SUSY precision spectroscopy and parameter determination at the ILC.

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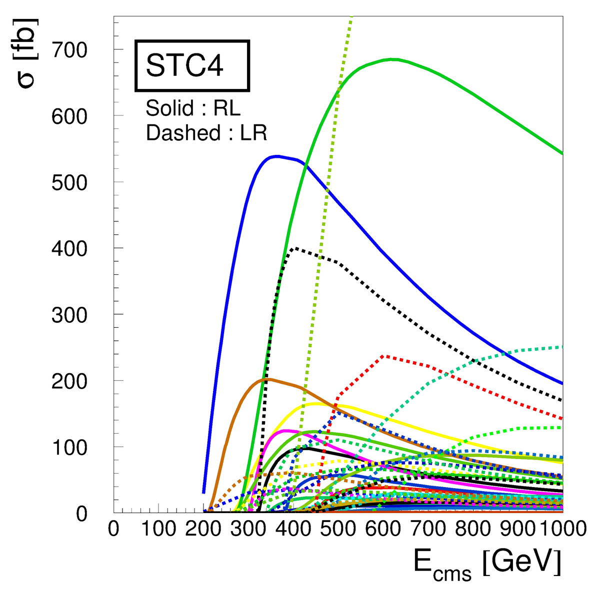
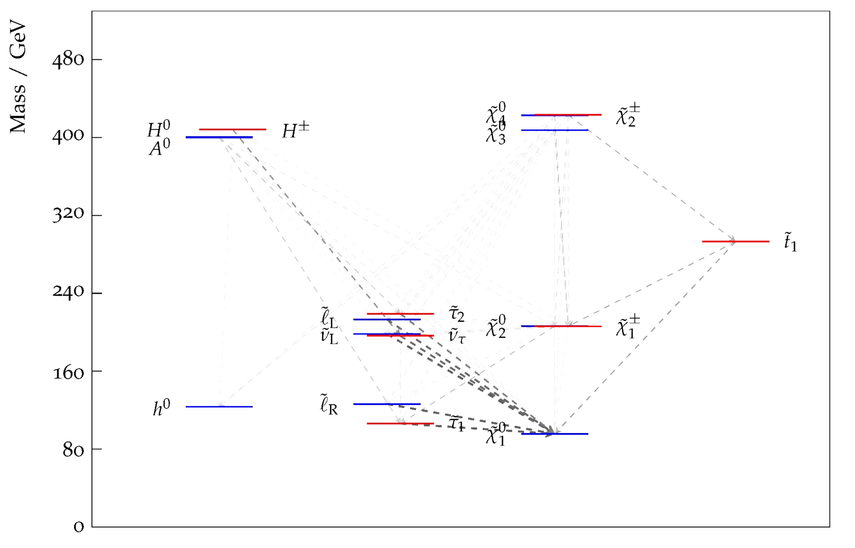
STC4 - An MSSM model with a rich spectrum

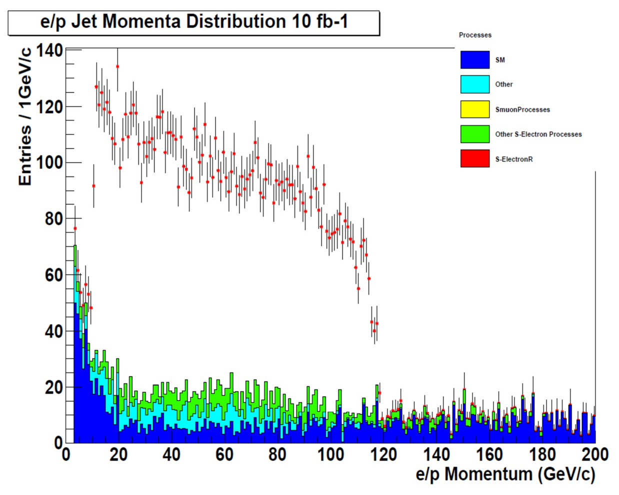
STC4 - for $\tilde{\tau}$-coannihilation model 4 - is a pMSSM model which is allowed by LHC8 data, but still has a very rich spectrum of bosinos and sleptons observable at the ILC running at $E_{\rm CMS}$ from 250 GeV to 1 TeV.
The figures below shows the production cross-section and decay modes of sparticles that can be produced at the ILC.



