Search for Supersymmetry at the LHC What have we learned so far?

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• Search Strategy for SUSY at the LHC (so far)

• Where are we today?

•What have we learned?

GGI; SUSY, Dark matter & LHC 25 Oct 2012 Imperial College

SUSY Searches at the LHC

SUSY Search Strategy in a Nutshell



Search Signatures

SUSY-like decay chains range from short to long and simple to very complicated.

> All physics objects, MET, jets, leptons, photons, b's taus, tops, W, Z, etc are involved

 Comprehensive coverage of all possible signature requires a topology oriented search strategy: References Analyses

0- leptons	1-lepton	OSDL	SSDL	≥3 Ieptons	2- photons	γ+lepton
Jets + MET	Single lepton + Jets + MET	Opposite- sign di- lepton + jets + MET	Same-sign di-lepton + jets + MET	Multi- lepton	Di-photon + jet + MET	Photon + lepton + MET

Already in less then two years of operation ATLAS & CMS managed to carry out the a full list of these core "SUSY References Analyses"!

Inclusive SUSY Searches



SUSY: What have we learned? O. Buchmüller

Inclusive SUSY Searches



SUSY Today – Only Limits!

		ATLAS SUSY	Searches* - 95% CL Lower Limits (Statu	s: ICHEP 2012)
	MSUGRA/CMSSM : 0 lep + i's + F	1 - 4 7 (b ⁻¹ 7 Toy (AT) AS CONE 2012 022	2 = Ž = Ž	
	MSUGRA/CMSSM : 1 lep + i's + $E_{T,miss}$	$l = 4.7 \text{ fb}^{-1}$ 7 TeV [AT LAS-CONF-2012-033]	1 20 TeV $\tilde{\mathbf{q}} = \tilde{\mathbf{q}}$ mass	f
E C	MSUGRA/CMSSM : 0 lep + multijets + E_{π}	/ =4.7 fb ⁻¹ , 7 TeV [1206.1760]	840 GeV Q mass (large m.)	$Ldt = (0.03 - 4.8) \text{ fb}^{-1}$
2	Pheno model : 0 lep + i's + E_T miss	/ =4.7 fb ⁻¹ , 7 TeV [ATLAS-CONE-2012-033]	1.38 TeV 0 mass (m@)<21	$ieV light \frac{1}{2}^{\circ}) (s = 7 TeV$
20	Pheno model : 0 lep + i's + $E_{T,miss}$	L=4.7 fb ⁻¹ , 7 TeV [ATLAS-CONF-2012-033]	940 GeV Q mass (m(g) < 2 TeV. light	7)
)	Gluino med. $\tilde{\gamma}^{\pm}(\tilde{q} \rightarrow q \bar{q} \tilde{\gamma}^{\pm})$: 1 lep + i's + E_{π}	L=4.7 fb ⁻¹ , 7 TeV [ATLAS-CONF-2012-041]	900 GeV $\tilde{\mathbf{q}}$ mass $(m(\tau^0) < 200 \text{ GeV}, n$	$n(\overline{\chi}^{+}) = \frac{1}{2}(m(\overline{\chi}^{0}) + m(\widetilde{q})) ATLAS$
	GMSB : 2 lep OSSF + ET miss	L=1.0 fb ⁻¹ , 7 TeV [ATLAS-CONF-2011-156]	810 GeV G mass (tanβ < 35)	Preliminary
	GMSB : $1-\tau + j's + E_{T,min}$	L=2.1 fb ⁻¹ , 7 TeV [1204.3852]	920 GeV g mass (tanβ > 20)	
	GMSB : $2-\tau + j's + E_{T,miss}^{\gamma,mas}$	L=2.1 fb ⁻¹ , 7 TeV [1203.6580]	990 GeV \tilde{g} mass $(\tan \beta > 20)$	
	$GGM: \gamma\gamma + E_{T,miss}^{\gamma,mas}$	L=4.8 fb ⁻¹ , 7 TeV [ATLAS-CONF-2012-072]	1.07 TeV \tilde{g} mass $(m(\chi^0) > 50 \text{ GeV})$	ŋ
	$\tilde{g} \rightarrow b \bar{b} \tilde{\chi}'$ (virtual \tilde{b}) : 0 lep + 1/2 b-j's + $E_{T miss}$	L=2.1 fb ⁻¹ , 7 TeV [1203.6193]	900 GeV \tilde{g} mass $(m(\chi^0) < 300 \text{ GeV})$	
90	$\tilde{g} \rightarrow b \tilde{b} \tilde{\chi}_{1}^{0}$ (virtual \tilde{b}) : 0 lep + 3 b-j's + $E_{T miss}$	L=4.7 fb ⁻¹ , 7 TeV [ATLAS-CONF-2012-058]	1.02 TeV \tilde{g} mass $(m(\tilde{\chi}_{4})^{\circ}) < 400$ GeV	0
liat	$\tilde{g} \rightarrow b \tilde{b} \tilde{\chi}_{\ell}^{0}$ (real \tilde{b}) : 0 lep + 3 b-j's + $E_{T miss}$	L=4.7 fb ⁻¹ , 7 TeV [ATLAS-CONF-2012-058]	1.00 TeV \tilde{g} mass $(m(\tilde{\chi}_1^{0}) = 60 \text{ GeV})$	
neo	$\tilde{g} \rightarrow t\bar{t} \chi_{\infty}^{\circ}$ (virtual \tilde{t}) : 1 lep + 1/2 b-j's + $E_{T,miss}$	L=2.1 fb ⁻¹ , 7 TeV [1203.6193]	710 GeV \tilde{g} mass $(m(\bar{\chi}_1^0) < 150 \text{ GeV})$	
0 0	$\tilde{g} \rightarrow t \tilde{t} \tilde{\chi}_{*}^{0}$ (virtual \tilde{t}) : 2 lep (SS) + j's + $E_{T,miss}$	L=2.1 fb ⁻¹ , 7 TeV [1203.5763]	650 GeV \tilde{g} mass $(m(\chi_1^0) < 210 \text{ GeV})$	
uin	$\tilde{g} \rightarrow t\bar{t}\chi^{\circ}_{4}$ (virtual \tilde{t}): 0 lep + multi-j's + $E_{T,miss}$	L=4.7 fb ⁻¹ , 7 TeV [1206.1760]	870 GeV \tilde{g} mass $(m(\bar{\chi}_1^0) < 100 \text{ GeV})$	
