Journal of Physics: Conference Series **203** (2010) 012142 doi:10.1088/1742-6596/203/1/012142

New observation of $2\beta2\nu$ decay of ^{100}Mo to the 0^+_1 level of ^{100}Ru in the ARMONIA[1] experiment

P. Belli[1], R. Bernabei[1], R.S. Boiko[2], F. Cappella[3], R. Cerulli[4], F.A. Danevich[2], S. d'Angelo[1], A. Incicchitti[3], V.V. Kobychev[2], B.N. Kropivyansky[2], M. Laubenstein[4], P.G. Nagornyi[5], S.S. Nagorny[2], S. Nisi[4], F. Nozzoli[1], D.V. Poda[2], D. Prosperi[3], O.G. Polischuk[2], V.I. Tretyak[2], I.M. Vyshnevskyi[2], S.S. Yurchenko[2]

[1]Dipartimento di Fisica, Università di Roma "Tor Vergata" and INFN, Sezione di Roma "Tor Vergata", I-00133, Roma, Italy
[2]Institute for Nuclear Research, MSP 03680 Kyiv, Ukraine
[3]Dipartimento di Fisica, Università di Roma "La Sapienza" and INFN, Sezione di Roma, I-00185, Roma, Italy
[4]INFN, Laboratori Nazionali del Gran Sasso, I-67010 Assergi (Aq), Italy
[5]Chemical Department, Kyiv National Taras Shevchenko University, 01033 Kyiv, Ukraine

E-mail: bernabei@roma2.infn.it

Abstract. Sample of $^{100}MoO_3$ with molybdenum enriched in ^{100}Mo to 99.5% and mass of 1199 g was measured deep underground (3600 m w.e.) in the Laboratori Nazionali del Gran Sasso of INFN (Italy) during 17249 h with a low-background set-up with 4 HP Ge detectors. After $2\beta2\nu$ decay of ^{100}Mo to the 0^+_1 excited level of ^{100}Ru ($E_{exc} = 1131$ keV), two γ quanta of 540 keV and 591 keV should be emitted in deexcitation process. Both these γ's are observed in the accumulated data as in coincidence spectrum as well in 1-dimensional sum spectrum. Measured half life is $T_{1/2} = (7.0^{+1.1}_{-0.8}) \times 10^{20}$ yr, in agreement with positive results obtained in previous experiments.

Neutrinoless (0ν) double beta (2β) decay is forbidden in the Standard Model (SM) due to violation of the lepton number by two units; however, it is predicted by many SM extensions where neutrinos are naturally expected to be Majorana particles ($\nu = \overline{\nu}$) with small but non-zero mass [1]. This process in not observed to-date, with positive observation reported recently only for ^{76}Ge [2]. In absence of experimental data on $2\beta0\nu$, observation of $2\beta2\nu$ decays is important tool to test theoretical models used for calculations of nuclear matrix elements for 2β processes.

Half lives for $2\beta2\nu$ decay of ^{100}Mo to the 0^+_1 excited level of ^{100}Ru ($E_{exc} = 1131$ keV) were measured in few experiments [3, 4, 5, 6] in the range of $(5.5 - 9.3) \times 10^{20}$ yr. These results are in some contradiction with earlier paper [7] where only limit $T_{1/2} > 1.2 \times 10^{21}$ yr was obtained at 90% C.L. Aim of the present experiment was remeasurement of $\simeq 1$ kg of Mo enriched in ^{100}Mo to 99.5%, used before in [7], to confirm observations [3, 4, 5, 6] or to set more severe $T_{1/2}$ limit.

Measurements were performed in the Laboratori Nazionali del Gran Sasso (LNGS) of INFN (Italy) in underground conditions on the depth of 3600 m w.e. If the 0^+_1 excited level of ^{100}Ru with $E_{exc} = 1130.5$ keV is populated, two γ quanta with energies of 590.8 keV and 539.6 keV will

[1] ARMONIA: meAsuReMent of twO NeutrIno 2β decAy of ^{100}Mo to the first excited 0^+_1 level of ^{100}Ru.

