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LHC Phenomenology of an E_6 Inspired SUSY SM

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Standard Model Puzzles

☐ The origin and fate of the Universe – and why is it so big and flat?

☐ The dark side of the Universe – why is 95% of mass-energy in a form that is presently unknown, including 23% dark matter and 72% dark energy?

☐ The origin of matter – the problem of why there is a tiny excess of matter over antimatter in the Universe, at a level of one part in a billion.

☐ The origin of mass - the origin of the weak scale, its stability under radiative corrections, and the solution to the hierarchy problem.

☐ The quest for unification - the question of whether the three known forces of the standard model (and gravity) may be unified.

☐ The problem of flavour - the problem of the three generations with fermion (incl. neutrino) masses and mixing angles and CPV phases, giving small FCNCs and tiny strong CPV.

Once upon a time, there was a naturalness problem...

Murayama

- At the end of 19th century: a “crisis” about electron
  - Like charges repel: hard to keep electric charge in a small pack
  - Electron is point-like
  - At least smaller than 10^{-17}cm
- Need a lot of energy to keep it small!

$$\Delta m_e c^2 \sim \frac{e^2}{r_e} \sim \mathrm{GeV}\frac{10^{-17}\mathrm{cm}}{r_e}$$

- Correction $\Delta m_e c^2 > m_e c^2$ for $r_e < 10^{-13}$cm
- Breakdown of theory of electromagnetism

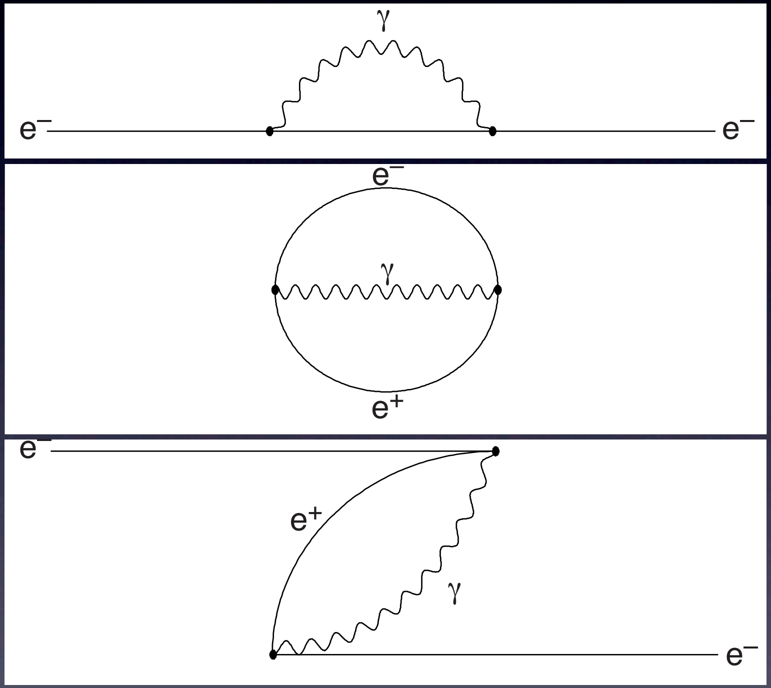
  ⇒ Can’t discuss physics below 10^{-13}cm

Anti-Matter Comes to Rescue by Doubling of #Particles

Murayama

- Electron creates a force to repel itself
- Vacuum bubble of matter anti-matter creation/annihilation
- Electron annihilates the positron in the bubble

⇒ only 10% of mass even for Planck-size $r_e \sim 10^{-33}$cm

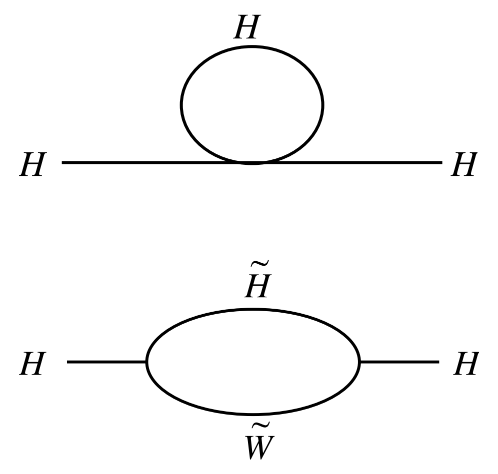


$$\Delta m_e \sim m_e \frac{\alpha}{4\pi} \log(m_e r_e)$$

History repeats itself?

Murayama

- Higgs also repels itself
- Double #particles again ⇒ superpartners
- “Vacuum bubbles” of superpartners cancel the energy required to contain Higgs boson in itself
- Standard Model made consistent with whatever physics at shorter distances



$$\Delta m_H^2 \sim \frac{\alpha}{4\pi} m_{SUSY}^2 \log(m_H r_H)$$

Minimal SUSY SM

Table 1: The MSSM Particle Spectrum

Superfield		Bosons	Fermions
Gauge			
$\widehat{G}$		g	$\widetilde{g}$
$\widehat{V}^a$		W^a	$\widetilde{W}^a$
$\widehat{V}'$		B	$\widetilde{B}$
Matter			
$\widehat{L}$	leptons	$\widetilde{L} = (\widetilde{\nu}, \widetilde{e}^-)_L$	$(\nu, e^-)_L$
$\widehat{E}^c$		$\widetilde{E} = \widetilde{e}^+_R$	e^c_L
$\widehat{Q}$	quarks	$\widetilde{Q} = (\widetilde{u}_L, \widetilde{d}_L)$	$(u, d)_L$
$\widehat{U}^c$		$\widetilde{U}^c = \widetilde{u}^*_R$	u^c_L
$\widehat{D}^c$		$\widetilde{D}^c = \widetilde{d}^*_R$	d^c_L
$\widehat{H}_d$	Higgs	H^i_d	$(\widetilde{H}^0_d, \widetilde{H}^-_d)_L$
$\widehat{H}_u$		H^i_u	$(\widetilde{H}^+_u, \widetilde{H}^0_u)_L$

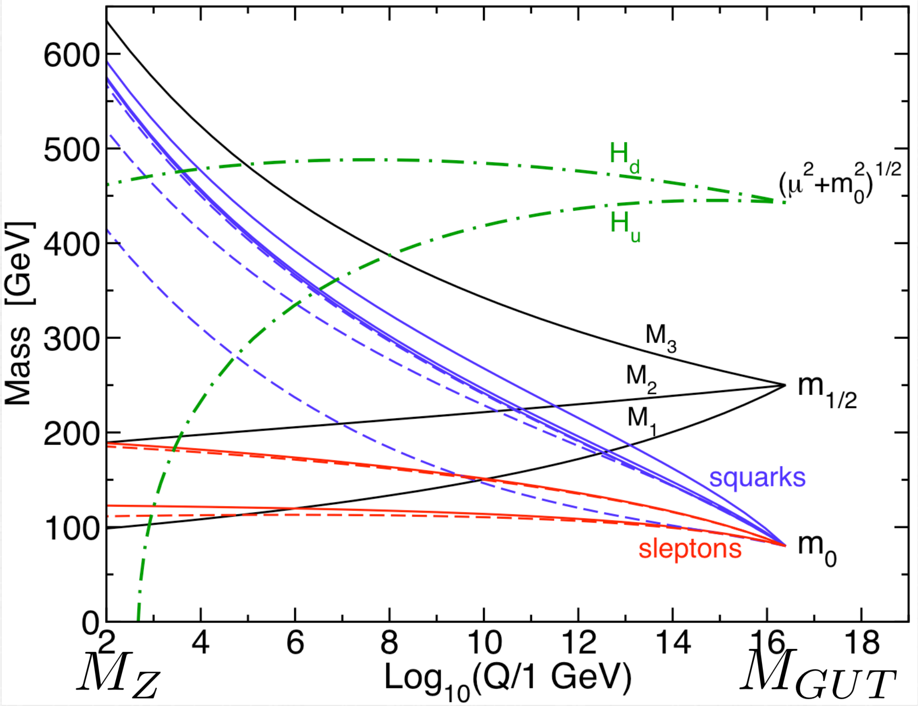
The μ problem

Higgsino mass

$$\mu \tilde{H}_u \tilde{H}_d$$

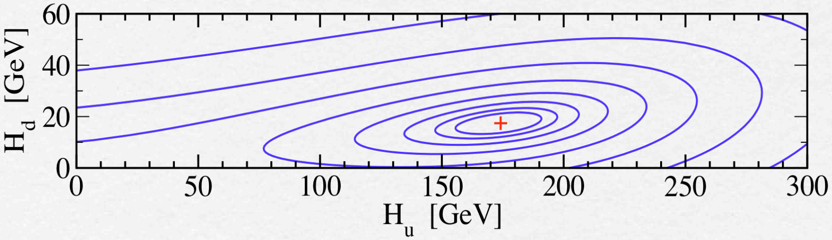
What is the origin of this mass term?

Constrained MSSM



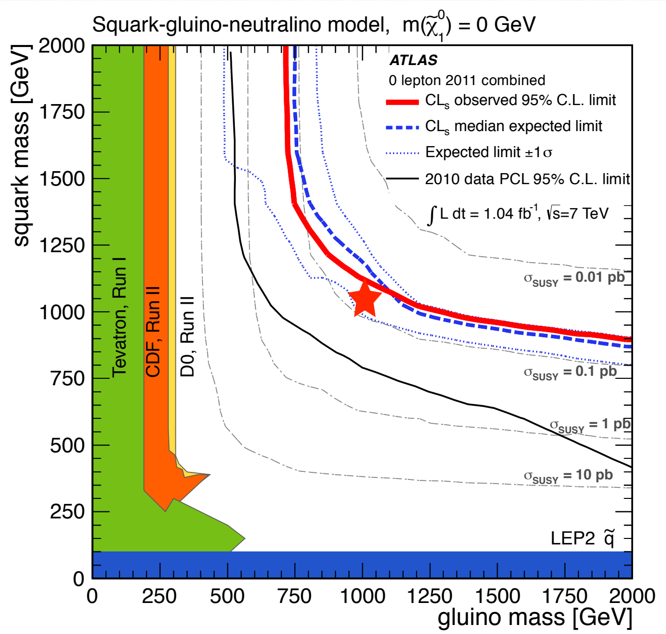
Two Higgs doublets get VEVs

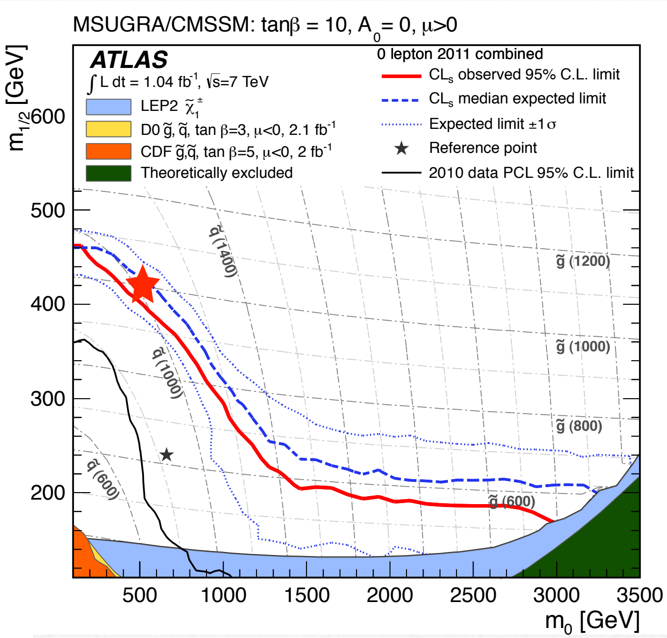
$$H_u = \begin{pmatrix} H_u^{\,+} \\ H_u^{\,0} \end{pmatrix} \quad H_d = \begin{pmatrix} H_d^{\,0} \\ H_d^{\,-} \end{pmatrix}$$

