Study of linearity and internal background for $LaBr_3$(Ce) gamma-ray scintillation detector

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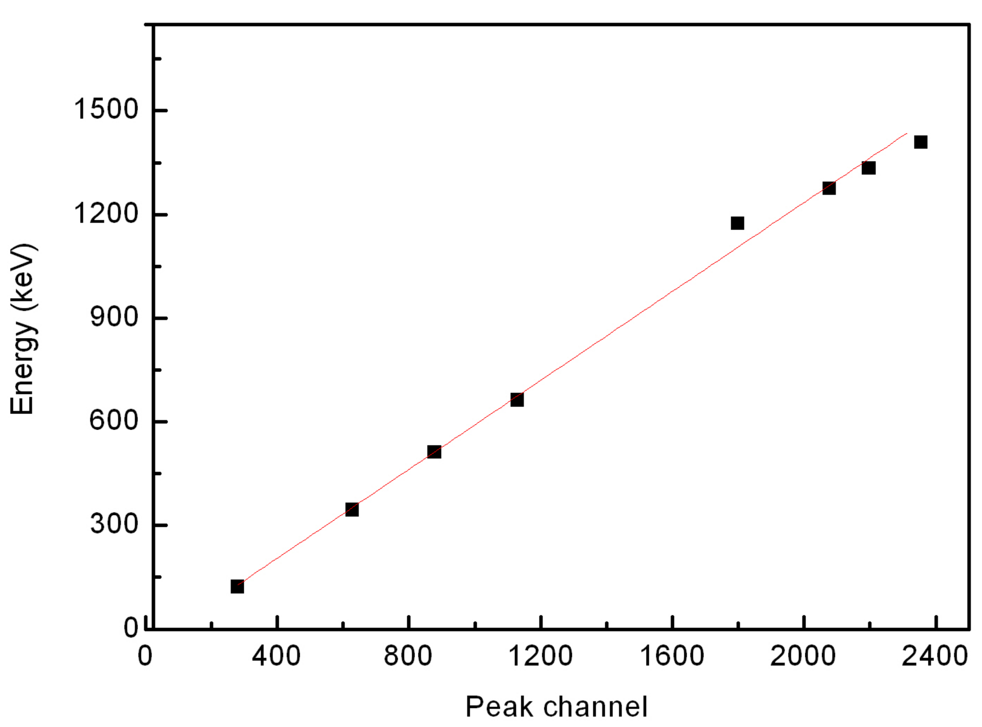
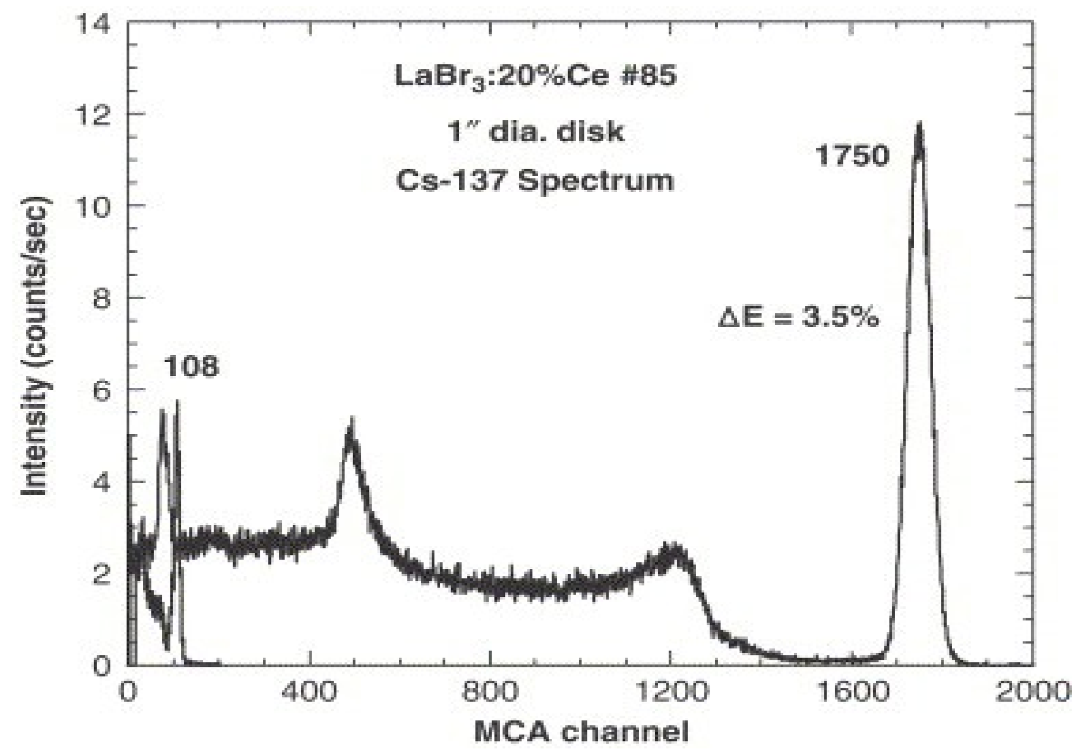
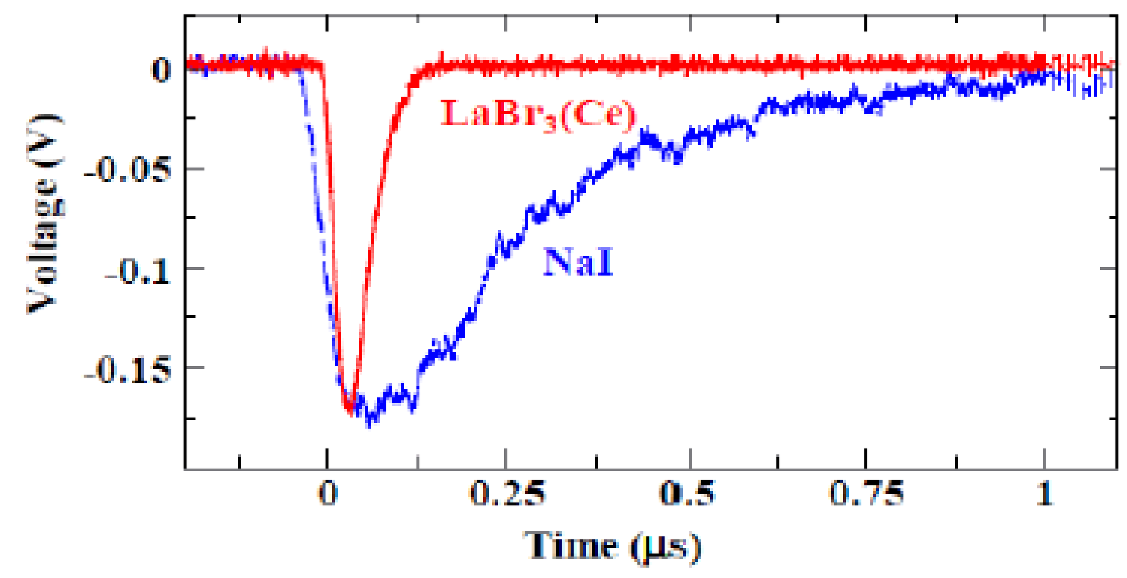
Most of the modern g-spectroscopy measurements require higher technological performances hence a new generation of scintillator detectors has been developed. Cerium-doped lanthanum bromide scintillator, $LaBr_3$(Ce), is very attracting for its high brightness (>65000 photons/MeV) that results in a very good energy resolution (<3% FWHM at ^{137}Cs photons of 662 keV, the best resolution never achieved by scintillators), its high density (5.1 gr/cm3) and its fast decay time (16 ns) that allows a timing comparable to BaF_2 that is the fastest between the scintillation counters. The general properties of $LaBr_3$(Ce) are described in Refs [1-3] together with comparison with other scintillators usually employed in g-spectroscopy. At the beginning of its commercialization $LaBr_3$(Ce) crystals have only been available in small size mainly due to the crystal anisotropic characteristics. In fact $LaBr_3$(Ce) shows strong anisotropy in thermal expansion, heat transfer and mechanical strength hence its larger ingots are likely to cracking during the cool down process after the growth. But larger crystals are necessary in order to reach a good efficiency and to stop all the energy delivered in g-ray interactions. In the last few years Saint Gobain Crystals firm has established a wide scale production of cylindrical counter 3" x 3" of $LaBr_3$ enriched at 5% with Ce under the trademark BrillLanCe 380R. Large crystal growing technology must show that the very good performances achieved in smaller crystals (typically 1" x 1") have not been spoiled due to material non-uniformity[4] or optical self-absorption of the emitted scintillation light. The purpose of this paper is to present the results of energy resolution, internal background and energy linearity for 3" x 3" $LaBr_3$(Ce) crystal.



