Decay spectroscopy of the N=Z+1 odd-mass nucleus ^{79}Y

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The proton-rich odd-mass strontium ($Z = 38$) and yttrium ($Z = 39$) nuclei are well known to exhibit a large prolate-deformed nuclear shape [1] due to the occupation of the intruder orbitals from the $d_{5/2}$ and the high-j $g_{9/2}$ subshells by the unpaired proton and/or neutron. The deformed shapes are well-stabilized by the $Z = 38$ gap in the single-particle energies. This gives rise to low-lying states which may form bandheads of rotational-like collective structures. Over the last decade, many of such collective bands of positive and negative parity built on low-lying prolate-deformed states have been identified in ^{79,81}Sr from in-beam work, see e.g., Ref. [2]. One of them, a highly-deformed band originating from the $1/2^+[431]$ Nilsson orbital, has been observed only in ^{81}Sr at a bandhead energy of 120 keV [3]. This band exhibits a quadrupole deformation of $\beta_2 \approx 0.4$ which translates into a transition quadrupole moment of $Q_t = 3.5$ eb.

The $1/2^+[431]$ bandhead state is expected in ^{79}Sr at a somewhat higher excitation energy as extrapolated from the single-particle energies for $N = 41$ at large prolate deformation. However, this band has been neither observed in previous in-beam γ-ray experiments to ^{79}Sr nor in ^{79}Y→^{79}Sr [4, 5] β decay. So far, only preliminary evidence has been presented for a high-spin band built on a $(1/2^+)$ level at 375 keV in ^{79}Sr [6].

Thus, we searched for non-yrast low-lying states in ^{79}Sr populated in the β decay of ^{79}Y by measuring of β-γ and β-γ-γ coincidences on mass-separated sources which, to our knowledge, has not been done so far. Our decay study was carried out at the GSI on-line mass separator by using the ^{46}Ti(^{40}Ca,$\alpha p2n$)^{79}Y fusion-evaporation reaction at 5.3 MeV/nucleon. In order to enhance the separation efficiency of the catcher-ion-source system for yttrium isotopes, the CF_4-fluorination technique was applied [7]. Small addition (partial pressure of 10^{-4} mbar) of CF_4 gas stimulated the production of $^{79}YF_2^+$ molecules at mass 79+38 which were efficiently separated from other reaction products leading to almost chemically pure mass-separated yttrium sources. In order to suppress the longer-lived ^{79}Sr daughter decays ($T_{1/2} = 2.3$ min), the mass-separated ^{79}Y activity ($T_{1/2} = 14.8$ s) was implanted into a tape at rest, measured (grow-in method) and subsequently removed from the measuring position with a cycle time of 64 s. The experimental setup included a plastic scintillator as β detector with an efficiency of about 80% and 15 Ge crystals for detection of γ radiation. An absolute γ-ray efficiency of about 4.5% was obtained for 1.33 MeV γ rays.

Besides the 511 keV annihilation line and the known decay lines at 153, 178 and 1106 keV, many new γ rays were observed. Most of the new transitions have been placed in a much extended decay scheme, see Fig. 1. In this way, a low-lying level structure in ^{79}Sr involving the 375, 443, 597, and 751 keV levels have been firmly established. Spin and positive-parity assignments are based on the apparent β feeding and the observed depopulation pattern.

The nucleus ^{79}Sr is known to show an excitation spectrum of a highly-deformed nuclear ellipsoid. Thus, particle-triaxial-rotor calculations [8] have been performed to further explore the evolution of the nuclear shape and the composition of the wave function to discuss the experimental properties of the low-lying states.

The $3/2^-$ ground state of ^{79}Sr and the $5/2^+$ state at 178 keV are interpreted to originate from the $3/2^-[301]$ and $5/2^+[422]$ Nilsson configurations, respectively, at a well-deformed prolate shape with a quadrupole deformation of $\beta_2 \approx 0.37$ [2]. Based on our model calculations, the $(1/2^+)$ state at 375 keV can be well interpreted as the bandhead of the $1/2^+[431]$ Nilsson orbital, with the levels at 443 and 597 keV being the $3/2^+$ and $5/2^+$ collective band members, respectively. There is only little level mixing between the $1/2^+[431]$ and the $5/2^+[422]$ configurations in the wave functions. Thus, the relatively weak population of the $1/2^+[431]$ band in ^{79}Sr via the β decay from the $5/2^+[422]$ ground state in ^{79}Y requires a $\Delta K = 2$ decay which seems to be retarded.

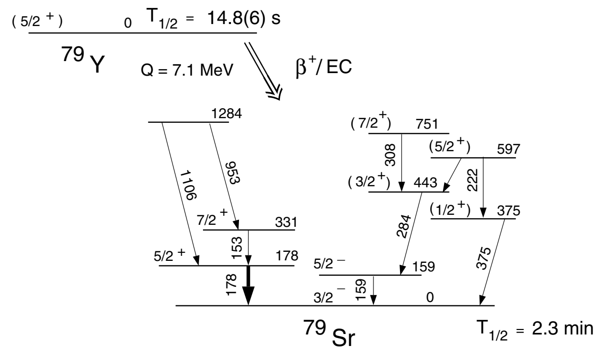

Figure 1: Partial ^{79}Y→^{79}Sr decay scheme.

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