Searches for SUSY with third-generation signatures in CMS

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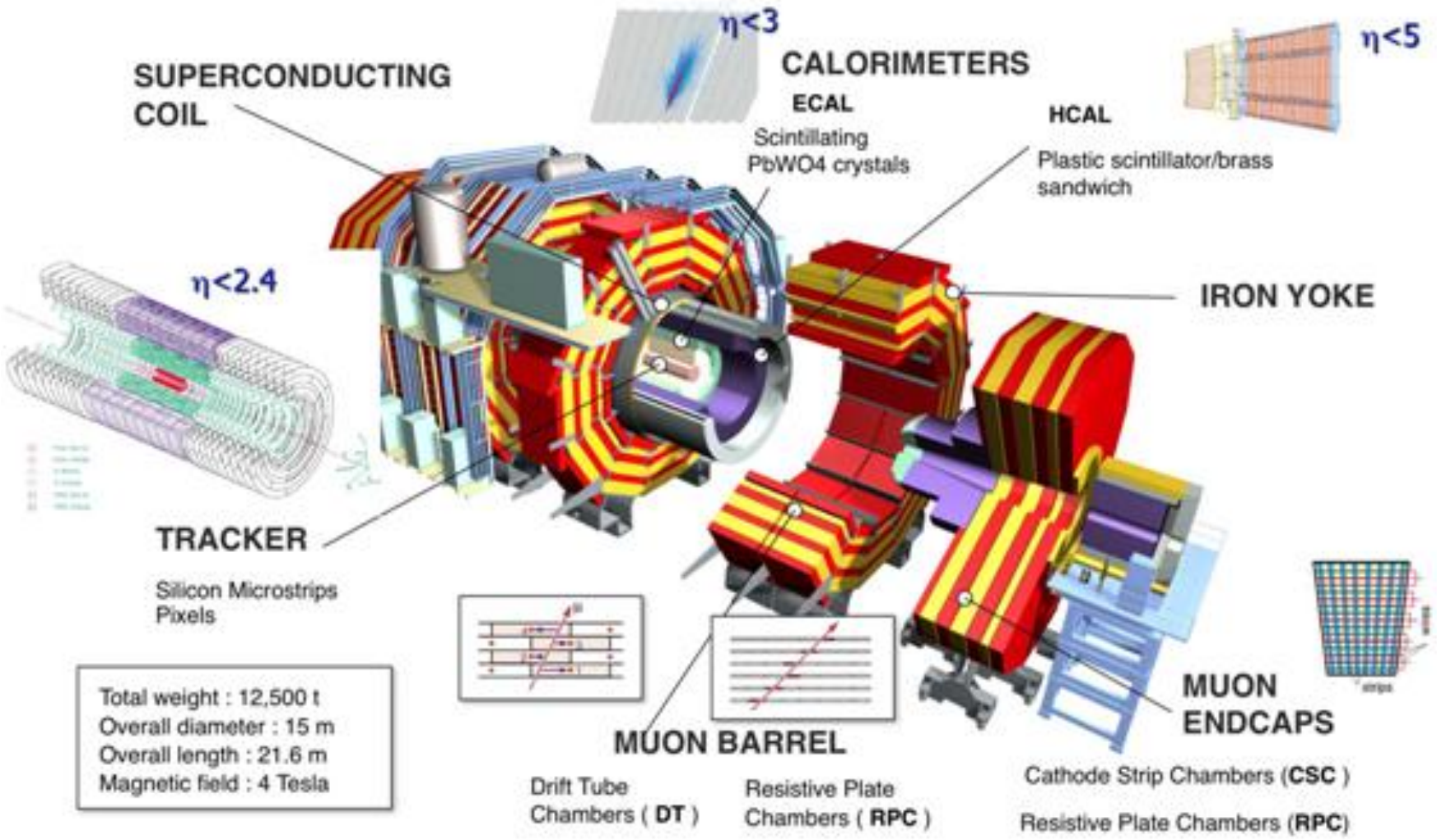
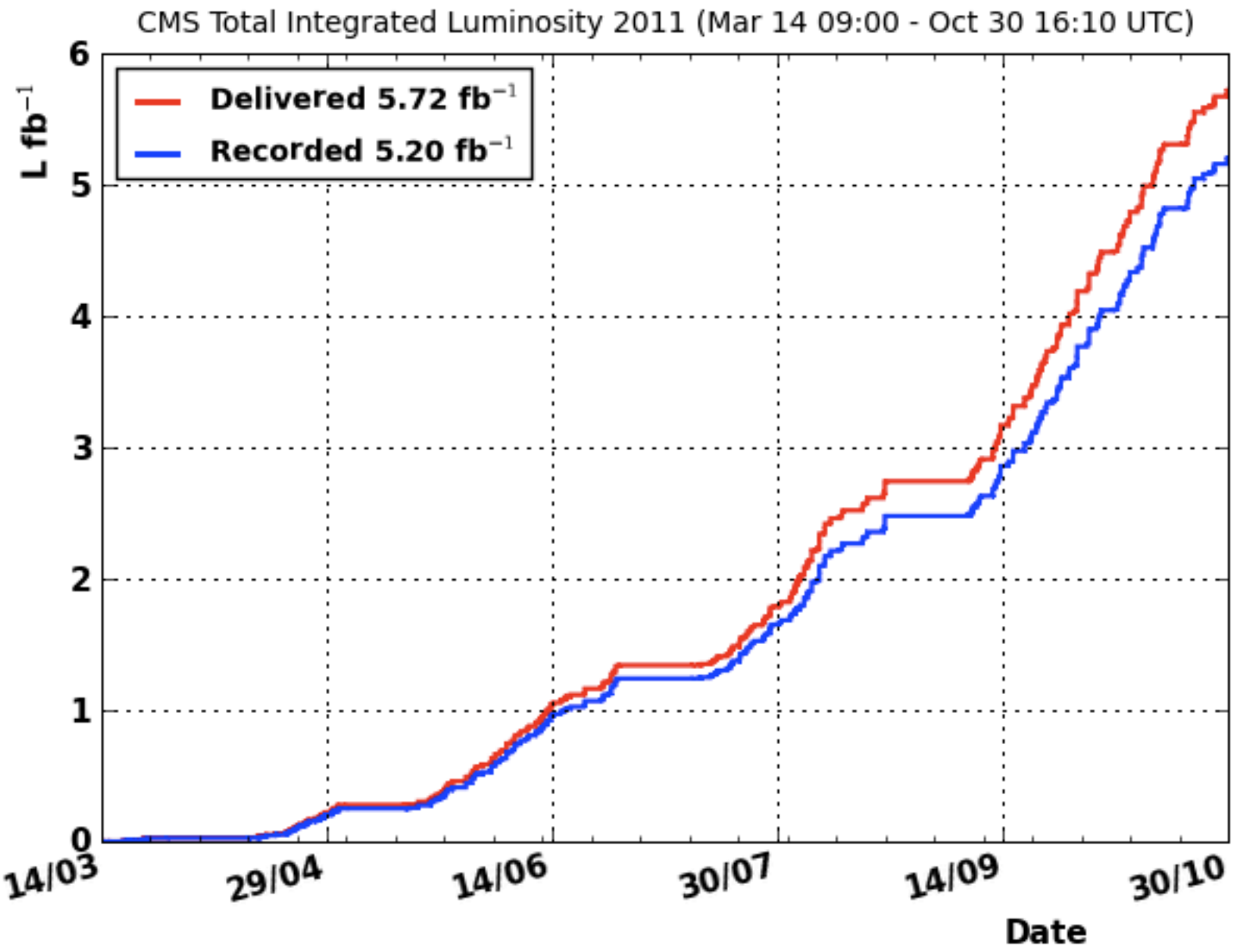
Deep Inelastic Scattering 2012

