# New physics constraints in SModelS

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# Overview

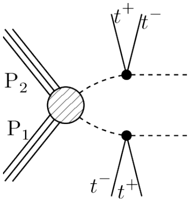
# Re-interpretation of LHC data

# Introduction

- The Standard Model (SM) is successful theory that explains many phenomena but falls short when explaining: Hierarchy Problem, Dark matter, Neutrino masses ...
- Many Beyond Standard Model (BSM) models have been proposed to resolve the SM's shortcomings.
- The LHC is presently engaged in searches for New Physics in different channels. Experimental analyses give limits in terms of specific (often simplified) models.
- Re-interpretation of LHC results proceeds to generalize these results to be tested against a larger number of models.

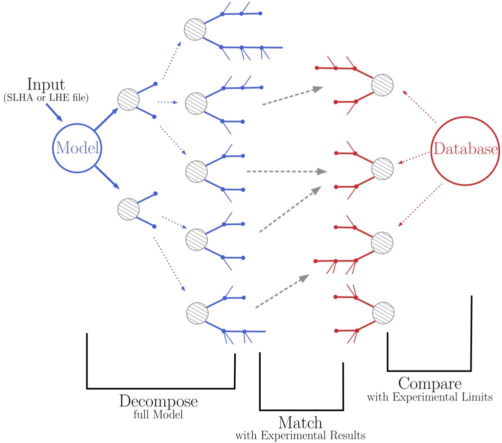
# Simplified Model Spectrum (SMS)

- The SMS is an effective-Lagrangian approach that considers only 2-3 new particles at a time.
- While still model-dependent, simplified models help reduce model dependency.




$$T1tttt \longrightarrow \tilde{g}\tilde{g}, \tilde{g} \longrightarrow tt\tilde{\chi}_1^0$$

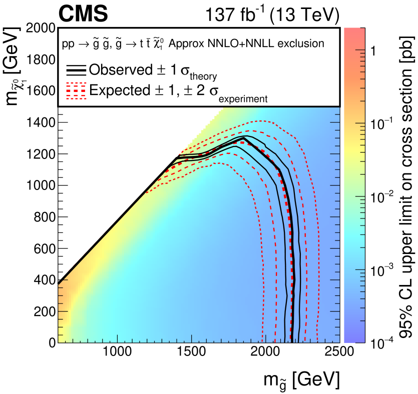
# SModelS

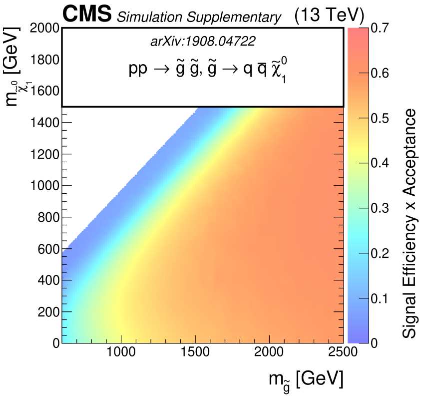



Schematic view of the working principle of SModelS. **https://smodels.github.io/**

- It decomposes BSM signatures into SMS topologies.
- Compare it to SMS topologies of experimental results.
- SModelS also provides upper limits corresponding to the cross-section and other features...

# SModelS and SMS




Upper limit maps

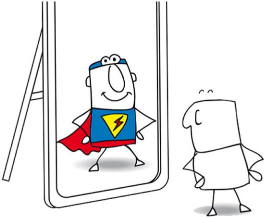
Efficiency maps

These maps are provided by ATLAS and CMS. **1908.04722**
They're used to define the database in SModelS.

