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Testing the Pauli Exclusion Principle with the NEMO-2 detector

NEMO collaboration, presented by Barabash A.S. [a]

[a]Institute of Theoretical and Experimental Physics, B.Cheremushkinskaya 25, 117259, Moscow, Russia

The Exclusion Principle is one of the most fundamental laws of nature. Nevertheless in more recent publications some attempts were made to introduce into the theory a small violation of PEP, but they have not been successful. Any model with PEP violation must be beyond the standard QFT. This does not restrict the experimental activity in searching the PEP violation. There are two types of experiments to test PEP violation. The first is the search for atoms or nuclei in a non-Paulian state. The second is the search for evidence of transitions of atoms and nuclei into a non-Paulian state. In this article we consider the second type processes, with the PEP-violation in nuclei. Fig. 1 shows these non-Paulian transitions in ^{12}C.

The NEMO-2 detector [1] was designed for double beta decay studies and operated in the Fréjus Underground Laboratory (4800 m w.e.). It consisted of tracking chamber (1x1x1 m^3) devided by the source plain onto two parts and calorimeter made of scintillating glass. During 1991-1997, the double beta decays of ^{100}Mo [2], ^{116}Cd [3], ^{82}Se [4] and ^{96}Zr [5] were investigated.

The NEMO-2 detector's experimental data from measurements with Cd, Se and Zr foils were used to estimate limits on non-Paulian transitions in the ^{12}C of the plastic scintilators. The total mass of ^{12}C under study was 170 kg. There were performed a search for γ-quanta (energy ~20 MeV), which would accompany the transition of a nucleon from the $2p$- to the filled $1s$-shell of ^{12}C nucleus and are detected as a pair (two tracks event coming from the foil) burned in the foils, and search for β^+ or β^- transitions of ^{12}C nuclei (with endpoint energy ~20 MeV) detected as crossing of the tracking volume by the charged particles.

No events with two tracks coming from the source foils and summed energy $\geq$ 4 MeV were found in the experiment with Se and Zr given an exposure of 10357 h and in the enriched Cd measurement with an exposure of 6588 h. From these data we obtained a limit on the PEP-violated transition of ^{12}C nucleus to $^{12}\tilde{\text{C}}$ at the 90% C.L.: $T_{1/2} > 5.3 \cdot 10^{23} y$.

The search for $\beta^{\pm}$ decay processes were performed through the selection of events with one electron traversing the detector from one calorimeter side to another. Consequently the data used here was obtained in a run with a paraffin shield (2162.8 h), which efficiently suppressed

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Table 1
Limits on the non-Paulian transitions in ^{12}C.

Channel	γ emission	β^- decay	β^+ decay
Window (MeV)	[4,20]	[4,20]	[4,20]
Number of events	0	1	1
Efficiency	$1.3 \cdot 10^{-4}$	$8.5 \cdot 10^{-3}$	$7.2 \cdot 10^{-3}$
$T_{1/2}$ (90% CL) present	$> 5.3 \cdot 10^{23}$ y	$> 3.1 \cdot 10^{24}$ y	$> 2.6 \cdot 10^{24}$ y
$T_{1/2}$ (99.7% CL) [6]	$> 1.3 \cdot 10^{20}$ y		
$T_{1/2}$ (90% CL) [7]		$> 8 \cdot 10^{27}$ y	$> 8 \cdot 10^{27}$ y

the neutron background. Only one event with summed energy deposit of $E > 4$ MeV was found in the experiment with Se and Zr. From the data we obtained limits on $\beta^{\pm}$ decays of ^{12}C to non-Paulian states of daughter nuclei $^{12}\tilde{\text{B}}$ and $^{12}\tilde{\text{N}}$ at the 90% C.L.: $T_{1/2} > 3.1 \cdot 10^{24} y$ for β^- and $T_{1/2} > 2.6 \cdot 10^{24} y$ for β^+. All obtained results are presented in table 1. Best previous limits are presented too.

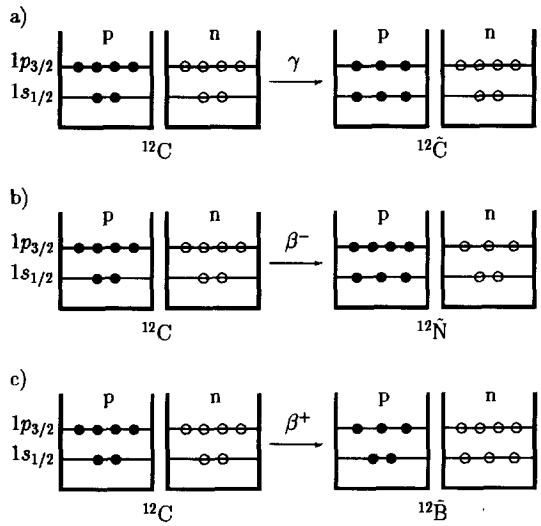

Figure 1. Schemes of non-Paulian transitions in ^{12}C. (a) transition of a proton from the p-shell to the fully occupied s-shell (a similar figure can be constructed for neutrons) (b) non-Paulian β^- transition of ^{12}C to $^{12}\tilde{\text{N}}$; (c) non-Paulian β^+ transition of ^{12}C to $^{12}\tilde{\text{B}}$.

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