Experimental results of electron beam intensity profiles obtained by profilometer based on the multi-angle scanning method

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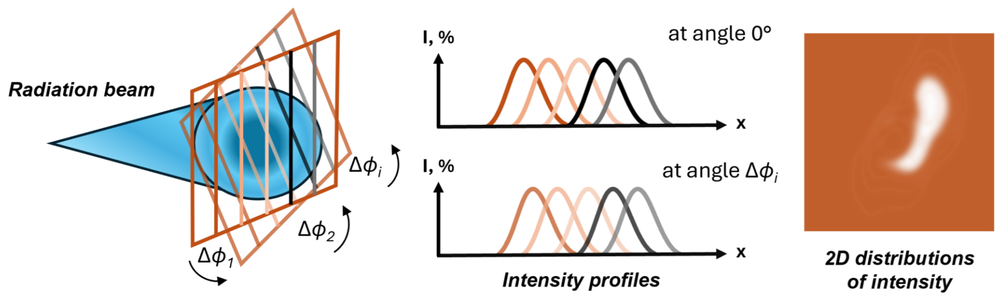
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Introduction

- Electron beams require precise transverse profile measurements for diagnostics.
- Existing methods suffer from detector degradation under high-intensity or wide-aperture beams (≥ several cm).
- Solution: ionization chambers (high radiation tolerance, real-time) + multi-angle scanning method [1] to measure transverse intensity distribution.

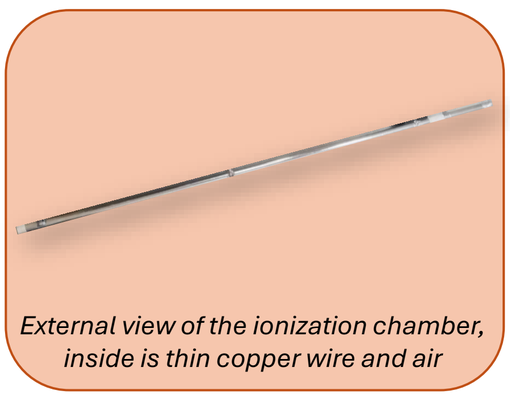
Multi-angle scanning method

- Multi-angle scanning: rotate profilometer around beam axis, capture transverse intensity distributions.
- Reconstruction: inverse Radon transform → 2D intensity map.
- Optimization: use detector array instead of single moving element → eliminates sequential transverse scanning.



The principle of operation of the ionization chamber

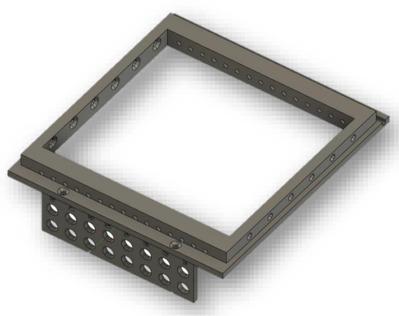
The ionization chamber is a metal tube with a 3 mm diameter, inside which is located a copper thread with a 0.2 mm diameter in air. The working volume of the chamber is accordingly 923 mm³.



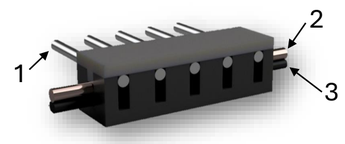
External view of the ionization chamber, inside is thin copper wire and air

The maximum achievable detector resolution is determined by the diameter of the detector as d/4 and equals 0.75 mm.

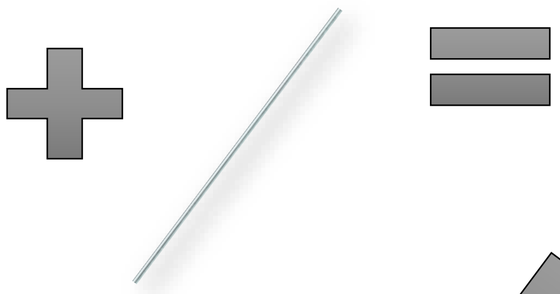
The electron beam profilometer design and appearance



