Reconstructing Supersymmetric Theories at the Linear Collider

Grahame A. Blair

Royal Holloway, Univ. of London, Egham, Surrey TW20 0EX,UK

Abstract. High precision measurements at the linear collider will allow a model-independent reconstruction of nature at high energy scales. The method of bottom-up extrapolation from the electroweak scale to the GUT scale is explained and both a universal minimal supergravity and a gaugino-mediated model are presented as examples. Comparisons are made with the LHC-only case.

Introduction

If supersymmetry (SUSY) is realised in nature, one of the major goals of the linear collider (LC) will be to determine how this symmetry is broken [1]. This problem is equivalent to determining the structure of the theory at high energy scales where the mechanism of SUSY breaking influences directly the parameters of the theory. This report presents a model-independent approach where the SUSY parameters are reconstructed via extrapolations from the electroweak scale to the GUT scale, assuming the precision measurements that may be performed at a high luminosity e^+e^- LC [2]. More details are presented in Ref. [3].

The Bottom-Up Approach

A widely employed method to determine the fundamental SUSY parameters at the LHC [4] and the LC [5] is to assume a SUSY breaking scenario and then fit to the corresponding experimentally determined low-energy particle spectrum. While this approach gives a useful indication of the SUSY measurement potential, the scenario assumptions are effectively constraints in the fit and so may give a false impression. This danger is particularly present for models with pseudo-fixed point structures, where the low-energy effective theories will be quite similar for a range of fundamental parameters. Additionally, nature may not be regular at the GUT scale or may possess new intermediate scales that are not immediately apparent from a top-down approach.

For these reasons a model-independent method is adopted where the structure of the theory is extrapolated via the renormalisation group equations (RGEs) from low-energy to high energy, with input to the RGEs from experimental measurement alone. In this bottom-up approach new intermediate scales may indeed become apparent, in which case the RGEs would need to adjusted accordingly. An example of such a case is the gauge mediated scenario that was addressed in Ref. [3]. The bottom-up approach manifests the quality of the reconstruction in a transparent form and stresses the need for high accuracy measurements, especially in those cases where universality at the GUT scale may be only slightly broken.

The Models and Experimental Input

Presented here are two studies. Model A is minimal supergravity [6] with parameters $M_{\frac{1}{2}}$=190 GeV, M_0=200 GeV, A_0=550 GeV, $\tan\beta$=30, sign(μ)=$-$. Model B is inspired by the gaugino-mediated scenario [7] with $M_{\frac{1}{2}}$=200 GeV, M_0=5 GeV, A_0=0 GeV, $\tan\beta$=2.5, M_{H_1}=300 GeV, M_{H_2}=200 GeV, sign(μ)=$-$. A gauge-mediated model is presented in Ref. [3].

The experimental input to this study consists of particle masses and polarized production cross-sections. The analysis requires a total integrated luminosity of about 1 ab^{-1}. For the particle mass precisions, threshold scans are assumed such as discussed in Ref. [5]. For the squarks and gluino, a generic precision of 10 GeV is assumed from the LHC [4]. Only statistical errors are included for the cross-sections and the polarisations are taken as 80% for e^- and 60% for e^+. For model A, where the large $\tan\beta$ gives rise to multi-tau final states, we assume a reconstruction efficiency of 20% and inflate the errors on masses and cross-sections accordingly. For model B we assume a reconstruction efficiency of 80% and also allow for the fact that the sneutrinos happen to decay invisibly.

The results of the extrapolations of the gaugino and scalar soft breaking terms for model A, using LC and LHC data, are shown in Fig. 1. It is immediately clear that the high precision slepton measurements at the LC give excellent evidence for uniformity at the GUT scale. The corresponding results assuming generic LHC-only mass errors of 3 GeV for the non-coloured states are shown in Fig. 2. The effect of losing the complementary LC precision data is clear.

The corresponding LC+LHC extrapolations for model B are shown in Fig. 3 where the no-scale structure is apparent at the GUT-scale. Clearly this approach can distinguish between various scenarios, without any *a priori* model-dependent assumptions.

