SUSY Searches at LHC

IHEP'13, June 26-28, 2013

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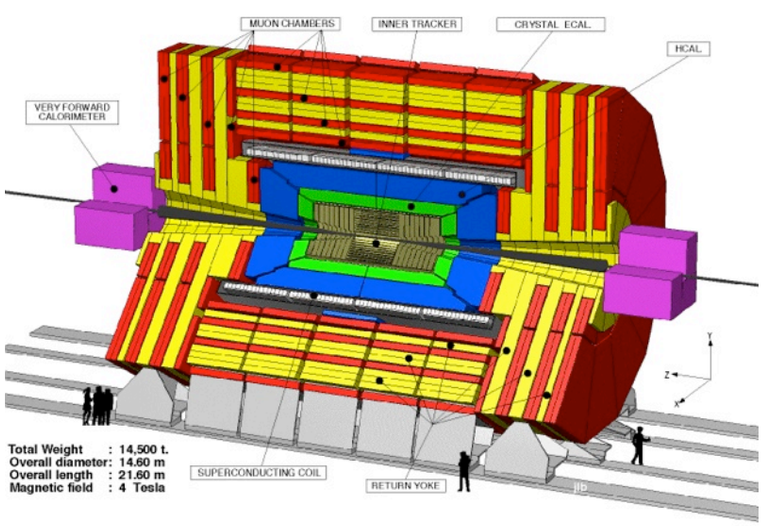
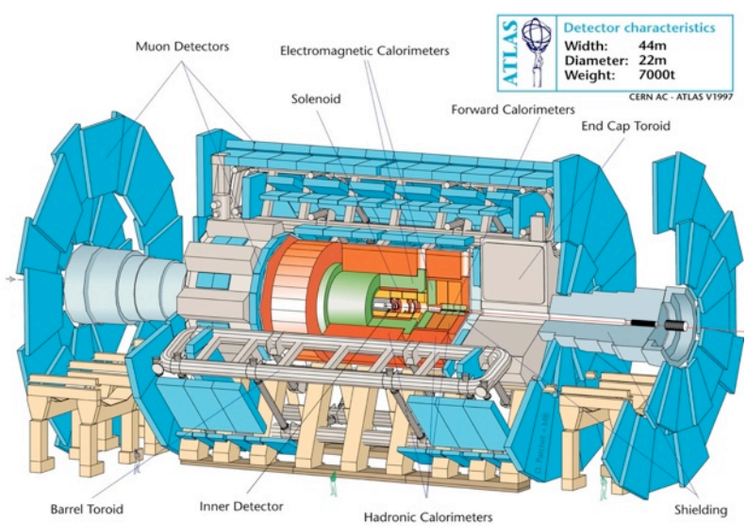
for the **CMS** & **ATLAS** Collaborations

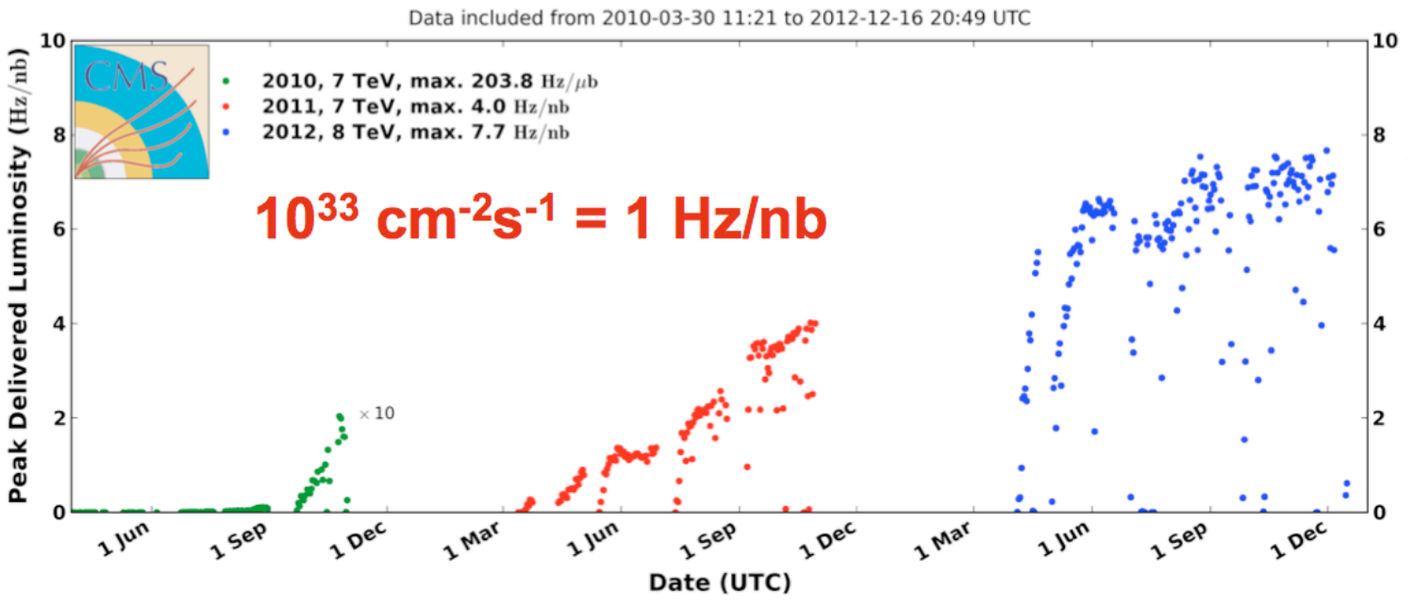


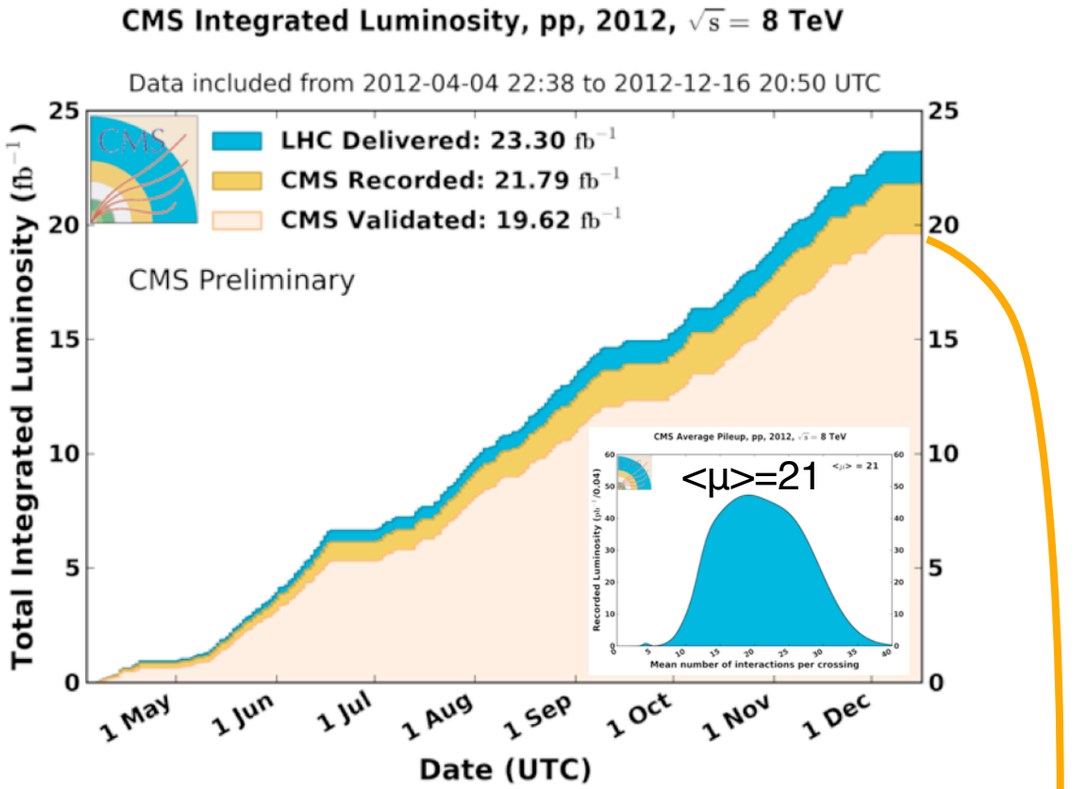


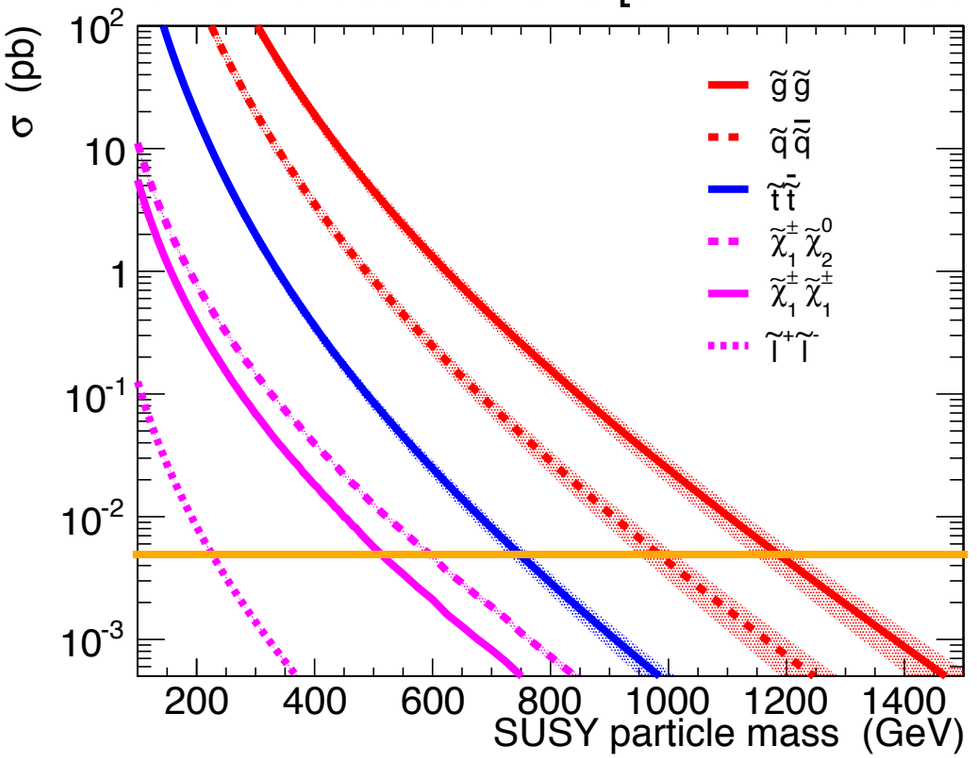
Outlook

- Physics data
- Search strategy
- Physics interpretations
  - mSUGRA
  - simplified models
  - Bayesian
- “Natural SUSY” searches
  - stop
  - ewkino
  - gluino
- Phenomenological MSSM
- Model independent approach
- Summary

Collected LHC Data







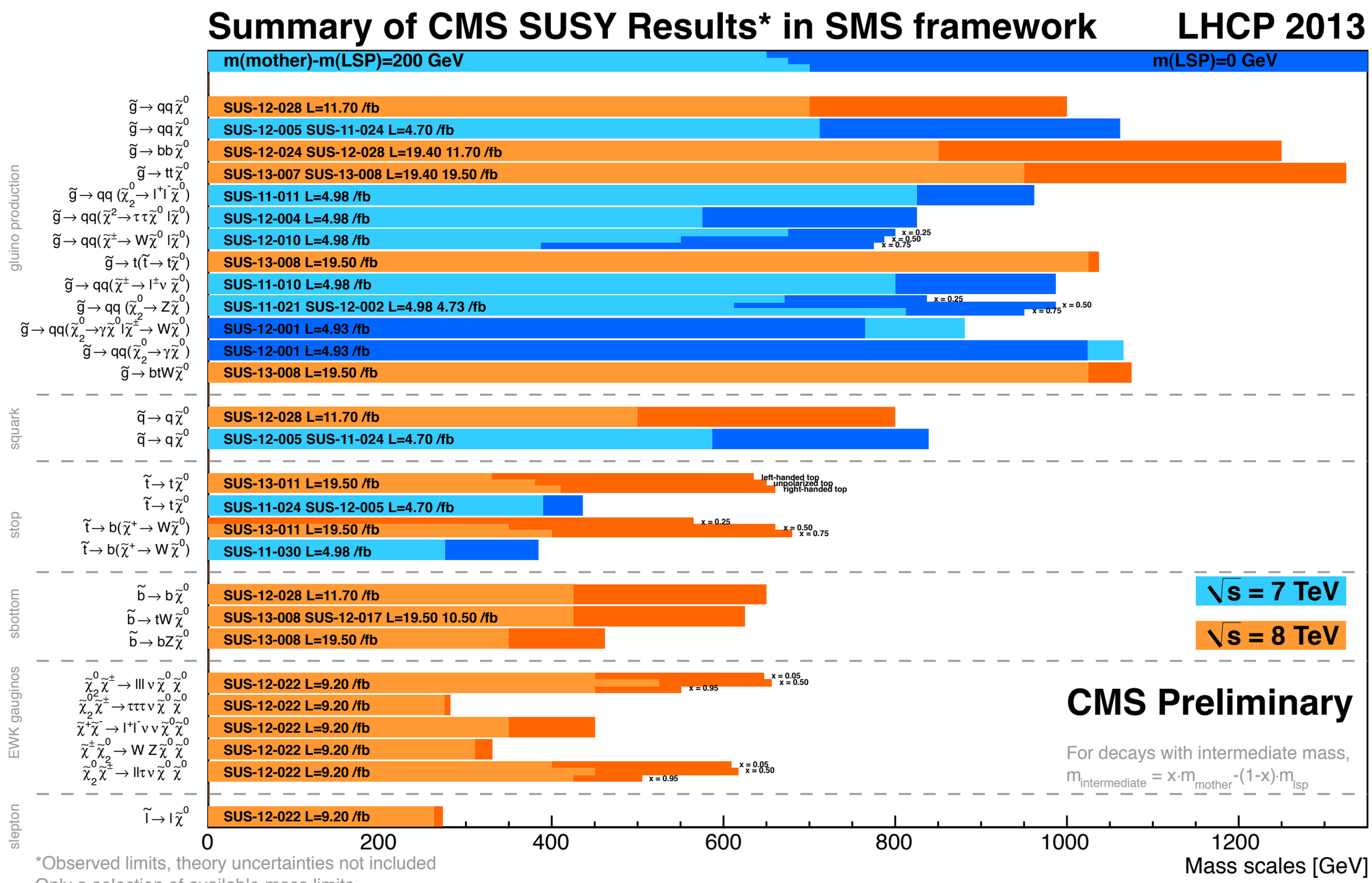
- CMS and ATLAS would have produced ~100 events for:
  - 1.2 TeV gluinos
  - 700 GeV stops
  - 600 GeV charginos/neutralinos a.k.a. ewkinos

General Search Strategy

- Reconstruct pronounced signatures in the event
  - missing transverse energy, a.k.a. MET
    - primary signature for RPC SUSY searches
  - high-p_T leptons: e, μ, $\tau_{leptonic}$, $\tau_{hadronic}$
  - high-E_T photons
  - b-jets a.k.a. B-tag
  - high-p_t jets
  - total event energy H_T
  - combined kinematical variables
    - α_T, M_T, M_{CT}, ...
- Combine several signatures: determine a region in phase space
  - with significant expected contribution from BSM events
  - with low and/or well determined contribution from SM events
    - simulation driven background estimates
    - data driven background estimates

CMS SUSY Summary

No significant deviation from SM expectations → constrain SUSY model parameters



*Observed limits, theory uncertainties not included
Only a selection of available mass limits
Probe *up to* the quoted mass limit

ATLAS SUSY Summary

ATLAS SUSY Searches* - 95% CL Lower Limits

Status: LP 2013

ATLAS Preliminary

$\int \mathcal{L}\, dt$ = (4.4 - 22.9) fb^{-1} $\sqrt{s}$ = 7, 8 TeV

	Model	e, μ, τ, γ	Jets	E_T^{miss}	$\int \mathcal{L}\, dt$[fb^{-1}]	Mass limit		Reference
Inclusive Searches	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($\tilde{q}$)	ATLAS-CONF-2013-054
	$\tilde{q}\tilde{q}, \tilde{q}\to q\tilde{\chi}_1^0$	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
	$\tilde{g}\tilde{g}\to qqqq\ell\ell(\ell\ell)\tilde{\chi}_1^0\tilde{\chi}_1^0$	2 e, μ (SS)	3 jets	Yes	20.7	$\tilde{g}$ 1.1 TeV	m($\tilde{\chi}_1^0$)<650 GeV	ATLAS-CONF-2013-007
	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	0	Yes	4.8	$\tilde{g}$ 1.07 TeV	m($\tilde{\chi}_1^0$)>50 GeV	1209.0753
	GGM (wino NLSP)	1 $e, \mu + \gamma$	0	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
3rd 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	$\tilde{g}$ 1.14 TeV	m($\tilde{\chi}_1^0$) <200 GeV	ATLAS-CONF-2013-054
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	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
3rd 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	$\tilde{b}_1$ 100-630 GeV	m($\tilde{\chi}_1^0$)<100 GeV	ATLAS-CONF-2013-053
	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\to t\tilde{\chi}_1^\pm$	2 e, μ (SS)	0-3 b	Yes	20.7	$\tilde{b}_1$ 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	$\tilde{t}_1$ 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	$\tilde{t}_1$ 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), $\tilde{t}_1\to b\tilde{\chi}_1^\pm$	2 e, μ	0-2 jets	Yes	20.3	$\tilde{t}_1$ 150-440 GeV	m($\tilde{\chi}_1^0$)=0 GeV, m($\tilde{t}_1$)-m($\tilde{\chi}_1^\pm$)=10 GeV	ATLAS-CONF-2013-048
	$\tilde{t}_1\tilde{t}_1$(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	ATLAS-CONF-2013-053
	$\tilde{t}_1\tilde{t}_1$(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
	$\tilde{t}_1\tilde{t}_1$(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	$\tilde{t}_2$ 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	0	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($\tilde{\chi}_1^0$)=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
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to W^*\tilde{\chi}_1^0 Z^*\tilde{\chi}_1^0$	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
Long-lived particles	Direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^\pm$	0	1 jet	Yes	4.7	$\tilde{\chi}_1^\pm$ 220 GeV	1<$\tau(\tilde{\chi}_1^\pm)$<10 ns	1210.2852
	Stable, stopped $\tilde{g}$ R-hadron	0	1-5 jets	Yes	22.9	$\tilde{g}$ 857 GeV	m($\tilde{\chi}_1^0$)=100 GeV, 10 μs<$\tau(\tilde{g})$<1000 s	ATLAS-CONF-2013-057
	GMSB, stable $\tilde{\tau}$	1-2 μ	0	-	15.9	$\tilde{\tau}$ 385 GeV	5<tanβ<50	ATLAS-CONF-2013-058
	Direct $\tilde{\tau}\tilde{\tau}$ prod., stable $\tilde{\tau}$ or $\tilde{\ell}$	1-2 μ	0	-	15.9	$\tilde{\tau}$ 395 GeV	m($\tilde{\tau}$)=m($\tilde{\ell}$)	ATLAS-CONF-2013-058
	GMSB, $\tilde{\chi}_1^0\to\gamma\tilde{g}$, long-lived $\tilde{\chi}_1^0$	2 γ	0	Yes	4.7	$\tilde{\chi}_1^0$ 230 GeV	0.4<$\tau(\tilde{\chi}_1^0)$<2 ns	1304.6310
	$\tilde{\chi}_1^0\to qq\mu$ (RPV)	1 μ	0	Yes	4.4	$\tilde{q}$ 700 GeV	1 mm<$c\tau$<1 m, $\tilde{g}$ decoupled	1210.7451
RPV	LFV $pp\to\tilde{\nu}_\tau + X, \tilde{\nu}_\tau\to e + \mu$	2 e, μ	0	-	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 $e, \mu + \tau$	0	-	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	0	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 $e, \mu + \tau$	0	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 jets	-	4.6	$\tilde{g}$ 666 GeV		1210.4813
	$\tilde{g}\to\tilde{t}_1 t, \tilde{t}_1\to bs$	2 e, μ (SS)	0-3 b	Yes	20.7	$\tilde{g}$ 880 GeV		ATLAS-CONF-2013-007
Other	Scalar gluon	0	4 jets	-	4.6	sgluon 100-287 GeV	incl. limit from 1110.2693	1210.4826
	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

