Constraining the MSSM

and implications for searches at the LHC

at

Theory - LHC France

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by

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The Model: MSSM-UG

Bélanger et. al, `arXiv:0906.5048 [hep-ph]`

- SUSY breaking parameters are defined at weak scale
- The gauge unification condition $M_2 = 2M_1 = M_3/3$ is used.
- Common slectron mass is assumed $M_{\tilde{l}} = m_{\tilde{\ell}_{L,R}}$.
- Common squark mass is assumed $M_{\tilde{q}} = m_{\tilde{q}_{L,R}}$.
- All the trilinear couplings except A_t are set to zero.

The Model: MSSM-UG

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Symbol	stands for	General range
μ	μ parameter	$[-3000, 3000]$ GeV
M_2	Gaugino mass, $2M_1 = M_2 = M_3/3$	$[30, 2000]$ GeV
$M_{\tilde{l}}$	Common slepton mass, $M_{\tilde{l}} = m_{\tilde{\ell}_{L,R}}$	$[50, 4000]$ GeV
$M_{\tilde{q}}$	Common squark mass, $M_{\tilde{q}} = m_{\tilde{q}_{L,R}}$	$[50, 4000]$ GeV
A_t	Trilinear coupling of $\tilde{t}$	$[-3000, 3000]$ GeV
$\tan\beta$	$\tan\beta$	$[5, 65]$
M_A	Mass of CP-odd Higgs boson	$[100, 2000]$ GeV
m_t	mass of t-quark	$[165, 180]$ GeV

Parameter sampling

Bayes' Theorem:

$$p(m|d) = p(d|m)\frac{p(m)}{p(d)}$$

or

$$\frac{p(m_1|d)}{p(m_2|d)} = \frac{p(d|m_1)\, p(m_1)}{p(d|m_2)\, p(m_2)} = \frac{L(m_1)}{L(m_2)}$$

$p(m_1) = p(m_2) \Rightarrow$ Flat prior over model space.

Likelihood function: $L(\mathbf{X}) = \prod_j L(O_j(\mathbf{X}))$

Proposal function: $Q(\mathbf{X}, \mathbf{X_a}) = \prod_i \exp\left[\frac{-(X^i - X^i_a)^2}{2\,(\Delta X^i)^2}\right]$

Acceptance probability: $\min\left[1, \frac{L(\mathbf{X})}{L(\mathbf{X_a})}\right]$

Parameter sampling

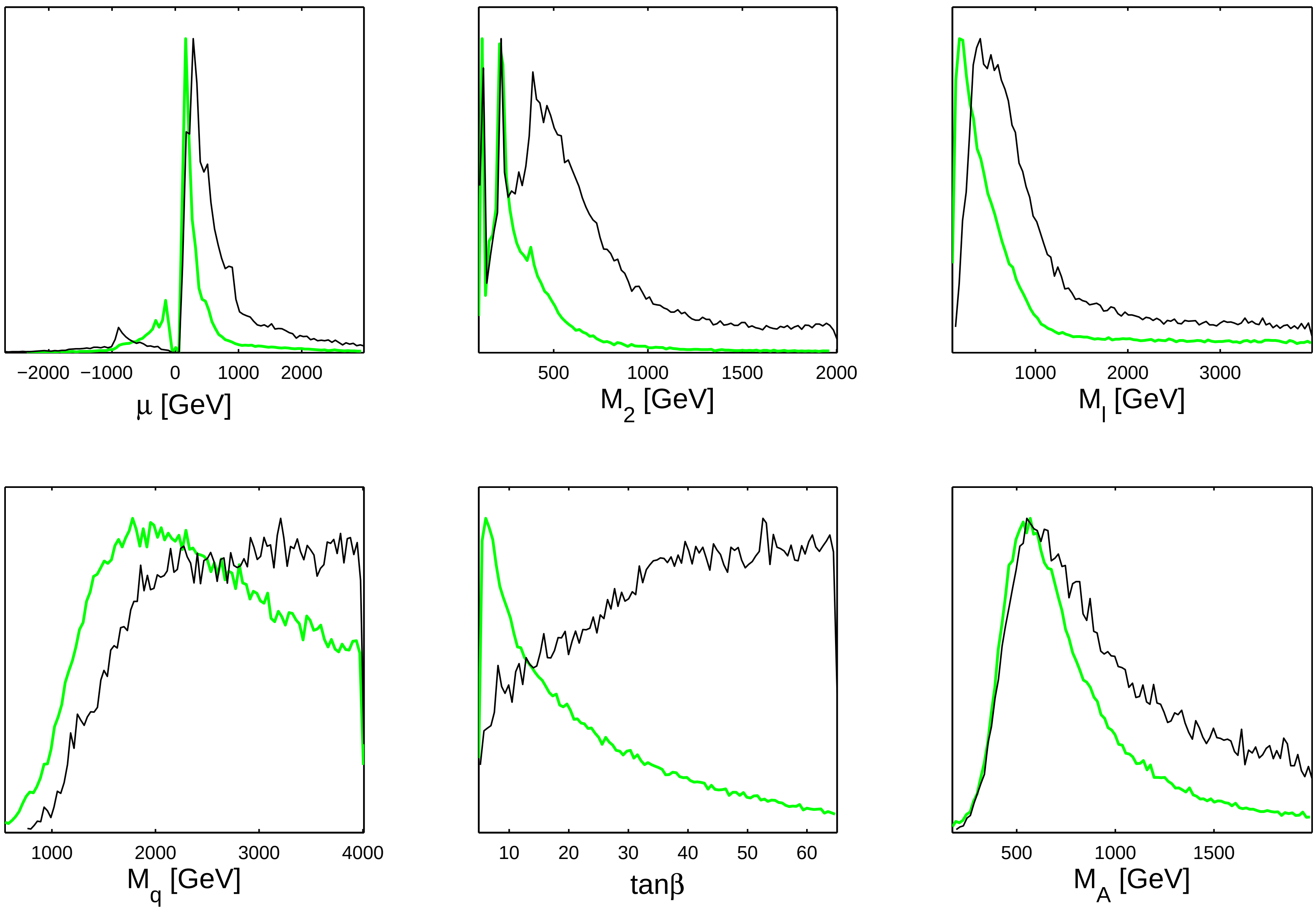
Constraints:

Observable O_j	Limit	Likelihood function $L(O_j)$
δa_μ	$(27.8 \pm 8.5) \times 10^{-10}$	$\mathbf{G}(x, 27.8 \times 10^{-10}, 8.5 \times 10^{-10})$
$B(b \to s\gamma)$	$(3.55 \pm 0.24) \times 10^{-4}$	$\mathbf{G}(x, 3.55 \times 10^{-4}, 0.24 \times 10^{-4})$
Ωh^2	0.113 ± 0.0105	$\mathbf{G}(x, 0.113, 0.0105)$
$B(B_s \to \mu^+\mu^-)$	$\leq 0.8 \times 10^{-7}$	$\mathbf{F}(x, 0.8 \times 10^{-7}, -0.8 \times 10^{-9})$
$R(B \to \tau^+\nu)$	1.11 ± 0.52	$\mathbf{G}(x, 1.11, 0.52)$
m_h	≥ 114.5 GeV	$\mathbf{F}(x, 114.5, 0.6)$
m_t	171.4 ± 2.1 GeV	$\mathbf{G}(x, 171.4, 2.1)$

$$\mathbf{G}(O, O_{exp}, \Delta O) = \exp\left[\frac{-(O - O_{exp})^2}{2\,(\Delta O)^2}\right]$$

$$\mathbf{F}(O, O_{exp}, \Delta O) = \frac{1}{1 + \exp[\pm(O - O_{exp})/\Delta O]}$$

