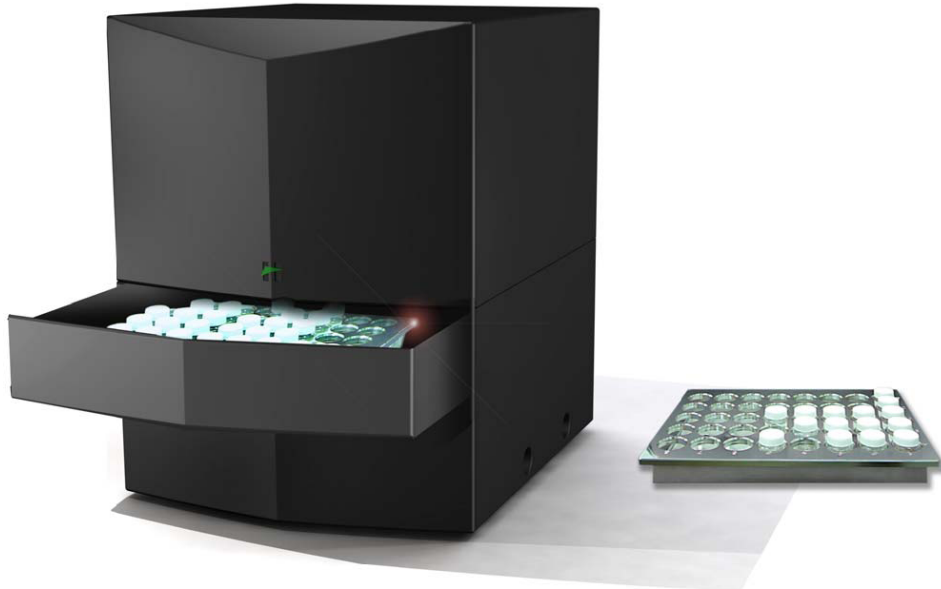




Uncertainty of a result of tritium activity measurement carried out with counter SL-300 at simplified and conventional processing of measurement results



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Simplified model of LS counter SL-300 (ICRM-2009)

Three photomultipliers, disposed at 120° from each other

The double and triple coincidence circuits with resolving time of 35 ns

Two outputs:

A ratio double coincidence to triple coincidence count rate –TDCR

A logical sum of the double coincidences count rate – D

The detection efficiency is taken to be equal to the TDCR parameter

$$Eff(D) = TDCR = \frac{N_T}{N_D}$$

Improved LS counter SL-300 model

The electronic coincidence unit has five outputs:

- three double coincidences (AB, BC and AC)**
- triple coincidences (T)**
- a logical sum of the double coincidences, including the triple ones (AB+BC+AC=D)**

Possibility of obtaining spectrum of each photomultiplier

Possibility of changing of the discriminator level

The discrimination level is the same for all three photomultipliers

Adjustment of threshold for each PMT has not been provided in this modification

MAIN TASKS

➤ *To evaluate the uncertainty budget of the H-3 activity measurement result obtained by simplified version of TDCR-method*

➤ *To check up the applicability of the TDCR method in measuring H-3 activity*

Sample preparation

Radionuclide	Standardization method	Activity concentration certified value, Bq/g	Expanded uncertainty (k=2), %
^3H	Calorimeter/ Precise dilution	$8.523 \cdot 10^3$	1

Sample composition

10 ml: Ultima Gold^{AB},
200 mg standardized solution of tritiated water

➤ **Quantity of calibration solution diluted in LS is accurately determined with a pycnometer and Mettler AE250 microbalance**

