Summary of LHC SUSY and Exotic search results

2013
PASCOS
19th International Symposium on
Particles, Strings and Cosmology

PASCOS 2013: 19th International Symposium on Particles, Strings and Cosmology
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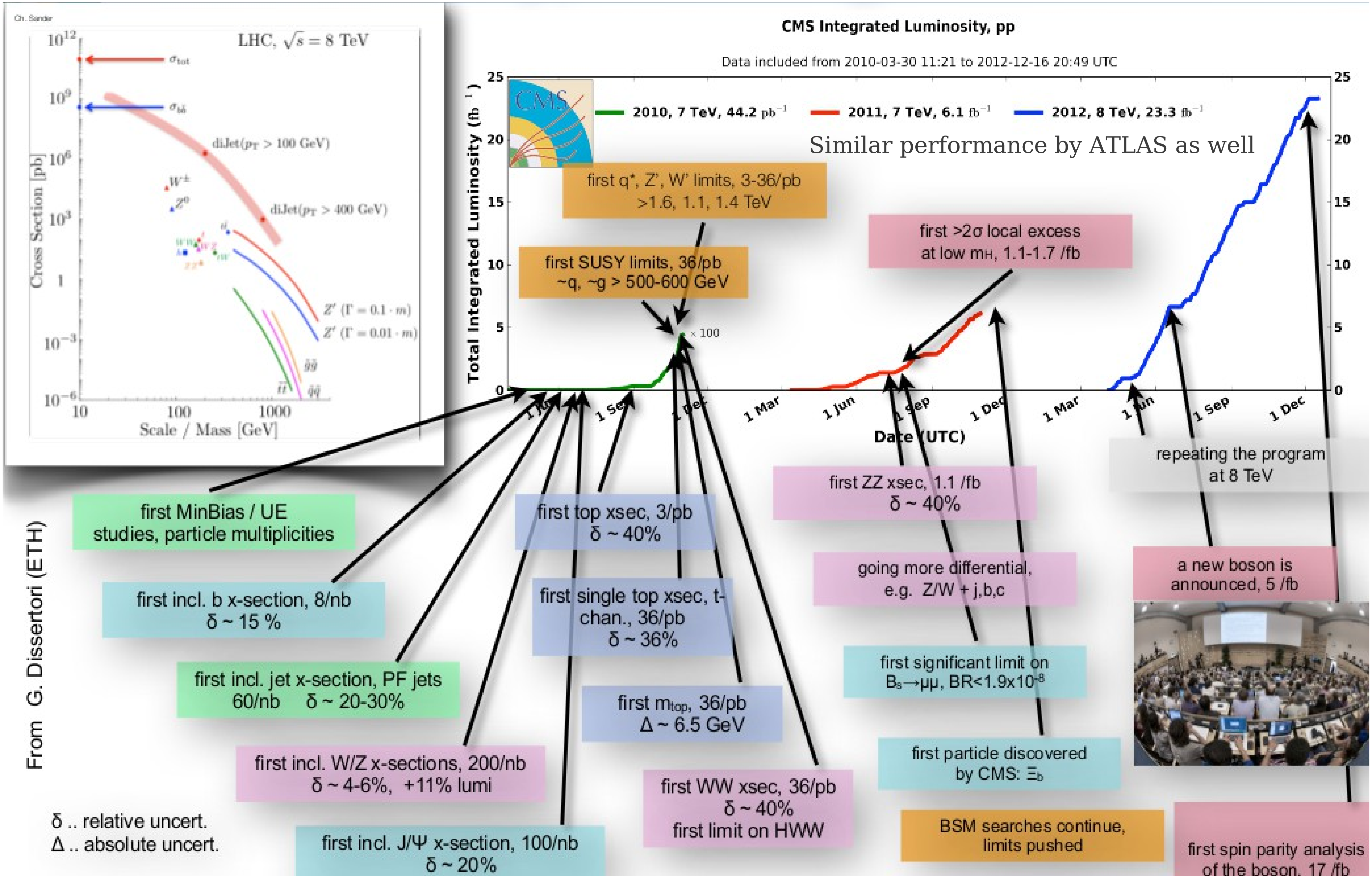
Special Invited Session

Sanjay Padhi

(On behalf of the ATLAS and CMS Collaborations)

FNAL LPC/University of California, San Diego

Amazing LHC!!!



Similar performance by ATLAS as well

first q*, Z', W' limits, 3-36/pb
>1.6, 1.1, 1.4 TeV

first SUSY limits, 36/pb
~q, ~g > 500-600 GeV

first >2σ local excess
at low m_H, 1.1-1.7 /fb

repeating the program
at 8 TeV

first MinBias / UE
studies, particle multiplicities

first incl. b x-section, 8/nb
δ ~ 15 %

first incl. jet x-section, PF jets
60/nb δ ~ 20-30%

first incl. W/Z x-sections, 200/nb
δ ~ 4-6%, +11% lumi

first incl. J/Ψ x-section, 100/nb
δ ~ 20%

first top xsec, 3/pb
δ ~ 40%

first single top xsec, t-chan., 36/pb
δ ~ 36%

first m_{top}, 36/pb
Δ ~ 6.5 GeV

first WW xsec, 36/pb
δ ~ 40%
first limit on HWW

first ZZ xsec, 1.1 /fb
δ ~ 40%

going more differential,
e.g. Z/W + j,b,c

first significant limit on
$B_s \to \mu\mu$, BR<1.9×10^{-8}

first particle discovered
by CMS: Ξ_b

BSM searches continue,
limits pushed

a new boson is
announced, 5 /fb

first spin parity analysis
of the boson, 17 /fb

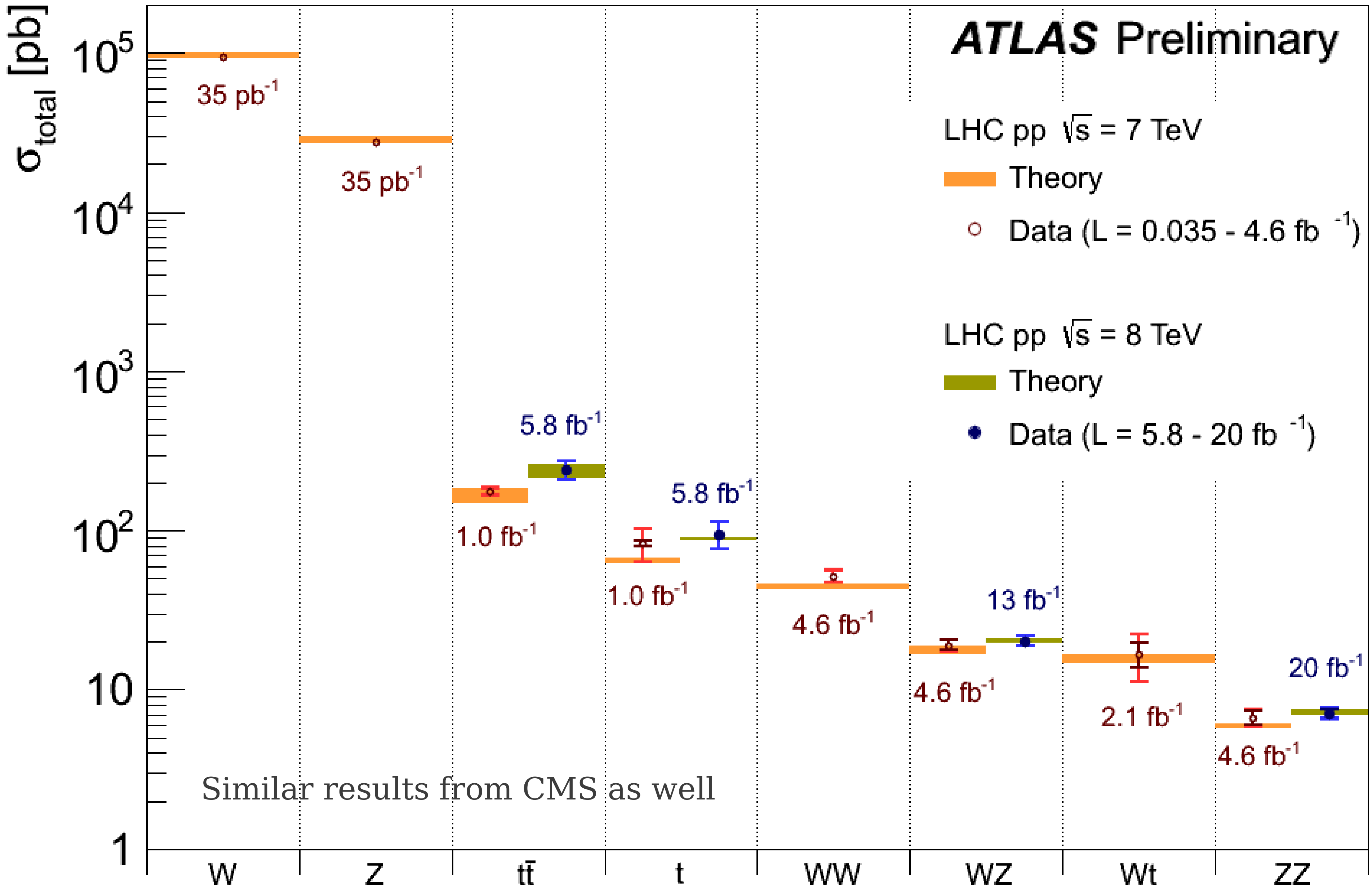
δ .. relative uncert.
Δ .. absolute uncert.

From G. Dissertori (ETH)

Outline

- Re-discovery of the Standard Model
- Search for Supersymmetry (SUSY) at the LHC
  - Searches in SUSY Colored Sector
  - Searches in SUSY Electroweak sector
  - R-parity violating searches
- Search for Exotic (non SUSY) signatures at the LHC
  - Dark Matter
  - New Physics with resonances
  - Top and Bottom like beyond SM signatures
- Summary and Conclusion

Re-discovery of the SM at the energy frontier

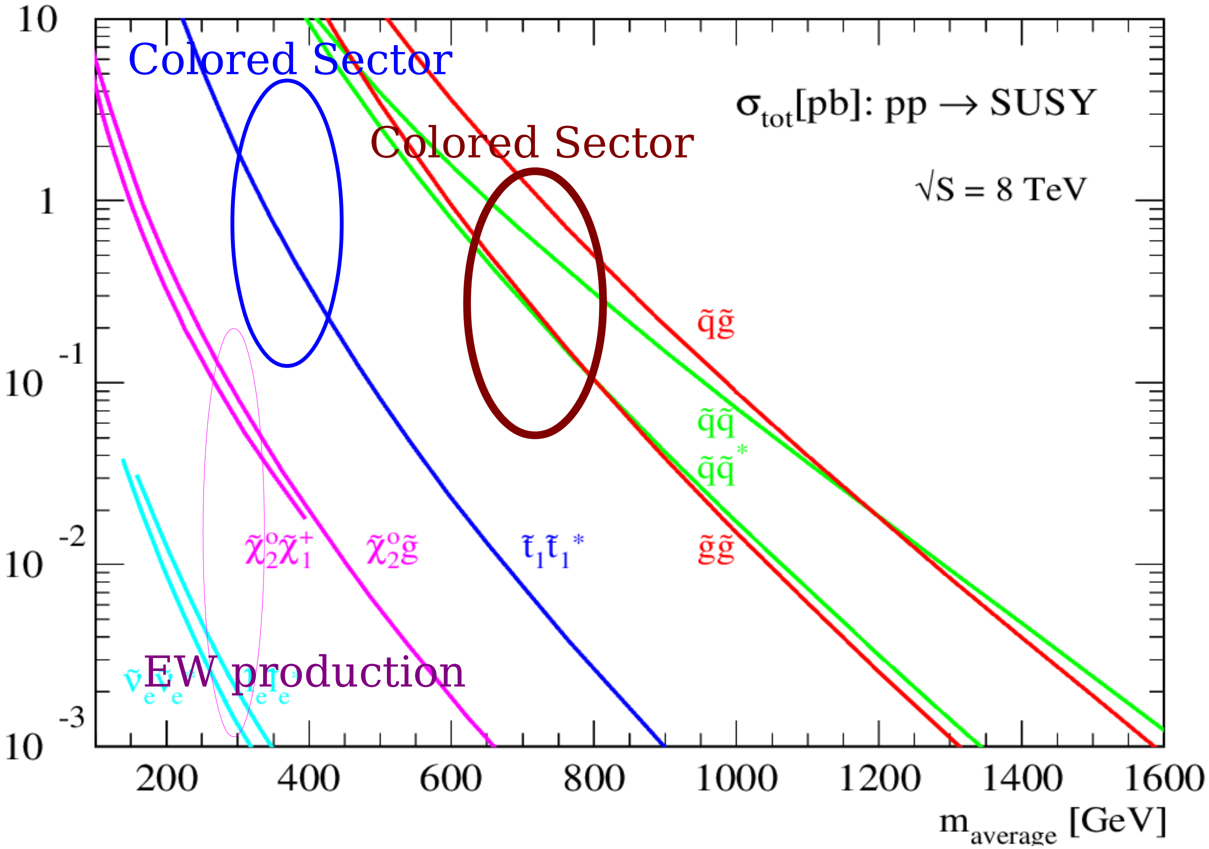


Similar results from CMS as well

Search for Supersymmetry (SUSY) at the LHC

Search for Supersymmetry

SUSY search strategy was driven by cross section and thus luminosity



https://twiki.cern.ch/twiki/bin/view/LHCPhysics/SUSYCrossSections (arXiv:1206.2892)

Early analyses were dominated by broad inclusive searches

- mainly gluino and squark production

Increase in luminosity gave access to rarer channels

- Also with added motivation from *Natural* SUSY paradigm

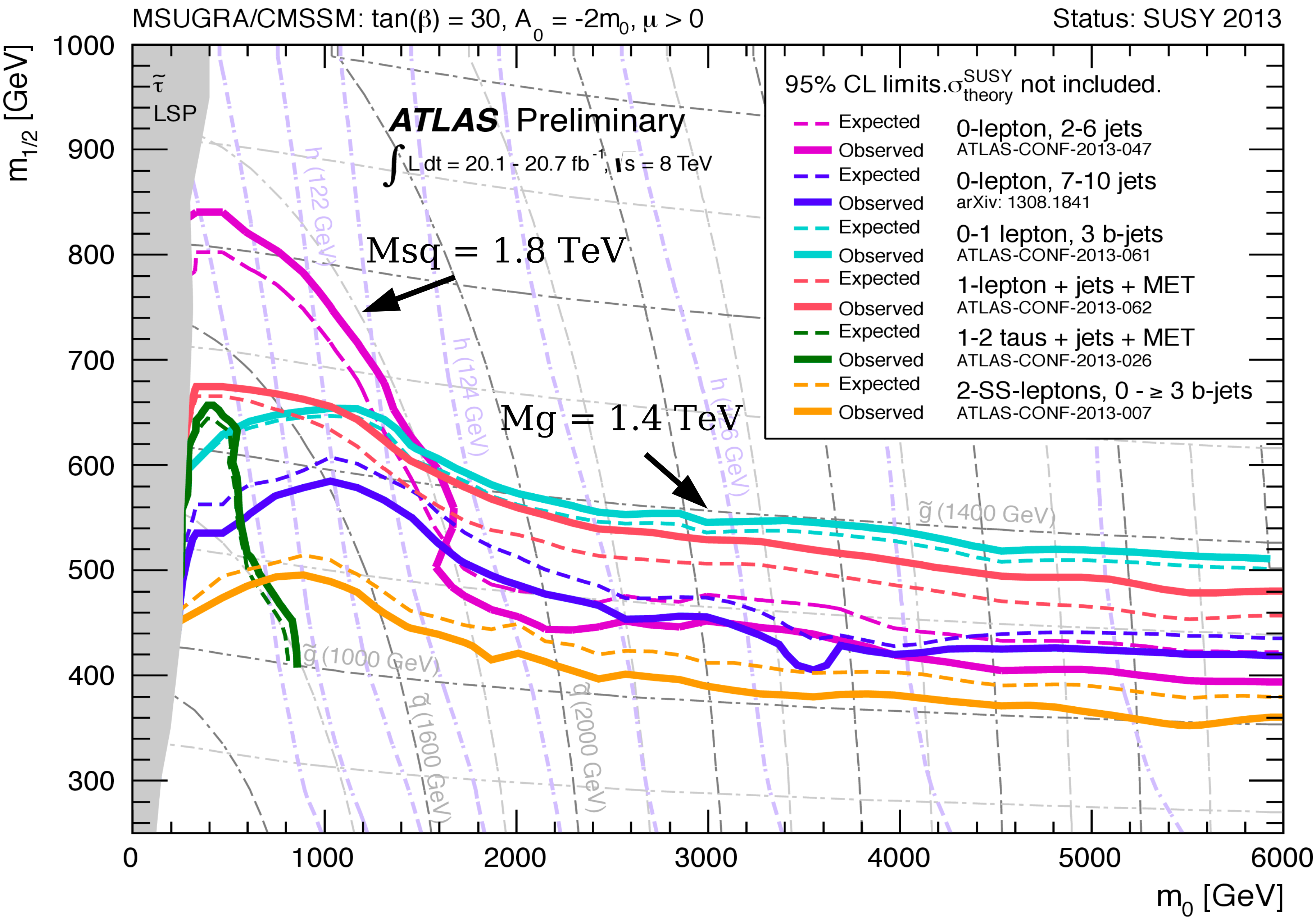
It was quickly realized to develop exclusive search modes to cover full spectrum

SUSY Status – post 7 TeV LHC

- Various constrained SUSY models like mSUGRA. CMSSM were severely put under pressure by the the LHC limits!
- Experiments were bound to define new benchmarks and use simplified SUSY models in order to present the results and its interpretation
- Aided by the discovery of a Higgs boson, the focus of the experimental search strategy and corresponding interpretation moves towards "*Natural SUSY*" scenarios:
  - Expect to see dedicated 3rd generation searches
  - Electroweak studies (also with Higgs in the final state)

The goal from the experiments was to leave no stone unturned

Inclusive SUSY searches



Msq = 1.8 TeV

Mg = 1.4 TeV

The LHC has pushed the mass scale in constraint SUSY models to a new level!

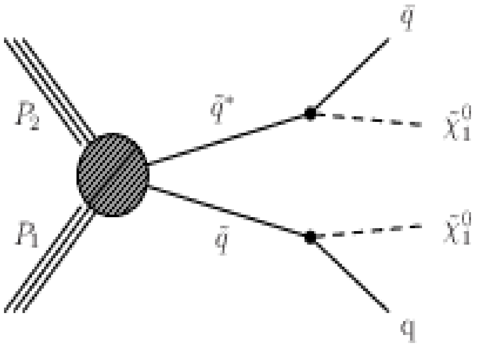
Inclusive search for 1st and 2nd generation squarks

Simplified models: captures bulk of characteristics of real models

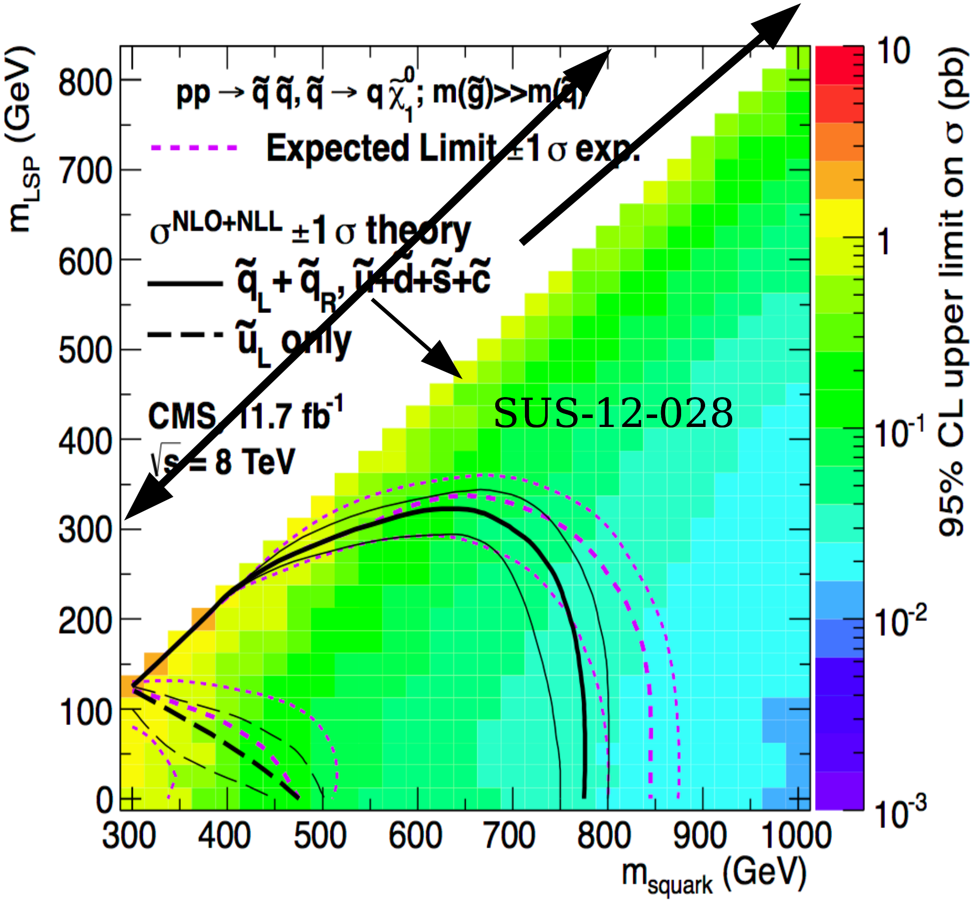
Assume 100% BR in both legs.

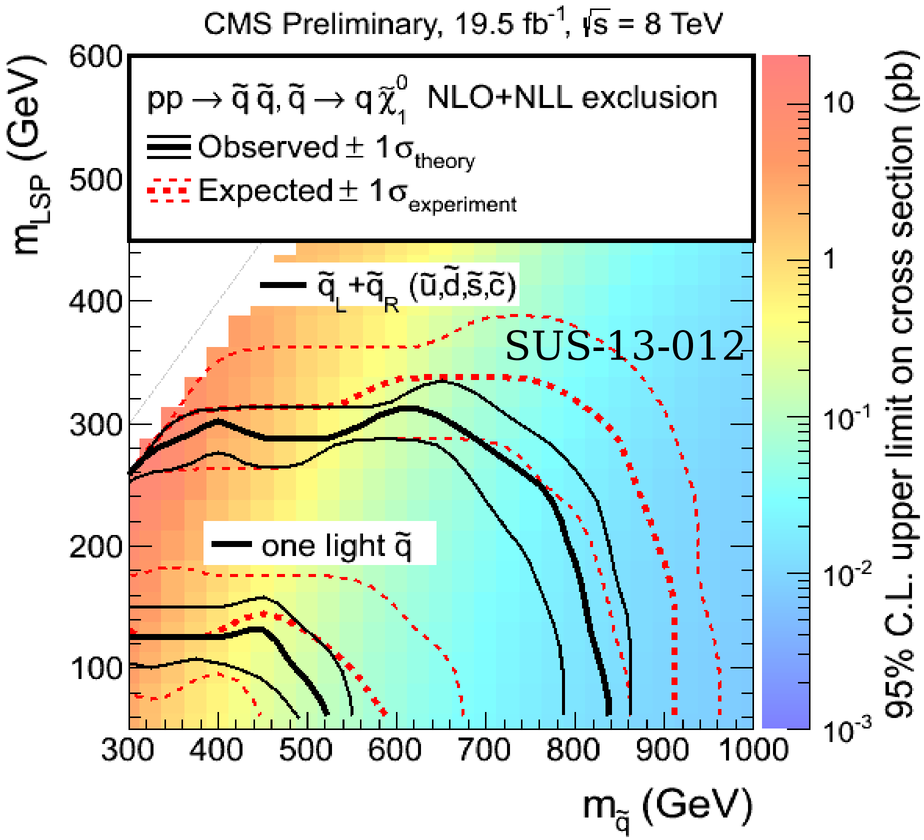
Normalize using SUSY NLO+NLL cross sections

Clean representation of potential (Not sure about the theory)



“Remember the gaps”

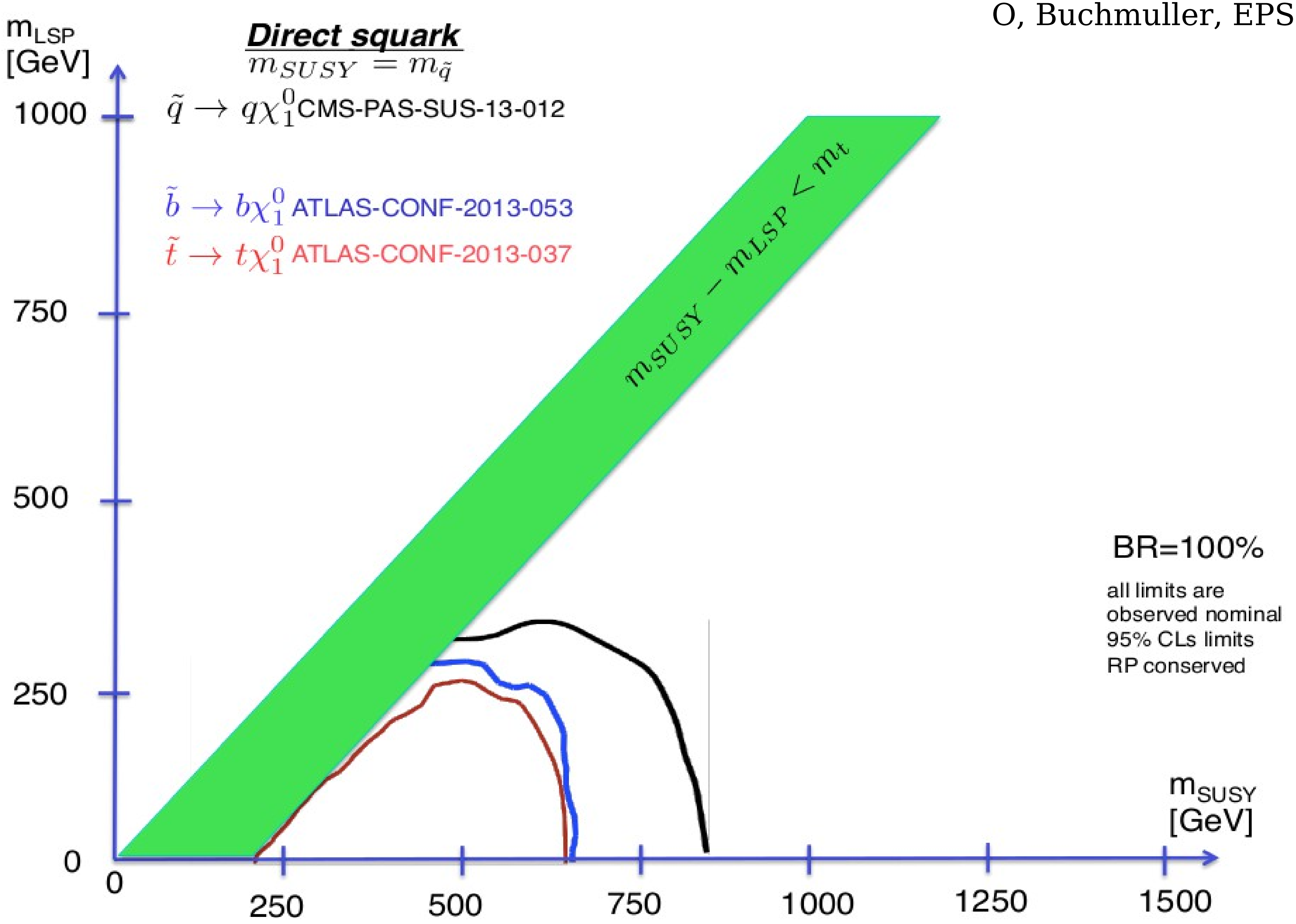




See talk by S. Paramesvaran in the parallel session

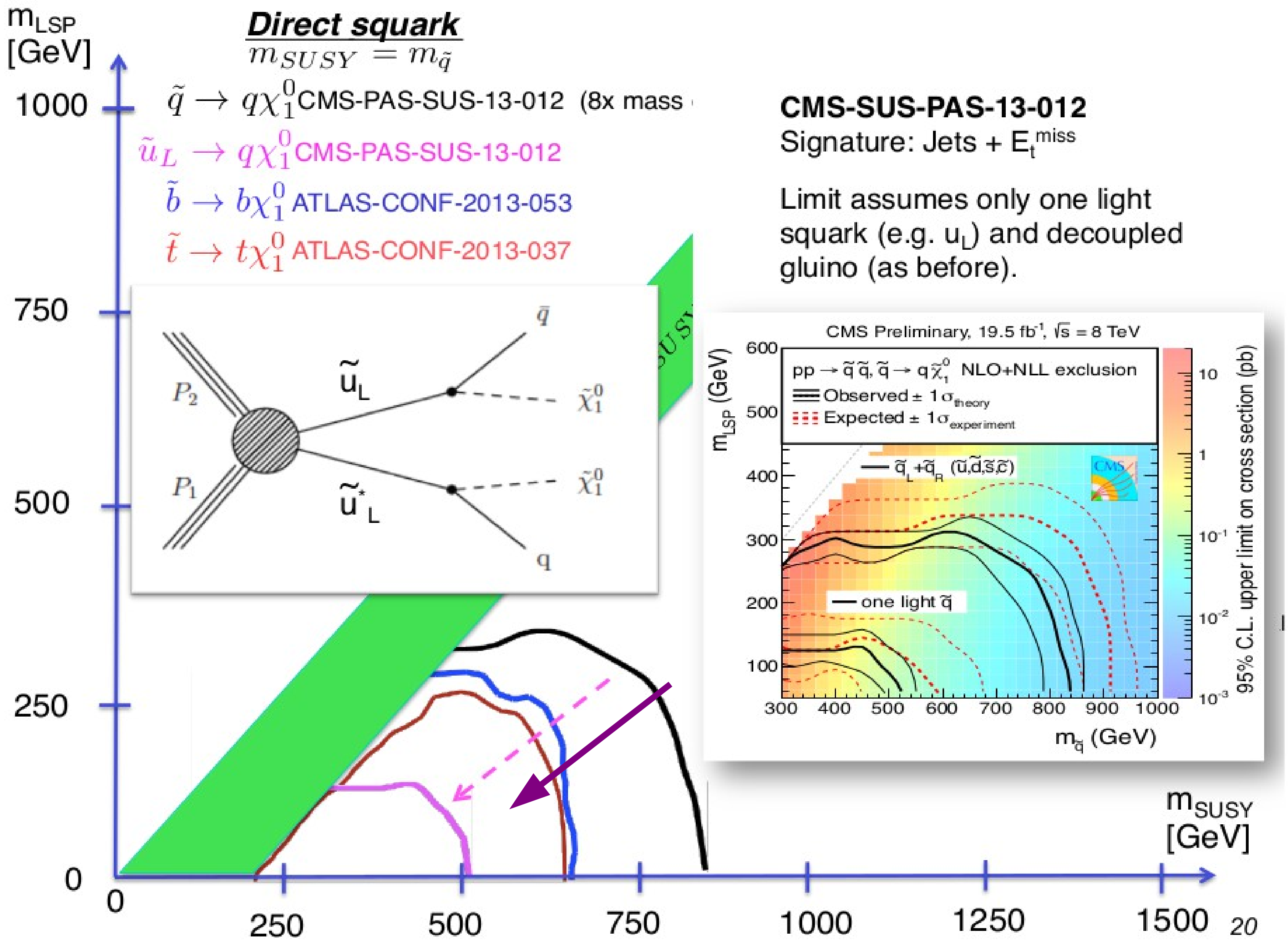
Inclusive search for 1st and 2nd generation squarks

O, Buchmuller, EPS



Inclusive search for 1^{st} and 2^{nd} generation squarks

ATLAS and CMS 1st & 2nd generation squark limits are only better than the 3^{rd} generation when assuming BR=100%! Eight-fold mass degeneracy!!



