MEASUREMENT OF THE ELECTRON BEAM PROFILE BY THE MULTI-ANGLE SCANNING METHOD

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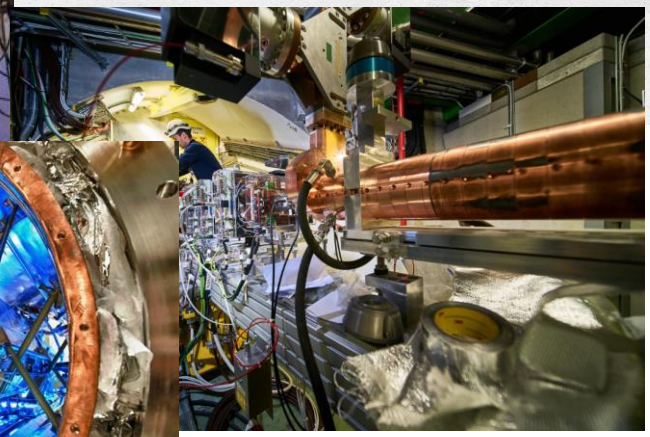
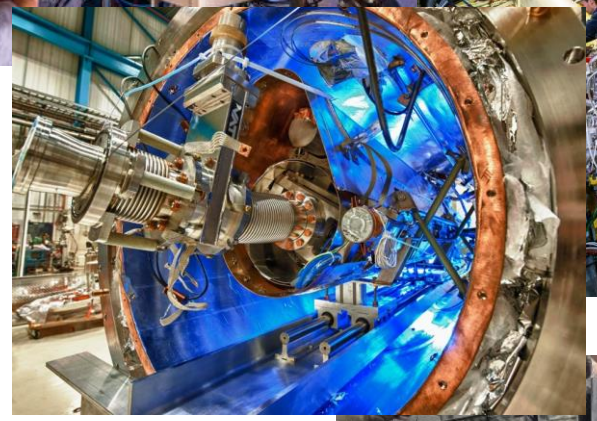
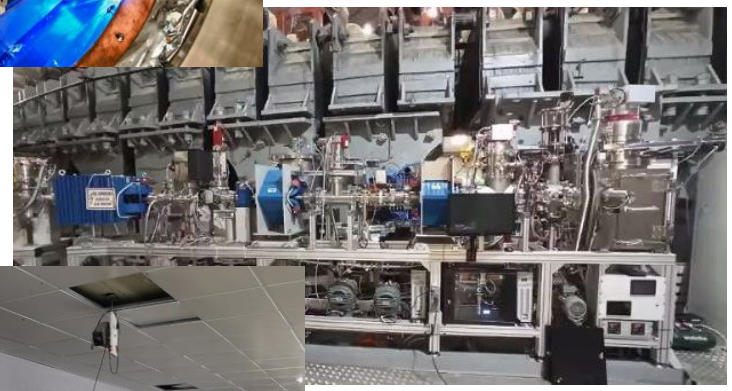
12/17/2024

RELEVANCE

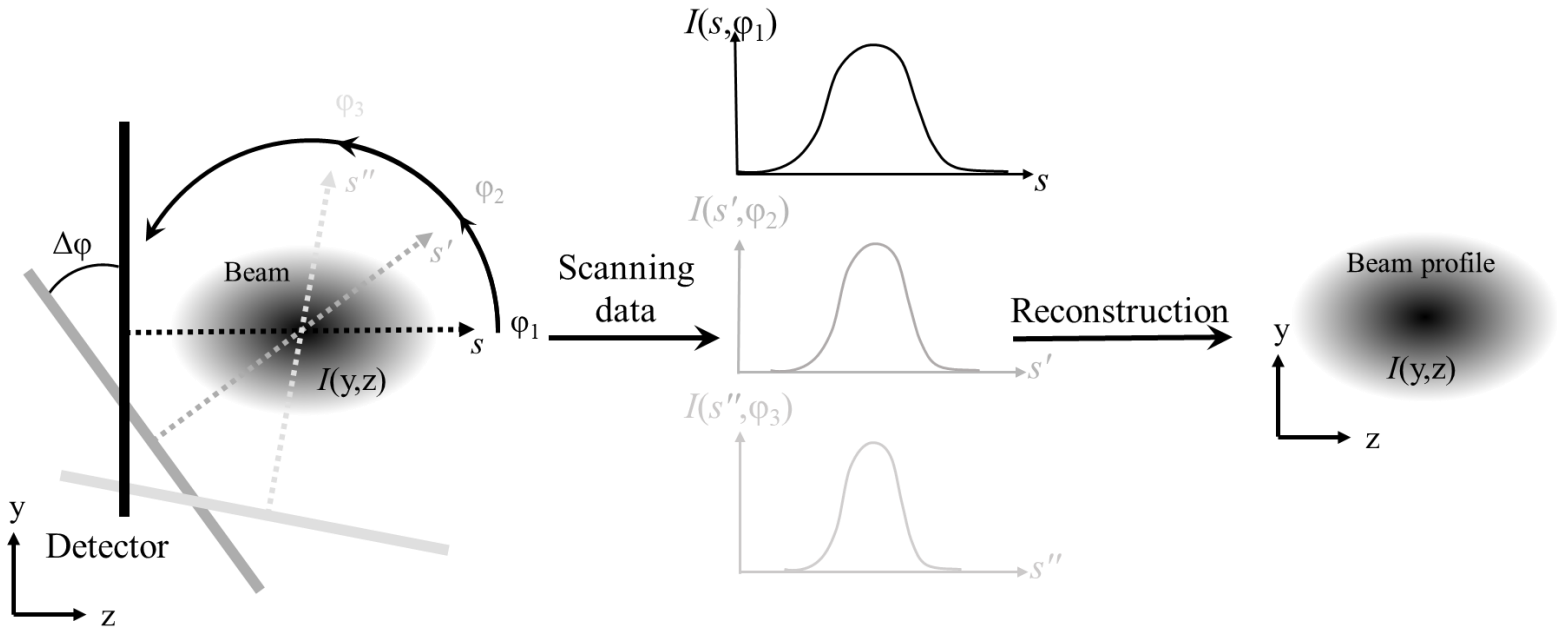






In the context of modern accelerator technology, it is essential to guarantee the specified characteristics of the extracted electron beam. In addition to the information regarding the energy and intensity of the beam, it is crucial to ascertain its spatial and angular distribution. The position of the particle beam in space and its transverse intensity distribution can be determined by means of profilometry. The detectors of profilometers are of various types, dependent on the method employed for the acquisition of the profile.

MULTI-ANGLE SCANNING METHOD



The multi-angle scanning method is based on the reconstruction of data using mathematical methods (inverse Radon transform), obtained in the process of multiple transverse scanning of a beam of ionizing radiation by a thin detecting element at different angles.

* Bulavskaya A. A., et al. Multiangle Scanning for Measuring Radiation Beam Profiles with a Typical Size of 10 Millimetres — Proof-of-Principle Experiments // J. Instrum. 2022. V. 17. P. T07004.

