

Reconstructing Supersymmetric Theories

by Coherent LHC/LC Analyses

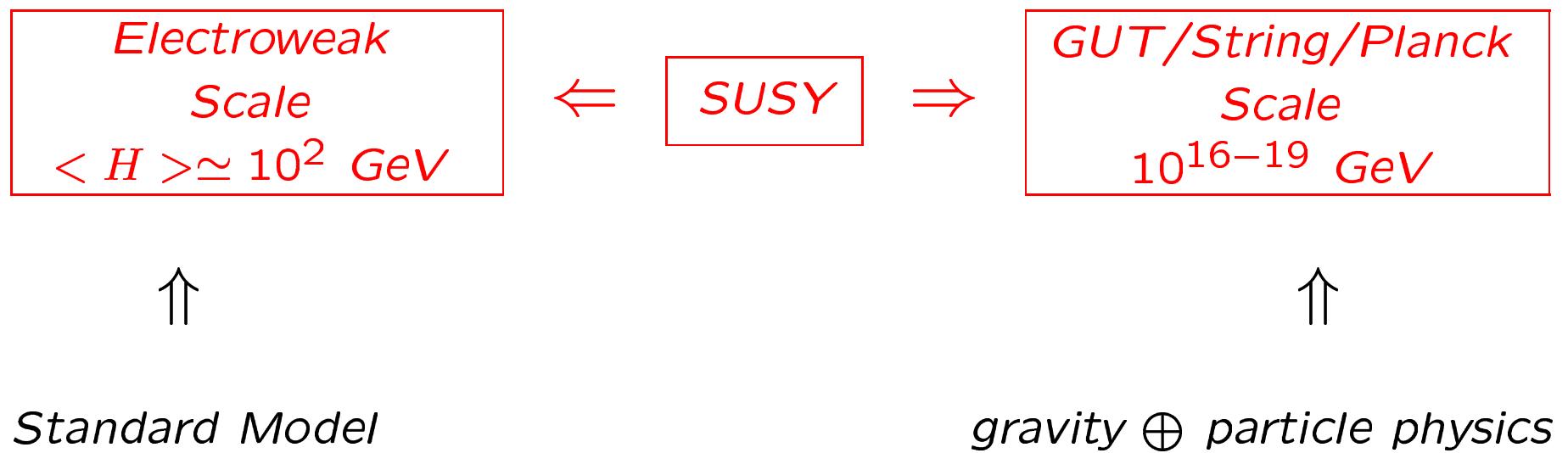
Werner Porod

LCWS04, Paris '04

work done in collaboration with B. C. Allanach, G. A. Blair, S. Kraml,
H. U. Martyn, G. Polesello, and P. M. Zerwas,

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Two Scale Picture of Nature



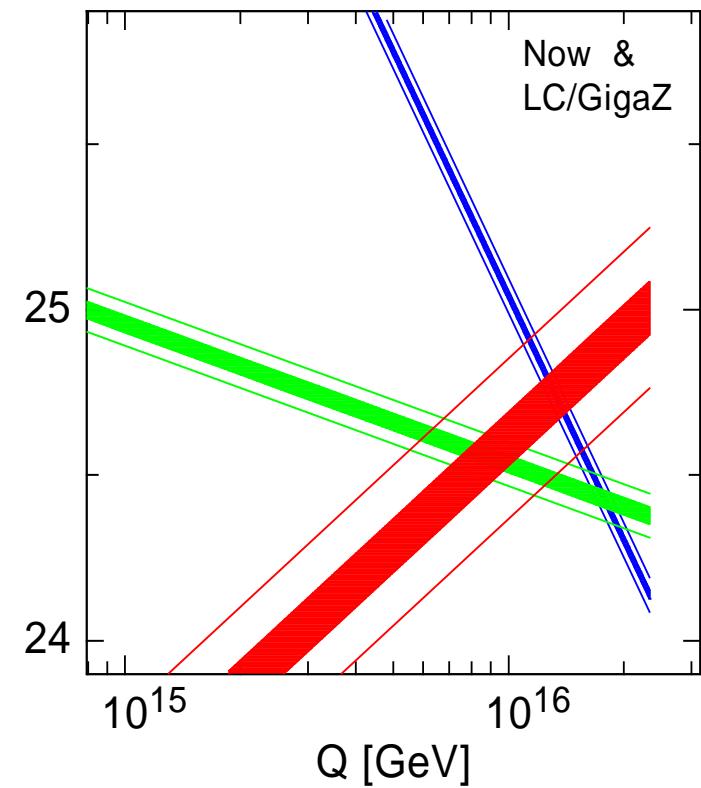
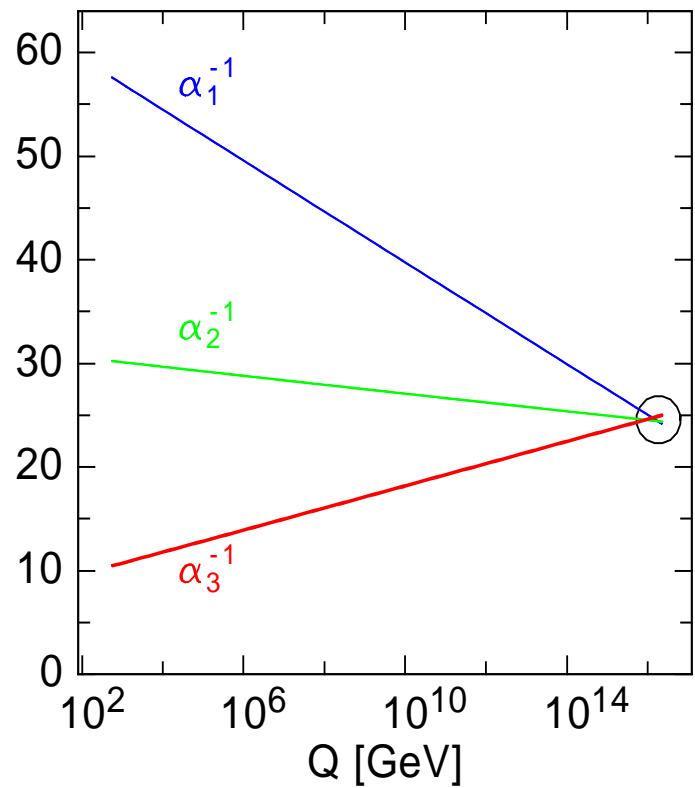
Exploring high scale structures (GUT,PL ...)

