



HAL
open science

Neutron detection using a Gadolinium covered CdZnTe detector

Romain Coulon, Vladimir Kondrasovs, Jonathan Nicolas Dumazert, Karim Boudergui

► **To cite this version:**

Romain Coulon, Vladimir Kondrasovs, Jonathan Nicolas Dumazert, Karim Boudergui. Neutron detection using a Gadolinium covered CdZnTe detector. 2016 ISOE International Symposium - Information Symposium on Occupational Exposure Management at Nuclear Facilities, the European Technical Centre, Brussels (BE), Jun 2016, Bruxelles, Belgium. cea-04149609

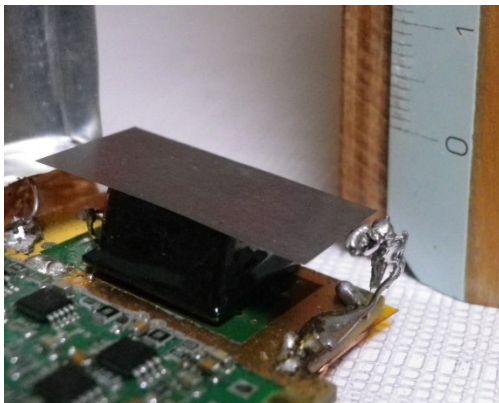
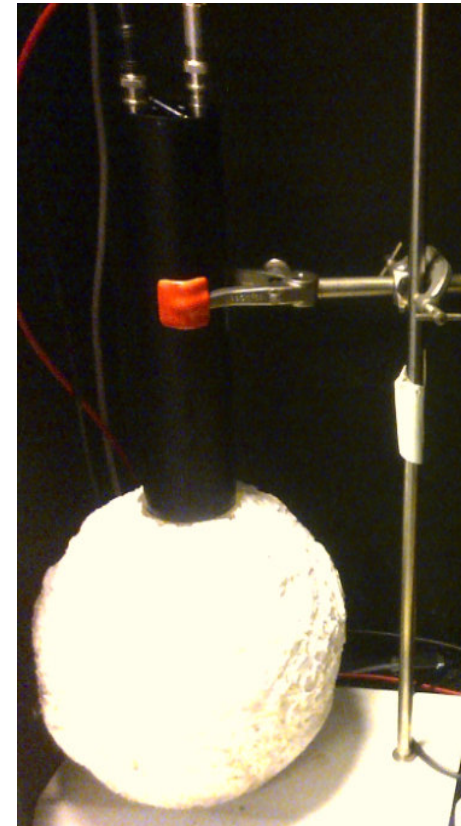
HAL Id: cea-04149609

<https://cea.hal.science/cea-04149609v1>

Submitted on 3 Jul 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



NEUTRON DETECTION USING A GADOLINIUM COVERED CDZnTE DETECTOR

ISOE International Symposium Brussels, 1-3 June 2016
COULON Romain, KONDRASOV Vladimir, DUMAZERT Jonathan, BOUDERGUI Karim

