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The Sandwich spectrometer for ultra low-level γ-ray spectrometry

J.S. Elisabeth Wieslander [a,d], Mikael Hult [a,*], Joël Gasparro [a], Gerd Marissens [a], Marcin Misiaszek [b], Werner Preusse [a,c]

[a] EC-JRC-IRMM, Institute for Reference Materials and Measurements, Retieseweg 111, B-2440 Geel, Belgium
[b] M. Smoluchowski Institute of Physics, Jagiellonian University, ul. Reymonta 4, 30-059 Krakow, Poland
[c] Saxon State Laboratories for Environmental Radioactivity, Dresdner Street 183, D-09131 Chemnitz, Germany
[d] Department of Physics, P.O. Box 35 (YFL), FIN-40014 University of Jyväskylä, Finland

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ABSTRACT

The technical details and performance of the newly developed Sandwich spectrometer for ultra low-level γ-ray spectrometry are presented. The spectrometer, which consists of two HPGe detectors, an active muon shield and a lead/copper shield with a convenient and rapid opening mechanism, is located in an underground laboratory at a depth of 500 m water equivalent. The data is collected in list mode, which enables off-line data analysis to identify muon-induced events and possible Ge detector crosstalk due to Compton scattering. The background count-rate from 40 to 2700 keV normalised to the mass of the Ge crystals is 220 day^{-1} kg^{-1}.

1. Introduction

In the quest for lower detection limits in γ-ray spectrometry (Hult, 2007), a new spectrometer for ultra low-level gamma-ray spectrometry (ULGS) has been developed and characterised in an underground laboratory. Since the detection limit in γ-ray spectrometry is inversely proportional to the detection efficiency, it is of interest to design low-level detection systems with high efficiency. The detector presented here includes two Ge detectors facing each other between which the sample is placed: this approach effectively doubles the detection efficiency compared to using a single Ge detector. The new spectrometer design is intended for measurements of levels of activity in the mBq to μBq range in small samples. The high efficiency allows faster measurements, which is suitable for a wide range of applications.

2. Properties of the Sandwich spectrometer

The sandwich spectrometer is located in the underground laboratory HADES (Hult et al., 2006, 2003) at a depth of 500 m water equivalent and located at the premises of the Belgian nuclear Centre SCK·CEN in Mol, Belgium. Fig. 1 shows a side and a top view of the Sandwich spectrometer while the electronics are described in Fig. 2.

During the design process for the Sandwich spectrometer extra attention was paid to the following points that affect system performance:

- Use of radiopure materials for the detectors and shielding.
- Radon reduction by minimising the empty cavities inside the shield and by flushing with liquid nitrogen boil-off from the two dewars.
- Easy access for changing samples as well as installing/removing detectors.

2.1. HPGe detectors

The technical details of the two coaxial p-type HPGe detectors in Fig. 1, Ge-6 and Ge-7, are listed in Table 1. The samples are placed on Ge-6, which is always in a fixed position. Ge-7 can be moved vertically to accommodate bigger or smaller samples, which minimises not only the distance to the sample for both detectors but also the amount of air inside the measurement volume.

The relatively thick dead layer of Ge-6 in combination with the Cu endcap has the advantage of lower background and summing effects from low energy X-rays. The benefit of the Al endcap of Ge-7 in combination with the thin dead layer of its crystal is generally improved detection limits for γ-rays below 100 keV. Both detectors were well calibrated since they had been in use in the underground laboratory before they were installed in the Sandwich spectrometer, for which they were made available. Due to the multifunctional design of the lead shield, the Ge-detectors can easily be exchanged if necessary.

* Corresponding author. Tel.: +32 14 571 269; fax: +32 14 584 273.
E-mail addresses: elisabeth.wieslander@gmail.com (J.S. Elisabeth Wieslander), mikael.hult@ec.europa.eu (M. Hult).

