a Tool for Making Systematic Use of Simplified Models Results

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In collaboration with the SModelS group
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TOOLS 2017
Corfu, Greece, 10 – 15 September 2017

NP Models

- SUSY
  MSSM
  mSUGRA
  GMSB, AMSB
  NMSSM
  RPV, CPV,...
- TeXColour
- Extra-dim
- Little Higgs
- $f^\star$, V'
- Black Holes (!)

Spectrum Calc

- FeynHiggs
- NMHDECAY⋆
- RGE Codes Isasusy
  SoftSusy
  Spheno

  Suspect

Flavour Calc

Dark Matter

- SIsoRelic
- micrOMEGAs
  SloopS⋆
- DARKSUSY
- IsaRED/RES

Cross sections Calc, MEG

- Tree-level,any
  CalcHEP, CompHEP
  GRACE, FORMCalc
  Madgraph
  SHERPA/Amegic++
  Whizard/O'Mega
- 1-loop dedicated
  AF's SLEPTONS
  Prospino, hprod
- 1-loop/General GRACE-SUSY

  FormCalc,SloopS

Decay Codes

- BRIDGE
- HDECAY
- NMHDECAY⋆
- SDECAY

- [Isajet]
- Herwig++
- Pythia
- Sherpa

Fitters

- Fittino
- SFitter
- SuperBayes
- HiggsBounds
- MasterCode !

(Fawzi's introductory slide)

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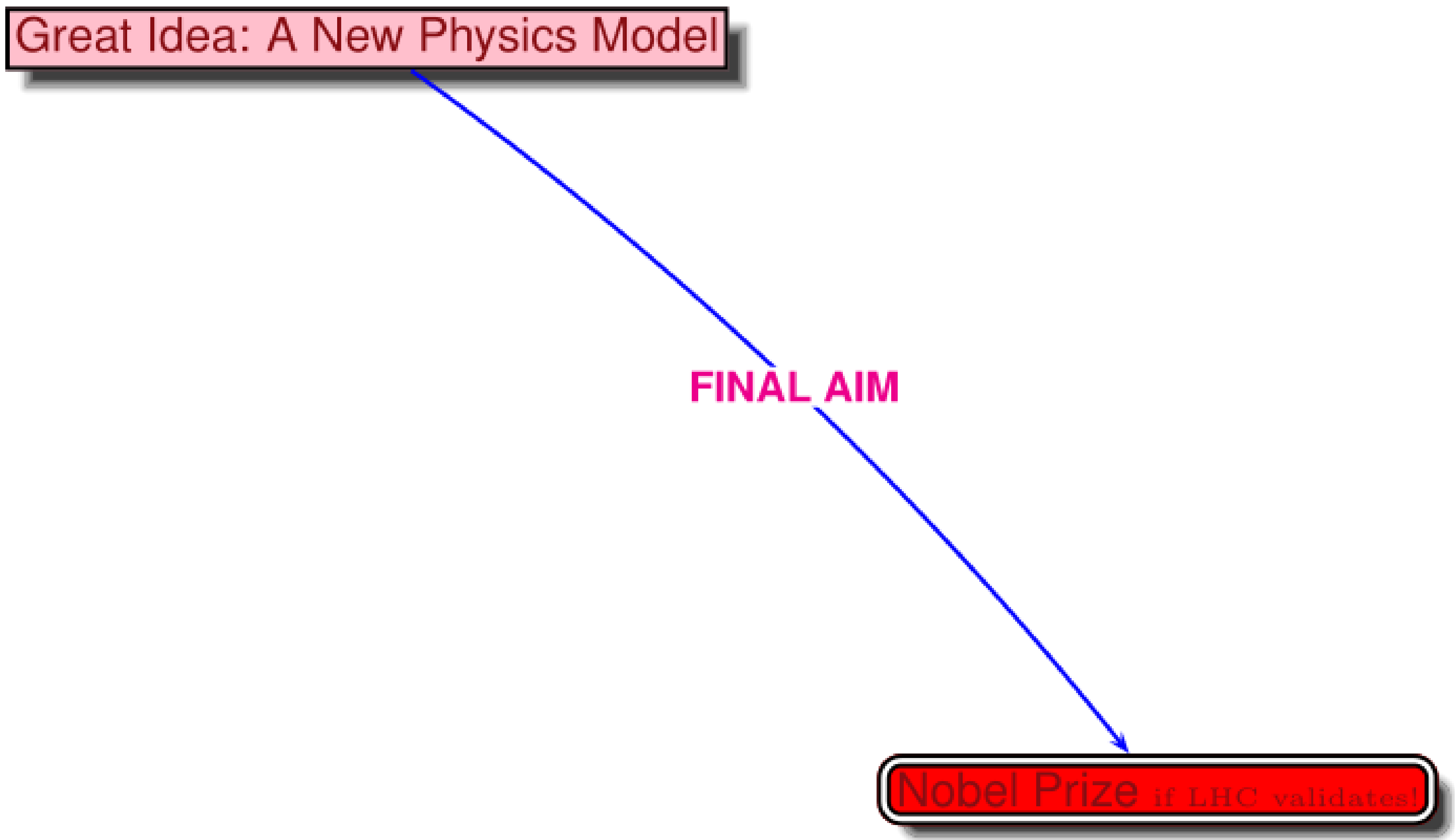
Nobel Dreams

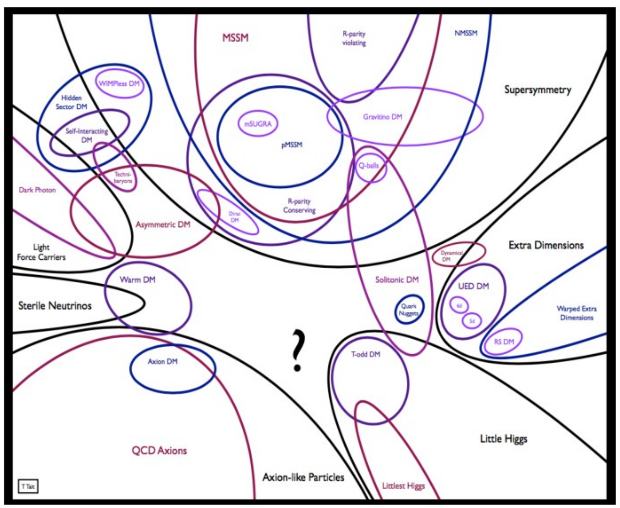


(Fawzi's introductory slide)

Nobel Dreams

Great Idea: A New Physics Model

More and more models of New Physics from Tim Tait

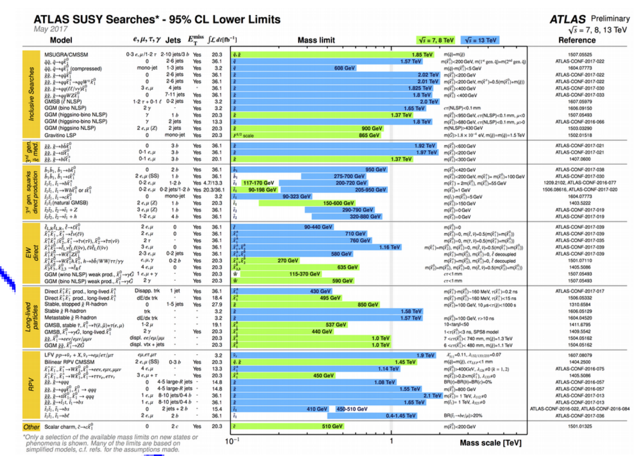


F. BOUDJEMA (LAPTh) Tools 2017 Corfu, Sep.

A large number of models

FINAL AIM

A large number of results

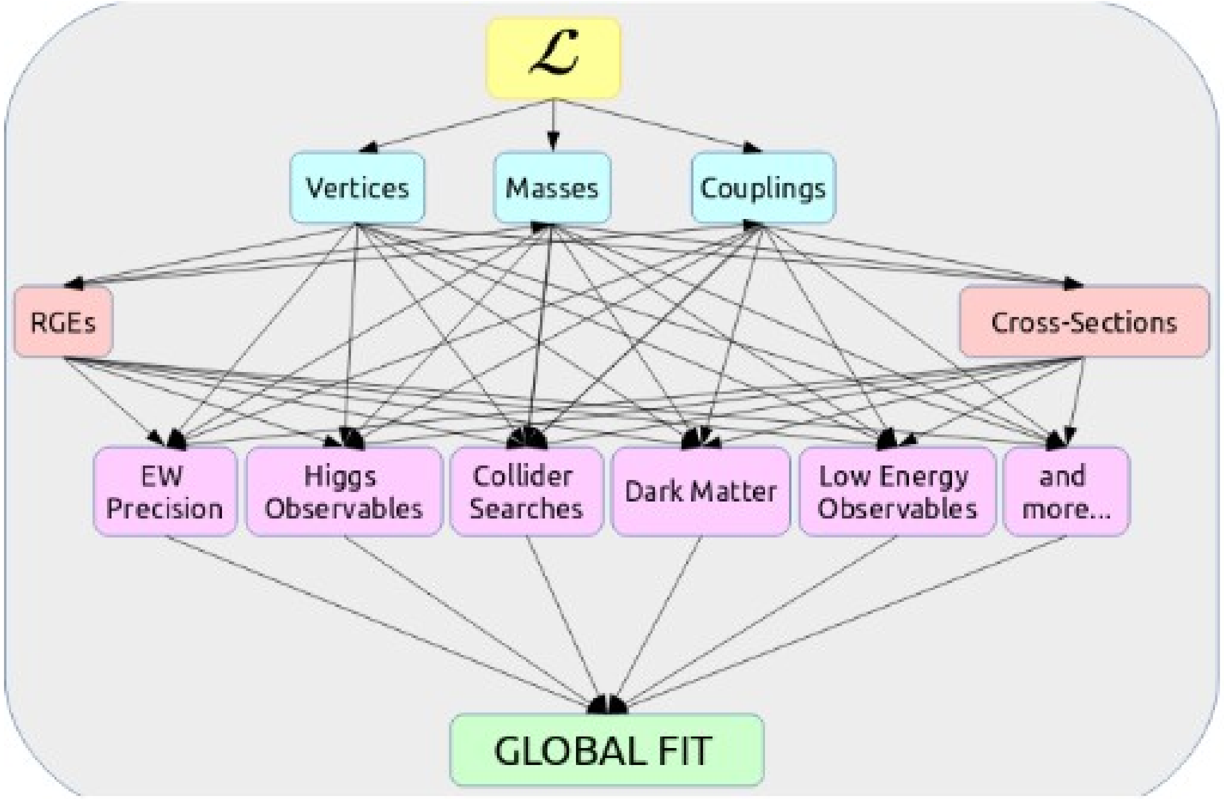


Nobel Prize if LHC validates!

