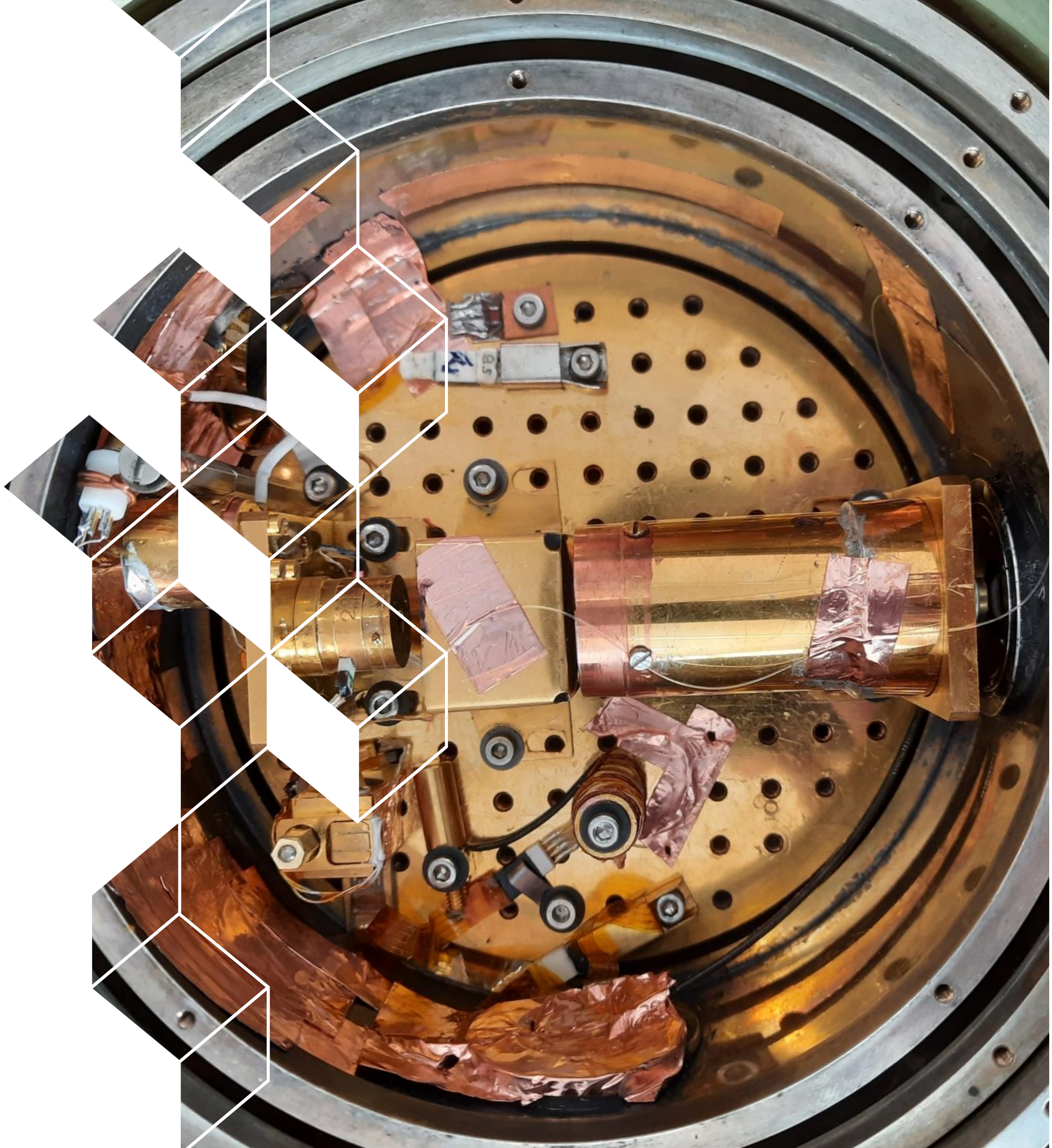
# H2020 Project SANDA

## WP2 : New nuclear data

## Measurement of half-life and γ-ray emission probabilities of beta emitters

Mark A. Kellett



# Outline

Motivation

Development of cryogenic electric substitution system for HPGe calibration

- More precise γ-ray emission probabilities possible

Development of a dedicated half-life measurement system

- Measurement of the half-life of two radionuclides ($^{51}Cr$ and $^{67}Ga$)

Outlook and conclusions

# 1. Precise γ-ray emission probabilities

# Motivation

Accurate measurement of γ- and X-ray emission intensities, requires **well-calibrated photon spectrometers**

In the **conventional approach**, efficiency calibration is carried out by using radionuclide standards, calibrated in activity, and **previously known photon emission intensities**

$$\varepsilon(E) = \frac{N(E)}{A\, I(E)\, t} \prod_i C_i$$

*N(E): Net peak area*

*A: source activity*

*t: counting time (live time)*

*I(E): photon emission intensity*

*Ci: correction factors*

- Photon emission intensity measurements and efficiency calibration are strongly correlated

  **Intrinsic limitation**: we rely on the same quantity we intend to measure

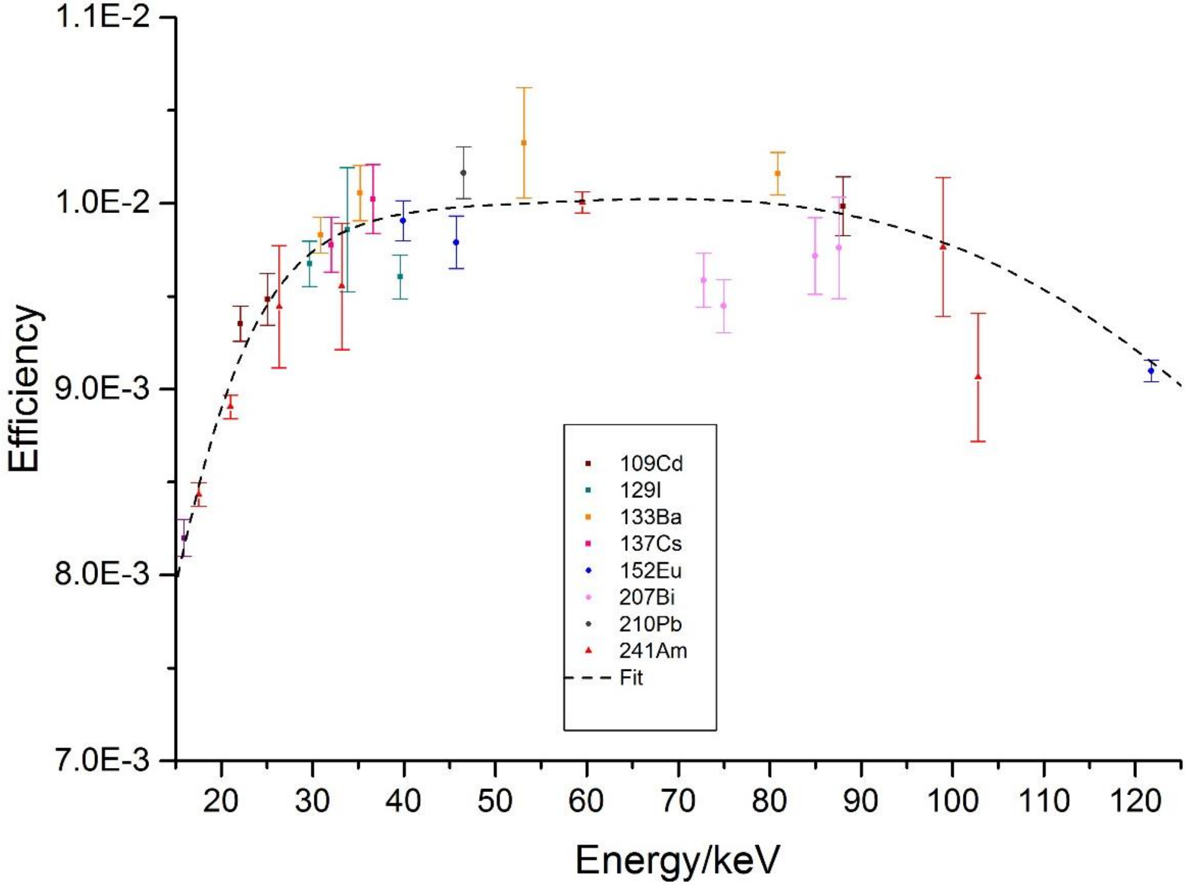
- Limited number of radionuclides for calibration

