Monte Carlo calculations of the beam quality conversion factor, k_Q, for cylindrical ionization chambers

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Abstract

This report contains individual plots of Monte Carlo calculated k_Q values for all 32 ion chambers reported on in "Monte Carlo calculations of k_Q, the beam quality conversion factor", Med. Phys. 37 (2010) 5939 – 5950 by the same authors along with comparisons to various other calculations and measurements. These data are also relevant to a related paper: "Measured and Monte Carlo calculated k_Q factors: accuracy and comparison, Med. Phys. 38(2011)4600– 4609 by Muir, McEwen and Rogers.

Contents

I. Introduction

The EGSnrc user-code egs_chamber has been used to calculate k_Q directly for 32 ionization chambers as described in a paper recently published in Medical Physics.[1] Plots of k_Q could not be provided for all chambers in that document. Instead, a figure was given to show typical trends of k_Q calculations as a function of $\%dd(10)_{\mathsf{x}}$ for representative ion chambers. Here, the graphs of k_Q vs. $\%dd(10)_{\mathsf{x}}$ are provided for all of the chambers described in the paper along with values available in the literature from previous experiments, Monte Carlo calculations and dosimetry protocols. The k_Q values in TRS-398 are given as a function of TPR^{20}_{10}. In this report, TRS-398 k_Q values are plotted where available as a function of $\%dd(10)_{\mathsf{x}}$ converted from TPR^{20}_{10} using the formula of Kalach and Rogers.[2] High precision quadratic fits to our calculated k_Q values are plotted with the k_Q values. Tables of the fit parameters as a function of $\%dd(10)_{\mathsf{x}}$ and TPR^{20}_{10} are provided in the paper. Table 1 provides the chamber specifications and materials used for the calculations with the exception of the Exradin ion chambers. Exradin ion chambers were modeled from proprietary blueprints so the User Manual data is given here although blueprint models were used for the simulations. The PTW 31013 chamber was not included in the paper[1] but is included here. The model of the NE2561 has been updated since publication[1] using detailed drawings of the chamber. The plot provided here for the NE2561 shows k_Q calculations using the updated model as well as calculations for the NE2611 chamber. The NE2611 is identical to the NE2561 chamber except that the protective sleeve securing the thimble is composed of Aluminum instead of polyoxymethylene. The statistical uncertainty on our data points are less than or about equal to the size of the symbols for our Monte Carlo values in all plots.

Table 1: The specifications of the ionization chamber models used. The materials are Air Equivalent Plastic (C552), Tissue Equivalent Plastic (A150), Silver Plated Copper Covered Steel (SPC), Polymethylmethacrylate (PMMA), Graphite (Gr), Aluminum (Al) and Polyoxymethylene (POM). The chambers are loosely divided into nine groups designated by a letter a to i with similar characteristics as described in the text. Each chamber's group is given here. The cavity length is the maximum length of the cavity. Chambers that are not water-proof are modeled with a 1 mm thick PMMA sleeve.

Chamber	Wall		Electrode			Active Cavity		Water-
(Group,V(cm^3))	Material	Thickness (mm)	Material	Radius (mm)	Length (mm)	Radius (mm)	Length (mm)	proof
Exradin								
A12 (a,0.65)	C552	0.5	C552	0.5	21.6	3.05	24.8	Y
A19 (a,0.62)	C552	0.5	C552	0.5	21.6	3.05	25.0	Y
A2 (a,0.54)	C552	1.0	C552	0.5	8.4	4.7	12.0	Y
T2 (b,0.54)	A150	1.0	A150	0.5	8.4	4.7	12.0	Y
A12S (a,0.25)	C552	0.5	C552	0.5	7.4	3.05	10.6	Y
A18 (a,0.125)	C552	1.0	C552	0.5	5.9	2.45	8.3	Y
A1 (a,0.057)	C552	1.0	C552	0.5	4.4	2.0	6.0	Y
T1 (b,0.057)	A150	1.0	A150	0.5	4.4	2.0	6.0	Y
A1SL (a,0.057)	C552	1.1	C552	0.5	4,4	2.025	6.0	Y
A14 (g,0.016)	C552	1.0	SPC	0.165	1.5	2.0	2.0	Y
T14 (h,0.016)	A150	1.0	SPC	0.165	1.5	2.0	2.0	Y
A14SL (g,0.016)	C552	1.1	SPC	0.165	1.5	2.025	2.0	Y
A16 (g,0.007)	C552	0.5	SPC	0.165	1.3	1.2	2.4	Y
PTW								
30010 (e,0.6)	PMMA/Gr	0.335/0.09	Al	0.55	20.4	3.05	23.4	N
30011 (d,0.6)	Gr	0.425	Gr	0.5	20.4	3.05	23.4	N
30012 (c,0.6)	Gr	0.425	Al	0.55	20.4	3.05	23.4	N
30013 (e,0.6)	PMMA/Gr	0.335/0.09	Al	0.55	20.5	3.05	23.4	Y
31013* (e,0.3)	PMMA/Gr	0.55/0.15	Al	0.45	14.25	2.75	16.25	Y
31010 (e,0.125)	PMMA/Gr	0.55/0.15	Al	0.55	6.0	2.75	6.5	Y
31016 (i,0.016)	PMMA/Gr	0.57/0.09	Al	0.09	1.45	1.45	2.9	Y
31014 (i,0.015)	PMMA/Gr	0.57/0.09	Al	0.09	4.0	1.0	5.0	Y
IBA								
FC65-G (c,0.65)	Gr	0.43	Al	0.5	21.3	3.1	23.1	Y
FC65-P (f,0.65)	POM	0.4	Al	0.5	21.3	3.1	23.1	Y
CC25 (a,0.25)	C552	0.4	C552	0.5	7.6	3.0	10.0	Y
FC23-C (a,0.23)	C552	0.4	C552	0.5	7.0	3.1	8.8	Y
CC13 (a,0.13)	C552	0.4	C552	0.5	3.2	3.0	5.8	Y
CC08 (a,0.08)	C552	0.4	C552	0.5	1.4	3.0	4.0	Y
CC04 (a,0.04)	C552	0.4	C552	0.5	2.5	2.0	3.6	Y
CC01 (g,0.01)	C552	0.5	Steel	0.175	2.7	1.0	3.6	Y
Other								
NE2581 (b,0.6)	A150	0.36	A150	1.5	20.5	3.15	24.0	N
NE2571 (c,0.6)	Gr	0.36	Al	0.5	20.5	3.14	24.0	N
NE2611/2561 (0.3)	Gr	0.53	Al	1.0**	6.5	3.7	9.0	N
PR06C/G (a,0.65)	C552	0.28	C552	0.8	22.0	3.22	24.0	N

* The PTW 31013 was modeled from proprietary drawings from PTW - specifications from the PTW detector catalog are given here. It was not included in the paper.[1]

** The NE2561 has a hollow electrode with a 0.2 mm thick aluminum shell. The air inside the aluminum layer is not considered part of the active cavity.

II. Figures

II.A. Exradin

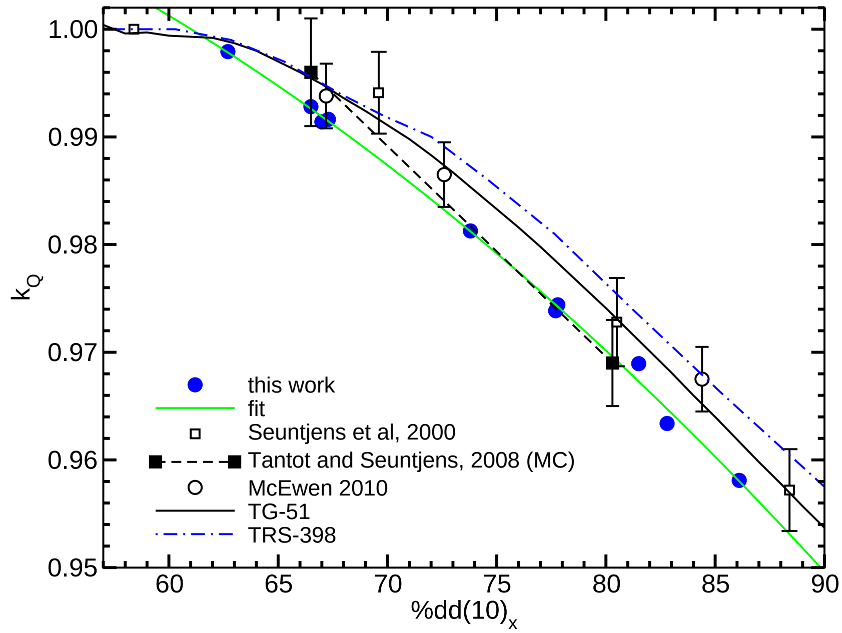

Figure 1: Monte Carlo calculated k_Q factors for the Exradin A12 ion chamber (a,0.65 cm^3) along with measurements from Seuntjens et al[3] and McEwen,[4] Monte Carlo calculated values from Tantot and Seuntjens[5] and protocol values.[6,7] The fit is to our Monte Carlo values.

