Testing SUSY Unification

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Two Scale Picture of Nature

Electroweak Scale $< H > \simeq 10^2$ *GeV*	$\Leftarrow$	$\Rightarrow$	*GUT/String/Planck Scale* 10^{16-19} *GeV*
$\Uparrow$			$\Uparrow$
Standard Model			*gravity* $\oplus$ *particle physics*

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Electroweak Scale $< H > \simeq 10^2$ GeV	$\Leftarrow$	SUSY	$\Rightarrow$	GUT/String/Planck Scale 10^{16-19} GeV
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SUSY: allows also for gauge coupling unification, radiative electroweak symmetry breaking, . . .

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

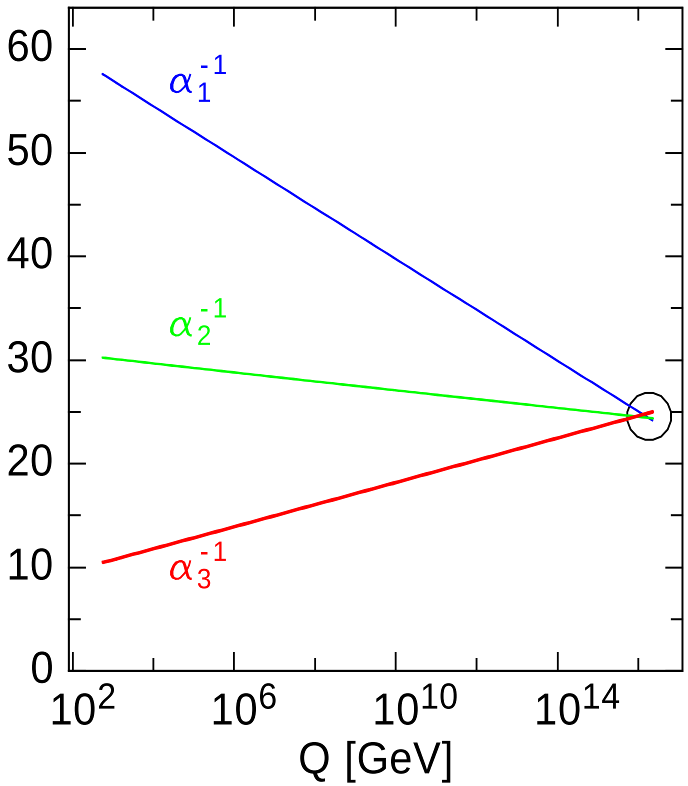
- *LEP/Tevatron:*
  Higgs heavier than 100 GeV
  charginos/sleptons heavier than 100 GeV
  squarks (except $\tilde{t}, \tilde{b}$), gluinos heavier than 200 GeV

- *rare decays:*
  bounds on flavour violation beyond CKM

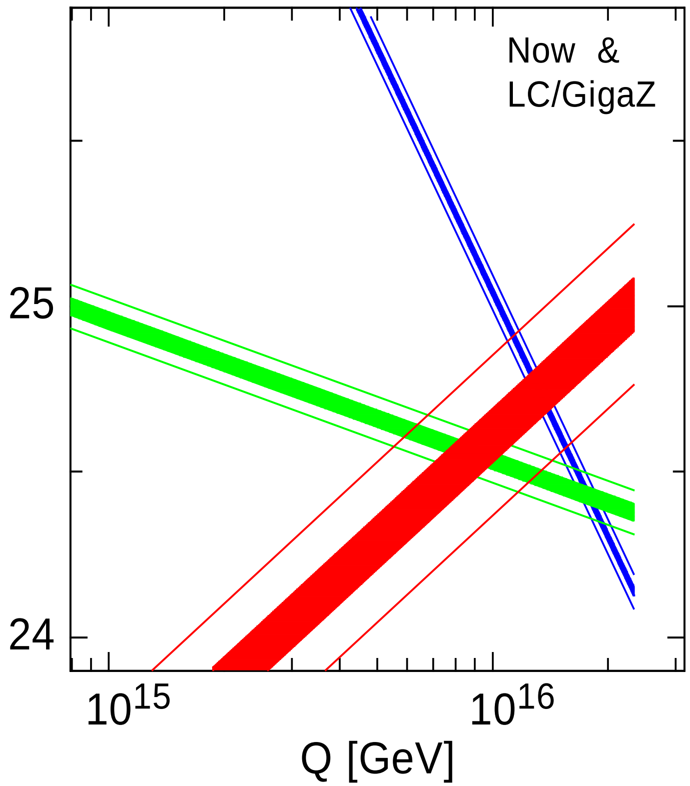
- *Cold dark matter:* $\Omega h^2 \lesssim 0.11$

