Direct Measurements of Carbon Burning at Astrophysical Energies

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Fusion reactions play an essential role in the energy production, the nucleosynthesis of chemical elements and the evolution of massive stars. Among these reactions, carbon burning is a crucial ingredient to understand the late stages of massive stars [1] essentially driven by the $^{12}C+^{12}C$ reaction. It presents prominent resonances at energies ranging from a few MeV/nucleon down to sub-Coulomb barrier energies, possibly due to molecular ^{12}C-^{12}C configurations of ^{24}Mg [2,3]. The possible persistence of these resonances to deep sub-Coulomb barrier relative energies causes colossal uncertainties of extrapolations of $^{12}C+^{12}C$ fusion cross section towards the experimentally challenging region of astrophysics interest with extremely small cross sections. The direct measurement of key fusion reactions at stellar energies offers an unbiased and evident experimental access, but calls for innovative measures for efficient background reduction.

This contribution will discuss recent results obtained in the $^{12}C+^{12}C$ system at deep sub-barrier energies using the STELLA setup combined with the UK-FATIMA detectors for the exploration of fusion cross-sections of astrophysical interest [4]. Characteristic gamma-rays of the exit channels have been measured with an array of $LaBr_3$ detectors and the protons and alpha particles associated to the major final states were identified using double-sided silicon strip detectors. A novel rotating target system employing large thin self-supporting target foils has been developed to sustain carbon beams with micro-A intensity delivered by the ANDROMEDE 4 MV Pelletron facility of the University Paris-Saclay and IJC Lab (France). The gamma-particle coincidence technique combined with the merit of nanosecond-timing measurements have been used to minimize background contributions for cross-section determination at the highest precision reached so far. This has allowed to obtain astrophysical S-factors, which will be presented and discussed in terms of sub-barrier hindrance effects as well as possible resonant features in the ^{24}Mg compound system, down to the Gamow window [5]

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