– a Tool for Making Systematic Use of Simplified Models

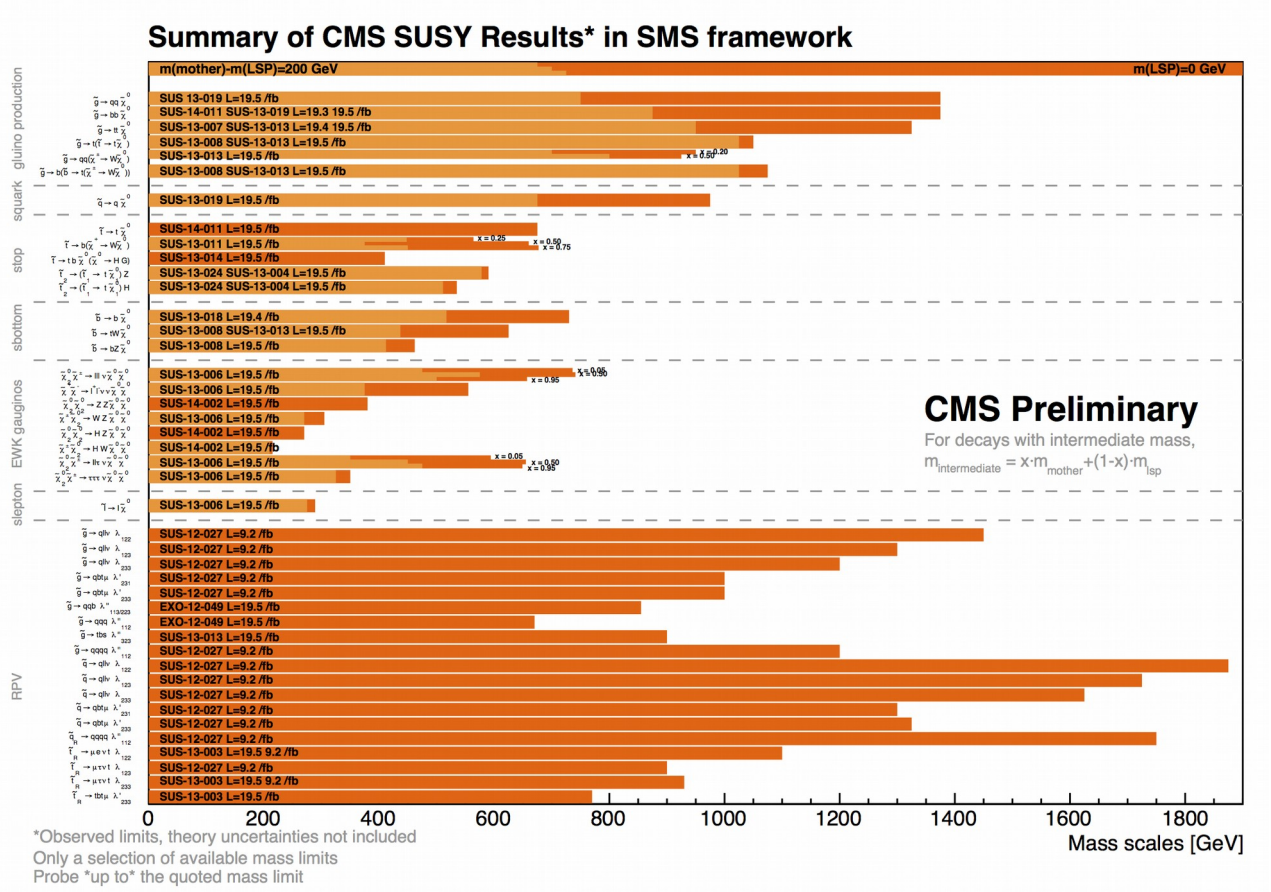
Wolfgang Waltenberger
HEPHY Vienna

In collaboration with the SModelS group
S. Kraml, S. Kulkarni, U. Laa, A. Lessa, W. Magerl, D. Proschofsky-Spindler

ACAT 2016
Valparaiso, Chile, 18 – 22 January 2016

Searching for Physics Beyond the Standard Model

A huge number of searches for BSM physics has been performed by CMS and ATLAS:



CMS,
8 TeV results
SUSY,
ICHEP 2014

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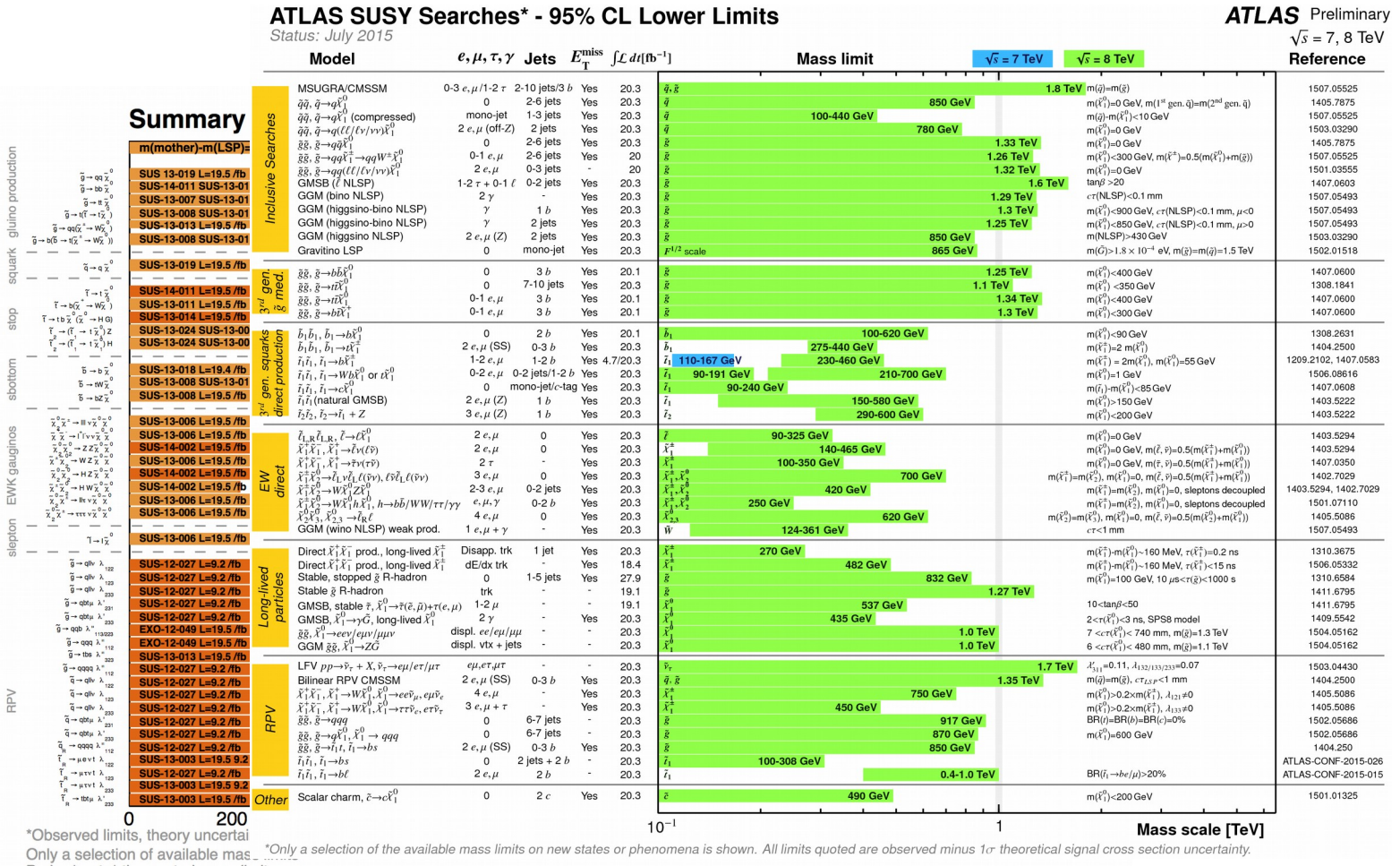

ATLAS
7 + 8 TeV
SUSY
July 2015
(incomplete!)

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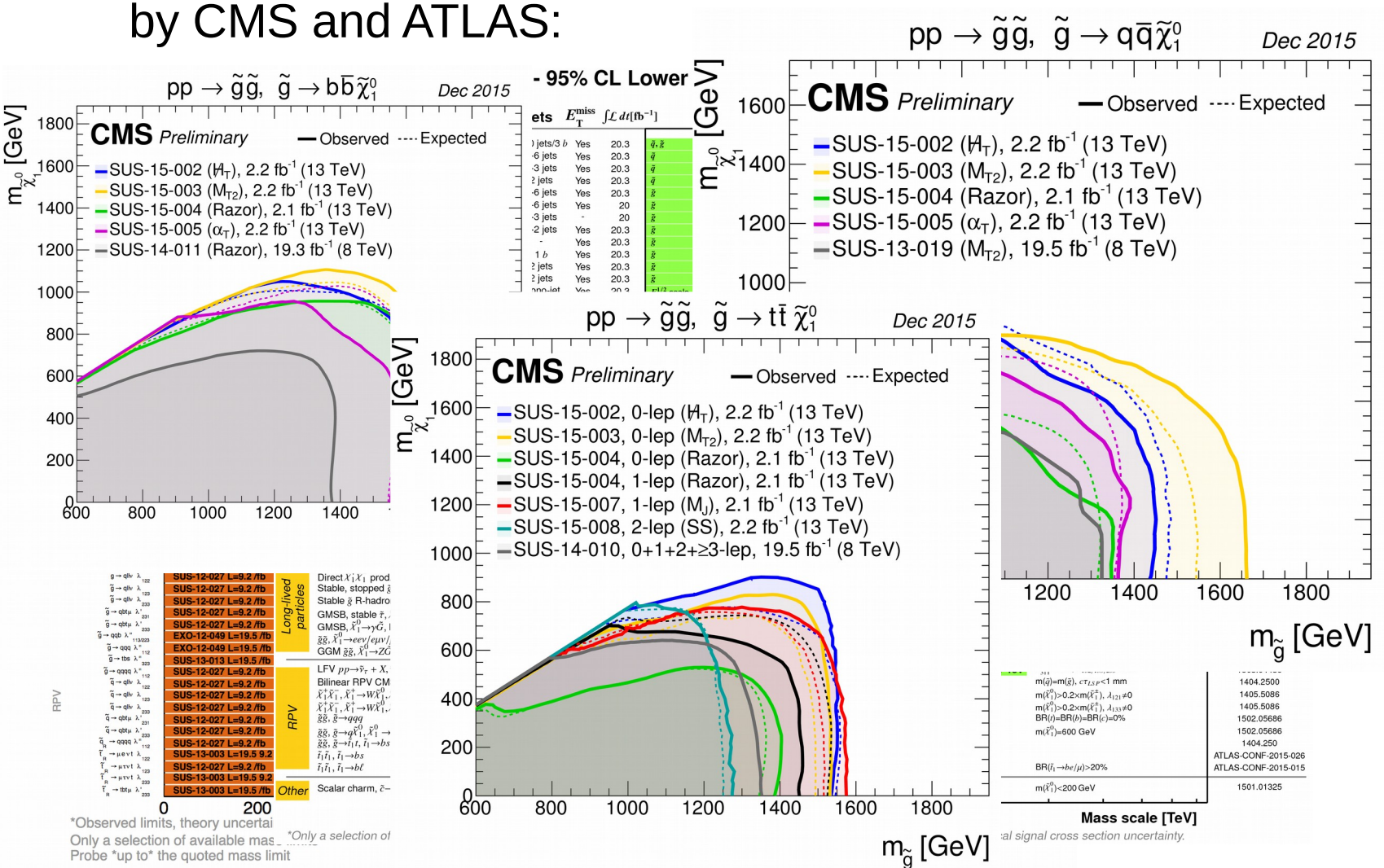

