



HAL
open science

MV reference dosimetry in TRS-398: State-of the art and research supporting an updated code of practice

Franck Delaunay, C Andersen, L De Prez, S. Duane, M. Pimpinella, P. Teles, J Tikkanen, K Zink

► **To cite this version:**

Franck Delaunay, C Andersen, L De Prez, S. Duane, M. Pimpinella, et al.. MV reference dosimetry in TRS-398: State-of the art and research supporting an updated code of practice. ESTRO 38, 26-30 April 2019, Milan, Italy, ESTRO, Apr 2019, Milan, Italy. pp.S117-S118, <10.1016/S0167-8140(19)30656-5>. <hal-04554292>

HAL Id: hal-04554292

<https://hal.science/hal-04554292v1>

Submitted on 24 Apr 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



HAL Authorization

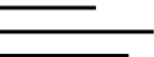


Dear Sir, Madam,

Please find herewith the PowerPoint template to be used for ESTRO38.
This will be the only template accepted at the Congress.

You will find that the template uses the new ESTRO branding, which will be officially unveiled during the Congress. Therefore, we kindly ask you not to disclose this new branding to third parties.

Kind regards,
The ESTRO Team



NOTE

Please note that the slides of this presentation cannot be shared on social media.

Thank you for your kind cooperation.



F Delaunay¹, C Andersen², L De Prez³, S Duane⁴, M Pimpinella⁵, P Teles⁶, J Tikkanen⁷, K Zink⁸

¹ CEA- LIST, LABORATOIRE NATIONAL HENRI BECQUEREL LNE-LNHB, F-91191 GIF-SUR-YVETTE, FRANCE.

² DTU, CENTER FOR NUCLEAR TECHNOLOGIES, KONGENS LYNGBY, DENMARK.

³ VSL, DUTCH METROLOGY INSTITUTE, DELFT, the NETHERLANDS.

⁴ NATIONAL PHYSICAL LABORATORY, CHEMICAL- MEDICAL & ENVIRONMENTAL SCIENCE DEPARTMENT, TEDDINGTON, UNITED KINGDOM.

⁵ ENEA, NATIONAL INSTITUTE OF IONIZING RADIATION METROLOGY INMRI, ROME, ITALY.

⁶ UNIVERSITY OF LISBON, GPSR- CENTRE OF NUCLEAR SCIENCES AND TECHNOLOGY- IST, LISBON, PORTUGAL.

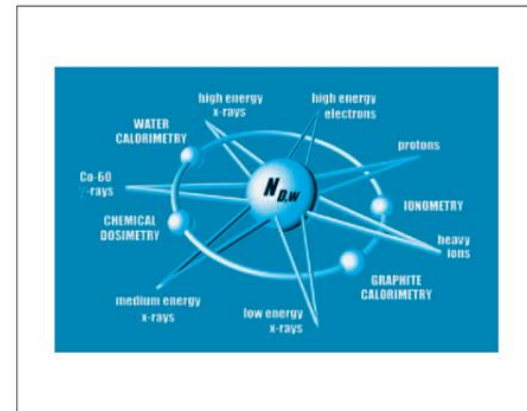
⁷ STUK, Radiation and Nuclear Safety Authority, HELSINKI, FINLAND.

⁸ UNIVERSITY OF APPLIED SCIENCES GIESSEN, INSTITUTE OF MEDICAL PHYSICS AND RADIATION PROTECTION, GIESSEN, GERMANY.

corresponding author: franck.delaunay@cea.fr



MV reference dosimetry in TRS-398: State-of-the art and research supporting an updated Code of Practice



TECHNICAL REPORTS SERIES No. **398**

**Absorbed Dose Determination in
External Beam Radiotherapy**

**An International Code of Practice for Dosimetry
Based on Standards of Absorbed Dose to Water**

Sponsored by the IAEA, WHO, PAHO and ESTRO

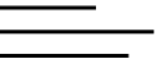


INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA, 2000

Conflict of Interest

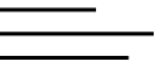


- no conflict of interest

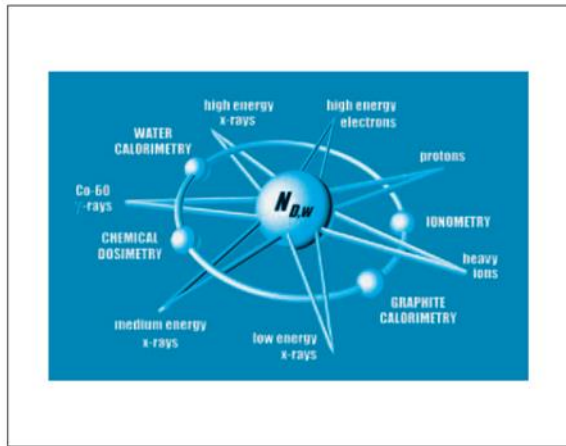


Synopsis

- Reasons to update
- IAEA requirements for volunteers
- RTNORM Euramet project
- Monte Carlo
 - ICRU 90
 - first results
- Measurements
 - calorimeters
 - first results
- Preliminary conclusions
- IAEA Workgroups



Reasons to update ?



TECHNICAL REPORTS SERIES No. 398

Absorbed Dose Determination in
External Beam Radiotherapy
An International Code of Practice for Dosimetry
Based on Standards of Absorbed Dose to Water

Sponsored by the IAEA, WHO, PAHO and ESTRO



- IAEA TRS 398 - 2000

Absorbed dose determination in external beam radiotherapy (V.12 2006)

- new dosimeters
- FFF beams
- small fields (IAEA TRS 483 2017)
- PSDLs with D_w references
- reliable Monte Carlo codes
- ICRU 90 - 2016

Key data for ionizing-radiation dosimetry:
measurement standards and applications

Christaki K, IAEA project leader

Andreo P, « father » of the former TRS 398

IAEA requirements for volunteers

- IAEA asked by the end of 2015 volunteers to measure (based on primary standard dosimeters) and calculate with Monte Carlo codes k_{Q,Q_0} values for reference-class ionization chambers

$$k_{Q,Q_0} = N_{D,w,Q} / N_{D,w,Q_0} \quad Q_0 = {}^{60}\text{Co} \rightarrow k_Q$$

