Limits with simplified models

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On behalf of the CMS collaboration

Characterization of new physics at the LHC, II, Geneve, 5-6 november

Introduction

Once the analysis is run on the data, one of the following situations will occur:

1. Evidence for new physics is unveiled, which needs to be characterized with respect to available models.
2. No beyond the Standard Model (BSM) physics is observed

   In that case exclusion limits can be set.

   I will touch upon this aspect only.

A classic "SUSY" analysis

Analysis strategy:

- We can look for an excess of events with respect to SM by selecting events with >=N jets, HT>X, MET>Y, 0 or 1 lepton, …

- All of the backgrounds need to be known. A set of data driven methods are in place to estimate each of them.

- The high MET and high HT regions can be used to set limits.

Setting limit

With a certain amount of integrated luminosity and X events passing the selection and Y% uncertainty on the background, a hypothetical model that produces ≥ N_{max} events passing the selection can be excluded at 95% CL

$$(\sigma \times BR)_{max} = \frac{N_{max}}{Luminosity * Acceptance * Efficiency}$$

cross section above this will be excluded

Limits in MSUGRA

Until recently, the SUSY search groups focused on mSUGRA and GMSB models. Many benchmark points have been identified with the goal to provide many different topology to study.

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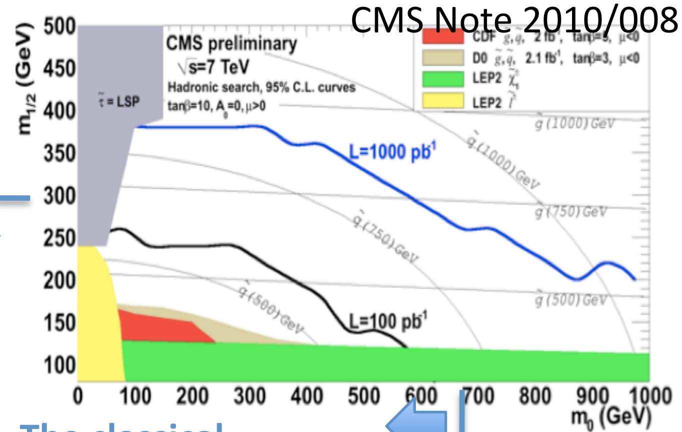
The very first LHC results will likely come in this form … (it also offers a direct comparison with Tevatron)

CMS Note 2010/008



Cross-Sec above ~ 10pb

The classical 4j+LSP,2j+LSP live here

Limits in MSUGRA

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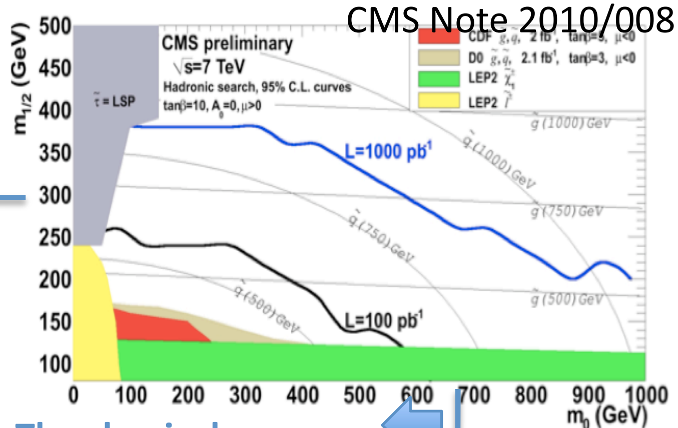

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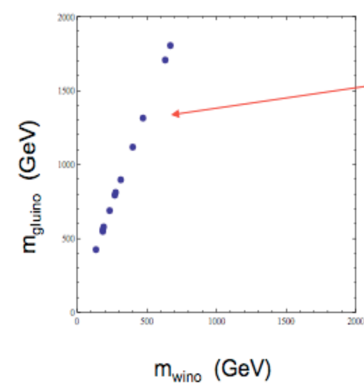
CMS SUSY TDR benchmarks



Stretched Gauge Ordered Spectra

Relatively Low σ

Led to Expectation that Need O(100' s) pb^{-1} to go Beyond Tevatron

(Gaugino Unification)

MSUGRA is not completely representative of SUSY … and a long list of models can be added like GMSB/SplitSusy

Limits: a different approach

It is possible to use simplified models and to set a limit on **X-sections * Branching Fraction**

Other models can be decomposed in this basis of distinguishable models and a limit on these models can be derived.

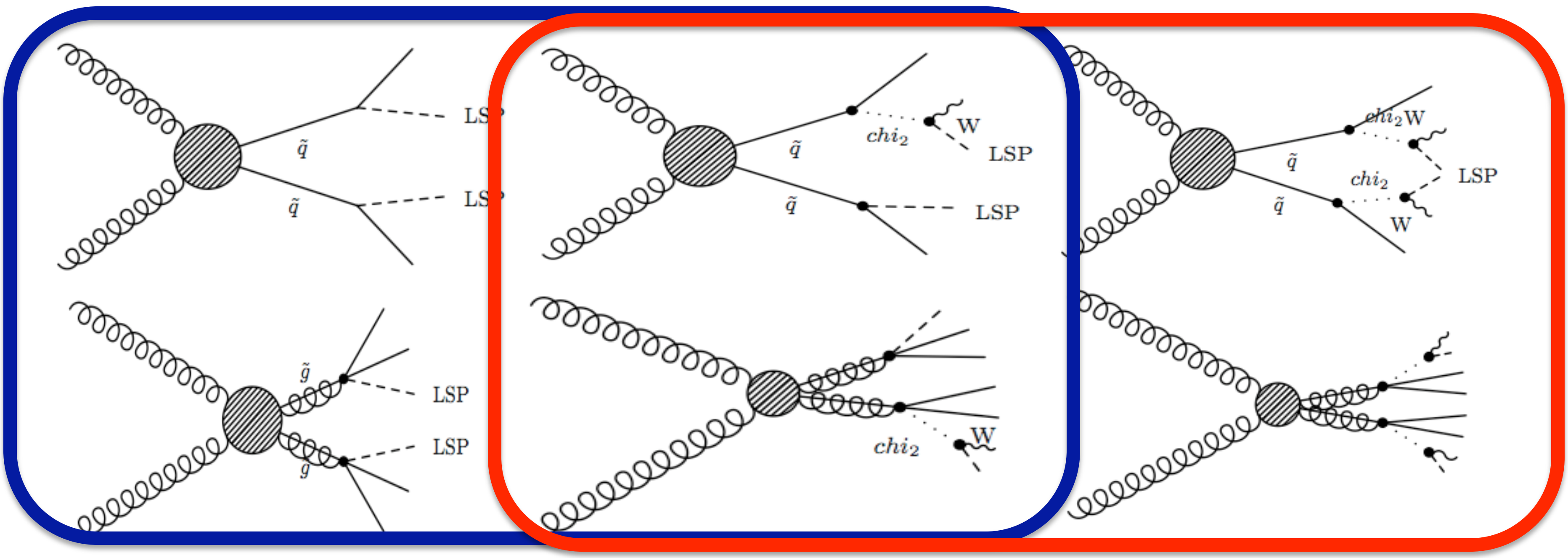
In the rest of the talk, all the ingredients needed to apply this procedure are reviewed.