CMS Searches for gluinos 13 TeV

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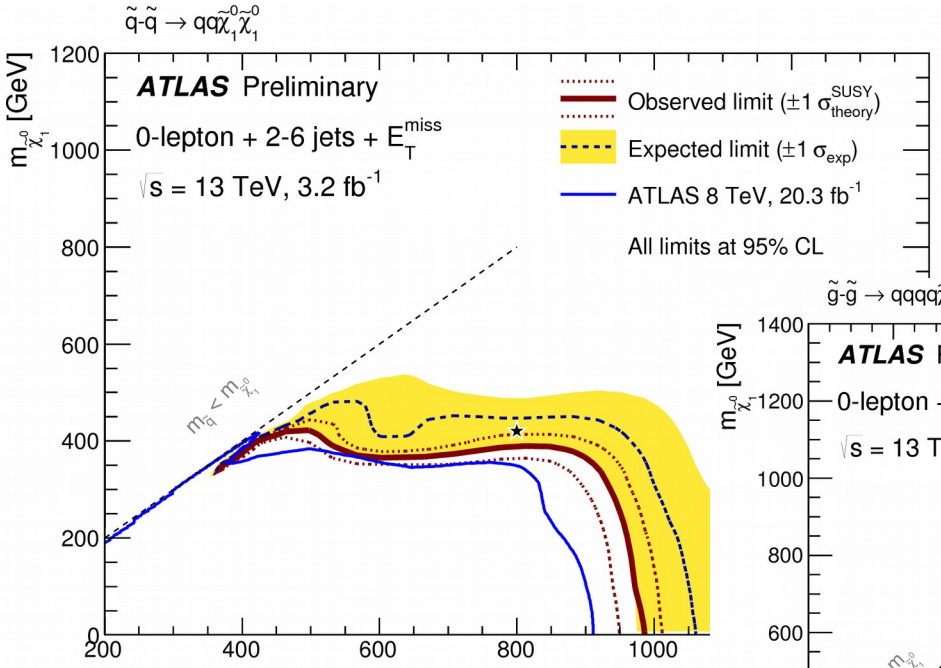

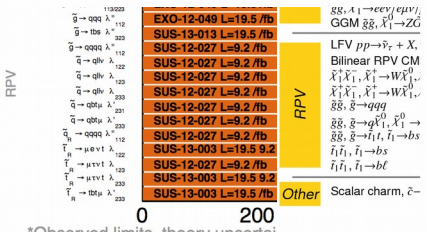

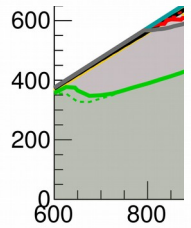

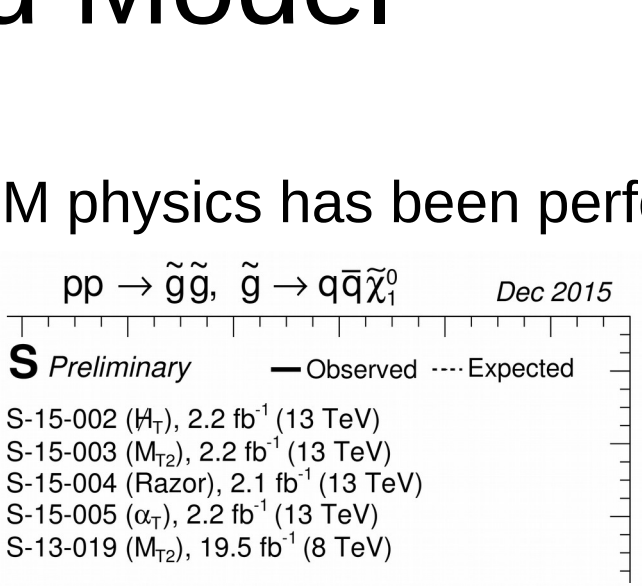

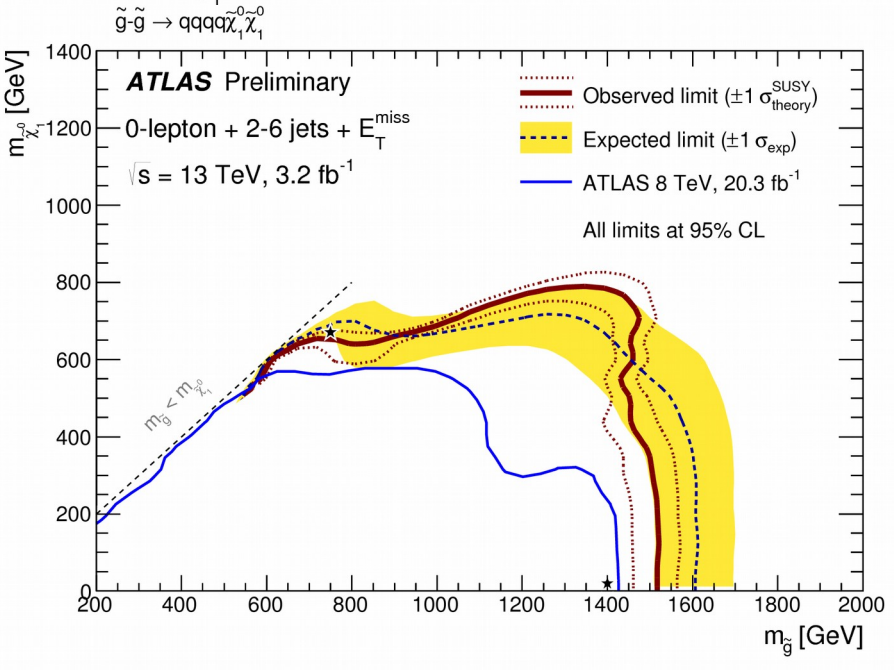

ATLAS Searches for SUSY 13 TeV

Searching for Physics Beyond the Standard Model

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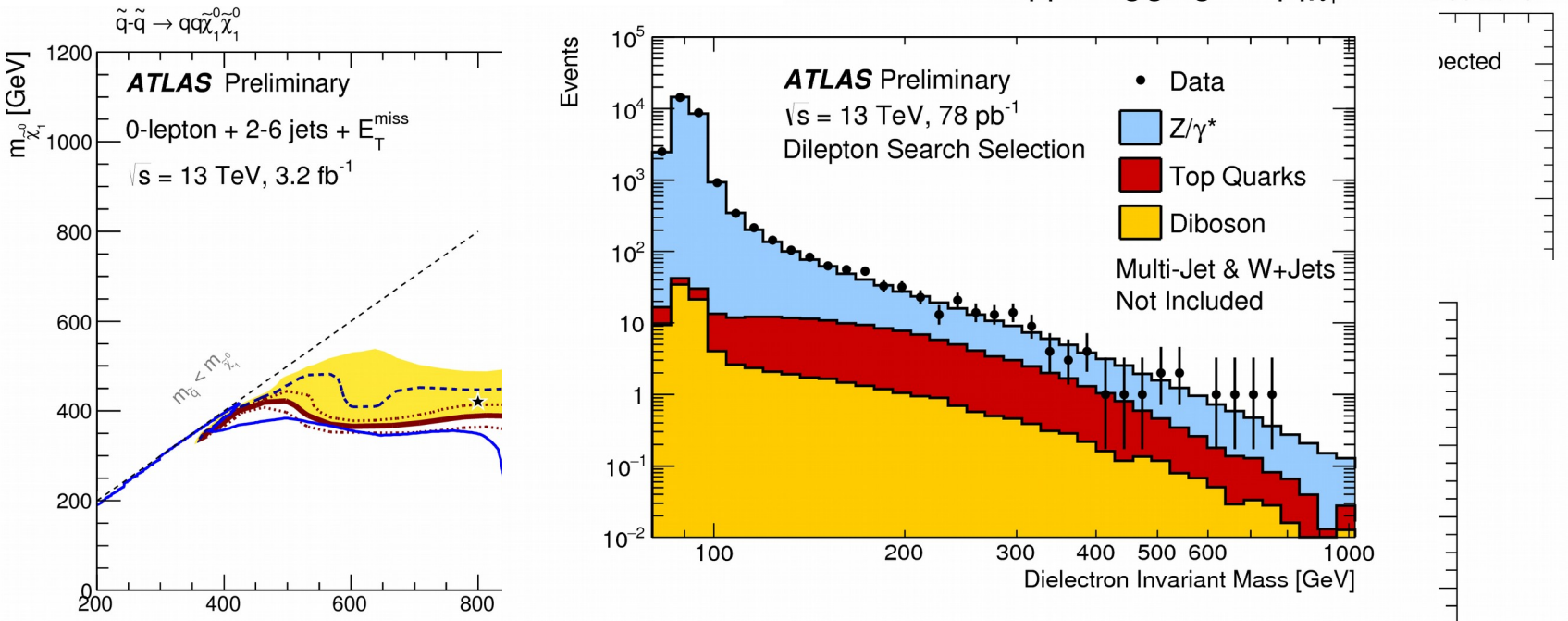

ATLAS Exotic Searches 13 TeV

Searching for Physics Beyond the Standard Model

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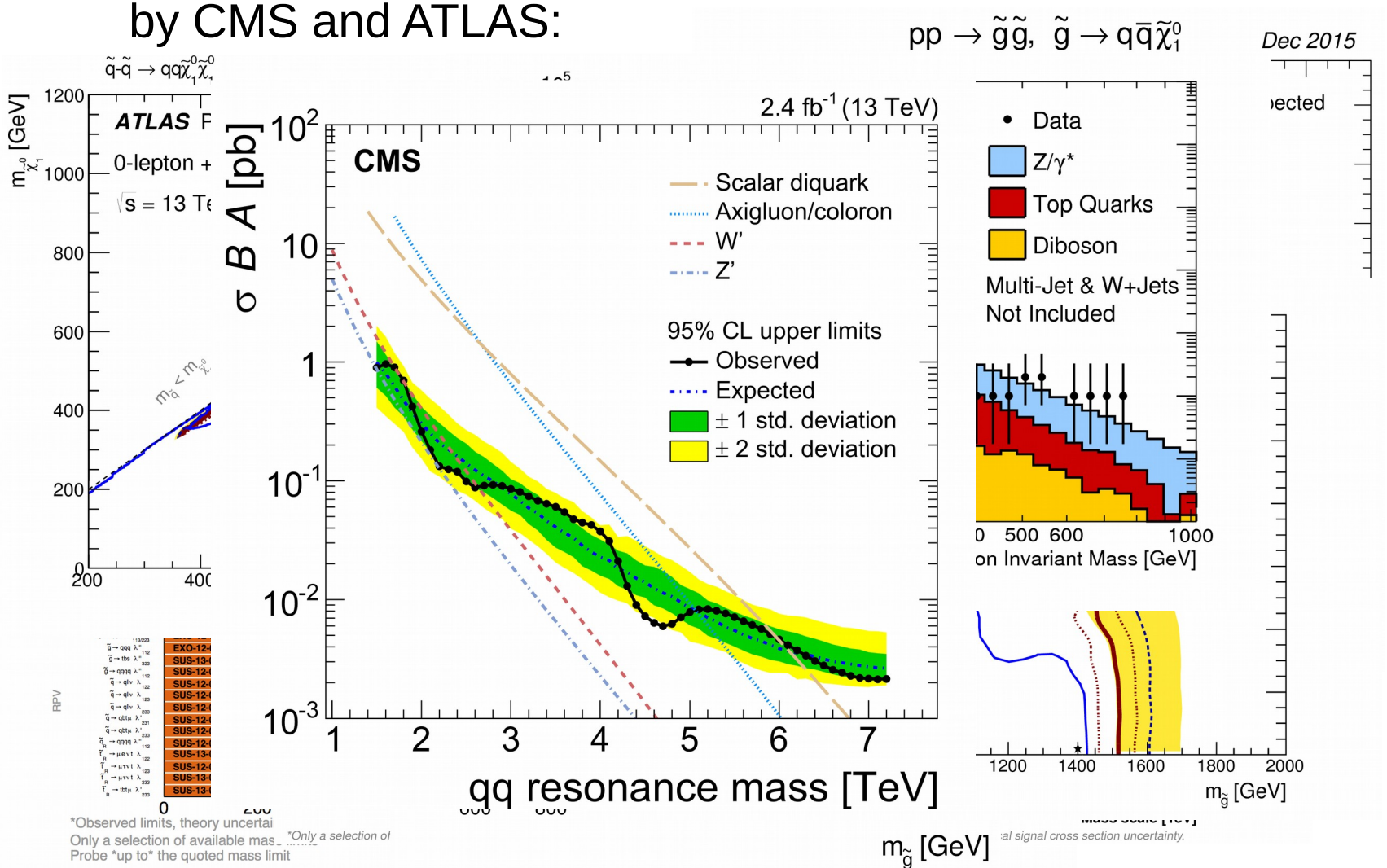
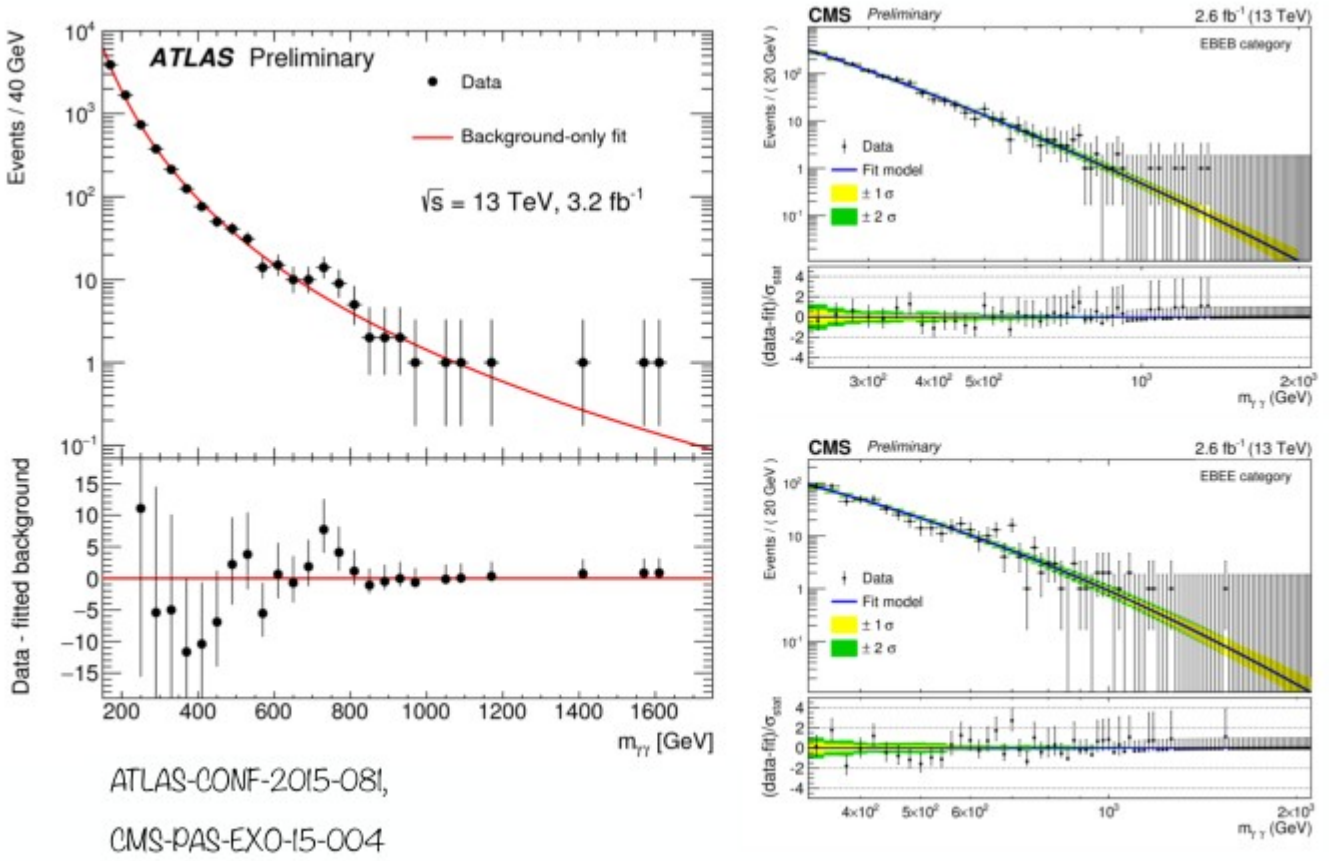


