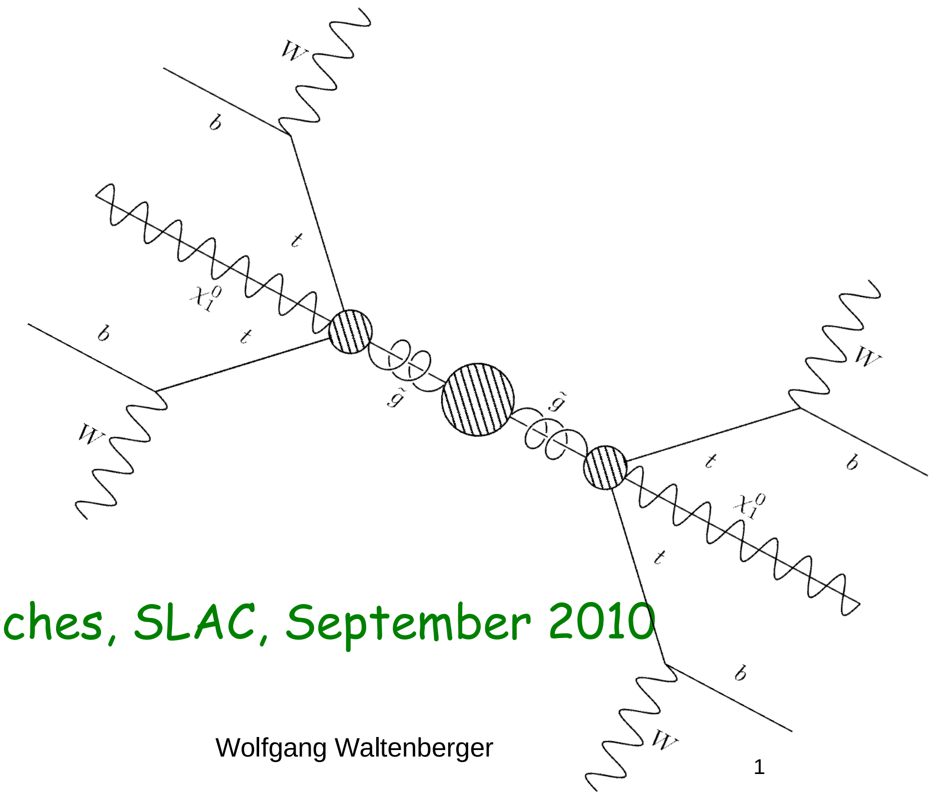
CMS Perspectives on Topology-Based Approaches for Beyond the SM Searches

Wolfgang Waltenberger,
for the
CMS collaboration



Workshop on topologies for early LHC searches, SLAC, September 2010

LHC - A situation unlike any in the past

Past

Gauge bosons (W, Z) [1983]:

Masses and production rates were predicted, signals stood out "like being hit on the head with a hammer" [© Joe Incandela]. Interpretation was unambiguous.

Top quark [1995]:

Signal was much harder to dig out, but people knew "it had to be there", production and decay properties were predicted.

Present moment

Higgs boson [?]:

Situation is much like the top quark case: we know it has to be somewhere. Given the mass, production and decay properties are known (SM Higgs, as well as many alternative models).

Going Beyond the Standard Model [?]:

We have a whole plethora of interesting models, all of which come with a nice amount of model parameters. Production and decay properties are unknown. For a start, we can only search for very generic features, e.g. missing energy due to production of WIMPs.

A situation unlike in the past asks for novel tools and techniques.

As to the near future ...

There are always two very distinct situations:

Option A: we dont see BSM (beyond-the-standard-model) physics.

We will need to describe what can be excluded. Additionally to excluding on a model-per-model basis, OSETs enable us to describe what we dont see in a more generic fashion.

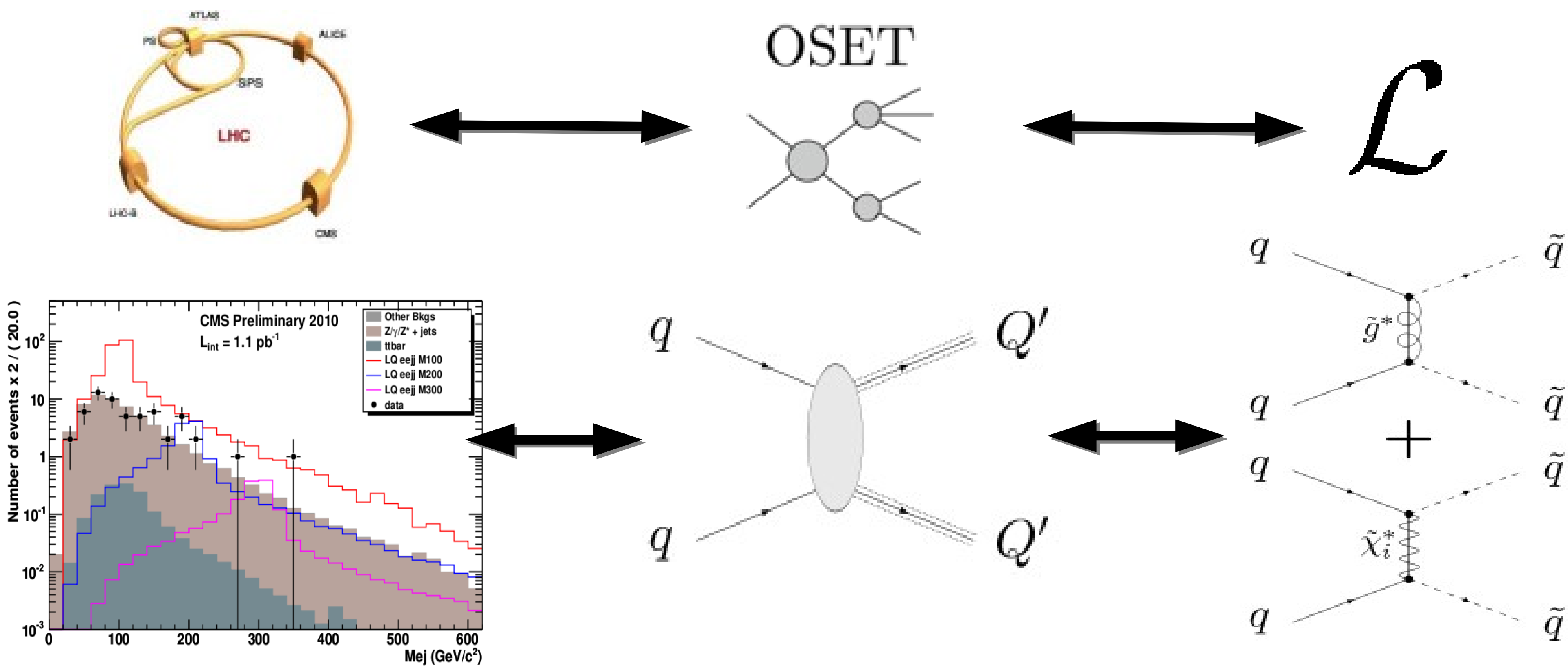
Option B: we have evidence for new physics.

What would we do next? How would we interpret it?
SUSY, UED, Conformal Technicolor, Little Higgs models have many things in common. E.g. they all have partners to existing standard model particles.
So how do we envisage to discriminate between all these different models?
All of them can be tuned all too easily.

The work is too complicated and too much for us experimentalists to do it ourselves.
We want and need close collaboration with the theorists. Also, the theorists cannot do it by themselves – the experiments are far too complicated for this. We need to collaborate. We need a common language.

Communication and division of labor

Going towards new physics, we experimentalists cannot do the work by ourselves. We need a dialog with theorists, we need to iterate on the questions we ask and the answers we find. For this, we need an efficient way to communicate between the two communities, and the language which seems adequate here is the language of on-shell effective theories (OSETs).

