

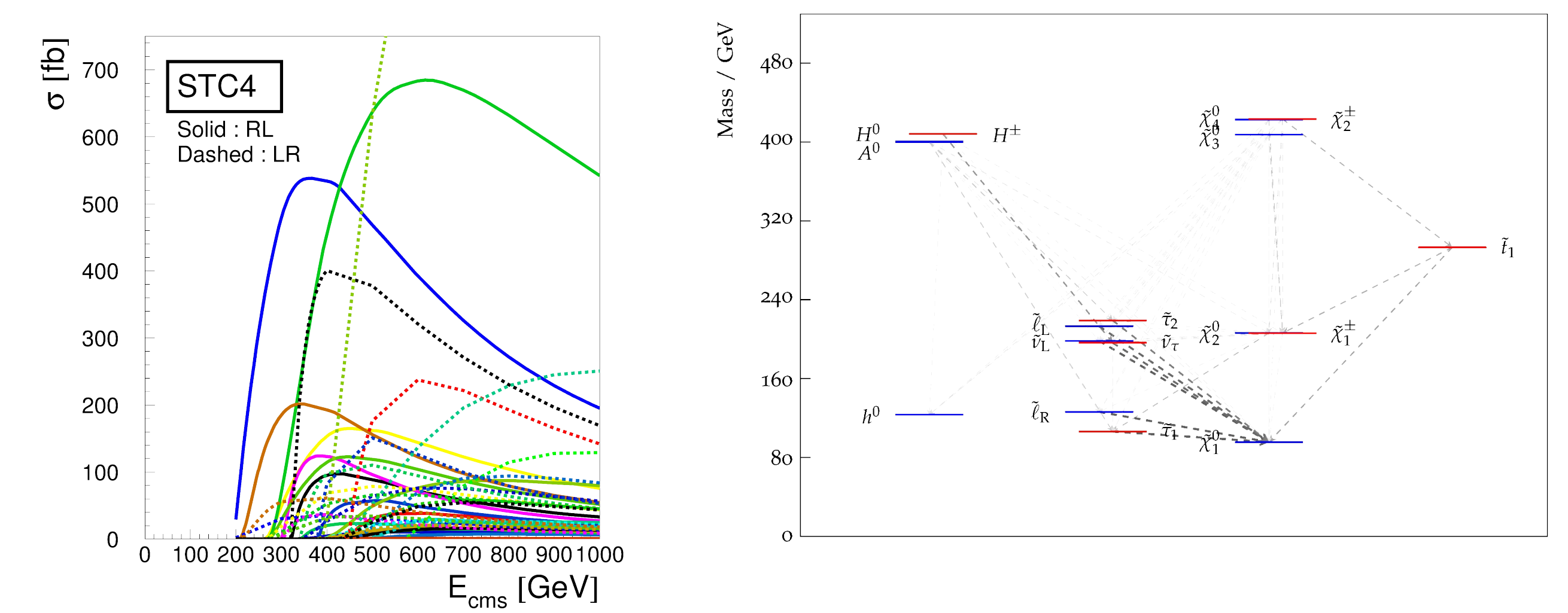
SUSY precision spectroscopy and parameter determination at the ILC.

