Hi!

A generic SMS decomposition of SUSY spectra

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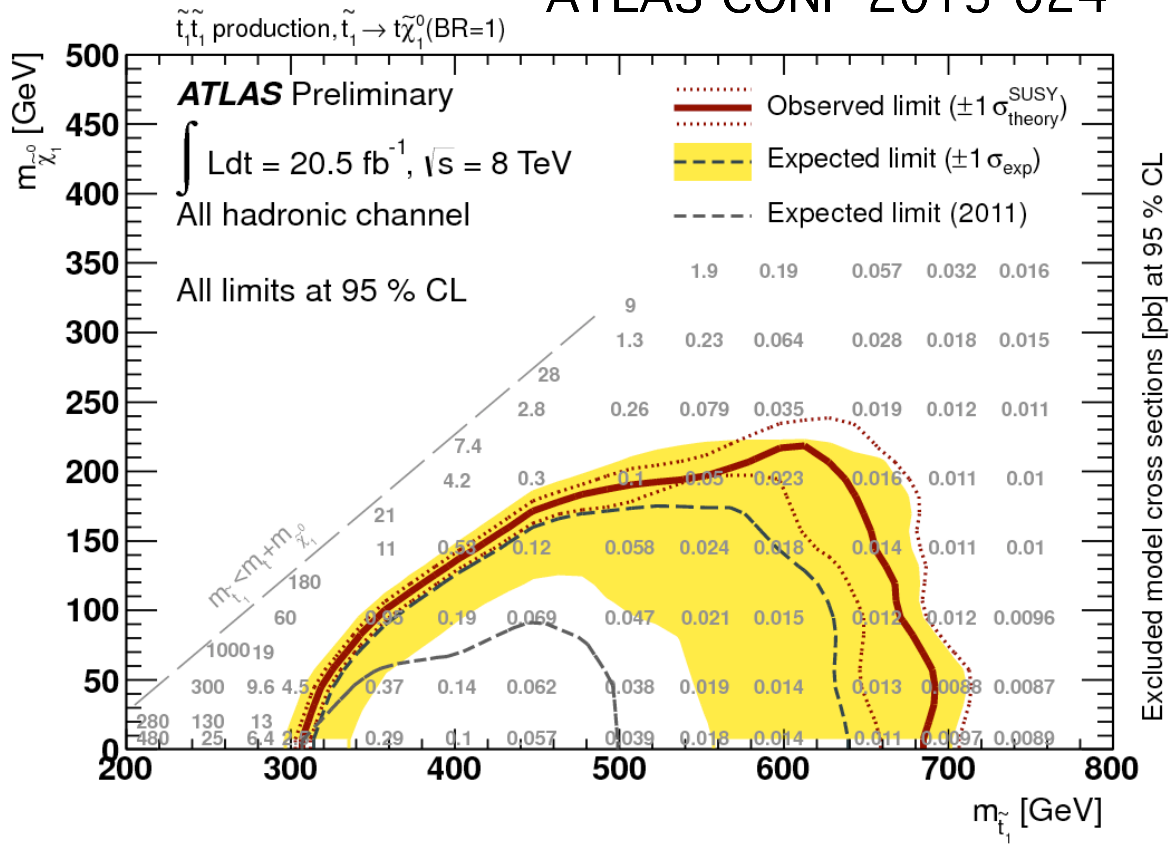
Motivation

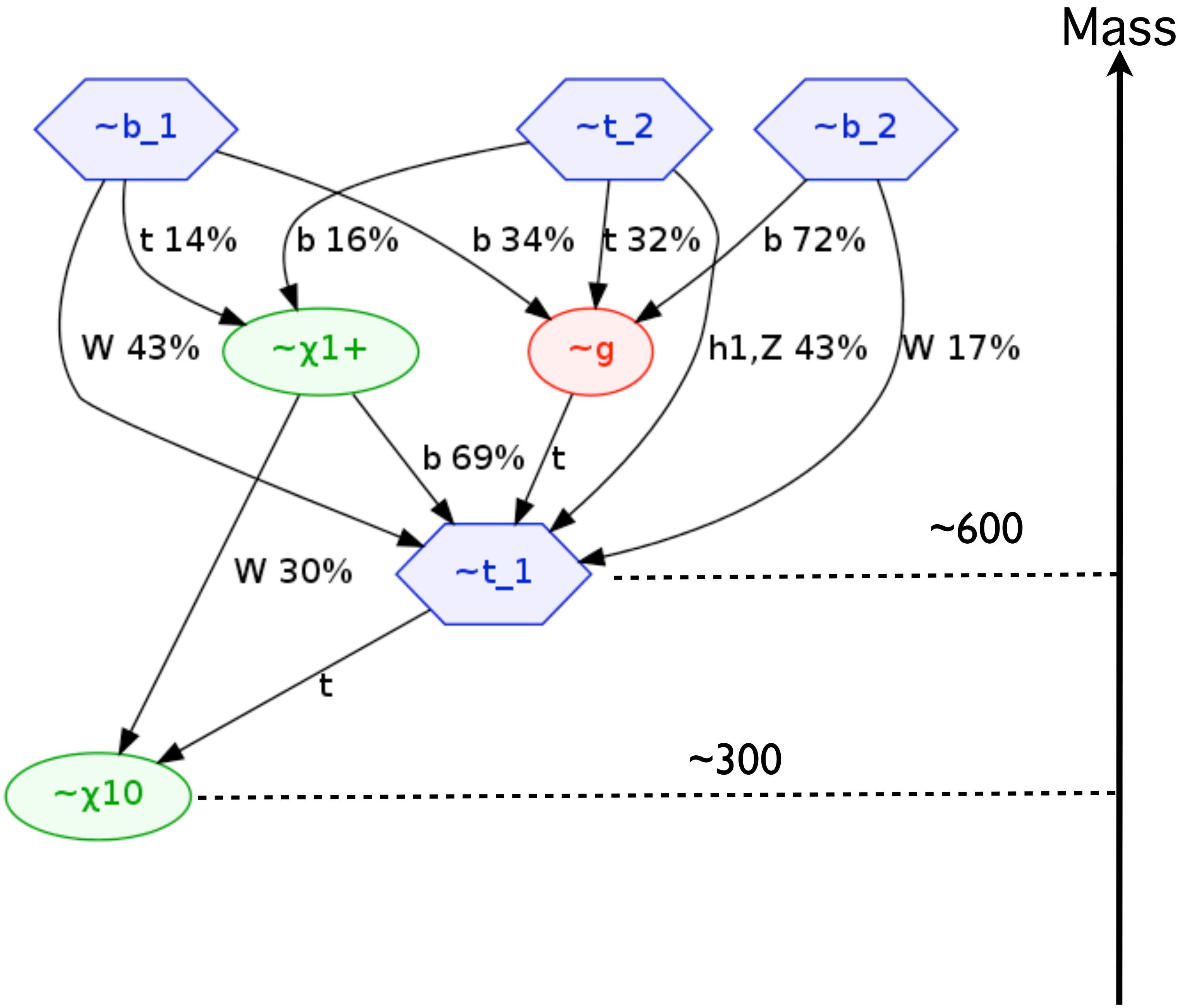
Note: the grid numbers on the plot are more important than the exclusion lines

