

Theory of two-proton decay and prospective candidates for experimental studies.

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Since the idea of two-proton radioactivity was proposed in the original paper of Goldansky [1], the theoretical studies of the phenomenon have been limited by various forms of quasiclassical estimates. Only recently a quantum mechanical three-body cluster model of two-proton decays has been developed [2]. The model treats the penetration of two protons through the Coulomb barrier completely dynamically and impose approximately correct boundary conditions for the three-body Coulomb problem. It has been tested with a range of nuclear systems, having three-body decay mode, with a good result. For example, comparison of the three-body model predictions with the recent ⁴⁵Fe data [3,4] is given in the Figure 1.

In our recent studies [5] we have addressed question of pragmatic interest for experimentalists. The widths of the lightest two-proton emitters (like ⁶Be, ¹²O, maybe ¹⁶Ne) can be measured by invariant (missing) mass technique. Heavier nuclei (like ⁴⁵Fe) can be implanted and lifetime deduced from measurement of subsequent activity. There exist, however, a number of anticipated ground state two-proton emitters in between, which lifetimes are probably not measurable by either technique. An experimental layout for studies of the in-flight decays of such systems was proposed in [6] (see Figure 2). Idea of experiment is to reconstruct the decay trajectories of fragments and and to find the distribution of decay vertexes along the trajectory, which straightforwardly give the lifetime.

In papers [5] we have performed a dedicated theoretical studies to understand the feasibility of such experiments for (yet unobserved nuclei) ¹⁹Mg, ³⁰Ar, and ³⁴Ca (see Figure 1). For ¹⁹Mg we were able to estimate carefully the Coulomb displacement energy compared to mirror system. We concluded that ¹⁹Mg lifetime is in the range accessible for “decay-in-flight” experiment with a high probability (possible lifetimes and separation energies are within gray rectangle in the Figure 1). Less certain is the situation with ³⁰Ar and ³⁴Ca, where reliable estimates of separation energies are not accessible. However, the obtained lifetime dependencies can be useful if a reliable two-proton separation energy information becomes available for these nuclei.

References

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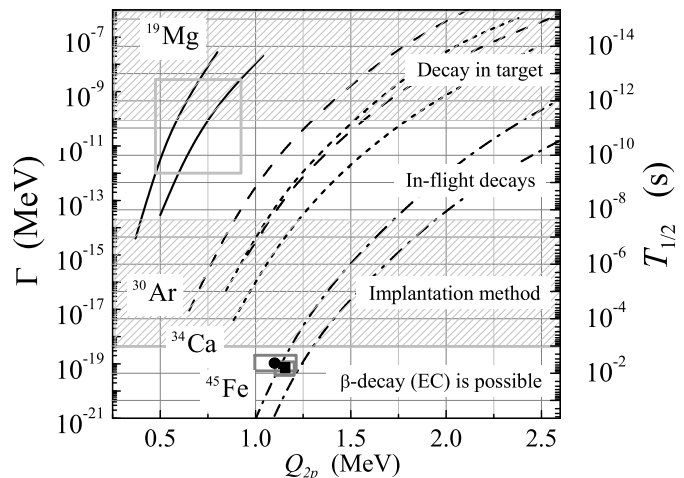


Figure 1: Calculated “lifetime bands” for some anticipated two-proton emitters (uncertainties are due to structure uncertainty). Hatching shows lifetime ranges accessible by different experimental techniques. Circle is experiment [3] and square is experiment [4] for ⁴⁵Fe.

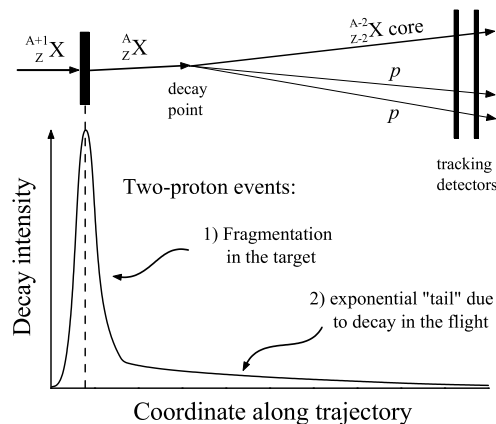


Figure 2: Schematic layout of possible experiment to study in-flight two-proton decay.