The ILC as a natural SUSY discovery machine and precision microscope: From light higgsinos to tests of unification

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Radiatively driven natural SUSY

Supersymmetry with radiatively-driven naturalness is especially compelling in that it reconciles electroweak naturality with (multi TeV) LHC sparticle mass limits and Higgs boson mass measurements. The most fundamental consequence of radiatively-driven natural SUSY is the prediction of four light higgsinos (χ_{0j}), with masses 100–300 GeV (the lower the better). Such light higgsinos are difficult (but perhaps not impossible) to see at LHC, but would be easily visible at ILC operating with \( \sqrt{s} \geq 5 \text{ TeV} \). In this case, the ILC, initially constructed as a Higgs factory, would turn out to be a higgsino factory! Thus, for this highly motivated scenario, ILC could serve as both a SUSY discovery machine, and a SUSY precision microscope.

Fit model parameters and evolve to GUT

When these measurements are combined with precision Higgs boson measurements, fits to both weak scale SUSY and high scale SUSY model parameters can be made, either with 10 free MSSM parameters, or only the four directly involved in the higgsino properties at tree-level. Thanks to the combination of the measured masses, BR:s and Higgs properties, all 10 weak-scale parameters gets constrained, for all three benchmark cases. In particular, the lines and dots SUSY breaking masses \( M_1 \) and \( M_2 \) - the ones most directly related to the higgsinos - can be determined at percent level. The fitted weak-scale parameters can be evolved with the appropriate RGE:s to higher scales. This allows to verify or discard the idea of GUT-scale unification of \( M_1 \) and \( M_2 \).

Predict the spectrum

The determined parameters can be used to predict the masses of the yet unobserved particles. The figures illustrate the predictions obtained in the \( \text{pMSSM-10} \) parameter, or the corresponding \( \text{pMSSM-4} \) fit with \( M_1, M_2, \mu \) and \( \tan \beta \) only, for ILC. All four parameters can be determined accurately. This results in predictions for the masses of the heavier electroweakinos with predicted \( \delta(\text{masses}) = 1.6 \text{-} 3\% \).

Take-home message

- Light higgsinos motivated by naturalness
- ILC would probe higgsinos complementary to LHC reach
  - Either exclude masses up to \( \sqrt{s} \geq 500 \text{ GeV} \) for 1 TeV upgrade → wide coverage of natural SUSY scenario
  - or discover regardless of mass scale of heavier states
- ILC would measure properties of higgsinos to sub-percent-level precision.
- Precise measurements allow for extracting GUT and weak scale parameters and predicting mass scales of unobserved sparticles.

ILC is the SUSY exploration instrument!

More info:
- \[ \text{http://www.linearcollider.org/} \]
- \[ \text{https://www.desy.de/} \]
- \[ \text{http://www-universe.okstate.edu/} \]
- \[ \text{https://www.universitaet-hamburg.de/} \]
- \[ \text{https://www.desy.de/} \]
- \[ \text{https://www.desy.de/} \]

After the full ILC program, and depending on model, channel, and polarisation, we find experimentally that measured \( \delta(\text{masses}) = 0.5 \text{-} 1\% \), \( \delta(\sigma \times \text{BR}) = 1 \text{-} 6\% \).