Simplified Models in CMS

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for the CMS Collaboration

Outline

- What good are Simplified Models?
- Topologies Considered
- CMS SUSY Selections
- CMS Results
- Future
- Lessons
- Questions

The Two Hats of SM

- CMS Hat

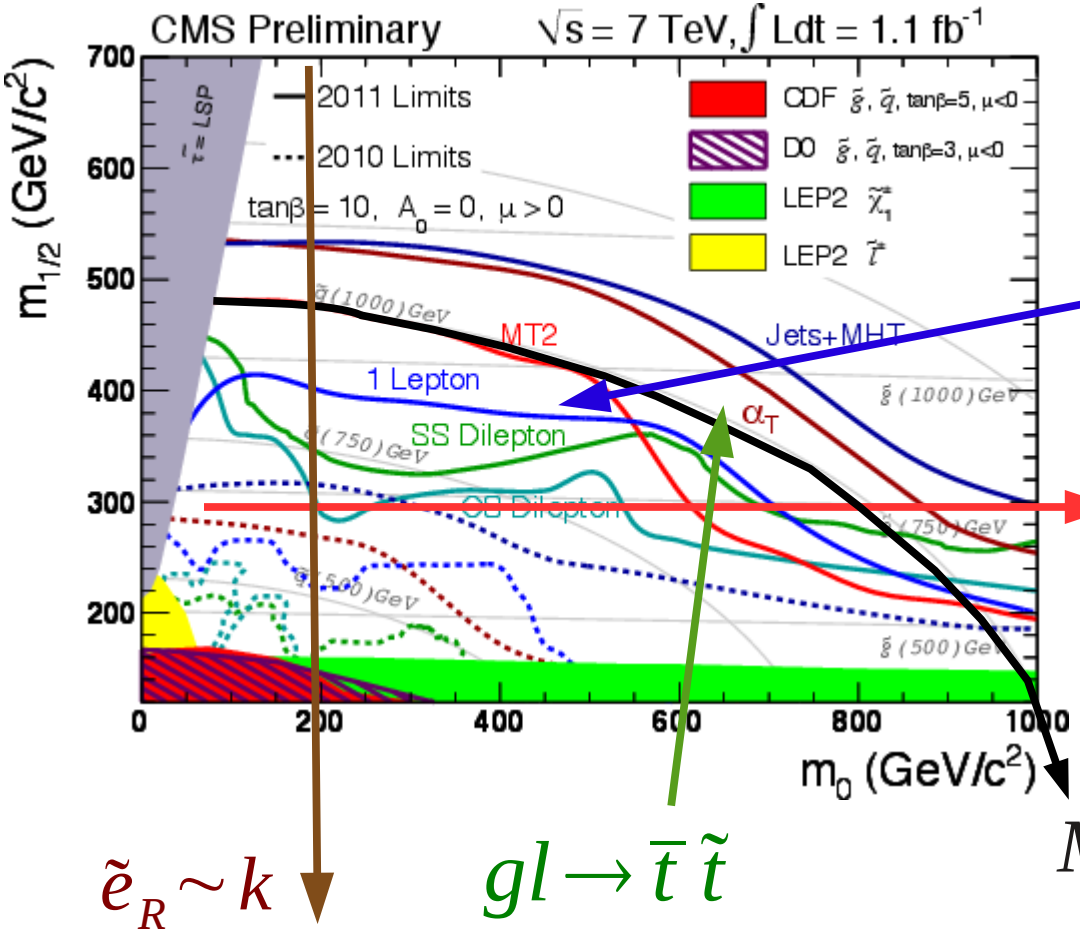
- “Theorist” Hat

What are SMS Good For?

?

What Are SMS *Great* For?

- Generating Models based on Topology and Objects for Hypothesis Testing on SIGNAL
  - Bard,Marmoset (SM+notables)
- Could be used to make more generic interpretations of search limits
  - Wacker,Schuster,Toro,Alwall others



$$BR(N_2 \to N_1 h) = 1$$

$$M_{gl} : M_{C_1} : M_{N_1} \sim 6:2:1$$

$$\tilde{e}_R \sim k$$

$$gl \to \bar{t}\,\tilde{t}$$

$$M_{\tilde{Q}} \sim c$$

+ Many Different Signatures
– Built-in Correlations
How does the limit depend upon mass splittings?

What are SMS good for?

- Check the robustness of the event selections
- Study the sensitivity of selection to certain process types
- Overcome small BRS imposed by mSugra/cMSSM correlations

Why are SMS better than the pMSSM?

- They aren't
  - Want to study effect of having many topologies at once
- Complementarity
  - Study (optimize?) topologies in isolation
  - What if only one excess appears at first?

T(opologies)N

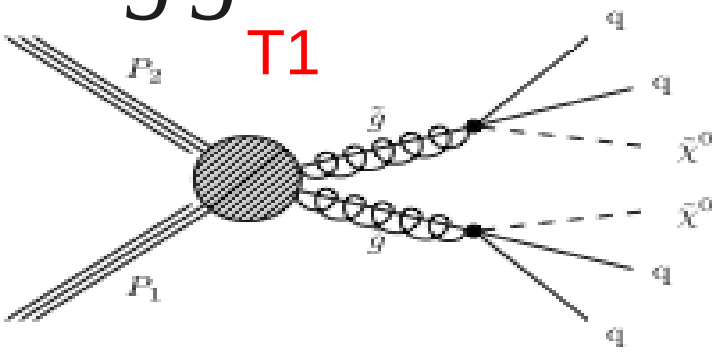
- Limited Set: focus on primary analyses
- Assume SUSY-like

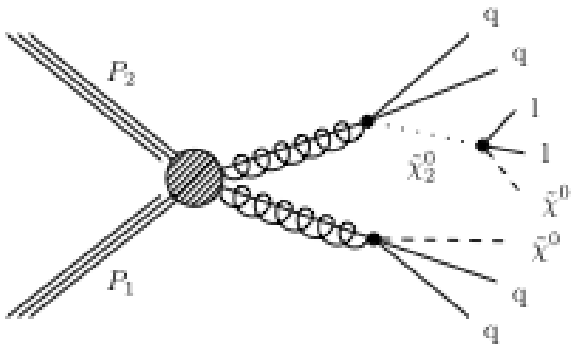
GG G → j j N1 **T1**	GG G → bb~N1 **T1bbbb**	G1 G2 G1 → j j N1 G2 → j j N2 N2 → l+l- N1 **T1lh**
QQ*, Q → j N1 **T2**	GG G → j j C1 C1-> l nu N1 **T1lnu**	GG G → j j N2 N2 → Z N1 **T5zz**

