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RECONSTRUCTION of FUNDAMENTAL SUSY PARAMETERS

ECFA/DESY SUSY Collaboration *

ELW scale 10^2 GeV	SUPERSYMMETRY	GUT/Planck scale $10^{16}/10^{19}$ GeV
SUSY particle experiments → LE SUSY params	RGE	a) SUSY brkg mech. b) gravity c) string physics

2 Examples: 1.) minimal supergravity mSUGRA
2.) string effective field theory

Bottom-up approach:
- max exploitation of le measurements
- merciless revealing of facts / fancy

1.) MINIMAL SUPERGRAVITY

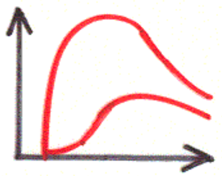
$\leftarrow$ universal masses and couplings at unification scale

typ spectrum SPS#1A:

gauginos	: 200 to 400 GeV	LC
sleptons	: 200 to 300 GeV	LC
squarks/gluinos	: 400 to 600 GeV	LHC+CLIC
light/heavy Higgs	: 114 // 400 GeV	LHC+LC+CLIC

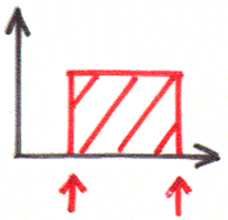
LC Precision Experiments:

MASSES: threshold scans
$e^+e^- \to \tilde{\chi}\tilde{\chi}, \tilde{l}\tilde{l}$

