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Fraunhofer Institute for Technological Trend Analysis INT

CLYC Scintillators – A Possible Enhancement for Hand-held OSI Detectors

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Abstract

Many detection systems detect either gamma or neutron radiation or combine the detection of both nuclear radiation types by integrating two detectors in one system. For hand-held systems a very small ^{3}He-tube is often combined with a scintillation crystal of e.g. NaI or $LaBr_3$. The recently developed detector material CLYC promises to detect gammas and neutrons simultaneously with good resolution and efficiency for fast and reliable isotope identification and efficient neutron counting. In the paper we report on tests with a CLYC detector (Fig.1).

Detector Materials

The scintillation material of CLYC-detectors (Cs_2LiYCl_6:Ce) contains enriched ^{6}Li. Via the nuclear reaction $^{6}Li(n,\alpha)t$ alpha particles and high energetic tritons are generated by neutron irradiation. The ions generate a light pulse while travelling through the crystal. Gamma radiation excites electrons in the scintillator.

Neutron and gamma radiation have a unique pulse shape, enabling the distinct discrimination of induced pulses. For neutrons, due to the limited range of the ions all energy of the nuclear reaction is deposited within the material. Neutron pulses with low amplitudes are basically absent which greatly improves the discrimination.

Fig.1: CLYC

Picture of the CLYC detector with base.

CLYC Characterization

- Dimensions of the crystal: 2″ x 2″
- Determination of resolution, efficiency with conventional NIM electronics. Ortec 133 Preamplifier, 572A Amplifier, 919 SpectrumMaster MCA
- Different Gamma-Sources (^{60}Co, ^{137}Cs, ^{133}Ba, ^{152}Eu) and Neutron sources (^{252}Cf, AmBe, AmLi) (Fig.2).
- Discrimination of neutrons even by energy possible.
- Intrinsic efficiency for γ (^{137}Cs) was determined as 15.40% ± 1.83%. Measurement time was 3600s.

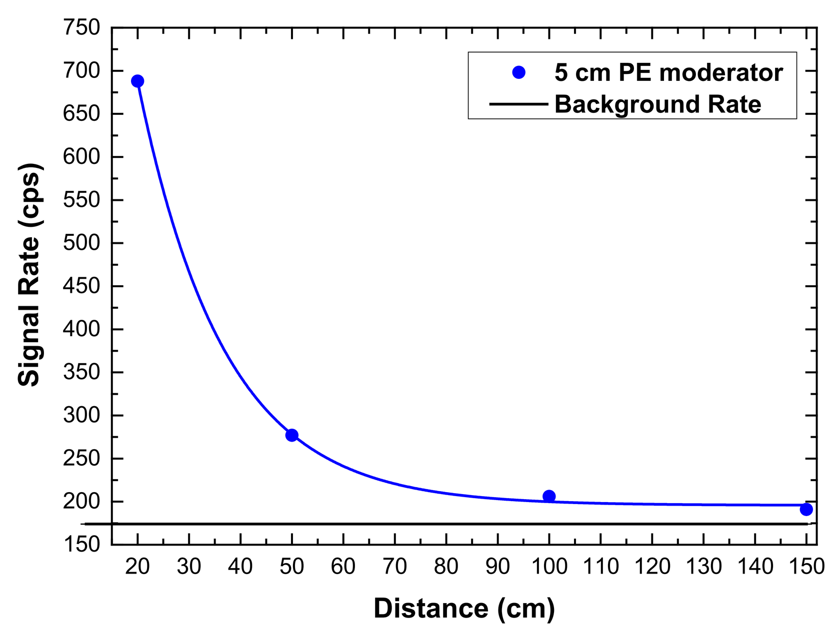

Fig.2: ^{252}Cf with moderator

Signal rate for a ^{252}Cf source in varying distance to the CLYC detector.

