

Better Measured Estimates of Effective Dose for Radiation Protection

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Effective Dose E (Sv)

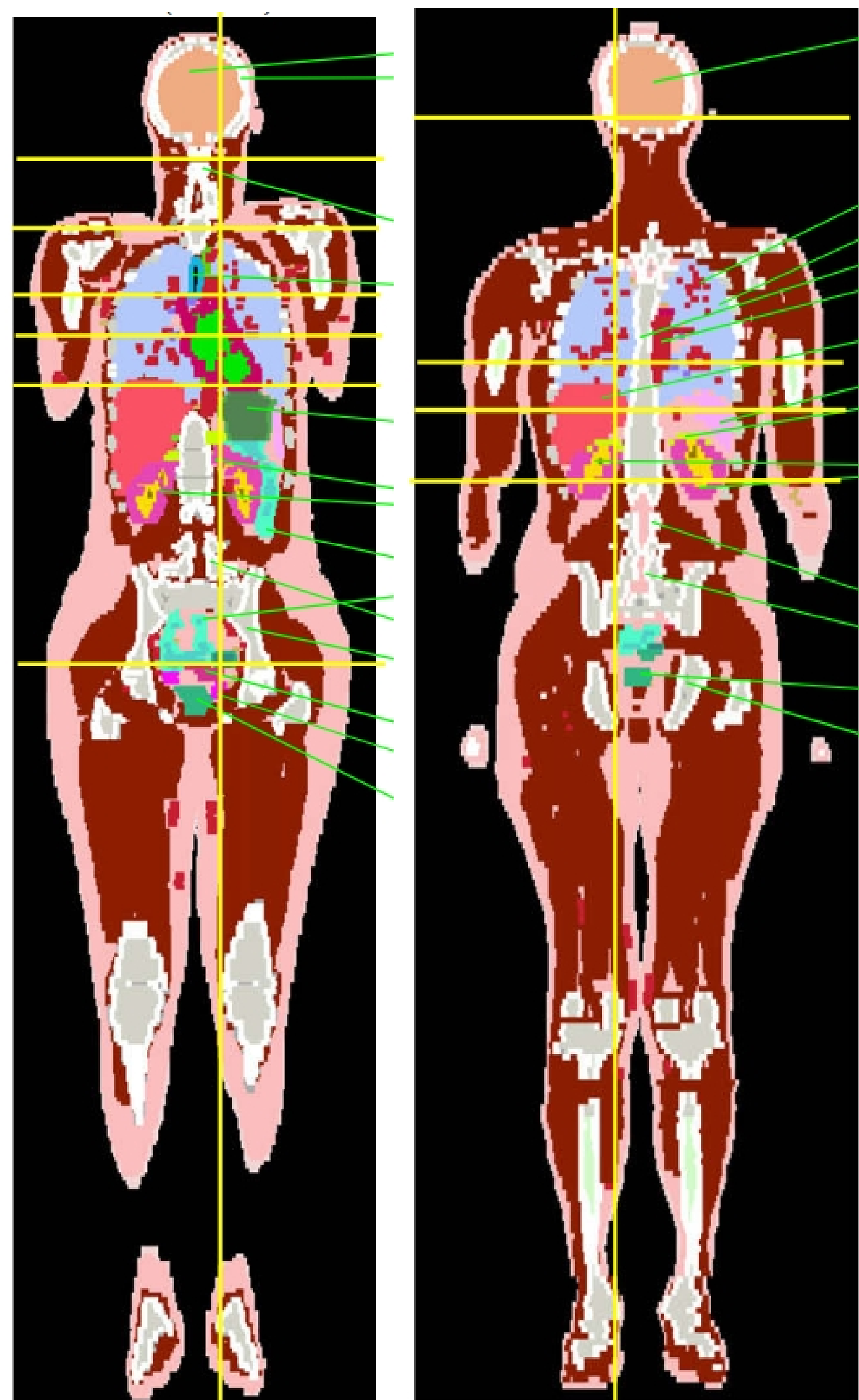
E was defined in 1990 (rev. 2007) by the International Commission on Radiological Protection (ICRP) as a **protection quantity** for whole-body exposure (ICRP Publications 60 & 103). It embodies the radiobiological knowledge of stochastic effects (occurrence of cancer) from moderate doses of ionising radiation (<0.1 Sv). It serves to define legal dose limits and constraints.

