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92-11-360
高エネ研図書室

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN–PPE/92–146
04.09.1992.

MAGNETIC DIPOLE MOMENT OF ^{127}Sb BY NMR/ON

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Abstract

The technique of NMR on Oriented Nuclei has been applied to ^{127}Sb to measure magnetic dipole moment of ^{127}Sb ground state. Resonant destruction of gamma-ray anisotropy from ^{127}Sb^{g} ($I^{\pi} = 7/2^{+}$) has been observed at 139.5(2)MHz for B_{app}=0.6T and at 137.0(1)MHz for B_{app}=0.2T. The deduced magnetic moment is $|\mu| = 2.668(3)\,\mu_N$.

(IS301)

Presented at the IXth International Conference on Hyperfine Interactions,
Toyonaka, Osaka, Japan, 17-21 August 1992
To be published in Hyperfine Interactions

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1 INTRODUCTION

The accurate measurement of the magnetic dipole moments of nuclear states and their variation with changes in proton and neutron number provides valuable nuclear structure information. Measurements of this type can be made on nuclei far from stability using NMR technique on oriented nuclei (NMR/ON) where the orientation is produced at low temperature after mass separation and implantation into polarised host, normally iron. In this method, a destruction of nuclear orientation (a destruction of gamma-ray anisotropy) is expected, due to a partial equalisation of the nuclear magnetic substate populations by resonant RF absorption. The resonant frequency corresponding to the gB-product is determined unambiguously with a precision which is typically $\sim 10^{-3}$ [1].

Near double-closed shells rather pure shell model configurations are expected to dominate the structure of the ground state and low-lying excitations in odd-A nuclei. Antimony, with Z=51, one proton above the strong magic number Z=50, should exhibit only small deformation effects and thus measured nuclear moments should fall within the scope of a nearly spherical shell-model description. High accuracy (1 in 10^3) measurements of the magnetic dipole moments of $^{127-133}$Sb using low-temperature nuclear orientation of isotope-separator implanted short-lived radioisotopes and NMR/ON can be used to examine how the collective component in the $7/2^+$ Sb ground state magnetic dipole moment varies as a function of neutron number. Coupling schemes characterizing the odd nucleons and the ground state deformation can be extracted from the nuclear moments. With (double magic + 1) ^{133}Sb as the reference, the main goal of these experiments is to examine whether the collective component in $7/2^+$ Sb ground state magnetic dipole moment varies as expected according to particle-core-coupling calculations carried out for Sb (Z=51) isotopes [2]. Comparison of the 1-proton-particle excitations in Sb to 1-proton-hole states in In nuclei will shed light on differences between particle and hole excitations as understood within the present model. Comparison of results on Sb isotopes with those in Tl will yield information on the effect of the differing underlying shell structure upon the mean field at the beginning and the end of the 50-82 proton shell.

The present experiment is thus the starting point in a systematic study of magnetic dipole moments of heavy odd-A Sb isotopes.

Previous to this study Krane and Steyert carried out the nuclear orientation study of gamma-rays emitted by ^{127}Sb polarised in iron[3]. From the 0-90° anisotropies of the angular distributions, the ground state magnetic dipole moment was deduced to be:| $\mu(^{127}\mathrm{Sb})| = 2.59(12)\ \mu_N$. This value is in agreement with systematics of other $g_{7/2}$ levels in the odd-mass Sb isotopes, but poor accuracy does not allow any precise comparison with particle-core-coupling calculations.

2 EXPERIMENTAL DETAILS AND RESULTS

The radioactive source of ^{127}Sb was prepared by mass separation of A = 127 nuclei from the fission products of ^{235}U at the OSIRIS facility mass separator on-line to a nuclear reactor at Studsvik[4]. The sample employed in the experiment was a disk of diameter 6mm and at the start of the experiment the activity was of order of 3 μCi .

