# Susy model-building in view of LHC data







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gauge coupling running at 2 loops



Unification below Planck scale, high enough for proton stability

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Elegance

 $S = \int \mathrm{d}^4 x \left( \mathrm{d}^2 \theta \mathrm{d}^2 \bar{\theta} \, \Phi_i^* \exp\left(2g_A T_A^a V_A^a\right) \Phi_i + \left\{ \mathrm{d}^2 \theta \left[ \mathcal{W}(\{\Phi_i\}) + \frac{1}{4} W_A^a W_A^a \right] + \mathrm{h.c.} \right\} \right)$ 



José Ramón Espinosa's talk

## An anti-hint?

#### ATLAS SUSY Searches\* - 95% CL Lower Limits (Status: Dec 2012)

|               | MSUGBA/CMSSM 0 lep + i's + E-   | $1 = 5.8 \text{ fb}^{-1}$ 8 TeV [ATL AS-CONE-2012-109] $1 = 0$ TeV $\alpha = \alpha$ mass   |  |  |  |  |
|---------------|---|---|--|--|--|--|
|               | MSUGRA/CMSSM : 1 lep + i's + $E_{T}$ miss   | $L=5.8 \text{ fb}^{-1}$ . 8 TeV [ATLAS-CONF-2012-104] 1 24 TeV $\tilde{Q} = \tilde{Q}$ mass   |  |  |  |  |
| (0)           | Pheno model : 0 lep + i's + $E_T$ miss  | L=5.8 fb <sup>-1</sup> . 8 TeV [ATLAS-CONF-2012-109] 1.18 TeV $\widetilde{\mathbf{Q}}$ mass $(m(\widetilde{\mathbf{q}}) < 2$ TeV, light $\widetilde{\boldsymbol{\chi}}^0$ )   | ATLAS  |  |  |  |
| hes           | Pheno model : 0 lep + i's + $E_{T,miss}$  | <i>L</i> =5.8 fb <sup>-1</sup> . 8 TeV [ATLAS-CONF-2012-109] <b>1.38 TeV</b> $\tilde{Q}$ [mass $(m(\tilde{q}) < 2 \text{ TeV}, \text{light} \tilde{\chi}^0)$  | Preliminary  |  |  |  |
| arci          | Gluino med. $\tilde{\gamma}^{\pm}$ ( $\tilde{\alpha} \rightarrow q \bar{\alpha} \tilde{\gamma}^{\pm}$ ) : 1 lep + i's + $E_{\pm}$   | L=4.7 fb <sup>-1</sup> , 7 TeV [1208.4688] 900 GeV $\widetilde{\mathbf{Q}}$ mass $(m(\widetilde{\chi}^0) < 200 \text{ GeV}, m(\widetilde{\chi}^{\pm}) = \frac{1}{2}(m(\widetilde{\chi}^0) + m(\widetilde{\mathbf{q}}))$   | <b>900 GeV</b> $\widetilde{\mathbf{Q}}$ <b>mass</b> $(m(\widetilde{\mathbf{y}}^0) < 200 \text{ GeV}, m(\widetilde{\mathbf{y}}^\pm) = \frac{1}{2}(m(\widetilde{\mathbf{y}}^0) + m(\widetilde{\mathbf{q}}))$ |  |  |  |
| Seá           | $GMSB(\widetilde{I} NI SP) : 2 lep (OS) + i's + F$  | <i>L</i> =4.7 fb <sup>-1</sup> , 7 TeV [1208.4688] <b>1.24 TeV</b> $\widetilde{Q}$ [mass] (tan $\beta$ < 15)  |  |  |  |  |
| 9             | GMSB ( $\tilde{\tau}$ NLSP) : 1-2 $\tau$ + 0-1 lep + j's + $E_{\tau}^{T,miss}$  | <i>L</i> =4.7 fb <sup>-1</sup> , 7 TeV [1210.1314] <b>1.20 TeV</b> $\widetilde{\mathbf{Q}}$ mass $(\tan\beta > 20)$   |  |  |  |  |
| isi           | GGM (bino NLSP) : $\gamma\gamma + E_T^{T,miss}$   | L=4.8 fb <sup>-1</sup> , 7 TeV [1209.0753] 1.07 TeV $\tilde{g}$ mass $(m(\tilde{\chi}^0) > 50 \text{ GeV})$   | (21 - 130) fb <sup>-1</sup>  |  |  |  |
| וטנ           | GGM (wino NLSP) : $\gamma$ + lep + $E_{-}^{\gamma,\text{miss}}$   | L=4.8 fb <sup>-1</sup> , 7 TeV [ATLAS-CONF-2012-144] 619 GeV g mass   | (2.1 - 10.0) 10  |  |  |  |
| 1             | GGM (higgsino-bino NLSP) : $\gamma + b + E_{T}^{\gamma,miss}$   | L=4.8 fb <sup>-1</sup> , 7 TeV [1211.1167] 900 GeV $\tilde{g}$ mass $(m(\tilde{\chi}^0) > 220 \text{ GeV})$   | √s = 7.8 TeV   |  |  |  |
|               | GGM (higgsino NLSP) : Z + jets + $E_{T \text{ miss}}^{I,\text{miss}}$   | L=5.8 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2012-152] 690 GeV $\widetilde{g}$ (m(H) > 200 GeV)   | •••••  |  |  |  |
|               | Gravitino LSP : 'monojet' + $E_{T miss}$  | L=10.5 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2012-147] 645 GeV $\vec{F}^{1/2}$ SCale $(m(\vec{G}) > 10^{-4} \text{ eV})$   |  |  |  |  |
| <i>5</i> . 73 | $\tilde{q} \rightarrow b \tilde{b} \tilde{\gamma}^{0}$ (virtual $\tilde{b}$ ) : 0 lep + 3 b-i's + $E_{T}$ miss  | L=12.8 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2012-145] 1.24 TeV $\widetilde{g}$ mass $(m(\chi^0) < 200 \text{ GeV})$   |  |  |  |  |
| . sı<br>neı   | $\tilde{q} \rightarrow t \tilde{\chi}^{01}$ (virtual $\tilde{t}$ ) : 2 lep (SS) + i's + $E_{T}$ miss  | L=5.8 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2012-105] 850 GeV $\widetilde{g}$ Mass $(m(\widetilde{\chi}^0) < 300 \text{ GeV})$   |  |  |  |  |
| ien<br>o r    | $\widetilde{q} \rightarrow t \widetilde{\chi}^0$ (virtual $\widetilde{t}$ ) : 3 lep + i's + $E_{\tau, \text{miss}}$   | L=13.0 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2012-151] 860 GeV $\tilde{g}$ mass $(m(\chi^0) < 300 \text{ GeV})$  | 8 TeV results  |  |  |  |
| d g<br>uin    | $\tilde{q} \rightarrow t \tilde{\chi}$ (virtual $\tilde{t}$ ) : 0 lep + multi-i's + $E_{\tau}$  | L=5.8 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2012-103] 1.00 TeV $\widetilde{g}$ mass $(m(\tilde{\chi}^0) < 300 \text{ GeV})$  | 7 ToV results  |  |  |  |
| gl<br>gl      | $\widetilde{q} \rightarrow t\widetilde{t} \widetilde{\chi}^0$ (virtual $\widetilde{t}$ ) : 0 lep + 3 b-i's + $E_T$ miss   | L=12.8 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2012-145] 1.15 TeV $\widetilde{g}$ mass $(m(\chi)^0) < 200 \text{ GeV})$  | 7 10 7 1030113   |  |  |  |
|               | $\widehat{bb}, \widehat{b}, \rightarrow \widehat{b\gamma}^0$ : 0 lep + 2-b-iets + $E_{T,miss}$  | L=12.8 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2012-165] 620 GeV b mass $(m(\tilde{\chi}^0) < 120 \text{ GeV})$  |  |  |  |  |
| 'ks<br>on     | $\widetilde{bb}, \widetilde{b} \rightarrow t\widetilde{\gamma}^{\pm}$ : 3 lep + i's + $E_{\tau}$  | L=13.0 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2012-151] 405 GeV b mass $(m(\tilde{\chi}^{\pm}) = 2 m(\tilde{\chi}^{-0}))$   |  |  |  |  |
| uai           | $\tilde{t}\tilde{t}$ (light), $\tilde{t} \rightarrow b\tilde{\chi}^{\pm 1}$ : $1/2^{1}$ lep (+ b-jet) + $E_{T,\text{miss}}^{T,\text{miss}}$   | L=4.7 fb <sup>-1</sup> , 7 TeV [1208.4305, 1209.2102]67 GeV $\tilde{t}$ mass $(m(\tilde{\chi}^0) = 55 \text{ GeV})$   |  |  |  |  |
| bs            | $\widetilde{t}$ (medium), $\widetilde{t} \rightarrow b \widetilde{\chi}^{\pm}$ : 1 lep + b-jet + $E_{T \text{ miss}}$   | L=13.0 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2012-166] 160-350 GeV $\widetilde{t}$ mass $(m(\chi^0) = 0 \text{ GeV}, m(\chi^{\pm}) = 150 \text{ GeV})$   |  |  |  |  |
