Method of Setting Optimal Operating Voltage for Radiation Detectors contains thin Plastic Scintillators

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Abstract

In this paper we discuss the method of setting the optimal operating voltage on the photomultipliers of radiation detectors containing thin plastic scintillators. The ionizing radiation on the thin plastic scintillators is not fully absorbed and therefore it is not possible to determine the position of the Compton edge. We developed a simple method for this purpose and carried out tests with newly developed smart frisking probe. The results are presented.

Characteristics of the Plastic Scintillator

The plastic scintillators coated with the ZnS(Ag) layer thick enough can stop incident alpha particles while allowing the low energy beta radiation to pass, e.g., C-14. We used of 0.25 mm thick plastic scintillator type EJ-444 from Eljen Technology. Parameters of the plastic scintillator are stated in Tab. 1

Properties	EJ-212	ZnS(Ag)
Light Output (% Anthracene)	65	300
The wavelength of Maximum Emission (nm)	423	450
Decay Time (ns)	2.4	200
Density (mg·cm^{-2})	1023	-
Phosphor Density (mg·cm^{-2})	-	3.25 ± 0.25

Table 1: Parameters of the plastic scintillator coated ZnS(Ag) layer.

Method of the Setting Optimal Operating Voltage

The process of the high voltage adjustment contains plateau measurement and calculation of the optimal working voltage.
Radionuclide of ^{241}Am has been used for plateau measurement. Derivation of the alpha plateau curve we find inflection point corresponding to high voltage HV_1, see Fig. 1 and low level discrimination LLD_1. At the end of the plateau curve we will choose LLD_2 parametr, see Fig. 1
Operating high voltage HV_2 for radiation detector we can calculated according to following formula:

$$HV_2 = HV_1 \cdot \left(\frac{LLD_2}{LLD_1}\right)^{\frac{1}{\alpha \cdot N_{dyn}}}, \quad (1)$$

HV_1 - High voltage corresponds with inflection point;
LLD_1 - level of comparator corresponds with HV_1;
LLD_2 - level of comparator corresponds with HV_2;
α - dynode voltage amplification coefficient;
N_{dyn} - number of PMT dynodes.

The 10 dynodes PMT with 0.82 voltage amplification coefficient has been used.

Experimental Setup

Prototype of alpha/beta smart radiation probe has been used for high voltage adjustment procedure, see Fig. 1. The mechanical construction of the probe is designed for maximum light collection from the surface of the detector. The body and handle of the radiation probe is made from aluminum.