Some Cartoons

$\tilde{g}\tilde{g}$

T1

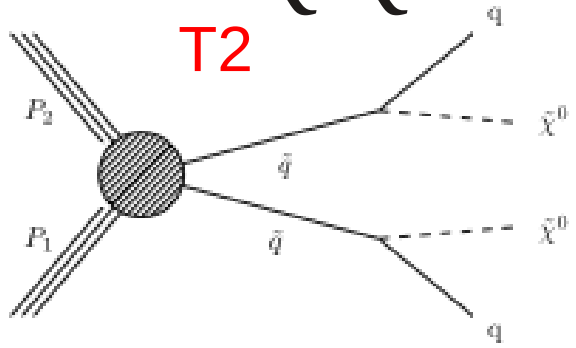


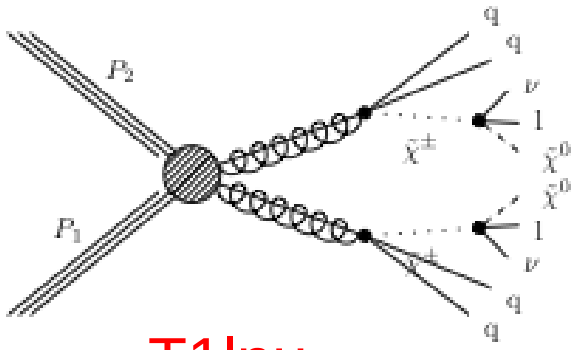


T1lh
l=leptons
h=hadrons

$\tilde{Q}\tilde{Q}^*$

T2



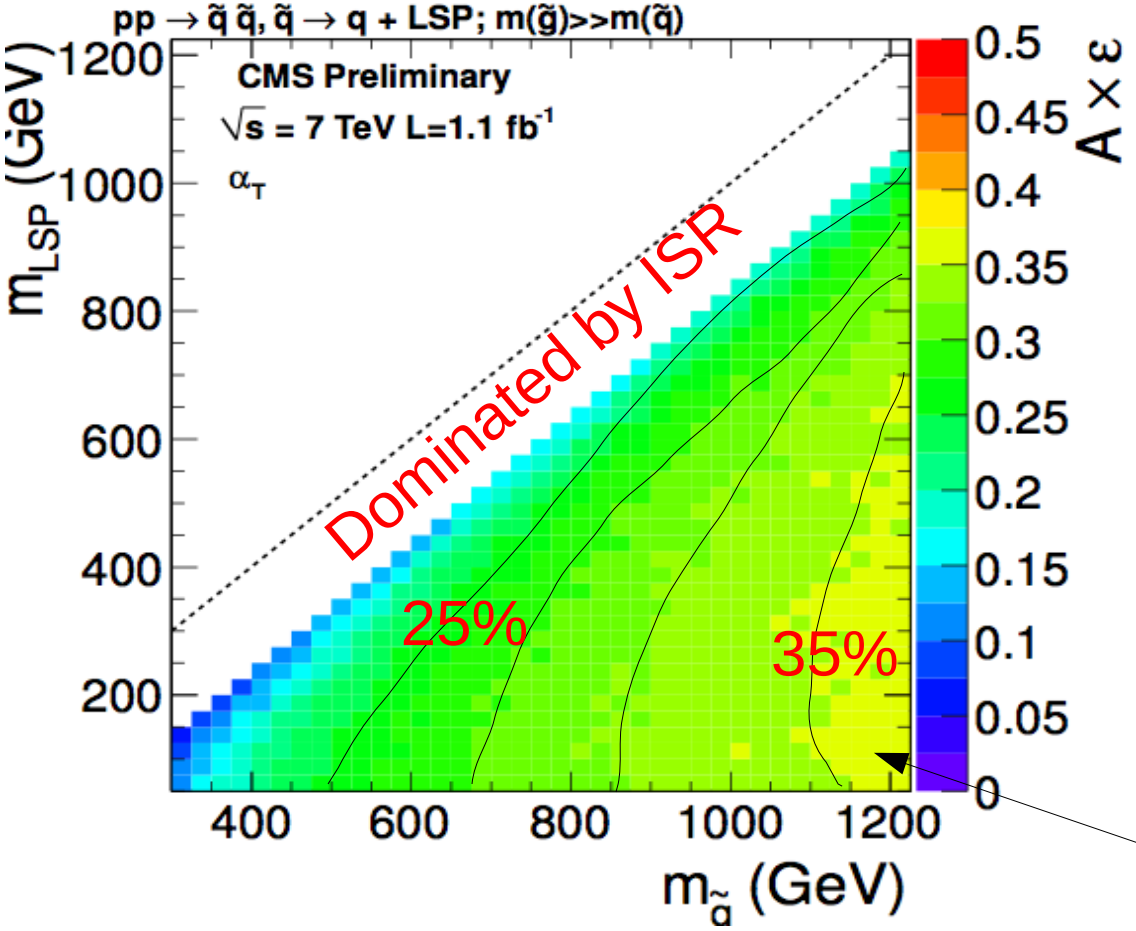


T1lnu
W → l nu

CMS Analyses with SMS

NAME	SIMPLIFIED SELECTION	NAIVE TOPOLOGY	REF
α_T	Angle btw leading jets	T2 + T1	***SUS-11-003***
M_{T2}	Generalized transverse mass	T2 + T1	***SUS-11-005***
Jets + mET + b-jets	Large HT/mET Sig d-Phi b-jets	T1bbbb	***SUS-11-006***
Z	High pT Z, large mET	T5zz	***SUS-11-017 (SUS-11-012)***
OS DiLepton	Moderate pT leptons+extra variable	T1lnu+T1lh+T5zz	***SUS-11-011***
SS DiLepton	Moderate pT leptons	T1lnu + T5zz	***SUS-11-010***

