Application of CMS and ATLAS Simplified Models Results to Theories Beyond the Standard Model (BSM)

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Interpreting SUSY Searches

The full Minimal Supersymmetric Standard Model (MSSM) has more than 100 free parameters

$\Rightarrow$ interpret results in a constrained model, for example:

- constrained MSSM (cMSSM) (4 parameters + one sign free)
- phenomenological MSSM (pMSSM) (19 parameters free)

(see e.g. Djouadi et al, arxiv:hep-ph/9901246 (1998); Berger et al, JHEP 0902, 023 (2009); AbdusSalam et al, Phys. Rev. D 81, 095012 (2010))

BUT: many mass patterns and signatures not covered by cMSSM and pMSSM has a large parameter space

$\Rightarrow$ alternative approach: Simplified Models Spectra

Idea of Simplified Models Spectra (SMS)

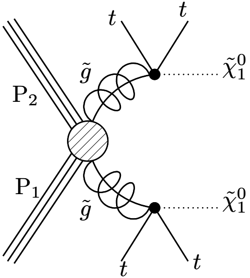
Idea: characterize new physics using effective Lagrangians, consider only a reduced set of particles

Parameters:

- phenomenologically observable masses,
- production cross sections and
- decay modes of the candidate new particles

Each event can be associated with a diagram, for example the T1tttt topology:

LHC results $\Longleftrightarrow$

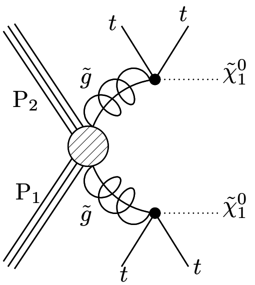


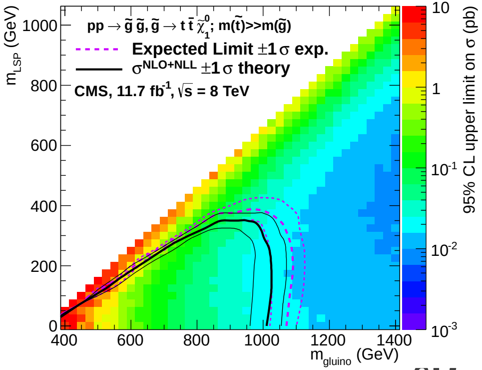
$\Longleftrightarrow$ $\mathcal{L}$

SModelS

Experimental Results

SUSY search results from CMS, ATLAS are interpreted in terms of Simplified Models → maps of upper limits on production cross sections





arXiv:1303.2985

SModelS

SModelS Idea

SModelS – a collaboration of phenomenologists and experimental physicists
Goal: make systematic use of the Simplified Models results
$\rightarrow$ introduce SModelS formalism

Ingredients:

- database of experimental SMS results
- generic decomposition scheme that can decompose arbitrary fundamental models
- describe experimentally considered SMS in the language of SModelS (so in terms of conditions and constraints)
- compare a fundamental theory to the experimental results through the SModelS formalism

Database

Store upper limit maps, make the associated information accessible

Information stored in one database entry:

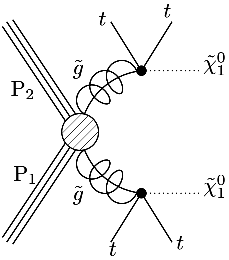
- map of upper limits on cross sections
- analysis name and reference
- center-of-mass energy, integrated luminosity
- SMS topology name
- SModelS description in terms of constraints, conditions

Current status: about 30 analyses included

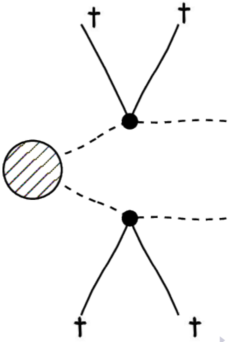
Constraints

Generalize language of topologies for systematic application of SMS results.
Analyses are relatively insensitive to quantum numbers other than masses
$\rightarrow$ first approximation: BSM particles are fully described by their mass.

In that language, a topology is described by an abstraction of the associated diagrams, defined by the outgoing SM particles.



