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Observation of the 2+ rotational excitation of the Hoyle state

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We present the first clear observation of the 2+ rotational excitation of the Hoyle state in a beta decay experiment. Coincident detection of β-3α particles from the cascade 12N(β)12C(α1)8Be(α2)α3 have been used to obtain β-α1 angular correlation, which then has been used to determine the strength of the 2+ state relative to that of the 0+ in the 9-12 MeV energy region. The experiment has been performed at the IGISOL facility at JYFL, Jyväskylä, Finland.
This second 2+ state of the 12C nucleus is of great importance to nuclear astrophysics reaction rate calculations and also to nuclear cluster structure studies. The triple-α process, which is responsible for 12C production, primarily proceeds through a resonance in the 12C nucleus, famously known as the Hoyle state. The cluster nature of the Hoyle state allows the formation of a rotational band built upon it. The first member of the band is thought to be in the 9-11 MeV region, with $J\pi$=2+ [1-4], with the most recent data indicating an energy of 10.03 MeV [5]. Further knowledge of this state would help not only to understand the debated structure of the 12C nucleus in the Hoyle state, but also to determine the high-temperature (> 1 GK) reaction rate of the triple-α process more precisely [6,7]. The precise evaluation of the rate of this reaction is required to be able to understand the final stages of stellar nucleosynthesis and the elemental abundances in the universe. Due to the significance of the resonance, a reconciliation of the data from different available probes is highly desirable.
We therefore, for the first time, present a clean identification of the 2+ resonance populated in beta decay through application of the novel technique of beta-triple-alpha coincidence studies. We further discuss the impact of the resonance on high-temperature astrophysical scenarios.

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