Energy resolution of $LaBr_3$:Ce in a Phoswich configuration with CsI:Na and NaI:Tl scintillator crystals

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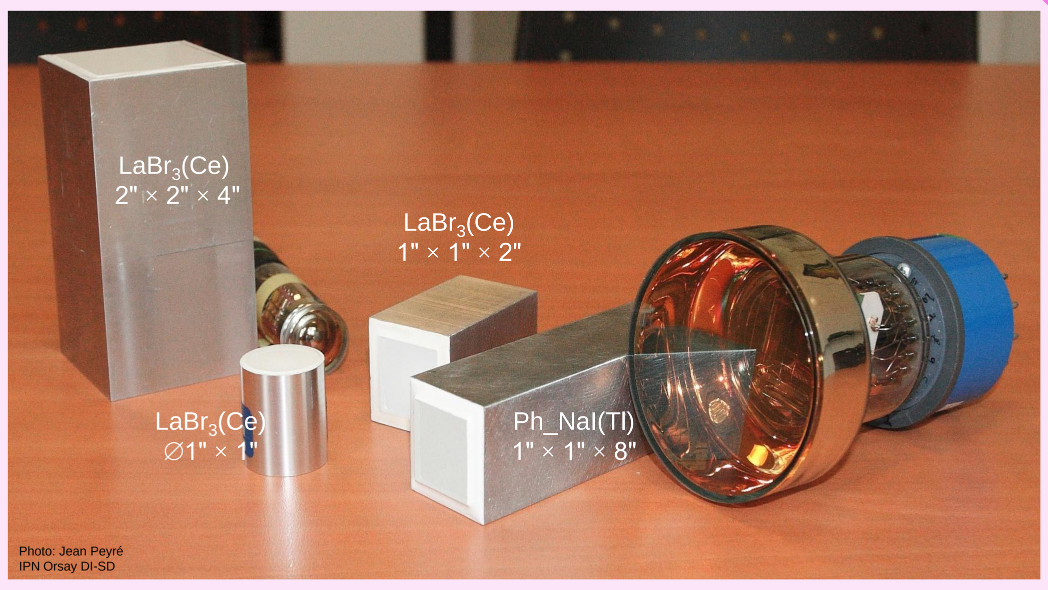
Summary: The scintillation properties of $LaBr_3$(Ce), at present the brightest scintillator commercially available, providing an energy resolution as good as 2.8% at 662 keV (for small sized crystals), have been extensively studied in these latest years. However, the high cost of these crystals is the main drawback to use them in large apparatus experiment. Thus, coupling $LaBr_3$(Ce) crystal to another one, in the so-called Phoswich configuration, appears to be an attractive solution that must be confirmed by detailed measurements, because of the scarcity of published results.

We studied the performances of the $LaBr_3$(Ce) scintillator when optically coupled to 6"-long NaI(Tl) and CsI(Na) for the R&D of the gamma ray calorimeter PARIS (Photon Array for the studies with Radioactive Ion and Stable beams). This detector has the purpose to measure γ-energies in a wide range (100 keV-50 MeV), and it will be used principally as a part of the SPIRAL2 instrumentation at GANIL. The current project envisages the use of the advanced technology of the $LaBr_3$(Ce), either in a stand alone or in a phoswich configuration.

In this communication we will report on the study of the light yield and energy resolution under gamma excitation realized by coupling the phoswiches with various photomultiplier tubes, providing different characteristics. We were interested in investigating the degradation of the scintillation light produced by the $LaBr_3$(Ce) due to the fact that it has to pass through all the coupled crystal, before being detected on the photocathode.