ATLAS-CONF-2013-024



- Simplified Model Spectra (SMS) are an effective-Lagrangian description of BSM involving a limited set of new particles.
- Every SMS interpretation is based on a set of assumptions and is applicable for specific topologies
- Generic point in e.g. SUSY parameter space contains many topologies and is sensitive to more than one SMS analyses
- We present an automated tool for decomposing generic SUSY (or other BSM) spectra into SMS topologies and compare them against the experimental results

Real life example - 1a



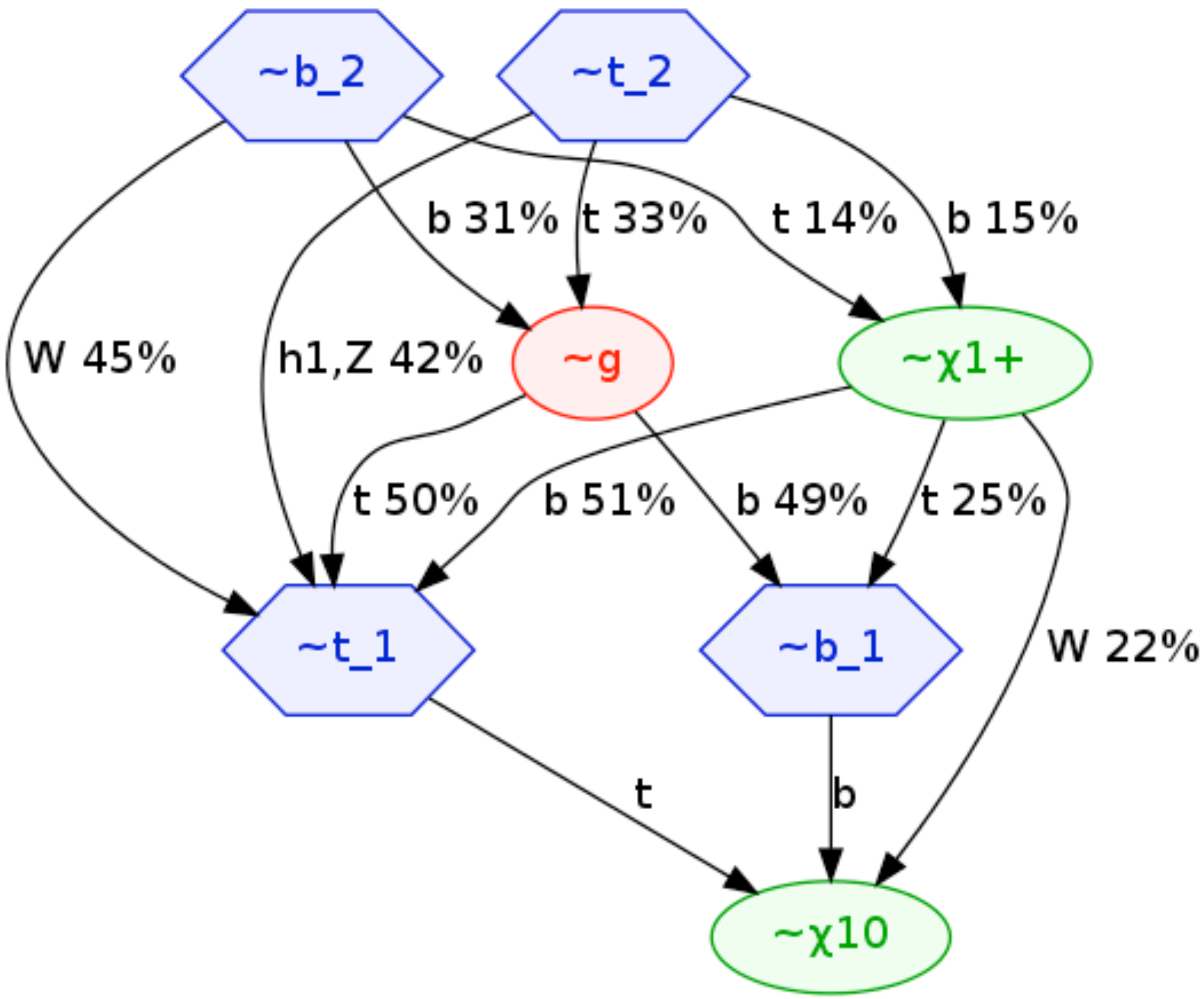
Bino-like neutralino

- Final states involving tops
- Tested by ~10 different analyses e.g.
    - ★ CMS-SUS-11-022
    - ★ CMS-SUS-12-028
    - ★ ATLAS-CONF-2013-024
    - ★ ATLAS-CONF-2013-037

