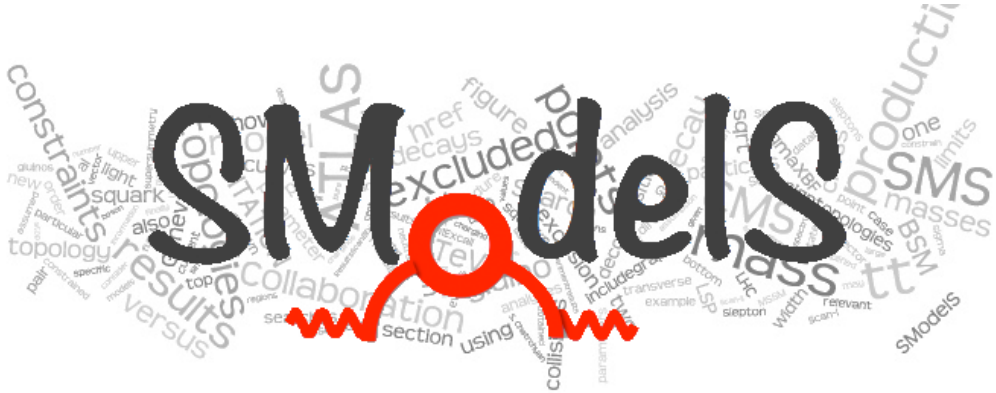

A Tool for Making Systematic Use of Simplified Models

Andre Lessa

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CENTRO DE CIÊNCIAS NATURAIS E HUMANAS
Universidade Federal do ABC

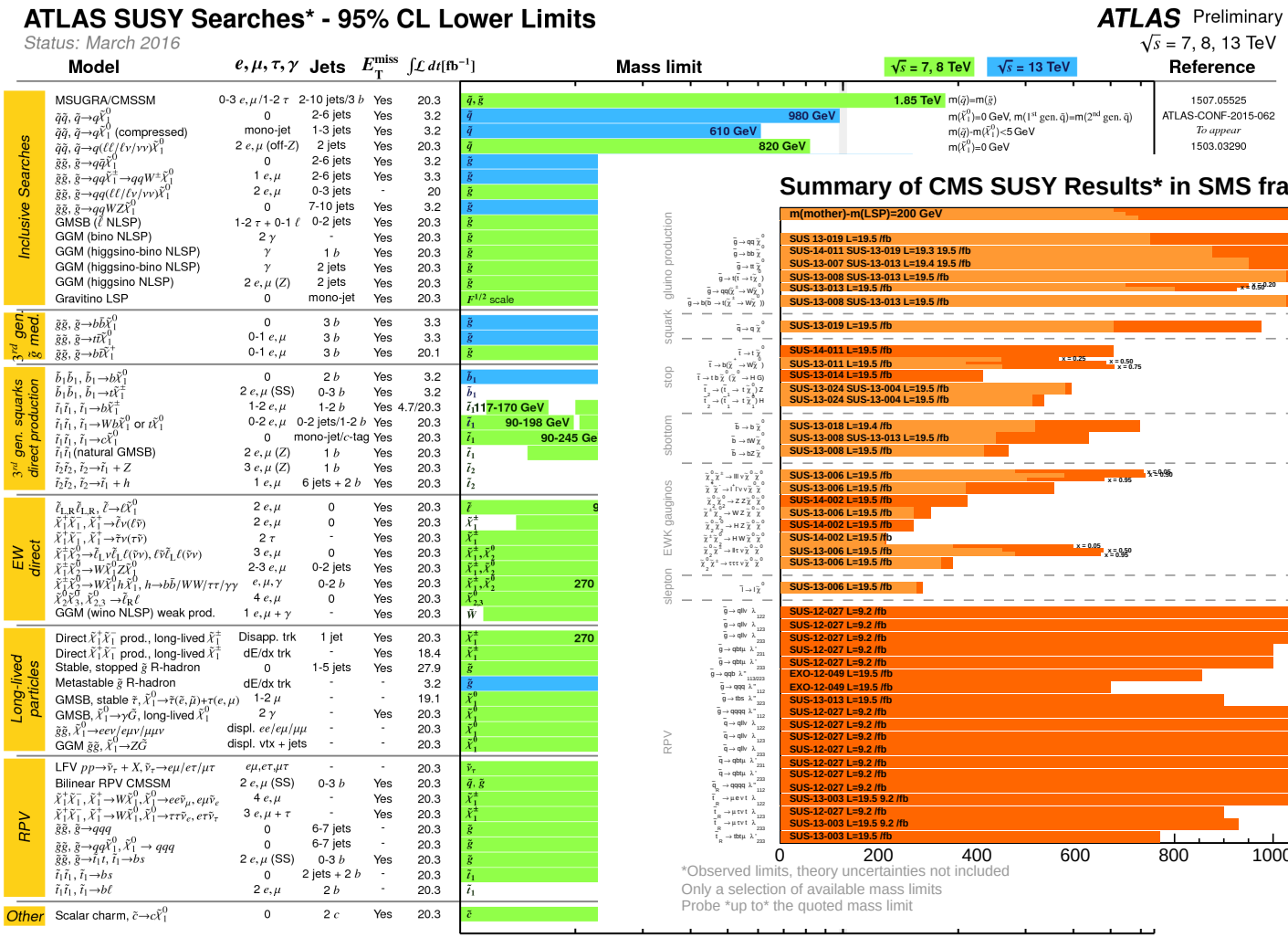
Universidade Federal do ABC

(Re)interpreting the results of new physics searches at the LHC
Cern - June 15th, 2016

*In collaboration with the SModelS group
(F. Ambrogi, S. Kraml, S. Kulkarni, U. Laa, W. Magerl, W. Waltenberger)

Simplified Models Results @ LHC

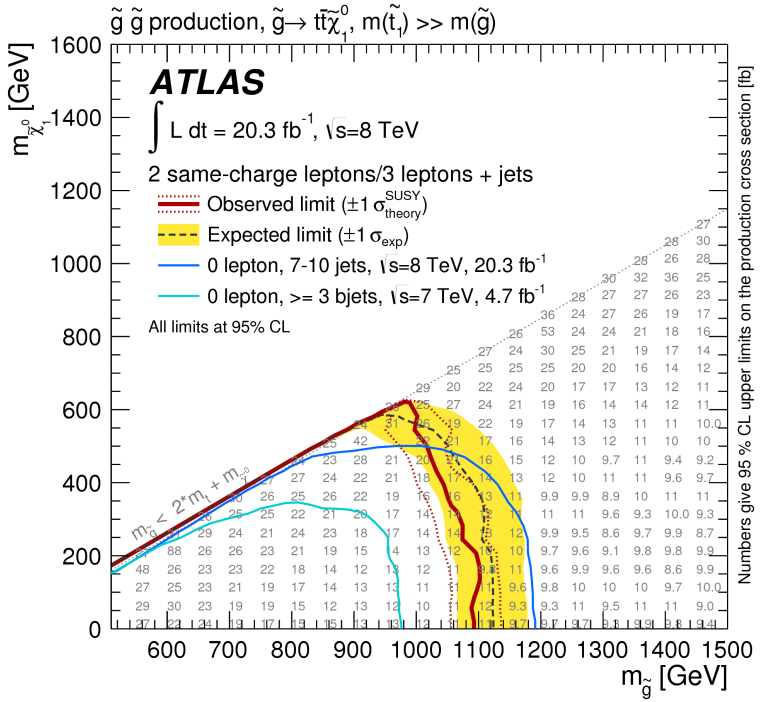
- There is a continuous effort from the experimental collaborations to present/intrepret LHC results on BSM physics in terms of Simplified Models (SMS):



