NCBJ contribution to "T17-07 DT scenario extrapolation"

The following report describes Monte Carlo simulations of the gamma-ray detector response function performed for gamma-ray energy above 10 MeV.

Detector response function is used to determine an output of detectors when they are exposed to radiation sources, e.g., gamma-rays or neutrons. Such a function is needed to get a response of a detector to a known radiation source or to perform a spectrum analysis to find a type and quantity of a source irradiated a detector. If it is possible, experimentally determined response functions should be used in the first place.

We performed Monte Carlo simulations to evaluate a detector response to gamma radiation which allows to reconstruct spectra measured with scintillators. For all simulations, we use the Geant4 code due to its well-defined physics, including scintillation processes, flexibility and good reliability. A point-like gamma-ray source was put at a fixed distance from the face of the detector.

First, we compared measured and simulated gamma-ray spectra registered with a $LaBr_3$:Ce-scintillator. The $LaBr_3$:Ce scintillator, installed in the upgraded Gamma-ray Camera at JET, has a diameter of 25.4 mm and a length of 16.9 mm. Measurements were done with PuBe and PuC sources, emitting 4.4 MeV and 6.1 MeV gamma-rays, respectively. The geometry used in simulations was the same as in measurements. For both sources a distance from the scintillator face to the source was 40 mm.

In Fig. 1, a comparison of measured and simulated gamma-ray spectra is shown: in the upper part for the PuBe and in the lower part for PuB source. The $LaBr_3$:Ce scintillator has a diameter equal to 25.6 mm and a length of 16.9 mm. A total energy deposited in the scintillator is presented in all spectra. Simulated spectra were normalized to experimental ones. FWHM equal to 3% was assumed in simulations.

