

Metrological Needs for the future of Radiological Protection

Metrology for Regulation –
Open Public Consultation
23 October 2023

ICRP



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ICRP – C2 Chair

Fit for Purpose

**The System of Radiological Protection
is robust and has performed well**

however

**it must adapt to address changes in
science and society to remain fit for
purpose**

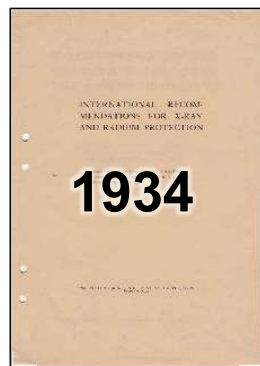
General Recommendations



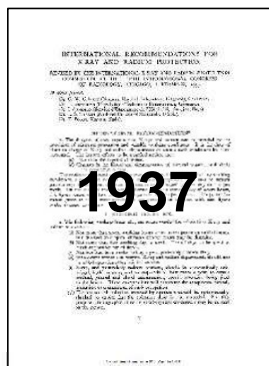
3y



3y

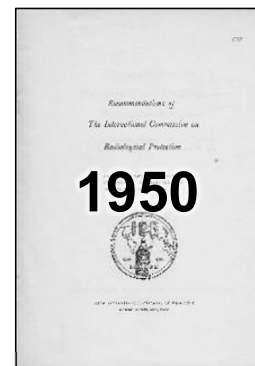


3y

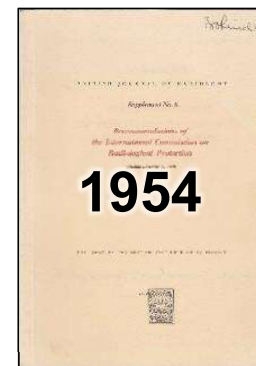


World War II

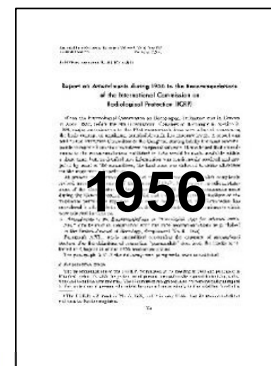
13y



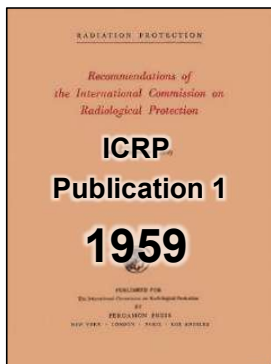
4y



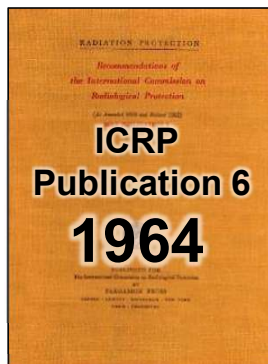
2y



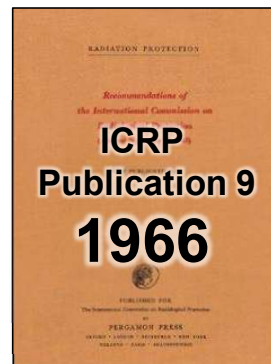
3y



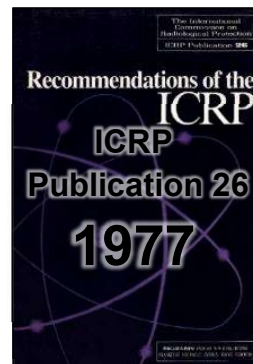
5y



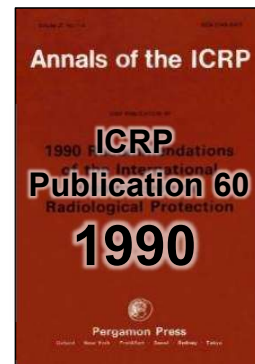
2y



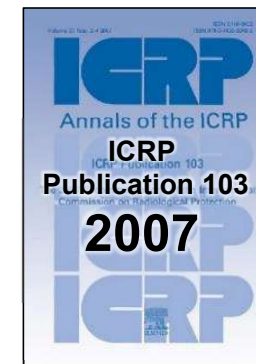
11y



13y



17y



>20y



Towards the Next General Recommendations

Development of the next General Recommendations is a major project managed by the Main Commission

- Including the work of ~40 current and upcoming TGs
- Drafting of the next General Recommendations will start early next term, aiming for 2031

