2026 JOINT AAPM | COMP MEETING
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Monte Carlo Comparison of Dose-to-Air-Kerma Ratios for Kilovoltage Ionization Chamber Dosimetry

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Abstract

In this work, we calculated the **ratio of the dose to the chamber gas versus the air kerma in air (D_{gas}/K_{air}) for the PTW 34013 parallel-plate chamber** using E-Brachy, a Geant4-based software package for PTB T-series reference beams (TW15–TW50). We also investigated **K_Q, the ratio of D_{gas}/K_{air} value for the TW30 versus the Xoft beam quality.** Geant4 values were compared with published EGSnrc/CAVITY values. Geant4 ratios ranged from 0.849±0.002 to 0.859 ±0.003. **Published EGSnrc values were systematically higher by ~3%–7%, showing that kilovoltage chamber response calculations have non-negligible code/model dependence.**

Introduction

Air-kerma calibrated ionization chambers are attractive for kilovoltage dosimetry because they are stable, reproducible, and traceable. However, converting chamber readings to absorbed dose to water requires knowing the chamber response in the calibration beam. To obtain the beam quality conversion factor, C_Q, that takes the reading of the chamber and converts it to the dose to water, the relationship between **dose to chamber gas (D_{gas}) and air kerma (K_{air}) in air** with the reference beams needs to be established.

At kilovoltage energies this ratio is sensitive to wall, window, electrode, and cavity geometry, as well as photoelectric absorption, coherent scatter, atomic relaxation, and short secondary-electron ranges.

Objective: To compare Geant4 D_{gas}/K_{air} values with published EGSnrc/CAVITY values for the PTW 34013 chamber in PTB TW15–TW50 beams.

Methods and Materials

Formulations:

$$C_Q(z) = \left[\frac{D_{\mathrm{gas}}(z)}{K_{\mathrm{air}}(z)}\right]_{Q_0}\left[\frac{D_{\mathrm{w}}(z)}{D_{\mathrm{gas}}(z)}\right]_Q$$

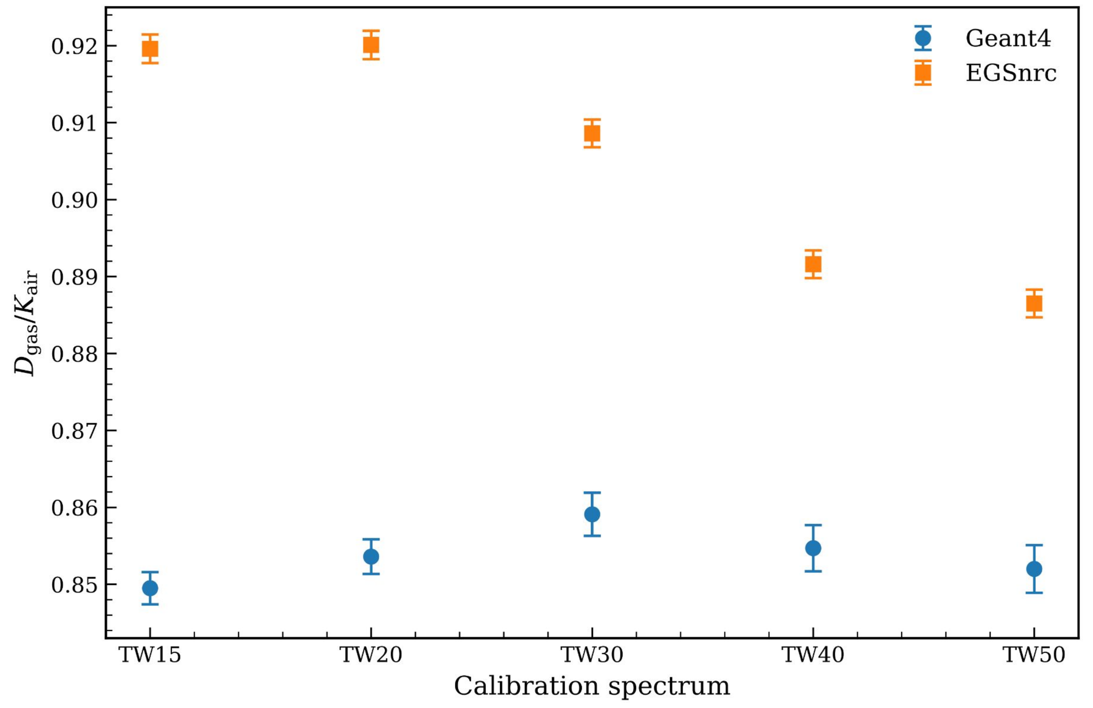
$$k_Q = \frac{N_{K,Q}}{N_{K,\mathrm{T30}}} = \frac{(D_{\mathrm{gas}}/K_{\mathrm{air}})_{\mathrm{T30}}}{(D_{\mathrm{gas}}/K_{\mathrm{air}})_Q}$$