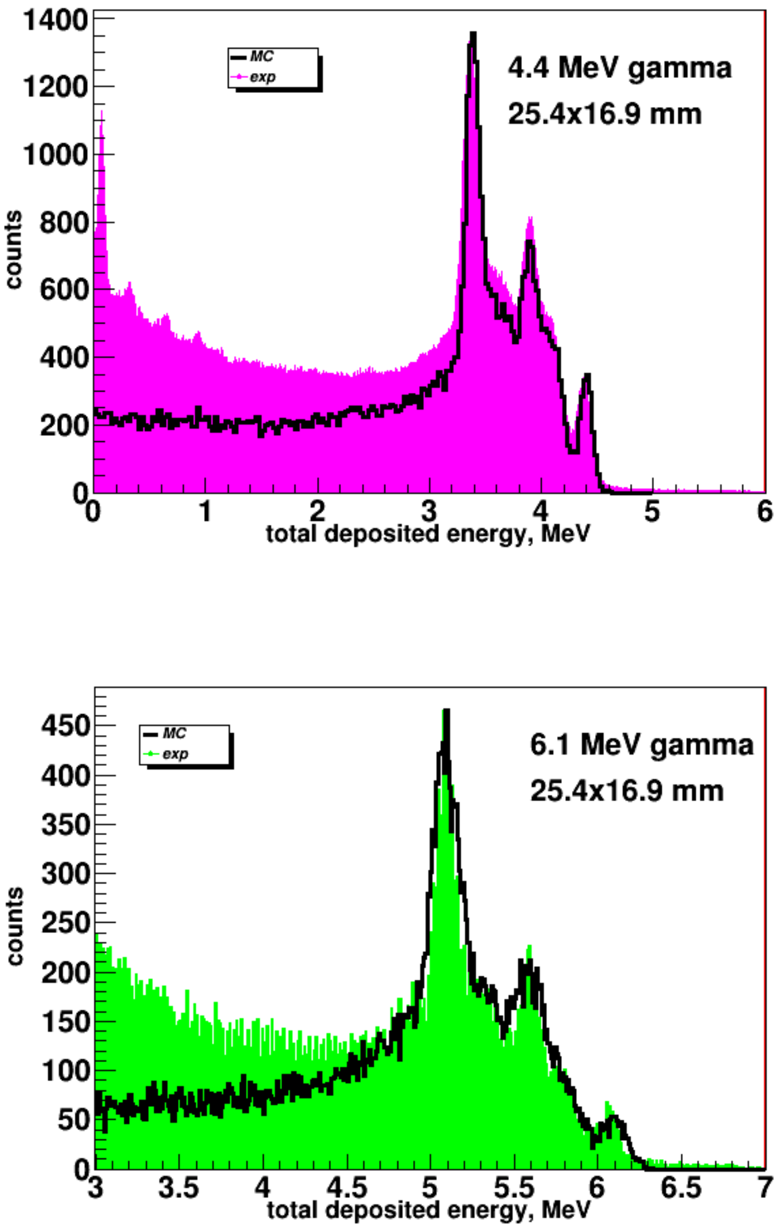
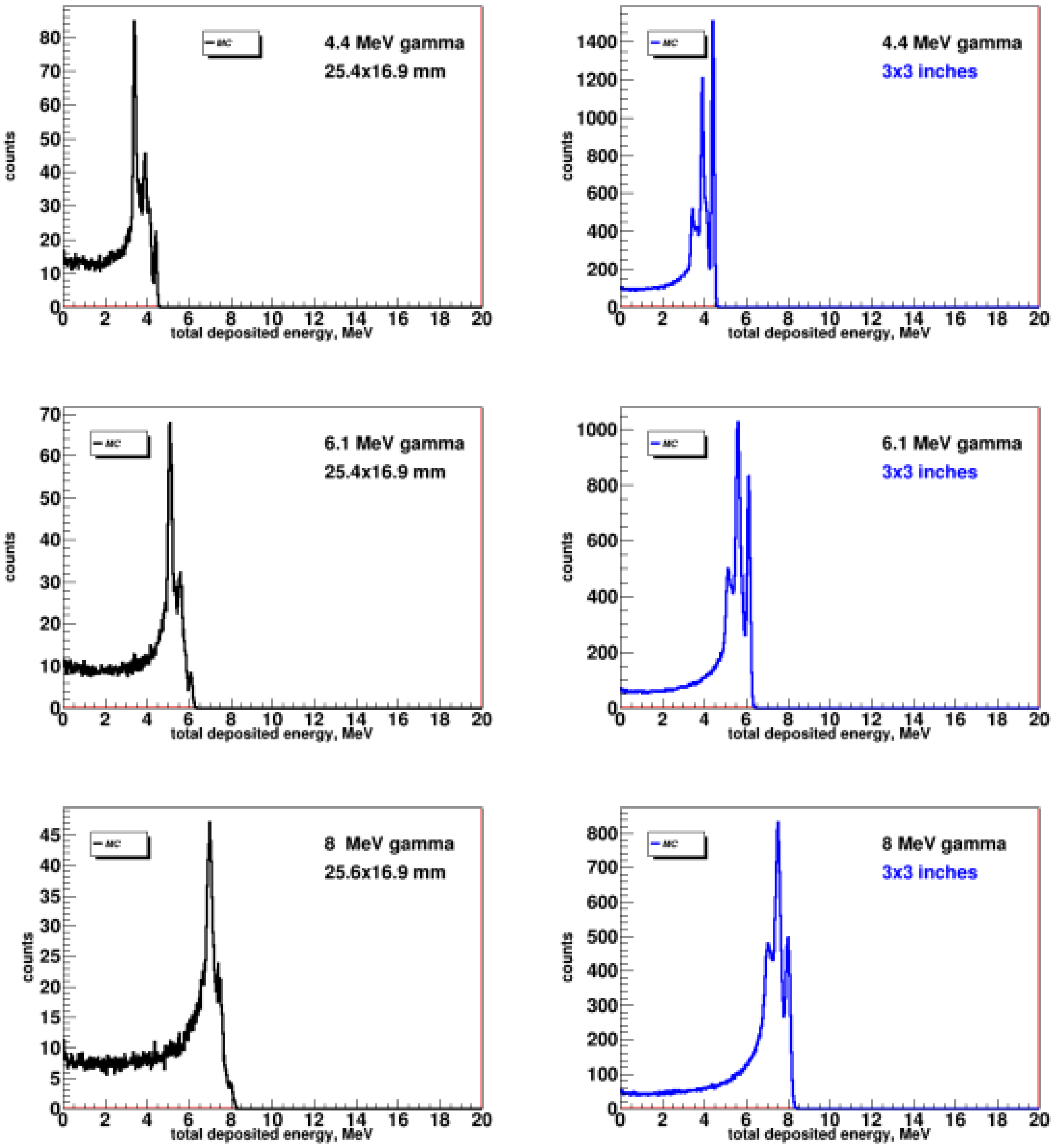


Fig. 1. Measured (non black) and simulated (black) gamma-ray spectra for PuBe (upper) and PuC (lower) sources.