© 2010 IOP Publishing Ltd

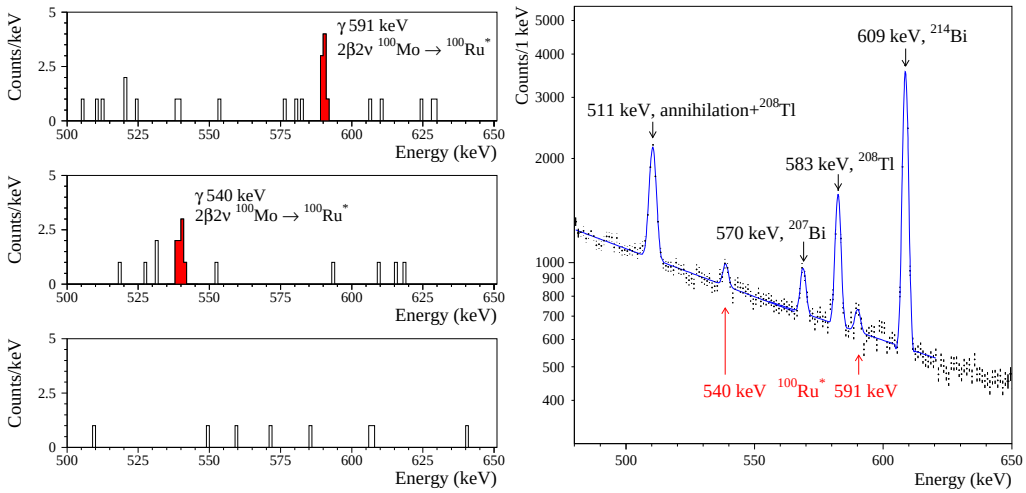

Figure 1. Left: Coincidence spectra accumulated with the $^{100}MoO_3$ sample during 17249 h with the 4 HP Ge set-up, when energy of one detector is fixed as 540 ± 2 keV (top), 591 ± 2 keV (middle) and 545 ± 2 keV (bottom). Right: Sum of spectra of 4 HP Ge detectors in the energy range of $480 - 650$ keV.

be emitted in a cascade in subsequent deexcitation. To search for these γ quanta, we use set-up with 4 low-background HP Ge detectors mounted in one cryostat with a well in the center. The HP Ge detectors were of 225.2, 225.0, 225.0, and 220.7 cm^3 volume. Typical energy resolution (FWHM) of the detectors is 2.0 keV at the 1332 keV line of ^{60}Co. The set-up is enclosed in a lead and copper passive shielding and has a nitrogen ventilation system against radon.

Sample of $^{100}MoO_3$ with mass of 1199 g was measured during 17249 h. Data acquisition system gave possibility to take into account coincidence between individual HP Ge detectors. Fixing the energy of one of detectors to the expected energy of γ quanta emitted in $2\beta2\nu$ decay to ^{100}Ru* (540 or 591 keV; width of window ± 2 keV is in accordance with the energy resolution of HP Ge at these energies), we observe coincidence peak at the corresponding supplemental energy (591 or 540 keV), see Fig. 1 (left). Bottom part of the figure shows background events, when energy window is shifted to the neighbouring value of 545 ± 2 keV. Eight events detected in coincidence correspond to half life $T_{1/2} = (6 \pm 2) \times 10^{20}$ yr for $2\beta2\nu$ decay of ^{100}Mo $\rightarrow$ ^{100}Ru*.

Sum of the spectra of 4 HP Ge detectors is shown in Fig. 1 (right) in the energy range of $480 - 650$ keV. Both peaks at 540 keV and 591 keV expected for ^{100}Mo $\rightarrow$ ^{100}Ru* $2\beta2\nu$ decay are observed in the experimental data. Fit of the spectrum, also shown in Fig. 1 (right), gives number of events in these peaks as 310 ± 54 and 255 ± 51, respectively. Together with efficiencies calculated with the GEANT4 and EGS4, which gave close results, it gives $T_{1/2} = (7.0^{+1.1}_{-0.8}) \times 10^{20}$ yr, consistent with $T_{1/2}$ derived from the coincidence spectrum.

Present observation is in agreement with positive observations [3, 4, 5, 6] and does not confirm negative result [7].

References

[1] Avignone III F T, Elliott S R, Engel J 2008 *Rev. Mod. Phys.* **80** 481
[2] Klapdor-Kleingrothaus H V, Krivosheina I V 2006 *Mod. Phys. Lett.* A **21** 1547
[3] Barabash A S et al. 1995 *Phys. Lett.* B **345** 408
[4] Barabash A S et al. 1999 *Phys. At. Nucl.* **62** 2039
[5] Arnold R et al. 2007 *Nucl. Phys.* A **781** 209
[6] Kidd M F et al. 2009 *Nucl. Phys.* A **821** 251
[7] Blum D et al. 1992 *Phys. Lett.* B **275** 506