^{8}Be and ^{9}B nuclei in dissociation of relativistic ^{10}B and ^{11}C nuclei

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^{8}Be and ^{9}B nuclei in dissociation of relativistic ^{10}B and ^{11}C nuclei

D A Artemenkov[1,2], V Bradnova[1], E Firu[3], N K Kornegrutsa[1], M Haiduc[3], K Z Mamatkulov[1], R R Kattabekov[1], A Neagu[3], P A Rukoyatkin[1], V V Rusakova[1], R Stanoeva[4], A A Zaitsev[1,5], P I Zarubin[1,5,6] and I G Zarubina[1,5]

[1] Joint Institute for Nuclear Research, Dubna, Russia
[2] National Research Nuclear University MEPhI (Moscow Engineering Physics Institute), Kashirskoe highway 31, Moscow, 115409, Russia
[3] Institute of Space Science, Magurele, Romania
[4] South-Western University, Blagoevgrad, Bulgaria
[5] P. N. Lebedev Physical Institute of the Russian Academy of Sciences, Moscow, Russia

E-mail: zarubin@lhe.jinr.ru

Abstract. Progress in the study of nuclear clustering in the relativistic ^{10}B and ^{11}C nuclei dissociation in nuclear track emulsion is presented. The contribution of the unbound ^{8}Be and ^{9}B nuclei to their structure is determined on the basis of measurements of the emission angles of relativistic He and H fragments.

1. Introduction

Nuclear track emulsion (NTE) is exposed at the JINR Nuclotron to relativistic nuclei ^{7,9}Be, ^{8,10}B, ^{10,11}C and ^{12}N for the experimental study of the evolution of the cluster structure of light nuclei [reviewed in ref. [1], [2]]. Virtual cluster configurations in an incident nucleus are completely captured in coherent dissociation in which the target nucleus is not destroyed visibly ("white"stars, an example in figure 1). Therefore, the contributions of cluster states to the structure of the nucleus in question can be estimated by the probability of appearance of respective fragment ensembles. The nuclei ^{7}Be, ^{8}Be in the ground (^{8}Be$_{g.s.}$) and first excited states (^{8}Be$_{2+}$), as well as the ^{9}B may serve as a basis for the neighboring nuclei contributing to them with particular probabilities. Verification of this concept can be carried out on the sequence of the nuclei ^{9}Be, ^{10}B, ^{10,11}C and ^{12}N.

Reconstruction of the decays of relativistic ^{8}Be and ^{9}B nuclei is possible by the energy variable Q = M* - M, where $M^{*2} = (\Sigma P_j)^2 = \Sigma(P_i \cdot P_k)$, M the total mass of fragments, and their $P_{i,k}$ 4-momenta defined under the assumption of conservation of an initial momentum per nucleon by fragments. For the "white"stars of ^{9}Be and ^{10}C nuclei the assumption that He fragments correspond to ^{4}He, and H ones in ^{10}C – ^{1}He is justified. Then ^{8}Be and ^{9}B identification is reduced to measurements the opening angles of between the directions of fragment emission.

Distributions over the opening angle Θ_{2He} for pairs of He fragments of "white"stars ^{9}Be→2He and ^{10}C → 2He + 2H (82% of the ^{10}C statistics) produced at energy of 1.2 A GeV are presented

[6] To whom any correspondence should be addressed.