- *Proton decay*
- *Cosmology at early time of the universe*
- *Neutrino physics (see-saw), fermion mass textures*
- *Extrapolation of high precision parameters:
gauge and Yukawa couplings
SUSY parameters*

Experimental information

- *LEP/Tevatron:*
Higgs heavier than 114 GeV
charginos/sleptons heavier than 100 GeV
squarks (except \tilde{t}, \tilde{b}), gluinos heavier than 200 GeV
- *rare decays:*
bounds on flavour violation beyond CKM
- *Cold dark matter: $\Omega h^2 \lesssim 0.13$*
⇒ *talks by Peskin, Baer, Battaglia, Zhang, Belanger*
- *high precision measurements of gauge couplings*
⇒ *unification if SUSY is present*

Evolution of gauge couplings



Supersymmetry breaking

mSUGRA: $M_0, M_{1/2}, A_0, \tan\beta, \text{sign}(\mu)$

GMSB: $M_m = \lambda S, \Lambda = F/S, \tan\beta, \text{sign}(\mu)$

$$M_{1/2} = g(x)n_5\alpha_i\Lambda, M_i^2 = f(x)n_5 \sum C_i\alpha_i^2\Lambda^2, x = \Lambda/M_m$$

String effective field theories: $m_{3/2}, s, t_i, \sin\vartheta, n_i, \tan\beta, \text{sign}(\mu)$

$$M_{1/2} = -\sqrt{3}g^2m_{3/2}s\sin\vartheta, M_i^2 = m_{3/2}^2(1 + n_i\cos^2\vartheta)$$

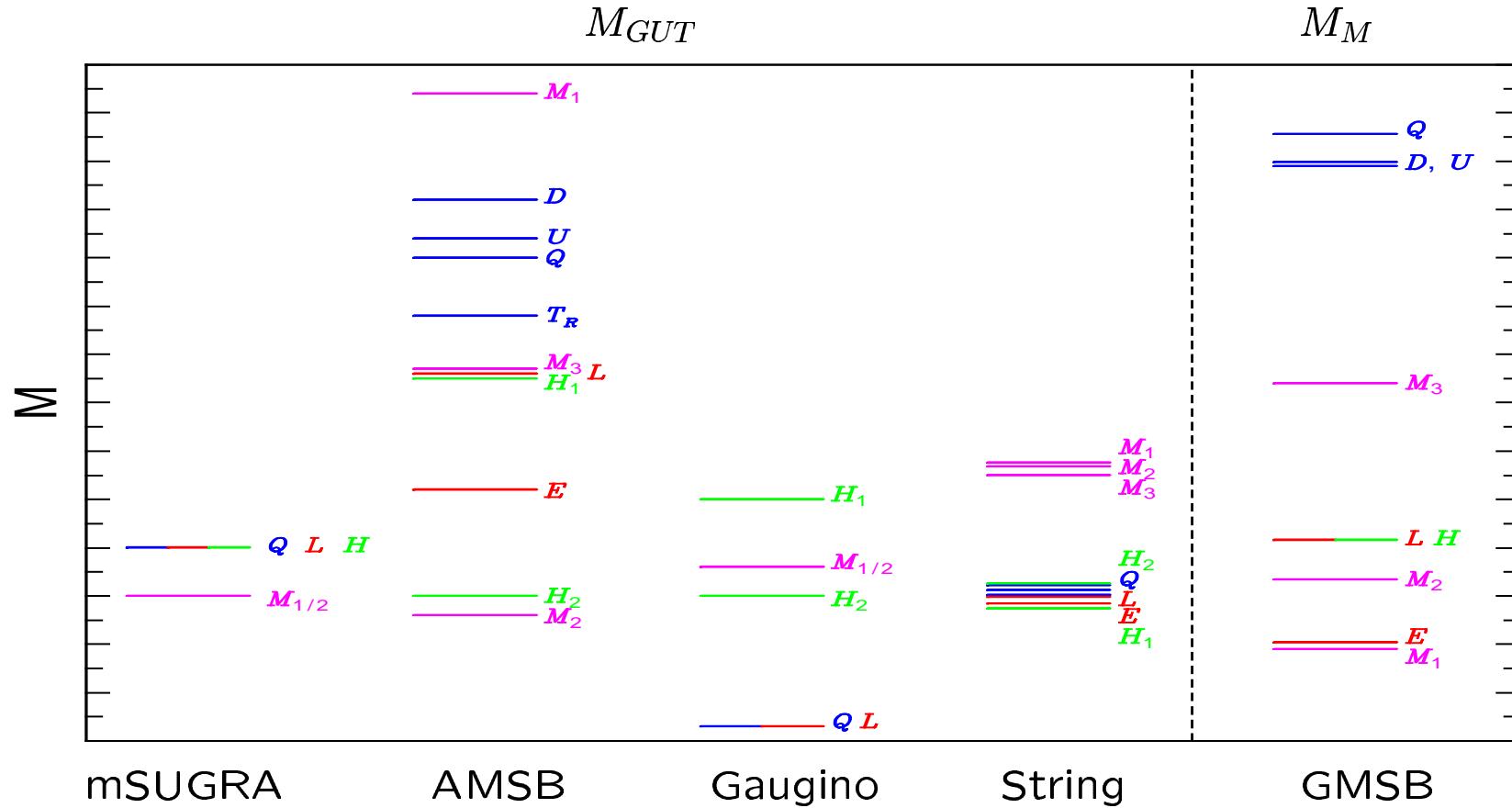
AMSB: $m_{3/2}, M_0, \tan\beta, \text{sign}(\mu)$