(Fawzi's introductory slide)

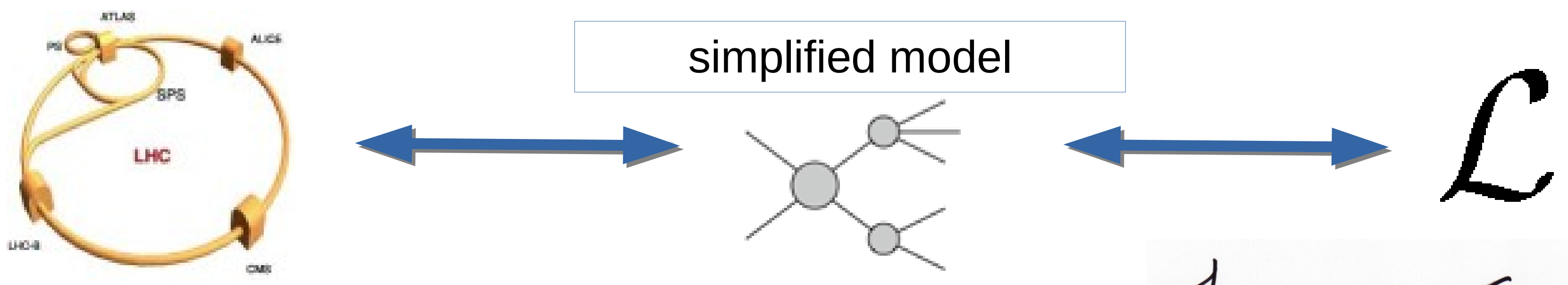
In the presence of (several) positive results, global “frequentist” fits would actually run into conceptual problems.

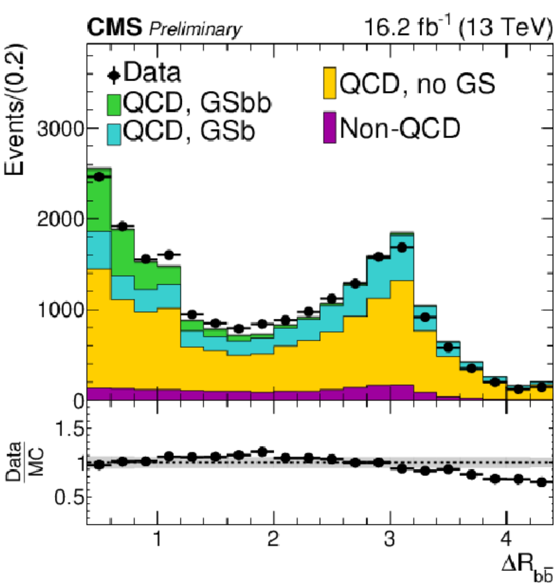
(E.g. how do we fit 100+ free parameters? How do we choose between an n-dimensional SUSY model and an m-dimensional alternative model? How do we decide if our model is acceptable, with 100+ free parameters? How do we verify we found the global maximum? How do we decide if we need to make changes to our model?)

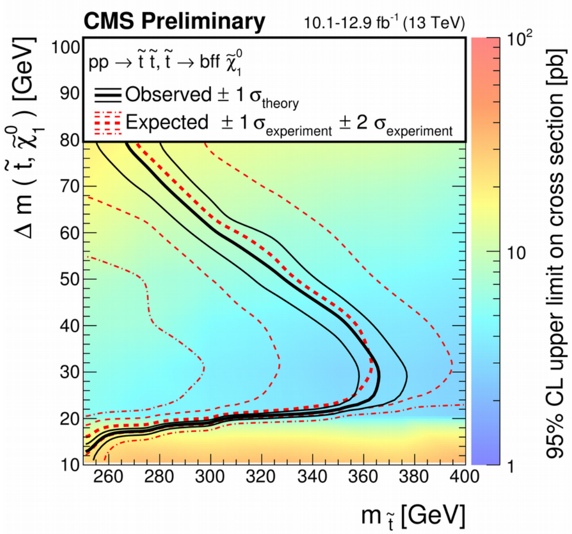


(Jamie Tattersall, oct 2016)

Alternative (in addition to global fits, not instead of them): incremental, bottom-up approach, starting from data, using simplified models as an "abstraction layer":







$$\mathcal{L} = -\frac{1}{4} F_{\mu\nu} F^{\mu\nu} + i\bar{\Psi} \not{D} \psi + h.c. + \bar{\psi}_i y_{ij} \psi_j \phi + h.c. + |D_\mu \phi|^2 - V(\phi)$$

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- Theory
  - Decomposition of a model
  - Computation of cross sections
  - Compressing the spectra

- Applications
- The Future

The Idea behind SModelS

SModelS is a tool to confront BSM models with

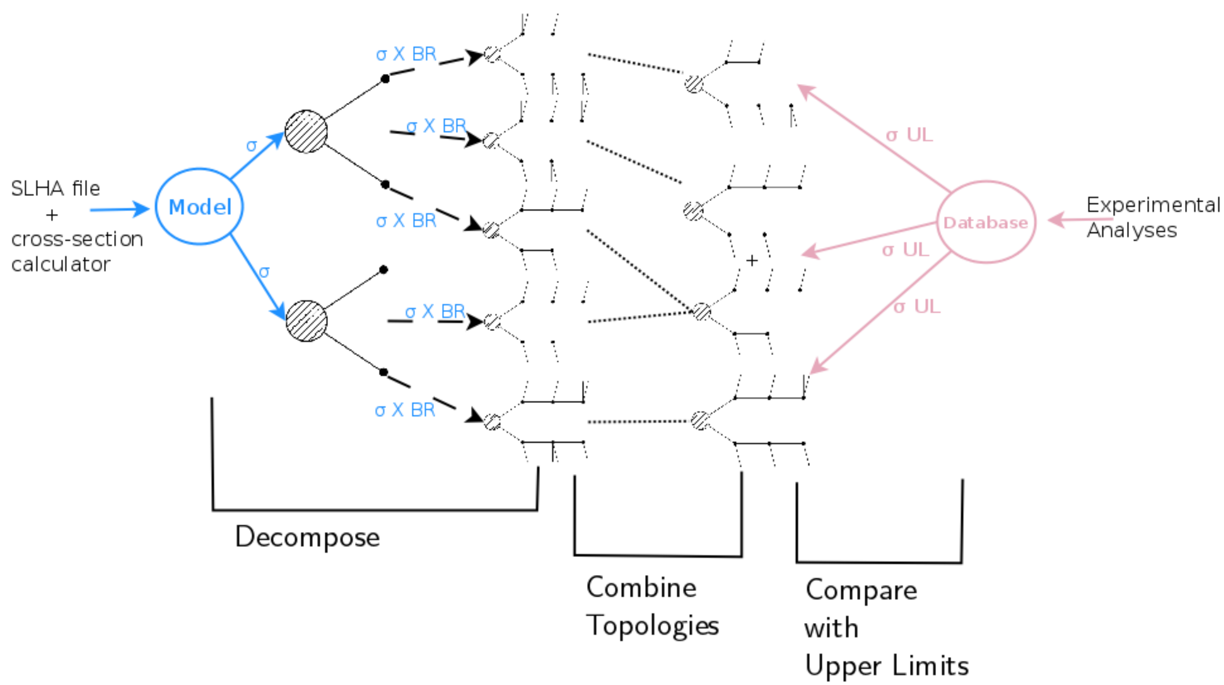
LHC results.

Contrary to MadAnalysis or CheckMATE,
SModelS does not recast analyses;
rather it makes systematic use of the simplified models results
– both upper limits and efficiency maps –

given by the experimentalists.

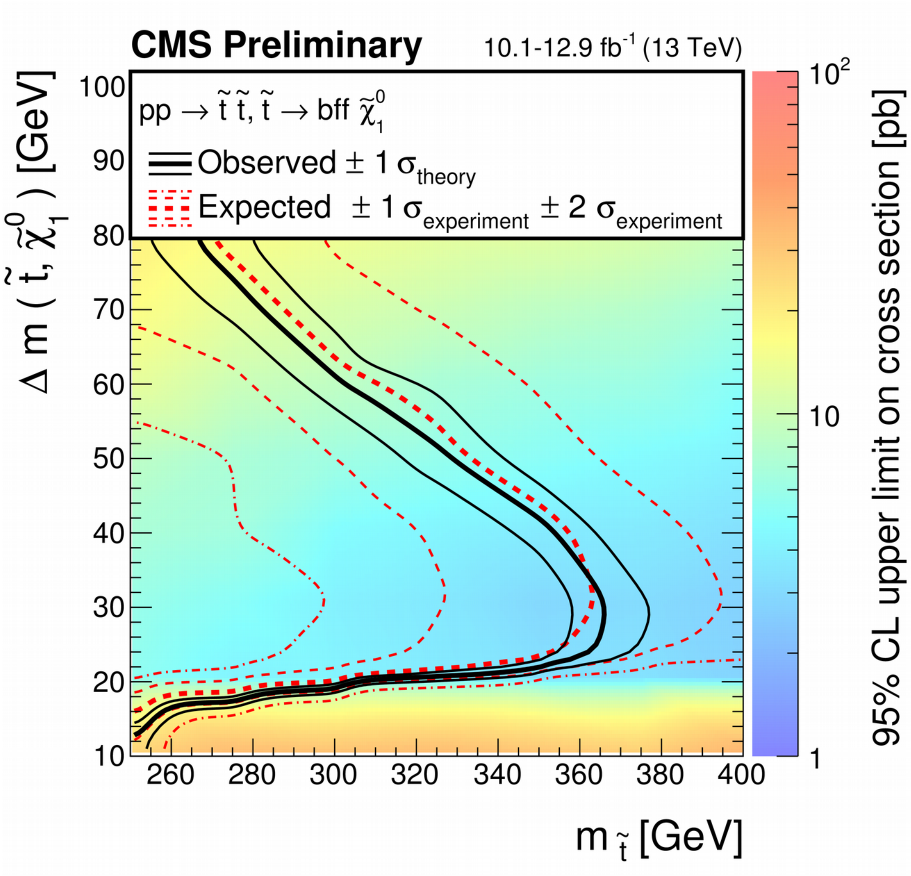
The Idea behind SModelS

SModelS confronts a BSM theory with LHC results by decomposing full models into their simplified models topologies, and comparing the cross section predictions of these individual topologies with a database of SMS results.