| эn.<br>pra    | $\tilde{t}\tilde{t}$ (medium), $\tilde{t} \rightarrow b\tilde{\chi}^{\pm}$ : 2 lep + $E_{T \text{ miss}}$   | L=13.0 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2012-167] <b>160-440 GeV</b> $\widetilde{t}$ mass $(m(\chi_{-}^{0}) = 0 \text{ GeV}, m(\widetilde{t}) - m(\chi_{-}^{\pm}) = 10 \text{ GeV})$  |  |  |  |  |
| l gé          | $\widetilde{t}t, \widetilde{t} \rightarrow t \widetilde{\chi}^0$ : 1 lep + b-jet + $E_{T \text{ miss}}$   | L=13.0 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2012-166] 230-560 GeV $\widetilde{t}$ mass $(m(\tilde{\chi}_{4}^{0}) = 0)$  |  |  |  |  |
| 3rc<br>dir    | $\widetilde{t}t, \widetilde{t} \rightarrow t \widetilde{\chi}^0$ : 0/1/2 lep (+ b-jets) + $E_{\tau \text{ miss}}$   | L=4.7 fb <sup>-1</sup> , 7 TeV [1208.1447,1208.2590,1209.4186] <b>230-465 GeV</b> $\widetilde{t}$ mass $(m(\widetilde{\chi}_{4}^{0}) = 0)$  |  |  |  |  |
|               | $\tilde{t}$ (natural $\tilde{G}$ MSB) : Z( $\rightarrow$ II) + b-jet + E  | L=2.1 fb <sup>-1</sup> , 7 TeV [1204.6736] 310 GeV $\tilde{t}$ MASS (115 < $m(\tilde{\chi}_{0}^{0})^{-1}$ 230 GeV)  |  |  |  |  |
|               | $\widetilde{I_{i}I_{i}}, \widetilde{I} \rightarrow \widetilde{I_{\chi}}$ : 2 lep + $E_{T \text{ miss}}$   | L=4.7 fb <sup>-1</sup> , 7 TeV [1208.2884] 85-195 GeV   MASS $(m(\tilde{\chi}_{*}^{0}) = 0)$  |  |  |  |  |
| W<br>ect      | $\widetilde{\chi}_{1}^{+}\widetilde{\chi}_{2}^{+}, \widetilde{\chi}_{1}^{+} \rightarrow \widetilde{I}v(\widetilde{V}) \rightarrow Iv\widetilde{\chi}_{1}^{+}: 2 \text{ lep } + E_{T \text{ miss}}$                          | L=4.7 fb <sup>-1</sup> , 7 TeV [1208.2884] 110-340 GeV $\tilde{\chi}_{4}^{\pm}$ mass $(m(\tilde{\chi}_{4}^{0}) < 10 \text{ GeV}, m(\tilde{l}, \tilde{v}) = \frac{1}{2}(m(\tilde{\chi}_{4}^{\pm}) + m(\tilde{\chi}_{4}^{0})))$   |  |  |  |  |
| Ш įЗ          | $\widetilde{\chi}_{1}^{\pm}\widetilde{\chi}_{2}^{0} \rightarrow \widetilde{I}_{1}^{1} v \widetilde{I}_{1}^{1} (\widetilde{v}v), \widetilde{v} \widetilde{I}_{1}^{1} (\widetilde{v}v) : 3 \text{ lep } + E_{T \text{ miss}}$ | <b>L=13.0 fb<sup>-1</sup>, 8 TeV [ATLAS-CONF-2012-154] 580 GeV</b> $\widetilde{\chi}_{1}^{\pm}$ <b>Mass</b> $(m(\widetilde{\chi}_{1}^{\pm}) = m(\widetilde{\chi}_{0}^{0}), m(\widetilde{\chi}_{1}^{0}) = 0, m(\widetilde{l}, \widetilde{v})$ as above)  |  |  |  |  |
|               | $\widetilde{\chi}_{1}^{\pm}\widetilde{\chi}_{2}^{\pm}\rightarrow W^{(*)}\widetilde{\chi}_{1}^{0}Z^{(*)}\widetilde{\chi}_{2}^{0}: 3 \text{ lep } + E_{T \text{ miss}}^{T,\text{miss}}$                                       | L=13.0 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2012-154] 140-295 GeV $\widetilde{\chi}_{1}^{\pm}$ MASS $(m(\widetilde{\chi}_{1}^{\pm}) = m(\widetilde{\chi}_{2}^{0}), m(\widetilde{\chi}_{1}^{0}) = 0,$ sleptons decoupled)  |  |  |  |  |
| σ             | Direct $\tilde{\chi}_{1}^{\pm}$ páir prod. (AMSB) : long-lived $\tilde{\chi}_{1}^{\pm}$   | L=4.7 fb <sup>-1</sup> , 7 TeV [1210.2852] 220 GeV $\widetilde{\chi}_{1}^{\pm}$ mass $(1 < \tau (\widetilde{\chi}_{1}^{\pm}) < 10 \text{ ns})^{-1}$   |  |  |  |  |
| ive<br>les    | Stable $\tilde{g}$ R-hadrons : low $\beta$ , $\beta\gamma$ (full detector)  | L=4.7 fb <sup>-1</sup> , 7 TeV [1211.1597] 985 GeV g mass   |  |  |  |  |
| ig-l<br>rtic  | Stable $\tilde{t}$ R-hadrons : low $\beta$ , $\beta\gamma$ (full detector)  | L=4.7 fb <sup>-1</sup> , 7 TeV [1211.1597] 683 GeV t mass   |  |  |  |  |
| -on<br>pa     | GMSB : stable $	ilde{	au}$  | <b>L=4.7 fb<sup>-1</sup>, 7 TeV [1211.1597] 300 GeV</b> $\tilde{\tau}$ <b>MASS</b> (5 < tan $\beta$ < 20)   |  |  |  |  |
| 7             | $\widetilde{\chi}^{"} \rightarrow qq\mu (RPV) : \mu + heavy displaced vertex$   | <b>L=4.4 fb<sup>-1</sup>, 7 TeV [1210.7451] 700 GeV</b> $\widetilde{\mathbf{q}}$ <b>mass</b> $(0.3 \times 10^{-5} < \lambda_{211} < 1.5 \times 10^{-5}, 1 \text{ mm} < c\tau < 1 \text{ m}, \widetilde{\mathbf{g}} \text{ det})$  | ecoupled)  |  |  |  |
|               | LFV : pp $\rightarrow \tilde{v}_{\tau} + X, \tilde{v}_{\tau} \rightarrow e + \mu$ resonance   | L=4.6 fb <sup>-1</sup> , 7 TeV [Preliminary] 1.61 TeV $\tilde{\nu}_{\tau}$ MASS ( $\lambda_{311}^{*}$ =0.10, $\lambda_{132}^{*}$ =0.05)   |  |  |  |  |
|               | LFV : pp $\rightarrow \tilde{v}_{\tau} + X$ , $\tilde{v}_{\tau} \rightarrow e(\mu) + \tau$ resonance  | <b>L=4.6 fb<sup>-1</sup>, 7 TeV [Preliminary] 1.10 TeV</b> $\widetilde{v}_{I}$ ( $\lambda_{311}^{2}$ =0.10, $\lambda_{1(2)33}$ =0.05)   |  |  |  |  |
| $\geq$        | Bilinear RPV CMSSM : 1 lep + 7 j's + $E_{\tau, miss}$   | <i>L</i> =4.7 fb <sup>-1</sup> , 7 TeV [ATLAS-CONF-2012-140]<br>1.2 TeV $q = g$ mass ( $c\tau_{LSP} < 1$ mm)  |  |  |  |  |
| B             | $\widetilde{\chi}_{1}^{+}\widetilde{\chi}_{-}^{-}\widetilde{\chi}_{1}^{+} \rightarrow W\widetilde{\chi}_{0}^{0}, \widetilde{\chi}_{0}^{0} \rightarrow eev_{\mu}, e\mu v_{\mu} : 4 lep + E_{T.miss}$                         | <b>L=13.0 fb<sup>-1</sup>, 8 TeV [ATLAS-CONF-2012-153] 700 GeV</b> $\chi_1^{-1}$ <b>Mass</b> $(m(\chi_1^{0}) > 300 \text{ GeV}, \lambda_{121} \text{ or } \lambda_{122} > 0)$   |  |  |  |  |
|               | $ L_L, L_{\perp} \rightarrow  \widetilde{\chi}_{\mu}, \widetilde{\chi}_{\mu} \rightarrow eev_{\mu}, e\muv_{\mu} > 4 lep + E_{T,miss}$   | <b>L=13.0 fb<sup>-1</sup>, 8 TeV [ATLAS-CONF-2012-153]</b><br><b>430 GeV I MASS</b> $(m(\tilde{\chi}_1^0) > 100 \text{ GeV}, m(\tilde{l}_e) = m(\tilde{l}_{\mu}) = m(\tilde{l}) = m(\tilde{l}) = m(\tilde{l}) = m(\tilde{l}) = m(\tilde{l}) $ |  |  |  |  |
|               | ģ → qqq : 3-jeť resonance pair  | L=4.6 fb <sup>-1</sup> , 7 TeV [1210.4813] 666 GeV $\tilde{g}$ mass   |  |  |  |  |
| 14/18/        | Scalar gluon : 2-jet resonance pair   | L=4.6 fb <sup>-1</sup> , 7 TeV [1210.4826] 100-287 GeV Sgluon mass (incl. limit from 1110.2693)   |  |  |  |  |
| VVIIV         | IF INTERACTION (D5, DIFAC $\chi$ ) : MONOJET + E<br>T,miss  | <b>L=10.5 fb<sup>-1</sup>, 8 TeV [ATLAS-CONF-2012_1147] 704 GeV</b> $M^*$ <b>\$Cale</b> ( $m_{\chi} < 80$ GeV, limit of < 687 GeV for P8)   |  |  |  |  |
|               |   |   |  |  |  |  |
|               |   | $10^{-1}$ 1 10  |  |  |  |  |

