

1. Introduction

Purpose: Preclinical studies with small animals require precise control to yield conclusive results. Small animal irradiations differ from clinical irradiations and can push dose calculation algorithm to their limits: small volumes, small fields, superficial treatments. In vivo dosimetry can ascertain dose calculation and delivery accuracy, but a single measurement point can't detect all problems, especially in high gradients. Our purpose is thus to use a plastic scintillation dosimeter array (PSD) to control preclinical irradiation accuracy.

Animal study: An IRB-approved animal study designed to characterize the healing of skin damage following radiation treatments was used as a context for this work.

2. Method

Radiation planning and delivery: Twelve animals (6 males, 6 females) were irradiated to deliver 45-Gy to the skin using a Varian's Truebeam linac. Two tangential fields were used with a field size of 18 mm. A bolus material and special animal holder (Fig. 1) was used to achieve a uniform dose distribution. Animals were anesthetized prior to irradiation. While a single treatment plan was used for all animals, a CBCT was acquired following each irradiation to confirm the animal position and perform dose calculation a posteriori for comparison with the measured dose.

PSD detector array and in vivo monitoring: A four-point PSD array developed by Medscint and read using the Hyperscint scintillation dosimetry platform was used. Each point has a sensitive volume of 1 mm diameter by 1 mm length. The readout frequency was 1 Hz. A full PSD calibration was performed prior to the animal irradiations and consistency checks using a large uniform field were performed every 3-4 animals to make sure that the detector response did not drift. The animal holder was 3D printed with holes to receive the PSDs. Thus, measurement points were distributed around the treated area, above the isocenter (Fig. 2).

