The Operational Quantities and New Approach by ICRU

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ICRP Committee 2 & ICRU Report Committee 26

Japan Atomic Energy Agency

Background

ICRP Publication 116

Conversion Coefficients for Radiological Protection Quantities for External Radiation Exposures

- Reference data set based on the 2007 Recommendations
- Supersedes ICRP74 and extends particle types and energy ranges

⇨ Important issue on radiation monitoring

ICRP Publication 118

ICRP Statement on Tissue Reactions/Early and Late Effects of Radiation in Normal Tissues and Organs

- Recommends reducing dose limit for the lens of the eye

⇨ Dose assessment by better modeling is required

Protection quantities

Based on absorbed doses in specified tissues and organs

- ***Equivalent dose in a tissue or organ***

$$H_{\mathrm{T}} = \sum_{\mathrm{R}} w_{\mathrm{R}} D_{\mathrm{T,R}}$$

- ***Effective dose***

$$E = \sum_{\mathrm{T}} w_{\mathrm{T}} \sum_{\mathrm{R}} w_{\mathrm{R}} D_{\mathrm{T,R}}$$

$D_{\mathrm{T,R}}$: Mean absorbed dose from radiation R in a tissue or organ T

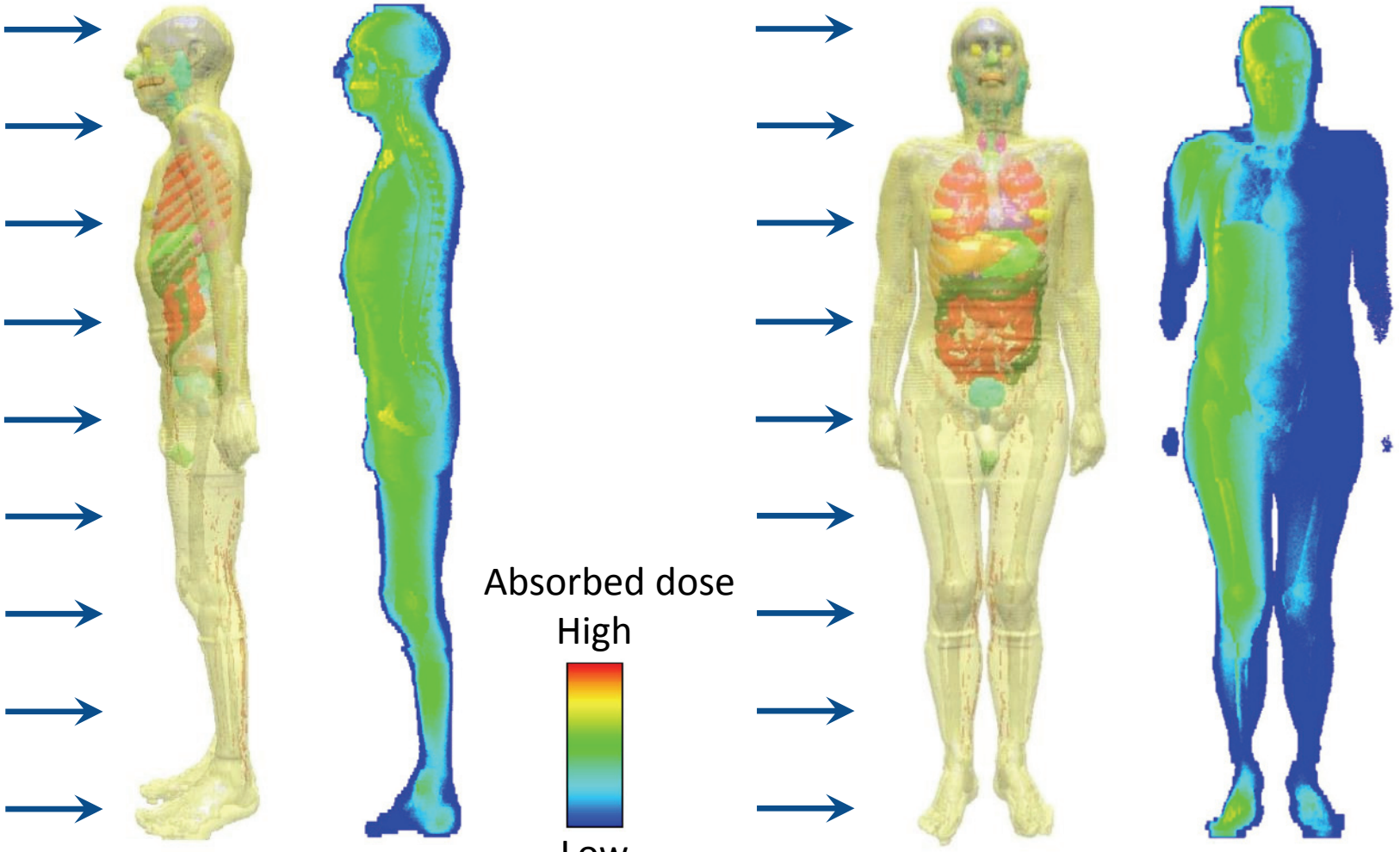
w_{R} : Radiation weighting factor

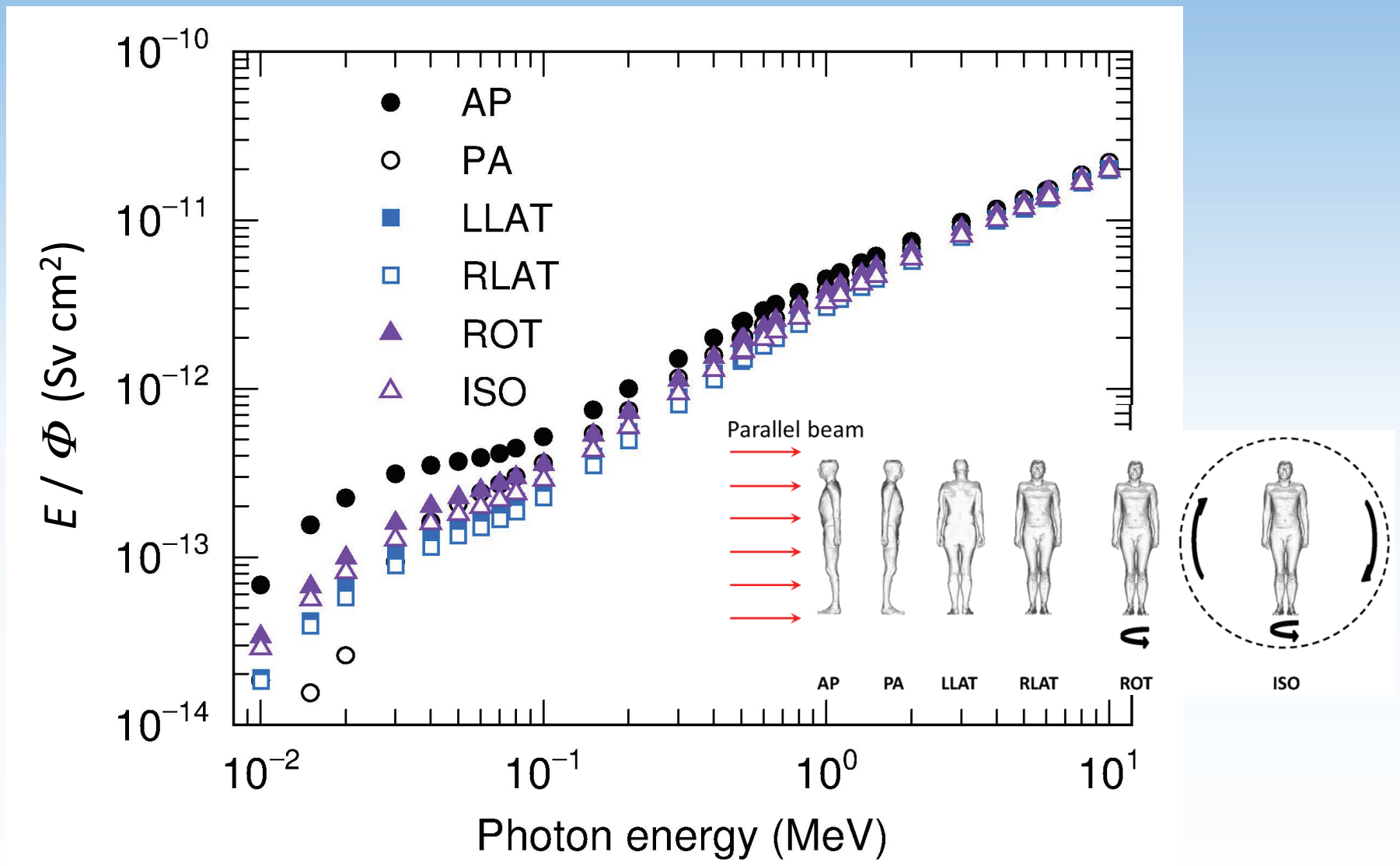
w_{T} : Tissue weighting factor

Absorbed dose distribution

Antero-posterior

Right-lateral