CMS Exotic Searches 13 TeV

Searching for Physics Beyond the Standard Model

In addition we have the 750 GeV puzzle:



Slide taken from S. Kulkarni

Where do we go from here?

Can we systematically build up a Next Standard Model from this treasure trove of results?

Can we automate (parts of) the task?

Can we solve the Inverse Problem algorithmically? (After all, we are at a computing conference)

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In this talk, I will not answer these questions.

I will give one answer to a smaller question:

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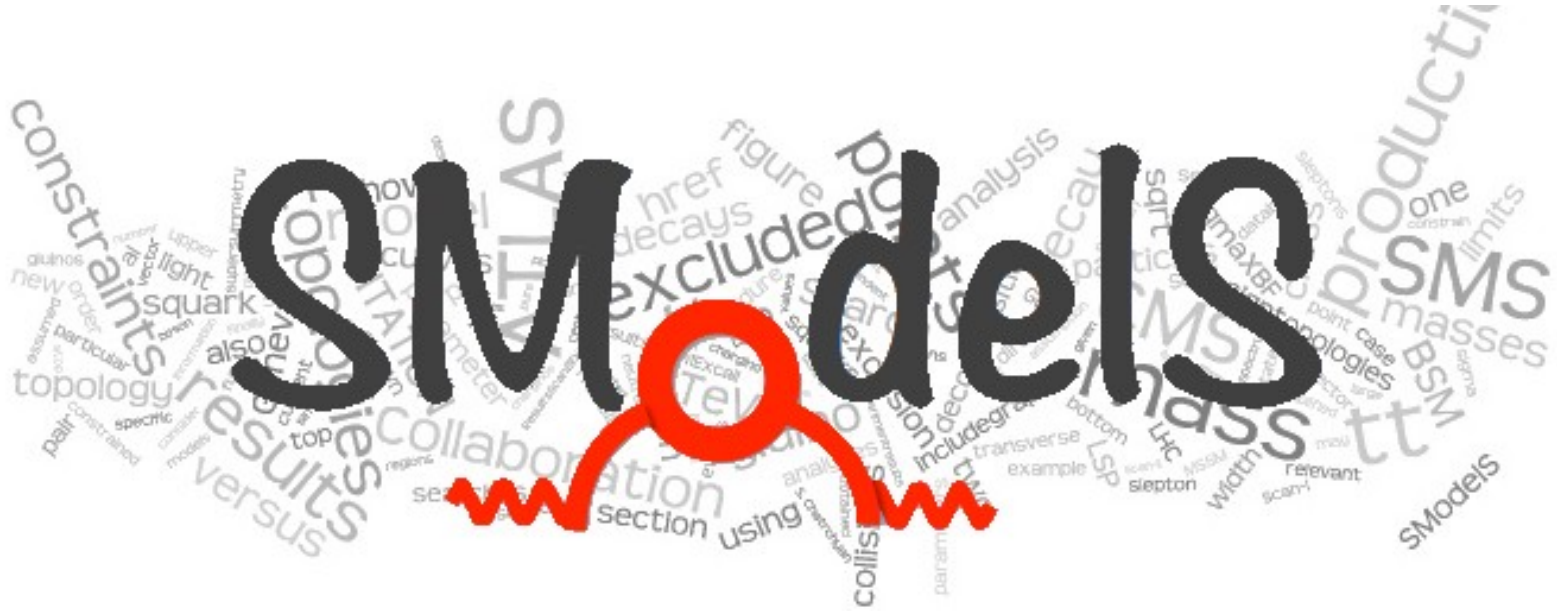
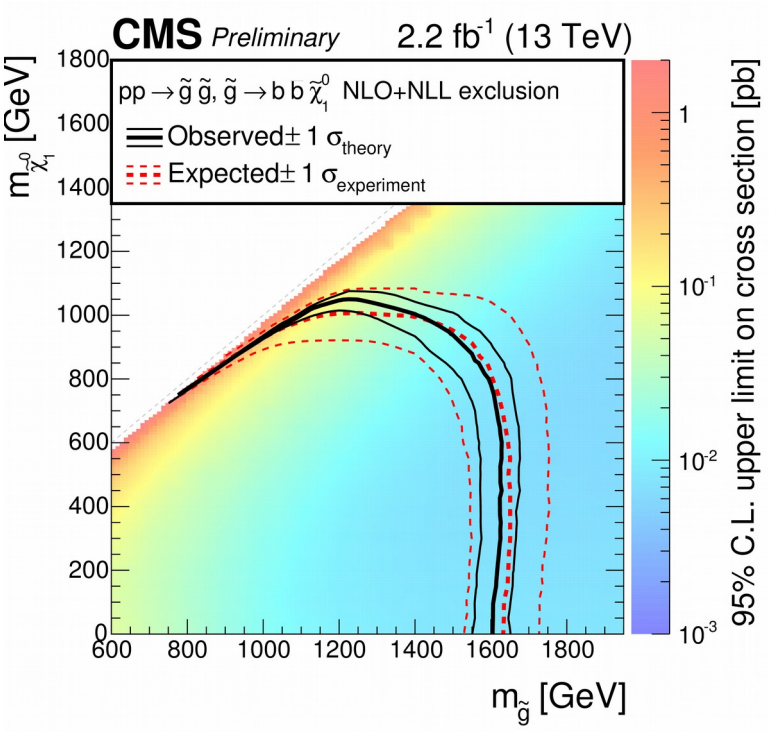
One way:

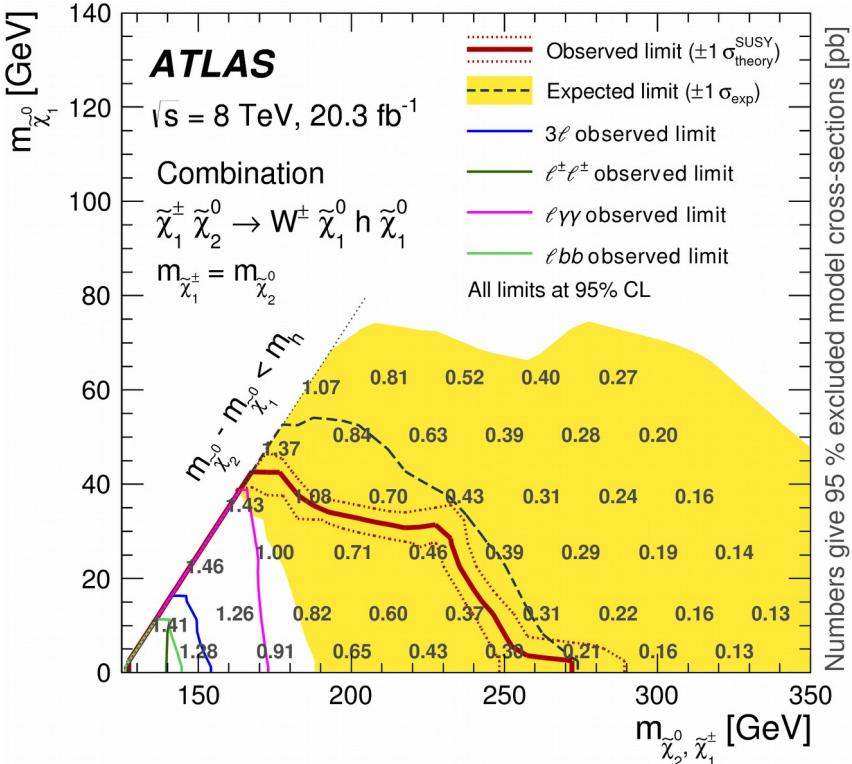


– a Tool for Making Systematic Use of Simplified Models (Null Results)

Step #1: we built up a database with the CMS/ATLAS Simplified Models results

Almost all SUSY searches and many exotica searches have been interpreted by the experimental collaborations in the context of simplified models spectra (SMS)