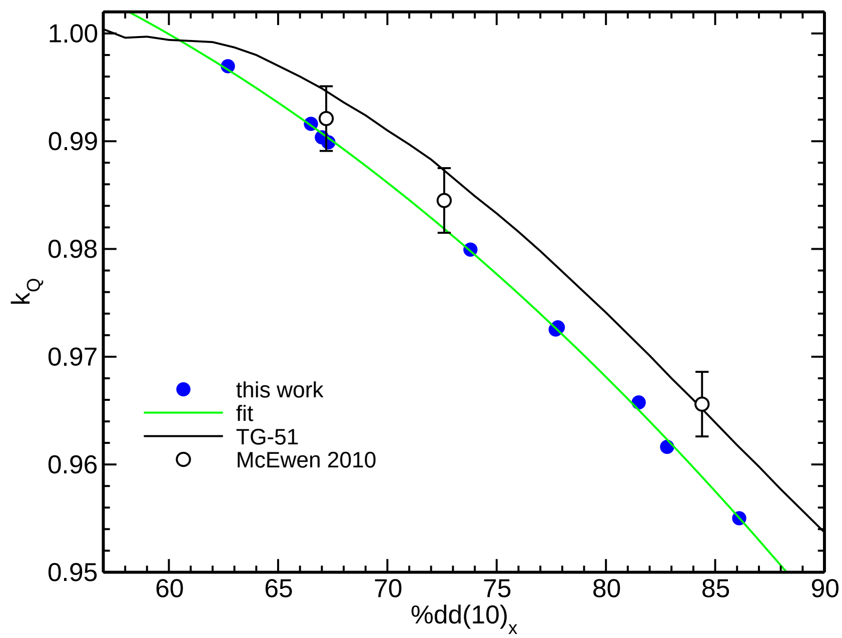

Figure 2: Monte Carlo calculated k_Q factors for the Exradin A19 ion chamber (a,0.62 cm^3) along with measurements from McEwen[4] and TG-51 values.[6] The fit is to our Monte Carlo values.

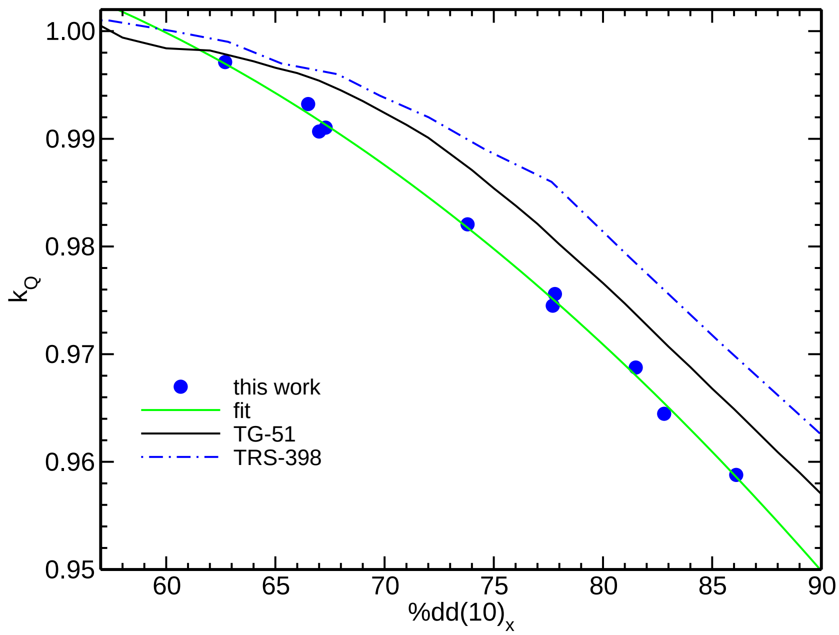

Figure 3: Monte Carlo calculated k_Q factors for the Exradin A2 ion chamber (a,0.54 cm^3) along with TG-51 and TRS-398 values.[6,7] The fit is to our Monte Carlo values.

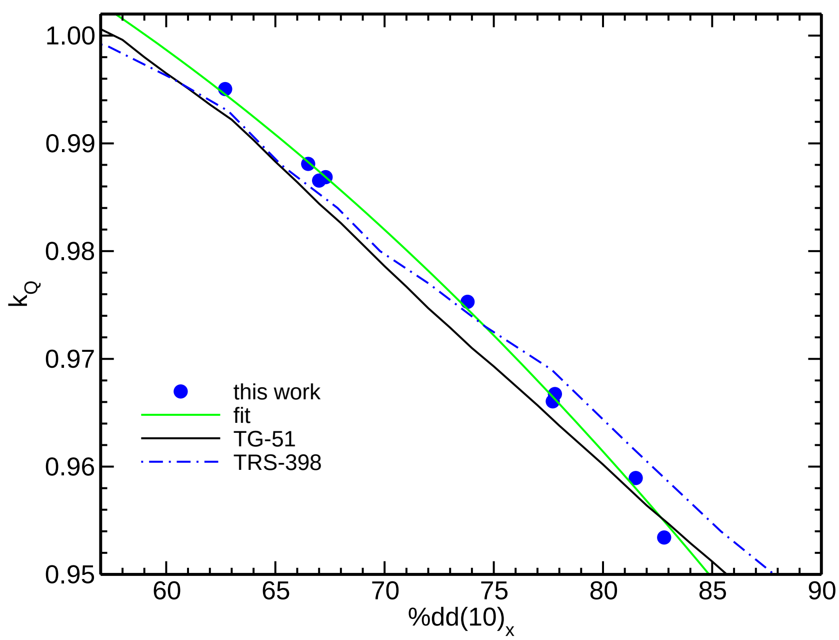

Figure 4: Monte Carlo calculated k_Q factors for the Exradin T2 ion chamber (b,0.54 cm^3) along with TG-51 and TRS-398 values.[6,7] The fit is to our Monte Carlo values.

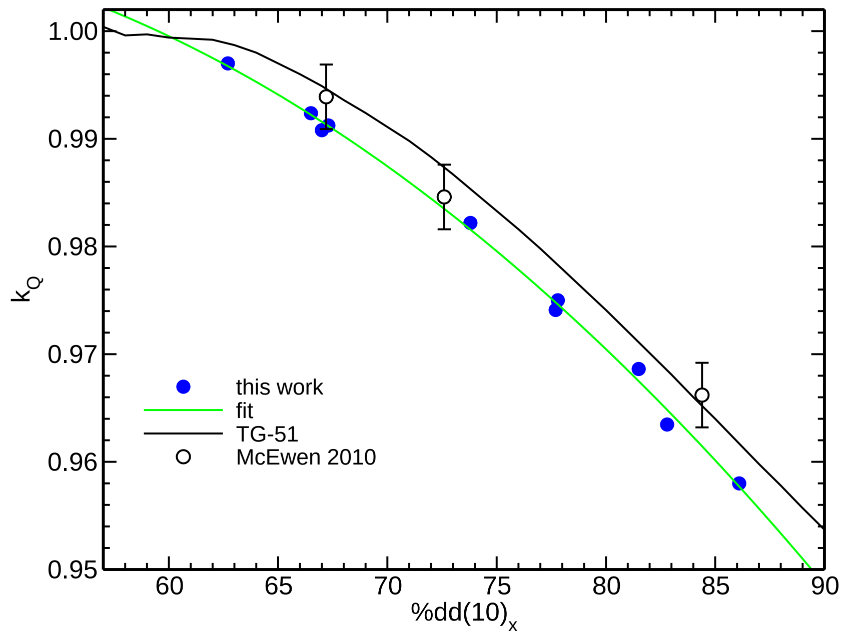

Figure 5: Monte Carlo calculated k_Q factors for the Exradin A12S ion chamber (a,0.25 cm^3) along with measurements from McEwen[4] and TG-51 values.[6] The fit is to our Monte Carlo values.

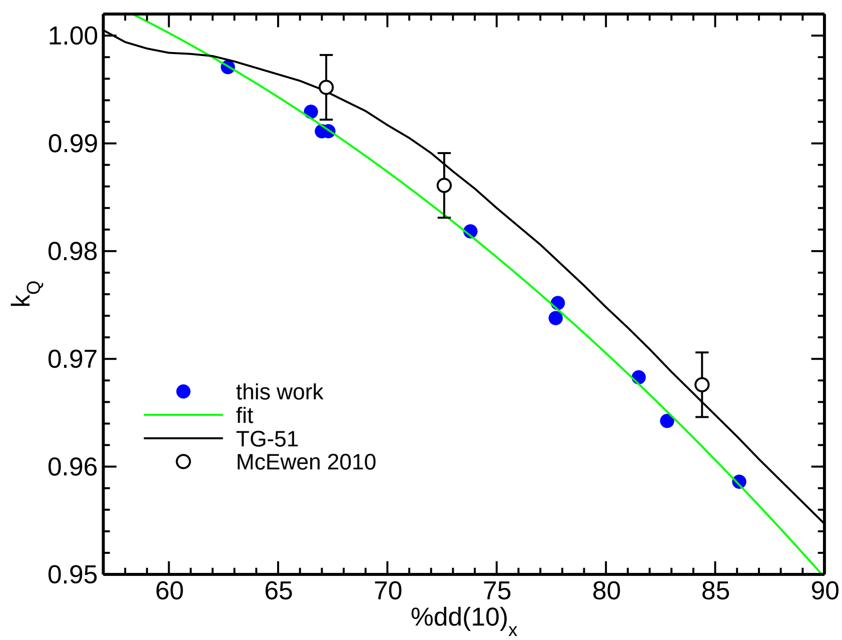

Figure 6: Monte Carlo calculated k_Q factors for the Exradin A18 ion chamber (a,0.125 cm^3) along with measurements from McEwen[4] and TG-51 values.[6] The fit is to our Monte Carlo values.