Bonn , 28.3.12

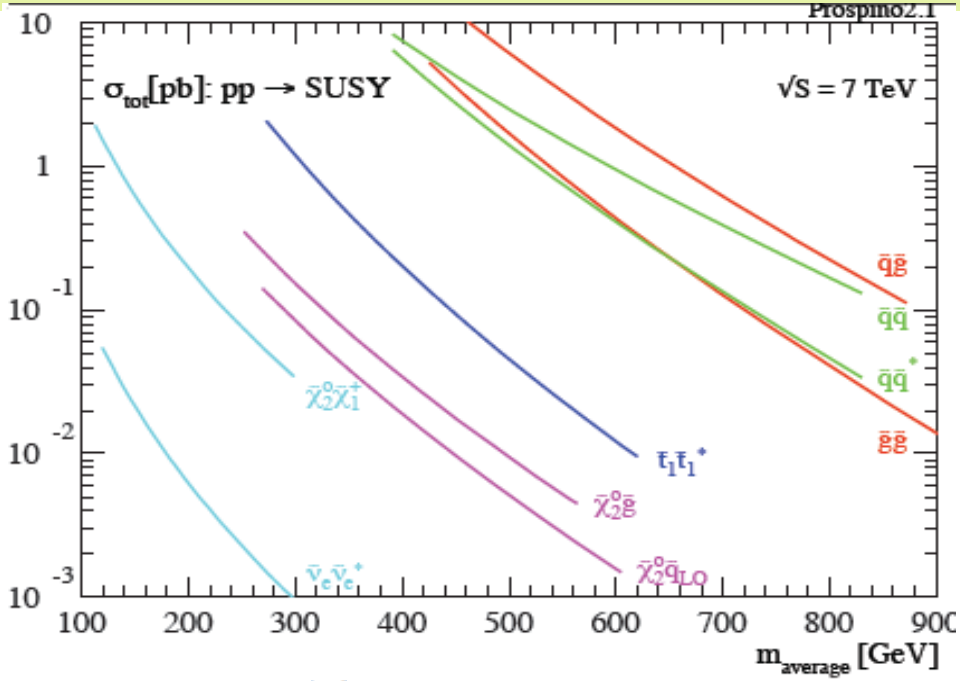
Main Parts of the **C**ompact **M**uon **S**olenoid (**CMS**)





https://twiki.cern.ch/twiki/bin/view/CMSPublic/LumiPublicResults

Motivation

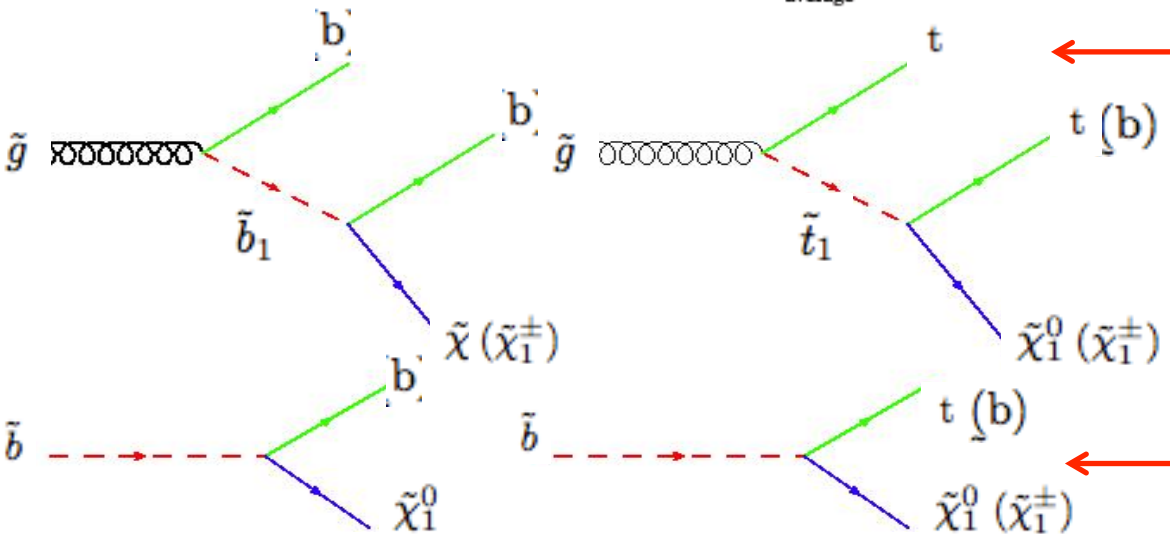


- **Motivation for SUSY : "naturalness"**

Higgs Mass is stabilized w.o. fine-tuning

- Protected by some (underlying) symmetry? Which? Prediction of stop -squarks (SUSY, little-Higgs)

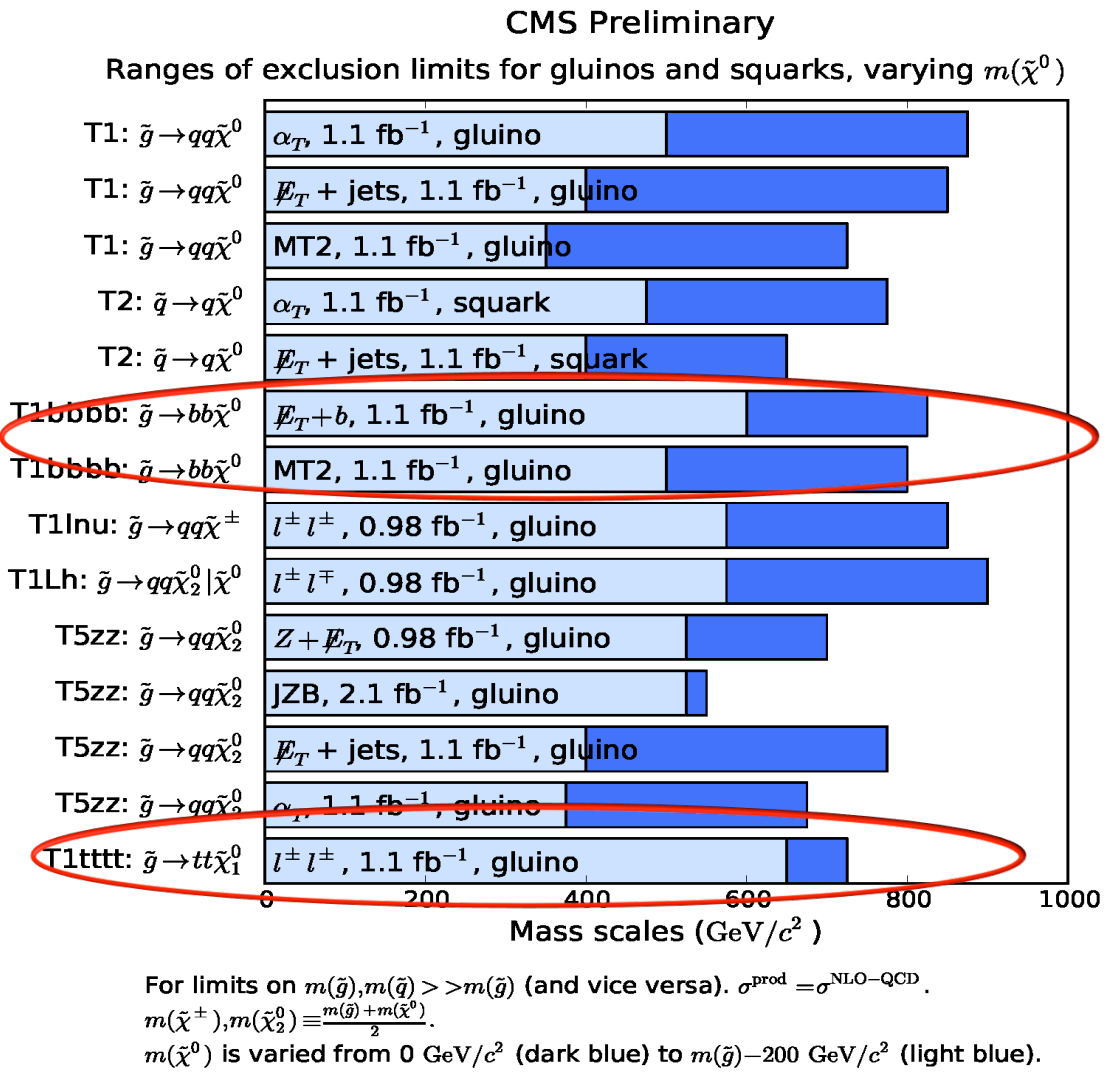
- 3rd Gen-Squarks can be lighter than all squarks due to large mixing



← Gluino cascade decays

← Direct pair production

3rd generation studies



Simplified Model Spectrum interpretation in:

SameSign dileptons, b-tagged jets + MET(4.7/fb) – SUS-11020

Hadronic final states using M_{T2} (1.1/fb) – SUS-11005

Search with b-quark Jets and MET (1.1/fb) – SUS-11006

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS

Same-sign dileptons, b-tagged jets and MET

SUS-11020

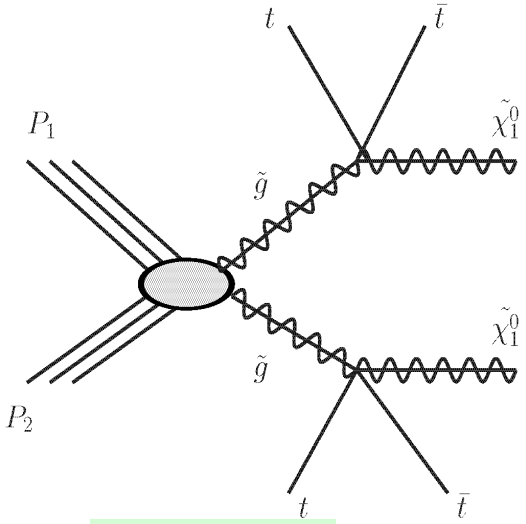
A search for anomalous production in the same-sign dilepton final state

- Potential discriminant for SUSY : In SM SS +jets +MET signatures are rare
- At least 2 b-jets and missing energy
- Jets: Production from light flavor & models with sbottom/stops lighter than all squarks

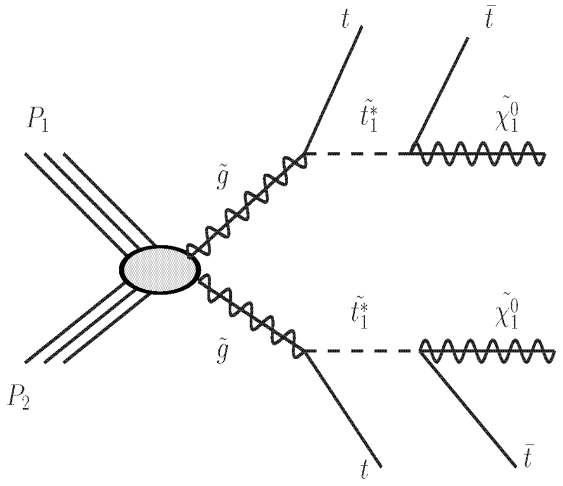
- Also considered models with same topology :
- Z'-boson : flavor violating (u-t coupl) – Proposed to explain the tt for-back asymmetry (Tevatron)
- MaxFV : Models of maximal flavor violation
- Background - dominated by semi-leptonic tt decays
  - Suppress it with 2-b jets
    - b's in tt are very unlikely to produce 3 distinct objects, (i.e., 2 b-tag jets +1 iso high pT lepton)
  - Other – Rare processes (MC), fake-lep & q-flip (ControlDataSamples)