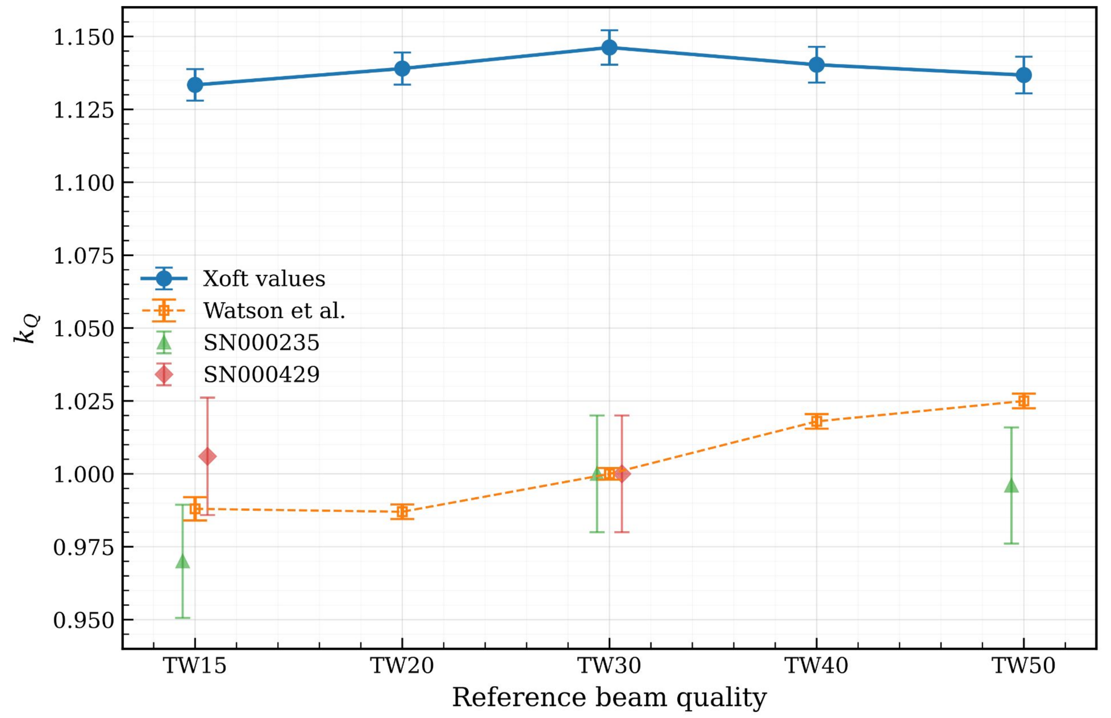
Chamber Model:

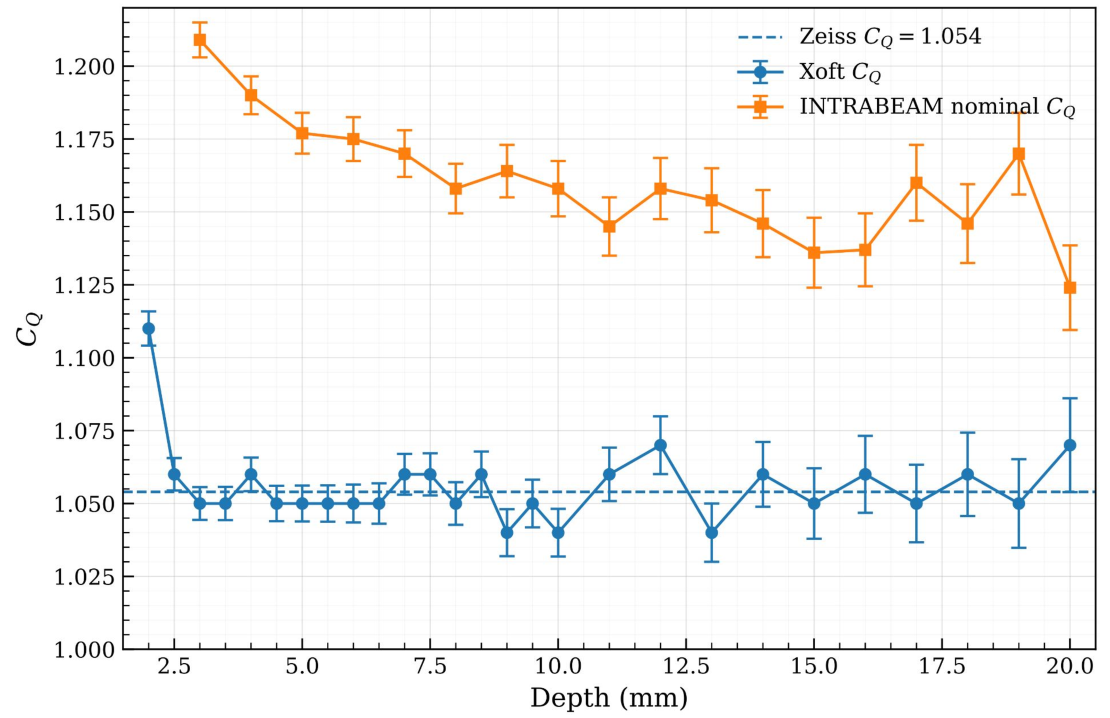
Figure 1. PTW 34013 ion chamber Model in EBrachy