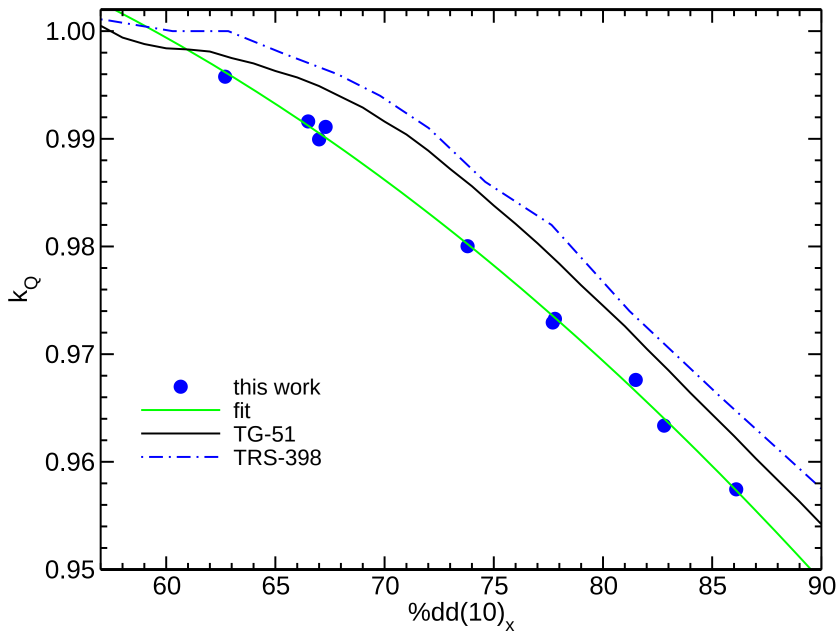

Figure 7: Monte Carlo calculated k_Q factors for the Exradin A1 ion chamber (a,0.057 cm^3) along with TG-51 and TRS-398 values.[6,7] The fit is to our Monte Carlo values.

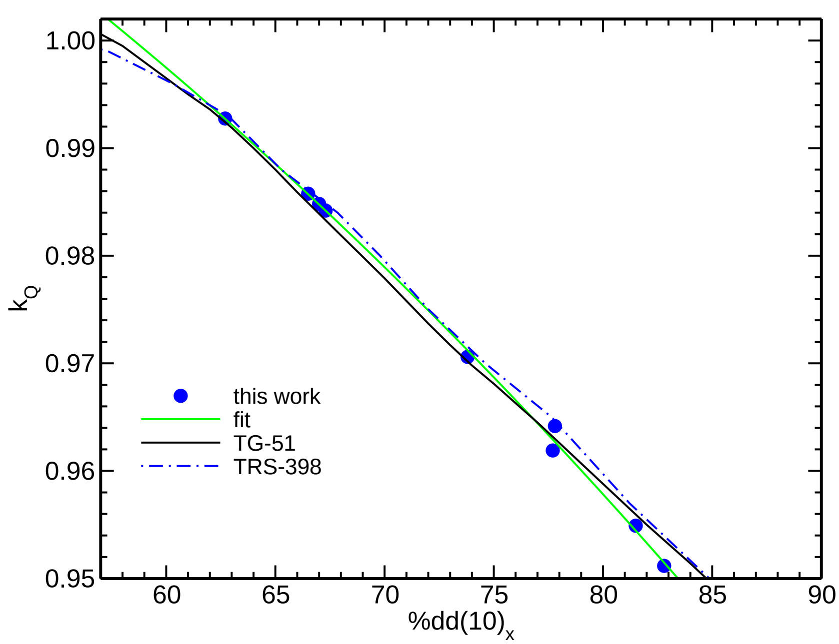

Figure 8: Monte Carlo calculated k_Q factors for the Exradin T1 ion chamber (b,0.057 cm^3) along with TG-51 and TRS-398 values.[6,7] The fit is to our Monte Carlo values.

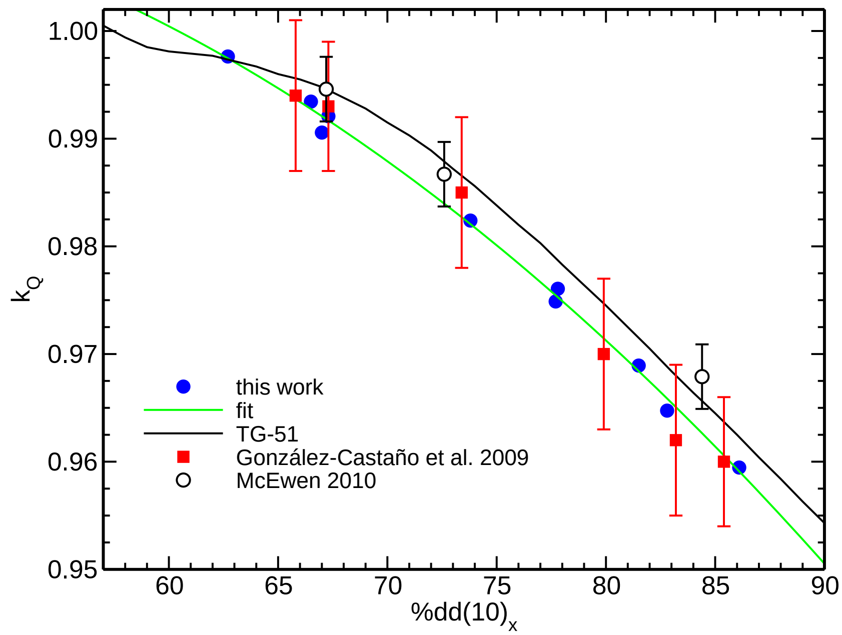

Figure 9: Monte Carlo calculated k_Q factors for the Exradin A1SL ion chamber (a,0.057 cm^3) along with measurements from McEwen,[4] TG-51 values[6] and Monte Carlo data from González-Castaño[8] et al. The fit is to our Monte Carlo values.

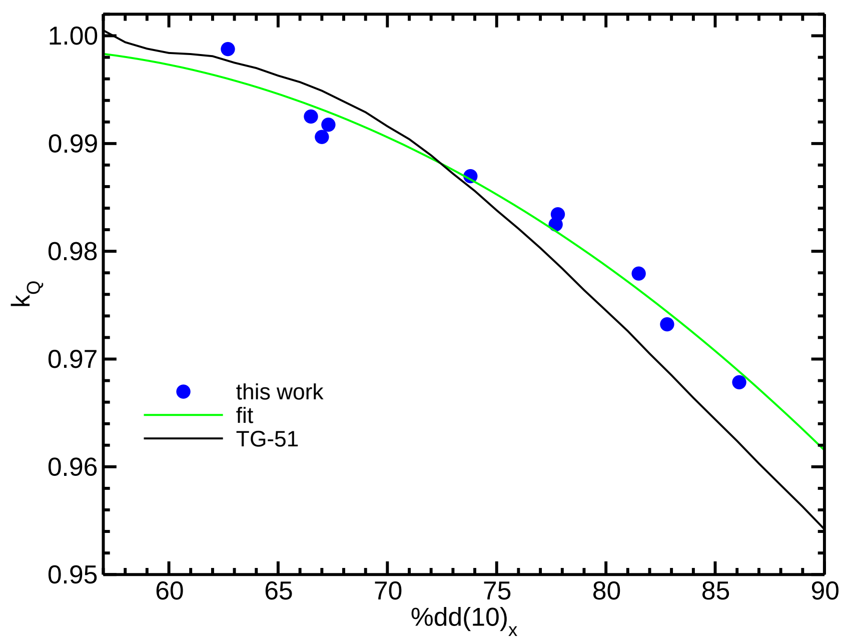

Figure 10: Monte Carlo calculated k_Q factors for the Exradin A14 ion chamber (g,0.016 cm^3) along with TG-51 values.[6] The fit is to our Monte Carlo values.

