Synthesis of atomic nuclei in the early Universe started with the production of deuteron in the $p + n \rightarrow {}^{2}H + \gamma$ reaction. The probability of this reaction to occur influences the aboundances of heavier elements (helium and small amounts of lithium) produced in subsequent reactions of primordial nucleosynthesis. Elements heavier than lithium are produced in thermonuclear reactions in interiors of evolving stars or in catastrophic events like a supernova explosion. Nuclosynthesis in quiescent starts proceeds in stages. At the beginning of their lives stars burn hydrogen and convert it into helium. After burning almost the whole hydrogen, stars start to burn helium. At this stage three alpha particles fuse together in the so called 3α process to form a carbon nucleus. Carbon nuclei after attaching a subsequent alpha particle can be converted into oxygen with simultaneous emission of gamma-rays. Oxygen and carbon are the most aboundant elements heavier than helium in the Sun and similar stars. These elements are a basic components of all organic compounds and shape the form of biological life in our Universe. It turns out that the relative aboundance of carbon and oxygen is determined by the probability (cross section) of the ${}^{12}C + {}^{4}He \rightarrow {}^{16}O + \gamma$ reaction taking place in stars at temperatures $\sim 10^{8}$ K. Under such conditions the probability of the ${}^{12}C + {}^{4}He \rightarrow {}^{16}O + \gamma$ is extremely small due to the Coulomb repulsion of interacting particles and direct measurement of this quantity under laboratory conditions is not possible. Therefore, development of nuclear models is needed for a reliable extrapolation of reaction cross sections from the energy regions were the experimental data are accessible to the energy domain characteristic for thermonuclear reactions occurring in stars or early Universe.

We propose to study the $p + n \rightarrow {}^{2}H + \gamma$ and ${}^{12}C + {}^{4}He \rightarrow {}^{16}O + \gamma$ reactions by investigating the inverse processes: ${}^{2}H + \gamma \rightarrow {}^{1}H + n$ and ${}^{16}O + \gamma \rightarrow {}^{12}C + {}^{4}He$, respectively, induced by high energy gamma rays. The symmetry of laws of physic with respect of the direction of the time flow enables the direct connection of the results of the studies of the ${}^{16}O + \gamma \rightarrow {}^{12}C + {}^{4}He$ reaction with properties of the inverse process: ${}^{12}C + {}^{4}He \rightarrow {}^{16}O + \gamma$. An analogous relation holds for the ${}^{2}H + \gamma \leftrightarrow {}^{1}H + n$ reactions.

The measurements planned will be conducted by using the gamma beam delivered by the High Intensity Gamma Source (HIγS) at Duke University, USA. In the HIγS facility, the gamma beam is produced in the scattering of laser-generated light on electrons accelerated to a velocity close to the speed of light. The energy of the beam can be changed in the 2-100 MeV range and beam intensities up to $2 \cdot 10^{8}$ γ/s can be achieved.

The reactions will be investigated by using a dedicated detector (HIγS TPC). The main element of this detector is a chamber filled with a gas containing the nuclei on which reactions will occur. In the planned studies it will be ${}^{16}O$ in the form of carbon dioxide and ${}^{2}H$ in the form of deuterated methane. The nuclei of the gas contained in the chamber will serve as reaction targets. Gamma quanta interacting with ${}^{16}O$ nuclei will decompose them into ${}^{12}C$ and alpha particle while deuteron nuclei will be dissociated into a proton and neutron. The charged particles produced will be stopped in the gas and generate ionization electrons. These electrons will drift in the electric field prevailing in the active volume of the detector toward a charge amplification structures. The amplified charge will be collected on a set of strip electrodes. Signals from the HIγS TPC detector, after being processed by specialized FPGA processors, will enable the reconstruction of trajectories of the reaction products, the determination of their energies and momenta. The analysis of these observables will allow us to get insight into the properties of the studied reactions and will provide new, essential information needed to improve theoretical models used in the description of astrophysical processes of nucleosynthesis.