Final state matters

In next four examples gluinos ~ 1600 GeV

Real life example - 1b

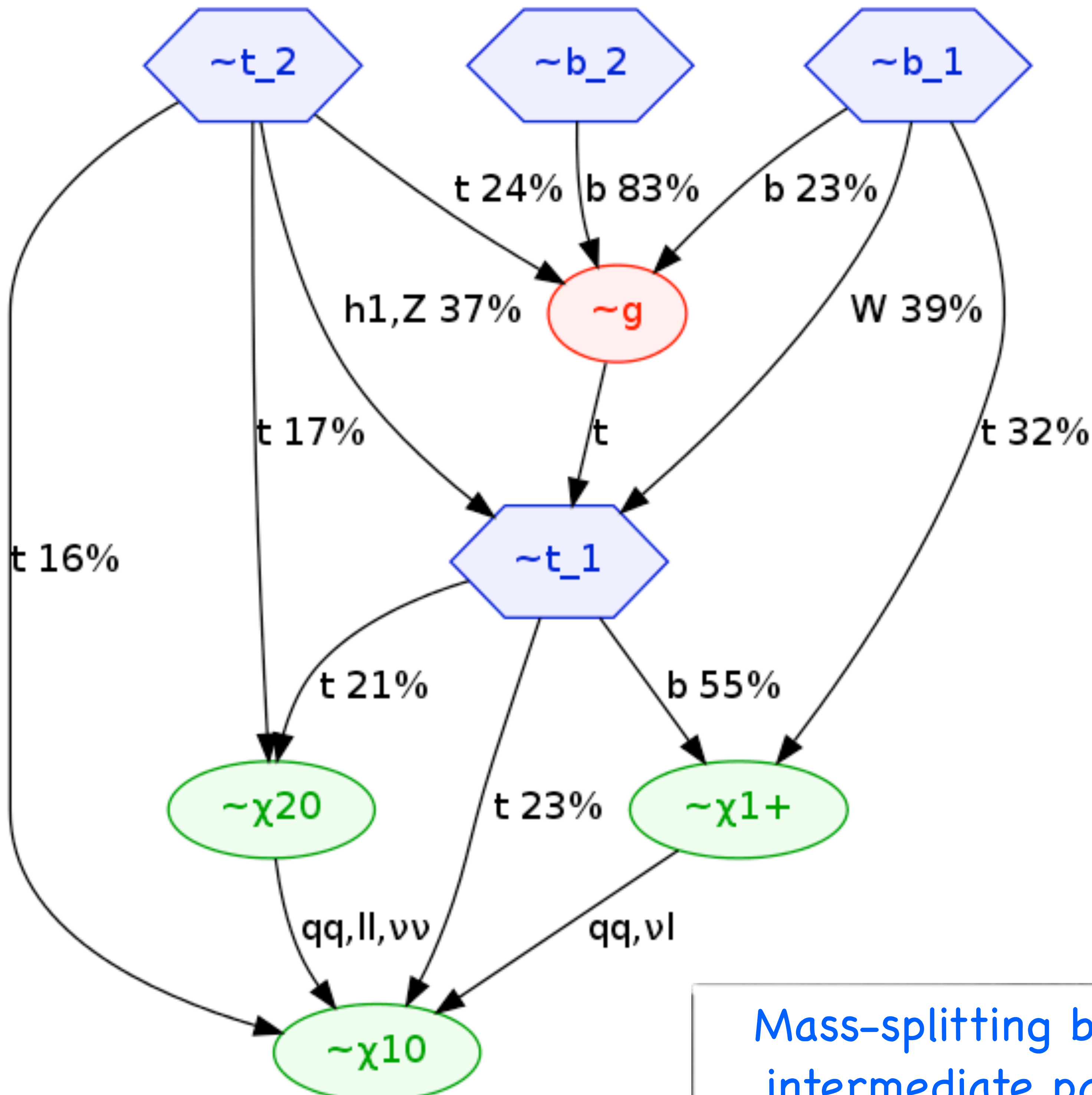


Final state matters

Bino-like neutralino

- Final states involving tops and bottoms
- Tested by
  - ~10 stop pair production
  - ~4 sbottom pair production analyses

Real life example - 2a

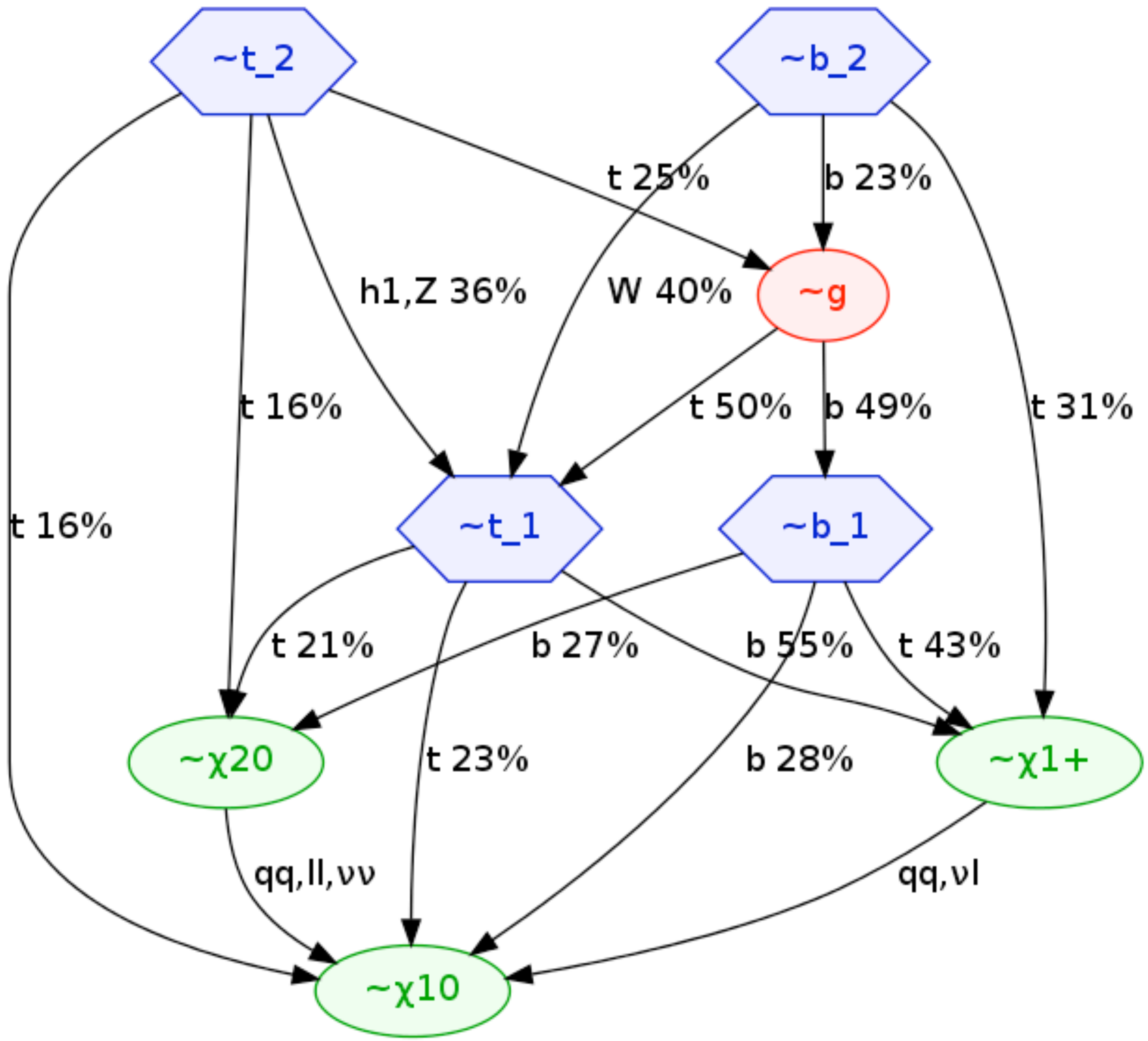


Higgsino-like neutralino

- Final states involving tops
- Small mass splitting between neutralino and chargino, add up cascades
- Tested by
  - ★ ~10 stop pair production
  - ★ ~4 sbottom pair production analyses