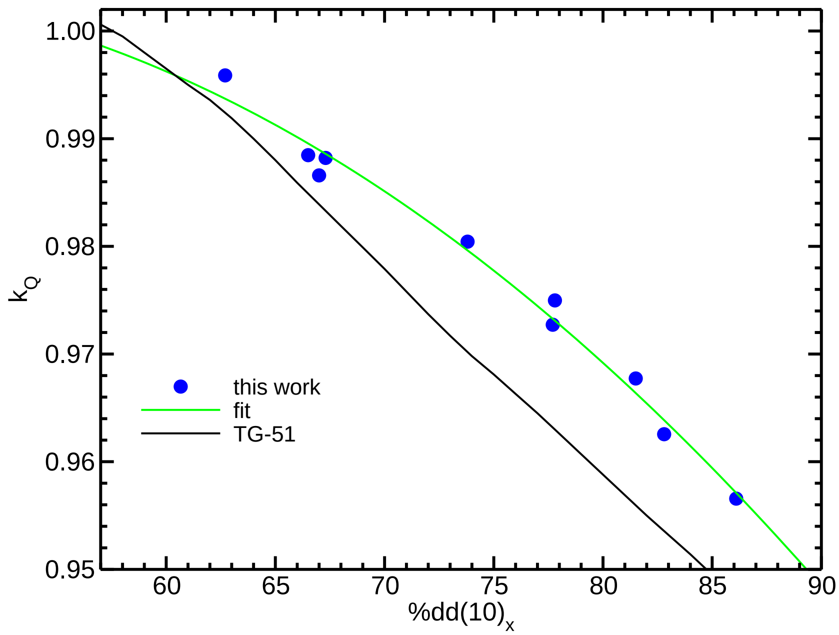

Figure 11: Monte Carlo calculated k_Q factors for the Exradin T14 ion chamber (h,0.016 cm^3) along with TG-51 values.[6] The fit is to our Monte Carlo values.

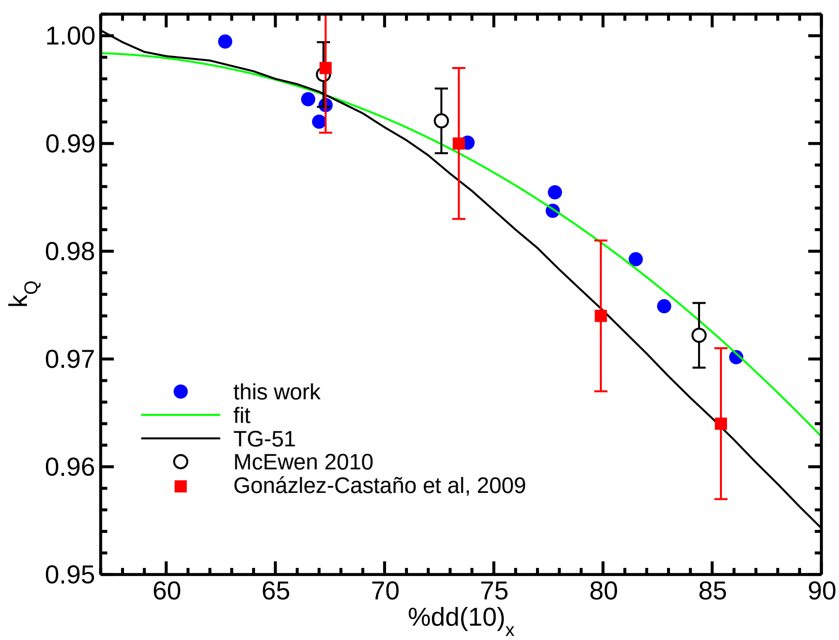

Figure 12: Monte Carlo calculated k_Q factors for the Exradin A14SL ion chamber (g,0.016 cm^3) along with measurements from McEwen,[4] TG-51 values[6] and Monte Carlo data from González-Castaño[8] et al. The fit is to our Monte Carlo values.

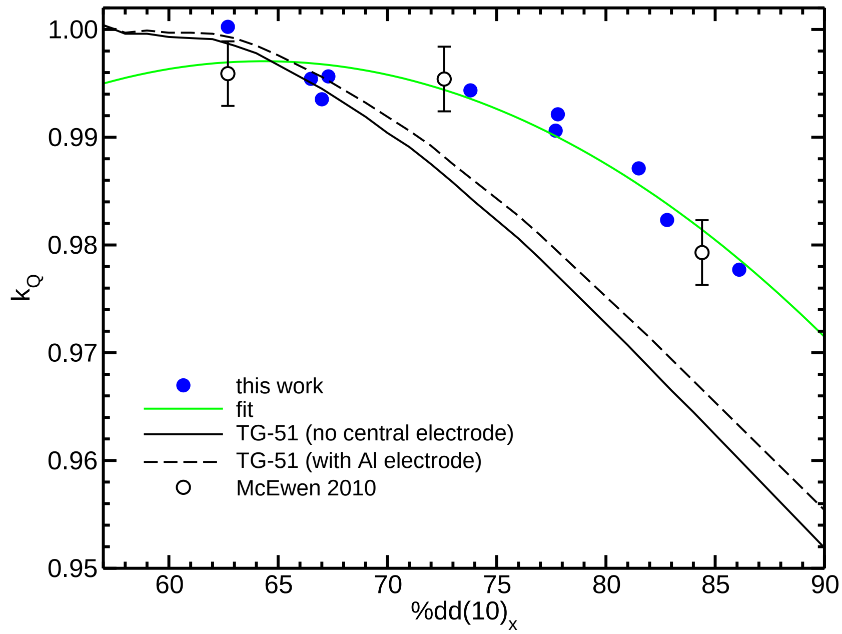

Figure 13: Monte Carlo calculated k_Q factors for the Exradin A16 ion chamber (g,0.007 cm^3) along with measurements from McEwen[4] and TG-51 values with and without an aluminum electrode.[6] The fit is to our Monte Carlo values.

II.B. PTW

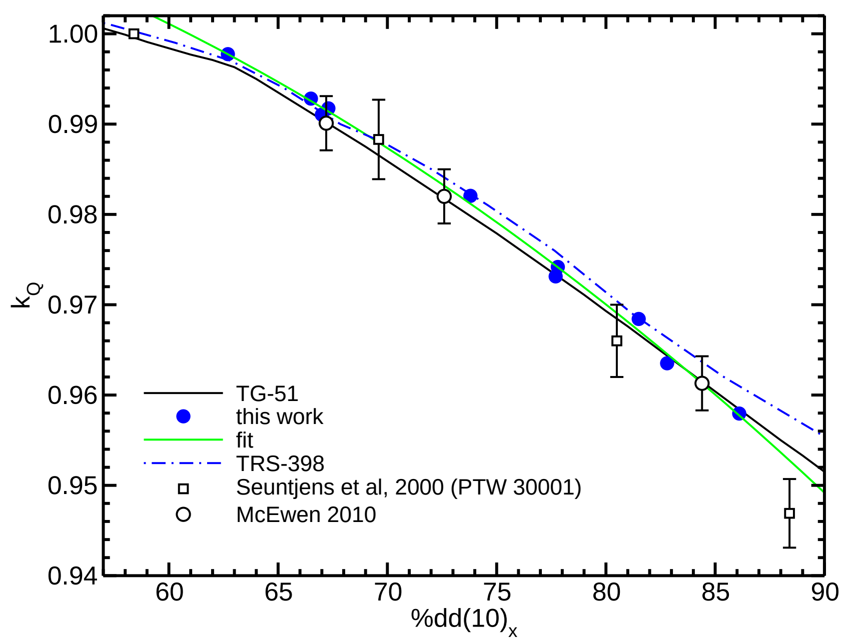

Figure 14: Monte Carlo calculated k_Q factors for the PTW30010 ion chamber (e,0.6 cm^3) along with measurements from McEwen[4] and Seuntjens[3] et al and TRS-398 and TG-51 protocol values.[6,7] The fit is to our Monte Carlo values.

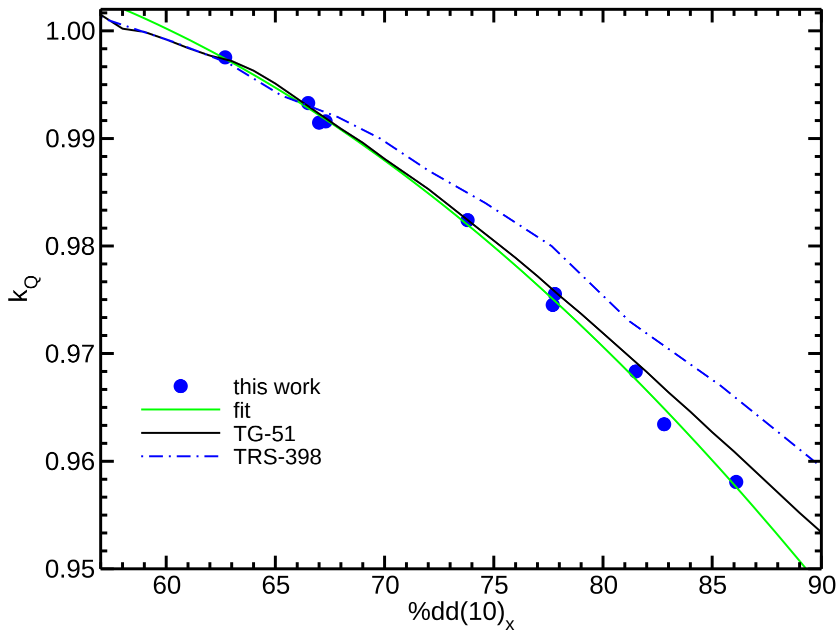

Figure 15: Monte Carlo calculated k_Q factors for the PTW30011 ion chamber (d,0.6 cm^3) along with TRS-398 and TG-51 protocol values.[6,7] The fit is to our Monte Carlo values.