$$M_j = \frac{\beta_i}{g}m_{3/2}, M_i^2 = -\frac{\dot{\gamma}_i}{4}m_{3/2}^2 + c_iM_0^2, A_k = -\frac{\gamma_k}{2}m_{3/2}$$

Gaugino mediated / brane induced: $M_{1/2}, \tan\beta, \text{sign}(\mu)$

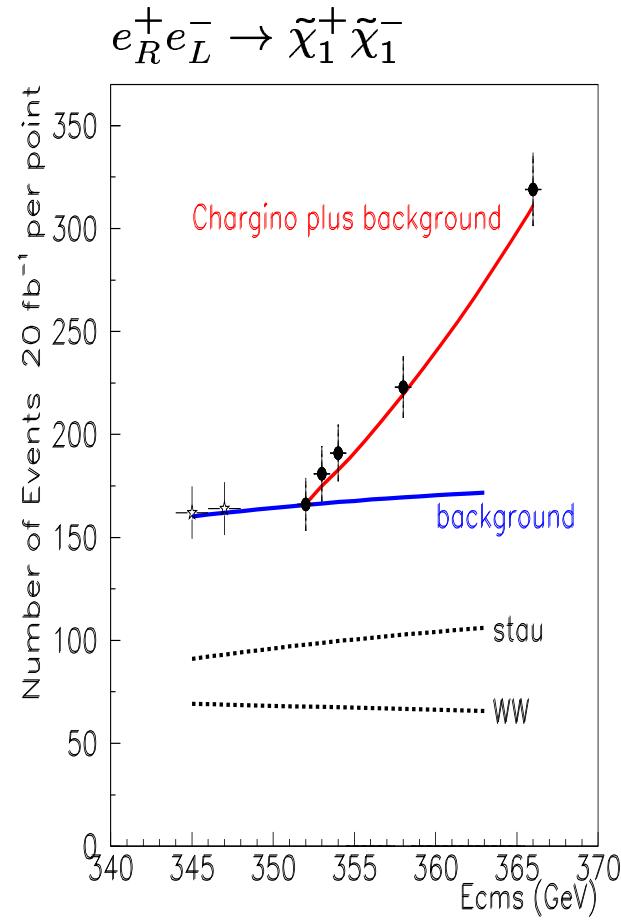
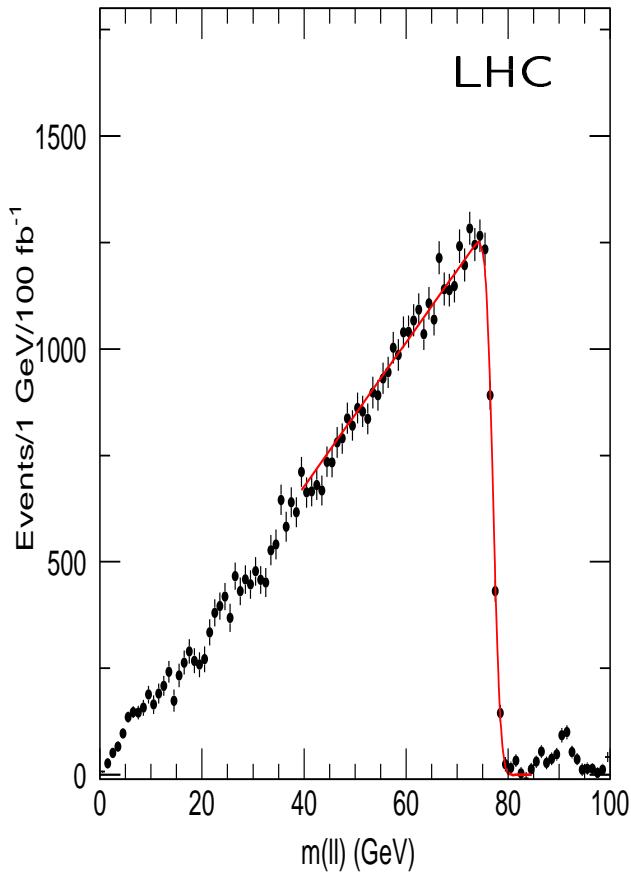
$$M_{H_i} = O(M_{1/2}), M_{\tilde{F}}^2 = O\left(\frac{M_{1/2}^2}{16\pi^2}\right), A = O\left(\frac{M_{1/2}}{16\pi^2}\right)$$

