The possibilities of using of monoenergetic electron production in a pyroelectric accelerator for calibration of different detectors

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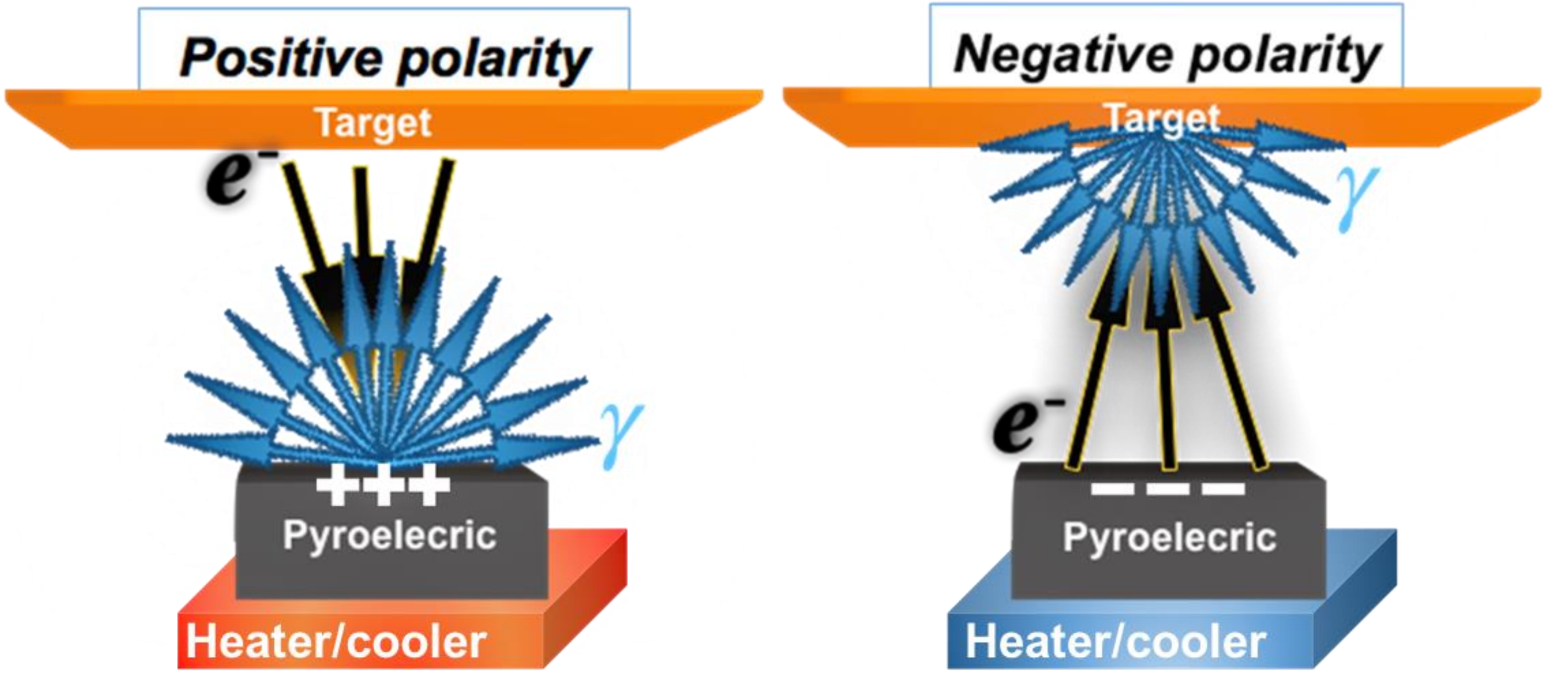
Moscow, 2nd of December, 2022

THE SCHEME OF ELECTRON GENERATION IN A PYROELECTRIC ACCELERATOR



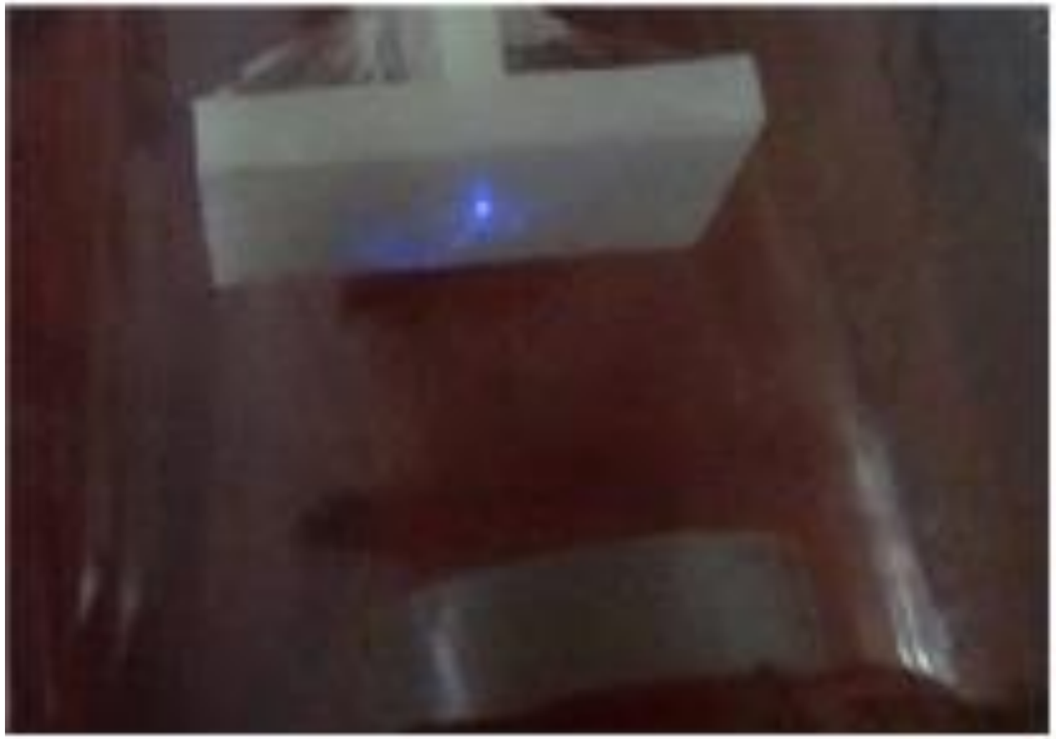
Used pyroelectric materials	Temperature change range	Pressure range	Electron flow current	Electron flow energy	Peak X-ray intensity
Lithium tantalate ($LiTaO_3$) Lithium niobate ($LiNbO_3$)	From 10 °C	Up to 100 mTorr (about 15 Pa)	Up to 1 nA	Up to 200 keV	Up to 10^9 ph/s in 4π

THE ELECTRON FLOW IN A PYROELECTRIC ACCELERATOR (1/2)

