CHARACTERISTICS OF A THYROID SPECTROMETER BASED ON A $LaBr_3(Ce)$ DETECTOR

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1. Introduction

The Whole Body Monitoring Laboratory (WBML) at IFIN-HH performs *in vivo* monitoring of I-131 retention in the thyroid by gamma ray spectrometry for people working in hospital nuclear medicine departments and in radiopharmaceuticals production centers.

To estimate committed effective doses and the corresponding radiological risk, it is important to perform accurate measurements using sensitive detectors appropriate for the measurement of the I-131 gamma lines at 80.2 keV, 284.3 keV, 364.5 keV, 637 keV and 723 keV, under conditions of good shielding, suitable collimation and calibration.

Traditionally, thyroid gamma spectrometry systems use scintillation detectors based on NaI(Tl) crystals. Such detectors are considered appropriate for monitoring iodine in the thyroid because of their high efficiency, reasonable energy resolution and room temperature operation.

Recently, a new type of scintillation detector material, $LaBr_3(Ce)$, has been used in different applications of high energy physics research and medical imaging. It is available in small sizes, with better resolution than NaI(Tl) crystals, and may provide an attractive alternative for *in vivo* measurements of I-131 activity in thyroid.

2. Objectives

The **main** aim of the paper is:
To explore the suitability of a $LaBr_3(Ce)$ detector for in vivo measurements of I-131 activity in the thyroid

The following issues were considered:

- **The beneficial** characteristics of $LaBr_3(Ce)$ detectors for *in vivo* gamma-ray spectrometry applications, i.e.:
  - very good energy resolution
  - high temperature stability
  - good gamma detection efficiency
  - operation at room temperature
  - promising technology for manufacturing crystals at larger sizes
- **The particular** characteristics of $LaBr_3(Ce)$ scintillator crystals, i.e.:
  - The presence of La-138, a long-lived radioisotope of lanthanum La-138 decays by electron capture and by beta-minus decay to stable radioisotopes, Ba-138 and Ce-138, producing gamma rays (788.7 keV, 1435.8 keV), Ba K x-ray (34.7 keV) and a beta continuum background with an endpoint energy at 255 keV

Resulting goal: *to investigate how much the background radioactivity of the $LaBr_3(Ce)$ detector limits the spectrometric detection of I-131 in thyroid*

3. Methods

The experimental gamma spectrometric system we used for the measurements has the following components:

- 1.5" x 1.5" $LaBr_3(Ce)$ detector, based on BriLanCe-380 crystal manufactured by Saint-Gobain Crystals
- Cylindrical detector shielding made of lead, with collimator, to reduce the environmental background
- Associated electronics:
  - Phototube high voltage supply, ORTEC type 556
  - Preamplifier, CANBERRA type 2005
  - Amplifier, ORTEC type 671
  - Dual Multichannel Buffer, ORTEC ASPEC-927
- Dedicated multichannel analyzer emulation software ORTEC-Gamma Vision 32 v-6 for data acquisition and gamma spectra analysis

For *energy calibration* of the gamma spectrometer in the energy range 30 keV – 1000 keV, gamma-ray standard point sources certified by the Radionuclide Metrology Laboratory, IFIN-HH were used.

For *efficiency calibration*, an ORTEC thyroid phantom, equivalent to the IAEA/ANSI phantom, filled with radioactive I-131 solution and positioned 10 cm from the detector was used.

4. Results and discussion

- **Energy calibration** of $LaBr_3(Ce)$ gamma spectrometer

The pulse height spectrum obtained with Am-241, Ba-133 and Cs-137 calibration sources is shown in Fig.1.

