Dark photon and dark Z mediated B meson decays

Introduction

We study flavor changing neutral current decays of B and K mesons in the dark $U(1)_D$ model, with the dark photon/dark Z mass between 10 MeV and 2 GeV. Although the model provides an improved fit (compared to the standard model) to the differential decay distributions of $B \to K^{(*)} l^+ l^-$, with $l = \mu$, e, and $B_s \to \varphi\, \mu^+ \mu^-$, the allowed parameter space is ruled out by measurements of atomic parity violation, $K^+ \to \mu^+ +$ *invisible decay*, and $B_s - B_s$ mixing, among others. To evade constraints from low energy data, we extend the model to allow for (1) additional invisible Z_D decay,(2) a direct vector coupling of Z_D to muons, and (3) a direct coupling of Z_D to both muons and electrons, with the electron coupling fine-tuned to cancel the Z_D coupling to electrons via mixing. We find that only the latter case survives all constraints.

The Lagrangians

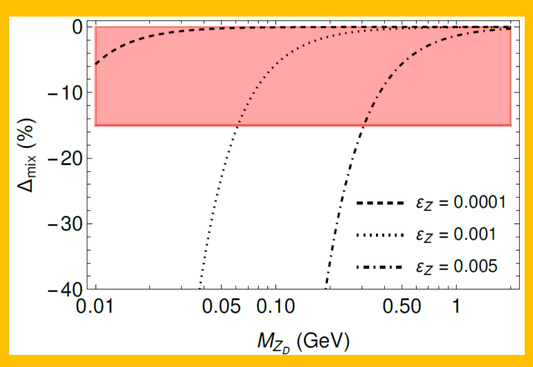
$$\mathcal{L}_{\text{gauge}} = -\frac{1}{4}B_{\mu\nu}B^{\mu\nu} + \frac{1}{2}\frac{\varepsilon}{\cos\theta_W}B_{\mu\nu}Z_D^{\mu\nu} - \frac{1}{4}Z_{D\mu\nu}Z_D^{\mu\nu}\,,$$
$$B_{\mu\nu} = \partial_\mu B_\nu - \partial_\nu B_\mu\,, \qquad Z_{D\mu\nu} = \partial_\mu Z_{D\nu} - \partial_\nu Z_{D\mu}\,,$$

$$\mathcal{L}_D^{\text{em}} \supset e\varepsilon Z_D^\mu J_\mu^{\text{em}} - ie\varepsilon\left[\left[Z_D W^+ W^-\right]\right]$$

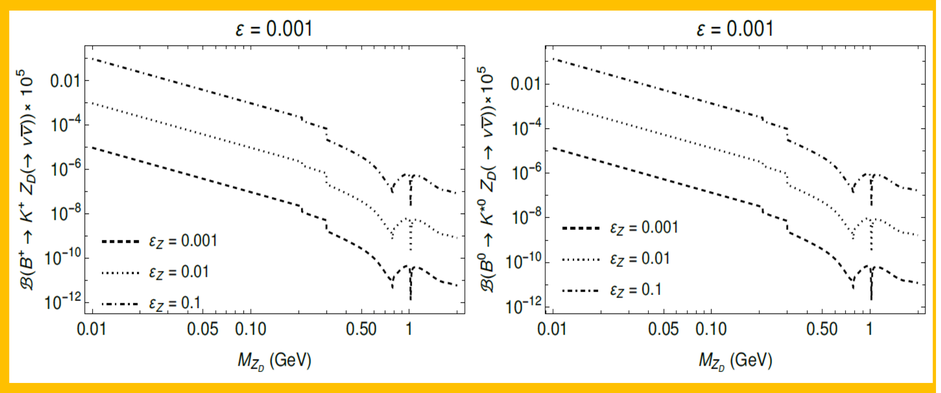
$$\mathcal{L}_D^Z \supset \frac{g}{\cos\theta_W}\varepsilon_Z Z_D^\mu J_\mu^Z - ig\cos\theta_W\varepsilon_Z\left[\left[Z_D W^+ W^-\right]\right]$$

