Observation of probable Hoyle analog states in ^{20}Ne and ^{16}O in ^{12}C + ^{12}C reaction

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Introduction

Hoyle state of ^{12}C has been in the forefront of research ever since it was first predicted[1] by Fred Hoyle in 1954. The predicted state at 7.65 MeV has baffled scientists regarding the structure of the state. Many models have been proposed till date. Still there is ambiguity if the state has a three alpha linear chain structure or it is something else altogether[2]. Assuming a 3-α cluster condensate we can arrive at the 7.65 state. Similar 4-α and 5-α condensate structures of ^{16}O & ^{20}Ne have been proposed at 15.1 MeV[3] and near the 5-α breakup threshold at 19.17 MeV[4] respectively. We report here a possible decay channel of ^{24}Mg in the form of ^{24}Mg $\rightarrow$ ^{20}Ne + α and ^{20}Ne $\rightarrow$ ^{16}O + α with both ^{20}Ne and ^{16}O populated in Hoyle analog α cluster state.

Experimental Details

The measurement was performed at the Pelletron Linac facility (PLF), Mumbai using ^{12}C beam of energy 65 MeV. A self-supported 175 $\mu g/cm^2$ thick natural carbon target was used in the experiment. For detecting the charged particles, ΔE & E telescopes consisting of silicon strip detectors (SSD) of thicknesses 50 & 1500 μm, respectively, were used. The active area of the ΔE & E SSDs were 50x50 mm^2. The E detector having 16 vertical strips at the front 16 horizontal strips at the back provided the x,y position information of the interacting particle. The ΔE & E were placed on a suitable mount at a relative separation of about 13 mm. Two such telescopes Tel-1 & Tel-2 were set at 15.9 cm from the target on two independent arms of a 1.5m diameter scattering chamber. Here we will be presenting the result of preliminary data analysis for the reactions ^{24}Mg $\rightarrow$ ^{20}Ne + α & ^{20}Ne $\rightarrow$ ^{16}O + α with the detectors set at angles $-36°$ & $36°$ for Tel-1 and Tel-2 respectively. The data was recorded in list mode in a VME based data acquisition system. The trigger was generated if at least one event occurred in one of the telescopes. The SSDs were calibrated using a ^{229}Th α-source.

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Data Analysis & Results

The data was analyzed for the reaction ^{24}Mg $\rightarrow$ ^{20}Ne + α & ^{20}Ne $\rightarrow$ ^{16}O + α. We analyzed the data using proper particle identification timing and energy gates. To capture the reaction channel as mentioned above, one α was detected in each of the two telescopes in coincidence. Events with more than one α detected in same telescope were excluded. Energy of the recoil nuclei were calculated using the principle of conservation of linear momentum. The excitation energies of both ^{20}Ne and ^{16}O were determined and some of the excited states were clearly identified. A correlation spectrum is also plotted in Fig.1 to see any correlation between different excited states of these two nuclei.
The idea was to see which excited states of ^{20}Ne were feeding the excited states of ^{16}O, in order to investigate if the 6-α cluster state of ^{24}Mg was indeed decaying into the 5-α cluster state of ^{20}Ne and successively if the 5-α cluster state of ^{20}Ne was decaying to the 4-α cluster state of ^{16}O. Next, a gate of width $\tilde{1}$.5 MeV around 15.1 MeV excitation energy (Hoyle analog state) of ^{16}O was put and the excitation energy distribution of ^{20}Ne is plotted as shown in Fig.2.

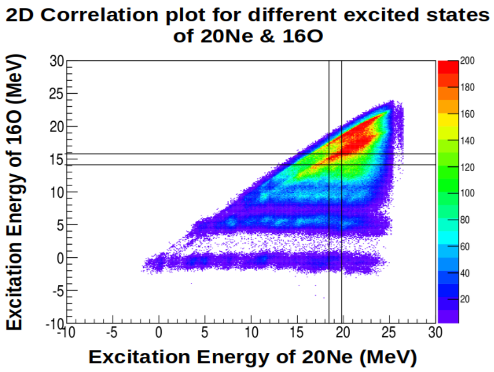

FIG. 1: Correlation plot for excitation energies of ^{16}O and ^{20}Ne.

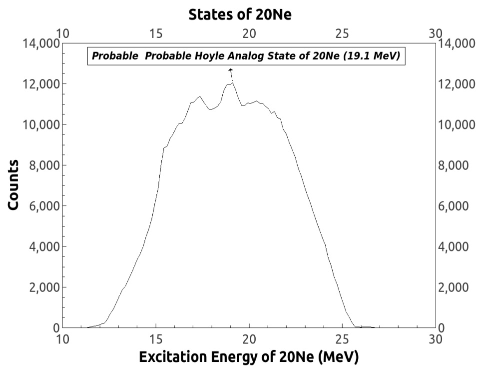

FIG. 2: States of ^{20}Ne which are feeding the Hoyle like state of ^{16}O (15.1 MeV).

The Hoyle analog state of ^{20}Ne is predicted near the 5-α breakup threshold of ^{20}Ne (19.17 MeV). So, a gate of width $\tilde{1}$.5 MeV around 19 MeV excitation energy of ^{20}Ne was put and the excitation energy distribution of ^{16}O is plotted as shown in Fig.3.

From the above plots it is observed that the Hoyle analog state of ^{16}O is correlated with the probable Hoyle analog state of ^{20}Ne. So, it can be inferred that there is a certain probability of decay of α cluster like states into other α clusters, i.e. 6-α cluster of ^{24}Mg decaying into 5-α cluster of ^{20}Ne and further into 4-α cluster of ^{16}O. Although there is an ambiguity in the excitation energy of the Hoyle like state of ^{20}Ne, one can say that the states near the 5-α breakup threshold of ^{20}Ne are feeding the well known Hoyle analog state[3] of ^{16}O.

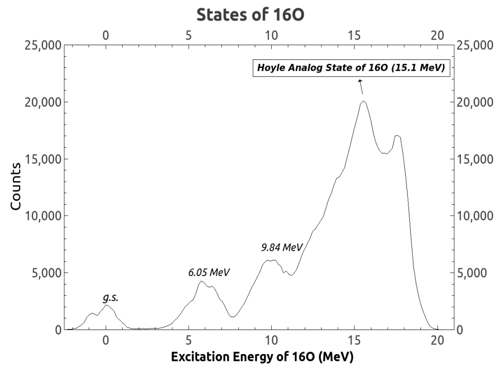

FIG. 3: States of ^{16}O which are fed by the Hoyle like state of ^{20}Ne ($\tilde{1}$9.1 MeV).

Conclusion

Possible correlated Hoyle analog states of ^{20}Ne and ^{16}O were observed in coincidence which implies the existence of sequential decay of α cluster states through α emission. Further investigation is required to find out if the above trend follows down to ^{12}C.

References

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