Physikalisch-Technische Bundesanstalt
Braunschweig and Berlin
National Metrology Institute

From dosemeter development to routine use – Standards and Uncertainties – RAP25-16

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PTB, Department ”Radiation protection dosimetry” (6.3)

Hyperlinks underlined and in light blue

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The concept of dosimetry

Standardization

- Structures
- Reference radiation fields
- Dosemeters
  Type tests and Uncertainties
- Calibration and routine tests

Conclusions

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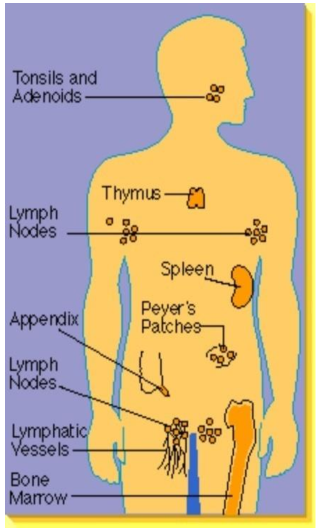
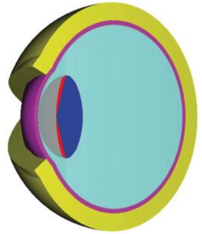
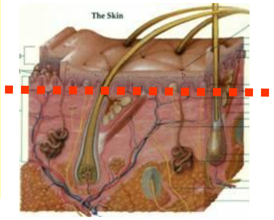
Dosimetry in radiation protection: the concept

Quantities „spread over the body“
(finite size of organs) –
by definition NOT measurable







Protection quantities
***E*, *H*$_T$: limits**

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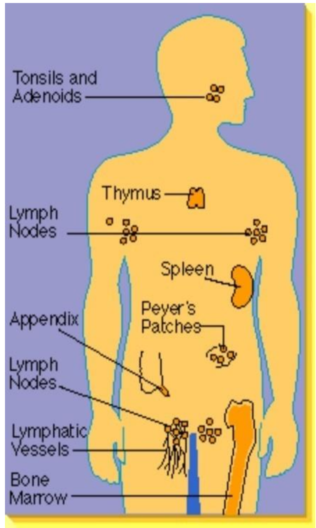

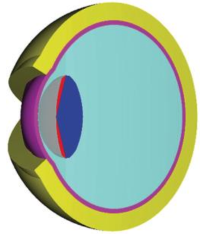

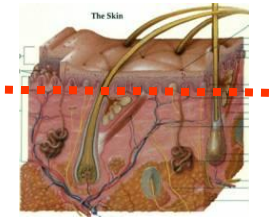

Protection quantities
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Point quantities (defined in
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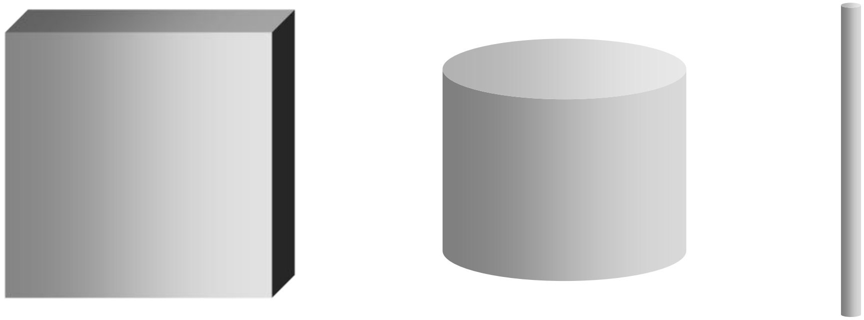

ICRU 4-element tissue

Measuring quantities

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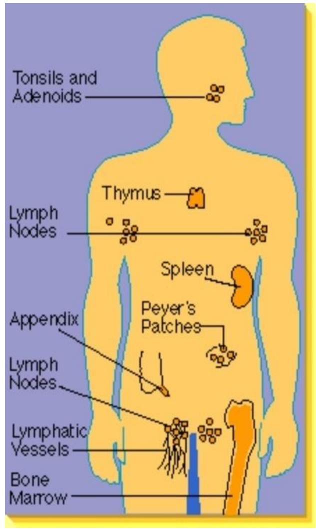

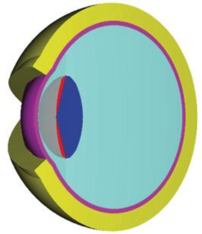

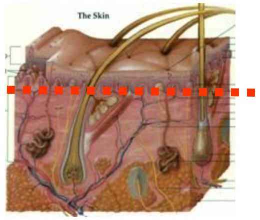

ICRP

Protection quantities E, H_T: limits

ICRU

Measuring quantities

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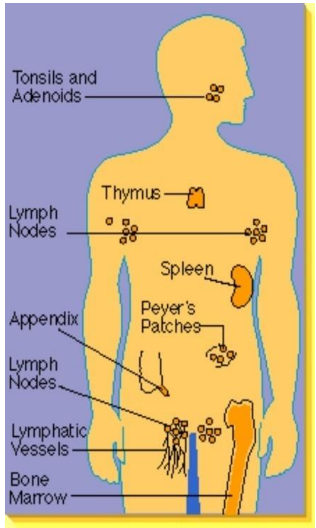

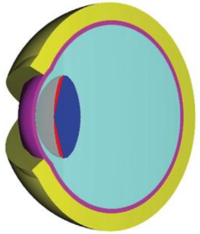

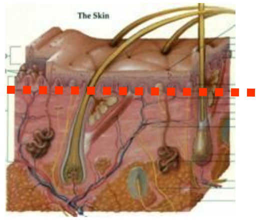

ICRP

Protection quantities
***E*, *H*$_T$: limits**

Point quantities (defined in
infinitesimally small point) –
by definition measurable

ICRU

Measuring quantities

Devices
Indicated value

Dosimetry in radiation protection: **the concept**

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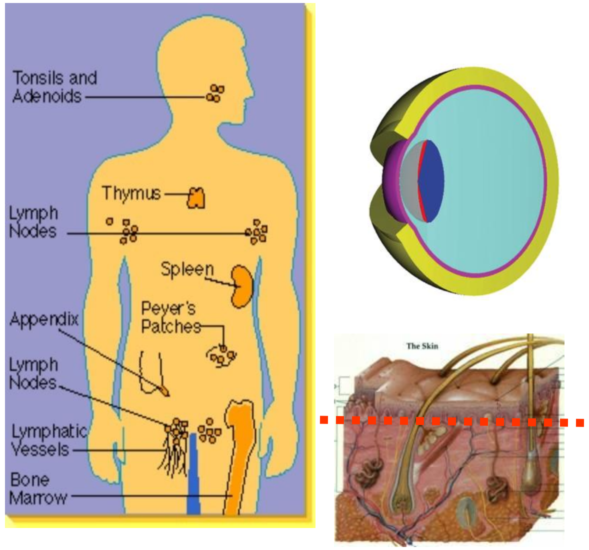

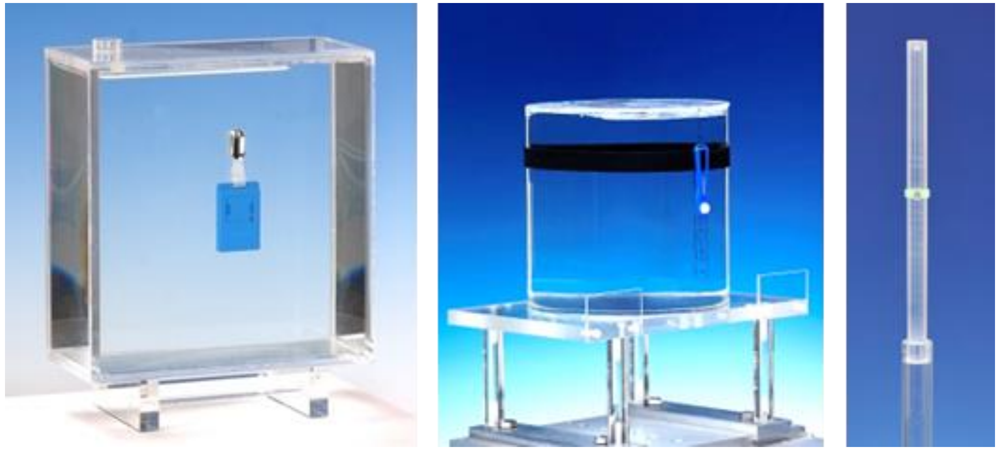

Appropriate definition of measuring (operational) quantities

Protection quantities $\lesssim$ **Measuring quantities** $\approx$ **Devices**
Indicated value

E, H_T: limits

Type test and calibration

Dosimetry in radiation protection: **standards**

How can we ensure that devices measure correctly?

- Type tests and calibration/verification
  → Requirements to dosemeters in IEC and ISO standards

- Comparable and traceable measurements/tests
  → Reference radiation fields in ISO and IEC standards

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Standardization

- **Structures ➔ *… to give an overview …***
- Reference radiation fields
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Structures in Standardization

	Standards on procedures	Standards on performance requirements for instruments
International level: **production of most standards**	International Organization for Standardization: *TC85 – SC2: Radiological protection* *WG 2:* Reference radiation fields *WG 19:* Individual monitoring	International Electrotechnical Commission *TC45 – SC45B:* *Radiation protection instrumentation* *WG 8:* Active pocket and portable dose (rate) meters and monitors and passive dosimetry systems
European region: **adoption of IEC and ISO standards as EN standards on a** **case by case decision**	European Committee for Standardization *CEN/TC430: Nuclear energy, nuclear technologies, and radiological protection* **modifications of ISO standards NOT possible**	European Committee for Electrotechnical Standardization *CLC/TC45B: Radiation protection instrumentation* **small modifications of IEC standards possible**
National level: **adoption mandatory**	DIN (DE), BSI (UK), AFNOR (FR), UNI (IT), UNE (ES), PKN (PL) etc.: **modifications of EN standards NOT possible** adoption in states of the European Union (EU), the European Free Trade Association (EFTA), Turkey (if the area is standardized in the state); **contradicting national standards must be withdrawn**	

Structures in Standardization

	Standards on procedures	Standards on performance requirements for instruments
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Gulf region: **adoption of IEC and ISO standards**	هيئة التقييس الخليجية GCC Standardization Organization https://www.gso.org.sa/en/	
National level: **potential adoption**	YSMO (YE), KOWSMD (KW), QS (QA), DGSM (OM), SASO (SA), BSMD (BH), MoIAT (AE)	

Structures in Standardization

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South Asian region: adoption of IEC and ISO standards	SAARC SARSO South Asian Regional Standards Organization https://sarso.org/	
National level: potential adoption	ANSA (AF), BSTI (BD), BSB (BT), BIS (IN), MoED (MV), NBSM (NP), PSQCA (PK), SLSI (LK)	