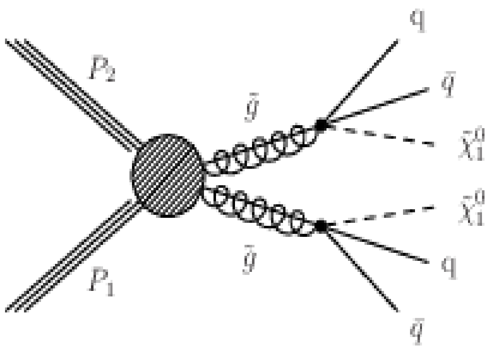
CMS-SUS-PAS-13-012
Signature: Jets + E_t^{miss}

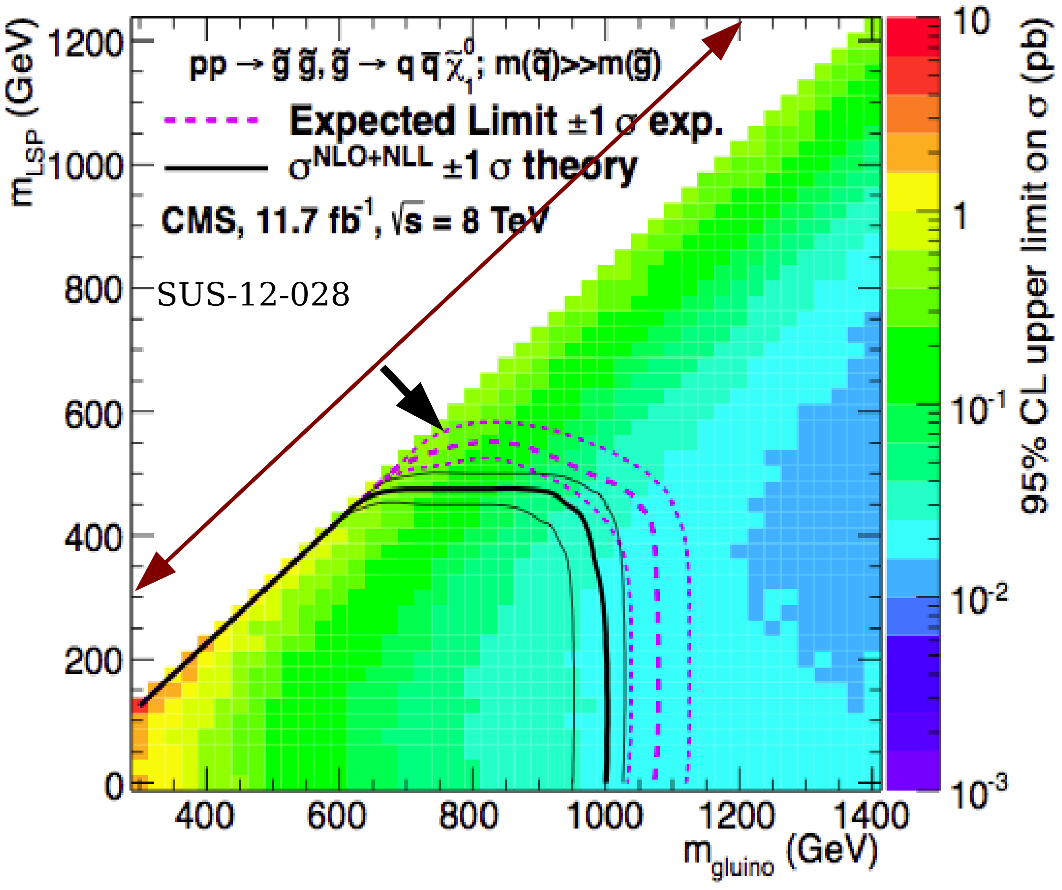
Limit assumes only one light squark (e.g. u_L) and decoupled gluino (as before).

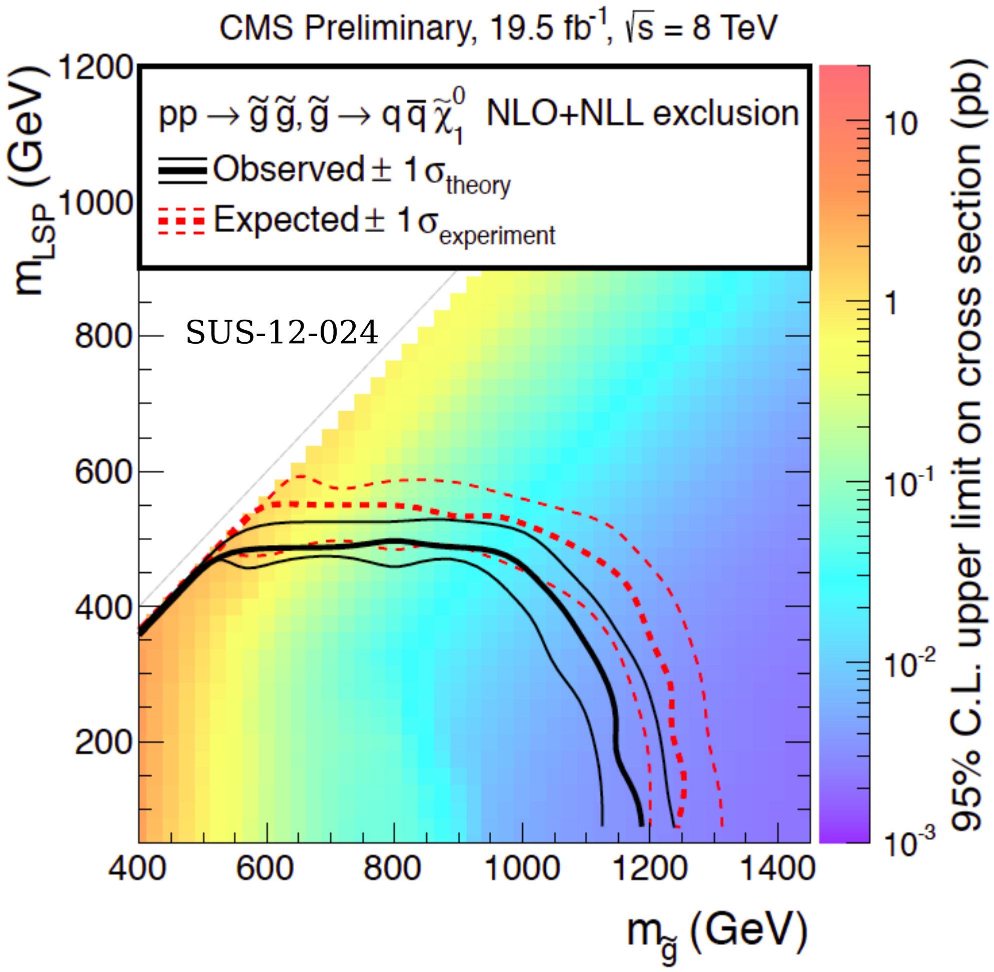
Inclusive search for gluinos cascade decays (via squarks)

Hadronic searches probes:

- Gluino masses up to 1.2 TeV
- "Compressed regions" better covered
  - in inclusive Jet/MET study







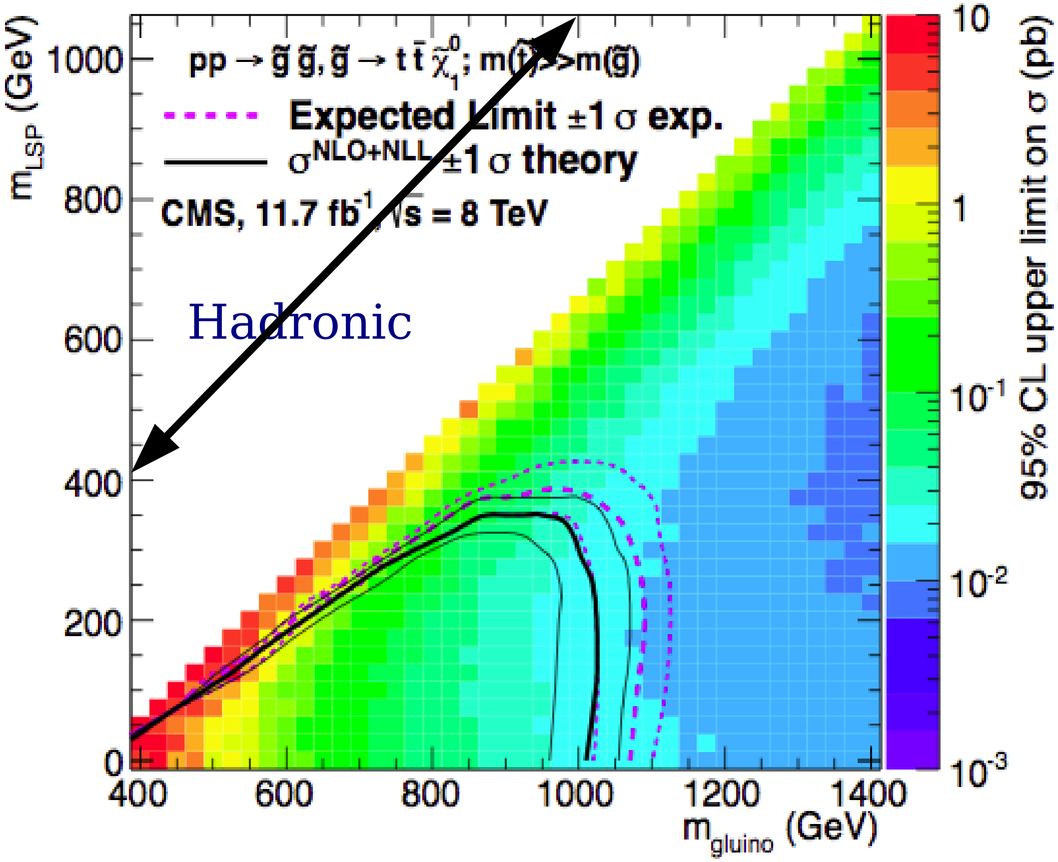
Inclusive search for gluinos cascade decays (via stops)

Gluino via stops:

- Gluino masses up to 1.3 TeV using 1-lepton analysis

- A large "compressed" region available for future studies

SUS-12-028



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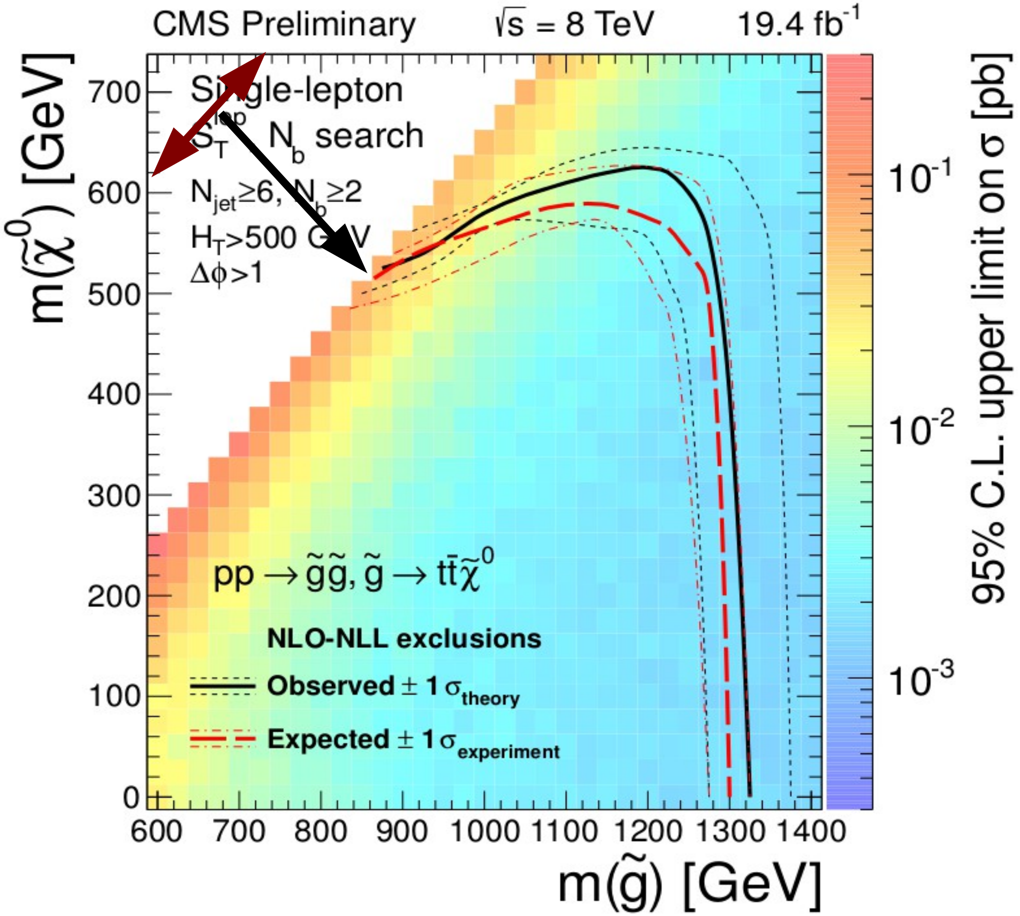
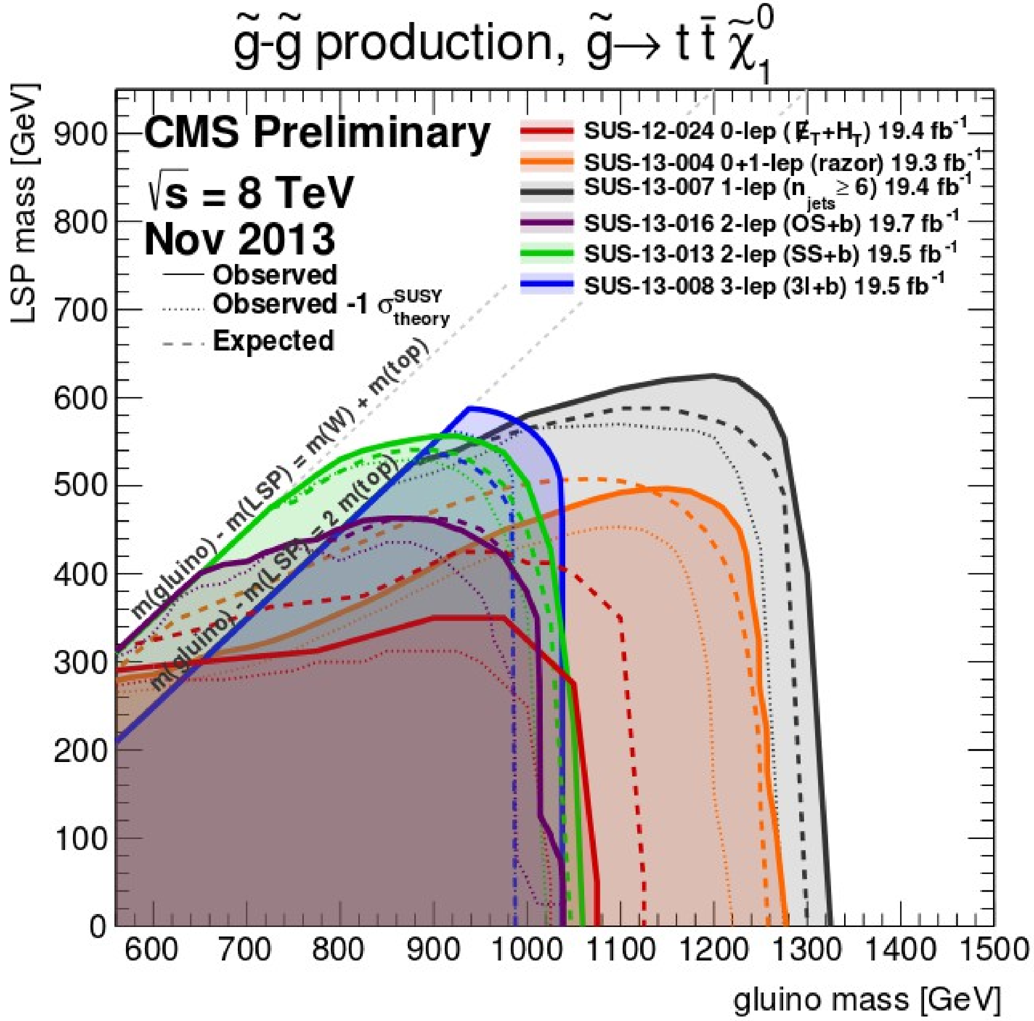


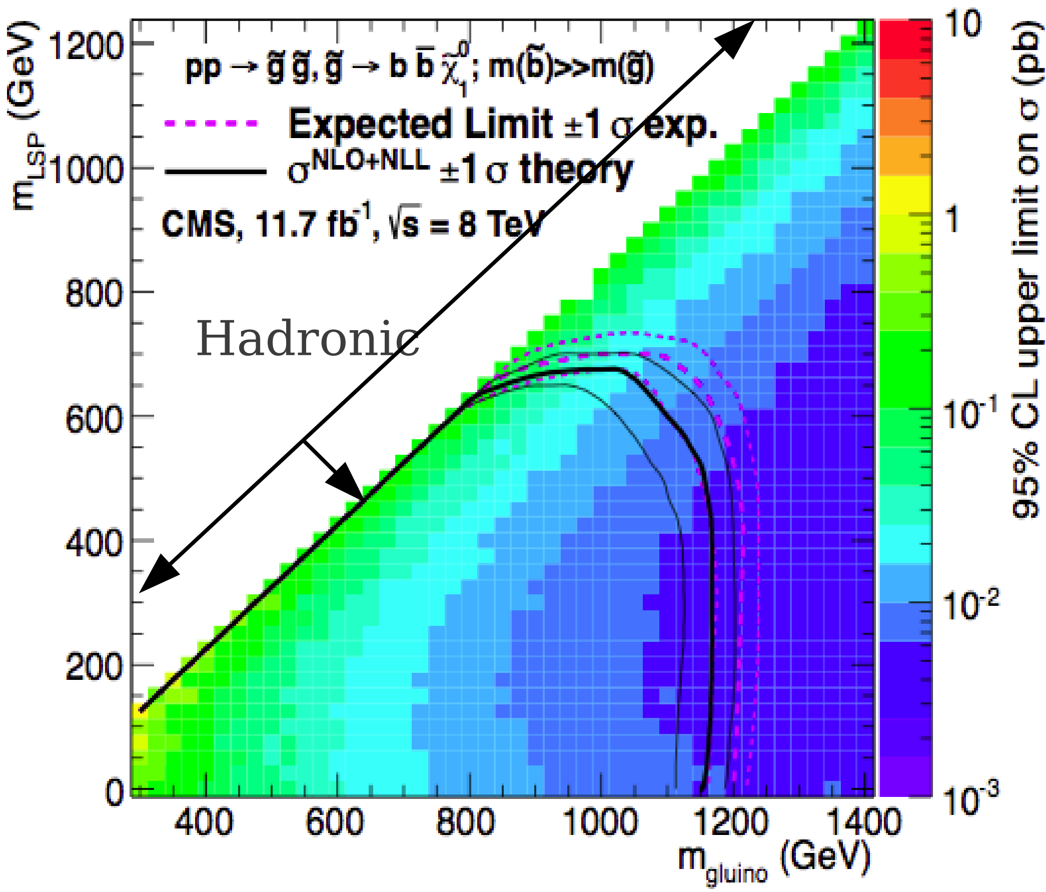
Inclusive search for gluinos cascade decays (via stops and sbottoms)

Gluino via stops or sbottoms:

- Gluino masses up to 1.32 TeV using One lepton analysis

- A large “compressed” region available for future studies

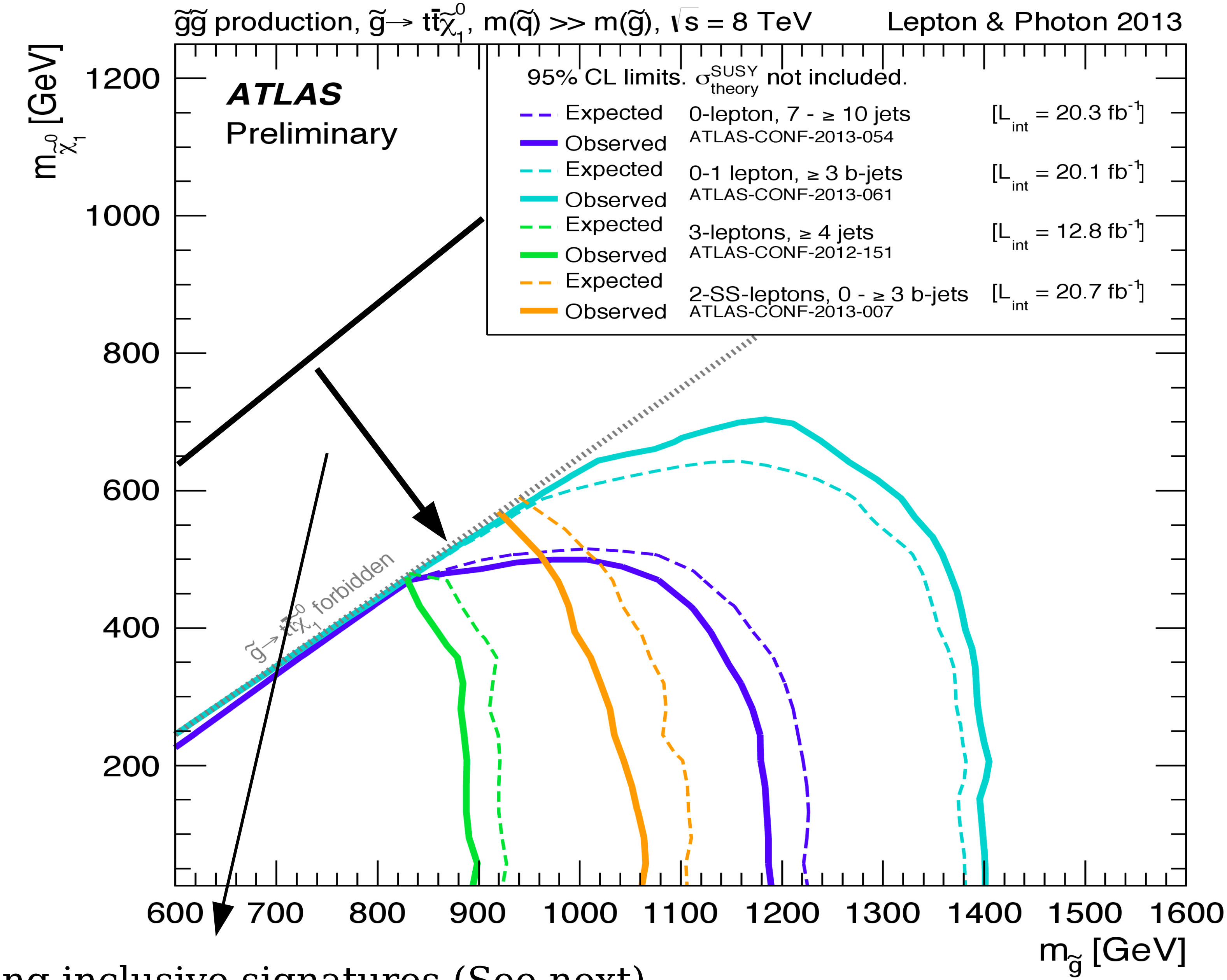




Hadronic

Inclusive search for gluinos cascade decays

See talk by L. Morvaj & A. Tudorache in the parallel session



Probe using inclusive signatures (See next)

Inclusive search for gluinos cascade decays

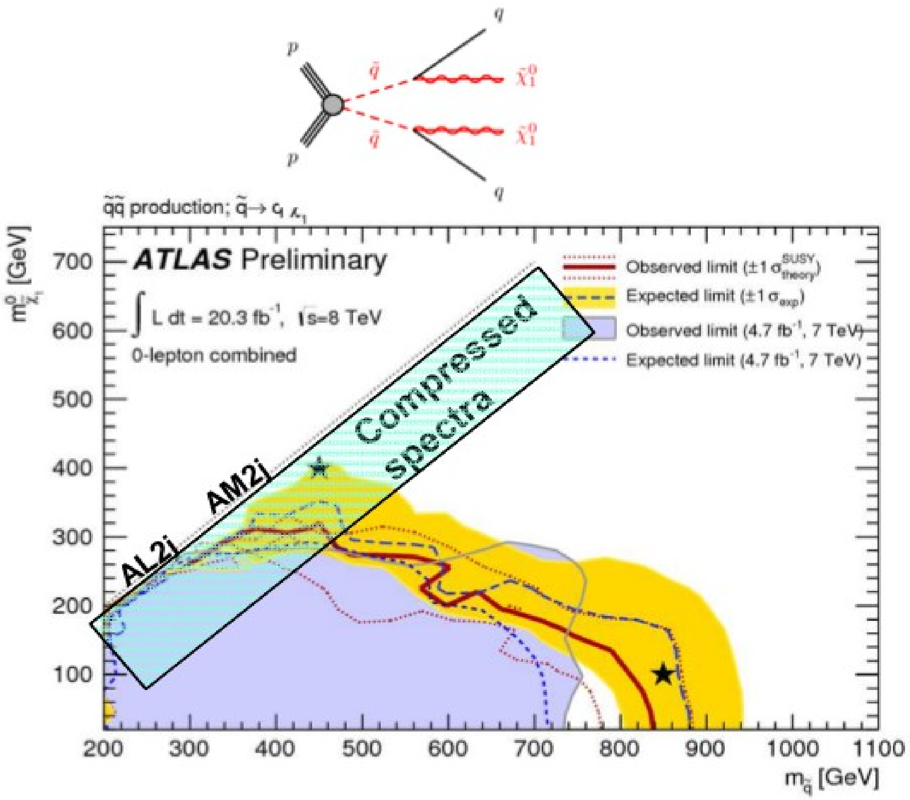
Low $(m_{SUSY} - m_{LSP})/m_{SUSY}$ (Compressed region) ATLAS-CONF-2013-062, ATLAS-CONF-2013-007

