Effects of lepton flavor violation on chargino production

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Motivation

Production of charginos in MSSM at the linear collider:

$$e^+e^- \longrightarrow \widetilde{\chi}_i^+ \widetilde{\chi}_j^-$$

$\Longrightarrow$ determining the parameters $\mu, M_2, \tan\beta$

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$\Longrightarrow$ 1-loop corrections to these processes $\lesssim$ 10%

Blank and Hollik, LC-TH-2000-054, [hep-ph/0011092]

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$\Longrightarrow$ Influence of lepton flavor violation (LFV) on $e^+e^- \longrightarrow \widetilde{\chi}_i^+ \widetilde{\chi}_j^-$:

How does it arise?

How large could it be?

Hohenwarter-Sodek and Kernreiter, JHEP 06 (2007) 071

Sneutrino mass matrix

Sneutrino mass matrix, in the basis $(\widetilde{\nu}_e, \widetilde{\nu}_\mu, \widetilde{\nu}_\tau)$

$$M^2_{\tilde{\nu},\alpha\beta} \quad = \quad M^2_{L,\alpha\beta} + \frac{1}{2}\, m_Z^2 \;\cos 2\beta \;\delta_{\alpha\beta}$$

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For example if $M^2_{L,13} \neq 0$ ($M^2_{L,12} = M^2_{L,23} = 0$)

$$R^{\tilde{\nu}} = \begin{pmatrix} \cos\theta_{13} & 0 & \sin\theta_{13} \\ 0 & 1 & 0 \\ -\sin\theta_{13} & 0 & \cos\theta_{13} \end{pmatrix}$$

Sneutrino mass eigenstates:

$\widetilde{\nu}_1 = \cos\theta_{13}\, \widetilde{\nu}_e + \sin\theta_{13}\, \widetilde{\nu}_\tau \qquad \widetilde{\nu}_3 = -\sin\theta_{13}\, \widetilde{\nu}_e + \cos\theta_{13}\, \widetilde{\nu}_\tau$

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$\Longrightarrow \widetilde{\nu}_k$ are superpositions of $\widetilde{\nu}_e,\ \widetilde{\nu}_\mu,\ \widetilde{\nu}_\tau$

$\Longrightarrow \widetilde{\ell}_k$ are superpositions of $\widetilde{e}_L,\ \widetilde{\mu}_L,\ \widetilde{\tau}_L,\ \widetilde{e}_R,\ \widetilde{\mu}_R,\ \widetilde{\tau}_R$

Lepton flavor violation: LFV rare decays

$\Longrightarrow$ nonvanishing Yukawas for $\ell = e, \mu, \tau$

LFV	$\longleftrightarrow$	LFC
$\ell\ \widetilde{\nu}_{1,2,3}\ \widetilde{\chi}^+$		$\ell\ \widetilde{\nu}_\ell\ \widetilde{\chi}^+$
$\ell\ \widetilde{\ell}_{1,\ldots,6}\ \widetilde{\chi}^0$		$\ell\ \widetilde{\ell}\ \widetilde{\chi}^0$

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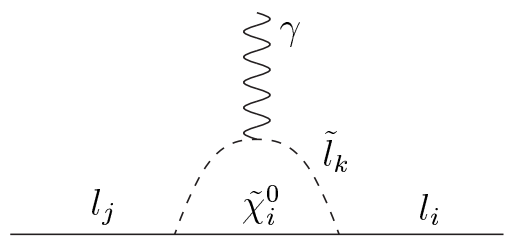

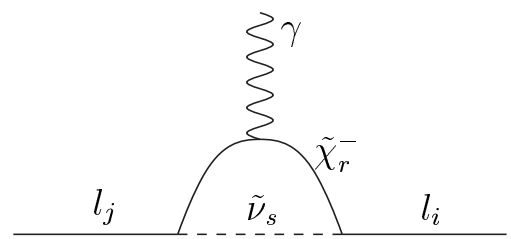

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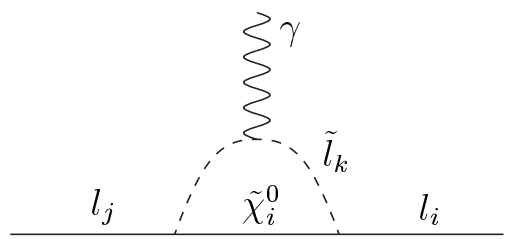
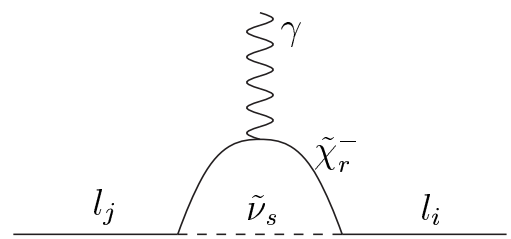