Discrimination of Neutrons by Energy

- Neutrons have a gamma equivalent energy of approx. 3.2 MeV. By analyzing the energy spectrum, a discrimination between neutrons and gamma rays is possible (Fig.3,4,5).

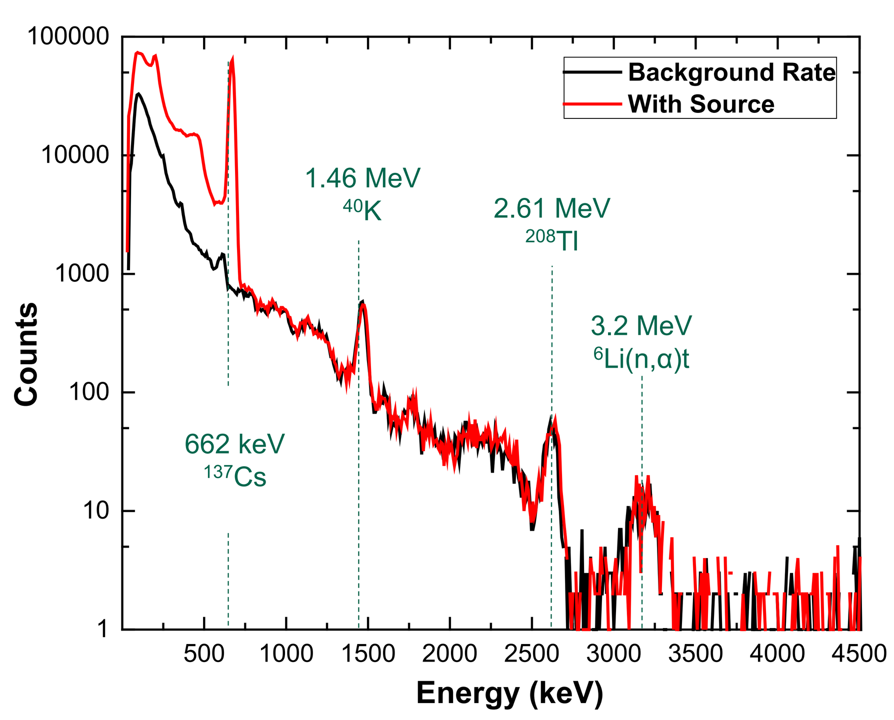

Fig.3: ^{137}Cs gamma source

Spectrum of a ^{137}Cs source in 100cm distance to the CLYC detector.

