Contribution ID: **98** Type: **Poster**

Alpha and helion particle nuclear charge determination from precision measurements in quantum degenerate helium

Wednesday 12 June 2024 18:00 (2 hours)

Precision measurements on calculable systems are widely used for tests of e.g. quantum electrodynamics (QED) calculations, determinations of some of the fundamental constants, and as sensitive probes to search for new physics beyond the standard model. In this context we perform high-precision spectroscopy on the doubly forbidden $2^3S_1 - 2^1S_0$ transition at 1557nm in both ^{3}He and ^{4}He trapped in a magic wavelength optical dipole trap.

We will present our recent measurement in a degenerate Fermi gas of ^{3}He with an accuracy of 170 Hz, and the resulting ^{3}He - ^{4}He isotope shift [1][2]. This measurement enables us to determine the squared charge radius difference between the alpha and helion particle with unprecedented accuracy. Compared to a recent determination of the absolute charge radii from spectroscopy of muonic He+ ions [3], we find a remarkable 3.6 sigma disagreement. Our measurement serves as a check of the consistency of QED theory in helium atoms and of nuclear polarization effects in muonic helium ions.

Currently, we are working on improving the $2^3S_1 - 2^1S_0$ transition in ^{4}He to an accuracy of 50 Hz. Together with our recent ^{3}He measurement, we expect a factor of 2 improvement in the determination of the squared charge radius difference.

[1]: arXiv:2306.02333 [physics.atom-ph]
[2]: Nature Phys 14, 1132 (2018)
[3]: arXiv:2305.11679 [physics.atom-ph]

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Session Classification: Poster Session 2