Search for gluing-mediated stopproduction in ATL

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An experimental view:

May 13, 2013



AS

SUSY searches at ATLAS

	MSUGRA/CMSSM : 0 lep + j's + E _{7 miss}	1.50 TeV [4TLAS-CONF-2012-159] 8.50 TeV [4TLAS-CONF-2012-159]
	MSUGRA/CMSSM : 1 lep + j's + E T min	L=5.8 fb ⁻¹ 8 TeV [ATLAS-CONF-2012-154] 1.24 TeV [] = [] mass
62	Pheno model : 0 lep + j's + E _{T min}	L+5.5 fb ⁻¹ .5 TeV [ATLAS CONF-2012-109] 1.18 TeV [g mass (m(g) < 2 TeV, light 2)] ATLAS
2	Pheno model : 0 lep + i's + E	2-52 m ² , 8 TeV (ATLAS-CONF-2012-108) 1.38 TeV (Q mass (m(Q) < 2 TeV, lock 5 ¹) Preliminary
2	Gluing mod $\tilde{s}^{1} (\tilde{a} \rightarrow a \pi \tilde{s}^{1}) \cdot 1 \log + i s + E$	(24 7 th ⁻¹ 7 th/ (1001 464) 900 GeV (0 th) - 200 GeV (0 th ⁻¹) - 200 GeV (0 th ⁻¹) - 100 ⁽¹⁾ (1000)
69	CAMER (INI CD) + 2 los (OC) + 2 + 5	
03	GMISE (# NI SD) - 1-2 + 70 + E 7 miss	
-5	GGM (bino NI SP) : yy + E ^{T min}	
fus	GGM (wing NI SP) : y + log + E ^{T miss}	Ldt = (4.4 - 20.7) fb
20	COM (White the All CD) on the CT miss	L+4.8 Ib (7 TeV [ATLAS-CON+2012-144] B19 GeV g ITI355
	COM (nggsino-bino NEOF) . 1+ b+ E	2×48 fb ⁻ , 7 fbV (1211,1147) 900 GeV g (Mass (m(z,) > 220 GeV) (s = 7.8 TeV
	GGM (higgsino NLSP) : Z + jets + E 7,miss	2+58.96 ⁺ , 8 TeV (ATLAS-CONF-2012-152) 690 GeV g mass (m(H) > 200 GeV)
	Gravitino LSP : 'monojet' + E T.miss	2=10.5 fb ⁺ , 8 TeV [ATLAS-CONV-2012-147] 645 GeV F ⁺⁺⁺ SCBIe (m(G) > 10 ⁺ eV)
- c 0	$\tilde{g} \rightarrow b \bar{b} \tilde{\chi}^0$: 0 lep + 3 b-j's + $E_{T min}$	L=12.8 fb ⁺ , 8 TeV [ATLAS-CONF-2012-145] 1.24 TeV g mass (m() ¹ / ₂) < 200 GeV)
ate jer		L=20.7 fb ¹ .8 TeV [ATLAS-CONF-2013-007] 900 GeV g mass (any m(t ² ₁)) 8 TeV, all 2012 data
250	$\tilde{q} \rightarrow t t \tilde{\chi}^{\circ}$: 0 lep + multi-j's + E	L=55.8 b ⁺ , 8 TeV (ATLAS-CONF-2012-103) 1.00 TeV g mass (m(g ⁺) < 300 GeV) 8 ToV portiol 2012 de
30	$\bar{q} \rightarrow t\bar{t}\bar{\chi}^{0}$: 0 lep + 3 b-j's + E	E=12.8 fb ⁺ , 8 TeV [ATLAS-CONF-2012-145] 1.15 TeV G mass (m(t ² ₀) < 200 GeV)
	$bb, b \rightarrow b\bar{y}^0$: 0 lep + 2-b-iets + E	L=12.8 fb ⁺ 8 TeV (ATLAS-CONF-2012-165) 620 GeV D mass (m(2 ⁰) < 120 GeV) 7 TeV, all 2011 data
S C	bb, b →ty : 2 SS-lep + (0-3b-)i's + E	L=20.7 (b ⁺ , 8 TeV (ATLAS-CONF-2015-001) 430 GeV D M3SS (m(2 ⁺) = 2 m(2 ⁺))
X (2)	tt (light) $t \rightarrow b\tilde{x}^2$: 1/2 lep (+ b-iet) + E	1+47 9-17 TeV (1901 4305 1260 2162) 167 GeV (mRSS (m/c ²) = 55 GeV)
nc n	If (medium) $t \rightarrow b\tilde{x}^2 + 1$ len + b-jet + E	1-99 7 61 8 TAY (ATLAS, CONF, 2013, 037) 166 410 GeV [MBSS (695) = 0.GeV (95) = 150 GeV)
20 S	If (medium) T-shit 2 len + F	
n d	W (heaved) L still st less the let the	
of 3	II (heavy), $I \rightarrow IZ$: Thep + D-jet + $E_{T,min}$	2000 00 (111035 (m(z,)=0)
2 and	It (network $CNSP$) + 7(-10) + b lot + 5	220-56 (WQ.) = 0