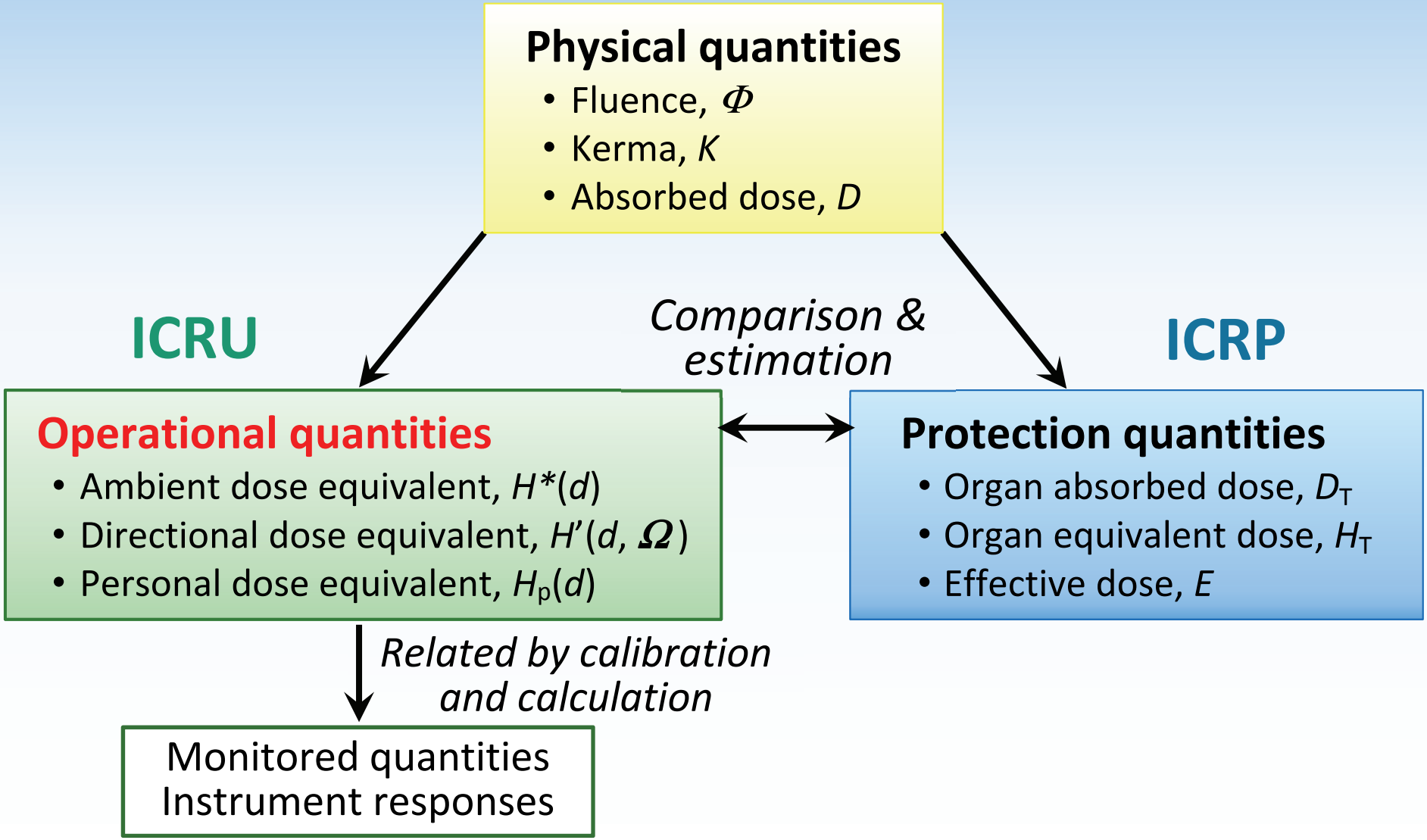




Effective dose depends on incident direction of photons

⇨ The quantity is not suitable for measurement

System of radiation protection dosimetry



Dose equivalent

$$H = DQ$$

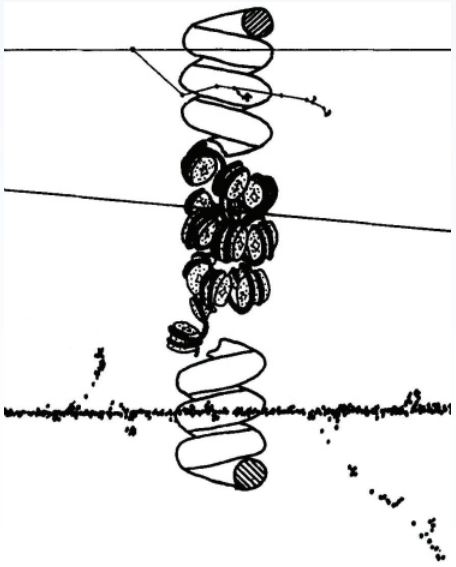
D : Absorbed dose at a point in tissue

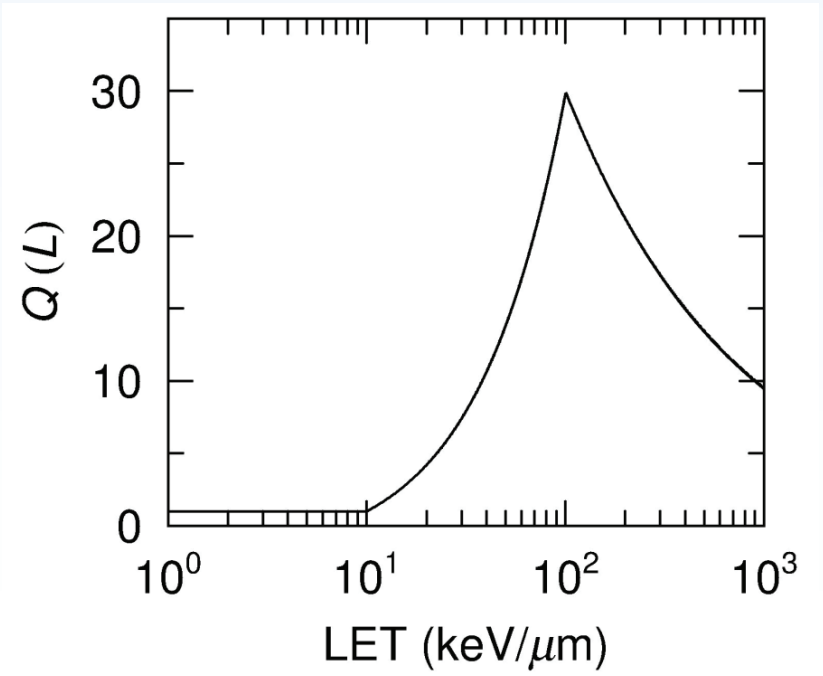
Q : Quality factor for the specific radiation at that point

⇨ Characterizes biological effectiveness based on ionization density

Low LET

High LET





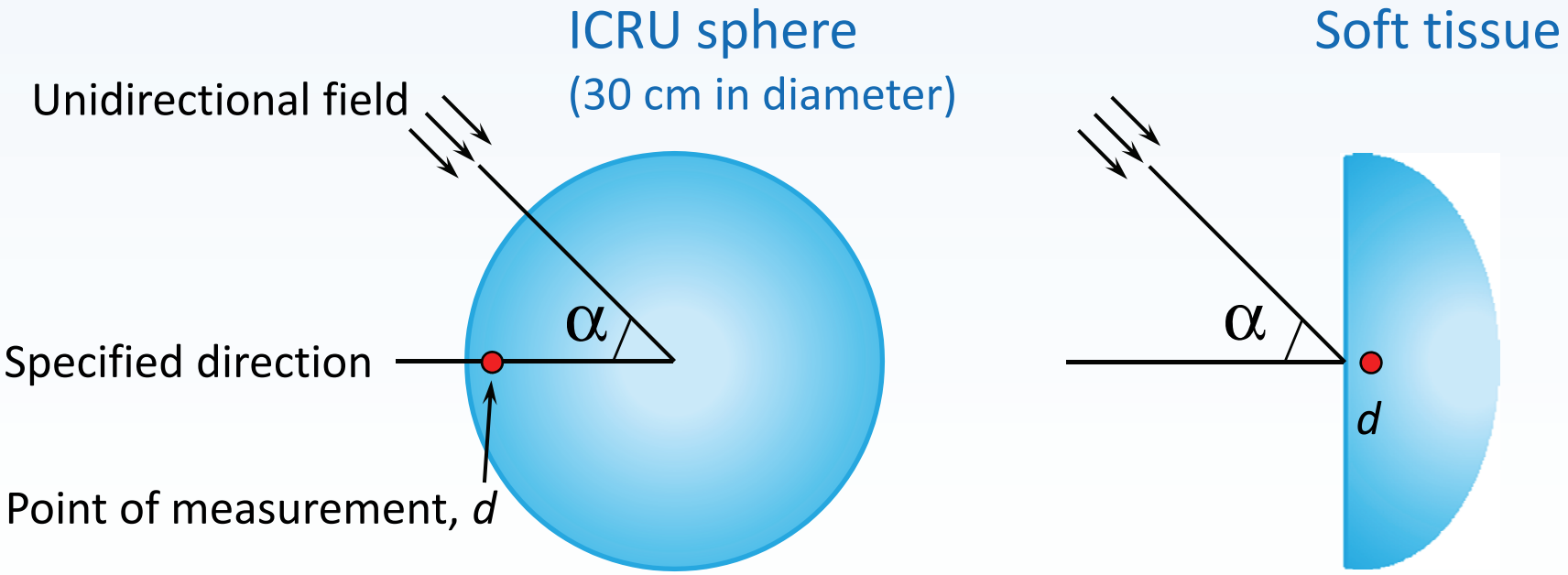
Operational quantities currently used

Area monitoring

- Ambient dose equivalent, $H^*(d)$
- Directional dose equivalent, $H'(d, \Omega)$