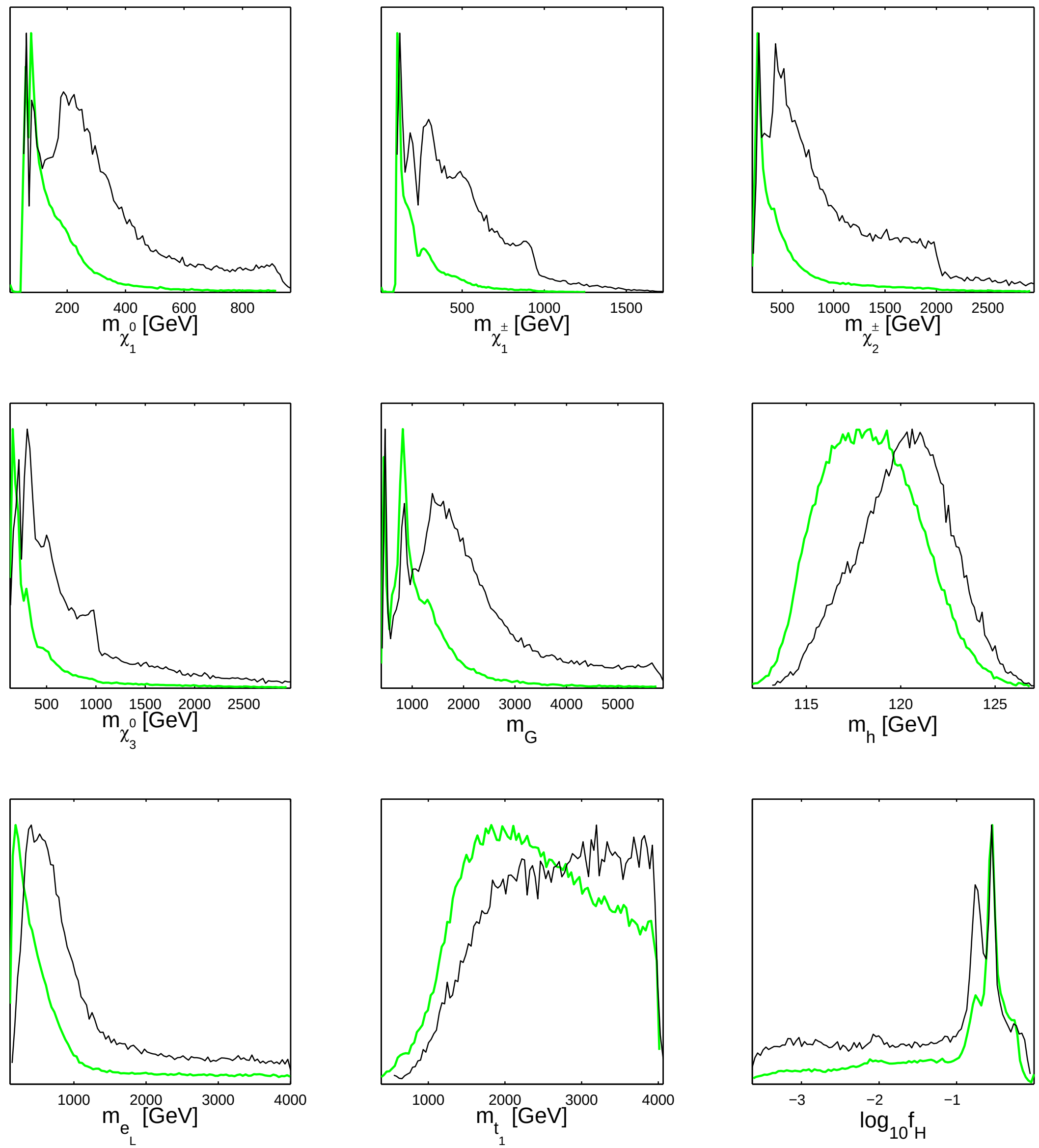
Posterior PDF: model parameters



Posterior PDF: model parameters

Parameter	Linear prior				Log prior			
	68% interval		95% interval		68% interval		95% interval	
μ [GeV]	197.7	1193	−983.5	2471	−158.9	560.1	−850.9	2001
M_2 [GeV]	259.8	1077	119.6	1845	102.2	524.0	102.2	1252
$M_{\tilde{l}}$ [GeV]	398.4	2270	225.4	3700	100.0	1591	100.0	3582
$M_{\tilde{q}}$ [GeV]	1824	3602	1236	3938	1514	4006	1001	4006
A_t [GeV]	−1735	2239	−2785	2876	−337.6	814.0	−2113	2430
$\tan\beta$	19.5	65.0	8.15	65.0	4.85	39.7	4.85	58.9
M_A [GeV]	537.1	1489	370.2	1904	475.0	1130	338.0	1759
m_t [GeV]	169.6	173.7	167.6	175.6	169.7	173.8	167.7	175.8