16	$\tilde{g} \rightarrow t \tilde{t} \tilde{\chi}^{\circ}_{*}$ (virtual \tilde{t}) : 0 lep + 3 b-j's + $E_{T,miss}$	L=4.7 fb ⁻¹ , 7 TeV [ATLAS-CONF-2012-058]	940 GeV \widetilde{g} mass $(m(\overline{\chi}_1^0) < 50 \text{ GeV})$	
	<u> <u> </u></u>	L=4.7 fb ⁻¹ , 7 TeV [ATLAS-CONF-2012-058]	820 GeV \tilde{g} mass $(m(\chi_1^{o}) = 60 \text{ GeV})$	
S	$b\underline{b}, b_1 \rightarrow b\overline{\chi}_1^{\circ}$: 0 lep + 2-b-jets + $E_{\tau, miss}$	L=2.1 fb ⁻¹ , 7 TeV [1112.3832]	390 GeV b mass $(m(\overline{\chi}_1) < 60 \text{ GeV})$	
ctio	tt (very light), t $\rightarrow b\tilde{\chi}_1^{\pm}$: 2 lep + $E_{T,\text{miss}}$	L=4.7 fb ⁻¹ , 7 TeV [CONF-2012-059] 135 Ge	\mathbf{v} t mass $(m(\overline{x}_1) = 45 \text{ GeV})$	
dr.	tt (light), t $\rightarrow b\tilde{\chi}_{1}^{\pm}$: 1/2 lep + b-jet + $E_{T,\text{miss}}$	L=4.7 fb ⁻¹ , 7 TeV [CONF-2012-070] 120-17	3 GeV t mass $(m(\chi_1) = 45 \text{ GeV})$	
bro	\underline{tt} (heavy), $\underline{t} \rightarrow t \overline{\chi}_{0}$: 0 lep + b-jet + $E_{T,\text{miss}}$	L=4.7 fb ⁻¹ , 7 TeV [CONF-2012-074]	380-465 GeV t mass $(m(\chi)) = 0$	
Sct	tt (heavy), $t \rightarrow t \chi_0$: 1 lep + b-jet + $E_{T,miss}$	L=4.7 fb ⁻¹ , 7 TeV [CONF-2012-073]	230-440 GeV t mass $(m(\tilde{\chi}_1) = 0)$	
dire	tt (heavy), t \rightarrow t χ : 2 lep + b-jet + $E_{T,miss}$	L=4.7 fb ⁻¹ , 7 TeV [CONF-2012-071]	298-305 GeV [t mass $(m(\chi_1) = 0)$	
	tt (GMSB) : $Z(\rightarrow II)$ + D-jet + E	L=2.1 fb ⁻¹ , 7 TeV [1204.6736]	310 GeV t mass (115 < $m(\chi_1)$ < 230 GeV)	
sot .	$\prod_{i=1}^{+} \prod_{j=1}^{+} \prod_{i=1}^{+} \prod_{j=1}^{+} \prod_{j$	L=4.7 fb ⁻¹ , 7 TeV [CONF-2012-076] 93-1	BO GeV I MASS $(m(\chi_1) = 0)$	
걸	$\chi_{\chi}, \chi \rightarrow v(v) \rightarrow v\chi : 2 \text{ lep } + E_{T,\text{miss}}$	L=4.7 fb ⁻¹ , 7 TeV [CONF-2012-076]	120-330 GeV χ_1 mass $(m(\chi_1) = 0, m(\chi) = \frac{1}{2}(m(\chi_1) + m(\chi_1)))$	-
	$\chi_1 \chi_2 \rightarrow 3I(NV) + V + 2\chi_1): 3 \text{ lep } + E_{T,\text{miss}}$	L=4.7 fb ⁻¹ , 7 TeV [CONF-2012-077]	$\frac{60-500 \text{ GeV}}{\pi} \chi_1 \text{ mass} \qquad (m(\chi_1^{-}) = m(\chi_2), m(\chi_1) = 0, m(\chi_2), m(\chi_1) = 0, m(\chi_2), m(\chi_2) = 0, m(\chi_2), m(\chi_2), m(\chi_2), m(\chi_2) = 0, m(\chi_2), m(\chi_2), m(\chi_2), m(\chi_2), m(\chi_2) = 0, m(\chi_2), m($	l,v) as above)
	AIVISE : long-lived χ_1	L=4.7 fb ', 7 TeV [CONF-2012-034]118 GeV	χ_1 mass (1 < t(χ_1) < 2 hs, 90 GeV limit in [0.2,90] hs)	
es	Stable g R-hadrons : Full detector	L=4.7 fb , 7 TeV [ATLAS-CONF-2012-075]	985 Gev ginass	
rtic.	Stable b R-hadrons : Full detector	L=4.7 fb , 7 TeV [ATLAS-CONF-2012-075]	BIZ GEV DINASS	
pa	Stable t R-hadrons : Full detector	L=4.7 fb ⁻¹ 7 Toy IATLAS CONF-2012-075	910 Gov G mass ((G) > 10 or)	
	Metastable g K-hadrons : Mixel det. Only CMSR : stable #	$l = 4.7 \text{ fb}^{-1}$ 7 TeV [ATLAS-CONE-2012-075]	310 GeV T MASS (5 < tan8 < 20)	
	RPV : high-mass eu	$l = 1.1 \text{ fb}^{-1}$, 7 TeV [1109.3089]	1.32 TeV V mass (2 =0.10	a =0.05)
	Bilinear RPV : 1 lep + i's + E	L=1.0 fb ⁻¹ , 7 TeV [1109.6606]	760 GeV $\tilde{q} = \tilde{q}$ mass (ct < 15 mm)	312
	BC1 RPV : 4 lep + E _{T min}	L=2.1 fb ⁻¹ , 7 TeV [ATLAS-CONF-2012-035]	1.77 TeV @ mass	
	Hypercolour scalar gluons : 4 jets, m ₌ ≃ m ₌	L=34 pb ⁻¹ , 7 TeV [1110.2693] 100-1	85 GeV SQIUON MASS (not excluded: man = 140±3 GeV)	
2	Spin dep. WIMP interaction : monojet + E	L=4.7 fb ⁻¹ , 7 TeV [ATLAS-CONF-2012-084]	709 GeV M* scale (m, < 100 GeV. vector	D5, Dirac χ)
5	Spin indep. WIMP interaction : monojet + $E_{T miss}$	L=4.7 fb ⁻¹ , 7 TeV [ATLAS-CONF-2012-084]	548 GeV M* scale (m _x < 100 GeV, tensor D9,	Dirac χ)
		10 ⁻¹	1	10

*Only a selection of the available mass limits on new states or phenomena shown

SUSY:

SUSY Today – Only Limits!