Simplified Models Results @ LHC

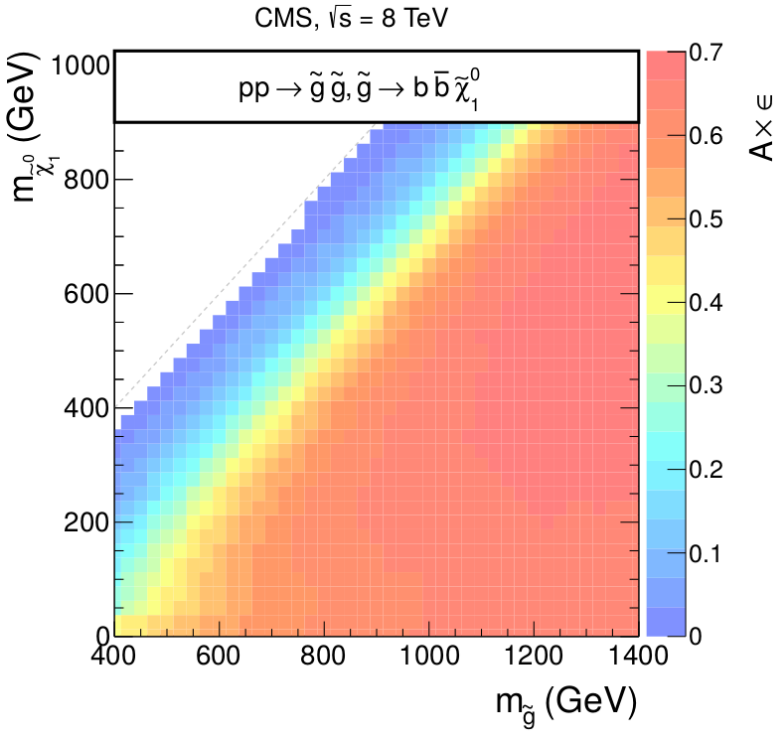
- BSM Interpretations (experimental result) are usually presented as..

Upper Limit (UL) maps:



(ATLAS SUSY-2013-09)

Efficiency maps:

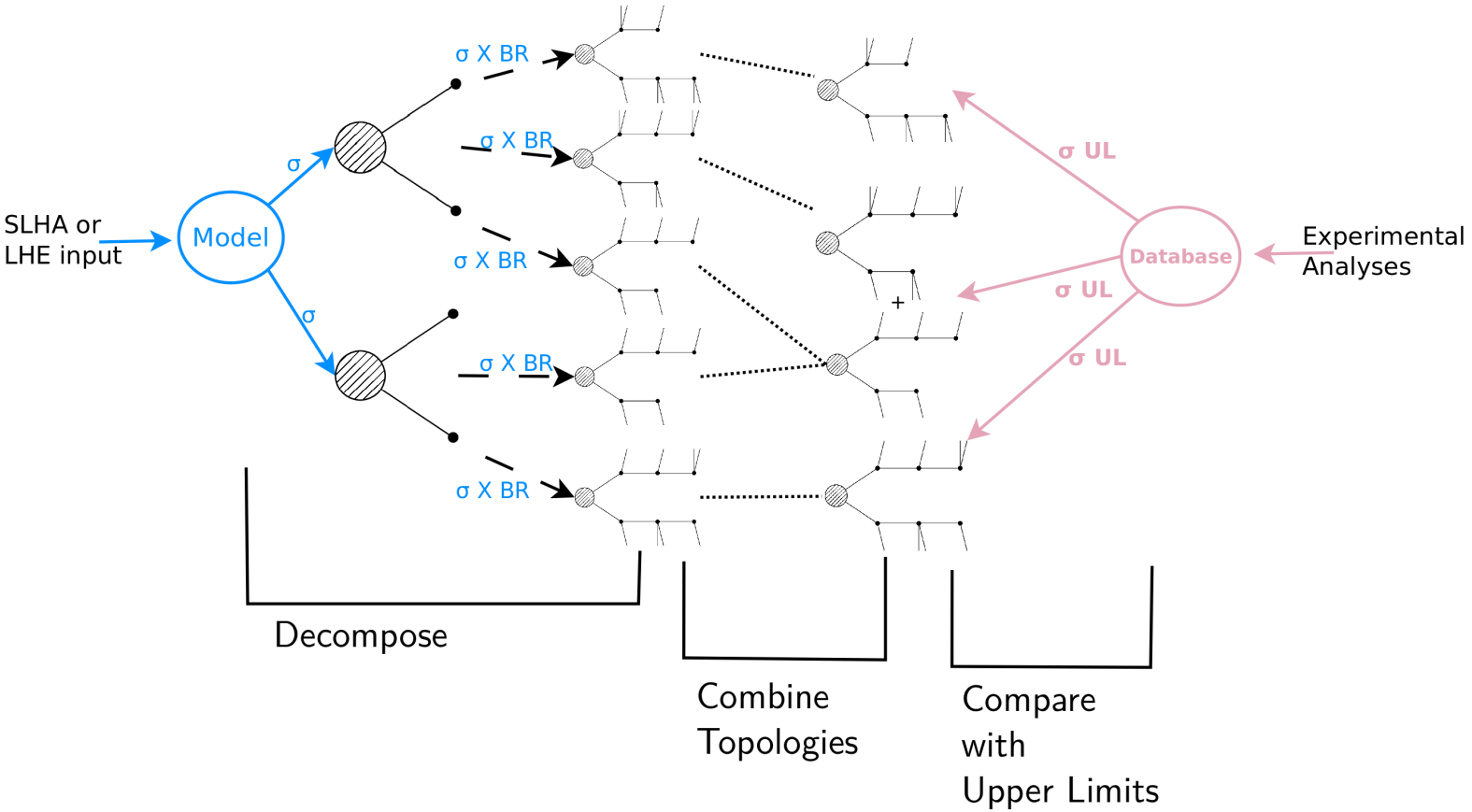


(CMS SUS-12-024)

signal region: MET2-HT1-nb3

SModelS: Overview

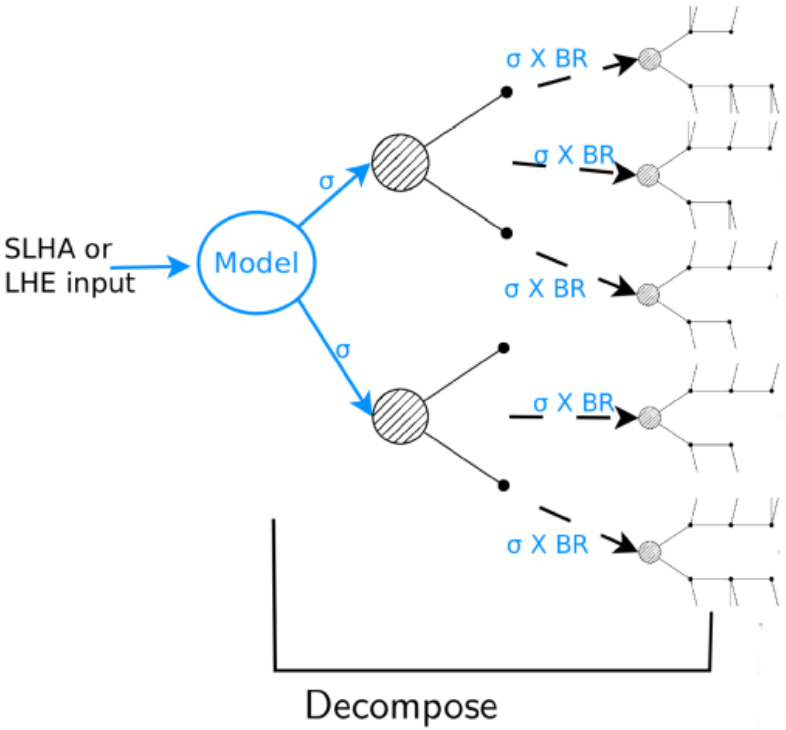
SModelS is a tool/software for applying Simplified Model results (constraints) to full BSM models



SModelS: Decomposition

How SModelS works...