The focus of the talk is on the procedure rather than the performance of the analysis.

A few simplified models

Ingredient #1

Considered so far a few different topologies with different mass splitting.

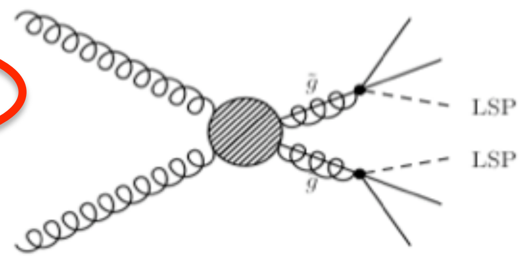


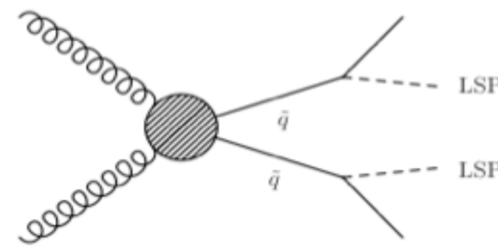
Are these enough to start with for a fully hadronic /leptonic search?

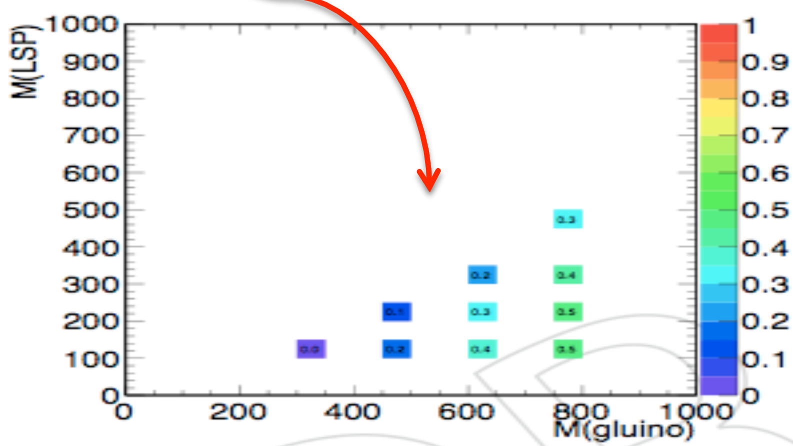
Acceptance*efficiency

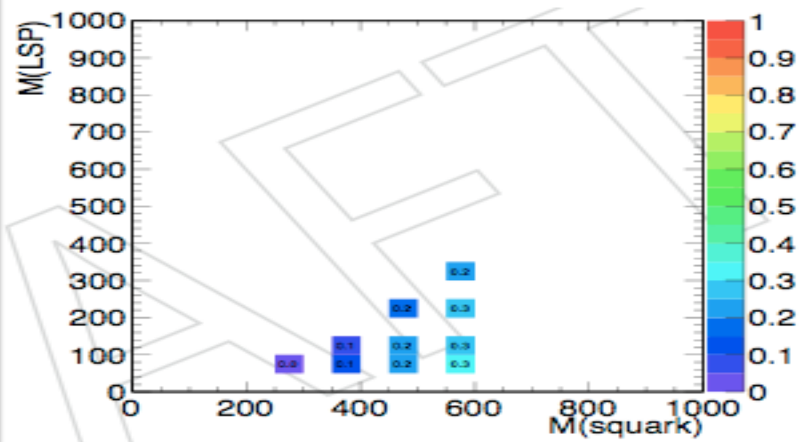
Ingredient #2

$$(\sigma \times BR)_{max} = \frac{N_{max}}{Luminosity * Acceptance * Efficiency}$$









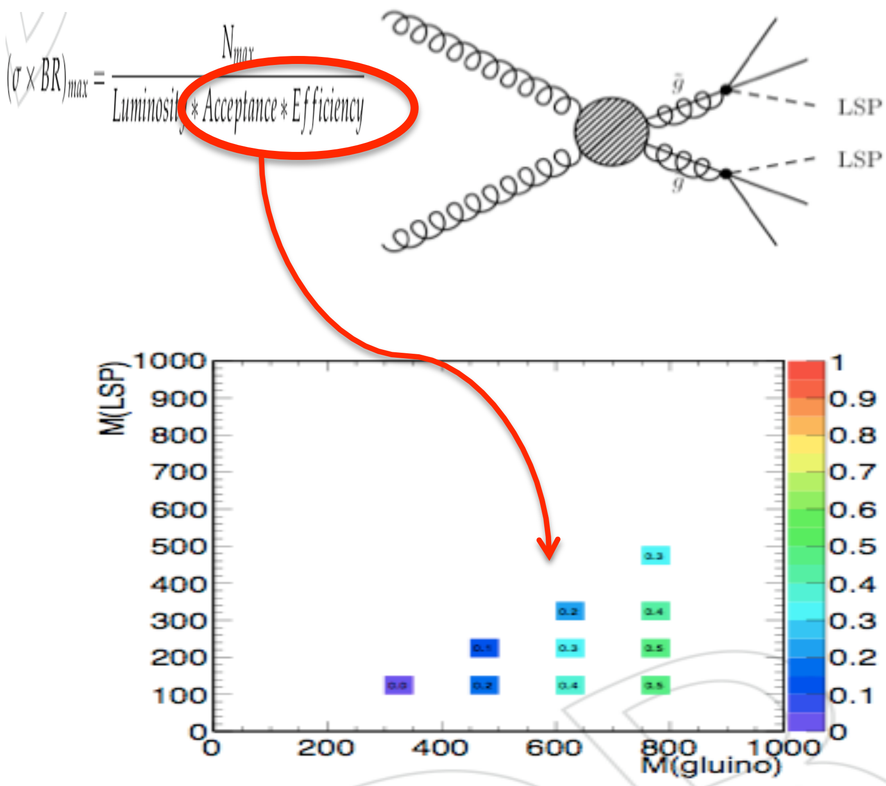
Comments #1:

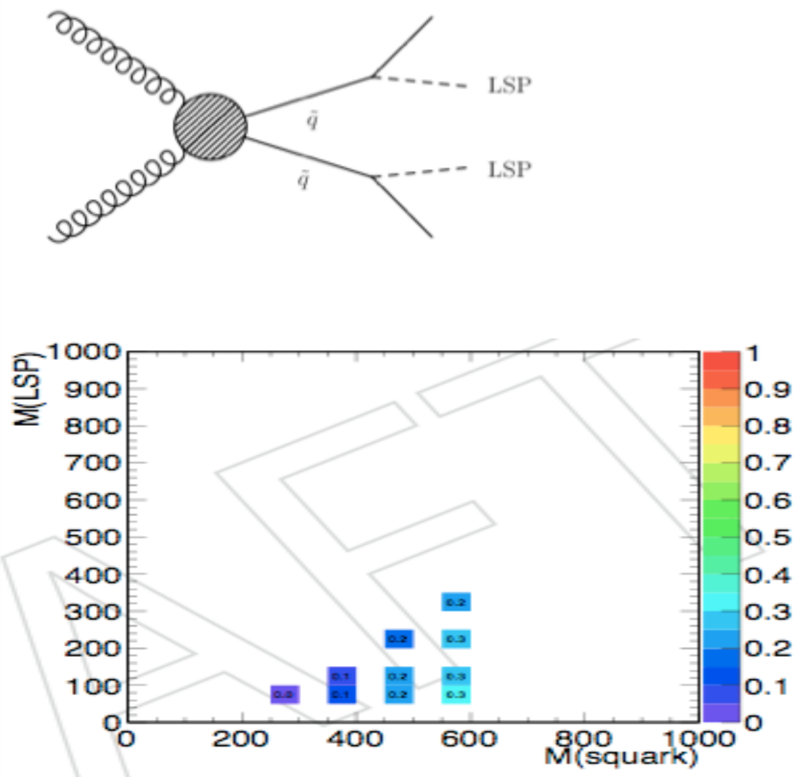
A discrete mass grid was chosen here to get an idea of what is going on in this plane.

We will likely provide contour plots.

Acceptance*efficiency

Ingredient #2





Comments #2:

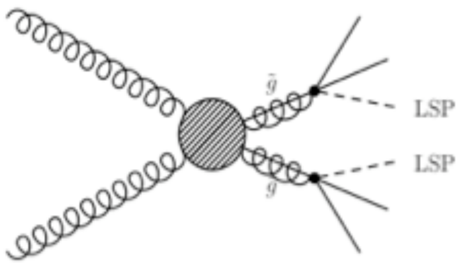
Do we need to split the acceptance*efficiency into two pieces ?

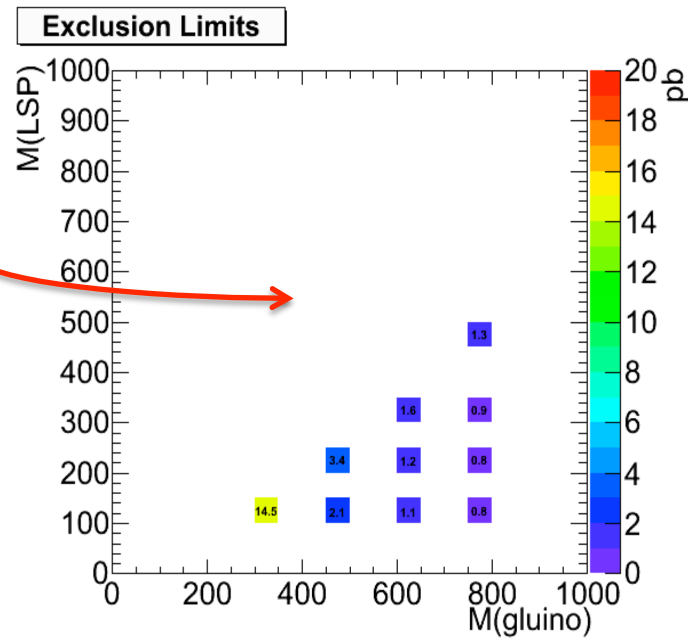
If yes, we need to define what constitutes "acceptance" and "efficiency"

Limits

Ingredient #2

$$(\sigma \times BR)_{max} = \frac{N_{max}}{Luminosity * Acceptance * Efficiency}$$





An example of how $(\sigma * BR)_{max}$ looks like:
with some pb-1 , we can exclude gluino pair production and decay to 4 jets + 2 LSPs with mass(gluino)=X mass(LSP)=Y and cross section above Z pb.

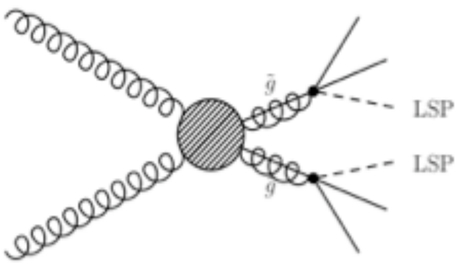
Comments #3:
Is a plot in this fashion in additional to the previous one helpful?

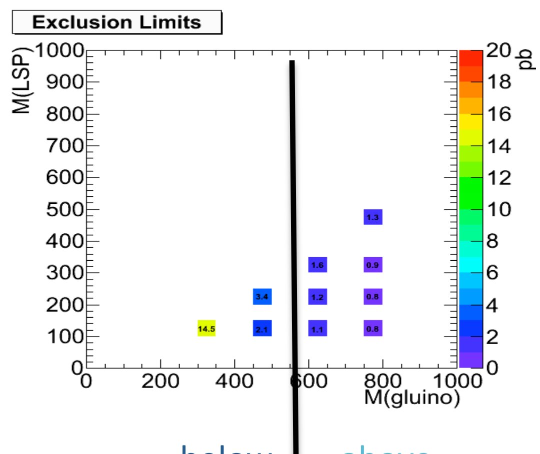
In the rest of the talk I will plot this

Usage of a reference cross section

Ingredient #3

As comparison the gluino pair production cross section calculated from Prospino (with m(squark)=Inf) are M=300 GeV σ=62 pb; M=450 GeV σ=4.76 pb; M=600 GeV σ=0.617 pb; M=750 GeV σ=0.16 pb





below above

the “reference” GG production

Hadronic analysis

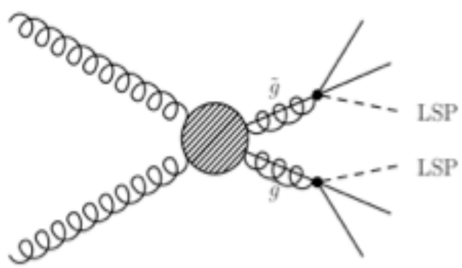
The next slides contain sets of limits on the cross section * BR for different topologies. This “reference cross section” line will be drawn to guide reading off the results.