Mikael Berggren, DESY, on behalf of the ILC concept group



STC4 - An MSSM model with a rich spectrum

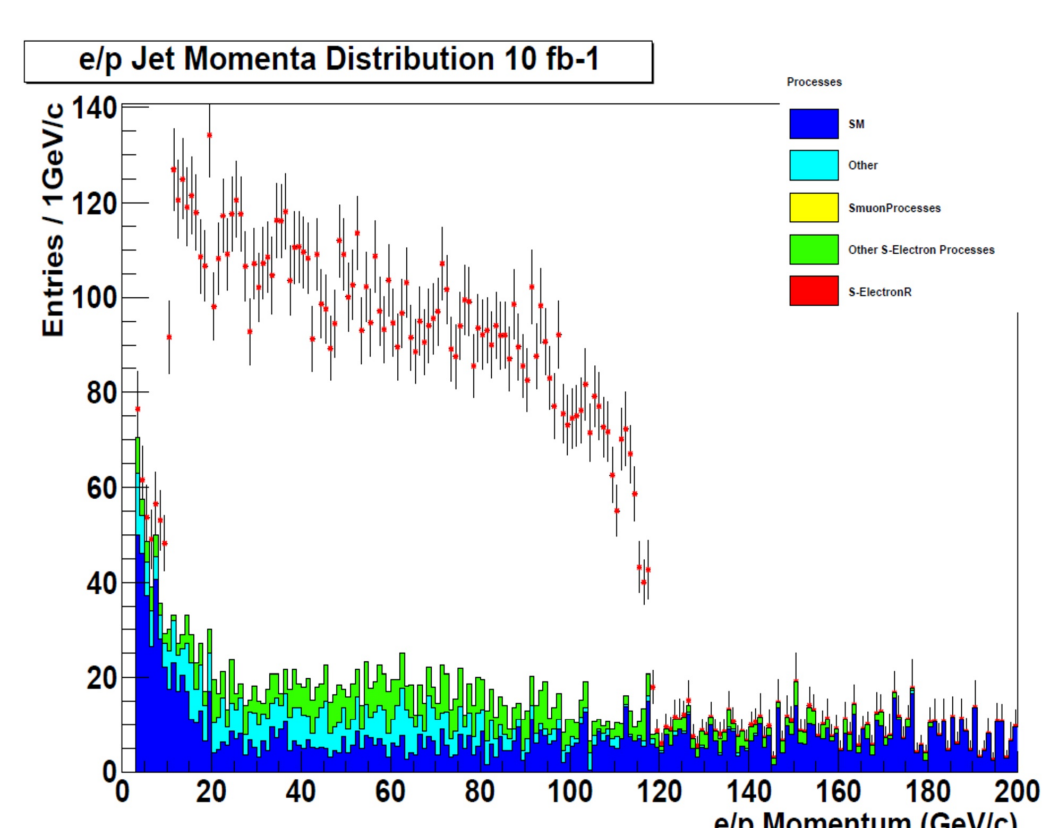
STC4 - for $\tilde{\tau}$ -coannihilation model 4 - is a pMSSM model which is allowed by LHC8 data, but still has a very rich spectrum of bosinos and sleptons observable at the ILC running at E_{CMS} from 250 GeV to 1 TeV. The figures below shows the production cross-section and decay modes of sparticles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



\tilde{e}_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 $E_{\text{CMS}} = 250$ GeV, then $e^+e^- \rightarrow \tilde{\tau}_1 \tilde{\tau}_1$ and $\tilde{\chi}_1^0 \tilde{\chi}_1^0 \gamma$ 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 $E_{\text{CMS}} \gtrsim 270$ GeV, the e^+e^- + missing 4-momentum signature would see a striking signal within a few days:

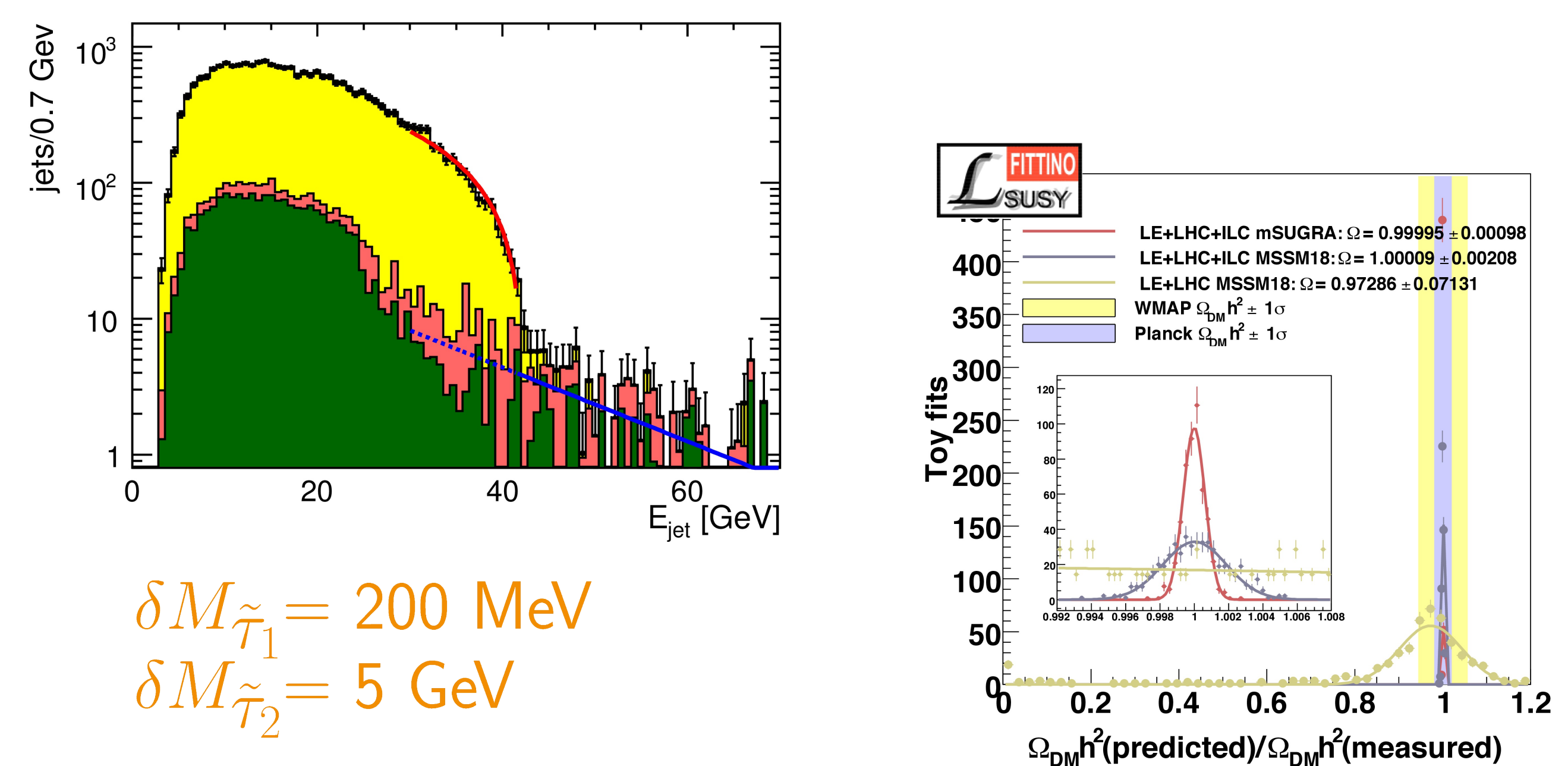


SUSY in a week.

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 $\tilde{\chi}_1^0$ is indeed the dominant Dark Matter constituent. With the ILC at $E_{\text{CMS}} = 500$ 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 $\tilde{\chi}_1^0$ is the only contribution to Dark Matter. This was studied by the Fittino group in a similar model, in particular the $\tilde{\chi}_1^0$ and $\tilde{\tau}_1$ properties were identical to STC4. Fit with 18 free parameters, and predict $\Omega_{\text{CDM}} h^2$.