MULTICHANNEL DETECTOR FOR IMPLEMENTING THE MULTI-ANGLE SCANNING METHOD

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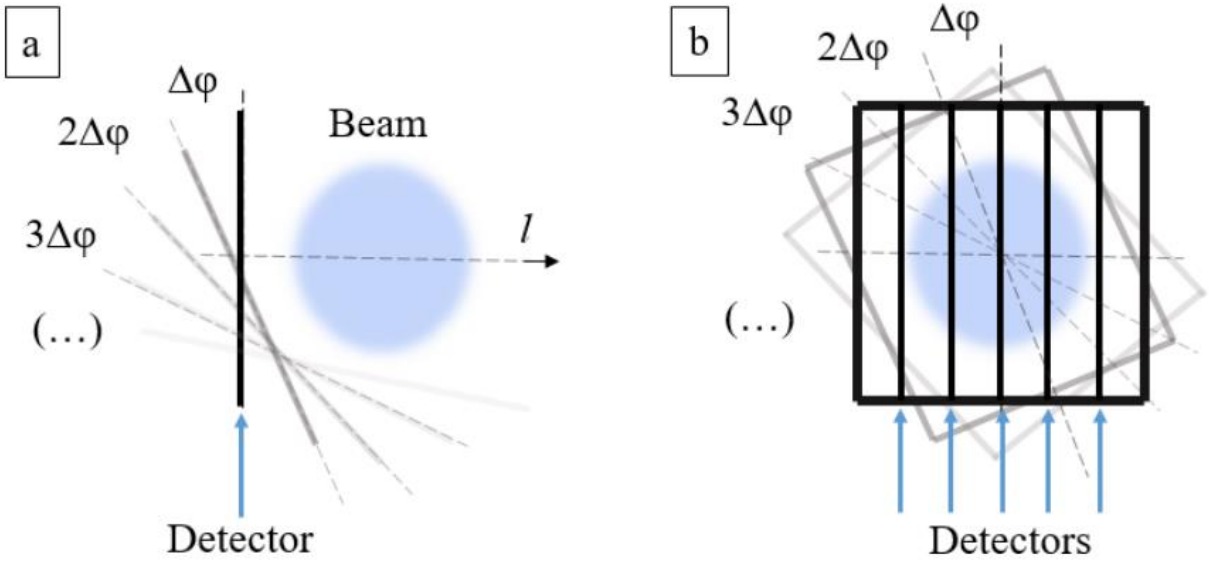
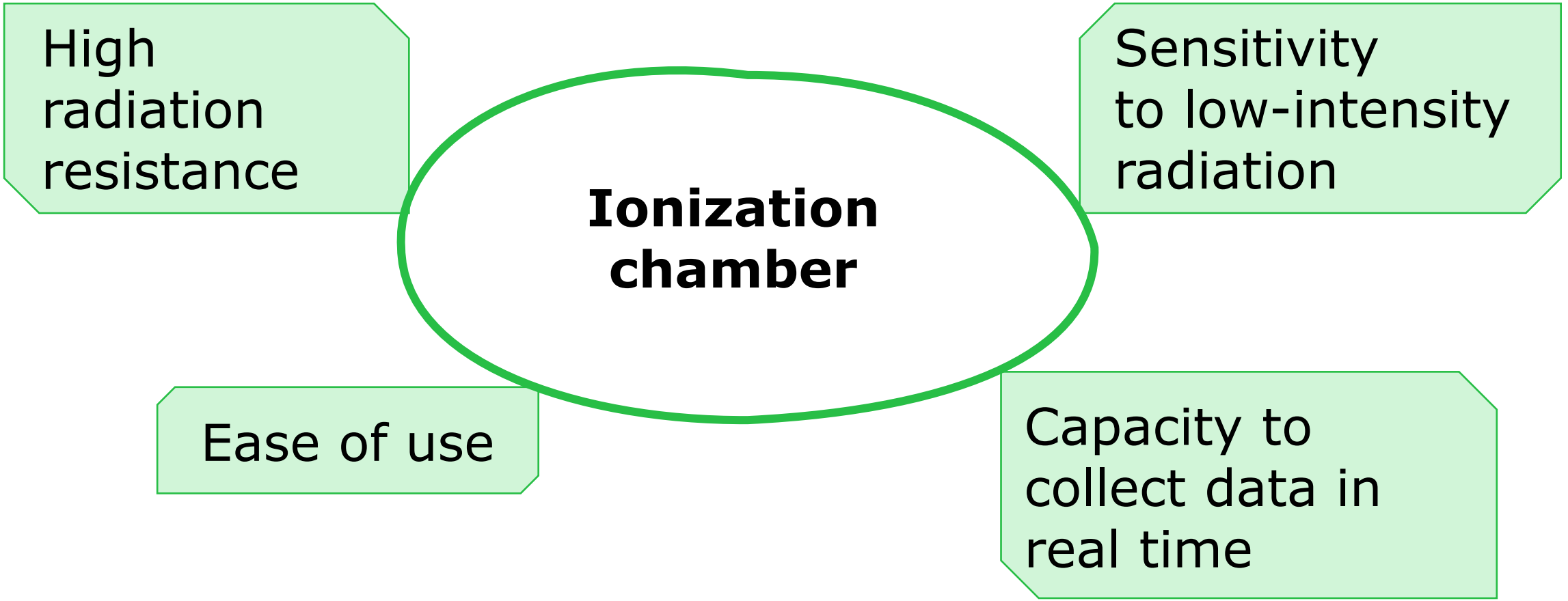


Concept of the multi-angle scanning method:
a – with one detecting element,
b – with several detecting elements.

To optimize the multi-angle scanning method, it is proposed to use an array of detecting elements (b) instead of one detecting element moving along an axis perpendicular to the beam propagation direction (a).
In this case, there is no need for sequential movement of the detecting element in the transverse plane.

*M. Banshchikova, et al., Determination of the optimal number of detectors for the multiangle wire beam scanning method // J. Instrum. 2024. V. 19. No. 09. P. C09002.

CHOICE OF THE DETECTOR FOR REALIZATION OF MULTI-ANGLE SCANNING METHOD



AIM AND OBJECTIVES

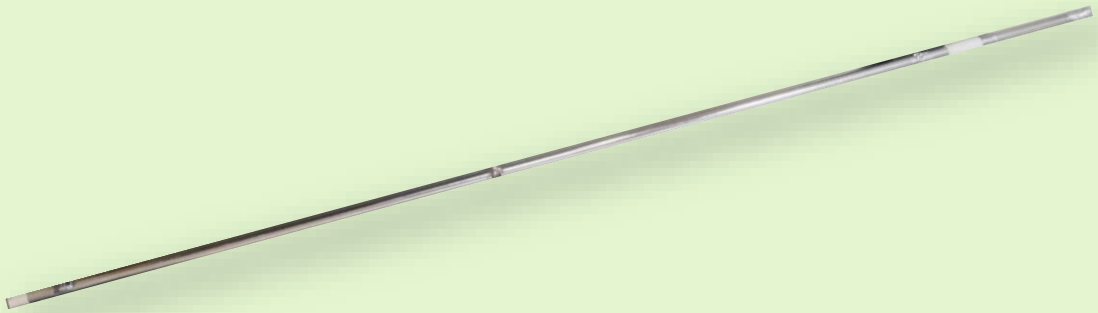
Aim of this work is to measure of the electron beam profiles by the multi-angle scanning method.

Objectives:

1. Develop of the prototype profilometer with the set of ionization chambers;
2. Conduct the experimental study on a beam of high-energy electrons in order to test the proposed method;
3. Obtain the profiles of high-energy electron beam and the transverse distributions of the electron beam intensity.