- *high precision measurements of gauge couplings*
  $\Rightarrow$ *unification if SUSY is present*

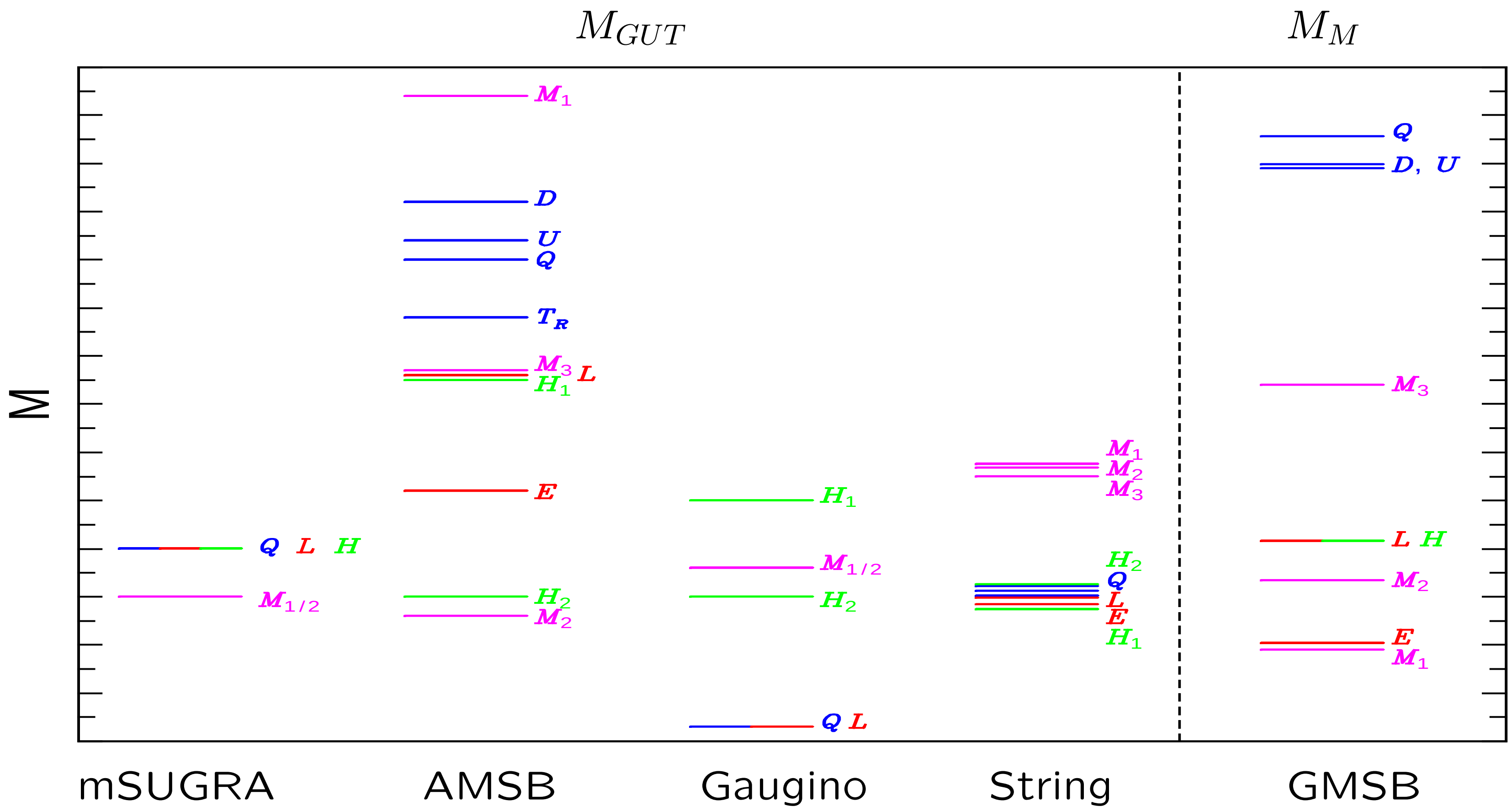
Evolution of gauge couplings



$\Rightarrow$



Regularities at High Scales



Low Energy Parameters

Measurements:

- *masses*
- *cross sections*
- *polarization*

$\Downarrow$

SUSY parameters:

- *gaugino parameters* M_i
