Evaluating the ILC SUSY reach in the most challenging scenario: $\widetilde{\tau}$ NLSP, low ΔM, lowest cross-section.

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Abstract: It is well-known that e^+e^- colliders have the power to with certainty exclude or discover any SUSY model that predicts a Next to lightest SUSY particle (an NLSP) that has a mass up to slightly below the half the centre-of-mass energy of the collider. We plan to make this statement more precise by studying in detail the case where the NLSP is the $\tilde{\tau}$, most probably the most challenging case.

There are several reasons why a $\tilde{\tau}$ NLSP would be the most challenging SUSY scenario to detect:

- The $\tilde{\tau}$ will decay to a τ which in turn decays partially invisible, making the detectable system softer than for any other NLSP candidate at the same mass and mass-difference.
- The $\tilde{\tau}$ mixes, and at a mixing angle of $\sim 53°$, the $\tilde{\tau}$ does not couple to the Z^0, only to the photon. This means that the pair-production cross-section would be much suppressed w.r.t. other sfermion production processes at the same mass.
- Depending on the $\tilde{\tau}$ mixing angle and the higgsino/gaugino composition of the LSP, it is possible that the $\tau^{-(+)}$ from the $\tilde{\tau}^{-(+)}$-decay will be dominantly left(right)-handed, and that thus the neutrino in the τ-decay would preferentially be emitted in the direction-of-flight of the $\tilde{\tau}$. This will further soften the spectrum of the detectable system.

Indeed, with all these considerations taken into account, the current loop-hole free exclusion limit on the $\tilde{\tau}$ is from LEPII, and is only $M_{\widetilde{\tau}} > 28$ GeV(any $\tilde{\tau}$- mixing, $\Delta(M) \geq m_\tau$)[1].

We intend to study the prospects to detect $\tilde{\tau}$ production - including this worst-case scenario - at the ILC. Initially, we will do so using the SGV [2] fast detector simulation, including all SM background processes. We will take into account the assumed ILC beam-conditions: beam-spectrum, beam-polarisation, running scenario, spurious same-bunch crossing $\gamma\gamma$ events, and e^+e^- pairs created by beam-beam effects. At a later stage, we will turn to full simulation of the proposed ILD [3] at ILC. This study will be an extension to the one made for Snowmass 2013[4], which was a generic, fast simulation-only one. We will now concentrate on the $\tilde{\tau}$, and more specifically in detail study the case of the lowest mass-differences (including $\Delta(M) < m_\tau$), and the case when $M_{\widetilde{\tau}}$ is quite close to the kinematic limit.

We select the $\tilde{\tau}$ as the target of our study because it is, for reasons given above, the experimentally most difficult NLSP candidate to find. This means that conclusions on the reach of a $\tilde{\tau}$-search also holds for *any* NLSP candidate: any other candidate cannot be more difficult to find. Hence, discovery- or exclusion-reach for the $\tilde{\tau}$-NLSP actually is the reach for *SUSY as a whole.* Strictly speaking, our limits are valid for RPC-SUSY, but experience from LEP shows that, at least at e^+e^--machines, RPV SUSY models obtain the stricter limits, when confronted to the same data. Most likely - this would be a topic for theory input - the same would be true also in the case for CPV SUSY, or extensions to MSSM. such an nMSSM.

In addition to directly estimating the potential for "guaranteed" discovery or exclusion of SUSY (i.e. without any loop-holes to the statement), the outcome of the analysis can be re-cast to estimate the potential of searches for other BSM models that features the same kind of topology - possibly with other couplings and angular distributions.

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While this is not the topic of this LOI, it is worth pointing out that at e^+e^--colliders, the SUSY discovery reach is quite close to the exclusion reach, and that the realm of precision measurements (i.e. where cross-sections can be measured with percent-level precision) is quite close to the discovery reach ("5 σ means 20% error on the cross-section"). Indeed, several studies of $\tilde{\tau}$-production at the ILC[5][6], at various benchmark points, shows that percent-level precision on cross-section and per mil-level ones on SUSY masses can be obtained. The benchmarks of these studies assumed $\tilde{\tau}$ masses not very far - $\sim$ 10 GeV- from the periphery of expected exclusion regions.

References

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