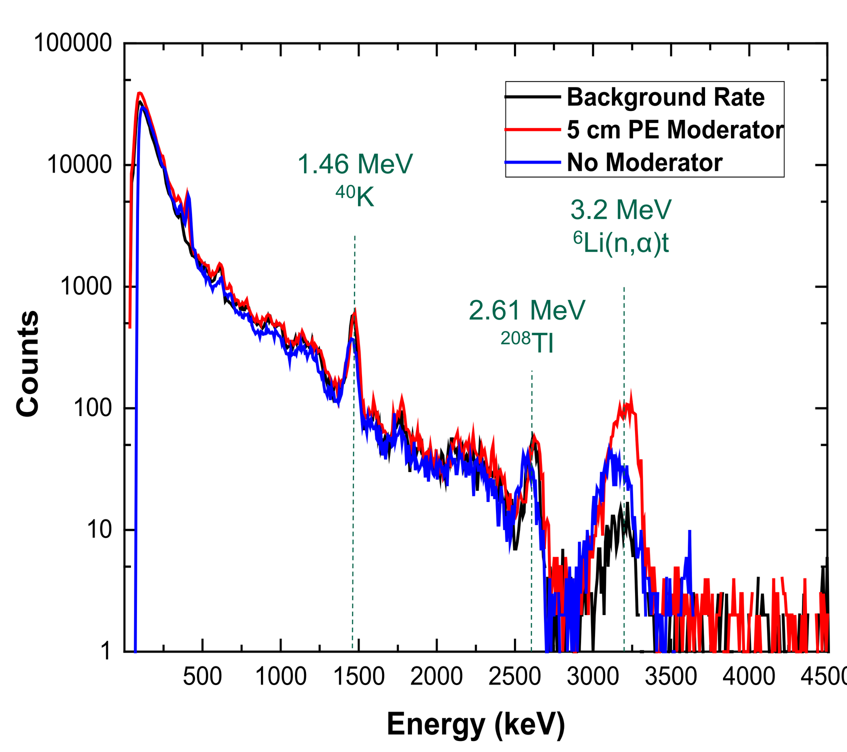

Fig.4: ^{252}Cf neutron source

Spectra of a ^{252}Cf source in 100cm distance to the CLYC detector. The blue spectrum shows the source without moderation, the red spectrum describes the measured data with a 5cm thick polyethylene cylinder around the source.

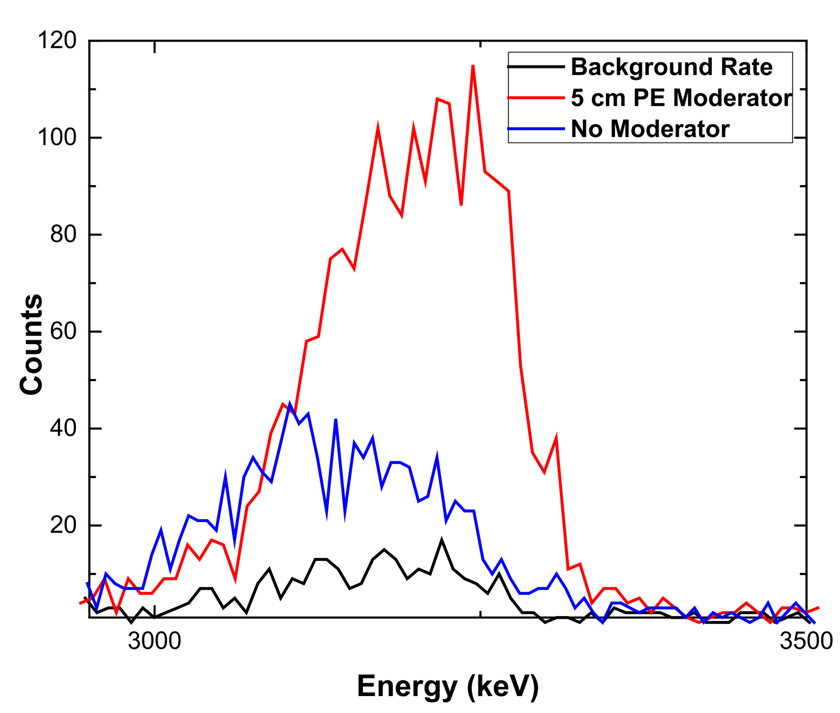

Fig.5: ^{252}Cf neutron source:

Detail of Fig. 4. The diagram represents the differences in detection of moderated and unmoderated neutrons linearly.

Pulse Shape Discrimination

- Pulse shape discrimination (PSD) was performed with a FPGA by a processing algorithm, comparing the produced data with a library in real-time (Fig.6,7).
- National Instruments PXI System with PXIe-5122 Digitizer and PXIe-7966 FPGA
- The overall energy resolution determined in preliminary tests using a conventional setup was 4.0% for ^{137}Cs with a shaping time of 6 µs.