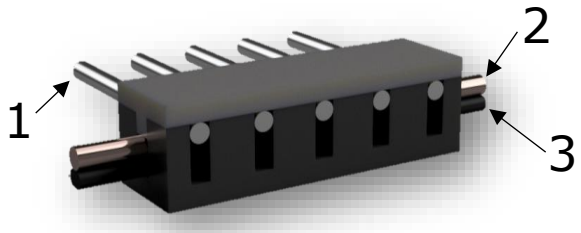
THE PRINCIPLE OF OPERATION OF THE IONIZATION CHAMBER

The ionization chamber is a metal tube with a diameter of 3 mm, inside which is located a copper thread with a diameter of 0.2 mm in air. The working volume of the chamber is accordingly 3693 mm^3. **The maximum achievable detector resolution** is determined by the diameter of the detector as d/4 and equals ~1 mm.

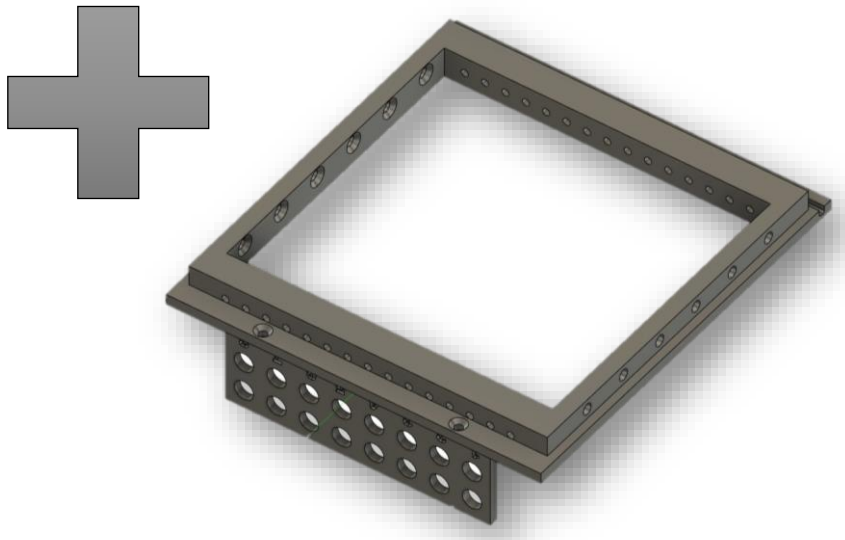


External view of the ionization chamber, inside is thin copper wire and air

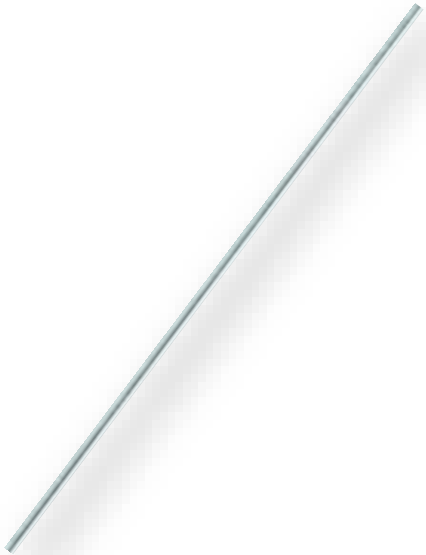
THE PROTOTYPE PROFILOMETER DESIGN



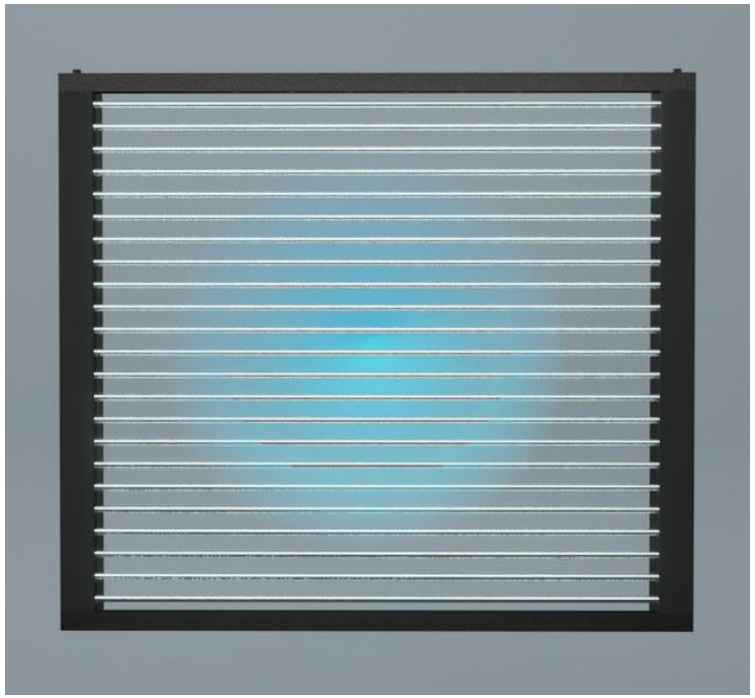
Clamp of ionization chambers in the frame: 1 – chamber, 2 – copper wire, 3 – rubber gasket