Individual monitoring

- Personal dose equivalent, $H_p(d)$



Relation of protection quantities and operational quantities for external exposure

Protection quantities			
Control of	Effective dose E	Equivalent dose to lens of eye H_{lens}	Equivalent dose to local skin H_{skin}
	⇕	⇕	⇕
Area monitoring	Ambient dose equivalent $H^*(10)$	Directional dose equivalent $H'(3, \Omega)$	Directional dose equivalent $H'(0.07, \Omega)$
Individual monitoring	Personal dose equivalent $H_p(10)$	Personal dose equivalent $H_p(3)$	Personal dose equivalent $H_p(0.07)$
Operational quantities			

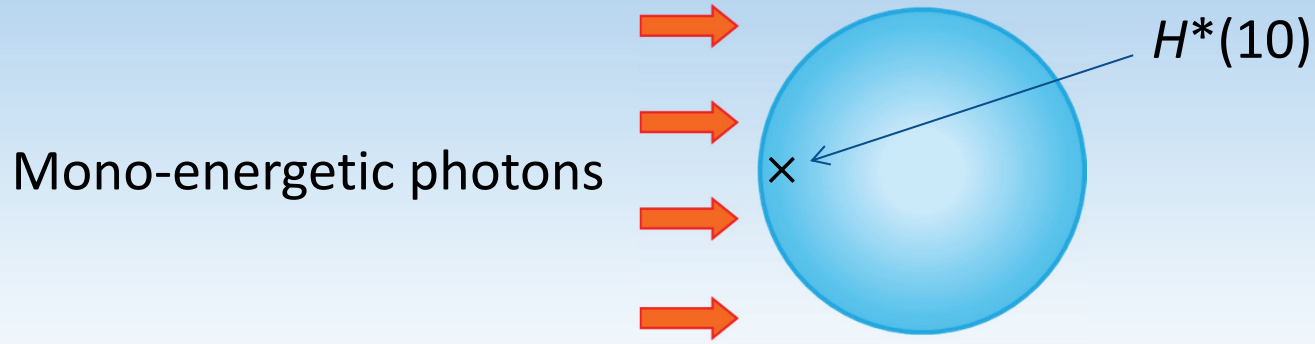
Limitations of the current system

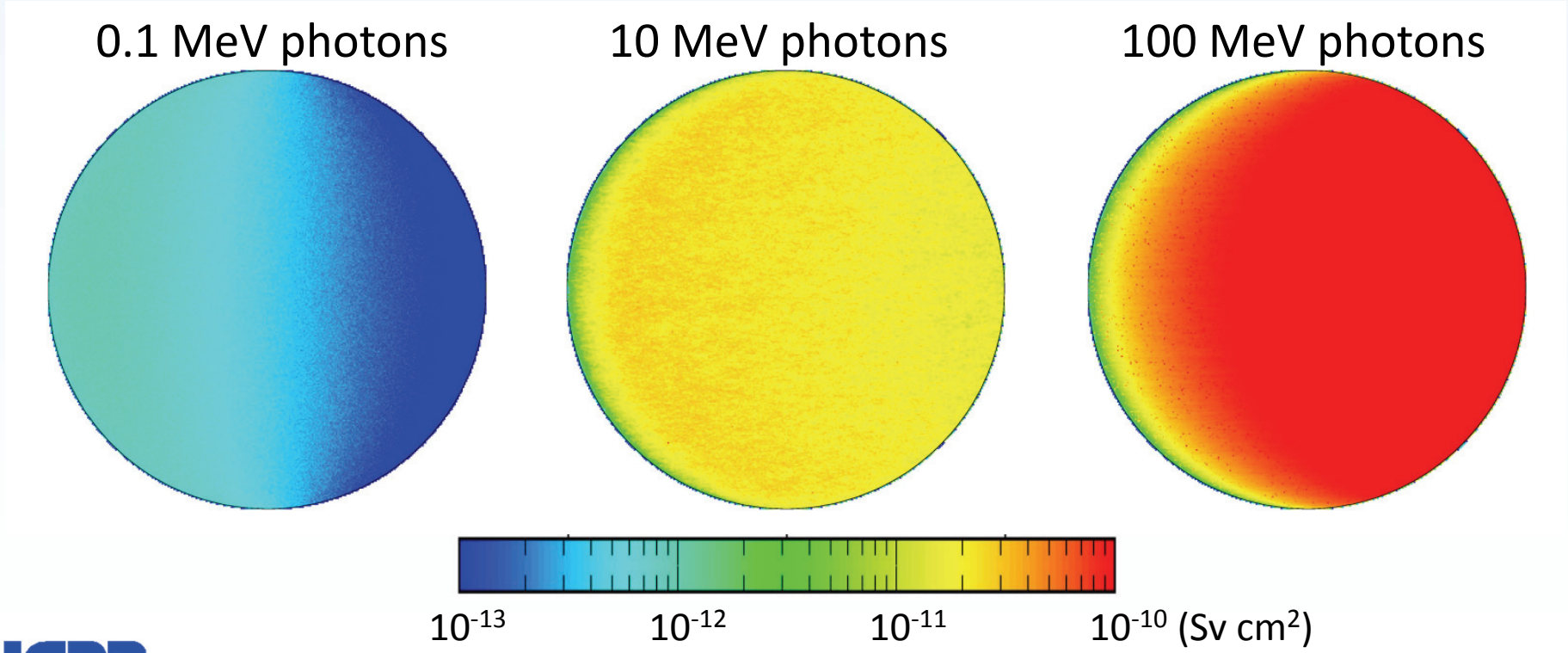
ICRP Publication 116 extends dose conversion coefficients for external exposure for various radiations *up to higher energies* compared with ICRP74

