Magnetic moment of $^{104}$Ag$^m$ and hyperfine magnetic field of Ag in Fe using nuclear magnetic resonance on oriented nuclei

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Nuclear magnetic resonance (NMR/ON) measurements with β and γ ray detection have been performed on oriented $^{104}$Ag$^m$ nuclei with the NICOLE $^3$He-$^3$He dilution refrigerator setup at ISOLDE/CERN. For $^{104}$Ag$^m$ ($I^e = 5^+$) the γ-NMR/ON resonance signal was found at $\nu = 266.70(5)$ MHz. Combining this result with the known magnetic moment for this isotope the magnetic hyperfine field of Ag impurities in an Fe host at low temperature (≈1 K), is found to be $|B_{hf}(Ag,Fe)| = 44.709(3)$ T. A detailed analysis of other relevant data available in the literature yields three more values for this hyperfine field. Averaging all four values yields a new and precise value for the hyperfine field of Ag in Fe i.e. $|B_{hf}(Ag,Fe)| = 44.692(30)$ T. For $^{104}$Ag$^m$ ($I^e = 2^+$), the anisotropy of the β particles provided the NMR/ON resonance signal at $\nu = 627.7(4)$ MHz. Using the new value for the hyperfine field of Ag in Fe this frequency corresponds to the magnetic moment $\mu^{(104m)Ag} = +3.691(3) \mu_N$, which is significantly more precise than previous results. The magnetic moments of the even-\(A\) $^{102-110}$Ag isotopes are discussed in view of the competition between the $(\pi g_9/2)^{-3}_{7/2+} (\nu d_{5/2} \nu g_{7/2})_{5/2}^{-2}$, and $(\pi g_9/2)^{-3}_{9/2+} (\nu d_{5/2} \nu g_{7/2})_{9/2}^{-2}$ configurations. The magnetic moments of the ground and isomeric states of $^{104}$Ag can be explained by an almost complete mixing of these two configurations.

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I. INTRODUCTION

Nuclear magnetic moments are an important tool for the study of nuclear structure as they provide a sensitive test of the nuclear coupling scheme. The light even-\(A\) $^{102-110}$Ag isotopes provide a very interesting case. In the heavier $^{106-110}$Ag isotopes the $(\pi g_9/2)^{-3}_{7/2+}$ proton group and the $(\nu d_{5/2})_{5/2}^{-1}$ neutron state couple to produce $I^e = 1^+$ and $I^e = 6^+$ ground and isomeric states, respectively. In the lighter $^{102-104}$Ag isotopes the ground and isomeric states have, respectively, $I^e = 5^+$ and $I^e = 2^+$ and are resulting from a mixture of the $(\pi g_9/2)^{-3}_{7/2+}$ and $(\pi g_9/2)^{-3}_{9/2+}$ proton groups coupling to a $(\nu d_{5/2} \nu g_{7/2})_{5/2}^{n}$ neutron configuration, where $n = 5$ or 7. (Henceforth, for brevity, the neutron occupation number will be omitted). Thus, whereas in most cases isomeric states have excitation energies of several hundred keV and a higher spin than the corresponding ground state, the silver isotopes $^{102,104}$Ag provide a different picture: the excitation energies of the isomeric states do not exceed a few keV, and their spins are lower than those of the ground states. The exact nature of the mixing of different configurations to produce the wave functions of these isomeric and ground states turns out to be an intriguing problem, to which precise values of the nuclear magnetic moments of these states can provide important information.

The nucleus $^{104}$Ag has a $I^e = 5^+$ ground state with half-life $t_{1/2} = 69$ min, and a $I^e = 2^+$ isomeric state with $t_{1/2} = 33.5$ min at an excitation energy of only 6.9 keV. For the $I^e = 5^+$ ground state the magnetic moment was determined with high accuracy in a γ-NMR/ON measurement as $\mu = 3.914(8) \mu_N$ [1] and later also in an atomic beam magnetic resonance experiment, i.e. $\mu = 3.919(3) \mu_N$ [2]. For the isomeric state the only value for the magnetic moment that is available in the literature, i.e. $\mu = +3.7(2) \mu_N$ [3], is not very precise though. Note that by careful comparison of the works of Ames et al [3], Greenebaum and Phillips [4], and van Walle [5] we found that the value $\mu = 4.12(25) \mu_N$ listed for $^{104}$Ag$^m$ in Table 3.8 of Ref. [5], and which was copied in Ref. [6] and later also in Ref. [7], is in fact the value that was obtained by Greenebaum and Phillips [4] for $^{102}$Ag$^m$.

Previously already, the proton ground state configuration of $^{104}$Ag was found to be a mixture of the $(\pi g_9/2)^{-3}_{7/2+}$ and $(\pi g_9/2)^{-3}_{9/2+}$ proton groups [3]. A clear indication for a transition from $(\pi g_9/2)^{-3}_{7/2+}$ being the dominant component in the wavefunction, to $(\pi g_9/2)^{-3}_{9/2+}$ was found when going from $^{103}$Ag (with $I^e = 7/2^+$) to $^{101}$Ag (with $I^e = 9/2^+$), and also when going from $^{105}$Ag to $^{102}$Ag [5].
For the isomeric state $^{104}\text{Ag}^m$ with $I^\pi = 2^+$ a mixing of these two proton groups was assumed on the basis of the not very precise magnetic moment value from an atomic beam experiment [3]. We have therefore performed a new measurement on $^{104}\text{Ag}^m$ in order to get a more precise value for the magnetic moment of this isomeric state, thus permitting to shed more light on its exact configuration as well as on the evolution of the proton configuration in the $^{102-106}\text{Ag}$ isotopes. The method of nuclear magnetic resonance on oriented nuclei was used, observing the destruction of the $\beta$ particle emission asymmetry by radio frequency radiation ($\beta$ NMR/ON). The nuclei were oriented with the method of low temperature nuclear orientation [8].

$^{104}\text{Ag}^m$ was obtained from the decay of $^{104}\text{Cd}$ parent nuclei ($t_{1/2} = 57.7$ min) that were implanted in the sample foil. As the $^{104}\text{Ag}$ ground state was found to be present in the sample as well, we measured in the same experimental run also the resonance signal for $^{104}\text{Ag}$. The fact that the magnetic moment of this state had previously been determined already with good accuracy from hyperfine structure measurements, yielding $\mu = 3.913(3) \mu_N$ [2], allowed us to obtain a new and precise value for the hyperfine field of Ag impurities in Fe.

Note, finally, that the magnetic moment of $^{104m}\text{Ag}$ determined here also served as calibration for a measurement of the $\beta$ emission asymmetry in the decay of this isotope, for the study of isospin mixing [9].