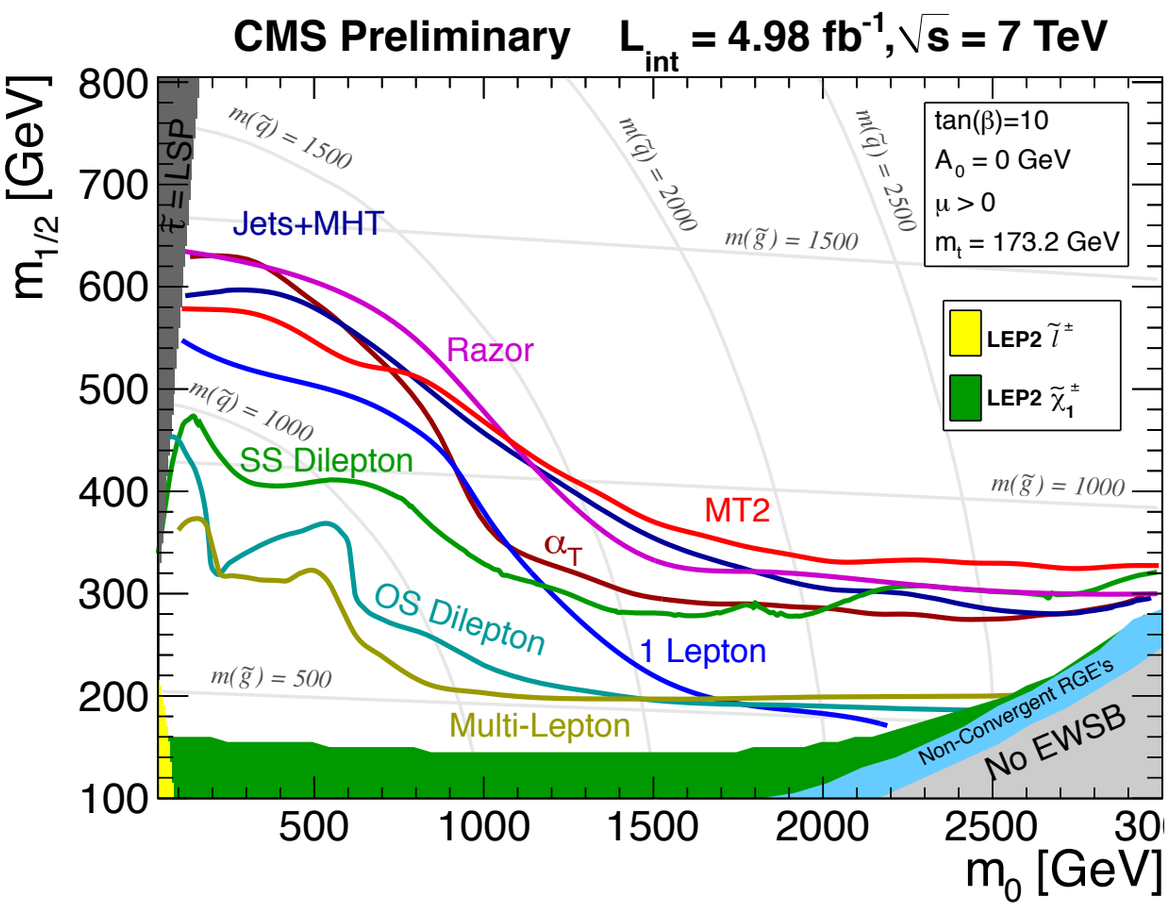
10^{-1} 1 **Mass scale [TeV]**

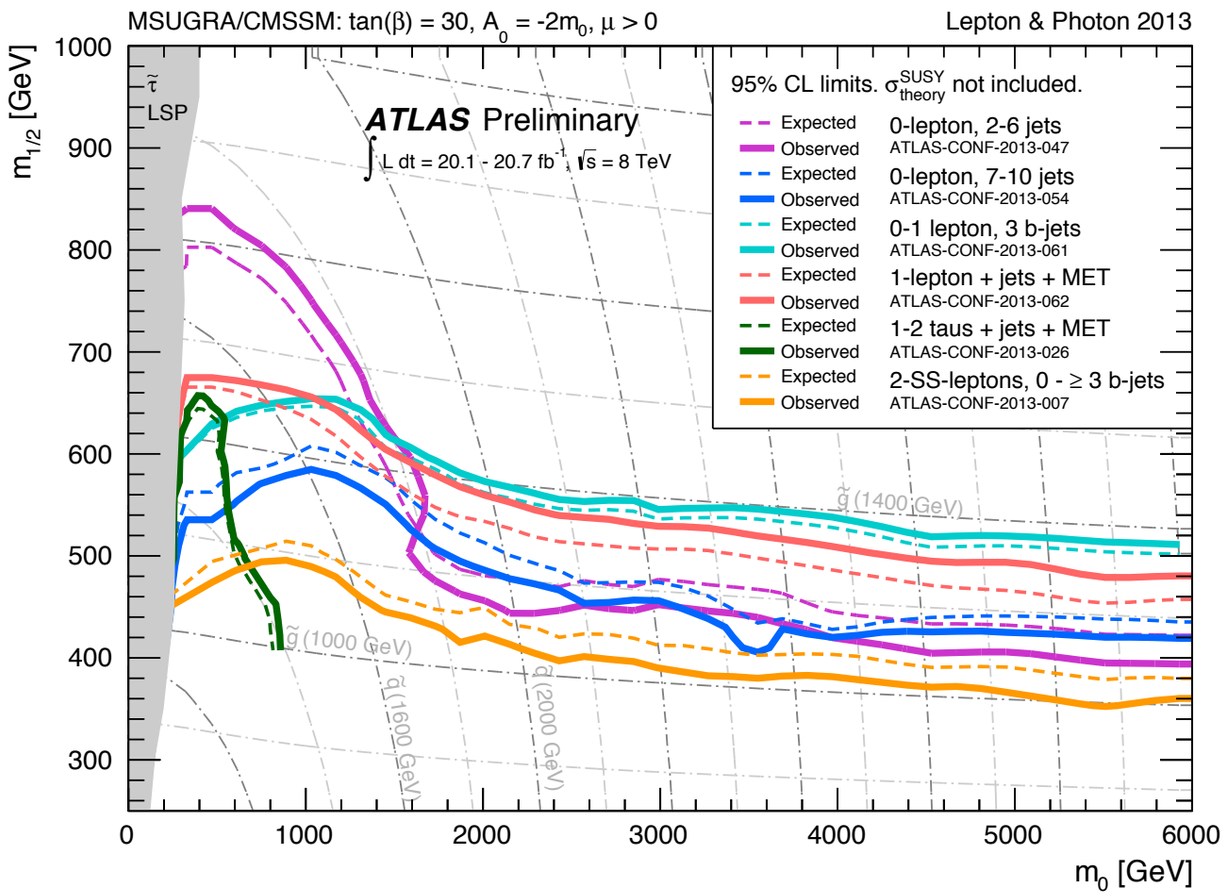
**Only a selection of the available mass limits on new states or phenomena is shown. All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.*

Necessity for Interpretations

- Experimental analysis techniques becoming more advanced
  - multiple objects
  - correlated efficiencies
  - shape analyses
  - dedicated optimizations
  - neural networks, BDT
  - multiple channels combinations
- Extremely hard to produce well defined model independent results
  - however sometimes it is possible
- Need specific models to convert observations into parameters
  - Complimentary approaches (with different pro and contra):
    - at LHC startup: minimal physics SUSY models
    - currently: signature based
      - interpret results in terms of “simplified models” a.k.a. SMS with well defined signatures
    - new, promising approach: Bayesian sampling of generic models

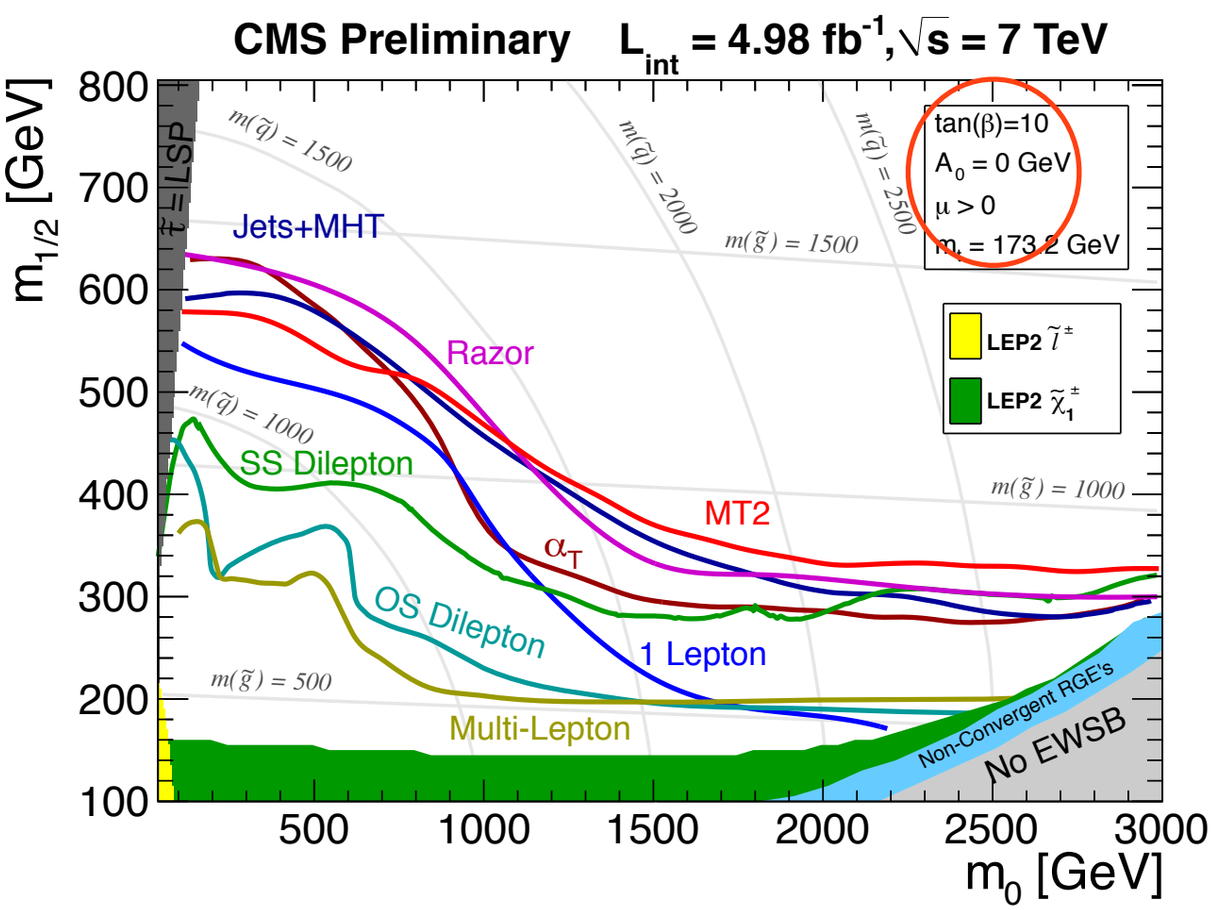
Search for cMSSM a.k.a. mSUGRA

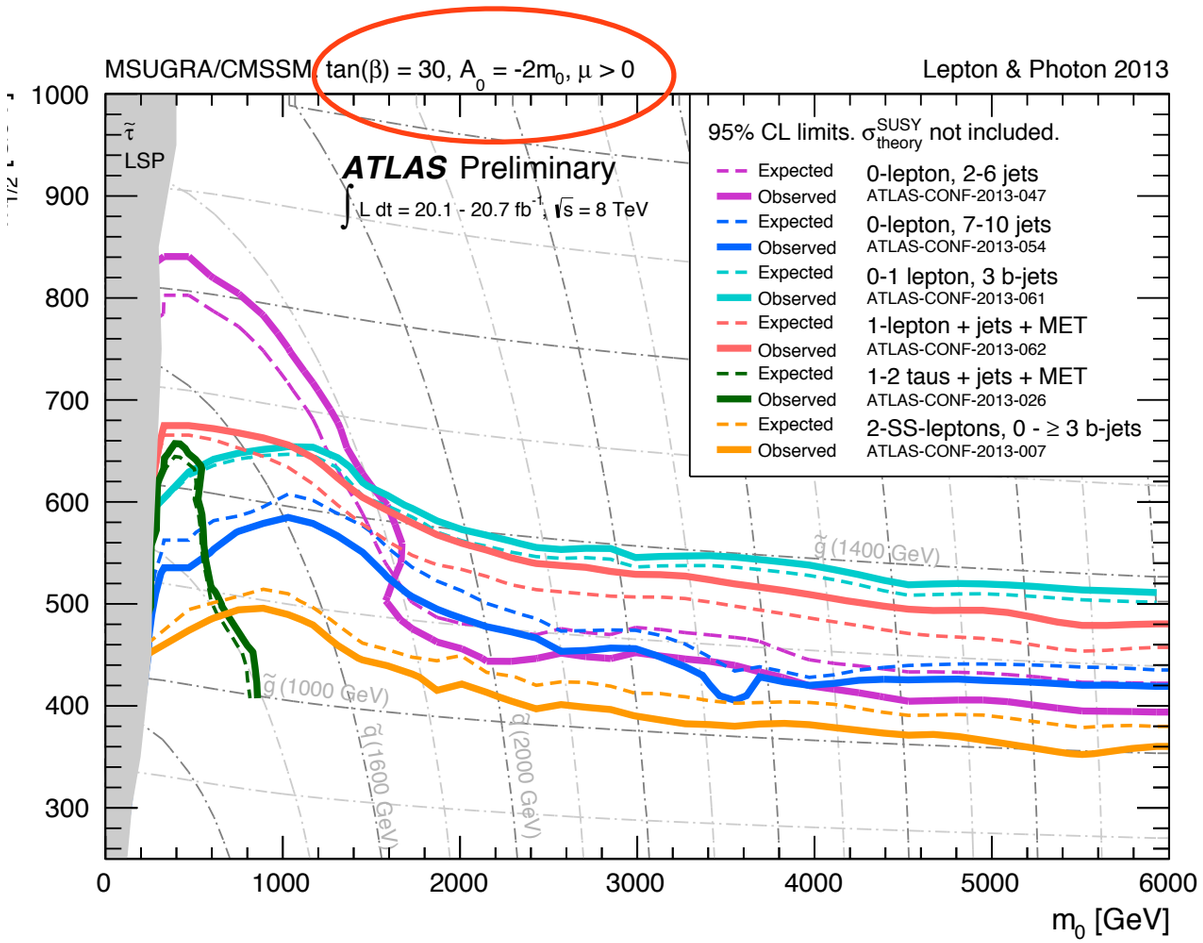




- Very minimal SUSY model
  - 5 parameters
  - used to fix tan(β), A_0, sign(μ), present results in m_0:$m_{1/2}$ plane
    - hard to express result in generic form
  - CMS stopped doing cMSSM interpretations since 7 TeV data
  - ATLAS continues producing cMSSM plots

Search for cMSSM a.k.a. mSUGRA





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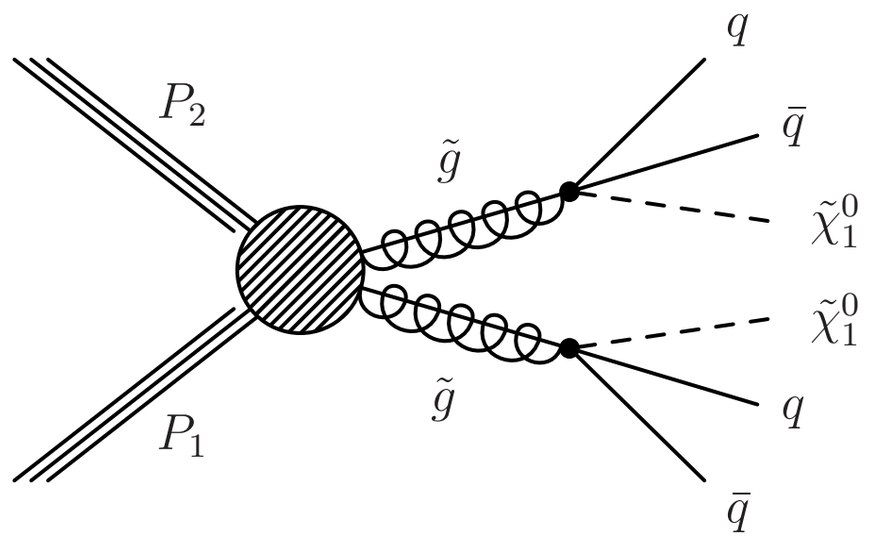
“Signature Based” Simplified Models

- Even simplest SUSY model cMSSM has 5 parameters
  - hard to interpret obtained experimental results
- cMSSM is excluded up to high m_0 and $m_{1/2}$ masses
  - need to get out cMSSM box



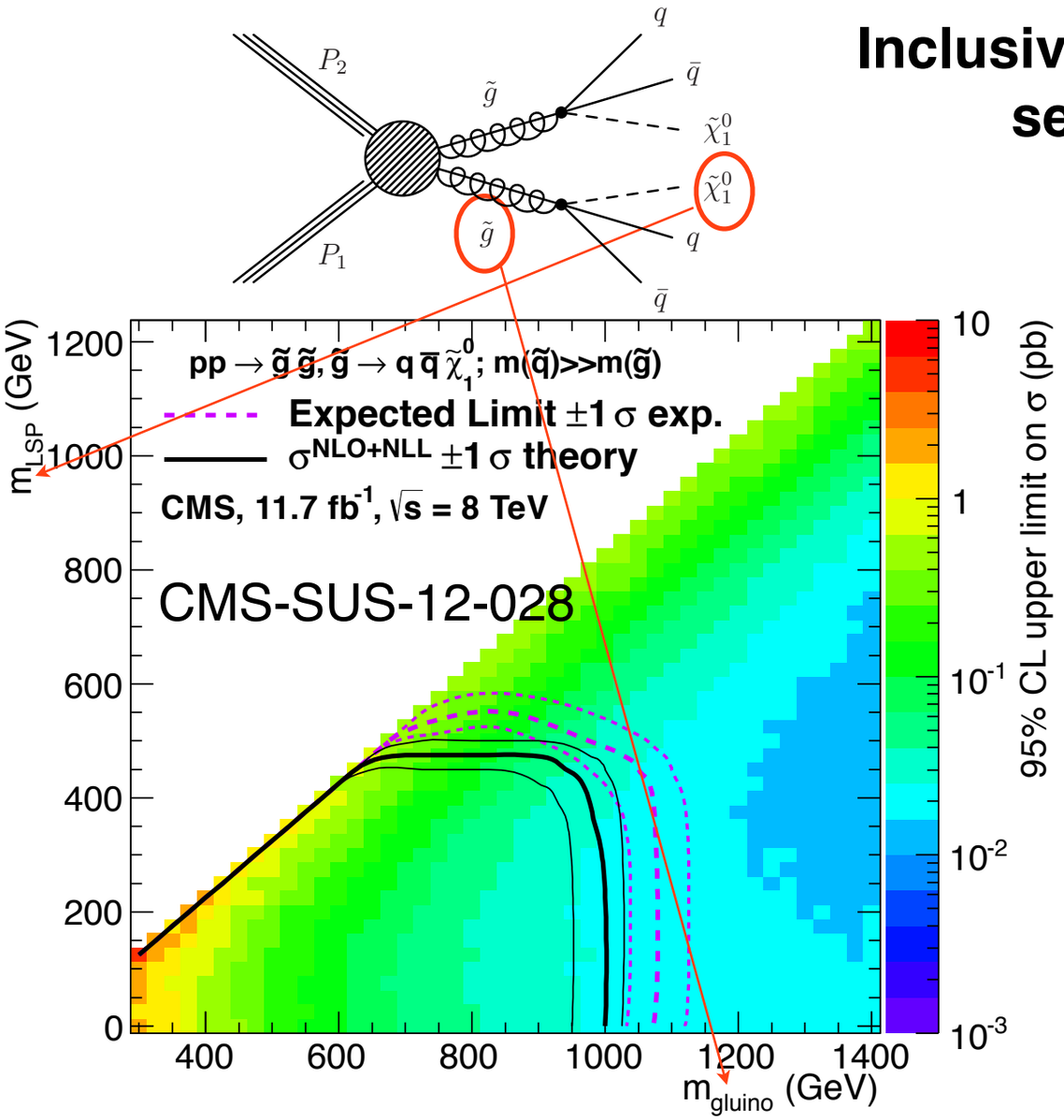
- **Signature based approach**:
  - assumes one primary production mechanism
    - e.g. gluino production
  - assumes simple mass spectra with most of SUSY Zoo decoupled
    - e.g. squarks and ewkino≠LSP are heavy and decoupled
  - assume particular decay mode
    - e.g. gluino→q qbar neutralino
  - Interpret experimental results in terms of such a “simplified model” a.k.a. SMS

