Experimental study of the possibility of 3D localization of the compact gamma sources in soft tissues

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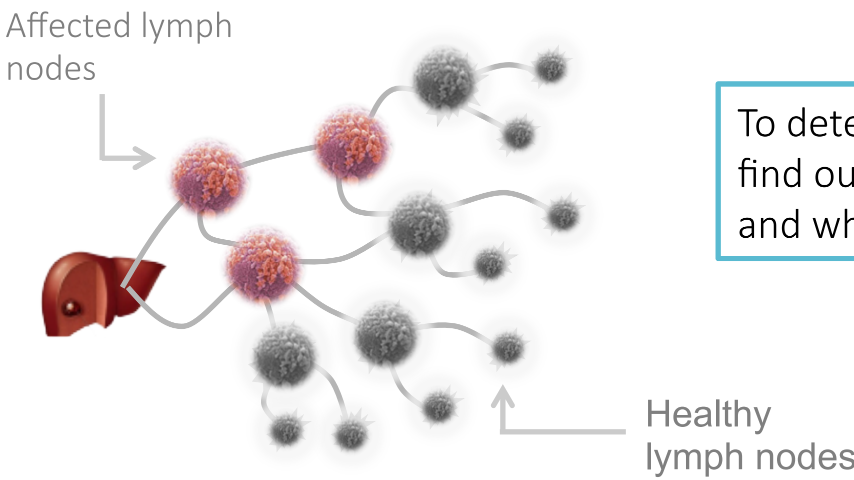
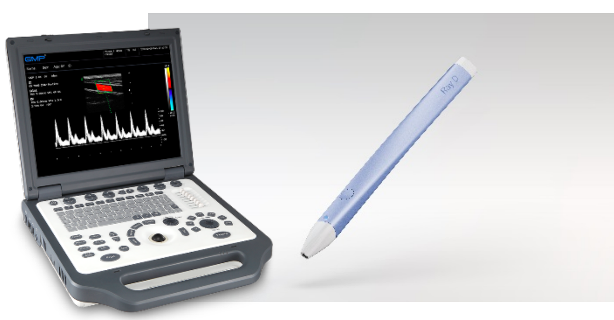
Medical gamma probe

Gamma probe is a handheld lightweight and compact gamma ray detector to be used for localization of gamma-radiation emitted by radionuclides such as ^{99m}Tc, ^{125}I, ^{111}In



To determine the extent of tumor spread it is necessary to find out which lymph nodes are affected by metastasis, and which are not

Radiotracers which emit gamma rays have an ability to accumulate in the areas of metastasis presence



Gamma probe detects gamma rays and determine the 2D projection of location of affected lymph nodes

Commercially available gamma probes can not determine depth of the lymph node placement in soft tissues

3D localization method

If a medical gamma source has two or more emission lines, it is possible to measure the intensities of these lines at the surface of the patient's body after passing through a layer of soft tissues

- **Narrow beam geometry:**

$$I = I_0 e^{-\mu x},$$

where: I **– the intensity of gamma rays after passing through the slab of material,**
I_0 **– the initial intensity,**
μ **– linear attenuation coefficient of the material,**
x **– thickness of the layer of the material**

