PROCEEDINGS OF SCIENCE

SUSY precision spectroscopy and parameter determination at the ILC

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A systematic study of a SUSY model with a rich spectrum accessible at the ILC running below and up to the centre-of-mass energy of 500 GeV is presented. The model point – the STC4 point of Baer & List [1] – is such that all sleptons and most bosinos would be produced at the ILC, while the gluino and the first and second generation squarks are beyond the current LHC reach. The model is consistent with all current experimental limits and measurements. However, due to the many open channels and long cascade-decay chains, it would be a challenge to the ILC experiments to interpret. This study aims at exploiting this model fully by suggesting a running scenario, where beam-time is allotted in an optimal way to threshold scans and measuring the continuum production at both intermediate and the highest possible centre-of-mass energies, with different beam polarisations. The obtainable experimental precisions are then used to make an MSSM parameter determination with 18 free parameters using the Fittino framework.

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1. STC4 - An MSSM model with a rich spectrum

STC4 [1] - for $\tilde{\tau}$-coannihilation model 4 - is a pMSSM model which is allowed by LHC8 data, but still has a rich spectrum of bosinos and sleptons observable at the ILC [3] with E_{CMS} = 250 to 1000 GeV. Figure 1 shows masses and decay modes of sparticles that can be produced at the ILC. If this model is realised in nature, the study in [2] shows that it is likely to be discovered at LHC14.

The first channel to manifest itself at the ILC depends on the running scenario. If the ILC starts as a Higgs factory at $E_{\mathrm{CMS}} = 250$ GeV, then $\mathrm{e}^+\mathrm{e}^- \to \tilde{\tau}_1\tilde{\tau}_1$ and $\tilde{\chi}^0_1\tilde{\chi}^-_1\gamma$ would be the observable channels. As soon E_{CMS} is raised past the threshold for right-handed slepton-pairs, in STC4 to $\gtrsim$ 270 GeV, a signal in the e^+e^-+ missing 4-momentum ($\not{P}$) topology would appear within a few days, see fig. 1. The cross-section for $\tilde{\mu}_{\mathrm{R}}$ pair production is much lower than for $\tilde{\mathrm{e}}_{\mathrm{R}}$ due to the absence of a t-channel. Still $\delta M_{\tilde{\mu}_{\mathrm{R}}}$ can be determined to 200 MeV by scanning the threshold, see fig 1 (from [4]). By measuring E_μ precisely close to the threshold, $\delta M_{\tilde{\chi}^0_1}$ will be similar to $\delta M_{\tilde{\mu}_{\mathrm{R}}}$.

The main contributions to the $\mu^+\mu^-+\not{P}$ signature at 500 GeV are from $\tilde{\mu}_{\mathrm{R}}$ and $\tilde{\tau}_1$ decays, but $\tilde{\mu}_L$ can also be studied in detail. After dedicated selections, the E_μ spectra at the kinematic edges allows to determine $\delta M_{\tilde{\mu}_L}$ to 400 MeV [5]. The even smaller contribution from $\tilde{\chi}^0_1\tilde{\chi}^0_2 \to \mu\mu\tilde{\chi}^0_1\tilde{\chi}^0_1$ can also be identified in the $M_{\mu\mu}$-spectrum, see fig. 1. From this channel alone, $\delta M_{\tilde{\chi}^0_2}$ can be determined to about 1 GeV, depending on the assumed $\delta M_{\tilde{\mu}_{\mathrm{R}}}$ and $\delta M_{\tilde{\chi}^0_1}$ [5].

A particularly interesting channel is $\mathrm{e}^+\mathrm{e}^- \to \tilde{\chi}^0_2\tilde{\chi}^0_2$ with the $\tilde{\chi}^0_2$ decaying to $\tilde{\mu}_{\mathrm{R}}\mu$ or to $\tilde{\mathrm{e}}_{\mathrm{R}}e$, even if the branching ratio is only a few percent, as it is in STC4. Such decays can be fully kinematically constrained at the ILC, and promises to yield $\delta M_{\tilde{\mu}_{\mathrm{R}}}$ and $\delta M_{\tilde{\mathrm{e}}_{\mathrm{R}}}$ of the order of 25 MeV. This is