Conclusion

The bottom-up approach is a model-independent method of extrapolating low-energy measurements to higher scales. It avoids any assumptions about high-energy

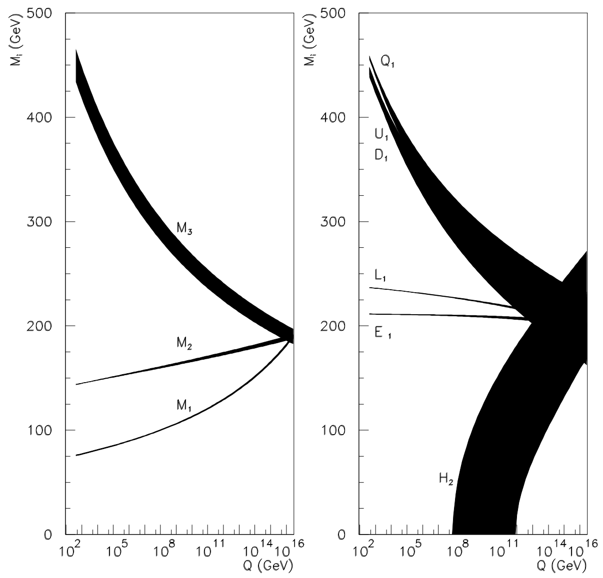

FIGURE 1. Extrapolation of model A gaugino (left) and scalar (right) soft breaking parameters from the electroweak scale to the GUT scale assuming a combination of LC and LHC errors.

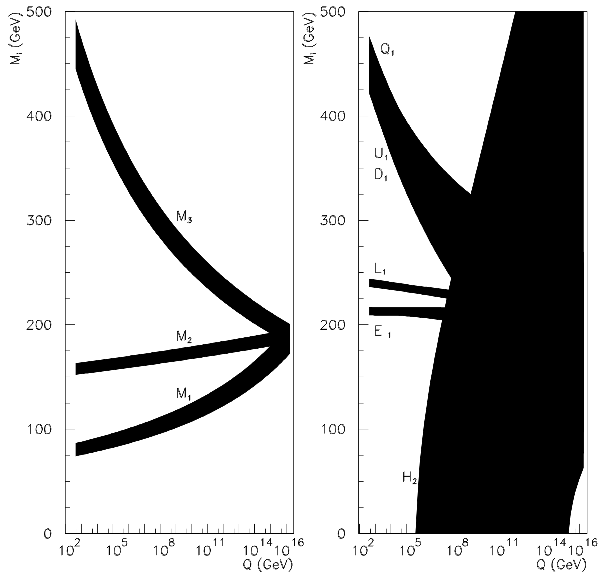

FIGURE 2. Model A, assuming generic LHC-only errors. The uniformity at the GUT scale is not so apparent.

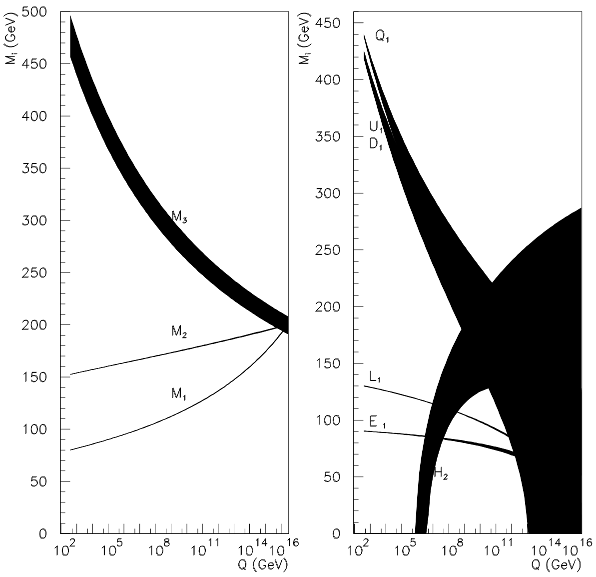

FIGURE 3. Extrapolation to the GUT scale for model B, assuming LHC and LC data. The result is clearly distinguishable from model A.

structure and instead uses the experimental input alone to reconstruct the theory. Complementing the LHC data with high precision measurements from the LC will provide an excellent extrapolated view of physics at the GUT scale.

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