

Two-Dimensional Scintillation Imaging Dosimetry for Validation of Pencil-Beam Proton Delivery from Two Matched Gantry-Mounted Synchrocyclotrons

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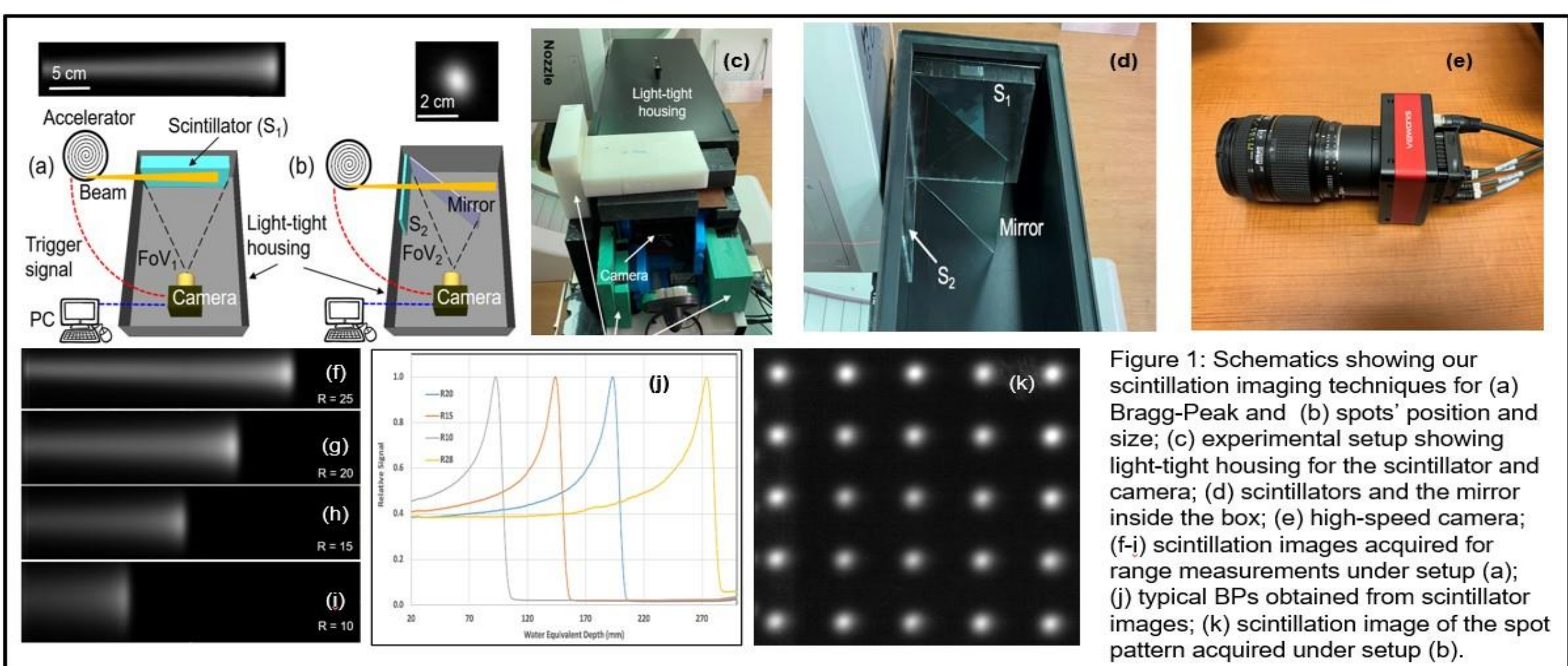
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PURPOSE / OBJECTIVES

Conventional methods for testing proton pencil-beams require multiple quality assurance tools that lacks efficiency and spatiotemporal resolutions. Here, we used our efficient ultra-high-resolution scintillation imaging system to verify that two gantry-mounted synchrocyclotrons are dosimetrically equivalent.

MATERIAL & METHODS

A high-speed CMOS-camera and two plastic scintillator blocks (BC-408) were used to acquire ultra-high-resolution scintillation images (0.08 mm/pixel) and characterize proton beams. Longitudinal dose-profiles (Bragg-Peak) obtained using a 30×30×5cm³ plastic-scintillator provided proton range (distal R90%), distal fall-off (80%-20%), and Bragg-peak widths at different peak-heights. In addition, pencil beam widths at multiple depths were extracted. Six ranges (5-28 cm) were evaluated at four airgaps (3.6, 13.6, 23.6 and 33.6 cm snout-extension). Five vertically positioned spots at Y=-9.0, -4.5, 0, +4.5 and +9.0 cm were tested. Spots' positions and widths were measured utilizing a 30×30×0.5 cm³ plastic-scintillator perpendicular to the beam direction while a 45°-mirror reflected the scintillation images onto the camera sensor. A plan consisting of 25 spots (5×5 array, 3.5 cm spot-spacing) using Rmax of 32.2cm were tested. All measurements were performed on both synchrocyclotrons, and the results were compared.