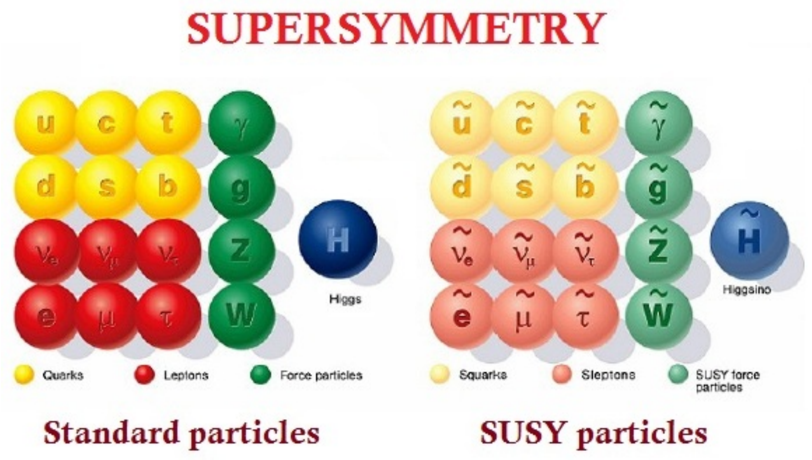
# Supersymmetry

# Motivation for SUSY

- Supersymmetry (SUSY) is one of the many Beyond Standard Model theories.
- It extends the SM by adding a new symmetry between fermions and bosons resolving some of the SM problems.
- Some CMS and ATLAS experiments are dedicated to search for Supersymmetric signals.
- They interpret their results and publish them. At the same time, providing the public information needed for re-interpretation.



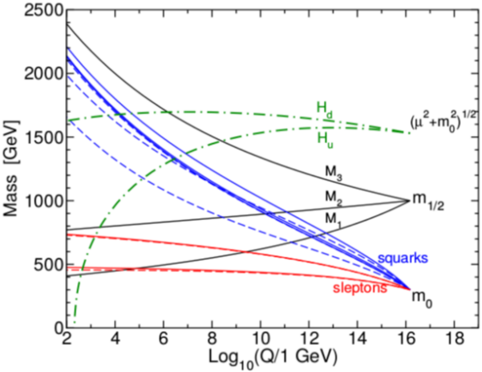
# Minimal Supersymmetric Standard Model (MSSM)



# Constrained MSSM: CMSSM

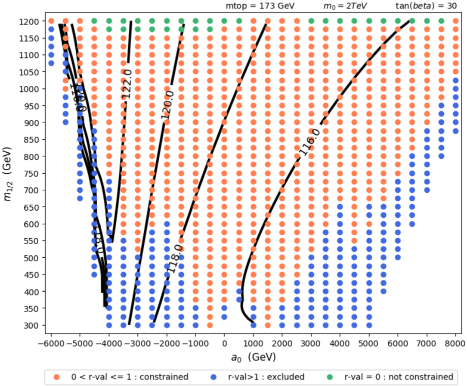
- One of the most commonly studied variants of the MSSM.
- At the GUT scale 3 parameters are unified: scalar $m_0$ and gaugino $m_{1/2}$ masses and the trilinear couplings $a_0$.
- This reduces the number of parameter from 120 to 5.

S.Martin hep-ph/9709356




Evolution of scalar and gaugino masses in the CMSSM.

# CMSSM : $m_0 = 2$ TeV




Exclusion plot for $m_t = 173$GeV

- Blank region for large $|a_0|$: the stop $\tilde{t}$ or the stau $\tilde{\tau}$ is a tachyon particle.
- Blank region for small $|a_0|$: $\mu^2 \leq 0$ implying that electroweak symmetry is not broken successfully.

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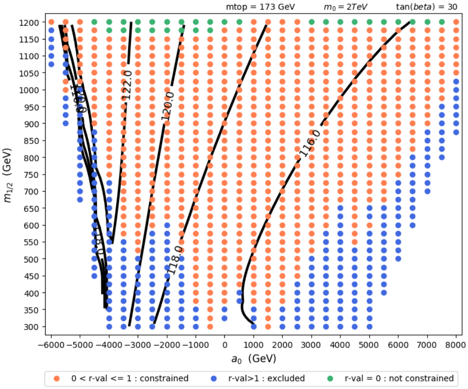