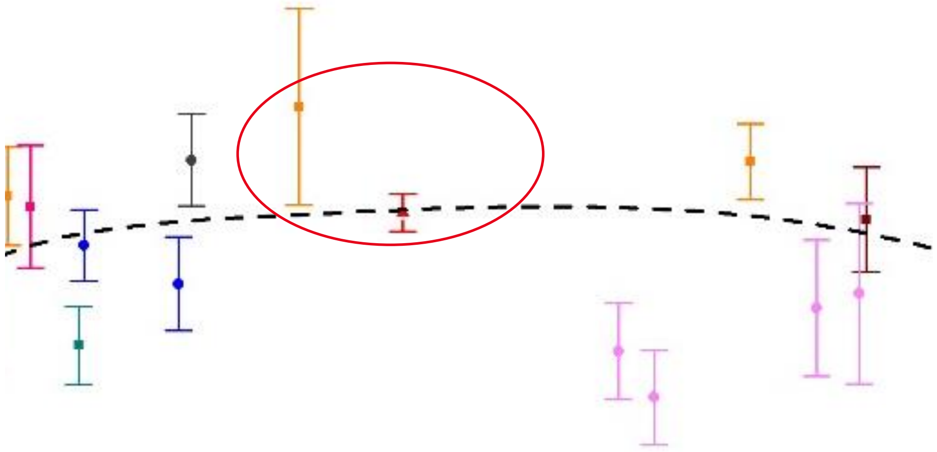
- Correlation between γ- and X-ray emission intensities

$$I_{XK} = P_\gamma \frac{\alpha_K}{1+\alpha_T}\,\omega_K$$

# Motivation

- Inconsistency in nuclear data and problems with the efficiency calibration of HPGe spectrometers below 100 keV
- e.g. systematic difference of experimental results using $^{133}$Ba (53.2 keV) and $^{241}$Am (59.5 keV)



# Motivation

## SOLUTION

Use of well-measured photon fluxes whose calibration is **independent** of any previously measured **photon emission intensities**

This approach requires
**ABSOLUTE MEASUREMENT OF PHOTON FLUXES**

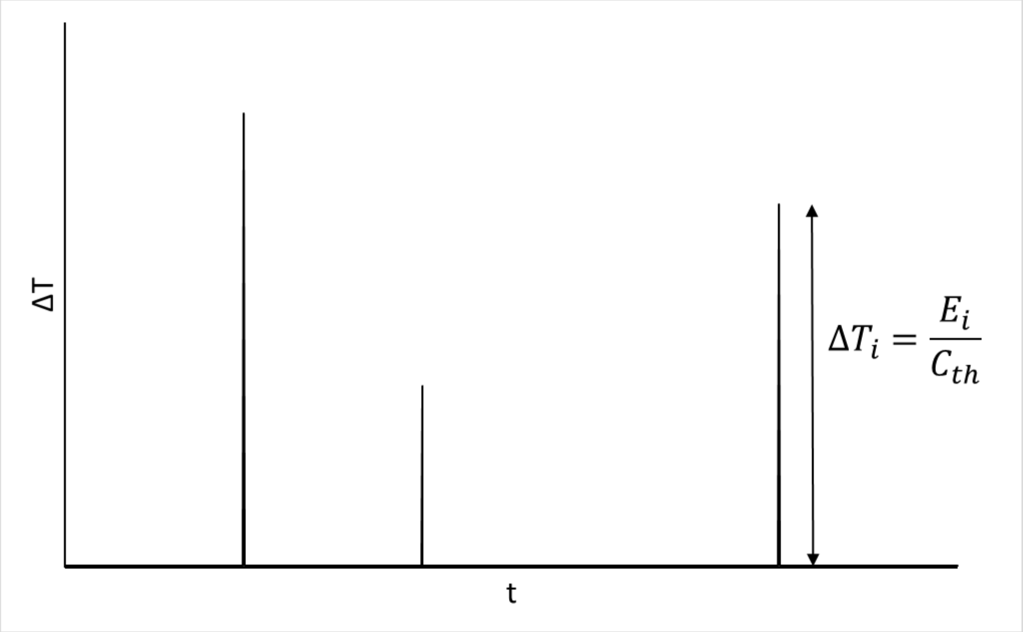
⬇

**CRYOGENIC DETECTORS**

# Cryogenic detectors

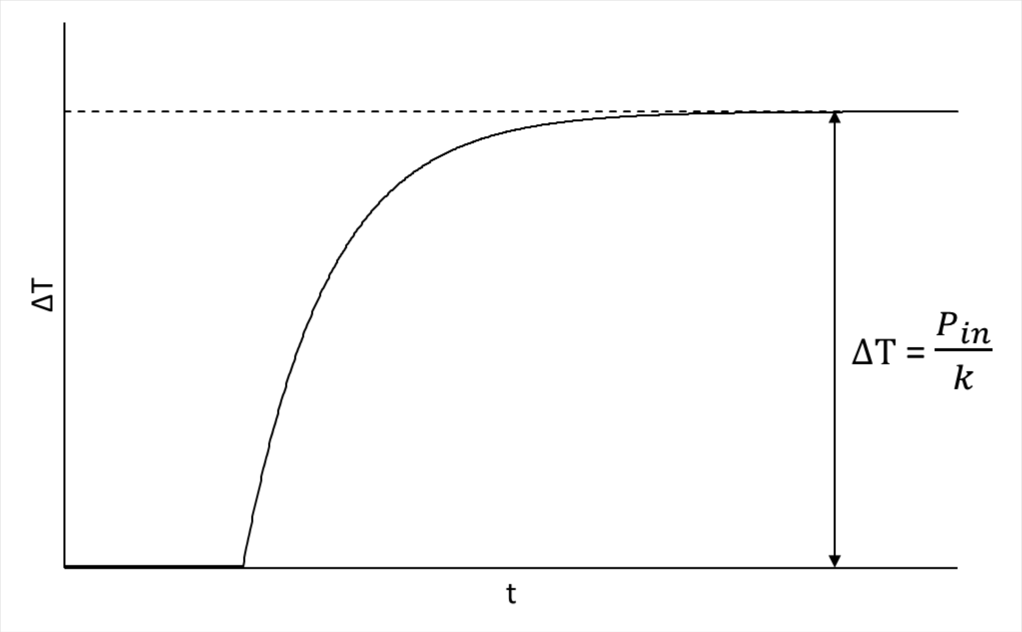
**When radiation interacts with an absorber, it provokes a temperature rise, ΔT, which is proportional to the energy of the incident radiation**

