An independent measurement of the $^{12}C(\alpha,\gamma)^{16}O$ cross section with the Karlsruhe 4π BaF_2 detector

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The $^{12}C(\alpha,\gamma)^{16}O$-reaction is considered as one of the most important processes in nuclear astrophysics since it determines the ratio of ^{12}C to ^{16}O during stellar Helium burning. Together with the triple-alpha-process this reaction is crucial for the further evolution of the star.

Due to the Coulomb repulsion, the cross section in the astrophysical energy range at $E_{c.m.}$=300 keV is about 10^{-17} b. This extremely small value implies that a direct measurement remains impossible in the foreseeable future. For this reason, the cross section has to be measured at higher energies and needs to be extrapolated to the interesting energy range.

So far, all relevant direct measurements have been performed with Germanium detectors and were restricted to energies above 870 keV. The low gamma-ray efficiency of these detectors had to be compensated by very intense beam currents, which may cause considerable uncertainties due to severe target degradation. A verification of these data with a completely different approach, which could reveal systematic uncertainties was still missing.

The realization of such an independent measurement was performed with the Karlsruhe 4π BaF_2 array, which consists of 42 individual modules. Due to the high efficiency of more than 90% for single gamma-rays the beam current could be reduced by more than a factor of 100. The experiment was carried out with an average current of 6 μA thus minimizing the thermal load of the target and avoiding sputtering effects.

The suppression of background especially from the $^{13}C(\alpha,n)^{16}O$-reaction plays a crucial role for this measurement. Background events were therefore suppressed by the use of highly enriched ^{12}C, a pulsed alpha beam, and an active shielding. The measurement of angular distributions, which are necessary for the extrapolation of the cross section, could be accomplished simultaneously due to the high granularity of the detector.

The cross section was measured at $E_{c.m.}$=1002, 1308, 1416 and 1510 keV. The resulting E1- and E2-contributions being in perfect agreement with the best previous measurements helped to resolve discrepancies in previous data. The cross section for transitions with two-step cascades was obtained for the first time in this energy region. Previously extrapolated S-factors were confirmed by an R-matrix analysis based on the new data.

Even though the measurement has been performed in a relatively short period of time, the achieved precision is comparable to long-lasting experiments with Germanium detectors. While the potential of these conventional setups seems to be exhausted, the sensitivity of the measurement with the BaF_2 detector can be further increased. By several improvements the available energy range can be extended down to 750 keV.