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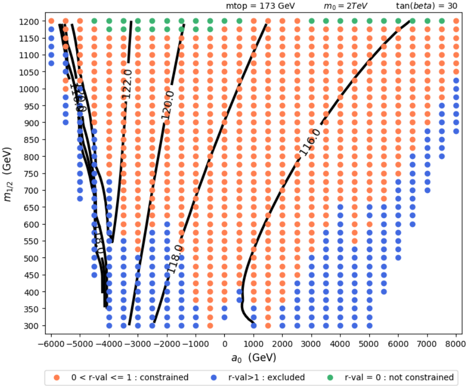
*What is causing this?*

$$m_Z^2 = -2(|\mu|^2 + m_{H_u}^2) + \mathcal{O}(1/\tan^2\beta)$$

where

$$-m_{H_u}^2 = 1.793 m_{1/2}^2 - 0.39 a_0 m_{1/2} - 0.022 m_0^2$$

# CMSSM : $m_0 = 2$ TeV

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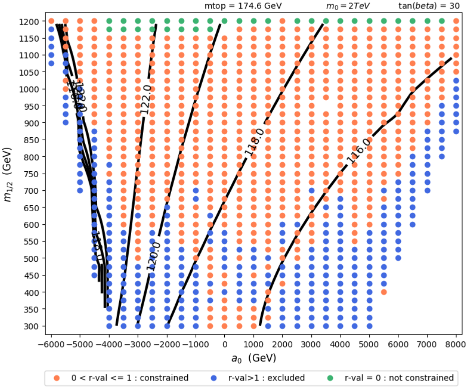
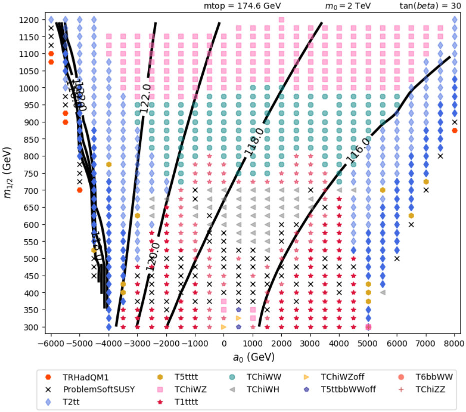
*How to improve this?*

$$m_t \longrightarrow m_t + 2\sigma + \sigma_{theo}$$
$$\longrightarrow 174.6GeV$$

# CMSSM : $m_0 = 2$ TeV

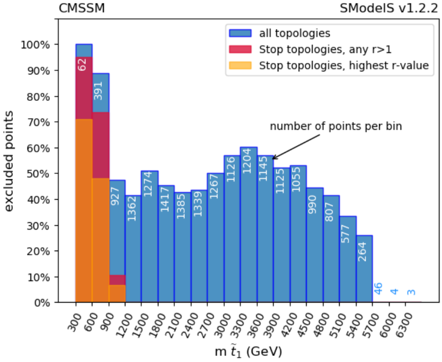



Exclusion plot for $m_t = 174.6$GeV

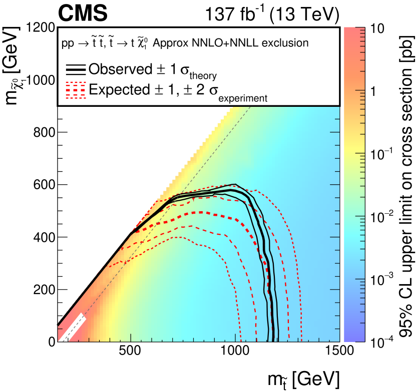



Leading topologies for $m_t = 174.6$GeV

# CMSSM : Random Scan




Percentage of excluded points in function of $m_{\tilde{t}_1}$




Exclusion limits at 95% CL for top squark pair production **1908.04722**

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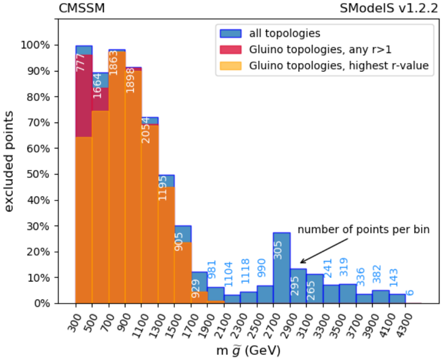
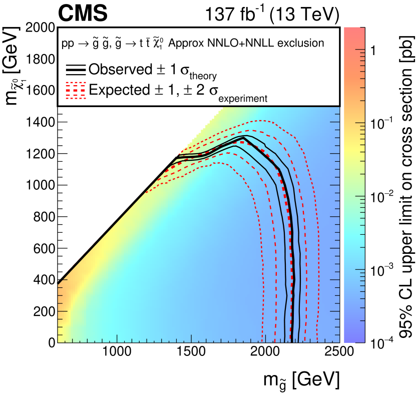