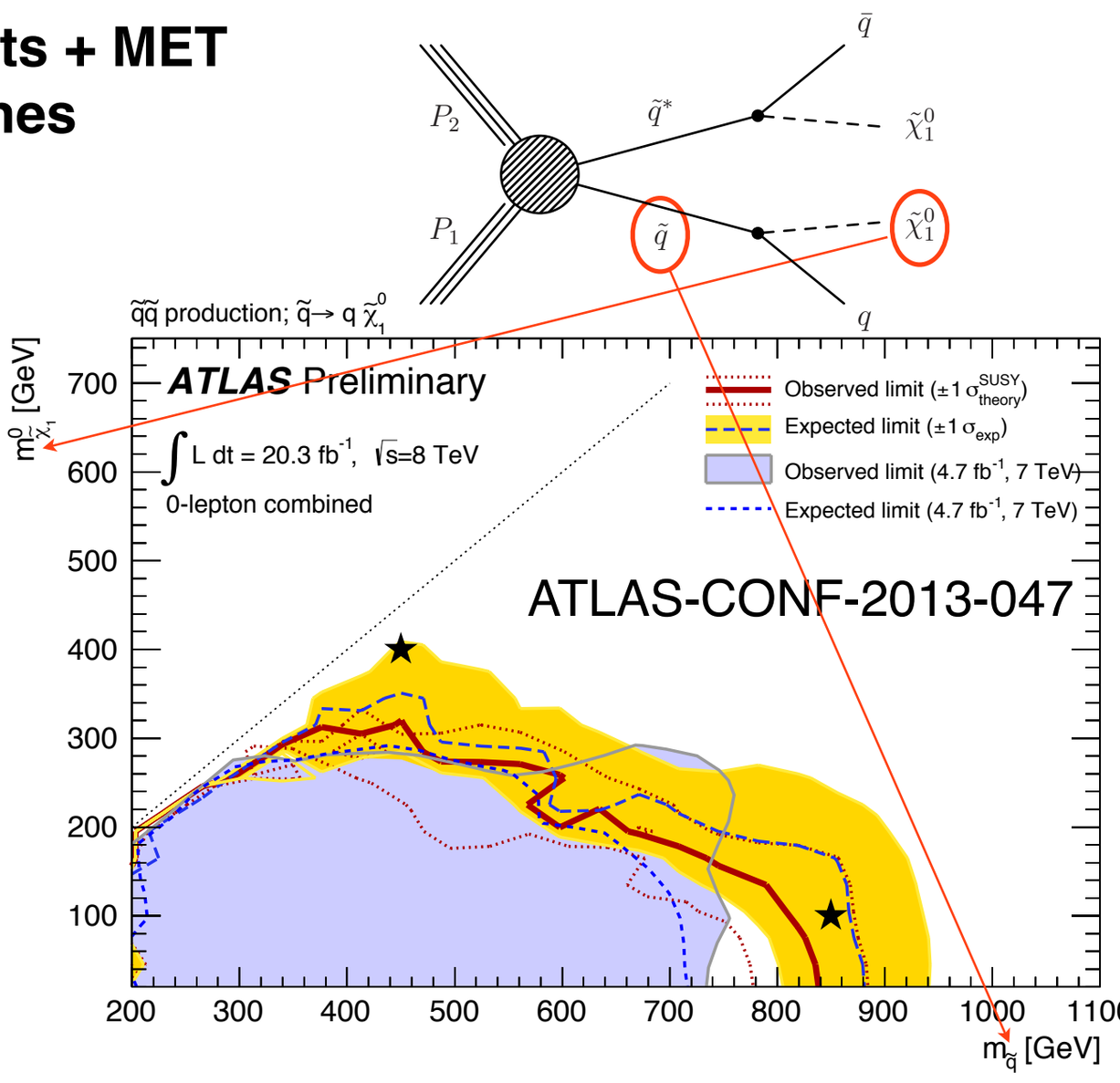
- Experimental signature of the physics SUSY model may be considered as a superposition of several SMS
  - in many cases one contribution is dominating

- **Approach to present experimental results without *a priori* knowledge of the target physics model**

Instantiation of the Signature Based Approach

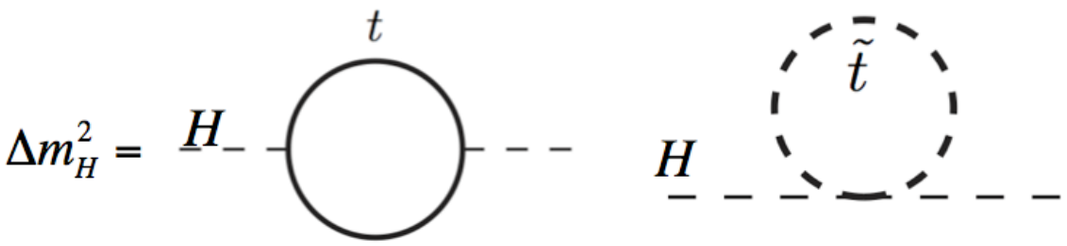
Inclusive Jets + MET searches

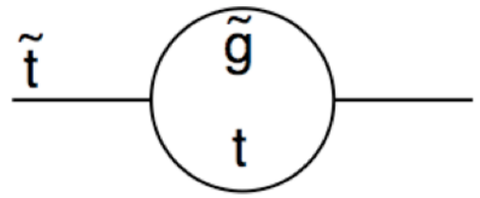




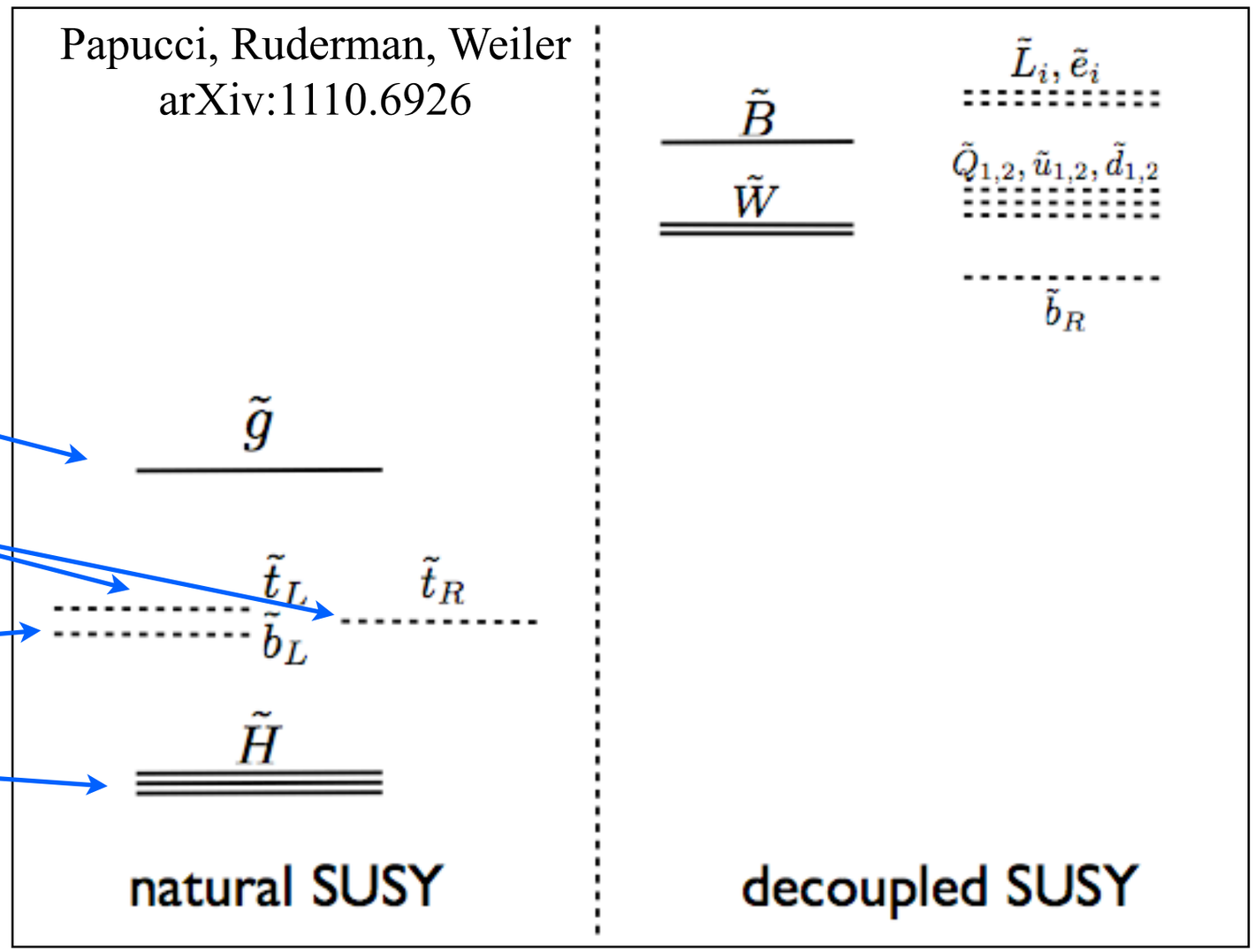
- Assume non-playing SUSY particles are decoupled
- Assume corresponding branchings are 100%
- Exclusion curve is the “best case scenario”
  - in fact it draws a line beyond which the analysis is insensitive to the given process
  - **it is not a solid exclusion for physics SUSY models, careful projection is necessary**

Light Higgs → Natural SUSY



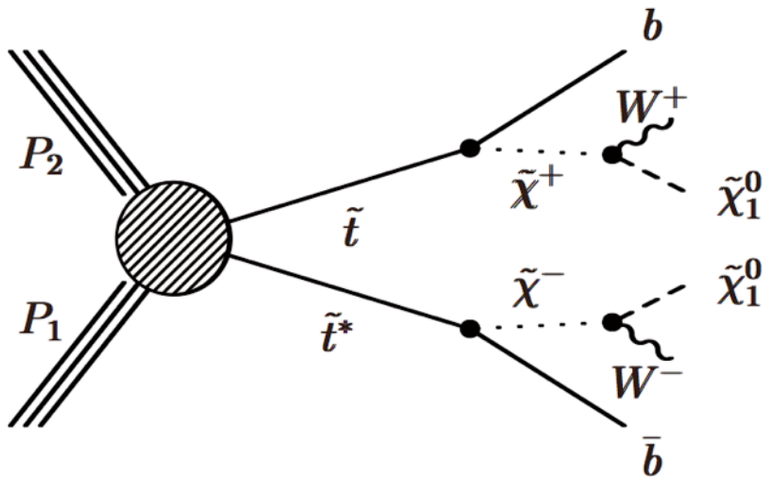


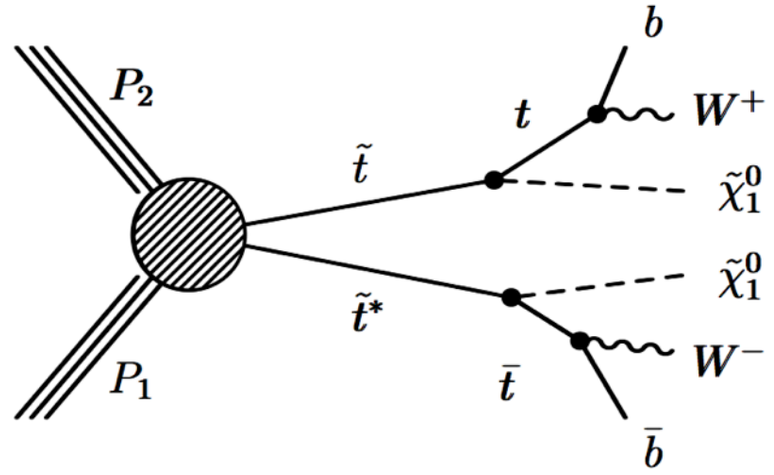
- A natural SUSY spectrum
- gluino, m ≈ 1.5 TeV
- 2 stops, m ≈ 0.5 TeV
- 1 sbottom, tied to stop
- 3 higgsinos, m ≈ 0.2 TeV



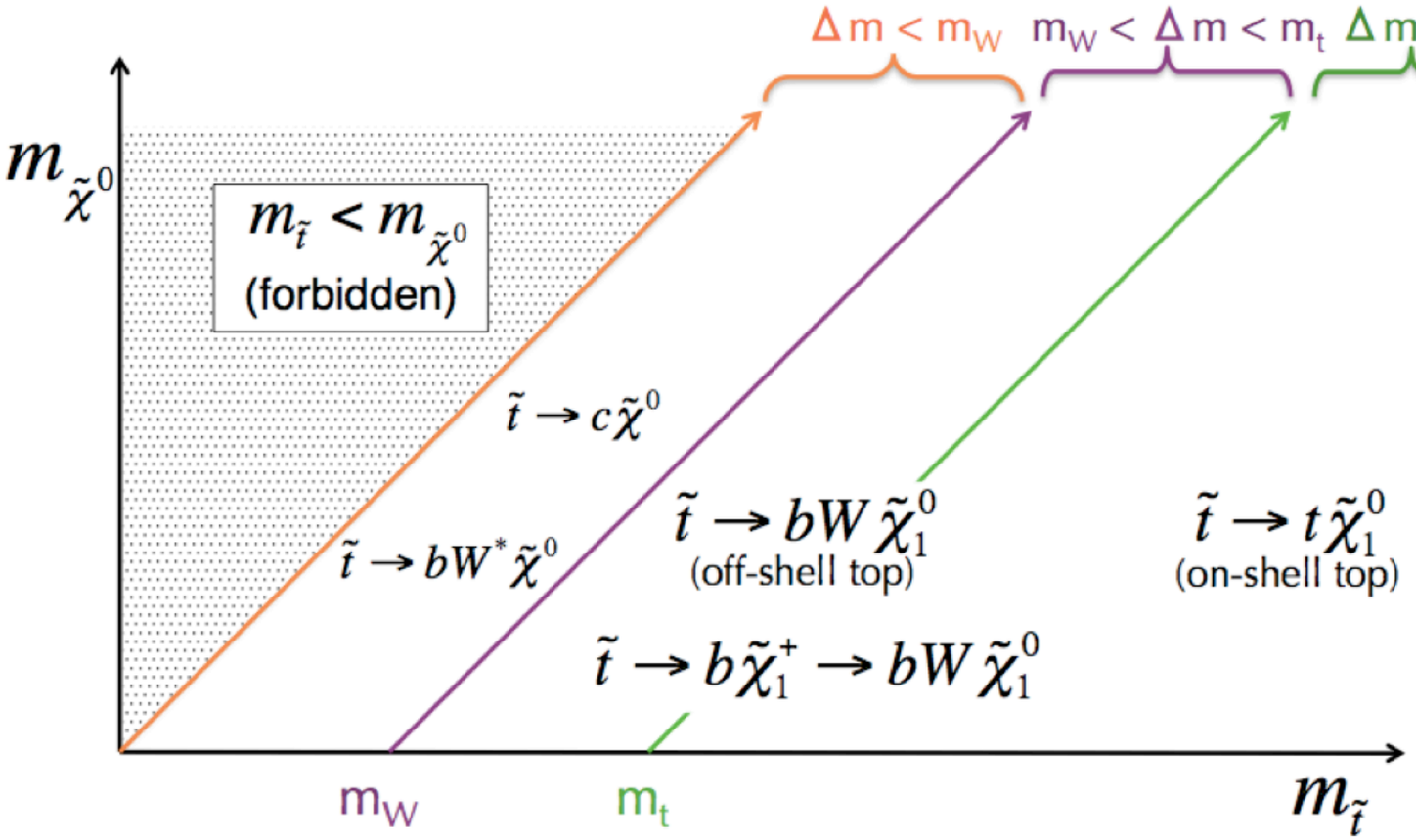
Concentrate on gluino, stop/sbottom, and ewkino searches

Top Squarks Searches





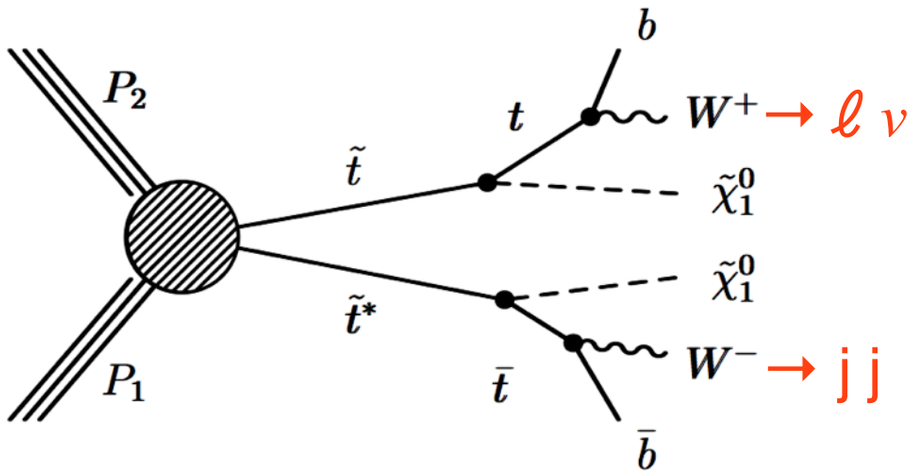
$$\Delta m \equiv m_{\tilde{t}} - m_{\tilde{\chi}^0}$$



- Signature looks like tt+MET from neutralinos
- Different possible modes with 0, 1, 2 leptons
  - SMS parameters: m_{stop}:$m_{neutralino}$
  - extra SMS parameter: $m_{chargino}$

Search in Lepton + Jets Channel

CMS SUS-13-11



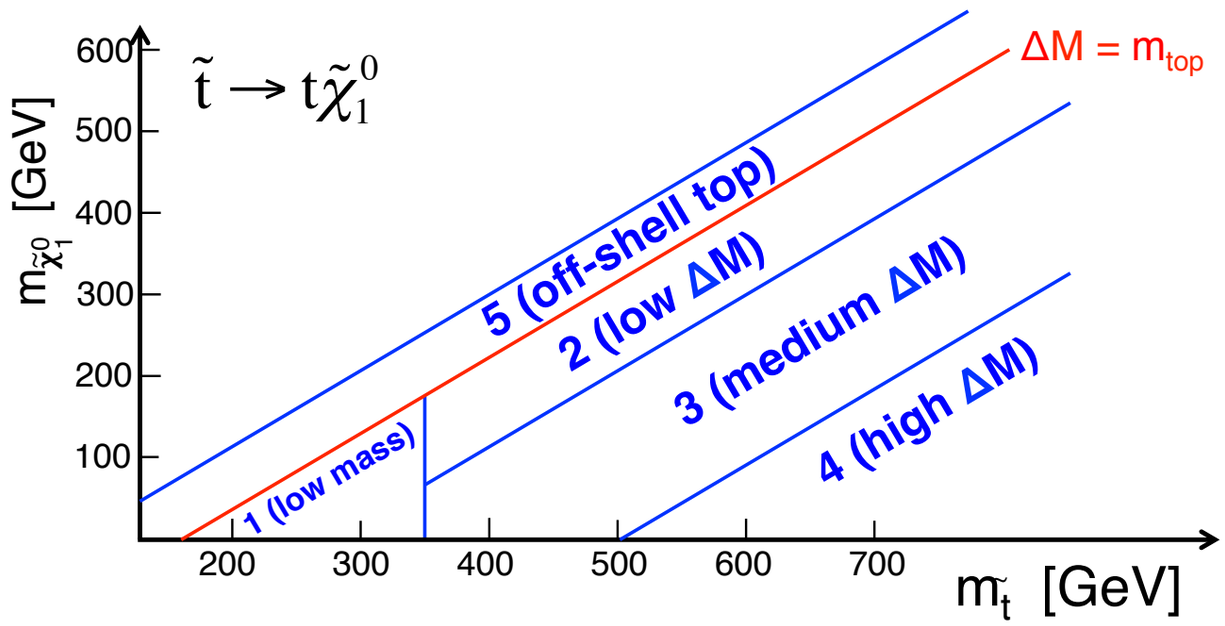
- 1 high-p_T isolated e or μ
- ≥ 4 jets with ≥ 1 b-jets
- Moderate MET
- Veto events with isolated track or $\tau_{hadronic}$ candidate
  - suppress tt→$\ell\ell$
- Search in MT(ℓ,MET) > 120 GeV
  - suppress tt→ ℓ + jets, W+jets

