SUPERSYMMETRY: NON-COLLIDER LIMITS FOR COLLIDER SEARCHES

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— Supersymmetric dark matter for collider physicists

Impact of supersymmetry breaking

Constraints with ‘minimal’ assumptions

— CP phases and electric dipole moments

Measurement at a LC

DARK MATTER AND SUPERSYMMETRY

Matter density in the universe

– CMB, supernovae, galactic rotation curves... $\Omega_\mathrm{M} h^2 \sim 0.15$ [WMAP]

– big bang nucleosynthesis $\Omega_\mathrm{B} h^2 \lesssim 0.02$ [Burles, Nollet, Truran, Turner]

– luminous matter $\Omega_\mathrm{L} \lesssim 0.01$ [Fukugita, Hogan, Peebles]

– large scale structures $\Omega_\mathrm{DM} h^2 \sim \Omega_\mathrm{CDM} h^2 \gtrsim 0.1$ *e.g.* $\Omega_\nu h^2 < 0.0076$

$\to$ pre-WMAP CMB results: $\Omega_\mathrm{CDM} h^2 = 0.12 \pm 0.04$ [Melchiorri & Silk]
$\Omega_\mathrm{M} h^2 - \Omega_\mathrm{B} h^2 = 0.096 \cdots 1.115$ [WMAP 95%$C.L.$]

R parity in supersymmetric theories

– electroweak precision data: light Higgs boson

$\to$ TeV scale supersymmetry to solve hierarchie problem

$\to$ lepton and baryon number violation, *e.g.* SQL vertex

$\to$ proton decay, FCNC, APV, all kind of leptoquark trouble [Dreiner...]

$\to$ R parity, *i.e.* partner number conservation [Ellis & Nanopoulos, Weinberg]

$\to$ collider physics: LSP pair at end of cascade decays
cosmology: stable CDM particle [usually assuming $\Omega_\mathrm{CDM} h^2 = 0.1 \cdots 0.3$]

Supersymmetry Spectrum

Particle Content of the MSSM

		spin	charge	d.o.f.		(N)LSP candidate
quarks	q_L, q_R	1/2	$2/3\ ,\ -1/3$	1+1		
squarks	$\tilde{q}_L, \tilde{q}_R$	0	$2/3\ ,\ -1/3$	1+1	6 flavors	$\tilde{t}_1$
gluon	G_μ	1	0	2		
gluino	$\tilde{g}$	1/2	0	2	Majorana	$\tilde{g}$
leptons	ℓ_L, ℓ_R, ν	1/2	$\pm 1, 0$	1+1		
sleptons	$\tilde{\ell}_L, \tilde{\ell}_R, \tilde{\nu}$	0	$\pm 1, 0$	1+1	3 families	$\tilde{\nu}, \tilde{\tau}_1$
gauge bosons	γ, Z	1	0	2+3		
Higgs bosons	h^o, H^o, A^o	0	0	3		
neutralinos	$\tilde{\chi}_i^o$	1/2	0	$4 \cdot 2$	Majorana	$\tilde{\chi}_1^o$
gauge bosons	$W^\pm$	1	± 1	$2 \cdot 3$		
Higgs bosons	$H^\pm$	0	± 1	2		
charginos	$\tilde{\chi}_i^\pm$	1/2	± 1	$2 \cdot 4$	Dirac	$\tilde{\chi}_1^\pm$

LSP as dark matter candidates

– colored/charged LSP: bound states, *i.e.* exotic isotope searches

– squarks/gluinos: Tevatron searches to ~ 185 GeV

– direct detection: $\sigma_{N\tilde{\nu}}$ large for minimum mass
LEP1 $m_{\tilde{\nu}} > m_Z/2 \quad \Rightarrow \quad m_{\tilde{\nu}} \gtrsim 20$ TeV [Heidelberg-Moskow, CDMS]

$\rightarrow \tilde{\chi}_1^o \sim \tilde{B}, \tilde{H}$

– beyond usual MSSM: gravitino (currently hopeless to detect)

Dark Matter Density

Relic Density

– high temperatures $T \gg m_\chi$:
  eqilibrium, $n_\chi \sim n_\gamma$; annihilation rate $\Gamma \sim \sigma_{\chi\chi} v n_\chi \sim T^3 \sigma_{\chi\chi} v > H$

– annihilation region $T \lesssim m_\chi$:
  $n_\chi \sim e^{-m_\chi/T} n_\gamma$

– freeze out $\Gamma < H$:
  n_χ should give $\Omega_\chi h^2 \sim 0.1 \cdots 0.13$

$\to$ dominant parameters: $m_\chi, \sigma(\chi\chi \to \mathrm{StandardModel})$

LSP annihilation

– pair annihilation: $\tilde{\chi}^o \tilde{\chi}^o \to \ell^+ \ell^-$
  $\tilde{\chi}^o = \tilde{B}$: t channel $\tilde{\ell}$
  $\tilde{\chi}^o = \tilde{H}$: s channel Z, A^o [*e.g.* Drees & Nojiri]

– co-annihilation with quasi-degenerate NLSP
  $\tilde{\chi}^o \tilde{\tau}$ [Ellis, Falk, Olive]
  $\tilde{\chi}^o \tilde{t}$ [Böhm, Djouadi, Drees; Ellis, Olive, Santoso]
  $\tilde{\chi}^o \tilde{\chi}^\pm$ [Greist & Seckel; Mizuka & Yamaguchi]
  $\to$ improvement for large SUSY masses

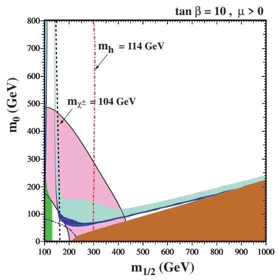
$\Rightarrow$ knowledge of entire MSSM spectrum crucial

mSUGRA or CMSSM

Most naive supersymmetry breaking: gravity mediated

- assume SUSY breaking blind for anything: quantum numbers, flavor...
  inspired by gauge coupling unification at GUT scale
- maximal unification $\leftrightarrow$ minimum number of parameters
  scalar mass: m_0 (squarks, sleptons, Higgs bosons)
  gaugino mass: $m_{1/2}$ (bino, wino, gluino, $M_1 \sim M_2/2$)
  trilinear coupling: A_0 (large A_t: stop mass splitting)
  ratio of Higgs vevs: $\tan\beta$ (possible enhancement of bottom Yukawa)
  radiative symmetry breaking: $\text{sign}(\mu)$ ($\mu < 0$ disfavored by $g_\mu - 2$)
- only parametrizing our ignorance, GMSB, AMSB, $\tilde{\text{G}}$MSB, etc.

mSUGRA and dark matter



(1) typical mSUGRA scenario:
$\tilde{B}$-LSP, small $\tan\beta$, $M_1 : M_2 : M_3 = 1 : 2 : 8$, light $\tilde{\tau}_1$
constrained by: $m_h, m_{\tilde{\chi}^\pm}, b \to s\gamma, g_\mu - 2$

(2) 'focus point' scenario [Drees & Martin; Feng, Matchev, Wilczek]

$$\mu^2 + \frac{1}{2}m_Z^2 \sim -m_0^2 - 0.52 m_{1/2}^2 + \frac{1}{1-\cot^2\beta}\left(\frac{m_t(m_t)}{150\text{GeV}\sin\beta}\right)^2 (0.9 m_0^2 + 2.1 m_{1/2}^2)$$

possible solution $m_0 \gg m_{1/2} \gtrsim m_Z \sim |\mu|$ if $m_t(m_t) \lesssim 155$ GeV

Impact on Collider Searches

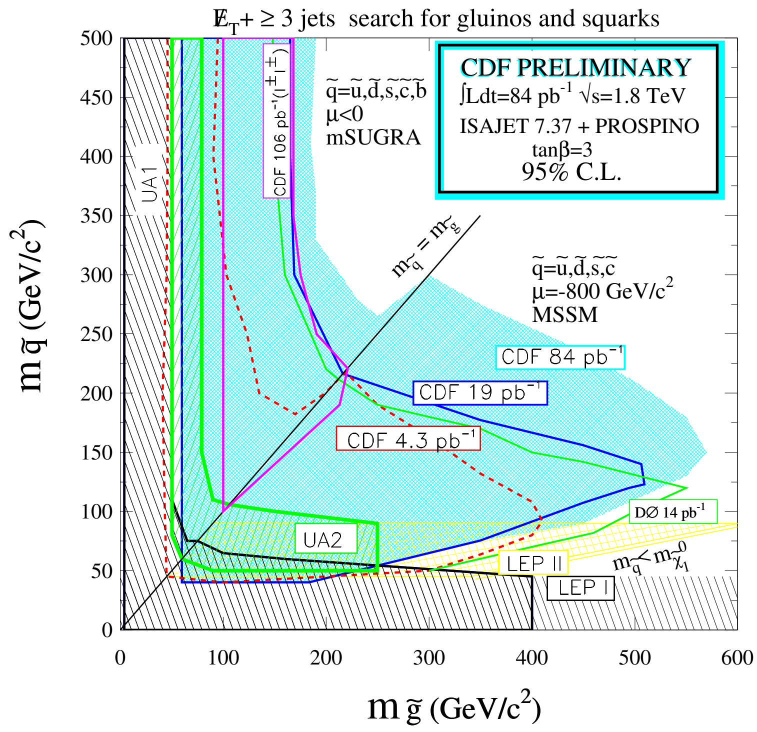
LSP mass in cascade decays

– squarks/gluinos respective t channel particles, *i.e.* 2D analysis

– look for light squarks, heavy gluinos

$\rightarrow$ gaugino mass unification: heavy $\tilde{B}$ LSP

$\rightarrow$ no boost of LSP: no trigger



Even more important for $\tilde{\chi}_2^0 \tilde{\chi}_1^{\pm}$ or $\tilde{\chi}_1^+ \tilde{\chi}_1^-$ production at Tevatron and LHC