Posterior PDF: masses

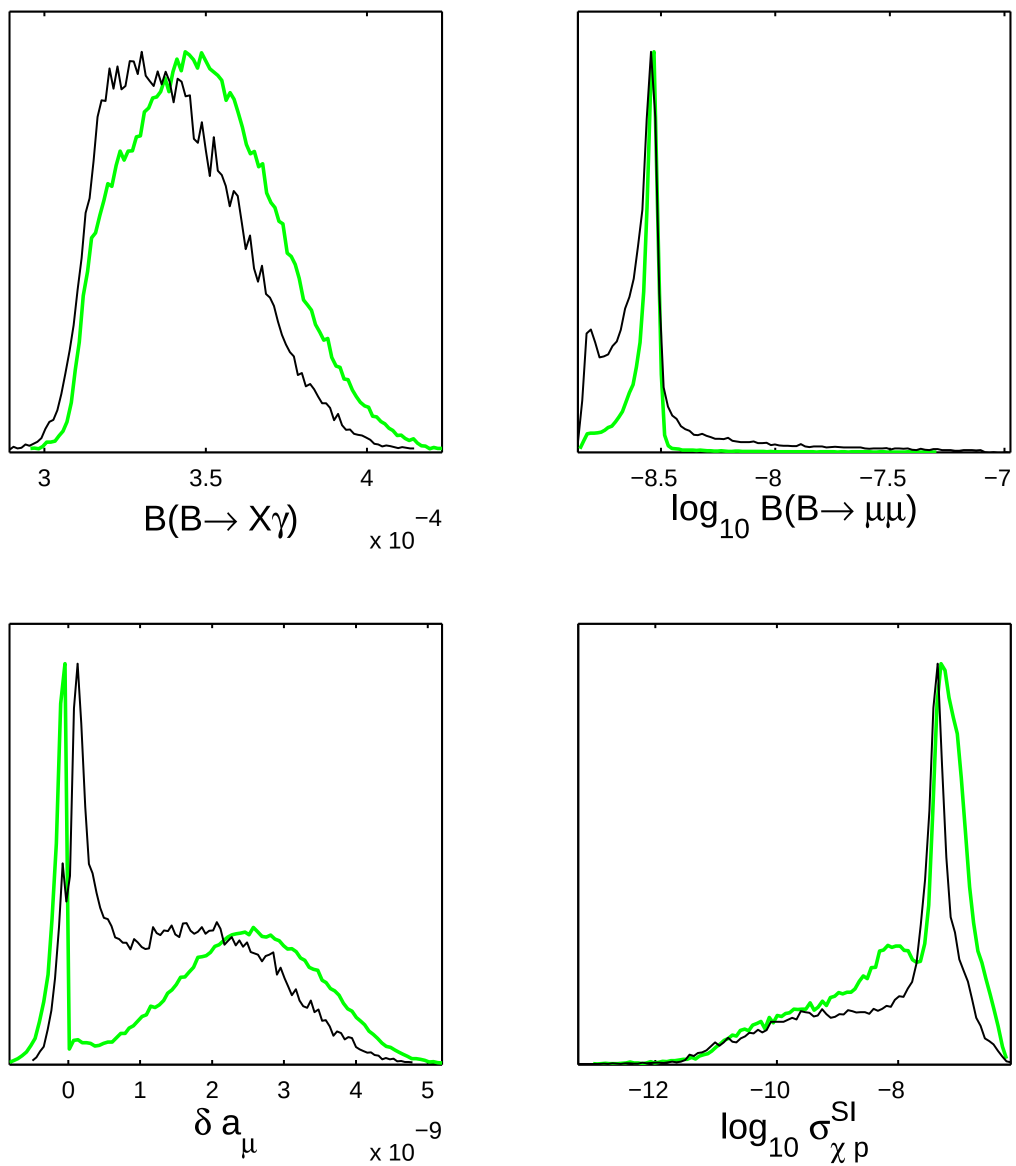


Posterior PDF: masses

Mass	Linear prior				Log prior			
	68% interval		95% interval		68% interval		95% interval	
m_h	117.6	122.6	115.3	124.8	115.7	121.0	114.0	123.6
m_H	537	1489	370	1900	475	1130	338	1759
$m_{\tilde{\chi}_1^0}$	52.2	522	52.2	874	69.1	249	52.9	584
$m_{\tilde{\chi}_3^0}$	269	1300	158	2500	130	728	130	2061
$m_{\tilde{\chi}_1^+}$	103	749	103	1180	112	399	103	768
$m_{\tilde{\chi}_2^+}$	410	1640	262	2490	266	905	226	2050
$m_{\tilde{e}_L}$	410	2280	235	3710	114	1598	114	3590
$m_{\tilde{\tau}_1}$	103	2260	103	3690	96.4	1586	96.4	3584
$m_{\tilde{u}_L}$	1840	3650	1230	3990	1535	3422	1019	3934
$m_{\tilde{b}_1}$	1820	3620	1200	3960	1524	3413	1003	3924
$m_{\tilde{t}_1}$	1770	3590	1130	3930	1500	3389	911	3897
$m_{\tilde{g}}$	952	3320	478	5400	637	1757	442	3764

95% BCI $m_h = 120.2^{+4.6}_{-4.9}$ GeV (linear) and $m_h = 118.4^{+5.2}_{-4.4}$ GeV (log).

