

Advanced Technologies: An optimized compact microbeam source for preclinical studies

F. Treibel^{1,2,3}, J.J. Wilkens^{1,3}, S.E. Combs^{1,2}, S. Bartzsch^{1,2}

¹ Technical University of Munich, School of Medicine, Klinikum rechts der Isar, Department of Radiation Oncology, Munich, Germany

² Helmholtz Zentrum München, Institute of Radiation Medicine (IRM), Neuherberg, Germany

³ Technical University of Munich, Physics Department, Munich, Germany

Purpose

Microbeam Radiation Therapy (MRT) spatially fractionates dose in arrays of 50-100 μm wide X-ray microbeams. In preclinical research, MRT has demonstrated impressive normal tissue tolerance and excellent tumor control. However, the specific requirements of MRT such as high dose rates and low beam divergence are currently only met by large synchrotrons. For preclinical in-vivo studies with MRT, we developed a compact microbeam source using the research platforms XenX and SARRP from Xstrahl.

Materials and Methods

A tungsten collimator forms the microbeam field in a source distance of 212 mm. Tilted slits account for beam divergence. A movable plate placed between two fixed plates provides variable slit widths between 0 and 100 μm and a center-to-center distance of 400 μm .

Monte-Carlo simulations in Geant4 guided the development of the experimental setup and optimized PVDR, peak dose rate and beam penumbras. A main focus was set on analyzing the impact of the slit widths and the collimator position relative to the source. Moreover, the beam emission angle under which the collimator sees the anode surface was decreased by collimator rotation to reduce the projected focal spot size. The experimental setup was benchmarked with radiochromic film dosimetry.

Results and Discussion

The collimator system was successfully set up and is currently in use for in-vitro experiments. Variation of the slit width with a precision of 1 μm and positioning of the collimator with 100 μm accuracy provide high reproducibility of the beam parameters.

For 50 μm slit width, peak dose rates of 1.41 and 0.74 Gy/min were achieved for 1 and 20 mm depth in PMMA. Apart from small deviations caused by manufacturing inaccuracies, the peak dose is constant across the radiation field. For a reduction of the beam emission angle from 20° to 12°, the simulations predicted an improvement in peak dose rate and PVDR of 17% and 13% in 2 cm depth, respectively. Experimentally, an even higher enhancement of 32% and 31% was observed.

The setup provides significant improvements in terms of field homogeneity, beam width and PVDR compared to previously investigated compact microbeam sources [1-3].