Sources of uncertainty

➤ **Instrumental correction for a dead time**

➤ **Measurement variability**

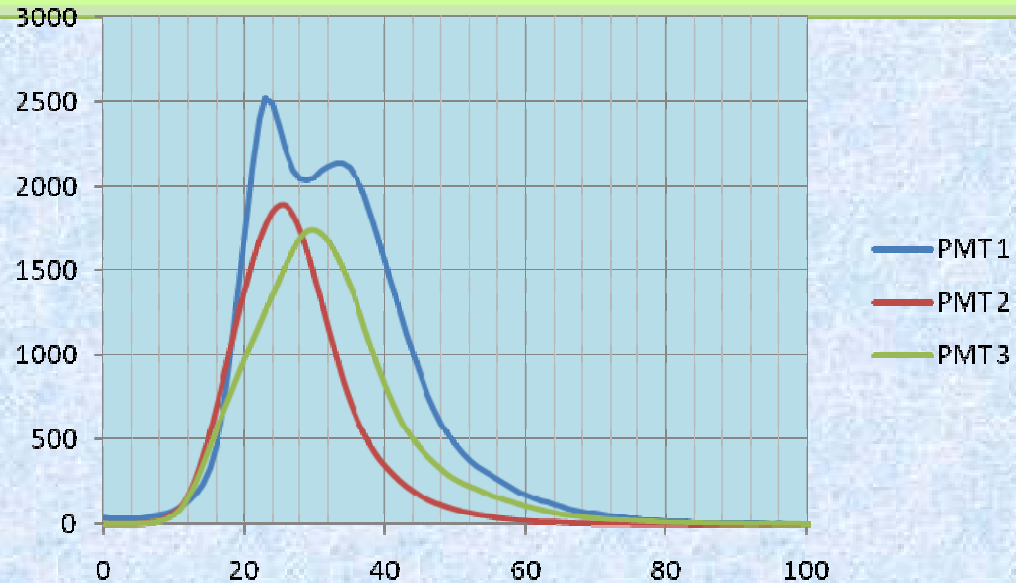
➤ **Discrimination level**

➤ **Degree of quenching of the sample**

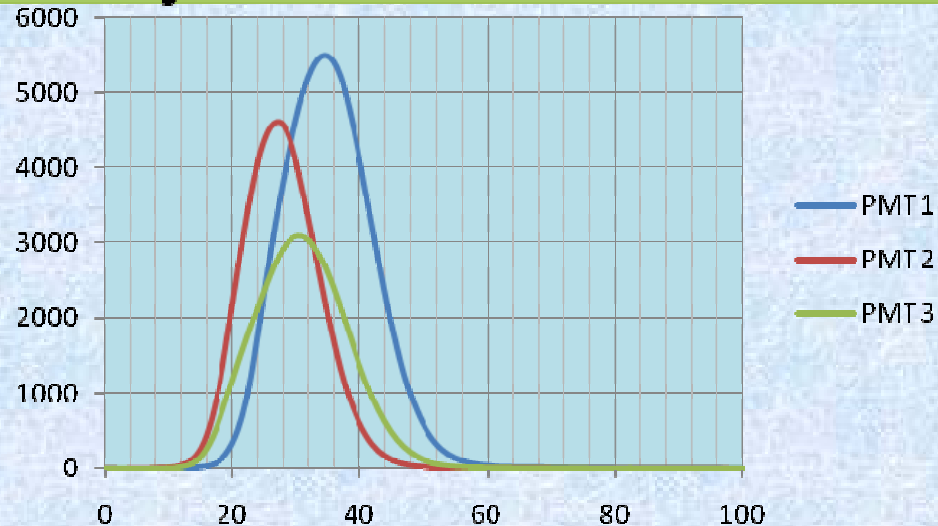
➤ **Volume of the solution mixed with LS**

The photomultiplier high voltage settings recommended by the producer

H-3 spectrum obtained using a strongly quenched source (TDCR=0.11) with the help of a red scotch for simulating single electron pulses. Recommended voltage adjustment at a minimally possible threshold



