Nuclear Structure with Gamma-ray Tracking Arrays

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In the past decades, a great amount of Nuclear Structure information has been obtained with γ spectroscopy techniques based on the use of arrays of Compton-suppressed high-purity germanium (HPGe) detectors. With about one hundred detector modules, the largest set-ups of this type, EUROBALL and GAMMASPHERE, could reach full-peak efficiencies of 10%, working ideally in experiments with heavy ion stable beams producing nuclei with moderate recoil velocities.

The present trend towards experiments with radioactive ion beams is, however, very challenging for these detection systems. First of all it is clear that quite larger full peak efficiencies are needed to cope with the much lower beam intensities. Furthermore, when produced at high energy fragmentation facilities, the nuclei of interest move with relativistic velocities, resulting in severe Doppler broadening of the γ-ray spectra due to the large detector opening-angles needed to achieve sufficient efficiency. In this situation, the conclusion was soon reached that conventional techniques cannot achieve the required levels of efficiency and selectivity.

The gamma-ray spectroscopy community decided to embark on the search for a new detection paradigm and, after a decade of development, the first modules based on the new concept of γ-ray tracking have eventually started operating in real experiments.

Tracking of gamma rays is based on the capability to determine both energy and position of the individual interactions by which gamma rays are absorbed inside the large-volume high-purity germanium crystals used in gamma ray spectroscopy. If these quantities are known with sufficient precision, the gamma rays of the detected event can be reconstructed (tracked) and characterized in details. The required position sensitivity inside the germanium crystals is achieved by the combination of electrical segmentation of the outer electrode, fully-digital data acquisition techniques and detailed analysis of the signals induced on the segments by the charge collection process. The development of this technology has been pushed by the AGATA and GRETA projects, both aiming at the ultimate 4π germanium-only detector.

These two instruments are expected to play a major role in the future nuclear structure studies at the very limits of nuclear stability.