CONCEPTION OF PIEZOELECTRIC ACCELERATOR

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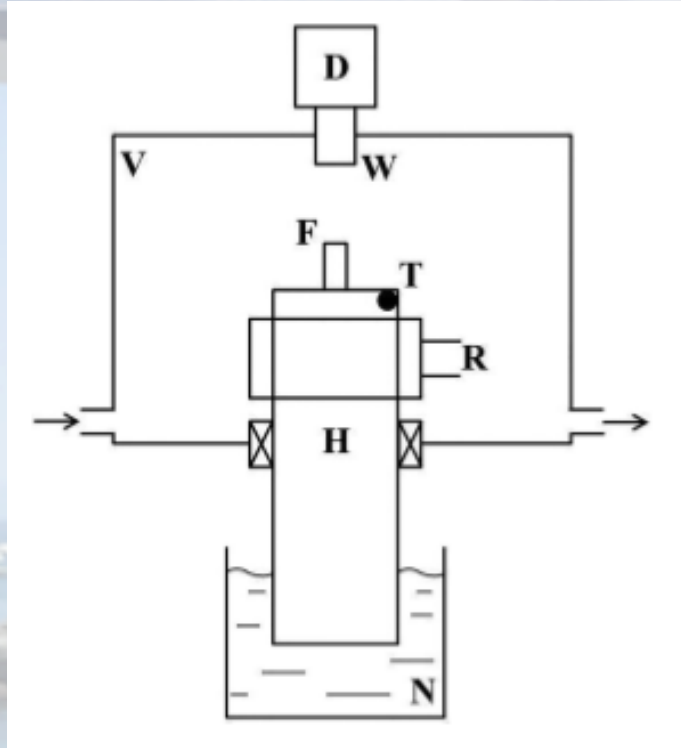
THE FIRST EXPERIMENTAL INVESTIGATION OF THE POSSIBILITY OF USING PIEZOELECTRIC CERAMICS IN PYROELECTRIC X-RAY SOURCES

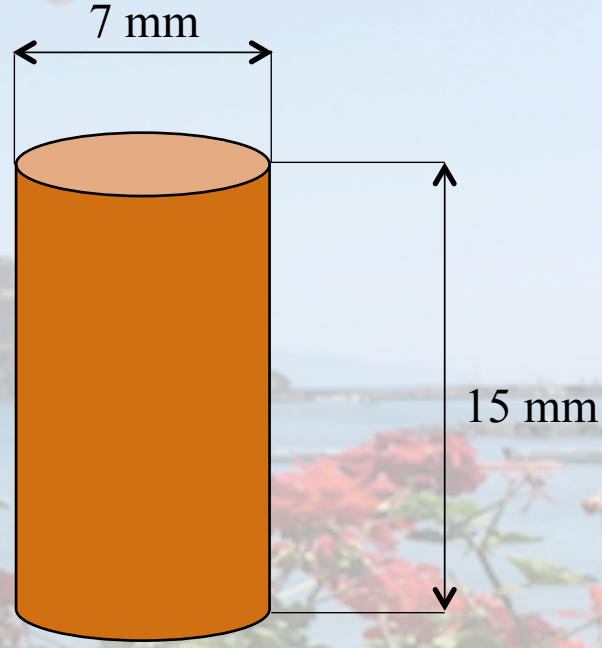
In 2015, scientists from Kharkov and Belgorod under the guidance of Shchagin A.V. were experimentally confirmed the possibility of generating X-rays with energy of at least 60 keV in during change temperature of piezoelectric ceramic.