Mass scale [TeV]

#### Colored susy > TeV ? colored sparticles

|                 |  | ATLAS SUSY S   | arches* - 95% CL l  | wer Limits (Status: Dec 2012)   |
|-----------------|--|--|---|---|
|                 | MSUGBA/CMSSM 0 len + i's + F-  | / -5.8.fb <sup>-1</sup> .8.TeV [ATLAS_CONE-2012-109]           | 150   |   |
|                 | MSUGRA/CMSSM : 1 lep + j's + $E_{T,miss}$  | L=5.8 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2012-104]           | 1.24 Te   | $\tilde{q} = \tilde{q}$ mass  |
| (0              | 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  | $\widetilde{q}$ mass $(m(\widetilde{q}) < 2 \text{ TeV}, \text{ light } \widetilde{\chi}^0)$ <b>ATLAS</b>                     |
| hea             | Pheno model : 0 lep + j's + $E_{T miss}$   | L=5.8 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2012-109]           | 1.38 T  | $\widetilde{q} \text{ mass } (m(\widetilde{g}) < 2 \text{ TeV}, \text{ light } \widetilde{\chi}^0_{,})$ Preliminary           |
| arc             | Gluino med. $\tilde{\chi}^{\pm}$ ( $\tilde{g} \rightarrow q\bar{q}\tilde{\chi}^{\pm}$ ) : 1 lep + j's + $E_{T \text{ miss}}$   | L=4.7 fb <sup>-1</sup> , 7 TeV [1208.4688]                     | 900 GeV ĝ   | <b>ASS</b> $(m(\tilde{\chi}_1^0) < 200 \text{ GeV}, m(\tilde{\chi}^{\pm}) = \frac{1}{2}(m(\tilde{\chi}^0) + m(\tilde{g}))$    |
| Se              | GMSB ( $\tilde{I}$ NLSP) : 2 lep (OS) + j's + $E_{T miss}$   | L=4.7 fb <sup>-1</sup> , 7 TeV [1208.4688]                     | 1.24 Te\  | $\tilde{g}$ mass' (tan $\beta$ < 15)  |
| ive             | GMSB ( $\tilde{\tau}$ NLSP) : 1-2 $\tau$ + 0-1 lep + j's + $E_{T,\text{miss}}^{T,\text{miss}}$   | L=4.7 fb <sup>-1</sup> , 7 TeV [1210.1314]                     | 1.20 TeV  | $\tilde{g}$ mass (tan $\beta$ > 20)   |
| sni             | GGM (bino NLSP) : $\gamma\gamma + E$   | L=4.8 fb <sup>-1</sup> , 7 TeV [1209.0753]                     | 1.07 TeV  | mass $(m(\tilde{\chi}_1) > 50 \text{ GeV})$ $Ldt = (2.1 - 13.0) \text{ fb}^{-1}$  |
| lnc             | GGM (WIND NLSP) : $\gamma$ + IEP + E   | L=4.8 fb <sup>-1</sup> , 7 TeV [ATLAS-CONF-2012-144]           | 619 Gev g mass  | J T   |
|                 | GGW (Higgsino-bino NLSP) $\cdot \gamma + b + E$  | L=4.8 fb <sup>-1</sup> , 7 TeV [1211.1167]                     | 900 GeV g   | $\text{RSS}(m(\chi_1) > 220 \text{ GeV})$ (S = 7, 8 TeV   |
|                 | GGM (NIggsino NLSP) : $Z + \text{Jets} + E_{T,\text{miss}}$  | L=5.8 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2012-152]           | 690 GeV g mas   | (m(H) > 200  GeV)   |
|                 | Gravilino LSP . monojet $+E_{T,miss}$  | L=10.5 fb <sup>-</sup> , 8 TeV [ATLAS-CONF-2012-147]           | 645 GeV F SC  | $(m(G) > 10^{-9} C)$  |
| sq              | $g \rightarrow bb\gamma$ (Virtual b): 0 lep + 3 b-j's + $E_{T,miss}$   | L=12.8 fD , 8 IEV [ATLAS-CONF-2012-145]                        | 1.24 Tev  | $g_{\text{mass}}(m(\chi_1) < 200 \text{ GeV})$  |
| еп.<br>Ст       | $g \rightarrow it \chi$ (virtual i) $\cdot 2 \text{ lep } (55) + 15 + E_{T,\text{miss}}$   | L=3.0 fb <sup>-1</sup> 8 TeV [ATLAS-CONF-2012-105]             | 860 GeV G I   | $SS_{(m(\chi))} < 300 \text{ GeV} $ 8 TeV results   |
| d ge<br>uinc    | $\widetilde{q} \rightarrow t_{\infty}$ (virtual t): 0 lep + 15 + $L_{T,miss}$  | $l = 5.8 \text{ fb}^{-1}$ 8 TeV [ATLAS-CONF-2012-103]          | 1 00 TeV  | $\frac{100}{100} \left( \frac{m_{\chi_{1}}}{m_{\chi_{2}}} < 300 \text{ GeV} \right) = 7.75 \text{ M} \text{ max}$             |
| 3rc<br>glu      | $q \rightarrow t \overline{\chi}$ (virtual t) : 0 lep + find ti-j s + $E_{T,miss}$   | $L=12.8 \text{ fb}^{-1}$ . 8 TeV [ATLAS-CONF-2012-145]         | 1.15 TeV  | $1 \text{ mass } (m(\chi_1) < 200 \text{ GeV})$   |
|                 | $bh = b\tilde{\gamma}^0$ 0 lep + 2-b-jets + $F_{-}$  | L=12.8 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2012-165]          | 620 GeV b mass  | $n(\tilde{\chi}^0) < 120 \text{ GeV}$   |
| 'ks<br>on       | $\widetilde{bb}, \widetilde{b}, \rightarrow t\widetilde{\gamma}^{\pm}$ : 3 lep + i's + $E_{\tau}$ miss   | L=13.0 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2012-151]          | <b>405 GeV</b> b mass $(m(\tilde{\chi}^{\pm}))$               | $m(\tilde{\chi}))$  |
| uai<br>ucti     | $\tilde{t}\tilde{t}$ (light), $\tilde{t} \rightarrow b\tilde{\chi}^{\pm 1}$ : $1/2^{1}$ lep (+ b-jet) + $E_{T \text{ miss}}^{T,\text{miss}}$   | L=4.7 fb <sup>-1</sup> , 7 TeV [1208.4305, 1209.2102]67 GeV    | <b>MASS</b> $(m(\tilde{\chi}_{4}^{0}) = 55 \text{ GeV})$      |   |
| bs              | $\widetilde{t}$ (medium), $\widetilde{t} \rightarrow b \widetilde{\chi}_{+}^{\pm}$ : 1 lep + b-jet + $E_{T \text{ miss}}$  | L=13.0 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2012-166]          | -350 GeV $\widetilde{t}$ mass $(m(\widetilde{\chi}_1^0) = 0$  | eV, m(χ̃_1^±) = 150 GeV)  |
| en.             | $\tilde{t}t$ (medium), $\tilde{t} \rightarrow b\tilde{\chi}_{1}^{\pm}$ : 2 lep + $E_{T,miss}$  | L=13.0 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2012-167]          | 160-440 Gev t mass (m(x)                                      | 0 GeV, $m(\tilde{t}) - m(\tilde{\chi}_{1}^{\pm}) = 10$ GeV)   |
| d g<br>'eci     | $\widetilde{tt}, \widetilde{t} \rightarrow t \widetilde{\chi}_1^\circ$ : 1 lep + b-jet + $E_{T, \text{miss}}$  | L=13.0 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2012-166]          | 230-560 Gev t mass (  | $\zeta_{1}^{0} = 0$   |
| 3r<br>dii       | tt, t $\rightarrow$ t $\chi^{\circ}$ : 0/1/2 lep (+ b-jets) + $E_{T,\text{miss}}$  | L=4.7 fb <sup>-1</sup> , 7 TeV [1208.1447,1208.2590,1209.4186] | 230-465 GeV t mass (m(x                                       | = 0)  |
|                 | tt (natural GiMSB) : $Z(\rightarrow II) + D$ -jet + E  | L=2.1 fb <sup>-1</sup> , 7 TeV [1204.6736]                     | <b><u>10 GeV</u></b> t mass $(115 < m(\tilde{\chi}_1^\circ))$ | 230 GeV)  |
| st '            | $\sim^+\sim^-\sim^+ \sim \lim_{z \to z} \lim_$ | L=4.7 fb <sup>-1</sup> , 7 TeV [1208.2884] 85-195 Ge           | I mass $(m(\chi_1) = 0)$                                      | ~ ~ . 1. ~ ~ 0  |
| ≡W<br>irec      | $\chi_{\chi}, \chi \rightarrow lv(lv) \rightarrow lv\chi : 2 lep + E_{T,miss}$   | L=4.7 fb <sup>-</sup> , 7 TeV [1208.2884]                      | -340 GeV $\chi_1$ mass $(m(\chi_1) < 10^{\pm}$                | $GeV, m(I,v) = \frac{1}{2}(m(\chi_{i}) + m(\chi_{i})))$   |
| d b             | $\chi_1 \chi_2 \rightarrow I_1 \vee I_1 I(\vee V),  V _1 I(\vee V) : 3 \text{ lep } + E^{T,\text{miss}}$   | L=13.0 fD , 8 IeV [AILAS-CONF-2012-154]                        | 580 GeV $\chi_1$ IIIass                                       | $m(\chi_1) = m(\chi_2), m(\chi_1) = 0, m(l,v) \text{ as above}$   |
|                 | $\chi \chi \rightarrow W \chi \chi \chi , 3 \text{ Iep } + E_{T,\text{miss}}$<br>Direct $\tilde{\chi}^{\pm}$ Direct $\tilde{\chi}^{\pm}$ pair prod (AMSB) : long-lived $\chi^{\pm}$  | L=13.0 ID , 8 IeV [A1LAS-CONF-2012-134] 140                    | $\widetilde{\chi}^{\pm}$ mass $(m(\chi_1) = m$                | $(\chi_1) = 0$ , sieptons decoupled)  |
| ied<br>Se       | Stable $\tilde{\alpha}$ R-badrons : low $\beta_1 \beta_2$ (full detector)  | $I = 4.7 \text{ fb}^{-1}$ 7 TeV [1210.2002] 220 (              |   | lass  |
| j-liv<br>ticl€  | Stable $\hat{f}$ B-badrons : low $\beta$ , $\beta\gamma$ (full detector)   | $L=4.7 \text{ fb}^{-1}$ , 7 TeV [1211.1597]                    | 683 GeV T mass  |   |
| ong             | GMSB : stable $\tilde{\tau}$   | L=4.7 fb <sup>-1</sup> , 7 TeV [1211.1597]                     | <b>0 GeV</b> $\tilde{\tau}$ <b>MASS</b> (5 < tan $\beta$ < 2  |   |
| P L             | $\tilde{\gamma}^0 \rightarrow \text{ggu} (\text{RPV})$ : $\mu$ + heavy displaced vertex  | L=4.4 fb <sup>-1</sup> , 7 TeV [1210.7451]                     | 700 Gev q mas   | $(0.3 \times 10^{-5} < \lambda'_{0.1} < 1.5 \times 10^{-5}, 1 \text{ mm} < c\tau < 1 \text{ m}, \tilde{g} \text{ decoupled})$ |
|                 | LFV : pp $\rightarrow \tilde{v}_1 + X, \tilde{v}_2 \rightarrow e + \mu$ resonance  | L=4.6 fb <sup>-1</sup> , 7 TeV [Preliminary]                   | 1.6   | eV $\tilde{\nu}_{\tau}$ mass ( $\lambda'_{311}=0.10, \lambda_{132}=0.05$ )  |
|                 | LFV : pp $\rightarrow \tilde{v}_{\tau} + X, \tilde{v}_{\tau} \rightarrow e(\mu) + \tau$ resonance  | L=4.6 fb <sup>-1</sup> , 7 TeV [Preliminary]                   | 1.10 TeV  | mass $(\lambda'_{311}=0.10, \lambda'_{1(2)33}=0.05)$  |
| $\sum_{\alpha}$ | Bilinear RPV CMSSM : 1 lep + 7 j's + $E_{T,miss}$  | L=4.7 fb <sup>-1</sup> , 7 TeV [ATLAS-CONF-2012-140]           | 1.2 TeV   | $\tilde{q} = \tilde{g} \text{ mass} (c\tau_{LSP} < 1 \text{ mm})$   |
| Ы               | $\widetilde{\chi}_{1}^{+}\widetilde{\chi}_{2}^{-}\widetilde{\chi}_{1}^{+} \rightarrow W\widetilde{\chi}_{0}^{0}, \widetilde{\chi}_{0}^{0} \rightarrow eev_{\mu}, e\mu v_{\mu} : 4 lep + E_{T.miss}$  | L=13.0 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2012-153]          | 700 Gev χ ma  | $(m(\tilde{\chi}_{1}^{0}) > 300 \text{ GeV}, \lambda_{121} \text{ or } \lambda_{122} > 0)$                                    |
|                 | $ L_{L}, L_{J} \rightarrow [\widetilde{\chi}_{1}, \widetilde{\chi}_{1}] \rightarrow eev_{\mu}, e\mu v_{\lambda} : 4 lep + E_{T, miss}$   | L=13.0 fb <sup>-1</sup> , 8 TeV [ATLAS-CONF-2012-153]          | <b>430 Gev</b> I mass $(m(\widetilde{\chi}_1^0))$             | 100 GeV, $m(l_e) = m(l_\mu) = m(l_\tau)$ , $\lambda_{121}$ or $\lambda_{122} > 0$ )   |
|                 | g̃ → qqq : 3-jet resonance pair  | L=4.6 fb <sup>-1</sup> , 7 TeV [1210.4813]                     | 666 GeV g mass  |   |
| \ <u>\</u> /IN/ | Scalar gluon : 2-jet resonance pair  | L=4.6 fb <sup>-1</sup> , 7 TeV [1210.4826] 100-                | GeV Sgluon mass (incl. lir                                    | rom 1110.2693)  |
| T,miss.         |  | L=10.5 fb <sup>-</sup> , 8 TeV [ATLAS-CONF-2012-147]           | 704 GeV IVI^ SC   | $e^{-(m_{\chi} < 80 \text{ GeV, limit of } < 687 \text{ GeV for } 08)}$   |
|                 |  | 10 <sup>-1</sup>   | 1   | 10  |

TeV

Mass scale [TeV]

Fermi scale

\*C Al

# Colored susy > TeV ? colored sparticles



# Why expect susy to be light?

- Gauge coupling unification?
- Dark matter? 🗡
- Higgs mass? 🗡
- Naturalness?