- *scalar masses:* $M^2_{H_i}$, M^2_E, M^2_L, ...
- *Higgs/Higgsino parameters:* μ, $\tan\beta$
- *trilinear couplings:* A_t, A_b, A_τ

Mass measurements, LHC

SPS1a (bulk region)
m_0 = 100 GeV,
$m_{1/2}$ = 250 GeV,
A_0 = -100 GeV,
$\tan(\beta)$=10 , μ>0

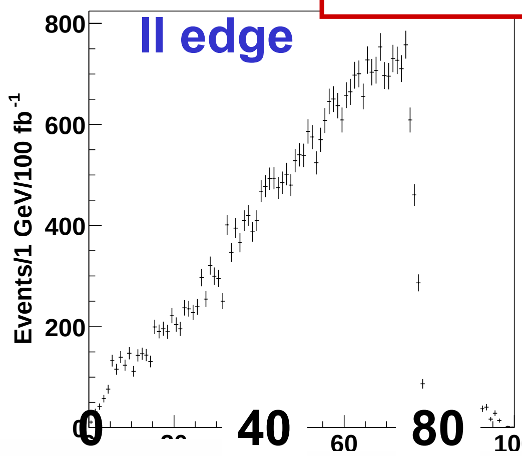
Left squark cascade decay

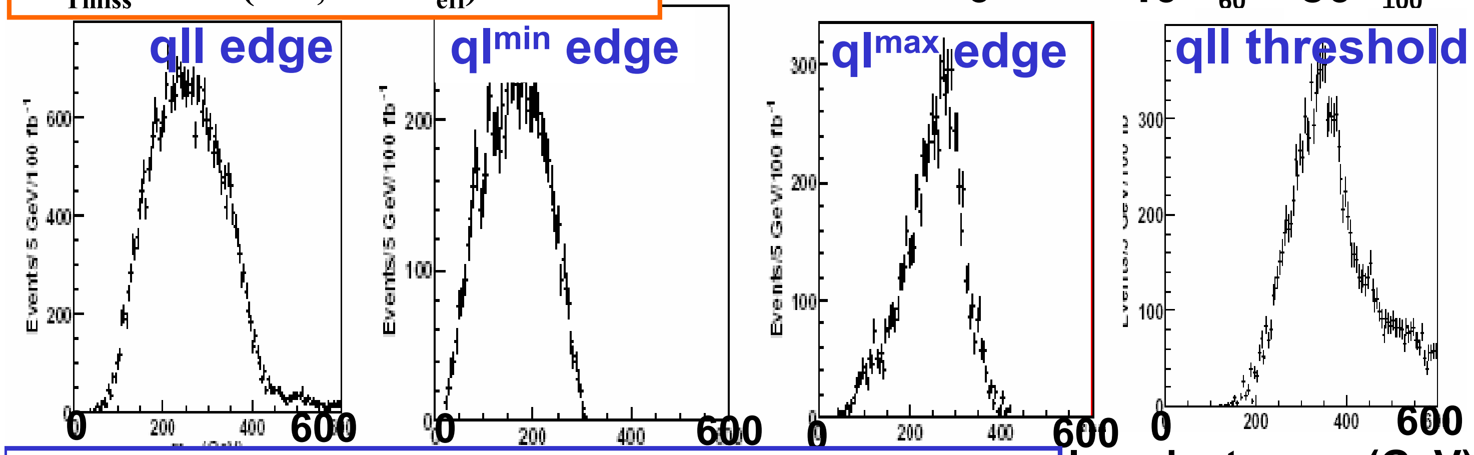
fast sim.