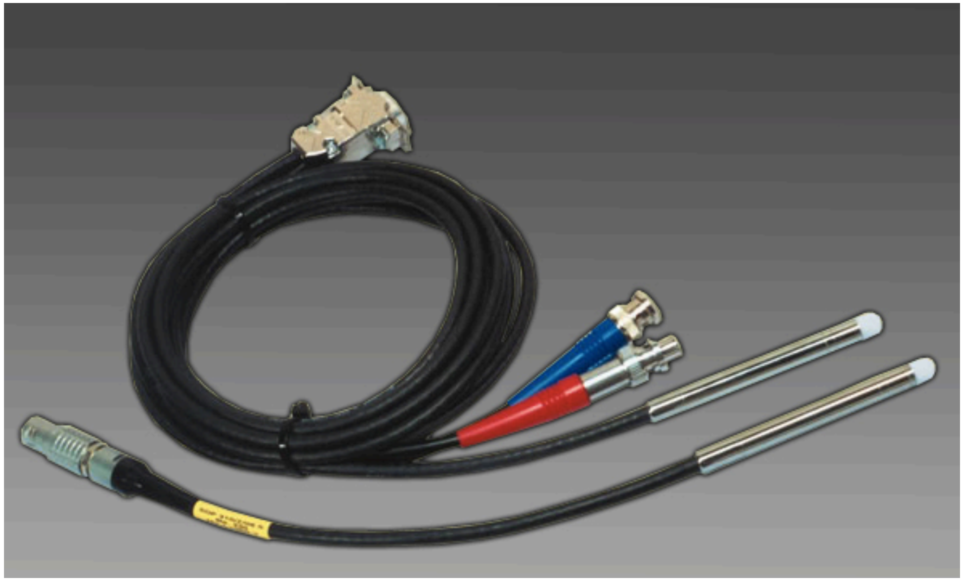
- **Wide beam geometry:**

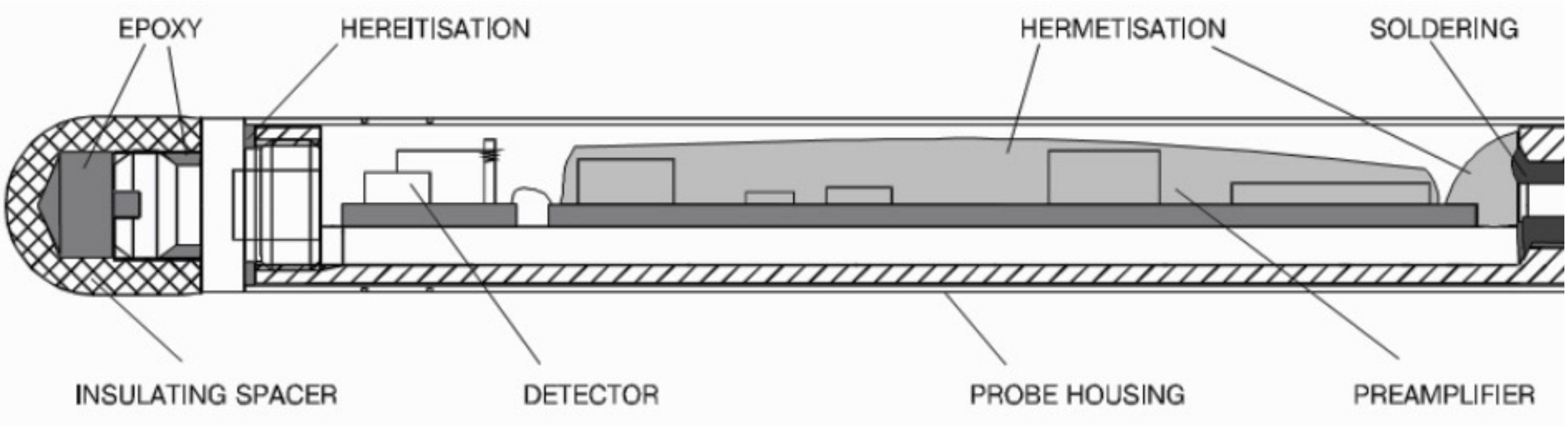
$$I_1/I_2 = \frac{I_0^1 e^{-\mu_1 x} B_1}{I_0^2 e^{-\mu_2 x} B_2} = I_0^1/I_0^2 \, e^{-(\mu_1 - \mu_2)x} B_{21},$$

where B_{21} **is the total buildup factor**

CZT gamma probe

- Semiconductor spectrometric gamma probe SDP310/Z/60(S) Standart, manufactured by Baltic Scientific Instruments, consists of a quasi-hemispherical CdZnTe crystal with a sensitive volume of 50÷60 mm^3
- Energy resolution (FWHM) is > 25 keV @ 662 keV