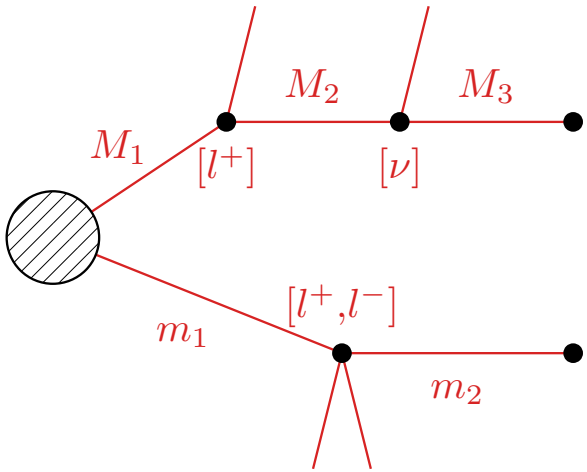
- First Step: Decomposition (Mapping)
  - Input: SLHA file (cross-sections, masses, BRs) or LHE file (parton level)



- The BSM model must have a $\mathbf{Z}_2$ symmetry (DM inspired) $\rightarrow$ R-Parity, KK-parity,...
- For now we only consider pair production of $\mathbf{Z}_2$-odd particles (no resonances,...)
- The decomposition produces a set of simplified model topologies (or elements)

SModelS: Decomposition

- Simplified Model Topology:



$= [[l^+],[\nu]]$

$= [[l^+],[\nu]]$

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

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

$= [[l^+,l^-]]$

- Each topology is described by:
  - topology shape + final states
  - BSM masses
  - Weight ($\sigma \times BR$)
- The mapping ignores spin, color, . . . of BSM states
- It is ”model independent” (no reference to original model)

SModelS: Decomposition

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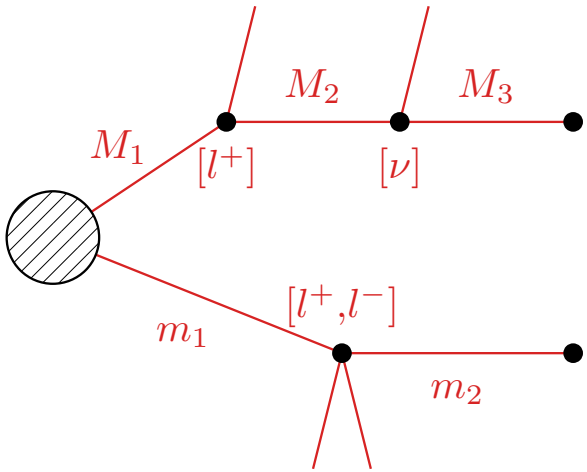

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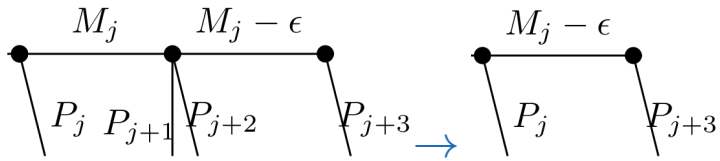
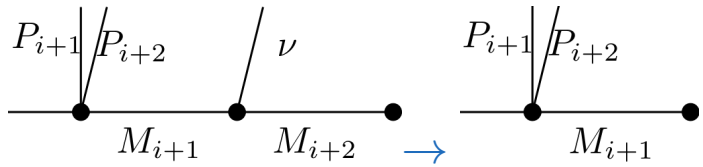
- Compressed spectra can be mapped to simpler topologies



- Invisible final states can be grouped as effective LSPs



SModelS: Theory Predictions

- Second Step: Compute Theory Predictions
  - Which experimental analyses constrain the decomposed topologies?
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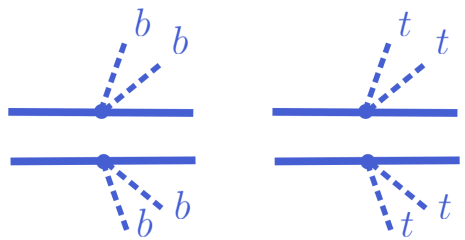
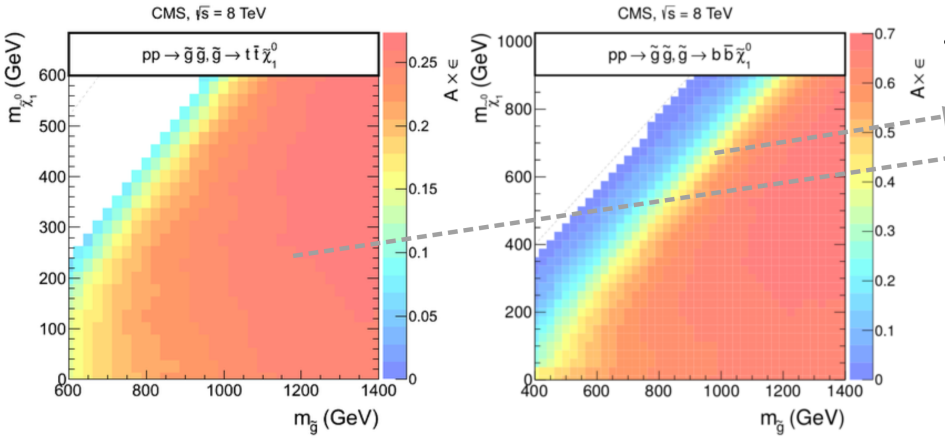
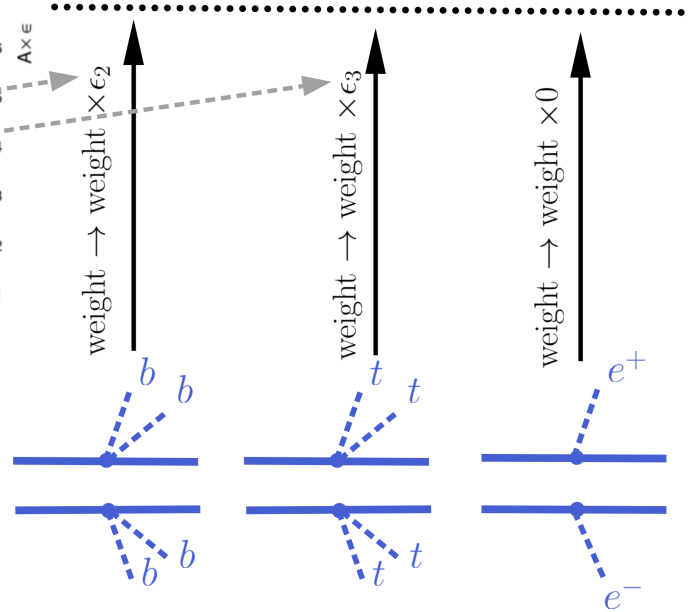
- *Efficiency Map Result:

$$\text{weight} \times \epsilon_2 + \text{weight} \times \epsilon_3 + 0 = \sigma \times BR \times \epsilon$$
$$(\textit{Theory Prediction})$$



Experimental Result (EM)





Decomposition Elements:

*Not included in the public version

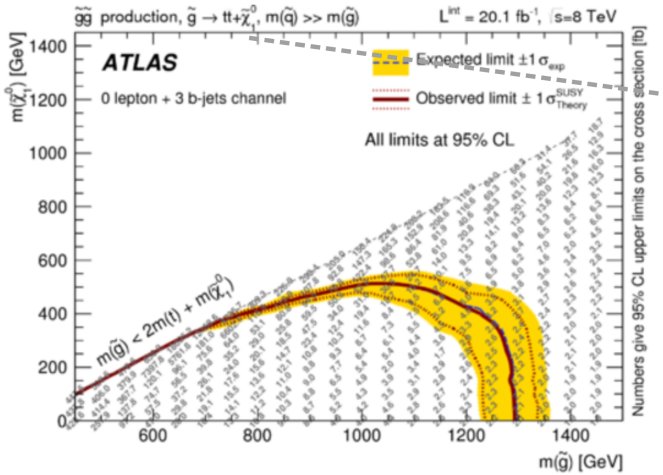
SModelS: Theory Predictions

- **Second Step: Compute Theory Predictions**
  - Which experimental analyses constrain the decomposed topologies?
  - Compute efficiencies and effective signal σ (theory prediction)

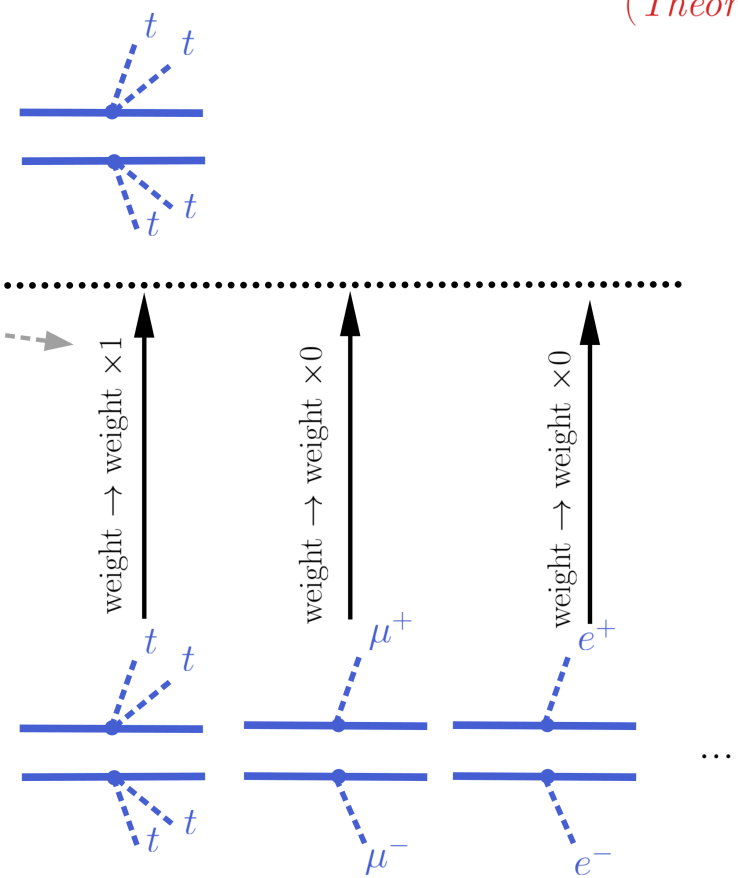
- **Upper Limit Map Result:**

$$\text{weight} + 0 + 0 = \sigma \times BR$$
$$(\textit{Theory Prediction})$$

Experimental Result (UL)

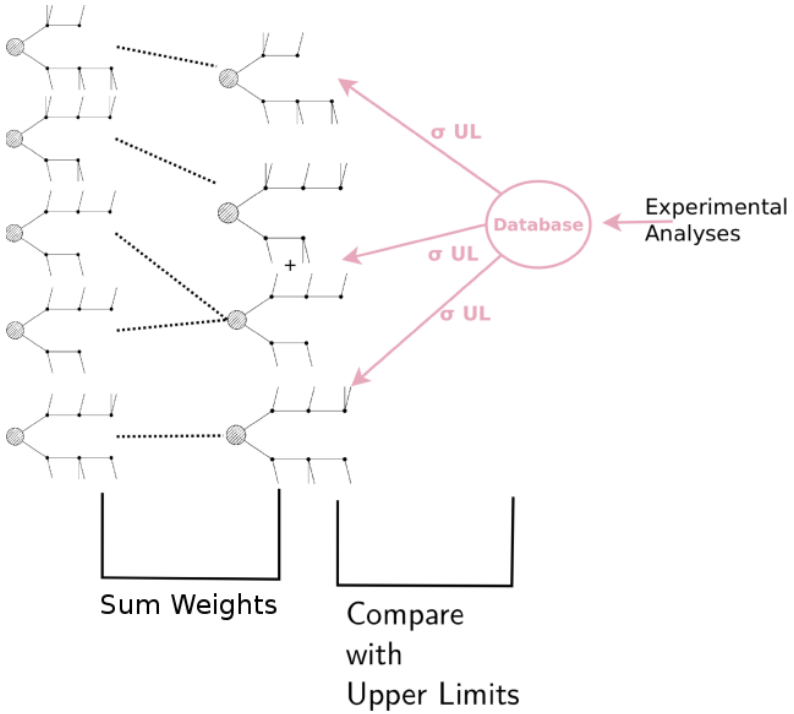


Decomposition Elements:



SModelS: Simplified Topologies vs Database

- Third (Trivial) Compare the theoretical predictions with upper limits



- Upper Limit Results:
  - Theory Prediction $= \sigma \times BR$ (single topology)
  - σ_{UL} from upper limit map
- Efficiency Map Results:
  - Theory Prediction $= \sum \sigma \times BR \times \epsilon$
  - σ_{UL} from $N_{observed}$ and $N^{BG}_{expected} \pm$ error

- $r =$ (Theory Prediction) $/\sigma_{UL}$
- The model is considered excluded if there is at least *one* analysis with $r > 1$
- For UL results constraints are conservative

SModelS: Output

./runSModelS -f <slhafile>

```
Input status: 1
Decomposition output status: 1 #decomposition was successful
# Input File: inputFiles/slha/gluino_squarks.slha
# maxcond = 0.2
# minmassgap = 5.
# sigmacut = 0.03
# Database version: 1.0.91
================================================================================
#Analysis  Sqrts  Cond. Violation  Theory_Value(fb)  Exp_limit(fb)  r

     CMS-SUS-13-019  8.00E+00    0.0  1.773E+00  3.762E+00  4.714E-01
 Signal Region:  (UL)
 Txnames:  T2
--------------------------------------------------------------------------------
 ATLAS-SUSY-2013-02  8.00E+00    0.0  6.617E+00  1.718E+01  3.851E-01
 Signal Region:  (UL)
 Txnames:  T6WW
--------------------------------------------------------------------------------
 ATLAS-SUSY-2013-02  8.00E+00    0.0  5.525E-01  1.839E+00  3.005E-01
 Signal Region:  SR2jt
 Txnames:  T1, T2
....
================================================================================
The highest r value is = 4.71E-01
================================================================================
Missing topologies with the highest cross-sections (up to 10):
Sqrts (TeV)   Weight (fb)        Element description
  8.0  5.958E+01    #                                [[[W]],[[W]]]
  8.0  1.567E+01    #                [[[jet],[W]],[[jet,jet],[W]]]
...
```

- Decomposition
- Analyses database
- Constraints
- Missing topologies
- Long cascade decays
- Asymmetric branches
- . . .

SModelS: Database

- The Database is a fundamental part of SModelS
- What is included in the SModelS **Database**?