Percentage of excluded points in function of $m_{\tilde{g}}$



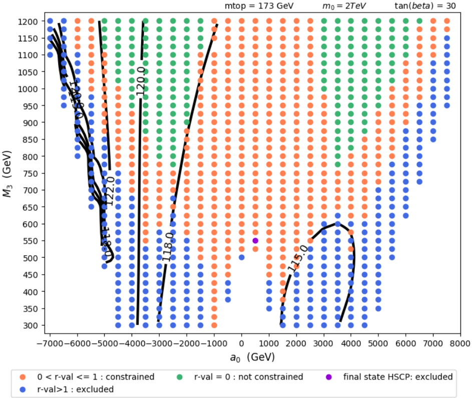

Exclusion limits at 95% CL for gluino pair production **1908.04722**

# Non-Universal Gaugino Masses

- NUGM unifies scalar masses $m_0$ and trilinear couplings $a_0$, but not gaugino masses.
- There is a correlation between the gaugino masses that is based on the adjoint representation of a GUT gauge group:

| SU(5) | $M1 : M2 : M3$ |
|---|---|
| 1 | 1:1:1 |
| 24 | -1:-3:2 |
| 75 | -5:3:1 |
| 200 | 10:2:1 |

# NUGM : $m_0 = 2$ TeV




Exclusion plot for $m_t = 173$GeV

- Blank regions similar to the CMSSM.
- The region where EWSB is not successful is larger here.

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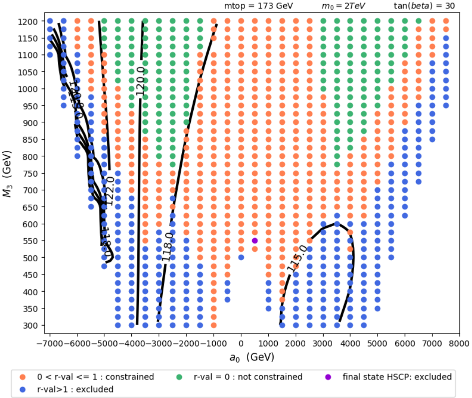


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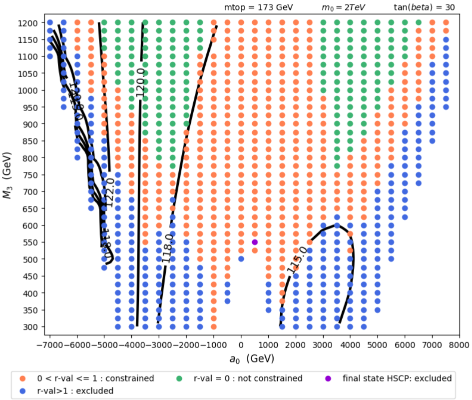
*Why is it larger?*

$$m_Z^2 = -2(|\mu|^2 + m_{H_u}^2) + \mathcal{O}(1/\tan^2\beta)$$

where

$$-m_{H_u}^2 = 1.099M_3^2 - 0.215a_0M_3 - 0.022m_0^2$$

# NUGM : $m_0 = 2$ TeV

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$$\Longrightarrow$$

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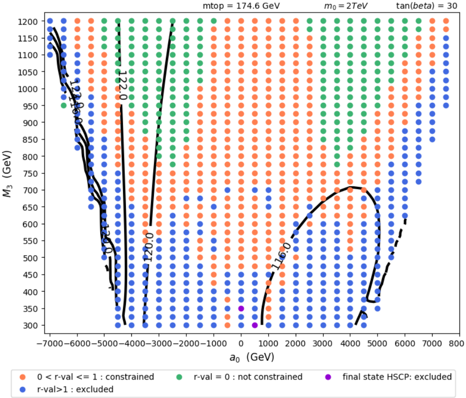