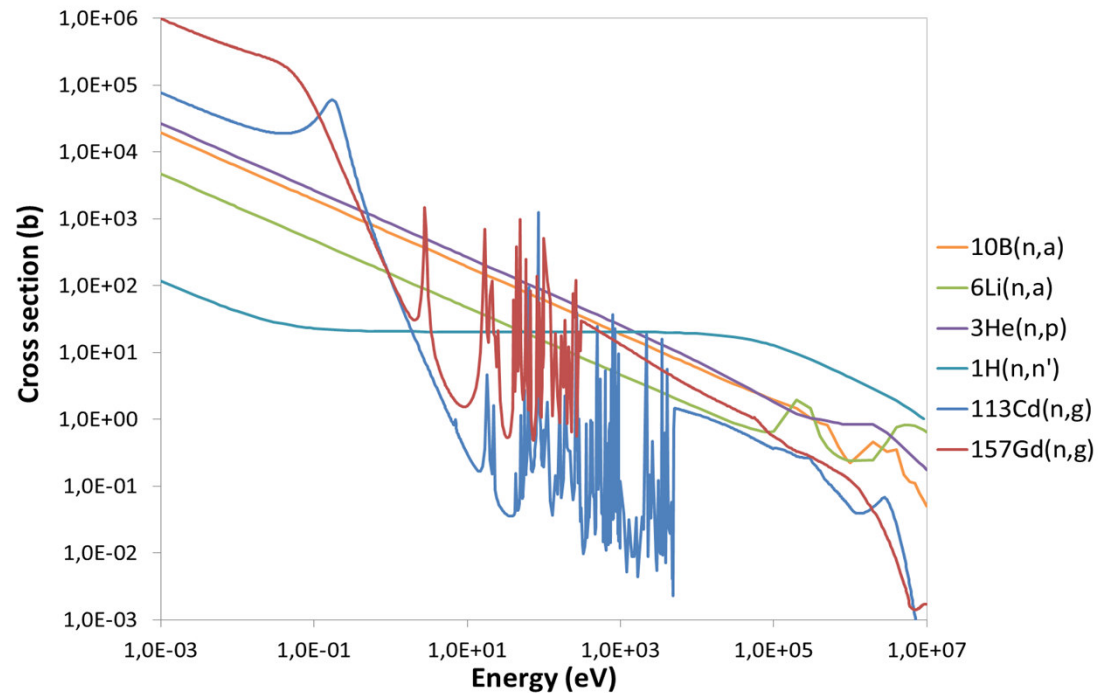


- **CONTEXT:**
- The need: miniaturized neutron detector.
- State of the art: Silicon technology implementing Boron, lithium, and PE convertors.
- Limitation: Low neutron efficiency / high detection limits.

- **RESEARCH PATH:**
- The use of Gadolinium convertor (higher cross section than ^{10}B , ^6Li and ^3He).
- The use of CdZnTe diode to detect the radiative signal from Gd captures.
- The use of a reliable compensation techniques.

THE CHALLENGE WITH GADOLINIUM

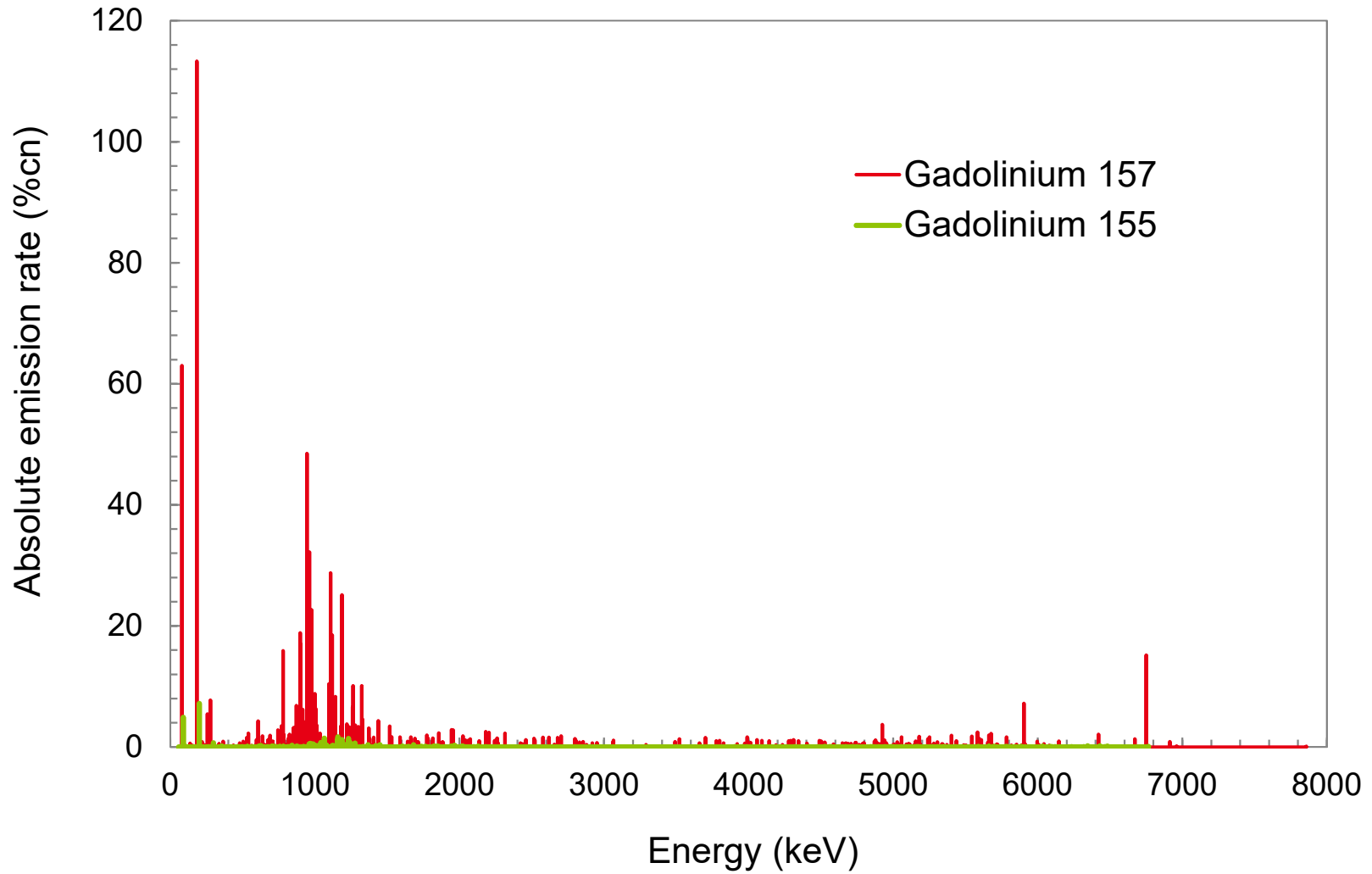
- **ADVANTAGES**
- The highest neutron cross-section (50000 barns)
- The availability and cost efficiency of the material
- The high energy released by the reaction (8 MeV)



