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Effective Point of Measurement of Cylindrical Ionization Chambers in Kilovoltage X-ray Beams

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INTRODUCTION

The goal of this work was to experimentally determine an effective point of measurement (EPOM) by aligning each ionization chamber relative depth-response curve to the PTW microDiamond 60019 response curve. EPOM represents a spatial sampling displacement due to where ionization track structures deposit dose relative to the collecting electrode of the detector. In MV beams, the EPOM of a cylindrical chamber is upstream, towards the source [1]. In kV x-ray beams, however, photoelectric interactions and differences in attenuation and scatter in the wall or surrounding material may change the magnitude and direction of the displacement. AAPM TG-61 and TRS-398 Rev. 1 define chamber positioning as the geometric center [2-3]. However, a Monte Carlo study reported nonzero EPOM shifts in kV x-ray beams, with larger effects observed in softer beam qualities [4]. Although air kerma is the primary calibration quantity used in kV dosimetry, the development of absorbed-dose-to-water formalisms provides motivation to determine whether detector-specific shifts to account for EPOM are necessary to implement for relative dosimetry.

METHODS

- Water tank step-and-shoot depth-ionization measurements were performed using an Exradin A1SL thimble chamber, Exradin A12 Farmer chamber, Exradin A10 parallel plate chamber, and a PTW microDiamond detector, with the latter serving as the reference detector.
- Measurements performed at source-to-surface distance of 100 cm in accredited M-series kilovoltage x-ray beams spanning half-value layers from 0.75 to 18.49 mm Al.
- The A1SL and A12 were aligned at depth to the center of the sensitive volume as depicted in Fig.1. The A10 was aligned to the 1.2 mm in from the front surface [1]. The microDiamond was aligned to the surface of the sensitive crystal.
- Depths from 20–100 mm in water were sampled using a motorized stage.
- A minimum of 4, 120 s measurements were acquired per depth per trial.
- Multiple trials were performed per detector per beam quality.