Discriminating Variables

CMS SUS-13-11

Selection	$\tilde{t} \to t\tilde{\chi}_1^0$ cut-based Low ΔM	$\tilde{t} \to t\tilde{\chi}_1^0$ cut-based High ΔM	$\tilde{t} \to t\tilde{\chi}_1^0$ BDT	$\tilde{t} \to b\tilde{\chi}_1^+$ cut-based Low ΔM	$\tilde{t} \to b\tilde{\chi}_1^+$ cut-based High ΔM	$\tilde{t} \to b\tilde{\chi}_1^+$ BDT
E_T^{miss}(GeV)	> 150,200, 250,300	> 150,200, 250,300	yes	> 100,150, 200,250	> 100,150, 200,250	yes
M_{T2}^W (GeV)		> 200	yes		>200	yes
min $\Delta\phi$	> 0.8	> 0.8	yes	> 0.8	> 0.8	yes
H_T^{ratio}			yes			yes
χ^2	<5	<5	(on-shell top)			
leading b-jet p_T (GeV)			(off-shell top)		> 100	yes
ΔR(ℓ,leading b-jet)						yes

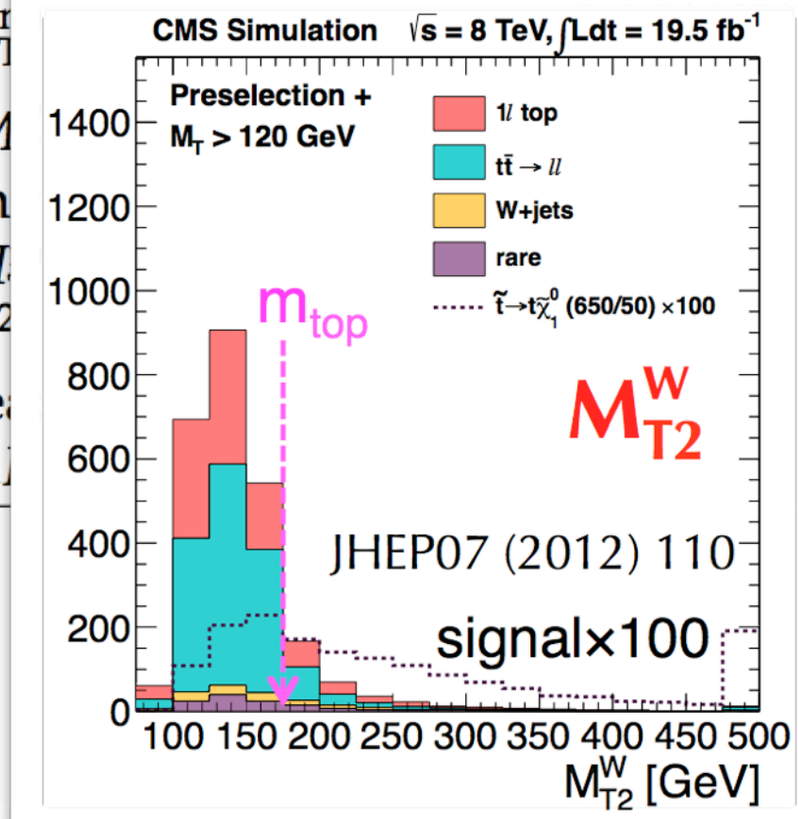
- BDT multi-variable analysis
  - cut-based analysis as a cross check

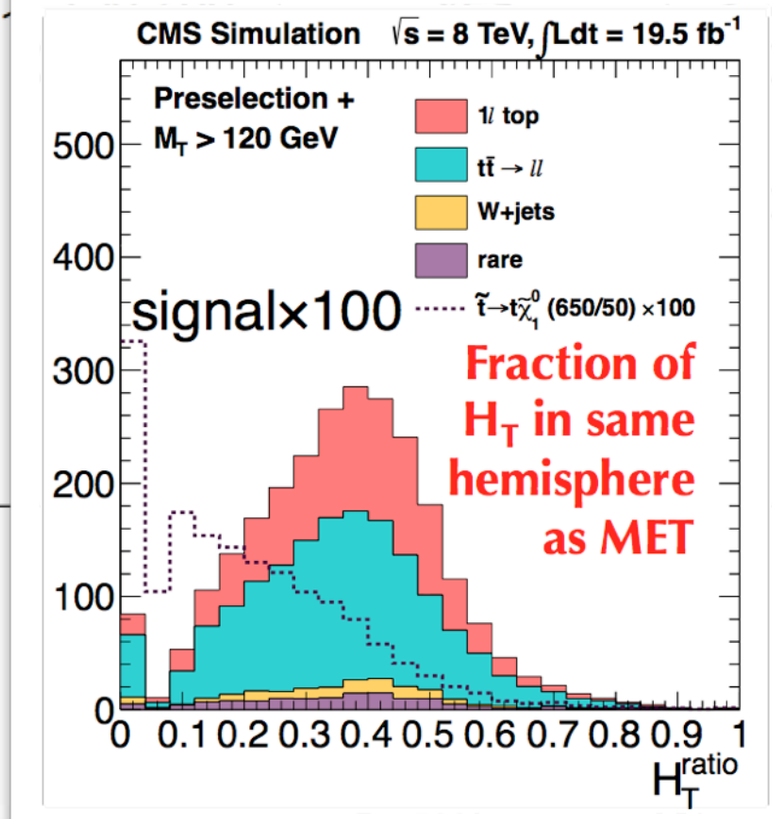


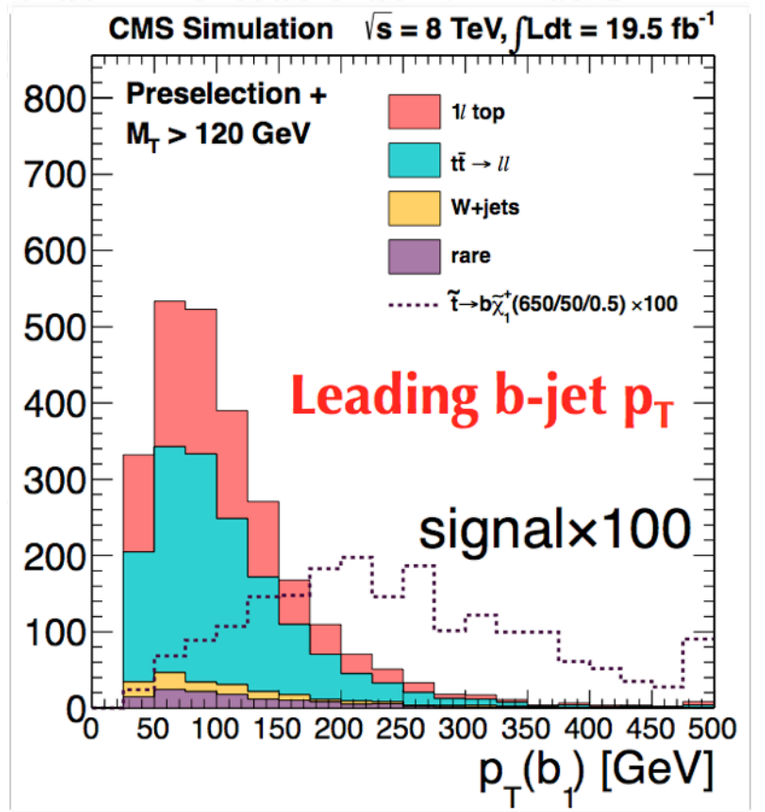
Discriminating Variables

CMS SUS-13-11

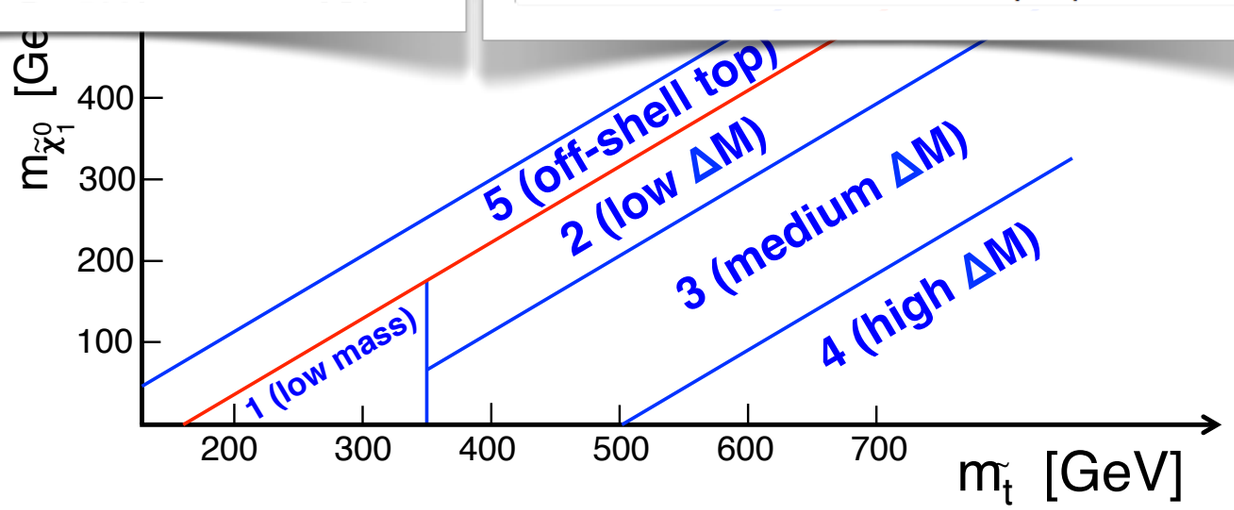
Selection	$\tilde{t} \to t\tilde{\chi}_1^0$ cut-based Low ΔM	$\tilde{t} \to t\tilde{\chi}_1^0$ cut-based High ΔM	$\tilde{t} \to t\tilde{\chi}_1^0$ BDT	$\tilde{t} \to b\tilde{\chi}_1^+$ cut-based Low ΔM	$\tilde{t} \to b\tilde{\chi}_1^+$ cut-based High ΔM	$\tilde{t} \to b\tilde{\chi}_1^+$ BDT
E_T^{miss}						
M_{T2}^W						
m_{top}						
H_T^{ratio}						
χ^2						
leptons						
ΔM						



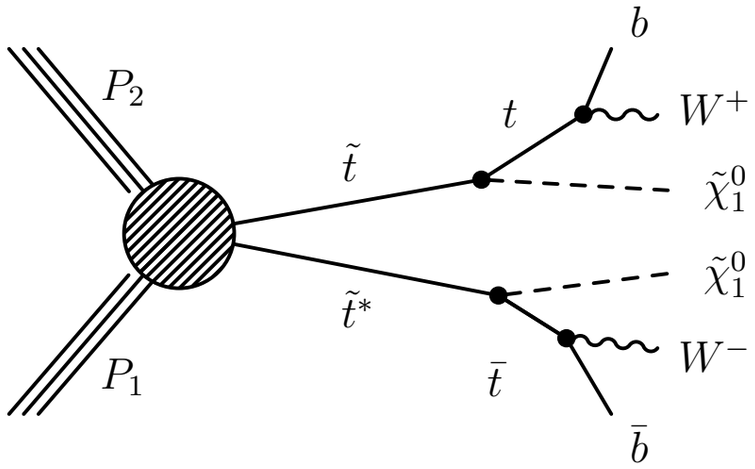


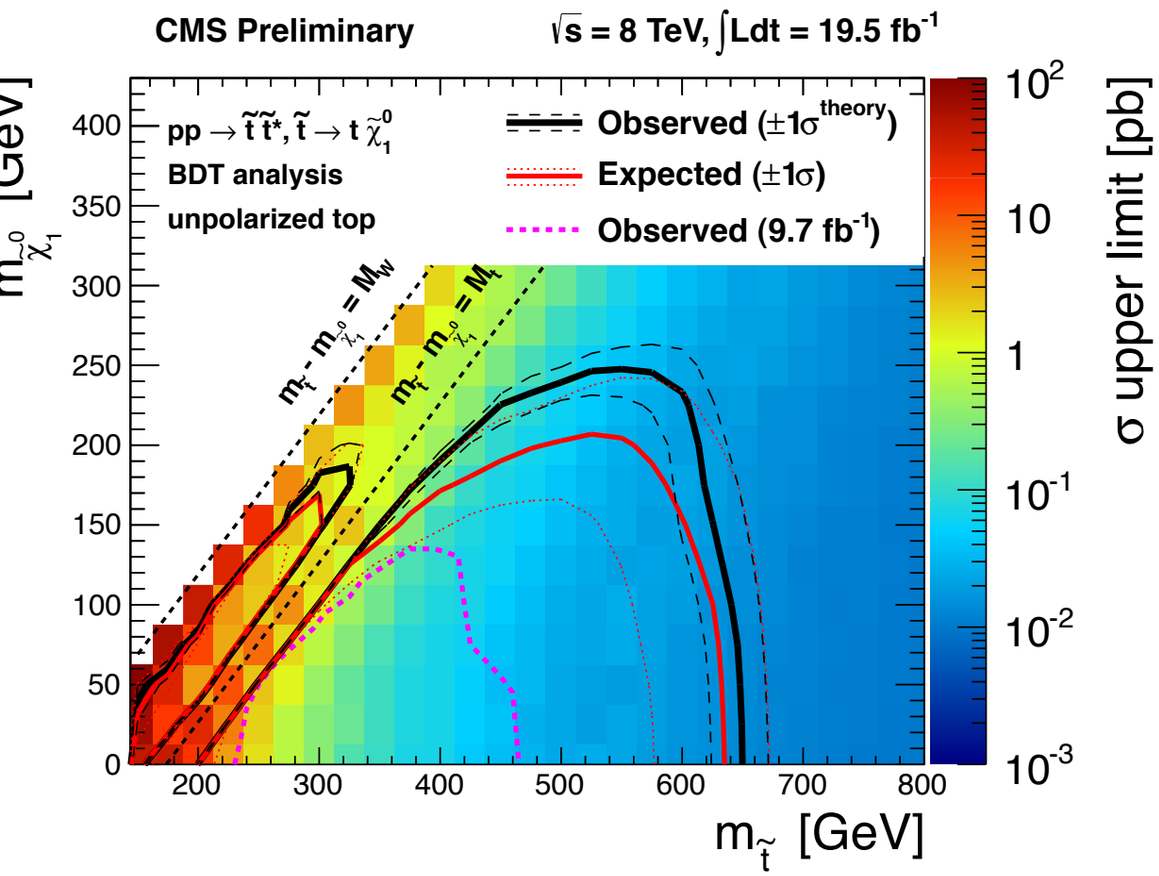


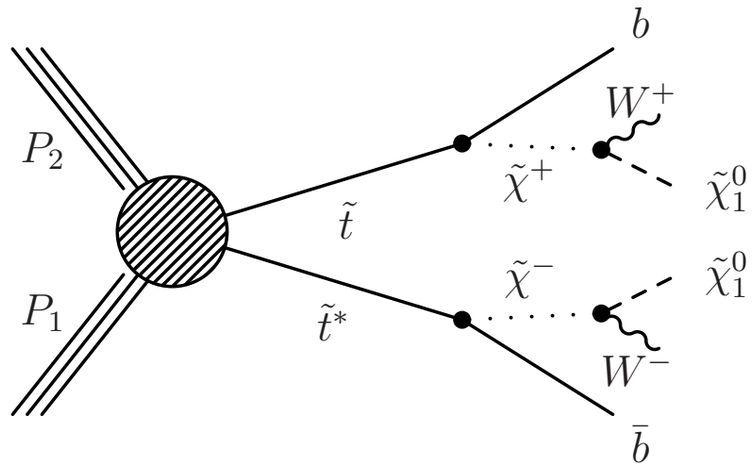
- BDT multi-variable analysis
  - cut-based analysis as a cross check