L=100 fb^{-1}

$$\tilde{q}_L \to \tilde{\chi}_2^0\, q \to \tilde{l}_R\, l\, q \to llq\, \tilde{\chi}_1^0$$

2 SFOS lep., p_T>20, 10 GeV
≥ 4 jets, p_T>150,100,50,50 GeV
M_{eff} > 600 GeV
E_{Tmiss} >max(100, 0.2 M_{eff})





Gjelsten, Lytken, Miller, Osland, Polesello, ATL-PHYS-2004-007

Mass measurements, LHC

L=100 fb^{-1}

Fit results

Edge	Nominal Value	Fit Value	Syst. Error Energy Scale	Statistical Error
$m(ll)^{\text{edge}}$	77.077	77.024	0.08	0.05
$m(qll)^{\text{edge}}$	431.1	431.3	4.3	2.4
$m(ql)^{\text{edge}}_{\text{min}}$	302.1	300.8	3.0	1.5
$m(ql)^{\text{edge}}_{\text{max}}$	380.3	379.4	3.8	1.8
$m(qll)^{\text{thres}}$	203.0	204.6	2.0	2.8

Mass reconstruction

5 endpoints measurements, 4 unknown masses

$$\chi^2 = \sum \chi_j^2 = \sum \left[\frac{E_j^{\text{theory}}(\vec{m}) - E_j^{\text{exp}}}{\sigma_i^{\text{exp}}} \right]^2$$

$$E_j^i = E_j^{\text{nom}} + a_j^i \sigma_j^{\text{fit}} + b^i \sigma_j^{Escale}$$

$m(\chi_1^0) =$ 96 GeV
$m(l_R) =$ 143 GeV
$m(\chi_2^0) =$ 177 GeV
$m(q_L) =$ 540 GeV

$\Delta m(\chi_1^0) =$ 4.8 GeV, $\Delta m(\chi_2^0) =$ 4.7 GeV,
$\Delta m(l_R) =$ 4.8 GeV, $\Delta m(q_L) =$ 8.7 GeV

