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^{18}F STANDARDIZATION BY MEANS OF A 4πβ–γ SOFTWARE COINCIDENCE SYSTEM

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ABSTRACT

The standardization of ^{18}F, a positron emitter of short half-life, used in PET (Positron Emission Tomography) by means of a software 4πβ–γ coincidence system is described. The 4πβ–γ coincidence system consists of a gas-flow proportional counter (PC) in 4π geometry operated at 0.1 MPA coupled to a 50 x 50 mm NaI(Tl) crystal. The data collection was made by means of a Software Coincidence System (SCS) developed at the LMN (Nuclear Metrology Laboratory) of the IPEN-CNEN/SP. The extrapolation technique was applied to determine the activity of the solution.

1. INTRODUCTION

This paper describes the procedure followed by LMN (Nuclear Metrology Laboratory) at IPEN for the standardization of ^{18}F, which is an important radionuclide in nuclear medicine used for studies of heart, lungs and brain metabolism and it is also used for imaging tumors in oncology in Positron Emission Tomography equipment. The ^{18}F decays with a short half-life ($T_{1/2}$ = 1.8 h), by positron emission (96.86%) and by electron capture (3.14%) to the ground state of ^{18}O, emitting annihilation photons at 511 keV and low energy X-rays (0.53 keV) in the process [1], as shown in Fig 1.

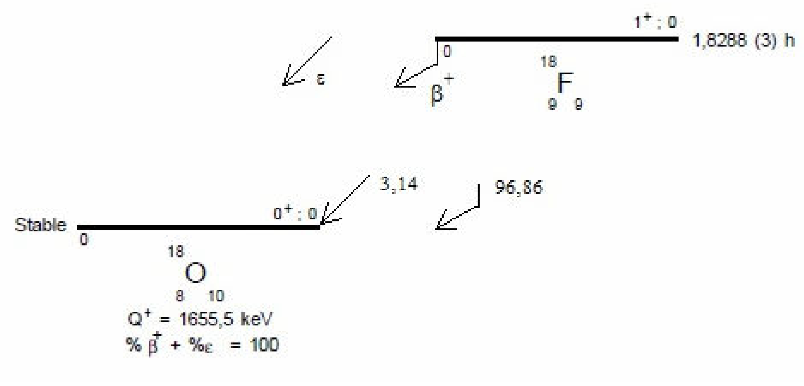

Figure 1: Decay scheme of ^{18}F [1].

The measurement were performed in a 4πβ−γ coincidence system which consists of gas-flow proportional counter (PC) in 4π geometry, operated with P-10 gas mixture at 0.1 MPA, and coupled to a NaI(Tl) crystal. The data collection was carried out by means of a Software Coincidence System (SCS) developed at the LMN [2].

2. EXPERIMENTAL METHOD

2.1. Source Preparation

The ^{18}F solution was supplied by the IPEN Radiopharmaceutical Center and diluted in distilled H_2O. The radioactive sources were prepared by dropping known aliquots on Collodion substrate, previously coated with 10 μg cm^{-2} gold layer on both sides to make the film conductive. The source masses were determined by the pycnometer technique. A seeding agent (Cyastat SM) was used to improve the deposit uniformity and the sources were dried under a nitrogen jet at 45 °C. Three sources with masses of 25.2 mg, 23.2 mg and 43.6 mg, respectively, were prepared for solution standardization.

2.2. 4πβ−γ Coincidence Method

The 4πβ−γ coincidence system consisted of a 4π proportional counter (PC) filled with P-10 gas mixture (90% Argon + 10 % Methane), operated at 0.1 MPa, for detecting the positron emission and the X-rays and Auger electrons coming from the electron capture process decay. The PC counter was coupled to a 50 x 50 mm NaI(Tl) crystal [3] for detecting the emitted gamma rays.

The standardization was performed by selecting the 511 keV annihilation photons absorption peak, in the gamma detector. The beta plus efficiency was varied by pulse height discrimination defined by software after the acquisition was completed. Fig. 2 shows the electronic diagram of the 4πβ−γ coincidence system coupled to the SCS.