II. EXPERIMENTAL DETAILS

A. Sample preparation and detection set-up

The Ag isotopes used for the NMR/ON studies reported here were obtained from the decay of the $^{104}\text{Cd}$ precursor produced with the ISOLDE facility [10, 11]. The radioactive $^{104}\text{Cd}$ ($t_{1/2} = 57.7$ min) was produced with a 1.4-GeV proton beam ($8 \cdot 10^{12}$ protons per pulse, staggered mode) from the CERN Proton Synchrotron Booster accelerator (PS Booster), bombarding a tin liquid metal target [12]. Reaction products diffused out of the target and effused via a hot transfer line to the ion source. The atoms were ionized to $1^+$ ions, extracted, accelerated to 60 keV and then mass separated by the ISOLDE General Purpose Separator (GPS). Finally, the $^{104}\text{Cd}$ beam was transported through the beam distribution system and implanted into a 125 $\mu$m thick, 99.99 % pure iron foil soldered onto the cold finger of the $^3\text{He}^4\text{He}$ refrigerator of the NICOLE low-temperature nuclear orientation set-up [13, 14]. The iron foil supplied by GoodfellowTM was first polished and then annealed under a hydrogen atmosphere at $\approx 800^\circ$C for about 6 hours.

Prior to the implantation of the $^{104}\text{Cd}$ beam a polarizing magnetic field of $B_{\text{ext}} = 0.5$ T was applied with the superconducting split coil magnet in the refrigerator, in order to fully magnetize the iron foil. This field was then lowered to $B_{\text{ext}} = 0.1008(3)$ T to reduce its influence on the trajectories of the $\beta$ particles. The fact that part (i.e. about 10% [15]) of the saturation magnetization of the Fe foil was lost when the field was reduced to this lower value slightly reduced the sensitivity but did not further affect the measurements.

The geometry of the experimental set-up was very similar to the one we used for our previous $\beta$-NMR/ON experiments [9, 17, 18] and is shown schematically in Figure 1. The angular distribution of beta particles was observed with two planar HPGe particle detectors [19, 20] with a sensitive area of about 110 mm$^2$, mounted inside the 4 K radiation shield of the refrigerator at a distance of about 32 mm from the sample. Operating these detectors inside the 4K radiation shield, i.e. without any material between source and detector, avoids energy losses and reduces scattering of the $\beta$ particles. They were mounted at an angle of $15^\circ$ with respect to the magnetic field $B_{\text{ext}}$. Large volume HPGe $\gamma$ detectors are installed outside the refrigerator.

FIG. 1: (Color online) Schematic lay-out of the experimental set-up. The radioactive sample is prepared by implanting the ISOLDE beam, that is not shown here and is arriving perpendicular to the plane of the drawing, in the Fe foil on the Cu sample holder. A polarizing magnetic field $B_{\text{ext}}$ is created by the split-coil superconducting magnet. The RF coil provides a field perpendicular to $B_{\text{ext}}$ for the NMR/ON measurements. The $\beta$ particles are observed with planar HPGe detectors installed inside the 4K-shield of the refrigerator at an angle of about $15^\circ$ with respect to the magnetic field $B_{\text{ext}}$. Large volume HPGe $\gamma$ detectors are installed outside the refrigerator.
anisotropy of the 136 keV γ ray from a calibrated $^{57}$CoFe
nuclear orientation thermometer [21, 22] that was sold-
dered on the back side of the sample holder.

B. Angular distribution formalism

The angular distribution of radiation emitted from an
axially symmetric ensemble of oriented nuclei is given by [23]

$$ W(\theta) = 1 + f \sum_{\lambda} B_\lambda (\mu B_{tot} / k_B T, I) U_\lambda A_\lambda Q_\lambda P_\lambda (\cos \theta), \quad (1) $$

where $f$ represents the fraction of the nuclei that expe-
rienced the full orienting hyperfine interaction, while the rest ($1 - f$) is supposed to feel no orienting interaction at all; the $B_\lambda$ describe the nuclear orientation; the $U_\lambda$ are the deorientation coefficients which account for the
effect of unobserved intermediate radiations; the $A_\lambda$ are the directional distribution coefficients which depend on the properties of the observed radiation and the nuclear levels involved; the $Q_\lambda$ are solid angle correction factors and $P_\lambda(\cos \theta)$ are the Legendre polynomials. The detec-
tion angle $\theta$ is measured relative to the direction of the saturation magnetization axis of the Fe host foil which is defined by the applied horizontal magnetic field. The orientation coefficients $B_\lambda$ depend on the temperature of the sample $T$, the spin $I$ and the magnetic moment $\mu$ of the orientated state, and on the total magnetic field $B_{tot}$ the nuclei experience (with $k_B$ the Boltzmann constant).

This field is given by

$$ B_{tot} = B_{hf} + B_{ext}(1 + K) - B_{dem} \quad (2) $$

where $B_{hf}$ is the hyperfine magnetic field of Ag in Fe (see Sec.IV.A), $B_{ext}$ is the externally applied field, $K$ is the Knight shift parameter and $B_{dem}$ is the demagnetization field [24].

Three measurements of the Knight shift for silver in iron are reported in the literature. All three determined the Knight shift in γ-NMR/ON experiments, yielding $K(^{100}$AgFe) = −0.03(2) [25], $K(^{107}$AgFe) = −0.08(8) [26] and $K(^{110}$mAgFe) = −0.047(5) [27]. We will use here the weighted average of these three results, i.e. $K(\text{AgFe}) = −0.046(5)$.

For γ rays only λ-even terms occur in Eq. (1). For positrons from allowed β decays only the $\lambda = 1$ term is present and Eq.(1) transforms to [23]

$$ W(\theta) = 1 + f \frac{v}{c} B_1 A_1 Q_1 \cos \theta, \quad (3) $$

where $v/c$ is the positron velocity relative to the speed of light.

Experimentally the angular distribution is obtained by

$$ W(\theta) = \frac{N_{\text{cold}}(\theta)}{N_{\text{warm}}(\theta)} \quad (4) $$

with $N_{\text{cold, warm}}(\theta)$ the count rates when the sample is ‘cold’ (about 10 mK; oriented nuclei) or ‘warm’ (about 1 K; unoriented nuclei). In on-line experiments, where the count rates vary with beam intensity, it is customary to construct a double ratio, combining count rates in two different detectors in order to eliminate effects of beam intensity fluctuations and avoid the need to correct for the lifetime of the isotope. In the present work the double ratio

$$ R = \left[ \frac{N(15^\circ)}{N(165^\circ)} \right]_{\text{cold}} / \left[ \frac{N(15^\circ)}{N(165^\circ)} \right]_{\text{warm}} \quad (5) $$

was used for the β particles and

$$ R = \left[ \frac{N(0^\circ)}{N(90^\circ)} \right]_{\text{cold}} / \left[ \frac{N(0^\circ)}{N(90^\circ)} \right]_{\text{warm}} \quad (6) $$

for γ rays. All data were corrected for the dead time of the data acquisition system using a precision pulse generator.