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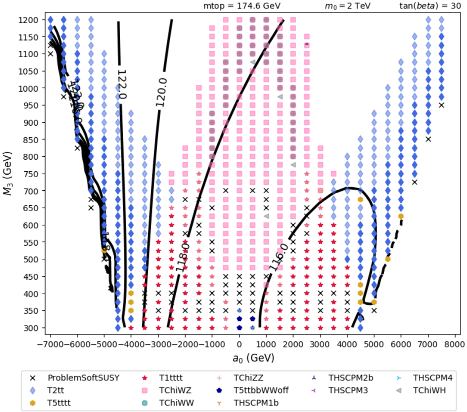
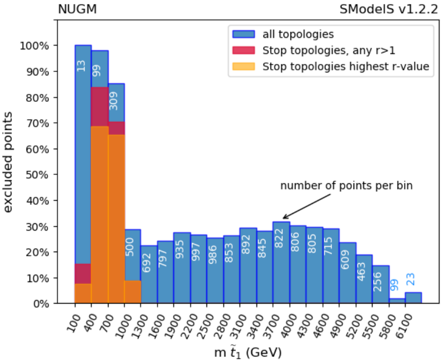
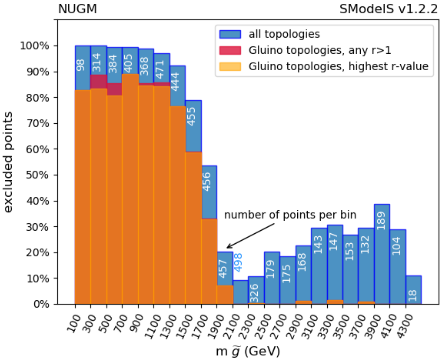



Leading topologies for $m_t = 174.6$GeV

# NUGM : Random Scan




Percentage of excluded points in function of $m_{\tilde{t}_1}$




Percentage of excluded points in function of $m_{\tilde{g}}$

# Summary

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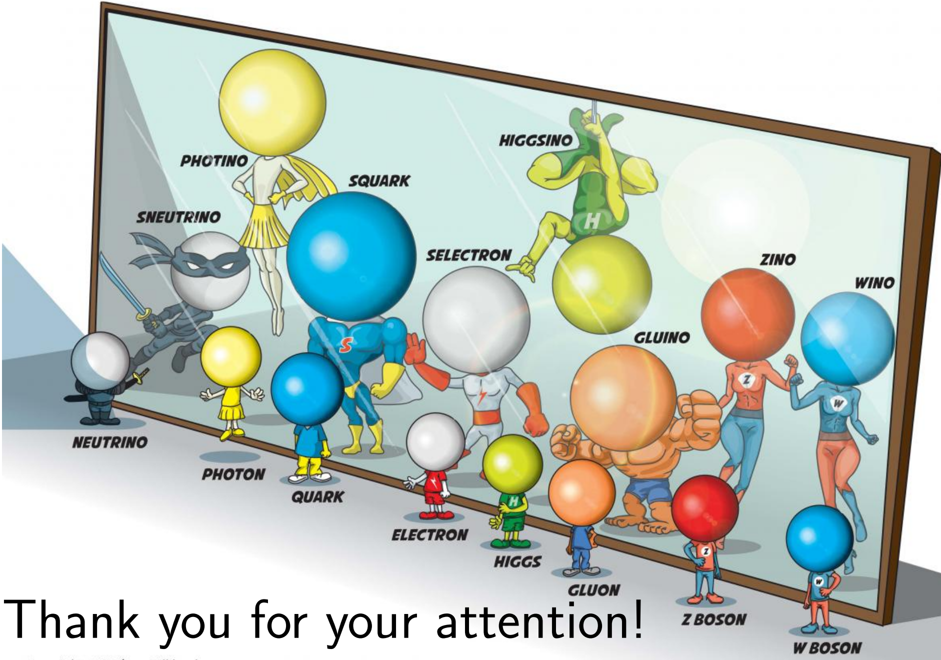
- The SMS approach is convenient for re-interpreting experimental results. It provides a wide range of possible signatures of new physics.
- Covering a large parameter space, the SMS displays a similar outcome when compared to the experimental results.
- Re-interpretation can also be done with the recasting approach or with machine learning.