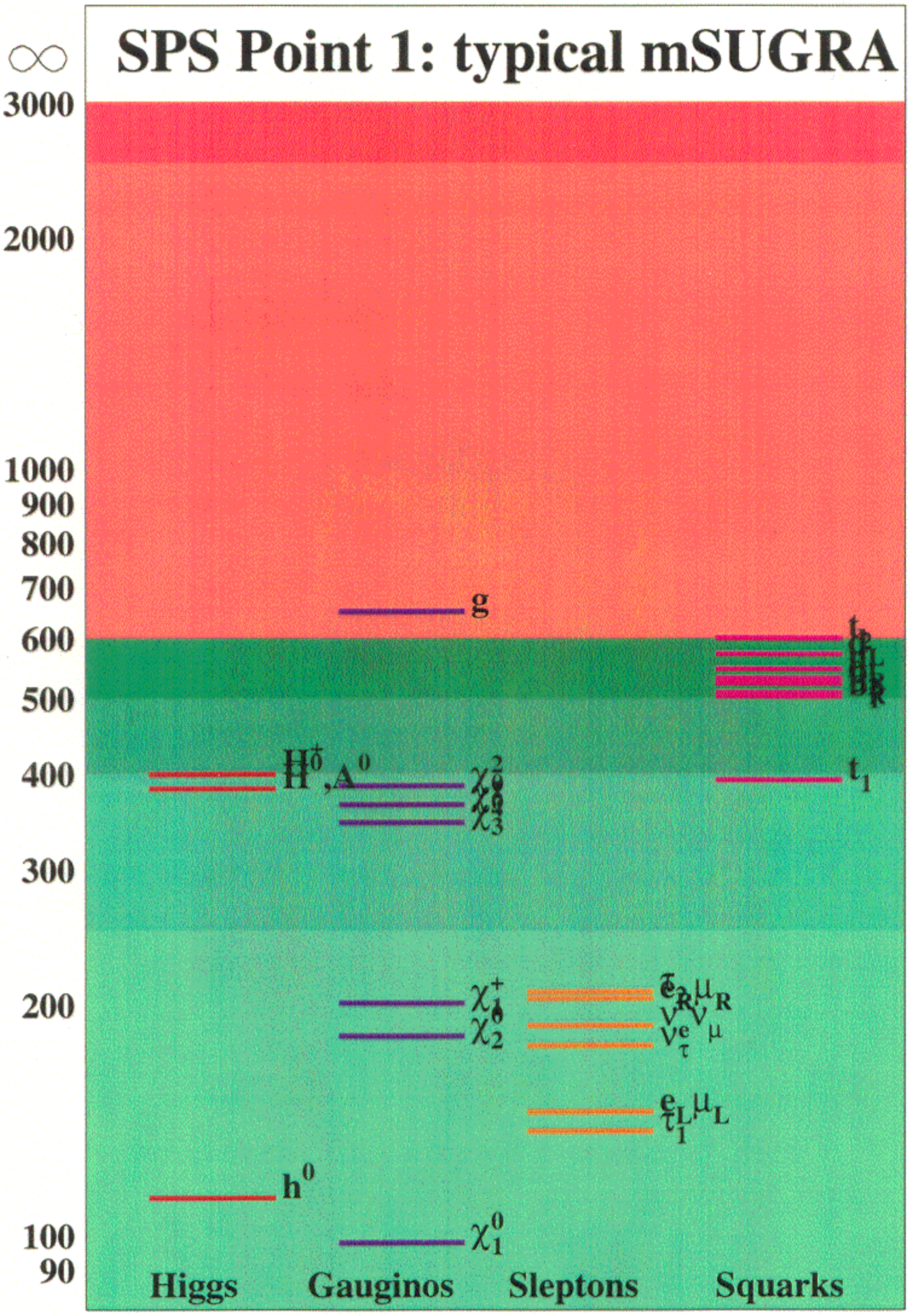


$\sim \beta$: $J = 1/2$ & $\tilde{e}$
$\sim \beta^3$: $J = 0$ F

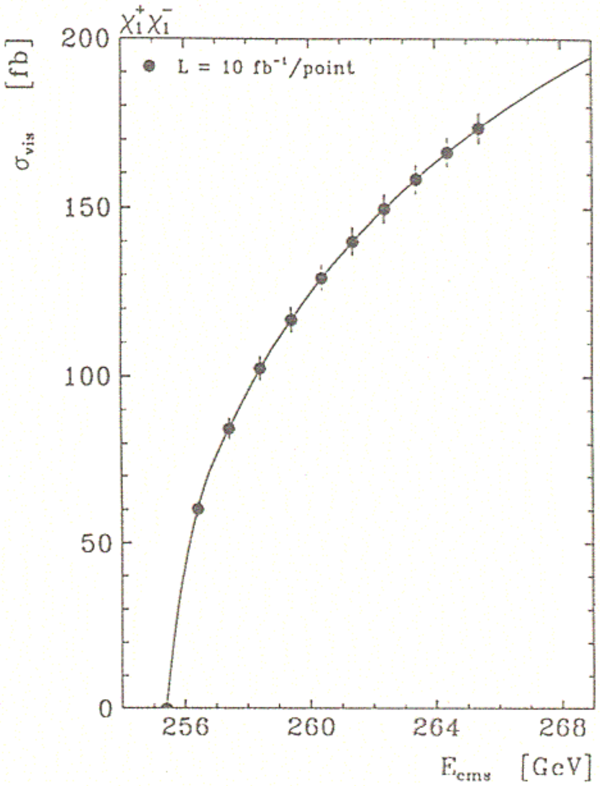
decay spectra
$\tilde{l} \to l\, \tilde{\chi}_1^0$