Structures in Standardization

	Standards on procedures	Standards on performance requirements for instruments
International level: production of most standards	International Organization for Standardization: *TC85 – SC2: Radiological protection* *WG 2:* Reference radiation fields *WG 19:* Individual monitoring	International Electrotechnical Commission *TC45 – SC45B:* *Radiation protection instrumentation* *WG 8:* Active pocket and portable dose (rate) meters and monitors and passive dosimetry systems
African region: adoption of IEC and ISO standards	(see map below)	African Electrotechnical Standardization Commission https://afsec-africa.org/
National level: potential adoption		

https://www.arso-oran.org/

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- **Reference radiation fields** ➔ ***Primary and secondary standard labs (PSDL and SSDL)***
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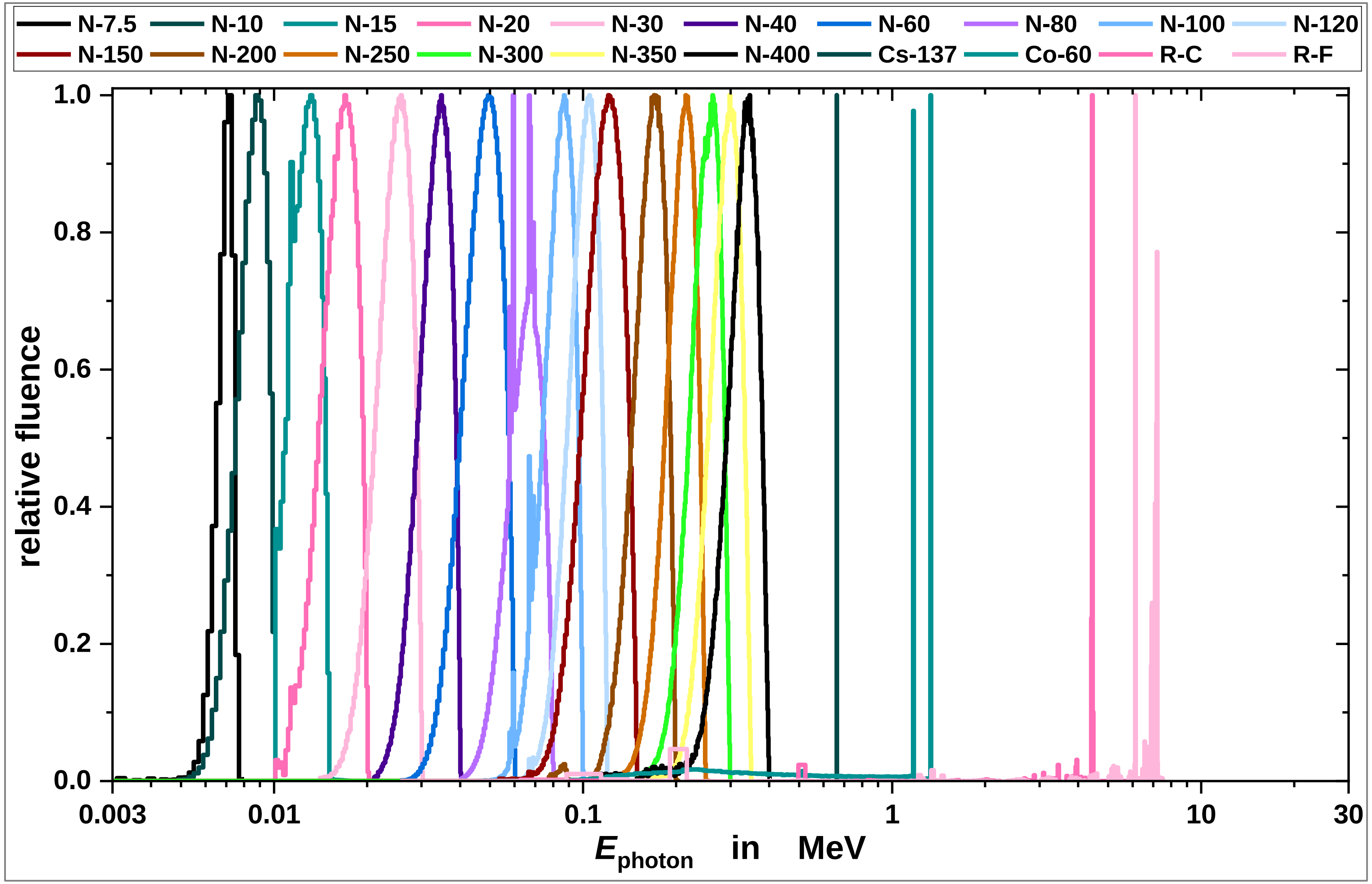
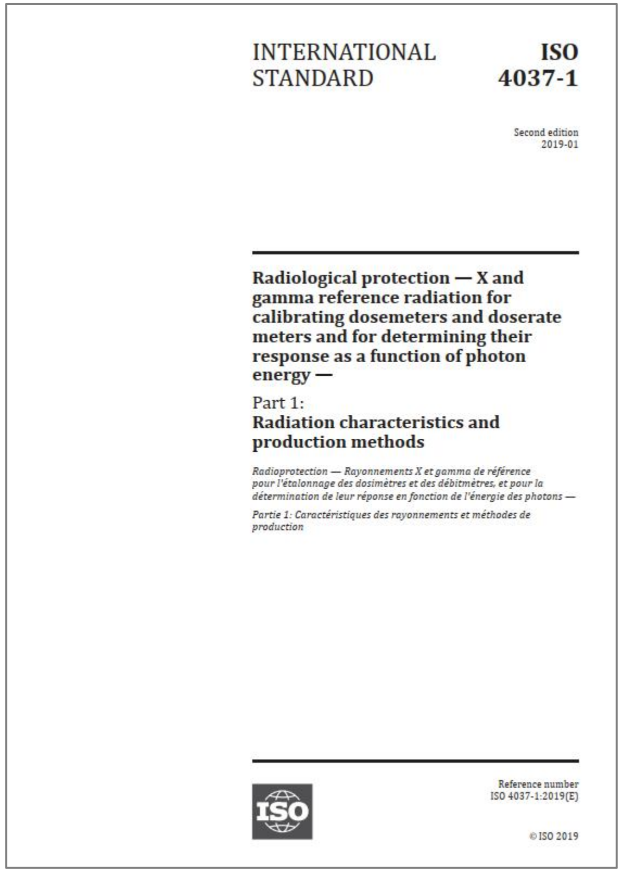
Standards for reference radiation fields – Overview

	Photons	Neutrons	Betas
General standard	ISO 29661:2012 & Amd.1:2015: **Reference radiation fields** for radiation protection — Definitions and **fundamental concepts** — ***Revision in progress***		
Characteristics and methods of production	ISO 4037-1:**2019** X-rays, radionuclides, nuclear reactions	ISO 8529-1:**2021** Radionuclides, nucl. react.; updated spectra	ISO 6980-1:**2023** Radionuclides
Primary calibration of the fields; basic quantity	ISO 4037-2:**2019** Air kerma, K_a, H	ISO 8529-2:2000 Fluence, Φ ***Revision planned***	ISO 6980-2:**2023** Absorbed dose, D_t Corr. factors simulated
Calibration of dosemeters and their energy and angular response; conversion coefficients from basic quantity to dose equivalent, *H*	ISO 4037-3:**2019** $h_{pK}(0.07)$, $h_{pK}(3)$, $h_{pK}(10)$ $h'_K(0.07)$, $h'_K(3)$, $h^*_K(10)$	ISO 8529-3:**2023** $h_{p\Phi}(10)$ $h^*_\Phi(10)$	ISO 6980-3:**2023** $h_{pD}(0.07)$, $h_{pD}(3)$ $h'_D(0.07)$, $h'_D(3)$
Special considerations	ISO 4037-4:**2019** low energy photons	—	—
Pulsed radiation	ISO TS 18090-1:2015 ***Revision in progress***	ISO TS 18090-2 planned	—

Reference radiation fields – Photons (nearly mono-energ.)





INTERNATIONAL STANDARD

ISO 4037-1

Second edition 2019-01

Radiological protection — X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy —

Part 1:
Radiation characteristics and production methods

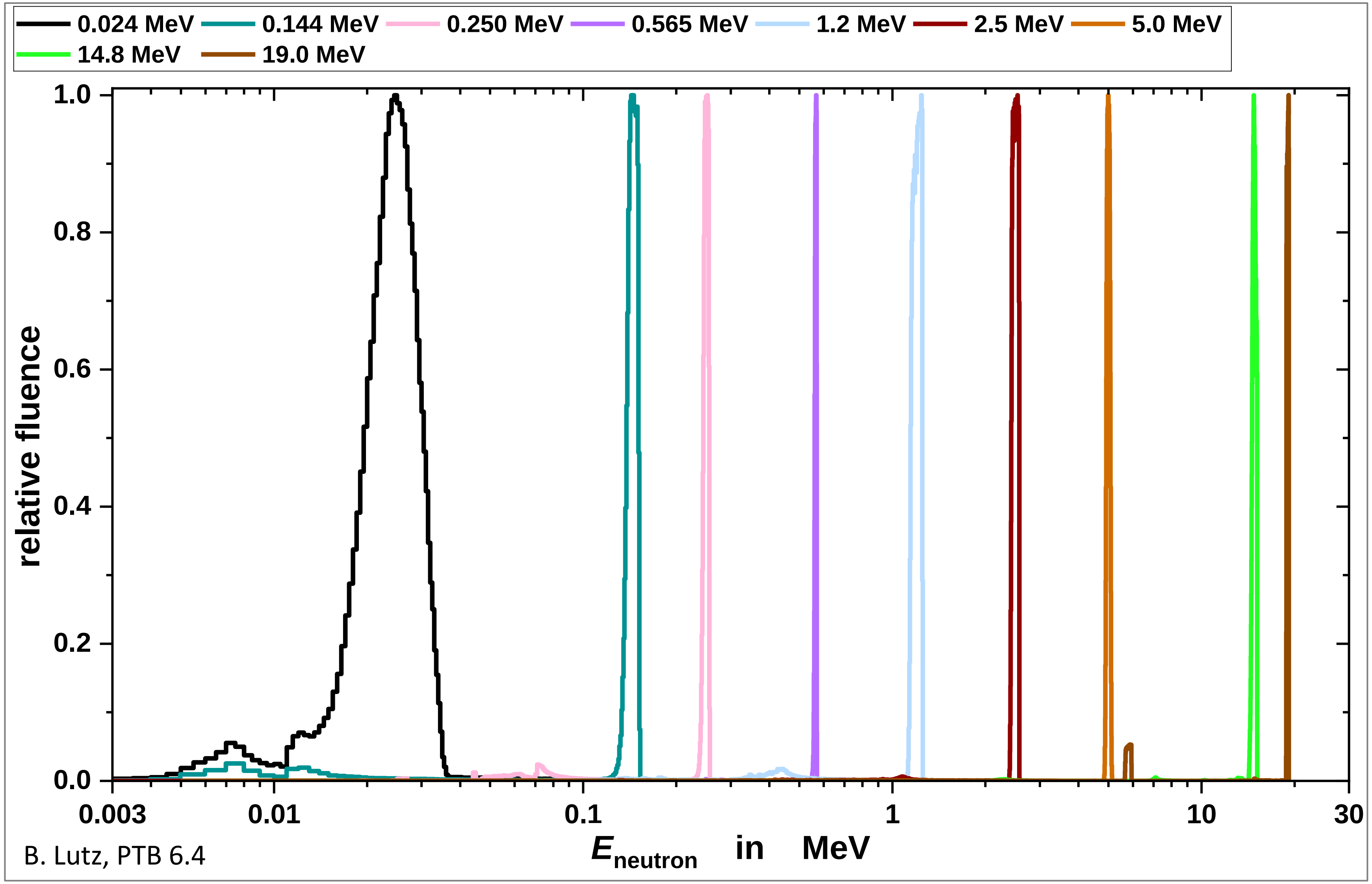
Radioprotection — Rayonnements X et gamma de référence pour l'étalonnage des dosimètres et des débitmètres, et pour la détermination de leur réponse en fonction de l'énergie des photons —

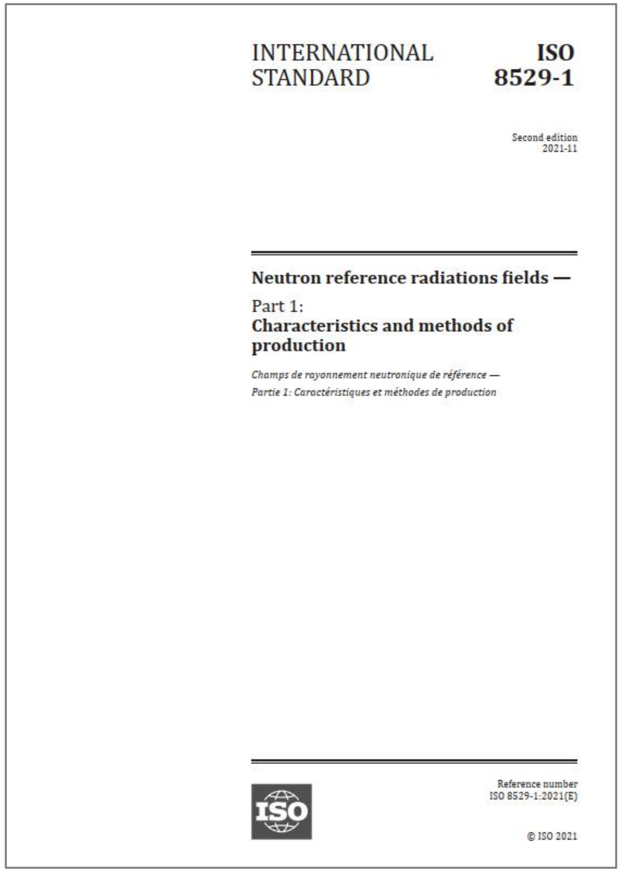
Partie 1: Caractéristiques des rayonnements et méthodes de production

Reference number ISO 4037-1:2019(E)

© ISO 2019

Reference radiation fields – Neutrons (mostly mono-energ.)





