Measurements of Transient Magnetic Fields in Gd on Single-Electron ^{52}Cr Ions ◇

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Transient magnetic fields (TF) of several kTesla strength act on nuclei when ions penetrate polarized ferromagnetic materials [1]. They arise from the polarization of ns-electrons in inner-shells of the moving ion by spin-exchange interactions with the polarized $3d$- or $4f$-electrons of the ferromagnet [2]. Due to their exceptional strength they have been widely used for g-factor measurements of short-lived nuclear states with lifetimes in the ps- and subps-range.

As a general behaviour of TF, one finds a steady increase of strength with atomic number Z and velocity of the ion, reaching a maximum value at the $1s$-electron Bohr velocity $v = Zv_0(v_0 = c/137)$. In the specific situation, where the probe ions are predominantly in the H-like charge state with polarized $1s$-electrons, the TF strength is well described by [1]

$$B_{TF} = p_{1s}(v, Z_{host}) \cdot q_{1s}(v, Z_{host}) \cdot B_{1s}(Z)$$

where $B_{1s}(Z) = 16.7 \cdot Z^3$ Tesla is the Fermi contact field, q_{1s} the ion fraction with $1s$-electrons and p_{1s} its degree of polarization.

From experimental data for light probe ions it is evident, that p_{1s} is rather independent of the ion velocity but decreases with the atomic number [3]. Whether this feature holds also for heavier ions at correspondingly higher velocities, was one of the main motivations of the present measurements.

In earlier experiments on ^{62}Ni in Fe [4] and ^{54}Fe in Gd [5] surprisingly small precessions have been observed which was attributed to the deteriorating effect of the ion beam on the TF [6]. This finding turned out to be the main obstacle in determining the real strength of TF.

The first 2^+-state in ^{52}Cr at 1434 keV, with lifetime $\tau = 0.980(19)$ps and g-factor $g = 1.50(25)$, was Coulomb excited by scattering a $^{52}Cr^{16+}$ ion beam of 14.5 A MeV and 0.1 pnA intensity of the UNILAC from a Gd target. Targets consisted of a 26 mg/cm^2 thick Gd-layer on a thin Ta foil being sandwiched between thin Cu layers for thermal reasons. For magnetization an external field of 0.05 Tesla was found to be sufficient. In these conditions the Cr ions had a mean velocity in Gd of $21v_0$, at which a $\simeq$ 40% abundance of H-like ions has been estimated.

The experimental setup with detectors for the γ-rays and the forward scattered Cr ions was almost identical to that described in [4,5].

Detailed γ-angular correlations have been measured as a function of the azimuth angle defined by the appropriate sections of the position sensitive gas detector. The correlation was determined from counting rate ratios of two pairs of γ-detectors placed symmetric to the beam direction in the forward und backward hemispheres of the γ-detection plane (see Fig.1). The data have been fitted using COULEX calculations by including hyperfine interactions (HFI) of electron configurations due to the ions' recoil into vacuum. The attenuation coefficients deduced

$$G_2^{exp} = 0.80(2) \qquad G_4^{exp} = 0.33(6)$$

are quite similar to earlier data [4,5] which can be understood in terms of the HFI of various ion configurations [4].

Eventual contributions from quadrupole interactions by transient electric field gradients [5] are further pursued in a more detailed analysis of this data.

At such a high velocity we obtained for the first time a significant precession angle

$$\Phi = 14.4(4.8) \text{ mrad}$$

which refers to a TF strength $B_{TF} = 0.67(26)$ kTesla.

Including the known effect of ion-beam attenuation [6] one obtains a degree of polarization $p_{1s}^{exp} = 0.03(1)$. This result is consistent with the value obtained from the extrapolation of light ion data [3,5]. A more elaborate analysis and interpretation of this data is in progress.

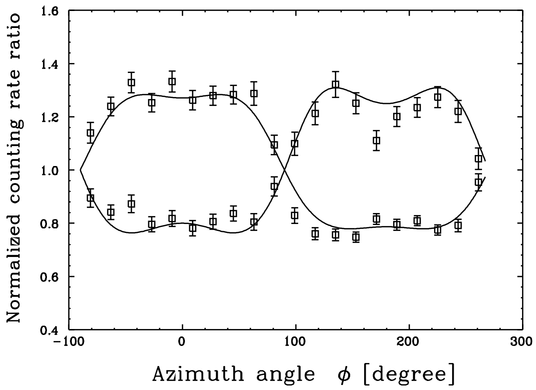

Fig. 1: Measured particle-γ-angular correlations with fits to the data.

References

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