$\longrightarrow$



$\longrightarrow$ [[[t,t]],[[t,t]]]

Conditions

Constraints tell us, what parts of a theory an experimental result can be applied to. In this example: those parts that produce two decay branches with two vertices with two top quarks from each vertex (plus missing energy)

However: depending on the assumptions made by an analysis, there may be additional conditions that need to be fulfilled in order for the experimental result to be applicable

⇒ express these implicit assumptions as Conditions

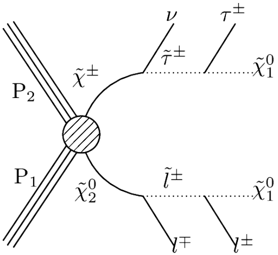
Example for Constraints and Conditions

The analysis assumes flavor democracy for all three generations on the second branch $\rightarrow$ general expression for e,μ,τ in the Constraint

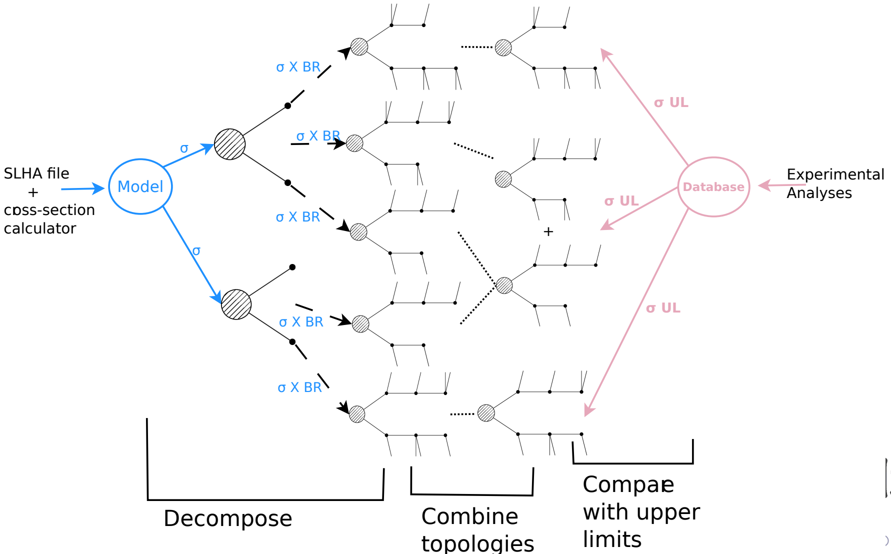
Constraint: [[[nu],[tau]],[[L],[L]]]

BUT: different efficiencies for the different flavors $\rightarrow$ experimental upper limit not applicable if there are too many taus in the theory. This gives

Condition: [[[nu],[tau]],[[L],[L]]] > 3 [[[nu],[tau]],[[tau],[tau]]]



How it works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Database
Experimental
Analyses
Decompose
Combine
topologies
Compae
with upper
limits

Application to a simple model

First application: random scan over a simple test model
Test model: simplified version of the pMSSM, with the parameters

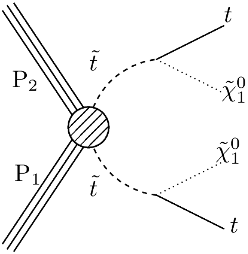
Parameter	Range	Description
M1	100 - 1000 GeV	Gaugino mass
M01	0 - 3000 GeV	first/ second generation sfermion
M03	0 - 1000 GeV	third generation sfermion
MA	100 - 2000 GeV	Pseudoscalar Higgs
μ	100 - 1000 GeV	
tanβ	2 - 50	
Ab	-1000 - 1000 GeV	Trilinear coupling, sbottom
Atau	-1000 - 1000 GeV	Trilinear coupling, stau
At	-3 - 3$*$M03	Trilinear coupling, stop

Evaluating the model

We consider only points that:

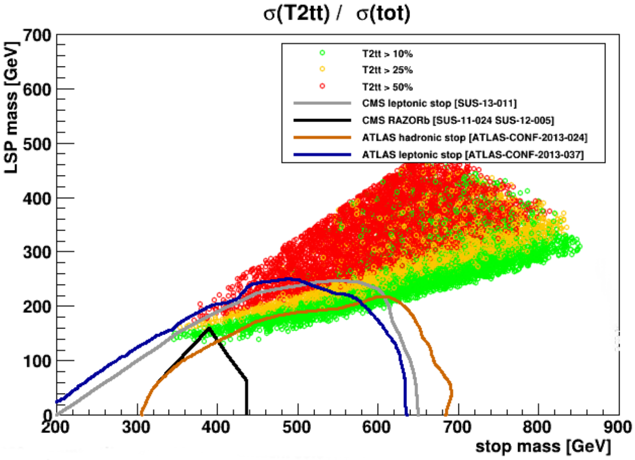
- satisfy the LEP constraints on sparticle masses
- produce a Higgs boson within a mass window of [123 GeV,128 GeV]
- comply with the low energy observables b→sγ, $B_s \to \mu^+\mu^-$