E is defined as weighted average of absorbed doses (Gy) in body tissues. Weighting factors reflect radiation efficiency (R) and tissue sensitivity (T):

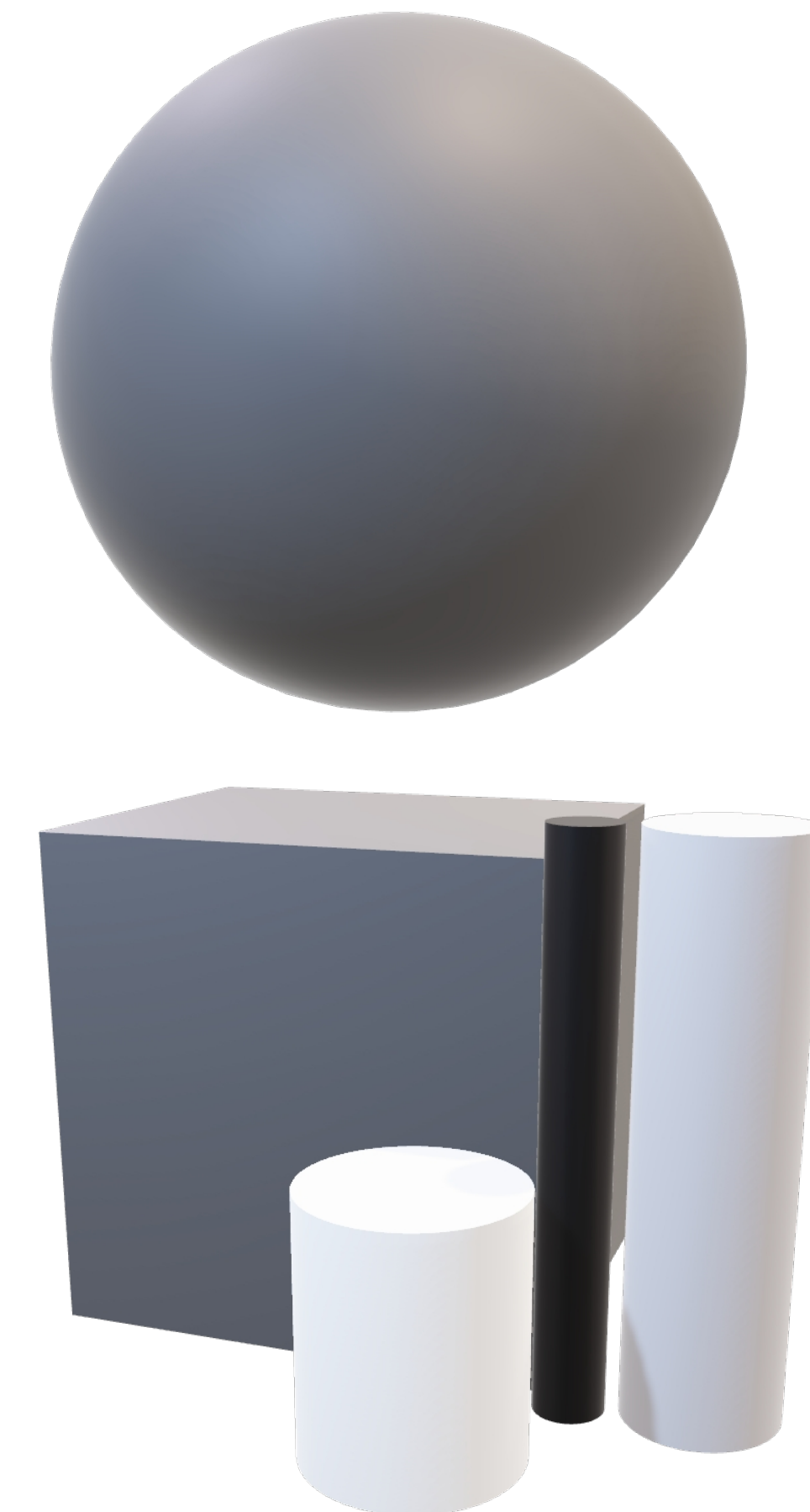
$$E = \sum_T w_T \sum_R w_R D_{T,R}$$

E is calculated with anthropomorphic numerical phantoms (voxel, ICRP Pub. 110)

Effective dose is defined over the extended volume of a body and cannot be measured



Cut through female and male voxel phantoms



Today's Solution: Personal and Ambient Dose Equivalent

The International Commission on Radiation Units and Measurements (ICRU) has defined in 1985 (rev. 1993) point-like and measurable **operational quantities** (ICRU Reports 39 & 51). The definition of these quantities follows an earlier concept with a radiation quality factor Q , depending on linear energy transfer L .

