Search for an Hoyle state analogous state in ^{16}O using the thick target inverse kinematics technique

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Searching for alpha cluster states analogous to the ^{12}C Hoyle state in heavier alpha-conjugate nuclei can provide tests of the existence of alpha condensates in nuclear matter. Such states are predicted for ^{16}O, ^{20}Ne, ^{24}Mg, ^{28}Si etc. at excitation energies slightly above the multi-alpha particle decay threshold [1-3].

The Thick Target Inverse Kinematics (TTIK) [4] technique can be used to study the breakup of excited self-conjugate nuclei into many alpha particles. The reaction ^{20}Ne+α at 12 and 9.7 AMeV was studied at Cyclotron Institute at Texas A&M University. A picture of the experimental setup is shown in Fig. 1. The TTIK method was used to study both single α-particle emission and multiple α-particle decays. The analysis of the three α - particle emission data allowed the identification of the Hoyle state and other ^{12}C excited states decaying into three alpha particles. Some results are reported in ref [5, 6] and compared with other data available in the literature. In this report we update the results of the analysis of the events with alpha multiplicity four. In order to minimize accidentals, only events in which the four

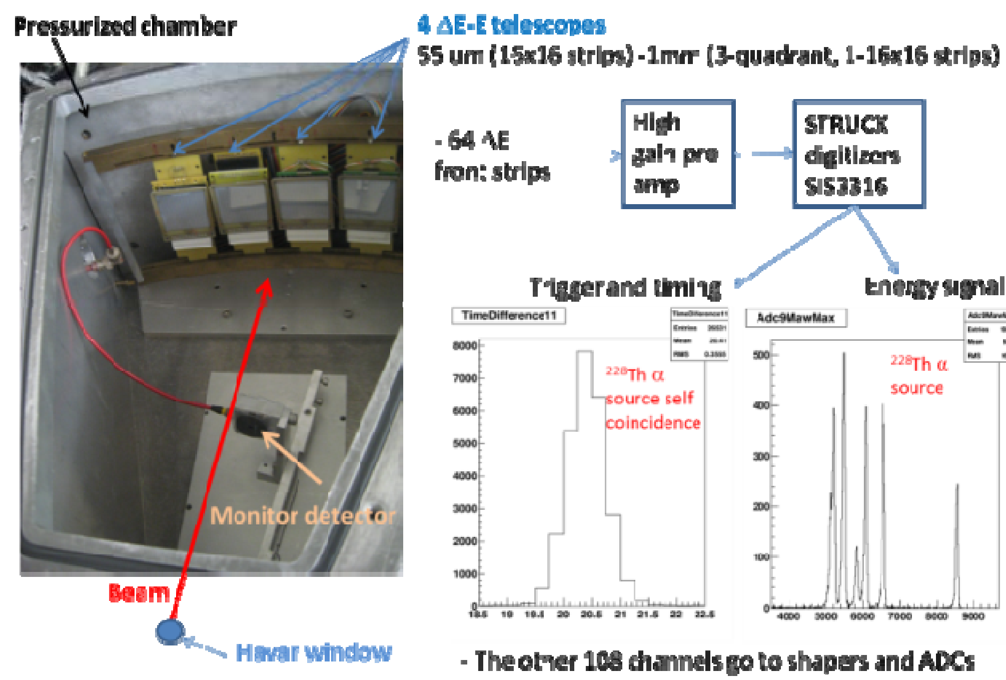

FIG. 1. Experimental setup and scheme of the electronics. Good energy and time resolution are obtained by using the STRUCK digitizers SIS3316.

alpha particles arrive to the detectors in a time window of 30 ns are selected. Due to the very low beam intensity used during this run we estimate one beam particle per beam burst.

The excitation function of ^{16}O is shown in Fig. 2. The left panel shows the result obtained at maximum beam energy of 12A MeV, the right panel shows the excitation function obtained from the experiment performed at maximum beam energy of 9.7A MeV. The two excitation functions in Fig. 2 show an interesting structure at 15.2 MeV, very close to the energy (15.1 MeV) predicted by Funaki *et al*. [8] for a state in ^{16}O with the structure of the "Hoyle" state in ^{12}C coupled to an alpha particle.