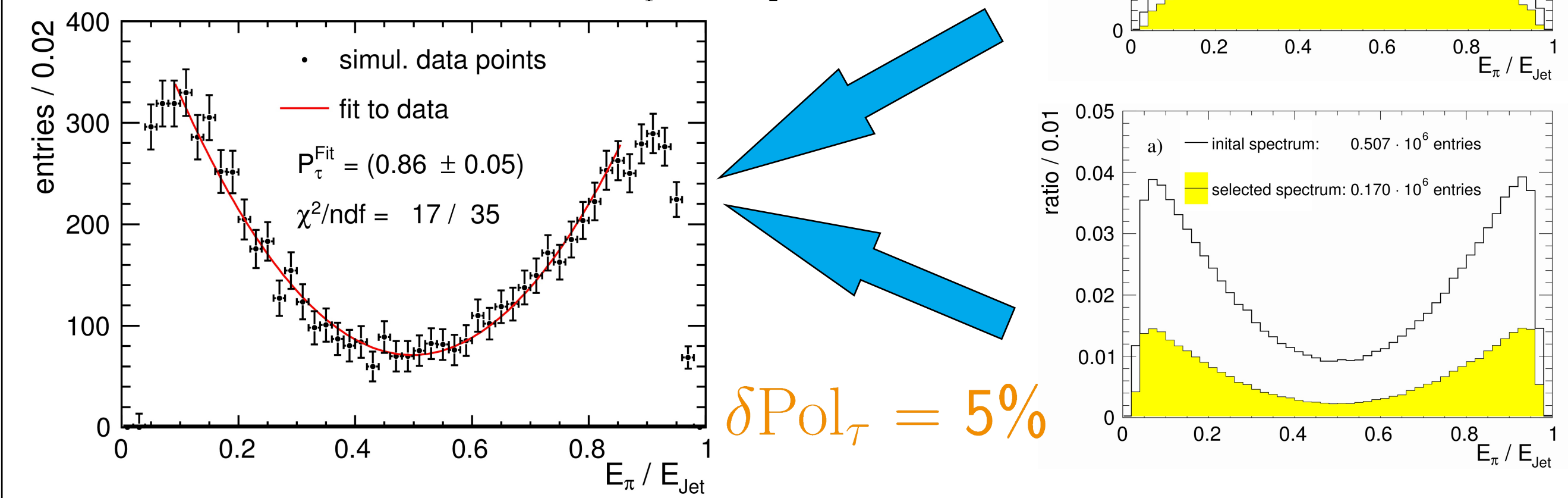


$$\delta M_{\tilde{\tau}_1} = 200 \text{ MeV}$$

$$\delta M_{\tilde{\tau}_2} = 5 \text{ GeV}$$

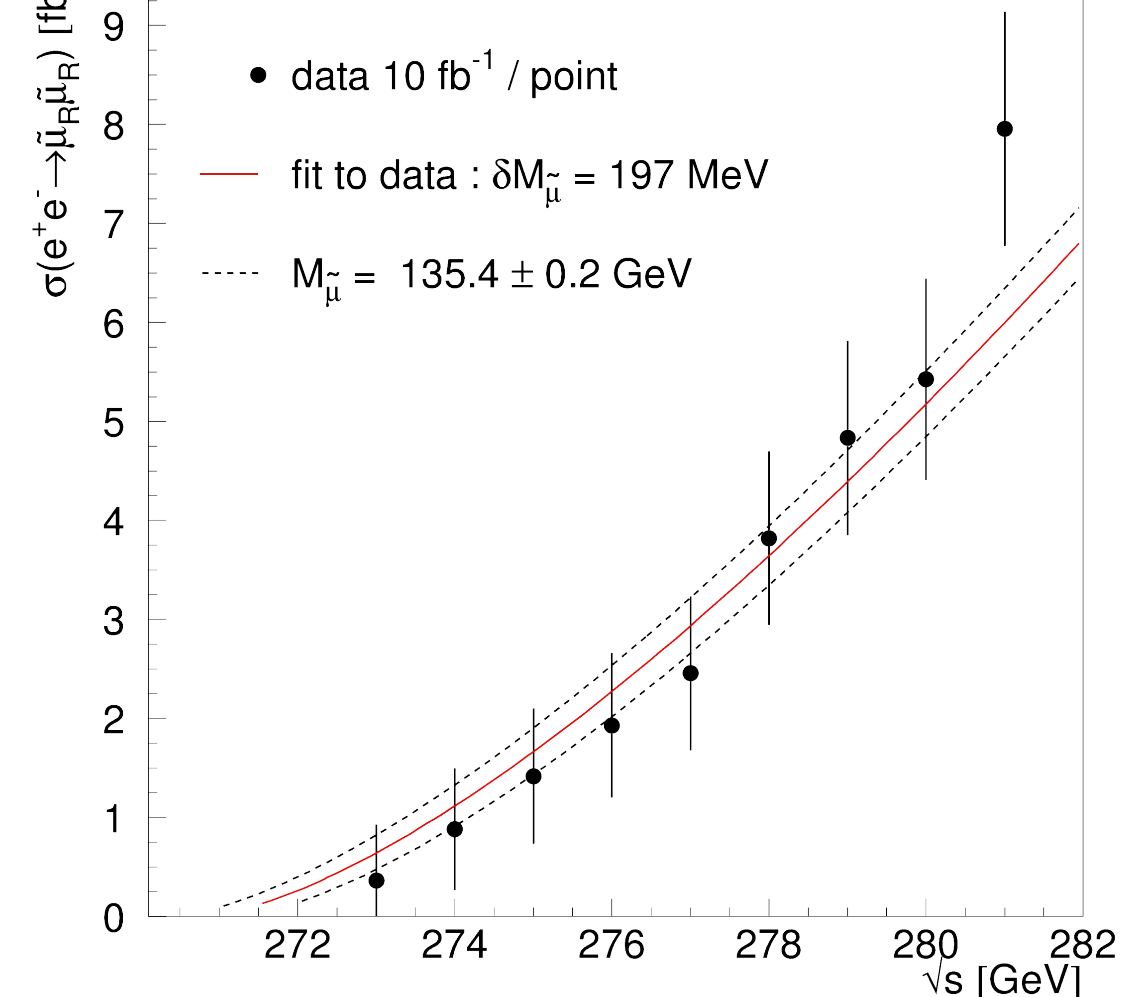
τ polarisation and mixing and $\tilde{\chi}_1^0$ nature

The polarisation of τ -leptons from the $\tilde{\tau}_1$ decay, which gives access to the $\tilde{\tau}_1$ and $\tilde{\chi}_1^0$ mixing - gauginos conserve chirality, higgsinos flips it - can be measured with an accuracy better than 10%, eg. from $\tau \rightarrow \pi^+ \nu_\tau$ decays. From decays to ρ -mesons ($\tau \rightarrow \rho^+ \nu_\tau \rightarrow \pi^+ \pi^0 \nu_\tau$). In this case, the observable $R = E_\pi / E_{\text{jet}}$ 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 $M_{\tilde{\tau}_2}$.



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

Threshold scan of $\tilde{\mu}_R$



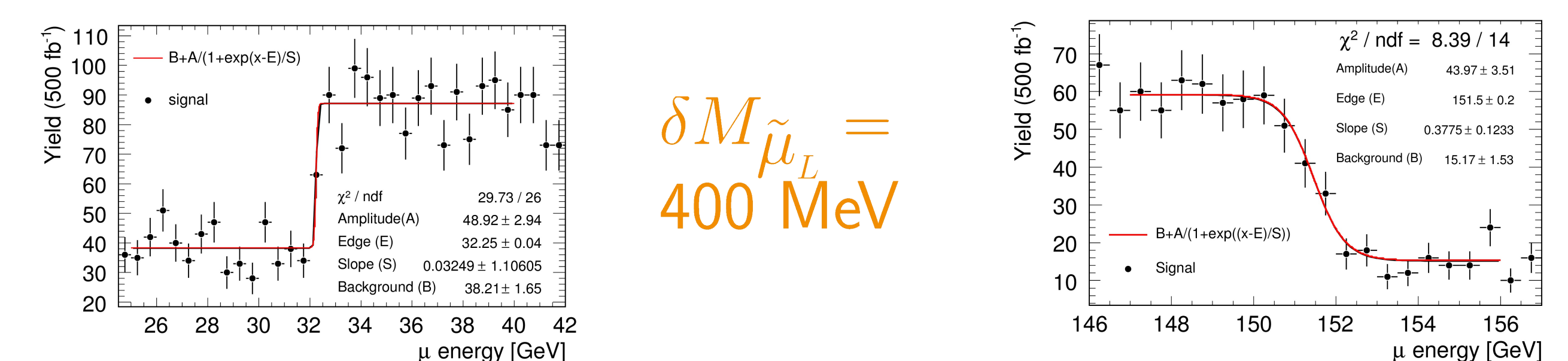
The cross-section for $\tilde{\mu}_R$ pair production is much lower than for \tilde{e}_R due to the absence of a t -channel. Still the $\tilde{\mu}_R$ mass can be determined to ~ 200 MeV by scanning the production threshold near 270 GeV. By measuring the momenta of the muons from the $\tilde{\mu}_R$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

$$\delta M_{\tilde{\mu}_R} = 200 \text{ MeV}$$

$$\delta M_{\tilde{\chi}_1^0} = 200 \text{ MeV}$$

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

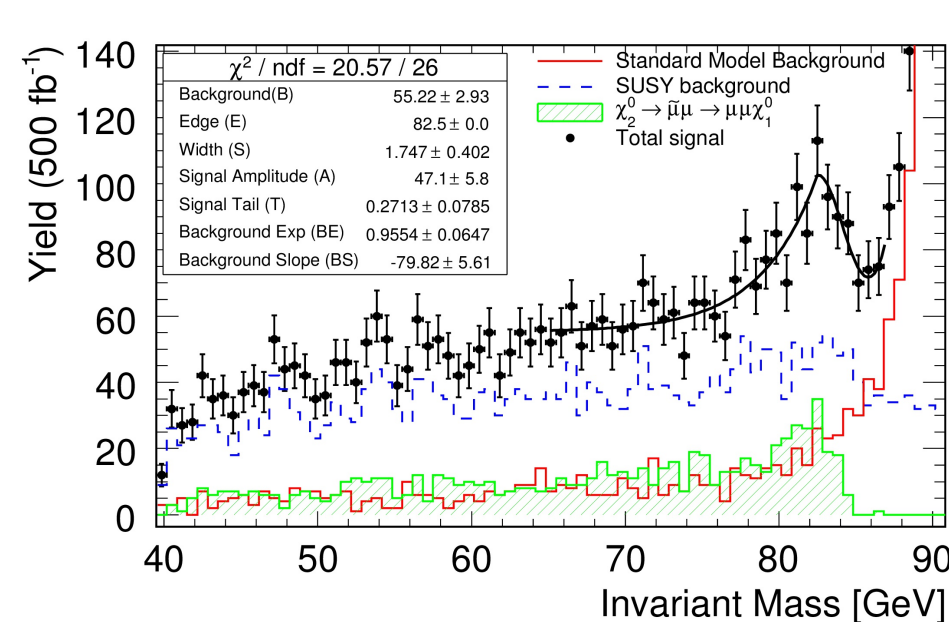
The largest contributions to the di-muon + missing 4-momentum at $E_{\text{CMS}}=500$ GeV signature comes from $\tilde{\mu}_R$ and $\tilde{\tau}_1$ decays. $\tilde{\mu}_L$ can also be studied in detail. Here we show zooms into the muon energy spectrum at the kinematic edge regions for $\tilde{\mu}_L$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



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

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

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

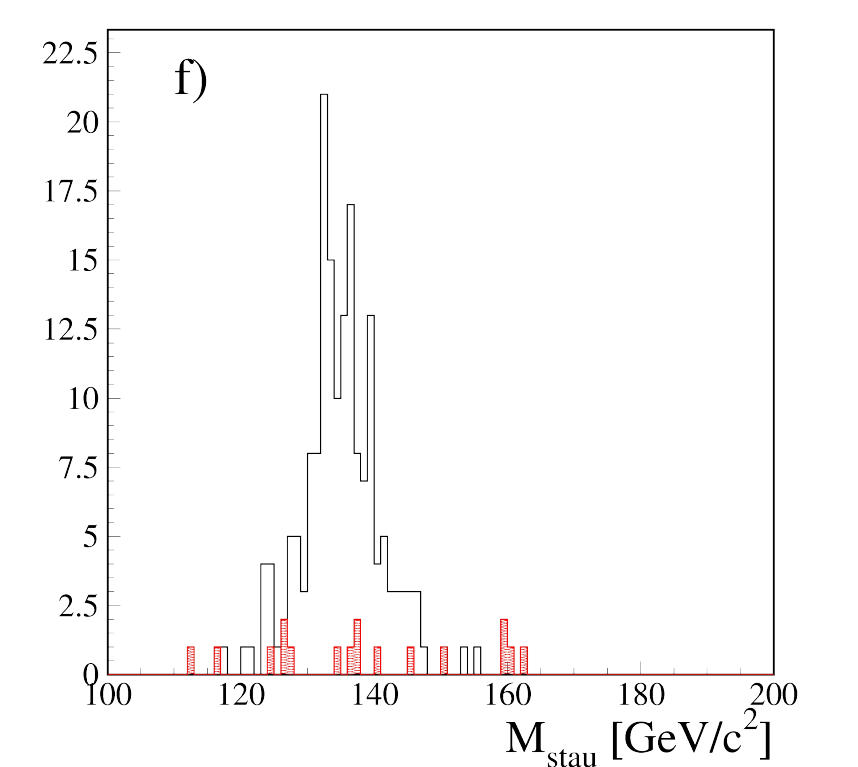
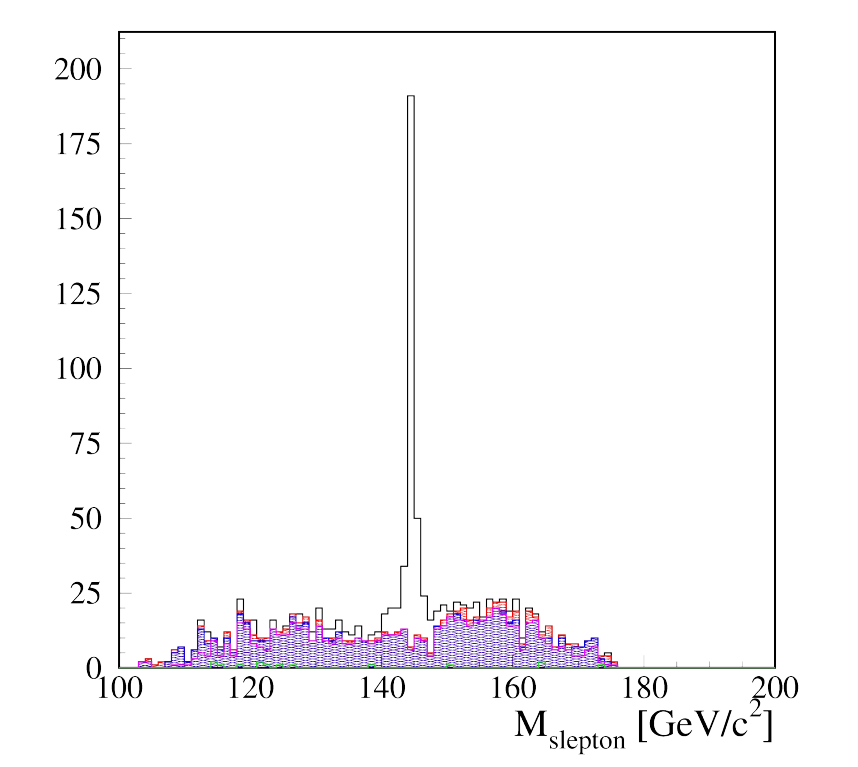


$$\delta M_{\tilde{\chi}_2^0} = 1 \text{ GeV}$$

Cascade decays and slepton reconstruction:

SUSY is a peak !

A particularly interesting channel is $e^+e^- \rightarrow \tilde{\chi}_2^0 \tilde{\chi}_2^0$ and the $\tilde{\chi}_2^0$ decay to $\tilde{\mu}_R \mu$ or to $\tilde{e}_R e$, 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 $\tilde{\mu}_R$ and \tilde{e}_R masses than the threshold scans, of the order of 25 MeV. This is estimated on 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 $\tilde{\mu}_R$ 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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- P. Bechtel, & al. Phys. Rev. D **82**, 055016 (2010) [arXiv:0908.0876 [hep-ex]].
- M. Berggren, in "Proceedings, LCWS 2004, Paris, France," arXiv:hep-ph/0508247.
- P. Bechtel, & al. Eur. Phys. J. C **66** (2010) 215 [arXiv:0907.2589 [hep-ph]].
- N. D'Ascenzo, DESY-THESIS-2009-004.
- <http://www.linearcollider.org/ILC/Publications/Technical-Design-Report>

