3D Dose verification of an electronic brachytherapy source with a plastic scintillation detector

Peter Georgi[a)], Gustavo Kertzscher[b)], Lars Nyvang[b)], Jaroslav Šolc[c)], Thorsten Schneider[d)], Kari Tanderup[a, b)], Jacob Graversen Johansen[a, b)]

a) Department of Clinical Medicine, Aarhus University, Aarhus, Denmark, b) Department of Oncology, Aarhus University Hospital, Aarhus, Denmark c) Czech Metrology Institute, Brno, Czech Republic, d) Department for Dosimetry and Radiation Therapy and Diagnostic Radiology, Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

DCCC Radiotherapy BiGART2021

ISSUE: Despite being considered safe and having good clinical outcome, Electronic brachytherapy (eBT) lacks standardized QA procedures. Consequently, widespread use is hampered.

SOLUTION: Provide QA methods suitable for eBT. We propose verification of the 3D dose distribution in water using plastic scintillation detectors (PSD).

WHY A PSD?: A PSD emits light when struck by radiation, giving a real-time measure of dose-rate. They can be made in any desired shape or size, enabling measurements with high spatial resolution. This is essential for eBT, where the use of very low-energetic X-rays (<100 keV) results in *very* steep dose-gradients.

WHY IN WATER?: Verification of dose to water is widely considered a vital reference for any radiation therapy modality. Solid water blocks are less suitable for eBT, because the low-energy photons react differently to solid water and water.

Credit: *This project (18NRM02 PRISM-eBT) has received funding from the EMPIR programme co-financed by the Participating States and from the European Union's Horizon 2020 research and innovation Programme.*