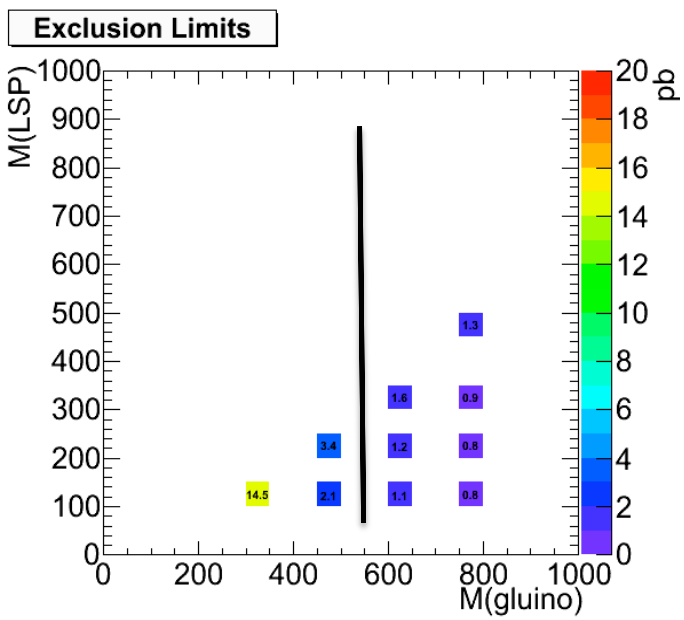
Only available for gluino pair-production (waiting for the squark reference xsec from theorists)

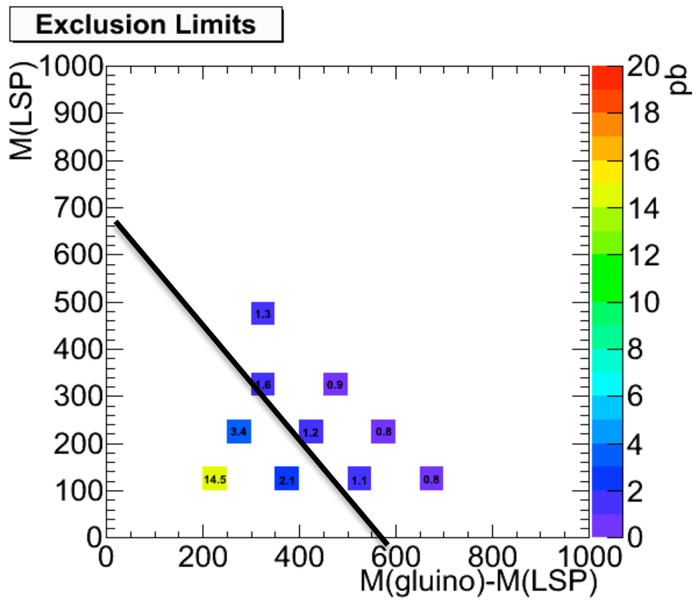
Axes variables

Hadronic analysis

Ingredient #4







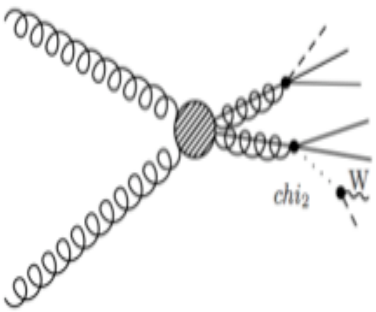
These are the same as the left column
Just different axes.

As a function of which mass do we represent this?

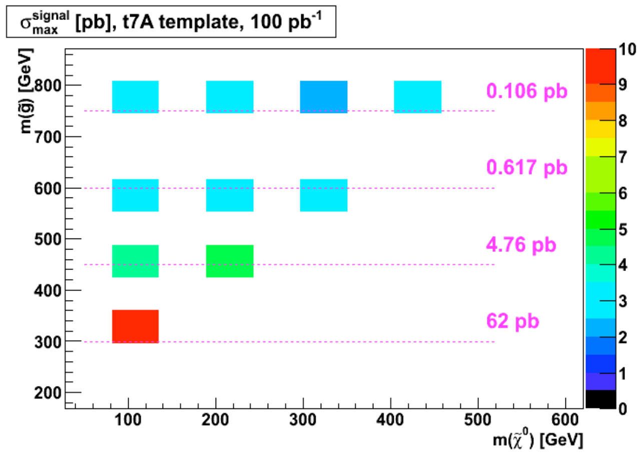
Variables on the axis

leptonic analysis

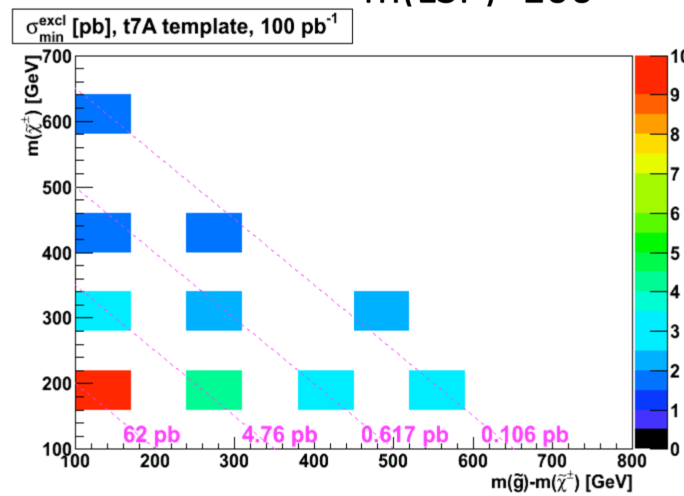
Ingredient #4



m(chi2)-m(LSP)=200



m(LSP)=100



Same results, two representations ☺

With more than two masses in the game, what is the best way to present the results for this topology? Which is the fixed mass? Which on the axis?

Limits and search optimization

General Comment

Different analyses are being finalized which look at:

- different signatures

  for example MET+jets vs MET+jet+leptons

- the same signature (i.e. fully hadronic) but with :
  - different kinematic cuts: high HT(MET);
  - other alternative variables sensible to the mass scale of the new particles (i.e Razor)
  - powerful variables able to kill different background (i.e. alphaT).

