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GASTLY: a new apparatus for detection of low-energy light charged-particles in nuclear astrophysics experiments

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A new detection array called GASTLY (GAs-Silicon Two-Layer sYstem) has been designed to detect and identify low-energy light charged-particles (p,d,alpha,…) emitted in nuclear reactions of astrophysical interest. Devoted to the measurement of nano-barn cross-sections, the system is optimised for large solid angle coverage and for low-energy detection thresholds. The array consists of eight modules, each comprising an ionisation chamber (IC) and a large area silicon strip detector (SSD), both housed in an aluminium pyramidal case, and providing the DE-E information used for particle identi1cation. The IC key components are an entrance window (2.6 um thick Havar foil) acting as a cathode, a Frisch grid (gold-coated tungsten wires having 20 um diameter and 3 mm pitch size), an anode (1.5 um thick Mylar foil, metallised with 50 ug/cm2 of aluminium) and a serie of 25 guard rings surrounding the IC active region and ensuring the uniformity of the electric field. The IC is operated with CF4 gas, flowing (0.1-1.0 litres/h) and maintained at a constant pressure (300 mbar max) and the length of the active region is of 116 mm. The SSD is about 58x58 mm2 large and 300 um thick and its front face is segmented in 16 strips (3.5x58.0 mm2 each), while the conductive back plane is unsegmented. The readout electronics, mainly consisting in home-made low-noise charge preamplifiers (plus a 16-channel ASIC chip, when the individual strip analysis is required), is also placed inside the pyramid, near and behind the detectors, to reduce the environmental electromagnetic noise. The distance between the target and the entrance window of the GASTLY modules is of 54 mm (74 mm for two modules) and a total solid angle of about 0.7 sr is subtended by the whole apparatus. The angular uncertainty Dtheta, for angular distribution measurements, due to the width of the strips and to their rectangular shape, is of about 1.0°-1.5°. We will report on the performance of the GASTLY array as obtained during its commissioning phase with standard alpha-particle sources and during in-beam tests with an intense 12C beam. Typical energy resolutions DE(FWHM)/E of about 3% and 2% were obtained for the IC and the SSD, respectively. The GASTLY modularity and versatility allow for use in a variety of experiments and the apparatus is presently installed at the Centre for Isotopic Research on the Cultural and Environmental heritage (CIRCE) of the Università della Campania "L. Vanvitelli"(Caserta, Italy) for the study of one of the most important reactions in nuclear astrophysics, namely the fusion of two 12C nuclei known as carbon burning. At characteristic temperatures of 0.3 - 1.9 GK, corresponding to interaction energies Ecm = 1.0 - 3.5 MeV, carbon fusion proceeds through two main channels: 12C(12C,p)23Na (Q-value = 2.24 MeV) and 12C(12C,alpha)20Ne (Q-value = 4.62 MeV) and a number of excited states in the residual nuclei can be populated, leading to ejected proton- and alpha-particle energies up to a few MeV, depending on beam energy and detection angle. The GASTLY features successfully allowed the contemporary detection and identi1cation of protons and alpha-particles emitted in such reactions.

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