The ARTEMIS experiment for precision measurement of the electron g-factor in highly charged ions

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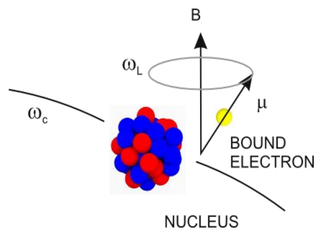
Abstract

The ARTEMIS (AsymmetRic Trap for the measurement of Electron Magnetic moment in IonS) experiment in GSI Darmstadt aims to precisely measure the magnetic moment of the electron in highly charged ions via laser-microwave double-resonance spectroscopy. The first major phase of the experiment is a proof of principle to be performed on boron-like Ar^{13+} ions stored in a Penning trap at pressures estimated to be as low as 9×10^{-16} mbar within a 7-Tesla magnetic field. Long storage times allow prolonged studies of ion ensemble properties such as cooling behaviour, ion density and ensemble temperature. The results point towards fluid-like behaviour of the ion ensembles. Measurements are projected to be performed on much heavier ions, such as hydrogen-like Bi^{82+}, extracted from the HITRAP facility at GSI eventually.

Measurement Principle

Larmor frequency of the bound electron:

$$\omega_L{}^e = \frac{g_J}{2}\frac{e}{m_e}B$$



Ion cyclotron frequency:

$$\omega_c{}^{ion} = \frac{Q}{M_{ion}}B$$

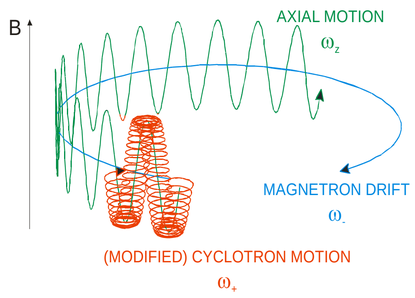
$$g_J = 2 \cdot \frac{\omega_L{}^e}{\omega_c{}^{ion}} \cdot \frac{m_e}{M_{ion}} \cdot \frac{Q^{ion}}{e}$$

→ 'experimental g-factor'
→ comparison with theory

our measurement

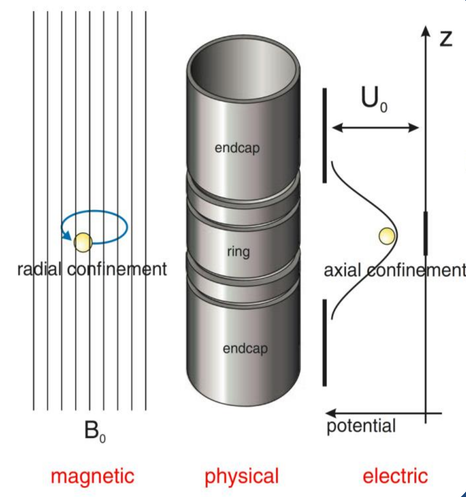
external input parameter

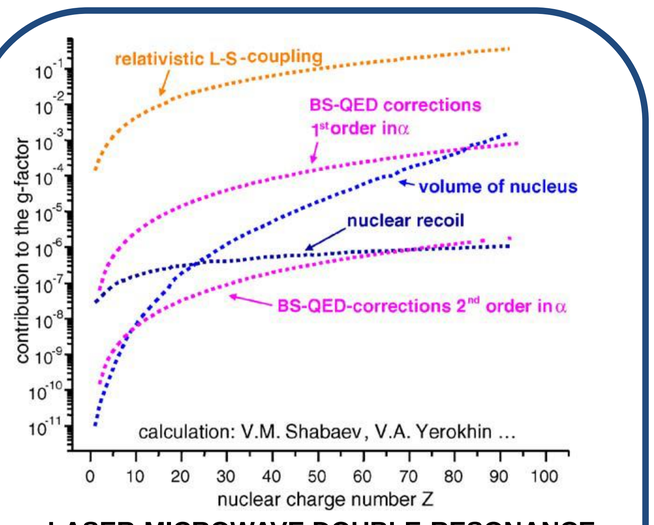
ION MOTION IN A TRAP



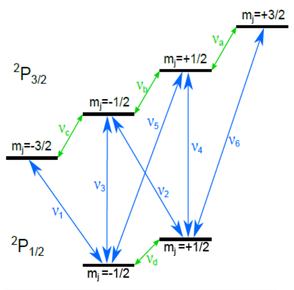
Brown-Gabrielse invariance theorem:

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

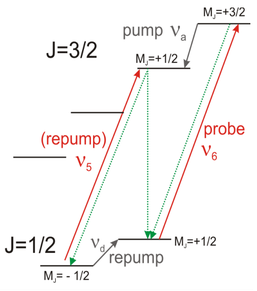




LASER-MICROWAVE DOUBLE-RESONANCE SPECTROSCOPY



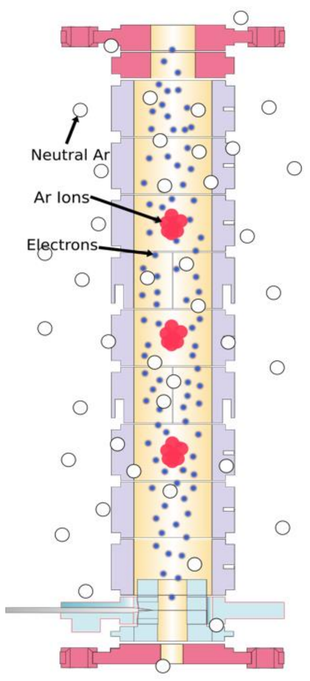
Possible transitions for $2^2P_{1/2}$ – $2^2P_{3/2}$ for boron-like Ar^{13+}



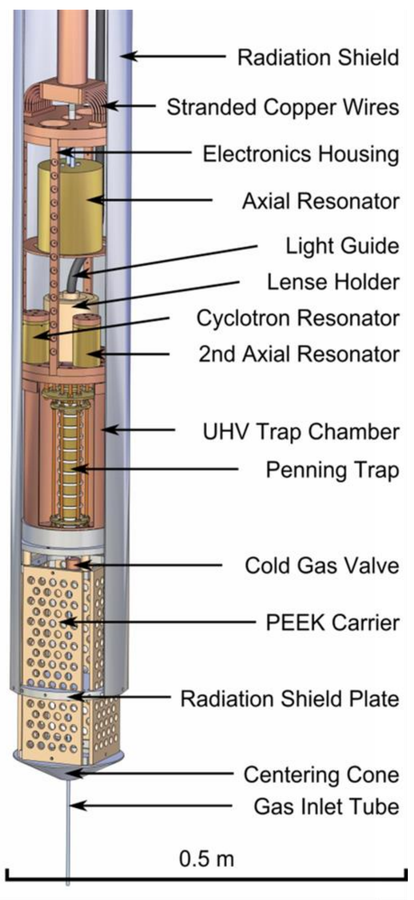
Level structure for double-resonance spectroscopy in boron-like Ar^{13+}