Non-Unified Higgs Masses

Start relaxing the boundary conditions

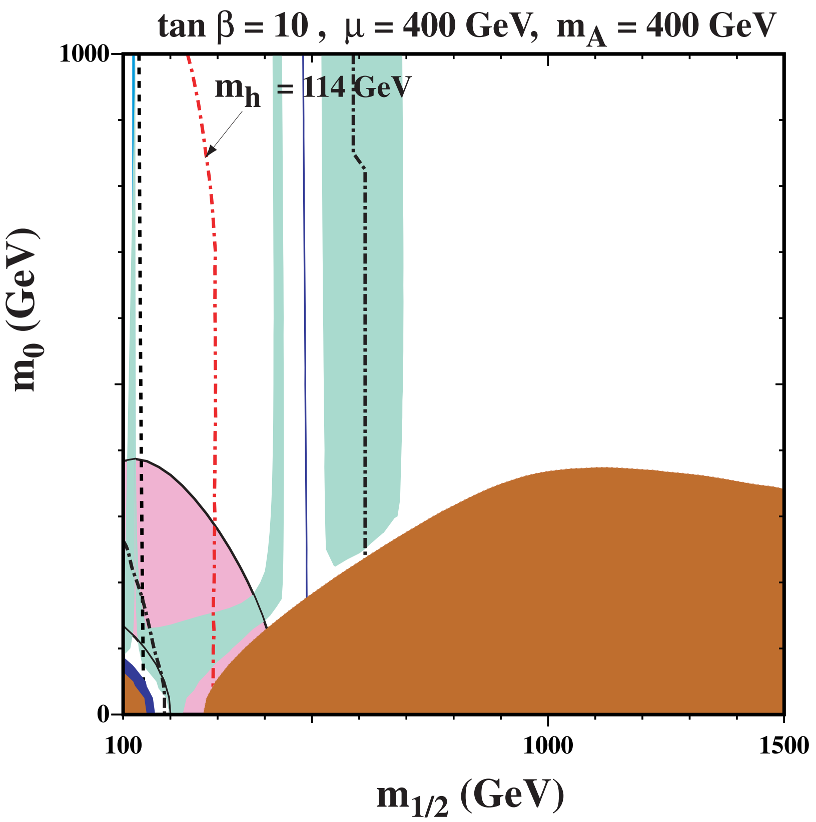
– problem combining LSP properties with m_A and $b \to s\gamma$

– assume light sleptons, *i.e.* squarks less relevant

– m_h driven mostly by loop corrections $m_{\tilde{t}_1}$ and $\tan\beta$

$\to$ 'rapid annihilation funnel' for $m_A \sim 2m_\chi$

$\to$ make sure $m^2_{H_i} + \mu^2 > 0$ at M_{GUT}



[Ellis, Falk, Olive, Santoso]

Plain MSSM

Go all the way: no unification

– ‘minimal’ assumptions on SUSY breaking

$m_A \gtrsim 150$ GeV (to avoid $b \to s\gamma$)

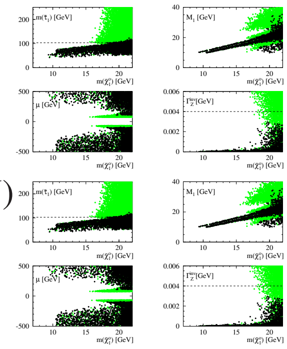
$m_{\tilde{\ell}_L} = m_{\tilde{\nu}}$ at $M_{\rm GUT}$

– experimental limits

Tevatron: $m_{\tilde{q}} > 185$ GeV (no impact of squarks)

LEP2: $m_{\tilde{\chi}^\pm}, m_{\tilde{\ell}} > 103$ GeV (improved for small $m_{\tilde{\chi}^0}$)

LEP: $\Gamma_{Z\to\chi\chi} < 4.2$ MeV



neutralino LSP, M_1 free parameter

– $\tilde{H}$ or $\tilde{W}$ LSP: $m_{\tilde{\chi}^0} \sim m_{\tilde{\chi}^\pm} \gtrsim m_Z/2$ (probably LEP2: 103 GeV)

$\to$ $\tilde{B}$ LSP, usually $\Omega_\chi h^2 \gg 0.13$ for $m_{\rm LSP} \ll m_Z$

$\to$ annihilation through light t channel $\tilde{\tau}$, but $m_{\tilde{\tau}} > 103$ GeV

$\to$ $m_{\tilde{\chi}^0} \gtrsim 18$ GeV for $\Omega_\chi h^2 < 0.3$

$m_{\tilde{\chi}^0} \gtrsim 26$ GeV for $\Omega_\chi h^2 < 0.13$ [confirmed by Bottino etal, Belanger etal.]

conspiracies?

(1) $\tilde{\tau}\tilde{\chi}^0$ co-annihilation

$\to$ $\tilde{\tau}^+\tilde{\tau}^-$ at LEP2 with little boost in decay $\tilde{\tau} \to \tau\tilde{\chi}^0$

$\to$ boost from 10 GeV $\tilde{\tau}$ should trigger

(2) $m_A = 90 \cdots 130$ GeV $\to m_{\tilde{\chi}^0} \gtrsim 6$ GeV (need to cancel $b \to s\gamma$)

Supersymmetry with CP Phases

New sources for CP violation in the MSSM

$\mu \hat{H}_1 \hat{H}_2$ $\rightarrow$ higgsino mass matrix including ϕ_μ

$M_i \tilde{\lambda}_i \tilde{\lambda}_i$ $\rightarrow$ gaugino mass matrix including ϕ_i

$B\mu H_1 H_2$ $\rightarrow$ Higgs boson mass and couplings

$A_i h_i \tilde{Q}_i \tilde{U}_i^c H_2 \cdots$ $\rightarrow$ trilinear squark/slepton couplings

– some (most) phases absorbed into field redefinitions (*e.g.* ϕ_2 of all ϕ_i)

– generally unification scenarios with fewer free phases

(*e.g.* gaugino mass unification $\rightarrow \phi_1 \equiv \phi_2 \equiv \phi_3 \equiv 0$)

– only ϕ_μ and ϕ_A in mSUGRA

Impact on LSP mass limits [Falk, Olive, Srednicki]

– enhanced annihilation rate $\tilde{\chi}^0 \tilde{\chi}^0 \rightarrow f \bar{f}$

– weakened upper bound on $m_{\tilde{\chi}^0}$

– additional term proportional to $\sin^2 \theta_f$, *i.e.* little effect in mSUGRA

NEUTRALINOS AND CHARGINOS

Neutralino/chargino mass matrices with two additional parameters

$$\mathcal{M}_{\rm neut} = \begin{pmatrix} |M_1|\, e^{i\phi_1} & 0 & -m_Z s_w c_\beta & m_Z s_w s_\beta \\ 0 & M_2 & m_Z c_w c_\beta & -m_z c_w s_\beta \\ -m_Z s_w c_\beta & m_Z c_w c_\beta & 0 & -|\mu|\, e^{i\phi_\mu} \\ m_Z s_w s_\beta & -m_Z c_w s_\beta & -|\mu|\, e^{i\phi_\mu} & 0 \end{pmatrix}$$

$$\mathcal{M}_{\rm char} = \begin{pmatrix} M_2 & \sqrt{2} m_W s_\beta \\ \sqrt{2} m_W c_\beta & |\mu|\, e^{i\phi_\mu} \end{pmatrix}$$

Inversion problem

model parameters

$|M_1|$, M_2, $|\mu|$, $\tan\beta$

ϕ_1, ϕ_μ

$\Updownarrow$

measured observables

4 neutralino masses: $\tilde{\chi}_i^0$

2 chargino masses: $\tilde{\chi}_i^\pm$

9+1 neutralino cross sections

3 chargino cross sections

additional constraints

electron, neutron, mercury EDM

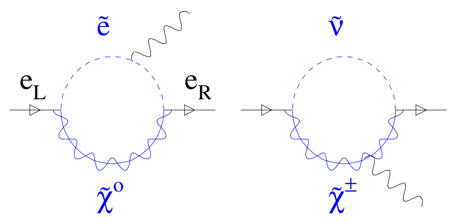
mass limits

cold dark matter, co-annihilation,...

theoretical arguments

fine tuning and perturbation theory

Electric Dipole Moments



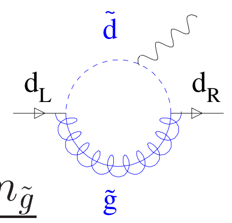
(1) Electron electric dipole moment

– leading chargino contribution: $\frac{d_e}{e} \sim \frac{\alpha}{4\pi \sin^2\theta_w} \tan\beta \, \sin\phi_\mu \, \frac{m_e}{m_{\tilde{\nu}}^2}$