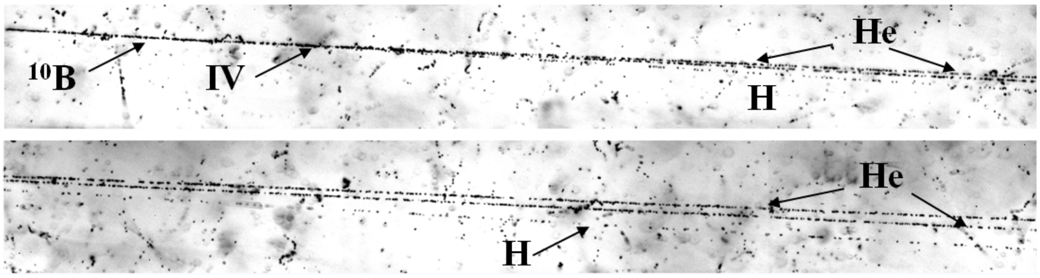

Figure 1. Macro photo of the coherent dissociation event ("white"star) of 1 A GeV ^{10}B nucleus into He nucleus pair and single H nucleus; IV - approximate position of the dissociation vertex ($\Theta_{2\alpha}$ = 5.3 mrad, $Q_{2\alpha}$ = 87 keV, $Q_{2\alpha p}$ = 352 keV)

in figure 2. In both cases the values of Θ_{2He} of 75-80% of the pairs are distributed about equally in the intervals of $0 < \Theta_{n(arrow)} < 10.5$ mrad and $15.0 < \Theta_{w(ide)} < 45.0$ mrad. The remaining pairs are attributed to a "medium"$10.5 < \Theta_m < 15.0$ and "widest"of $15.0 < \Theta_{vw} < 45.0$ intervals. The Q distribution directly connected with Θ_{2He} point out that "narrow"pairs of Θ_n are produced via ^{8}Be$_{g.s.}$ while pairs Θ_w via ^{8}Be$_{2+}$. There is a peak in the interval Θ_m reflecting the level 5/2- (2.43 MeV) of ^{9}Be. Fractions of events in the intervals Θ_n and Θ_w are equal to 0.56 ± 0.04 and 0.44 ± 0.04 for ^{9}Be, while for ^{10}C 0.49 ± 0.06 and 0.51 ± 0.06, i. e. they practically coincide. They indicate to a simultaneous presence of virtual ^{8}Be$_{g.s.}$ and ^{8}Be$_{2+}$ states in the ground states of the ^{9}Be and ^{10}C nuclei. Earlier, basing on the $Q_{2\alpha}$ energy distribution of the triples $2\alpha + p$ from the "white"stars $^{10}C \rightarrow 2\alpha + 2p$ it was concluded that in the structure of the ^{10}C nucleus the core ^{9}B is manifested with a probability of around (30 ± 4)%, and the ^{8}Be$_{g.s.}$ decays are arise only through the ^{9}B decays. These conclusions allow one to interpret a significant fraction of "white"stars produced by ^{11}C and ^{10}B nuclei only on the basis of angular measurements.

2. Dissociation of relativistic ^{11}C nuclei

It is already established that 144 "white"stars produced by the ^{11}C in NTE are distributed over the charge channels in the following way: 2He + 2H (50%), 3He (17%), ^{7}Be + He (13%), He + 4H (11%), B+H (5%), Li + He + H (3%), 6H (2%). The distributions of He fragments over the opening angle Θ_{2He} (Figure 3) show that ^{8}Be$_{g.s.}$ decays are presented in 21% 2He + 2H and 19% in the 3He events. These distributions allow one to assume a strong contribution of ^{8}Be$_{2+}$ decays but it is a subject of future consideration.

The ^{9}B nucleus can exist in ^{11}C as an independent virtual component or as a component of a virtual basis ^{10}B. Decays ^{9}B$_{g.s.}$ in "white"stars $^{10}C \rightarrow$ 2He + 2H are identified in accordance with a limitation on the opening angle between directions of ^{8}Be$_{g.s.}$ and each H fragments $\Theta(^8$Be$_{g.s.}$ + H) < 40 mrad (figure 4) [3]. Application of such a condition the "white"stars $^{11}C \rightarrow$ 2He + 2H allows one to identify 20 ^{9}B$_{g.s.}$ decays (figure 4) constituting 30% of events in this charge channel or 18% of the ^{11}C "white"stars.