Simplified Models results

CMS-SUS-16-025: upper limits



Upper limits, parametrized in the mass space of a simplified model

Simplified Models results

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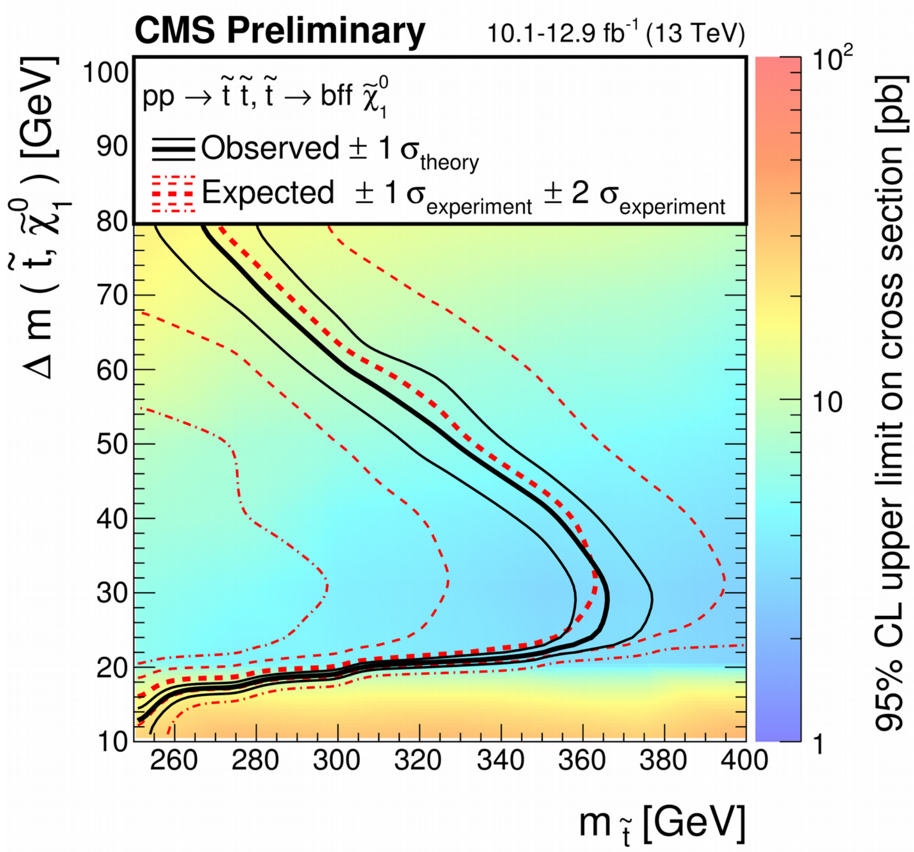


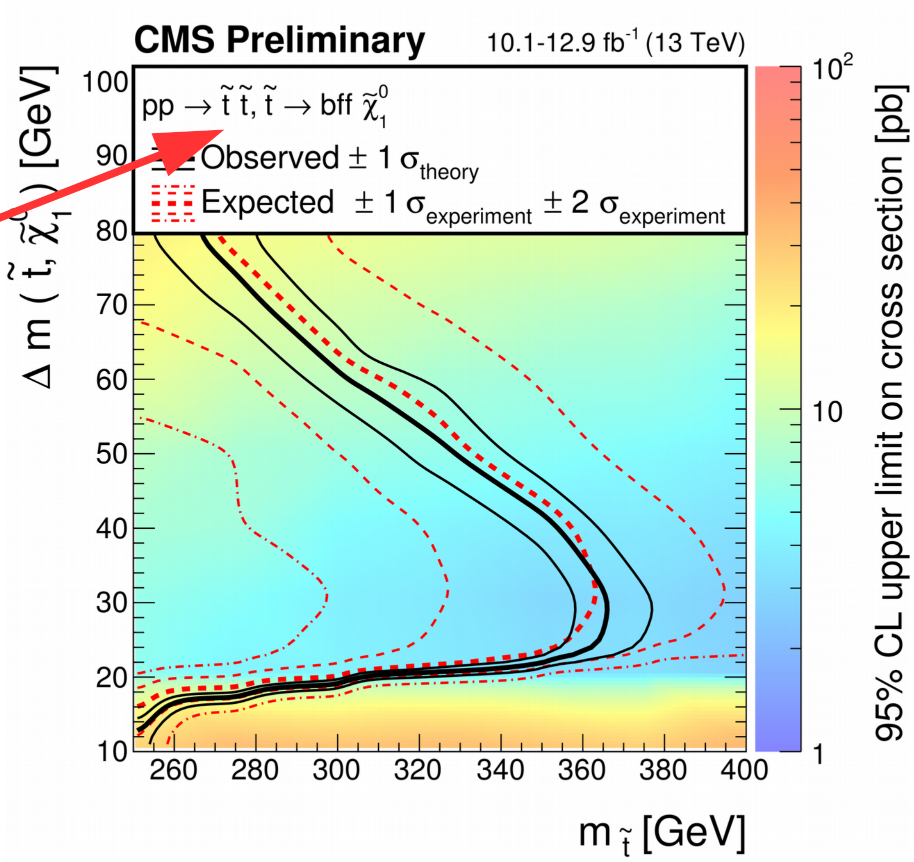
Upper limits, parametrized in the mass space of a simplified model

Simplified Models results

CMS-SUS-16-025: upper limits

$\tilde{t}\,\tilde{t},\ \tilde{t} \rightarrow \text{bff}\ \tilde{\chi}$

defines what part of a full theory the result *constrains*



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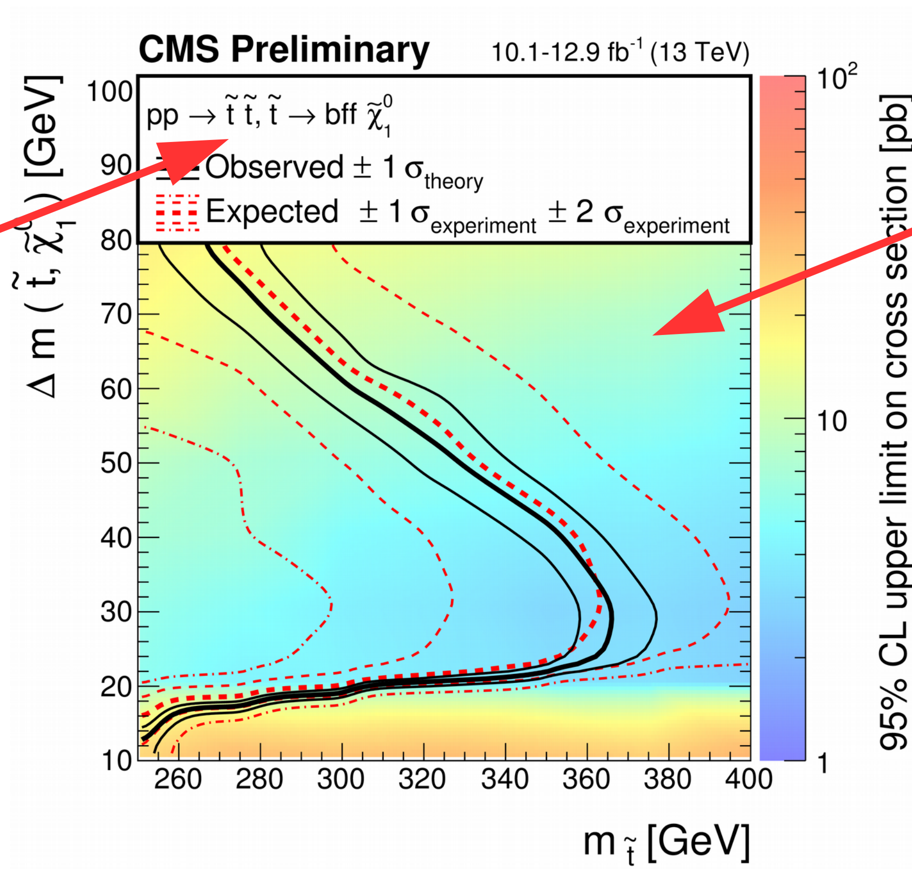

temperature plot = upper limit as a function of masses

Upper limits, parametrized in the mass space of a simplified model

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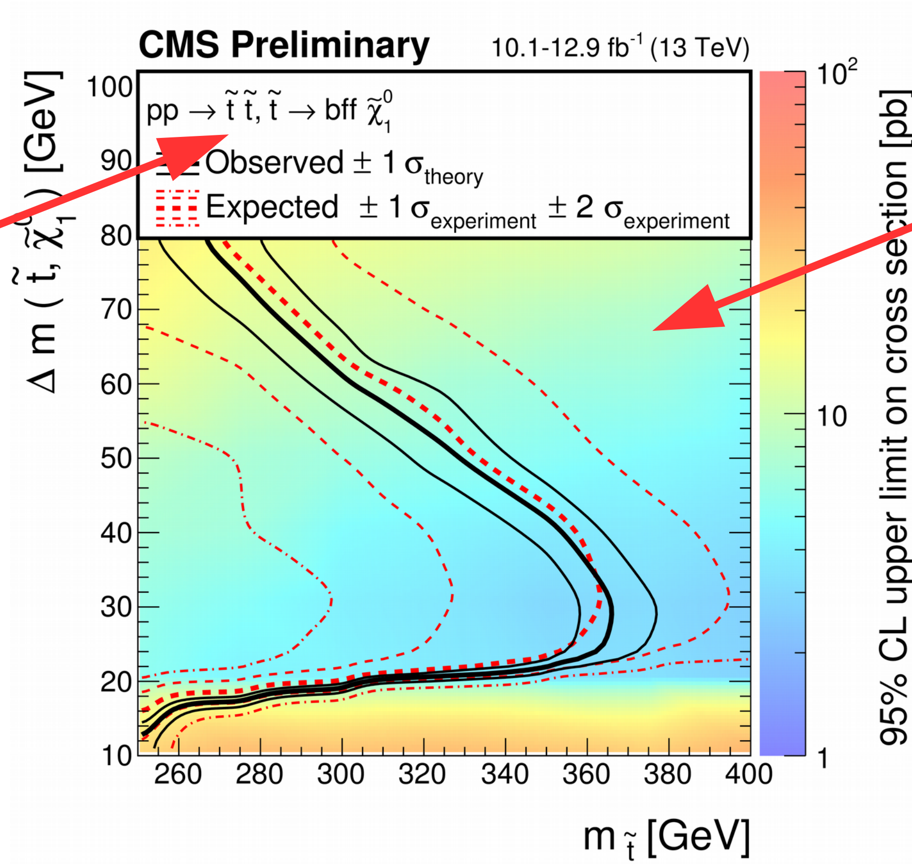
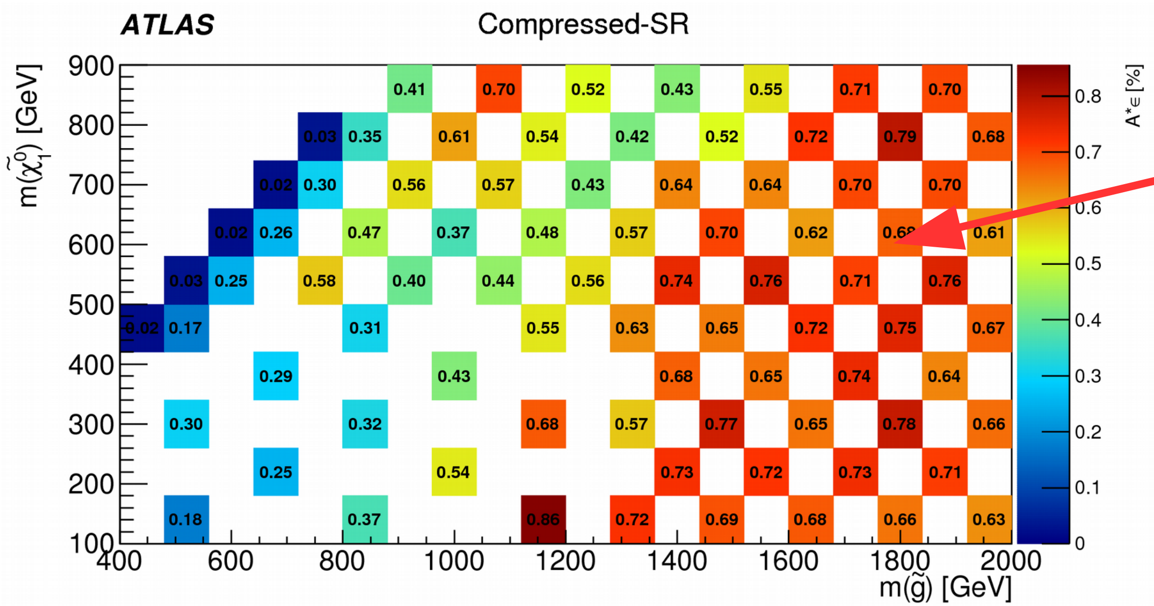