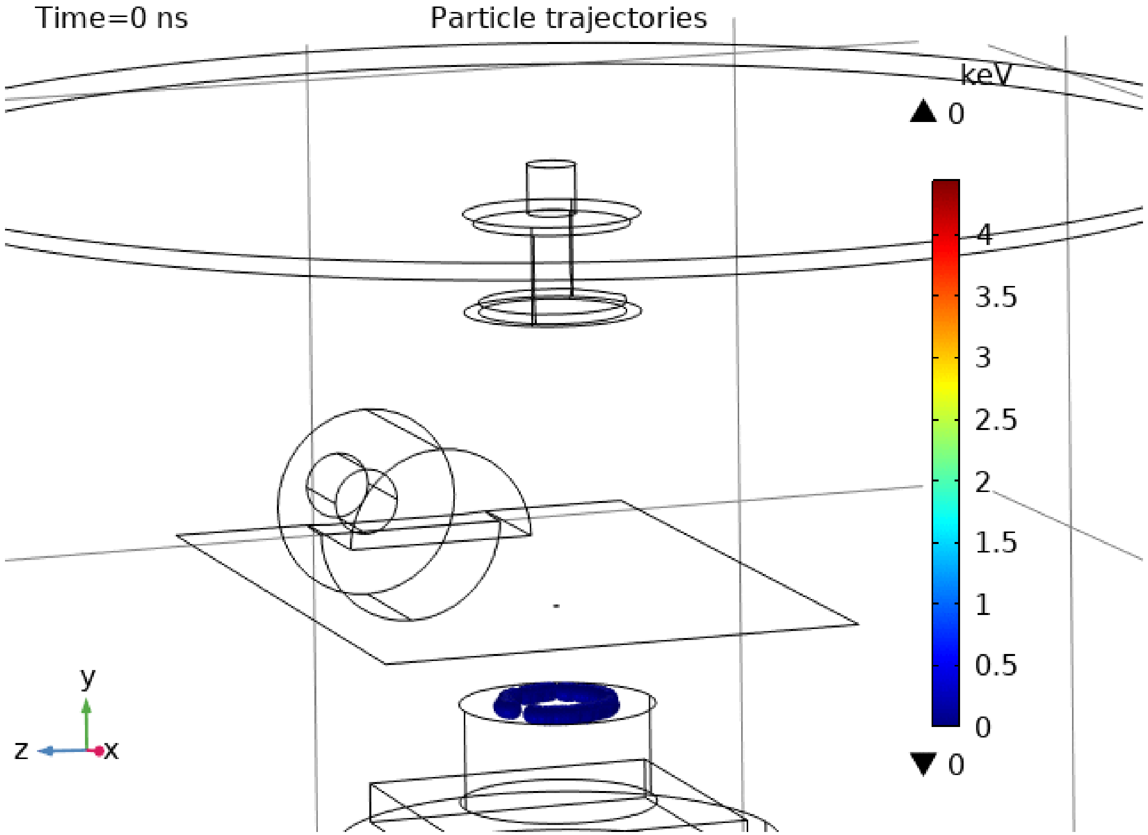
SELF-FOCUSING

Our poster about that was presented at Thursday.

173. P. Shapovalov, A. Oleinik, A. Klenin, Simulation of self-focused electron beam in a pyroelectric accelerator



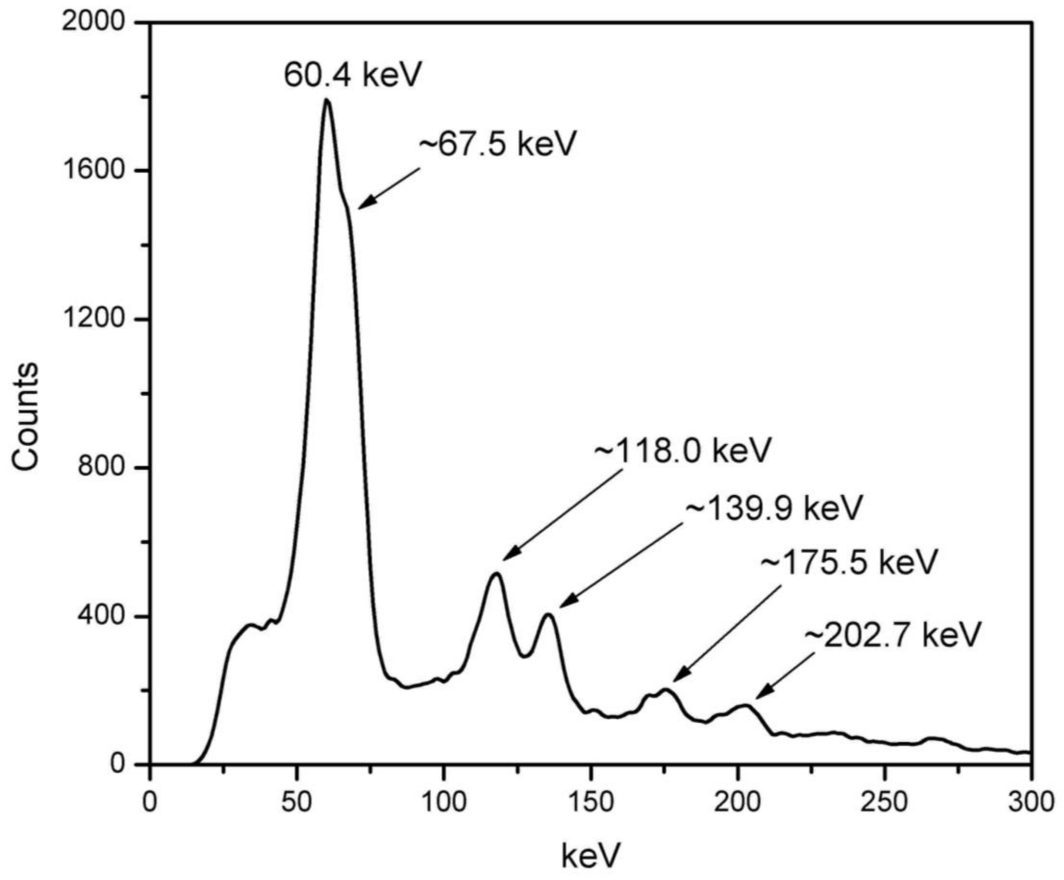
The spot of the self-focused electron flow emitted from a pyroelectric crystal (R. Ghaderi and F.A. Davani, Appl. Phys. Lett. 105 (2014) 232906.)

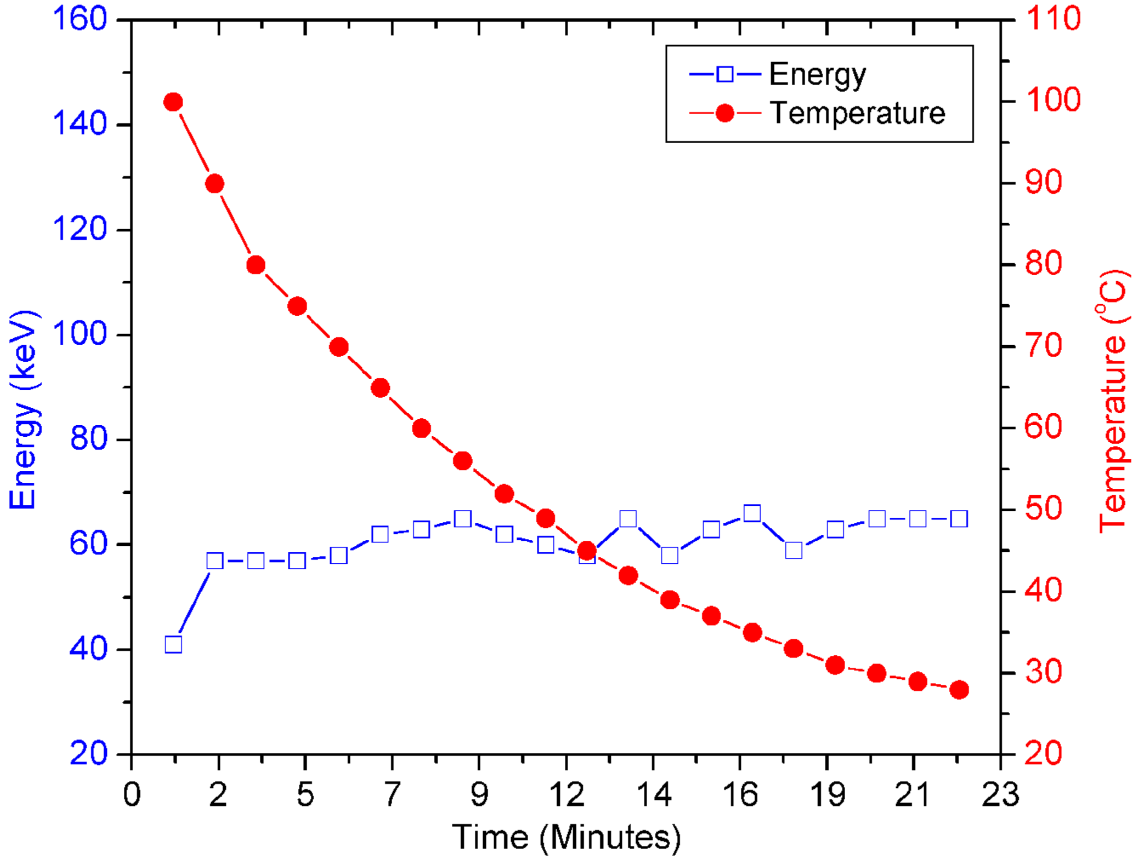


The simulation of self-focused electron flow based on a ring-like charge model

THE ELECTRON FLOW IN A PYROELECTRIC ACCELERATOR (2/2)

LONG-TIME MONOENERGETIC ELECTRON FLOW





The electron flow spectrum (left) and change in peak energy during cooling phase(right).
(J.D. Brownridge, Trends in Electro-Optics Research, Nova Science Publishers, (2005)).

