Alpha-capture measurements with a recoil separator

Abstract:
Radiative capture reactions, like (α,γ)- and (p,γ)-reactions, are of utmost importance for the understanding of the different burning phases in stars. In most cases laboratory studies of some key reactions are very difficult due to the low cross section at the relevant Gamow energy, where the stellar burning occurs. In particular, the reactions $^{12}C(\alpha,\gamma)^{16}O$ and $^{3}He(\alpha,\gamma)^{7}Be$ are those case with high astrophysical interest. The capture reaction $^{12}C(\alpha,\gamma)^{16}O$ takes place in the helium burning of Red Giants and determines not only the nucleosynthesis of elements up to the iron region but also the subsequent evolution of massive stars, the dynamics of a supernova, and the kind of remnant after a supernova explosion. The $^{3}He(\alpha,\gamma)^{7}Be$ reaction plays an important role in the interpretation of the results of the solar neutrino experiments, while the estimate of the oscillation parameters relies on the solar neutrino spectrum, calculated by solar models, where the relevant nuclear reaction cross sections are included. The uncertainty in the $^{3}He(\alpha,\gamma)^{7}Be$ cross section is also one of the larger contributions to the uncertainty on primordial ^{7}Li abundances in Big Bang Nucleosynthesis calculations.
For these reasons, the cross section should be known with a precision of at least 10 %. In spite of tremendous experimental efforts in measuring the cross section over nearly 40 years, one is still far from this goal. This situation is similar for many other key reactions. A different approach to measure these capture cross sections involves a two-sided differentially pumped gas target and a recoil mass separator as detection system. This combination allows a direct measurement of the produced recoils in inverse kinematics. The direct observation of the recoils requires an efficient recoil mass separator to filter out the incident beam particles from the recoils. The recoil separator must not only have a high filtering power but also a high transmission of the recoils (for the selected charge state) between the gas target and the ΔE-E telescope at the end of the separator.
The total cross section of $^{12}C(\alpha,\gamma)^{16}O$ and $^{3}He(\alpha,\gamma)^{7}Be$ was measured for the first time by a direct and ungated detection of the 16O and 7Be recoils. These measurements using the recoil mass separator ERNA at the 4MV Dynamitron Tandem Laboratory at the Ruhr-University Bochum, Germany, allowed collecting data with high precision over a wide range of energy. The data represent new information for the determination of the astrophysical S(E) factor. The experimental results will be presented and implication will be discussed.