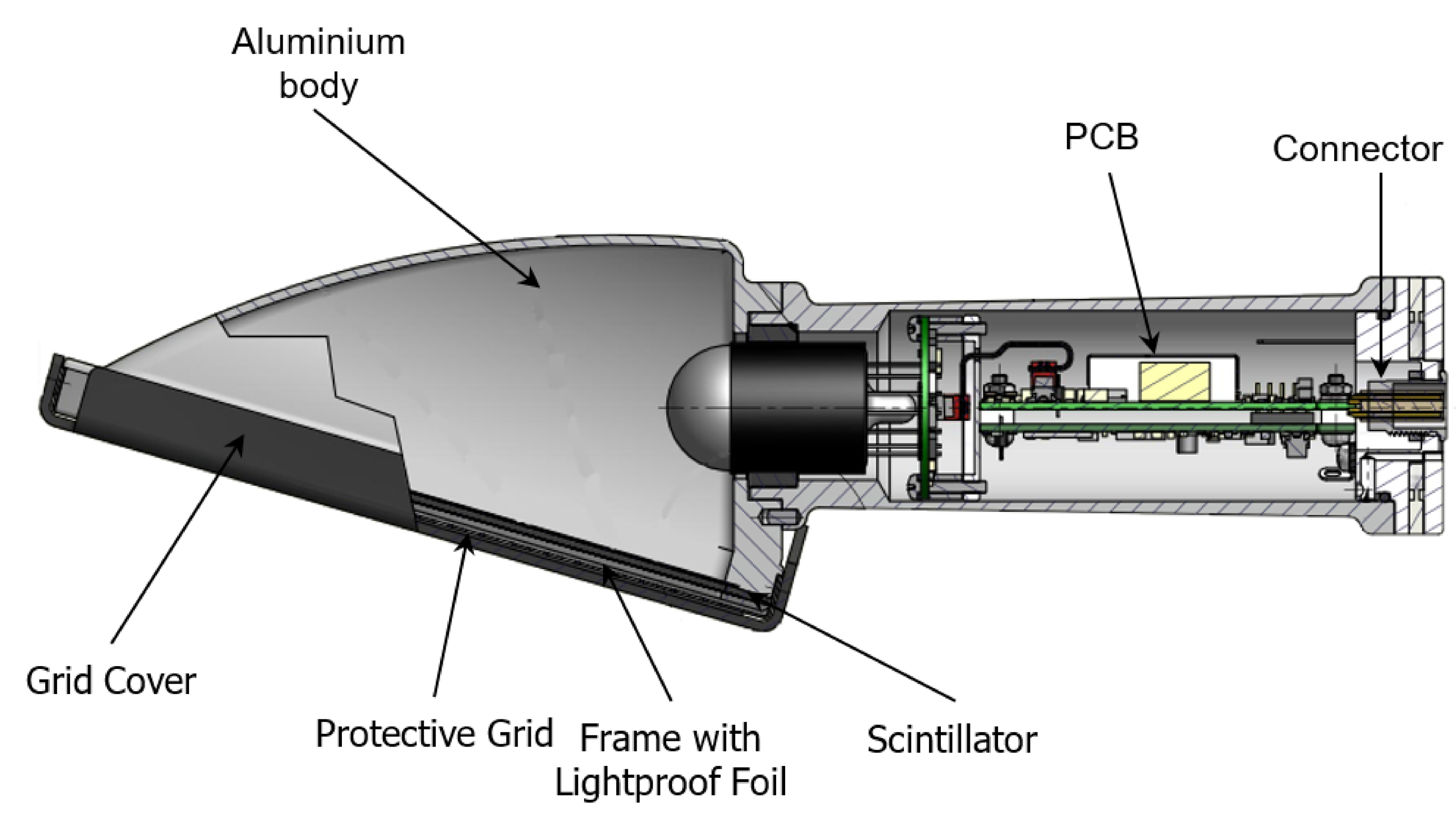

Fig. 1: Alpha/Beta radiation probe.

The plastic scintillator thickness of 0.25 mm with ZnS(Ag) layer was used. Separation of alpha/beta particles is based on pulse length and pulse amplitude. When the alpha channel is activated, the beta channel is blocked. The handle of probe contains PMT, electronics and connector for communication and power supply. The PMT is connected to an active voltage divider.

Results and discussion

The plateau has been measured with the following parameters LLD_1= 40 mV and counting time of 60 s. High volatage in the range of (290 - 550) V with a step of 10 V has been changed and detector count rate was measured. The sensitivity R of of the detector in (cps/Bq) was calculated according to the following formula:

$$R = \frac{n_{net}}{A} = \frac{n_s - n_{bg}}{A_{ref} \cdot 2^{\frac{(t_{end} - t_{start})}{T_{1/2}}}}, \quad (2)$$

n_{net} - net count rate (cps);
A - activity to date of measurement (Bq);
A_{ref} - reference activity (Bq);
t_{start} - date and time of measurement start [yy-mm-dd];
t_{end} - date and time of measurement end [yy-mm-dd];
$T_{1/2}$ - half-life (days).

Parameters of the sensitivity, high voltage, inflection point and low level discrimination are depicted in the graph, see Fig. 2