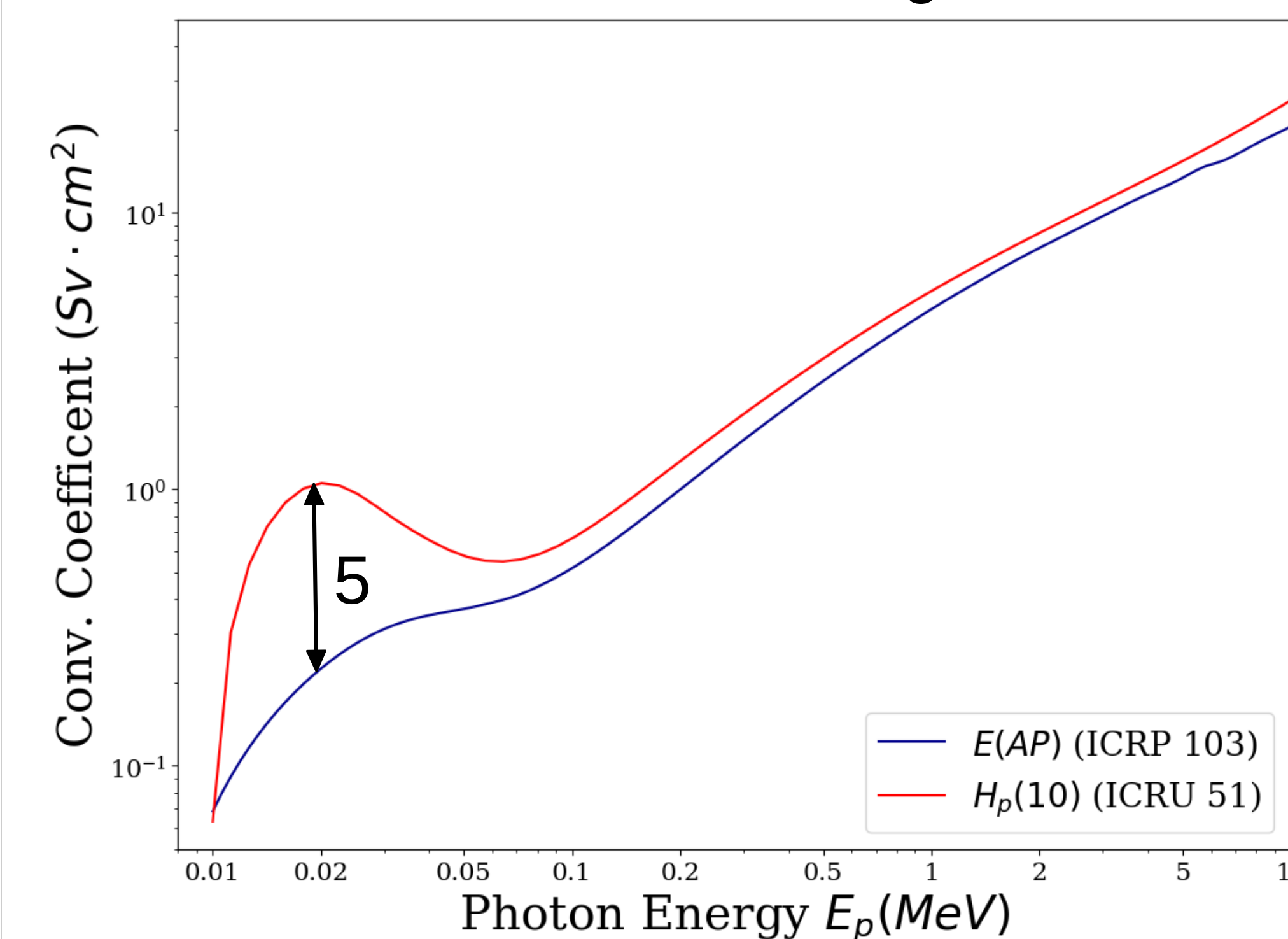
$$H = D * Q(L)$$

Operational quantities are defined and calculated with simple geometric bodies: sphere, slab, cylinder as surrogates for the human body or parts of it.

For personal dosimetry, the operational quantity is *personal dose equivalent* $H_p(10)$, calculated with the slab phantom, for ambient dosimetry *ambient dose equivalent* $H^*(10)$, calculated with the ICRU sphere.