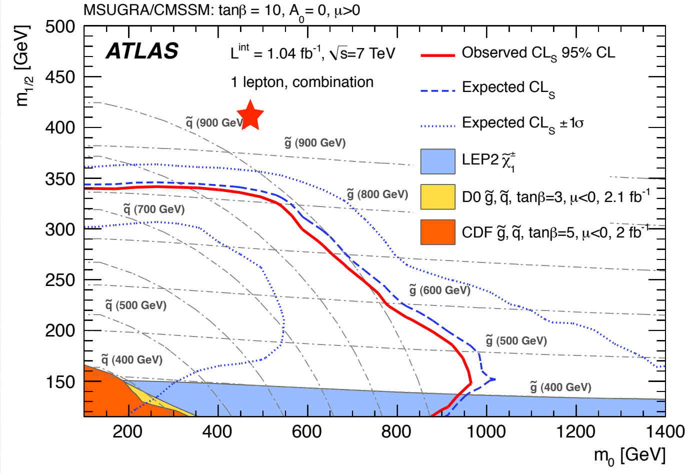


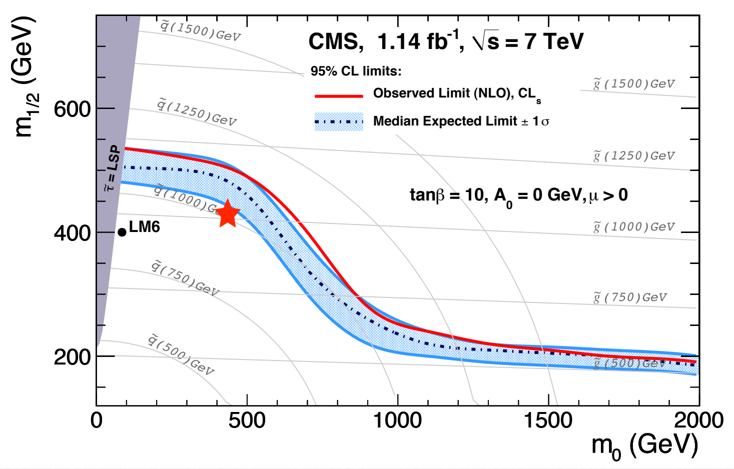
$$\tan\beta = \frac{v_u}{v_d}$$

LHC SUSY limits









★ stars indicate squark = gluino = 1 TeV

More general SUSY models

Focus on models which provide a dynamical origin of μ term:

SH_uH_d where singlet $<S> \sim \mu \sim$ TeV

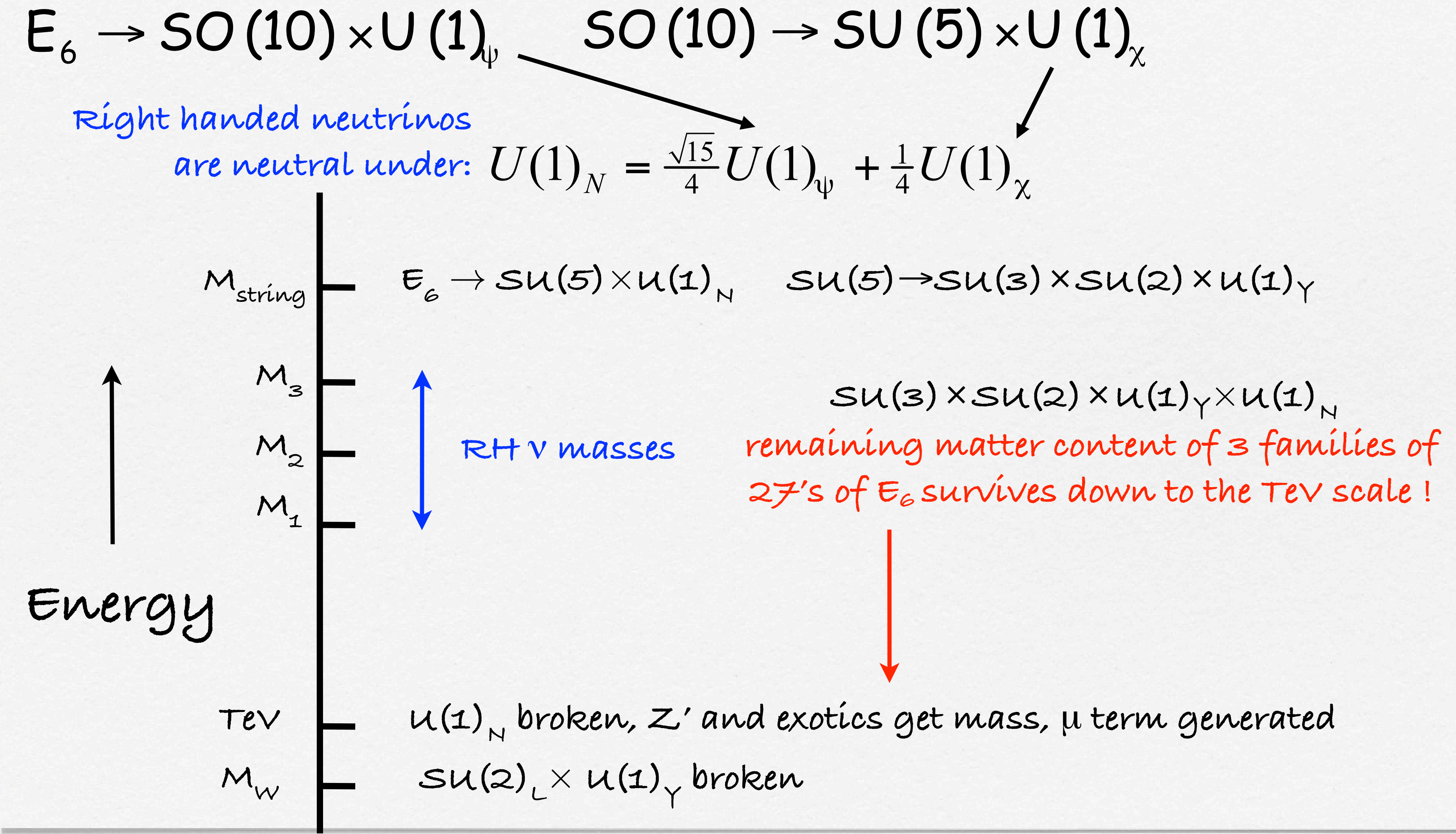
Danger from weak scale axion due to global U(1) symmetry

Need to avoid axion somehow

- In NMSSM we add S^3 to break U(1) to Z_3 – but this results in cosmological domain walls (μS^2, $\mu^2 S$ reintroduces μ problem)
- In USSM we gauge the U(1) symmetry to eat the axion resulting in a massive Z' gauge boson – but not anomaly free
- In E_6SSM the anomalies of the USSM are cancelled by three complete 27's of E_6 at the TeV scale with $U(1) \in E_6$

Exceptional SUSY SM (E_6SSM)

King, Moretti, Nevzorov



$E_6 \rightarrow SO(10) \times U(1)_\psi$ $SO(10) \rightarrow SU(5) \times U(1)_\chi$

Right handed neutrinos are neutral under: $U(1)_N = \frac{\sqrt{15}}{4} U(1)_\psi + \frac{1}{4} U(1)_\chi$

M_{string} $E_6 \rightarrow SU(5) \times U(1)_N$ $SU(5) \rightarrow SU(3) \times SU(2) \times U(1)_Y$

M_3

M_2 RH ν masses

M_1

$SU(3) \times SU(2) \times U(1)_Y \times U(1)_N$

remaining matter content of 3 families of 27's of E_6 survives down to the TeV scale !

Energy

TeV $U(1)_N$ broken, Z′ and exotics get mass, μ term generated

M_W $SU(2)_L \times U(1)_Y$ broken

Matter Content of 27’s of E$_6$

All the SM matter fields are contained in one 27-plet of E$_6$ per generation.

Miller

$$[27]_i \Rightarrow [10, 1]_i + [5^*, 2]_i + [5^*, -3]_i + [5, -2]_i + [1, 5]_i + [1, 0]_i$$

$[10, 1]_i$: $Q_i,\ u^c_i,\ e^c_i$

$[5^*, 2]_i$: $L_i,\ d^c_i$

$[5^*, -3]_i$: $H_{1\,i} = \begin{pmatrix} H^0_{1\,i} \\ H^-_{1\,i} \end{pmatrix},\ \bar{D}_i$

$[5, -2]_i$: $H_{2\,i} = \begin{pmatrix} H^+_{2\,i} \\ H^0_{2\,i} \end{pmatrix},\ D_i$

$[1, 5]_i$: S_i

$[1, 0]_i$: N^c_i

3 generations of “Higgs”

exotic quarks

singlets

right handed neutrino

SU(5) reps.

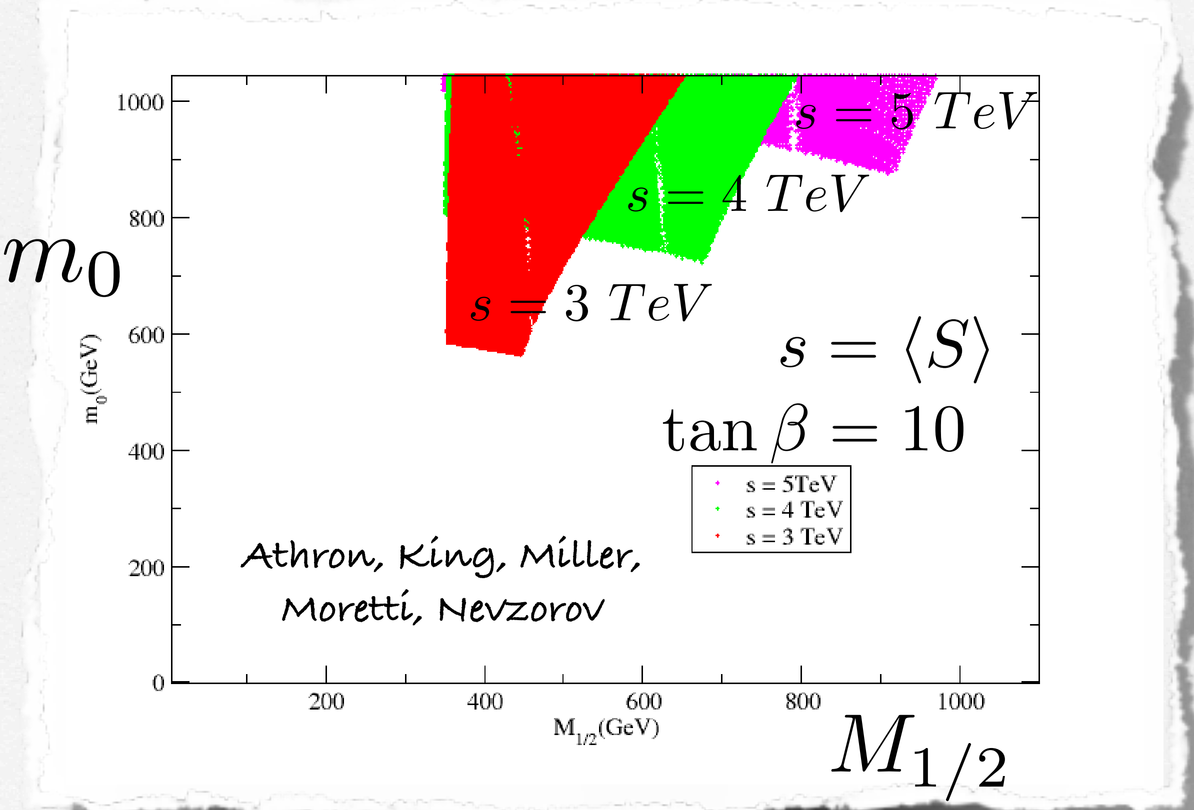
U(1)$_N$ charge × √40

LHC phenomenology of E_6SSM

- ☐ SUSY - typical spectrum has heavier squarks and lighter gluinos, with gluinos having longer decay chains than MSSM, and extra neutralinos and charginos
- ☐ Higgs - "Higgs boson" invisible decays allowed, richer Higgs spectrum than MSSM with possibility of heavier "Higgs boson"
- ☐ Exotics - Z', D-leptoquarks/diquarks (maybe long lived)