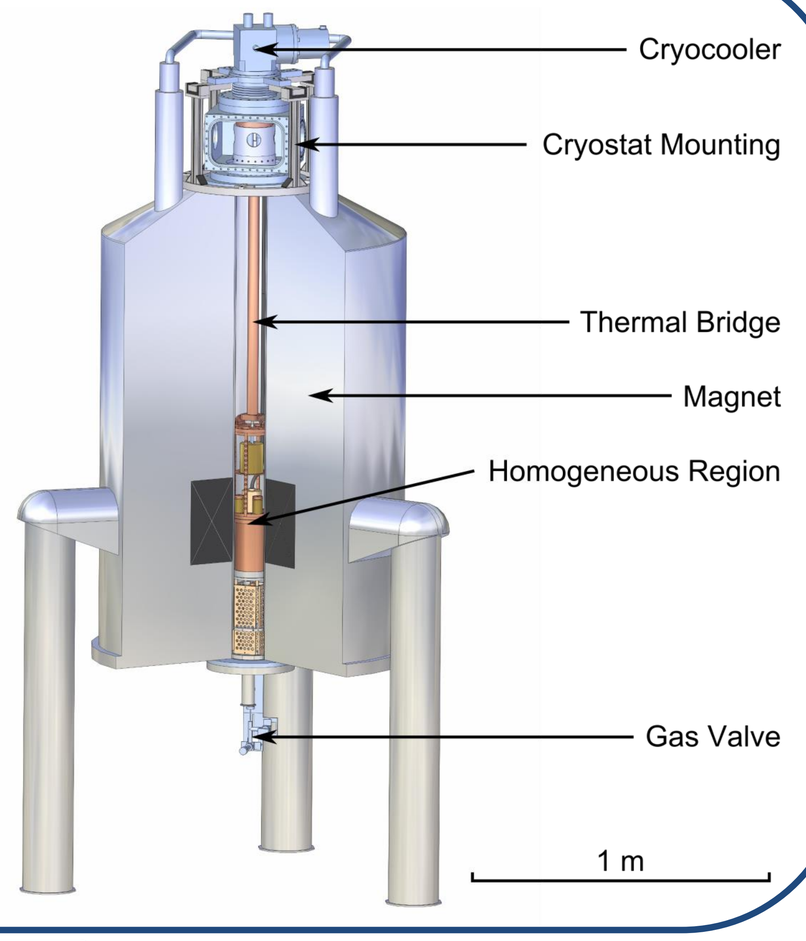
2p fine structure splitting ~ Z^4 ; here: λ =441nm, ν_a =130GHz, ν_d = 65GHz

ARTEMIS (AsymmetRic Trap for the measurement of Electron Magnetic moments in IonS)

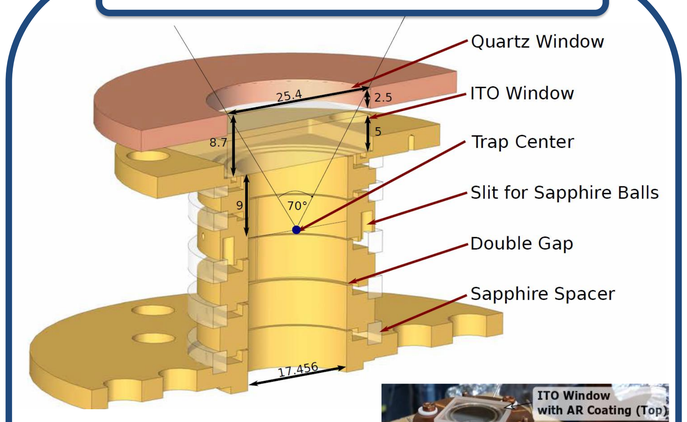


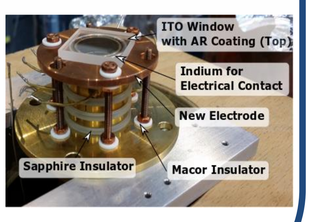
- Argon ions are created using the field emission technique.
- Creation trap acts as a mini-EBIT.
- The gas is injected through the gas inlet tube.
- Electrons are emitted from the tungsten tip, the field emission point, with sufficient energy, so as to ionise the neutral gas atoms.





