LC-PHSM-2004-020
hep-ph/0408351

Experimental Tools for SPA

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Abstract

Provided SUSY is realized in Nature, future colliders like the Large Hadron Collider (LHC) and a future e^+e^- linear collider (LC) will provide a wealth of data on SUSY phenomena. One important task will be to extract the Lagrangian parameters at the electroweak scale from the numerous measured observables and to extrapolate them to a high scale to check whether unification takes place or to learn about the SUSY breaking mechanism. To accomplish such a task, two new programs, SFITTER and Fittino, have recently been developed. This talk introduces both programs and presents first results obtained with them.

Proceedings of the International Conference on Linear Colliders (LCWS 04)
Paris, April 19-23, 2004

EXPERIMENTAL TOOLS FOR SPA

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Provided SUSY is realized in Nature, future colliders like the Large Hadron Collider (LHC) and a future e^+e^- linear collider (LC) will provide a wealth of data on SUSY phenomena. One important task will be to extract the Lagrangian parameters at the electroweak scale from the numerous measured observables and to extrapolate them to a high scale to check whether unification takes place or to learn about the SUSY breaking mechanism. To accomplish such a task, two new programs, SFITTER and Fittino, have recently been developed. This talk introduces both programs and presents first results obtained with them.

1 Introduction

Assuming Supersymmetry (SUSY) will be established experimentally, future colliders like the Large Hadron Collider (LHC) and a future e^+e^- linear collider will abundantly produce SUSY particles. Huge data sets will allow precise measurements of SUSY phenomena. Since theory parameters are in general not observables, one of the important tasks will be to extract Lagrangian parameters from the available measurements. This requires a mapping between observables and theory parameters within a certain theory framework, e. g. the Minimal Supersymmetric Standard Model (MSSM).

On tree-level some SUSY sectors depend only on a small number of parameters (e. g. the chargino sector). Analytical relations can be derived to easily calculate the low scale Lagrange parameters from the measurements. On loop-level the situation is more complicated. In principle every parameter depends on every observable and vice versa. Therefore some elaborate method is needed to include loop corrections in precise SUSY parameter determinations. The Supersymmetry Parameter Analysis (SPA) Project [1] has been set up to develop such techniques.

2 SFITTER and Fittino

In the recently presented programs SFITTER [2] and Fittino [3], an iterative approach has been chosen to tackle the challenge described in Section 1. Starting from parameter start values obtained from a coarse scan (as done in SFITTER) or tree-level formulae (as done in Fittino), the corresponding observables are calculated (including loop corrections) using a SUSY calculation package. The calculated observables are compared to the measured ones. Subsequently the Lagrangian parameters are varied until the corresponding calculated observables agree with the measurements. As fit output a set of SUSY parameters is obtained including the full error matrix and, if requested, two-dimensional uncertainty contours. A sketch of the chosen iterative procedure is shown in Fig. 1.

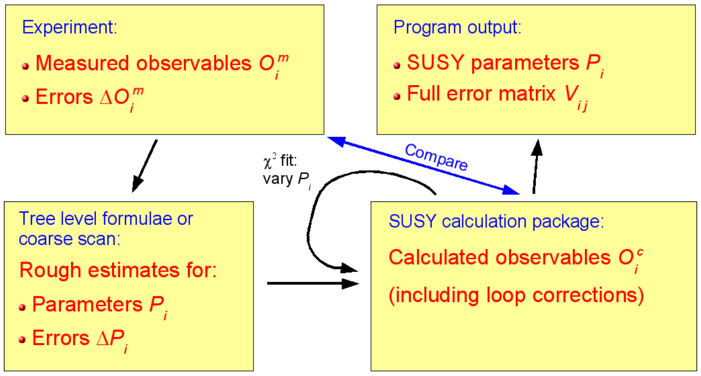

Figure 1: The iterative method used to extract the Lagrangian parameters from the measured observables.

In their present versions SFITTER and Fittino make use of different program components. SFITTER utilizes SUSPECT [4] for mass predictions, MSMlib [5] for branching ratios and e^+e^- cross sections, and PROSPINO 2.0 [6] for pp cross sections. Fittino employs SPheno 2.2.0 [7] for masses, branching ratios and e^+e^- cross sections. Both programs use MINUIT [8] to perform the fit. The communication between SFITTER/Fittino and the various SUSY calculation packages takes place using the SUSY Les Houches Accord (SLHA) [9]. This ensures that the SUSY calculation packages can be easily exchanged and thus allows to cross-check the fit results without much effort.

3 SPS1a Example Fits

To verify the procedure described in Section 2, example fits have been carried out for the SPS1a scenario [10]. Anticipated measurements of masses, cross sections and branching ratios at LHC and a TeV linear collider serve as input to various fits. A detailed list of used measurements can be found in [11] for the SFITTER fits (only masses are used as input) and in [12] for the Fittino results (both masses and cross-sections serve as input).