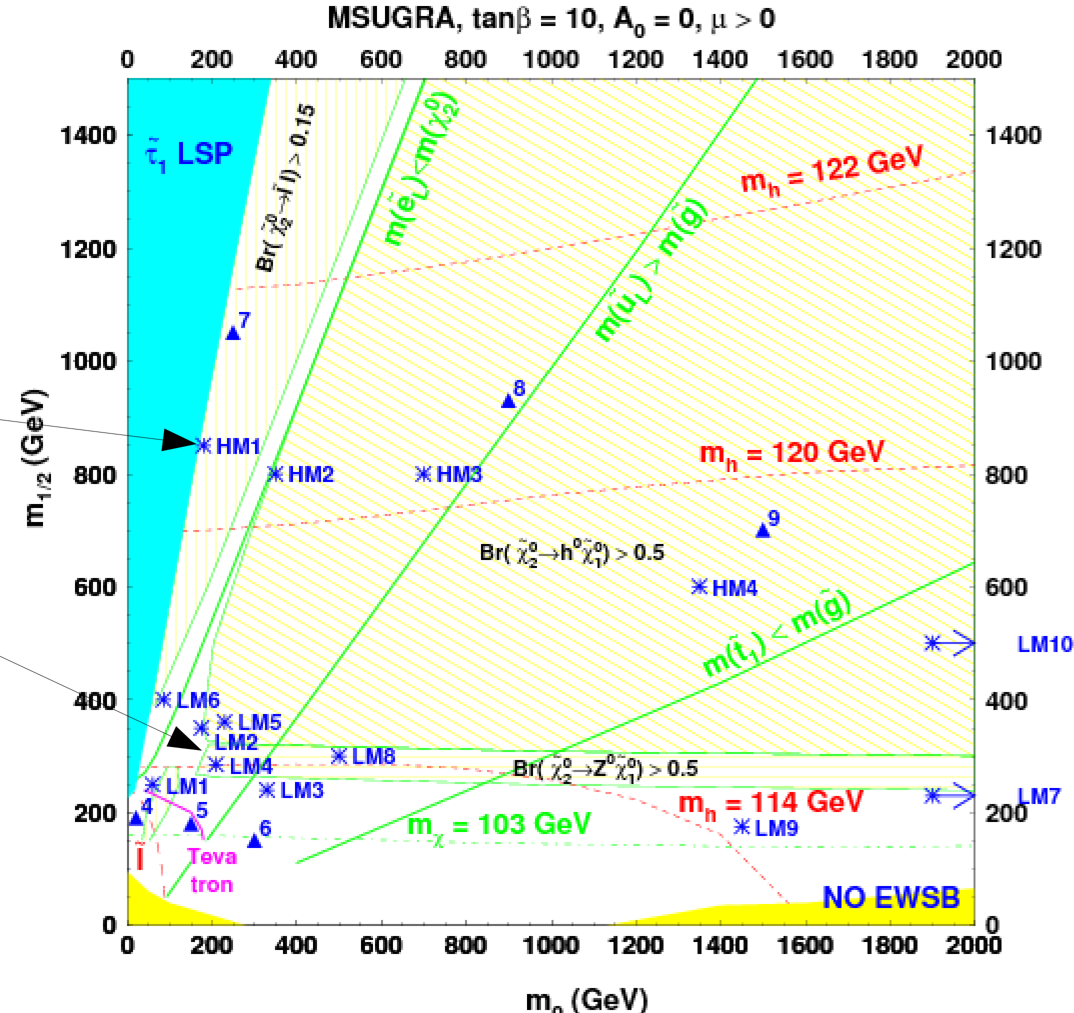


How we evaluated our search strategies until recently

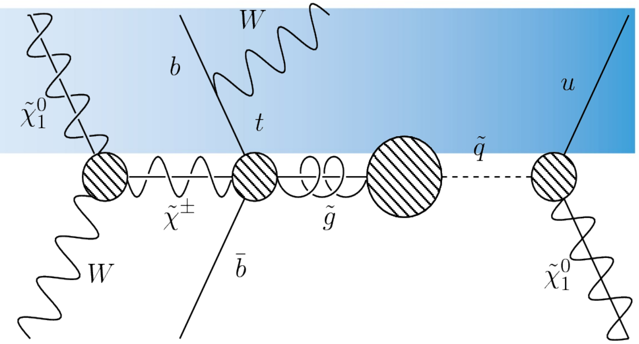
Until recently, the CMS SUSY search groups focussed on the mSUGRA and the GMSB models. Even more specifically, special working points have been defined within these models.

HM: High mass points

LM: Low mass points

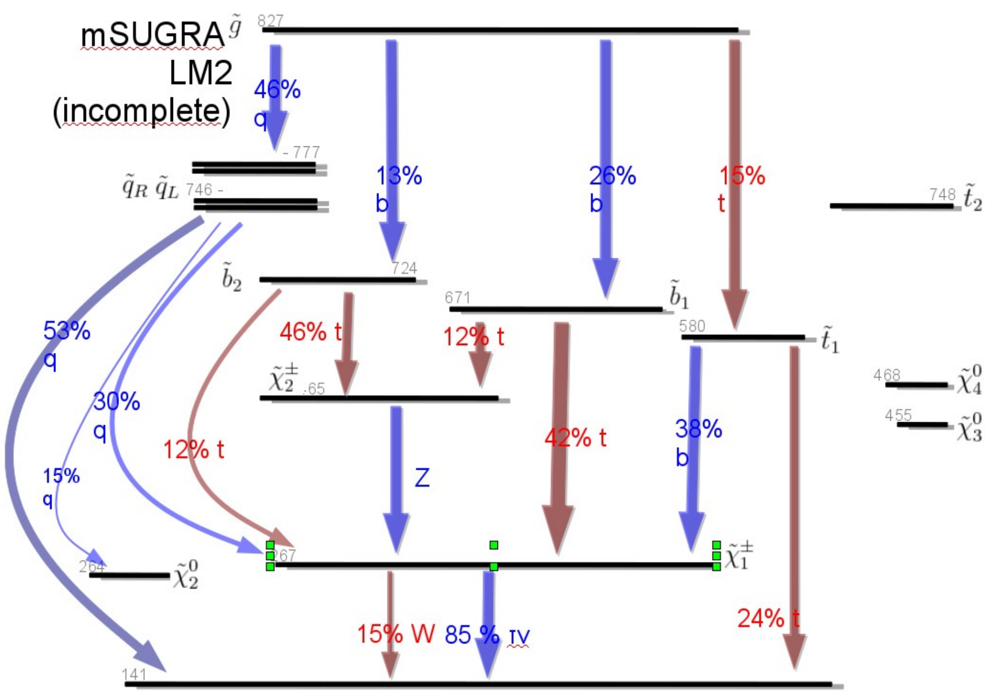


The power of simplification

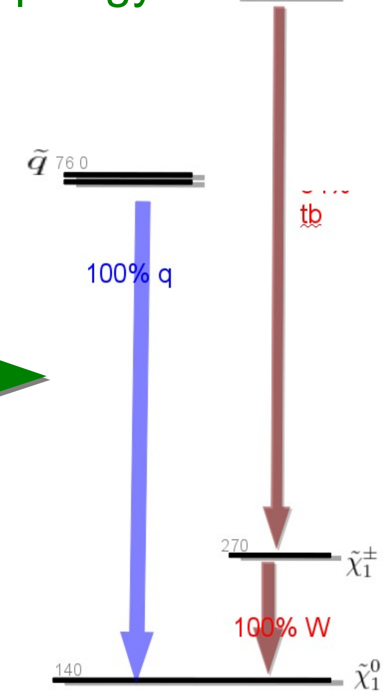


A comparison between "full" mSUGRA events and highly simplified OSET events.

incomplete decay table of a certain mSUGRA point



complete decay table of the simplified OSET topology



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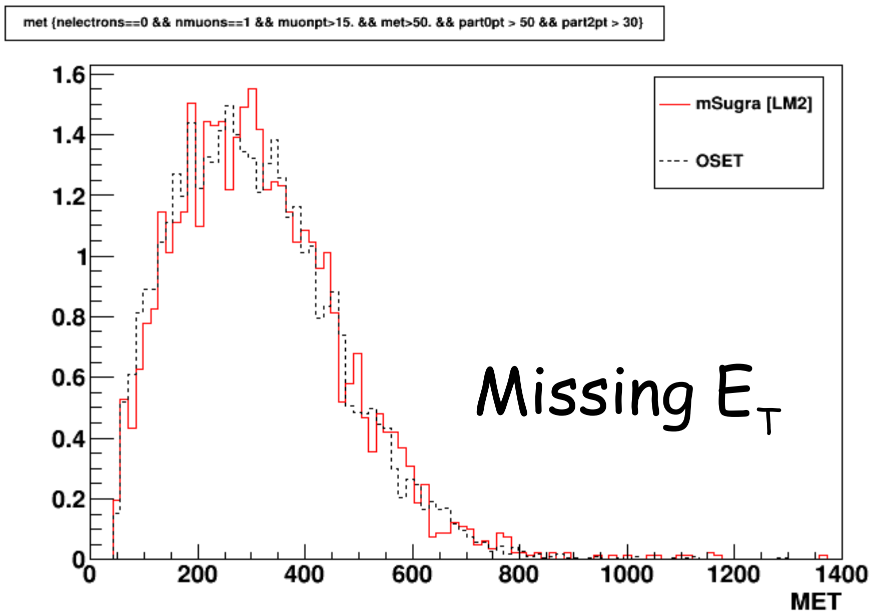
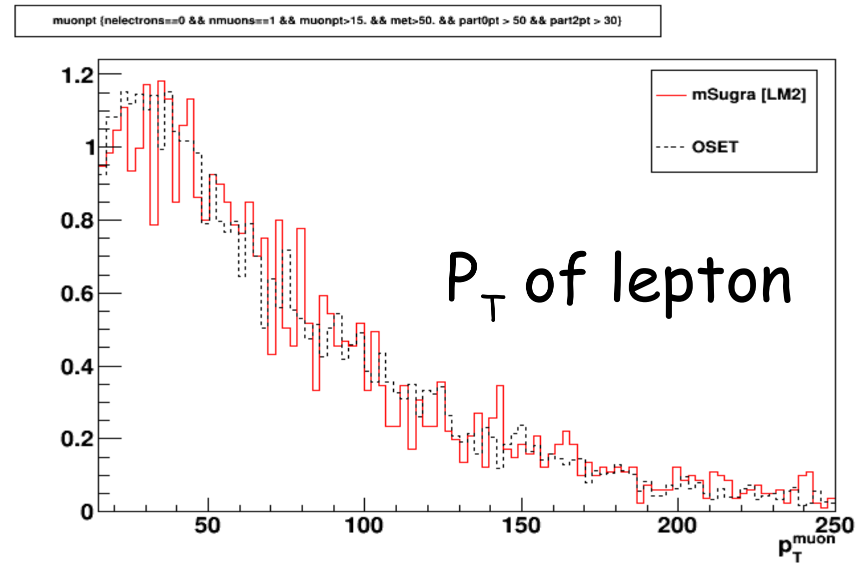
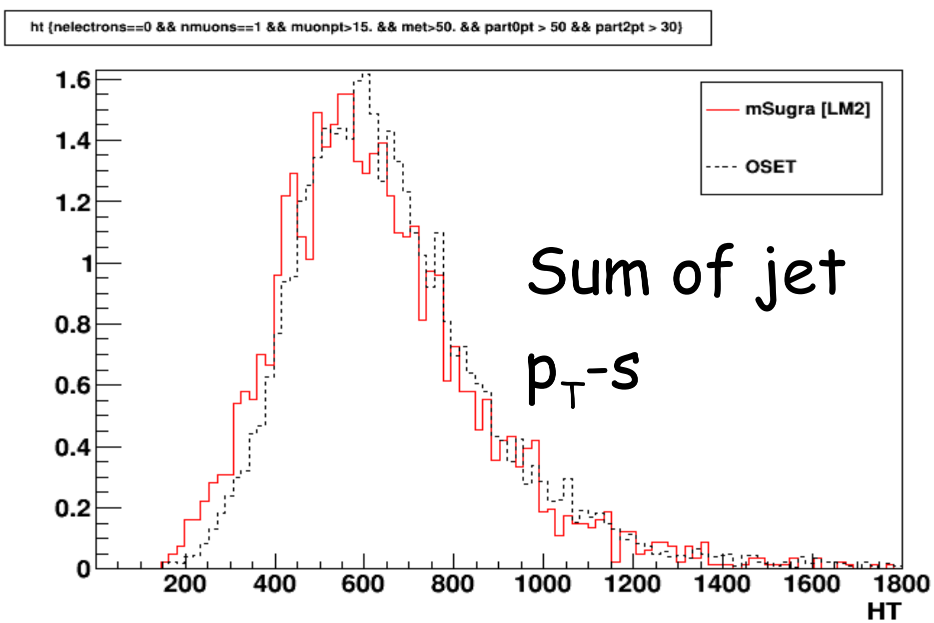
The power of simplification



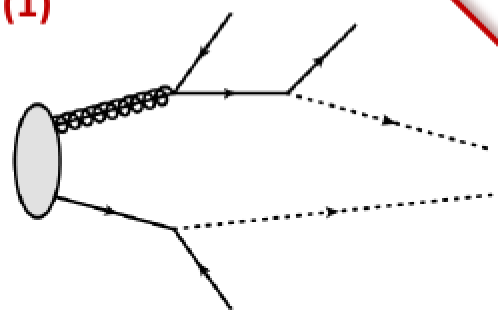




Comparison of distributions *before* detector effects!

