# Beyond the SM searches: 'LHC14' prospects

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#### **Present status and BSM**

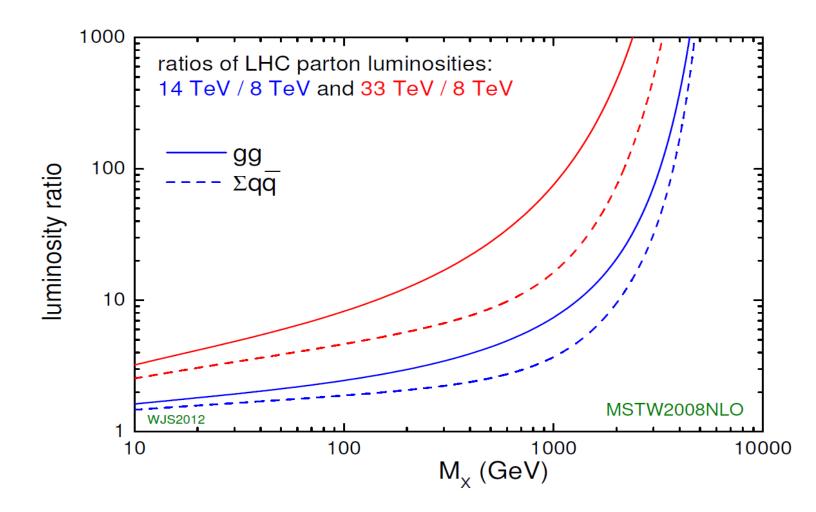
- Let us assume in this talk that the Standard Model is a solid baseline:
  - At least in the sense that we have discovered a particle that matches as long as we could test – the last missing piece of the SM puzzle



So now we are really entering a true BSM phase, exploring new territory. Next discoveries will surely be 'unpredicted' to a higher or lesser extent...

### **Basic picture**

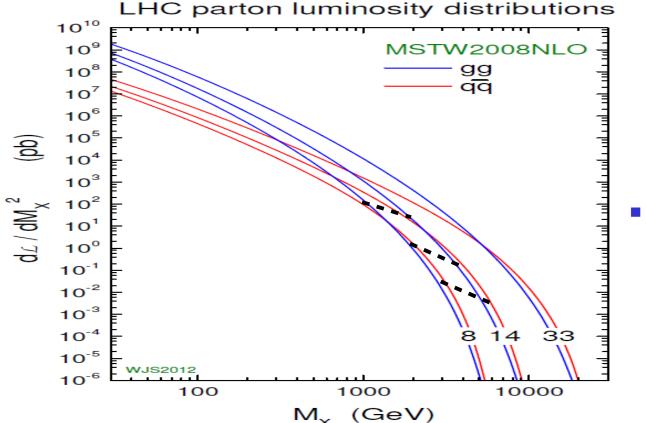
 √s ≈ 13 TeV versus √s ≈ 8 TeV: big step in physics reach at the highest scales/masses



# **Basic picture: highest mass reach**

I3 TeV, L ≈ 300 fb<sup>-1</sup> vs √s ≈ 8 TeV, L ≈ 20 fb<sup>-1</sup>

- > 1.5 times the current center-of-mass energy
- $\approx$  15 times the current integrated luminosity:  $\approx$  4 increase in sensitivity



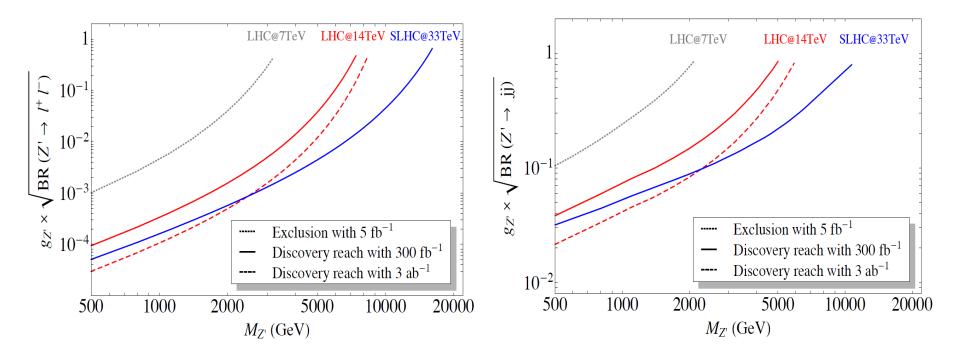
<sup>1</sup> TeV → ≈2 TeV

 Correspondence in mass reach largely independent of the parton composition in the inital state

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## **Other simple estimates**

#### Contribution from the LHCC WG on Exotics tp ESG-Krakow

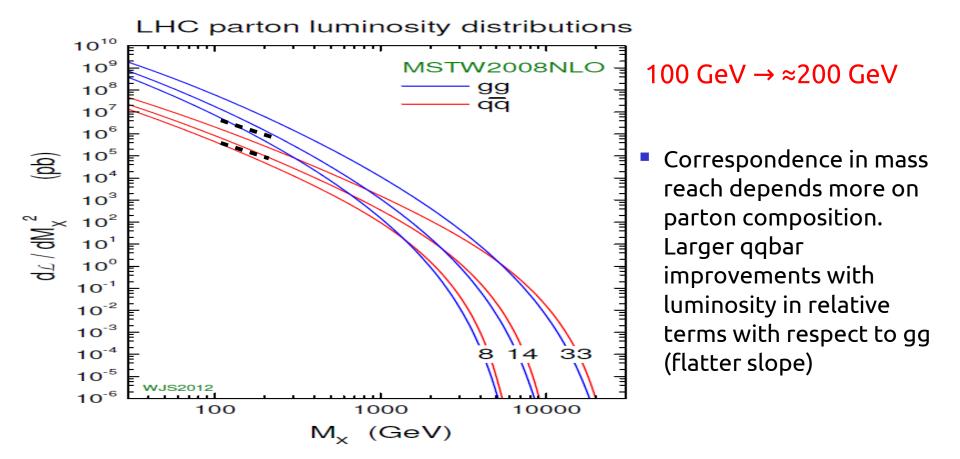


For dilepton and dijet final state resonances: just confirming the previous numbers (1 TeV → ≈2 TeV, 2 TeV → ≈4 TeV, 3 TeV → ≈6 TeV)

#### New physics at lower masses

I3 TeV, L ≈ 300 fb<sup>-1</sup> vs √s ≈ 8 TeV, L ≈ 20 fb<sup>-1</sup>

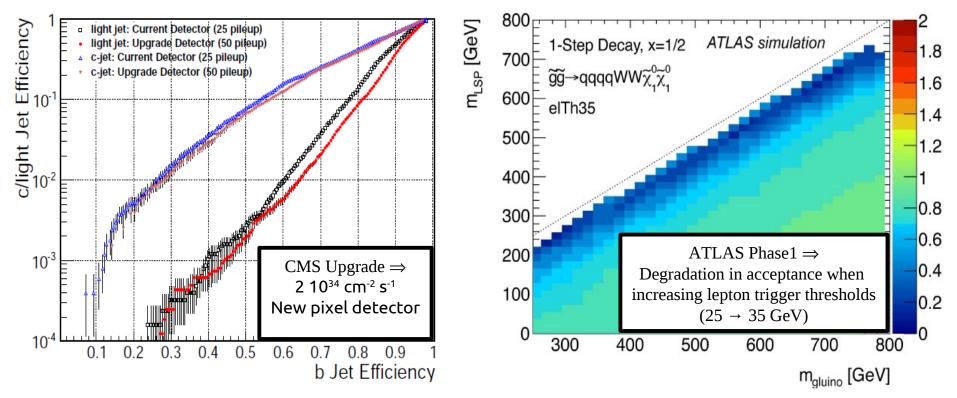
- > 1.5 times the current center-of-mass energy
- $\approx$  15 times the current integrated luminosity:  $\approx$  4 times more sensitivity



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# **Experimental environment**

- All these 'rule of thumb' estimates assume no changes in performance at the detector level or in the collision environment:
  - Planned improvements (better granularity, trigger, tracking, ...)
  - Higher collision rate, multiplicity, pileup ⇒ higher trigger thresholds, more complicated pattern recognition, ...



# New physics at the TeV?

- What we know today:
  - The scalar that we have found looks rather 'standard' at first sight
  - No SUSY found until now (simplest scenarios excluded for the sparticles and masses that can be accessed at √s = 8 TeV)
  - No strict need for SUSY at the TeV scale to explain why  $M_{\mu} \approx 126 \text{ GeV}$
- The good news:
  - It still seems 'unnatural' the absence of new physics at the TeV scale
  - Dark matter explanations point to WIMPs at the electroweak scale
- Our most promising links to new physics:
  - Neutrinos (but probably connecting to physics >> TeV scale)
  - Higgs: already at the weak scale, connected to mass (and gravity?)
  - Top: highest mass and coupling to Higgs, key ingredient to find any natural explanation for the light value of the Higgs mass

#### **Current ATLAS status: SUSY**

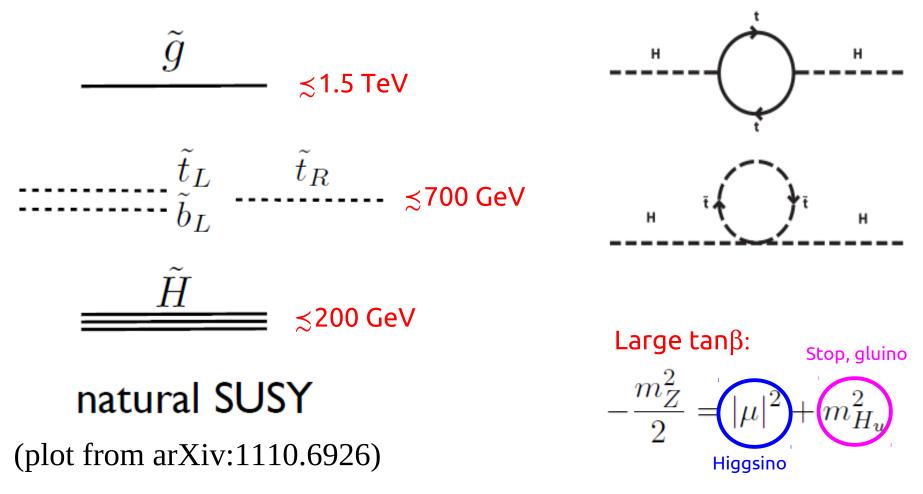
#### ATLAS SUSY Searches\* - 95% CL Lower Limits (Status: March 26, 2013)

		AILAS SUST	Searches - 95% CL Lower Limits (Status: M	arch 20, 2013)						
		L=5.8 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2012-109]								
	MSUGRA/CMSSM : 0 lep + j's + $E_{T,miss}$		h.50 TeV g̃ = g̃ mass	1						
	MSUGRA/CMSSM : 1 lep + j's + E <sub>T,miss</sub>	L=5.8 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2012-104]	1.24 TeV $\widetilde{q} = \widetilde{g}$ mass	ATLAS						
GS	Pheno model : 0 lep + j's + $E_{T,miss}$	L=5.8 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2012-109]	1.18 TeV g mass (m(q) < 2 TeV, light							
ch	Pheno model : 0 lep + j's + $E_{T,miss}$	L=5.8 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2012-109]	<b>1.38 TeV</b> q mass (m(g) < 2 TeV, lig							
Sar	Gluino med. $\tilde{\chi}^{\pm}$ ( $\tilde{g} \rightarrow q q \tilde{\chi}^{\pm}$ ) : 1 lep + j's + $E_{T,miss}$	L=4.7 fb <sup>-1</sup> , 7 TeV [1208.4688]	900 GeV $\tilde{g}$ mass $(m(\chi_1^0) < 200 \text{ GeV}, m(\chi^{\pm}) = 0$	$\frac{1}{Z}(m(\tilde{\chi})+m(\tilde{g}))$						
SI	GMSB (Ĩ NLSP) : 2 lep (OS) + j's + Ε <sub>T,miss</sub> GMSB (τ NLSP) : 1-2 τ + j's + Ε <sub>T</sub>	L=4.7 fb <sup>-1</sup> , 7 TeV [1208.4688]	<b>1.24 TeV ğ</b> mass (tanβ < 15)							
Inclusive searches	GGM (bino NLSP) : $\gamma\gamma + E_{T \text{ miss}}^{T,\text{miss}}$	L=20.7 fb <sup>-1</sup> , 8 TeV [1210.1314]	1.40 TeV g̃ mass (tanβ > 18)	ſ						
Ins	CCM (wine NILCD) we leave E <sup>T,miss</sup>	L=4.8 fb <sup>-1</sup> , 7 TeV [1209.0753]	<b>1.07 TeV</b> $\tilde{g}$ mass $(m(\bar{\chi}_1^0) > 50 \text{ GeV})$	$Ldt = (4.4 - 20.7) \text{ fb}^{-1}$						
nc	GGM (wino NLSP) : $\gamma$ + lep + $E_{T,miss}^{T,miss}$ GGM (higgsino-bino NLSP) : $\gamma$ + b + $E_{T,miss}^{T,miss}$	L=4.8 fb <sup>-1</sup> , 7 TeV [ATLAS-CONF-2012-144]	619 GeV g mass	5						
	CCM (higgsino-billo NLSP) : Y + D + E	L=4.8 fb <sup>-1</sup> , 7 TeV [1211.1167]	900 GeV g̃ mass (m(x̄₁) > 220 GeV)	s = 7, 8 TeV						
	GGM (higgsino NLSP) : Z + jets + $E_{T,miss}$	L=5.8 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2012-152]	690 GeV $\widetilde{G}$ mass $(m(\widetilde{H}) > 200 \text{ GeV})$ 645 GeV $F^{1/2}$ scale $(m(\widetilde{G}) > 10^4 \text{ eV})$	•						
	Gravitino LSP : 'monojet' + $E_{T, miss}$	L=10.5 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2012-147]								
3rd gen. gluino mediated	$\tilde{g} \rightarrow bb\tilde{\chi}_{1}^{0}: 0 \text{ lep } + 3 \text{ b-j's } + E_{T,miss}$ $\tilde{g} \rightarrow tt\tilde{\chi}_{1}^{0}: 2 \text{ SS-lep } + (0-3b-)j's + E_{T,miss}$	L=12.8 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2012-145]	1.24 TeV g̃ mass (mα( <sup>0</sup> <sub>1</sub> ) < 200 GeV)	8 TeV, all 2012 data						
rrd gen. gluino nediateo	$\tilde{g} \rightarrow tt \tilde{\chi}_1^\circ : 2 \text{ SS-lep} + (0.3b-)J's + E_{T,miss}$	L=20.7 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2013-007]	900 GeV $\tilde{g}$ mass (any $m(\tilde{\chi}_1^0)$ )	8 TeV, all 2012 data						
3rd gen. gluino mediateo	$\tilde{g} \rightarrow tt \chi^0$ : 0 lep + multi-j's + $E_{T,miss}$	L=5.8 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2012-103]	<b>1.00 TeV</b> $\widetilde{g}$ mass $(m(\overline{a}_1^0) < 300 \text{ GeV})$	8 TeV, partial 2012 data						
5 6	$q \rightarrow tt\chi^0$ : 0 lep + 3 b-j's + $E_{T,miss}$	L=12.8 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2012-145]	<b>1.15 TeV</b> $\tilde{g}$ mass $(m\bar{\chi}_{\gamma}^{0}) < 200 \text{ GeV}$							
	$\widetilde{bb}, \widetilde{b}_1 \rightarrow b\widetilde{\chi}_1^0: 0 \text{ lep } + 2\text{-b-jets } + E_{T,\text{miss}}$	1-12.8 fb <sup>-1</sup> .8 TeV IATLAS.COME.2012.1651		7 TeV, all 2011 data						
3rd gen. squarks direct production	$\tilde{b}\tilde{b}, \tilde{b}_1 \rightarrow t\tilde{\chi}_1^{\pm}: 2$ \$S-lep + (0-3b-)j's + $E_{T,miss}$	L=20.7 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2013-007]	<b>430 GeV</b> b mass $(m(\overline{\chi}_1^{\pm}) = 2m(\overline{\chi}_1^{\circ}))$							
Icti	$\widetilde{t}t$ (light), $\widetilde{t} \rightarrow \widetilde{b} \widetilde{\chi}_{1}^{\pm}$ : 1/2 lep (+ b-jet) + $E_{T, \text{miss}}$		<b>167 GeV</b> t mass $(m(\chi_1^0) = 55 \text{ GeV})$							
squ	$\widetilde{t}\widetilde{t}$ (medium), $\widetilde{t} \rightarrow b\widetilde{\chi}_{1}^{\pm}$ : 1 lep + b-jet + $E_{T,miss}$	L=20.7 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2013-037]	<b>160-410 GeV</b> t mass $(m(\overline{\alpha}_1^0) = 0 \text{ GeV}, m(\overline{\alpha}_1^{\pm}) = 150 \text{ GeV})$							
pro	$\widetilde{t}\widetilde{t}$ (medium), $\widetilde{t} \rightarrow b\widetilde{\chi}_1^{\pm}$ : 2 lep + $E_{T,miss}$	L=13.0 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2012-167]	<b>160-440 GeV</b> t mass $(m(\overline{\alpha}_1^0) = 0 \text{ GeV}, m(\overline{t}) - m(\overline{\alpha}_1^+) = 10 \text{ GeV})$							
ge	$\widetilde{\text{tt}}$ (heavy), $\widetilde{t} \rightarrow t \widetilde{\chi}_{1}^{0}$ : 1 lep + b-jet + $E_{T,\text{miss}}$	L=20.7 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2013-037]	<b>200-610 GeV</b> t mass $(m(\overline{x}_1^0) = 0)$							
lire	tt (heavy), $t \rightarrow t \tilde{\chi}^0$ : 0 lep + 6(2b-)jets + $E_{T,miss}$ tt (natural GMSB): Z( $\rightarrow$ II) + b-jet + $E_{T,miss}$	L=20.5 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2013-024]	<b>320-660 GeV</b> t mass $(m(\tilde{\chi}_1^0) = 0)$							
6 0	tt (natural GMSB) : $Z(\rightarrow II) + D$ -Jet + E	L=20.7 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2013-025]	500 GeV t mass $(m(\overline{\alpha}_1^0) > 150 \text{ GeV})$							
	$\tilde{t}_2 \tilde{t}_2, \tilde{t}_2 \rightarrow \tilde{t}_1 + Z : Z(\rightarrow II) + 1 \text{ lep } + b \text{-jet} + E_{F, \text{miss}}^{T, \text{miss}}$	L=20.7 fb <sup>-1</sup> .8 TeV IATLAS-CONE-2013-0251	<b>520 GeV</b> $t_{\alpha}$ mass $(m(\tilde{t}) = m(\tilde{r}^{0}) + 180 \text{ GeV})$							
	$[[, \mapsto [\chi]^0 : 2 \text{ lep } + E_{T, \text{miss}}]$	L=4.7 fb <sup>-1</sup> , 7 TeV [1208.2884]	<b>85-195 GeV</b> I mass $(m(\bar{\chi}_1^0) = 0)$							
Sct	$\tilde{\chi}_{\tau}^{+}\tilde{\chi}_{\tau}, \tilde{\chi}_{\tau}^{+} \rightarrow \tilde{h}v(\tilde{h}v): 2 \text{ lep } + E_{T,\text{miss}}$ $\tilde{\chi}_{\tau}^{+}\tilde{\chi}_{\tau}, \tilde{\chi}_{\tau}^{+} \rightarrow \tilde{\tau}v(\tau\tilde{v}): 2\tau + E_{T,\text{miss}}$	L=4.7 fb <sup>-1</sup> , 7 TeV [1208.2884]	<b>110-340 GeV</b> $\tilde{\chi}_{1}^{\pm}$ mass $(m(\bar{\chi}_{1}^{\circ}) < 10 \text{ GeV}, m(\bar{l}, \bar{\nu}) = \frac{1}{2}(m(\bar{\chi}_{1}^{\pm}) + m(\bar{\chi}_{1}^{\circ})))$							
EW direct	$\chi_{\chi}, \chi \to \psi(\psi): 2\psi + E_{T,miss}$	L=20.7 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2013-028]	<b>180-330 GeV</b> $\widetilde{\chi}_1^{\pm}$ <b>Mass</b> $(m\widetilde{\chi}_1^0) < 10 \text{ GeV}, m(\overline{\tau}, \overline{\nu}) = \frac{1}{2} (m\widetilde{\chi}_1^{\pm}) + m(\widetilde{\chi}_1^0))$	10111011						
	$\widetilde{\chi}_{1}^{\pm}\widetilde{\chi}_{2}^{0} \rightarrow \widetilde{[}_{V}\widetilde{[}_{1}(\widetilde{v}v), [v]_{1}(\widetilde{v}v)] : 3 \text{ lep } + E^{T,\text{miss}}$	L=20.7 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2013-035]	<b>600 GeV</b> $\widetilde{\chi}_{1}^{\pm}$ mass $(m(\widetilde{\chi}_{1}^{\pm}) = m(\widetilde{\chi}_{2}^{0}), m(\widetilde{\chi}_{1}^{0}) = 0, m(\widetilde{l}, \widetilde{v}) \in \mathbb{R}^{2}$	as above)						
		L=20.7 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2013-035]	<b>315 GeV</b> $\widetilde{\chi}_{1}^{\pm}$ <b>mass</b> $(m(\overline{\chi}_{1}^{\pm}) = m(\overline{\chi}_{2}^{0}), m(\overline{\chi}_{1}^{0}) = 0$ , sleptons decoupled)							
s	Direct $\tilde{\chi}_1^{\pm}$ pair prod. (AMSB) : long-lived $\tilde{\chi}_1^{\pm}$	L=4.7 fb <sup>-1</sup> , 7 TeV [1210.2852]	<b>220 GeV</b> $\widetilde{\chi}_1^{\pm}$ mass $(1 < \tau (\overline{\chi}_1^{\pm}) < 10 \text{ ns})$							
cle	Stable $\tilde{g}$ , R-hadrons : low $\beta$ , $\beta\gamma$	L=4.7 fb <sup>-1</sup> , 7 TeV [1211.1597]	985 GeV ĝ mass							
ng	GMSB, stable $\tilde{\tau}$ : low $\beta$	L=4.7 fb <sup>-1</sup> , 7 TeV [1211.1597]	<b>300 GeV</b> $\tilde{\tau}$ mass (5 < tan $\beta$ < 20)							
Long-lived particles	GMSB, $\tilde{\chi}_{0}^{0} \rightarrow \gamma \tilde{G}$ : non-pointing photons	L=4.7 fb <sup>-1</sup> , 7 TeV [ATLAS-CONF-2013-016]	<b>230 GeV</b> $\tilde{\chi}_1^{\circ}$ mass (0.4 < $\tau(\chi_1^{\circ})$ < 2 ns)							
	$\widetilde{\chi}^0_+ \rightarrow qq\mu \ (RPV)^1: \mu + heavy displaced vertex$	L=4.4 fb <sup>-1</sup> , 7 TeV [1210.7451]	700 GeV q mass (1 mm < cτ < 1 m, g decoupled)	1 0.05						
	LFV : $pp \rightarrow \tilde{v}_{\tau} + X, \tilde{v}_{\tau} \rightarrow e + \mu$ resonance	L=4.6 fb <sup>-1</sup> , 7 TeV [1212.1272]	1.61 TeV $\tilde{v}_{\tau}$ mass $(\lambda_{311}^2=0.10)$							
	LFV : $pp \rightarrow \tilde{v}_{\tau} + X, \tilde{v}_{\tau} \rightarrow e(\mu) + \tau$ resonance Pilipoor DDV CMSSM + 1 lop + 7 i's + F	L=4.6 fb <sup>-1</sup> , 7 TeV [1212.1272]	<b>1.10 TeV</b> $\tilde{V}_{\tau}$ mass $(\lambda'_{311}=0.10, \lambda_{1(2)33}=0.10, \lambda_{1(2)33}=0$	0.05)						
RPV	Bilinear RPV CMSSM : 1 lep + 7 j's + $E_{T,miss}$ $\widetilde{\chi}_1^*\widetilde{\chi}_1, \widetilde{\chi}_1^* \rightarrow W \widetilde{\chi}_1^0, \widetilde{\chi}_1^0 \rightarrow eev_{\mu}, e\mu v_{\mu}: 4 lep + E_{T,miss}$	L=4.7 fb <sup>-1</sup> , 7 TeV [ATLAS-CONF-2012-140]	<b>1.2 TeV</b> $\tilde{q} = \tilde{g} \text{ mass}$ (c $\tau_{LSP} < 1 \text{ mm}$ <b>760 GeV</b> $\tilde{\chi}^+_{*}$ mass ( $m(\tilde{\chi}^0_{*}) > 300 \text{ GeV}, \lambda_{**} > 0$ )							
RI	$\chi_1 \chi_1, \chi_1 \rightarrow W \chi_1, \chi_1 \rightarrow e e v_{\mu}, e \mu v_e$ : 4 lep + $E_{T,miss}$	L=20.7 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2013-036]	<b>350 GeV</b> $\tilde{\chi}_1^+$ <b>Mass</b> $(m(\chi_1^0) > 80 \text{ GeV}, \chi_{121} > 0)$ <b>350 GeV</b> $\tilde{\chi}_1^+$ <b>mass</b> $(m(\chi_1^0) > 80 \text{ GeV}, \chi_{133} > 0)$							
	$\widetilde{\chi}_{1} \widetilde{\chi}_{1}' \dots, \widetilde{\chi}_{1} \rightarrow \tau \tau v_{e}, e \tau v_{\tau} : 3 \text{ lep } + 1\tau + E_{T, \text{miss}}$	L=20.7 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2013-036]	$\frac{350 \text{ GeV}}{666 \text{ GeV}} = \frac{(m(\chi_1) > 80 \text{ GeV}, \lambda_{133} > 0)}{\tilde{q} \text{ mass}}$							
	$\tilde{g} \rightarrow qqq : 3$ -jet resonance pair	L=4.6 fb <sup>-1</sup> , 7 TeV [1210.4813]	5							
	ğ→tt, t→bs : 2 SS-lep + (0-3b-)j's + E Scalar gluon : 2-jet resonance pair	L=20.7 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2013-007]	880 GeV g mass (any m(t))	I						
WIM	P interaction (D5, Dirac $\chi$ ) : 'monojet' + E	L=4.6 fb <sup>-1</sup> , 7 TeV [1210.4826]	100-287 GeV Sgluon mass (incl. limit from 1110.2693)	11 ( D0)						
	T,miss	L=10.5 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2012-147]	<b>704 GeV</b> M* scale ( <i>m</i> <sub>x</sub> < 80 GeV, limit of < 687 G	ev for DB)						
		10 <sup>-</sup>	1 1	10						
		10								
*Only a	selection of the available mass limits on new st	ates or phenomena shown.		*Only a selection of the available mass limits on new states or phenomena shown. Mass scale [TeV]						

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

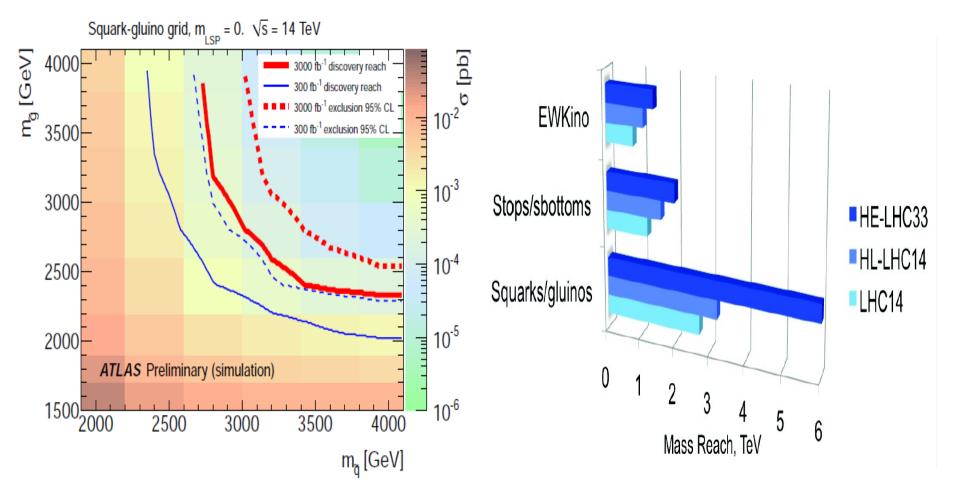
### **Naturalness and SUSY**

Choosing masses appropriately to evade current SUSY limits (little hierarchy problem):



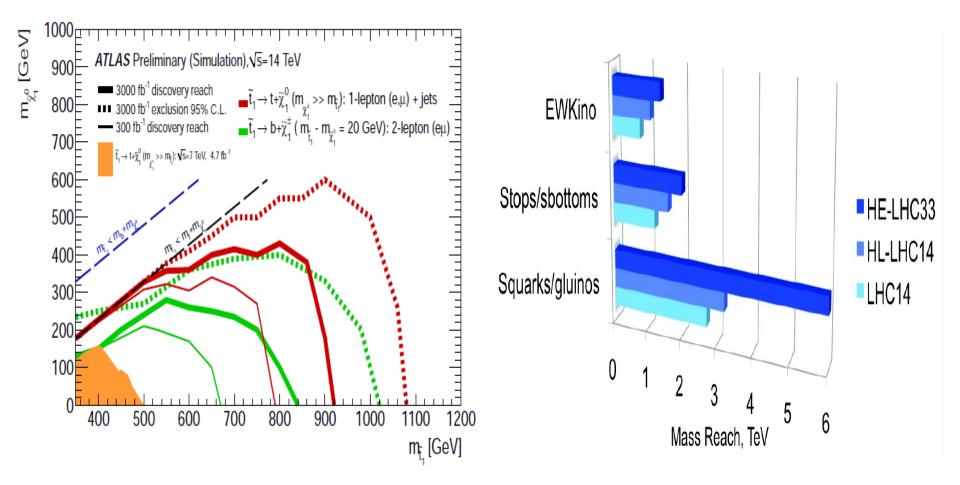
## **SUSY expectations**

- Current limits in s-hadron decay chains (m<sub>LSP</sub>=0): ≈ 1 TeV
- Estimated reach for  $\sqrt{s} \approx 14 \text{ TeV}$ , 300 fb<sup>-1</sup>:  $\approx 2-2.5 \text{ TeV}$



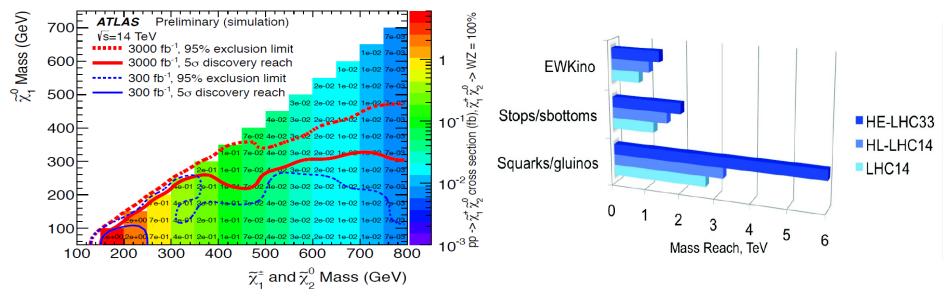
# **SUSY expectations**

- Current limits in direct stop production decay ( $\rightarrow t\chi^0, m_{LSP}$  small)  $\approx 600 \text{ GeV}$
- Estimated reach in stop→t $\chi^0$  for  $\sqrt{s} \approx 14$  TeV, 300 fb<sup>-1</sup>: approaching 1 TeV



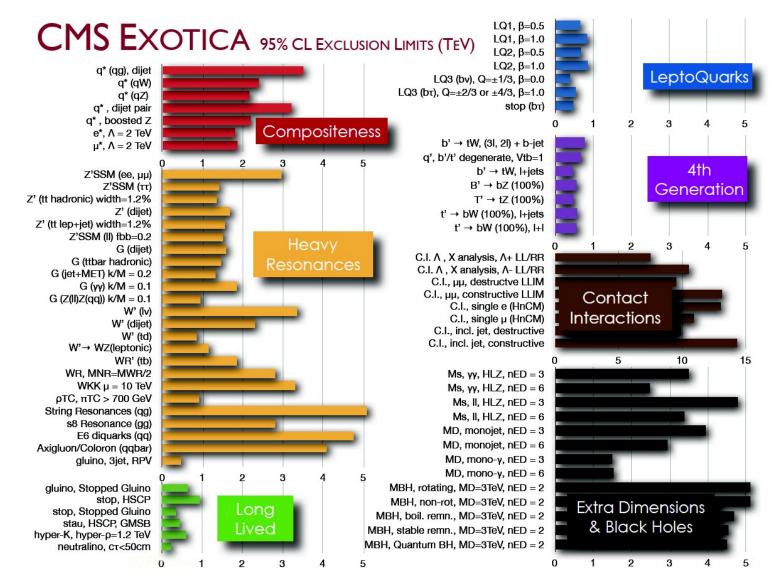
# **More SUSY expectations**

- Current tightest limits in ewkino masses via EWK production (with sleptons decoupled, m<sub>LSP</sub>≈0) ≈ 300 GeV.
- Significant improvements expected for  $\sqrt{s} \approx 14$  TeV, 300 fb<sup>-1</sup>



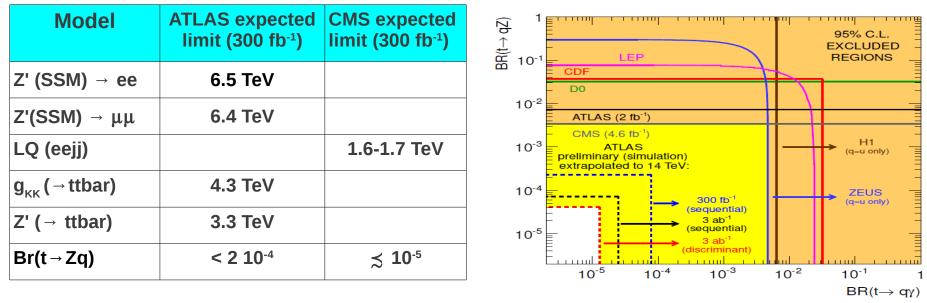
- If we do not see hints of natural SUSY in the presence of significant missing energy, we should still exploit other possibilities:
  - Compressed spectra (small missing energy, pathological signatures)
  - R-parity violation models
  - More exotic SUSY possibilities?
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#### **Current CMS searches: exotics**



#### **New resonances, FCNC**

- Typical lower limits with 8 TeV data for Z' SSM: ≈ 3 TeV (CMS)
  - Expected limits for  $\sqrt{s} \approx 14$  TeV, 300 fb<sup>-1</sup>:  $\approx 6.5$  TeV (ATLAS)
- Current Z' → ttbar limit ≈ 1.5 TeV (CMS)
  - Expected limit for  $\sqrt{s} \approx 14$  TeV, 300 fb<sup>-1</sup>:  $\approx 3.3$  TeV (ATLAS)
- Leptoquark limit (first generation): 0.8 TeV (CMS)
  - Expected limit for √s ≈ 14 TeV, 300 fb<sup>-1</sup>: ≈ 1.6-1.7 TeV (CMS)
- Significant increase in sensitivity for FCNC in the top sector



#### New physics via effective Lagrangians

A different way to look for deviations, more model independent, giving access (potentially) to higher energy scales but without specifying any particular model. Extending the SM in a linear way:

$$\mathcal{L}(\sqrt{s} \ll \Lambda) = \mathcal{L}_{SM} + \sum_{n=5}^{\infty} \frac{1}{\Lambda^{n-4}} \left( \sum_{j} f_{nj} \mathcal{O}_{nj} \right)$$

where:

- $\mathcal{O}_{nj}$  are terms containing SM fields
- *f<sub>nj</sub>* are adimensional couplings of order "1"
- $\Lambda$  is large, of the order of the scale of new physics
- Corrections to the SM are suppressed by powers of  $\frac{\sqrt{s}}{\Lambda}$  (and also  $\frac{v}{\Lambda}$ , with v = 246 GeV)
- Dominant terms respecting the SU(2)<sub>L</sub> × U(1)<sub>Y</sub> symmetry of the SM were collected already in 1986 (W. Buchmüller and D. Wyler, Nucl.Phys.B268:621,1986)
- Many examples: searches for anomalous couplings, contact interactions, effects of (non-resonant low-scale gravity), ...
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#### Limits on new scales, anomalous couplings, ...

Anomalous coupling limits:

$$egin{array}{rcl} \Delta g_1^Z & o & i \; rac{f}{\Lambda^2} (D_\mu \Phi)^\dagger (ec{ au} \, W^{\mu
u}) (D_
u \Phi) \ \ \Delta k_Z & o & i \; rac{f}{\Lambda^2} (D_\mu \Phi)^\dagger B^{\mu
u} (D_
u \Phi) \ \ \lambda_\gamma & o \; rac{f}{\Lambda^2} \; \epsilon_{IJK} \; W^{I
u}_\mu \; W^{J
ho}_
u \; W^{K\mu}_
ho \end{array}$$

(CMS estimates, based on Eur.Phys.J. C39 (2005) 293)

coupling	LHC	Approximate scale probed
$g_1^Z$	0.0030	4.5 TeV
$\lambda_{\gamma}$	0.0009	2.7 TeV
$\lambda_Z$	0.0023	1.7 TeV
$\kappa_{\gamma}$	0.026	1.5 TeV
$\kappa_Z$	0.037	1.3 TeV

- Testing new physics effects via loops at the TeV scale...
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#### **Deviations in boson-boson scattering**

 Vector boson scattering effective interactions (EWK chiral Lagrangian): a<sub>4</sub>[Tr(V<sub>µ</sub>V<sub>ν</sub>)]<sup>2</sup>
 300 fb<sup>-1</sup> at 14 TeV are sensitive to a<sub>4</sub>>0.066 (ATLAS); precision electroweak constraints of order 10<sup>-3</sup>-10<sup>-2</sup>

• They also lead to resonances (using unitarization of amplitudes):

There is a minimary of a minim						
model	baseline	500 GeV scalar	800 GeV vector	1150 GeVvector		
$(a_4, a_5)$	(0, 0)	(0.01, 0.009)	(0.009, -0.007)	(0.004, -0.004)		
S/B	$(3.3 \pm 0.3)\%$	$(0.7 \pm 0.1)\%$	$(4.9 \pm 0.3)\%$	$(5.8 \pm 0.3)\%$		
$S/\sqrt{B} (L = 300 \text{fb}^{-1})$	$2.3 \pm 0.3$	$0.6 \pm 0.1$	$3.3 \pm 0.4$	$3.9 \pm 0.4$		

Table 2: Summary of sensitivity to various resonance hypotheses in the semi-leptonic WW channel.

### Outlook

- In general, the LHC with  $\sqrt{s} \approx 13$  TeV and L = 300 fb<sup>-1</sup> represents a significant step forward in the search for physics effects beyond the SM:
  - In most cases we will be sensitive to twice the value of the mass limits set at √s ≈ 8 TeV
  - We will be able to study in detail new particles with masses not so far from the present exclusion limits
  - Effects from higher physics scales could also manifest in several precision measurements/searches: contact interactions, anomalous couplings, FCNC searches, ...
- If SUSY is close to 'natural' we should be able to see new physics signals, although the experimental path could be rather complicated in some pathological scenarios
- It is probably time to find something unexpected at the TeV scale, and for sure non-SM, so stay tuned!