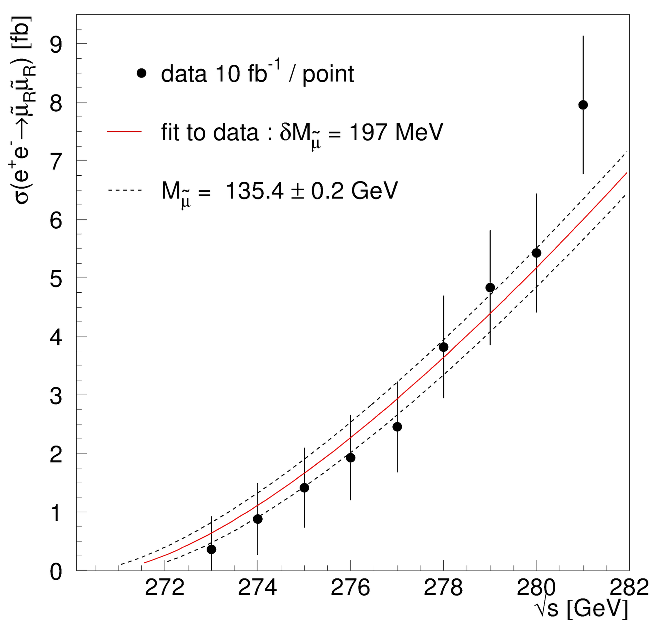


$\tilde{e}_{\rm R}$ - Early discovery at a staged ILC

The first channel to manifest itself at the ILC depends on the assumed running scenario. If the ILC starts out as a Higgs factory at $E_{\rm cms} = 250$ GeV, then $e^+e^- \to \tilde{\tau}_1\tilde{\tau}_1$ and $\tilde{\chi}^0_1\tilde{\chi}^0_1\gamma$ would be the first observable channels.
As soon as the centre-of-mass energy is raised past the pair production threshold for right-handed sleptons, in STC4 when $E_{\rm CMS} \gtrsim 270$ GeV, the e^+e^-+ missing 4-momentum signature would see a striking signal within a few days:



SUSY in a week.



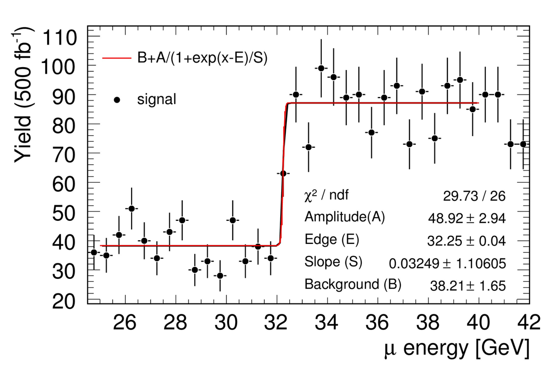
Threshold scan of $\tilde{\mu}_{\rm R}$

The cross-section for $\tilde{\mu}_{\rm R}$ pair production is much lower than for $\tilde{e}_{\rm R}$ due to the absence of a t-channel. Still the $\tilde{\mu}_{\rm R}$ mass can be determined to ~ 200 MeV by scanning the production threshold near 270 GeV. By measuring the momenta of the muons from the $\tilde{\mu}_{\rm R}$ decays very precisely close to the threshold, $M_{\tilde{\chi}^0_1}$ can also be extracted with an error $\sim \delta M_{\tilde{\mu}_{\rm R}}$.