Mass-splitting between intermediate particles matters

Real life example - 2b

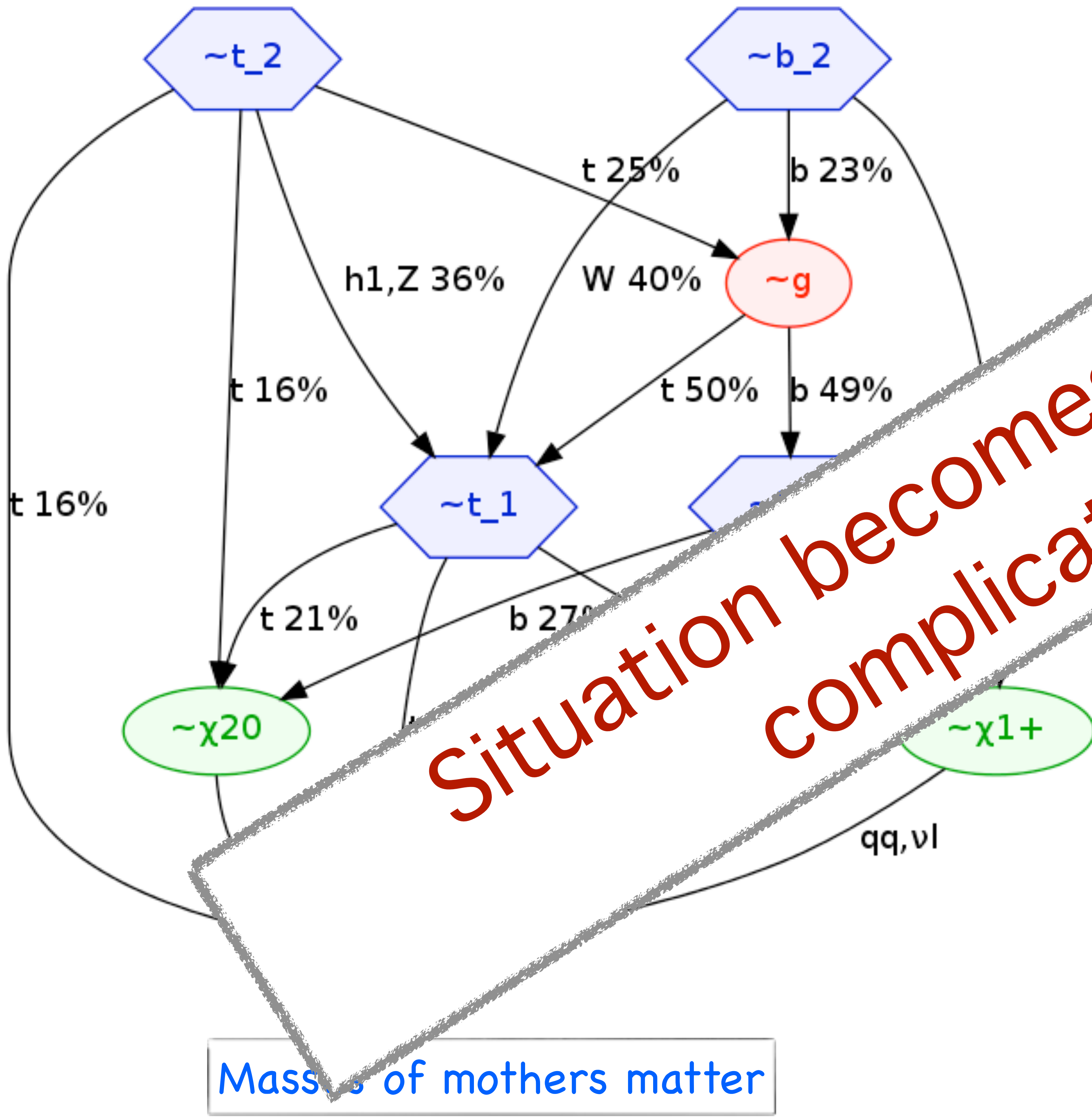


Masses of mothers matter

Higgsino-like neutralino

- Final states involving tops
- Small mass splitting between neutralino and chargino, add up cascades
- Additional complication - add all the stop and sbottom pair production leading to same final state
- Tested by
  - ★ ~10 stop pair production
  - ★ ~4 sbottom pair production analyses

Real life example - 2b



Higgsino-l e neutralino

- Final st tops
-
- o and up cascades
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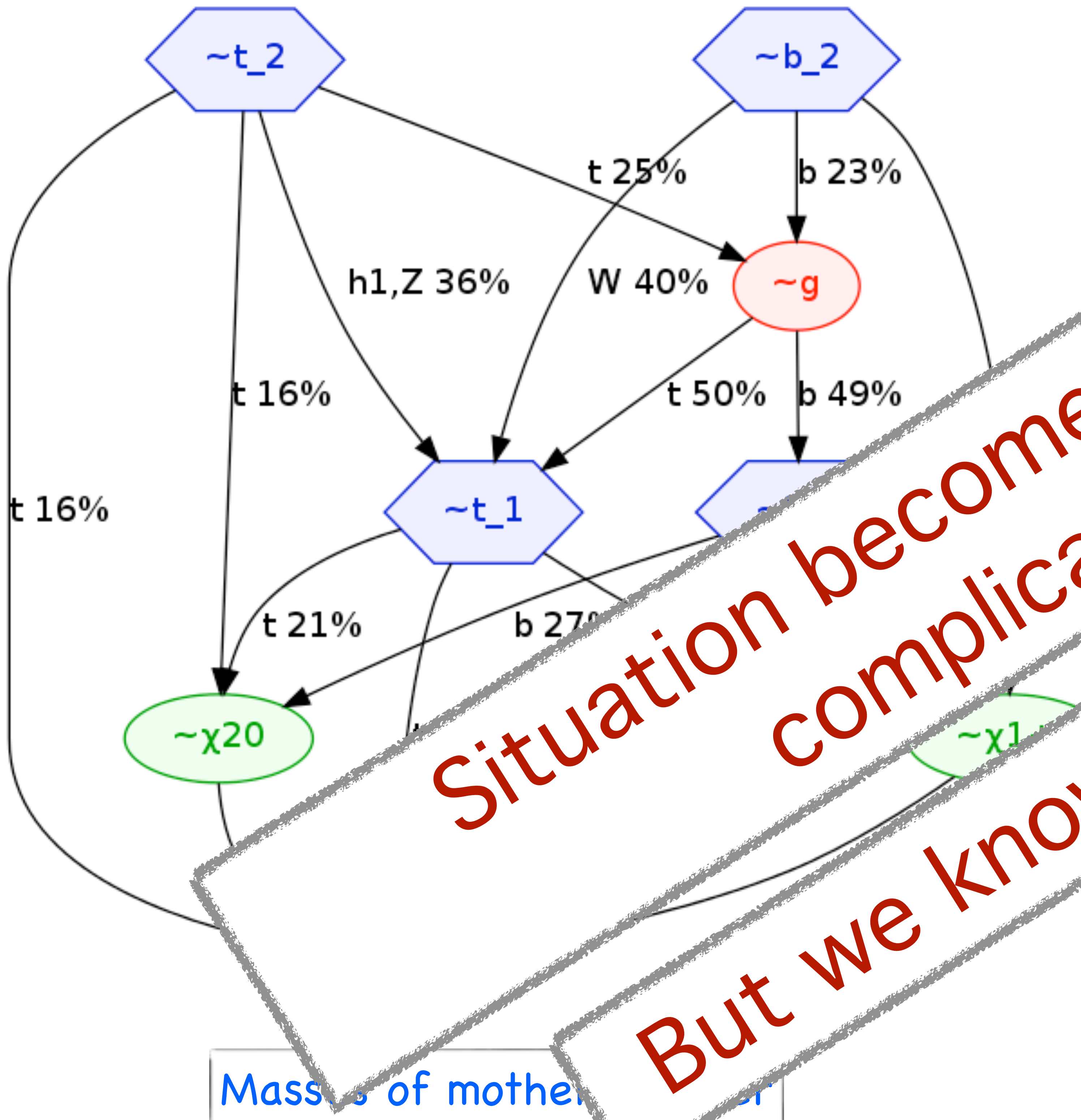
Situation becomes quickly complicated

