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Parity non-conservation in the γ-decay of polarized $17/2^-$ isomers in ^{93}Tc

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Abstract. The determination of the 0°–180° asymmetry (A_γ), which arises due to the parity violating matrix element, in the 751 keV γ-decay of polarized $17/2^-$ isomers in ^{93}Tc with respect to the direction of polarization is reported. A combined analysis of the present results together with those of M. Hass *et al.* (Phys. Lett. B **371**, 25 (1996)) yields $A_\gamma = 4.8(2.1) \times 10^{-4}$.

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1 Introduction

Parity non-conservation (PNC) in bound nuclear systems is an interesting probe for the weak interaction part of the nuclear Hamiltonian [1,2], in particular for the non-leptonic and non-strangeness changing sector and thus it is complementary to the β-decay studies. However, it has been studied in the past in only a few cases, mostly with marginal statistical accuracy, such as ^{18}F, ^{19}F, ^{21}Ne, ^{93}Tc and ^{180}Hf [3], and there has been virtually no new experimental information in the last several years. The $\frac{17}{2}^-$-$\frac{17}{2}^+$ parity doublet with 300 eV proximity in ^{93}Tc presents a unique possibility among bound nuclei for detecting a non-zero PNC effect through the 751 keV γ-decay, together with meaningful shell model calculations. In a simple model, the high-spin parity doublet has only a two-body component for ^{93}Tc and hence is different from the cases studied in light nuclei [3].

2 Experimental details

In a previous communication [3] we have reported the results of three measurements of the parity violating matrix element $|\langle \frac{17}{2}^- | H_{\rm pnc} | \frac{17}{2}^+ \rangle|$ in ^{93}Tc. The measurements were carried out with tilted foil polarized $\frac{17}{2}^-$ isomeric nuclei. The 0°–180° anisotropy w.r.t the polarization axis

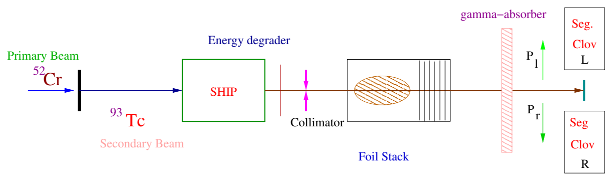

Fig. 1. A schematic of our experimental setup.

was found to be $A_\gamma = 8.4(2.7) \times 10^{-4}$. We report here on a new measurement carried out at the SHIP facility at GSI with improved detectors and higher count rates in order to improve the statistical significance. For details see ref. [3]. A brief description together with the improvements on this setup (fig. 1) are given here. The secondary beam of $^{93\rm m}$Tc isomeric beam was produced at the UNILAC at GSI by the ^{45}Sc(^{52}Cr, 2p2n)^{93}Tc reaction. The primary beam ^{52}Cr of 900 pA at $E_{\rm lab} = 170$ MeV on a ^{45}Sc target of 1 mg/cm^2 thickness mounted on a rotating wheel resulted in a high rate for the secondary isomer beam. The SHIP velocity-filter separated and transfered the ^{93}Tc $\frac{17}{2}^-$ ($T_{1/2} = 10.2(3)\,\mu$sec) isomers of $E_{\rm lab} = 65$ MeV to the focal-plane area where they were polarized using an array of sixteen, $15 + 15\,\mu$g/cm^2 thick collodin-carbon foils tilted by 70° w.r.t the isomer beam direction. The SHIP parameters were optimized for the maximum transmission of ^{93}Tc isomers by monitoring them in a particle detector at the entrance of the foil stack and by counting the isomer γ-rays. The direction of the polarization was changed every three minutes by rotating the foils by 180°. The

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Table 1. The triple $TR(i)$ ratios. Column 1: Energy of the γ-ray. Column 2: From ref. [3]. Column 3: From the present work. Column 4: The average of Column 2 and Column 3.

E_γ (keV)	Ref. [3]	Present	Average
544 (^{93}Ru)	1.00107 (73)	0.99912 (122)	1.00056 (63)
629 (^{93}Tc)	1.00055 (53)	1.00088 (66)	1.00068 (41)
711 (^{93}Tc)	0.99989 (38)	0.99962 (41)	0.99977 (28)
751 (^{93}Tc)	0.99833 (54)	1.00028 (71)	0.99904 (43)
1392 (^{93}Ru)	0.99933 (84)	0.99972 (112)	0.99947 (67)
1432 (^{93}Tc)	0.99977 (39)	1.00038 (31)	1.00015 (24)

^{93}Tc isomers were subsequently implanted in a Pb stopper of 32.1 mg/cm^2, which preserves the alignment and polarization over the isomer lifetime [4]. The decay γ-rays were detected in two Compton-suppressed GSI clover Ge detectors, (active volume; 2×4 HPGe crystals of 7 cm wide and 14 cm long) placed at 0° and 180° with respect to the induced polarization. The detection efficiency was 4 times higher as compared to ref. [3], essentially due to the increase in the number and size of the HPGe crystals. This arrangement resulted in the geometrical attenuation coefficient of $Q = 0.70$ and clean γ spectra. Digital signal scan electronic modules were used for signal processing, allowing for high count rates with minimal dead time.

