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Two-neutron-transfer to ^{178}Yb and Population of ^{178m2}Hf via Incomplete Fusion

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The DIAMANT light-charged-particle detector from ATOMKI was coupled with the AFRODITE gamma-ray spectrometer at iThemba LABS in a collaboration enabled by a bilateral agreement between the governments of South Africa and Hungary. This facilitated the study of incomplete fusion reactions in the bombardment of a Ytterbium-176 target with a beam of 50 MeV Lithium-7 ions. The beam was generated as a collaborative effort between ion source experts at iThemba LABS and the Flerov Laboratory for Nuclear Reactions (FLNR) of the Joint Institute for Nuclear Reactions (JINR), Dubna.

Particle-Identification (PID) spectra from DIAMANT generated from the ATOMKI custom-built VXI electronics clearly show the detection of protons, tritons and alpha particles, which, when gated on, allowed the selection of gamma-ray coincidences detected with AFRODITE when the respective complementary Helium-6, Helium-4 (α) and triton fragments fused with the target.

Analysis of the charged-particle-selected gamma-ray coincidence data enabled the identification of Hafnium-180 in the proton-gated Eγ -Eγ correlation matrix, as well as Hafnium-178, including the band based on the $T_{1/2}$ = 31a, $K^{\pi} = 16^{+}$ four-quasiparticle state. Hafnium-178 is also evident in the triton-gated matrix, which suggests that this nucleus is populated via two incomplete fusion channels, this one in which the fused fragment is Helium-4, and the other in which a Helium-6 neutron-rich fragment fuses with the Ytterbium-176 target.

The relative contribution from the (^{7}Li,p4n) fusion evaporation channel is unclear, but there is other evidence for Helium-6-induced reactions in the population of neutron-rich Ytterbium-178 whereby two neutrons have been transferred to the target. The ground-state band of Ytterbium-178 can be clearly observed in both the proton-gated and alpha-gated matrices, which supports the assignment of the ^{176}Yb(^{7}Li,αp)^{178}Yb reaction. The deuteron yield is comparatively weak which has hampered the unambiguous confirmation of the ^{176}Yb(^{7}Li, αd)^{177}Yb reaction.

The comparatively strong population of Hafnium-178 via the two reaction channels discussed above has allowed the population ratio Iγ(proton-gated)/ Iγ(triton-gated) of the ground-state, two-quasiparticle $K^{\pi} = 8^{-}$ and four-quasiparticle $K^{\pi} = 14^{-}$ and $K^{\pi} = 16^{+}$ bands to be extracted as function of spin . There is evidence for a marked increase in relative population of the $K^{\pi} = 16^{+}$ band when compared to the other lower-spin band structures.

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Quarks in Nuclei: From Neutron Halo to the Boundary of Nuclear Stability

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In the framework of the semi-empirical quark model of nuclear structure that is based on the quark model of the nucleon, the Strongly Correlated Quark Model (SCQM) [1] we construct nuclei from light to heavy ones, including halo nuclei. Nucleons inside nuclei are bound due to junctions of SU(3) color fields of quarks [1]. According to SCQM, arrangement of nucleons within nuclei reveals the emergence of the face-centered cubic (FCC) symmetry [2]. The model of nuclear structure becomes isomorphic to the shell model and, moreover, composes the features of cluster models. Binding of nucleons in stable nuclei are provided by quark loops which form three and four nucleon correlations. Three nucleon correlations are responsible for the structure of "halo" nuclei. Quark loops leading to four-nucleon correlations are responsible for binding energy enhancement in even-even nuclei. In turn, four-nucleon correlations can be considered as virtual alpha-clusters. In this way all inner closure shells are rearranged into the face-centered cubic lattice with alternating spin-isospin