Improved precision on the experimental $E0$ decay branching ratio of the Hoyle state

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Stellar carbon synthesis occurs exclusively via the 3α process, in which three α particles fuse to form ^{12}C in the excited Hoyle state followed by electromagnetic decay to the ground state. The Hoyle state is energetically above the α threshold, and the rate of stellar carbon production depends directly on the radiative width of this state. The radiative width cannot be measured directly, and must instead be deduced by combining three separately measured quantities. One of these quantities is the $E0$ decay branching ratio of the Hoyle state, and the current $\approx 10\%$ uncertainty on the radiative width stems mainly from the uncertainty of this ratio. The rate of the 3α process is an important input parameter in astrophysical calculations on stellar evolution, and a high precision is imperative to constrain the possible outcomes of different astrophysical models. We have carried out a series of pair conversion measurements of the $E0$ and $E2$ transitions depopulating the Hoyle state and 2_1^+ state in ^{12}C, respectively, with the aim to deduce a new, more precise value on the $E0$ decay branching ratio. The excited states were populated by the $^{12}\text{C}(p,p')$ reaction at 10.5 MeV beam energy, and the pairs were detected with the electron-positron pair spectrometer, Super-e, at the Australian National University. The deduced branching ratio required knowledge on the proton population of the two states, as well as the alignment of the 2_1^+ state in the reaction. For this purpose, proton scattering and γ-ray angular distribution experiments were also performed. An averaged $E0$ branching ratio of $\Gamma_\pi^{E0}/\Gamma = 7.47(46)\cdot 10^{-6}$, with an uncertainty of 6%, was deduced. Based on a weighted average of previous literature values and the new result we recommend a value of $\Gamma_\pi^{E0}/\Gamma = 7.21(37)\cdot 10^{-6}$. The new recommended value on the $E0$ branching ratio is about 7% larger than the previous adopted value of $\Gamma_\pi^{E0}/\Gamma = 6.7(6)\cdot 10^{-6}$, and the uncertainty has been reduced from 9% to 5%. The experimental methods, results, and implications will be discussed in this presentation.

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