– possible cancellation between chargino and neutralino:

$$-\frac{m_e}{m_{\tilde{e}}^2} \left[A_e \sin(\phi_1 + \phi_A) + \mu \tan\beta \sin(\phi_\mu - \phi_1)\right]$$

– experimental limit $d_e < 4 \cdot 10^{-27}\,\mathrm{e\,cm}$
$\rightarrow$ naively with $m_{\tilde{\nu}} \sim 100\,\mathrm{GeV}$: $\phi_\mu \lesssim 10^{-3}$ [Ellis, Falk, Olive]



(2) Neutron electric dipole moment

– additional gluino contribution: $\frac{d_d}{e} \sim \frac{\alpha_s}{\pi} \mathrm{Im}(A^* + \mu \tan\beta) \frac{m_d \, m_{\tilde{g}}}{m_{\tilde{d}}^4}$

– possible cancellation between chargino and gluino:

$$-\frac{m_d}{m_{\tilde{e}}^2} \left[A_d \sin(\phi_3 + \phi_A) + \mu \tan\beta \sin(\phi_\mu - \phi_3)\right]$$

– experimental limit $d_N < 1.1 \cdot 10^{-25}\,\mathrm{e\,cm}$
$\rightarrow$ naively with $m_{\mathrm{SUSY}} \sim 100\,\mathrm{GeV}$: $\arg(A^* + \mu \tan\beta) \lesssim 10^{-3}$

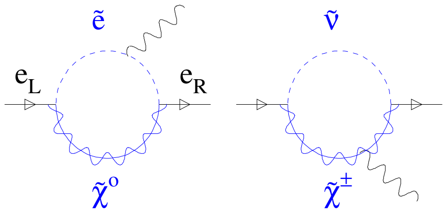
– hadronic uncertainties, gluonic operators,...

(3) Mercury electric dipole moment

– experimental constraint $d_{Hg} < 9 \cdot 10^{-28}\,\mathrm{e\,cm}$
$\rightarrow$ naively with $m_{\mathrm{SUSY}} \sim 100\,\mathrm{GeV}$: $\arg(A^* + \mu \tan\beta) \lesssim 10^{-4}$

[Falk, Olive, Pospelov, Roiban]

EDM Constraints



Dipole moments of electron, neutron, mercury
can be suppressed through

(1) small phases $\phi \lesssim 10^{-3}$ [Ellis, Falk, Olive, Pospelov, Roiban]

(2) large SUSY masses $m_{\text{SUSY}} \gtrsim 1\text{TeV}$

(3) large cancellations between diagrams [Ibrahim & Nath; Brhlik, Good, Kane]

(4) some of (1) to (3)

Check fine tuning

— scan over parameter space (SUSY masses below 1TeV)

(collider phenomenology, relic density constraints)

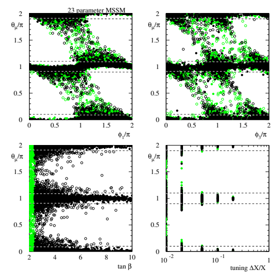
— find solutions to all EDM constraints

— vary all parameter by $\Delta X/X = 0.1 \cdots 0.01 \cdots 0.001$

— require that all EDM constraints are still fulfilled

(stability of regions in perturbaxtion theory)

$\rightarrow$ mainly ϕ_μ correlated with fine tuning



Observed neutralino sector

— require $m_{\tilde{\chi}_1} + m_{\tilde{\chi}_2} < 500\,\text{GeV}$

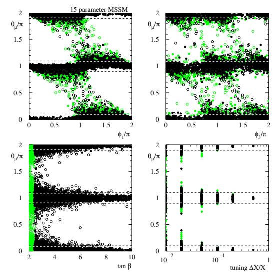
— require tuning parameter $> 1\%$

$\rightarrow$ $\phi_\mu \lesssim \pi/10$ for $M_2, \mu \lesssim 800\,\text{GeV}$

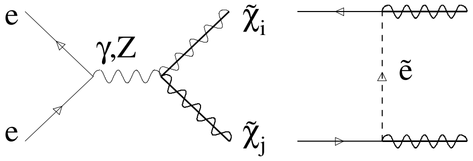
$\rightarrow$ $\phi_\mu \lesssim \pi/20$ for $\tan\beta \gtrsim 4$

$\rightarrow$ $\phi_\mu \lesssim \pi/20$ for mSUGRA

$\rightarrow$ in other words: *ϕ_μ is small*



NEUTRALINOS AND CHARGINOS AT A LC



Previous LC analysis [Barger, Han, Li, T.P]

– determine complete set of neutralino/chargino parameters

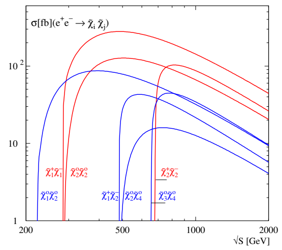
– experimental (statistical) errors included

→ large set of masses and cross sections needed [c.f. Kneur & Moultaka; Choi et al.]

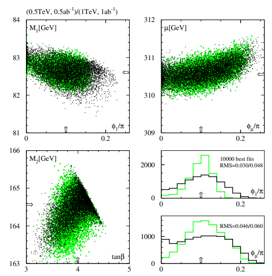
→ mass measurements from threshold scan [Blair & Martyn]

→ large luminosity required for heavy higgsinos ($e.g.$ $1\mathrm{TeV}, 1\mathrm{ab}^{-1}$)

→ phases $\phi_1, \phi_\mu \lesssim \pi/10$ not distinguishable from zero



Measurement at Linear Collider:
1. define scenario with 'true' set masses and cross sections
2. assume mass measurements through threshold scan
3. choose 10000 smeared pseudo-mesurements
4. fit mass and phase parameters to each pseudo-measurement
5. determine phase distribution of pseudo-measurements
6. central value, width, Gaussian?



Improved analysis

(A) How can we make use of the EDM constraints?

(B) Can we measure something with a smaller collider?

PUTTING THE PIECES TOGETHER

EDM constraints and a medium energy Linear Collider

+ $\tan\beta$ small (*i.e.* measured in Higgs sector?!)
+ ϕ_μ could as well be zero $\rightarrow$ no phase in chargino sector
+ ϕ_1 unconstrained and uncorrelated
− not all neutralinos/charginos observed (no mass measurement)
− t channel selectrons/sneutrinos not seen

Minimal inversion problem

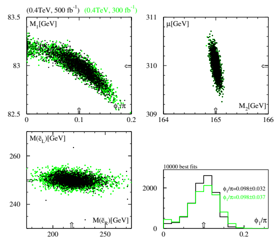
Model Parameters:
$\lvert M_1\rvert, M_2, \mu, m_{\tilde{e}_L}, m_{\tilde{e}_R}, \phi_1$

$\Longleftrightarrow$

Measured Observables:
3 neutralino masses: $\tilde{\chi}^0_i$
1 chargino mass: $\tilde{\chi}^\pm_1$
3 neutralino cross sections
1 chargino cross section

Variety of models

	Fit ϕ_1	RMS
complete analysis	0.097	0.030
free sleptons, fixed $\tan\beta$	0.099	0.028
only one phase ϕ_1	0.101	0.030
only $\tilde{\chi}^0_3$ $(E = 400\,\mathrm{GeV})$	0.101	0.028
'true' $\phi_\mu = \pi/20$	0.100	0.028
'true' $\phi_\mu = \pi/20, \tan\beta = 4.2$	0.083	0.028
decoupled sleptons	0.105	0.041
low luminosity $300\,\mathrm{fb}^{-1}$	0.102	0.034
large $\phi_1 = \pi/2$	0.501	0.025
light higgsinos $\mu = 150\,\mathrm{GeV}$	0.100	0.014



Particle	Mass [GeV]	Error [GeV]
$\tilde{\chi}^0_1$	71.9	0.05
$\tilde{\chi}^0_2$	130.3	0.07
$\tilde{\chi}^0_3$	319.8	0.30
$\tilde{\chi}^0_4$	348.0	0.52
$\tilde{\chi}^+_1$	127.7	0.04
$\tilde{\chi}^+_2$	345.8	0.25
$\tilde{e}_L$	250	fitted
$\tilde{e}_R$	218	fitted

Looking for an Asymmetry

Define a CP asymmetry in $\tilde{\chi}_1^0 \tilde{\chi}_i^0$ production

– best proof of CP phases: asymmetry

– non-identical pair production (*s* channel Z vs. t channel $\tilde{e}$ with destructive interference)

dominant diagrams: s channel for higgsinos, t channel for gauginos

– one particle decaying $\tilde{\chi}_i^0 \to \tilde{\chi}_1^0 \, e^- e^+$ (Z and $\tilde{e}$ diagram on/off shell)

– reconstructed momenta: $p_{e^-}^{(\mathrm{in})}, k_{e^-}^{(\mathrm{out})}, k_{e^+}^{(\mathrm{out})} \to \cos\theta \propto \vec{p}_{e^-} \cdot \left(\vec{k}_{e^-} \wedge \vec{k}_{e^+} \right)$

