Probing Fundamental Physics with Molecules

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Molecules are among the most powerful probes of new physics beyond the Standard Model [1, 2]. Such new physics is closely connected to violation of fundamental symmetries, which can be enhanced by many orders of magnitude in molecules due to the internal electronic structure. In particular simultaneous parity and time-reversal violation ($\mathcal{P},\mathcal{T}$-violation) is enhanced in polar heavy elemental molecules by several orders of magnitude compared to atoms. Thereby effect sizes steeply scale with increasing nuclear charge number of the electro-positive atom, making heavy-element containing molecules most interesting in the search for new physics [3]. Recent developments enable precision spectroscopy even with short-lived isotope containing molecules [4]. Such isotopes have often a rich nuclear structure, such as octupole deformations, that can enhance symmetry violating effects by several orders of magnitudes as for instance in the isotopes ^{223}Ra, ^{225}Ra and ^{229}Pa [5, 6]. Due to combined large enhancement effects in the electronic as well as in the nuclear structure, ^{229}Pa containing molecules may increase the sensitivity to nuclear spin-dependent $\mathcal{P},\mathcal{T}$-violation such as the nuclear Schiff moment by several orders of magnitude [6].
In this contribution the advantages of using radioactive molecules like RaF with long isotope chains for increasing the sensitivity to different sources of discrete symmetry violation in molecular systems are highlighted [7]. Furthermore, prospects to embed the short-lived isotope ^{229}Pa into a polar molecule with favorable properties for fundamental physics searches are discussed.

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