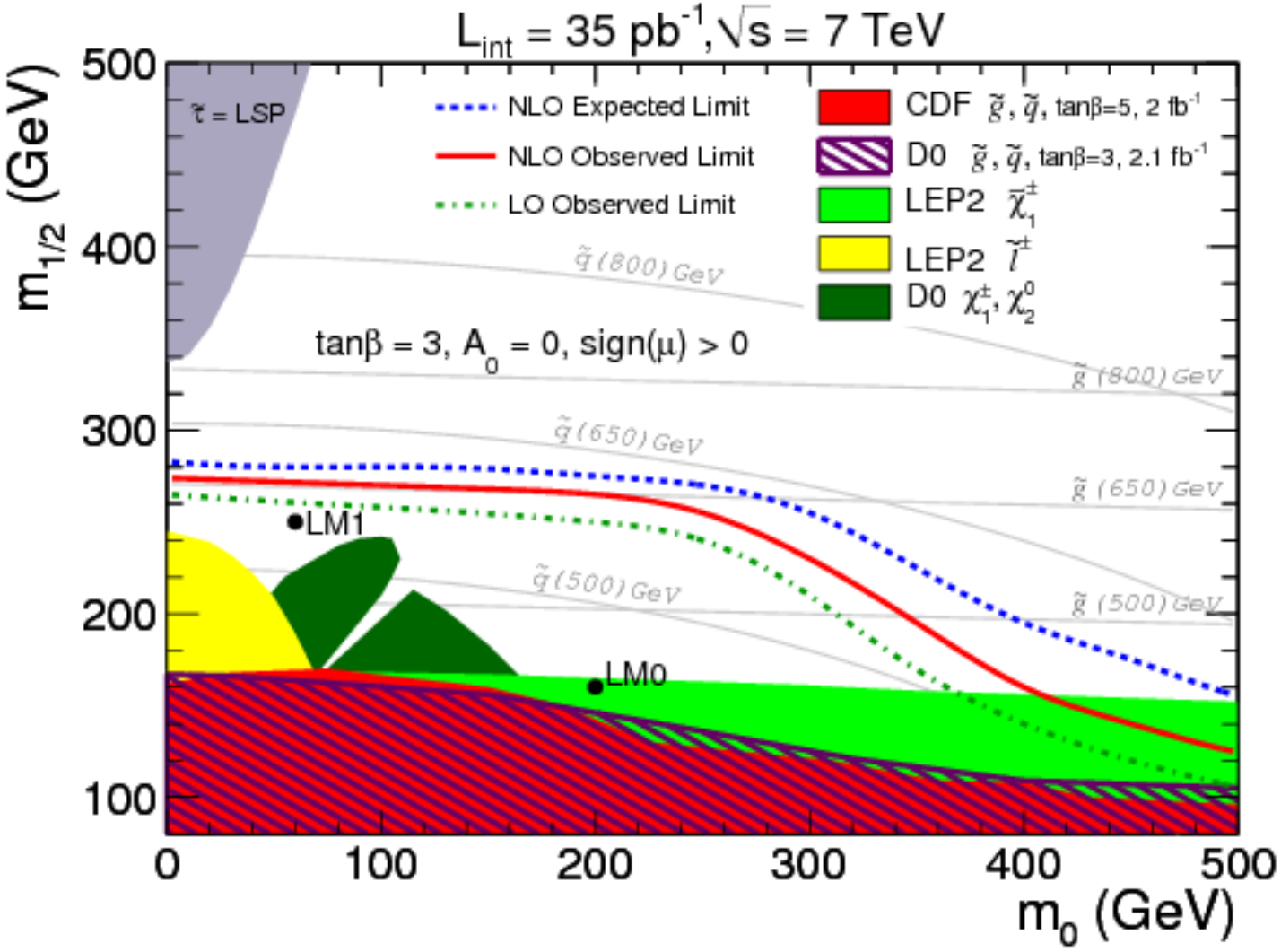
CMS: progress report on simplified models approach

Wolfgang Waltenberger, on behalf of the CMS collaboration.

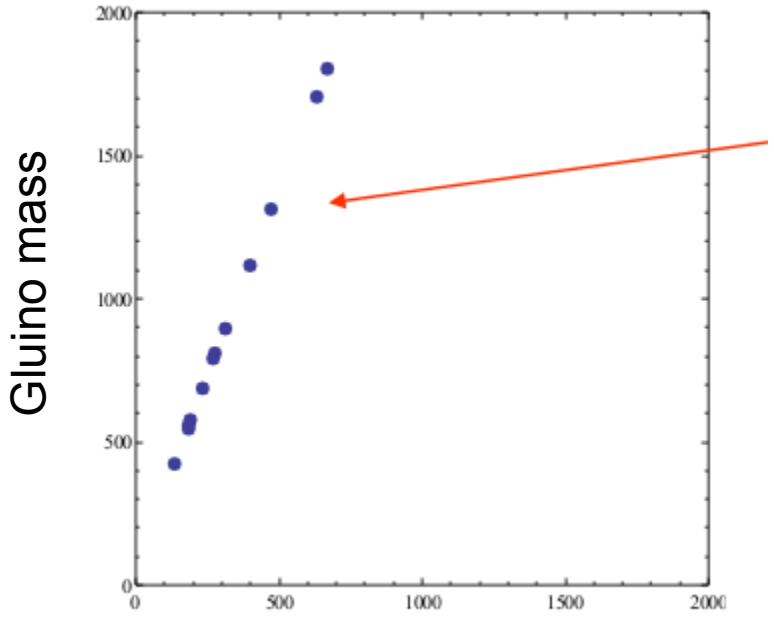
CMS-SUS-10-003

Recently published an analysis in MET + jets in "alpha_T".



One (of a few) problems with mSUGRA

"We are walking along thin lines in larger parameter spaces"