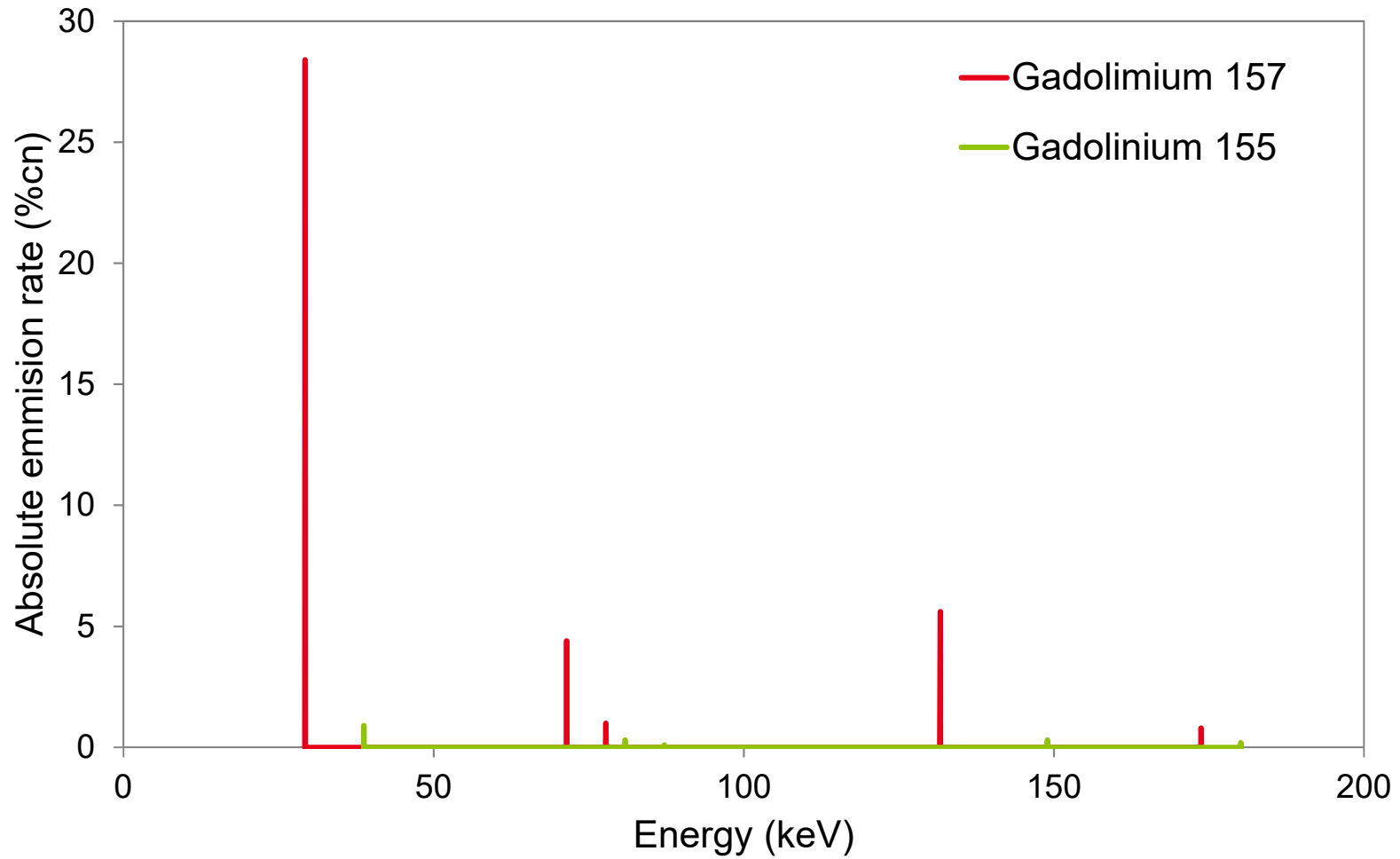
- DRAW-BACKS
- The mainly radiative forms of the signature
- The escape of the signal of interest
- No discrimination with background gamma rays