INTERNATIONAL STANDARD

ISO 8529-1

Second edition 2021-11

Neutron reference radiations fields —

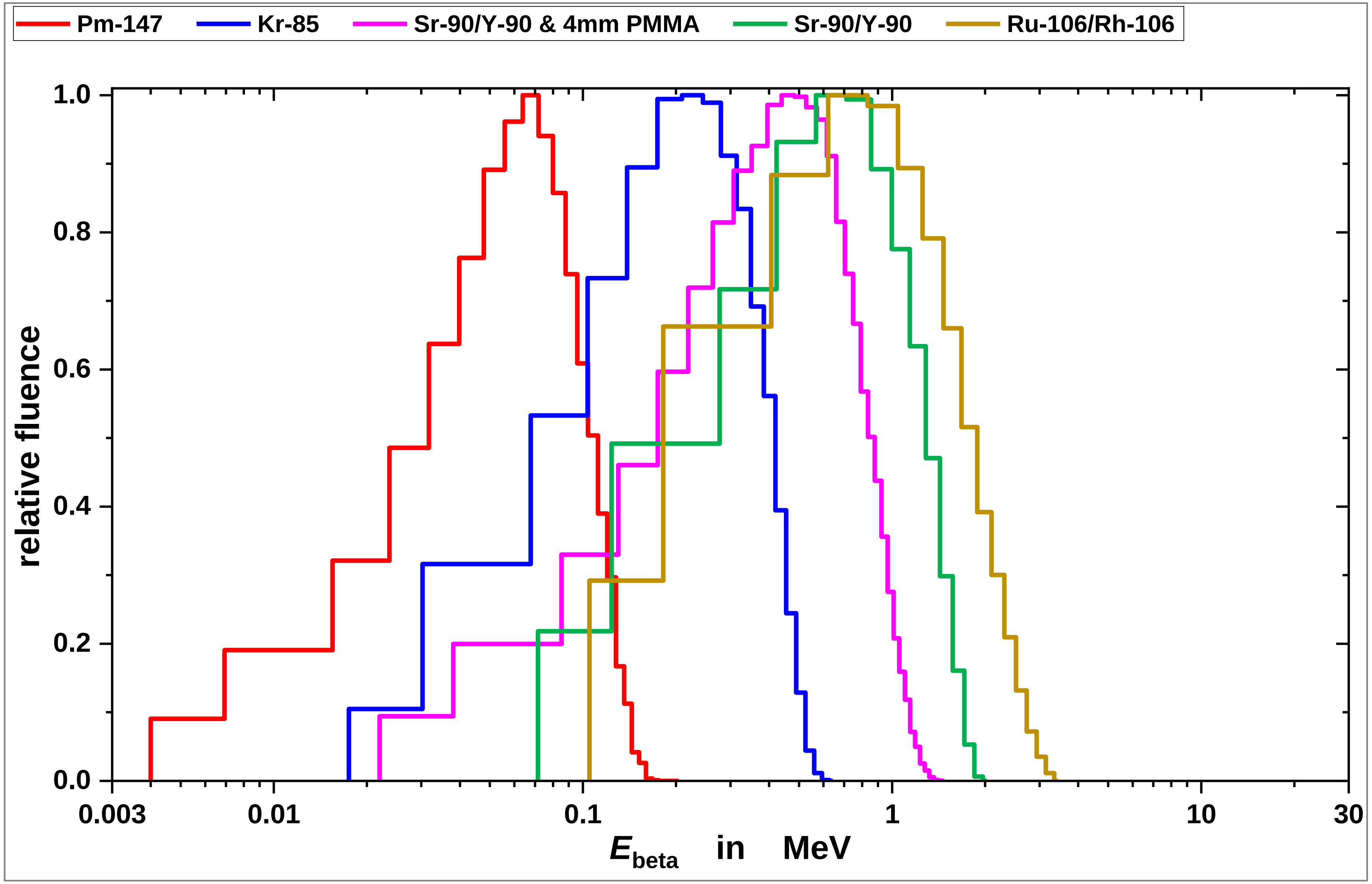
Part 1:
Characteristics and methods of production

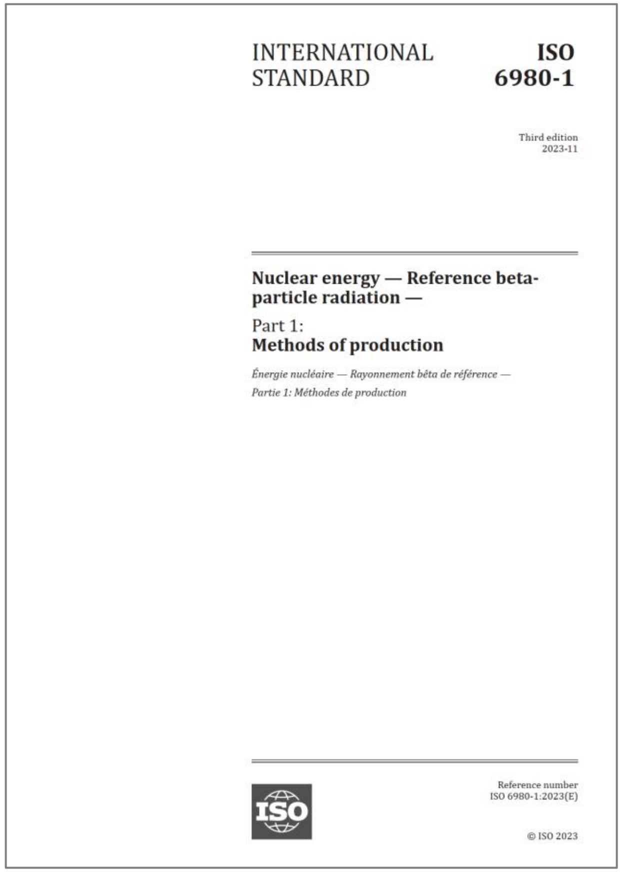
Champs de rayonnement neutronique de référence —
Partie 1: Caractéristiques et méthodes de production

Reference number ISO 8529-1:2021(E)

© ISO 2021

Reference radiation fields – Betas (rather broad)





INTERNATIONAL STANDARD

ISO 6980-1

Third edition 2023-11

Nuclear energy — Reference beta-particle radiation —

Part 1:
Methods of production

Énergie nucléaire — Rayonnement bêta de référence — Partie 1: Méthodes de production

Reference number ISO 6980-1:2023(E)

© ISO 2023

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- **Dosemeters** ➔ ***Manufacturers, testing labs and rad. prot. offi. / exp. (RPO/RPE)***
  Type tests and Uncertainties
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Conclusions

Standards for type-tests – for whom?

Manufacturers:

- How secure (malfunction or manipulation – accidental or intentional)?
- How good must our dosemeter measure?
- What do we need to document?

Type-test laboratories:

- What to test?
- How to test?
- How to document?

Radiation protection officers / experts (RPOs/RPEs):

- What can a “type-tested” dosemeter measure?
- Does this cover my workplace (radiation type, energy, angle, temperature, …)?
- How large is its uncertainty?

Dosemeter life-cycle

Who		What happens?	What is addressed?
Manufacturer	→	Dosemeter development (prototype)	– Characteristics and quality
Testing lab	→	Type test (a few prototype specimens)	– Relative response ∈ stated limits?
Manufacturer	→	Adjustment (each serial copy)	– Absolute response
Authority	→	Verification (each serial copy)	– Absolute response ∈ stated limits?
Exposed staff	→	Use of dosemeter	– Dose monitoring
Authority	→	Re-Verification (each serial copy)	– Absolute response ∈ stated limits?

…

Standards for type-tests – Overview

<table>
<tr><th colspan="2"></th><th>Photons</th><th>Betas</th><th>Neutrons</th></tr>
<tr><td rowspan="5">Area dosemeters: $H^*(10)$, partly $H'(3)$ & $H'(0.07)$</td><td rowspan="4">Active</td><td>IEC 61017:2016
Environm. monitoring</td><td rowspan="2"></td><td rowspan="2">IEC 61005:2014
Rate meters;
revision in progress
➔ updated techniques</td></tr>
<tr><td>IEC 60532:2010
Fixed inst. in NPPs</td></tr>
<tr><td colspan="2">IEC 60846-1:2009
Portable; revision in progress ➔ $H'(3)$</td><td rowspan="2">IEC 61322:2020
Fixed installed</td></tr>
<tr><td colspan="2">IEC 60846-2:2015
Emergency: portable and probes</td></tr>
<tr><td>Passive dosim. systems</td><td colspan="2">IEC 62387:2020
All quantities – all types incl. hybrid dosemeters</td><td>—</td></tr>
<tr><td rowspan="2">Personal dosemeters: $H_p(10)$, partly $H_p(3)$ & $H_p(0.07)$</td><td>Active</td><td colspan="3">IEC 61526:2024
All types – incl. hybrid dosemeters and updated neutron requirements</td></tr>
<tr><td>Passive dosim. systems</td><td colspan="2">IEC 62387:2020
All quantities – all types incl. hybrid dosemeters</td><td>ISO 21909-1:2021
All types
ISO 21909-2:2021
Workplace considerations</td></tr>
</table>

List of standards available: *https://www.ptb.de/cms/fileadmin/internet/fachabteilungen/abteilung_6/6.3/information/norm_lst.pdf*

Standards for type-tests – Software

Software …

- **calculates dose**
- **indicates dose**
- **transmits data**
- **…**

… must not be changed during or after test

➔ separate in data relevant (e.g., dose calc.) and non-data relevant part (e.g., font, color)

Topics addressed …

- **Identification**
- **Authenticity**
- **Data storage and transmission**
- **Interfaces (hard- and software)**
- **Documentation**
- **…**

Ambient conditions (AC), EMC & SW

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AC; EMC; SW</td></tr>
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</table>

Still standards without requirements to the software!

List of standards available: https://www.ptb.de/cms/fileadmin/internet/fachabteilungen/abteilung_6/6.3/information/norm_lst.pdf

Standards for type-tests – Procedure (Photons)

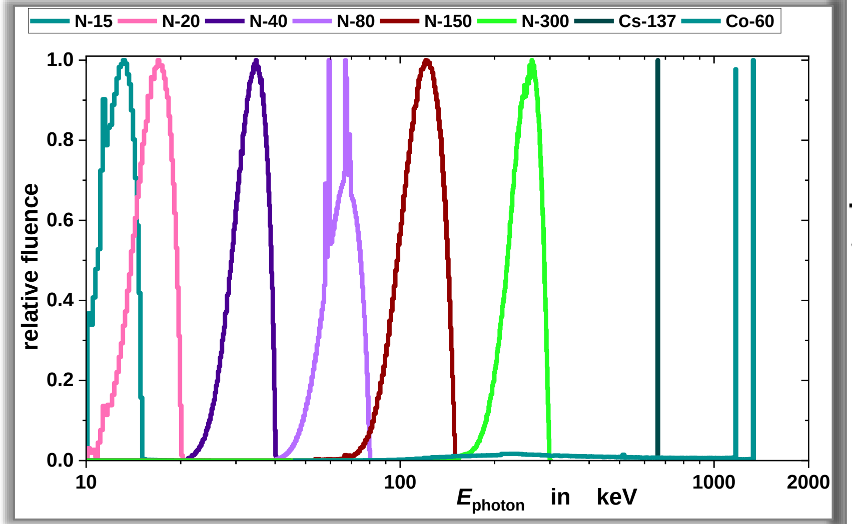
- **Standards require mandatory (minimum) ranges**
  - **Energy and angle**, e.g., 80 keV … 1.25 MeV ➔ $r \in [0.71…1.67]$
  - **Temperature**, e.g., −10 °C … +40 °C ➔ $r \in [0.83…1.25]$
  - **Non-linearity**, e.g., 0.1 mSv … 1 Sv ➔ $r \in [0.87…1.18]$
  - **…**