*pulse mode*




Allows spectroscopy

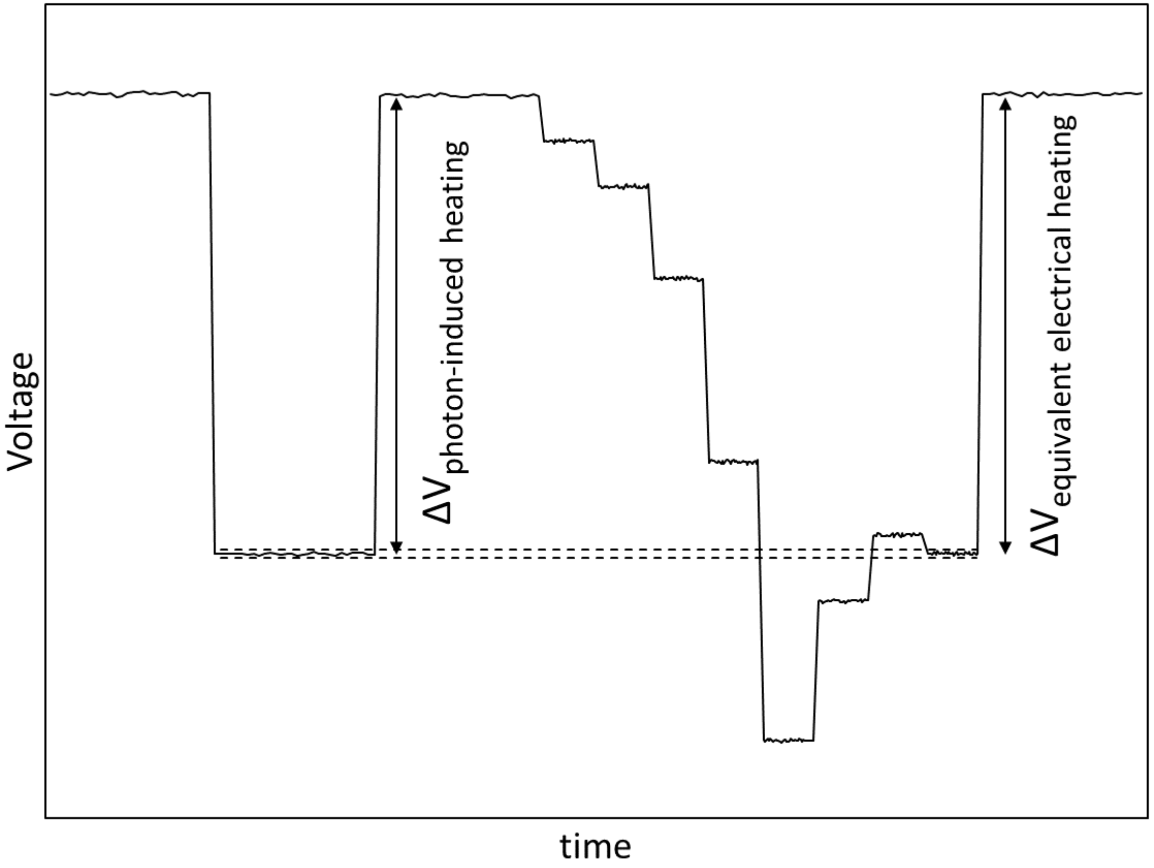
*continuous mode*




Allows measurement of high photon fluxes

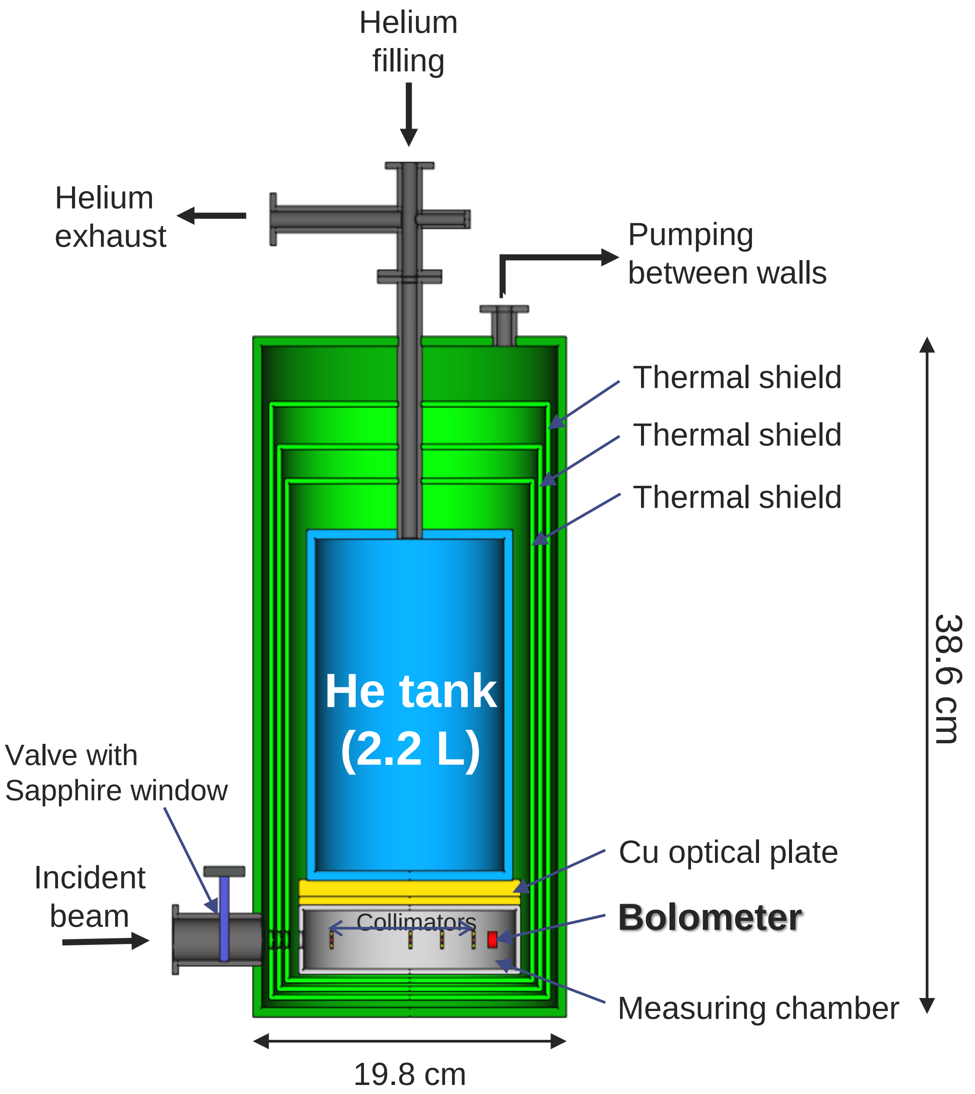
# Cryogenic detectors

## PRINCIPLE OF ELECTRICAL SUBSTITUTION



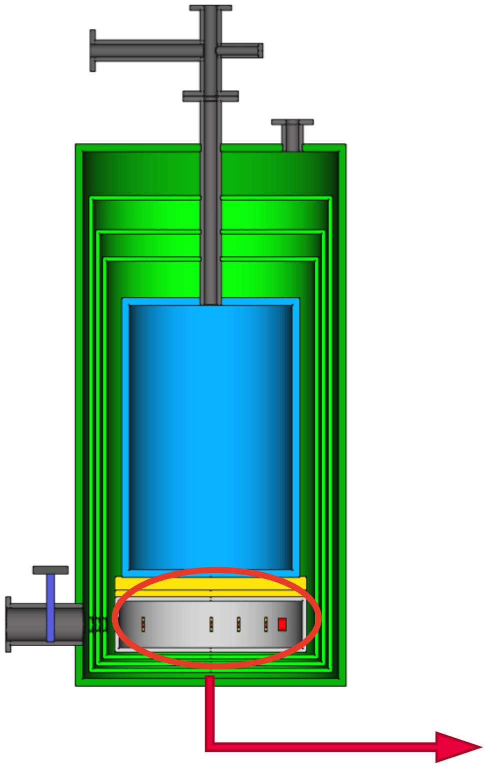

The amount of energy deposited by the radiation can be determined by finding the **electrical power** that needs to be transferred to the absorber in order to obtain **the same temperature rise**

