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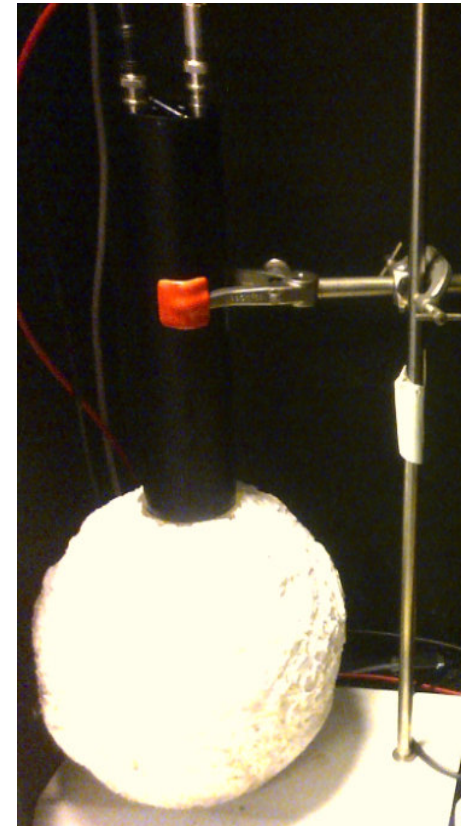
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NEUTRON DETECTION USING A GADOLINIUM COVERED CDZnTE DETECTOR

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

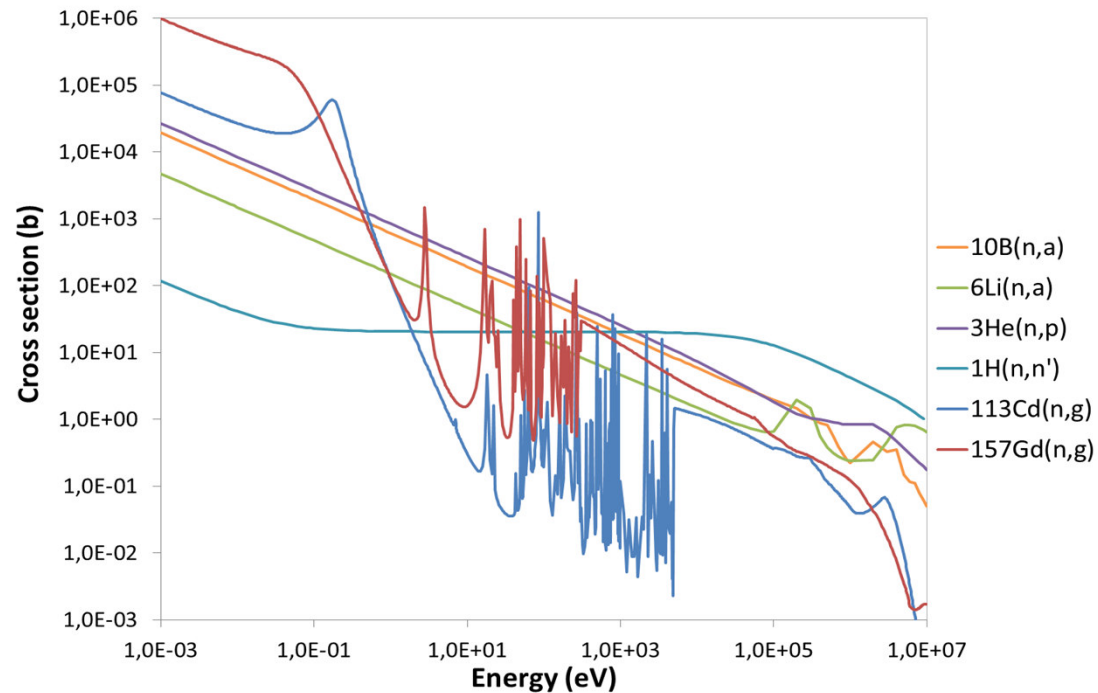


- **CONTEXT:**
- The need: miniaturized neutron detector.
- State of the art: Silicon technology implementing Boron, lithium, and PE convertors.
- Limitation: Low neutron efficiency / high detection limits.