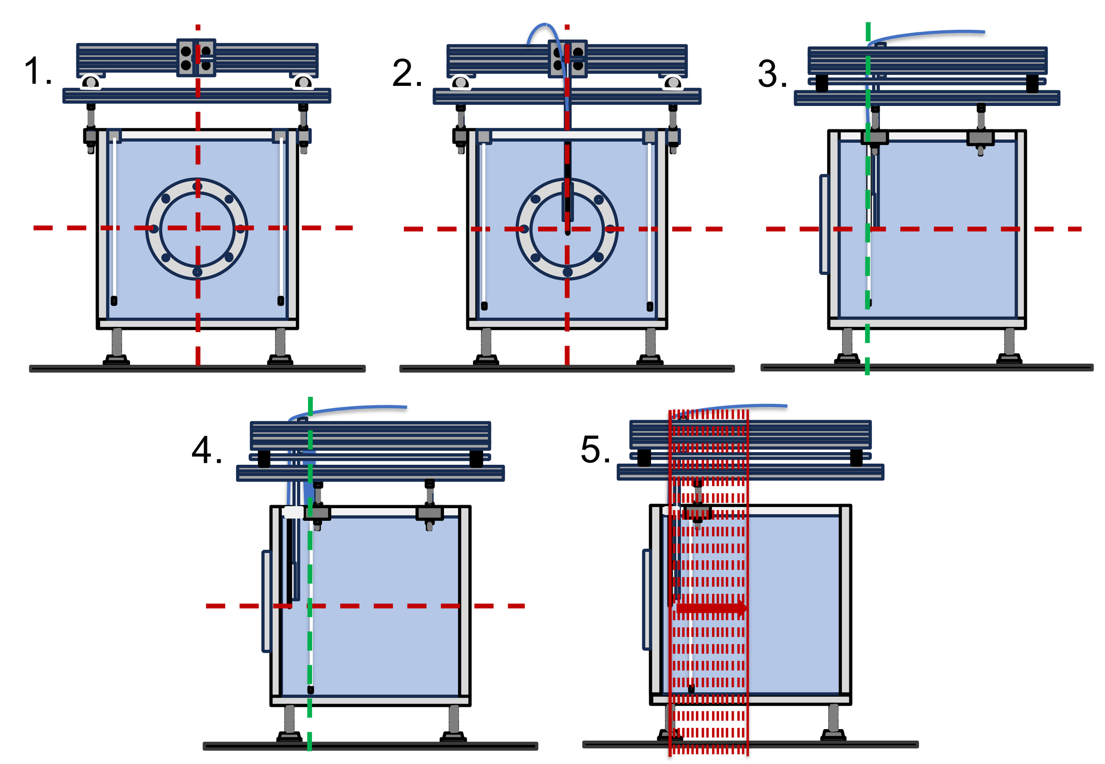

Figure 1. Steps for the setup of the water tank and detector system.

- EPOM shifts were calculated relative to the chamber's cavity radius using a chi-square minimization to determine a a best-fit shift per beam quality.

$$X^2(a,\Delta z)=\sum_{i=1}^{N}\left[\frac{r_i(a,\Delta z)}{\sigma_i}\right]^2=\sum_{i=1}^{N}\left[\frac{R(z_i)-aC(z_i+\Delta z)}{\sigma_i}\right]^2$$

RESULTS

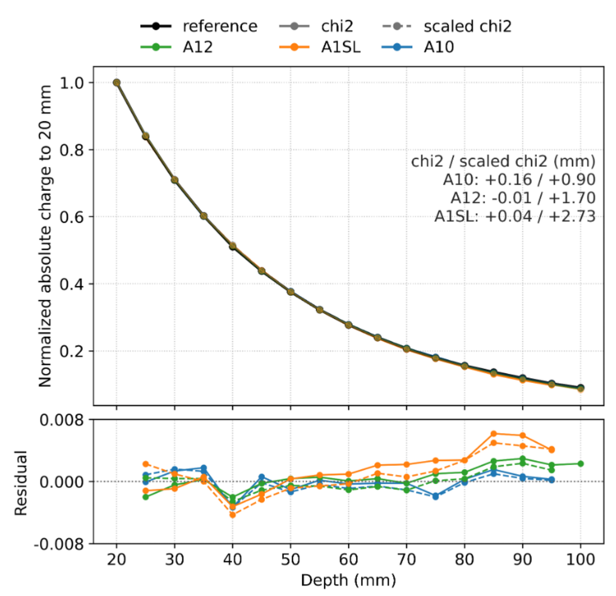

Figure 2. Percent-depth ionization (PDI) curves using UW-M50 beam quality for all detectors before and after applying the shift. Results are shown for the chi-squared statistical fitting method (a=1) and the fit containing a free multiplicative scale factor

- **Fig. 2 Takeaway:** Adding a free multiplicative scale factor resulted in shifts significantly larger than those restricting the scale factor to 1.

