– a Tool for Making Systematic Use of Simplified Models

Results

Wolfgang Waltenberger
HEPHY Vienna

In collaboration with the SModelS group

LHCP 2016
Lund, Sweden, 13 – 18 June 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
Searching for Physics Beyond the Standard Model

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

### ATLAS SUSY Searches - 95% CL Lower Limits

<table>
<thead>
<tr>
<th>Model</th>
<th>E_\text{T} \geq 750 GeV</th>
<th>\sqrt{s} = 7, 8, 13 TeV</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEWSSM</td>
<td>90-410 GeV</td>
<td>1.38 TeV</td>
</tr>
<tr>
<td>DCM</td>
<td>90-410 GeV</td>
<td>1.38 TeV</td>
</tr>
<tr>
<td>EWK</td>
<td>90-410 GeV</td>
<td>1.38 TeV</td>
</tr>
<tr>
<td>Heavy Higgs</td>
<td>90-410 GeV</td>
<td>1.38 TeV</td>
</tr>
<tr>
<td>Higgs boson</td>
<td>90-410 GeV</td>
<td>1.38 TeV</td>
</tr>
<tr>
<td>GMSB</td>
<td>90-410 GeV</td>
<td>1.38 TeV</td>
</tr>
<tr>
<td>DM</td>
<td>90-410 GeV</td>
<td>1.38 TeV</td>
</tr>
</tbody>
</table>

### ATLAS Preliminary

\[ \sqrt{s} = 7, 8, 13 \text{ TeV} \]

- **ATLAS SUSY Searches - 95% CL Lower Limits**
  - MEWSSM: \( 90-410 \text{ GeV} \)
  - DCM: \( 90-410 \text{ GeV} \)
  - EWK: \( 90-410 \text{ GeV} \)
  - Heavy Higgs: \( 90-410 \text{ GeV} \)
  - Higgs boson: \( 90-410 \text{ GeV} \)
  - GMSB: \( 90-410 \text{ GeV} \)
  - DM: \( 90-410 \text{ GeV} \)

- **Summary**
  - ATLAS 7 + 8 + 13 TeV SUSY March 2016 (incomplete!)
Searching for Physics Beyond the Standard Model

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

[Graph and table showing search results for SUSY particles in CMS and ATLAS at 13 TeV]
Searching for Physics Beyond the Standard Model

Yes, in addition to all the null results we see mild excesses e.g. in the 750 GeV di-photons:

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Spin-0</th>
<th>Spin-2</th>
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</thead>
<tbody>
<tr>
<td>Target</td>
<td>Extended Higgs sector</td>
<td>KK-graviton</td>
</tr>
<tr>
<td>Selection</td>
<td>2 isolated-γ's: $E_T/m_γ &gt; 0.3, 0.4$</td>
<td>2 isolated-γ's: $E_T(γ_1, 2) &gt; 55, 55$ GeV</td>
</tr>
</tbody>
</table>

Using 3.2 fb$^{-1}$ of $\sqrt{s} = 13$ TeV data collected in 2015

Taken from Thorsten Wengler (monday plenary)
Null results for BSM searches are typically presented as:

Upper Limit (UL) maps:

Efficiency maps:

(ATLAS SUSY-2013-09)

(CMS SUS-12-024)
SM
dels

– a tool for making systematic use of simplified models null results

SLHA file + cross-section calculator

Model

Decompose

Combine Topologies

Compare with Upper Limits

Database

Experimental Analyses
How \textit{SM\textsubscript{odelS}} works:

1) Decomposition of a fundamental model

Input: SLHA file (mass spectrum, BRs) or LHE file (parton level)

Currently the model must have a \( \mathbb{Z}_2 \) symmetry.

The decomposition produces a set of simplified model topologies (dubbed “elements”)
How works:

Simplified Model Topology:

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

We (currently) ignore spin, color, etc of the BSM particles

It is model independent, there is no reference to the original model
How \textit{SMoDelS} works:

Simplified Model Topology:

\begin{align*}
  M_1 & \quad [l^+] \\
  M_2 & \quad [\nu] \\
  M_3 & \quad = [[[l^+],[\nu]]] \\
  m_1 & \quad [l^+, l^-] \\
  m_2 & \quad = [[[l^+], [\nu]], [[[l^+], [l^-]]]] \\
  & \quad = [[M_1, M_2, M_3], [m_1, m_2]]
\end{align*}

Soft particles are ommitted:

Invisible final states are grouped into effective LSPs:
How SModels works:

2) Computation of predicted signal strength:

For **efficiency map results** we have signal efficiencies for various “elements”, and we can add them together:

\[
\text{weight} \times \epsilon_2 + \text{weight} \times \epsilon_3 + 0 = \sigma \times BR \times \epsilon
\]

(Theory Prediction)

---

**Experimental Result (EM)**

**Decomposition Elements:**
How SModelS works:

2) Computation of predicted signal strength:

Upper limit results we cannot add up:
How SM delS works:

3) Comparison of predicted signal strengths with experimental result:

- **Upper Limit Results:**
  Predicted signal strength = $\sigma \times \text{BR}$
  Experimental result: $\sigma_{UL}$

- **Efficiency Map Results:**
  Predicted signal strength = $\sum \sigma \times \text{BR} \times \varepsilon$
  Experimental result: $\sigma_{UL} = \frac{N_{UL}}{L}$ from $N_{\text{observed}}$, expected(BG), error(BG)

- $r = \frac{\text{predicted}}{\sigma_{UL}}$

- Model is excluded if most constraining analysis has $r > 1$
How SMoDelS works:

SLHA file + cross-section calculator → Model → Decompose Topologies

Model → σ X BR → σ X BR

σ UL → Database → Experimental Analyses

Combine Topologies

Compare with Upper Limits
What's in the database?

~ 30 ATLAS CONF-Notes/publications

<table>
<thead>
<tr>
<th>Experimental Result</th>
<th>$\sqrt{s}$</th>
<th>lumi</th>
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~ 20 CMS CONF-Notes/publications

<table>
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</tbody>
</table>

We can and will (and do) extend our database by using efficiency maps produced outside the experimental collaborations (using recasting tools like MadAnalysis5)
Validation

For validating our database, we define:
full model := simplified model

And check if we can reproduce the official exclusion curves. When we have efficiencies, we can also check $\sigma_{UL}$ for every point in the “mass planes”: 
Physics Applications

SModelS has so far been used to:

- quickly identify regions of model parameter space that can easily be excluded by analyses, before employing more “heavy weight” strategies for exploring model parameter spaces.

- identify the most constraining analyses for a model

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

- Very quickly recast results to different models
Physics Applications

Graphs showing the relationship between various particle masses and decay channels for ATLAS and CMS experiments.
Physics Applications

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

⇒ LHC constraints on 2HDM
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 likelihoods
- Make use of positive results ("excesses")
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
- Recast results to different scenarios
- Since it does not have to run simulations, it is very fast

Limitations:

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