Regularities at High Scales

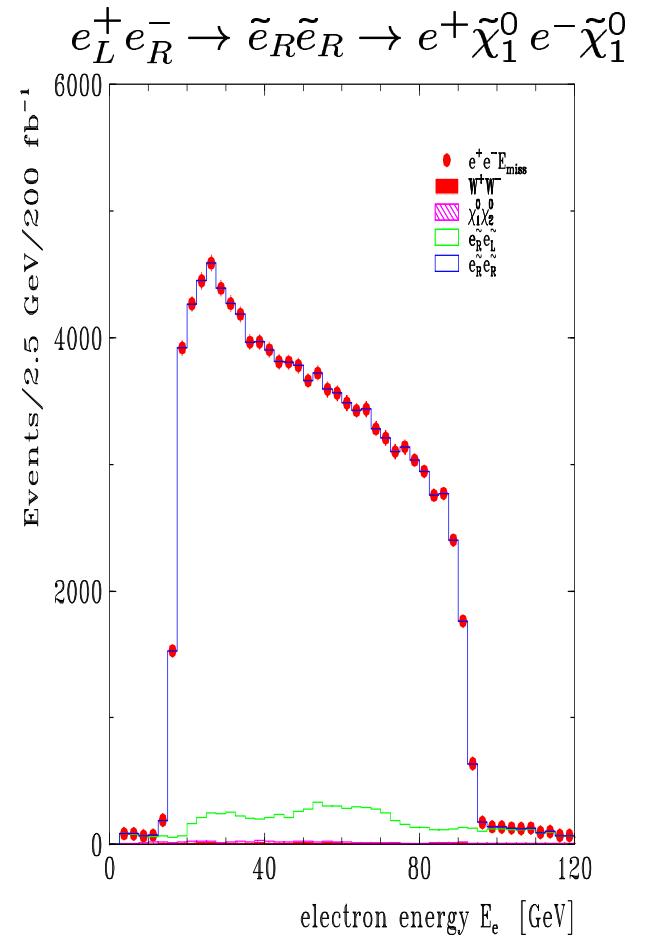


Mass measurements

G. Polesello



B. Blair, U. Martyn



Expected Accuracies

mSugra: $M_0 = 100$ GeV, $M_{1/2} = 250$ GeV, $A_0 = -100$ GeV, $\tan \beta = 10$

	<i>Mass, ideal</i>	"LHC"	"LC"	"LHC+LC"
$\tilde{\chi}_1^\pm$	179.7		0.55	0.55
$\tilde{\chi}_1^0$	97.2	4.8	0.05	0.05
$\tilde{\chi}_2^0$	180.7	4.7	1.2	0.08
$\tilde{\chi}_4^0$	381.9	5.1	3-5	2.23
\tilde{e}_R	143.9	4.8	0.05	0.05
\tilde{e}_L	207.1	5.0	0.2	0.2
$\tilde{\nu}_e$	191.3	—	1.2	1.2
$\tilde{\tau}_1$	134.8	5-8	0.3	0.3
\tilde{q}_R	547.6	7-12	—	5-11
\tilde{q}_L	570.6	8.7	—	4.9
\tilde{t}_1	399.5		2.0	2.0
\tilde{b}_1	515.1	7.5	—	5.7
\tilde{g}	604.0	8.0	—	6.5
h^0	110.8	0.25	0.05	0.05
H^0	399.8		1.5	1.5

Low Energy Parameters

Measurements:

masses
cross sections
distributions of leptons & jets

↓ *Procedure similar as described by P. Wienemann*

SUSY parameters:

gaugino parameters M_i
scalar masses: $M_{H_i}^2, M_E^2, M_L^2, \dots$
Higgs/Higgsino parameters: $\mu, \tan \beta$
trilinear couplings: A_t, A_b, A_τ

RGE structures

implicit solutions:

$$\begin{aligned}M_i &= Z_i M_{1/2} \\M_{\tilde{j}}^2 &= M_0^2 + c_j M_{1/2}^2 + c'_{j\beta} \Delta M_\beta^2 \\A_k &= d_k A_0 + d'_k M_{1/2}\end{aligned}$$

explicit solutions:

$$\begin{aligned}M_1 &= 0.41 M_{1/2} && \Rightarrow M_{1/2} \text{ easy} \\M_L^2 &= M_{0,L}^2 + 0.47 M_{1/2}^2 && \Rightarrow M_{0,L} \text{ easy} \\M_Q^2 &= M_{0,Q}^2 + 5.1 M_{1/2}^2 && \Rightarrow M_{0,Q} \text{ difficult} \\M_{H_2}^2 &= -0.03 M_{0,H}^2 - 1.34 M_{1/2}^2 + \dots && \Rightarrow M_{0,H} \text{ very difficult}\end{aligned}$$