		ATLAS SUSY Searches* - 95% (CL Lower Limits (Status: ICHEP 2012)
	MSLIGRA/CMSSM : 0 lep + i's + F		
	MSUGRA/CMSSM : 1 lep + i's + $E_{T,miss}$	1 =4.7 (b ⁻¹ .7 TeV [ATLAS-CONE-2012-033]	
es S	MSUGRA/CMSSM : 0 lep + multijets + E_{-}	$l = 4.7 (h^{-1} 7 TeV [1206 1750] $	$Ldt = (0.03 - 4.8) \text{ fb}^{-1}$
rch	Pheno model : 0 lep + i's + E_{π}	1 = 4.7 (b ⁻¹ .7 Tay IATI AS_CONE_2012_033)	138 TeV $\tilde{\alpha}$ mass $(m\tilde{\alpha}) < 2 \text{ TeV}$ $[\sin t \pi^0)$ (s = 7 TeV
ea	Pheno model : 0 lep + i's + E_{-}	$I = 4.7 \text{ fb}^{-1} 7 \text{ TeV} [AT LAS-CONF-2012-033]$	A40 GeV $\tilde{\mathbf{Q}}$ mass $(m(\tilde{q}) < 2 \text{ TeV})$ in $ht \pi^0$
9	Gluipo med $\tilde{x}^{\pm}(\tilde{a} \rightarrow a \tilde{a} \tilde{x}^{\pm}): 1 \text{ lep } + i \text{'s } + E$	$l = 4.7 \text{ fb}^{-1} \text{ 7 TeV} [AT AS_CONE_2012_041] $	00 GeV $\tilde{0}$ mass $(m/2^{\circ}) < 200 \text{ GeV} m/2^{\circ}) = \frac{1}{(m/2^{\circ}) + m/2^{\circ})} ATLAS$
Siv	GMSB : 2 len OSSE + $E_{T,miss}$	/ =1.0 (b ⁻¹ .7 Tay IATI AS_CONE_2011_1551 810	GeV \tilde{q} mass $(m_{\chi_1}) < 250 \text{ GeV}, m_{\chi_1} / - 2(m_{\chi_1} / m_{\chi_2}))$ Preliminary
clu	GMSB : $1-\tau + i's + E^{T,miss}$	$L = 2.4 \text{ (b}^{-1} \text{ 7 Tay (4204.2053)}$	$\tilde{\alpha}$ mass (lang + 33)
LI I	GMSB : $2-\tau + i's + E^{T,miss}$	$I = 2.1 \text{ fb}^{-1} \text{ 7 TeV} [1203.6580]$	990 GeV $\tilde{\mathbf{Q}}$ mass $(\tan \beta > 20)$
	GGM ; $\gamma\gamma + E^{T,miss}$	/ =4.8 (h ⁻¹ 7 TeV [ATI AS_CONE_2012_072]	107 TeV $\tilde{\Omega}$ mass $(m(x^0) > 50 \text{ GeV})$
	$\tilde{\alpha} \rightarrow b h \tilde{x}^0$ (virtual h) : 0 len + 1/2 h-i's + F	$l = 2.1 \text{ (h}^{-1} \text{ 7 TaV} [1203.6403] $	In GeV $\tilde{\mathbf{G}}$ mass $(m/z^0) < 300 \text{ GeV}$
SD	$\tilde{\alpha} \rightarrow b \tilde{p} \tilde{v}^{0}$ (virtual b): 0 lep + 3 b-i's + E	/ =4.7 fb ⁻¹ .7 TeV [ATLAS-CONF-2012-058]	102 TeV $\tilde{\mathbf{q}}$ mass $(m(\pi^0) < 400 \text{ GeV})$
iarl ate	$\tilde{a} \rightarrow b \tilde{b} \tilde{x}^0$ (real \tilde{b}): 0 lep + 3 b-i's + E _{1,miss}	L=4.7 fb ⁻¹ , 7 TeV IATLAS-CONF-2012-0581	1.00 Te
squ edi	\tilde{q}	$l = 2.1 \text{ (b}^{-1}, 7 \text{ TeV} [1203.6193]$ 710 G	
. E	$\tilde{\alpha}$ \rightarrow $\tilde{t}\tilde{r}_{2}^{(i)}$ (virtual \tilde{t}): 2 lep (SS) + i's + E_{-}	/ =2.1 fb ⁻¹ 7 TeV (1203.5763) 650 GeV	
ge ino	$\tilde{q} \rightarrow t \tilde{t} \tilde{\tau}$ (virtual \tilde{t}): 0 lep + multi-i's + $E_{\tau,miss}$	L=4.7 fb ⁻¹ , 7 TeV [1206.1760] 87	
3rd glu	$\tilde{q} \rightarrow t \tilde{t} \tilde{z}$ (virtual \tilde{t}): 0 lep + 3 b-i's + $E_{T,miss}$	L=4.7 fb ⁻¹ , 7 TeV IATLAS-CONF-2012-0581	
	$\tilde{q} \rightarrow t \tilde{r}_{1}^{0}$ (real \tilde{t}): 0 lep + 3 b-i's + $E_{T,miss}$	L=4.7 fb ⁻¹ , 7 TeV IATLAS-CONF-2012-0581 820	SQUARKS & QIUINOS
10 0	bb b $\rightarrow b\bar{\gamma}$: 0 lep + 2-b-iets + E_{π}	L=2.1 (b ⁻¹ , 7 TeV [1112.3832] 390 GeV D ma	
tion	$\tilde{t}t$ (very light), $\tilde{t} \rightarrow b\tilde{\tau}^{\pm}$: 2 lep + E_{π}	L=4.7 fb ⁻¹ , 7 TeV [CONF-2012-059] 135 GeV \tilde{t} mass $(m(\tau^0) = 45 \text{ GeV})$	
luci	$\tilde{t}t$ (light), $\tilde{t} \rightarrow b\tilde{\gamma}^{\pm}$; 1/2 lep + b-jet + E_{π}	L=4.7 fb ⁻¹ , 7 TeV [CONF-2012-070] 120-173 GeV T Mass (m(z) = 45	
. SI	$\tilde{t}t$ (heavy), $\tilde{t} \rightarrow t\tilde{\tau}^{0}$; 0 lep + b-jet + E_{τ} and	L=4.7 fb ⁻¹ , 7 TeV [CONF-2012-074] 380-465 GeV t n	nass
jen it p	$t\bar{t}$ (heavy), $\bar{t} \rightarrow t\bar{z}$: 1 lep + b-iet + E_{T} miss	L=4.7 fb ⁻¹ , 7 TeV [CONF-2012-073] 230-440 GeV t m	ass (= 0)
rd ($\tilde{t}\tilde{t}$ (heavy), $\tilde{t} \rightarrow t\tilde{\chi}^0$: 2 lep + b-jet + $E_{\tau min}$	L=4.7 fb ⁻¹ , 7 TeV [CONF-2012-071] 298-305 GeV T mass	$(m(\chi^0) =$
6 6	tt (GMSB) Z(→II) + b-jet + E	L=2.1 fb ⁻¹ , 7 TeV [1204.6736] 310 GeV t mass	(115 < n < 230 GeV)
ц.	$ \widetilde{I}_1, \widetilde{I}_2 \rightarrow \widetilde{\chi}_1^0$: 2 lep + $E_{T \text{ miss}}^{T,\text{miss}}$	L=4.7 fb ⁻¹ , 7 TeV [CONF-2012-076] 93-180 GeV \tilde{I} mass $(m(\chi^0) = 0)$	
N Lie	$\tilde{\chi}_{\tau}^{\dagger}\tilde{\chi}_{\tau}, \tilde{\chi}_{\tau}^{\dagger} \rightarrow \tilde{l}v(\tilde{l}\tilde{v}) \rightarrow lv\tilde{\chi}_{\tau}^{0}: 2 \text{ lep } + E_{\tau \text{ miss}}$	L=4.7 fb ⁻¹ , 7 TeV [CONF-2012-076] 120-330 GeV $\widetilde{\chi}_{\pm}^{\pm}$ mass	S $(m(10, m(\tilde{1}_{N}) = \frac{1}{2}(m(\tilde{\chi}^{\pm}) + m(\tilde{\chi}^{0})))$
9	$\overline{\chi}_{\chi}^{\pm 10} \rightarrow 3l(hvv) + v + 2\overline{\chi}_{\chi}^{0}$: 3 lep + E_{χ} miss	L=4.7 fb ⁻¹ , 7 TeV [CONF-2012-077] 60-500 GeV X	$max_{max}^{\pm} = m(\overline{\chi}^{\pm}) = m(\overline{\chi}^{0}), m(\overline{\chi}^{0}) = 0, m(\overline{l}, \overline{v}) \text{ as above})$
	AMSB : long-lived 2	L=4.7 fb ⁻¹ , 7 TeV [CONF-2012-034] 118 GeV $\tilde{\chi}_{s}^{\pm}$ Mass $(1 < \tau(\chi_{s}^{\pm}) < 2 \text{ ns},$	90 GeV in [0.2,90] ns
s	Stable g R-hadrons : Full detector	L=4.7 fb ⁻¹ , 7 TeV [ATLAS-CONF-2012-075]	985 German mass
-liv	Stable b R-hadrons : Full detector	L=4.7 fb ⁻¹ , 7 TeV [ATLAS-CONF-2012-075] 612 GeV	b ma
ng. arti	Stable T R-hadrons : Full detector	L=4.7 fb ⁻¹ , 7 TeV [ATLAS-CONF-2012-075] 683 Ge	v ťn
рï	Metastable g R-hadrons : Pixel det. only	L=4.7 fb ⁻¹ , 7 TeV [ATLAS-CONF-2012-075] 9	10 GeV MASS (τ(ĝ) > 10 ns)
	GMSB : stable t	L=4.7 fb ⁻¹ , 7 TeV [ATLAS-CONF-2012-075] 310 GeV 7 mass	(5 < tar 20)
	RPV : high-mass eμ	L=1.1 fb ⁻¹ , 7 TeV [1109.3089]	1. V \tilde{V}_{π} mass $(\lambda_{311}^*=0.10, \lambda_{312}^*=0.05)$
PI PI	Bilinear RPV : 1 lep + j's + $E_{T,miss}$	L=1.0 fb ⁻¹ , 7 TeV [1109.6606] 760 0	GeV C MASS (cr _{LSP} < 15 mm)
~	BC1 RPV : 4 lep + E _{7,miss}	L=2.1 fb ⁻¹ , 7 TeV [ATLAS-CONF-2012-035]	.77 TeV ĝ mass
5	Hypercolour scalar gluons : 4 jets, m _{ij} ≃ m _{kl}	L=34 pb ⁻¹ , 7 TeV [1110.2693] 100-185 GeV Sgluon mass (n	ot exclution n _{sg} ≈ 140±3 GeV)
Othe	Spin dep. WIMP interaction : monojet + $E_{T,miss}$	L=4.7 fb ⁻¹ , 7 TeV [ATLAS-CONF-2012-084] 709 G	eV Male $(m_{\chi} < 100 \text{ GeV}, \text{ vector D5}, \text{Dirac } \chi)$
0 5	Spin indep. WIMP interaction : monojet + E _{T.miss}	L=4.7 fb ⁻¹ , 7 TeV [ATLAS-CONF-2012-084] 548 GeV	M^* So $(m_{\chi} < 100 \text{ GeV}, \text{ tensor D9}, \text{Dirac } \chi)$
		10 ⁻¹	1 10