RESULTS

Thousands of images were analyzed to verify the equivalency of the two machines. Range measurements compared to those using a multi-layer-ionization chamber as well as relative comparison between the two synchrocyclotrons revealed that the measured ranges are within ±0.5 mm. Bragg-peak widths were within ±0.4 mm, distal penumbra widths (80%-20%) were within ± 0.3 mm and the pencil beam widths were within ± 0.1 mm. Spot sizes were within ± 0.4 mm, and the spots' positions were within ± 0.8 mm indicating a close agreement between both machines.

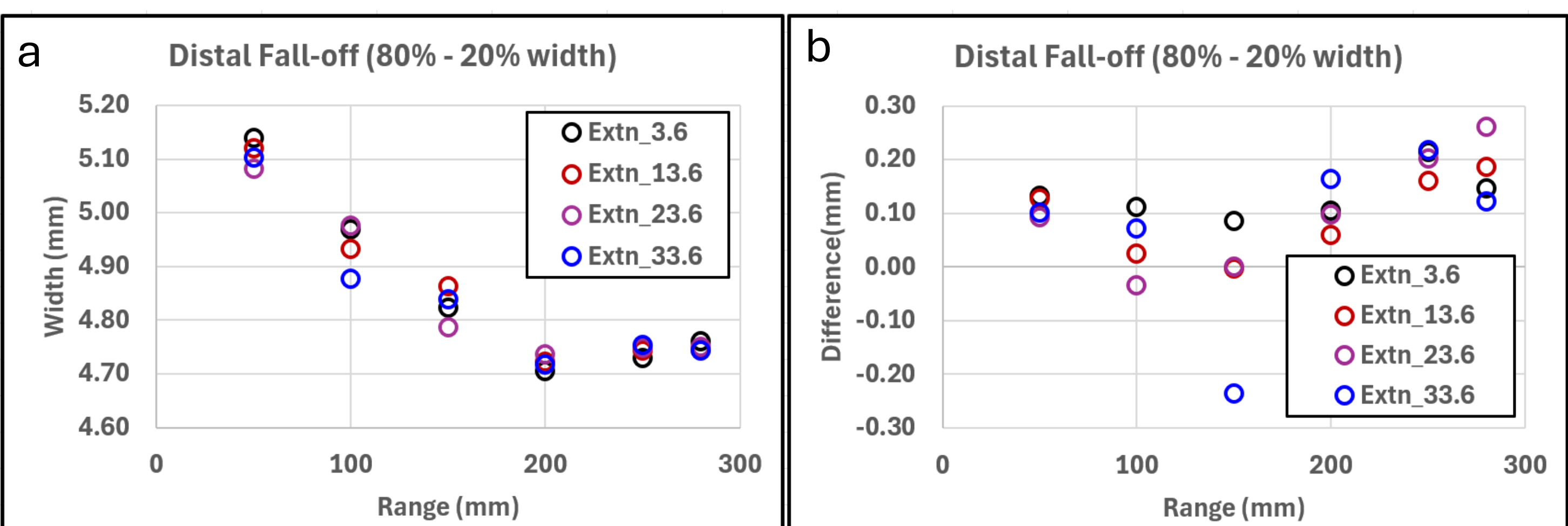


Figure 2. Distal penumbra (80% - 20%) at different air-gaps for programmed ranges from 50 mm to 280 mm; (2a) distal fall-off in mm and (2b) difference between vaults 1 and 2.