E_l end-points F

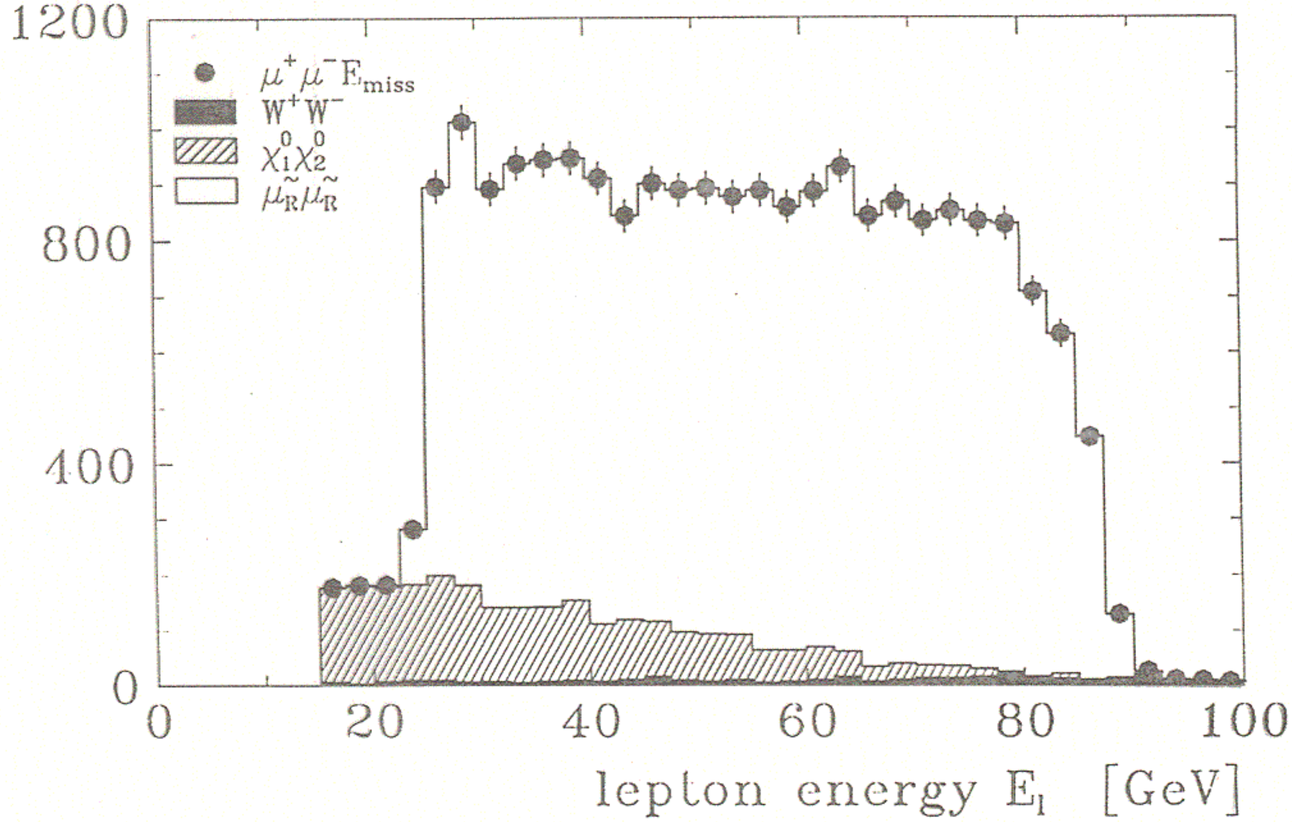

SPS Point 1: typical mSUGRA
∞
3000
2000
1000
900
800
700
600
500
400
300
200
100
90
g
H^0, H^+, A^0
t_1
χ_1^+, χ_2^0
χ_1^0
h^0
Higgs
Gauginos
Sleptons
Squarks

$e_L^- e_R^+ \to \chi_1^- \chi_1^+$



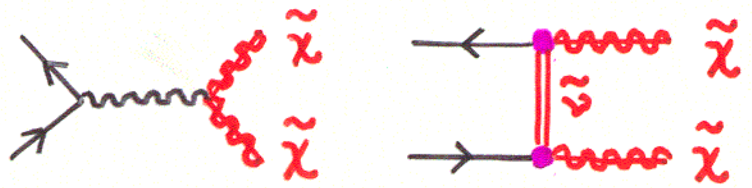
$m_{\chi_1^\pm} = 127.7 \pm 0.04$ GeV

$e^+e^- \to \tilde{\mu}_R^+ \tilde{\mu}_R^-$



$m_{\tilde{\mu}_R} = 132.0 \pm 0.3$ GeV $\quad m_{\chi_1^0} = 71.9 \pm 0.2$ GeV

MIXINGS/ COUPLINGS — continuum cross-sections



F

PARTICLE MASSES

COUPLINGS

$\tilde{\chi}_1$	183.05 ± 0.05 GeV	LC
$\tilde{e}_R$	224.82 ± 0.03 GeV	LC
$\tilde{u}_R$	572 ± 10 GeV	LHC+CLIC
$\tilde{g}$	600 ± 10 GeV	LHC
$\tilde{g}_1/g_1$	0.04	LC
$\tilde{g}_2/g_2$	0.008	LC
$\tilde{g}_3/g_3$	~ 0.05	LHC+CLIC