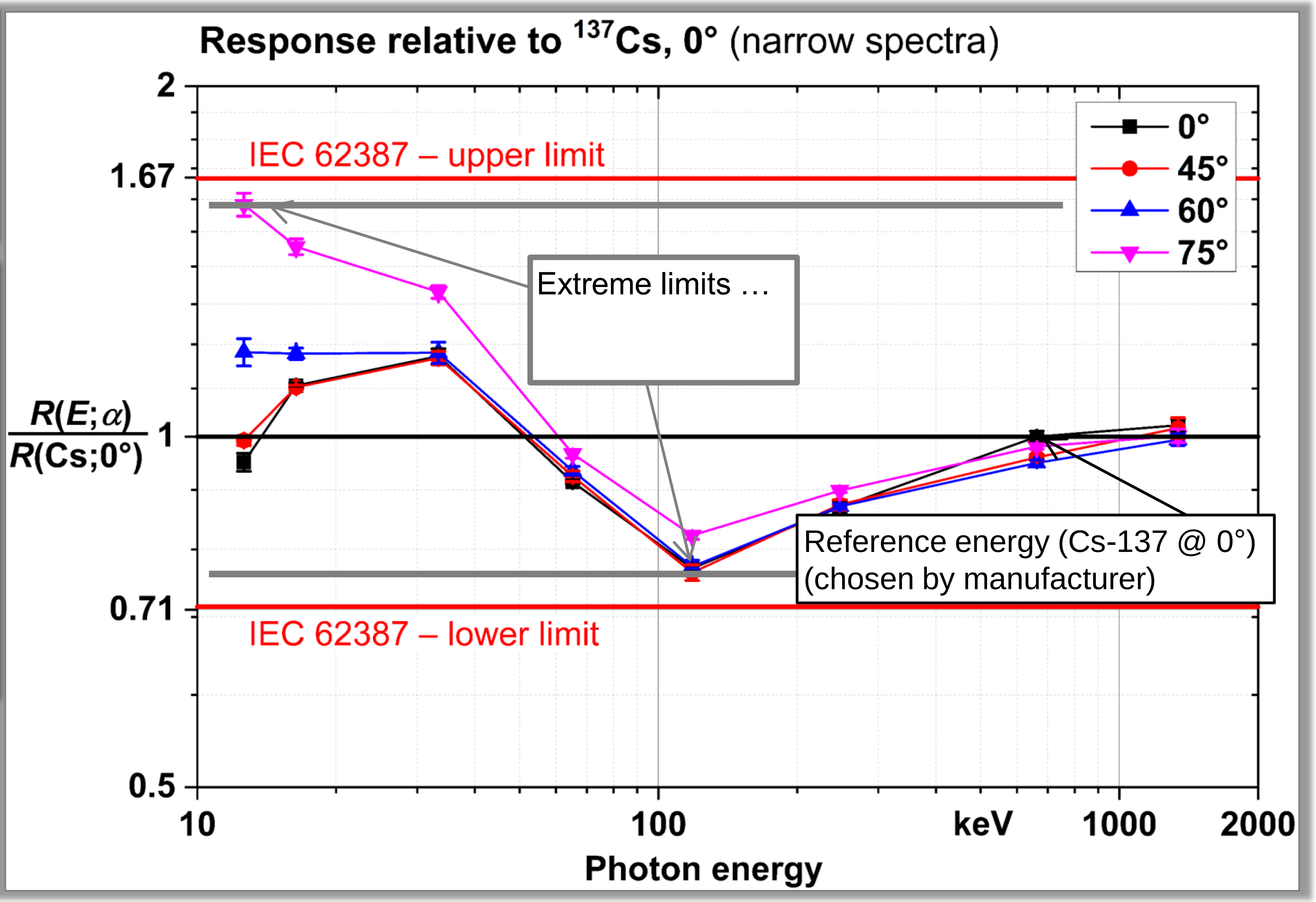
- **Relative response, *r*, is tested – NO absolute calibration,**
  i.e., response relative to response @ reference conditions,
  e.g., ^{137}Cs, 0°, 20 °C, 1 mSv …

- **Influence quantities tested one by one**
  - ➔ **presumption: independent of each other!**
    - ➔ **Additivity is required!**

Standards for type-tests – Example: energy and angle

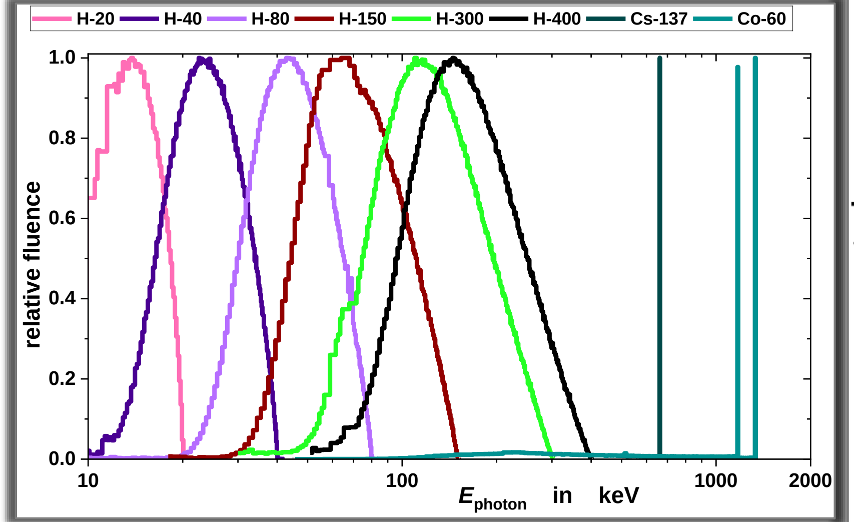
Energy and angle:
– **determine extreme response @ nearly mono-energ. rad.**

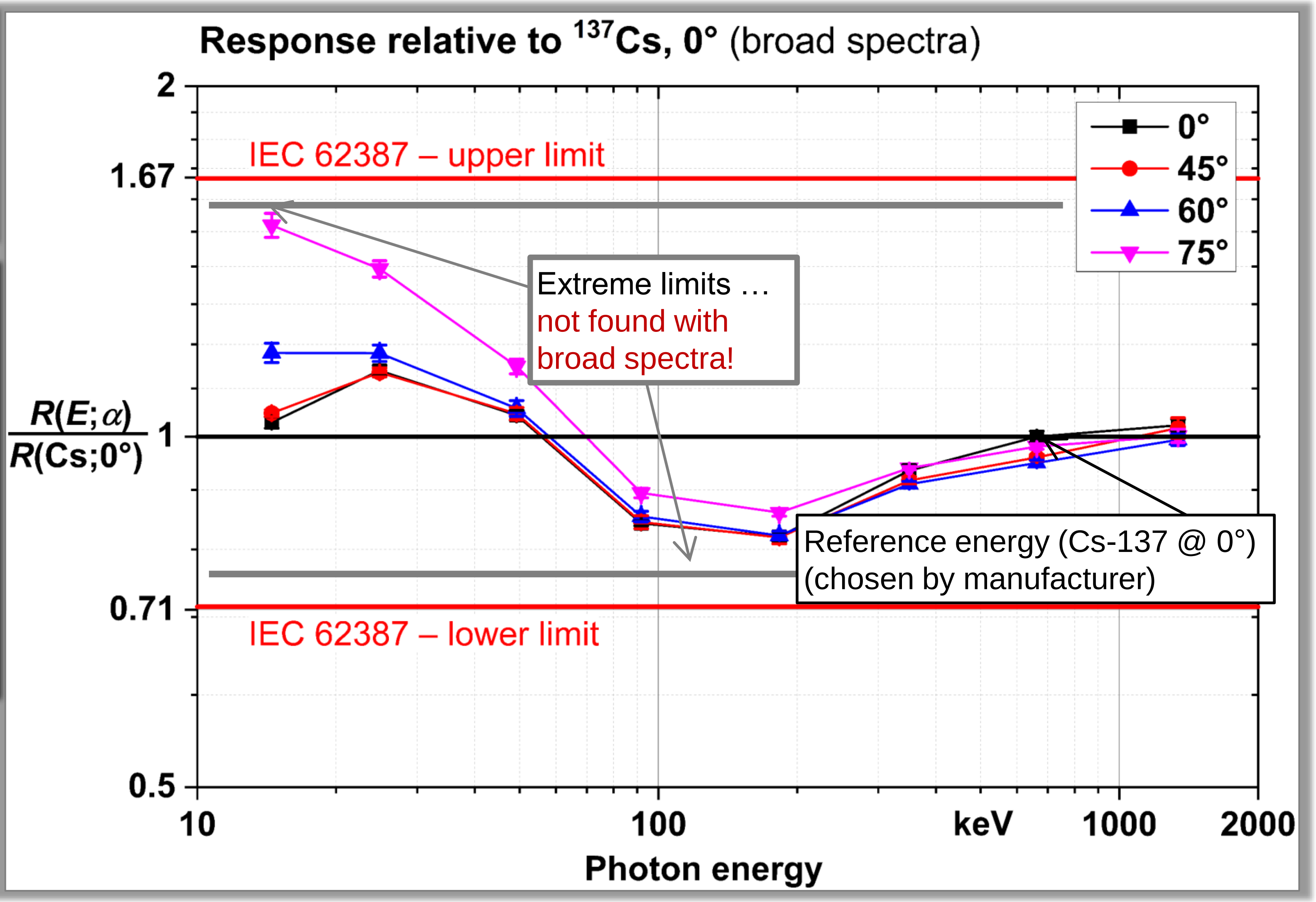




Standards for type-tests – Example: energy and angle

Energy and angle:
- **determine extreme response @ nearly mono-energ. rad.**
- **broad spectra “smear out”!**





Standards for type-tests – Example: energy and angle

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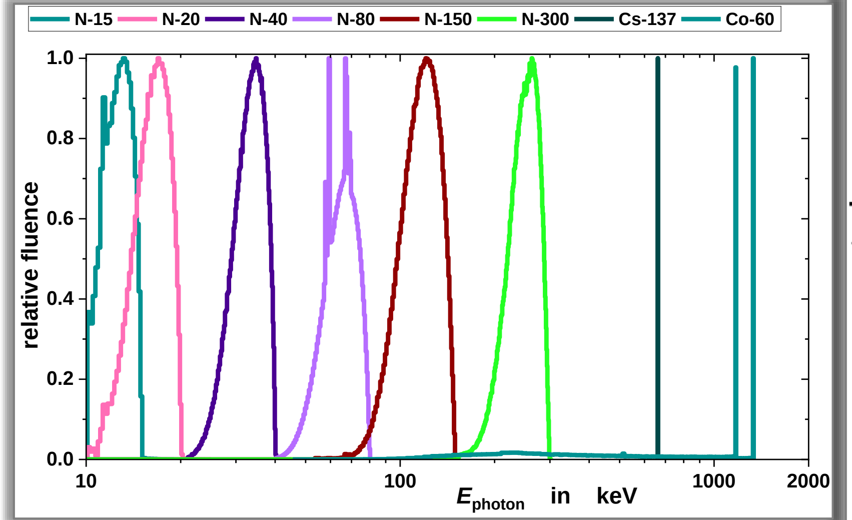
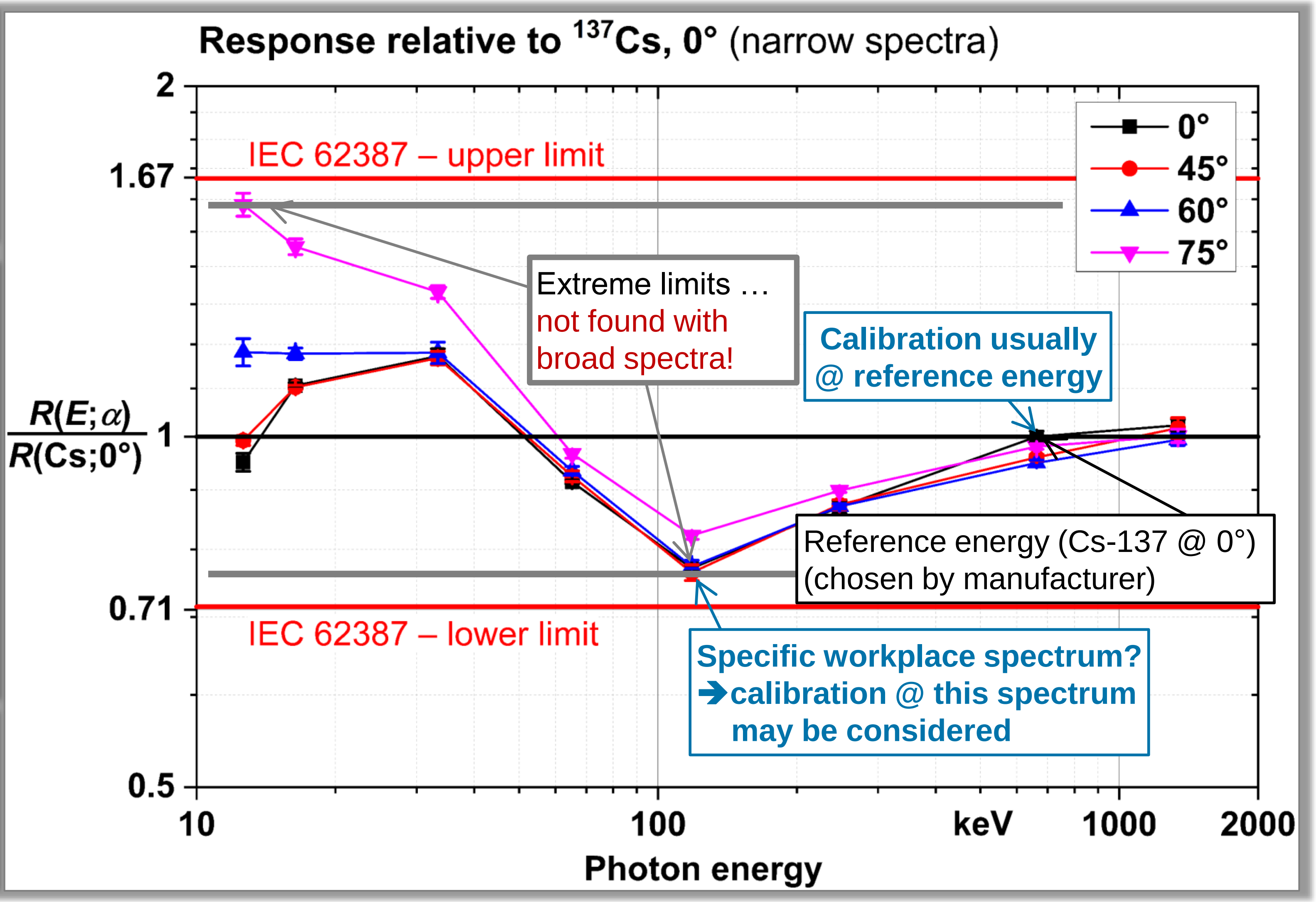