$\to$ spectacular but small signal

$\to$ large asymmetry disfavored by couplings

Conclusions

⋆ WMAP results constraining SUSY-CDM

⋆ Crucial parameter for collider searches (LHC,LC)

– mSUGRA/CMSSM particularly well constrained

– non-unified Higgs masses with little impact

– general result combining LEP2 and WMAP: $m_{\tilde{\chi}} > 26$ GeV

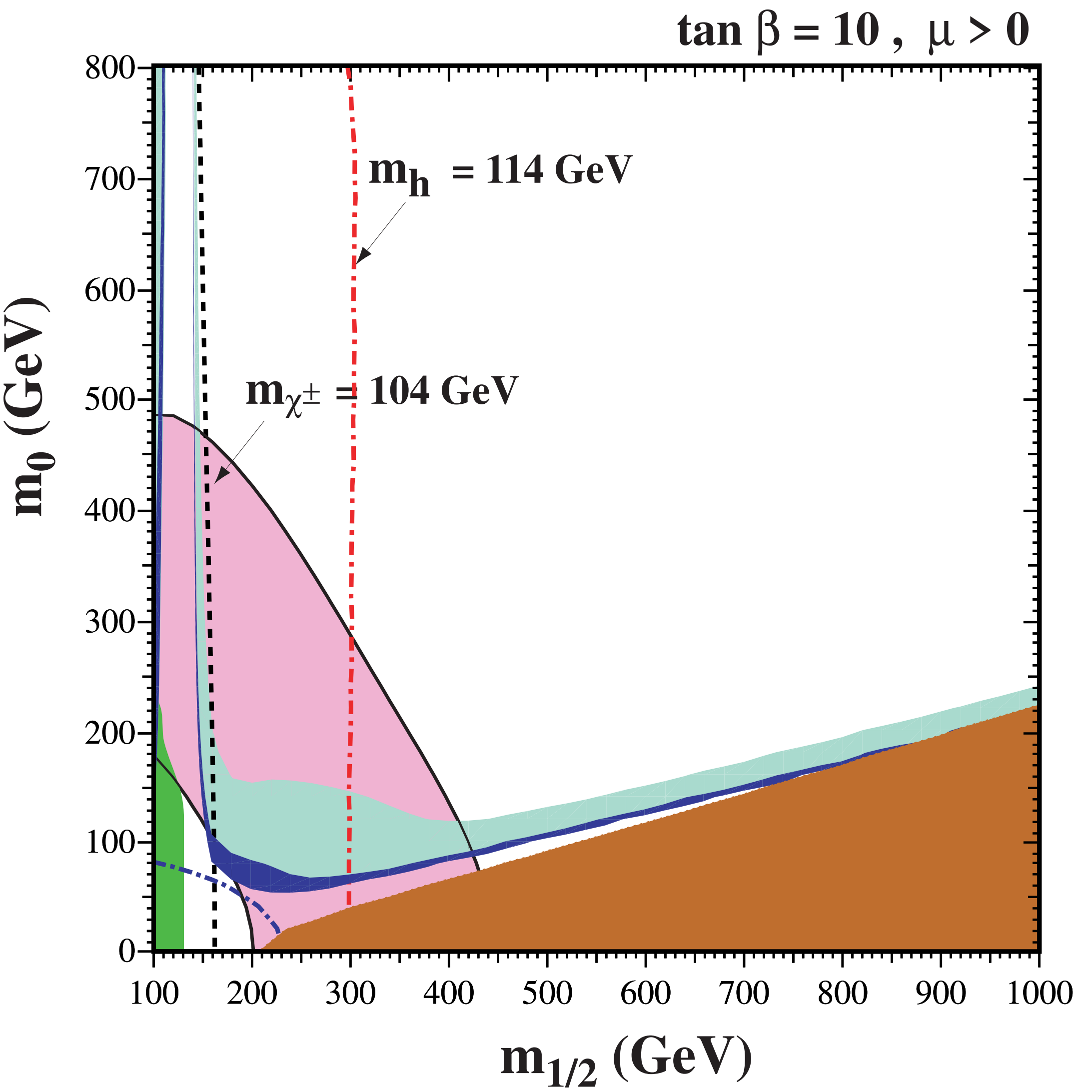
⋆ CP violating MSSM phases impacting CDM constraints

⋆ LC precision analysis needed

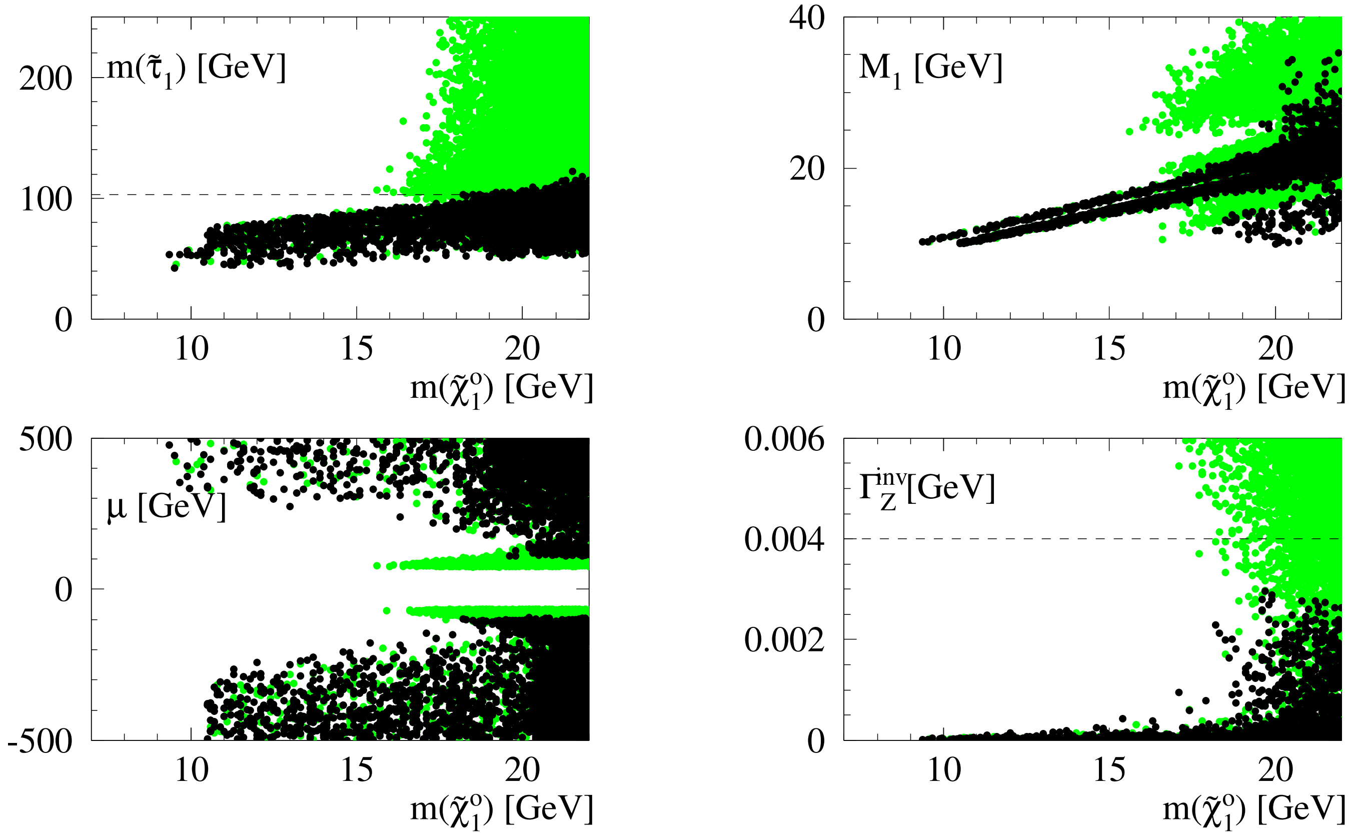
– large phases no problem at the LC $(\Delta\phi_1 \gtrsim \pi/30,\ \Delta\phi_\mu \gtrsim \pi/20)$