Ceramics ZTBP-3M, made in Vitebsk «Monolit» – factory of radios

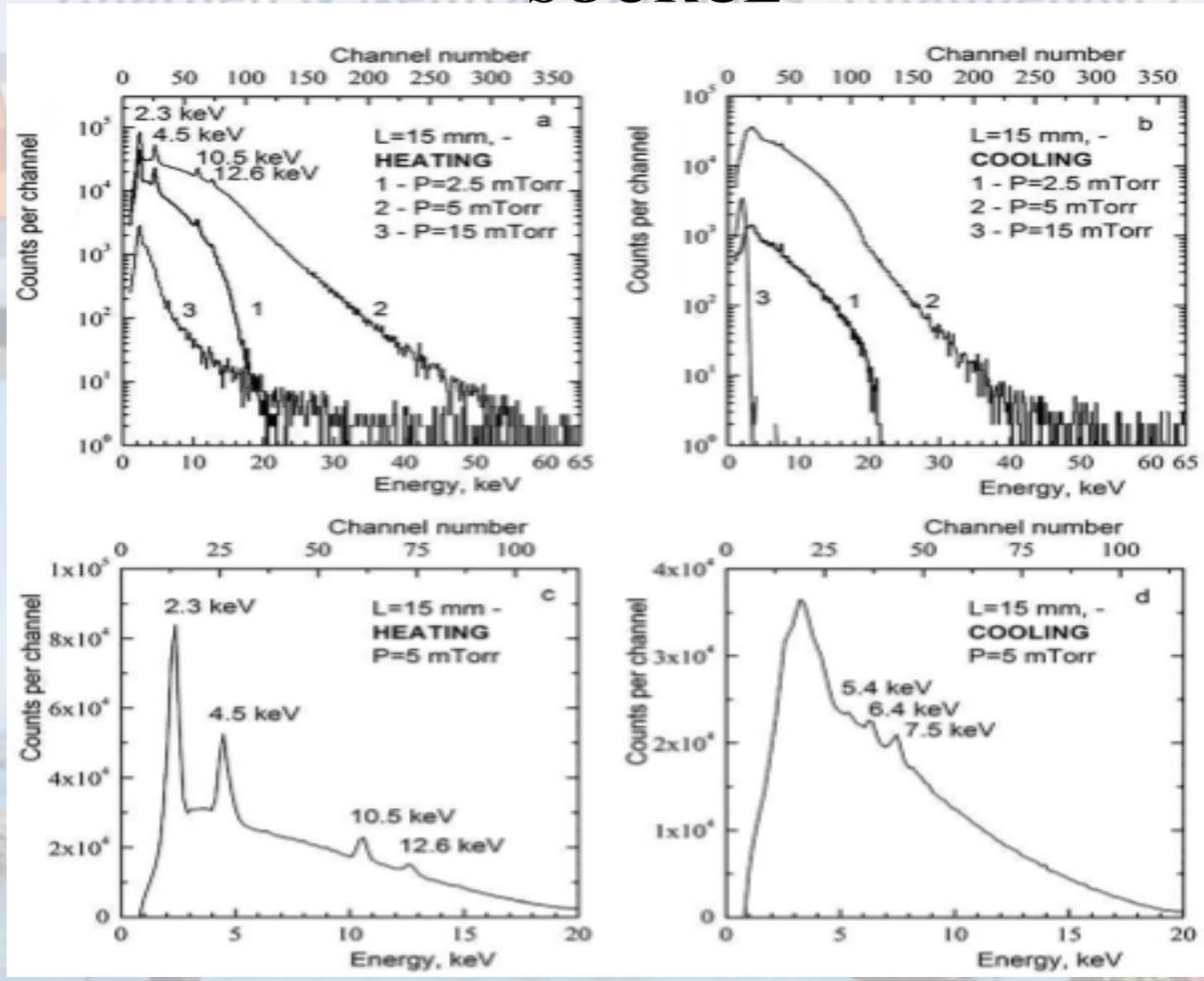
$\varepsilon = 600\text{-}1300$

$d = 1.7 \times 10^{-10}$ C/N



Shchagin, A.V., Miroshnik, V.S., Volkov, V.I. & Oleinik, A.N. Ferroelectric ceramics in a pyroelectric accelerator. *Appl. Phys. Lett.* 107, 233505 (2015).

THE FIRST EXPERIMENTAL RESULTS. CERAMIC PYROELECTRIC SOURCE



The range of change of temperature was from -50 ^{0}C to +85^{0}C.

CONCEPTION OF PIEZOELECTRIC ACCELERATOR

The potential difference or voltage V between the surfaces of piezoelectric ceramics is

$$V = Q/C \quad (1)$$

where Q is the surface charge per unit of area which arises due to the piezoelectric effect,

$$Q = d_{33} \cdot P \quad (2)$$

d_{33} is the piezoelectric modulus, C is the capacity per unit of area,

$$C = \varepsilon \cdot \varepsilon_0 / h \quad (3)$$

$\varepsilon_0 = 8.85 \cdot 10^{-12}\ F/m$ is the dielectric permittivity of free space, ε is the relative dielectric permittivity of the piezoelectric ceramics. As a result, the voltage is

