Title
NMR on Beta-Emitting Fragment {sup 43}Ti

Permalink
https://escholarship.org/uc/item/4dz7r48b

Authors
Matsuta, K.
Ozawa, A.
Nojiri, Y.
et al.

Publication Date
1992-08-01

LBL-32818
UC-413

Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA

Presented at the Sixth International Conference on Nuclei Far from Stability and the Ninth International Conference on Atomic Masses and Fundamental Constants, Bernkastel-Kues, Germany, July 19–24, 1992, and to be published in the Proceedings

NMR on Beta-Emitting Fragment ^{43}Ti

K. Matsuta, A. Ozawa, Y. Nojiri, To. Minamisono, M. Fukuda,
S. Momota, T. Ohtsubo, S. Fukuda, K. Sugimoto, I. Tanihata,
K. Yoshida, K. Omata, J.R. Alonso, G.F. Krebs, and T.J.M. Symons

August 1992

NUCLEAR SCIENCE DIVISION

Prepared for the U.S. Department of Energy under Contract Number DE-AC03-76SF00098

DISCLAIMER

LBL - 32818

NMR on Beta-Emitting Fragment ^{43}Ti

K. Matsuta, A. Ozawa, Y. Nojiri, To. Minamisono, M. Fukuda, S. Momota, T. Ohtsubo,
S. Fukuda, K. Sugimoto, I. Tanihata, K. Yoshida, K. Omata, J.R. Alonso, G.F. Krebs,
and T.J.M. Symons

Nuclear Science Division, Lawrence Berkeley Laboratory
University of California, Berkeley, California 94720, USA

August, 1992

This work was supported by the Director, Office of Energy Research, Division of Nuclear Physics of the Office of High Energy and Nuclear Physics of the U.S. Department of Energy under Contract DE-AC03-76SF00098

NMR on Beta-Emitting Fragment ^{43}Ti

K. Matsuta, A. Ozawa, Y. Nojiri, T. Minamisono, M. Fukuda, S. Momota,
T. Ohtsubo, S. Fukuda, K. Sugimoto, I. Tanihata,[A] K. Yoshida,[A] K. Omata,[B]
J.R. Alonso,[C] G.F. Krebs,[C] and T.J.M. Symons[C]

Department of Physics, Osaka Univ., Toyonaka, Osaka 560, Japan
(A) RIKEN, Wako, Saitama 351-01, Japan
(B) INS, The Univ. of Tokyo, Tanashi, Tokyo 188, Japan
(C) Lawrence Berkeley Laboratory, Berkeley, CA 94720, USA

Abstract. NMR has been observed on beta-emitting ^{43}Ti produced in the 116 *A*MeV ^{46}Ti on C collision by means of asymmetric beta decay. The observed spin polarization of ^{43}Ti showed a reversed tendency in its momentum dependence compared with that observed for fragments produced in the ^{40}Ca on Au collision. This suggests negative angle deflection of ^{43}Ti due to the nuclear attractive potential. From the observed NMR spectrum, the magnetic moment of ^{43}Ti was determined to be $|\mu|= (0.85 \pm 0.02)\ \mu_N$. The value is significantly quenched from the single particle value -1.91 μ_N, which shows a strong effect due to meson exchange currents and configuration mixing.

1. Introduction

The projectile fragmentation process in high energy heavy ion collisions provides us with unstable nuclei far from the stability line. Utilizing both an isotope separation technique and the beta-NMR (Nuclear Magnetic Resonance) technique, we have been studying magnetic moments of $f_{7/2}$ shell mirror nuclei. Since using collision to create polarization is an important technique for the study, clear understanding of the mechanism is crucial.

Polarization phenomena in heavy ion collisions have been studied experimentally in various energy regions from 10 to 100 *A*MeV [1-3]. A simple fragmentation model [4] explained qualitatively the experimental polarizations fairly well. Fragment polarization was found to be an excellent probe for the sign of the deflection angle [2, 3]. In the case of heavy targets like Au, the sign was positive. In the case of light targets, however, the sign is not clear yet. A study has been carried out at intermediate energies with lighter fragments [5], but not at high energies.

