Comsol's Contribution to the Current Knowledge of the Proton Mass

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Abstract

Penning-trap mass spectrometers are the tools of choice for mass-ratio measurements of two different single ions with highest precision.
The investigated ions are stored consecutively in a combination of an electric quadrupole potential and a homogeneous magnetic field at ultra-high vacuum. The magnetic field is produced by a superconducting magnet. The electric potential is created by applying voltages to hollow cylindrical shaped electrodes surrounding the ion.
Penning traps can reach a relative precision in the mass ratio of a few parts per trillion. At this precision even tiny effects shift the result of the experiment significantly and the limited knowledge of these effects starts to limit the achievable precision of the experiment. One of them is that the stored ion induces surface charges onto the surrounding electrodes. On the one hand these charges on the surface are needed to detect the ion but on the other hand they create an additional electric field which acts back on the ion. This effect is the leading uncertainty in modern Penning-trap mass spectrometers.
Today it is possible to simulate this effect with COMSOL Multiphysics® with an uncertainty below 1%, which is 5 times better than any approach before.
By that Comsol contributed to the current most precise measurement of the atomic mass of the proton [1].

This contribution will give an introduction to Penning-trap mass spectrometry, as well as how Comsol helped to solve the problem described above and how the uncertainty of 1% of the simulation is determined.

[1] F. Heiße et al., Physical Review Letter 119, 033001, (2017)