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Letter of intent:

Study of the $\pi h_{11/2}^{-1}$ isomeric states in ^{201,203,205}Au

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Abstract:

Excited states have been identified in only two of the N=126 closed shell nuclei 'below' ^{208}Pb: ^{207}Tl and ^{206}Hg. We aim to extend our knowledge of the neutron-rich N=126 nuclei by observing the internal decay of the $\pi h_{11/2}^{-1}$ state in ^{205}Au, which is expected to be isomeric. In addition, the decay of the analogous states in the N=122 and N=124 ^{201,203}Au will be studied. The lifetimes of the expected isomeric states are crucial for the success of the experiment, and they are estimated to be in the range of 0.3-20 s. These are long enough to enable the extraction from the source, but shorter than the beta-decay halflives. Proton single-particle energies and transition rates will be extracted, providing information about the robustness of the N=126 shell-closure.

Gold beams are at the moment not available at ISOLDE. This letter of intent is submitted in order to ask for such developments.

1. Introduction and motivation

The understanding of how shell structure arises and develops is a major goal in nuclear physics. Nuclei close to the stability line exhibit magic numbers at proton and neutron numbers of 2, 8, 20, 28, 50, 82, 126 etc. By exploring the properties of neutron-rich nuclei it is known that the well established shell structure changes. Evidence for such effects has been observed for N=8,20,28,50 and even 82 [1]. These changes (shell quenching) are generally understood to come from a reduction of the spin-orbit splitting, in other words the Woods-Saxon potential changes towards a harmonic-oscillator type. No such effects have been observed or predicted so far for the N=126 nuclei.

^{208}Pb with 82 protons and 126 neutrons is a classic shell model core. The present proposal aims to investigate the robustness of the N=126 closed shell, by studying long-lived isomeric decays in neutron-rich gold isotopes.

Information on the neutron-rich N=126 nuclei is very scarce. Below the doubly magic ^{208}Pb nucleus there is experimental information on only three isotones: ^{207}Tl, ^{206}Hg and ^{205}Au. While in both ^{207}Tl [2] and ^{206}Hg [3] excited states have been observed (including isomeric states, see fig. 1), in ^{205}Au only the ground state is known (I^{π}=($3/2^{+}$) [4]).

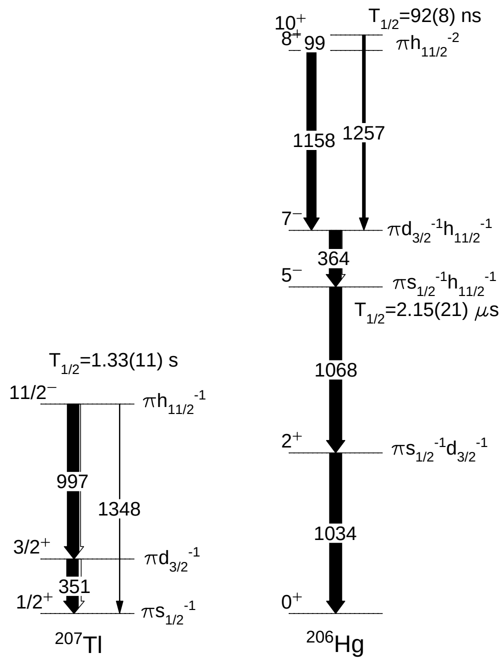

Figure 1: Partial level schemes of the neutron-rich N=126 nuclei ('below' ^{208}Pb) showing the isomers and the states populated by their decay [2, 3]. The configurations of the levels are given. In the N=126 ^{205}Au nucleus an isomer with the same configuration as in ^{207}Tl, $\pi h_{11/2}^{-1}$ is expected.

The lack of information on nuclei 'below' ^{208}Pb is due to the difficulties in populating these neutron-rich nuclei. However, spallation has proved to be an efficient tool to produce exotic nuclear species. When it is combined with high sensitivity gamma detection arrays, structure information can be gained for otherwise inaccessible nuclei. The present proposal seeks to obtain nuclear structure information on ^{201,203,205}Au nuclei, with N=122,124,126, respectively.