- **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

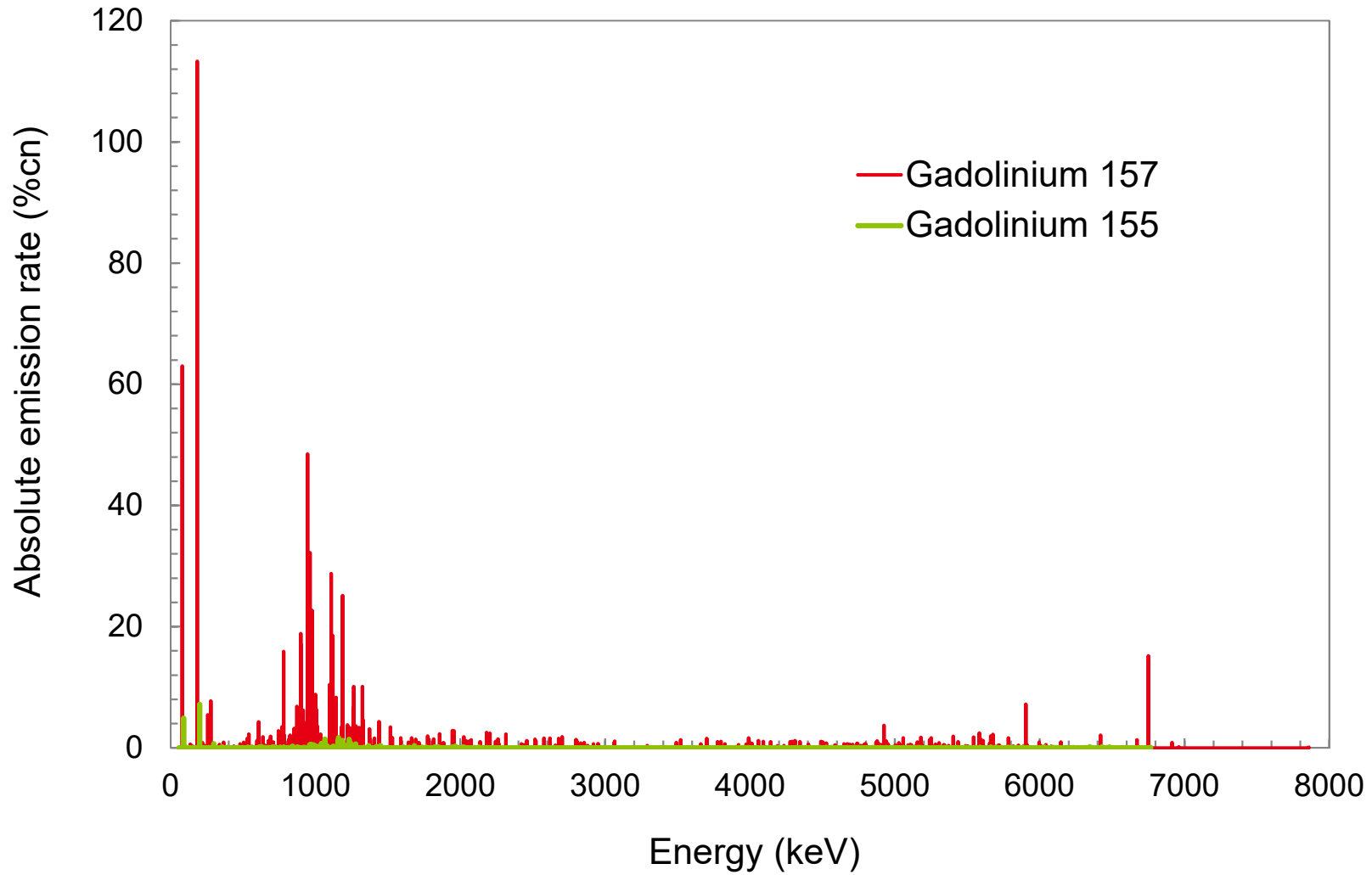
- **ADVANTAGES**
- The highest neutron cross-section (50000 barns)
- The availability and cost efficiency of the material
- The high energy released by the reaction (8 MeV)