	tit (fiatural GWGB) . 2(→ii) + 0-jet + 2	LA20,716 (816V [ATLAS-CON-2015-025] SIU GEV [TTTIGSS (M(2,1)>150 GEV)
	$l_2 l_2, l_2 \rightarrow l_1 + 2 \cdot 2 (\rightarrow i) + 1 \text{ rep + b-jet + } E_{T,nim}$	L=20.7 fb ⁺ . 8 TeV (ATLAS-CONF-2015-025) 520 GeV L ₂ THASS (m(t ₁) = m(t ₂) = 180 GeV)
	$(1, 1 \rightarrow i\chi) : 2 \text{ lep } + E_{T, miss}$	L=47.6-7,7 TeV [1208.2894] 85-195 GeV IMASS (m(2,)=0)
of <	$\tilde{\chi}, \tilde{\chi}, \tilde{\chi}, \tilde{\chi} \rightarrow N(I\tilde{v}): 2 \text{ lep } + E_{T,miss}$	L=4.7 fb ⁻¹ , 7 TeV [1208.2884] 110.340 GeV χ_{ij}^{*} mass $(m_{ij}^{*}) < 10$ GeV, $m_{ij}(\vec{x}_{ij}) < m_{ij}^{*}$ (i)
EV Inc	$\chi_1 \chi_1 \chi_1 \chi_2 \rightarrow \tau v (\tau v) : 2 \tau + E_{T,min}$	L=20.7 fb ⁺ , 8 TeV [ATLAS-CONF-2013-028] 180-330 GeV χ_1^- mBSS $(m(\chi_1^-) < 10 \text{ GeV}, m(\chi_1^-) = \frac{1}{2}(m(\chi_1^-) + m(\chi_1^-)))$
0	$\chi_1^*\chi_2^* \rightarrow [v][(vv), v][(vv)]: 3 \text{ lep } + E_{\tau \text{ mins}}$	L=20.7 fb ⁺ , 8 TeV [ATLAS-CONF-2015-035] 600 GeV $\tilde{\chi}_{1}^{+}$ (MBSS $(m(\tilde{\chi}_{1}^{+}) = m(\tilde{\chi}_{1}^{+}), m(\tilde{\chi}_{1}^{+}) = 0, m(\tilde{\chi})$ as above)
	$\tilde{\chi}_{,\chi}^{*} \rightarrow W^{*} \tilde{\chi}_{,Z}^{*} \tilde{\chi}_{,Z}^{*} : 3 \text{ lep } + E_{T \text{ min}}$	L=20.7 fb ¹ , 8 TeV (ATLAS-CONF-2013-035) 315 GeV χ^+_{\perp} (MSS (m($\chi^+_{\perp}) = m(\chi^{\perp}), m(\chi^{\perp}) = 0,$ sleptons decoupled)
70	Direct \$\overline{\chi}\$ pair prod. (AMSB) : long-lived \$\overline{\chi}\$	Z=4.7 (b ⁻¹ , 7 TeV [1210.2852] 220 GeV $\tilde{\chi}_{1}^{+}$ (MASS (1 < t($\tilde{\chi}_{1}^{+}$) < 10 ms)
es es	Stable ğ, R-hadrons : low β, βγ	2#47.7b ⁻¹ .7Tev [1211.1597] 985 GeV ĝ mass
28	GMSB, stable τ : low β	L=4.7 fb ⁻¹ , 7 TeV [1211.1597] 300 GeV τ Mass (5 < tanβ < 20)
UC IB	GMSB, $\tilde{\chi}^0 \rightarrow \gamma \tilde{G}$: non-pointing photons	L=4.7 fb ⁻¹ , 7 TeV [ATLAS-CONF-2015-016] 230 GeV 2 mass (0.4 < (2,) < 2 m)
7 4	$\tilde{\tau}^0 \rightarrow qqu (RPV)$; $\mu + beavy displaced vertex$	2+44 (b ⁺ , 7 TeV (1210,7451) 700 GeV 0 MaSS (1 mm < ct < 1 m, 0 decoupled)
	LEV: np→ỹ ±X, ỹ →e±µ resonance.	1.41 TeV (1212.1272) 1.61 TeV (V, mass (2, =0.10.2, =0.05)
	$ FV : nn \rightarrow \tilde{v} + X, \tilde{v} \rightarrow e(u) + \tau$ resonance	(add the 1 Tark (1912 1923)
	Bilinear RPV CMSSM : 1 len + 7 i's + F-	(*************************************
2	2'2' 2' - W2' 2' - eev euv : 4 len + F	1 2017 0 1 TO (101 AS COME 2015 A161 740 GAV 2 MASS (m(G) > 30)
2	2 2 2 2 Arth Arth Arth 3 len + 1r + F	
	λ ₁ λ ₁ ,, λ ₁ , λ ₁ , λ ₁ , δ, λ ₁ , λ_1, λ_1	
	g → qqq : 3-jet resonance pair	2440 to , / rev [210,4613] 000 Gev [2] (1355
	g-rit, t-roa . 2 00-lep + (0-30-)) S + E	
WIN	AP interaction (D5, Dirac x) : 'monoiet' + F	Less to / rev proversity of the sector of th
	Trim	2010 MWY M SCale (m, < 80 GeV, limit of < 687 GeV for D8)
		10 ⁻¹ 1 10
		10