3. Dissociation of relativistic ^{10}B nuclei

An analysis of the NTE exposure to 1 A GeV ^{10}B nuclei has pointed out that triples 2He + H (about 65%) dominate among "white"stars. However, the nature of this effect has not been studied, being in the "shadow"of studies with radioactive nuclei. In connection with the discussed analysis the balance should be established of probabilities of ^{10}B coherent dissociation via decays ^{8}Be$_{g.s.}$, ^{8}Be$_{2+}$ and ^{9}B. Recently, 250 2He + H "white"stars are selected in an

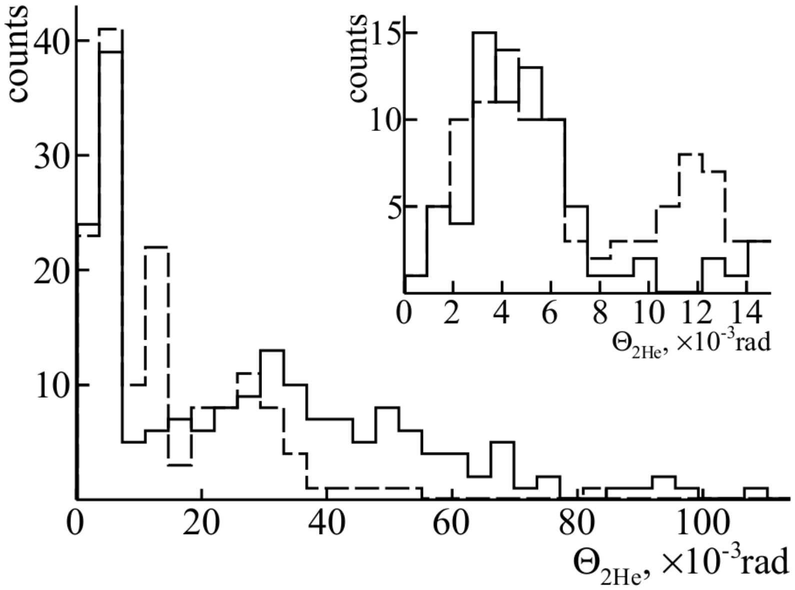

Figure 2. Distributions over the opening angle Θ_{2He} of α-particle pairs in "white"stars $^{10}C \rightarrow 2He + 2H$ (solid histogram) and $^{9}Be \rightarrow 2He$ (dashed histogram) at 1.2 A GeV; insertion part of the distribution in an interval Θ_n

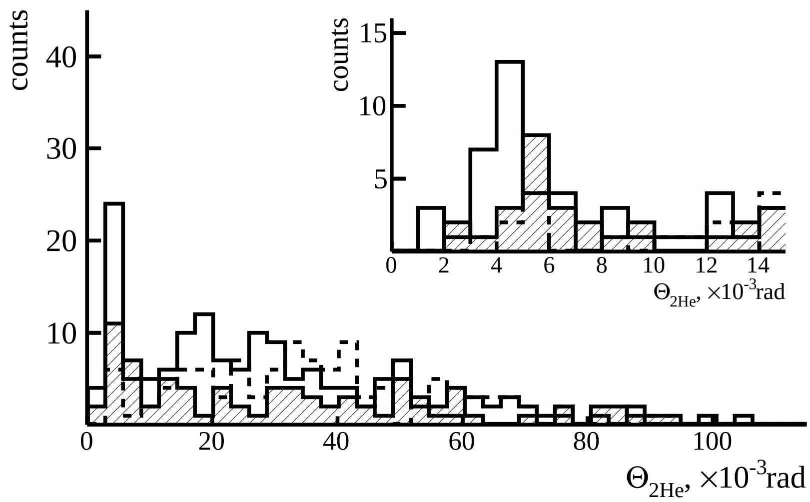

Figure 3. Distribution over the opening angle Θ_{2He} of α-particle pairs in "white"stars $^{11}C \rightarrow 2He + 2H$ (solid histogram), $^{11}C \rightarrow 3He$ (dashed histogram) at 1.2 A GeV and $^{10}B \rightarrow 2He + H$ (hatched histogram) at 1 A GeV; insertion part of the distribution in interval Θ_n.