C. NMR/ON resonance set-up and formalism

For the NMR/ON measurements an RF oscillating field was applied perpendicular to the external magnetic field (see Fig. 1). The NMR coil producing this oscillating field consisted of a pair of two-turn coils mounted on a teflon frame that was fixed inside the 300 mK radiation shield surrounding the sample. The coil was fed from the top of the refrigerator by coaxial cables connected to a digital Marconi frequency generator with a range from 10 kHz to 3.3 GHz. In addition to the NMR coil a pick-up coil for monitoring the RF signal was present too. A linear RF amplifier with a constant gain of 46 dBm was installed between the frequency generator and the RF coil. The intensity of the RF signal was kept as small as possible in order to avoid too strong RF heating and subsequent reduction in anisotropy for the β particles and γ rays.

The resonance measurements were performed at sample temperatures in the range from 8 to 12 mK by scanning the radio frequency, $\nu$, and observing the variation of the anisotropy of the β particles and γ rays emitted by the Ag nuclei. At resonance, transitions between the Zeeman split nuclear sublevels are induced which partially equalize the originally unequal populations of the sublevels, thus reducing the degree of nuclear orientation and therefore the magnitude of the anisotropy $R - 1$. The resonance frequency $\nu_{\text{res}}$ is related to the nuclear magnetic moment through the relation

$$ \nu_{\text{res}}[\text{MHz}] = \left| \frac{7.6226 \mu_\alpha}{{\mu}_N} \frac{B_{tot}[T]}{I} \right| \quad (7) $$

When pro mille precision is required and the nucleus is situated in a medium other than vacuum and being subject to an external applied magnetic field, the nuclear
magnetic moment value has to be corrected for diamagnetism. This is a reduction of the field experienced by the nuclei due to the polarization of the medium, which leads to an apparent reduction in the nuclear magnetic dipole moment if no correction to the applied field strength is made. The corrected magnetic moment value is then given by

$$\mu_{\text{corr}} = \mu_{\text{uncorr}} \left[ 1 - \sigma \frac{B_{\text{ext}}}{B_{\text{ext}} + B_{\text{hf}}} \right]^{-1}$$  

with $\sigma$ the diamagnetic correction. For silver nuclei $\sigma = 0.005555$ [6].

### III. DATA COLLECTION AND ANALYSIS

Due to the rather long half-life of both isotopes and their rather large magnetic hyperfine interaction strengths $T_{\text{int}} = |\mu B/k_B|$, i.e. $T_{\text{int}} \simeq 13$ mK for $^{104}\text{Ag}^g$ and $T_{\text{int}} \simeq 30$ mK for $^{104}\text{Ag}^g$, relaxation of the nuclear spins to thermal equilibrium was sufficiently fast and no problems with incomplete spin-lattice relaxation [28–30] were expected.

The decay of the $5^+ \ 104\text{Ag}^g$ ground state (Figure 2) is distributed over many $EC/\beta^+$ branches resulting in three rather intense $\gamma$ rays with energies of 555.8 keV, 767.6 keV, and 941.6 keV and intensities of 93%, 66% and 25%, respectively. Whereas the 555.8 keV transition is also clearly present in the decay of the isomeric state, the $\beta$ decay of the isomer contributes very little (i.e. only $\simeq 1\%$) to the intensity of the 767.6 keV transition, while the 941.6 keV transition is even completely absent in the decay of the isomer [16]. The last two $\gamma$ rays are therefore especially well suited for the determination of the magnetic moment of $^{104}\text{Ag}^g$ in a $\gamma$-NMR/ON experiment.

For $^{104}\text{Ag}^m$ the main $EC/\beta^+$ branch represents $\simeq 70\%$ of the total decay strength and populates the $2^+$ level at 555.8 keV in $^{104}\text{Pd}$ [16]. All other branches represent less than 2% each of the total decay strength. As the 555.8 keV $\gamma$ transition depopulating the $2^+$ first excited state is also one of the stronger $\gamma$ lines in the decay of $^{104}\text{Ag}^g$ (see Fig. 2) and the next most intense $\gamma$ transition in the decay of $^{104}\text{Ag}^m$ has an intensity of only about 4%, it was decided to use the $\beta$ transition to the first excited state to search for the resonance signal of $^{104}\text{Ag}^m$.

Typical $\gamma$ ray and $\beta$ particle spectra are shown in Figs. 3 and 4, respectively.

#### A. $\gamma$-NMR/ON on $^{104}\text{AgFe}$

The nuclear magnetic resonance signal for the ground state $^{104}\text{Ag}^g$ was obtained by observing the change of the anisotropy of the 555.8, 767.6, 941.6 keV $\gamma$ rays as a function of the frequency of the applied RF field. Using a triangular modulation frequency of 100 Hz, a modulation
bandwidth of 0.5 MHz and an RF signal level of -32 dBm, the center RF frequency was varied in steps of 0.5 MHz over the resonance search region from 263.5 MHz to 270 MHz. The search region could be chosen so narrow since two precise and mutually consistent values are available in the literature for both the hyperfine field of Ag in Fe, i.e. $|B_{hf}(AgFe)| = 44.7$ T [25, 34], and the magnetic moment of $^{104}$Ag, i.e. $\mu = 3.92 \mu_N$ [1, 2]. Two scans were performed, stepping the frequency region in both upward and downward directions, in order to avoid possible shifts of the (effective) resonance centers due to a finite spin-lattice relaxation time. At each frequency data were accumulated for 300 s.

An NMR effect was observed for all three $\gamma$ rays (see e.g. Fig. 5). Table I summarizes the results of the fits of a Gaussian line and a linear background to the data for the three different lines with the MINUIT minimization package [32]. The weighted average of the three central frequencies, obtained in a magnetic field of $B_{ext} = 0.1008(3)$ T, is

$$|\nu_{res}(^{104}Ag^{m}Fe)| = 266.70(5) \, MHz.$$  \hspace{1cm} (9)

This value is in agreement with, but an order of magnitude more precise than the previous result obtained in a similar experiment by Vandeplasche et al. [1], i.e. $\nu_{res} = 266.3(5) \, MHz$. It was used to determine a new precision value for the hyperfine field of Ag in Fe, as will be discussed below.