The power of simplification

(1)



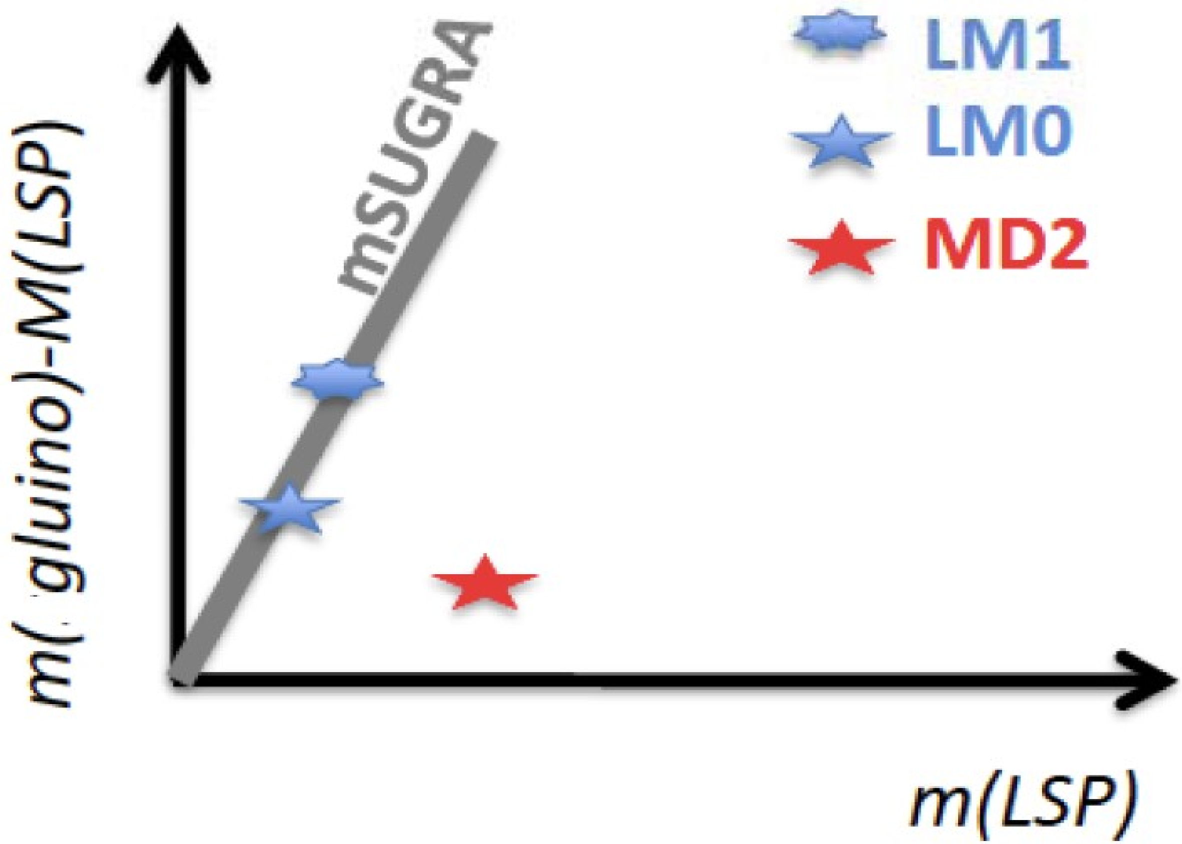
gluino > ubar sup
sup > u LSP

The recommended OSET model for each LM point here is indicated by the number of particles, i.e. (1) for all but LM4 and LM5.

	σ (pb)	M(G)	M(U)	M(C)	M(LSP)	χ^2/ndf
LM1	16.06	600	500 [(-)]		100	10
LM2	2.42	830	700 [(-)]		140	15
LM4	6.70	690	640	210	150 [(+)]	28
LM5	1.94	850	780	270	180 [(+)]	37
LM6	1.28	930	780 [(-)]		160	21
LM11	3.24	780	680 [(-)]		130	38

The power of generalization

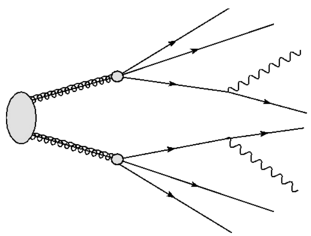
OSETs allow us to generalize to regions outside of the mSUGRA parameter space.



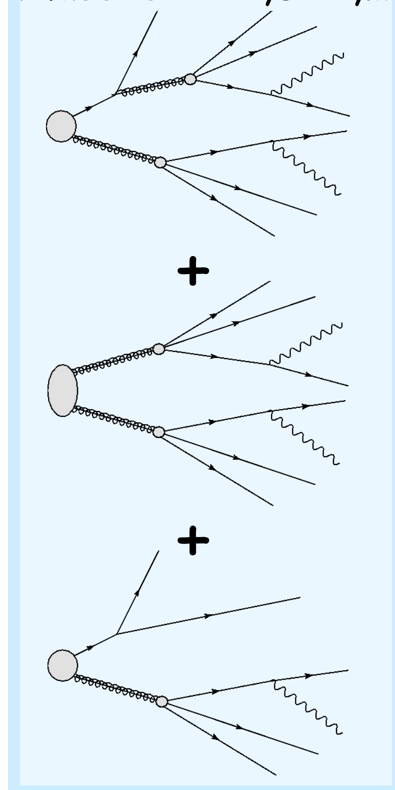
CMS searches for new Physics with OSETS

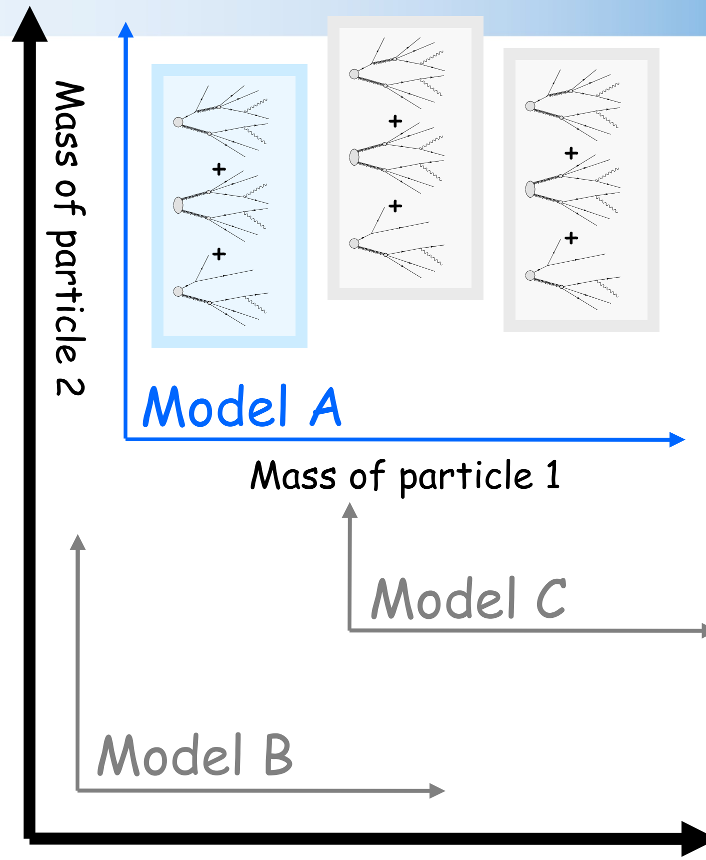
OSET Process | OSET Model | BSM Physics

Masses=200,600,...



Masses=200,600,...