$$V = d_{33} \cdot P \cdot h/\varepsilon \cdot \varepsilon_0 \quad (4)$$

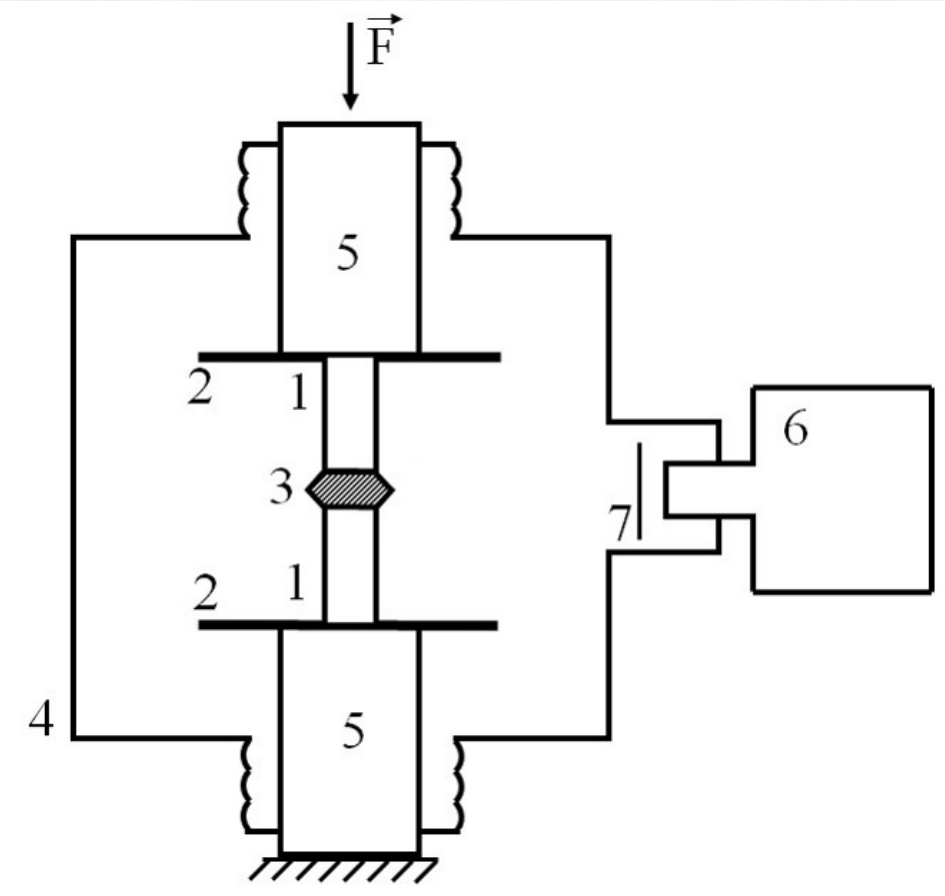
$d_{33} = 1.7 \cdot 10^{-10}\ C/N$, ε = 1300, h = 10 cm and maximum mechanical strength $P_{max} = 3.35 \cdot 10^{8}\ N/m2$

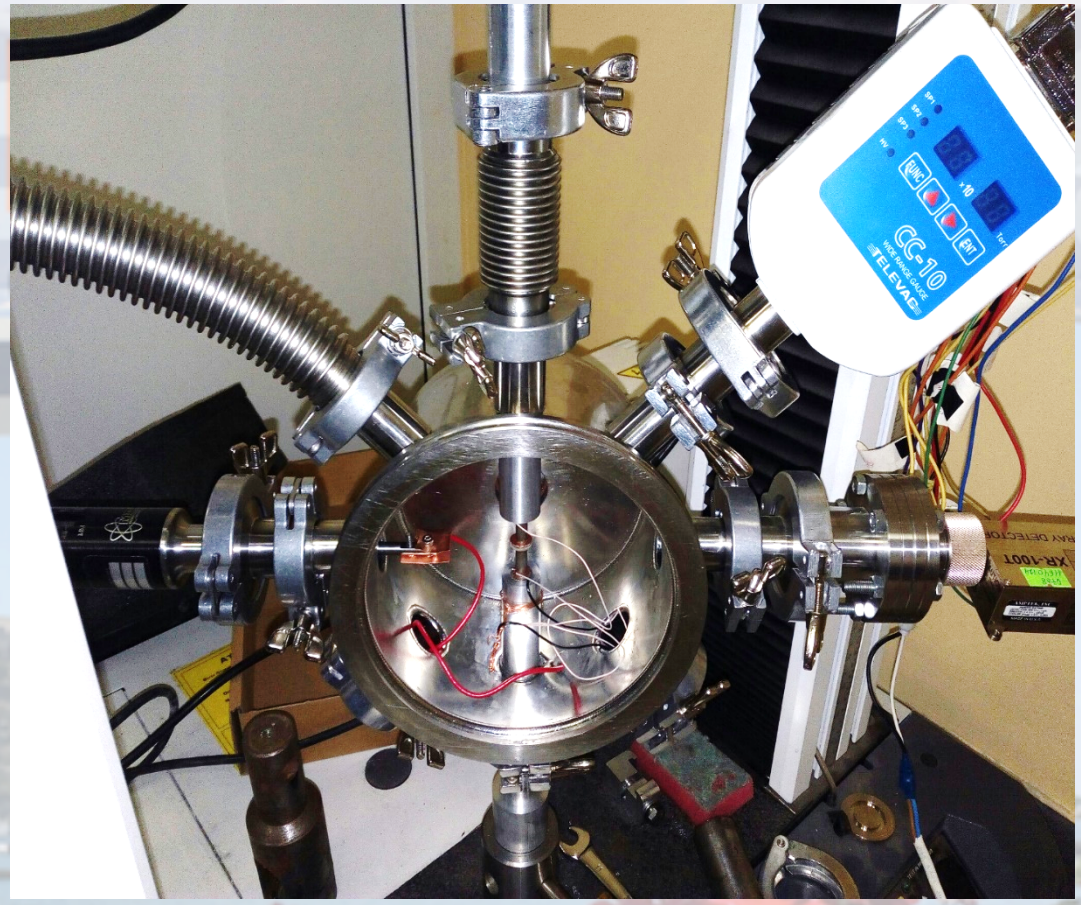
maximal voltage is V=0.5 MV and electric field strength is