- Regarding the extension of energy range, Paragraph (248) of ICRP116 states

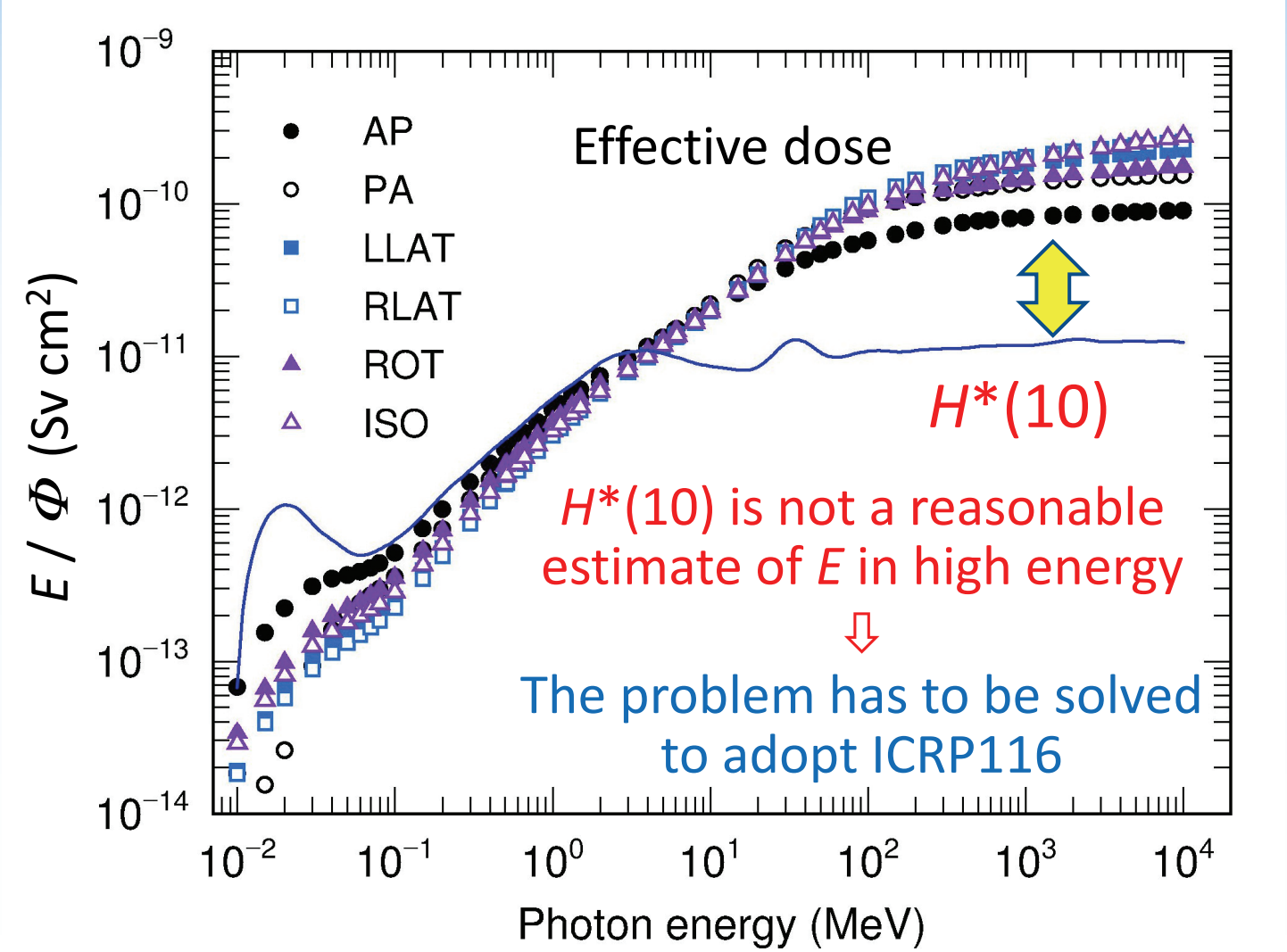
  "*For operational quantities* ***at these higher energies,*** *comparisons with a small sample of the data published since 1996 demonstrate that* ***there is a need to further examine the relationship of the operational and protection quantities.*** *In 2010, ICRU undertook the task to re-evaluate the definitions of the operational quantities.*"

Dose equivalent in the ICRU sphere





E vs. *H**(10)


AP
PA
LLAT
RLAT
ROT
ISO
Effective dose
*H**(10)
*H**(10) is not a reasonable estimate of *E* in high energy
⇩
The problem has to be solved to adopt ICRP116
E / Φ (Sv cm²)
Photon energy (MeV)
10⁻⁹
10⁻¹⁰
10⁻¹¹
10⁻¹²
10⁻¹³
10⁻¹⁴
10⁻²
10⁻¹
10⁰
10¹
10²
10³
10⁴

ICRU Report Committee 26 (ICRU RC26)

Aim:

Proposes a new system of the operational quantities, which replaces ICRU Report 51 and, in part, Report 57

- Examines the rationale for the operational quantities
  - Taking account of the update of definitions of the protection quantities in ICRP103, and the extension of particle types and energy ranges in ICRP116
- Examines the relationships of the operational quantities with the protection quantities
- Examines the impact of changes on routine measurement practice, including instrument design and calibration

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Nolan Hertel (USA)