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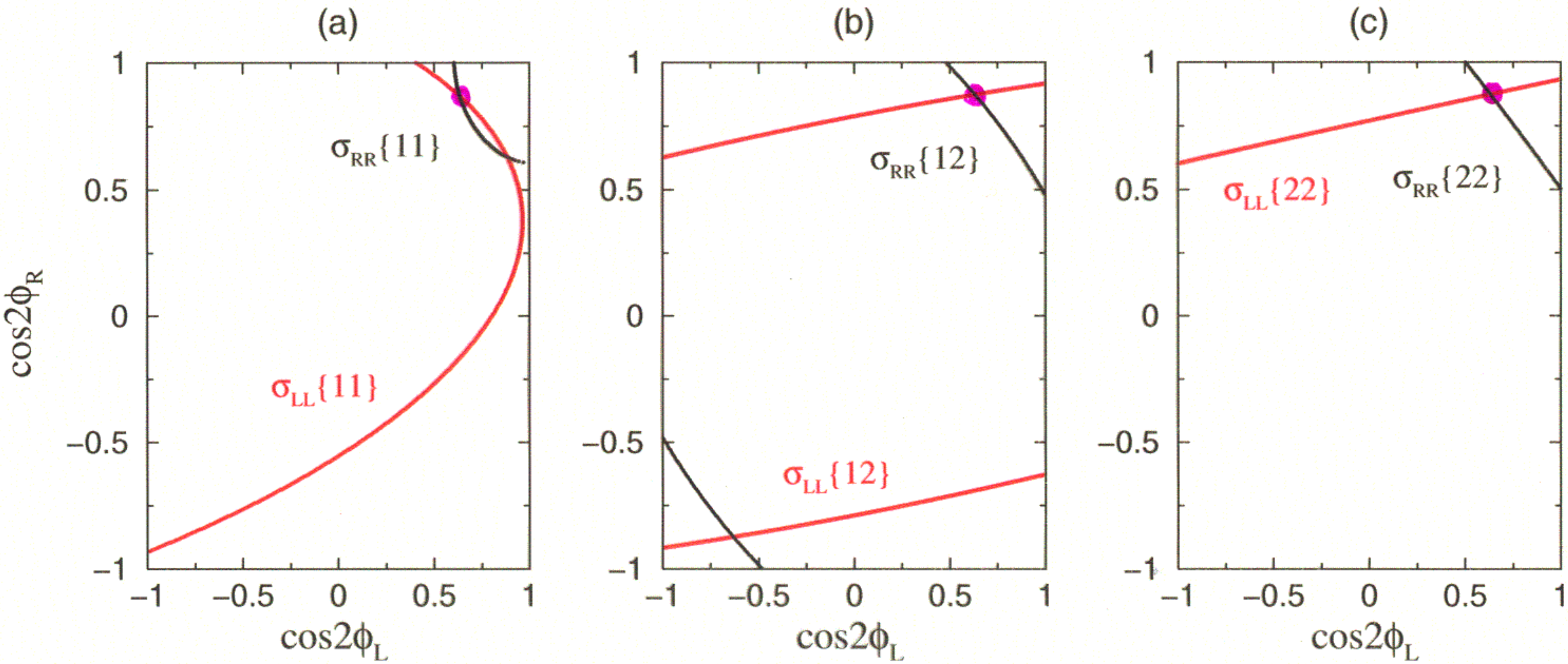
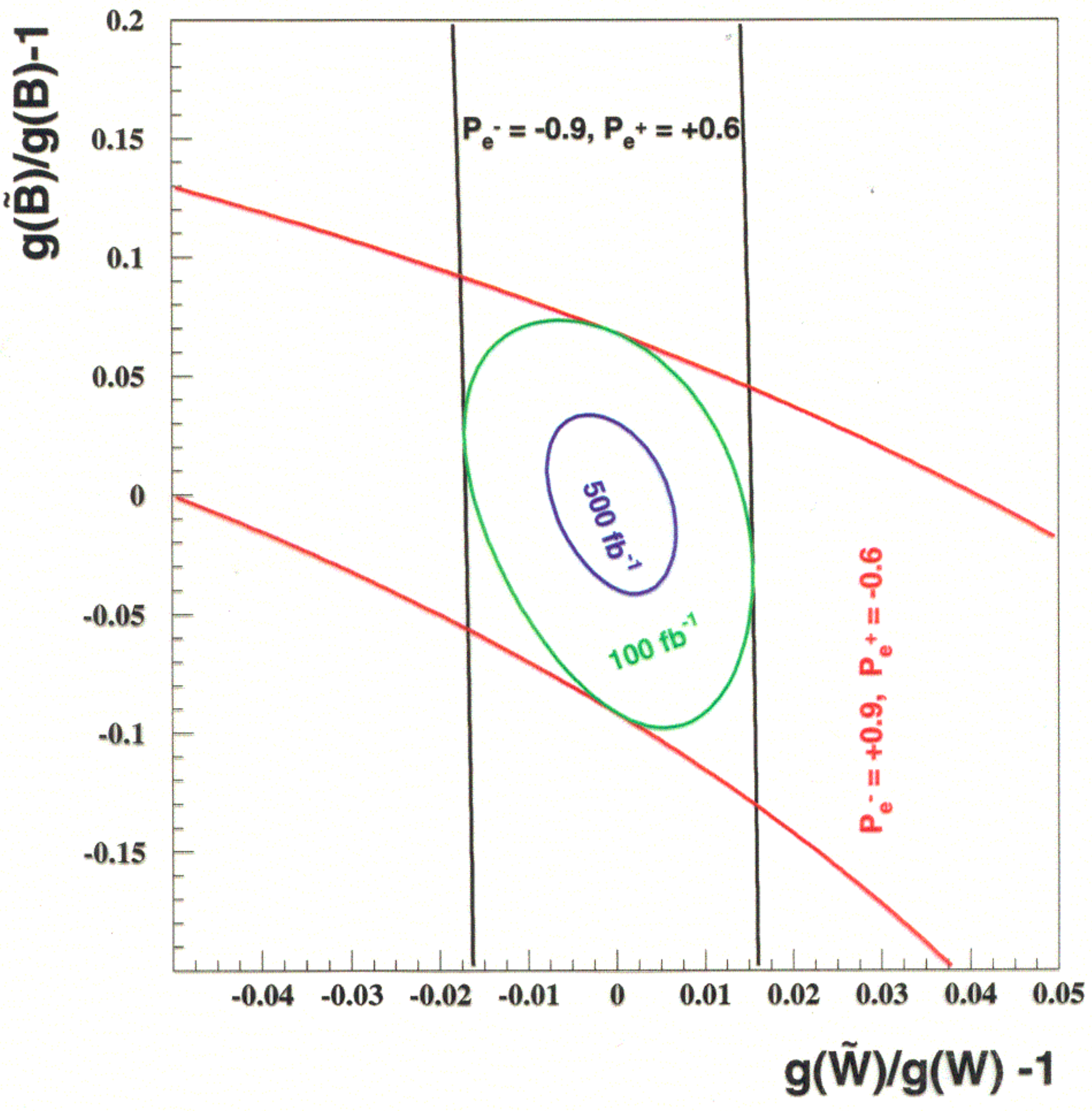