$$V/h = 50\ kV/cm \quad (5)$$

Results of estimations: Conception of Piezoelectric accelerator is valid.

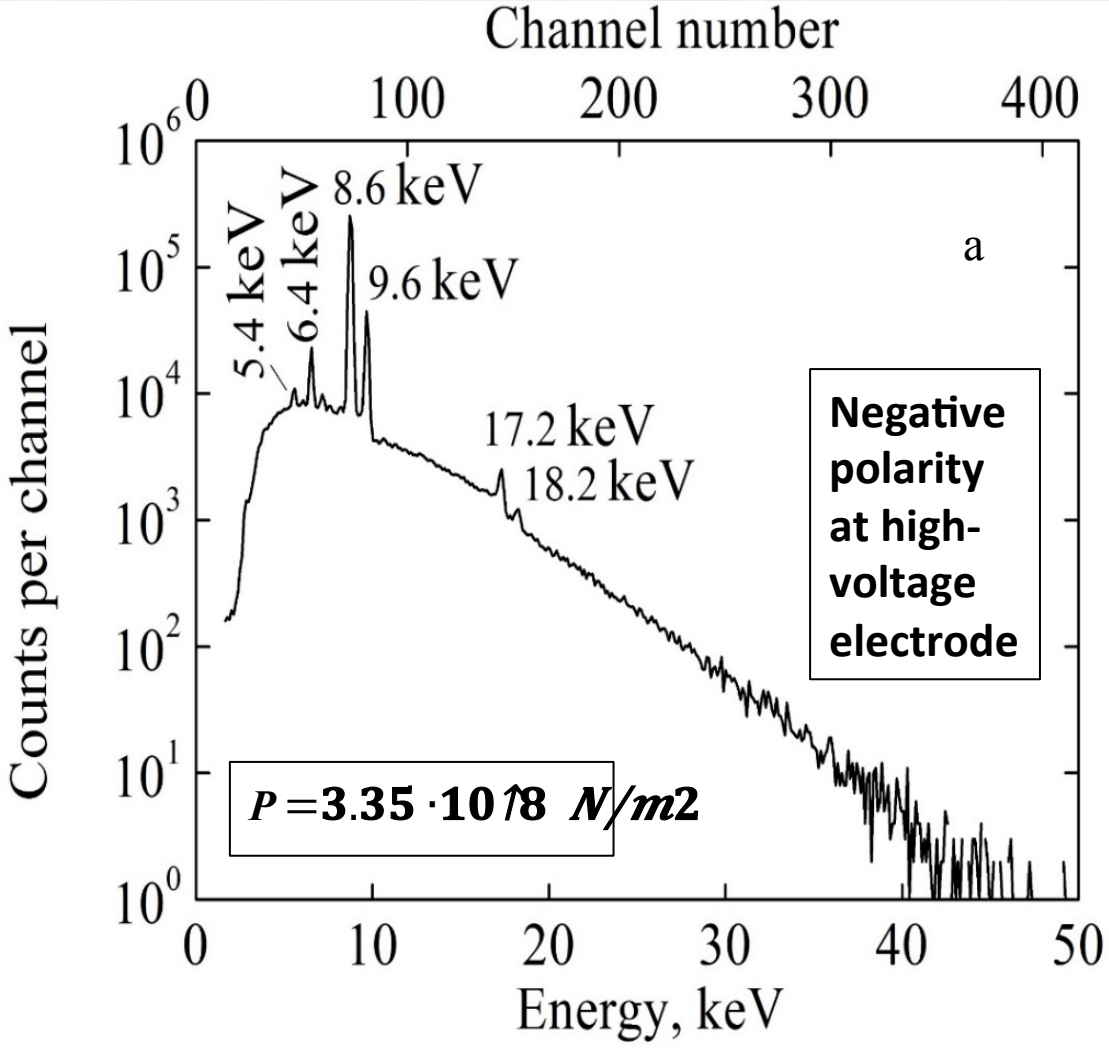
Piezoelectric accelerator - PROOF-OF-PRINCIPLE EXPERIMENT

