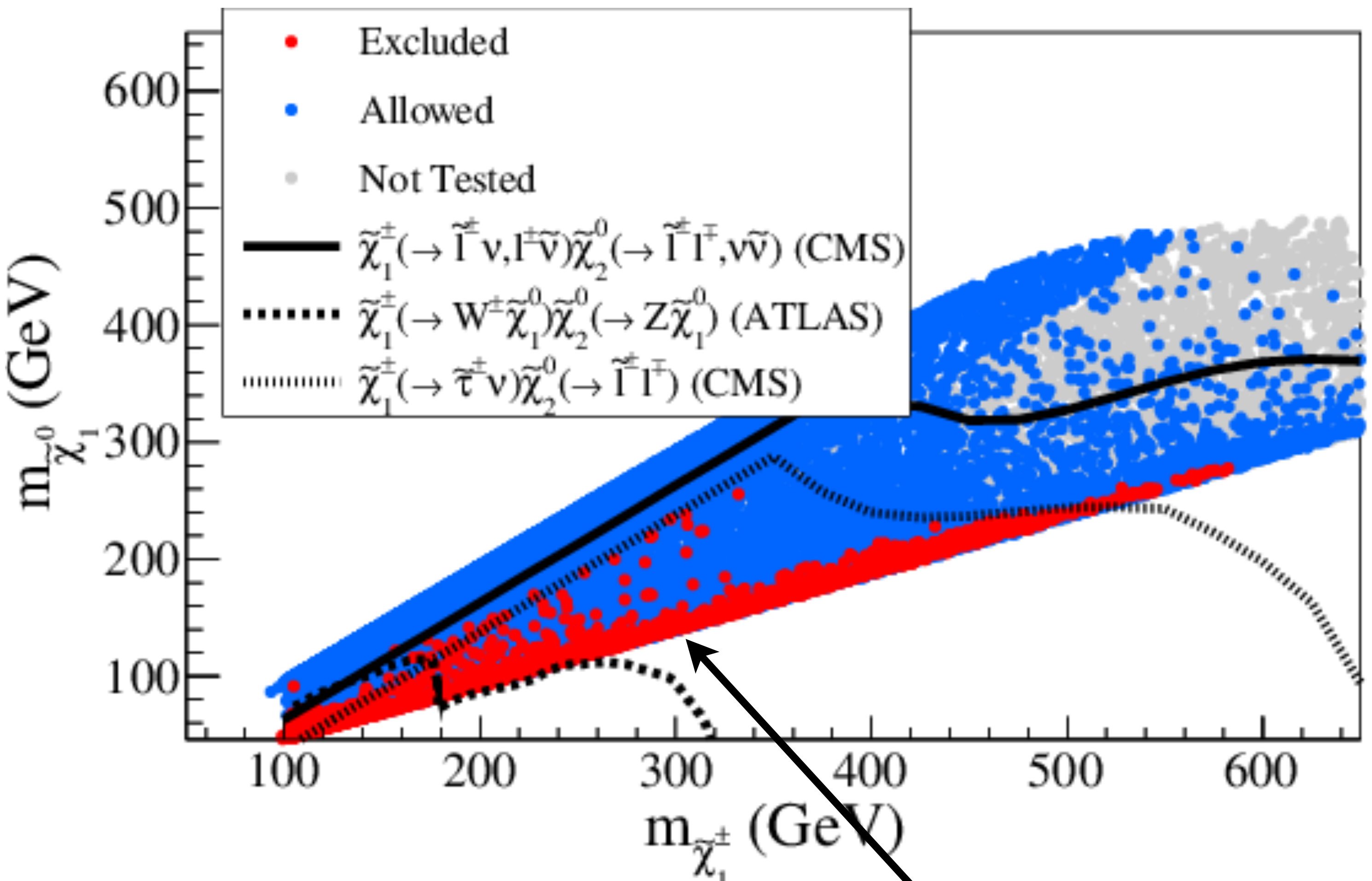

Edge due to GUT relations

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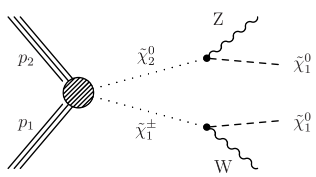

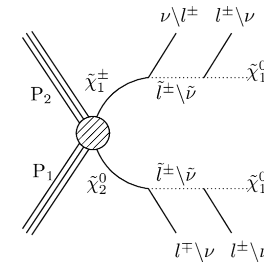

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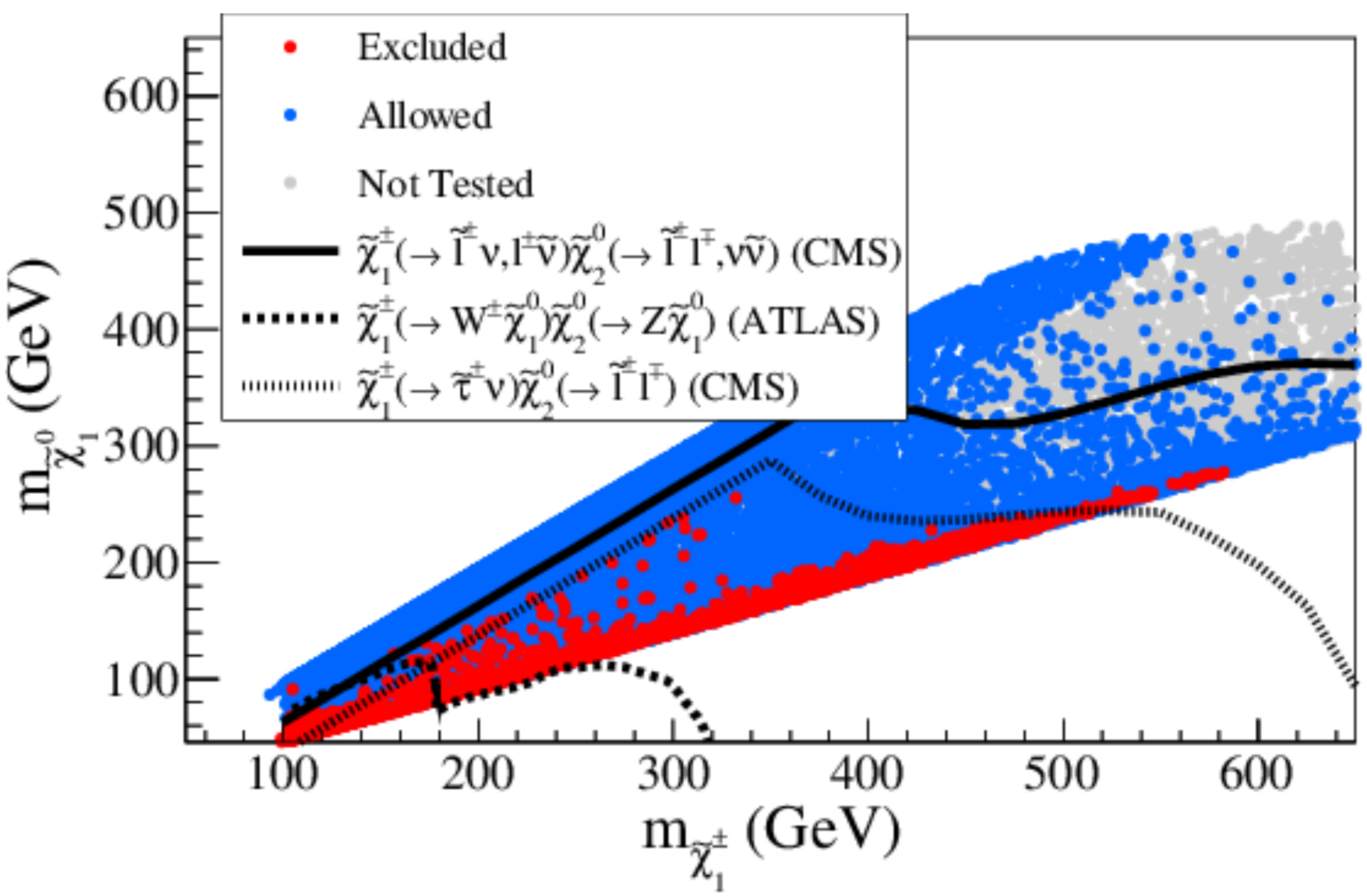

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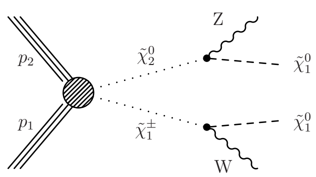
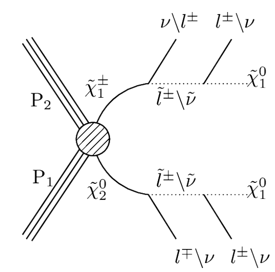
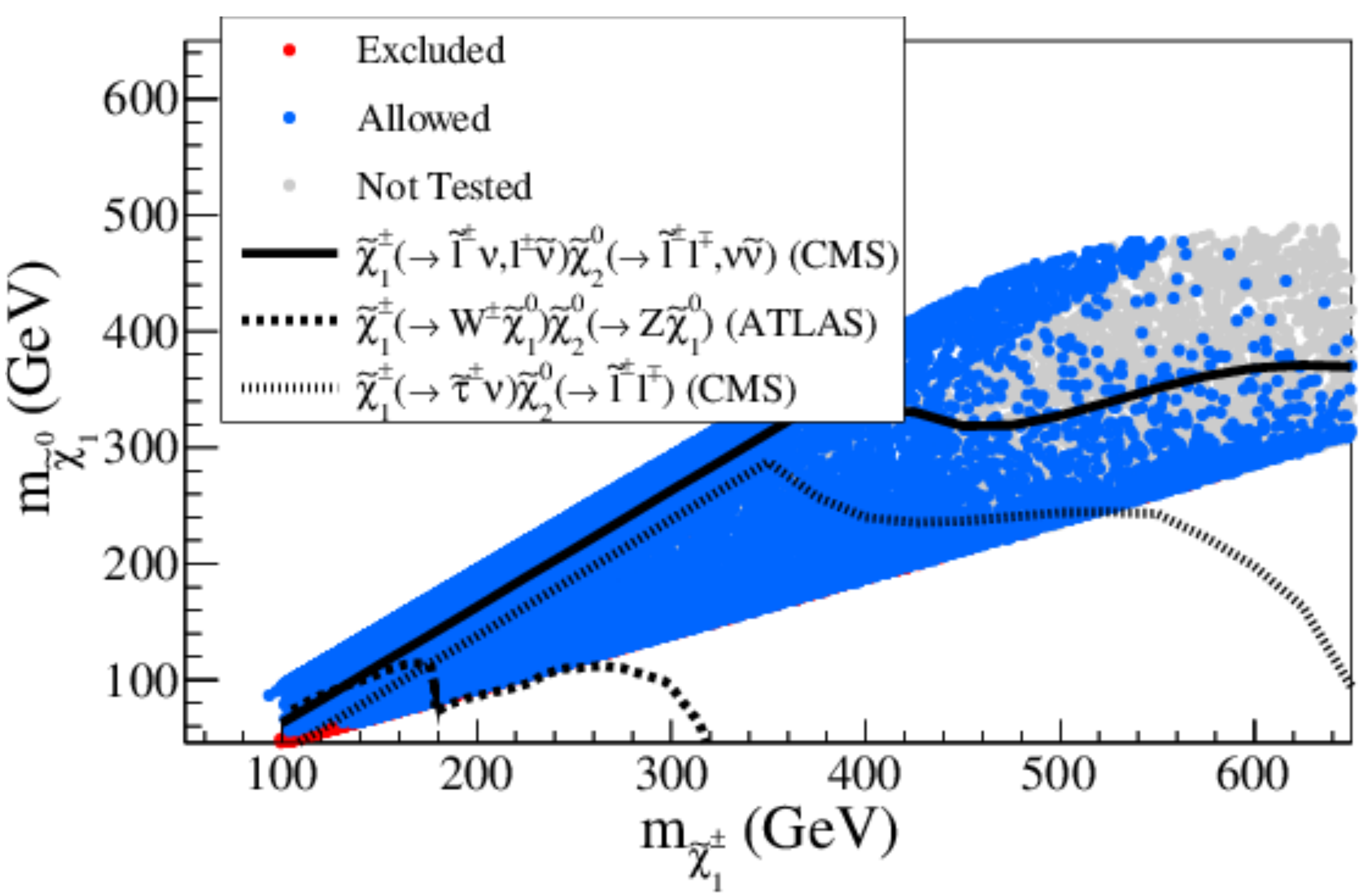




Allowed points



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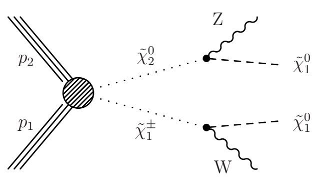

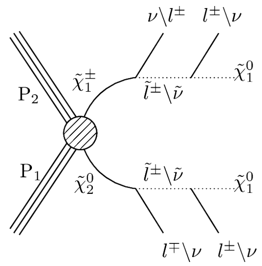

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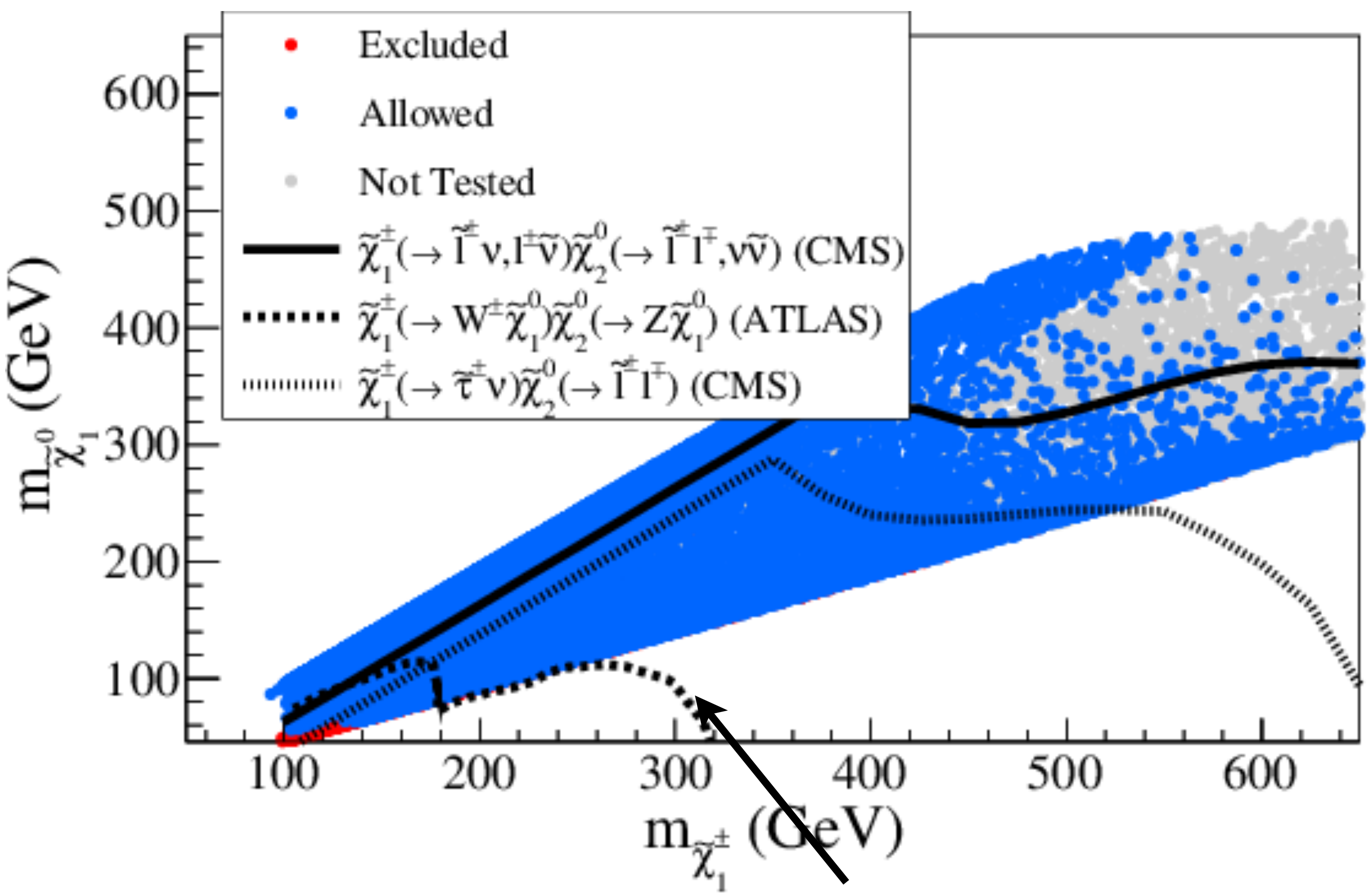
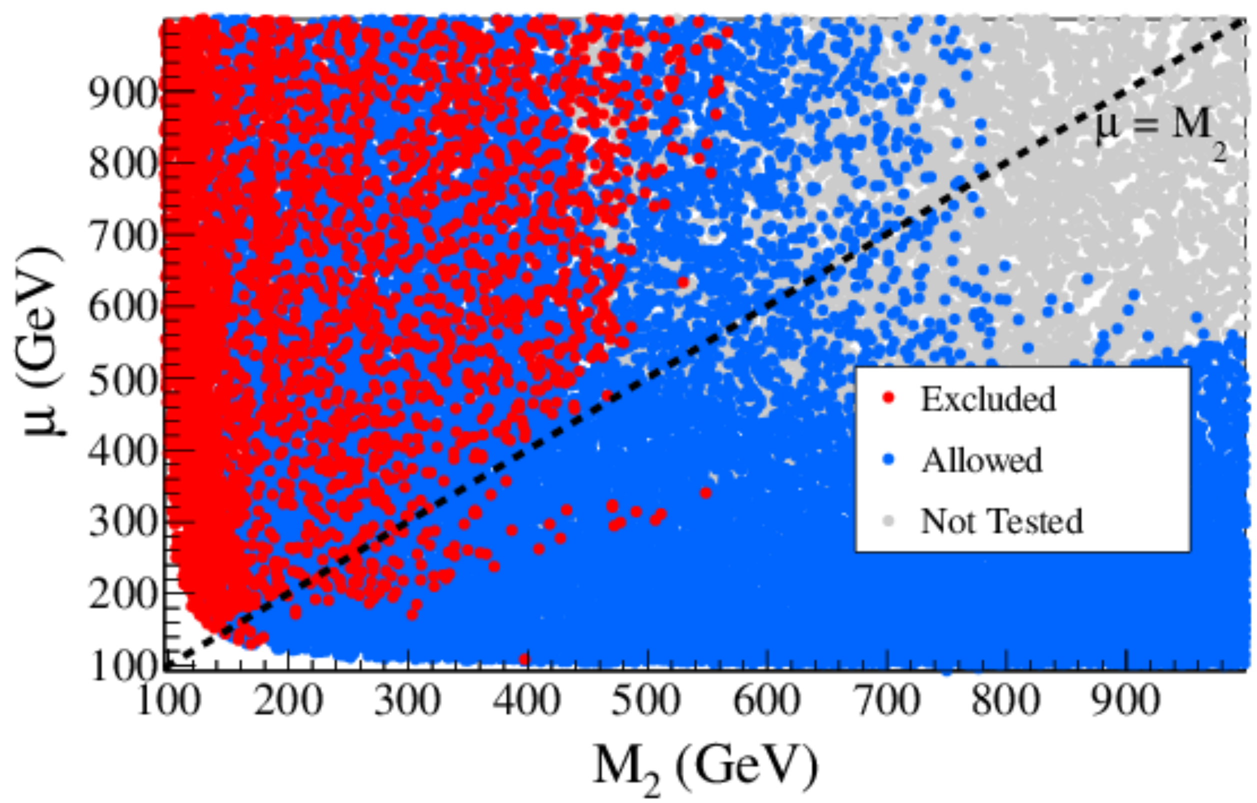
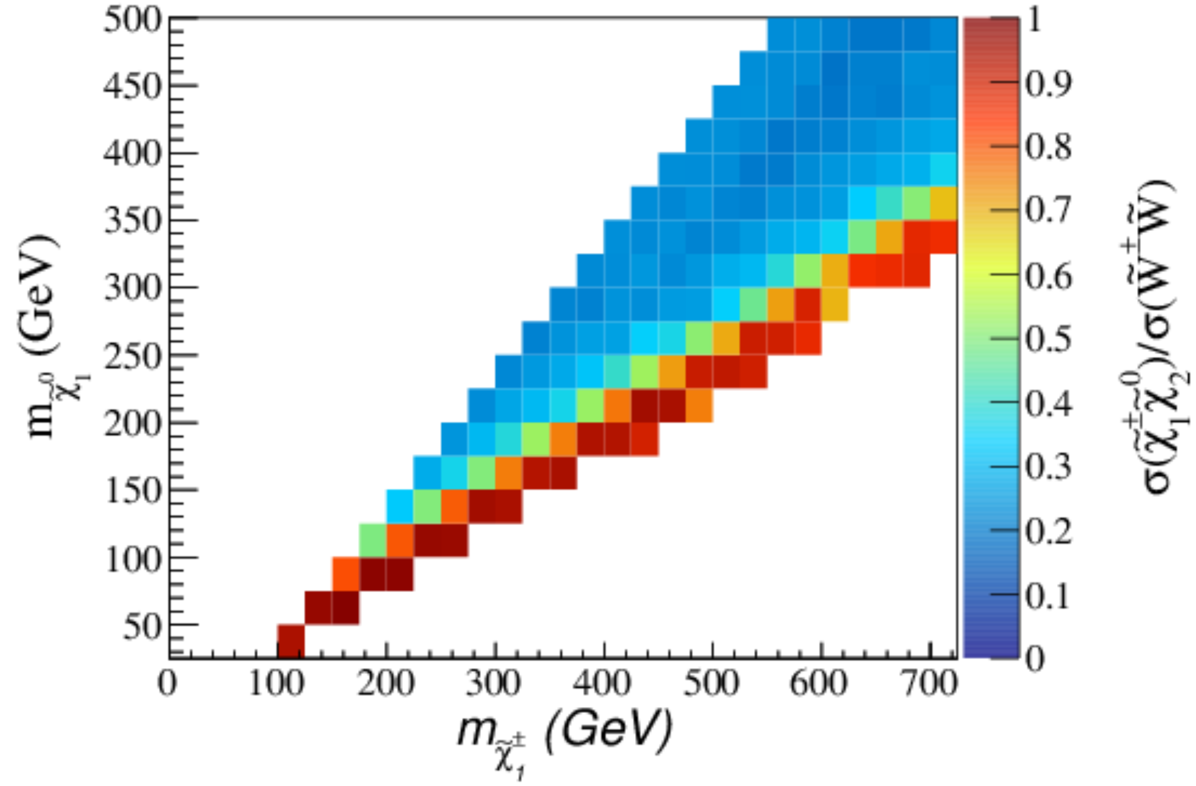