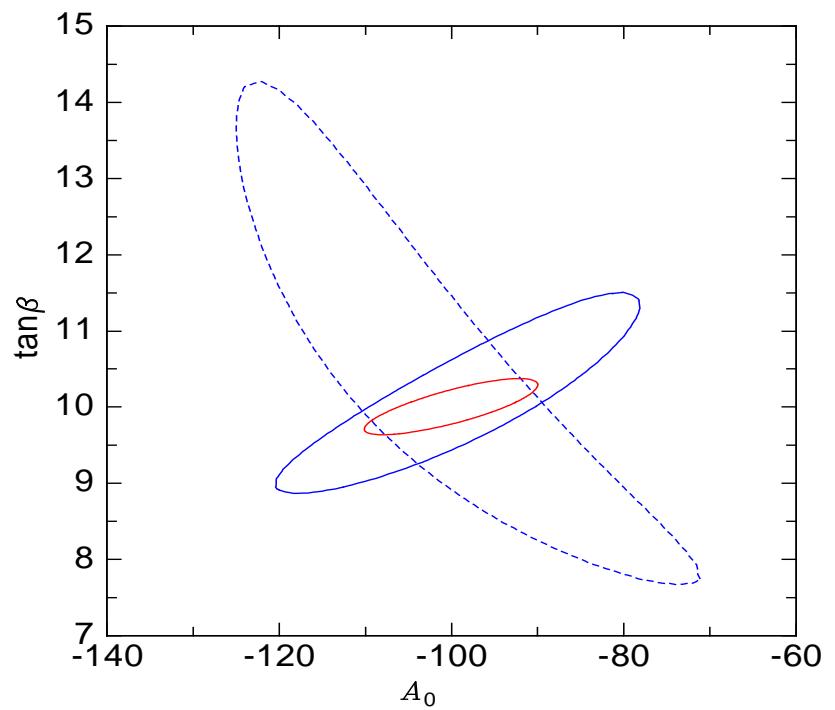
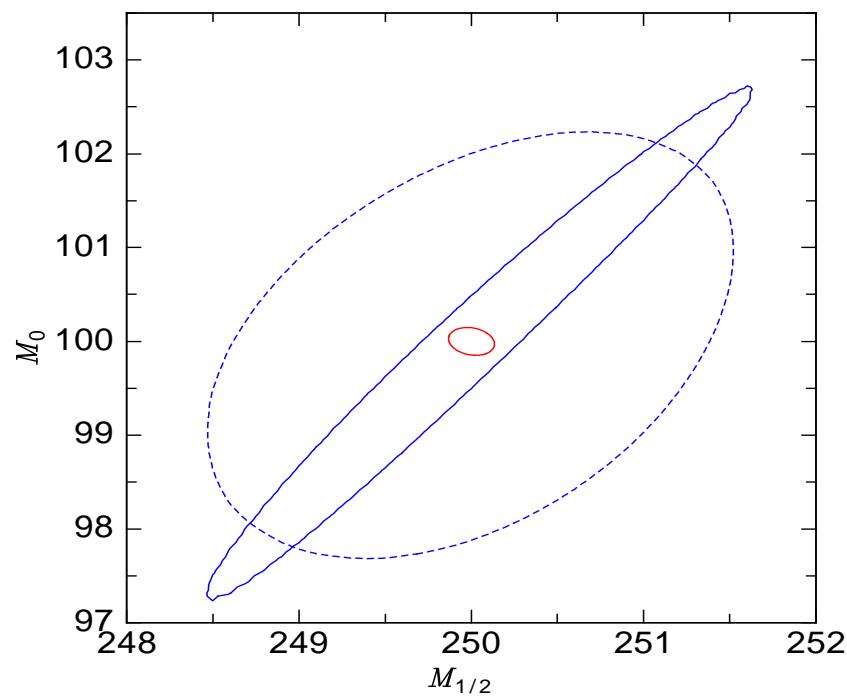
Test of high scale models

Two methods:

- *Top-Down*
 - + does not require complete spectrum
 - model-dependent
- *Bottom-Up*
 - + does not depend on high scale model
 - requires complete spectrum