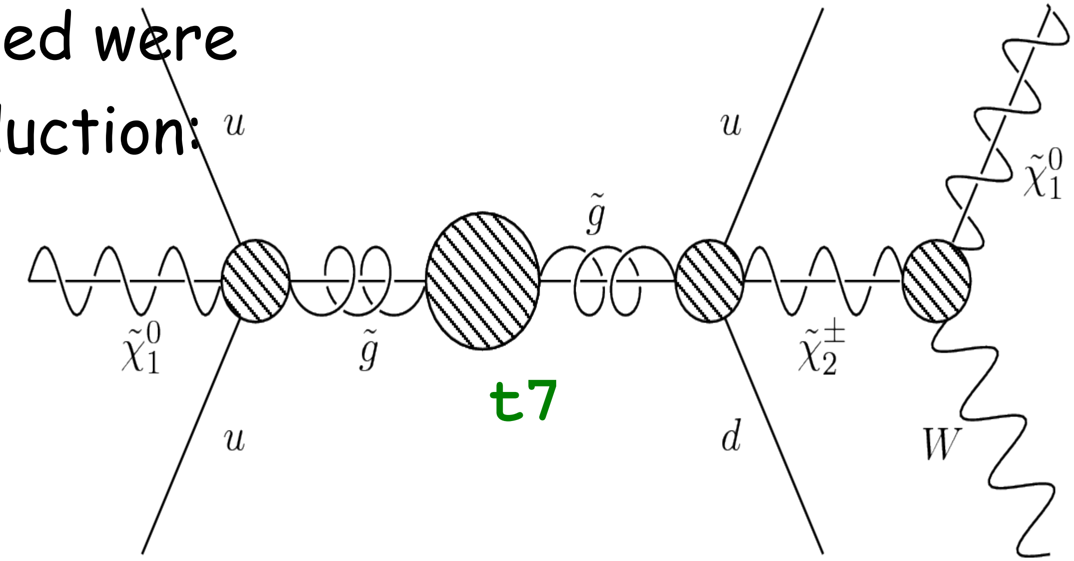




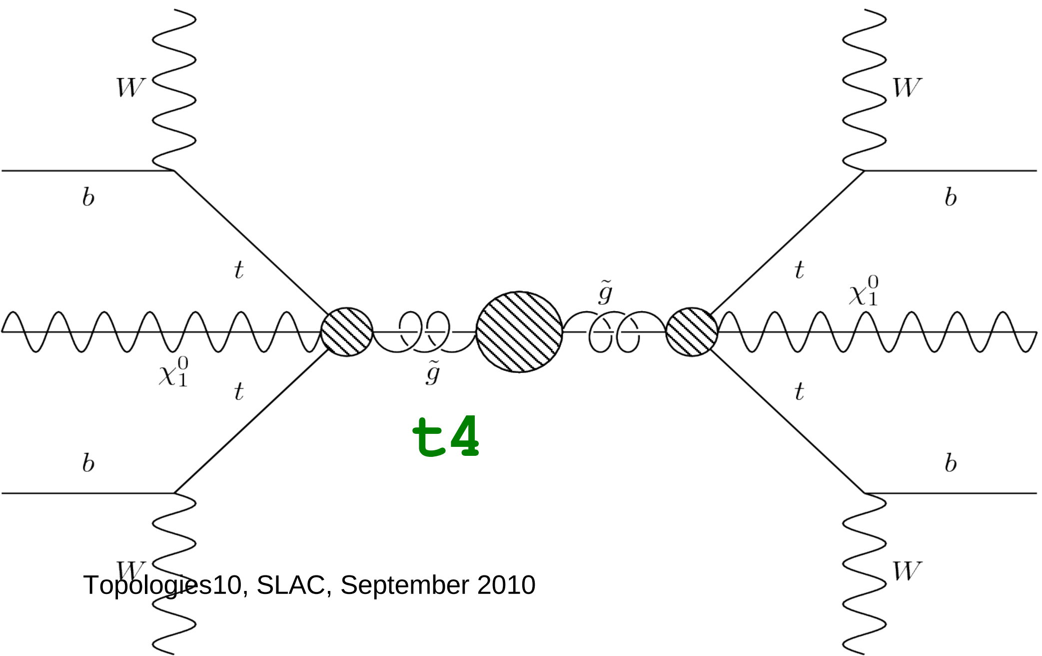
- Is there any hope of a > ε contribution?
- Can this combination of processes fit together reasonably to explain signal?
- For a given model: What are the "best" choice of masses for the particles?

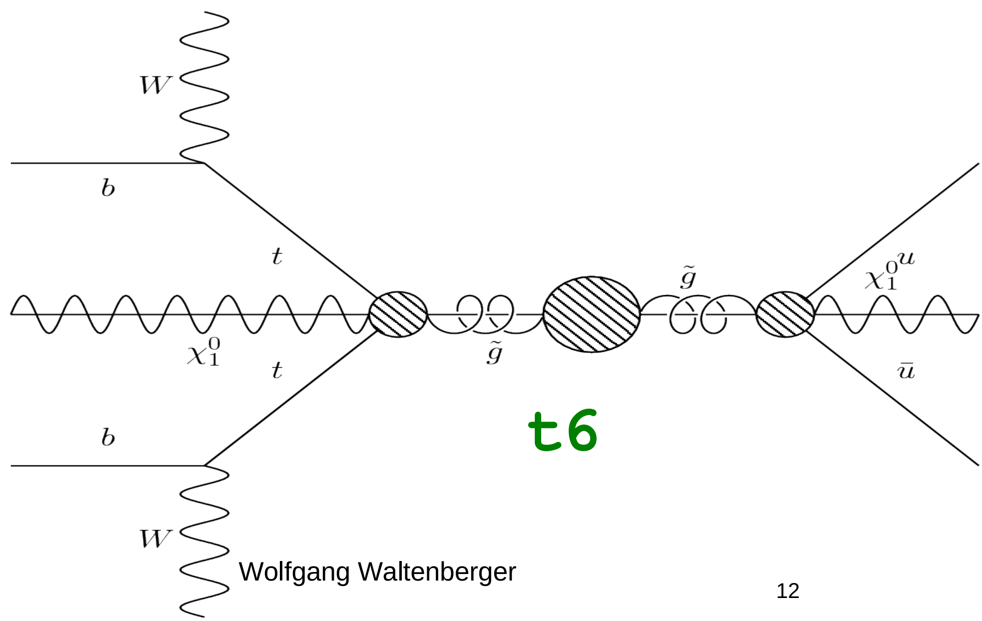
Templates tried so far

The first templates we have tried were SUSY-inspired gluon-gluon production:



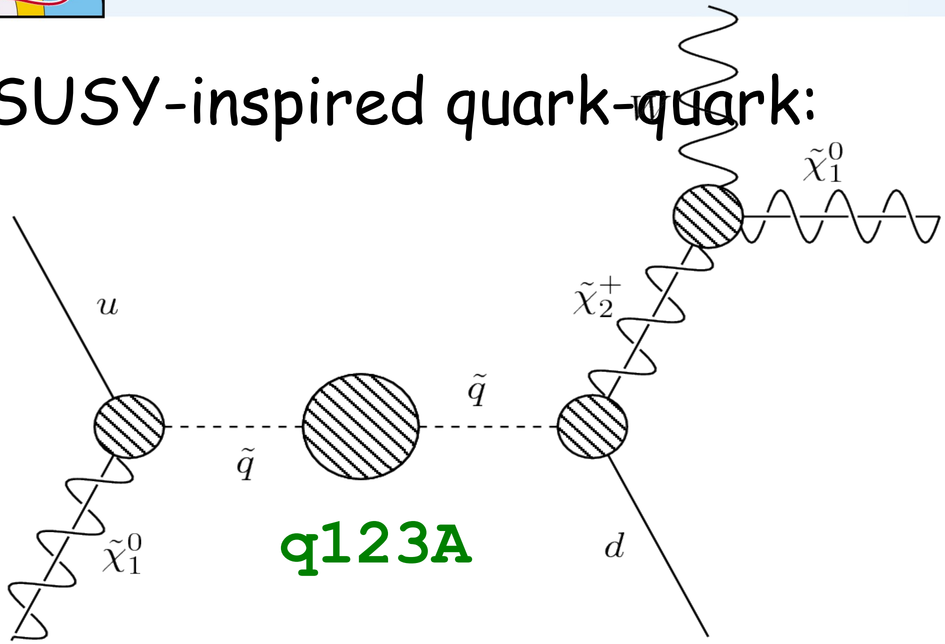
All templates have been "designed" by Philipp and Natalia

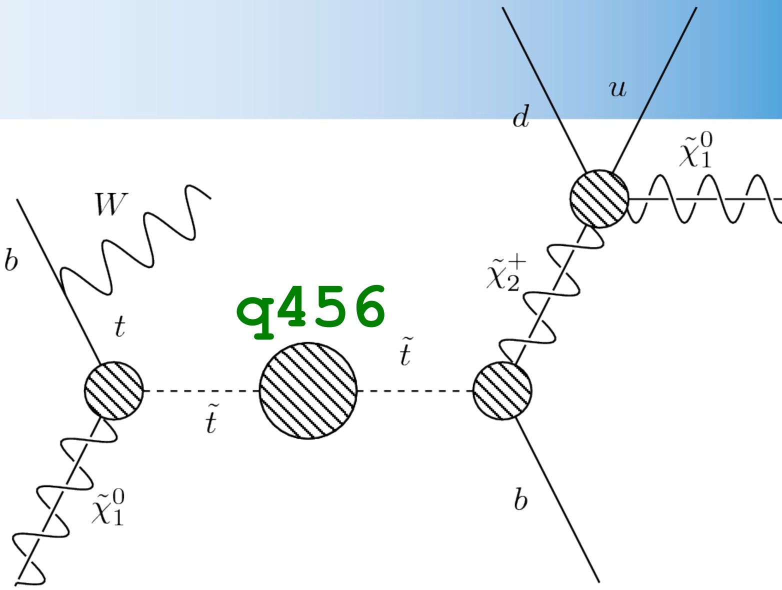




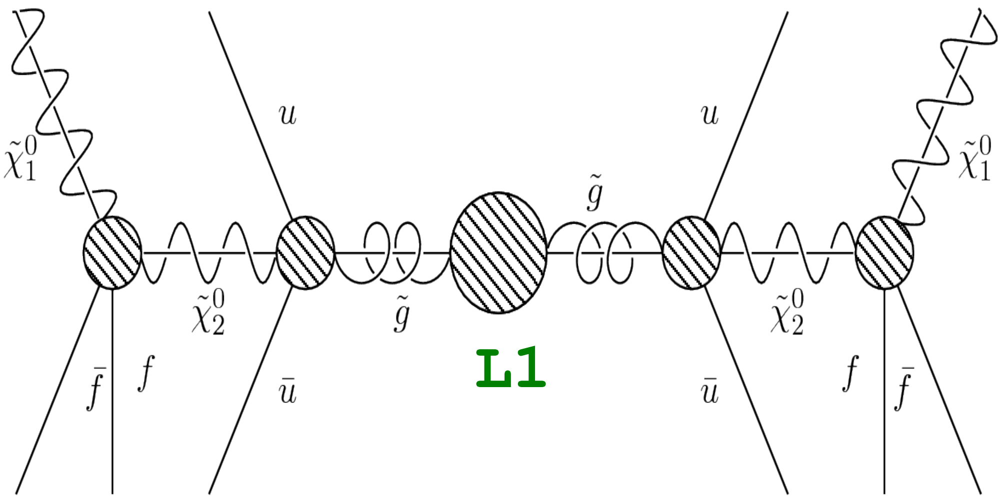
Templates tried so far

SUSY-inspired quark-quark:





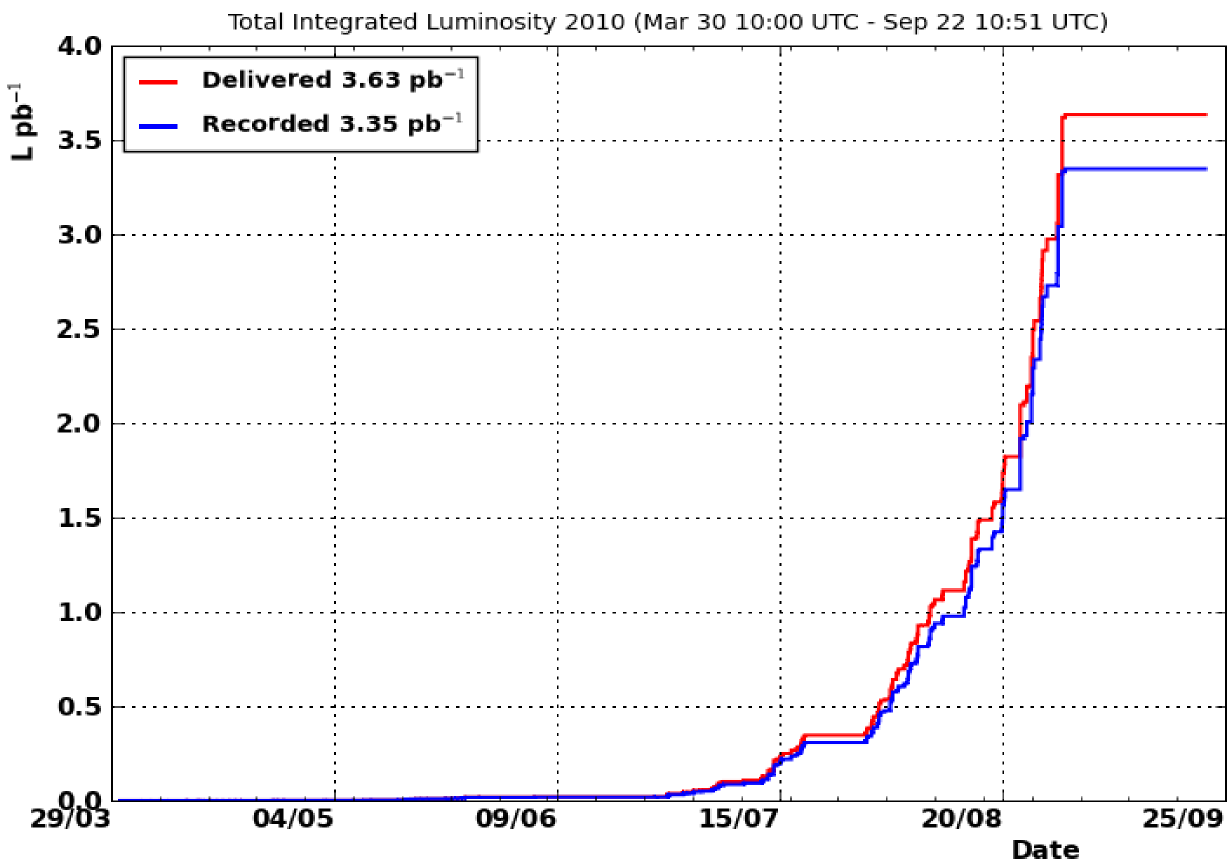
"Exotic":



CMS status (in terms of integrated Luminosity)

This year has two more months of LHC data taking. Our guess for the end of the year is ~ 30 pb^{-1}

The promise is to have 1 fb^{-1} by the end of next year.

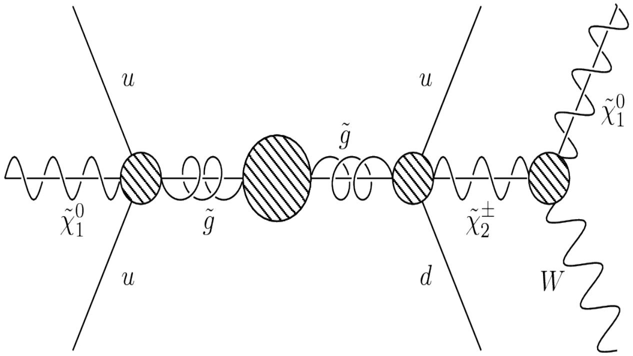


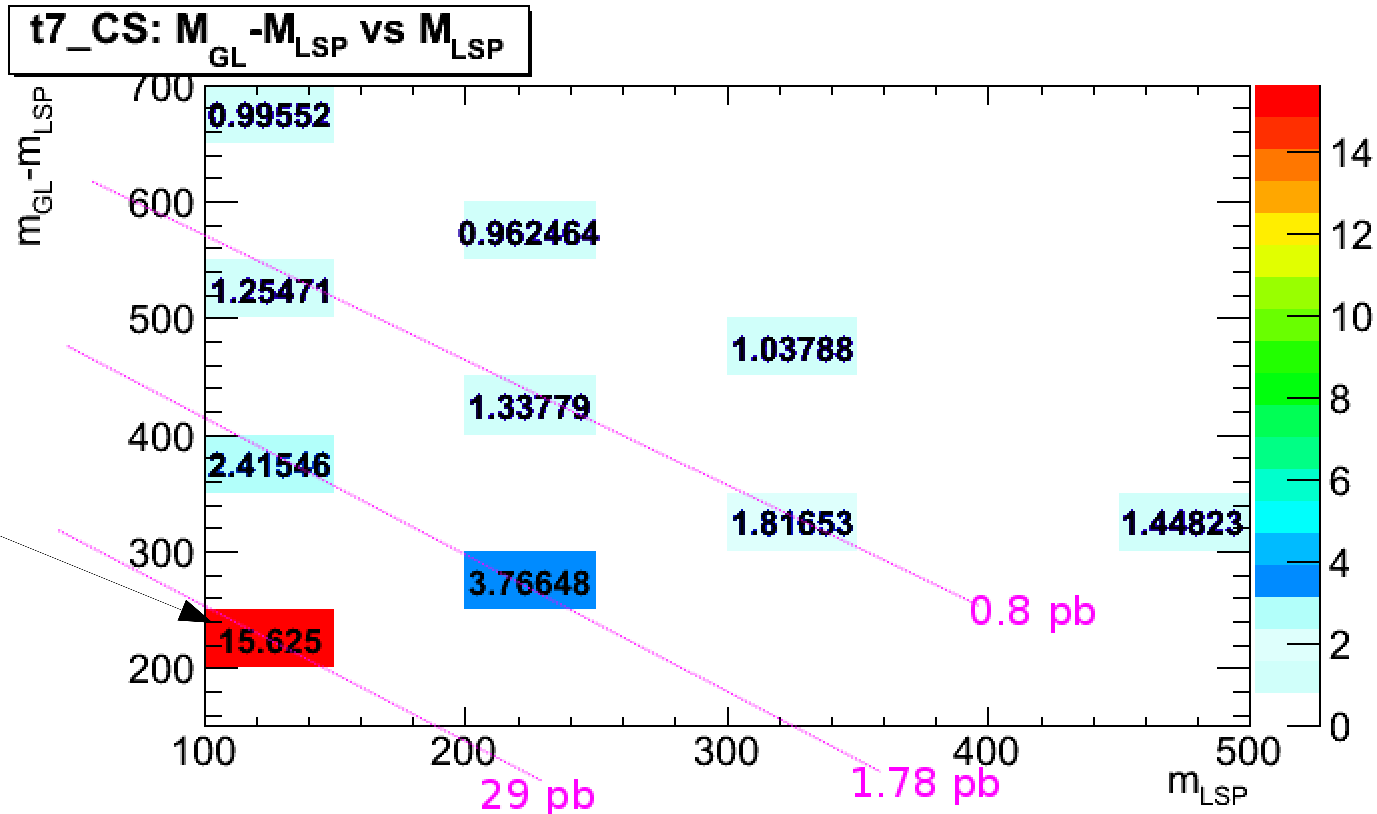
Description of the **feasibility studies**

- Now we go from the generator to the reco level.
- We applied our standard selection cuts on the OSET Samples.
- We did not employ a full blown analysis; more specifically, we did not use our standard background estimation techniques. Rather, we considered the Poissonian error of the backgrounds as our statistical error plus
- We subsumed many nuisances into a systematic error.

Hadronic searches
(jets + MET)

What can we exclude with 100 pb^{-1}?