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

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



SUSY searches at ATLAS

		ATLAS SUSY Sear	ches* - 95% CL Lower Limits (Status: M	arch 26, 2013)
	MSUGRA/CMSSM : 0 loo + Pe + F	LAS 8 0-1 8 TAV INT AS COME ON S 4461	50 Tay 0 = 0 more	
	MSUCRA/CMSSM : 1 lop + 7e + F		4 24 74 A = 2 mass	
	Phono model : 0 lon + i's + E		24 104 q - g 11035	ΔΤΙ Δ.S
68	Phone model : 0 lop + i's + E	LASTER - S TEV (ATEAS-CONF-2012-109)	the few grindss (wigh < 2 lev, lpt)	Broliminan
to to	Chuine med 3 ¹ (3 + e ^{mp1}) + 1 len + 24 + 5	2-5.5 ID . 6 IEV (AILAS-CONF-2012-16V)		1 rentinialy
69	Gluino med. (g-)qqx). Thep + Js + ET miss	Long dam union real	g mass (m(x) < 200 GeV, m(x) =	Zinnx hundh
0	GMSB (INLSP): 2 IEP (US) + 1S + E7 miss	1294/7 HD 1 7 149 [1205/4635]	1.24 TeV g (11835 (allp < 15)	
2/12	GGM (bino NLSP) : xx + E ^T min	L #20,7 fb ; 8 lev [1210.1314]	1.40 lev g mass (and > 18)	ſ
fus	CCM (wine NI SP) : y + log + E ^{T,miss}	L#4.816 . 7 TeV [1209.0753]	1.07 lev g mass (m(χ ₁) > 50 GeV)	$Ldt = (4.4 - 20.7) \text{ fb}^{-1}$
20	CCM (biggsing bing NI SP) : w + b + E ^T miss	L+4.816 .7 TeV (ATLAS-CONF-2012-144)	era dev g mass	J (,
	COM (higgshorbino NEGP) . 7 + 0 + E	L=4.8 fb ⁻¹ , 7 TeV (1211.1167)	900 GeV g mass (m(x,) > 220 GeV)	s = 7.8 TeV
	GGM (niggsino NLSP) : Z + jets + E _{7,min}	L+5.8 fb ⁻¹ , 8 TeV [ATLAS-CONF-2012-152]	690 GeV g mass (m(H) > 200 GeV)	
	Gravitino LSP : monojet + E 7,miss	L=10.5 fb", 8 TeV [ATLAS-CONF-2012-147]	645 GeV F SCBIE (m(G) > 10 ⁻ eV)	
, o	$\tilde{g} \rightarrow bb\chi^{*}$: 0 lep + 3 b-j's + $E_{T,miss}$	L=12.8 fb ⁻¹ , 8 TeV (ATLAS-CONF-2012-145)	1.24 TeV g mass (m(2) < 200 GeV)	8 ToV all 2012 data
ge ri h	Trains	L=20.7 fb", 8 TeV [ATLAS-CONF-2013-007]	900 GeV g mass (any m(X,))	o lev, ali zo iz data
glt gl	g→tty 0 lep + multi-j's + t 7,miss	L=5.8 fb ⁻¹ , 8 TeV [ATLAS-CONF-2012-103]	1.00 TeV g mass (m()() < 300 GeV)	8 TeV, partial 2012 data
3 3	$g \rightarrow tt \chi^{-}$: 0 lep + 3 b-j's + $t_{T,miss}$	L=12.8 fb ⁻¹ , 8 TeV [ATLAS-CONF-2012-145]	1.15 TeV g mass (m(X_) < 200 GeV)	
	200, 0	L=12.8 fb ⁻¹ .8 TeV (ATLAS-CONF-2012-165)	620 GeV D MASS (m(2) < 120 GeV)	7 TeV, all 2011 data
ks DU	bb, $b_1 \rightarrow t \tilde{\chi}_1^2$: 2 SS-lep + (0-3b-))'s + $E_{\tau,miss}$	L=20.7 fb ⁻¹ , 8 TeV [ATLAS-CONF-2013-007]	430 GeV b mass $(m(\tilde{\chi}_{1}^{*}) = 2m(\tilde{\chi}_{1}^{*}))$	