temperature plot = upper limit as a function of masses

Upper limits, parametrized in the mass space of a simplified model

Simplified Models Results

ATLAS-SUSY-2016-01: efficiency maps



signal efficiencies

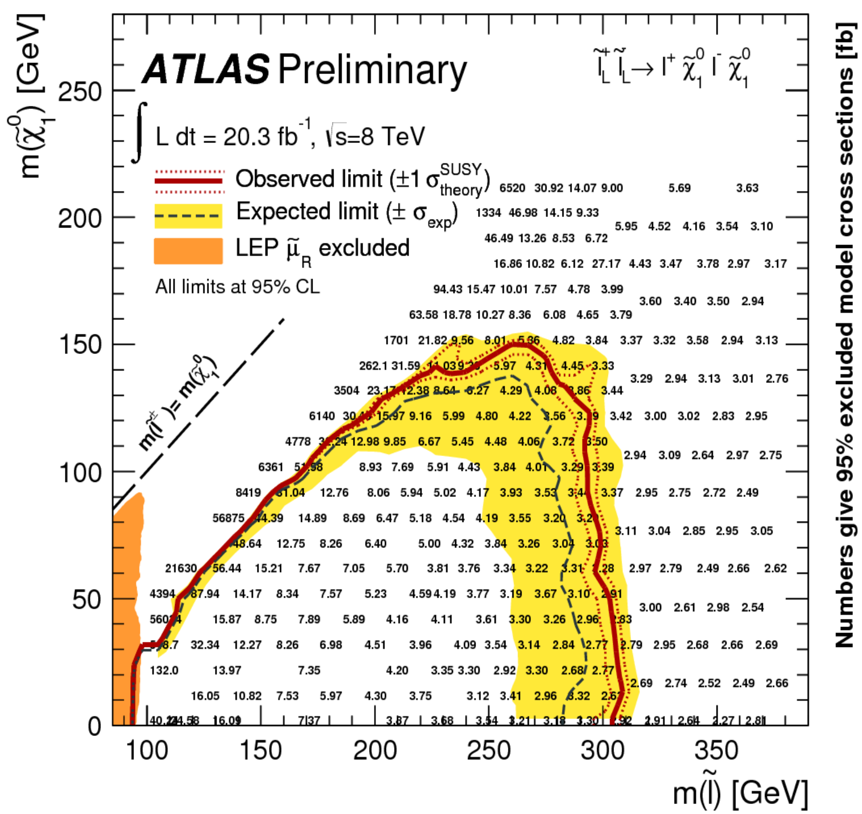
We use the signal efficiencies to compute upper limits on production cross sections. Additional ingredients are: the number of observed events, number of expected (background) events, and the error on the number of expected events!

Signal efficiencies, parametrized in the mass space of a simplified model

Formal language to describe the applicability of an SMS result

A formal language

A formalism is needed to describe which part of a
fundamental theory is constrained by what model under what conditions.



ATLAS-CONF-2013-049

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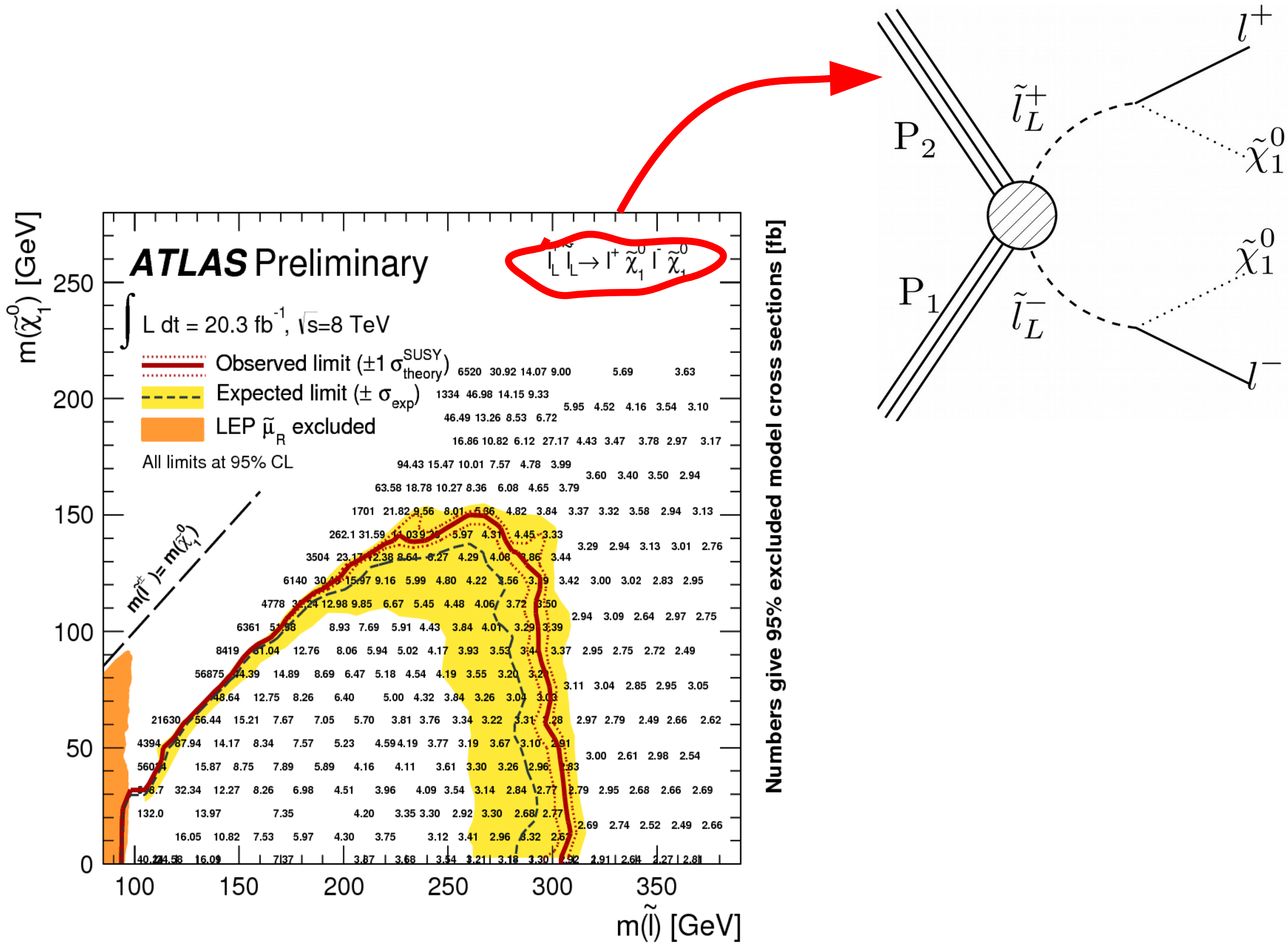

