Candidate for a state analogous the Hoyle state observed in ^{16}O at about 15 MeV excitation energy 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 successfully used to study the breakup of excited self-conjugate nuclei into many alpha particles. The reaction ^{20}Ne+α at 10 and 12 AMeV was studied at Cyclotron Institute at Texas A&M University. A picture of the experimental setup is shown in Fig. 1.

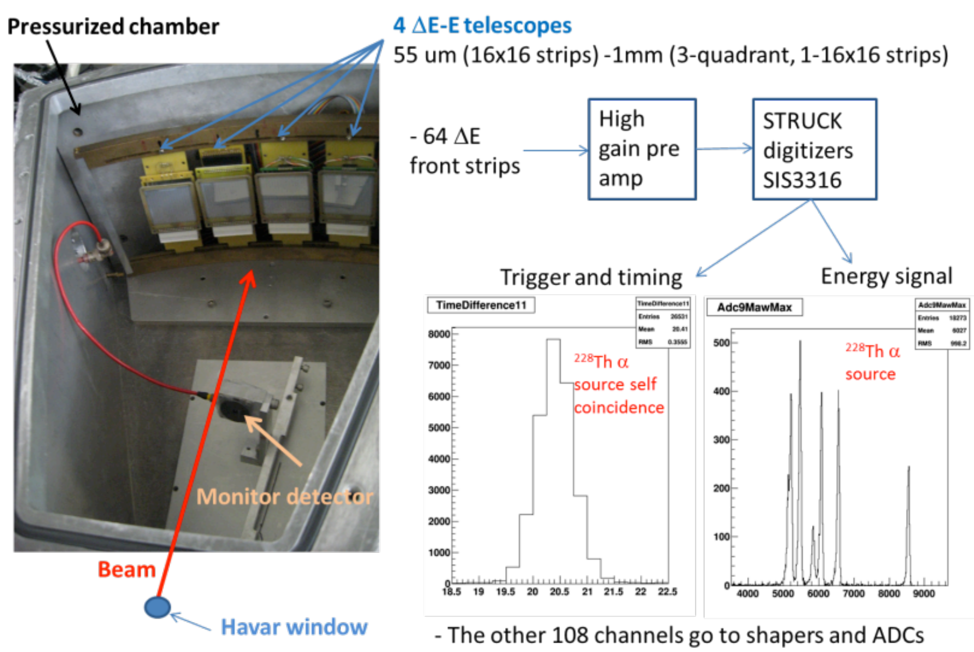

FIG. 1. Experimental setup and scheme of the electronics. Good energy and time resolution are obtained by using the STRUCK digitizers SIS3316.

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 summarize the results obtained from the analysis of the events with alpha multiplicity four. In order to minimize the contribution due to accidentals, only events in which the four alpha particles arrive to the detectors in a time window of 15 ns are selected. Due to the very low beam intensity used during this run we estimate one beam particle per beam burst.

The reconstruction of the position of the interaction point for alpha multiplicity four events is based on a recursive procedure using the reaction kinematics, energy and momentum conservation. This reconstruction is based on the assumption tof 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 preliminary analysis of these events shows very promising results.

Fig. 2 shows the reconstructed excitation function of ^{16}O. The peak at around 15 MeV is a good candidate for Hoyle state analogous in ^{16}O; the other peaks correspond to known states in ^{16}O.

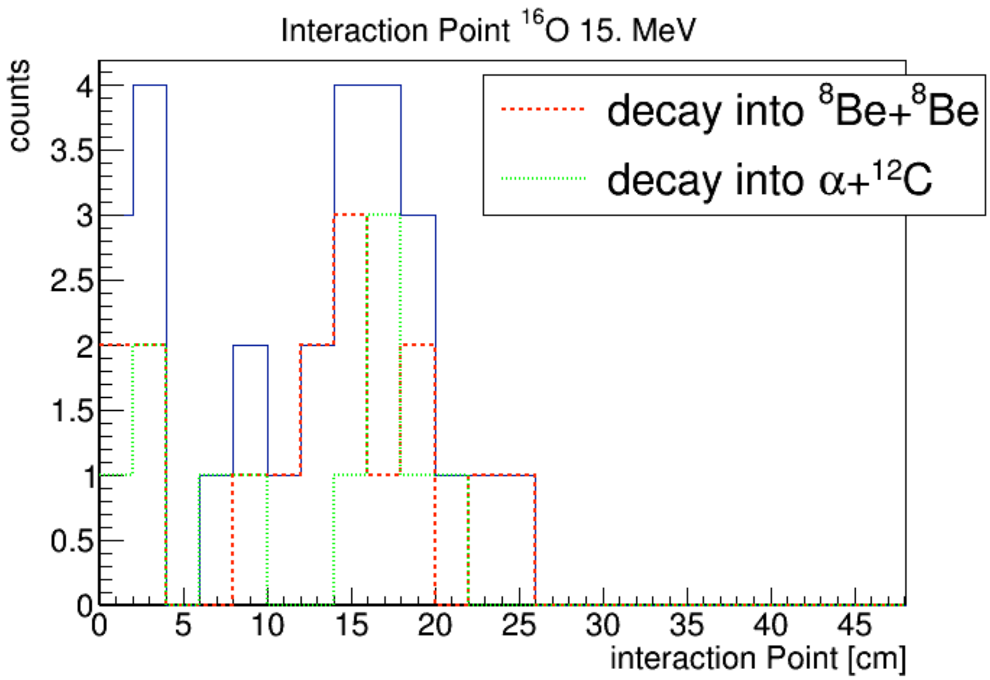

FIG. 2. Reconstructed excitation energy of ^{16}O obtained from the events with multiplicity 4. The arrows mark the position of known states in ^{16}O decaying into alpha particles [7,8].