cti	tt (light), t→bχ ² : 1/2 lep (+ b-jet) + E _{T miss}	L=4.7 fb ⁻¹ , 7 TeV [1208.4305, 1269.2162] 167 GeV	t mass (m(2)) = 55 GeV)	
np sdr	tt (medium), $t \rightarrow b \tilde{\chi}_{1}^{2} \ge 1$ lep + b-jet + $E_{T,miss}$	L+20.7 fb ⁻¹ , 8 TeV (ATLAS-CONF-2013-037)	160-410 GeV t mass $(m(\chi_1^2) = 0 \text{ GeV}, m(\chi_1^2) = 150 \text{ GeV})$	
2.5	tt (medium), t→bỹ ¹ : 2 lep + E _{T min}	L=13.0 fb ⁻¹ , 8 TeV [ATLAS-CONF-2012-167]	160-440 GeV I MBSS $(m(\tilde{\chi}_{1}^{0}) = 0 \text{ GeV}, m(\tilde{t}) \cdot m(\tilde{\chi}_{1}^{1}) = 10 \text{ GeV})$	
ct a	tt (heavy), t→t ² _x : 1 lep + b-jet + E _{7,min}	L=20.7 fb ⁻¹ , 8 TeV [ATLAS-CONF-2013-037]	200-610 GeV t mass (m(\(\car(\)) = 0)	
p 2	tt (heavy), $t \rightarrow t \tilde{\chi}_{1}^{0}$: 0 lép + 6(2b-)jets + $E_{T,riss}$	L=20.5 fb ⁻¹ , 8 TeV [ATLAS-CONF-2013-024]	320-660 GeV t mass (m(2) = 0)	
6.6	tt (natural GMSB) : Z(→II) + b-jet + E T min	L=20.7 fb ⁻¹ , 8 TeV [ATLAS-CONF-2013-025]	500 GeV t mass (m(2,) > 150 GeV)	
	$t_2t_2, t_2 \rightarrow t_1+Z : Z(\rightarrow II) + 1 \text{ lep + b-jet + }E_T$	L=20.7 fb ⁻¹ , 8 TeV [ATLAS-CONF-2013-025]	520 GeV t ₂ mass (m(t ₁) = m(t ₂) = 180 GeV)	
	$[l_i, \rightarrow l_i]$: 2 lep + $E_{T,miss}$	L=4.7 fb ⁻¹ , 7 TeV [1208.2884] 85-195 Ge	I mass (m(2)) = 0)	
5	$\tilde{\chi}_{\tau}^* \tilde{\chi}_{\tau}, \tilde{\chi}_{\tau}^* \rightarrow h(\tilde{v}): 2 \text{ lep } + E_{\tau \text{ miss}}$	L=4.7 fb ⁻¹ , 7 TeV [1208.2884]	110-340 GeV $\tilde{\chi}_{1}^{2}$ MASS $(m(\tilde{\chi}_{1}^{2}) < 10 \text{ GeV}, m(\tilde{\chi}) = \frac{1}{2}(m(\tilde{\chi}_{1}^{2}) + m(\tilde{\chi}_{1}^{2})))$	
ie E	$\chi_{\chi}^{2}\chi_{\chi}^{2}\chi_{\chi}^{2}\rightarrow \bar{\tau}v(\tau\bar{v}): 2\tau + E_{\tau,riss}$	L+20.7 fb ⁻¹ , 8 TeV (ATLAS-CONF-2013-028)	180-330 GeV χ_1^- MASS $(m(\chi_1^+) \le 10 \text{ GeV}, m(\tilde{\tau}, \tilde{\tau}) = \frac{1}{2}(m(\chi_1^+) * m(\chi_1^-)))$	
- 6	$\tilde{\chi}_{1}^{*}\tilde{\chi}_{2}^{*} \rightarrow \lfloor \nu \lfloor I(\tilde{\nu}\nu), I\tilde{\nu} \lfloor I(\tilde{\nu}\nu) : 3 \text{ lep } + E_{\tau}$	L=20.7 fb ⁻¹ , 8 TeV (ATLAS-CONE-2013-035)	600 GeV $\widetilde{\chi}_{1}^{\pm}$ mass $(m(\widetilde{\chi}_{1}^{\dagger}) = m(\widetilde{\chi}_{1}^{0}), m(\widetilde{\chi}_{1}^{0}) = 0, m(\widetilde{\theta}, \widetilde{v})$	as above)