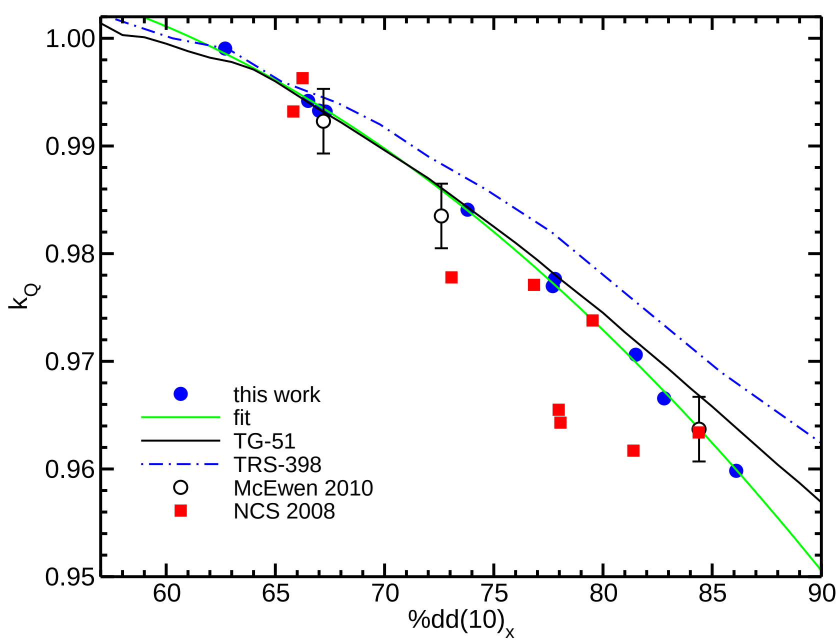

Figure 16: Monte Carlo calculated k_Q factors for the PTW30012 ion chamber (c,0.6 cm^3) along with measurements from McEwen,[4] TRS-398 and TG-51 values[6,7] and values measured for the Netherlands Commission on Radiation Dosimetry Code of Practice.[9] The fit is to our Monte Carlo values.

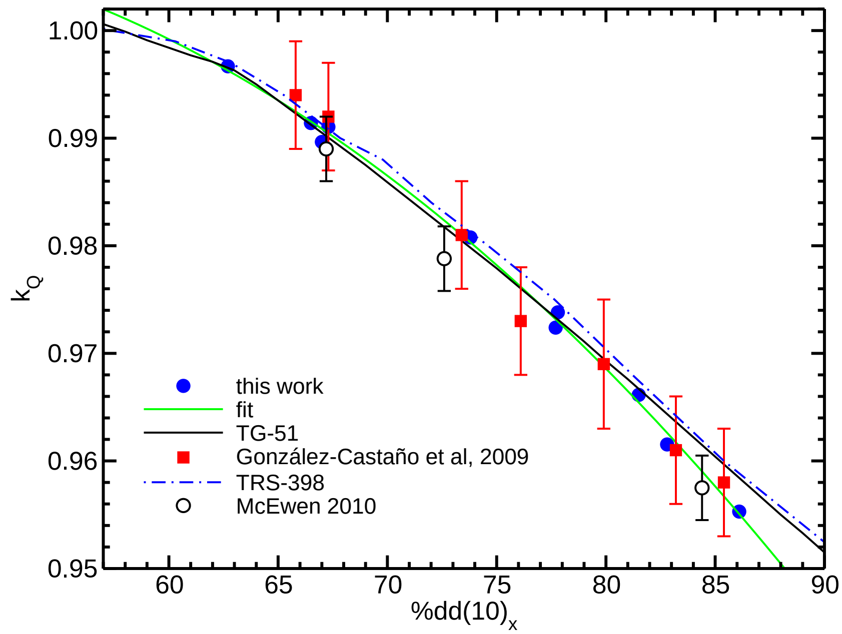

Figure 17: Monte Carlo calculated k_Q factors for the PTW30013 ion chamber (e,0.6 cm^3) along with measurements from McEwen,[4] TRS-398 and TG-51 values[6,7] and Monte Carlo data from González-Castaño[8] et al. The fit is to our Monte Carlo values.

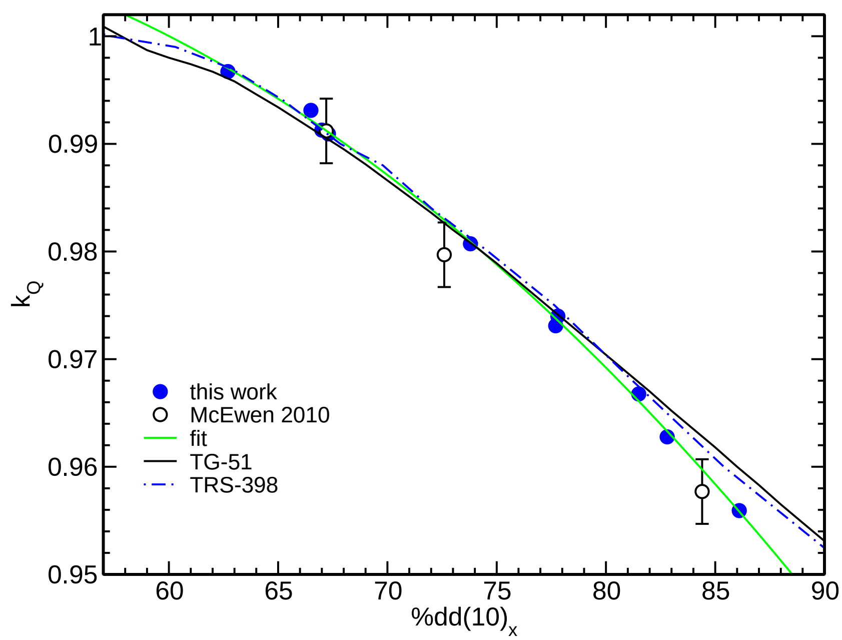

Figure 18: Monte Carlo calculated k_Q factors for the PTW31013 ion chamber (e,0.3 cm^3) along with measurements from McEwen,[4] as well as TRS-398 and TG-51 values.[6,7] The fit is to our Monte Carlo values.

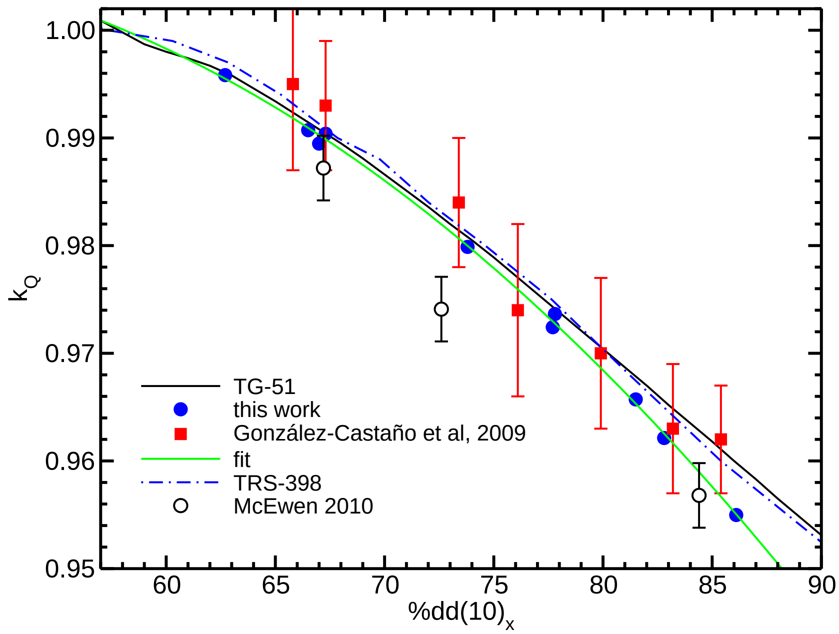

Figure 19: Monte Carlo calculated k_Q factors for the PTW31010 ion chamber (e,0.125 cm^3) along with measurements from McEwen,[4] TRS-398 and TG-51 values[6,7] and Monte Carlo data from González-Castaño[8] et al. The fit is to our Monte Carlo values.

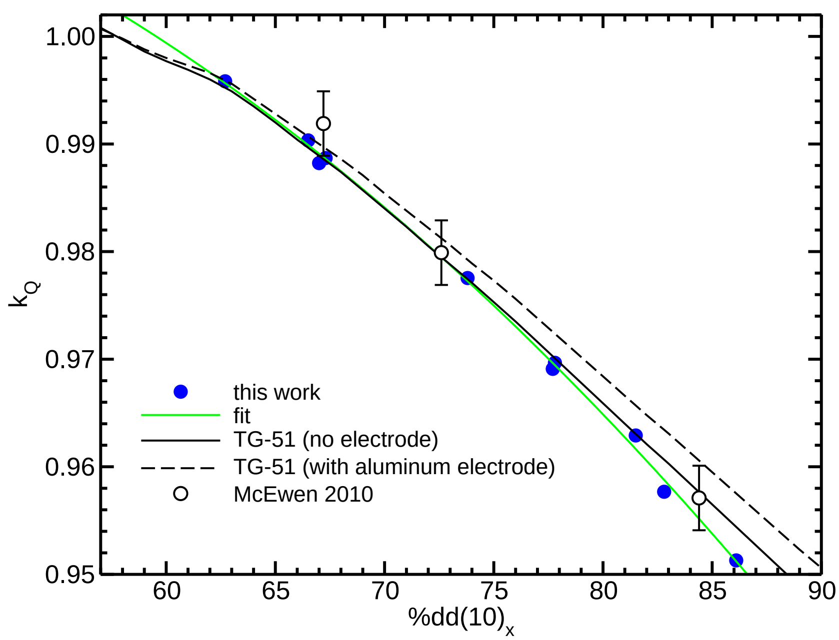

Figure 20: Monte Carlo calculated k_Q factors for the PTW31016 ion chamber (i,0.016 cm^3) along with measurements from McEwen[4] and TG-51 values with and without an aluminum central electrode.[6] The fit is to our Monte Carlo values.