➔ response fine for "mono-en."?
  ➔ fine @ any spectrum & angle in documented (rated) range



Standards for type-tests – Additivity

Badge 1 irradiated with H_{E1}
+
Badge 2 irradiated with H_{E2}

$\overset{?}{=}$ Badge 3 irradiated with H_{E1}&H_{E2}

+

$\overset{?}{=}$

$$M_{E1} + M_{E2} \overset{?}{=} M_{E1\&E2}$$

Standards for type-tests – Additivity

Badge 1 irradiated with H_{E1} **+** **Badge 2 irradiated with H_{E2}**	**$\stackrel{?}{=}$**	**Badge 3 irradiated with H_{E1}&H_{E2}**

Dosemeter construction	Method of dose calculation		Additivity fulfilled?
One detector element / signal S →	dose ~ signal S		➔ yes
Two or more detector elements / signals ↗	dose ~ linear combination or lin. optimization of signals		➔ yes
Two or more detector elements / signals ↘	dose ~ **branching** algorithm, e.g.,	$S_1/S_2 > 1$ ➔ algorithm A $S_1/S_2 \leq 1$ ➔ algorithm B	➔ often not ➔ **test needed**

Standards for type-tests – Additivity

Badge 1 irradiated with H_{E1}
+
Badge 2 irradiated with H_{E2}
?
= Badge 3 irradiated with H_{E1}&H_{E2}

Influence quantities … not independent of each other …,

- **e.g., branching** (see above) ➔ test @ mixture of radiation qualities
- **e.g., linearity depends on energy** (often the case for film dosemeters)
  ➔ test linearity @ different energies
- **e.g., coefficient of var. depends on temperature** (can the case for active counting detectors)
  ➔ test coefficient of variation @ different temperature
- …

Standards for type-tests – Uncertainty

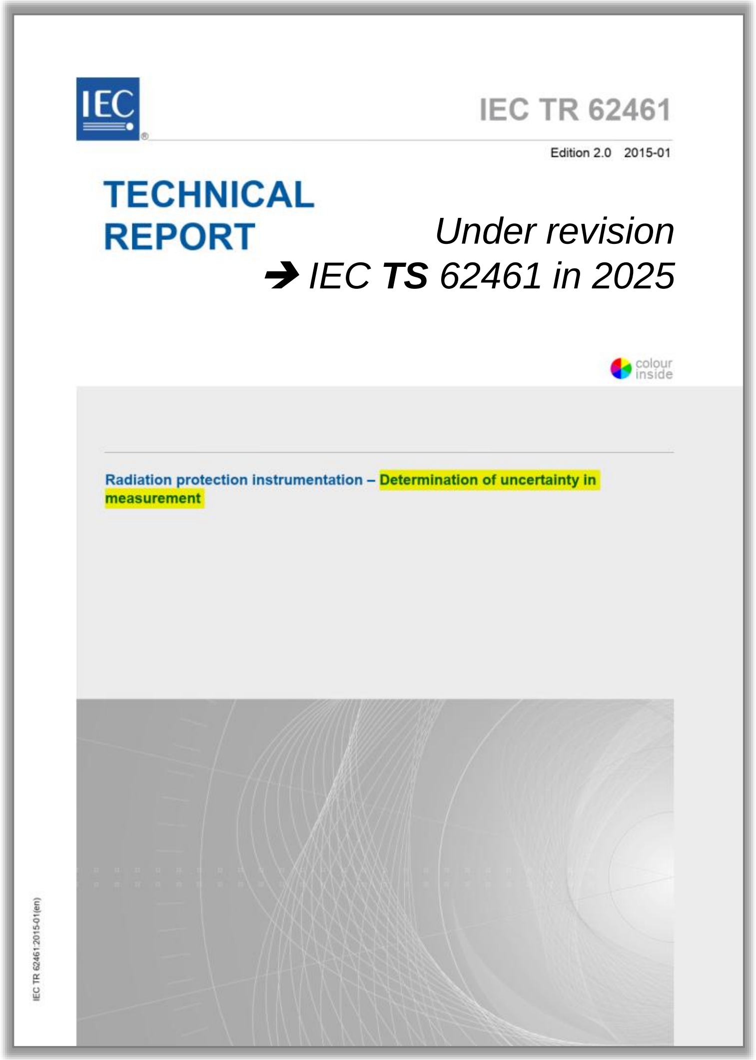
Influence quantities = Uncertainty contributions

Energy and angle: $r \in [0.71 \ldots 1.67]$

Temperature: $r \in [0.83 \ldots 1.25]$

Non-linearity: $r \in [0.87 \ldots 1.18]$

…



Under revision

*➔ IEC **TS** 62461 in 2025*

Standards for type-tests – Uncertainty − examples

IEC 62387 just fulfilled,
i.e.,

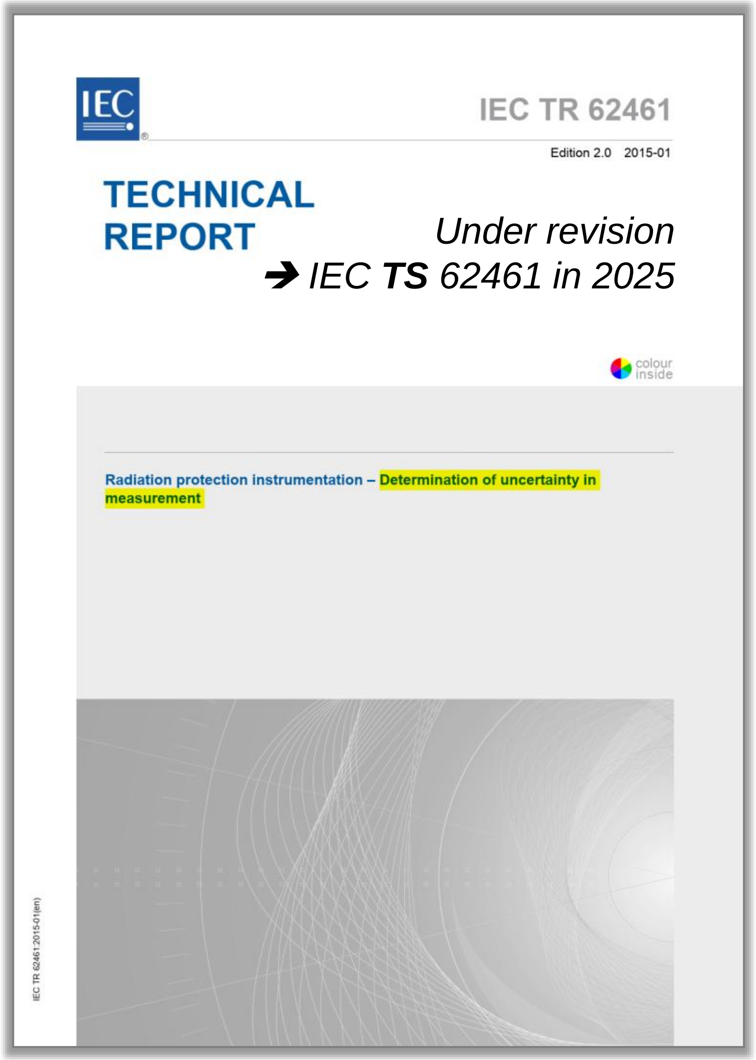
Energy and angle: $r \in [0.71 \ldots 1.67]$
Temperature: $r \in [0.83 \ldots 1.25]$
Non-linearity: $r \in [0.87 \ldots 1.18]$
…

➔ ***U* ≈ ± 40 %** (k=2; 95 % cov. prob.)

IEC 62387 more than fulfilled,
for example,

Energy and angle: $r \in [0.94 \ldots 1.06]$
Temperature: $r \in [0.96 \ldots 1.04]$
Non-linearity: $r \in [0.95 \ldots 1.05]$
…

➔ ***U* ≈ ± 10 %** (k=2; 95 % cov. prob.)

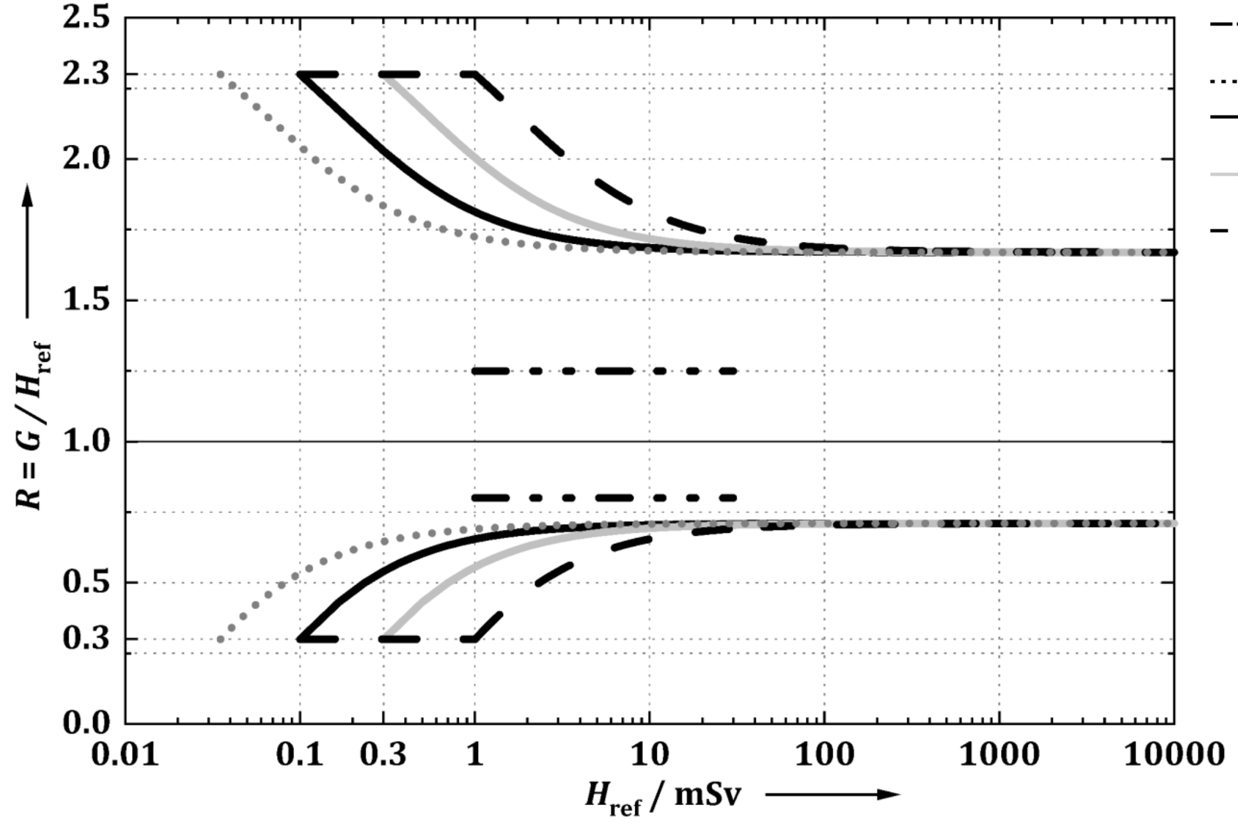

IEC
IEC TR 62461
Edition 2.0 2015-01
TECHNICAL REPORT
Under revision
*➔ IEC **TS** 62461 in 2025*
colour inside
Radiation protection instrumentation – Determination of uncertainty in measurement