Experiment: Unobserved $\Rightarrow$ upper bounds on decay rates

BR$(\mu^- \to e^- \gamma) < 1.2 \times 10^{-11}$ M.L. Brooks *et al.* [MEGA Coll.], PRL 83, (1999) 1521

BR$(\tau^- \to e^- \gamma) < 1.1 \times 10^{-7}$ B. Aubert *et al.* [BABAR Coll.], PRL 96 (2006) 041801

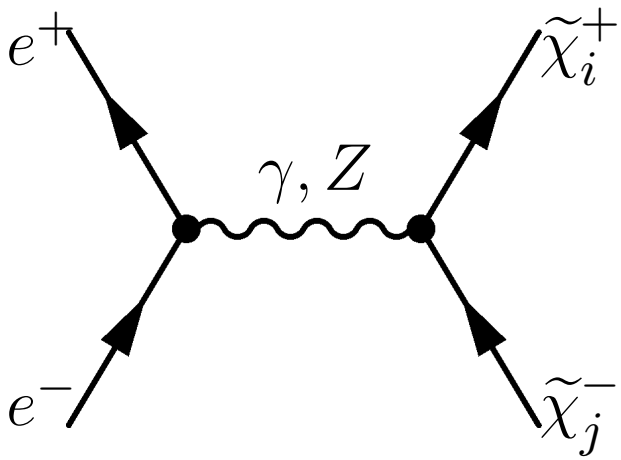
BR$(\tau^- \to \mu^- \gamma) < 4.5 \times 10^{-8}$ K. Abe *et al.* [Belle Coll.], [arXiv:hep-ex0609049]

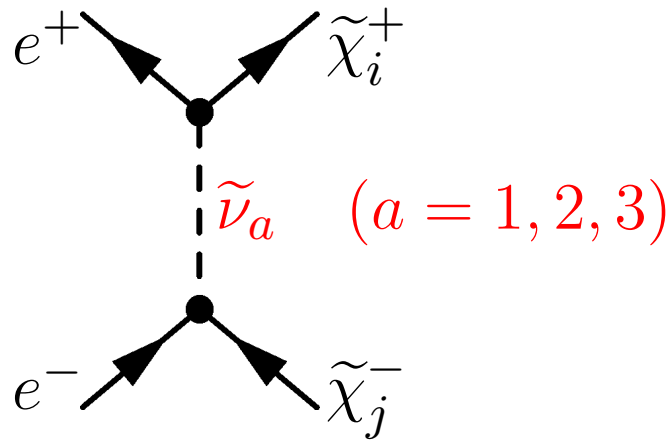
$\Longrightarrow$ Yukawas restricted by limits on LFV lepton decays

Chargino production cross section

$\Longrightarrow$ Same Yukawas can contribute to SUSY processes already at <u>tree level</u>

Consider chargino production at linear collider:





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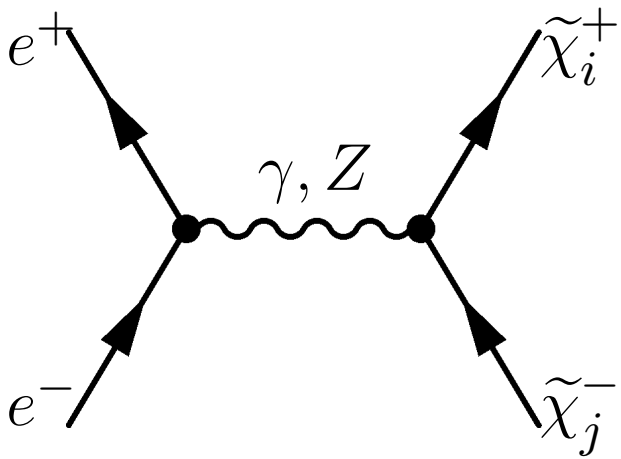
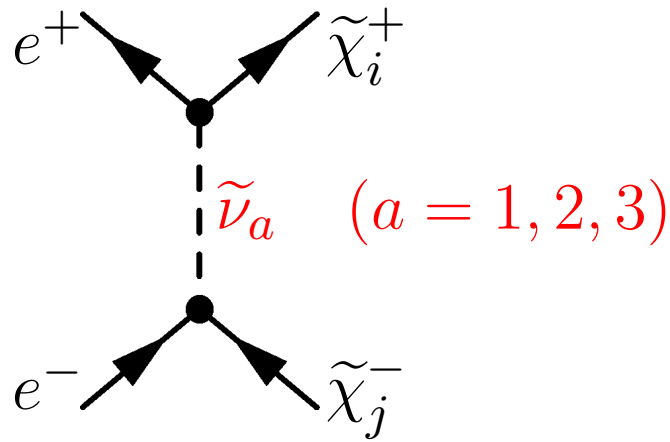