(a)
(b)
(c)
$\cos 2\phi_R$
$\cos 2\phi_L$
$\cos 2\phi_L$
$\cos 2\phi_L$
$\sigma_{RR}\{11\}$
$\sigma_{LL}\{11\}$
$\sigma_{RR}\{12\}$
$\sigma_{LL}\{12\}$
$\sigma_{LL}\{22\}$
$\sigma_{RR}\{22\}$
1
0.5
0
−0.5
−1



$P_{e^-} = -0.9$, $P_{e^+} = +0.6$
500 fb^{-1}
100 fb^{-1}
$P_{e^-} = +0.9$, $P_{e^+} = -0.6$
$g(\tilde{B})/g(B)-1$
$g(\tilde{W})/g(W)-1$
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.04
-0.03
-0.02
-0.01
0
0.01
0.02
0.03
0.04
0.05

Extracting Basic LE Parameters:

$$|\mu| = M_W \sqrt{\Sigma + \Delta[c_{2R} + c_{2L}]} \quad \text{and sign}(\mu)$$

$$M_2 = M_W \sqrt{\Sigma - \Delta[c_{2R} + c_{2L}]}$$

$$M_1^2 = \sum m^2_{\tilde{\chi}^0} - M_2^2 - \mu^2 - 2M_Z^2 \quad \text{sign: } ee \to \tilde{\chi}^0_1 \tilde{\chi}^0_2$$

$$M_3 = m_{\tilde{g}}$$

$$\tan\beta = \sqrt{1 + \Delta(c_{2R} - c_{2L})} \Big/ \sqrt{1 - \Delta(c_{2R} - c_{2L})}$$

$$\Delta = \frac{m^2_{\tilde{\chi}^\pm_2} - m^2_{\tilde{\chi}^\pm_1}}{4M_W^2}$$

$$\Sigma = \frac{m^2_{\tilde{\chi}^\pm_2} + m^2_{\tilde{\chi}^\pm_1}}{2M_W^2} - 1$$

Experimental simulations:

M_1	102.31 ± 0.15 GeV	per-mille
M_2	192.21 ± 0.46 GeV	per-mille
M_3	586 ± 12 GeV	per-cent
$\tilde{M}_{eR}$	219.68 ± 0.16 GeV	per-mille
$\tilde{M}_{uR}$	554 ± 9 GeV	per-cent
A_t	-445 ± 13	per-cent
$\tan\beta$	10 ± 0.9	$>$ per-cent

REMARKS:

a) low spectrum sufficient

b) large $\tan\beta$: Higgs cplg.

$\tilde{\tau} \to \tau$ pol.

Evolution to High Scales:

RGE: gauge couplings: $\alpha_i \to \alpha_U = Z_i^{-1}\alpha_i$ $\qquad Z_i^{-1} = 1 + \frac{b_i\alpha_U}{2\pi}\log\frac{M_U}{M_Z}$

gaugino masses: $M_i \to M_{1/2} = Z_i^{-1} M_i$

scalar masses : $\tilde{M}_j^2 \to \tilde{M}_0^2 = \tilde{M}_j^2 - c_j M_{1/2}^2 - c'_{j\beta}\Delta M_\beta^2$

trilin. cplgs. : $A_k \to A_0 = [A_k - d'_k M_{1/2}]/d_k$

F : (1) unification of gaugino masses can be proven experimentally at per-cent to per-mille level
(2) slepton masses at per-mille level
(3) squark masses at per-cent level