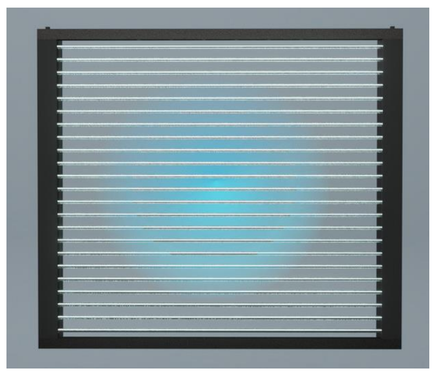
3D model of the frame



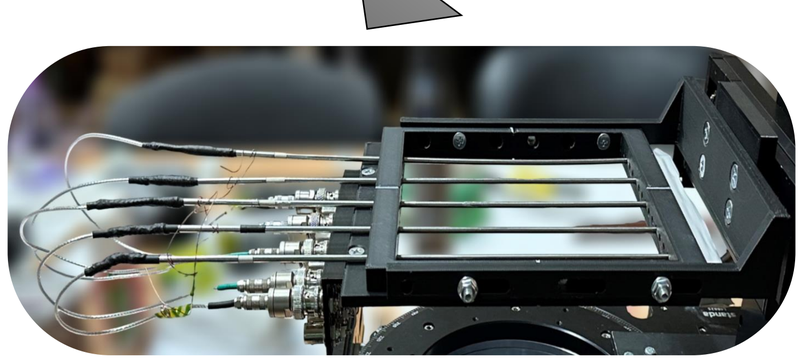
Clamp of ionization chambers in the frame: 1 – chamber, 2 – copper wire, 3 – rubber gasket



The ionization chamber



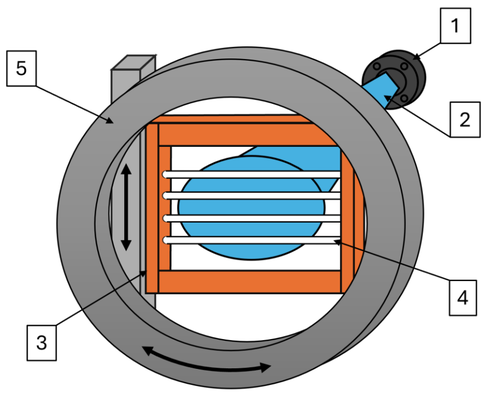
3D model of the profilometer



External appearance of the profilometer

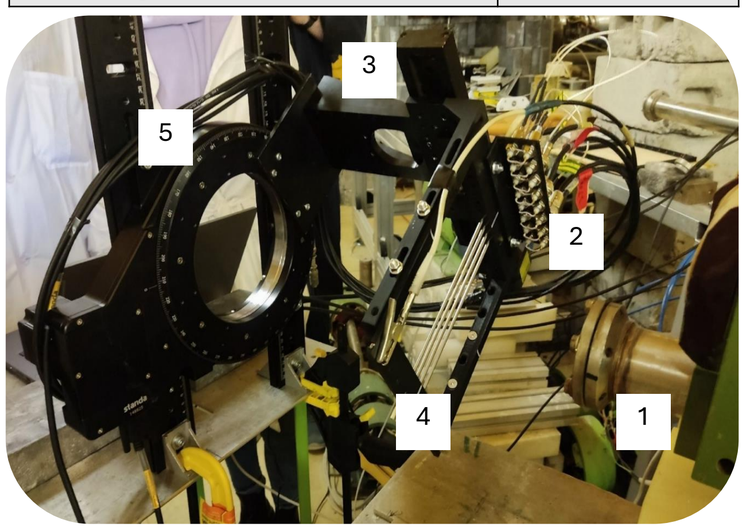
Experimental study on electron beam

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



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

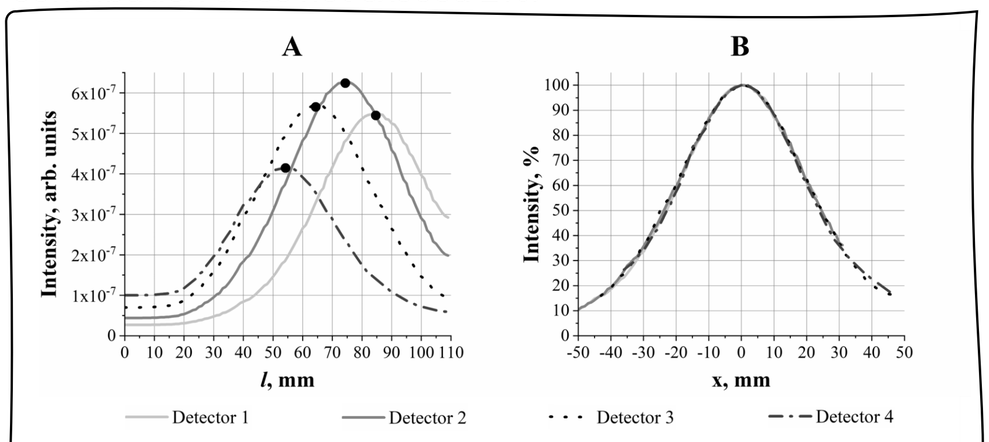
Parameter of experimental study	Value
Electron energy	7 MeV
Average beam current	0,5 μA
Frequency	380 Hz
The distance between the accelerator output window and the detector	125/320/420 mm
Output window	Be, 200 μm
Detector offset step	1 mm
Distance between detectors	10 mm
Offset length	45/120/120 mm