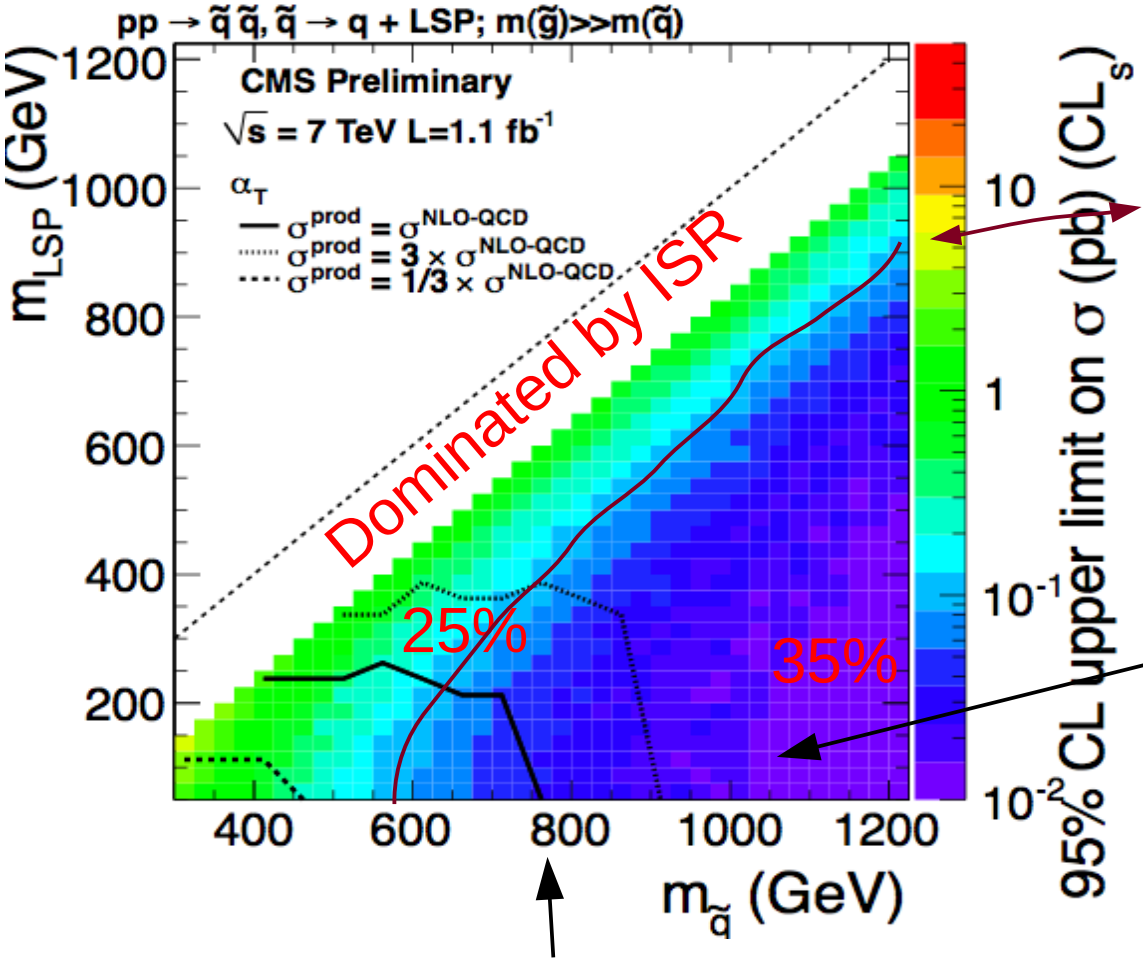
T2 and α_T : Efficiency



$$\frac{pass\ selection}{generated}$$

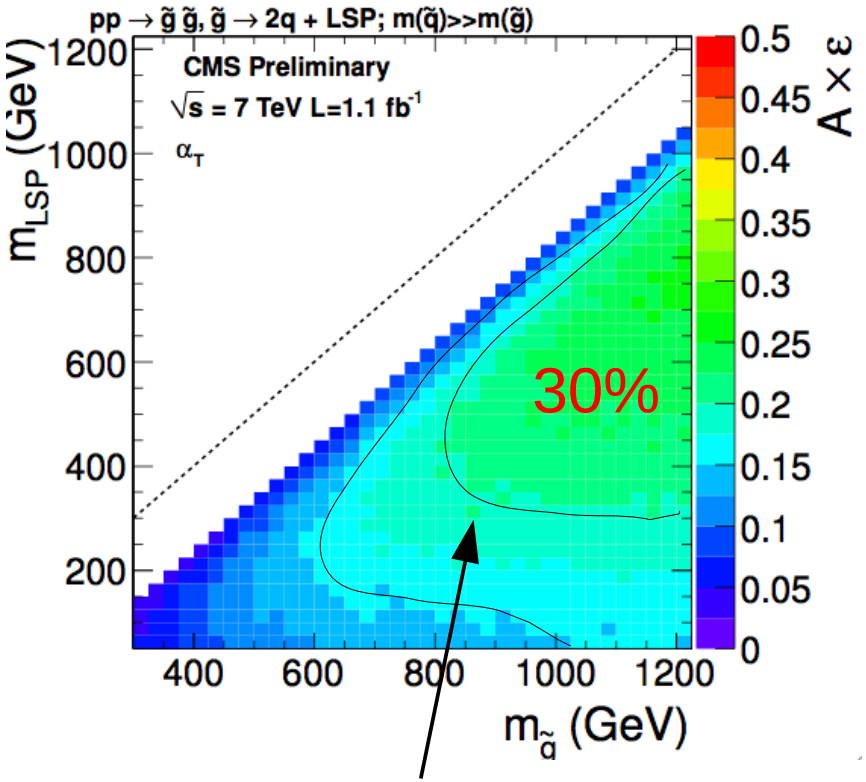
High Mass:
Large Acceptance

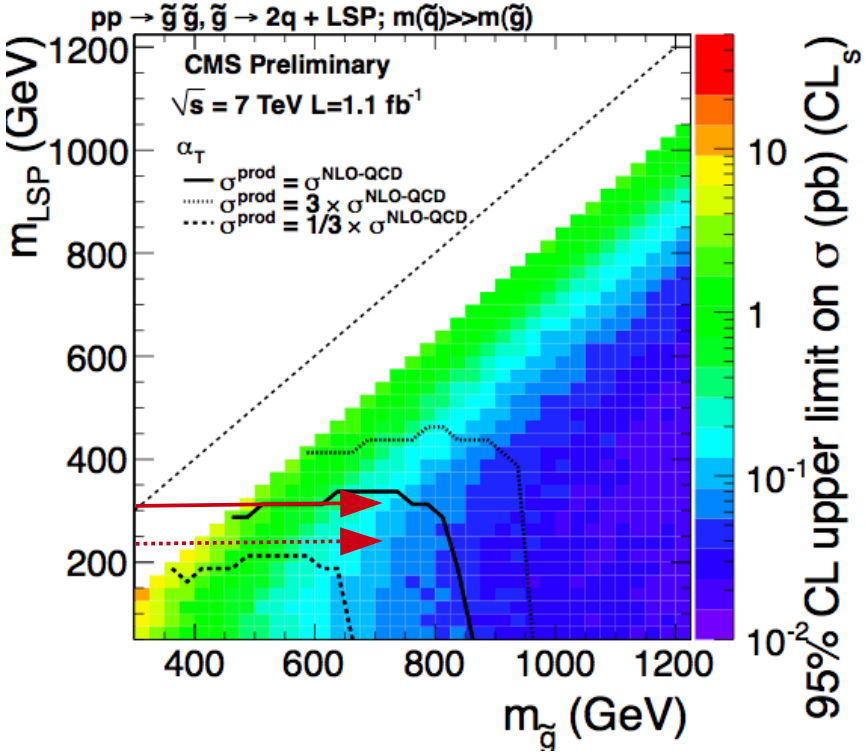
T2 and α_T : σ x BR



T1 and α_T

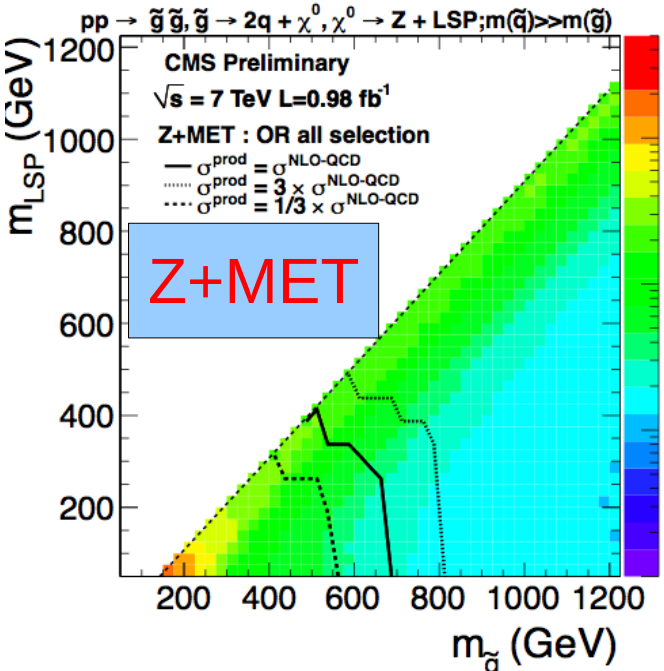
GG
G → j j
N1

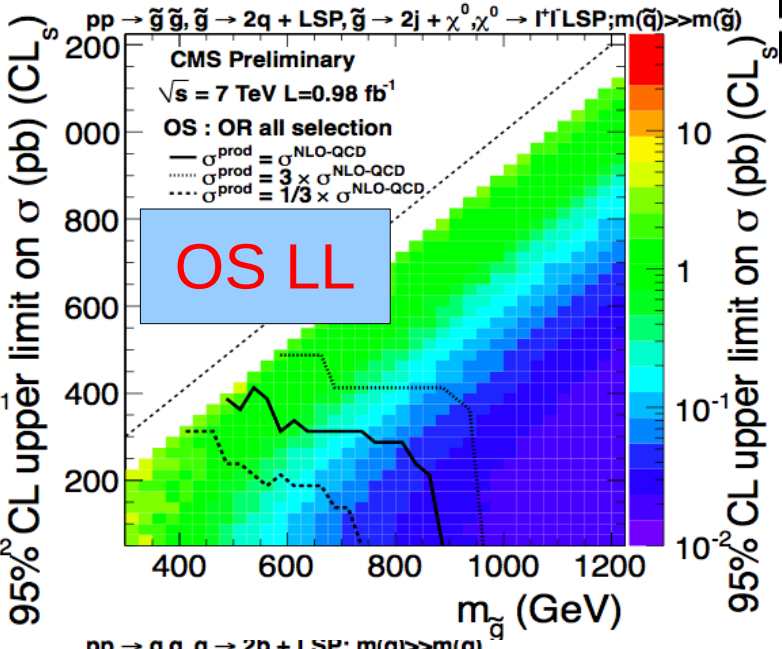


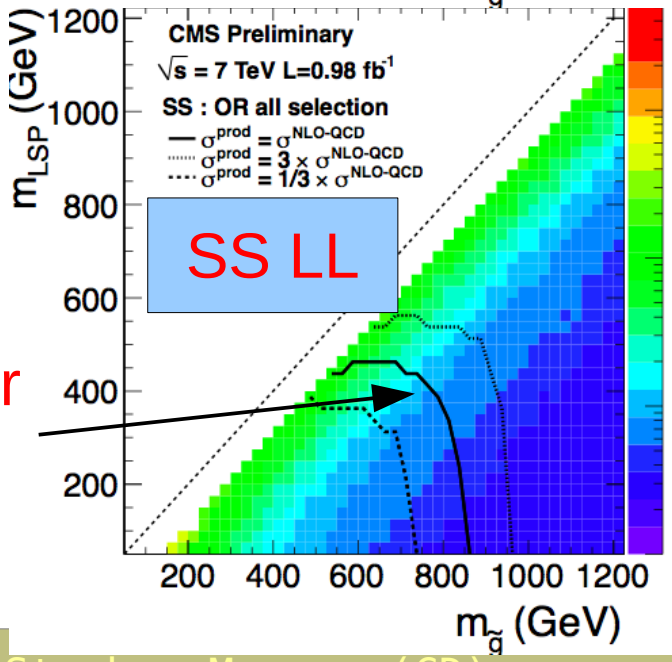


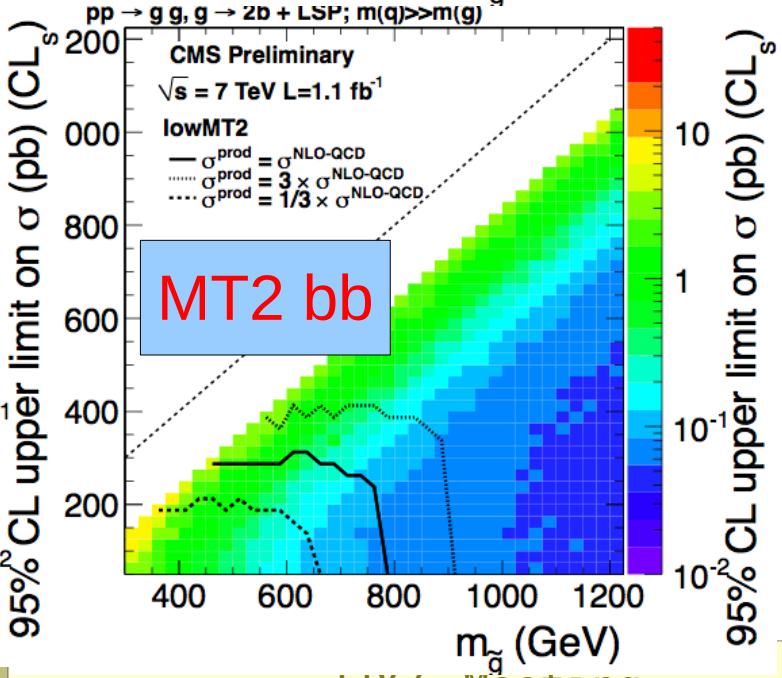
Different Acceptance Contours

Prospino GG, M(Q)>>M(G)


pp → g̃ g̃, g̃ → 2q + χ⁰,χ⁰ → Z + LSP;m(q̃)>>m(g̃)
CMS Preliminary
√s = 7 TeV L=0.98 fb⁻¹
Z+MET : OR all selection
σprod = σNLO-QCD