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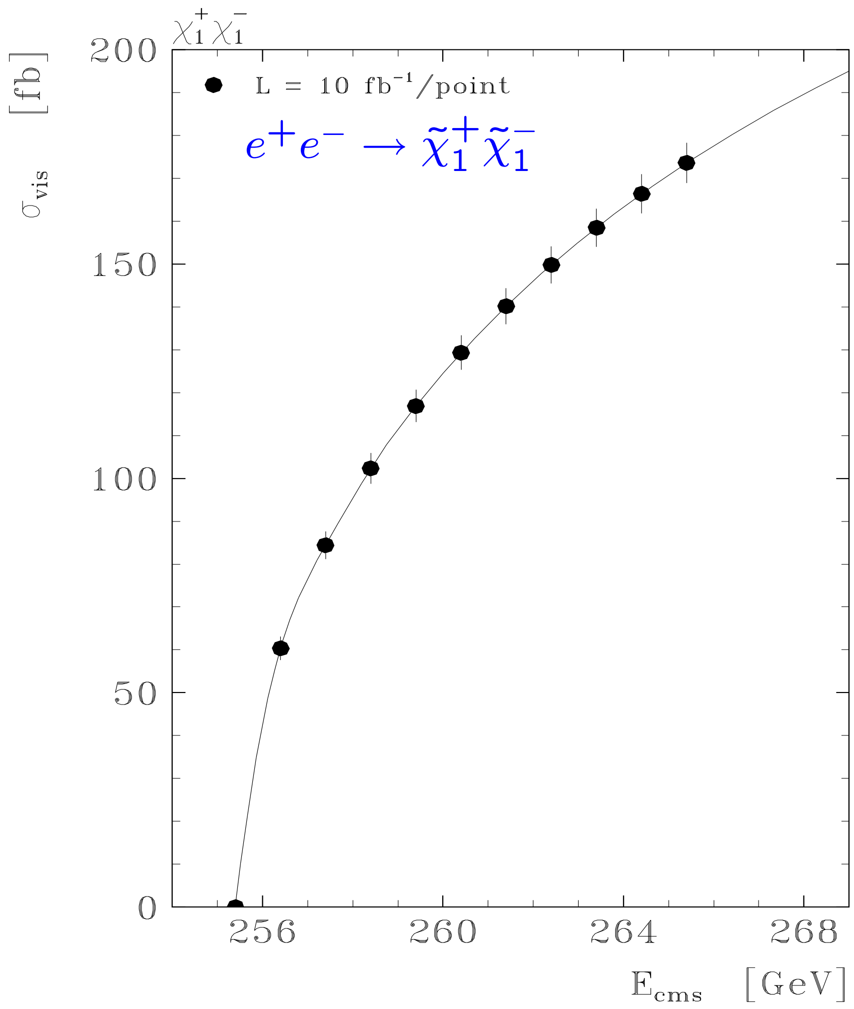
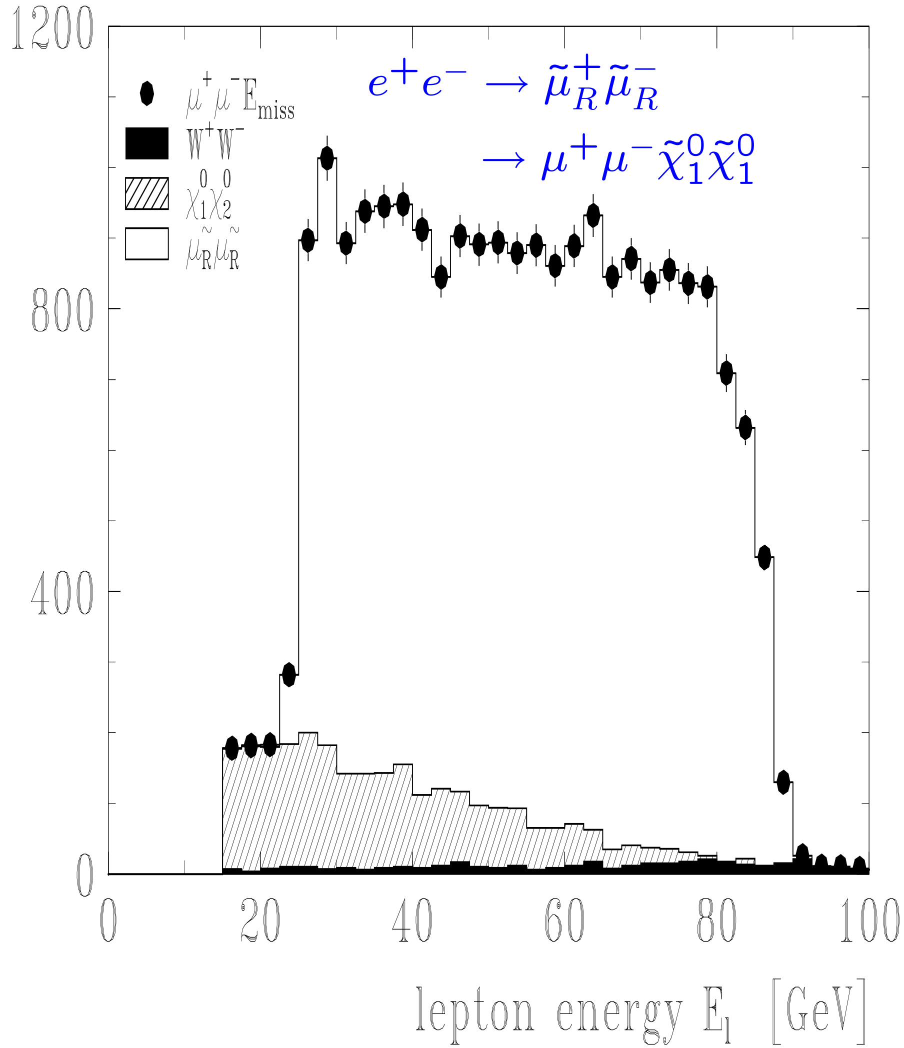
Mass measurements, ILC