After adjustment of the threshold recommended



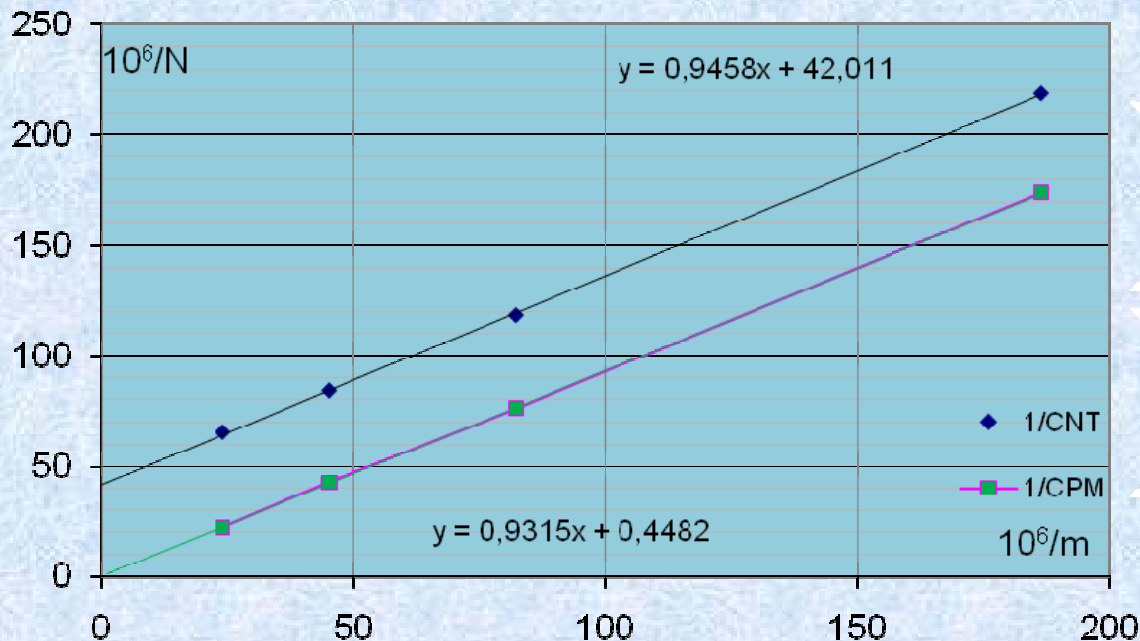
Dead time/live time

4 sources of Am-241: 5370 Bq, 12180 Bq, 22000Bq, 41620Bq

$$\frac{1}{N_i} = \tau + \frac{1}{m_i} \cdot \text{const}$$

N_i – is the counting rate from the i -th source according to instrument indications without taking into account the dead time, s^{-1}