Use loose/medium signal regions to probe topologies with $m_{SUSY} \sim m_{LSP}$

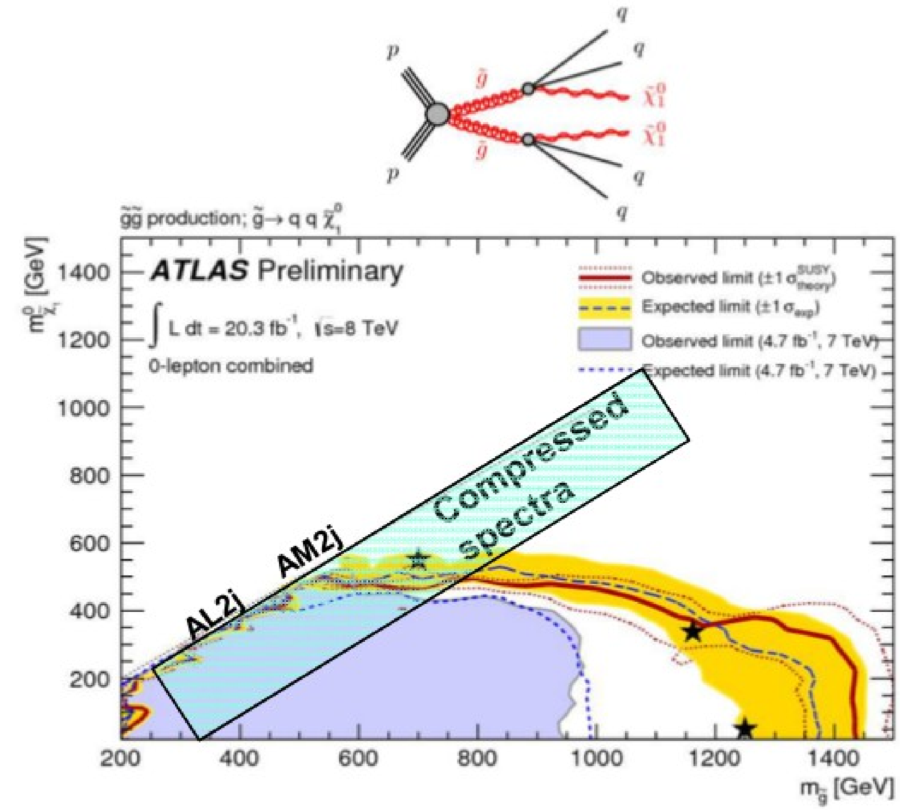
- In this region, jets from gluinos/squarks are very light (relaxed Meff cuts)
- Large SM backgrounds

- Sensitive to Initial State Radiation (ISR) jets boosted by heavy particle production

Only 2 sparticles : degenerate squark 1rst,2nd gene., LSP

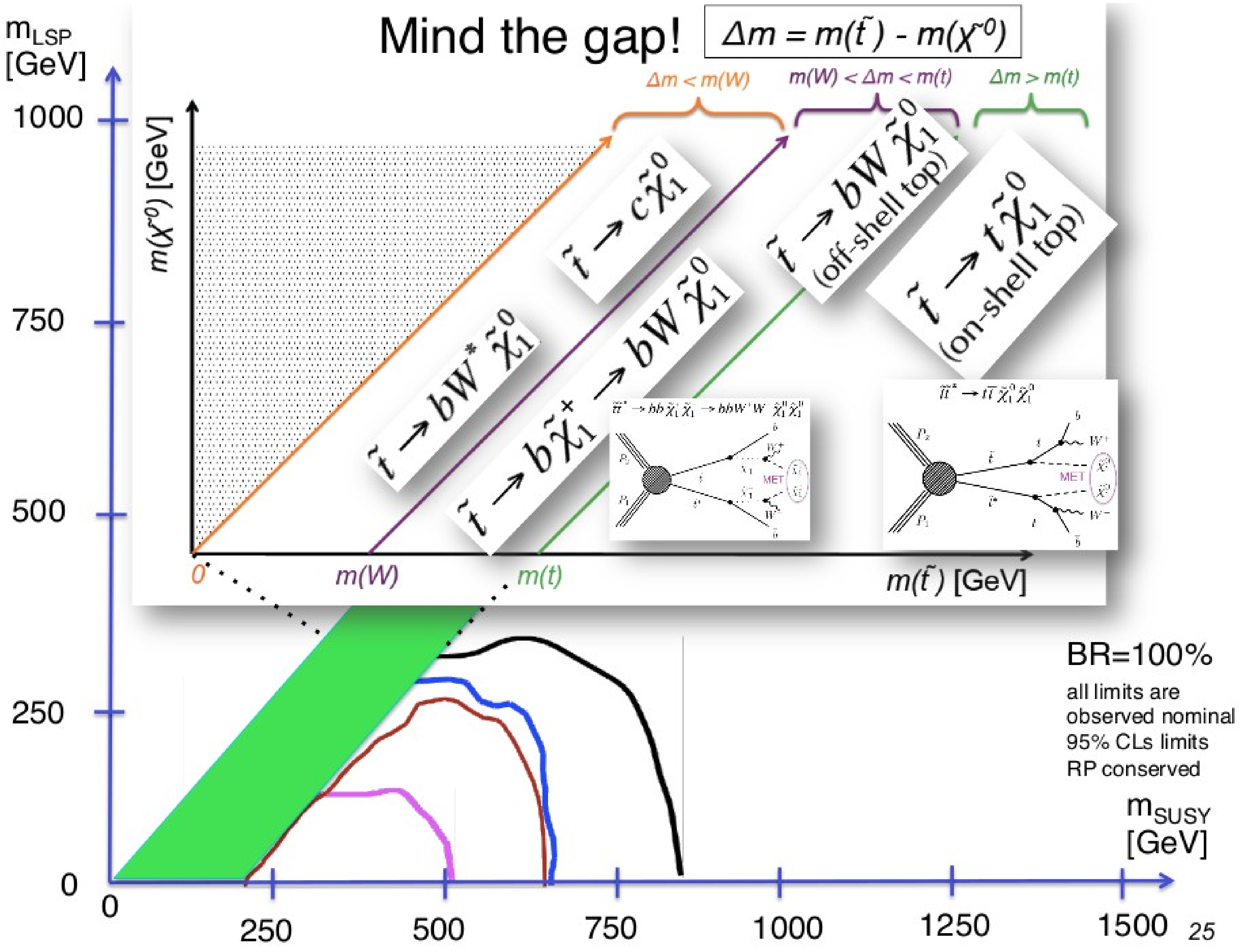


Only 2 sparticles: gluino, LSP



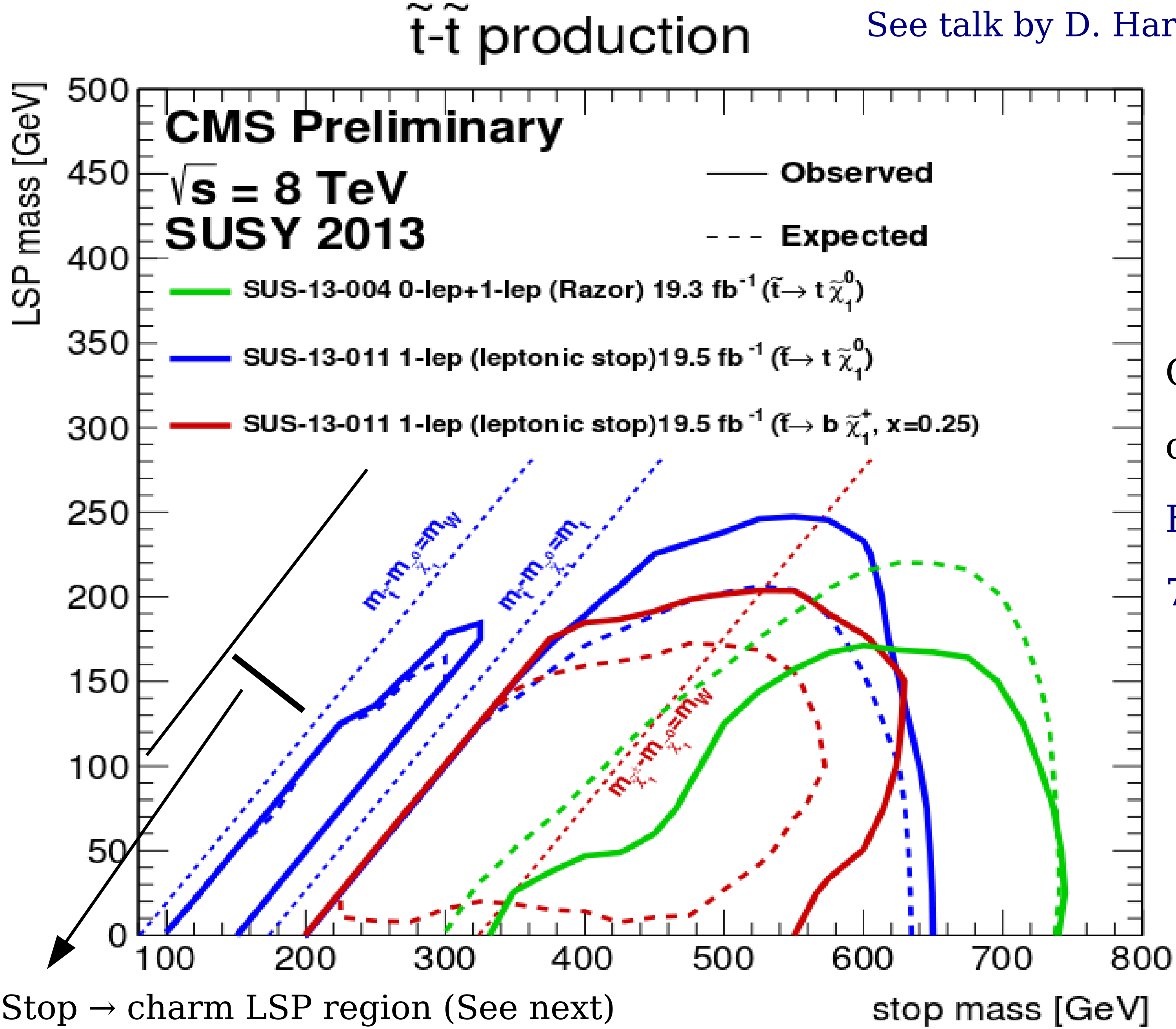
Significantly less stronger limits ….

Third generation searches



Direct stop pair production

See talk by D. Hare in the parallel session



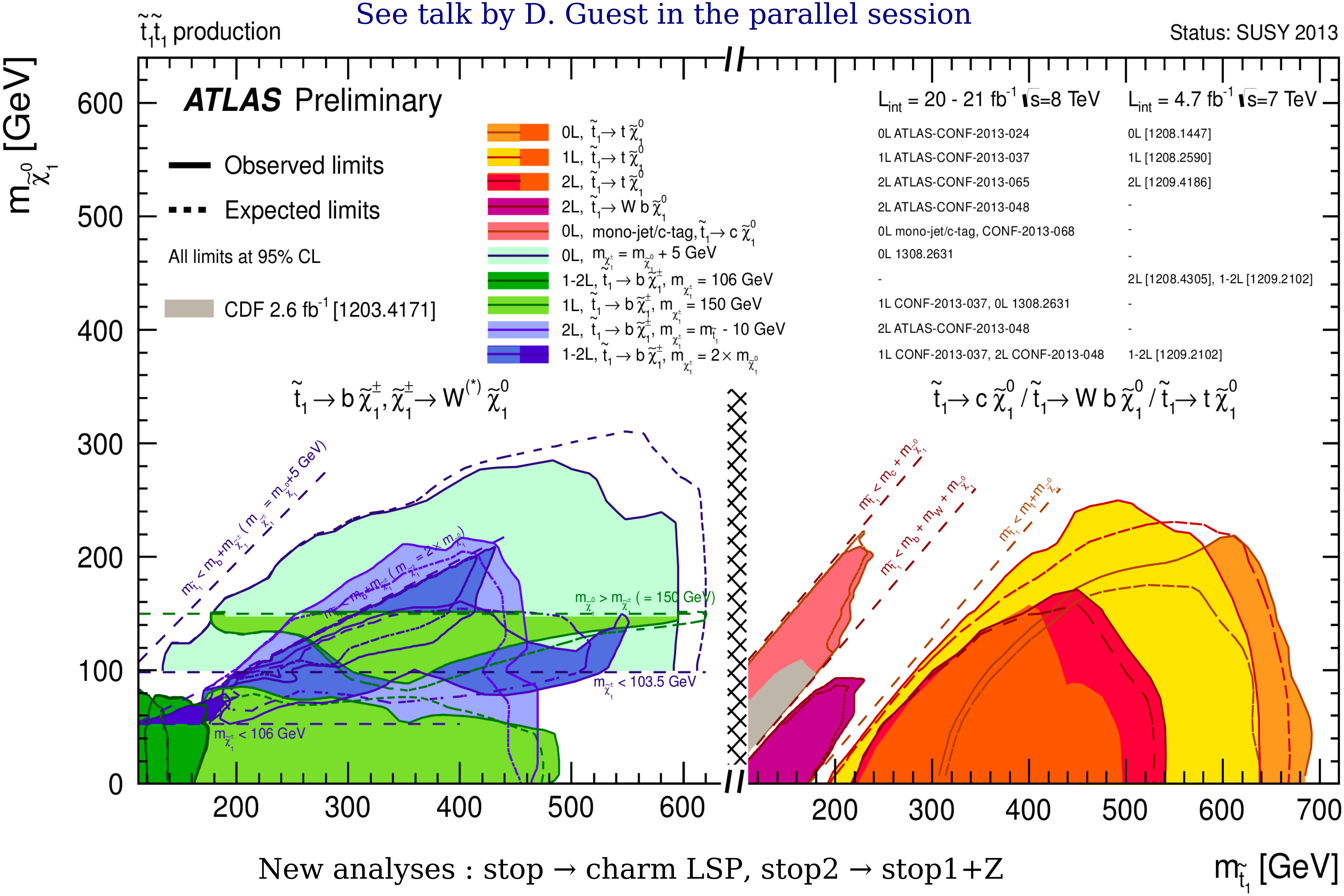
Covers a large range of mass scale.

Excluded regions up to 750 GeV (100% BR)

Stop → charm LSP region (See next)

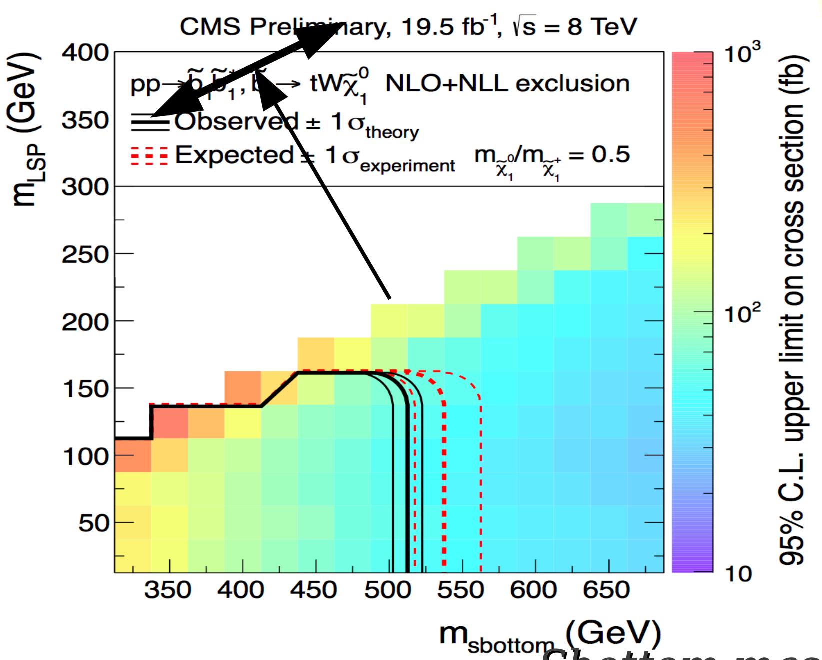
Direct stop pair production

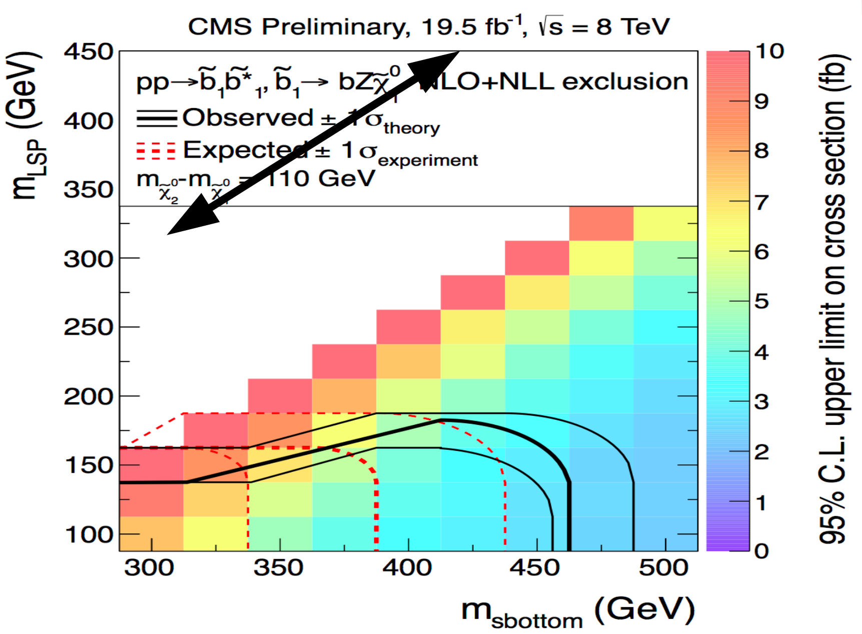
See talk by D. Guest in the parallel session



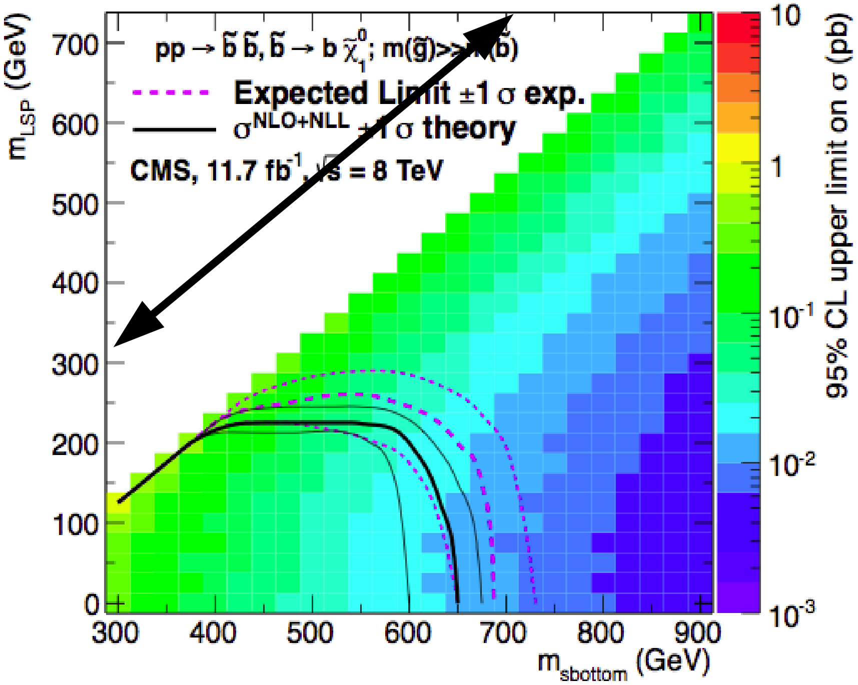
New analyses : stop → charm LSP, stop2 → stop1+Z

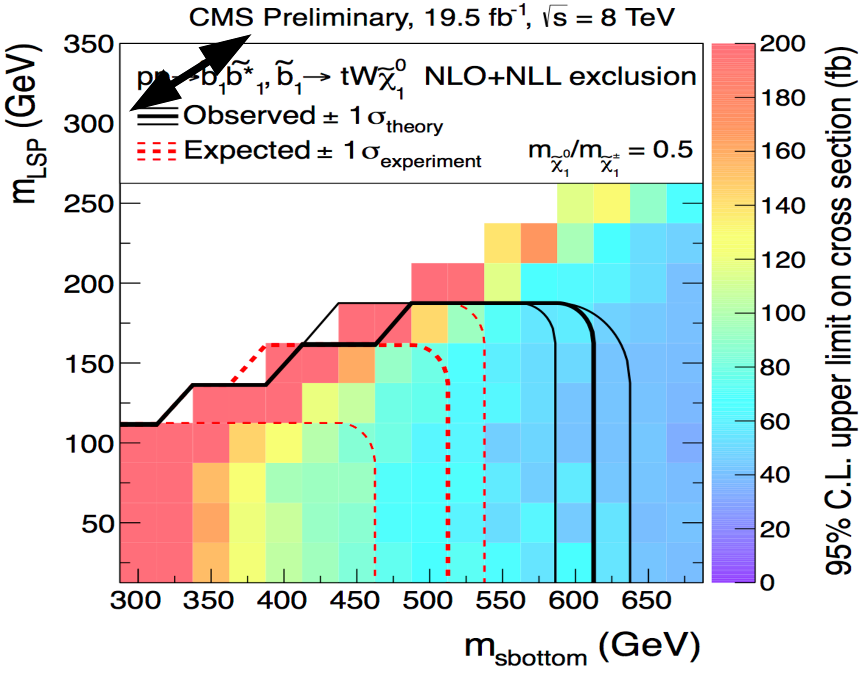
Direct sbottom pair production



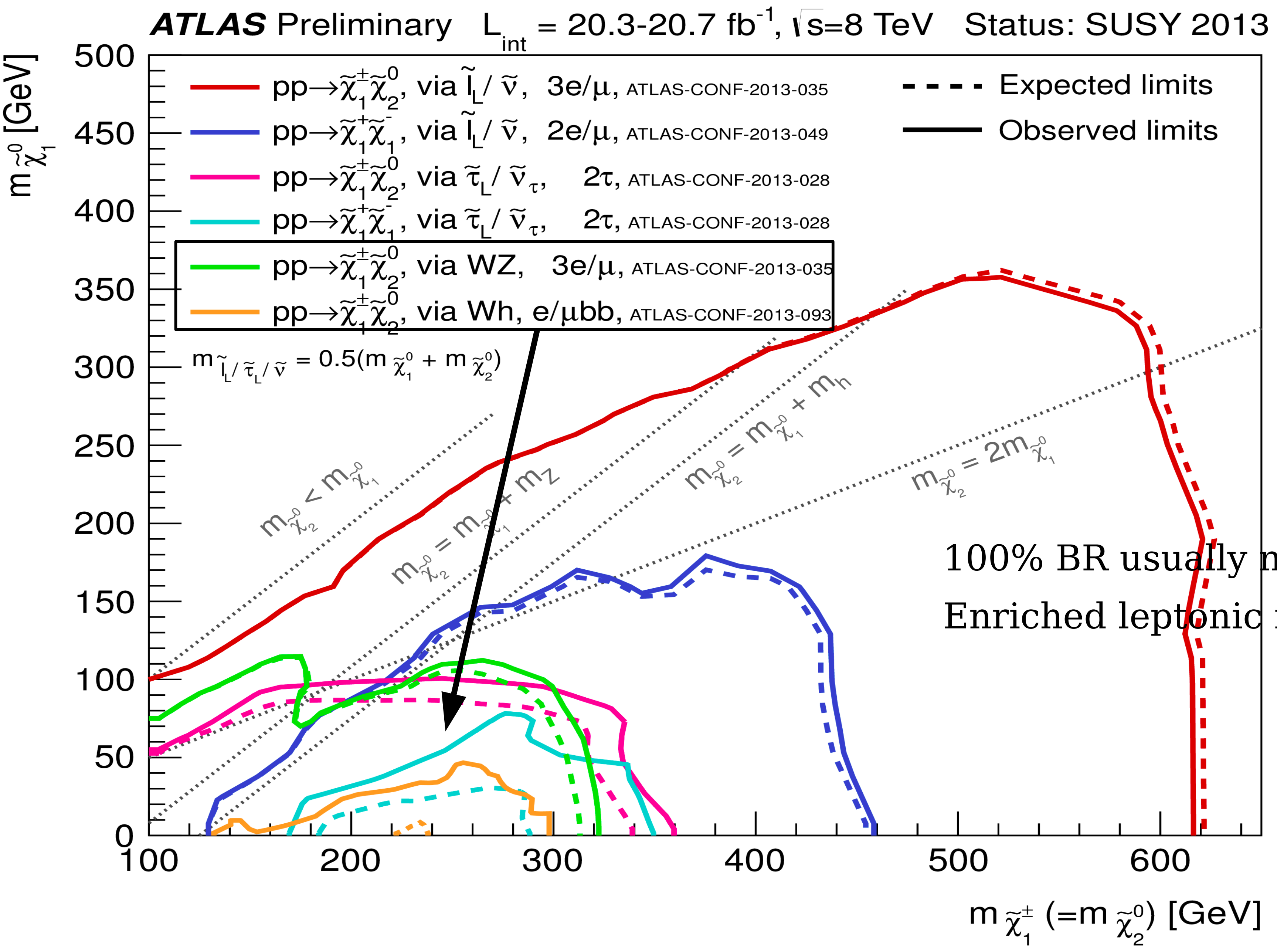


Sbottom mass up to 650 GeV is excluded





SUSY Electroweak production

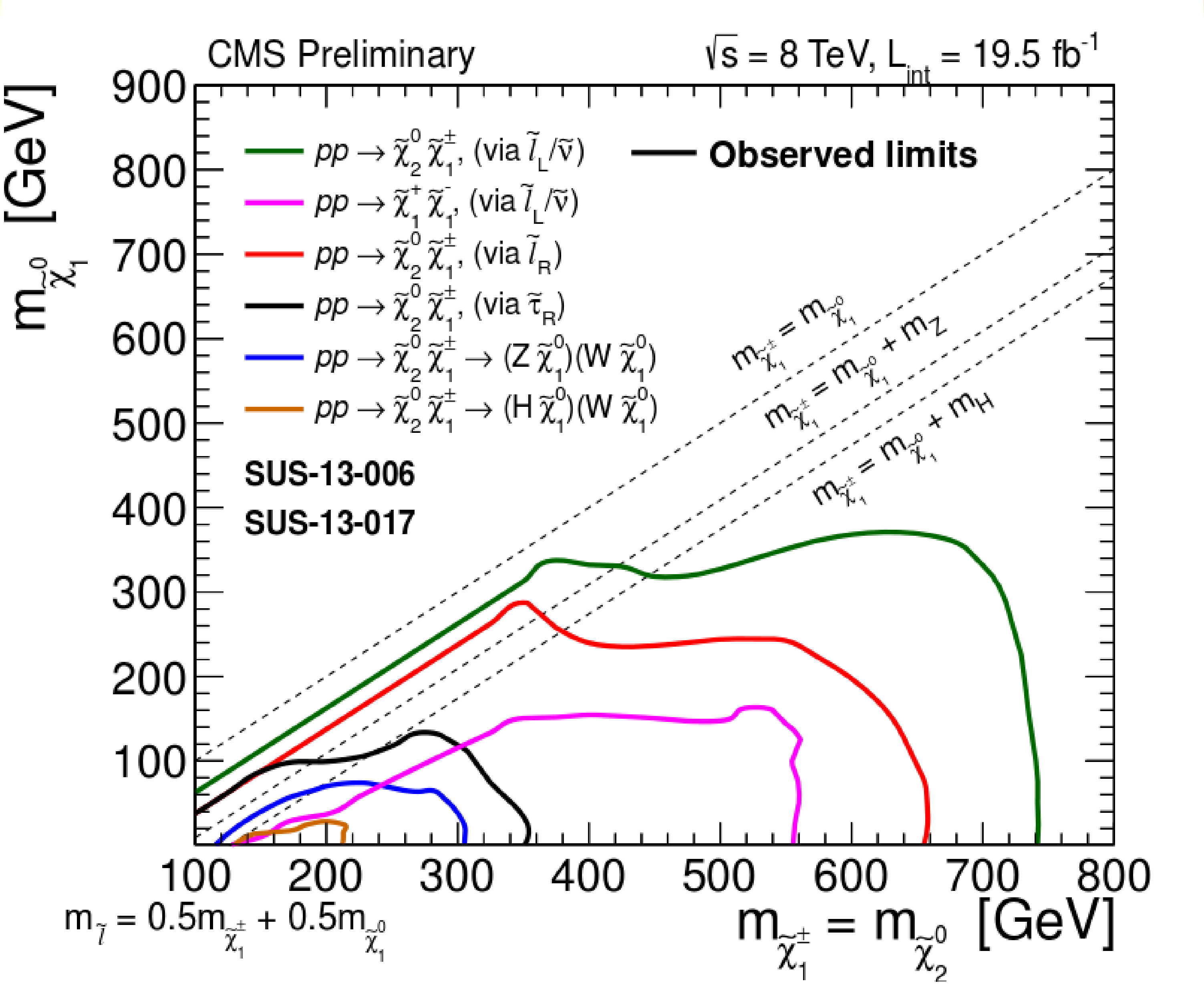


100% BR usually not realized

Enriched leptonic final state

In pure EW sector these limits are weak: opportunity to explore using 13/14 TeV LHC

