Accuracy Required to Discriminate SUSY Models

by

Ben Allanach (DAMTP, Cambridge)

Based on work performed with D. Grellscheid and F. Quevedo[1]

Talk outline

- Motivation and method
- Models and results
- Future possibilities

[1] hep-ph/0111057, JHEP 0205 (2002) 048

Basic Idea

Previous approaches tended to focus on one model:

- mSUGRA parameter scans
- Running soft parameters up to GUT scale
- Accuracy of measurement of sparticle masses with particular model parameters

Idea: Take different models, scan over their SUSY breaking parameters, and ask:

$\mathcal{Q}$: What accuracy do we need on sparticle masses do we need to distinguish the different scenarios?

Method

- Take several SUSY breaking models with small number of free (high-scale) parameters
- Scan over free parameters,
- Apply experimental constraints
- Plot ratios of sparticle masses
- Look for disjoint regions in 2-D ratio space in order to define *minimum ratio distance* in mass ratios

Ratio space

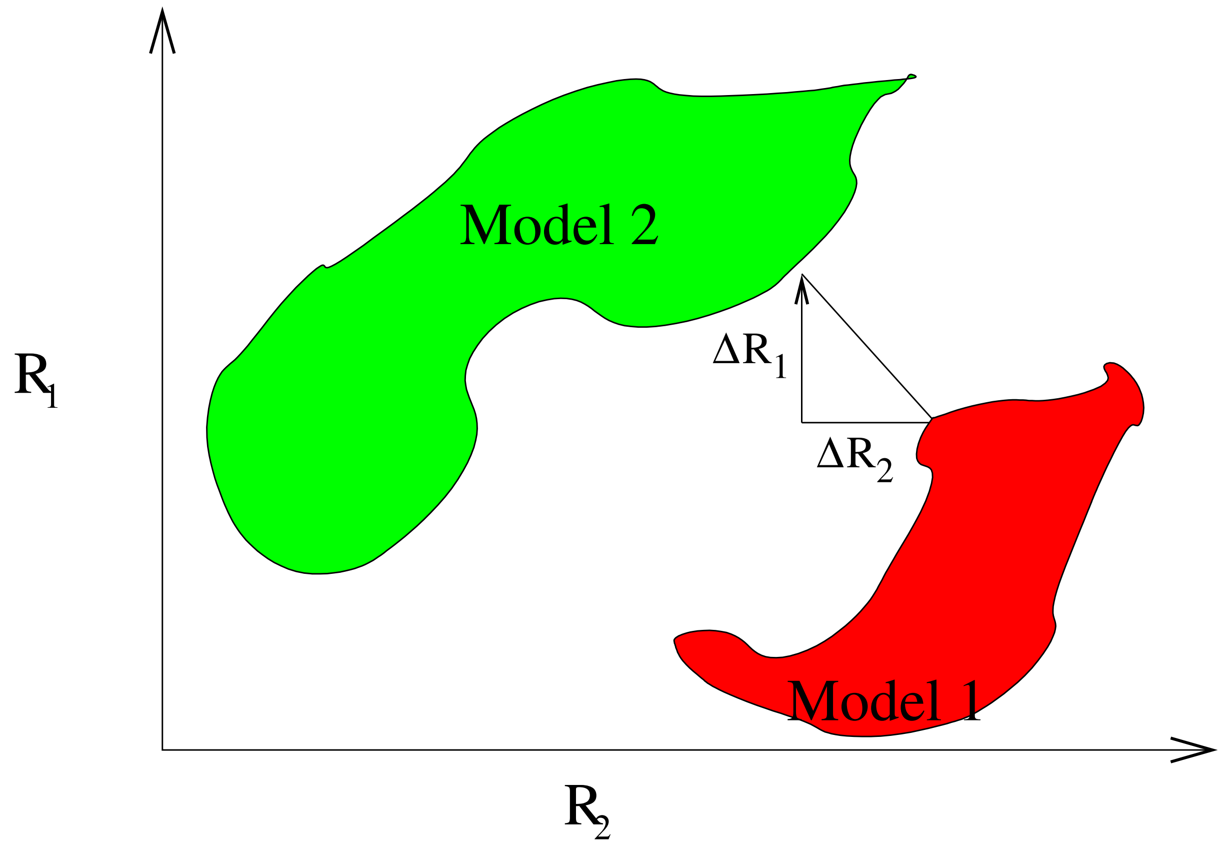

Figure 1: Accuracy required to discriminate two different models. In practice, they will be populated by a random scan in high-scale SUSY breaking input parameters