σprod = 3 × σNLO-QCD
σprod = 1/3 × σNLO-QCD
Z+MET
mLSP (GeV)
mq̃ (GeV)
95% CL upper limit on σ (pb) (CLs)

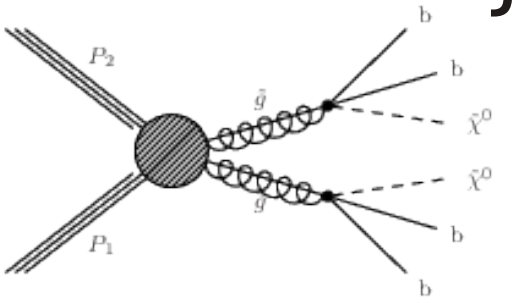

pp → g̃ g̃, g̃ → 2q + LSP, g̃ → 2j + χ⁰,χ⁰ → l⁺l⁻LSP;m(q̃)>>m(g̃)
CMS Preliminary
√s = 7 TeV L=0.98 fb⁻¹
OS : OR all selection
σprod = σNLO-QCD
σprod = 3 × σNLO-QCD
σprod = 1/3 × σNLO-QCD
OS LL
mq̃ (GeV)
95% CL upper limit on σ (pb) (CLs)

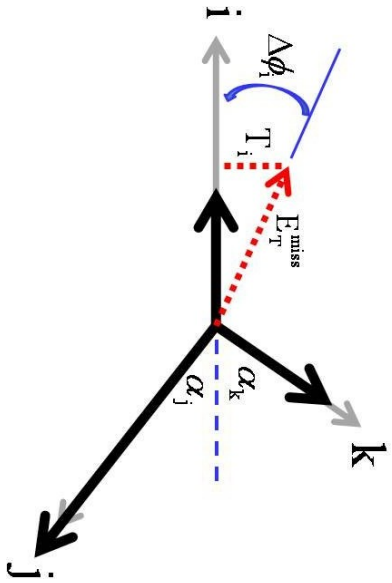

CMS Preliminary
√s = 7 TeV L=0.98 fb⁻¹
SS : OR all selection
σprod = σNLO-QCD
σprod = 3 × σNLO-QCD
σprod = 1/3 × σNLO-QCD
SS LL
mLSP (GeV)
mq̃ (GeV)
95% CL upper limit on σ (pb) (CLs)