Same-sign dileptons, b-tagged jets and MET

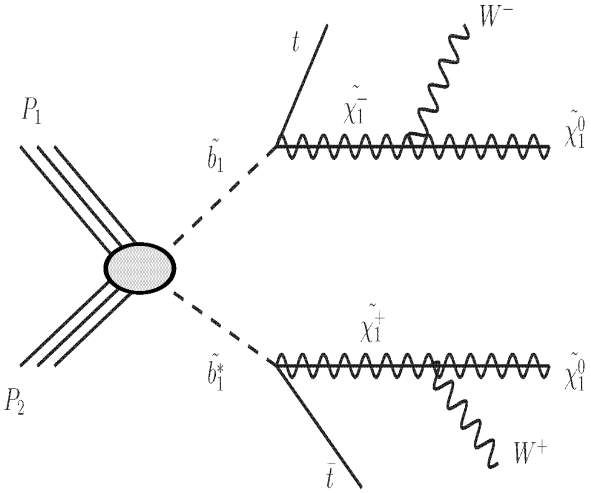
SUS-11020



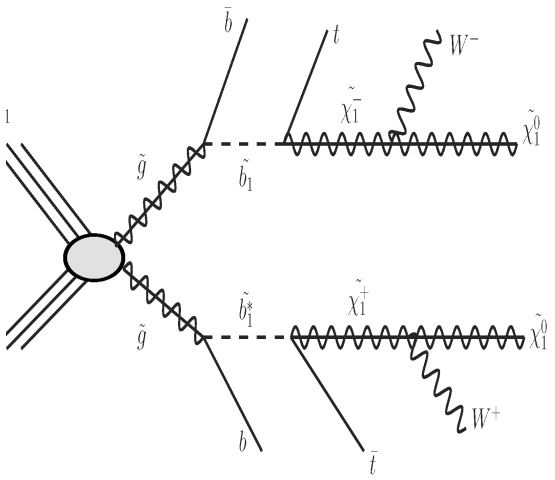
ModelA1



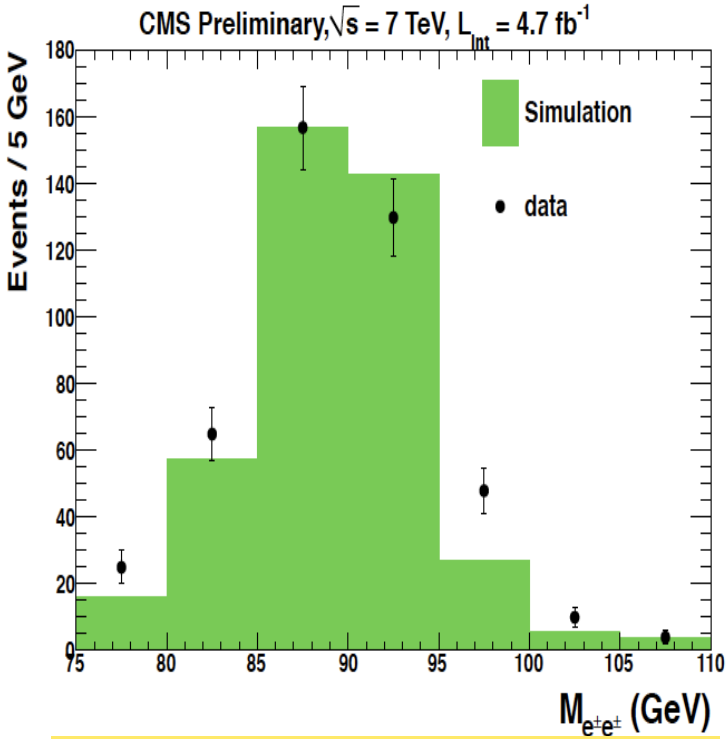
ModelA2



Model B1



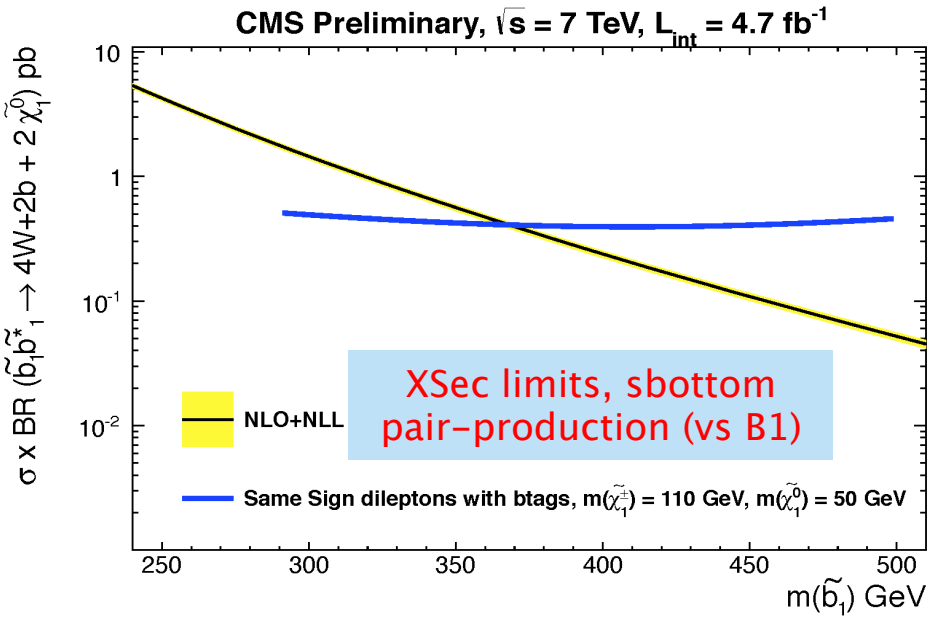
Model B2



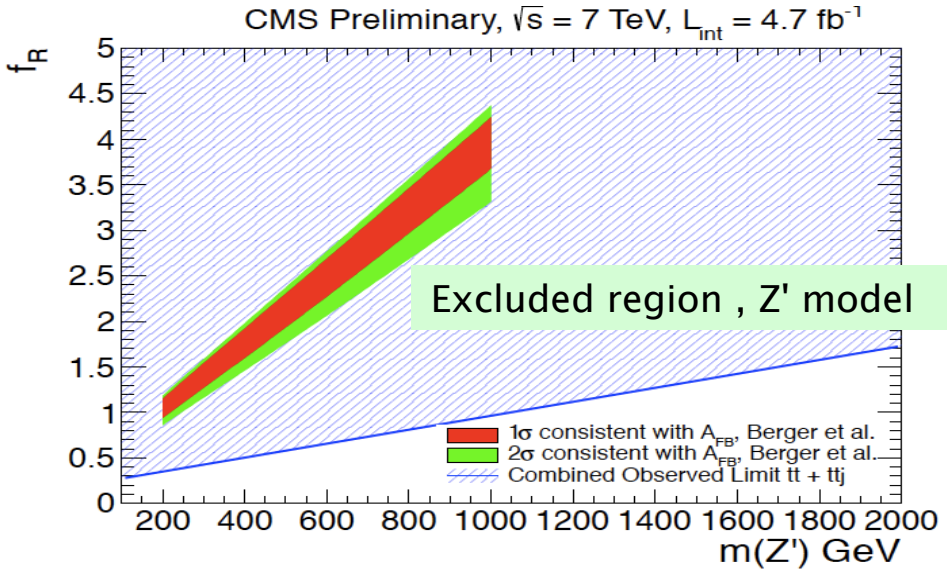
Invariant mass of Same Sign e+e+

Interpretation in several models…

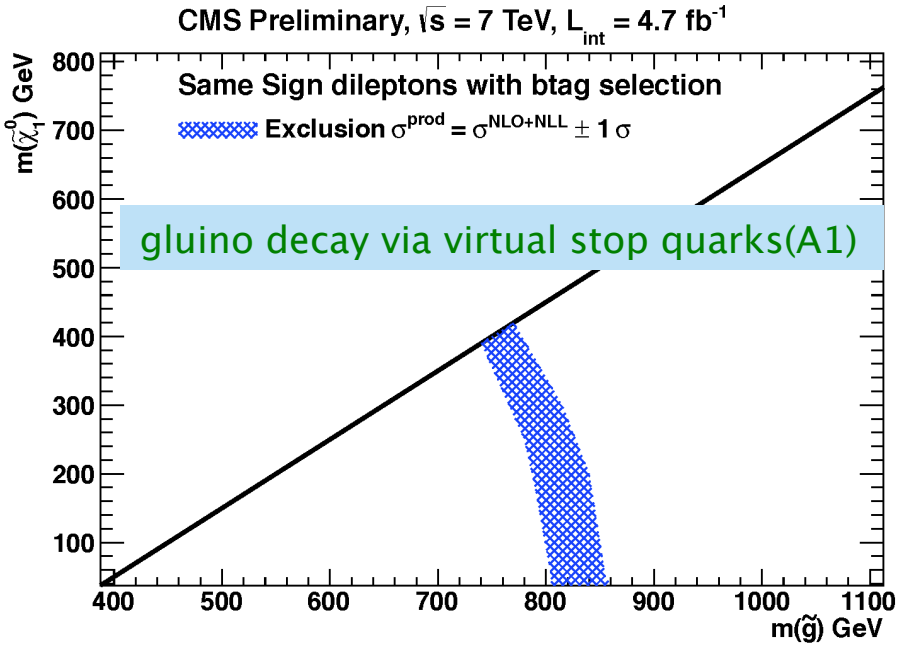
SUS-11020



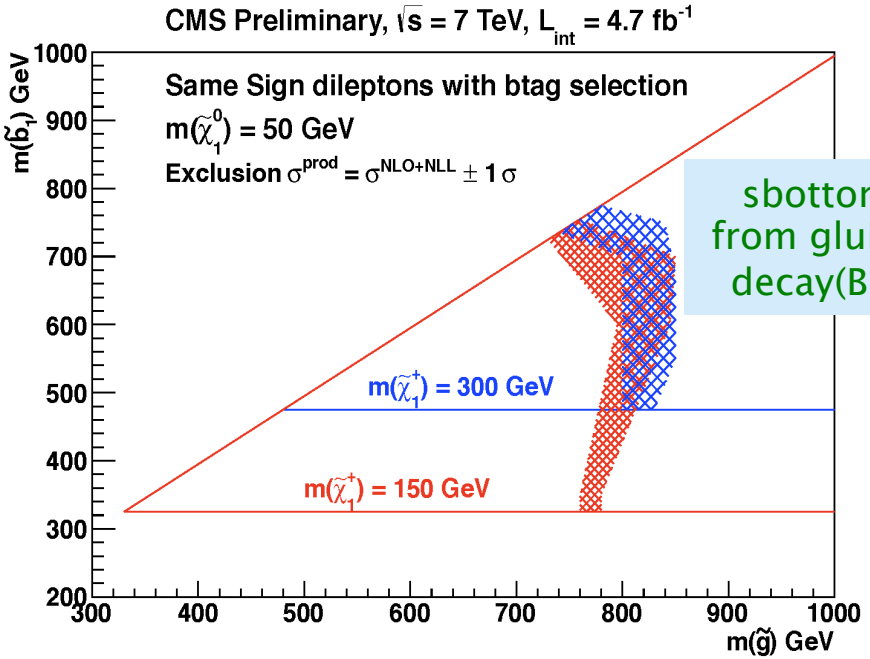
XSec limits, sbottom pair-production (vs B1)



Excluded region , Z' model



gluino decay via virtual stop quarks(A1)



sbottom from gluino decay(B2)

Search for SUSY in hadronic final states using M_{T2}

1.1/fb

SUS-11005

$$M_{T2}(m_\chi) = \min_{p_T^{\chi(1)}+p_T^{\chi(2)}=p_T^{miss}} \left[\max\left(m_T^{(1)}, m_T^{(2)}\right)\right]$$

with

$$(m_T^{(i)})^2 = (m^{vis(i)})^2 + m_\chi^2 + 2\left(E_T^{vis(i)}E_T^{\chi(i)} - \vec{p}_T^{\,vis(i)}\cdot\vec{p}_T^{\,\chi(i)}\right)$$

M_{T2} (or stransverse mass) measures the mass of pair-produced particles where final state particles are undetected (LSP)
Assumes that the s-particles, give identical types of decay chains, defined with by their P_T, E_T, and masses.

High M_{T2} : Heavy squarks, light gluinos (go-go)->3BD.

- data-driven bgk estimation
- HT>600 GeV, Njets>2, $Jet_{1,2}pT$ > 100 GeV , $|\eta|<2.4$

maxDiff (MET- HT) = 70 GeV (reject high contr of soft/forward jets to the mom. imbalance)

- veto on isolated electrons and muons.
- SR MT_2 > 400 GeV , CR ($200 \leq M_{T2} \leq 400$ GeV)

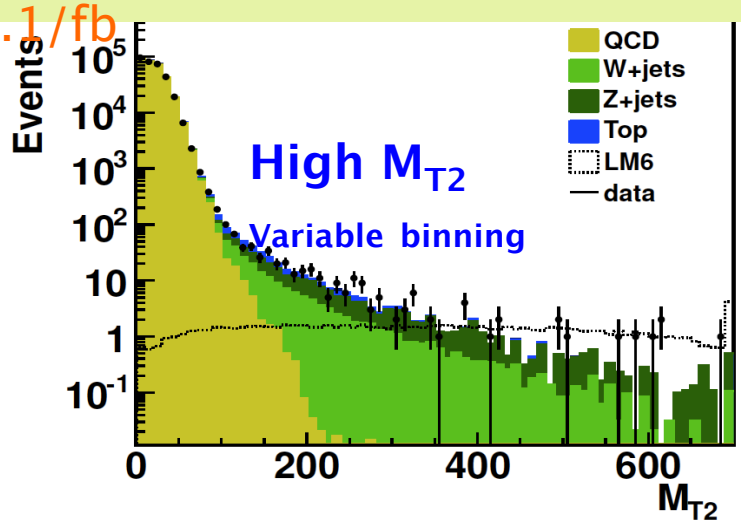
Low M_{T2} : Increased sensitivity to off-shell squark mediated decays, rich in b-quarks