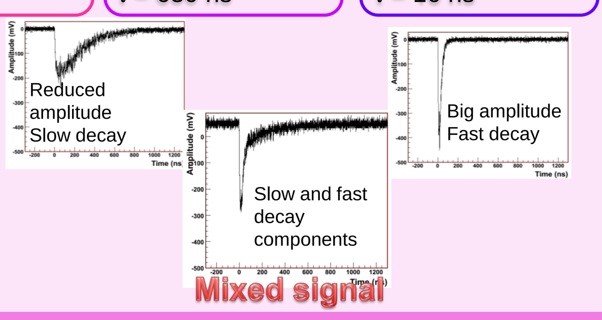
Experimental equipment

Crystals	
$LaBr_3$(Ce)	1" × 1" × 2"
$LaBr_3$(Ce)	2" × 2" × 4"
$LaBr_3$(Ce)	∅ 1" × 1"
Ph_(1")NaI(Tl)	1" × 1" × 2" $LaBr_3$(Ce) 1" × 1" × 6" NaI(Tl)
Ph_(2")NaI(Tl)	2" × 2" × 2" $LaBr_3$(Ce) 2" × 2" × 6" NaI(Tl)
Ph_CsI(Na)	1" × 1" × 2" $LaBr_3$(Ce) 1" × 1" × 6"CsI(Na)



Nominal values

NaI:Tl	CsI:Na	$LaBr_3$:Ce
LY = 38γ/keV R ~ 7% @ 662 keV τ = 250ns	LY = 85% of NaI:Tl R ~ 6% @ 662 keV τ = 630 ns	LY = 63γ/keV R ~ 3% @ 662 keV τ = 16 ns



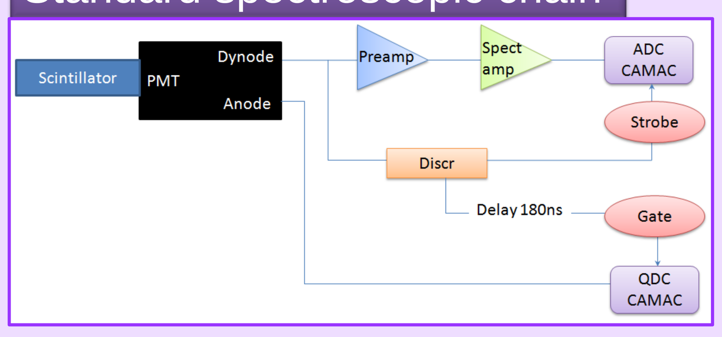
PMT	Diameter [Inches]	# stages	Cathode Sensitivity [mA/lmF-b]	Q.E. [%]
XP5300	3	8	14.6	36.3
XP2282	2	8	<<9	<<20
R2083	2	8	10.5	26.1
R7899-01	1	10	10.2	25.4
R7723-100	2	8	15.8	39.1

Photomultipliers

The acquisition system

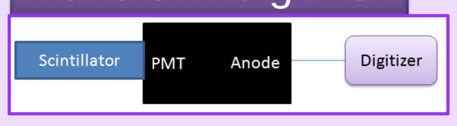
For this study we employed two different read-out systems, each providing a different level of events separation

1 Standard spectroscopic chain

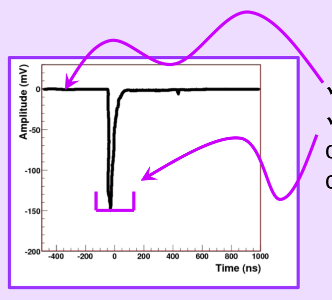


The PMT's dynode signal is sent to a Cremat preamplifier, then to an Ortec mod.672 shaping amplifier ($LaBr_3$(Ce) st=0.5 µs, NaI(Tl)/CsI(Na) st= 3 µs) and finally recorded with a CAMAC ADC module. The QDC measures the charge collected at the PMT's anode and is employed to discriminate the light produced in the $LaBr_3$(Ce) from that produced in NaI(Tl)/CsI(Na). The QDC gate is delayed with respect to the signal itself, in order to identify off-line the events not produced in the $LaBr_3$(Ce) as those with a charge, measured in the delayed gate, different from zero.