mSUGRA, Top-Down

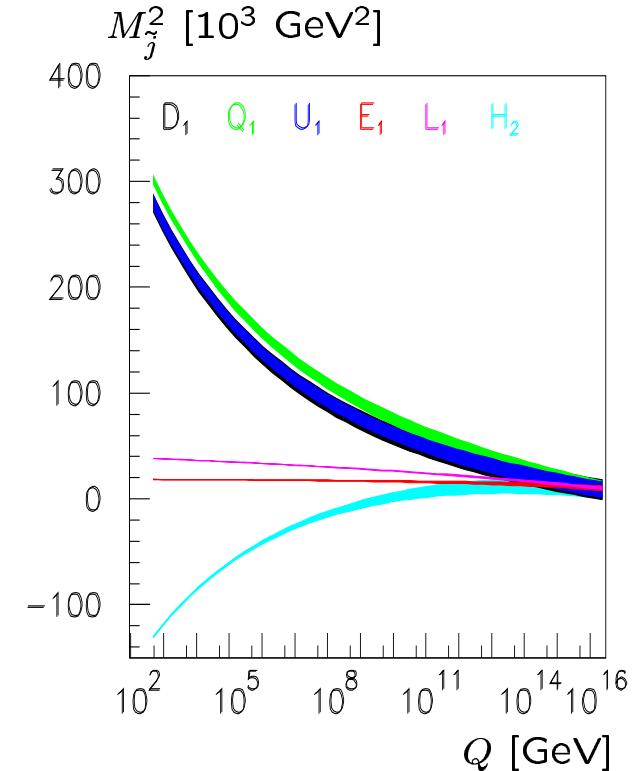
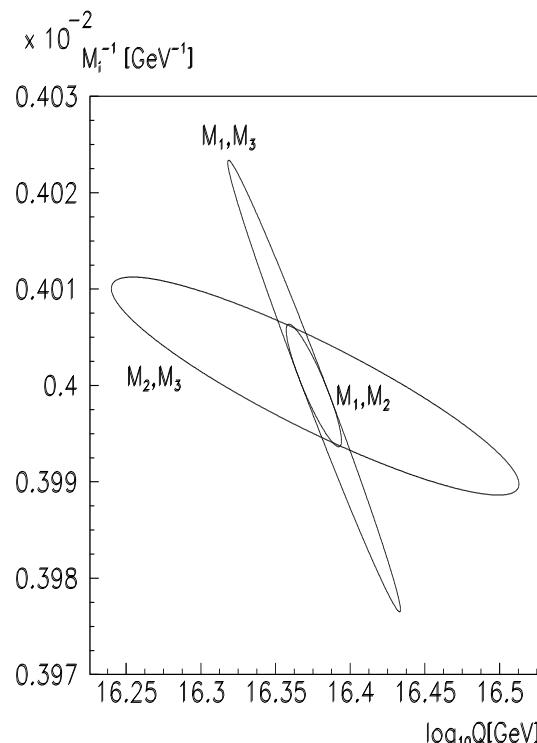
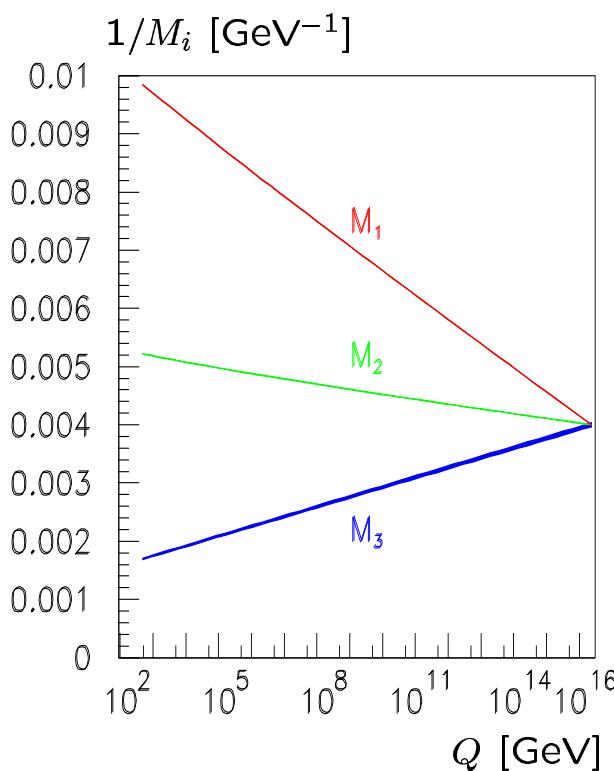
$\tan \beta = 10, M_0 = 200 \text{ GeV}, M_{1/2} = 250 \text{ GeV}, A_0 = -100,$
 $\text{sign}(\mu) = 1$ (1σ errors)



- “LHC”, experimental errors
- - - “LHC”, experimental errors + todays theoretical error (scale dep.)
- “LHC+LC”, experimental errors

mSUGRA, Bottom-Up

$\tan \beta = 10, M_0 = 100 \text{ GeV}, M_{1/2} = 250 \text{ GeV}, A_0 = -100,$
 $\text{sign}(\mu) = 1$



1 σ error bands
"LHC+LC" analyses

mSUGRA + $\tilde{\nu}_R$

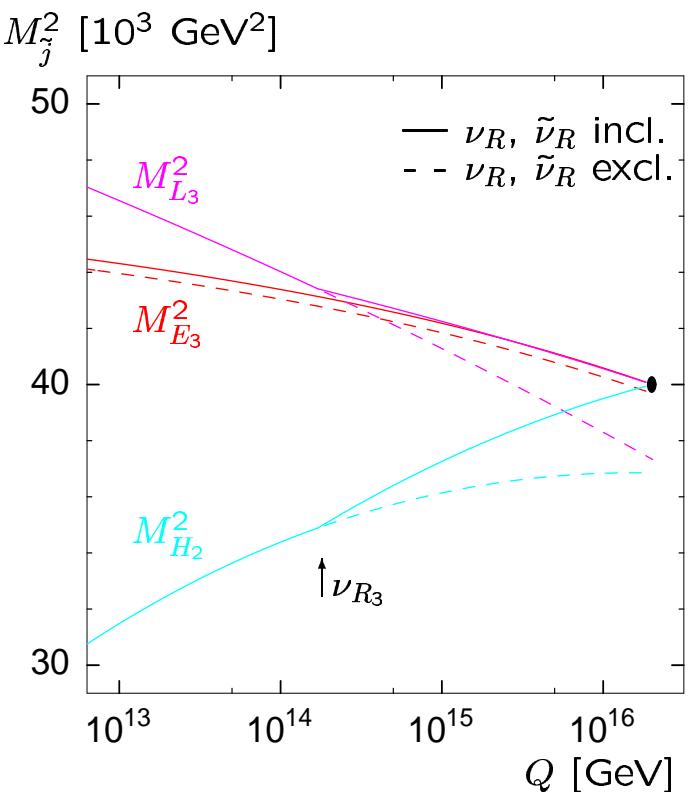
$$m^2 = \begin{pmatrix} M_{\tilde{L}}^2 + \text{D term} & M_{LR}^2 \\ M_{LR}^2 & M_{\tilde{R}}^2 + M_{\tilde{\nu}_R}^2 \end{pmatrix}$$

$$M_{LR}^2 = \frac{1}{\sqrt{2}} Y_\nu (A_\nu v_2 - \mu v_1)$$

$$m_{\tilde{\nu}_1}^2 \simeq M_L^2 + \text{D term} - M_{LR}^4/M_{\tilde{\nu}_R}^2$$