Contents

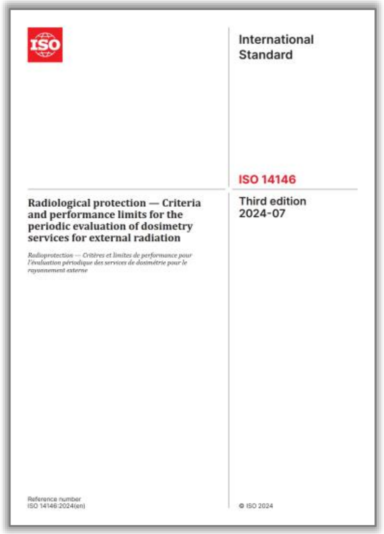
Calibration and routine tests (photons & betas)

ISO 14146:2024: Performance limits for individual monitoring services (IMS)

- ➔ **absolute calibration** (ph,ß,n) **< factor 1.25 ≈ *R* ∈ 0.8…1.25:** test @ reference energy
- ➔ **overall performance** (ph,ß) **≲ factor 1.5 (ICRP 75) ≈ *R* ∈ 0.71…1.67:** (usually) with broad spectra (routine)



- for reference conditions for neutrons and photons (with $\bar{E}$ > 10 keV) and betas (with $\bar{E}$ > 0,2 MeV): 1 mSv to 30 mSv
- for environmental $H^*(10)$ dosemeters for neutrons and photons (with $\bar{E}$ > 10 keV): 0,035 mSv to 10 Sv
- for workplace $H^*(10)$ dosemeters for neutrons and photons (with $\bar{E}$ > 10 keV) and for whole-body $H_p(10)$ dosemeters for photons (with $\bar{E}$ > 10 keV): 0,1 mSv to 10 Sv
- for area $H'(3)$ and eye lens $H_p(3)$ dosemeters for photons (with $\bar{E}$ > 10 keV) and betas (with $\bar{E}$ > 0,2 MeV): 0,3 mSv to 10 Sv
- for extremity and whole-body $H_p(0{,}07)$ and area $H'(0{,}07)$ dosemeters for photons (with $\bar{E}$ > 10 keV) and betas (with $\bar{E}$ > 0,2 MeV): 1 mSv to 10 Sv and in addition for whole-body $H_p(0{,}07)$ dosemeters from 0,1 mSv to 1 mSv

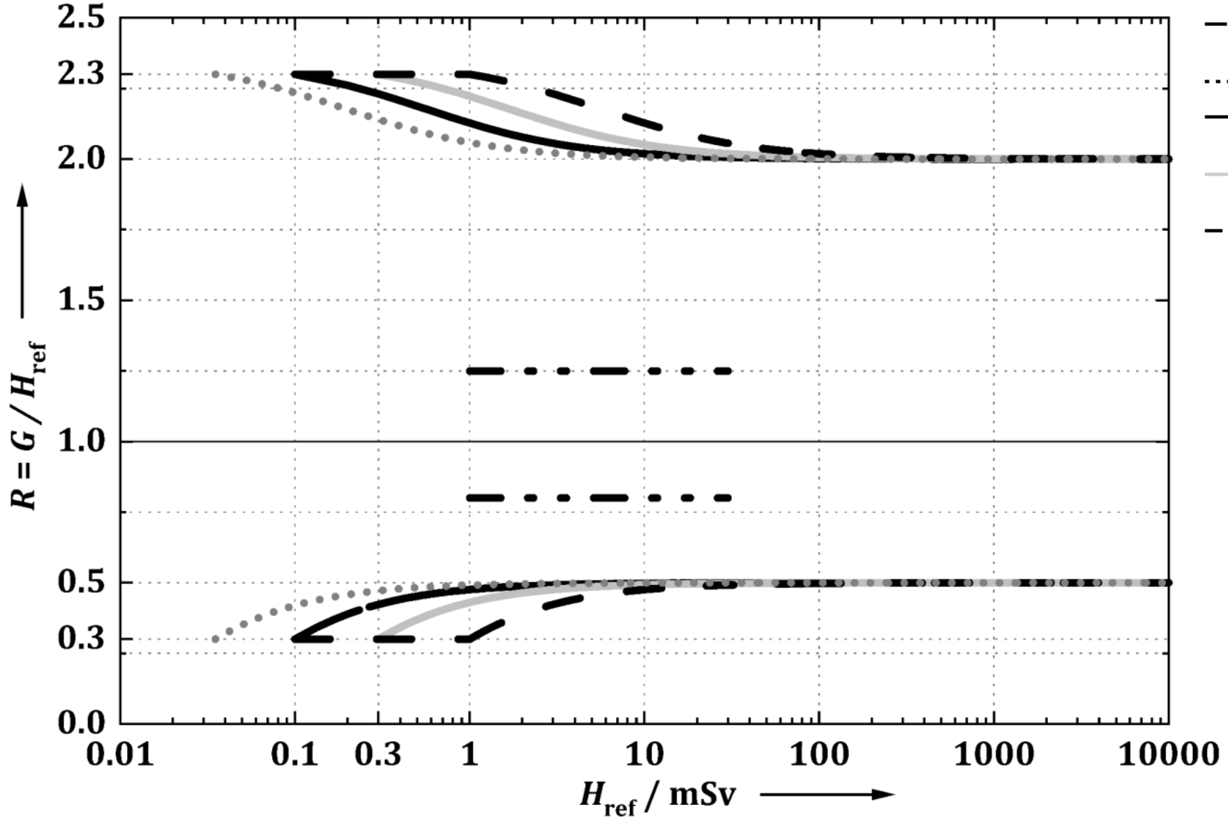


Calibration and routine tests (neutrons)

ISO 14146:2024: Performance limits for individual monitoring services (IMS)

➔ **absolute calibration** (ph,ß,n) **< factor 1.25 ≈ R ∈ 0.8…1.25:** test @ reference energy

➔ **overall performance** (neutrons) **≲ factor 2 (ICRP 75) ≈ R ∈ 0.5…2.0:** (usually) with broad spectra (routine)



for reference conditions for neutrons and photons (with $\bar{E}$ > 10 keV) and betas (with $\bar{E}$ > 0,2 MeV): 1 mSv to 30 mSv

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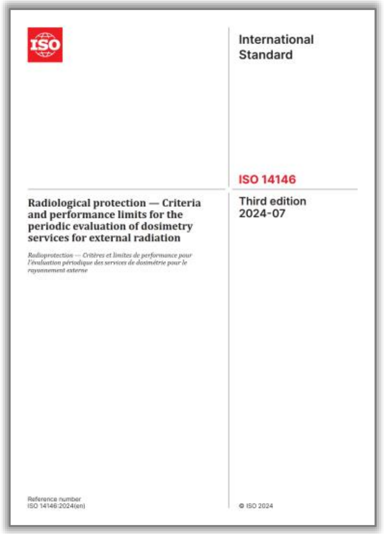
International Standard

ISO 14146

Third edition 2024-07

Radiological protection — Criteria and performance limits for the periodic evaluation of dosimetry services for external radiation

Calibration and routine tests

ISO 14146:2024: Performance limits for individual monitoring services (IMS)

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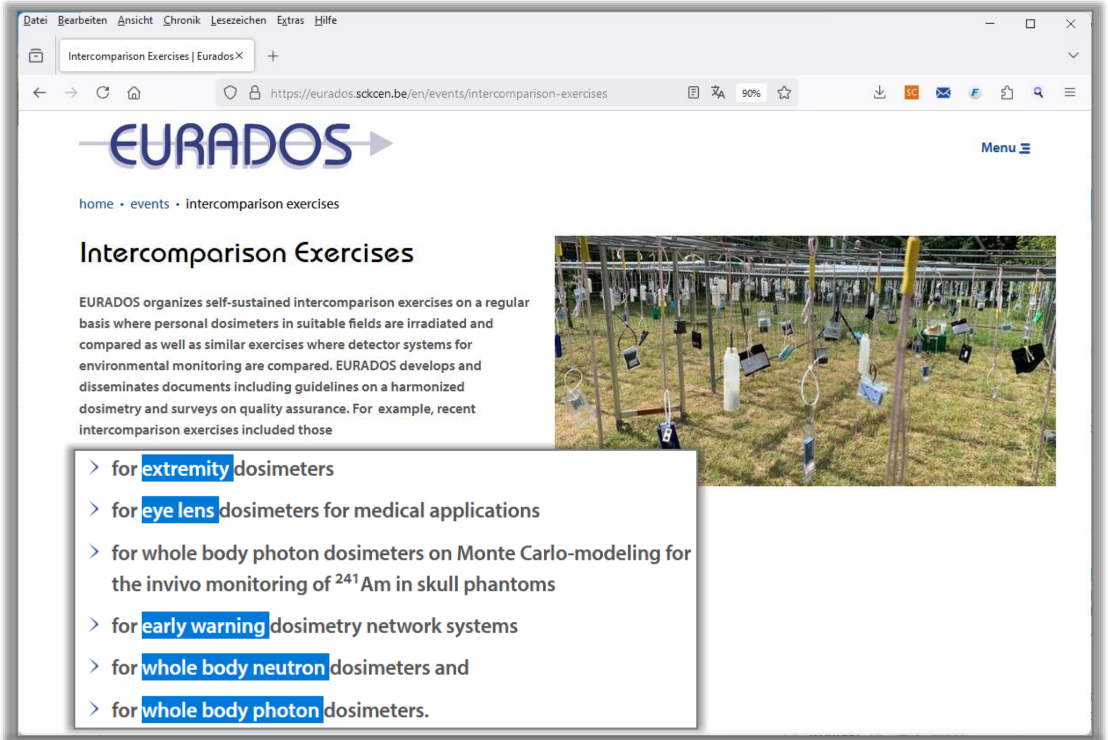
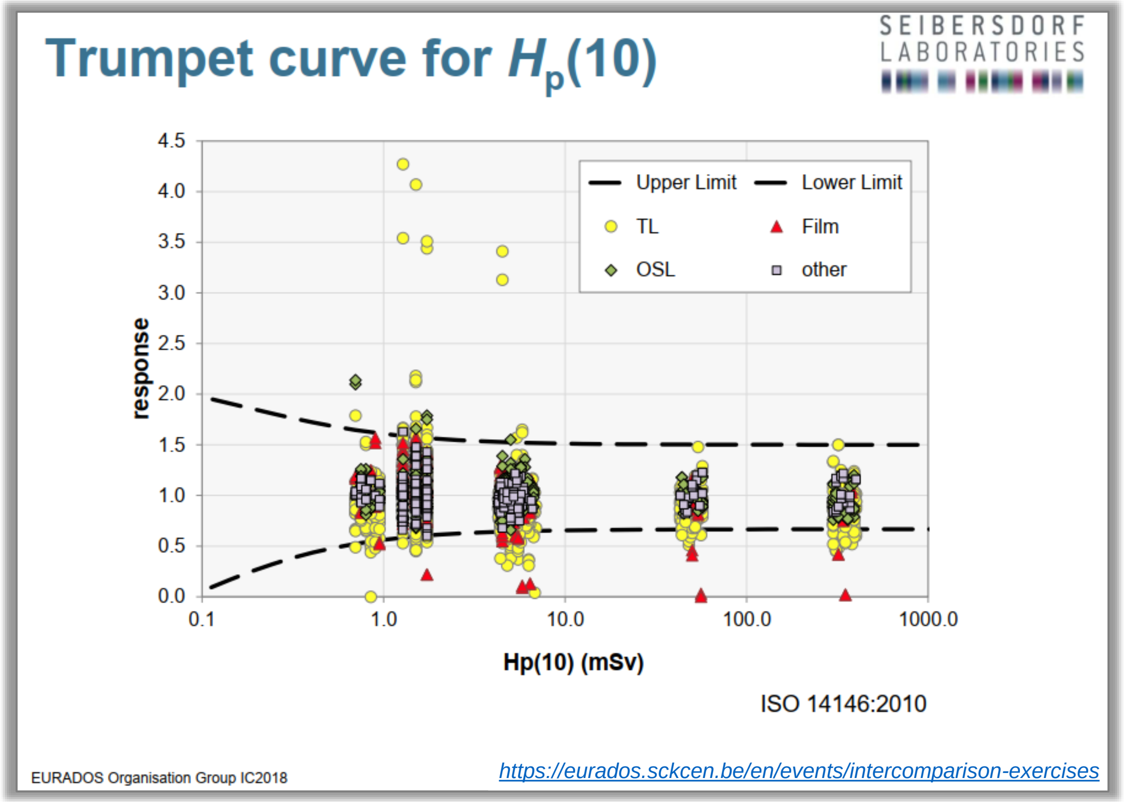
➔ **demonstrated by many EURADOS (WG2,WG3) intercomparisons** (a success story…)