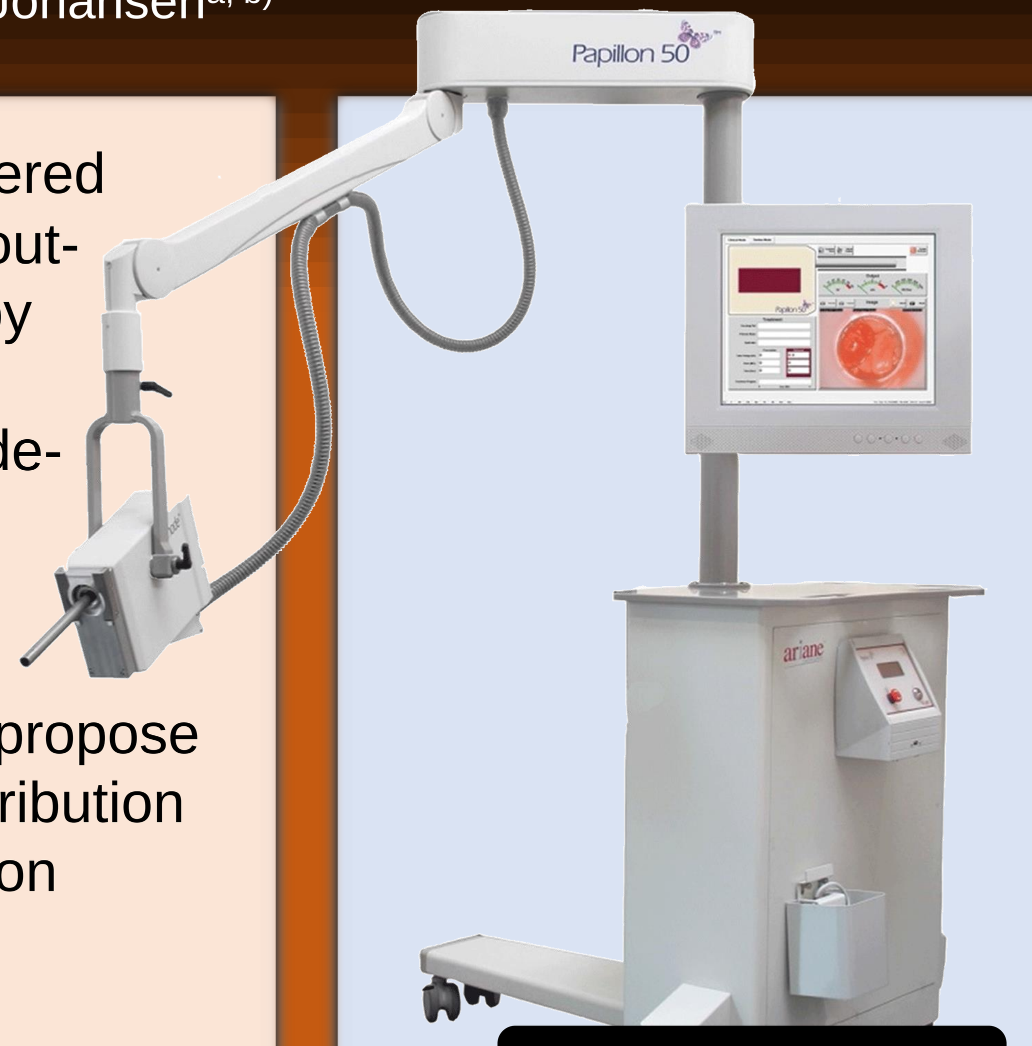

Figure 1: Papillon 50

HOW?: We used a laboratory developed PSD (fig. 2) on a high precision motorised stage in a water tank (MP3, PTW, Germany, fig. 3) to measure the 3D dose distribution of a Papillon 50 (P50) (Ariane, UK, fig. 1) eBT source. We validated the results by comparison with Monte Carlo simulations in Geant 4.

P50: The P50 is an eBT source mainly used for treating rectal, vaginal, and skin cancer (fig. 1). 50 kVp X-rays are produced in a miniature X-ray tube. Cylindrical steel applicators are placed over the tube to adjust the beam shape. We used a 25 mm diameter applicator.

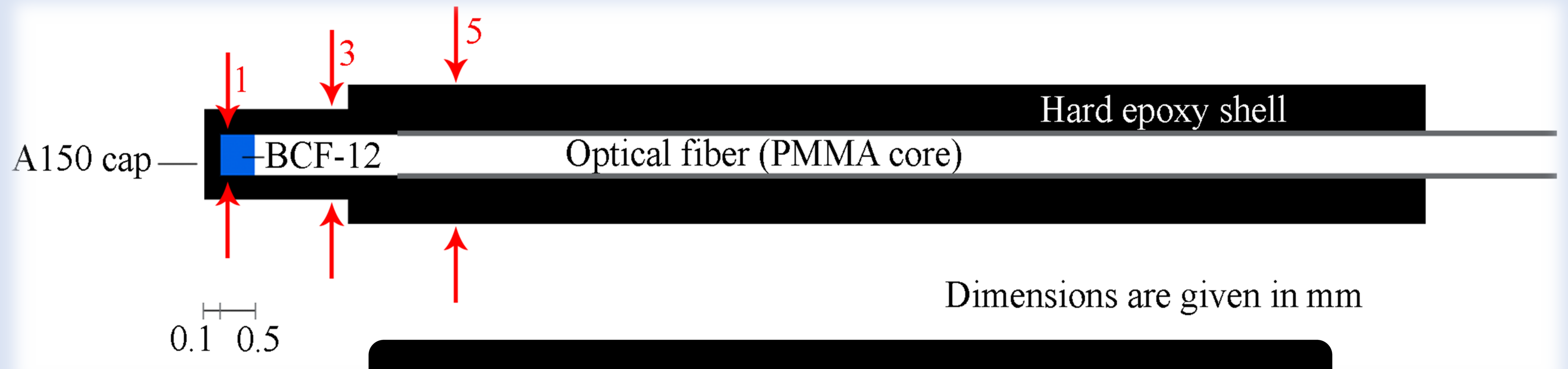

Figure 2: Plastic scintillation detector sketch

PSD: Our PSD consisted of a 1 mm diameter and 0.5 mm length BCF-12 scintillating fibre probe. The scintillation light is led via an optical fibre to a photo-multiplier tube (PMT) (H5783 SEL2, Hamamatsu). The photon induced current in the PMT was measured with an electrometer (UNIDOS Webline, PTW).