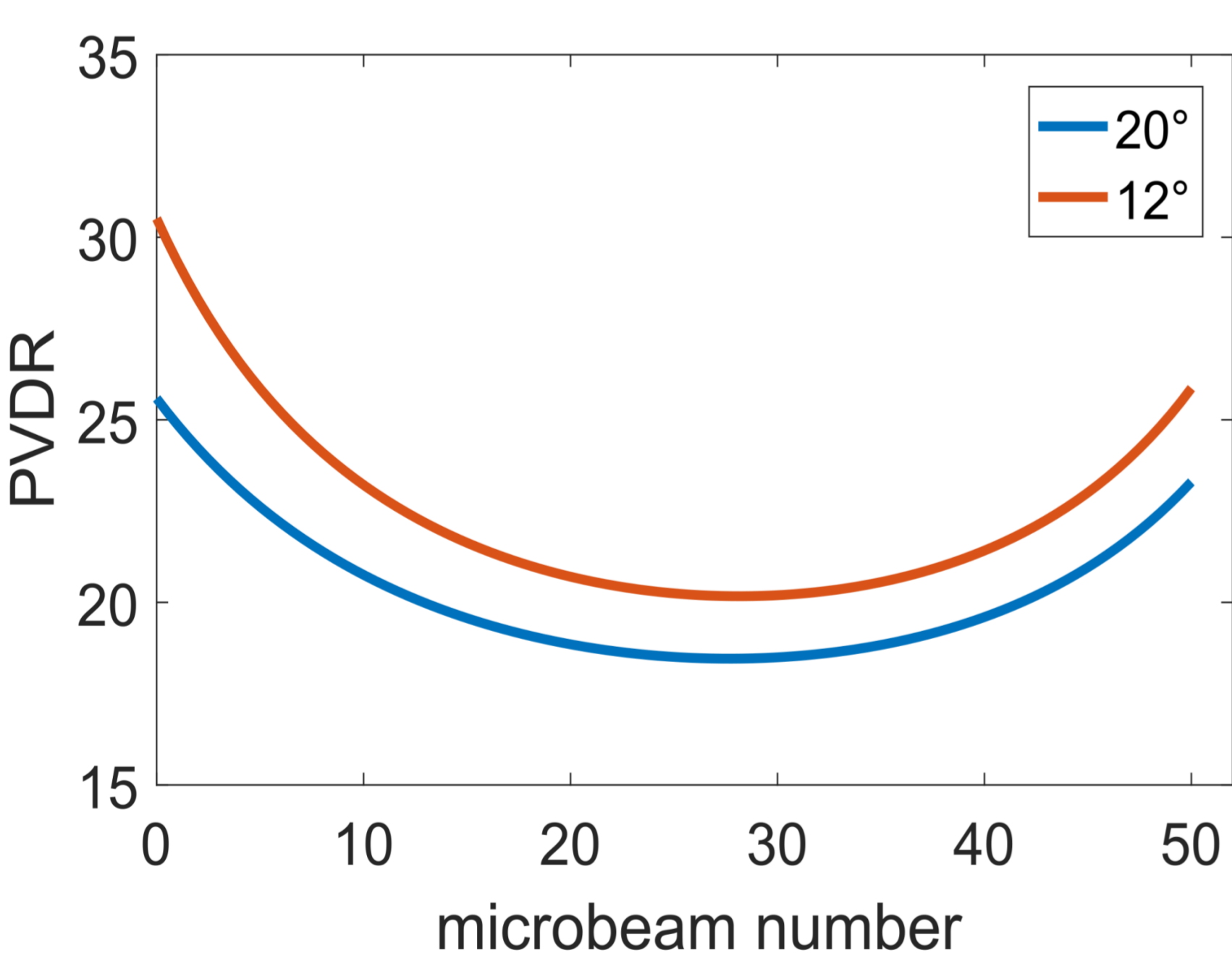


Fig 3: Impact of the beam emission angle on the PVDR in 2 cm depth for 50 μm slit width (MC).