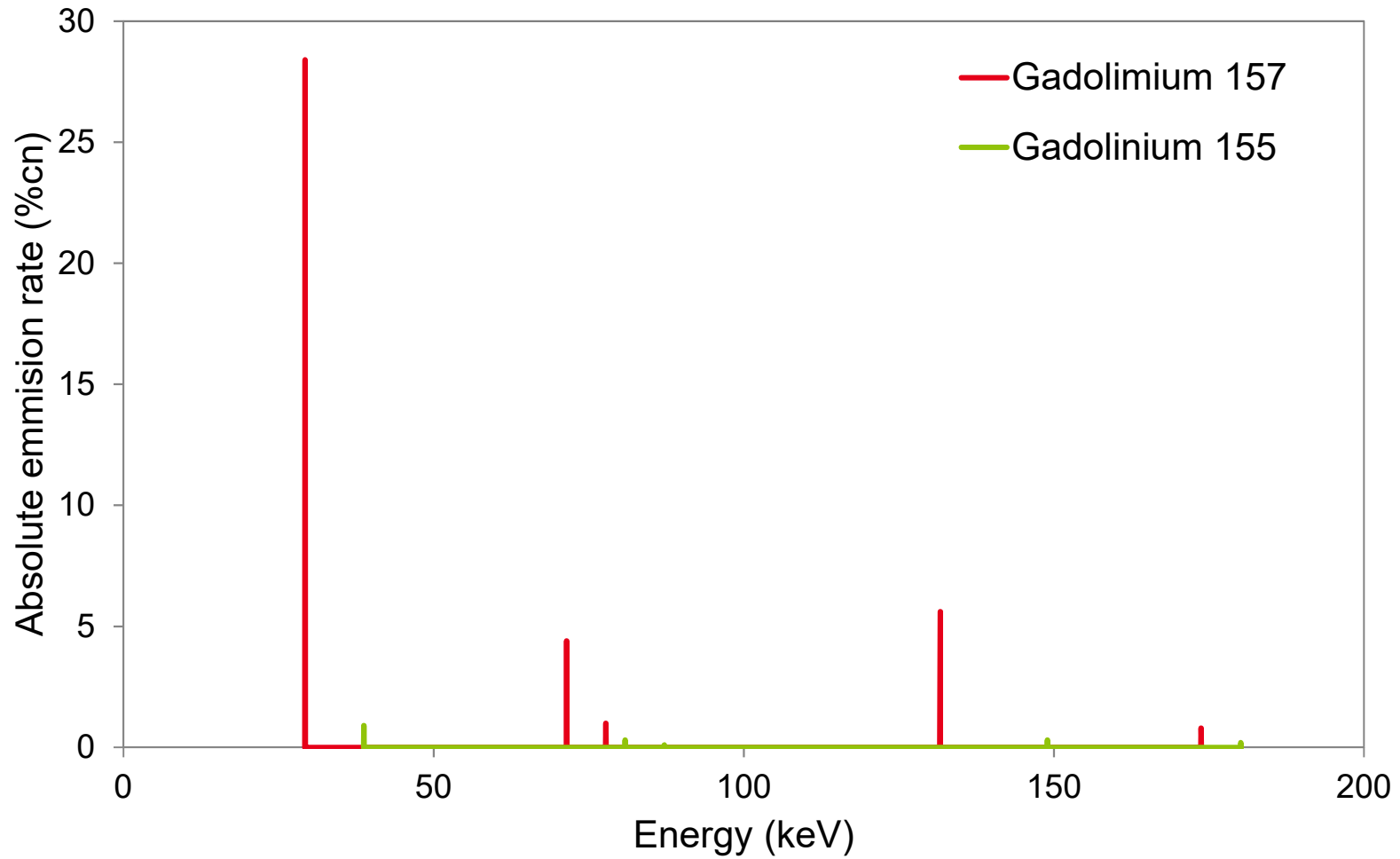
- DRAW-BACKS
- The mainly radiative forms of the signature
- The escape of the signal of interest
- No discrimination with background gamma rays



