Spectroscopy of Doubly Magic ^{100}Sn and Lighter Nuclei

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The doubly magic nucleus ^{100}Sn is unique in the nuclear chart, since it is the heaviest one with equal proton- and neutron-number (see [1]). Therefore the same orbitals are active for protons and neutrons and in the β-decay of ^{100}Sn a pure Gamow-Teller spin flip transition of one out of ten $g_{9/2}$ protons to a $g_{7/2}$ neutron is possible. This transition is expected to have extremely large strength. In nuclei below ^{100}Sn excited states are formed by the same orbitals and also particle-hole excitations across the shell gap are possible.

In large collaborations, with the TU München group playing a dominant role, we used fragmentation reactions of relativistic ^{124}Xe beams from the SIS18 at the GSI in Darmstadt to produce ^{100}Sn and lighter nuclei. The fragments were separated according to mass/charge ratio and energy loss in the fragment separator FRS. In addition they were uniquely identified, fragment by fragment, using position, velocity and energy loss measurements. A number of the necessary detectors were developed by the MLL group and tested at the MLL tandem accelerator. Finally the identified fragments were stopped in an active stopper; the most sophisticated version of this was also developed at the MLL. It consists of a total of 25 large area Si detectors. Two give the x- and y-position of the incoming fragment. Three DSSD's are used to finally stop the particles and to deliver the 3-dim. position information with 1mm resolution. They also detect the β-particles of the decay and allow a position and time-correlation with preceding implantations. The total energy of β-particles is detected with ten 1*mm* thick Si detectors each in forward and in backward direction.

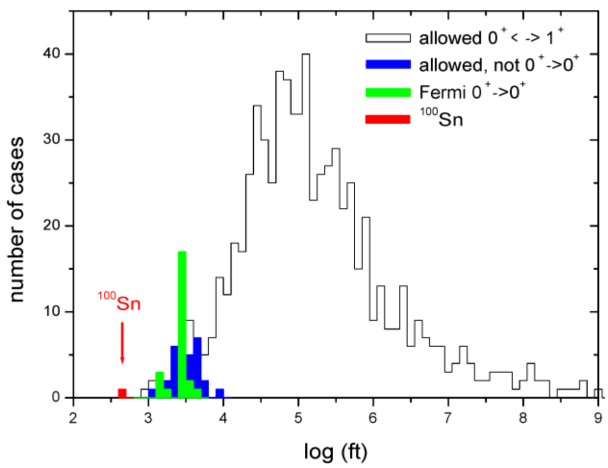

Figure 1: Histogram of log(ft) values for allowed transitions only. ^{100}Sn has by far the strongest transition.

In about 14 days of beam time we identified 259 nuclei of ^{100}Sn. We could determine its half-life to 1.16(20) *s* and the β-end point energy to 3.29(20) *MeV*. With the RISING array of 105 Ge-detectors we also obtained a γ-spectrum after β-decay, where we identified five transitions in ^{100}In. These confirm that dominantly a single 1^+ state in ^{100}In is fed by the β-decay of ^{100}Sn. These informations together yield the smallest log(ft)-value of $2.62^{+0.13}_{-0.11}$ in the whole nuclear chart (fig. 1) proving the pure single particle character of both ^{100}Sn and ^{100}In (for details see [2]).

In the same experiment we also observed for the first time the N=Z-1 nuclei ^{99}Sn, ^{97}In, and ^{95}Cd and could determine the half-life of the latter two nuclei with 26^{+47}_{-10} *ms* and 73^{+53}_{-28} *ms* resp.

Another experiment, again with RISING and a more simple implantation Si-detector, concentrated more on high-spin states and their γ-decay. In the two-proton hole nucleus ^{98}Cd we could confirm the 12^+ isomeric state at 6.635 MeV which requires the excitation of the core since the two proton holes can only couple to spin 8 [3]. In addition we find another week branch with a 4.157 *MeV* γ-ray showing the same half-life as the 12^+ state. This is interpreted as the E2-transition from the previously unknown 10^+ fed by a low-energy transition from the 12^+ isomer.