CMS-SUS-16-025

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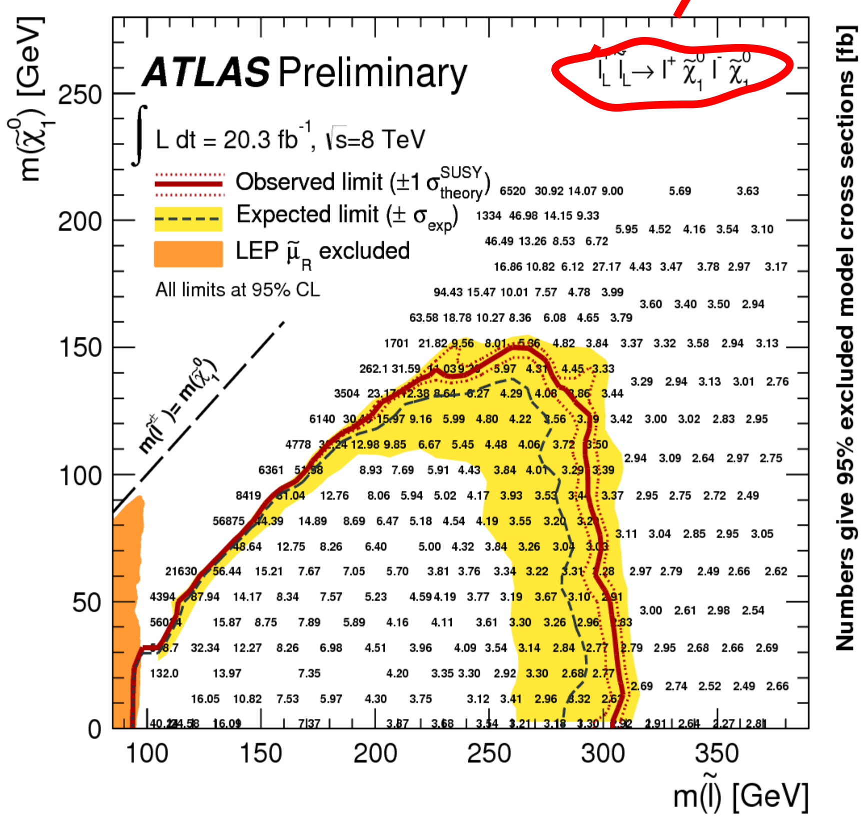
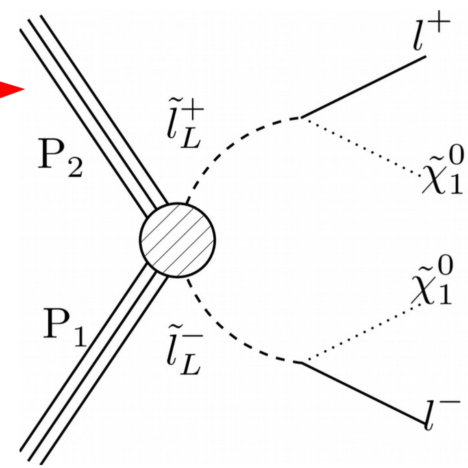
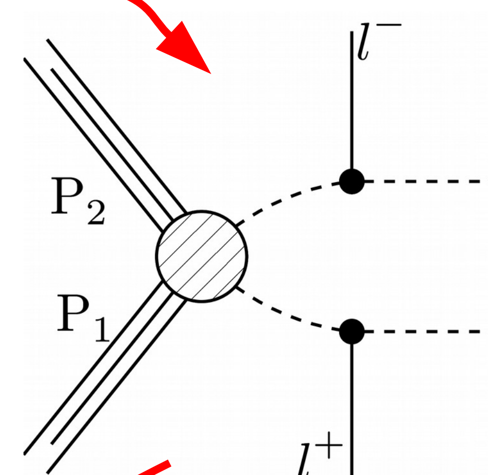




We ignore the nature of the BSM particles



And describe the "constraint" in our formal language:

constraint: [[[e^+]],[[e^-]] + [[μ^+]],[[μ^-]]]

CMS-SUS-16-025

A formal language

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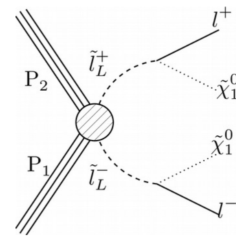

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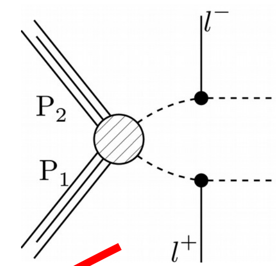
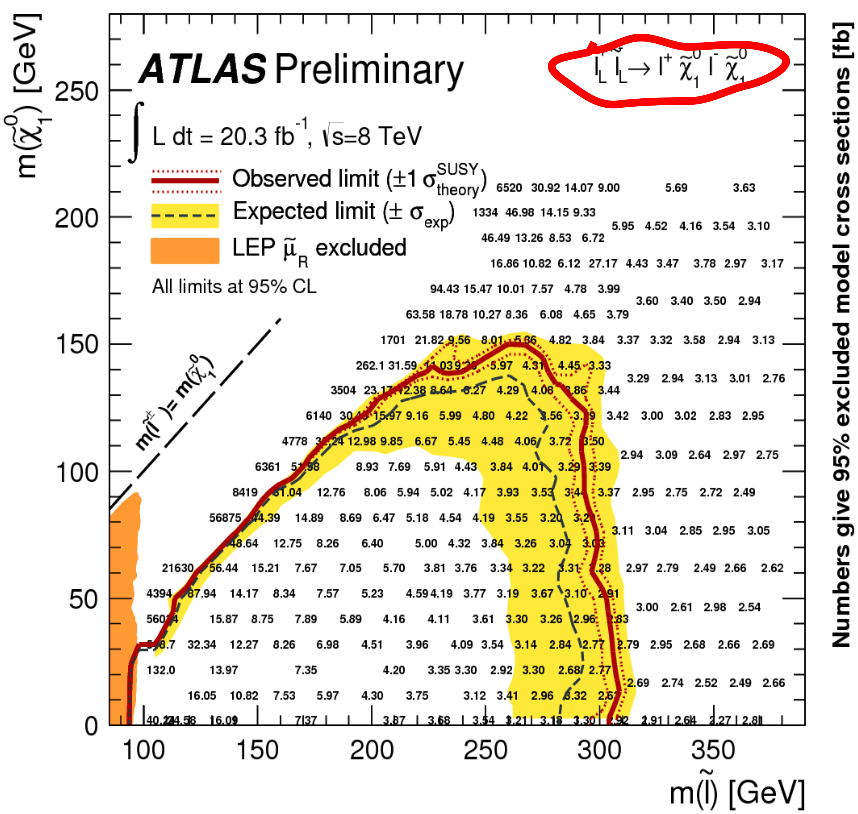




CMS-SUS-16-025

And describe the "constraint" in our formal language:

constraint: [[[e$^+$]],[[e$^-$]] + [[μ$^+$]],[[μ$^-$]]]

In this case, the experiments make the implicit assumption that:

σ([[[e$^+$]],[[e$^-$]]])=σ([[[μ$^+$]],[[μ$^-$]]])

We take this into account by demanding from the theory that:

condition: [[μ$^+$]],[[μ$^-$]] ≥ [[e$^+$]],[[e$^-$]] - ε

Building up a database

Construction of the SModelS database

ID	Topologies	Type	$\mathcal{L}$ [fb^{-1}]	$\sqrt{s}$
CMS-SUS-PAS-15-002	3: T1, T1bbbb, T1tttt[off]	ul	2.2	13
CMS-PAS-SUS-13-015	1: T2tt[off]	ul	19.4	8
CMS-PAS-SUS-13-015	1: T2tt[off]	eff	19.4	8
CMS-PAS-SUS-13-016	1: T1tttt[off]	ul	19.7	8
CMS-PAS-SUS-13-016	1: T1tttt[off]	eff	19.7	8
CMS-PAS-SUS-13-018	1: T2bb	ul	19.4	8
CMS-PAS-SUS-13-023	2: T2tt[off], T6bbWW[off]	ul	18.9	8
CMS-PAS-SUS-14-011	3: T1bbbb, T1tttt[off], T2tt[off]...	ul	19.3	8
CMS-SUS-12-024	2: T1bbbb, T1tttt[off]	ul	19.4	8
CMS-SUS-12-024	2: T1bbbb, T1tttt[off]	eff	19.4	8
CMS-SUS-12-028	6: T1, T1bbbb, T1tttt, T2, T2bb...	ul	11.7	8
CMS-SUS-13-002	1: T1tttt	ul	19.5	8
CMS-SUS-13-004	3: T1bbbb, T1tttt[off], T2tt[off]...	ul	19.3	8
CMS-SUS-13-006	5: TChiChipmSlepL, TChiChipmSlepStau...	ul	19.5	8
CMS-SUS-13-006	1: TChiWH	eff	19.5	8
CMS-SUS-13-007	2: T1tttt[off], T5tttt[off]	ul	19.3	8
CMS-SUS-13-007	1: T1tttt[off]	eff	19.3	8
CMS-SUS-13-011	2: T2tt[off], T6bbWW[off]	ul	19.5	8
CMS-SUS-13-011	1: T2tt[off]	eff	19.5	8
CMS-SUS-13-012	3: T1, T1tttt[off], T2	ul	19.5	8
CMS-SUS-13-013	2: T1tttt[off], T6ttWW[off]	ul	19.5	8
CMS-SUS-13-013	1: T1tttt[off]	eff	19.5	8
CMS-SUS-13-019	6: T1, T1bbbb, T1tttt[off], T2, T2bb...	ul	19.5	8
CMS-SUS-14-010	1: T1tttt[off]	ul	19.5	8
CMS-SUS-14-021	1: T2bbWW[off]	ul	19.7	8
CMS-SUS-14-021	1: T2bbWW[off]	eff	19.7	8

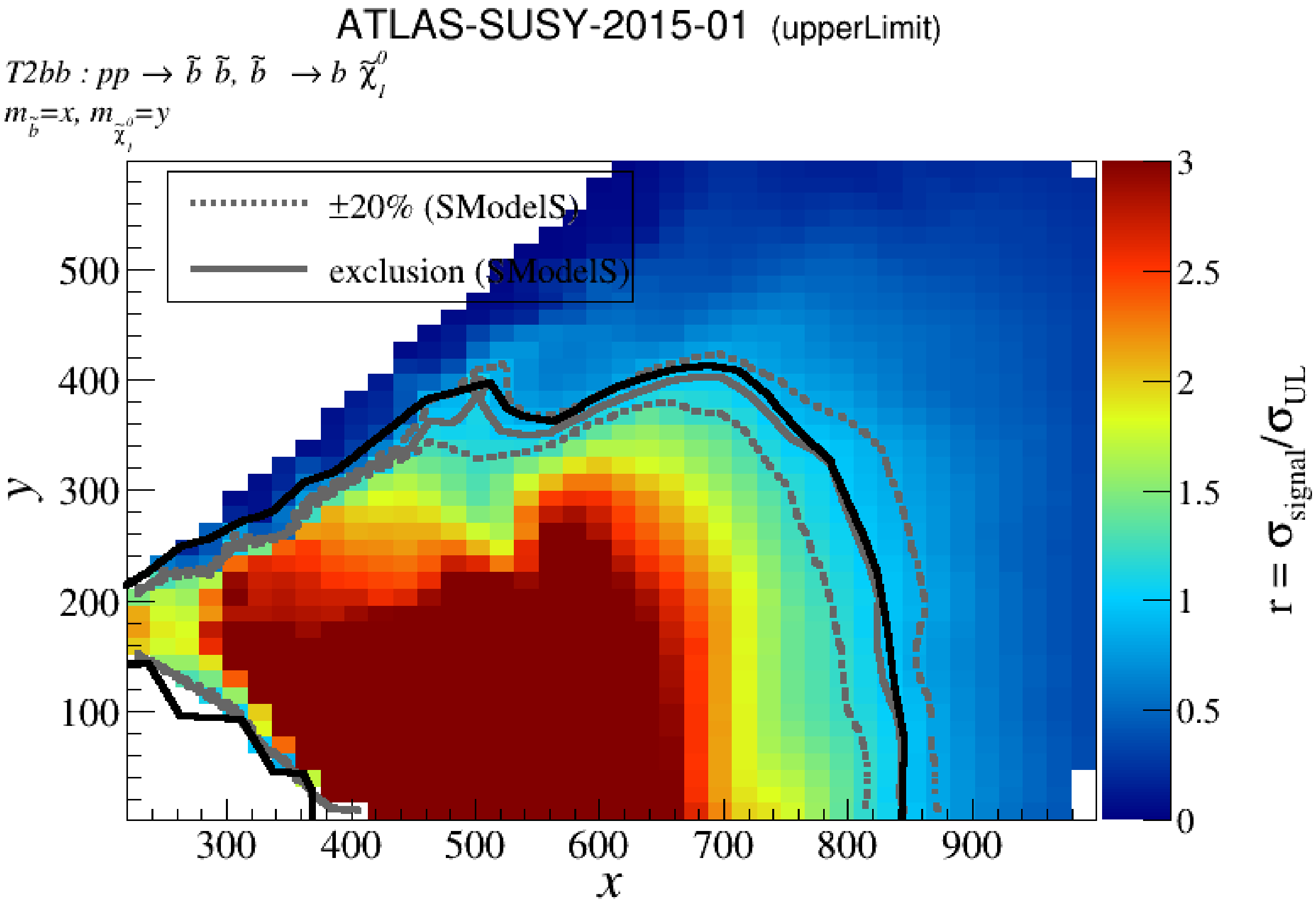
Table 1: SModelS database (CMS)