## Gauge coupling unification

Hall et al.



## Gauge coupling unification

Hall et al.



## Higgs mass vs. susy scale

High-scale Supersymmetry

Guidice/Strumia



# Natural susy

## Natural Ascetic susy



rspectful istentewi ts, and he hass range of **r problen** led stop, the

om the point

for hissing

Figure 2: Expected and observed 95% C.L. exclusion limits in the  $\tilde{q} \to t \bar{t} \tilde{\chi}_1^0$  (via off mass-shell  $\tilde{t}$ ,

## Natural EWSB in times of austerity

Barbieri/Guidice

MSSM,NMSSM, ...

Fine-tuning of (Higgs mass)<sup>2</sup>

$$\frac{m_{Higgs}^2}{2} = -|\mu|^2 + \ldots + \delta m_H^2$$

# Natural EWSB in times of austerity

Fine-tuning of (Higgs mass)<sup>2</sup>

$$\frac{m_{Higgs}^2}{2} = -|\mu|^2 + \ldots + \delta m_H^2$$
Higgsinos

MSSM, NMSSM, ...

#### Natural EWSB in times of austerity **Barbieri/Guidice** MSSM,NMSSM, ... Fine-tuning of (Higgs mass)<sup>2</sup> $\frac{m_{Higgs}^2}{2} = -|\mu|^2 + \ldots + \delta m_H^2$ Higgsinos $\delta m_H^2|_{stop} = -\frac{3}{8\pi^2} y_t^2 \left( m_{U_3}^2 + m_{Q_3}^2 + |A_t|^2 \right) \log\left(\frac{\Lambda}{\text{TeV}}\right)$ lloop stops, sbottom $\delta m_H^2|_{gluino} = -\frac{2}{\pi^2} y_t^2 \left(\frac{\alpha_s}{\pi}\right) |M_3|^2 \log^2\left(\frac{\Lambda}{\text{TeV}}\right)$ 2loop gluino

# MSSM stops vs. mH

Delgado, Isidori et al.



# Direct stop searches



# $(m_{\tilde{t}_1} - m_{LSP}) < 30 - 40 \,\text{GeV}$

Delgado, Isidori et al.



# Limit on squarks



| Naturalness requires split squarks                     |   |  |  |  |
|--|---|--|--|--|
| M  | $(\tilde{u}, \tilde{d})_L, \ \tilde{u}_R, \ \tilde{d}_R,$ |  |  |  |
| $egin{array}{ccc} & & & & & & & & & & & & & & & & & &$ | $(c,s)_L, c_R, s_R$                                       |  |  |  |

# Splitting via RGE?

Papucci, Ruderman, AW '11

#### Splitting via renormalization group does not help

$$\delta m_H^2 \simeq 3 \left( m_{Q_3}^2 - m_{Q_{1,2}}^2 \right) \simeq \frac{3}{2} \left( m_{U_3}^2 - m_{U_{1,2}}^2 \right)$$
  
Higgs fine-tuning = RGE mass splitting

I-loop, LLog, tanß moderate

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I-loop, LLog, tanß moderate

Higgs fine-tuning = RGE mass splitting

→ Flavor non-trivial susy breaking!



 $\tilde{u}_R, \ \tilde{c}_R$ 

#### Degenerate

#### Minimal Flavor

Anarchy!

![](_page_25_Figure_5.jpeg)

#### Back of the envelope estimate

Cross-sections roughly scale like ~1/m^6.

Example: 8 light squarks  $\rightarrow$  2 light squarks Shift limit only by  $\sim 4^{1/6}-1\approx 25\%$ 

#### → too naive!

# Dedicated study needed

- Production cross-section can be flavor dependent through p.d.f's (u vs. d, sea vs. valence)
- Experimental efficiencies have thresholds and current limits are on the thresholds

### Squark searches

M. Papucci, J. Ruderman G. Perez, R. Mahbubani, AW

#### Effect of the efficiency threshold:

![](_page_28_Figure_3.jpeg)

#### Pythia/MadEvent

+Prospino/NLLfast +checks with MLM matched sample

![](_page_30_Picture_0.jpeg)

Pythia/MadEvent

+Prospino/NLLfast +checks with MLM matched sample

#### simplified Model available → CMS

ee Seeree

![](_page_31_Picture_1.jpeg)

![](_page_31_Picture_2.jpeg)

+Prospino/NLLfast +checks with MLM matched sample

![](_page_31_Picture_4.jpeg)

![](_page_32_Figure_0.jpeg)

![](_page_33_Figure_0.jpeg)

 $\Pi_i \text{poiss}(s_i + b_i \delta b_i) \text{ gauss}(\delta b_i) \to CL_s$ 

![](_page_34_Figure_0.jpeg)

M. Papucci, J. Ruderman G. Perez, R. Mahbubani, AW

![](_page_35_Figure_0.jpeg)

G. Perez, R. Mahbubani, AW


G. Perez, R. Mahbubani, AW

### Collider vs. Flavor for sea & valence squarks



 $H_{\text{eff}} = C_1 \, (\overline{u}^i \gamma_\mu P_L \, c^i) \, (\overline{u}^j \gamma^\mu P_L \, c^j) \,, \qquad x_D \simeq 2.6 \times 10^{10} \text{ Re } C_1$ Assuming full down alignment, calculated w/o MIA



### Gauge Mediation

see e.g. Giudice/Rattazzi



### $G_{\rm SM} = SU(3) \times SU(2) \times U(1)$

### Flavor Gauge Mediation

U(1): Kaplan, Kribs '99; Craig, McCullough, Thaler '12



$$W = \frac{1}{M_{S_u}} S_u H_u Q U^c + \frac{1}{M_{S_d}} S_d H_d Q D^c$$

$$egin{aligned} \langle m{S}_{m{u}} 
angle &= \left(egin{aligned} v_{u1} & 0 & 0 \ 0 & v_{u2} & 0 \ 0 & 0 & v_{u3} \end{array}
ight), & \langle m{S}_{m{d}} 
angle &= V_{ ext{CKM}} \left(egin{aligned} v_{d1} & 0 & 0 \ 0 & v_{d2} & 0 \ 0 & 0 & v_{d3} \end{array}
ight) V_{ ext{CKM}}^T \ &\propto Y_U & & \propto Y_D \end{aligned}$$

### 2-loop soft masses Craig, McCullough, Thaler '12

 $\sum_{v=1}^{N_{v}} \sum_{v=1}^{N_{v}} \sum_{v=1}^{N_{$ 

### 2-loop soft masses

Craig, McCullough, Thaler '12



 $rac{ ilde{m}_{i}}{ ilde{m}_{0}}$ 

 $\frac{M_V^2}{M^2}$ 

 $\delta$ 

# The missing missing energy

## **RPV SUSY**

- R parity violated: LSP can decay
- Typically also the proton decays...

# is conversionally we now estimate the size of $\overline{d}^{i}$ is $\overline{d}^{i}$

Siscanding abserced for the second of the se Le saddiwh i Cypica ky alson be aver o cologies in the MEX labour only i Simalizable correction to the superpotential: Indices, With Sun ere w'' is an unl how <u>R(1) coefficient In combination</u> with the MFV structures and the interesting phenomenology of our model a set from this l R-parity  $\forall i$  ola (i) (u) (u) (d) (d) (d) (d) (f) (f)The allowed k and B terms are m direct correst  $\lambda_{uds}'' \sim \lambda^3 t_{\beta}^2 \frac{m_d m_s m_u}{2 m_t^3}$  ns, and have simplified to the structure of the set  $\lambda_{uds}'' \sim \lambda^3 t_{\beta}^2 \frac{m_d m_s m_u}{2 m_t^3}$ ubject to non-universal corrections. At the rend

MFV RPV II Berger, Csaki, Heidenreich, Grossman Search for colored resonances/no-MET...  $\bar{b}$ Depending  $On \tilde{t} \to P$ , interesting phenometry Figure 12: Slepton LSP de Faigvettout deutrinbequette anywiten gittinds (and off same and off sa energy) on the right! For a neutralino L P, displaced vertices can searches are very promising the very state of the state this particular experiment would not all y remove the motivation for these theories, since this search relies on the production of a light gluino. Another relev nt search is for massive colored scalars in 4-jet event masses of the four is ht masses of the two pairs is searched or. Stop pair production for by decays to jets vous bout of decay this channel. The current bounds on the mass of the colored scalar u ing 2010 LHC data are in the 150 - 100 GeV range  $m_{ ilde{ au}}$ Throughout this paper we have been assuming a squark mass scale of order a few-bundred

GeV. This is necessary to make SUSY a natural solution of the hierarchy problem. However,  $2048^{\circ}$ 

# Small missing energy without RPV

### Stealth Susy

Fan, Reece, Ruderman 'I I



Standard picture



#### Fan, Reece, Ruderman 'I I



New sector with small susy breaking



#### Fan, Reece, Ruderman 'I I



### Stealth Susy



### Stealth limits

#### Fan, Reece, Ruderman 'I I



### Conclusions

- Vanilla susy models pushed to high scales
- If supersymmetry is realized, could well be beyond MSSM
- Light squarks might be buried, stealthy, RPV, natural
- Intensify non-standard susy searches
- Still hoping for surprises!

