Neutron detection with NaI spectrometers

Due to the worldwide shortage of ^{3}He , alternative methods to detect neutrons are actively studied. One alternative approach for neutron detection is to use high-energy gamma-rays produced in (n,γ)-reactions. In addition to the neutron capture gamma-rays, neutron sources also emit high energy gamma-rays by themselves. The method has potential in security applications due to the low background, the easy penetration of the high energy gamma-rays and the small amount of modification needed for gamma-spectrometers already in use. STUK studied the use of a NaI portal monitor as a neutron detector.

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Features

- Performance comparable with ^{3}He-tube
- Gamma-spectrometry up to 8 MeV
- Plastic moderator and converter
- Easy integration in regular gamma spectrometers
- Low background
- Characterization of neutron source properties
- Simple analysis with combined neutron and gamma detection
- Automated detection and consistent with VASIKKA software

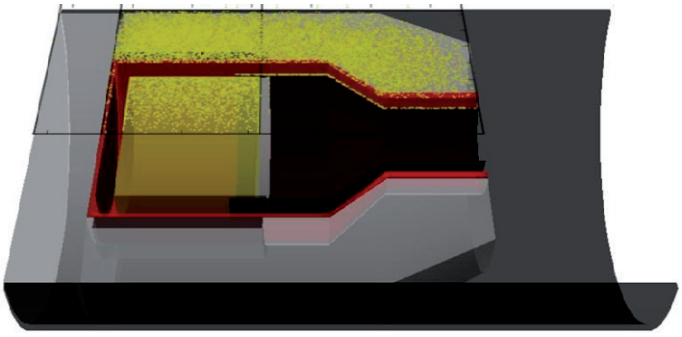

Fig. 1. GEANT4 model of a 5”x4” cylindrical NaI detector surrounded by a moderator. The yellow dots indicate neutron capture reactions.

Fig. 2. 4”x4”x16” NaI detector moderated with PE.

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Neutron detection by gamma-spectrometry

Concept

In field gamma spectrometry often relies on NaI detectors. Spectrometers are normally set to cover the energy region from 0 to 3 MeV. The covered range is partly restricted by the commercially available hardware, i.e., Multi Channel Analyzers, which often only produce spectra with 1024 channels. Recently, integrated systems able to produce 2048 channel spectra have become commercially available. This development enables the extension of energy range up to about 8 MeV without significantly worsening the resolution.

The neutron induced gamma rays up to 8 MeV were measured using a 4”x4”x16” and a cylindrical (diameter 4” and thickness 5”) NaI detector [1]. Similar measurements were performed in Ref. [2]. The neutron detection efficiency can be improved significantly by adding moderators and converters around the detector.

Results

Fig. 3 shows the gamma-spectrum of an 18 kBq ^{252}Cf source at a distance of about 55 cm. The measurement, which was performed with the moderated 5”x4” NaI detector, shows the significant yield of high energy gamma-rays in the presence of the neutron source. The peaks at 6.8 MeV and 6.3 MeV are mostly due to iodine, but also sodium. Because of the small and even background, all counts over 3.5 MeV can be utilized for neutron detection.

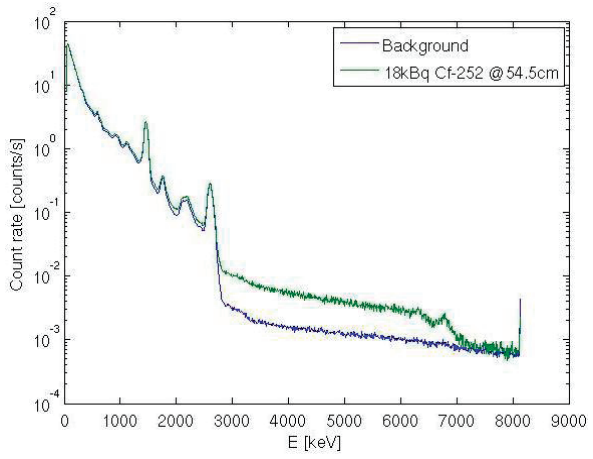

Fig. 3. Spectra showing the increased count rate at high energies due to the ^{252}Cf source. The neutron flux was about 0.06 neutrons/(scm^2) at the detector surface.

The effect on different converters and moderators (Fe, PVC and PE) surrounding the NaI portal monitor was studied. Fig. 4 shows how moderators and converters improve the detection efficiency. Note that with thin converters/moderators, the improvement of the efficiency is due to the moderator. However, with thicker layers of materials, the effect of the converter is significant.

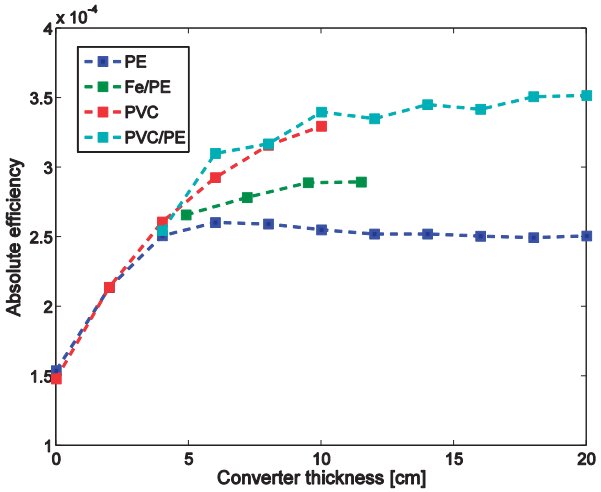

Fig. 4. Absolute neutron efficiencies with boosters of different thickness. The measurements were performed with a Cf-252 source at a source-detector distance of 2 m.

Applications

The NaI portal monitor was compared to a ^{3}He-based portal monitor of similar size. A 10-cm-thick PVC/PE sandwich converter was used with the NaI portal monitor. The minimum detectable activities (MDA) of the portal monitors were similar. In fact, the indirect gamma spectrometric method produced better results for shielded neutron sources. The NaI detector is thus very suitable for neutron portal monitoring and other security applications. The combined neutron and gamma detection is cheap, analysis is easy to perform and neutron sources can to some extent be characterized with the spectral information.

References

[1] P. Holm et al., Nuclear Instruments and Methods in Physics Research A 697 (2013) 59.

[2] D. J. Mitchell et al., IEEE Transactions on Nuclear Science 57 (2010) 2215.

Technology Readiness Level 7

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