In ^{96}Cd both the proton-hole pair and the neutron-hole pair can couple to spin 8^+. Therefore a 16^+ spin gap isomer was expected below the 14^+ and even the 12^+ state, similarly as the β-decaying 12^+ state in ^{52}Fe, which is formed by four $f_{7/2}$ holes . We have now observed a γ-cascade following the β-decay of ^{96}Cd [4]. This cascade is depopulating the 15^+ isomer in ^{96}Ag and therefore we can conclude that this state is fed by the β-decay of the 16^+ isomer in ^{96}Cd.

In ^{96}Ag we find that the 15^+ state, which has the maximum spin possible for the three $g_{9/2}$ neutron holes and the proton $g_{9/2}$ hole, is fed by two high energy lines of > 4 MeV. Therefore we have to assume close lying core excited 17^+ and 19^+ states, the latter being isomeric due to the necessary E4 transition to the 15^+ state [5].

Even more complex gets the spectrum in the 6-hole nucleus ^{94}Pd, where we find a new isomeric state ($T_{1/2}$=197(22) *ns*) with a long γ-cascade towards the ground state [6]. Based on γ-singles and γ–γ coincidences we could construct a level scheme (see Fig. 2) and attribute the new isomer to a 19^- state, which is the next to largest spin value possible within the $g_{9/2}$,$p_{1/2}$ model space. The largest would be the $\pi(g_{9/2})^{-4}\ \nu(g_{9/2})^{-2}\ 20^+$ state.

The β-decay of ^{94}Pd to ^{94}Rh was also investigated [7] through the following γ-transitions. There we see feeding of four 1^+ states which corresponds to about 30% of the total Gamow-Teller strength observed in earlier work. Therefore the total strength must be fragmented to many more 1^+ states. The total strength can only be reproduced in shell model calculations if excitations across the N=50 shell to the $g_{7/2}$ orbital are included.

Making use of the much higher beam intensity at the RIBF facility at the RIKEN Nishina Centre, Japan, further experiments have been carried out in 2012 and 2013 to explore this region of the nuclear chart in more detail.

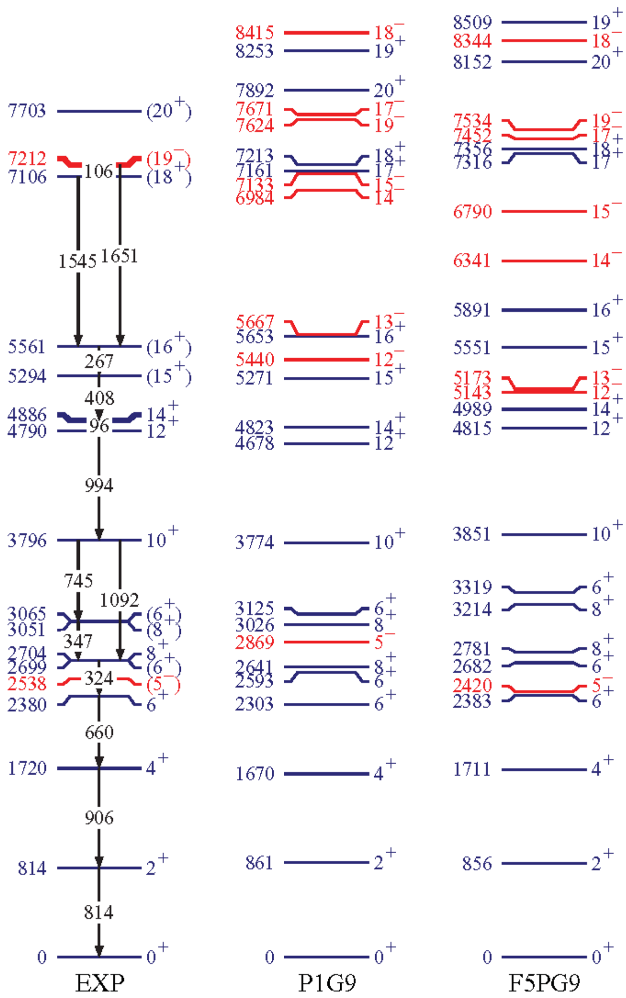

Figure 2: Experimental level scheme of ^{94}Pd and shell model calculations with a model space restricted to the $g_{9/2}$,$p_{1/2}$ (P1G9) and including the $f_{5/2}$,$p_{3/2}$ orbitals (F5PG9).

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