Constrained E_6SSM

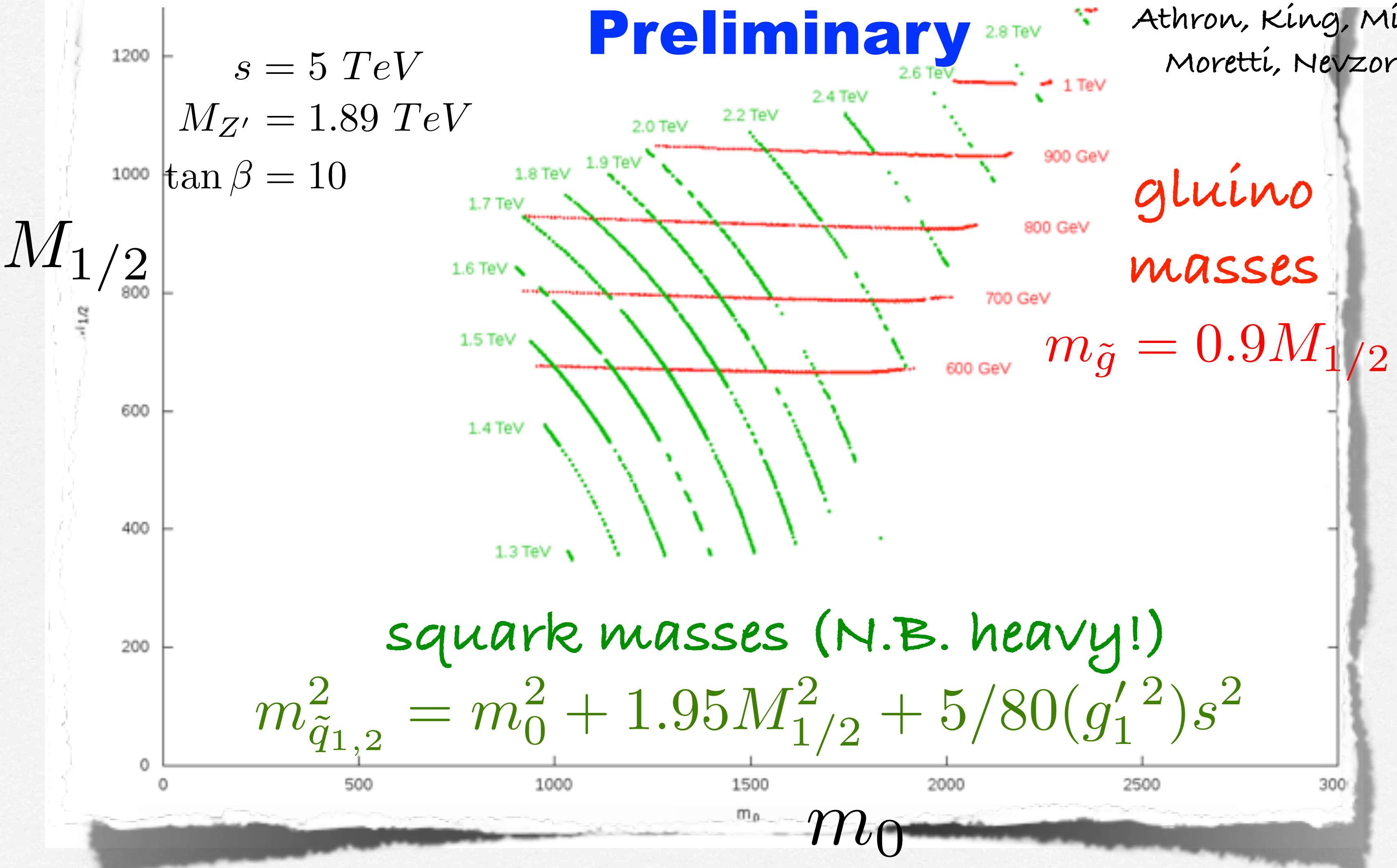
Assume universal soft parameters at GUT scale $m_0^2 27_i 27_i^* + A_0 Y_{ijk} 27_i 27_j 27_k$



Athron, King, Miller, Moretti, Nevzorov

Allowed regions of parameter space with correct EWSB and $m_h > 115$ GeV

Squark and gluino masses



Preliminary

Athron, King, Miller, Moretti, Nevzorov

$s = 5\ TeV$

$M_{Z'} = 1.89\ TeV$

$\tan\beta = 10$

gluino masses

$m_{\tilde{g}} = 0.9 M_{1/2}$

squark masses (N.B. heavy!)

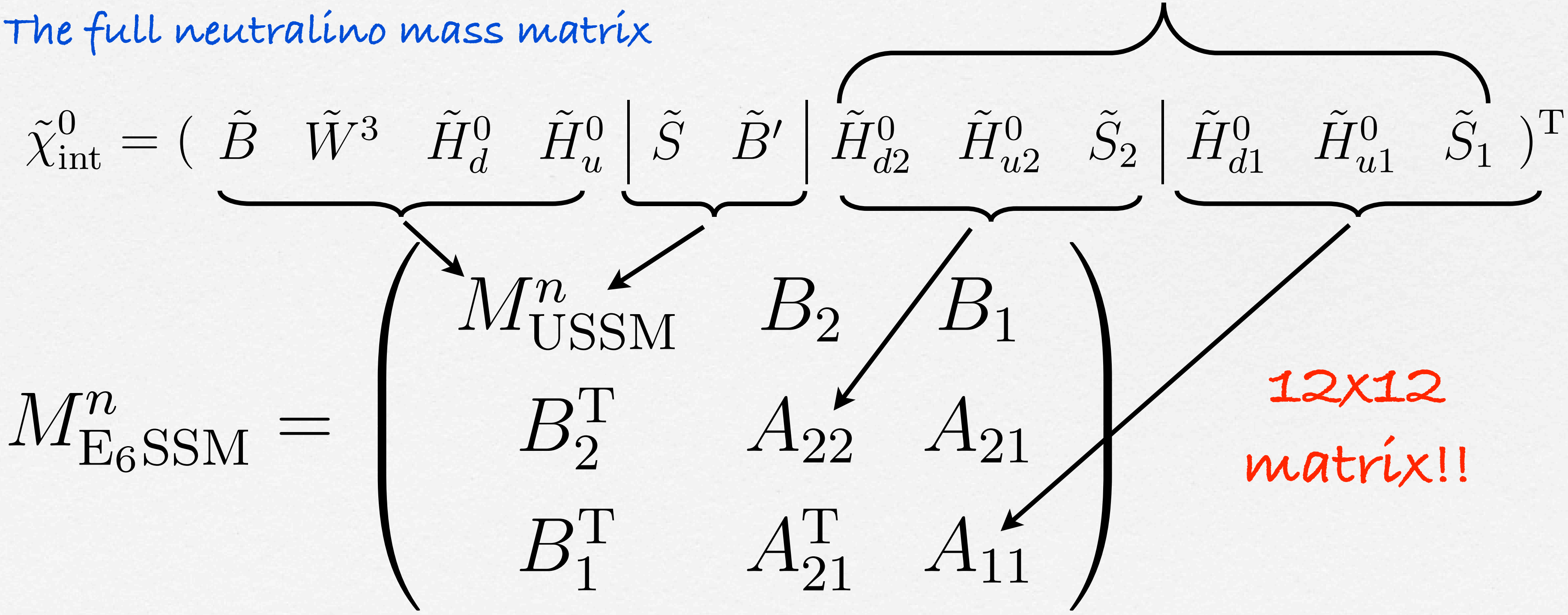
$$m^2_{\tilde{q}_{1,2}} = m_0^2 + 1.95 M^2_{1/2} + 5/80(g_1'{}^2)s^2$$

Neutralinos in E_6SSM

Hall, King

- ☐ 3 Higgs families = 1 MSSM family H_u H_d + 2 inert families H_{u1} H_{d1} H_{u2} H_{d2}
- ☐ 3 families of Singlets = 1 NMSSM singlet S + 2 inert singlets S_1 S_2

The full neutralino mass matrix



$$\tilde{\chi}^0_{\rm int} = (\underbrace{\tilde{B} \quad \tilde{W}^3 \quad \tilde{H}^0_d \quad \tilde{H}^0_u} \,|\, \underbrace{\tilde{S} \quad \tilde{B}'} \,|\, \overbrace{\underbrace{\tilde{H}^0_{d2} \quad \tilde{H}^0_{u2} \quad \tilde{S}_2} \,|\, \underbrace{\tilde{H}^0_{d1} \quad \tilde{H}^0_{u1} \quad \tilde{S}_1}})^{\rm T}$$

$$M^n_{\rm E_6SSM} = \begin{pmatrix} M^n_{\rm USSM} & B_2 & B_1 \\ B_2^{\rm T} & A_{22} & A_{21} \\ B_1^{\rm T} & A_{21}^{\rm T} & A_{11} \end{pmatrix}$$

12x12 matrix!!

Hall, King

The Inert Neutralino Sector

$$A_{\alpha\beta} = -\frac{1}{\sqrt{2}} \begin{array}{cc} \begin{array}{ccc} \tilde{H}^0_{d\beta} & \tilde{H}^0_{u\beta} & \tilde{S}_\beta \end{array} & \\ \begin{pmatrix} 0 & \lambda_{\alpha\beta} s & \tilde{f}_{\beta\alpha} v \sin\beta \\ \lambda_{\beta\alpha} s & 0 & f_{\beta\alpha} v \cos\beta \\ \tilde{f}_{\alpha\beta} v \sin\beta & f_{\alpha\beta} v \cos\beta & 0 \end{pmatrix} & \begin{array}{c} \tilde{H}^0_{d\alpha} \\ \tilde{H}^0_{u\alpha} \\ \tilde{S}_\alpha \end{array} \end{array}$$

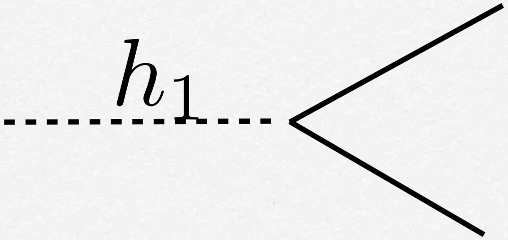
$$m_{\chi^0_1} \approx \frac{f^2}{\lambda} \frac{v^2}{s} \sin 2\beta \quad \begin{cases} \text{Inert LSP is naturally light} \sim v^2/s \\ \text{Inert LSP is inert Higgsino/singlino} \end{cases}$$

☐ Inert LSP would be natural dark matter candidate

☐ Higgs and gluinos can decay into inert LSP (invisible Higgs decays, longer gluino chains)