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$\sim$ 14 publications + 16 CONF notes

Experimental Result	$\sqrt{s}$	lumi	data type
ATLAS-CONF-2012-105	8	5.8	upperLimit
ATLAS-CONF-2012-166	8	13.0	upperLimit
ATLAS-CONF-2013-001	8	12.8	upperLimit
ATLAS-CONF-2013-007	8	20.7	upperLimit
...	...	...	...
ATLAS-SUSY-2013-14	8	20.3	upperLimit
ATLAS-SUSY-2013-15	8	20.3	efficiencyMap
ATLAS-SUSY-2013-15	8	20.3	upperLimit
ATLAS-SUSY-2013-16	8	20.1	efficiencyMap
ATLAS-SUSY-2013-16	8	20.1	upperLimit
ATLAS-SUSY-2013-18	8	20.1	efficiencyMap
ATLAS-SUSY-2013-18	8	20.1	upperLimit
ATLAS-SUSY-2013-19	8	20.3	upperLimit
ATLAS-SUSY-2013-23	8	20.3	upperLimit
ATLAS-SUSY-2014-03	8	20.3	efficiencyMap
ATLAS-SUSY-2015-09	13	3.2	upperLimit

$\sim$ 13 publications + 5 PAS

Experimental Result	$\sqrt{s}$	lumi	data type
CMS-SUS-12-024	8	19.4	efficiencyMap
CMS-SUS-12-024	8	19.4	upperLimit
CMS-SUS-12-028	8	11.7	upperLimit
CMS-SUS-13-002	8	19.5	upperLimit
CMS-SUS-13-004	8	19.3	upperLimit
CMS-SUS-13-006	8	19.5	upperLimit
CMS-SUS-13-007	8	19.3	efficiencyMap
CMS-SUS-13-007	8	19.3	upperLimit
CMS-SUS-13-011	8	19.5	efficiencyMap
CMS-SUS-13-011	8	19.5	upperLimit
CMS-SUS-13-012	8	19.5	efficiencyMap
CMS-SUS-13-012	8	19.5	upperLimit
CMS-SUS-13-015	8	19.4	efficiencyMap
CMS-SUS-13-015	8	19.4	upperLimit
CMS-SUS-13-019	8	19.5	upperLimit
...	...	...	...
CMS-SUS-PAS-13-016	8	19.7	upperLimit
CMS-SUS-PAS-13-018	8	19.4	upperLimit
CMS-SUS-PAS-15-002	13	2.2	upperLimit

SModelS: Additional Tools

- Cross-section calculator:
  - for MSSM and SLHA input only
  - NNLO for strong cross-sections (NLLfast)
  - LO for weak cross-sections (Pythia 6)
  - writes the Les-Houches XSECTION block (pyslha-compatible)

`runTools.py xseccomputer -f <slhafile> -s <SQRTS> -e <NEVENTS>`

```
XSECTION  8.00E+03  2212 2212 2 1000021 1000037   # Nevts: 10000 xsec unit: pb
  0  0  0  0  0  0    4.00683855E-05 SModelS 0.99

XSECTION  8.00E+03  2212 2212 2 1000001 1000003   # Nevts: 10000 xsec unit: pb
  0  2  0  0  0  0    2.49305494E-04 SModelS 0.99

XSECTION  8.00E+03  2212 2212 2 -1000002 2000002   # Nevts: 10000 xsec unit: pb
  0  2  0  0  0  0    1.16052469E-03 SModelS 0.99
 ....
```

- Input file checks
  - for SLHA and LHE formats

SModelS: Additional Tools

- Database browser:
  - Easy to extract general info and upper limits,. . .
  - Example:

SModelS: Additional Tools

- **Database browser:**
  - Easy to extract general info and upper limits,...
  - Example:

```
In [2]: import sys
        sys.path.append('/home/lessa/smodels')
        from smodels.tools import databaseBrowser
        from smodels.tools.physicsUnits import GeV
        browser = databaseBrowser.Browser('/home/lessa/smodels-database')
In [3]: print browser.getValuesFor(attribute='dataType')

['efficiencyMap', 'upperLimit']

In [7]: browser.selectExpResultsWith(txName = 'TSlepSlep')
        print len(browser),'results constrain slepton pair production\n'
        for exp in browser:
            print exp.getValuesFor('id'),exp.getValuesFor('dataType')

5 results constrain slepton pair production

['ATLAS-CONF-2013-049'] ['upperLimit']
['ATLAS-SUSY-2013-11'] ['upperLimit']
['ATLAS-SUSY-2013-11'] ['efficiencyMap']
['CMS-SUS-13-006'] ['upperLimit']
['CMS-SUS-PAS-12-022'] ['upperLimit']

In [6]: mslep = 300.*GeV
        mlsp = 100.*GeV
        print 'UL=',browser.getULFor(expid='ATLAS-SUSY-2013-11', txname='TSlepSlep',
                                     massarray = [[mslep,mlsp],[mslep,mlsp]])

UL= 2.49E-03 [pb]
```

SModelS: Validation

- How do we know it works?
  - Input $\rightarrow$ Simplified Model
  - Obtain excluded region
  - Compare with official (experimental) exclusion curve