m_i is the i -th source mass, mg

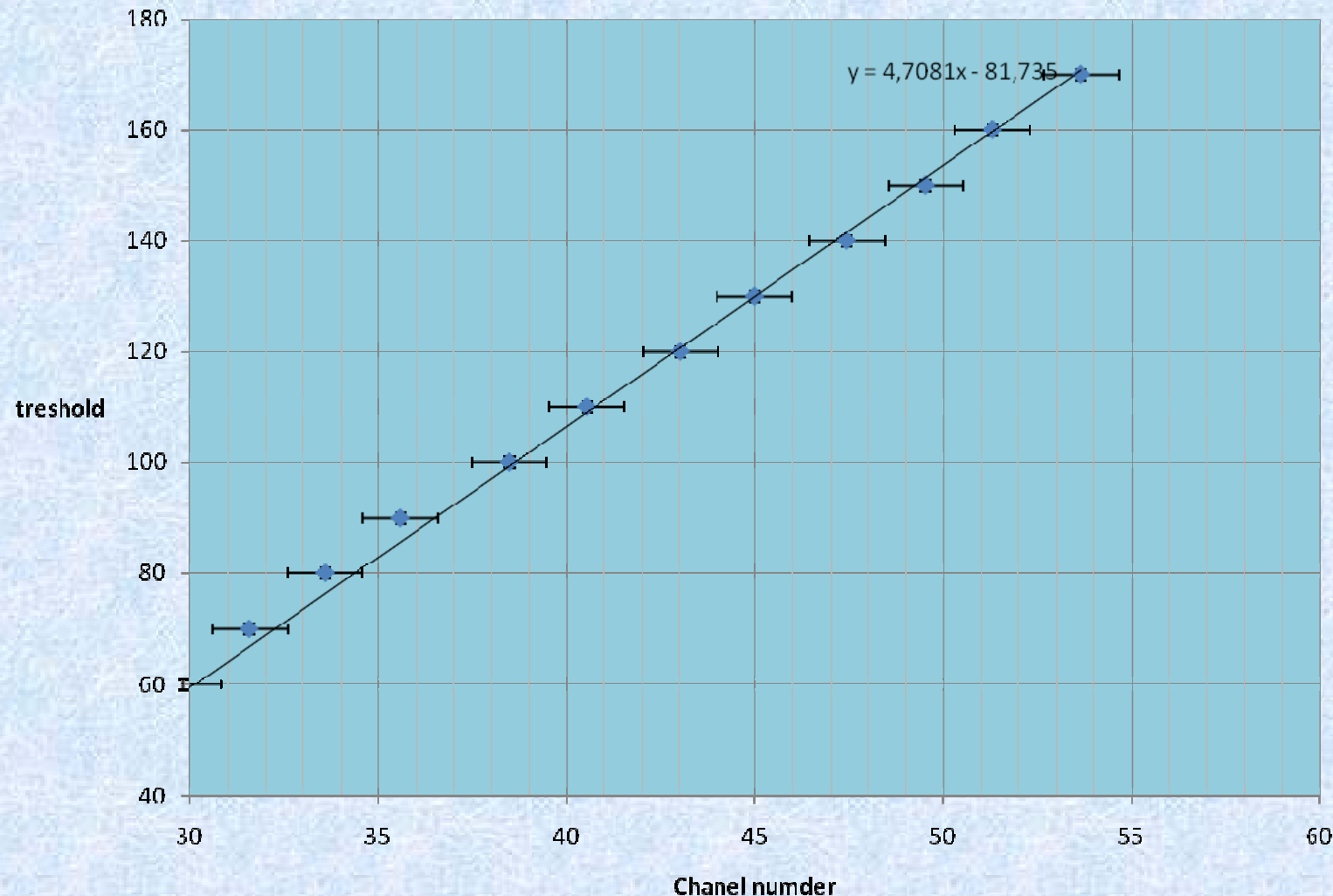


The dead time/live time uncertainty – 0.45 μs

$$\tau = (42 \pm 1) \mu s$$

The contribution to the result uncertainty at the counting rate of $2000 s^{-1}$ is equal to 0,09%

