

Exploring the structure of ^{12}C using the thick target inverse kinematics technique

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The reaction ^{20}Ne on α was studied using the Thick Target Inverse Kinematics (TTIK) technique [1]. This technique allows the exploration of a large range of incident energies in the same experiment. Moreover, in inverse kinematics, the reaction products are focused at forward angles and can be detected with detectors covering a relatively small portion of the solid angle in the forward direction.

A ^{20}Ne beam of energy 11 AMeV was delivered by the K150 cyclotron at Texas A&M University. The effective beam energy after the entrance window was 9.7 AMeV. The reaction chamber was filled with ^4He gas at a pressure sufficient to stop the beam at few centimeters from the detectors (3800 mbar). In this way we could detect light particles emitted at zero degrees. The energy of the light reaction products was measured by three silicon detector telescopes placed at a radial distance of 48 cm from the entrance window. Each telescope consisted of two $5 \times 5 \text{ cm}^2$ Micron Semiconductors DC quadrant detectors (Design G). The time of flight of the detected particles was also measured relative to the cyclotron radiofrequency. A monitor detector was used to measure the intensity of the incident beam. The details of the experimental setup are given in [2].

According to the Ikeda picture [3] ^{24}Mg can be described as $^{20}\text{Ne} + \alpha$, $^{16}\text{O} + 2\alpha$, $^{12}\text{C} + 3\alpha$ or a cluster of 6 α particles. Each configuration is expected to be observable at excitation energies around the corresponding threshold values. The preliminary results from the analysis of the events with alpha multiplicity one and two are shown in [2]. Here we focus on the analysis of the events with alpha multiplicity three. Alpha multiplicity one and two events show interesting resonant structures when looking at events where the alpha particles are emitted at angles near zero degrees. Therefore, considering the events with alpha multiplicity three, first we analyzed the events where three alpha particles are detected in the telescope centered at 1.5 degrees.

The left panel of Fig. 1 shows the sum of the energies of the three alpha particles detected in the

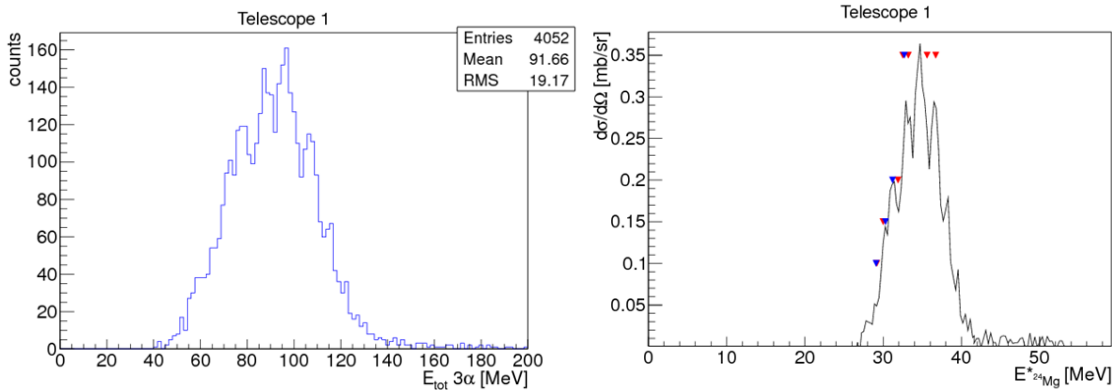


FIG. 1. Left panel: Sum of the energy of the 3 alpha particles with subtraction of the uncorrelated event spectrum obtained summing the energies of three alpha particles from different events. Right panel: Reconstructed excitation energy of ^{24}Mg assuming that the excited magnesium is decaying into two carbons one in the ground state, the other with enough excitation energy to split in three alphas. The blue and red triangles show the excitation energies of ^{24}Mg decaying into two ^{12}C as found in refs. [4,5] respectively.

