Gamma spectrometer upgrade at JET

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The α-particle diagnostics at JET are based on the gamma-radiation emitted as one of the products of the nuclear reaction between beryllium impurity ions and confined α particles, i.e. $^{9}Be(\alpha,n\gamma)^{12}C$. During the DT campaign the gamma-ray detector must fulfil requirements for high count rate measurements. The existent BGO scintillator with long decay time should be replaced by a new detector module DM2 based on a $CeBr_3$ or $LaBr_3$:Ce scintillator. The module consists of a 3”×3” scintillator coupled with a photomultiplier tube and a voltage divider.

$CeBr_3$ is characterized by a short decay time and low noise conditions. $CeBr_3$ is an alternative to a $LaBr_3$:Ce scintillator, already tested at JET. During 2015 the properties of a detector based on a $CeBr_3$ scintillator were determined [1].

Table 1. Parameters of a 3”×3” $CeBr_3$ scintillator equipped with a Scionix voltage divider.

γ-ray energy (keV)	γ-ray source	energy resolution (FWHM, %)	detection efficiency (%)
511	^{22}Na	4.8±0.1	56±2
662	^{137}Cs	4.2±0.1	51±2
1115	^{65}Zn	3.5±0.1	38±2
1173	^{60}Co	3.4±0.1	34±1
1275	^{22}Na	3.3±0.1	32±1
1332	^{60}Co	3.3±0.1	32±1

In order to study the performance of the detector at high count rates, use was made of a highly active ^{137}Cs source.

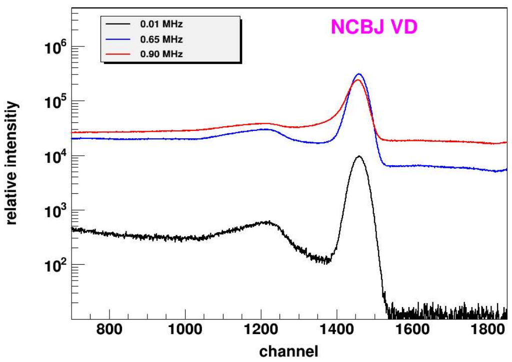

Fig. 1. ^{137}Cs gamma-ray spectra measured with a 3”×3” $CeBr_3$ scintillator and the NCBJ dedicated active voltage divider.

Such measurements were performed using an active voltage divider specially designed for high count rates, produced at NCBJ. The spectra were recorded at count rates of 0.06, 0.58 and 0.89 MHz. The relative difference in the ^{137}Cs peak position is less than 0.5%.

Measurements of gamma rays emitted from standard sources performed using $LaBr_3$:Ce and $CeBr_3$ showed that the detection efficiency of both scintillators is comparable, while $LaBr_3$:Ce is characterized by better energy resolution.

Table 2. FWHM of 3”×3” $CeBr_3$ (with Scionix VD) and 3”×3” $LaBr_3$:Ce scintillators.

γ-ray energy (keV)	γ-ray source	FWHM, %	
		$CeBr_3$	$LaBr_3$:Ce
511	^{22}Na	4.8±0.1	3.4±0.1
662	^{137}Cs	4.2±0.1	3.0±0.1
1115	^{65}Zn	3.5±0.1	2.4±0.1
1173	^{60}Co	3.4±0.1	2.4±0.1
1274	^{22}Na	3.3±0.1	2.4±0.1
1332	^{60}Co	3.3±0.1	2.2±0.1

We also compared the intrinsic activity of $CeBr_3$ (produced as a ‘low background’ crystal) and $LaBr_3$:Ce (standard crystal). Peaks originating from gamma transitions observed in natural background (1.461 MeV from ^{40}K and 2.615 MeV from ^{208}Tl) are clearly seen. Both scintillators show peaks between 1.5 MeV and 2.5 MeV related to contamination by α-radioactive actinides. $LaBr_3$:Ce is also contaminated with ^{138}La decaying by electron capture (EC) or β^-.

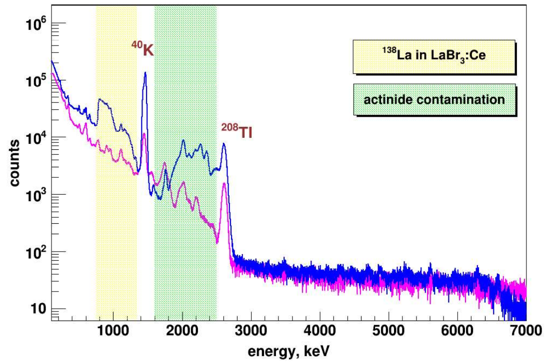

Fig. 2. Response of 3”×3” $CeBr_3$ and $LaBr_3$:Ce crystals to natural background radiation.

References

[1] Scintillators for high temperature plasma diagnostics
[2] Ł. Świderski et al., Proceedings of Science PoS(ECPD2015)162

This work was partly supported by the Polish Ministry of Science and Higher Education within the framework of the scientific financial resources in the years 2015-2017 allocated for the realization of international co-financed projects.