All these different nuances might lead to :

some analyses being better at catching some topology than the other

i.e. high HT is good for some topology and the high MHT is better for some other one

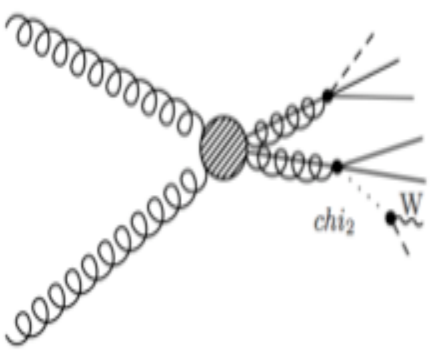
for the same topology, some stronger/weaker limit

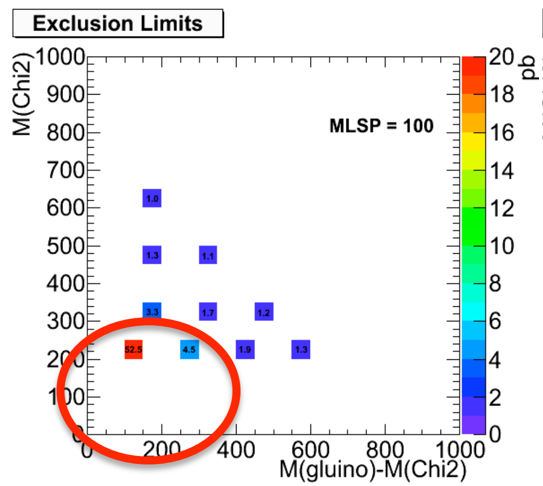
i.e. with 1 on shell W the leptonic searches can perform better than the hadronic.

The community can profit from more competitive limits for each topology/masses.

Different cut flow

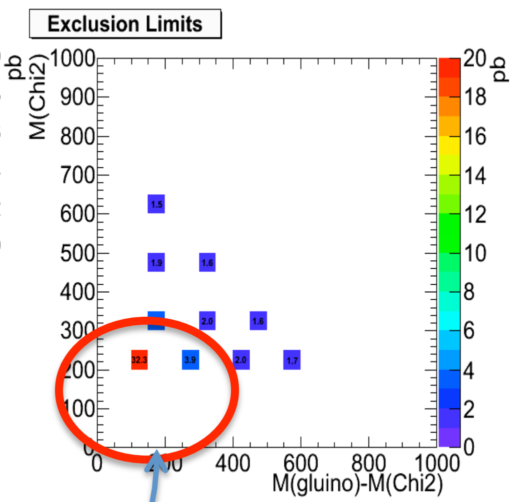
Adding more topologies
adding another selection





highMHT

Hadronic analysis



highHT

Hadronic analysis

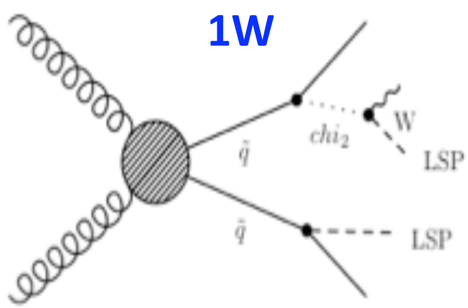
For the gluino pair/one-step cascade the high HT cut flow is more competitive than the high MHT cut flow. For example it provides a factor 2 reduction in σ max.

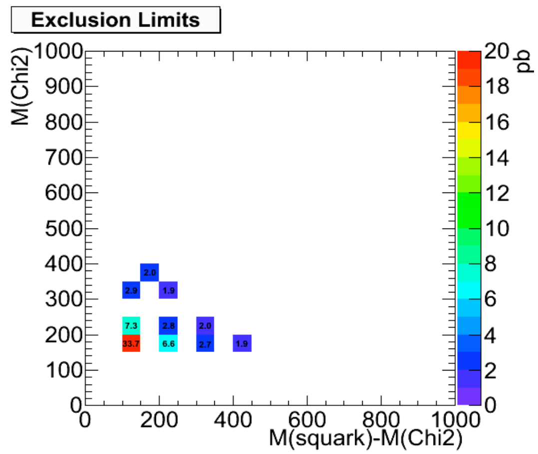
Search Optimization:

this is an important use case of simplified models

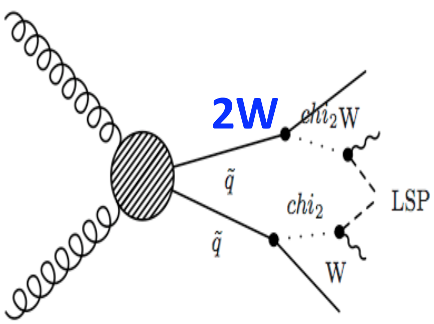
one vs two W cases

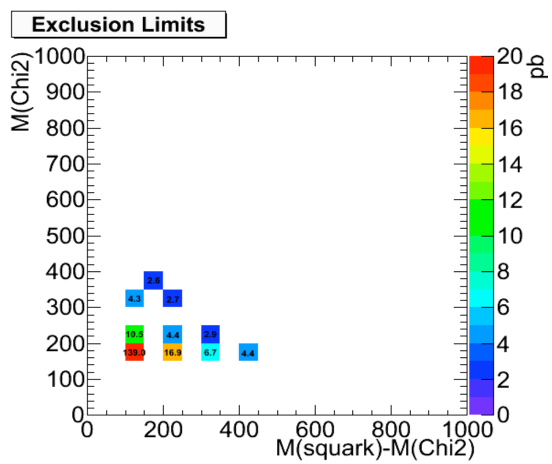
Adding more topologies





In the 1W channel the hadronic analysis performs well enough to be compared to the leptonic analysis.



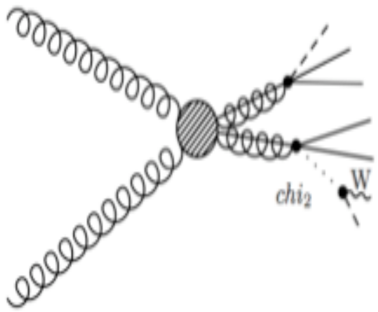


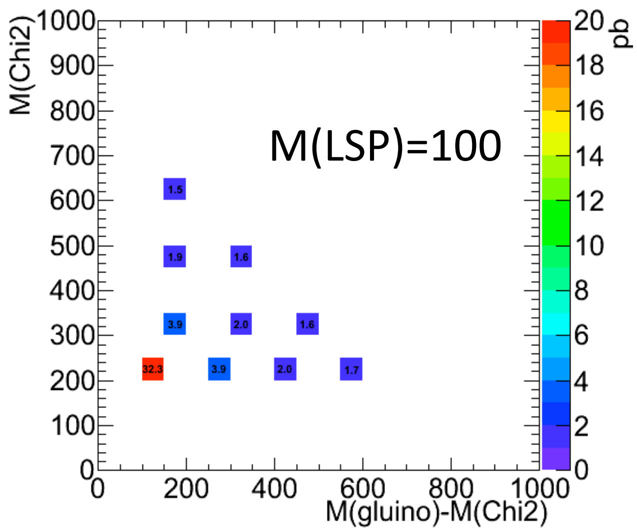
The hadronic analysis will have less selection efficiency compared to 0W decay chain due to