PRACTICAL PERSPECTIVES OF A PYROELECTRIC ACCELERATOR

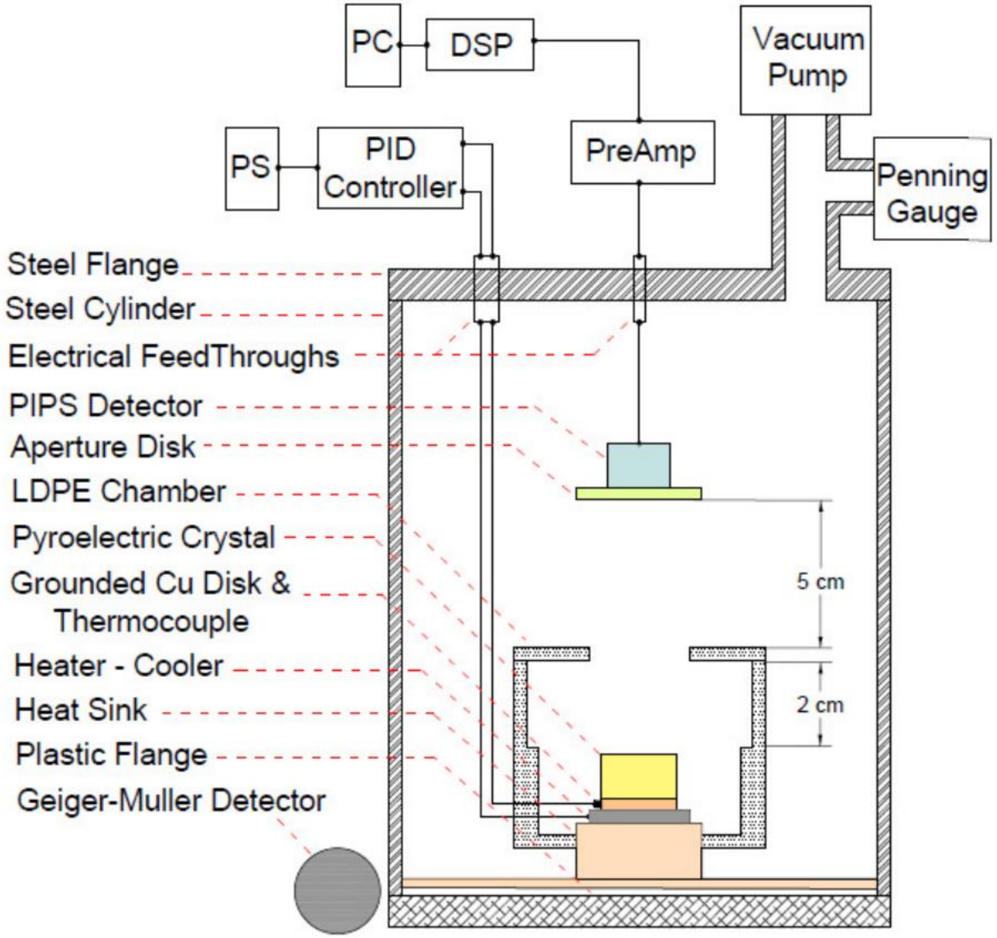
Pyroelectric X-ray source – AMPTEK COOL-X

Applications

- Portable x-ray instrumentation
- Teaching laboratories
- Instrument calibration
- Radiography (X-Ray Film Imaging)
- Research

https://www.amptek.com/internal-products/cool-x-pyroelectric-x-ray-generator

The concept of pyroelectric accelerator device for calibration of the commercial particle detectors



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PROS AND CONS OF A PYROELECTRIC ACCELERATOR

+ Compactness

+ Low voltage power

+ No radioactive materials

+ Possibility of quasimonoenergetic flux

+ Self-focusing promotes to more applicable flux

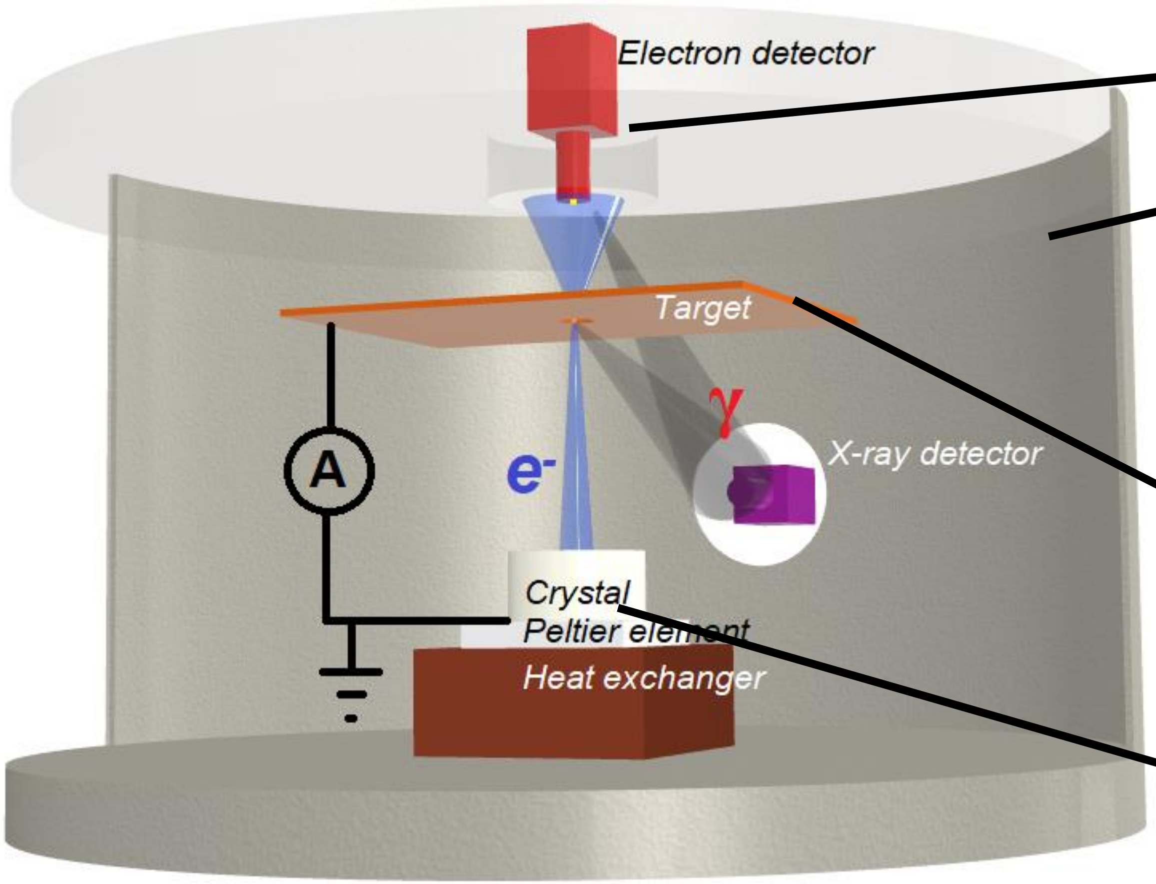
- **Limitation on energy and intensity of the electron flux**
- **Dead time more than 50% of operation time**
- **Requirement in the vacuum conditions**
- **Weak reproducibility of electron flux from cycle to cycle**
- **Interruption of the flux by electric breakdowns**