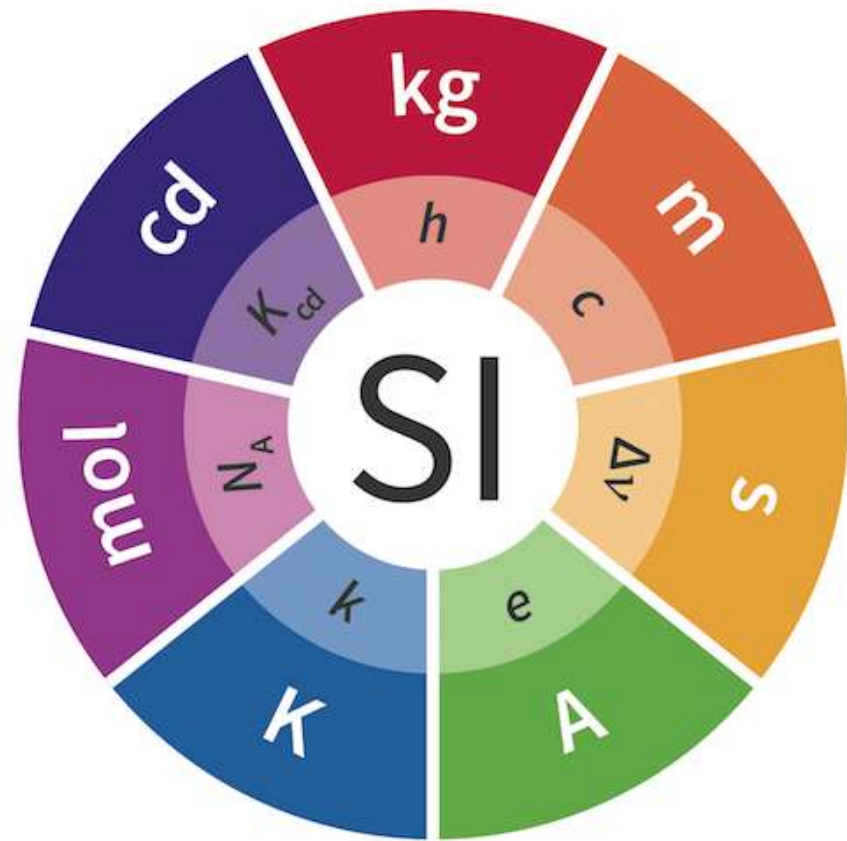
Timeliness in developing publications

- Typically 4-5 years from establishing a TG to publishing
- Delays must be managed to avoid unduly delaying the next General Recommendations

Continuous input from and collaboration with the RP & broader community

- Open workshops & webinars are an integral part of most Task Groups

Unit sievert



SI definition of the sievert

Explanations 2005

The quantity **dose equivalent H** is the product of

- the **absorbed dose D** of ionizing radiation
- and the dimensionless **factor Q (quality factor)** defined as a function of linear energy transfer by the ICRU:

$$H = Q \cdot D.$$

ICRP and ICRU definitions of the sievert



Pub 130 (2015)
Pub 133 (2016)

The special name for the SI unit (J kg^{-1}) of **equivalent dose** and **effective dose**

Pub 118 (2012)

should not be used in the quantification of radiation doses or in determining the need for any treatment in situations where **tissue reactions** are caused

Pub 147 (2021)