ID	Topologies	Type	$\mathcal{L}$ [fb^{-1}]	$\sqrt{s}$
ATLAS-SUSY-2015-09	1: T1tttt	ul	3.2	13
ATLAS-CONF-2013-024	1: T2tt	ul	20.5	8
ATLAS-CONF-2013-024	24: T1, T1bbbb, T1bbbt, T1bbqq, T1bbtt...	eff	20.5	8
ATLAS-CONF-2013-024	24: T1, T1bbbb, T1bbbt, T1bbqq, T1bbtt...	eff	1.0	8
ATLAS-CONF-2013-024	24: T1, T1bbbb, T1bbbt, T1bbqq, T1bbtt...	eff	1.0	8
ATLAS-CONF-2013-035	24: T1, T1bbbb, T1bbbt, T1bbqq, T1bbtt...	eff	20.7	8
ATLAS-CONF-2013-036	1: TChiChiSlepSlep	ul	20.7	8
ATLAS-CONF-2013-037	24: T1, T1bbbb, T1bbbt, T1bbqq, T1bbtt...	eff	20.7	8
ATLAS-CONF-2013-047	24: T1, T1bbbb, T1bbbt, T1bbqq, T1bbtt...	eff	20.3	8
ATLAS-CONF-2013-048	24: T1, T1bbbb, T1bbbt, T1bbqq, T1bbtt...	eff	20.3	8
ATLAS-CONF-2013-049	24: T1, T1bbbb, T1bbbt, T1bbqq, T1bbtt...	eff	20.3	8
ATLAS-CONF-2013-053	24: T1, T1bbbb, T1bbbt, T1bbqq, T1bbtt...	eff	20.1	8
ATLAS-CONF-2013-053	24: T1, T1bbbb, T1bbbt, T1bbqq, T1bbtt...	eff	1.0	8
ATLAS-CONF-2013-054	24: T1, T1bbbb, T1bbbt, T1bbqq, T1bbtt...	eff	20.3	8
ATLAS-CONF-2013-061	24: T1, T1bbbb, T1bbbt, T1bbqq, T1bbtt...	eff	20.1	8
ATLAS-CONF-2013-062	1: T5WW[off]	ul	20.3	8
ATLAS-CONF-2013-062	24: T1, T1bbbb, T1bbbt, T1bbqq, T1bbtt...	eff	20.3	8
ATLAS-CONF-2013-089	2: T5WW[off], T6WW[off]	ul	20.3	8
ATLAS-CONF-2013-093	1: TChiWH	ul	20.3	8
ATLAS-CONF-2013-093	24: T1, T1bbbb, T1bbbt, T1bbqq, T1bbtt...	eff	20.3	8
ATLAS-SUSY-2013-02	6: T1, T2, T5WW[off], T5tctc, T6WW[off]...	ul	20.3	8
ATLAS-SUSY-2013-02	2: T1, T2	eff	20.3	8
ATLAS-SUSY-2013-04	1: T1tttt	ul	20.3	8
ATLAS-SUSY-2013-04	3: T1tttt, T5WW[off], T5ZZ[off]...	eff	20.3	8
ATLAS-SUSY-2013-05	2: T2bb, T6bbWW[off]	ul	20.1	8
ATLAS-SUSY-2013-05	1: T2bb	eff	20.1	8
ATLAS-SUSY-2013-08	1: T6ZZtt	ul	20.3	8
ATLAS-SUSY-2013-09	1: T1tttt	ul	20.3	8
ATLAS-SUSY-2013-09	1: T1tttt	eff	20.3	8
ATLAS-SUSY-2013-11	4: TChiWW, TChiWZ, TChipChimSlepSnu...	ul	20.3	8
ATLAS-SUSY-2013-11	1: TSlepSlep	eff	20.3	8
ATLAS-SUSY-2013-12	4: TChiChipmSlepL, TChiChipmStauL...	ul	20.3	8
ATLAS-SUSY-2013-14	2: TChiChipmStauL, TChipChimStauSnu...	ul	20.3	8
ATLAS-SUSY-2013-15	3: T2bbWW, T2tt, T6bbWW	ul	20.3	8
ATLAS-SUSY-2013-15	1: T2tt	eff	20.3	8
ATLAS-SUSY-2013-16	1: T2tt	ul	20.1	8
ATLAS-SUSY-2013-16	2: T2tt, T6bbWW[off]	eff	20.1	8
ATLAS-SUSY-2013-18	2: T1bbbb, T1tttt	ul	20.1	8
ATLAS-SUSY-2013-18	2: T1bbbb, T1tttt	eff	20.1	8
ATLAS-SUSY-2013-19	3: T2bbWW, T2tt, T6bbWW[off]	ul	20.3	8
ATLAS-SUSY-2013-21	3: T2bb, T2bbWW[off], T2cc	eff	20.3	8
ATLAS-SUSY-2013-23	1: TChiWH	ul	20.3	8
ATLAS-SUSY-2014-03	1: TScharm	eff	20.3	8

We collect the results of the experimental collaborations, and augment them with recast analyses (MadAnalysis5, CheckMATE), creating our own efficiency maps.
SModelS v1.1.1 ships with ~ 70 analyses, and close to 200 results.
http://smodels.hephy.at/wiki/ListOfAnalysesv111

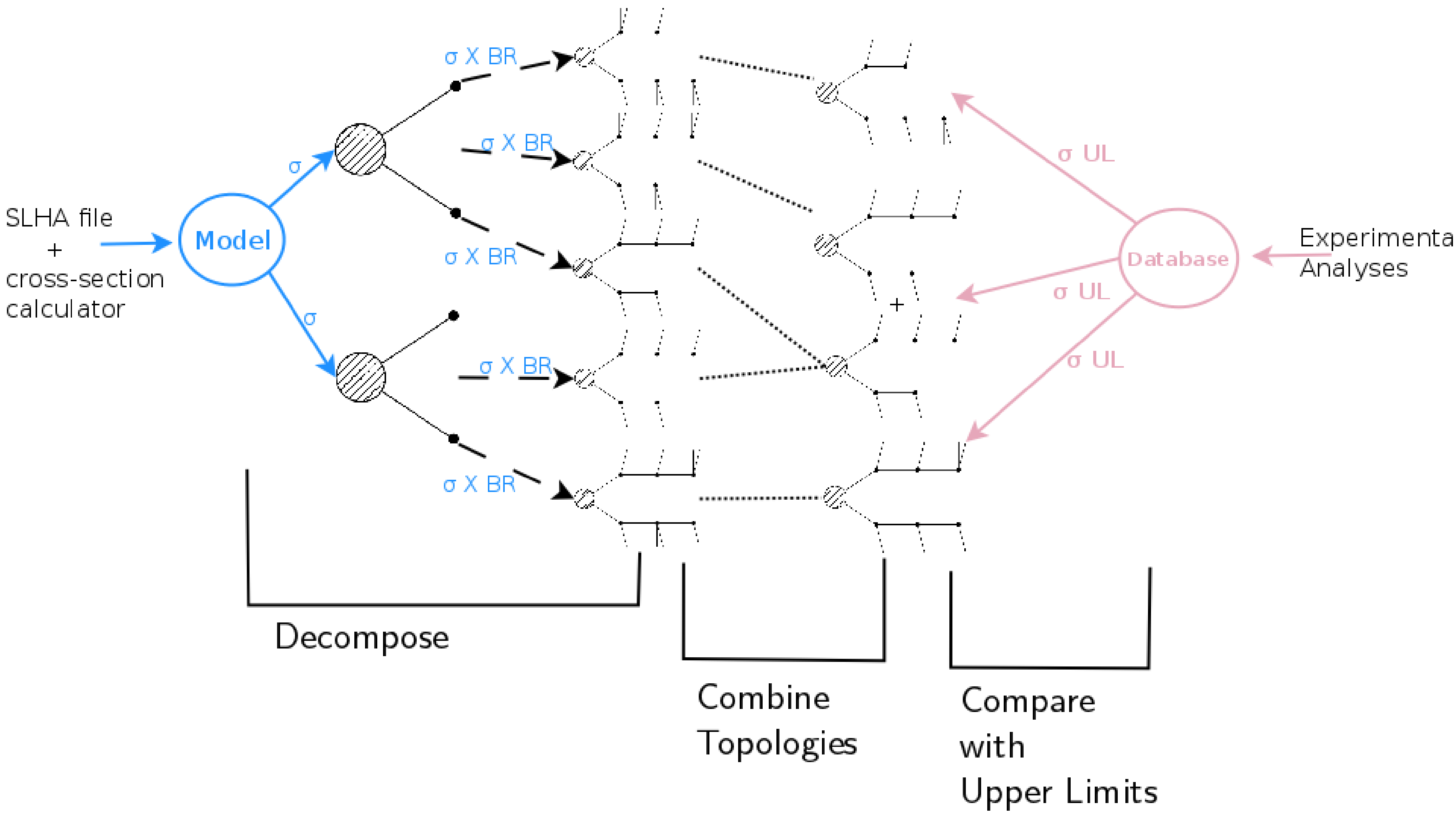
Construction of the SModelS database

We validate by defining the full model := simplified model, and check if we can reproduce the exclusion curves