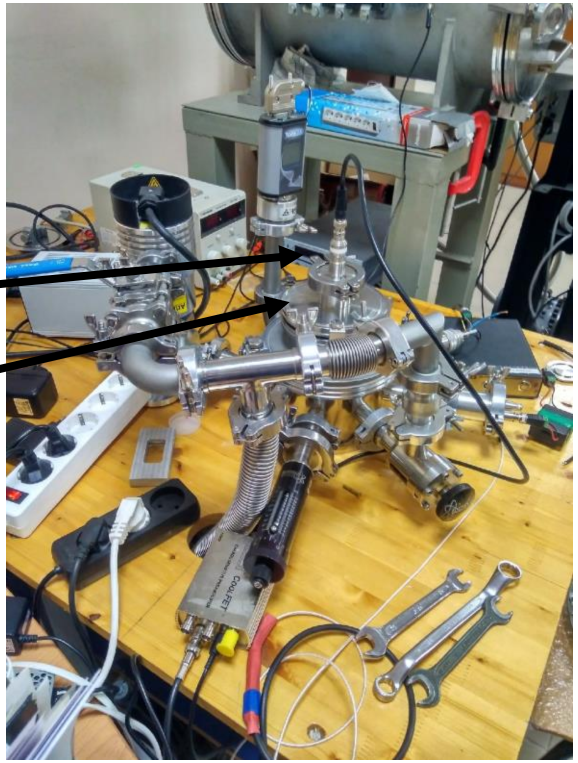
can be solved by accurate modulation of temperature change law