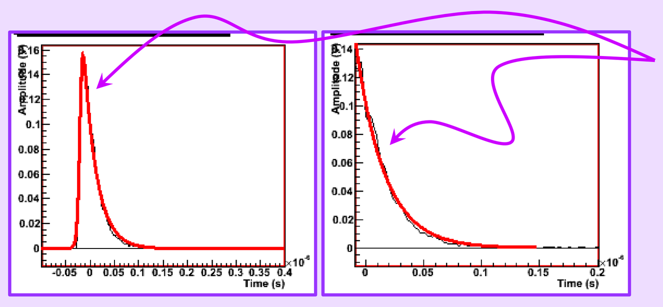
2 Waveform digitizer



The PMT's anode signal is sent to a MATACQ for digitization (sampling at 1GS/s, dynamic range [-0.5, +0.5] V).The charge and the decay time of the collected signals can then be evaluated off-line.

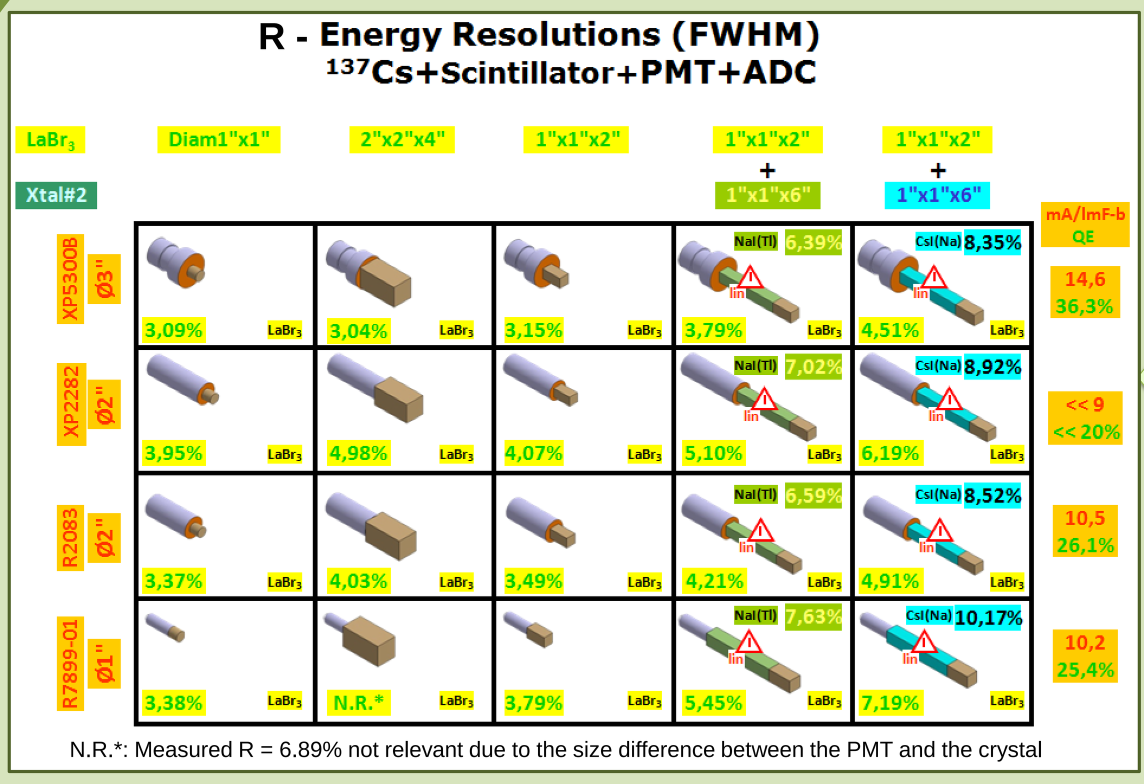


✓ Baseline evaluation
✓ Integral of the signal on a defined gate for charge measurement