- primary standards \equiv graphite and water calorimeters
- measurements of 5 ICs of the same type, ideally from different manufactured batches (repeated at least once + polarity, recombination, *volume averaging*)
- calculations with Monte Carlo codes passing the Fano test like EGSnrc and PENELOPE + *volume averaging*

Reminders

- Volume averaging correction: lack of uniformity of the lateral beam profiles of reference fields over the sensitive volume of the detector (in the absence of the detector)
- Reference-class IC = as 0.6 cm³ Farmer-type : quick stabilization, small leakage, small polarity effect, expected recombination behaviors, small k_Q variability, stable in time in temperature and humidity usual conditions (McEwen 2010 Med Phys 37 2179)

RTNORM (2017/05 - 2019/10) as example of volunteer



<http://www.rtnorm.eu/>
Coordinator: Pinto M of ENEA

kV x-rays, MV x-rays, scanned
proton beams

MV photon beams

- Monte Carlo calculations:

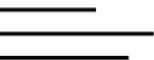


- Measurements:



Synopsis

- Reasons to update
- IAEA requirements for volunteers
- RTNORM Euramet project
- **Monte Carlo**
 - ICRU 90
 - first results
- Measurements
 - calorimeters
 - first results
- Preliminary conclusions
- IAEA Workgroups

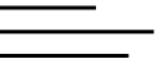


Monte Carlo - ICRU 90 for MV beams



ICRU 37 - **Stopping Powers** for Electrons and Positrons (1984)

for air, graphite and water → ICRU 90 - Key data for ionizing-radiation dosimetry: measurement standards and applications (2016)



ICRU 90 - stopping powers

- Mean excitation energy I (Bethe formula)

- air: 85.7 eV \rightarrow 85.7 eV

- graphite : 78 eV \rightarrow 81 eV

$$\frac{1}{\rho} S_{col}(W < W_c) = \frac{2 \pi r_e^2 mc^2}{u} \frac{1}{\beta^2} \frac{Z}{A} z^2 \left[\ln \left(\frac{2 mc^2 \beta^2 W_c}{I^2 (1 - \beta^2)} \right) - \beta^2 \right]$$

- water: 75 eV \rightarrow 78 eV

- Graphite crystalline density of 2.265 g/cm³ for the density correction
- Water at 20 °C

ICRU 90 - stopping powers

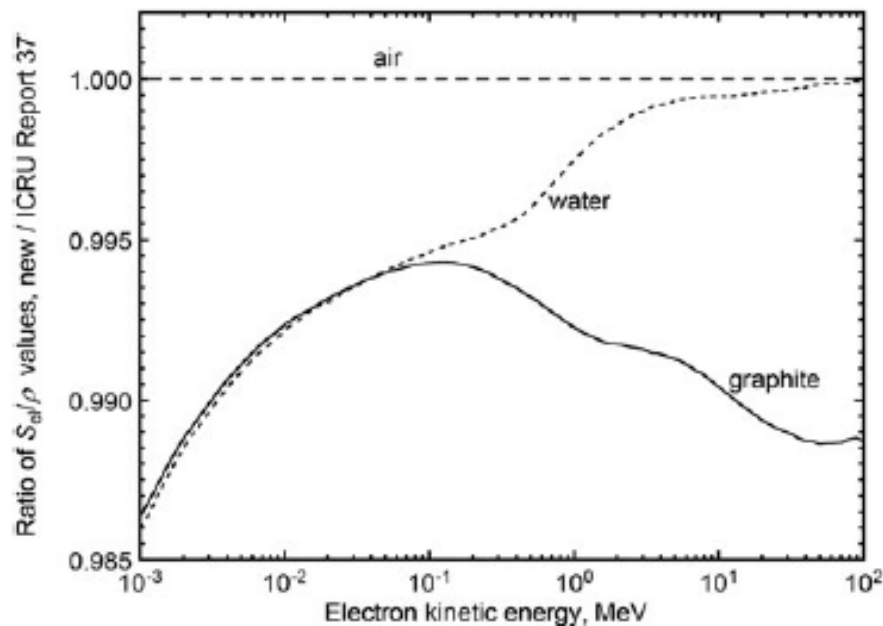


Figure 7.1. Ratios of the mass electronic stopping power for electrons recommended in this Report to those given in ICRU Report 37 (1984a), as a function of the electron energy, for graphite (solid line), liquid water (short dashes), and air (long dashes).

Monte Carlo - EGSnrc - work done



| | ENEA | STUK | THM |
|---------------------------------------|------|------|----------|
| Number of beams | 7 | 6 | 12 to 14 |
| Exradin A1SL (0.053 cm ³) | | | v |
| IBA CC13 (0.13 cm ³) | v | | |
| IBA FC65-G | v | v | |
| IBA FC65-P | v | | |
| NE 2571 | v | v | v |
| PTW 30013 | v | | v |
| PTW 31010 (0.125 cm ³) | | | v |
| PTW 31013 (0.3 cm ³) | | | v |
| PTW 31021 (0.07 cm ³) | | v | v |

- ENEA:
Pimpinella *et al* (2019)
Phys Med **57** 221
no volume averaging corrections
(water: \varnothing 2.0 or 0.5 cm)
- STUK:
volume of water \equiv air cavity of
the ionization chamber
- THM:
Czarnecki *et al* (2018)
Phys Med Biol **63** 155015
TRS 383 method for volume
averaging corrections