Official exclusions over-estimate exclusions

MSSM scan - weak sector





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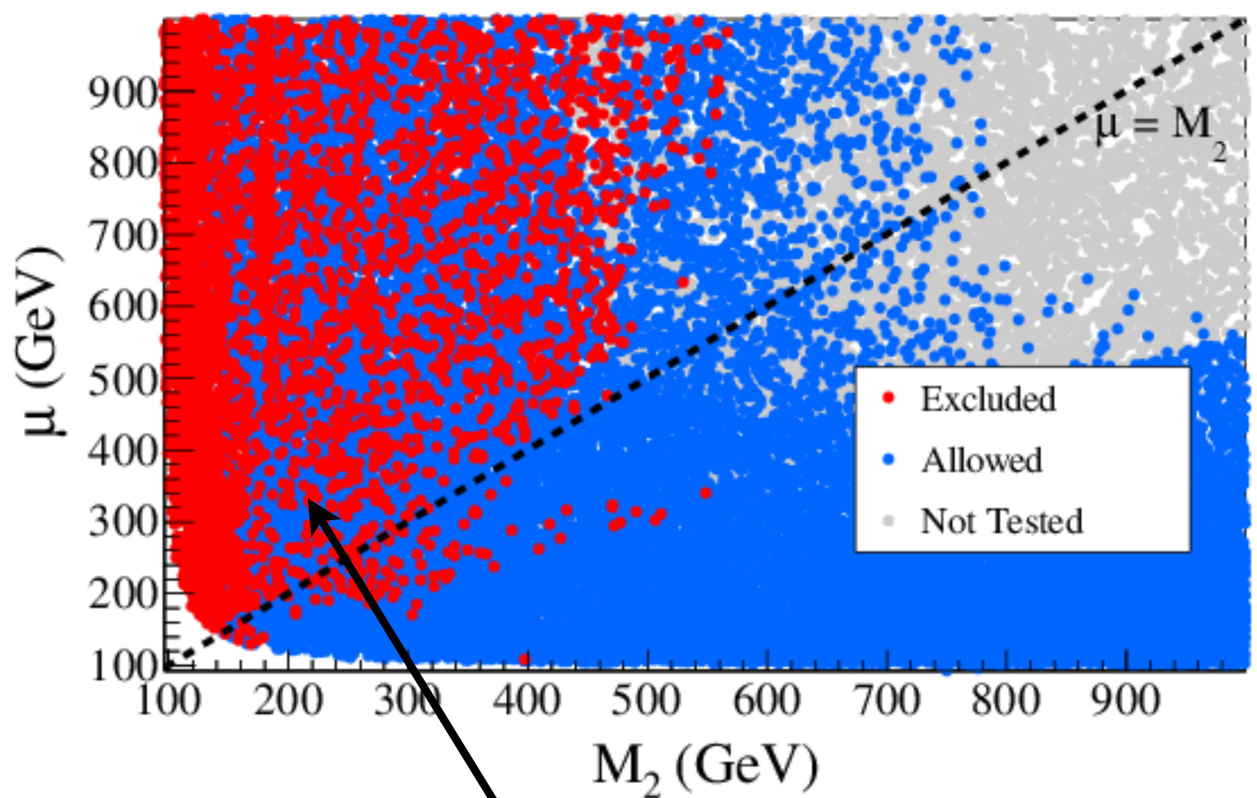
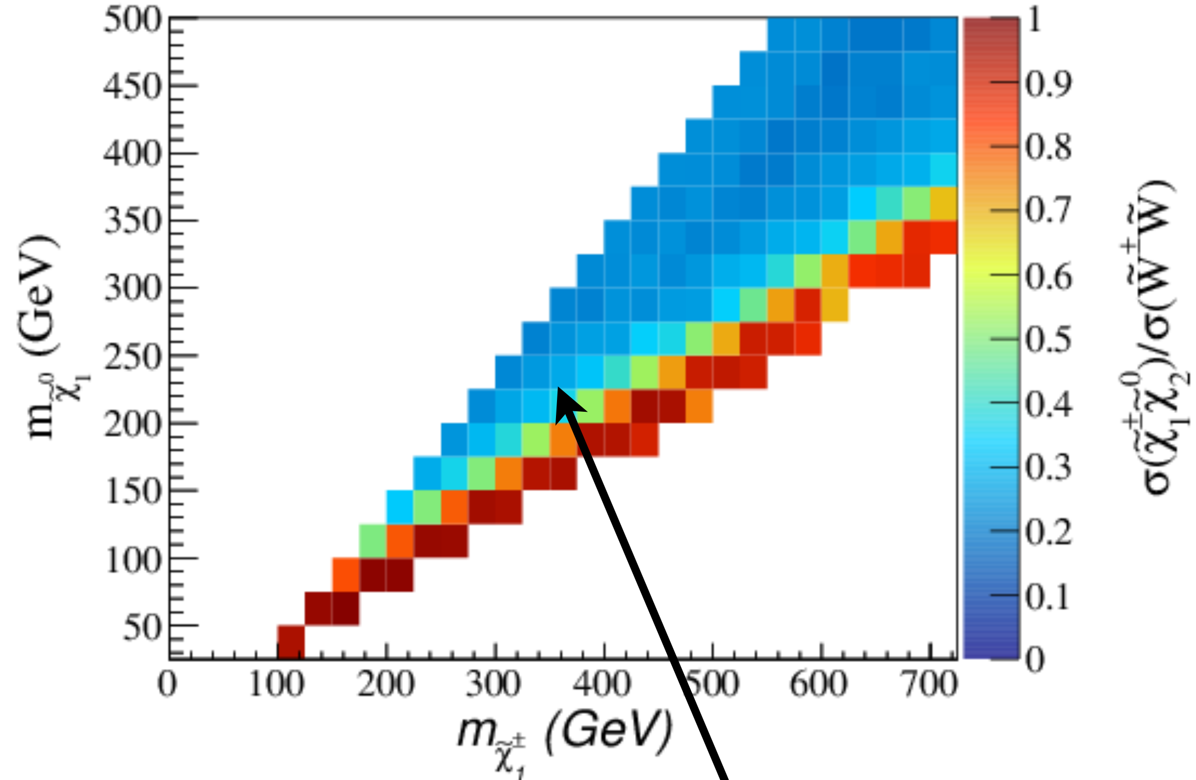
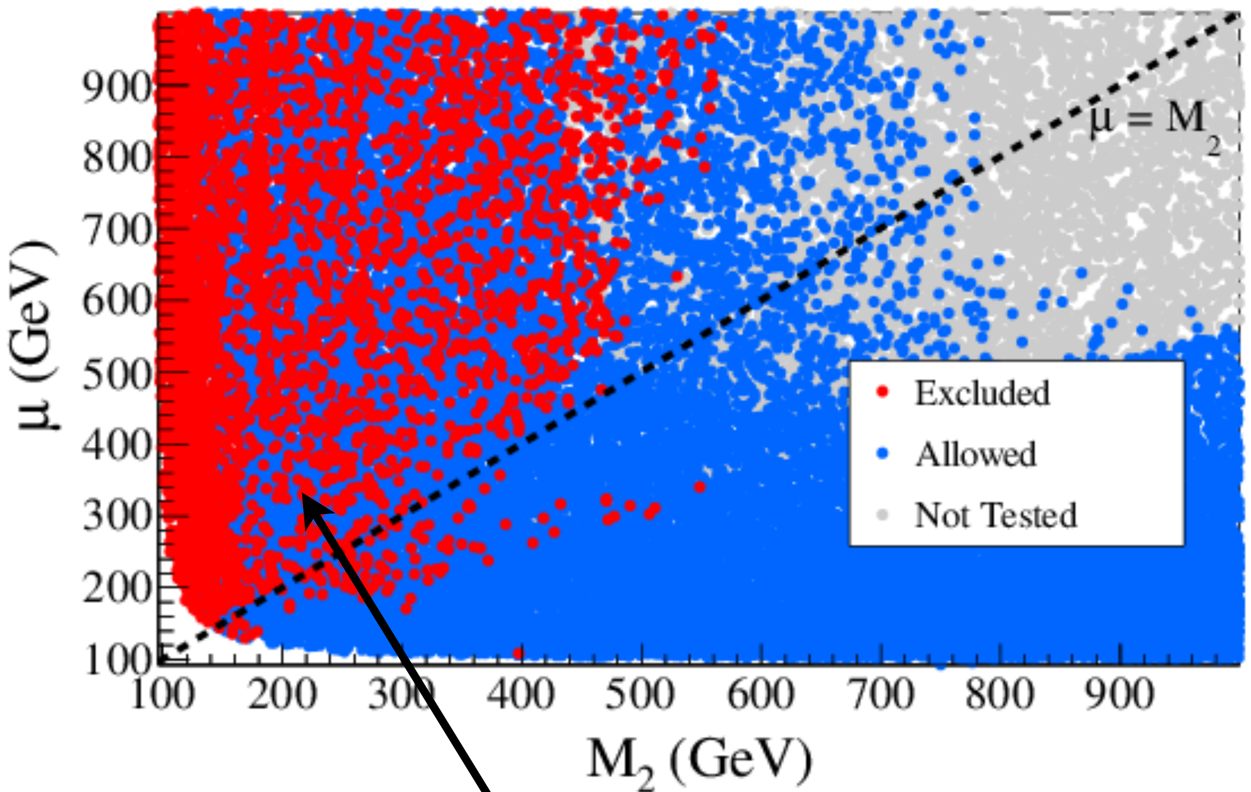


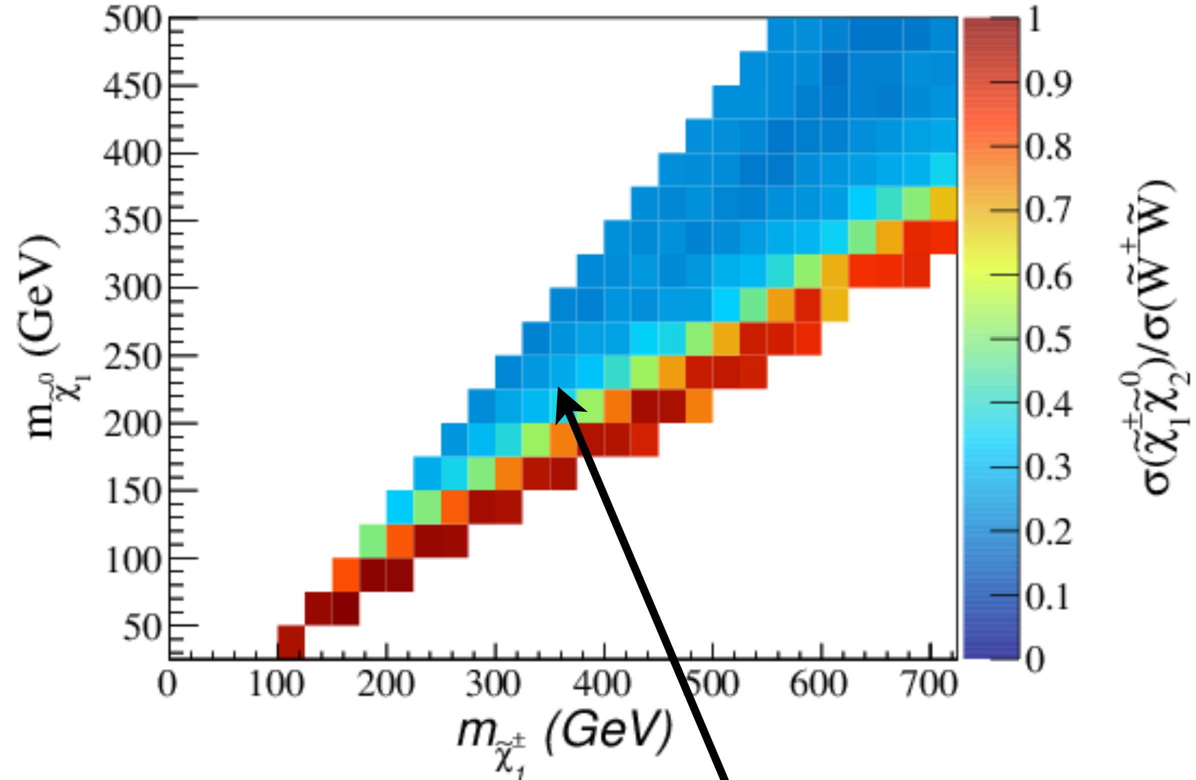
Stronger exclusions for wino-like charginos



Production cross-sections drop as chargino receives higgsino component

MSSM scan - weak sector





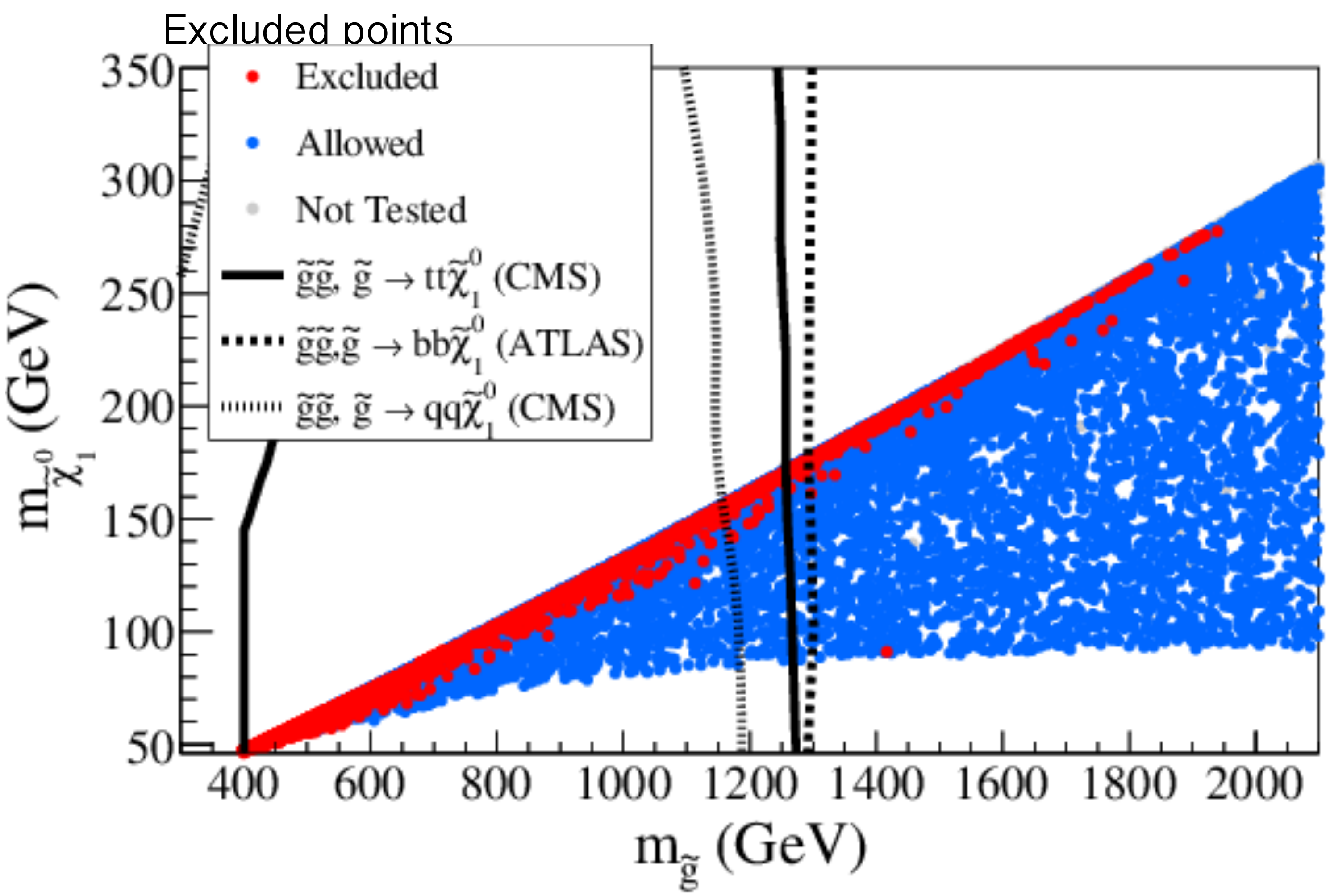
Stronger exclusions for wino-like charginos

Production cross-sections drop as chargino receives higgsino component

- Take home message: Nature of sparticle (wino-higgsino mixing) matters, as the production cross-section depends on it

MSSM scan - weak sector

- Available SMS gluino topologies: gluino pair production, decay via off-shell stop, sbottom, or 1st/2nd gen. squarks
- Perfectly realized in this scenario



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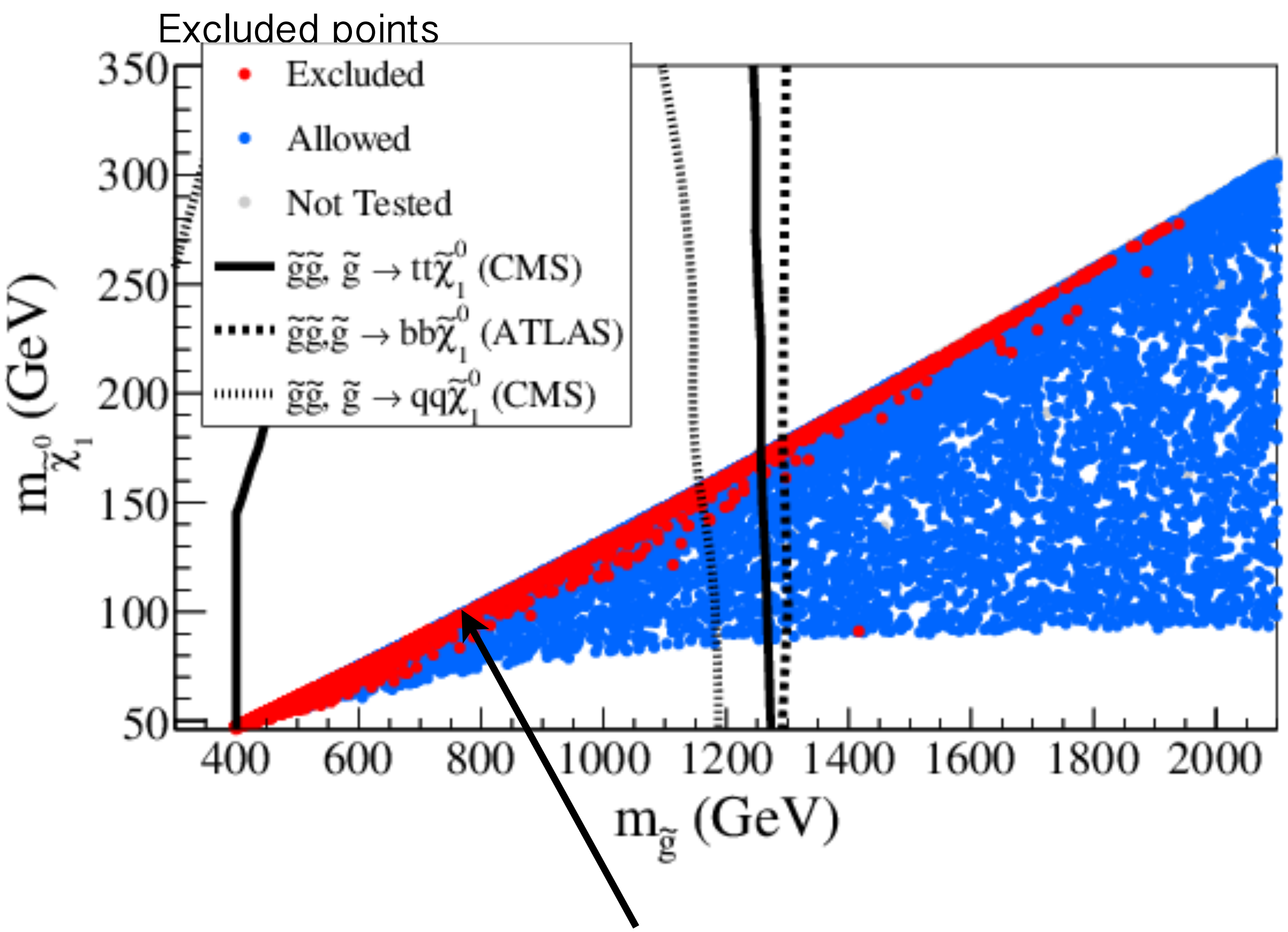