# Light non-degenerate squarks at the LHC



# Do the 1st & 2nd gen' squarks have to be degenerate?

Μ

8 dof  $(\tilde{u}, \tilde{d})_L, \tilde{u}_R, \tilde{d}_R,$  Because of flavor constraints?  $(\tilde{u}, \tilde{d})_L, \tilde{u}_R, \tilde{d}_R,$  Not really.  $(\tilde{c}, \tilde{s})_L, \tilde{c}_R, \tilde{s}_R$  $(3, 2)_{1/6} (3, 1)_{2/3} (3, 1)_{-1/3}$ 

### **Assumed spectrum in ATLAS/CMS plots**

### The SM flavor puzzle

 $Y_D \approx \operatorname{diag} \left( \begin{array}{ccc} 2 \cdot 10^{-5} & 0.0005 & 0.02 \end{array} \right)$  $Y_U \approx \left( \begin{array}{ccc} 6 \cdot 10^{-6} & -0.001 & 0.008 + 0.004i \\ 1 \cdot 10^{-6} & 0.004 & -0.04 + 0.001 \\ 8 \cdot 10^{-9} + 2 \cdot 10^{-8}i & 0.0002 & 0.98 \end{array} \right)$ 

Other dimensionless parameters of the SM: gs  $\approx$  1, g  $\approx$  0.6, g'  $\approx$  0.3,  $\lambda_{\text{Higgs}} \approx$  1,  $|\theta| < 10^{-9}$ 

| Operator                                       | Bounds on $\Lambda$ in TeV $(c_{ij} = 1)$ |                  | Bounds on $c_{ij}$ ( $\Lambda = 1$ TeV) |                       | Observables                    |
|--|---|------------------|---|-----------------------|--------------------------------|
|  | ${ m Re}$                                 | Im               | Re                                      | Im                    |                                |
| $\overline{(ar{s}_L \gamma^\mu d_L)^2}$        | $9.8 \times 10^2$                         | $1.6 	imes 10^4$ | $9.0 \times 10^{-7}$                    | $3.4 \times 10^{-9}$  | $\Delta m_K; \epsilon_K$       |
| $(\bar{s}_R  d_L)(\bar{s}_L d_R)$              | $1.8 	imes 10^4$                          | $3.2 	imes 10^5$ | $6.9 \times 10^{-9}$                    | $2.6 \times 10^{-11}$ | $\Delta m_K; \epsilon_K$       |
| $(ar{c}_L \gamma^\mu u_L)^2$                   | $1.2 \times 10^3$                         | $2.9 	imes 10^3$ | $5.6 \times 10^{-7}$                    | $1.0 \times 10^{-7}$  | $\Delta m_D;  q/p , \phi_D$    |
| $(\bar{c}_R  u_L)(\bar{c}_L u_R)$              | $6.2 	imes 10^3$                          | $1.5 	imes 10^4$ | $5.7 \times 10^{-8}$                    | $1.1 \times 10^{-8}$  | $\Delta m_D;  q/p , \phi_D$    |
| $\overline{(\overline{b}_L \gamma^\mu d_L)^2}$ | $5.1 \times 10^2$                         | $9.3 	imes 10^2$ | $3.3 \times 10^{-6}$                    | $1.0 \times 10^{-6}$  | $\Delta m_{B_d}; S_{\psi K_S}$ |
| $(\overline{b}_R  d_L) (\overline{b}_L d_R)$   | $1.9 	imes 10^3$                          | $3.6	imes10^3$   | $5.6 \times 10^{-7}$                    | $1.7 \times 10^{-7}$  | $\Delta m_{B_d}; S_{\psi K_S}$ |
| $\overline{(\overline{b}_L \gamma^\mu s_L)^2}$ | 1.1                                       | $1 \times 10^2$  | 7.6 2                                   | $\times 10^{-5}$      | $\Delta m_{B_s}$               |
| $(\overline{b}_R  s_L) (\overline{b}_L s_R)$   | 3.7                                       | $7 \times 10^2$  | 1.3 :                                   | $\times 10^{-5}$      | $\Delta m_{B_s}$               |

UTfit 08, Isidori, Perez, Nir'10

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| $(\overline{b}_R  s_L) (\overline{b}_L s_R)$   | 3.7                                       | $7 \times 10^2$   | 1.3 >                                   | $\times 10^{-5}$      | $\Delta m_{B_s}$               |

Very strong suppression! New flavor violation must either approximately (exactly?) follow SM structure...

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| $\overline{(b_L \gamma^\mu d_L)^2}$            | $5.1 \times 10^2$                         | $9.3 	imes 10^2$  | $3.3 \times 10^{-6}$                    | $1.0 \times 10^{-6}$  | $\Delta m_{B_d}; S_{\psi K_S}$ |
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| $\overline{(\overline{b}_L \gamma^\mu s_L)^2}$ | 1.1                                       | $1 \times 10^{2}$ | 7.6 2                                   | $\times 10^{-5}$      | $\Delta m_{B_s}$               |
| $(ar{b}_Rs_L)(ar{b}_L s_R)$                    | 3.7                                       | $7 \times 10^2$   | 1.3 :                                   | $\times 10^{-5}$      | $\Delta m_{B_s}$               |

Very strong suppression! New flavor violation must either approximately (exactly?) follow SM structure...

... or exist only at very high scales ( $10^2 - 10^5 \text{ TeV}$ )

UTfit 08, Isidori, Perez, Nir '10

Flavor Bounds (K, D, B, Bs mixing, ...) controlled by

$$(\delta_{ij}^q)_{MM} = \frac{1}{\tilde{m}_q^2} \sum_{\alpha} (K_M^q)_{i\alpha} (K_M^q)_{j\alpha}^* \Delta \tilde{m}_{q\alpha}^2$$

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mixing matrices

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mixing matrices mass splitting

Flavor Bounds (K, D, B, Bs mixing, ...) controlled by

$$(\delta^q_{ij})_{MM} = \frac{1}{\tilde{m}_q^2} \sum_{\alpha} (K^q_M)_{i\alpha} (K^q_M)^*_{j\alpha} \Delta \tilde{m}^2_{q\alpha}$$

mixing matrices mass splitting

| (m=ITeV) |    |                        |                                |  |  |
|----------|----|------------------------|--------------------------------|--|--|
| q        | ij | $(\delta^q_{ij})_{MM}$ | $\langle \delta^q_{ij}  angle$ |  |  |
| d        | 12 | 0.03                   | 0.002                          |  |  |
| d        | 13 | 0.2                    | 0.07                           |  |  |
| d        | 23 | 0.6                    | 0.2                            |  |  |
| U        | 12 | 0.1                    | 0.008                          |  |  |

Flavor Bounds (K, D, B, Bs mixing, ...) controlled by

$$(\delta_{ij}^q)_{MM} = \frac{1}{\tilde{m}_q^2} \sum_{\alpha} (K_M^q)_{i\alpha} (K_M^q)_{j\alpha}^* \Delta \tilde{m}_{q\alpha}^2$$

mixing matrices mass splitting

$$(m=1\text{TeV})$$

$$\begin{array}{c|cccc} q & ij & (\delta^q_{ij})_{MM} & \langle \delta^q_{ij} \rangle \\ \hline d & 12 & 0.03 & 0.002 \\ \hline d & 13 & 0.2 & 0.07 \\ \hline d & 23 & 0.6 & 0.2 \\ \hline u & 12 & 0.1 & 0.008 \\ \end{array}$$

large mixing means splitting must be << 1

# 



### Fully degenerate





# What has the LHC done to your favorite Model?

iated with jets with high transverse momentum (n) The gluino and squark masses. More LSP from the gluino de Carastel m to the SUSY events. In add Missing PT DM Events from the standard mod

ving cuts are often applied itsnge

ne jet with  $P_T > 100 \text{ GeV}$  and the

satisfy  $M_{\rm eff} > 400$  GeV, where the and  $E_{\rm Tmiss}$  answerse momentum of

eff 
$$M_{\text{eff}} \equiv \sum_{i=1,\dots4} p_{Ti} + \sum_{\text{leptons}} p_{Tl} + E_{\text{Tmiss}}$$
  
s,  $N_{\text{eff}} \equiv \sum_{i=1,\dots4} p_{Ti} + \sum_{\text{leptons}} p_{Tl} + E_{\text{Tmiss}}$ 



### DYI limits

#### CERN-PH-EP-2011-145

Search for squarks and gluinos using final states with jets and missing transverse momentum with the ATLAS detector in  $\sqrt{s} = 7$  TeV proton-proton collisions

The ATLAS Collaboration

Example: jets+ MET, I ifb

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The ATLAS Collaboration



### Example: jets+ MET, I ifb

| Signal Region   | $\geq$ 2-jet | $\geq$ 3-jet | ≥ 4-jet    | High mass |
|---|--------------|--------------|------------|-----------|
| $E_{ m T}^{ m miss}$  | > 130        | > 130        | > 130      | > 130     |
| Leading jet $p_{\rm T}$   | > 130        | > 130        | > 130      | > 130     |
| Second jet $p_{\rm T}$  | > 40         | > 40         | > 40       | > 80      |
| Third jet $p_{\rm T}$   | _            | > 40         | > 40       | > 80      |
| Fourth jet $p_{\rm T}$  | _            | _            | > 40       | > 80      |
| $\Delta \phi$ (jet, $\vec{P}_{\rm T}^{\rm miss}$ ) <sub>min</sub> | > 0.4        | > 0.4        | > 0.4      | > 0.4     |
| $E_{\rm T}^{\rm miss}/m_{\rm eff}$                                | > 0.3        | > 0.25       | > 0.25     | > 0.2     |
| $m_{\rm eff}$   | > 1000       | > 1000       | > 500/1000 | > 1100    |

signal bins


| Process                | Signal Region            |                          |                                  |                                   |                          |
|------------------------|--------------------------|--------------------------|----------------------------------|-----------------------------------|--------------------------|
| 1100035                | > 2-iet                  | > 3-iet                  | $\geq$ 4-jet,                    | $\geq$ 4-jet,                     | High mass                |
|                        | <u> </u>                 | <u> </u>                 | $m_{\rm eff} > 500 \; {\rm GeV}$ | $m_{\rm eff} > 1000 \; {\rm GeV}$ | ingii muss               |
| $Z/\gamma$ +jets       | $32.3 \pm 2.6 \pm 6.9$   | $25.5 \pm 2.6 \pm 4.9$   | $209 \pm 9 \pm 38$               | $16.2 \pm 2.2 \pm 3.7$            | $3.3 \pm 1.0 \pm 1.3$    |
| W+jets                 | $26.4 \pm 4.0 \pm 6.7$   | $22.6 \pm 3.5 \pm 5.6$   | $349 \pm 30 \pm 122$             | $13.0 \pm 2.2 \pm 4.7$            | $2.1 \pm 0.8 \pm 1.1$    |
| <i>tt</i> + single top | $3.4 \pm 1.6 \pm 1.6$    | $5.9 \pm 2.0 \pm 2.2$    | $425 \pm 39 \pm 84$              | $4.0 \pm 1.3 \pm 2.0$             | $5.7 \pm 1.8 \pm 1.9$    |
| QCD multi-jet          | $0.22 \pm 0.06 \pm 0.24$ | $0.92 \pm 0.12 \pm 0.46$ | $34 \pm 2 \pm 29$                | $0.73 \pm 0.14 \pm 0.50$          | $2.10 \pm 0.37 \pm 0.82$ |
| Total                  | $62.4 \pm 4.4 \pm 9.3$   | $54.9 \pm 3.9 \pm 7.1$   | $1015 \pm 41 \pm 144$            | $33.9 \pm 2.9 \pm 6.2$            | $13.1 \pm 1.9 \pm 2.5$   |
| Data                   | 58                       | 59                       | 1118                             | 40                                | 18                       |

Table 2: Fitted background components in each SR, compared with the number of events observed in data. The  $Z/\gamma$ +jets background is constrained with corregions CR1a and CR1b, the QCD multi-jet, W and top quark backgrounds by control regions CR2, CR3 and CR4, respectively. In each case the first (see quoted uncertainty is statistical (systematic). Background components are partially correlated and hence the uncertainties (statistical and systematic) on the background estimates do not equal the quadrature sums of the uncertainties on the components.