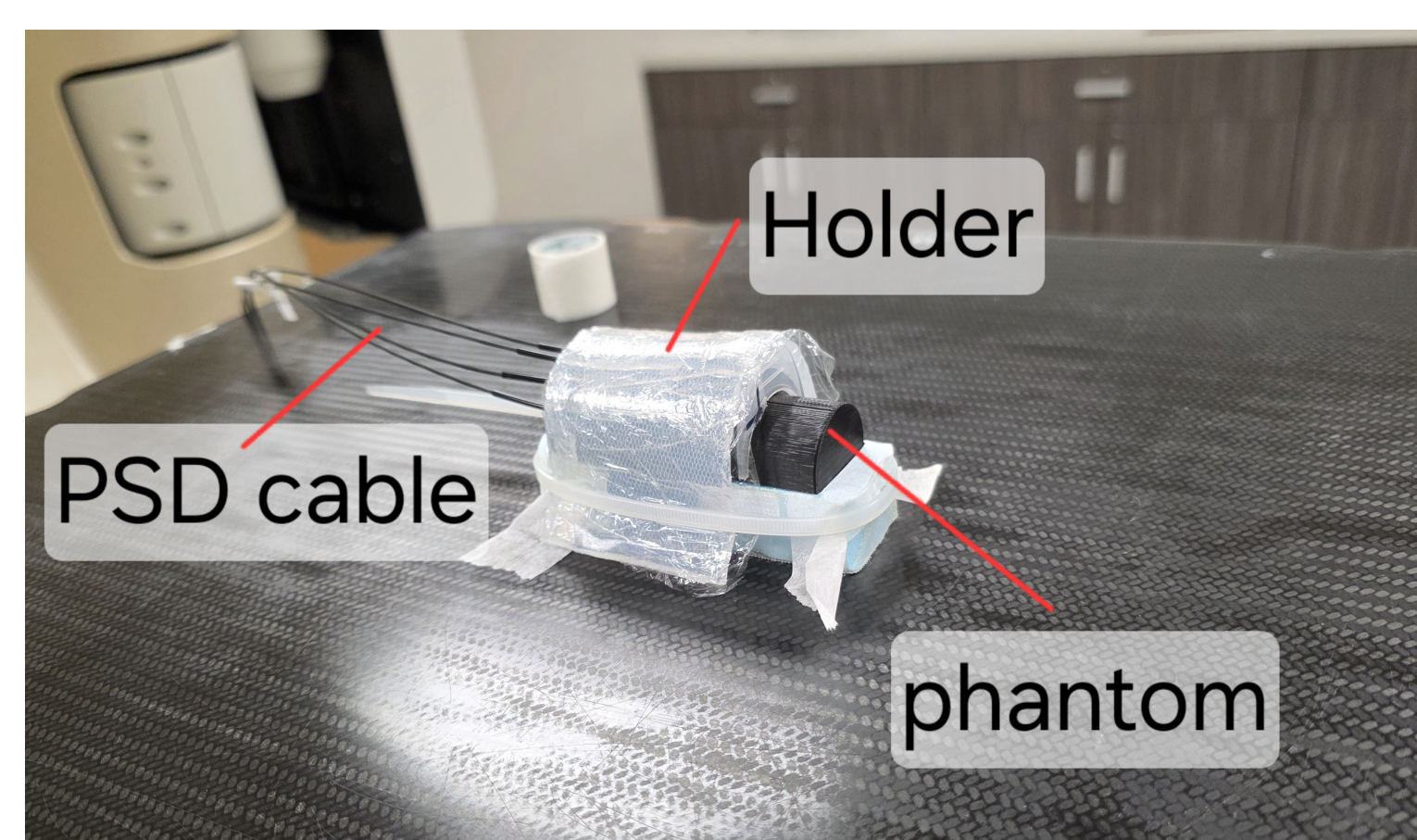


Fig. 1: The detector array and GK phantom

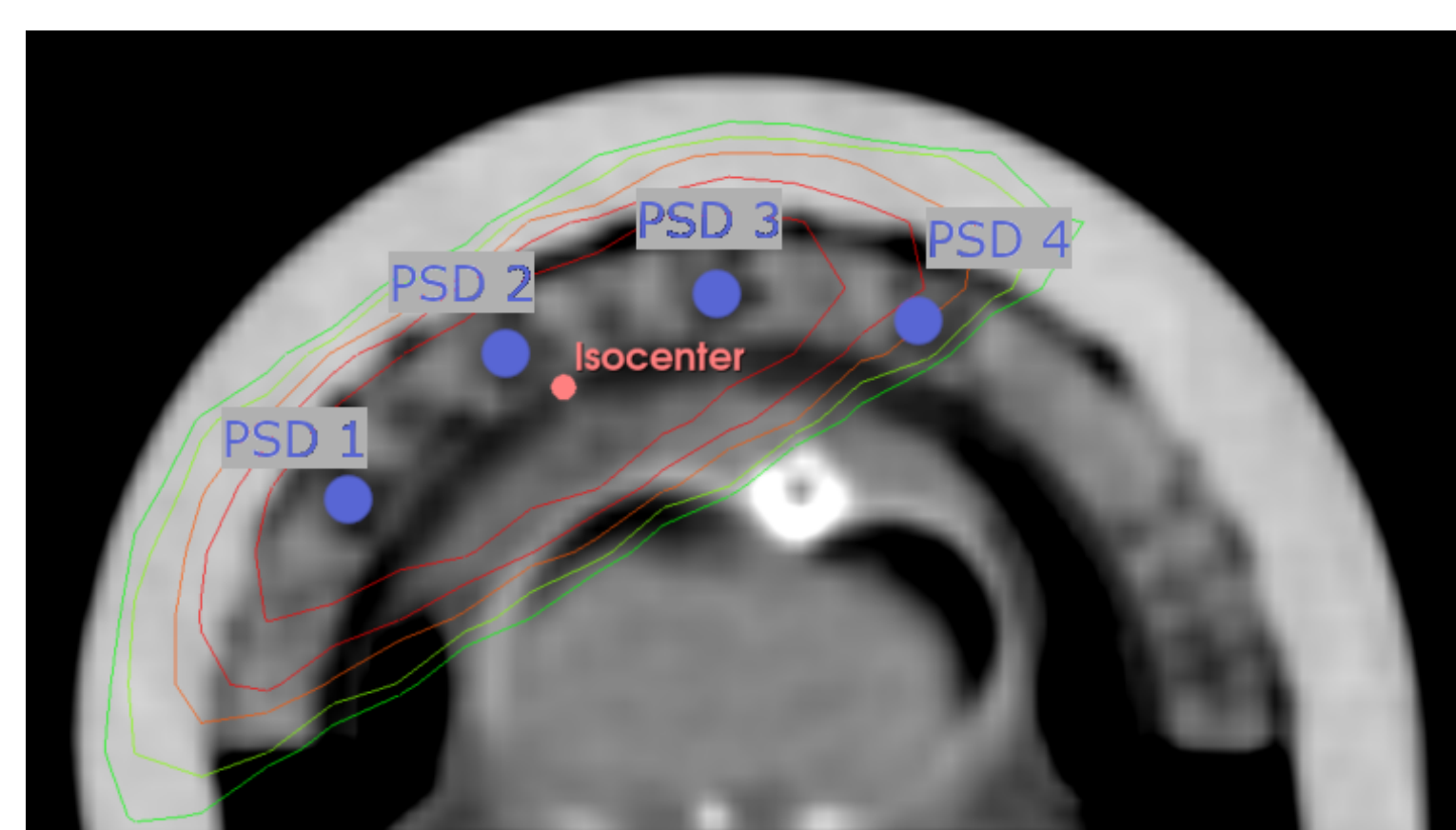


Fig. 2: CBCT with isodoses and PSD

3. Results

Error detection

Two unplanned errors were detected with in vivo monitoring during the course of this study

Error 1: in one case, the height of the treatment couch was not properly adjusted causing the beam to pass several centimeters above the animal. Online monitoring showed all four dosimeters measuring only a few percent of the expected dose. The team promptly stopped the irradiation (within 20 s of the start) to investigate. The error was then discovered and corrected.