1. leptonVeto
2. less visible/invisible energy

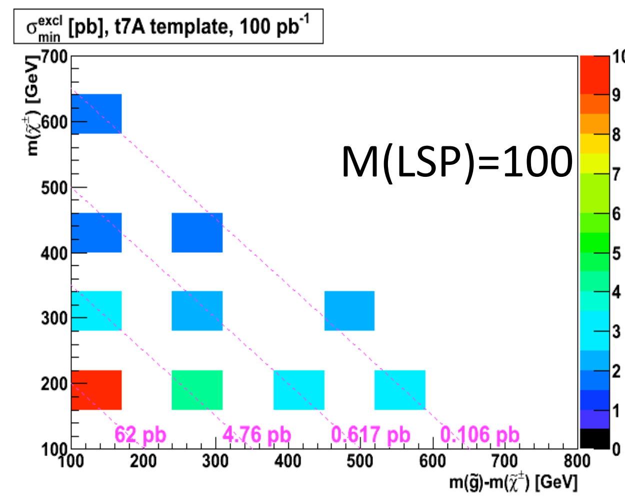
The leptonic analysis will do better than the hadronic analysis on the 2W channel.
The hadronic analysis will not evaluate the efficiency on the 2 W final state

Comparison had/lept searches





Hadronic analysis



Leptonic analysis

The leptonic analysis does better than the hadronic one for low masses …

now the W daughters (W->jj) are not boosted enough to produce the high pt jets pt>50
while on the contrary the lepton Pt can go lower

Comparable limits for the two analyses are seen for the high masses.

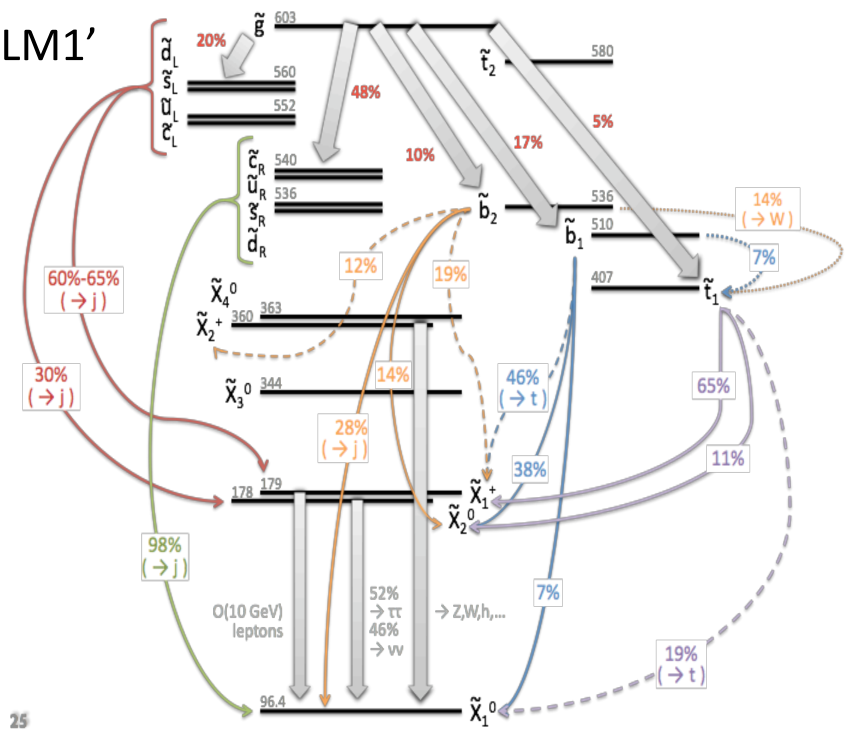
Combining results can give us more powerful limits

A use case

Last Ingredient

A theorist will have his/her own BSM model … for example “LM1” and he/she wants to know what are the limits on his/her model

‘LM1’



A few options:

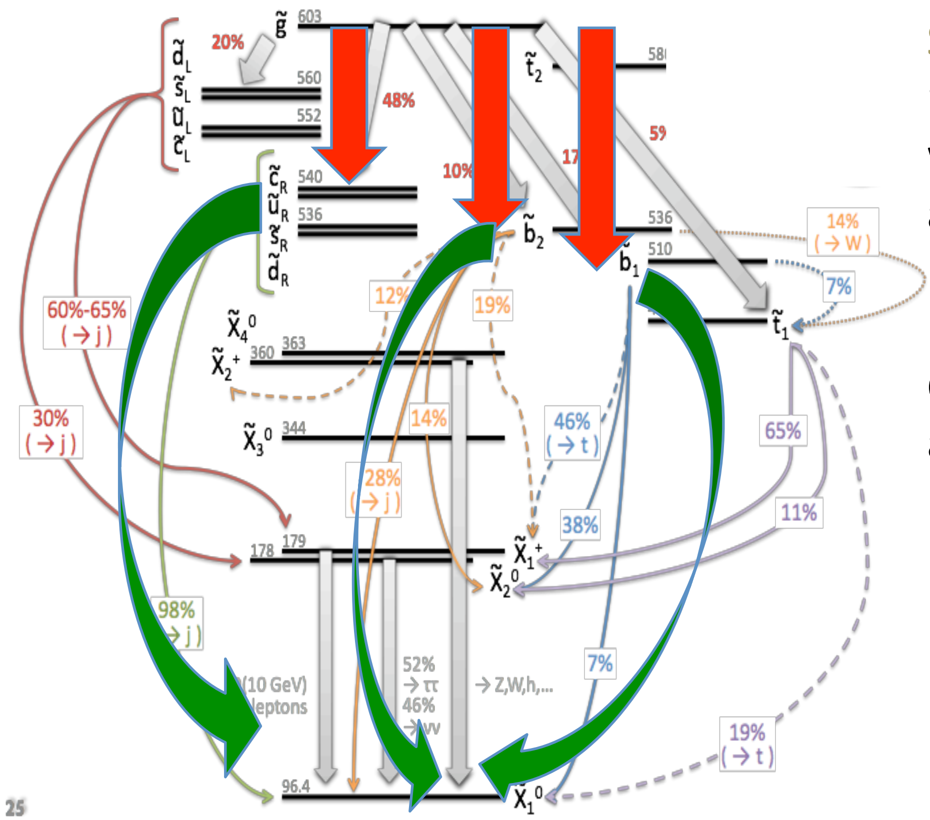
1. ask the experiments to evaluate his/her model

2. use a conservative approach (some ideas to start with in the next slides)

3. be more creative …
   homework for the next workshop

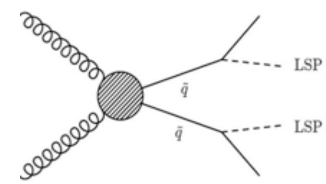
“LM1” = One of the CMS benchmark MSUGRA point

Approximate approach



Step1: As starting points we can compare "LM1" decay chains "close" to the topology for which the experiments have evaluated their acceptance/efficiency.