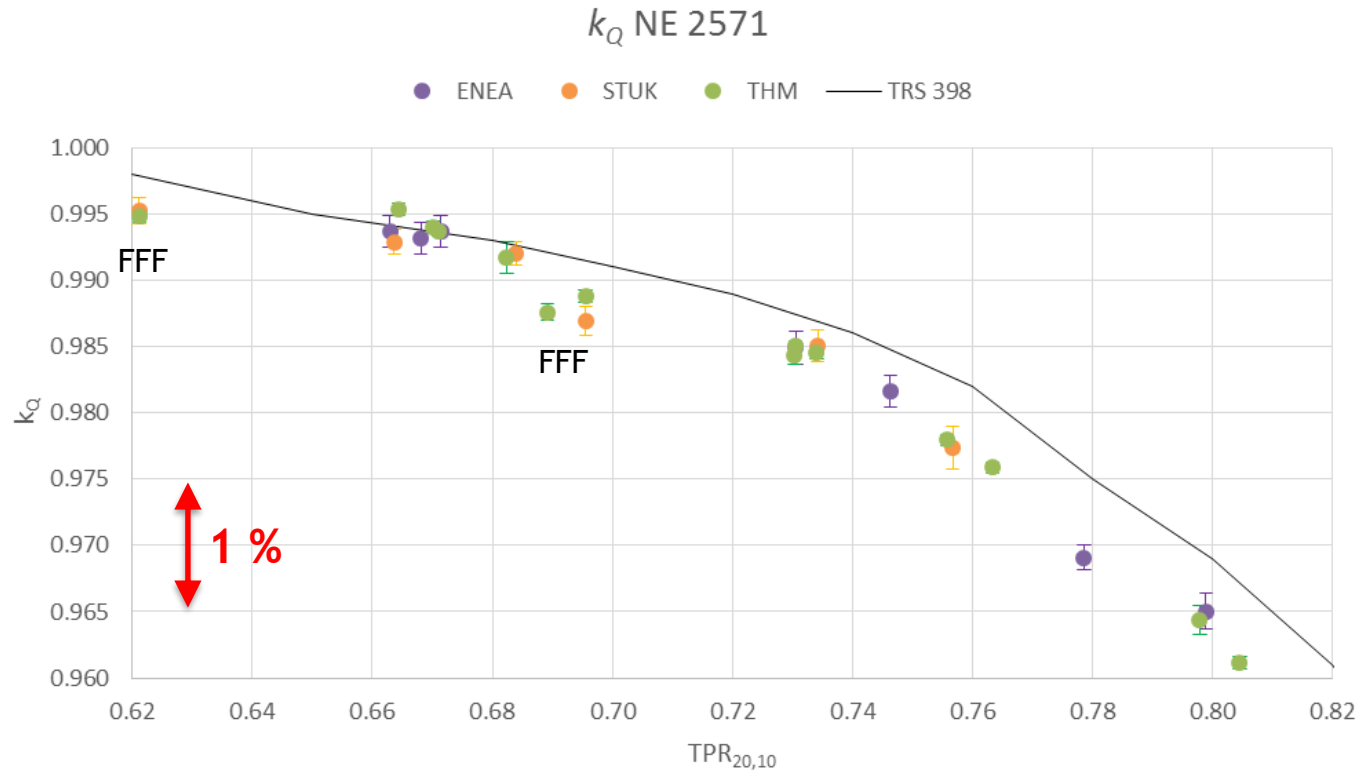
Synopsis

- Reasons to update
- IAEA requirements for volunteers
- RTNORM Euramet project
- Monte Carlo
 - ICRU 90
 - **first results**
- Measurements
 - calorimeters
 - first results
- Preliminary conclusions
- IAEA Workgroups

