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Radiation detection for OSI – A study of non-He-3 neutron detectors

T3.1-P30

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Abstract

Within the past decade a significant shortage of He-3 and consequently an enormous increase in cost has occurred. Detectors equipped with He-3 are widely used in neutron detection applications, e.g. by first responders, during on-site inspections, and in other applications where nuclear and radioactive material has to be detected, localized and possibly identified. Therefore replacement materials need to be considered, selected, implemented in corresponding detectors, and thoroughly tested. Another development in the field of hand-held radiation detection devices focuses on simultaneous neutron and gamma ray detection with a single scintillator. These may lead to a new type of small and efficient hand-held devices, utilizing non-He-3 neutron detection.

In this study we examined Li based neutron detectors. The outcome of a study with a neutron detector implemented in a hand-held Radiation Isotope Identifier Device (RIID), the D3S from Kromek, will be shown. Additionally, results of the scintillators CLYC and CLLB, which allow a simultaneous measurement of gamma and neutron radiation, will be presented in this contribution. Differences in the detection of neutron radiation will be explored and analyzed regarding their potential use in on-site inspections.

Test Procedure

Fraunhofer INT operates a testing facility whose development was supported by the EU project ITRAP+10 PII. A static (see Fig. 2) and a dynamic (see Fig. 1) measurement test system have been set up. Among other, for handheld devices (like PRD or RIID) or portal monitors for pedestrians, luggage or small vehicles (RPM and SRPM) radiological tests according to corresponding IEC, ANSI N42 and ITRAP+10 testing procedures are possible.

The D3S has been tested according to IEC, ANSI N42 and ITRAP+10 testing procedures. As it functions as PRD as well as RIID, it was tested according to procedures for both device classes.

CLYC and CLLB have been tested regarding their Pulse Shape Discrimination (PSD) capabilities.

Fig.1: Dynamic test system
Picture of the dynamic test system.

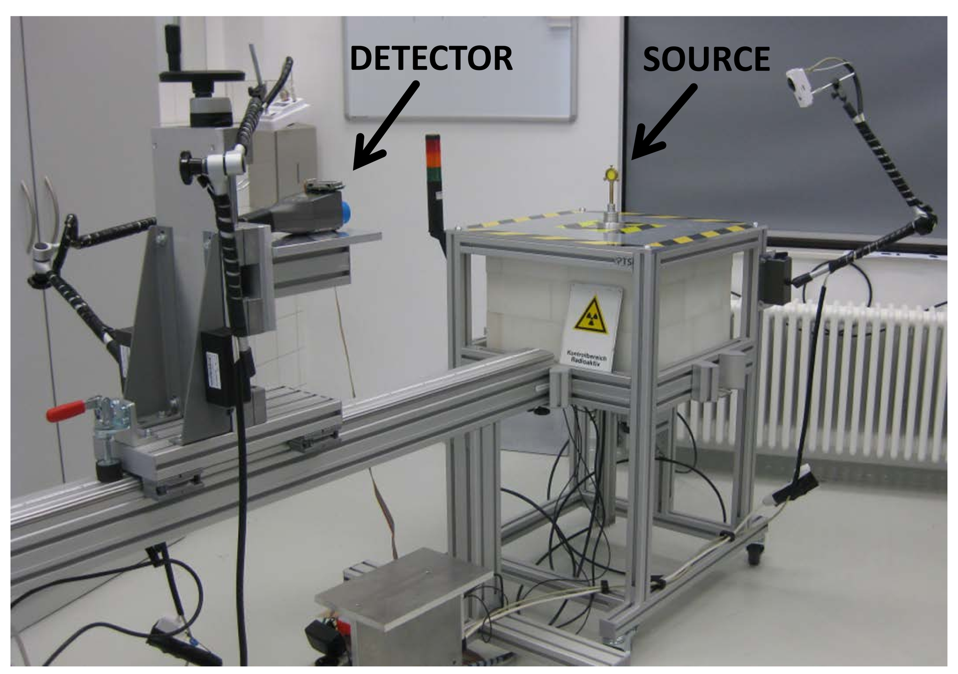

Fig.2: Static test system
Picture of the static test system.