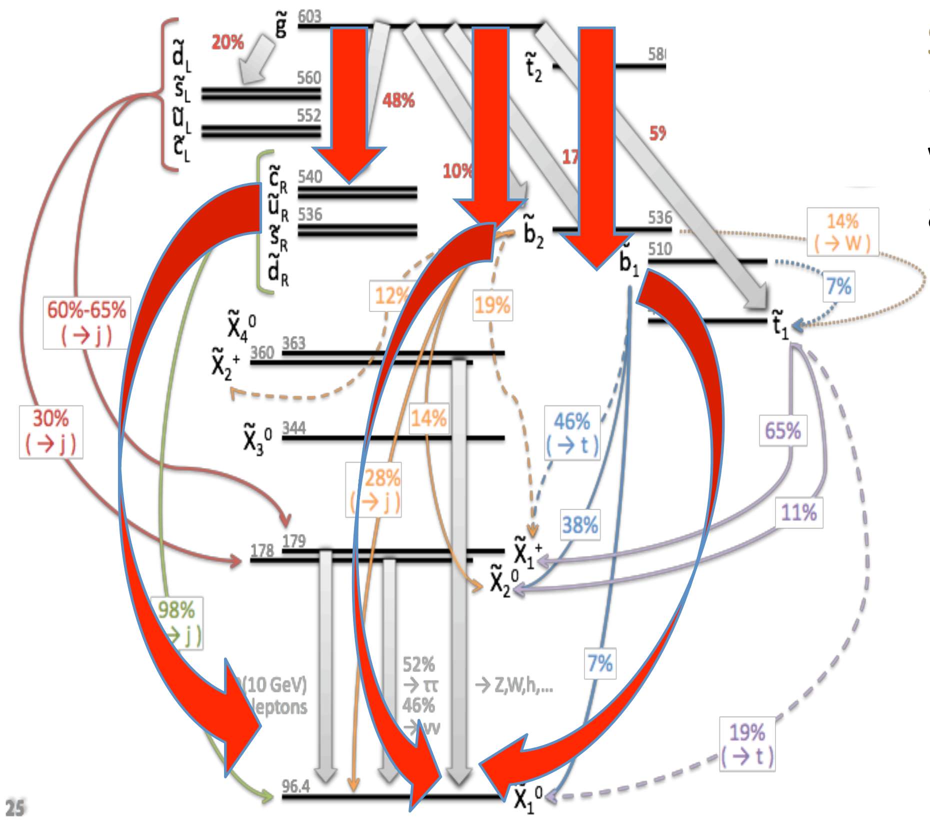
Conservatively, "close" means exact masses and the exact topology.



This may leave out some part of the "LM1".

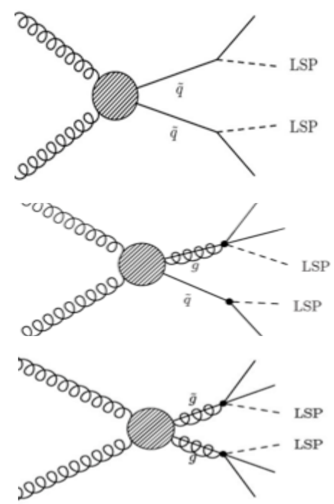
This fraction "not close" to simplified model will vary between models and how smart we have been in choosing the simplified models we use as basis.

Approximate approach



Step1: As starting points we can compare "LM1" decay chains "close" to the topology for which the experiments have evaluated the acceptance/efficiency.

But we have all these



$(\sigma^{*}BR_{qq}/\sigma_{tot})$

$(\sigma^{*}BR_{gq}/\sigma_{tot})$

$(\sigma^{*}BR_{gg}/\sigma_{tot})$

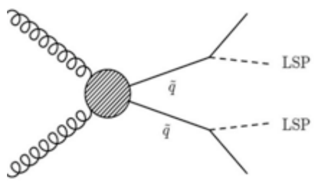
How do we define "close"? *compare distributions of your model to the simplified model*
And obtain effective fractions by fitting these distributions.

Approximate approach

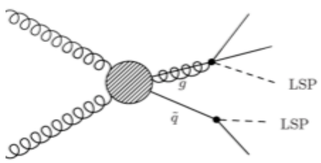
Nmax

theorist

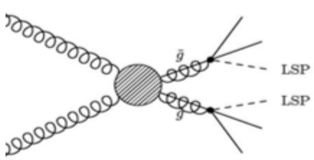
Experiments
(central value plus uncertainties)



$(\sigma * BR_{qq} / \sigma_{tot})\ A * \varepsilon_{qq}$



$(\sigma * BR_{gq} / \sigma_{tot})\ A * \varepsilon_{gq}$



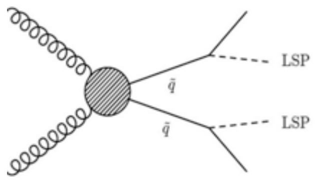
$(\sigma * BR_{gg} / \sigma_{tot})\ A * \varepsilon_{gg}$

Step2: Take from the *"experiments bank"* the acceptance/efficiency corresponding to mass and topology and the number Nmax.

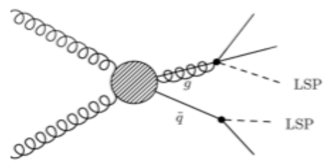
Approximate approach

Nmax

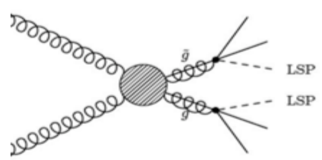
theorist — Experiments (central value plus uncertainties)



$(\sigma * BR_{qq} / \sigma_{tot})\ A * \varepsilon_{qq}$



$(\sigma * BR_{gq} / \sigma_{tot})\ A * \varepsilon_{gq}$



$(\sigma * BR_{gg} / \sigma_{tot})\ A * \varepsilon_{gg}$

Step 3: apply the simplified model limit **ONLY** to closely related topologies from a specific model

Write the approximate limit:

$$(\sigma \times BR)_{max}(approximate) = \frac{N_{max}}{Luminosity * ((\sigma * BR)_{gg} * \epsilon_{gg} + (\sigma * BR)_{qg} * \epsilon_{qg} + (\sigma * BR)_{qq} * \epsilon_{qq})}$$

Ideal case

$$\sigma x BR > \frac{N_{max}}{Luminosity * \Sigma f_i \epsilon_i}$$

All channels

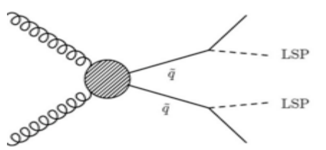
Advantage: you can get very easily this approximate limit on your model immediately after the experiments' publications.