Monte Carlo - NE 2571 0.6 cm³ 1 mm PMMA waterproof sleeve

type A
uncertainties,
1 standard
deviation

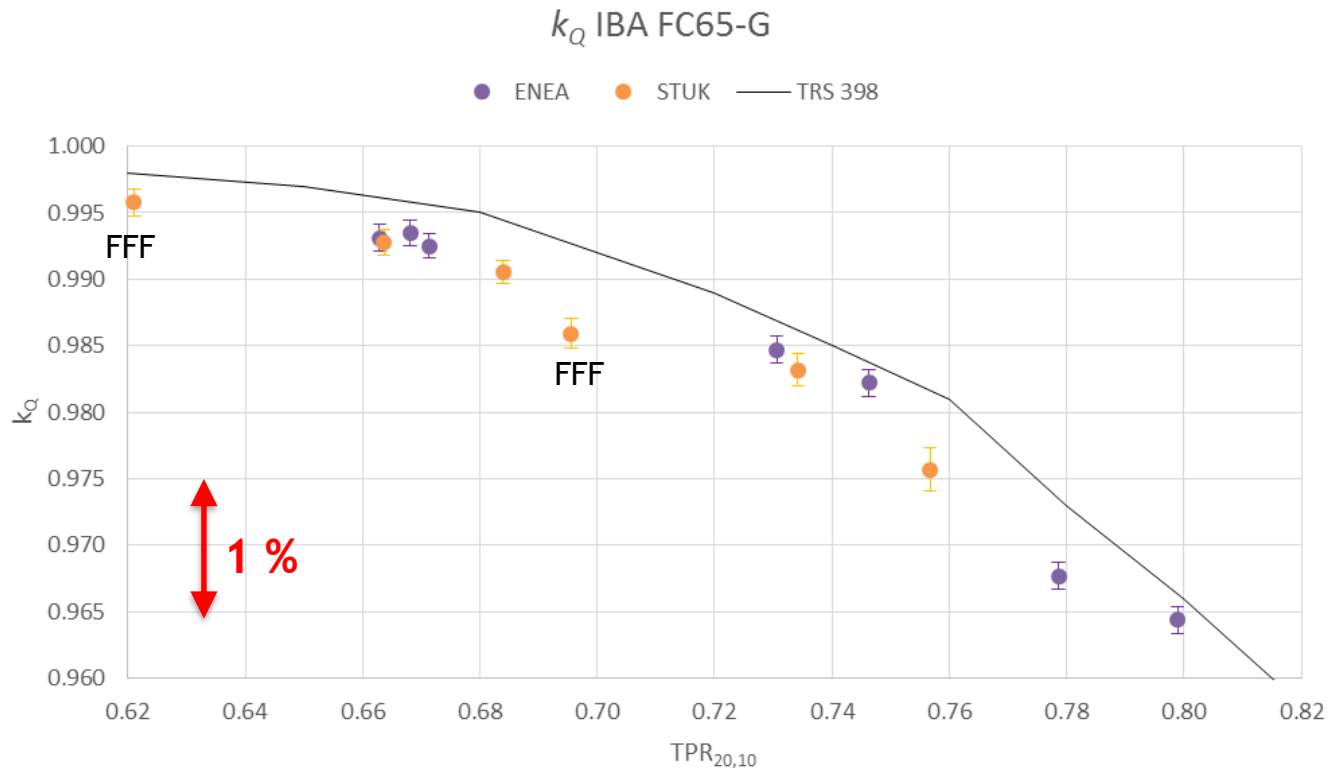
TRS 398 - 1 %



Monte Carlo - FC65-G 0.65 cm³

type A
uncertainties,
1 standard
deviation

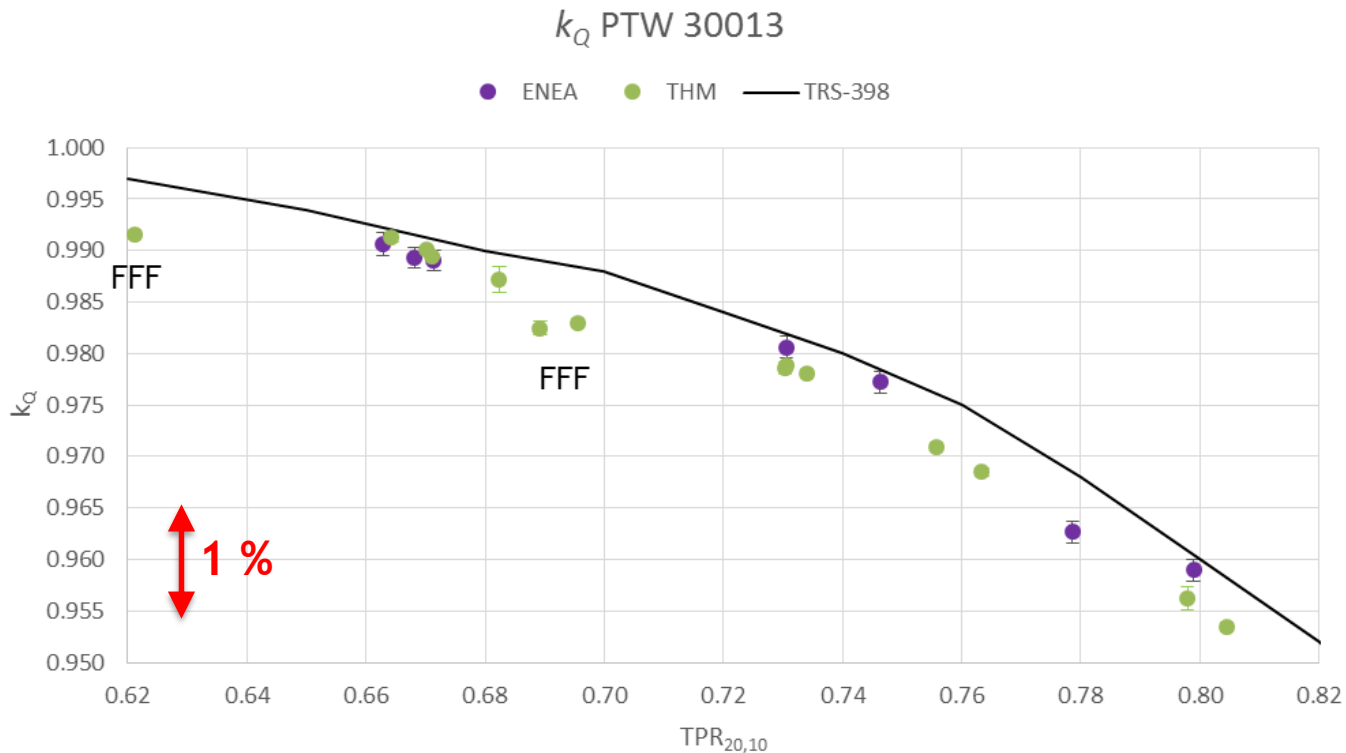
TRS 398 - 1 %



Monte Carlo - PTW 30013 0.6 cm³

type A
uncertainties,
1 standard
deviation

TRS 398 - 1 %



Monte Carlo - PTW 31021 0.07 cm³

k_Q PTW 31021

● STUK ● THM

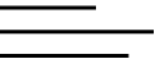


type A
uncertainties,
1 standard
deviation

no data from
TRS-398

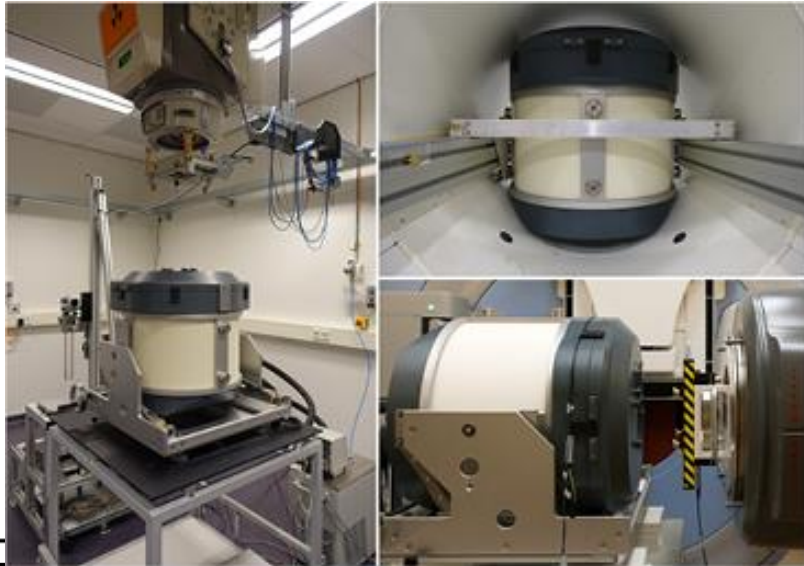
Synopsis

- Reasons to update
- IAEA requirements for volunteers
- RTNORM Euramet project
- Monte Carlo
 - ICRU 90
 - first results
- **Measurements**
 - calorimeters
 - first results
- Preliminary conclusions
- IAEA Workgroups