Models

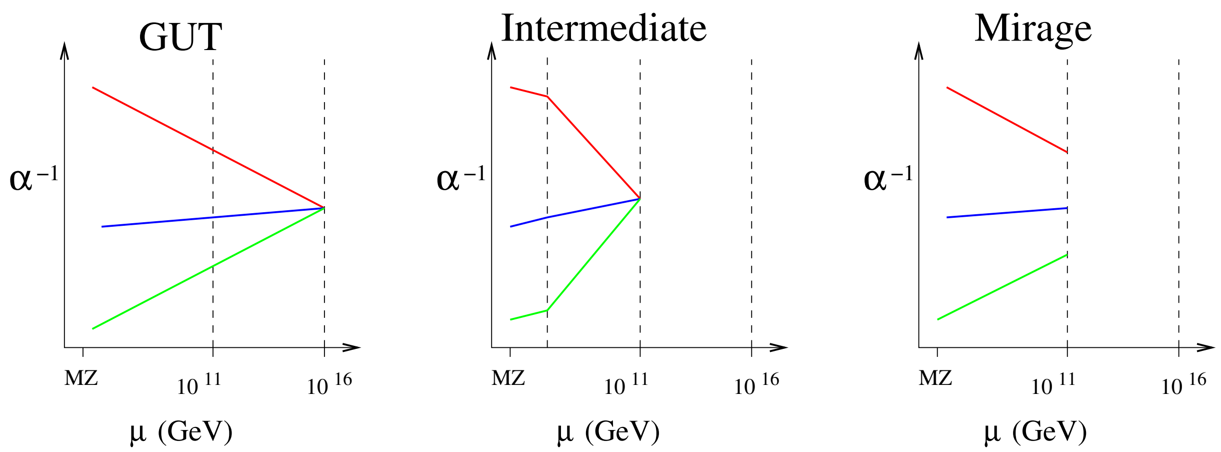

Figure 2: Model scenarios from Type I strings[2]

Intermediate scale has some advantages:

- Less charge and colour breaking
- SUSY CP problem ameliorated
- Axion at correct scale to solve strong CP problem

SUSY Breaking Parameters

Come from F terms of dilaton/moduli fields:

$$\begin{pmatrix} F_S \\ F_T \\ F_M \end{pmatrix} = \begin{pmatrix} \sin\theta \\ \cos\theta\sin\phi \\ \cos\theta\cos\phi \end{pmatrix} F_{TOT}$$

and induce a subset of mSUGRA:

$$\begin{aligned} {m_0}^2 &= m_{3/2}^2\left(1-\cos^2\theta\sin^2\theta\right) \\ M_a &= \sqrt{3}m_{3/2}\frac{\alpha_a}{\alpha_{GUT}}(\sin\theta - \\ &\quad \frac{s_a}{8\pi}\alpha_{GUT}\cos\theta(\frac{\delta_{GS}}{\sqrt{3}}\sin\phi+\cos\phi)) \\ A_0 &= -\sqrt{3}m_{3/2}\sin\theta \end{aligned}$$

Constraints

- Correct REWSB: specifies μ, B parameters
- Neutral LSP
- $-4.2 \times 10^{-10} < \delta a_\mu^{new} < 41.3 \times 10^{-10}$ i.e. 90% $g-2$ of muon measurement
- $m_{\chi_1}^0 > 45$ GeV
- $m_{\chi_1^\pm} > 103$ GeV
- $m_{h^0} > 113.5$ GeV

