$\tilde{\tau}$ searches at future e^+e^- colliders

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The direct pair-production of the tau-lepton superpartner, $\tilde{\tau}$, is one of the most interesting channels to search for SUSY.
Future electron-positron colliders are ideally suited for $\tilde{\tau}$ searches. They will feature increased luminosity and center-of-mass energy, as well as improved accelerator, detector and analysis technologies with respect to previous electron-positron colliders. With respect to hadron colliders, they will profit from a cleaner environment, known initial state and trigger-less operation of the detectors

Motivation for stau searches

Satisfies both conditions SUSY searches are focused on: best motivated NLSP candidates and most difficult scenarios

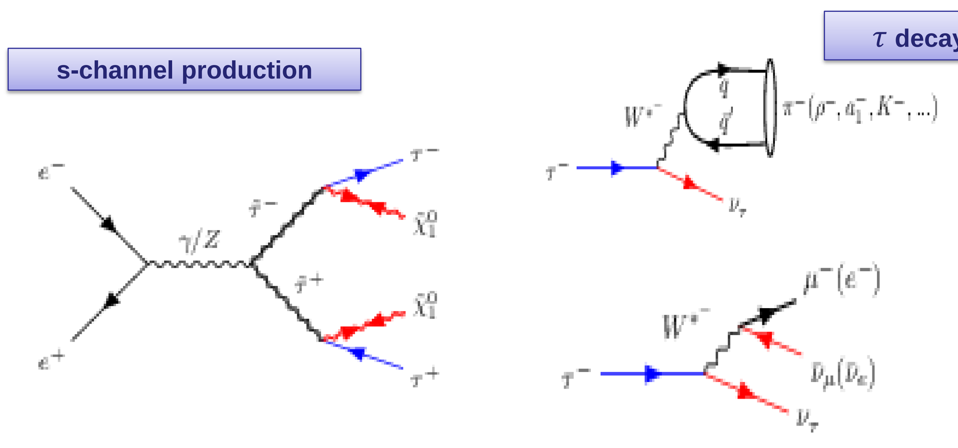
- Two weak hypercharge eigenstates ($\tilde{\tau}_R$, $\tilde{\tau}_L$) not mass degenerate
- Mixing yields to the physical states ($\tilde{\tau}_1$, $\tilde{\tau}_2$), the lightest one being with high probability the lightest sfermion (stronger trilinear couplings)
- With assumed R-parity conservation:
  - pair produced (s-channel via Z^0/γ exchange, low σ since $\tilde{\tau}$-mixing suppresses coupling to the Z^0)
  - decay to LSP and τ, implying more difficult signal identification than the other sfermions

SUSY models with a light $\tilde{\tau}$ can accommodate the observed relic density ($\tilde{\tau}$ - neutralino coannihilation)

Studies using the full detector simulation and reconstruction procedures of the International Large Detector concept (ILD) at the International Linear Collider (ILC)

s-channel production

τ decays



Signal events with the (visible) decay products of two τ's being the only detectable activity

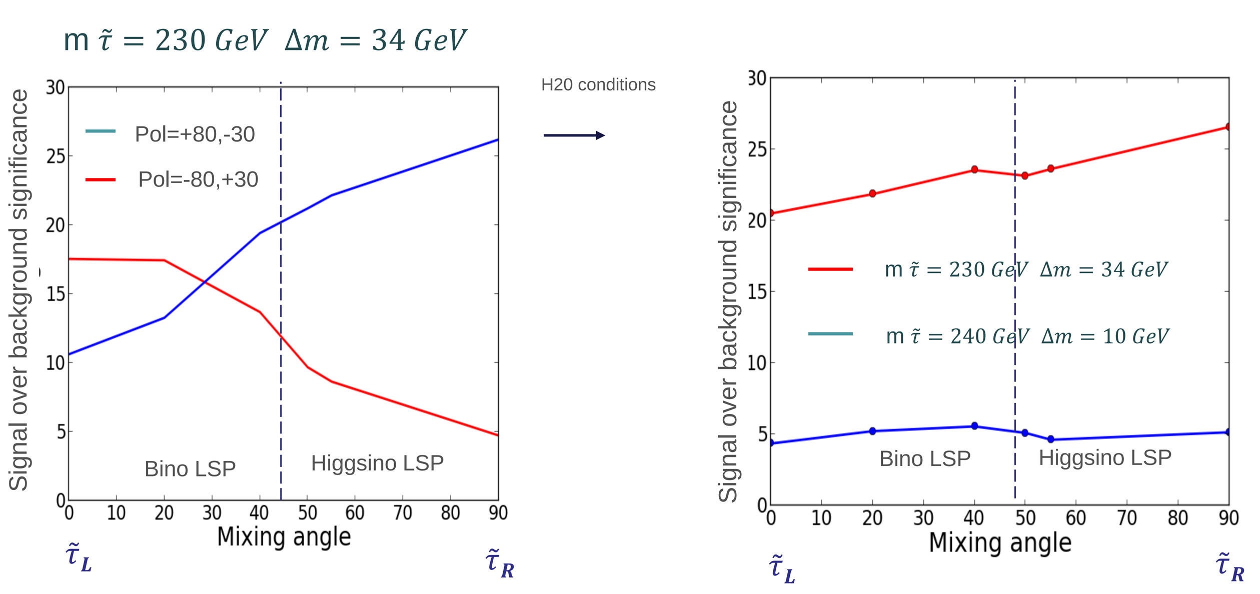
Signature:
- large missing energy and momentum
- large fraction of detected activity in central detector (isotropic production of scalar particles)
- large angle between the two τ-lepton directions
- unbalanced transverse momentum
- zero forward-backward asymmetry

Detector simulation and reconstruction for the signal done using the SGV fast simulation with beam-spectrum and photons in the beam added from the full simulated background samples

- $\sqrt{s}$ = 500 GeV (extrapolated to 250 GeV and 1 TeV)
- Both main polarisations, P(+80%, -30%) and P(-80%, +30%), with $\mathcal{L}$ = 1.6 ab^{-1} each (H20 scenario)
- Including all SM and beam-induced backgrounds

Analysis of worst scenario (worst mixing)

Likelihood ratio statistics used to weight both polarisations



Equal sharing of P(+80, -30) and P(-80, +30) forseen in H20 ensures an uniform sensitivity to all mixing angles

Mixing angle of 53 degrees selected for the study

Effect of overlay-only events

Overlay-only events are ~10^3 times higher than any SM background included in the analysis

$\gamma\gamma \rightarrow low\ pT\ hadrons$ similar to visible products from $\tilde{\tau}$ production for small (≤ 10 GeV) LSP- $\tilde{\tau}$ mass differences

Overlay-only events can be misidentified as signal events

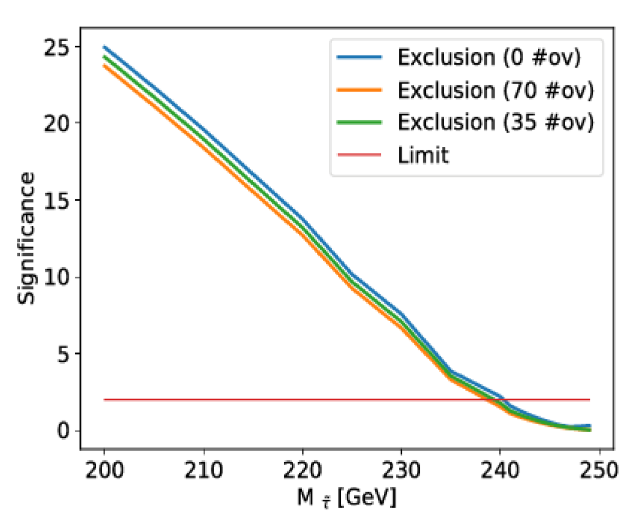
A suppression stronger than 10^{-9} is needed to make the background from overlay-only events negligible

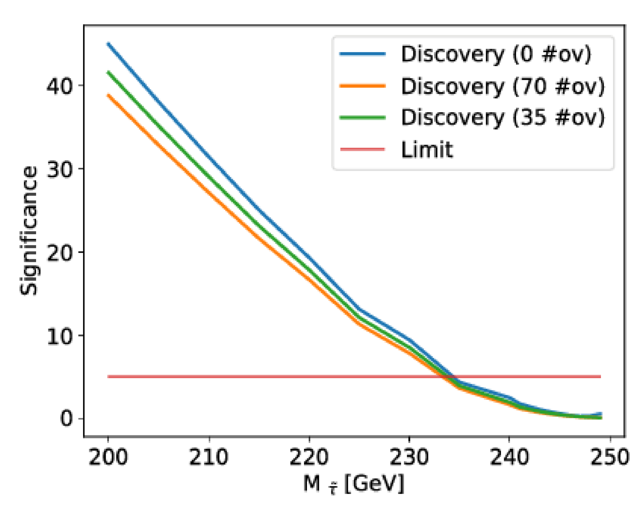
Using the H20 running scenario the number of overlay-only events was estimated to about 70 for each polarization for the cuts applied to the Δ M = 2 GeV model point and 30 for the Δ M = 10 GeV one

For Δ M = 2 GeV the remaining SM background is of the order of the remaining overlay-only event, being two orders of magnitude larger for Δ M = 10 GeV

Negligible effect for Δ M = 10 GeV

Effect for Δ M = 2 GeV:





Additional cuts based on ISR and vertex requirements were needed for M= 2 GeV

Results have to be considered as the worst case, since due to the lack of statistics sets of independent cuts war used for getting the required suppression without killing all the overlay-only events

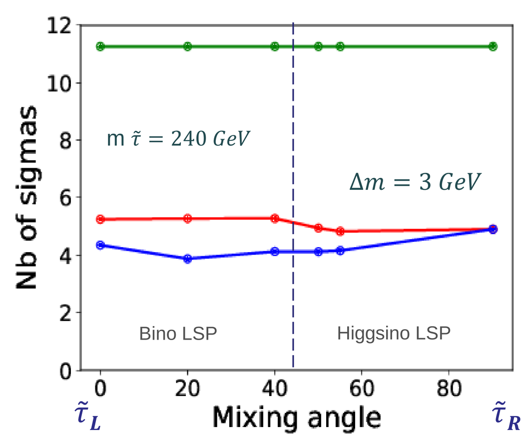
Beam induced backgrounds in e^+e^- colliders

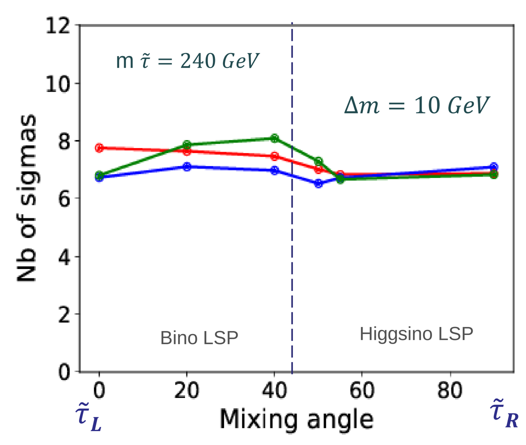
e^+e^- beams are accompanied by real (beamstrahlung) and virtual (Weizsäcker-Williams process) photons.

Interaction between them produce:
- e^+e^- pairs (by scattering of two real photons), 10^5 pairs per bunch crossing, very low p_T (< 1GeV), curl up in magnetic field, interesting for BeamCal studies
- low p_T hadrons (by vector meson fluctuations of real or virtual photons), <1.05> events per bunch crossing at $\sqrt{s}$ = 500 GeV, low p_T, travelling through the detector

$\gamma\gamma$ interactions are independent of the e^+e^- process, but can happen simultaneously to it (overlay-on-physics events) or not (overlay-only events)

Effect of overlay-on-physics events





Larger effect of overlay tracks in low DM case since they are more similar to the signal ones: strong reduction of signficance

Full simulation

Not cut on overlay tracks

Cut on tracks based on transverse momentum, angular distribution and input parameter significance

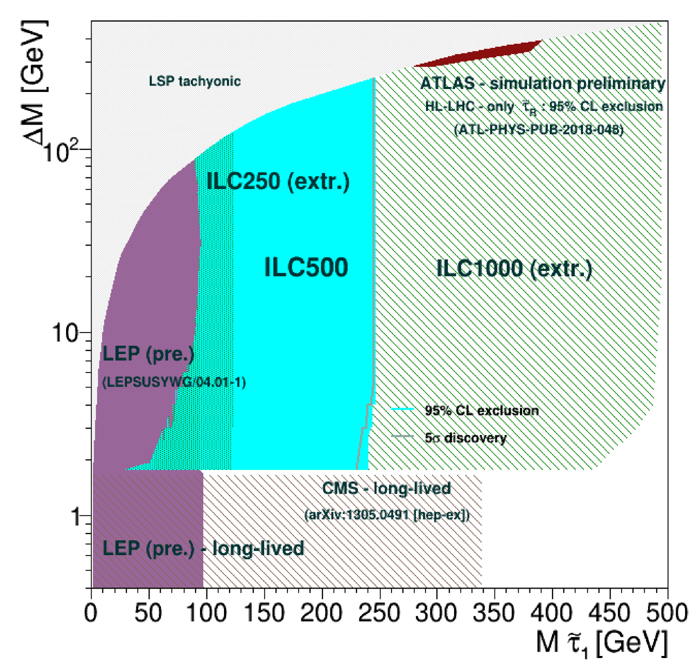
Fast simulation (SGV) – not overlay tracks

Limits

Current model-independent limits for $\Delta M > \tau$ mass come from LEP
They exclude a stau with mass below 26.3 GeV for any mixing and any $\Delta M > \tau$ mass

Limits from LHC and HL-LHC prospects are highly model dependent
They do not have discovery potential for the most well-motivated scenarios: $\tilde{\tau}$ coannihilation or $\tilde{\tau}_R$ pair production

Even after HL-LHC $\tilde{\tau}$ -LSP mass plane will remain almost unexplored



ILC will discover/exclude $\tilde{\tau}$'s for any $\tilde{\tau}$ - LSP mass difference and any $\tilde{\tau}$-mixing nearly up to the kinematic limit

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