THE SIGNATURE (PROMPT GAMMA RAYS)



THE SIGNATURE (INTERNAL CONVERSION ELECTRONS)



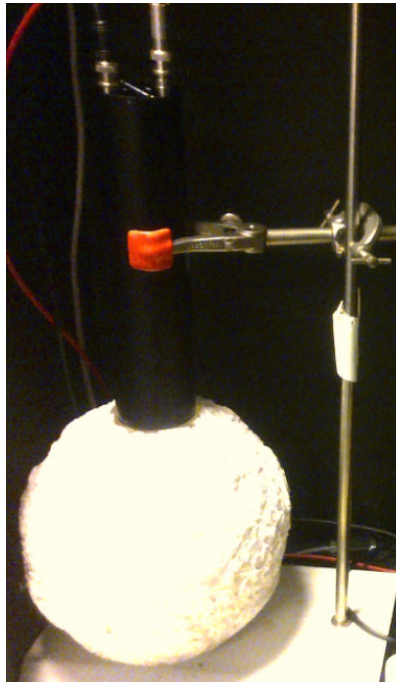
THE SIGNATURE

- **Low energy signature [0; 200] keV (electron IC & γ rays)**
 - Measurement based on compensation techniques
 - Small size detector
 - 242 %cn
- **Medium energy signature [0.2; 3] MeV (γ rays)**
 - Measurement based on compensation techniques
 - High size detector
 - 155 %cn
- **High energy signature [3; 8] MeV (γ rays)**
 - Measurement based on pulse height discrimination techniques (PHD)
 - High size detector
 - 52 %cn

2 strategies :

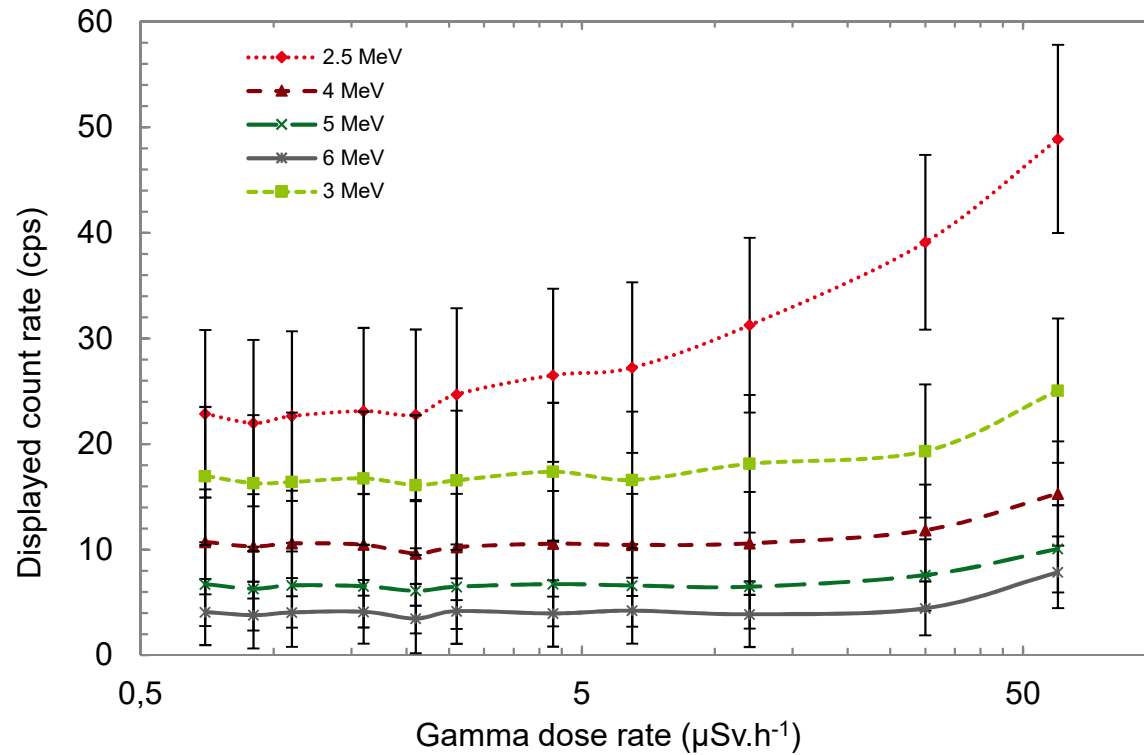
- **The low energy signature [0; 200] keV : compact sensor in compensation**
- **the high energy signature [3; 8] MeV : large sensor in PHD**

- The large sensor strategy (mobile or fixed systems)



GADOPHERE®

Spherical scintillator w/ Gd core
Radius 12 cm.