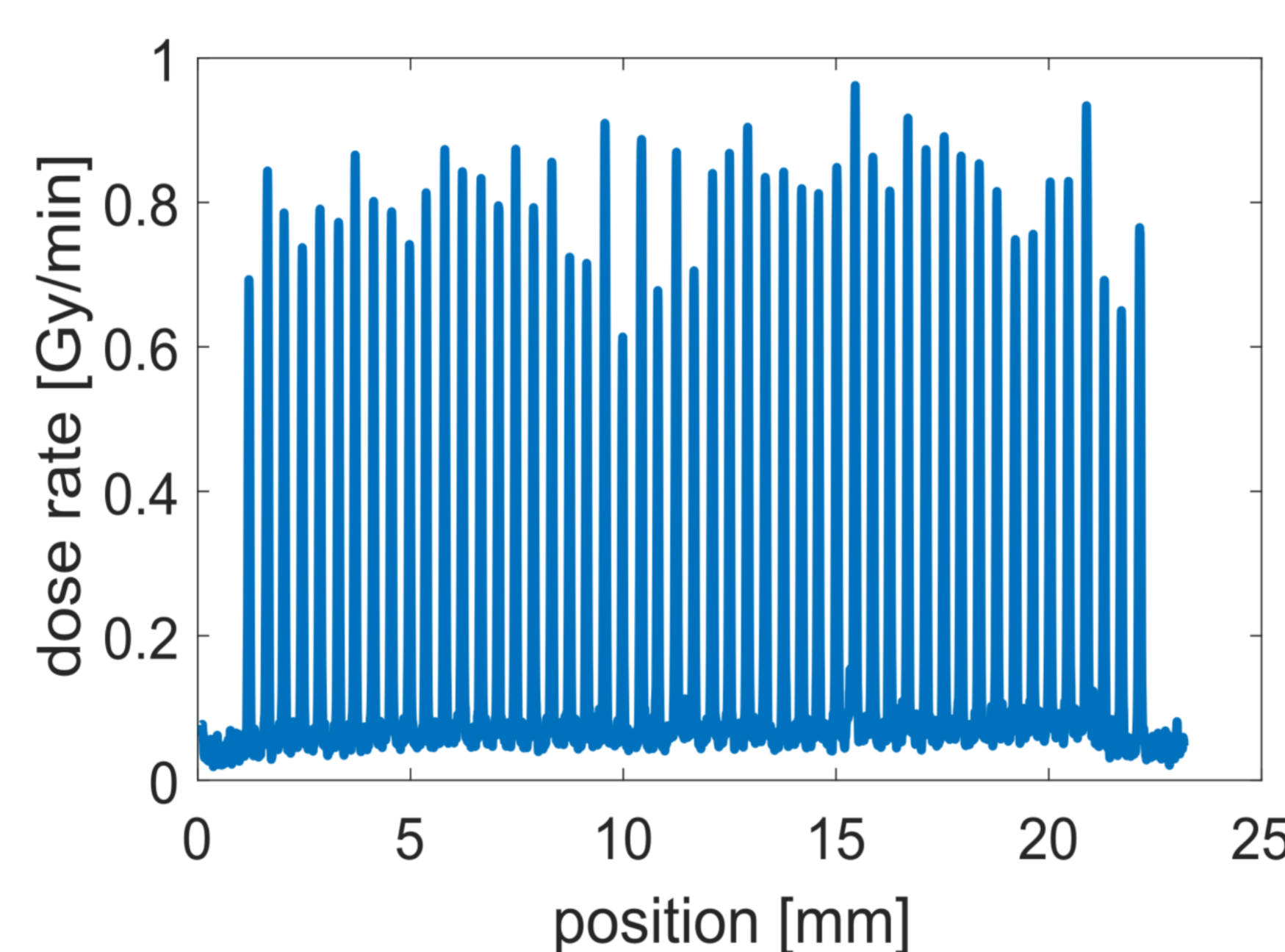


Fig 4: Microbeam profile measured by film dosimetry for 50 μm slit width.