SUSY Electroweak production

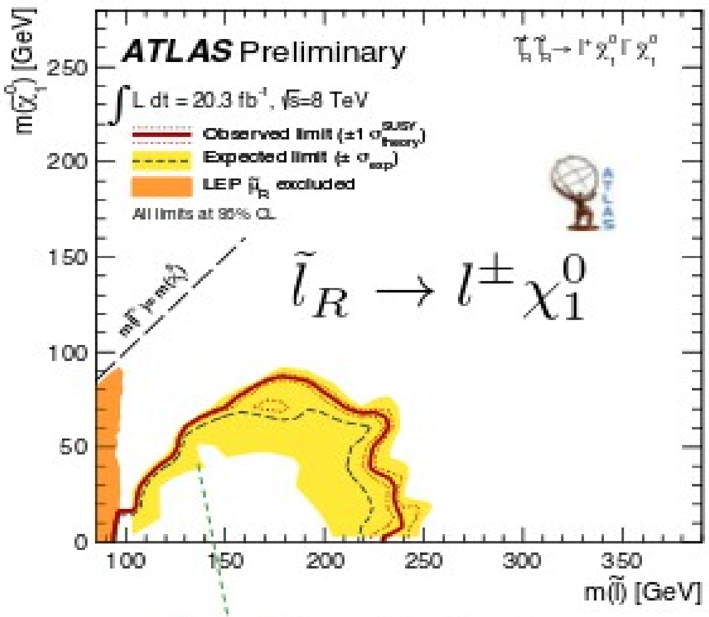


Enriched leptonic final states

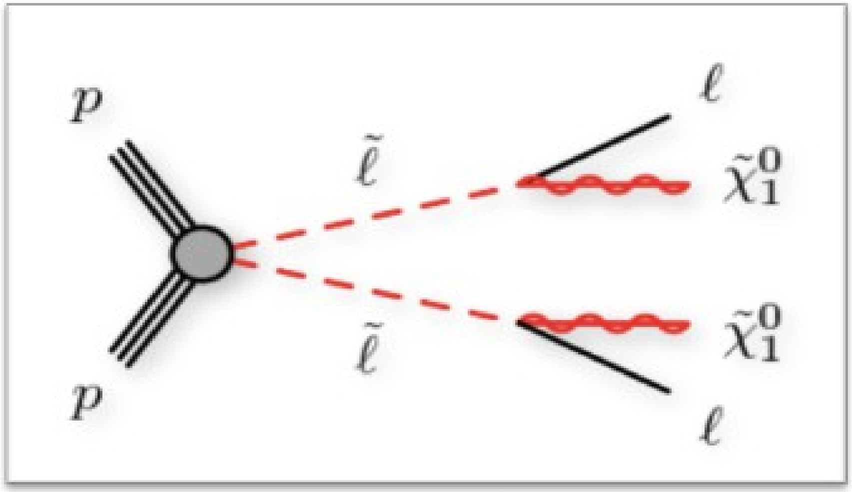
Limits are weak in M1, M2 and μ space – See arXiv:1309.7342

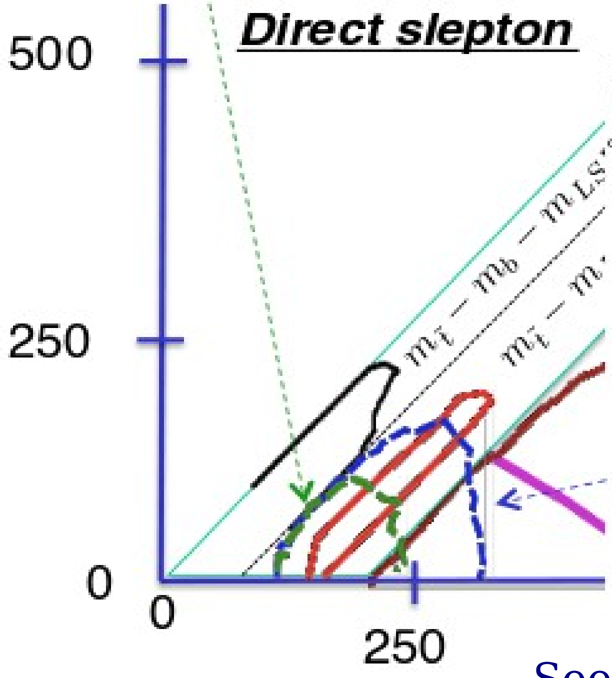
Direct slepton production

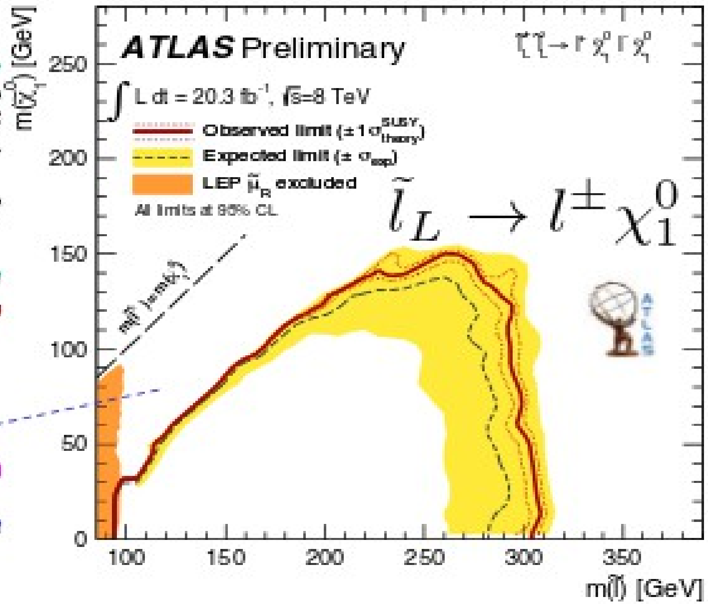
CMS Similar

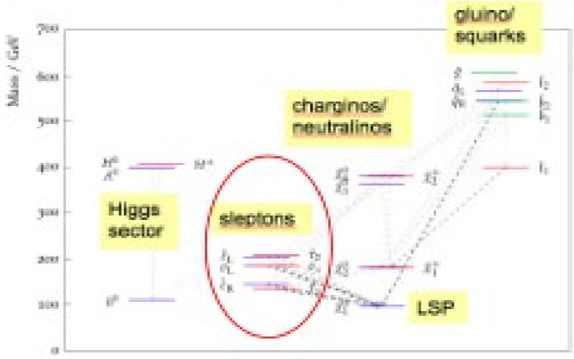


Direct slepton production









ATLAS-CONF-2013-049

Signature

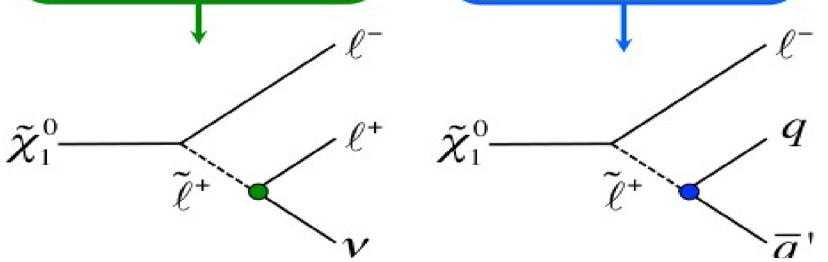
2 lepton + E_T^{miss}

See talk by S. Williams in the parallel session

RPV Studies and Interpretations

“leptonic RPV” “semi-leptonic RPV”

$$\Delta L_{RPV} = \boxed{\frac{1}{2}\lambda^{ijk}L_iL_j\bar{e}_k} + \boxed{\lambda'^{ijk}L_iQ_j\bar{d}_k} + \ldots$$



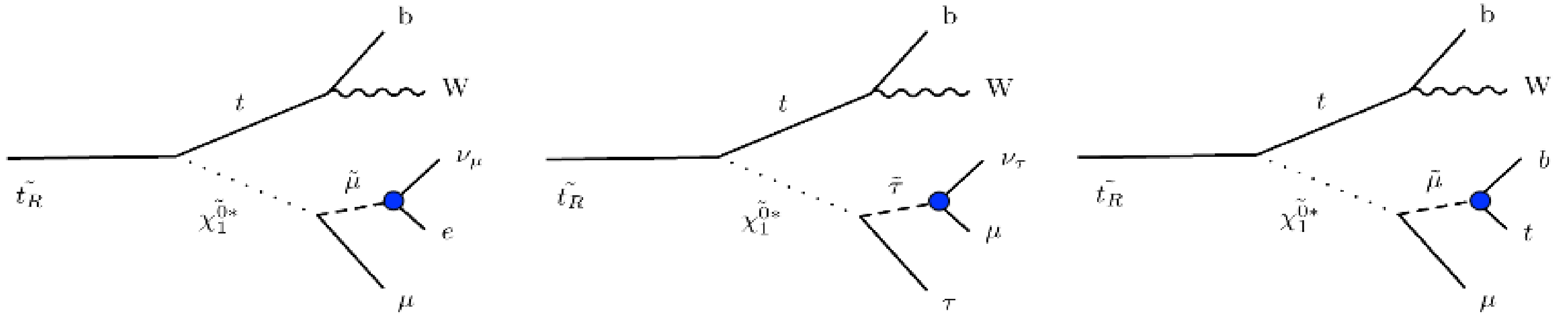
Lepton enriched final states

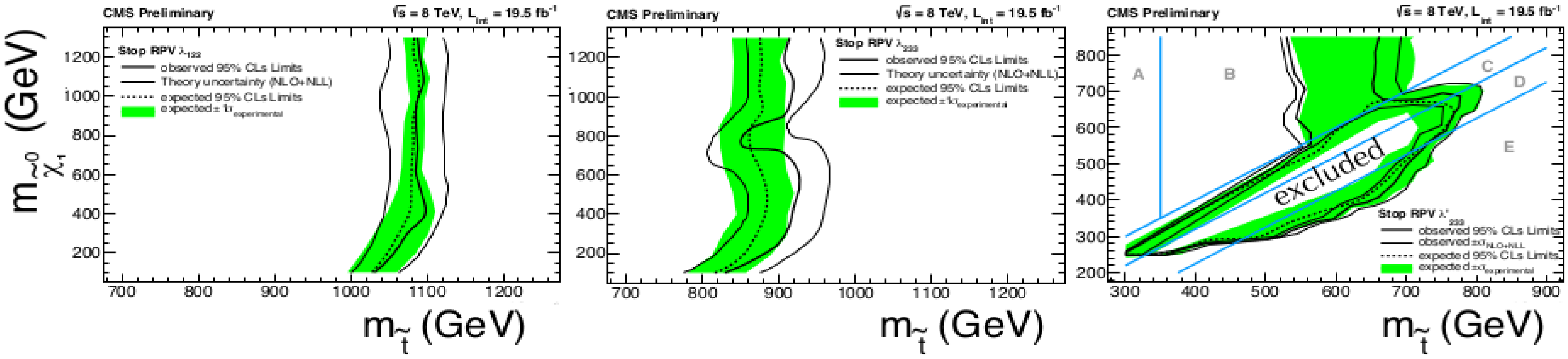
(With no MET) SUS-13-003

leptonic RPV
λ_{122}: e,μ-enriched

leptonic RPV
λ_{233}: μ,τ-enriched

semi-leptonic RPV
λ'_{233}: μ,b,t-enriched

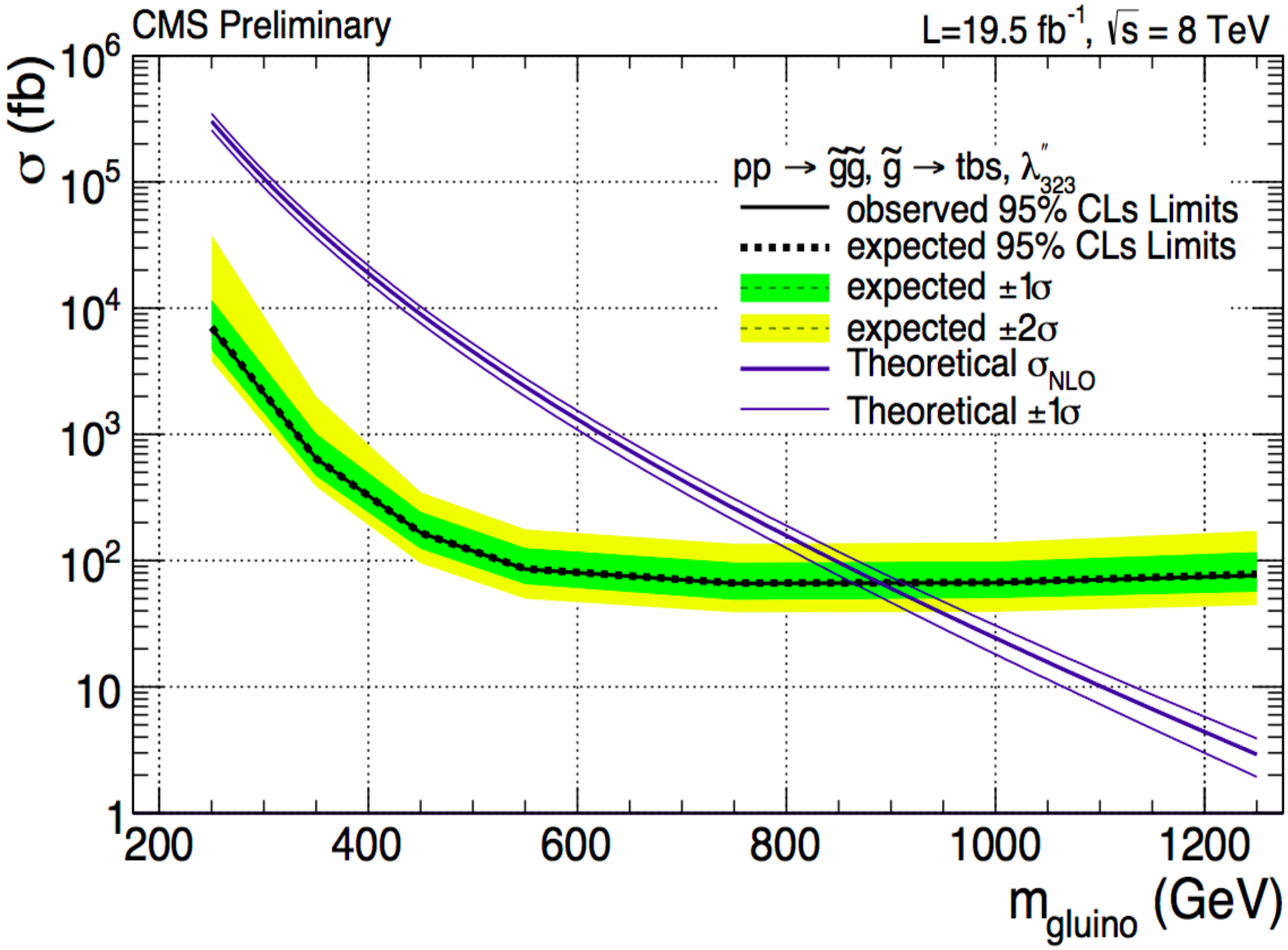




Probes stops in RPV mode up to 1.1 TeV (ATLAS Similar)

RPV Studies and Interpretations

Same sign dilepton study can also constrain RPV gluino decays



Gluino mass up to 950 GeV can be excluded

ATLAS: See talk by Benitez in the parallel session

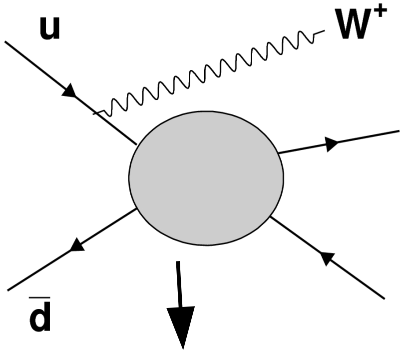
Search for Exotic (non SUSY) signatures at the LHC

Dark Matter and Monojets

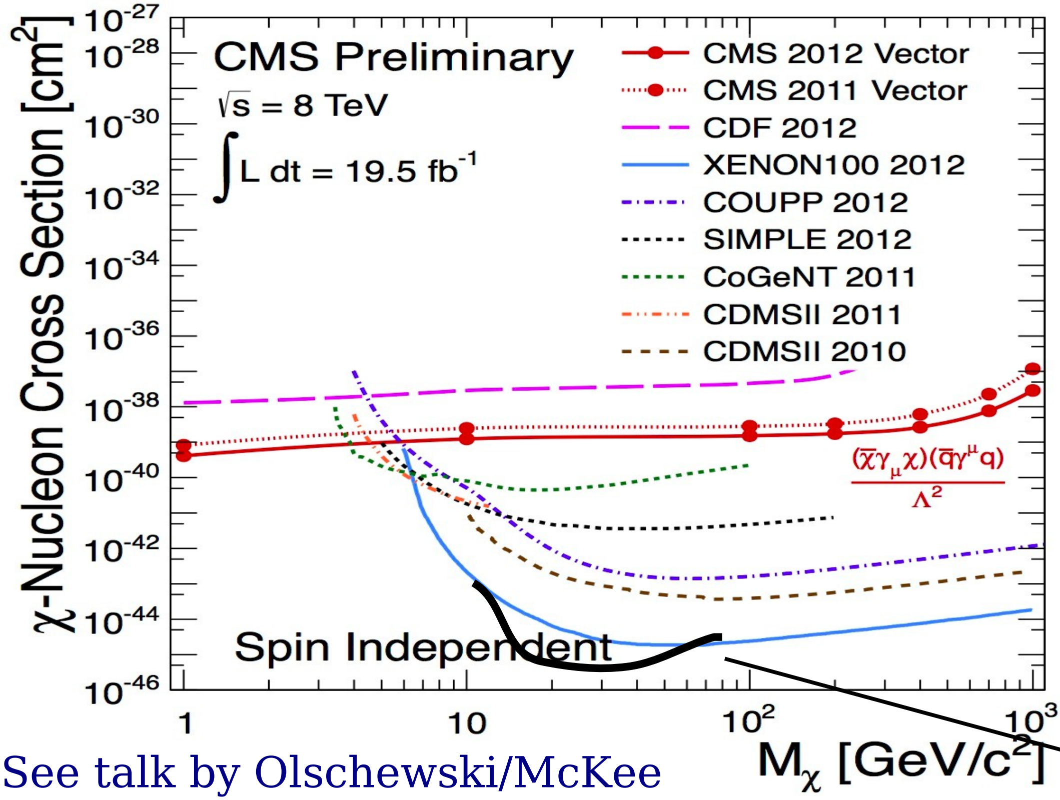
Pair-production of DM (χ) characterized by a contact interaction effective theory

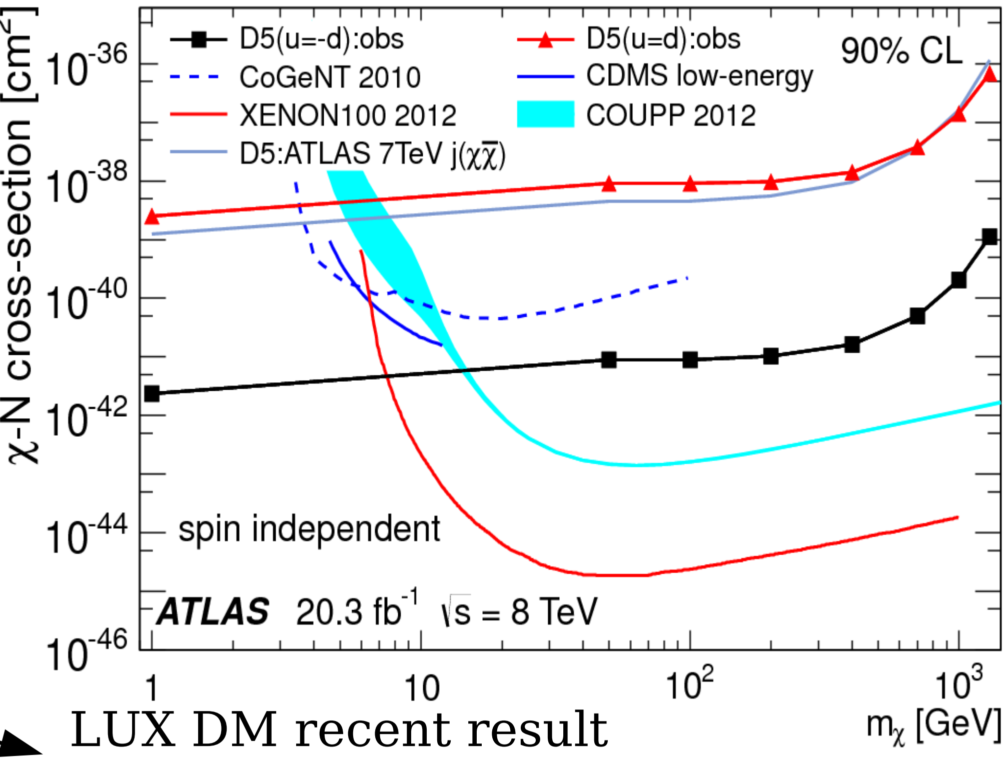
Derived limits using LHC data and compared to direct-detection experiments

ATLAS & CMS results are similar for 7 TeV, improved with 8 TeV



Started to extend simple contact interaction scenarios to new operators – scan over mediator mass





See talk by Olschewski/McKee

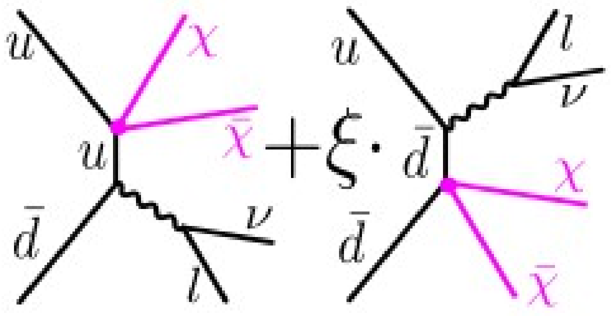
LUX DM recent result

See talk by P. Sorensen in the parallel session

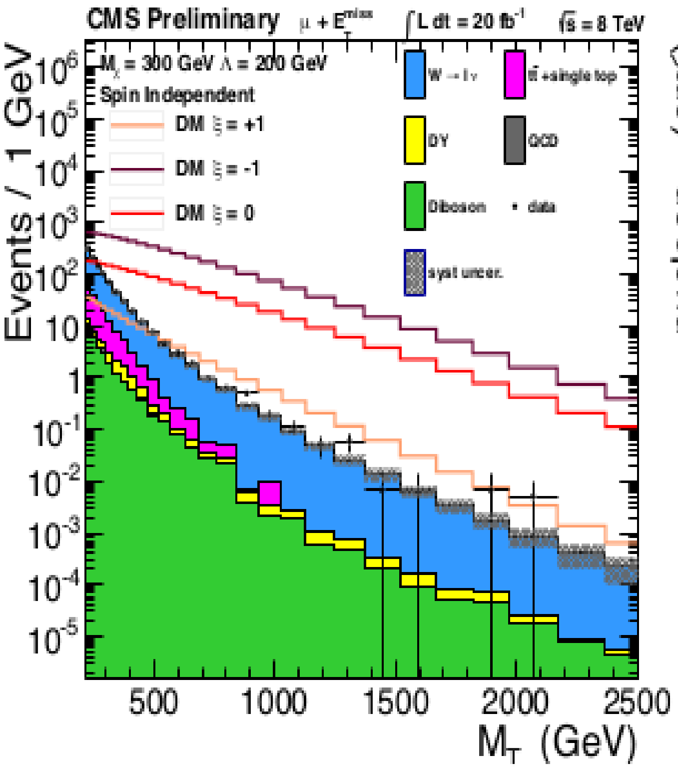
Mono-lepton Dark Matter

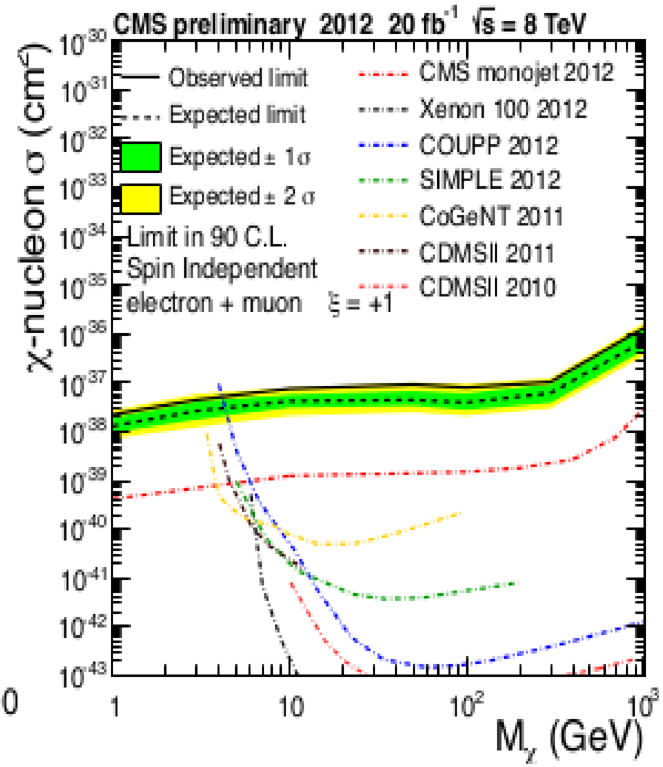
Consider two couplings and interferences

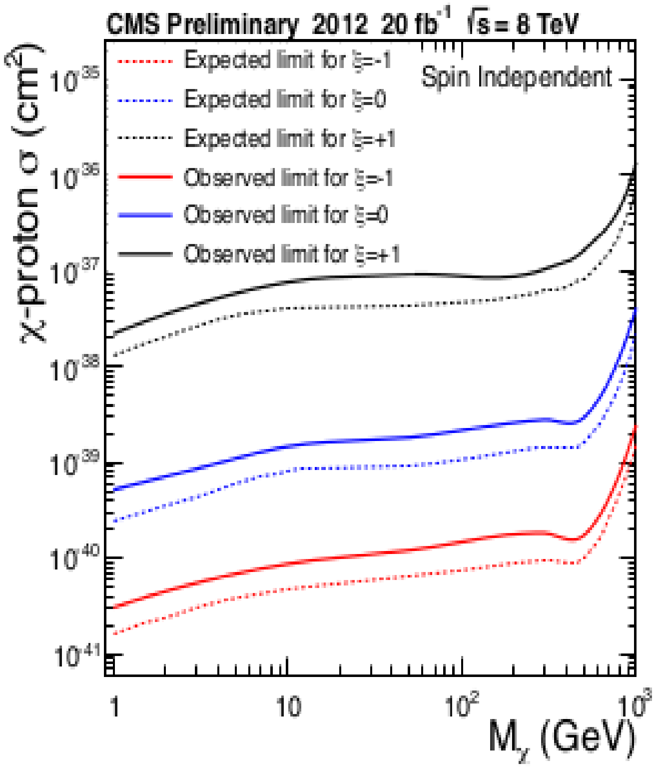
- Vector- and axial-vector like couplings considered
- Unlike monojets, they have interference effects
- Parameterize interference effects by ζ (See W^+ right)



First LHC results on “monolepton” dark matter







New Physics with resonances – di-leptons

Event selection

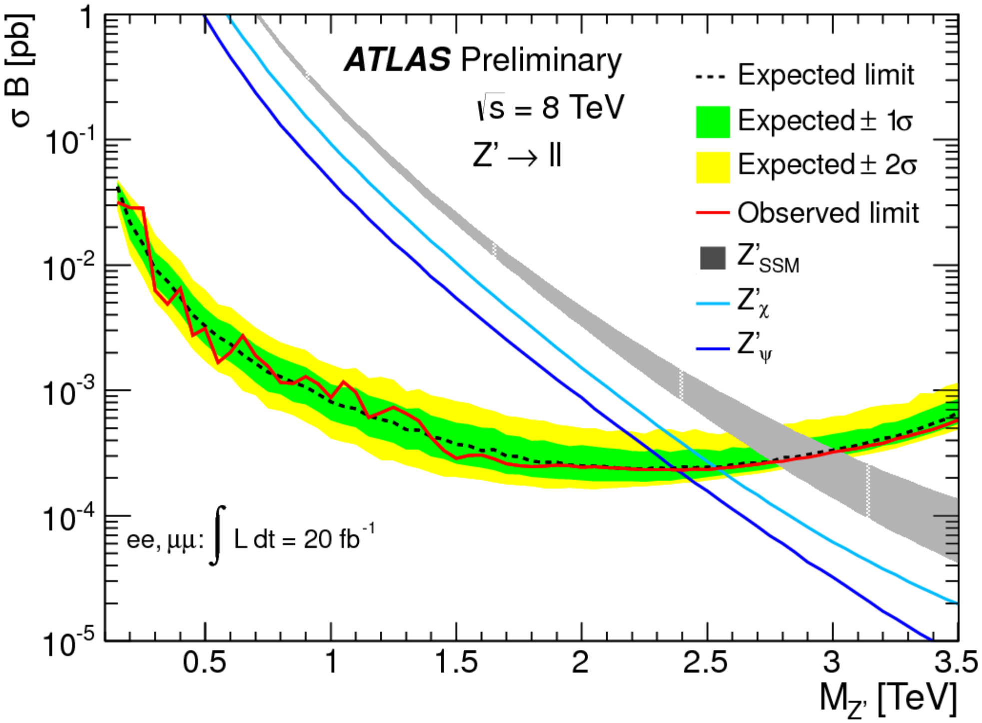
- ATLAS: Isolated leptons with $p_T(e1, e2) > (40, 30)$ GeV, $p_T(\mu1, \mu2) > 25$ GeV
- CMS: Isolated leptons with $p_T(e1, e2) > 35$ GeV, $p_T(\mu1, \mu2) > 45$ GeV