Stability curves of the systems

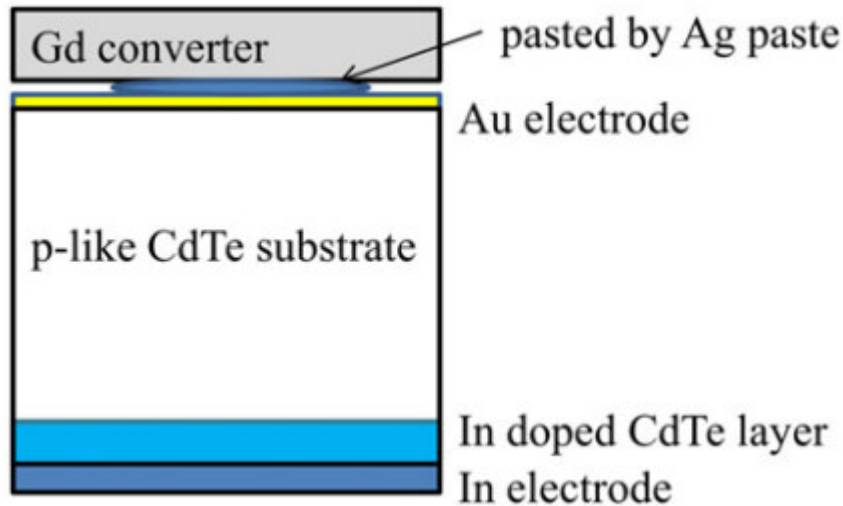
Promising system: Sensitivity close to ³He Bonner sphere

THE STATE OF THE ART

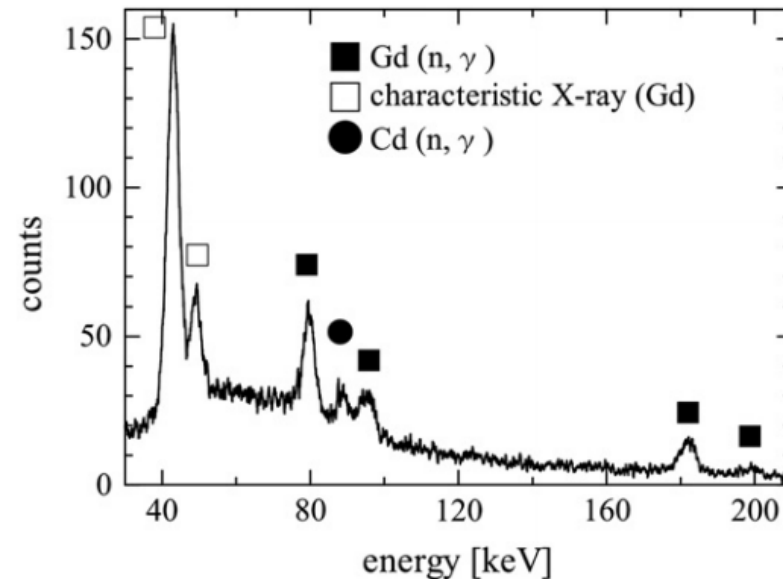
- The compact sensor strategy (portable systems)

N.H. Lee, et. al, IEEE Trans. Nucl. Sci. 57 (2010) 3489-3492
P. Kandlakunta and L. Cao, Rad. Prot. Dos.151 (2012) 586-590
M. Fasasi, et. al, Rad. Rad. Prot. Dos.23 (1988) 429-431
A. Miyake, et. al, Nuc. Instr. Meth. A 654 (2011) 390-393