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Concept for new approach

For control of effective dose

Operational quantities are defined based on effective dose

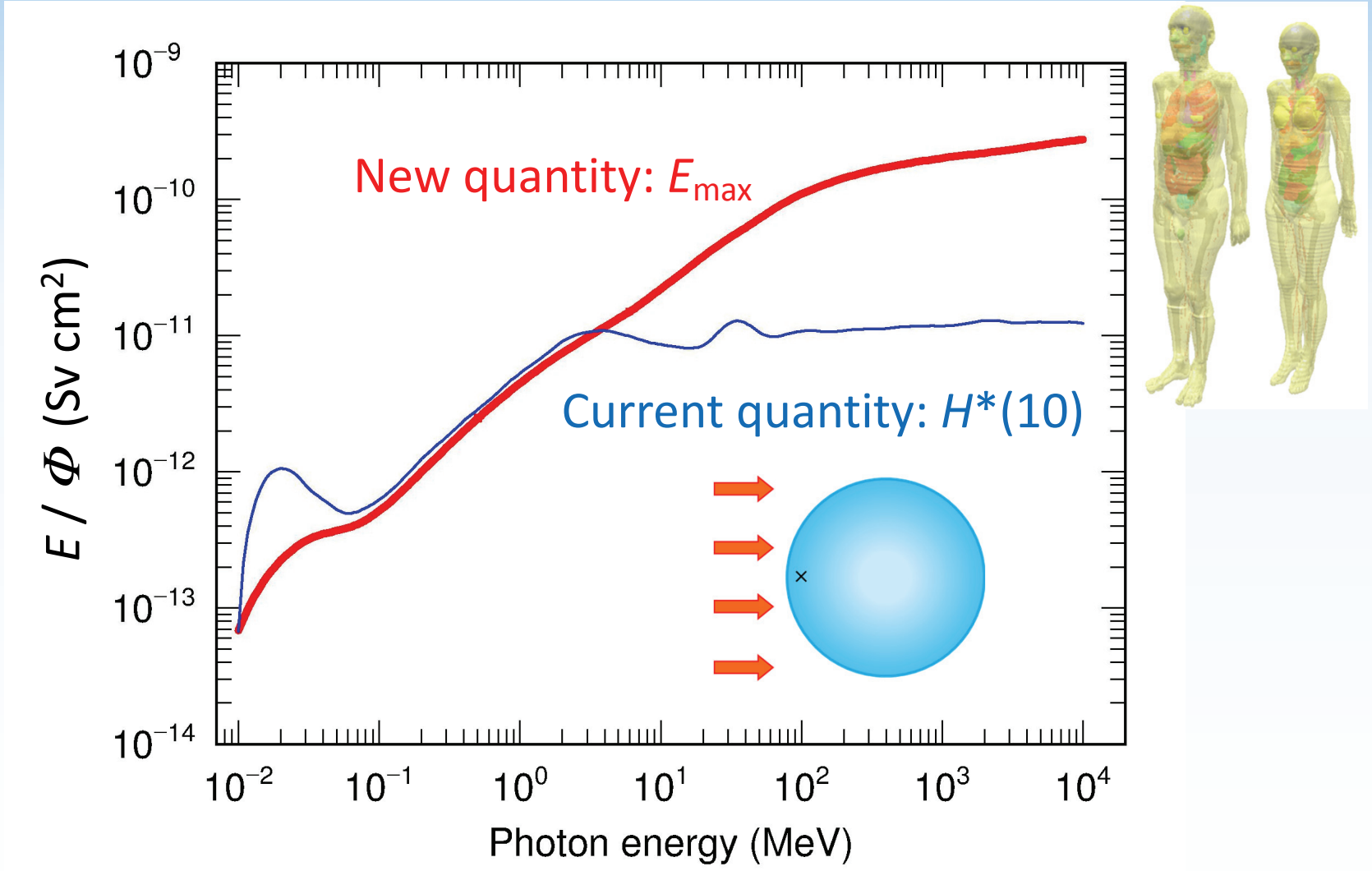
- We have reference values of effective dose conversion coefficients calculated using the reference phantoms (ICRP110, 116)

For prevention of deterministic effects

Operational quantities are defined by absorbed dose

- Equivalent dose is the product of absorbed dose and w_R, which is only defined for stochastic effects
  ⇨ Dose for the lens of the eye and local skin could more appropriately be set in terms of absorbed dose