# BOLUX - BOLometer for Use in the range of X-rays

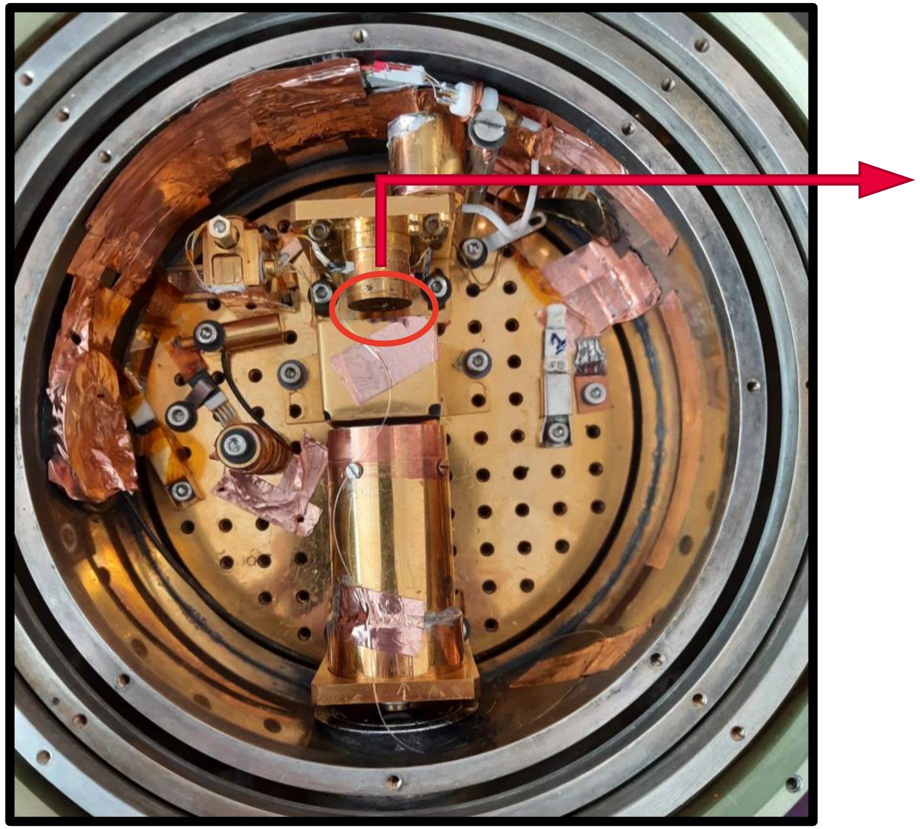


# BOLUX - BOLometer for Use in the range of X-rays

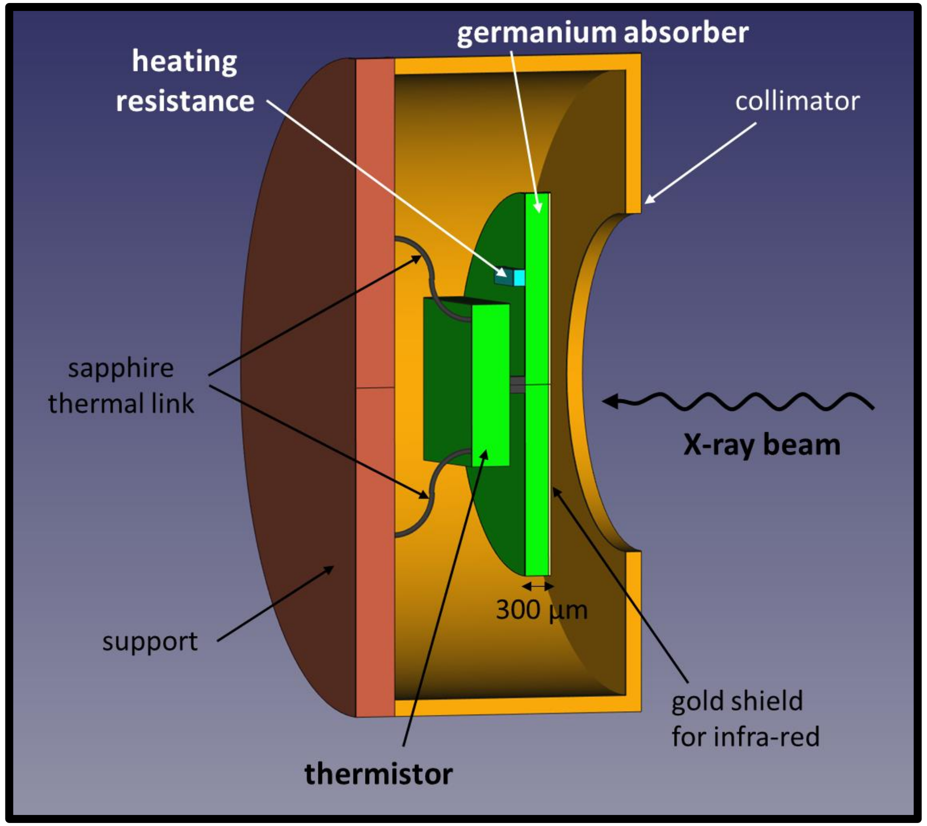
Cryostat



Measuring chamber



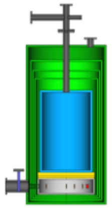
Bolometer



# Measurements to calibrate a HPGe detector

1st step, with a high photon flux (~ $10^9$ ph/s)

***BOLUX***
Measurement of the beam power



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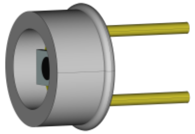
**Photodiode**
Measurement of the current induced

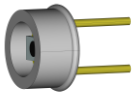


**Efficiency of the photodiode**

$$Eff = \frac{Current\ (A)}{Beam\ Power\ (W)}$$

2nd step, with a much lower photon flux (~ $10^3$ ph/s)

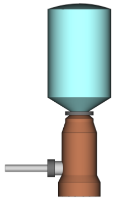
**Photodiode**
Measurement of the number of emitted photons per second



$$\frac{Current}{Eff \cdot E_{photon}}$$

+

**Semiconductor detector**
Measurement of count rate



**Efficiency of the semiconductor detector**

$$\frac{Count\ rate}{Emitted\ photons/second}$$

*The efficiency of BOLUX, the photodiode and the semiconductor detector depend on the **photon's energy***