should be used only for **stochastic effects**



Rep 95 (2020)
together with ICRP

should be used only for **stochastic effects**

**Organ
equivalent dose**

$$H_T = \sum_R w_R D_{T,R},$$

**Effective
dose**

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

**Ambient
dose**

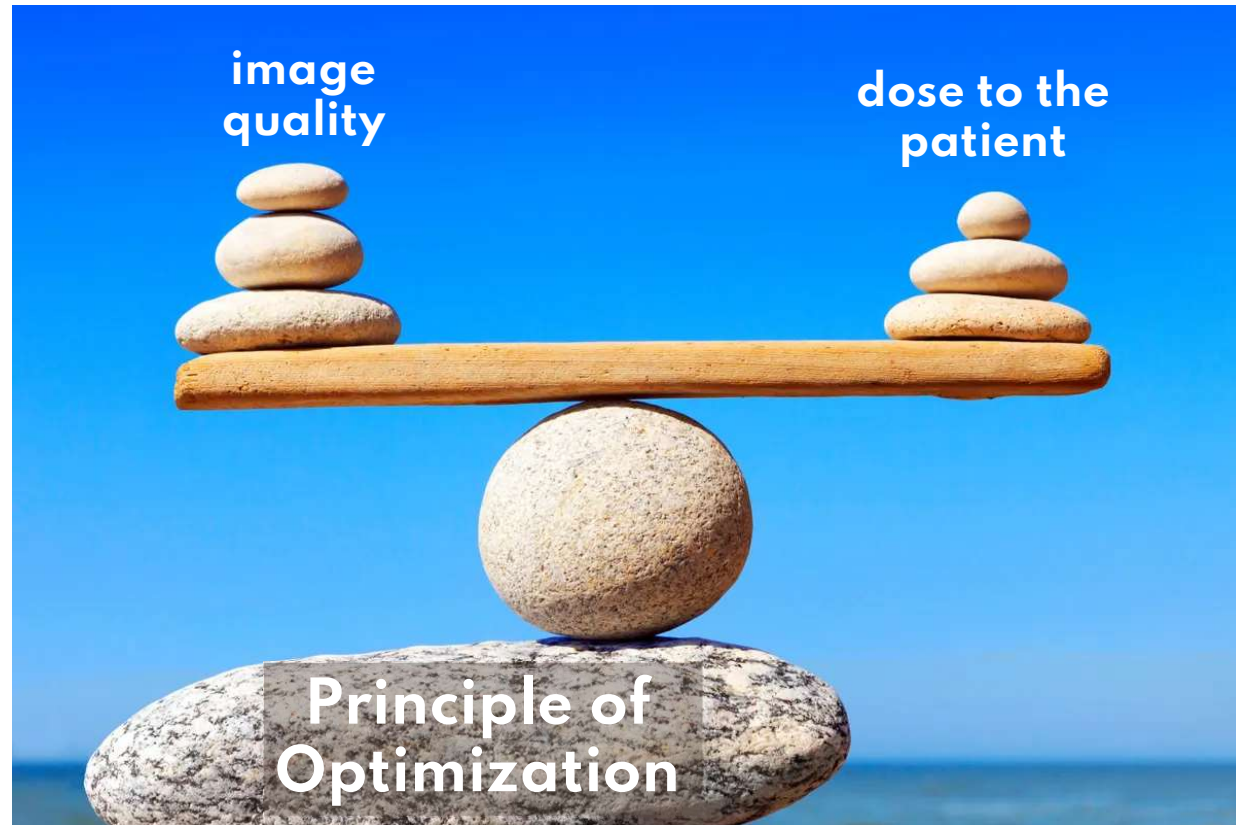
$$H_i^* = \int h_i^*(E_p) \left[\frac{d\Phi_i(E_p)}{dE_p} \right] dE_p,$$

**Personal
dose**

$$H_{p,i} = \iint h_{p,i}(E_p, \Omega) \left[\frac{d^2\Phi_i(E_p, \Omega)}{dE_p d\Omega} \right] dE_p d\Omega,$$



Image Quality



<https://www.forbes.com/sites/forbeshumanresourcescouncil/2020/09/30/work-life-balance-is-no-longer-just-a-company-issue/>