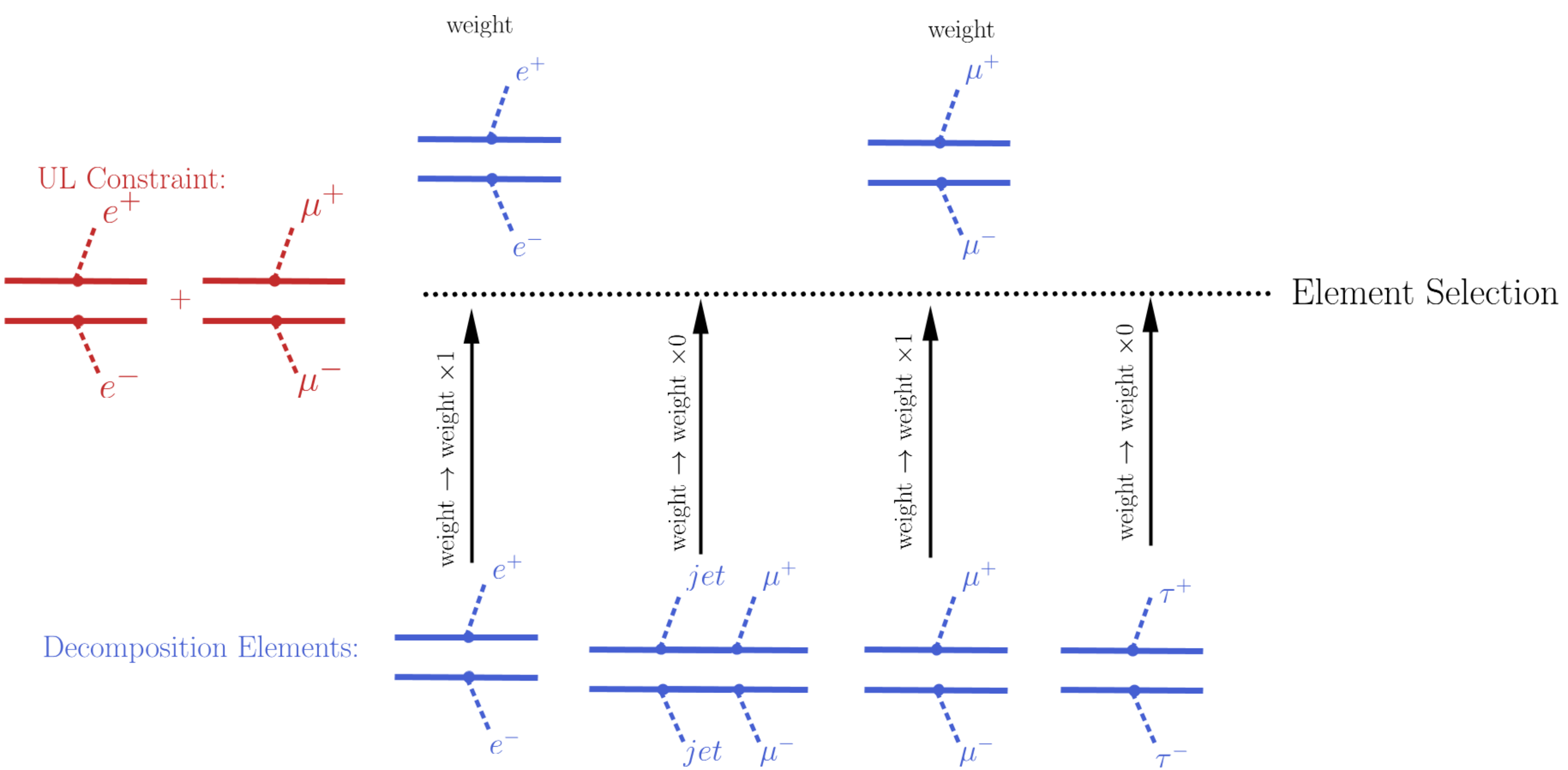
official plot:
https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/SUSY-2015-01/fig_04.png

Putting it all together



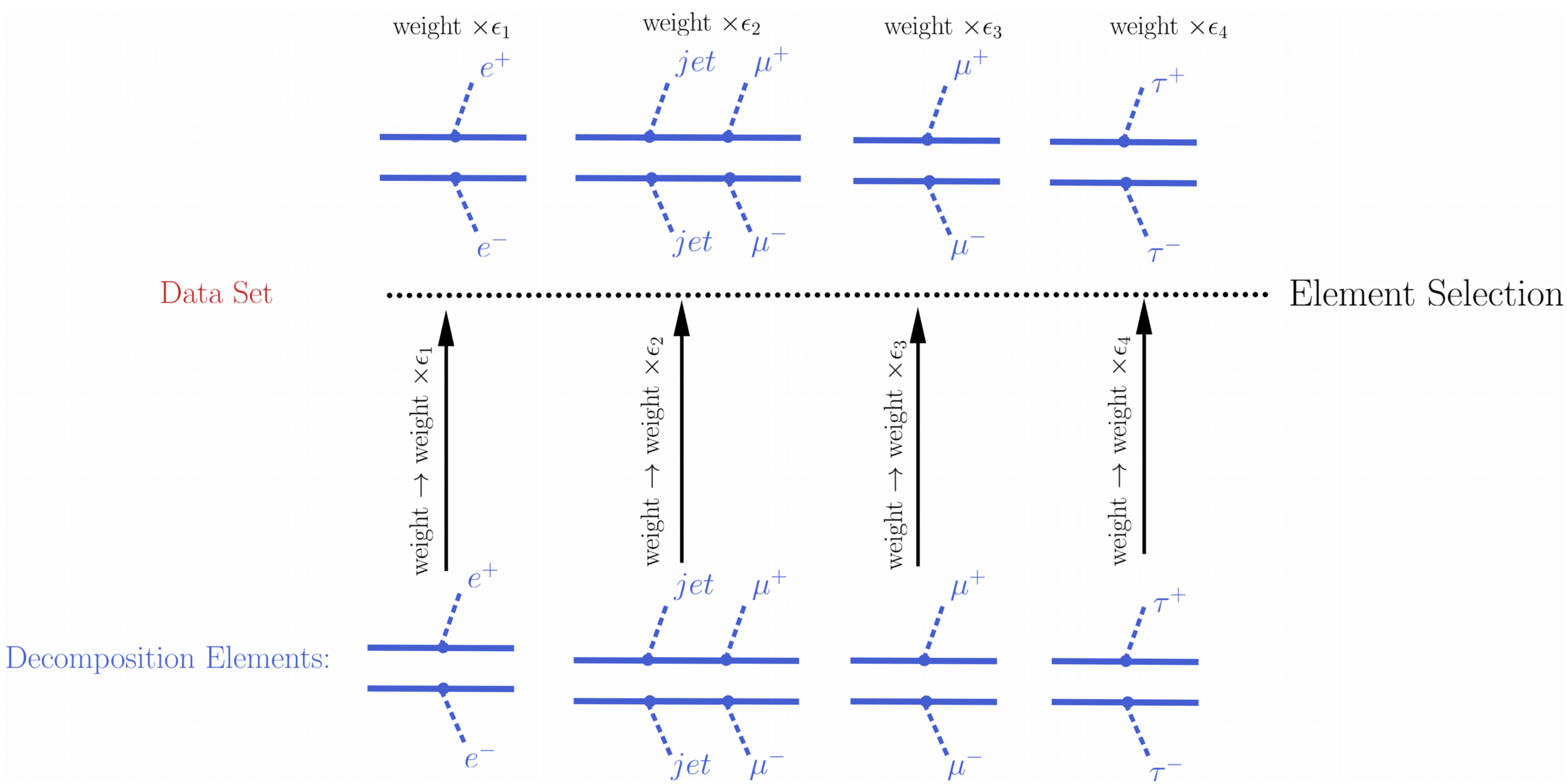
Putting it all together: upper limits

For upper limit results, we cannot combine results given for different topologies. We can only apply them one-by-one. Therefore the final upper limits are very conservative. (On the positive side: it is fairly straightforward for us to add an official SMS result to our database)



Putting it all together: efficiency maps

In the case of efficiency maps results we can combine efficiency maps for all topologies that an analysis has. (If e.g. an analysis vetoes jets, then the efficiencies for topologies involving jets would ~ 0).
As a consequence, the final upper limits tend to be less conservative.



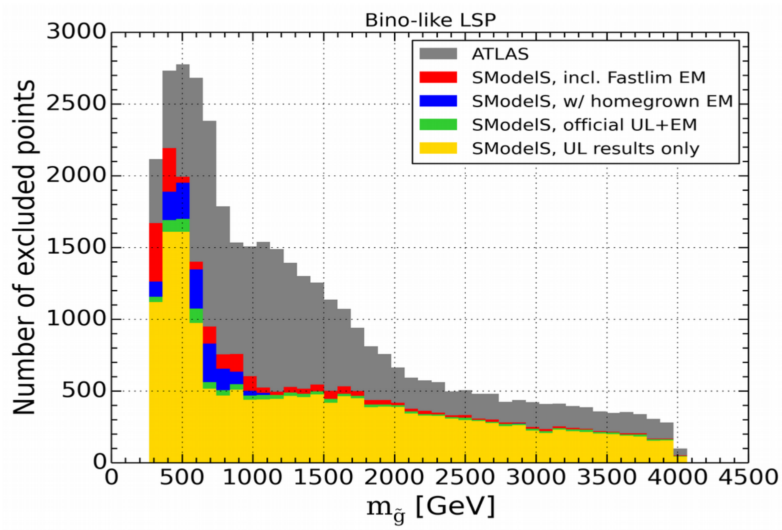
Applications

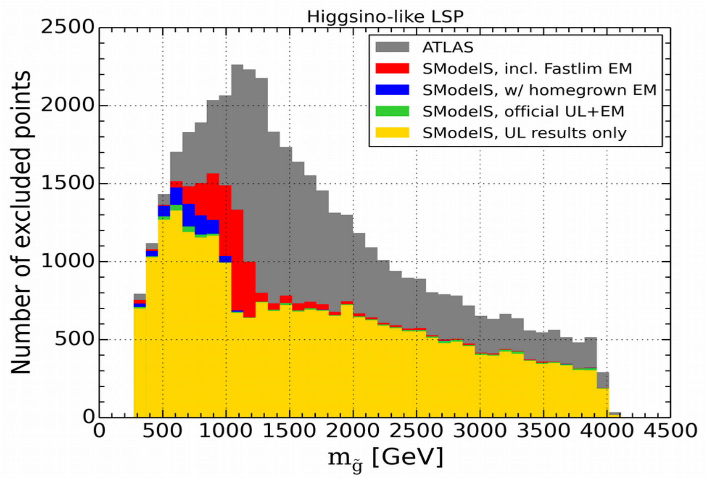
We envisage SModelS to be used for the following goals:

- To quickly eliminate uninteresting points in model scans
- To identify the most constraining analyses, and thus guide recasting efforts
- To identify “missing” topologies and “uncovered” mass ranges and thus guide the design of new analyses and changes in existing analyses
- A quick and cheap method to reinterpret LHC analyses in context of models other than the pMSSM (UEDs, NMSSM, ...)
- A quick and cheap way to produce conservative likelihoods that may be combined with other data.