https://eurados.sckcen.be/en/events/intercomparison-exercises



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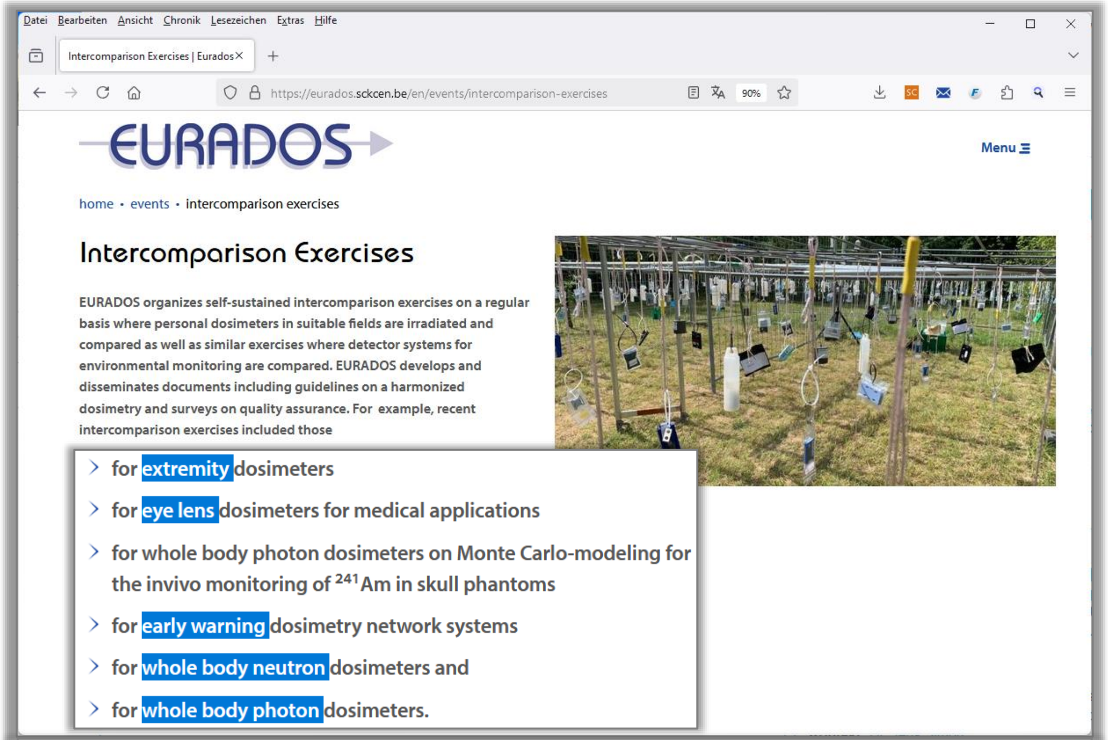

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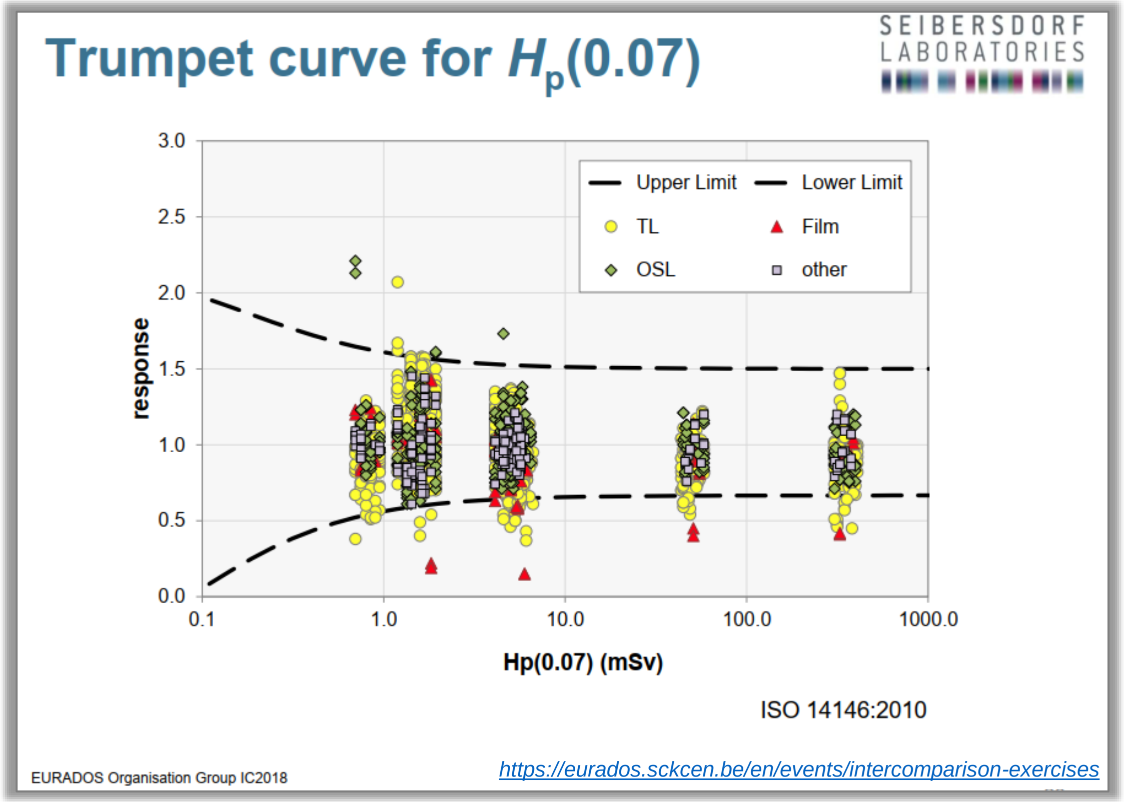

Calibration and routine tests

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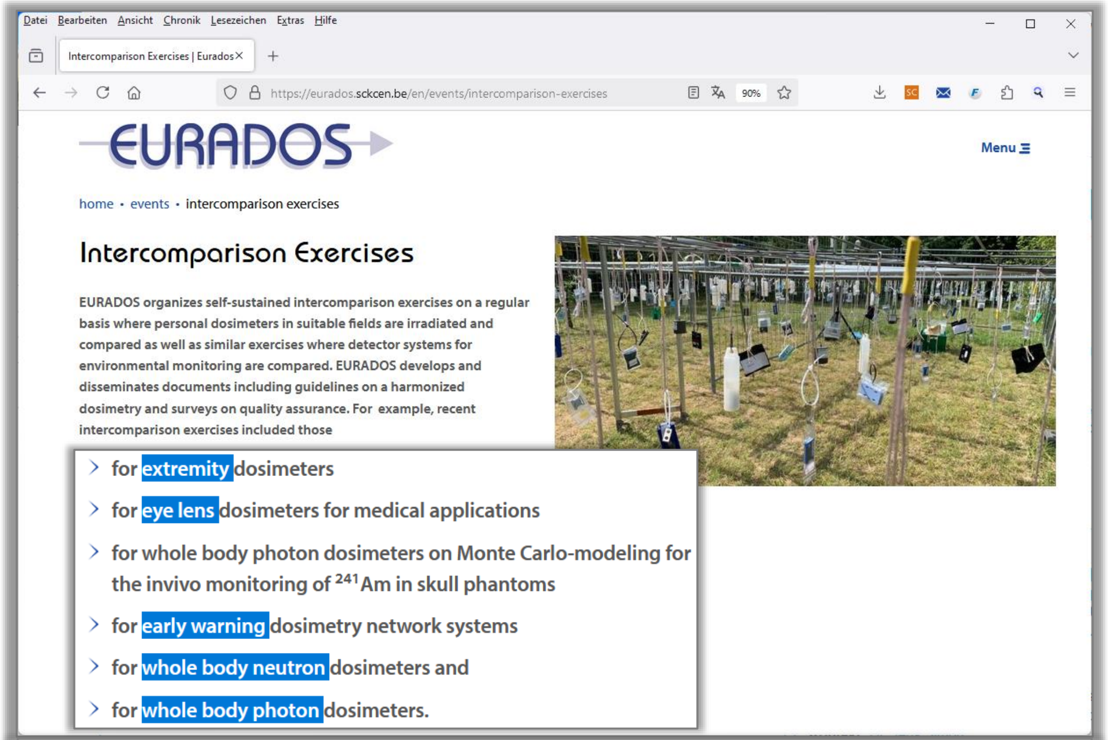
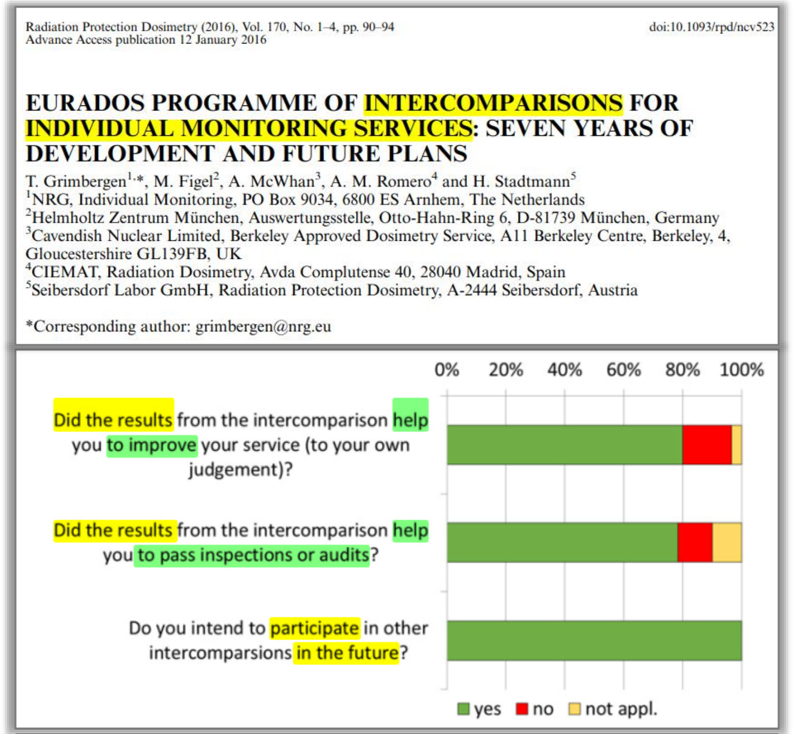


https://eurados.sckcen.be/en/events/intercomparison-exercises



Radiation Protection Dosimetry (2016), Vol. 170, No. 1–4, pp. 90–94
Advance Access publication 12 January 2016 doi:10.1093/rpd/ncv523

EURADOS PROGRAMME OF INTERCOMPARISONS FOR INDIVIDUAL MONITORING SERVICES: SEVEN YEARS OF DEVELOPMENT AND FUTURE PLANS

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https://doi.org/10.1093/rpd/ncv523

Contents

Conclusions

- Production of most standards at international level
- Adoption at regional and national level ➔ (e.g., EN and DIN) standards
  ➔ contribution at international level is most influential

- Type-test standards ➔ demonstrate performance of a dosemeter in rated ranges
  ➔ RPO/RPE: workplace in rated ranges?

- Calibration @ reference energy or workplace spectrum advisable
  - ➢ Uncertainty (k=2; 95 % cov. prob.) ∈ ICRP 75 ($R_{photon,beta} \lesssim$ factor 1.5; $R_{neutron} \lesssim$ factor 2))!

