Probing the structure of ^{95}Mo

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1 Motivation

^{94,95}Mo nuclei have few neutrons outside the N=50 shell closure and are placed in a region where a transition from spherical to deformed shape is expected to occur. The low-spin states in ^{94}Mo have been successfully described in the framework of the shell model as arising from the $\pi(p_{1/2}, g_{9/2})$ and $\nu(d_{5/2}, s_{1/2}, g_{7/2})$ single particle orbitals. The high-energy transitions, placed on top of the $J = 13\hbar$ state were interpreted as neutron excitations across the N=50 shell gap. The positive-parity states in ^{95}Mo have been interpreted in the framework of the shell model as single-particle configurations coupled to the ^{94}Mo core. In 1998, a negative parity band, consisting of stretched E2 transitions was observed on the top of the 1333-keV level [1]. It has been interpreted as arising from the $\nu h_{11/2}$ configuration. However, to make a more definitive assignment a need of lifetimes measurements has been emphasized [1]. Later, in [2], it has been suggested that the $11/2^-$ level lies at 1938 keV and decays via a 386-keV transition to 1551-keV level, which is non-yrast and decays via a branch of transitions to the yrast sequence. The appearance of $11/2^-$ state at higher energies fits to the lower intensity of the band sequence, based on $11/2^-$ state with respect to the yrast-sequence of states. And while the positive-parity part of the level scheme of ^{95}Mo is successfully described in the framework of both shell model and vibarional model the negative-parity band remains not well studied. Therefore, with the present proposal we suggest to measure the half-life of the negative-parity band head in ^{95}Mo. The lifetime of the level is directly related to the reduced transition probabilities and give the opportunity to test the nuclear wave function in a region deep bellow N=82, where $\nu h_{11/2}$ is expected to emerge.

2 Half-life estimation

The negative-parity band in ^{95}Mo has a similar structure to the negative-parity band in ^{97}Mo (Fig. 1). Both bands are observed to decay via stretched E2 transitions to the $11/2^-$ state. The half-life of the $11/2^-$ state in ^{97}Mo has been measured to be 2.5 (3) ns [3]. It decays via 320-keV E1 transition to the $9/2^+$ state and via 778-keV M2 transition to the 7/2+ state. Given that the branching ratio is $BR = I_{320}/(I_{320} + I_{778}) = 0.9$ we estimate the partial half-life $T^{320\gamma}_{1/2}$ on 2.3 ns. The Weisskopf estimates for a stretched E1 320-keV transition is $9.7{\times}10^{-15}$s., which leads to a hindrance factor of $F_w = T^{320\gamma}_{1/2}/T_{W.e.} = 2.3 \times 10^5$.