The dependence of the relationship between a threshold value and channel number

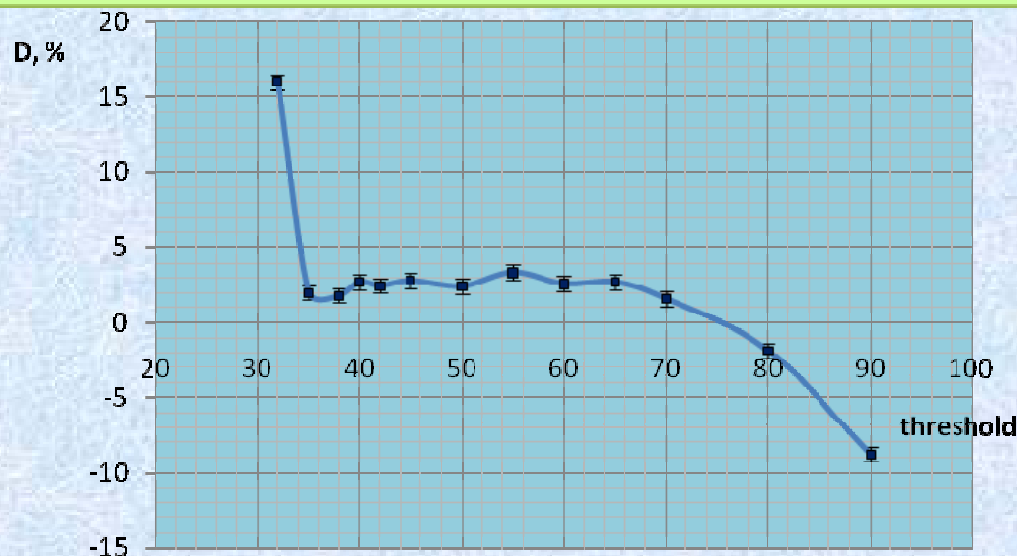


In this modification there was not provided for any identification of the channel number for the threshold value adjusted

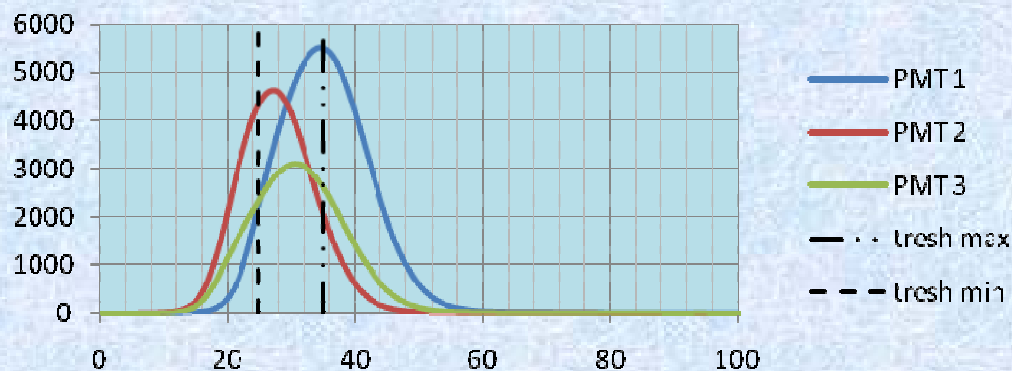
Contribution to the uncertainty due to the adjustment of the threshold

3 samples of H-3: 1738 Bq, 1614 Bq, 1865Bq

$$D = \frac{A_{SL} - A_{ref}}{A_{ref}}$$



Contribution to the uncertainty due to the adjustment of the threshold within the range from the 26-th channel to the 31-st channel (vertical straight lines) has been evaluated as the standard deviation of a separate measurement and is equal to 0.46%



Degree of quenching of the sample

**The measurements of the samples
with various quenching values (the TDCR from 0.35 to 0.56).
Contribution to the uncertainty of the result is equal to 0.9 %.**

Volume of the radioactive solution mixed in LS

**The measurements of the samples into which various quantities of
distilled water were added (from 2 ml to 10 ml).
Contribution to the result uncertainty is equal to 1.5 %**