GUT relations

Mostly bino-LSP excluded

MSSM scan - weak sector

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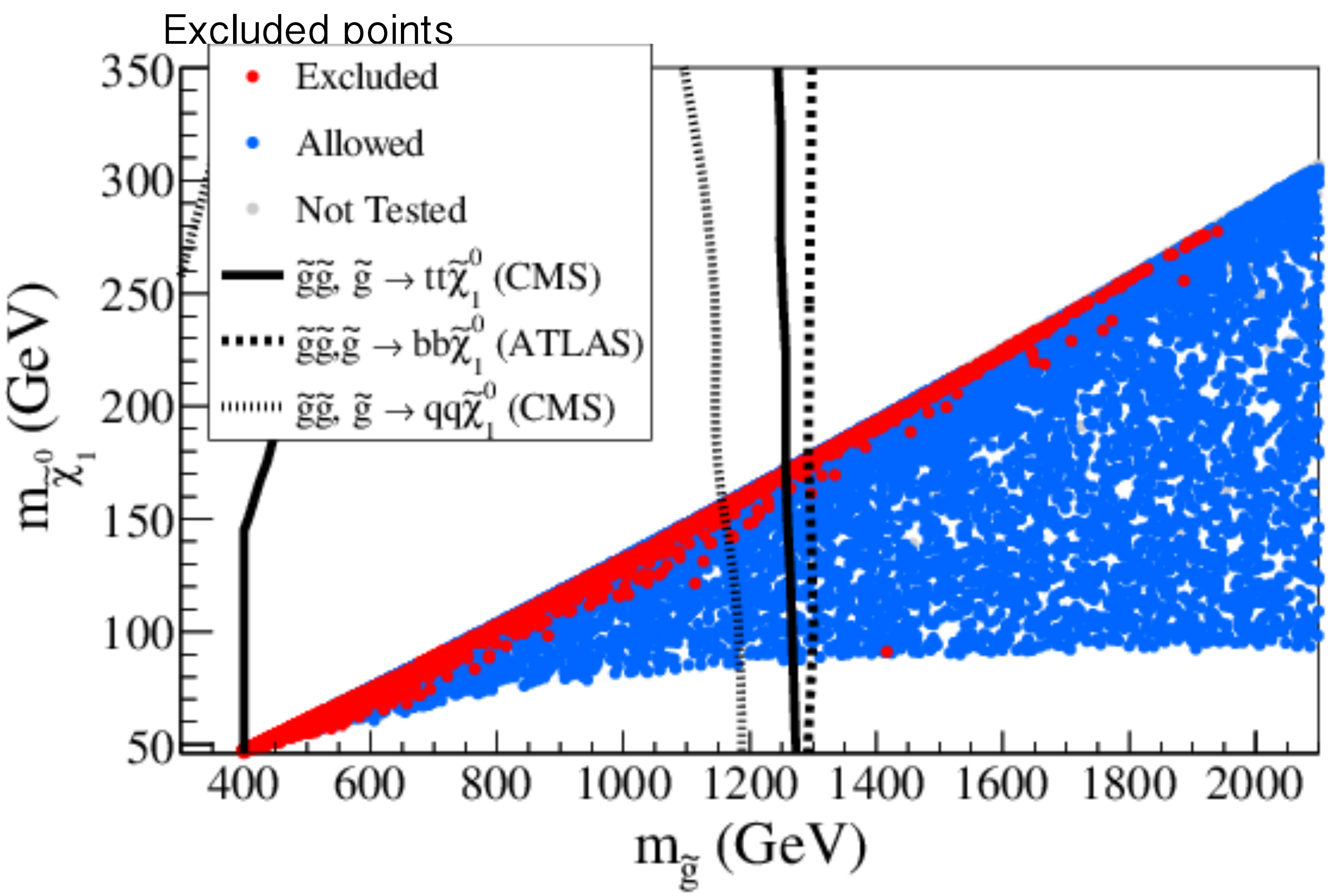

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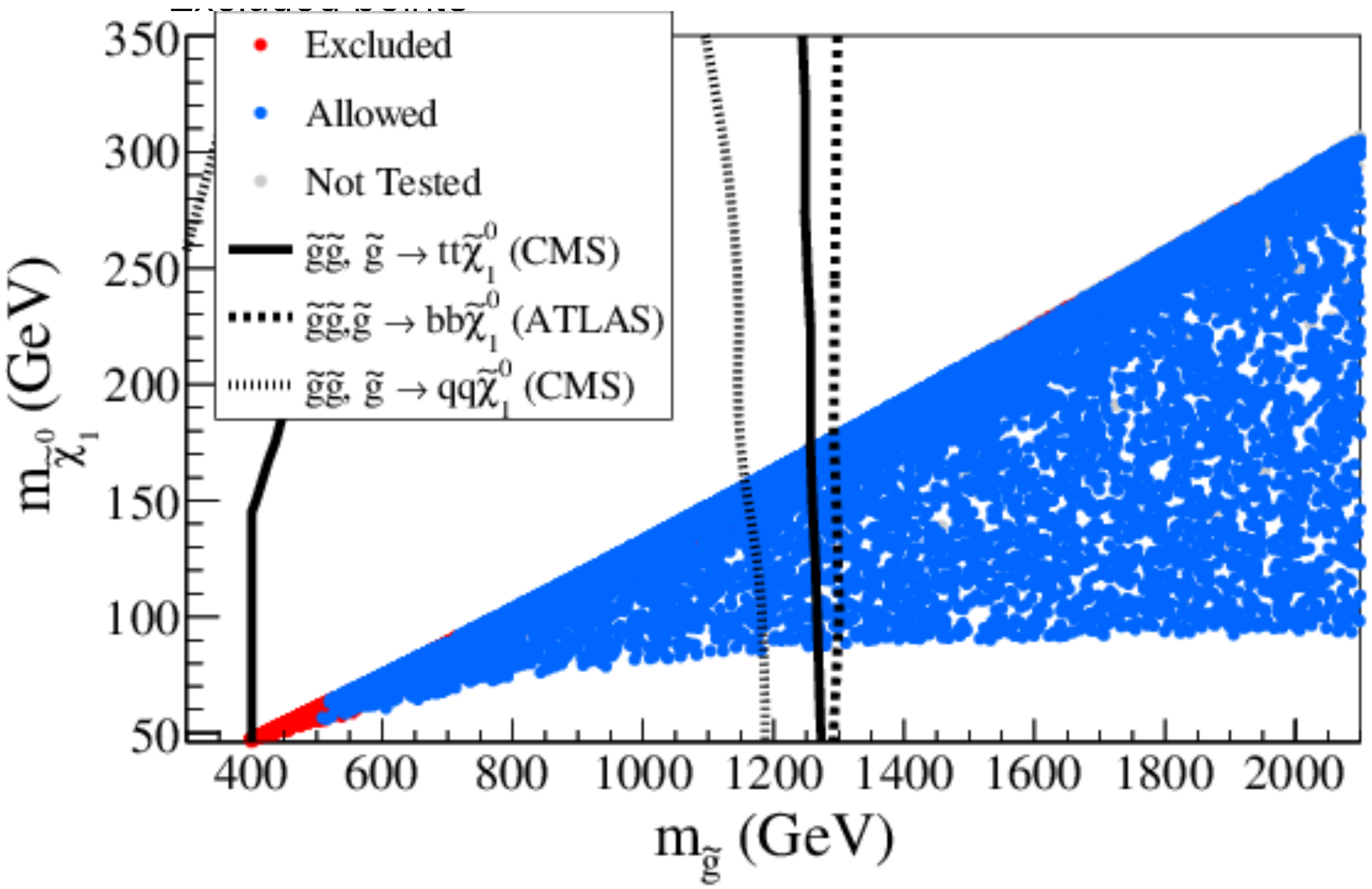
Allowed points



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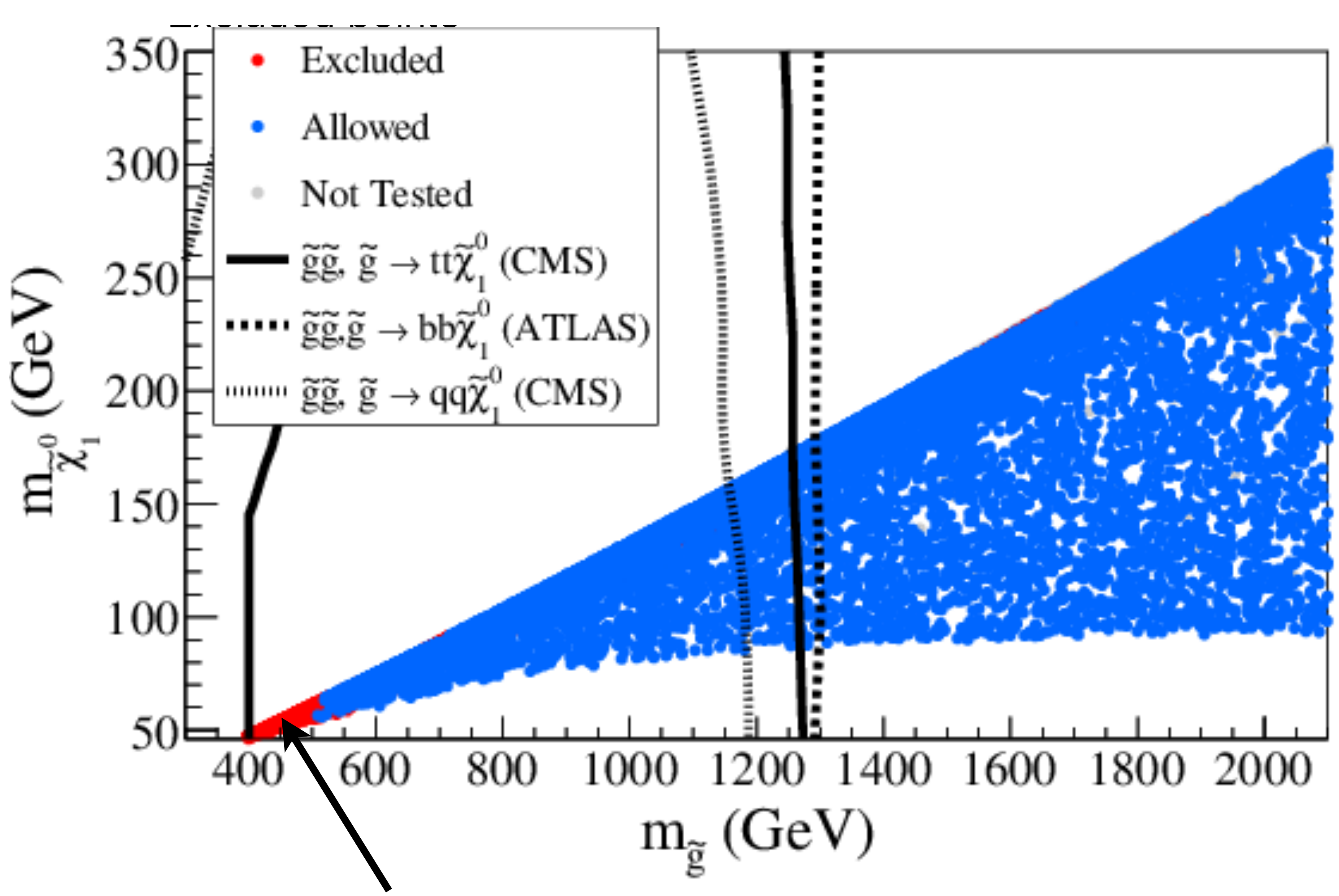
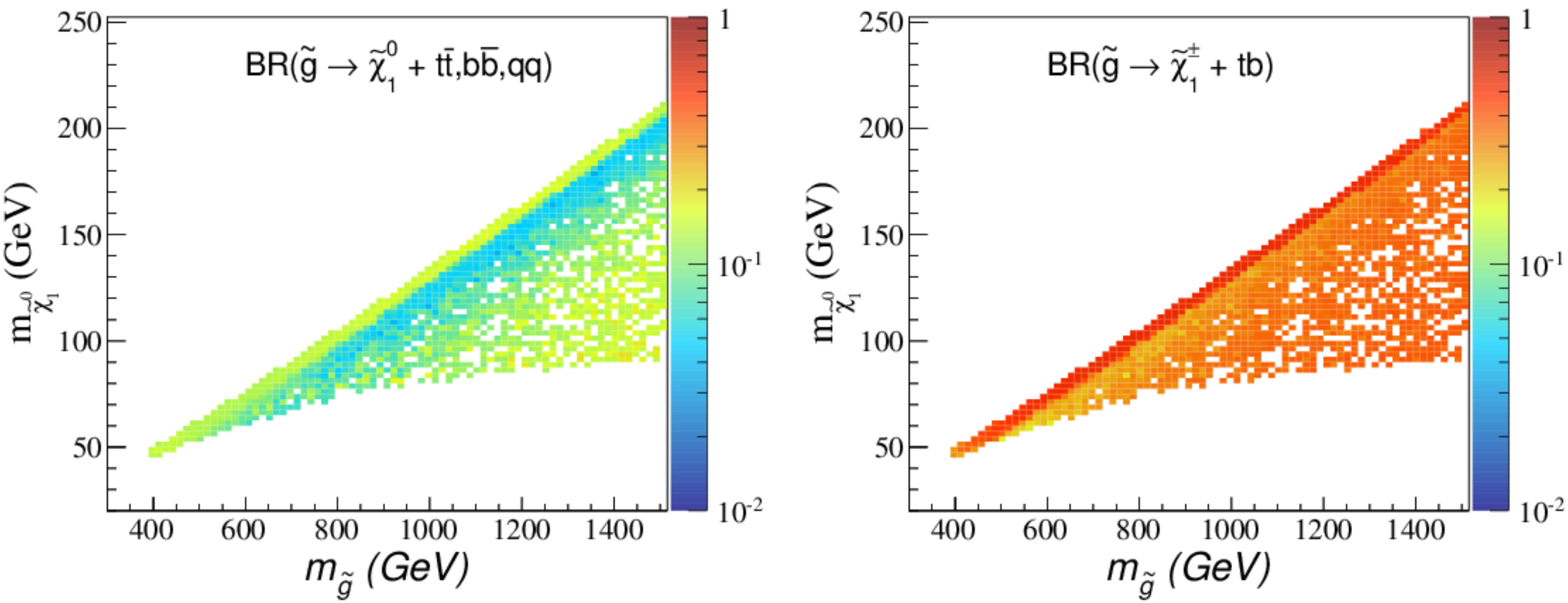


Only very small portion of parameter space strictly excluded

MSSM scan - weak sector



- Gluino decays to chargino + tb final state clearly dominate over the direct decays to the LSP
- Points with dominant direct decays to LSP are indeed ruled out by SMS results
- Take home message: not all relevant SMS topologies are indeed considered in the experimental results

