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Comprehensive radioassays of samples using the PANDA device

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ABSTRACT

The PANDA (Particles And Non-Destructive Analysis) device is a measuring system developed for non-destructive analysis of samples for safety, security and safeguards. It consists of two complementary measurement positions. The position sensitive alpha–gamma coincidence setup of PANDA has been updated with a pile-up rejection circuit. This article demonstrates, using a ^{241}Am source, that this circuit can be used to identify gamma-ray sum peaks in the spectra. The second measurement position reported here hosts a 10-mm^2 windowless silicon drift detector that detects electrons and X-rays with a very good energy resolution. An experimental value of 0.30 keV for full width at half maximum was obtained at 17.7 keV energy (Np X-rays). Conversion electron spectrometry, for example, provides an independent, complementary means to study actinides whose low energy transitions are often highly converted.

1. Introduction

A new measurement device called PANDA (Particles And Non-Destructive Analysis) was presented in the article by Turunen et al. [1]. Since then the PANDA device has been in both operational and research use, see for example Peräjärvi et al. [2].

In the present follow-up article we describe the upgrades made to PANDA. The improvements include a complementary measurement position equipped with a prototype silicon drift detector (SDD) that can be used to detect electrons and X-rays down to energies of 1 keV. The X-ray peaks reveal the properties of an element. The conversion electron transitions are isotope-specific allowing independent and complementary determination of isotope ratios, such as ^{239}Pu/^{240}Pu [3]. A study comparing alpha and conversion electron spectroscopy in isotopic analysis of plutonium was published by DeVol et al. [4]. The ability of PANDA to perform conversion electron spectrometry is significant since most of the low energy transitions of actinides are highly converted. The SDD can also be used to measure isotope-specific beta spectra that can reveal the presence of otherwise hard to detect nuclides such as ^{241}Pu. The PANDA setup is designed so that both measurement positions can be used to analyze the samples without breaking the vacuum.

Based on the measurement experiences gained with the position sensitive alpha–gamma coincidence setup of PANDA, a pile-up rejector circuit has now been introduced to it. The circuit allows experimental identification of the possible sum peaks in the alpha-gated gamma spectra. The performance and usefulness of this circuit along with the use of the second measurement position featuring the silicon drift detector are demonstrated with the measurements of a ^{241}Am sample. In addition to these upgrades, a few other practical technical improvements have been implemented and are presented here.

2. Improvements of PANDA

PANDA has now two measurement positions operating inside a vacuum chamber, see Fig. 1(a). The full operation of Measurement Position 1 (MP1) is described in [1]. MP1 hosts a double-sided silicon strip detector (DSSSD) and an HPGe detector (BEGe). The DSSSD is used for detecting alpha particles and the BEGe for gamma- and X-rays. The detectors are facing each other and the samples are placed between them. The data collection in MP1 is in event mode and each event is time stamped. This enables, for example, to create position sensitive alpha–gamma coincidence spectra.

2.1. Pile-up rejector circuit to Measurement Position 1

The detectors in the MP1 of PANDA are usually 8 mm apart (from the end cap of the HPGe to the front surface of the DSSSD). The source-to-detector distance is typically 3 to 5 mm. The HPGe measurement geometry is made as tight as possible in order to achieve good counting statistics since the activity of the samples is often low. Due to this close measurement geometry summing of multiple events are registered by the HPGe detector. When an X-ray and a gamma-ray, or two X- or two gamma-rays, hit the