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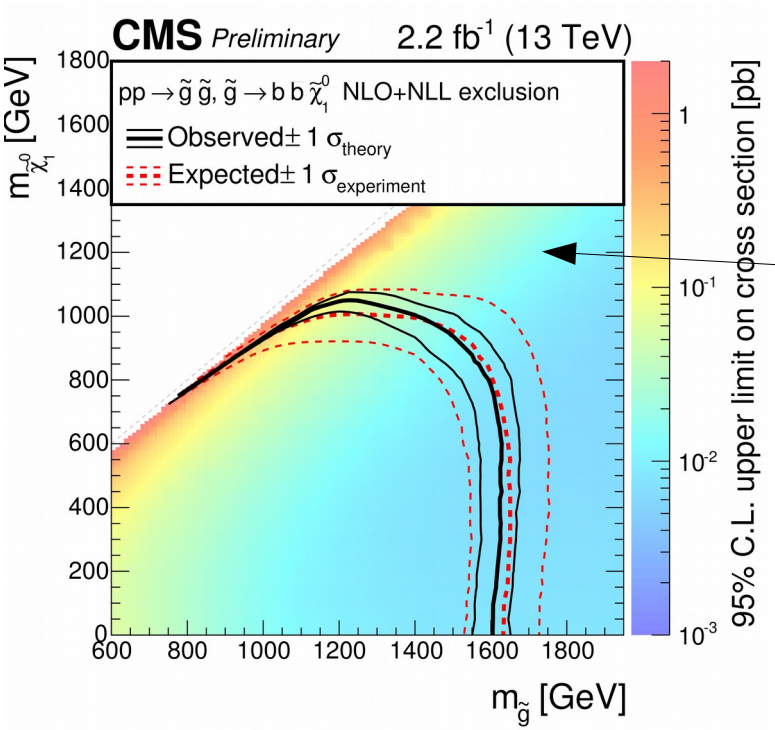
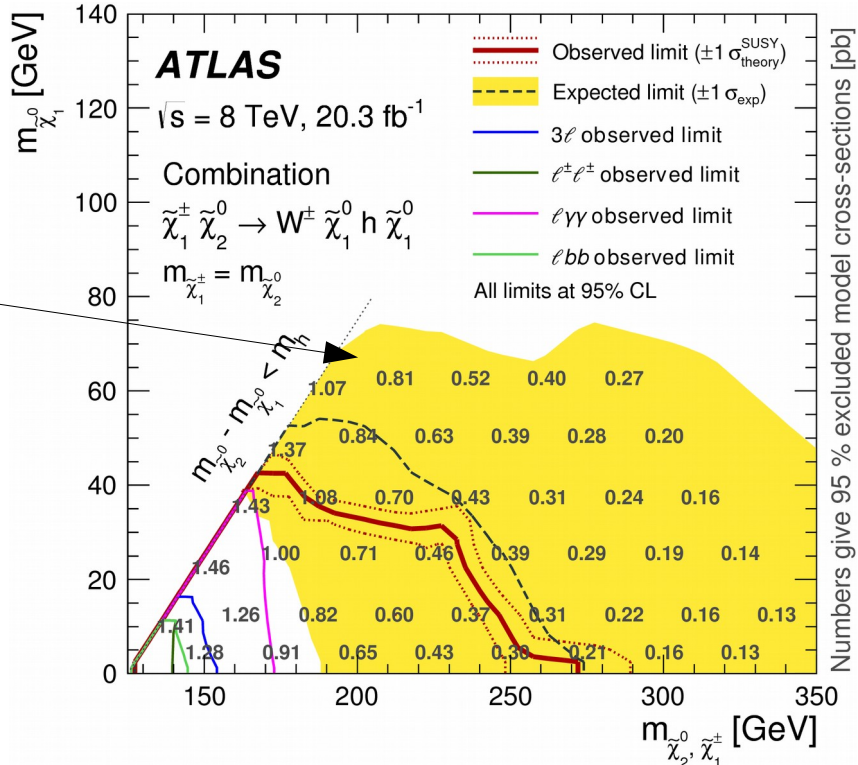


Upper limits on production cross sections (independent of branchin ratios!!) as a function of particle masses



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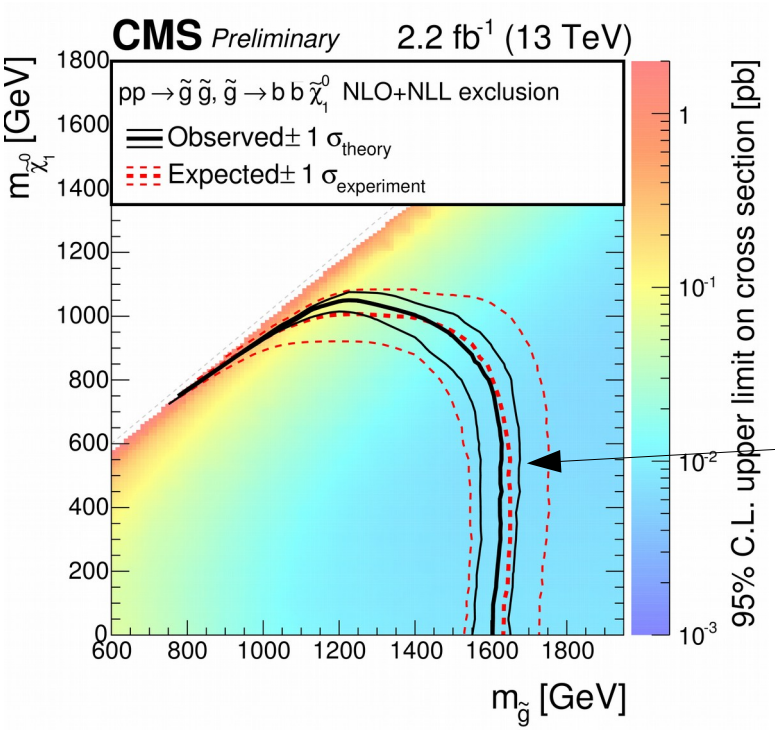
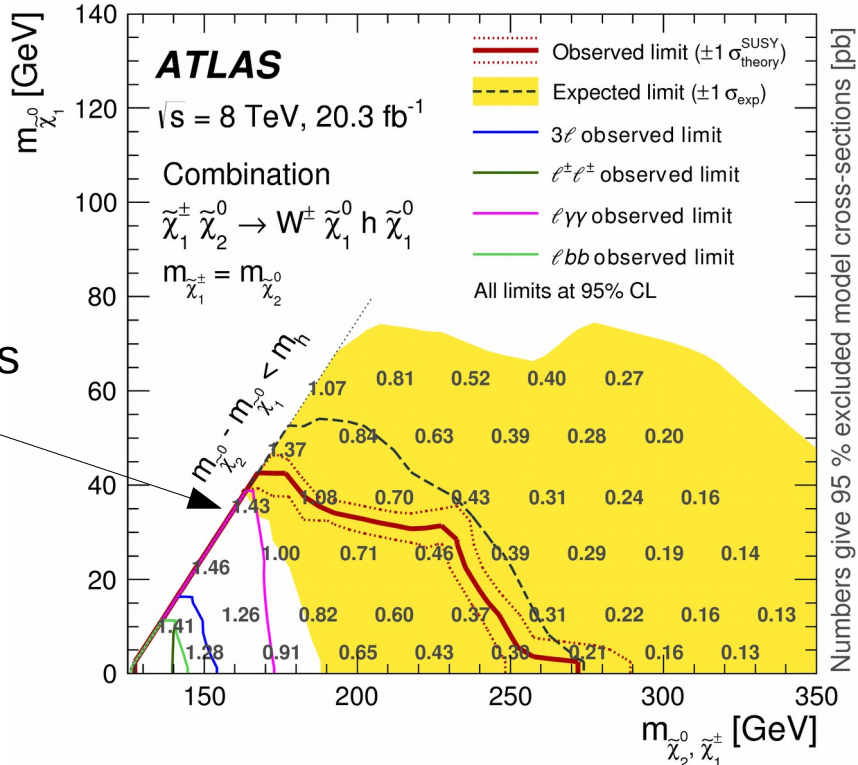


Exclusion lines for reference cross sections and BR=1.
Only used for validation.



Step #1: we built up a database with the CMS/ATLAS Simplified Models results

ID	short description	L	Ref.	Tx names
ATLAS-SUSY-2013-02	0 leptons + 2–6 jets + $\not{E}_T$	20.3	[16]	T1, T2
ATLAS-SUSY-2013-04	0 leptons + ≥7–10 jets + $\not{E}_T$	20.3	[17]	T1tttt
ATLAS-SUSY-2013-05	0 leptons + 2 b-jets + $\not{E}_T$	20.1	[18]	T2bb
ATLAS-SUSY-2013-11	2 leptons (e, μ) + $\not{E}_T$	20.3	[19]	TChiWZ, TSlepSlep
ATLAS-SUSY-2013-12	3 leptons (e, μ, τ) + $\not{E}_T$	20.3	[20]	TChiWH, TChiWZ(off)
ATLAS-SUSY-2013-14	2 taus + $\not{E}_T$	20.3	[21]	TStauStau
ATLAS-SUSY-2013-15	1 lepton + 4(1 b-)jets + $\not{E}_T$	20.3	[22]	T2tt, T2bbWW
ATLAS-SUSY-2013-19	2 leptons + (b)jets + $\not{E}_T$	20.3	[23]	T2tt, T2bbWW, T6bbWW
ATLAS-CONF-2012-105	2 SS leptons + ≥4 jets + $\not{E}_T$	5.7	[24]	T1tttt
ATLAS-CONF-2013-007	2 SS leptons + 0–3 b-jets + $\not{E}_T$	20.7	[25]	T1tttt
ATLAS-CONF-2013-024	0 lepton + 6 (2 b-)jets + $\not{E}_T$	20.5	[26]	T2tt
ATLAS-CONF-2013-061	0–1 leptons + ≥3 b-jets + $\not{E}_T$	20.1	[27]	T1bbbb, T1tttt
ATLAS-CONF-2013-065	2 leptons + (b)jets + $\not{E}_T$	20.3	[28]	T2tt

ID	short description	L	Ref.	Tx names
CMS-SUS-12-024	0 leptons + ≥3(1 b-)jets + $\not{E}_T$	19.4	[29]	T1bbbb, T1tttt(off), T5tttt
CMS-SUS-12-028	jets + $\not{E}_T$, α_T	11.7	[30]	T1, T1bbbb, T1tttt, T2, T2bb
CMS-SUS-13-002	≥3 leptons (+jets) + $\not{E}_T$	19.5	[31]	T1tttt
CMS-SUS-13-006	EW productions with decays to leptons, W, Z, and Higgs	19.5	[32]	TChiWZ(off), TSlepSlep, TChiChipmSlepL, TChiChipmSlepStau
CMS-SUS-13-007	1 lepton + ≥2 b-jets + $\not{E}_T$	19.3	[33]	T1tttt(off)
CMS-SUS-13-011	1 lepton + ≥4(1 b-)jets + $\not{E}_T$	19.5	[34]	T2tt, T6bbWW
CMS-SUS-13-012	jet multiplicity + $\not{H}_T$	19.5	[35]	T1, T1tttt(off), T2
CMS-SUS-13-013	2 SS leptons + (b-)jets + $\not{E}_T$	19.5	[36]	T1tttt(off),
CMS-PAS-SUS-13-008	3 leptons + (b)jets + $\not{E}_T$	19.5	[37]	T6ttWW, T1tttt
CMS-PAS-SUS-13-016	2 OS leptons + ≥4(2b-)jets + $\not{E}_T$	19.7	[38]	T1tttt(off)
CMS-PAS-SUS-13-018	1–2 b-jets + $\not{E}_T$, M_{CT}	19.4	[39]	T2bb
CMS-PAS-SUS-13-019	hadronic M_{T2}	19.5	[40]	T1, T1bbbb, T1tttt(off), T2, T2tt, T2bb
CMS-PAS-SUS-14-011	razor with b-jets	19.3	[41]	T1bbbb, T1tttt(off), T2tt

- Only validated resuts in database

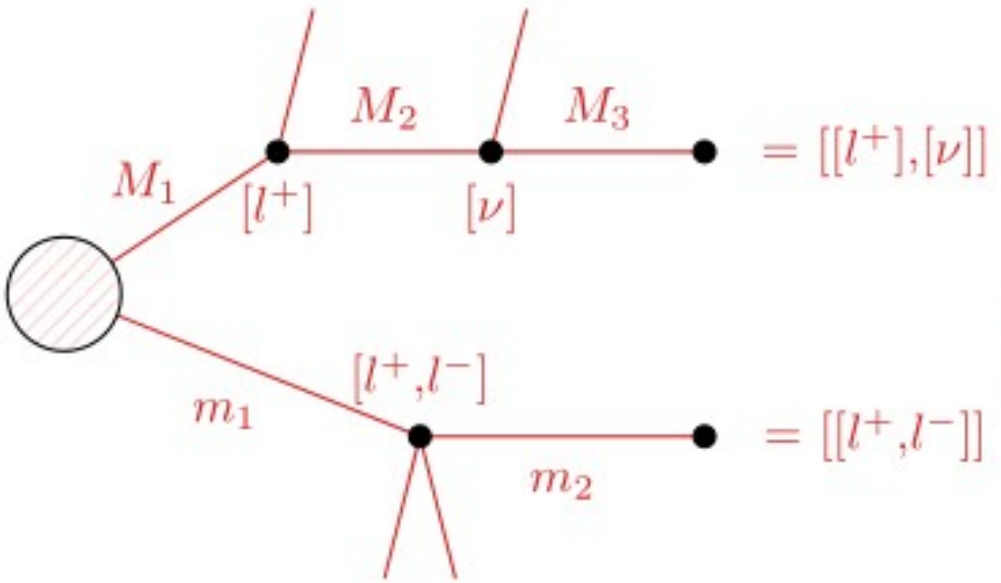
- Some results we could not validate

- State of late 2014, want to release updated version soon

- Will include SMS results that come from outside experimental collaborations (i.e. re-interpretations performed by phenomenologists)

Step #2: we devised a formal language to describe SMSes model-independently

- Simplified Model Topology:



$= [\ [[l^+],[\nu]]\ ,\ [[l^+,l^-]]\ ]$ $(+\ \sigma \times BR)$

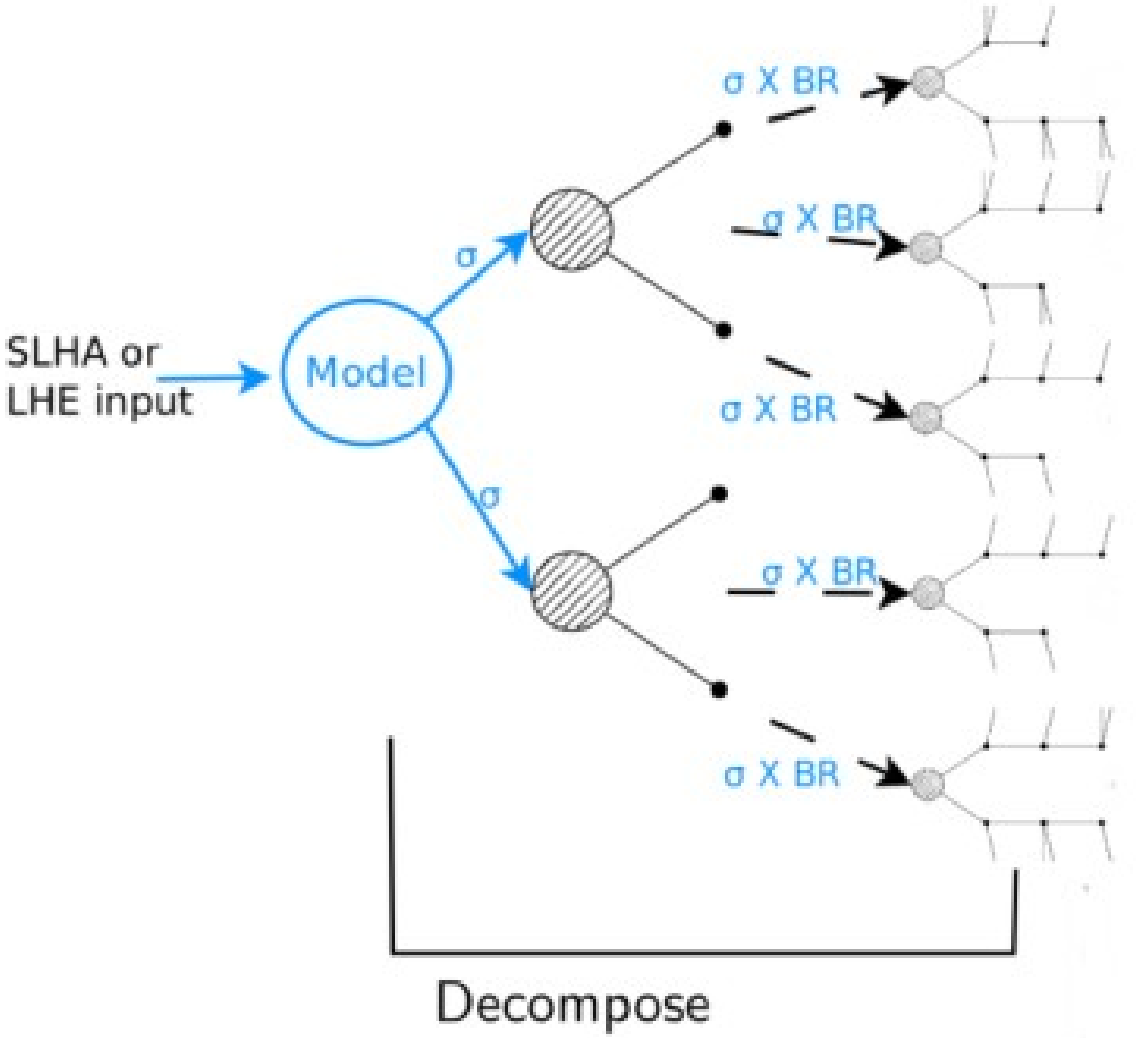
$([[M_1,M_2,M_3],[m_1,m_2]])$

We explicitly ignore the nature of the BSM particles – We assume that e.g. the spin can be ignored in a first approximation!

- Each topology is described by:
  - topology shape + final states
  - BSM masses
  - Weight ($\sigma \times BR$)

Taken from A. Lessa

Step #3: we wrote a program that decomposes a full model into its Simplified Models Spectrum



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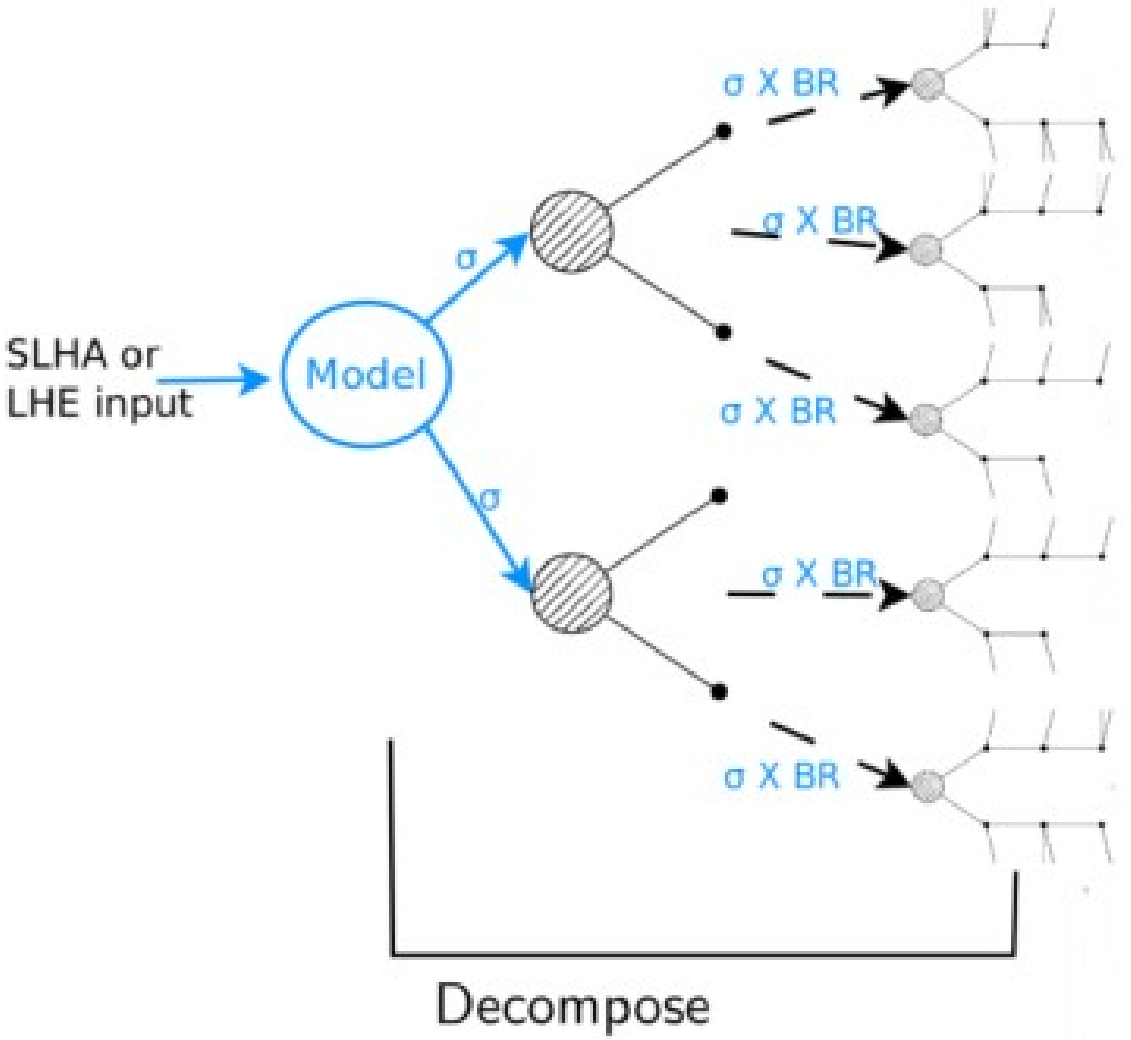

- Works with any BSM model (currently it needs a Z_2 symmetry)

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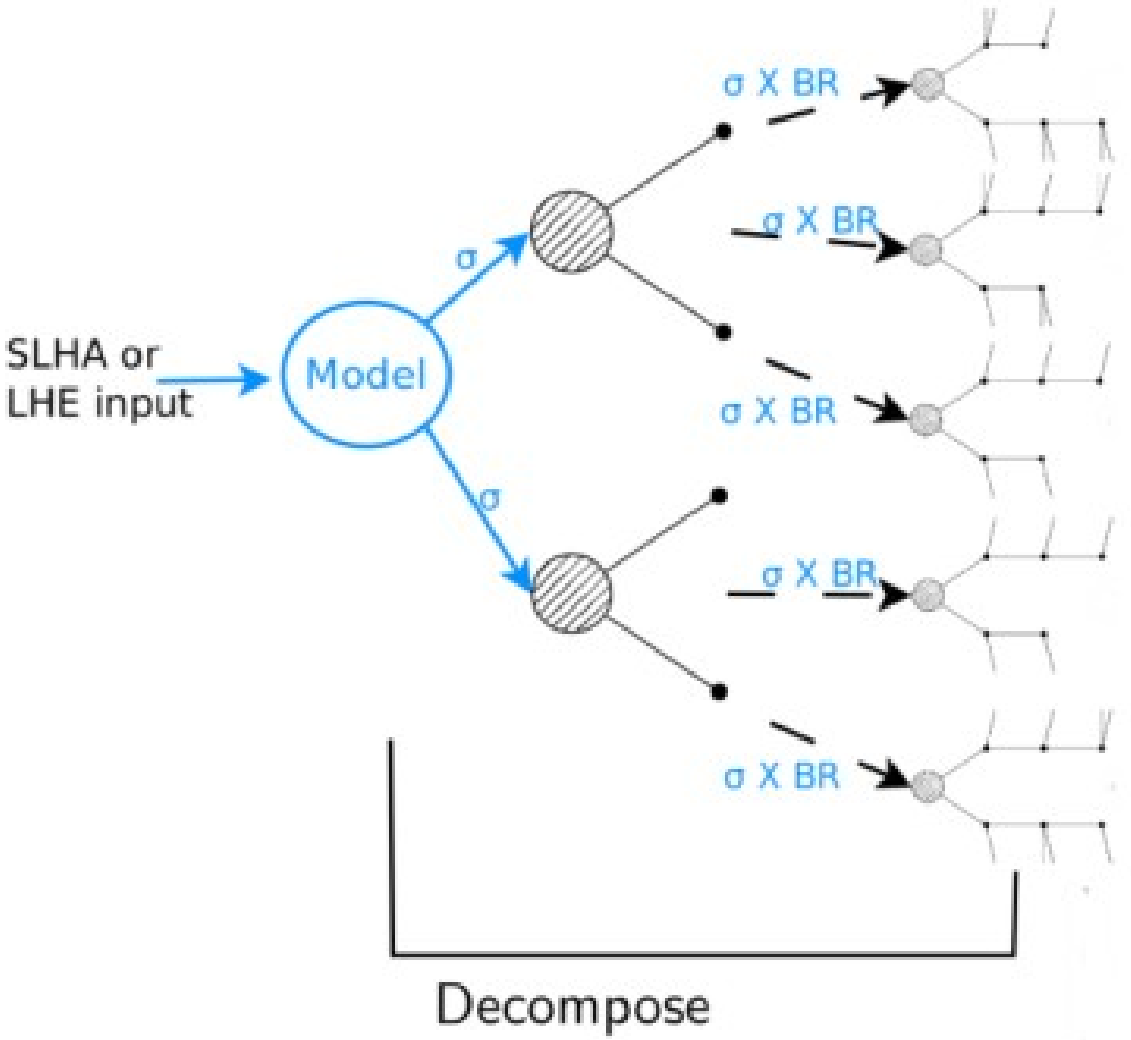