Fast but conservative

pMSSM scan performed by ATLAS [1]. We wanted to know how much more conservative we are [2]:

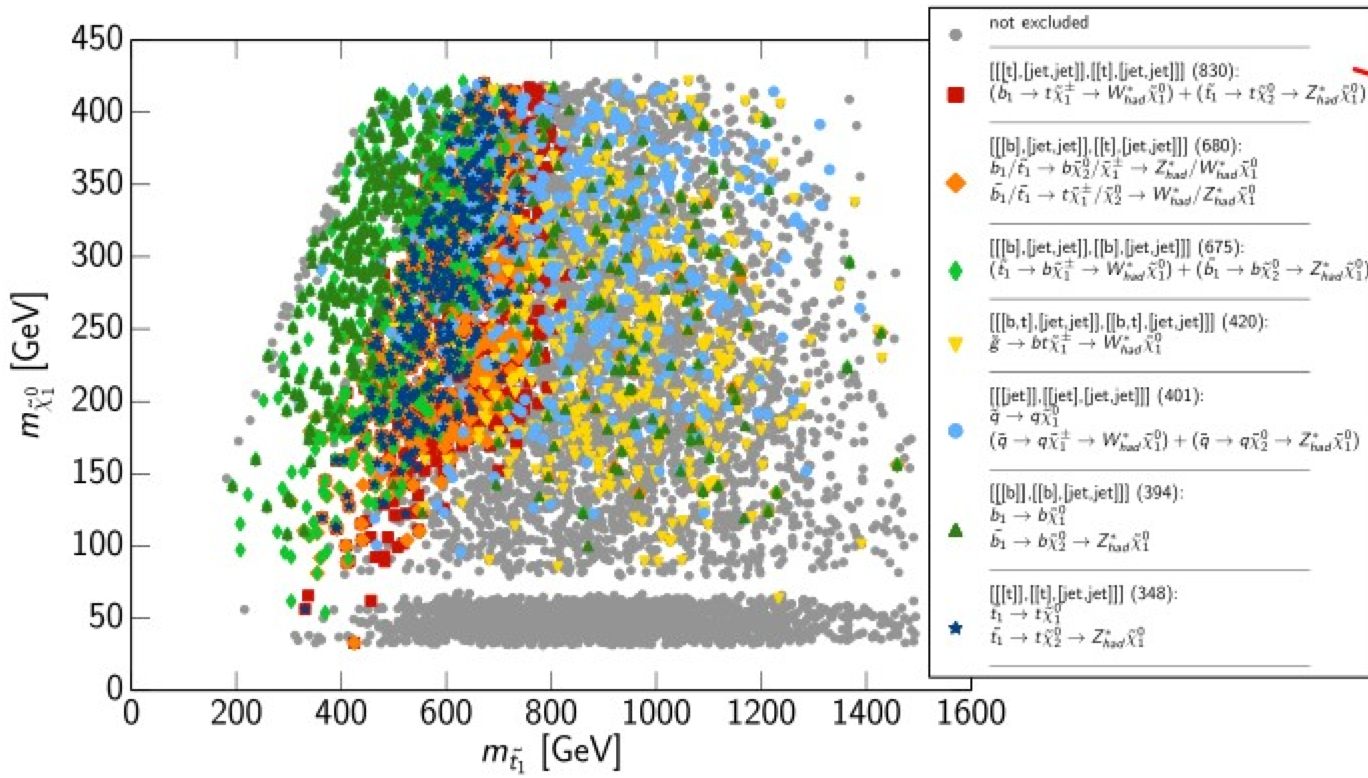




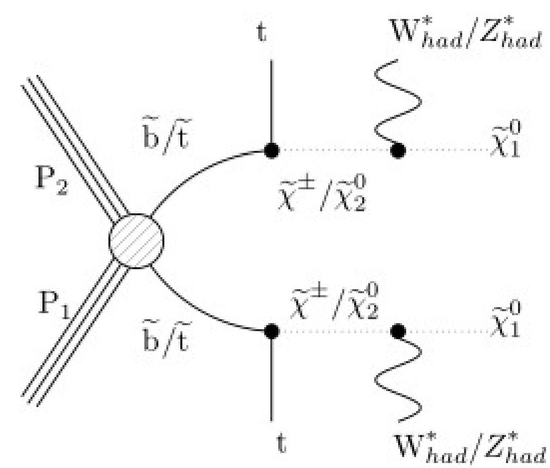
	Bino LSP	Higgsino LSP
# points tested	38,575	45,594
# points excluded by SModelS (UL)	16,957 (44%)	25,024 (55%)
# points excluded by SModelS (UL+EM)	21,151 (55%)	28,669 (63%)

[1] arXiv:1508.06608 [2] arXiv:1707.09036

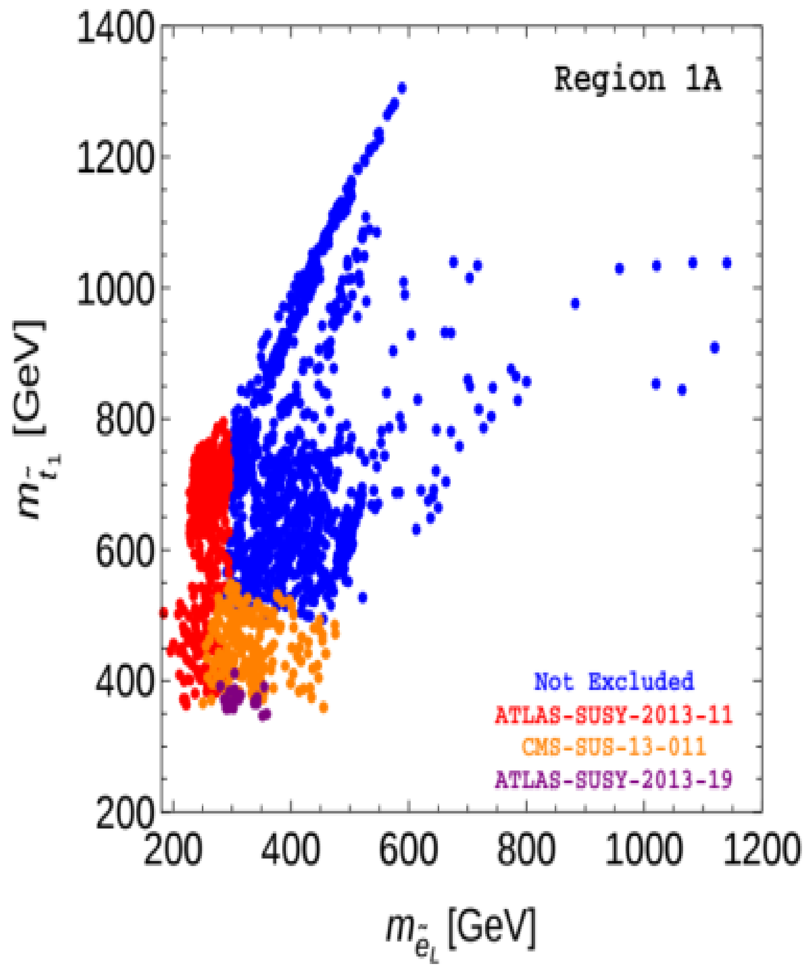
Applications: Low Fine-Tuning Scan

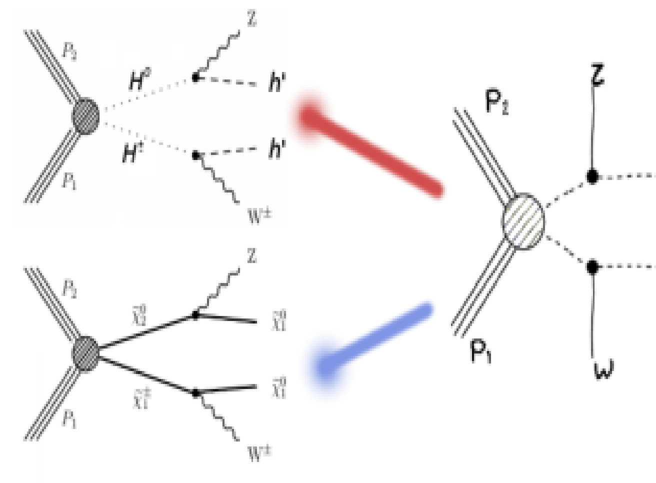


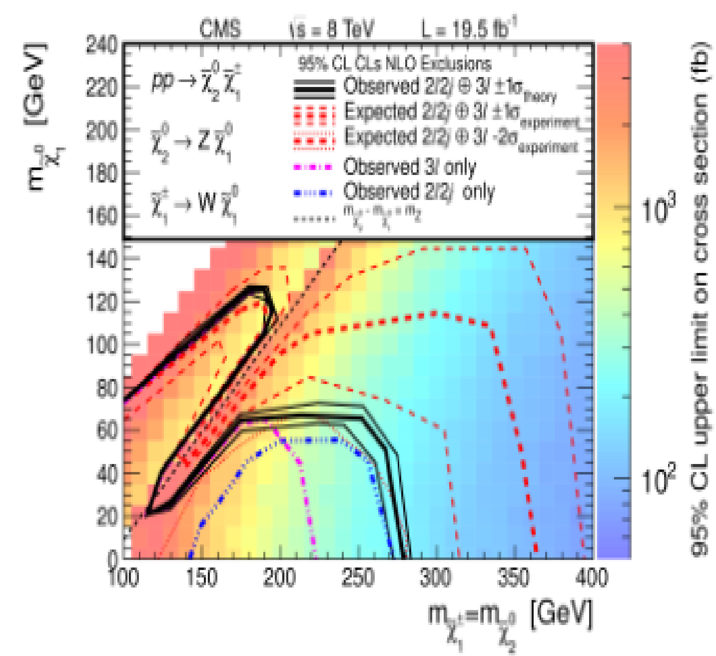
$[[[t],[jet,jet]],[[t],[jet,jet]]]$



Applications: 2HDM







D. Barducci, G. Bélanger, C. Hugonie and A. Pukhov, JHEP 1601 (2016) 050

⇒ LHC constraints on 2HDM

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) and other “exotic” signatures
- Combine signal regions with covariances (think e.g. CMS-SUS-16-050), and analyses with little to no overlap (e.g. CMS 13 TeV with ATLAS 8 TeV)
- Support for positive results
- Create mockup analyses that extrapolate to e.g. HL-LHC (is quite easy for us)

http://smodels.hephy.at
http://github.com/SModelS/smodels

pip install smodels

arXiv:1701.06586