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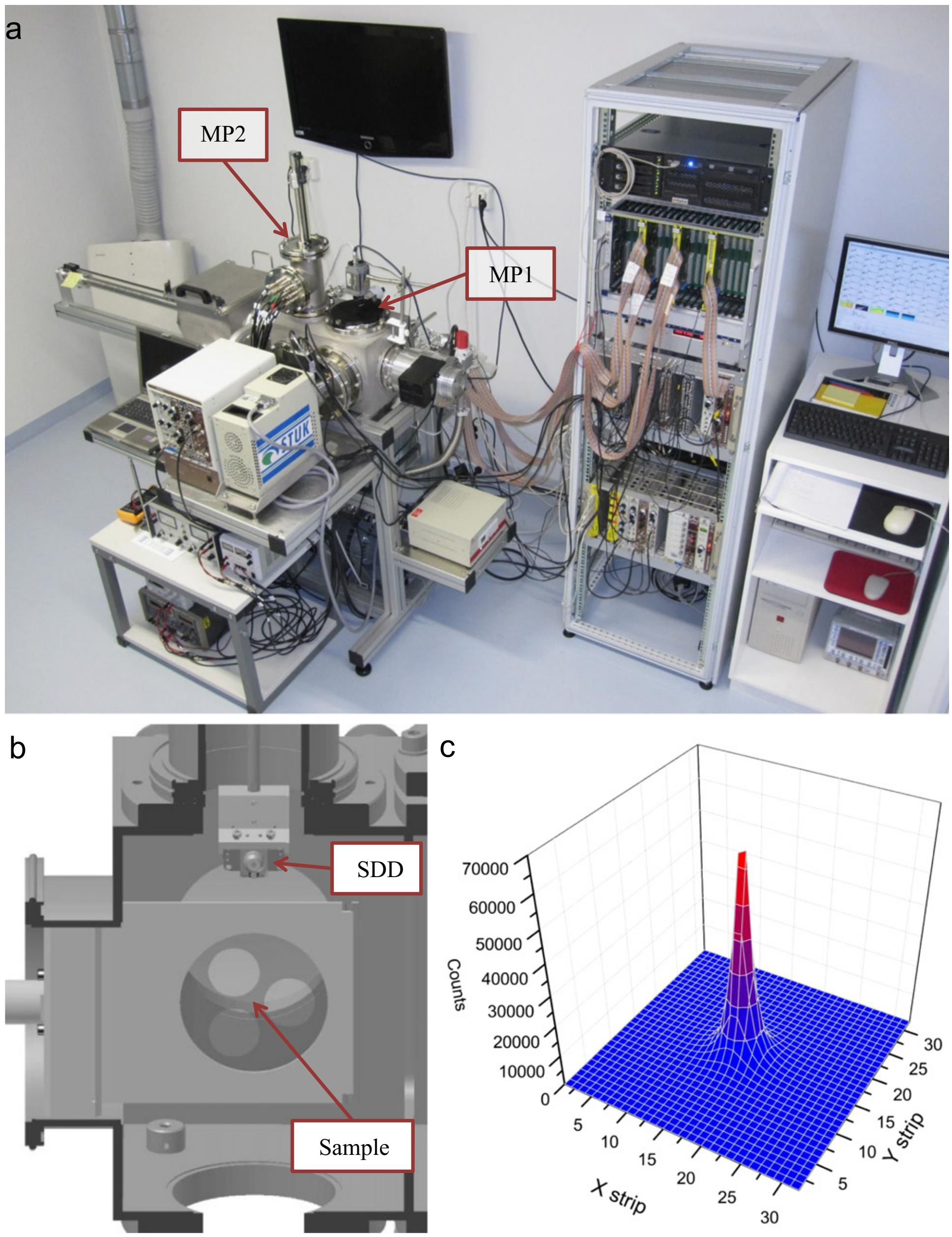

Fig. 1. Upgraded PANDA setup. (a) Photograph of the setup (b) Technical drawing showing MP2. The samples are transported between the measurement positions using a horizontally moving linear feedthrough and the SDD detector is moved with a vertically moving linear feedthrough. (c) Alpha particle hitmap of a ^{241}Am sample measured using the position sensitive DSSSD in MP1. The hitmap information can be used to set the interesting part of the sample to directly face the SDD.

detector almost simultaneously, the detector sees them as one single event with amplitude that sums the two single events. Sum peaks caused by these events are highly unwanted, especially in the case of alpha-gated gamma spectra where the background can otherwise be very close to zero.

As shown in Turunen et al. [5] a large part of the γ–X sum peaks can be removed from the spectra by placing a Ti foil between the HPGe detector and the sample. However, this approach also removes the possibility to use the X-rays in the analysis. Of course measurements with and without the Ti foil could be made but this would double the overall time required for the measurements. The signal processing of PANDA's MP1 was modified to be able to identify the unwanted sum peaks experimentally. A model 572 amplifier from Ortec, USA, was adopted to the signal processing of the HPGe detector. The 572 has a pile-up rejector circuit that gives an inhibit signal output when the energy signal is composed of multiple events. The energy signal of the BEGe detector was directed to the 572 amplifier input. Three outputs were taken: the amplified energy signal, a CRM (count rate meter) signal and an inhibit signal. The amplified energy signal produces the standard gamma-ray spectrum. The CRM output was used in the trigger logic since it gives a logic pulse each time the input signal exceeds the baseline restorer discriminator threshold. The inhibit output provides a pulse when the internal pile-up rejection logic detects a distortion of the input signal due to pile-up. Just like the standard energy signal, the inhibit output was recorded as a parameter with the MP1's data acquisition system. Since the data in the MP1 are collected in event mode, these inhibit signals can be used as an extra condition while gating the BEGe data. As an example, alpha-gated gamma-ray spectra of only those events that were registered together with the pile-up rejector signal can be produced.