$L_\mu - L_\tau$ and Nondecoupling SUSY

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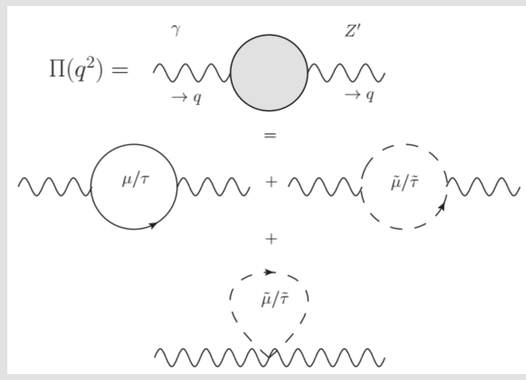
Introduction

The radiative contribution of charged sleptons to the γ-Z' kinetic mixing is nondecoupling in the presence of a gauged $L_\mu - L_\tau$ symmetry.

This striking feature, arising out of the breaking of the enhanced symmetry in the limit of degenerate (s)leptons, can be tested at the BELLE-II e^+e^- collider.

We propose that the $\gamma + \not{E}$ signal at BELLE-II will be a smoking gun for supersymmetry (SUSY). Any significant excess in any but the highest photon energy bin would be a telltale sign of such heavy charged scalars coupling to Z'.

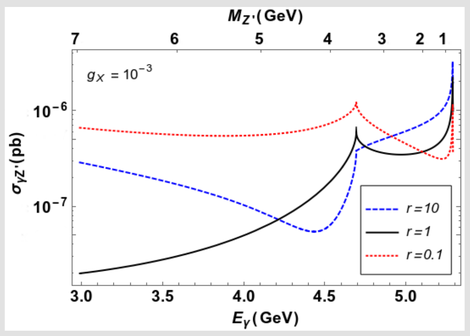
Kinetic Mixing



$$\mathrm{L}_{kin-mix} = \frac{\epsilon}{2}(\hat{W}^{(em)\alpha}\hat{W}_\alpha^{L_\mu - L_\tau})_F$$

$$\epsilon \equiv \Pi(q^2) = \frac{8eg_X}{(4\pi)^2}\int_0^1 x(1-x)\ln\frac{m_\tau^2 - x(1-x)q^2}{m_\mu^2 - x(1-x)q^2}dx + \frac{2eg_X}{(4\pi)^2}\int_0^1 (1-2x)^2\ln\frac{m_{\tilde{\tau}}^2 - x(1-x)q^2}{m_{\tilde{\mu}}^2 - x(1-x)q^2}dx$$