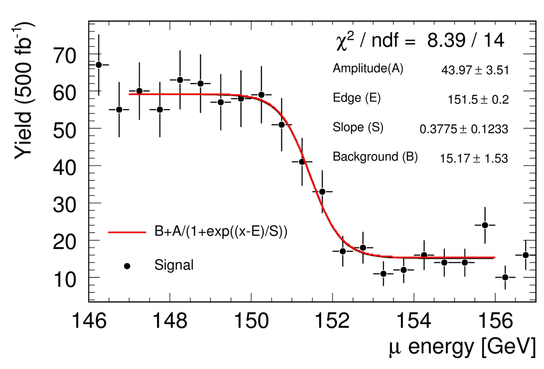
$\delta M_{\tilde{\mu}_{\rm R}} = 200$ MeV
$\delta M_{\tilde{\chi}^0_1} = 200$ MeV

ILC at full speed: The $\tilde{\mu}_L$

The largest contributions to the di-muon + missing 4-momentum at $E_{\rm CMS}$=500 GeV signature comes from $\tilde{\mu}_{\rm R}$ and $\tilde{\tau}_1$ decays, $\tilde{\mu}_L$ can also be studied in detail. Here we show zooms into the muon energy spectrum at the kinematic edge regions for $\tilde{\mu}_L$ after dedicated selection. From the edge positions, the $\tilde{\mu}_L$ mass can be determined to 400 MeV

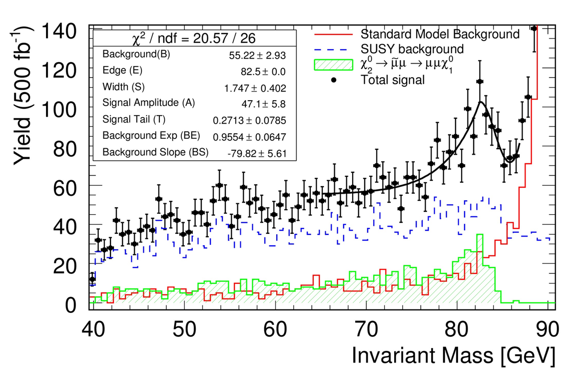


$\delta M_{\tilde{\mu}_L} = 400$ MeV



Muons from $\tilde{\chi}^0_2$ decays

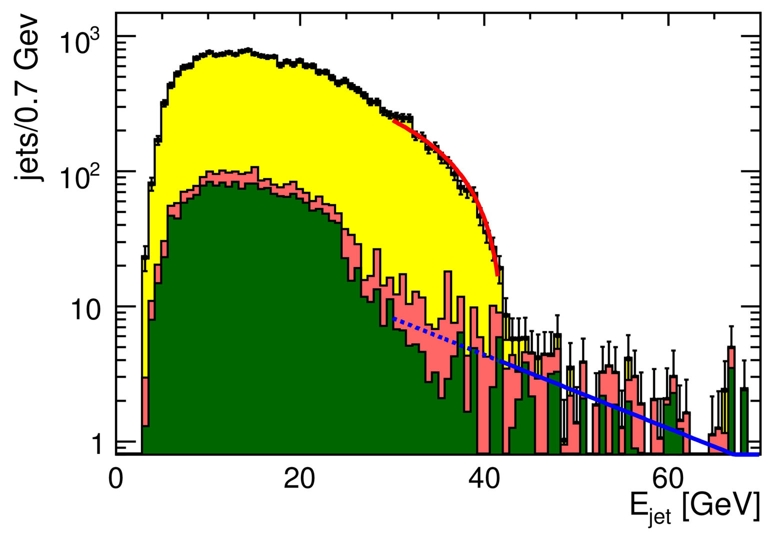
The even smaller contribution from $\tilde{\chi}^0_1\tilde{\chi}^0_2 \to \mu\mu\tilde{\chi}^0_1\tilde{\chi}^0_1$ can also be identified, eg. in the invariant mass spectrum of the two muons. From this channel alone, the mass of the $\tilde{\chi}^0_2$ can be determined to a precision of about 1 GeV, depending on the assumed precision for the mass of $\tilde{\mu}_{\rm R}$ and $\tilde{\chi}^0_1$.