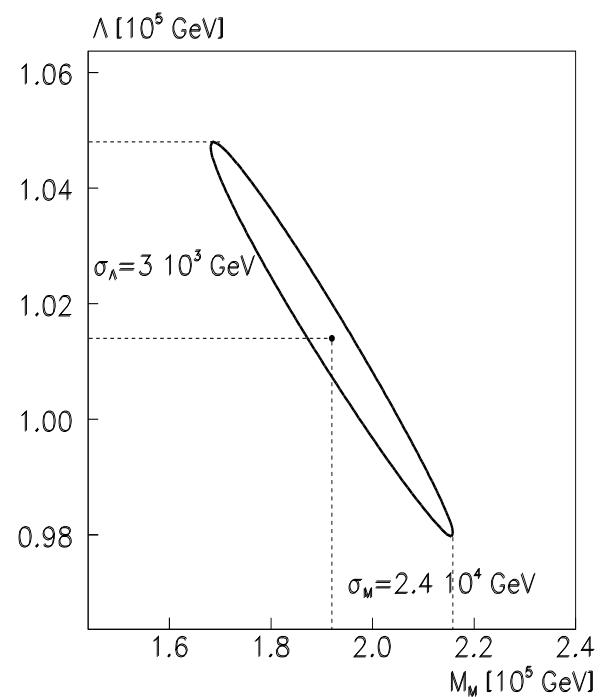
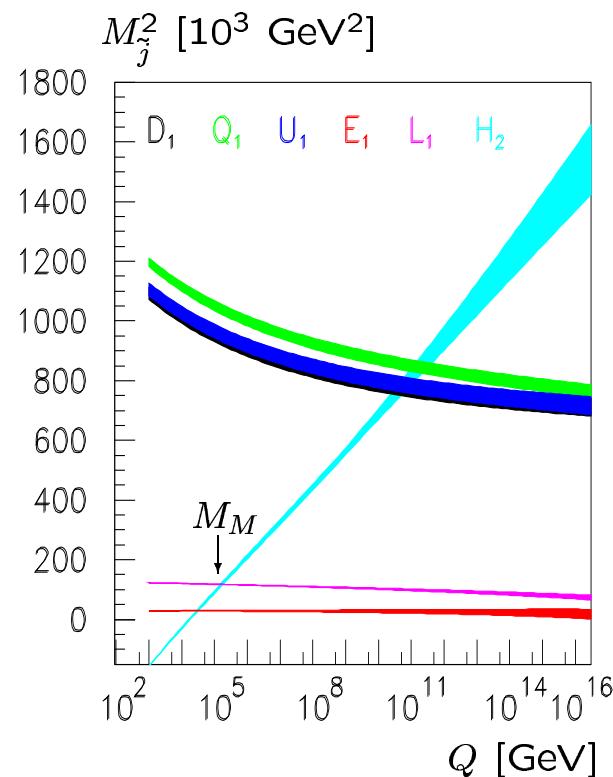
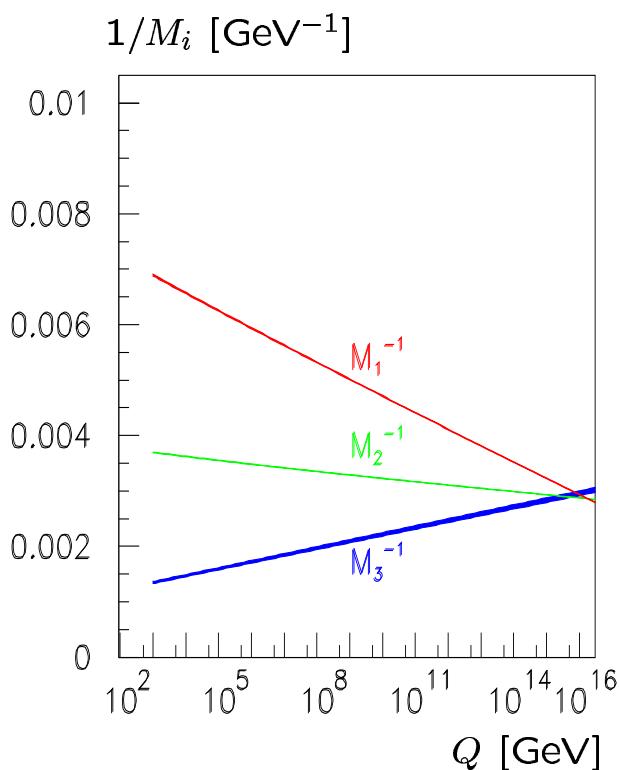
$$m_{\tilde{\nu}_2}^2 \simeq M_{\tilde{\nu}_R}^2 + M_{\tilde{R}}^2 + M_{LR}^4/M_{\tilde{\nu}_R}^2$$

$\tan \beta = 10, M_0 = 200 \text{ GeV},$
 $M_{1/2} = 250 \text{ GeV}, A_0 =$
 $-100 \text{ GeV}, \text{sign}(\mu) = 1,$
 $m_{\tilde{\nu}_{R,3}} = 1.7 \cdot 10^{14} \text{ GeV}$