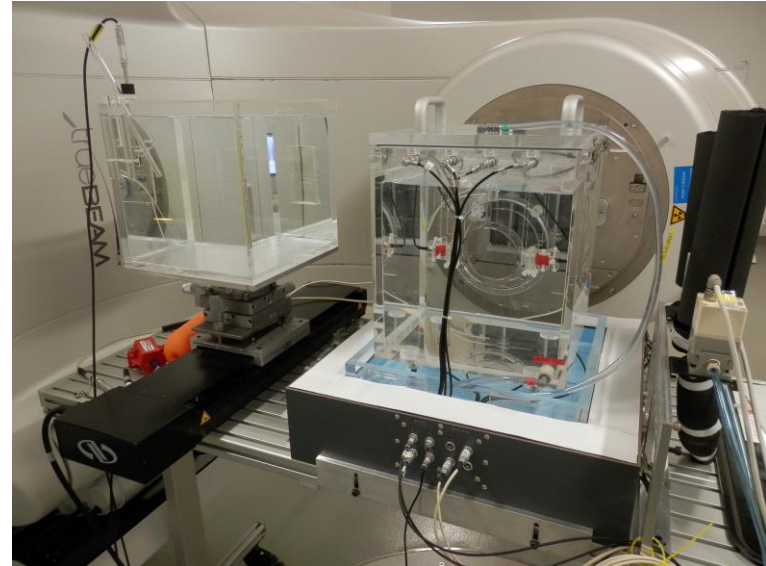


Calorimetry - water (VSL, LNHB)

VSL water calorimeter
De Prez *et al* (2016)
Phys Med Biol 61 5051



LNHB water calorimeter
B. Rapp *et al* (2013)
Phys Med Biol 58 2769



Calorimetry - water (VSL)

$$D_w = \Delta T_w \frac{c_p}{1 - h} k_p k_c k_R$$

c_p water specific heat capacity

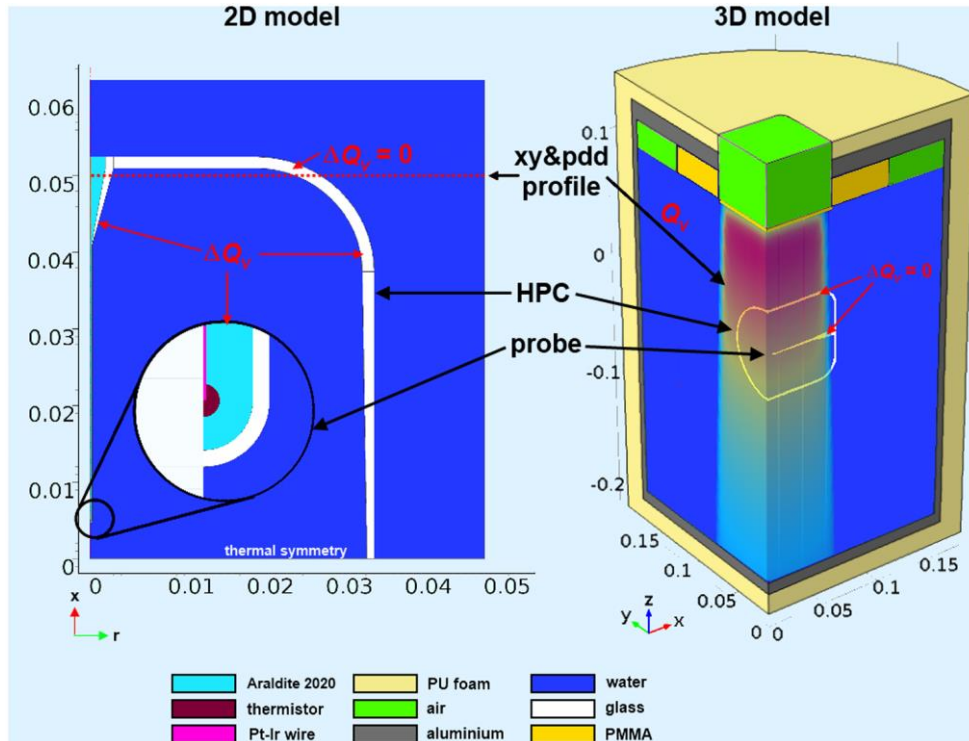
h heat defect

k_p non-water materials

k_c conductive heat flow

k_R depth and radial non-uniformity

Calorimetry - water



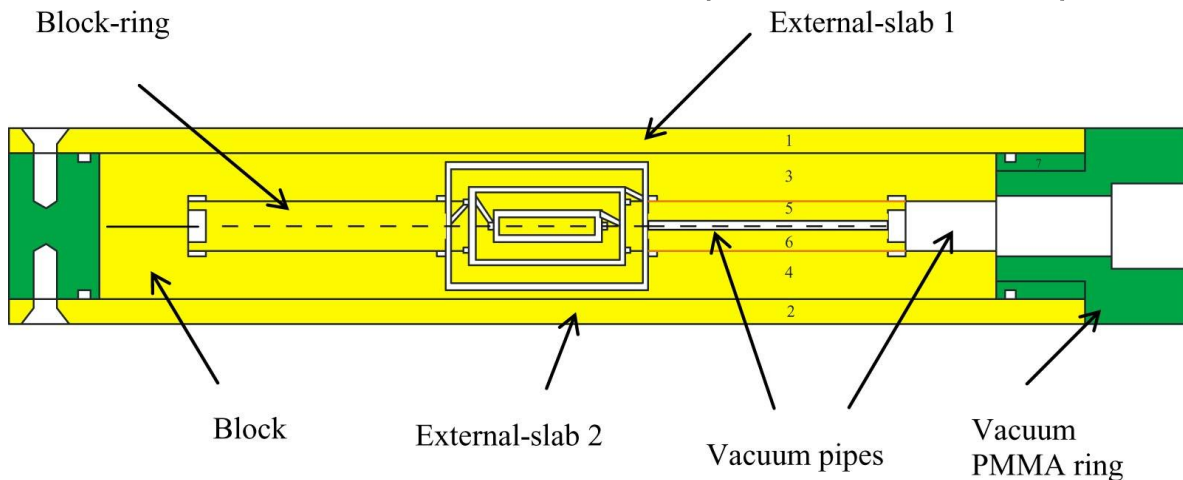
The 2D and 3D COMSOL models of the VSL calorimeter with an example 3D dose input for 10 MV photon beams, based on measured lateral and depth dose profiles (right). Dimensions are in meters.