Real life example - 2b



Higgsino-l neutralino

- Final st tops
- o and
  up c ades
  onal
  d all
  sh production
  same final state
  sted by
  - ★ ~10 stop pair production
  - ★ ~4 sbottom pair production analyses

Situation becomes quickly complicated

But we know what matters

Approach

Decompose BSM model point

Make a database of most generic BSM physics results and look them up

They form the basis of this talk

This approach is an improved and more generic version of the Walkding

Walkding: http://www.hephy.at/user/walten/pmssm

SModelS is born...

- SMS results - Upper Limit on sigma X BR for a given final state
- They are not sensitive to the nature of BSM particles produced, only to their masses and final state (SM) particles
- Fundamental assumptions in SModelS
  - ★ LSP is a stable particle - there is a conserved Z2 symmetry like R-parity
- Count the number of events leading to same final state instead of separating on the basis of production mechanism (more to come...)
- Leads to model independent decomposition as we are not concerned about the nature of new states, just about their masses

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This talk - concentrate on SUSY

SModelS is born...

- What matters (theory) -
  - ★ Final states
  - ★ Masses of mother and intermediate particles
  - ★ Particles coming out of each vertex
- What matters (experiment) -
  - ★ How exactly are SMS limits obtained?
    - Assumptions on branching ratios
    - Charges and flavors of final state particles
- Theoretically decompose the spectra and then combine the decomposition depending on analysis assumptions

Decomposing the spectra

Assumptions

- R-parity is conserved
- Only two branches (no VBF type of interactions)
- No (SM) daughters decay further (there are no grand-daughters)
- Mothers have the same mass (Experimental)
- Both branches lead to same LSP (Experimental)

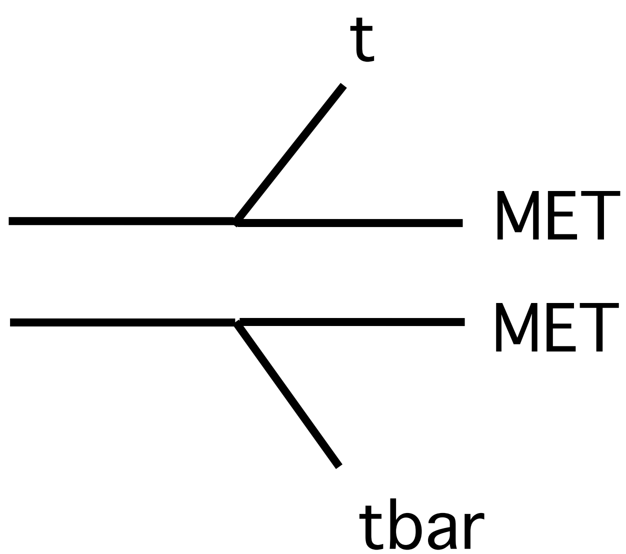
Start with an event file

Decomposing the spectra

Step -I

Decomposing the spectra

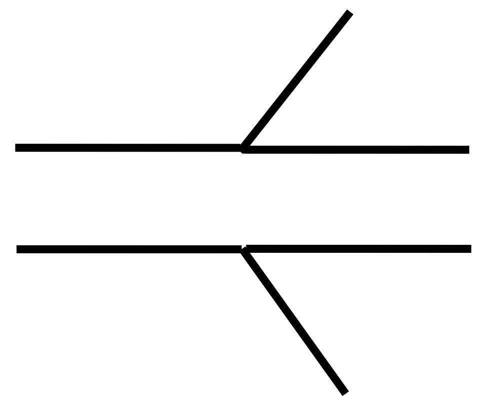
Step -I



Decomposing the spectra

Step -I

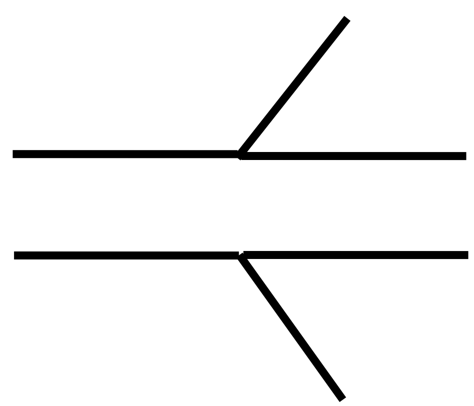
- Create an empty skeleton defining the event - Global topology



Decomposing the spectra

Step -I

- Create an empty skeleton defining the event - Global topology



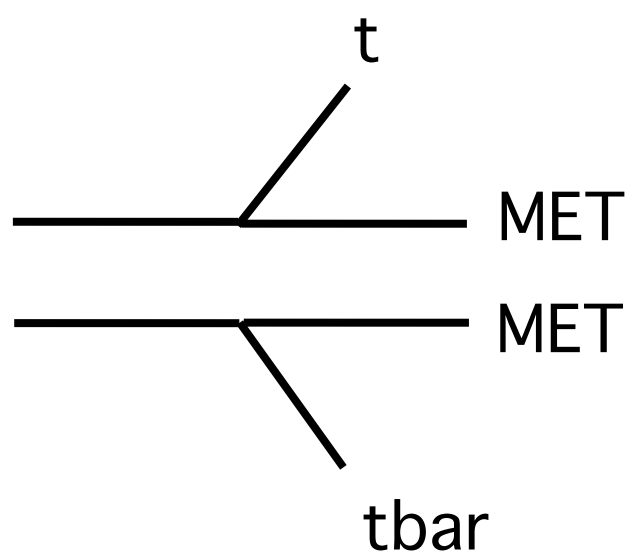
GTop = [[1,0][1,0]]

- Global topology - list of number of vertices and SM insertions for each vertex

Decomposing the spectra

Step -II

- Fill the details in global topology - create an element

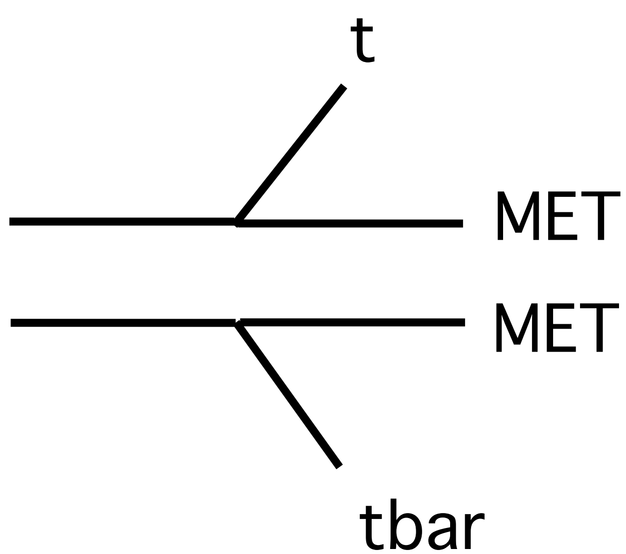


- Each element knows the particles in each insertion and masses of all the intermediate particles

