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Towards parts per trillion mass measurements on the proton and other light nuclei at LIONTRAP

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The precise knowledge of the atomic masses of various light nuclei, e.g. of the proton, deuteron, helion and triton are of utmost importance for several tests of fundamental physics. For example, the mass of the proton itself and the mass ratio of the electron and the proton are important input parameters for experiments in atomic physics. Furthermore, an essential consistency check of the KATRIN experiment will require an ultra-precise measurement of the mass difference of triton and helion on a so far unrivalled level of precision of 6meV or smaller. However, five sigma discrepancies between high-precision measurements of these light nuclear masses question their current literature values and give strong motivation for a new and independent experiment, LIONTRAP (Light ION TRAP), aiming for relative uncertainties of a few parts per trillion.
The new setup contains a cryogenic stack of five cylindrical Penning traps enclosed in hermetically sealed vacuum chamber. The measurement principle is based on a non-destructive phase-sensitive comparison of the single proton's cyclotron frequency to that of a single bare carbon nucleus. In order to measure both frequencies in the same electric and magnetic field configuration, both single ions are transported alternately into an ultra-harmonic, doubly compensated Penning trap. Exactly the same electric field configuration for both ions with different charge/mass ratio requires two separate, precisely tuned axial resonators for non-destructive frequency detection. To overcome the statistically limiting magnetic field fluctuations, simultaneous phase-sensitive measurements are planned in neighbouring traps.
At this conference, the new LIONTRAP setup including a variety of novel techniques and improvements will be introduced. Furthermore, first results on the atomic mass of the proton will be presented. This new proton mass value is 3 times more precise than the current literature value and reveals a disagreement of about 3 standard deviations to it [1].
[1] F. Heiße et al., Phys. Rev. Lett. 119, 033001 (2017)

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