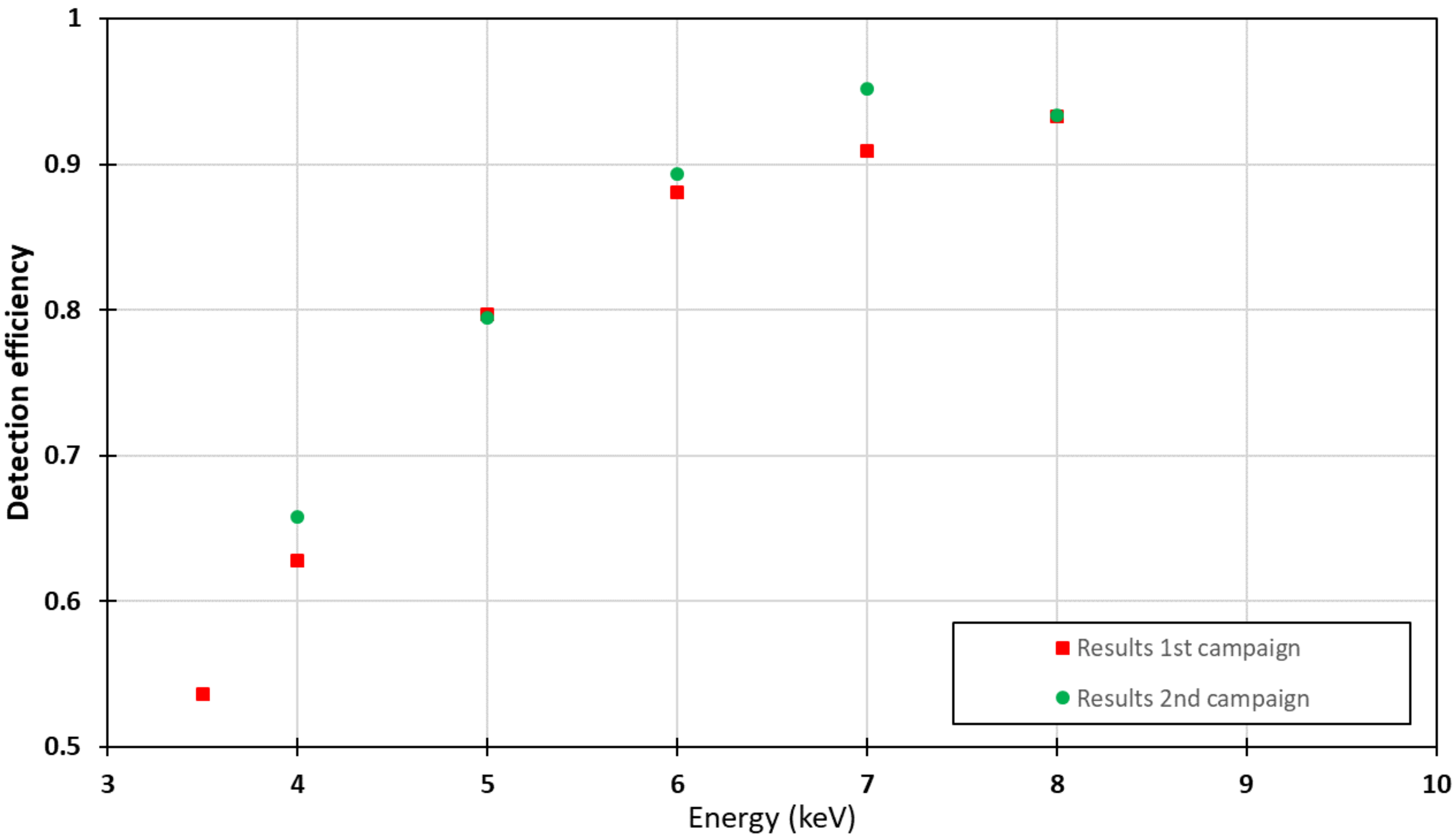
*but BOLUX and the photodiode are not able to discriminate photons by energy*