Posterior PDF: observables



$B(B \to \mu^+\mu^-) > 1.8\ 10^{-8}$

Tevatron reach

$\Downarrow$

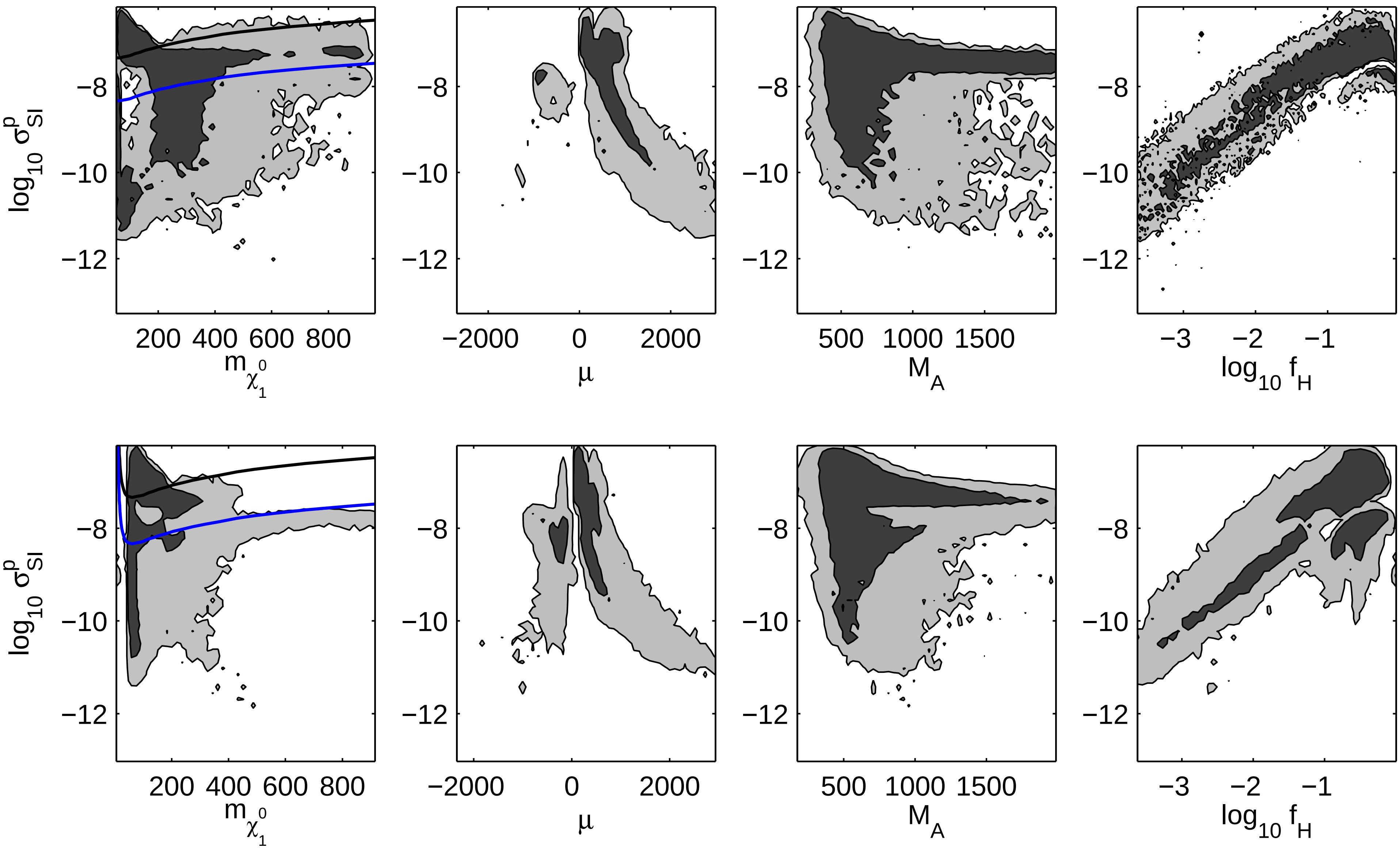
Heavy Higgs signal
at LHC

Posterior PDF: observables

Observable	Linear prior			
	68% interval		95% interval	
Ωh^2	0.102	0.123	0.091	0.133
$\delta a_\mu \times 10^{10}$	1.49	27.2	-1.45	37.5
$B(B \to X\gamma) \times 10^4$	3.19	3.62	3.08	3.86
$B(B \to \mu^+\mu^-) \times 10^9$	1.82	3.31	1.48	20.4
$R(B \to \tau\nu)$	0.698	0.981	0.382	0.997
$\sigma_{\chi p}^{SI}$ (pb)	$2.51\ 10^{-10}$	$6.76\ 10^{-8}$	$9.77\ 10^{-12}$	$2.24\ 10^{-7}$

Observable	Log prior			
	68% interval		95% interval	
Ωh^2	0.102	0.123	0.092	0.134
$\delta a_\mu \times 10^{10}$	-0.58	33.5	-3.23	42.4
$B(B \to X\gamma) \times 10^4$	3.25	3.73	3.12	3.97
$B(B \to \mu^+\mu^-) \times 10^9$	2.29	3.02	1.60	3.68
$R(B \to \tau\nu)$	0.808	1.000	0.476	1.000
$\sigma_{\chi p}^{SI}$ (pb)	$5.29\ 10^{-10}$	$1.08\ 10^{-7}$	$1.59\ 10^{-11}$	$3.02\ 10^{-7}$

Posterior PDF: Direct-detection



LHC vs Direct-detection

$m_{\tilde{q}},\ m_{\tilde{g}} > 2$ TeV $\Rightarrow$ No colored particles at LHC

Linear prior (34%)			
Heavy Higgs at LHC	$\sigma^{SI}_{\chi p}$(pb)	$B(B \to \mu^+\mu^-)$ $> 5. \times 10^{-9}$	$< 5. \times 10^{-9}$
Yes 24.2%	20.6% ($> 10^{-9}$) 3.6%($< 10^{-9}$)	5.6% 1.7%	15% 1.9%