Hall, King, Pakvasa Nevzorov, Sher

Invisible Higgs Decays

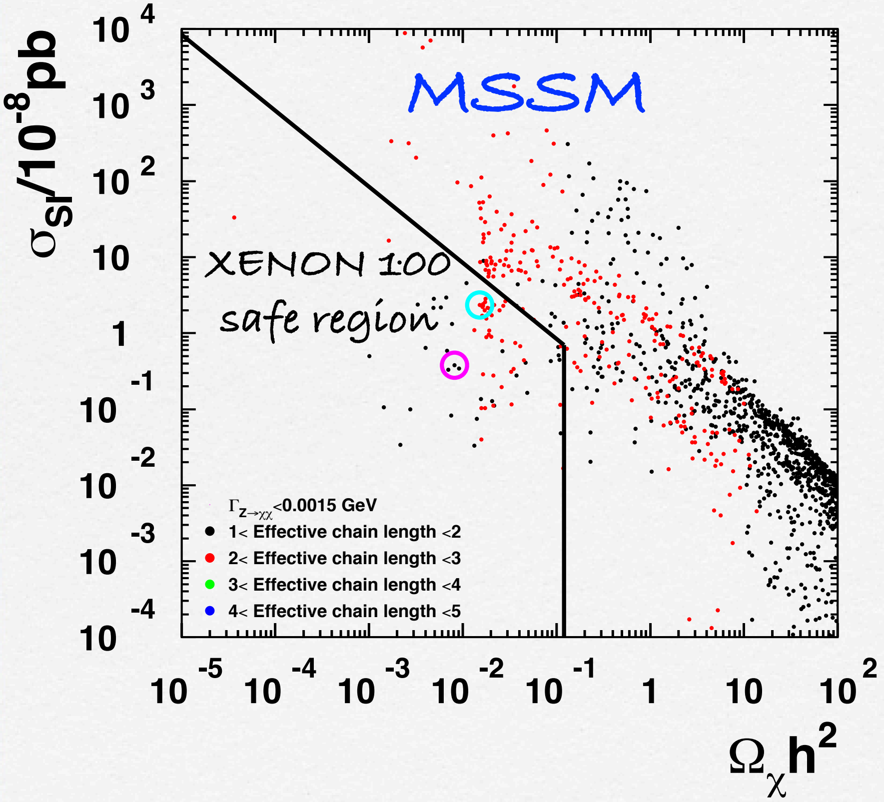


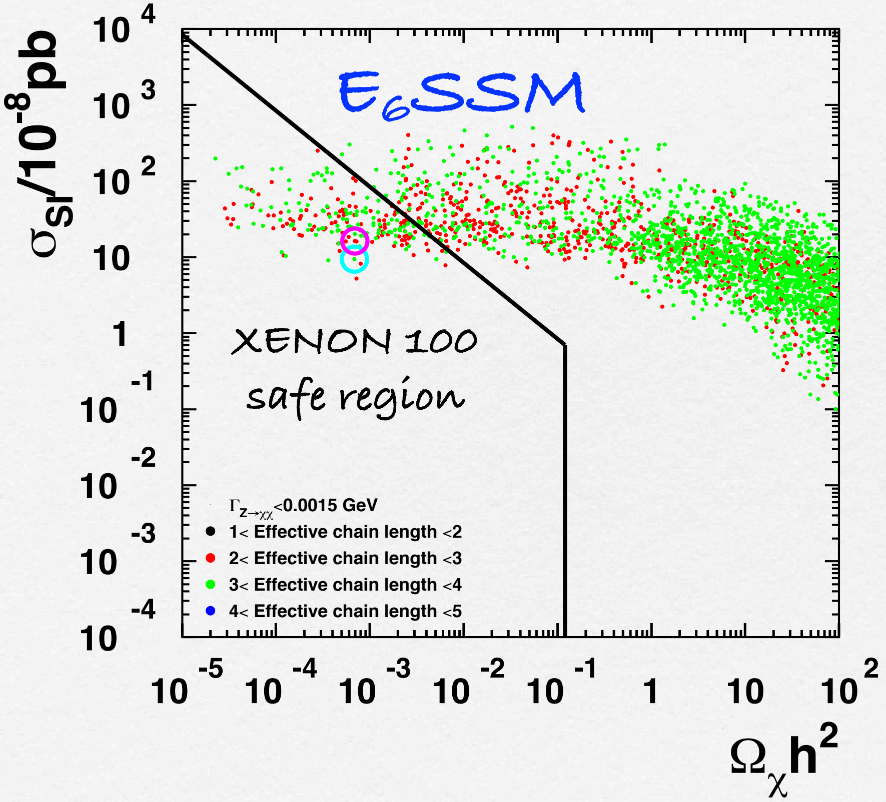
$$\Gamma(h_1 \to \chi^0_\alpha \chi^0_\beta) \gg \Gamma(h_1 \to f\bar{f})$$

- ☐ due to large coupling of inert neutralinos to Higgs ~M_χ/v with $M_\chi \sim M_Z/2$
- ☐ gives large SI DD cross-sections -- challenged by XENON 100

Belyaev, Hall, King, Svantesson (preliminary)

Dark Matter Constraints





Also shown are gluino decay chain lengths

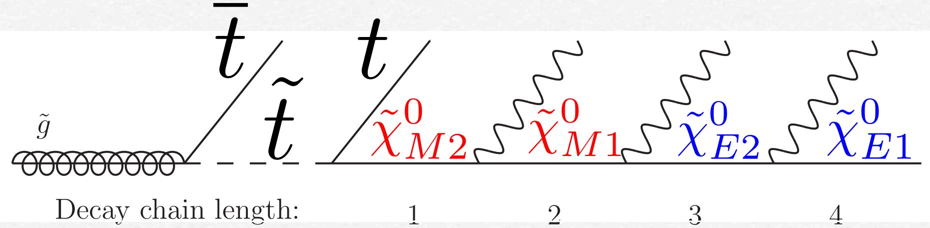
Benchmarks

Belyaev, Hall, King, Svantesson (preliminary)

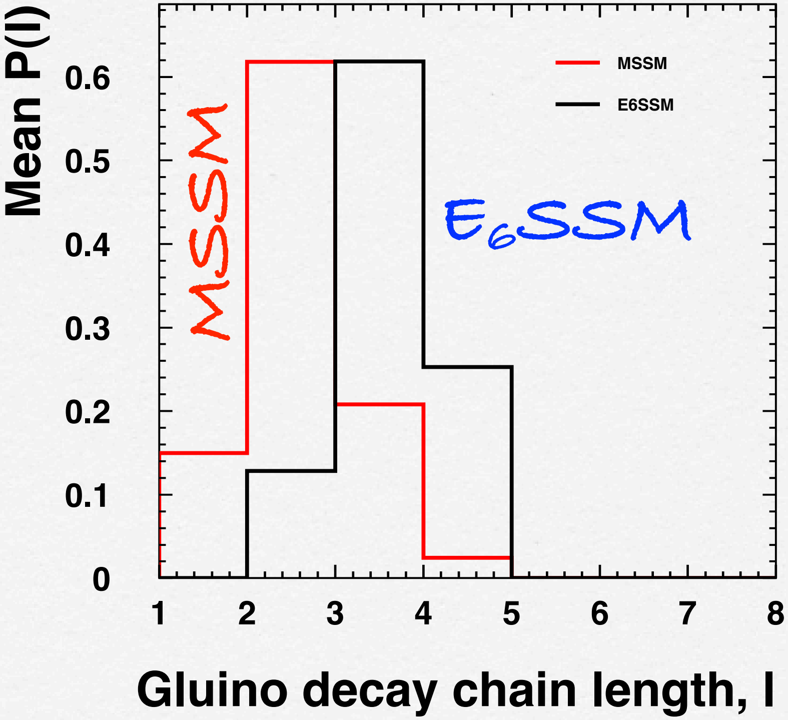
		○ MSSM-A	○ MSSM-B	○ E$_6$SSM-A	○ E$_6$SSM-B	
	$\tan\beta$	9.9	39.2	1.42	1.77	
	λ	-	-	0.65	-0.4767	
	s	-	-	3099	3187	[GeV]
	μ	-112.6	1578	(1425)	(-1074)	
	$A_t = A_b = A_\tau$	-724.6	-566.1	-2684	476.2	
	M_A	1593	302.5	2791	2074	
	M_1	150	150	150	150	
	M_2	285	285	300	300	
	$M_{1'}$	-	-	151	151	
	$m_{\tilde{g}}$	800.3	800.2	800.0	800.0	
	$m_{\tilde{\chi}^0_{M1}}$	94.1	148.9	148.6	151.2	[GeV]
	$m_{\tilde{\chi}^0_{M2}}$	128.8	302.8	294.6	303.7	
MSSM-inos →	$m_{\tilde{\chi}^0_{M3}}$	163.0	1580	1434	1066	
	$m_{\tilde{\chi}^0_{M4}}$	323.5	1581	1452	1068	
	$m_{\tilde{\chi}^\pm_{M1}}$	112.2	302.8	298.6	300.9	
	$m_{\tilde{\chi}^\pm_{M2}}$	323.5	1582	1427	1076	
USSM-inos →	$m_{\tilde{\chi}^0_{U1}}$	-	-	1040	1110	[GeV]
	$m_{\tilde{\chi}^0_{U2}}$	-	-	1215	1254	
	$m_{\tilde{\chi}^0_{E1}}$	-	-	43.5	45.2	[GeV]
	$m_{\tilde{\chi}^0_{E2}}$	-	-	48.6	53.2	
E$_6$SSM-inos →	$m_{\tilde{\chi}^0_{E3}}$	-	-	131.3	141.6	
	$m_{\tilde{\chi}^0_{E4}}$	-	-	163.6	187.4	
	$m_{\tilde{\chi}^0_{E5}}$	-	-	197.0	227.8	
	$m_{\tilde{\chi}^0_{E6}}$	-	-	224.3	265.6	
	$m_{\tilde{\chi}^\pm_{E1}}$	-	-	119.9	122.7	
	$m_{\tilde{\chi}^\pm_{E2}}$	-	-	185.8	225.1	
	m_h	120.4	119.0	133.8	116.3	
	$P(l=1)$	0.09847	0.188	$< 10^{-5}$	$< 10^{-5}$	
	$P(l=2)$	0.4705	0.812	0.01524	0.1723	
	$P(l=3)$	0.387	0	0.2336	0.7986	
	$P(l=4)$	0.04387	0	0.7512	0.02915	
	$P(l=5)$	$< 10^{-4}$	0	$< 10^{-7}$	0	
	Ωh^2	0.01513	0.00816	0.0006842	0.0006937	
	σ_{SI}	2.35×10^{-8}	0.3808×10^{-8}	9.35×10^{-8}	16.35×10^{-8}	[pb]

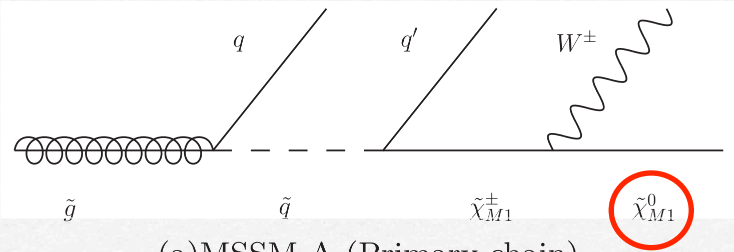
Gluino decay chains

Belyaev, Hall, King, Svantesson (preliminary)