**monochromatic radiation**

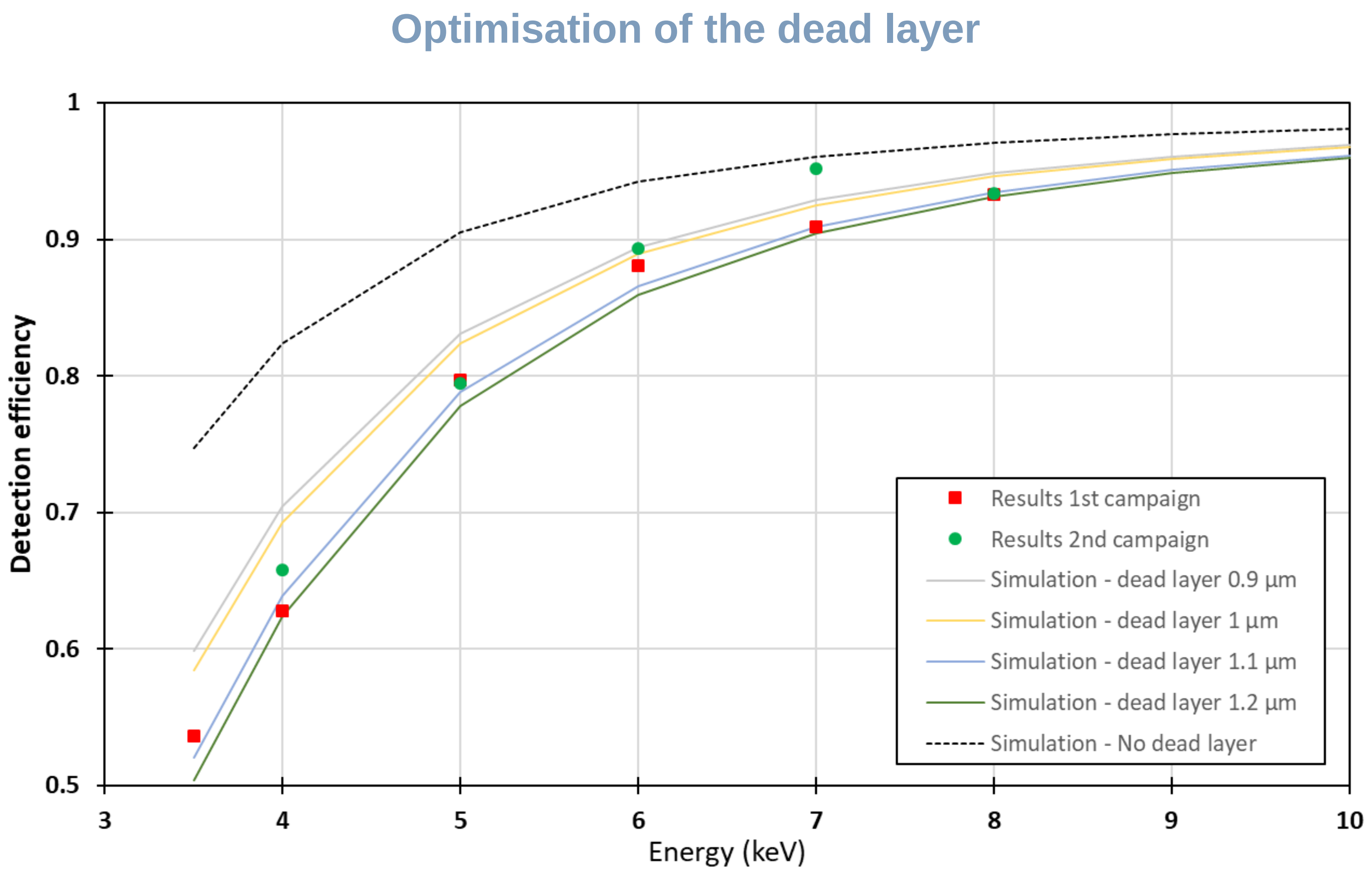
SOLEIL SYNCHROTRON

# Measurements to calibrate a HPGe detector

## Results for 3.5 keV – 8 keV

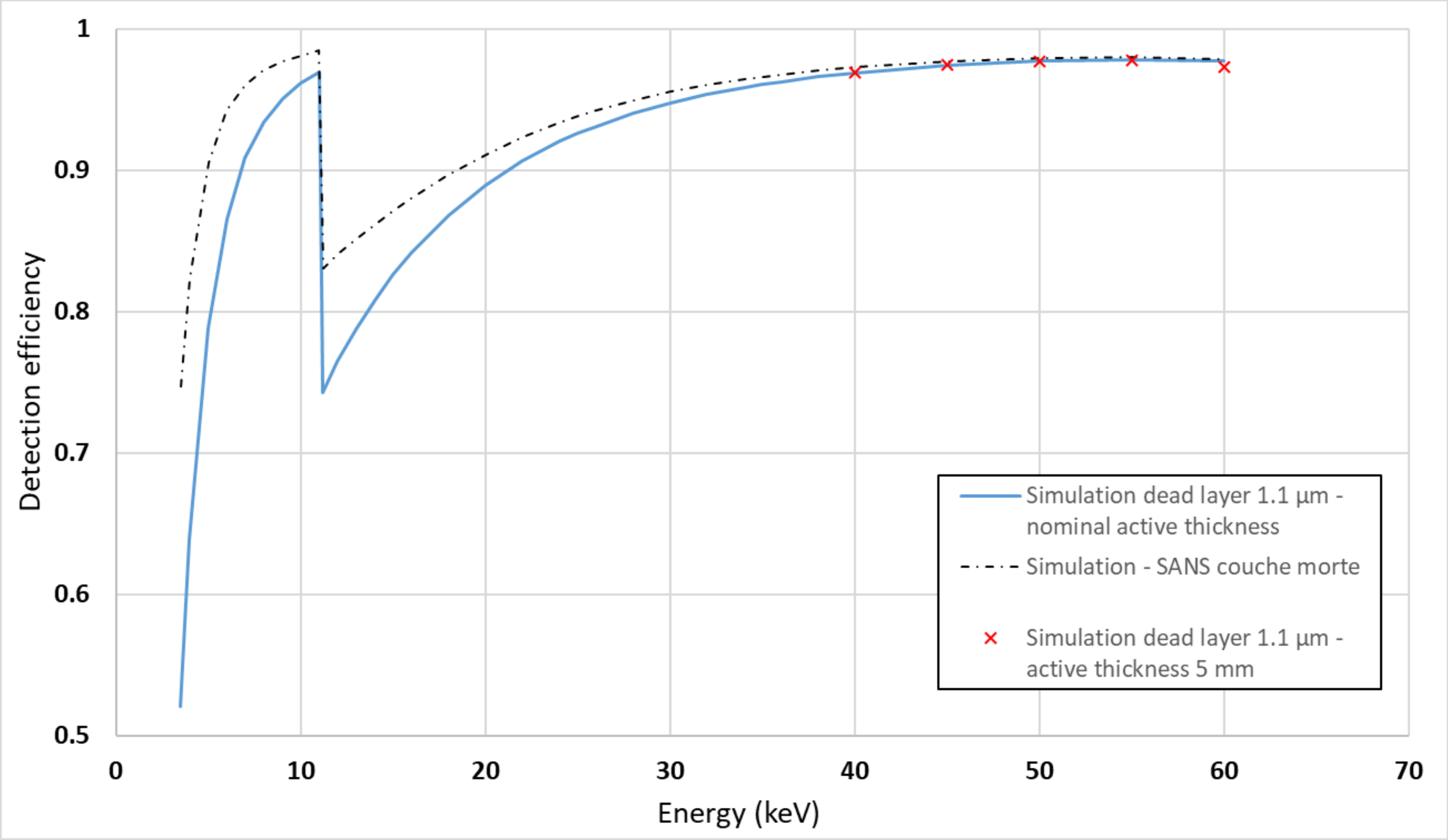


# Measurements to calibrate a HPGe detector



# Exploiting experimental results

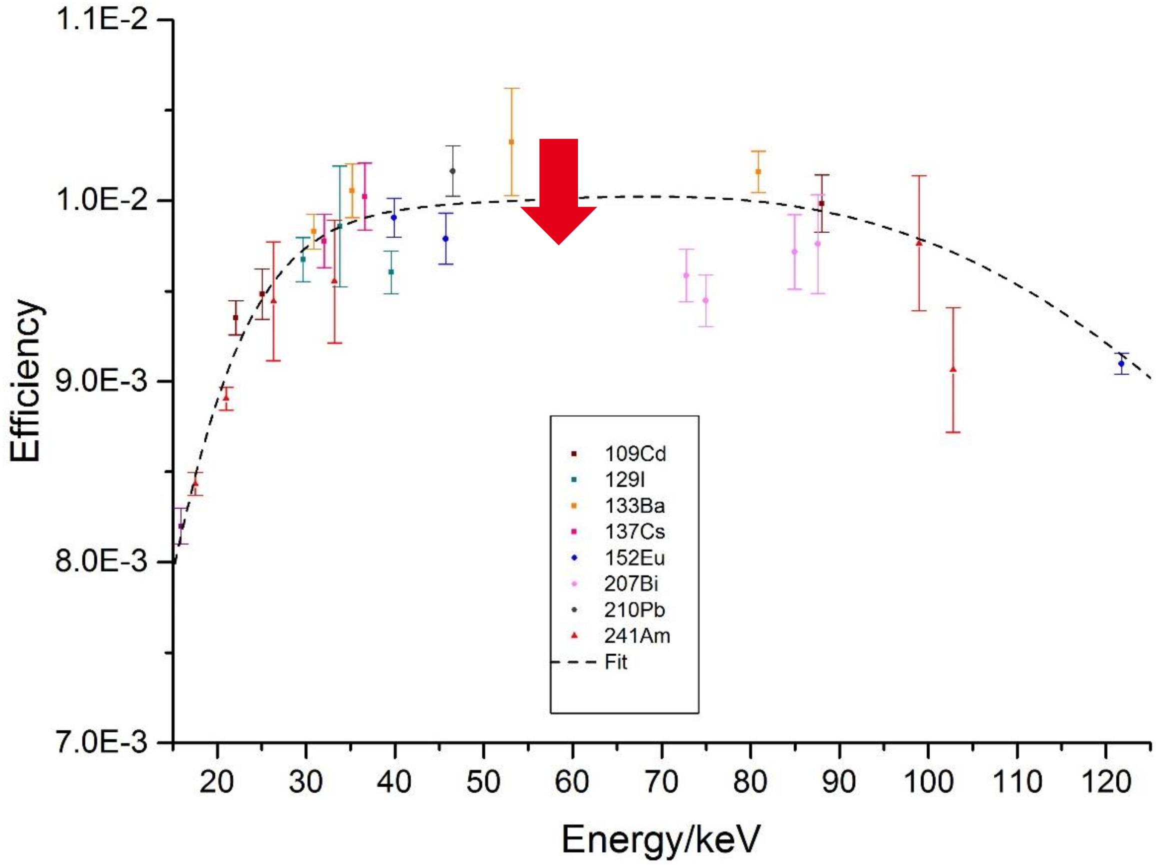
## Extension of the energy interval via Monte Carlo simulations



# Application to the determination of photon emission intensities

## Preliminary measurement of $I_\gamma$ 53 keV of $^{133}$Ba

| $I_\gamma$ (53 keV) $^{133}$Ba | |
|---|---|
| DDEP 2004 | 2.14 (3) |
| DDEP 2016 | 2.14 (6) |
| **This work** | **2.25** |
| Lépy et al. (2018) * | 2.229 (23) |