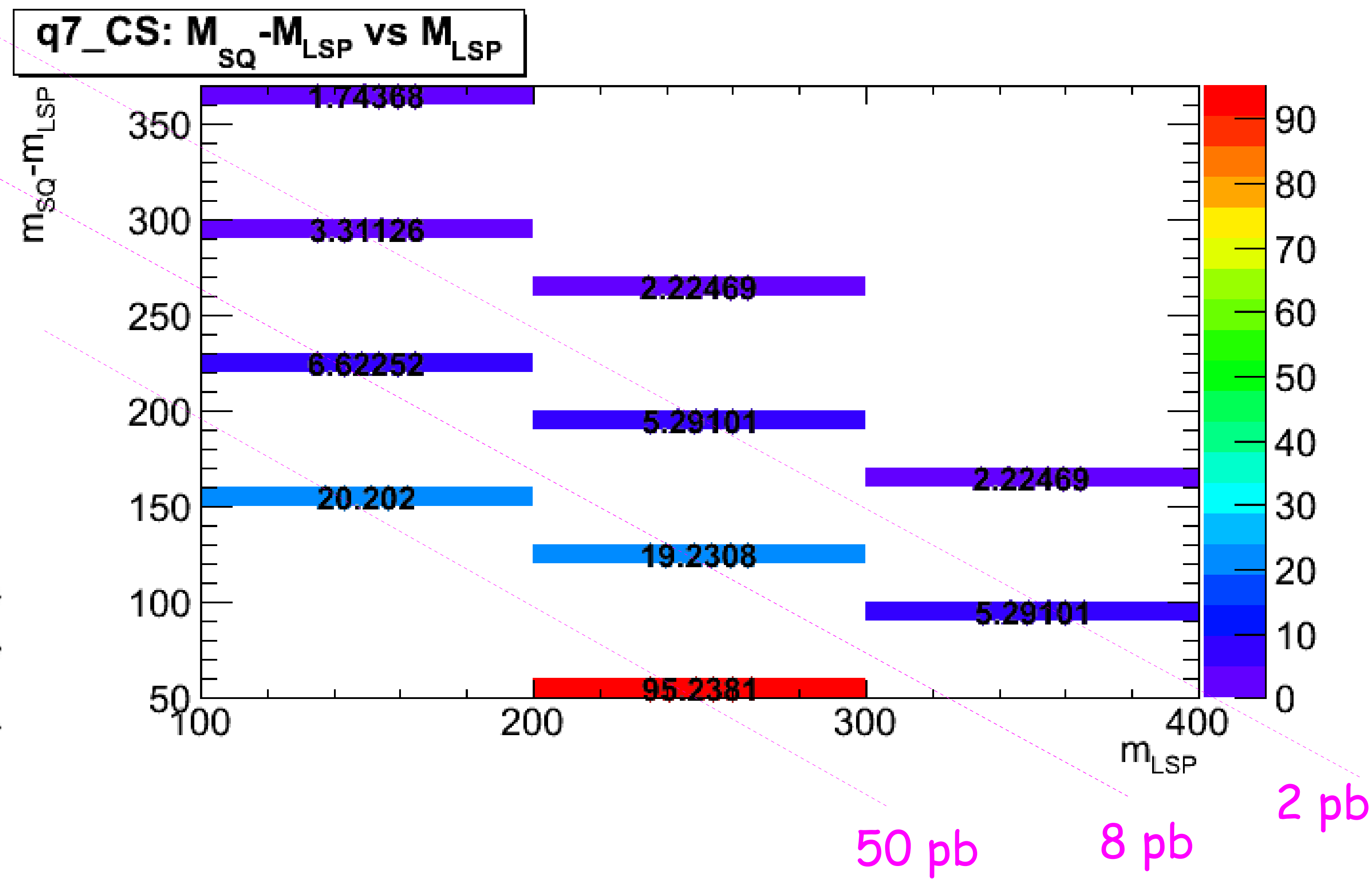


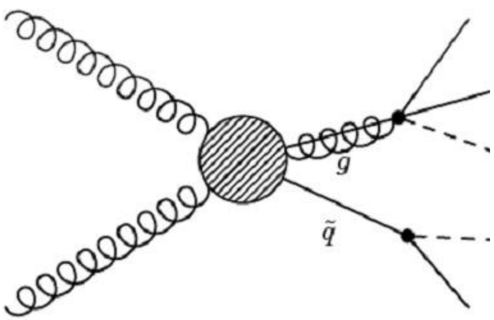
Minimum cross section we can exclude with 100 pb^{-1}

SUSY cross section

Assuming a systematic error of 50 %; analysis not yet optimised for template.

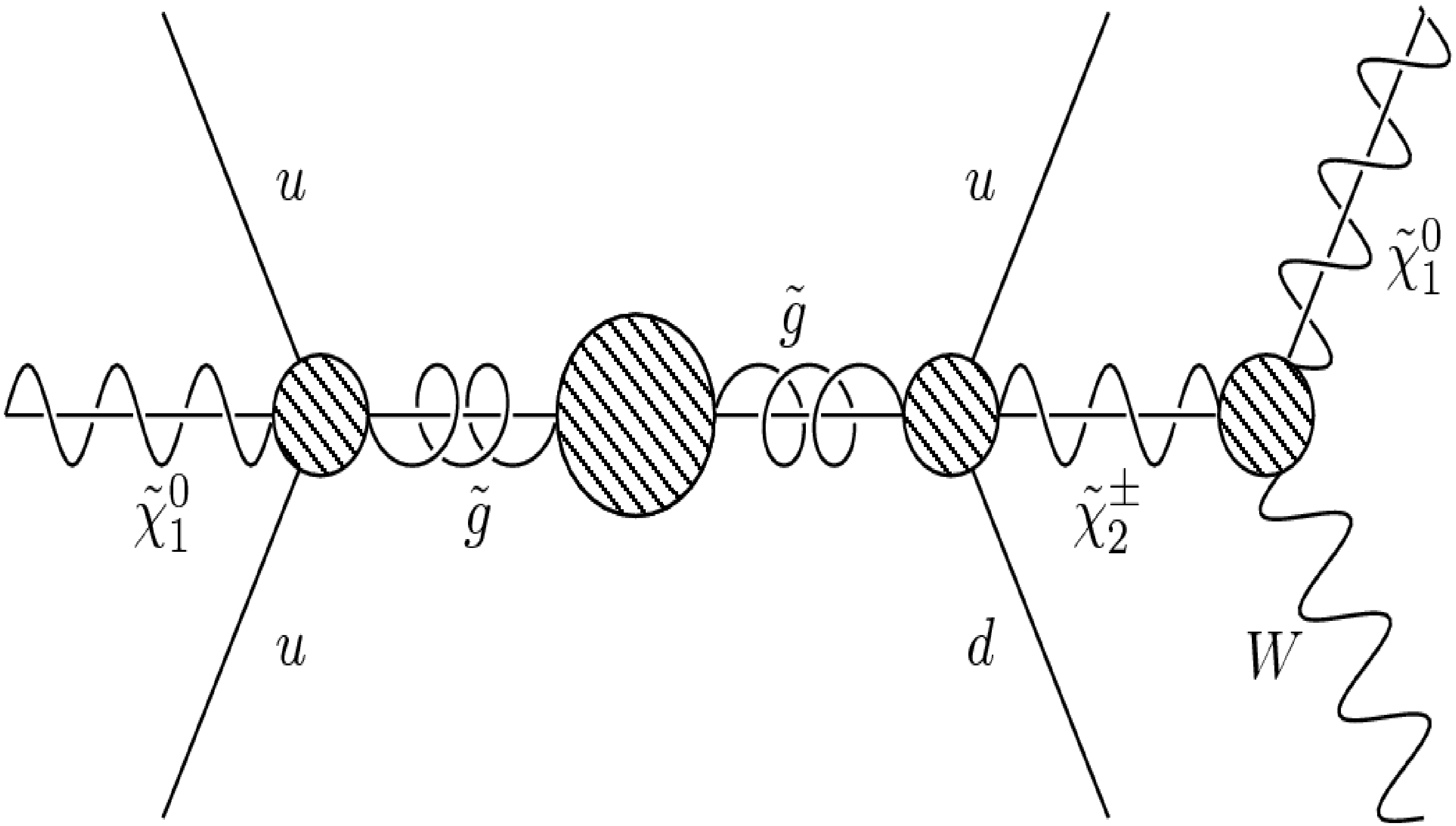
What can we exclude with 100 pb^{-1}?

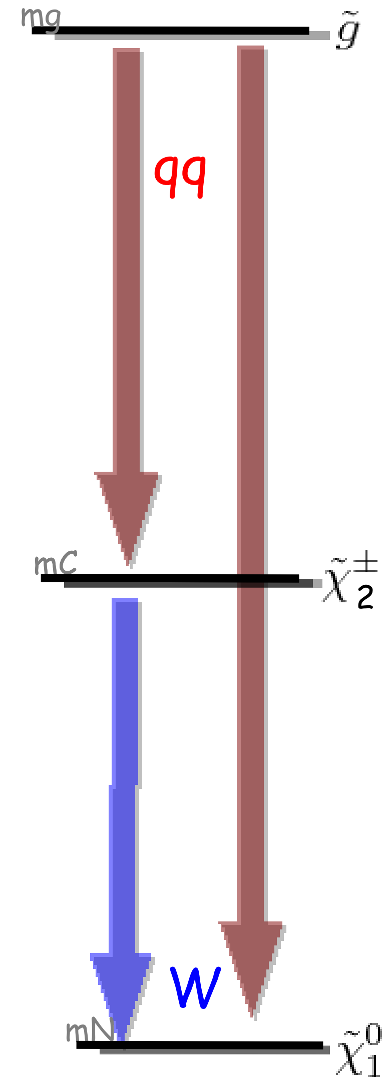




q7(1)

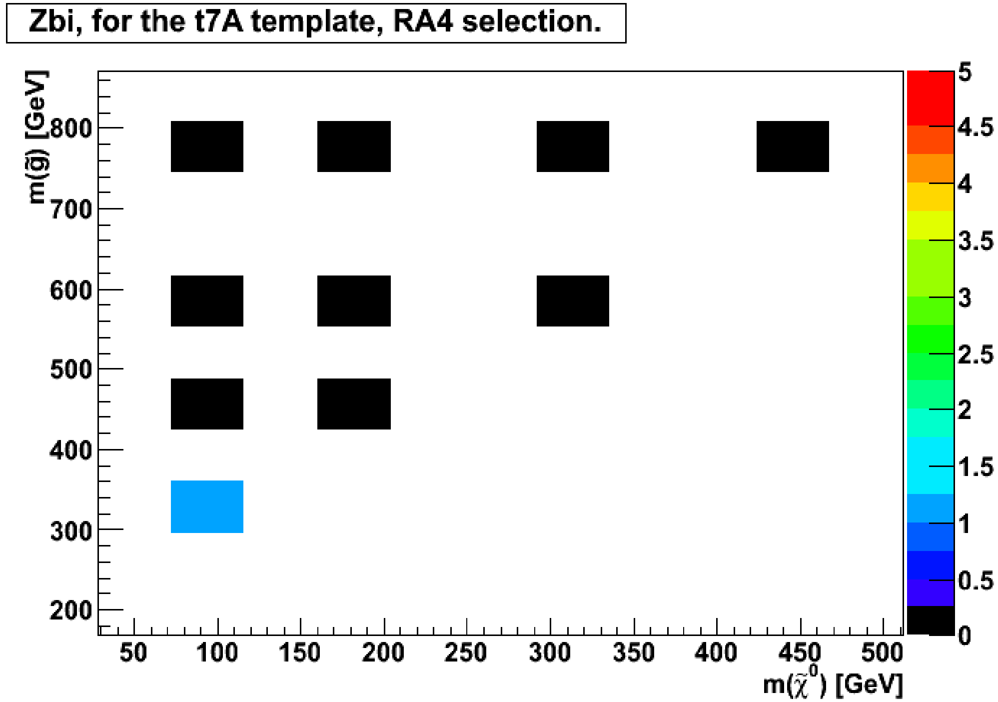
Leptonic Searches
(jets + MET + leptons)





B-suppression as a way to find new physics?