| Process                | Signal Region            |                          |                              |                                   |                          |  |
|------------------------|--------------------------|--------------------------|------------------------------|-----------------------------------|--------------------------|--|
| 1100055                | $> 2_{\text{iet}}$       | > 3_iet                  | $\geq$ 4-jet,                | $\geq$ 4-jet,                     | High mass                |  |
|                        | <u>&gt;</u> 2-jet        | 2 5-jet                  | $m_{\rm eff} > 500~{ m GeV}$ | $m_{\rm eff} > 1000 \; {\rm GeV}$ | Tingii illass            |  |
| $Z/\gamma$ +jets       | $32.3 \pm 2.6 \pm 6.9$   | $25.5 \pm 2.6 \pm 4.9$   | $209 \pm 9 \pm 38$           | $16.2 \pm 2.2 \pm 3.7$            | $3.3 \pm 1.0 \pm 1.3$    |  |
| W+jets                 | $26.4 \pm 4.0 \pm 6.7$   | $22.6 \pm 3.5 \pm 5.6$   | $349 \pm 30 \pm 122$         | $13.0 \pm 2.2 \pm 4.7$            | $2.1 \pm 0.8 \pm 1.1$    |  |
| <i>tt</i> + single top | $3.4 \pm 1.6 \pm 1.6$    | $5.9 \pm 2.0 \pm 2.2$    | $425 \pm 39 \pm 84$          | $4.0 \pm 1.3 \pm 2.0$             | $5.7 \pm 1.8 \pm 1.9$    |  |
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| Data                   | 58                       | 59                       | 1118                         | 40                                | 18                       |  |

Table 2: Fitted background components in each SR, compared with the number of events observed in data. The  $Z/\gamma$ +jets background is constrained with corregions CR1a and CR1b, the QCD multi-jet, W and top quark backgrounds by control regions CR2, CR3 and CR4, respectively. In each case the first (see quoted uncertainty is statistical (systematic). Background components are partially correlated and hence the uncertainties (statistical and systematic) on the background estimates do not equal the quadrature sums of the uncertainties on the components.

[5] has improved the ATLAS reach at large  $m_0$ . The five signal regions are used to set limits on  $\sigma_{new} = \sigma A \epsilon$ , for non-SM cross-sections ( $\sigma$ ) for which ATLAS has an acceptance A and a detection efficiency of  $\epsilon$  [44]. The excluded values of  $\sigma_{new}$  are 22 fb, 25 fb, 429 fb, 27 fb and 17 fb, respectively, at the 95% confidence level.

upper bound on signal xsec



| Process                | Signal Region            |                          |                              |                                   |                          |  |
|------------------------|--------------------------|--------------------------|------------------------------|-----------------------------------|--------------------------|--|
| 1100055                | $> 2_{\text{iet}}$       | > 3_iet                  | $\geq$ 4-jet,                | $\geq$ 4-jet,                     | High mass                |  |
|                        | <u>&gt;</u> 2-jet        | 2 5-jet                  | $m_{\rm eff} > 500~{ m GeV}$ | $m_{\rm eff} > 1000 \; {\rm GeV}$ | Tingii illass            |  |
| $Z/\gamma$ +jets       | $32.3 \pm 2.6 \pm 6.9$   | $25.5 \pm 2.6 \pm 4.9$   | $209 \pm 9 \pm 38$           | $16.2 \pm 2.2 \pm 3.7$            | $3.3 \pm 1.0 \pm 1.3$    |  |
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| <i>tt</i> + single top | $3.4 \pm 1.6 \pm 1.6$    | $5.9 \pm 2.0 \pm 2.2$    | $425 \pm 39 \pm 84$          | $4.0 \pm 1.3 \pm 2.0$             | $5.7 \pm 1.8 \pm 1.9$    |  |
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upper bound on signal xsec

### "Only" need efficiency x Acceptance of the signal bins for your model...



| Process                | Signal Region            |                          |                              |                                   |                          |  |
|------------------------|--------------------------|--------------------------|------------------------------|-----------------------------------|--------------------------|--|
| 1100055                | $> 2_{-iet}$             | > 3_iet                  | $\geq$ 4-jet,                | $\geq$ 4-jet,                     | High mass                |  |
|                        | 2-jet                    | 2 5-jet                  | $m_{\rm eff} > 500~{ m GeV}$ | $m_{\rm eff} > 1000 \; {\rm GeV}$ | 111gii Illass            |  |
| $Z/\gamma$ +jets       | $32.3 \pm 2.6 \pm 6.9$   | $25.5 \pm 2.6 \pm 4.9$   | $209 \pm 9 \pm 38$           | $16.2 \pm 2.2 \pm 3.7$            | $3.3 \pm 1.0 \pm 1.3$    |  |
| W+jets                 | $26.4 \pm 4.0 \pm 6.7$   | $22.6 \pm 3.5 \pm 5.6$   | $349 \pm 30 \pm 122$         | $13.0 \pm 2.2 \pm 4.7$            | $2.1 \pm 0.8 \pm 1.1$    |  |
| <i>tt</i> + single top | $3.4 \pm 1.6 \pm 1.6$    | $5.9 \pm 2.0 \pm 2.2$    | $425 \pm 39 \pm 84$          | $4.0 \pm 1.3 \pm 2.0$             | $5.7 \pm 1.8 \pm 1.9$    |  |
| QCD multi-jet          | $0.22 \pm 0.06 \pm 0.24$ | $0.92 \pm 0.12 \pm 0.46$ | $34 \pm 2 \pm 29$            | $0.73 \pm 0.14 \pm 0.50$          | $2.10 \pm 0.37 \pm 0.82$ |  |
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upper bound on signal xsec

"Only" need efficiency x Acceptance of the signal bins for your model...





| Process                | Signal Region            |                          |                              |                                   |                          |  |
|------------------------|--------------------------|--------------------------|------------------------------|-----------------------------------|--------------------------|--|
| 1100033                | > 2-iet                  | > 3-iet                  | $\geq$ 4-jet,                | $\geq$ 4-jet,                     | High mass                |  |
|                        | <u> 2</u> -jot           | 2 5-jet                  | $m_{\rm eff} > 500~{ m GeV}$ | $m_{\rm eff} > 1000 \; {\rm GeV}$ | ingn mass                |  |
| $Z/\gamma$ +jets       | $32.3 \pm 2.6 \pm 6.9$   | $25.5 \pm 2.6 \pm 4.9$   | $209 \pm 9 \pm 38$           | $16.2 \pm 2.2 \pm 3.7$            | $3.3 \pm 1.0 \pm 1.3$    |  |
| W+jets                 | $26.4 \pm 4.0 \pm 6.7$   | $22.6 \pm 3.5 \pm 5.6$   | $349 \pm 30 \pm 122$         | $13.0 \pm 2.2 \pm 4.7$            | $2.1 \pm 0.8 \pm 1.1$    |  |
| <i>tt</i> + single top | $3.4 \pm 1.6 \pm 1.6$    | $5.9 \pm 2.0 \pm 2.2$    | $425 \pm 39 \pm 84$          | $4.0 \pm 1.3 \pm 2.0$             | $5.7 \pm 1.8 \pm 1.9$    |  |
| QCD multi-jet          | $0.22 \pm 0.06 \pm 0.24$ | $0.92 \pm 0.12 \pm 0.46$ | $34 \pm 2 \pm 29$            | $0.73 \pm 0.14 \pm 0.50$          | $2.10 \pm 0.37 \pm 0.82$ |  |
| Total                  | $62.4 \pm 4.4 \pm 9.3$   | $54.9 \pm 3.9 \pm 7.1$   | $1015\pm41\pm144$            | $33.9 \pm 2.9 \pm 6.2$            | $13.1 \pm 1.9 \pm 2.5$   |  |
| Data                   | 58                       | 59                       | 1118                         | 40                                | 18                       |  |

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upper bound on signal xsec

"Only" need efficiency x Acceptance of the signal bins for your model...





## Simplified Models

ATLAS and CMS provide efficiencies for a small set of simplified models



Unfortunately, simplified models are usually not sufficient.

Susy example: jets + MET



Simplified models do not cover associate production, pair produced non-degenerate squarks, ...

Unreasonable to produce simplified models for every conceivable case\* (especially for only setting limits)

One needs to do something else...

Have to extract E\*A ourselves (and compare with information provided)

\* see e.g. <u>http://www.lhcnewphysics.org</u> for an attempt at an exhaustive list

### **ATOM:** automatic test of models A fast, local way to (approximately) "re-interpret" LHC analyses Plots Applying search **Events** Efficiencies strategies **Statistics** Warnings Database of analyses "Theorist-level" Limits

### w/ M. Papucci (LBL), D. Neuenfeld

Analyses (12k lines), Atom Core (~25k lines)

Two options:

I) "Truth level" (within 20-30% right answer)

- o lepton isolation (projection) according to various requirements of ATLAS and CMS
- b and T tagging done by looking in jet for a b or T progenitor and applying efficiency factor/fake factor
   o residual (20%) efficiency correction: compare with available data

Extract efficiency corrections by comparing with available data

2) Apply efficiencies and smearing defined per object per experiment per year, pT and  $\eta$ - dependent

