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**Narrow linewidth spectroscopy in quantum degenerate metastable helium** REMY NOTERMANS, ROBERT RENGELINK, WIM VASSEN, Vrije Univ (Free Univ) — Combined with high-precision spectroscopy, QED theory allows extraction of the nuclear charge radius from spectroscopy in simple atomic systems. This recently lead to a significant discrepancy in the proton charge radius determined from hydrogen and muonic hydrogen spectroscopy, now known as the 'proton size puzzle'. Spectroscopy in helium can provide additional insight in this conundrum. Our group previously measured the very weak $2\ ^3S \rightarrow 2\ ^1S$ transition ($\lambda = 1557$ nm, $\Gamma = 2\pi \times 8$ Hz) to $10^{-11}$ relative accuracy in quantum degenerate ($T = 0.2\ \mu$K) metastable $^4$He and $^3$He, allowing a 1% accurate determination of the charge radius difference of the $\alpha$ particle and the helion. Recent measurements in muonic He$^+$ aim for a precision of $3 \times 10^{-4}$. In order to provide a similar precision, we aim to remeasure the transition to sub-kHz precision by reducing the linewidth of the spectroscopy laser by over an order of magnitude to the kHz level and by implementing a magic wavelength ($\lambda = 320$ nm) dipole trap operating at 2 W CW power. First measurements in a helium BEC have shown a 10 kHz asymmetric line profile due to mean-field effects. This allows for the first determination of the unknown $2\ ^3S - 2\ ^1S$ scattering length.

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