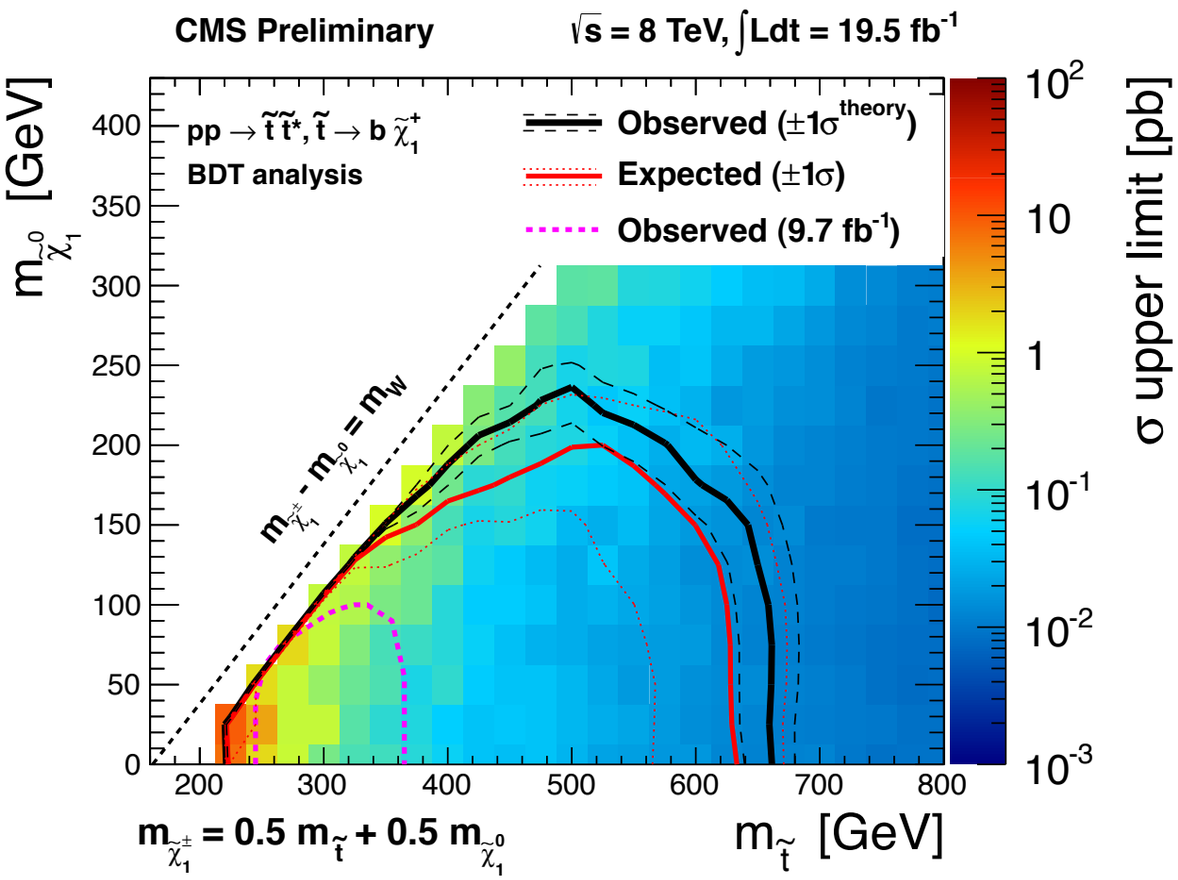


Lepton + Jets Search: SMS Result CMS SUS-13-11



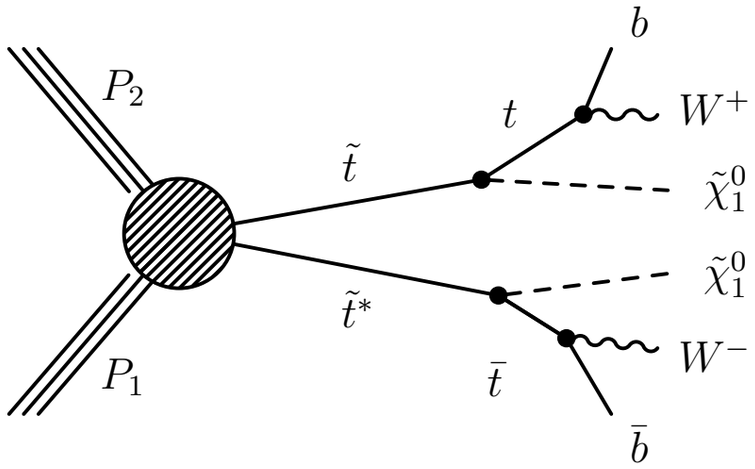


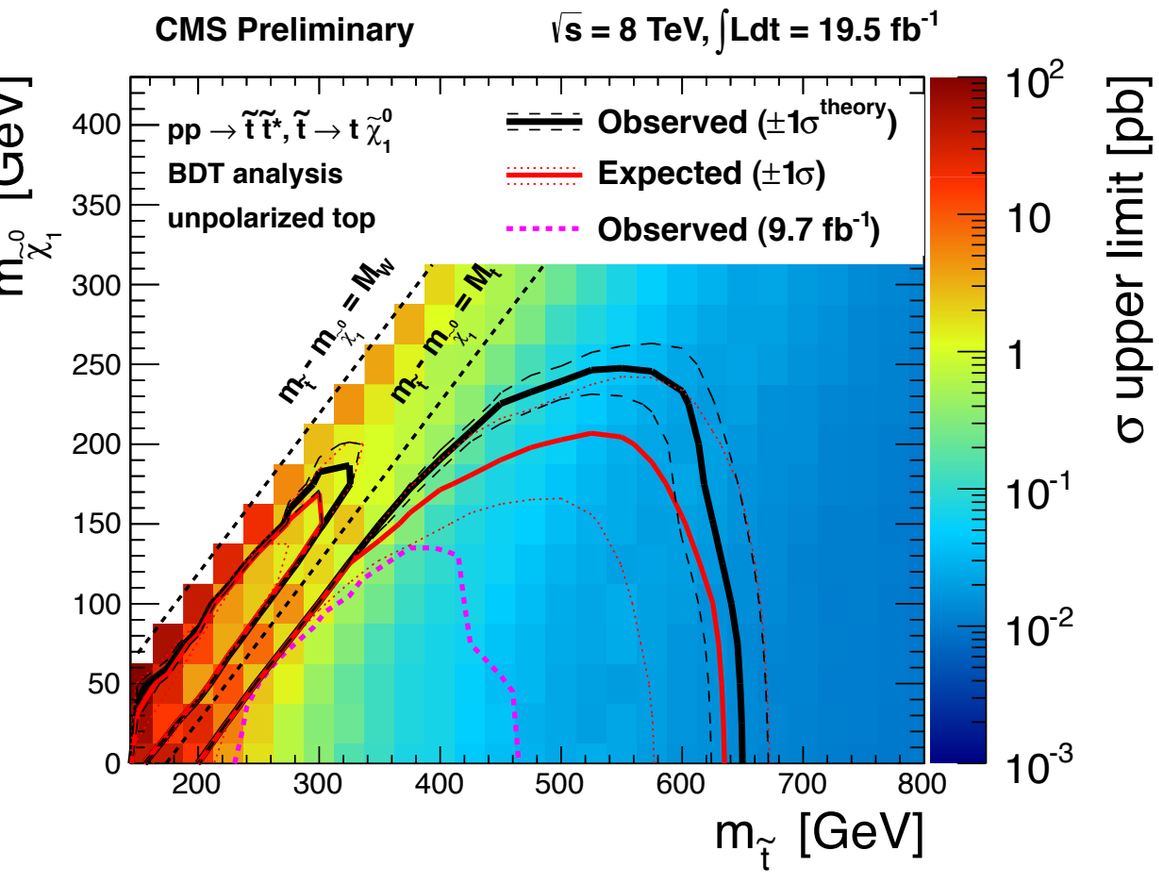


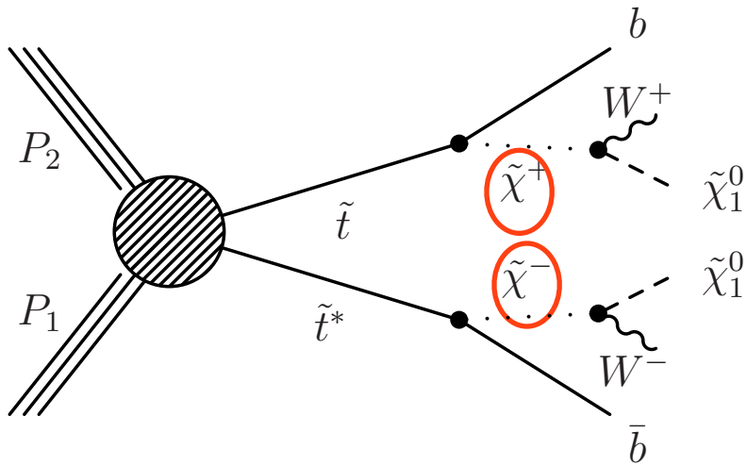


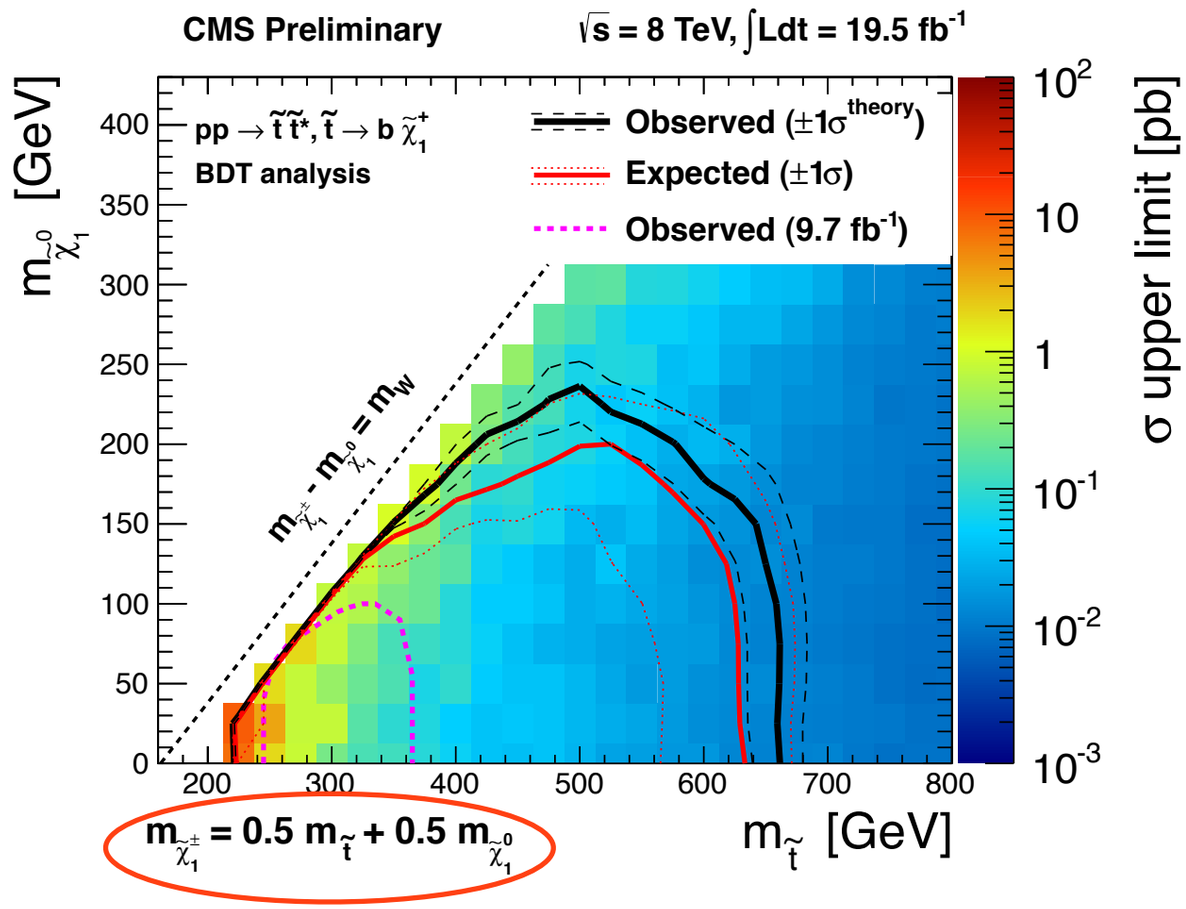
- Probe (not exclude!) stop masses up to 650 GeV

Lepton + Jets Search: SMS Result CMS SUS-13-11





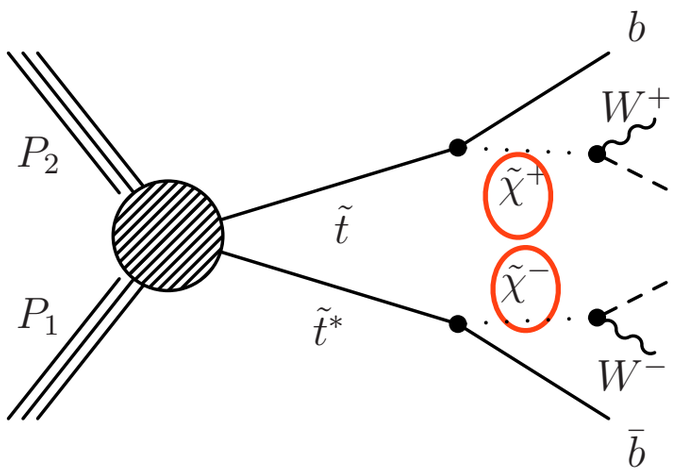


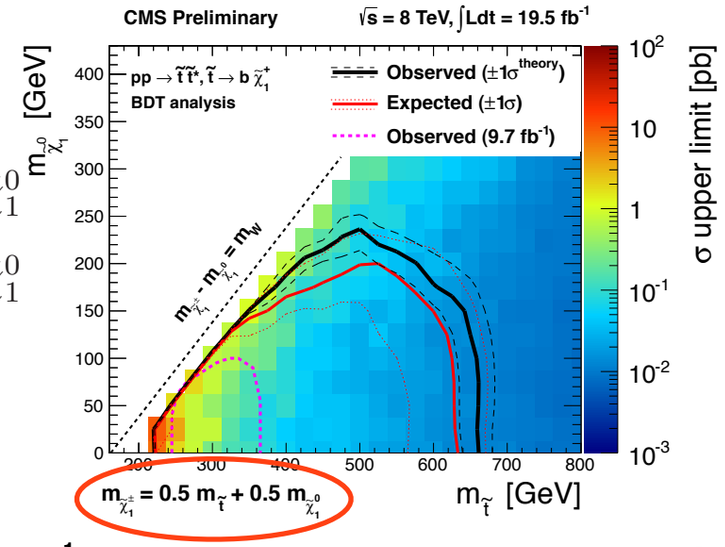


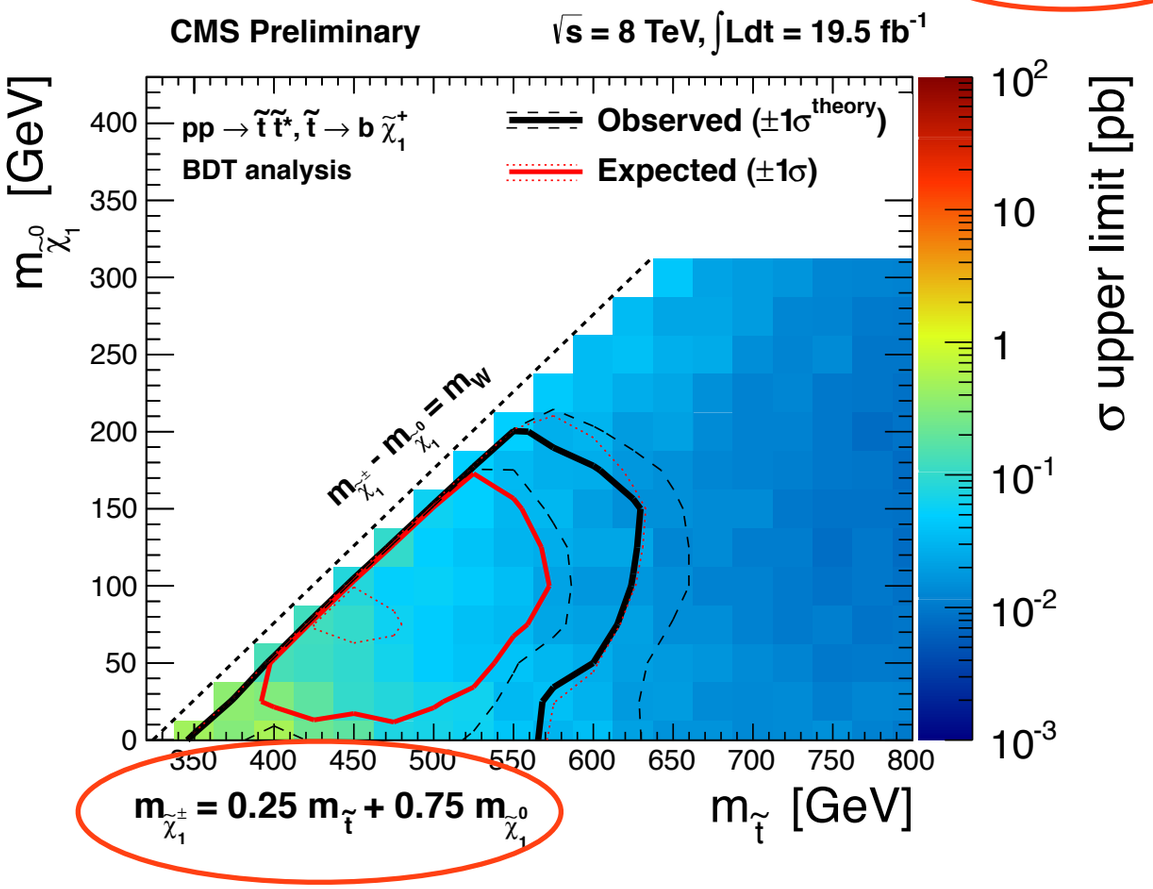
- What's the effect of the chargino mass?