Linearity plot of the $LaBr_3$(Ce) 3" x 3" scintillator.
The centroid channel of the peak is plot vs the photon energy

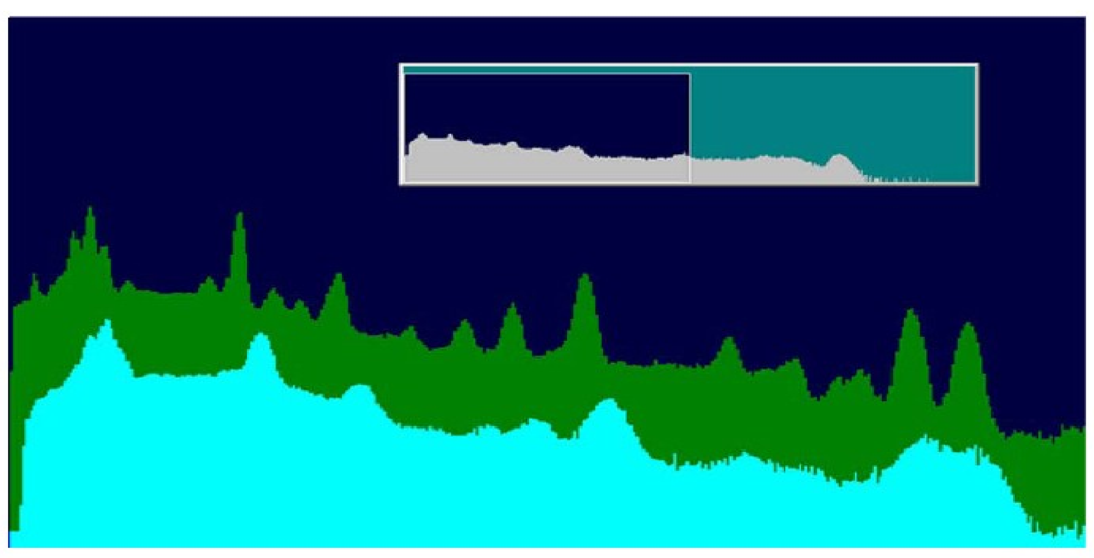


^{137}Cs reference spectrum of 1" diameter disk of $LaBr_3$(Ce)