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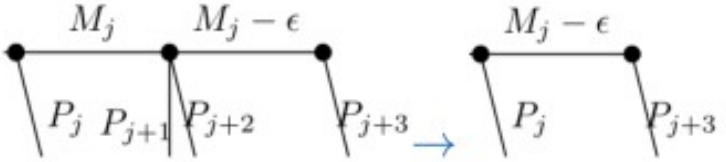
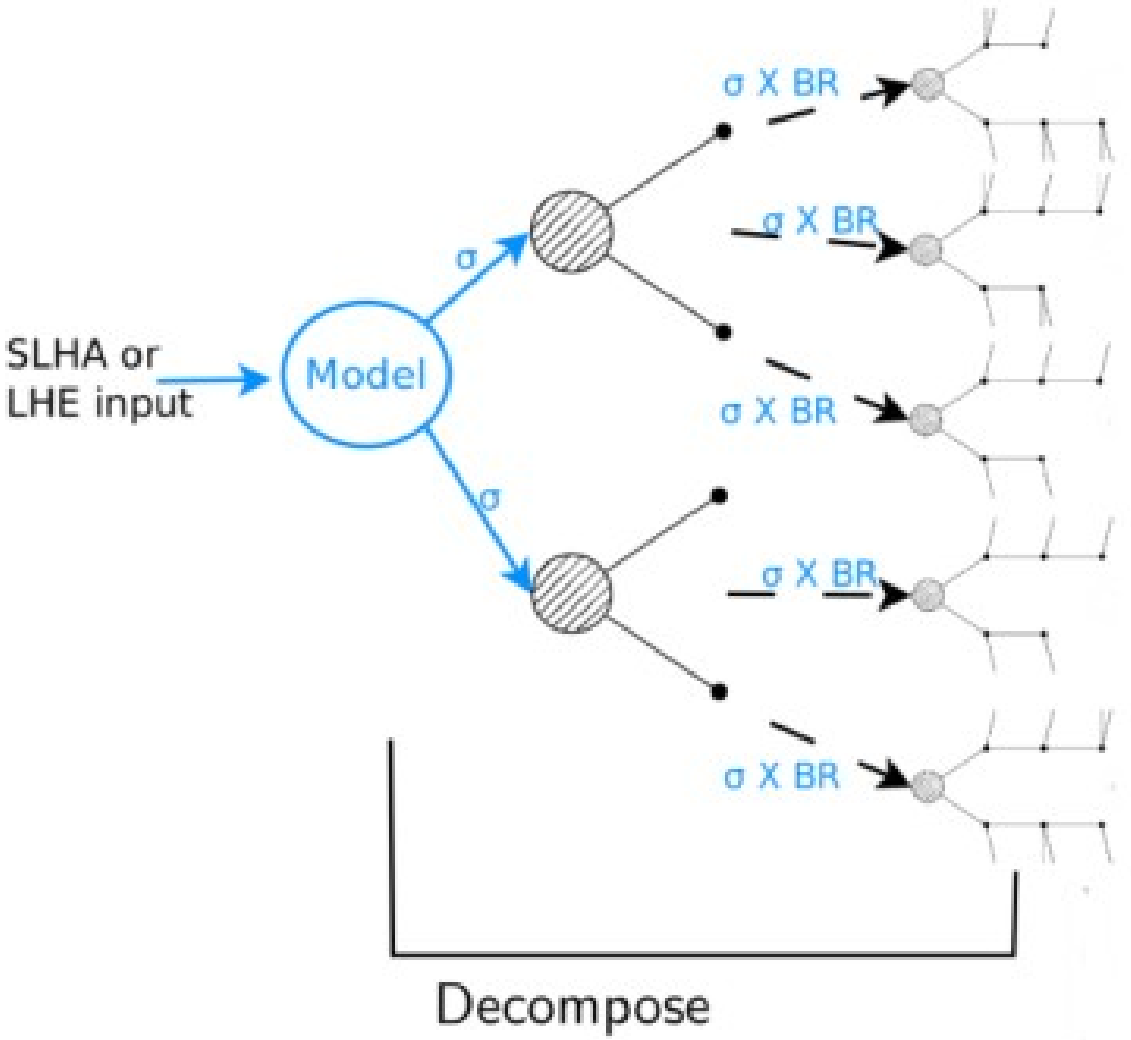
- Compressed spectra can be mapped to simpler topologies



Step #3: we wrote code that decomposes a full model into its Simplified Models Spectrum



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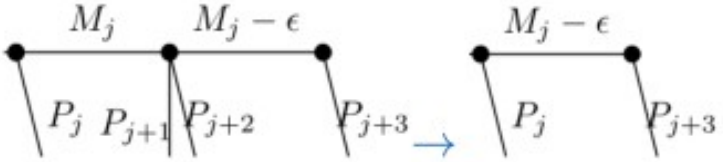
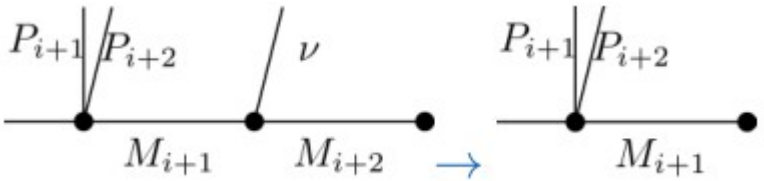
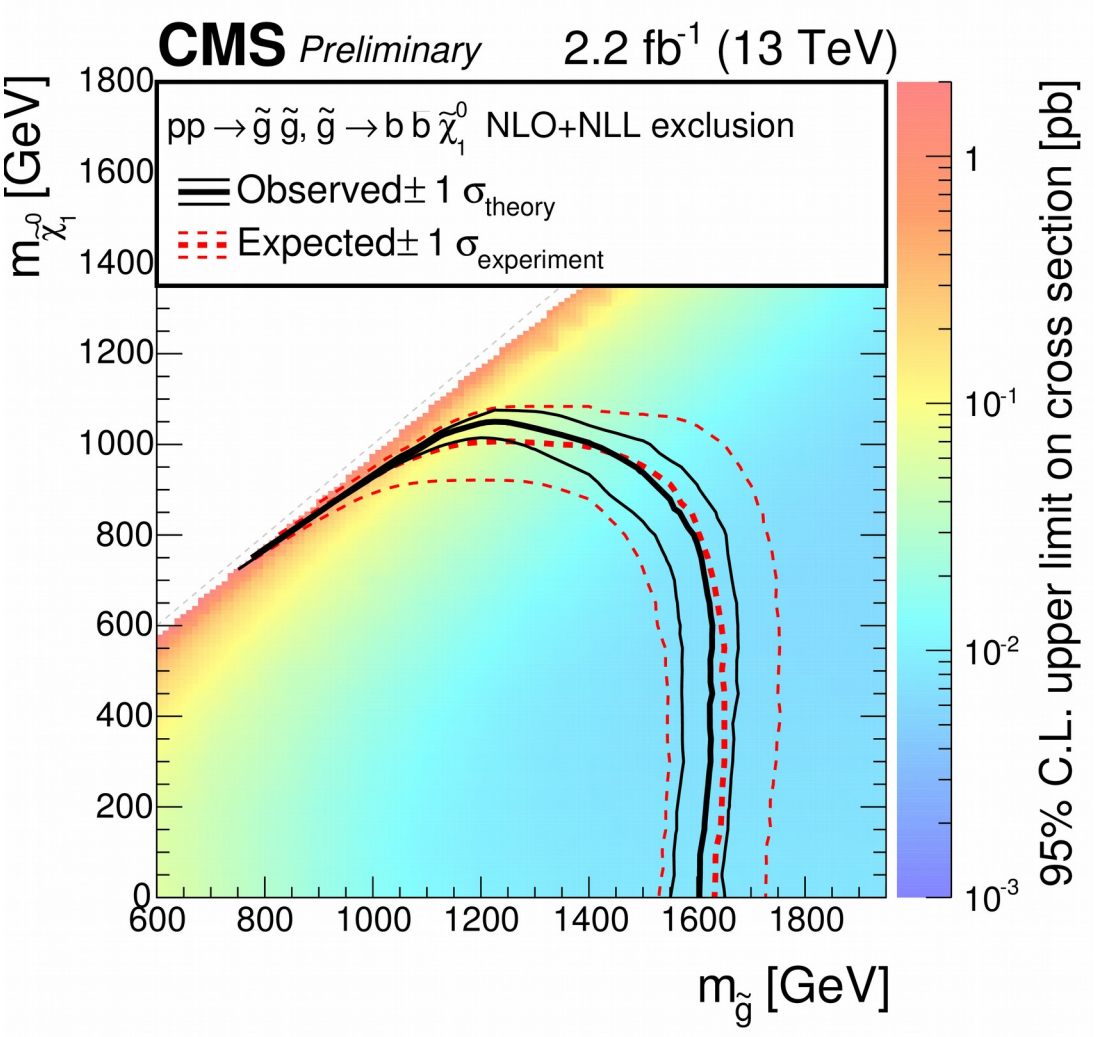


- Invisible final states can be grouped as effective LSPs



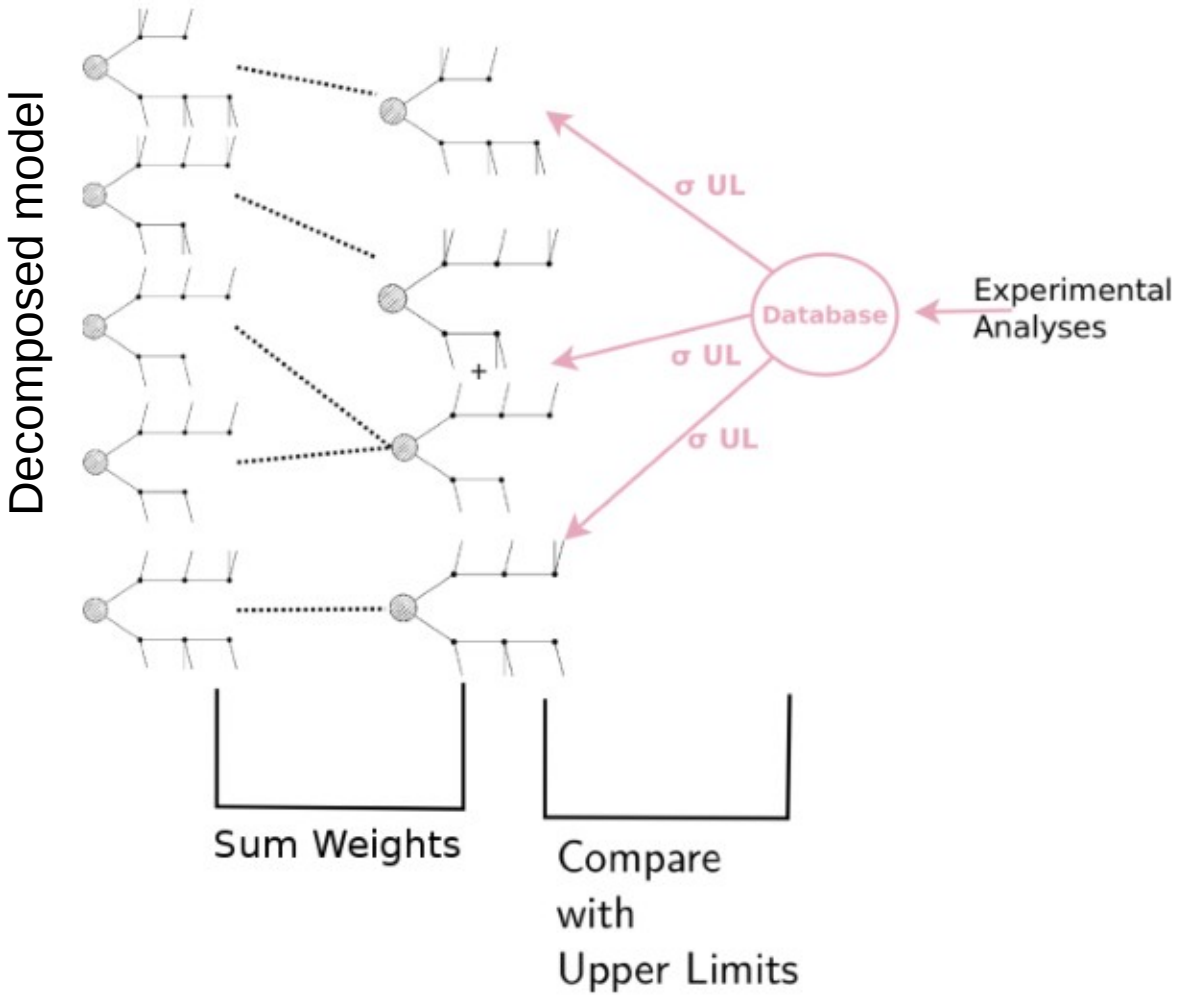
Step #4: we describe what parts of a full model an experimental result “constrains” (and what conditions need to be met), using our formalism



$$\tilde{g}\tilde{g}, \tilde{g} \rightarrow b b \tilde{\chi}^0$$

constraint:
[[b,b]],[[b,b]]

Step #5: we “match” the decomposed model with the experimental results and check if the result excludes the model



