Polarization measurements of ^{39}S for β-NMR studies

A. Gladkov,[*1,*2] Y. Ichikawa,[*1] Y. Ishibashi,[*1,*3] A. Takamine,[*1] T. Fujita,[*1,*4] K. Imamura,[*1,*5] T. Nishizaka,[*6] H. Ueno,[*1] W. Y. Kim,[*2] L. C. Tao,[*1,*7] T. Egami,[*6] H. Yamazaki,[*1] D. Tominaga,[*6] K. Asahi,[*8] T. Kawaguchi,[*6] Y. Ohtomo,[*1,*8] C. Funayama,[*8] S. Kojima,[*8] and T. Sato[*8]

In this experimental campaign, we focus on the search for the ground state electromagnetic moments of S isotopes close to the magic number $N = 28$, for which erosion of the shell gap has been suggested[1,2]. As the AP value obtained for ^{41}S is quite small[3], the AP value achieved for ^{39}S whose decay scheme has been partly established[4] is tested before the ^{41}S and ^{43}S measurements. Here A and P denote the asymmetry parameter for the β-ray emission and the degree of polarization, respectively.

For these purposes, we employ the method of β-nuclear magnetic resonance (β-NMR) in combination with adiabatic fast passage technique (AFP) and the particles of interest are provided by the well-established method to produce spin-polarized RI beams[5]. However, in order to conduct the β-NMR measurement in an efficient way, it is highly desirable to determine the optimal beam settings resulting in the largest value of the figure-of-merit $Y \times P^2$ beforehand, where Y and P denote the yield and polarization of the secondary beam, respectively. Therefore, we employ the adiabatic field rotation (AFR) system[6,7] that enables us to determine the polarization through a change in the β-ray asymmetry caused by the adiabatic rotation of the holding field, without the use of the NMR technique and prior to the actual β-NMR measurement.

A strong holding field B_0 provides better preservation of polarization and higher probability of spin reversal. To increase the magnetic field within the space and motor power limitations, the magnet part of the AFR device was modified by employing the Halbach array magnet configuration[8] instead of a common dipole design. The type of Halbach array that we use consists of eight Nd magnet segments placed in such a way that the entire construction forms a circular shape. Each segment has a different direction of the magnetic field so that the magnetic field lines are within the magnet material. Thus, the key feature of the array is that the magnetic field is mostly enclosed within the array and is negligibly weak outside of it, providing the most efficient use of the magnet material. With such a configuration, a 0.495 T magnetic field was obtained, which is almost twice as large as that for the previous dipole design.

In addition, the rectangular planar plastic scintillators were replaced with cylindrical scintillators covering a solid angle of nearly 2π sr. This allowed us to enlarge the stopper so that it is the same size as that in the β-NMR setup.

The AFR experiment was conducted at the RIPS facility at the RIBF prior to the β-NMR measurements. A secondary beam of ^{39}S was produced from the projectile fragmentation reaction of ^{48}Ca on a 0.5 mm-thick beryllium target at an energy of 63 MeV/nucleon and beam current of 200 pnA at the target. In order to ensure polarization of ^{39}S, an emission angle selection $\theta_F > 2°$ was applied with a momentum window of $p_F = p_0 \times (1.02 \pm 0.02)$. Here p_0 represents the central momentum of the fragment. In these conditions, a beam purity of 77% was achieved by the two-stage $B\rho$ selection. After separation, the particles of interest were implanted in a 0.5 mm-thick CaS stopper within the AFR setup. The emitted β-rays were detected by two pairs of plastic scintillators placed above and below the stopper.

The measurements were carried out according to the following sequence. The stopper was irradiated for 16 s of the beam-on period. The AFR magnet array was then rotated by 180° for 150 ms. As the rotation causes small vibrations, an additional margin of 70 ms was added to ensure stabilization. After that the β-particles were counted for 16 s. The AP value was calculated from the four-fold ratio considering four configurations of up/down direction of the rotating field and normal/reversed spin of the implanted particles.

In this measurement, an AP value of $-0.37 \pm 0.12\%$ was obtained with 3.1σ significance on the CaS stopper. The determined beam settings were applied in the β-NMR measurements following the AFR experiment to determine the g-factor of the ^{39}S ground sate. Further analysis of data obtained from both experiments is in progress.

References

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*1 RIKEN Nishina Center
*2 Department of Physics, Kyungpook National University
*3 Department of Physics, University of Tsukuba
*4 Department of Physics, Osaka University
*5 Department of Physics, Meiji University
*6 Department of Physics, Hosei University
*7 The School of Physics and State Key Laboratory of Nuclear Physics and Technology, Pekin University
*8 Department of Physics, Tokyo Institute of Technology