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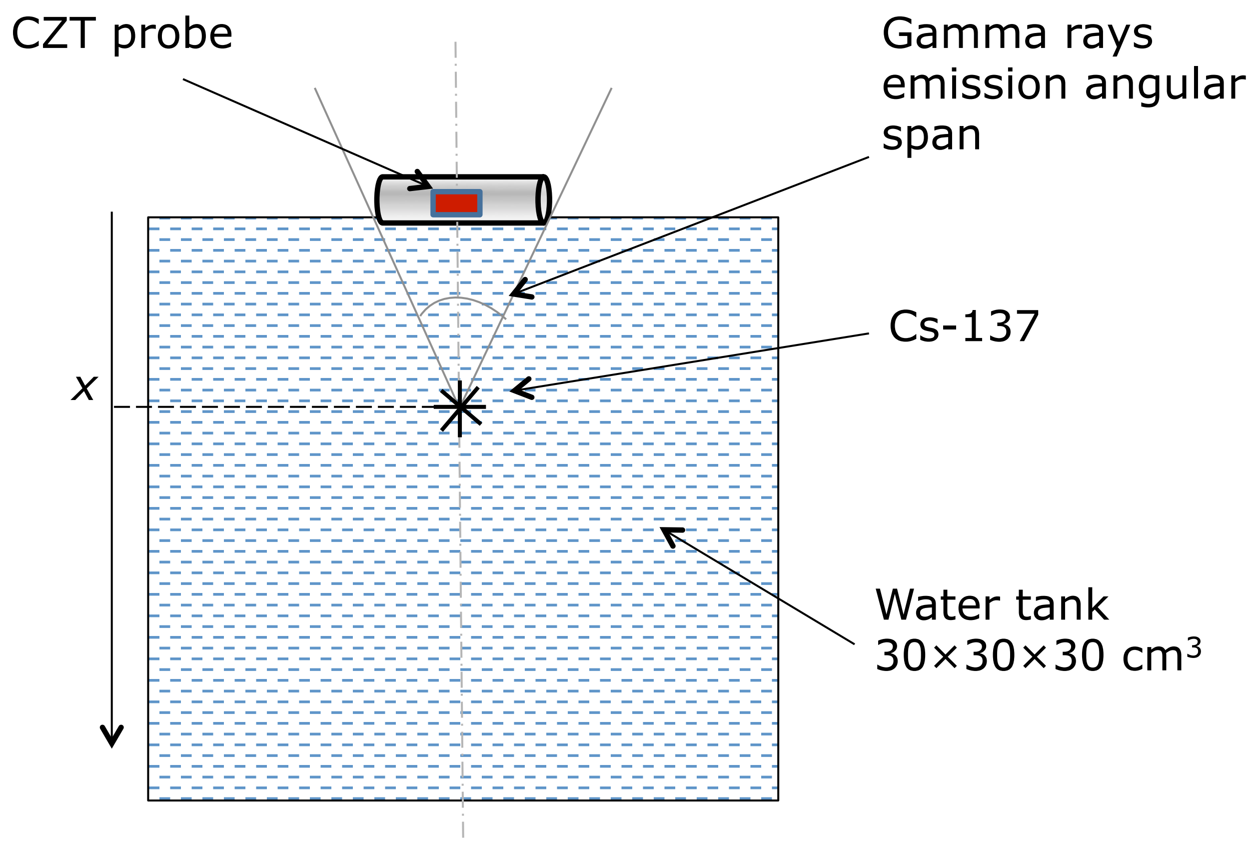
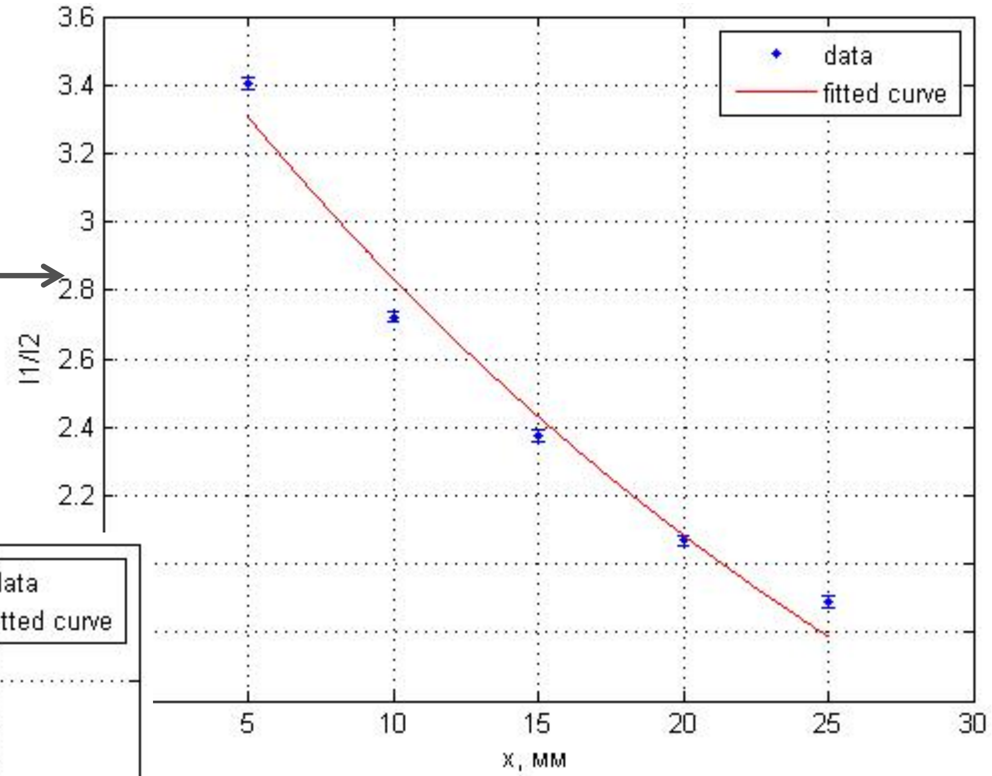
Monte-Carlo simulations