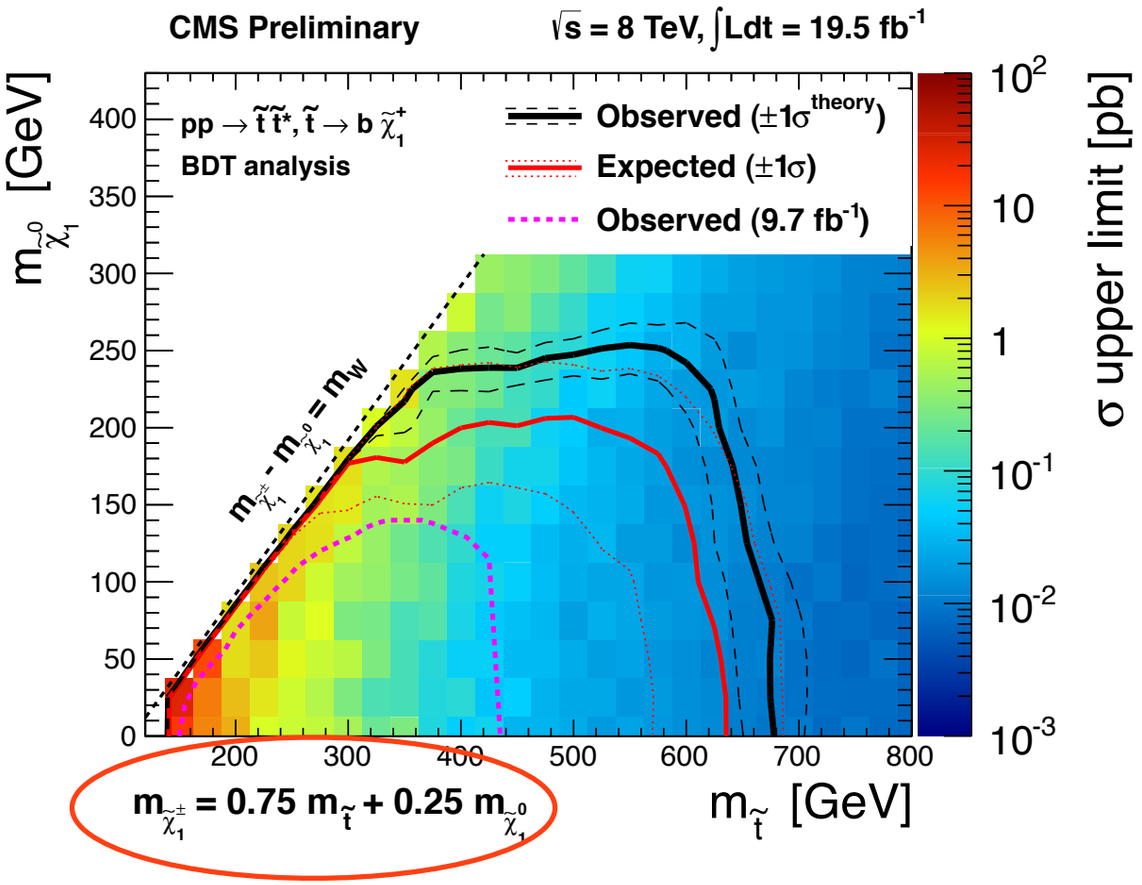
Effect of the Chargino Mass

CMS SUS-13-11







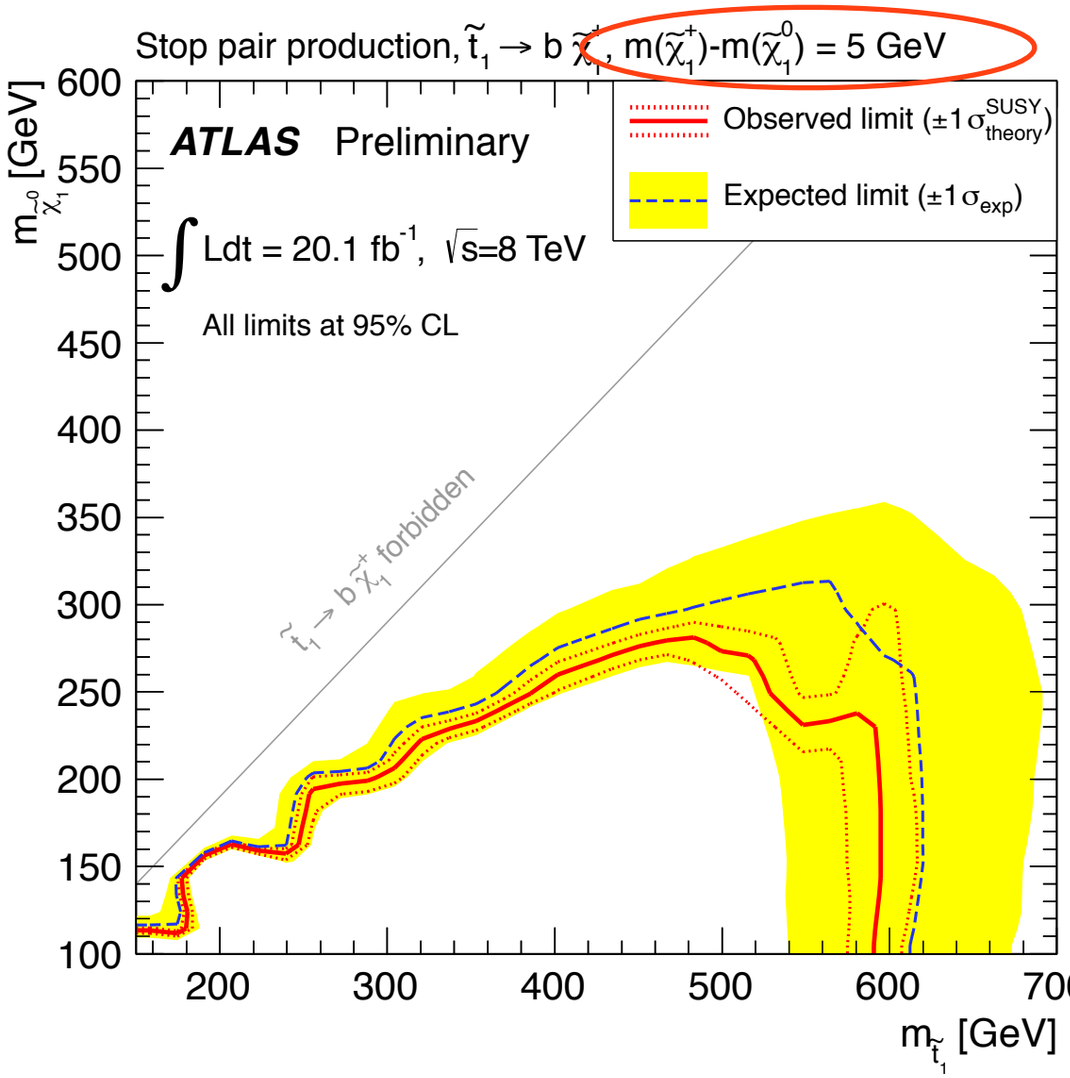


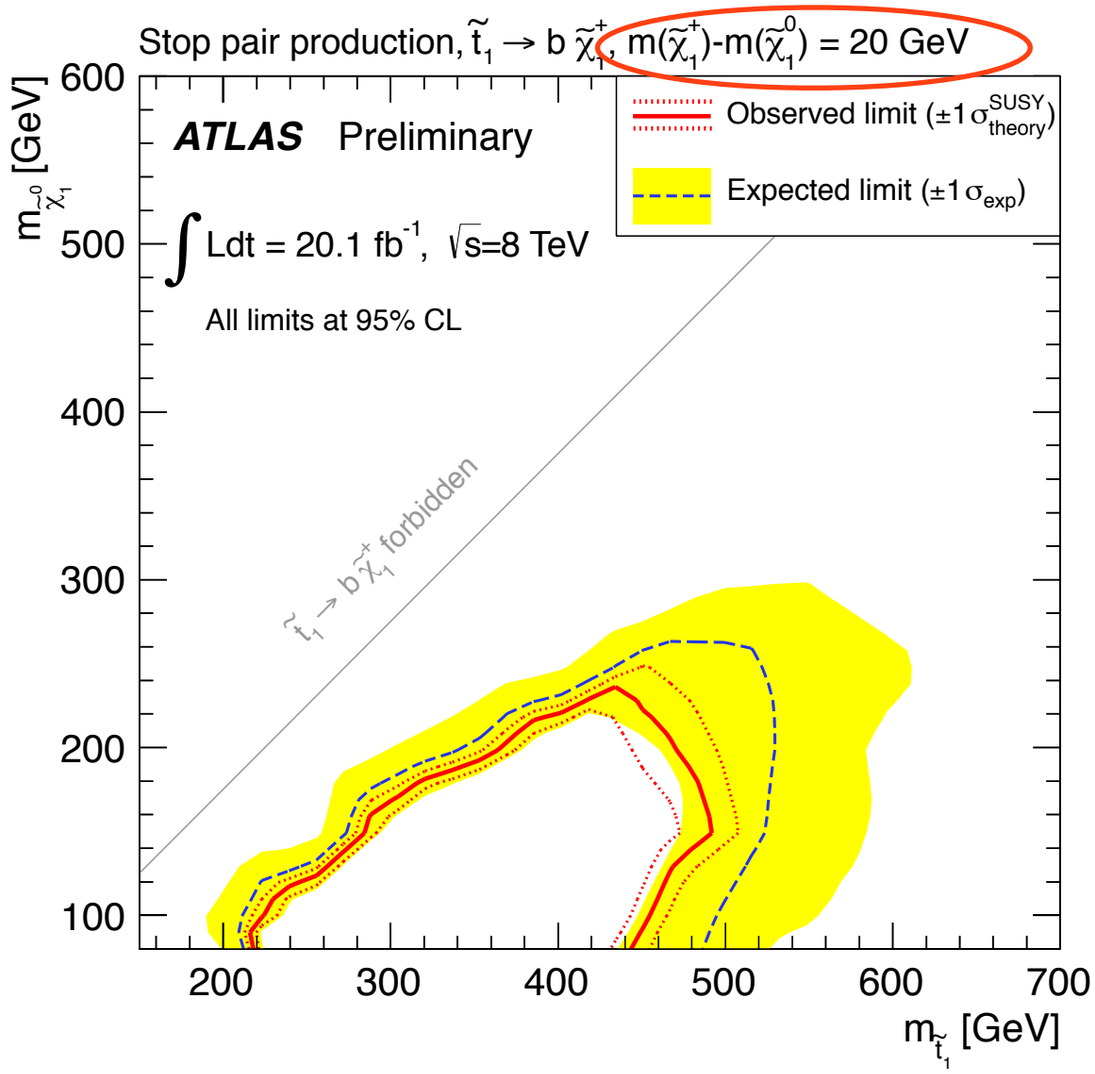
- Read fine prints carefully!

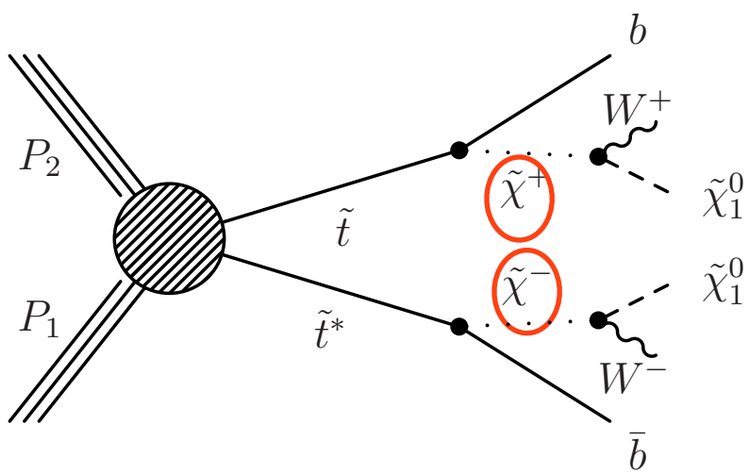
Effect of the Chargino Mass

ATLAS-CONF-2013-053

MET + 2 b-jets analysis
better sensitivity to small
$m_{chargino}$ - $m_{neutralino}$

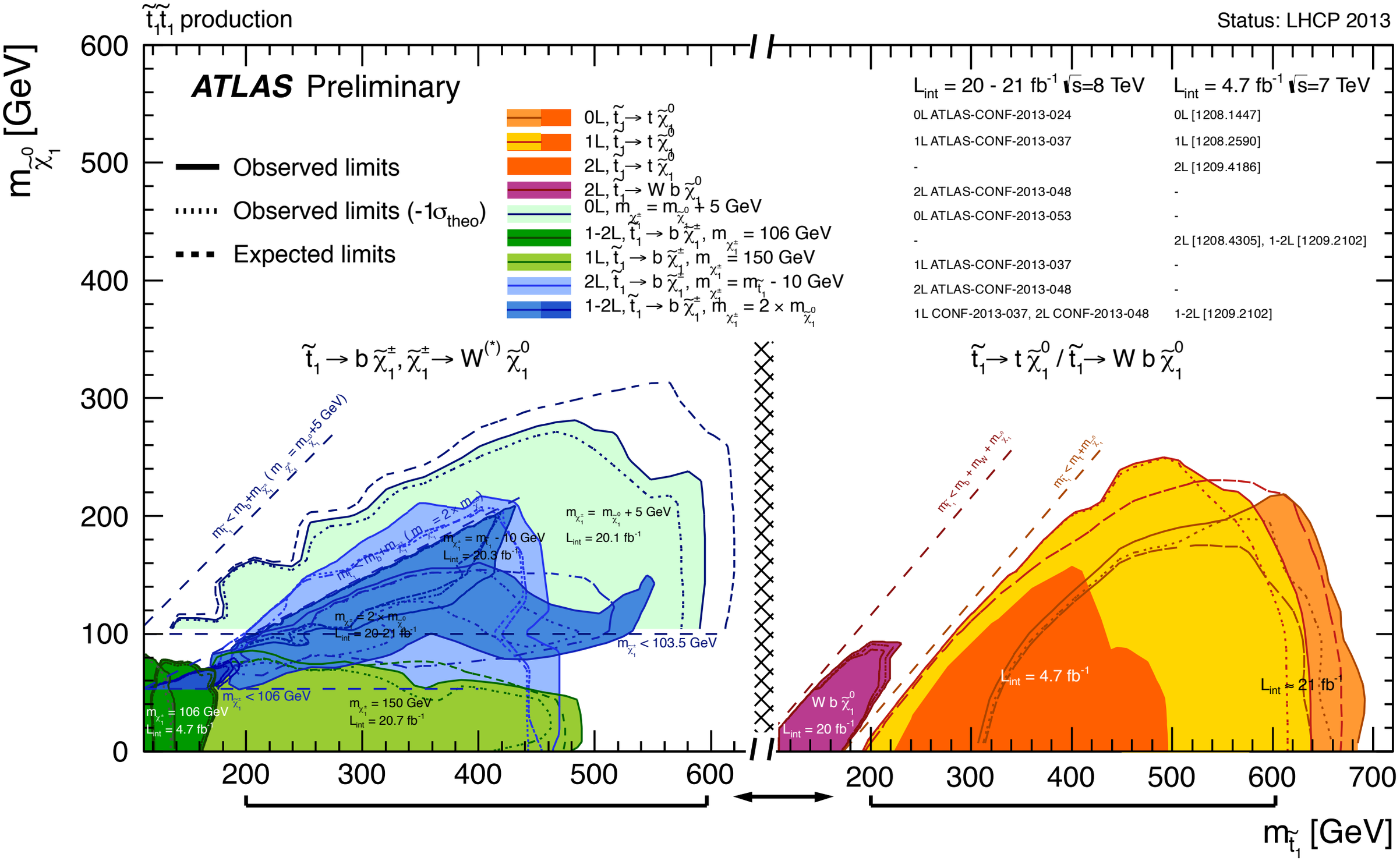




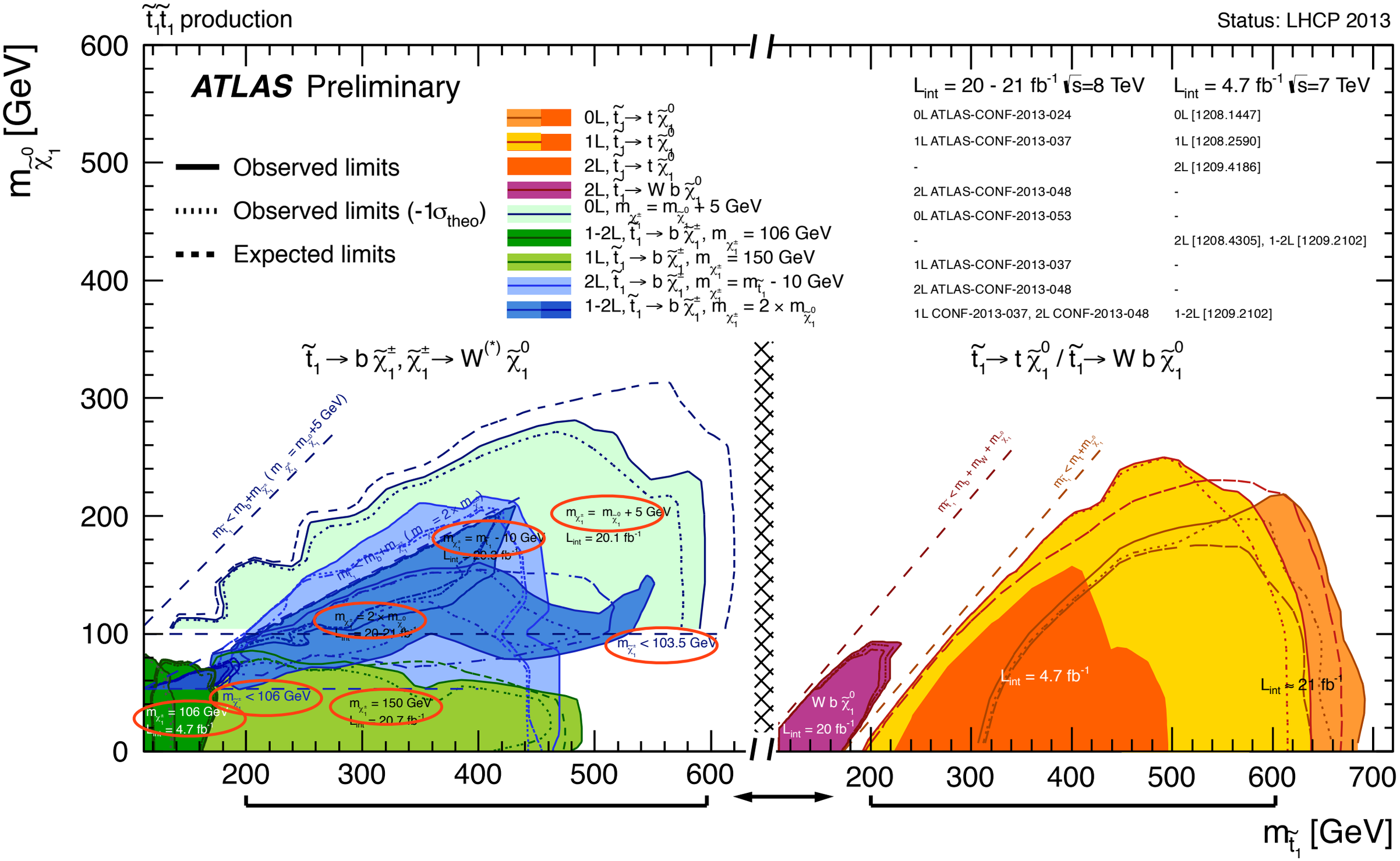


- Read fine prints carefully!