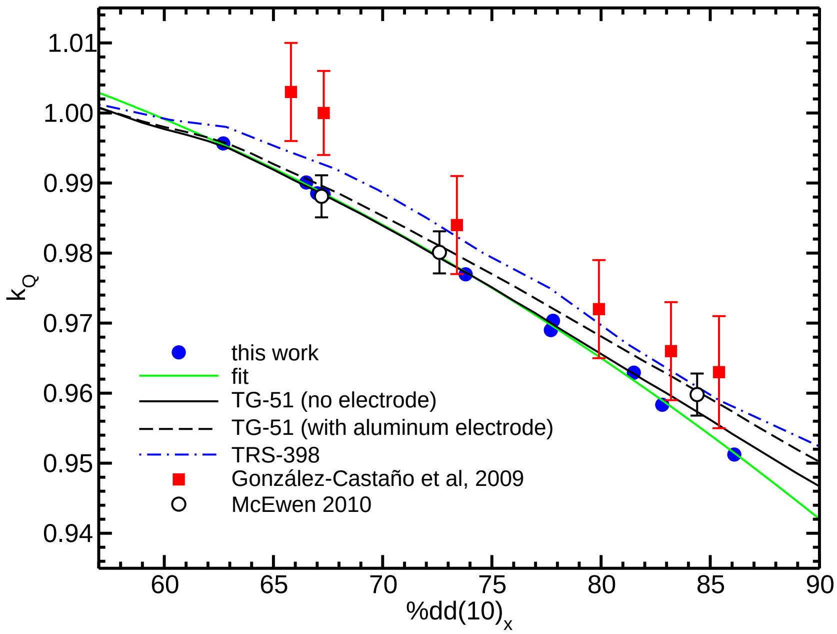

Figure 21: Monte Carlo calculated k_Q factors for the PTW31014 ion chamber (i,0.015 cm^3) along with measurements from McEwen,[4] TG-51 values with and without an aluminum central electrode,[6] TRS-398 values[7] and Monte Carlo data from González-Castaño[8] et al. The fit is to our Monte Carlo values.

II.C. IBA

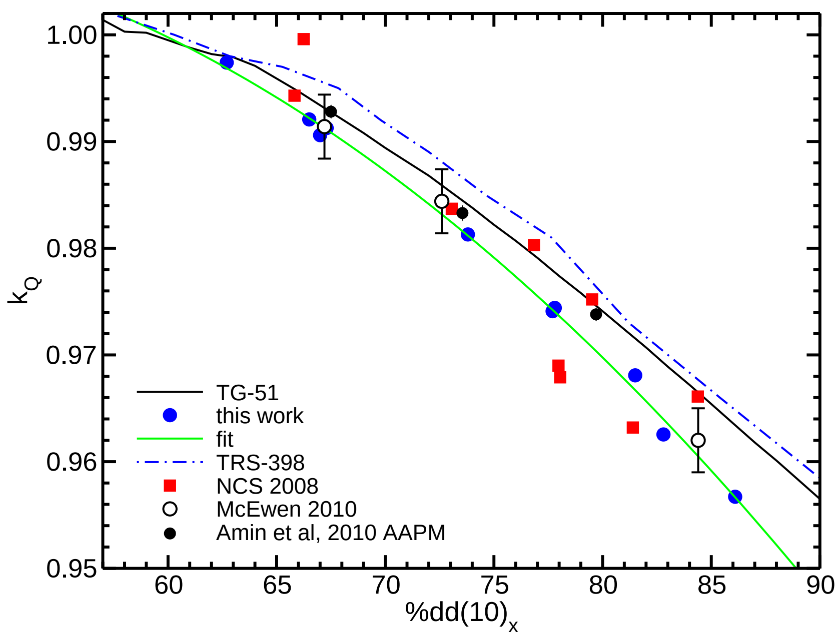

Figure 22: Monte Carlo calculated k_Q factors for the IBA FC65G ion chamber (c,0.65 cm^3) along with measurements from McEwen,[4] TG-51 values with and without an aluminum central electrode,[6] TRS-398 values[7] and Monte Carlo data from González-Castaño[8] et al. The fit is to our Monte Carlo values.

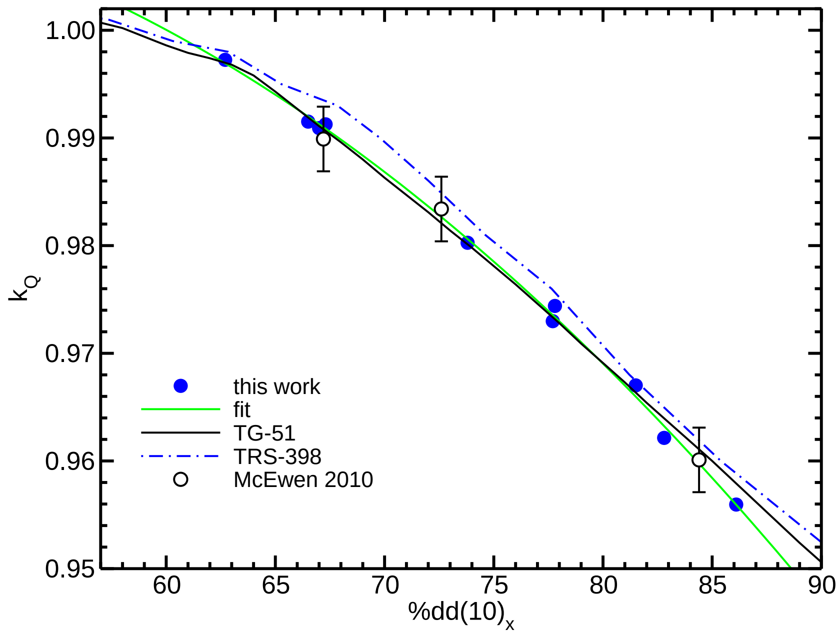

Figure 23: Monte Carlo calculated k_Q factors for the IBA FC65P ion chamber (f,0.65 cm^3) along with measurements from McEwen,[4] TG-51[6] and TRS-398 values.[7] The fit is to our Monte Carlo values.

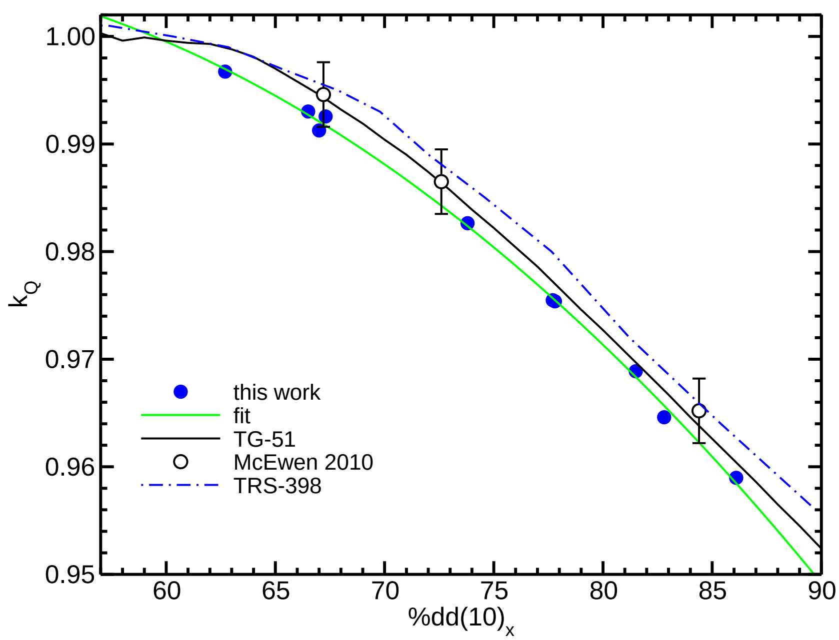

Figure 24: Monte Carlo calculated k_Q factors for the IBA CC25 ion chamber (a,0.25 cm^3) along with measurements from McEwen,[4] TG-51[6] and TRS-398 values.[7] The fit is to our Monte Carlo values.