– small phases unobservable $\phi \lesssim \pi/10$

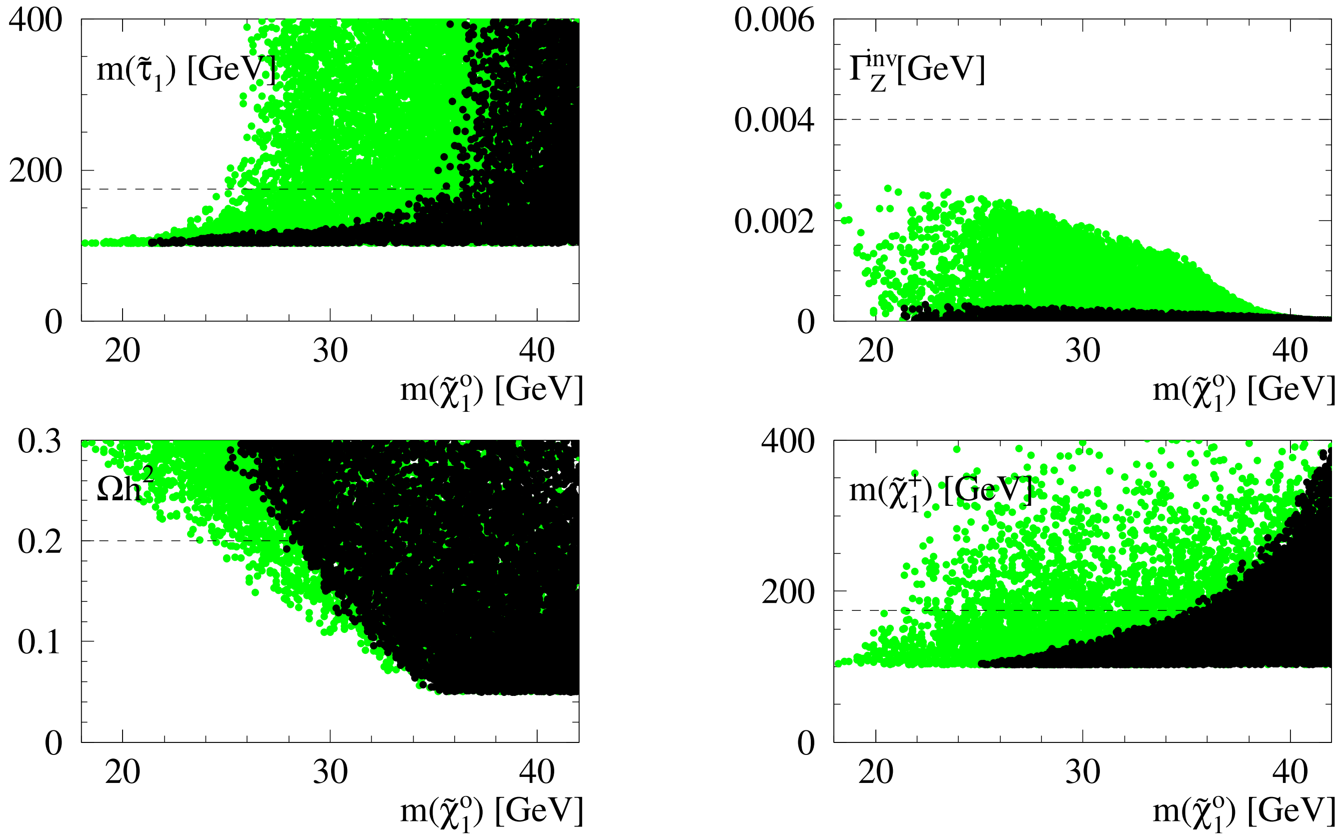
– EDM constraints excluding large $\phi_\mu \gtrsim \pi/10$



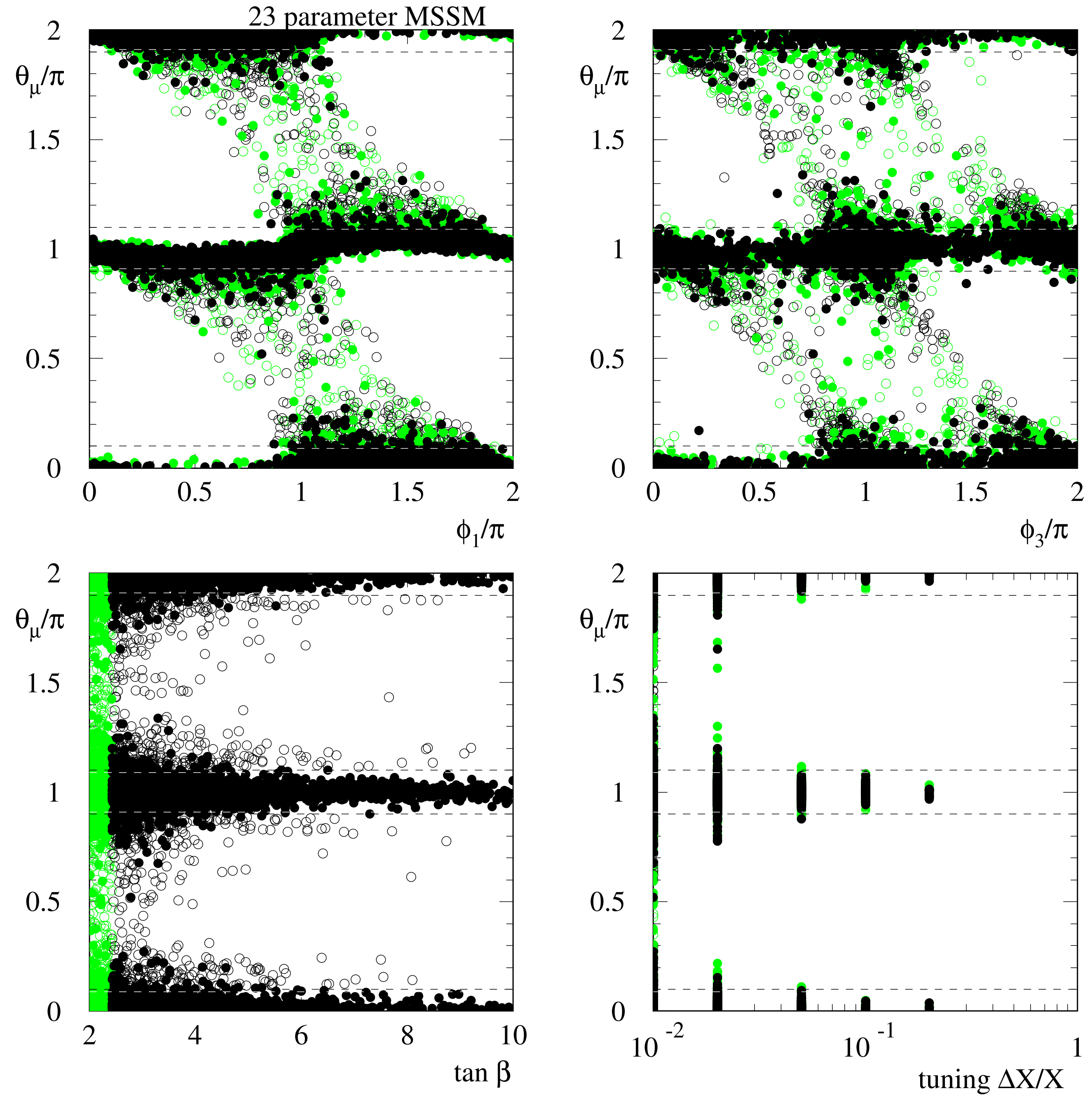
tan β = 10 , μ > 0
m_h = 114 GeV
m_χ± = 104 GeV
m_0 (GeV)
m_1/2 (GeV)
0
100
200
300
400
500
600
700
800
100
200
300
400
500
600
700
800
900
1000



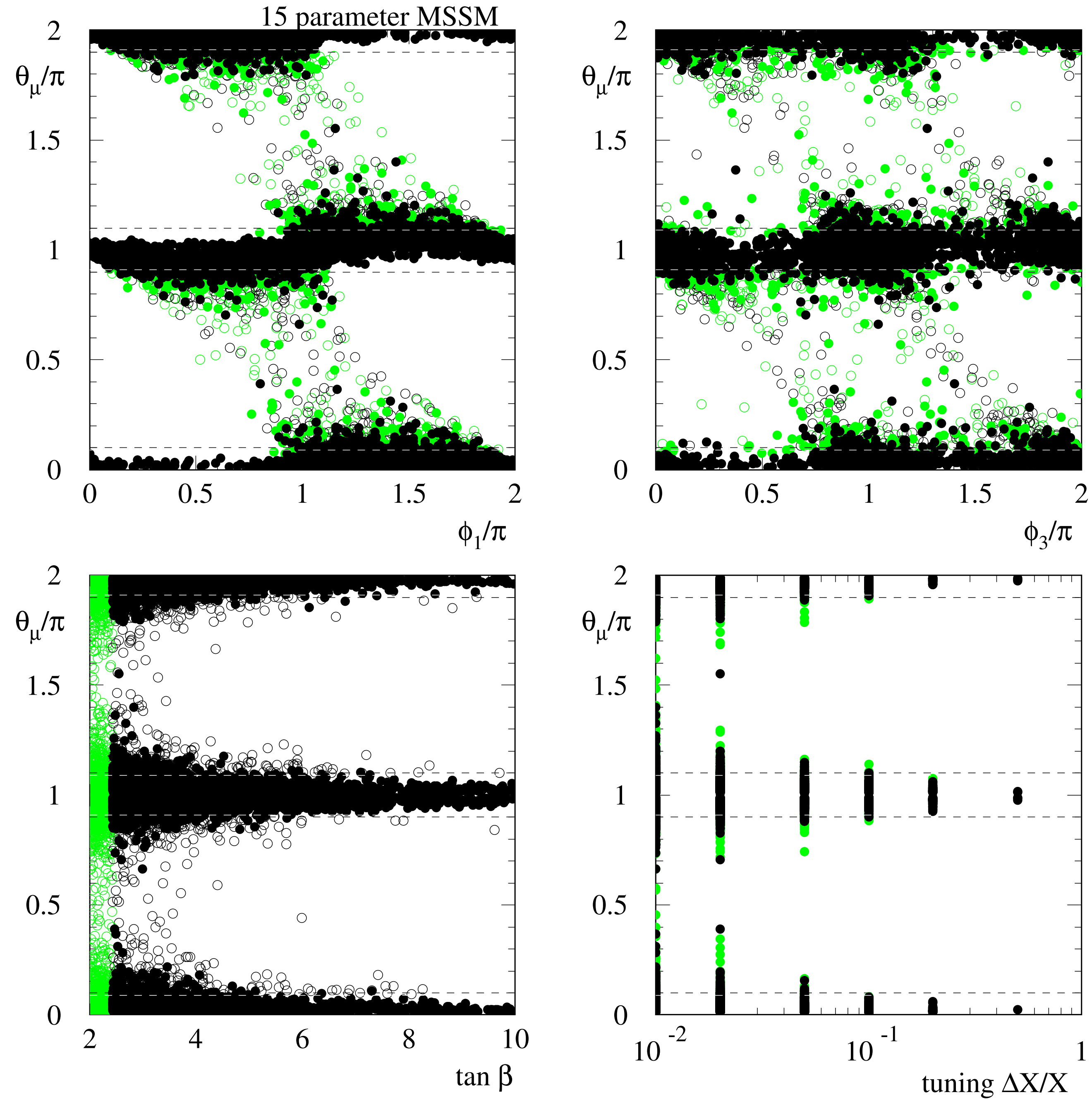
m($\tilde{\tau}_1$) [GeV]
M$_1$ [GeV]
μ [GeV]
Γ_Z^{inv}[GeV]
m($\tilde{\chi}_1^o$) [GeV]
0
100
200
20
40
500
-500
0.002
0.004
0.006
10
15



