Corrected Lifetime Measurement of the 0_2^+ State in ^{90}Zr

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In order to test the sensitivity limit of the new build target chamber and the β − E0 coincidence measurement detecting conversion electrons in a Mini-Orange spectrometer and β decay electrons in a plastic scintillation detector as used for the E0 transition measurement in ^{30}Mg [1], the known weak E0 transition in ^{90}Zr was studied [3]. Therefore an ^{90}Y source with an activity of ∼ 120 kBq was produced at the Radio-Chemistry Institute of the Technical University Munich. A reservoir of ^{90}Sr was flushed with hydrocloride acid and a drip of 10 μl of the solution was dripped on a 20 $\mu g/\mathrm{cm}^2$ thick carbon foil before being dried using an infrared lamp.

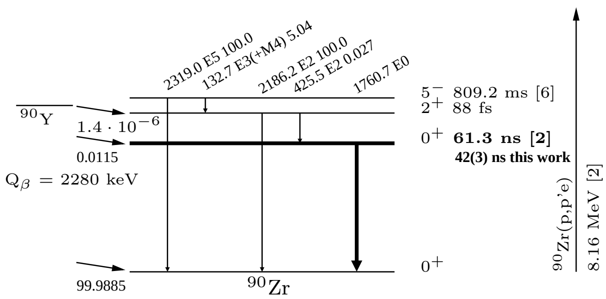

Fig. 1: Part of the level scheme of ^{90}Zr [7] including the β decay properties of ^{90}Y. The corrected halflife of the 0_2^+ state, as determined in this work, is indicated and compared to previous results from inelastic proton scattering [2].

Fig. 1 shows the β decay properties of ^{90}Y. It decays with a halflife of ∼ 64.1 hours ($Q_\beta = 2.28$ MeV) by almost 100% to the ground state of ^{90}Zr. A weak E0 transition with a transition energy of 1761 keV, a lifetime of 61.3 ns of the 0_2^+ state [2] leading to an electric monopole strength of $\rho^2(\mathrm{E0}) = 3.30(17) \cdot 10^{-3}$ [5] and an absolute intensity of 0.0115% is known [7].

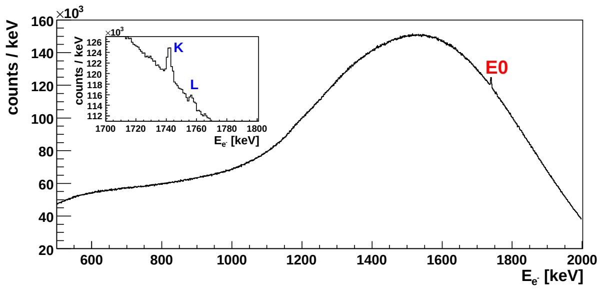

Fig. 2: Total electron spectrum of the ^{90}Y decay folded with the transmission curve of the Mini-Orange and measured with the Si(Li) detector. The initial source activity was ∼ 120 kBq. The K and L conversion electron lines at 1743 keV and 1758 keV are clearly visible (see insert).

The experimental setup used for the measurement is shown in [4]. Since the E0 transition energy of 1761 keV is relatively high compared to $Q_\beta = 2280$ keV, the remaining energy of the β decay electron $E_\beta \leq 519$ keV with a maximum around 250 keV is not sufficient to pass a 75 μm thick Mylar foil as used in [4] in front of the β detector. Therefore the experimental setup was slightly changed. A 5 mm thick scintillator plate (material: NE-110, diameter: 89 mm) was used as window to the vacuum chamber and the photomultiplier was glued onto it from the outside using optical grease.

Fig. 2 shows the electron singles spectrum of the ^{90}Y decay. The K and L conversion lines are visible on top of the β decay background folded with the transmission curve of the Mini-Orange spectrometer.

To select events satisfying the β − E0 coincidence condition a TDC (Caen V775) was used to measure the time difference between the signals of the two electron detectors. This measurement allows to determine the lifetime of the 0_2^+ state.

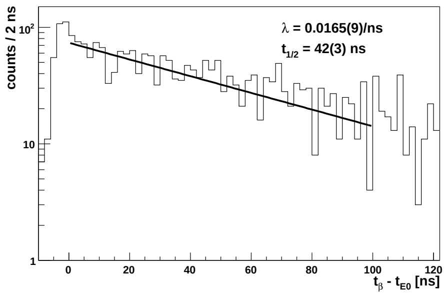

Fig. 3: Background-subtracted time spectrum of the 0_2^+ state in ^{90}Zr. In order to derive the lifetime of the 0_2^+ state, the spectrum was fitted using an exponential function. The resulting decay constant $\lambda = 0.0165(9)$/ns allows to determine a halflife of the 0_2^+ state of $t_{1/2} = 42(3)$ ns.

Fig. 3 shows the background-subtracted time information of the K- line at 1743 keV. Since the transmission function is linear in a small range around the K line, the background is determined setting two windows with half of the coincidence window width below and above the K line in the electron singles spectrum. In order to determine the halflife of the 0_2^+ state in ^{90}Zr, the histogram in Fig. 3 was fitted using an exponential function. The decay constant λ was determined as $\lambda = 0.0165(9)$/ns, which results in a halflife of the 0_2^+ state of $t_{1/2} = 42(3)$ ns, which is drastically in contrast to the only published value of 61.3 ns [2] which dates back to a measurement in 1972.

The published value was determined via the ^{90}Zr(p,p'e) reaction using a 8.16 MeV proton beam. In this reaction the isomeric 5^- state at 2319.0 keV with a lifetime of 809.2 ms [6] was populated. It decays via an E5 transition to the ground state and via an E3(+M4) transition into a 2^+ state at 2186.3 keV, which then populates the 0_2^+ state via an E2 transition (see Fig. 1). In our experiment the isomeric 5^- state could not be populated, because the Q-value of the ^{90}Y β-decay is smaller than the excitation energy of this state, thus avoiding feeding contributions as obviously present in the old data. So our new measurement leads to the correct halflife of the 0_2^+ state of $t_{1/2} = 42(3)$ ns, resulting also in a corrected value for the E0 strength of $\rho^2(\mathrm{E0}) = 5.0(4) \cdot 10^{-3}$.

References

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