} Silicon detectors
 } CdTe detectors



Gd covered CdTe of Miyake



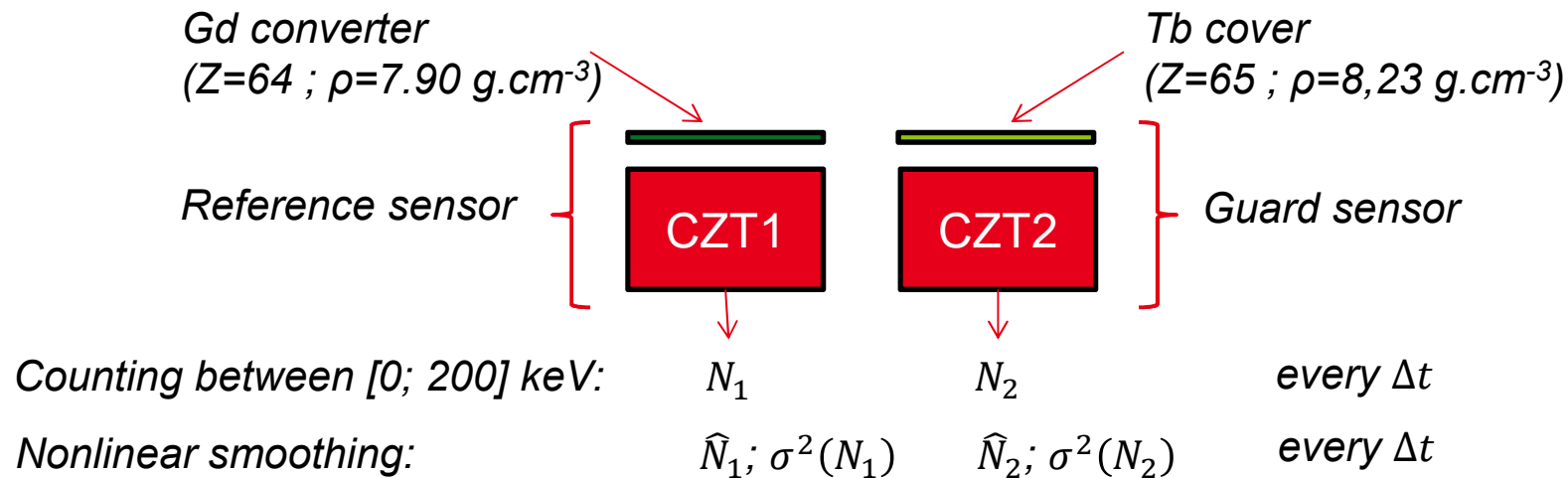
Spectrum measured under neutron flux by the Miyake detector

**CdTe & CdZnTe are well suited to measure the Gd signature between [0; 200] keV
 How compensate gamma rays background and provide neutron counting?**

THE RUGGED COMPENSATION

- Design of a compact neutron counter

The optimal value for Gd converter is 25 μm . (cf. D.A. Abdushukurov, Nova Science Publishers, Inc. 2010)



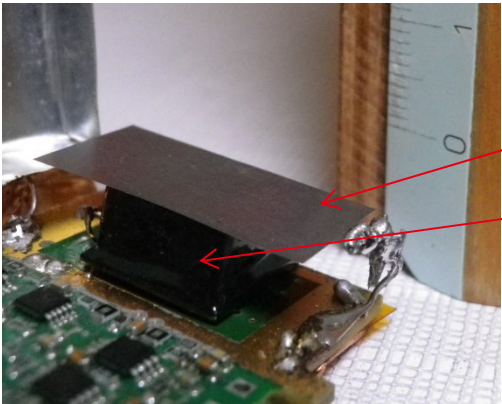
Cf. R. Coulon, et. al, Rad. Meas. 87 (2016) 13–23.

Compensation algorithm (hypothesis test):

If	$\hat{N}_1 - \hat{N}_2 > K\sqrt{\sigma^2(N_1) + \sigma^2(N_2)}$
Then	$\hat{S}_n = \hat{N}_1 - \hat{N}_2$
Else	$\hat{S}_n = 0$

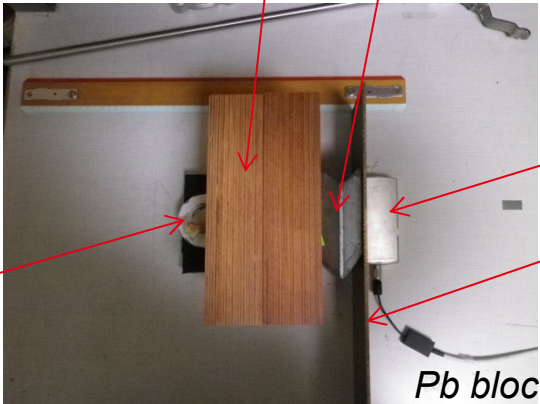
EXPERIMENTAL TEST

- Experimental setup:



Gd or Tb Foil
 CdZnTe (500 mm³)
 252Cf source

Borated wood (10 cm) Pb bloc (5 cm)



Detector
 Cu foil (2 mm)

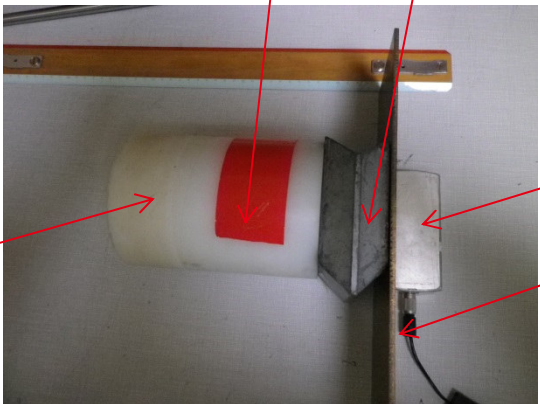
Pb bloc (5 cm)

PEHD (10 cm)

Cf. K. Boudergui, et. al, . ANIMMA 2011.



