

Mediator Decay through mixing with Degenerate Spectrum

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The decay of the mediator particle into standard model (SM) particles plays a significant role in exploring the dark sector scenario. We consider such a decay, taking the dark photon mediator as an example that mixes with the SM photon. We find that it requires a careful analysis of the decay rate in the presence of an SM vector boson (e.g., Z boson, ρ meson, and true muonium, etc.) nearly degenerate with the mediator particle in mass. The decay rate of the mediator particle calculated in the mass eigenstate basis $\{\mathbf{b}\}$ does not agree with the correct result, given by the imaginary parts of the poles for the vector boson propagators, when the mixing parameter is smaller than a specific value. In such a case, the decay rate calculated by treating the mixing as a perturbative parameter is in agreement with the correct result. We clarify specific values for the mixing parameter quantitatively using several concrete examples of the SM vector bosons degenerate with the dark photon.

When the mass mixing between the vector boson and dark photon is smaller (larger) than the decay width of the vector boson, the latter (former) method to calculate the decay rate of the mediator particle gives the correct result.

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