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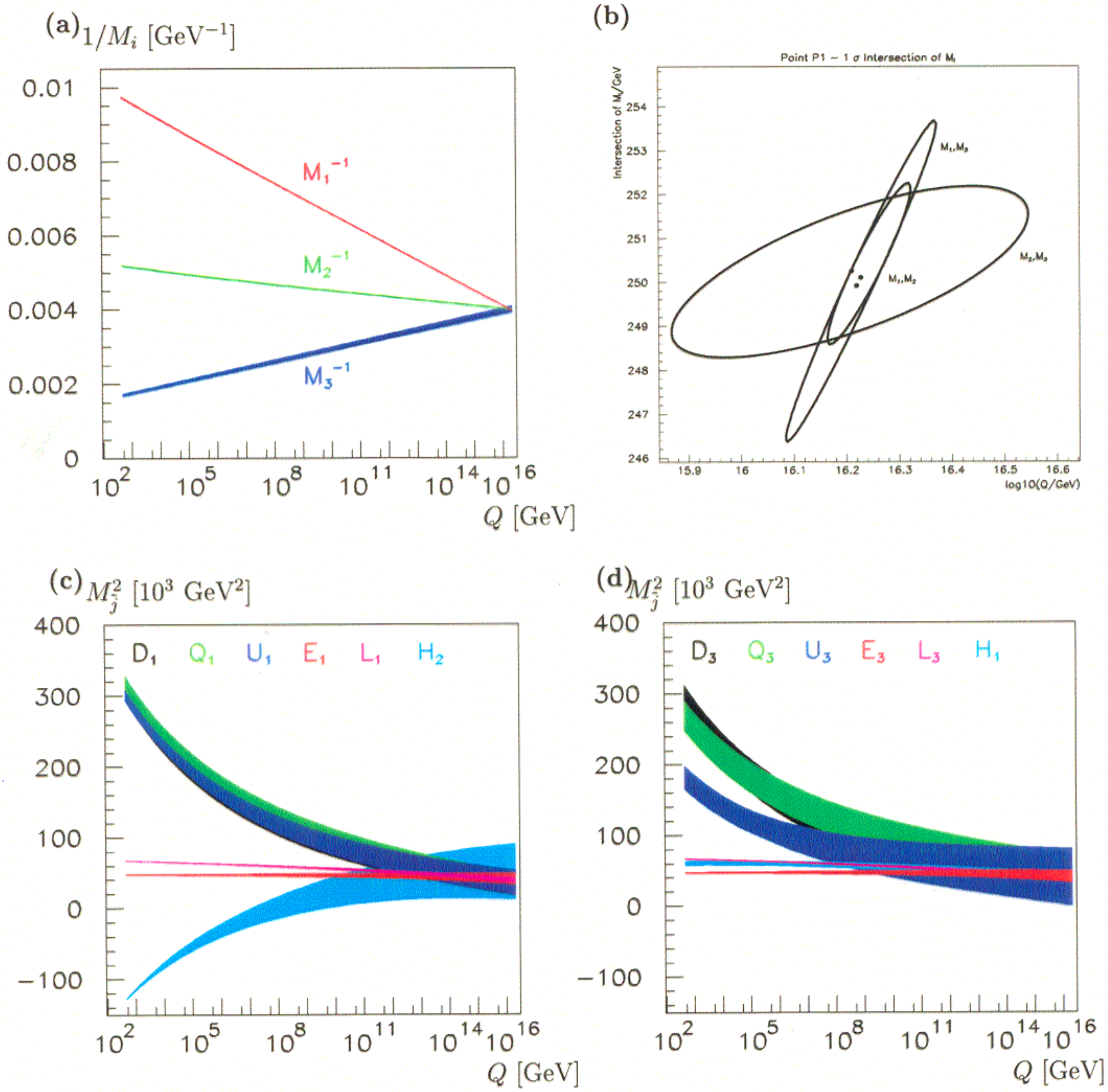
mSUGRA Parameters:

$$M_{1/2} = 250.20 \pm 0.33 \text{ GeV}$$
$$\tilde{M}_0^2 = (3.97 \pm 0.41) \cdot 10^4 \text{ GeV}^2$$
$$A_0 = -97 \pm 54 \text{ GeV}$$


(a) 1/M_i [GeV^-1]
0.01
0.008
0.006
0.004
0.002
0
M_1^-1
M_2^-1
M_3^-1
10^2 10^5 10^8 10^11 10^14 10^16
Q [GeV]
(b)
Point P1 – 1 σ Intersection of M_i
Intersection of M_i/GeV
254
253
252
251
250
249
248
247
246
M_1,M_3
M_2,M_3
M_1,M_2
15.9 16 16.1 16.2 16.3 16.4 16.5 16.6
log10(Q/GeV)
(c) M_j^2 [10^3 GeV^2]
400
300
200
100
0
−100
D_1 Q_1 U_1 E_1 L_1 H_2
10^2 10^5 10^8 10^11 10^14 10^16
Q [GeV]
(d) M_j^2 [10^3 GeV^2]
400
300
200
100
0
−100
D_3 Q_3 U_3 E_3 L_3 H_1
10^2 10^5 10^8 10^11 10^14 10^16
Q [GeV]