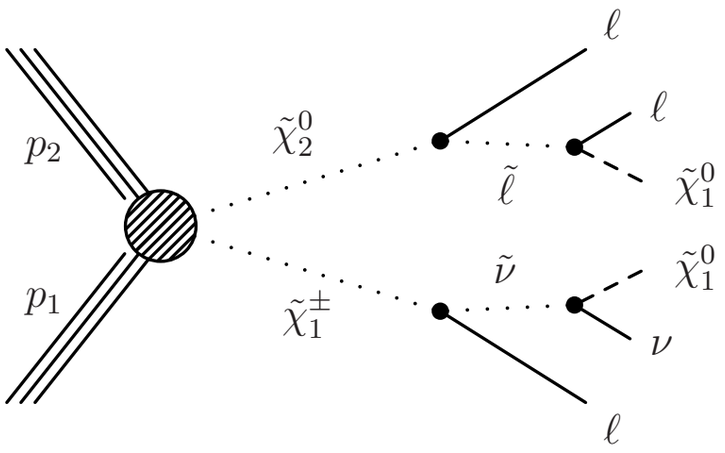
Summary of ATLAS Stop Searches



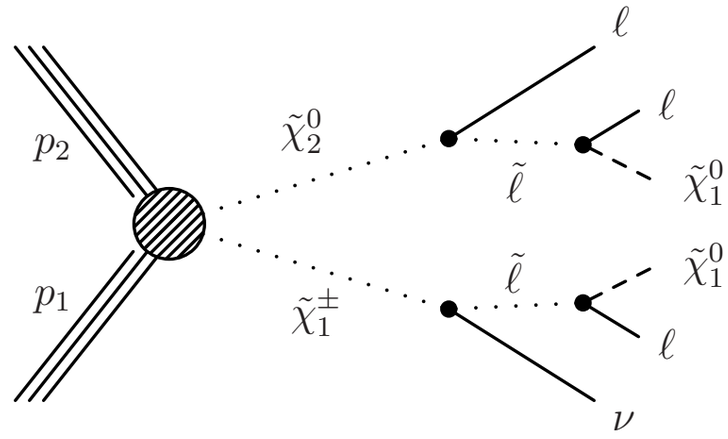
Summary of ATLAS Stop Searches



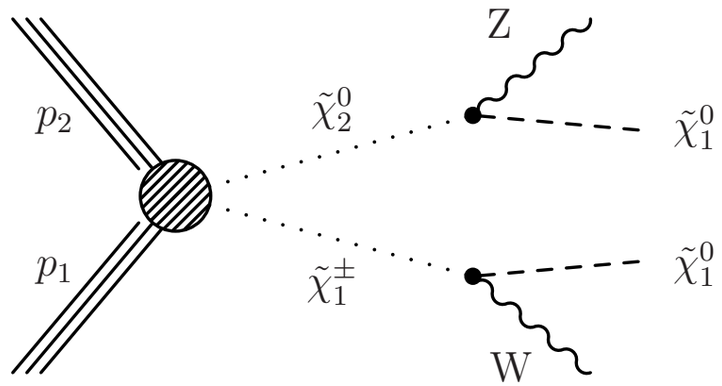
EWKino Searches in Multileptons

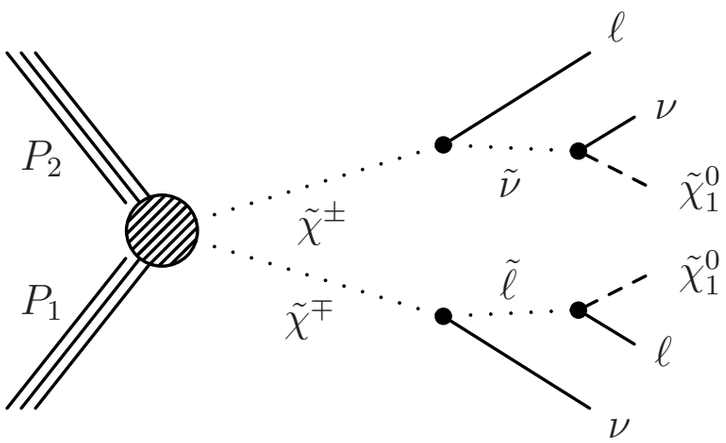


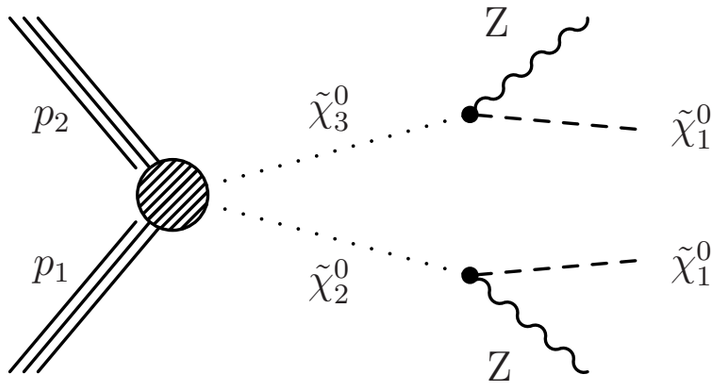
larger cross section
on-shell sleptons



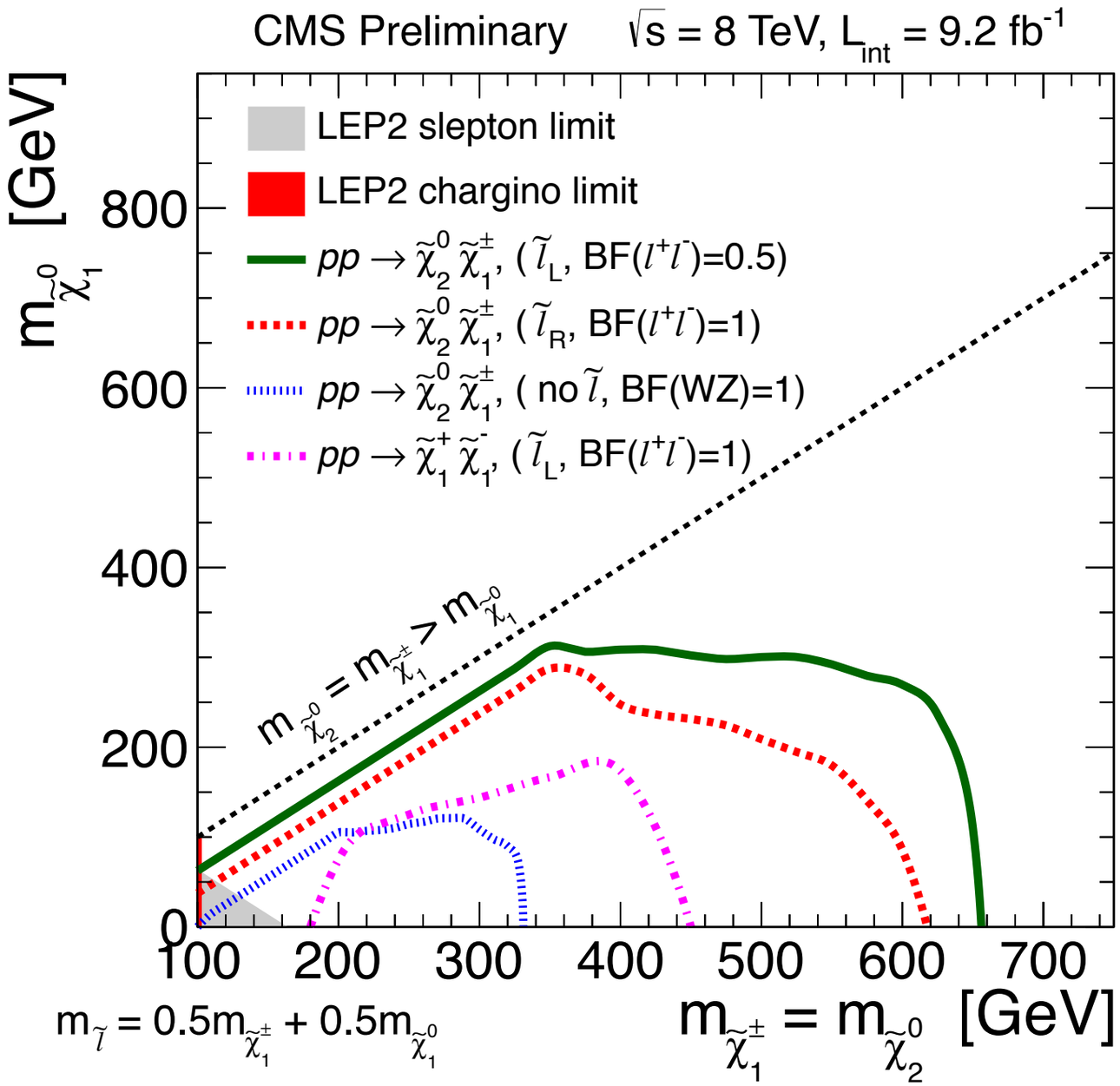
larger cross section
heavy sleptons

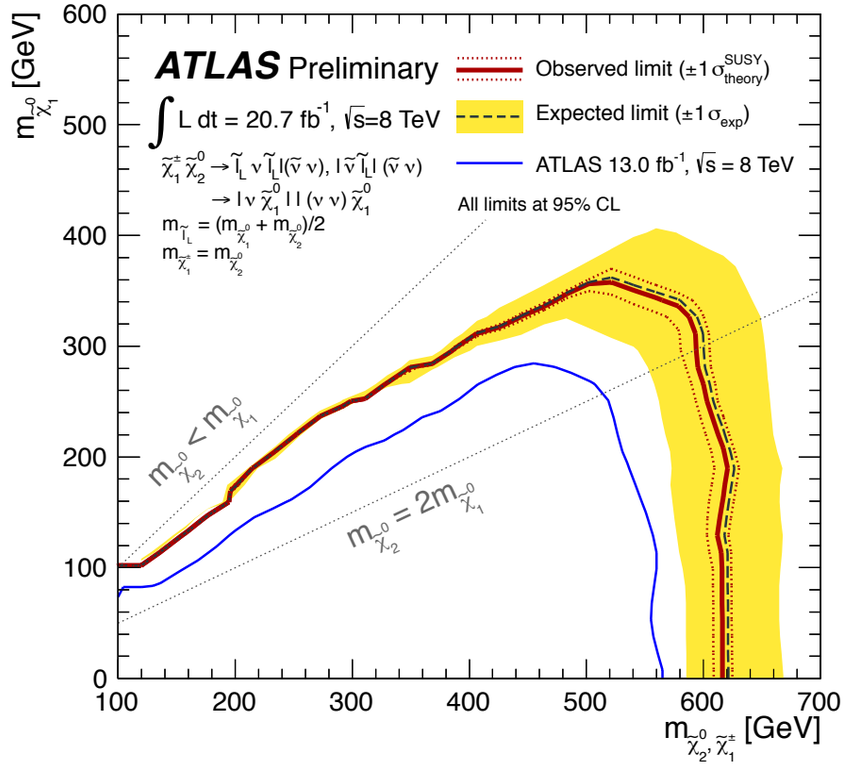


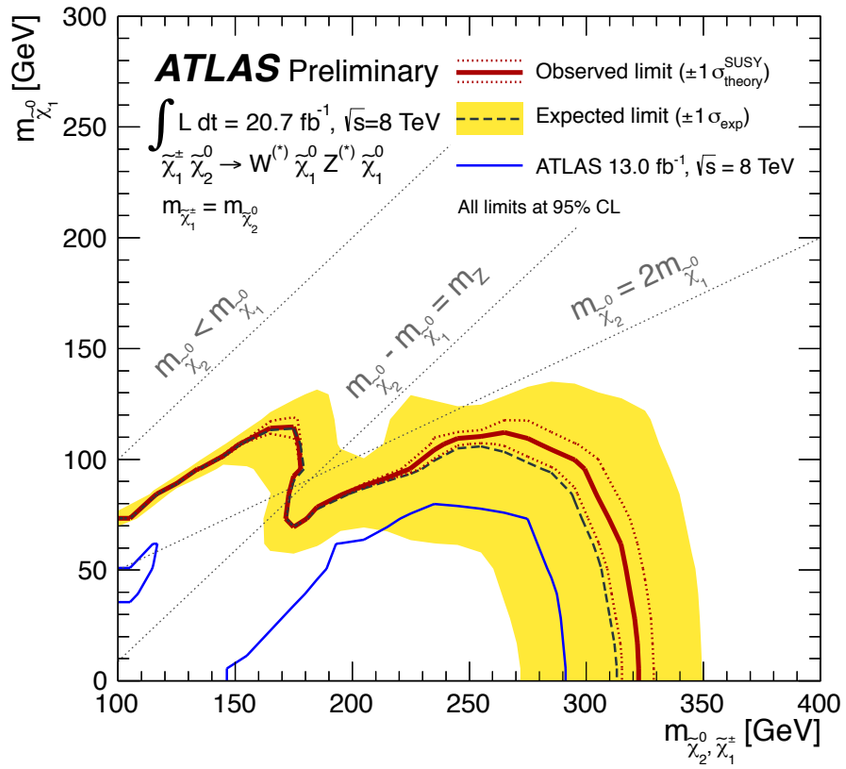




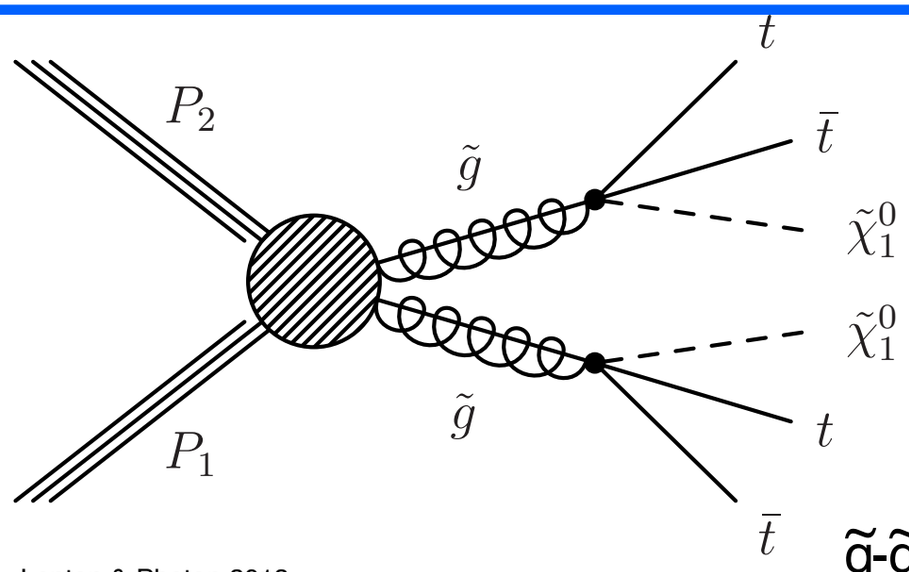
EWKino Results

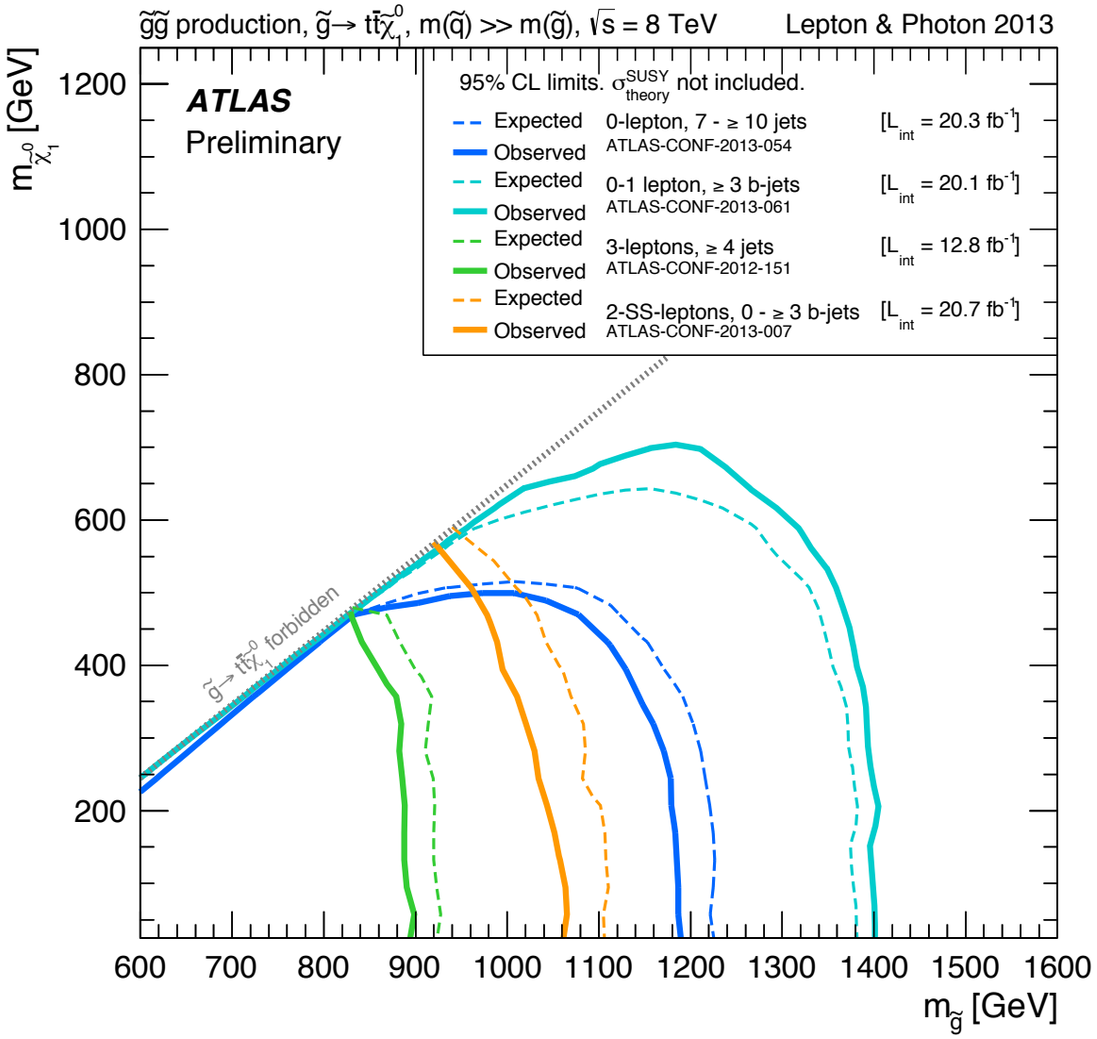


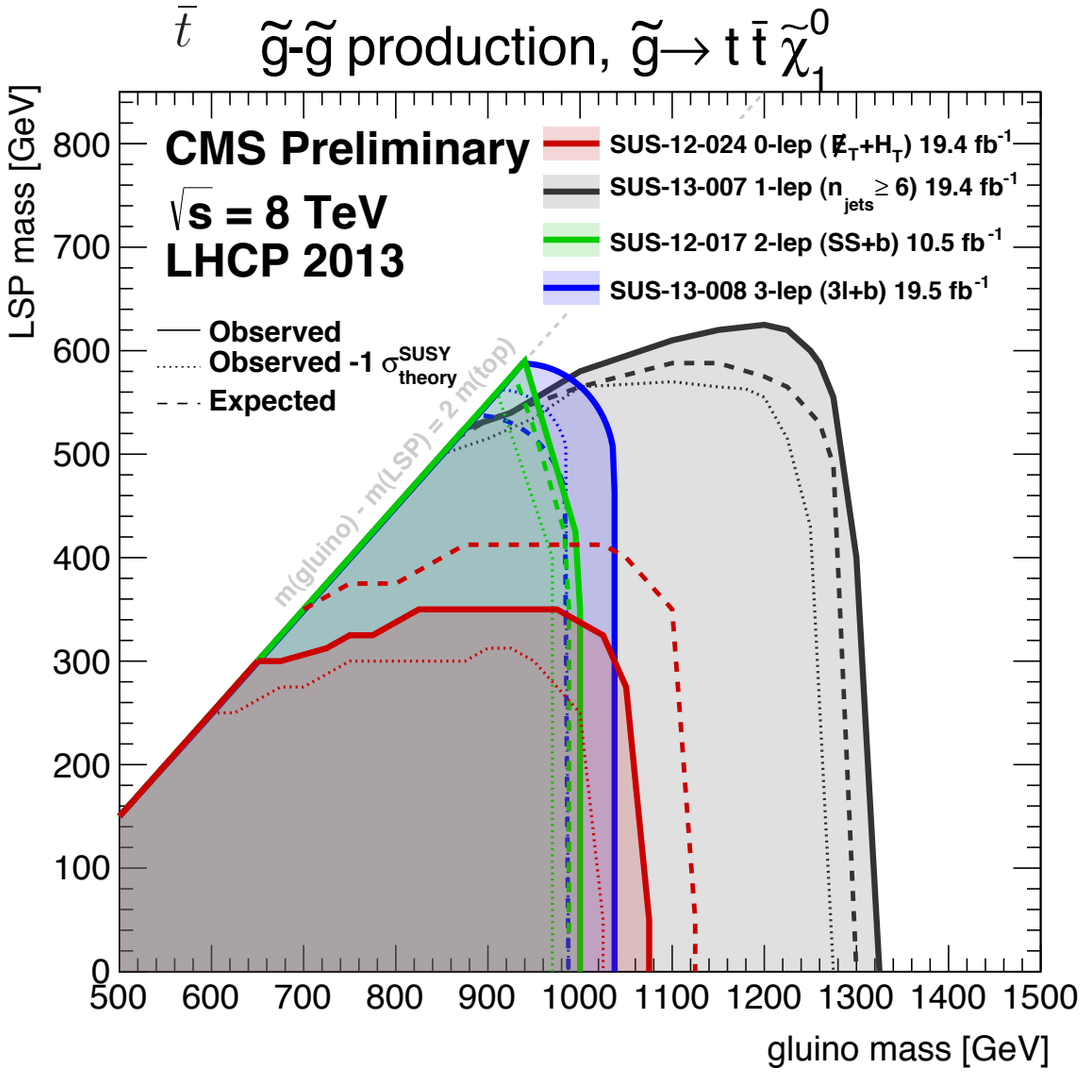




Gluino Searches in Natural SUSY



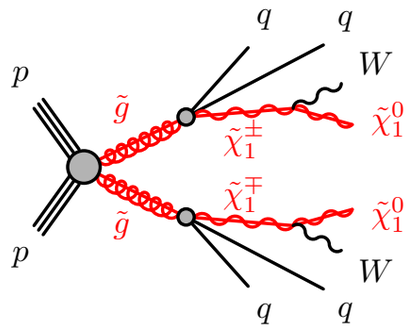


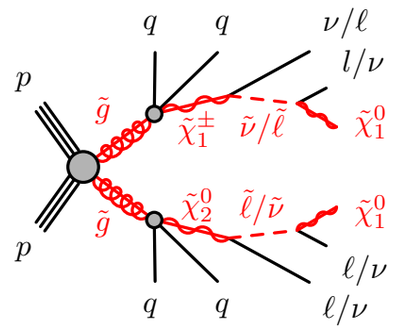


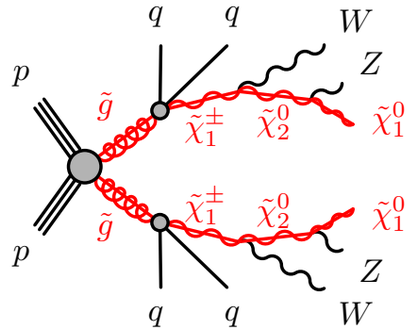
One Analysis Can Constrain Many Models

ATLAS-CONF-2013-062

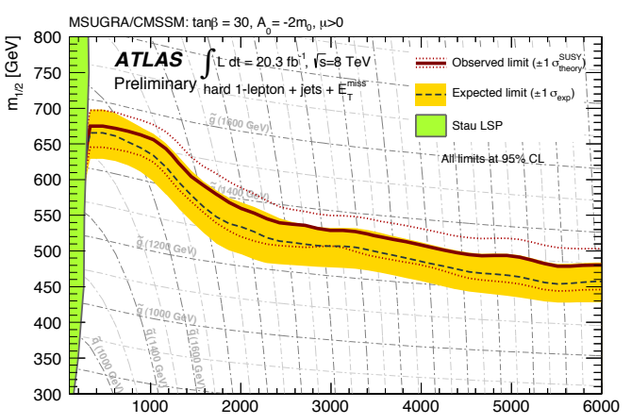
- Lepton+MET+Jet analysis
- Event selection categories
  - hard single lepton
  - soft single lepton
  - soft dimuon
  - soft single lepton + 1 b-jet
  - soft single lepton + 2 b-jets

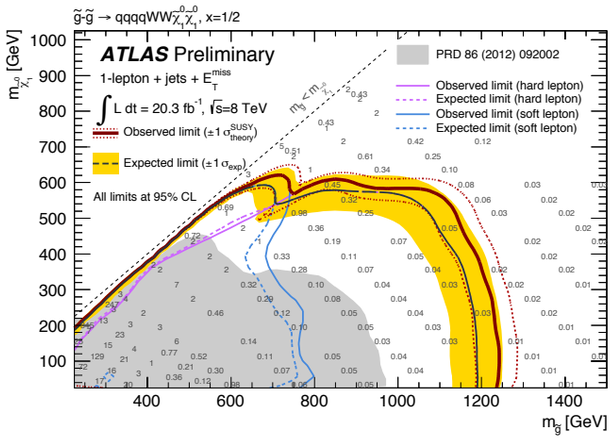


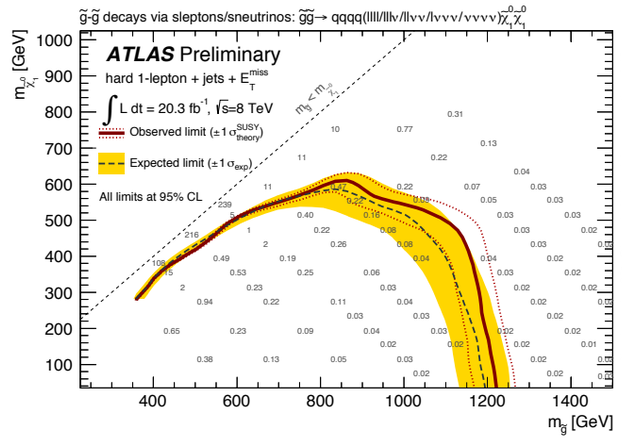


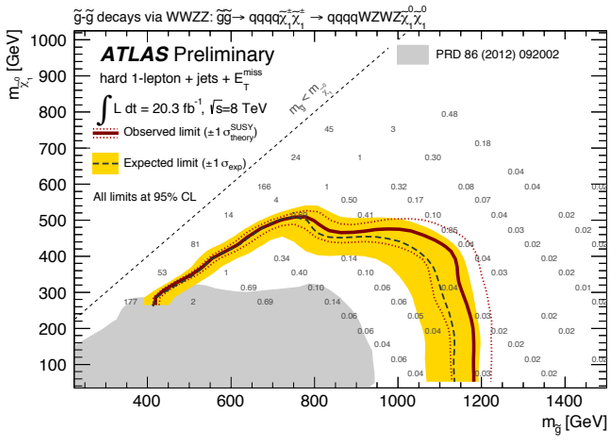


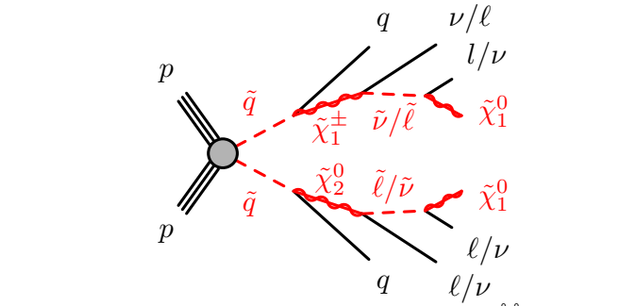
cMSSM

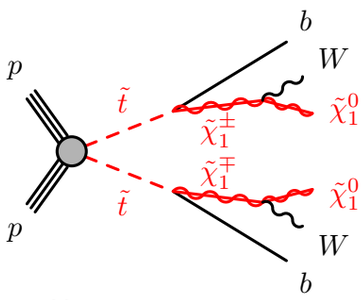


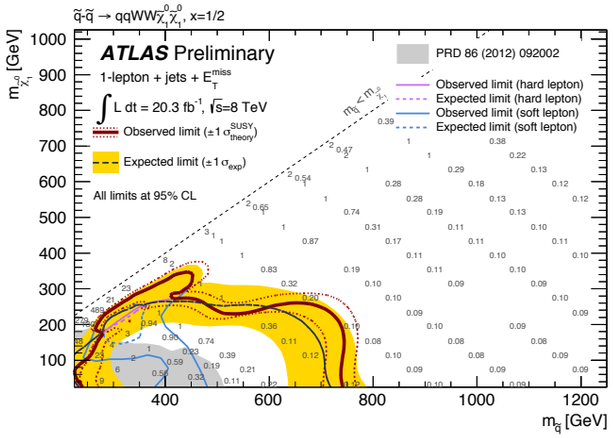


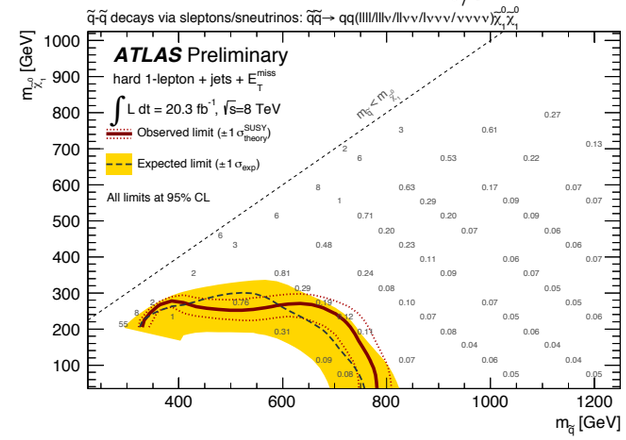


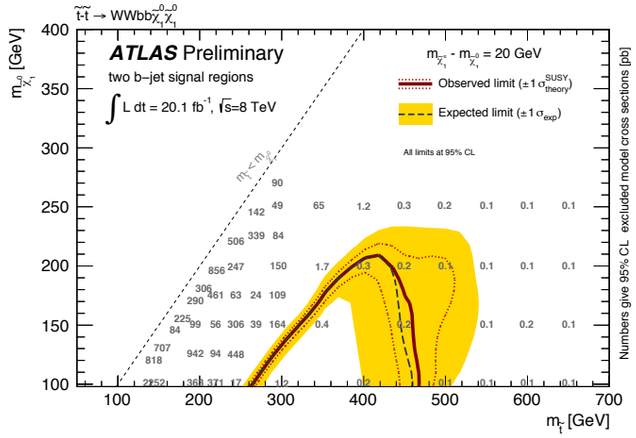












Search for Generic SUSY: pMSSM approach

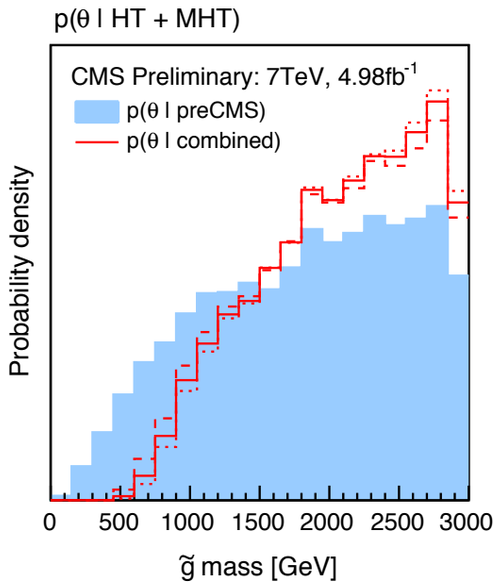
- SMS is a nice approach
  - easy interpretation of results by experiments
  - give clear idea about experimental sensitivity
- However it has limitations
  - external re-interpretations is usually not straightforward
  - can hardly represent spectra with more than 3 parameters