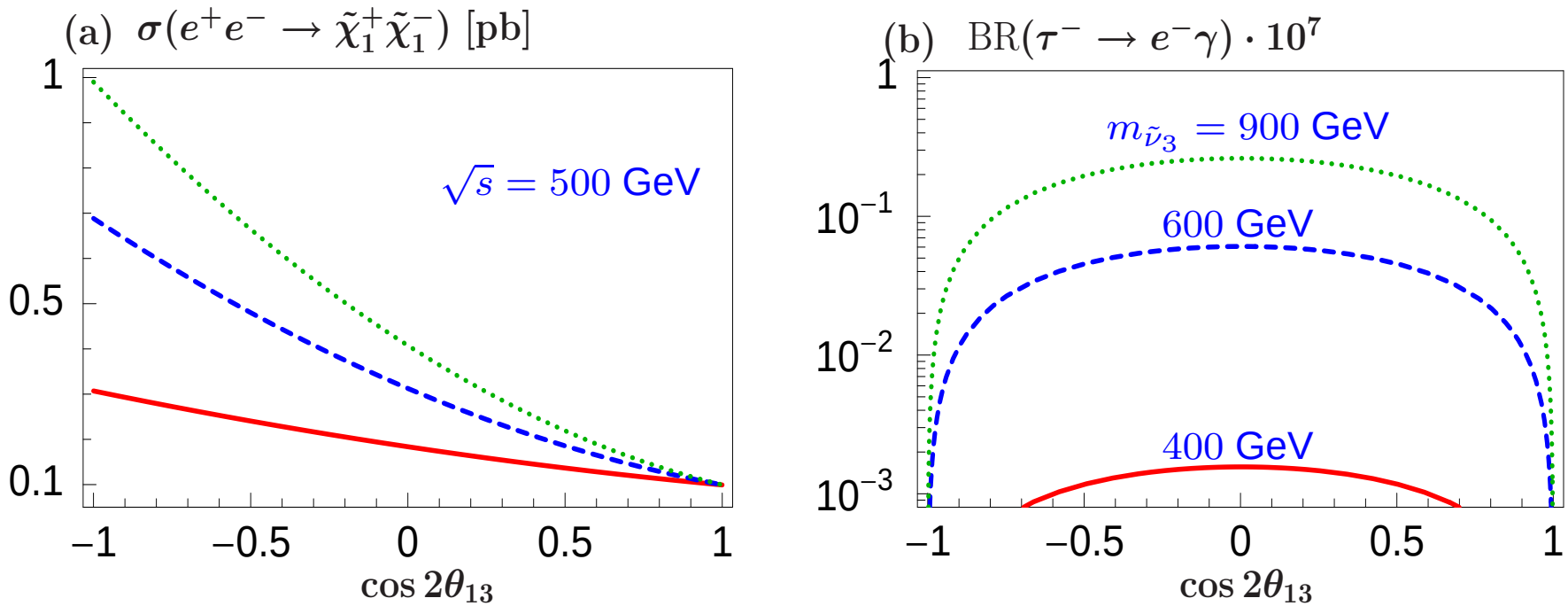


$\Longrightarrow$ $t-$channel sneutrino contribution gets modified $\Rightarrow$ without LFV only $\widetilde{\nu}_e$ contributes

Consider $M^2_{L,12} = M^2_{L,23} = 0$ and $M^2_{L,13} \neq 0$

$\Rightarrow \tan 2\theta_{13} = \frac{2M^2_{L,13}}{M^2_{L,11} - M^2_{L,33}}$

LFV effects on $\sigma(e^+e^- \to \widetilde{\chi}_1^+\widetilde{\chi}_1^-)$



Light SUSY spectrum:

$m_{\chi_1^+} = 238$ GeV, $m_{\tilde{\nu}_1} = 300$ GeV, $m_{\tilde{\nu}_2} = 350$ GeV, $m_{\chi_1^0} = 119$ GeV, $m_{\chi_2^0} = 237$ GeV, $m_{\tilde{\ell}_1} = 309$ GeV, $m_{\tilde{\ell}_2} = 358$ GeV

MSSM parameters:

$\tan\beta = 5$, $M_2 = 250$ GeV, $\mu = 1500$ GeV

$M_{E,11} = 700$ GeV, $M_{E,22} = 800$ GeV, $M_{E,33} = 900$ GeV, $M_{E,i\neq j} = 0$, $A_{ij} = 0$