Image Quality

Fryback and Thornbury's framework of the efficacy of diagnostic imaging

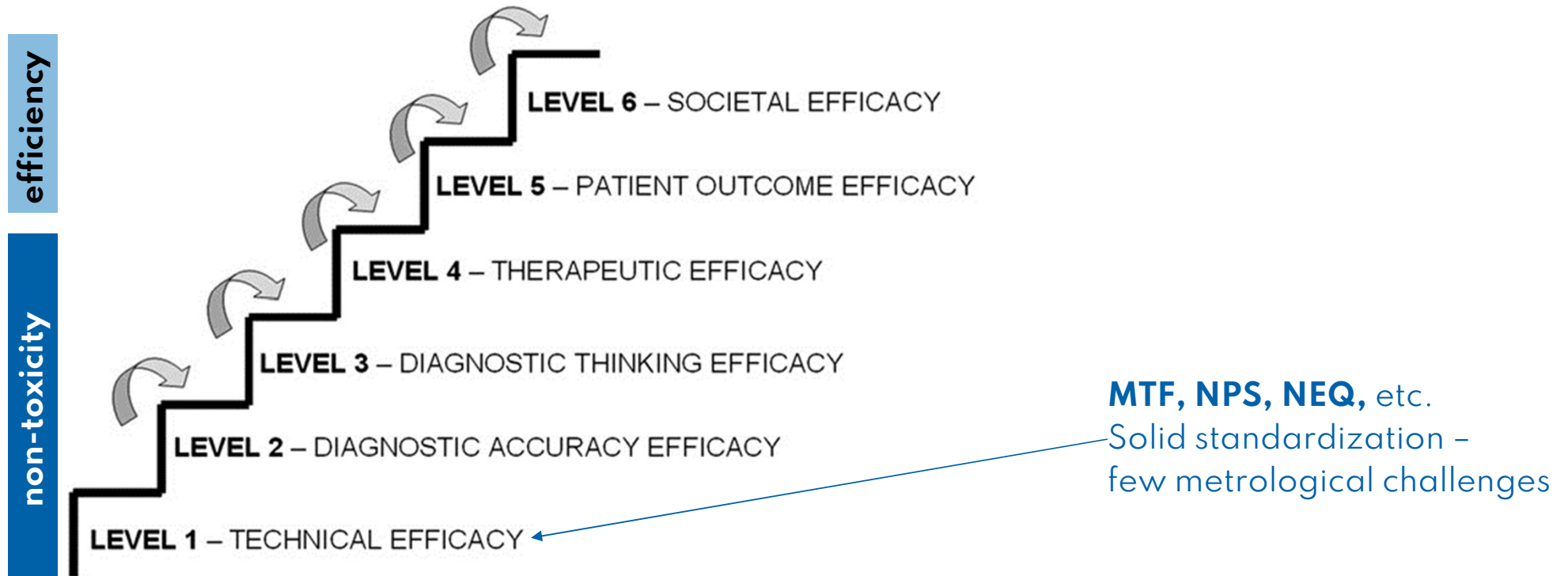
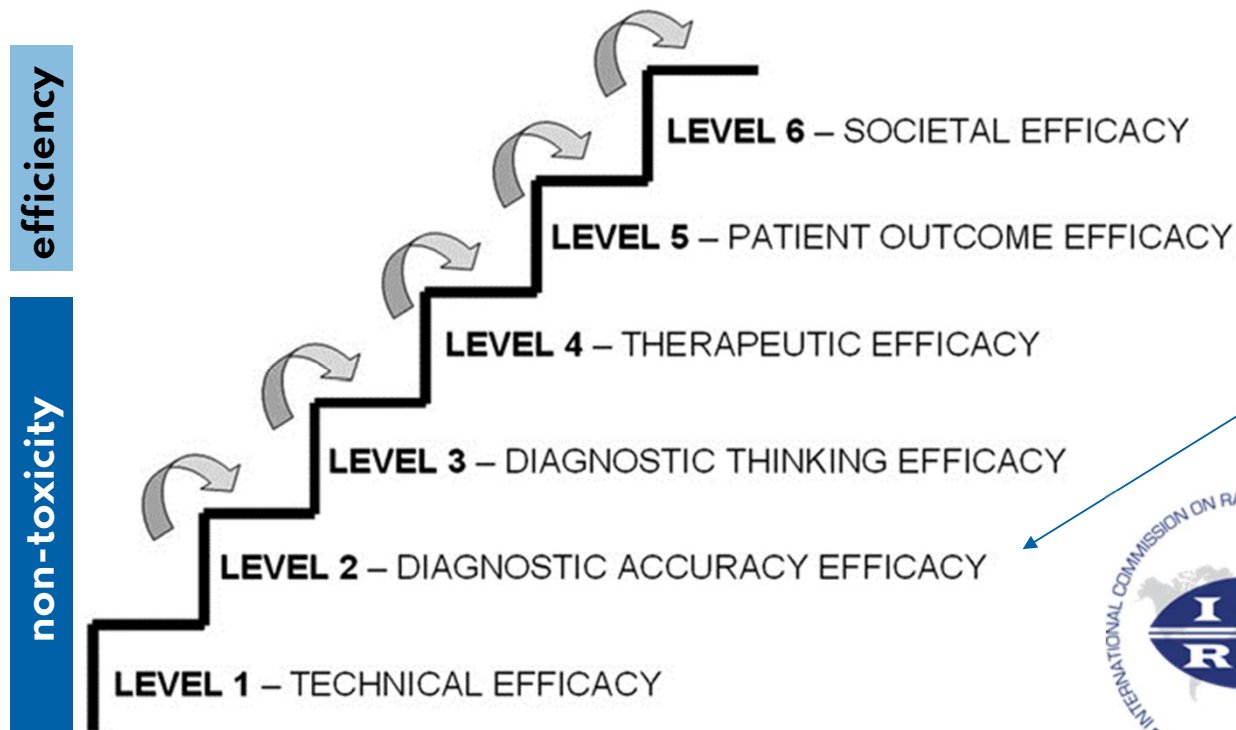