MP3 WATER PHANTOM: A large plexiglass tank with an in-built motorised stage, on which we placed the PSD probe. We mounted the P50 on the phantom as well.

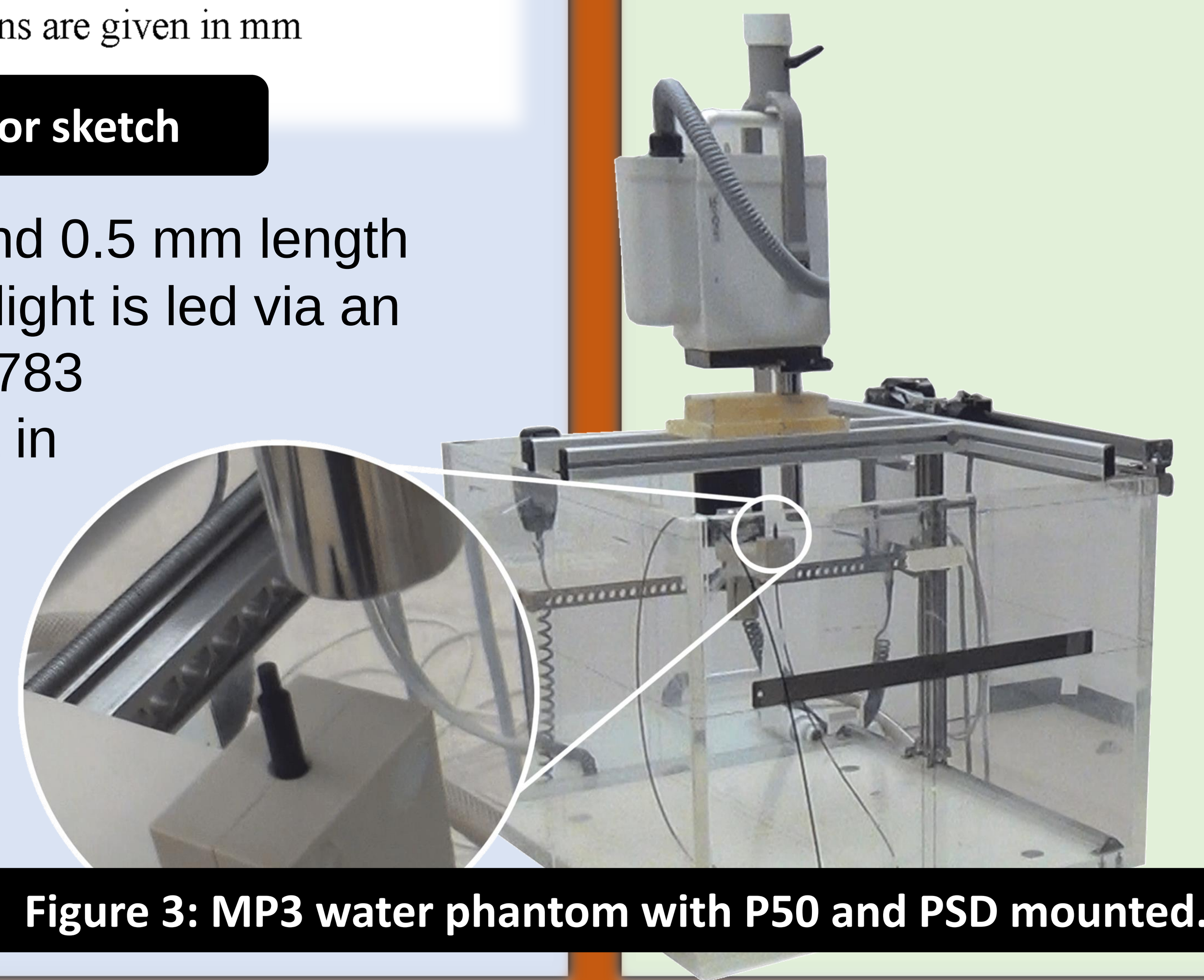

Figure 3: MP3 water phantom with P50 and PSD mounted.