Going to simplified models

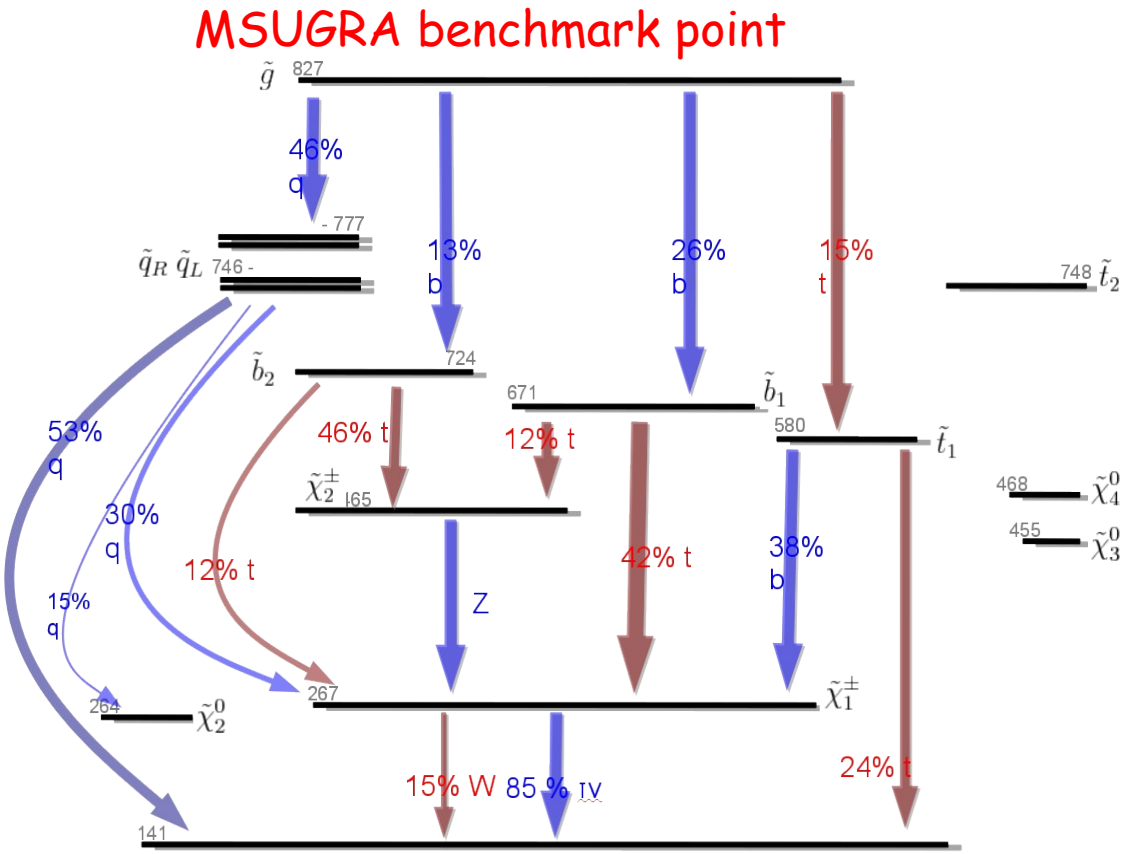
Two ways to go beyond mSUGRA / CMSSM:

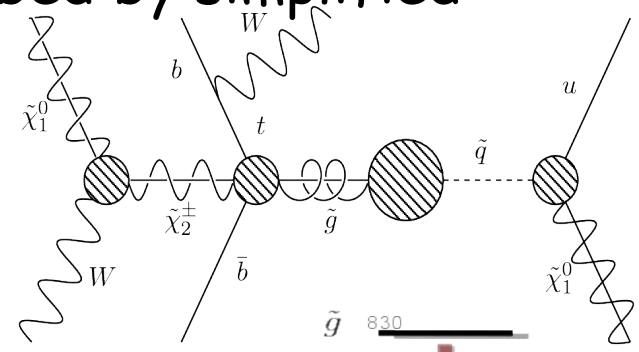
- go to more generalized models (e.g. pMSSM)

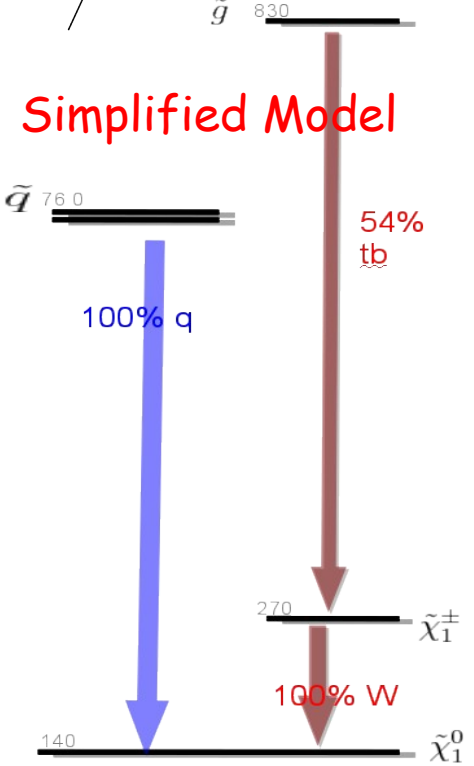
- describe discoveries and exclusions in terms of simplified models. Decouple all mass parameters, couplings, etc.
Will talk about these efforts.

Simplified models and mSUGRA

Our default mSUGRA points can indeed be described by simplified models:



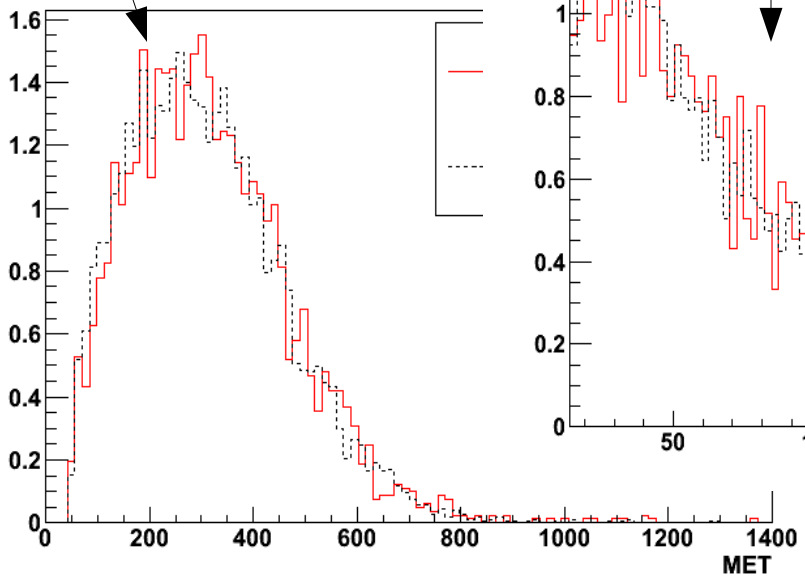




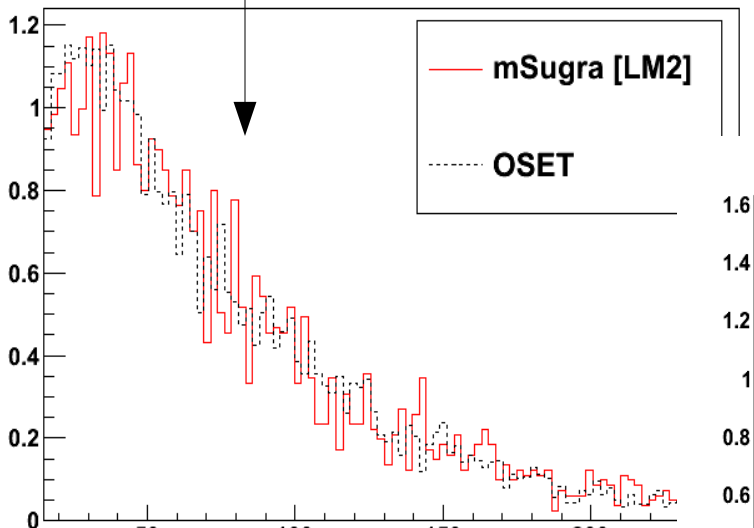
Simplified models and mSUGRA

Already at the generator level, no difference is visible in our typical search variables!