THE SIGNATURE (PROMPT GAMMA RAYS)



THE SIGNATURE (INTERNAL CONVERSION ELECTRONS)



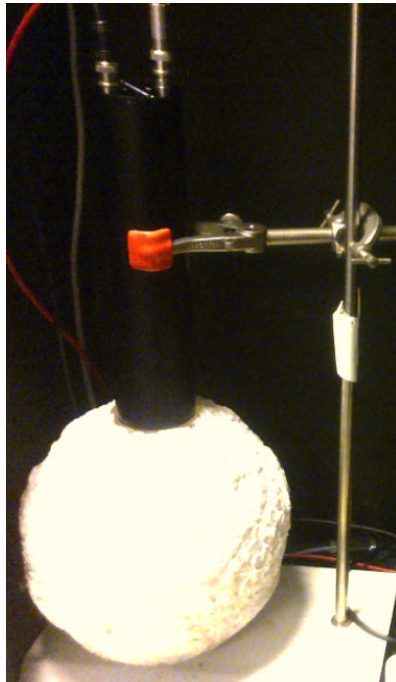
THE SIGNATURE

- **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 :

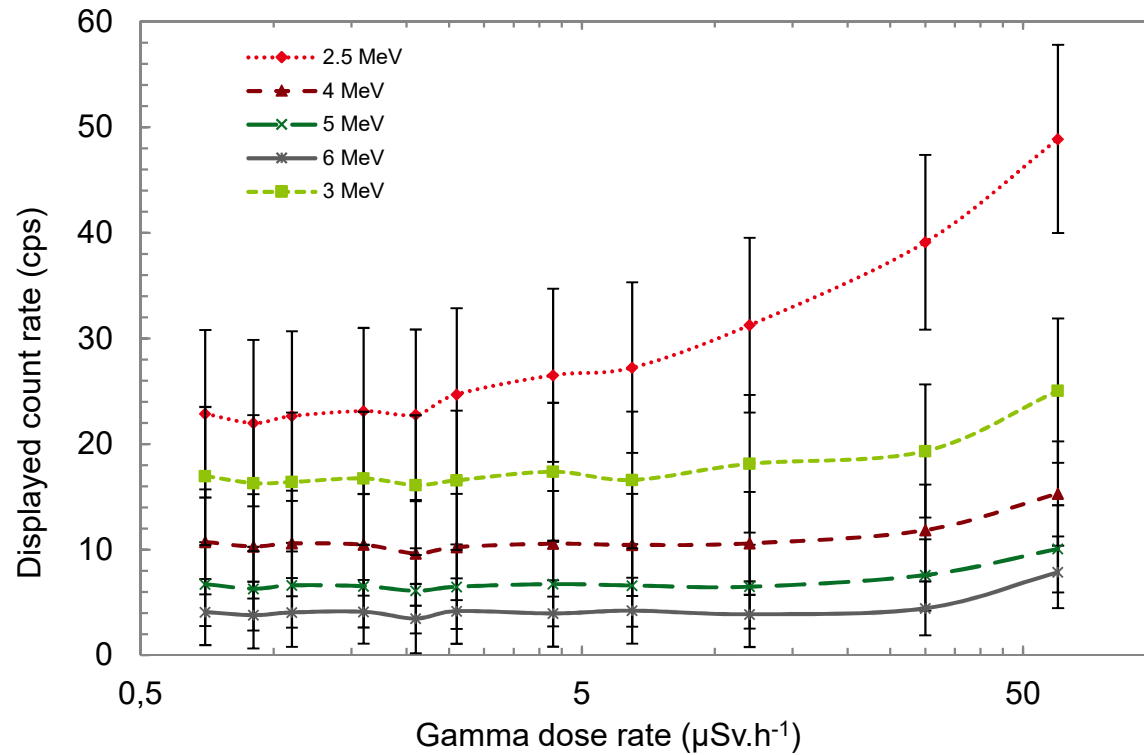
- **The low energy signature [0; 200] keV : compact sensor in compensation**
- **the high energy signature [3; 8] MeV : large sensor in PHD**