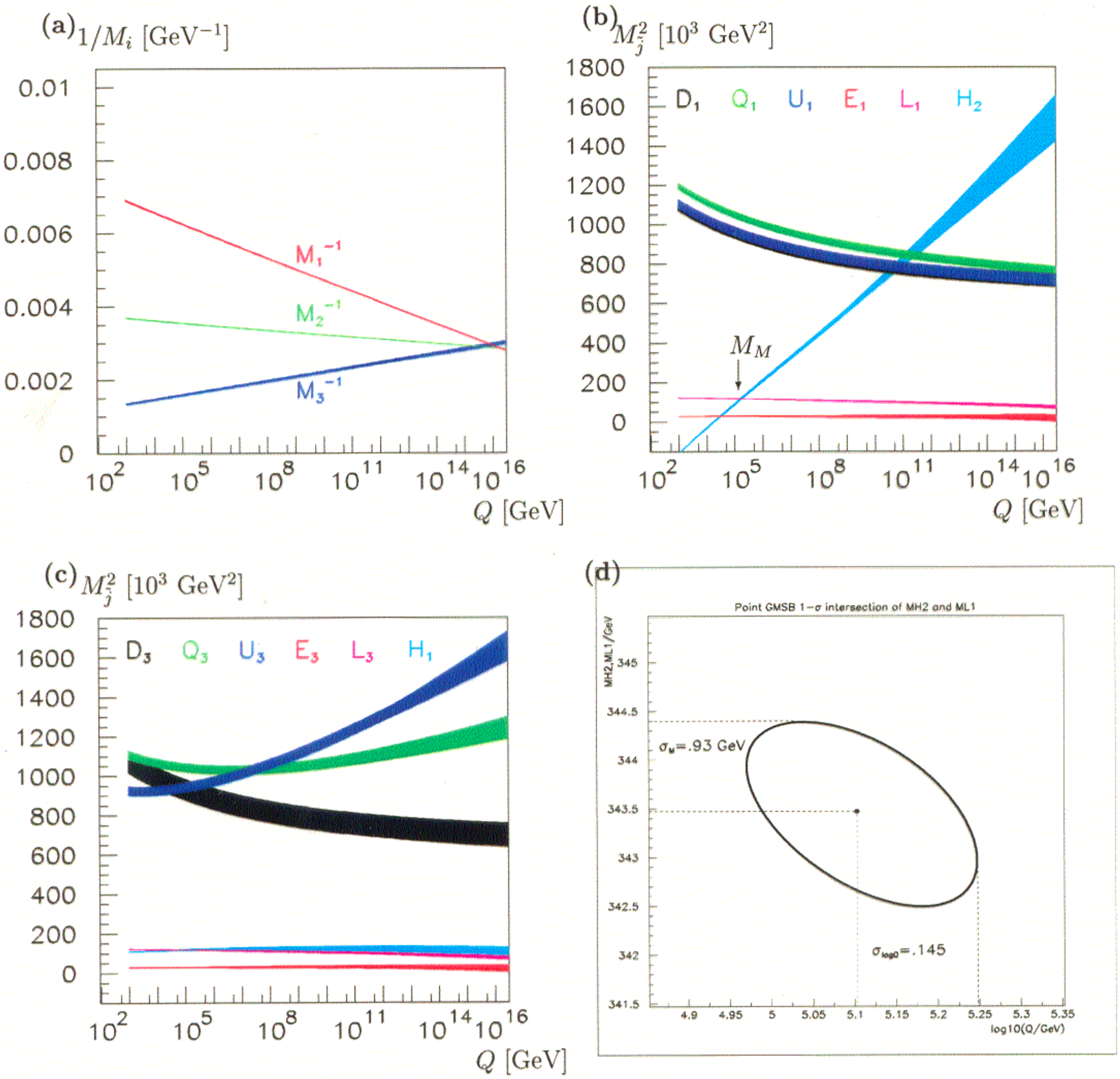
<u>REMARKS:</u> a) mSUGRA extended to LR-SUGRA: estimate of M_{ν_R}
b) mSUGRA extrapolation wildly different from GMSB: sensitivity to SUSY breaking

2.) STRING EFFECTIVE FIELD THEORY

Example: <u>Orbifold compactification of heterotic string:</u>

SUSY breaking / masses of gauginos and fermions
$\leftarrow$ generated, non-perturbatively, by string induced superposition of vacuum fields:

$\tilde{G} = \sin\theta\,\tilde{S} + \cos\theta\,\tilde{T}$: $\tilde{G}$ = gravitino field
$\tilde{S}$ = dilaton field
$\tilde{T}$ = (universal) moduli fields


(a) 1/M_i [GeV^-1]
0.01
0.008
0.006
0.004
0.002
0
M_1^-1
M_2^-1
M_3^-1
10^2 10^5 10^8 10^11 10^14 10^16
Q [GeV]
(b) M_j^2 [10^3 GeV^2]
1800
1600
1400
1200
1000
800
600
400
200
0
D_1 Q_1 U_1 E_1 L_1 H_2
M_M
10^2 10^5 10^8 10^11 10^14 10^16
Q [GeV]
(c) M_j^2 [10^3 GeV^2]
1800
1600
1400
1200
1000
800
600
400
200
0
D_3 Q_3 U_3 E_3 L_3 H_1
10^2 10^5 10^8 10^11 10^14 10^16
Q [GeV]
(d)
Point GMSB 1−σ intersection of MH2 and ML1
MH2,ML1/GeV
345
344.5
344
343.5
343
342.5
342
341.5
σ_M=.93 GeV
σ_logQ=.145
4.9 4.95 5 5.05 5.1 5.15 5.2 5.25 5.3 5.35
log10(Q/GeV)