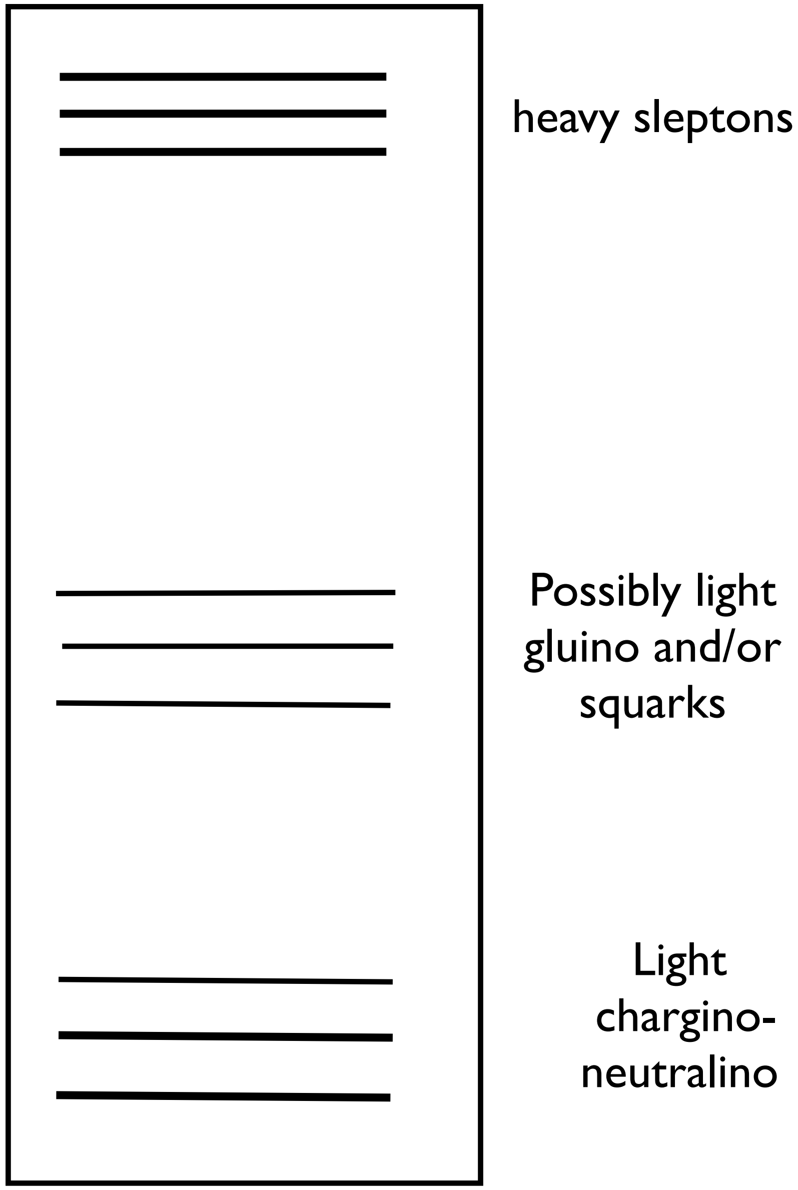
MSSM scan - strong sector

- Weak scale MSSM scan over 9 parameters

– Gaugino masses obey GUT relation

– Flavor constraints, invisible Z width, Higgs mass, LEP limits imposed

– Scan ranges

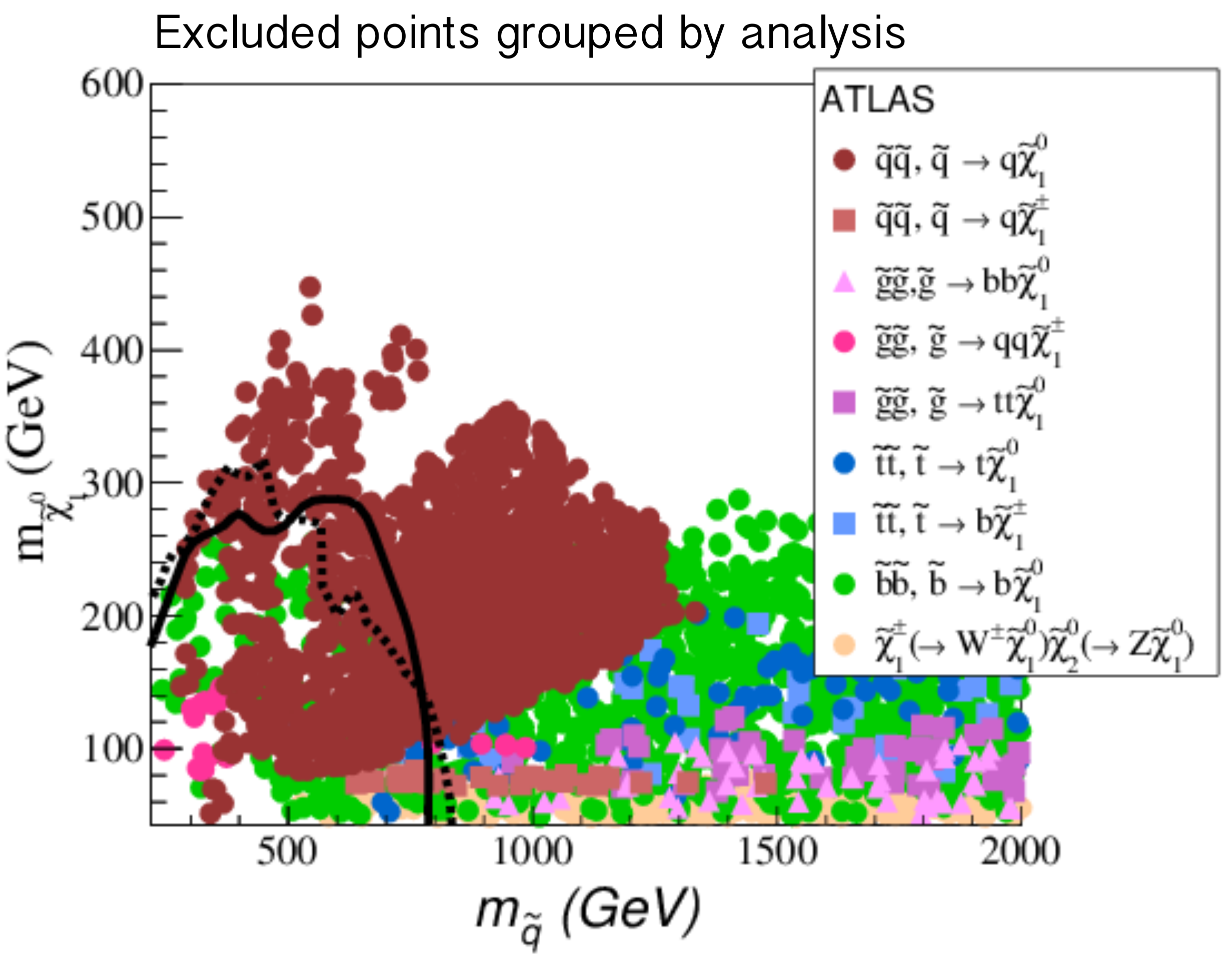


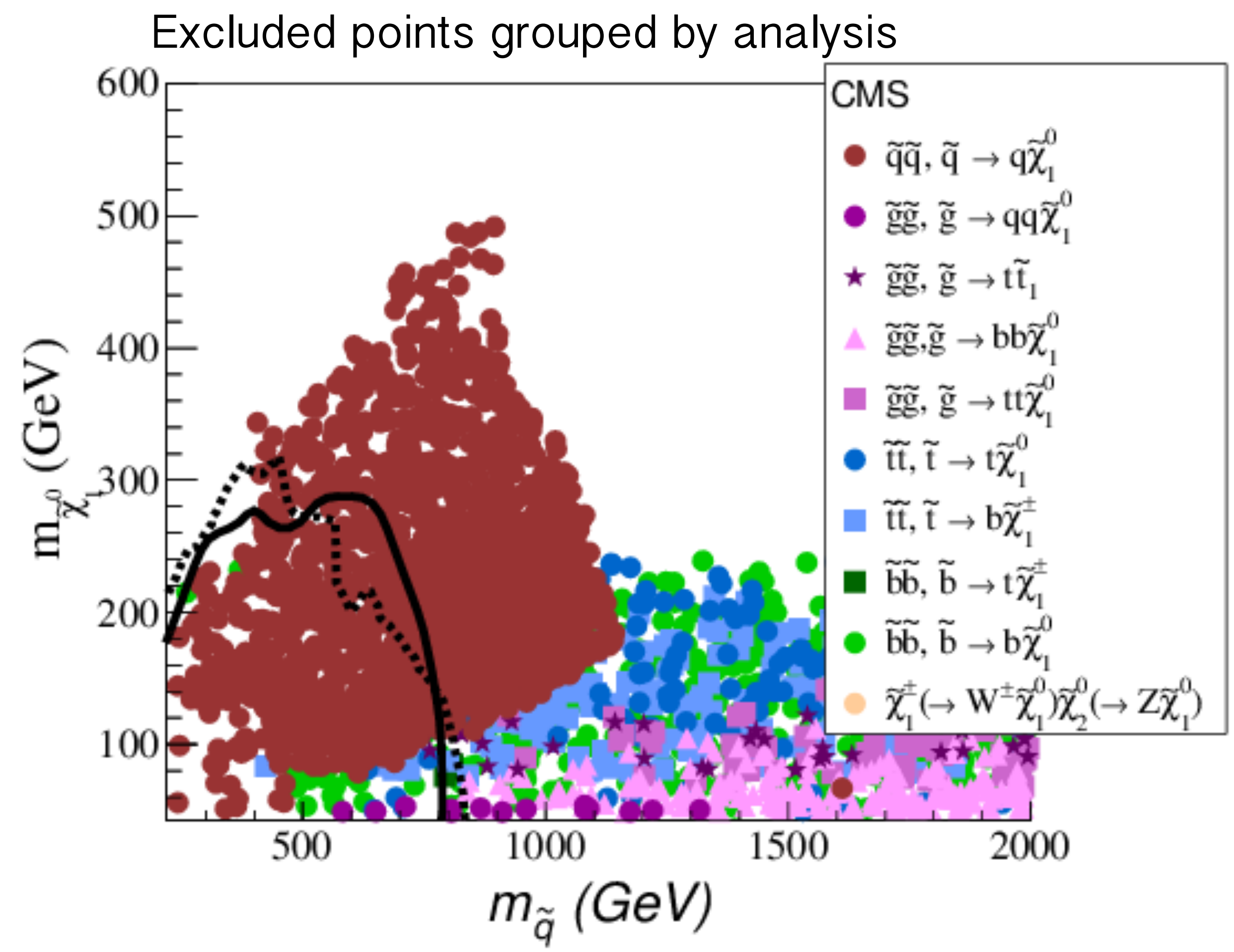
M_2	μ	$\tan\beta$	$M_{\tilde{q}}$	$M_{\tilde{Q}_3}$	$M_{\tilde{D}_3}$	$M_{\tilde{U}_3}$	A_t	A_b
0.1–1	0.1–1	3–60	0.1–5	0–2	0–2	0–2	$[1,3]\max(M_{\tilde{Q}_3}, M_{\tilde{Q}_3})$	±1

MSSM scan - strong sector

- Topologies being tested:
  - Squark production;
    - -- direct decays to quarks + LSP
    - -- three body decay via off-shell gluino
  - Direct stop and sbottom production and decays
  - Gluino production;
    - -- three body decay via off-shell squarks
    - -- decays via on-shell stop and sbottom
  - Chargino-neutralino production and decay to WZ final state (no intermediate sleptons possible)

MSSM scan - strong sector

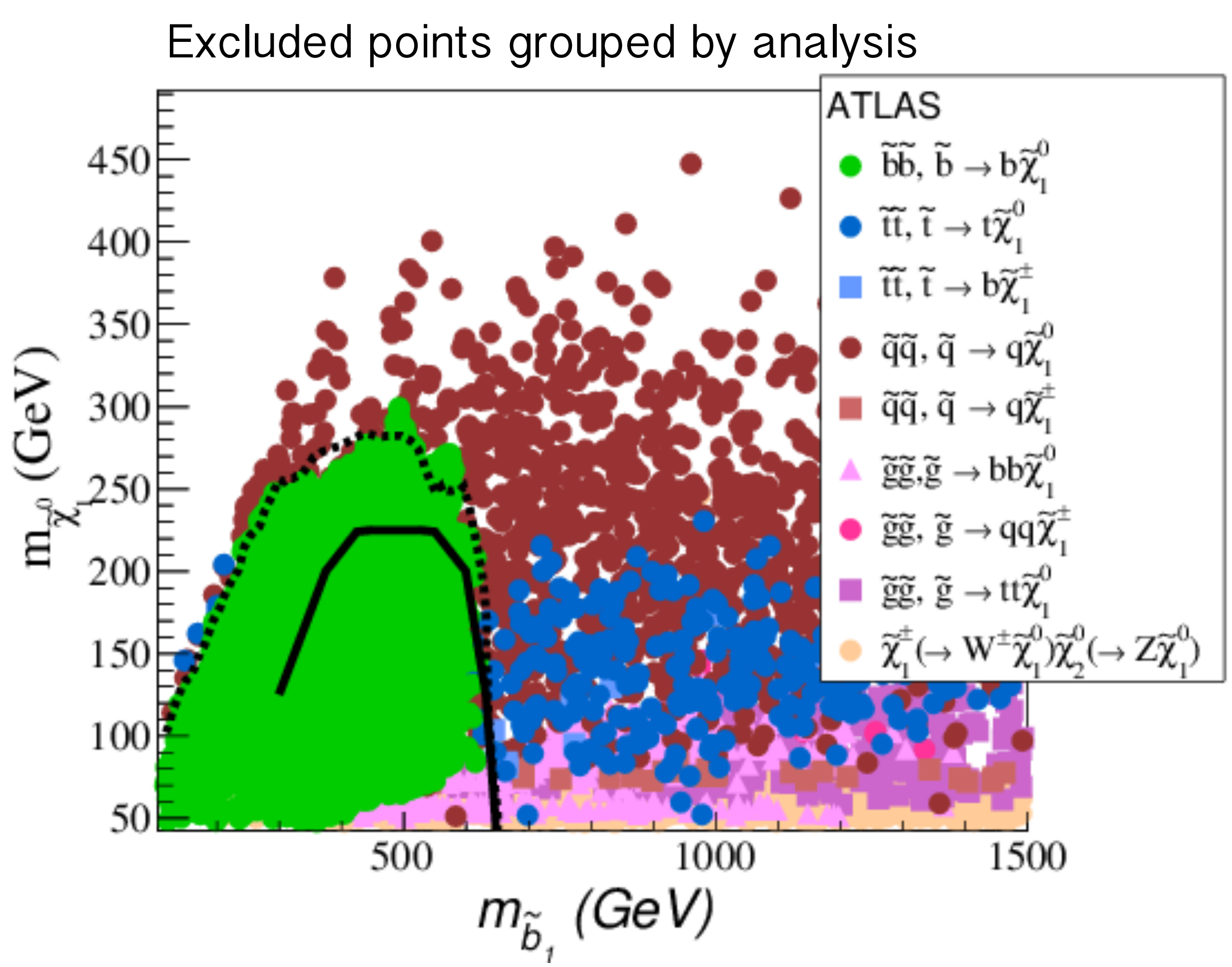


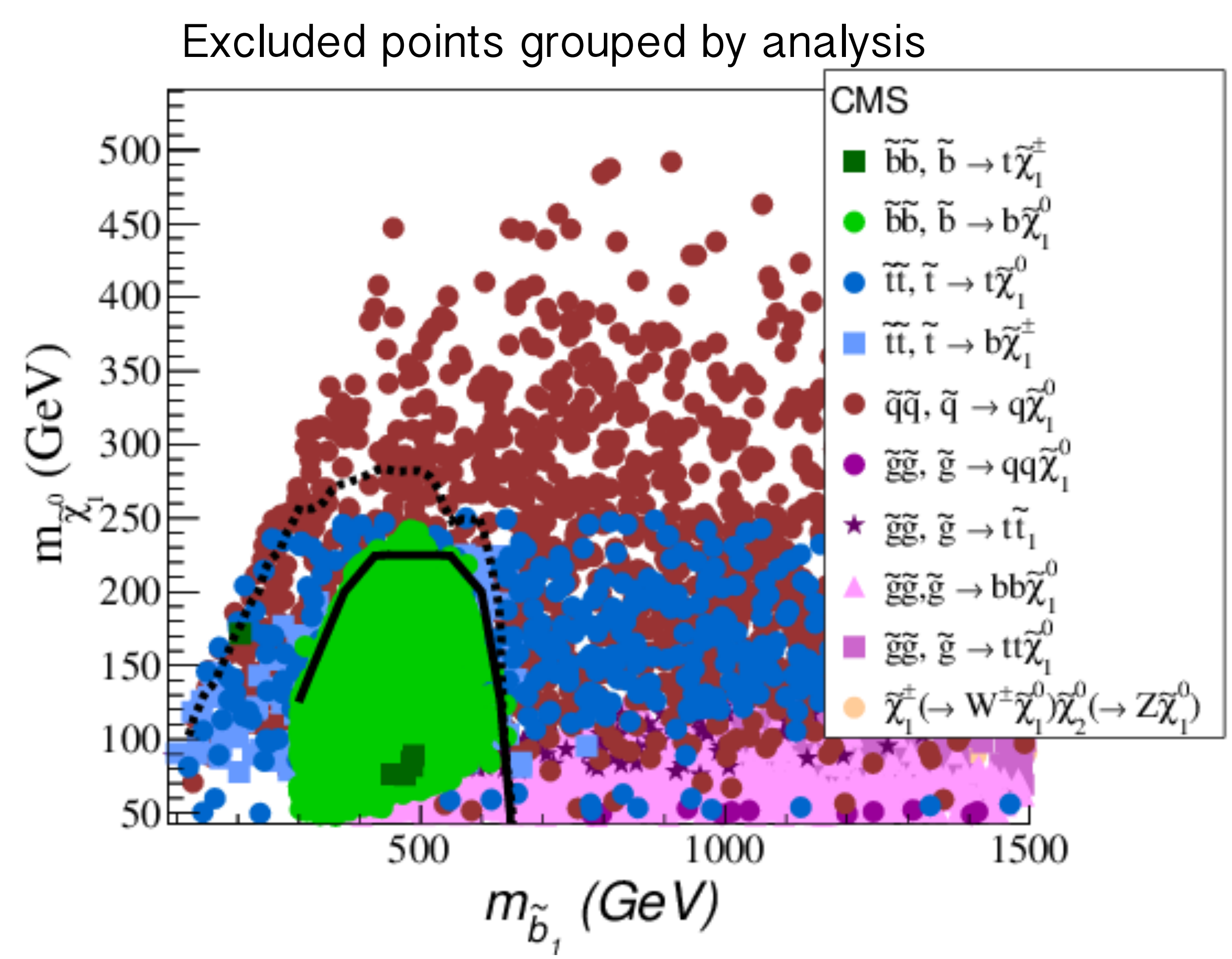


- A different way of looking at the SMS results: excluded points grouped according to the strongest analysis
- Exclusions for direct squark production from SModelS stronger than experimental exclusions because gluino not decoupled → increases squark pair production cross-section
- Take home message: limits depend on precise scenario, including production channel mechanisms

Strongest analysis = analysis with highest theory to expt ratio

MSSM scan - strong sector





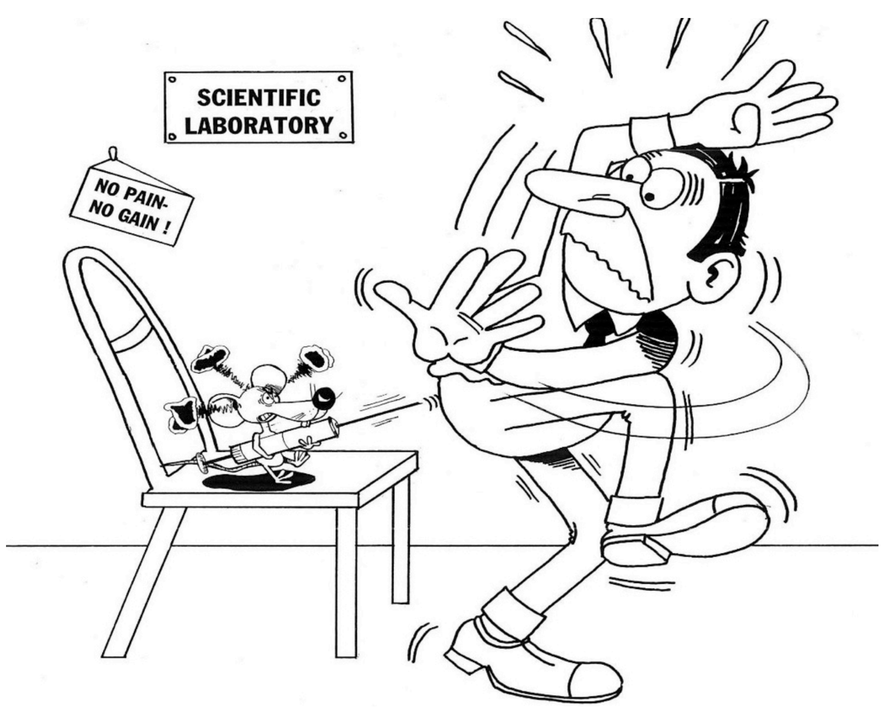
- Exclusions for sbottom masses pretty robust, most of the topologies covered
- Take home message: sometimes it works beautifully! ;)

Going beyond the MSSM

Two examples

NMSSM - an additional singlet field to the usual MSSM fields

MSSM with Sneutrino LSP - an additional right handed sneutrino field to the usual MSSM fields

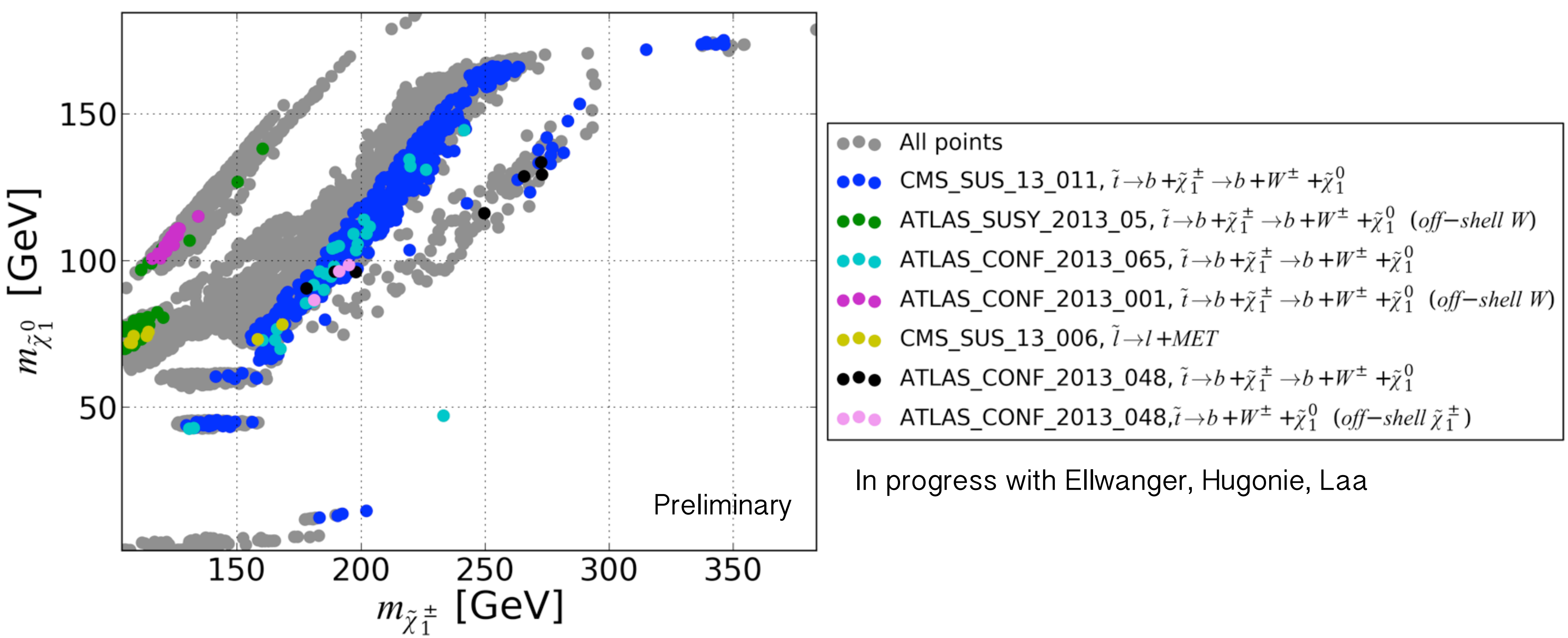


NMSSM - what can we constrain?