### B. $\beta$-NMR/ON on $^{104}Ag^{m}Fe$

To determine the magnetic moment of the isomeric state the change of the $\beta$ particle anisotropy as a function of the RF frequency was observed. The only value for the magnetic moment of $^{104}Ag^{m}$ available in the literature is not very precise, i.e. $\mu(^{104}Ag^{m}) = +3.7(2) \mu_N$ [3]. The magnetic moment was therefore first determined, prior to our measurement but during the same beam time, by scanning the frequency of the first of the two lasers used to selectively ionize Ag atoms in the RILIS ion source [33]. On-line analysis of this laser scan yielded

$$\mu(^{104}Ag^{m}) = 3.7(1) \, \mu_N, \hspace{1cm} (10)$$

corresponding to a frequency $\nu_{res} = 630 \pm 17$ MHz, which was then used as the search region for the $\beta$-NMR/ON experiment.

In order to maximize statistics, the destruction of the $\beta$ anisotropy effect

$$R = 1 - \frac{W(15^\circ)}{W(165^\circ)}, \hspace{1cm} (11)$$

was monitored in the energy region from 600 keV to the endpoint at 2708 keV. In spite of the fact that the magnitude of a $\beta$ anisotropy decreases towards lower energies because of its dependence on $v/c$ (see Eq. (3)), the size of the anisotropy was still rather large, i.e. $R \simeq 0.50$. The energy region below 600 keV was not used as it suffered from background of Compton scattered 511 keV annihilation and 555.8 keV decay $\gamma$ rays. A triangular modulation frequency of 100 Hz was again used. Several frequency scans were performed. For most of these the frequency step width was 2 MHz and the modulation amplitude $\pm 1$ MHz with a nominal RF power level of $-42$ dBm. For each scan the frequency region was always stepped both in upward and in downward directions. No difference between the center frequencies was found for passes in opposite directions, indicating that relaxation effects were indeed negligible.

The first scans were performed with continuous modulation of the RF signal. These data were again fitted using a simple Gaussian with a constant background. Thereafter four scans were performed by recording the spectrum for each frequency first without and immediately thereafter with frequency modulation. This FM-off/FM-on mode was used to obtain a better definition of the line shape. This was considered to be helpful since resonance lines in iron hosts at high frequencies are rather broad due to the inhomogeneous broadening of about 1%. Fig. 6 shows the destruction, $S$, of the $\beta$ asymmetry as

| Energy (keV) | $\nu_{res}$ (MHz) |
|-------------|------------------|
| 555.8       | 266.77(13)       |
| 767.6       | 266.66(6)        |
| 941.6       | 266.74(9)        |
| weighted average | 266.70(5) |

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**FIG. 4:** Typical $\beta$ spectrum for $^{104}Ag^{m}$, obtained in 300 s of counting. The endpoint energy for the decay of $^{104}Ag^{m}$ (i.e. 2708 keV) is indicated. At low energy the 122 keV and 136 keV $\gamma$ rays from the $^{57}$CoFe nuclear thermometer, the 511 keV annihilation peak and the 555.8 keV $\gamma$ ray from the $^{104}Ag^{m}$ decays are also visible.

**TABLE I:** $\gamma$-NMR/ON resonance centre frequencies ($\nu_{res}$) obtained for the three most intense $\gamma$ rays in the decay of $^{104}Ag^{m}$.

| Energy (keV) | $\nu_{res}$ (MHz) |
|-------------|------------------|
| 555.8       | 266.77(13)       |
| 767.6       | 266.66(6)        |
| 941.6       | 266.74(9)        |
| weighted average | 266.70(5) |
a function of frequency. This destruction \( S \) is defined as the difference between the ratio \( W(15°)/W(165°) \) with FM on and FM off normalized to the ratio with FM off:

\[
S = \frac{\left( \frac{W(15°)}{W(165°)} \right)_{\text{FM on}} - \left( \frac{W(15°)}{W(165°)} \right)_{\text{FM off}}}{\left( \frac{W(15°)}{W(165°)} \right)_{\text{FM off}}}
\]  \hspace{1cm} (12)

The total destruction observed was about 4%. This value is smaller than in our previous experiments with \(^{59}\text{Cu} (S \approx 45\%) \) [17] and \(^{69}\text{As} (S \approx 10\%) \) [18] and also smaller than the destruction obtained here for the \(^{104}\text{Ag}\) resonances (i.e. \( S \approx 25\%) \) (Figure 5). This is most probably due to the non-resonant background from \( \beta \) particles of the non-resonant \(^{104}\text{AgFe} \) in the energy region used for analysis. Nevertheless, the resonance frequency value could still be determined with good accuracy. Table II lists the results for the various scans that were performed. The weighted average resonance frequency, again obtained in a magnetic field of \( B_{\text{ext}} = 0.1008(3) \) T is

\[
\nu_{\text{res}}(^{104}\text{Ag}^{m}\text{Fe}) = 627.7(4) \text{ MHz}.
\]  \hspace{1cm} (13)

IV. RESULTS

A. Hyperfine field of Ag impurities in Fe

To extract a precise magnetic moment value for \(^{104}\text{Ag}^{m}\) from the NMR/ON frequency obtained, a precise value for the hyperfine magnetic field of Ag impurities in Fe host, \( B_{\text{hf}}(\text{AgFe}) \), is required. Two values are quoted in the literature. The first, \( |B_{\text{hf}}(\text{AgFe})| = 44.72(2) \) T, was obtained in a NMR/ON experiment with \(^{110}\text{Ag}\) in Fe [34]. However, from the reported resonance frequency of 203.75(10) MHz in a field of 0.220 T, and with the magnetic moment of 3.604(4) \( \mu_N \) used by the authors, one obtains \( |B_{\text{hf}}(\text{AgFe})| = 44.72(5) \) T, i.e. the same value but with a significantly larger error bar. It seems that the error on the magnetic moment was neglected in Ref. [34]. Later, Eder et al. [25] quoted the value \( |B_{\text{hf}}(\text{AgFe})| = 44.69(5) \) T which they deduced from the NMR/ON frequency \( \nu(^{110}\text{Ag}^{m}\text{Fe}) = 204.78(2) \) MHz reported in Ref. [35] and the magnetic moment value \( |\mu(^{110}\text{Ag}^{m})| = 3.607(4) \) \( \mu_N \) from Refs. [36] and [37]. In the mean time several new hyperfine interaction mea-
TABLE II: $\beta$-NMR/ON results for various scans of $^{104m}$Ag. Every measurement consists of two scans over the frequency region from 613 MHz to 647 MHz, one in upward and the other in downward direction. The measurements were performed with different stepsize and for different measurement times. The weighted average of the seven individual measurements (i.e. 14 scans) is indicated as well.

| Meas. Modulation | $\nu_{\text{res}}$ (MHz) | Step (MHz) | Coll. time (s) |
|-------------------|--------------------------|------------|---------------|
| 1 on              | 628.3(8)                 | 2          | 150           |
| 2 on              | 627.0(8)                 | 2          | 300           |
| 3 on              | 628.3(9)                 | 5          | 300           |
| 4 off/on          | 627.2(7)                 | 2          | 300           |
| 5 off/on          | 628.0(11)                | 2          | 150           |
| 6 off/on          | 629.1(29)                | 2          | 150           |
| 7 off/on          | 628.1(19)                | 2          | 150           |
| $\nu_{\text{res}}$ | 627.7(4)                 |            |               |

Measurements on $^{110}$Ag$^m$, $^{106}$Ag$^m$ and $^{104}$Ag$^g$ have been reported, allowing one to deduce four precise values for $B_{\text{hf}}$(AgFe), as will be discussed in the following paragraphs. An overview is given in Table III.