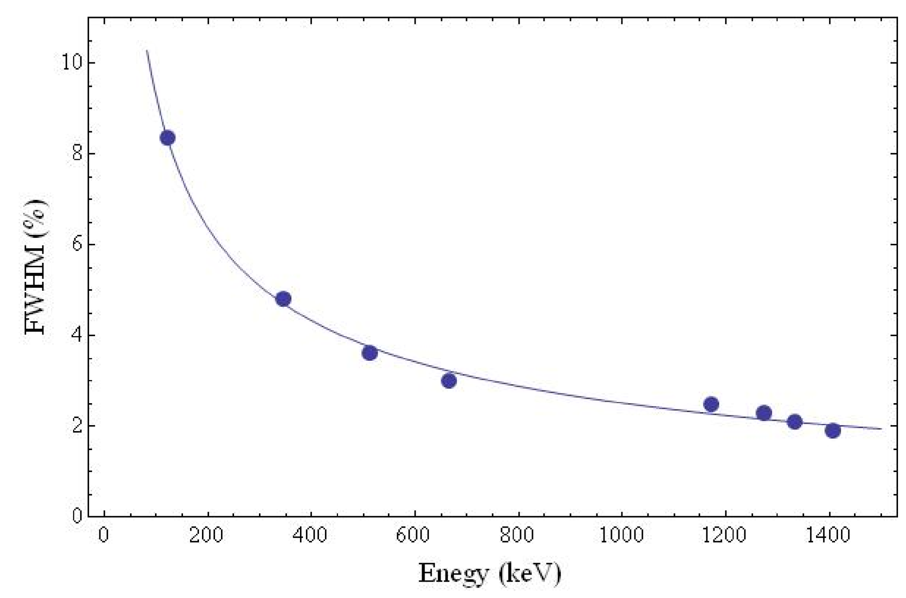


PMT electric signals comparison

$LaBr_3$:Ce



^{232}Th spectra from $LaBr_3$(Ce) (upper) and NaI (lower)



FWHM energy resolution (full circles) for 3" x 3" scintillator measured with the use of different collimated γ sources (^{152}Eu, ^{137}Cs, ^{60}Co, ^{22}Na) compared to the expected $E_\gamma^{-1/2}$ behaviour (full line).

Conclusions

$LaBr_3$:5% Ce is presently available in large ingots (>100 cm^3). The large crystals do not show any sensible degradation with respect to small ones (1"x 1" see [4-6]), maintaining the same performances in energy resolution, linearity and internal activity. This study on $LaBr_3$(Ce) started in order to investigate the possibility to use it as an interesting alternative to HpGe detectors in underground nuclear astrophysics experiments at INFN Gran Sasso National Laboratories (see [7-9]) when the spectra under investigation are not very complex. In this kind of measurements we deal with induced nuclear reactions at energy under the Coulomb barrier and events are collected at low trigger rates (few triggers per hours). An internal activity of 320 cts/s in all the detector, corresponding to 0.92 cts/s/cm^3, is worse than what we expect to find using HpGe covering the same solid angle (with a better resolution), but if the detector must surround the target as in the clover case [7] and/or if angular distributions are to be measured, the $LaBr_3$(Ce) solution assures an acceptable energy resolution with a strong convenience from the cost side. Another possible application for $LaBr_3$(Ce) is when a selective (anti)coincidence is required covering a (relatively) large solid angle near the target. In this situation its excellent intrinsic energy resolution allows to set a much more precise and efficient energy windows (thresholds) than for instance NaI, with the additional option, if needed, of a much faster response.

Self-activity in 3" x 3" $LaBr_3$(Ce) crystal

Isotope	Decay mode	β^- Energy (keV)	Branching ratio (%)	γ-ray Energy (keV)
^{138}La	β^- EC	255 +/- 12	34 66	789 1436
^{211}Pb	β^-	1378 +/- 8	100	
^{207}Ti	β^-	1423 +/- 5	100	

Reference.
[1] E.V.D. van Loef et al., Nucl. Instr. and Meth. A 486 (2002) 254.
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[4] P.R. Menge et al., Nucl. Instr. and Meth A 579 (2007) 6.
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[6] R. Nicolini et al., Nucl. Instr. and Meth A 582 (2007) 554.
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[9] C. Casella et al., Nucl. Instr. and Meth. A 489 (2002) 160.