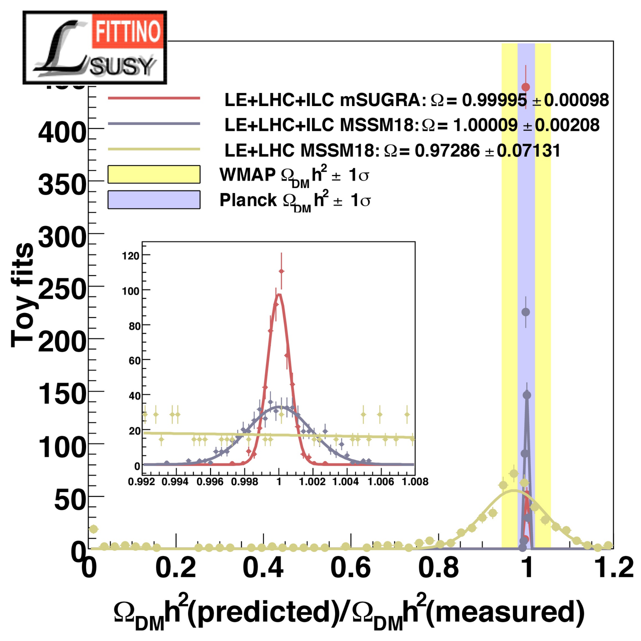
$\delta M_{\tilde{\chi}^0_2} = 1$ GeV

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 $E_{\rm CMS} = 500$ 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%
By using all available collider observables to determine the SUSY parameters, one can predict the relic density based on the assumption that the $\tilde{\chi}^0_1$ is the only contribution to Dark Matter.
This was studied by the Fittino group in a similar model, in particular the $\tilde{\chi}^0_1$ and $\tilde{\tau}_1$ properties were identical to STC4.
Fit with 18 free parameters, and predict $\Omega_{\rm CDM}h^2$.

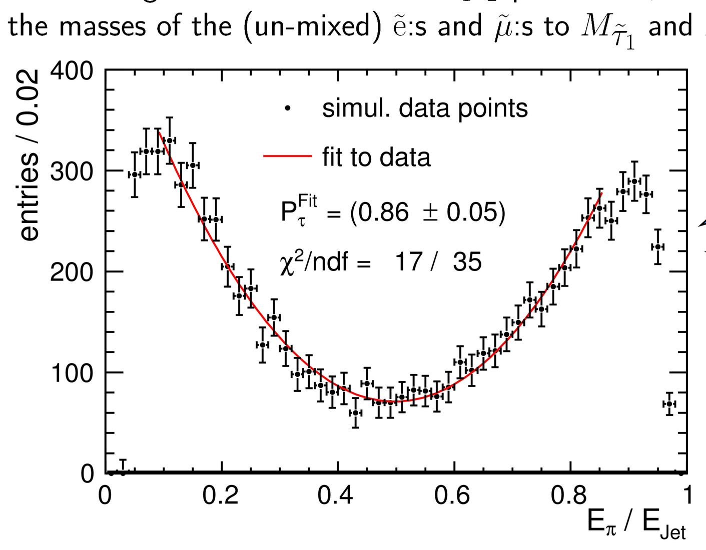


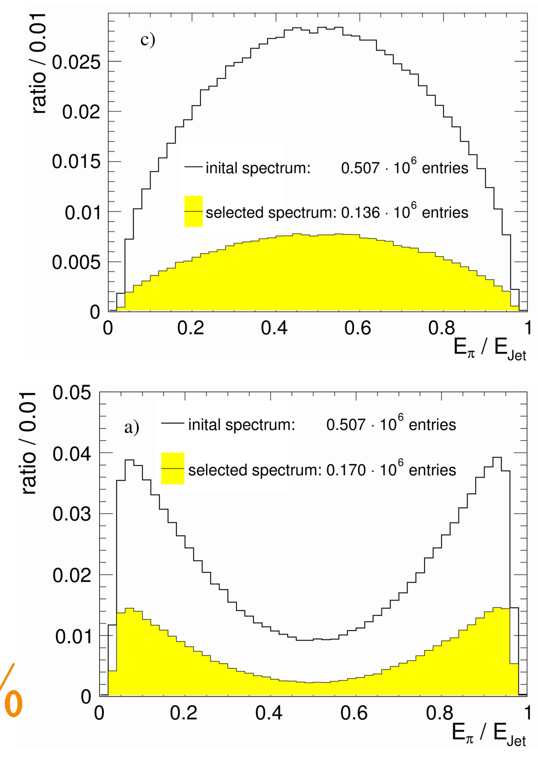
$\delta M_{\tilde{\tau}_1} = 200$ MeV
$\delta M_{\tilde{\tau}_2} = 5$ GeV