Two values for $B_{\text{hf}}$(AgFe) can be obtained from data for $^{110}$Ag$^m$. The two magnetic moment values for $^{110}$Ag$^m$ reported in Refs. [38] and [39] agree well and, after being corrected for diamagnetism [6], lead to the weighted average value $|\mu(110Ag)业绩|=3.608(3) \mu_N$. Combining this with the resonance frequency for this isotope in Fe host reported in Ref. [35], i.e. $\nu(110AgFe)=204.78(2)$ MHz, Eq. (7) yields for the hyperfine field of Ag impurities in Fe the value

$$|B_{\text{hf}}(AgFe)|_1 = 44.675(37) \text{T.} \quad (14)$$

Note that no correction for the Knight shift is required as the resonance frequency was quoted for $B_{\text{ext}}=0$, while a correction for $B_{\text{dem}}$ can be neglected at the present level of precision since a very thin foil was used.

Further, the nuclear magnetic moment of $^{110}$Ag$^m$ cited above, i.e. $|\mu(110Ag)业绩|=3.608(3) \mu_N$, and the resonance frequency $\nu(110AgFe)=203.75(10)$ MHz reported in Ref. [34], yield $|B_{\text{hf}}(AgFe)| = 44.451(43)$ T. The frequency was obtained with a 3 $\mu$m thin foil, rendering the correction for $B_{\text{dem}}$ again negligible, and in $B_{\text{ext}}=0.220$ T. Taking then also the Knight shift parameter $K=-0.046(5)$ into account (which was not yet known at the time of Ref. [34]) one derives from Eq. (2)

$$|B_{\text{hf}}(AgFe)|_2 = 44.661(43) \text{T.} \quad (15)$$

A third value for $|B_{\text{hf}}(AgFe)|$ is obtained from data for $^{106m}$Ag; NMR/ON resonance frequencies for this isotope were determined in both a Ag and an Fe host. Eder et al. [26] obtained $|\nu(106AgFe)业绩|=210.57(3)$ MHz in $B_{\text{ext}}=0$ with a stack of foils of 2 $\mu$m thickness (such that $B_{\text{dem}}=0$). Ohyara et al. [40] reported $|\nu(106Ag^mAg)业绩|=56.128(26)$ MHz in an external field of about 12 T. The exact value of this applied field could be deduced from the resonance frequency of $^{110}$Ag$^m$ in Ag for the same field setting, which was found at 54.640(11) MHz [41].

Using for the magnetic moment of $^{110m}$Ag the weighted average value from Refs. [38] and [39], i.e. $|\mu(110Ag^m业绩)|=3.588(3) \mu_N$ (this time not corrected for diamagnetism as the nuclear orientation in the NMR/ON experiments of Refs. [40] and [41] was induced solely by an external magnetic field), Eq. (7) yields $|B_{\text{tot}}|=11.987(10)$ T. The ratio $r=3.7516(18)$ of the two above mentioned frequencies for $^{106m}$Ag$^m$ can be written as

$$r = \frac{|\mu(106Ag^m业绩)|_{\text{corr}} |B_{\text{hf}}(AgFe)|}{|\mu(106Ag^m业绩)|_{\text{uncorr}}} |B_{\text{tot}}|^2,$$

$$11.987(10) \text{T}, \quad (16)$$

with $|\mu(106Ag^m业绩)|_{\text{corr}}/|\mu(106Ag^m业绩)|_{\text{uncorr}} = 1.00586$ the factor for the diamagnetic correction [6], so that

$$|B_{\text{hf}}(AgFe)|_3 = 44.720(43) \text{T.} \quad (17)$$

Finally, a hyperfine field value can also be obtained from data for $^{104}$Ag$^g$. Indeed, combining our NMR/ON resonance frequency for $^{104}$Ag$^g$ in Fe, i.e. $|\nu(104Ag^gFe)业绩|=266.70(5)$ MHz, with the magnetic moment value $|\mu(104Ag^g业绩)|=3.919(3) \mu_N$ from optical hyperfine spectroscopy measurements [2], Eq. (7) yields $|B_{\text{tot}}(AgFe)| = 44.639(35)$ T. Correcting this result according to Eq. (2) for the external magnetic field $B_{\text{ext}}=0.1008(3)$ T, for the Knight shift parameter $K=-0.046(5)$, and for the demagnetization of the 125 $\mu$m thick Fe foil used, i.e. $B_{\text{dem}}=0.026(5)$ T (a 20% error was adopted in order to account for approximations made in the equations used to calculate $B_{\text{dem}}$ [9]), results in

$$|B_{\text{hf}}(AgFe)|_4 = 44.709(35) \text{T.} \quad (18)$$

When combining the four above mentioned hyperfine fields to one weighted average, the correlations between the first three values, which all rely on the same value for the magnetic moment of $^{110m}$Ag, were duly taken into account by incorporating the full covariance matrix (e.g. [46]). Using then further standard error propagation techniques yields for the magnetic hyperfine field of Ag impurities in Fe the value

$$|B_{\text{hf}}(AgFe)| = 44.692(30) \text{T} \quad (19)$$

(the error would be 0.020 T instead of 0.030 T if correlations would not have been taken into account). This value is in agreement with and more precise than the value of 44.69(5) T cited in [25]. It will be used further in the analysis of our NMR/ON results for $^{104}$Ag$^m$ in the next section.
Table III: Input data leading to the hyperfine magnetic field for Ag impurities in Fe and the values obtained from these.