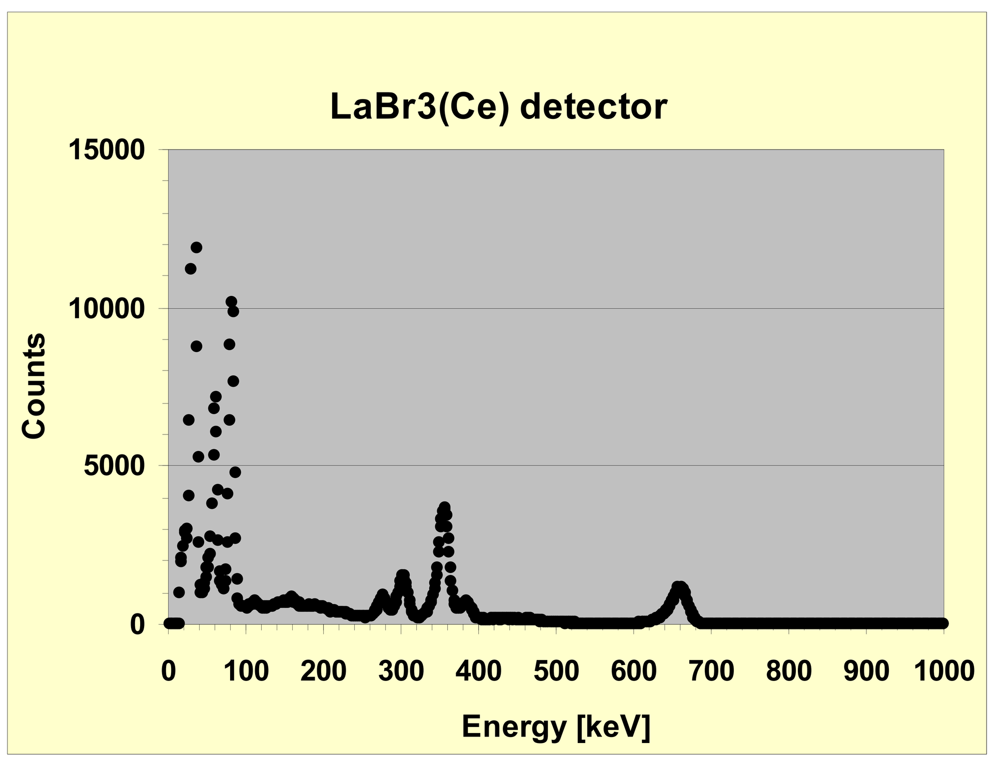

Fig.1 Mixed radioactive source calibration spectra

The energy calibration curve (Fig.2) can be described using a second order polynomial function:

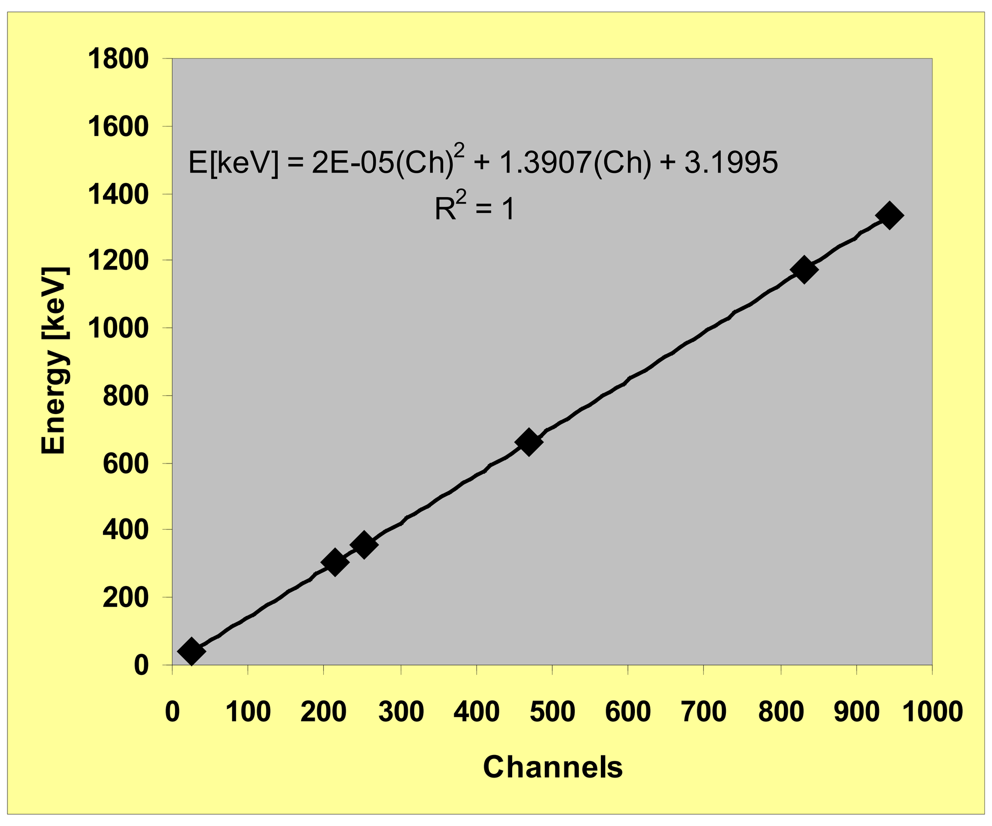

Fig.2 Energy calibration curve. R² = 1 demonstrates the goodness of data fit

- **Energy resolution** of $LaBr_3(Ce)$ detector
  - Excellent resolution: 3.3% at Cs-137 energy line at 661.7keV
  - A comparison of the resolutions of the $LaBr_3(Ce)$ detector and a NaI(Tl) detector of similar size is shown in Fig.3.

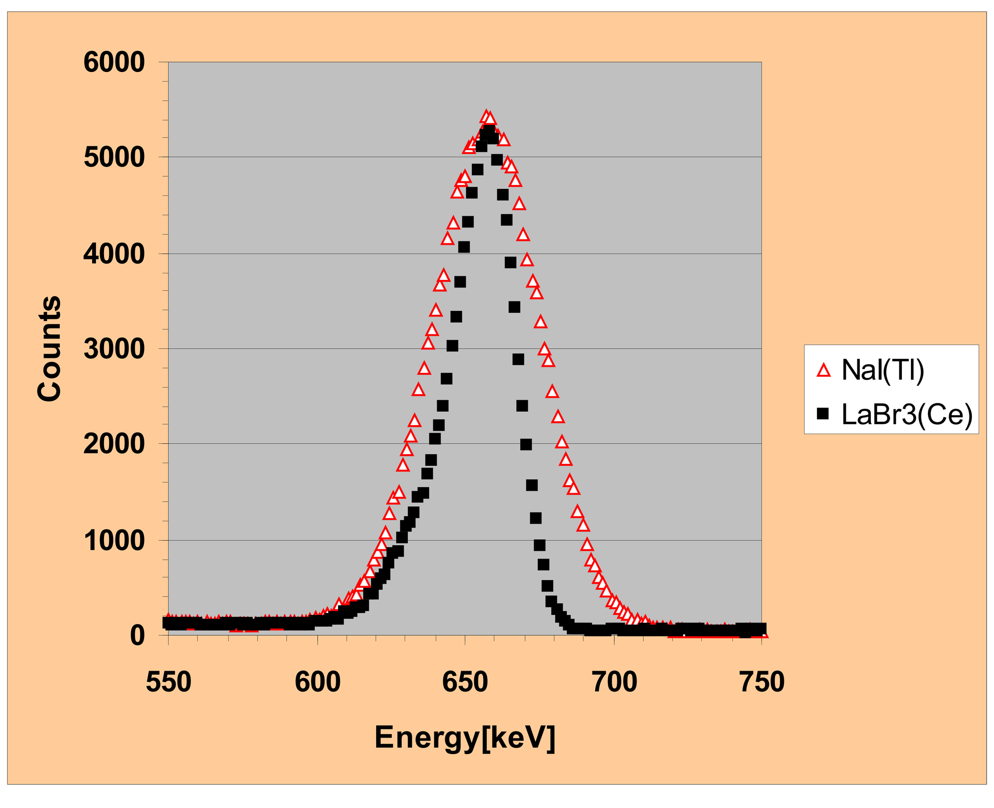

Fig.3 Cs-137 (661.7 keV peak) spectra for $LaBr_3(Ce)$ and NaI(Tl) detectors

- **Qualitative analysis of** $LaBr_3(Ce)$ background spectra (Fig.4):
  - 2 dominant gamma peaks in the energy range 30keV-1600keV are due to the radioisotope La-138 from LaBr3(Ce) crystal:
    - Ba K x-ray at 34.7 keV
    - gamma ray at 1435.8 keV overlapping the K-40 line at 1460keV
  - gamma rays of natural radionuclides: Pb-214, Ac-228, Tl-208 and Bi-214, in the energy interval 300-700keV containing the I-131 main energy line at 364.5 keV

