

# Measurement of the (anti)proton $g$ -factor - Status of the experiment\*

S. Ulmer<sup>†1,2</sup>, K. Blaum<sup>1,3</sup>, S. Kreim<sup>1</sup>, H. Kracke<sup>1</sup>, C.C. Rodegheri<sup>1</sup>, W. Quint<sup>2,3</sup>, S. Stahl<sup>4</sup>, J. Walz<sup>1</sup>

<sup>1</sup>Institut für Physik, Johannes Gutenberg-Universität, 55099 Mainz, Germany, <sup>2</sup>Ruprecht-Karls-Universität, 69047 Heidelberg, Germany,

<sup>3</sup>GSI, Planckstraße 1, 64291, Darmstadt, Germany <sup>4</sup>www.Stahl-Electronics.com, 67582 Mettenheim, Germany

The precise determination of the  $g$ -factor of the proton and the antiproton together with their comparison is a stringent test of the CPT invariance theorem on the baryonic sector [1]. In our experiment, which is part of the FLAIR collaboration, the  $g$ -factor of a single, isolated (anti)proton will be determined by utilizing the continuous Stern-Gerlach effect [2] in a hybrid double Penning trap setup [3]. Measuring the free cyclotron frequency  $\omega_c$  and the Larmor frequency  $\omega_L$  the  $g$ -factor can be determined via the relation

$$g = 2 \frac{\omega_L}{\omega_c} . \quad (1)$$

The free cyclotron frequency can be calculated by means of the Brown-Gabrielse invariance theorem [4]  $\omega_c^2 = \omega_+^2 + \omega_-^2 + \omega_z^2$  where  $\omega_i$  are the eigenfrequencies of the particle inside the trap. These eigenmotions can be measured via detection of image currents induced in the electrodes by the moving particle in the trap.

Single particle detection needs highly-sensitive electronics. The two key pieces of such a detection system are a helical resonator with a high quality factor  $Q$  and a low noise amplifier [5].

To achieve a high signal-to-noise ratio (SNR) of the detector, a high  $Q$ -value of the resonator should be reached. In case of the axial detector driven at  $\nu_z = 680$  kHz, coil and shield are made of type II superconducting NbTi with a critical temperature of 9.5 K. The Use of a type II superconductor allows us to place the resonator in the high magnetic field near the trap, thus parasitic capacitances can be avoided, resulting in a higher SNR. Systematic rf loss mechanism studies were performed and the tank circuit was optimized. Finally a free  $Q$ -value  $>40000$  at 1.6 MHz was reached. With the parasitic capacitance of the trap the system will be tuned to the axial resonance frequency.

This resonator was used to investigate the effect of an externally applied magnetic field on the superconducting ac resistance. With the unique possibility to move our cryostat along the axis of the horizontal bore of a superconducting 1.9 T magnet the  $Q$ -value could be measured as a function of the magnetic field (see fig.1). These data are of high interest and may have impact on the design of future trap experiments as planned e.g. at the HITRAP facility.

As second key piece of the single particle detector a low noise cryogenic field effect transistor (FET) amplifier was

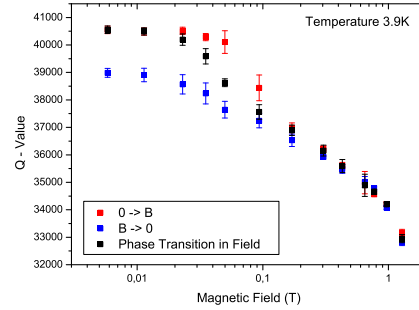


Figure 1: Variation of the  $Q$  value of a 1.6 MHz helical resonator as a function of an externally applied magnetic field. Red points: Superconducting phase transition (SCPT) outside the magnet; blue points: SCPT in high magnetic field of 1.1 T; black points: SCPT in position dependent field.

designed and tested. Electronic feedback will heat the amplitudes of the trapped particle, leading to line-width broadening. Thus, care was taken to assemble a feedback-free low noise amplifier. Finally at the axial frequency a voltage noise of  $1.4 \text{ nV}/\sqrt{\text{Hz}}$  and a current noise of  $\approx 3 \text{ fA}/\sqrt{\text{Hz}}$  was reached. With the complete detection system a  $Q$ -value of 6500 was measured.

In case of the cyclotron detection system driven at 29 MHz we proceeded in the same way. With a copper resonator a cryogenic  $Q$ -value of 1300 and a voltage noise of  $0.6 \text{ nV}/\sqrt{\text{Hz}}$  were obtained.

In addition to the single particle detection systems further electronic components as filter boards and room temperature amplifiers were designed and tested. To flip the particles spin a standard NMR method will be used. In case of the Penning trap the difficulty of the copper electrodes acting as efficient rf shields exists. Thus, a resonant rf coil assembly at a frequency of 80 MHz was developed to drive the needed radial magnetic field component.

The whole experimental setup including trap and electronics is mounted and the cryostat is tested to achieve trap temperatures  $> 4$  K. The next step will be the creation of a single proton, afterwards a spin-flip should be induced and detected.

## References

- [1] R. Bluhm et al., Phys. Rev. Lett. **79**, 1432 (1997).
- [2] R.S. Van Dyck et al., Phys. Rev. Lett. **59**, 26 (1987).

\* work supported by BMBF under contact number 06MZ2271, HGF under contract number VH-NG-037 and DFG under contract number QU122/3-1-2

<sup>†</sup> ulmers@uni-mainz.de

- [3] J. Verdu, AIP Conf. Proc. LEAP **796**, 260 (2005).
- [4] L. S. Brown, G. Gabrielse, Rev. Mod. Phys. **58**, 233 (1986)
- [5] S. Jefferts et al., Rev.Sci. Instr. **64**, 737 (1993)