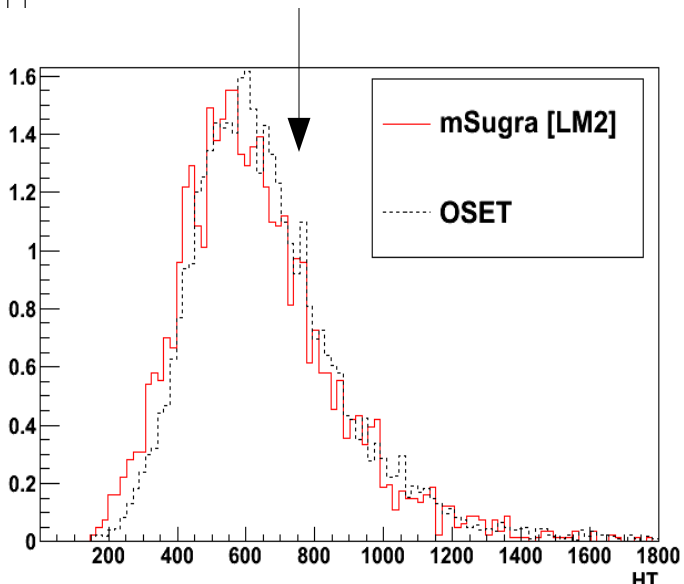
Missing transverse energy



Lepton pt



"HT" variable



Simplified models and CMS

A few of our groups are in the process of presenting exclusion limits in terms of simplified models:

di-photons

Paper is being written which contains simplified models, results are approved.

jets + MET – "MET" analysis

Paper will contain simplified models exclusion plots with 2010 LHC data.

Simplified models and the CMS reference analyses

jets + MET + single-lepton

Paper will contain simplified models.

jets + MET – "alpha_T" method

Paper will contain simplified models.

jets + MET + multileptons

Paper will contain simplified models.

Disclaimer

In this talk, I will discuss what the analysis groups are doing, and how.

Only one physics result will be shown (the di-photon case),

all other plots are for illustration purposes only!

LHC New Physics Working Group

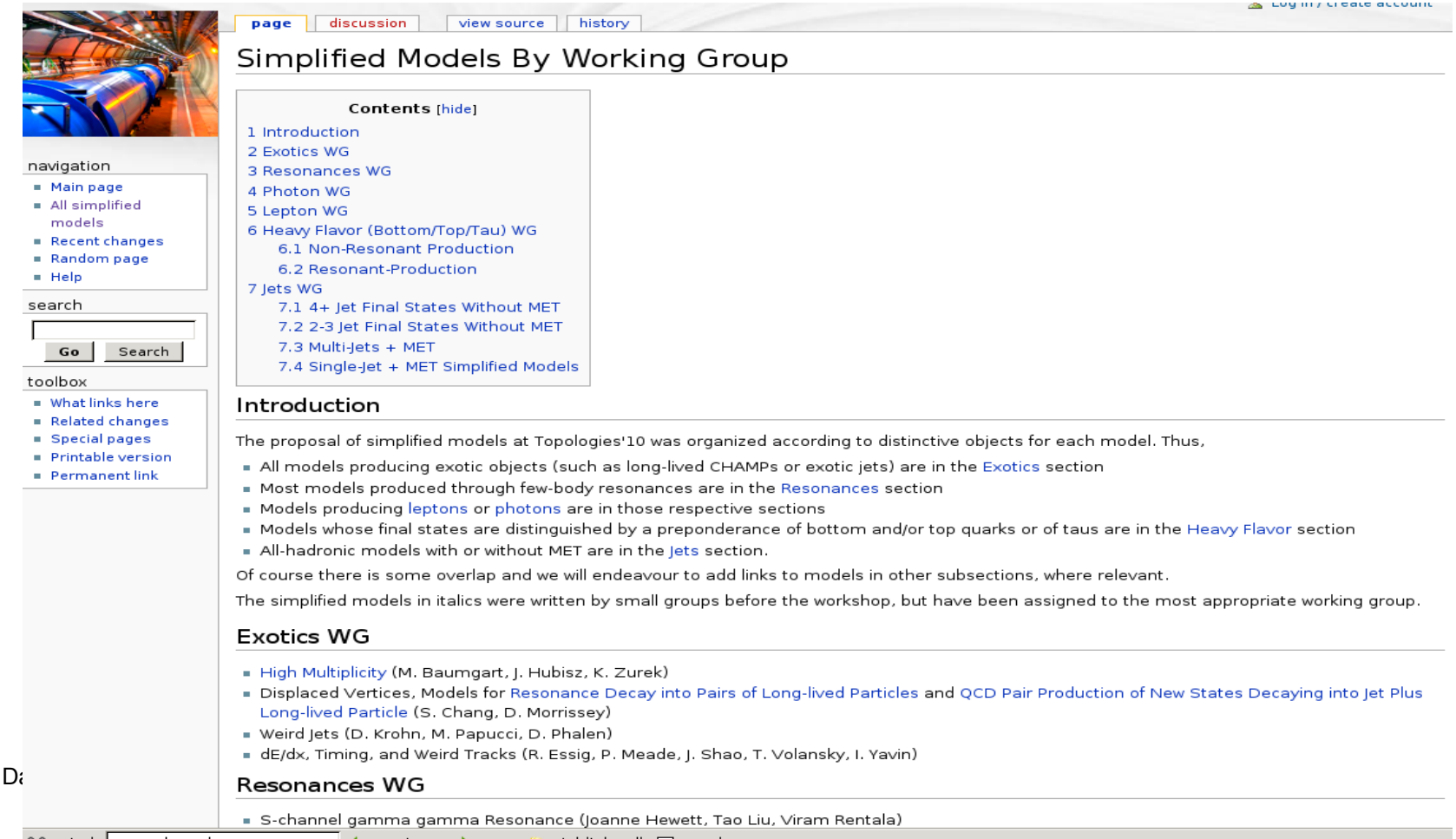
We are following closely the recommendations proposed by the "New Physics Characterization Working Group":

https://twiki.cern,ch/twiki/pub/CMS/SUSY/referenceTopologies_Dec13.pdf

http://lhcnewphysics.org/web/Overview.html

LHC New Physics Working Group

O(100) theorists who compiled a set of O(50) simplified models, adapted for search for new physics with LHC data



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Simplified Models By Working Group

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Introduction

The proposal of simplified models at Topologies'10 was organized according to distinctive objects for each model. Thus,

- All models producing exotic objects (such as long-lived CHAMPs or exotic jets) are in the Exotics section
- Most models produced through few-body resonances are in the Resonances section
- Models producing leptons or photons are in those respective sections
- Models whose final states are distinguished by a preponderance of bottom and/or top quarks or of taus are in the Heavy Flavor section
- All-hadronic models with or without MET are in the Jets section.