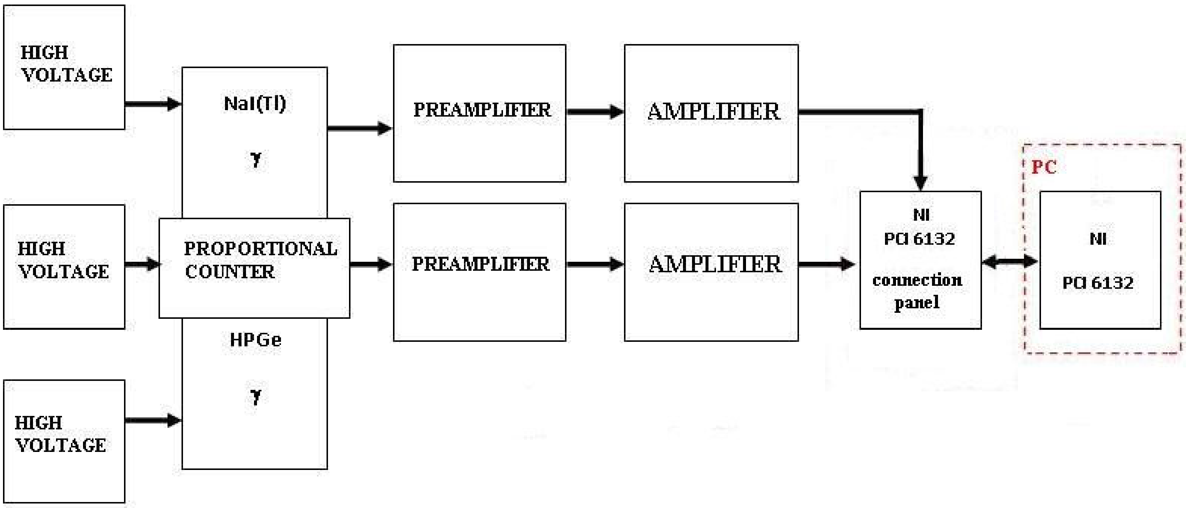

Figure 2: Electronic diagram of the 4πβ–γ coincidence system coupled to the [SCS].

2.3. Software Coincidence System (SCS)

The Software Coincidence System (SCS) is based on the National Instruments PCI-6132 card capable of up to four independent analog inputs at a 2.5 MS/s rate, the signals are processed by means of LabView Version 8.5 acquisition program.

This system records the pulses from the amplifier connected to each detector at the coincidence system: proportional counter, NaI(Tl) scintillator and HPGe detectors in order to record the data related to the time and pulse height of the event. A fourth input was inserted, corresponding to a reference pulser for checking dead time corrections.

A computer program, developed in LMN, called SCTAC version 6.0 [3] allows the reconstruction of beta and gamma spectra as shown in fig 3 and 4. This code performs the discrimination of beta spectrum, and the selection of the gamma window, including subtraction of Compton events from higher gamma quanta, which may interfere with the peak of interest.

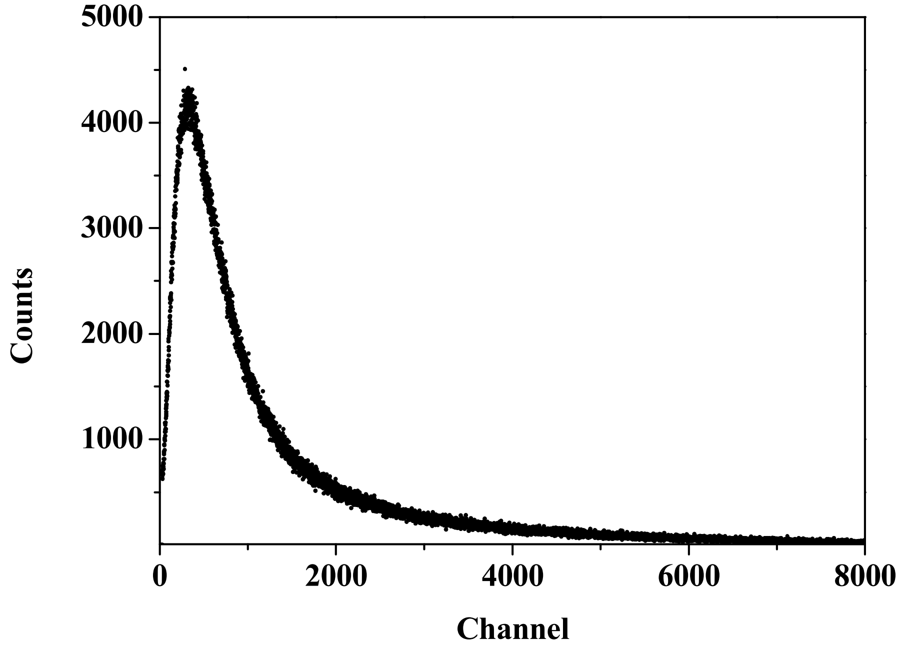

Figure 3: Beta Channel spectrum obtained by the SCS system.

