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# Status of RPC SUSY Searches at the LHC

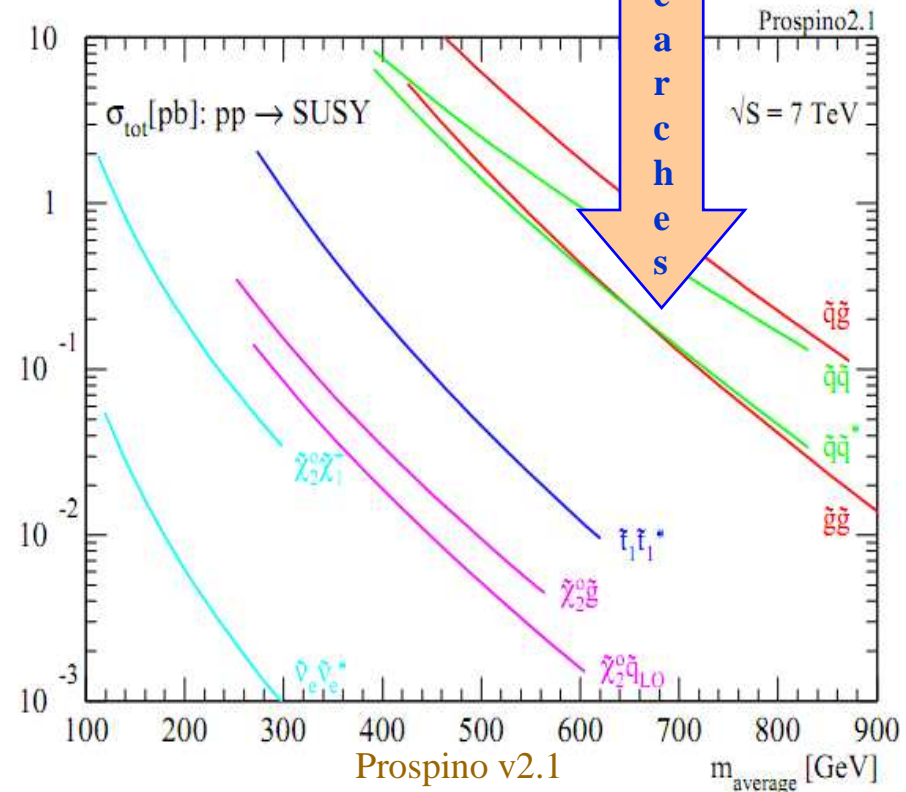
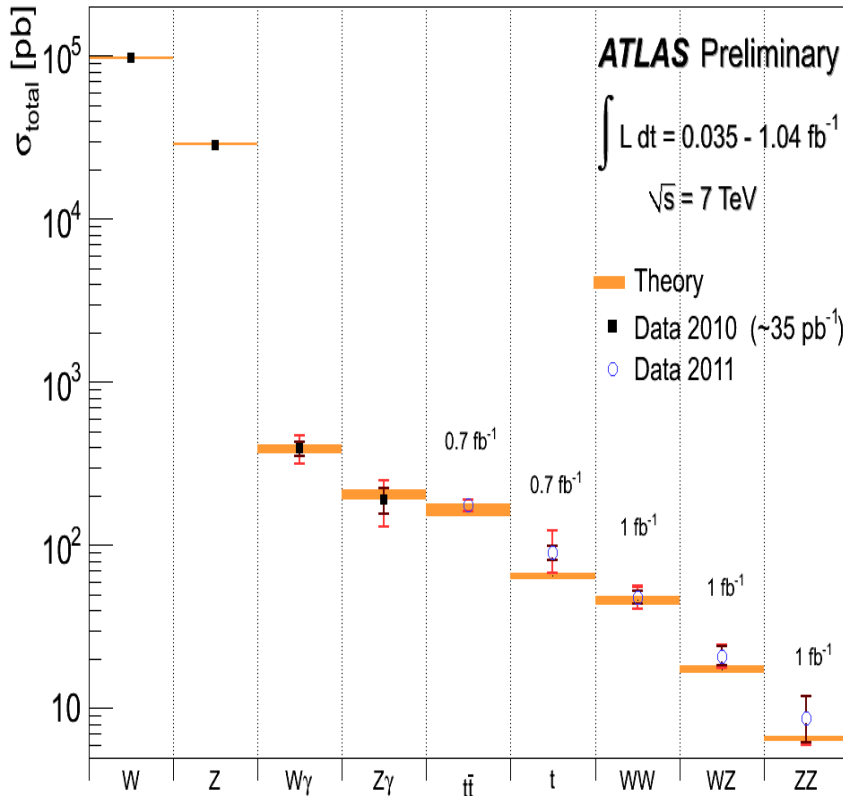
As usual LHC sensitivity to SUSY is limited:

- mainly by the CoM energy
- secondly by the L

=> Firstly sensitive to SUSY-QCD

$$\sigma_{LO}(p+p \rightarrow \tilde{q} + \tilde{g} / \tilde{q} + \tilde{q} / \tilde{g} + \tilde{g}) \sim \alpha_s^2$$

with large  $K = \frac{\sigma_{NLO}}{\sigma_{LO}}$



NB: all S and B are normalized at NLO QCD at least  
 Data-driven estimates of several background processes



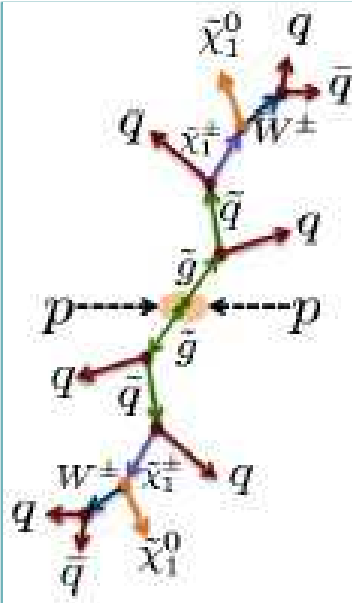
## Inclusive Topologies

- 0-lep+jets+mET
  - with explicit e/ $\mu$  veto
- 0-lep+b-jets+mET
- 1-lep+jets+mET
- 1-lep+b-jet+mET
- 2-lep (SS)+jets+mET
- 2-lep (OS)+jets+mET
- 3-lep+mET
- 4-lep+mET

## Trigger: Examples

- ATLAS:
  - j75+mET45 (@ EM Scale)
    - pT > 130 & 130 GeV (offline, JES)
  - 2 $\gamma$ +mET20
  - ...
- CMS:
  - 1e: pT > 65 GeV
  - 1 $\mu$ : pT > 17 GeV
  - 2 $\mu$ : pT > 13 & 7 GeV
  - 2e: pT > 17 & 8 GeV
  - 1e+1 $\mu$ : pT > 17 & 8 GeV
  - ...