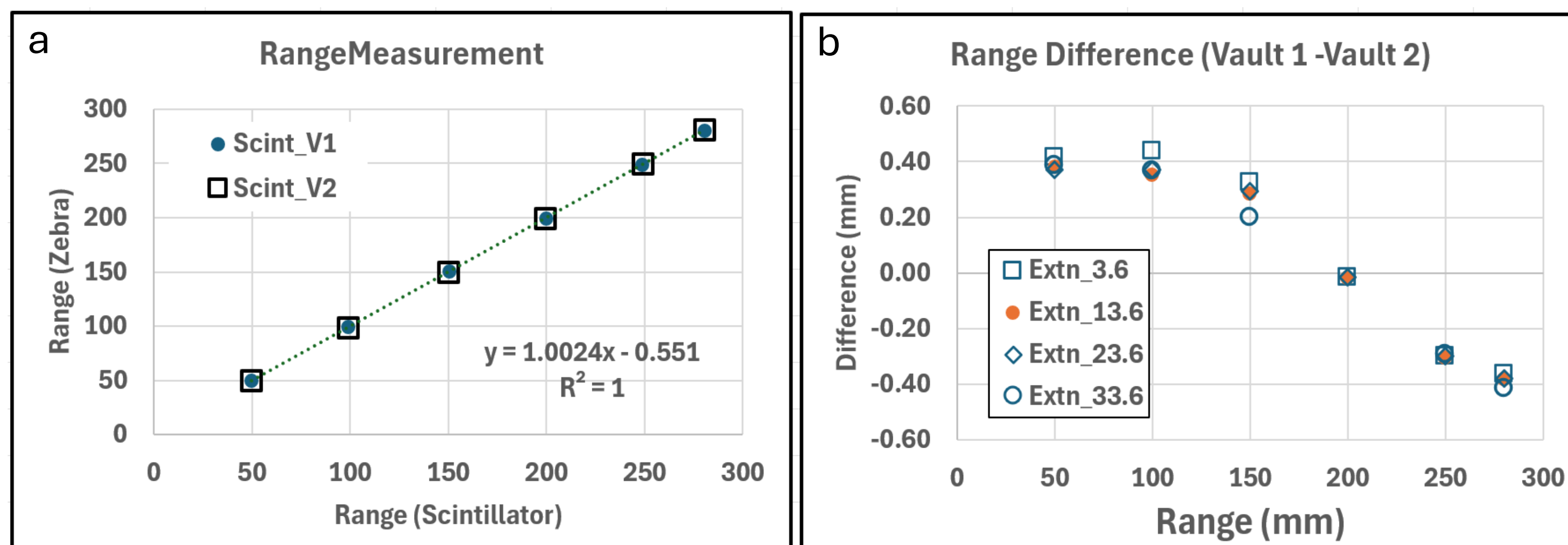


Figure 3. Ranges measured by the scintillator versus multi-layer ionization chamber (Zebra) device for 6 different beam energies; (a) scintillator vs Zebra; (b) measured difference between vaults 1 and 2.

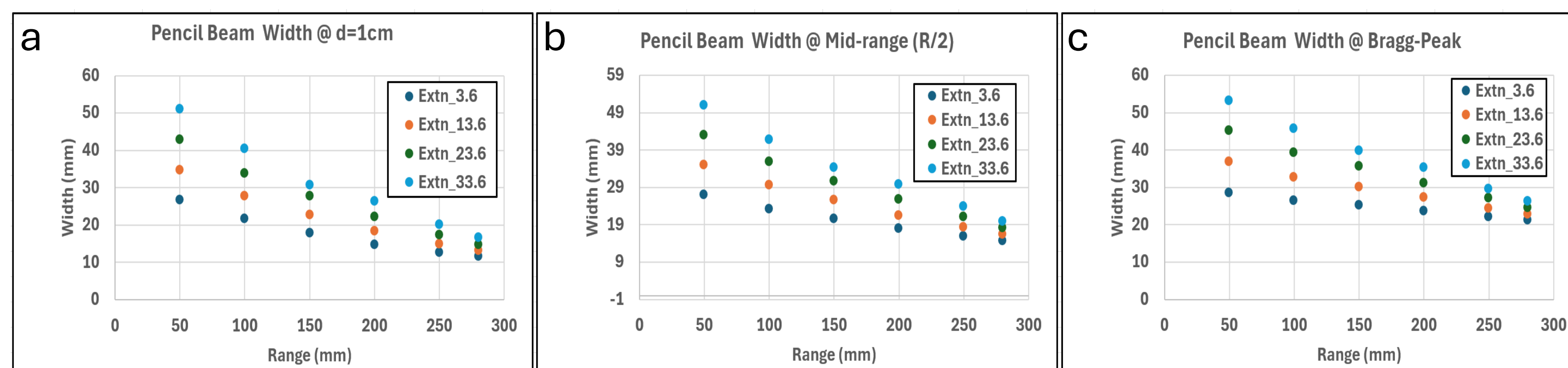


Figure 4. Pencil-beam widths (mm) in y-direction measured by the scintillator at different depth of penetration. Six different beam energies delivered at 4 different air gaps were tested; PB widths at (a) 1 cm depth; (b) half of the programmed range and (c) at Bragg-peak position.