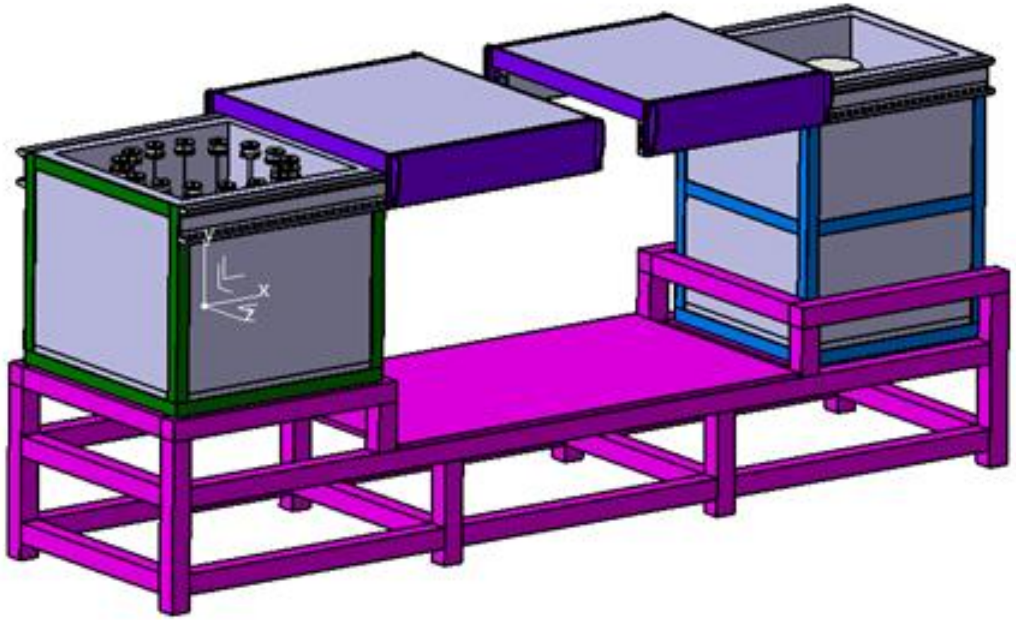

* M.-C. Lépy, L. Brondeau, Y. Ménesguen, S. Pierre, J. Riffaud
Appl. Radiat. Isot., 134 (2018), pp. 131-136

# 2. Half-life measurements

# Half-life measurements

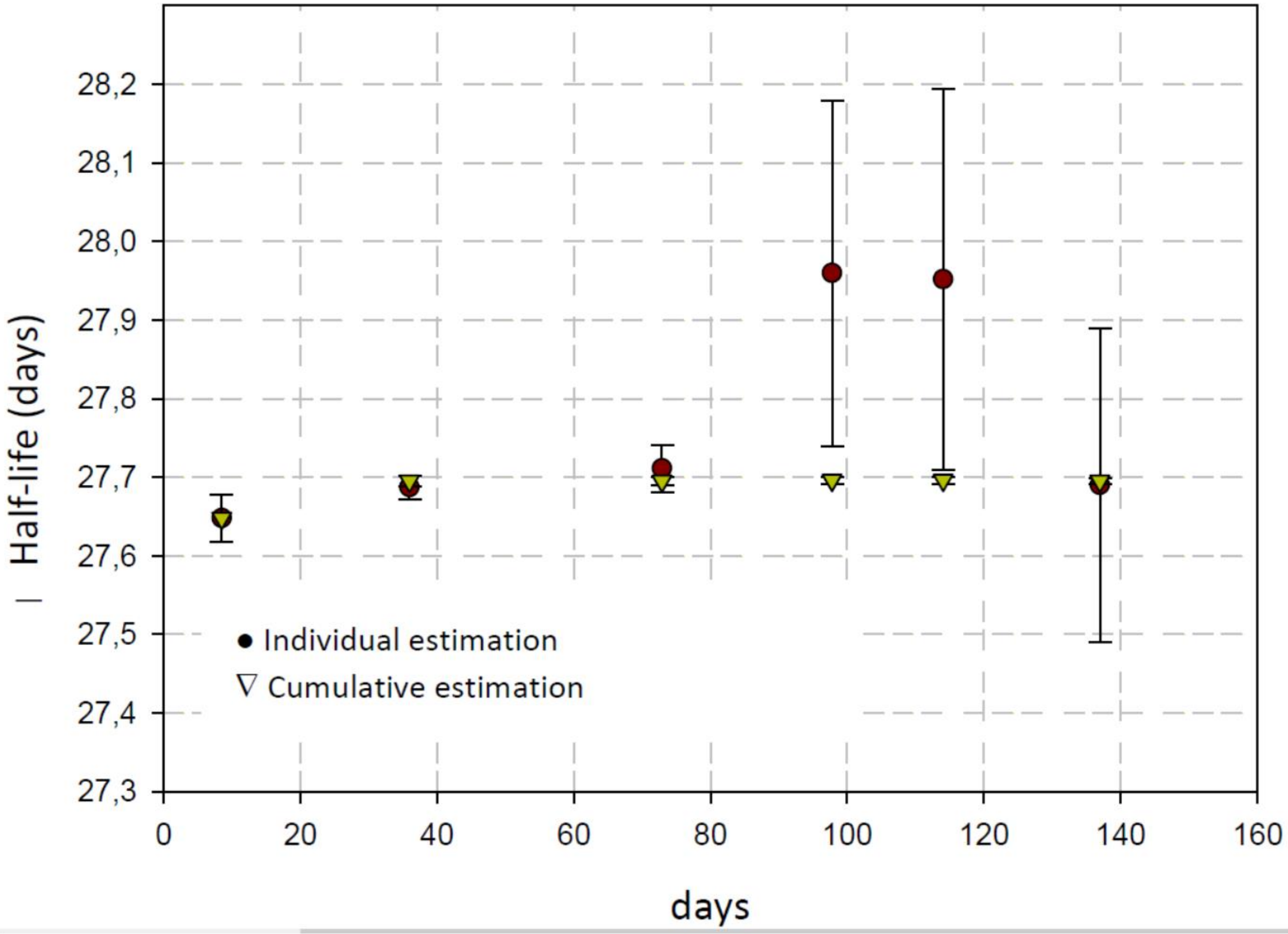
Development of a dedicated half-life measurement system using a well-type ionisation chamber

Measurement of the half-life of a number of radionuclides ($^{51}Cr$, $^{67}Ga$ and $^{99m}Tc$)