The Problem:

Due to the very different definition, the operational quantities $H_p(10)$ and $H^*(10)$ do not model E well over all energies.

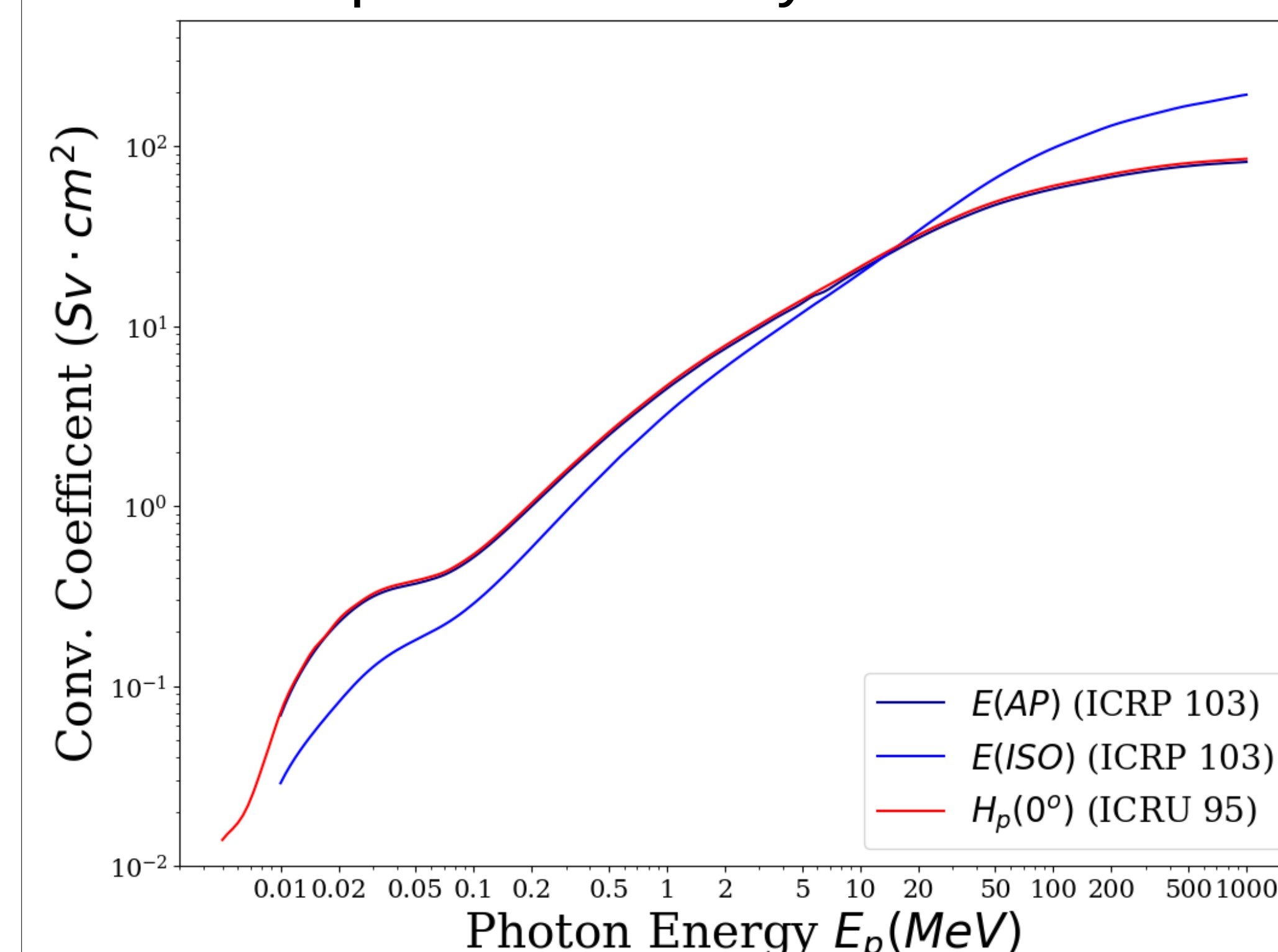


For low-energy photons (Energy < 50 keV), $H_p(10)$, $H^*(10)$ overestimate E by a factor 5.

A New Solution: ICRU Report 95

In 2020, ICRU published new operational quantities: personal dose H_p and ambient dose H^* .

They are point-like and based on the ICRP concept of weighting factors. Their calculation uses the ICRP anthropomorphic voxel phantoms. Numerical values of H_p and H^* are thus equal to E or very close to it.