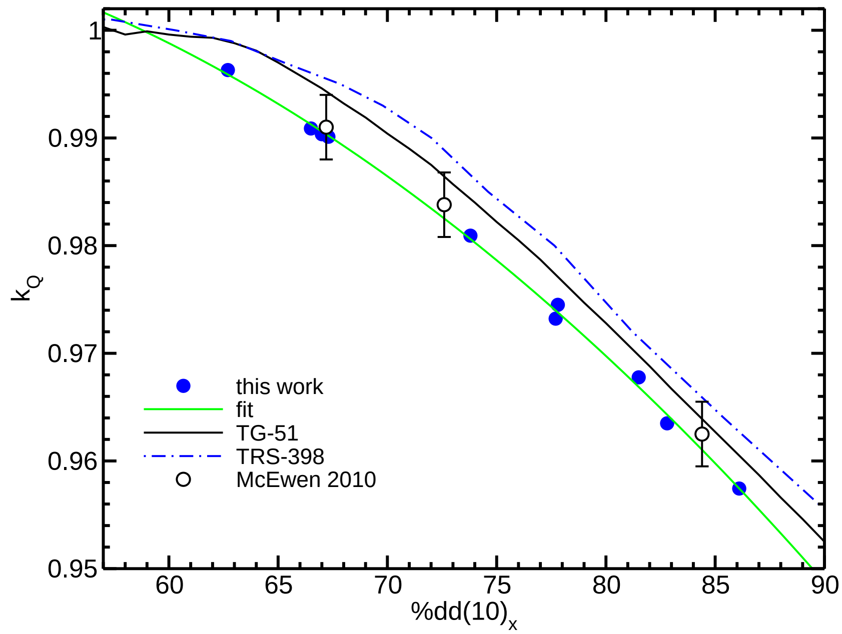

Figure 25: Monte Carlo calculated k_Q factors for the IBA FC23C ion chamber (a,0.23 cm^3) along with measurements from McEwen,[4] TG-51[6] and TRS-398 values.[7] The fit is to our Monte Carlo values.

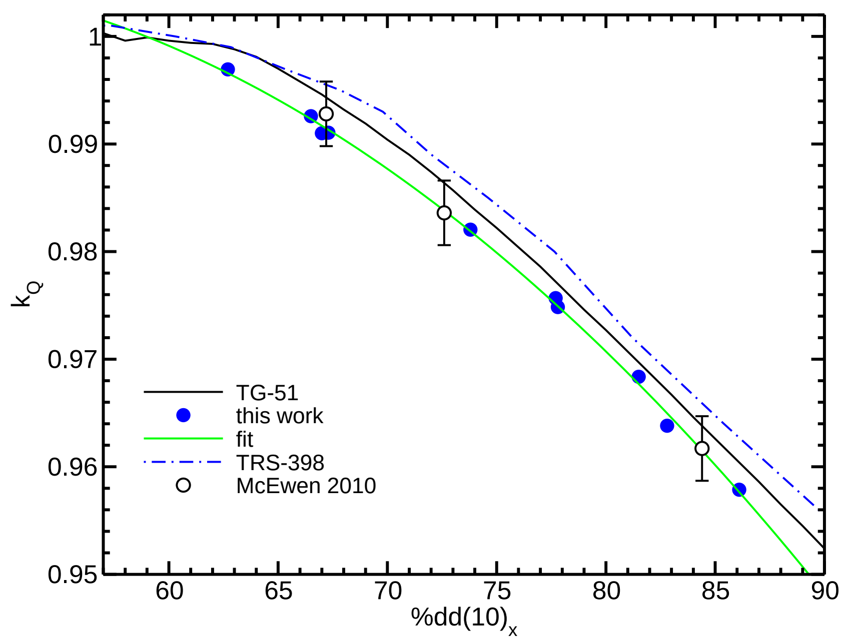

Figure 26: Monte Carlo calculated k_Q factors for the IBA CC13 ion chamber (a,0.13 cm^3) along with measurements from McEwen,[4] TG-51[6] and TRS-398 values.[7] The fit is to our Monte Carlo values.

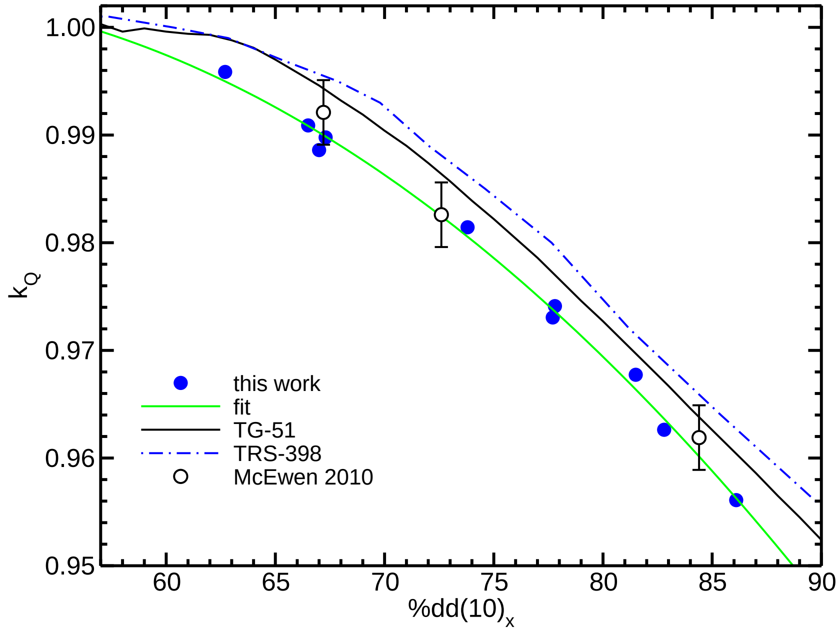

Figure 27: Monte Carlo calculated k_Q factors for the IBA CC08 ion chamber (a,0.08 cm^3) along with measurements from McEwen,[4] TG-51[6] and TRS-398 values.[7] The fit is to our Monte Carlo values.

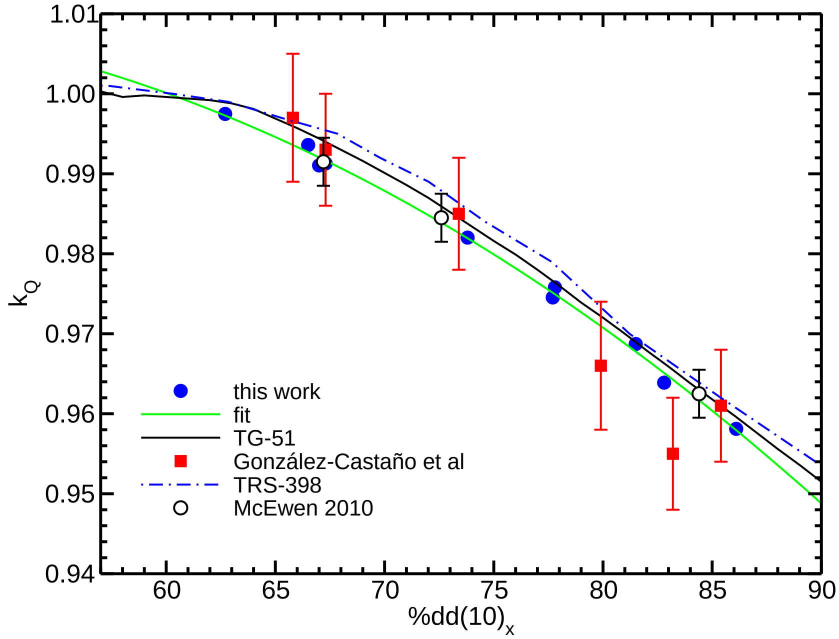

Figure 28: Monte Carlo calculated k_Q factors for the IBA CC04 ion chamber (a,0.04 cm^3) along with measurements from McEwen,[4] TG-51[6] and TRS-398 values[7] and Monte Carlo data from González-Castaño[8] et al. The fit is to our Monte Carlo values.

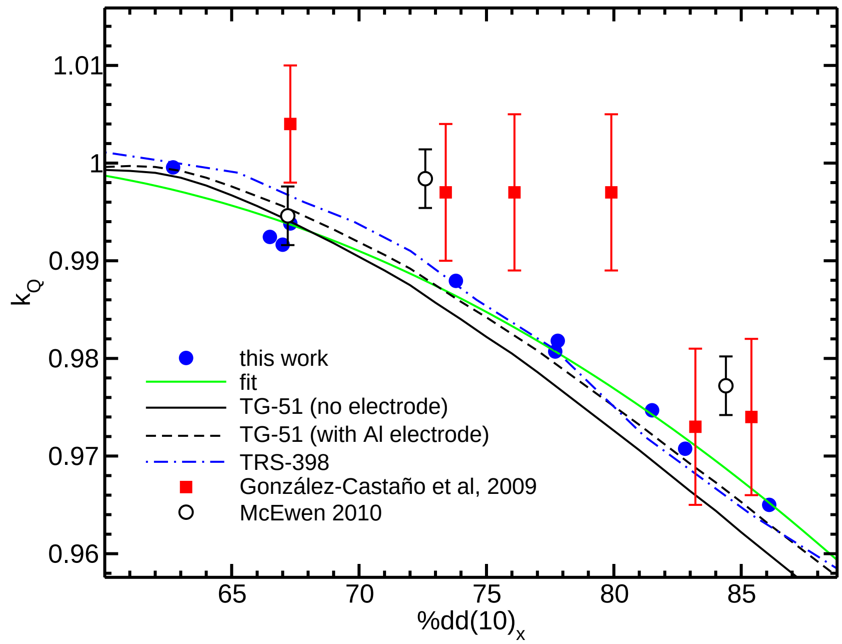

Figure 29: Monte Carlo calculated k_Q factors for the IBA CC01 ion chamber (g,0.01 cm^3) along with measurements from McEwen,[4] TG-51 values with and without an aluminum electrode,[6] TRS-398 values[7] and Monte Carlo data from González-Castaño[8] et al. The fit is to our Monte Carlo values.