GMSB

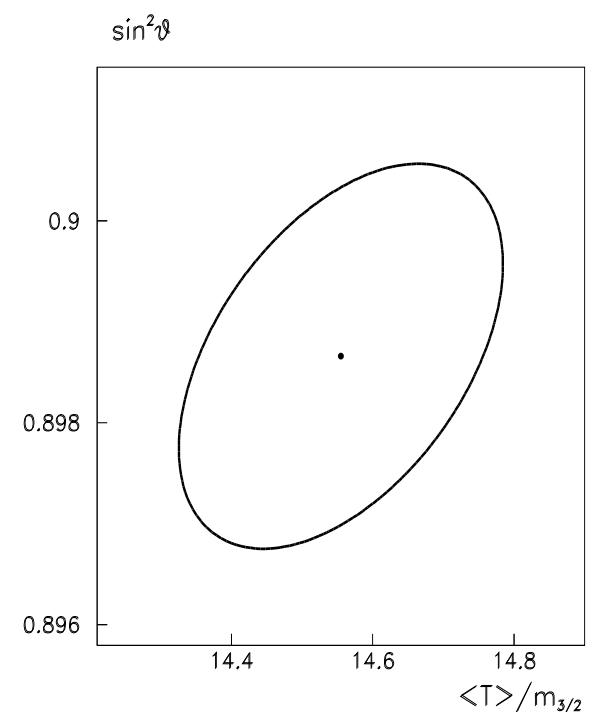
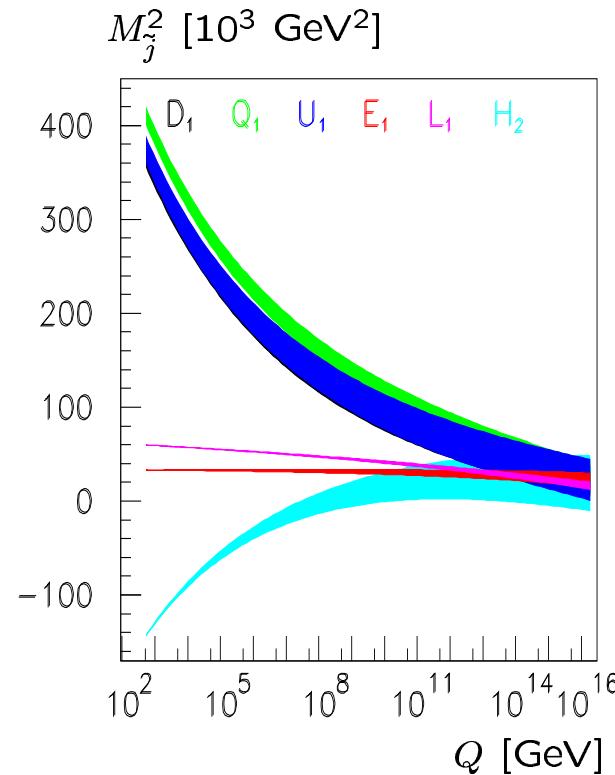
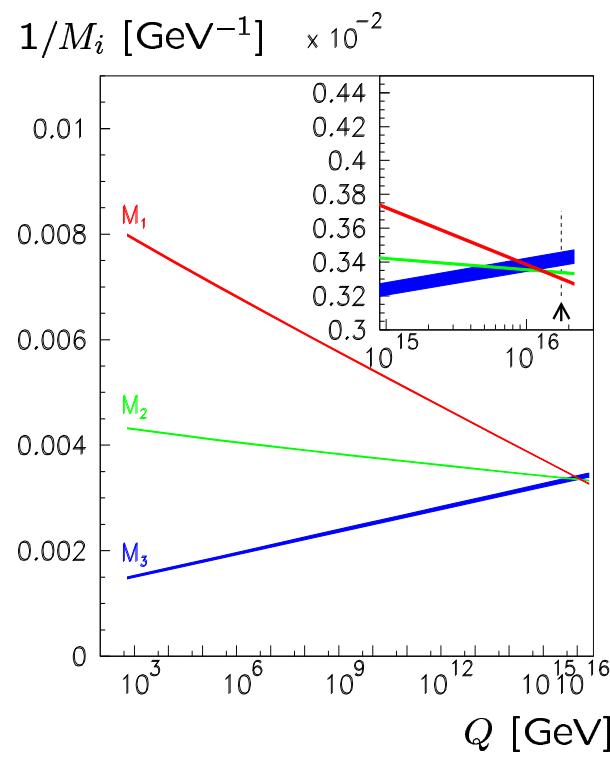
$M_M = 200 \text{ TeV}$, $\Lambda = 100 \text{ TeV}$, $N_5 = 1$, $\tan\beta = 15$, $A_0 = 0$,
 $\text{sign}(\mu) = 1$



1 σ error bands

String Effective Field Theory

$\tan \beta = 10, M_{3/2} = 180 \text{ GeV}, \sin^2 \vartheta = 0.9, O-I, n_Q = 0, n_D = 1, n_U = -2, n_L = -3, n_E = -1, \text{ and } n_{H_1} = n_{H_2} = -1, \text{ sign}(\mu) = -1$



1σ error bands

String Parameter Determination

$m_{3/2}$	180	179.9 ± 0.4
t	14	14.6 ± 0.2
$\langle s \rangle$	2	1.998 ± 0.006
δ_{GS}	0	0.1 ± 0.4
$\tan \beta$	10	10 ± 0.1
n_{H_2}	-1	-1.00 ± 0.02
n_L	-3	-2.94 ± 0.04
n_E	-1	-1.00 ± 0.05
n_Q	0	0.02 ± 0.02

Trying OII scheme:

$n_E = -1.4 \pm 0.02$, similar for other n_i , and $\chi^2 = O(10^2)$

Trying mSUGRA scheme: errors in the per-cent range, $\chi^2 = O(10^2)$

Summary

- *Reconstruction of the underlying high scale theory is feasible*
- *LHC measurements + high precision measurements at future e^+e^- colliders are necessary*