Calorimetry - graphite (NPL, LNHB)

NPL calorimeter: Pearce *et al* (2011) Metrologia 48 365

LNHB calorimeter: Delaunay *et al* (2014) Metrologia 51 552

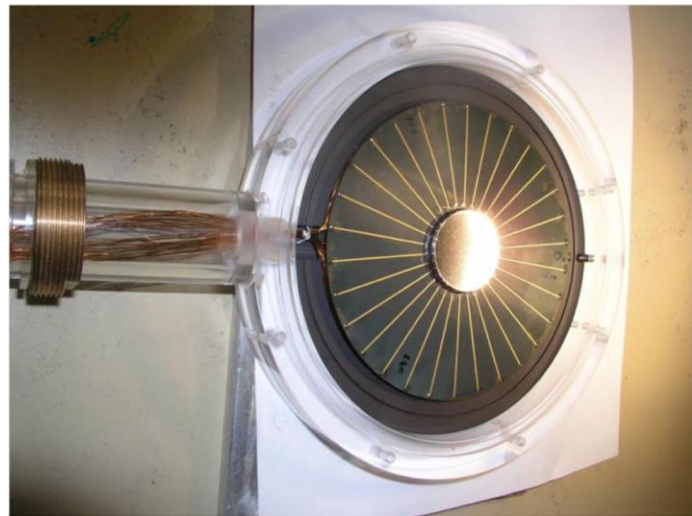
Lateral sectional view of the GR-9 graphite calorimeter (LNHB)
≡ Russian dolls (Matriochkas)



Calorimetry - graphite (LNHB, NPL)

$$D_w(C) = D_{core} k_i \left[\frac{D_w(V)}{D_{core}} \right]_{MC} k_{prof}(V)$$

View of the inside of the graphite calorimeter GR-9 (diameter of the core: 1.6 cm). The core and its two jackets are in the gleaming disc in the middle. The golden spokes are connected to the thermistors inside the middle disc and to the reader outside the calorimeter.



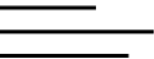
Measurements - work done

| | DTU | LNHB | VSL |
|---------------------------------------|-----|--------|-----|
| Number of beams | 7 | 3 to 4 | 4 |
| Exradin A1SL (0.053 cm ³) | | v | |
| IBBA CC13 (0.13 cm ³) | | | |
| IBA FC65-G | v | | v |
| IBA FC65-P | | | |
| NE 2571 | v | v | v |
| PTW 30013 | v | v | v |
| PTW 31010 (0.125 cm ³) | | | |
| PTW 31013 (0.3 cm ³) | | | |
| PTW 31021 (0.07 cm ³) | v | | |

- DTU: *calibrated by VSL*
Varian TrueBeam (FFF and wFF)
data still analyzed
- LNHB:
GE Saturne 43 (3 beams wFF)
Varian TrueBeam (4 beams wFF)
- VSL: *data still analyzed*
de Prez et al (2018)
Phys Med Biol 63 045023
Elekta Versa HD (FFF and wFF)

Synopsis

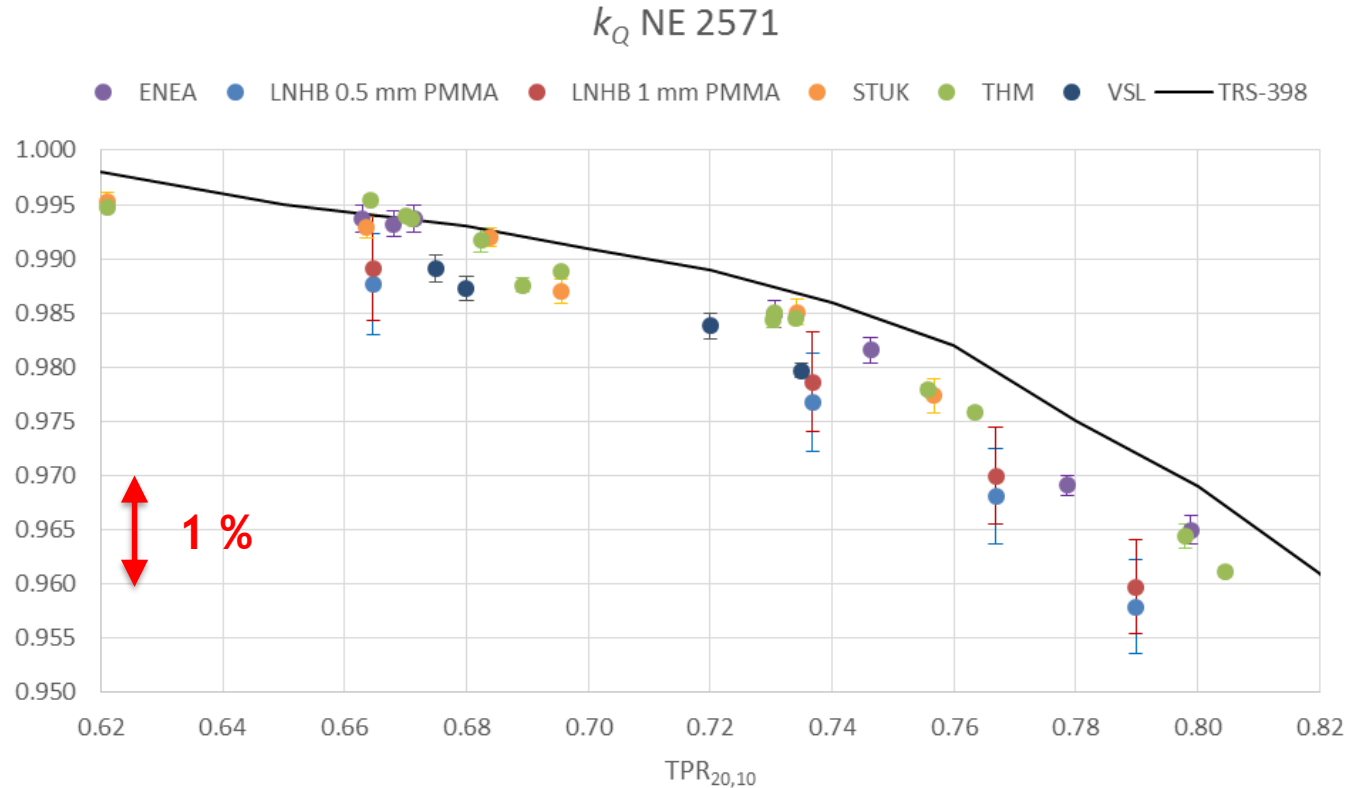
- Reasons to update
- IAEA requirements for volunteers
- RTNORM Euramet project
- Monte Carlo
 - ICRU 90
 - first results
- Measurements
 - calorimeters
 - **first results**
- Preliminary conclusions
- IAEA Workgroups