τ polarisation and mixing and $\tilde{\chi}^0_1$ nature

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%, eg. from $\tau \to \pi^+\nu_\tau$ decays. from decays to ρ-mesons ($\tau \to \rho^+\nu_\tau \to \pi^+\pi^0\nu_\tau$). In this case, the observable $R = E_\pi/E_{jet}$ can be used to measure the τ-polarisation to $\pm 5\%$ by a fit of templates to the data. The $\tilde{\tau}$ mixing itself can be extracted in several ways: Comparing the cross-section at different beam-polarisations, determining the cross-section for $\tilde{\tau}_1\tilde{\tau}_2$ production, or from the comparing the masses of the (un-mixed) $\tilde{e}$:s and $\tilde{\mu}$:s to $M_{\tilde{\tau}_1}$ and $M_{\tilde{\tau}_2}$.



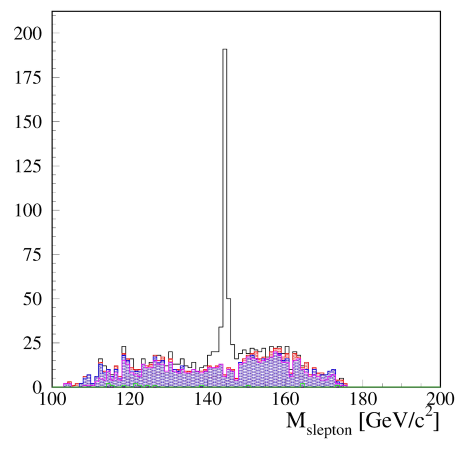


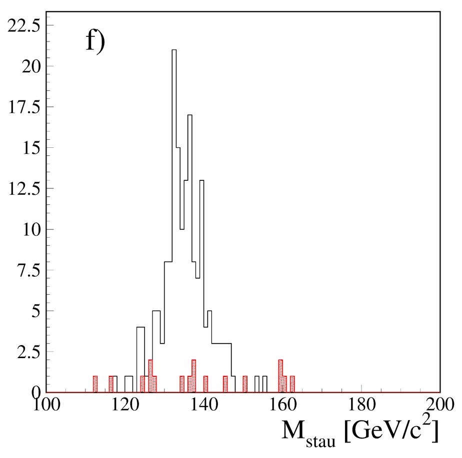
$\delta {\rm Pol}_\tau = 5\%$

Cascade decays and slepton reconstruction:

SUSY is a peak !

A particularly interesting channel is $e^+e^- \to \tilde{\chi}^0_2\tilde{\chi}^0_2$ and the $\tilde{\chi}^0_2$ decay to $\tilde{\mu}_{\rm R}\mu$ or to $\tilde{e}_{\rm R}e$), even if the branching ratio is at the level of a few percent like in our example point. These cascade decays can be fully kinematically constrained at the ILC, and would promise to yield even lower uncertainties on the $\tilde{\mu}_{\rm R}$ and $\tilde{e}_{\rm R}$ masses than the threshold scans, of the order of 25 MeV. This is extrapolated from an earlier study in a scenario with about twice as large branching ratios for the considered decay mode, where a precision of 10 MeV was found. The corresponding distribution of the reconstructed $\tilde{\mu}_{\rm R}$ mass is shown including all SM and SUSY backgrounds. Even the dominating decays to $\tilde{\tau}_1\tau$ can be constrained as shown in the right part and could yield comparable results to a threshold scan.





More info:

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