No 75.8%	54.9%($> 10^{-9}$) 20.9%($< 10^{-9}$)	0.3% 0.7%	**54.6%** **20.2%**

Log prior (9%)			
Yes 11.4%	10.6% ($> 10^{-9}$) 0.8%($< 10^{-9}$)	0.8% 0.1%	9.8% 0.7%
No 88.6%	63.0%($> 10^{-9}$) 25.6%($< 10^{-9}$)	$< 0.1\%$ $< 0.1\%$	**63.0%** **25.6%**

$\approx$ 7% (2%) cases have no signature

LHC vs Direct-detection

$m_{\tilde{q}} < 2$ TeV or $m_{\tilde{g}} < 2$ TeV $\Rightarrow$ (at least one) colored particle at LHC

Linear prior (66%)			
Heavy Higgs at LHC	$\sigma_{\chi p}^{SI}$(pb)	$B(B \to \mu^+\mu^-)$ $> 5. \times 10^{-9}$	 $< 5. \times 10^{-9}$
Yes 24.5%	21.9% ($> 10^{-9}$) 2.7%($< 10^{-9}$)	**7.2%** 1.6%	14.7% 1.1%
No 75.5%	53.7%($> 10^{-9}$) 21.8%($< 10^{-9}$)	0.6% 1.1%	**53.1%** 20.7%

Log prior (91%)			
Yes 13.2%	12.8% ($> 10^{-9}$) 0.3%($< 10^{-9}$)	**1.1%** < 0.1%	11.7% 0.3%
No 86.8%	68.3%($> 10^{-9}$) 18.5%($< 10^{-9}$)	0.4% 0.1%	**67.9%** 18.4%

$\approx$ 5% (1%) cases have all signature

Conclusions

- 95% BCI $m_h = 120.2^{+4.6}_{-4.9}$ GeV (linear) and $m_h = 118.4^{+5.2}_{-4.4}$ GeV (log).
- $B(B \to \mu^+\mu^-) > 1.8\ 10^{-8}$ i.e. within Tevatron reach ⇒ Heavy Higgs signal at LHC.
- About 18% (9%) of models have signal in only direct detection experiments.
- About 53% (67%) of models show complementarity between direct detection signal and some of the LHC signals.