The sample was soft-soldered to the copper cold finger of a ^{3}He/^{4}He dilution refrigerator. The temperature of the sample was measured using a ^{54}Mn**Ni** sample whose well known moment and decay scheme allow an accurate temperature measurement. The gamma-rays following the β^- decay of the ^{127}Sb into ^{127}Te were detected using two Ge detectors, one placed along (axial) and the other perpendicular (equatorial) to the applied magnetic field used to polarise the iron foil and so define the axis of nuclear orientation.

Two gamma transitions $E_{\gamma 1}$ = 686keV and $E_{\gamma 2}$ = 474keV were used to look for the NMR resonant destruction of anisotropy.

A search for the ^{127}Sb^{g}**Fe** resonance was made in the range 134 - 142 MHz in three sweeps. The first scan was made at 0.6T applied magnetic field (B_{app} over the range 136 - 142 MHz with ± 1MHz modulation at 100Hz increasing the frequency in 1MHz steps. In the second scan search was made over the range 134 - 140 MHz in 0.5 MHz steps with B_{app}=0.2T and in the third scan the range was 135-139MHz, steps were 0.25MHz and B_{app} = 0.2 T. In the two last scans the modulation was ±0.5MHz. At each frequence the countrate in the axial detector was measured with the frequency modulation on (N_{FM}) and with a carrier wave only present (frequency modulation off) (N_{CW}). The destruction of anisotropy may be defined as

$$D(\%) = [(N_{FM} - N_{CW})/(N_{W} - N_{CW})] * 100 \tag{1}$$

where N_W is the axial countrate when the iron foil is warm (T∼1K) giving no nuclear orientation. All countrates were corrected for source decay.

In the resonance case the eq.(2) is fulfilled:

$$h\nu_0 = g\mu_N[B_{hf} + B_{app}(1 + K)] \tag{2}$$

The resonance centre frequence can be expressed in terms of the magnetic moment μ, the hyperfine field B_{hf} and the external applied field B_{app} by

$$\nu_0 = (\mid \mu \mid /Ih)[\mid B_{hf} + B_0(1 + K)] \tag{3}$$

where K is the Knight shift parameter which is estimated to be |K(SbFe|∼ $2x10^{-3}$ using the Korringa constant for ^{125}SbFe [5] and the Korringa relationship [6]. Adopting K = 0 in eq.(3) introduces a negligible error into our result for $\mid \mu(^{127}\mathrm{Sb}^g) \mid$.

The most accurate determination of the hyperfine field at antimony isotopes in iron is the spin-echo experiment of Koi et al.[7]. They gave $B_{hf}(^{123}\mathrm{SbFe}) = +23.387(10)\mathrm{T}$.

A fit to the variation of D with frequency (evaluated for each transition separately and summed) for B_{app} = 0.6T gave the resonance frequence center at $\nu_0(B_{app}$=0.6T) = 139.5(2) MHz with FWHM for the resonance of 1.3 MHz, and for B_{app}=0.2T $\nu_0(B_{appl}$=0.2T) = 137.0(1) MHz with FWHM = 1.3 MHz. These fits are shown in fig.2 and fig.3 . These results yield for the ground state magnetic moment the value:

$$\mid \mu \mid = 2.668(3)\ \mu_N$$

The sign of the magnetic moment cannot be determined using NMR/ON but it is assumed to be positive on the basis of the systematics of other $g_{7/2}$ levels in the odd-mass Sb isotopes (see Table 1).

Particle-core-vibration coupling calculations carried out for the Sb isotopes [2] predict that the variation in moment should reflect the variations in the 2^+ state of the Sn core nucleus. As this energy rises only very slowly in ^{124,126,128}Sn the observed continued slow change in odd-A Sb magnetic moment is as expected, greater changes being predicted closer to the 132 shell closure.

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Figure Caption

Figure 1: Partial decay of ^{127}Sb to the levels in ^{127}Te.