Error 2: in another case, a slight misalignment of the animal caused one of the 4 PSD to be on the field edge. Because only a single detector measured a dose lower than expected (about 50%), it was decided to not stop the irradiation. The post-treatment CBCT confirmed the misalignment, but the planned skin dose was still achieved. Figure 3 compares two cases: Case 1 without error and Case 2 with position error.

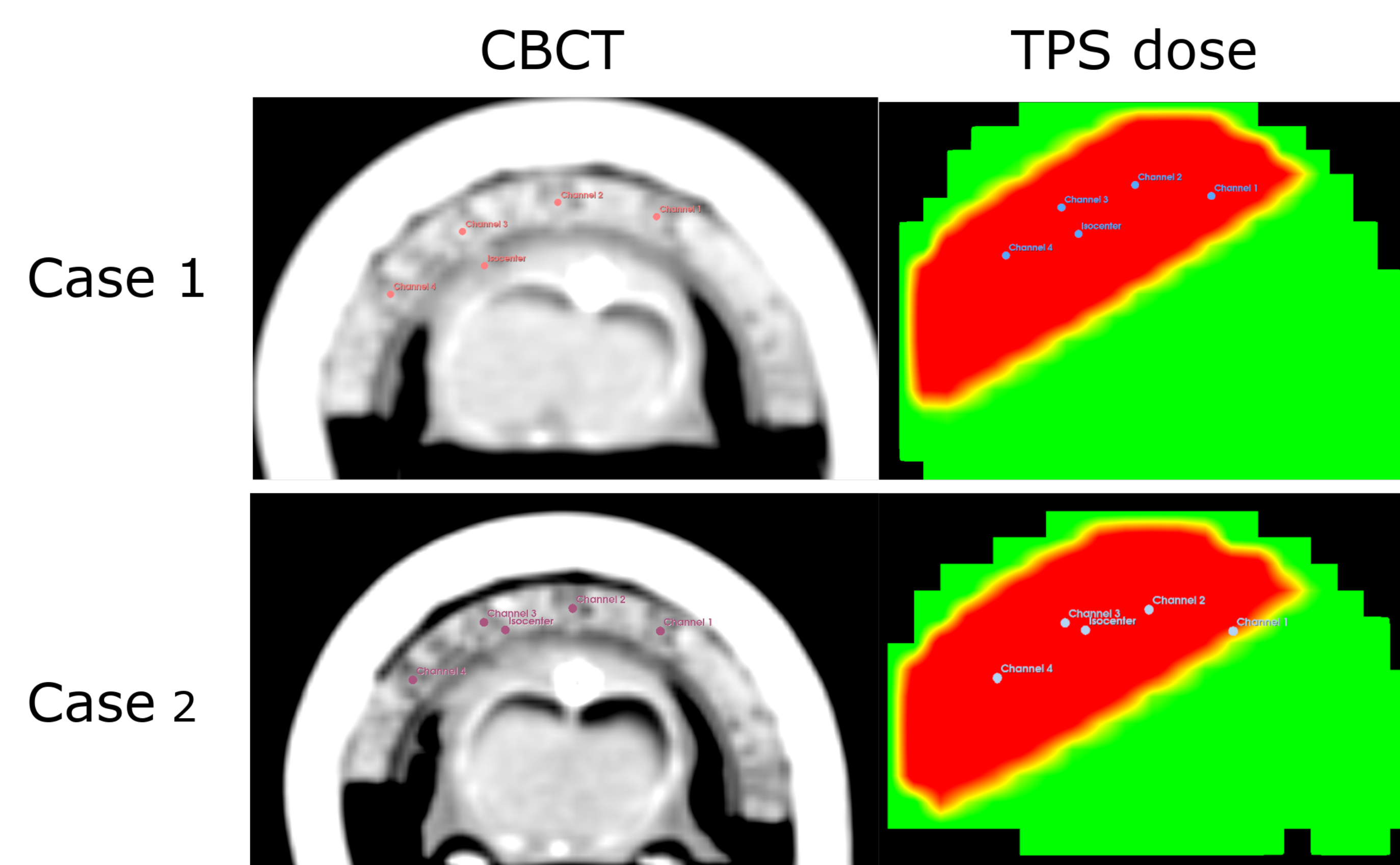


Fig. 3: Example of an irradiation without error (Case 1) and with a small positioning error (Case 2). The left column shows post-irradiation CBCT and the right column shows the planned dose distribution with the position of the 4 PSD

Dose comparison

Post-treatment CBCT were used for (1) dose calculation using the Eclipse treatment planning system (TPS) and (2) perform a Monte Carlo simulation (MC). Then, comparison was made between the in vivo measured dose and MC as well as between TPS and MC at the location of the PSDs (Fig. 4).