3D model of the frame

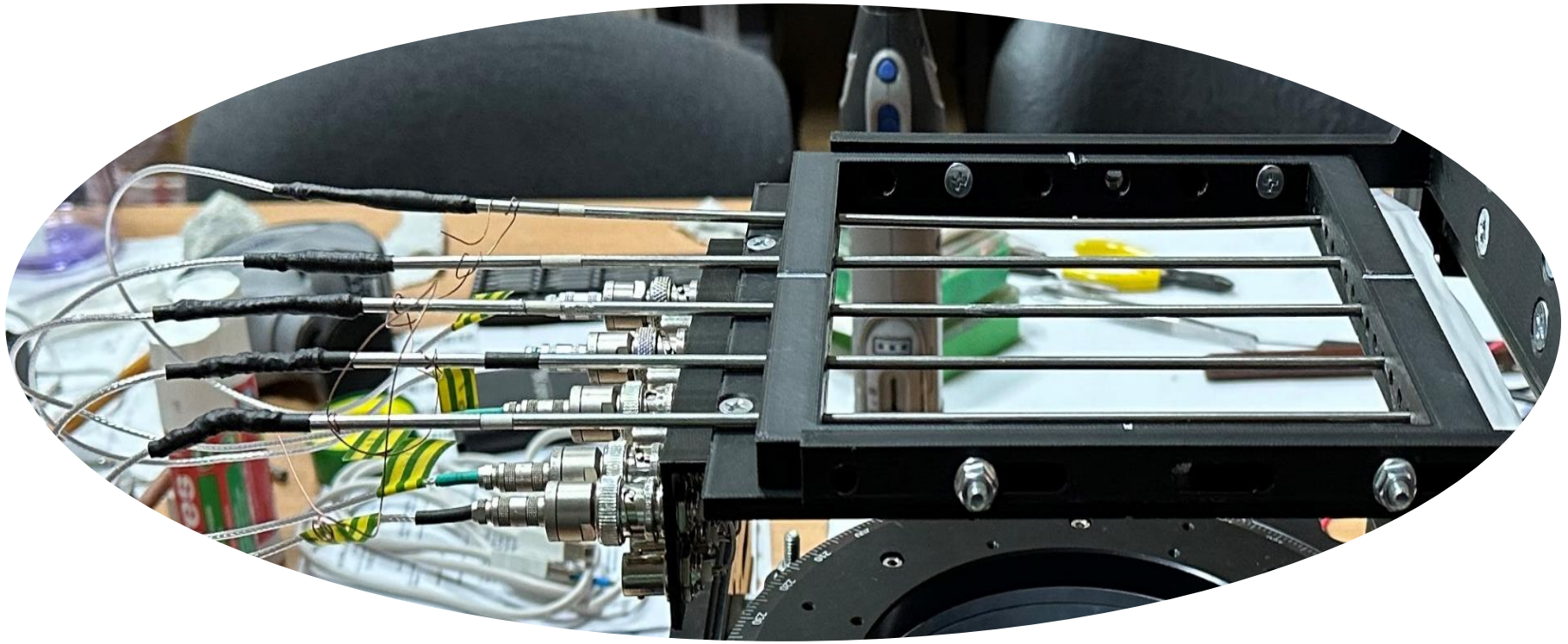


The ionization chamber



3D model of the profilometer prototype

THE PROTOTYPE PROFILOMETER DESIGN

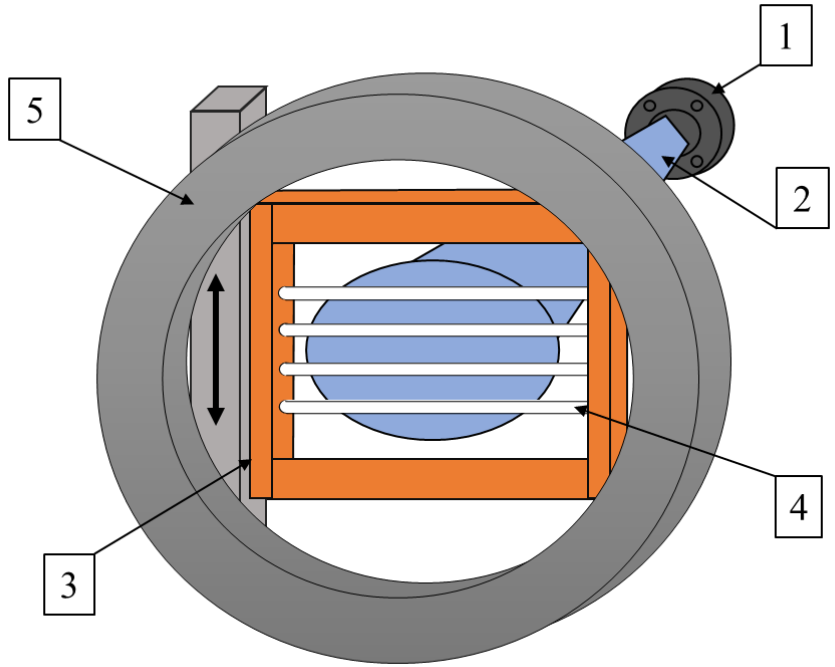


External appearance of the profilometer prototype

EXPERIMENTAL STUDY ON ELECTRON BEAM

The experiment was conducted on the MT-25 microtron, located in the Laboratory of Nuclear Reactions (JINR).

Parameter of experimental study	**Value**		
Electron energy	7 MeV		
Average beam current	0,5 μA		
Frequency	380 Hz		
The distance between the accelerator output window and the detector	125 mm	320 mm	420 mm
Output window	Be, 200 μm		
Detector offset step	1 mm		
Distance between detectors	10 mm		
Offset length	45 mm	120 mm	120 mm



Scheme of the experimental setup: 1 – output window of the MT-25 microtron, 2 – electron beam, 3 – prototype profilometer, 4 – detectors (ionization chambers), 5 – rotation device

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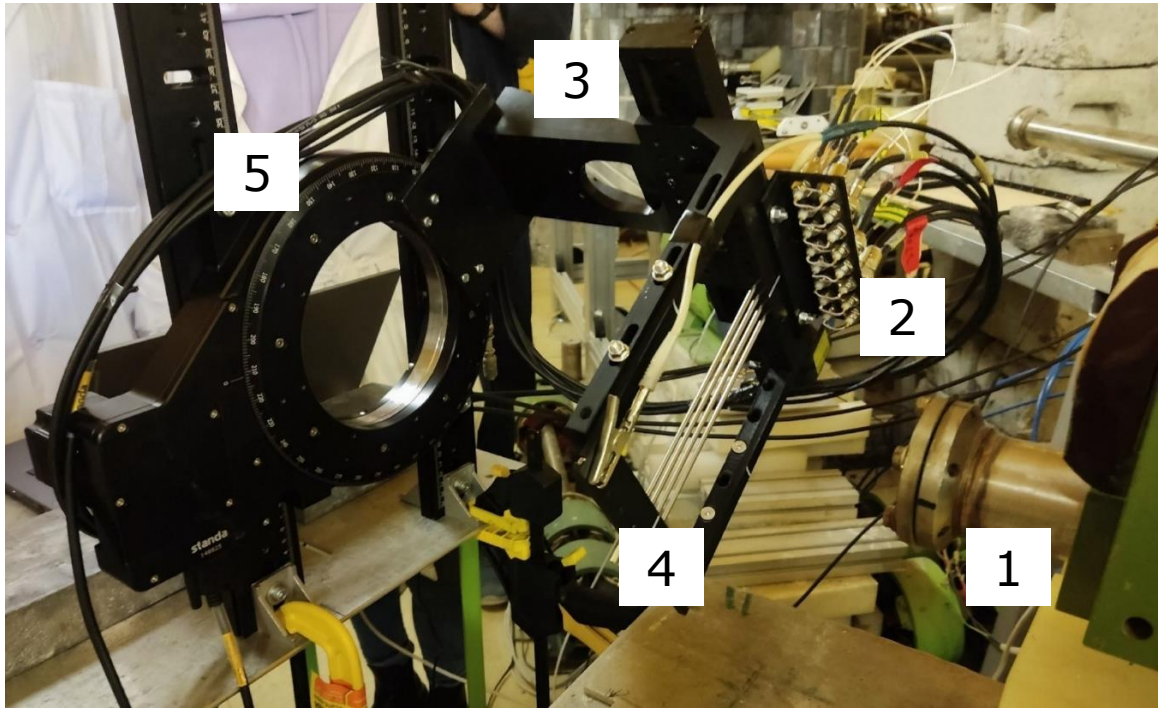
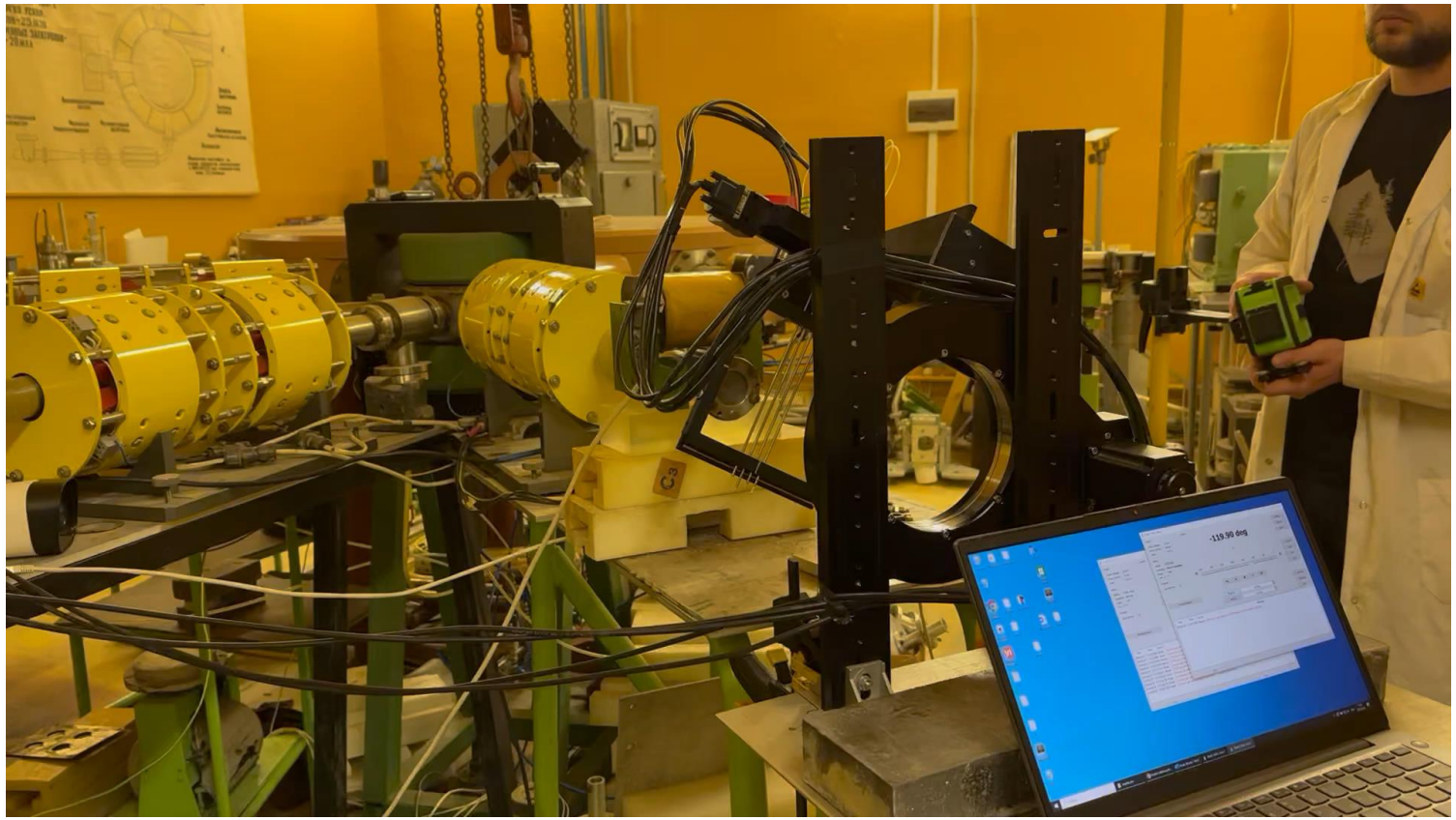


