The proton g-factor experiment

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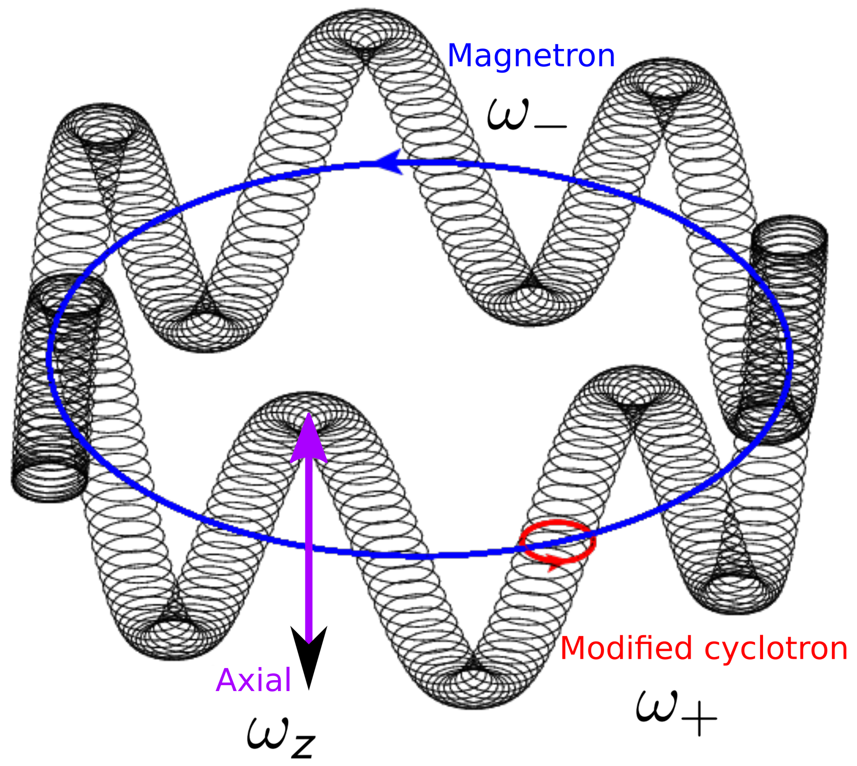
Motivation

In our universe, an **asymmetry** between the abundance of matter and antimatter is observed. However, our current knowledge indicates that both matter and antimatter are **symmetric** regarding their fundamental properties, also referred to as CPT-theorem.

The BASE-collaboration aims to resolve this lack of understanding by performing high-precision measurements on both the proton's and anti-proton's g-factor.

Measurement principle

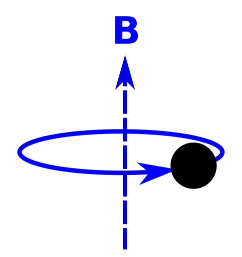
Particle motion in a Penning trap:



The three eigenmotions are connected via the invariance theorem [1]:

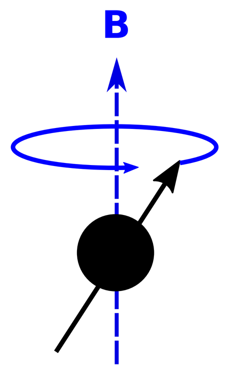
$$\omega_c = \sqrt{\omega_+^2 + \omega_-^2 + \omega_z^2}$$

Idea to obtain the g-factor:



Cyclotron frequency:

$$\omega_c = \frac{q}{m} B$$



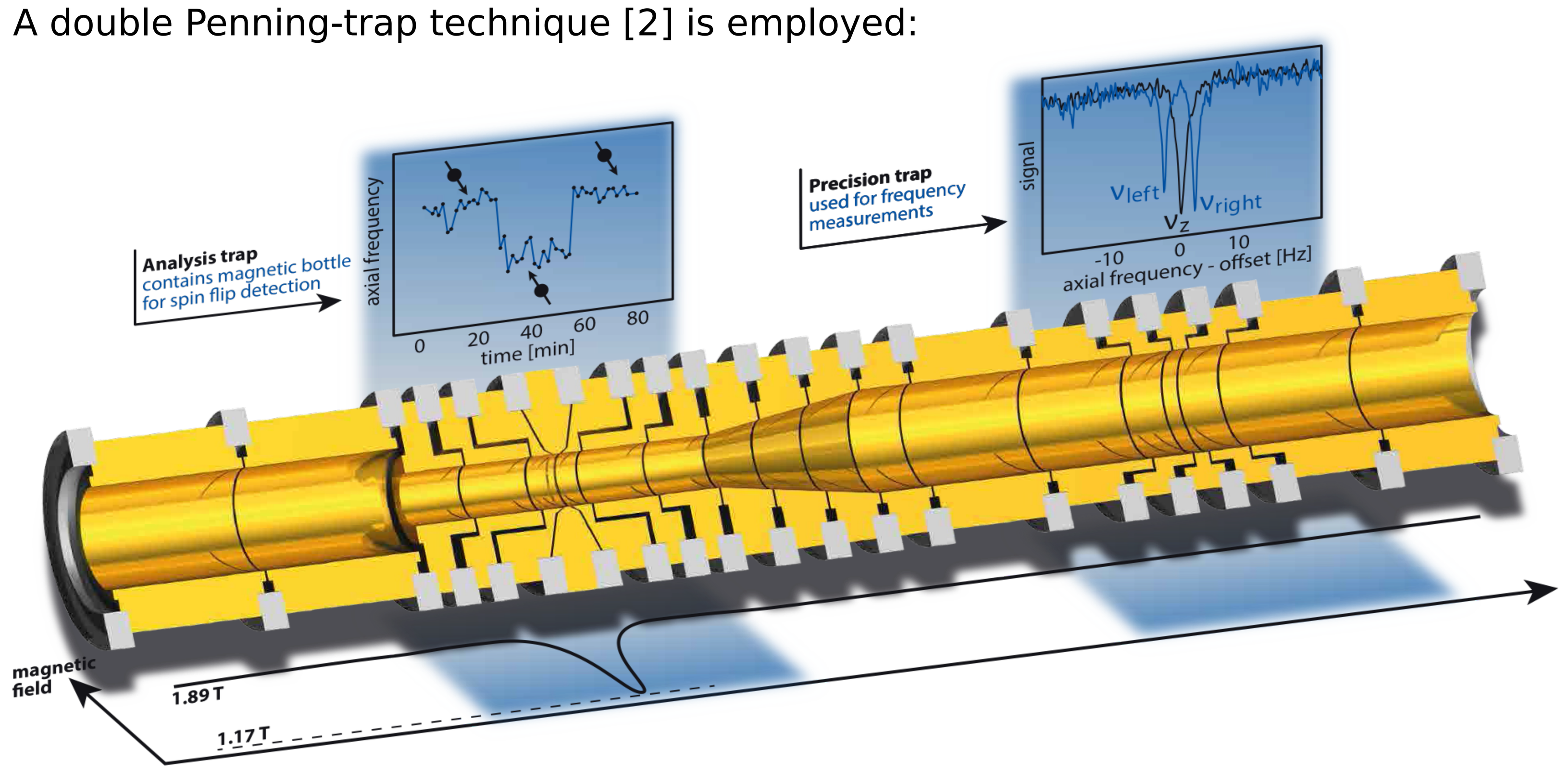
Lamor frequency:

$$\omega_L = \frac{g}{2} \frac{q}{m} B$$

$$\Rightarrow \frac{\omega_L}{\omega_C} = \frac{g}{2}$$

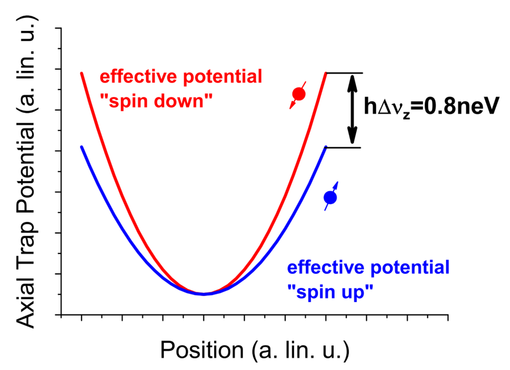
Experimental technique

A double Penning-trap technique [2] is employed:

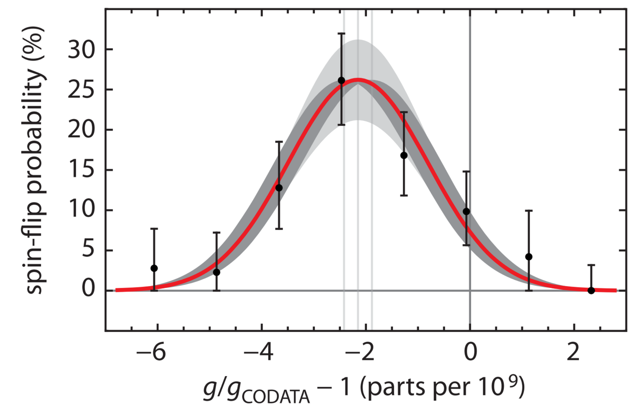


In the precision trap, all the frequency measurements are performed. While the axial frequency is determined directly, the modified cyclotron frequency is measured by applying an electrical field close to $\omega_+ - \omega_z$ This couples the frequencies and results in a double dip spectrum from which ω_+ can be calculated. The determination of ω_- works analogously.

In the analysis trap, the particles are subject to an extremely inhomogeneous magnetic field (B_2 = 300 000 T/m^2). This results in a shift of the axial frequency depending on the spin-state [3]. The spin state can be changed by applying an RF field whose frequency is near ω_L [5]. By recording axial frequency measurements while sweeping the RF frequency, the spin-flip probability as a function of ω_{RF} is obtained. This curve has its maximum at ω_L [4].