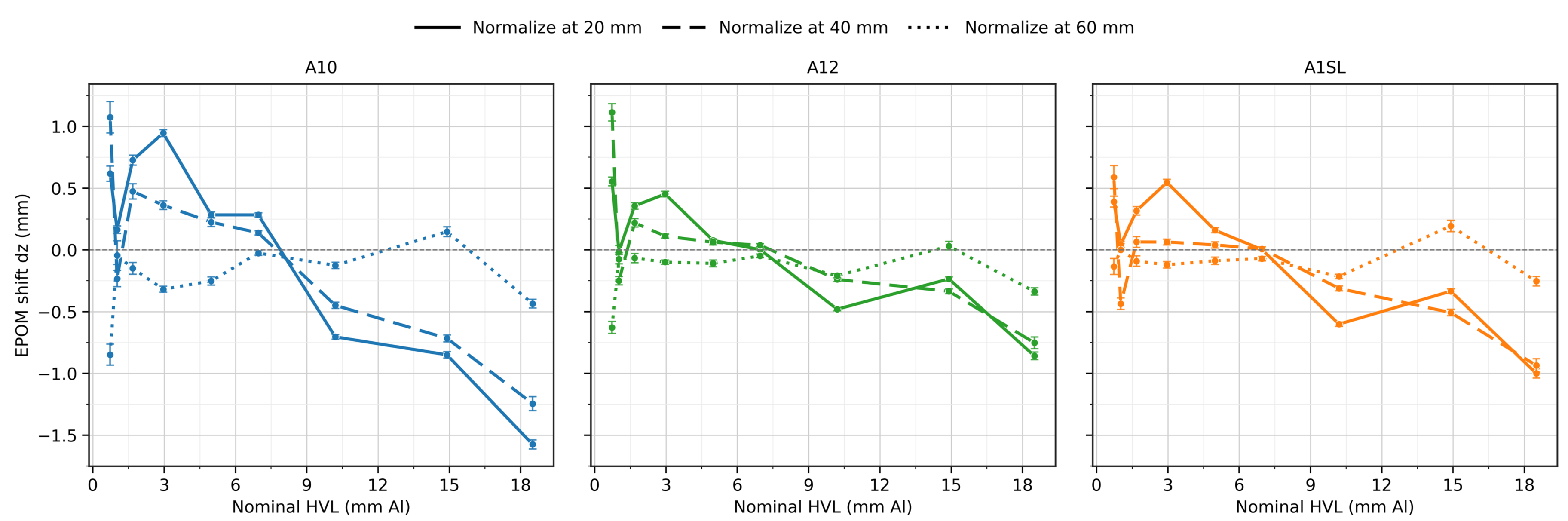

Figure 3. Shift determined for all relative detectors over all beam qualities when normalized to three depths in water

- **Fig. 3 Takeaway:**
  (1) The shift is normalization depth dependent.
  (2) The degree of dependence is also detector specific.
  (3) The degree of dependence is also beam quality dependent.

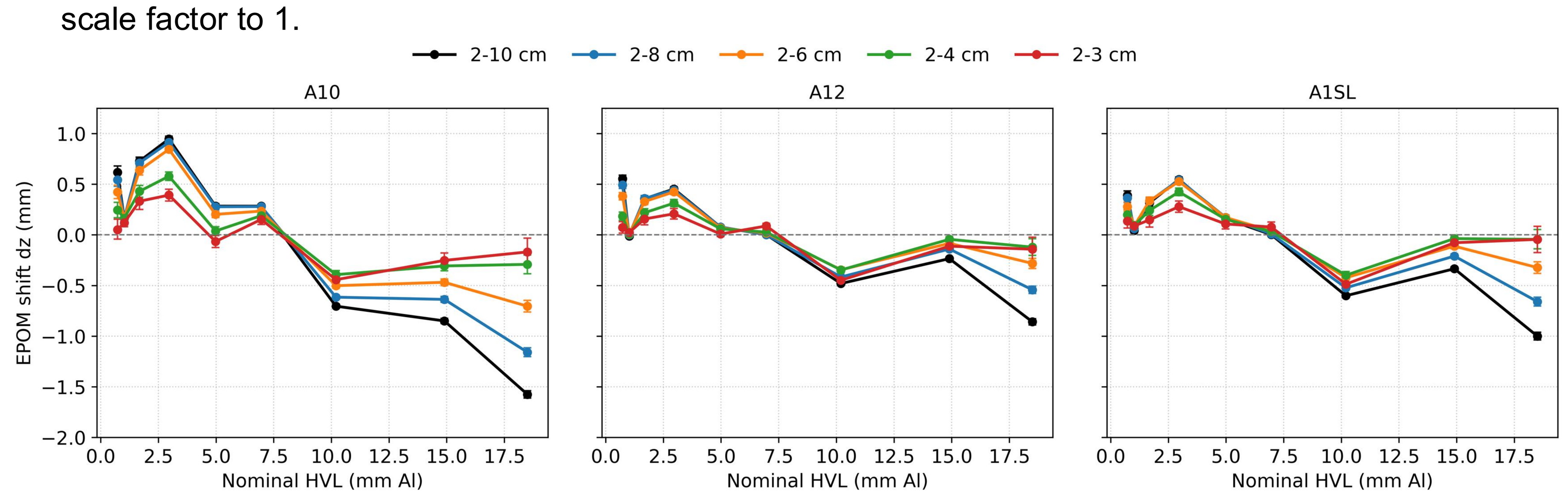

Figure 4. Shift determined for all relative detectors over all beam qualities when evaluated over five intervals in water

- **Fig. 4 Takeaway:** Restricting the fit to shallower intervals produced larger changes with respect to the largest interval evaluated.