- The large sensor strategy (mobile or fixed systems)



GADOPHERE®

*Spherical scintillator w/ Gd core
Radius 12 cm.*



Stability curves of the systems

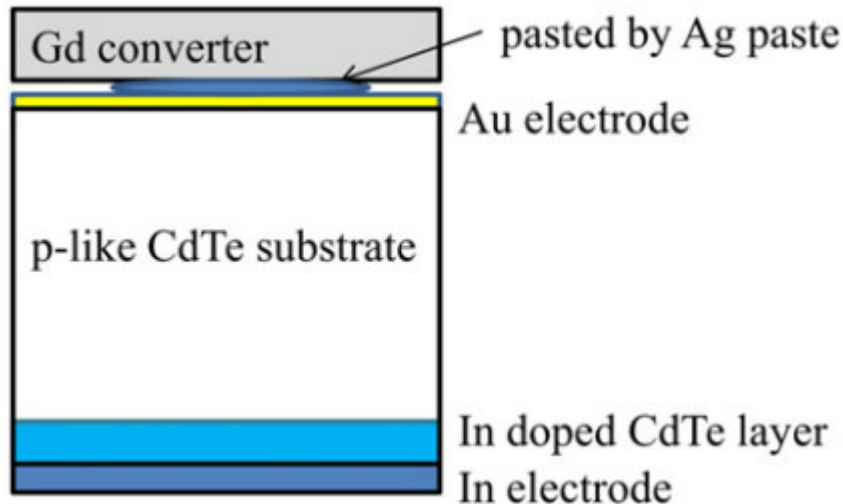
Promising system: Sensitivity close to ³He Bonner sphere

THE STATE OF THE ART

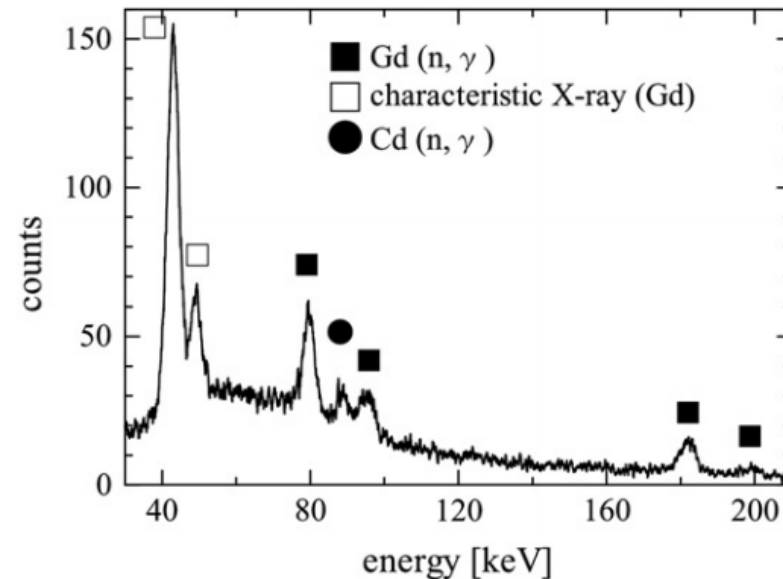
- The compact sensor strategy (portable systems)