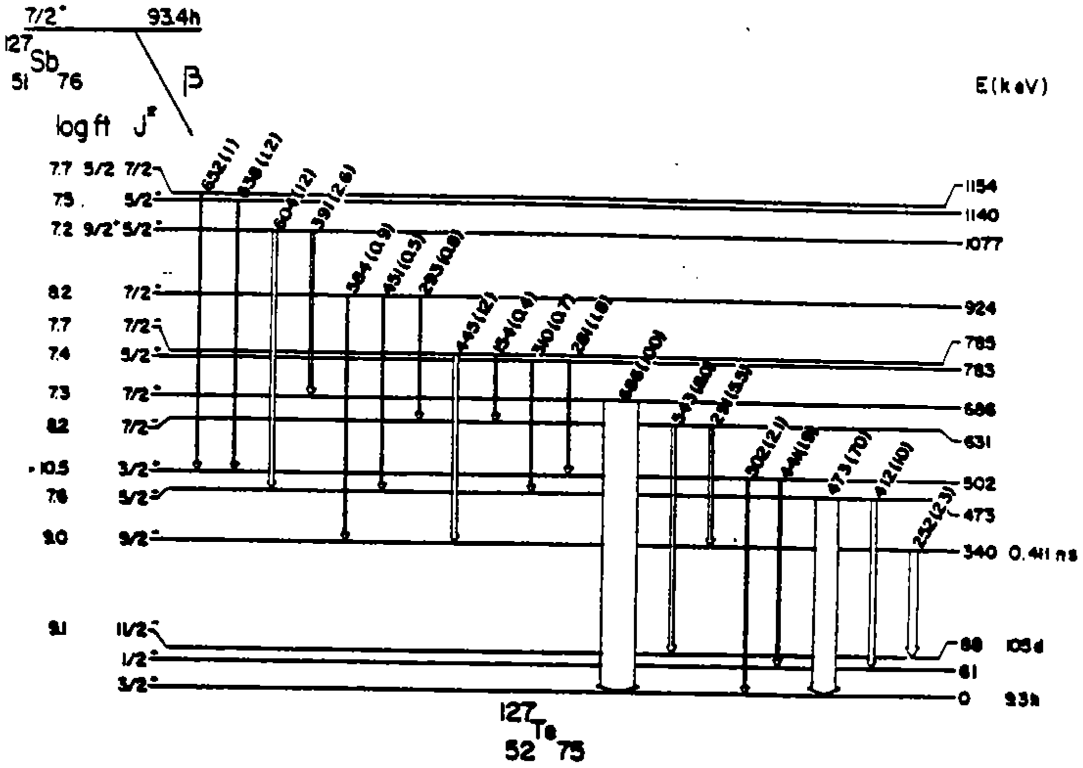
Figure 2: Destruction of anisotropy of 474keV and 686keV transitions $B_{app} = 0.6T$

Figure 3: Destruction of anisotropy of 474keV and 686keV transitions $B_{app} = 0.2$ T

Table 1: Measured magnetic moments of $7/2^+_1$ odd-A Sb isotopes[8]

Isotope	**State**	$\mu[\mu_n]$
$^{121}\mathrm{Sb}^m$	(37keV-3.5ns)	+2.518(7)
$^{123}\mathrm{Sb}$	ground state	+2.5498(2)
$^{125}\mathrm{Sb}$	ground state	+2.5859(13)†
$^{127}\mathrm{Sb}$	ground state	+2.668(3)

† recalculated from ν(B=0)=131.71(3)MHz and B_{hf} = 23.387(10)T[7][9]