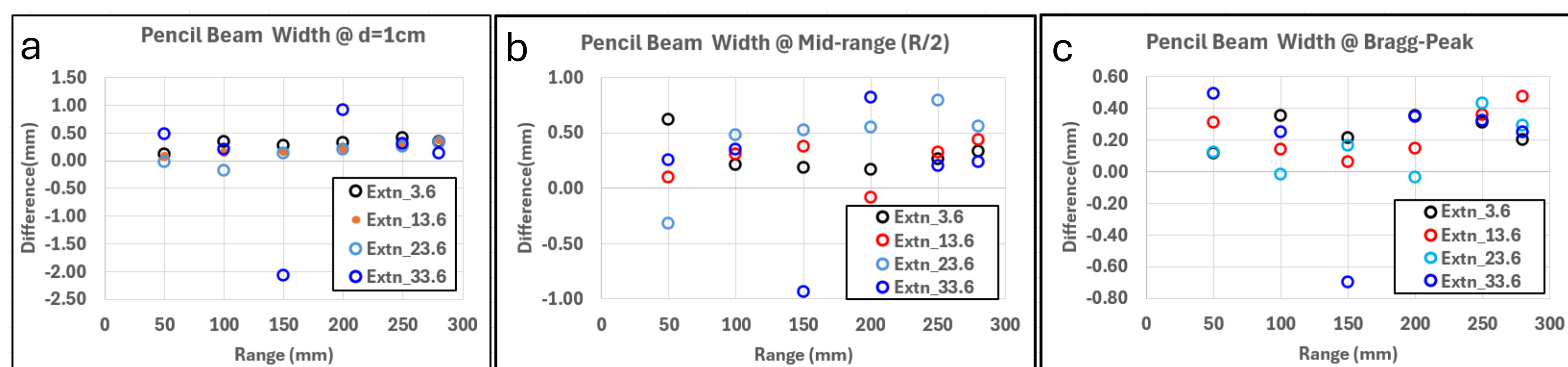


Figure 5. Pencil-beam width difference (mm) in y-direction measured by the scintillator at different depth of penetration. Six different beam energies delivered at 4 different air gaps were tested; PB widths at (a) 1 cm depth; (b) half of the programmed range and (c) at Bragg-peak position.

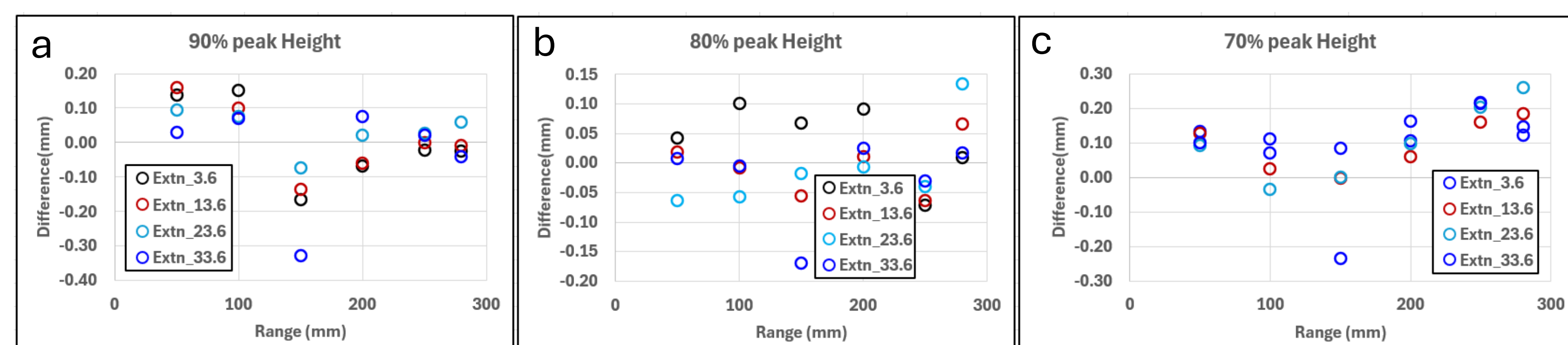


Figure 6. Bragg-peak width differences between Vault 1&2 for six different incident energy beams delivered at 4 different air gaps; (a) 90%, (b) 80% and (c) 70% of their peak heights.

SUMMARY / CONCLUSION

Scintillation imaging is highly efficient for simultaneously extracting multiple beam parameters of proton therapy pencil-beams. Traditional methods only measure one metric at a time while our scintillation-dosimetry-system allows acquisition of several beam parameters simultaneously, minimizing beam-on time on the machine.

REFERENCES

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