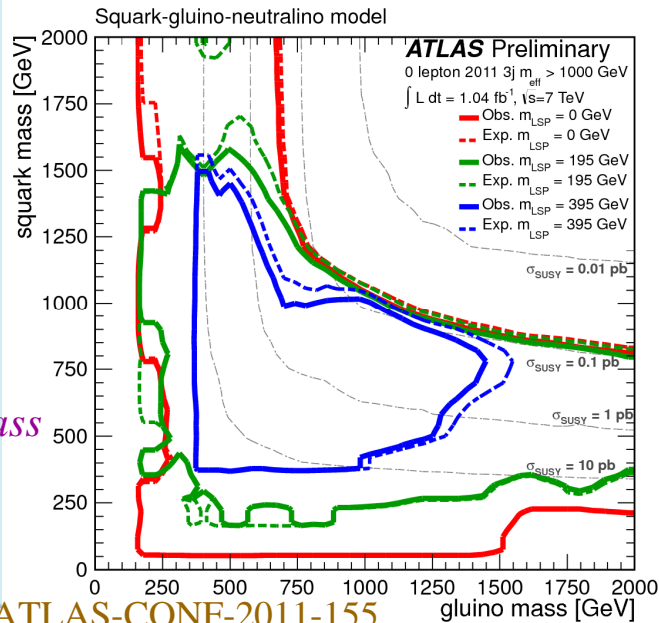
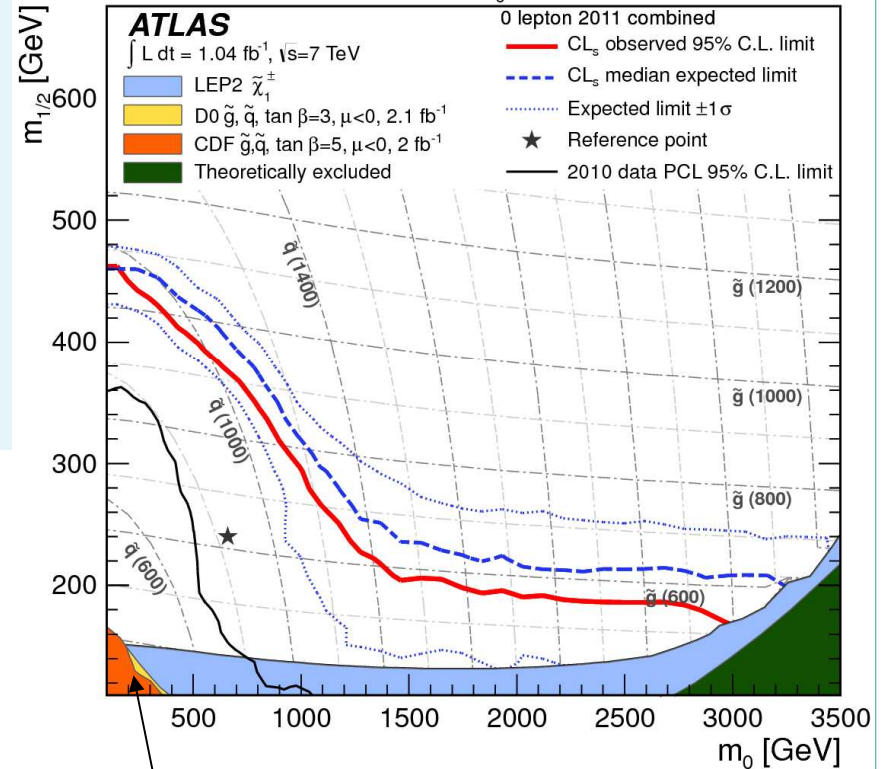
$0 \ell^\pm + \text{jets} + E_T$



$0 \ell^\pm + 3 \text{jets} + E_T$

$0 \ell^\pm + 6 \text{jets} + E_T$

MSUGRA/CMSSM:  $\tan\beta = 10, A_0 = 0, \mu > 0$



Varying LSP mass

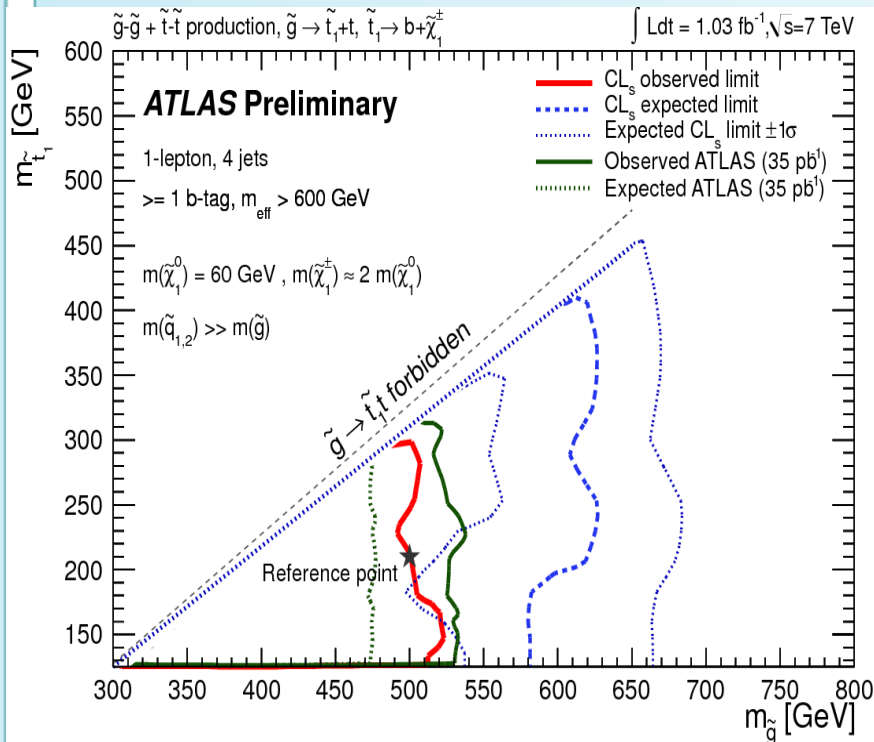
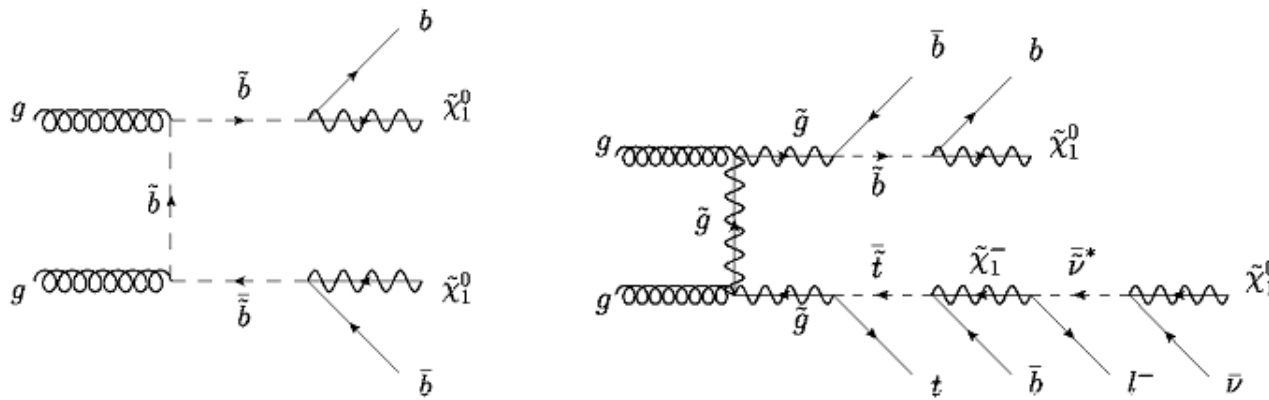
ATLAS-CONF-2011-155