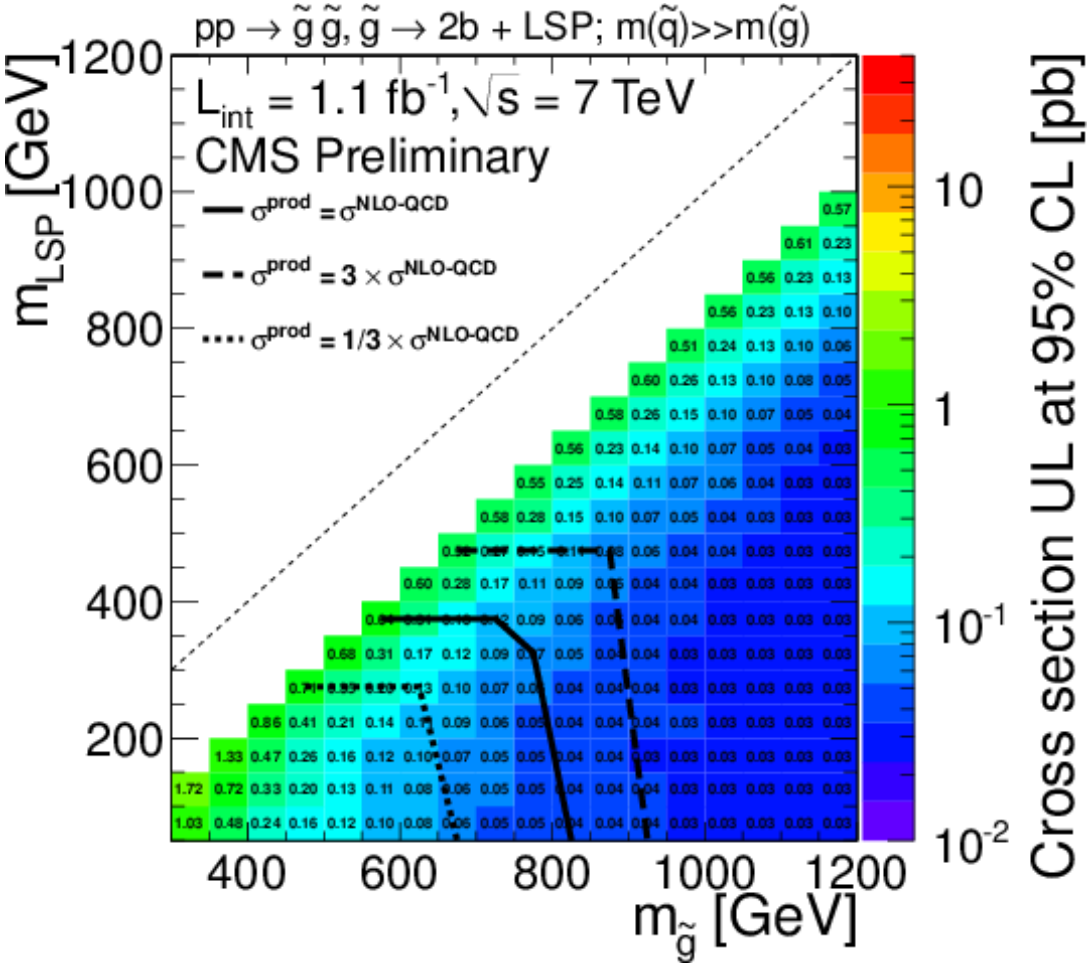

pp → g g, g → 2b + LSP; m(q)>>m(g)
CMS Preliminary
√s = 7 TeV L=1.1 fb⁻¹
lowMT2
σprod = σNLO-QCD
σprod = 3 × σNLO-QCD
σprod = 1/3 × σNLO-QCD
MT2 bb
mq̃ (GeV)
95% CL upper limit on σ (pb) (CLs)

Smaller mET

Jets + MET + b-Jets







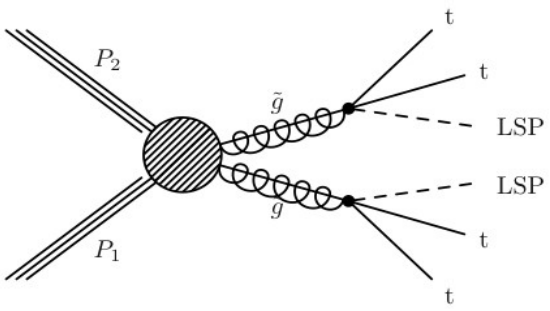
SUS-11-006

For limits on $m(\tilde{g}), m(\tilde{q}) >> m(\tilde{g})$ (andvice versa), $\sigma^{\text{prmd}} = \sigma^{\text{NLO+QCD}}$, $m(\tilde{\chi}^\pm), m(\tilde{\chi}_2^0) = \frac{m(\tilde{g}) + m(\tilde{\chi}^0)}{2}$. $m(\tilde{\chi}^0)$ is varied from 0 GeV/c^2 (darkblue) to $m(\tilde{g}) - 200\,GeV/c^2$ (lightblue).

CMS Overview on SMS

- SMS add insight to kinematic effects
  - Only T1 and T2 for 35/pb, now leptonic and b-enhanced SMS
- SMS limits ~worse, but more general than our cMSSM benchmark
- Large interest in heavy flavor SMS, e.g. T1tttt, T2tt
- Other topologies to decompose cMSSM:
  - QQ (vs QQ*) and QG

Coming Soon

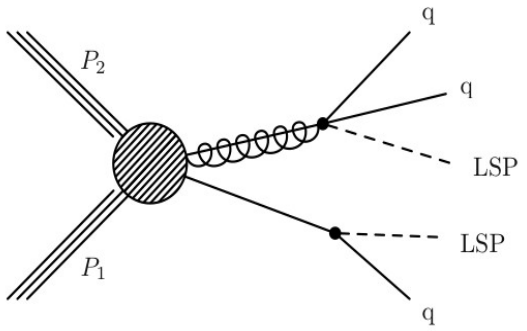


T1tttt

SUS-11-010 *(SS)*
SUS-11-006 *(RA2b)*

SS analysis has the best prospects, given BR and backgrounds

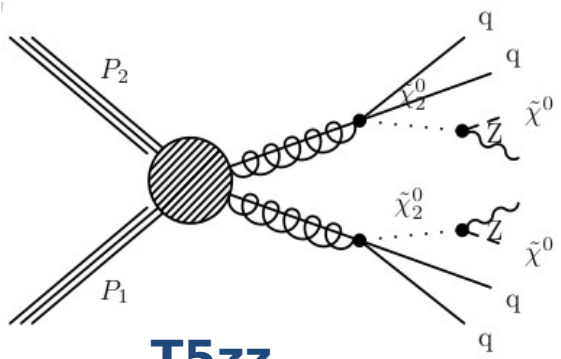
RA2b builds on T1bbbb, and should give best hadronic limit.



TGQ

SUS-11-003 *(RA1)*
SUS-11-004 *(RA2)*

Useful for consistency check with cMSSM



T5zz

SUS-11-003 *(RA1)*
SUS-11-004 *(RA2)*

Test fully hadronic searches with cascade decays

Re-cast results from Z to W and Z to H(100)

Check complementarity with other leptonic results

CMS Lessons

- We learned a lot about how to perform massive scans within our computing model
  - CMS DataOps was very patient and helpful
- Despite our successes, it is clear the problem doesn't scale
  - Too many “small”, but reasonable variations that affect acceptance

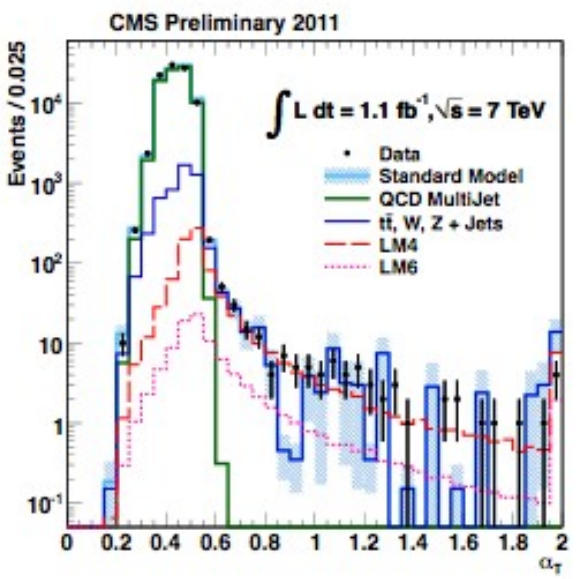
Questions?