Funaki *et al.* [9] 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 peak is very close to this prediction. Kokalova *et al.* suggest that the signature for multi-alpha condensed states would be the decay of the excited system into pieces that are condensates themselves, ie. ^{8}Be$_{gs}$, ^{12}C$_{Hoyle}$, etc.[10]. A total of 33 events were found in the 15 MeV peak. We further analyzed these events to determine wether they decay by two ^{8}Be in the ground state or an alpha-particle and a ^{12}C in the Hoyle state. The events decaying into two ^{8}Be were identified looking for two couples of alpha particles with relative energy less than 180 keV. The events decaying with one alpha and a ^{12}C only have one couple of alpha particles with relative energy less than 180keV. 17 events were found to decay into two ^{8}Be and 16 events into alpha plus ^{12}C in the Hoyle state. A monte carlo simulation of the two decay modes shows that the detection efficiency of our experimental setup is 45% for the first case and 40% for the latter. This indicates that within the experimental errors the events in the 15 MeV peak equally decay into the two possible decay branches. According to ref. [10] this is a signature for an alpha condensate state.

The position of the reconstructed interaction point for the events in the 15 MeV peak is reported in Fig. 3.

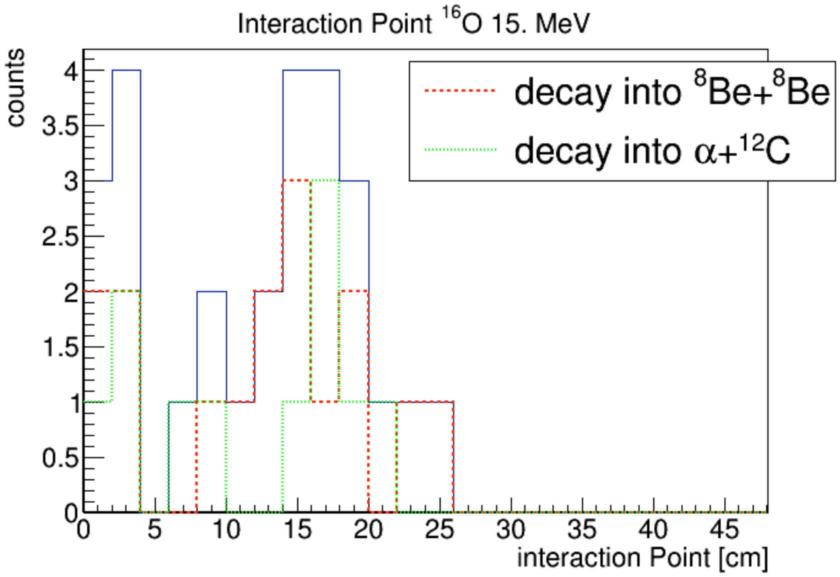

FIG. 3. Reconstructed interaction point for events in the 15MeV peak. Blue solid line: all events; red dotted line: events decaying into two ^{8}Be; green line: events decaying into alpha plus ^{12}C Hoyle state.

The left panel in Fig. 4 shows the reconstructed position of the interaction point as a function of the measured kinetic energy of the ^{16}O, after energy loss correction. The right panel shows the kinetic energy of the undetected ^{8}Be as a function of the kinetic energy of the ^{16}O at the interaction point. It is

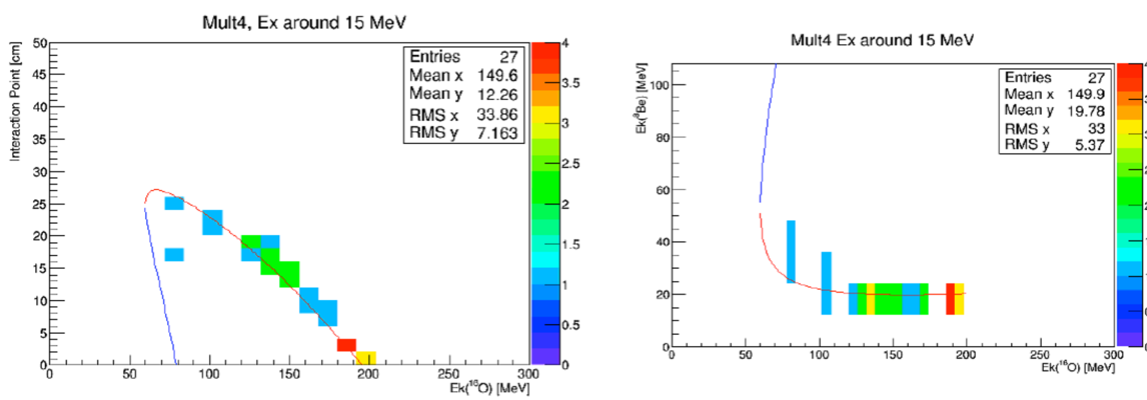

FIG. 4. Events in the 15 MeV peak. Left panel: reconstructed interaction point versus kinetic energy of the decaying ^{16}O after energy loss correction. Right panel: Calculated kinetic energy of the undetected ^{8}Be as a function of the kinetic energy of the ^{16}O. In both panels, the lines show the corresponding kinematic calculation.

clear from this picture that the energy of the two alphas from the undetected ^{8}Be would be too low to be identified in the telescopes with the deltaE-E technique.

The data analysis is still in progress to finalize the result. Higher statistics is necessary to reduce the statistical error.

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