cf. arXiv:1405.6647
cf. talk by J. Gunion on Monday

- Points with light stop, EW-kino, obeying relic density constraints

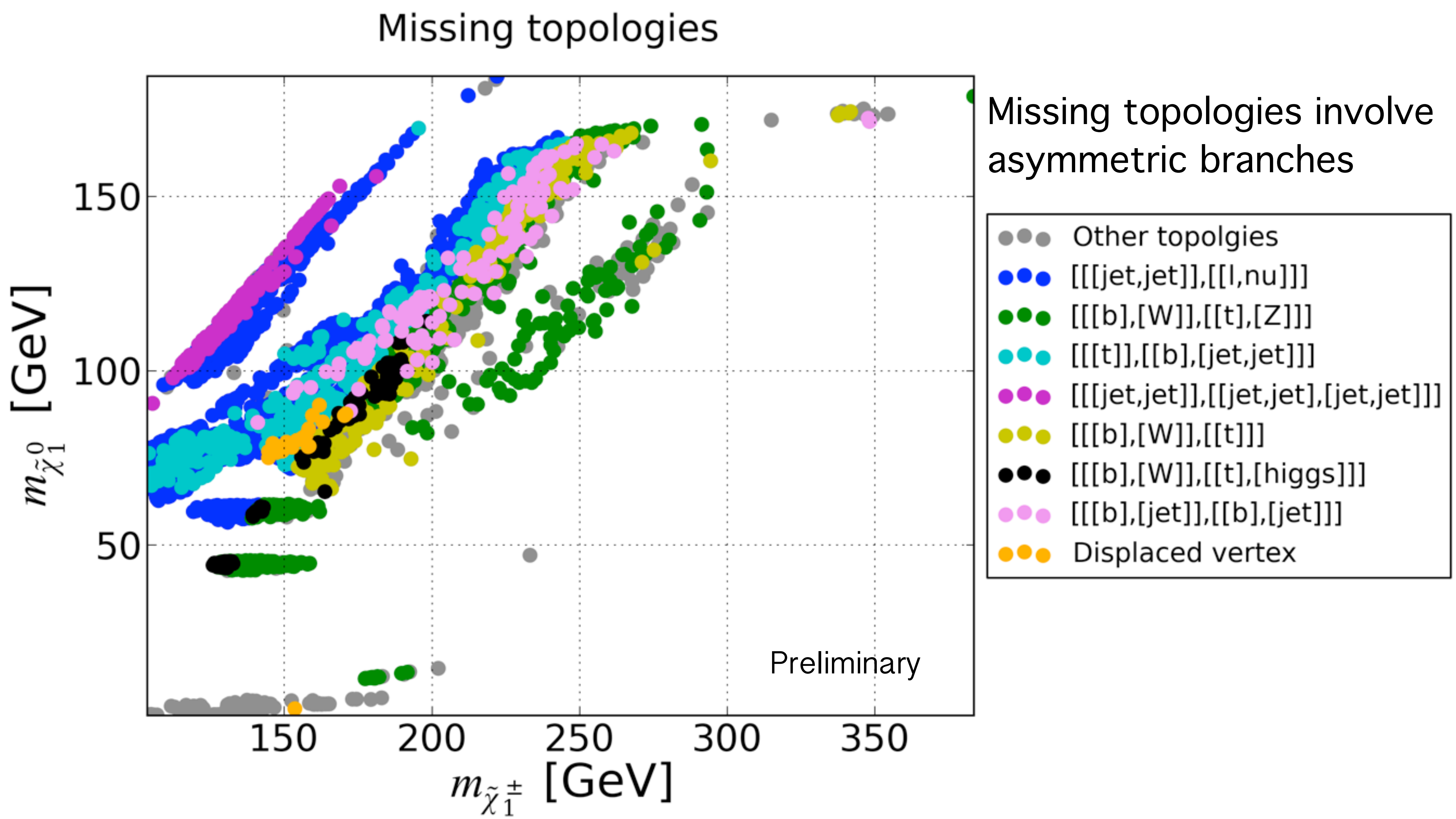
Excluded points grouped according to the analyses and topolgoy



In progress with Ellwanger, Hugonie, Laa

- Points excluded due to stop decays to b + chargino
- Stop decays to t + LSP play no role due to singlino nature of the LSP

NMSSM - what do we miss?



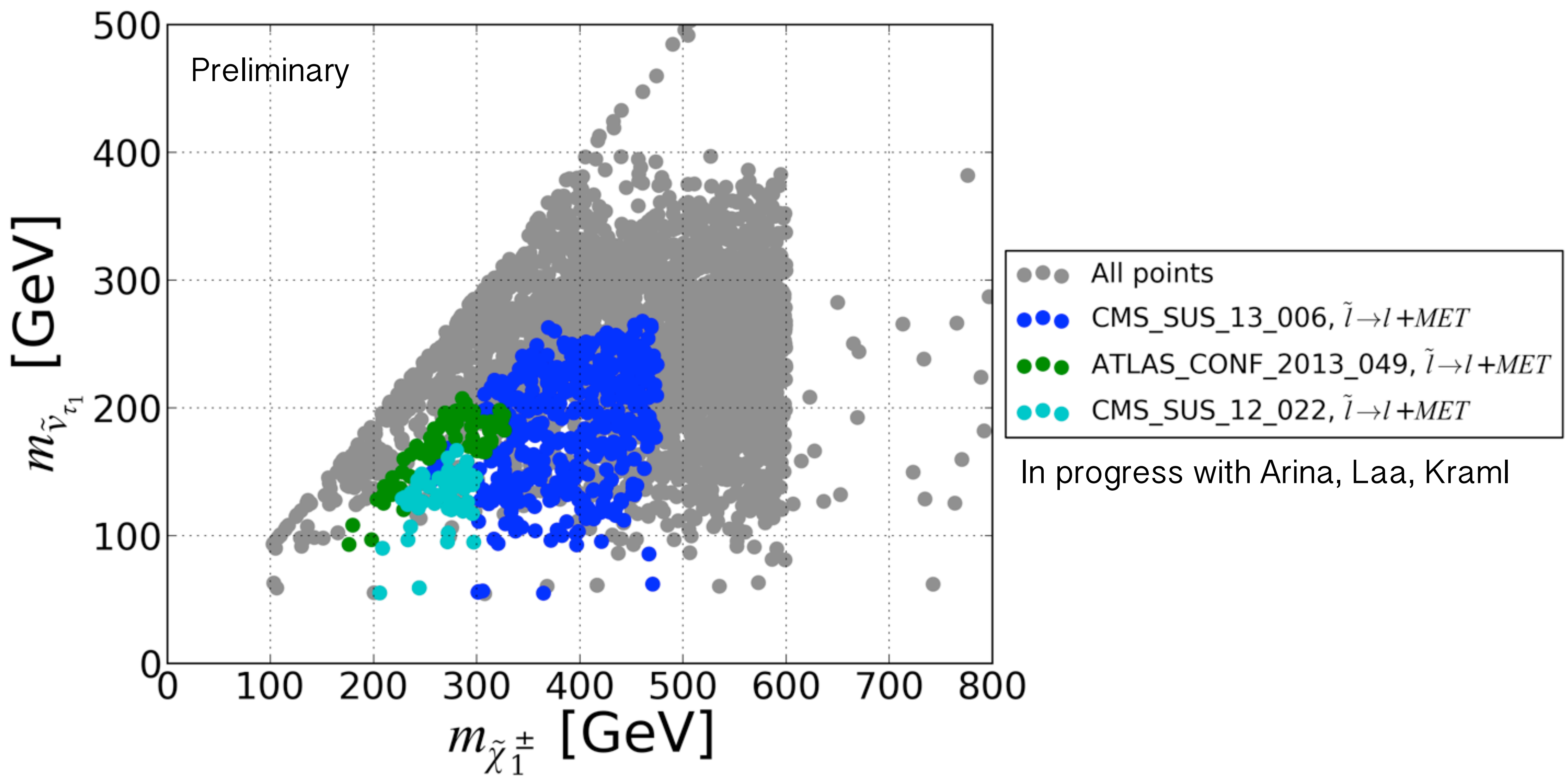
Missing topologies involve asymmetric branches

- Most dominant topologies in parameter space can be identified, useful for prioritization of SMS results
- SModelS can also identify topologies with displaced vertices

Sneutrino LSP - what can we constrain?

- Points with sneutrino LSP obeying relic density constraints (spectra contains light gluino, light scalars, light EW-kino) cf. arXiv:1311.6549

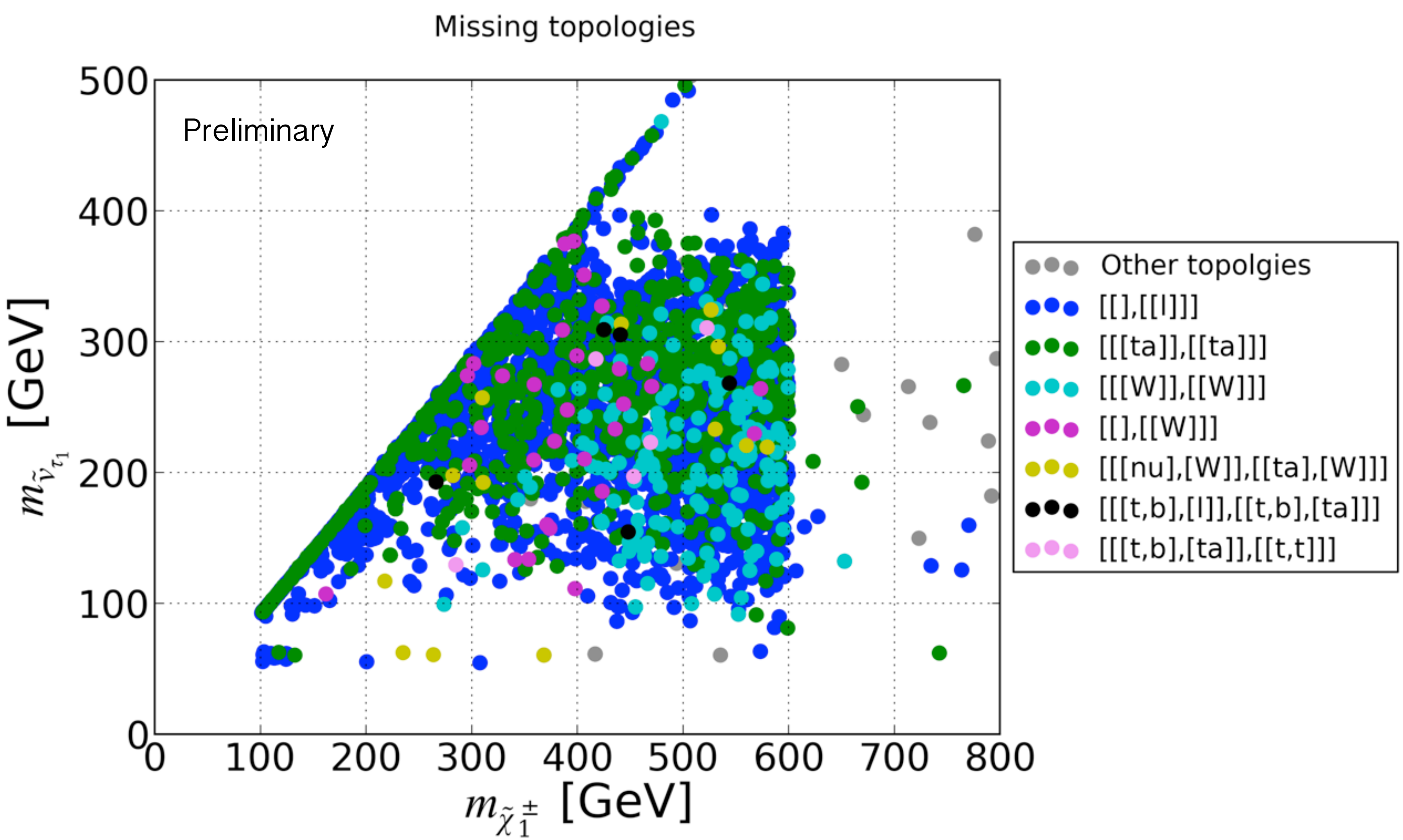
Excluded points grouped according to the analyses and topolgoy



In progress with Arina, Laa, Kraml

- Points excluded by direct slepton searches, originate from chargino production decay to sneutrino

Sneutrino LSP - what do we miss?



- Single-lepton topology dominant → mono-lepton searches?(CMS-PAS-EXO-13-004)
- Di-tau final state - no SMS results available

SMS approach - caveats

- Statistical interpretation of results obtained by SModelS is not possible at the moment
- Combination of two different SMS results is not easy, no sound way known
- It is not easy to test parameter space containing complicated cascade decays with SMS approach; going for analysis re-implementation is a good idea, approach taken by checkMATE, MadAnalysis public database ➔ cf. Talk by S. Kraml
- Two different SMS topologies leading to the same final state can not be combined within SModelS, going via efficiency maps is a good idea in this case, approach taken by FastLim
- SModelS relies to a large extent on the results provided by the experimentalists, we request the experimentalists to always provide us with the upper limits and digitized data of their results

Conclusions

- SModelS is an automated tool, which uses simplified models results given by experimentalists to constrain BSM scenarios
- The tool can not only be used to test the parameter space but can also be used to find the dominant missing topologies in a given parameter space

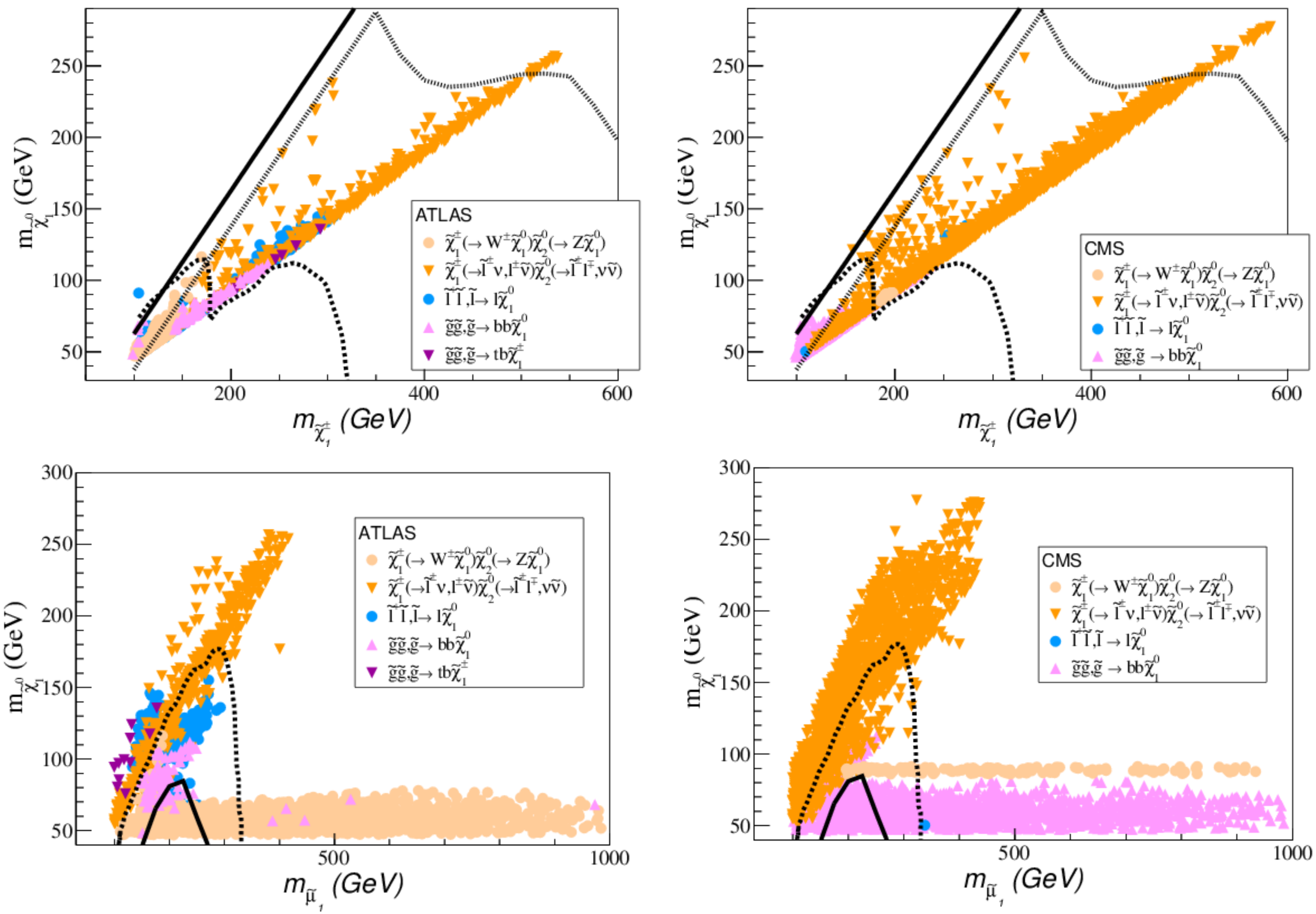
Conclusions

- SModelS is an automated tool, which uses simplified models results given by experimentalists to constrain BSM scenarios
- The tool can not only be used to test the parameter space but can also be used to find the dominant missing topologies in a given parameter space
- In general, theory space can evade SMS results depending on the nature of particles, availability of SMS results and off-shell effects
- For NMSSM parameter space with light stops, direct stop decays to LSP do not lead to constraints due to singlino nature of the LSP
- The sneutrino LSP parameter space can be constrained by using single lepton +MET final state searches at the LSP