No significant difference is seen in the energy range above 3 MeV and 4.5 MeV for PuBe and PuC sources, respectively. For lower energies, a difference in measured and simulated spectra is observed because in Monte Carlo simulations any additional gamma-ray sources, e.g., from long-lived naturally occurring ^{138}La isotopes or natural background, were not included [SOFT_GCU]. In [SOFT_GSU], a comparison of measured and experimental spectra is presented for 0.662 MeV and 4.4 MeV for a 3”x3” $LaBr_3$:Ce scintillator.

As a next step, we performed a series of Monte Carlo simulations for gamma-ray energies up to 15 MeV: 4.4, 6.1, 8.0, 10.0, 12.0 and 15.0 MeV. $LaBr_3$:Ce scintillators with three sizes were used in simulations: 25.4x16.9 mm, 3”x3” and 3”x6”.

All spectra, shown in Fig. 2, are normalized to 10^6 events on the input.



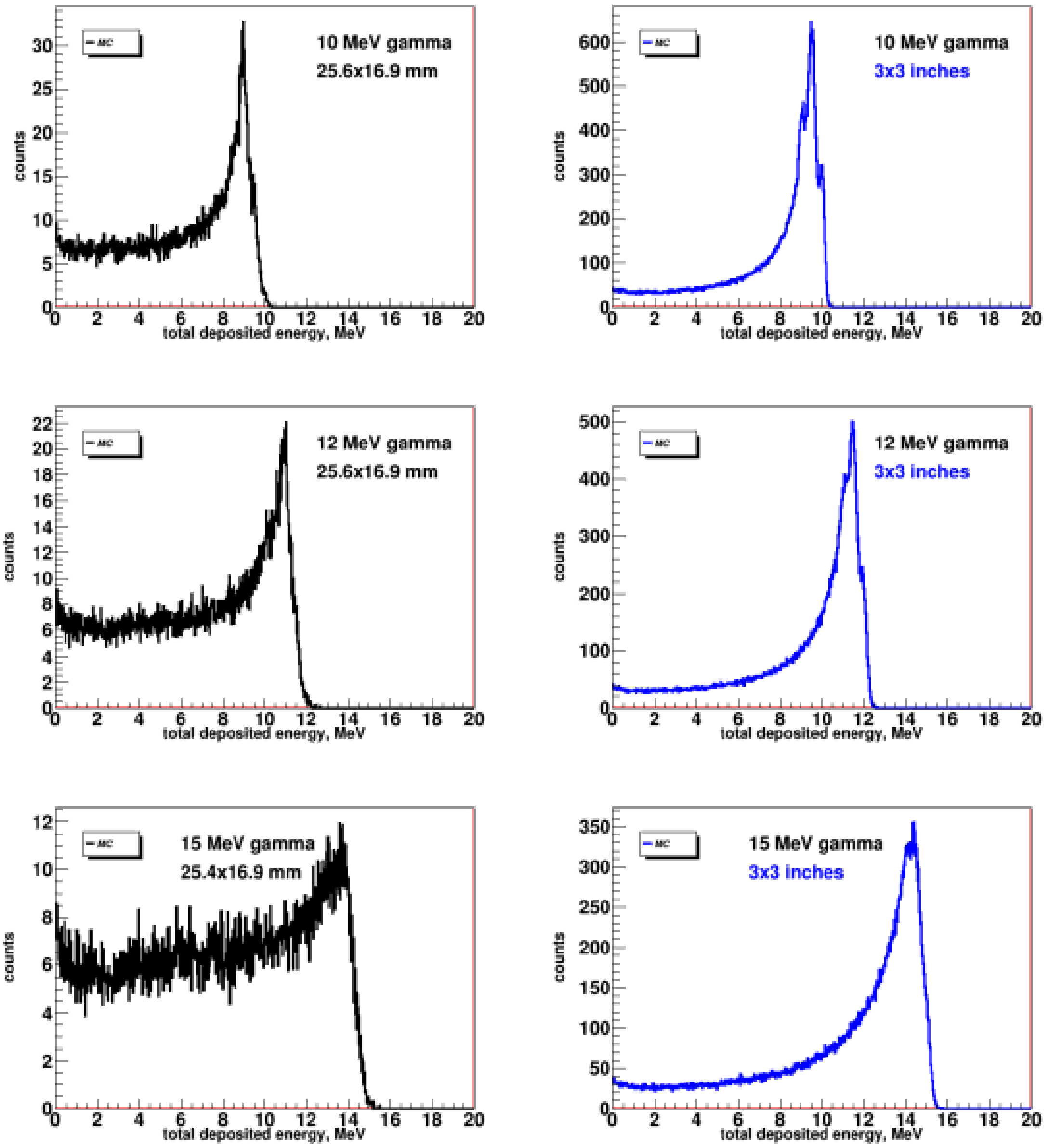
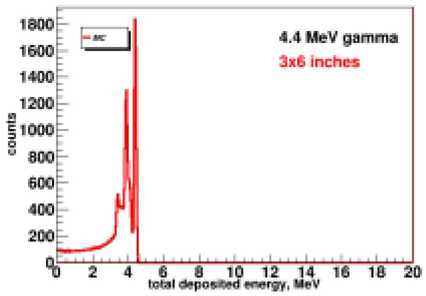
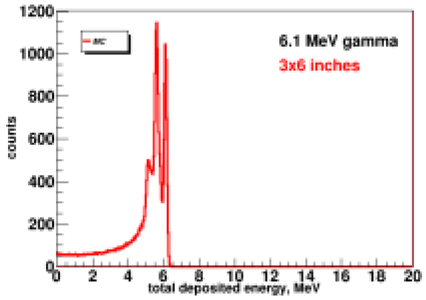
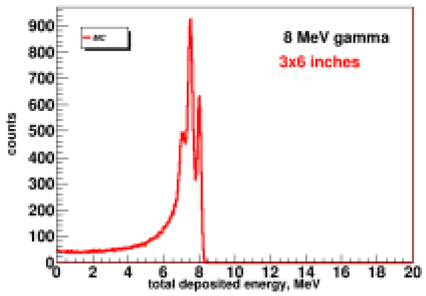