Decomposing the spectra

Step -II

- Fill the details in global topology - create an element



Element = [[t],[t]]
[[600,300], [600,300]]

$m_{\tilde{t}_1}$ $m_{\tilde{\chi}_1^0}$

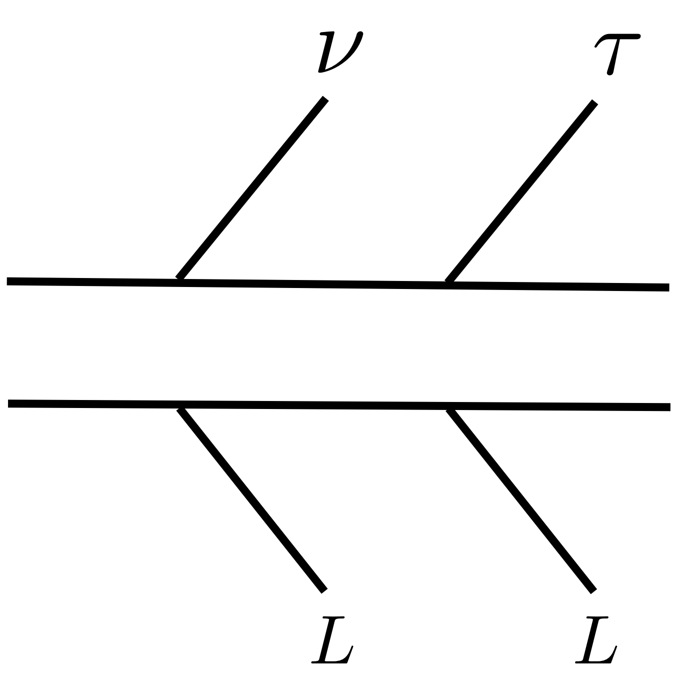
- Each element knows the particles in each insertion and masses of all the intermediate particles

Decomposing the spectra

Step -III

- For every SMS plot produced by an analysis, identify all the assumptions made
- Keep track of these assumptions while making the database

Tau - enriched scenario CMS SUS-12-022



$$[[L, L], [\nu, \tau]] \approx 3 * [[\tau, \tau], [\nu, \tau]]$$

$$L = \{e, \mu, \tau\}$$

Flavor democratic decay for the second branch

Decomposing the spectra

Step -III

- For every SMS plot produced by an analysis, identify all the assumptions made
- Keep a track of these assumptions while making the database

Step -IV

- Combine the theoretical decomposition depending on the experimental analysis - e.g. combine electron and muon final states
- Compare the resulting combinations with assumptions, if they are obeyed, get the limits

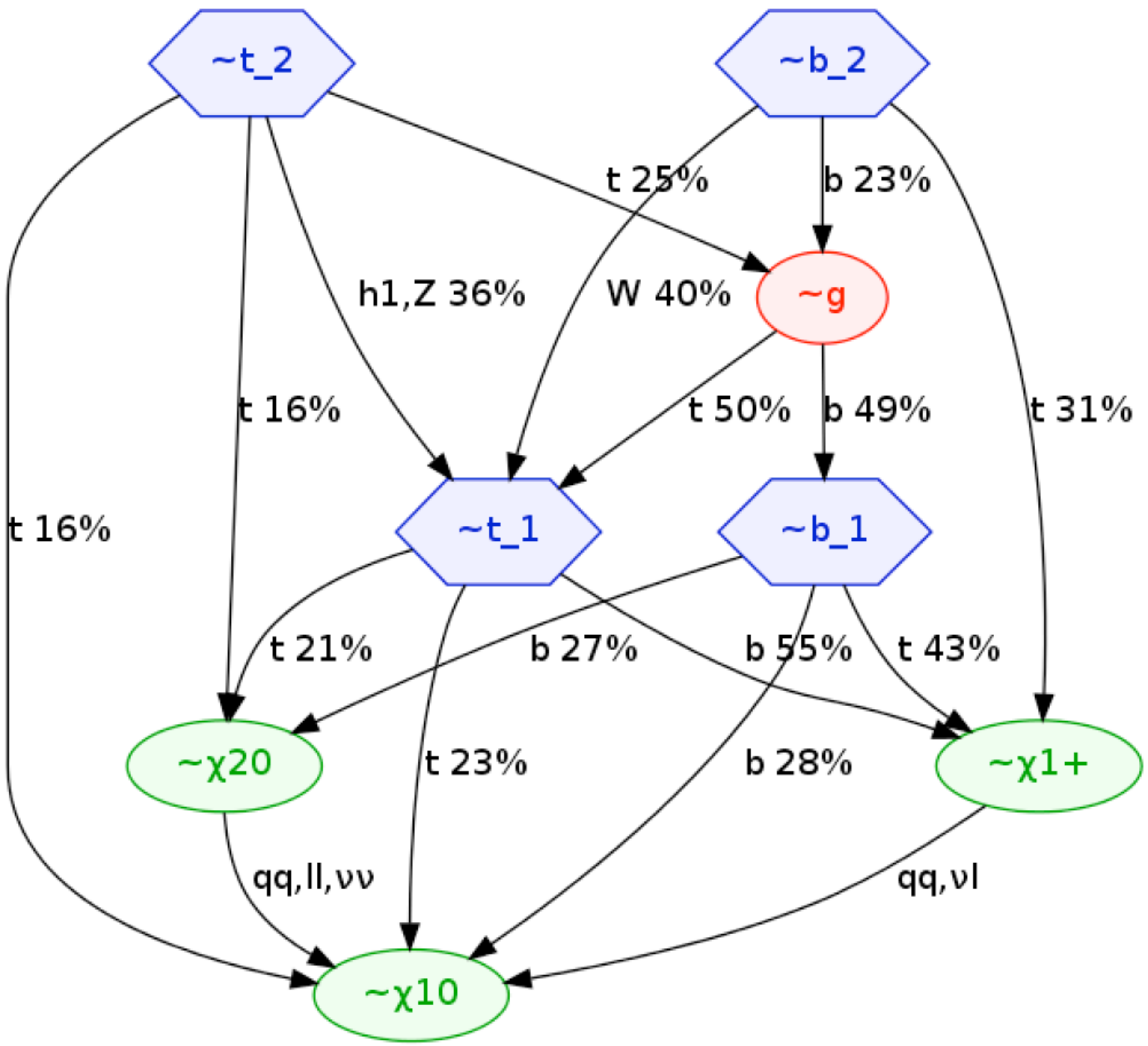
Tools used

- We rely on:
  - ★ Availability of SLHA spectrum file
  - ★ Event file in LHE format
- We use:
  - ★ Language used - Python
  - ★ Spectrum generator, decay calculator, ROOT
  - ★ PySLHA - SLHA reader
  - ★ Pythia - event generator
  - ★ NLLfast - Cross-section NLO for colored particles