External view of the experimental setup:
1 – output window of the MT-25 microtron,
2 – prototype profilometer, 3 – linear translator,
4 – detectors (ionization chambers), 5 – rotation device

EXPERIMENTAL STUDY ON ELECTRON BEAM



Demonstration of the operation of the multi-angle scanning method

PROCESSING OF DATA OBTAINED FROM IONIZATION CHAMBERS

DATA
(current)

Normalization of DATA

Layout of DATA into special matrix

Program Diada

Диада

Sinogram

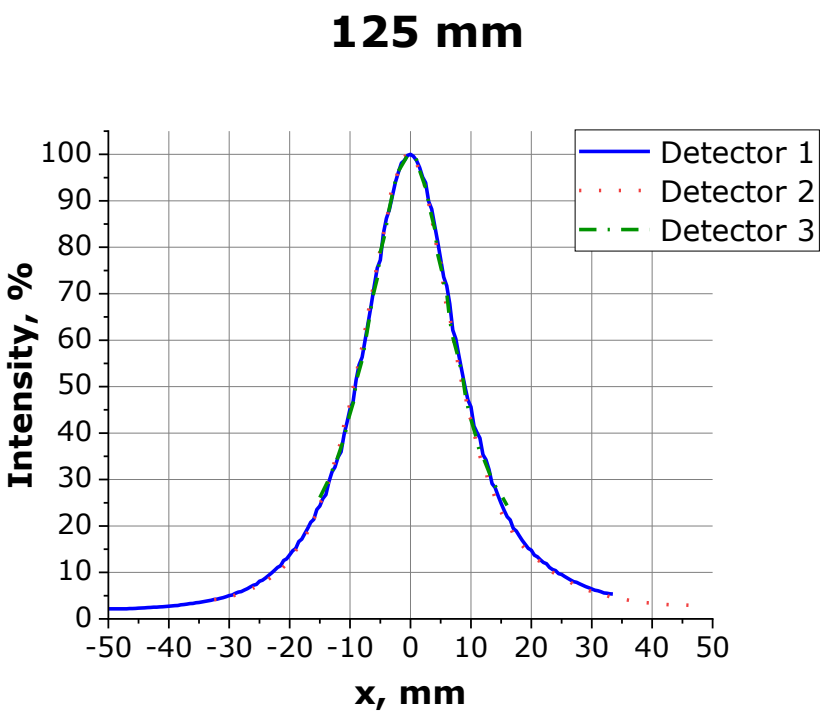
Program InkCT

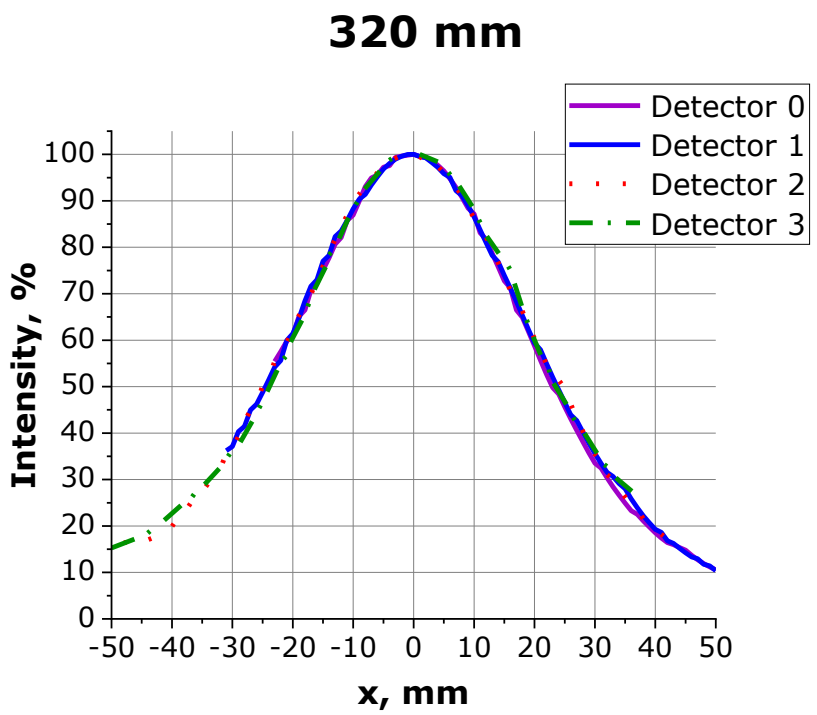
INKCT

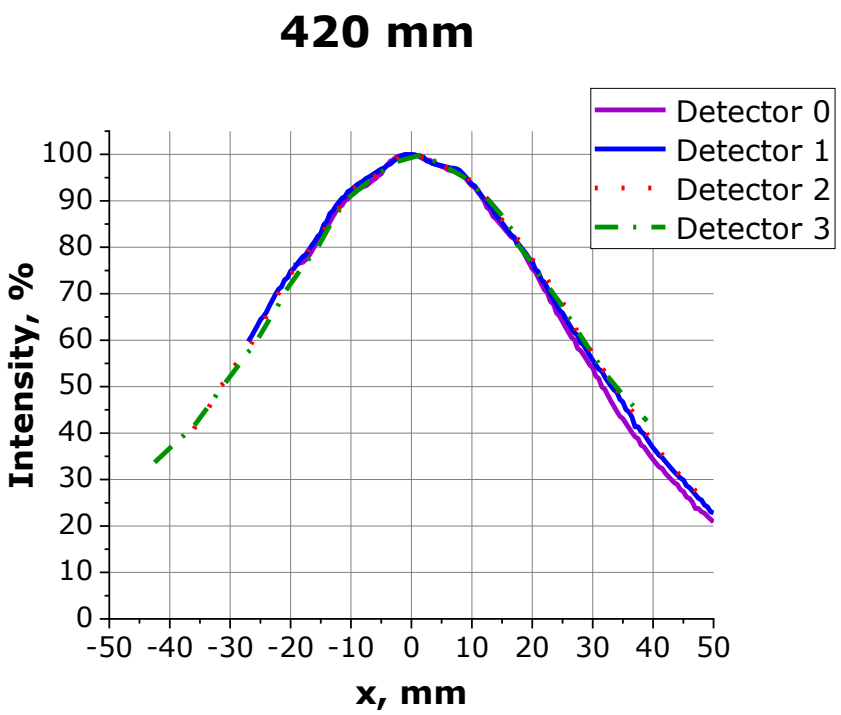
TRANSVERSE DISTRIBUTIONS OF INTENSITY

PROFILES

OBTAINED ELECTRON BEAM PROFILES FROM PROTOTYPE PROFILOMETER (CALIBRATION)

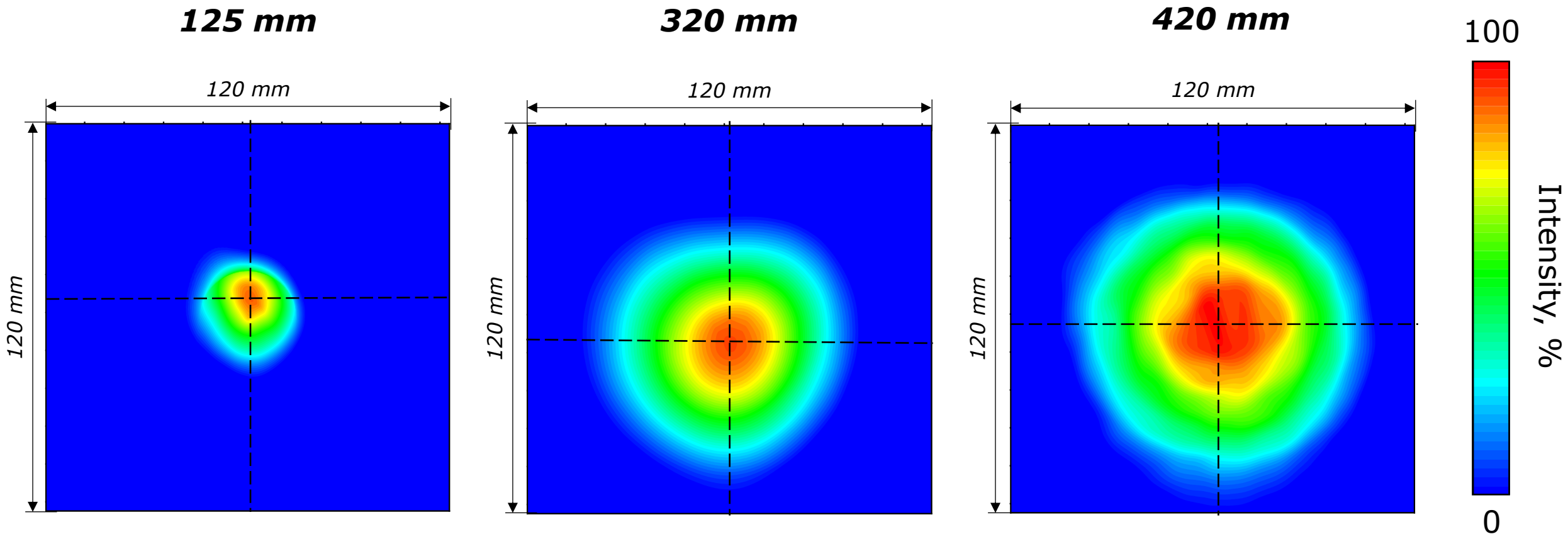






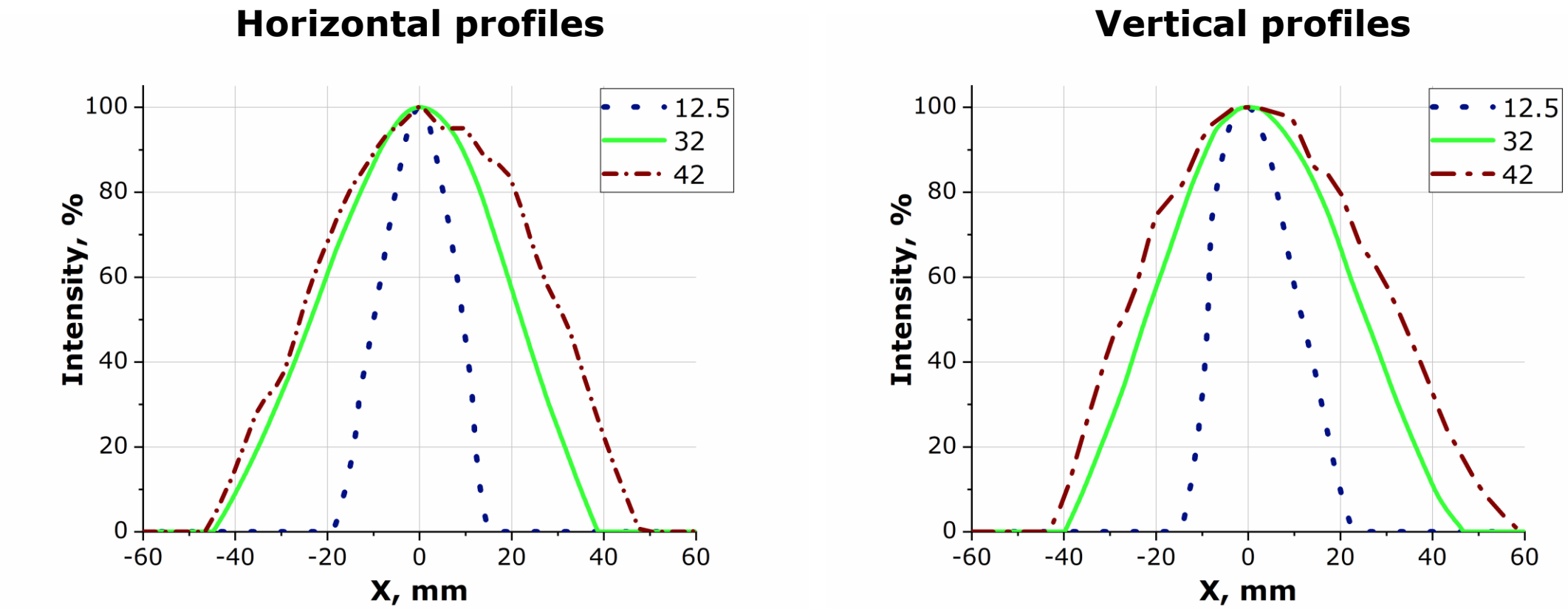
Electron beam profiles at different distances from the exit window obtained from ionization chambers