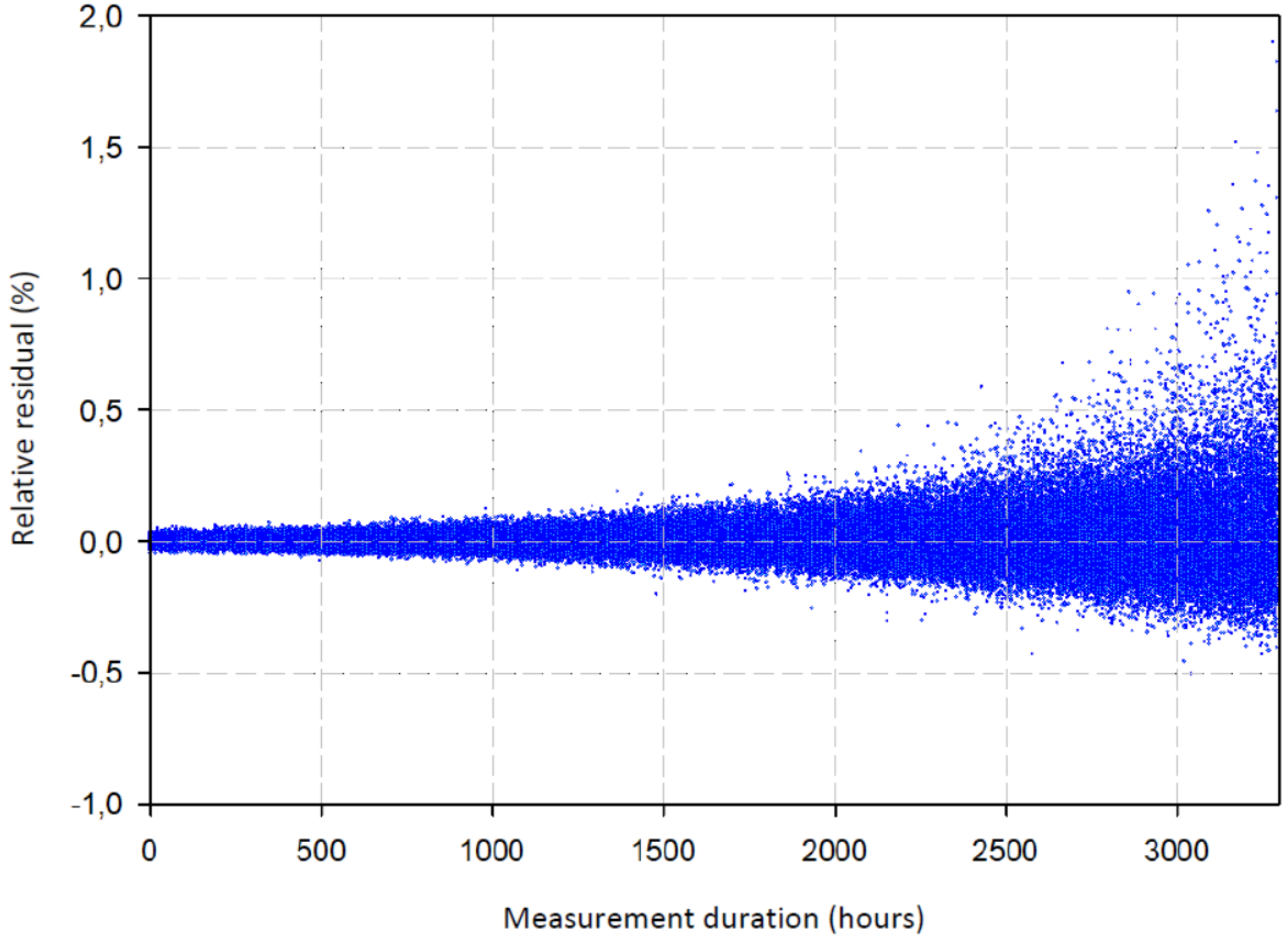


# Half-life measurements: $^{51}Cr$

Evaluated half-life (from DDEP) is 27.704 (4) d



# Half-life measurements: $^{51}Cr$

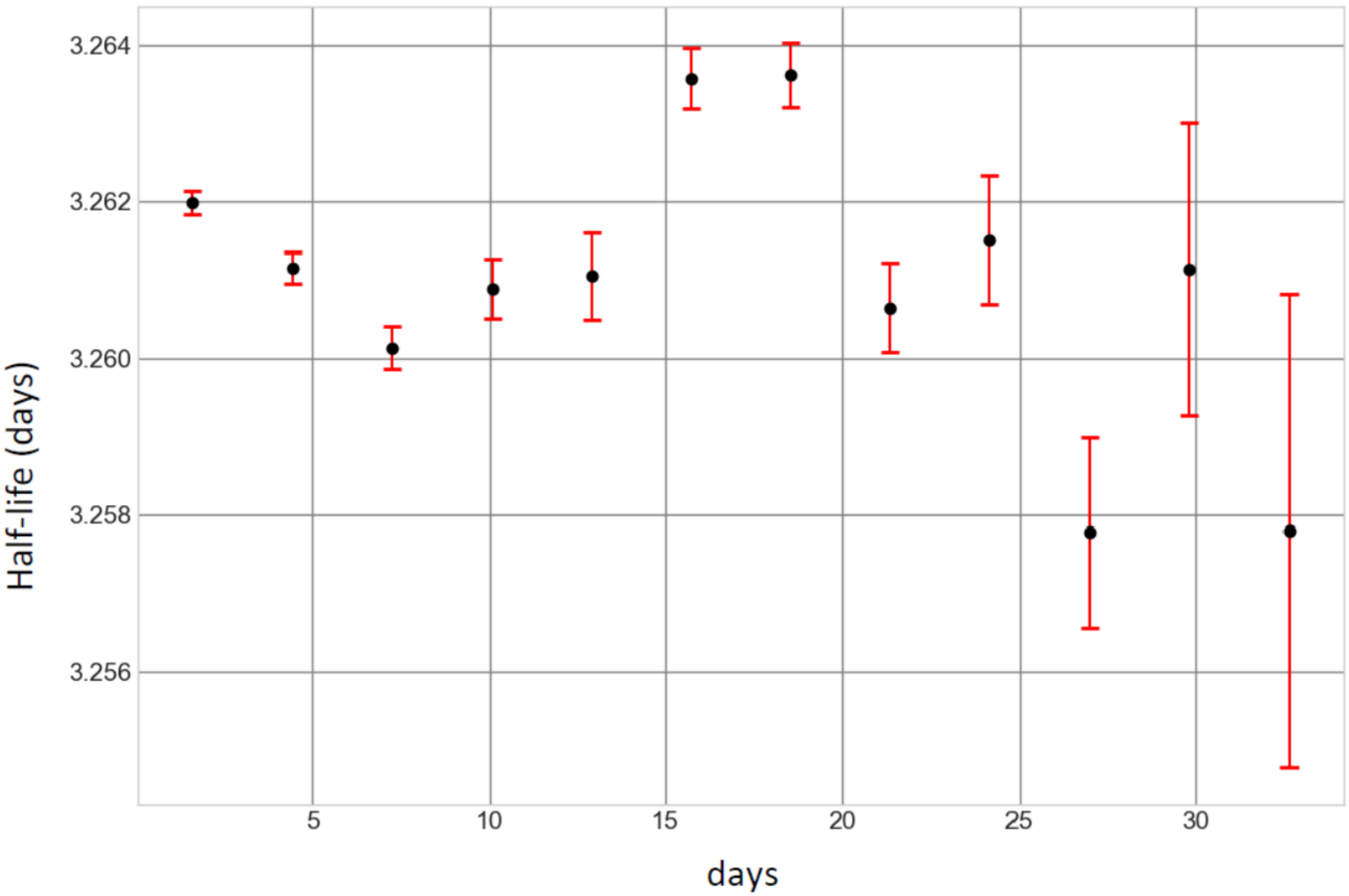



| Component | $u(T_{1/2})$ / % |
|---|---|
| Statistical | 0.02 |
| Time variation and linearity | 0.04 |
| Background correction | 0.04 |
| Relative uncertainty | 0.06 |

Evaluated value: 27.704 (4) d

Our measurement: 27.695 (17) d

# Half-life measurements: $^{67}$Ga




Evaluated value: 3.2613 (5) d

Our measurement: 3.2614 (5) d

# Outlook and conclusions

**Successfully accomplished**

Absolute γ-ray emission intensity measurements

- Set-up of cryogenic radiometer *BOLUX*
- Absolute measurement of synchrotron photon flux intensities
- Determination of the intrinsic efficiency of a HPGe in the energy range where the thickness of the dead layer is critical
- Extrapolation of the efficiency curve via Monte Carlo simulations to the whole energy range where the active thickness is not critical (3 - 55 keV)
- Measurement of $^{133}$Ba γ-ray emission intensity at 53 keV – improvement of the calibration curve for our HPGe

Half-life measurements

- Development of a dedicated measurement system, based on a well-type ionisation chamber
- Improvement of analysis tools based on Python and uncertainty budget estimation
- Measurement of the half-life for a number of radionuclides

LABORATOIRE NATIONAL DE MÉTROLOGIE ET D'ESSAIS

Laboratoire National Henri Becquerel

# Thank you for your attention

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