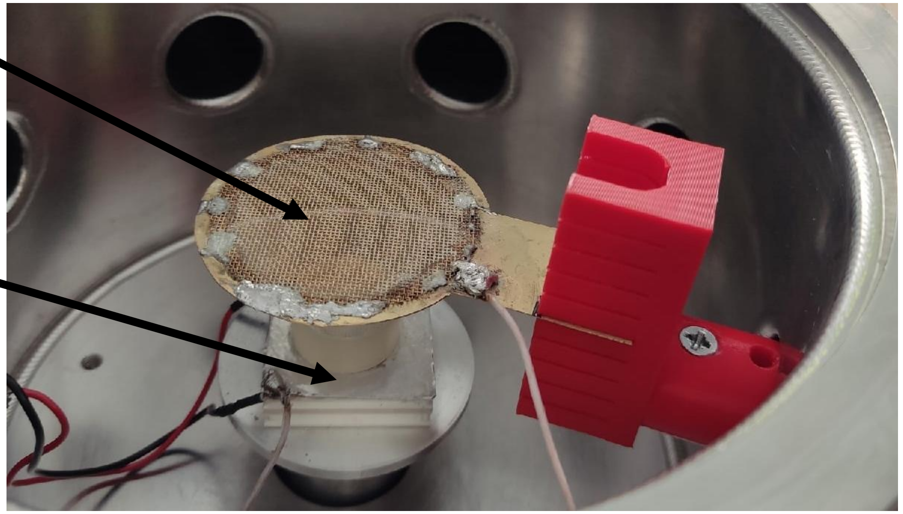
The main aim of our current work

EXPERIMENTAL SETUP IN BELGOROD STATE UNIVERSITY

Standard scheme

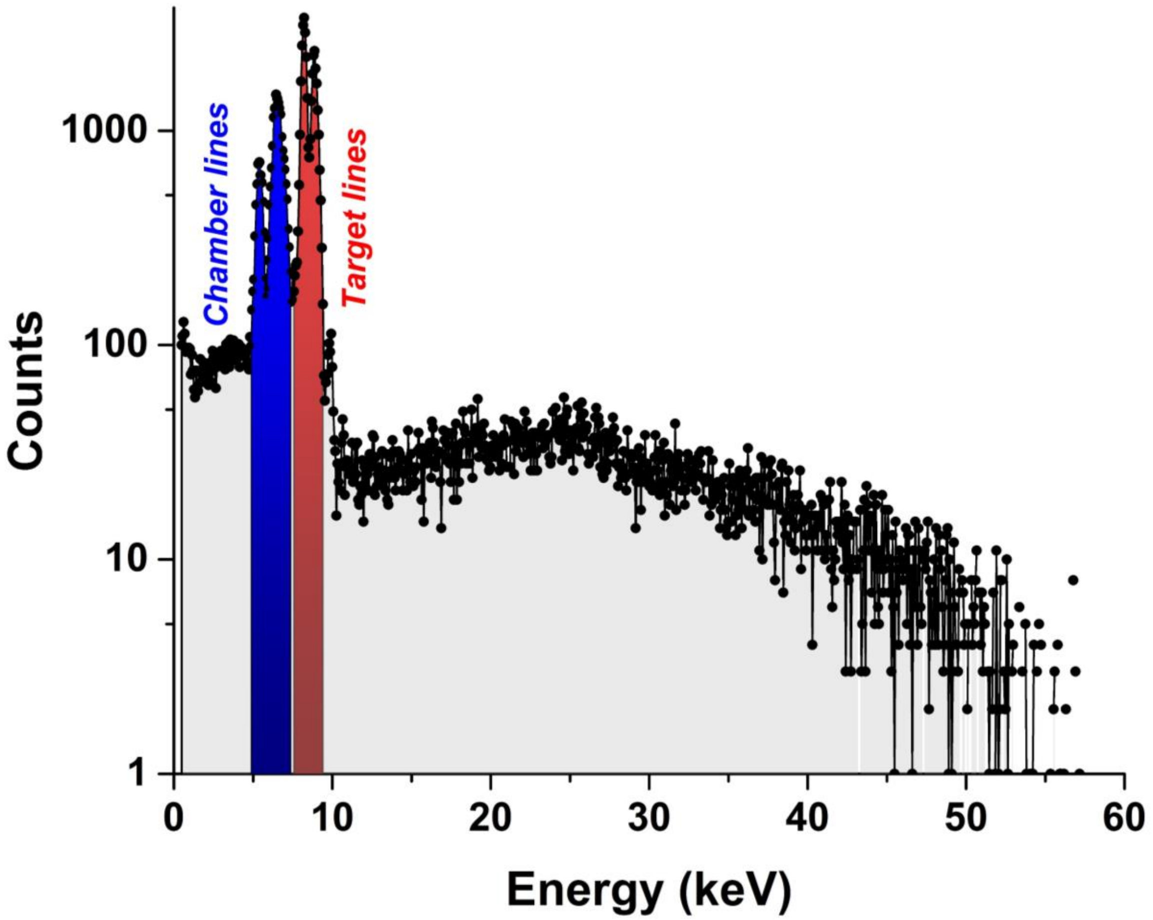




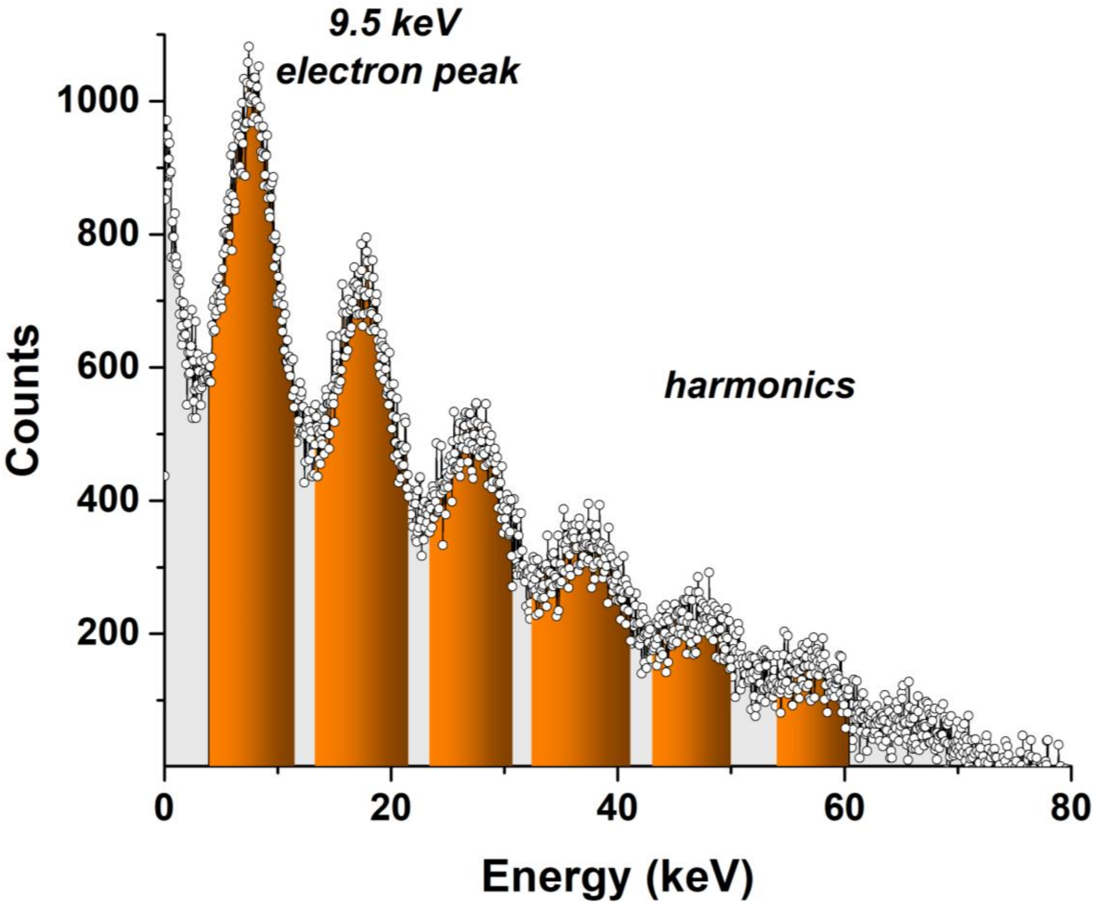


X-RAY AND ELECTRON SPECTRA AT A NEGATIVE POLARITY PHASE