Agreement with MC for both TPS and PSD is within 5%, therefore supporting the fact that PSD measurements can accurately evaluate the delivered dose. Measurements are slightly closer to MC (3.8%) than TPS to MC (4.5%) although that difference is not statistically significant.

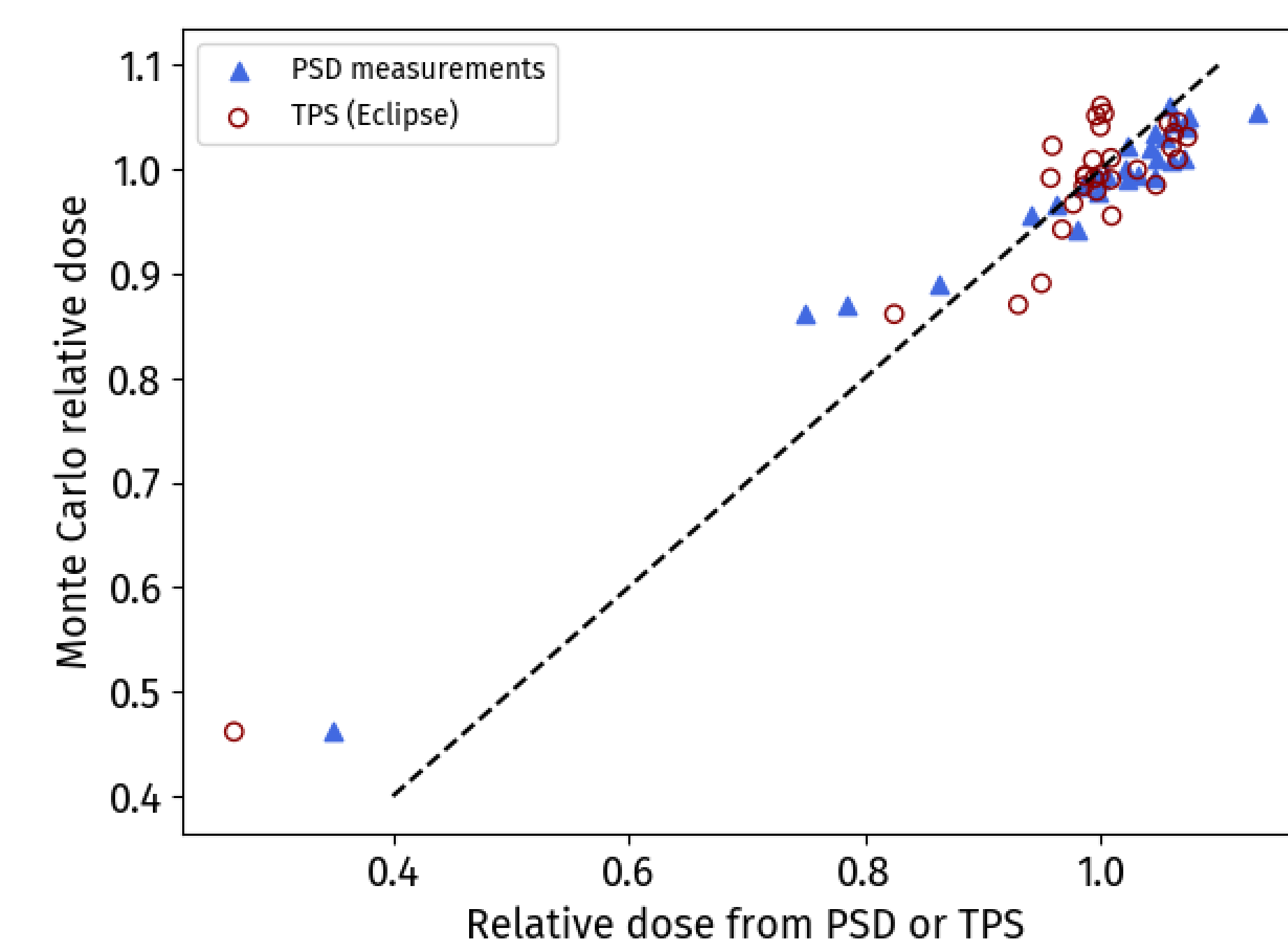


Fig. 4: Comparison with Monte Carlo simulations

4. Conclusions

- In vivo dosimetry can (and did) catch delivery error!
 - PSD based in vivo dosimetry can provide accurate measurements
 - Using multiple measurement points helps provide context:
 - Single detector deviation: small position error
 - Deviation from all detectors: there is a problem with the treatment
- ⇒ A PSD array is the right tool to guarantee the dosimetric accuracy of preclinical studies

Contact

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