Direct Capture Strength in the $^{16}O(\alpha,\gamma)^{20}Ne$ Reaction

The $^{16}O(\alpha,\gamma)^{20}Ne$ reaction is of significant importance for stellar Helium burning. The reaction rate is low at temperatures of stellar helium burning and is therefoe identified as the "end-point" of the main reaction chain $^{4}H(2\alpha,\gamma)^{12}C(\alpha,\gamma)^{16}O(\alpha,\gamma)^{20}Ne$ which is induced by the triple alpha process. The reaction rate is low because the lack of resonances in the Gamow window which is located around E_o= 300 keV. At these energies the reaction is dominated by non resonant direct radiative capture (DC) components while at higher energies resonant capture through several low energy resonances is possible. The strength of the DC contribution is not known. Previous experiments provided only upper limits [1]. Recent simulations and calculations of the direct capture strength [2] suggest that the dominant direct capture contribution is coming from s-wave capture to the first excited state of ^{20}Ne. The goal of the present study is to obtain better or more stringent information on the DC components by fitting experimental data in the energy region dominated by the interference between resonant and DC contributions. The R-Matrix computer code AZURE has been used to fit the experimental radiative capture and elastic scattering data in the energy range between E_{cm} = 0.8 and 2.75 MeV.

Detailed reaction yield data were taken at the University of Stuttgart using the gas target system Rhinocerus (PhD project: A. Mayer). New complimentary data have been taken at the University of Notre Dame using a solid target setup. The focus was to determine absolute cross section data near the 1.99 MeV 0^+ resonance that is characterized by strong interference with the DC.

The R-Matrix analysis was performed for the the low energy total radiative capture yield to ground state and first excited state in ^{20}Ne as well as $^{16}O(\alpha,\alpha)^{16}O$ scattering data with the code AZURE taking into account the gas target thickness and the stopping power. Figure 1 shows the best fit taking only resonance contributions into account. The fit suggests that additional d-wave E2 DC to the 2^+ first excited state is necessary to match the observed yield. Possible M1 DC contributions are too weak to add appreciably to the reaction yield [2]. Figure 2 shows the fit taking the E2 DC component into account. The DC component produces several interfence effects that bring the theoretical yield curve into much closer agreement with the data, particularly in the low energy tail region of the 0^+ 1.99 MeV resonance. Partial scattering and gamma widths were extracted and agree well with previosly reported values.

An S-Factor extrapolation was performed down to astrophysical energies to determine the contribution of the non resonant E2 DC reaction components to the reaction rate. Figure 4 shows the total S-factor in the here considered energy range. The figure demonstrates clearly that the total S-factor is dominated by the DC in the Gamow range of 300 keV. These results are in good agreement with the predictions of the previous theoretical analysis of this reaction process [2].

[1] K. H. Hahn, K. H. Chang, T. R. Donoghue, B. Filippone, Phys. Rev. C **36**, 892 (1987)
[2] P. Mohr, Phys. Rev. C **72**, 035803 (2005)

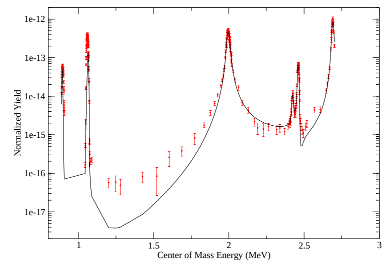

Figure 1: resonance contributions in

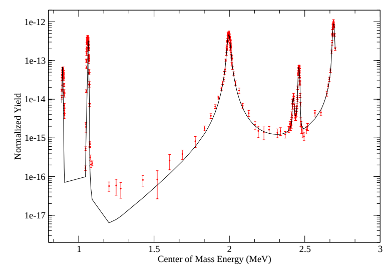

Figure 2: Resonance and direct capture components in the total

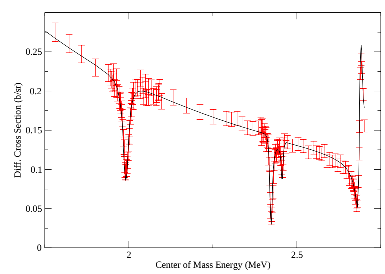

Figure 3: R-matrix fit to the $^{16}O(\alpha,\alpha)^{16}O$

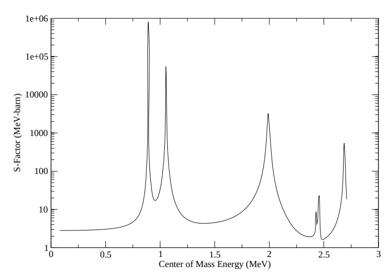

Figure 4: S-factor for the low energy range of the $^{16}O(\alpha,\gamma)^{20}Ne$ reaction.

Researchers:

H. Costantini [1], R. deBoer [2], J. Görres [2], W. Hammer [2], M. Wiescher [2]

[1] INFN, Genova, Italy
[2] U. Notre Dame