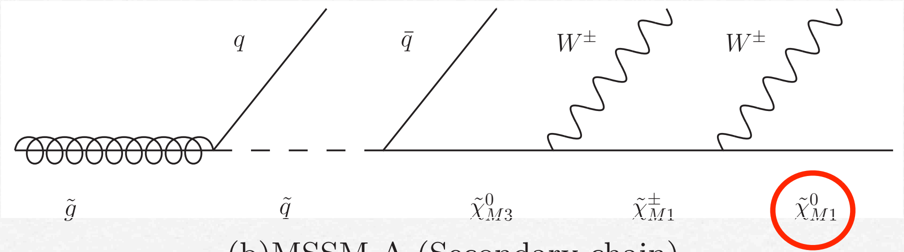


E_6SSM has longer gluino chains with a lighter LSP at the end

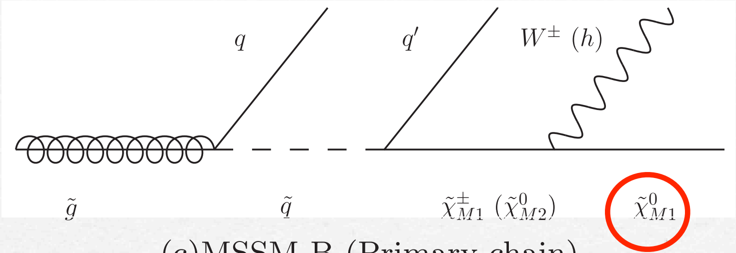




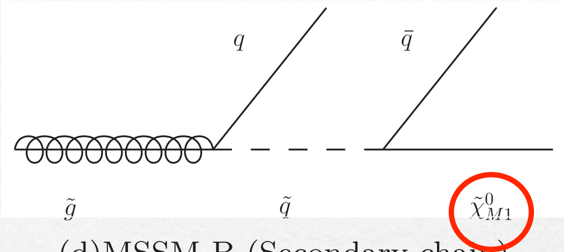
(a)MSSM-A (Primary chain)



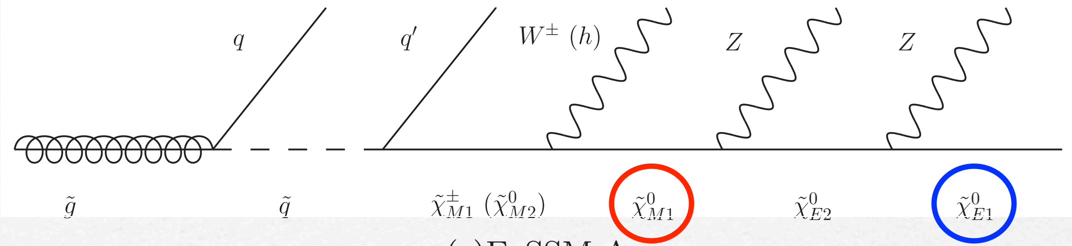
(b)MSSM-A (Secondary chain)



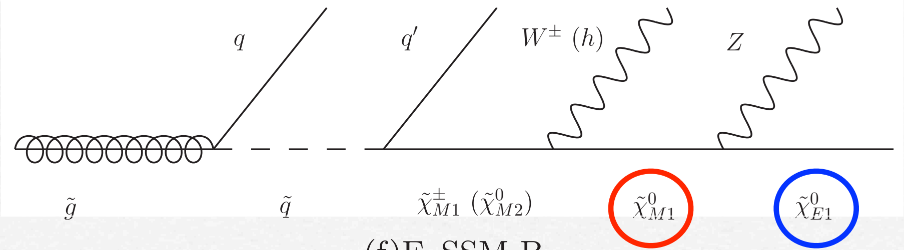
(c)MSSM-B (Primary chain)



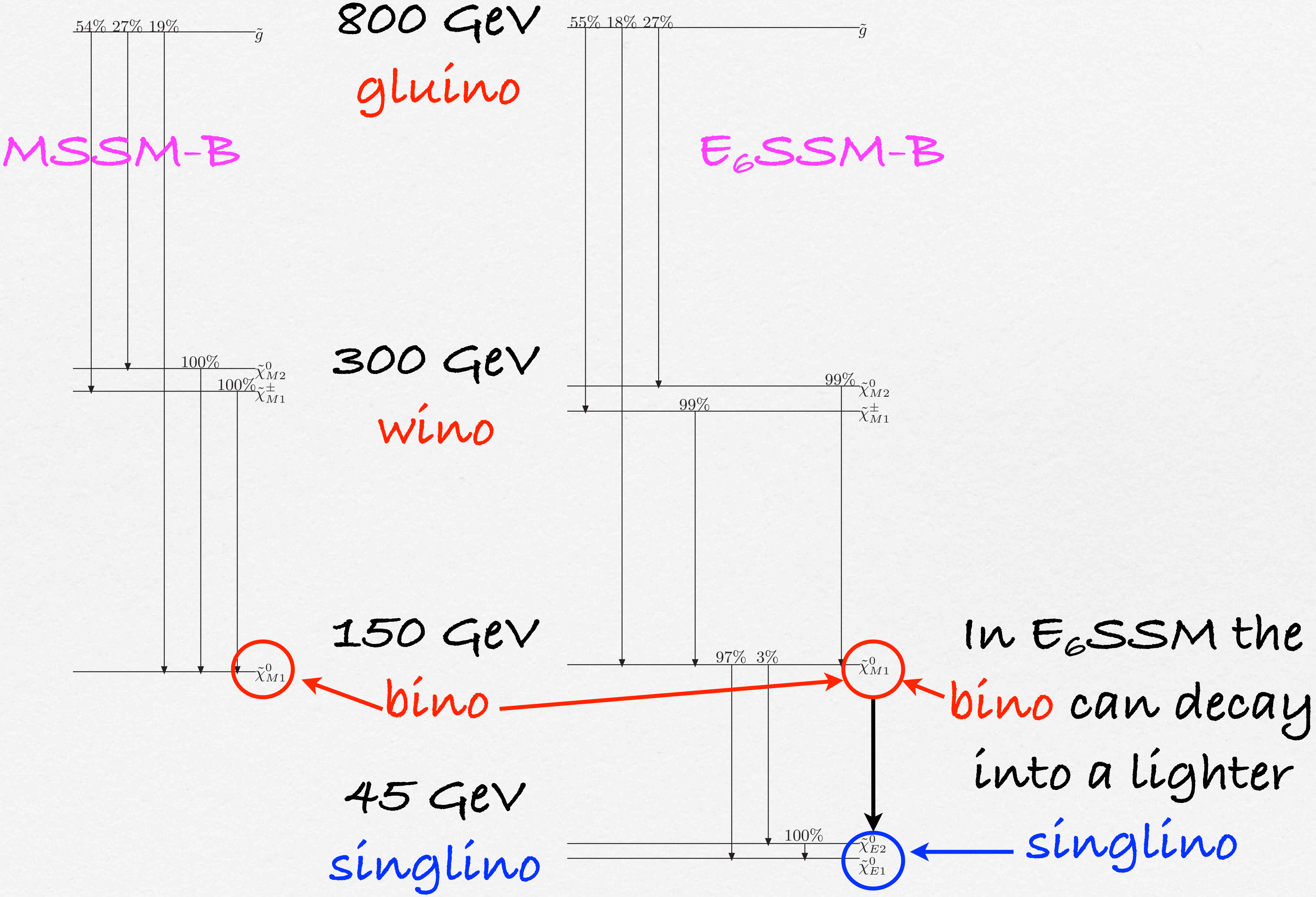
(d)MSSM-B (Secondary chain)



(e)E$_6$SSM-A



(f)E$_6$SSM-B



MSSM-B

E$_6$SSM-B

800 GeV
gluino

300 GeV
wino

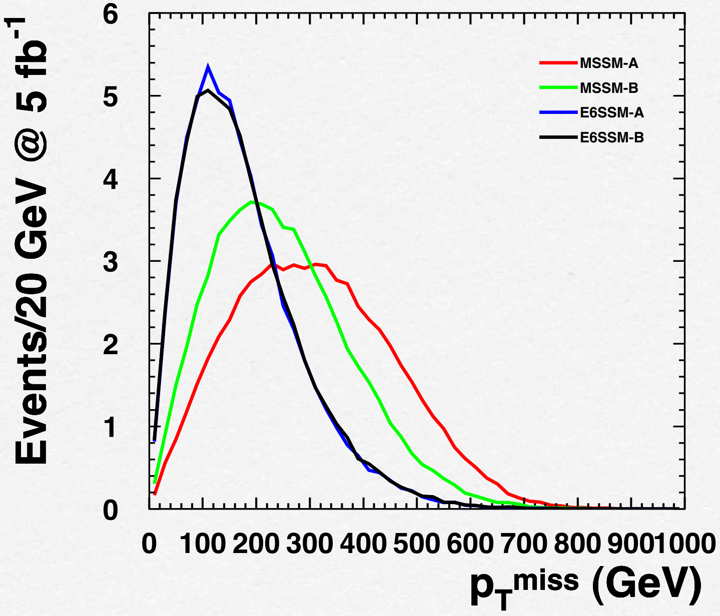
150 GeV
bino

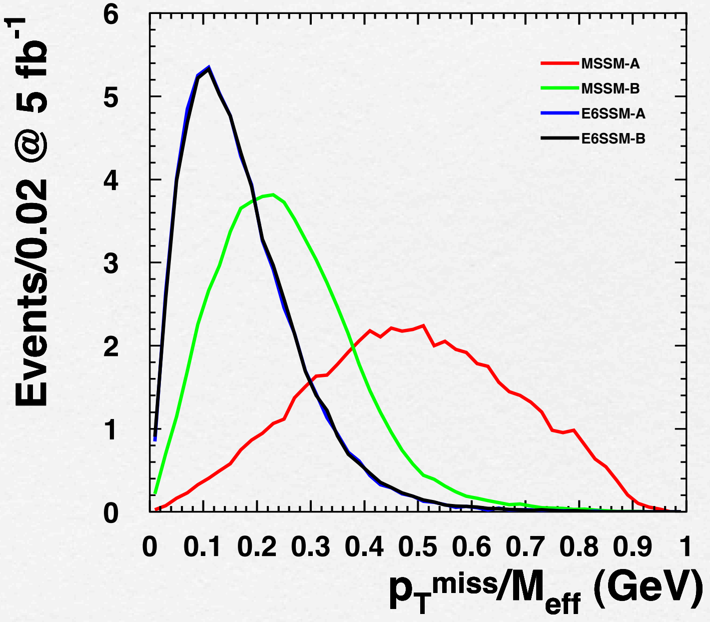
45 GeV
singlino

In E$_6$SSM the bino can decay into a lighter singlino

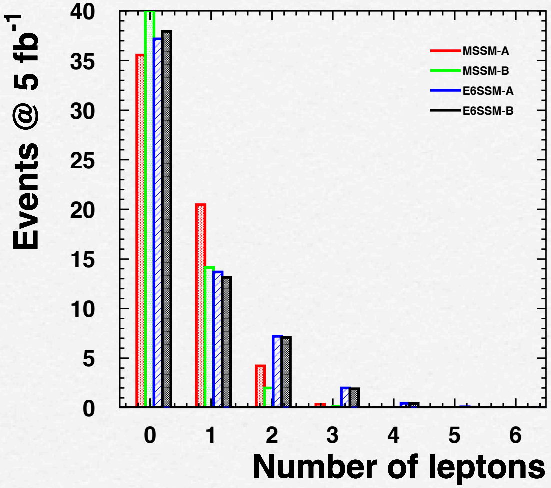
E_6SSM gives less p_T^{miss}

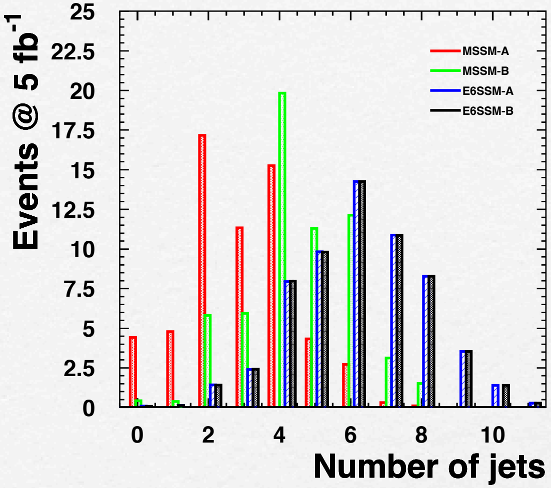
Belyaev, King, Svantesson
(preliminary)



