^{2}He emission from an excited state of ^{6}Be

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The decay of an excited state of the ^{6}Be nucleus has been studied. In ~25% of the cases, the decay occurs through ^{2}He emission.

The mechanism proposed by Gol'danskiĭ[1] for the decay of specific nuclear states through the emission of a diproton (^{2}He) has stimulated several experiments. Recent studies[2,3] of the decay of excited states of ^{22}Mg and ^{26}Si, populated through β decay, yielded negative results. The decay was found to occur through the sequential emission

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of protons through several intermediate states. A study[4] of the two-proton decay of the 0^+ ground state of ^{6}Be does not lead to a definite conclusion regarding the possible emission of ^{2}He. In the present letter we report the first indication of a significant role of ^{2}He emission in the decay of an excited state of ^{6}Be ($J^\pi = 2^+$, $E^* = 1.67$ MeV, $\Gamma = 1.16$ MeV).

The experimental procedure is basically the same as in Ref. 4. The ^{6}Be nuclei are produced in the reaction $^6\mathrm{Li}(^3\mathrm{He},t)^6\mathrm{Be}$ at a ^{3}He ion energy of 38.7 MeV. The α particles produced in the decay of the ^{6}Be are detected at an angle of 25.4° in coincidence with tritium nuclei ($\theta_t = -91.6°$), whose spectrum has two clearly defined peaks which characterize the production of ^{6}Be in 0^+ and 2^+ states. By selecting events corresponding to the central parts of these peaks, we singled out the spectra of decaying α particles. The solid angles of the detectors were reduced substantially (to 2×10^{-4} sr) in comparison with the values in the earlier measurements,[4] and the threshold for the detection of the α particles was lowered to 8 MeV. The resulting spectrum of α particles produced in the decay of the ^{6}Be ground state agrees within the experimental errors with that from the earlier studies.

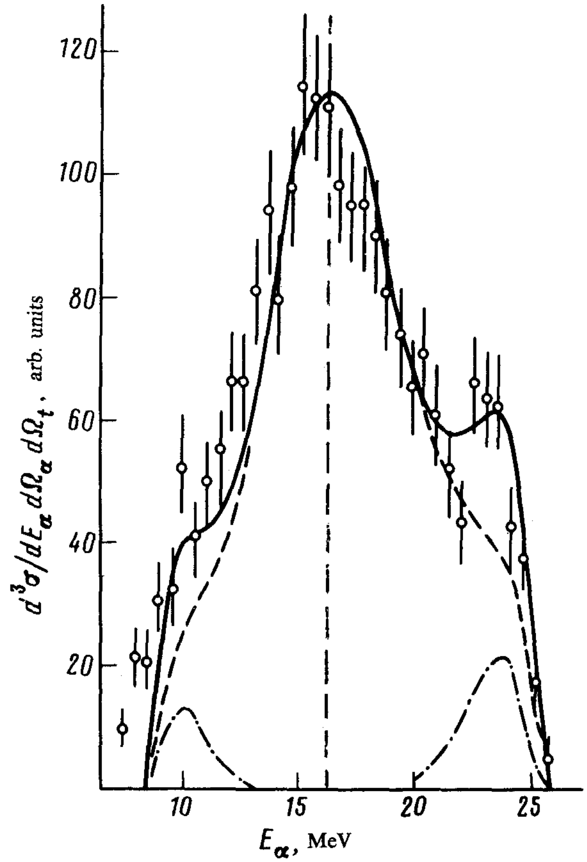

FIG. 1. Spectrum of α particles from the decay of ^{6}Be(2^+) (laboratory frame of reference).

Figure 1 shows the spectrum of α particles from the decay of the excited state of ^{6}Be in the laboratory frame of reference. The vertical dashed line shows the energy corresponding to the minimum velocity of the α particles in the rest frame of the beryllium at the excitation energy $E^* = 1.67$ MeV (a zero velocity is not reached because the ^{6}Be nuclei are emitted at an angle of 24.9°, i.e., not directly toward the α detector). To the left of this dashed line, the emission of α particles occurs in the direction opposite the motion of the ^{6}Be, while to the right of this line the emission occurs into the forward hemisphere. The shape of the parts of the spectrum to the left and right of the dashed line should be qualitatively the same; a quantitative difference is attributed to the particular kinematics of the reaction.

It can be seen from this figure that the α yield is greatest near the center of the spectrum, because of a kinematic intensification. We also see a peak at ~ 23 MeV, where we would expect to see evidence of the emission of ^{2}He. The corresponding peak on the left side of the spectrum should be less pronounced because of kinematic effects.

The role played by a sequential decay through an intermediate ^{5}Li nucleus can be evaluated with the help of the R-matrix theory for the cascade.[5] The expression for the probability amplitude for the decay includes a resonant Breit-Wigner factor, corresponding to the ^{5}Li compound nucleus, and (because of the large width of the 2^+ level of ^{6}Be) an analogous resonant factor for this level. Furthermore, the expression for the decay probability should include the sum of products of spherical harmonics and the coefficients for combining vectors. For simplicity, we first ignore the dependence on this sum. The identical nature of the emitted protons is taken into account in the expression for the amplitude for the process. The distribution $d^3\sigma / dE_\alpha^{\text{c.m.}} d\Omega_\alpha^{\text{c.m.}} dE^*$ calculated for the rest frame of beryllium (the center-of-mass frame) is converted into the spectrum $d^3\sigma / dE_\alpha d\Omega_\alpha \times dE_t$ in the laboratory frame, which is then projected onto the E_α axis. In the transformation from the c.m. frame to the laboratory frame we use the Monte Carlo method to calculate the finite dimensions of the detectors and of the beam at the target. The final result is shown by the dashed line Fig. 1. We see that the calculation gives a good description of the central region, but it does not reproduce the peak at ~ 23 MeV.

We have attempted to describe the remainder of the spectrum under the assumption that a diproton is emitted. The decay probability is then proportional to the square of the wave function of the relative motion of the protons, multiplied by the penetrability factor for the ^{2}He-^{4}He system and by the resonant Breit-Wigner factor corresponding to the 2^+ state of the ^{6}Be nucleus. The dot-dashed line in Fig. 1 shows the distribution in the laboratory frame found by the method described in the preceding paragraph. The solid line shows the sum of the contributions of the processes under consideration, found by a least-squares fit of the experimental data (the adjustable parameters are the branching ratios for these two channels and the total yield of α particles). We see that the entire experimental spectrum can be reproduced well when we allow for the possible emission of ^{2}He.

We have thus obtained the first evidence for the emission of ^{2}He; this event corresponds to $25 \pm 6\%$ of the cases of the decay of ^{6}Be(2^+).

The same model-based approach is not as successful in describing the data on the decay of the ^{6}Be ground state.[4] One possible explanation is that while the emission of the proton from the excited level occurs with $Q \sim 1$ MeV, the ground state in fact lies 0.59 MeV below the ^{5}Li level. Although a sequential emission is possible in this case because of the large width of ^{5}Li ($\Gamma = 1.5$ MeV), it may be quite arbitrary to distinguish between the sequential emission and the simultaneous emission of the protons. This question requires further study.

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