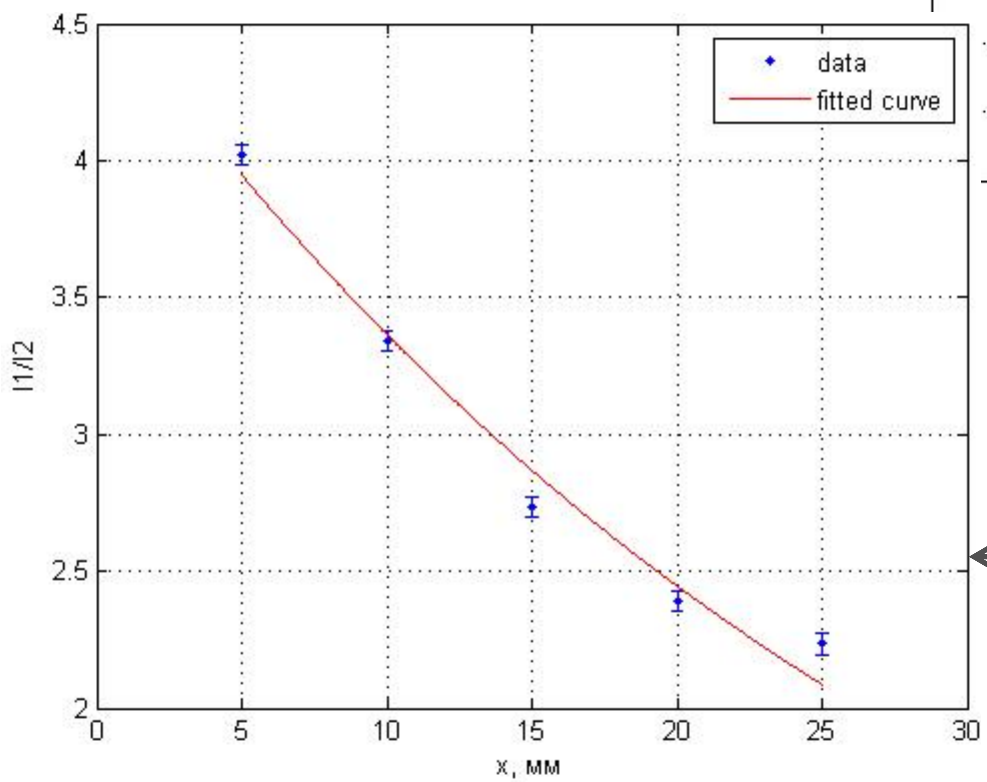


- geant4/Gate simulations of the narrow and wide beam geometry were carried out to obtain the expected I_1/I_2 dependences from the probe to source distance and to evaluate the buildup factor
- Cs-137 (662 keV 85%, 32 keV 6%) was placed in a water tank at the centerline of gamma probe at the increasing distances
- Resulting energy spectra at each distance were used to calculate areas of both photopeaks

Simulation results

Ratio of I_1 (32 keV emission line intensity) to I_2 (662 keV emission line intensity) vs depth of the source in water; **narrow** beam geometry