Example: leptonic t7A



Significances ($1fb^{-1}$) for a our standard leptonic SUSY analysis, for the t7A template, as a function of the mass parameters (taking SUSY cross sections), assuming now an optimistic 20 % systematic error.

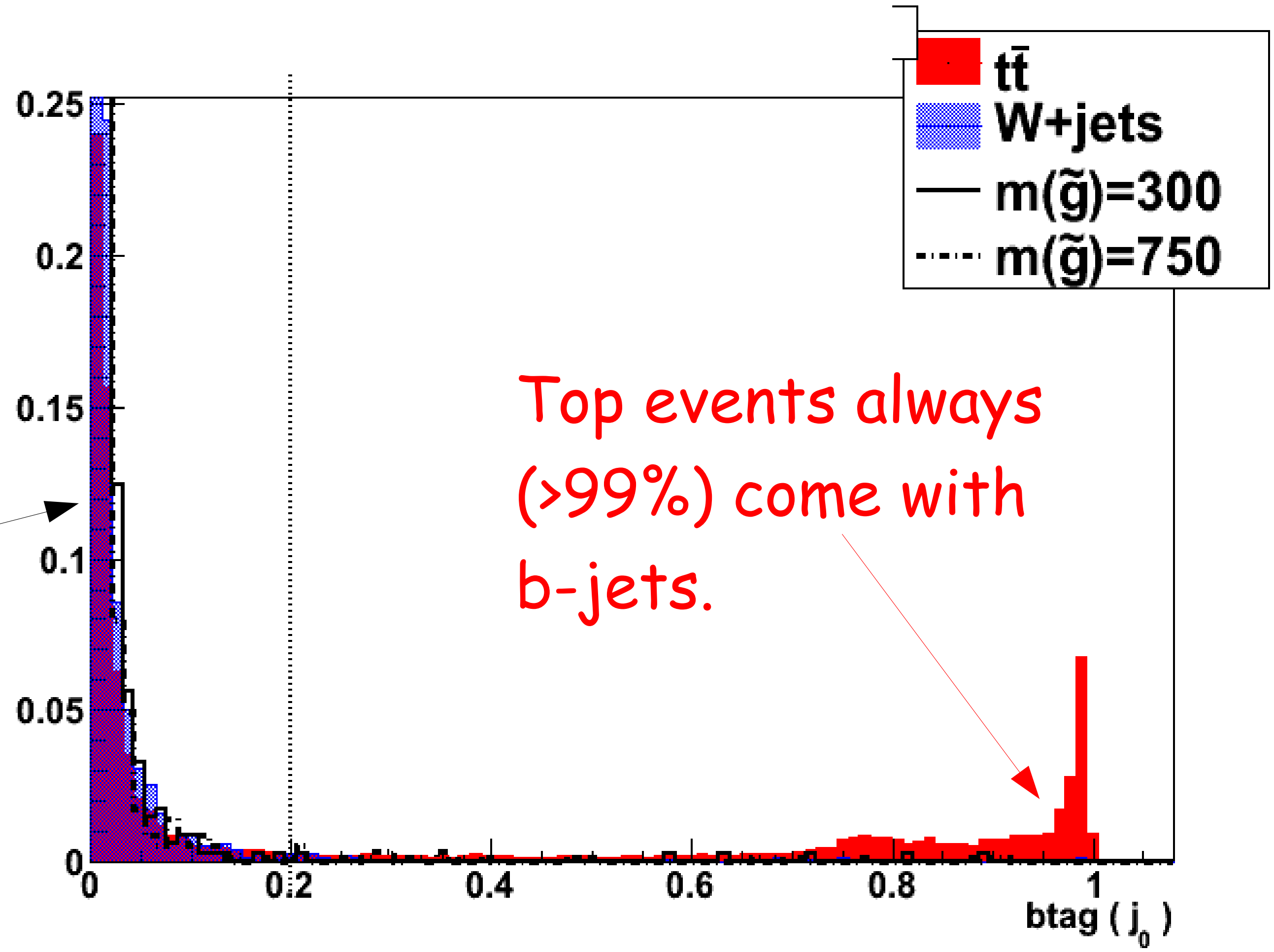
t7A – b-tag of leading jet

The "plausibility" of the leading (in p_T) jet being a b-jet.

With a veto on b's we can cut away our most difficult background (ttbar),

while possibly keeping a large portion of the signal.

Many (although not all) signal events would be b-free.



Btagger used: combined sv

Cut flow, for a special point in t7A

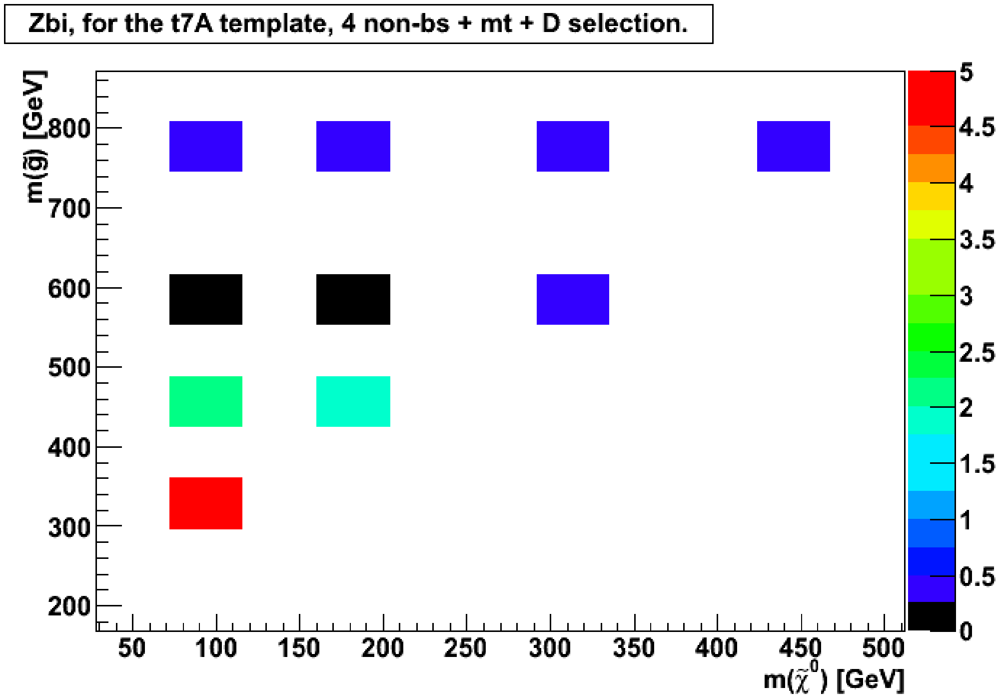
Significance ($1 fb^{-1}$)

cut	signal xsec	bg xsec	Zbi
preselection	3.55	267.99	---
jets + met + leptons	1.73	24.18	---
leptonic base	0.99	14.35	---
leptonic msugra search(*)	**0.40**	**1.71**	**0.38**
leptonic base + 4 non-bs	0.97	2.63	0.70
+ 4 non-bs + D region	0.51	0.59	1.71
+ 4 non-bs + mt + D region	**0.29**	**0.07**	**6.10**

(*) leptonic msugra search refers to one specific search in the leptonic channel that includes the following cuts: metsig > 7.0, ht2 > 450, 3 jets > 40 GeV, one muon, muon pt > 15 GeV.

Requiring non-b jets removes the ttbar background!

t7A in the leptonic search channel

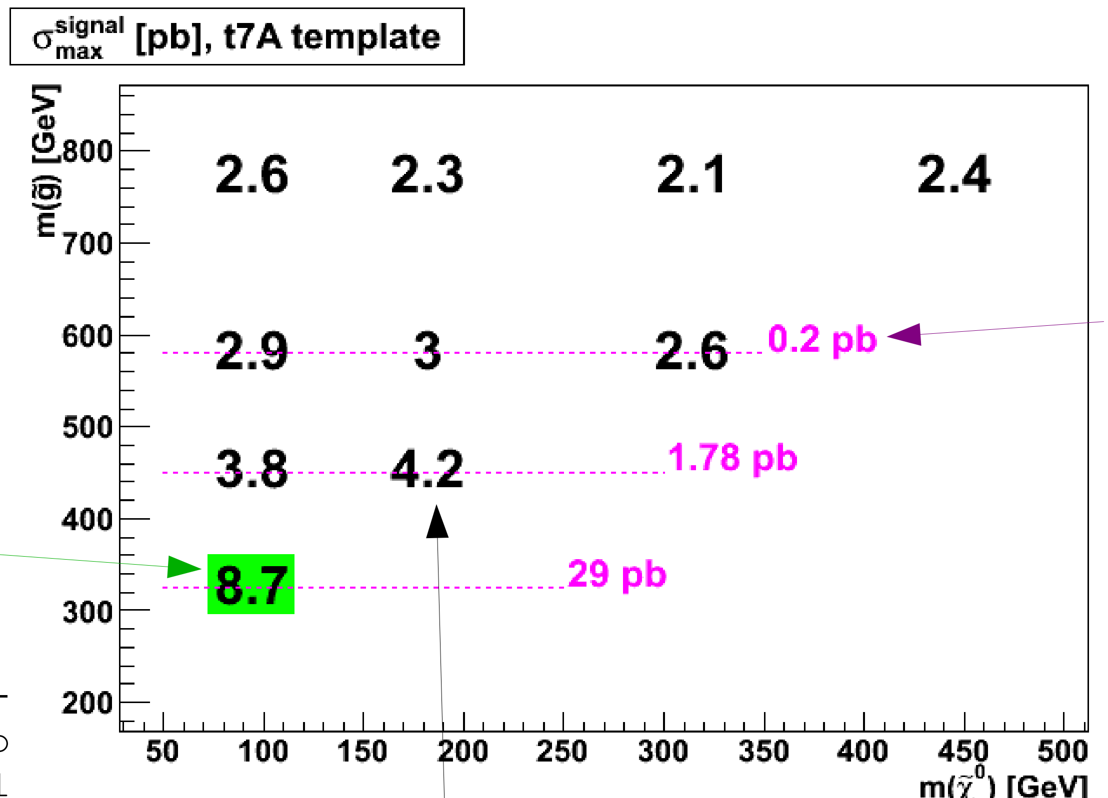


Significances, as a function of the masses, of the t7A template, with 1 fb^{-1} of "leptonic" data.

