1. Experiment TGV-2 – search for double beta decay of ¹⁰⁶Cd

 γ 2741

3+

0+

2+

0+

JINR Dubna, Russia IEAP, CTU Prague, Czech Republic CU Bratislava, Slovakia LSM Modane, France

Phase III ~ 23.2 g of ¹⁰⁶Cd (99.57%) (~ 1.3 x 10²³ atoms of ¹⁰⁶Cd) (Feb.2014 –) in progress T >42500 h



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EC/EC $2e_{b}$ -+ ${}^{106}Cd \rightarrow {}^{106}Pd$ + $(2v_{e})$ + (γ) **Observables: 2KXPd** (+ γ for e.s.) β +/EC e_b-+ ¹⁰⁶Cd \rightarrow ¹⁰⁶Pd + e+ + (2ν_e) + (γ) **Observables: KXPd + 2\gamma 511 (+ \gamma for e.s.)** β +β+ ¹⁰⁶Cd \rightarrow ¹⁰⁶Pd + e⁺ + e⁺ + (2ν_e) + (γ) **Observables:** 4γ **511** (+ γ for e.s.) 2741.0 106**Cd** 2717.6 β**+**β+ 1.25% 1160 γ 2229 **β+/EC** EC/EC 1557.7 Q(EC/EC) = 2775.39 ± 0.10 keV 1133.8 2vEC/EC (0⁺g.s.-0⁺g.s.) 2KX Pd (~21 keV) 511.9 0vEC/EC Resonant Decay of ¹⁰⁶Cd $Q = 2775.39 \pm 0.10 \text{ keV}, E_{\kappa} = 24.3 \text{ keV}, E_{L} = 3.33 \text{ keV}$ $E_{1}^{*} = 2741.0 \text{ keV}$ KL observables $\gamma - 2741 (2229+512) \text{ keV}$ $E_{2}^{*}= 2717.6 \text{ keV KK}$ observables $\gamma - (1160 + 1046 + 512) \text{ keV}$ $E_{3}^{*}= 2737 \text{ keV}$ (?) KL observables $\gamma -$ 106Pd Phase III - Search for 0ν EC/EC decay of 106 Cd \rightarrow Obelix det.



E, keV



KK TGV signal patterns KK-pair

Two types of TGV-2 analysis to find possible KXPd-KXPd events*





1D method

A signal in the 19–22 keV energy window in one detector, while a signal from another face-to-face neighbor detector was collected in another. A final accumulated spectrum was fitted with a 1D-model which included the KXPd multiplet as signal, and the Cadmium KX-ray (KXCd) multiplet with linear underlay as background.

2D method

The double coincidence events from neighboring face-to-face detectors, both in the 16-30 keV energy range, were collected in a 2Dhistogram. The final 2D-spectrum was fitted by a 2D-model consisting of the 2D-Gaussian KXPd multiplet as signal, and the KXCd 2D-Gaussian multiplet together with the 2D-background slope as background

* N.I. Rukhadze et al. / Nuclear Physics A 852 (2011) 197–206

Suppression of TGV-2 background by using coincidence techniques.



One dimensional spectra of double coincidence events, obtained in measurement of enriched ¹⁰⁶Cd in phase III of experiment TGV-2 during 42500 h



Pd peak: 30.5±25.2 events

Preliminary limits on double beta decay of ¹⁰⁶Cd

Decay mode	Final level	T _{1/2} , y (90%CL)	T _{1/2} , y (90%CL)
	of ¹⁰⁶ Pd	Phase II*	Phase III*
2vEC/EC	0+g.s.	4.2×10^{20}	7.2×10 ²⁰
	2+, 511.9 keV	1.2×10^{20}	8.9×10 ²⁰
	0 ⁺ ₁ , 1134 keV	1.0×10^{20}	$7.2 imes 10^{20}$
0v <i>EC</i> / <i>EC</i>	2717.6 keV	1.6× 10 ²⁰	1.4× 10 ²⁰ (Obelix)
0v <i>EC</i> / <i>EC</i>	4+, 2741 keV	1.8×10^{20}	0.9×10 ²⁰ (Obelix)
$2\nu\beta^+/EC$	0+g.s.	1.1×10^{20}	6.6× 10 ²⁰
	2+, 511.9 keV	1.1×10^{20}	7.9×10 ²⁰
	0 ⁺ ₁ , 1134 keV	1.6× 10 ²⁰	9.0× 10 ²⁰
$2\nu\beta^+\beta^+$	0+g.s.	1.4×10^{20}	3.9×10 ²⁰
	2+, 511.9 keV	1.7×10^{20}	4.7×10^{20}

 $T_{1/2}$ theor. (2v*EC*/*EC*) ~ 10²⁰ – 10²²

*N.I.Rukhadze et al., *Journal of Physics: Conference Series* 375 (2012) 042020 *N.I.Rukhadze on behalf of TGV collaboration, TAUP 2021, Valencia, Spain, 26.08-03.09.2021

2. Search for double beta decay of ⁸²Se to excited states of ⁸²Kr with low-background highly sensitive HPGe detector Obelix

Double beta decay to excited states of daughter nuclei are accompanied by emission of γ -quanta in de-excitation of excited states. These γ -quanta may be detected by low background HPGe detectors with high efficiency and good energy resolution.

 $2v2\beta^{-}$ decay to excited states was detected in ¹⁰⁰Mo - ¹⁰⁰Ru (0⁺₁, 1130.3 keV) the most accurate result was obtained with the Obelix HPGe spectrometer (R. Arnold et al. Nucl. Phys. A 925 (2014) 25) and ¹⁵⁰Nd - ¹⁵⁰Sm (0⁺₁, 740.4 keV).

Detector Obelix*

P type coaxial HPGe detector Canberra in U-type ultra low background cryostat located at LSM, France (4800 m w.e.) Sensitive volume 600 cm³ Efficiency ~160% Peak / Compton 83 Energy resolution ~1.2 keV at 122 keV (⁵⁷Co), ~2 keV at 1332 keV (⁶⁰Co) Distance from cap 4 mm Entrance window Al, 1.6 mm *JINST 12 (2017) P02004.





Passive Shielding ~12 cm arch. Pb ~20 cm low active Pb, Radon free air



Measurement of ⁸²Se with the Obelix detector

Sample of enriched ⁸²Se (enrichment ~95%) with a mass of 6019.9g of ⁸²Se was prepared in Marinelli of Obelix detector in Gran Sasso in July 2020.









Recently there were two attempts to measure DBD of ⁸²Se to excited states of ⁸²Kr but positive signal was not detected:

1) by CUPID-0 collaboration (O. Azzolini et al., Eur.Phys.J. C78 (2018) no.11, 888), $T_{1/2} > 4x10^{21}$ years;

2) By NEMO-3 collaboration (R. Arnold, arXiv: 2001.06388 [physics .ins-det]), $T_{1/2} > 1.3 \times 10^{21}$ years.

According to our estimation we can reach a level of sensitivity $T_{1/2} \sim 6 \ge 10^{22} = 9$ with the Obelix detector and ~6 kg of ⁸²Se sample and hope to detect DBD of ⁸²Se to excited states of ⁸²Kr for the first time.

Before sending the ⁸²Se sample in LSM short test measurement of ⁸²Se was performed in LNGS during 62 days but previous limits on DBD of ⁸²Se to excited states of ⁸²Kr were not improved.

Our measurement of ⁸²Se was started with the Obelix detector 10.12.2021