1. Introduction
The Whole Body Monitoring Laboratory (WBML) at IFIN-HH performs in vivo monitoring of 131-I 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 1-131 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, LaBr₃(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 1-131 activity in the thyroid.

2. Objectives
The main aim of the paper is to explore the suitability of a LaBr₃(Ce) detector for in vivo measurements of 1-131 activity in the thyroid.

The following issues were considered:

- **The beneficial characteristics of LaBr₃(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 LaBr₃(Ce) scintillator crystals**, i.e.:
  - the presence of La-138, a long-lived radionuclide of lanthanum La-138, decays by electron capture and by beta-minus-decay to stable radionuclides, Ba-138 and Ce-138, producing gamma rays (788.3 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 LaBr₃(Ce) detector limits the spectrometric detection of I-131 in the thyroid.

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

- **1.5’’ x 1.5’’ LaBr₃(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**: Photonlab high voltage supply, ORTEC type 556; Preamplifier, CANBERRA type 205; Amplifier, ORTEC type 671; Dual Multichannel Buffer, ORTEC ASPEC-927; Phototube high voltage supply, ORTEC type 556.
- **Dedicated multichannel analysis software** ORTEC-Vision 32 v-6 for data acquisition and gamma spectra analysis.

For energy calibration, the gamma spectrometer in the energy range 30 keV – 1000 keV, gamma-ray standard point sources certified by the Radionuclides Metrology Laboratory, IFIN-HH were used. For efficiency calibration, an ORTEC thyroid phantom, equivalent to the IAEA594 phantom, filled with radioactive I-131 solution and positioned 10 cm from the detector was used.

**The experimental gamma spectrometric system** we used for the analysis of a mixed radioactive source was described in (Fig.1).

4. Results and discussion
- **Energy calibration of LaBr₃(Ce) gamma spectrometer**: The pulse height spectrum obtained with Am-241, Ba-133 and Cs-137 calibration sources is shown in Fig.3.

**Fig.3 Energy calibration curve. R² = 1 demonstrates the goodness of data fit**

- **Qualitative analysis of LaBr₃(Ce) background spectra** (Fig.4):
  - 2 dominant gamma peaks in the energy range 390keV – 1600keV are due to the radionuclide 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 300-700 keV containing the I-131 main energy line at 364.5 keV

- **Energy resolution of LaBr₃(Ce) detector**:
  - Excellent resolution: 3.3% at Cs-137 energy line at 661.7 keV
  - A comparison of the resolutions of the LaBr₃(Ce) detector and a NaI(Tl) detector for La-138 radioisotope from LaBr₃(Ce) spectra compared with those obtained with an NaI(Tl) detector
  - For the pulse height spectra of the I-131 standard source, calibrated with the LaBr₃(Ce) detector, the resolution, the efficiency and the Detection Limit at 394.4keV 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.

5. Conclusions
- **Scintillation detectors** remain a very good choice for room temperature detectors used in vivo measurements.
- The excellent energy resolution of the LaBr₃(Ce) detector was confirmed by the measurements performed in the WBML Laboratory, IFIN-HH.
- The contributions to the background of the natural La-138 radionuclide and of the natural radionuclides belonging to Th-222 and U-238 natural decay series, in the region of interest of the 1-131 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 LaBr₃(Ce) detectors.
- Our research shows that lanthanum bromide scintillation detectors offer an attractive alternative to NaI(Tl) detectors for gamma-ray spectrometry applications, i.e.:
  - excellent energy resolution
  - high temperature stability
  - very good energy resolution

**Fig.2. Energy calibration curve, R² = 1 demonstrates the goodness of data fit for LaBr₃(Ce) and NaI(Tl) detectors**

**Table 1. Results obtained from background and I-131 spectra of LaBr₃(Ce) and NaI(Tl) scintillators of comparable sizes**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>LaBr₃(Ce)</th>
<th>NaI(Tl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Count rate (cps) for the energy interval (300keV-700keV), background spectra</td>
<td>9.30±0.09</td>
<td>4.97±0.02</td>
</tr>
<tr>
<td>Count rate (cps) in the ROI for the 364.5 keV I-131 peak, background spectra</td>
<td>1.22±0.004</td>
<td>1.09±0.003</td>
</tr>
<tr>
<td>Detection Limit (Bq) for the 364.5 keV I-131 peak</td>
<td>20.5±0.09</td>
<td>14.86±0.09</td>
</tr>
<tr>
<td>Resolution at 364.5 keV [% I-131 spectra]</td>
<td>4.34±0.04</td>
<td>8.74±0.14</td>
</tr>
</tbody>
</table>

- The contribution in the background of the natural La-138 radionuclide, present in the lanthanum crystal, is shown in the energy interval (300keV-700keV), by the higher values of the count rate determined from the LaBr₃(Ce) background spectra compared with those obtained with an NaI(Tl) detector
- The La-138 radionuclide 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, Th-228, 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 LaBr₃(Ce) detector at 364.5keV is, consistently, higher than the resolution of the NaI(Tl) detector.