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Measurement of the γ Decay Probability of the Hoyle State

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The triple alpha (3α) reaction is one of the most important processes in the nucleosynthesis. In this reaction, an α particle is captured by the 2α resonance of $^{8}\mathrm{Be}$, and form a 3α cluster state with weakly bound α particles. Most of the 3α resonance states decay to three α particles, but a tiny fraction of them decays to the ground state in $^{12}\mathrm{C}$ via radiative processes of γ decay or $e^{+}e^{-}$-pair emission. Therefore, the γ-decay probability is an important parameter that directly determines the amount of $^{12}\mathrm{C}$ produced in the nucleosynthesis. Many γ decay probability measurements were performed by 1976 and radiative-decay probability $\Gamma_{\mathrm{rad}}/\Gamma = 4.16(10) \times 10^{-4}$ [1] from the Hoyle state has been widely accepted.

Recently, a striking result of the γ decay probability of the Hoyle state was reported from a measurement of two γ rays from the cascade decay of the Hoyle state. The new value of $\Gamma_{\mathrm{rad}}/\Gamma = 6.2(6) \times 10^{-4}$ [2] is 50% higher than the recommended value in Ref.[1]. Most of the old data were taken by measuring $^{12}\mathrm{C}$ nuclei surviving after the Hoyle state decayed. The authors of Ref.[2] claimed that such measurement might not be appropriate and the discrepancy between the new and old results should be due to the different experimental methods. In order to solve this puzzle, it is necessary to measure surviving $^{12}\mathrm{C}$ nuclei and γ rays at the same time.

In this study, the experiment was performed at the tandem accelerator facility of IFIN-HH in Romania. We populated Hoyle state in $^{12}\mathrm{C}$ by the α+$^{12}\mathrm{C}$ scattering using a α particle beam at $\mathrm{E}_{\mathrm{beam}}$ = 25 MeV, and emitted charged particles are detected by a DSSD and γ rays by the ROSPHERE LaBr_3 detector array [3]. In this talk, we will report the experimental details and results of the γ decay probability measurements.

[1] J. Kelley, J. Purcell, and C. Sheu, Nucl. Phys. A **968**, 71 (2017).
[2]T. Kibedi *et al.*, Phys. Rev. Lett. **125**, 182701 (2020).
[3]D. Bucurescu *et al.*, Nucl. Instrum. Methods Phys. Res. A, **837**, 1 (2016).

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