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Observation of gamma-delayed three-alpha breakup in 12C: a complete kinematics approach to study multi-particle final state reactions

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Hans Bethe was the first to establish the concept of nucleon synthesis in stars [1] proposing the CNO cycle and the PP chain, but was unsuccessful in solving the 12C formation mechanism. Not until the introduction of the Hoyle state [2] in 1953 one was getting close to a solution. However, 50 years later the 12C break-up is still not fully solved and the quest for learning more about the reaction rates in stars by studying the triple-alpha process is continuing.

In this work we have studied the break-up of 12C following the reactions 10B(3He,pααα) and 11B(3He,dααα). The study was performed at the 5MV tandem accelerator at the Centro de Micro Analysis de Materials (CMAM) [3] at the Universidad Autónoma de Madrid. The break-up give us information on excited states in 12C from the famous Hoyle state up to an energy of almost 18 MeV. Using a highly segmented experimental set-up the simultaneous detection of the three alpha particles in coincidence with a proton or a deuteron, respectively, made possible a full kinematic reconstruction of the break-up. On the basis of the energies of the three alpha particles and their angular correlations it has been possible to separate the branching of the break-up through the ground state and the first excited 2+ state in 8Be, as well as to determine the spin and parity of states for cases where the assignment have been doubtful.

Some of these levels will also de-excite via electromagnetic emission. The comparison between the energy of the proton (or deuteron) that populate a state of 12C and the sum of the energies of the 3alpha emitted from the same state makes possible to determine the presence of electromagnetic disintegration (γ) to lower states within 12C followed by the 3α break-up. This technique permits to identify γ-emissions between states where the gamma radiation emitted does not correspond to a peak [4].

In this contribution we will discuss the experimental set-up followed by a detailed description of the analysis method to reach the results obtained.

[1] H.A. Bethe, Energy production in stars, Phys. Rev. 55(1939)434

[2] F. Hoyle et al., Phys. Rev. 92(1953)1095

[3] http://www.cmam.uam.es/

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