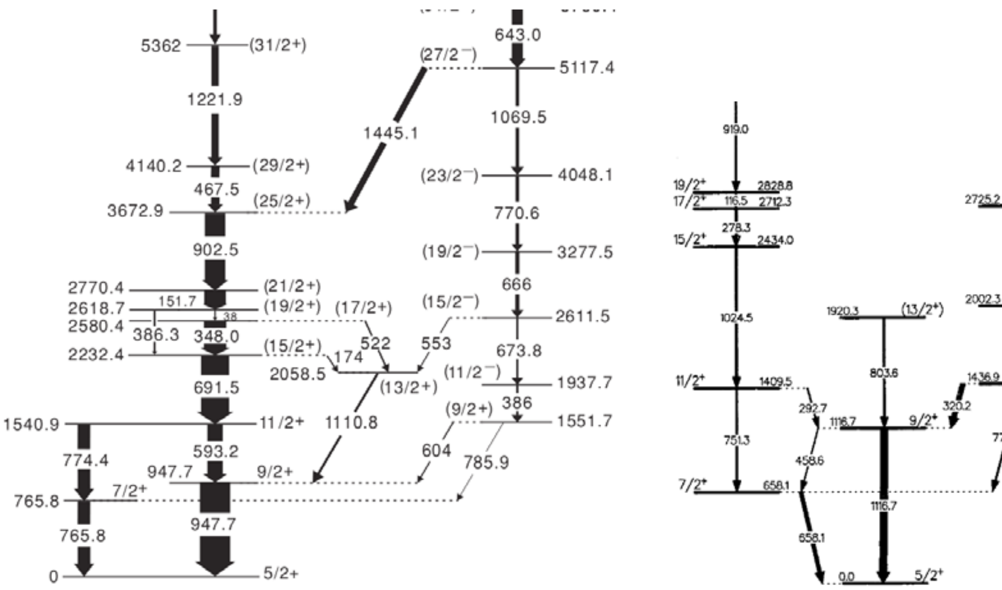

Figure 1: Partial level schemes of ^{95}Mo [2] (left) and ^{97}Mo [4] (right)

The half-life of the $11/2^{-}$ state in ^{95}Mo can be estimated if the state has a similar to the $11/2^{-}$ state in ^{97}Mo structure. Given that the $11/2^{-}$ level in ^{95}Mo decays via a branch of transitions with 386-keV E1 transition being the strongest branch the half-life is estimated to be $T^{exp}_{1/2} = 1/BR \times F_W \times T^{W.e}_{1/2} = 1/0.544 \times 2 \times 10^5 \times 5.6 \times 10^{-15}$ s, i.e $T^{exp}_{1/2} = 2 \times 10^{-9}$ s.

Upper limit of $T_{1/2}$ for $11/2^{-}$ state in ^{95}Mo has also been estimated by NNDC [3] on 6.9 ns. Both values, the calculated in the present proposal and the NNDC value, are within the range of the fast-timing setup in Magurele. In addition to the $11/2^{-}$ state a number of excited single particle states with $J^{\pi} = 15/2^{+}$ to $19/2^{+}$, which decay by low-energy M1 transition, are estimated to have half-lives of order of few hundreds of picoseconds. The precise value of the half-life will give additional spectroscopic information and will allow a more definitive configuration assignment of the states bellow the Z=50 shell gap.

3 Experimental Set Up

Lifetimes in the sub-nanosecond range will be measured by using the specially designed system for in-beam fast-timing measurements at NIPNE. It comprises 8 HPGe detectors working in coincidence with 5 $LaBr_3$:Ce detectors [5]. The system is triggered by two $LaBr_3$:Ce fired in coincidence with one HpGe detector. The half-life of the level of interest will be measured by using the time interval between the feeding and de-exciting gamma-rays detected by two of the five $LaBr_3$:Ce detectors under the condition that the cascade is fed by a third transition detected by HpGe detector.

4 Preceding experience

In 2009 and 2010 a cycle of four experiments have been performed at the Tandem accelerator of NIPNE-Magurele, Romania. The aim of the experiments was to measure short-lived states in ^{103,105,107}Cd [6]. The first experiment of the cycle was a test experiment and aimed on the first excited 7/2+ state in ^{107}Cd, which has a half-life of 710 ps. In a following experiment, the half-life of the first $7/2^{+}$ states in the neighbouring ^{105}Cd and ^{103}Cd nuclei have been also