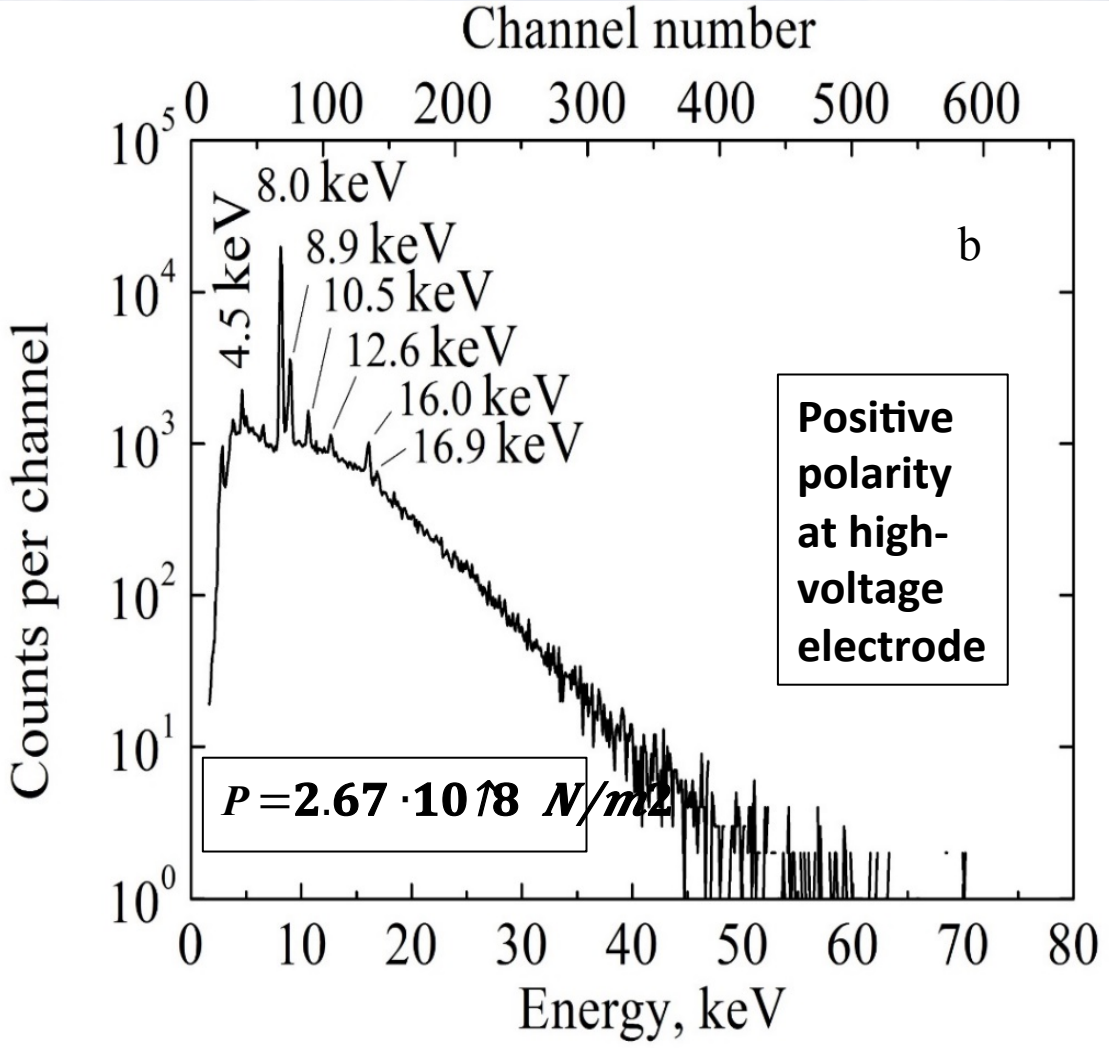




The cylindrical assembly of two piezoelectric ceramics cylinders 1 with copper high-voltage electrode 3 is installed in vacuum chamber 4 between two metal grounded disks 2. The variable force $\vec{F}$ can be applied along the assembly axis through metal cylinders 5. The spectra of X-ray radiation are measured with X-ray detector 6. Mylar foil 7 is installed before the entrance window of the detector.