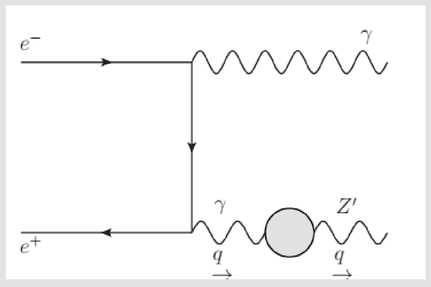
The Cross Section



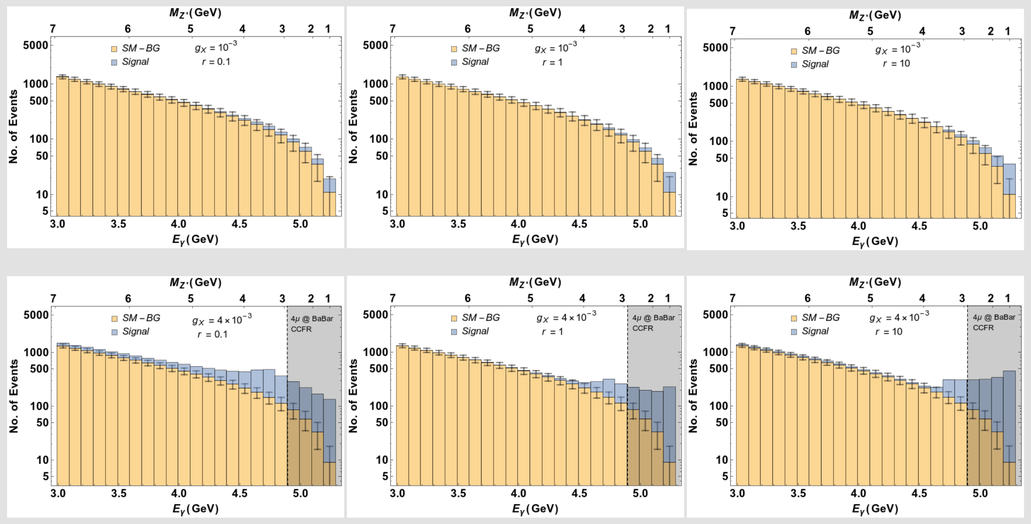
The signal process $e^+e^- \to \gamma Z'$ with Z' decaying to $\nu\bar{\nu}$ leading to the final state $e^+e^- \to \gamma + \not{E}$.

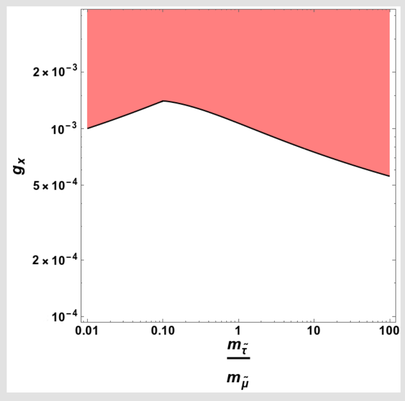
$$r = \frac{m_{\tilde{\tau}}}{m_{\tilde{\mu}}}$$

$$\sigma(e^+e^- \to \gamma + Z') = \frac{2\pi\alpha^2|\Pi(M_{Z'}^2)|^2}{s}\left[1 - \frac{M_{Z'}^2}{s}\right] \times \left[\left\{1 + \frac{2sM_{Z'}^2}{(s - M_{z'}^2)^2}\right\}\ln\frac{(1+\cos\theta_{\max})(1-\cos\theta_{\min})}{(1-\cos\theta_{\max})(1+\cos\theta_{\min})} - \cos\theta_{\max} + \cos\theta_{\min}\right].$$

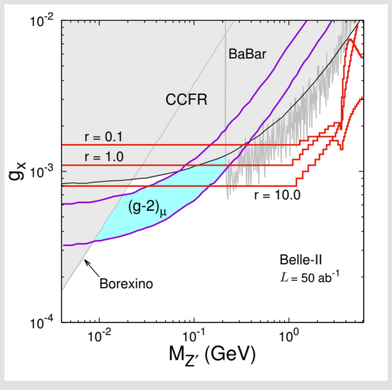


Looking for a single monochromatic photon with missing energy





3σ exclusions on the hitherto free slepton mass ratio vs. g_X plane



3σ exclusions on the M'_Z - g_X plane

Conclusions

Any significant excess in all but the highest photon energy bin would be an undeniable signature of such heavy scalar fields in SUSY coupling to Z'.

The number of signal events depends crucially on the logarithm of the ratio of stau to smuon mass in the presence of SUSY. In addition, the number is also inversely proportional to the e^+e^- collision energy, making a low-energy, high-luminosity collider like Belle-II an ideal testing ground for this channel.

This process can probe large swathes of the slepton mass ratio vs the additional gauge coupling (g_X) parameter space. More importantly, it can explore the narrow slice of $M_{Z'} - g_X$ parameter space still allowed in gauged $L_\mu - L_\tau$ models for superheavy sparticles.

This work is based on:
H. Banerjee and S. Roy, Phys. Rev. D **99**, no. 3, 035035 (2019)

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