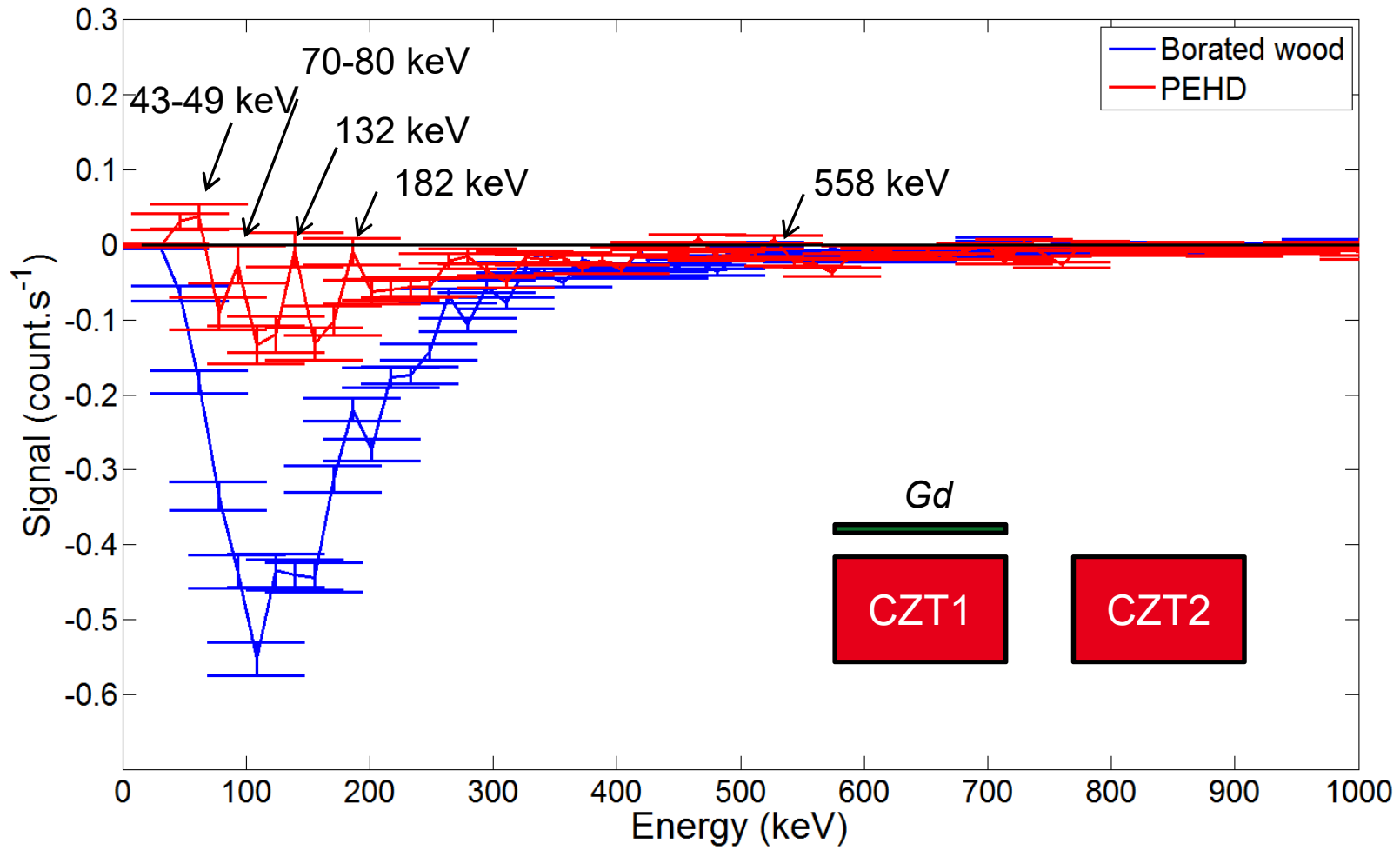
Micro-sized Gamma Spectrometer from IMS.



