# NaI spectrometers for indirect detection of neutrons

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## 1. Introduction

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 [1]. In addition to the neutron capture gamma-rays, neutron sources also emit high-energy gamma-rays by themselves (Fig. 1).

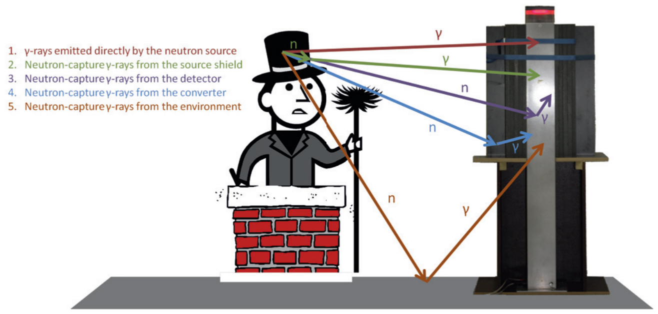


**Figure 1.** Origins of high-energy gamma-rays.

## 2. Objectives

The objectives were to optimize the neutron response of the NaI detector system and to compare NaI and $^{3}He$ detectors in evasive scenarios.

## 3. Methods

The neutron induced gamma-rays up to 8 MeV were measured with a 4"x4"x16" NaI portal monitor in the radiation metrology laboratory of STUK. The employed neutron signal (gamma-rays between 3.5 and 8 MeV) can be enhanced by covering three sides of the detector with moderators and converters (Figs. 1 and 2). One side was left uncovered for normal gamma spectrometry. A Thermo Fischer $^{3}He$ counter of comparable dimensions was also used.

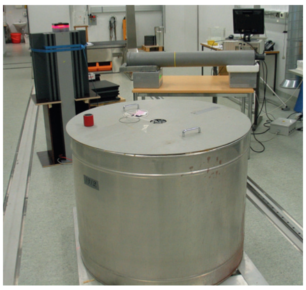

**Figure 2.** NaI portal monitor (back left), moderated $^{3}He$-tube (back right) and a cylindrical borated polyethylene (BPE) neutron shield (front).

## 4. Results

Figure 3 presents typical gamma spectra generated by $^{252}Cf$ and AmBe sources. The AmBe source was shielded with Pb to attenuate the 60 keV peak.

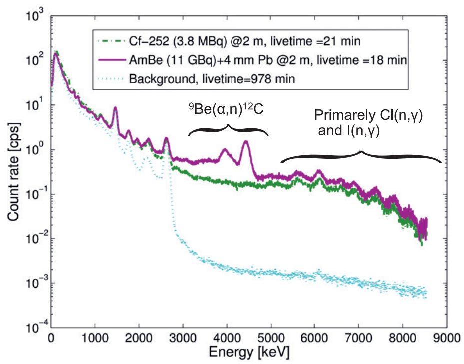


**Figure 3.** Spectra recorded using PVC/PE converter/moderator showing the increased count rate at high energies due to the $^{252}Cf$ and AmBe sources.

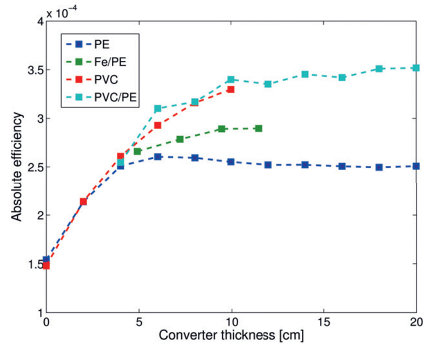


**Figure 4.** Absolute detection efficiency per emitted neutron with converter/moderator structures of various thicknesses. Measurements were performed with $^{252}Cf$ source at source-detector distance 2 m.

A 10 cm-thick sandwich converter/moderator composed of 2 cm-thick PVC and PE slabs was chosen as a compromize between performance and size (Fig. 4). This configuration was compared to the $^{3}He$-tube with and without neutron shielding around the sources. Table 1 presents minimum detectable activities (MDA) with1 s acquisition time and 100 s background measurement time in these conditions.

**Table 1.** MDA with source-detector distance 2 m [2]. The AmBe source was shielded with 4 mm Pb.

| Source | MDA (NaI) [Bq] | MDA ($^{3}He$) [Bq] |
|---|---|---|
| $^{252}Cf$ | $3.9 \times 10^{5}$ | $2.5 \times 10^{5}$ |
| $^{252}Cf$/23 cm PE* | $4.1 \times 10^{6}$ | $6.3 \times 10^{6}$ |
| $^{252}Cf$/50 cm BPE** | $1.5 \times 10^{7}$ | $2.0 \times 10^{7}$ |
| AmBe | $4.9 \times 10^{8}$ | $5.3 \times 10^{8}$ |
| AmBe/23 cm PE* | $1.8 \times 10^{9}$ | $5.3 \times 10^{9}$ |
| AmBe/50 cm BPE** | $3.4 \times 10^{9}$ | $8.9 \times 10^{9}$ |

* PE = Polyethylene
** BPE = Borated polyethylene

## 5. Conclusions

By utilizing the high-energy gamma-rays induced and emitted by neutron sources, the NaI detector is superior to the $^{3}He$-counter in evasive scenarios. In addition, the characterization of neutron sources is possible.

## Acknowledgements

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## References

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