Executive summary of the work carried out

The structure of nuclei located along the proton stability line constitutes an important research direction with implications in astrophysics. The goal of the 2025 phase is the implementation of methods for describing nuclear structure in this region. These refer to:

1. The Deformed Cluster–Hartree–Fock–Bogoliubov (dCHFB) method

The self-consistent calculation of the nuclear mean field using a two-body interaction within the Hartree–Fock–Bogoliubov (HFB) method is a central topic of nuclear physics. We generalized the spherical cluster mean-field calculation method (CHFB) to deformed nuclei by using, in addition to the usual two-body interaction, a term centered on the deformed nuclear radius, which simulates the generation of α clusters in the low nuclear density region. We derived the system of coupled dCHFB equations, and for their iterative numerical solution we developed a computational code that uses the diagonalization procedure of the nuclear mean field in the harmonic oscillator basis.

2. The Multi-Step Shell Model (MSM) method for the description of nuclei above the doubly magic nucleus ^{100}Sn

We developed a computational code for determining the states of the nucleus ^{104}Te, consisting of two parts. In the first step, we described the nuclei ^{102}Te (pp), ^{102}Sn (nn), and ^{102}Sb (pn) with two particles above ^{100}Sn using the Tamm–Dankoff approximation (TDA) with a factorized two-body residual interaction of multipole–multipole type. In the second step, we coupled the TDA solutions into a quartet that describes the nucleus ^{104}Te, having ppnn and pnpn components. The system of equations contains the TDA energies and the norm matrix. We obtained results in agreement with experimental values by eliminating states with norms smaller than N_{min} = 0.1, which violate the Pauli exclusion principle. The results were submitted for publication in the paper:

S.A. Pencu and D.S. Delion, *Simple approach to describe ^{104}Te*, Romanian Journal of Physics (submitted for publication).

3. The R-matrix method and pn-dQRPA for the description of beta-delayed emission of protons, two protons, and alpha particles

We used the R-matrix method to solve two problems:

a) Analysis of experimental energy spectra in β-delayed proton emission, determining the decay widths (development of computational code).

b) Analysis of decay widths as a product between the penetrability through the Coulomb plus centrifugal barrier and the reduced width (development of computational code). Based on the analysis of experimental data regarding the reduced width of proton, two-proton, and α-particle emission as a linear function of the fragmentation potential, we predicted the emission widths in similar β-delayed emission processes.

We also developed a computational code for determining the effective axial-vector parameter g_A of the weak interaction in the proton stability region using the pn-dQRPA method (proton–neutron deformed Quasiparticle Random Phase Approximation) in order to calculate β-decay rates in this region. The results were submitted for publication in the paper:

D.S. Delion and S.A. Pencu, *Proton emission systematics along proton drip line*, Physical Review C (submitted for publication). https://arxiv.org/pdf/2511.00866

4. Semiclassical description of nuclear dynamics for triaxial nuclei

We analyzed the low-energy states in the chiral bands of triaxial nuclei using a semiclassical approach. These were described phenomenologically in a consistent manner as harmonic oscillations of the total angular momentum vector. The starting point is a rigid triaxial rotor Hamiltonian expressed in terms of the total angular momentum and two single-particle spins. The inertial parameters are related to the hydrodynamic moment of inertia, parameterized by the triaxial deformation γ. We considered that the two quasiparticles are rigidly aligned along the core axes. We demonstrated that ^{105}Rh is a good candidate for a harmonic chiral oscillator, as an extended series of its states can be explained through harmonic oscillations of the projection of the total angular momentum on the core rotation axis. The results were published in the papers:

R. Budaca and A.I. Budaca, *Harmonic chiral vibration in triaxial nuclei*, Physics Letters B 868, 139794 (2025).

R. Budaca, *The energy staggering of the alternating parity band in pear-shaped nuclei*, European Journal of Physics A 151, 34002 (2025).

As an educational output of this project, one of the participants: Alexandru Pencu, is PhD student under the supervision of the project director.

The obtained scientific results are significant for the experimental groups at the Tandem laboratory Magurele (Romania), Ganil (France) and Jyvaskyla (Finland). They were disseminated through participation in

Scientific conferences

1. A. Dumitrescu and D.S. Delion, *Particle emission in a self-consistent field*, European Nuclear Physics Conference, 22–26 September 2025, Caen, France, oral presentation https://indico.in2p3.fr/event/30430/contributions/157658/attachments/95980/147244/Presentation_54_Dumitrescu.pdf
2. S.A. Pencu and D.S. Delion, *Study of Beta Delayed Proton Emissions in ^{21}Mg*, European Nuclear Physics Conference, 22–26 September 2025, Caen, France, poster https://indico.in2p3.fr/event/30430/contributions/160858/

Scientific seminars

1. S.A. Pencu, *Study of Beta Delayed Proton Emissions in ^{21}Mg*, IFIN-HH Seminar, Department of Theoretical Physics, 21 October 2025