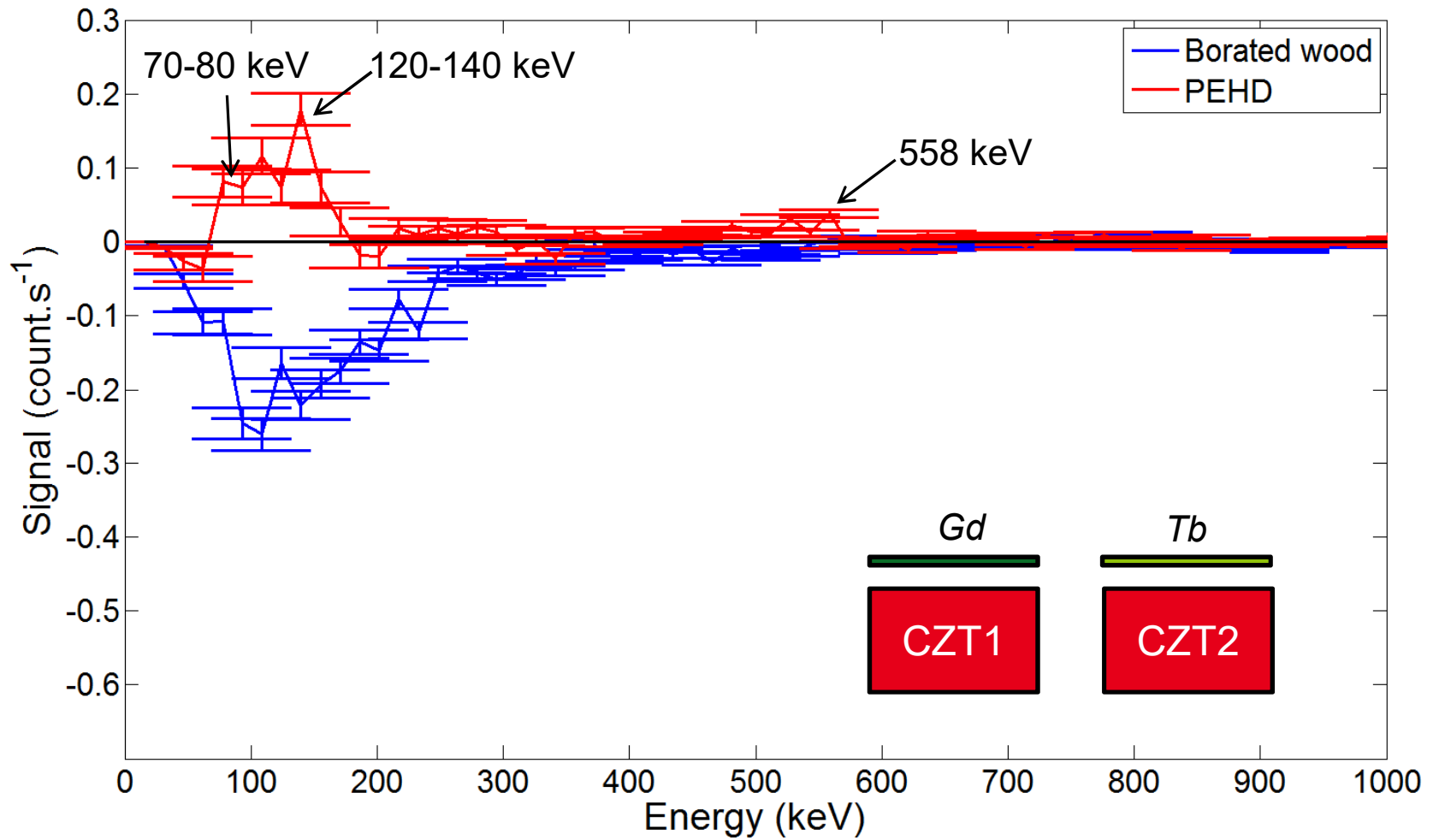
Detector
 Cu foil (2 mm)

252Cf source

RESULTS



RESULTS



RESULTS

	PEHD	Borated wood
Gd / void [60; 200] keV	-0.65 ± 0.34	-3.64 ± 0.30
Gd / Tb [60; 200] keV	$+0.55 \pm 0.33$	-1.76 ± 0.29
Gd / void [500; 600] keV	-0.13 ± 0.07	-0.098 ± 0.052
Gd / Tb [500; 600] keV	$+0.102 \pm 0.066$	-0.070 ± 0.051
Gd / void [60; 600] keV	-1.23 ± 0.39	-4.88 ± 0.34
Gd / Tb [60; 600] keV	$+0.79 \pm 0.38$	-2.45 ± 0.33

Sensitivity ≈ 0.5 (c/s)/nv

CONCLUSION

- According to the state of the art, the CdZnTe is convenient to measure low energy prompt gamma rays from ^{157}Gd .
- A reliable compensation measurement could be implemented using a nonlinear smoothing and a hypothesis test.
- A significant gain in efficiency has been obtained by the implementation of a terbium covered guard CdZnTe.
- The concept has been proven and R&D works will be continued to design a portable neutron detector.

Commissariat à l'énergie atomique et aux énergies alternatives
Institut List | CEA SACLAY NANO-INNOV | BAT. 861 – PC142
91191 Gif-sur-Yvette Cedex - FRANCE
www-list.cea.fr

Établissement public à caractère industriel et commercial | RCS Paris B 775 685 019