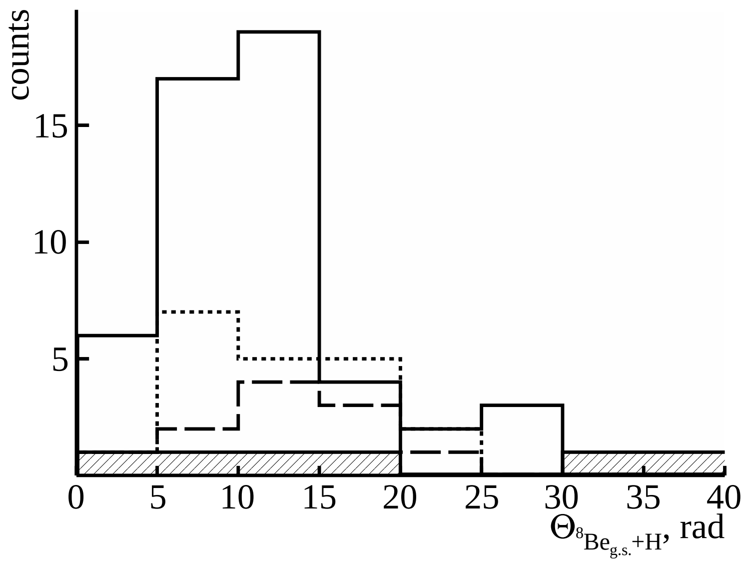

Figure 4. Distributions over the opening angle $\Theta(^8\mathrm{Be}_{g.s.}$ + H) in "white"stars ^{10}C → $^8\mathrm{Be}_{g.s.}$ + 2H (solid histogram), ^{11}C → $^8\mathrm{Be}_{g.s.}$ + 2H (dashed histogram), ^{10}B → $^8\mathrm{Be}_{g.s.}$ + H (hatched histogram) all found stars ^{11}C → $^8\mathrm{Be}_{g.s.}$ + 2H (dotted histogram)

accelerated search. Measurements of the first 84 stars pointed to four decays $^8\mathrm{Be}_{g.s.}$ (figure 3), six of which originated from $^9\mathrm{B}_{g.s.}$ decays (figure 4). Perhaps, decays $^9\mathrm{B}_{g.s.}$ will be the main source decays $^8\mathrm{Be}_{g.s.}$ in ^{10}B "white"stars as in the ^{10,11}C cases. Then the cluster configuration involving the deuteron $^8\mathrm{Be}_{2+}$ + d can be a source of $^8\mathrm{Be}_{2+}$ decays. Measurements of "white"stars ^{10}B, including identification of He and H isotopes by a multiple scattering method, are in progress now. The distributions of the energy of α-particle pairs, $Q_{2\alpha}$ and triples $2\alpha + p$, $Q_{2\alpha p}$ from the ^{10}B →2 $\alpha + p$ events for ongoing experiment are shown in figures 5 and 6 respectively.

Consideration of the nucleosynthesis toward ^{10,11}B, ^{11,10}C and ^{12}N in the "hot break-out"^{7}Be(^{3}He,γ)^{10}C(e$^+$,ν)^{10}B assists to recognize the relationship of their structures. The increase of α-clustering in ^{10}C provides a "window"for the synthesis via the intermediate states ^{9}B + p, $^8\mathrm{Be}_{2+}$ + 2p and ^{6}Be + α. These clusters are preserved in subsequent reactions ^{10}C(e$^+$,ν)^{10}B(p,γ)^{11}C(e$^+$,ν)^{11}B. "Window"of the reaction ^{7}Be(^{4}He,γ)^{11}C allows only association of the ^{7}Be and ^{4}He clusters, also contributing to the ^{11}C and ^{10}B structure. Thus a hidden variety of virtual configurations in the nuclei ^{10,11}C and ^{10,11}B arises. In turn, these nuclei provide a basis for capture reactions of protons or He isotopes (or in neutron exchange) for synthesis of the subsequent nuclei which leads to translation of the preceding structures.