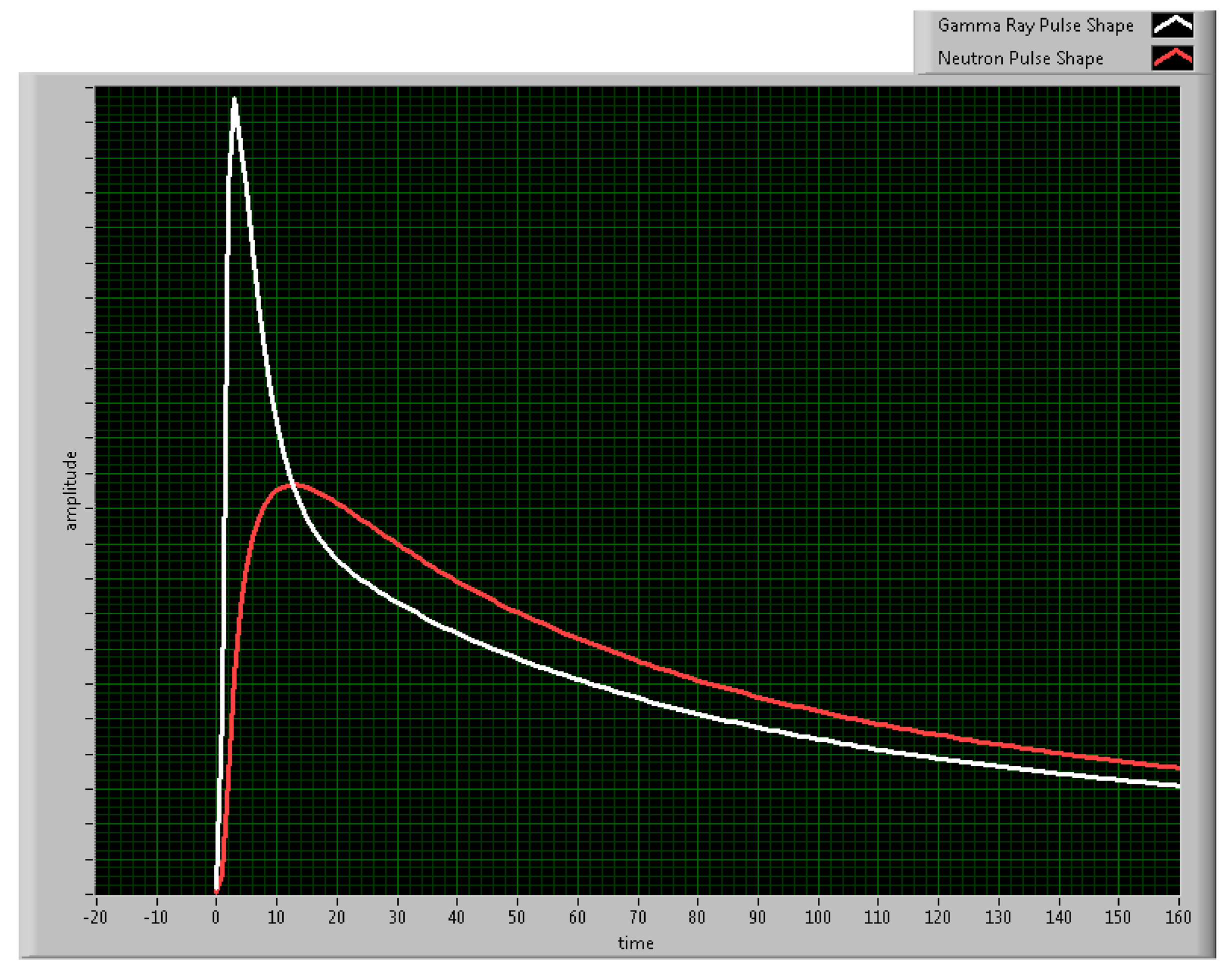

Fig.6: n,γ Discrimination

Pulse shapes of gamma and neutron pulses, measured by preliminary tests using a LabView-based processing algorithm on FPGA hardware. Timebase 100 MHz.