| line | measured/deduced quantity | value       | Ref.   | remark                        |
|------|---------------------------|-------------|--------|-------------------------------|
| 1    | | 3.607(4) $\mu_N$ $^a$ | [38]   | ABMR $^b$                      |
| 2    | $|\mu_{(110^{Ag})m}|$ | 3.609(4) $\mu_N$ $^a$ | [39]   | BF-NMR/ON $^c$          |
| 3    | $|\mu_{(110^{Ag})g}|$ | 3.608(3) $\mu_N$ | | weighted average of above two values |
| 4    | $|\mu_{(110^{Ag^{28}Fe})}|$ | 204.78(2) MHz | [35]   | from the resonance frequency in line 4 and the magnetic moment value in line 3 |
| 5    | $|B_{hf}(AgFe)|$ | 44.675(37) T | |                                                         |
| 6    | $|B_{hf}(AgFe)|$ | 203.75(10) MHz | [34]   | from the resonance frequency in line 6 and the magnetic moment value in line 3 |
| 7    | $|B_{hf}(AgFe)|$ | 44.661(43) T | |                                                         |
| 8    | $|\nu_{(106^{Ag})m}|$ | 210.57(3) MHz | [26]   | NMR/ON, for $B_{ext} = 0$ T |
| 9    | $|\nu_{(106^{Ag})g}|$ | 56.128(26) MHz | [40]   | BF-NMR/ON $^c$ in $B_{tot} = 11.987$ T |
| 10   | $|B_{hf}(AgFe)|$ | 44.720(43) T | | from the ratio of the resonance frequencies in lines 8 and 9 (see also Eq. (16)) |
| 11   | $|\nu_{(104^{Ag^{28}Fe})}|$ | 266.70(5) MHz | this work | NMR/ON, in $B_{ext} = 0.1008$ T |
| 12   | $|\mu_{(104^{Ag})g}|$ | 3.919(3) $\mu_N$ | [2]    | optical spectroscopy |
| 13   | $|B_{hf}(AgFe)|$ | 44.709(35) T | | from the resonance frequency of this work (line 11) and the magnetic moment value in line 12 |
| 14   | $|B_{hf}(AgFe)|$ | 44.692(30) T | | weighted average of the values in lines 5, 7, 10 and 13 |

$^a$Corrected for diamagnetism according to [6].
$^b$Atomic beam magnetic resonance.
$^c$Brute-force nuclear magnetic resonance on oriented nuclei.

B. Nuclear magnetic moment of $^{104^{Ag}}$

With the value for the hyperfine magnetic field of Ag impurities in Fe being established we can now deduce a precise value for the magnetic moment of $^{104^{Ag}}$ from our resonance frequency $|\nu_{(104^{Ag^{28}Fe})}| = 627.7(4)$ MHz. Taking into account the external field $B_{ext}=0.1008(3)$ T and the Knight shift parameter $K = -0.046(5)$, and correcting for the demagnetization field opposite to the direction of the external field, i.e. $B_{dem} = 0.026(5)$ T (see above), the total magnetic field experienced by the nuclei is found to be $|B_{tot}| = 44.622(30)$ T. Eq. (7) then yields for the magnetic moment

$$|\mu_{(104^{Ag})m}| = 3.691(3) \mu_N. \quad (20)$$

Correcting for diamagnetism does not change this value. This is the first precision value for the magnetic moment of this isomer.

V. MAGNETIC MOMENTS OF $^{102-110^{Ag}}$

The magnetic moments of the odd-odd even-$A$ Ag isotopes are listed in Table IV.

Extended magnetic moment calculations for even-$A$ odd-odd Ag isotopes are not available in the literature. Table V presents an overview of the experimental values for the magnetic moments of the ground and isomeric states in the even-$A$ $^{102-110^{Ag}}$ Ag isotopes as well as a comparison with values calculated with the additivity rule [49]

$$\mu_I[\mu_N] = \frac{1}{2}I(g_n+g_p)+(g_n-g_p)[I_n(I_n+1)-I_p(I_p+1)]/2(I+1). \quad (21)$$

For this we used Schmidt single particle moments, modified single particle moments, as well as the mean values of experimental magnetic moments of neighboring odd-even nuclei.

The Schmidt single particle magnetic moments for the $\pi g_9/2$ and $\nu d_{5/2}$ orbitals that determine the spins and magnetic moments of the light $^{101-110^{Ag}}$ nuclei are +6.793 $\mu_N$ and -1.913 $\mu_N$, respectively [50]. Modified single particle moments take into account the effects of the nuclear medium, i.e. configuration mixing, core polarization and meson exchange [51] by using the effective gyromagnetic ratios $g^{mod}_{\nu} = +1.1$, $g^{mod}_{\pi} = -0.05$ and $g^{mod}_{\nu} = 0.7 g^{free}_{\pi}$, i.e. $g^{mod}_{\pi} = 3.910$ and $g^{mod}_{\nu} = -2.678$, thus yielding $\mu^{mod}_{\nu}(\nu_{g_9/2}) = +6.355 \mu_N$ and $\mu^{mod}_{\pi}(\nu_{d_{5/2}}) = -1.439 \mu_N$. Finally, using experimental $g$ factors from neighboring odd-even nuclei has the advantage that configuration mixing and possible $g$ factor quenching in the odd-$A$ nuclei are automatically taken into account. For the $g$ factor of the $g_9/2$ protons, the value of the lower mass odd-$A$ silver isotope was each time used. For the $g$ factor of the $d_{5/2}$ neutrons the geometrical mean of the $g$ factors of the neighboring isotopes of Ru, Pd and Cd with the neutron in the $d_{5/2}$ orbital were used.

Note that nearly all neighboring odd-neutron Ru, Pd, Cd and Sn isotopes with $N = 55, 57, 59, 61$ and $63$ have
a 5/2\(^+\) ground state. For the isotopes with N = 55 this is due to the hole in the \(\nu d_{5/2}\) orbit. For the isotopes with N = 57 to 63, filling the \(\nu g_{7/2}\) orbit, this indicates that with adding neutron pairs these predominantly couple to spin 0, leaving the hole in the \(\nu d_{5/2}\) orbit, and this all the way up to N = 64. This is why in the calculations of magnetic moments presented in Table V the \((\nu d_{5/2})^{-1}\) configuration has always been used. The 7/2\(^+\) state related to a filled \(\nu d_{5/2}\) orbit and an odd number of neutrons in the \(\nu g_{7/2}\) orbit is in almost all isotopes found as an excited state at excitation energies ranging from 188 keV to 416 keV, except for \(^{111}\)Sn where it is the ground state. It is not understood why this predominant coupling of neutron pairs in the \(\nu g_{7/2}\) orbit occurs. However, the configuration is complex as can be seen from the g factors of the odd-neutron states in this mass region which are found to have values of about -0.30 (see column 5 in Table V) which in absolute value is considerably smaller than the modified Schmidt value of -0.576 for the \(\nu d_{5/2}\) orbit (the modified Schmidt g factor for the \(\nu g_{7/2}\) orbit is +0.242). Note that this issue is to some extent also related to the current debate about the ground state of \(^{101}\)Sn being \(\nu d_{5/2}\) or \(\nu g_{7/2}\) (e.g. \([52, 53]\)).

