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Rare weak decays and nuclear structure

Jouni Suhonen[1]

[1] *Department of Physics, University of Jyväskylä, P.O. Box 35 (YFL), FI-40014, Jyväskylä, Finland*

Contact email: *jouni.suhonen@phys.jyu.fi*

Weak interactions, as the name indicates, are indeed weak if we measure weakness in terms of time scales of processes they generate, say in atomic nuclei where they prompt disintegration phenomena in the time scale of seconds. However, notable exceptions to this state of affairs are caused by (a) extremely small decay energies (Q-values), (b) initial and final nuclear states with large difference in angular momentum and (c) weak-interaction processes of higher order. These extreme conditions of decay lead to processes that involve time scales far beyond the seconds scale, to scales much longer than the age of the Universe. Typically such processes have half-lives of the order of 10^{20} years (practically the age of the Universe squared!) and thus can be called 'ultra slow'. The related transitions need special experimental facilities and dedicated experimental techniques in order to be detected. The detection sites of such rare processes need to be protected against cosmic rays, i.e. the flux of particles from outer space. This is why the dedicated experiments go underground, in deep mine shafts or under huge amount of massive mountain rock. Hence the related scientific effort is appropriately called 'underground physics', or to contrast it with the research done in particle accelerator facilities, 'non-accelerator physics'.

In Fig. 1 below an example of the above-listed points (b) and (c) is given. Here the mother nucleus ^{96}Zr decays to states in ^{96}Nb via ultra-slow beta transitions, retarded by the large differences in angular momentum between the initial state (spin 0) and the final states (spins 4-6). In addition to the ultra-slow beta transitions there is a very interesting ultra-slow direct transition from ^{96}Zr to the ground state of ^{96}Mo. In this case the decay jumps past the nucleus ^{96}Nb and goes directly to the ground state of ^{96}Mo and thus it falls into the category (c) in our classification of ultra-slow processes. These higher-order transitions form a class of transitions called generically the nuclear double beta decay.

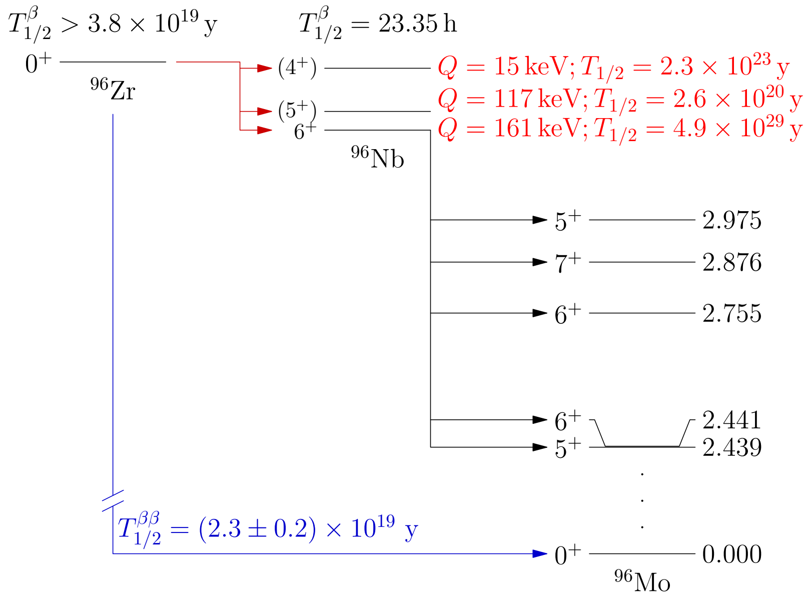

Figure 1: *Ultra-slow beta-decay transitions from the ground state of ^{96}Zr to states in ^{96}Nb, and the subsequent beta decay to states in ^{96}Mo. Shown is also the direct double-beta-decay transition to the ground state of ^{96}Mo.*