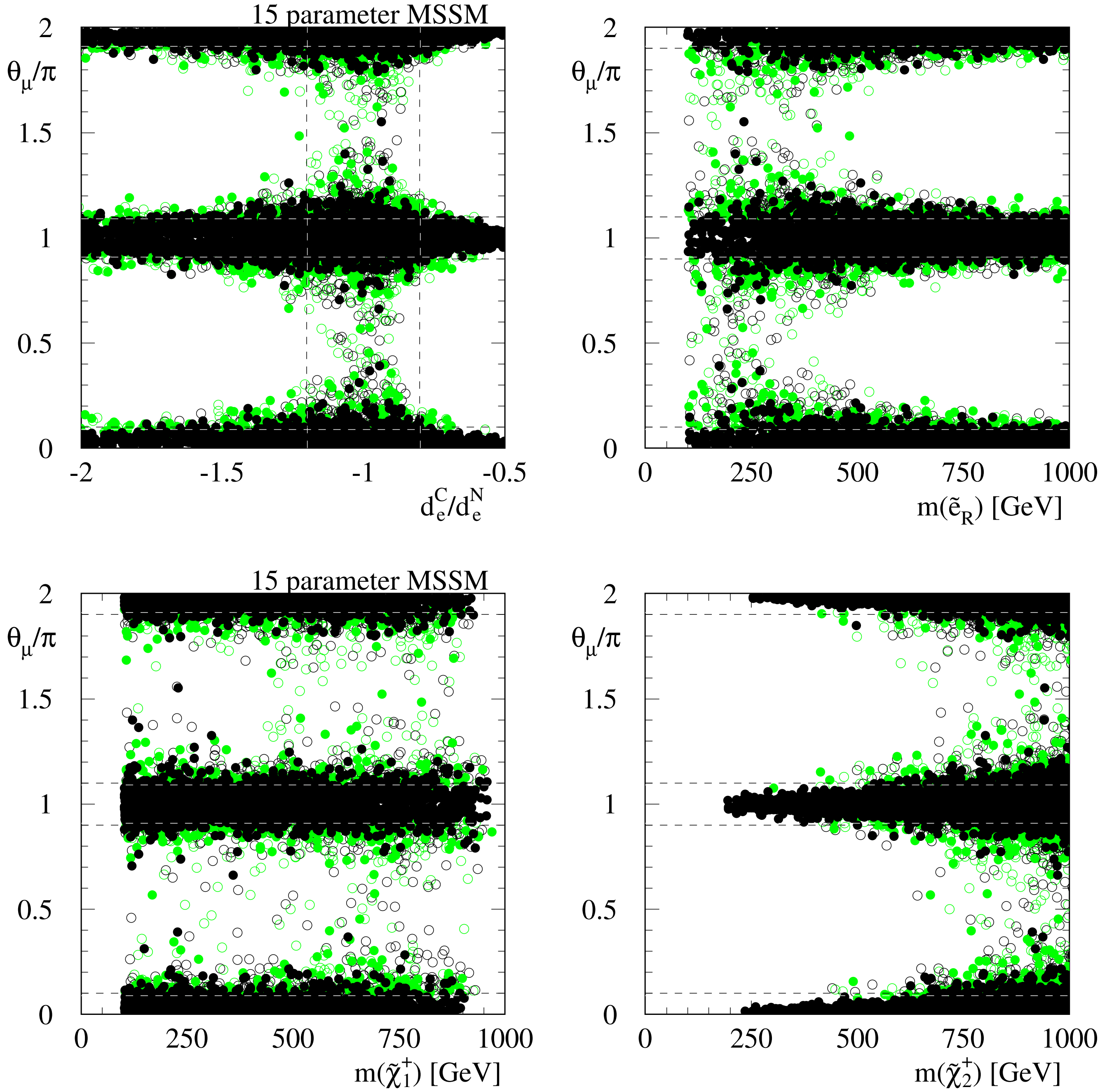
$m(\tilde{\tau}_1)$ [GeV]
400
200
0
20
30
40
$m(\tilde{\chi}_1^o)$ [GeV]
Γ_Z^{inv}[GeV]
0.006
0.004
0.002
0
20
30
40
$m(\tilde{\chi}_1^o)$ [GeV]
Ωh^2
0.3
0.2
0.1
0
20
30
40
$m(\tilde{\chi}_1^o)$ [GeV]
$m(\tilde{\chi}_1^+)$ [GeV]
400
200
0
20
30
40
$m(\tilde{\chi}_1^o)$ [GeV]



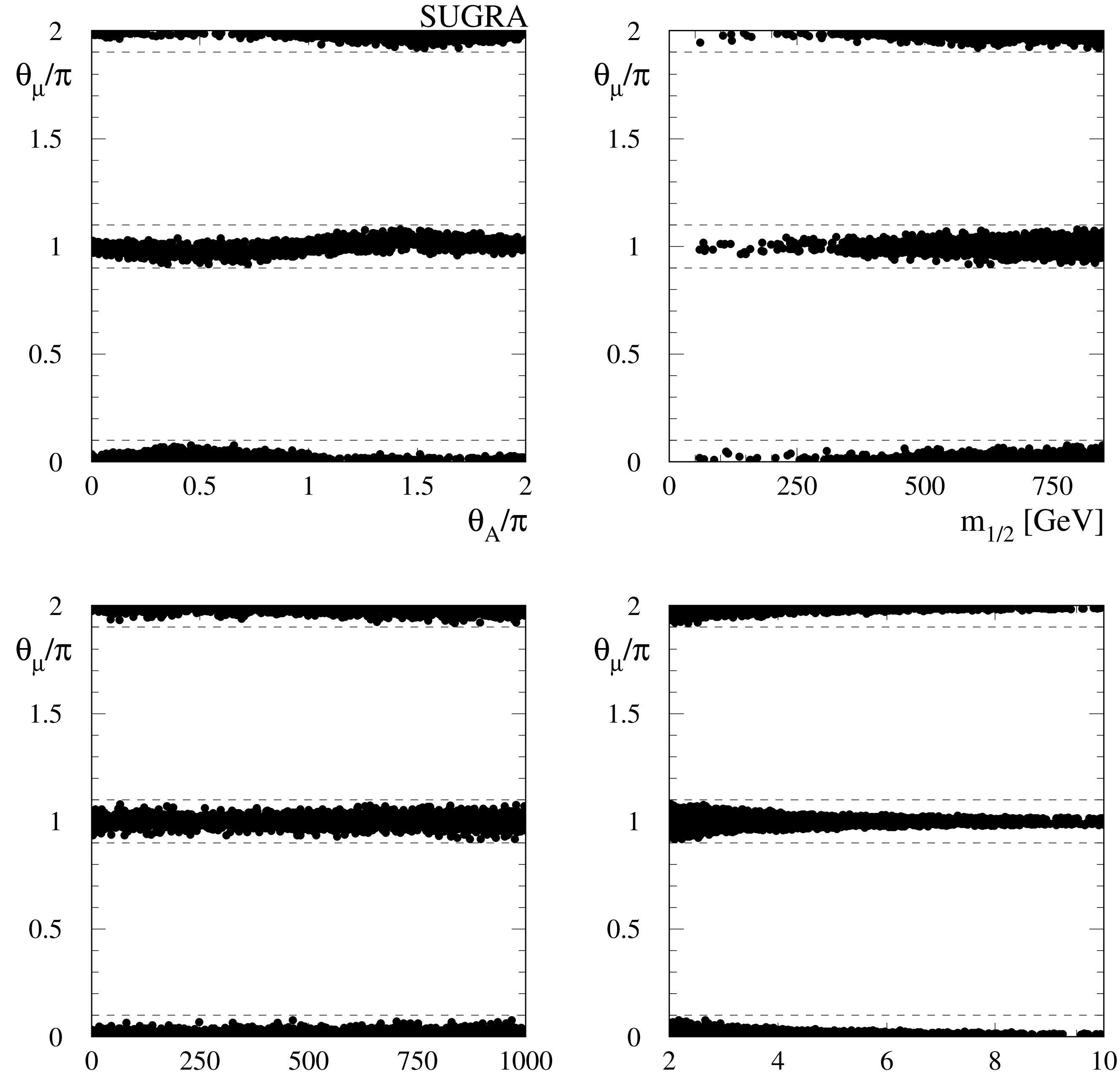
23 parameter MSSM
θ_μ/π
ϕ_1/π
ϕ_3/π
tan β
tuning ΔX/X
0
0.5
1
1.5
2
2
4
6
8
10
10^{-2}
10^{-1}