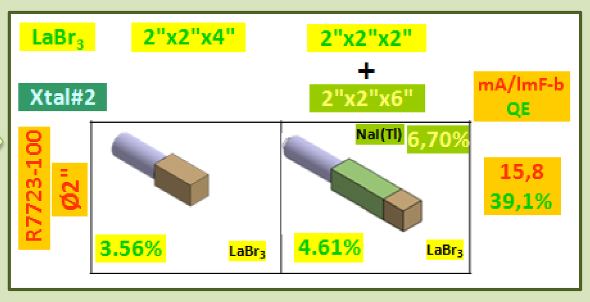
Fit of the signal waveform for the crystal decay time evaluation

The energy resolution measurements

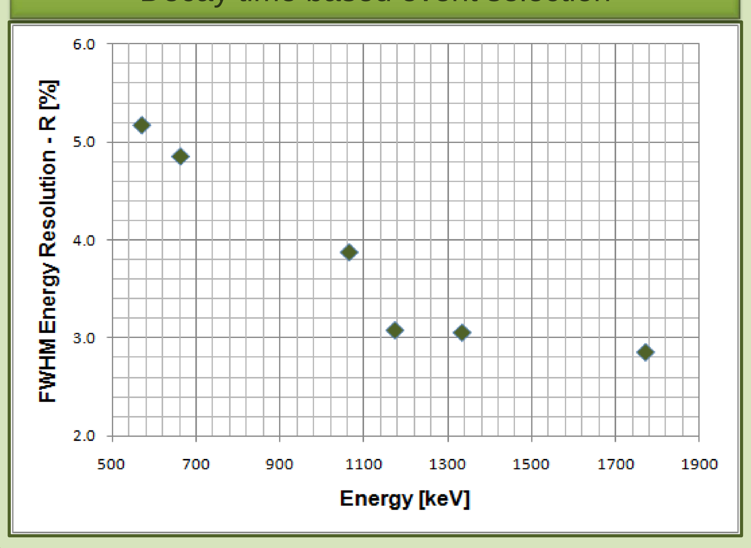


✓ R for the $LaBr_3$(Ce) in the Ph_(1")NaI(Tl) between 17 and 30% worst than that of a same sized stand-alone crystal
✓ R for the $LaBr_3$:Ce in the Ph_CsI(Na) between 30 and 50% worst than that of a same sized stand-alone crystal
✓ R for CsI(Na) worst than nominal value→NON-HOMOGENEITIES?

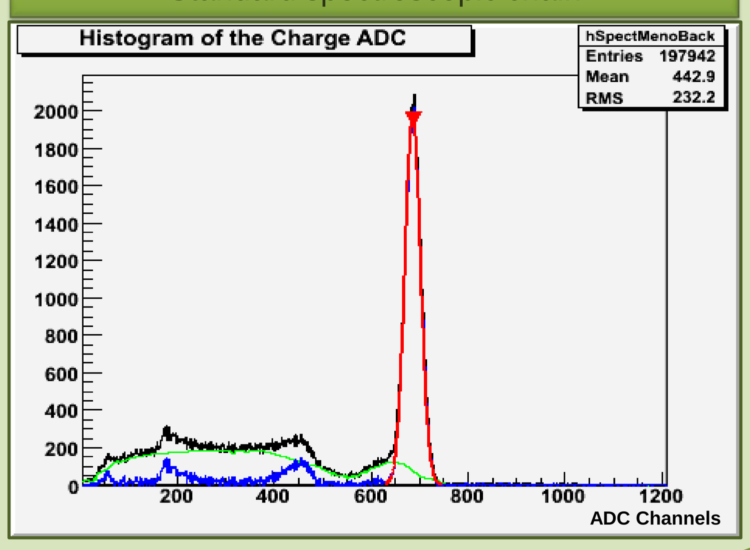
R for the $LaBr_3$(Ce) in the Ph_(2")NaI(Tl) is ~ 30% worst than that of a 2"×2"×4" stand-alone crystal