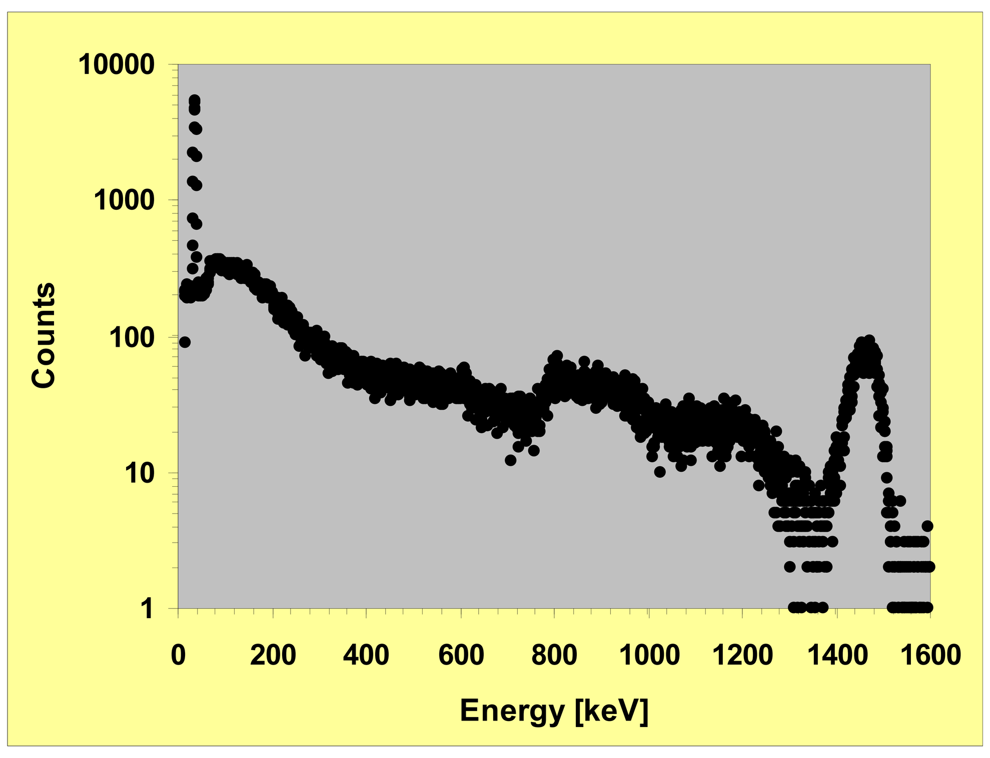

Fig.4. Background spectra acquired with $LaBr_3(Ce)$ detector.

- **Quantitative analysis of I-131 and background spectra** obtained with $LaBr_3(Ce)$ detector and the ORTEC thyroid phantom (Fig.5)