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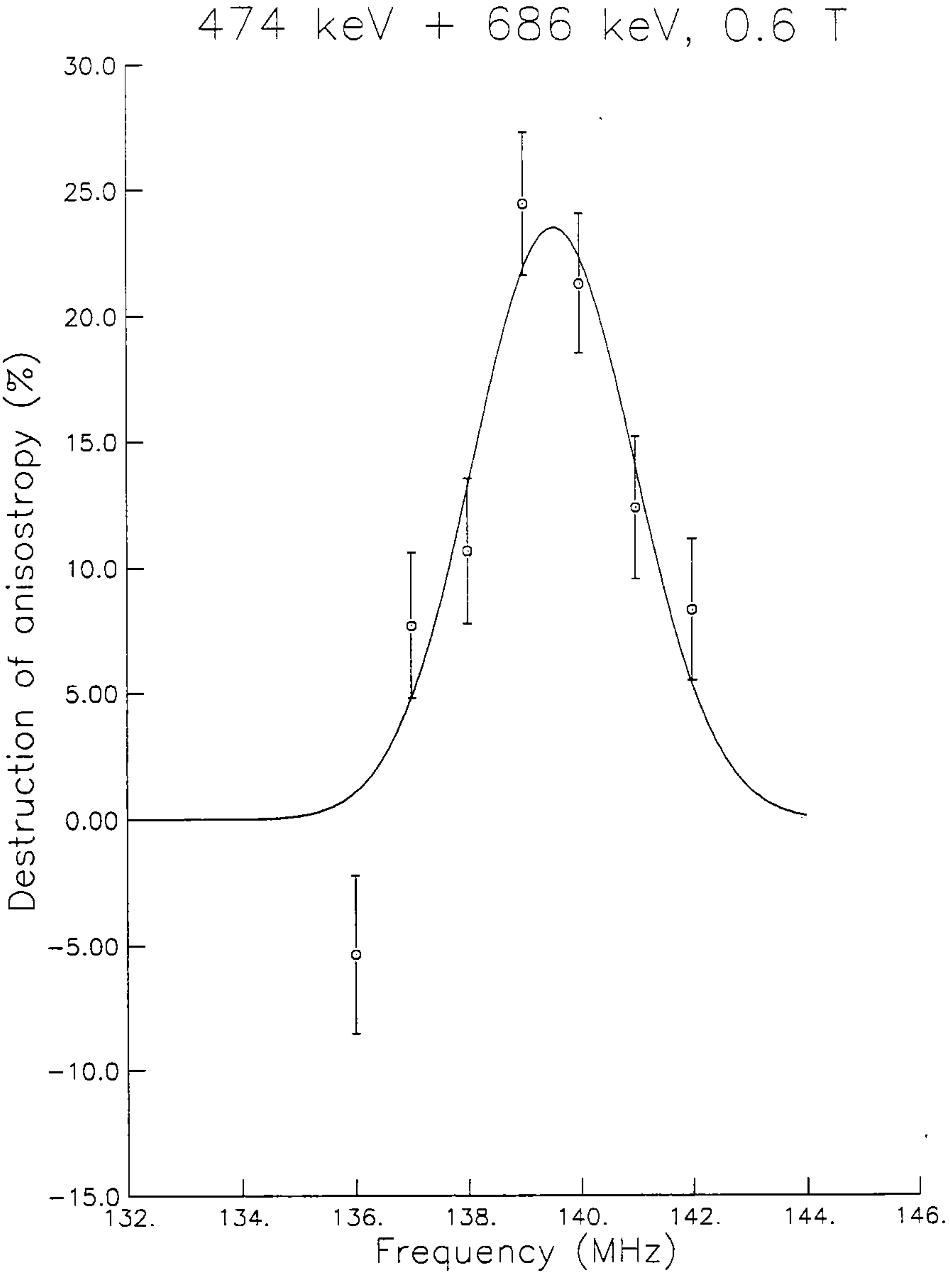

Figure 2: Destruction of anisotropy of 474keV and 686keV transitions $B_{app} = 0.6T$