Category	Specification
Code and physics	E-Brachy 3.0 / Geant4 11.4.3 with Livermore low-energy electromagnetic physics[1–3]
Chamber	PTW 34013 parallel-plate chamber using manufacturer-provided geometry and material specifications
Reference beams	PTB T-series spectra: TW15, TW20, TW30, TW40, and TW50
Geometry	30 cm source-to-detector distance and 3 cm diameter field at the detector plane
Scoring	K_{air} scored in air without the chamber; D_{gas} scored in the chamber gas cavity with the chamber present
Histories	2×10^{10} in-air histories
Transport settings	0.1 mm production cut; 250 eV lower transport limit
Atomic processes	Fluorescence, electron-impact ionization, and Meitner–Auger processes enabled
Data libraries	G4EMLOW 8.6.1 with EADL, EEDL, and EPDL[4 - 7]
Benchmark	Published EGSnrc/CAVITY values; literature benchmark rather than a fully matched inter-code comparison[8]

Results







D_{gas}/K_{air}: Geant4 values were **3%–7% lower** than published EGSnrc/CAVITY results

k_Q: Xoft values were consistently higher than published INTRABEAM values.

$C_Q(z)$: Xoft values showed **~2.9% depth dependence** over 2–20 mm, but were consistently lower than INTRABEAM values.

Discussion

The systematically lower Geant4 values indicate that D_{gas}/K_{air} value is sensitive to the Monte Carlo implementation used for low-energy ionization chamber calculations. Geant4 used the Livermore electromagnetic models and EADL/EEDL/EPDL libraries, whereas the published EGSnrc implementation used PEGS4 material data and different photon and electron interaction datasets and transport thresholds.

A systematic difference of several percent in D_{gas}/K_{air} can ultimately propagate into the absorbed dose determined from an air-kerma-calibrated chamber.

The present results should consequently be interpreted as motivation for a future controlled inter-code comparison using identical chamber dimensions, materials, spectra, transport thresholds, scoring regions, and uncertainty methods.

Conclusions

- Geant4 D_{gas}/K_{air} values were 3%–7% lower than published EGSnrc/CAVITY values.
- The largest difference occurred at TW15, the lowest beam quality.
- Kilovoltage chamber dose-to-air-kerma ratios should not be assumed to be code independent.
- Matched geometry, materials, transport thresholds, scoring volumes, and libraries are needed for a controlled inter-code comparison.
- Code/model dependence should be included as Type B uncertainty when deriving k_Q or $C_Q(z)$.

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References

1Esmaelbeigi A, et al. **E-Brachy: New dosimetry package for electronic brachytherapy sources.** *Med Phys.* 2025;52:662–672.
Agostinelli S, et al. **Geant4—a simulation toolkit.** *Nucl Instrum Methods Phys Res A.* 2003;506:250–303.
Allison J, et al. **Recent developments in Geant4.** *Nucl Instrum Methods Phys Res A.* 2016;835:186–225.
Apostolakis J, et al. **GEANT4 low-energy electromagnetic models for electrons and photons.** 1999.
Cullen DE, Hubbell JH, Kissel L. **EPDL97: Evaluated Photon Data Library.** LLNL; 1997.
Perkins ST, et al. **Evaluated Atomic Data Library, EADL.** LLNL; 1991.
Perkins ST, Cullen DE, Seltzer SM. **Evaluated Electron Data Library, EEDL.** LLNL; 1991.
Watson PGF, Popovic M, Seuntjens J. **Determination of absorbed dose to water from a miniature kilovoltage x-ray source using a parallel-plate ionization chamber.** *Phys Med Biol.* 2018;63:015016.