Of course there is some overlap and we will endeavour to add links to models in other subsections, where relevant.

The simplified models in italics were written by small groups before the workshop, but have been assigned to the most appropriate working group.

Exotics WG

- High Multiplicity (M. Baumgart, J. Hubisz, K. Zurek)
- Displaced Vertices, Models for Resonance Decay into Pairs of Long-lived Particles and QCD Pair Production of New States Decaying into Jet Plus Long-lived Particle (S. Chang, D. Morrissey)
- Weird Jets (D. Krohn, M. Papucci, D. Phalen)
- dE/dx, Timing, and Weird Tracks (R. Essig, P. Meade, J. Shao, T. Volansky, I. Yavin)

Resonances WG

- S-channel gamma gamma Resonance (Joanne Hewett, Tao Liu, Viram Rentala)

Simplified models interpretation of LHC 2010 data

Exclusion only, suppose no significant discrepancy is found.

$$\sigma \times BR \approx N^{max}_{sig} / \varepsilon$$

We

- measure the event yield in the signal region
- compute the expected event yield from the background regions (data driven techniques)
- take the signal efficiency from simplified models Monte Carlo.
  How about the theoretical uncertainties?
- formulate the result in terms of σ x BR upper limits, as a function of the mass parameters of the model,
- compare with σ x BR predictions from sQCD for exclusion plots.

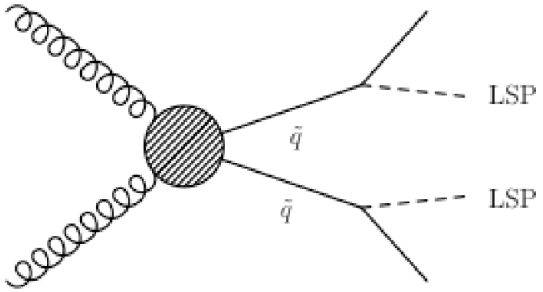
Large-scale productions on the grid

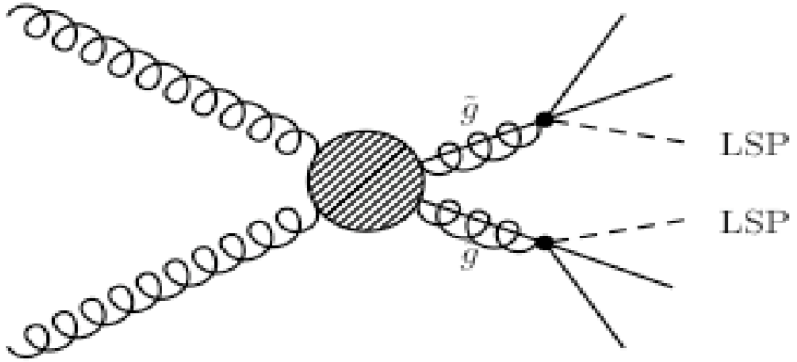
Large-scale productions of mass parameter scans of our topologies are already carried out:

Name	Description	Signatures	Events	
T1	QQ → jNjN	jets + MET	335 x 10000	Squark pair production
T2	GG → jjNjjN	Jets + MET	336 x 10000	Gluino pair production

Q: Squark
G: Gluino
N: Neutralino

All made with Pythia!



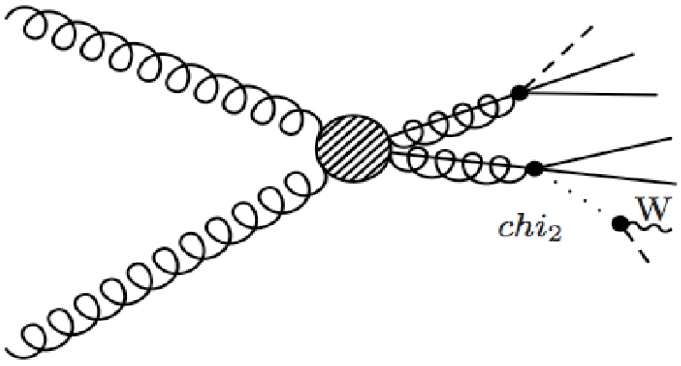


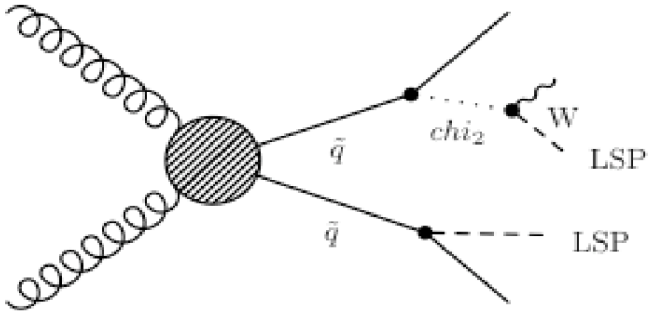
Large-scale productions on the grid – one stage cascades

Name	Description	Signatures	Events	
T3	QQ → jN jC	Jets + MET (+ Lepton)	372 x 10000	Squark one stage cascarde
T4	GG →jjN jjC	Jets + MET (+ Lepton)	371 x 10000	Gluino one stage cascade
T5	QQ → jC jC	Jets + MET (+ Leptons)	372 x 10000	
T6	GG → jjC jjC	Jets + MET (+ Leptons)	372 x 10000	

Q: Squark
G: Gluino
N: Neutralino
C: Chargino

C → W N





Leptonic and Hadronic Ws will allow us to compare between different channels.

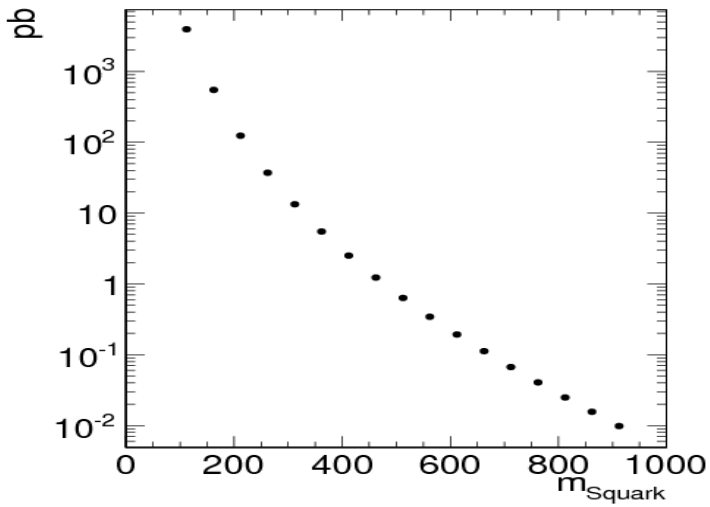
Mass parameter ranges

Q ("squarks"): 400 GeV – 1 TeV (100 GeV steps)
G ("gluinos"): 400 GeV – 1 TeV (100 GeV steps)
N ("LSP"): 100 GeV – 950 GeV (50 GeV steps)
C ("chargino"): 182 GeV – 782 GeV (50 GeV steps)