D3S

Fig.3: D3S Pictures of the D3S detector (left) and the display device in both modes.

The D3S (see Fig. 3) by Kromek is equipped with two embedded scintillators – CsI(Tl) for gamma-ray detection and LiF:ZnS for neutron detection. The sizes of gamma and neutron scintillators are 2" x 1" x ½" and 32 mm x 100 mm, respectively.

Search Mode (see Fig. 4, upper picture): In this mode the D3S continuously scans the count rate for neutron and gamma radiation.
Confirmation Mode (see Fig. 4, lower picture): In this mode the D3S samples for 30 seconds and provides an energy spectrum.

A neutron alarm was generated under neutron irradiation. The neutron component is not sensitive to high gamma radiation.

Tests with D3S according to ITRAP+10 testing procedures	PRD	RIID
False identification tests	✓	✓
Time-to-alarm photons PRD: 2 s, RIID: 3 s	✗	✓
Accuracy tests for photons	^{241}Am: ✗ ^{137}Cs: ✗ ^{60}Co: ✓	^{241}Am: ✗ ^{137}Cs: ✗ ^{60}Co: ✗
Over-range characteristics for ambient dose equivalent rate indication	✓	✓

RIID – Tests with D3S according to ITRAP+10 testing procedures Radionuclide Identification (no SNM tested)

^{232}Th	No shielding: ✓ 5mm steel: ✗
^{133}Ba	No shielding: ✓ 5mm steel: ✗
^{152}Eu	No shielding: ✓ 5mm steel: ✗
^{137}Cs	No shielding: ✓ 5mm steel: ✓
^{60}Co	No shielding: ✓ 5mm steel: ✓
^{241}Am	No shielding: ✗ 5mm steel: -

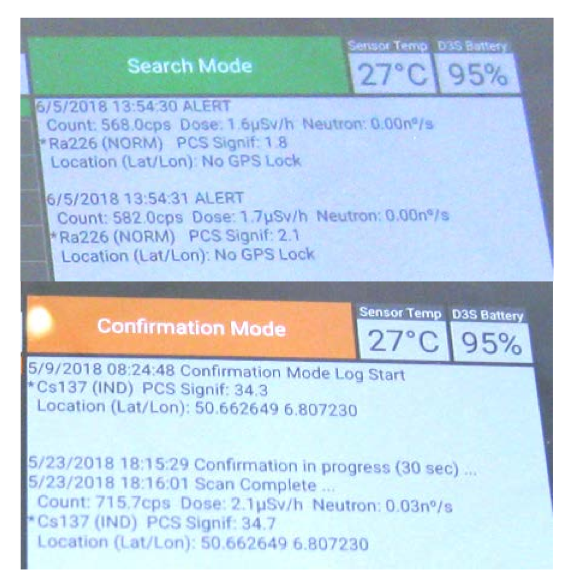

Fig.4: Operational Modes D3S
The upper picture shows a screenshot of D3S in Search Mode. The lower picture shows a screenshot of D3S in Confirmation Mode.

CLYC

The scintillation material of CLYC-detectors (Cs_2LiYCl_6:Ce) contains ^{6}Li enriched Lithium. Via the nuclear reaction ^{6}Li(n,α)t alpha particles and high energetic tritons are generated by neutron irradiation. A photo of the detector CLYC is shown in Fig. 5. Standardized test procedures (e.g. according to ANSI N42) do not apply to CLYC, only complete detectors including an evaluation unit are cover by these standards

Fig. 6 presents the result of a ^{252}Cf measurement using the charge comparison method for pulse shape discrimination.

Fig.5: CLYC
Picture of the CLYC detector with base.

