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Investigation of $\beta\beta$ decay in ^{150}Nd and ^{148}Nd to the excited states of ^{150}Sm and ^{148}Sm

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Abstract. Double beta decay of ^{150}Nd and ^{148}Nd to the excited states of daughter nuclei have been studied using a 400 cm^3 low-background HPGe detector and an external source consisting of 3046 g of natural Nd_2O_3 powder. The half-life for the two-neutrino double beta decay of ^{150}Nd to the excited 0^+_1 state in ^{150}Sm is measured to be $T_{1/2} = [1.33^{+0.36}_{-0.23}(stat)^{+0.27}_{-0.13}(syst)]\cdot 10^{20}$ y. For other $(0\nu + 2\nu)$ transitions to the 2^+_1, 2^+_2, 2^+_3, and 0^+_2 levels in ^{150}Sm, limits are obtained at the level of $\sim (2-8)\cdot 10^{20}$ y. In the case of ^{148}Nd only limits for the $(0\nu + 2\nu)$ transitions to the 2^+_1, 0^+_1, and 2^+_2 excited states in ^{148}Sm were obtained and are at the level of $\sim (4-8)\cdot 10^{20}$ y.

1. Introduction

In this article, results of an experimental investigation of the $\beta\beta$ decay of ^{150}Nd and ^{148}Nd to the excited states in ^{150}Sm and ^{148}Sm are presented (see Ref. [1] for details). The search for $\beta\beta$ transitions of ^{150}Nd and ^{148}Nd to excited states has been carried out using a HPGe detector to look for γ-ray lines corresponding to their decay schemes. A preliminary result for $\beta\beta$ decay of ^{150}Nd to the 0^+_1 excited state of ^{150}Sm was published in Ref. [2].

2. Experimental study

The experimental work was performed in the Modane Underground Laboratory (depth of 4800 m w.e.). A 400 cm^3 low-background HPGe detector was used to measure a 3046 g sample of Nd_2O_3 powder in a special Marinelli delrin box which was placed on the detector endcap. Taking into account the natural abundance there are 153 g of ^{150}Nd (5.64%) and 154 g of ^{148}Nd (5.76%) in the sample. Data were collected for 11320.5 h.

3. Analysis and results

3.1. Search for $\beta\beta$ processes in ^{150}Nd

Double beta decays of ^{150}Nd to 2^+_1 (333.86 keV), 0^+_1 (740.38 keV), 2^+_2 (1046.04 keV), 2^+_3 (1193.73 keV) and 0^+_2 (1255.40 keV) levels in ^{150}Sm have been investigated. The result together with available data on $\beta\beta$ decay of ^{150}Nd from other experimental works are presented in Table 1.

Table 1. Experimental results for $(0\nu + 2\nu)\beta\beta$ decay of ^{150}Nd to the excited states of ^{150}Sm. All limits are given at the 90% C.L.

Excited state	Energy of γ-rays (efficiency)	$(T_{1/2}^{0\nu+2\nu})_{exp}$ (10^{20} y) this work	other works
$2_1^+(333.86)$	333.9 (2.60%)	> 2.2	> 0.91[3]
			$> 24^a$ [4]
$0_1^+(740.38)$	333.9 (2.30%)	$= [1.33^{+0.36}_{-0.23}(stat)^{+0.27}_{-0.13}(syst)]^b$	> 1.5 [5]
	406.5 (2.29%)		> 1 [3]
			$> 2.4^a$ [4]
$2_2^+(1046.04)$	712.2 (1.78%)	> 8.0	> 1.4 [6]
$2_3^+(1193.73)$	1193.7 (0.95%)	> 5.4	> 0.027 [7]
$0_2^+(1255.40)$	921.5 (1.45%)	> 4.7	> 2 [3]

[a] Only 0ν decay mode
[b] Half-life value for 2ν decay (see Ref. [1] for the details)

Table 2. Experimental results for $(0\nu + 2\nu)\beta\beta$ decay of ^{148}Nd to the excited states of ^{148}Sm. All limits are given at the 90% C.L.

Excited state	Energy of γ-rays (efficiency)	$(T_{1/2}^{0\nu+2\nu})_{exp}$ (10^{20} y) this work	other works
$2_1^+(550.26)$	550.3 (2.36%)	> 6.6	> 0.03 [7]
$0_1^+(1424.46)$	550.3 (2.16%)	> 7.9	-
	874.2 (1.83%)		
$2_2^+(1454.12)$	550.3 (1.11%)	> 3.8	> 0.027[7]
	903.9 (0.87%)		

3.2. Search for $\beta\beta$ processes in ^{148}Nd

A search for the double beta decays of ^{148}Nd to the 2_1^+, 0_1^+, and 2_2^+ excited states of ^{148}Sm was carried out by looking for γ-rays with energies of 550.3, 874.2, and 903.9 keV accompanying these transitions. The result together with available data on $\beta\beta$ decay of ^{148}Nd from other experimental works are presented in Table 2.

4. Conclusion

Double beta decay of ^{150}Nd and ^{148}Nd to the excited states of daughter nuclei was investigated with a high level of sensitivity. The half-life for the $2\nu\beta\beta$ decay of ^{150}Nd to the excited 0_1^+ state in ^{150}Sm is measured to be $T_{1/2} = [1.33^{+0.36}_{-0.23}(stat)^{+0.27}_{-0.13}(syst)] \cdot 10^{20}$ y. The strongest limits for other transitions were established. The sensitivity of this experiment could still be increased by a few times using a pure Nd_2O_3 (or Nd) sample. Also further increases in the sensitivity could be reached using an enriched Nd sample and a multicrystal HPGe installation to study larger masses of Nd samples.

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