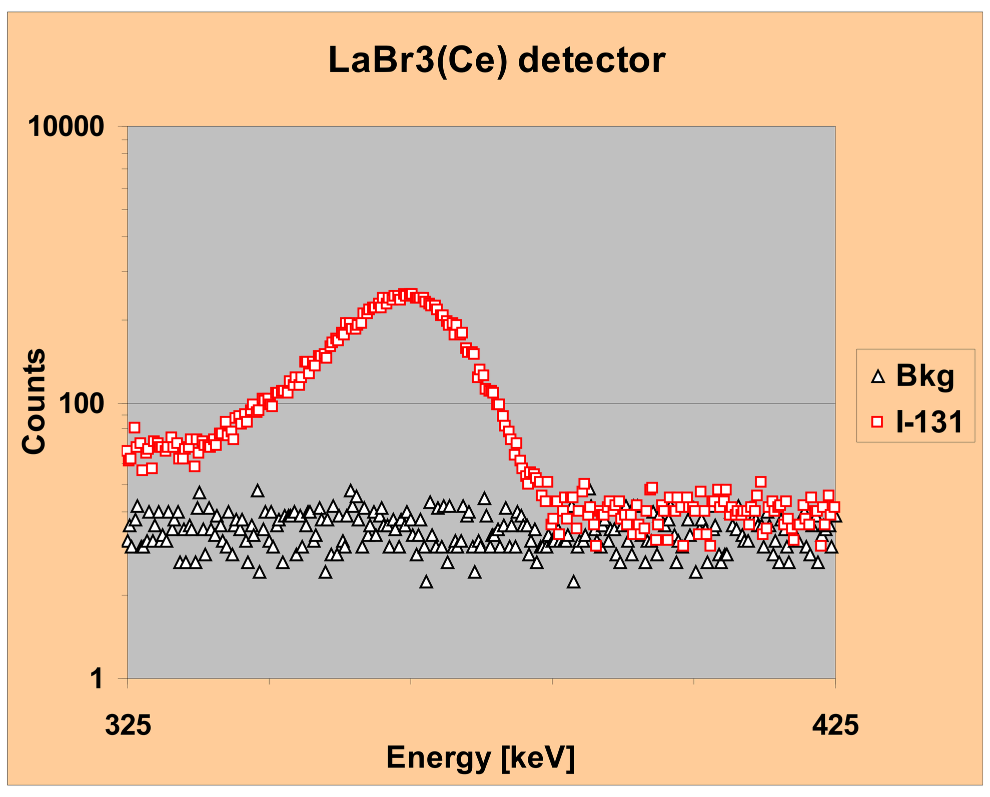

Fig.5 Background and I-131 spectra measured with $LaBr_3(Ce)$ detector

- Count rates (cps) in the background spectra were determined for the energy interval 300 keV -700 keV, which includes the I-131 main peak at 364.5 keV, and for the energy interval 325 keV – 425 keV, defined as the region of interest (ROI) corresponding to the I-131 main peak.
- From the pulse height spectra of the I-131 and background spectra, acquired with the $LaBr_3(Ce)$ detector, the resolution, the efficiency and the Detection Limit at 364.5keV were determined.
- All the results are shown in Table 1, together with those obtained under the same measurement conditions for an NaI(Tl) scintillation detector of similar dimensions. The uncertainties due to counting statistics are given in terms of one standard deviation.

Table 1. Results obtained from background and I-131 spectra of $LaBr_3(Ce)$ and NaI(Tl) scintillators of comparable sizes

Parameter	$LaBr_3(Ce)$	NaI(Tl)
Count rate (cps) for the energy interval (300keV-700keV)- background spectra	9.30±0.03	4.97±0.02
Count rate (cps) in the ROI for the 364.5 keV I-131 peak – background spectra	1.229±0.004	1.090±0.003
Detection Limit [Bq] for the 364.5keV of I-131 peak	20.11±0.06	14.86±0.05
Resolution at 364.5 keV [%] – I-131 spectra	4.34±0.04	8.74±0.14

- The contribution to the background of the natural La-138 radioisotope, present in the lanthanum crystal, is shown, in the energy interval (300keV-700keV), by the higher values of the count rate determined from the $LaBr_3(Ce)$ background spectra compared with those obtained with an NaI(Tl) detector
- The La-138 radioisotope does not affect the count rate in the region of interest of the I-131 main peak at 364.5 keV. The count rates show a slight difference for the two detectors that contribute to the different values of the detection limits.
- The contribution of the natural radionuclides Ac-228, Tl-208, Pb-214 and Bi-214, is shown by the large difference between the count rate for the whole energy interval (300keV-700keV) and that corresponding to the 364.5keV I-131 ROI, for the two detectors.
- The resolution of the $LaBr_3(Ce)$ detector at 364.5keV is, consistently, higher than the resolution of the NaI(Tl) detector.

5. Conclusions

- Scintillation detectors remain a very good choice for room temperature detectors used for *in vivo* measurements.
- The excellent energy resolution of the $LaBr_3(Ce)$ detector was confirmed by the measurements performed in the WBM Laboratory, IFIN-HH.
- The contributions to the background of the natural La-138 radioisotope and of the natural radionuclides belonging to Th-232 and U-238 natural decay series, in the region of interest of the I-131 gamma line, 364.5 keV, are not significant. The measurements revealed similar background count rates in the energy interval 325-425 keV for the NaI(Tl) and $LaBr_3(Ce)$ detectors.
- Our research shows that lanthanum bromide scintillation detectors offer an attractive alternative to NaI(Tl) detectors for *in vivo* measurements of I-131 retention in the thyroid by gamma spectrometry.

13th International Congress of the International Radiation Protection Association
13 - 18 May 2012 Glasgow Scotland