Susy model-building in view of LHC data







ERN 22:08:14 2012 CEST 000 Rencontres de Physique de la Vallée d'Aoste 2013-3-1

gauge coupling running at 2 loops



Unification below Planck scale, high enough for proton stability

gauge coupling running at 2 loops



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gauge coupling running at 2 loops



Unification below Planck scale, high enough for proton stability

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 ⁻¹ . 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 ⁻¹ . 8 TeV [ATLAS-CONF-2012-109] 1.38 TeV \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 ⁻¹ , 7 TeV [1208.4688] 900 GeV $\widetilde{\mathbf{Q}}$ mass $(m(\widetilde{\chi}^0) < 200 \text{ GeV}, m(\widetilde{\chi}^{\pm}) = \frac{1}{2}(m(\widetilde{\chi}^0) + m(\widetilde{\mathbf{q}}))$	900 GeV $\widetilde{\mathbf{Q}}$ mass $(m(\widetilde{\mathbf{y}}^0) < 200 \text{ GeV}, m(\widetilde{\mathbf{y}}^\pm) = \frac{1}{2}(m(\widetilde{\mathbf{y}}^0) + m(\widetilde{\mathbf{q}}))$			
Seá	$GMSB(\widetilde{I} NI SP) : 2 lep (OS) + i's + F$	<i>L</i> =4.7 fb ⁻¹ , 7 TeV [1208.4688] 1.24 TeV \widetilde{Q} [mass] (tan β < 15)				
9	GMSB ($\tilde{\tau}$ NLSP) : 1-2 τ + 0-1 lep + j's + $E_{\tau}^{T,miss}$	<i>L</i> =4.7 fb ⁻¹ , 7 TeV [1210.1314] 1.20 TeV $\widetilde{\mathbf{Q}}$ mass $(\tan\beta > 20)$				
isi	GGM (bino NLSP) : $\gamma\gamma + E_T^{T,miss}$	L=4.8 fb ⁻¹ , 7 TeV [1209.0753] 1.07 TeV \tilde{g} mass $(m(\tilde{\chi}^0) > 50 \text{ GeV})$	(21 - 130) fb ⁻¹			
וטנ	GGM (wino NLSP) : γ + lep + $E_{-}^{\gamma,\text{miss}}$	L=4.8 fb ⁻¹ , 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 ⁻¹ , 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 ⁻¹ , 8 TeV [ATLAS-CONF-2012-152] 690 GeV \widetilde{g} (m(H) > 200 GeV)	•••••			
	Gravitino LSP : 'monojet' + $E_{T miss}$	L=10.5 fb ⁻¹ , 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 ⁻¹ , 8 TeV [ATLAS-CONF-2012-145] 1.24 TeV \widetilde{g} mass $(m(\chi^0) < 200 \text{ GeV})$				
. sı neı	$\tilde{q} \rightarrow t \tilde{\chi}^{01}$ (virtual \tilde{t}) : 2 lep (SS) + i's + E_{T} miss	L=5.8 fb ⁻¹ , 8 TeV [ATLAS-CONF-2012-105] 850 GeV \widetilde{g} Mass $(m(\widetilde{\chi}^0) < 300 \text{ GeV})$				
ien o r	$\widetilde{q} \rightarrow t \widetilde{\chi}^0$ (virtual \widetilde{t}) : 3 lep + i's + $E_{\tau, \text{miss}}$	L=13.0 fb ⁻¹ , 8 TeV [ATLAS-CONF-2012-151] 860 GeV \tilde{g} mass $(m(\chi^0) < 300 \text{ GeV})$	8 TeV results			
d g uin	$\tilde{q} \rightarrow t \tilde{\chi}$ (virtual \tilde{t}) : 0 lep + multi-i's + E_{τ}	L=5.8 fb ⁻¹ , 8 TeV [ATLAS-CONF-2012-103] 1.00 TeV \widetilde{g} mass $(m(\tilde{\chi}^0) < 300 \text{ GeV})$	7 ToV results			
gl 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 ⁻¹ , 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 ⁻¹ , 8 TeV [ATLAS-CONF-2012-165] 620 GeV b mass $(m(\tilde{\chi}^0) < 120 \text{ GeV})$				
