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Nuclear Spectroscopy with HELIOS[1]

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Direct reaction studies have been instrumental in achieving our current understanding of nuclear structure through the measurement of angular distributions, the extraction of spectroscopic factors, and the determination of single-particle centroids. Traditionally, these experiments were carried out using a beam of light particles impinging on a heavy stable target. Over the last decade this important technique has been used with short-lived radioactive ion beams requiring these types of reactions to be carried out in inverse kinematics. There are numerous challenges to this approach, not least is the typical Q-value resolution being up to an order of magnitude worse than traditional measurements due mainly to the so-called kinematic compression. The Helical Orbit Spectrometer (HELIOS) is a detection system developed for the specific purpose of improving the Q value resolution for inverse direct reaction measurements, while also maintaining flexibility and high efficiency. The novel feature of HELIOS is use of a 3 Tesla solenoid inside which the reactions take place. This allows for light particles of interest to be measured at fixed longitudinal distances from the target as opposed to fixed laboratory angles. The subtle mapping from laboratory angle to longitudinal position removes the aforementioned kinematic compression effect improving the Q-value resolution by as much as a factor of five without out sacrificing detection efficiency. In addition, HELIOS provides a natural way to identify particles of interest, independent of energy, through their measured cyclotron period. The design and implementation of HELIOS at the Argonne Tandem Linear Accelerator System (ATLAS) on the site of Argonne National Laboratory will be presented. The device has been extremely successful as numerous early measurements have been conducted spanning masses $A = 11$ to 136, using varying reactions such as (d,p), (d,^{3}He), and (^{6}LI,d), as well as a range of beam energies. Physics highlights from these works will be discussed along with future prospects and developments, including the viability of HELIOS in conjunction with the exotic neutron-rich beams to be provided by the ATLAS Californium Rare Isotope Breeder Upgrade project (CARIBU).

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