Available online at www.sciencedirect.com
ScienceDirect
Nuclear Instruments and Methods in Physics Research A 566 (2006) 448–451
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A
www.elsevier.com/locate/nima

Measurement of the half-life for two ^{57}Fe excited states by a single-crystal scintillation time spectrometer

V.A. Morozov[a], N.V. Morozova[a], T. Badica[b], Gh. Cata-Danil[b,d], D. Ghita[b,*], I.V. Popescu[b,c]

[a]*Joint Institute for Nuclear Research,141980 Dubna, Russia*
[b]*National Institute for Physics and Nuclear Engineering, "Horia Hulubei", P.O. Box MG6, Bucharest 76900, Romania*
[c]*Valahia University of Târgoviste, Targoviste, Romania*
[d]*Politehnica University, Bucharest, Romania*

Received 21 July 2005; received in revised form 13 July 2006; accepted 24 July 2006
Available online 21 July 2006

Abstract

Half-lives measurements for two excited states of ^{57}Fe located at 14.4 and 136.5 keV, in the ^{57}Fe nucleus have been recently proposed using the Autocorrelation single-crystal scintillation time spectrometer (ASCSTS) .We have proved that ASCSTS has a reasonably high detection efficiency for γ–γ coincidences in the energy range around 5 keV, preserving its main distinctive feature: a large detection solid angle (close to 2π) in a wide time interval (from ~4 ns to 100 μs).

Keywords: Half-life measurement; Single crystal scintillation time spectrometer, SCSTS; Autocorrelation single-crystal scintillation time spectrometer, ASCSTS

In a recent work [1] some of us introduced the autocorrelation single-crystal scintillation time spectrometer (ASCSTS) with plastic scintillators, as a new instrument for studying nuclear isomeric states in the nano- and microsecond range. The new experimental method ensures detection with high efficiency of the delayed γ–γ coincidences, in a geometry closed to 4π. It allows the measurement of the half-lives for excited and ground states, in range of 4 ns to 100 μs. The use of a few millimeters thick plastic scintillators with short decay times, provides almost 100% detection efficiency of the charged particles (conversion electrons, β^- and α particles) emitted in radioactive decays. Generally, isomeric states are populated or depopulated by low-energy γ transitions, whose internal conversion coefficients are rather large. The low-energy limit for detecting radiation is defined only by the electronic noise of the (PMT). In our experiments we investigated very weak intensity sources (the activity of the studied sources was comparable with the background level in the laboratory) with complex isotopic composition resulting from long radioactive chains beginning with ^{225}Ac (8 radioactive decays) and ^{232}Th (11 radioactive decays) by measuring β^-–e^-, α–e^- or β^-–α delayed coincidences [1,2].

In the present paper, we attempt to test our ASCSTS instrument, working with optimum performance in the regime of γ–e^- and/or γ–γ delayed coincidences, using it to study nuclear isomeric states in ^{57}Fe. ^{57}Co decays to ^{57}Fe which has two short-lived isomeric states, at 14.4 and 136.5 keV. The ^{57}Co radioactive source was obtained by irradiating a natural iron foil (4 μm thickness) with a proton beam at the cyclotron accelerator at NIPNE-HH. The partial scheme of the ^{57}Co decay is shown in Fig. 1, [3].

The block diagram of the single-crystal time spectrometer is presented in Fig. 2. A XP2020 PMT, with low noise level ($\leqslant$5 keV) and a plastic scintillator type NE104 (40 mm diameter and 20 mm length) and decay time of $\tau = 1.9$ ns have been used. Start-and stop-time signals are taken from the constant fraction discriminator (D, ORTEC 473). By its design principle, ASCSTS uses only one-time discriminator with a threshold set to a value

*Corresponding author. Tel.: +40741122909.
E-mail address: dan.gabriel.ghita@gmail.com (D. Ghita).

0168-9002/$ - see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.nima.2006.06.059

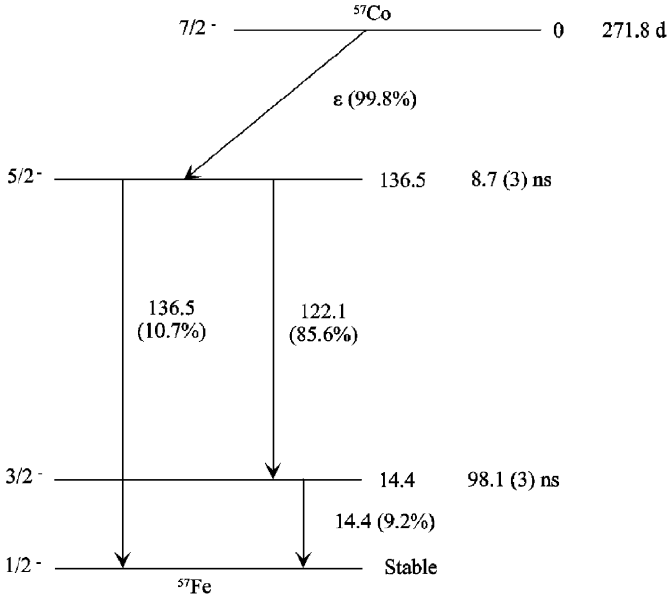

Fig. 1. Fragment of the ^{57}Co decay scheme [3].

