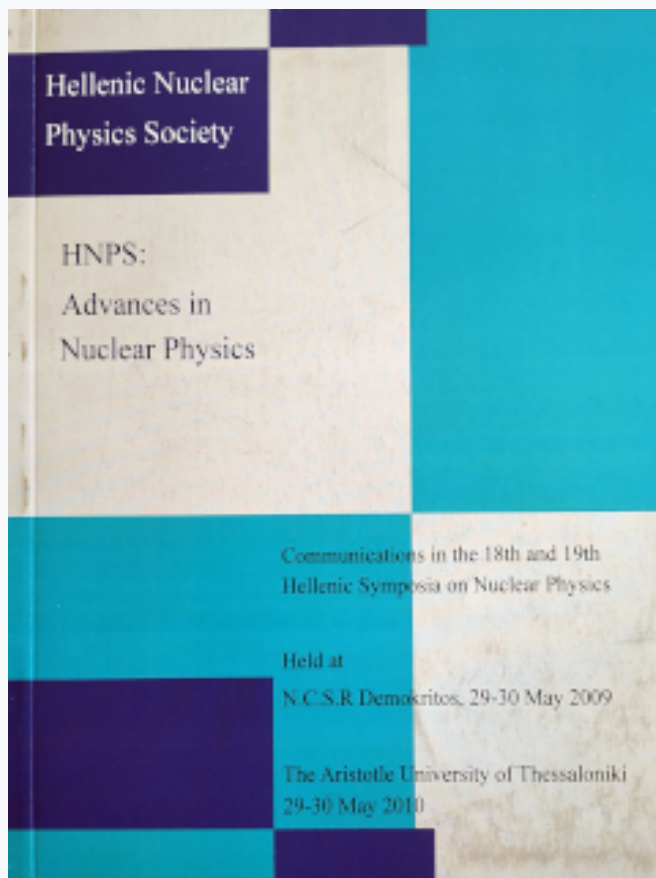# HNPS Advances in Nuclear Physics

Investigation of the Transient Field at High Velocities by magnetic-moment measurements in 74Ge and 70Zn

T. J. Mertzimekis

Investigation of the Transient Field at High Velocities by magnetic-moment measurements in ^{74}Ge and ^{70}Zn

T.J. Mertzimekis[a,*], for the LNS-HVTF collaboration

[a]*INP, NCSR "Demokritos", 15310, Aghia Paraskevi, Greece*

Abstract

The advent of radioactive beams at large experimental facilities has motivated extensive research work on the expansion of techniques to accommodate higher ion velocities. The application of the Transient Field technique in measuring magnetic moments of excited states in energetic nuclei is investigated at the INFN-LNS in Catania by means of re-measuring the $g(2_1^+)$ factors in ^{74}Ge and ^{70}Zn. The description of the experiment method and some preliminary angular correlation results are presented.

Keywords: Magnetic moments, Transient Field, HVTF parameterization

1. Introduction and Motivation

Radioactive beams (RIB) are available almost routinely at large experimental facilities around the world. By means of RIB, new phenomena may be studied, providing important input to our understanding of the nuclear landscape. In that framework, tools and techniques are re-visited, updated and expanded to keep up in pace with recent developments.

The Transient Field (TF) technique is an experimental method that has been utilized successfully for magnetic-moment measurements of nuclear states with lifetimes at the picosecond range. In general, the method is well applicable for ion velocities below the K-shell electron velocities $V_K = Zv_o$ [1, 2], with $v_o = c/137$ being the Bohr velocity. With the exception of several light nuclei in the range $6 < Z < 24$ (see Ref.[2] and references therein) the behavior of the TF strength has been studied at velocities $v_{ion} \ll Zv_o$. For that range several studies have been carried out up to $v_{ion} \sim Zv_o$, resulting in the observation of a steady increase of the TF strength, approaching its maximum value at Zv_o [1, 2, 3]. The lack of an analytic expression for TF is overcome by using strength parameterizations as a function of ion velocity and type and magnetization of the ferromagnetic host.

---

*Present address: Dept. of Physics, Univ. of Athens, 15784, Zografou Campus, Athens, Greece

Exotic nuclei produced as low-intensity radioactive beams are now available as projectiles at high velocities and may be studied at the maximum TF strength, expected to occur at v_K. This type of studies should allow for measurements of very short lived nuclear states and provide critical information on their structure. The application of the technique is based on the utilization of a ferromagnetic target where the TF is observed during the ion's flight through the host. In the low-velocity regime Gd is usually preferred as ferromagnetic layer compared to Fe. Larger precession angles may be achieved since Gd has a lower stopping power.

Older parameterizations do not cover the velocity ranges of ions produced in the modern RIB facilities and new data have to be provided to (a) understand the new physics associated with higher ion energies (b) improve the existing parameterizations, if possible, and (c) use the new information to improve the technique expanding its range of applicability. Such a recent parameterization using newly acquired data on magnetic moments of light ions experiencing the TF in a Fe foil has been established [3]. However, this parameterization needs to be tested further for heavier ions and additional ferromagnetic hosts, such as Gd.