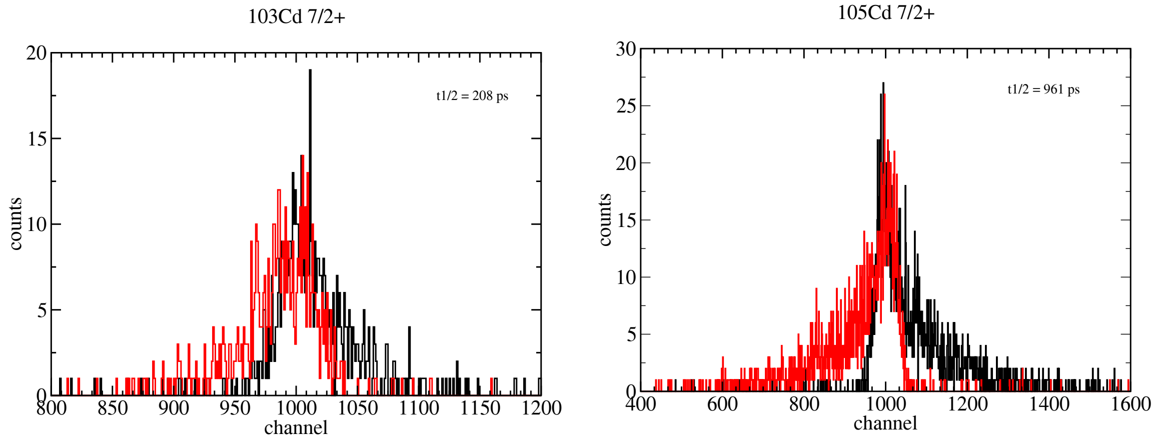

Figure 2: Time spectra for the 7/2+ states in ^{103}Cd and ^{105}Cd [6]

measured. Sample spectra, showing the measured half-times of the $7/2^{+}$ states are presented at Fig. 2. The $T_{1/2}$ for ^{105}Cd taken from NNDC is 1.75 ns and it has been re-evaluated in our experiment, while the $T_{1/2}$ for the $7/2^{+}$ state in ^{103}Cd has been measured for the first time.

The NNDC value for $T_{1/2}$ of $11/2^{-}$ in ^{107}Cd is 71 ns. The half-life of the $11/2^{-}$ state in ^{105}Cd has been measured for the first time at NIPNE and it has been found to be 142 ps. A sample spectrum is shown on Fig. 3. The half-life of $11/2^{-}$ in ^{103}Cd has been found to be prompt in our last experiment

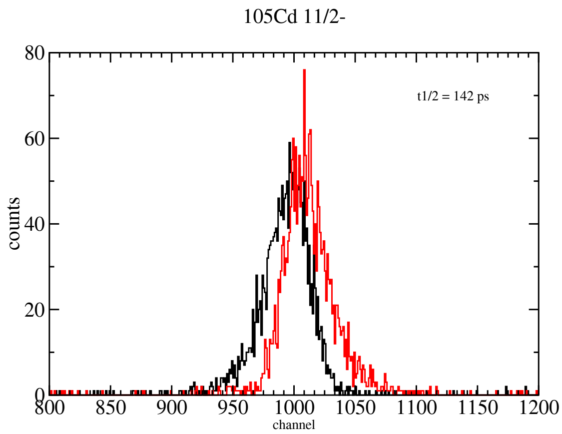

Figure 3: Time spectra for the 11/2- states in ^{105}Cd [6]

5 Beam time estimation

5.1 ^{95}Mo experiment

^{95}Mo will be studied via ^{18}O+^{82}Se reaction which has a cross section of 400 mb at beam energies at 68 MeV, as calculated wit the CASCADE code. Given that the energy loss of the 68 MeV ^{18}O beam in ^{82}Se target is approximately 3 MeV/(mg/cm^{2}) a target of 9 mg/cm^{2} thickness will be used. In order to stop the beam in the target the target will be backed with 15 μm of Au.

Then for a current of 100 pnA and for population of 4% of the $11/2^-$ with respect to the first excited state, and given that the LaBr3 detectors, with an intrinsic efficiency of 80% for low-energy γ-rays, are typically placed at 8 cm from the target, a total number of 800 de-exciting γ-rays per second in singles are expected, i.e. 4 counts in the $\gamma - \gamma$ matrix. Then the HpGe gated time spectrum will contain 124 counts per shift, i.e. 2604 counts in a week. Therefore, to obtain enough statistics to determine the half-life of the $11/2^-$ state in ^{95}Mo one week of beam time is requested.

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