'ks on	$\widetilde{bb}, \widetilde{b} \rightarrow t\widetilde{\gamma}^{\pm}$: 3 lep + i's + E_{τ}	L=13.0 fb ⁻¹ , 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 ⁻¹ , 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 ⁻¹ , 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. pra	$\tilde{t}\tilde{t}$ (medium), $\tilde{t} \rightarrow b\tilde{\chi}^{\pm}$: 2 lep + $E_{T \text{ miss}}$	L=13.0 fb ⁻¹ , 8 TeV [ATLAS-CONF-2012-167] 160-440 GeV \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 ⁻¹ , 8 TeV [ATLAS-CONF-2012-166] 230-560 GeV \widetilde{t} mass $(m(\tilde{\chi}_{4}^{0}) = 0)$				
3rc 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 ⁻¹ , 7 TeV [1208.1447,1208.2590,1209.4186] 230-465 GeV \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 ⁻¹ , 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 ⁻¹ , 7 TeV [1208.2884] 85-195 GeV MASS $(m(\tilde{\chi}_{*}^{0}) = 0)$				
W 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 ⁻¹ , 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	$\widetilde{\chi}_{1}^{\pm}\widetilde{\chi}_{2}^{0} \rightarrow \widetilde{I}_{1}^{1} v \widetilde{I}_{1}^{1} (\widetilde{v}v), \widetilde{v} \widetilde{I}_{1}^{1} (\widetilde{v}v) : 3 \text{ lep } + E_{T \text{ miss}}$	L=13.0 fb⁻¹, 8 TeV [ATLAS-CONF-2012-154] 580 GeV $\widetilde{\chi}_{1}^{\pm}$ Mass $(m(\widetilde{\chi}_{1}^{\pm}) = m(\widetilde{\chi}_{0}^{0}), m(\widetilde{\chi}_{1}^{0}) = 0, m(\widetilde{l}, \widetilde{v})$ 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 ⁻¹ , 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 ⁻¹ , 7 TeV [1210.2852] 220 GeV $\widetilde{\chi}_{1}^{\pm}$ mass $(1 < \tau (\widetilde{\chi}_{1}^{\pm}) < 10 \text{ ns})^{-1}$				
ive les	Stable \tilde{g} R-hadrons : low β , $\beta\gamma$ (full detector)	L=4.7 fb ⁻¹ , 7 TeV [1211.1597] 985 GeV g mass				
ig-l rtic	Stable \tilde{t} R-hadrons : low β , $\beta\gamma$ (full detector)	L=4.7 fb ⁻¹ , 7 TeV [1211.1597] 683 GeV t mass				
-on pa	GMSB : stable $ ilde{ au}$	L=4.7 fb⁻¹, 7 TeV [1211.1597] 300 GeV $\tilde{\tau}$ MASS (5 < tan β < 20)				
7	$\widetilde{\chi}^{"} \rightarrow qq\mu (RPV) : \mu + heavy displaced vertex$	L=4.4 fb⁻¹, 7 TeV [1210.7451] 700 GeV $\widetilde{\mathbf{q}}$ mass $(0.3 \times 10^{-5} < \lambda_{211} < 1.5 \times 10^{-5}, 1 \text{ mm} < c\tau < 1 \text{ m}, \widetilde{\mathbf{g}} \text{ det})$	ecoupled)			
	LFV : pp $\rightarrow \tilde{v}_{\tau} + X, \tilde{v}_{\tau} \rightarrow e + \mu$ resonance	L=4.6 fb ⁻¹ , 7 TeV [Preliminary] 1.61 TeV $\tilde{\nu}_{\tau}$ MASS (λ_{311}^{*} =0.10, λ_{132}^{*} =0.05)				
	LFV : pp $\rightarrow \tilde{v}_{\tau} + X$, $\tilde{v}_{\tau} \rightarrow e(\mu) + \tau$ resonance	L=4.6 fb⁻¹, 7 TeV [Preliminary] 1.10 TeV \widetilde{v}_{I} (λ_{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 ⁻¹ , 7 TeV [ATLAS-CONF-2012-140] 1.2 TeV $q = g$ mass ($c\tau_{LSP} < 1$ mm)				