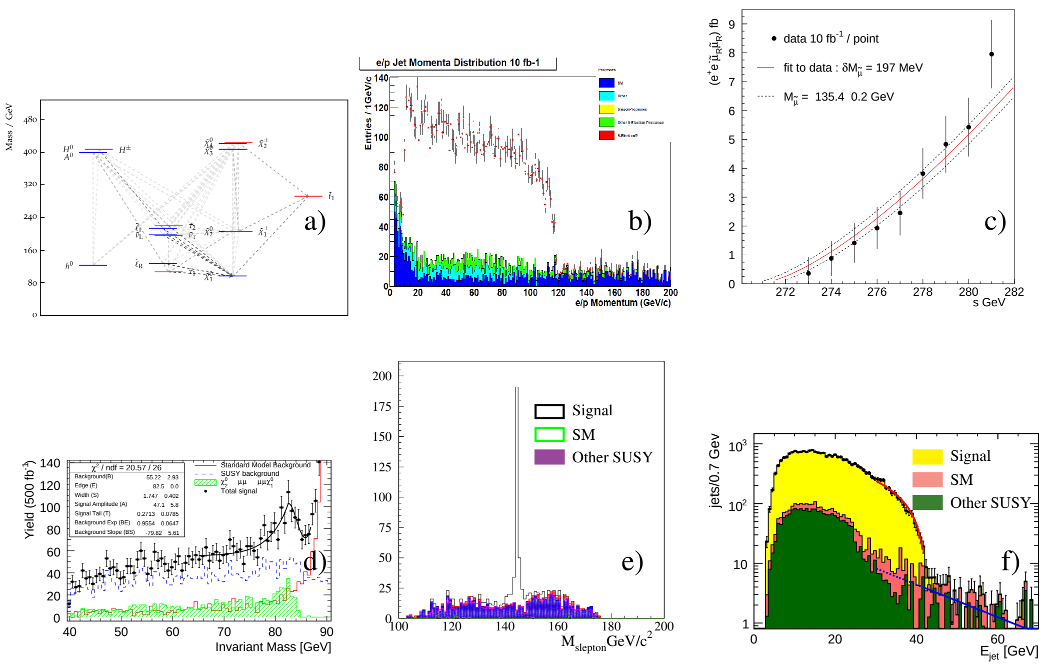

Figure 1: Aspects of STC4: a) Sparticle masses and decay modes; b) E_e distribution showing the $\tilde{\mathrm{e}}_{\mathrm{R}}$ signal with $\int\mathscr{L} = 10\ \mathrm{fb}^{-1}$; c) $\tilde{\mu}_{\mathrm{R}}$ threshold scan; d) $M_{\mu\mu}$ distribution showing the $\tilde{\chi}^0_1\tilde{\chi}^0_2$ signal; e) $M_{\tilde{\ell}}$ reconstructed from cascade decays ; f) E_{jet} distribution showing the $\tilde{\tau}_1$ signal, with end-point fit.

estimated from an earlier study in a scenario with larger branching ratios, where $\delta M_{\tilde{\mu}_R} = 10$ MeV [6] was found. Fig. 1 shows $M_{\tilde{\mu}_R}$ with SM and SUSY backgrounds.

2. The cosmic connection: $\tilde{\tau}$ mass and cross-section

Especially in $\tilde{\tau}$-coannihilation scenarios, a precise determination of the $\tilde{\tau}$ sector is essential in order to be able to predict the expected relic density with sufficient precision to test whether the $\tilde{\chi}^0_1$ is indeed the dominant Dark Matter constituent. With the ILC at E_{CMS} = 500 GeV, the $\tilde{\tau}_1$ mass can be determined to 200 MeV, and the $\tilde{\tau}_2$ mass to 5 GeV from the endpoint of the τ-jet energy spectrum. Production cross section for both these modes can be determined at the level of 4% The polarisation of τ-leptons from the $\tilde{\tau}_1$ decay, which gives access to the $\tilde{\tau}_1$ and $\tilde{\chi}^0_1$ mixing - gauginos conserve chirality, higgsinos flips it - can be measured with an accuracy better than 10% by analysing the τ decays. The $\tilde{\tau}$ mixing itself can be extracted by comparing the cross-section at different beam-polarisations, or from the cross-section for $\tilde{\tau}_1\tilde{\tau}_2$ production [7]. By using these observables to determine the SUSY parameters, the relic density can be predicted. The Fittino group performed an 18 parameter fit to a similar model, and could predict $\Omega_{\mathrm{CDM}}h^2$ to 0.2 % [8].

3. Conclusion

Studying the SUSY benchmark point STC4, we have shown how measurements of spectra, thresholds, cross-section, beam-polarisation dependence and decay-reconstruction allows to determine sparticle properties at the percent to sub-permil level. We also showed how these measurements can be used to predict the relic density to 0.2 %.

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