Image Quality

Fryback and Thornbury's framework of the efficacy of diagnostic imaging



Task-based methods

- poor standardization
- no metrological traceability
- no consensus on how to assess uncertainties

RC38 just started to work on a report about **model observers** in medical imaging



X-ray imaging in medicine



<https://www.cdc.gov/nceh/radiation/x-rays.html>

EURAMET – TraMeXi

Traceability in medical X-ray imaging dosimetry



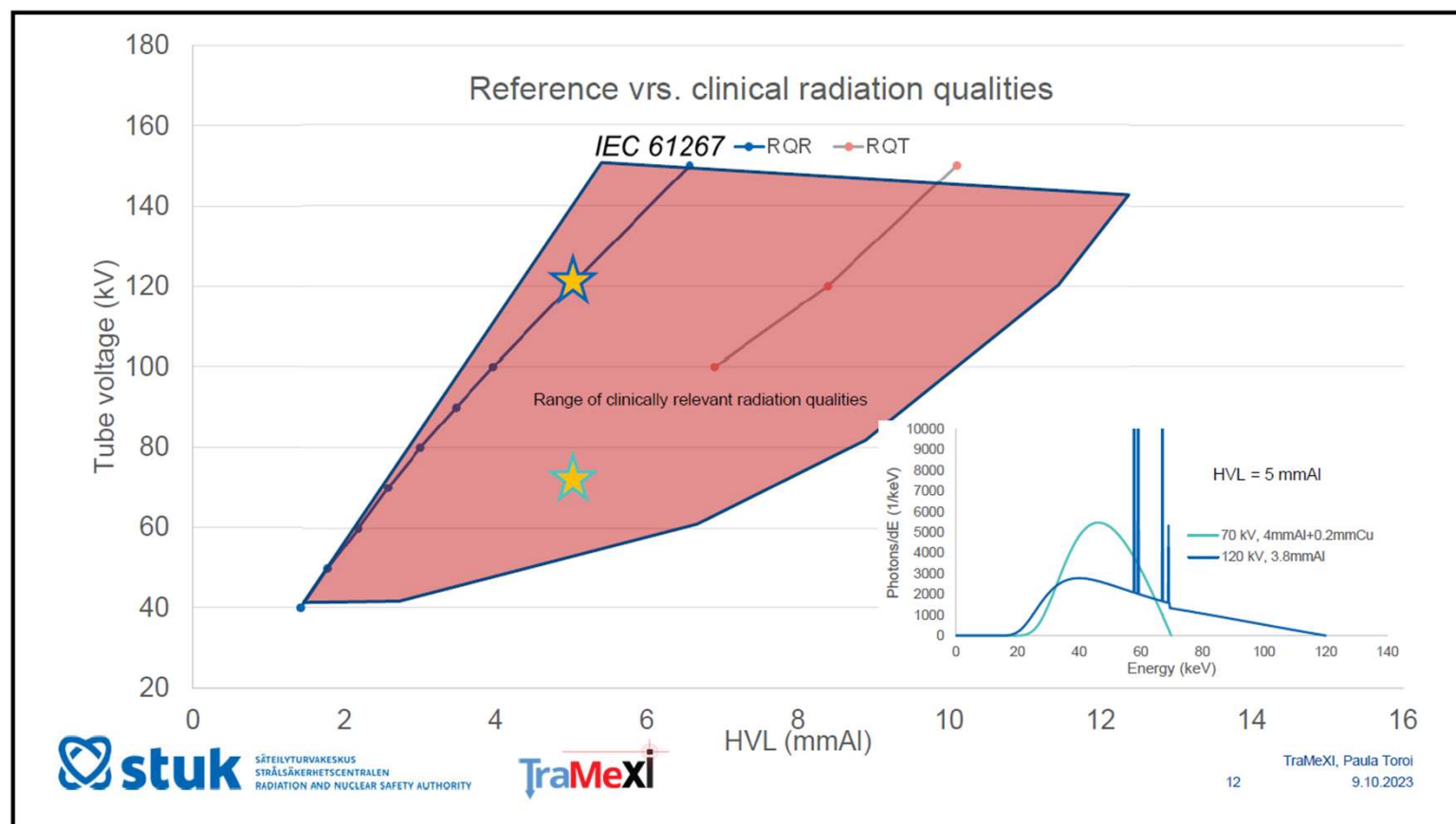
Improve metrological
traceability at the clinical level



Perfectly aligned with the ICRP's objectives!



