Two-proton radioactivity of sulphur-26

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As far as we approach the borders of known nuclear landscape, we are confronted with qualitatively new phenomena of nuclear dynamics and, near the thresholds of nuclear stability, cluster structure of nuclei is revealed. Clustering causes new characteristics of nuclear systems which are associated to few-body dynamics. Moving away far from the borders of nuclear stability one observes transition from discrete states to continuum and deals with many broad, and overlapping states. Two-proton radioactivity is a spontaneous break-up of elements (i.e., of long-lived nuclear states) by emission of two protons. It occurs when a resonance in any pair of fragments is located at higher energies than in the initial three-body (p+p+core) nucleus, and thus simultaneous emission of two protons (or true 2p emission) is the only decay channel. Such an exotic nuclear decay mode is still not much-explored issue though it had been predicted to be a regular phenomenon beyond the proton drip-line long time ago [1]. It has first been discovered for ^{45}Fe [2], and further observations of 2p-radioactivity reported (e.g. [3] have confirmed unexpectedly large half-lives of 2p-decay precursors.

The first quantum-mechanical theory of 2p-radioactivity which uses a three-body core+p+p model [4] interprets this observation as being due to a considerable influence of Coulomb and centrifugal barriers together with nuclear structure effects, and is able to predict the regular existence of considerably long-living 2p-decay precursors. Such a general feature of proton-unbound nuclei with a three-body structure may be of general interest, e.g. for nuclear astrophysics: the inverse reaction to 2p decay, namely 2p radiative capture, may play an important role in the synthesis of heavy elements in the Universe, possibly bridging some "waiting points" in the "hot" rp-process, see e.g. [5]. The measurements of 2p decays are the only way of studies of 2p radiative capture so far.

Experiment searching 2p radioactivity of unknown 2p-precursor ^{26}S with a primary beam of ^{36}Ar (E∼830 MeV/u) will be performed in the frame of the EXPERT [6] scientific program at GSI. It is expected that the ^{26}S nucleus might become the best investigated case in the 2p-radioactivity studies due to its very large yield expected in planned experiment. We intend to study the 2p decay of ^{26}S by the in-flight decay technique allowing to extract half-life and decay energy of the isotope using detector system based mainly on microstrip silicon detectors and array of scintillators (GADAST) for tagging gamma decays of excited states. The alternative way to observe this isotope is missing mass measurement in two neutron transfer reaction p(^{28}S,t)^{26}S available at ACCULINNA-2 fragment separator with the use ^{28}S projectile at E∼40 MeV/u. The detectors with electronics (independent of run) will be tested and employed at ACCULINNA-2 separator [7].

Main tasks of the proposed dissertation topic will become realization of the detailed Monte Carlo simulation of the experiment using GEANT4 and ROOT, processing of acquired experimental data and extracting of information on life-time and structure of ^{26}S. For the simulation of experiment, proper generator of physical events is needed. It will be developed on three-body model using hypershperical harmonics method combined with the reaction mechanism.

References

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