BACKUP

Limit from αT analysis

CMS-PAS-SUS-11-003

$$\alpha_T = \frac{E_T^{jet_2}}{M_T} = \frac{E_T^{jet_2}}{\sqrt{\left(\sum_{i=1}^{2} E_T^{jet_i}\right)^2 - \left(\sum_{i=1}^{2} p_x^{jet_i}\right)^2 - \left(\sum_{i=1}^{2} p_y^{jet_i}\right)^2}},$$

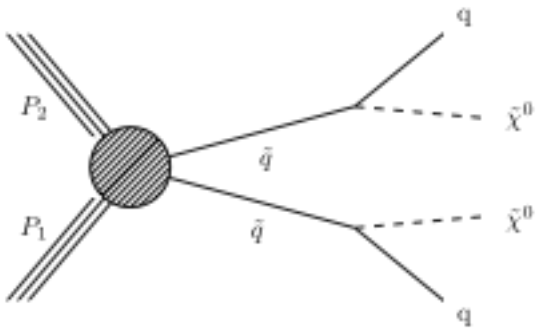


Rather than defining a specific signal region, this analysis searches for an excess of events in data over the Standard Model (SM) expectation in a range of exclusive bins of HT . This is done to makes the search optimization less dependent on the (unknown) energy scale of a new physics signal.

LM4: M(gluino)~690 GeV M(squark)~650 GeV

LM6: M(gluino)~930 GeV M(squark)~840 GeV

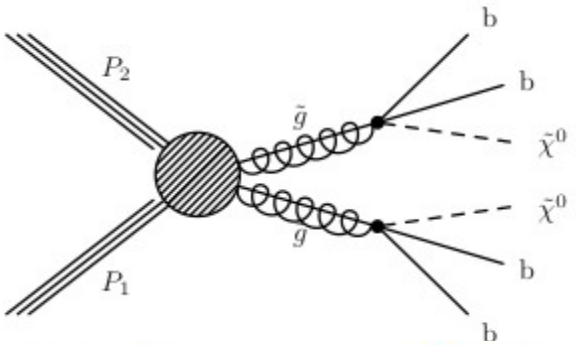
Limit on T2 topology



We use reference cross sections – for squark pair production in the limit of decoupled gluinos, and gluino pair production in the limit of decoupled squarks – calculated at next to leading order (NLO) precision using P R OS P I NO. These reference cross sections will be used to draw the 95 % exclusion contours on the cross section times branching fraction in the parameter space of the simplified models .
For the T2 topology the reference cross section is taken as the sum of the four light flavor.

Limit on T1bbbb topology from MT2 analysis

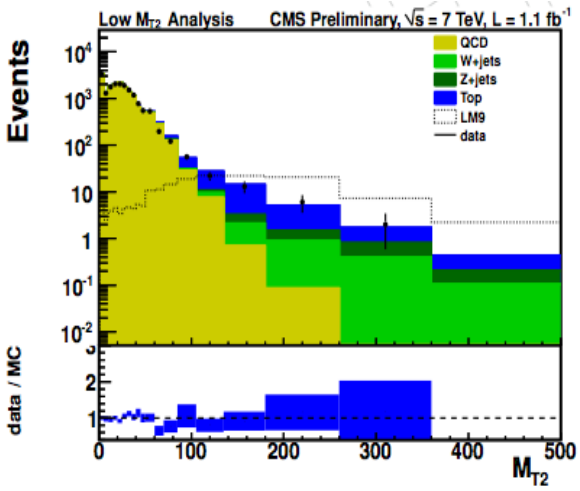
CMS-PAS-SUS-11-005

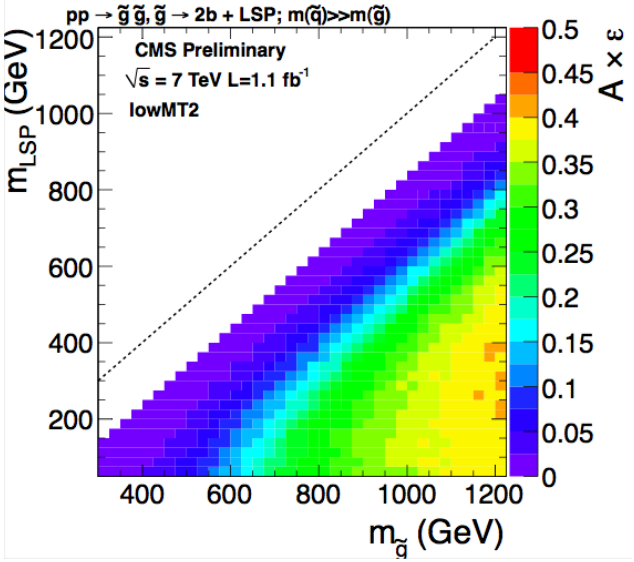


This topology look at the role of the 3rd generation.

This analysis uses the MT2 observable to suppress the background and requires at least one jet in the final state to be identified as b.

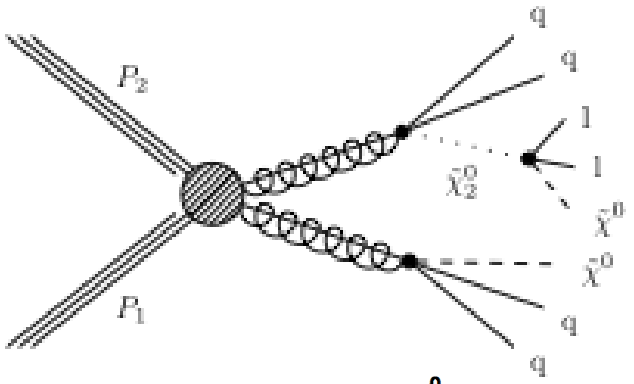
$$(M_{T2})^2 = 2A_T = 2p_T^{vis(1)} p_T^{vis(2)} (1 + cos\phi_{12}),$$





Limit on T1Lh topology from opposite-sign dilepton analysis

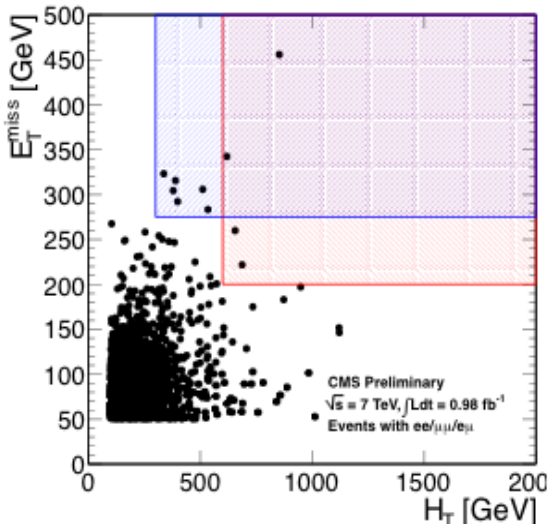
CMS-PAS-SUS-11-011

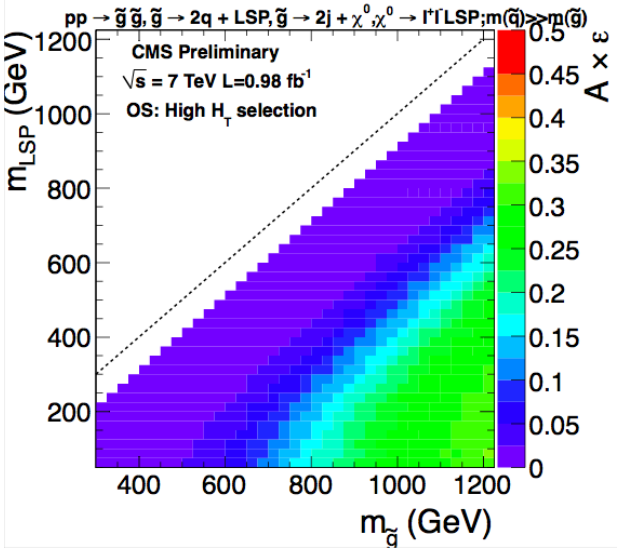


$$m(\tilde{\chi}^{\pm} l \tilde{\chi}_2^0) \equiv \frac{m(\tilde{g}) + m(\tilde{\chi}^0)}{2}$$

In this topology the neutralino is forced to decay in a 3 body final state.