As can be seen in Table V, for the heavier neutron deficient isotopes \(^{106}\)Ag, \(^{108}\)Ag, and \(^{110}\)Ag (with a 1\(^+\) ground state and a 6\(^+\) isomeric state) the magnetic moment for the isomeric state can be very well explained by a parallel coupled \((\pi g_{9/2})_{7/2}^{-3}(\nu d_{5/2})_{5/2}^{-1}\) configuration. The values calculated with the additivity relation (Eq. (21)) using Schmidt single particle moments or modified single particle moments are systematically lower than the experimental values, but the values calculated with experimental g factors are always very close to the experimental results.

For the 1\(^+\) ground state of \(^{106,108,110}\)Ag, coming from the antiparallel coupling of the \((\pi g_{9/2})_{7/2}^{-3}\) proton group and the \((\nu d_{5/2})_{5/2}^{-1}\) neutron state, the additivity rule with experimental g factors of neighboring isotopes yields values that are systematically about 0.3 to 0.5 \(\mu_N\) too small. Since the correction on this 1\(^+\) state due to core excitations is less than 0.1 \(\mu_N\) \([50]\) this deviation is probably due to the mixing of other states in the wave function. The \((\pi g_{9/2})_{7/2}^{-3}\) proton configuration is thus firmly established for \(^{106-110}\)Ag.

For the lower mass \(^{102,104}\)Ag isotopes Ames et al. \([3]\) already pointed out that the wave function would consist of a \((\nu d_{5/2})_{5/2}^{-1}\) neutron configuration coupled to a mixed \((\pi g_{9/2})_{9/2}^{-3}(\nu g_{7/2})_{7/2}^{-3}\) proton configuration. The experimental magnetic moments of both the ground and the isomeric state in \(^{104}\)Ag are in between the values calculated for the two pure proton-neutron configurations (see Table V) and support this suggestion. The magnetic moment of \(^{104}\)Ag\(^g\) \((I^\pi = 5^+)\) was previously already determined with high precision in two independent experiments \([1, 2]\). The measurement reported here now provides a precise value for \(^{104}\)Ag\(^m\) \((I^\pi = 2^+)\) as well. This now permits a more detailed analysis of the configuration mixture in the 2\(^+\), 5\(^+\) doublet of states (only 6.9 keV apart) in \(^{104}\)Ag. Writing the wave functions for both states as (see \([50]\)):

\[
\psi(104\text{Ag}^{g,m}) = \alpha \left( (\pi g_{9/2})_{7/2}^{-3}(\nu d_{5/2})_{5/2}^{-1} \right) + \beta \left( (\pi g_{9/2})_{9/2}^{-3}(\nu g_{7/2})_{7/2}^{-3} \right),
\]

(22)

with \(\alpha\) and \(\beta = \sqrt{1 - \alpha^2}\) the mixing amplitudes, the expectation value of the magnetic moment operator becomes

\[
<\mu> = \alpha^2 \left< \mu \left( (\pi g_{9/2})_{7/2}^{-3}(\nu d_{5/2})_{5/2}^{-1} \right) \right> + \beta^2 \left< \mu \left( (\pi g_{9/2})_{9/2}^{-3}(\nu g_{7/2})_{7/2}^{-3} \right) \right>.
\]

(23)

The mixing amplitudes, as obtained from the experimental magnetic moments, are listed in the last column of Table V and indicate a complete mixing of the two configurations (i.e. \(\alpha \approx \beta \approx 1/\sqrt{2} = 0.71\)) in \(^{104}\)Ag\(^g\) \((I^\pi = 5^+)\) and almost complete mixing in \(^{104}\)Ag\(^m\) \((I^\pi = 2^+)\). Performing the same analysis also for the doublet of 2\(^+\) and

| Isotope  | I  | \(\mu (\mu_N)\) | Ref. |
|---------|----|----------------|-----|
| \(^{102}\)Ag\(^g\) | 5  | 4.55(65)       | [42]* |
| \(^{104}\)Ag\(^g\) | 5  | 3.916(8)\(^b\) | [1, 5]\(^c\) |
|          | 3.919(3)   | [2]\(^d\) |
|          | +4.0(2)    | [3]\(^e\) |
| \(^{106}\)Ag\(^g\) | 1  | +2.83(20)      | [4]\(^e\) |
| \(^{108}\)Ag\(^g\) | 1  | 2.6884(7)\(^f\) | [43]\(^e\) |
| \(^{110}\)Ag\(^g\) | 1  | 2.7271(8)\(^f\) | [43]\(^e\) |
| \(^{102}\)Ag\(^m\) | 2  | +4.12(25)      | [4]\(^e\) |
| \(^{104}\)Ag\(^m\) | 2  | 3.691(3)       | this work\(^c\) |
|          | 3.7(1)     | this work\(^g\) |
|          | +3.7(2)    | [3]\(^e\) |
| \(^{106}\)Ag\(^m\) | 6  | 3.705(4)       | [40]\(^h\) |
|          | 3.709(4)   | [25]\(^c\) |
|          | 3.71(15)   | [44]\(^a\) |
|          | 3.82(8)    | [45]\(^a\) |
| \(^{108}\)Ag\(^m\) | 6  | 3.577(20)      | [36]\(^d\) |
| \(^{110}\)Ag\(^m\) | 6  | 3.607(4)\(^i\),\(^j\) | [38]\(^e\) |
|          | 3.609(4)\(^i\) | [39]\(^e\) |

*Low Temperature Nuclear Orientation (LTNO).
\(^b\)Recalculated using the hyperfine field value obtained in the previous section.
\(^c\)Nuclear Magnetic Resonance on Oriented Nuclei (NMR/ON).
\(^d\)Optical hyperfine spectroscopy.
\(^e\)Atomic Beam Magnetic Resonance (ABMR).
\(^f\)Corrected for diamagnetism.
\(^g\)Resonant Laser Ionization Source technique (RILIS).
\(^h\)Brute-Force Nuclear Magnetic Resonance on Oriented Nuclei (BF-NMR/ON).
TABLE V: Magnetic moments of the even-A Ag isotopes. Experimental magnetic moments are compared with values obtained with the addition theorem (Eq. (21)) using either Schmidt values, $\mu^{Sch}_{\text{add}}$, modified Schmidt values, $\mu^{mod}_{\text{add}}$, or experimental moment values from neighboring isotopes, $\mu^{\text{exp}}_{\text{add}}$. Note that in fact the $(\nu d_{5/2})^{1+}$ neutron configuration was used to calculate $\mu^{Sch}_{\text{add}}$ and $\mu^{mod}_{\text{add}}$ (see text). Since $g_{n,\text{exp}}$ was obtained from neighbouring isotopes with $I^e = 5/2^+$, the values for $\mu^{\text{exp}}_{\text{add}}$ in column 8 take into account the fact that the effective neutron configuration is a mixture of $\nu d_{5/2}$ and $\nu g_{7/2}$ coupling to a spin $5/2^+$. Further, since the Schmidt $g$-factors for $\nu d_{5/2}$ and $\nu g_{7/2}$ are -0.765 and 0.425, respectively, the fact that $g_{n,\text{exp}}$ varies between -0.252 and -0.0331 (see column 5) indicates that a considerable amount of mixing between the $\nu d_{5/2}$ and $\nu g_{7/2}$ states to be present. (table adapted from Ref. [5])