2. Experimental Details

An experiment was carried out at the INFN-Laboratori Nationali del Sud in Catana, Italy. The INFN-LNS K800 Superconducting Cyclotron produced and delivered 0.5 pnA, 40 MeV/u ^{74}Ge and ^{70}Zn beams. The beams impinged a Gd single-layer target which acted both as a Coulomb excitation layer and the ferromagnetic layer which is required for the application of the technique. The interacted target particles traversed the target, which was cooled at 50 K to obtain its ferromagnetic properties, and were detected by a 8-fold segmented plastic scintillator located after the target. The particle detector was designed with cylindrical symmetry and placed coaxially with the beam allowing non-interacted beam to travel all the way to a beam stop located several meters downstream.

The ions that were excited in the target further experienced the influence of the TF for as long as they were crossing the Gd foil. The direction of the TF was adjusted by a ≈ 600 G external polarizing magnetic field, which was controlled by a specially designed electronic circuit responsible to flip its direction every 5 min, mainly to eliminate any systematic effects.

De-excitation of the beam particles led to photon emission that was detected by eight (8) EXOGAM Clover detectors, located on a plane and positioned at $\pm 30°, \pm 90°, \pm 130°$ and $\pm 150°$ with respect to the beam axis. The left-right segments of the clover detectors were examined separately to double the number of angular data points in search for an improvement in angular correlation pattern. Furthermore, *gamma*-rays were selected in coincidence with the target particles detected in the plastic scintillator.

The analysis of data and extraction of the information has been described extensively in the past (see e.g. [2]). It is currently under progress and the

results presented in the next section are considered preliminary.

3. Results

Angular correlation data were extracted during the experimental run. The angular correlation function is necessary to extract the logarithmic slope, S. Then the slope is used together with the precession effect, ϵ to deduce the precession angle which is directly related to the g factor of the first 2^+ states in ^{74}Ge and ^{70}Zn. See Ref. [2] for further details.

Relativistic corrections due to high velocities were taken into account. The experimental angular correlation data are plotted in Fig. 1.
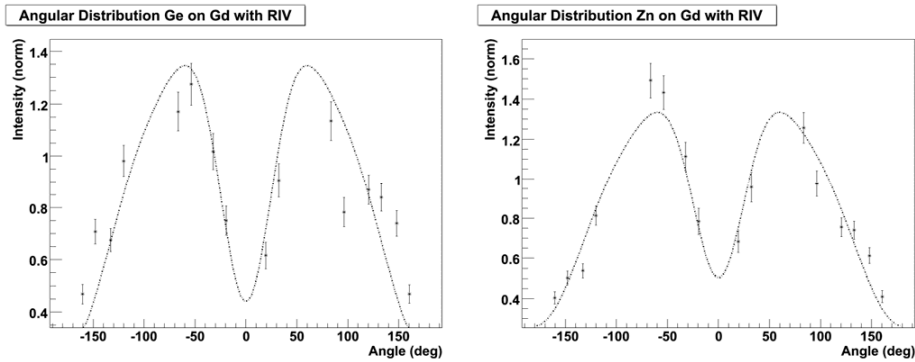

Figure 1: Angular correlation data for ^{74}Ge (left) and ^{70}Zn(right)

The solid lines reflect the best fit to the experimental points of a typical angular correlation function for an E2 transition, $W(\theta)$ of the form:

$$W(\theta) = 1 + a_2 G_2 P_2(\cos\theta) + a_4 G_4 P_4(\cos\theta) \qquad (1)$$

where $a_{2,4}$ and $G_{2,4}$ are coefficients needed to be estimated, and $P_{2,4}$ are standard Legendre polynomials. All parameters involved in the kinematics and interactions were taken into account for the best fit estimated by the code GKINT [4] and the current results for ^{74}Ge are:

$$
\begin{aligned}
a_2^{Ge} &= -0.614 & G_2^{Ge} &= 0.892 \\
a_4^{Ge} &= -0.211 & G_4^{Ge} &= 0.639
\end{aligned}
$$

while for ^{70}Zn the following values were estimated:

$$
\begin{aligned}
a_2^{Zn} &= -0.584 & G_2^{Zn} &= 0.886 \\
a_4^{Zn} &= -0.192 & G_4^{Zn} &= 0.620
\end{aligned}
$$

4. Conclusions

The applicability of the TF parameterization at higher ion velocities reached at RIB factories was studied by means of the angular correlation measurements as a first step in obtaining a reliable parameterization. Previously studied excited states of the ^{74}Ge and ^{70}Zn nuclei, excited by and precessed in Gd foils were used as reference. The experimental results provide well determined values for the angular correlation coefficients needed for the subsequent measurement of the magnetic moments of the excited states in these nuclei. Undergoing analysis [5] is expected to provide the required first excited 2^+ state g factor data to optimize the HVTF calibration for ions traversing ferromagnetic Gd foils at RIB velocities.

Acknowledgements

References

[1] N. Benczer-Koller *et al.*, Ann. Rev. Nucl. Part. Sci. 30, 53 (1980)

[2] K.-H. Speidel *et al.*, Prog. Part. Nucl. Phys. 49, 91 (2002)

[3] A.E. Stuchbery *et al.*, Phys. Lett. B 611, 81 (2005)

[4] A.E. Stuchbery, unpublished (2003)

[5] E. Fiori, Ph.D. thesis, (2010) - in preparation