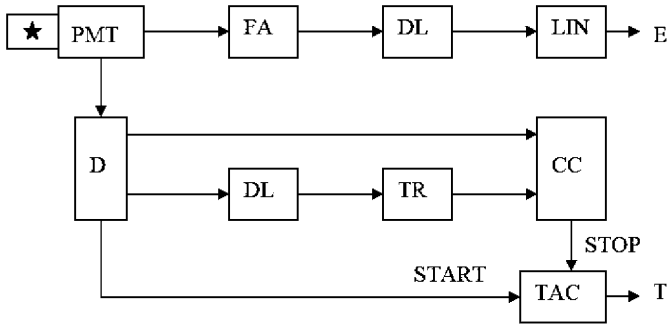

Fig. 2. Block diagram of the autocorrelation single-crystal time spectrometer. PMT—photomultiplier, FA—fast amplifier, DL—delay line, LIN—linear integration nanosecond pulse circuit, D—discriminator, TR—trigger, CC—coincidence circuit, TAC—time-to-amplitude converter.

slightly exceeding the level of PMT noise. This leads to: (i) the most highly achievable efficiency of recording populating and delayed radiation and (ii) a simple spectrometer with increased reliability. The ultimate stop signals are generated by a gated coincidence circuit (CC). The trigger (TR), produces a pulse with a width equal to the duration of the studied time range. A delay line (DL) eliminates self-coincidences. The signal taken from the PMT dynode, transferred through a fast amplifier (FA, ORTEC 579) to the linear nanosecond pulse integration circuit (DL), allows two-dimensional energy-time coincidence spectra. Decay scheme of ^{57}Co is very well known (the decay process populates only the two interesting levels: 14.4 and 136.5 keV), we did not use in the analysis the energy information and we have sorted the experimental data using only the time distribution spectra. The scintillation detector cannot ensure a satisfactory energy analysis due to poor energy resolution of the plastic scintillator. The precise determination of the energy for the isomeric state can be done by adding to the experimental setup a high-purity germanium detector [2].

In the present experiment the energy range was selected above E~5 keV. The measurements were performed in a geometry closed to 2π. The ^{57}Co radioactive source was placed at 1 mm from the face of the plastic scintillator. The conversion electrons from the 14.4 keV energy transition were completely absorbed by a polyethylene filter placed between the source and the plastic detector [4]. In this way, we reproduced the experimental conditions for the ASCSTS, similar to an on-line experiment with a thick target.

The results of the measurements are shown in Fig. 3. Curves 1 and 2 correspond to the time distribution of ^{57}Co decays and curve 3 to ^{137}Cs case. The main difference between the curves 1 and 2 is caused by the use of a thick polyethylene foil (1 mm thick) filter. Although a strong absorption of γ-rays having 14.4 keV energy takes place (the absorption coefficient equal to three), both curves have the same shape, but in case 2 the counting rate was lower. Curve 3 represents the time spectrum recorded with a radioactive ^{137}Cs source which gives an estimate of the time distribution for the accidental coincidences. All these spectra were recorded under the same working conditions.

In order to extract the half-life values from the experimental data, time scale calibration for the time spectrometer and an appropriate implementation of unfolding procedure for delayed coincidence spectra are required. A time calibration for the time-to-amplitude converter (TAC) has been obtained by introducing

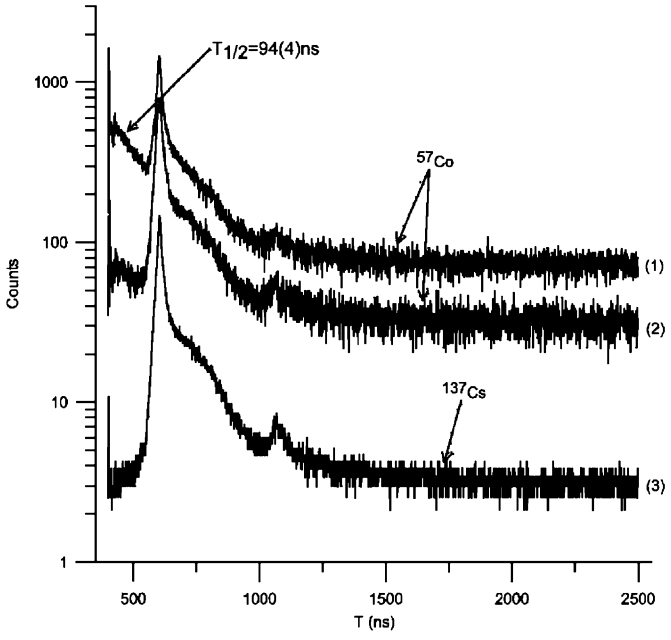

Fig. 3. Time spectra at decay of ^{57}Co (curves 1 and 2) and ^{137}Cs (curve 3). For the clarity of the figure, the amount of data in each channel was multiplied by 0.5 for the curve number 2 and by 0.1 for curve number 3.