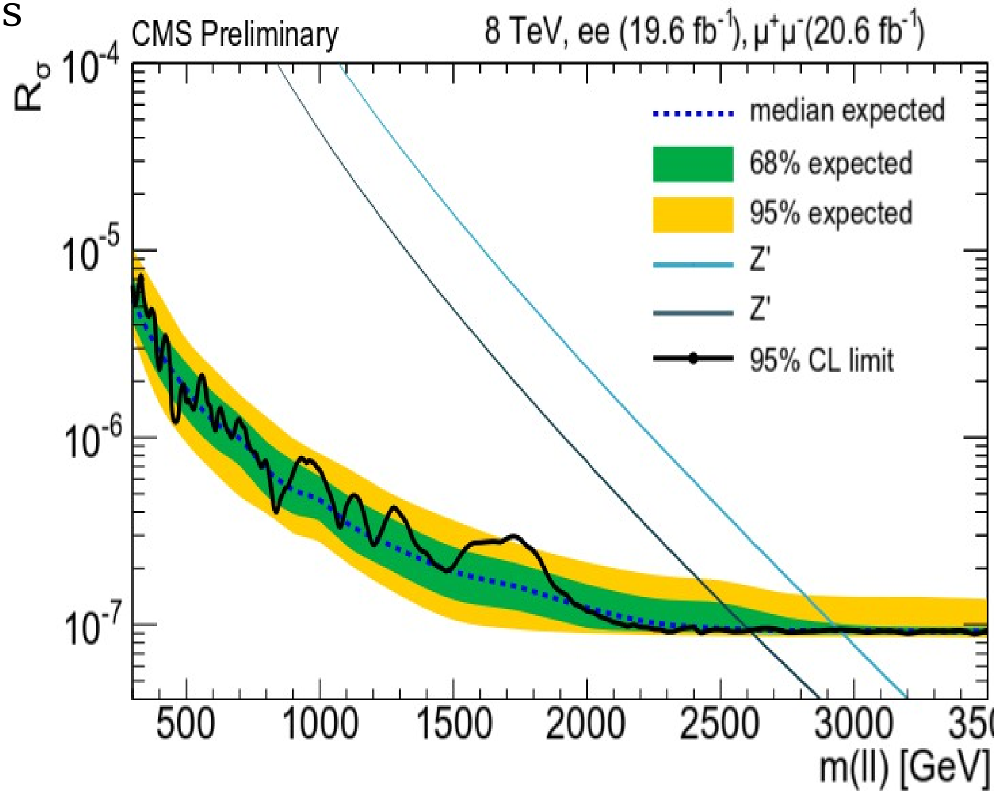
Backgrounds

- Z/γ^*, ttbar, tW, VV, $Z \to \tau\tau$, multi-jet with fakes
- estimated using functional fits

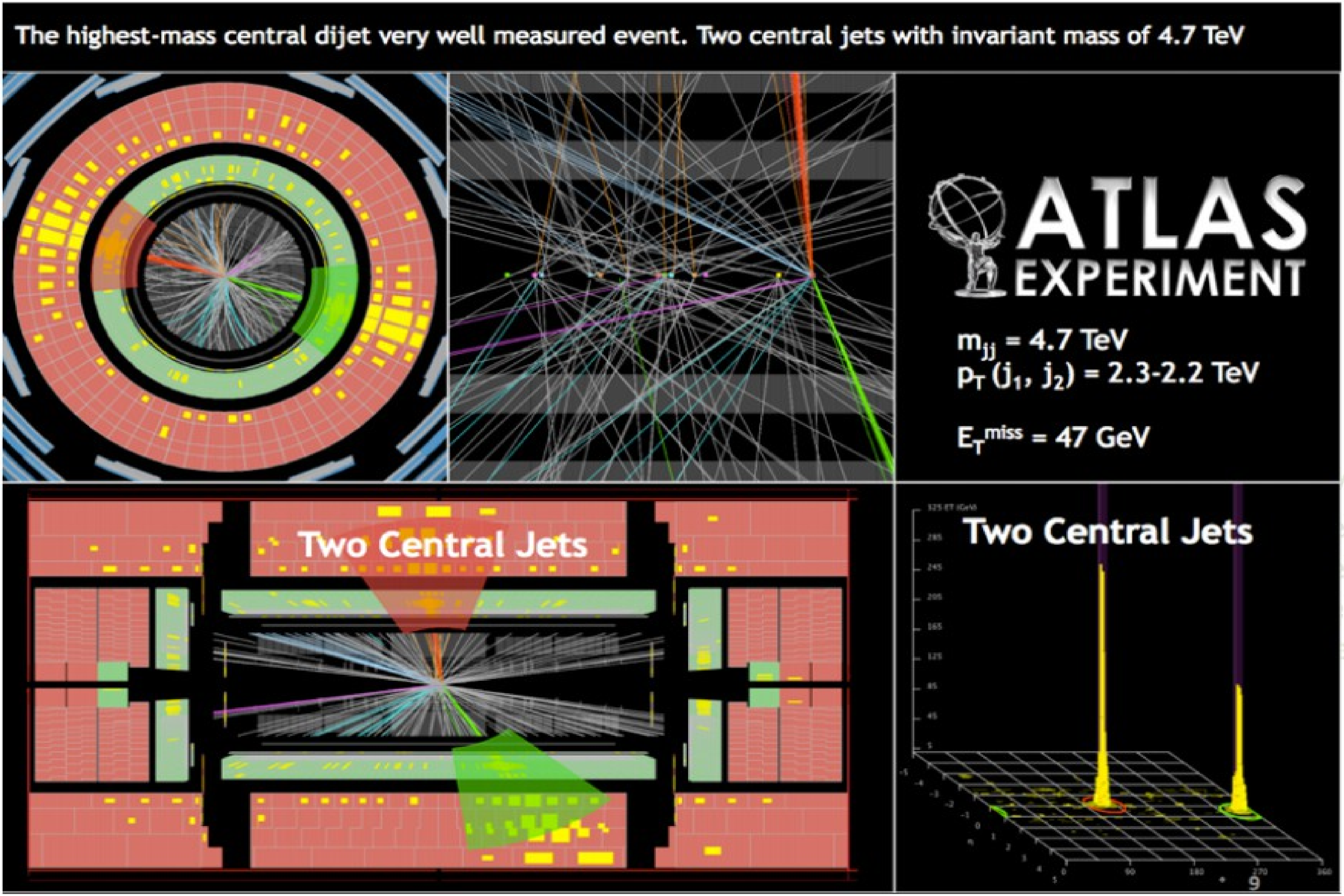
$M(Z'_{SSM})$	expected	observed
CMS	> 2.96 TeV	> 2.96 TeV
ATLAS	> 2.85 TeV	> 2.86 TeV

Limits set on variety of narrow resonance models





New Physics with resonances - di-jets



The highest-mass central dijet very well measured event. Two central jets with invariant mass of 4.7 TeV

m_{jj} = 4.7 TeV
p_T (j_1, j_2) = 2.3-2.2 TeV

E_T^{miss} = 47 GeV

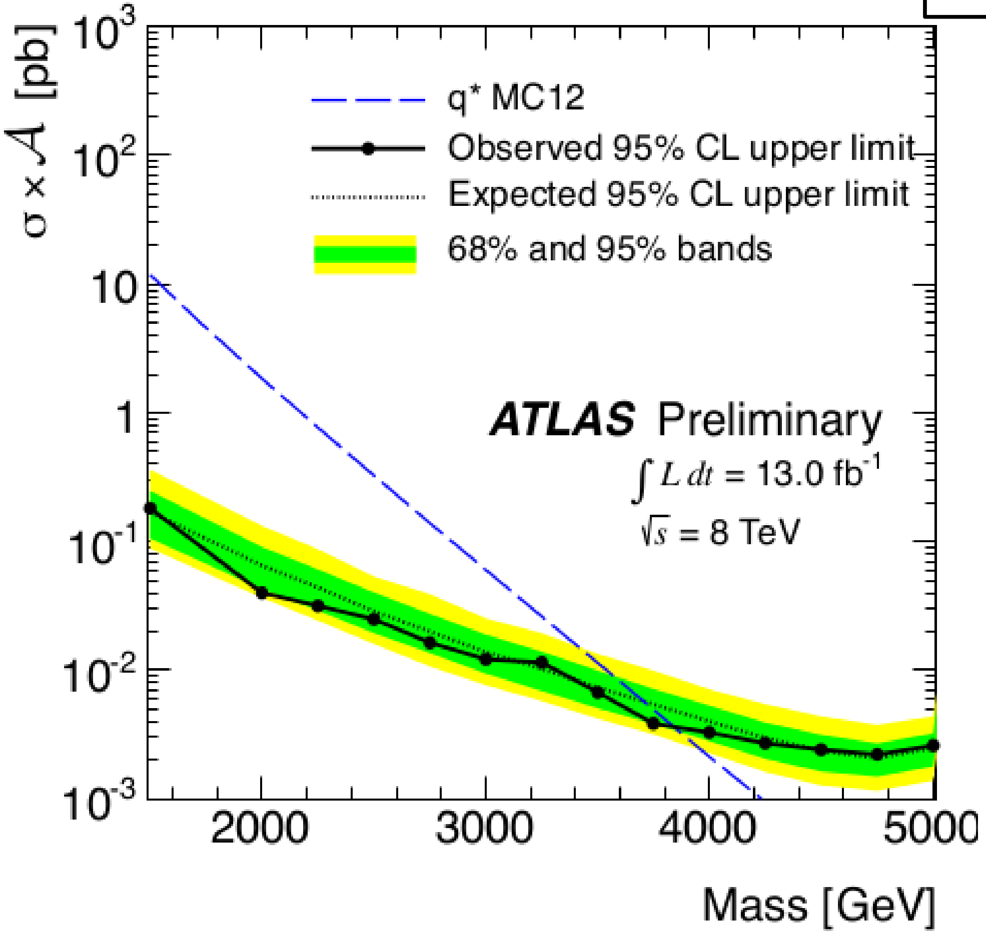
New Physics with resonances - di-jets

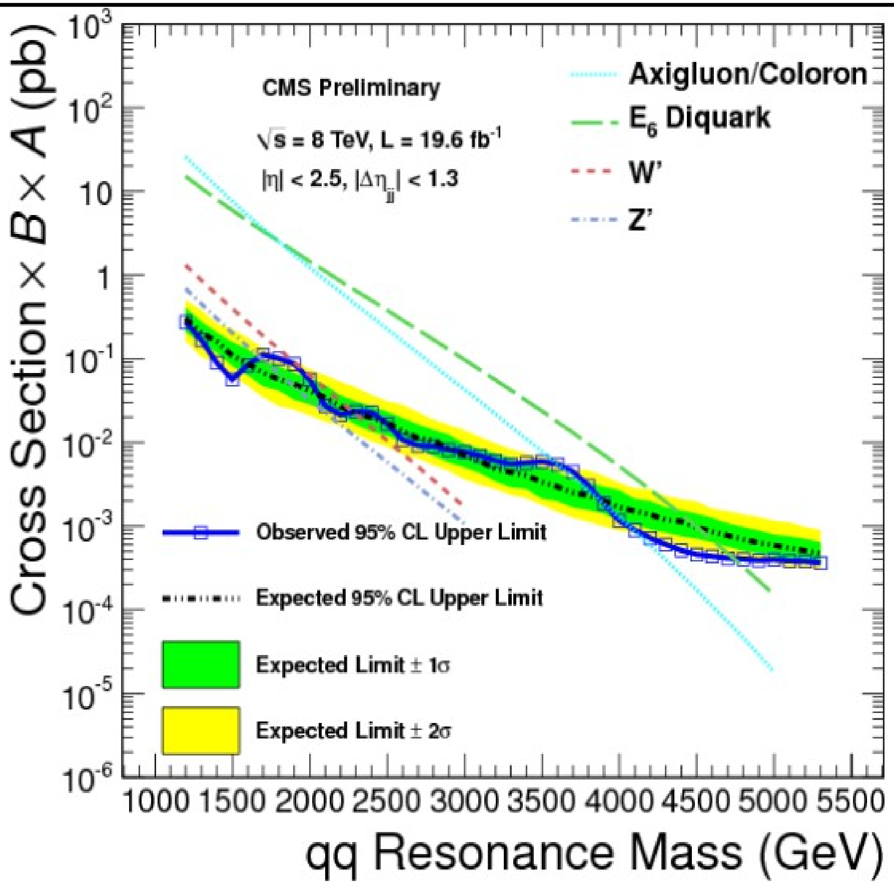
Search dijet spectrum for narrow resonances

- Background fit to smooth

$$\frac{d\sigma}{dm_{jj}} = \frac{P_0(1-x)^{P_1}}{x^{P_2+P_3\ln(x)}}$$

M(q*) 95% CL	Luminosity	Expected	Observed
ATLAS 2011	4.8	> 3.09 TeV	> 3.55 TeV
CMS 2011	5.0	> 3.27 TeV	> 3.05 TeV
ATLAS 2012	13.0	> 3.70 TeV	> 3.84 TeV
CMS 2012	19.6	> 3.75 TeV	> 3.50 TeV





Limits also set on qq, gg and bg (Z', G_{RS} and b* models) in 0, 1 and 2 b-tags

New Physics with resonances – ttbar (leptonic decays)

Search for heavy resonance decaying to ttbar pairs in e and μ + jets (X → ttbar)

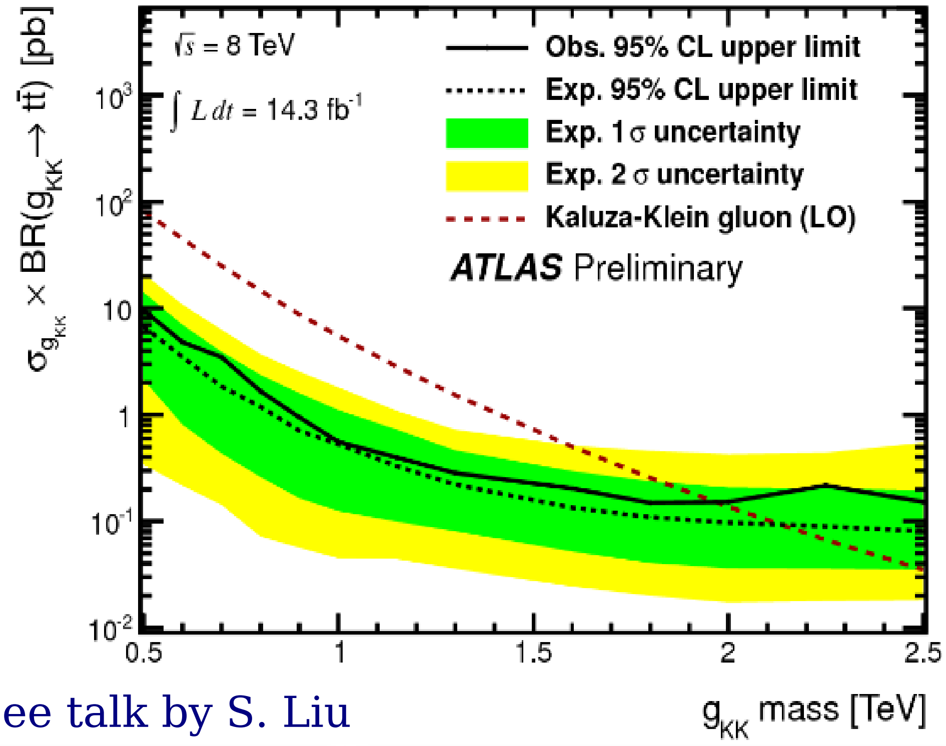
Many models favor such resonances: Z', top-color, bulk RS (KK gluon)

Search regions: Resolved jets and high lorentz boost (> 1 TeV)

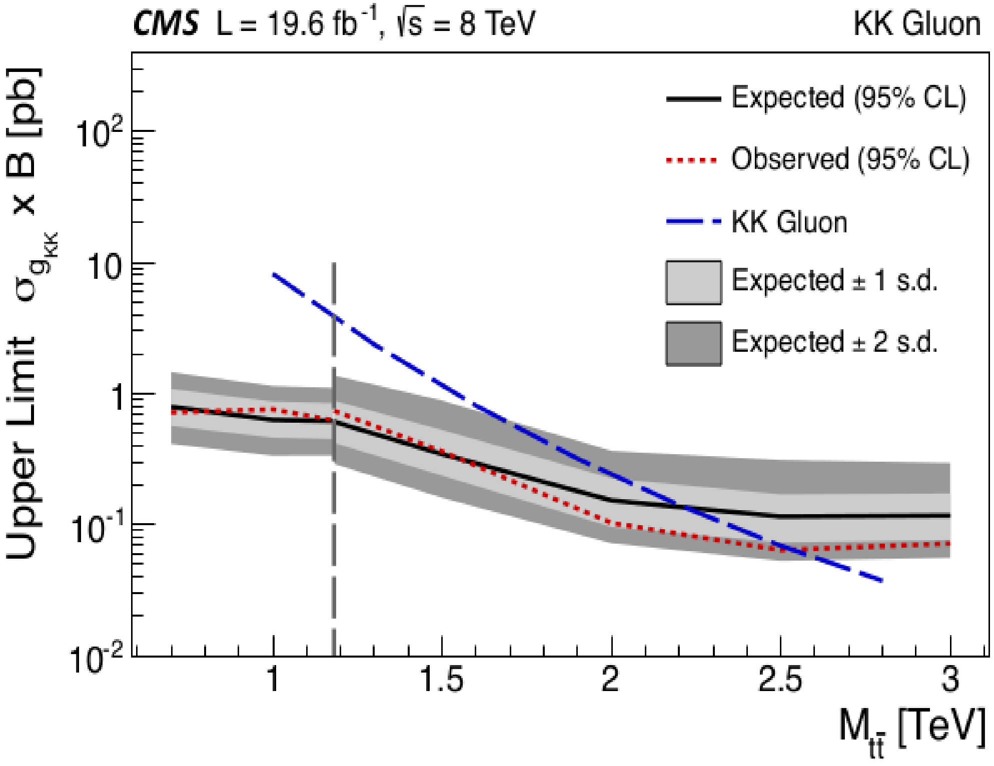
Combination of MC and data-driven used

SM ttbar, Single top (+Wjets) bkg (after b-tag)

M(Z′ or g_{KK}) 95%	Luminosity	Expected	Observed
ATLAS Z′	14.3	> 1.9 TeV	> 1.8 TeV
CMS Z′	19.6	> 2.0 TeV	> 2.1 TeV
ATLAS g_{KK}	14.3	> 2.1 TeV	> 2.0 TeV
CMS g_{KK}	19.6	> 2.2 TeV	> 2.5 TeV



See talk by S. Liu



New Physics with resonances – ttbar (hadronic decays)

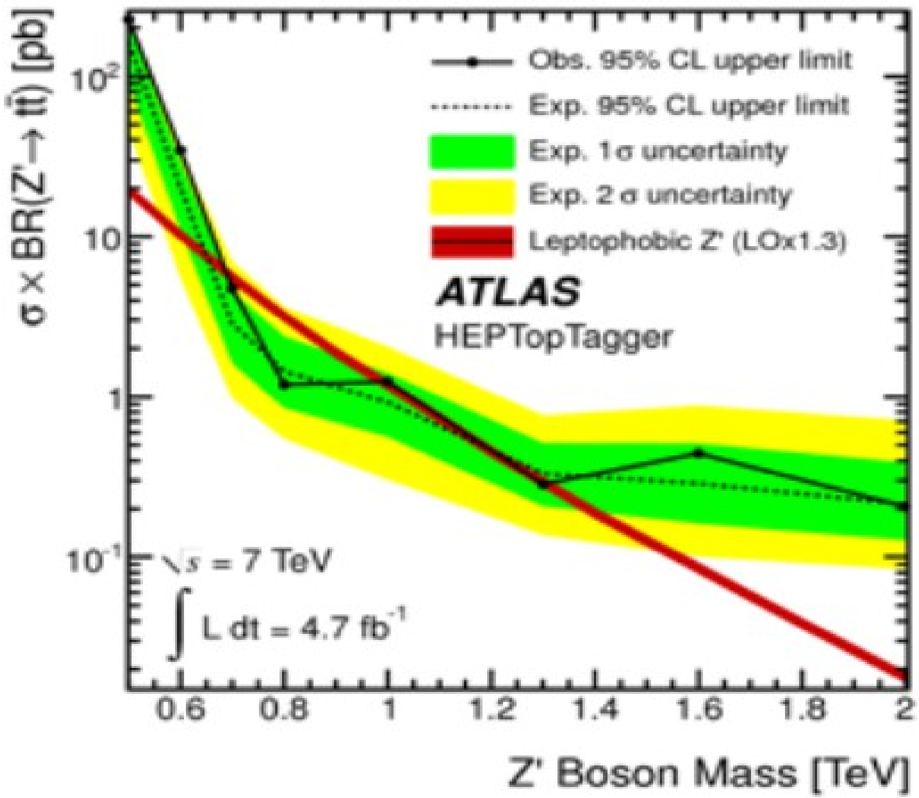
In hadronic mode the main challenge includes boosted top tagging

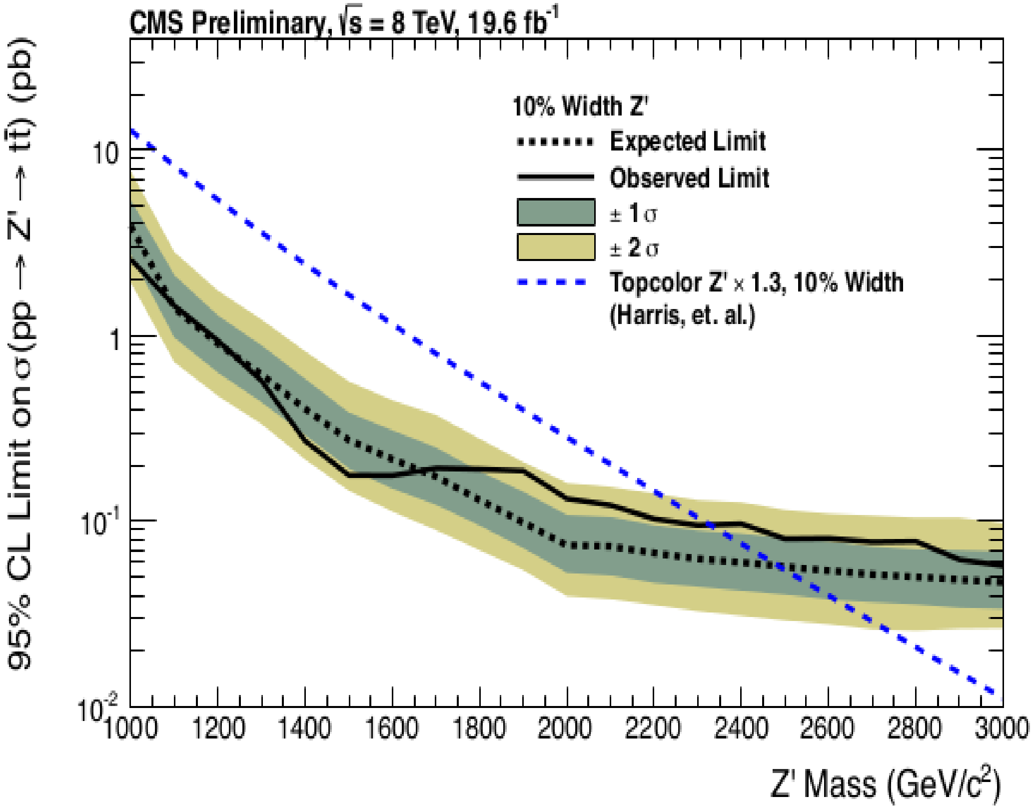
Top-tagging: requirement on # of subjets, jet mass and min. pair mass (W)

- ATLAS: Fat CA (R = 1.5) jets, split and re-cluster (HEPTopTagger)
- CMS CA (R=0.8) Top-tagger

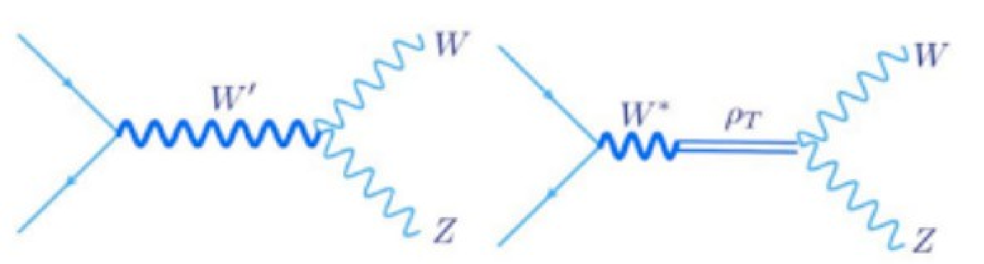
Main backgrounds: ttbar, multijets, etc.

Limits on $M(G_{KK}) < 1.8$ TeV, $M(Z') < 2.5$ TeV





New Physics with resonances – di-bosons (WZ)



$W'/\rho_{TC} \longrightarrow WZ \longrightarrow 3l + MET$

Analysis approach:

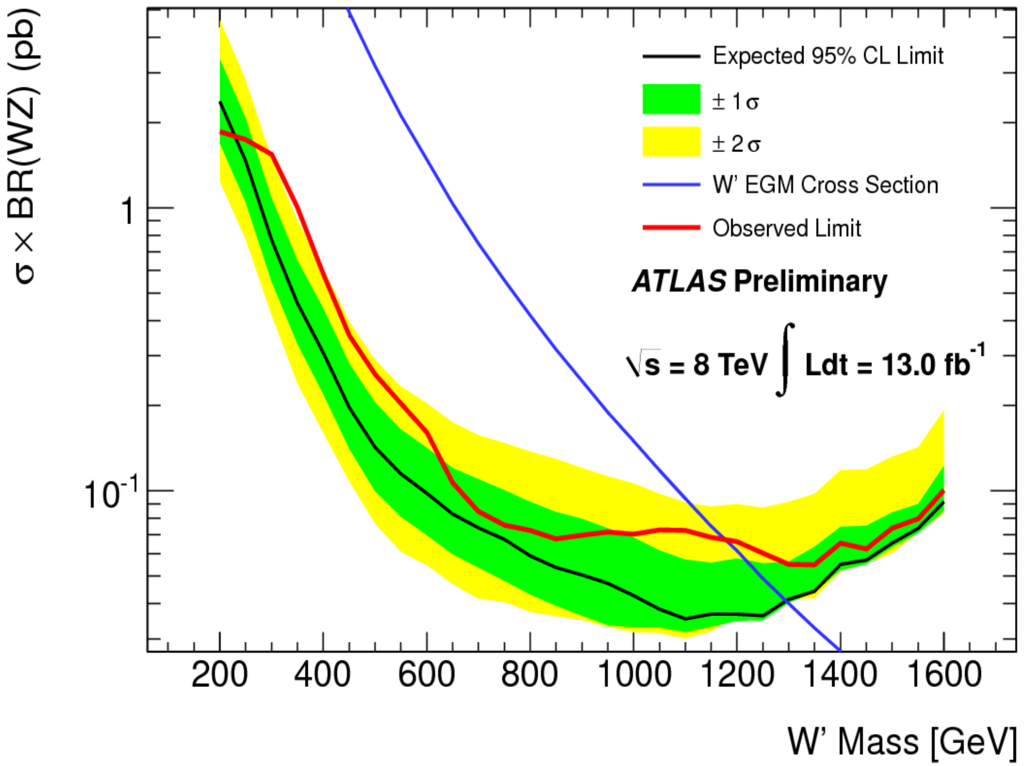
Compute M_{WZ}, taking MET into account

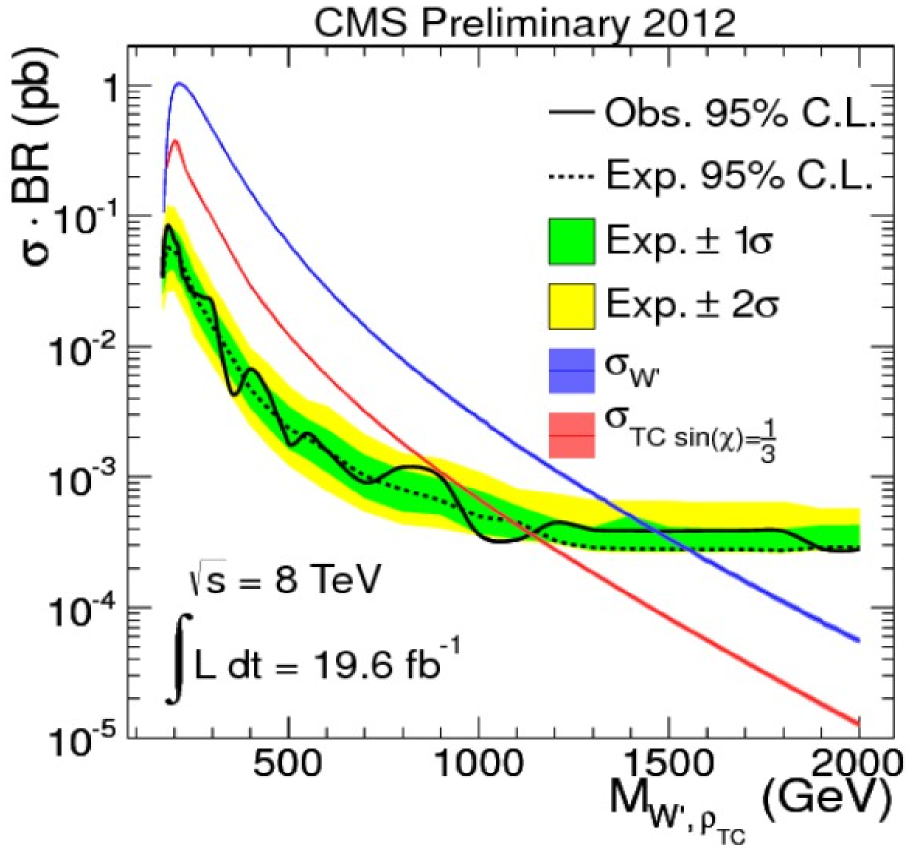
Main background from SM WZ process

Cuts are optimized for each signal regions

ATLAS: < 1.18 TeV @ 95% CL

CMS: (0.17 – 1.45) TeV @ 95% CL



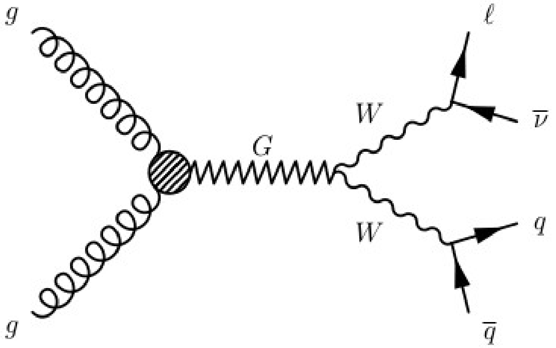


See talk by Endner/Varol in the parallel session

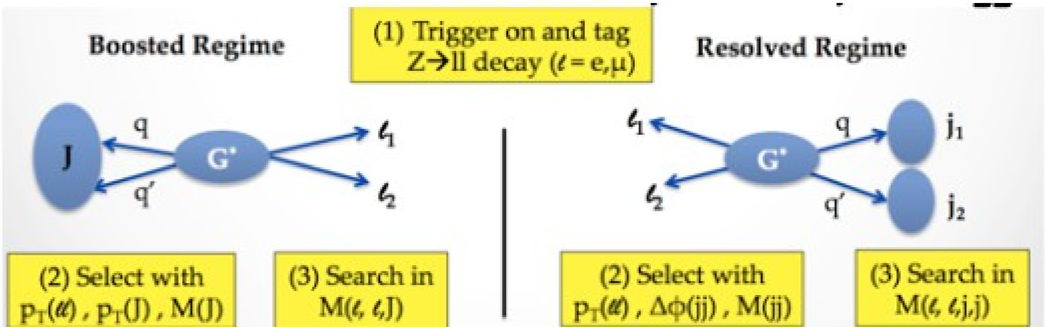
New Physics with resonances – di-bosons (WW/ZZ - leptonic)