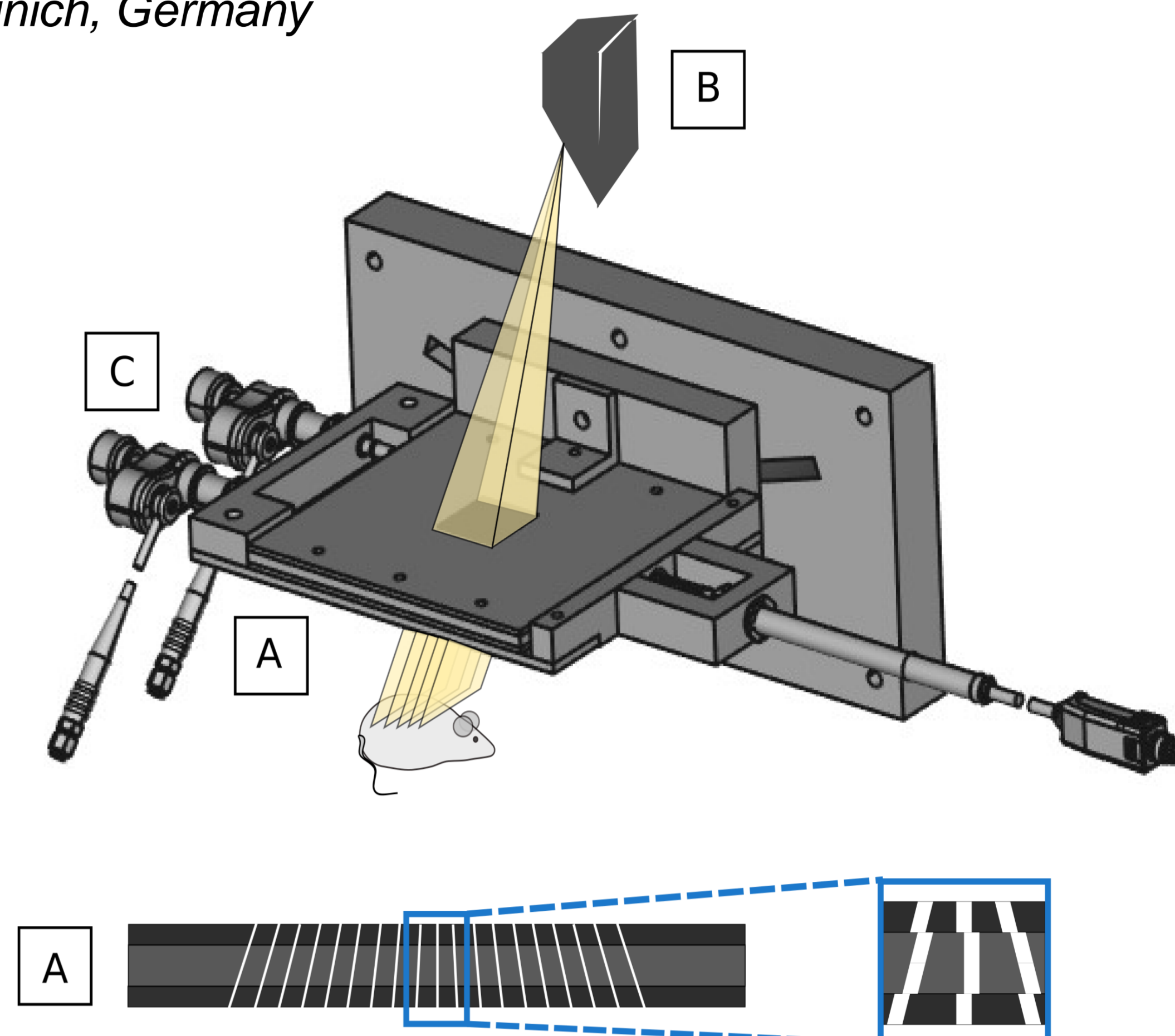


Fig 1: Schematic experimental setup. The layered collimator (A) can be pivoted around the X-ray source (B). Shifting of the middle plate by help of two piezo actuators (C) varies the slit width and tilted slits account for beam divergence.