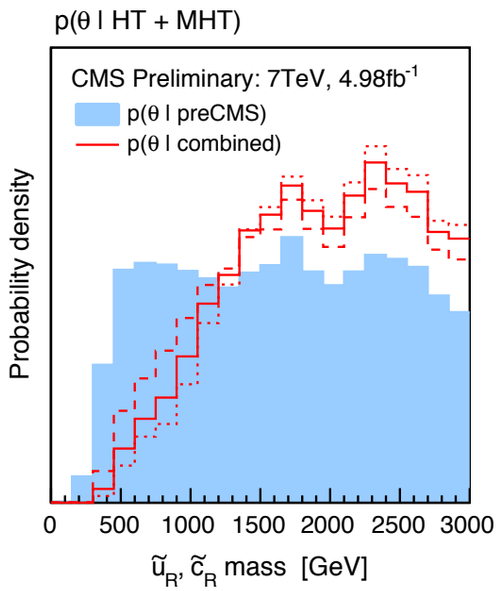
- Reference physics models now are MSSM (or NMSSM)
  - 100+ parameters, hard to even sample
- Consider “phenomenological” RPC MSSM a.k.a. **pMSSM** model
  - no new sources of CP violation
  - no flavor changing neutral currents
  - degeneracy between 1st and 2nd generation
- 19-D parameter space at EWK scale
  - M_1, M_2, and M_3 - ewkino masses
  - tanβ, μ, m_A
  - 10 sfermion mass parameters
  - A_t, A_b, and A_τ
- **captures most of the phenomenological features of the R-parity conserving MSSM**

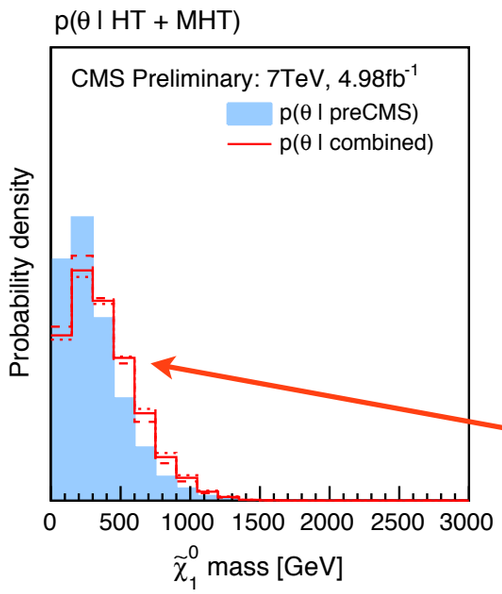
pMSSM: Sampling of Model Points

- This is essentially a Bayesian approach
- Sample parameters in 19-D cube
  - sparticle masses can go as high as ~3 TeV
- Take into account “pre-LHC” constraints
  - flavor physics observables
    - m_t, m_b, m_h, α_s, Δa_μ
    - sparticle mass limits from LEP
- Sample set of models accounting for pre-LHC prior
  - 7300 models in this analysis
- Apply constraints imposed by several CMS analyses
  - obtain posterior distribution for considered set of models

LHC Influence on pMSSM Parameters



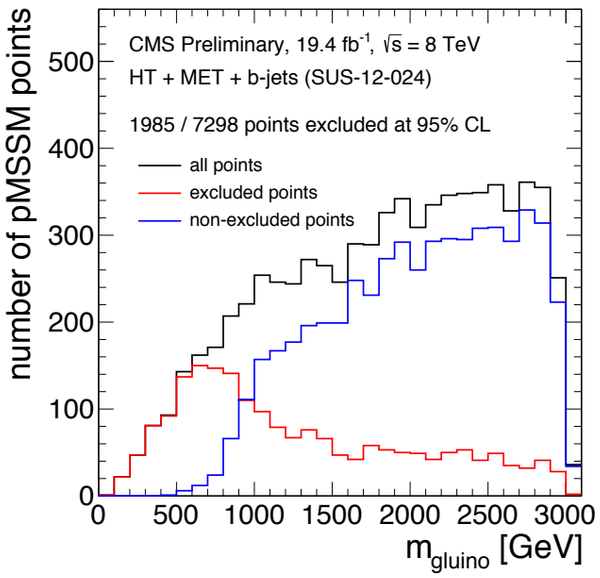


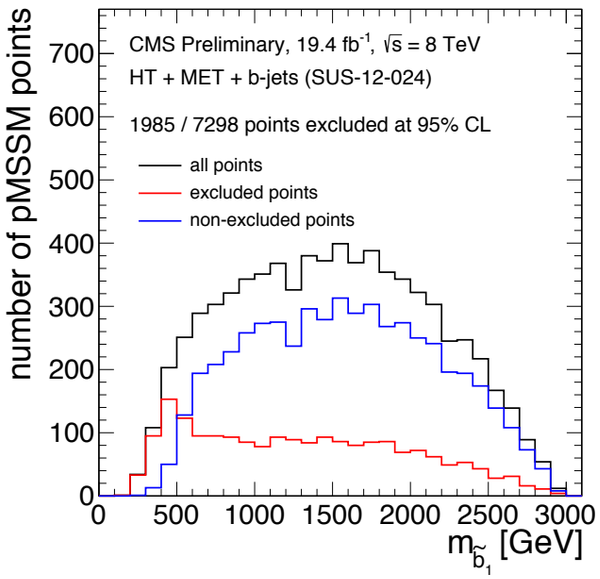


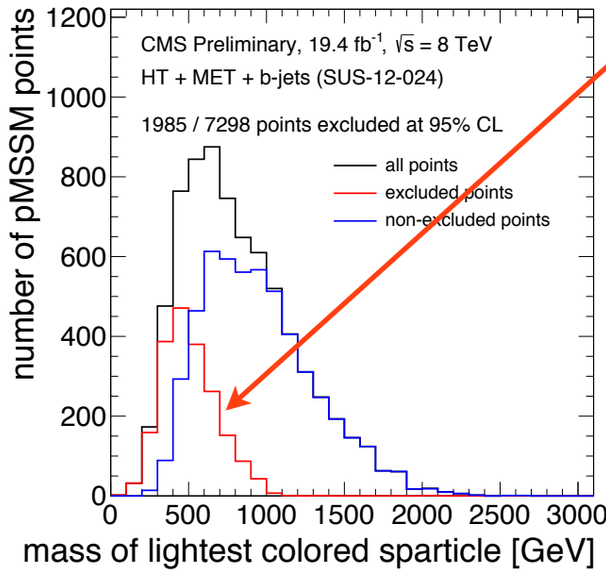
5/fb @ 7 TeV
CMS SUS-12-030

Bayesian posteriors

Excluded Models





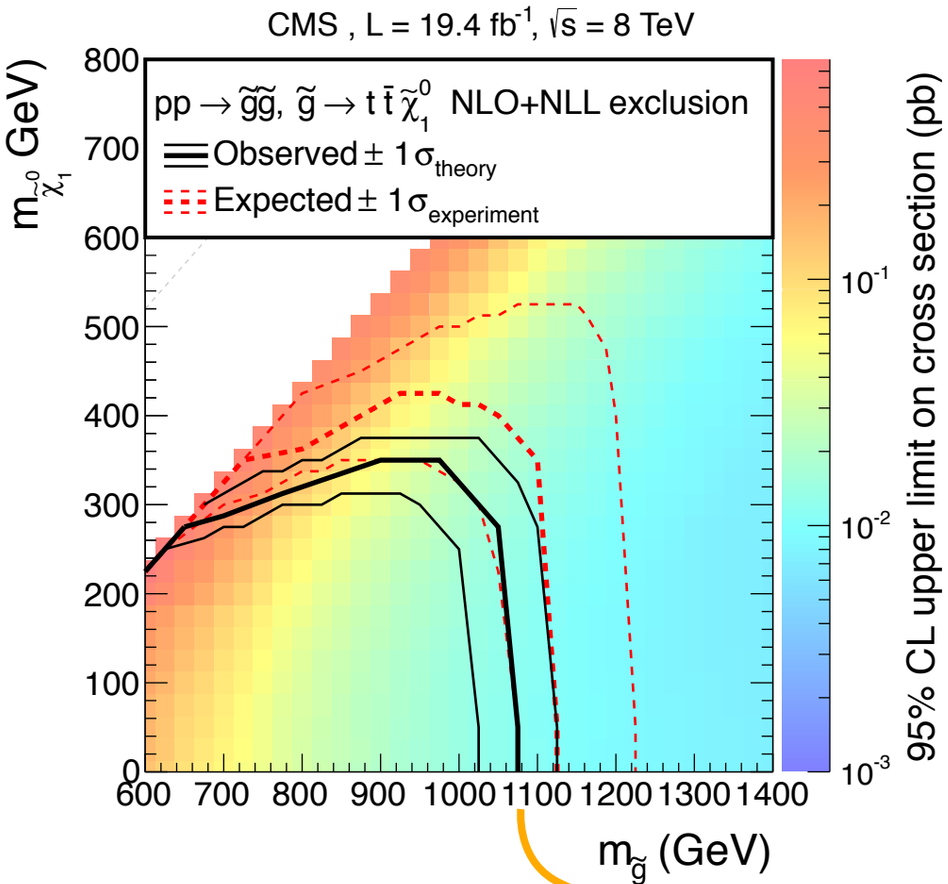


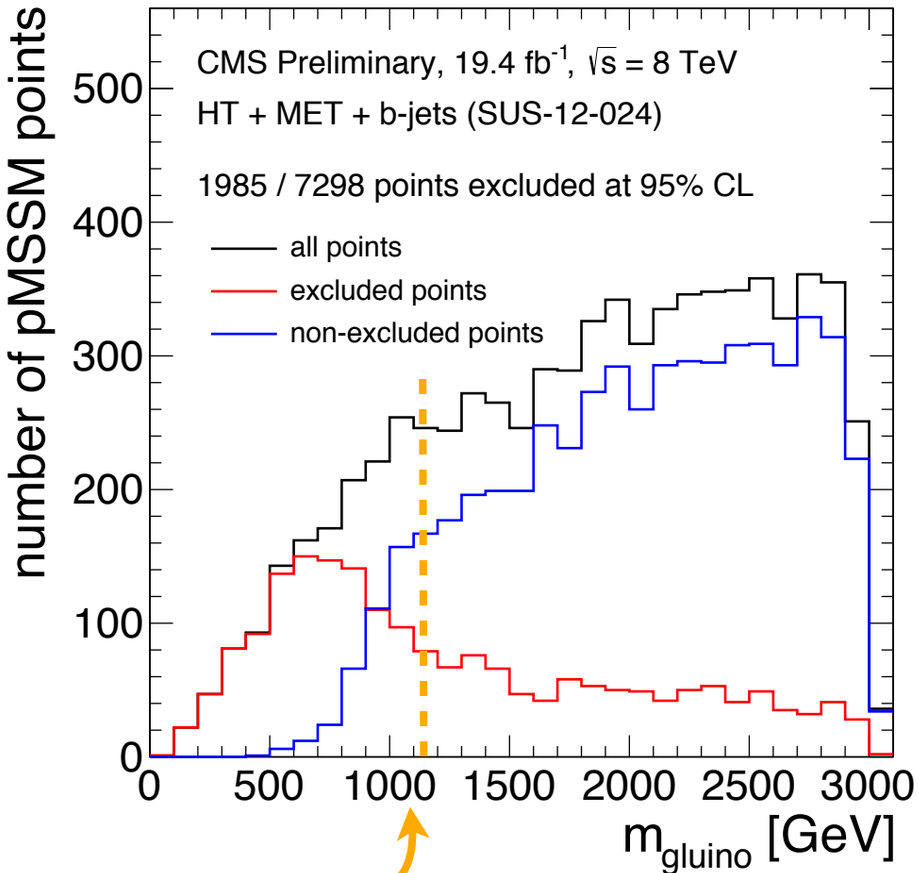
20/fb @ 8 TeV
CMS SUS-12-024

- LHC does make a difference!
- No significant holes in SUSY analyses planning found
- Those not excluded models with high enough cross section are mostly:
  - ewkino production with degenerated ewkino
  - squark production with low mass splitting

SMS vs pMSSM

20/fb @ 8 TeV: SUS-12-024

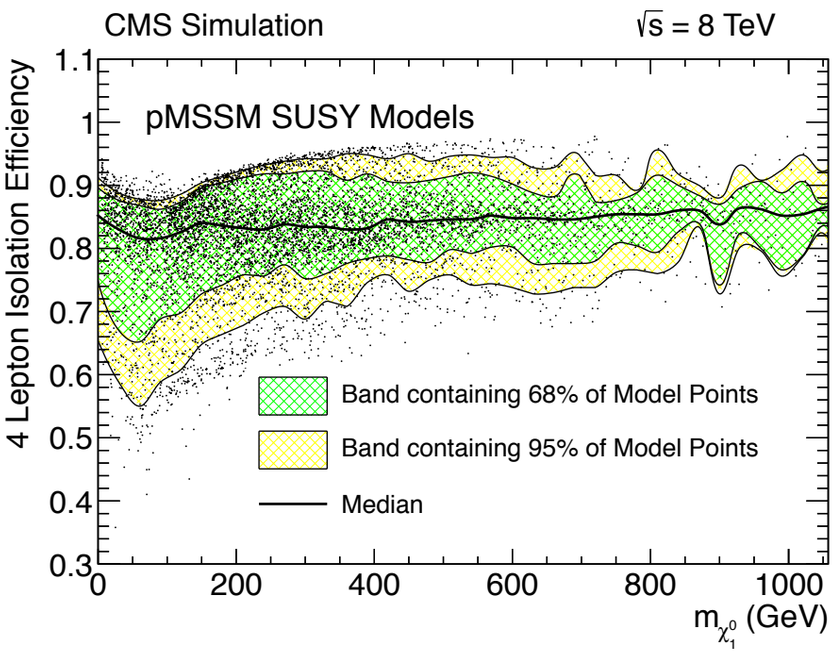


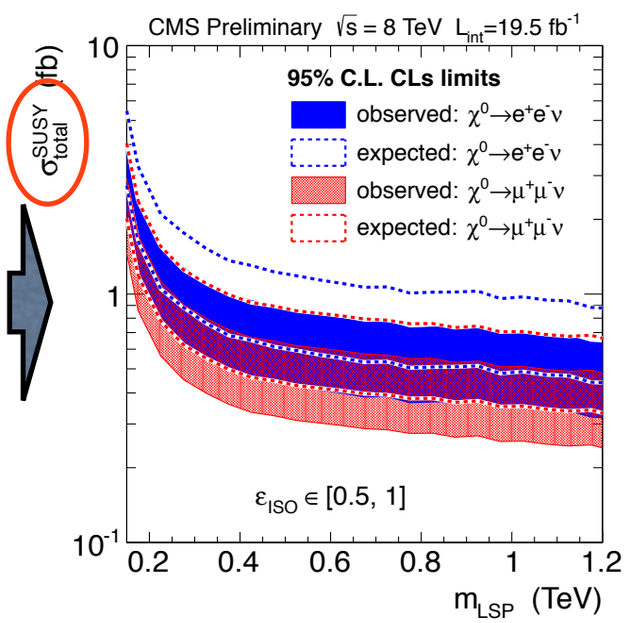


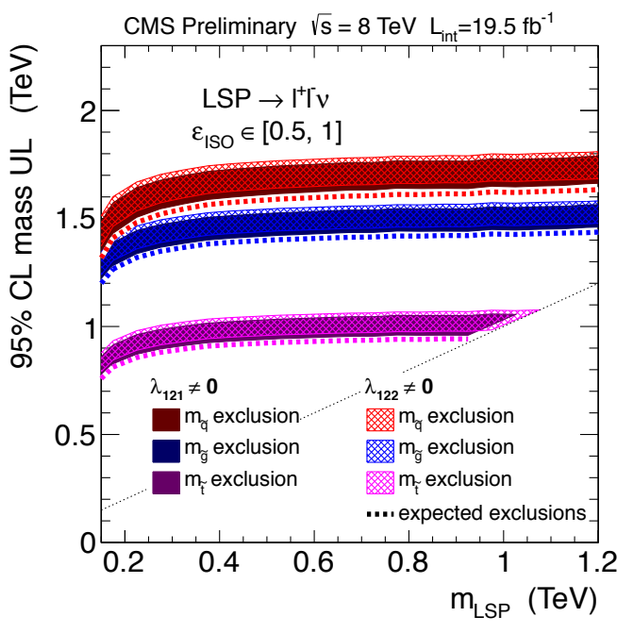
- Pretty close results, but...
  - ... take SMS results with a grain of salt

Model Independent SUSY Analyses

- pMSSM sampling helps to obtain generic results
- CMS SUS-13-010: RPV SUSY search in multileptons
- If leptonic RPV term λ≠0, LSP is unstable: $\chi^0 \rightarrow \ell\ell\nu$
  - 4 high-p_T charged leptons in every SUSY event
    - very clean signature after ZZ production suppression
    - efficiency depends from LSP mass and isolation efficiency
      - isolation efficiency depends from the occupancy of the SUSY event
        - how much?
    - Use pMSSM set as a generic SUSY sample and bracket the efficiency to [0.5, 1]
    - Convert observation to total SUSY production cross section
  - Model independent result in assumption that pMSSM does sample generic set of SUSY models







Conclusions

- Comprehensive physics program for SUSY search at Run-1 LHC is converging
  - the most of the accessible parameter space is systematically scanned
  - covering compressed spectra under way
    - more sophisticated analyses
      - using parked (collected but unprocessed in-line) data
- Different approaches of presenting result to the HEP community
  - are we doing well?
- Looking forward to another 2 orders of magnitude in sensitivity expected in LHC 14 TeV run

can not resist to share David Stuart's summary: