Study of $\tilde{\tau}$ in Gauge-Mediated SUSY Breaking Models

- Heavy Long-lived Charged Particles -

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Gauge-mediated SUSY-breaking models

LSP = gravitino ($\tilde{G}$)

NLSP = stau ($\tilde{\tau}^{\pm}$) or neutralino

If $\tilde{\tau}$ is the NLSP

$\rightarrow$ Long-lived heavy charged particle
for a large area of parameter space.

$$c\tau = 10\text{km} \times \left[\frac{\sqrt{F}}{10^7\text{GeV}}\right]^4 \left[\frac{100\text{GeV}}{m_{\tilde{\tau}}}\right]^5$$

$\sqrt{F}$: dynamical SUSY breaking scale

If $\sqrt{F} \stackrel{\sim}{>} 10^7$ GeV, then
$\tilde{\tau}$ mostly do not decay in the detector.

ISAJET simulation
(Includes initial-state radiation (ISR)
& beamstrahlung)

- $\sqrt{S} = 500$ GeV, $\int L dt = 50$ fb^{-1}

Signature: looks like $e^+e^- \rightarrow \mu^+\mu^-$ but heavy.

Tools for signal detection:

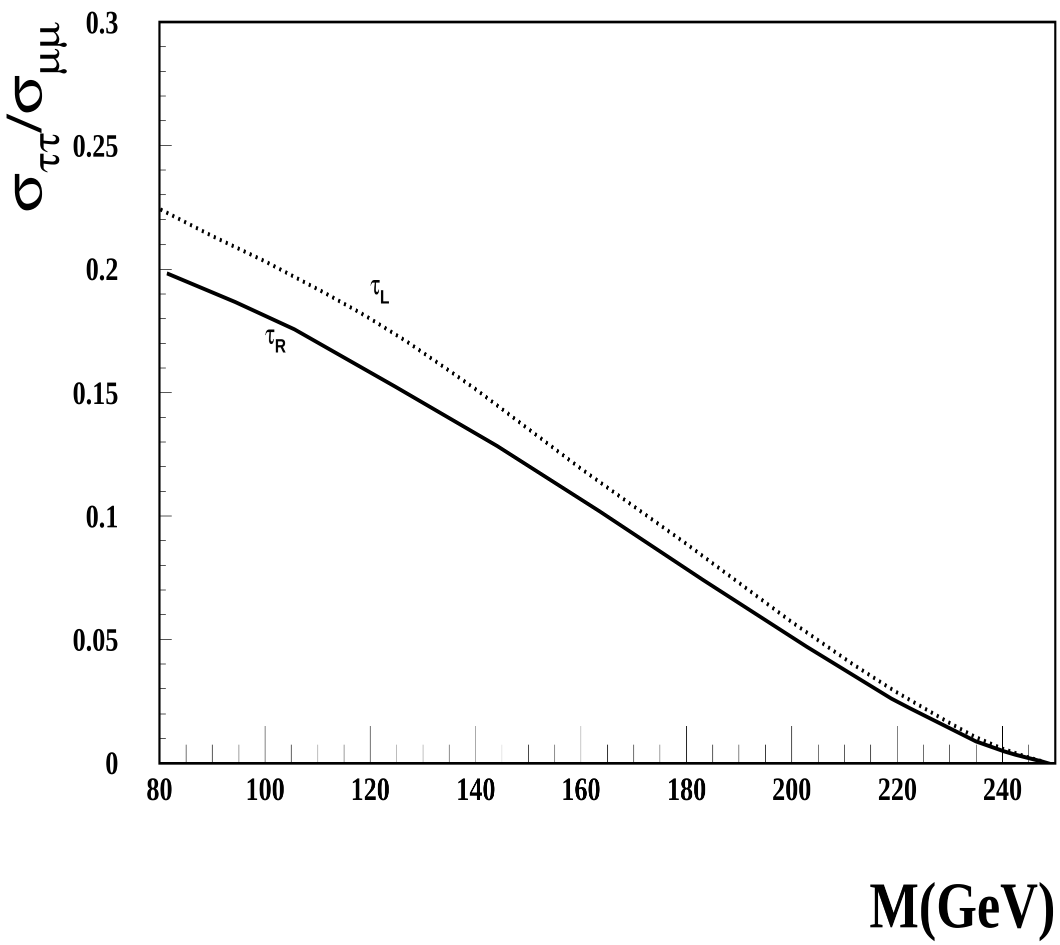
- Kinematics: $m^2 = E^2_{\mathrm{beam}} - p^2$
  $\delta p/p = 5 \times 10^{-5} p(\mathrm{GeV})$
  (Large detector scenario: 2m radius TPC)

- TOF ($\sigma_T = 50$ ps)

- dE/dx (5% resolution)

$e^+e^- \to \tilde{\tau}^+\tilde{\tau}^- \quad (\sqrt{s} = 500\ \text{GeV})$

The production cross section is quite model-independent.



$(\sigma_{\mu\mu} = 500\ \text{fb}^{-1})$

Backgrounds:

- π, K, p, e

  Require hits in muon chamber

- Two-photon events: $e^+e^- \to e^+e^-\mu^+\mu^-$
  Tau pairs: $e^+e^- \to \tau^+\tau^-$, $\tau \to \mu\nu\nu$

  $|p| > 0.5E_{\text{beam}}$, $|(P_{\text{tot}})_z| < 0.25E_{\text{beam}}$

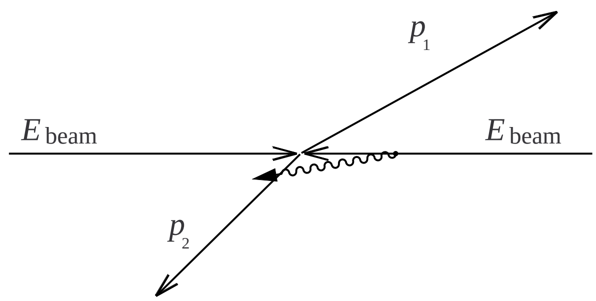
- Radiative $\mu\mu$: $e^+e^- \to \mu^+\mu^-\gamma$

  No photons detected anywhere

- $e^+e^- \to \mu^+\mu^-$

Kinematic mass reconstruction

Initial-state radiation and beamsstrahlung
($E_{\text{beam}} = 250$ GeV)



Assume single photon emission along the beam line.

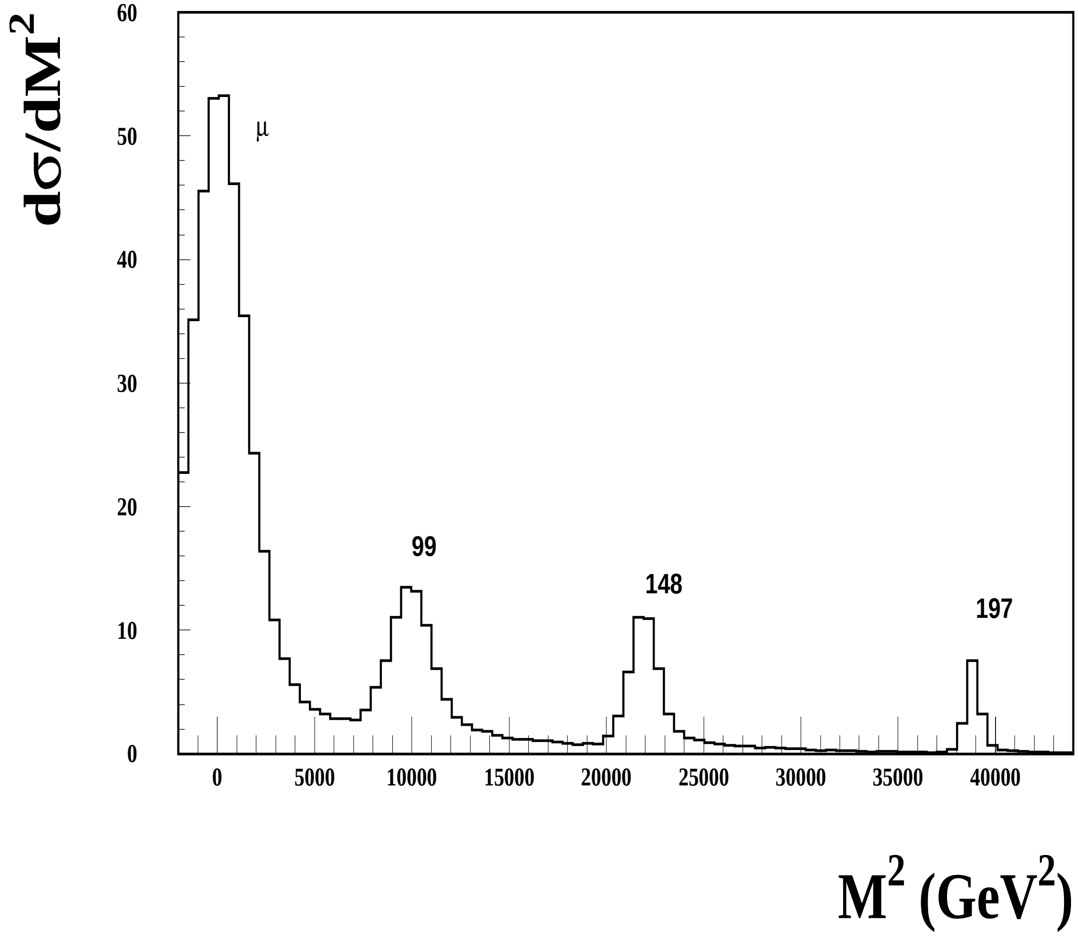
$$m_i^2 = \left(\frac{\sqrt{\hat{s}}}{2\gamma + \beta p_{zi}}\right)^2 - |\vec{p}_i|^2$$

$$\hat{s} = s(1 - |\Delta|)\,, \quad \beta = \frac{\Delta}{2 - |\Delta|}$$

$$\Delta = \frac{p_{z\text{tot}}}{E_{\text{beam}}}$$

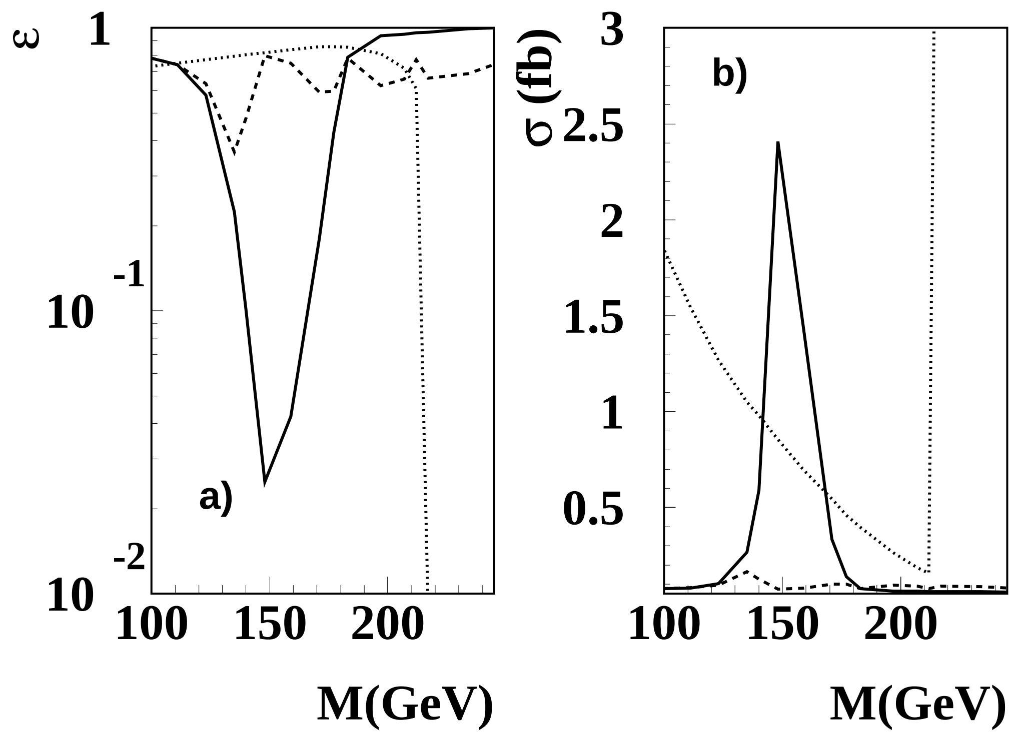
$\hat{s}$: invariant mass squared of p_1 and p_2

Mass measurements of $e^- e^+ \to \mu(\tilde{\tau})^- \mu(\tilde{\tau})^+$



With momentum smearing

Efficiency and $\sigma_{\tilde{\tau}^+\tilde{\tau}^-}$ upper limit
($E_{\text{beam}} = 250$ GeV, 50 fb^{-1})



...... kinematic mass estimation
- - - TOF
—— dEdx

Lifetime Measurement

- For kinematic identification and dEdx, need ~1m of track.
- IF decays to τ, it cannot be μ.
  $\rightarrow$ identifiable down to ~1cm.
- Try both of the above cases.

Simplified (but realistic) analysis:

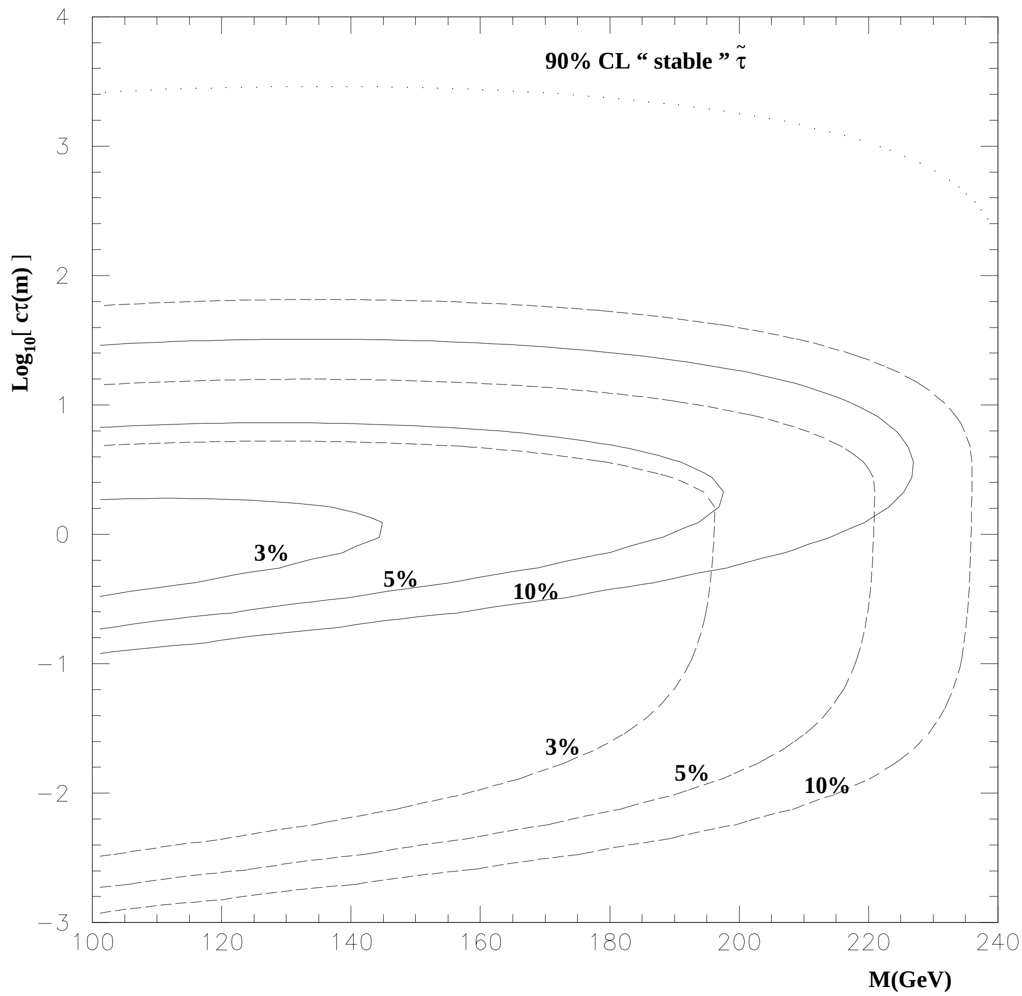
1. Count decays in two regions.
   - n_1: $r > r_{\text{max}}$
   - n_2: $r_{\text{min}} < r < r_{\text{max}}$

   Measure $\dfrac{n_1}{n_2}$ to extract lifetime.
   ($r_{\text{min}} = $ 1m or 1cm)

2. For given total number of decays, the best sensitivity is for $n_1/n_2 \sim 4$.
   $\rightarrow$ adjust the boundary (r_{max}) as long as $r_{\text{max}} <$ 2m.

(Assume all tracks perp to beam)

Lifetime Sensitivity

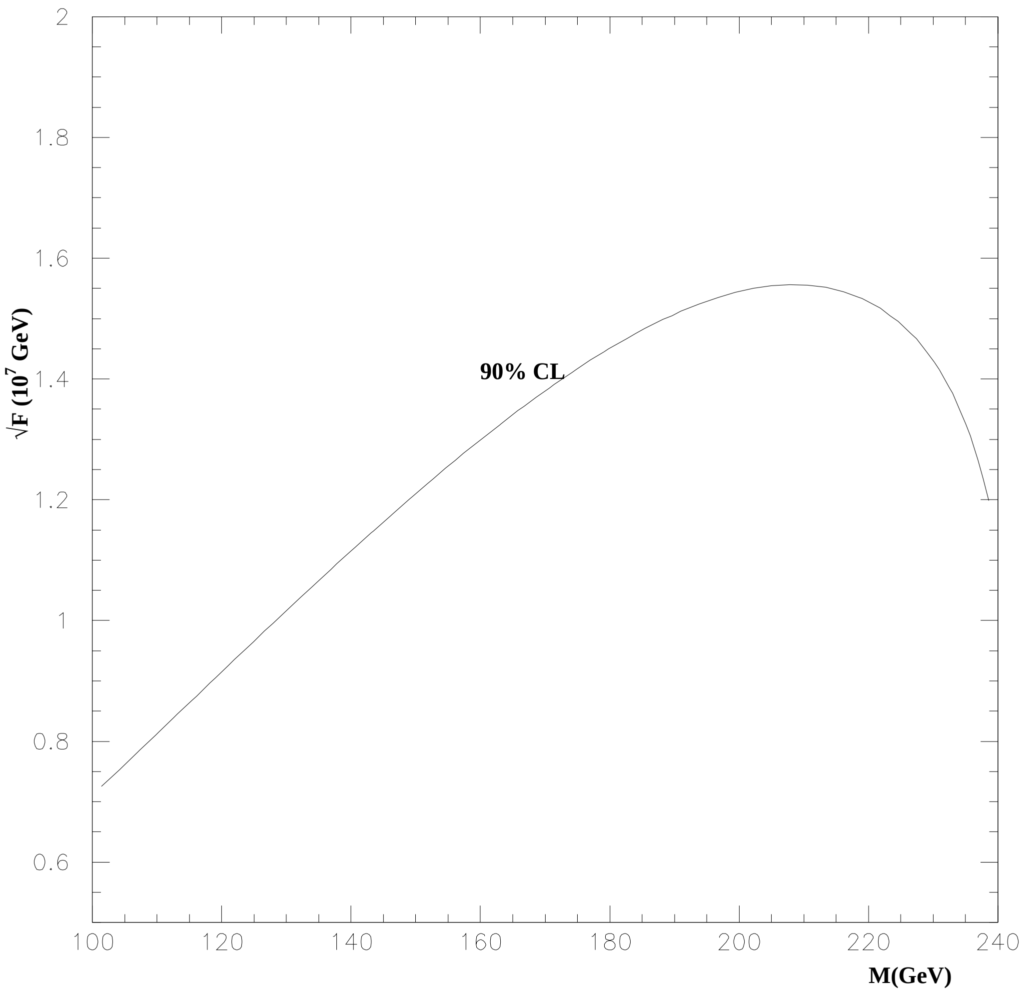


...... Lower limit when no decay in detector

- - - $r > 1$cm

—— $r > 1$m

Lowerlimit on $\sqrt{F}$
(when there is no decay observed)



To-do:

* Tau polarization in $\tilde{\tau}$ decay.
$\longrightarrow \tilde{\tau}$ mixing angle.