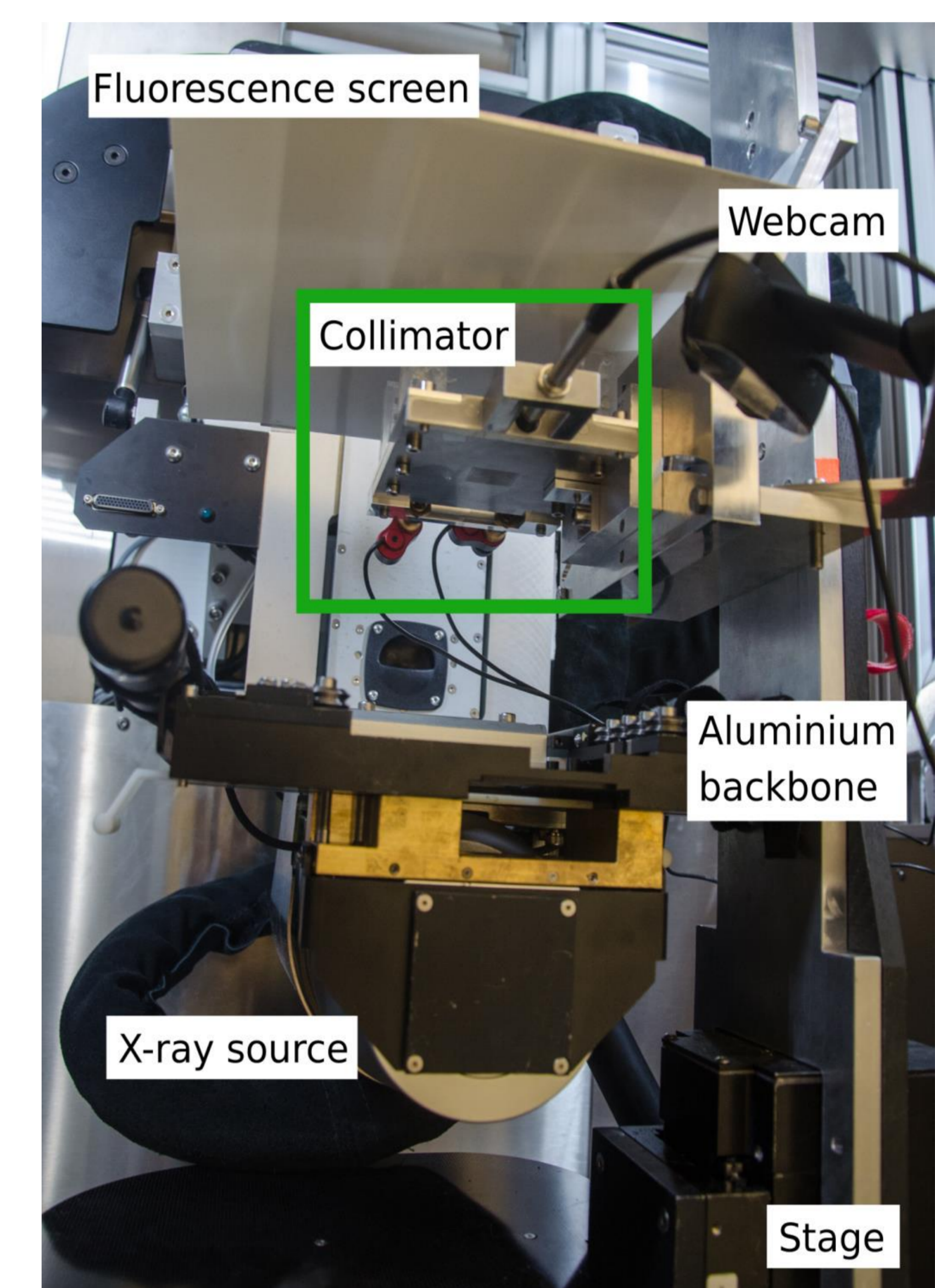


Fig 2: Integration of the setup into the XenX. The collimator is mounted to the motorized stage via an aluminum backbone. The radiation field behind the collimator is qualitatively monitored on a fluorescence screen by a webcam for calibration of the collimator position.

depth	20°		12°	
	Peak dose rate	PVDR	Peak dose rate	PVDR
1 mm	1.17 Gy/min	28	1.41 Gy/min	34
10 mm	0.83 Gy/min	18	1.09 Gy/min	25
20 mm	0.56 Gy/min	13	0.74 Gy/min	17

Table 1: Peak dose rates and PVDR measured in experiment for 50 μm slit width and emission angles of 20° and 12°.

Conclusions

Our investigations led to a compact microbeam source with reproducible radiation fields and high PVDR. Its independence of synchrotron radiation and the possibility to carry out in-vivo experiments with mice promote the establishment of preclinical microbeam therapy in clinical environment.

Future aims are the development of a treatment planning system for in-vivo irradiations and a further reduction of the beam emission angle.

Contact: f.treibel@tum.de, stefan.bartzsch@tum.de

References

- [1] M. Hadsell et al., "A first generation compact microbeam radiation therapy system based on carbon nanotube X-ray technology", *Applied Physics Letters*, vol. 103(18), 183505 (2013)
- [2] S. Bartzsch et al., "A preclinical microbeam facility with a conventional x-ray tube", *Medical Physics*, vol. 43(12), 6301-6308 (2016)
- [3] N. M. Esplen et al., "Monte-Carlo optimization of a microbeam collimator design for use on the small animal radiation research platform (SARRP)", *Phys. Med. Biol.*, vol. 63(17), 175004 (2018)