Best ratios

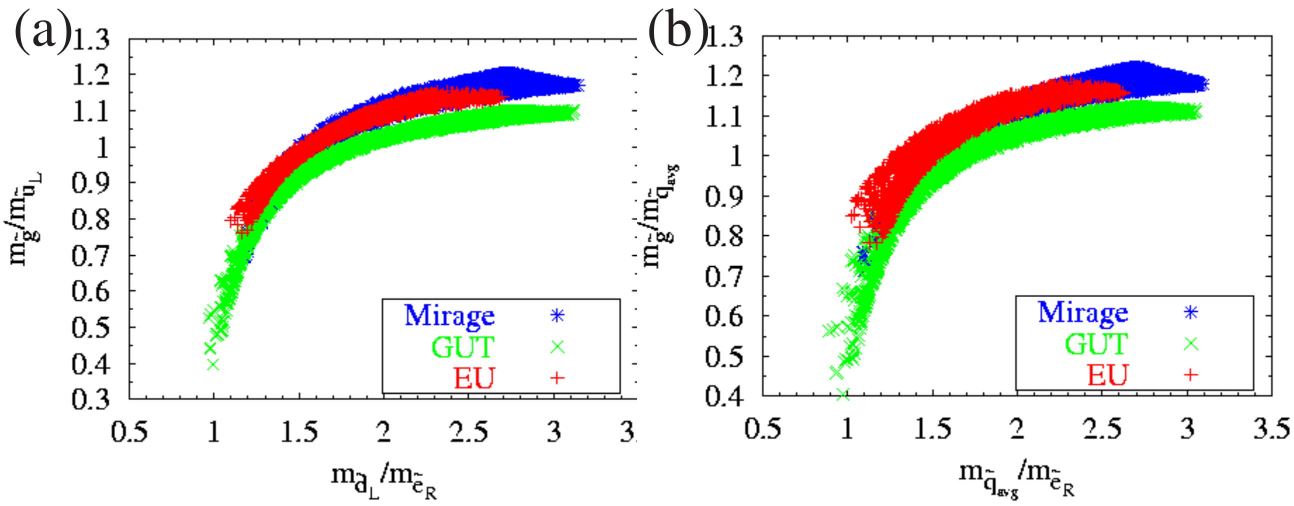

Figure 3: Best ratios with (a) flavour/handedness discrimination (b) average squark mass

$$m_{\tilde{q}_{avg}} \equiv \frac{1}{8} \sum_{i=L/R,f} m_{\tilde{q}_{if}} \quad (1)$$

Dilaton domination

An interesting hyperplane through parameter space ($\theta = 90^\circ$, any values for ϕ):

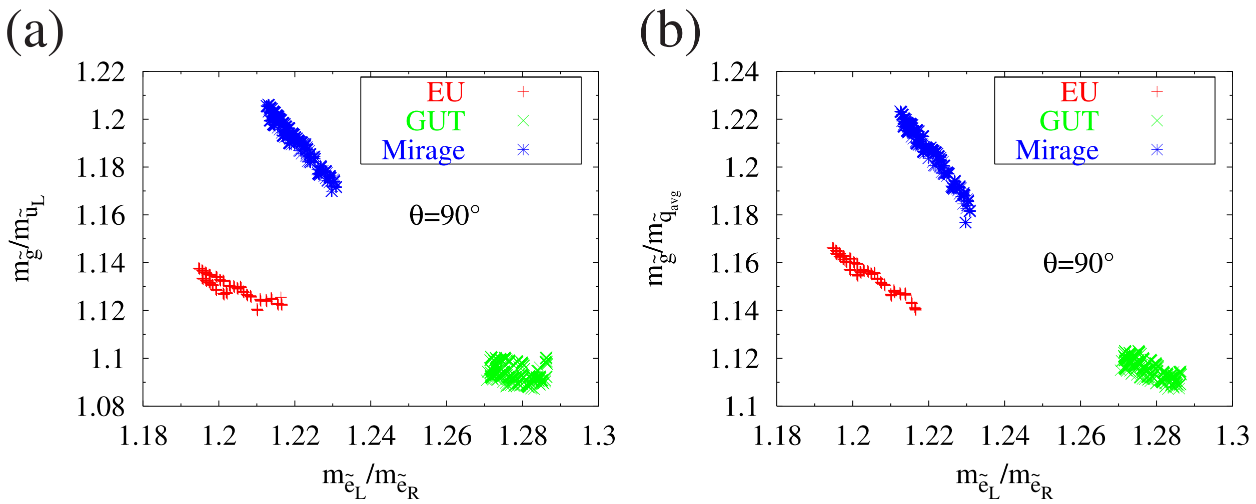

Figure 4: Highly discriminating ratios of sparticle masses for dilaton domination ($\theta = 90\,\mathrm{deg}$). Each plotted point corresponds to one $(m_{3/2}, \tan\beta)$-pair in the scan not excluded by any limits.