SPECTRA OF X-RAY RADIATION FROM PIEZOELECTRIC ACCELERATOR





Comparison of experimental and calculated of results

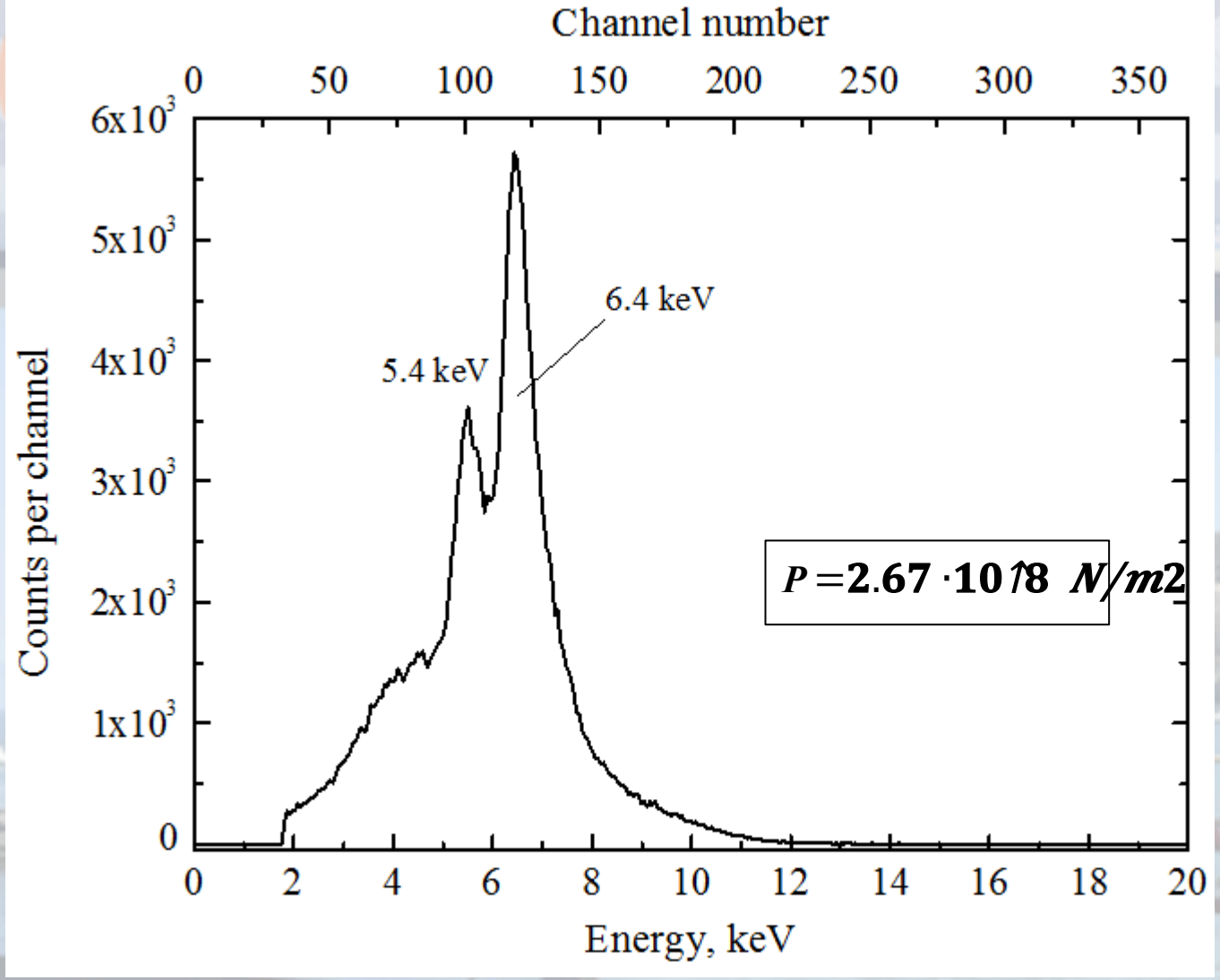
1) The negative potential calculated by formulae (4,5) at $d_{33} = 1.7 \cdot 10^{-10}$ *C/N* , $\varepsilon = 957$, $h = 1.5$ *cm*, $P = 3.35 \cdot 10^{8}$ *N/m2* is 51.5 kV that is close to the experimental value 45 kV.