X-ray spectrum over negative polarity phase



Electron spectrum at the beginning of negative polarity phase



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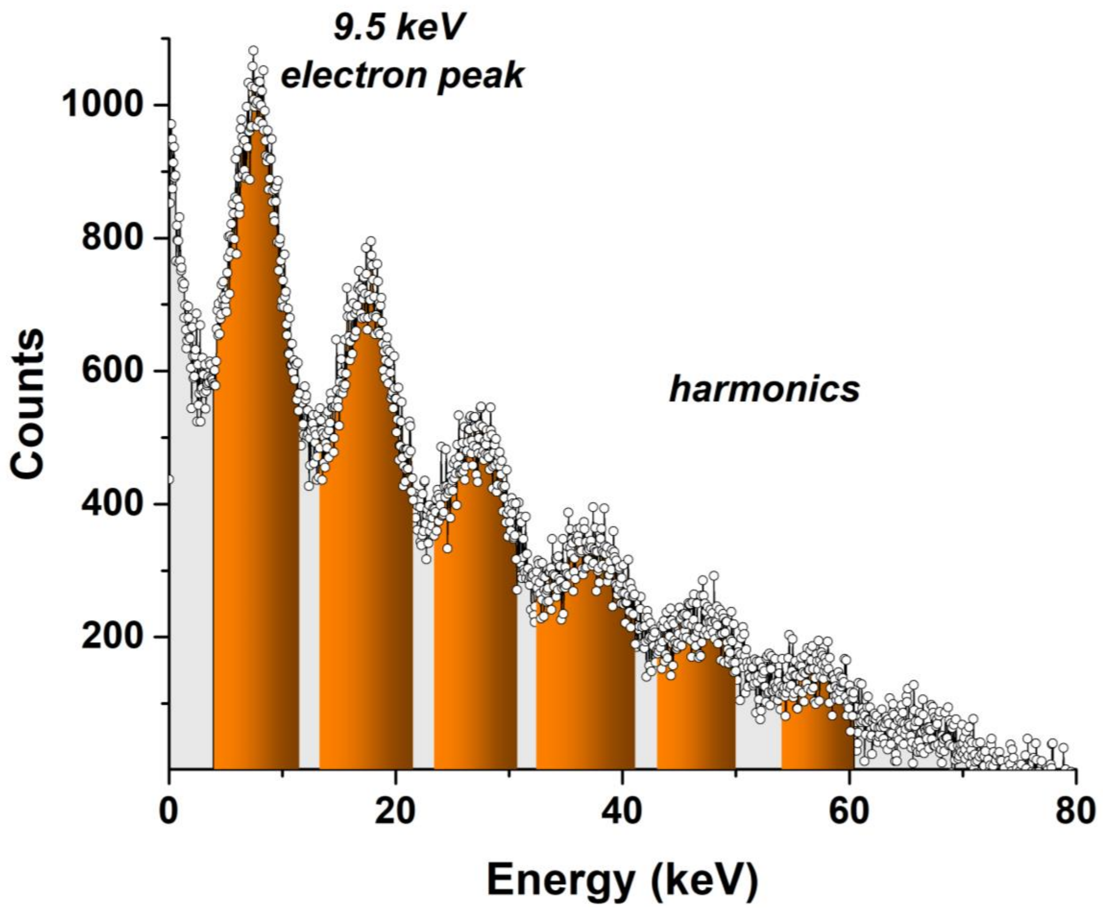
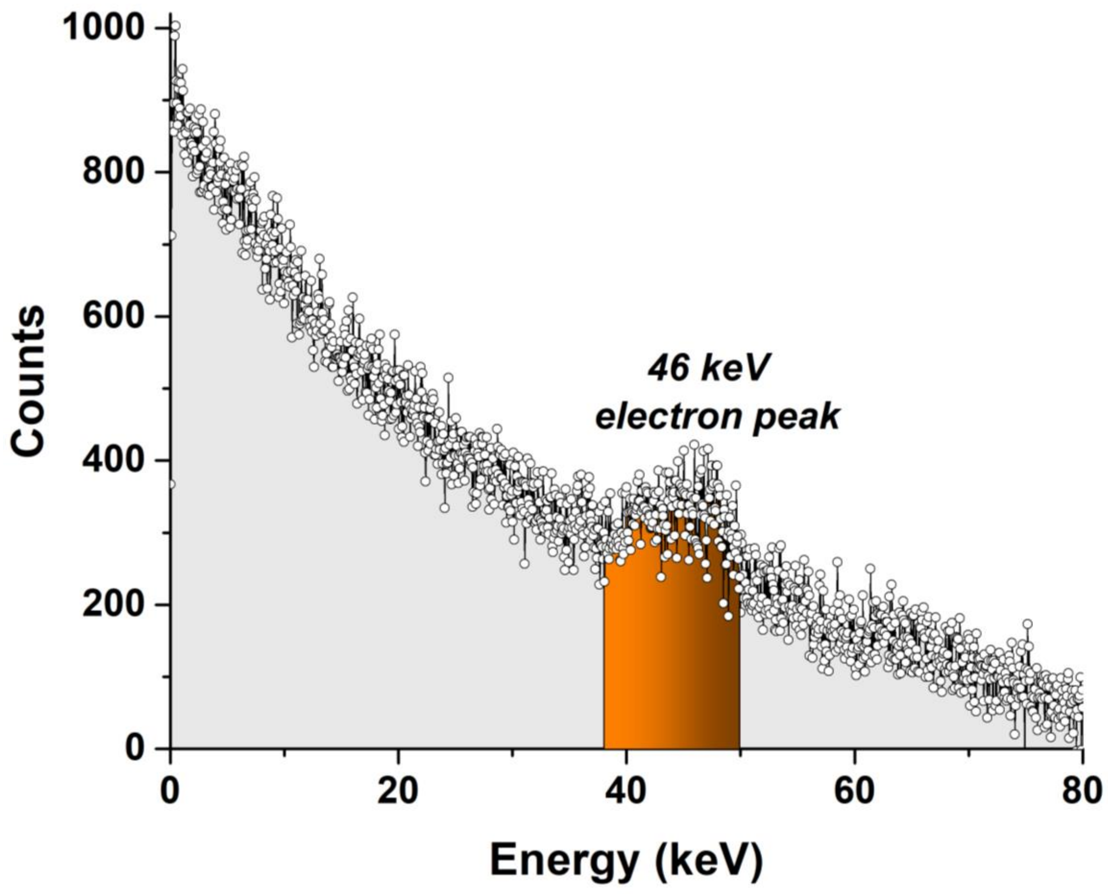
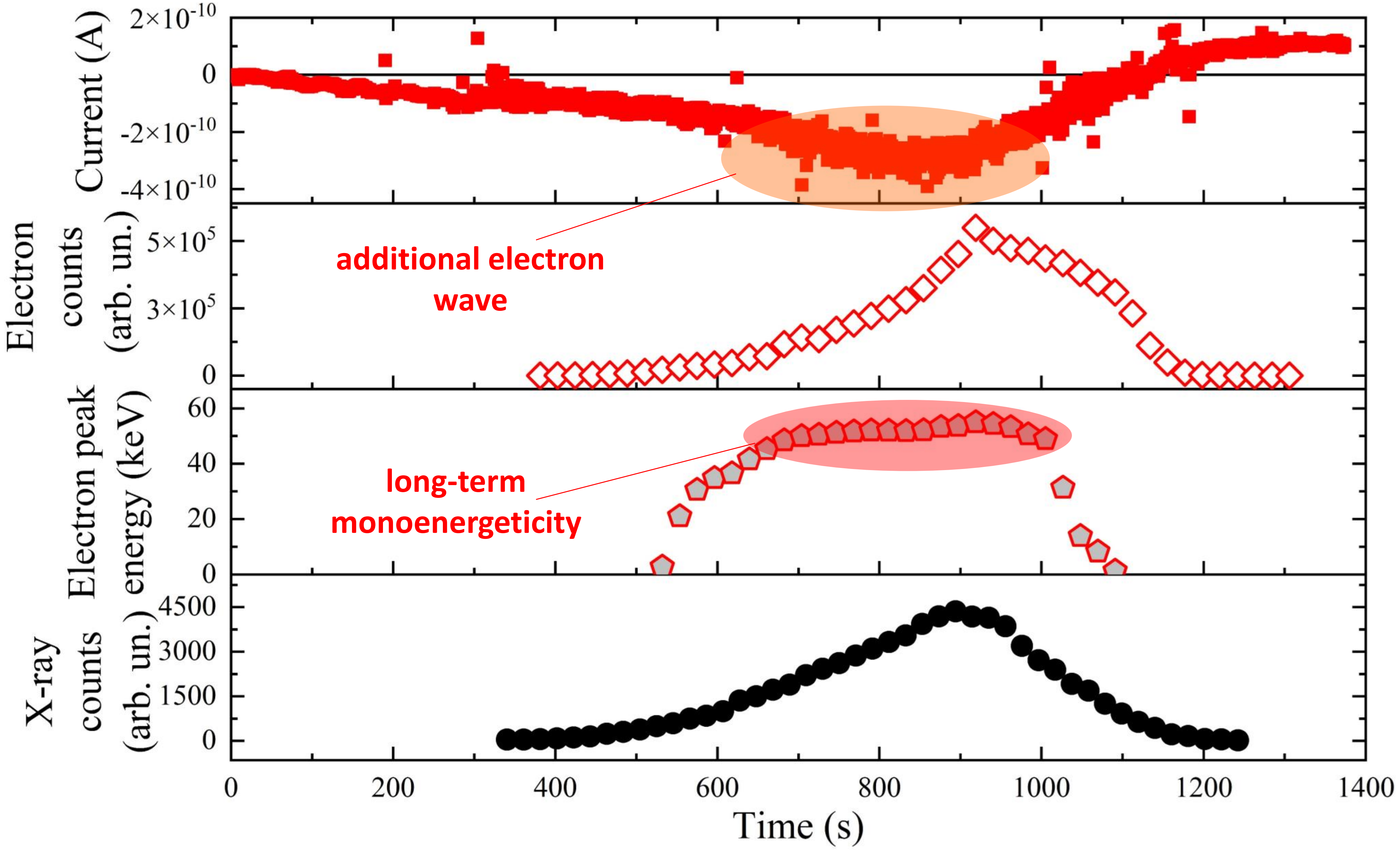