New definition - area monitoring



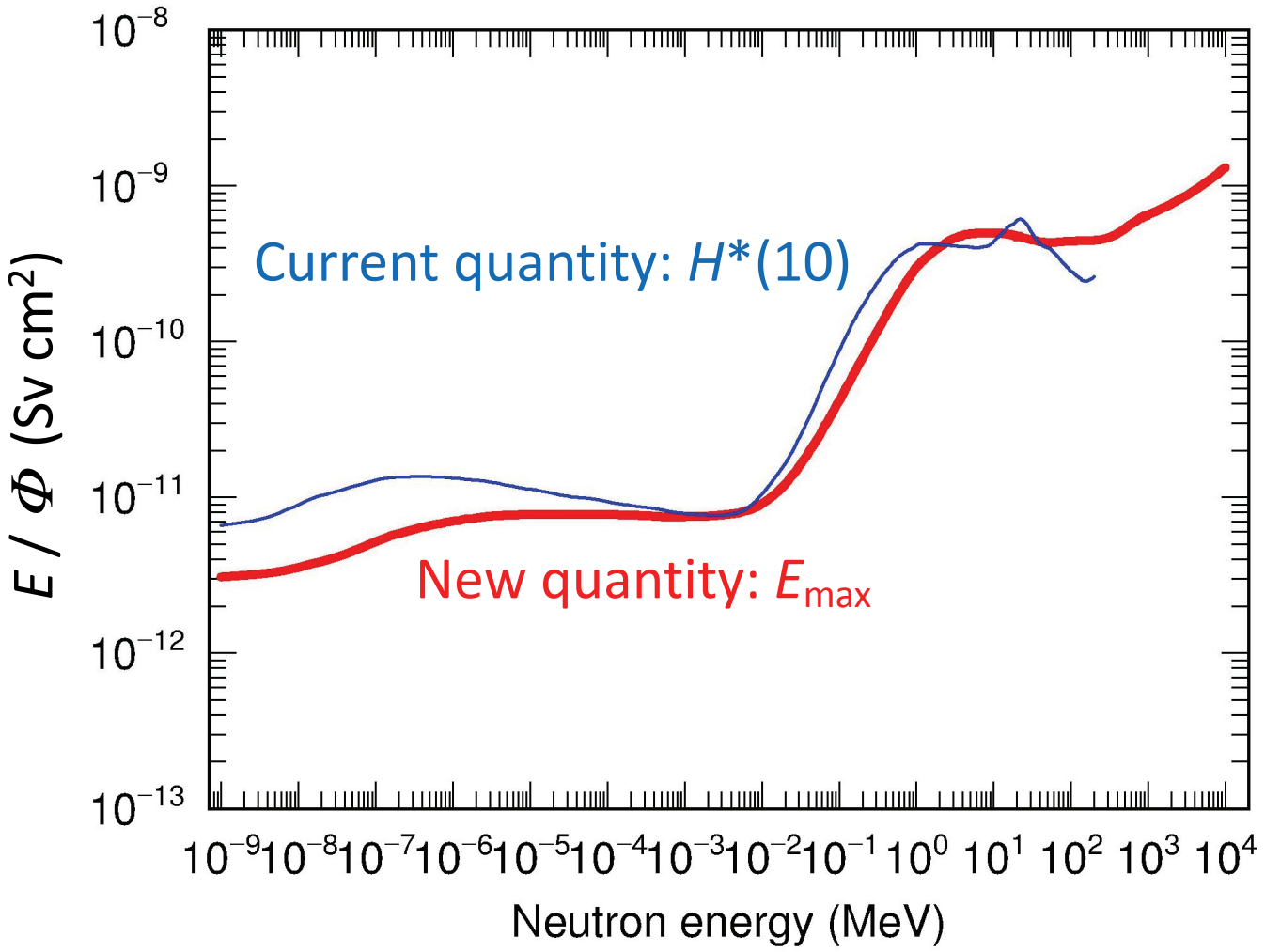
Ambient dose equivalent, *H**

$$H^* = h_{E_{\max}} \Phi$$

$$h_{E_{\max}} = E_{\max} / \Phi$$

Calculated using the ICRP reference phantoms

E_{max} for neutrons

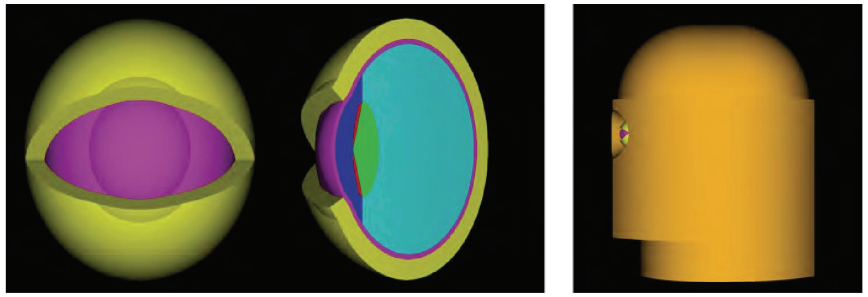


Directional absorbed dose - lens of the eye

$$D'_{\text{lens}}(\boldsymbol{\Omega}) = d'_{\text{lens}}(\boldsymbol{\Omega})\, \Phi(\boldsymbol{\Omega})$$

$$d'_{\text{lens}}(\boldsymbol{\Omega}) = D'_{\text{lens}}(\boldsymbol{\Omega}) \,/\, \Phi(\boldsymbol{\Omega})$$

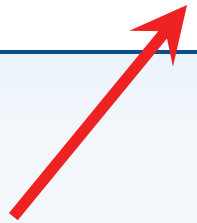
Calculated using the stylized eye model



R. Behrens, et al. Phys. Med. Biol. 54, 4069 (2009).
R. Behrens, et al. Phys. Med. Biol. 56, 415 (2011).
R. Behrens. Radiat. Prot. Dosim. 155, 224 (2013).

Directional absorbed dose - local skin

$$D'_{\text{local skin}}(\boldsymbol{\Omega}) = d'_{\text{local skin}}(\boldsymbol{\Omega})\, \Phi(\boldsymbol{\Omega})$$



$$d'_{\text{local skin}}(\boldsymbol{\Omega}) = D'_{\text{local skin}}(\boldsymbol{\Omega}) \,/\, \Phi(\boldsymbol{\Omega})$$

Calculated for the sensitive layer
using the tissue-equivalent phantom

Individual monitoring

- Personal dose equivalent

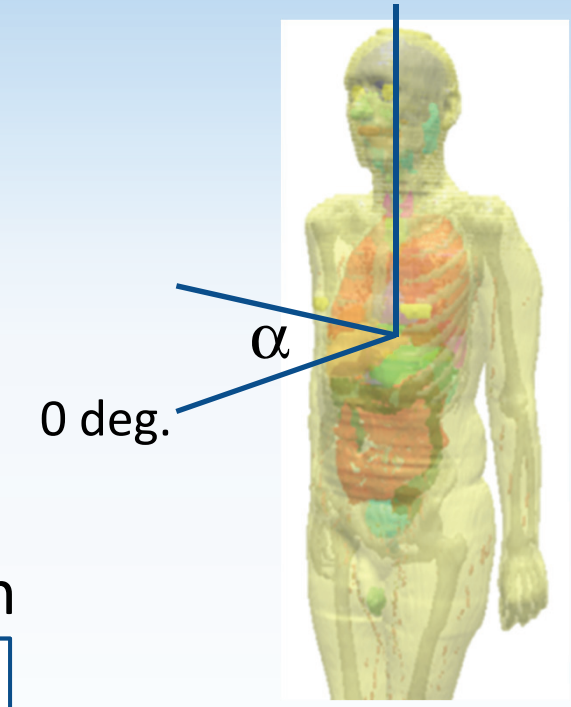
$$H_{\mathrm{p}} = h_E \, \Phi$$

- Personal absorbed dose to the lens

$$D_{\mathrm{p,\,lens}} = d_{\mathrm{lens}} \, \Phi$$

- Personal absorbed dose to the local skin

$$D_{\mathrm{p,\,local\ skin}} = d_{\mathrm{local\ skin}} \, \Phi$$



- Conversion coefficients, h_E, d_{lens} and $d_{\mathrm{local\ skin}}$, are given for various angles, α
- Calibration phantoms for personal dosimeters remain unchanged

Proposition

	New definition	Current definition
Area monitoring	***Whole body*** $H = \Phi \times$ conversion coefficient for effective dose	$H = Q \times$ absorbed dose in ICRU sphere
Individual monitoring	***Lens & skin*** $D = \Phi \times$ conversion coefficient for absorbed dose	$H = Q \times$ absorbed dose in soft tissue