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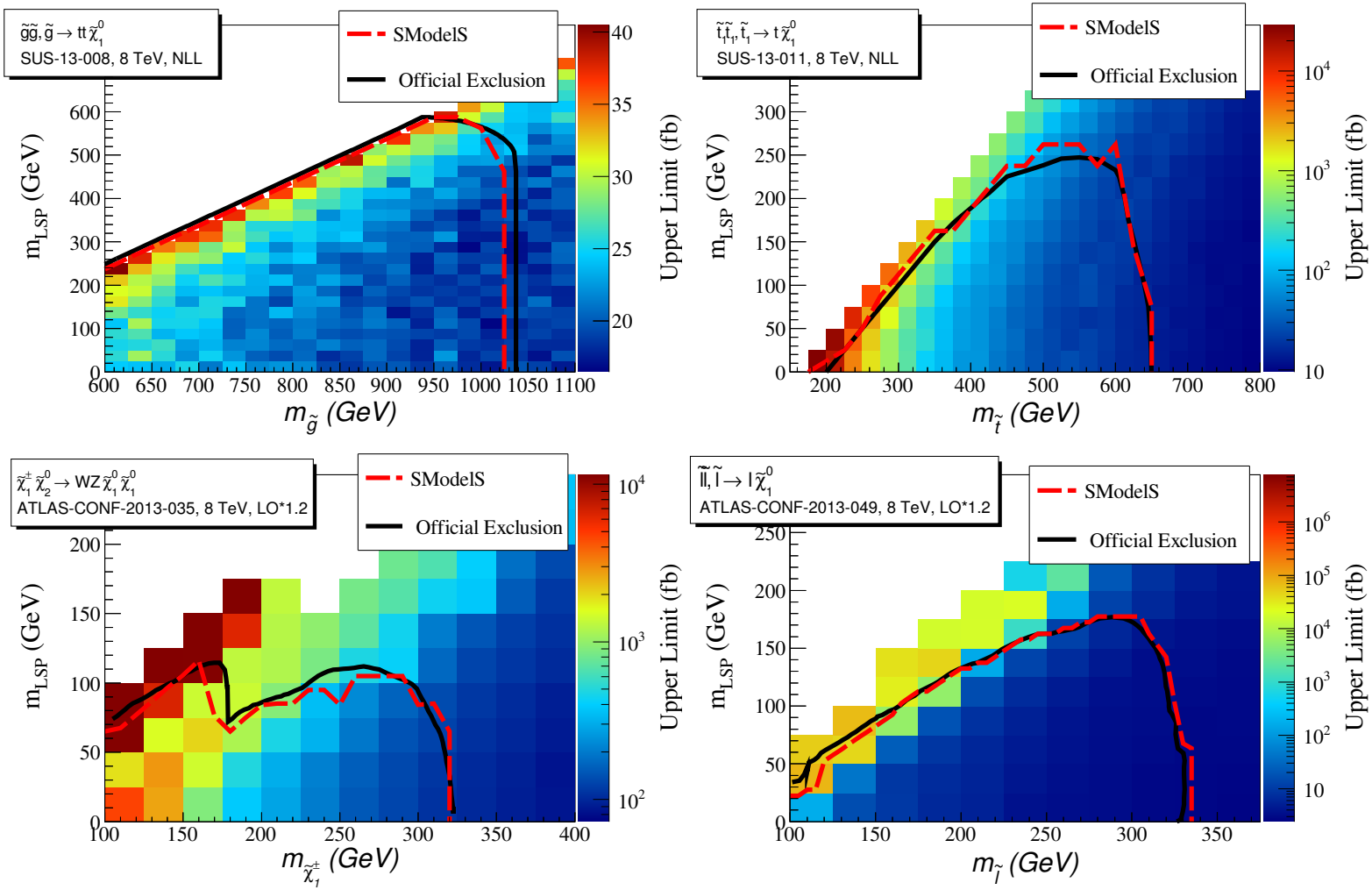
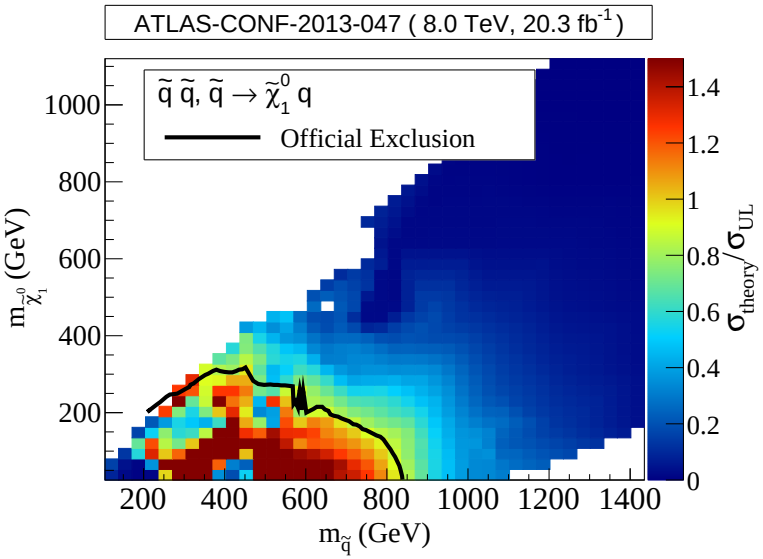
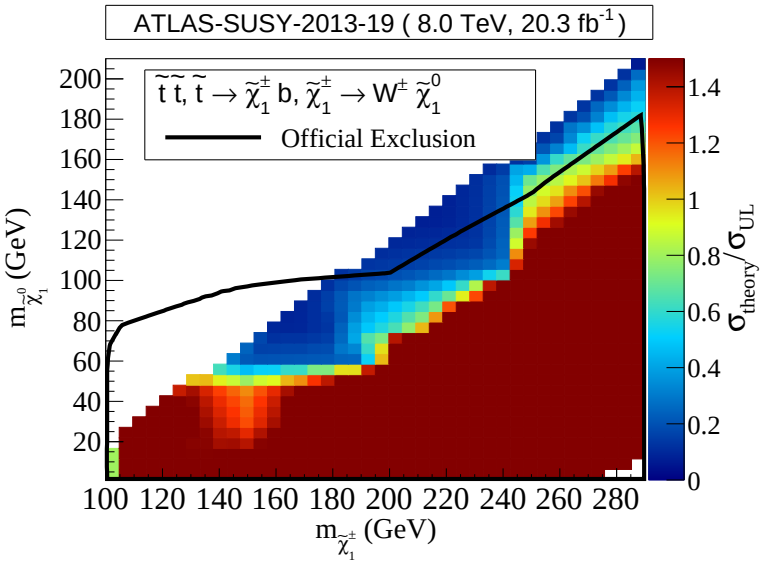


SModelS: Validation

- Validation fails for some results:
  - Poor data grid
  - Inconsistent grid values
  - ??





→ SModelS does not use non-validated results

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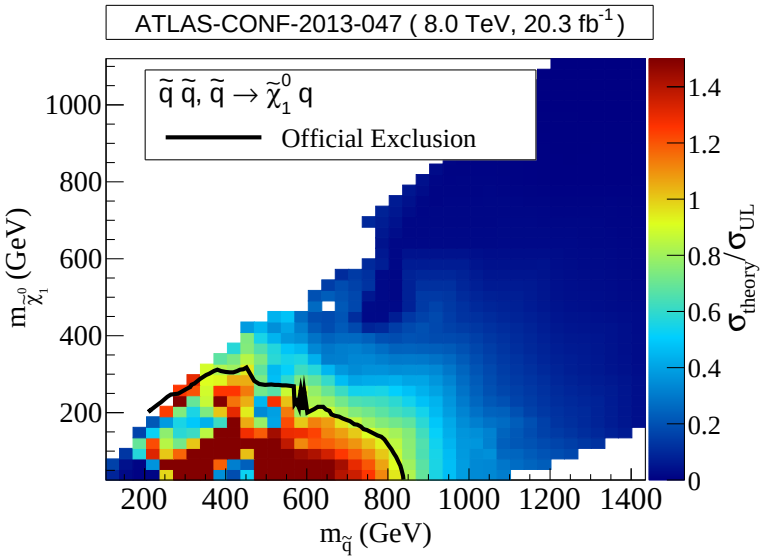

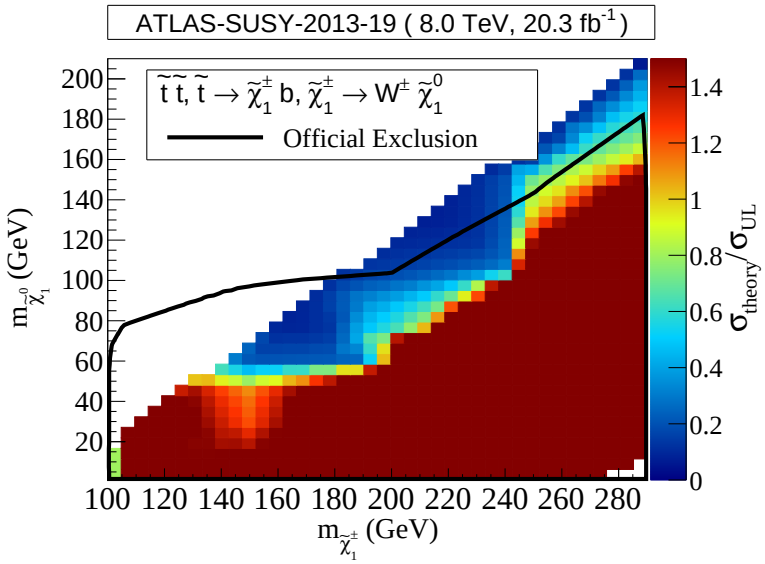

→ *SModelS does not use non-validated results*

- Other data-related issues:
  - Insufficient data for interpolation
  - Digitized data not available
  - ...