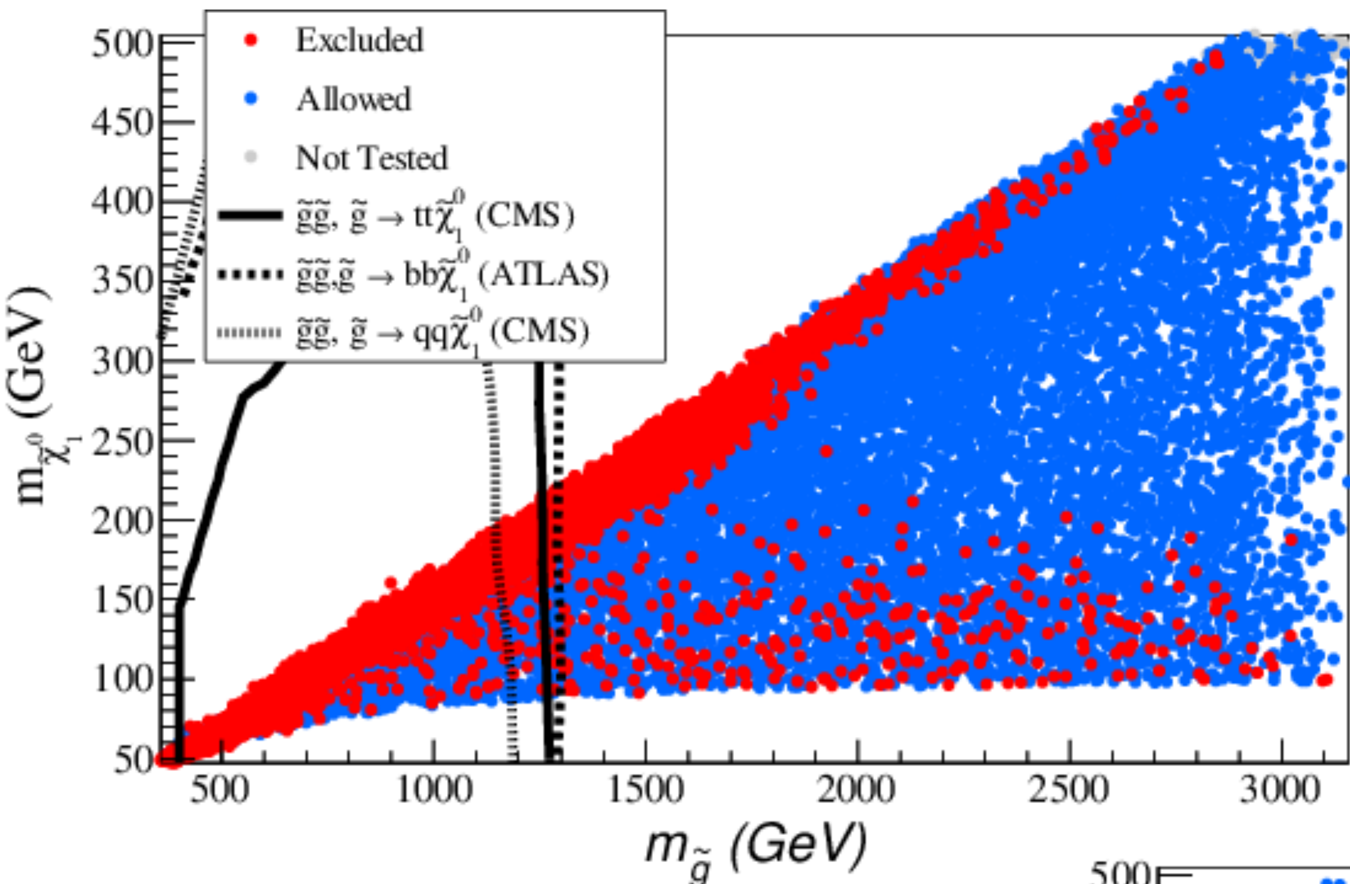
BACK-UP

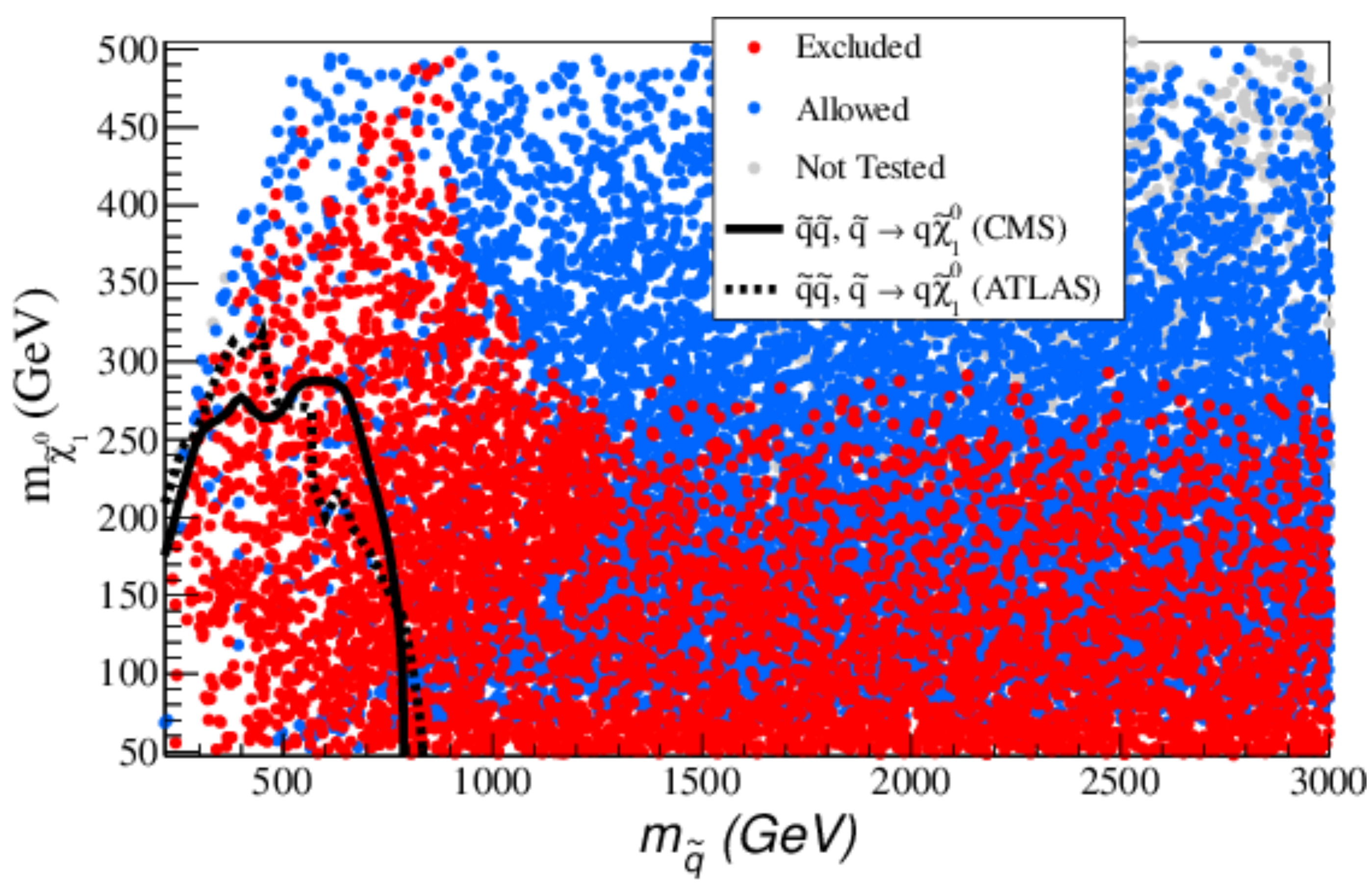
SUSY scan - weak sector

- Breakdown of the excluded parameter space by analysis

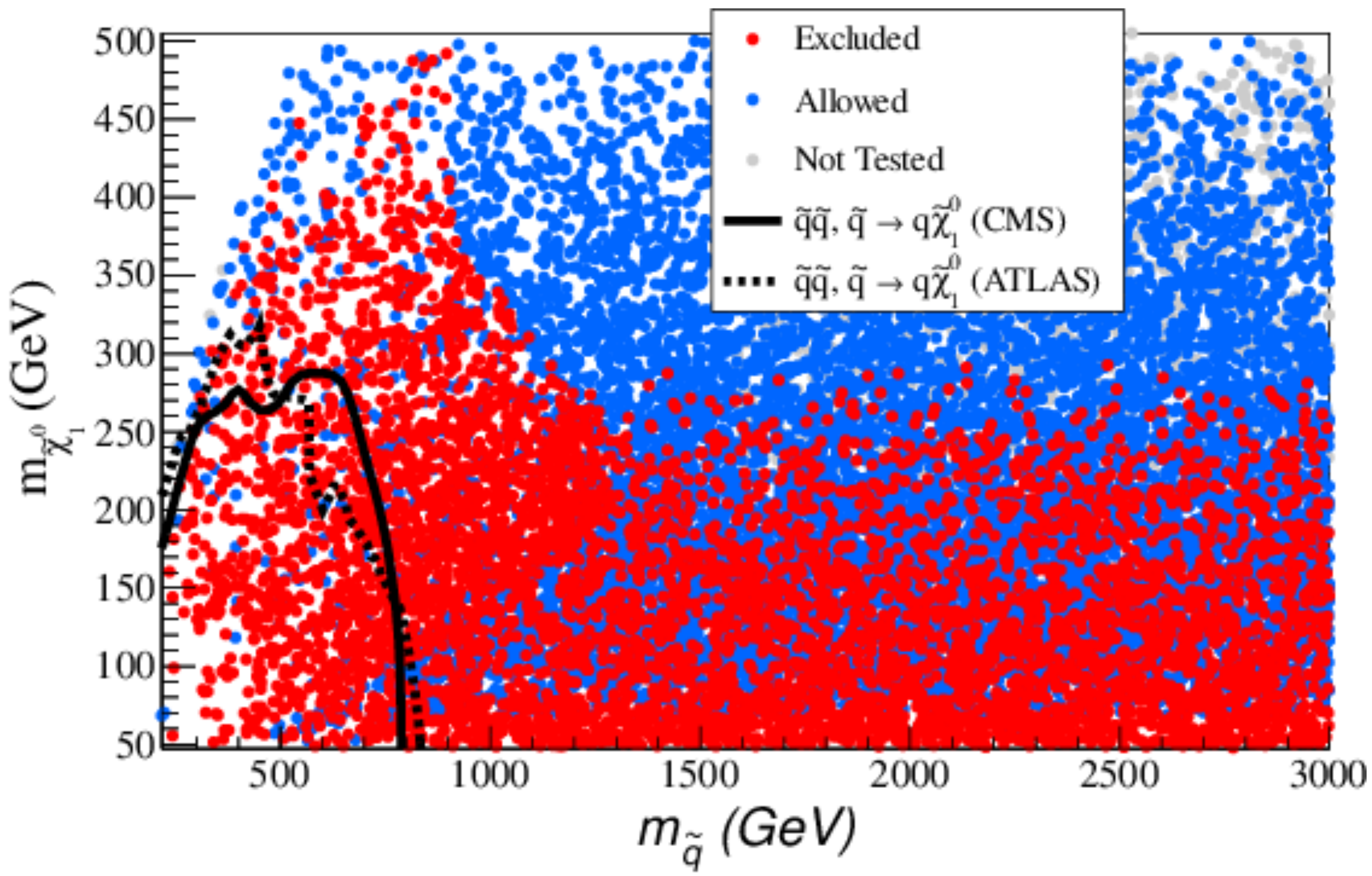


SModelS scan - strong focus



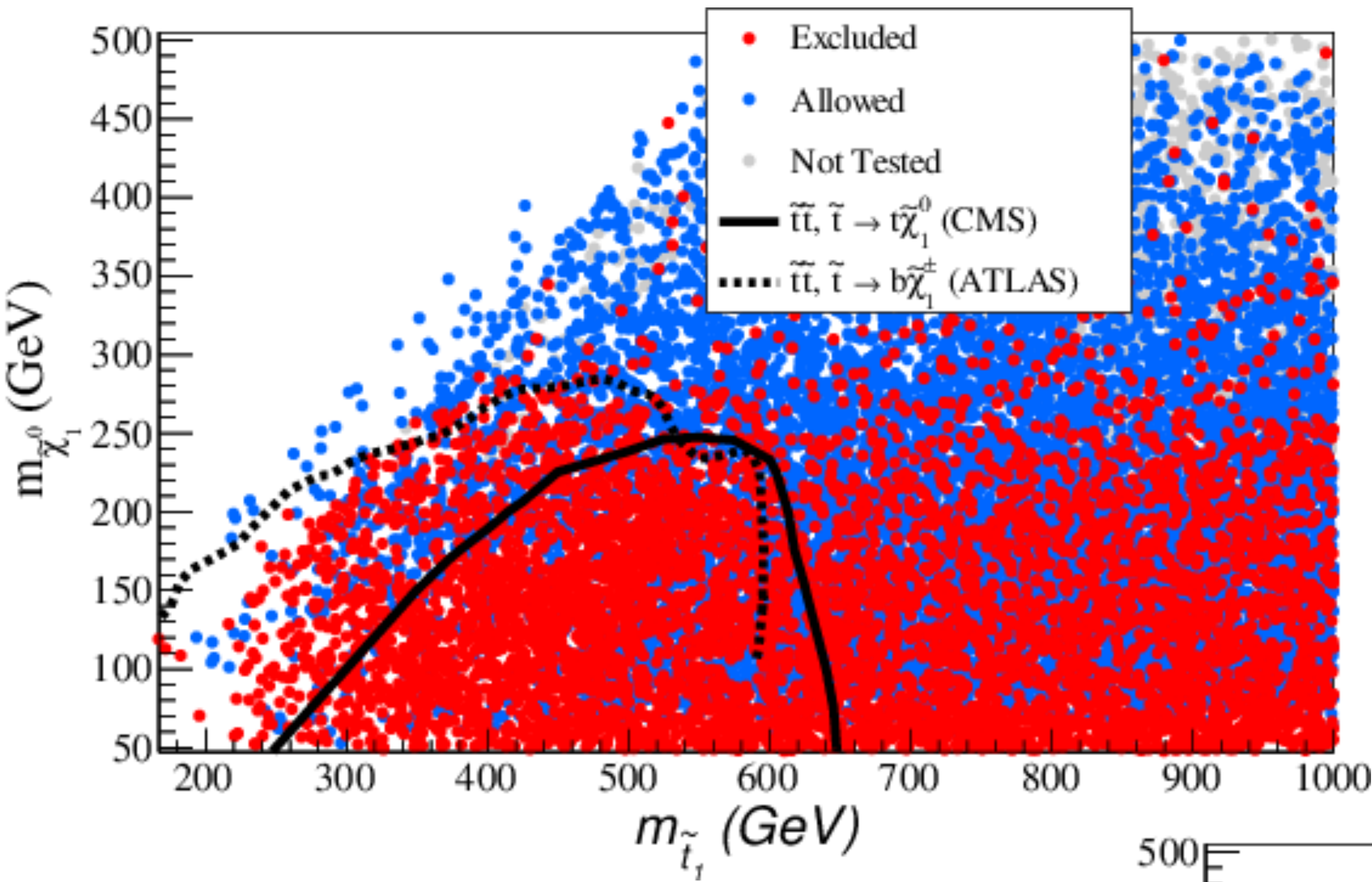


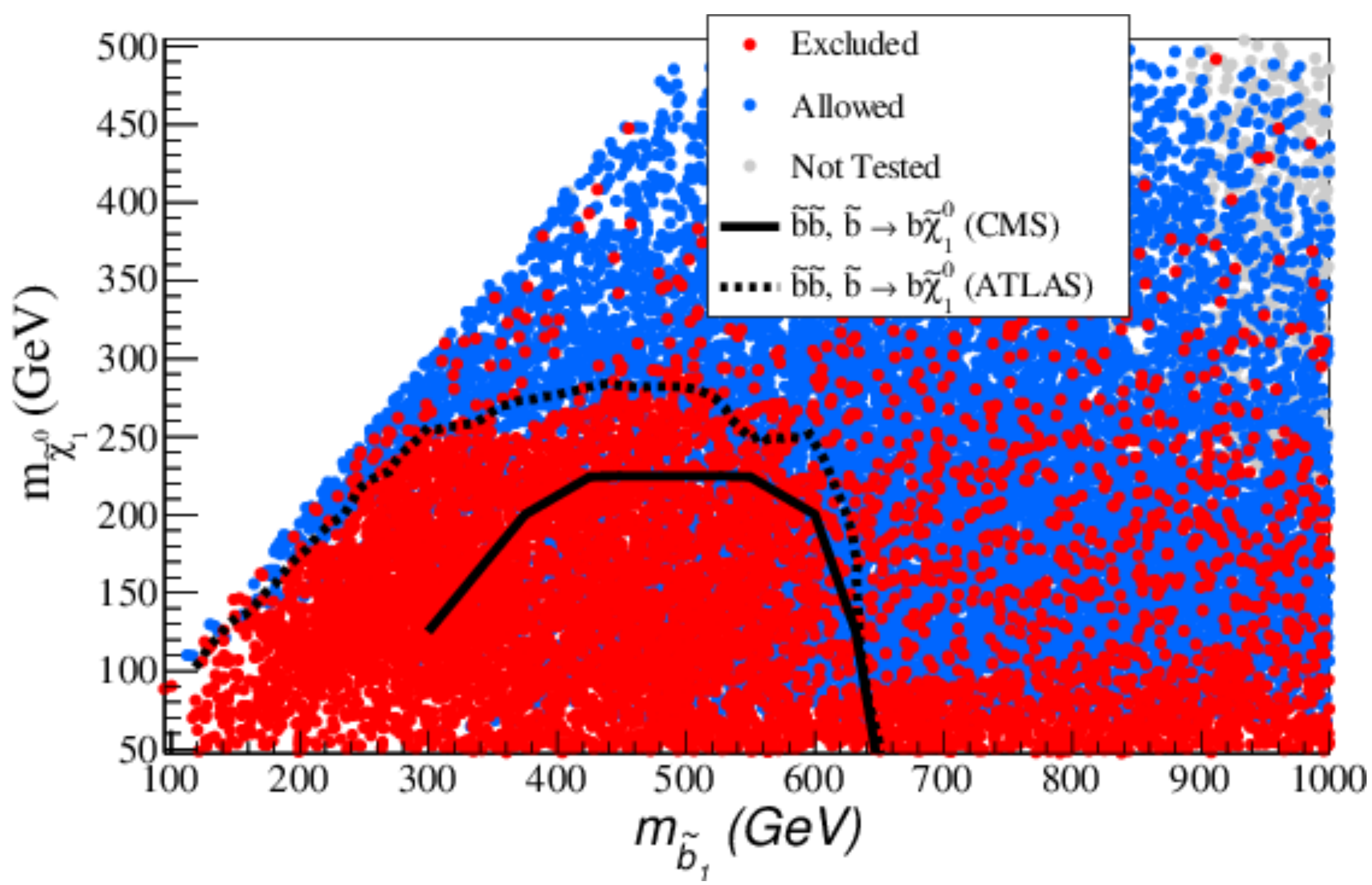
SModelS scan - s vs t channel



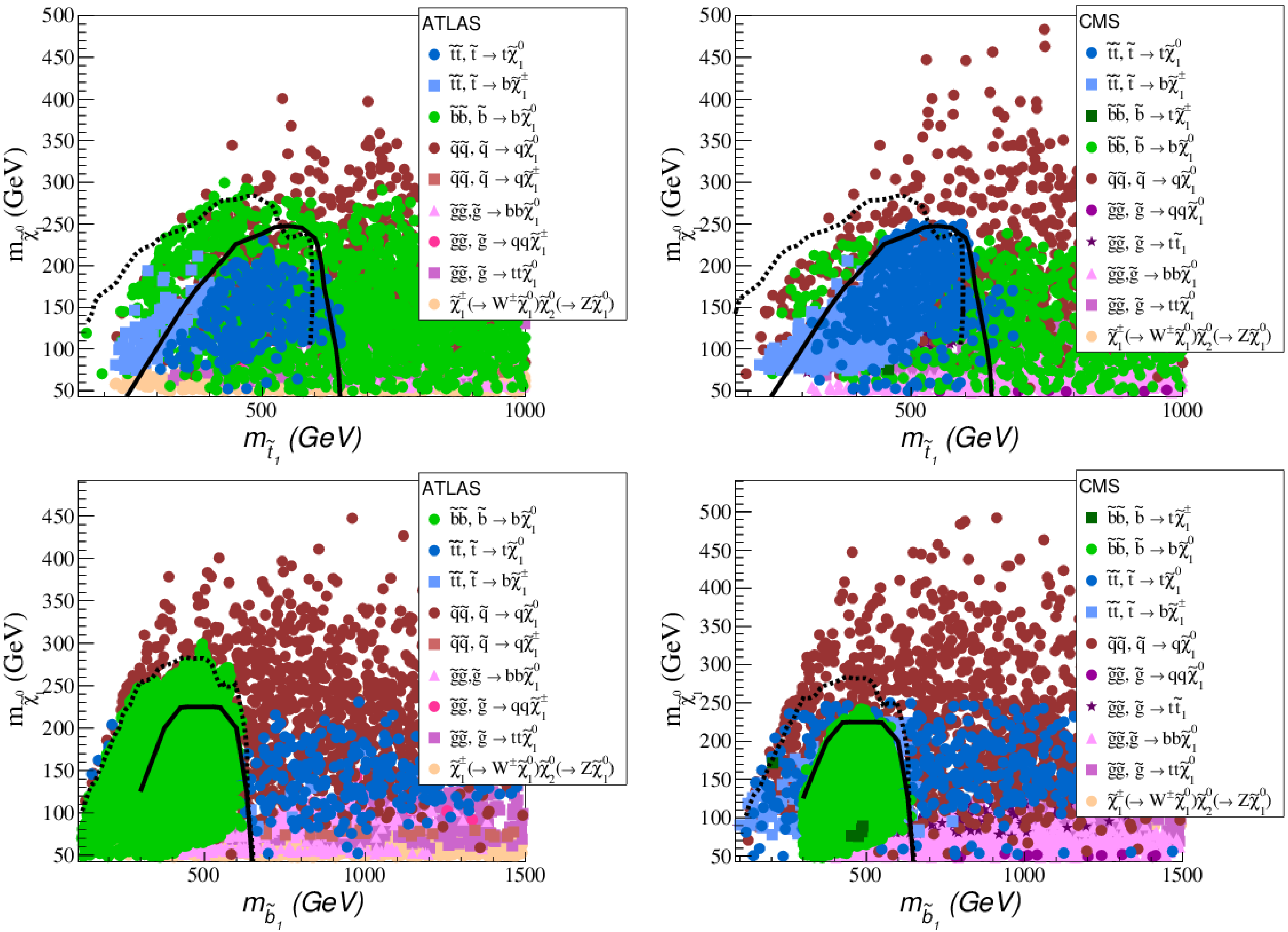
- For gluino pair production, the pT is not strongly dependent
- For squark pair production the pT can vary depending on s and t channel production