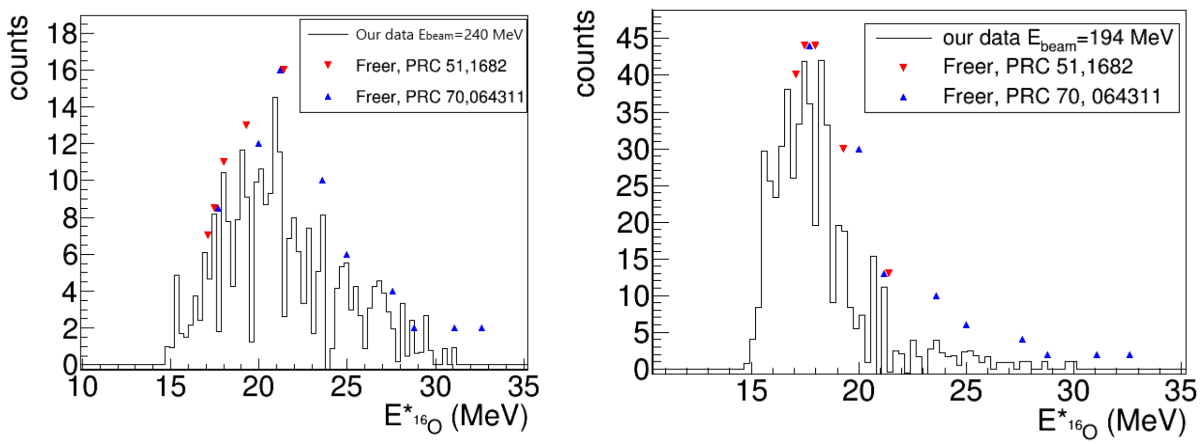

FIG. 2. Left Panel, excitation function at maximum beam energy 240 MeV. Right Panel, excitation function at maximum beam energy 194 MeV. The arrows mark the position of known states in ^{16}O decaying into alpha particles [7,9].

For some of the peaks in the excitation function including the 15.2 MeV, we determined the amount of events decaying into one alpha particle and one ^{12}C in the Hoyle state or two ^{8}Be in the ground state. To do this we considered the six possible combinations of two alpha particles (0-1, 2-3; 0-2, 1-3; 0-3, 1-2), the decay proceeded through two ^{8}Be in the ground state if the relative energies of 0-1 and 2-3 or 0-2 and 1-3 or 0-3 and 1-2 were less than 250 keV.

In the same way we considered the four possible combinations of three alpha particles 0-1-2, 0-1-3, 0-2-3, 1-2-3 and checked if the decay proceeded through the ^{12}C Hoyle state. In this case the sum of the kinetic energies of the three alpha particles in their center of mass should be less than 500 keV or 600 keV for the events in the higher energy states. The relative partial decay widths R were calculated as:

$$R = \frac{\Gamma(^{8}Be + {}^{8}Be)}{\Gamma(\alpha + {}^{12}C(0_2^+))} = \frac{Yield(^{8}Be + {}^{8}Be)}{Yield(\alpha + {}^{12}C(0_2^+))}$$

Monte Carlo simulations showed that the detection efficiency for the two decay modes is the same to within a few percent. The results are shown in Table I and compared with data from Freer et al. [13]. The ratios R for the states at 17, 19 and 21 MeV agree quite well with those measured by Freer et al. The peak at 15.2 MeV shows the same decay probability into two ^{8}Be ground states or α+ ^{12}C Hoyle state.

This might indicate that the state has the same characteristics of the ^{8}Be ground state and ^{12}C Hoyle state. A paper with the final results has been submitted to Physical Review C.

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Table I. Relative partial decay widths.

Energy	Γ(Be)/ Γ(Hoyle) this work, max beam energy 240 MeV	Γ(Be)/ Γ(Hoyle) this work, max beam energy 194 MeV	Γ(Be)/ Γ(Hoyle) Freer et al. [13]
15.2±0.2	1±0.7	0.96 ± 0.3	
17.1	0.6±0.3	0.7 ± 0.3	0.65 ± 0.16
17.5		0.6 ± 0.3	0.72± 0.18
19.7	0.43±0.2	0.6 ± 0.5	0.47± 0.15
21.4	5.3±2.8	3 ± 1	>3± 1.1

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