Ph_CsI(Na) + R2083 – WF digitizer
Decay time based event selection

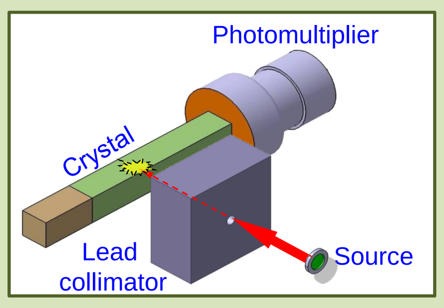


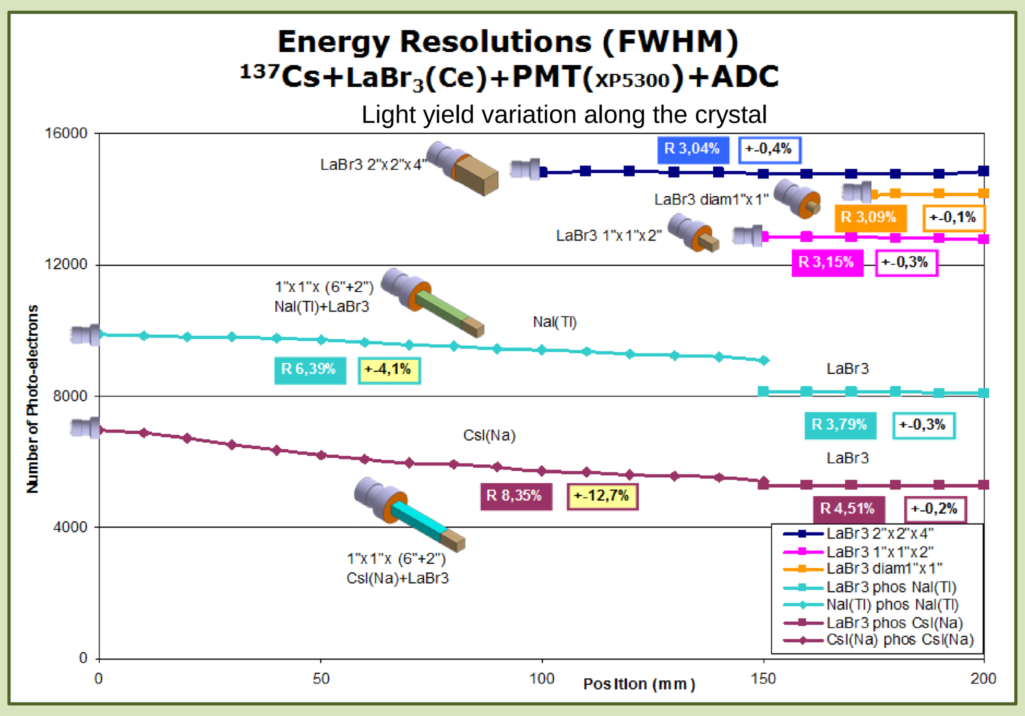
Ph_(2")NaI(Tl) + R7723-100
Standard spectroscopic chain



