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High Precision Mass Measurements on Light Ions

The former g-factor experiment located in Mainz performed various g-factor measurements on highly charged ions, resulting in tests of bound state QED [1] and the most precise value for the atomic mass of the electron [2]. These measurements will be continued within a new experiment at the MPIK with access to heavier highly charged ions. Meanwhile the follow-up experiment in Mainz, which is presented here, shifted its focus to high-precision mass measurements of light ions.
Light nuclei play a fundamental role in physics. The proton and the neutron, together with the electron make up all matter we encounter in our everyday life, making their properties highly interesting for metrology.
Another application is the determination of the electron-antineutrino mass at KATRIN˜[3], where the mass difference of tritium and helium-3 is required.
Our setup is dedicated to mass measurements of light ions by means of Penning-trap mass spectrometry. One highlight is a newly developed doubly compensated Penning trap, which has a harmonicity at least one order of magnitude better than all Penning traps described in the literature so far. We recently measured the proton mass at a relative uncertainty of 3×10^{-11} by comparing the cyclotron frequencies of a proton and a $^{12}C^{6+}$-ion [4]. The usage of two independend tank circuits connected to the measurement trap with their frequency ratio carefully tuned to the ratio of the charge-to-mass ratios of the ions allowed a rapid nondestructive measurement in the exact same field configuration. The optimized measurement scheme and the use of a phase-sensitve measurement technique yield a relative statistical uncertainty of 1.8×10^{-10} with a single measurement cycle.
As a next step we will focus on the mass of the deuteron, in order to extract the mass of the neutron using an improved value for the binding energy currently being measured at the ILL. At the same time, we are taking steps to push our uncertainties down to the 10^{-12}-regime

[1] F. Köhler-Langes et al., Nature Comm. 10246 (2016)
[2] S. Sturm et al., Nature 506, 467-470 (2014)
[3] Ch. Weinheimer, Prog Part Nucl Phys, Vol 48 (1) (2002)
[4] F. Heiße et al., PRL 119, 033001

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