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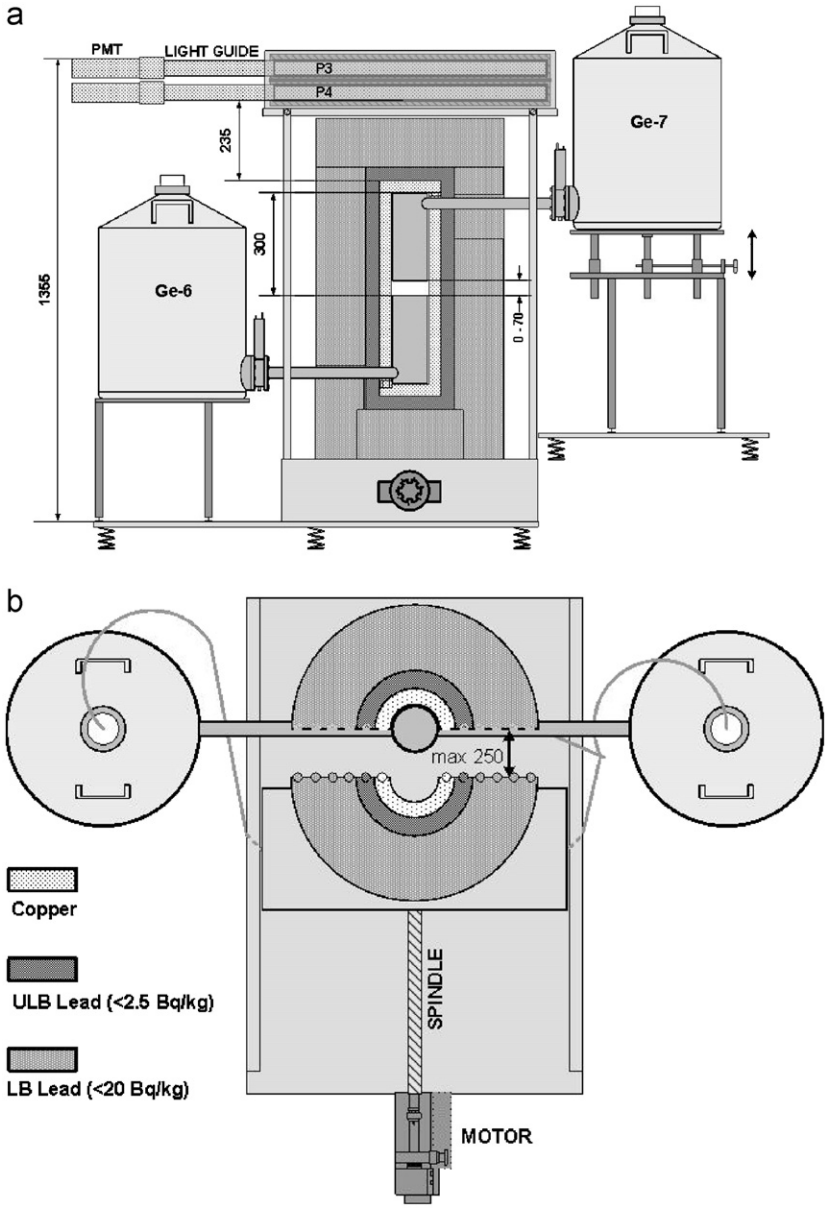

Fig. 1. The Sandwich spectrometer set-up including dimensions: (a) side view and (b) top view.

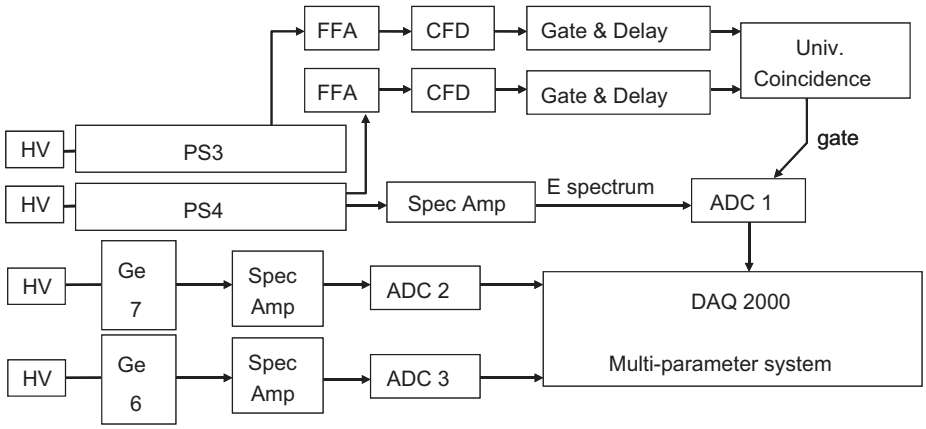

Fig. 2. The Sandwich spectrometer's electronics set-up showing how the two plastic scintillators, PS3 and PS4, and the two HPGe detectors, Ge-6 and Ge-7, are connected to the DAQ2000 multi-parameter system.