SUSY:

SUSY Today – Only Limits!

$\begin{array}{c} \text{MSUGRA/CMSSM}: 0 \ \text{lep} + \mathbf{j's} + E_{\tau,\text{miss}}\\ \text{MSUGRA/CMSSM}: 1 \ \text{lep} + \mathbf{j's} + E_{\tau,\text{miss}}\\ \text{MSUGRA/CMSSM}: 0 \ \text{lep} + \text{multijets} + E_{\tau,\text{miss}}\\ \text{MSUGRA/CMSSM}: 0 \ \text{lep} + \text{multijets} + E_{\tau,\text{miss}}\\ \text{Pheno model}: 0 \ \text{lep} + \mathbf{j's} + E_{\tau,\text{miss}}\\ \text{Pheno model}: 0 \ \text{lep} + \mathbf{j's} + E_{\tau,\text{miss}}\\ \text{Gluino med.} \ \mathbf{\tilde{\chi}}^{\pm} \ (\mathbf{\tilde{g}} \rightarrow \mathbf{q} \mathbf{\bar{q}} \mathbf{\tilde{\chi}}^{\pm}): 1 \ \text{lep} + \mathbf{j's} + E_{\tau,\text{miss}}\\ \text{GMSB}: 2 \ \text{lep} \ \text{OSSF} + E_{\tau,\text{miss}}\\ \text{GMSB}: 1 - \tau + \mathbf{j's} + E\\ \text{GMSB}: 2 - \tau + \mathbf{j's} + E^{\tau,\text{miss}}\\ \text{GMSB}: 2 - \tau + \mathbf{j's} + E^{\tau,\text{miss}}\\ \text{GGM}: \gamma \gamma + E^{\tau,\text{miss}}_{\tau,\text{miss}}\\ \mathbf{\tilde{g}} \rightarrow \mathbf{b} \mathbf{b} \mathbf{\tilde{\chi}}_{\star} \ (\text{virtual b}): 0 \ \text{lep} + 1/2 \ \text{b-j's} + E_{\tau,\text{miss}}\\ \mathbf{\tilde{g}} \rightarrow \mathbf{b} \mathbf{b} \mathbf{\tilde{\chi}}_{\star} \ (\text{virtual b}): 0 \ \text{lep} + 3 \ \text{b-j's} + E_{\tau,\text{miss}}\\ \end{array}$	ATLAS SUSY Searches* -	$\begin{array}{c c} \textbf{95\% CL Lower Limits (Status:}\\ \hline 1.40 \text{ TeV} & \vec{q} = \vec{g} \text{ mass}\\ \hline 1.40 \text{ TeV} & \vec{q} = \vec{g} \text{ mass}\\ \hline 1.20 \text{ TeV} & \vec{q} = \vec{g} \text{ mass}\\ \hline 1.20 \text{ TeV} & \vec{q} = \vec{g} \text{ mass}\\ \hline 1.38 \text{ TeV} & \vec{q} \text{ mass} & (m(\vec{g}) < 2 \text{ TeV}, \text{ Ii})\\ \hline 940 \text{ GeV} & \vec{g} \text{ mass} & (m(\vec{q}) < 2 \text{ TeV}, \text{ Iight } \vec{\chi}_1^0)\\ \hline 900 \text{ GeV} & \vec{g} \text{ mass} & (m(\vec{\chi}_1^0) < 200 \text{ GeV}, m(\vec{\chi}^\pm))\\ \hline 810 \text{ GeV} & \vec{g} \text{ mass} & (\tan\beta < 35)\\ \hline 920 \text{ GeV} & \vec{g} \text{ mass} & (\tan\beta > 20)\\ \hline 990 \text{ GeV} & \vec{g} \text{ mass} & (\tan\beta > 20)\\ \hline 1.07 \text{ TeV} & \vec{g} \text{ mass} & (m(\vec{\chi}_1^0) > 50 \text{ GeV})\\ \hline 900 \text{ GeV} & \vec{g} \text{ mass} & (m(\vec{\chi}_1^0) < 300 \text{ GeV})\\ \hline 1.02 \text{ TeV} & \vec{g} \text{ mass} & (m(\vec{\chi}_1^0) < 400 \text{ GeV})\\ \hline \end{array}$	ICHEP 2012) $\int Ldt = (0.03 - 4.8) \text{ fb}^{-1}$ $\lim_{\text{ight } \overline{\chi}_{1}^{0}} \text{ is = 7 TeV}$ $= \frac{1}{2}(m(\overline{\chi}^{0}) + m(\overline{g})) \text{ ATLAS}$ Preliminary
$ \begin{array}{lll} \begin{array}{lll} \widetilde{g} \rightarrow b \widetilde{p} \widetilde{\chi}_{+}^{*} (\text{real } b) : 0 \ \text{lep} + 3 \ \text{b-j's} + \mathcal{E}_{T, \text{mist}} \\ \widetilde{g} \rightarrow t \widetilde{t} \widetilde{\chi}_{+}^{0} (\text{virtual } \widetilde{t}) : 1 \ \text{lep} + 1/2 \ \text{b-j's} + \mathcal{E}_{T, \text{mist}} \\ \widetilde{g} \rightarrow t \widetilde{t} \widetilde{\chi}_{+}^{0} (\text{virtual } \widetilde{t}) : 2 \ \text{lep} (\text{SS}) + j's + \mathcal{E}_{T, \text{mist}} \\ \widetilde{g} \rightarrow t \widetilde{t} \widetilde{\chi}_{+}^{0} (\text{virtual } \widetilde{t}) : 0 \ \text{lep} + \text{multi-j's} + \mathcal{E}_{T, \text{mist}} \\ \widetilde{g} \rightarrow t \widetilde{t} \widetilde{\chi}_{+}^{0} (\text{virtual } \widetilde{t}) : 0 \ \text{lep} + 3 \ \text{b-j's} + \mathcal{E}_{T, \text{mist}} \\ \widetilde{g} \rightarrow t \widetilde{t} \widetilde{\chi}_{+}^{0} (\text{virtual } \widetilde{t}) : 0 \ \text{lep} + 3 \ \text{b-j's} + \mathcal{E}_{T, \text{mist}} \\ \widetilde{g} \rightarrow t \widetilde{t} \widetilde{\chi}_{+}^{0} (\text{virtual } \widetilde{t}) : 0 \ \text{lep} + 3 \ \text{b-j's} + \mathcal{E}_{T, \text{mist}} \\ \widetilde{g} \rightarrow t \widetilde{t} \widetilde{\chi}_{+}^{0} (\text{virtual } \widetilde{t}) : 0 \ \text{lep} + 2 \ \text{b-jets} + \mathcal{E}_{T, \text{mist}} \\ \widetilde{g} \rightarrow t \widetilde{t} \widetilde{\chi}_{+}^{0} (\text{real } \widetilde{t}) : 0 \ \text{lep} + 2 \ \text{b-jets} + \mathcal{E}_{T, \text{mist}} \\ \widetilde{g} \rightarrow t \widetilde{t} \widetilde{\chi}_{+}^{0} (\text{real } \widetilde{t}) : 0 \ \text{lep} + 2 \ \text{b-jets} + \mathcal{E}_{T, \text{mist}} \\ \widetilde{g} \rightarrow t \widetilde{t} \widetilde{\chi}_{+}^{0} (\text{real } \widetilde{t}) : 0 \ \text{lep} + 2 \ \text{b-jets} + \mathcal{E}_{T, \text{mist}} \\ \widetilde{t} (\text{light}), \widetilde{t} \rightarrow \widetilde{p} \widetilde{\chi}_{+}^{\pm} : 1/2 \ \text{lep} + \text{b-jet} + \mathcal{E}_{T, \text{mist}} \\ \widetilde{t} (\text{leavy}), \widetilde{t} \rightarrow t \widetilde{\chi}_{+}^{0} : 0 \ \text{lep} + \text{b-jet} + \mathcal{E}_{T, \text{mist}} \\ \widetilde{t} (\text{heavy}), \widetilde{t} \rightarrow t \widetilde{\chi}_{+}^{\pm} : 1 \ \text{lep} + \text{b-jet} + \mathcal{E}_{T, \text{mist}} \\ \widetilde{t} (\text{heavy}), \widetilde{t} \rightarrow t \widetilde{\chi}_{+}^{\pm} : 2 \ \text{lep} + \text{b-jet} + \mathcal{E}_{T, \text{mist}} \\ \widetilde{t} (\text{heavy}), \widetilde{t} \rightarrow t \widetilde{\chi}_{+}^{\pm} : 2 \ \text{lep} + \text{b-jet} + \mathcal{E}_{T, \text{mist}} \end{array} $	L=4.7 fb ⁻¹ , 7 TeV [ATLAS-CONF-2012-058] L=2.1 fb ⁻¹ , 7 TeV [1203.6193] L=2.1 fb ⁻¹ , 7 TeV [1203.5763] L=4.7 fb ⁻¹ , 7 TeV [1206.1760] L=4.7 fb ⁻¹ , 7 TeV [ATLAS-CONF-2012-058] L=4.7 fb ⁻¹ , 7 TeV [ATLAS-CONF-2012-058] L=2.1 fb ⁻¹ , 7 TeV [ATLAS-CONF-2012-058] L=2.1 fb ⁻¹ , 7 TeV [CONF-2012-059] 135 GeV T mass (m(χ L=4.7 fb ⁻¹ , 7 TeV [CONF-2012-070] 120-173 GeV T mass L=4.7 fb ⁻¹ , 7 TeV [CONF-2012-070] 120-173 GeV T mass L=4.7 fb ⁻¹ , 7 TeV [CONF-2012-073] 230-469 L=4.7 fb ⁻¹ , 7 TeV [CONF-2012-073] 230-440 L=4.7 fb ⁻¹ , 7 TeV [CONF-2012-071] 298-305 GeV	1.00 Te 710 GeV \tilde{g} 550 GeV \tilde{g} m 870 GeV 940 GeV 820 GeV 820 GeV $(m(\tilde{\chi}_{1}^{0}) = 45 \text{ GeV})$ 5 GeV \tilde{t} mass GeV \tilde{t} mass $(m(\tilde{\chi}_{1}^{0}) = 0)$ \tilde{t} mass $(m(\tilde{\chi}_{1}^{0}) = 0)$	/ limits on s & gluinos interaction)
$\begin{array}{c} \begin{array}{c} \begin{array}{c} \text{tt} \left(\text{GMSB}\right): Z(\rightarrow \text{II}) + \text{b-jet} + \\ \hline \text{I}_{[L_{1}}, \overline{\rightarrow} _{Z_{1}} : 2 \text{ lep} + \\ \hline \tilde{\chi}_{1}^{+} \overline{\chi}_{1}^{-} \overline{\chi}_{1}^{+} \rightarrow \overline{\text{Iv}}(\overline{\text{Iv}}) \rightarrow \text{Iv} \overline{\chi}_{1}^{-} : 2 \text{ lep} + \\ \hline \chi_{1}^{+} \overline{\chi}_{2}^{-} \rightarrow 3 \text{I}(\overline{\text{Ivv}}) + \text{v} + 2 \overline{\chi}_{1}^{-} : 3 \text{ lep} + \\ \hline \text{AMSB} : \text{ long-lin} \\ \hline \text{Stable } \tilde{\text{g}} \text{ R-hadrons : Full de} \\ \hline \text{Stable } \tilde{\text{R}} \text{ chadrons : Full detector} \\ \hline \text{Metastable } \tilde{\text{g}} \text{ R-hadrons : Full detector} \\ \hline \text{Metastable } \tilde{\text{g}} \text{ R-hadrons : Pixel det. only} \\ \hline \text{GMSB} : \text{stable } \tilde{\text{g}} \text{ R-hadrons : Pixel det. only} \\ \hline \text{CMSB} : \text{Stable } \tilde{\text{g}} \text{ R-hadrons : Pixel det. only} \\ \hline \end{array}$	200 to 400 GeV 100 to 400 GeV	$\begin{array}{c c c c c c c c c c c c c c c c c c c $,=0.05)
Bilinear RPV : 1 lep + j's + $E_{T,mist}$ BC1 RPV : 4 lep + $E_{T,mist}$ Hypercolour scalar gluons : 4 jets, $m_{ij} = m_{k}$ Spin dep. WIMP interaction : monojet + $E_{T,mist}$ Spin indep. WIMP interaction : monojet + $E_{T,mist}$	L=1.0 fb ⁻¹ , 7 TeV [1109.6606] L=2.1 fb ⁻¹ , 7 TeV [ATLAS-CONF-2012-035] L=34 pb ⁻¹ , 7 TeV [1110.2693] 100-185 GeV Sgluor L=4.7 fb ⁻¹ , 7 TeV [ATLAS-CONF-2012-084] L=4.7 fb ⁻¹ , 7 TeV [ATLAS-CONF-2012-084] 10-1 10 ⁻¹	760 GeV \widehat{c} mass ($c\tau_{LSP} < 15 \text{ mm}$) .77 TeV \widehat{g} mass ass (not excluse $r_{sg} = 140 \pm 3 \text{ GeV}$) 709 GeV M ale ($m_{\chi} < 100 \text{ GeV}$, vector D5, 100 GeV, tensor D9, Diraction ($m_{\chi} < 100 \text{ GeV}$)	Dirac χ) c χ) 10