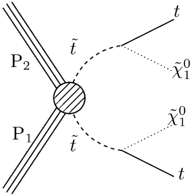
To get an idea of the results we can obtain:
look at the results for direct stop decay (T2tt)
compare the cross sections to the experimental upper limits



SModelS

T2tt - Where to look

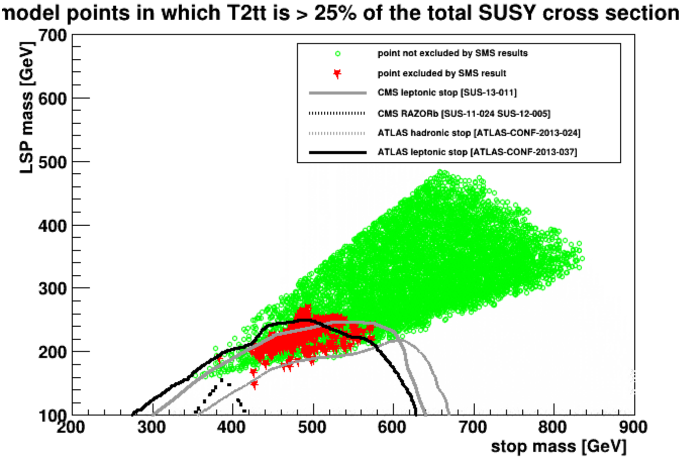


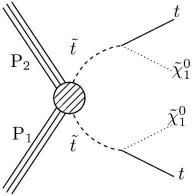


Branching ratio to T2tt

http://susy2013.ictp.it/lecturenotes/01_Monday/SUSY_Phenomenology/Lessa.pdf

T2tt - What we find





Excluded vs. not-excluded points

http://susy2013.ictp.it/lecturenotes/01_Monday/SUSY_Phenomenology/Lessa.pdf

Conclusion

We have:

- created an extensive database of SMS results
- created a formalism to systematically compare theories to these results
- applied the formalism to a simple test model

Next Steps:

- apply the results to different SUSY models (e.g. natural SUSY)
- apply the results to other models (e.g. UED)

analysis	$\sqrt{s}$	lumi	topologies	constraints
ATLAS-CONF-2012-105	8	5.8	T1tttt	[[[t+,t-]],[[t+,t-]]]
ATLAS-CONF-2012-166	8	13.0	T2tt	[[[t]],[[t]]]
			T6bbWW	[[[b],[W]],[[b],[W]]]
ATLAS-CONF-2013-001	8	12.8	T2bb	[[[b]],[[b]]]
ATLAS-CONF-2013-007	8	20.7	T1tttt	[[[t+,t-]],[[t+,t-]]]
			T1tbtb	[[[t,b]],[[t,b]]]
			T5WW	[[[jet,jet],[W]],[[jet,jet],[W]]]
ATLAS-CONF-2013-024	8	20.5	T2tt	[[[t]],[[t]]]
ATLAS-CONF-2013-025	8	20.7	T6ttZZ	[[[Z],[t]],[[Z],[t]]]
ATLAS-CONF-2013-028	8	20.7	TChiChipmStauL	2.*([[[nu],[ta]],[[ta+],[ta-]]] + [[[...
			TChipChimStauSnu	[[[ta-],[nu]],[[nu],[ta+]]] + [[[ta+]...
ATLAS-CONF-2013-035	8	20.7	TChiWZ	[[[W]],[[Z]]]
			TChiChipmSlepL	2.*([[[L],[L]],[[L],[nu]]] + [[[L],[L...
ATLAS-CONF-2013-036	8	20.7	TChiChiSlepSlep	[[[l+],[l-]],[[l+],[l-]]]+[[[l-],[l+]...
ATLAS-CONF-2013-037	8	20.7	T2tt	[[[t]],[[t]]]
			T6bbWW	[[[b],[W]],[[b],[W]]]
ATLAS-CONF-2013-049	8	20.3	TSlepSlep	[[[e+]],[[e-]]]+[[[mu+]],[[mu-]]]
ATLAS-CONF-2013-053	8	20.1	T2bb	[[[b]],[[b]]]
ATLAS-CONF-2013-061	8	20.1	T1tbtb	[[[t,b]],[[t,b]]]
			T1bbbb	[[[b,b]],[[b,b]]]
			T1tttt	[[[t,t]],[[t,t]]]
ATLAS-CONF-2013-062	8	20.0	T2bb	[[[b]],[[b]]]