Features

- Completely generic spectrum decomposition - can be applied to e.g. same spin partner scenarios
- Mass combinations - e.g. combining topologies for selectron and smuon production for small mass splitting
- Compressed spectra - e.g. combining topologies for higgsinolike neutralino as they all lead to MET in final state

Example



Un-compressed case:

$$\sigma(t\bar{t}+\mathrm{MET}) = \sigma(\tilde{\mathrm{t}}_1\bar{\tilde{\mathrm{t}}}_1)\times \mathrm{BR}(\tilde{\mathrm{t}}_1 \to \tilde{\chi}^0_1 + \mathrm{t})^2$$

$$\sigma(b\bar{b}+\mathrm{MET}) = \sigma(\tilde{\mathrm{b}}_1\bar{\tilde{\mathrm{b}}}_1)\times \mathrm{BR}(\tilde{\mathrm{b}}_1 \to \tilde{\chi}^0_1 + \mathrm{b})^2$$

Compressed case:

$$\sigma(t\bar{t}+\mathrm{MET})$$

$$\sigma(\tilde{t}_1\bar{\tilde{t}}_1)\times BR(\tilde{t}_1 \to \tilde{\chi}^0_1 + t)^2$$

$$\sigma(\tilde{t}_1\bar{\tilde{t}}_1)\times BR(\tilde{t}_1 \to \tilde{\chi}^0_2 + t)^2$$

$$\sigma(\tilde{b}_1\bar{\tilde{b}}_1)\times BR(\tilde{b}_1 \to \tilde{\chi}^+_1 + t)^2$$

$$\sigma(b\bar{b}+\mathrm{MET})$$

$$\sigma(\tilde{b}_1\bar{\tilde{b}}_1)\times BR(\tilde{b}_1 \to \tilde{\chi}^0_1 + b)^2$$

$$\sigma(\tilde{b}_1\bar{\tilde{b}}_1)\times BR(\tilde{b}_1 \to \tilde{\chi}^0_2 + b)^2$$

$$\sigma(\tilde{t}_1\bar{\tilde{t}}_1)\times BR(\tilde{t}_1 \to \tilde{\chi}^+_1 + b)^2$$

Example

Uncompressed case: 7 TeV LO

Signature	Theory reference CS [fb]	SModelS reference CS [fb]	SModelS analysis lookup [fb]	Excluded?
$\sigma(t\bar{t} + \mathrm{MET})$	0.188	0.213	54.32	No
$\sigma(b\bar{b} + \mathrm{MET})$	0.309	0.307	31.72	No

Compressed case: 7 TeV LO

Signature	Theory reference CS [fb]	SModelS reference CS [fb]	SModelS analysis lookup [fb]	Excluded?
$\sigma(t\bar{t} + \mathrm{MET})$	1.402	1.423	54.32	No
$\sigma(b\bar{b} + \mathrm{MET})$	2.274	2.227	31.72	No

SMS analysis: alphaT CMS-SUS-11-022

Current status

- Kind of topologies being dealt with
  - ★ All possible for which SMS results are available
  - ★ Currently dealing with third generation and ew-kino
- Number of results implemented
  - ★ 37 - CMS + ATLAS
  - ★ 22 - CMS
  - ★ 15 - ATLAS
- Testing underway
  - ★ Validated only a few out of 37

Limitations

- Not a precision tool - gain an overview of the kind of parameter space under consideration
- Number of events generated will increase running time
- Number of analyses might increase running time - so far this dependence is not large
- Not straightforward to implement R-parity violating scenarios
- No VBF type of interactions implemented yet
- SUSY searches without SMS interpretation cannot be included

Wish list

Interpretation of BSM searches in SMS formalism is a very nice way to present results of an experimental analyses

however...

- Plots of SMS results should be available in digitized form
  - ★ This includes the underlying grid of values rather than the exclusion curve
- Analyses should carefully list the assumptions involved in SMS re-interpretations
- For topologies involving two step decays, results for various intermediate masses are needed
- It would also be helpful to have a systematic overview per experiment of which analyses are relevant for which topology

Back-up

Example - I

Scenario: Light sbottoms and higgsinolike neutralino

$m_{\tilde{b}_1}$	363.25
$m_{\tilde{\chi}_1^0}$	65.16
$m_{\tilde{\chi}_2^0}$	74.90
$m_{\tilde{\chi}_1^+}$	70.38

Un-compressed case:

$$\sigma(b\bar{b} + \mathrm{MET}) = \sigma(\tilde{\mathrm{b}}_1\bar{\tilde{\mathrm{b}}}_1) \times \mathrm{BR}(\tilde{\mathrm{b}}_1 \to \tilde{\chi}_1^0 + \mathrm{b})^2$$

Compressed case:

$$\sigma(b\bar{b} + \mathrm{MET})$$

$$\sigma(\tilde{b}_1\bar{\tilde{b}}_1) \times BR(\tilde{b}_1 \to \tilde{\chi}_1^0 + b)^2$$

$$\sigma(\tilde{b}_1\bar{\tilde{b}}_1) \times BR(\tilde{b}_1 \to \tilde{\chi}_2^0 + b)^2$$

$$\sigma(\tilde{t}_1\bar{\tilde{t}}_1) \times BR(\tilde{t}_1 \to \tilde{\chi}_1^+ + b)^2$$

Example - I

Uncompressed case: 7 TeV NLO

Signature	Theory reference CS [fb]	SModelS reference CS [fb]	SModelS analysis looktup [fb]	Excluded?
$\sigma(b\bar{b} + \mathrm{MET})$	41.21	40.54	104.15	No

Compressed case: 7 TeV NLO

Signature	Theory reference CS [fb]	SModelS reference CS [fb]	SModelS analysis looktup [fb]	Excluded?
$\sigma(b\bar{b} + \mathrm{MET})$	140.41	133.80	104.15	Yes