k_Q NE 2571 - 0.6 cm³

uncertainties
at 1 standard
deviation

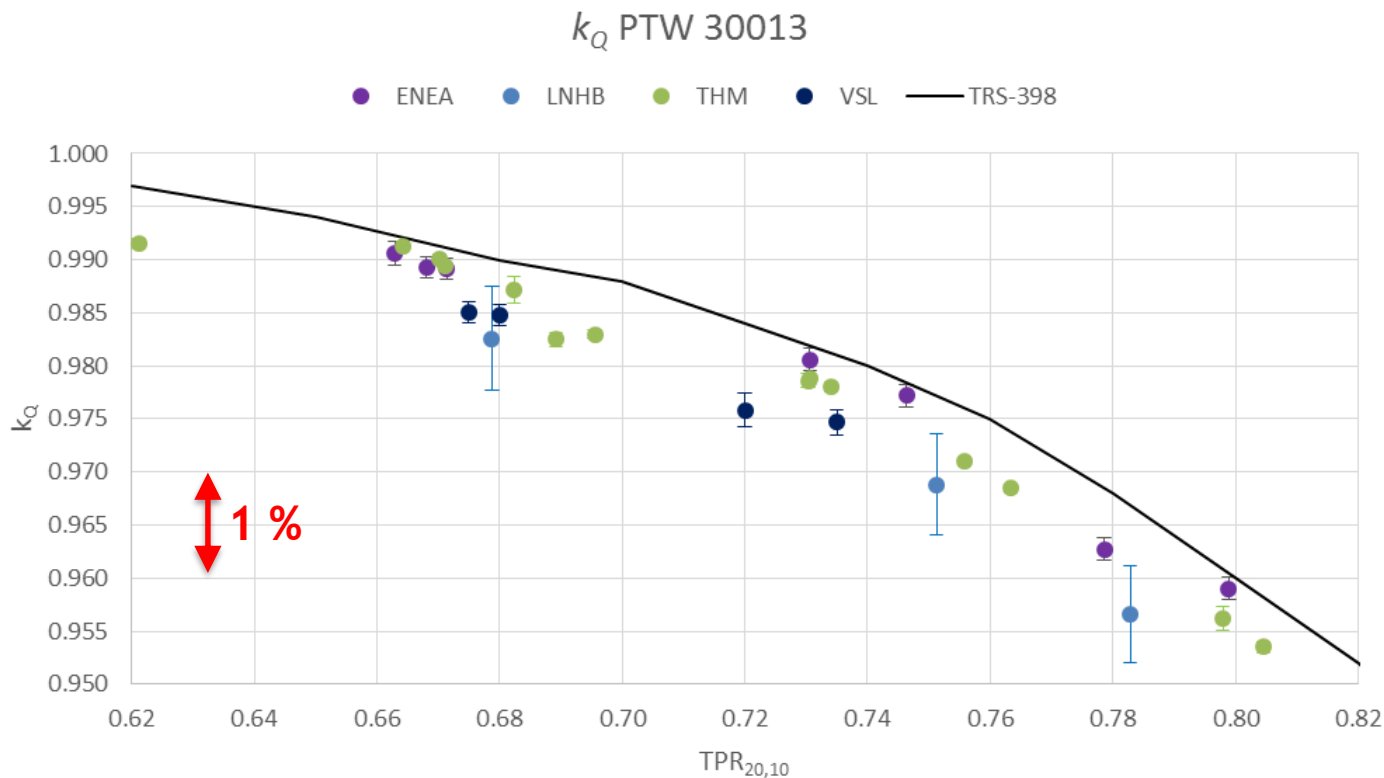
total combined
uncertainties
for **measured**
values (LNHB,
VSL)