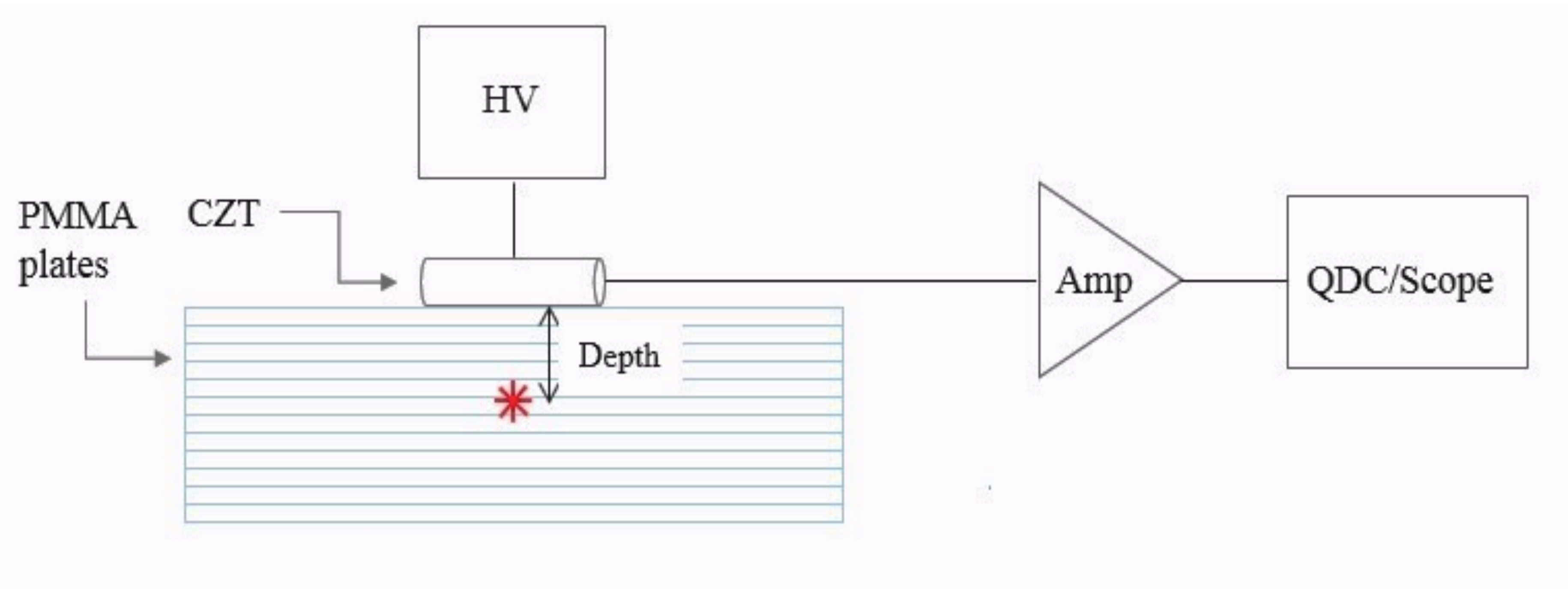




Ratio of I_1 (32 keV emission line intensity) to I_2 (662 keV emission line intensity) vs depth of the source in water; **wide** beam geometry

Experimental setup

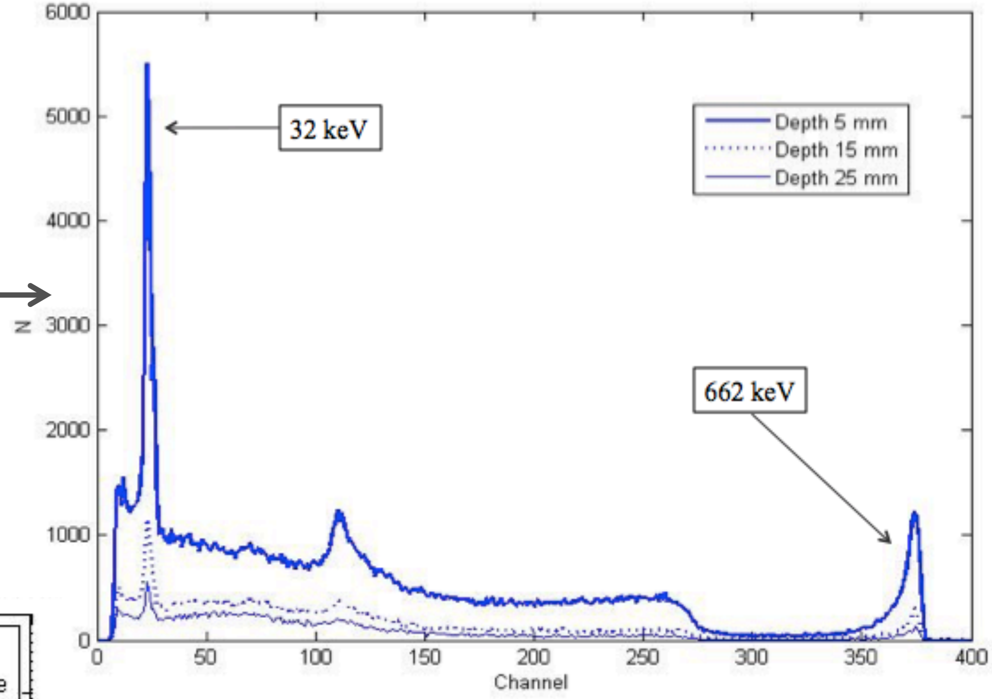
A set of polymethylmethacrylate (PMMA) plates with 1÷5 mm thickness was used as a phantom of human soft tissues. Point-like gamma source was placed between the plates at the increasing distances from the gamma probe. The probe was fixed on the top of the phantom, and the energy spectra were measured at different depths of gamma source