Constraints

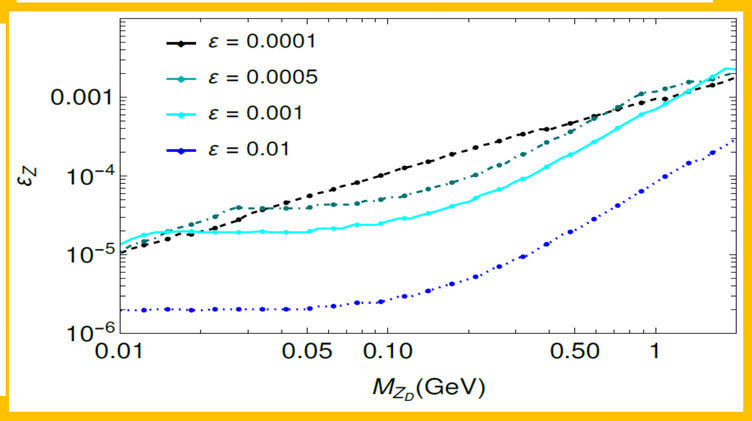
1 B_s mixing



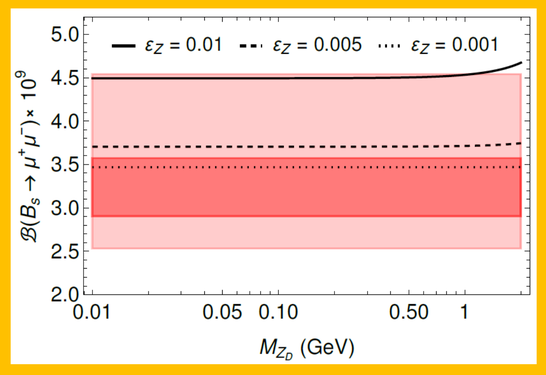
3 $B \to K^{(*)}\nu\bar{\nu}$



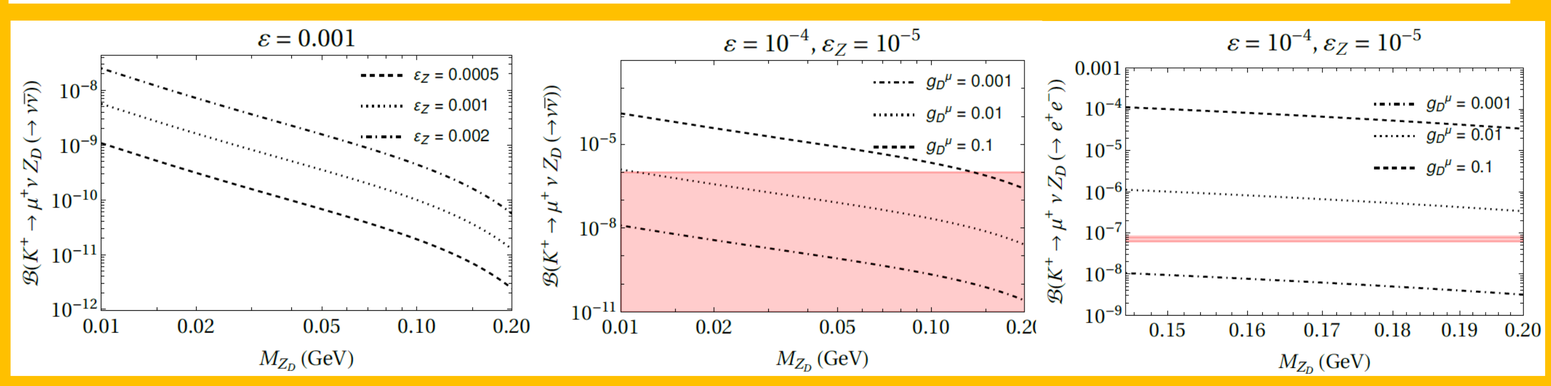
7 Atomic parity violation



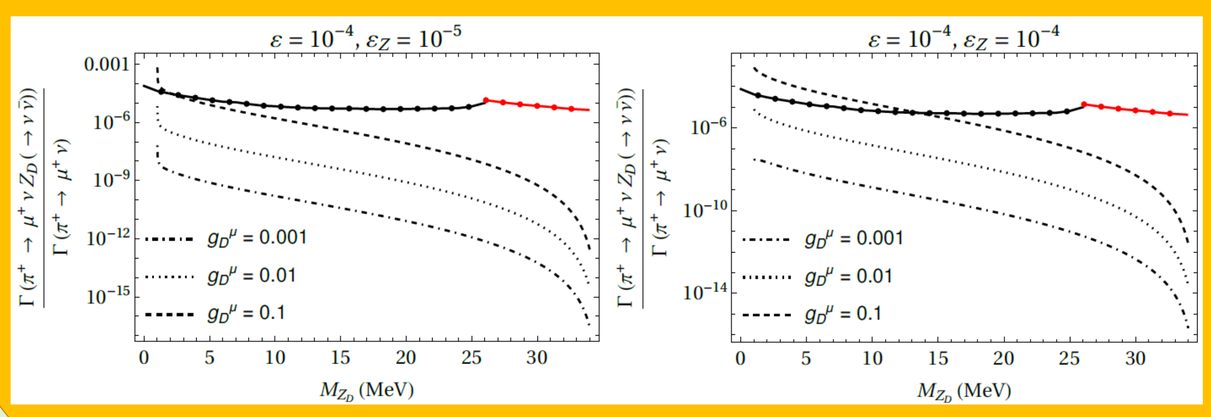
2 $B_s \to \mu^+\mu^-$



5 Radiative $K^+ \to \mu^+\nu_\mu Z_D$ decays



6 Radiative $\pi^+ \to \mu^+\nu_\mu Z_D$ decays

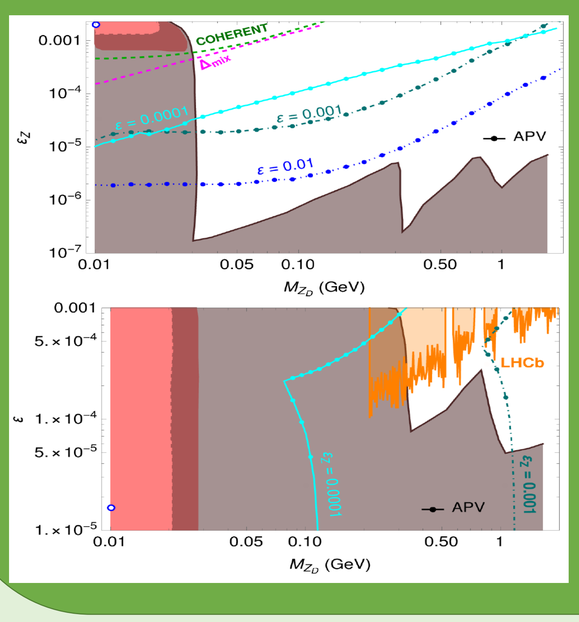