2) The positive potential calculated by the same formulae at $d_{33} = 1.7 \cdot 10^{-10}$ *C/N* , $\varepsilon = 1158$, $h = 1.5$ *cm*, $P = 2.67 \cdot 10^{8}$ *N/m2* is 66.4 kV that is close to the experimental value 60 kV.

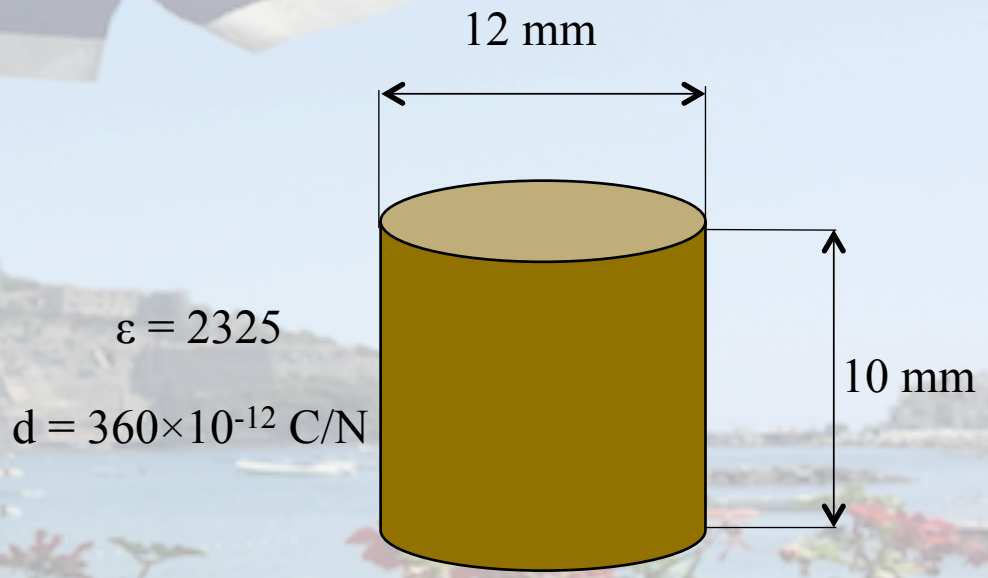
3) The both estimated voltages exceed the experimental data for about 11 – 15 %.

The exceeding may be due to some current leakage, the edge effects, and the capacity of the high-voltage electrode which were not taken into account in our simple estimation.