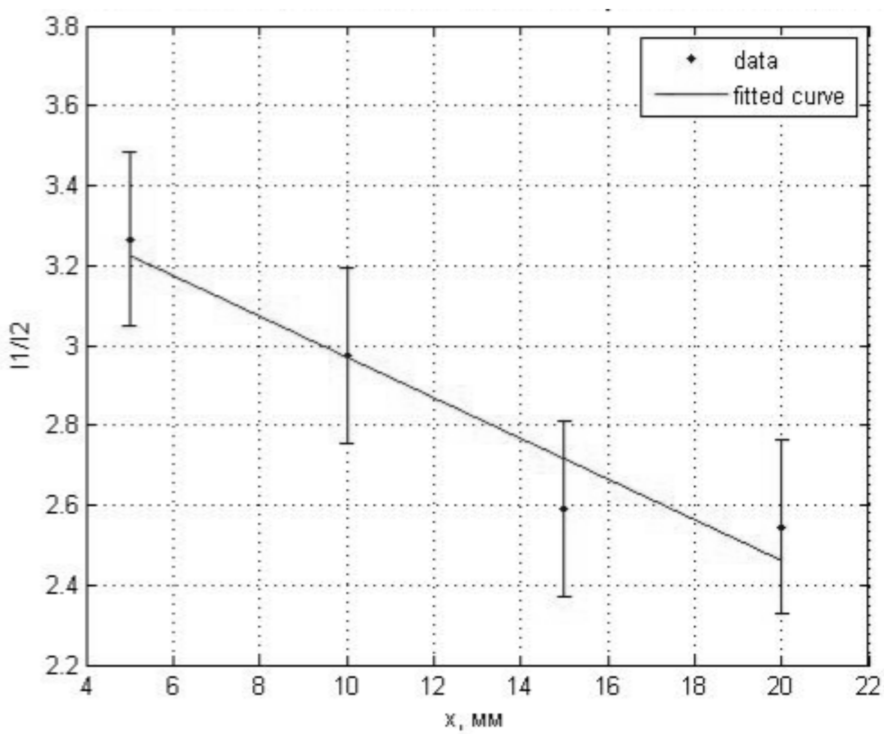


Detector (CZT) is biased through a preamplifier with +350V from a high voltage power supply (HV). Signal from the detector preamplifier is shaped and amplified with a spectrometric amplifier (Amp), and then passed to the input of Lecroy Waverunner oscilloscope, which can be used as a charge-to-digital converter (QDC/Scope).

Experimental results

Experimental energy spectra of ^{137}Cs at 5, 15, 25 mm PMMA layer thickness between the source and the CZT gamma probe





Ratio of 32 keV photopeak area to 662 keV photopeak area vs the thickness of PMMA layer

Conclusion

- Feasibility study of the implementation of the method of 3D localization of gamma sources in soft tissues is provided
- Experimental study with a point-like ^{137}Cs gamma source placed in a PMMA phantom and a room-temperature semiconductor gamma probe were carried out to obtain the dependence between the ratio of a 32 keV emission line intensity to the one of 662 keV and the PMMA layer thickness.
- Experimental results showed that the dependence is linear at first approximation, and can be used for the detecting system calibration. However, a relatively low activity of the gamma source did not allow to determine the calibrating coefficients with the satisfactory accuracy.

THANK YOU!