Electron spectrum at the maximal intensity of negative polarity phase

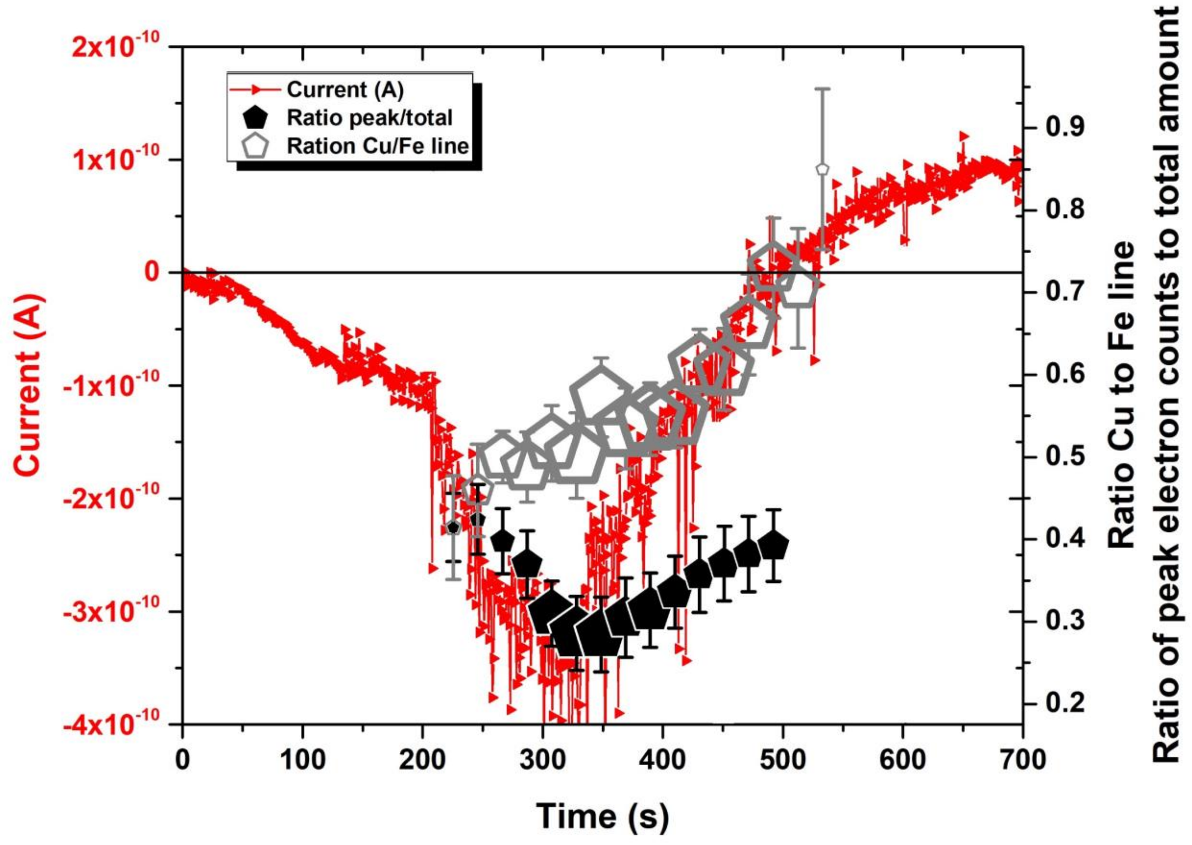


TYPICAL PICTURE OF A PARTICLE GENERATION OVER A NEGATIVE POLARITY

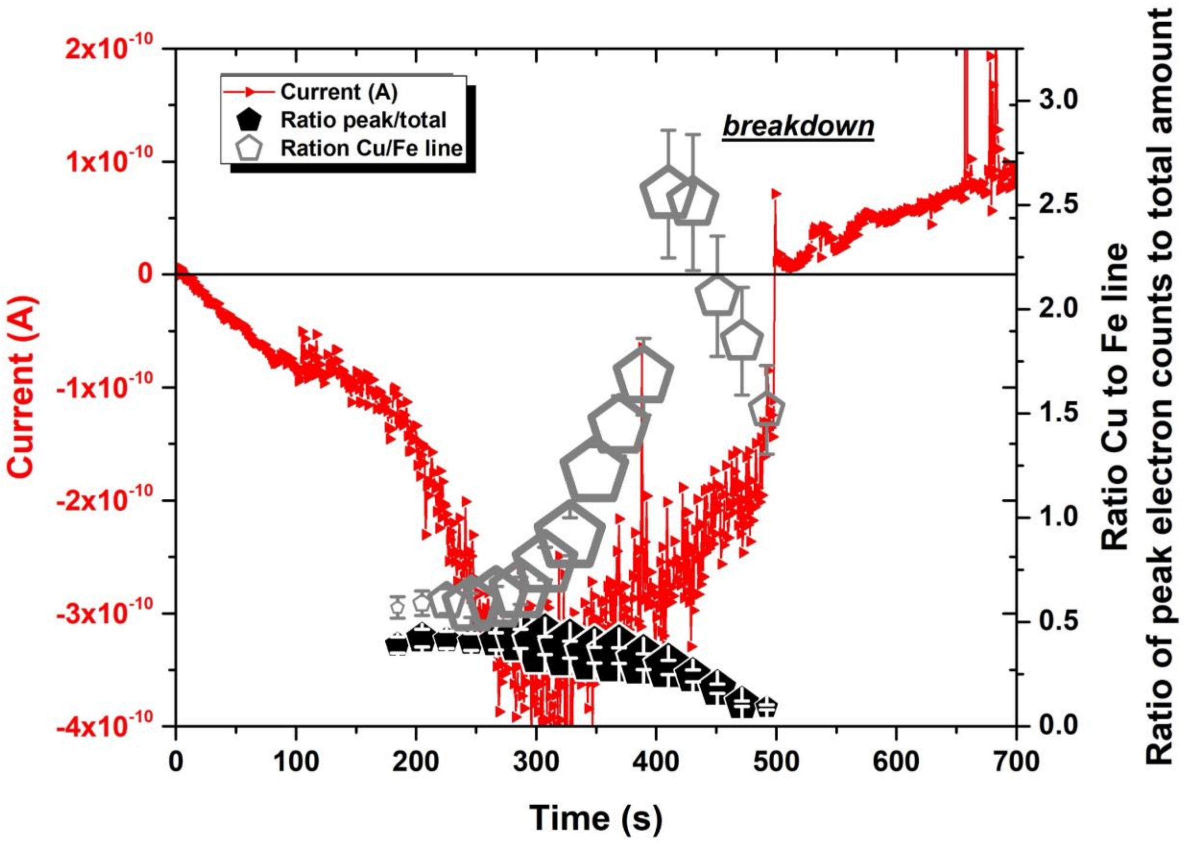


INDICATORS OF A ELECTRIC BREAKDOWN IN THE PYROELECTRIC ACCELERATOR

Case of stable operation



Case of breakdown

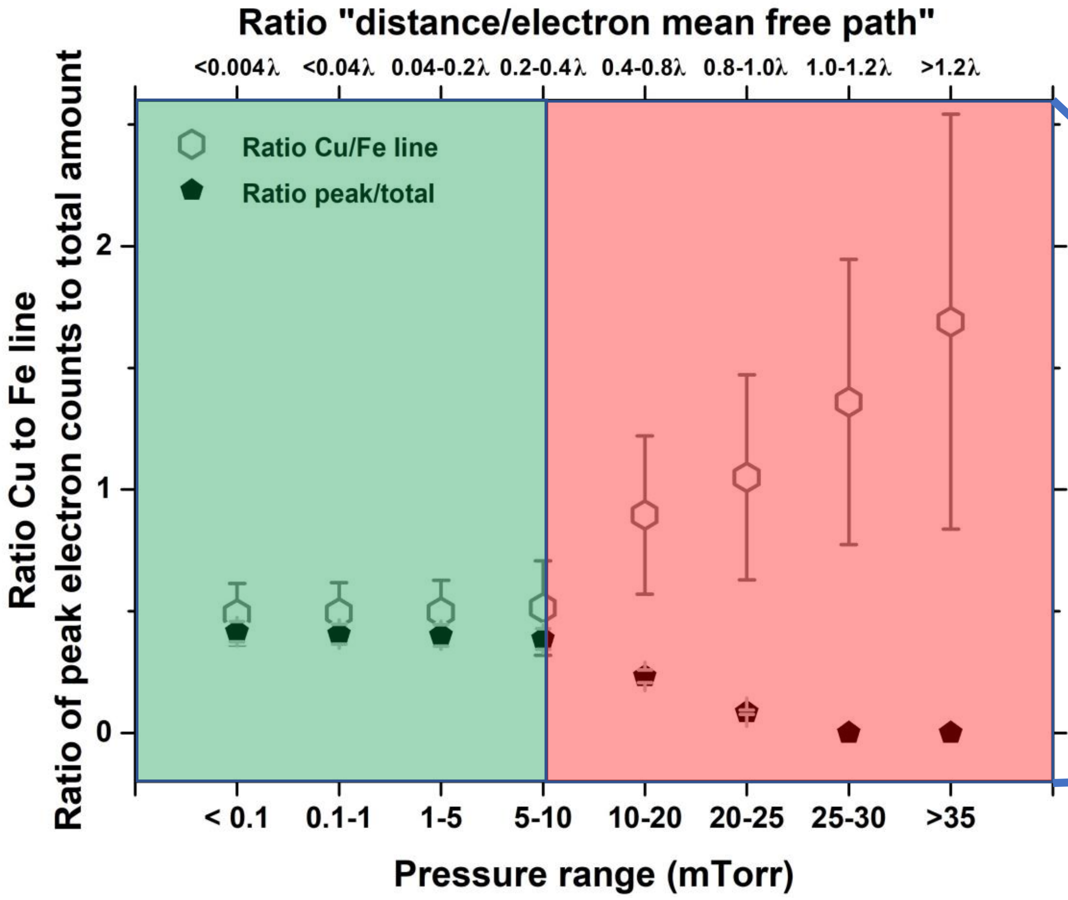


- ✓ Cu/Fe ratio gradually rises
- ✓ Peak/total ratio has a minimum and rises to an initial value