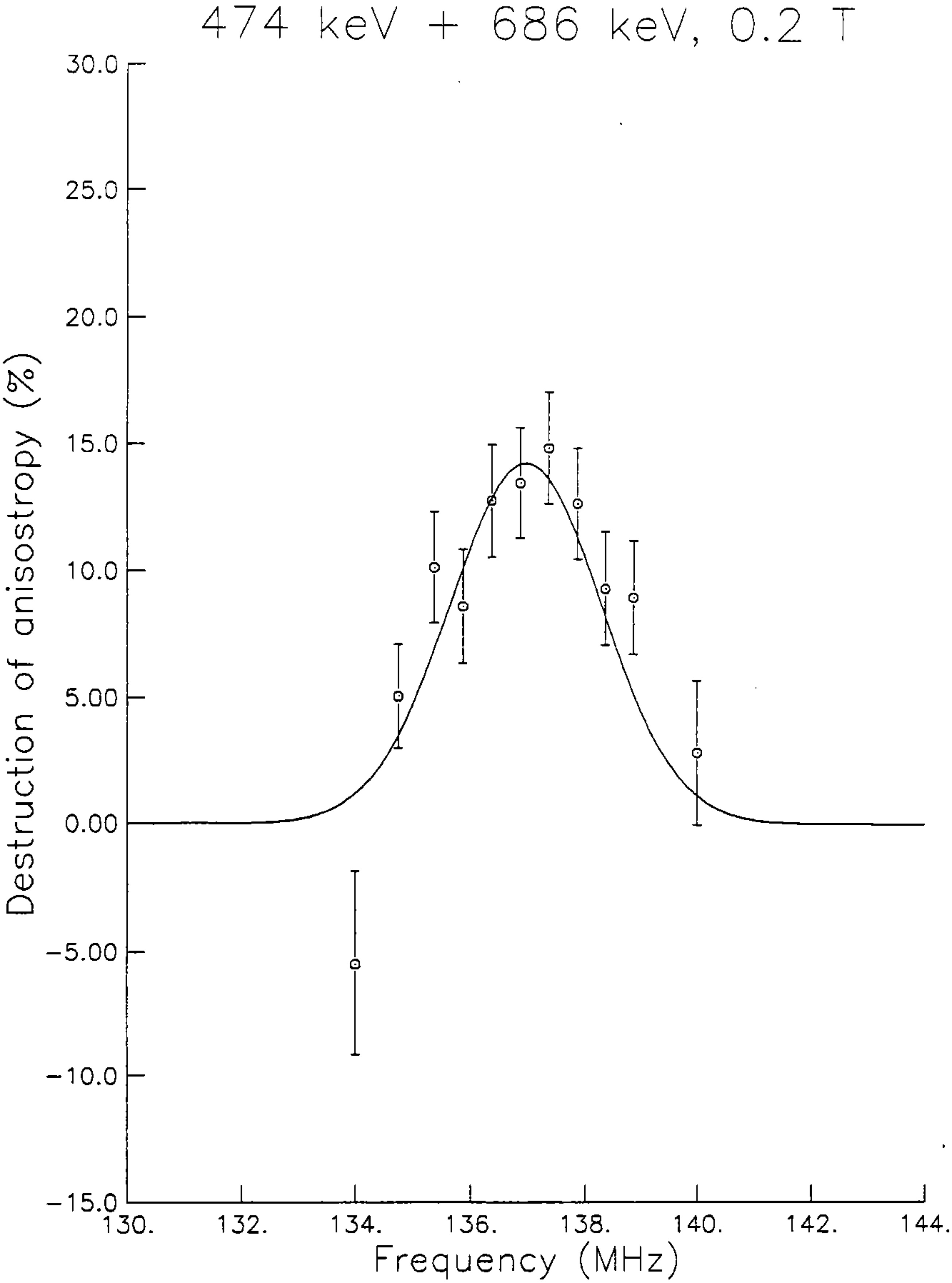

Figure 3: Destruction of anisotropy of 474keV and 686keV transitions $B_{app} = 0.2$ T