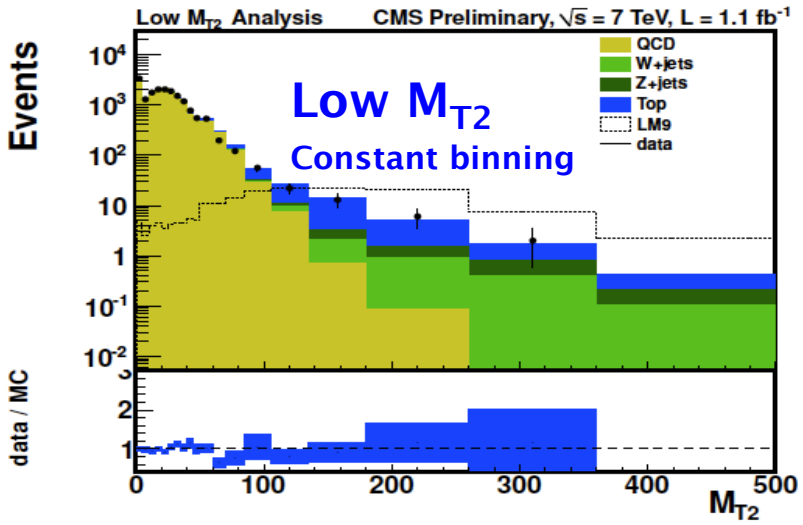
- HT >650,
- Njets>3 , Jet_1pt >150 GeV , 1>= b-tagged jet , $|\eta|<2.4$
- SR M_{T2} > 150 GeV

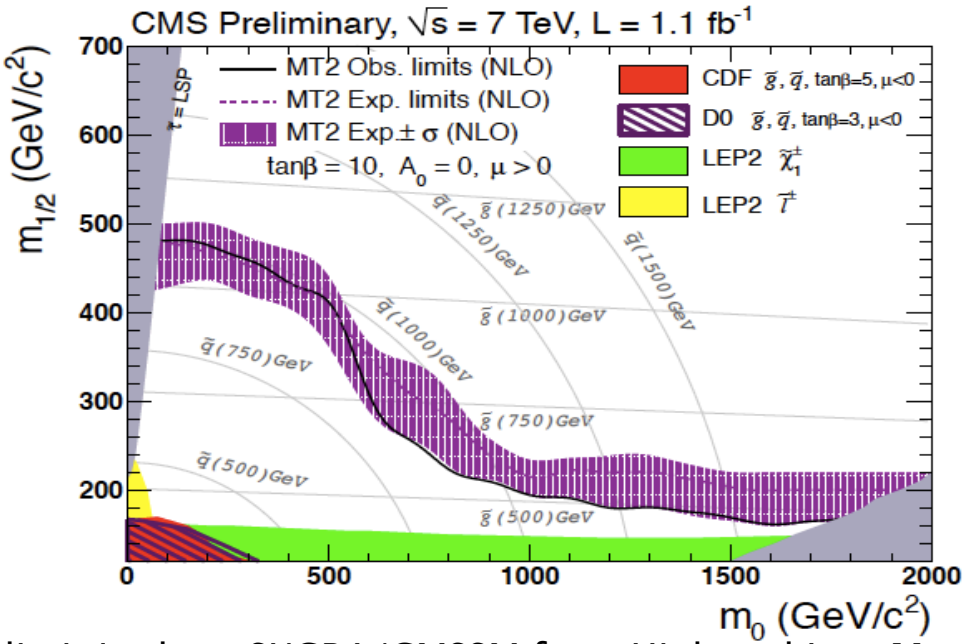
Search for SUSY in hadronic final states using M_{T2}

1.1/fb

11005





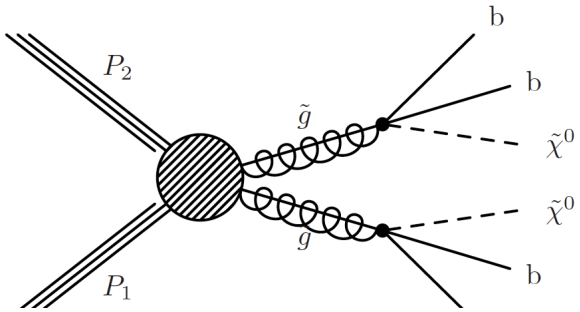


Combined Exclusion limit in the mSUGRA/CMSSM from High and Low $\mathbf{M_{T2}}$ selections (*tanb* = 10)

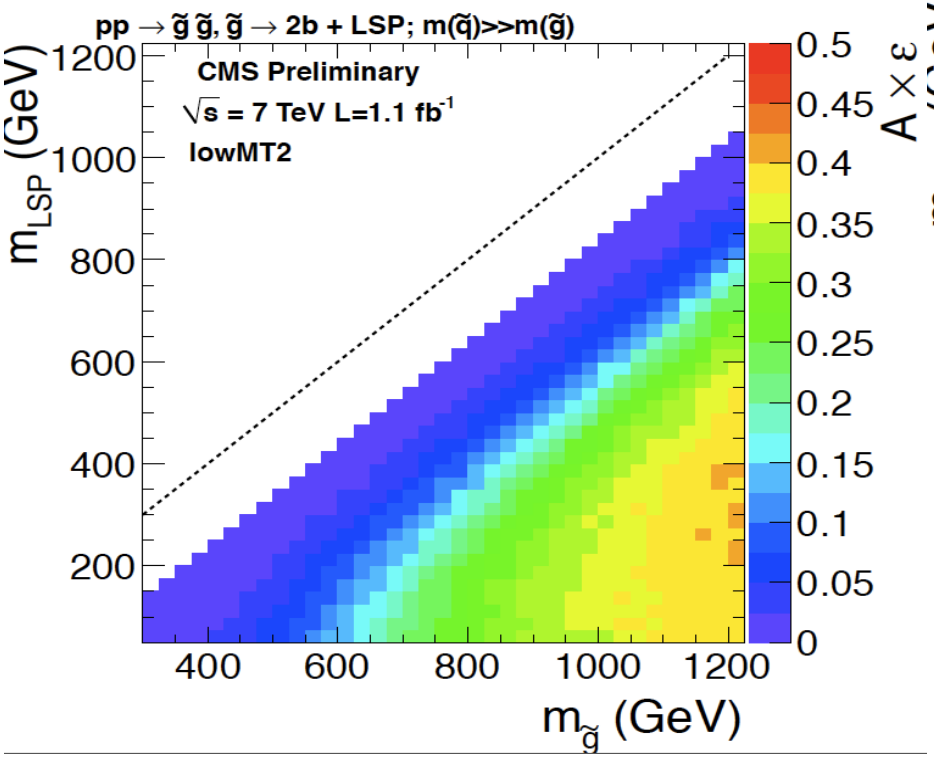
Search for SUSY in hadronic final states using M_{T2}