Model

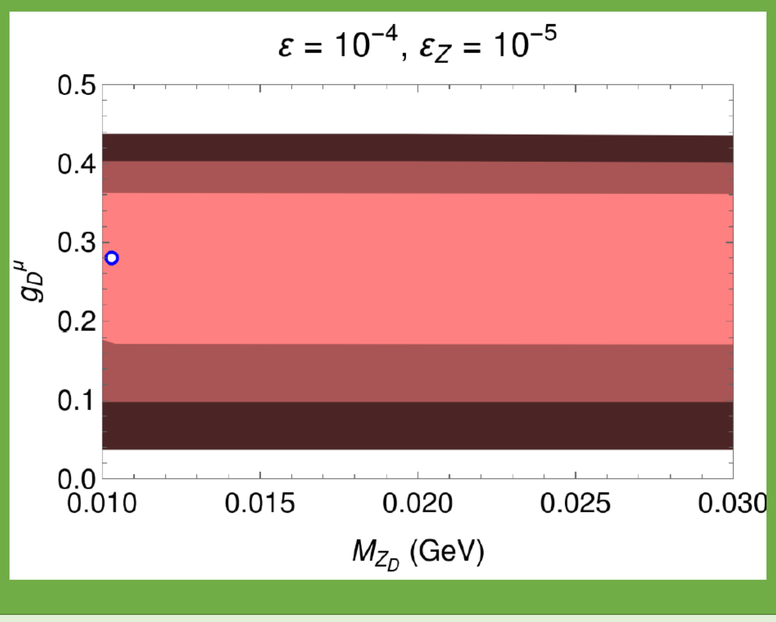
1. **Case A**: The model is the two Lagrangians above
2. **Case B**: A muonphilic Z_D in which Case A is extended with an additional direct interaction of the dark Z with muons
3. **Case C**: Case A is extended with additional direct interactions of the dark Z with both electrons and muons

Parameter fits

Case A



Case B



Case C