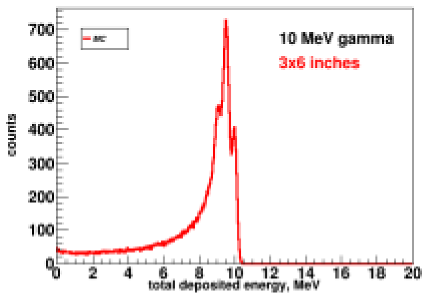
Fig. 2. Monte Carlo simulated spectra for a 25.4x26.9 mm $LaBr_3$:Ce scintillator (left) and a 3”x3”$LaBr_3$:Ce scintillator (right).

The biggest $LaBr_3$:Ce scintillator, available at JET, has a diameter of 3” and a length of 6”. Results of Monte Carlo simulations for such a detector are shown in Fig. 3.


4.4 MeV gamma
3x6 inches
counts
total deposited energy, MeV


6.1 MeV gamma
3x6 inches
counts
total deposited energy, MeV


8 MeV gamma
3x6 inches
counts
total deposited energy, MeV


10 MeV gamma
3x6 inches
counts
total deposited energy, MeV

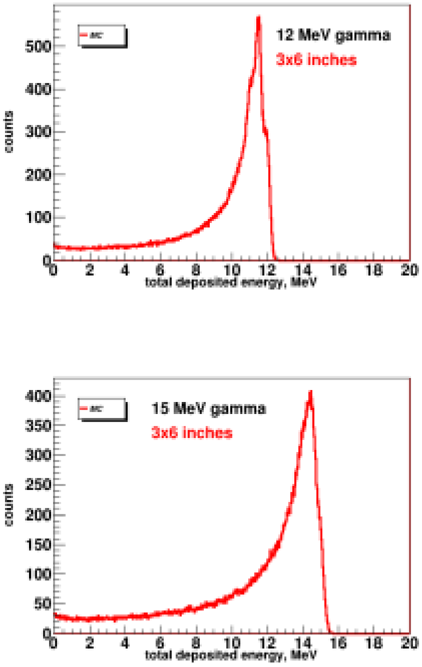


Fig. 3. Monte Carlo simulations for 3”x6” $LaBr_3$:Ce scintillator.

Detector efficiency- a complicated task

To calculate a detector efficiency for a specific energy, it is necessary to determine aa area under a specific peak. As it is seen from above distributions, only in a few cases this is possible in an easy way. In case of a distribution like in Fig. 3 for 15 MeV, only a rough estimation can be done. It can be taken a number of counts in a single channel at 15 MeV (or in 10 channels at this energy) as a “peak area”. It is possible to determine a TOTAL efficiency equal to the number of counts in the full spectrum range or in the energy range from E_{min} to E_{max}. Data for such a task could be extracted from presented spectra – for the moment there are in ROOT files.

The report was prepared by the NCBJ team

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This scientific work was partly supported by 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 the international co-financed project.

This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.