analysis	$\sqrt{s}$	lumi	topologies	constraints
SUS-13-011	8	19.5	T2tt	[[[t]],[[t]]]
			T6bbWW	[[[b],[W]],[[b],[W]]]
SUS-12-006	7	4.98	TChiWZ	[[[W]],[[Z]]]
SUS-11-013	7	4.98	TChiWZ	[[[W]],[[Z]]]
SUS-12-026	8	9.2	T1tttt	[[[t+,t-]],[[t+,t-]]]
SUS-12-011	7	4.98	T2	[[[jet]],[[jet]]]
SUS-13-012	8	19.5	T2	[[[jet]],[[jet]]]
			T1	[[[jet,jet]],[[jet,jet]]]
SUS-12-024	8	19.4	T1bbbb	[[[b,b]],[[b,b]]]
			T1tttt	[[[t,t]],[[t,t]]]
SUS-13-007	8	19.4	T1tttt	[[[t,t]],[[t,t]]]
SUS-12-005 SUS-11-024	7	4.7	T2	[[[jet]],[[jet]]]
SUS-13-006	8	19.5	TChiWZ	[[[W]],[[Z]]]
			TChiChipmStauStau	[[[ta],[ta]],[[nu],[ta]]]
			TSlepSlep	[[[l+]],[[l-]]]
			TChiChipmSlepStau	[[[L],[L]],[[nu],[ta]]]
			TChiChipmSlepL	2.*([[[L],[L]],[[L],[nu]]] + [[[L],[L...
			TChipChimSlepSnu	[[[L-],[nu]],[[nu],[L+]]] + [[[L+],[n...
SUS-13-008	8	19.5	T6ttWW	[[[t],[W]],[[t],[W]]]
			T1tttt	[[[t,t]],[[t,t]]]
			T6bbZZ	[[[b],[Z]],[[b],[Z]]]
			T7btbtWW	[[[b],[t],[W]],[[b],[t],[W]]]
			T5tttt	[[[t],[t]],[[t],[t]]]
SUS-13-013	8	19.5	T5WW	[[[jet,jet],[W]],[[jet,jet],[W]]]
			T6ttWW	[[[t+],[W-]],[[t+],[W-]]]+[[[t-],[W+]...
			T1tttt	[[[t+,t-]],[[t+,t-]]]
			T1tsttst	[[[t+],[t-]],[[t+],[t-]]]+[[[t-],[t+]...
SUS-12-022	8	9.2	TChiWZ	[[[W]],[[Z]]]
			TChiChipmStauStau	[[[ta],[ta]],[[nu],[ta]]]
			TSlepSlep	[[[l+]],[[l-]]]
			TChiChipmSlepStau	[[[L],[L]],[[nu],[ta]]]
			TChiChipmSlepL	2.*([[[L],[L]],[[L],[nu]]] + [[[L],[L...
			TChipChimSlepSnu	[[[L-],[nu]],[[nu],[L+]]] + [[[L+],[n...
SUS-11-022	7	4.98	T1bbbb	[[[b,b]],[[b,b]]]
			T2tt	[[[t]],[[t]]]
			T1tttt	[[[t,t]],[[t,t]]]
			T2	[[[jet]],[[jet]]]
			T1	[[[jet,jet]],[[jet,jet]]]
			T2bb	[[[b]],[[b]]]
SUS-12-028	8	11.7	T1bbbb	[[[b,b]],[[b,b]]]
			T2tt	[[[t]],[[t]]]
			T1tttt	[[[t,t]],[[t,t]]]
			T2	[[[jet]],[[jet]]]
			T1	[[[jet,jet]],[[jet,jet]]]
			T2bb	[[[b]],[[b]]]