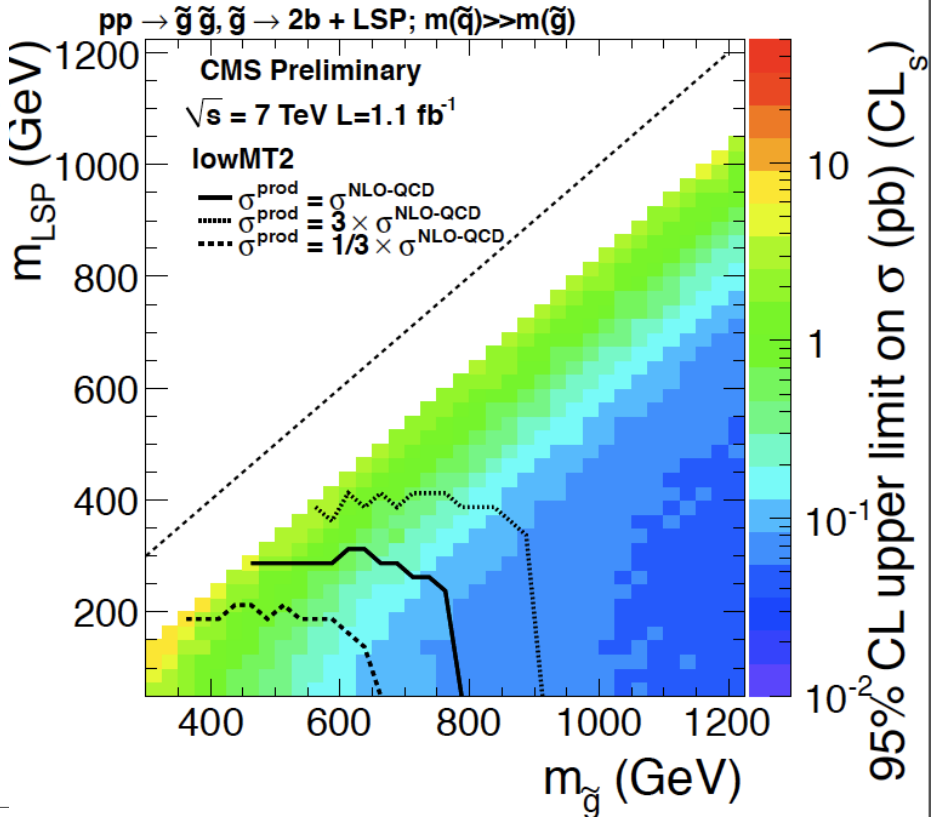
SUS-11005

1.1/fb



Interpretation on SMS framework





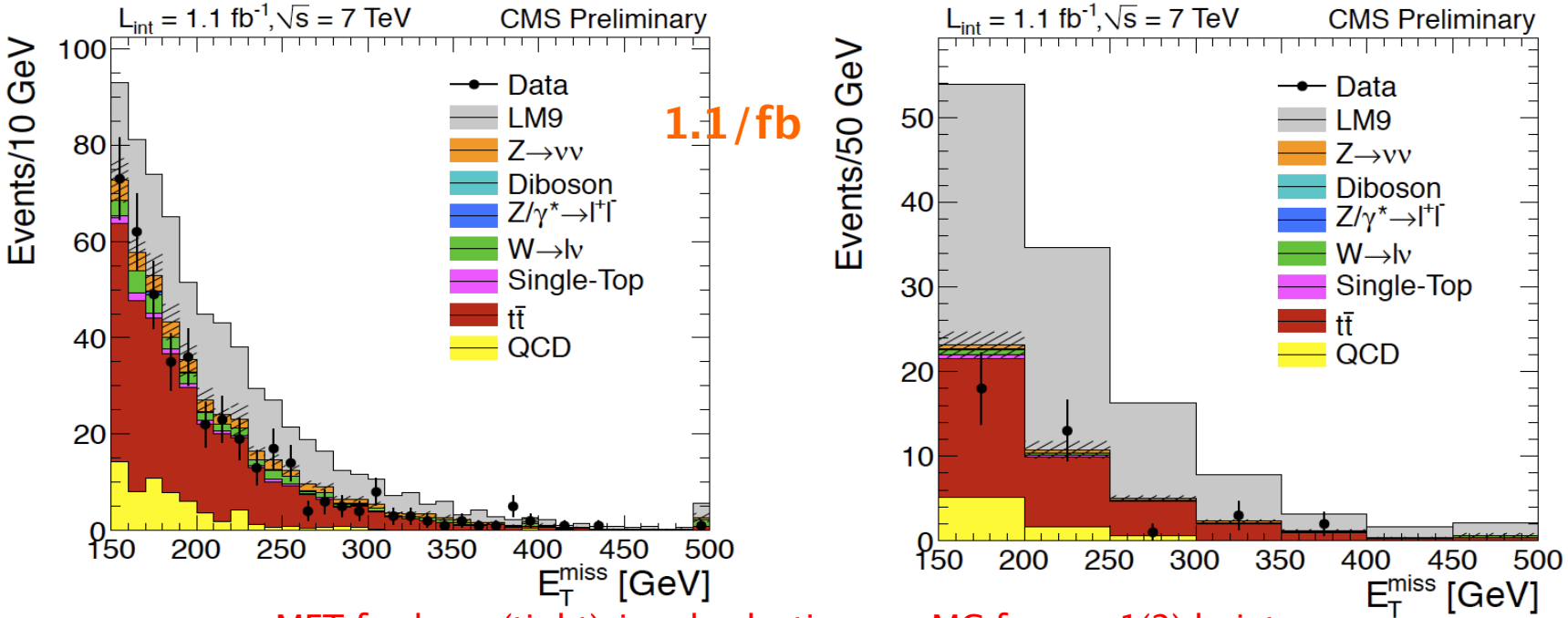
Upper limits for T1bbbb, assuming a branching ratio of 1. At 95% CL exclusion contours, for decoupled squarks: m(~q)>>m(~g).

Search for SUSY with b-quark Jets and MET

SUS-11006

Events with large MET, no identified leptons, 3 ≥ jets, 1≥ b-jets

- Sideband region : 150 < MET < 200 GeV
- Low-sideband region : 50 < MET < 100 GeV
- low $\Delta\varphi_{min}$N region : ΔφminN < 4.0 lowMET ==> peak $\Delta\varphi_{min}$ ~0
- Loose selection : HT > 350 GeV (SB ,SIG) MET > 200 GeV (SR)
- Tight selection : like loose, but with HT > 500 GeV ,MET > 300 GeV



MET for loose(tight)signal selections vs MC for >= 1(2) b-jets.