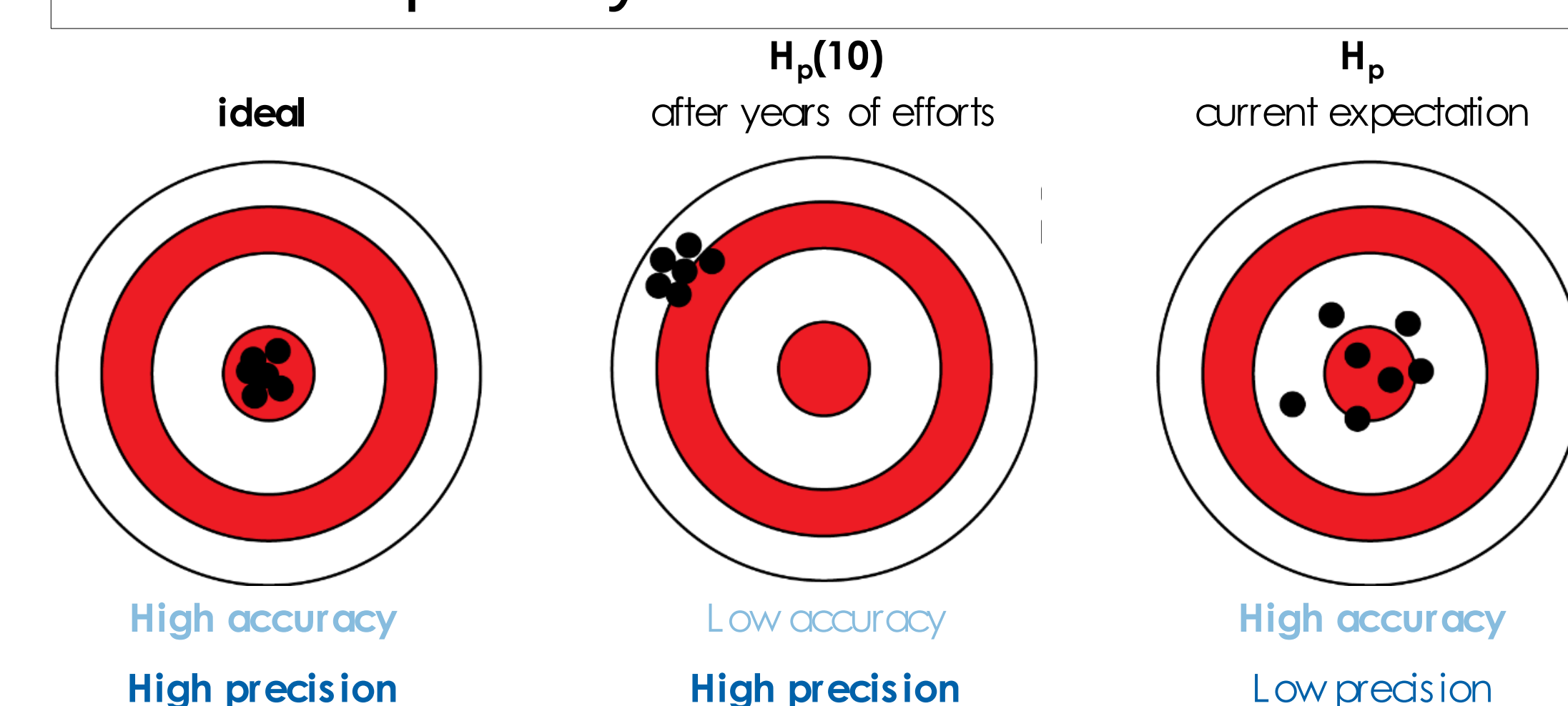
How to Measure H_p and H^*

Today's monitors and personal dosimeters are optimised for the present operational quantities $H_p(10)$ and $H^*(10)$. This means, for example, that they would **overestimate** H_p and H^* for low photon energies.



For many workplaces (radionuclides, nuclear industry,) a simple re-calibration of existing dosimeters is possible. A universal dosimeter for all energies will require more development work.

We may exchange a precise measurement of a not very accurate quantity against a less precise measurement of a more accurate quantity.



Conclusion

- The new operational quantities H_p and H^* provide a better approximation of Effective Dose E .
- They reflect the present scientific knowledge of stochastic radiation effects.
- They remove unjustified conservatism
- Their introduction simplifies the system of radiation protection dosimetry by unifying the approach and removing old concepts.
- Additional R&D is required for dosimeters.