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 AMeV was studied at Cyclotron Institute at Texas A&M University. A picture of the experimental setup is shown in Fig. 1.

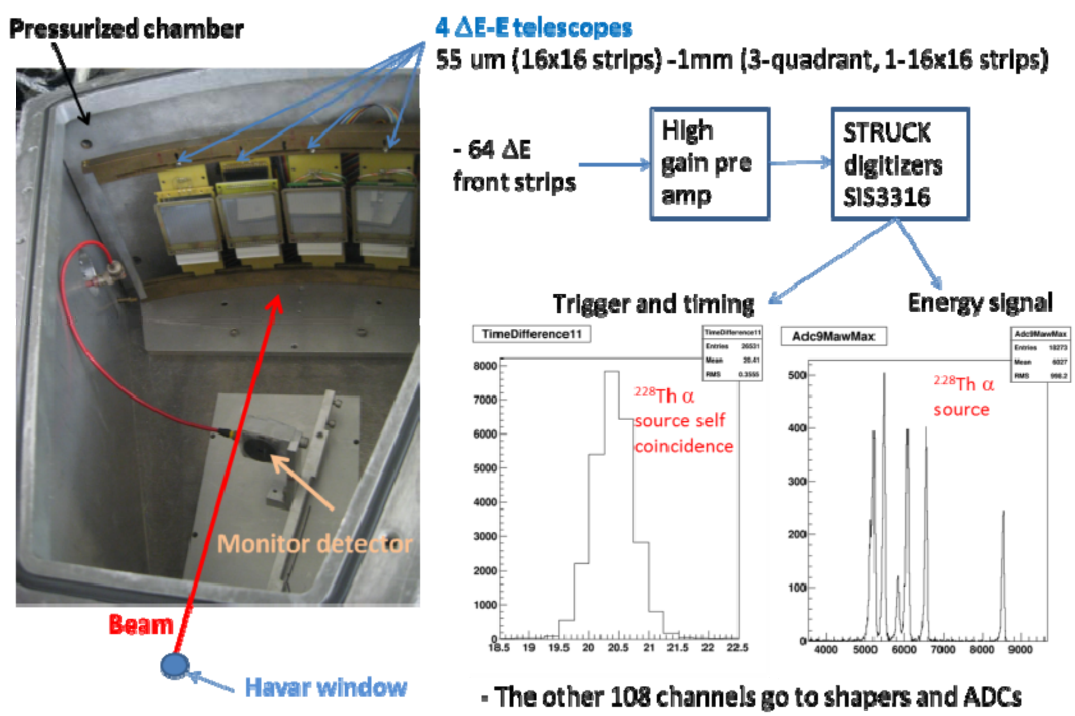

FIG. 1. Experimental setup and scheme of the electronics. Good energy and time resolution are obtained by using the STRUCK digitizers SIS3316.

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 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. To eliminate events that erroneously appear as multiplicity four, but are indeed lower multiplicity, we required that if more one alpha particle is detected in a given telescope, they should be detected by different quadrants in the E detectors. With this additional condition in the event selection the number of events with multiplicity four is reduced.

Two reconstruction algorithms are used to determin the position of the interaction point. One is based on a recursive procedure using the reaction kinematics, energy and momentum conservation. This reconstruction is based on the assumption of having, in the exit channel, ^{8}Be in the ground state (undetected) and ^{16}O (with enough excitation energy to decay into 4 alpha particles). The other is based on the average time of flight of the four alpha particles.

The excitation function of ^{16}O is shown in Fig. 2. The left panel shows the result obtained with the first reconstruction method, the right panel shows the excitation function obtained with the reconstruction based on the time of flight. The two excitation functions in Fig. 2 are qualitatively similar. Funaki *et al.* [8] predicted a state in ^{16}O at 15.1 MeV (the state) with the structure of the "Hoyle" state in ^{12}C coupled to an alpha particle. Our excitation function shows few events at about 15 MeV, but the statistics is too low to make any claim.

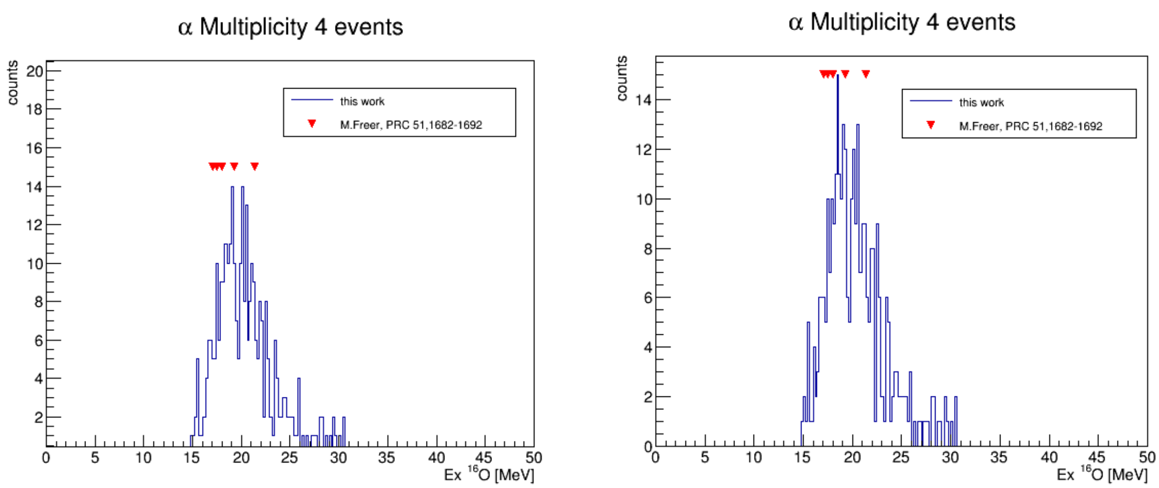

FIG. 2. Reconstructed excitation energy of ^{16}O obtained from the events with multiplicity 4. The arrows mark the position of known states in ^{16}O decaying into alpha particles [7].

[1] K. Ikeda, N. Takigawa, and H. Horiuchi, Prog. Theor, Phys. Suppl. Extra Number, 464 (1968).

[2] W. von Oertzen, M. Freer, and Y. Kanada-Enýo, Phys. Rep. **432**, 43 (2006).

[3] C. Beck, J. Phys. Conference Series **436**, 012014 (2013).

[4] K. Artemov *et al.*, Sov. J. Nucl. Phys. **52**, 406 (1990).

[5] M. Barbui *et al.*, Eur. Phys. J. Web of Conferences **66**, 03005 (2014).

[6] M. Barbui *et al.*, Eur. Phys. J. Web of Conferences **117**, 07013 (2016).

[7] M. Freer *et al.*, Phys Rev C **51**,1682

[8] Y. Funaki *et al.*, Phys. Rev. Lett. **101**, 082502 (2008).