The light yield homogeneity test

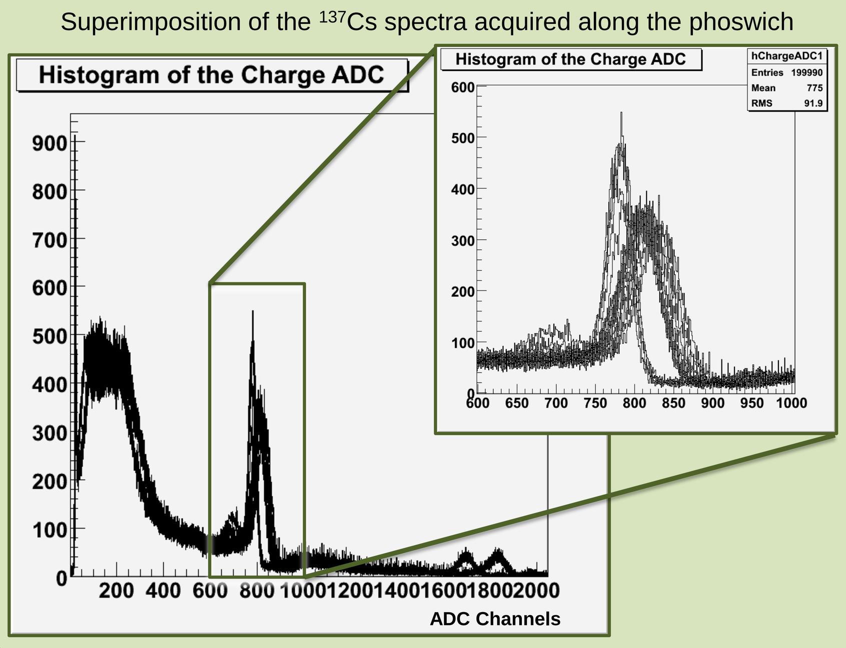
Scan along the phoswiches length with a collimated ^{137}Cs source to test the scintillators light yield homogeneity

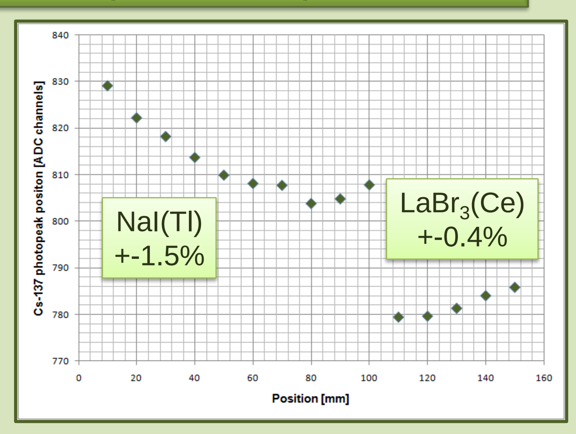


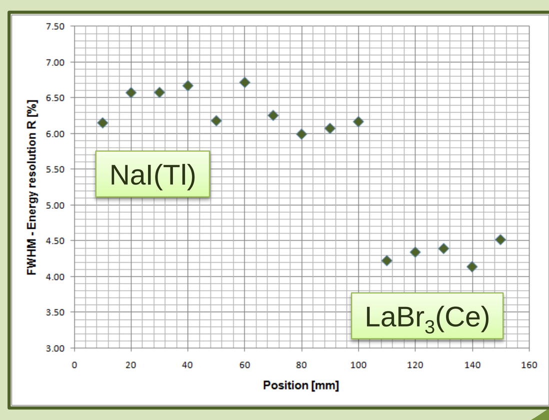


Ph_(2")NaI(Tl) coupled to PMT R7723-100 spectroscopic chain

Superimposition of the ^{137}Cs spectra acquired along the phoswich







Conclusions and perspectives: In this work we tested three $LaBr_3$(Ce)-based phoswiches coupled to various PMTs. The Ph_CsI(Na) showed a serious degradation of the $LaBr_3$(Ce) energy resolution and a high level of light yield non-homogeneity, thus excluding the possibility to employ this scintillator for the PARIS apparatus. For the Ph_NaI(Tl) phoswiches we observed a degradation of the $LaBr_3$(Ce) energy resolution between 17 and 30%. The $LaBr_3$(Ce) in the Ph_(2")NaI(Tl) coupled to the PMT R7723-100 provided an energy resolution of 4.6% at 662 keV, which is still appealing for the PARIS experiment. As a matter of fact this configuration was the one chosen by the collaboration to build a 3x3 compact cluster as a demonstrator detector. The 3x3 cluster assembly is expected by the end of the year.