#### % atom --list-analyses

| ATLAS_2010_CONF_2010_049 | Cross-section of and fragmentation function in anti-kt track jets                     |
|--------------------------|---|
| ATLAS_2010_\$8591806     | Charged particles at 900 GeV in ATLAS   |
| ATLAS_2010_\$8755477     | \$Dijet mass distriubtion\$   |
| ATLAS_2010_\$8814007     | Dijet Angular distributions at 7 TeV with \$3.1pb^{-1}\$.                             |
| ATLAS_2010_\$8817804     | Inclusive jet cross section and di-jet mass and chi spectra at 7 TeV in ATLAS         |
| ATLAS_2010_58894728      | Track-based underlying event at 900 GeV and 7 TeV in ATLAS                            |
| ATLAS_2010_58914249      | Diphoton+MET search   |
| ATLAS_2010_\$8914702     | Inclusive isolated prompt photon analysis   |
| ATLAS_2010_\$8918562     | Track-based minimum bias at 900 GeV and 2.36 and 7 TeV in ATLAS                       |
| ATLAS_2010_S8919674      | W+jets jet multiplicities and pT  |
| ATLAS_2011_CONF_2011_036 | Anomalous MET in ttbar Events at the LHC 7TeV with \$35pb^{-1}\$.                     |
| ATLAS_2011_CONF_2011_039 | Trileptons search at 7 TeV with \$35pb^{-1}\$.  |
| ATLAS_2011_CONF_2011_086 | Jets+MET at 7 TeV with \$165pb^{-1}\$.  |
| ATLAS_2011_CONF_2011_090 | <pre>1lepton+jets+MET at 7 TeV with \$165pb^{-1}\$.</pre>                             |
| ATLAS_2011_CONF_2011_096 | <insert atlas_2011_conf_2011_096="" description="" short=""></insert>                 |
| ATLAS_2011_CONF_2011_098 | bjets+MET+0L at 7 TeV with \$830pb^{-1}\$.  |
| ATLAS_2011_CONF_2011_123 | <insert atlas_2011_conf_2011_123="" description="" short=""></insert>                 |
| ATLAS_2011_CONF_2011_126 | Search for Anomalous Production of Prompt Like-sign Muon Pairs with 1.6 \$fb^{-1}\$.  |
| ATLAS_2011_CONF_2011_130 | bjets+llept+jets+MET SUSY search at 7TeV with \$1fb^{-1}\$                            |
| ATLAS_2011_CONF_2011_144 | <insert atlas_2011_conf_2011_144="" description="" short=""></insert>                 |
| ATLAS_2011_1919017       | Measurement of ATLAS track jet properties at 7 TeV                                    |
| ATLAS_2011_1925932       | Measurement of the W pT with electrons and muons at 7 TeV                             |
| ATLAS_2011_1926145       | Measurement of electron and muon differential cross-section from heavy-flavour decays |
| ATLAS_2011_1944826       | KS0 and Lambda production at 0.9 and 7 TeV with ATLAS                                 |
| ATLAS_2011_1945498       | Z+jets in pp at 7TeV  |
| ATLAS_2011_58924791      | Jet shapes at 7 TeV in ATLAS  |
| ATLAS_2011_S8970084      | <pre>1lepton+jets+MET at 7 TeV with \$35pb^{-1}\$.</pre>                              |
| ATLAS_2011_58971293      | Dijet azimuthal decorrelations  |
| ATLAS_2011_58983313      | Jets+MET at 7 TeV with \$35pb^{-1}\$.   |
| ATLAS_2011_58994773      | Calo-based underlying event at 900 GeV and 7 TeV in ATLAS                             |
| ATLAS_2011_58996709      | <insert atlas_2011_s8996709="" description="" short=""></insert>                      |
| ATLAS_2011_59002537      | Muon charge asymmetry in W events at 7 TeV in ATLAS                                   |
| ATLAS_2011_59011218      | bjets+MET at 7 TeV with \$35pb^{-1}\$.  |
| ATLAS_2011_59019553      | SF lepton pairs SUSY search at 7 TeV with \$35pb^{-1}\$.                              |
| ATLAS_2011_S9019561      | 2leptons+MET at 7TeV with \$35pb^{-1}\$.  |
| ATLAS_2011_59108483      | <insert atlas_2011_s9108483="" description="" short=""></insert>                      |
| ATLAS_2011_S9120726      | Diphoton+MET at 7TeV with \$36 pb^{-1}\$  |
| ATLAS_2011_59120807      | Inclusive isolated diphoton analysis  |
| ATLAS_2011_S9126244      | Measurement of dijet production with a veto on additional central jet activity        |
| ATLAS_2011_59128077      | Measurement of multi-jet cross sections   |
| ATLAS_2011_59131140      | Measurement of the Z pT with electrons and muons at 7 TeV                             |
| ATLAS_2011_S9203559      | <insert atlas_2011_s9203559="" description="" short=""></insert>                      |
| ATLAS_2011_59225137      | multijet SUSY search at 7TeV  |
| ATLAS_2012_CONF_2012_033 | 2-6 jets + MET SUSY search at 7TeV  |
| ATLAS_2012_11082009      | <pre>\$D^{*\pm}\$ production in jets</pre>  |
| ATLAS_2012_11082936      | Inclusive jet and dijet cross sections at 7 TeV                                       |
| ATLAS_2012_11083318      | W+jets production at 7 TeV  |
| ATLAS_2012_11084540      | Rapidity gap cross sections measured with the ATLAS detector in pp collisions at sqrt |
| ATLAS_2012_11091481      | Azimuthal ordering of charged hadrons   |
|                          |   |

#### % atom --list-analyses

|                         |  | 62     | CMS_2011_S9120041      | Traditional leading jet U                         |  |
|-------------------------|--|--------|------------------------|---|--|
| TLAS 2010 CONF 2010 049 | Cross-section of and fragmentatio  | 63     | CMS_2011_S9215166      | Forward energy flow in MB                         |  |
| TLAS 2010 \$8591806     | Charged particles at 980 GeV in A  | 64     | CMS_PAS_EX0_11_017     | Search for quark composite                        |  |
| TLAS 2010 S0766477      | thiat mare distributions   | 65     | CMS_PAS_EX0_11_036     | <insert cms_pas_ex0,<="" short="" th=""></insert> |  |
| TLAC 2010 0014007       | Dijet Angular distributions at 7   | 66     | CMS_PAS_EX0_11_050     | <insert cms_pas_exo<="" short="" th=""></insert>  |  |
| LAS_2010_30014007       | Traductor discribucions at r   | 67     | CHS_PAS_EX0_11_051     | Search for pair production                        |  |
| TLAS_2010_58817804      | Inclusive jet cross section and d  | 68     | CHS_PAS_SUS_10_005     | HI, MHI SUSY Search in jets                       |  |
| TLA5_2010_58894728      | Track-based underlying event at 9  | 78     | CHS_FAS_505_10_005     | taloba Tt analysis on jetster                     |  |
| TLAS_2010_S8914249      | Diphoton+MET search  | 71     | CNS PAS SUS 11 003     | Jets+MET with \$\aloba T\$                        |  |
| TLAS_2010_\$8914702     | Inclusive isolated prompt photon   | 72     | CNS PAS SUS 11 004     | CInsert short CMS PAS SUS                         |  |
| TLAS_2010_S8918562      | Track-based minimum bias at 900 G  | 73     | CMS_PAS_SUS_11_005     | <insert cms_pas_sus<="" short="" th=""></insert>  |  |
| TLAS_2010_S8919674      | W+jets jet multiplicities and pT   | 74     | CMS_PAS_SUS_11_006     | <insert cms_pas_sus<="" short="" th=""></insert>  |  |
| TLAS_2011_CONF_2011_036 | Anomalous MET in ttbar Events at   | 75     | CMS_PAS_SUS_11_010     | <insert cms_pas_sus<="" short="" th=""></insert>  |  |
| TLAS_2011_CONF_2011_039 | Trileptons search at 7 TeV with \$   | 76     | CMS_PAS_SUS_11_011     | <insert cms_pas_sus<="" short="" th=""></insert>  |  |
| TLAS_2011_CONF_2011_086 | Jets+MET at 7 TeV with \$165pb^{-1   | 77     | CMS_PAS_SUS_11_015     | <insert cms_pas_sus<="" short="" th=""></insert>  |  |
| TLAS_2011_CONF_2011_090 | 1lepton+jets+MET at 7 TeV with \$1   | 78     | CMS_PAS_SUS_11_017     | Search for New Physics in                         |  |
| TLAS 2011 CONF 2011 096 | <insert 2011="" 201<="" atlas="" conf="" short="" th=""><th>79</th><th>CMS_PAS_SUS_11_028</th><th><insert cms_pas_sus<="" short="" th=""></insert></th></insert> | 79     | CMS_PAS_SUS_11_028     | <insert cms_pas_sus<="" short="" th=""></insert>  |  |
| TLAS 2011 CONF 2011 098 | biets+MET+0L at 7 TeV with \$830ob   | 80     | CMS_PAS_SUS_12_011     | Resideranidity distribution                       |  |
| TLAS 2011 CONE 2011 123 | Closert short ATLAS 2011 CONE 201  | 82     | DB 2888 \$4488767      | Transverse momentum of the                        |  |
| TLAS 2011 CONE 2011 126 | Search for Anomalous Production of   | 83     | D8 2881 \$4674421      | Tevatron Run I differenti                         |  |
| TIAS 2011 CONE 2011 120 | biotest] ontwinter NET SUSY coarch   | 84     | D0_2004_S5992206       | Run II jet azimuthal deco                         |  |
| TLAS 2011_CONF_2011_130 | Jets+Itept+jets+AEI SUST Search  | 85     | D0_2006_\$6438750      | Inclusive isolated photon                         |  |
| TLAS_2011_CONF_2011_144 | KINSERT SHOPT ATLAS_2011_CONF_201  | 86     | D8_2887_\$7875677      | \$Z/\gamma^* + X\$ cross-set                      |  |
| LTV2_5011_1010011       | Measurement of AILAS track jet pr  | 87     | D8_2888_\$6879855      | Measurement of the ratio                          |  |
| TLAS_2011_1925932       | Measurement of the W pT with elec  | 88     | D8_2888_\$7554427      | \$Z/\gamma^* + X\$ cross-set                      |  |
| TLAS_2011_1926145       | Measurement of electron and muon   | 89     | D8_2888_\$7662678      | Measurement of D0 Run II (                        |  |
| TLAS_2011_1944826       | KS0 and Lambda production at 0.9   | 90     | D0_2008_57719523       | Isolated \$\gamma\$ + jet c                       |  |
| TLAS_2011_1945498       | Z+jets in pp at 7TeV   | 91     | D0_2008_57837160       | Measurement of W charge as                        |  |
| TLAS_2011_S8924791      | Jet shapes at 7 TeV in ATLAS   | 92     | D8 2889 \$8282443      | \$7/\cammaA#\$ + iot + \$X\$                      |  |
| TLAS_2011_S8970084      | 1lepton+jets+MET at 7 TeV with \$3   | 94     | D8 2889 58328168       | Dijet angular distributio                         |  |
| TLAS_2011_S8971293      | Dijet azimuthal decorrelations   | 95     | D8_2009_58349509       | Z+jets angular distribution                       |  |
| TLAS_2011_S8983313      | Jets+MET at 7 TeV with \$35pb^{-1}   | 96     | D8_2010_\$8566488      | Dijet invariant mass                              |  |
| TLAS_2011_S8994773      | Calo-based underlying event at 98  | 97     | D8_2010_\$8570965      | Direct photon pair product                        |  |
| TLAS_2011_58996709      | <insert atlas_2011_s8996709<="" short="" th=""><th>98</th><th>D0_2010_\$8671338</th><th>Measurement of differentia</th></insert>                                 | 98     | D0_2010_\$8671338      | Measurement of differentia                        |  |
| TLAS_2011_S9002537      | Muon charge asymmetry in W events  | 99     | D8_2010_\$8821313      | Precise study of Z pT usin                        |  |
| TLAS_2011_59011218      | bjets+MET at 7 TeV with \$35pb^{-1   | 100    | D0_2011_I895662        | 3-jet invariant mass                              |  |
| TLAS 2011 \$9019553     | SF lepton pairs SUSY search at 7   | 101    | DELPHI_1995_53137023   | Strange baryon production                         |  |
| TLAS 2011 \$9019561     | 2leptons+MET at 7TeV with \$35pb^{   | 182    | DELPHI_1996_53430090   | Deconi MC tuning on event                         |  |
| TLAS 2011 59108483      | <insert 2011="" atlas="" s9108483<="" short="" th=""><th>descr</th><th>iption&gt;</th><th></th></insert>   | descr  | iption>                |   |  |
| TLAS 2811 59128726      | Diphoton+NFT at 7TeV with \$36 ph4   | -115   |                        |   |  |
| TI 45 2811 59128887     | Inclusive isolated diphoton analys   | de la  |                        |   |  |
| TLAS 2011 S0126344      | Nessurement of dijet production wi   | *      | veto on additional con | tral ist activity                                 |  |
| TLAS 2011 50120244      | Neasurement of sulti int cross of  | til a  | veco un addretonat cen | trat jet activity                                 |  |
| TLAS_2011_59128077      | Measurement of multi-jet cross set   | c Tona |                        |   |  |
| LAS_2011_59131140       | Measurement of the Z pT with electrons and muons at 7 TeV  |        |                        |   |  |
| TLAS_2011_59203559      | <insert atlas_2011_s9203559="" description="" short=""></insert>   |        |                        |   |  |
| TLA5_2011_59225137      | multijet SUSY search at 7TeV   |        |                        |   |  |
| TLAS_2012_CONF_2012_033 | 2-6 jets + MET SUSY search at 7TeV   |        |                        |   |  |
| TLAS_2012_11082009      | <pre>\$D^{*\pm}\$ production in jets</pre>   |        |                        |   |  |
| TLAS_2012_I1082936      | Inclusive jet and dijet cross sect   | ions   | at 7 TeV               |   |  |
| TLAS_2012_I1083318      | W+jets production at 7 TeV   |        |                        |   |  |
| TLAS_2012_I1084540      | Rapidity gap cross sections measured with the ATLAS detector in pp collisions at sqrt(   |        |                        |   |  |