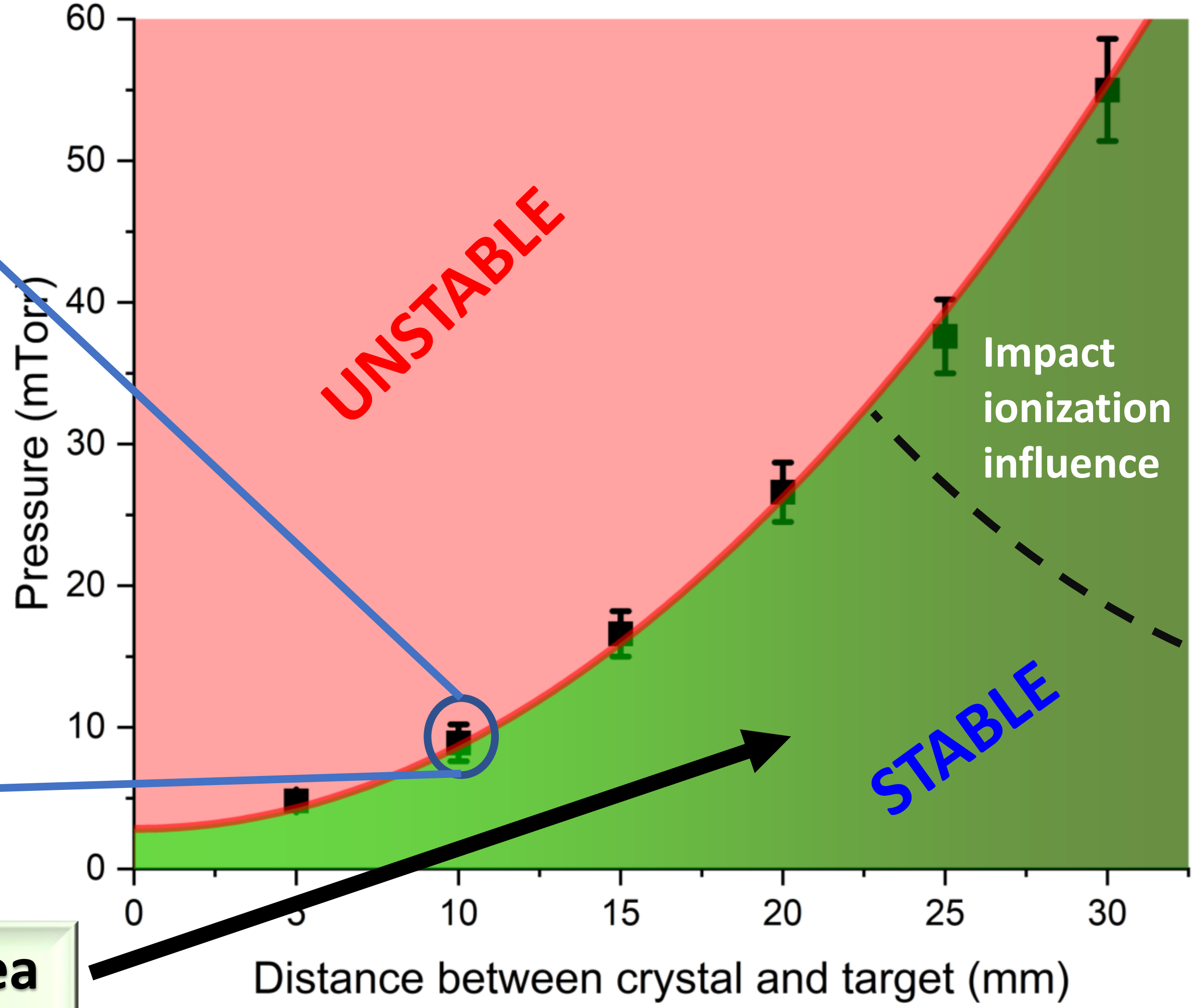
- ✘ Cu/Fe ratio sharply rises and falls before breakdown
- ✘ Peak/total ratio falls with a increase in the rate

STABLE PARTICLE GENERATION AREA IN A PYROELECTRIC ACCELERATOR

Case of distance between crystal and target of 10 mm



Area of stable particle generation in "pressure-distance" space

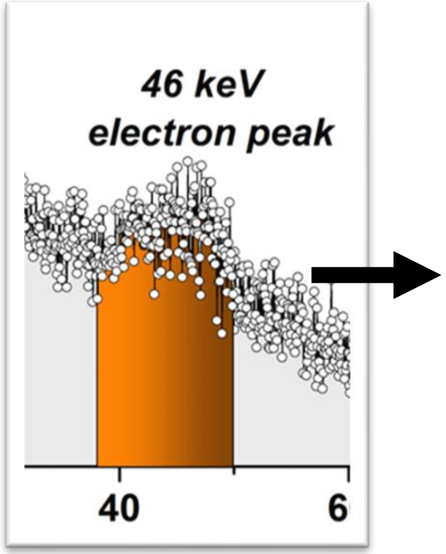


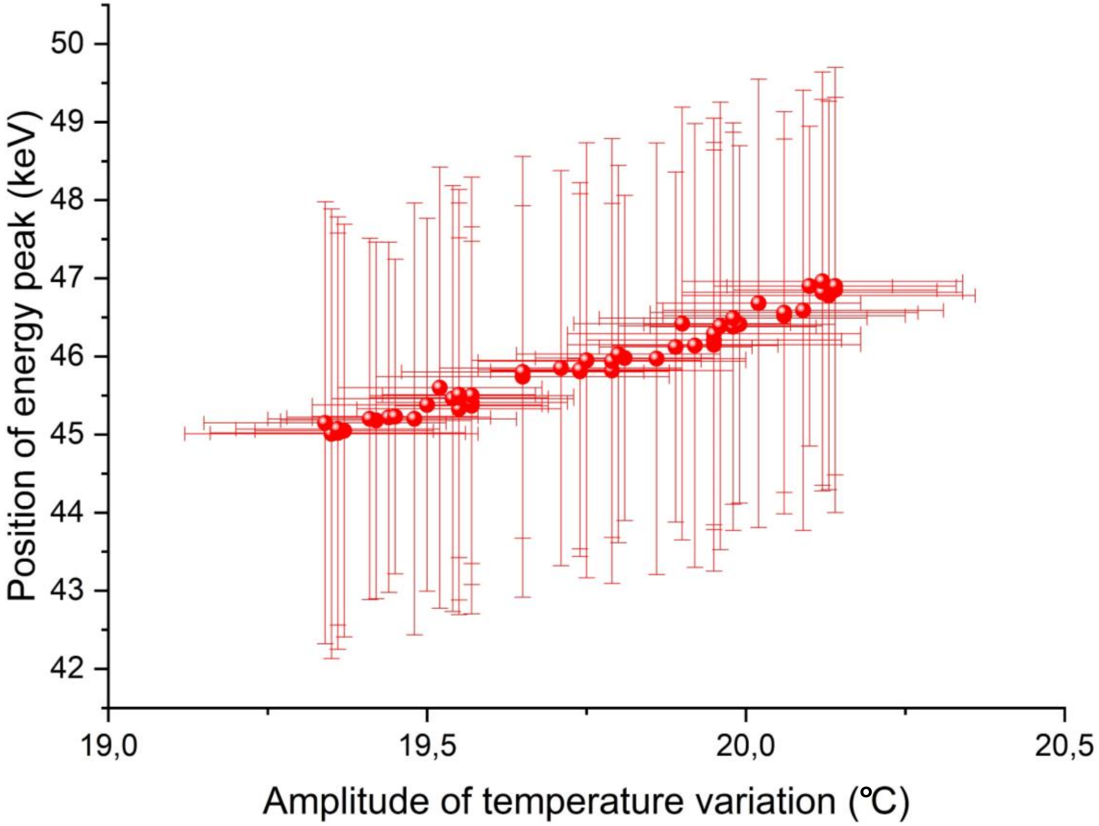
There is a stable particle generation area in a pyroelectric accelerator

APPLICABILITY FOR CALIBRATION OF PARTICLE DETECTORS

It was performed over 50 thermal cycles at next conditions:

- $LiTaO_3$ single crystal, 20x20x10 (z) mm, cylinder shape;
- Brass target, 50x50x0.4 mm with hole of 0.3 mm diameter;
- Pressure range is 1.5-5 mTorr
- Temperature variation amplitude is 19.3-20.1 °C
- **Ortec-CR-012-025-100 surface-barrier particle detector** was used to measure electron flux.





CONCLUSION

- ✓ **There is an area with stable and reproducible electron generation (in space "pressure-distance") with minimized risk of electric breakdown (at certain temperature variation level)**

- ✓ **This area is limited by an influence of impact ionization, the role of secondary electron emission is not so unambiguous**

- ✓ **The position of energy peak of electron flux is very sensitive to value of pressure, amplitude of temperature variation, but it is reproducible and can be controllable**

- ✓ **Devices based on pyroelectric accelerator concept can be implemented as calibration instruments for different electron detectors with tunable energy peak about several tens of keV**

THANK FOR YOUR ATTENTION!

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Some of results were published in next article:

P. Karataev, A. Oleinik et. al., Indicators of upcoming electric breakdown in a pyroelectric accelerator,
Applied Physics Express; 2022 15 066001
doi:10.35848/1882-0786/ac6b82