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Measurements of the 20Ne+4He resonant elastic scattering for characterization of the 24Mg states at relevant excitations for carbon - carbon burning process

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Detailed knowledge on complex spectroscopy of the ^{24}Mg nucleus at excitation energies between 14 and 19 MeV has large impact on understanding of clustering in nuclei and on carbon - carbon burning, the ^{12}C+^{12}C fusion, in massive stars. The ^{12}C+^{12}C and ^{16}O+^{8}Be cluster structures (threshold energies are 13.9 and 14.1 MeV respectively) become active in this energy region mixing with already strong ^{20}Ne+^{4}He clustering (threshold energy is 9.3 MeV). Their interplay and effects of strong α-clustering in ^{12}C and ^{20}Ne lead to unique structural properties and very complex spectroscopy of the ^{24}Mg. In this energy region are expected to exist the band heads of a number of rotational bands associated with the ^{12}C+^{12}C cluster structure whose high spin members are identified at higher excitations. It is cruical to identify low spin members of these rotational bands to improve understanding of their origin. The ^{12}C+^{12}C clustering has a strong effect on the C-C burning which play an essential role in many astrophysical phenomena, both quiescent and explosive. Existing data in astrophysically relevant energy range show large discrepancies in the S-factors and substantial improvements in future direct measurements are required to make further progress.

Indirect experimental approach through measurements of the ^{20}Ne+^{4}He resonant elastic scattering was used to search for ^{24}Mg states which may increase C-C burning rate. Observation of the 0^+ (or 1^-) resonance at excitations between 15 and 18 MeV would strongly indicate enhanced reaction rate of the ^{12}C+^{12}C fusion while its non-observation would imply non-resonant nature of the C-C burning, and hence its reduced contribution in many stellar phenomena. Measurements of the ^{20}Ne+^{4}He excitation functions by use of the 36.07, 45.45 and 53.17 MeV ^{20}Ne beams delivered by the PIAVE-ALPI facility of Laboratori Nazionali di Legnaro INFN and a thick ^{4}He gas target which stops the beam in front of the detector were performed. This beam energy range corresponds to the ^{12}C+^{12}C relative energy range of prime importance for astrophysics. Scattered α-particles were detected in large area highly segmented silicon strip detector telescope built of 20 μm thick ΔE SSSD and 1000 μm thick E DSSSD. Telescope was positioned at 0^o. Detailed measurements of the beam energy loss and beam intensity, needed for an accurate data analysis, were performed.

Elastic scattering excitation functions were extracted for data between -5^o and 5^o and normalized to previously taken data. Large number of overlapping resonances is detected in the excitation functions. Strong contribution of the inelastic scattering to the first excited ^{20}Ne state was observed and further analysis was performed for data free of inelastic scattering events. Using all available results on ^{24}Mg states at these excitations, attempts to fully characterize the observed resonances in the excitation functions in terms of spin, parity, width and partial widths were done using R-matrix calculations. No clear evidence for the 0^+ or 1^- state was found. Obtained results show the limitations of performed experiment and give clue for improved experiment. Complementary measurements using resonant scattering technique with the ^{20}Ne beam and low density ^{4}He gas target which will provide high resolution data for larger angular range were recently performed at LNL INFN and obtained data are being analysed.

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