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The Hoyle Family: precision break-up measurements to explore nuclear α -condensates

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The 0^+ excited state of ^{12}C at 7.65 MeV is named after Sir Fred Hoyle, who proposed its existence in order to account for stellar abundances of carbon [1,2]. Aside from this astrophysical significance, it is thought to possess a curious α -cluster structure. However, many questions still remain. To what extent can this state be described as three interacting α -particles, and if so, what geometric configuration do they take – a linear chain, equilateral triangle or something in-between? Is it that the bosonic nature of the α -particle dominates the dynamics of this nucleus meaning that it could be the nuclear analogue of a Bose Einstein Condensate?

Since its discovery [3], measurements of the Hoyle state excitations and radius have provided indirect insights into its structure [4]. However, another way to examine its structure could be to examine the energy distributions of the α -particles emitted during its rare three-body direct break-up [5]. Their relative energies in the final state could reflect the initial structure. Previous studies have set an upper limit on the branching ratio for the direct break-up process at 0.2% [6].

We present a recent high statistics, low background measurement of the 3α decay of the Hoyle state [Seven]. The $^{12}\text{C}(\alpha,\alpha)3\alpha$ reaction at 40 MeV beam energy was measured using the Birmingham MC40 cyclotron. The particles were detected in complete kinematics and the upper limit on the direct break-up branching ratio was lowered by almost an order of magnitude compared with previous measurements. This places it below what is predicted by a number of theoretical models, opening new intriguing questions about the structure of this important state.

I will finally discuss the Optical Readout Time Projection Chamber (O-TPC) at HI γ S [8] and the previous determination of the direct 3α decay branching ratio of the Hoyle state 2^+ excitation [9]. This has allowed us to extrapolate down in energy and calculate a theoretical upper limit for the direct 3α branching ratio of the Hoyle state.

[1] E. Öpik, Proc. R. Ir. Acad. A 54 (1951) 49.

[2] E.E. Salpeter, Astrophys. J. 115 (1952) 326.

[3] D.N.F. Dunbar, R.E. Pixley, et. al., Phys. Rev. 92 (1953) 649.

[4] M. Freer, H.O.U. Fynbo, Prog. Part. Nucl. Phys. 78 (2014) 1-23.

[5] Ad. R. Raduta et al., Phys. Lett. B 705, 65 (2011).

[6] M. Itoh, et al., Phys. Rev. Lett. 113, 102501 (2014).

[7] R. Smith, Tz. Kokalova, C. Wheldon, J. E. Bishop, M. Freer, N. Curtis, and D. J. Parker, Phys. Rev. Lett. 119, 132502 (2017).

[8] M. Gai, et al., JINST 5 (2010).

[9] W. R. Zimmerman et al. Phys. Rev. Lett. 110

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