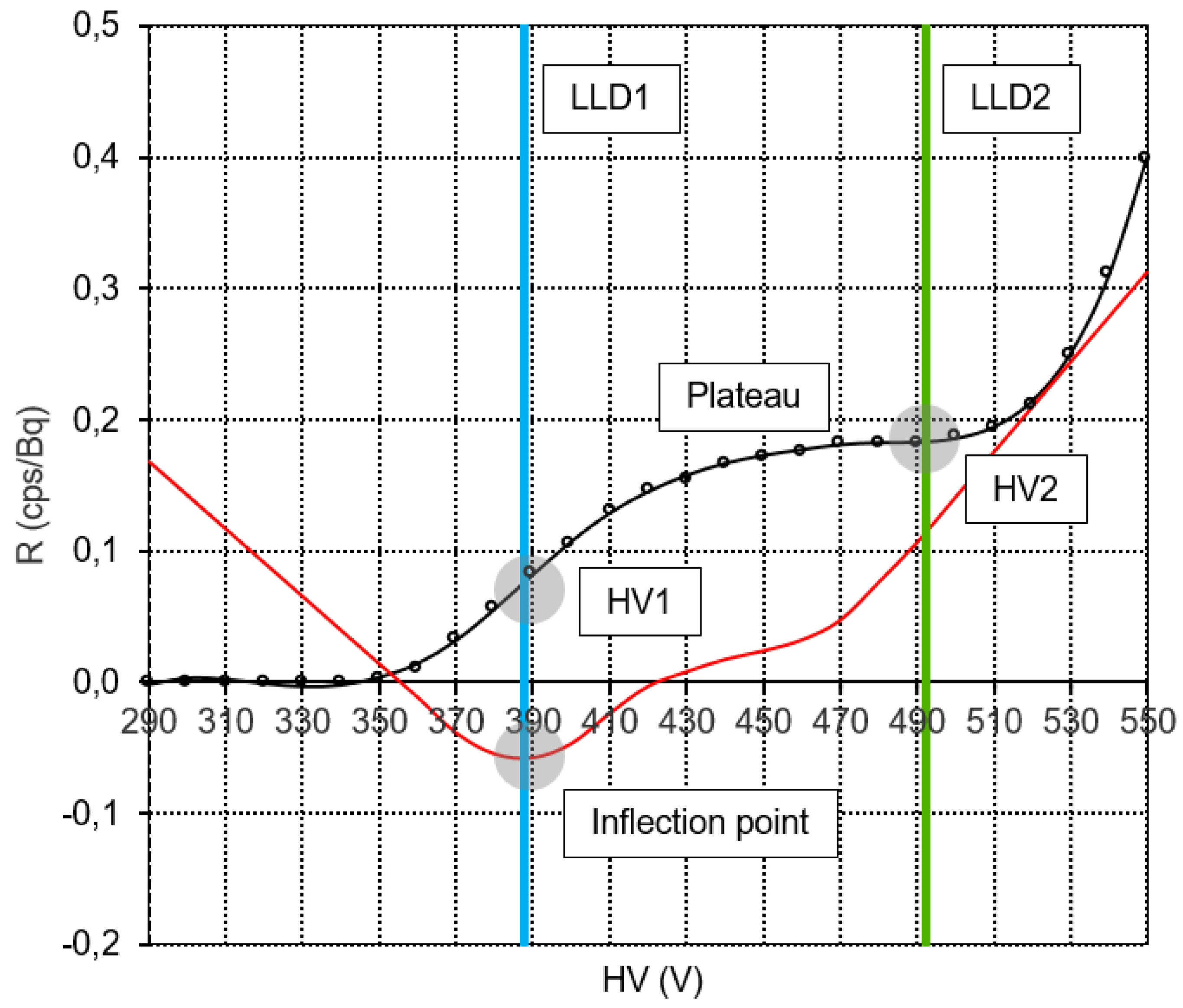

Fig. 2: Plateau of alpha/beta radiation probe with radionuclide of ^{241}Am.

Optimal working voltage on the radiation probe has been established, see Eqn. 1. The radiation probe working properly, i.e. current through the photomultiplier < 1μA, radiation detector reach a maximum of sensitivity for alpha and beta radionuclides and values of the detector are stable in time.