Search for WW/ZZ resonance at high mass

- Identify boosted in W-jets (CMS N-subjettiness)
- Study performance of W-tagging in data (See next slide)



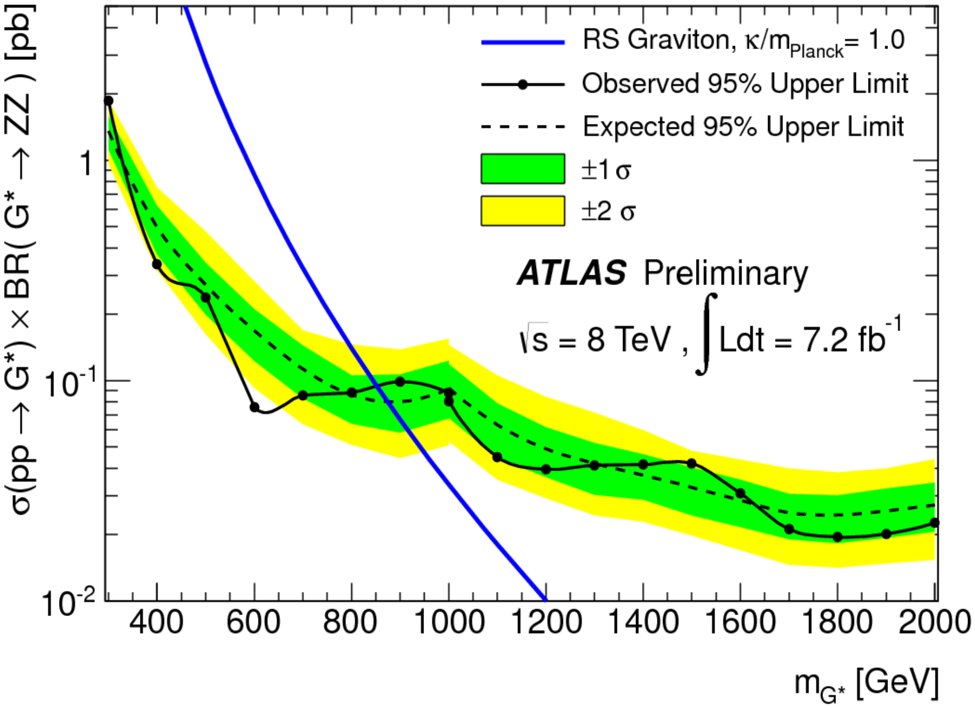
ATLAS (ZZ → lν jj), Bkg: Fit to the data

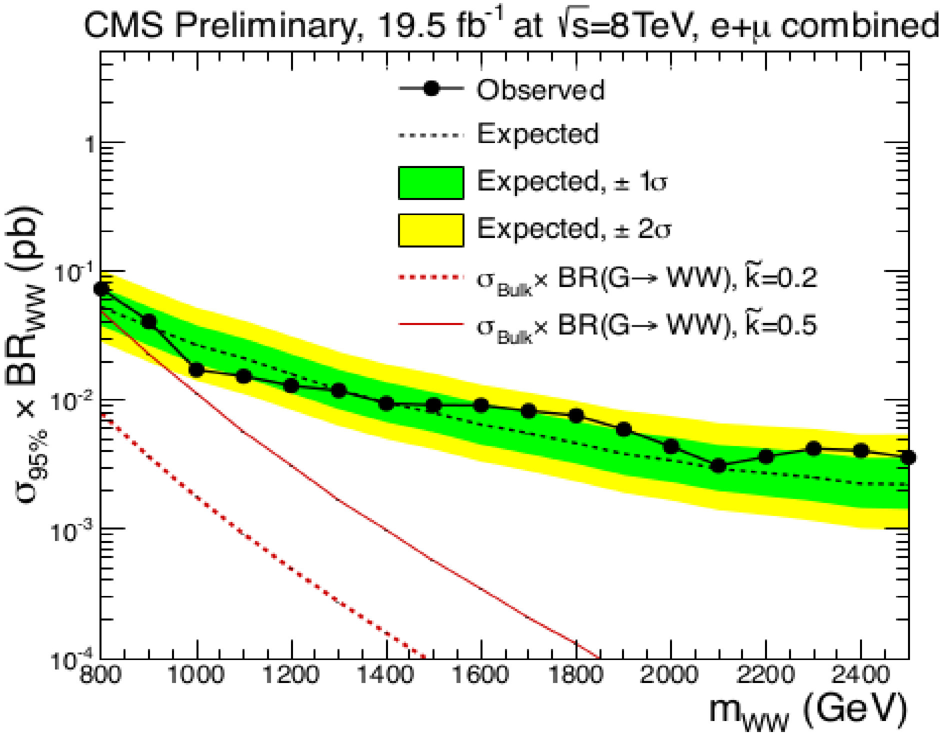


RS Graviton:

ATLAS (ZZ): mass < 850 GeV (excluded)

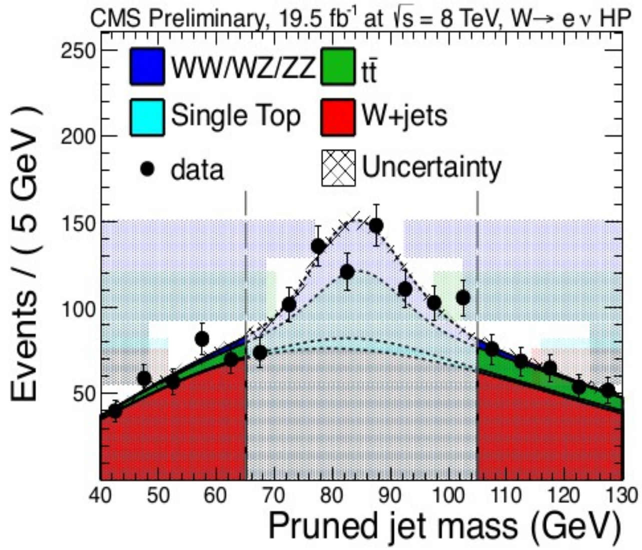
CMS (WW): Limit 70 – 3 fb (0.8 - 2.5) TeV

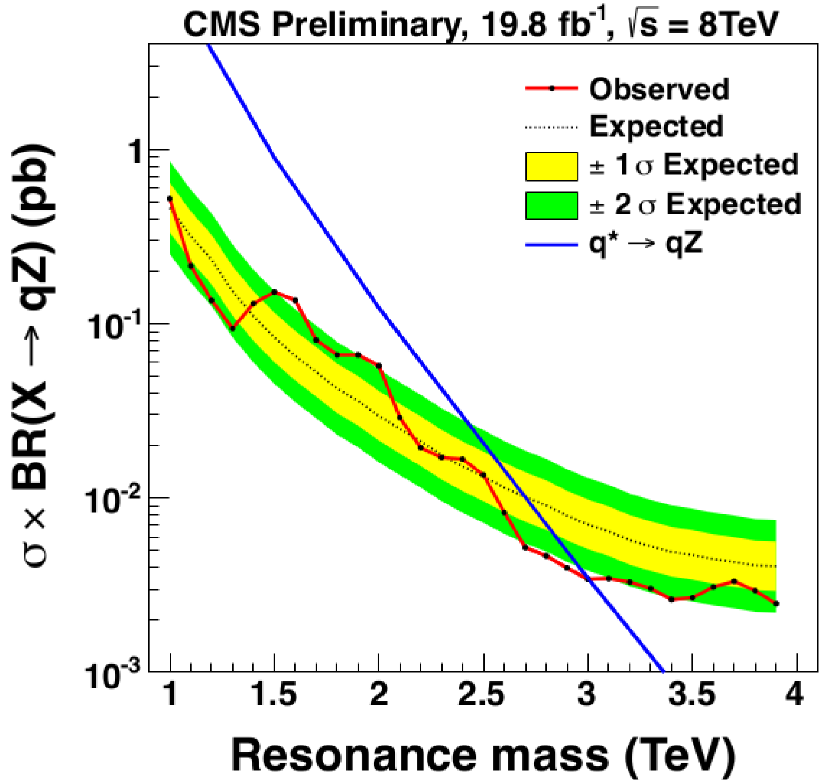


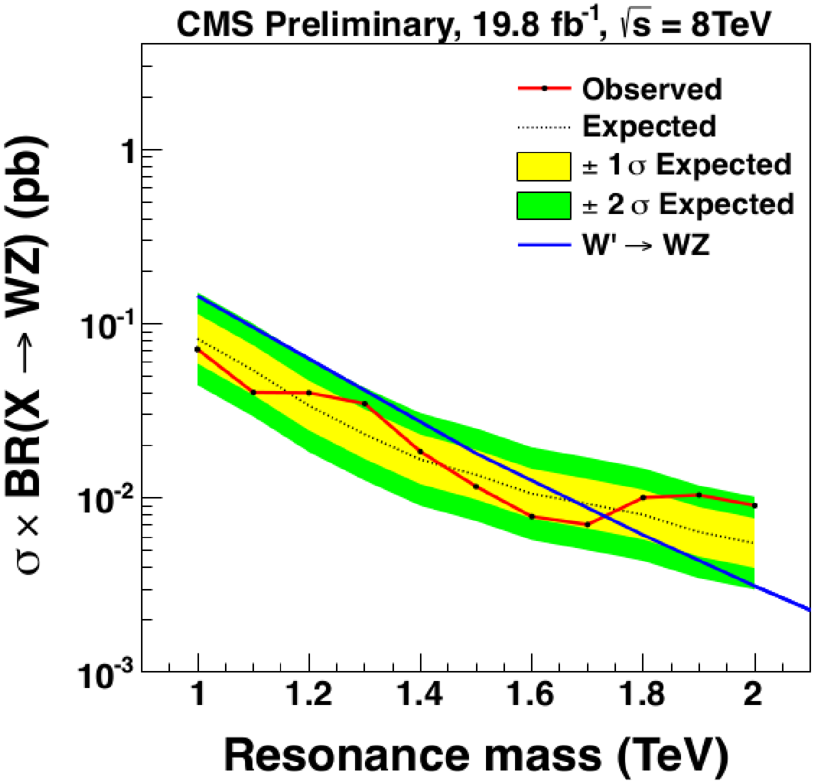


New Physics with resonances: di-bosons (WW/WZ/ZZ hadronic)

- $G_{RS} \longrightarrow WW/ZZ$ and $W' \longrightarrow WZ$ in dijets
  - Fully hadronic VV decays, $W \longrightarrow jj$ and/or $Z \longrightarrow jj$
  - Jets from W/Z typically boosted and merged into a single jet
  - QCD only significant background, suppressed by $|\eta_{jet1} - \eta_{jet2}| < 1.3$
- Each jet is required to pass the "W/Z-tagger"
  - pruned jet mass: $70 < M_{jet} < 100$ GeV/c^2
  - N-subjettiness (same as previous): $\tau_{21} < 0.5$ for high purity, and $0.5 < \tau_{21} < 0.75$ for low







New Physics with resonances: di-bosons (WW/WZ/ZZ hadronic)

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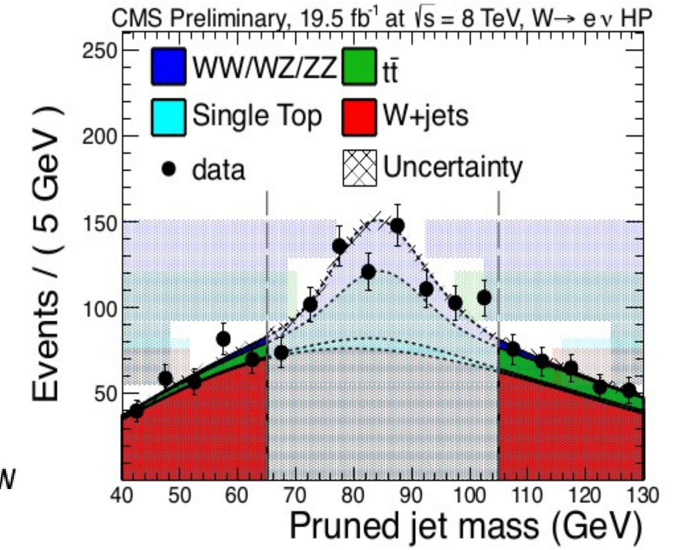
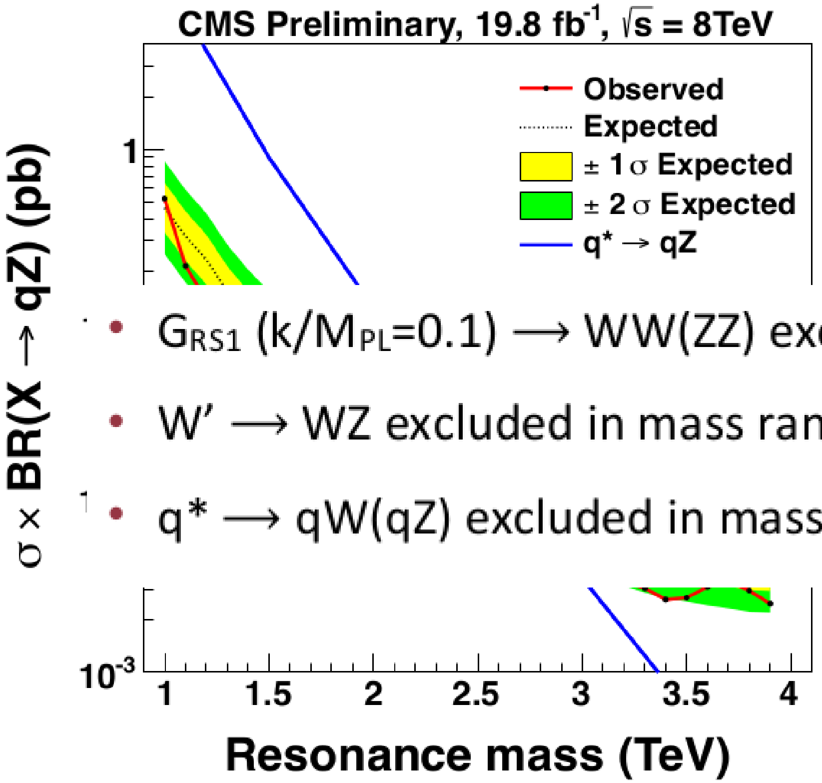
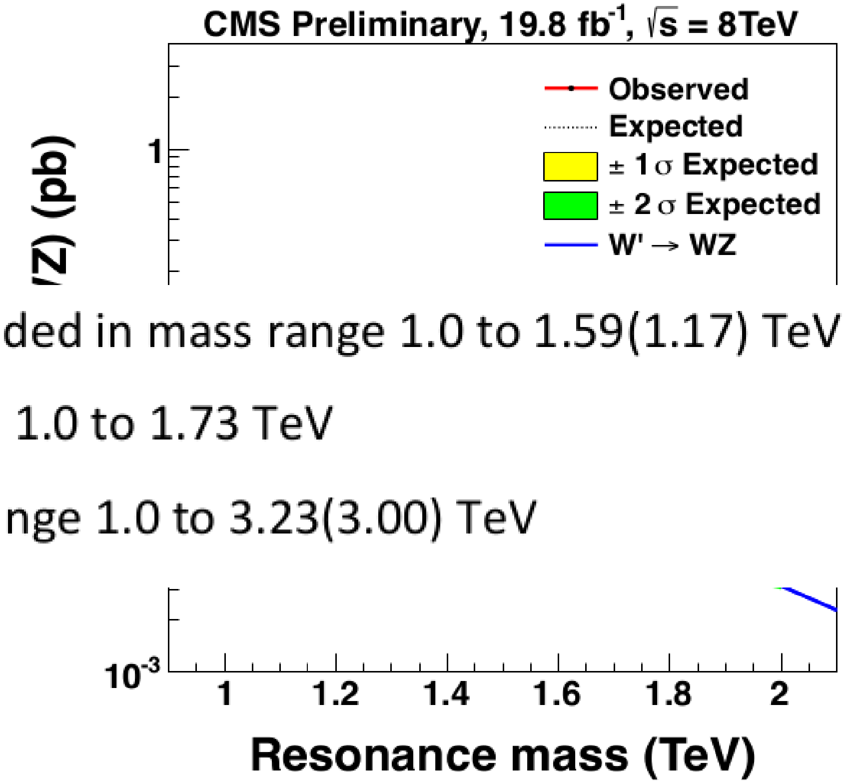






- G_{RS1} (k/M_{PL}=0.1) ⟶ WW(ZZ) excluded in mass range 1.0 to 1.59(1.17) TeV
- W’ ⟶ WZ excluded in mass range 1.0 to 1.73 TeV
- q* ⟶ qW(qZ) excluded in mass range 1.0 to 3.23(3.00) TeV

Top and Bottom like beyond SM signatures

VECTOR-LIKE T′⟶ tZ/tH/bW

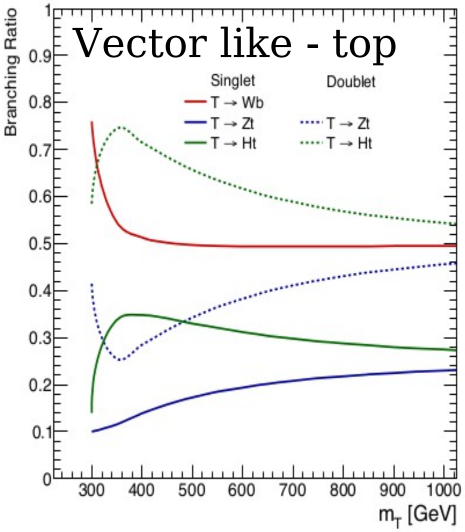
GIM mechanism is broken, tree level FCNC arises

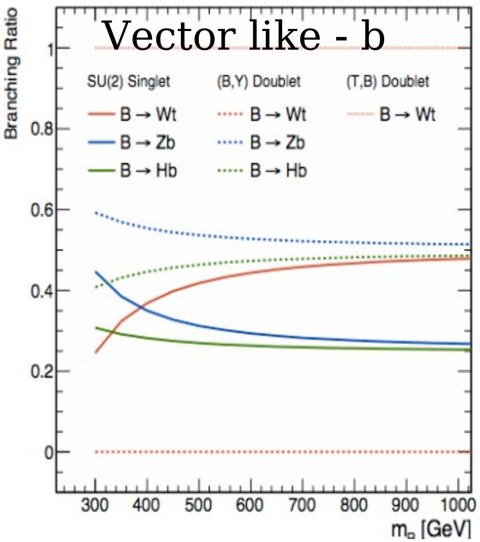
Vector like multiplets with new charge

Mixing primarily with 3rd gen. (but not required)

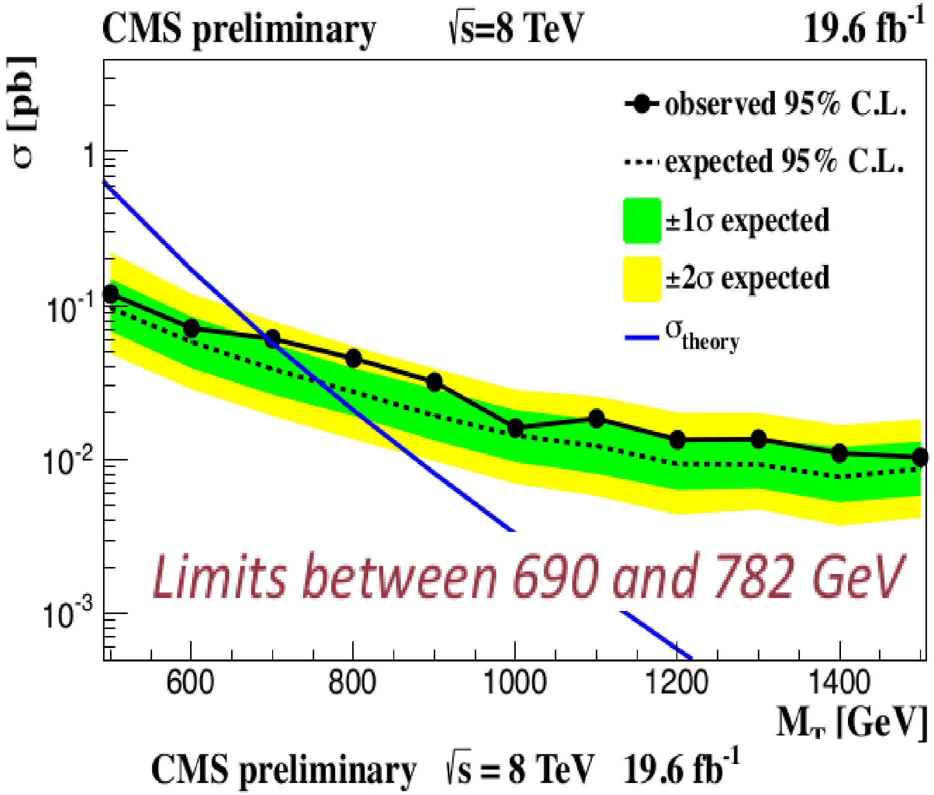
ATLAS: Ht+X, Wb+X, Zb/t+X, SS.

CMS: 1lep, OS, SS and multi-leptons (+jets)

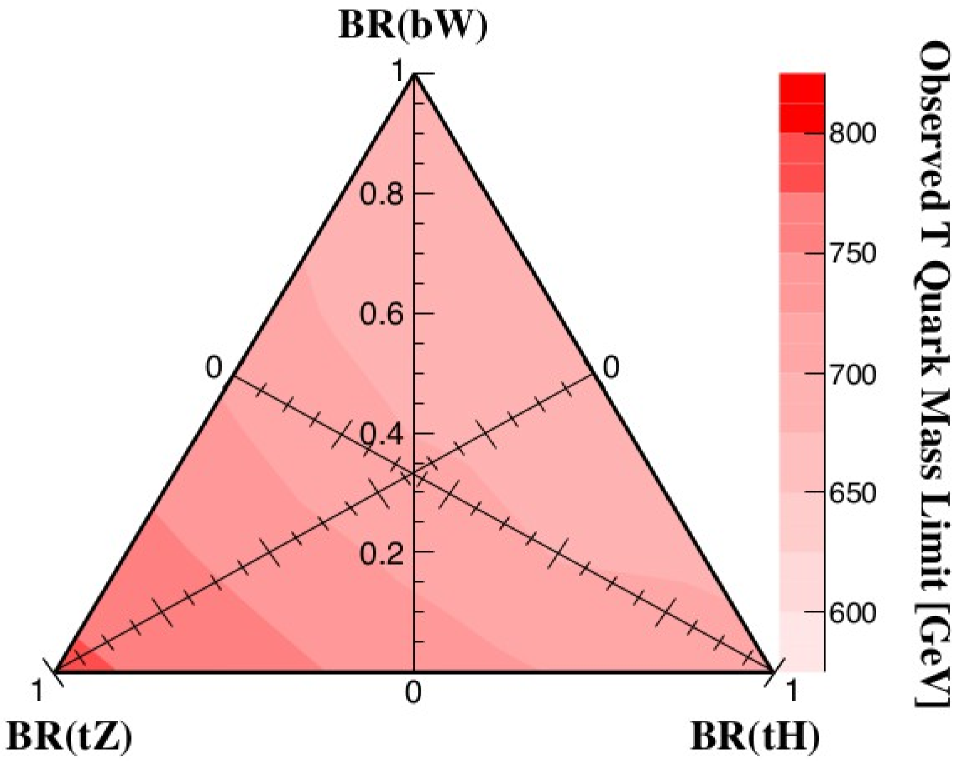




BR(T′→bW/tH/tZ)=50/25/25%

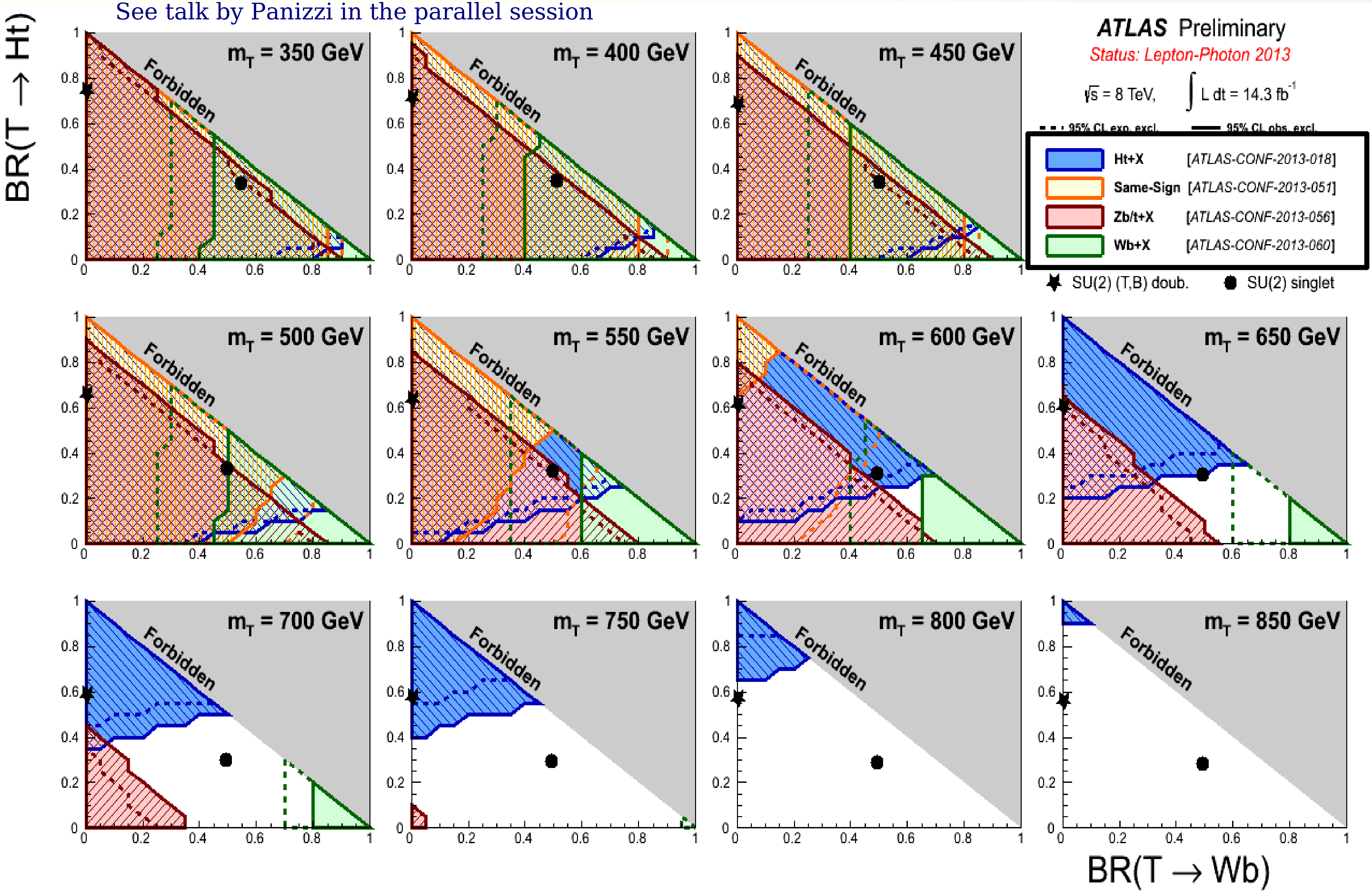


Limits between 690 and 782 GeV



Top and Bottom like beyond SM signatures

See talk by Panizzi in the parallel session



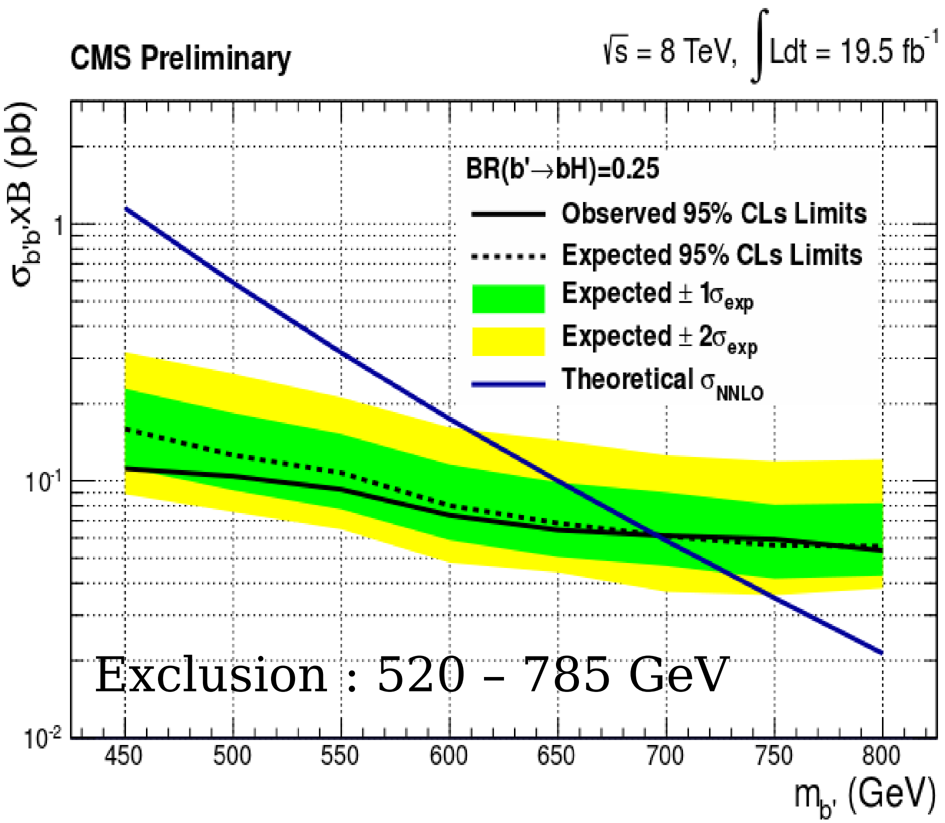
Top and Bottom like beyond SM signatures