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



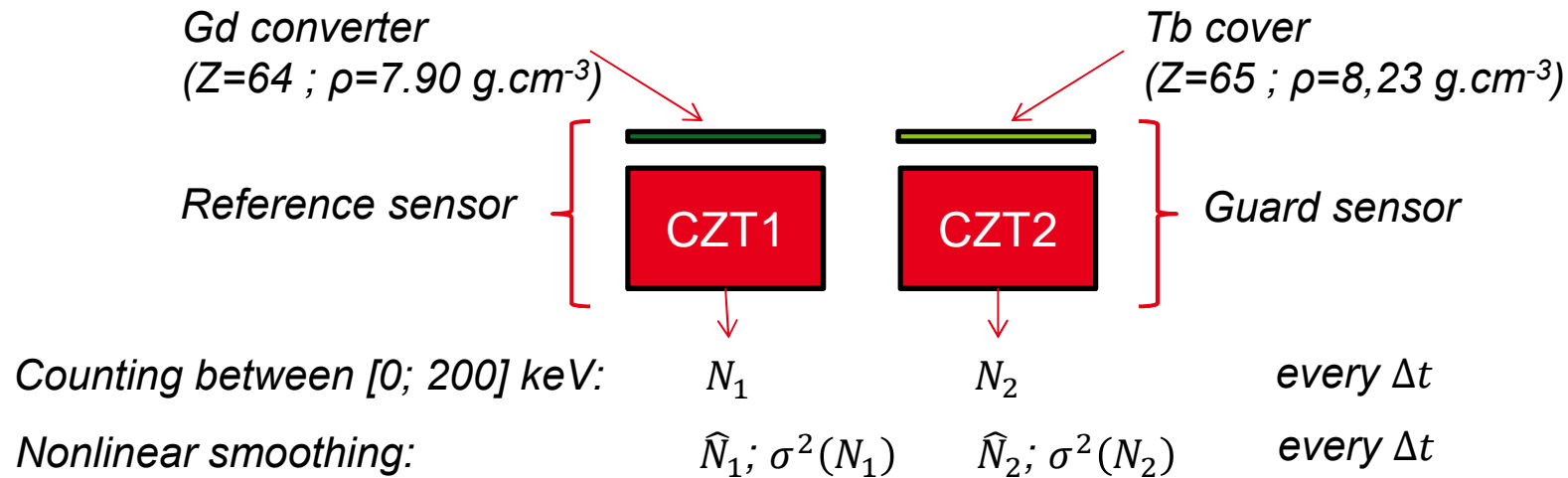
Spectrum measured under neutron flux by the Miyake detector

**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)



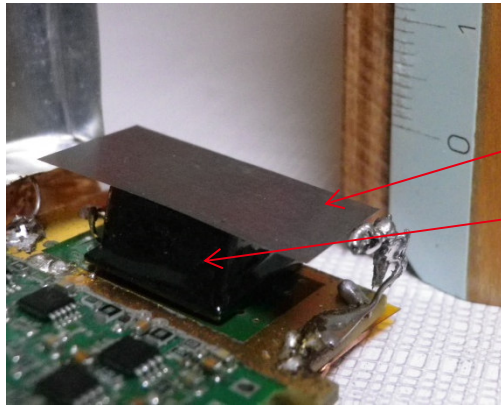
Cf. R. Coulon, et. al, Rad. Meas. 87 (2016) 13–23.

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	$\hat{S}_n = 0$

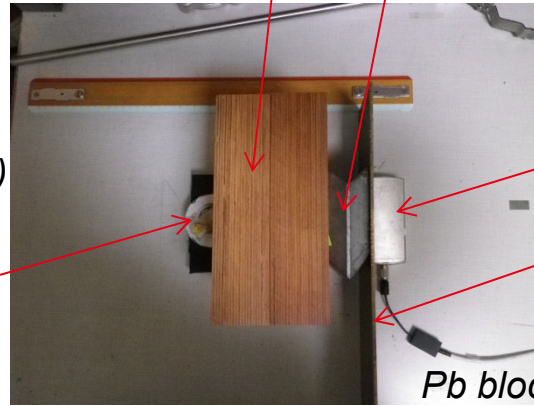
EXPERIMENTAL TEST

- Experimental setup:



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

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



Detector
Cu foil (2 mm)

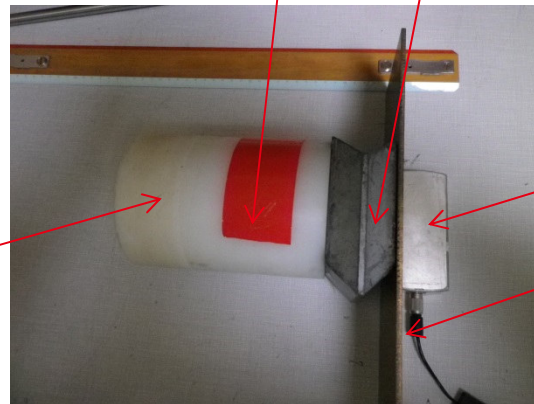
Pb bloc (5 cm)