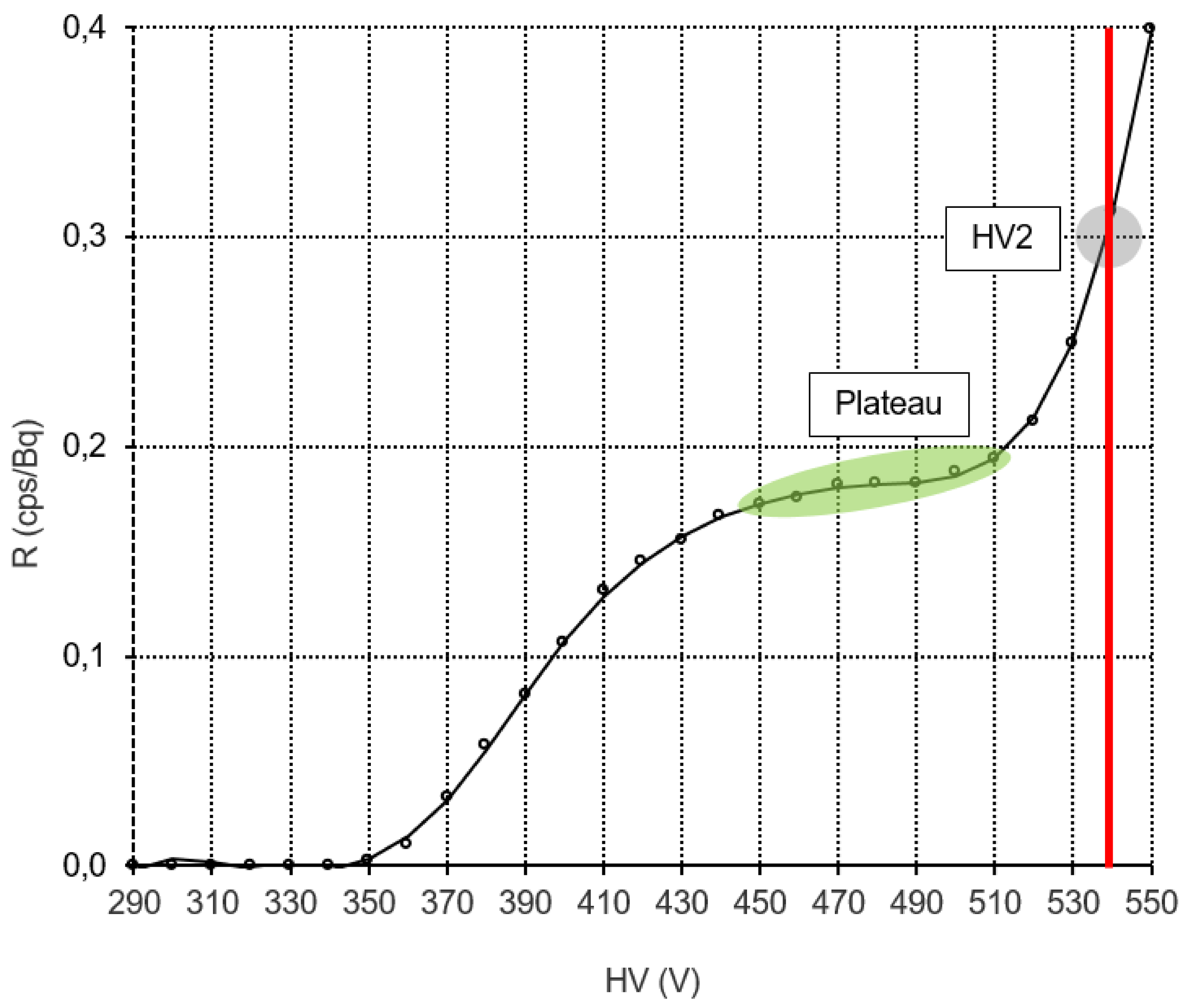

Fig. 3: Example of the non-stable setting up of radiation probe.

If you set up the high voltage without knowing a plateau measurement, high current can flow through the photomultiplier of the detector. This causes drift, instability and destruction of the photomultiplier, see Fig. 3

Conclusion

A newly developed alpha/beta radiation probe has been adjusted and tested according to the presented method. Using this method we are able to guarantee the same energy calibration in the range of energies 150 keV to 3 MeV for non-spectrometric plastic scintillators. Sensitivity parameters have been verified by Monte Carlo (MC) simulations, see Tab. 2

Radionuclide	MC sensitivity simulation (cps/Bq)	MC efficiency simulation (%)	Sensitivity meas. (cps/Bq)	Efficiency meas. (%)
^{14}C	0.09	15	0.08	13
^{36}Cl	0.32	51	0.33	51
^{60}Co	0.21	33	0.19	30
^{90}Sr/Y	0.35	51	0.34	50
^{137}Cs	0.32	43	0.32	43
^{204}Tl	0.29	44	0.27	41
^{239}Pu	0.20	40	0.19	38
^{241}Am	0.22	44	0.21	44

Table 2: Comparison of the Monte Carlo simulations with practical measurement.

There is a good agreement between measurements and simulations (max. ± 15 %). This method can be used for all types of radiation detectors contains alpha/beta sensitive plastic scintillators.

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