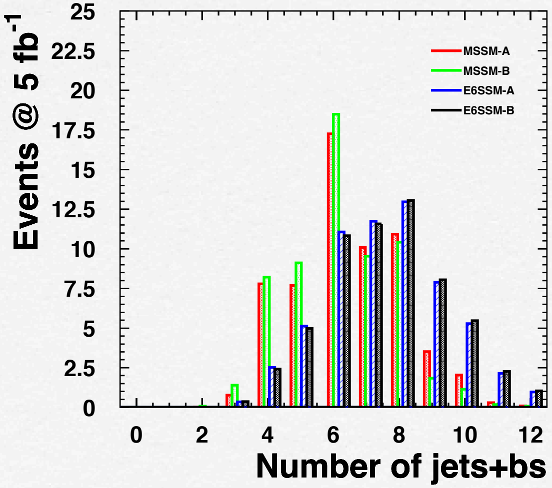


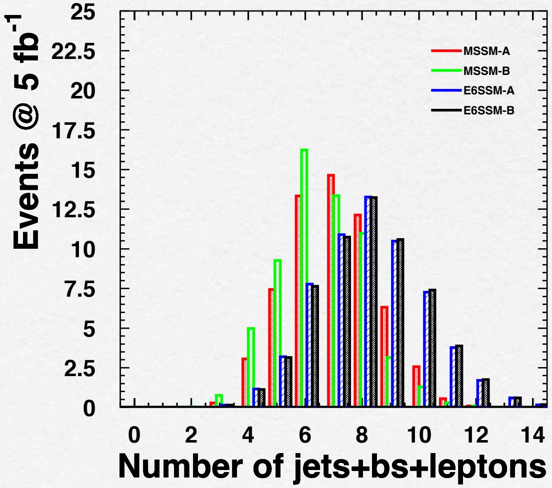
Lepton/jet multiplicity





Belyaev, Hall,
King, Svantesson
(preliminary)

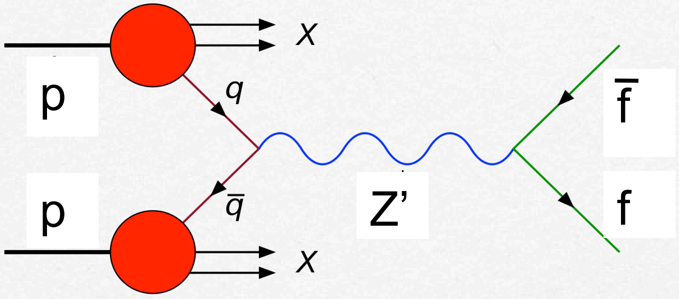


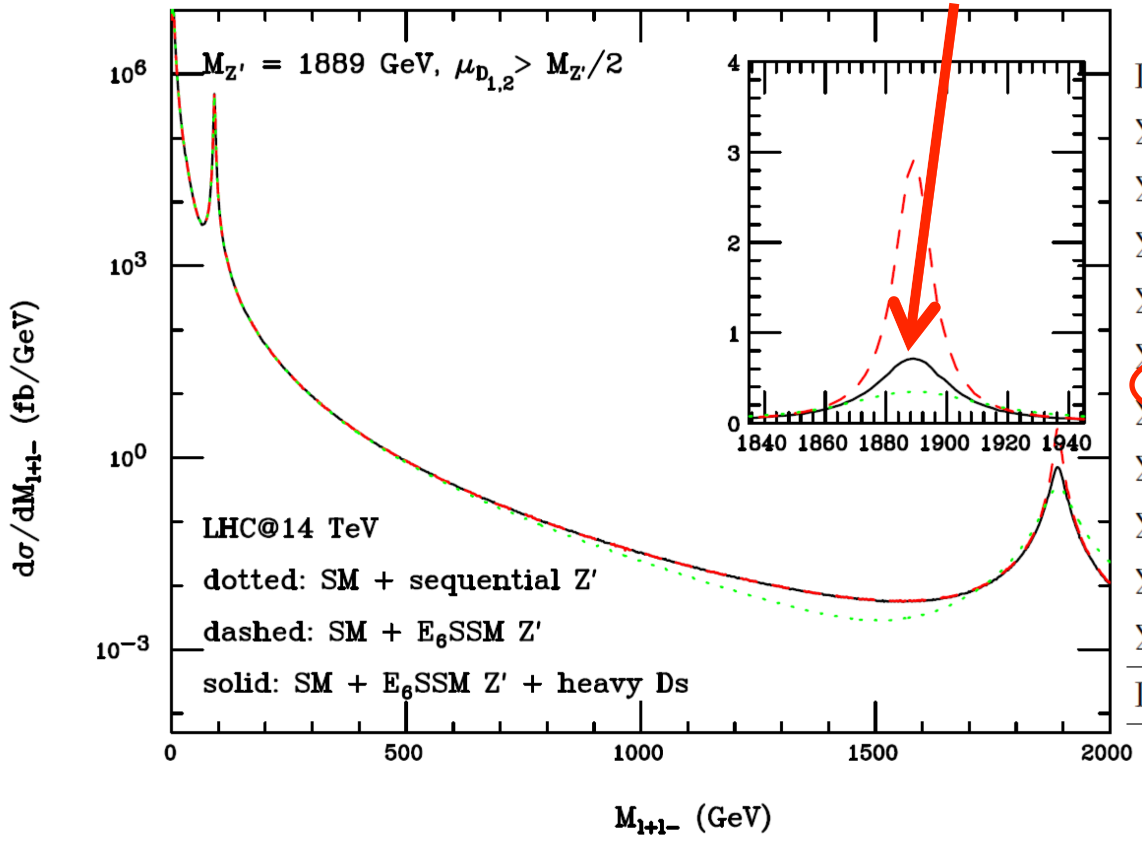


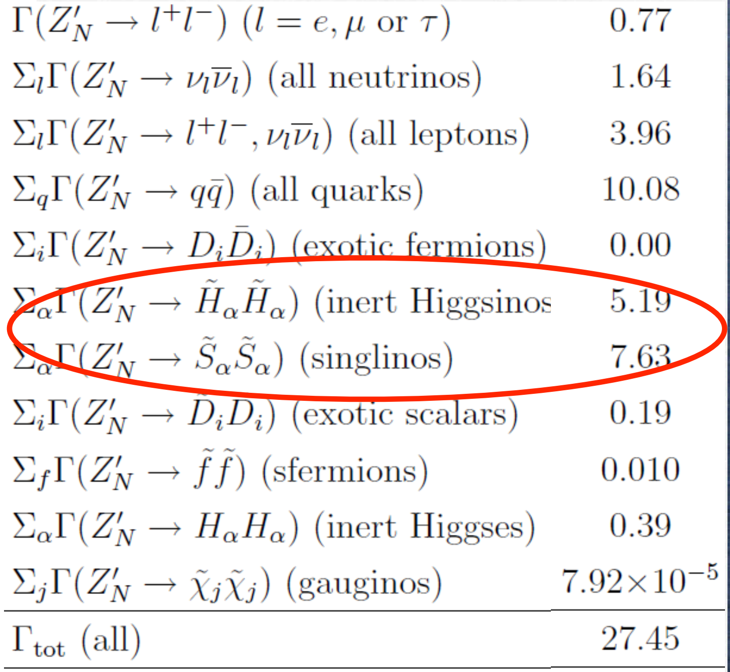
Athron, SFK, Miller, Moretti, Nevzorov

Z'_N

Latest ATLAS limit is $M_{Z'_N} > 1520\ GeV$ but exotic decays makes Z' peak smaller and harder to discover







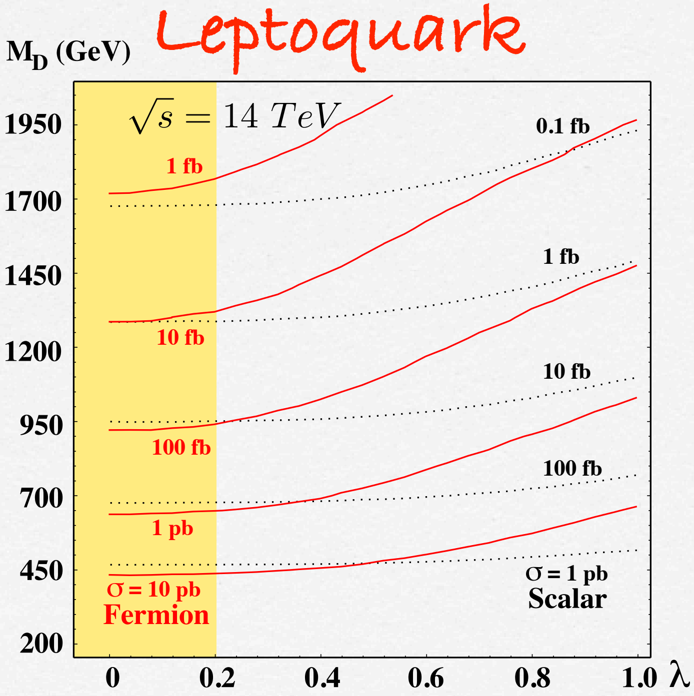
$\Gamma(Z'_N \to l^+l^-)$ ($l = e, \mu$ or τ)	0.77
$\Sigma_l\Gamma(Z'_N \to \nu_l\bar{\nu}_l)$ (all neutrinos)	1.64
$\Sigma_l\Gamma(Z'_N \to l^+l^-, \nu_l\bar{\nu}_l)$ (all leptons)	3.96
$\Sigma_q\Gamma(Z'_N \to q\bar{q})$ (all quarks)	10.08
$\Sigma_i\Gamma(Z'_N \to D_i\bar{D}_i)$ (exotic fermions)	0.00
$\Sigma_\alpha\Gamma(Z'_N \to \tilde{H}_\alpha\tilde{H}_\alpha)$ (inert Higgsinos	5.19
$\Sigma_\alpha\Gamma(Z'_N \to \tilde{S}_\alpha\tilde{S}_\alpha)$ (singlinos)	7.63
$\Sigma_i\Gamma(Z'_N \to D_iD_i)$ (exotic scalars)	0.19
$\Sigma_f\Gamma(Z'_N \to \tilde{f}\tilde{f})$ (sfermions)	0.010
$\Sigma_\alpha\Gamma(Z'_N \to H_\alpha H_\alpha)$ (inert Higgses)	0.39
$\Sigma_j\Gamma(Z'_N \to \tilde{\chi}_j\tilde{\chi}_j)$ (gauginos)	7.92×10^{-5}
$\Gamma_{\rm tot}$ (all)	27.45