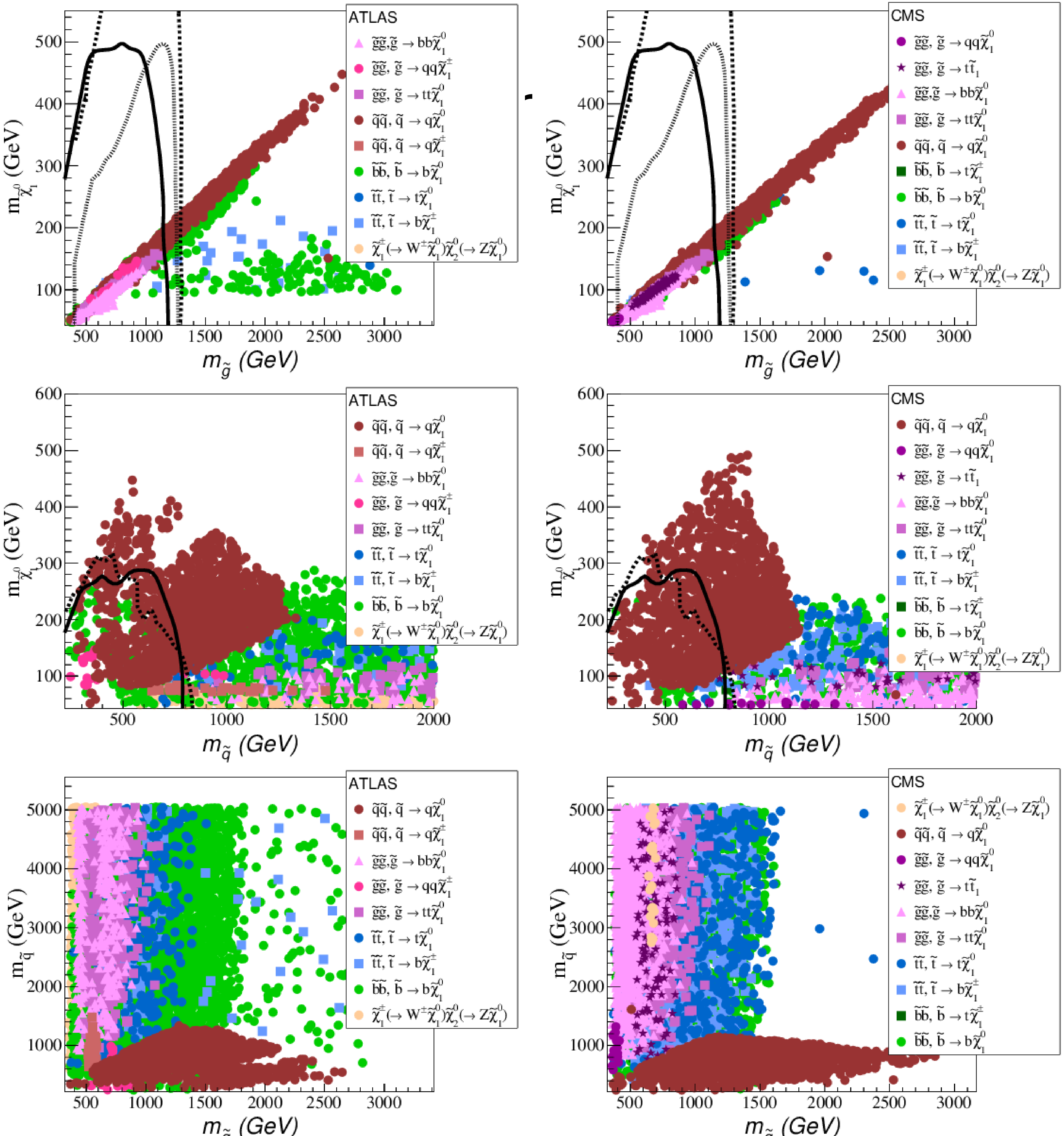
SModelS scan - strong focus





SModelS scan - strong focus





ATLAS
CMS
$m_{\tilde{\chi}_1^0}$ (GeV)
$m_{\tilde{g}}$ (GeV)
$m_{\tilde{q}}$ (GeV)
$\tilde{g}\tilde{g}, \tilde{g} \to bb\tilde{\chi}_1^0$
$\tilde{g}\tilde{g}, \tilde{g} \to qq\tilde{\chi}_1^\pm$
$\tilde{g}\tilde{g}, \tilde{g} \to tt\tilde{\chi}_1^0$
$\tilde{g}\tilde{g}, \tilde{g} \to qq\tilde{\chi}_1^0$
$\tilde{g}\tilde{g}, \tilde{g} \to t\tilde{t}_1$
$\tilde{q}\tilde{q}, \tilde{q} \to q\tilde{\chi}_1^0$
$\tilde{q}\tilde{q}, \tilde{q} \to q\tilde{\chi}_1^\pm$
$\tilde{b}\tilde{b}, \tilde{b} \to b\tilde{\chi}_1^0$
$\tilde{b}\tilde{b}, \tilde{b} \to t\tilde{\chi}_1^\pm$
$\tilde{t}\tilde{t}, \tilde{t} \to t\tilde{\chi}_1^0$
$\tilde{t}\tilde{t}, \tilde{t} \to b\tilde{\chi}_1^\pm$
$\tilde{\chi}_1^\pm(\to W^\pm\tilde{\chi}_1^0)\tilde{\chi}_2^0(\to Z\tilde{\chi}_1^0)$

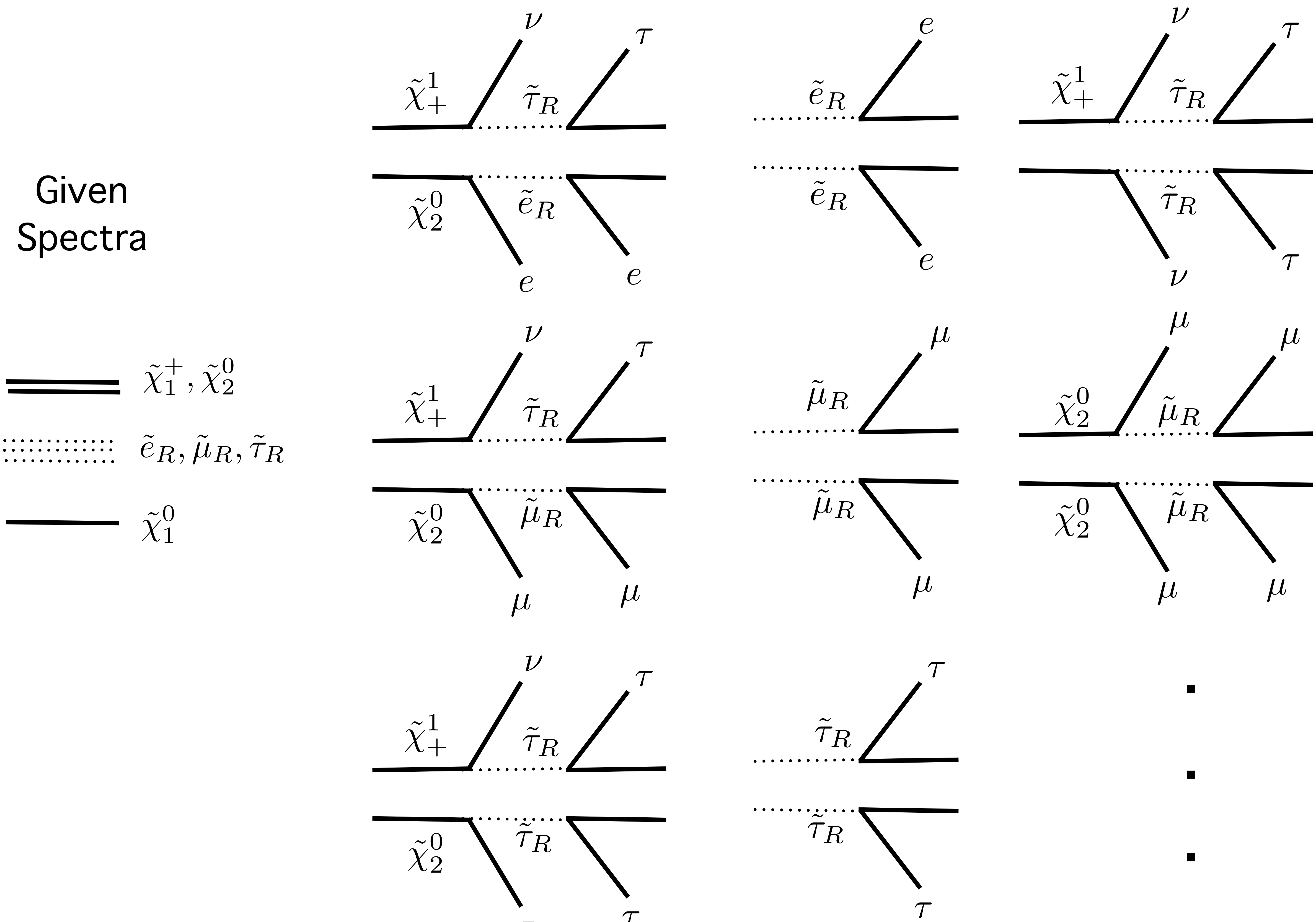
Given
Spectra

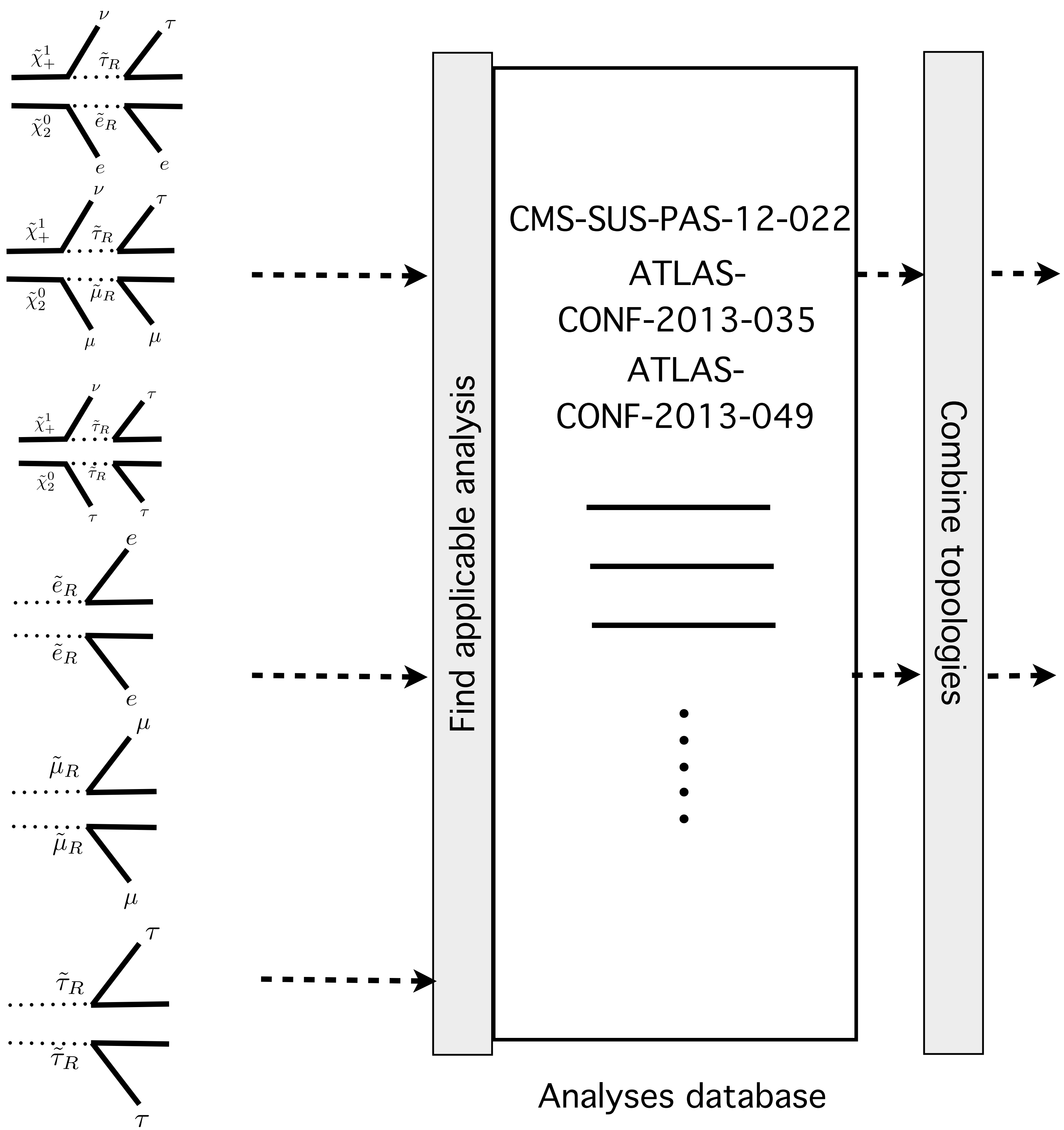
$\tilde{\chi}_1^+, \tilde{\chi}_2^0$

$\tilde{e}_R, \tilde{\mu}_R, \tilde{\tau}_R$

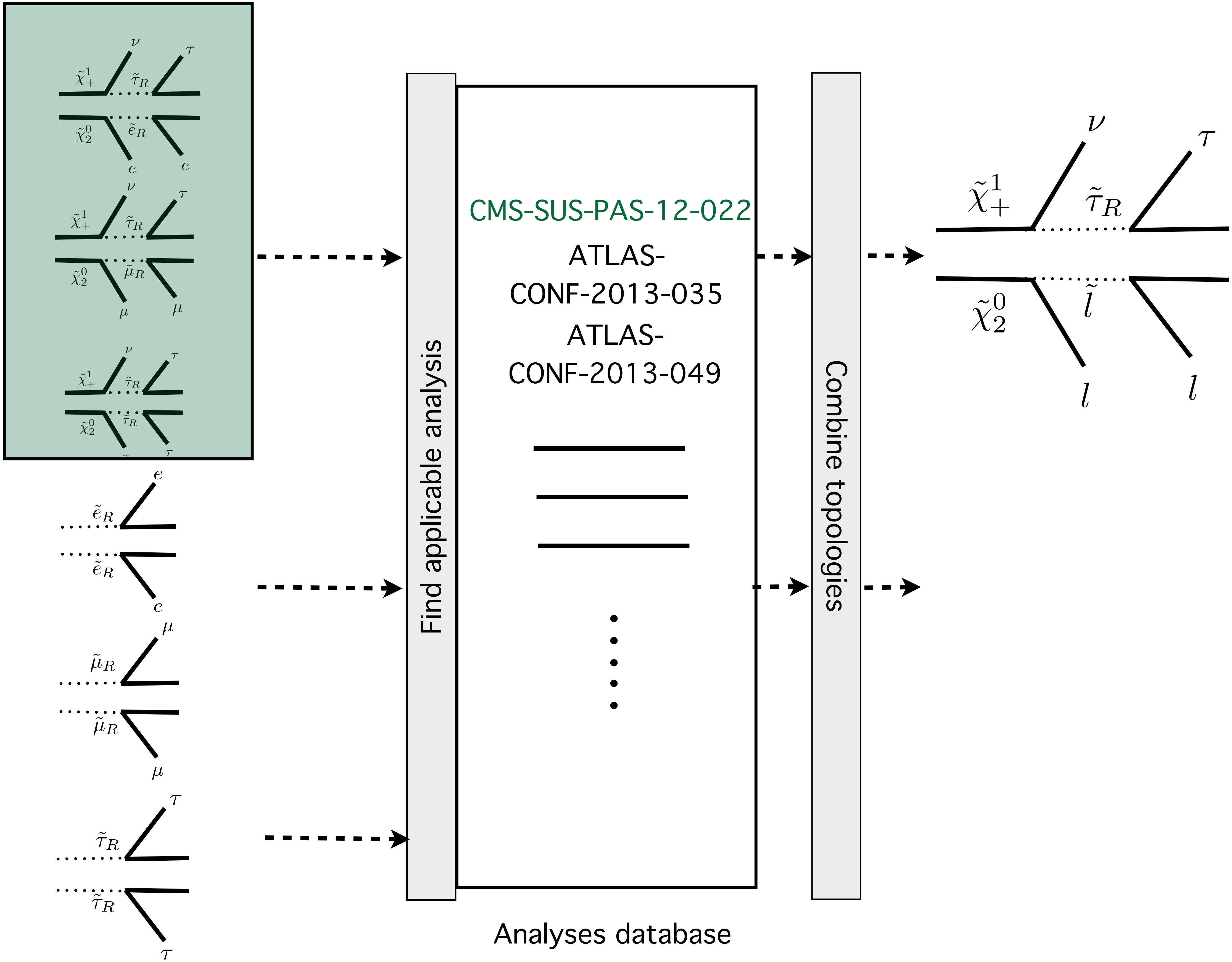
$\tilde{\chi}_1^0$

Decomposition





ν
τ
$\tilde{\chi}^1_+$
$\tilde{\tau}_R$
$\tilde{\chi}^0_2$
$\tilde{e}_R$
e
e
ν
τ
$\tilde{\chi}^1_+$
$\tilde{\tau}_R$
$\tilde{\chi}^0_2$
$\tilde{\mu}_R$
μ
μ
ν
τ
$\tilde{\chi}^1_+$
$\tilde{\tau}_R$
$\tilde{\chi}^0_2$
$\tilde{\tau}_R$
τ
τ
e
$\tilde{e}_R$
$\tilde{e}_R$
e
μ
$\tilde{\mu}_R$
$\tilde{\mu}_R$
μ
τ
$\tilde{\tau}_R$
$\tilde{\tau}_R$
τ
Find applicable analysis
CMS-SUS-PAS-12-022
ATLAS-CONF-2013-035
ATLAS-CONF-2013-049
Combine topologies
Analyses database



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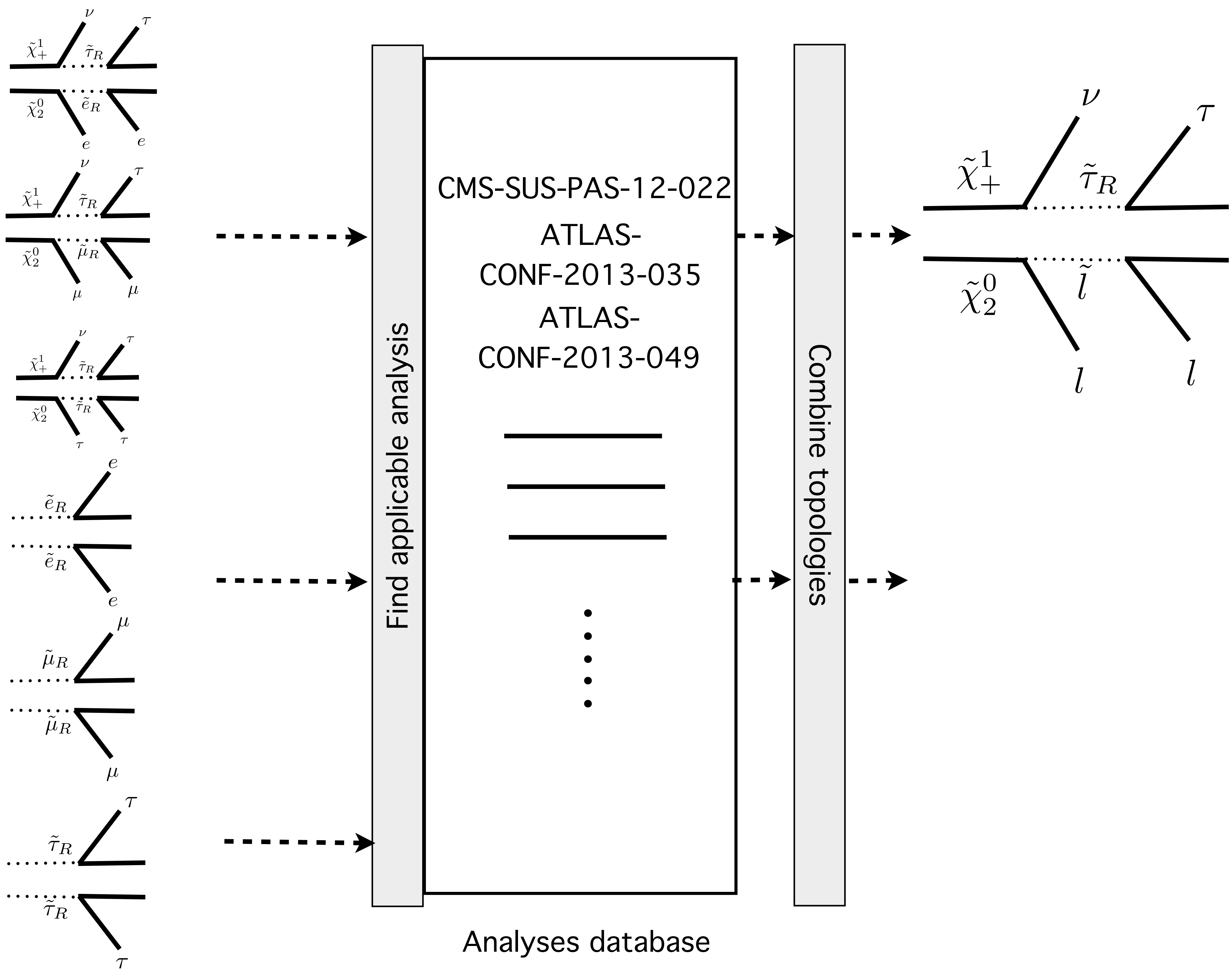