- The CMSSM and NUGM are similar yet certainly have phenomenological differences:
  - NUGM has higher exclusion percentages, which agrees more with experiments, but CMSSM is more constrained than NUGM.
  - NUGM is more sensitive to EWSB.




# Thank you for your attention!

# Back Up

# EWSB & Higgs mass

The following equation should be respected in order to have a successful electroweak symmetry breaking (EWSB).

$$m_Z^2 = -2(|\mu|^2 + m_{H_u}^2) + \mathcal{O}(1/\tan^2\beta)$$

Where $m_{H_U}^2$ is dependent on gaugino masses and it is given for $\tan\beta = 10$ and not too large $m_0$.

$$\begin{aligned} -m_{H_u}^2 = & 1.82M_3^2 - 0.21M_2^2 + 0.16M_3M_2 + 0.023M_1M_3 + 0.006M_1M_2 - 0.006 \\ & - 0.32a_0M_3 - 0.07a_0M_2 - 0.022m_0^2 \end{aligned} \quad (1)$$

# CMSSM : $a_0/m_0 = -2$

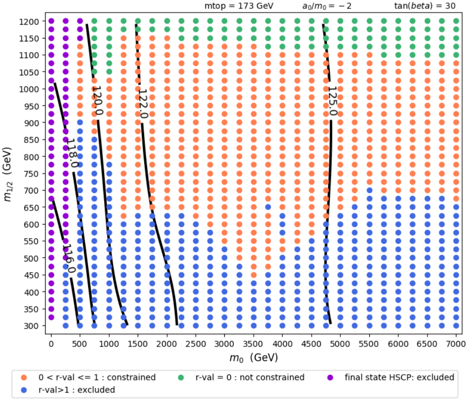



Figure 1: Exclusion plot for $a_0/m_0 = -2$

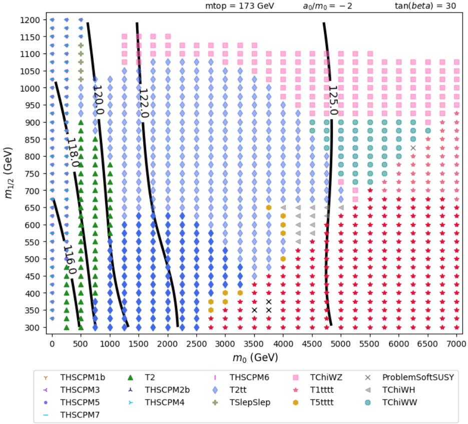



Figure 2: Leading topologies plot for $a_0/m_0 = -2$

# NUGM : $a_0/m_0 = -2$

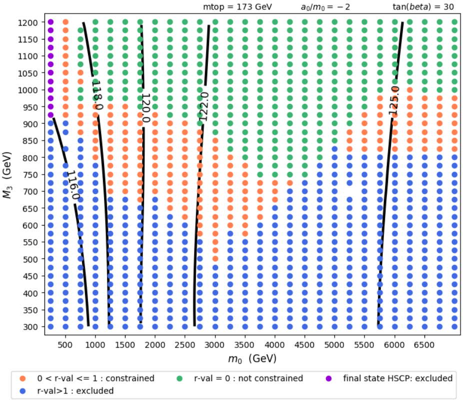



Figure 3: Exclusion plot for $a_0/m_0 = -2$

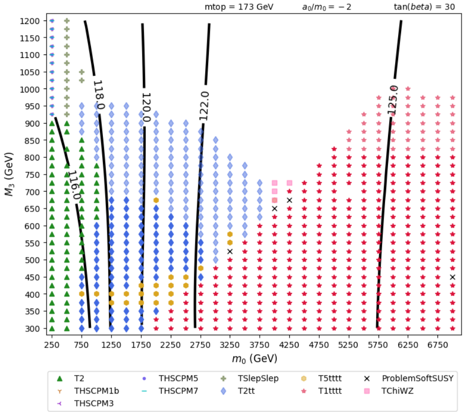



Figure 4: Leading topologies plot for $a_0/m_0 = -2$