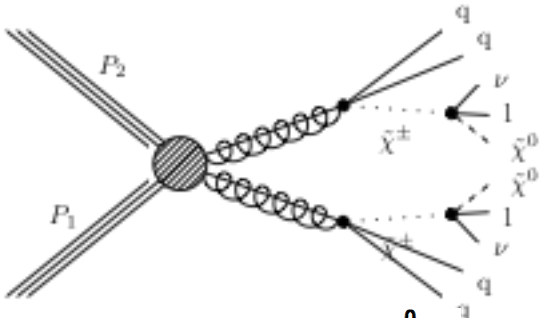
We search for an excess of events with opposite flavor or same flavor and outside the Z mass window accompanied by large MET and HT.





Limit on T1lnu topology from same-sign (SS) dilepton analysis

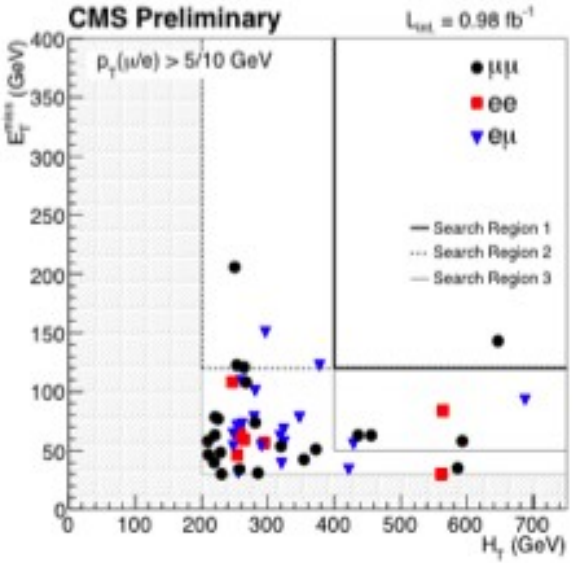
CMS-PAS-SUS-11-010

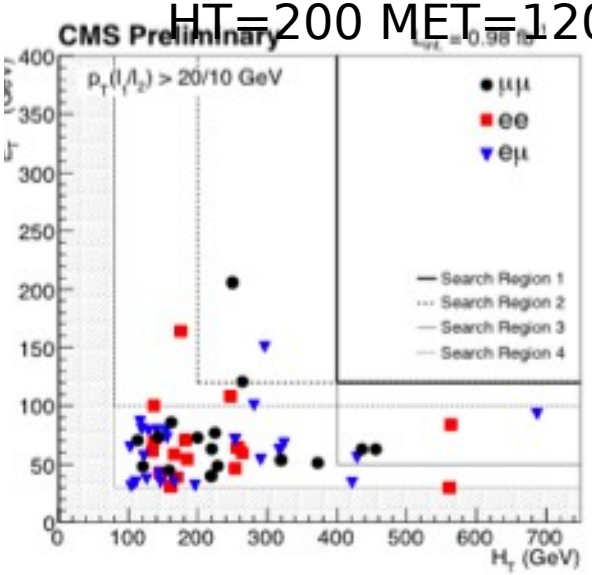


$$m(\tilde{\chi}^{\pm} \, l \, \tilde{\chi}_2^0) \equiv \frac{m(\tilde{g}) + m(\tilde{\chi}^0)}{2}$$

A search for the SS dileptons profits from low SM background.

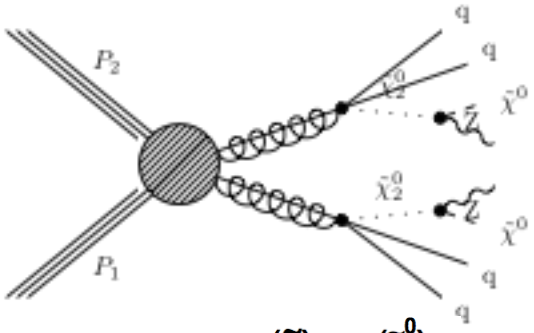
Best limit from high pt leptons
ΔM(gluino,LSP)>300 GeV from region
HT=400 MET=120
ΔM(gluino,LSP)<300 GeV from region
HT=200 MET=120



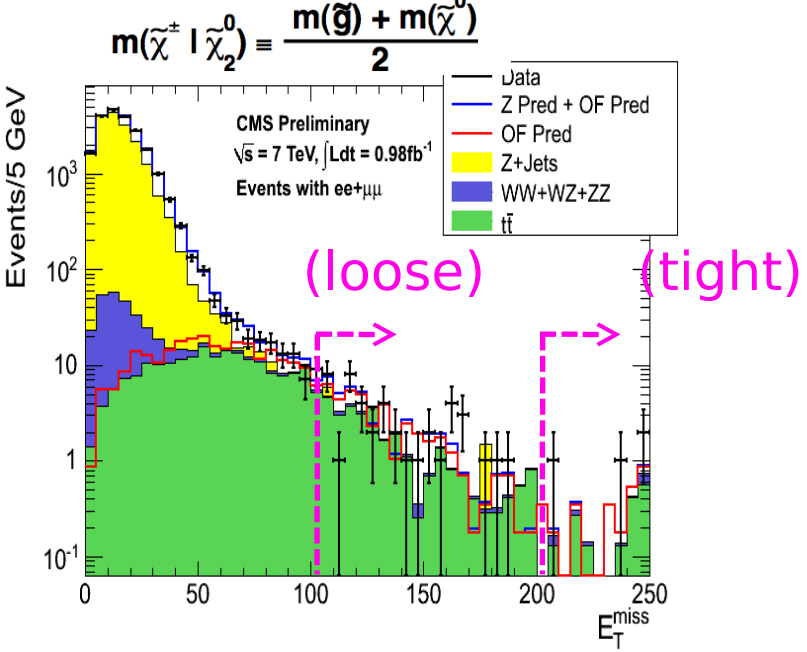


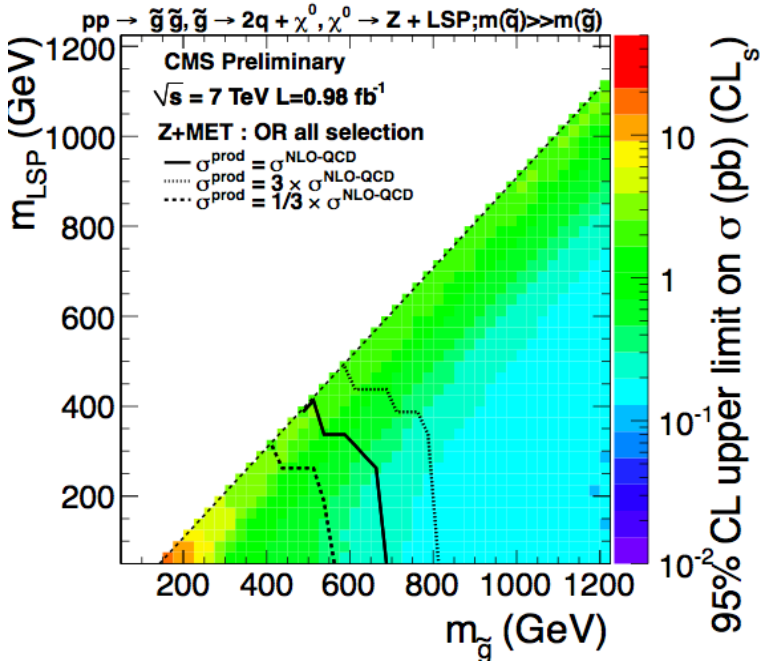
Limit on T5zz topology from Z analysis

CMS-PAS-SUS-11-017

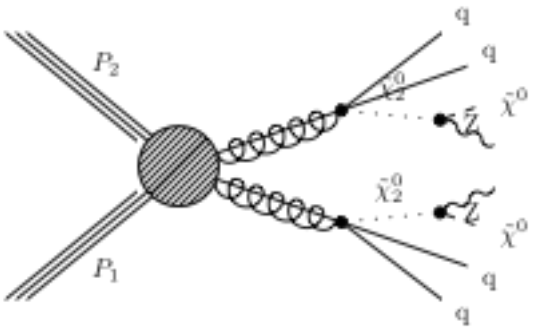


A search for the Z to leptons plots jets final state allows a low threshold on the jet activity requirements.
Low gluino-LSP mass splitting can be probed with the loose met selection.