Avoids introduction of ICRU sphere and Q-L function

Simplifies the system of radiation monitoring and dose assessment

Impact of changes

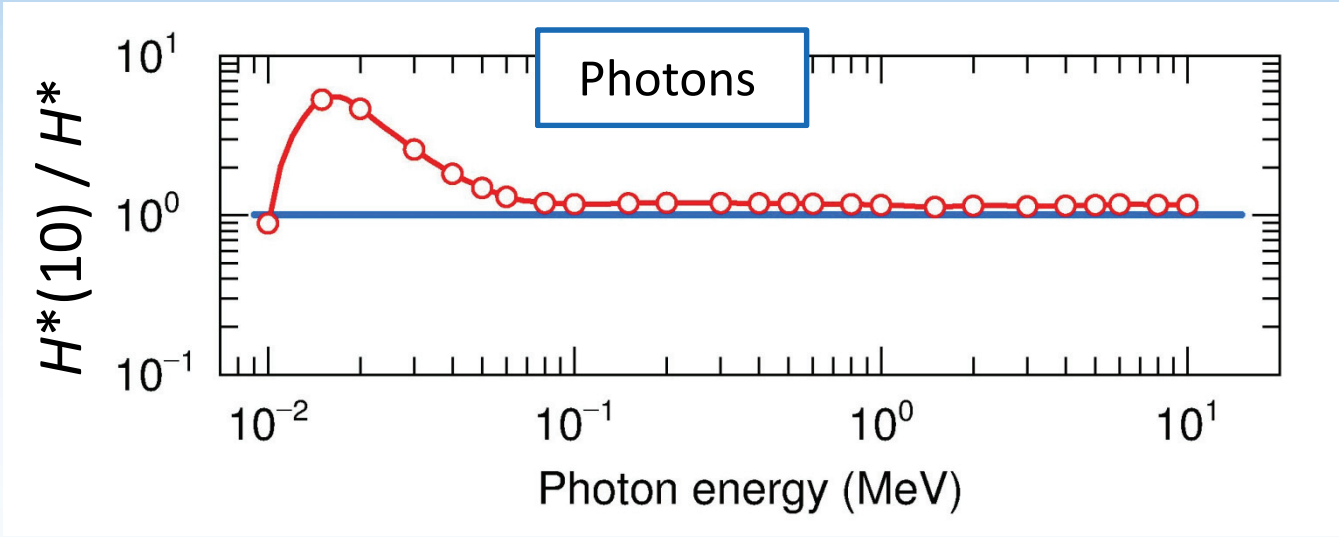
Changing the system affects

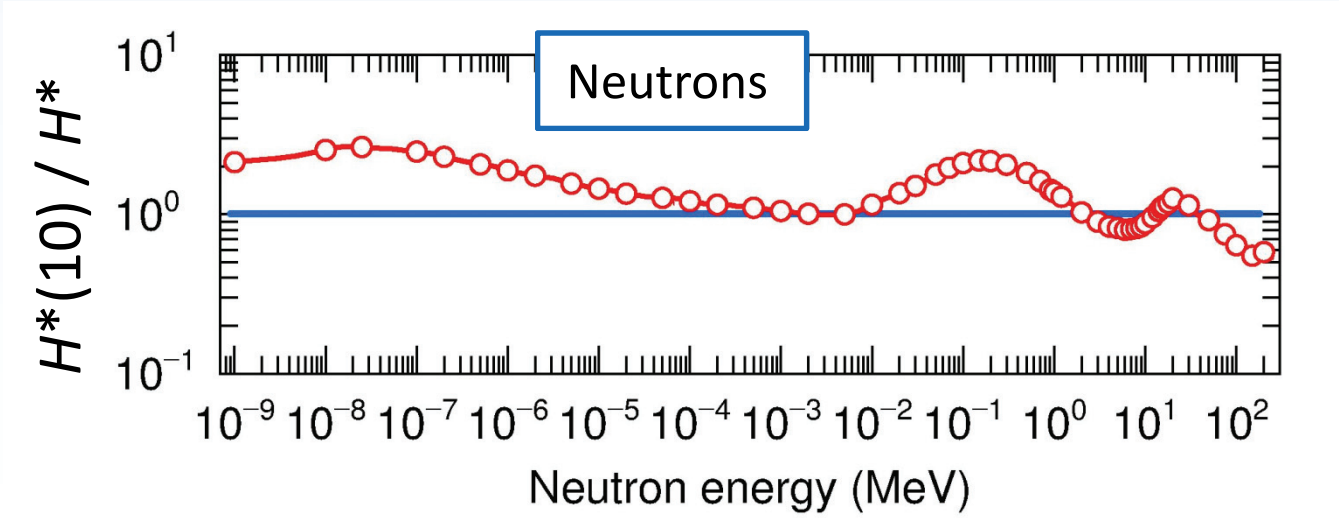
- Radiation protection practice, legislation and regulations, Instrumentation and calibration, etc

Calibration of instrument

- Calibration phantoms: **Unchanged**
  - water slab, water cylinder, water pillar, and PMMA rod
- Reference fields: **Unchanged**
  - fluence for neutrons, air kerma for photons, absorbed dose to ICRU tissue for electron
- Conversion coefficients: **Revised**
  - fluence-, air kerma-, or absorbed dose-to-E_{max}, D'_{lens}, etc.

Ratios of $H^*(10)$ / H^*





Conclusions

ICRU Report Committee 26 proposes a new system of operational quantities for external radiations

For control of effective dose

- Defines operational quantities based on effective dose

For prevention of deterministic effects

- Defines operational quantities by absorbed dose

This approach to operational quantities

- Harmonizes with protection quantities
- Provides reasonable estimates of protection quantities

⇨ Simplifies the system of radiation monitoring & dose assessment, and assists in the comprehension of radiation protection quantities

Status

- A draft of the ICRU Report is mostly completed except for data gaps
  - The Committee is now collecting conversion coefficients and calculating data that are not currently available

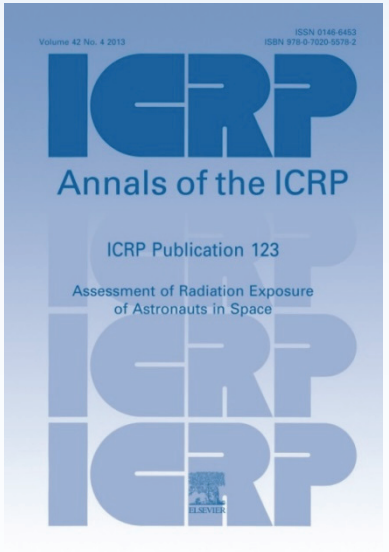
- The draft will be sent to the ICRU Commission for review, and then distributed to related organizations including ICRP for comments

The Report Committee of ICRU welcomes your opinions

In Memoriam
Dr. Günther Dietze

Günther served on many national and international committees including the Chair of ICRP Task Group 67

Passed away on
25 January 2015



ICRP Publication 123
Assessment of Radiation Exposure of Astronauts in Space

Thank you for your kind attention

www.icrp.org