arXiv:1110.2299

accept'd JHEP

TEVATRON limits by far superseded

# 1 $\ell^\pm$ + b - jets + jets + $E_T$



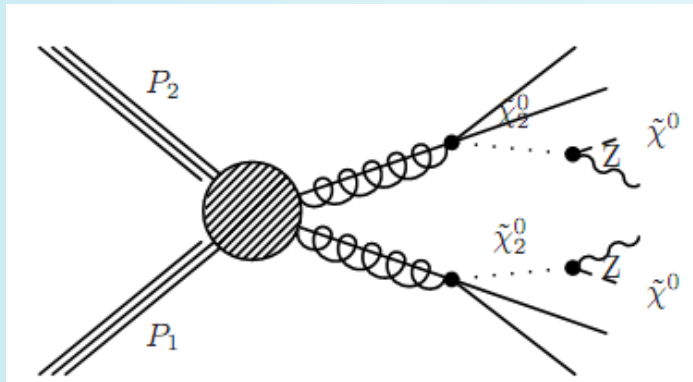
Hypotheses:

$$\begin{cases} m_{\tilde{q}} > m_{\tilde{g}} \\ m_{\tilde{\chi}_1^\pm} \sim 2 \cdot m_{\tilde{\chi}_1^0} \\ \tilde{\chi}_1^\pm \rightarrow W^\pm + \tilde{\chi}_1^0 \end{cases}$$

ATLAS-CONF-2011-130

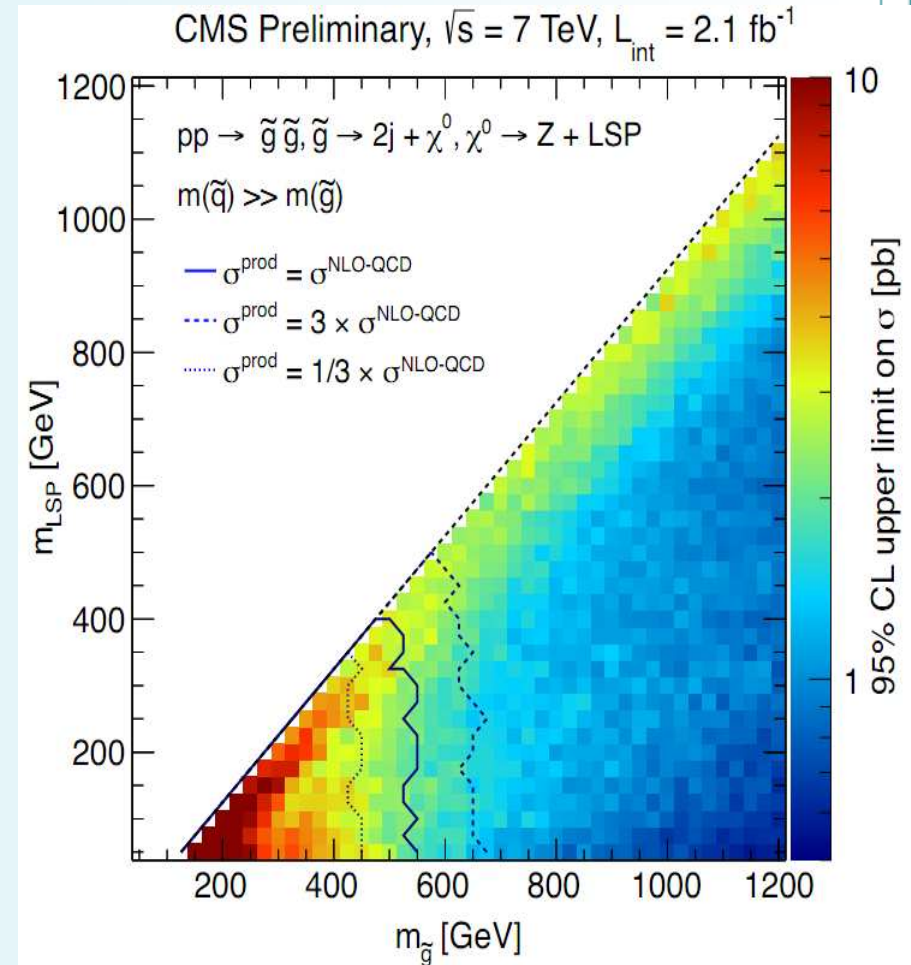
# $2 \ell^\pm (OS) + \text{jets} + \cancel{E}_T$

Simplified Model:  
« On-shell Z »



$$\tilde{g} \rightarrow q + \bar{q} + \tilde{\chi}_2^0$$

$$\tilde{\chi}_2^0 \rightarrow Z + \tilde{\chi}_1^0$$



CMS-PAS-SUS-11-019

# 3 or 4 $\ell^\pm + E_T$

Explicit veto on Z mass window

## CMSSM

Hypotheses:

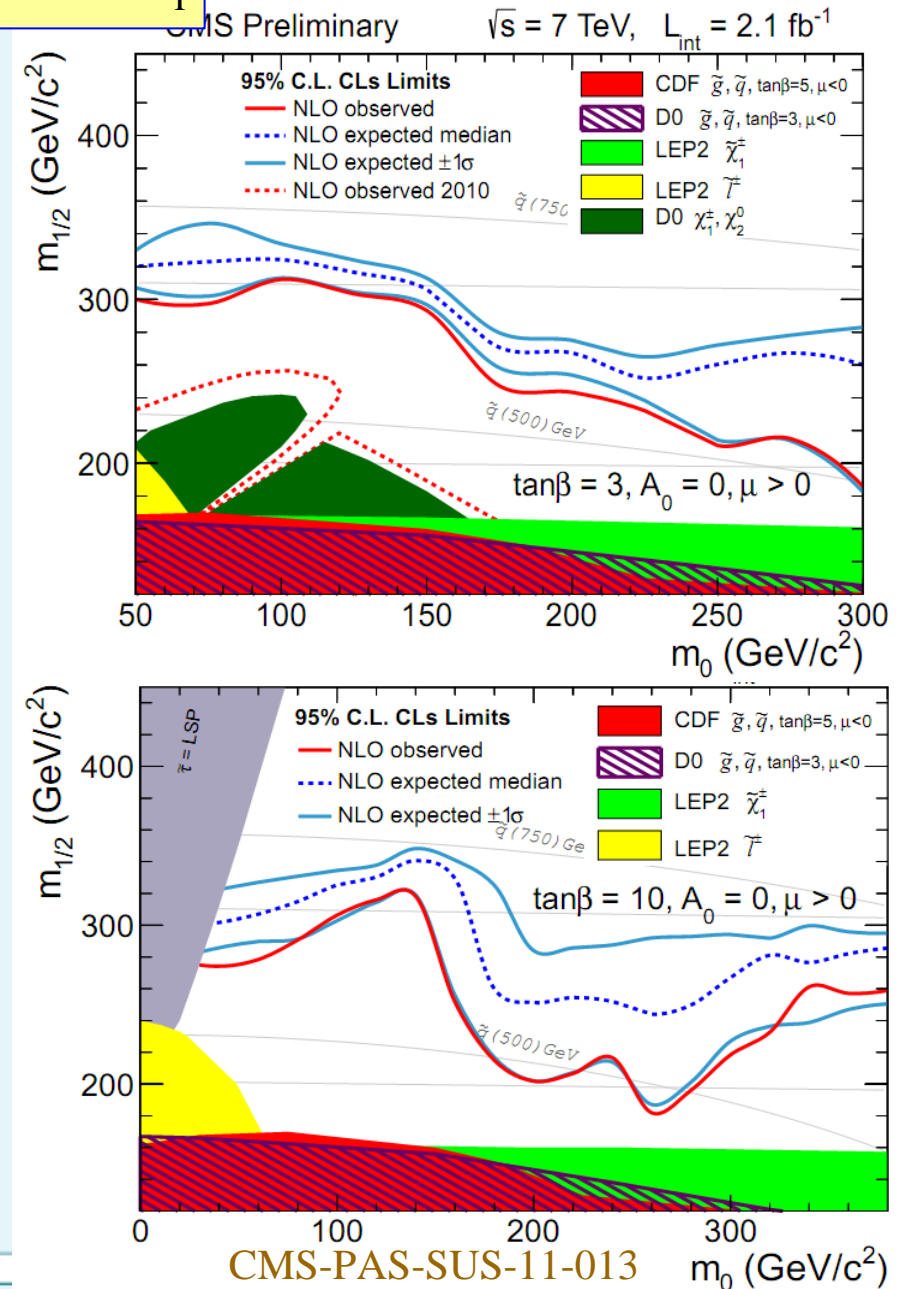
- Slepton NLSP
- LSP:  $\tilde{\chi}_1^0$

## GMSM

Hypotheses:

- Selectron<sub>L</sub> smuon<sub>L</sub> co-NLSP
- LSP:

Gauge Mediation w/ Split Messenger:  
arXiv:0008070





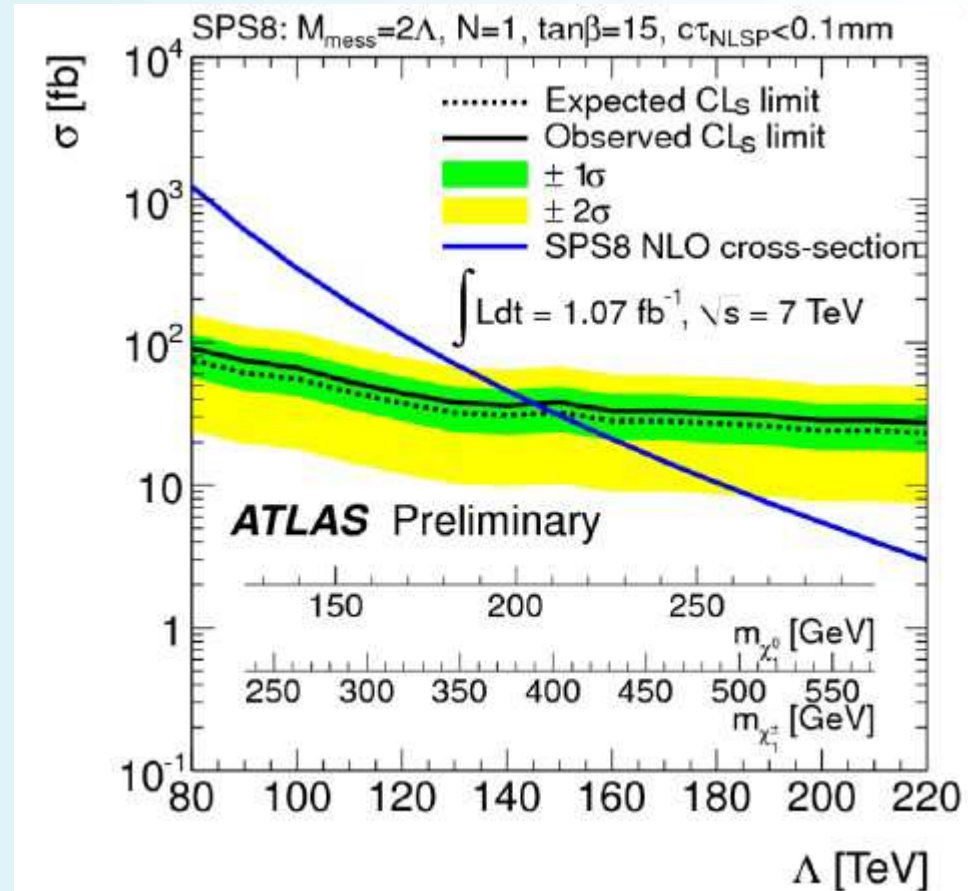
$$2\gamma + \mathbb{E}_T$$

### Gravitino LSP:

- in mGMSB
  - SPS8 slope
- in GGM
  - with bino-like  $\tilde{\chi}_1^0$

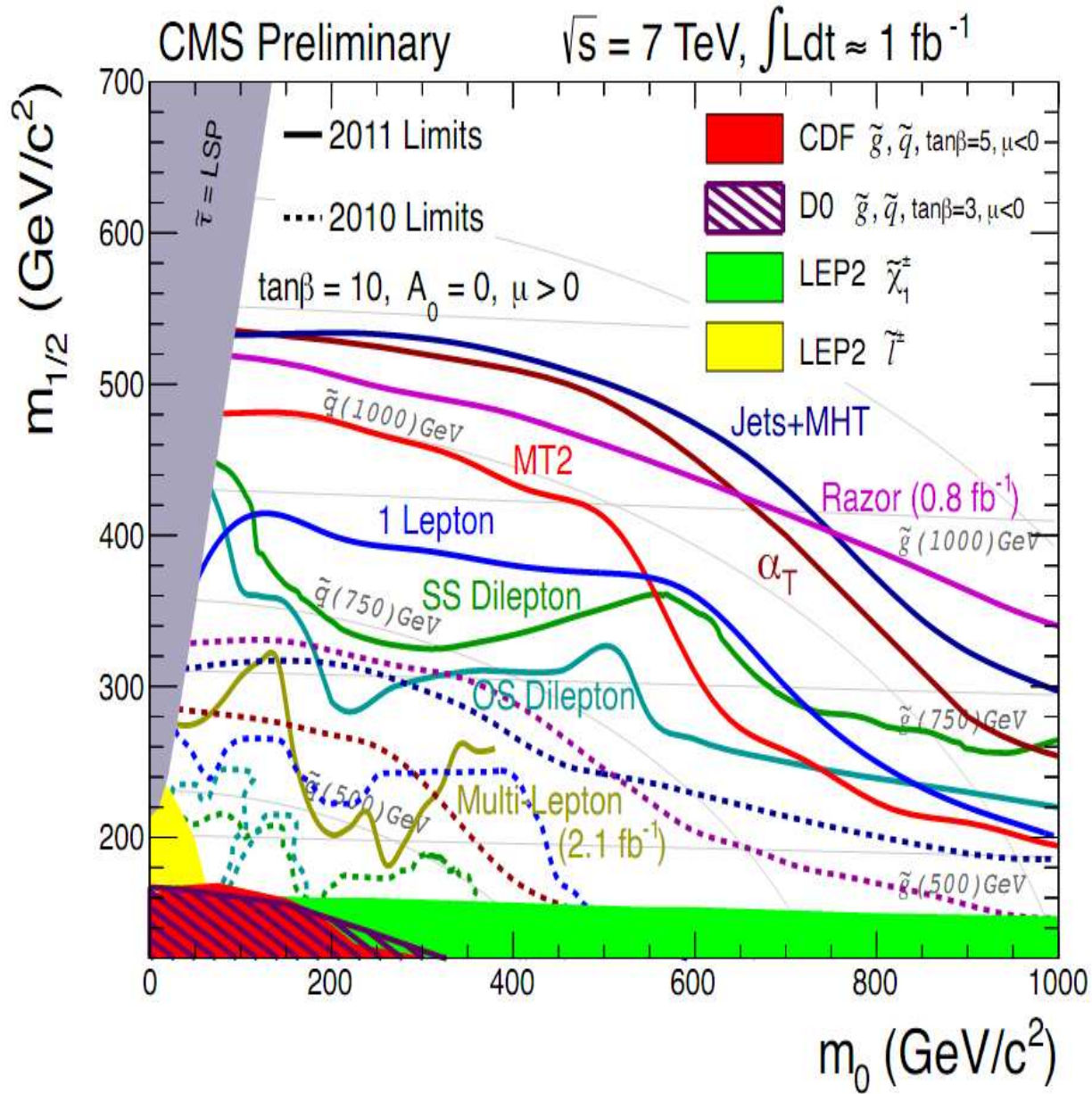
### Hypotheses:

- NLSP:  $\tilde{\chi}_1^0$
- Ends of decay chains:
 