ATLAS\_2012\_I1091481 Azimuthal ordering of charged hadrons

| 57  | CNS 2011 58950903    | Dilet azimuthal decorrelations in SODS collisions at Sisdrifs) = 75 lev                                    |
|-----|----------------------|--|
| 53  | CMS 2011 58957746    | Event shapes   |
| 54  | CMS 2011 58968497    | Measurement of dijet angular distributions and search for guark compositeness in SopS collisions at S)     |
| 55  | CMS 2011 58973270    | B/anti-B angular correlations based on secondary vertex reconstruction in pp collisions                    |
| 56  | CMS 2011 58978280    | Kshort, Lambda, and Cascade- transverse momentum and rapidity spectra from proton-proton collisions at     |
| 57  | CMS 2011 S8990433    | Diphoton+NET at 7 TeV with \$35pb^{-1}\$.  |
| 58  | CNS 2011 S8991847    | OS dilectors at TTeV with \$350b^(-1)\$  |
| 59  | CNS 2011 59036504    | Same Sign dileptons at TTeV in \$35pb/(-1)\$   |
| 68  | CMS 2011 59086218    | Measurement of the inclusive jet cross-section in SopS collisions at \$\sqrt{s} = 75 TeV                   |
| 61  | CMS 2011 59088458    | Measurement of ratio of the 3-jet over 2-jet cross section in pp collisions at sort(s) = 7 TeV             |
| 62  | CMS 2011 59120041    | Traditional leading jet UE measurement at \$\sqrt(s)=0.95 and 7 TeV  |
| 63  | CMS 2011 S9215166    | Forward energy flow in MB and dijet events at 0.9 and 7 TeV  |
| 64  | CMS PAS EXO 11 017   | Search for quark compositeness in dijet angular distributions from \$pp\$ collisions at \$\sqrt{s} = 7\$ 1 |
| 65  | CHS PAS EX0 11 036   | <pre><insert cms_pas_ex0_11_036="" description="" short=""></insert></pre>                                 |
| 66  | CMS PAS_EX0_11_050   | <pre><insert 050="" 11="" cms="" description="" ex0="" pas="" short=""></insert></pre>                     |
| 67  | CMS_PAS_EX0_11_051   | Search for pair production of a fourth-generation t' quark in the lepton-plus-jets channel with the CM     |
| 68  | CMS_PAS_SUS_10_005   | HT,MHT susy search in jets+MET at 7 TeV with \$35pb^{-1}\$.  |
| 69  | CMS_PAS_SUS_10_009   | razor analysis on jets+MET and llepton+jets+MET at 7 TeV with \$35pb^{-1}\$.                               |
| 70  | CMS_PAS_SUS_10_011   | <pre>\$\alpha_T\$ analysis on b jets+MET at 7 TeV with \$35pb^{-1}\$.</pre>                                |
| 71  | CMS_PAS_SUS_11_003   | Jets+MET with \$\alpha_T\$ variable with \$1.1 fb^{-1}\$   |
| 72  | CMS_PAS_SUS_11_004   | <insert cms_pas_sus_11_004="" description="" short=""></insert>  |
| 73  | CMS_PAS_SUS_11_005   | <insert cms_pas_sus_11_005="" description="" short=""></insert>  |
| 74  | CMS_PAS_SUS_11_006   | <insert cms_pas_sus_11_006="" description="" short=""></insert>  |
| 75  | CMS_PAS_SUS_11_010   | <insert cms_pas_sus_11_010="" description="" short=""></insert>  |
| 76  | CMS_PAS_SUS_11_011   | <insert cms_pas_sus_11_011="" description="" short=""></insert>  |
| 77  | CMS_PAS_SUS_11_015   | <insert cms_pas_sus_11_015="" description="" short=""></insert>  |
| 78  | CMS_PAS_SUS_11_017   | Search for New Physics in Events with a Z Boson and Missing Transverse Energy                              |
| 79  | CMS_PAS_SUS_11_028   | <insert cms_pas_sus_11_028="" description="" short=""></insert>  |
| 80  | CMS_PAS_SUS_12_011   | <insert cms_pas_sus_12_011="" description="" short=""></insert>  |
| 81  | CMS_QCD_10_024       | Pseudorapidity distributions of charged particles at sqrt(s)=0.9 and 7 TeV                                 |
| 82  | D8_2888_\$4488767    | Transverse momentum of the W boson   |
| 83  | D0_2001_\$4674421    | Tevatron Run I differential W/Z boson cross-section analysis   |
| 84  | D8_2884_\$5992286    | Run II jet azimuthal decorrelation analysis  |
| 85  | D0_2006_\$6438750    | Inclusive isolated photon cross-section, differential in pT(gamma)   |
| 86  | D8_2887_\$7875677    | <pre>\$Z/\gamma^* + X\$ cross-section shape, differential in \$y(Z)\$</pre>                                |
| 87  | D8_2888_S6879855     | Measurement of the ratio sigma(\$Z/\gamma^*\$ + \$n\$ jets)/sigma(\$Z/\gamma^*\$)                          |
| 88  | D8_2888_\$7554427    | <pre>\$Z/\gamma^* + X\$ cross-section shape, differential in \$pT(Z)\$</pre>                               |
| 89  | D8_2888_\$7662678    | Measurement of D0 Run II differential jet cross sections   |
| 90  | D8_2888_\$7719523    | Isolated \$\gamma\$ + jet cross-sections, differential in pT(\$\gamma\$) for various \$y\$ bins            |
| 91  | D0_2008_57837160     | Measurement of W charge asymmetry from D0 Run II   |
| 92  | D0_2008_\$7863608    | Measurement of differential \$Z/\gamma**\$ + jet + \$X\$ cross sections                                    |
| 93  | D8_2889_58282443     | \$Z/\gamma^*\$ + jet + \$X\$ cross sections differential in pT(jet 1,2,3)                                  |
| 94  | D8_2089_58328168     | Dijet angular distributions  |
| 95  | D8_2009_58349509     | Z+jets angular distributions   |
| 96  | D8_2018_58566488     | Dijet invariant mass   |
| 97  | D8_2010_58570965     | Direct photon pair production  |
| 98  | D0_2010_58671338     | Measurement of differential \$Z/\gamma^*\$ pT  |
| 99  | D8_2818_58821313     | Precise study of Z pT using novel technique  |
| 100 | D8_2811_1895662      | 3-jet invariant mass   |
| 101 | DELPHI_1995_53137023 | Strange baryon production in \$Z\$ hadronic decays at Delphi   |
| 102 | DELPHI_1996_53430090 | Delphi MC tuning on event shapes and identified particles.   |

# o Cut flow efficiencies, and final efficiencies per subprocess

| Cuts     |                           |            | (click to collapse) |
|----------|---------------------------|------------|---------------------|
| Cut Flow | Description               | Efficiency | Derivative          |
| Ht       | description of Ht cut     | 20.00%     | -0.767              |
| MHt      |                           | 11.72%     | -1.089              |
| dphiJ1   | description of dphiJ1 cut | 11.53%     | 0.000               |
| dphiJ2   |                           | 10.54%     | -0.164              |
| dphiJ3   |                           | 9.78%      | 0.000               |
| lowHt    |                           | 1.15%      | 0.382               |
| lowHt1   |                           | 0.61%      | 0.714               |
| lowHt2   |                           | 0.54%      | 0.000               |
| lowHt3   |                           | 0.00%      | 0.000               |
| lowHt4   |                           | 0.00%      | 0.000               |
| medHt    |                           | 1.73%      | 0.000               |
| high1Ht  |                           | 1.71%      | 0.000               |
| high1Ht1 |                           | 0.65%      | 0.000               |
| high1Ht2 |                           | 0.79%      | 1.894               |
| high1Ht3 |                           | 0.28%      | -5.356              |
| high2Ht  |                           | 1.83%      | 0.240               |
| high2Ht1 |                           | 0.80%      | 0.000               |
| high2Ht2 |                           | 1.03%      | -1.862              |
| high3Ht  |                           | 3.36%      | -4.281              |
| high3Ht3 |                           | 3.36%      | -1.299              |
| medHt1   |                           | 0.20%      | 2.246               |
| medHt2   |                           | 1.15%      | 0.383               |
| medHt3   |                           | 0.19%      | 0.000               |
| medHt4   |                           | 0.19%      | 0.000               |
|          |                           |            |                     |



### Check:

- kinematic distortions (shape)
- signal  $\epsilon \times \mathcal{A}$  (normalization)
- + compare to all available limit plots...
  - ~ 50 GeV accuracy (usually better)

## Remark on prospino



 $\begin{bmatrix} \tilde{q} \\ -\tilde{q} \end{bmatrix} \qquad \frac{1}{m_{\tilde{g}}} \tilde{q} \tilde{q} u_R u_R \quad \text{dim5 operator} \\ \xrightarrow{q} \qquad \rightarrow \qquad \sigma \sim 1/m_{\tilde{g}}^2$ 

## Remark on prospino







## Remark on prospino



 $\frac{1}{m_{\tilde{g}}} \tilde{q} \tilde{q} u_R u_R \quad \text{dim5 operator} \\ \rightarrow \quad \sigma \sim 1/m_{\tilde{g}}^2$ 



With heavy gluinos prospino fails at reproducing the decoupling behavior

## One light squark vs. gluino mass

sea vs. valence squark









## MFV splitting - flavor trivial light squarks



## Collider vs. Flavor for sea & valence squarks



 $H_{\text{eff}} = C_1 \, (\overline{u}^i \gamma_\mu P_L \, c^i) \, (\overline{u}^j \gamma^\mu P_L \, c^j) \,, \qquad x_D \simeq 2.6 \times 10^{10} \text{ Re } C_1$ Assuming full down alignment, calculated w/o MIA

## Outlook