3 Results and discussion

The data analysis was carried out by using the ROOT package based go4 code [5]. Standard double ratios [3] of γ-ray yields defined by

$$DR = \sqrt{\frac{rl}{rr}\Big/\frac{ll}{lr}} = \frac{W(\pi)}{W(0)} = \frac{1 - A_\gamma}{1 + A_\gamma}, \quad (1)$$

where, *e.g.*, rl refer to the counts in the right detector for the left-polarized isomers, were then derived. This provides a measurement of the 0°–180° asymmetry (A_γ) of the 751 keV $17/2^-$-$13/2^+$ $M2/E3$ transition from ^{93}Tc that is independent of the relative efficiency of the detectors, and of the beam-current fluctuations. However, artifacts due to the interaction of the isomer beam with the foil stack [3] can still arise and can be eliminated by forming the triple ratios,

$$TR(i) = \frac{DR(i)}{\overline{DR}(i \neq 751)}, \quad (2)$$

where i goes over all the isomer lines and the denominator is an average for all the isomer lines excluding 751 keV. For the γ transitions (other than 751 keV) depopulating the $17/2^-$ isomer as well as for γ-rays from ^{93,94}Ru, and ^{93,94}Mo PNC asymmetry is not expected and any asymmetry ("null-asymmetry" effect) observed determines the quality of the experiment. Table 1 presents the triple ratios ($\overline{DR}(i \neq 751) = 0.99601(16)$) for the γ-decays of interest from ref. [3] and from a partial set of the present data. Further analysis will include the remaining data

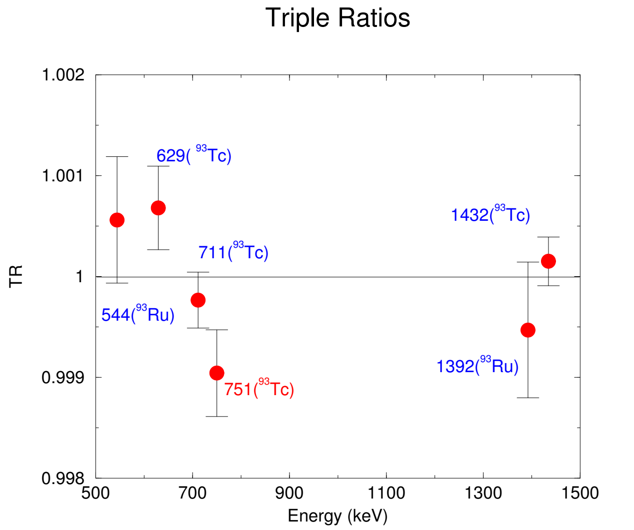

Fig. 2. The triple ratios for isomer lines plotted here are an average of the data from ref. [3] and from the present work.

with similar statistics. After correcting for the differences in Q, an average of $TR(i)$ is given in the last column. The $TR(751)$, which is free of the above-mentioned artifacts, is related to A_γ and the PNC matrix element is obtained from the relations [3]:

$$A_\gamma = \frac{1 - TR(751)}{1 + TR(751)},$$
$$\left|\left\langle \frac{17}{2}^- |H_{\mathrm{pnc}}| \frac{17}{2}^+ \right\rangle\right| = 91(28)\frac{|A_\gamma|}{p_l Q}\ \mathrm{meV}, \quad (3)$$

where p_l is the magnitude of polarization. The value of p_l was measured under similar conditions in a quadrupole interaction measurement [6]. From a preliminary and partial analysis of the present measurement we have the result $A_\gamma = -1.4(3.6) \times 10^{-4}$ for the 751 keV γ-decay. The present result differs by $\approx$ 2 standard deviations (table 1) when compared to our previous result of $A_\gamma = 8.4(2.7) \times 10^{-4}$ [3]. Figure 2 shows the preliminary results on the triple ratios ($TR(i)$) when averaged with the data from ref. [3]. This leads to an overall result of all the four measurements of: $A_\gamma = 4.8(2.1) \times 10^{-4}$ and $|\langle H_{\mathrm{pnc}}\rangle| = 0.34(14)(25)$ meV. This is a much reduced (although statistically consistent) anisotropy and a larger relative error. With 2.4 standard deviations the present partial result is at the verge of statistical significance. A full account of the over all and final analysis will be given elsewhere.

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