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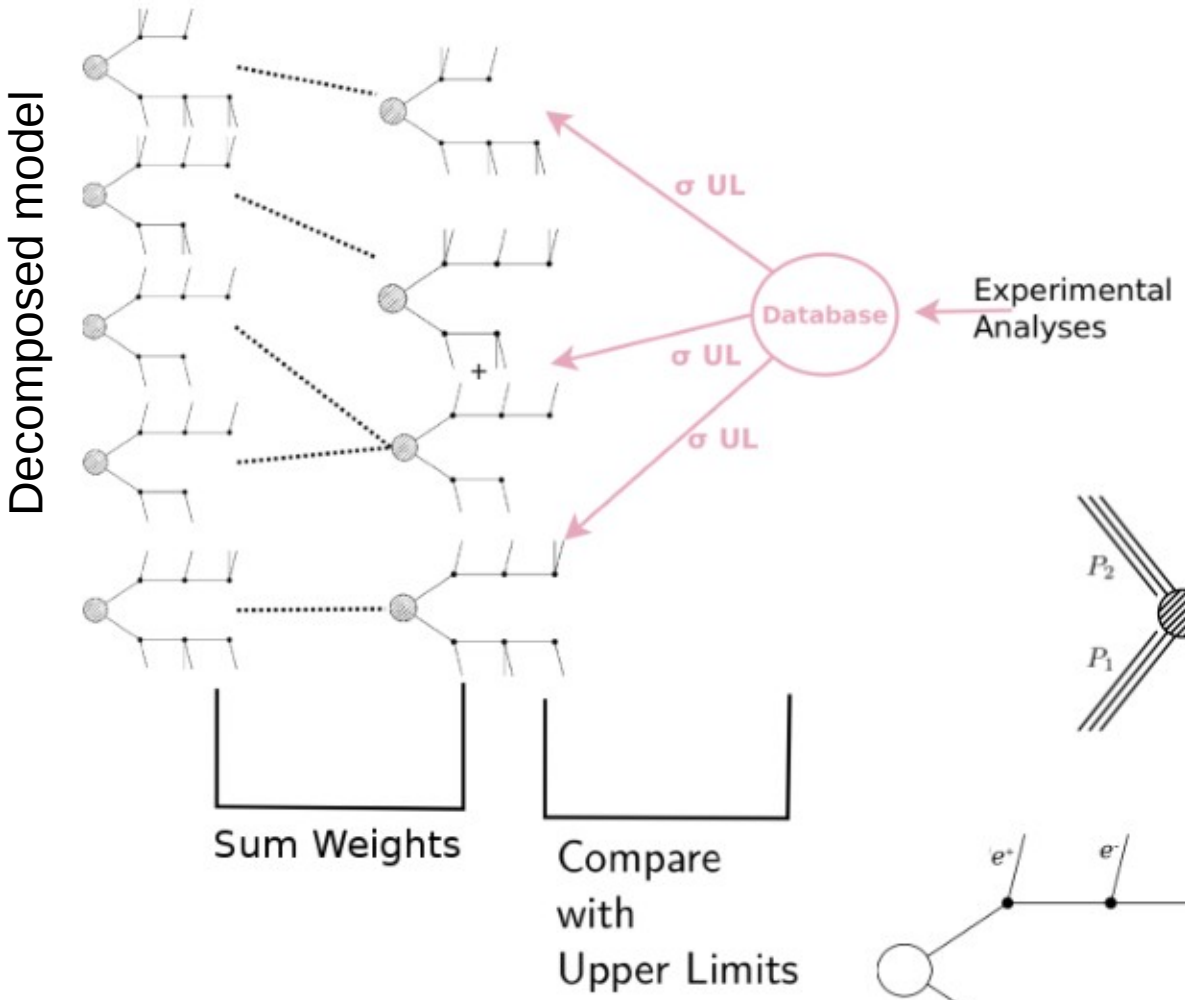
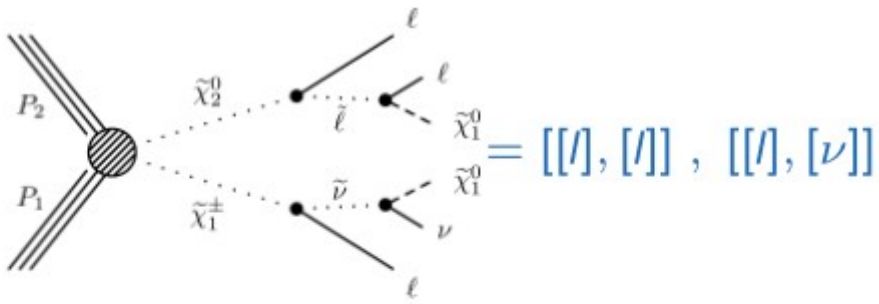
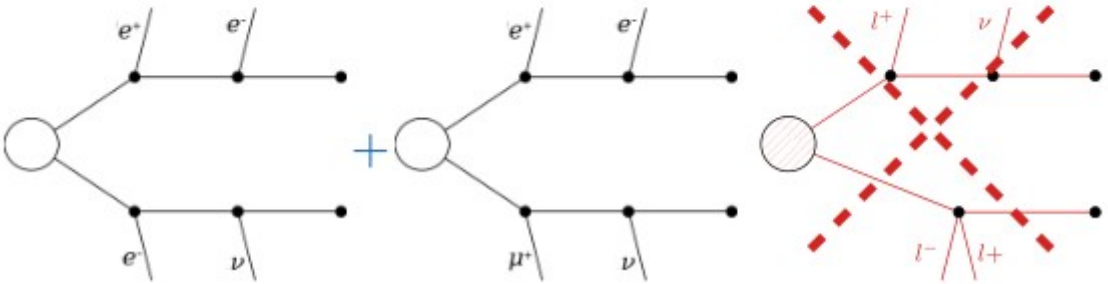


-) If an experimental results excludes the sum of several basic topologies, the cross sections of the individual results are added up for the theory prediction





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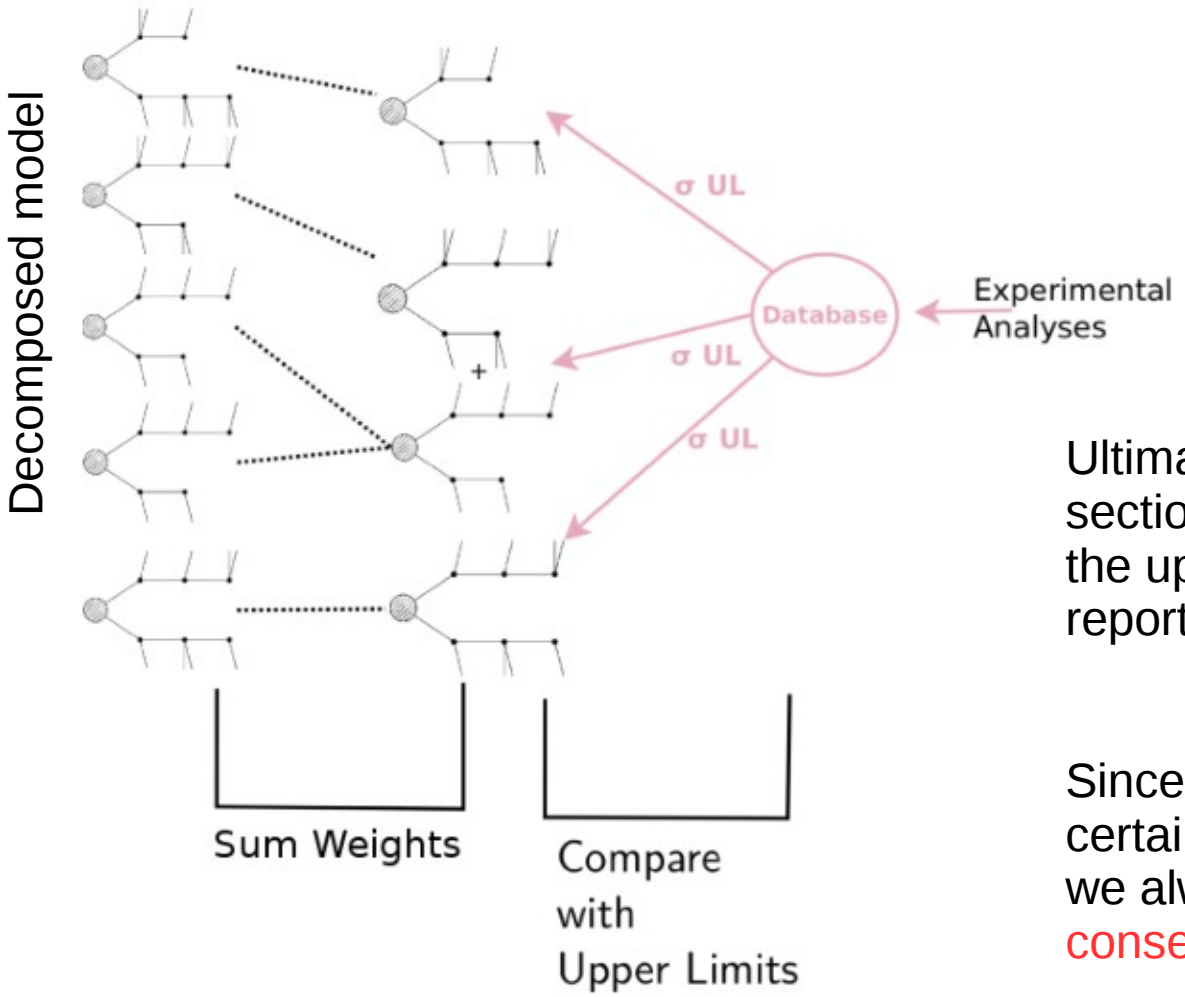
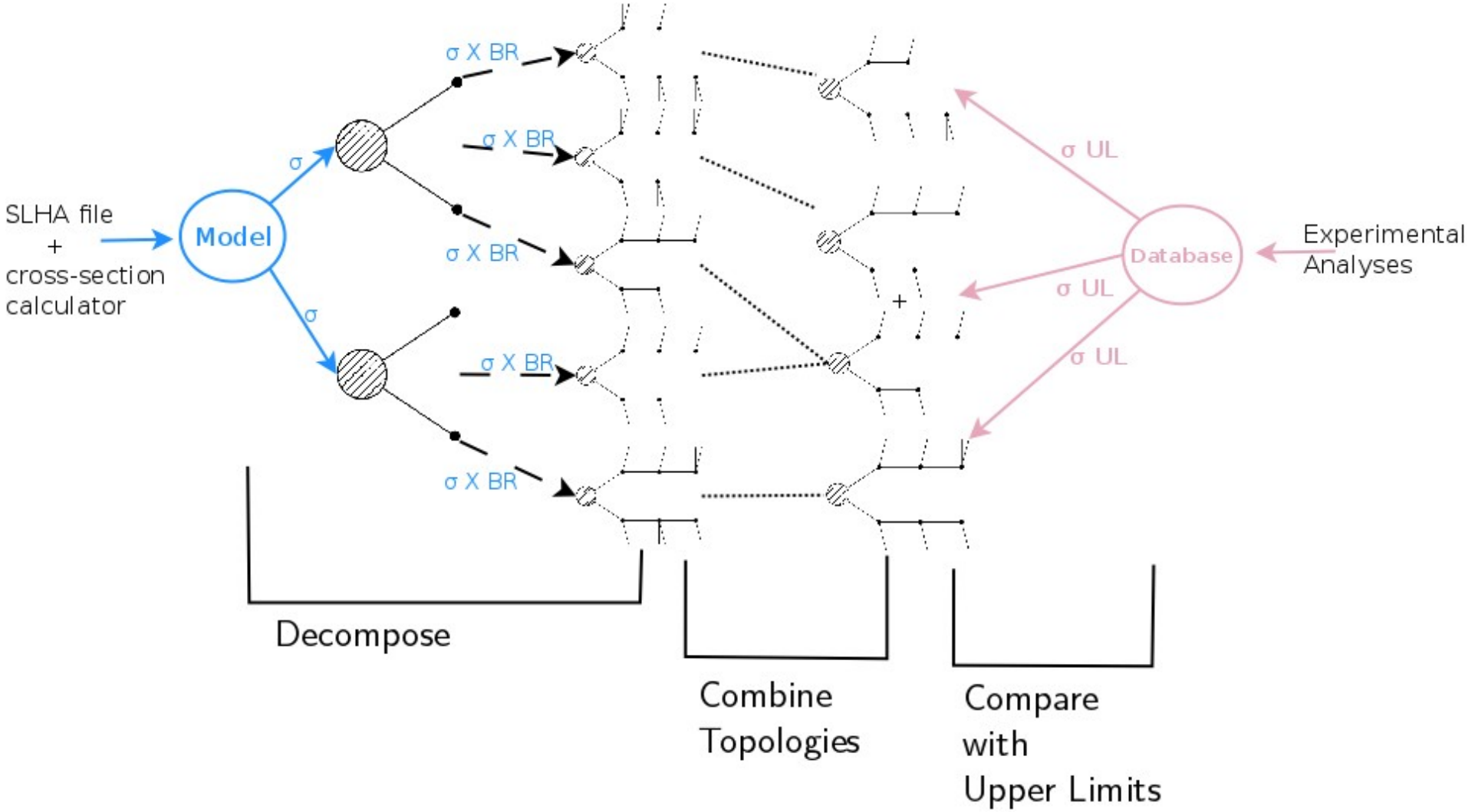


Ultimately, we compare the cross section predicted by the theory against the upper limit on the cross section reported by the experiment.