central telescope, after subtraction of the uncorrelated events. This spectrum is obtained from the measured energies without any energy loss correction. It is interesting to note that the total energy spectrum shows a series of peaks. We can interpret those peaks as resonant states in ^{24}Mg decaying into two ^{12}C , one in the ground state, the other with enough excitation energy to split in three alphas. With this assumption we can reconstruct the interaction point position using the reaction kinematics and the energy and momentum conservation in a recursive procedure. The result is shown in the right panel of Fig. 1 and compared with the data in refs [4, 5]. The excitation energy of the ^{12}C splitting into 3 alpha particles is obtained from the sum of the kinetic energies of the 3 alpha particles in the center of mass of the ^{12}C and the Q value. The result is shown in the left panel of Fig. 2, together with the spectrum of the uncorrelated events obtained by randomly mixing three alpha particle energies from different events. The spectra in Fig. 2 show two peaks one at 7.65 MeV corresponding to the energy of the Hoyle state and one at 9.64 MeV corresponding to a (3^-) state. In order to determine if the decay is proceeding through the

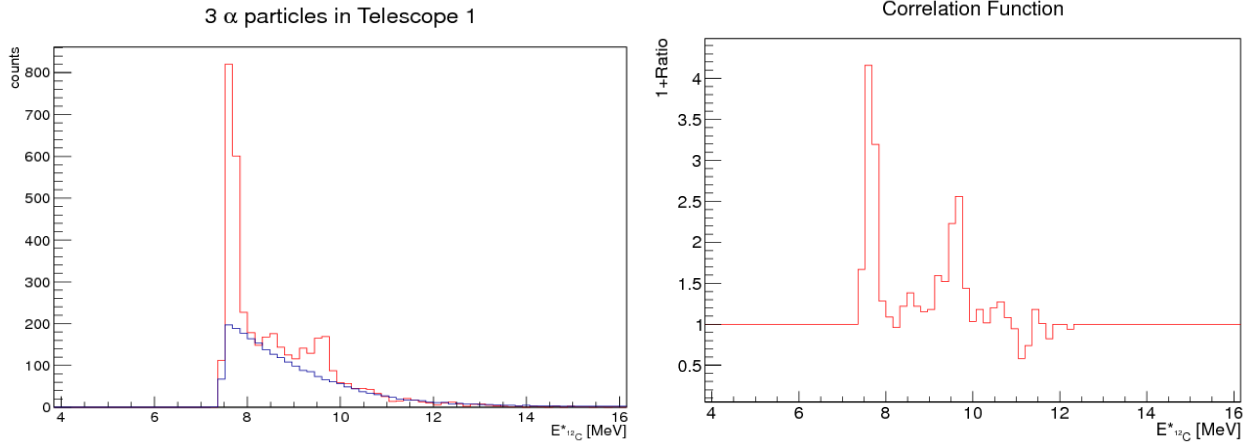


FIG. 2. Left panel: (Red line) excitation energy of ^{12}C splitting into 3 alpha particles, (Blue line) spectrum of uncorrelated events obtained by mixing three alpha particles from different events. Right panel: Correlation function obtained by dividing the two spectra in the right panel.

ground state of ^8Be we calculated event by event the relative energy of the three possible couples of alpha particle. The minimum two alphas relative energy spectrum is shown in Fig.3 for the Hoyle state and the (3^-) state. The two spectra in Fig.3 show a clear peak around 100 keV, corresponding to the separation