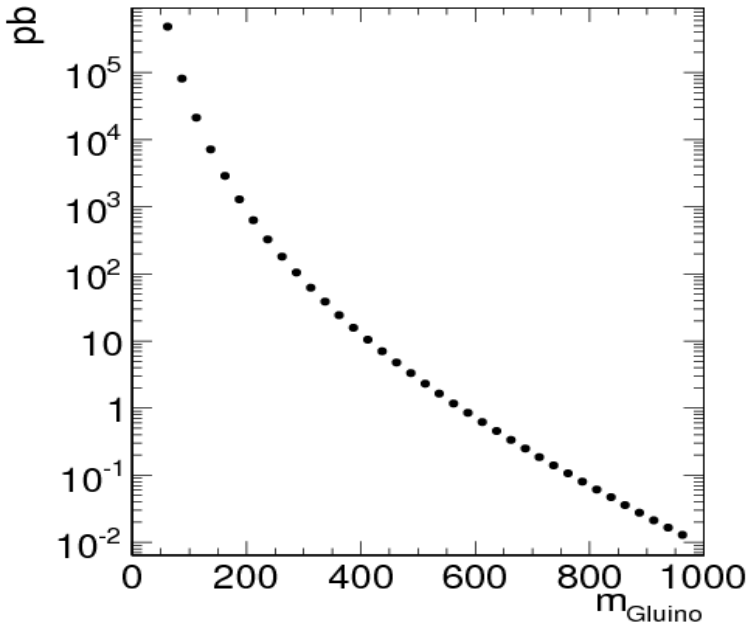
Work is underway to take the gluino masses down to 300 GeV. Additionally to the official production, groups are likely to run more specialised private productions.

Reference cross sections

For the exclusion plots we needed to assume values for the cross sections. Prospino has been used to compute these values. For the gluino-pair production we let the squark mass go to infinity and vice versa – the gluino mass is assumed to be Infinity for the squark-pair production modes. These numbers will be standardized among our groups



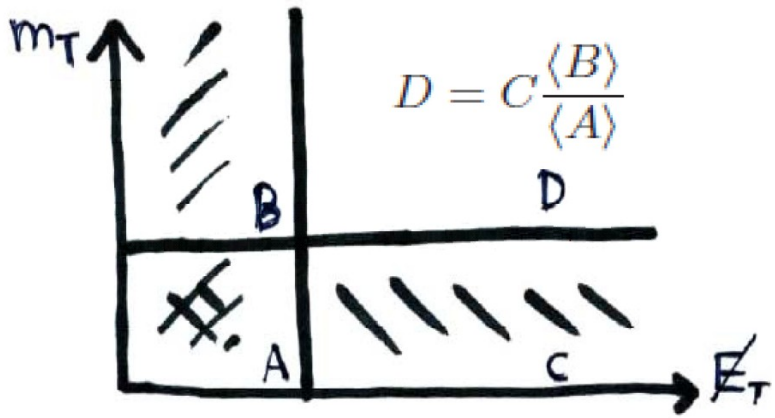
Computed by Eder Izaguirre



Event selection, background estimation, systematics, and signal contamination

Tasks that are common to all groups are:

- selection of signal events
- estimation of SM background (via data driven methods, e.g. ABCD) from "control" regions
- quantification of systematic uncertainties



For the estimation of SM background, every reference analysis will employ several methods and compare them.

It is also very likely that different event selection will be employed within one group for
the different simplified models.

It is not yet fully clear to us, how to deal with signal contamination in the control regions. Input from the theoretical community would be appreciated!

Statistics

Although not yet implemented, efforts have begun to standardize the statistical procedures
Among the groups. Because of its versatility, roostat will be the default technology.
We will implement the CMS statistics committee's proposal,
It seems natural, though, that more than one procedure will be used.
Both a frequentist and a Bayesian approach should be employed, robustness with respect to the choice of priors will need to be shown.
Currently in use for the computation of the upper limit on non-SM events:

Jets + MET "alpha_T": Feldman-Cousins method generalized to a profile-likelihood ratio method, based already on roostat.

Jets + MET "MET": Bayesian framework, own code.

Jets + MET + lepton: Synchronizing with Jets + MET "alpha_T"