B	$\widetilde{\chi}_{1}^{+}\widetilde{\chi}_{-}^{-}\widetilde{\chi}_{1}^{+} \rightarrow W\widetilde{\chi}_{0}^{0}, \widetilde{\chi}_{0}^{0} \rightarrow eev_{\mu}, e\mu v_{\mu} : 4 lep + E_{T.miss}$	L=13.0 fb⁻¹, 8 TeV [ATLAS-CONF-2012-153] 700 GeV χ_1^{-1} Mass $(m(\chi_1^{0}) > 300 \text{ GeV}, \lambda_{121} \text{ or } \lambda_{122} > 0)$				
	$ L_L, L_{\perp} \rightarrow \widetilde{\chi}_{\mu}, \widetilde{\chi}_{\mu} \rightarrow eev_{\mu}, e\muv_{\mu} > 4 lep + E_{T,miss}$	L=13.0 fb⁻¹, 8 TeV [ATLAS-CONF-2012-153] 430 GeV I MASS $(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 ⁻¹ , 7 TeV [1210.4813] 666 GeV \tilde{g} mass				
14/18/	Scalar gluon : 2-jet resonance pair	L=4.6 fb ⁻¹ , 7 TeV [1210.4826] 100-287 GeV Sgluon mass (incl. limit from 1110.2693)				
VVIIV	IF INTERACTION (D5, DIFAC χ) : MONOJET + E T,miss	L=10.5 fb⁻¹, 8 TeV [ATLAS-CONF-2012_1147] 704 GeV M^* \$Cale ($m_{\chi} < 80$ 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 ⁻¹ .8.TeV [ATLAS_CONE-2012-109]	150	
	MSUGRA/CMSSM : 1 lep + j's + $E_{T,miss}$	L=5.8 fb ⁻¹ , 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 ⁻¹ , 8 TeV [ATLAS-CONF-2012-109]	1.18 TeV	\widetilde{q} mass $(m(\widetilde{q}) < 2 \text{ TeV}, \text{ light } \widetilde{\chi}^0)$ ATLAS
hea	Pheno model : 0 lep + j's + $E_{T miss}$	L=5.8 fb ⁻¹ , 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 ⁻¹ , 7 TeV [1208.4688]	900 GeV ĝ	ASS $(m(\tilde{\chi}_1^0) < 200 \text{ GeV}, m(\tilde{\chi}^{\pm}) = \frac{1}{2}(m(\tilde{\chi}^0) + m(\tilde{g}))$
Se	GMSB (\tilde{I} NLSP) : 2 lep (OS) + j's + $E_{T miss}$	L=4.7 fb ⁻¹ , 7 TeV [1208.4688]	1.24 Te\	\tilde{g} mass' (tan β < 15)
ive	GMSB ($\tilde{\tau}$ NLSP) : 1-2 τ + 0-1 lep + j's + $E_{T,\text{miss}}^{T,\text{miss}}$	L=4.7 fb ⁻¹ , 7 TeV [1210.1314]	1.20 TeV	\tilde{g} mass (tan β > 20)
sni	GGM (bino NLSP) : $\gamma\gamma + E$	L=4.8 fb ⁻¹ , 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) : γ + IEP + E	L=4.8 fb ⁻¹ , 7 TeV [ATLAS-CONF-2012-144]	619 Gev g mass	J T
	GGW (Higgsino-bino NLSP) $\cdot \gamma + b + E$	L=4.8 fb ⁻¹ , 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 ⁻¹ , 8 TeV [ATLAS-CONF-2012-152]	690 GeV g mas	(m(H) > 200 GeV)
	Gravilino LSP . monojet $+E_{T,miss}$	L=10.5 fb ⁻ , 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. Ст	$g \rightarrow it \chi$ (virtual i) $\cdot 2 \text{ lep } (55) + 15 + E_{T,\text{miss}}$	L=3.0 fb ⁻¹ 8 TeV [ATLAS-CONF-2012-105]	860 GeV G I	$SS_{(m(\chi))} < 300 \text{ GeV} $ 8 TeV results
d ge 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 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 ⁻¹ , 8 TeV [ATLAS-CONF-2012-165]	620 GeV b mass	$n(\tilde{\chi}^0) < 120 \text{ GeV}$
