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Precision molecular experiments as a tool in the search for New Physics

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Molecules that include heavy element atoms can be utilized in precision experiments to investigate "new" physics beyond the Standard Model, specifically by examining violations of spatial parity (P) and time reversal (T) symmetries in fundamental interactions. A prominent candidate for T and P violation in molecules is the electric dipole moment (EDM) of the electron [1]. Currently, a non-zero EDM for the electron has not been observed, but limits on its value have been established. The most precise limit was determined by the JILA group through experiments involving hafnium monofluoride (HfF^+) molecular cations [2]. Furthermore, an upcoming experiment with the barium monofluoride (BaF) molecule is expected to provide a similarly close independent constraint [3].

The violation of time reversal (T) and parity (P) symmetries in fundamental interactions within molecules can occur not only due to the electron electric dipole moment (eEDM) but also through the exchange of virtual axion-like particles between electrons and between electrons and nuclei. In this study, we explored this phenomenon in the HfF^+ molecular cation and the BaF molecule. Our calculations for the electron-nucleus interaction incorporated the finite size of the nucleus. By analyzing the molecular parameters related to these interactions, we established constraints on the products of interaction coupling constants that align with the current sensitivity of the HfF^+ experiment [2] and the anticipated sensitivity of future BaF experiments [3]. The results were published in references [4] and [5]. Furthermore, we will present new insights into parity violation effects that were not addressed in those publications.

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