Photons + Jet + MET: Bayesian Framework

Presentation of exclusion limits

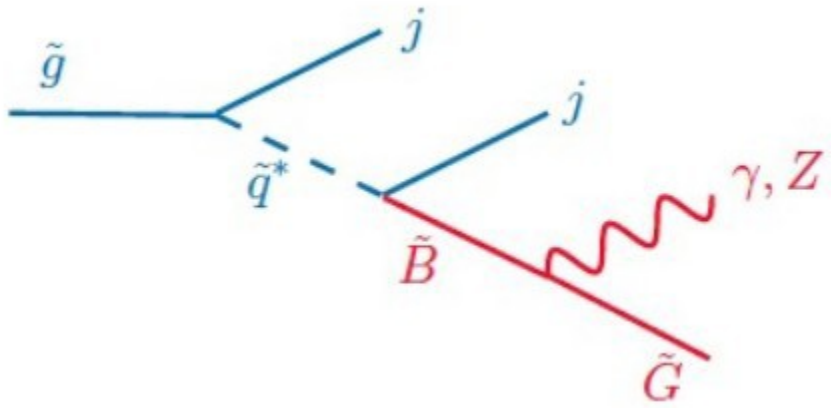
Photons + jets + MET

GGM-based scenario

$$\tilde{g} \to q\tilde{q} \to qq\chi_1^0 \to \gamma + \tilde{G}$$

-> γ + X + MET

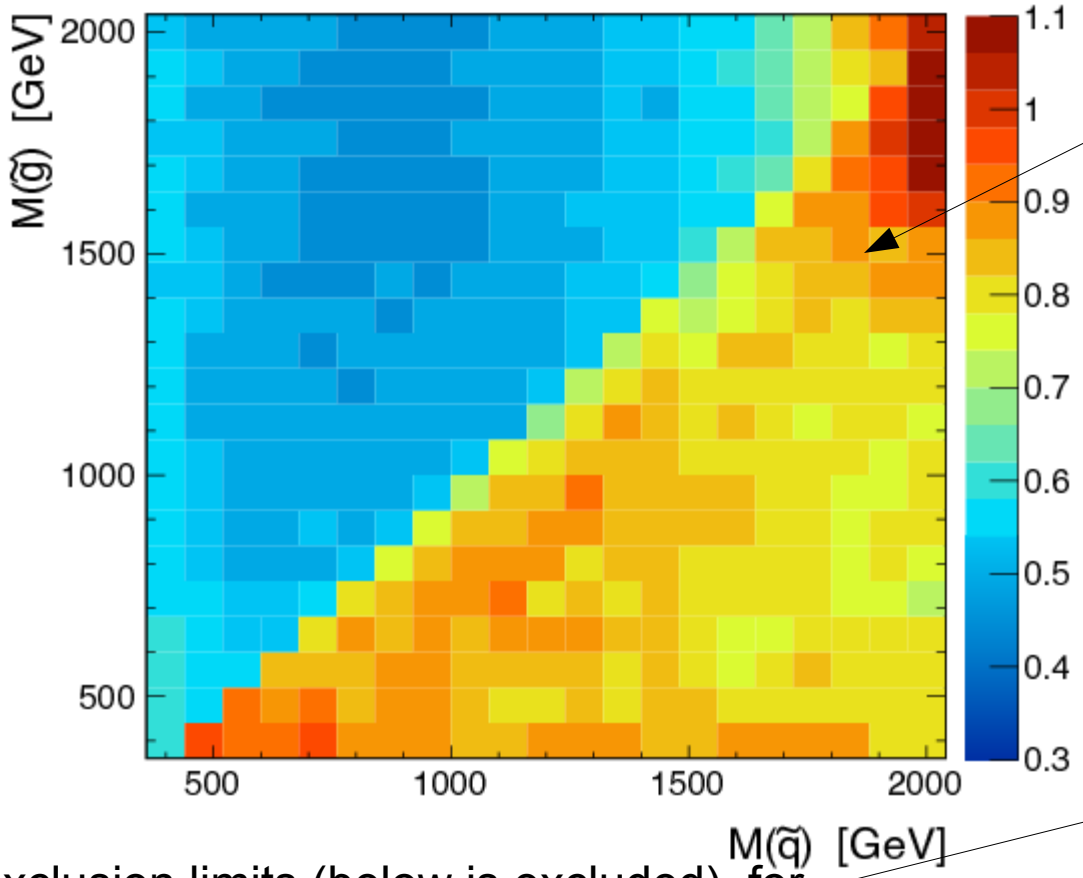
The pt of the photon and the amount of MET is determined by the neutralino/Bino mass



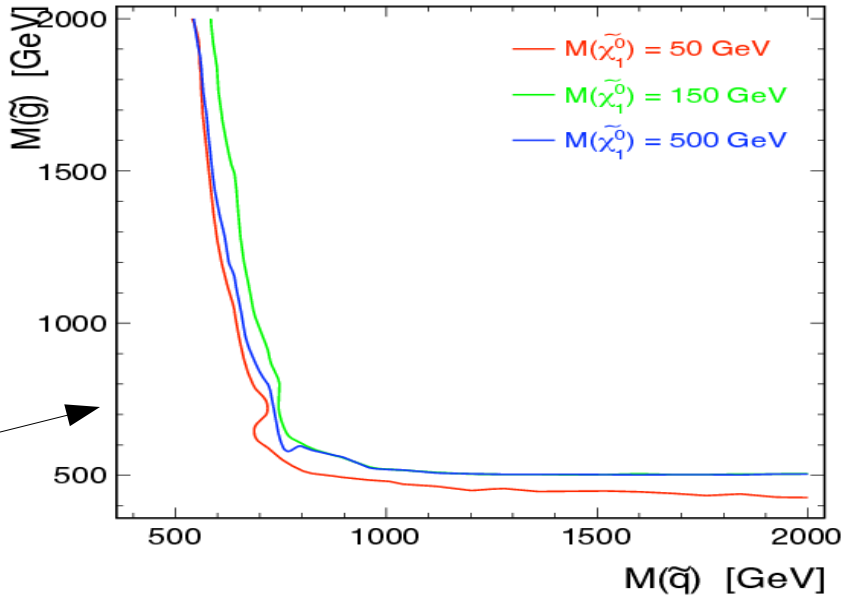
http://www.lhcnewphysics.org/wiki/index.php?title=SimplifiedModels:General_Neutralino_NLSP

Photons + jets + MET

Result published with the 35.5 pb^{-1} 2010 data: CMS-SUS-10-002



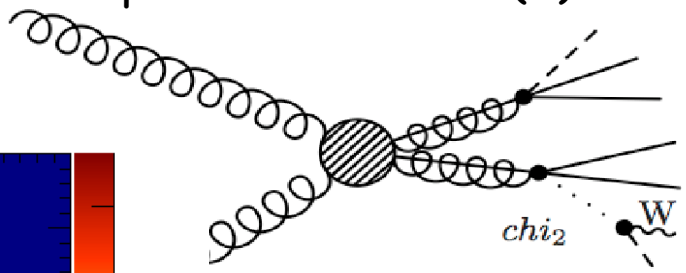
Upper limits [pb]



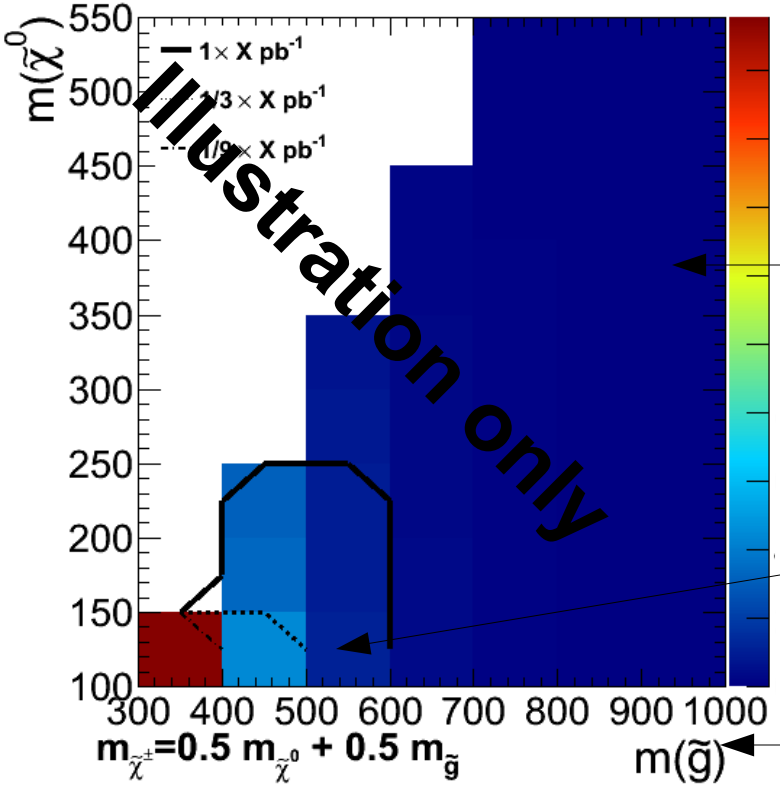
Exclusion limits (below is excluded), for LO expected GGM cross section

Presentation of exclusion limits – one-stage cascade decay

The one-stage cascade decays have three free parameters: m(G|Q), m(C), m(N). Two-dimensional projections will be presented with m(C) = x m (G) + (1 – x) m(N), fixed x.