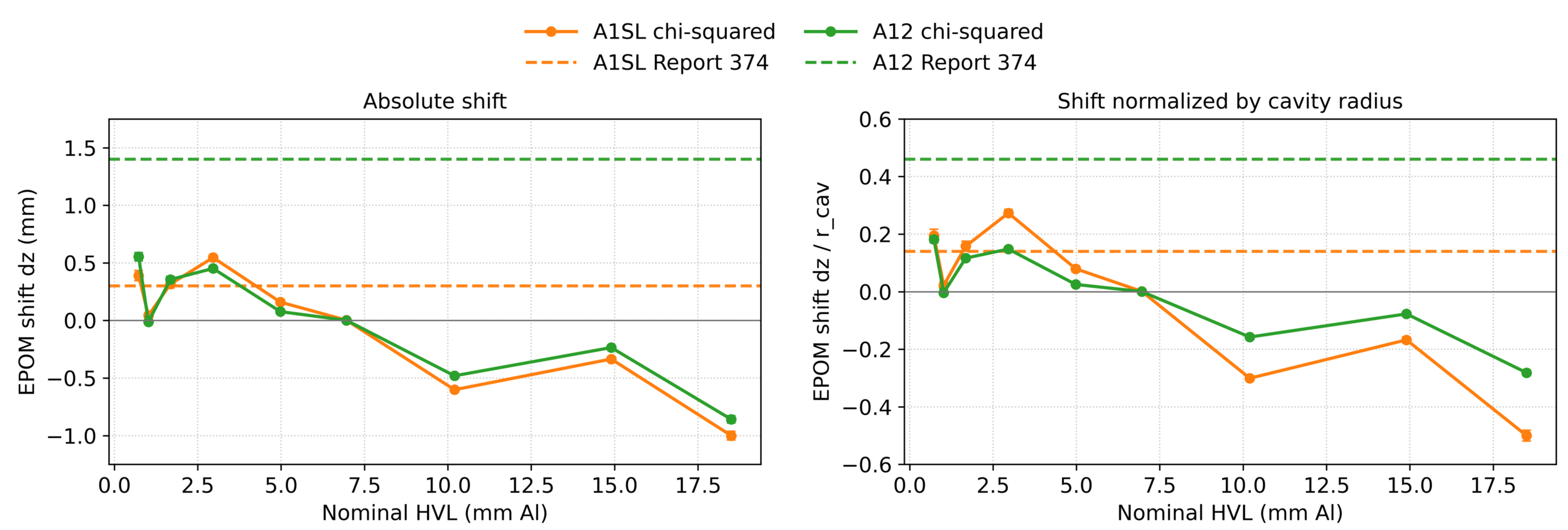

Figure 5. Shift determined using a 20 – 100 mm measurements interval, 20 mm depth normalization, and chi-squared statistical fitting method compared to the detector specific EPOM shift averaged over 6-25 MV [1]

- **Fig. 5 Takeaway:** Kilovoltage x-ray shifts are not equivalent to the published results for MV beams.

DISCUSSION

1) The EPOM shift is not a unique detector constant across the moderately filtered kV x-ray beam qualities.
2) Normalization depth and interval changes in selection produce submillimeter changes.
3) Contrary to the initial hypothesis, the shift became increasingly negative as beam quality hardened.
   - Softer beams were expected to produce more photoelectric interactions in the chamber materials.
   - This could potentially weight the EPOM downstream of the collecting electrode.
4) Future work will use Monte Carlo to differentiate EPOM from detector wall and stem corrections.

REFERENCES

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