3.1 mSUGRA fit

Assuming gravity mediated SUSY breaking (mSUGRA), the SUSY Lagrangian is only determined by four high-scale parameters and the sign of the Higgsino mass parameter μ. These four parameters are the universal scalar and gaugino masses m_0, $m_{1/2}$, the trilinear coupling A_0 and the ratio of the two Higgs vacuum expectation values $\tan\beta$. A fit of the four high-scale parameters has been performed with SFITTER for three different input sets: "LHC only" and "LC only" measurements and a combined set using anticipated results from both machines. sign(μ) has been fixed. The results for the three different input sets are shown in Tab. 1. As can been seen, the determination of the

	SPS1a	LHC	Δ_{LHC}	LC	Δ_{LC}	LHC+LC	$\Delta_{\mathrm{LHC+LC}}$
M_0 (GeV)	100	100.03	4.0	100.03	0.09	100.04	0.08
$M_{1/2}$ (GeV)	250	249.95	1.8	250.02	0.13	250.01	0.11
$\tan\beta$	10	9.87	1.3	9.98	0.14	9.98	0.14
A_0 (GeV)	-100	-99.29	31.8	-98.26	4.43	-98.25	4.13

Table 1: Results of the mSUGRA fit obtained with SFITTER [11].

mSUGRA parameters are dominated by the LC measurements. The contraints imposed by mSUGRA unification bring about that the missing strongly interacting particles at a LC have no influence on the precision of the parameter determination.

3.2 General MSSM fit

Moreover fits have been performed in the general MSSM scenario which does not make any assumptions on the SUSY breaking scenario. The price for this generality is that one ends up with 105 SUSY parameters (masses, phases, mixing angles). To make a fit feasible, it has been assumed that there is no mixing between generations and within the first two generations and that all phases vanish. Imposing these contraints, 24 SUSY parameters remain. In addition unification in the first two generation has been imposed. To take parametric uncertainties of SUSY observables into account, the top quark mass has been fitted simultaneously. The trilinear couplings A_{top}, A_{bottom} and A_τ are replaced by the mixing parameters $X_{\mathrm{top}} = A_{\mathrm{top}} - \mu/\tan\beta$, $X_{\mathrm{bottom}} = A_{\mathrm{bottom}} - \mu\tan\beta$ and $X_\tau = A_\tau - \mu\tan\beta$ in order to reduce correlations with $\tan\beta$. The outcome of a fit with Fittino under the above assumptions is shown in Tab. 2. All fitted parameters agree well with the predicted values from SPheno 2.2.0. It was verified that the parameter uncertainties obtained from the fit are properly estimated by looking at pull distributions from fits with smeared observables for all fitted parameters.

	SPS1a	Value	Error		SPS1a	Value	Error
$\tan\beta$	10.0	10.0	0.3	μ (GeV)	358.6	358.6	1.1
X_τ (GeV)	-3837	-3837	131	$M_{\tilde{e}_R}$ (GeV)	135.76	135.76	0.39
$M_{\tilde{\tau}_R}$ (GeV)	133.33	133.33	0.75	$M_{\tilde{e}_L}$ (GeV)	195.21	195.21	0.18
$M_{\tilde{\tau}_L}$ (GeV)	194.4	194.4	1.2	$X_{\rm top}$ (GeV)	-506	-506	30
$X_{\rm bottom}$ (GeV)	-4441	-4441	1765	$M_{\tilde{d}_R}$ (GeV)	528	528	18
$M_{\tilde{b}_R}$ (GeV)	524.7	524.7	7.7	$M_{\tilde{u}_R}$ (GeV)	530	530	19
$M_{\tilde{t}_R}$ (GeV)	424.4	424.4	8.5	$M_{\tilde{u}_L}$ (GeV)	548.7	548.7	5.2
$M_{\tilde{t}_L}$ (GeV)	500.0	500.0	8.1	M_1 (GeV)	101.81	101.81	0.06
M_2 (GeV)	191.76	191.76	0.10	M_3 (GeV)	588.8	588.8	7.9
$m_{\rm A}$ (GeV)	399.8	399.8	0.7	$m_{\rm top}$ (GeV)	174.3	174.3	0.3

Table 2: Results of the general MSSM fit obtained with Fittino [12].

4 Conclusion

An iterative procedure has been developed to determine SUSY Lagrangian parameters from measured observables. The method has proven successful in example fits for the SPA1a scenario. It was verified that both the fit values and uncertainties have been properly estimated in these fits. Therewith two powerful tools are available for SPA.

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