For one specific model



sQCD cross section x epsilon

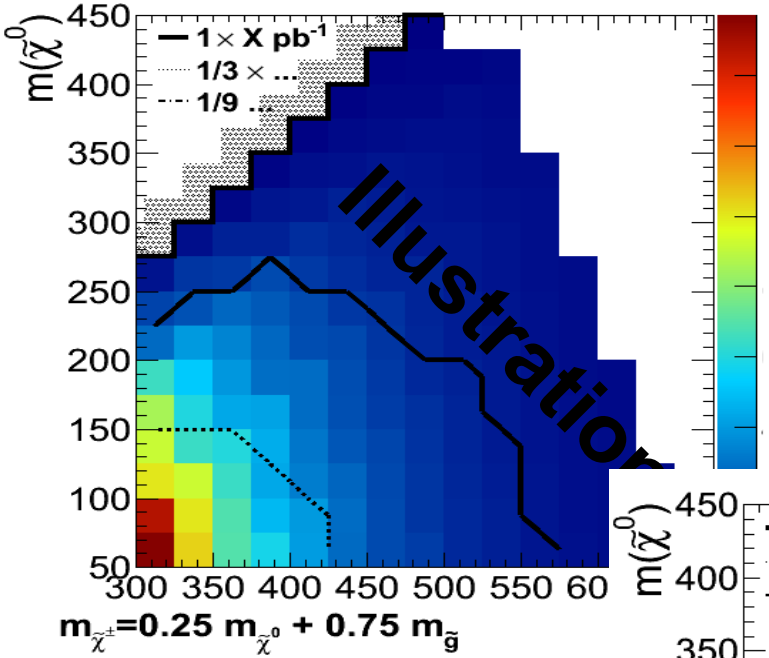
Exclusion limits for n x X pb^{-1}

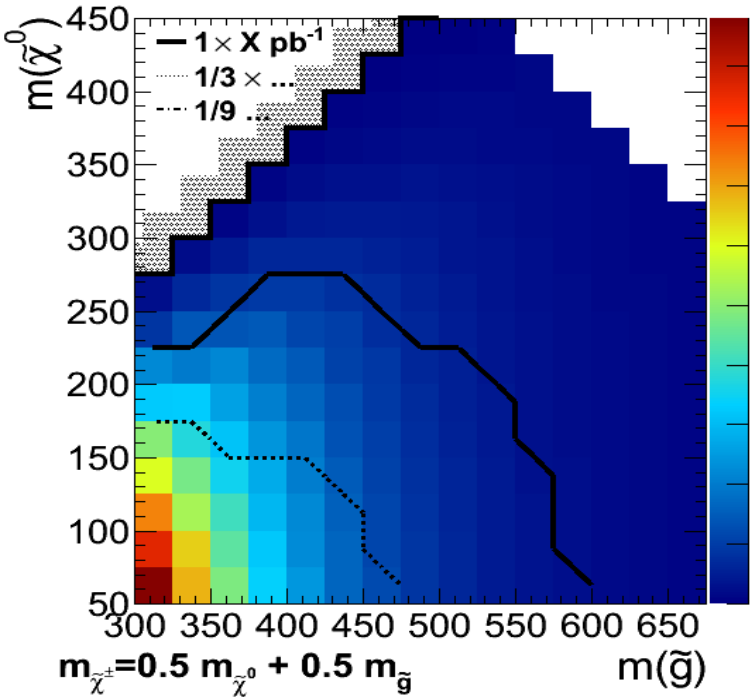
m(G) versus m(N)