LHC edges

From kinematical endpoints of sparticle decay chain products, eg:

$$(m_{ll}^{\max})^2 = \frac{(m^2_{\chi^0_2} - m^2_{\tilde{l}_R})(m^2_{\tilde{l}_R} - m^2_{\chi^0_1})}{m^2_{\tilde{l}_R}},$$

$$(m_{lq(\text{low})})^2 = \min\left[\frac{(m^2_{\tilde{q}} - m^2_{\chi^0_2})(m^2_{\chi^0_2} - m^2_{\tilde{l}_R})}{m^2_{\chi^0_2}}, \right. \quad (2)$$

$$\left. \frac{(m^2_{\tilde{q}} - m^2_{\chi^0_2})(m^2_{\tilde{l}_R} - m^2_{\chi^0_1})}{2m^2_{\tilde{l}_R} - m^2_{\chi^0_1}}\right],$$

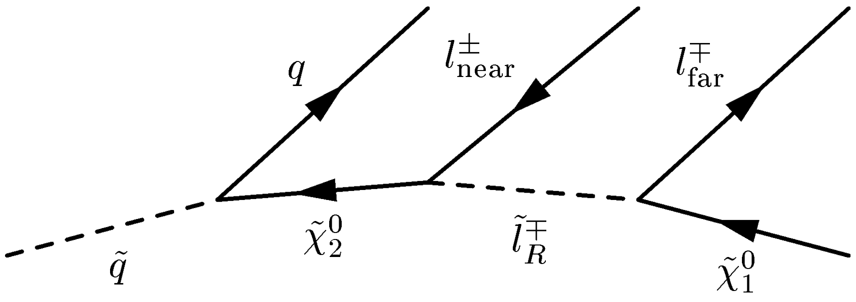

Figure 5: $\tilde{q} \to q\chi^0_2$, $\chi^0_2 \to l\tilde{l}$, then $\tilde{l} \to l\chi^0_1$

LHC Edge Discrimination

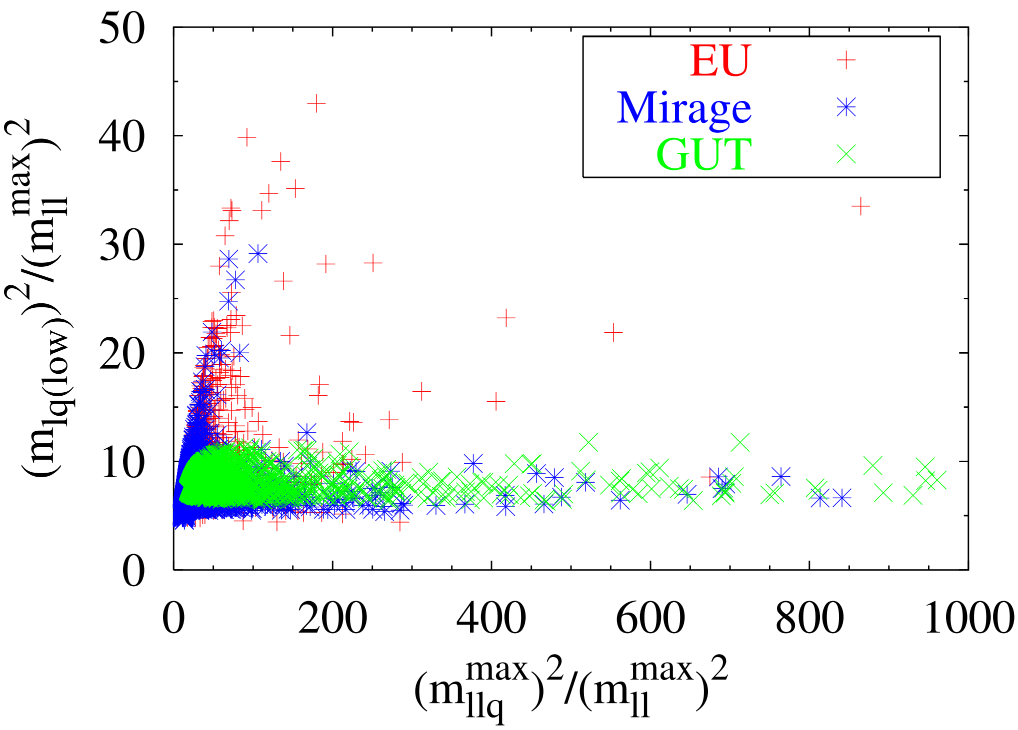

Figure 6: Ratios of LHC edge variables. Each plotted point corresponds to one scan point that is not excluded by the imposed limits and where $m_{\chi_2^0} > m_{\tilde{l}_R}$.

edge variable	accuracy
$m_{ll}^{\max}$	0.1%
$m_{llq}^{\max}$	1%
$m_{lq(\text{low})}$	1%

Summary/interpretation

- LHC on its own will find it tough to discriminate from the edge measurements
- Percent-level measurement of sparticle masses needed
- Theoretical errors in sparticle mass prediction must be reduced
- Future possibilities:
  - Multi-dimensional mass vector idea
  - Experimental weighting of “distance”: eg slepton mass determination
  - Same idea with experimental observables?