	$\tilde{\chi}_{,\tilde{\chi}_{,\tilde{v}}}^{*} \rightarrow W^{*}\tilde{\chi}_{,\tilde{z}}^{*}\tilde{\chi}_{,\tilde{v}}^{*}: 3 \text{ lep } + E_{T \text{ min}}$	L+20.7 fb ⁻¹ , 8 TeV [ATLAS-CONF-2013-035]	315 GeV $\tilde{\chi}_{\pm}^{\pm}$ mass $(m(\tilde{\chi}_{\pm}^{\pm}) = m(\tilde{\chi}_{\pm}^{0}), m(\tilde{\chi}_{\pm}^{0}) = 0$, sleptons decoupled)	
70	Direct $\tilde{\chi}_{i}^{r}$ pair prod. (AMSB) : long-lived $\tilde{\chi}_{i}^{r}$	L=4.7 fb ⁻¹ , 7 TeV [1210.2852] 220	GeV χ̃ mass (1 < τ(χ̃) < 10 ms)	
es les	Stable ğ, R-hadrons : low β, βγ	L=4.7 fb ⁻¹ , 7 TeV [1211.1597]	985 GeV ĝ mass	
동음	GMSB, stable τ : low β	L=4.7 fb ⁻¹ , 7 TeV [1211.1597]	300 GeV τ MASS (5 < tanβ < 20)	
on o	GMSB, χ̃ ⁰ →γG̃: non-pointing photons	L=4.7 fb ⁻¹ , 7 TeV [ATLAS-CONF-2013-016] 230	GeV χ̃, mass (0.4 < τ(χ̃) < 2 ms)	
	$\tilde{\chi}^{0} \rightarrow qq\mu (RPV)$: μ + heavy displaced vertex	L=4.4 fb ⁻¹ , 7 TeV [1210.7451]	700 GeV q mass (1 mm < ct < 1 m, g decoupled)	
	LFV : $pp \rightarrow \tilde{v}, +X, \tilde{v}, \rightarrow e+\mu$ resonance	L=4.6 fb ⁻¹ , 7 TeV [1212.1272]	1.61 TeV V, mass (k, =0.1	0. λ ₁₀ =0.05)
	LFV : $pp \rightarrow \tilde{v}_{\tau} + X, \tilde{v}_{\tau} \rightarrow e(\mu) + \tau$ resonance	L=4.6 fb ⁻¹ , 7 TeV [1212.1272]	1.10 TeV V, mass (λ, =0.10, λ,	0.05)
~	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 q = g mass (ct, a < 1 mm)
d	$\tilde{\chi}'\tilde{\chi}, \tilde{\chi}' \rightarrow W\tilde{\chi}^0, \tilde{\chi}^0 \rightarrow eev_{u}.euv : 4 lep + E_{v_{max}}$	L=20.7 fb ⁻¹ , 8 TeV (ATLAS-CONF-2013-036)	760 GeV X MASS (m(X) > 500 GeV, A = > 0	
12	$\tilde{\chi}$, $\tilde{\chi}$,, $\tilde{\chi} \rightarrow \tau \tau v$, $e \tau v$, $3 \text{ lep } + 1\tau + E$.	L=20.7 fb ⁻¹ , 8 TeV (ATLAS-CONF-2013-036)	350 GeV χ̃ mass (m(χ̃) > 60 GeV, λ ₁₁₁ > 0)	
	ã → ogg : 3-iet resonance pair	L=4.6 fb ⁻¹ , 7 TeV [1210.4813]	666 GeV & mass	
	g→Ĩt, Ĩ→bs : 2 SS-lep + (0-3b-)j's + E_	L+20.7 fb ⁻¹ , 8 TeV (ATLAS-CONF-2013-007)	880 GeV (2 mass (any m(t))	
	Scalar gluon : 2-iet resonance pair	L=4.6 fb ⁻¹ , 7 TeV [1210.4825] 10	0-287 GeV SQLUON MASS (incl. limit from 1110.2603)	
WIM	IP interaction (D5, Ďirac χ) : 'monojeť + E	L=10.5 fb1, 8 TeV (ATLAS-CONF-2012-147)	704 GeV M* scale (m. < 80 GeV, limit of < 687 G	V for D8)
	1,7488			
		10-1	1	10
		10	I	10