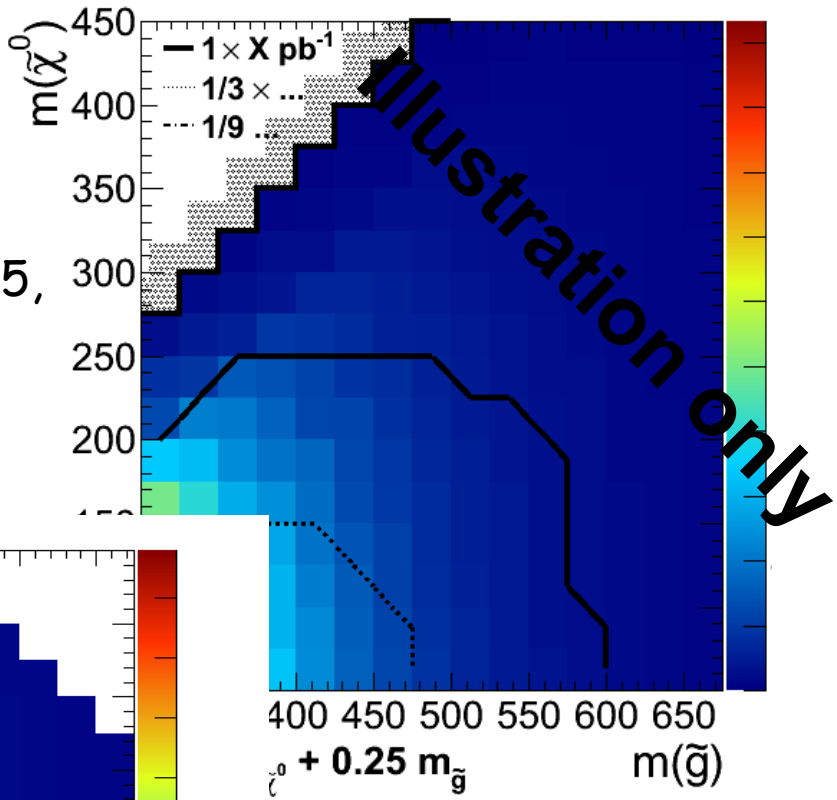
For fixed x

Presentation of exclusion limits – one-stage cascade decay

Jets + MET + leptons,
Same plots,
Finer binning.
For x=0.25, 0.5, 0.75



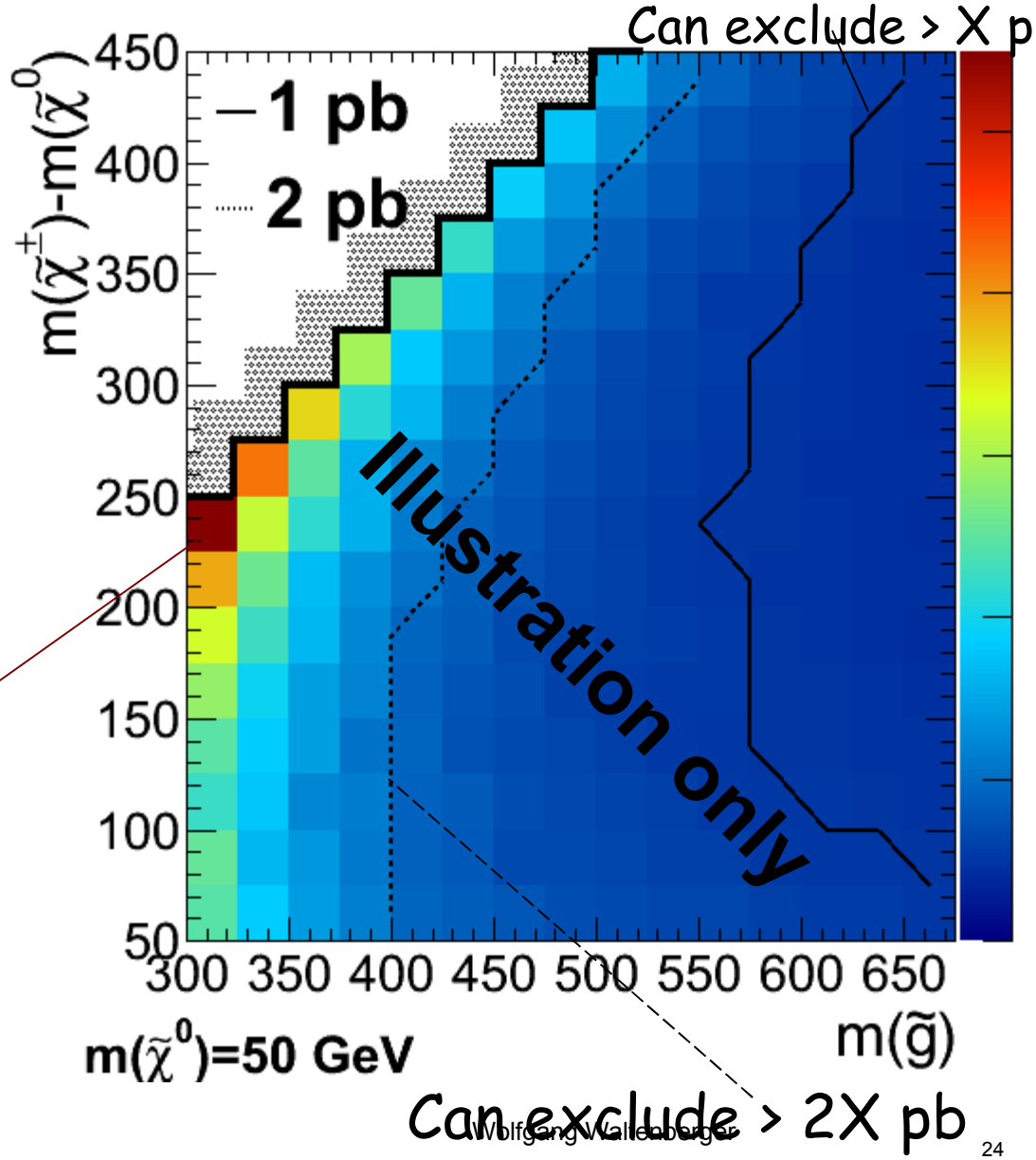




Presentation of exclusion limits – one-stage cascade decay

This plot shows the minimum cross section we can exclude, as a function of the mass Parameters.

m(gluino) ≈ m(chargino) → not enough jets → low signal efficiency → hard to exclude



Multi-leptons

With this simplified spectrum, the relevant parameters are the three masses: $M_{\tilde{g}}$, $M_{\tilde{B}}$, and $M_{\tilde{\ell}_R}$. The branching fractions are not free parameters; we have

$$\tilde{g} \to \tilde{B} + jets \quad (4)$$

and

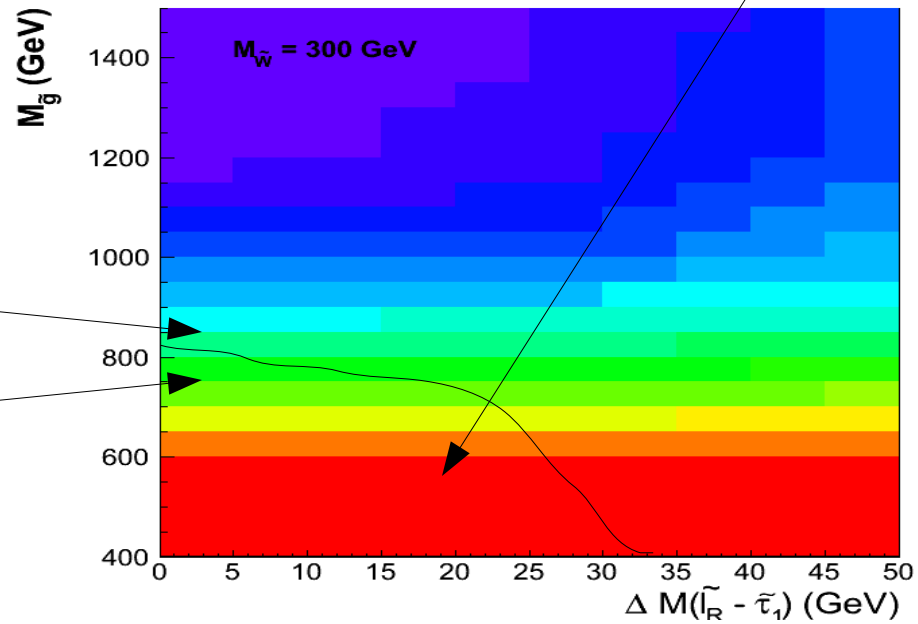
$$\tilde{B} \to (\tilde{e}_R^{\pm}, e^{\mp}),\ (\tilde{\mu}_R^{\pm}, \mu^{\mp}),\ (\tilde{\tau}_1^{\pm}, \tau^{\mp}) \quad (5)$$

with equal branching ratios (so 1/6 per final state). Finally, the slepton co-NLSPs always decay as:

$$\tilde{\ell}_R^{\pm} \to \ell^{\pm} + \tilde{G}$$

Large number of different cases, will present here Some thoughts from "multi-leptons + MET + jets":

Cross-section x epsilon



Can be excluded with X pb^{-1}

Function of three parameters: m(~g), m(~B), m(~l)

Conclusions

- The use of simplified models is growing in our analysis groups.

- They are used to summarize our findings in a more model-independant manner.

- We're working in close collaboration with the "New Physics Working Group" of theorists, implementing their proposals, as given in the december recommendation paper:

https://twiki.cern.ch/twiki/pub/CMS/SUSY/referenceTopologies_Dec13.pdf

- A large theory community will base their efforts to build A potential Next Standard Model on this – and similar – work.

Outlook

- A next common effort will be the combination of the results of the different groups, for the case that they share some models. (e.g. jets + MET and jets + MET + lepton)

- Would the theory community profit from a CMS paper that is entirely dedicated to simplified models?

- We want to compare results with the ATLAS groups.

- Work is ongoing to "connect" these simplified models with more generalized models (e.g. the pMSSM)