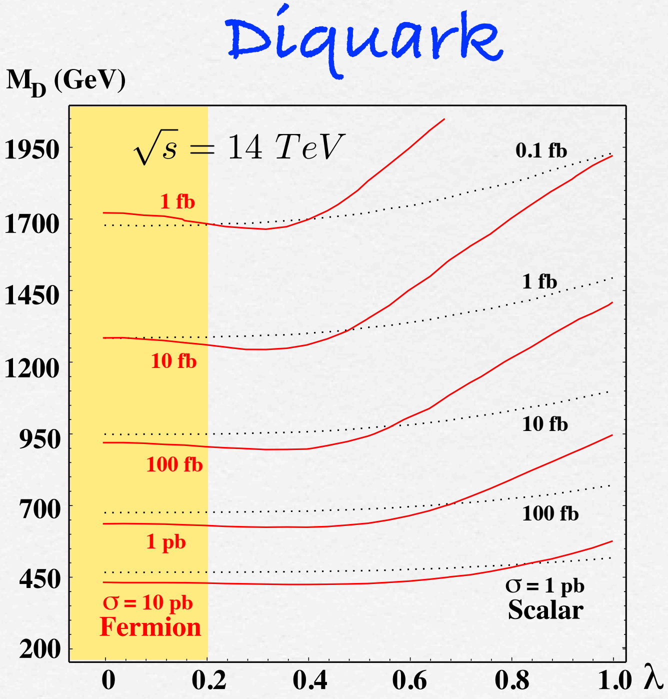
Exotic D-particles

Kang, Langacker, Nelson

D-particles are coloured and may be pair produced at LHC

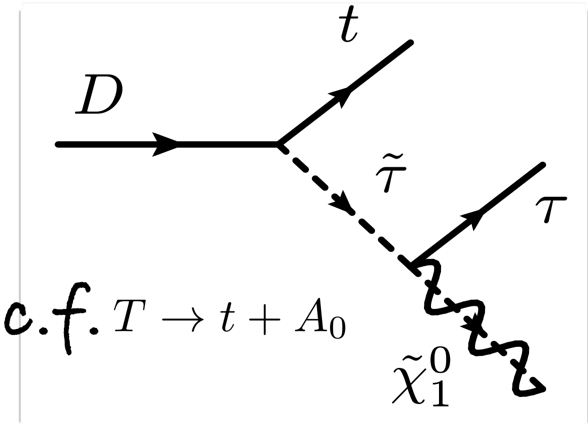
D-particles may be Leptoquarks D→LQ or Diquarks D→QQ





D-fermion decays

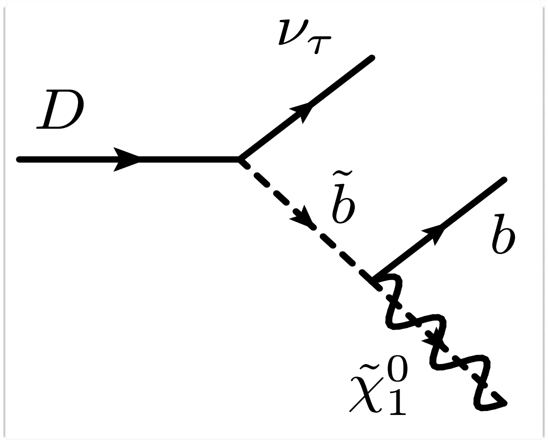
Leptoquark



c.f. $T \to t + A_0$

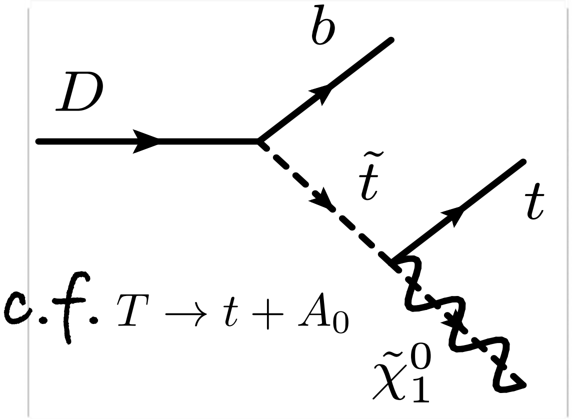
$$pp \to t\bar{t}\tau^+\tau^- + E_T^{miss} + X$$

Leptoquark



$$pp \to b\bar{b} + E_T^{miss} + X$$

Diquark



c.f. $T \to t + A_0$

$$pp \to t\bar{t}b\bar{b} + E_T^{miss} + X$$

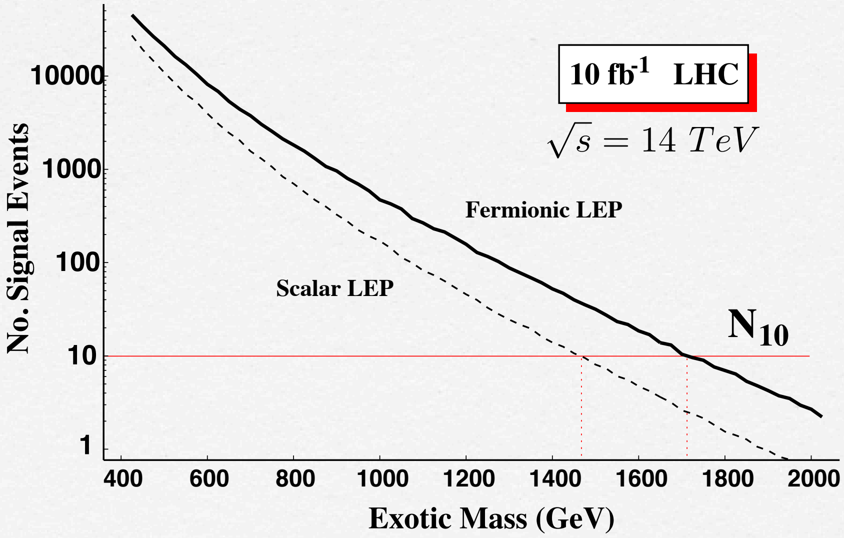
spectacular signals!

Kang, Langacker, Nelson

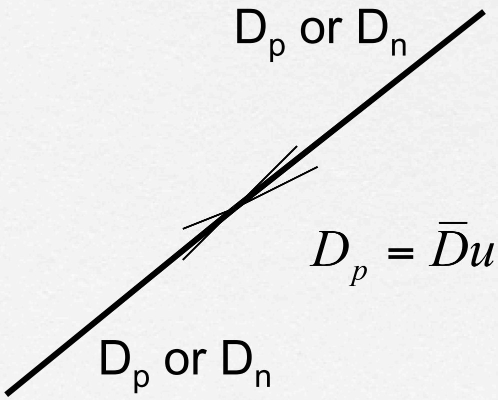
D-fermion as R-hadron

- ☐ Imposing B and L all couplings DFF forbidden
- ☐ D-particle are quasi-stable R-hadrons, decay via

$$\mathrm{dim5} \;:\; D^cQH_dS,\; D^cQQu^c,\; D^cQL\nu^c$$



punch through to muon chambers



$$D_p = \bar{D}u,\; D_n = \bar{D}d$$

Conclusion

- ☐ Hierarchy problem addressed by SUSY…
- ☐ …but SUSY is a symmetry not a model
- ☐ LHC can only test individual SUSY models
- ☐ Focus on dynamical solutions to mu problem
- ☐ NMSSM→E_6SSM (string theory) gives spectacular signals
- ☐ SUSY - typical spectrum has heavier squarks and lighter gluinos, with gluinos having longer decay chains than MSSM, and extra neutralinos and charginos
- ☐ Higgs - "Higgs boson" invisible decays allowed, richer Higgs spectrum than MSSM with possibility of heavier "Higgs boson"
- ☐ Exotics - Z', D-leptoquarks/diquarks (maybe long lived)

Extra Slides

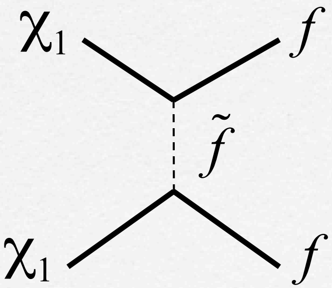
CMSSM Dark Matter

Neutralino mass matrix

$$\begin{array}{cccc} \tilde{B} & \tilde{W}_3 & \tilde{H}_d & \tilde{H}_u \\ \multicolumn{4}{c}{\begin{pmatrix} M_1 & & & \\ & M_2 & & \\ & & 0 & -\mu \\ & & -\mu & 0 \end{pmatrix}} \end{array}$$

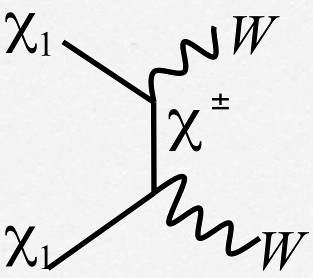
$$\chi_1 = N_1\tilde{B} + N_2\tilde{W} + N_3\tilde{H}_d + N_4\tilde{H}_u$$

$$\Omega_{DM}h^2 = C\frac{T_0^3}{M_P^2}\frac{1}{\langle\sigma v\rangle}$$



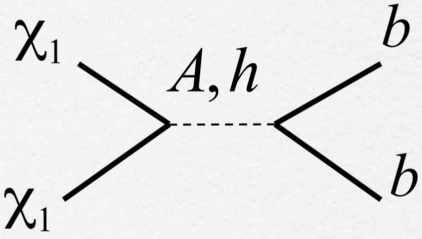
Bulk

$$m_{\tilde{f}} \approx m_{\chi_1}$$



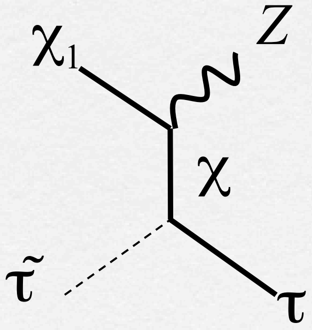
Focus

Higgsino LSP



Funnel

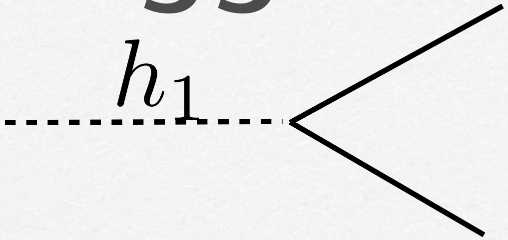
$$m_{A,h} \approx 2m_{\chi_1}$$



Co-annihilation

$$m_{\tilde{\tau}} \approx m_{\chi_1}$$

Invisible Higgs Decays



$$\Gamma(h_1 \to \chi^0_\alpha \chi^0_\beta) \quad \gg \quad \Gamma(h_1 \to f\bar{f})$$

☐ due to large coupling of inert neutralinos to Higgs ~M_χ/v with $M_\chi \sim M_Z/2$