'ks on	$\widetilde{bb}, \widetilde{b}, \rightarrow t\widetilde{\gamma}^{\pm}$: 3 lep + i's + E_{τ} miss	L=13.0 fb ⁻¹ , 8 TeV [ATLAS-CONF-2012-151]	405 GeV b mass $(m(\tilde{\chi}^{\pm}))$	$m(\tilde{\chi}))$
uai 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 ⁻¹ , 7 TeV [1208.4305, 1209.2102]67 GeV	MASS $(m(\tilde{\chi}_{4}^{0}) = 55 \text{ GeV})$	
bs	\widetilde{t} (medium), $\widetilde{t} \rightarrow b \widetilde{\chi}_{+}^{\pm}$: 1 lep + b-jet + $E_{T \text{ miss}}$	L=13.0 fb ⁻¹ , 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 ⁻¹ , 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 'eci	$\widetilde{tt}, \widetilde{t} \rightarrow t \widetilde{\chi}_1^\circ$: 1 lep + b-jet + $E_{T, \text{miss}}$	L=13.0 fb ⁻¹ , 8 TeV [ATLAS-CONF-2012-166]	230-560 Gev t mass ($\zeta_{1}^{0} = 0$
3r dii	tt, t \rightarrow t χ° : 0/1/2 lep (+ b-jets) + $E_{T,\text{miss}}$	L=4.7 fb ⁻¹ , 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 ⁻¹ , 7 TeV [1204.6736]	<u>10 GeV</u> t mass $(115 < m(\tilde{\chi}_1^\circ))$	230 GeV)
st '	$\sim^+\sim^-\sim^+ \sim \lim_{z \to z} \lim_$	L=4.7 fb ⁻¹ , 7 TeV [1208.2884] 85-195 Ge	I mass $(m(\chi_1) = 0)$	~ ~ . 1. ~ ~ 0
≡W irec	$\chi_{\chi}, \chi \rightarrow lv(lv) \rightarrow lv\chi : 2 lep + E_{T,miss}$	L=4.7 fb ⁻ , 7 TeV [1208.2884]	-340 GeV χ_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 χ_1 IIIass	$m(\chi_1) = m(\chi_2), m(\chi_1) = 0, m(l,v) \text{ as above}$
	$\chi \chi \rightarrow W \chi \chi \chi , 3 \text{ Iep } + E_{T,\text{miss}}$ Direct $\tilde{\chi}^{\pm}$ Direct $\tilde{\chi}^{\pm}$ pair prod (AMSB) : long-lived χ^{\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 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 ticl€	Stable \hat{f} B-badrons : low β , $\beta\gamma$ (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 ⁻¹ , 7 TeV [1211.1597]	0 GeV $\tilde{\tau}$ MASS (5 < tan β < 2	
P L	$\tilde{\gamma}^0 \rightarrow \text{ggu} (\text{RPV})$: μ + heavy displaced vertex	L=4.4 fb ⁻¹ , 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 ⁻¹ , 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 ⁻¹ , 7 TeV [Preliminary]	1.10 TeV	mass $(\lambda'_{311}=0.10, \lambda'_{1(2)33}=0.05)$
\sum_{α}	Bilinear RPV CMSSM : 1 lep + 7 j's + $E_{T,miss}$	L=4.7 fb ⁻¹ , 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 ⁻¹ , 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 ⁻¹ , 8 TeV [ATLAS-CONF-2012-153]	430 Gev I mass $(m(\widetilde{\chi}_1^0))$	100 GeV, $m(l_e) = m(l_\mu) = m(l_\tau)$, λ_{121} or $\lambda_{122} > 0$)
	g̃ → qqq : 3-jet resonance pair	L=4.6 fb ⁻¹ , 7 TeV [1210.4813]	666 GeV g mass	
\ <u>\</u> /IN/	Scalar gluon : 2-jet resonance pair	L=4.6 fb ⁻¹ , 7 TeV [1210.4826] 100-	GeV Sgluon mass (incl. lir	rom 1110.2693)
T,miss.		L=10.5 fb ⁻ , 8 TeV [ATLAS-CONF-2012-147]	704 GeV IVI^ SC	$e^{-(m_{\chi} < 80 \text{ GeV, limit of } < 687 \text{ GeV for } 08)}$
		10 ⁻¹	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