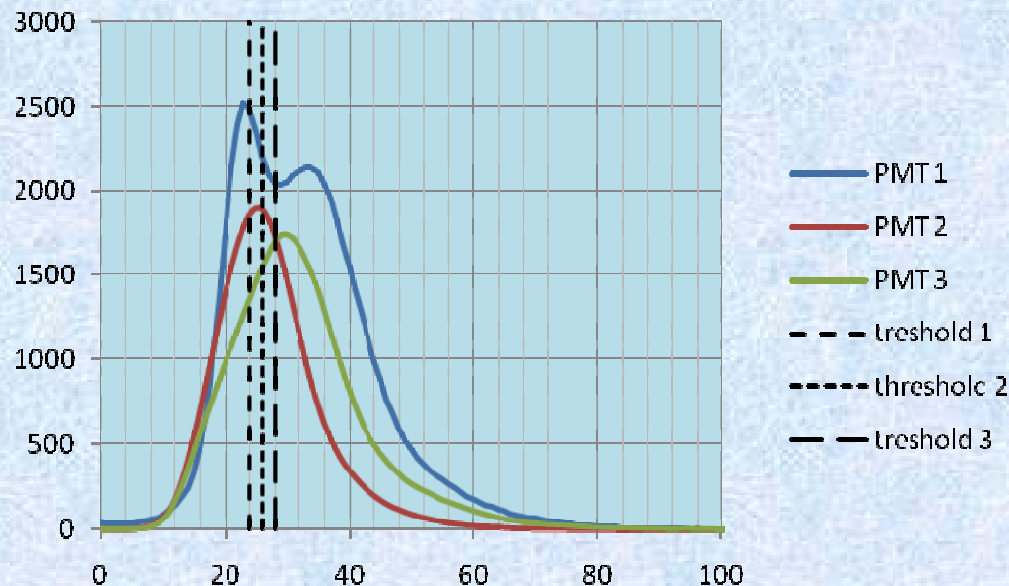
The uncertainty budget

Uncertainty components	Type A, %	Type B, %
dead time/live time, u_d		0.09
measurement variability, u_v	0.1	
threshold, u_{thr}		0.46
quenching		0.9
solution volume		1.5
counting statistic, u_{st}	0.1	
mass determination, u_m		0.06
reference solution, u_{ref}		0.5
Combined uncertainty, u_A		1.9

Expanded uncertainty ($k=2$) of H-3 activity is equal to 3.6%.

Result of normal statistical test $E_n=0.6$ shows that the deviation $\delta = 2,6\%$ of the value measured by simplified method from the reference activity is insignificant

Verification of the applicability of the classic TDCR –method for measuring the specific activity of tritium water