RESULTS: The dose measured along the central axis of the applicator decreased quickly with increasing depth (fig. 4). A factor 2 reduction of the surface dose was observed at 7 mm depth. The MC and measured dose agreed within 2% at 36 of 38 points.

The dose measured perpendicular to the central axis was highly confined within the FWHM (fig. 5). The dose-gradients were 50%/mm at the FWHM at 5 mm depth and 15%/mm at 50 mm depth. The FWHM increased linearly with depth being slightly larger for the MC results. Dose asymmetry was measured close to the source.

CONCLUSION: The PSD and MP3 phantom offers an efficient way to measure and verify the relative 3D dose-to-water distribution of a P50 eBT source. The observed asymmetries warrant such verification. The working principle of many eBT units are similar to the P50. Thus the method could be expanded to these with relative ease. The small size of the detector can also open up for *in vivo* dosimetry.

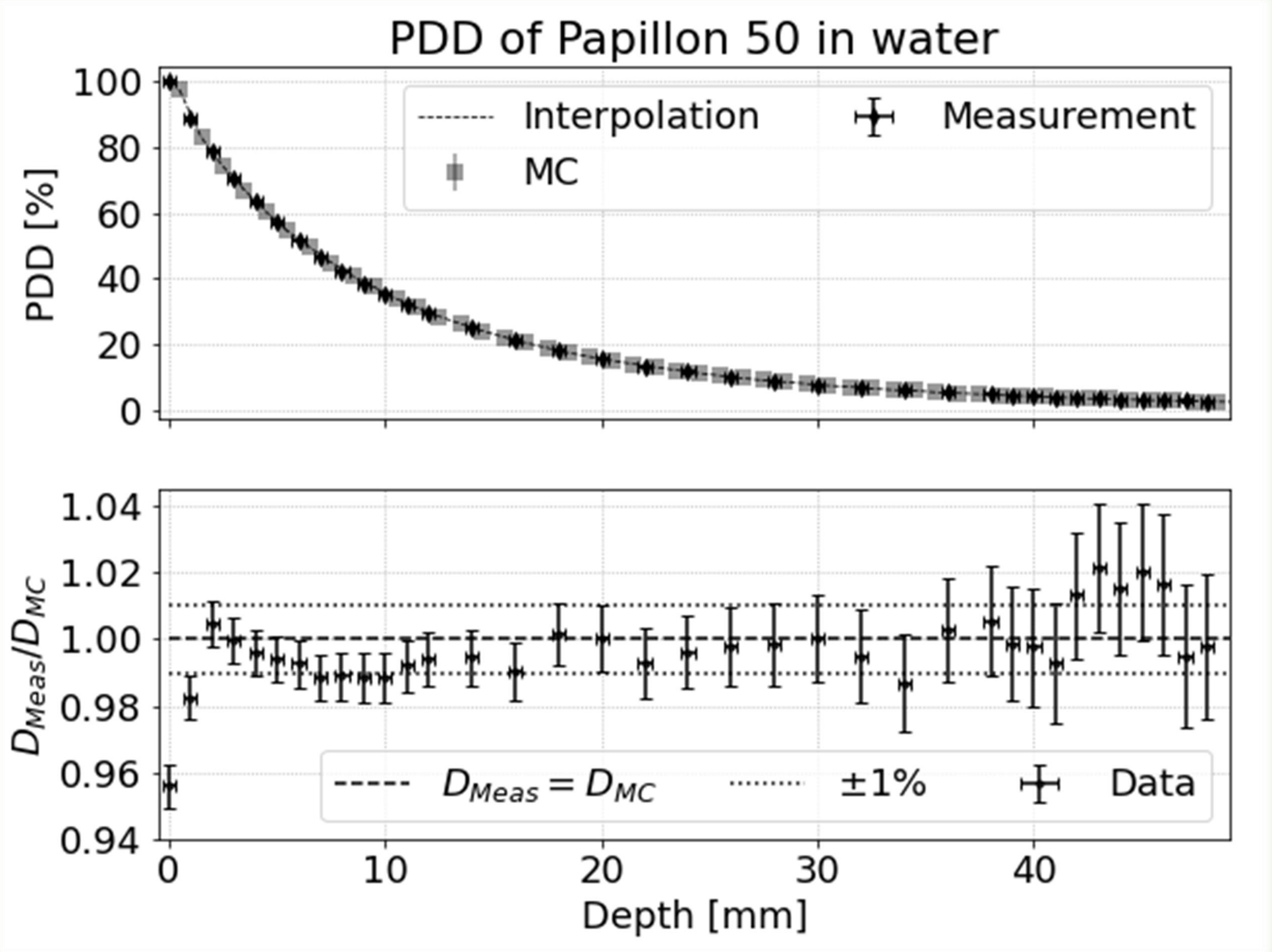

Figure 4: (top) Percentage-depth-dose curve of the P50. (bottom) Ratio of measured and MC scored dose.

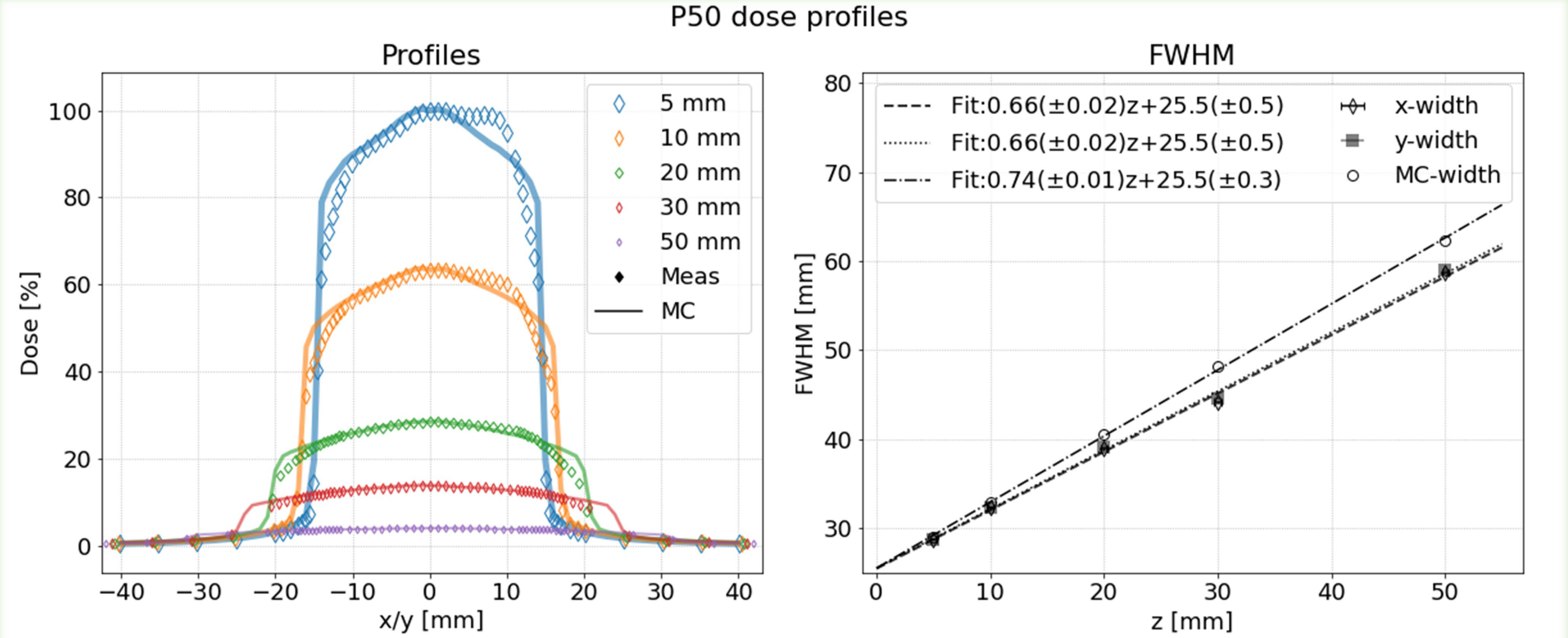

Figure 5: (left) P50 dose profiles at five depths measured as the mean value along two perpendicular axes. (Right) FWHM of the dose profiles.