Partial level schemes for the ^{201,203,205}Au nuclei are shown in figure 2. In ^{205}Au only the ground state is known, with spin-parity ($3/2^{+}$) [4]. The level structure of ^{201,203}Au has been studied in (t,α) reactions [5, 6]. The $\pi h_{11/2}^{-1}$ states have been identified with a precision of 5 keV. Since these states can decay only via M4 and E5 transitions, with transition strengths expected to be close to one Weisskopf unit, these states should be isomeric. In all three nuclei, ^{201,203,205}Au, the $\pi h_{11/2}^{-1} \rightarrow \pi p_{3/2}^{-1}$ transition is expected to be dominant (except that we don't know whether there is a state at 549(5) keV in ^{201}Au and its spin-parity). We note that recently in ^{203}Au a 563 keV transition with a lifetime of $T_{1/2}$=40^{+7000}_{-20} μs has been observed [9]. However this does not fit with the known excited states of [6]

The lifetimes of these isomers are crucial for the success of the experiment. Ideally they should be long enough to allow the extraction of the ions from the source, but shorter than the beta-decay half-lives of the nuclei of interest and contaminants (see section 2). The B(M4) value of the $\pi h^{-1}_{11/2} \rightarrow \pi p^{-1}_{3/2}$ transition is known in ^{197}Au to be B(M4)=2.4(8) W.u. [7]. Assuming the same strength in ^{201,203}Au, the estimated lifetimes are of $T_{1/2}$ ≈21 s and $T_{1/2}$ ≈13 s respectively. The lifetime of the $11/2^-$ state in ^{205}Au depends strongly on the unknown excitation energy ($\sim E^9$) of this state. For example it is estimated to be $T_{1/2}$ ≈6.3 s for E_x=700 keV and $T_{1/2}$ ≈0.33 s for E_x=1000 keV. (Similar lifetimes are estimated if we consider the B(M4)=3.2(3) W.u. transition strengths measured in ^{207}Tl [8].)

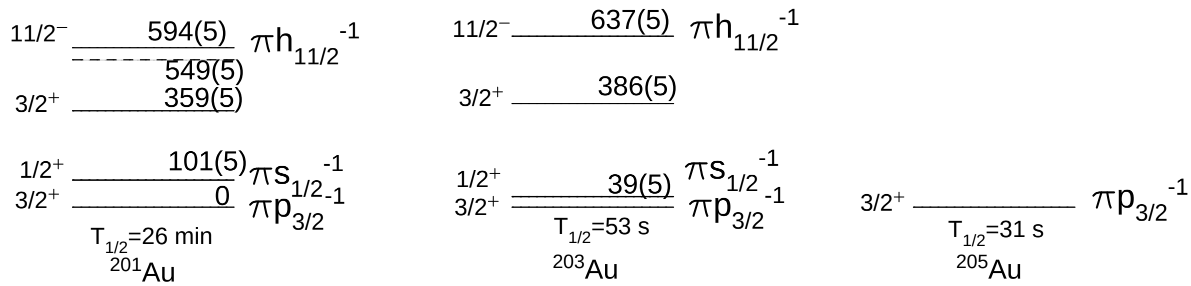

Figure 2: Partial level schemes of ^{201,203,205}Au [5, 6, 4]. The configuration of the levels are indicated.

2. Experiment

The ^{201,203,205}Au nuclei will be produced by bombarding a thick target (Pb,Bi,Th or U) with a high-energy, high-intensity proton beam. The ions of interest will be extracted from the source and accelerated to 60 keV. After mass separation (HRS) the ions will be implanted in a tape. The place of implantation will be surrounded by high efficiency Ge detectors and maybe an electron detector. The electron detector might help to distinguish between gamma-rays from internal isomeric decay and beta decay. The use of an orange spectrometer to detect the conversion electrons is also considered.

We expect that the lifetimes of the isomeric decays in ^{201,203,205}Au will be of the order of 0.3-20 s. These are shorter than the beta-decay lifetimes of the isobars. Therefore the tape system will be used to remove the long-lived beta-decaying nuclei. The beta decays of the nuclei of interest have been previously studied [5, 4].

The energies of the gamma rays expected to depopulate the isomers are about 600 keV. Considering a 10% full peak efficiency and that we need at least about 100 counts in the gamma peak, we need 1000 gold ions in isomeric state. Assuming a 10% isomeric ratio, thsi means in total 10000 gold ions (each isotope). This means that the experiment can be performed even at yields of few ion/s (it depends also on the contaminants).

This Letter of Intent is submitted in order to ask for development of Au beams at ISOLDE.

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