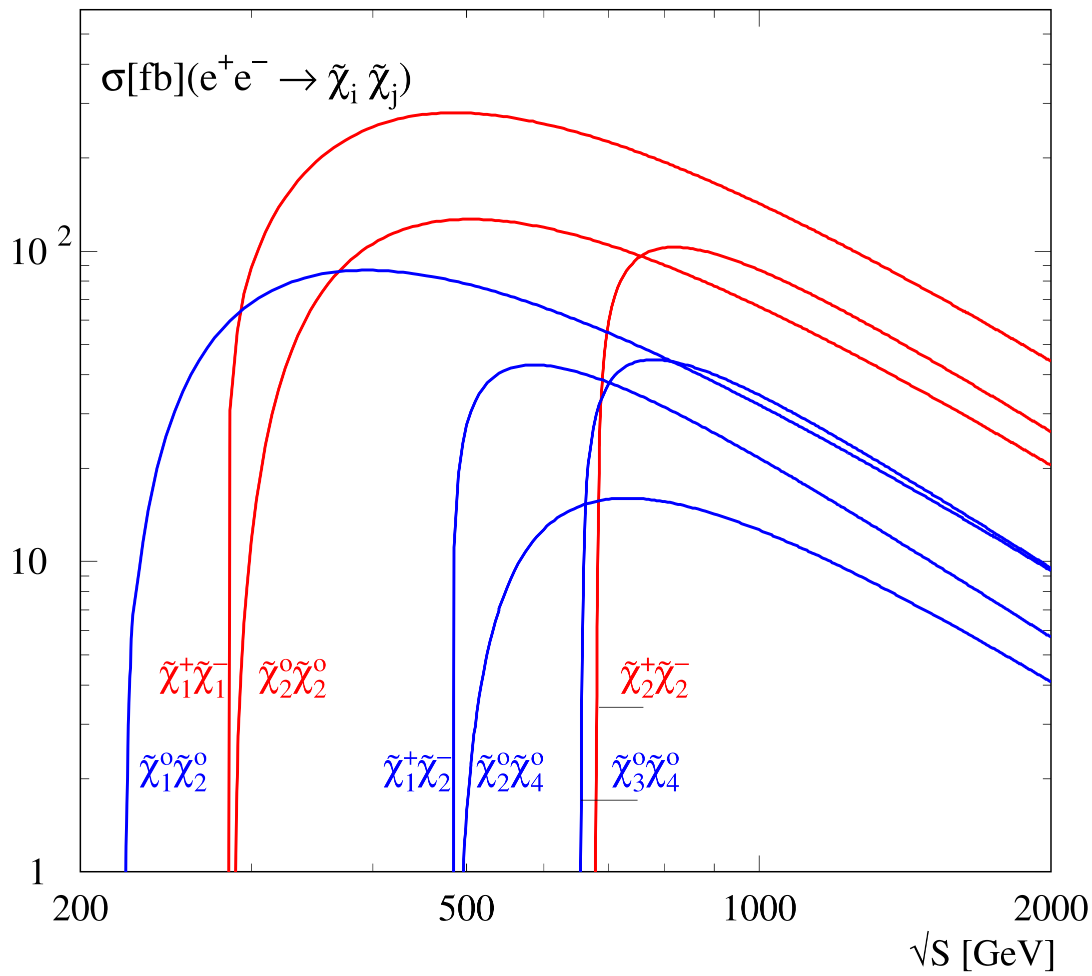
15 parameter MSSM
θμ/π
φ1/π
φ3/π
tan β
tuning ΔX/X



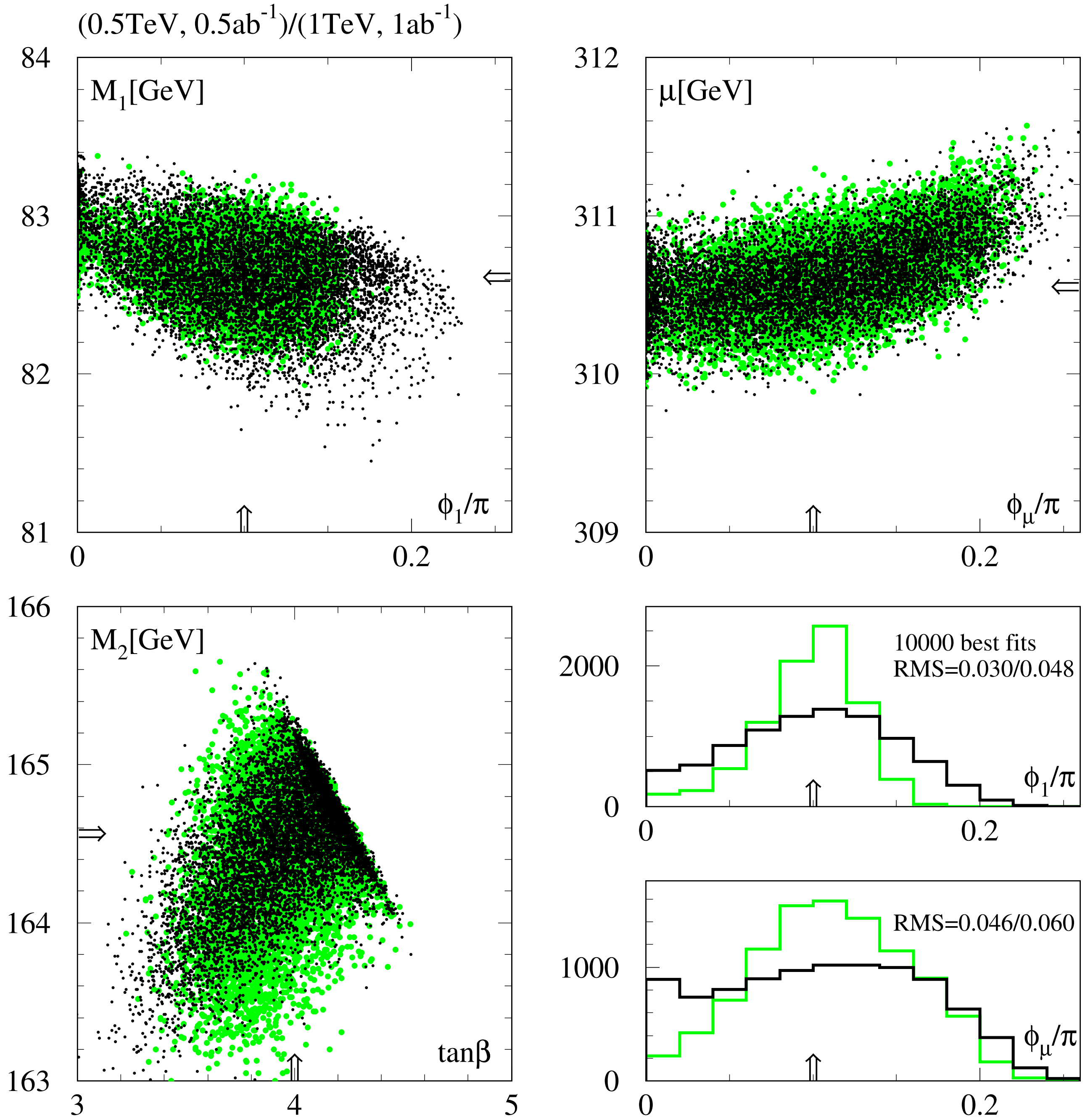
15 parameter MSSM
θ_μ/π
d_e^C/d_e^N
$m(\tilde{e}_R)$ [GeV]
15 parameter MSSM
$m(\tilde{\chi}_1^+)$ [GeV]
$m(\tilde{\chi}_2^+)$ [GeV]



