Study of 0^+ states at iThemba LABS

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The very strong attractive forces between nucleons in a nucleus cause the protons and neutrons each to pair off into time reversed orbits with magnetic quantum numbers *m* and *-m*. Thus the angular momentum of each nucleon is opposite to its pairing partner, giving zero angular momentum for the pair. In nuclei with even numbers of both protons and neutrons (e–e) all the nucleons are paired off and the lowest energy state, the "ground" state, has zero angular momentum and is spherically symmetric. This is written 0_1^+ where 1 is for the first state and + is the parity. Odd nuclei, e–e nuclei with an extra proton or neutron, then have the last nucleon in a "single particle" state outside the e–e core. The properties of this state depend critically on the shape of the nucleus.

Reactions where protons are stripped off the beam nucleus, so that the outgoing particle is a neutron, are difficult to carry out. In particular it is especially challenging to obtain sufficient neutron energy resolution. Examples of these neutron emitting direct reactions are (d,n) and (^{3}He,n) which donate one and two protons to the target nucleus respectively. One proton stripping can be made with the (^{3}He,d) reaction, but two proton stripping requires reactions using heavy ions such as (^{16}O,^{14}C) and very good resolutions are still difficult to achieve. The (^{3}He,xn) reaction has been applied, using the detection of the neutrons, to search for excited 0^+ states in the residual nucleus. Excellent energy resolution is achieved by the use of γ–ray detection.

In order to establish the two paired proton components of the ^{100}Ru and ^{150}Sm 0_2^+ states a wall of 12 neutron detectors has been constructed down-beam of the AFRODITE array to detect fast neutrons in coincidence with γ–rays from the (^{3}He,n) reaction on targets of ^{98}Mo and ^{148}Nd. This "direct" reaction is only 0.1% of the total cross–section. Most γ–rays come from fusion evaporation xn reactions whose associated neutrons have half the velocity of those from (^{3}He,n). A first analysis of the data is shows γ–rays from the 2^+, 4^+ and 6^+ ground state rotational band in ^{150}Sm. However a very small 406 keV peak is from the first excited 0_2^+ state. This demonstrates that this state has only a very small component that appears as its isotone ^{148}Nd + two paired protons. This supports recent assertions that these first excited 0_2^+ states are two neutron configurations lowered into the pairing gap by configuration dependent pairing. Results of these experiments will be presented.

There is a wealth of new experiments to be carried out using this innovative technique at iThemba LABS for the study of 0^+ states using such reactions and new approaches.