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Two-neutron-transfer to 178Yb and population of 178m2Hf via incomplete fusion

The DIAMANT light-charged-particle detector from ATOMKI has been 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 has 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 under an ongoing intergovernmental agreement, enabling a Tri-Partite Alliance to be formed between experimentalists from the respective institutions in the three countries.

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 Eɣ-Eɣ correlation matrix, as well as Hafnium-178, including the band based on the T1/2=31a K⍰ = 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 (7Li,p4n) fusion evaporation channel is at present 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 is consistent with the 176Yb(7Li, αp)178Yb reaction. The deuteron yield is comparatively weak which has hampered the unambiguous confirmation of the 176Yb(7Li, αd)177Yb reaction, though analysis is still in progress.

The comparatively strong population of Hafnium-178 via the two reaction channels discussed above has allowed the population ratio Iɣ(proton-gated)/ Iɣ(triton-gated) of the ground-state, two-quasiparticle K^pi = 8- and 4-quasparticle 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.

Primary author: Dr MULLINS, SIMON (iThemba LABS (Gauteng))

Co-authors: Dr EFREMOV, Andrei (JINR); Dr NYAKO, Barna (ATOMKI); Mr MAQABUKA, Bongani (University of Johannesburg); Dr LAWRIE, Elena (iThemba LABS); Mr KUTI, Istvan (ATOMKI); Dr MOLNAR, Jozsef (ATOMKI); Dr LAWRIE, Kobus (iThemba LABS); Dr PAPKA, Paul (University of Stellenbosch); Dr THOMAE, Rainer (iThemba LABS); Dr BARK, Robert (iThemba LABS); Mr MURRAY, Sean (iThemba LABS); Dr BOGOLOMOV, Sergei (JINR); Prof. CONNELL, Simon (University of Johannesburg); Mr MAJOLA, Siyabonga (University of Cape Town / iThemba LABS); Mr LOGINOV, Vladimir (JINR)

Presenter: Dr MULLINS, SIMON (iThemba LABS (Gauteng))