→ *See discussion session on Thursday*

SModelS: Physics Results

What can SModelS provide physics-wise? (*See U. Laa Talk on Friday)*

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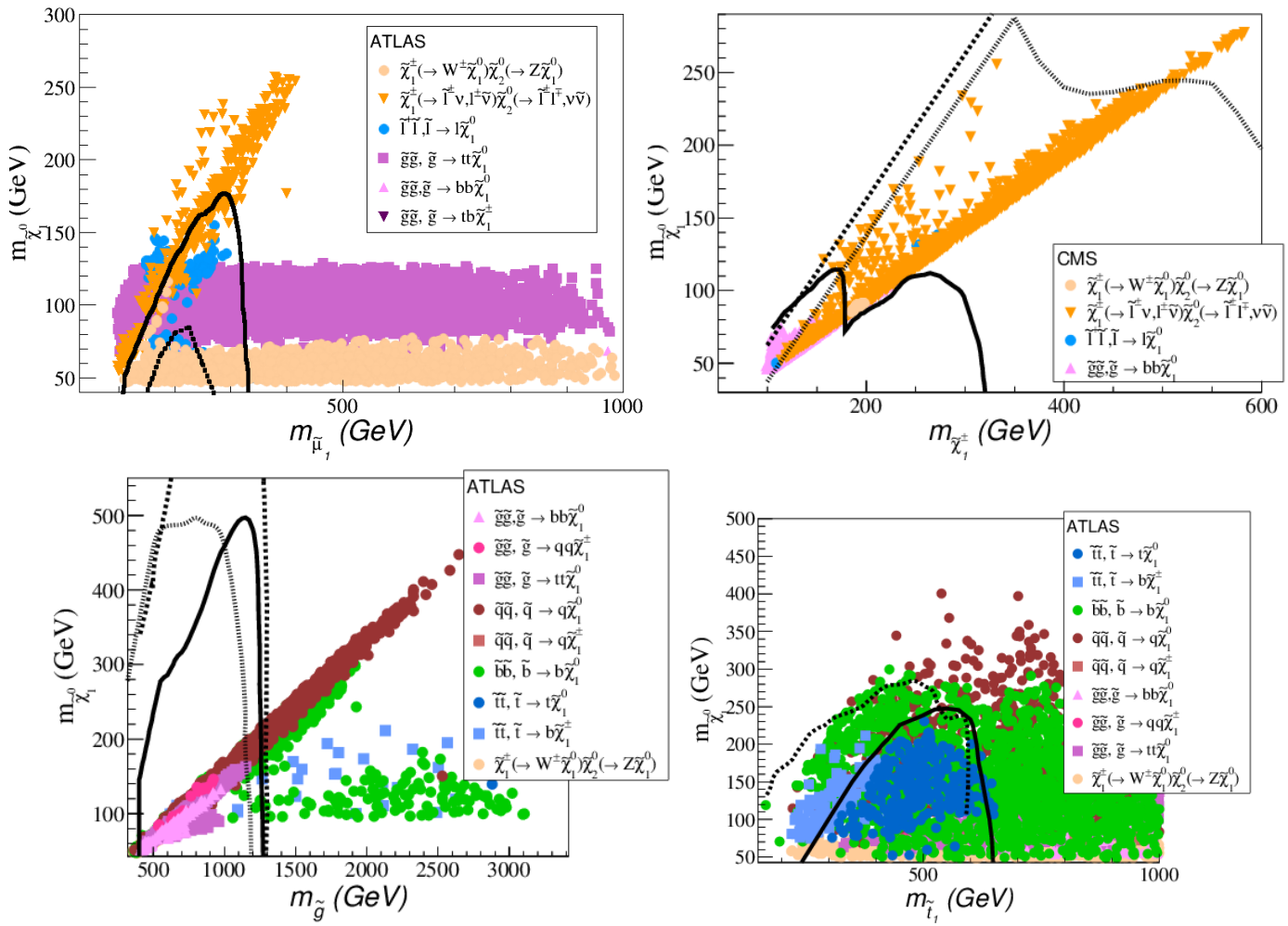
What can SModelS provide physics-wise? *(See U. Laa Talk on Friday)*

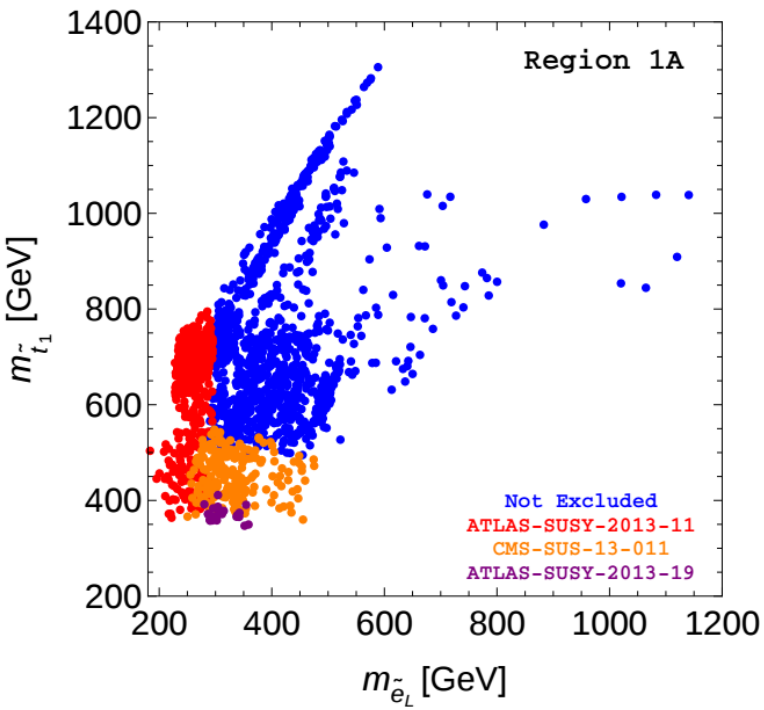
- It can identify the most constraining analysis in each region of parameter space
- Helps choosing which analyses to implement for Top-Down simulations



SModelS: Physics Results

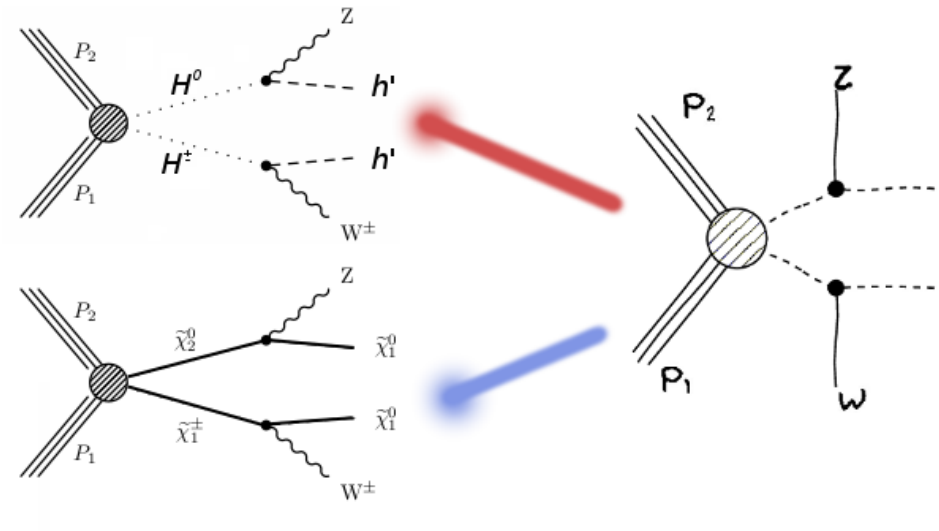
- It can be used to recast results:
  - Application to NMSSM, $\tilde{\nu}-$MSSM,. . .
  - Application to non-SUSY models (IDM)

- NMSSM constraints:



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

- 2HDM/IDM constraints:



N. Fonseca, R. Funchal, AL and L. Lopez-Honorez, JHEP 1506 (2015) 154

Conclusions

- *SModelS:* *fast python-based tool for confronting "generic" BSM models with the SMS constraints*
  - can identify the most constraining analyses
  - and the topologies "missed" by the experimentalists,
  - provides an "outsider's look" at the experimental interpration results
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  - Speed improvement
  - Inclusion of new experimental results
  - Additional tools: xml printer, database browser
  - . . .