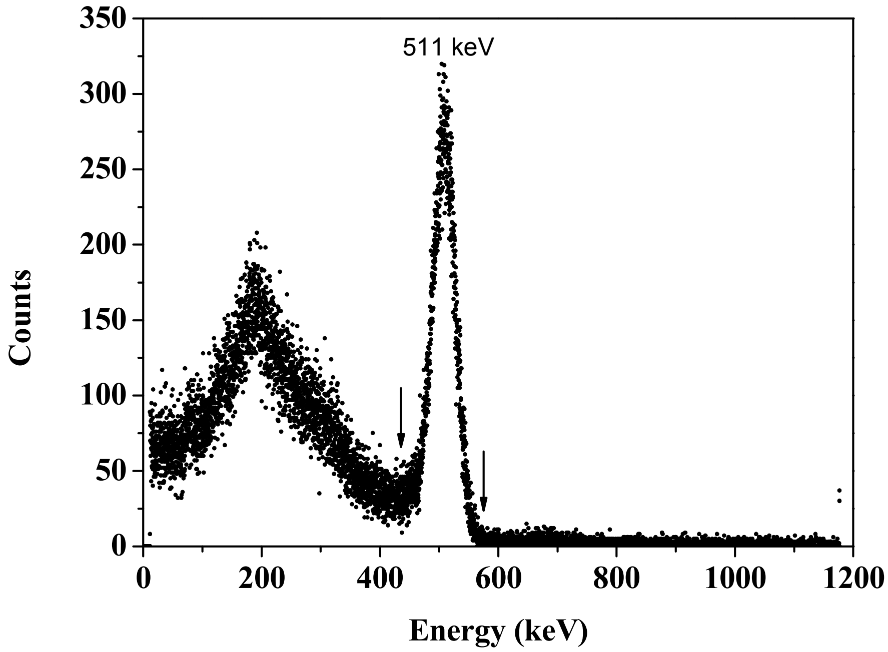

Figure 4: Gamma spectrum obtained by the SCS system, indicating the gamma window selected at the total absorption peak for the 511 keV annihilation photon.

3. RESULTS

The beta efficiency was changed by electronic discrimination from 98.3 to 90.4 %. Fig. 5 shows the extrapolation curve obtained for ^{18}F (continuous line and experimental data points). A linear square fitting, using the LINFIT [4] code, which takes into account all correlations involved and incorporates the covariance matrix methodology, was used between $N_\beta N_\gamma / N_C$ and the inefficiency parameter $(1 - N_C / N_\gamma)/(N_C / N_\gamma)$.

The best fit was obtained with 4 parameters and 23 degrees of freedom and the reduced Chi-square value was 1.17, indicating a satisfactory fit [5].

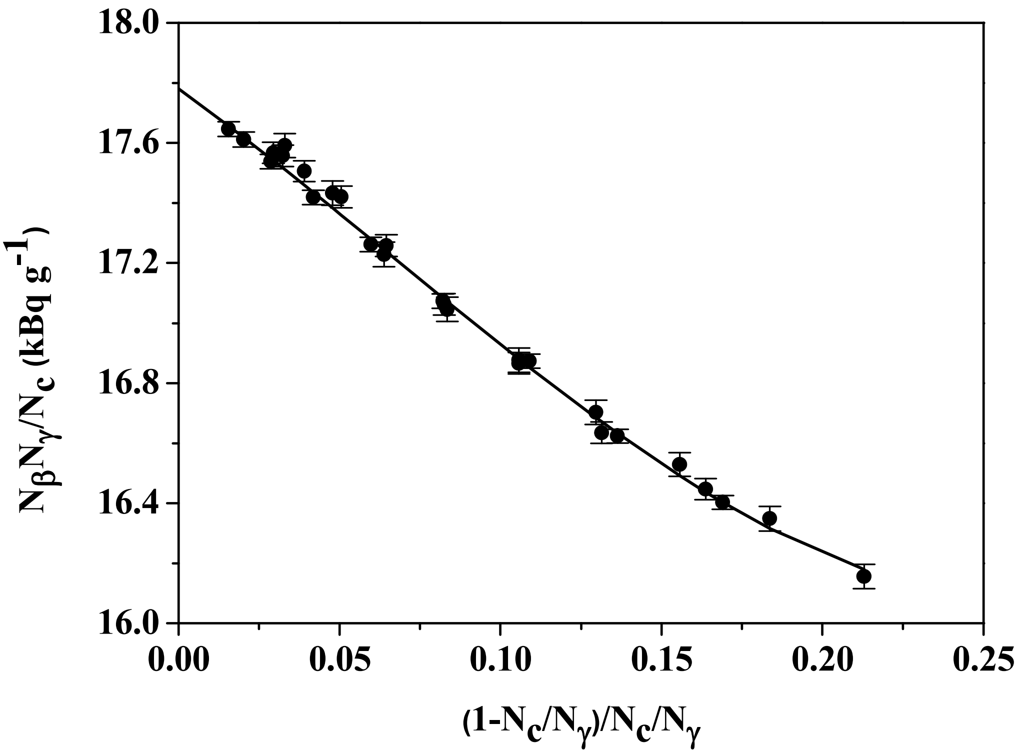

Figure 5: Extrapolation curve of $N_\beta N_\gamma/N_c$ as a function of $(1-N_c/N_\gamma)/N_c/N_\gamma$ of ^{18}F.