U. Martyn



Expected Accuracies

LHC: *masses of squarks, gluinos, winos, bino within a few per–cent*

LC: *sleptons, winos, bino within per–mile*

typical values for mSUGRA scenario

$\tilde{\chi}_1^+$ $\tilde{\chi}_2^+$	183.05 $\pm$ 0.15 385.28 $\pm$ 0.28	0.08 %	$\tilde{e}_R$ $\tilde{e}_L$	224.82 $\pm$ 0.15 269.09 $\pm$ 0.28	0.06 %
$\tilde{\chi}_1^0$ $\tilde{\chi}_2^0$	97.86 $\pm$ 0.20 184.65 $\pm$ 0.30	0.2 %	$\tilde{u}_R$ $\tilde{u}_L$	572.0 $\pm$ 10.0 589.0 $\pm$ 10.0	1.8 %

LHC + LC: *combining data of both machines can improve accuracies on some masses considerably, e.g.* $\Delta m_{\tilde{\chi}_2^0}$ *up to an order of magnitude. (B.K. Gjelsten, D. Miller, P. Osland and G. Polesello)*

RGE structures

explicit solutions of 1–loop RGEs:

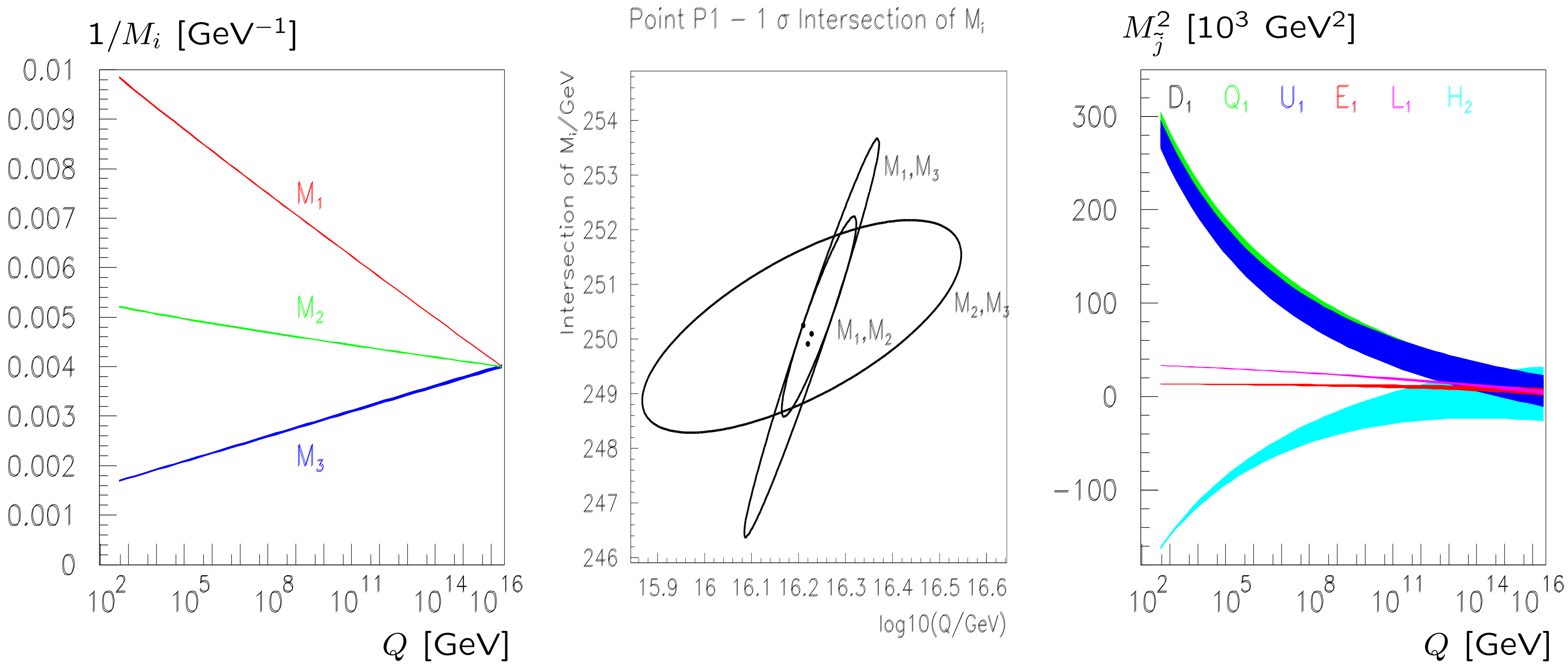
$$\begin{aligned} M_1 &= 0.41 M_{1/2} && \Rightarrow M_{1/2} \text{ easy} \\ M_L^2 &= M_0^2 + 0.47 M_{1/2}^2 && \Rightarrow M_0 \text{ easy} \\ M_Q^2 &= M_0^2 + 5.1 M_{1/2}^2 && \Rightarrow M_0 \text{ difficult} \\ M_{H_2}^2 &= -0.03 M_0^2 - 1.34 M_{1/2}^2 + \ldots && \Rightarrow M_0 \text{ very difficult} \end{aligned}$$

Top-Down *(taking mSUGRA as example)*

$$\begin{aligned} M_{1/2} &= 250 \pm 0.08 \ \text{GeV} \\ M_0 &= 200 \pm 0.09 \ \text{GeV} \\ A_0 &= -100 \pm 1.8 \ \text{GeV} \end{aligned}$$

mSUGRA

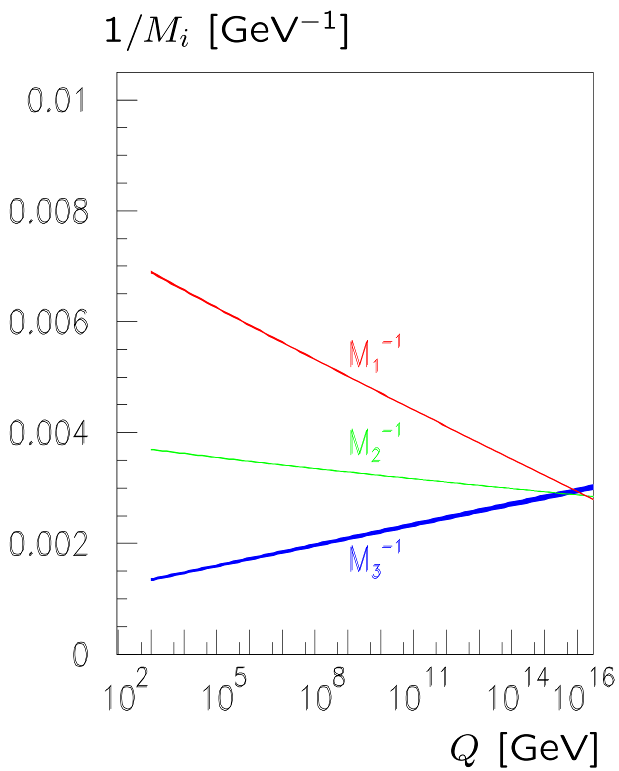
$\tan\beta = 10,\ M_0 = 70$ GeV, $M_{1/2} = 250$ GeV, $A_0 = -300$, sign$(\mu) = 1$