| $A$ | $I^e$ | configuration | $g_{\text{f,exp}}$ | $g_{n,\text{exp}}$ | $\mu^{Sch}_{\text{add}}$ | $\mu^{mod}_{\text{add}}$ | $\mu^{\text{exp}}_{\text{add}}$ | Ref. | $\mu_{\text{exp}}$ | mix. ampl. | $\alpha$ or $\beta$ |
|-----|------|---------------|-----------------|-----------------|----------------|----------------|----------------|-----|----------------|------------|----------------|
| 102 | $2^+$ | $[\pi g_{9/2}]^{-3}_{7/2} \ (\nu d_{5/2} \ \nu g_{7/2})_{5/2}^{5/2}$ | 1.250(2) | -0.279(29) | 3.40 | 3.16 | 2.76(1) | 4.12(25) | [4] | 0.66(11) |  |
| 5$^+$ | $[\pi g_{9/2}]^{-3}_{9/2} \ (\nu d_{5/2} \ \nu g_{7/2})_{5/2}^{5/2}$ | 6.81 | 6.14 | 5.05(5) | 0.75(9) |  |
| 104 | $2^+$ | $[\pi g_{9/2}]^{-3}_{7/2} \ (\nu d_{5/2} \ \nu g_{7/2})_{5/2}^{5/2}$ | 1.266(1) | -0.294(4) | 3.40 | 3.16 | 2.792(2) | 3.691(3) | this work | 0.79(1) |  |
| 5$^+$ | $[\pi g_{9/2}]^{-3}_{9/2} \ (\nu d_{5/2} \ \nu g_{7/2})_{5/2}^{5/2}$ | 6.81 | 6.14 | 5.129(5) | 0.61(2) |  |
| 106 | $1^+$ | $[\pi g_{9/2}]^{-3}_{7/2} \ (\nu d_{5/2} \ \nu g_{7/2})_{5/2}^{5/2}$ | 1.261(4) | -0.252(6) | 4.35 | 3.90 | 3.15(2) | 2.83(20) | [4] | - |  |
| 6$^+$ | $[\pi g_{9/2}]^{-3}_{7/2} \ (\nu d_{5/2} \ \nu g_{7/2})_{5/2}^{5/2}$ | 3.38 | 3.50 | 3.79(2) | 3.705(4) | [40] | - |  |
| 108 | $1^+$ | $[\pi g_{9/2}]^{-3}_{7/2} \ (\nu d_{5/2} \ \nu g_{7/2})_{5/2}^{5/2}$ | 1.257(2) | -0.331138(4) | 4.35 | 3.90 | 3.24(2) | 2.6884(7) | [43] | - |  |
| 6$^+$ | $[\pi g_{9/2}]^{-3}_{7/2} \ (\nu d_{5/2} \ \nu g_{7/2})_{5/2}^{5/2}$ | 3.37 | 3.50 | 3.57(2) | 3.577(20) | [36] | - |  |
| 110 | $1^+$ | $[\pi g_{9/2}]^{-3}_{7/2} \ (\nu d_{5/2} \ \nu g_{7/2})_{5/2}^{5/2}$ | 1.257(2) | -0.306(1) | 4.35 | 3.90 | 3.21(5) | 2.7271(8) | [43] | - |  |
| 6$^+$ | $[\pi g_{9/2}]^{-3}_{7/2} \ (\nu d_{5/2} \ \nu g_{7/2})_{5/2}^{5/2}$ | 3.37 | 3.50 | 3.63(5) | 3.609(4) | [39] | - |  |

\[a\] $g$ factor of $^{101}$Ag ($I^e = 9/2^+$) from Ref. [2].
\[b\] Average of the $g$ factors of $^{99}$Ru, $^{101}$Pd and $^{103}$Cd.
\[c\] $g$ factor of $^{103}$Ag ($I^e = 7/2^+$) from Ref. [2].
\[d\] Average of the $g$ factors of $^{101}$Ru and $^{105}$Cd.
\[e\] Other determinations of this magnetic moment have yielded $+3.7(2) \ \mu_N$ [3] and $3.7(1) \ \mu_N$ (this work, RILIS measurement).
\[f\] Other determinations of this magnetic moment have yielded $3.916(8) \ \mu_N$ [1] (see also Table IV), and $+4.0(2) \ \mu_N$ [3].
\[g\] $g$ factor of $^{105}$Ag$^{*+}$ ($I^e = 7/2^+$) from Ref. [2].
\[h\] Average of the $g$ factors of $^{105}$Pd and $^{107}$Cd.
\[i\] $g$ factor of $^{101}$Ag$^{*+}$ ($I^e = 7/2^+$) from Ref. [2].
\[j\] $g$ factor of $^{107}$Ag$^{*+}$ ($I^e = 7/2^+$) from Ref. [26].
\[k\] $g$ factor of $^{109}$Cd from Ref. [47].
\[l\] $g$ factor of $^{109}$Ag$^{*+}$ ($I^e = 7/2^+$) from Ref. [2].
\[m\] $g$ factor of $^{111}$Cd (level at 245 keV) from Ref. [48].
\[n\] Another determination of this magnetic moment has yielded $3.607(4) \ \mu_N$ [38].
5+ states of 102Agm and 102Agg, respectively (which differ only 9.3 keV in energy), indicates also almost complete mixing of the two different proton-neutron configurations in 102Agm (Iπ = 2+), although the error bars still allow for a smaller contribution from the (π8g9/2)-3 proton configuration. As for 102Agg (Iπ = 5+), the experimental magnetic moment value suggests an almost pure (π8g9/2)-3 configuration, although the large error bar still allows for a sizeable mixing from the (π8g9/2)-3 configuration (see Table V). A larger contribution of the (π8g9/2)-3 configuration in 102Agg, as is apparently observed, would be in line with the fact that the ground state in 101Ag has Iπ = 9/2+ and also with the magnetic moment of 101Ag. Indeed, the experimental magnetic moment of 101Ag, i.e. µN = 5.627(11) µN [2], is very close to the value of 5.67 µN that was calculated in Ref. [54] for the lowest 9/2+ state in the odd Ag isotopes based on a configuration that is dominated by the (π8g9/2)-3 proton group. New and precise measurements of the magnetic moments of the ground and isomeric state of 102Ag as well as of the lower mass even-Ag isotopes could help to further clarify this. An interesting new method in this respect, viz. in-gas-cell laser spectroscopy [55], was recently reported. This method is currently being applied to the isotopes 97–102Ag [56].

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