Search for SUSY with b-quark Jets and MET

Interpretation on SMS framework

SUS-11006

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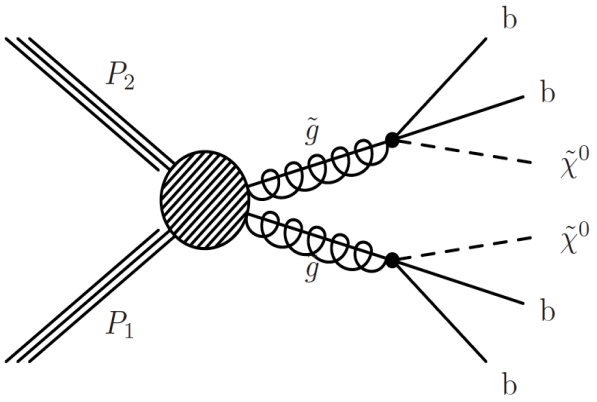
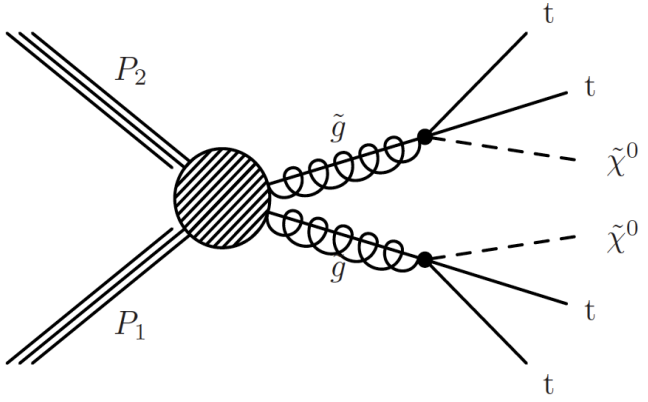
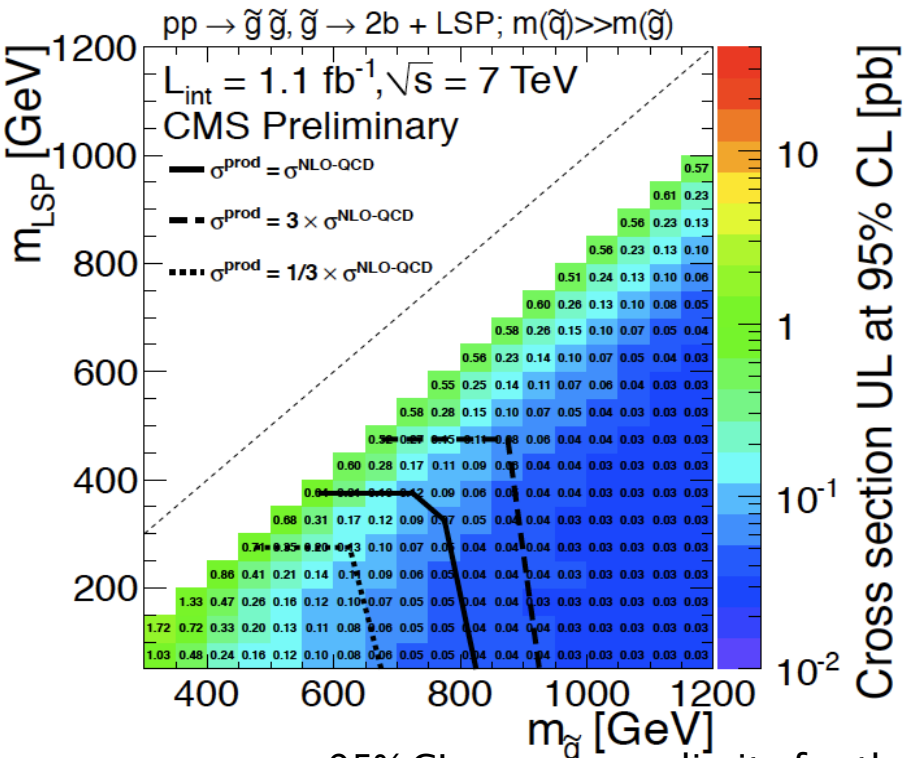
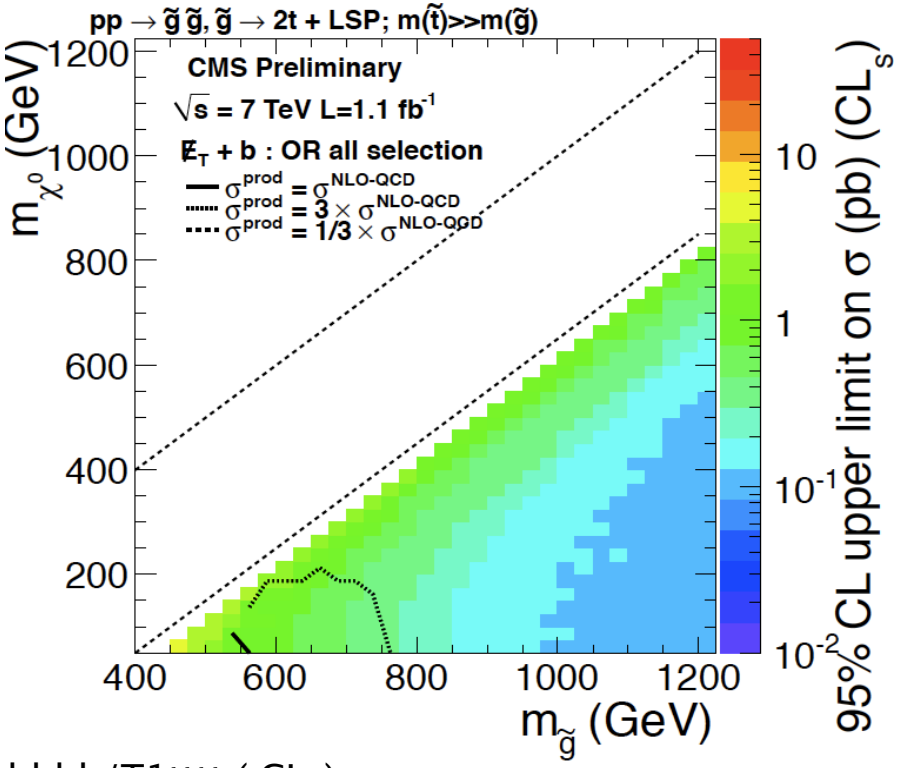








95% CL xsec upper limits for the T1bbbb/T1tttt (CLs)

Summary

- CMS delivers robust results
  - Many on-going diverse analyses for direct pair or gluino-decayed models
  - Effort to make coherent interpretation of already completed analyses

- Interpretation in Simplified Models framework
  - Exclusion contours in the gluino-LSP plane
  - Exclusion contours in the squark-chargino plane
  - Exclusion bands in the mSUGRA plane
  - Upper limits on cross-sections

- Analyses of the full 2011 data ongoing – **STAY TUNED!**

Backup

Search for SUSY in hadronic final states using M_{T2}

SUS-11005

Table 1: Definition of LM benchmark points, from [7]. For all points, the sign of μ is positive.

Benchmark point	LM1	LM2	LM3	LM4	LM5	LM6	LM7	LM8	LM9
m_0	60	185	330	210	230	85	3000	500	1450
$m_{1/2}$	250	350	240	285	360	400	230	300	175
$\tan\beta$	10	35	20	10	10	10	10	10	10
A_0	0	0	0	0	0	0	0	-300	0

Table 2: Expected background event yields and observed number of events in data after various M_{T2} cuts for events with ≥ 3 jets. "Other" backgrounds are mostly γ + jets.

Process	QCD	W+jets	Z+jets	Top	Other	Total Bkg.	data
After full selection	322001	869.4	409.2	1090.1	995.8	325365	325365
MT2 > 100 GeV	61.4	162.2	138.7	88.2	2.4	452.9	482
MT2 > 150 GeV	4.0	69.0	75.8	27.7	1.2	177.6	208
MT2 > 200 GeV	0.1	33.7	45.5	9.6	0.8	89.8	105
MT2 > 250 GeV	0.0	17.7	27.7	4.1	0.1	49.6	58
MT2 > 300 GeV	0.0	9.9	19.0	1.2	0.0	30.1	30
MT2 > 350 GeV	0.0	5.8	11.9	0.5	0.0	18.2	17
MT2 > 400 GeV	0.0	3.5	7.3	0.2	0.0	11.0	12
MT2 > 450 GeV	0.0	1.9	4.7	0.2	0.0	6.8	9
MT2 > 500 GeV	0.0	1.2	3.5	0.0	0.0	4.6	7

High M_{T2}

Search for SUSY in hadronic final states using M_{T2}

SUS-11005

Table 3: Expected signal event yields after various M_{T2} cuts for events with ≥ 3 jets. The last line gives the efficiency for the signal after cuts at 400 GeV.

Process	LM1	LM2	LM3	LM4	LM5	LM6	LM7	LM8	LM9
After full selection	1208.9	232.2	986.7	672.9	193.9	93.3	51.8	174.9	334.4
MT2 > 100 GeV	958.2	200.3	692.8	518.5	159.0	83.8	27.4	127.2	152.1
MT2 > 150 GeV	802.0	178.5	538.8	429.9	137.9	75.8	16.8	101.4	82.4
MT2 > 200 GeV	647.0	156.7	407.3	347.8	118.4	68.0	10.0	78.7	42.1
MT2 > 250 GeV	502.6	135.0	299.8	275.1	99.6	60.5	5.4	60.3	21.7
MT2 > 300 GeV	371.0	113.2	213.9	212.9	82.7	53.2	3.0	45.2	10.4
MT2 > 350 GeV	254.9	93.1	147.8	156.7	67.0	45.6	1.6	33.8	4.9
MT2 > 400 GeV	163.2	74.3	95.5	109.2	53.0	38.1	0.7	24.5	2.0
MT2 > 450 GeV	86.2	56.4	58.0	71.4	40.5	31.0	0.4	17.2	1.0
MT2 > 500 GeV	40.7	40.2	32.0	43.1	29.5	24.2	0.2	11.5	0.8
Efficiency (400 GeV), %	2.2	8.1	1.7	3.8	7.3	8.3	0.05	2.1	0.02

High M_{T2}

Table 4: Expected background event yields and observed number of events in data for all relaxed cuts after preselection for events with at least one b-tagged jet.