Since we always only compare with a certain subset of all decay chains, we always end up with conservative results.

Recap: how SModelS works

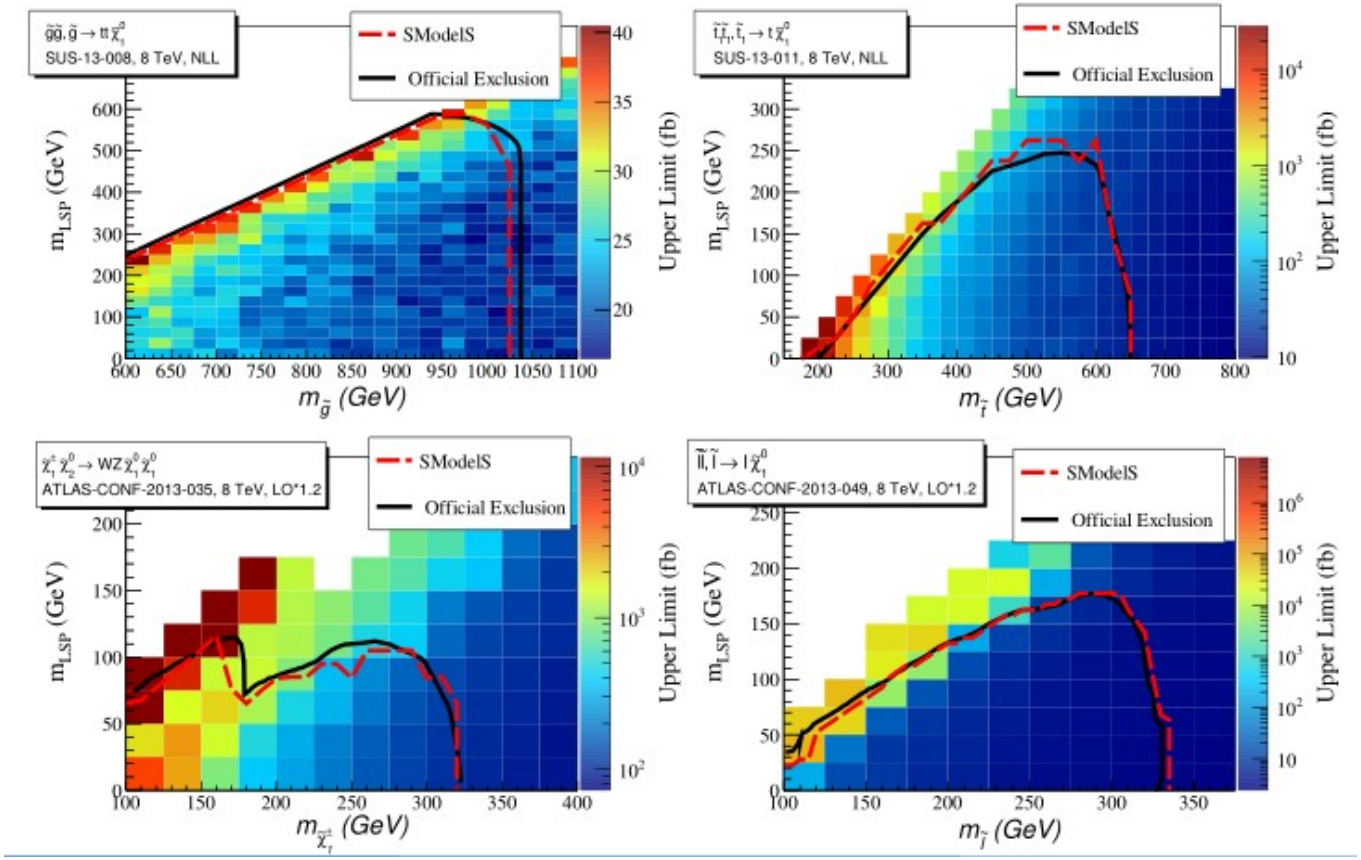


Validation

For validating our database, we define:

Full model := simplified model

And check if we can reproduce the official exclusion curves:

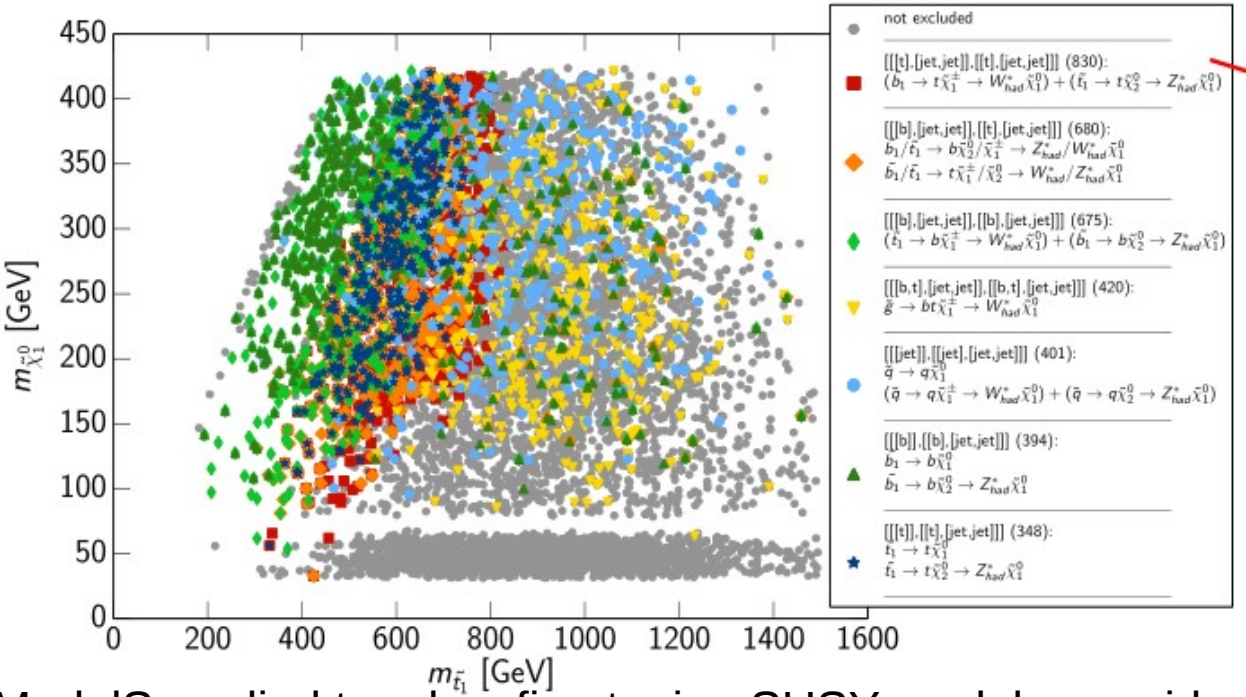


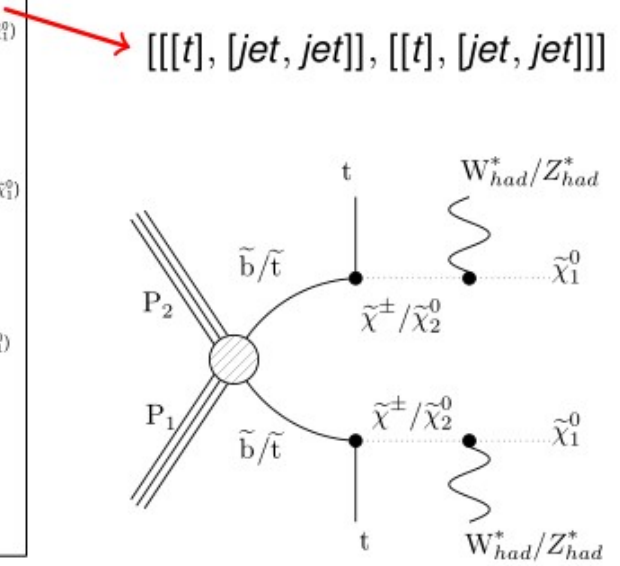
Applications

SModelS has been used to:

-) quickly identify regions of model parameter space that have been excluded by analyses

-) identify topologies and regions of parameter space that CMS and ATLAS are blind to.





SModelS applied to a low-fine tuning SUSY model scan, identifying the most important topologies (master's thesis, Veronika Magerl, TU Wien, 2015)

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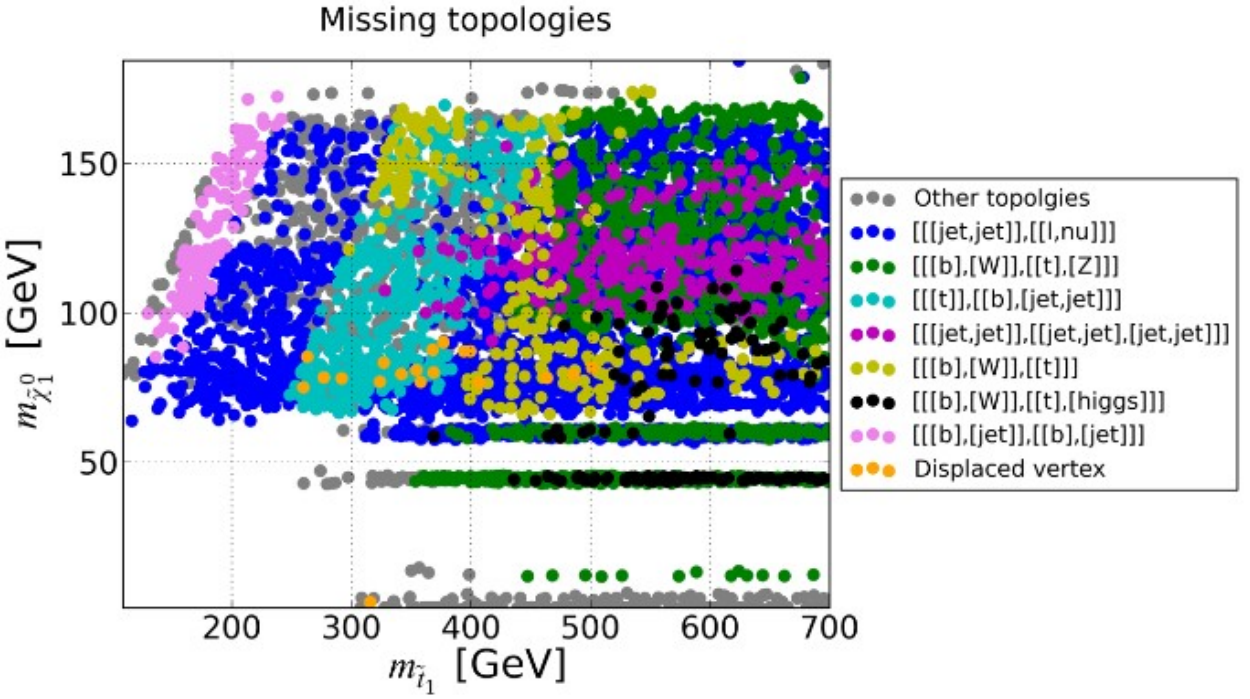

Missing topologies identified with SModelS in an NMSSM scan (presented at PASCOS 2014)

Availability

SModelS is written entirely in python and is available here:

http://smodels.hephy.at

It uses pythia and nllfast for the computation of the cross sections.

Future

We intend to extend the functionality of SmodelS in several ways:

- Extend to non-Z_2 / non-MET topologies
- Extend to long-lived particles (HCSP scenarios)
- Make use of signal efficiency maps created by people inside and outside the experimental collaborations
- Make use of likelihoods
- Make use of positive results

Summary

SModelS can be used to quickly:

- Identify the most constraining topologies and analyses for a given model
- Identify the topologies missed by CMS and ATLAS

Limitations:

- It is tied to the simplified models results, it is overly conservative
- No simplified models results available for long decay chains
- It is only as good as its database of results

Thanks!