$$\tilde{\chi}_1^0 \rightarrow \gamma + \tilde{G}$$
- Prompt NLSP decay

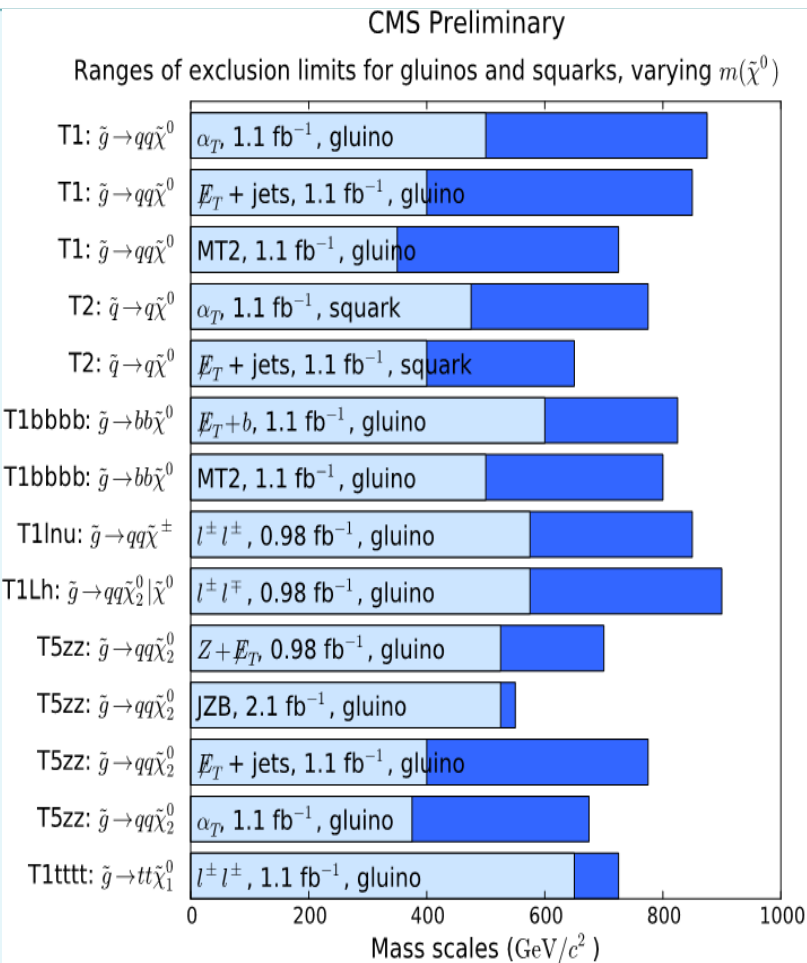
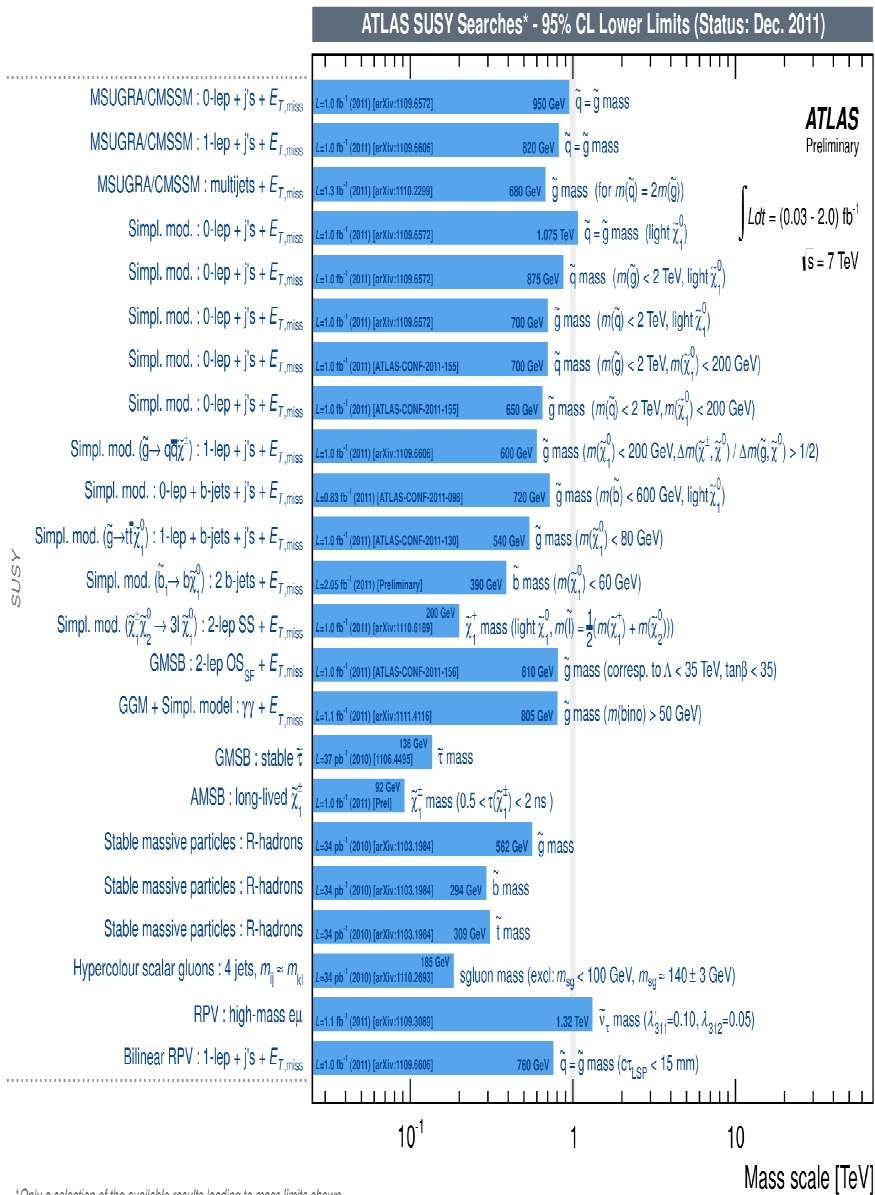


Most stringent limits to date

# Summary (1)



# Summary (2)



For limits on  $m(\tilde{g}), m(\tilde{q}) > m(\tilde{g})$  (and vice versa),  $\sigma^{\text{prod}} = \sigma^{\text{NLO-QCD}}$ .  
 $m(\tilde{\chi}^\pm), m(\tilde{\chi}_2^0) \equiv \frac{m(\tilde{g}) + m(\tilde{\chi}^0)}{2}$ .  
 $m(\tilde{\chi}^0)$  is varied from 0 GeV/c<sup>2</sup> (dark blue) to  $m(\tilde{g}) - 200$  GeV/c<sup>2</sup> (light blue).

## Varying LSP mass

# $B_s \rightarrow \mu^+ \mu^-$

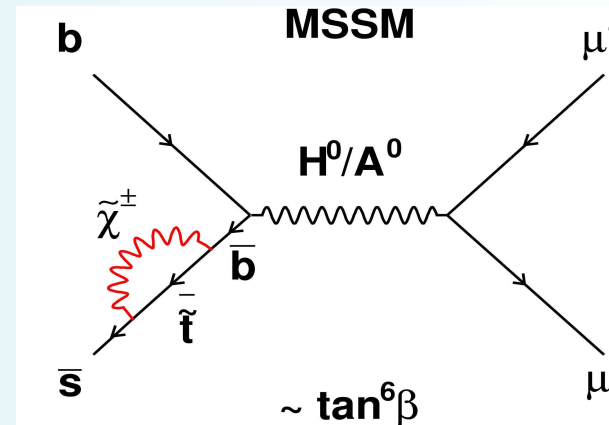
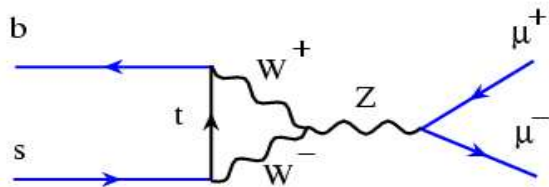
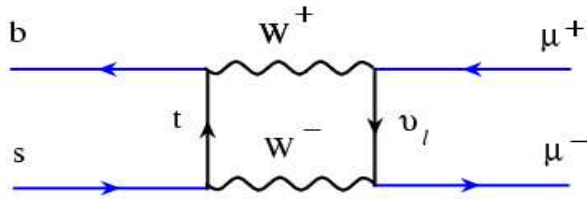
## SM expectation:

$$\text{BR}(B_s \rightarrow \mu^+ \mu^-) = (3.2 \pm 0.2) \times 10^{-9}$$

$$\text{BR}(B_d \rightarrow \mu^+ \mu^-) = (1.0 \pm 0.5) \times 10^{-10}$$

(FCNC suppression and helicity suppressed)

[A.J.Buras, arXiv:1012.1447]



LHCb  $0.3 \text{ fb}^{-1}$  (2010+2011)

$$\text{BR}(B_s \rightarrow \mu^+ \mu^-) < 1.5 (1.2) \times 10^{-8} \text{ @ } 95\% (90\%) \text{ C.L.}$$

LHCb-CONF-2011-037

CMS result using  $1.14 \text{ fb}^{-1}$  CMS-BPH-11-002

Expected limit  $< 1.8 \times 10^{-8}$  @ 95% C.L.

Observed limit  $< 1.9 \times 10^{-8}$  @ 95% C.L.

LHCb + CMS

$$\text{BR}(B_s \rightarrow \mu^+ \mu^-) < 1.08 (0.9) \times 10^{-8} \text{ @ } 95\% (90\%) \text{ C.L.}$$

LHCb-CONF-2011-047, CMS-PAS-BPH-11-019

## SUSY Global Fits (1)

- MasterCode: frequentist analysis

$\chi^2$  calculation:

→ global  $\chi^2$  likelihood function

combines all theoretical predictions with experimental constraints:

$$\chi^2 = \sum_i^N \frac{(C_i - P_i)^2}{\sigma(C_i)^2 + \sigma(P_i)^2} + \sum_i^M \frac{(f_{SM_i}^{obs} - f_{SM_i}^{fit})^2}{\sigma(f_{SM_i}^{fit})^2}$$

$$+ \chi^2(b \rightarrow s\gamma) \quad + \chi^2(g_\mu - 2) \quad + \chi^2(\Omega h^2) \quad + \chi^2(m_h)$$

$$+ \chi^2(\text{BR}(B_s \rightarrow \mu\mu)) + \chi^2(\text{LHC}) \quad + \chi^2(\text{XENON100})$$

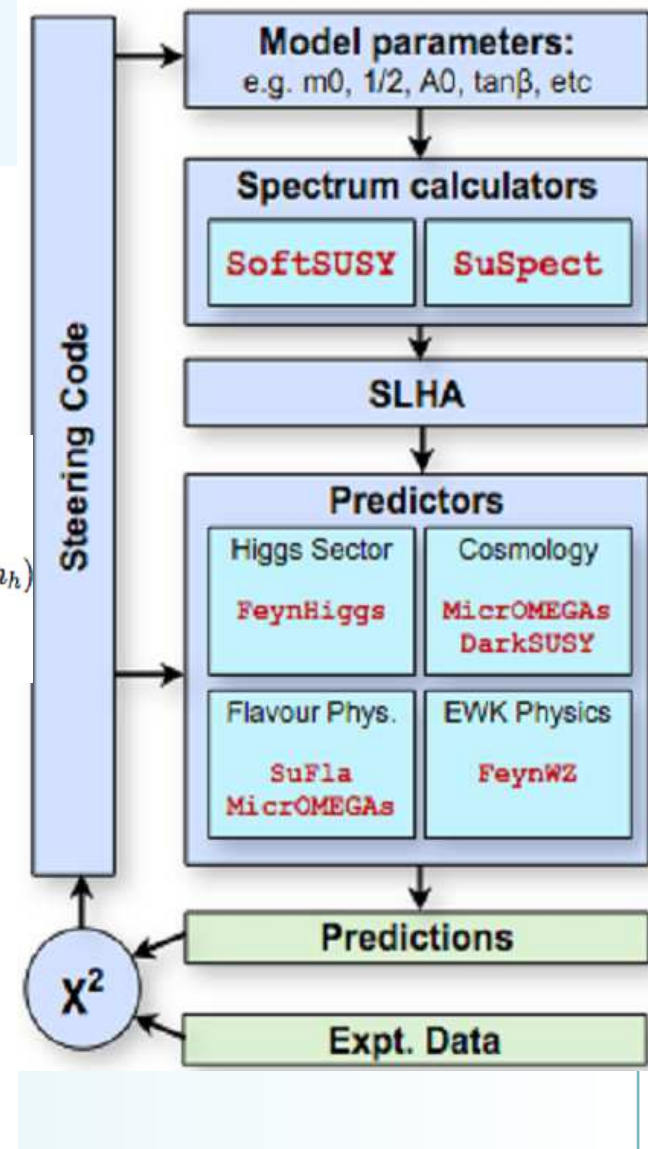
$N$ : number of observables studied

$M$ : SM parameters:  $\Delta\alpha_{had}, m_t, M_Z$

$C_i$ : experimentally measured value (constraint)

$P_i$ : MSSM parameter-dependent prediction for the corresponding constraint

Assumption: measurements are uncorrelated - fulfilled to a high degree



## SUSY Global Fits (2)

- Recent Data Include:
  - 2010: Xenon 100, ATLAS & CMS ( $\sim 35 \text{ pb}^{-1}/\text{exp}$ )
  - 2011: ATLAS & CMS ( $\sim 1 \text{ fb}^{-1}/\text{exp}$ ), LHCb ( $\sim 0.3 \text{ fb}^{-1}$ )
- Ref: [arXiv:1110.3568v1](https://arxiv.org/abs/1110.3568v1)