Process	QCD	W+jets	Z+jets	Top	Other	Total Bkg.	data
After full selection	16857.5	27.8	14.8	445.3	24.6	17370	17370
MT2 > 80 GeV	58.8	7.5	5.5	61.4	0.0	133.3	131
MT2 > 100 GeV	10.1	5.2	4.6	36.9	0.0	56.9	49
MT2 > 120 GeV	3.0	3.6	3.9	23.3	0.0	33.8	26
MT2 > 135 GeV	0.8	2.7	2.6	15.8	0.0	21.9	21
MT2 > 150 GeV	0.2	2.2	1.8	10.8	0.0	15.0	19
MT2 > 165 GeV	0.1	1.7	1.6	7.6	0.0	11.0	12
MT2 > 200 GeV	0.0	0.9	1.2	3.3	0.0	5.4	5
MT2 > 250 GeV	0.0	0.5	0.7	1.5	0.0	2.7	2
MT2 > 300 GeV	0.0	0.3	0.3	0.5	0.0	1.2	0
MT2 > 350 GeV	0.0	0.1	0.1	0.2	0.0	0.4	0

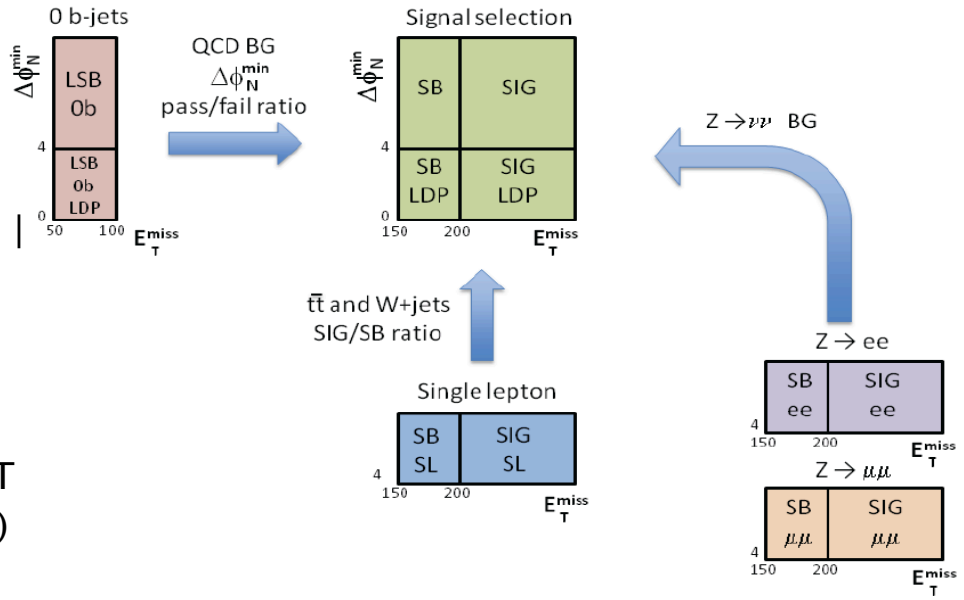
Low M_{T2}

Search for SUSY with b-quark Jets and MET

JS-11006

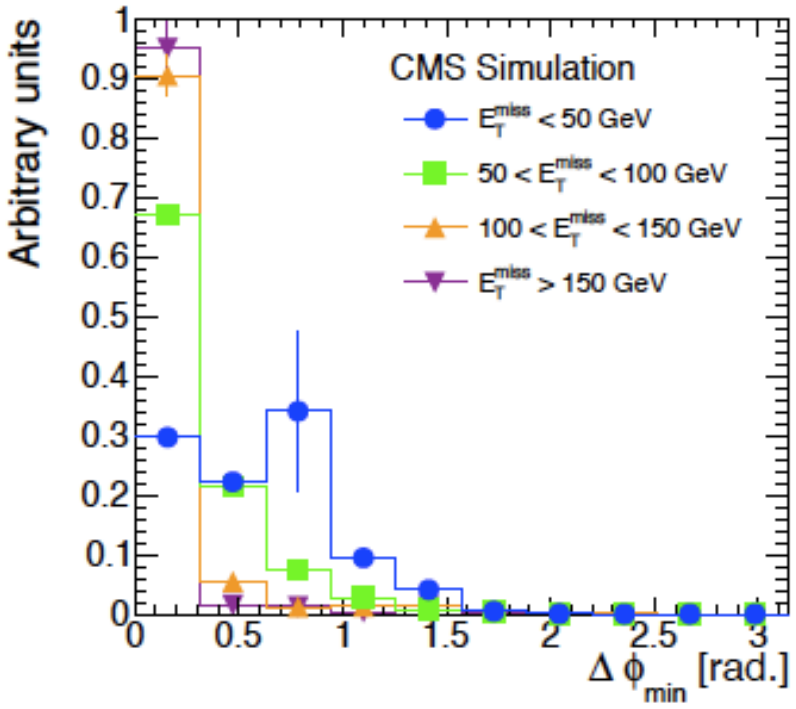
	$(H_T, E_T^{miss}) > (350, 200)$ GeV ≥ 1 b-jets	≥ 2 b-jets	$(H_T, E_T^{miss}) > (500, 300)$ GeV ≥ 1 b-jets	≥ 2 b-jets
Data	155	30	20	5
Total SM	183 ± 5	35.7 ± 1.3	25.1 ± 1.6	4.54 ± 0.37
$t\bar{t}$	122 ± 2	28.9 ± 0.7	14.7 ± 0.8	3.49 ± 0.24
Single top	4.54 ± 0.38	0.77 ± 0.09	0.59 ± 0.15	0.12 ± 0.04
W+Jets	17.0 ± 2.1	1.21 ± 0.45	4.20 ± 1.28	0.42 ± 0.28
$Z \to \nu\bar{\nu}$	22.5 ± 0.5	2.23 ± 0.10	4.25 ± 0.20	0.43 ± 0.04
$Z/\gamma^* \to \ell^+\ell^-$	0.17 ± 0.17	0.01 ± 0.01	0	0
Diboson	0.69 ± 0.07	0.10 ± 0.02	0.10 ± 0.02	0.006 ± 0.002
QCD	16.4 ± 3.9	2.5 ± 0.9	1.28 ± 0.40	0.08 ± 0.01
SUSY LM9	147 ± 5	60.0 ± 2.5	27.7 ± 2.2	10.1 ± 1.0

- >1 PV
- >2 jets, **p**T > 50 GeV and |**η**| < 2.4;
- 1>b-jet ((**p**T > 30 GeV)
- no identified, iso lepton, **p**T > 10 GeV; el (mu) | **η**| < 2.5, (|**η**| < 2.4)
- **Df**min N > 4.0
- 2 signal event samples, (loose/tight selection)
- Loose (tight) selection : **H**T > 350 GeV (500 GeV), where **H**T is calculated using jets with **p**T > 50 GeV and |η| < 2.4; **MET** > 200 GeV (300)

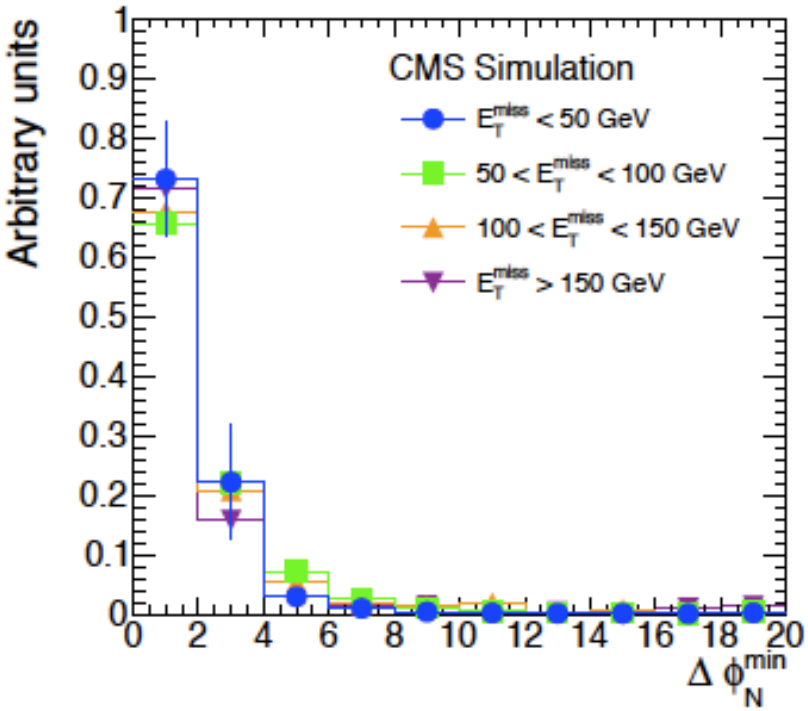


Search for SUSY with b-quark Jets and MET

SUS-11006



(a)



(b)

Figure 4: QCD MC results: The distribution of (a) $\Delta\phi^{\text{min}}$ and (b) $\Delta\phi_{\text{N}}^{\text{min}}$ in intervals of $E_{\text{T}}^{\text{miss}}$, for events with ≥ 1 b-jets selected with the loose criteria except for the requirement on $\Delta\phi_{\text{N}}^{\text{min}}$.