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

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.

Notes

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