☐ gives large SI DD cross-sections -- challenged by XENON 100

Hall, King, Pakvasa
Nevzorov, Sher

	i	ii	iii	iv	v
λ	0.6	0.6	0.468	0.468	0.468
$\tan(\beta)$	1.7	1.564	1.5	1.5	1.5
A_λ	1600	1600	600	600	600
$m_{H^\pm} \simeq m_A \simeq m_{h_3}/\mathrm{GeV}$	1977	1990	1145	1145	1145
m_{h_1}/GeV	133.1	134.8	115.9	115.9	115.9
λ_{22}	0.094	0.0001	0.094	0.001	0.468
λ_{21}	0	0.06	0	0.079	0.05
λ_{12}	0	0.06	0	0.080	0.05
λ_{11}	0.059	0.0001	0.059	0.001	0.08
f_{22}	0.53	0.001	0.53	0.04	0.05
f_{21}	0.05	0.476	0.053	0.68	0.9
f_{12}	0.05	0.466	0.053	0.68	0.002
f_{11}	0.53	0.001	0.53	0.04	0.002
$\tilde{f}_{22}$	0.53	0.001	0.53	0.04	0.002
$\tilde{f}_{21}$	0.05	0.4	0.053	0.49	0.002
$\tilde{f}_{12}$	0.05	0.408	0.053	0.49	0.05
$\tilde{f}_{11}$	0.53	0.001	0.53	0.04	0.65
$m_{\tilde{\chi}^0_1}/\mathrm{GeV}$	33.62	-36.69	35.42	-45.08	-46.24
$m_{\tilde{\chi}^0_2}/\mathrm{GeV}$	47.78	36.88	51.77	55.34	46.60
$m_{\tilde{\chi}^0_3}/\mathrm{GeV}$	108.0	-103.11	105.3	-133.3	171.1
$m_{\tilde{\chi}^0_4}/\mathrm{GeV}$	-152.1	103.47	-152.7	136.9	-171.4
$m_{\tilde{\chi}^0_5}/\mathrm{GeV}$	163.5	139.80	162.0	178.4	805.4
$m_{\tilde{\chi}^0_6}/\mathrm{GeV}$	-200.8	-140.35	-201.7	-192.2	-805.4
$m_{\tilde{\chi}^\pm_1}/\mathrm{GeV}$	100.1	101.65	100.1	133.0	125.0
$m_{\tilde{\chi}^\pm_2}/\mathrm{GeV}$	159.5	101.99	159.5	136.8	805.0
$\Omega_\chi h^2$	0.109	0.107	0.107	0.0324	0.00005
R_{Z11}	-0.144	-0.132	-0.115	-0.0217	-0.0224
R_{Z12}	0.051	0.0043	-0.045	-0.0020	-0.213
R_{Z22}	-0.331	-0.133	-0.288	-0.0524	-0.0226
$\sigma_{SI}/10^{-44}\ \mathrm{cm}^2$	1.7-7.1	2.0-8.2	3.5-14.2	6.0-24.4	6.1-25.0
$\mathrm{Br}(h \to \tilde{\chi}^0_1\tilde{\chi}^0_1)$	57.8%	49.1%	76.3%	83.4%	49.3%
$\mathrm{Br}(h \to \tilde{\chi}^0_1\tilde{\chi}^0_2)$	0.34%	3.5×10^{-11}	0.26%	7.6×10^{-9}	3.0×10^{-8}
$\mathrm{Br}(h \to \tilde{\chi}^0_2\tilde{\chi}^0_2)$	39.8%	49.2%	20.3%	12.3%	47.9%
$\mathrm{Br}(h \to b\bar{b})$	1.87%	1.59%	2.83%	3.95%	2.58%
$\mathrm{Br}(h \to \tau\bar{\tau})$	0.196%	0.166%	0.30%	0.41%	0.27%
$\Gamma^{tot}/\mathrm{MeV}$	141.2	169.0	82.0	58.8	90.1

Scanning regions

Belyaev, Hall, King, Svantesson (preliminary)

MSSM

parameter	min	max
$\tan\beta$	2	60
	[TeV]	[TeV]
$A_t = A_b = A_\tau = A_\mu$	-3	3
M_A	0.1	2
μ	-2	2

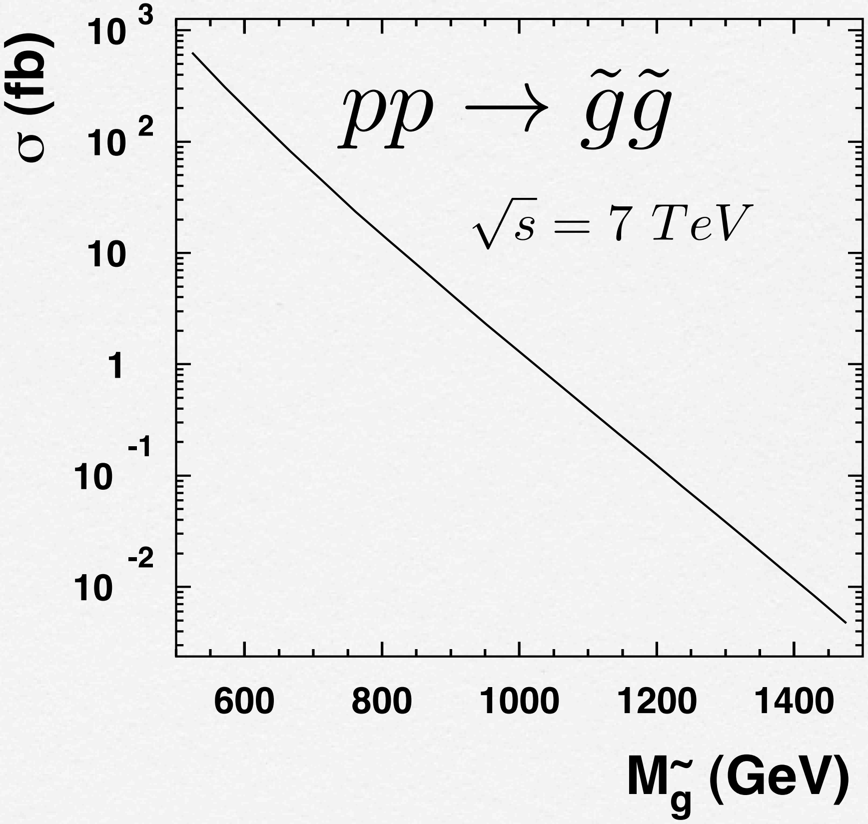
TABLE I: The MSSM scanning region. A common squark and slepton mass scale was fixed to $M_S = 2$ TeV. The gaugino masses were fixed to $M_1 = 150$ GeV, $M_2 = 285$ GeV and $M_3 = 619$ GeV, providing a gluino mass close to 800 GeV.

E_6SSM

parameter	min	max
$\tan\beta$	1.4	2
$\lvert\lambda\rvert$	0.3	0.7
λ_{22}	0.0001	0.01
λ_{21}	0.01	0.1
λ_{12}	0.01	0.1
λ_{11}	0.0001	0.01
f^d_{22}	0.0001	0.01
f^d_{21}	0.1	1
f^d_{12}	0.1	1
f^d_{11}	0.0001	0.01
f^u_{22}	0.0001	0.01
f^u_{21}	0.1	1
f^u_{12}	0.1	1
f^u_{11}	0.0001	0.01
x^d_2	10^{-4}	10^{-2}
x^d_1	10^{-4}	10^{-2}
x^u_2	10^{-4}	10^{-2}
x^u_1	10^{-4}	10^{-2}
z_1	10^{-3}	10^{-1}
z_2	10^{-3}	10^{-1}
	[TeV]	[TeV]
$A_t = A_b = A_\tau$	-3	3
M_A	1	3
s	2	5

TABLE II: The E_6SSM scanning region. A common squark and slepton mass scale was fixed to $M_S = 2$ TeV. The gaugino masses were fixed to $M_1 = 150$ GeV, $M_1' = 150$ GeV,$M_2 = 300$ GeV and $M_{\tilde{g}} = 800$ GeV.

Gluino production cross-section

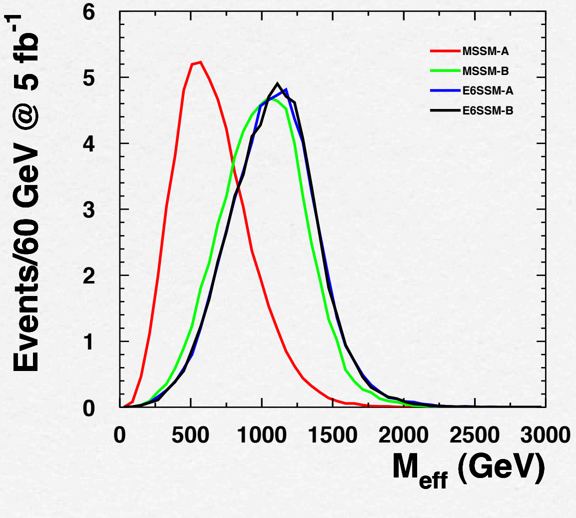


Belyaev, Hall, King,
Svantesson (preliminary)

Belyaev, Hall, King,
Svantesson (preliminary)

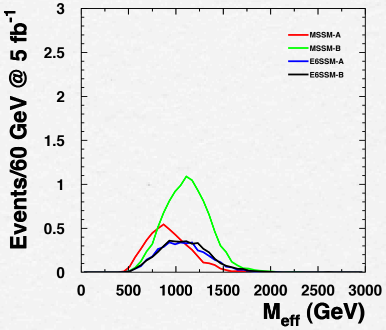
Meff

$$M_{eff} = p_T^{miss} + \sum_{jets} |p_T^{jet}|$$



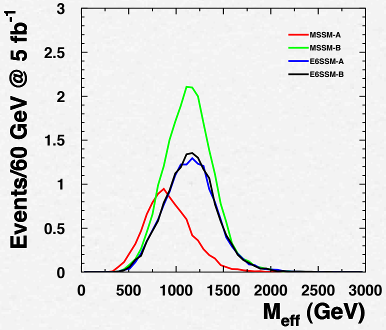
M_{eff} does not really help to distinguish models

ATLAS style cuts



CUT		MSSM-A		MSSM-B		E$_6$SSM-A		E$_6$SSM-B	
No.	limit	Eff.	Frac.	Eff.	Frac.	Eff.	Frac.	Eff.	Frac.
0	no cut	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00
1	$\not{p}_T$ >130	0.12	0.88	0.19	0.81	0.40	0.60	0.40	0.60
2	$p_T^{jet_1}$ >130	0.42	0.51	0.04	0.77	0.03	0.58	0.03	0.59
3	$p_T^{jet_2}$ >40	0.13	0.44	0.01	0.76	0.00	0.58	0.00	0.58
4	$p_T^{jet_3}$ >40	0.36	0.28	0.11	0.68	0.04	0.56	0.04	0.56
5	$p_T^{jet_4}$ >40	0.55	0.13	0.20	0.54	0.11	0.50	0.11	0.50
6	$\Delta\phi(\not{p}_T, jet)_{min} > 0.4$	0.28	0.09	0.37	0.34	0.59	0.20	0.58	0.21
7	$\not{p}_T/M_{eff}$ >0.25	0.15	0.08	0.49	0.17	0.69	0.06	0.68	0.07

CMS style cuts



CUT		MSSM-A		MSSM-B		E$_6$SSM-A		E$_6$SSM-B	
No.	limit	Eff.	Frac.	Eff.	Frac.	Eff.	Frac.	Eff.	Frac.
0	no cut	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00
1	$\not{H}_T > 200$ GeV	0.58	0.42	0.34	0.66	0.47	0.53	0.47	0.53
2	$p_T^{jet_1}$ >50 GeV	0.00	0.42	0.00	0.66	0.00	0.53	0.00	0.53
3	$p_T^{jet_2}$ >50 GeV	0.13	0.37	0.02	0.64	0.01	0.52	0.01	0.53
4	$p_T^{jet_3}$ >50 GeV	0.43	0.21	0.13	0.56	0.06	0.49	0.06	0.50
5	$\Delta\phi(\not{p}_T, jet_1) > 0.5$	0.02	0.21	0.02	0.55	0.03	0.48	0.03	0.48
6	$\Delta\phi(\not{p}_T, jet_2) > 0.5$	0.05	0.19	0.08	0.50	0.12	0.42	0.12	0.42
7	$\Delta\phi(\not{p}_T, jet_3) > 0.3$	0.04	0.19	0.07	0.47	0.10	0.38	0.10	0.38
8	$\Delta R(jet, lep)_{min} < 0.3$	0.18	0.15	0.24	0.36	0.37	0.24	0.36	0.25
9	$H_T > 800$ GeV	0.88	0.02	0.49	0.18	0.38	0.15	0.38	0.15