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

Mass scale [TeV]

SUSY production at LHC



- Expect copious production of coloured SUSY particles
- ▶ If $m(\tilde{g}) \simeq 800$ GeV we should already have ~1000 $p p \rightarrow \tilde{g} \tilde{g}$ events
- "Natural" SUSY: 3rd generation squarks are lightest:

masses of $ilde{t}_1,\, ilde{b}_1,\, ilde{g}\lesssim$ 1 TeV

Gluino-mediated stop production

- Search for $p p \rightarrow \tilde{g} \tilde{g}$ with $\tilde{g} \to \tilde{t}_1 \bar{t}$ and $\tilde{t}_1 \to t \tilde{\chi}_1^0$ and hadronic tops: $t \rightarrow b q \bar{q}'$. This means looking for a signature: $\tilde{\chi}_1^0$: $E_{\mathrm{T}}^{\mathrm{miss}}$ **q**: 12 jets **b**: 4 *b*-jets 🔀: e veto
 - \mathbf{X} : μ veto



But there are no events with 12 jets, of which 4 are b-jets \Rightarrow relax conditions:

- $\Rightarrow E_{\rm T}^{\rm miss}$, at least 6 jets, 3 *b*-jets
- $\Rightarrow E_{\rm T}^{\rm miss}$, multijets (8, 9, 10+)

Identification of Muons

- They are the easiest. If at muon chambers: it's a muon
- Example 1: $H \rightarrow ZZ \rightarrow \mu \bar{\mu} b \bar{b}$ \Longrightarrow
- Example 2: Cosmic muon





Identification of Electrons and Photons

They leave a characteristic deposit at the Electromagnetic Calorimeter.

- If it has a track associated: an electron
- No track or 2 tracks associated: a photon

Example 1: $H \rightarrow ZZ \rightarrow e\bar{e} b\bar{b}$



Example 2: $H \rightarrow \gamma \gamma + \text{jet}$



But jets also leave deposits at the Electromagnetic Calorimeter ...

Identification of Jets

- Collimated jets of hadrons are interpreted in terms of the fragmentation of quarks and gluons.
- Energy deposits in the electromagnetic and hadronic calorimeter are clustered using jet algorithms.
- The number and properties of the jets in an event depend on the algorithm used.





Identification of Jets

An example: a six-jet event



Identification of b-jets

- Exploits decay length of B hadrons: displaced tracks and secondary vertices.
- Combines information into a neural network.
- Three working points calibrated with data: 60%, 70% & 75% efficiency.



Non-interacting particles

$Z H ightarrow u ar{ u} \, b ar{b}$ candidate

Presence of non-interacting particles

(neutrinos, neutralinos?) is inferred

from momentum imbalance

in the transverse plane: $E_{\rm T}^{\rm miss}$

The jet energy resolution

- Jet energy resolution measured via p_T balance in dijet events
- Very good agreement with Monte Carlo predictions B.D.
- $\sigma(p_{\rm T}) \simeq \sqrt{p_{\rm T}} \implies 3 \times 300 \text{ GeV}$ jets event can have $E_{\rm T}^{\rm miss} \simeq 100 \text{ GeV}$



Summary of the analysis

- 1 Identify signal-rich regions
 - Choose variables that discriminate SUSY signal from SM background
 - Optimize cuts to maximize significance: $S = Signal/\Delta B$

12 quarks (4 b) + 2 $\tilde{\chi}_{1}^{0}$ $\begin{cases} \Rightarrow E_{T}^{miss}, \text{ at least 6 jets, 3 b-jets} \\ \Rightarrow E_{T}^{miss}, \text{ multijets (8, 9, 10+)} \end{cases}$

- 2 Background estimation
 - ▶ QCD, $t\bar{t}$, W+jets, $Z + b\bar{b}$, single top, Higgs... (data-driven and MC)
- 3 Systematic uncertainties (signal and background)
 - Detector: Energy calibration/resolution, b-tagging efficiency, pile-up
 - Theoretical: MC generador, PDF, factorization/renormalization scales ...
- 4 "Open the box" (look at data in signal regions)
 - Significant excess of data wrt estimated background?

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NOPE : set 95% CL limits YEAP : buy ticket to Stockholm

Trigger selection

Every 50 nsec we get:



Rate needs to be reduced from 20 MHz to ${\sim}600$ Hz.

Triggers: sets of restricted conditions applied online to decide which are de \sim 600 events to be stored per second to disk.

