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# Searching for new physics with isotope-shift spectroscopy of trapped ions

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I will present recent results of a search for new physics using isotope-shift spectroscopy of $Yb^+$ ions at MIT [1,2], and plans for IS spectroscopy experiments in $Ca^+$ at ETH Zurich. Recently, IS spectroscopy of atoms and ions has been proposed as a method to search for a new force between the neutron and the electron, mediated by a hypothetical dark-matter-candidate boson in the intermediate mass range (100eV to 100keV) [3]. The existence of this new force would cause neutron-number-dependent (and hence, isotope-dependent) shifts in atomic transition frequencies. To distinguish these shifts from standard model (SM) shifts (relating, for example, to small changes in the Coulomb potential of the nucleus between isotopes), one measures isotopes shifts on at least two transitions between three or more distinct pairs of isotopes. The data can then be plotted on a "King plot", which displays a nonlinearity if physics beyond first-order SM effects has contributed to the measured isotope shifts.

In the $Yb^+$ search, conducted at the Vuletic group at MIT, we found the first evidence of King nonlinearity in a search for new physics [1]. In a subsequent paper, we established the observation of this nonlinearity with more than $41\sigma$ certainty [2]. With $4\sigma$ confidence, we found that the nonlinearity originated from at least two distinct physical effects: the dominant effect originated from differences in the fourth nuclear charge moment, a higher-order SM effect that had not previously been measured at this level of precision. The second source remains unexplained as, from atomic structure calculations, it likely cannot be fully accounted for by the expected next-largest SM effect.

In the TIQI group at ETH, we plan on continuing this search for new physics with spectroscopy of singly-ionized calcium, an element that offers smaller SM backgrounds, having been shown to exhibit no King nonlinearity up to 20Hz measurement precision [4]. Using an entanglement-enhanced spectroscopy technique that was previously demonstrated on $Sr^+$ ions [5], we plan to perform spectroscopy at 10mHz measurement precision, breaching current bounds on new physics.

[1] J. Hur*, D. P. L. Aude Craik* et al, PRL 128, 163201 (2022)
[2] I. Counts*, J. Hur* et al, PRL 125 123002 (2020)
[3] J. Berengut et al, PRL 120, 091801 (2018)
[4] C. Solaro et al, PRL 125 123003 (2020)
[5] T. Manovitz et al, PRL 123, 203001 (2019)

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