*Only a selection of the available mass limits on new states or phenomena shown

Mass scale [TeV]

Lets make a short detour ...

Putting it all Together – Where are Toady?



Direct Dark Matter Searches

Example: Xenon100 New result: arXiv:1207.5988v1





The XENON100 experiment is located deep underground at the Gran Sasso National Laboratory in Italy.

34 kg liquid Xenon target 225 days of data taking

1.0±0.2 events expected 2 events observed \Rightarrow Exclude 2.0 × 10⁻⁴⁵ cm² for a M_{WIMP} = 55 GeV at 90% CL.

MasterCode Collaboration



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I Instituto de Fisica de Cantabria (CSIC-UC), E–39005 Santander, Spain
J INFN, Laboratori Nazionali di Frascati, Via E. Fermi 40, I–00044 Frascati, Italy
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L Institute for Particle Physics, ETH Zuerich, CH–8093 Zuerich, Switzerland
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- Collaboration of experimentalist and theorists was formed in 2007 to facilitate the interpretation of the LHC results in the context of particle physics and cosmology.
- The team consists of experts from different subjects (e.g. Higgs, SUSY, flavour physics, cosmology, etc.) and it operates on a truly international bases.
- Today the project resides under the London Centre for Terauniverse Studies (LCTS). It connects the three London universities: Imperial College, University College, and Kings College London as well as CERN.