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

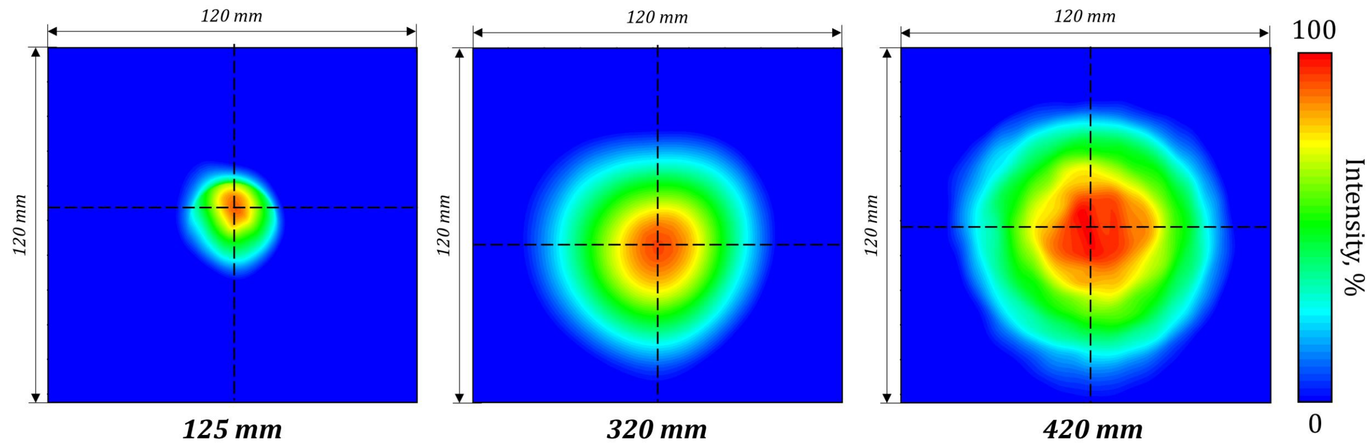
Experimental results

Beam profile measurements were performed, and calibration was performed by normalizing the signals to the maximum intensity. The profile half-width was estimated (24 mm), and it was determined that the background radiation contribution does not exceed 2%.



Electron beam profiles obtained by multi-detector system: A – without calibration coefficients (direct measurements), B – with calibration coefficients.

Using the multi-angle scanning method, the transverse distributions of the electron beam intensity were obtained at different distances from the accelerator output window by the profilometer based on the set of cylindrical ionization chambers.



The transverse distributions of the electron beam intensity at different distances from the accelerator output window obtained by the profilometer based on the set of cylindrical ionization chambers implementing the multi-angle scanning method.

- Beam shape not perfectly circular; scattering in air → becomes more Gaussian with distance from output window.
- Beam size increases with distance; divergence angle in air ≈ 8.5° (matches theory).
- Implication: For irradiations, account for beam shape, size, and divergence when choosing experimental geometry.

Conclusion

The obtained results confirm that the usage of a novel profilometer based on the set of cylindrical ionization chambers when implementing the multi-angle scanning method make it possible to record the real spatial characteristics of a given electron beam especially the transverse distributions of the electron beam intensity.

This study demonstrates the feasibility of a multi-detector system for high-energy electron beam diagnostics via the multi-angle scanning method.

Upcoming

In this regard, it is planned to increase the number of detectors in the multi-channel system to 16 in the future and conduct similar experimental studies.

Acknowledgments

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References

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64th meeting of the PAC for Particle Physics