Vector like b quarks → tW, bZ and bH final states

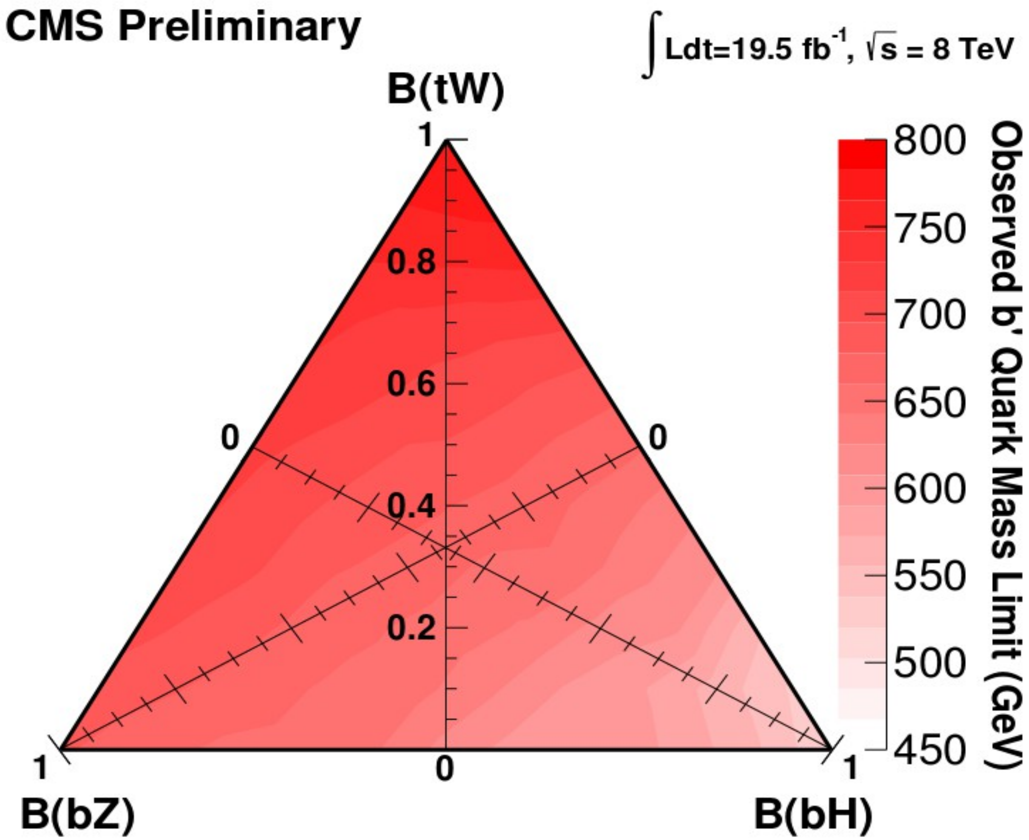
Multi-leptons (> 2) + jets study (bZbZ; tWtW; bHbH; bZtW; bZbH; and tWbH)

- SM Higgs with mass of 125 GeV is assumed
- Both on- and off-shell Z mass ranges are considered
- Main backgrounds: ttbar, dibosons and rare decays

b → tW (50%), bZ (25%), bH (25%)



Exclusion : 520 – 785 GeV



Top and Bottom like beyond SM signatures

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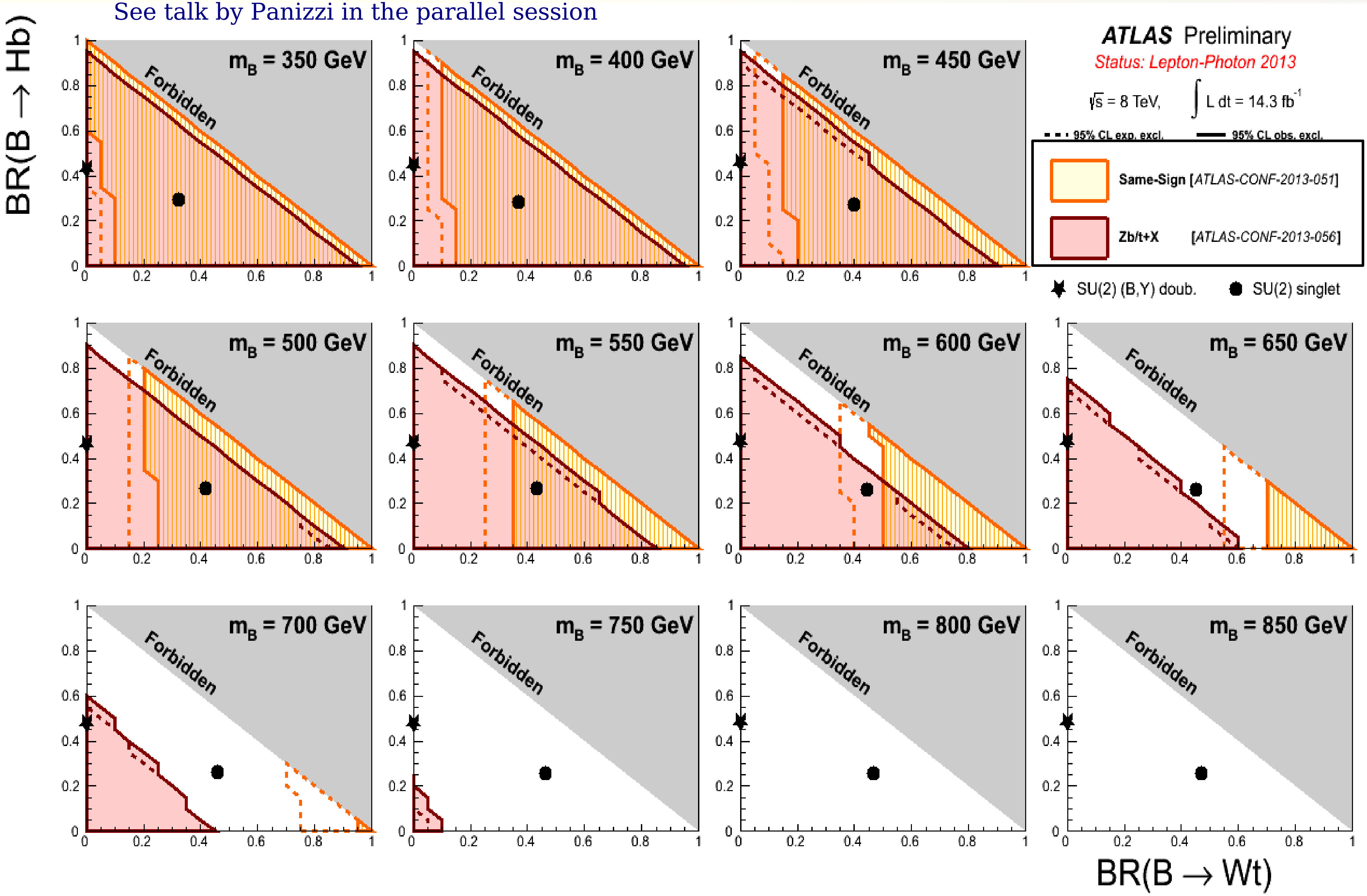
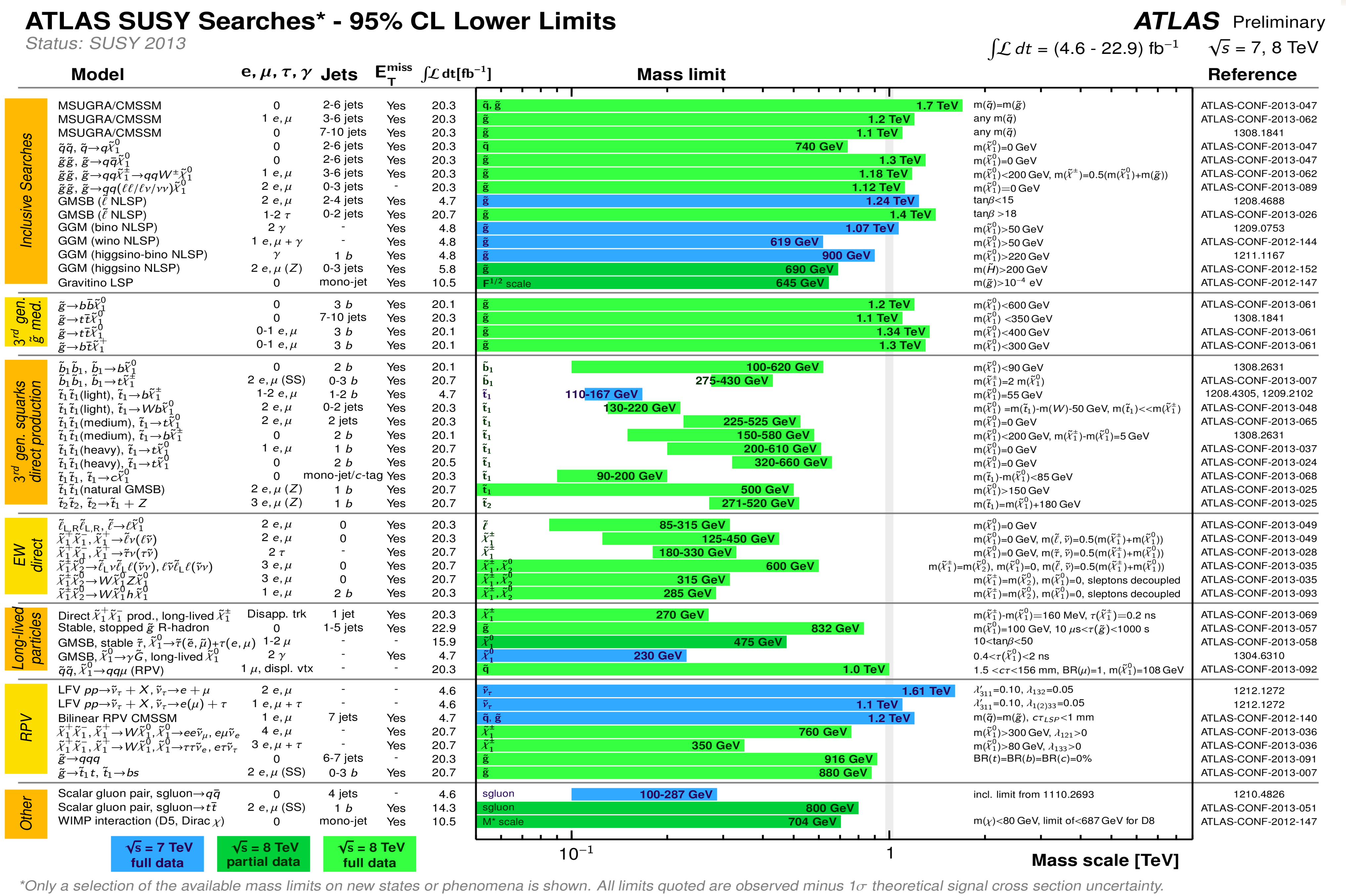


Summary of SUSY processes with mass scale excluded



ATLAS SUSY Searches* - 95% CL Lower Limits

Status: SUSY 2013

ATLAS Preliminary

$\int\mathcal{L}\,dt$ = (4.6 - 22.9) fb^{-1} $\sqrt{s}$ = 7, 8 TeV

	Model	e,μ,τ,γ	Jets	E_T^{miss}	$\int\mathcal{L}\,dt[\mathrm{fb}^{-1}]$	Mass limit			Reference
Inclusive Searches	MSUGRA/CMSSM	0	2-6 jets	Yes	20.3	$\tilde{q}, \tilde{g}$	1.7 TeV	m($\tilde{q}$)=m($\tilde{g}$)	ATLAS-CONF-2013-047
	MSUGRA/CMSSM	1 e,μ	3-6 jets	Yes	20.3	$\tilde{g}$	1.2 TeV	any m($\tilde{q}$)	ATLAS-CONF-2013-062
	MSUGRA/CMSSM	0	7-10 jets	Yes	20.3	$\tilde{g}$	1.1 TeV	any m($\tilde{q}$)	1308.1841
	$\tilde{q}\tilde{q}$, $\tilde{q}\to q\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{q}$	740 GeV	m($\tilde{\chi}_1^0$)=0 GeV	ATLAS-CONF-2013-047
	$\tilde{g}\tilde{g}$, $\tilde{g}\to q\bar{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{g}$	1.3 TeV	m($\tilde{\chi}_1^0$)=0 GeV	ATLAS-CONF-2013-047
	$\tilde{g}\tilde{g}$, $\tilde{g}\to qq\tilde{\chi}_1^\pm\to qqW^\pm\tilde{\chi}_1^0$	1 e,μ	3-6 jets	Yes	20.3	$\tilde{g}$	1.18 TeV	m($\tilde{\chi}_1^0$)<200 GeV, m($\tilde{\chi}^\pm$)=0.5(m($\tilde{\chi}_1^0$)+m($\tilde{g}$))	ATLAS-CONF-2013-062
	$\tilde{g}\tilde{g}$, $\tilde{g}\to qq(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}_1^0$	2 e,μ	0-3 jets	-	20.3	$\tilde{g}$	1.12 TeV	m($\tilde{\chi}_1^0$)=0 GeV	ATLAS-CONF-2013-089
	GMSB ($\tilde{\ell}$ NLSP)	2 e,μ	2-4 jets	Yes	4.7	$\tilde{g}$	1.24 TeV	tanβ<15	1208.4688
	GMSB ($\tilde{\ell}$ NLSP)	1-2 τ	0-2 jets	Yes	20.7	$\tilde{g}$	1.4 TeV	tanβ >18	ATLAS-CONF-2013-026
	GGM (bino NLSP)	2 γ	-	Yes	4.8	$\tilde{g}$	1.07 TeV	m($\tilde{\chi}_1^0$)>50 GeV	1209.0753
	GGM (wino NLSP)	1 $e,\mu+\gamma$	-	Yes	4.8	$\tilde{g}$	619 GeV	m($\tilde{\chi}_1^0$)>50 GeV	ATLAS-CONF-2012-144
	GGM (higgsino-bino NLSP)	γ	1 b	Yes	4.8	$\tilde{g}$	900 GeV	m($\tilde{\chi}_1^0$)>220 GeV	1211.1167
	GGM (higgsino NLSP)	2 e,μ (Z)	0-3 jets	Yes	5.8	$\tilde{g}$	690 GeV	m($\tilde{H}$)>200 GeV	ATLAS-CONF-2012-152
	Gravitino LSP	0	mono-jet	Yes	10.5	$F^{1/2}$ scale	645 GeV	m($\tilde{g}$)>10^{-4} eV	ATLAS-CONF-2012-147
3^{rd} gen. $\tilde{g}$ med.	$\tilde{g}\to b\bar{b}\tilde{\chi}_1^0$	0	3 b	Yes	20.1	$\tilde{g}$	1.2 TeV	m($\tilde{\chi}_1^0$)<600 GeV	ATLAS-CONF-2013-061
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0	7-10 jets	Yes	20.3	$\tilde{g}$	1.1 TeV	m($\tilde{\chi}_1^0$) <350 GeV	1308.1841
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0-1 e,μ	3 b	Yes	20.1	$\tilde{g}$	1.34 TeV	m($\tilde{\chi}_1^0$)<400 GeV	ATLAS-CONF-2013-061
	$\tilde{g}\to b\bar{t}\tilde{\chi}_1^+$	0-1 e,μ	3 b	Yes	20.1	$\tilde{g}$	1.3 TeV	m($\tilde{\chi}_1^0$)<300 GeV	ATLAS-CONF-2013-061
3^{rd} gen. squarks direct production	$\tilde{b}_1\tilde{b}_1$, $\tilde{b}_1\to b\tilde{\chi}_1^0$	0	2 b	Yes	20.1	$\tilde{b}_1$	100-620 GeV	m($\tilde{\chi}_1^0$)<90 GeV	1308.2631
	$\tilde{b}_1\tilde{b}_1$, $\tilde{b}_1\to t\tilde{\chi}_1^\pm$	2 e,μ (SS)	0-3 b	Yes	20.7	$\tilde{b}_1$	275-430 GeV	m($\tilde{\chi}_1^\pm$)=2 m($\tilde{\chi}_1^0$)	ATLAS-CONF-2013-007
	$\tilde{t}_1\tilde{t}_1$(light), $\tilde{t}_1\to b\tilde{\chi}_1^\pm$	1-2 e,μ	1-2 b	Yes	4.7	$\tilde{t}_1$	110-167 GeV	m($\tilde{\chi}_1^0$)=55 GeV	1208.4305, 1209.2102
	$\tilde{t}_1\tilde{t}_1$(light), $\tilde{t}_1\to Wb\tilde{\chi}_1^0$	2 e,μ	0-2 jets	Yes	20.3	$\tilde{t}_1$	130-220 GeV	m($\tilde{\chi}_1^0$) =m($\tilde{t}_1$)-m(W)-50 GeV, m($\tilde{t}_1$)<<m($\tilde{\chi}_1^\pm$)	ATLAS-CONF-2013-048
	$\tilde{t}_1\tilde{t}_1$(medium), $\tilde{t}_1\to t\tilde{\chi}_1^0$	2 e,μ	2 jets	Yes	20.3	$\tilde{t}_1$	225-525 GeV	m($\tilde{\chi}_1^0$)=0 GeV	ATLAS-CONF-2013-065
	$\tilde{t}_1\tilde{t}_1$(medium), $\tilde{t}_1\to b\tilde{\chi}_1^\pm$	0	2 b	Yes	20.1	$\tilde{t}_1$	150-580 GeV	m($\tilde{\chi}_1^0$)<200 GeV, m($\tilde{\chi}_1^\pm$)-m($\tilde{\chi}_1^0$)=5 GeV	1308.2631
	$\tilde{t}_1\tilde{t}_1$(heavy), $\tilde{t}_1\to t\tilde{\chi}_1^0$	1 e,μ	1 b	Yes	20.7	$\tilde{t}_1$	200-610 GeV	m($\tilde{\chi}_1^0$)=0 GeV	ATLAS-CONF-2013-037
	$\tilde{t}_1\tilde{t}_1$(heavy), $\tilde{t}_1\to t\tilde{\chi}_1^0$	0	2 b	Yes	20.5	$\tilde{t}_1$	320-660 GeV	m($\tilde{\chi}_1^0$)=0 GeV	ATLAS-CONF-2013-024
	$\tilde{t}_1\tilde{t}_1$, $\tilde{t}_1\to c\tilde{\chi}_1^0$	0	mono-jet/c-tag	Yes	20.3	$\tilde{t}_1$	90-200 GeV	m($\tilde{t}_1$)-m($\tilde{\chi}_1^0$)<85 GeV	ATLAS-CONF-2013-068
	$\tilde{t}_1\tilde{t}_1$(natural GMSB)	2 e,μ (Z)	1 b	Yes	20.7	$\tilde{t}_1$	500 GeV	m($\tilde{\chi}_1^0$)>150 GeV	ATLAS-CONF-2013-025
	$\tilde{t}_2\tilde{t}_2$, $\tilde{t}_2\to\tilde{t}_1+Z$	3 e,μ (Z)	1 b	Yes	20.7	$\tilde{t}_2$	271-520 GeV	m($\tilde{t}_1$)=m($\tilde{\chi}_1^0$)+180 GeV	ATLAS-CONF-2013-025
EW direct	$\tilde{\ell}_{L,R}\tilde{\ell}_{L,R}$, $\tilde{\ell}\to\ell\tilde{\chi}_1^0$	2 e,μ	0	Yes	20.3	$\tilde{\ell}$	85-315 GeV	m($\tilde{\chi}_1^0$)=0 GeV	ATLAS-CONF-2013-049
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\to\tilde{\ell}\nu(\ell\tilde{\nu})$	2 e,μ	0	Yes	20.3	$\tilde{\chi}_1^\pm$	125-450 GeV	m($\tilde{\chi}_1^0$)=0 GeV, m($\tilde{\ell}$, $\tilde{\nu}$)=0.5(m($\tilde{\chi}_1^\pm$)+m($\tilde{\chi}_1^0$))	ATLAS-CONF-2013-049
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\to\tilde{\tau}\nu(\tau\tilde{\nu})$	2 τ	-	Yes	20.7	$\tilde{\chi}_1^\pm$	180-330 GeV	m($\tilde{\chi}_1^0$)=0 GeV, m($\tilde{\tau}$, $\tilde{\nu}$)=0.5(m($\tilde{\chi}_1^\pm$)+m($\tilde{\chi}_1^0$))	ATLAS-CONF-2013-028
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to\tilde{\ell}_L\nu\tilde{\ell}_L\ell(\tilde{\nu}\nu)$, $\ell\tilde{\nu}\tilde{\ell}_L\ell(\tilde{\nu}\nu)$	3 e,μ	0	Yes	20.7	$\tilde{\chi}_1^\pm$, $\tilde{\chi}_2^0$	600 GeV	m($\tilde{\chi}_1^\pm$)=m($\tilde{\chi}_2^0$), m($\tilde{\chi}_1^0$)=0, m($\tilde{\ell}$, $\tilde{\nu}$)=0.5(m($\tilde{\chi}_1^\pm$)+m($\tilde{\chi}_1^0$))	ATLAS-CONF-2013-035
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to W\tilde{\chi}_1^0Z\tilde{\chi}_1^0$	3 e,μ	0	Yes	20.7	$\tilde{\chi}_1^\pm$, $\tilde{\chi}_2^0$	315 GeV	m($\tilde{\chi}_1^\pm$)=m($\tilde{\chi}_2^0$), m($\tilde{\chi}_1^0$)=0, sleptons decoupled	ATLAS-CONF-2013-035
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to W\tilde{\chi}_1^0h\tilde{\chi}_1^0$	1 e,μ	2 b	Yes	20.3	$\tilde{\chi}_1^\pm$, $\tilde{\chi}_2^0$	285 GeV	m($\tilde{\chi}_1^\pm$)=m($\tilde{\chi}_2^0$), m($\tilde{\chi}_1^0$)=0, sleptons decoupled	ATLAS-CONF-2013-093
Long-lived particles	Direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^\pm$	Disapp. trk	1 jet	Yes	20.3	$\tilde{\chi}_1^\pm$	270 GeV	m($\tilde{\chi}_1^\pm$)-m($\tilde{\chi}_1^0$)=160 MeV, τ($\tilde{\chi}_1^\pm$)=0.2 ns	ATLAS-CONF-2013-069
	Stable, stopped $\tilde{g}$ R-hadron	0	1-5 jets	Yes	22.9	$\tilde{g}$	832 GeV	m($\tilde{\chi}_1^0$)=100 GeV, 10 μs<τ($\tilde{g}$)<1000 s	ATLAS-CONF-2013-057
	GMSB, stable $\tilde{\tau}$, $\tilde{\chi}_1^0\to\tilde{\tau}(\tilde{e},\tilde{\mu})+\tau(e,\mu)$	1-2 μ	-	-	15.9	$\tilde{\chi}_1^0$	475 GeV	10<tanβ<50	ATLAS-CONF-2013-058
	GMSB, $\tilde{\chi}_1^0\to\gamma\tilde{G}$, long-lived $\tilde{\chi}_1^0$	2 γ	-	Yes	4.7	$\tilde{\chi}_1^0$	230 GeV	0.4<τ($\tilde{\chi}_1^0$)<2 ns	1304.6310
	$\tilde{q}\tilde{q}$, $\tilde{\chi}_1^0\to qq\mu$ (RPV)	1 μ, displ. vtx	-	-	20.3	$\tilde{q}$	1.0 TeV	1.5 <$c\tau$<156 mm, BR(μ)=1, m($\tilde{\chi}_1^0$)=108 GeV	ATLAS-CONF-2013-092
RPV	LFV $pp\to\tilde{\nu}_\tau+X$, $\tilde{\nu}_\tau\to e+\mu$	2 e,μ	-	-	4.6	$\tilde{\nu}_\tau$	1.61 TeV	λ'_{311}=0.10, λ_{132}=0.05	1212.1272
	LFV $pp\to\tilde{\nu}_\tau+X$, $\tilde{\nu}_\tau\to e(\mu)+\tau$	1 $e,\mu+\tau$	-	-	4.6	$\tilde{\nu}_\tau$	1.1 TeV	λ'_{311}=0.10, $\lambda_{1(2)33}$=0.05	1212.1272
	Bilinear RPV CMSSM	1 e,μ	7 jets	Yes	4.7	$\tilde{q}$, $\tilde{g}$	1.2 TeV	m($\tilde{q}$)=m($\tilde{g}$), $c\tau_{LSP}$<1 mm	ATLAS-CONF-2012-140
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\to W\tilde{\chi}_1^0$, $\tilde{\chi}_1^0\to ee\tilde{\nu}_\mu$, $e\mu\tilde{\nu}_e$	4 e,μ	-	Yes	20.7	$\tilde{\chi}_1^\pm$	760 GeV	m($\tilde{\chi}_1^0$)>300 GeV, λ_{121}>0	ATLAS-CONF-2013-036
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\to W\tilde{\chi}_1^0$, $\tilde{\chi}_1^0\to\tau\tau\tilde{\nu}_e$, $e\tau\tilde{\nu}_\tau$	3 $e,\mu+\tau$	-	Yes	20.7	$\tilde{\chi}_1^\pm$	350 GeV	m($\tilde{\chi}_1^0$)>80 GeV, λ_{133}>0	ATLAS-CONF-2013-036
	$\tilde{g}\to qqq$	0	6-7 jets	-	20.3	$\tilde{g}$	916 GeV	BR(t)=BR(b)=BR(c)=0%	ATLAS-CONF-2013-091
	$\tilde{g}\to\tilde{t}_1t$, $\tilde{t}_1\to bs$	2 e,μ (SS)	0-3 b	Yes	20.7	$\tilde{g}$	880 GeV		ATLAS-CONF-2013-007
Other	Scalar gluon pair, sgluon$\to q\bar{q}$	0	4 jets	-	4.6	sgluon	100-287 GeV	incl. limit from 1110.2693	1210.4826
	Scalar gluon pair, sgluon$\to t\bar{t}$	2 e,μ (SS)	1 b	Yes	14.3	sgluon	800 GeV		ATLAS-CONF-2013-051
	WIMP interaction (D5, Dirac χ)	0	mono-jet	Yes	10.5	M* scale	704 GeV	m(χ)<80 GeV, limit of<687 GeV for D8	ATLAS-CONF-2012-147