The trigger strongly restricts the optimization of the search

j75_a4tc_xe75: 1 jet $p_T > 75$ GeV and $E_T^{miss} > 75$ GeV

 \bigcirc Imposes a lower limit on $E_{\rm T}^{\rm miss}$ (150 GeV) and $p_{\rm T}^1$

(:)Allows lowering the $p_{\rm T}$ of sub-leading jets

5j55_a4tc: 5 jets $p_{\rm T} > 55 \,{\rm GeV}$

 \bigcirc Imposes lower limit on $p_{\rm T}$ of leading jets (70 GeV)

 (\Box) Allows lowering the $E_{\rm T}^{\rm miss}$ and the $p_{\rm T}$ of leading jet





Trigger efficiency

QCD background supression



- QCD: $E_{\rm T}^{\rm miss}$ comes from a mismeasured jet $\rightarrow \phi(E_{\rm T}^{\rm miss}) \approx \phi({\rm jet})$
- ▶ Define $\Delta \phi_{min}$: closest $\Delta \phi$ between E_{T}^{miss} and a jet $\Rightarrow \Delta \phi_{min}^{QCD} \approx 0$
- SUSY, W/Z, $t\bar{t}$: genuine $E_{\rm T}^{\rm miss} \rightarrow$ uniform $\Delta \phi_{min}$
- $\Delta \phi_{min} > 0.4$ requirement selectively suppresses QCD

QCD background supression



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- Require b-tagged jets to suppress SM bkgs with less b-quarks than signal (4 bs)
- Starting point: # b-jets = 0



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- ► # *b*-jets = 2: Removes W/Z→ Dominant bkg now $t\bar{t}$



- Require b-tagged jets to suppress SM bkgs with less b-quarks than signal (4 bs)
- Starting point: # b-jets = 0
- # *b*-jets = 1: Reduces W/Z
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- *# b*-jets ≥ 3: Suppresses tt
 → Signal now visible! ☺



 $t\bar{t}$ +jets, W/Z+jets, $t\bar{t}$ + $b\bar{b}$, $t\bar{t}$ +W/Z, ...

- Require b-tagged jets to suppress SM bkgs with less b-quarks than signal (4 bs)
- Starting point: # b-jets = 0
- # *b*-jets = 1: Reduces W/Z
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- # b-jets ≥ 3: Suppresses tīt
 → Signal now visible! ☺



Data is consistent with tt prediction but not with these SUSY models 🙁

Several $pp \rightarrow \tilde{g}\tilde{g}$ simplified models: Gtt, Gtb, Gbb (virtual or real \tilde{t}, \tilde{b})



All three topologies give 4 *b*-jets, E_{T}^{miss} , and possible jets

An example: Optimization for Gbb topologies

Common selections to all Signal Regions

- *p*_T leading jet > 130 GeV (trigger)
- *E*_T^{miss} > 160 GeV (trigger)
- ► Δφ_{min} > 0.4 (QCD)

- *E*_T^{miss}/m_{eff} > 0.2 (QCD)
- \geq 3 *b*-jets with $p_{\rm T}$ > 30 GeV
- At least 4 jets, p_T > 50 GeV

SIGNAL REGIONS

- 1-6: Signal regions with at least 1 or 2 b-jets
 - $\textbf{7}: \geq 3 \text{ b-tag}$ (60% WP), $\, m_{eff} > 500 \text{ GeV}$
 - $\textbf{8}: \geq 3 \text{ b-tag (60\% WP)}, \,\, m_{eff} > 700 \text{ GeV}$
 - $\textbf{9:} \geq 3 \text{ b-tag (70\% WP), } m_{eff} > 900 \text{ GeV}$



An example: Gbb acceptance and efficiency

Acceptance



Decreases as $m_{\tilde{\chi}_1^0} \to m_{\tilde{g}}$ (not enough phase space for jets) All in the 50-80% range

Efficiency

Experimental results: Model independent exclusion limits

			Observed (expected) 95% GL upper limit		
SR	SM prediction	data	N _{non-SM}	$\sigma_{ m vis}$ (fb)	
SR4-L	44.4 ± 10.0	45	23.8 (23.4)	5.1 (5.0)	
SR4-M	$\textbf{23.0} \pm \textbf{5.4}$	14	8.6 (12.8)	1.8 (2.7)	
SR4-T	$\textbf{13.3} \pm \textbf{2.6}$	10	7.1 (9.2)	1.5 (2.0)	
SR6-L	12.7 ± 3.6	12	9.6 (10.1)	2.0 (2.1)	
SR6-T	9.9 ± 2.6	8	7.1 (8.3)	1.5 (1.8)	

Disease Sale



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Model dependent exclusion limits: Gbb and Gtt (virtual squark)

Gbb

Gtt



- Solid red line: observed 95% CL limit
- Dotted red line: $\pm 1\sigma_{exp}$ uncertainty

- Solid black line: exp. 95% CL limit
- Yellow band: $\pm 1\sigma_{\text{Theory}}^{\text{SUSY}}$ uncertainty

Model dependent exclusion limits: Gbb and Gtt (real squark)