Within the framework of the relativistic approach the following picture of nuclear clustering emerges. As the fundamental elements of its structure atomic nuclei contain a virtual association of nucleons and clusters. Their simplest observable manifestations the lightest nuclei ^{4,3}He and ^{3,2}H having no excited states. Superposition of lightest clusters and nucleons form ^{7}Be, ^{8}Be in the ground and first excited states and ^{9}B ones which, in turn, serve as composing clusters. A balance of possible superpositions in states with an appropriate spin and parity determine binding and ground state parameters of corresponding nuclei. Further joining of nucleons and the lightest nuclei leads to shell type structure. Interlacing cluster and shell degrees of freedom does a group of nuclei in the beginning of the table of isotopes of a "laboratory"of nuclear

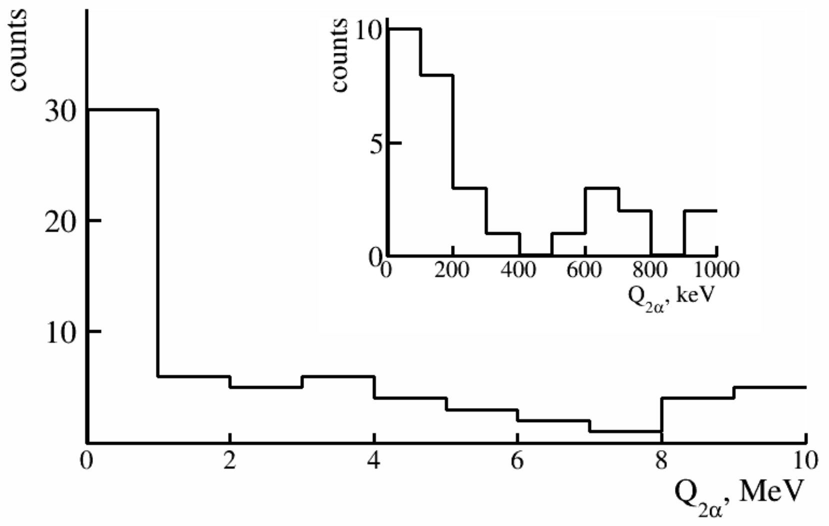

Figure 5. Distribution of the energy $Q_{2\alpha}$ of α-pairs from the $^{10}B \to 2\ \alpha + p$ events

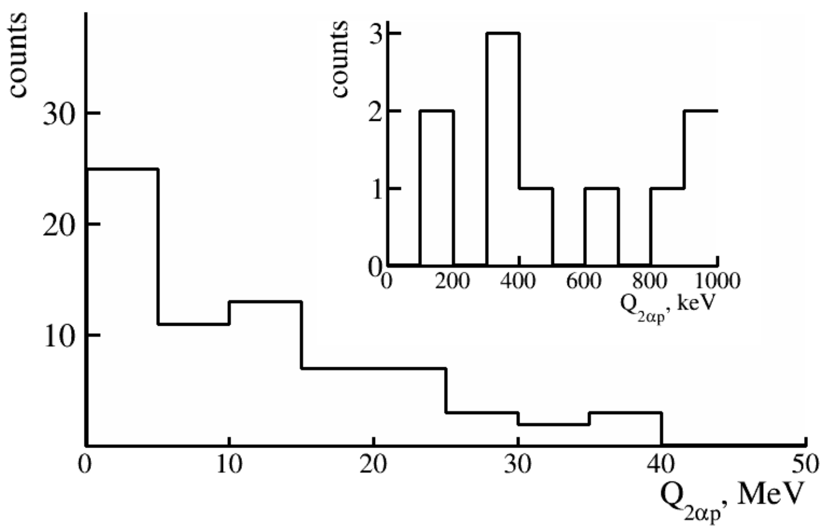

Figure 6. Distribution of the total energy $Q_{2\alpha p}$ of the triples $2\alpha + p$ from the $^{10}B \to 2\ \alpha + p$ events

quantum mechanics and nuclear astrophysics.

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