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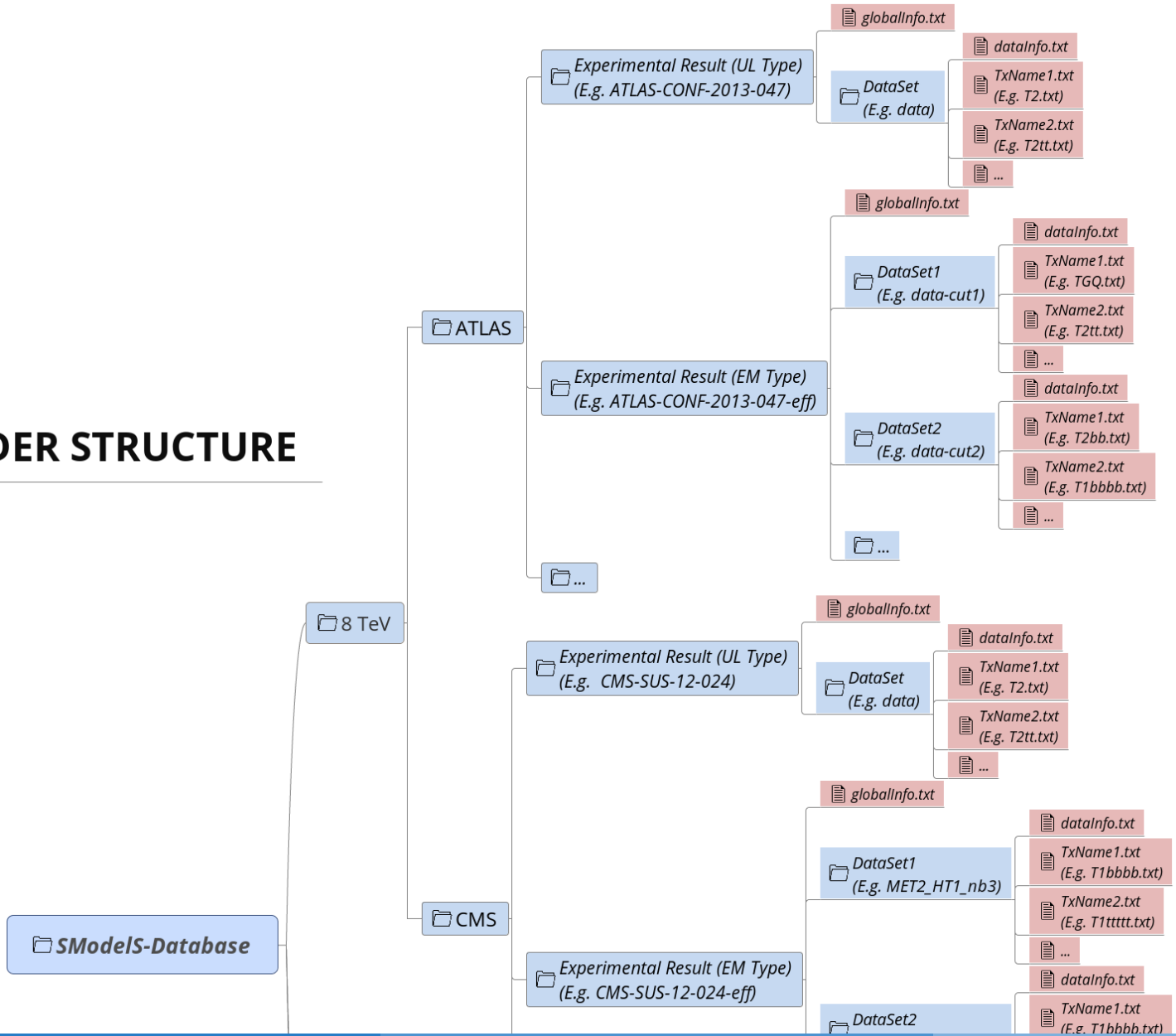
More info: http://smodels.hephy.at/

Thanks!

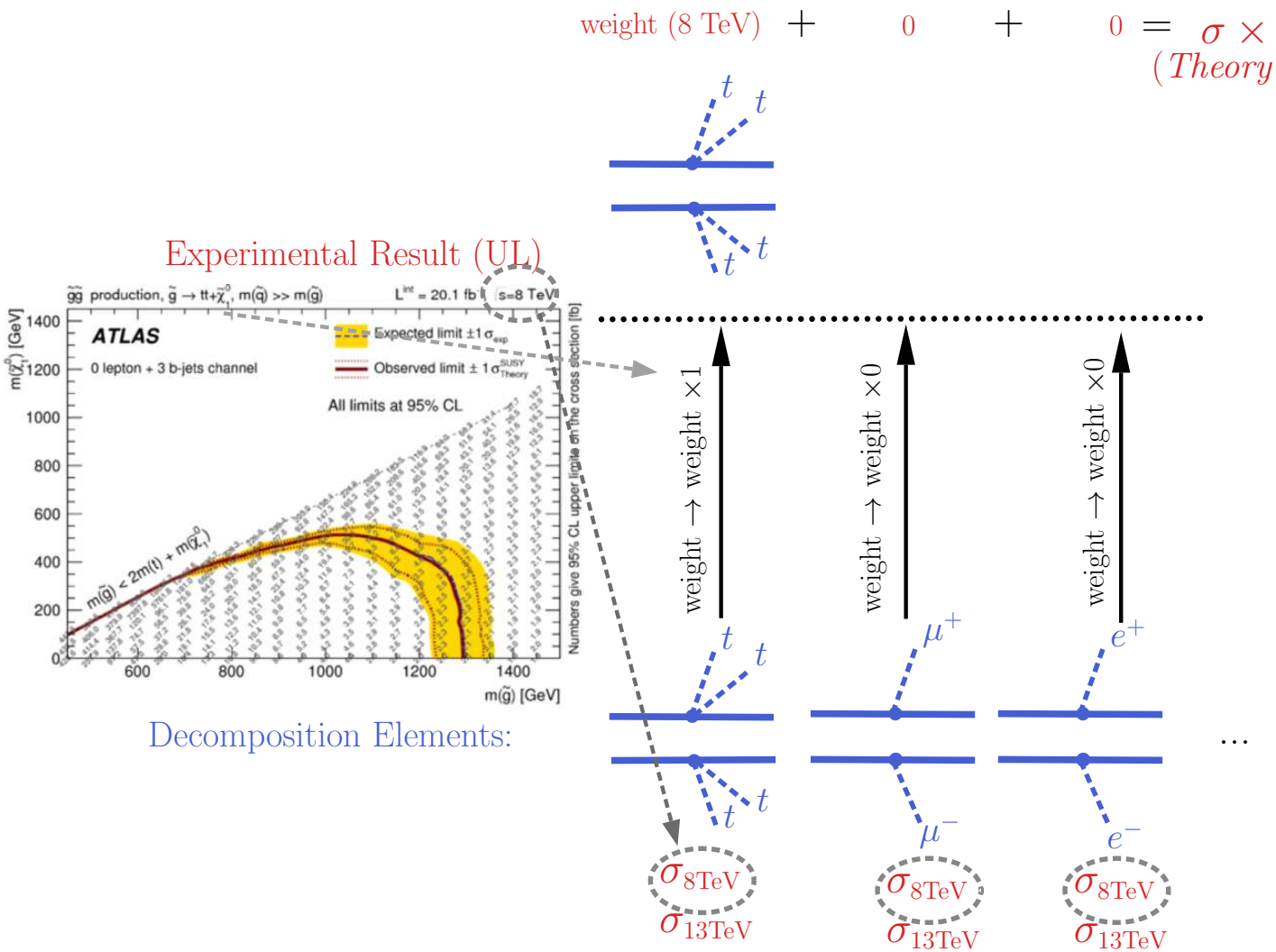
Backup: Database

FOLDER STRUCTURE



Backup: 13 TeV Results

- How smodels handle 8 TeV and 13 TeV constraints:



*as long as both cross-sections are provided

Backup: Database Browser (GUI)