II.D. Others - NE and Capintec

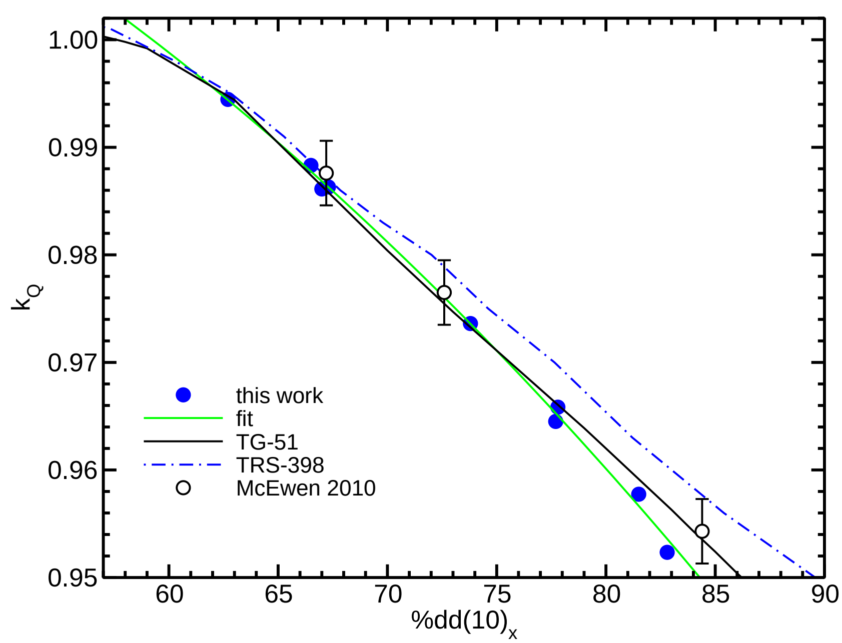

Figure 30: Monte Carlo calculated k_Q factors for the NE2581 ion chamber (b,0.6 cm^3) along with measurements from McEwen,[4] TG-51[6] and TRS-398 values.[7] The fit is to our Monte Carlo values.

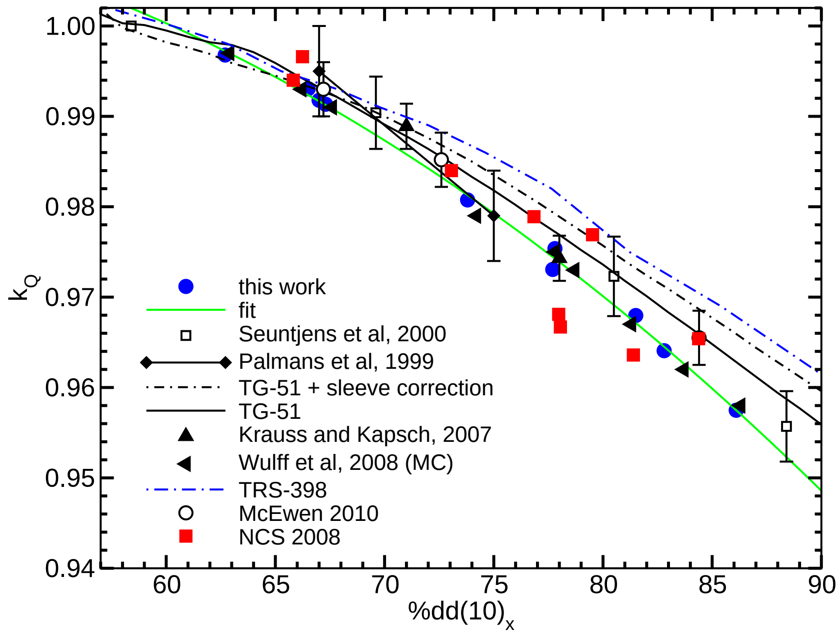

Figure 31: Monte Carlo calculated k_Q factors for NE2571 ion chamber (c,0.6 cm^3) along with measurements from Palmans et al,[10] McEwen,[4] Seuntjens et al,[3] Krauss and Kapsch[11] and the Netherlands Commission on Radiation Dosimetry Code of Practice,[9] Monte Carlo calculated values from Wulff et al[12] and values from the TG-51[6] and TRS-398[7] protocols. The fit is to our Monte Carlo values.

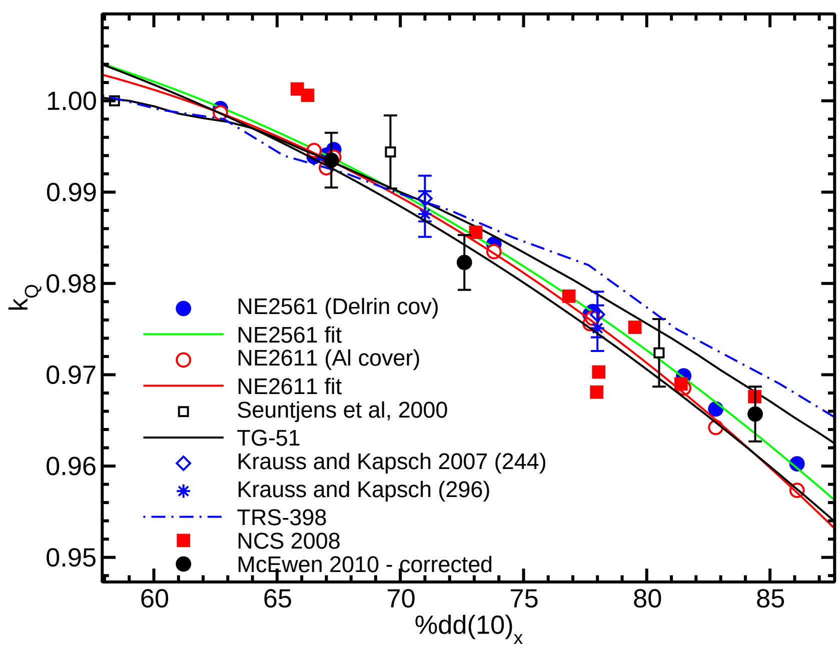

Figure 32: Monte Carlo calculated k_Q factors for the NE2561 and NE2611 ion chambers (c,0.3 cm^3) along with measurements from McEwen[4] (corrected, see Muir et al.[13] for details), Seuntjens et al,[3] Krauss and Kapsch[11] and the Netherlands Commission on Radiation Dosimetry Code of Practice[9] and values from the TG-51[6] and TRS-398[7] protocols. The fit is to our Monte Carlo values.

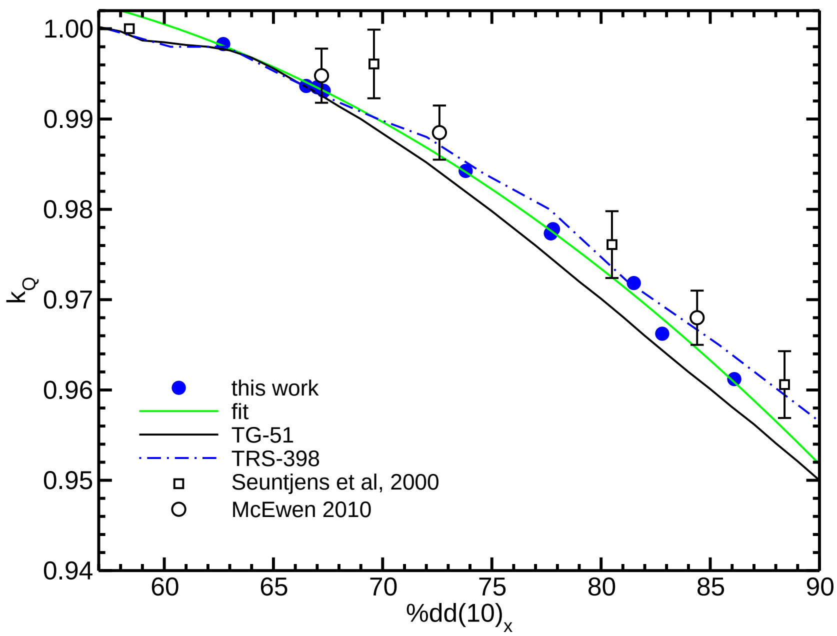

Figure 33: Monte Carlo calculated k_Q factors for the Capintec PR06C/G ion chamber (a,0.65 cm^3) along with measurements from McEwen[4] and Seuntjens et al[3] and values from the TG-51[6] and TRS-398[7] protocols. The fit is to our Monte Carlo values.

References

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