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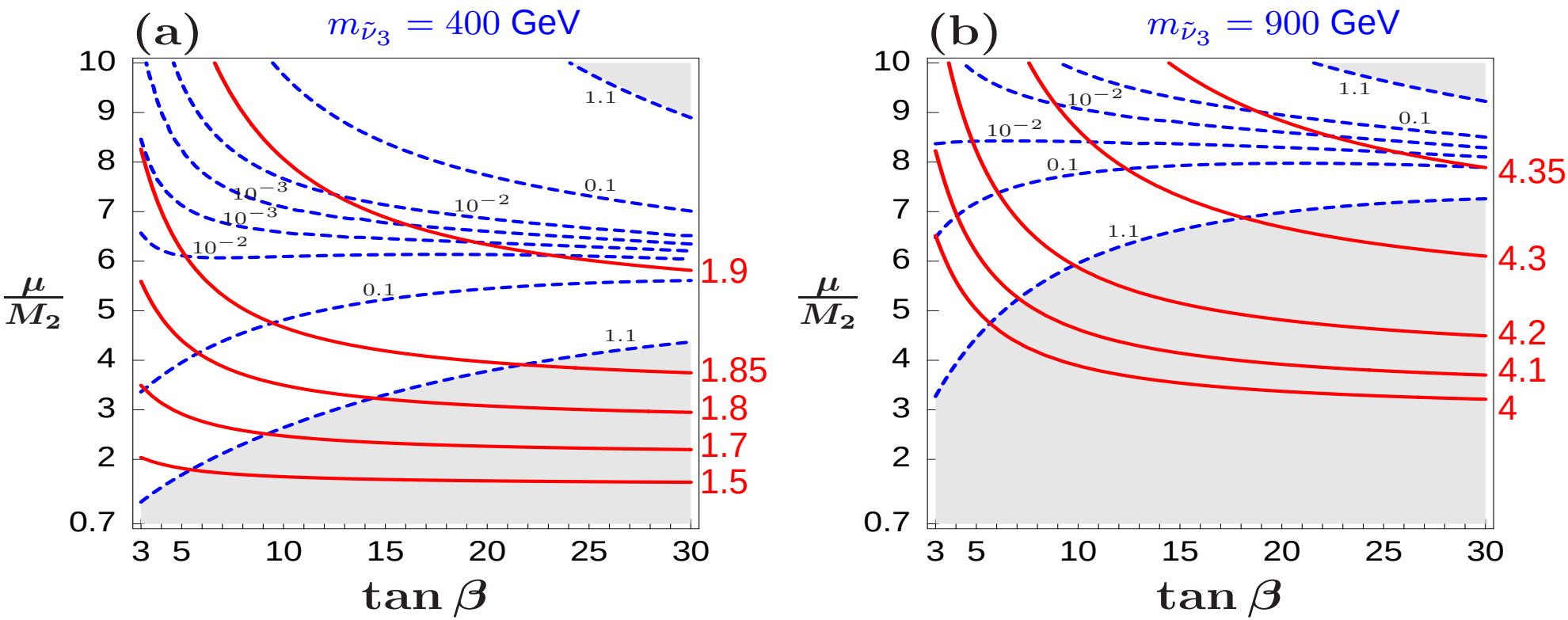

$10^7 \cdot \mathrm{BR}(\tau^- \to e^-\gamma) = (1.1, 0.1, 10^{-2}, 10^{-3})$

$$\frac{\sigma^{\mathrm{LFV}}(e^+e^- \to \widetilde{\chi}_1^+\widetilde{\chi}_1^-) \quad \text{for} \quad \theta_{13}=\frac{\pi}{4}}{\sigma^{\mathrm{LFC}}(e^+e^- \to \widetilde{\chi}_1^+\widetilde{\chi}_1^-) \quad \text{for} \quad \theta_{13}=0}$$

Summary and conclusions

- The influence of LFV parameters ($\cos 2\theta_{13}$) on the cross section $\sigma(e^+e^- \to \widetilde{\chi}_1^+\widetilde{\chi}_1^-)$ can be severe $\Rightarrow$ changes up to a factor 4

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- One should not forget about the effect of LFV!
  Measurement of e.g. $e^+e^- \to \widetilde{\nu}\bar{\widetilde{\nu}} \to e\,\tau + \widetilde{\chi}_1^+\widetilde{\chi}_1^-$
  Nomura, Phys.Rev.D64 (2001) 075001
  $\Longrightarrow$ determining $\cos 2\theta_{13}$