Lesson learned: consider also looking at b-depleted event selections! *Assuming that it's all about the ttbar background.*

First exclusions in leptonic channels

Assuming we dont see anything new, what kind of statements can we make?



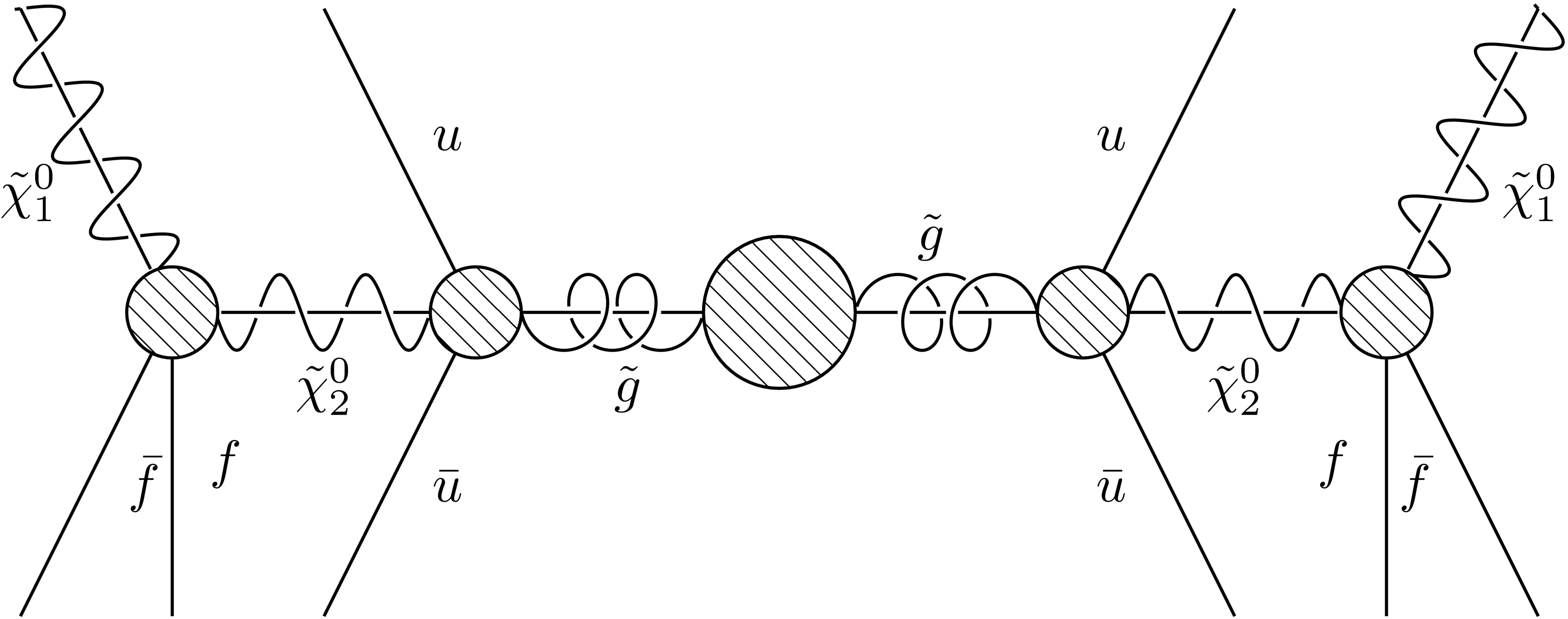
Approximate cross section taken from SUSY model

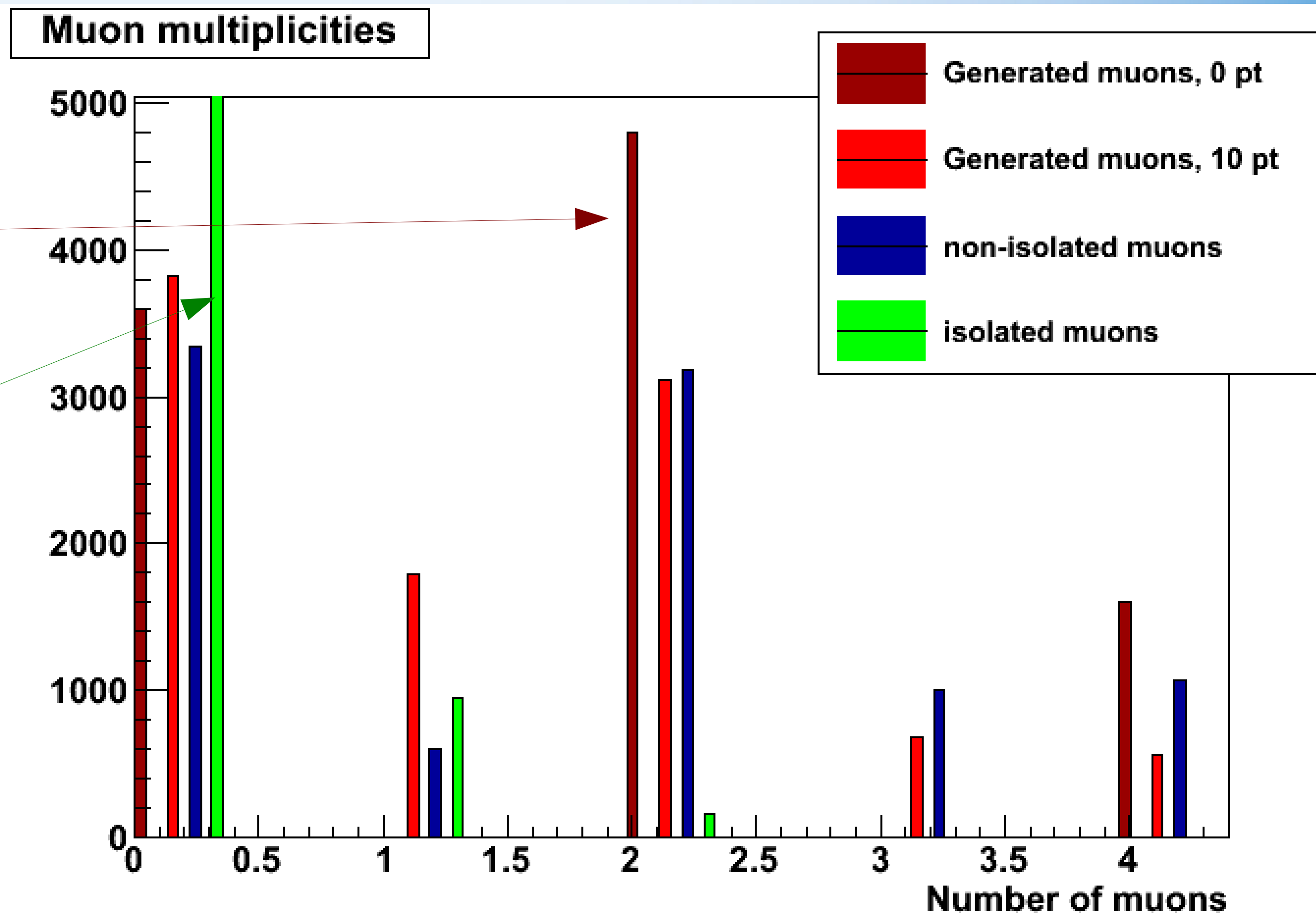
Susy σ > σ^{signal}_{max}

Yes not the whole x-sec needs to go into one specific channel

Minimum cross section we can exclude with 100 pb^{-1}

Example: L1 template and lepton isolation





"Real" number of muons in these events is typically 2 or 4.

"isolated" muons. We require these in our leptonic searches.

Lesson learned: Isolation cut totally kills our muons. Evidently, lepton jets would need different lepton selection: will cross-check with loose isolation cuts.

Ongoing and future work

MARMOSET is in the process of being integrated in CMSSW. It will soon be a fully supported event generator.

The official production team will use it to produce OSET event samples that will be part of the official CMS MC production.

Also, these days, special SUSY/Exotica triggers are being discussed; we intend to check with OSETs if the new triggers are efficient in a wider range of possible signals.

Summary

CMS is embracing MARMOSET in particular and the idea of OSETs in general as another approach towards a potential Next Standard Model. Integration efforts are ongoing.

Already we SUSY searchers have learned a lot about how we can open up our analyses towards a wider phenomenological spectrum:

- we will try a wider range of "jet-related" cuts
- (maybe counterintuitively) we may want to look at b-depleted rather than b-enriched regions
- for the leptons, we may also look at different kinds of isolations, to allow for collimated leptons
- ....

What else can we learn from new templates?

Questions from CMS to OSET theorists

Question 1:

Assume we have 20 – 50 pb^{-1} of data, what is the most pressing question we should answer? Which simple OSET template(s) should we look at and minimum exclusion cross sections for? What do we want for christmas?

The most interesting channels in the beginning are the purely Hadronic channel, and the photonic channel.
The leptonic channel comes later.

Question 2:

We are in the process of defining our triggers for spring next year. The bandwidth is saturated by now – our triggers need to get smarter. Whatever isnt triggered on, will be lost forever. Are there any templates which we should pay particular attention to, e.g. because they do not exhibit the “typical” characteristics of interesting physics?

Usually we trigger on jet p_Ts, missing energy, lepton p_Ts, btags, and combinations of the above. If e.g. we have a template which predicts production of many, many jets with very low pt, we might miss it.

Question 3:

Apart from triggers, are there templates with non-trivial "features" which we should be have in mind when designing our analyses?

Where "features" may be losely defined as the set of quantities that we are usually not thinking about in SUSY, e.g. displaced vertices, non-pointing tracks, particles which change their signs upon traversal of the detector, etc.