In the present experiment, the spin polarization of the projectile fragment, ^{43}Ti(I^{π}=7/2$^-$, $T_{1/2}$=0.50 sec) has been measured for the ^{46}Ti on C collision at a high incident energy of about 100 *A*MeV to study the sign of the deflection angle with the light target. NMR has been observed to determine the magnetic moment of the mirror nucleus and to study nuclear structure related to the moment. The experimental method is essentially the same as that in previous experiments on fragment polarization [3]. The ^{43}Ti nuclei were produced through the projectile fragmentation of ^{46}Ti at an effective energy of (116 ± 8) *A*MeV on a 260 mg/cm^2 thick C target. The ^{43}Ti nuclei emerging from the target at a certain deflection angle θ_L were purified and momentum analyzed by a fragment separator at the B44 beamline in the Bevatron at Lawrence Berkeley Laboratory. The ^{43}Ti nuclei were then implanted into a Pt foil cooled down to 90K to maintain the polarization created in the collision. NMR has been observed by means of asymmetric beta decay under the static magnetic field H_0=6.878 kOe.

2. Results and discussion

Prior to the polarization measurement, the production cross sections and the angular distributions of the ^{43}Ti fragment were measured for both Au and C targets. The observed cross section was smaller for the Au target than that for the C target by factor of 3. The target mass dependence cannot be reproduced by simple fragmentation models such as the abrasion-ablation model [6] where the production cross section should gradually increase with the target mass due to the gradual increase of the radius of the target nucleus. Besides the usual abrasion-ablation process, a new process such as immediate Coulomb breakup of the produced ^{43}Ti at the collision has to be taken into account to explain the smaller cross section for heavier targets.

Unlike the longitudinal distributions, the observed angular distributions, namely the transverse momentum distributions, were wider than those due to the Fermi momentum only (Goldhaber model [7]), for both the Au and the C targets. For the Au target, this broadening can be explained by orbital deflection due to Coulomb potential. For the C target, however, the distribution was even wider than the classical grazing angle, suggesting another mechanism such as the nuclear attractive potential.

In order to study the deflection mechanism, we measured spin polarization of the ^{43}Ti in the ^{46}Ti on C collision, which reflects the sign of the deflection angle. The sign of the deflection distinguishes deflection by the nuclear potential from Coulomb deflection. The spin polarization has been measured as a function of the fragment momentum as shown in Fig. 1. The sign of the polarization parallel to the vector $p_i x p_f$ is defined to be positive, where p_i and p_f are the momentum vectors of the incoming and the outgoing particles. The polarization was very close to zero on the low momentum side and was a negative finite value around the optimum momentum at which the yield is maximum. The optimum momentum (455 *A*MeV/c) was lower by 5 *A*MeV/c than the momentum corresponding to the beam velocity shown by an arrow. This decreasing trend in polarization was the reverse of that observed for the fragments produced in the ^{40}Ca on Au collision [3], where the polarization increased with momentum as predicted for the positive angle deflection. This trend in polarization suggests dominance of the negative angle deflection due to the nuclear attractive potential. However, compared with the theoretical calculation based on the simple fragmentation model [4] (broken line), there seems to be an additional energy dumping for the component of negative deflection, which is reasonable because of the longer interaction time for the component.

NMR effects for ^{43}Ti were observed as a function of radio frequency as shown in Fig. 2. A resonance was found at a frequency f= (1.27 ± 0.03) MHz. From the resonance frequency, the magnetic moment of ^{43}Ti was deduced to be $|\mu|$= (0.85 ± 0.02) μ_N. The value is significantly quenched from the single particle value -1.91 μ_N, which shows a strong effect resulting from meson exchange currents and configuration mixing. A shell model calculation with first order configuration mixing predicts - 0.754 μ_N [8], and the semi-empirical odd-nucleon model predicts - 0.784 μ_N [9], both of which reproduces the observed value fairly well.