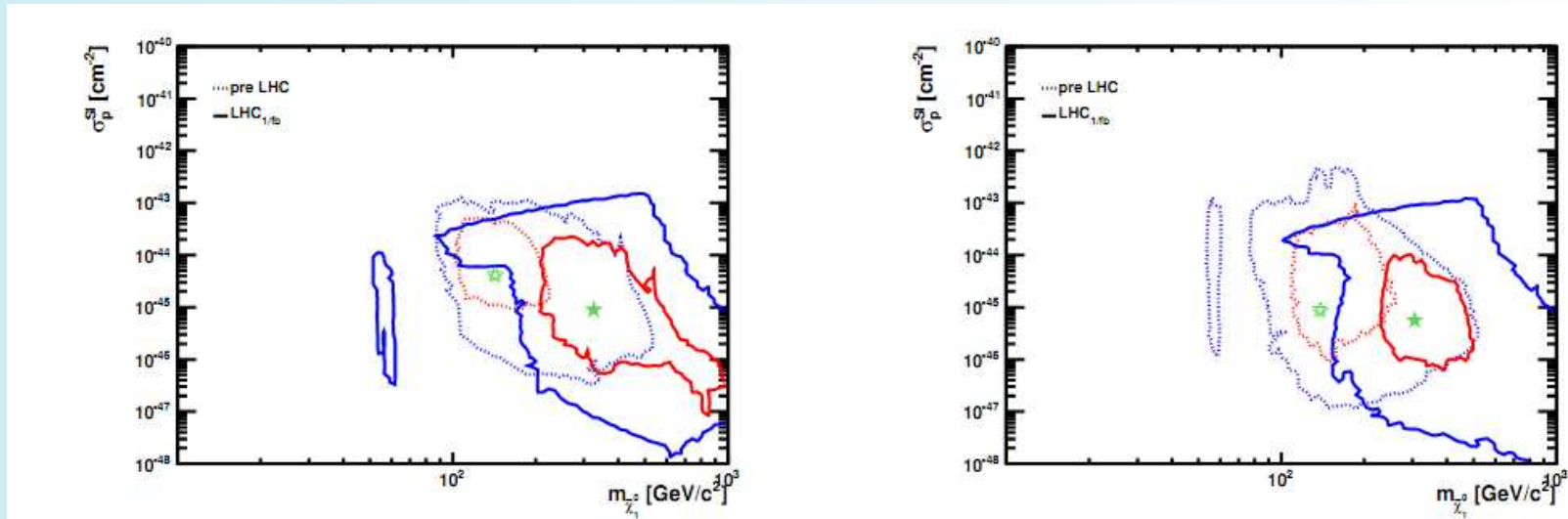


Figure 14. The 68% and 95% CL contours (red and blue, respectively) in the CMSSM (left) and the NUHM1 (right). The solid lines are for fits including the XENON100 [25] and  $LHC_{1/\text{fb}}$  data, whereas the dotted lines include only the pre-LHC data [5].

## Conclusions

- About 1-2 fb<sup>-1</sup> of ATLAS & CMS data analyzed
- No excess observed => improved exclusion limits
- If it exists:
  - SUSY mass spectrum relatively heavy or compressed
  - Preferred neutralino<sub>1</sub> mass around 300 GeV (CMSSM)
- Each experiment has 5 fb<sup>-1</sup> on tape
- More results at winter 2012 conferences

## Prospects

- CoM Energy: 2012 at 7 or 8 TeV
- L up to 15 (~13) fb<sup>-1</sup> per experiment @ 7 (8) TeV
- Boost sensitivities of direct SUSY searches at LHC
  
- Additional New Constraints:
  - Higgs,
  - B<sub>s</sub> → μμ,
  - CdM,...

# BACK-UP



## Models:

- Gravity Mediated SUSY Breaking:

- CMSSM
- mSUGRA

- Gauge Mediated SUSY Breaking:

- mGMSB
- GGM ([hep-ph arXiv:0801.3278](#), [arXiv:0812.3668](#))

- Simplified Models:

- Ref: [arXiv:1105.2838](#)

### Models Covered

		Boundary Conditions
CMSSM	$m_0, m_{1/2}, A_0, \tan(\beta), \text{sign}(\mu)$	Unification +
VCSSM	$m_0, m_{1/2}, A_0, \text{sign}(\mu)$	$B_0 = A_0 + m_0$
MSUGRA	$m_0, m_{1/2}, A_0, \text{sign}(\mu)$	$B_0 = A_0 + m_0; m_0 = m_{3/2}$
NUHM1	$m_0, m_{1/2}, A_0, m_{H_{1,2}}^2, \text{sign}(\mu)$	$m_{1,2} = m_0 + \Delta m_{H_{1,2}}$

$$Q_\alpha |S\rangle = |S \pm 1/2\rangle$$

S=1	S=1/2	S=0
	$\ell^\pm$	$\tilde{\ell}_R^\pm$ $\tilde{\ell}_L^\pm$
	$\tau^\pm$	$\tilde{\tau}_1^\pm$ $\tilde{\tau}_2^\pm$
	$\nu_L$	$\tilde{\nu}_L$
	$q$	$\tilde{q}_R$ $\tilde{q}_L$
	$b$	$\tilde{b}_1$ $\tilde{b}_2$
	$t$	$\tilde{t}_1$ $\tilde{t}_2$
$g$	$\tilde{g}$	
$W^\pm$	$\tilde{\chi}_1^\pm$ $\tilde{\chi}_2^\pm$	$\phi_1^+$ $\phi_2^-$
$\gamma$	$\tilde{\chi}_3^0$ $\tilde{\chi}_4^0$	
$Z$	$\tilde{\chi}_1^0$ $\tilde{\chi}_2^0$	$\phi_1^0$ $\phi_2^0$

• S=2:  $G_{\mu\nu}$       S=3/2:  $\tilde{G}_{\mu\alpha}$

$$M_{\tilde{t}}^2 = \begin{pmatrix} m_{\tilde{t}_L}^2 + m_t^2 & m_t(A_t - \mu/\tan\beta) \\ m_t(A_t - \mu/\tan\beta) & m_{\tilde{t}_R}^2 + m_t^2 \end{pmatrix}$$

$$M_{\tilde{b}}^2 = \begin{pmatrix} m_{\tilde{b}_L}^2 + m_b^2 & m_b(A_b - \mu\tan\beta) \\ m_b(A_b - \mu\tan\beta) & m_{\tilde{b}_R}^2 + m_b^2 \end{pmatrix}$$

R-Parity Conservation (RPC):

- Sparticles pair production
- LSP  $\tilde{\chi}_1^0$  or  $\tilde{G}_{\mu\alpha}$  stable  $\Rightarrow E_T$  signature