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High Resolution ^{148}Nd(^{3}He,nγ) Two Proton Stripping Reaction and the structure of the 0_2^+ State in ^{150}Sm

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The challenge of achieving high resolution in binary reactions involving an outgoing high energy neutron is solved by detecting the γ-ray decay of populated excited states in an array of escape suppressed HPGe detectors in coincidence with fast neutrons detected in a wall of scintillator detectors 2m down beam of the target. The selectivity of the arrangement is of the order of 1 in 1000. The time-of-flight difference is sufficient to separate fast neutrons from direct reactions from a large background of statistical neutrons from fusion-evaporation reactions. We have used the AFRODITE spectrometer at iThemba LABS to select γ-rays from the ^{148}Nd(^{3}He,nγ)^{150}Sm reaction, at a beam energy of 25 MeV, to pick out states populated in ***L=0*** two proton transfer. Our interest is in the wavefunction of the 0_2^+ state at 740 keV in the N=88 nucleus ^{150}Sm which is one of only two excited states observed [1] in 2β2ν double β-decay. The importance of understanding the microscopic configurations of these 0_2^+ states, and the ground 0_1^+ states of the parent and daughter nuclei, has been stressed in a recent review article [2]. The better the transition matrix elements can be calculated, the more accurately an effective neutrino mass can be extracted. There is also the ambition of using the double γ-ray decay from the 0_2^+ states to give a four-fold coincidence with the two electrons to improve the sensitivity of experiments so that the level of $\approx 10^{24}$ y partial half-life can be achieved. This is the estimated sensitivity required to detect 2β0ν neutrinoless double decay to determine the Majorana/Dirac nature of neutrinos.
The N=88 nuclei have remarkable features; they are at a peak in the $|M(E3)|^2$ strength of $0_1^+ \rightarrow 3_1^-$ transitions for even-even nuclei as a function of neutron number; they also have very strong E0 transitions from the band built on the 0_2^+ states to the ground state bands. It has been established [3,4] that the 0_2^+ states in N=88 and 90 nuclei are not β-vibrations but 2p-2h states lowered into the pairing gap by configuration dependent pairing. They are classic examples of 'pairing isomers' forming a 'second vacuum' [3] on which a complete set of excited deformed states are built that are congruent to those built on the 0_1^+ ground state. We have made extensive spectroscopic measurements in the nucleus ^{150}Sm reporting here on the first observation of consistent E1 transitions in deformed nuclei from the levels in the first excited 0_2^+ band to the lowest negative parity bands. The data will be discussed in terms of possible permanent octupole deformations [5].

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