PEHD (10 cm)

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



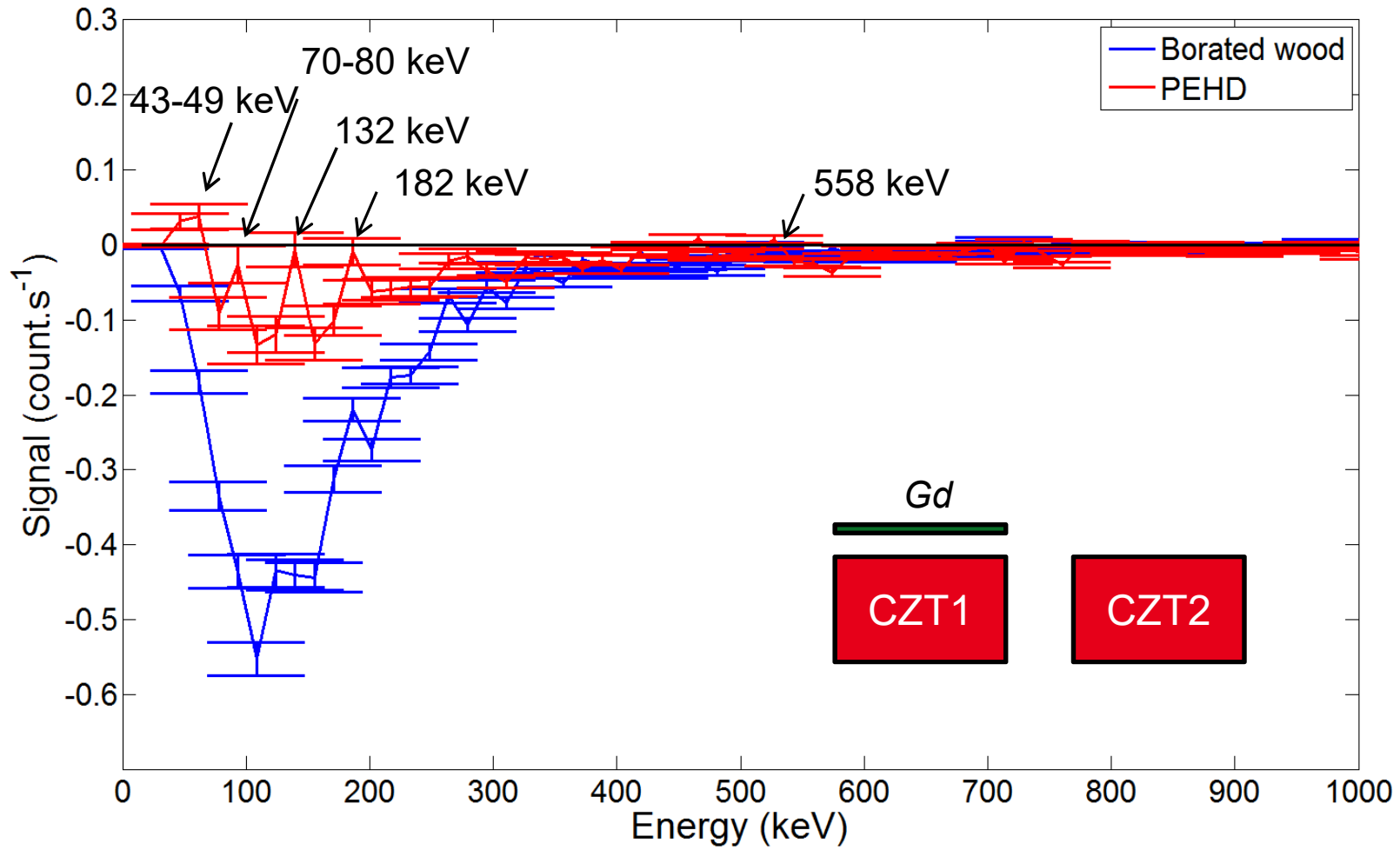
Micro-sized Gamma Spectrometer from IMS.