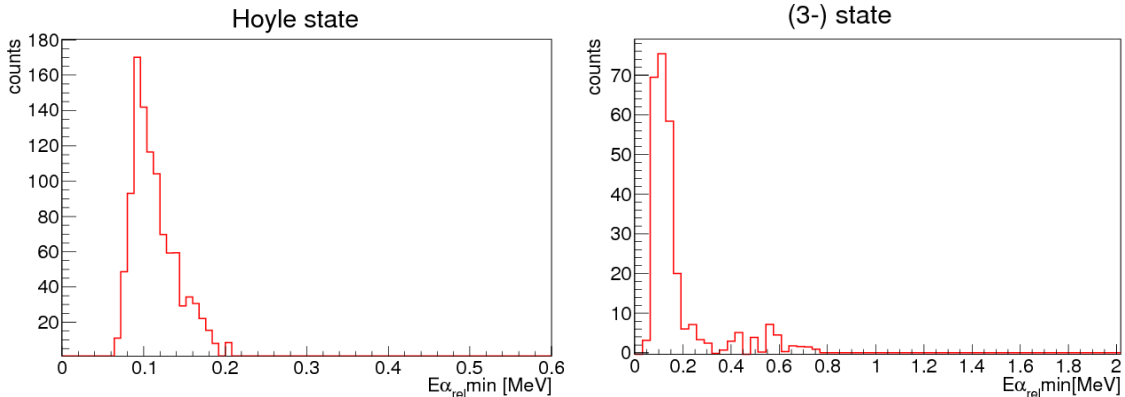


FIG. 3. Left panel: minimum relative energy of two alpha particles for the Hoyle state, with subtraction of the uncorrelated events. Right panel: minimum relative energy of two alpha particles for the (3^-) state, with subtraction of the uncorrelated events.

energy of ${}^8\text{Be}$. The Dalitz plots for the Hoyle state and the (3^-) state are also presented in Fig.4. Those plots confirm the decay of the two states through the ${}^8\text{Be}$ ground state.

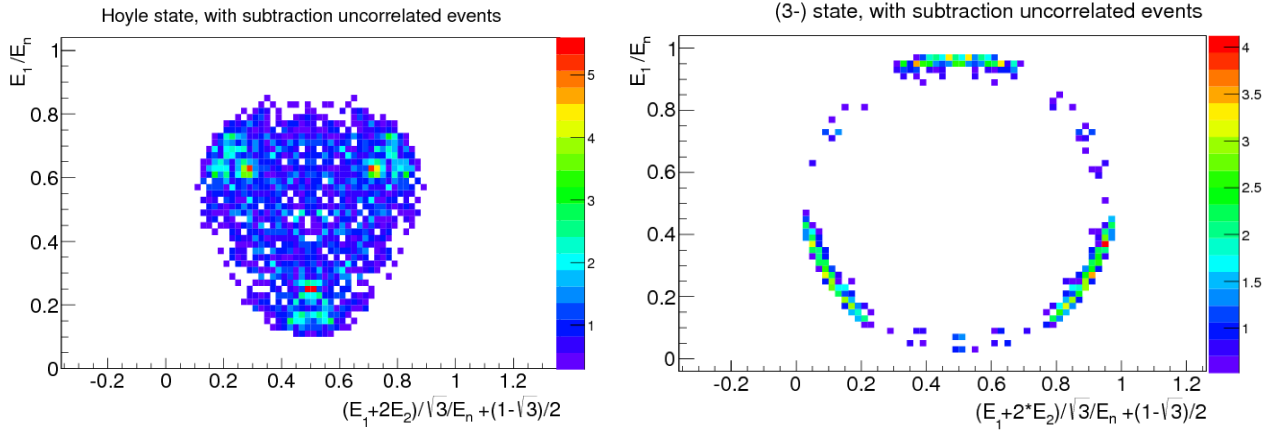


FIG. 4. Dalitz plots of the Hoyle state (left panel) and (3^-) state (right panel). The uncorrelated events are subtracted.

From the data in Figs. 3 and 4 we can conclude that the Hoyle state almost completely decays through the ground state of ${}^8\text{Be}$, and upper limit of less than 1% can be set for the direct decay into three alpha particles; the (3^-) state mostly decays through the ${}^8\text{Be}$ ground state, a few percent of the events are not decaying through the ${}^8\text{Be}$ ground state, as known from the literature.

During this run we did not observe any direct decay of ${}^{24}\text{Mg}$ into six alpha particles. We are planning a new experiment with an improved experimental setup with larger granularity and better efficiency to investigate the decay of self-conjugate nuclei in n-alpha particles.

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