OBTAINED TRANSVERSE DISTRIBUTIONS OF THE ELECTRON BEAM INTENSITY FROM PROTOTYPE PROFILOMETER



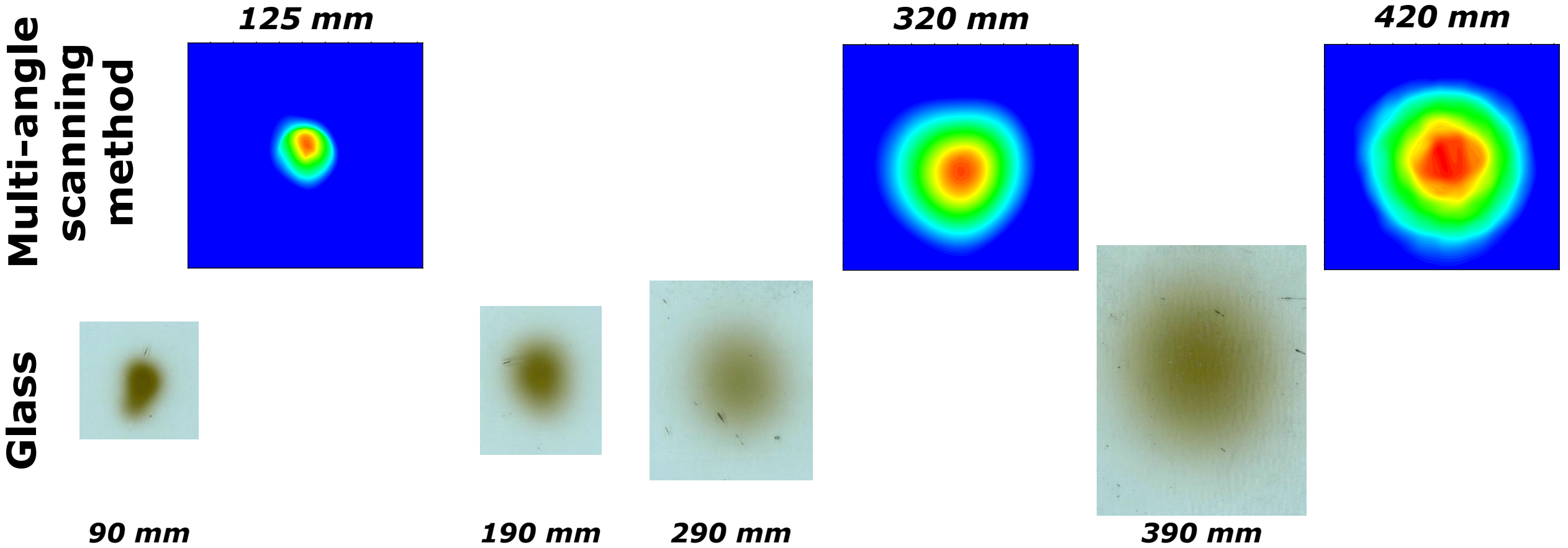
Obtained distributions of the electron beam by intensity at different distances from the accelerator output window

OBTAINED ELECTRON BEAM PROFILES FROM TRANSVERSE DISTRIBUTIONS OF INTENSITY



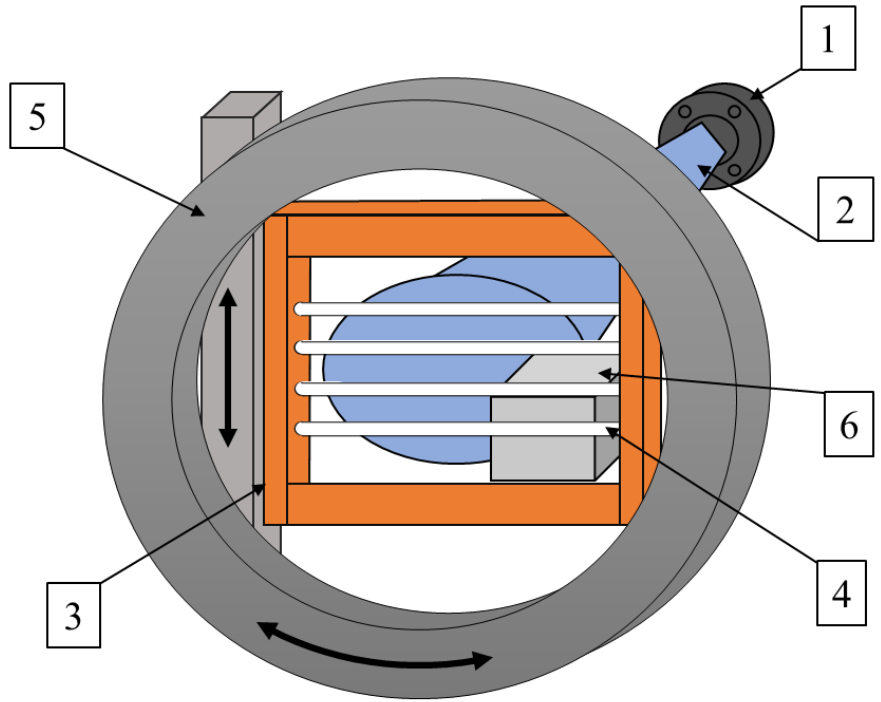
Electron beam horizontal and vertical profiles at different distances from the exit window