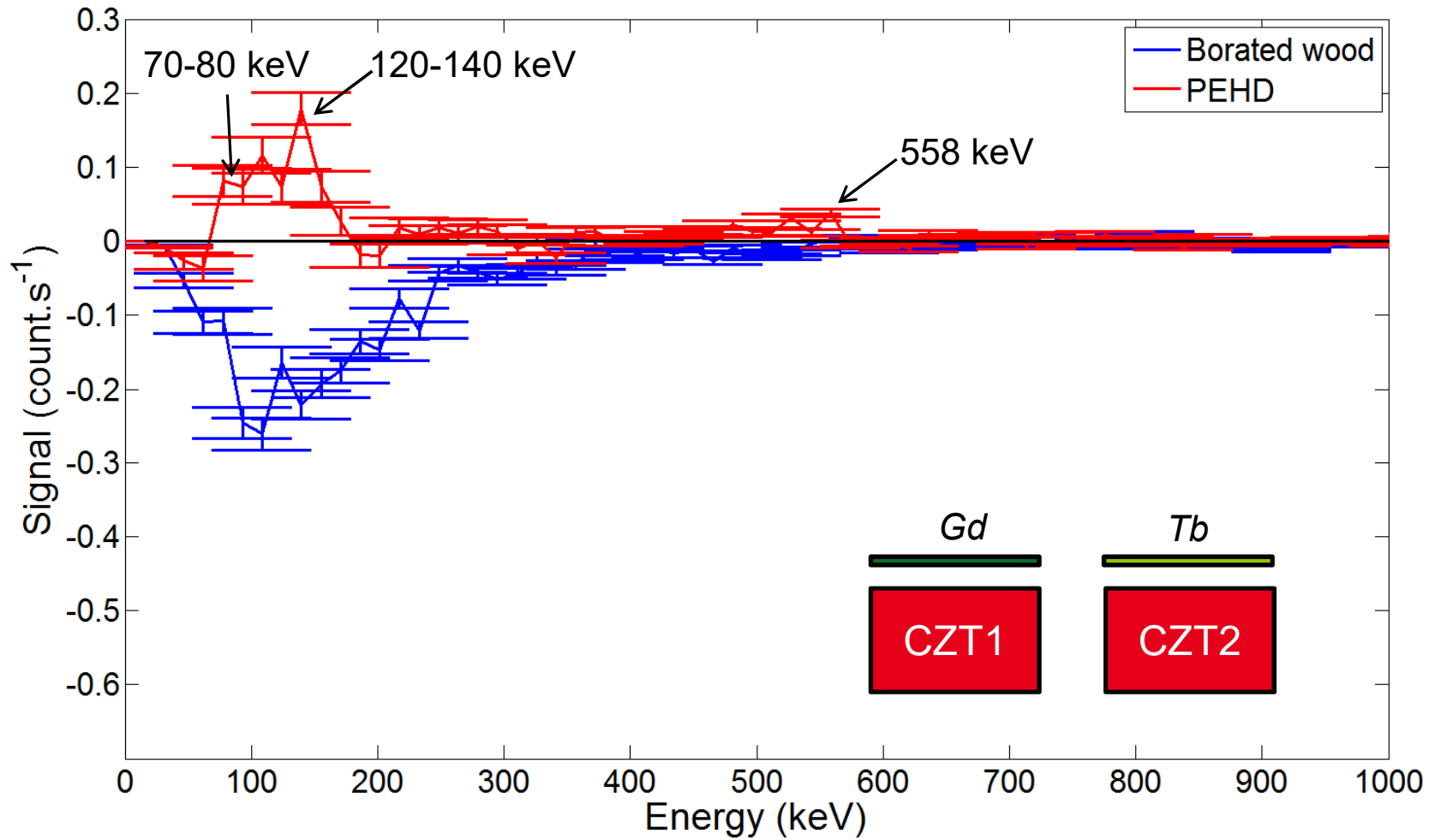
Detector
Cu foil (2 mm)

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.

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