Fig. 6 shows the relative residuals of the linear efficiency extrapolation least-square fit compared with the experimental data. The residuals show uniformity indicating no bias.

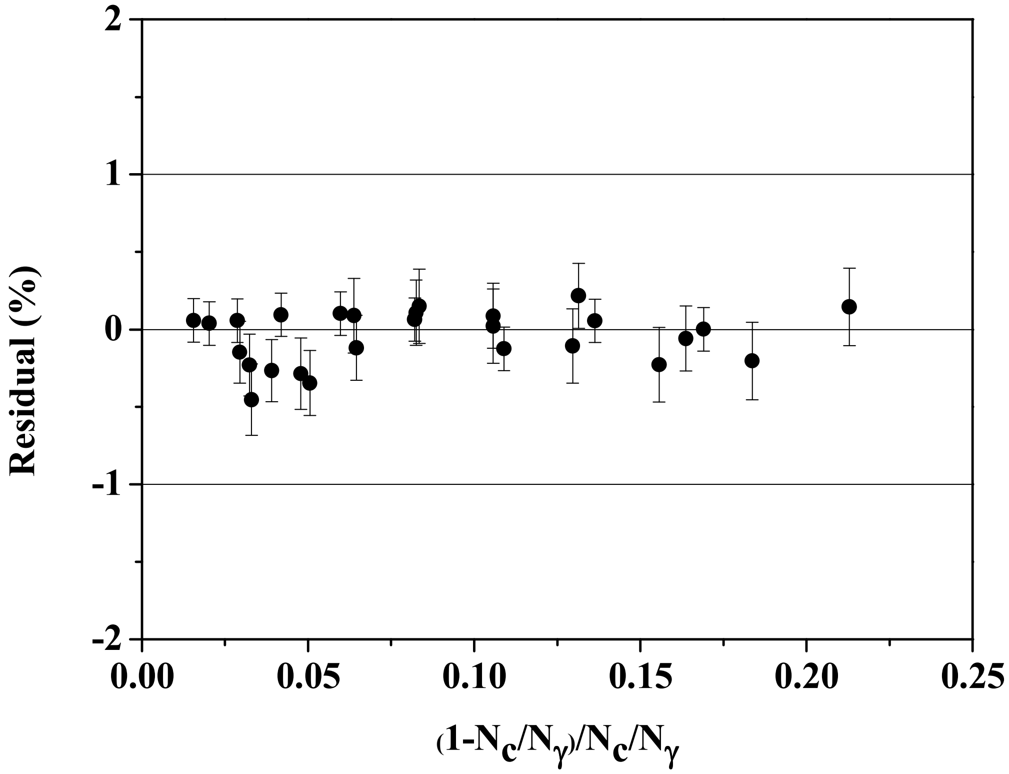

Figure 6: Relative residuals of the least-square fit of the linear efficiency function compared with the experimental data.

To obtain the final activity a correction due to the contribution from electron capture process was applied. This factor was *fce* = 1.0202(72) [6], and the final activity value resulted 18.14(15) $kBq.g^{-1}$.

Typical uncertainties components in % of the activity concentration are shown in Table 1. The main contribution to the overall uncertainty comes from the *fce* correction factor

Table 1: Partial uncertainties involved in activity determination (in percent, at 68% confidence level).

Component	%	Remarks
Counting statistics	0.07	Statistics
Weighing	0.21	Balance certificate
Dead time	0.10	Software
Background	0.30	Counting statistics
Decay	0.11	Half life
Resolving time	0.10	Statistics in accidental coincidence correction
Correction factor	0.70	Conversion electron probability per decay
Fitting	0.15	Extrapolation of efficiency curve
Combined uncertainty	0.82	

4. CONCLUSIONS

Applying the digital coincidence system it was possible to determine the activity with only one measurement and obtain the extrapolation curve. The standardization of ^{18}F by means the SCS was successful and made possible to accomplish all measurements in a single day.

The Monte Carlo simulation code ESQUEMA [7] version 9, developed by the LMN, will be used for simulating the efficiency extrapolation curve, considering the characteristics of the disintegration scheme and all geometric and material details of the detection system, and the results will be compared.

ACKNOWLEDGMENTS

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