Response function calculations for JET Detectors

I. Zychor
National Centre for Nuclear Research, Otwock-Świerk, Poland

At JET the α-particle diagnostics are based on the ^{9}Be(α,nγ)^{12}C nuclear reaction occurring between confined α-particles and beryllium impurity ions typically present in plasmas. The 4.4 MeV gamma line is emitted in the reaction:

$${}^{9}Be+\alpha \longrightarrow {}^{13}C \xrightarrow{n} {}^{12}C* \xrightarrow{\gamma(4.44MeV)} {}^{12}C_{g.s.}$$

Gamma-ray diagnostics of magnetically confined plasmas provide information on runaway electrons (fast electrons that often appear during plasma disruptions), fusion products and other fast ions due to nuclear reactions on fuel ions or main plasma impurities such as carbon and beryllium. The upgraded JET Gamma-ray Camera is now equipped with new detectors, based on fast $LaBr_3$:Ce scintillators.

To determine an output of detectors when they are exposed to radiation sources, e.g., gamma-rays or neutrons, a detector response function is used. 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. In case if it is possible, experimentally determined response functions should be used but Monte Carlo simulated distributions could be used as well.

We performed Monte Carlo simulations to evaluate a detector response to gamma radiation which allows to reconstruct spectra measured with a ϕ25.4×16.9 mm $LaBr_3$:Ce scintillator, installed at the upgraded Gamma-ray Camera. For all simulations, we used the Geant4 code due to its well-defined physics, flexibility and good reliability. A point-like gamma-ray source was put at a fixed distance from the face of the detector.

We compared measured and simulated gamma-ray spectra registered with a $LaBr_3$:Ce scintillator. 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. 10^6 events were simulated in all presented results.

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 PuC source. 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. Since in Monte Carlo calculations no gamma lines from natural sources were included, a discrepancy at lower energies is observed. A good agreement between experimental and measured spectra for gamma-ray energies up to ~6 MeV allows to predict a response function for higher energies. In Fig. 2 a simulated spectrum for 10 MeV gamma-rays is shown.

From three spectra simulated for 4.4, 6.1 and 10 MeV gamma-rays a conclusion is drawn that a scintillator efficiency drops drastically with an increasing gamma-ray energy and a scintillator with a diameter of 25.4 mm and a height of 16.9 mm is not suited for measurements of gamma-ray energies higher than a few MeV.

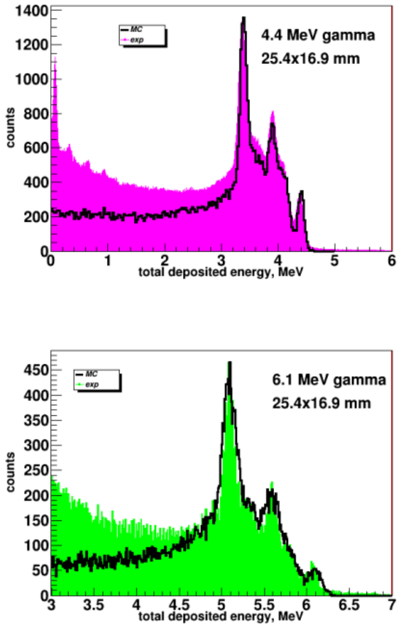

Fig. 1. Measured (non black) and simulated (black) gamma-ray spectra for PuBe (upper) and PuC (lower) sources.

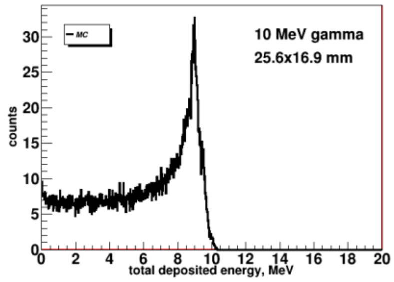

Fig. 2. Monte Carlo simulated gamma-ray spectrum for 10 MeV gamma-rays.

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