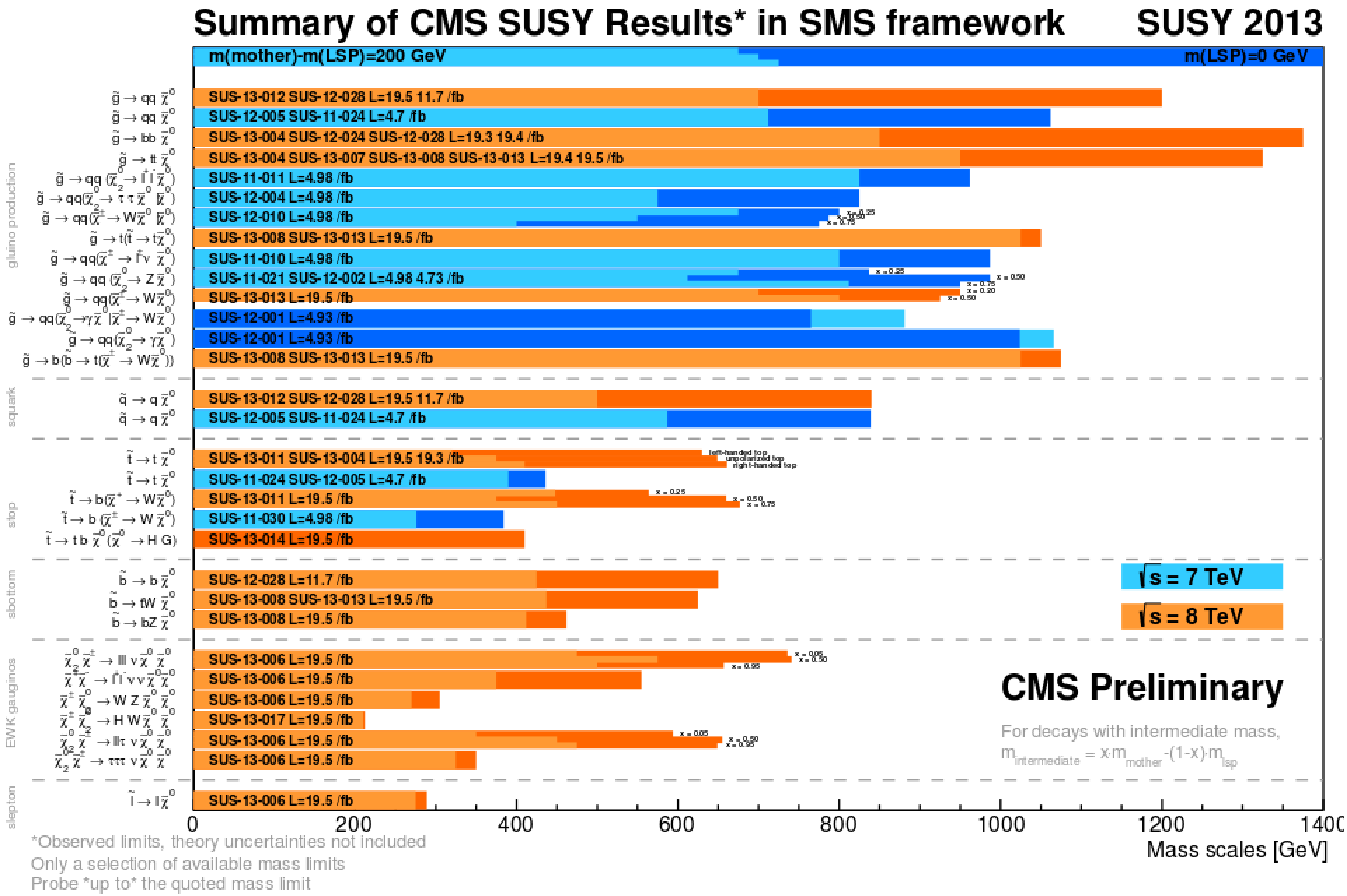
🟦 $\sqrt{s}$ = 7 TeV full data

🟩 $\sqrt{s}$ = 8 TeV partial data

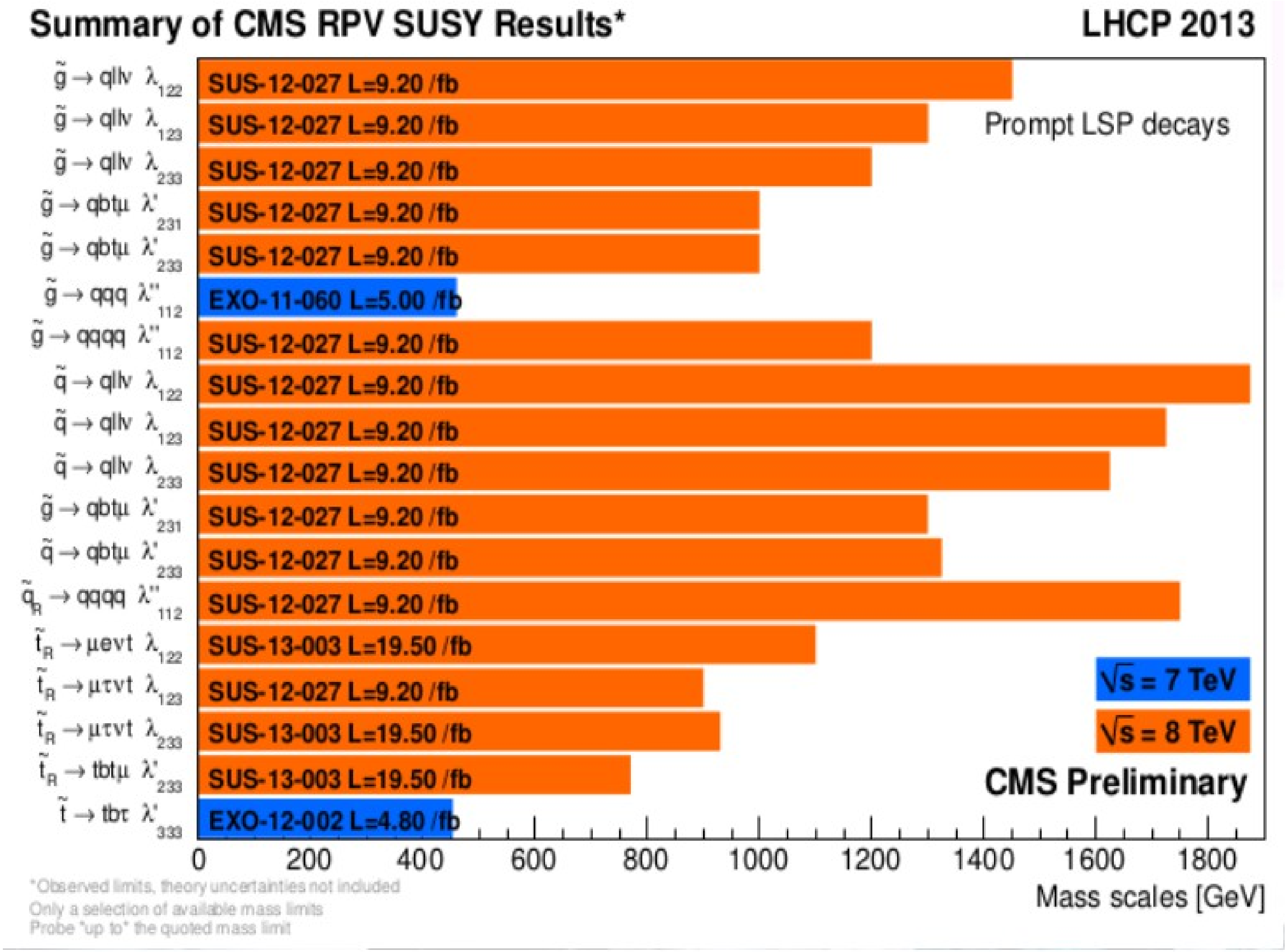
🟩 $\sqrt{s}$ = 8 TeV full data

**Only a selection of the available mass limits on new states or phenomena is shown. All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.*

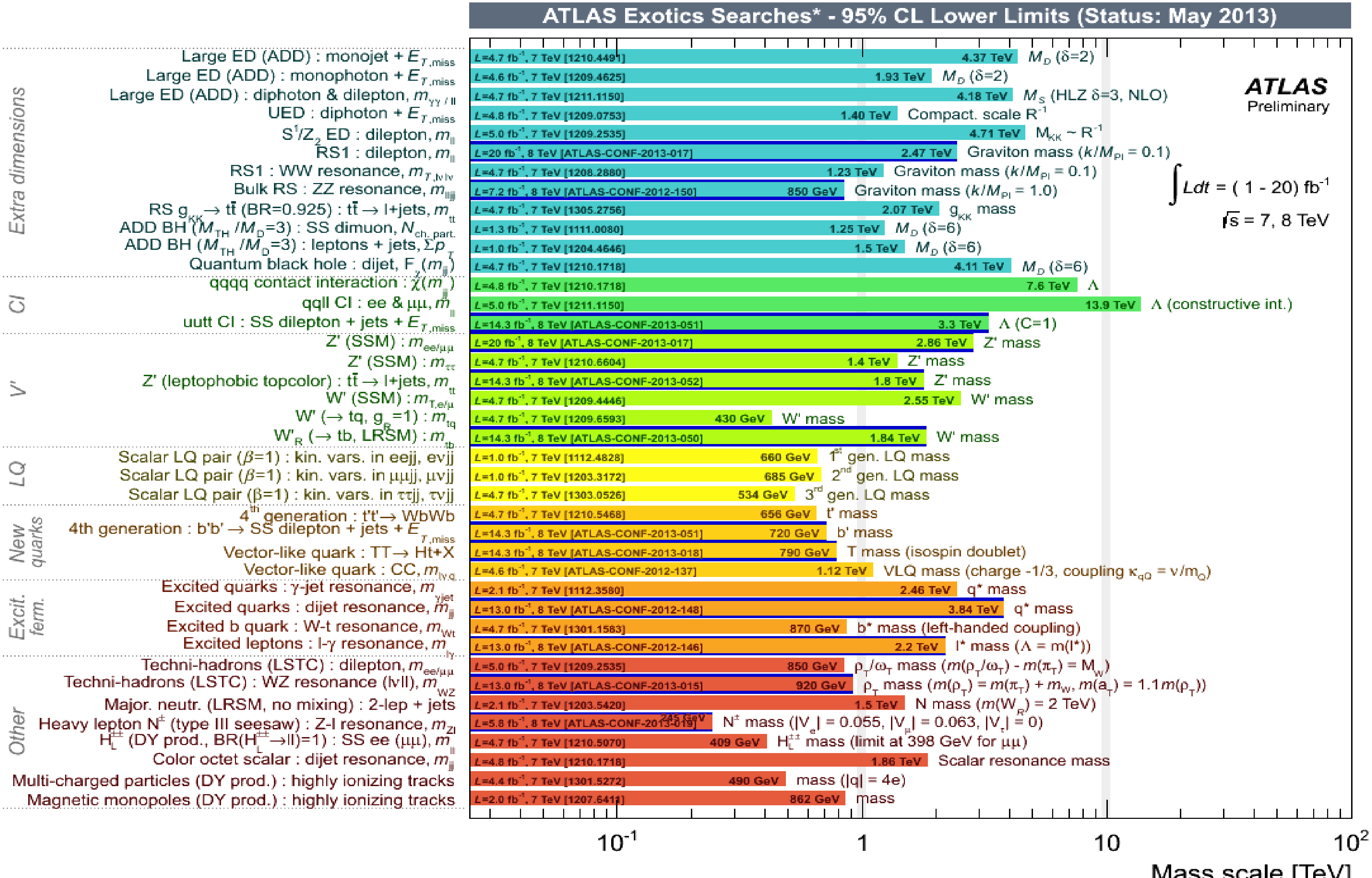
Summary of SUSY processes with mass scale excluded



RPV Studies and excluded mass ranges

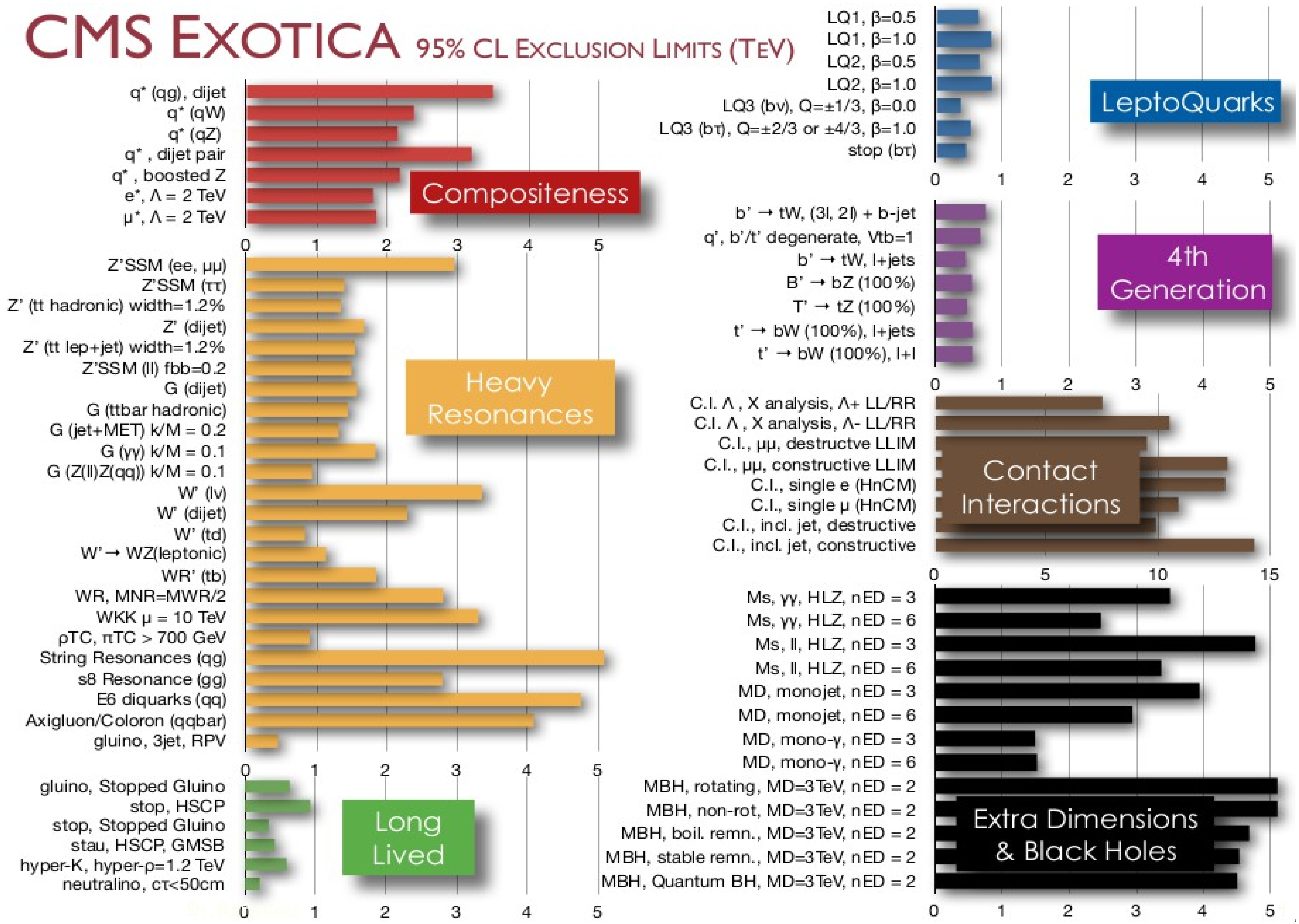


Summary of exotic processes with mass scale probed



*Only a selection of the available mass limits on new states or phenomena shown

Summary of exotic processes with mass scale probed



Summary and Conclusion

BSM results from ATLAS and CMS show the breath of physics analyses

First 35 pb^{-1} (2010)

- Observed all SM particles
- Validated data-driven methods for new physics searches
- First SUSY/EXO searches → Significant coverage beyond Tevatron!

Up to 5 fb^{-1} using 7 TeV (2011)

- Excluded “SUSY with/using MET” and EXO up to a ~TeV mass scale

20 fb^{-1} at 8 TeV (2012)

- Discovery of Higgs boson (hence understanding Natural SUSY took precedence)
- No new physics in the direct stop/sbottom sector
- “Partially” sensitive to pure SUSY electroweak sector
- Several RPV searches are ongoing or getting completed.
- Large number of BSM searches result in vast number of topologies/theoretical scenarios.

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults

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

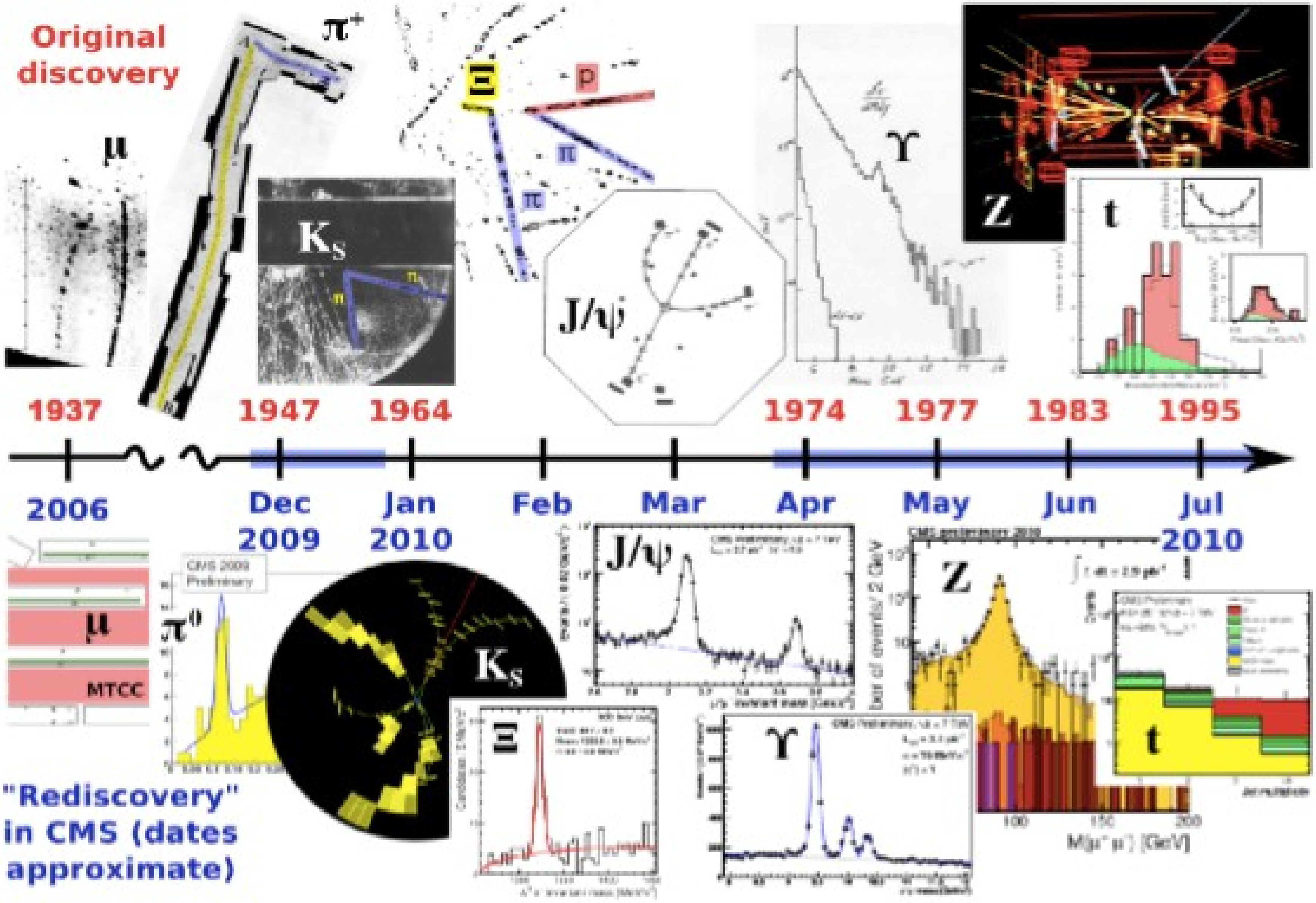
https://twiki.cern.ch/twiki/bin/view/AtlasPublic/ExoticsPublicResults

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

13/14 TeV LHC will enter to a new mass scale territory!

Backup slides

Re-Discovery of the Standard Model



Naturalness in Supersymmetry

arXiv:1203.5539

$$\frac{1}{2}M_Z^2 = \boxed{\frac{(m_{H_d}^2 + \Sigma_d) - (m_{H_u}^2 + \Sigma_u)\tan^2\beta}{(\tan^2\beta - 1)}} - \mu^2 \, .$$

“Tuned” due to the Higgs mass - Colored sector

SUSY weak sector

- Individual terms on right side should be comparable in magnitude

  - **“Large” cancellations are “unnatural”**

- |μ| can be a measure of naturalness

Stop mass

Σ - arises from radiative correction → $\Sigma_u \sim \frac{3 f_t^2}{16\pi^2} \times m_{\tilde{t}_i}^2 \left(\ln(m_{\tilde{t}_i^2}/Q^2) - 1 \right)$

For, $\Sigma \approx 1/2 M_Z^2 \to m_{\tilde{t}_i} \approx 500$ GeV

Assuming μ ~ 150 (200) GeV → Mass(stop) ~ 1 (1.5) TeV

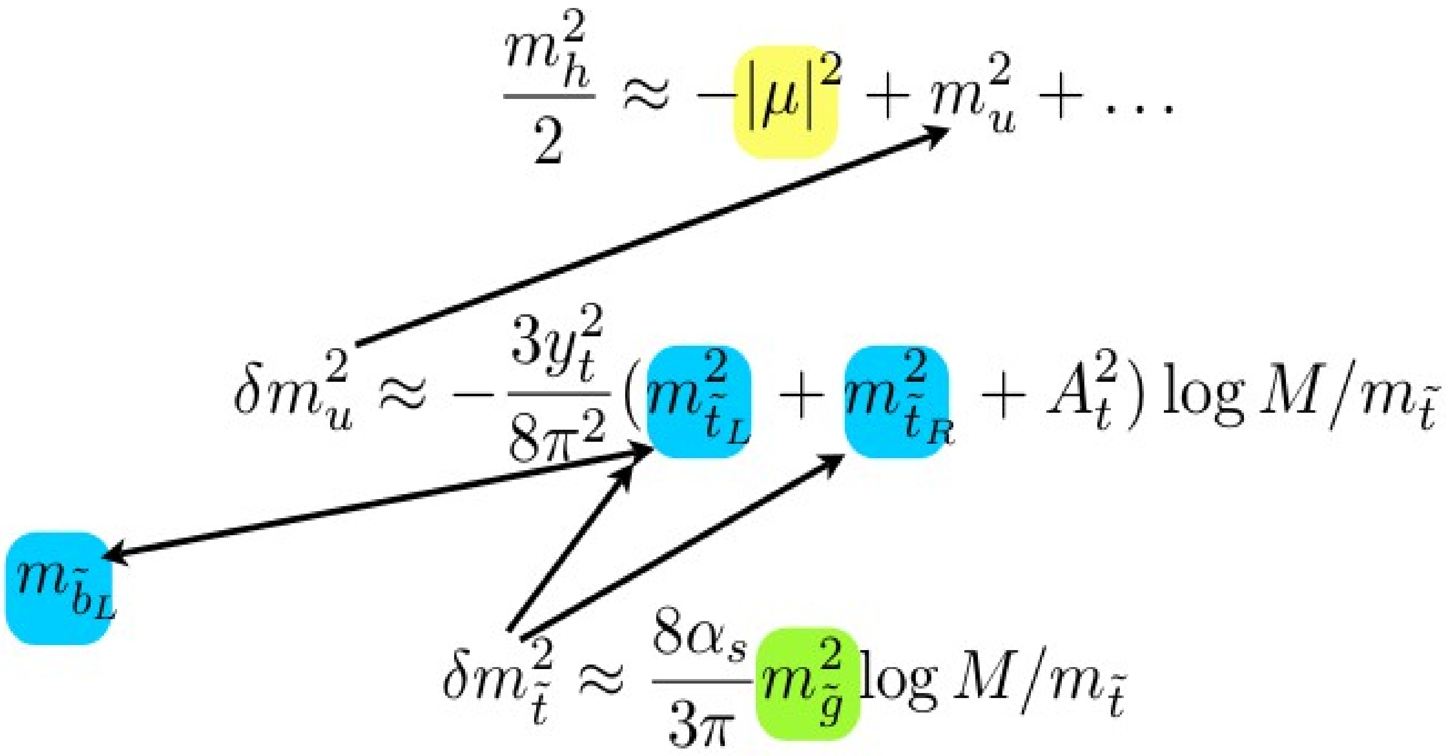
Other heavier Higgs can easily be in the TeV mass range and is perfectly natural:

$$m_A^2 \simeq 2\mu^2 + m_{H_u}^2 + m_{H_d}^2 + \Sigma_u + \Sigma_d$$

Naturalness in Supersymmetry

R. Barbieri

The key equations:



$$\frac{m_h^2}{2} \approx -|\mu|^2 + m_u^2 + \dots$$

$$\delta m_u^2 \approx -\frac{3y_t^2}{8\pi^2}\left(m_{\tilde{t}_L}^2 + m_{\tilde{t}_R}^2 + A_t^2\right)\log M/m_{\tilde{t}}$$

$m_{\tilde{b}_L}$

$$\delta m_{\tilde{t}}^2 \approx \frac{8\alpha_s}{3\pi} m_{\tilde{g}}^2 \log M/m_{\tilde{t}}$$

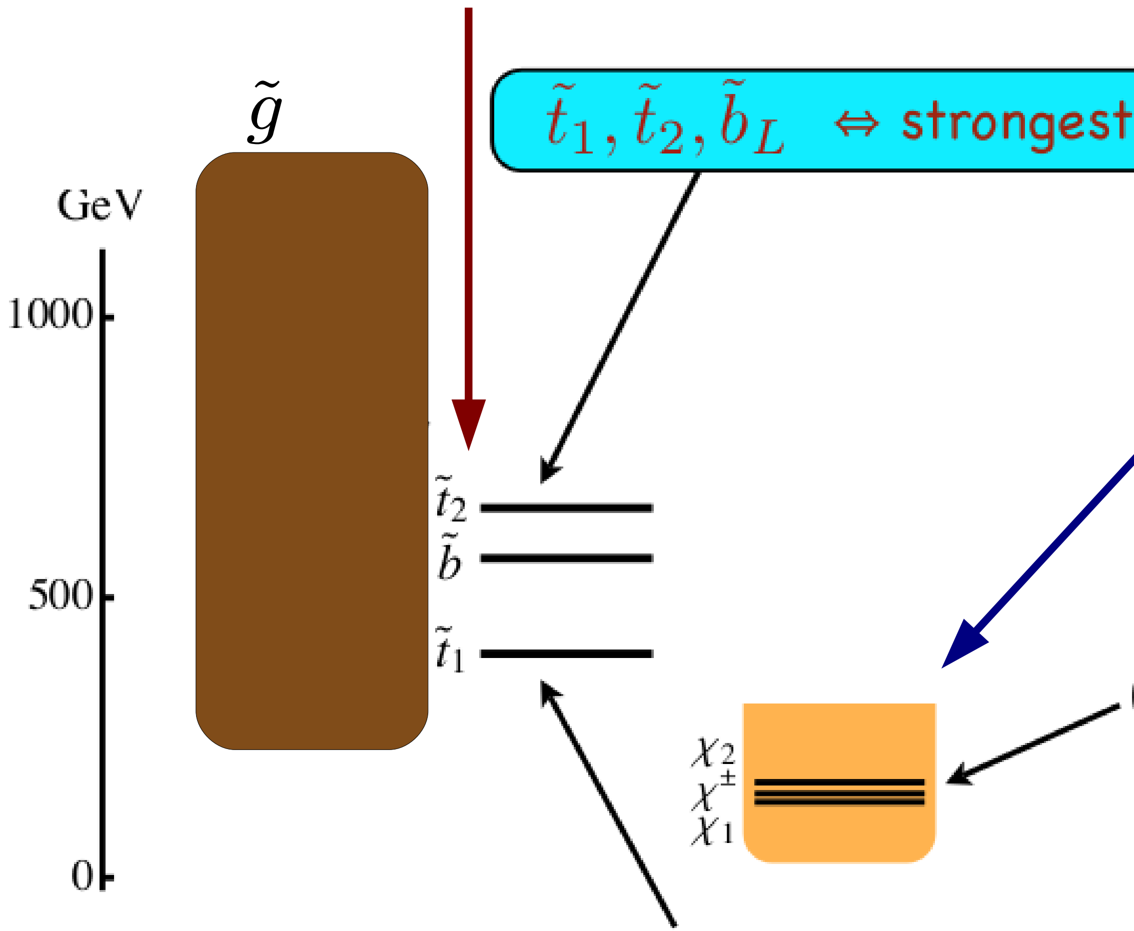
to be made more precise in any given SB-mediation scheme

see Dimopoulos, Giudice for SUGRA-mediation

Naturalness in Supersymmetry

$$\frac{1}{2}M_Z^2 = \boxed{\frac{(m_{H_d}^2 + \Sigma_d) - (m_{H_u}^2 + \Sigma_u)\tan^2\beta}{(\tan^2\beta - 1)}} - \mu^2 \,.$$

$\tilde{t}_1, \tilde{t}_2, \tilde{b}_L$ ⇔ strongest coupling to the Higgs system



(μ ⇔ M_Z at tree level)

$\tilde{q}_1, \tilde{q}_2, \tilde{b}_R$ heavy enough (≥ $\tilde{g}$)to be ~ irrelevant