VISUAL ASSESSMENT OF TRANSVERSE DISTRIBUTIONS OF THE ELECTRON BEAM INTENSITY

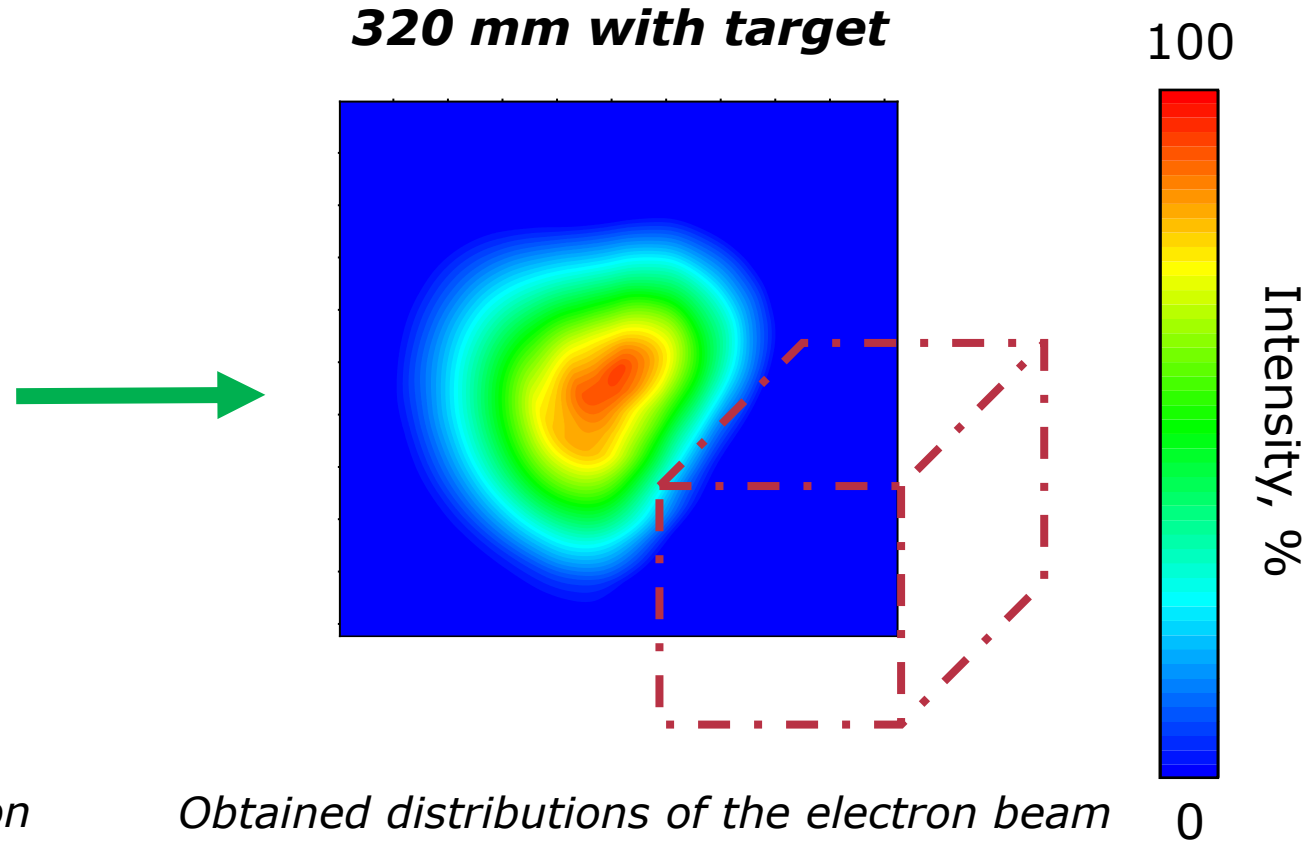


Obtained distributions of the electron beam by intensity at different distances from the accelerator output window

OBTAINED TRANSVERSE DISTRIBUTIONS OF THE ELECTRON BEAM INTENSITY FROM PROTOTYPE PROFILOMETER

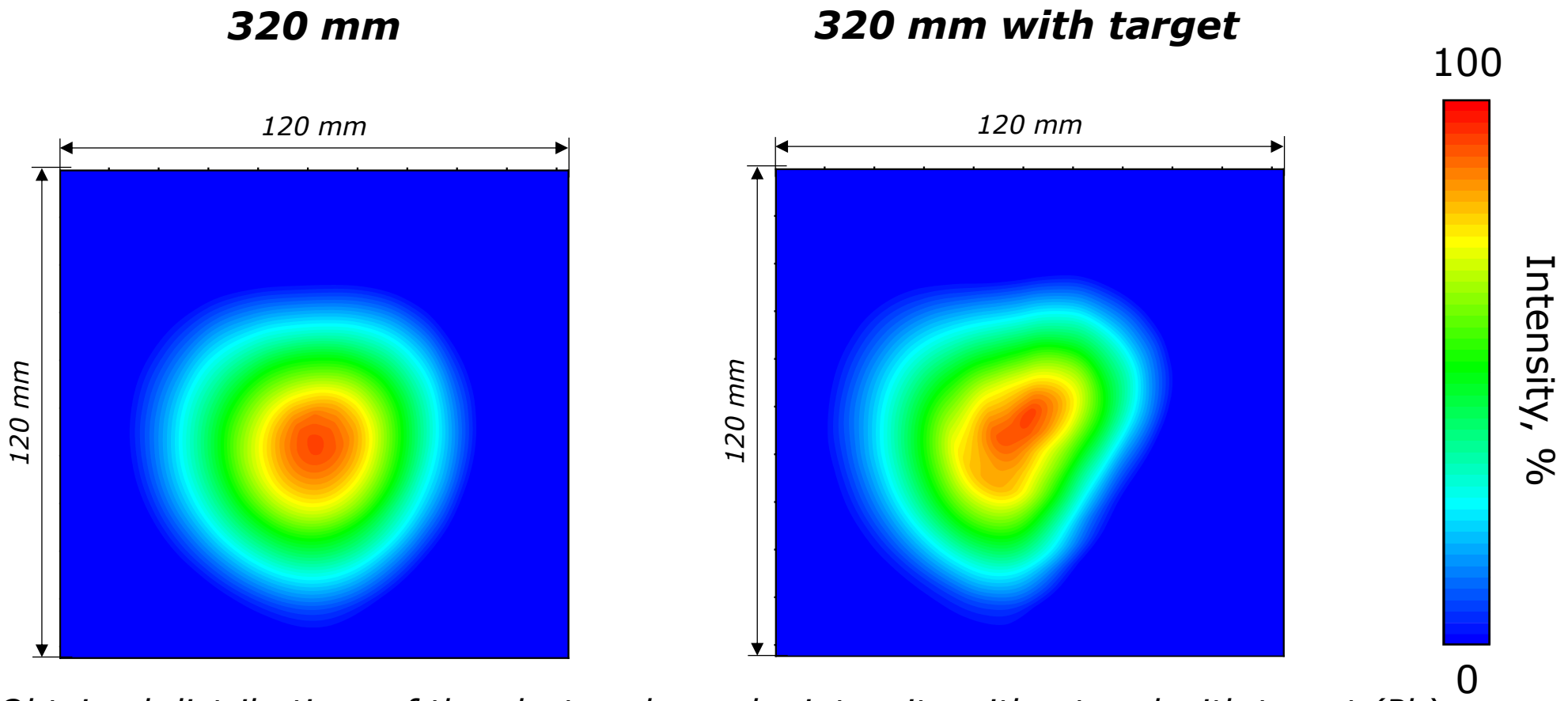


Scheme of the experimental setup with target:
1 – output window of the MT-25 microtron, 2 – electron beam, 3 – prototype profilometer, 4 – detectors (ionization chambers), 5 – rotation device, 6 – target (Pb)



Obtained distributions of the electron beam by intensity with target (Pb)

OBTAINED TRANSVERSE DISTRIBUTIONS OF THE ELECTRON BEAM INTENSITY FROM PROTOTYPE PROFILOMETER



Obtained distributions of the electron beam by intensity without and with target (Pb)

CONCLUSION

- The prototype profilometer with the set of ionization chambers was developed.
- The experimental studies conducted on the electron beam revealed that the ionization chamber is an effective tool for determining the position and measuring the size of the electron beam with high resolution (0.75 mm).
- Transverse distributions of the electron beam intensity were obtained at varying distances from the microtron output window and with target in front of output window.
- The study demonstrated the efficacy of utilizing the ionization chamber in the capacity of a detector for both the profilometer and a multi-angle scanning device.

THANK YOU FOR YOUR ATTENTION!

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