Abstract

The determination of the carbon-to-oxygen ratio produced during the final stages of helium burning in stars poses a significant challenge in nuclear astrophysics. The relevant reactions occur at energies below the Coulomb barrier, making direct measurements highly demanding and associated with considerable uncertainties.

Recently, the utilization of high-intensity γ-ray beams has offered a new opportunity to investigate the crucial $^{12}\mathrm{C}\,(\alpha,\gamma)\,^{16}\mathrm{O}$ reaction, which regulates the carbon-to-oxygen ratio, through the exploration of time-reversal photodisintegration $^{16}\mathrm{O}\,(\gamma,\alpha)\,^{12}\mathrm{C}$ reaction. This method presents certain advantages over previous measurement techniques, including reduced background and different systematic uncertainties.

To exploit this promising approach, a dedicated active-target Time Projection Chamber, known as the Warsaw TPC, has been developed at the University of Warsaw. The detector has been designed and optimized to facilitate comprehensive studies using high-intensity γ-ray beams. The detector utilizes an electronic redundant strip readout, DAQ system based on the General Electronics for TPCs (GET), and a stack of three Gas Electron Multiplier (GEM) foils for charge amplification.

In 2022, the Warsaw TPC was deployed for a series of measurements at the High Intensity Gamma-Ray Source (HIγS) facility, located at the Triangle Universities Nuclear Laboratory (TUNL) in Durham, NC, USA. These experiments focused on studying the time-inverse photodisintegration $^{16}\mathrm{O}\,(\gamma,\alpha)\,^{12}\mathrm{C}$ processes utilizing a high-intensity monochromatic γ-ray beam in the center-of-mass energy range of 1.35–6.7 MeV.

This thesis presents the first analysis of that experimental material and one of the first analyses done with any data collected with the Warsaw TPC. The results in form of relative cross-sections for E1 and E2 multipolarity components as well as the E1–E2 mixing phase angle were obtained on a limited statistics achieved with a manual event reconstruction.

The obtained results prove the Warsaw TPC and proposed techniques of data processing and analysis can be effectively used for studies of γ-beam induces nuclear reactions.