k_Q PTW 30013 - 0.6 cm³

uncertainties
at 1 standard
deviation

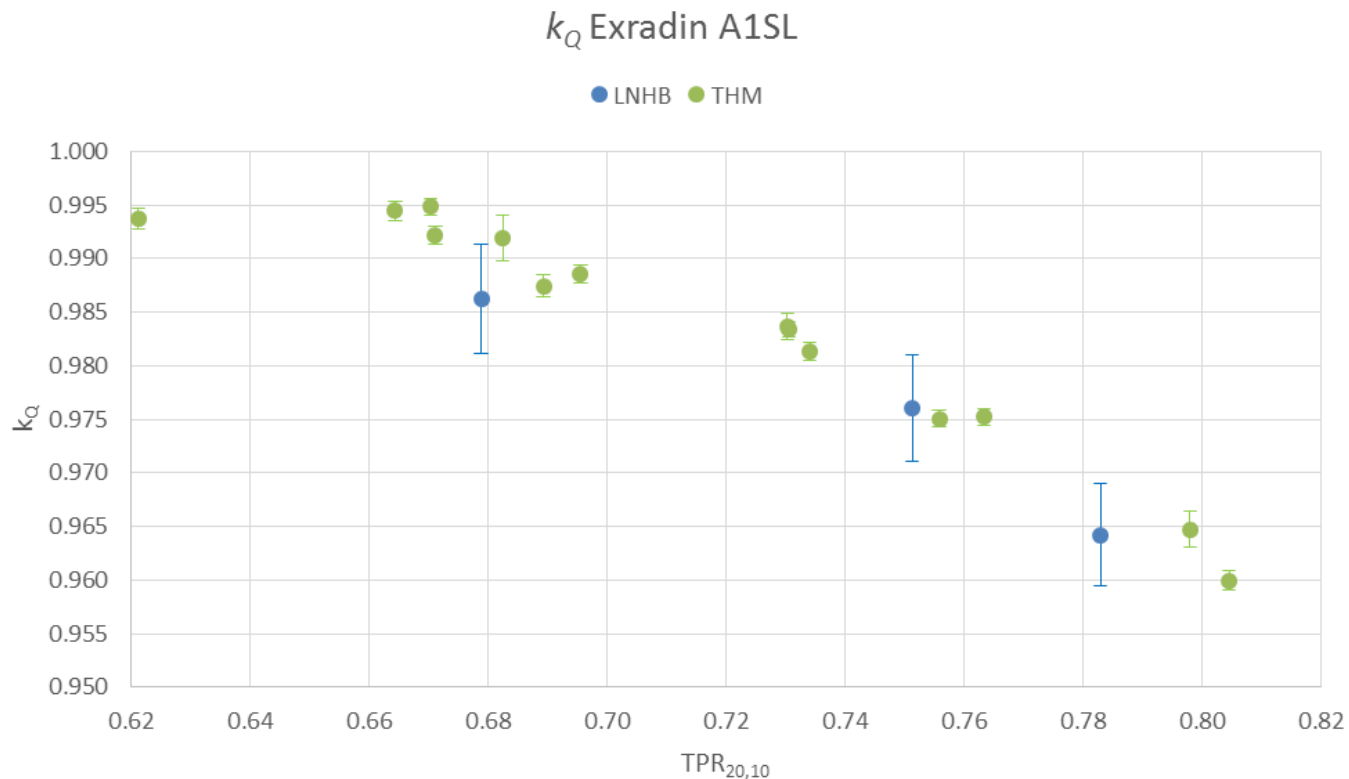
total combined
uncertainties
for **measured**
values (LNHB,
VSL)



k_Q Exradin A1SL - 0.053 cm³

uncertainties
at 1 standard
deviation

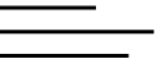
no data from
TRS-398



Preliminary conclusions



- EGSnrc calculated k_Q from the different RTNORM partners are in good agreement with each other and lower than the TRS-398 values for high energies (lower also for FFF beams).
- So far (only 2 RTNORM partners results available), measured k_Q are also in good agreement with each other but lower than the calculated ones

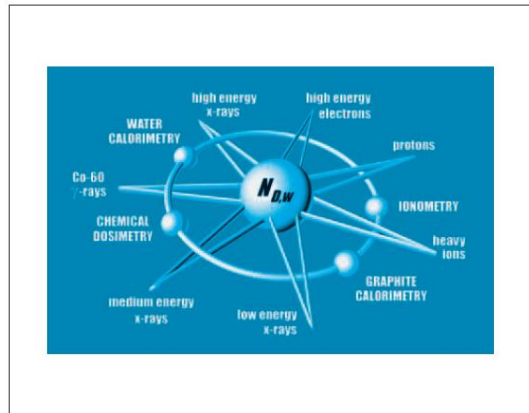


IAEA Workgroups



- Data are coming from all over the world (submission still opened)
 - Which data to include in the TRS 398 revision?
→ Workgroups
 - for kV beams
 - for MV beams
 - for e- beams
 - for proton beams
-
-

Thank you
for
your attention



TECHNICAL REPORTS SERIES No. 398

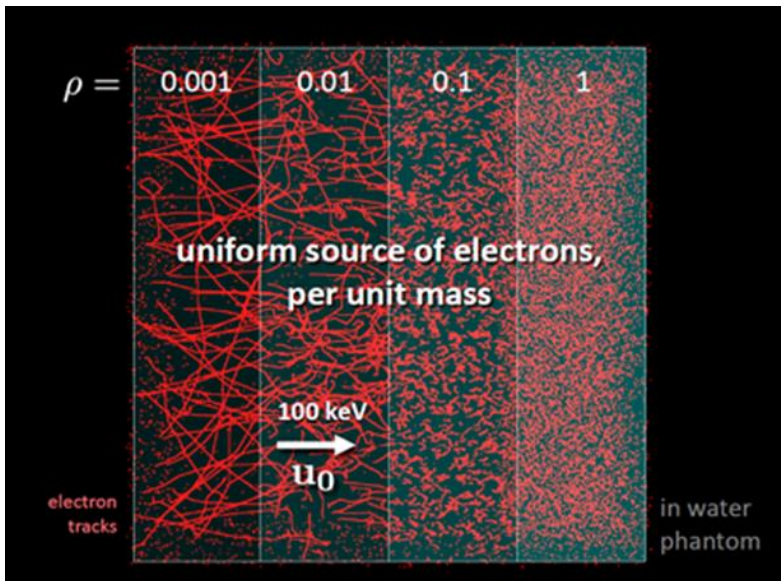
Absorbed Dose Determination in External Beam Radiotherapy

An International Code of Practice for Dosimetry Based on Standards of Absorbed Dose to Water

Sponsored by the IAEA, WHO, PAHO and ESTRO



Fano test



Fano test figures extracted from an NRC-CNRC presentation: Transport under magnetic fields with the EGSnrc simulation toolkit
Mainegra-Hing, Tessier, Walters (NRCC), Bouchard (Montreal U and NPL)

uniform electron source of energy E_0 per unit mass (N_0/m_T)

$$D_i = E_0 N_0/m_T$$

Fano test