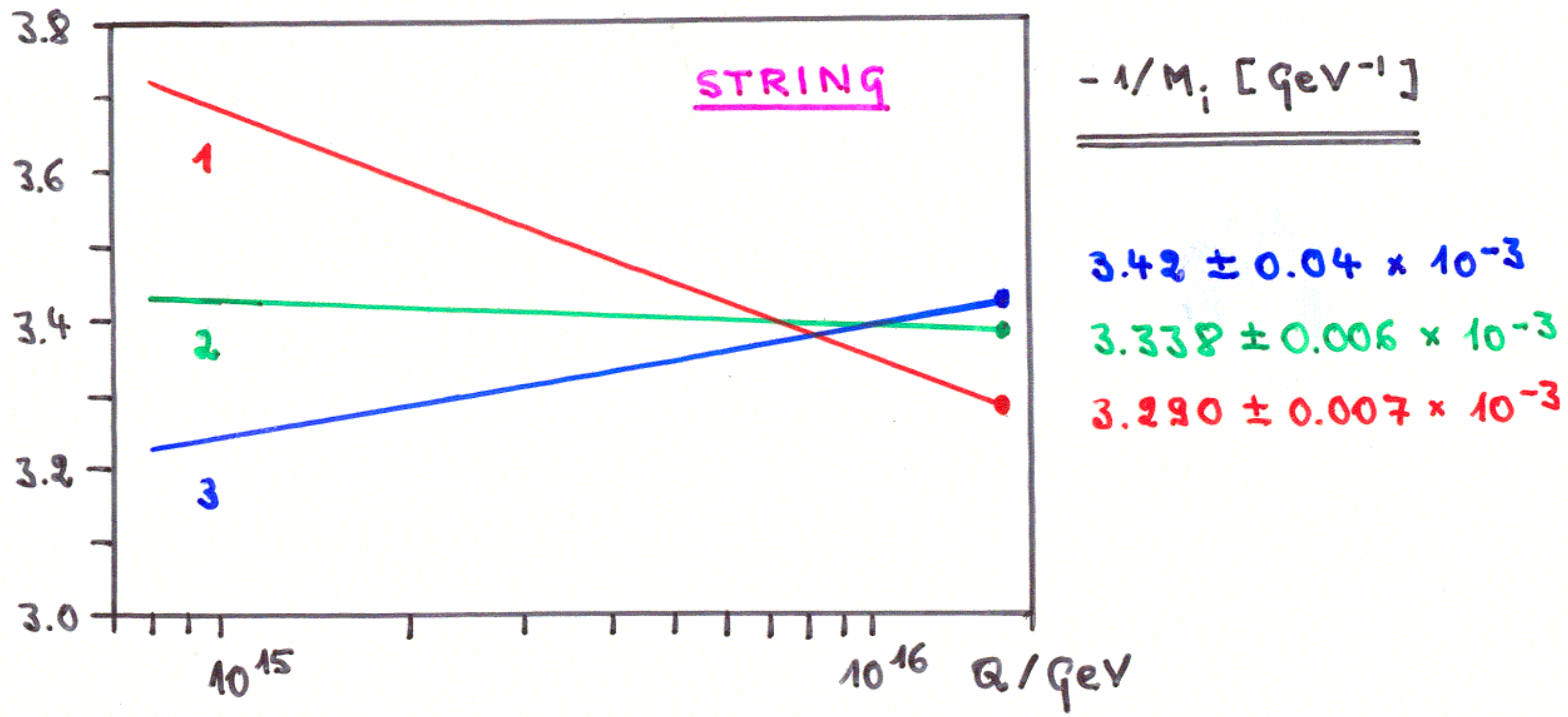
Task: determine string effective field parameters after extrapolation of masses, etc. to high scale:

$\alpha_i, M_i, \tilde{M}_j^2 \rightarrow$	gravitino mass	:	$m_{3/2}$
	dilaton, moduli fields	:	$\langle S \rangle$, $\langle T \rangle$
	. . . and mixing	:	$\sin\theta$
	modular weights, matter	:	n_j

$$M_i = \sqrt{3}\, g_i^2\, m_{3/2} \sin\theta \, \langle S \rangle \left[1 + \text{h.o.}\,(i, \delta_{\mathrm{GS}})\right]$$
$$\tilde{M}_j = m_{3/2}\,(1 + n_j \cos\theta) + \text{h.o.}$$

F : a) small but significant h.o. deviations from universal gaugino masses at high scale

b) dito for scalar masses



STRING
3.8
3.6
3.4
3.2
3.0
1
2
3
10^{15}
10^{16}
Q / GeV
$-1/M_i$ [GeV^{-1}]
$3.42 \pm 0.04 \times 10^{-3}$
$3.338 \pm 0.006 \times 10^{-3}$
$3.290 \pm 0.007 \times 10^{-3}$

RESULTS:

	ideal	exp. analysis
$m_{3/2}$	180 GeV	179.9 ± 0.1 GeV
$\langle S \rangle$	2	2.13 ± 0.08
$\langle T \rangle$	14	13.6 ± 0.2
δ_{GS}	0	-0.06 ± 0.02
n_{H_1}	-1	-1.06 ± 0.02
n_L	-3	-3.03 ± 0.02
n_Q	0	-0.02 ± 0.01

F

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3.) CONCLUSIONS

RG extrapolation of precisely measured SUSY parameters:

→ reconstruction of supersymmetric theory at high scale
exploring fundamental mechanism of SUSY breaking

→ determination of effective string parameters