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NUMEN: NUCLEI AND THE FUNDAMENTAL NATURE OF THE NEUTRINO

The May edition of the European Physical Journal, Hadrons and Nuclei has announced the first results of the NUMEN (NUclear Matrix Elements of Neutrinoless double beta decay) project, together with an updated, detailed overview of the R&D activities relating to the project and associated theoretical developments.

NUMEN is installed in the INFN Southern National Laboratories, in Catania, and brings together joint international cooperation, also including, for Italy, the INFN divisions of Catania, Turin and Genoa. The project focuses on studying the nuclear characteristics of the phenomenon of neutrinoless double beta decay, with its important implications for the physics of neutrinos and astroparticle physics, in order to study cosmic neutrinos and dark matter.

Neutrinos, which are particles with no electric charge and an extremely low mass, interact very little with matter, but play a central role in the functioning of stars, in supernovae explosions and in the formation of the elements during the Big Bang. One of the fundamental properties of neutrinos, which is the subject of study of various experimental groups, is still unknown: whether they are Majorana particles, identical to their antiparticles, or they are Dirac particles, distinguishable from their counterparts in antimatter. If neutrinos and antineutrinos were identical, we should be able to observe the phenomenon of neutrinoless double beta decay: a process that has never been experimentally observed, but which, although prohibited by the Standard Model of elementary particles, is predicted by a lot of reliable theories. In neutrinoless double beta decay, two neutrons inside a nucleus decay simultaneously into two protons and two electrons, without emitting any neutrinos. The search for neutrinoless double beta decay, is a tough battle against other much more common natural events, the so called “background processes”, which simulate the sought signal, thus contaminating it and making it difficult to detect.

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For this reason, the technique suggested by NUMEN at the Southern National Laboratories, suggests indirect study of the phenomenon through the use of appropriate Double Charge Exchange (DCE) nuclear reactions, carried out in the laboratory, to determine the probability of nuclear transition characterising neutrinoless double beta decay. Despite the fact that the two processes, neutrinoless double beta decay and DCE reactions, are triggered by different forces (the weak force and the strong nuclear force respectively) it is held that the two phenomena feature important analogies. In particular, the crucial aspect is the coincidence between the initial and the final quantum states of the nuclei involved in the double charge exchange and in the double beta decay reactions, a feature that allows quantitative information to be obtained about the process of neutrinoless double beta decay. The main experimental instruments for this project are the K800 Superconducting Cyclotron, for accelerating heavy ion beams of high resolution and low emittance, and the MAGNEX detector, a large angular and impulse acceptance magnetic spectrometer, for detecting the products of the reaction.

The first experimental results obtained from NUMEN for the reactions (^{18}O,^{18}Ne) and (^{20}Ne,^{20}O) on targets of ^{40}Ca,^{76}Ge,^{116}Cd and ^{130}Te at energies included between 270 and 300 MeV, provide an encouraging indication of the capacity of the proposed technique for giving access to significant quantitative information.

Although the technique gives good results in terms of resolution and sensitivity, NUMEN expects significant improvements in the near future in overall performance, thanks to the already planned upgrade (2019-2021) of the infrastructure of the INFN Southern National Laboratories. ■