[3]



[4]

Current experimental values

Proton vs. antiproton g-factor:

$$\frac{g_p}{2} = 2.792\,847\,344\,62\,(75\,\text{stat.})(34\,\text{sys.}) \quad [4]$$

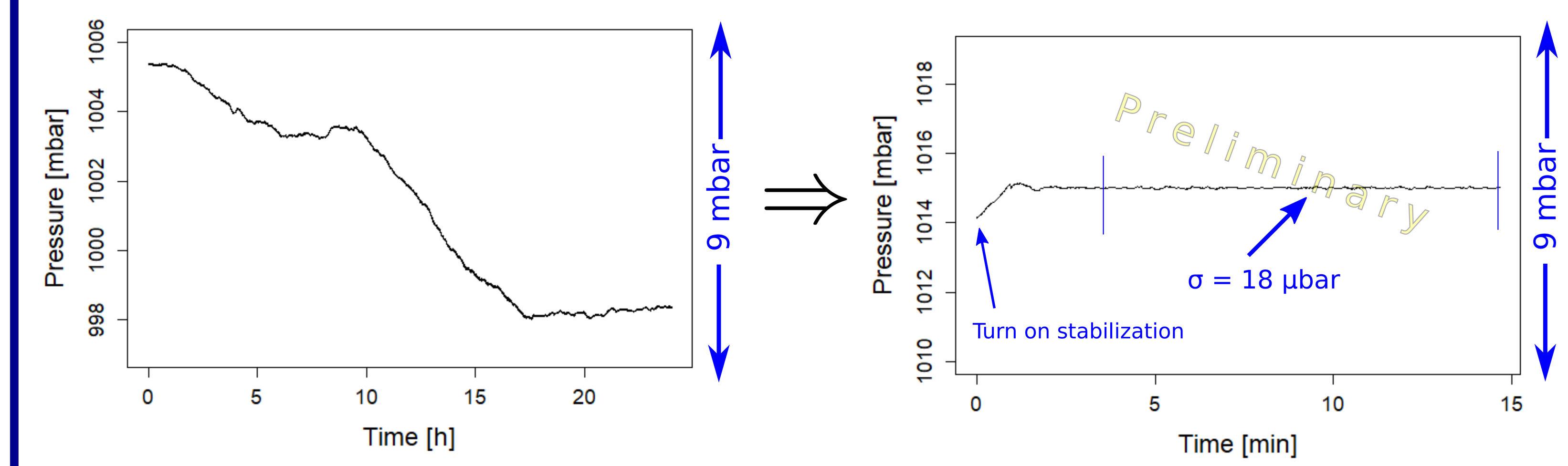
$$\frac{g_{\bar{p}}}{2} = 2.792\,847\,344\,1(42) \quad [6]$$

$\Longrightarrow$ Consistent within error bars, no CPT-violation observed.

Technical upgrades

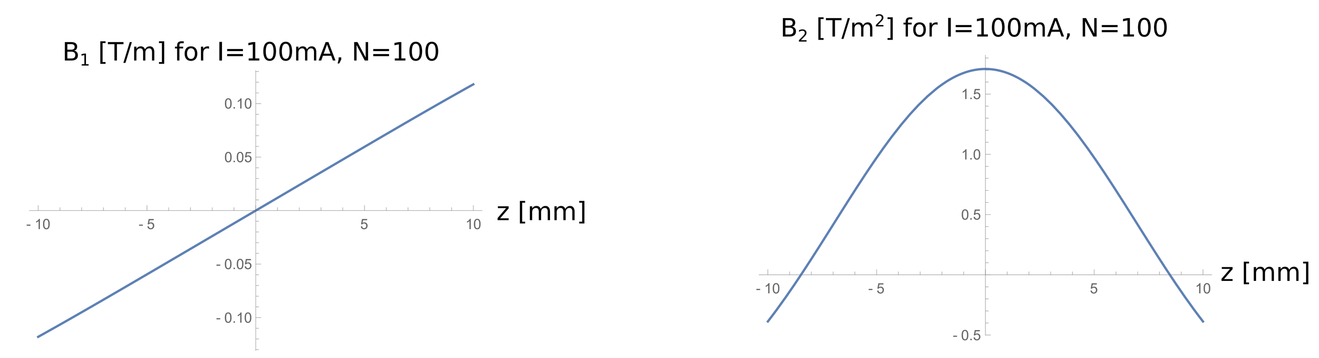
Pressure stabilization:

Compensate the pressure fluctuations of the LN2 and LHe exhaust by means of a flow controller. First test measurement at the LN2 exhaust:



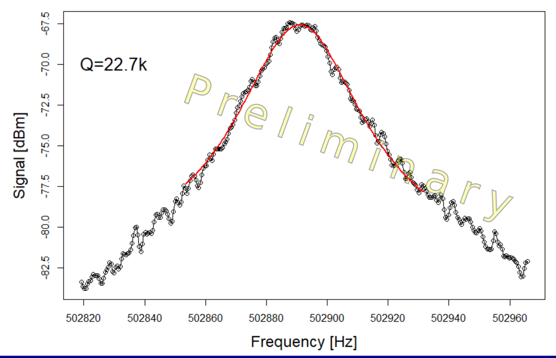
Shim coils:

Compensate magnetic field inhomogeneities (B1 and B2) in the precision trap with an additional set of two superconducting coils. Calculation of their magnetic field:



Axial detector and amplifier:

A new axial detector and amplifier have been constructed and are currently being tested.



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