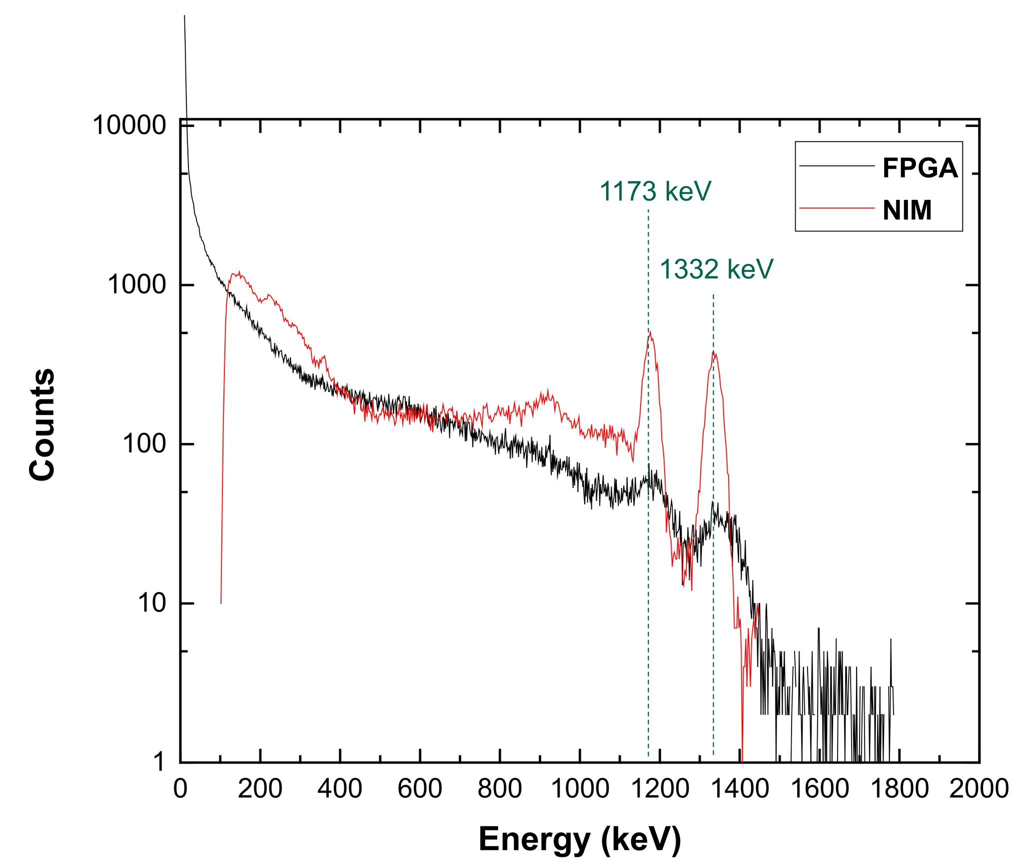

Fig.7: Proof of Concept

Comparison of a ^{60}Co- spectrum processed by NIM hardware and a ^{60}Co- spectrum processed by algorithm using a FPGA.

- The Figure of Merit (FOM) was determined by RMD, using a AmBe-source. The FOM is calculated by the quotient of (peak-)separation and sum FWHM of the PSD-counts-graph (Fig. 8,9).