Indium Tin Oxide Window

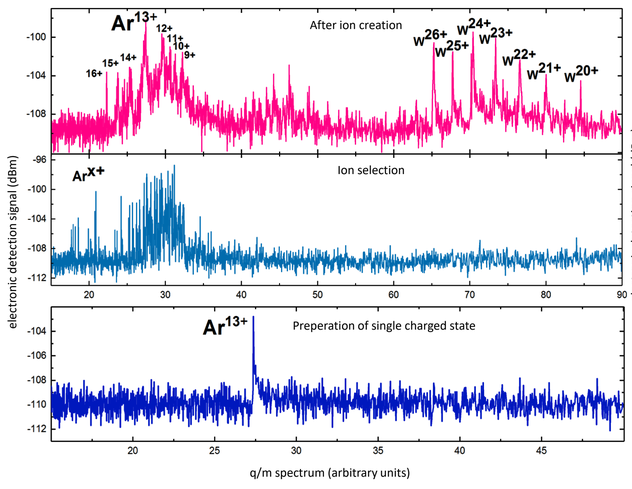




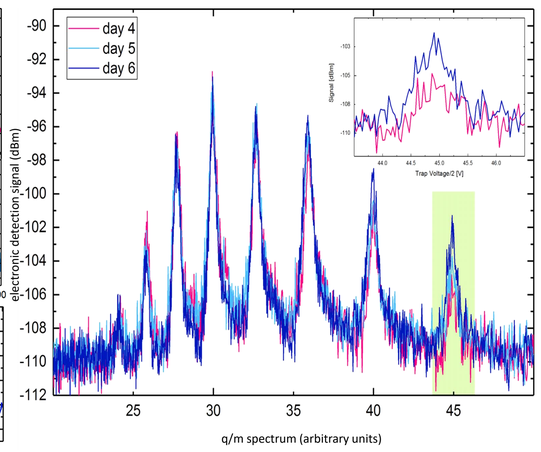
Asymmetric trap:
- ~10× solid angle of open endcaps
- harmonic trapping potential

Indium tin oxide window:
- ~75 % transmission at 441 nm
- conductive → utilised as electrode or charge-counter

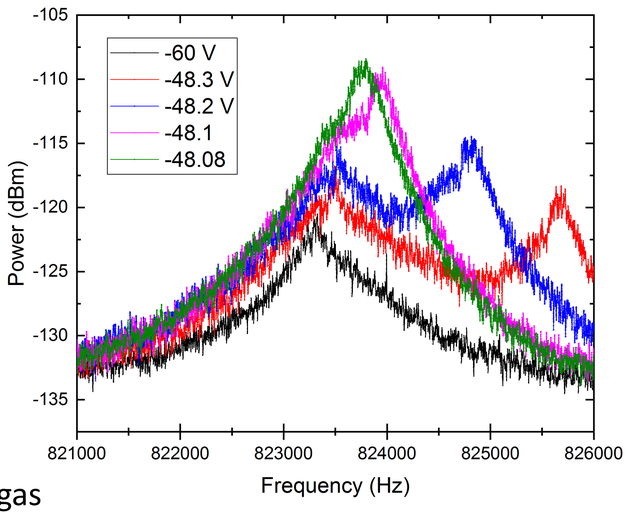
Measurements



Charge/mass spectrum



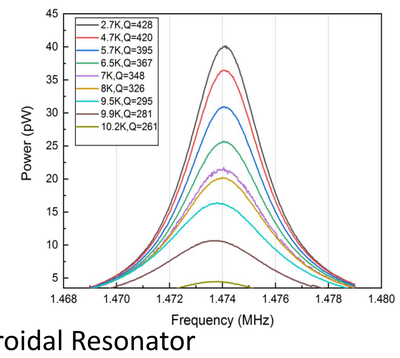
Storage time measurement (rest gas pressure in the trap chamber ≈ 10^{-15} mbar)



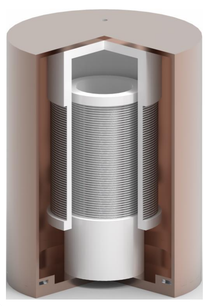
Ion oscillation frequency spectrum

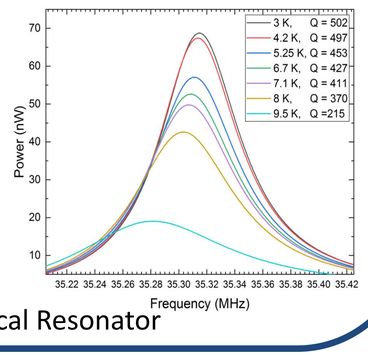
Non-Destructive Electronic Detection

Radio-frequency resonators for non-destructive electronic detection of induced image currents.