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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)²

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

Natural EWSB in times of austerity

Fine-tuning of (Higgs mass)²

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

MSSM, NMSSM, ...

Natural EWSB in times of austerity **Barbieri/Guidice** MSSM,NMSSM, ... Fine-tuning of (Higgs mass)² $\frac{m_{Higgs}^2}{2} = -|\mu|^2 + \ldots + \delta m_H^2$ 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!



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:



Pythia/MadEvent

+Prospino/NLLfast +checks with MLM matched sample



Pythia/MadEvent

+Prospino/NLLfast +checks with MLM matched sample

simplified Model available → CMS

ee Seeree





+Prospino/NLLfast +checks with MLM matched sample







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



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



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



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

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

 δ

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°

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 Λ in TeV $(c_{ij} = 1)$		Bounds on c_{ij} ($\Lambda = 1$ TeV)		Observables
	${ m Re}$	Im	Re	Im	
$\overline{(ar{s}_L \gamma^\mu d_L)^2}$	9.8×10^2	$1.6 imes 10^4$	9.0×10^{-7}	3.4×10^{-9}	$\Delta m_K; \epsilon_K$
$(\bar{s}_R d_L)(\bar{s}_L d_R)$	$1.8 imes 10^4$	$3.2 imes 10^5$	6.9×10^{-9}	2.6×10^{-11}	$\Delta m_K; \epsilon_K$
$(ar{c}_L \gamma^\mu u_L)^2$	1.2×10^3	$2.9 imes 10^3$	5.6×10^{-7}	1.0×10^{-7}	$\Delta m_D; q/p , \phi_D$
$(\bar{c}_R u_L)(\bar{c}_L u_R)$	$6.2 imes 10^3$	$1.5 imes 10^4$	5.7×10^{-8}	1.1×10^{-8}	$\Delta m_D; q/p , \phi_D$
$\overline{(\overline{b}_L \gamma^\mu d_L)^2}$	5.1×10^2	$9.3 imes 10^2$	3.3×10^{-6}	1.0×10^{-6}	$\Delta m_{B_d}; S_{\psi K_S}$
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$\overline{(\overline{b}_L \gamma^\mu s_L)^2}$	1.1	1×10^2	7.6 2	$\times 10^{-5}$	Δm_{B_s}
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UTfit 08, Isidori, Perez, Nir'10

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

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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

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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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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, $\vec{P}_{\rm T}^{\rm miss}$) _{min}	> 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/γ +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/γ +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.



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	<u>></u> 2-jet	2 5-jet	$m_{\rm eff} > 500~{ m GeV}$	$m_{\rm eff} > 1000 \; {\rm GeV}$	Tingii illass	
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[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 (σ) for which ATLAS has an acceptance A and a detection efficiency of ϵ [44]. The excluded values of σ_{new} are 22 fb, 25 fb, 429 fb, 27 fb and 17 fb, respectively, at the 95% confidence level.

upper bound on signal xsec



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



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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/γ +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 (σ) for which ATLAS has an acceptance A and a detection efficiency of ϵ [44]. The excluded values of σ_{new} are 22 fb, 25 fb, 429 fb, 27 fb and 17 fb, respectively, at the 95% confidence level.

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/γ +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	

Table 2: Fitted background components in each SR, compared with the number of events observed in data. The Z/γ +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.

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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 η - 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></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