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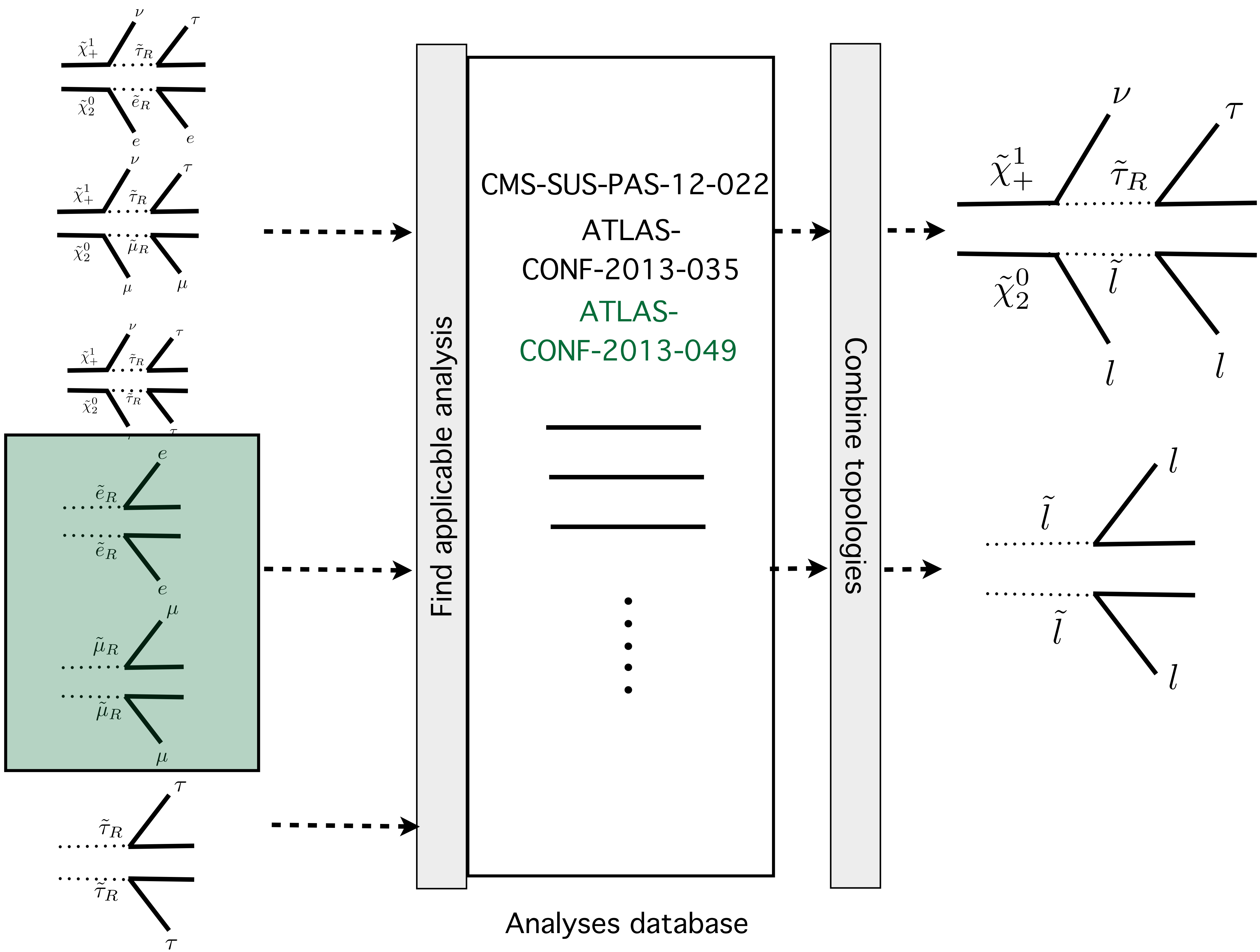

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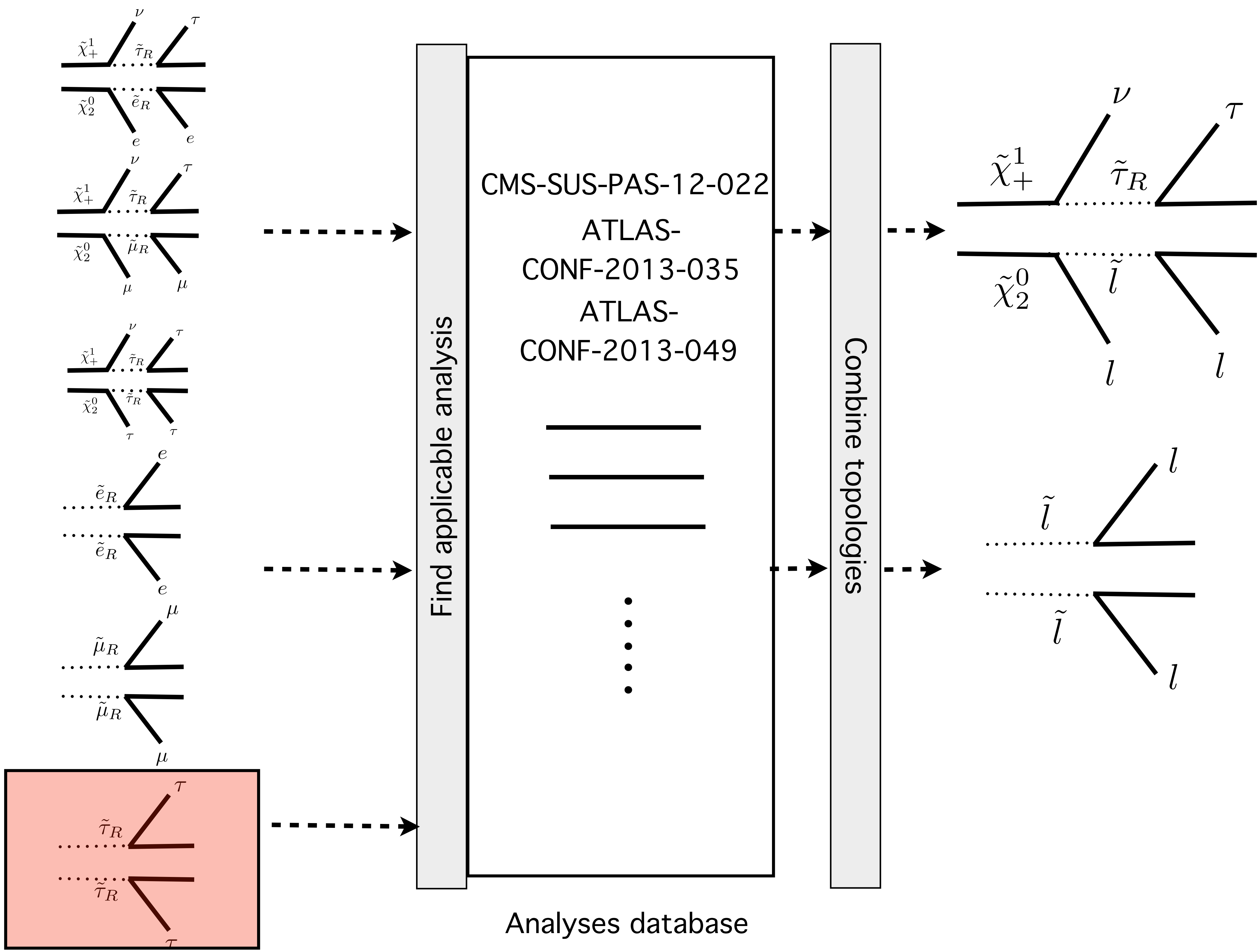

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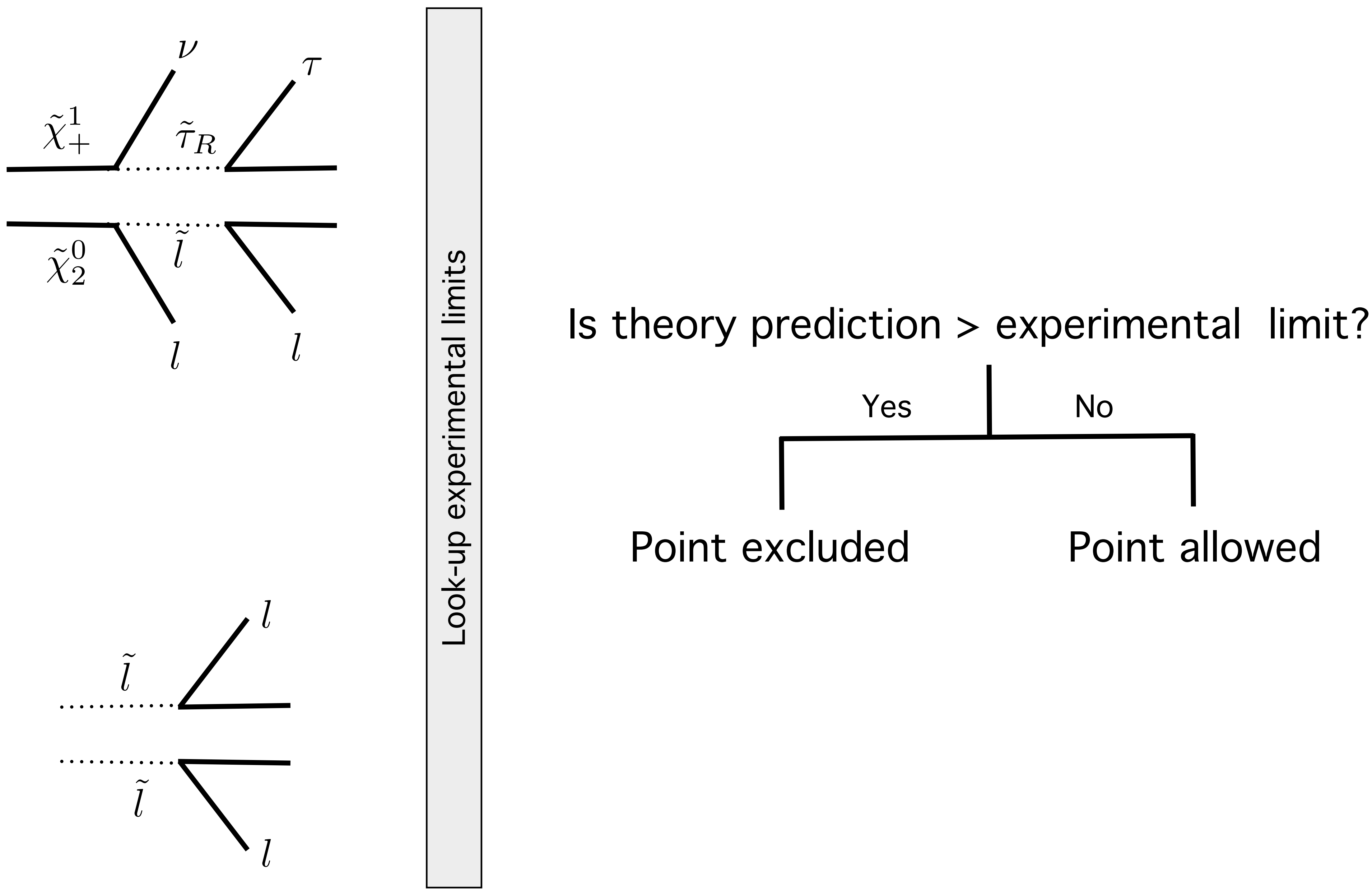


ν
τ
$\tilde{\chi}^1_+$
$\tilde{\tau}_R$
$\tilde{\chi}^0_2$
$\tilde{l}$
l
l
l
$\tilde{l}$
$\tilde{l}$
l
Look-up experimental limits
Is theory prediction > experimental limit?
Yes
No
Point excluded
Point allowed

SModelS framework

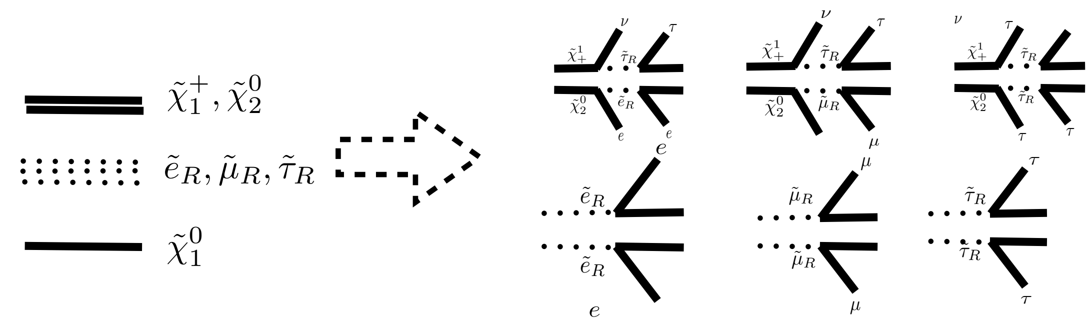
Decompose

Store final states, masses and sigma X BR for each topology

SModelS framework

Decompose

Store final states, masses and sigma X BR for each topology



SModelS framework

Decompose

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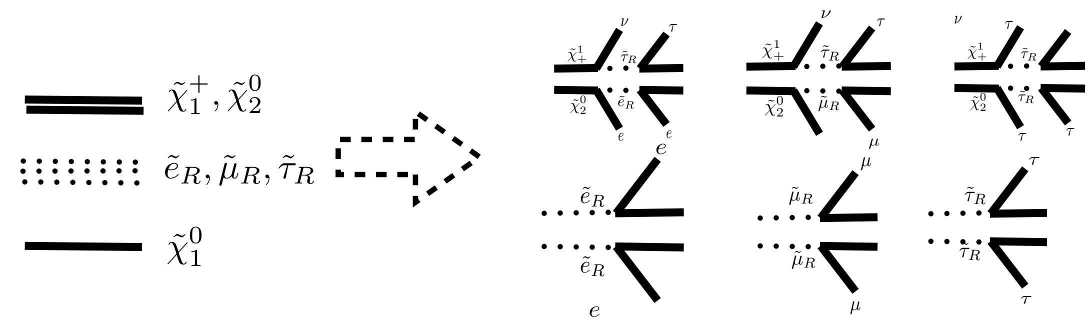


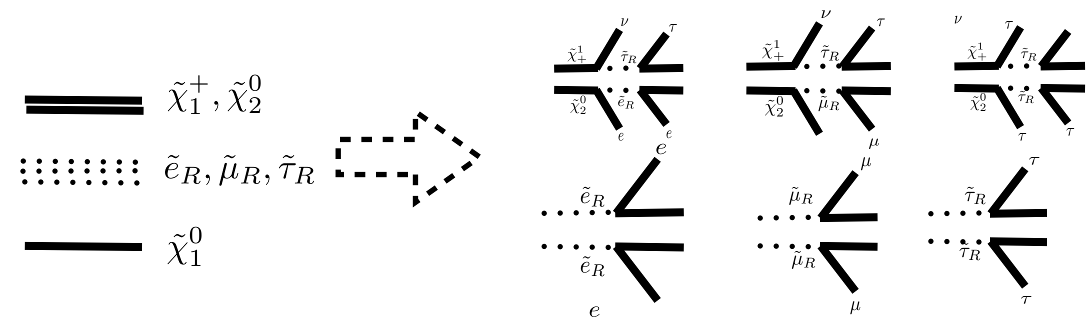
Cluster masses

Cluster masses if they can not be distinguished experimentally

SModelS framework

Decompose

Store final states, masses and sigma X BR for each topology



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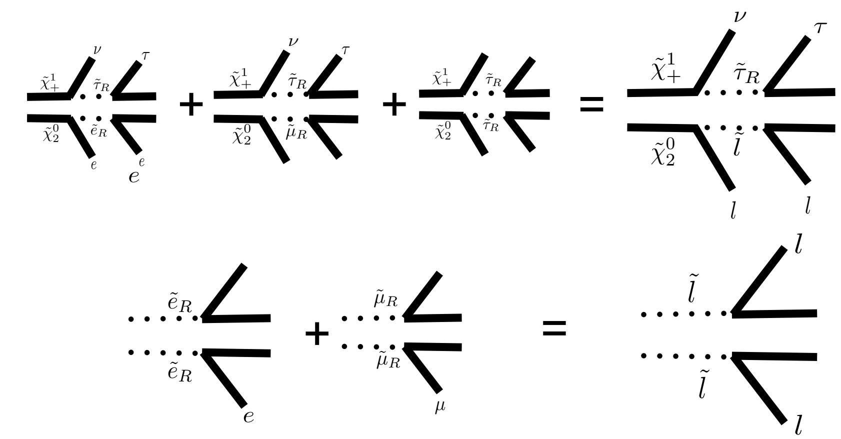
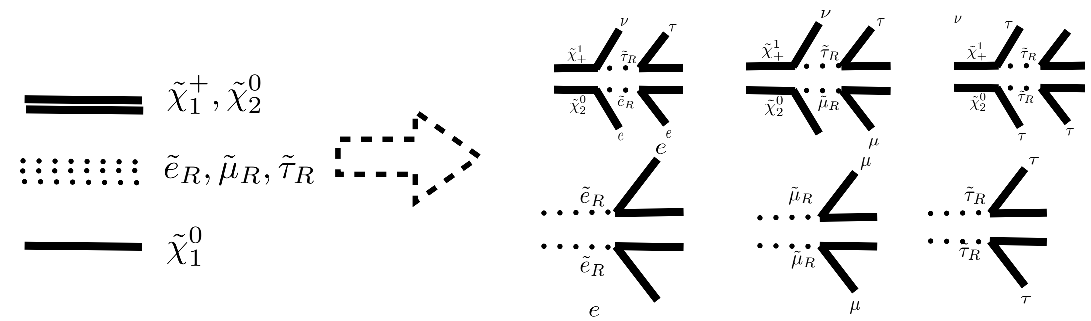


SModelS framework

Decompose

Store final states, masses and sigma X BR for each topology



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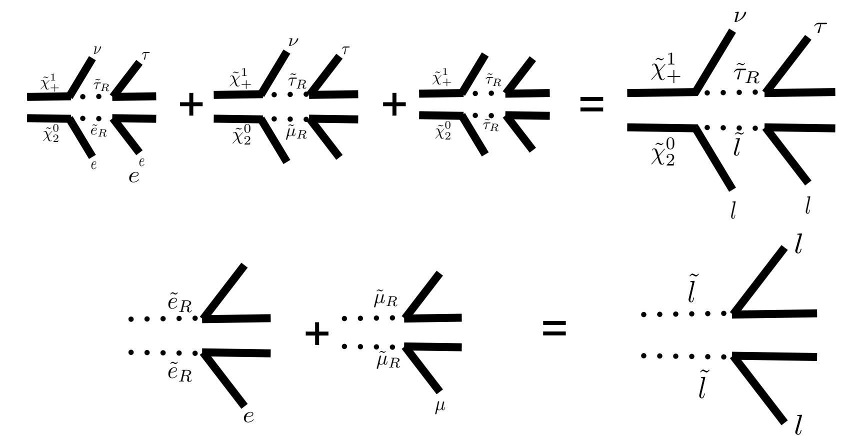


Check for upper limits

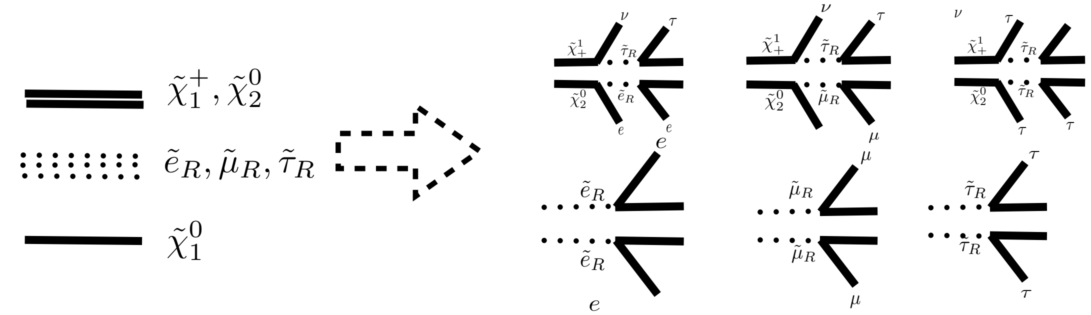
Linear interpolation between bins and intermediate masses

Estimate violation of experimental conditions

SModelS framework

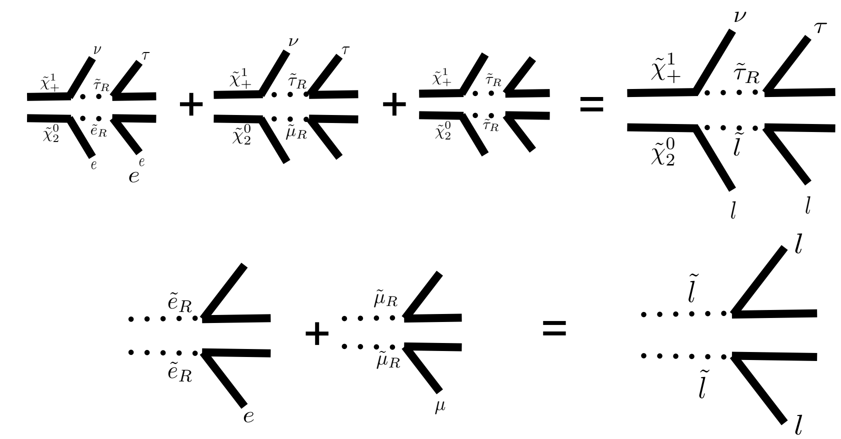
Decompose

Store final states, masses and sigma X BR for each topology



Cluster masses

Cluster masses if they can not be distinguished experimentally



Check for upper limits

Linear interpolation between bins and intermediate masses

Estimate violation of experimental conditions

Results

Give theory prediction, experimental U.L. and estimate violation of conditions where applicable

SModelS application NMSSM