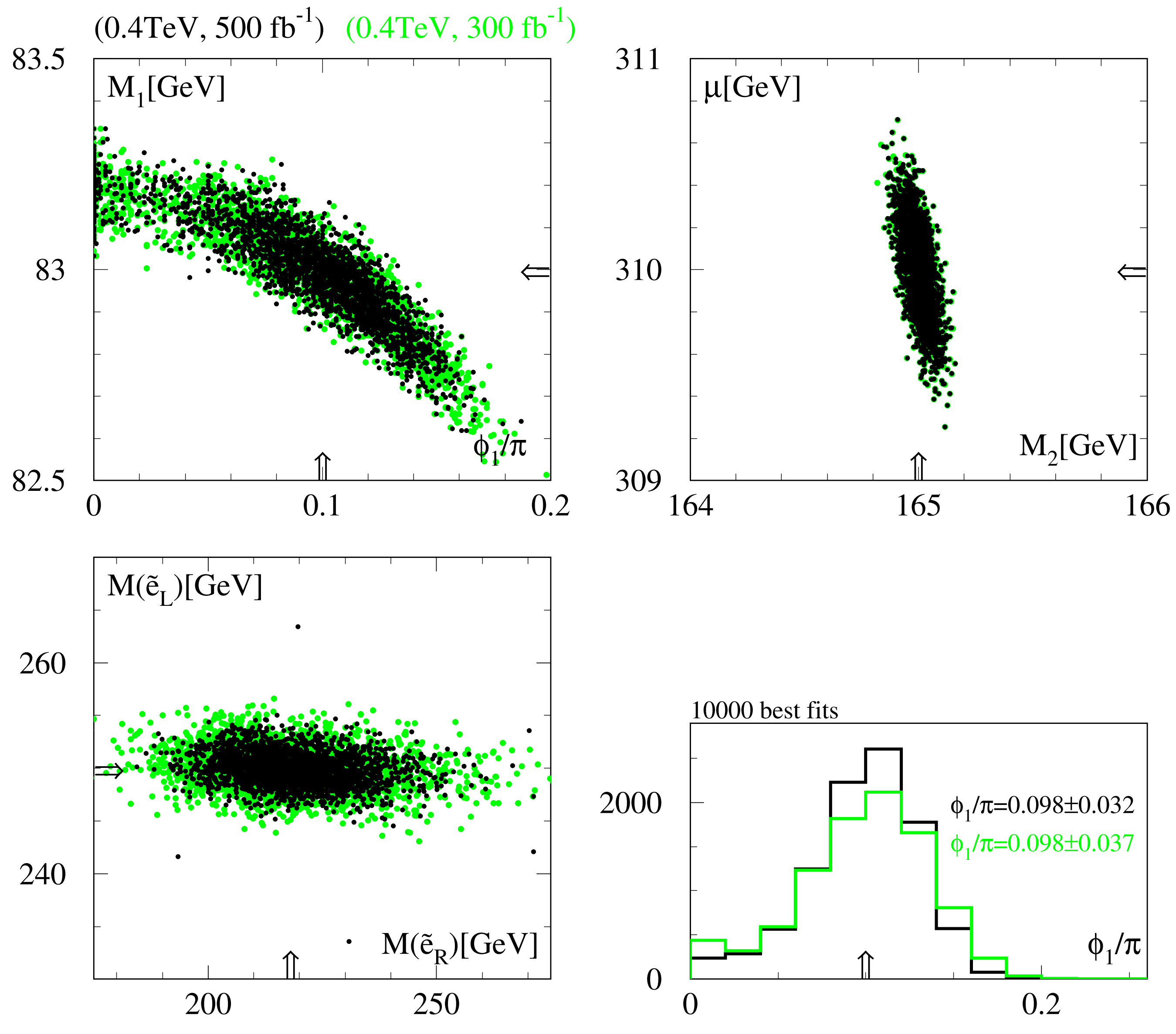
SUGRA
θ_μ/π
2
1.5
1
0.5
0
θ_A/π
0
0.5
1
1.5
2
$m_{1/2}$ [GeV]
0
250
500
750
m_0 [GeV]
0
250
500
750
1000
$\tan\beta$
2
4
6
8
10



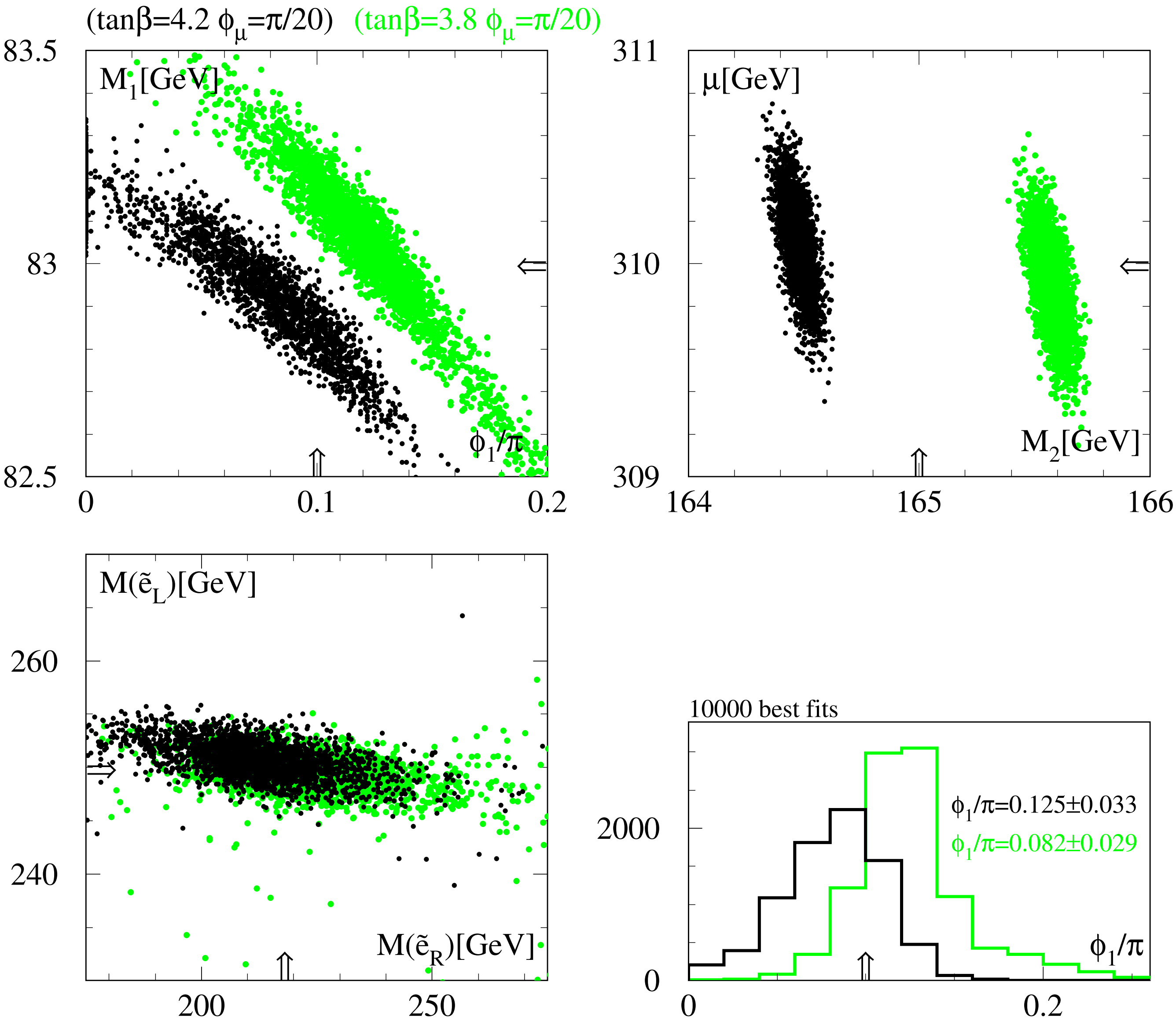
$\sigma[fb](e^+e^- \to \tilde{\chi}_i\,\tilde{\chi}_j)$
10^2
10
1
200
500
1000
2000
$\sqrt{S}$ [GeV]
$\tilde{\chi}^+_1\tilde{\chi}^-_1$
$\tilde{\chi}^o_2\tilde{\chi}^o_2$
$\tilde{\chi}^+_2\tilde{\chi}^-_2$
$\tilde{\chi}^o_1\tilde{\chi}^o_2$
$\tilde{\chi}^+_1\tilde{\chi}^-_2$
$\tilde{\chi}^o_2\tilde{\chi}^o_4$
$\tilde{\chi}^o_3\tilde{\chi}^o_4$



(0.5TeV, 0.5ab^{-1})/(1TeV, 1ab^{-1})
M$_1$[GeV]
84
83
82
81
ϕ_1/π
0
0.2
μ[GeV]
312
311
310
309
ϕ_μ/π
0
0.2
M$_2$[GeV]
166
165
164
163
tanβ
3
4
5
10000 best fits
RMS=0.030/0.048
2000
0
ϕ_1/π
0
0.2
RMS=0.046/0.060
1000
0
ϕ_μ/π
0
0.2



(0.4TeV, 500 fb^{-1}) (0.4TeV, 300 fb^{-1})
M$_1$[GeV]
ϕ_1/π
83.5
83
82.5
0
0.1
0.2
μ[GeV]
M$_2$[GeV]
311
310
309
164
165
166
M($\tilde{e}_L$)[GeV]
M($\tilde{e}_R$)[GeV]
260
240
200
250
10000 best fits
ϕ_1/π=0.098±0.032
ϕ_1/π=0.098±0.037
ϕ_1/π
2000
0
0
0.2



(tanβ=4.2 φ_μ=π/20) (tanβ=3.8 φ_μ=π/20)
M_1[GeV]
φ_1/π
83.5
83
82.5
0
0.1
0.2
μ[GeV]
M_2[GeV]
311
310
309
164
165
166
M(ẽ_L)[GeV]
M(ẽ_R)[GeV]
260
240
200
250
10000 best fits
φ_1/π=0.125±0.033
φ_1/π=0.082±0.029
φ_1/π
2000
0
0
0.2