Gbb $(m_{\tilde{h}_{\star}} < m_{\tilde{a}})$

- Sbottom produced via $ilde{g}
 ightarrow ilde{b}_1 b$
- \tilde{b}_1 assumed the lightest squark
- ▶ Results presented in $m_{\tilde{g}}, m_{\tilde{b}_1}$ plane



Gtt $(m_{\tilde{t}_{\star}} < m_{\tilde{a}})$

- Stop produced via $ilde{g}
 ightarrow ilde{t}_1 t$
- \tilde{t}_1 assumed the lightest squark
- Results presented in $m_{\tilde{g}}, m_{\tilde{t}_1}$ plane

 $(m_{\tilde{\chi}^0_1} \text{ fixed at 60 GeV})$



The Multijet Approach

Example of optimization procedure for a search with \geq 9 jets with $p_T >$ 50 GeV. Significance increases when requiring:

- more central jets: *t*-channel $t\bar{t}$ and QCD jets are more forward than *s*-channel $pp \rightarrow \tilde{g}\tilde{g}$.
- ► more massive jets ($M_J^{\Sigma} = \sum m_{jet}^{R=1.0}$): $m_{jet}^{R=1.0} \simeq 170$ GeV if fat jet comes from top.



The Multijet Approach

Significance increases with number of jets.

Region $E_{\rm T}^{\rm miss}/\sqrt{H_{\rm T}} > 4$ not unblinded yet.







The Multijet Approach: Interpretations

To be applied to several models.

R-parity conserving

- Gtt (off-shell stop) & Gtt-On-Shell (on-shell stop)
- **One-step** simplified model: $\tilde{g} \rightarrow q \, \bar{q} \, \tilde{\chi}^{\pm}, \, \tilde{\chi}^{\pm} \rightarrow W^{\pm} \, \tilde{\chi}_{1}^{0}$

►
$$m_{\tilde{\chi}^{\pm}} = (m_{\tilde{g}} + m_{\tilde{\chi}^{0}_{1}})/2$$

► $m_{\tilde{\chi}^{0}_{1}} = 60 \text{ GeV}$

- mSUGRA
- R-parity violating models
 - **RPV-UDD**: $\tilde{g} \rightarrow \tilde{t} + \bar{t}$, $\tilde{t} \rightarrow s + b$



Summary of gluino-mediated stop production searches in ATLAS - 2012



THANK YOU

2-jet event



$Z ightarrow \mu ar{\mu}$ + 3 jets



 $Z \rightarrow \mu^- \mu^+ + 3$ jets

Run Number 158466, Event Number 4174272 Date: 2010-07-02 17:49:13 CEST



A $Z \rightarrow \mu \bar{\mu}$ event but without removing pileup tracks



Object Selection Details

Muones: ID+MS

 $\begin{array}{l} \text{Selección (Medium++):} \\ \blacktriangleright \ p_{\mathrm{T}} > 20 \ \text{GeV y} \ |\eta| < 2.4 \\ \text{Señal (Tight++):} \ p_{\mathrm{T}} > 25 \ \text{GeV} \\ \vdash \ \sum_{\textit{track}}^{\Delta R < 0.2} p_{\mathrm{T}}(\textit{track}) < 1.8 \ \text{GeV} \\ \end{array}$

Electrones: ID+EM

Selección (Medium++):

► E_T > 20 GeV y |η|< 2.47</p>

Señal (Tight++): $E_{\rm T} > 25 \text{ GeV}$

• $\sum_{track}^{\Delta R < 0.2} p_{T}(track) < 0.1 \times p_{T}^{e}$

Jets: EM + HAD

- Algoritmo: anti- k_t con R = 0.4
- Inputs: clusters topológicos
- Calibración: EM+JES
- ▶ p_T >20 GeV y |η| < 2.8</p>

Eliminación de objetos coincidentes

 $\Delta R = \sqrt{(\Delta \phi)^2 + (\Delta \eta)^2}$

- 1. $\Delta R(j, e) < 0.2 \rightarrow$ electron
- **2.** $0.2 < \Delta R(j, e) < 0.4 \rightarrow \text{jet}$
- **3**. $\Delta R(j,\mu) < 0.4 \rightarrow \text{jet}$

Energía transversa faltante ($E_{\rm T}^{\rm miss}$)

Suma vectorial de:

- ▶ Jets (p_T >20 GeV y |η| < 4.5)</p>
- Leptones
- ► Clusters calorimétricos ∉ jets

b-jets: ID+EM+HAD

- Algoritmo MV1 (NN)
- ➤ 3 puntos de operación (OP): eficiencia 60%, 70% y 75% (tt)
- $p_{
 m T}$ > 30 GeV y $|\eta|$ < 2.5