Higgs: SUSY vs. SM





Example: "redo" SM fit in SUSY predicting the lightest higgs boson mass in the Constraint Minimal Supersymmeteric Standard Model (CMSSM)

SUSY: What have we learned? O. Buchmüller

MasterCode Collaboration

Dull for CNASSNA fit

OB (Exp), R. Cavanaugh (Exp), A. De Roeck (Exp), J. Ellis (Theo), H. Flaecher (Exp), S. Heinemeyer (Theo), G. Isidori (Theo), K. Olive (Theo), P. Paradisi, (Theo), F. Ronga (Exp), G. Weiglein (Theo)

C			IO ^{meas} -O ^m l/σ ^{meas}
Variable	Measurement	Fit	0 1 2
$\Delta \alpha_{had}^{(5)}(\mathbf{m}_{z})$	0.02758 ± 0.00035	0.02774	
m _z [GeV]	91.1875 ± 0.0021	91.1873	
$\Gamma_{\rm Z}$ [GeV]	2.4952 ± 0.0023	2.4952	
σ_{had}^0 [nb]	41.540 ± 0.037	41.486	
R ₁	20.767 ± 0.025	20.744	
$A_{fb}^{0,l}$	0.01714 ± 0.00095	0.01641	
$\mathbf{A}_{\mathbf{I}}(\mathbf{P}_{\tau})$	0.1465 ± 0.0032	0.1479	
R _b	0.21629 ± 0.00066	0.21613	
R _c	0.1721 ± 0.0030	0.1722	
$A_{fb}^{0,b}$	0.0992 ± 0.0016	0.1037	
A ^{0,c}	0.0707 ± 0.0035	0.0741	
A _b	0.923 ± 0.020	0.935	
A _c	$\boldsymbol{0.670 \pm 0.027}$	0.668	
A _l (SLD)	0.1513 ± 0.0021	0.1479	
$\sin^2 \theta_{\rm eff}^{\rm lept}(\mathbf{Q}_{\rm re})$	0.2324 ± 0.0012	0.2314	
m _w [GeV]	80.398 ± 0.025	80.382	
m _t [GeV]	170.9 ± 1.8	170.8	
R(b→sγ)	1.13 ± 0.12	1.12	
B _s →μμ [×10 ⁻⁸] < 8.00	0.33	N/A (upper limit)
Δa _μ [×10 ⁻⁹]	2.95 ± 0.87	2.95	
Ωh^2	0.113 ± 0.009	0.113	

The pre-LHC era





Model	Min χ^2	Prob	m _{1/2}	m_0	A_0	tan β
CMSSM	21.5	37%	360	90	400	15
NUHM1	20.8	29%	340	110	-520	13

For references NDF ~ 22

The "post-LHC" era in 2011 master.



- Chi² increases
 - > Shifting to higher masses, larger tan β
 - Plane relatively flat no real preferred minima anymore

CMSSM: Evolution with time master



CMSSM: Evolution with time master.



WHERE ARE WE TODAY?

Constrained SUSY models like the CMSSM are severely put under pressure by the LHC limits!

Although even these "simple" SUSY models are not yet fully ruled out several people have asked the question:

WHERE ARE WE TODAY?

Constrained SUSY models like the CMSSM are severely put under pressure by the LHC limits!

Although even these "simple" SUSY models are not yet fully ruled out several people have asked the question:

Is Supersymmetry Dead?

The grand scheme, a stepping-stone to string theory, is still high on physicists' wish lists. But if no solid evidence surfaces soon, it could begin to have a serious PR problem

By Davide Castelvecchi

Additional Interpretation

CMSSM

What we see is much more simple...

Simplified Model Spectra

So, is SUSY now on life support?

The answer to this question is NO!

See 2012 Experimental SUSY PDG review [OB & Paul De Jong]: http://pdg.lbl.gov/2012/reviews/rpp2012-rev-susy-2-experiment.pdf

Model	Assumption	$m_{ ilde{q}}$	$m_{ ilde{g}}$
	$m_{ ilde{q}}pprox m_{ ilde{g}}$	1400	1400
CMSSM	all $m_{ ilde{q}}$	-	800
	all $m_{ ilde{g}}$	1300	-
Simplified model $\tilde{g}\tilde{g}$	$m_{ ilde{\chi}_1^0} = 0$	-	900
	$m_{ ilde{\chi}_1^0}>300$	-	no limit
Simplified model $\tilde{q}\tilde{q}$	$m_{ ilde{\chi}^0_1}=0$	750	-
	$m_{ ilde{\chi}_1^0}>250$	no limit	-
Simplified model	$m_{\tilde{\chi}^0_1} = 0, m_{\tilde{q}} \approx m_{\tilde{g}}$	1500	1500
$ ilde{g} ilde{q}, ilde{g}ar{ ilde{q}}$	$m_{\tilde{\chi}_1^0} = 0$, all $m_{\tilde{g}}$	1400	-
	$m_{ ilde{\chi}_1^0}^{n=1}=0,~\mathrm{all}~m_{ ilde{q}}$	-	900

SUSY on life support?

The answer to this question is NO!

See 2012 Experimental SUSY PDG review [OB & Paul De Jong]: http://pdg.lbl.gov/2012/reviews/rpp2012-rev-susy-2-experiment.pdf

Model	Assumption	$m_{ ilde{q}}$	$m_{ ilde{g}}$	_
	$m_{ ilde{q}}pprox m_{ ilde{g}}$	1400	1400	In general, the LHC
CMSSM	all $m_{ ilde{q}}$	-	800	does not (yet) place
	all $m_{ ilde{g}}$	1300	-	limits on parameter
Simplified model $\tilde{g}\tilde{g}$	$m_{ ilde{m{v}}^0}=0$	-	900	space with
	$m_{\tilde{\chi}_1^0} > 300$	- (no limit	<i>M_{LSP}</i> >~400 GeV
Simplified model $\tilde{q}\tilde{q}$	$m_{ ilde{ u}^0}=0$	750		Leaving a very large
	$m_{\tilde{\chi}_1^0} > 250$	no limit		Region of the MSSM,
Simplified model	$m_{ ilde{\chi}^0_1} = 0, m_{ ilde{q}} pprox m_{ ilde{g}}$	1500	1500	<i>even at the mass</i>
$ ilde{g} ilde{q}, ilde{g}ar{ ilde{q}}$	$\widehat{m}_{ ilde{Y}_1^0}^{-1} = 0$, all $m_{ ilde{g}}$	1400	-	scale below 1 TeV,
	$m_{ ilde{\chi}_1^0}^{\sim_1}=0, ext{ all } m_{ ilde{q}}$	-	900	unexplored!

SUSY Coverage

SUSY Coverage

SUSY Coverage

Yet, even this is still optimistic!

Example: Gluion induced bb production.

Limit on M(gluino) is around 1.1 TeV and stems from an inclusive hadronic search (alpha T)

Looks impressive!

Yet, what does this mean?