3 values of discriminator level

3 sources of H-3

4 values of efficiency

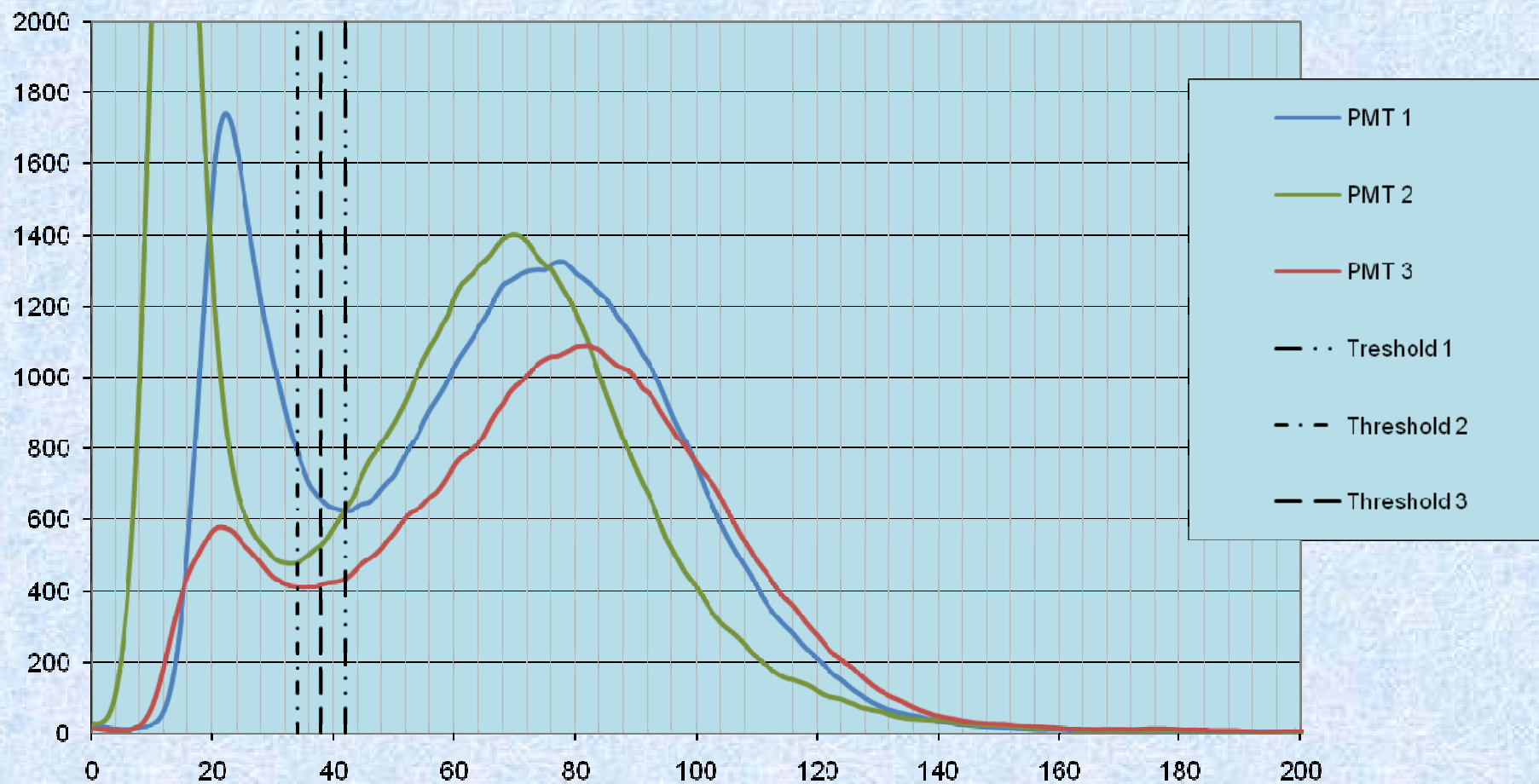
t=100 s, 3 repeats

$$D = \frac{A_{SL} - A_{ref}}{A_{ref}}$$

$$E_N = \frac{|A_{SL} - A_{ref}|}{2\sqrt{u_{A_{SL}}^2 + u_{A_{ref}}^2}}$$

Threshold, channel number	A (TDCRB-02), kBq/g	u (TDCRB-02), %	A _{ref} , kBq/g	u, %	Deviation, D %	E _N , %
24	8.076	4.0	8.523	0.5	-5	0.6
26	8.054	1.8			-5	1.4
28	7.565	4.9			-11	1.1

The optimization of the photomultipliers mode



The resolving time of 35 ns recommended by the manufacturer was not changed during this test

The processing results (TDCRB-02 software) at PMT's mode optimized.

3 values of discriminator level

3 sources of H-3

4 values of efficiency

t=100 s, 3 repeats

Threshold, channel number	A (TDCRB-02), kBq/g	u (TDCRB-02), %	A_{ref} kBq/g	u, %	Deviation, %	E_N, %
34	8.120	1.5	8.523	0.5	-4.7	1.6
38	8.165	1.1			-4.2	1.8
42	8.166	2.4			-4.2	0.9

**Realization of the classic TDCR-method
on the basis of the SL-300 results in
a significant systematic deviation of 4 %**

Summary

The expanded uncertainty of the result obtained in measurements of the tritium water specific activity performed by the simplified TDCR-method with the help of the improved SL-300 model at the settings recommended by the producer is evaluated as 3.8 %

The realization of the classic TDCR-method using the modified SL-300 results in a systematic deviation equal to 4 % of the value measured from the standard one at the settings which are close as much as possible to those which are required for the TDCR-method

Conclusions

Further optimization of the measurement electronics and counting parameters is needed

Investigation of the dependence of results on coincidence resolving time value

THANK YOU FOR ATTENTION