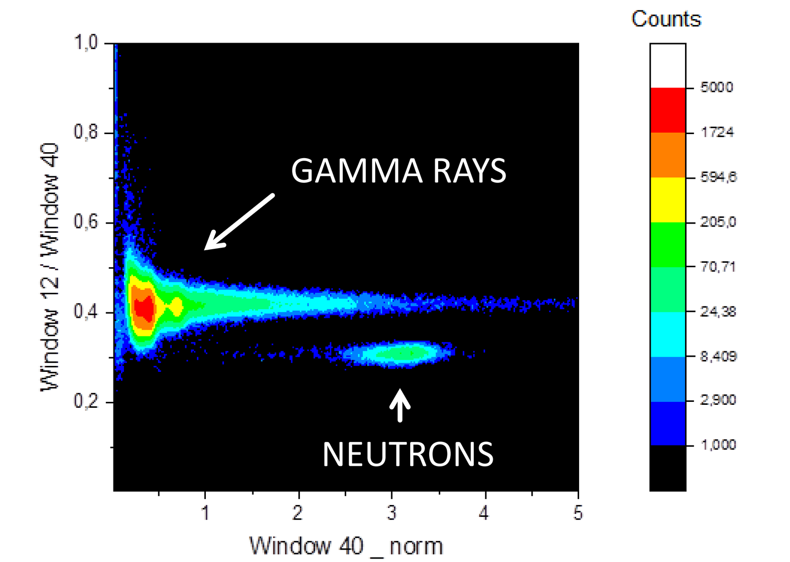

Fig.6: PSD CLYC
PSD intensity plots with a ^{252}Cf source. Windows were set [0,12] and [12,40] with a channel width of 10 ns.

CLLB

The scintillation material of CLLB-detectors ($Cs_2LiLaBr_6$:Ce) contains ^{6}Li in a natural ratio with ^{7}Li. A photo of the detector CLLB is shown in Fig. 7
Fig. 8 presents the result of a ^{252}Cf measurement using the charge comparison method for pulse shape discrimination.

Fig.7: CLLB
Picture of the CLLB detector with base.

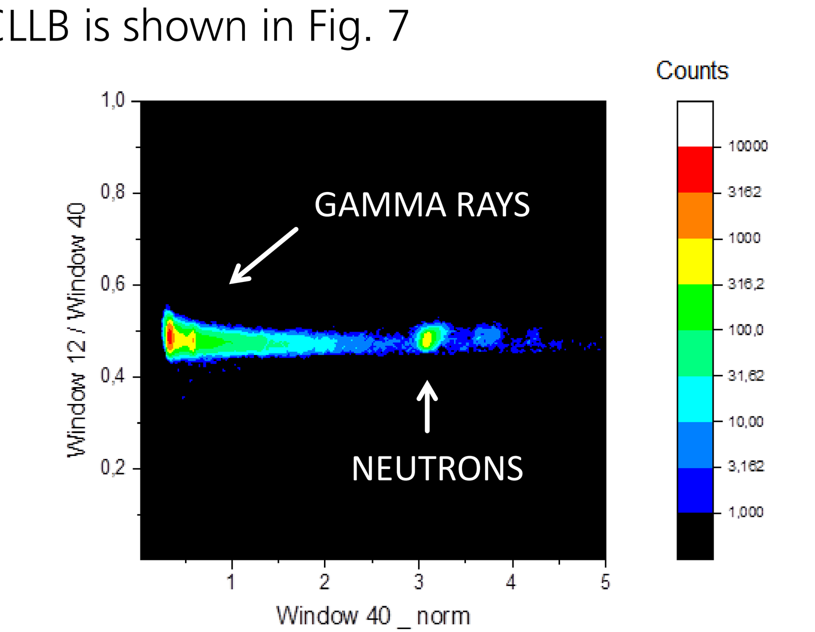

Fig.8: PSD CLLB
PSD intensity plots with a ^{252}Cf source. Windows were set [0,12] and [12,40] with a channel width of 10 ns.

Summary

We investigated ^{6}Li detection materials as alternative to ^{3}He for neutron detection. A dual detection device such as D3S with two integrated detectors and single scintillators with the ability to detect both neutron and gamma radiation, such as CLYC and CLLB, utilizing a ^{6}Li reaction could replace ^{3}He in next generation OSI systems.

References

D3S – results of qualification measurements of a wearable RIID for homeland security, M. Risse et al., 2019, INMM 60th Annual Meeting

CLYC Scintillator – A Possible Enhancement for Hand-held OSI Detectors, T. Köble et al., 2017, CTBT SnT 2017

PUTTING AN END TO NUCLEAR EXPLOSIONS