From the measured moment of ^{43}Ti and the known moment of ^{43}Sc, the isoscalar and the isovector moments of the mirror pair were deduced to be $\mu^{(0)}$= 1.89(2) μ_N and $\mu^{(1)}$= -2.74(2) μ_N , respectively. While the isoscalar moment is very close to the single particle value, the isovector moment is strongly quenched. The shell model calculation with first order configuration mixing predicts $\mu^{(1)} = -2.71\ \mu_N$, which agrees with the present value very well. However, this may not be an indication that the meson exchange effect is negligible, but that the second order configuration mixing effect almost cancels the meson exchange effect, as in the case of the mass $A=40\pm1$ system.

Acknowledgments

The authors thank K. Ogawa and H. Miyatake for discussions on the magnetic moment. The work was partially supported by the Grant in Aid for Scientific Research, and the Monbusho International Science Research Program of the ministry of Education, Culture and Science, Japan. Support was also given by the U.S.A.-Japan Collaborative Research, funded by both the Japan Scientific Foundation, and the National Science Foundation, U.S.A. It was also supported in part by the US Department of Energy, under contract No. DE-AC03-76SF0098, and by the Kurata Research Grant from the Kurata Foundation.

References

[1] K. Sugimoto et al., Phys. Rev. Lett. 39 (1977) 323.
[2] K. Asahi et al., Phys. Lett. B 251 (1990) 488.
[3] K. Matsuta et al., Phys. Lett. B 281 (1992)214.
[4] K. Asahi et al., Phys. Rev. C 43 (1991) 456.
[5] M. Ishihara, Nucl. Phys. A538 (1992) 309c.
[6] J. Hüfner, K. Schäfer, and B. Schürmann, Phys. Rev. C 12 (1975) 1888.
[7] A.S. Goldhaber, Phys. Lett. 53B (1974) 306.
[8] H. Miyatake, K. Ogawa, T. Shinozuka, and M. Fujioka, Nucl. Phys. A470 (1987) 328.
[9] S.M. Perez, Phys. Rev. C 36 (1987) 1202.

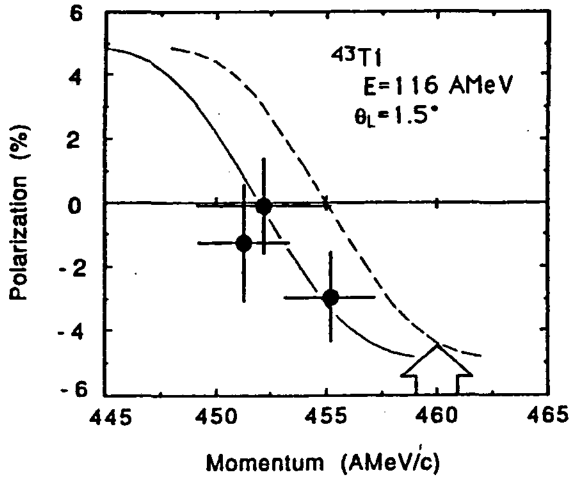

Fig. 1. Momentum dependence of spin polarization of ^{43}Ti. The arrow indicates the momentum corresponding to the beam velocity. The broken line is the polarization predicted by a simple model multiplied by 1/20. The solid line is the same curve shifted by 3 A MeV/c.

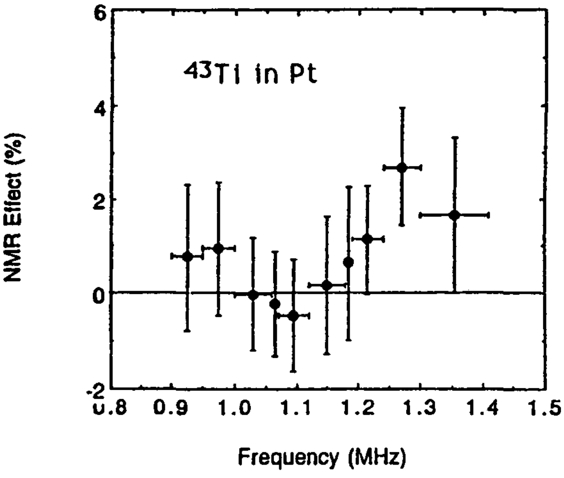

Fig. 2. NMR spectrum for ^{43}Ti in cooled Pt. The external field H_0=6.878 kOe.