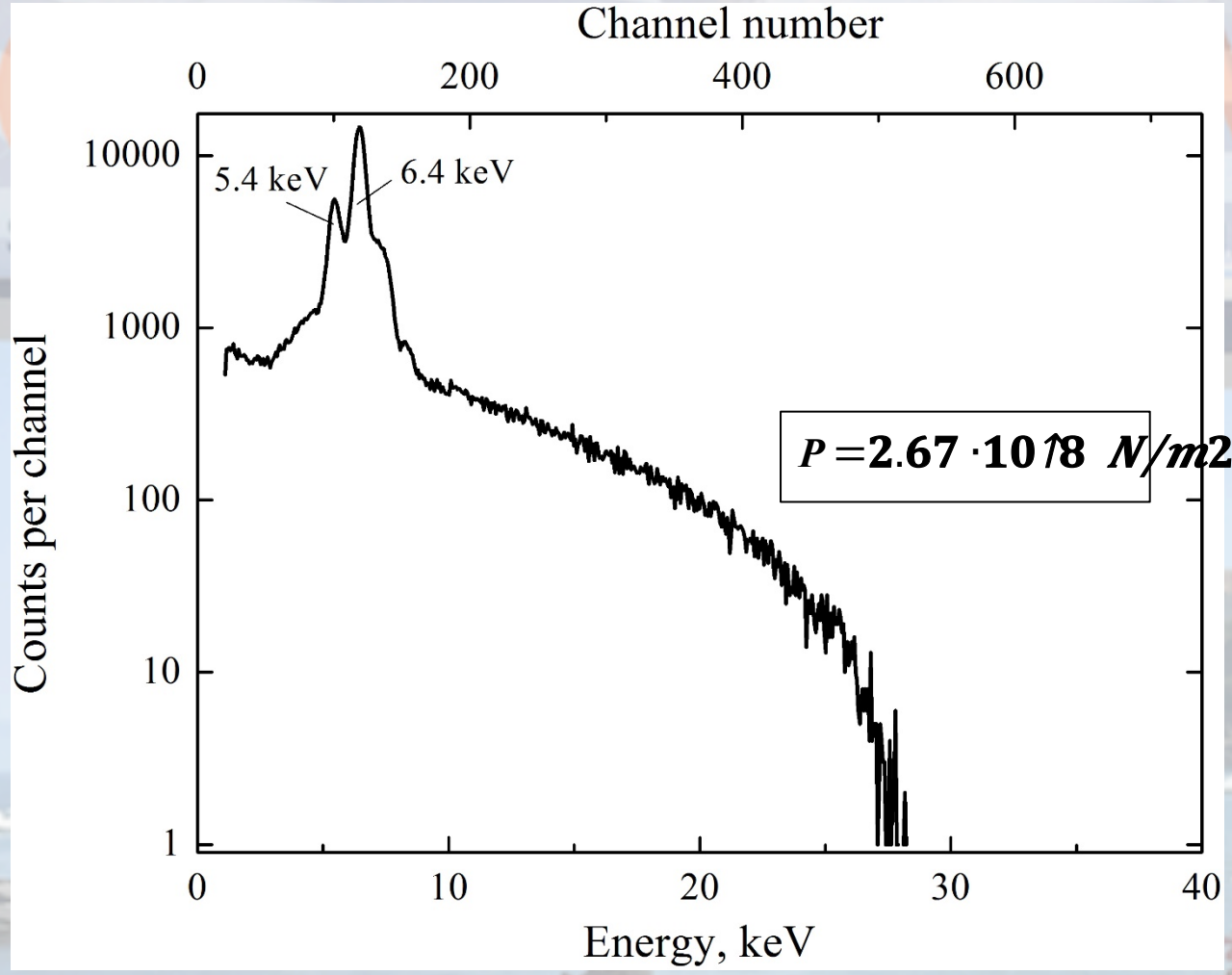
Experiments in other kinds of ceramics



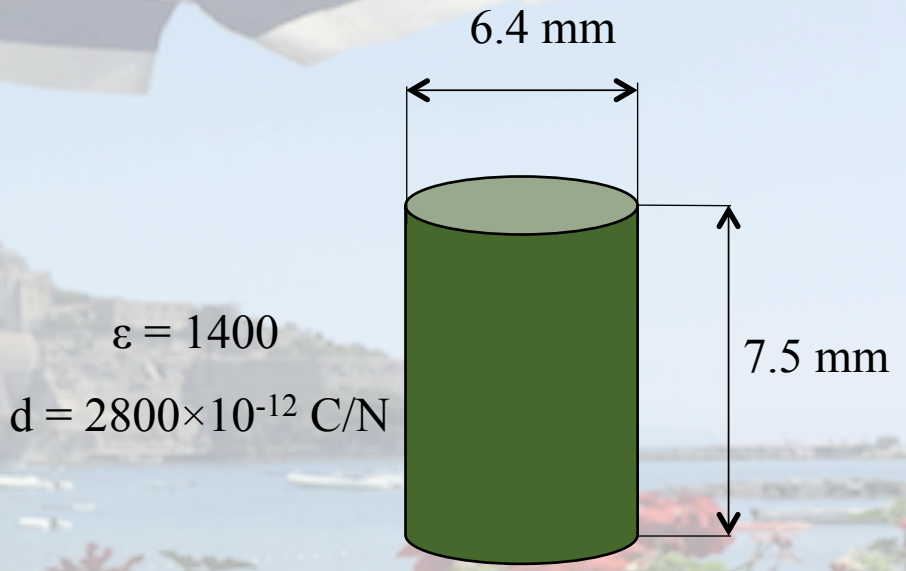
Ceramics ZTBP-3 (the lead barium zirconate titanate), made in Volgogdad «Avrora-ElMA»



Experiments in one more kind of ceramics (lead zirconate titanate)



Ceramics ZTP-43 (the lead zirconate titanate), made in Volgogdad «Avrora-ElMA»



Prospects for use of the piezoelectric accelerator

1) The piezoelectric can be use for making miniature X-RAY sources with minimum energy consumption.

2) The piezoelectric accelerator can be used for possibility to accelerate electron and ion beams at the energy about 100 keV, that when we use deuterium target we can get neutrons due to nuclear reactions (d,n). It means, that on the based of the piezoelectric accelerator we can make source of neutrons.

3) Such the piezoelectric miniature sources can be used for calibration X-RAY detector.

4) Also such advantages of the piezoelectric sources as small-size, mobility, simply operation and minimal energy consumption give possibility to use this X–Ray generator in different spheres (medicine, space technology and others).

5) There is a possibility to obtain x-ray imagens with using of the piezoelectric accelerator.

6) The paper detail description of the proof-of-principle experiment of piezoelectric accelerator now is submitted to journal «Scientific Reports»

Thank you for attention!