Limit on M(gluino) from T1bbbb

Lets do a little Gedankenexperiment: Assume two topology searches: a) all-hadronic (jets + MET) b) OSSF (jets + MET + l^+l^-)

0-leptons	1-lepton	OSDL	SSDL	≥3 leptons	2-photons	γ+lepton
Jets + MET	Single lepton + Jets + MET	Opposite- sign di- lepton + jets + MET	Same-sign di-lepton + jets + MET	Multi-lepton	Di-photon + jet + MET	Photon + lepton + MET

Also assume a

Signal Efficiency: Spectra 0

Limit on M(gluino) from T1bbbb

Lets do a little Gedankenexperiment: Assume two topology searches: a) all-hadronic (jets + MET) b) OSSF (jets + MET + I⁺I⁻)

Signal Efficiency: Spectra 1

Limit on M(gluino) from T1bbbb

Signal Efficiency: Spectra 2

SUSY: What have we learned? O. Buchmüller

Limit on M(gluino) from T1bbbb

Signal Efficiency: Spectra 3

SUSY: What have we learned? O. Buchmüller

Signal Efficiency

M(gluino) Limit

SUSY: What have we learned? O. Buchmüller

M(gluino) Limit

Refining SUSY Search Strategy

0-leptons	1-lepton	OSDL	SSDL	≥3 leptons	2-photons	γ+lepton
Jets + MET	Single lepton + Jets + MET	Opposite-sign di-lepton + jets + MET	Same-sign di- lepton + jets + MET	Multi-lepton	Di-photon + jet + MET	Photon + lepton + MET

- Focus more on 3rd Generation squark searches
 - Both interpretation of inclusive searches as well as dedicated searches

Example: "Natural SUSY" Use argument that light Higgs needs new physics to stabalise mass, which in turn motivates existences of a stop like particle.

Spectrum is model dependent but overall a good guideline for 3rd generation squark searches

Stop searches

Mixture of dedicated signature searches as well as • inclusive searches with b-tagging

> Example CMS: add 0,1,2,>2 b-tag categories to inclusive α_{T} search

Direct Stop Searches Today

Nice summary plot from ATLAS ...

Direct Stop Searches Today

Direct searches not yet adding much over inclusive searches! This needs more work!

Use the famous SPS1a benchmark point for illustration $[m_0=100, m_{12}=250, \tan\beta=10, A_0=-100, \mu>0]$

SUSY: What have we learned? O. Buchmüller

Use the famous SPS1a benchmark point for illustration $[m_0=100, m_{12}=250, \tan\beta=10, A_0=-100, \mu>0]$

SUSY: What have we learned? O. Buchmüller

Use the famous SPS1a benchmark point for illustration $[m_0=100, m_{12}=250, \tan\beta=10, A_0=-100, \mu>0]$ $sq_l sq_r$

Use the famous SPS1a benchmark point for illustration $[m_0=100, m_{12}=250, \tan\beta=10, A_0=-100, \mu>0]$ $sq_l sq_r$

Use the famous SPS1a benchmark point for illustration $[m_0=100, m_{12}=250, \tan\beta=10, A_0=-100, \mu>0]$

SUSY: What have we learned? O. Buchmüller

Summary

What have we learned so far?

> A lot! Yet, not as much as some people think.

We are just about to explore the 1 TeV scale and beyond and there are still major wholes in SUSY parameters space below the 1 TeV scale.

> So far SUSY has not revealed itself!

- Yet, with many of the powerful direct searches continuing to push the limits, discovery of a SUSY-like signal could now happen almost every day!
- It, however, might also take more time and ingenuity to claim a signal (or to rule out the most relevant parameter space).

> 13+ TeV operation in 2015 will be critical!

Pre-LHC 2008

Post-LHC (1/fb), Post-Xenon100 - 2011

Discovery of a new Boson

The summer's tale of 2012 (and beyond)

SM-like Higgs Boson

SM-like Higgs Boson

SM-like Higgs Boson

SUSY: Light Higgs Predictions

- Higgs important probe of SUSY
 - Predictions above produced based on analogous method to SM best-fit plots

→ No Higgs constraints imposed to make these plots!!

The "post-Higgs" era

- Assume a putative measurement of m_H=125 +/- 1.5(theo) +/- 1.0 GeV
 - > Further reduction in potential phase-space!

Post "LHC&Higgs" era in 2012

- Updated with
 - > 5/fb direct search results
 - > Updated BR(Bs-> $\mu \mu$) combination from the LHC (May 2012
- Prospects look bleak for constrained models
 - > p-value ~10% (max)

Supersymmetry

Extension of the Standard Model: Introduce a new symmetry Spin $\frac{1}{2}$ matter particles (fermions) \Leftrightarrow Spin 1 force carriers (bosons) Standard Model particles SUSY particles

First SUSY Search: α_T

Define: $H_T = \Sigma p_T(j_i)$, $MH_T = |-\Sigma p_T(j_i)|$, $\Delta H_T = E_T(pj_1) - E_T(pj_2)$

$$\begin{array}{l} \alpha_{\tau} \text{ for } \\ \text{dijets:} \end{array} a_{T} = \frac{E_{Tj2}}{M_{Tj1j2}} = \frac{\sqrt{E_{Tj2}/E_{Tj1}}}{\sqrt{2(1 - \cos\Delta\varphi)}} \leq 0.5 \qquad \alpha_{\tau} \text{ for } \\ n \text{ jets:} \end{array} a_{T} = \frac{1}{2} \frac{H_{T} - \Delta H_{T}}{M_{T}} \\ \mathcal{A}_{T} = \frac{1}{2} \frac{H_{$$

The Standard Model of Particle Physics

Over the last 100 years: combination of Quantum Mechanics and Special Theory of relativity along with all new particles discovered has led to the Standard Model of Particle Physics (SM). The new (final?) "Periodic Table" of fundamental elements

A crowning achievement of 20th Century Science

Yet, its most basic mechanism, that of granting mass to particles, is (was?) missing. Quantum of this field is the Spin Zero Higgs boson.

Supersymmetry

Extension of the Standard Model: Introduce a new symmetrySpin ½ matter particles (fermions) Spin 1 force carriers (bosons)Standard Model particlesSUSY particles

What do we call a "SUSY search"?

The definition is purely derived from the experimental signature. Therefore, a "SUSY search signature" is characterized by Lots of missing energy, many jets, and possibly leptons in the final state

Missing Energy:

from LSP

Multi-Jet:

• from cascade decay (gaugino)

Multi-Leptons:

from decay of charginos/neutralios

RP-Conserving SUSY is a very prominent example predicting this famous signature but ...

What is its experimental signature?

... by no means is it the only New Physics model predicting this experimental pattern. Many other NP models predict this genuine signature

Missing Energy:

• Nwimp - end of the cascade

Multi-Jet:

• from decay of the Ns (possibly via heavy SM particles like top, W/Z)

Multi-Leptons:

from decay of the N's

Model examples are Extra dimensions, Little Higgs, Technicolour, etc but a more generic definition for this signature is as follows.