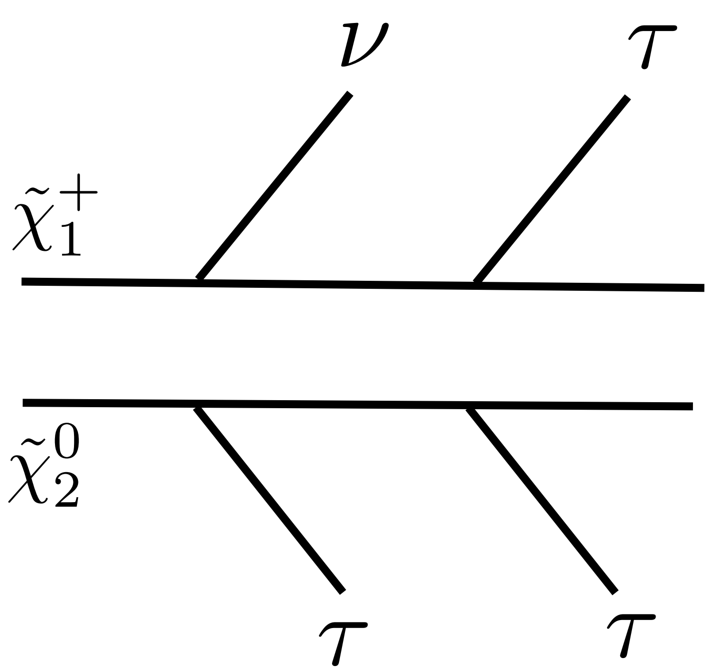
SMS analysis: alphaT CMS-SUS-11-022

First two generation squarks

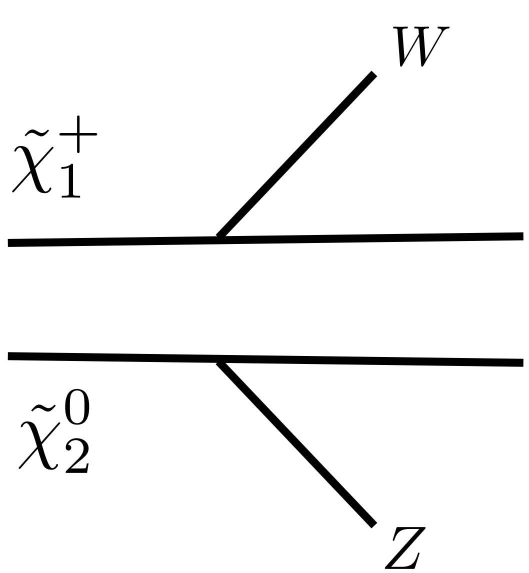
- Dealing with generic non-degenerate masses:
  - ★ Prospino can deal with NLO cross-section for non-degenerate masses
  - ★ Too time consuming to employ prospino to calculate NLO cross-sections
  - ★ NLLfast gives cross-sections assuming degenerate masses
  - ★ Take k-factors from NLLfast for individual squarks and rescale the pythia cross-sections, sum them up
  - ★ This is all that is needed as the results always sum over first two generations squarks

Dealing with mass combinations

- Consider...



- or...



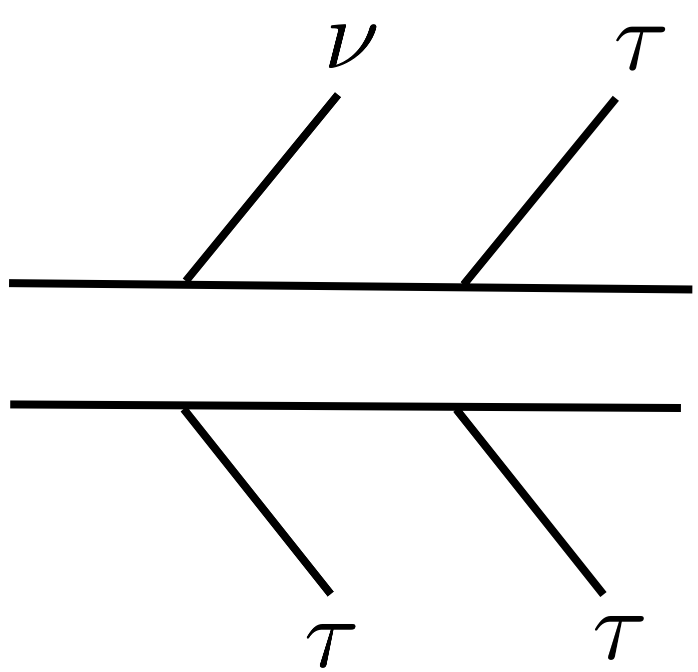
- To combine or not to combine:
  - ★ The chargino and neutralino can have different masses
  - ★ The experimental results always assume same masses
  - ★ When checking for such topologies, always check whether the masses are close enough
  - ★ Measure of closeness - fluctuations in the experimental results obtained when assuming

    $m_{\tilde{\chi}_2^0} = m_{\tilde{\chi}_1^+} = m_{\tilde{\chi}_2^0}$ or

    $m_{\tilde{\chi}_2^0} = m_{\tilde{\chi}_1^+} = m_{\tilde{\chi}_1^+}$

The curious case of intermediate mass

- Consider...



GTop = [[1,1,0],[1,1,0]]

Element-I = [[tau,tau],[nu,tau]]

Element-II = [[e,e],[nu,tau]]

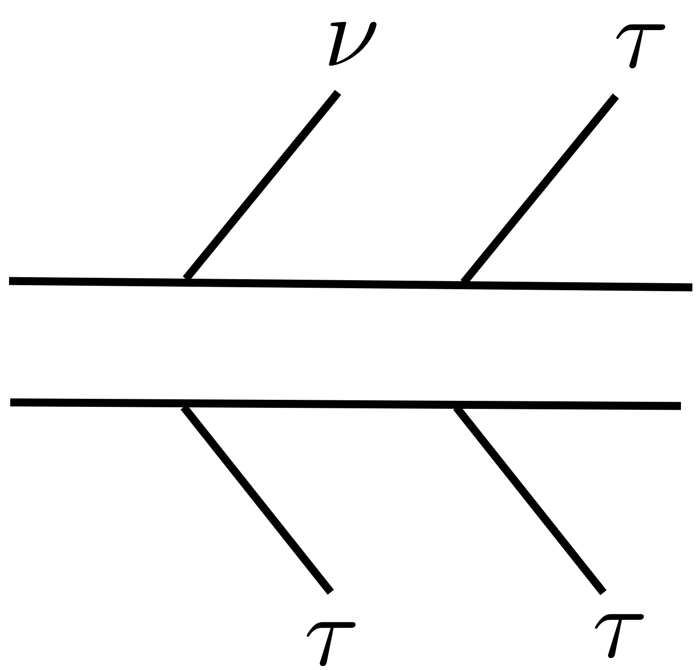
Element-III = [[mu,mu],[nu,tau]]

Combine two elements if:

- If the masses of selectron, smuon and stau are close enough
- The analysis does not differentiate between e, mu and tau
- Check if the analysis assumptions on the number of e + mu and tau is satisfied in the combined sample

The curious case of intermediate mass

- Consider...



GTop = [[1,1,0],[1,1,0]]

Element-I = [[tau,tau],[nu,tau]]

Element-II = [[e,e],[nu,tau]]

Element-III = [[mu,mu],[nu,tau]]

- Interpolate for the intermediate mass (over x-values)
- Do not take into account results with only one intermediate mass value