Needle with Diamant on board — winning the regatta

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Various aspects of nuclear structure are revealed by investigating nuclei far from the valley of β-stability. Studying the excited states of selected nuclei is based on γ-ray spectroscopic measurements, using large gamma-detector arrays. In such experiments, the nuclei of interest are produced with very small cross sections. Hence the experiments not only require sophisticated gamma-detector arrays with high efficiency and granularity, but for the efficient reaction channel selection, it is crucial that they are coupled with ancillary neutron- and charged-particle detectors.

The DIAMANT [1] charged-particle detector system has been developed with the major contribution of the Institute for Nuclear Research (ATOMKI, Debrecen, Hungary). The detector system consists of 64 to 96 CsI(Tl) scintillators depending on its configuration. Due to its compact size, the detector system is unique in the world by being capable of reliable particle separation mounted inside the reaction chamber even during high neutron yield experiments. DIAMANT has been an ancillary of large γ-detector arrays like EXOGAM [2] and AGATA [3] throughout many years, providing experimental support for various physics cases with significant results [4-6]. Recently, the detector was significantly improved, and the mechanics and front-end electronics were refurbished and optimised for the digital signal read-out.

Currently the accelerator facilities for nuclear physics in Europe and around the world are vastly increasing the experimental opportunities for pursuing such research. A project for the installation of state-of-the-art neutron detector NEDA (NEutron Detector Array) in connection with EAGLE (central European Array for Gamma Levels Evaluations) γ-detector array — the two forming NEEDLE — at HIL recently concluded in its first successful experimental campaign [7]. NEEDLE itself already proved to be a very capable setup; nonetheless, due to the nature of the reactions which will be used in the proposed experiments we can further exploit the possibilities by light-charged particle discrimination. With the integration of the completely revised 4Π DIAMANT array, the precise selection of the reaction channels will open a unique opportunity for studying N=Z and proton-rich nuclei.

A flagship example of an experiment possible only with DIAMANT is γ spectroscopy study of the excited states of ^{57}Cu, an important waiting-point in the *rp*-process. The experiment planned for the fall this year aims at the identification of the single-proton Shell Model states as well as N=Z=28 core excitation in this 1 valence proton neighbour of the doubly magic ^{56}Ni. Only decay data are available in the literature for this nucleus so far. The unambiguous assignment of newly observed γ-rays to ^{57}Cu will be only possible based on the analysis of spectra created with various combined DIAMANT–NEDA gates. A wealth of other physical phenomena will be possible to study thanks to the full evaporation channel identification, available thanks to DIAMANT.

We will present the scientific objectives of this experimental setup as well as the results of the commissioning. Prospects for new and innovative measurements using NEEDLE–DIAMANT setup will also be presented in this contribution.

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[3] E. Clément et al., NIM A 855 (2017) 1
[4] B. Cederwall et al., Nature 469 (2010) 68
[5] A. Ertoprak et al., The European Physical Journal A volume 56 (2020) 291
[6] B. Cederwall et al., Phys. Rev. Lett. 124 (2020) 062501
[7] Contribution of G. Jaworski