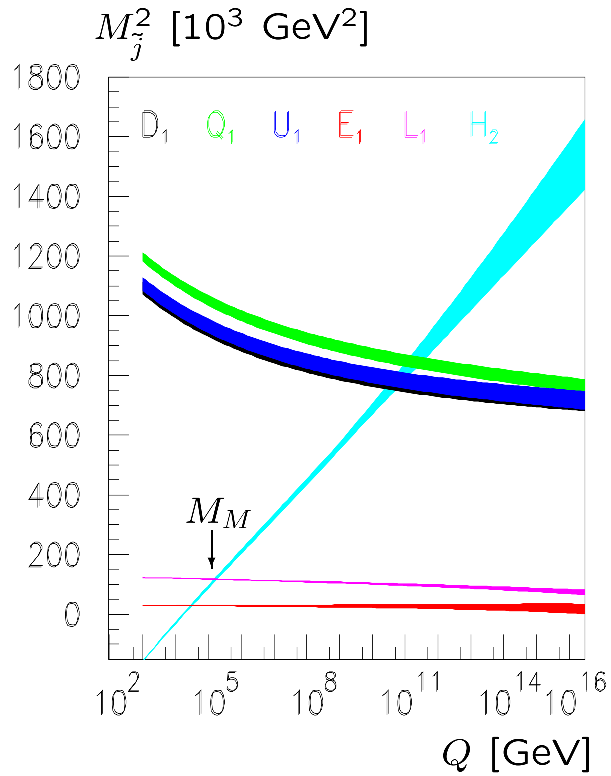


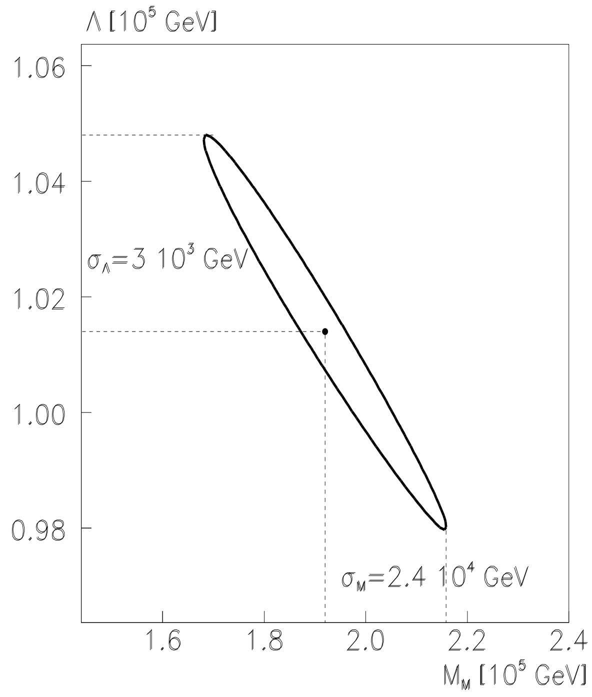
1 σ error bands

GMSB

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







1 σ error bands

Summary

- *Reconstruction of the underlying high scale theory is feasible*
- *– LHC allows for measurement in the per-cent range*
  – most likely information on spectrum will not be complete
  $\Rightarrow$ *top-down fits to exclude models*
- *High precision measurements at future e^+e^- colliders are necessary for bottom-up approach*