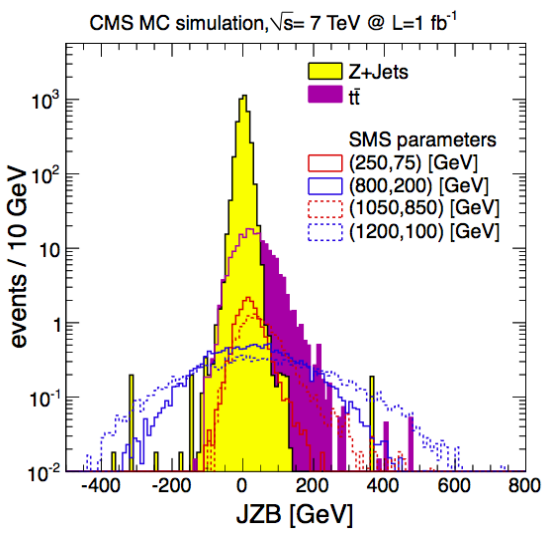




Limit on T5zz topology from Z analysis

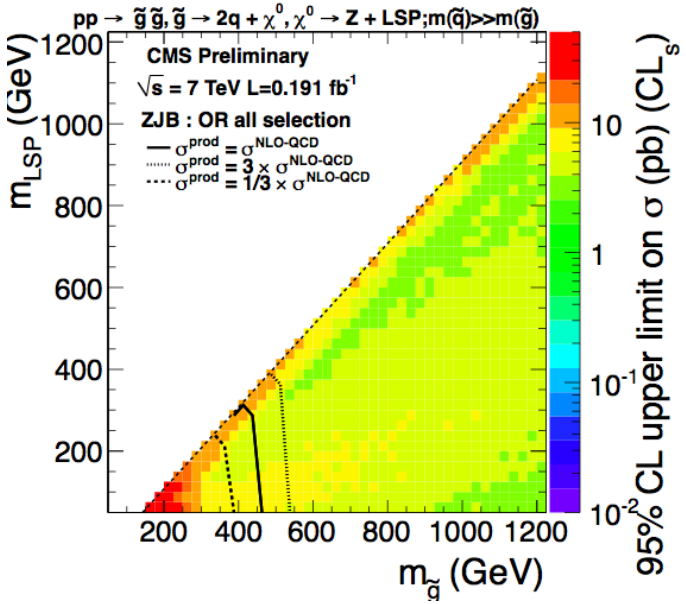


$$JZB = \left| -\sum_{\text{jets}} \vec{p}_T \right| - \left| \vec{p}_T^{(Z)} \right| =$$



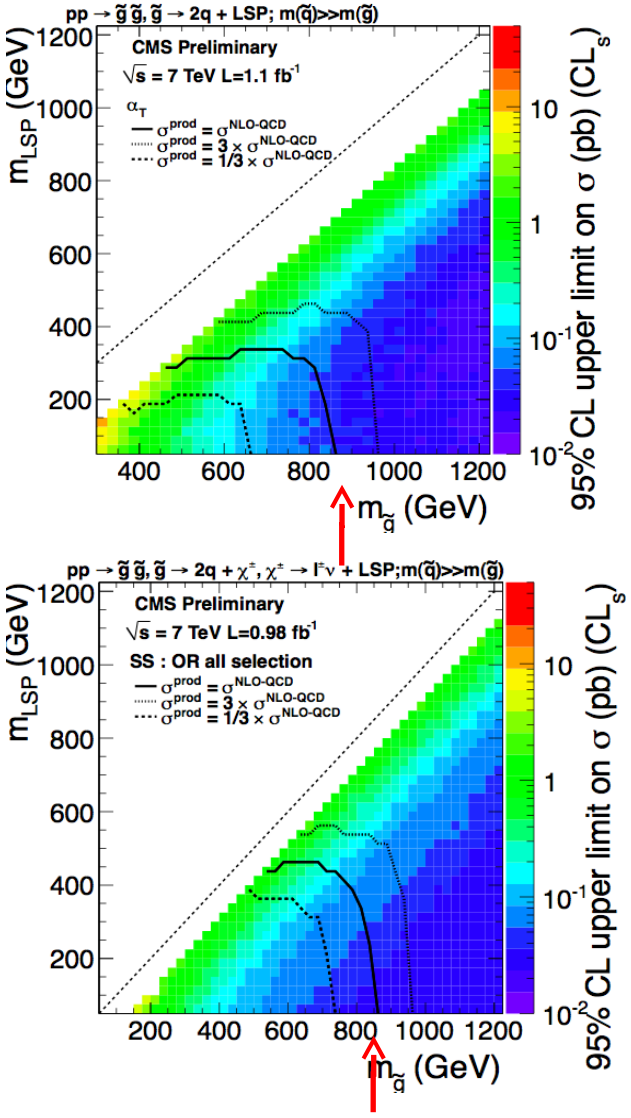
CMS-PAS-SUS-11-012

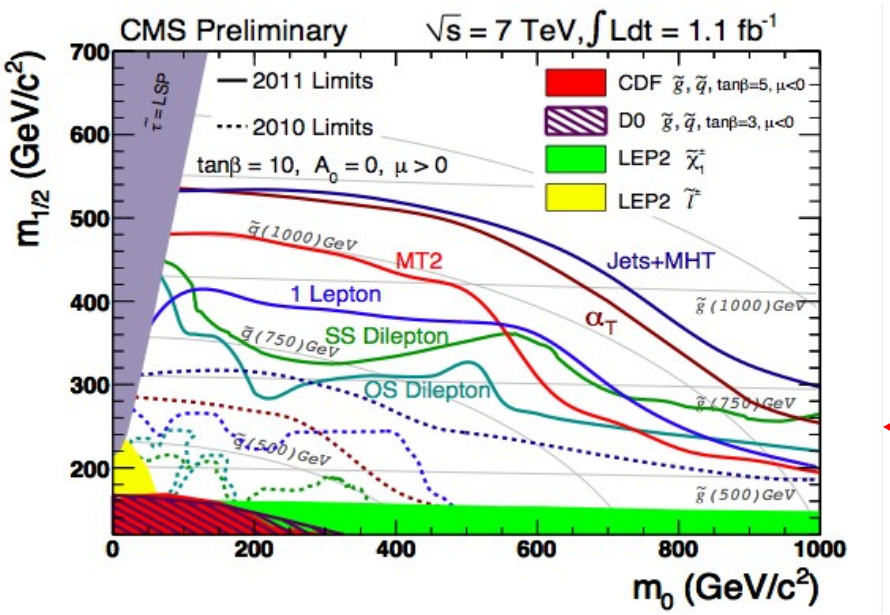
It is important to have different analyses looking at the same signature with orthogonal control sample for the background estimations.



Signal contamination in the data driven method prediction subtracted.

Summary





For models similar to the CMSSM (i.e. low LSP wrt gluino mass), the references exclusion limit is ~ 800 GeV in gluino mass ... but for more compressed spectra the picture changes to 500 GeV.

The SS dilepton analysis can more easily probe compressed spectra.