Approximate approach

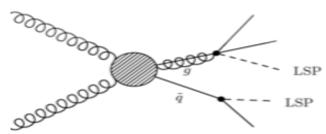
Nmax

theorist

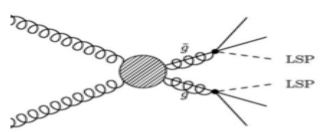
Experiments
(central value plus uncertainties)



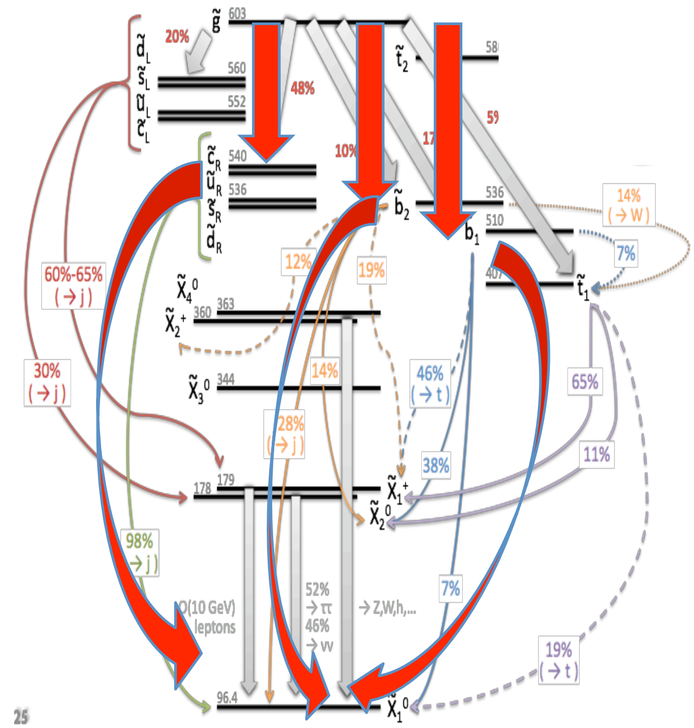
$(\sigma^* BR_{qq} / \sigma_{tot})\ A^* \varepsilon_{qq}$



$(\sigma^* BR_{gq} / \sigma_{tot})\ A^* \varepsilon_{gq}$



$(\sigma^* BR_{gg} / \sigma_{tot})\ A^* \varepsilon_{gg}$



Approximate limit ~ $(\sigma^* BR_{qq}/\sigma_{tot} {*} A^* \varepsilon_{qq} + \sigma^* BR_{qq}/\sigma_{tot}\ A^* \varepsilon_{qq} + \sigma^* BR_{gq}/\sigma_{tot}\ A^* \varepsilon_{qg})^{-1}$

~ 8.3 (moderateMET)

~ 12.5 (highMET)

Full blown LM1 limit ~ $1/(\sigma^* BR^* \varepsilon)$ ~ 6.6 (moderateMET)

~ 10 (highMET)

So the approximate limit is 20% weaker but it is because we used less information … → next slide

Some step more

- With the "approximate limit" approach, some sectors of the model are not probed.

We can reiterate:

- Might need to extend the set of reference topologies.
  - It is better to think now or will need to wait in line
  - Already now we could have added the QL > q (chi2 -> nu nubar chi1) ?-- about 14% of QL's -- which looks like the same simplified model but with masses 550-560 and 180.

- One might find a way to represent the unprobed sectors in terms of those topologies available now
  - For example. Can try to condense a 6 jets topology to 4 jets topology.

Summary

- Standard cut flows have been used to demonstrate the procedure to set limits using some simplified models.
- A few conventions are needed *(see next slide)*.
- An example of how to deduce an approximate limit on a specific BSM model is presented.

Summary of the questions raised

We need to agree on:

1. minimal set of topology for each search
2. contour lines instead of a mass grid
3. Variables to put on the axes: mass splitting or raw mass, in case of 3 new particles, which one has to be fixed?
4. variables to plot: efficiency or maximum cross sections allowed.
5. Draw reference cross sections line.
6. ...

Do we agree on these?

backup

Just for comparison

http://www.lhcnewphysics.org/wiki/index.php?title=SimplifiedModels:GluinoOneStage

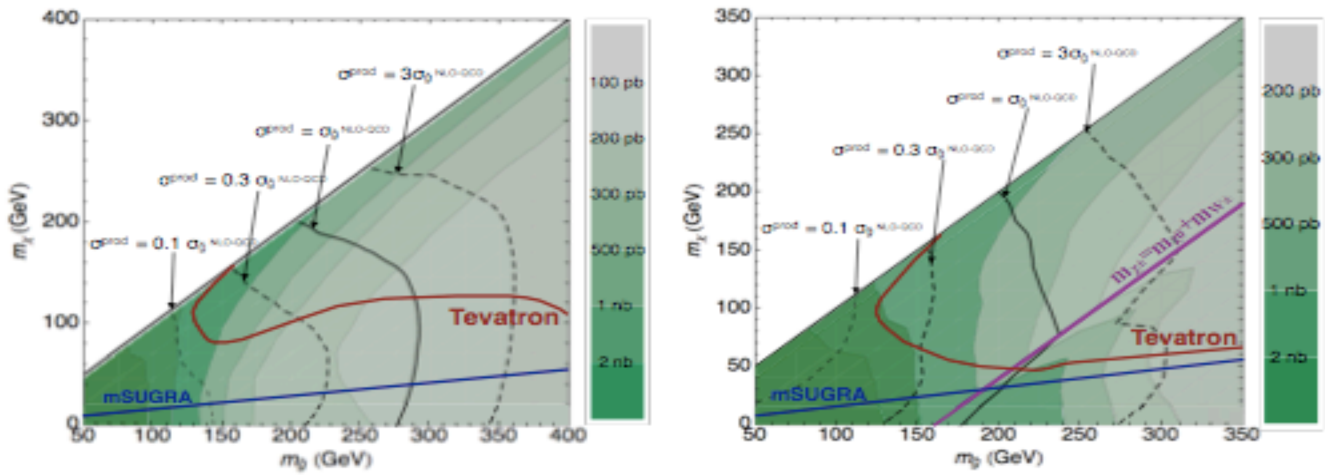


FIG. 1: Estimated limits from [5] based on re-interpretation of D0 (red line) and ATLAS (black lines and contours) searches in the context of this module, when only one "gluino" decay mode is turned on. The left figure corresponds to only the direct decay (Mode 1), and the right to only cascade decay (Mode 3). See text for explanation of each of the lines in the figure