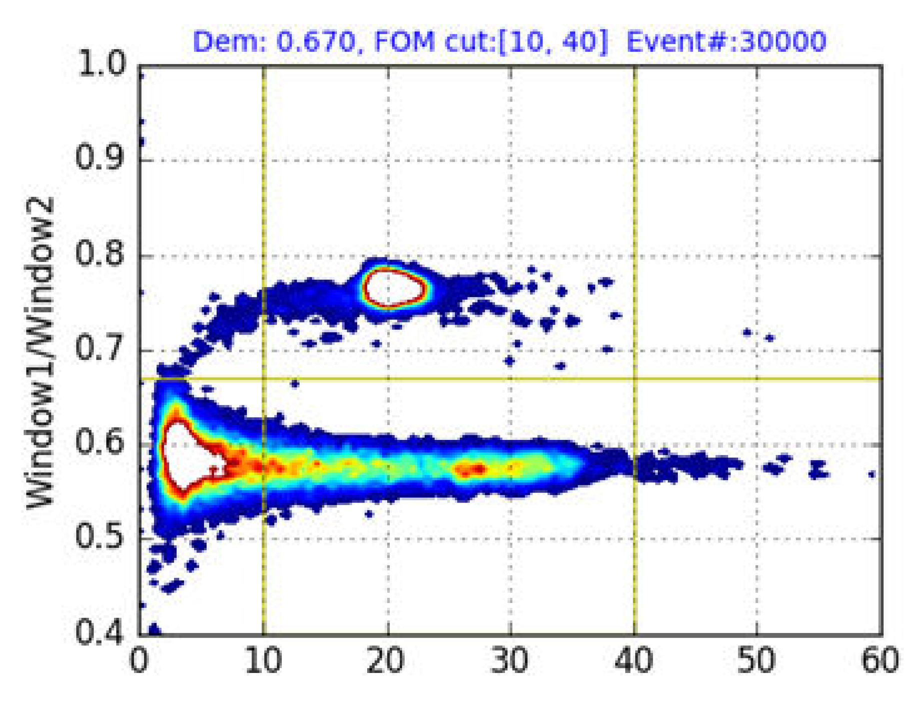

Fig.8: Peak height vs. FOM

Comparison of pulse shapes of gamma ray and neutron pulses of a AmBe-source, measured by the analysed CLYC detector. Windows were set [0:30] and [30:100] with channel width 4ns. Figure by RMD.

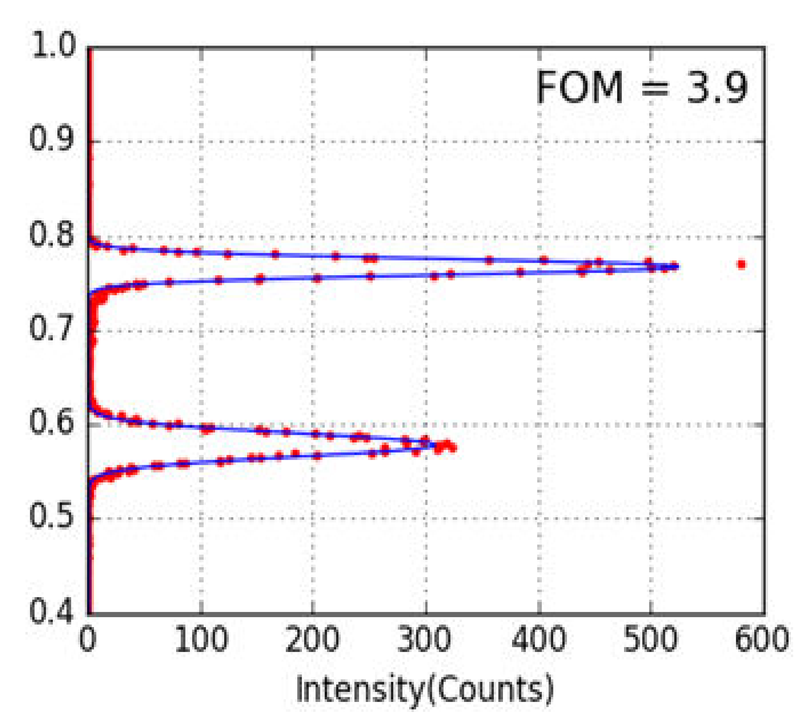

Fig.9: FOM Plot

Figure of Merit plot of the analysed CLYC detector by RMD. Source used was AmBe.

Conclusion

New detector materials like CLYC, which are able to detect gammas and neutrons simultaneously, may lead to a new type of small and efficient hand-held devices. These detectors have the potential to improve the detection of nuclear and radioactive material and may be used successfully in OSI.

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