- Overall performance to be demonstrated (intercomparisons)

- List of standards is available at PTB's website: http://www.ptb.de/cms/fileadmin/internet/fachabteilungen/abteilung_6/6.3/information/norm_lst.pdf

From dosemeter development to routine use – Standards and Uncertainties – RAP25-16

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PTB, Department ”Radiation protection dosimetry” (6.3)

Hyperlinks underlined and in light blue

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05/2025

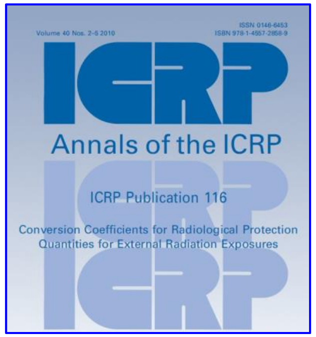
From dosemeter development to routine use – Standards and Uncertainties – RAP25-16

Rolf Behrens & Oliver Hupe

Additional material

Quantities in radiation protection

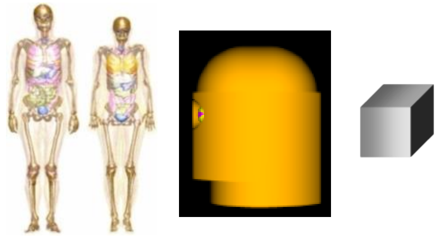
Protection vs. measuring quantities



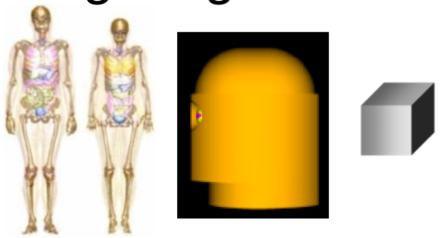
ICRP 116 – 2010

$$E = \sum_T w_T \cdot \sum_R w_R \cdot D_{T,R}$$

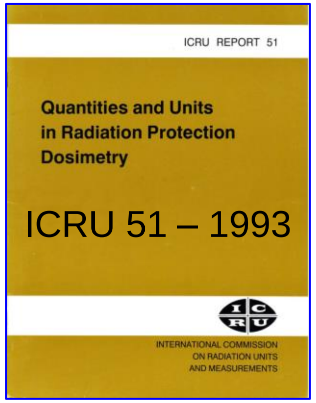
Effective dose = *Tissue- & Radiation-weighting factors* · *Absorbed dose in organs*



Definition in reference phantoms



For the calculation of conversion coefficients



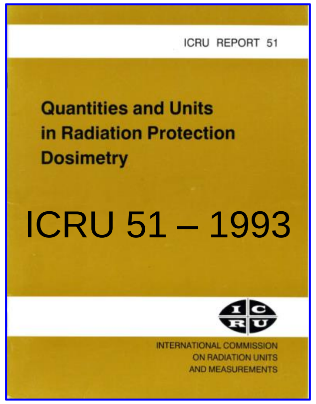
ICRU 51 – 1993

$$H = Q(L) \cdot D$$

Dose equivalent = *Quality factor in tissue* · *Absorbed dose in tissue*

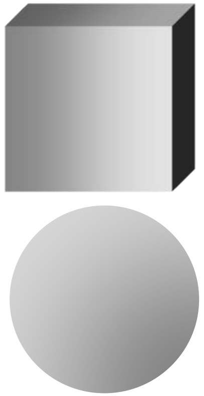
Definition in sphere or person: Area- and personal dose

Measuring quantities: *definition*



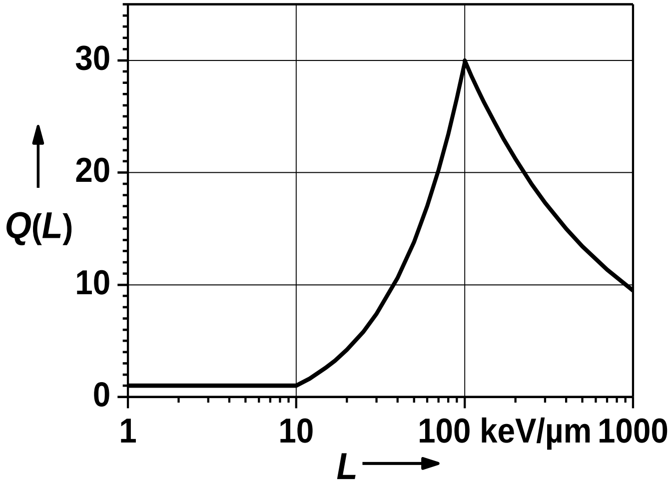
$$H = Q(L) \cdot D$$

H — *Dose equivalent*; *Q(L)* — *Quality factor in tissue*; *D* — *Absorbed dose in tissue*



$Q_{\mathrm{photon;beta}} = 1$

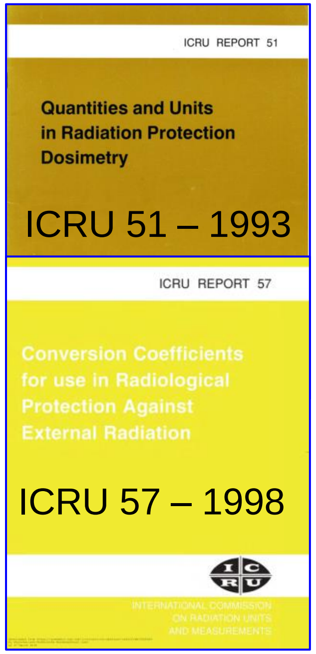
$1 < Q_{\mathrm{neutron}} < 30$



Q : Quality factor to take into account the biological effectiveness depending on the quality of the radiation

- *Q(L)* is a function of a physical quantity
- *L* is the linear energy transfer (in keV/µm) in water
- *L* can be measured with Tissue Equivalent Proportional Counters (TEPC)

Measuring quantities: *realization*

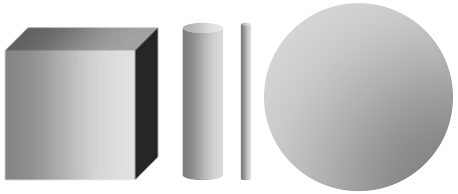


$$H = Q(L) \cdot D$$

H	$Q(L)$	D
Dose equivalent	*Quality factor in tissue*	*Absorbed dose in tissue*

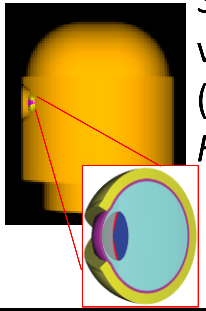
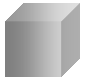
For representation $= h \cdot \Phi$ *bzw.* K_a

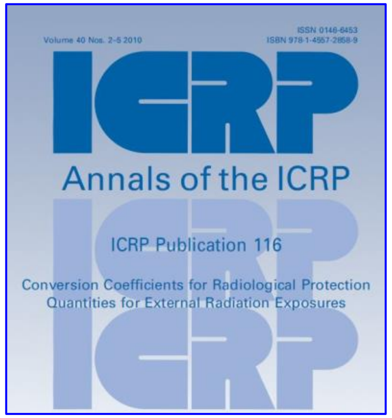
h	Φ bzw. K_a
Conversion coefficient	*Fluence or air kerma in air*



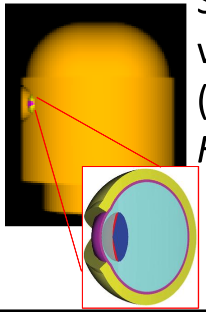
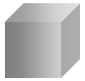
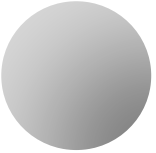
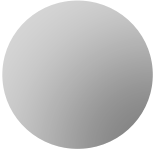
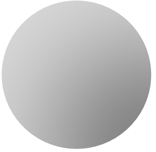
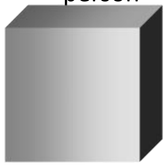
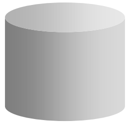
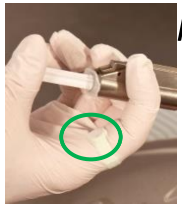
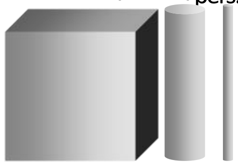
Protection vs. measuring quantities

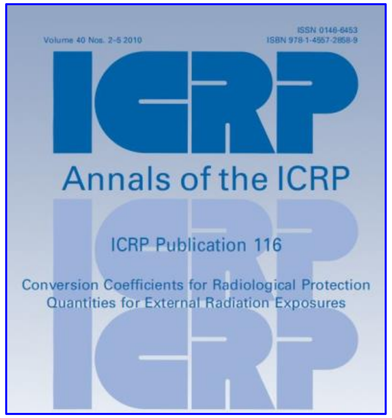
Sievert

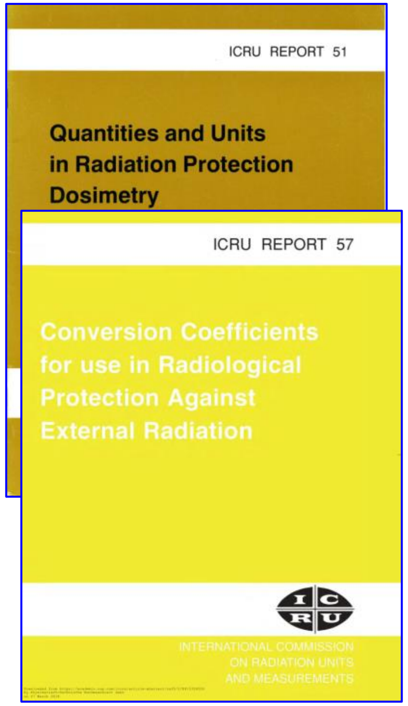
	Whole body	Lens of the eye	Local skin
Protection quantities (ICRP 116)	 ICRP reference voxel phantoms: $E_{eff} = \sum_T w_T \sum_R w_R D_{T,R}$	 Stylized eye model; whole lens (ICRP 116, Annex F): $H_{lens} = \sum_R w_R D_{lens,R}$	 Tissue-equivalent cube (10x10x10 cm3); 1 cm^2 area at 50 – 100 µm depth (ICRP 116, Annex G): $H_{local\ skin} = \sum_R w_R D_{local\ skin,R}$



Protection vs. measuring quantities

	Whole body	Lens of the eye	Local skin
Sievert — Protection quantities (ICRP 116)	 ICRP reference voxel phantoms: $E_{eff} = \sum_T w_T \sum_R w_R D_{T,R}$	 Stylized eye model; whole lens (ICRP 116, Annex F): $H_{lens} = \sum_R w_R D_{lens,R}$	 Tissue-equivalent cube (10x10x10 cm3); 1 cm^2 area at 50 – 100 µm depth (ICRP 116, Annex G): $H_{local\ skin} = \sum_R w_R D_{local\ skin,R}$
Operational quantities: definition: $H = Q(L) \cdot D$			
Sievert — Operational quantities for monitoring (ICRU 51/57) — Area	 ICRU 4-element tissue sphere: Ø = 30 cm: $H^*(10) = Q \cdot D(10)_{sph}$	 ICRU 4-element tissue sphere: Ø = 30 cm: $H'(3;\Omega) = Q \cdot D(3;\Omega)_{sph}$	 ICRU 4-element tissue sphere: Ø = 30 cm: $H'(0.07;\Omega) = Q \cdot D(0.07;\Omega)_{sph}$
Sievert — Operational quantities for monitoring (ICRU 51/57) — Individual	 $H_p(10) = Q \cdot D(10)_{person}$  For calibration: ICRU 4-elem. tiss. slab: 30x30x15 cm^3: $H_p(10) = Q \cdot D(10)_{slab}$	 $H_p(3) = Q \cdot D(3)_{person}$  For calibration: ICRU 4-elem. t. cylinder: Ø = h = 20 cm: $H_p(3) = Q \cdot D(3)_{cylinder}$	 $H_p(0.07) = Q \cdot D(0.07)_{pers.}$  For calibration: ICRU 4-el. tissue slab, pillar, rod (Ø = 73, 19 mm): $H_p(0.07) = Q \cdot D(0.07)_{slab,\ pillar,\ rod}$





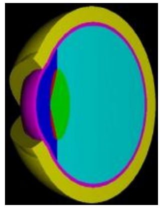
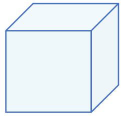
From dosemeter development to routine use – Standards and Uncertainties – RAP25-16

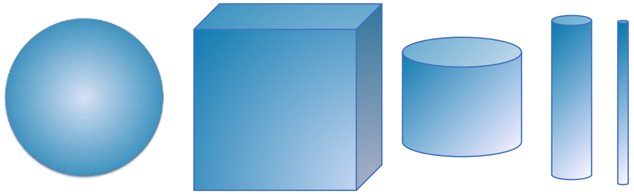
Rolf Behrens & Oliver Hupe

Additional material

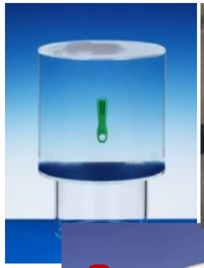
Phantoms at a glance …

Phantoms and their purpose - at a glance



(For calculation of conversion coefficients for calibrations)



Phantoms for the calculation of protection quantities

- *Anthropomorphic voxel, eye, and skin phantoms from ICRP*
- *To calculate the absorbed dose to the organ and the effective dose*

Phantoms for the calculation of operational quantities

- *Defined by the ICRU, consisting of ICRU 4-element tissue*
- *To calculate the conversion coefficients*
- *ICRU sphere (30 cm diameter) for area dosimetry*
- *ICRU slab/cylinder/pillar/rod phantom for personal dosimetry*
- *No realization required*

Phantoms for type tests and calibrations

- *defined by ISO, made from PMMA and water*
- *Simulate the backscattered radiation field*
- *ISO water slab phantom (with PMMA walls)*
- *ISO water cylinder phantom (with PMMA walls)*
- *ISO water pillar phantom (with PMMA walls)*
- *ISO PMMA rod phantom*
- *Calibration of area dosemeters without phantoms*