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Review for the project MONUMENT: "Muon Ordinary capture for the Nuclear Matrix elemENTs in ββ decays" proposed under the JINR research theme 03-2-1100 2019/2020 "Non accelerator neutrino physics and astrophysics"

In the present project MONUMENT it is proposed to measure ordinary muon capture (OMC) rates on ^{136}Ba (and later on ^{76}Se ,^{100}Ru and other nuclei) relevant for improving the accuracy of calculation of neutrinoless double beta decay nuclear matrix elements (0νββ NMEs) and fixing of the value of effective axial-vector coupling constant g_A is planned. This project is expected to be realized by the JINR team at home institute in Dubna and in collaborating with different institutes in Europe and other countries. The measurements itself will be conducted at meson factory at Paul Sherrer Institute in Switzerland (PSI Villingen).

The total lepton number violating 0νββ decay is the most powerful tool to clarify if the neutrino is a Dirac or a Majorana particle. The search for the 0νββ-decay represents the new frontiers of neutrino physics, allowing in principle to fix the neutrino mass scale, the neutrino nature and possible CP violation effects. Interpreting existing results as a measurement of effective Majorana mass and planning new experiments depends crucially on the knowledge of the corresponding NMEs that govern the decay rate. The NMEs for 0νββ-decay must be evaluated using tools of nuclear structure theory. There are no observables that could be directly linked to the magnitude of 0νββ-decay NMEs and, thus, could be used to determine them in an essentially model independent way. A reliable calculation of NMEs will be of help in predicting which are the most favorable nuclides to be employed for 0νββ-decay searches. The problem of so-called quenching of the axial weak current is of particular importance as well because effective g_A appears to the fourth power in the 0νββ-decay rate. There is not a consensus on its origin yet.

The improvement of the calculation of the 0νββ-decay NMEs and fixing of the value of effective g_A is a very important and challenging problem. The uncertainty associated with the calculation of the 0νββ-decay NMEs can be diminished by suitably chosen nuclear probes. Complementary experimental information from related processes such as charge-exchange and particle transfer reactions, OMC and charged-current (anti)neutrino nucleus reactions is very relevant. A direct confrontation of nuclear structure models with data from these processes improves the quality of nuclear structure models. The constrained parameter space of nuclear models is a promising way to reduce uncertainty in the calculated 0νββ-decay NMEs.

Recall that APPEC strongly supports the present range of searches for neutrino-less double-beta decay. Guided by the results of experiments currently in operation and in consultation with its global partners, APPEC intends to converge on a roadmap for the next generation of experiments into neutrino mass and nature by 2020 (see Double Beta Decay APPEC Committee Report:

arXiv:1910.04688 and https://www.appec.org/news/neutrinoless-double-beta-decay-report-from-the-appec-committee). In recommendation 6 it is stated that a dedicated theoretical and experimental effort, in collaboration with the nuclear physics community, is needed to achieve a more accurate determination of the NMEs.

The half-live of the 0νββ-decay depends strongly on the structure of the intermediate multipole states. In attempts to adjust the related nuclear-structure parameters from the β-decay or electron-capture data one can only probe the virtual transition through the lowest J^{π} intermediate state. Fortunately, the structure of intermediate states of a double-beta decay transition can be probed by the OMC. Due to the heavy mass of the muon (roughly 100 MeV), the final states in the OMC can be (highly) excited and the forbidden transitions are not as suppressed as in the case of beta decays. Experimental work on this process is currently conducted at J-PARC (see e.g., Phys.Rev. C97 (2018) no.1, 014617). Since the axial-vector component dominates the OMC rate (the partial rates are quite sensitive to the value of effective g_A), the OMC can be used to resolve the “g_A quenching” dilemma. Further measurements and computations of the OMC strength functions for final nuclei of double beta decays would enable a systematic anatomy of the OMC strength function to the effective in-medium values of the weak axial couplings. This, in turn, could help in improving the accuracy of calculations of the nuclear matrix elements of the 0νββ-decay.

The team leader Victor Brudanin and other members of the team (D. Zinatulina, M. Shirchenko, N. Rumyantseva and others) are outstanding scientists with a longtime experience in the field of experimental neutrino physics and physics of underground laboratories. They have expertise also in the subject of muon capture experiments being involved in their realization and analysis, in particular for Ar, Ti, Se, Kr, Cd, and Sm isotopes, within a period of about 15 years. The team size and its composition are adequate. It is recommended the scientific group to be extended with young and promising scientists from the JINR member states.

In summary, the proposal MONUMENT successfully addresses all relevant aspects of the scientific and technological excellence in question. The concept and objectives are well described. I sincerely recommend the Scientific Council of the Laboratory of Nuclear Problems and the Programmed Advisory Committee (PAC) of the JINR to approve this proposal with highest priority. It will enable the JINR scientists to gain important results in the field of particle and nuclear physics.

Sincerely yours,

Dubna, 06.04. 2020

Prof. Dr. Fedor Šimkovic