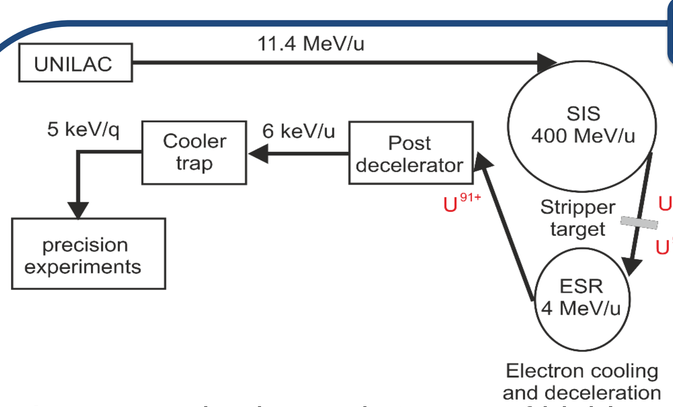
Toroidal Resonator

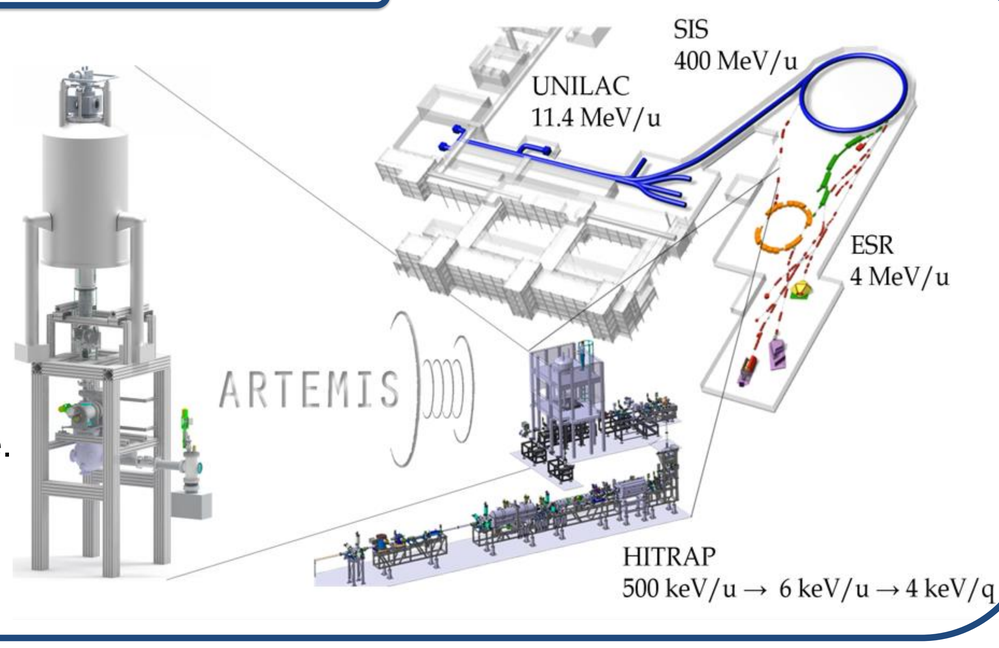




Helical Resonator

Summary and Outlook





- In-trap production and storage of highly charged ions.
- Laser-microwave double-resonance technique.
- g-factor measurements on B-like ions Ar^{13+}
- g-factor measurements on H-like ions Pb^{81+}, Bi^{82+}, U^{91+} by loading the ions from S-EBIT and HITRAP@ GSI.

Literature

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