Reference Beam Qualities



Radionuclide for nuclear medicine



<https://www.europeanpharmaceuticalreview.com/news/163118/new-radionuclides-network-to-revolutionise-nuclear-medicine-and-molecular-imaging/>

NUC medicine needs to know the activity

Emerging radionuclides

^{44}Sc ^{177}Lu
 ^{161}Tb ^{169}Er
 ^{175}Yt ^{223}Ra

some dome **decay schemes** are poorly known

not all of them have a **CIR ref value**

Short half-lives

^{13}N
 ^{15}O

not easy to measure $T_{1/2}$ because instruments need **long integrating times**

not easy to check what has been **injected to the patient**

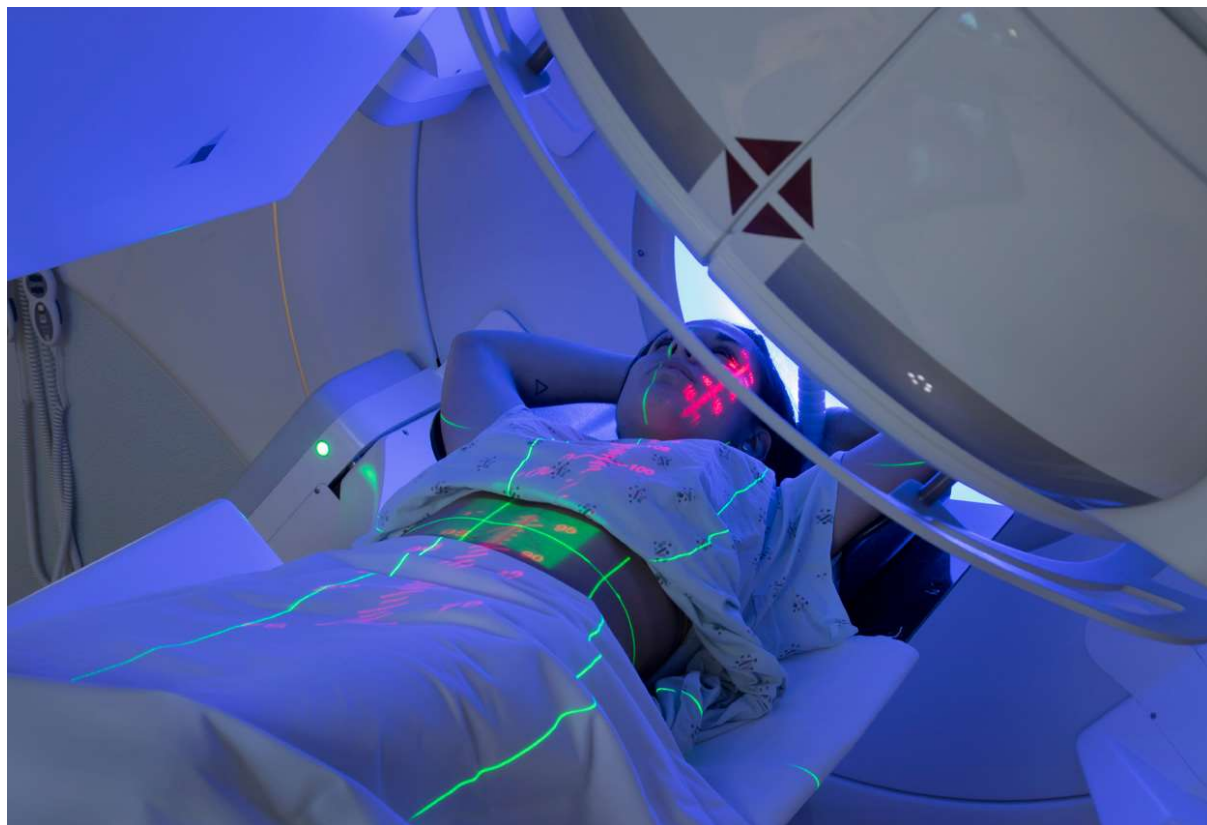
Tricky chemistry & numerous impurities

^{44}Sc
 ^{225}Ac
 ^{228}Ac

which **impurities**?

what **spectrometer** should be used?

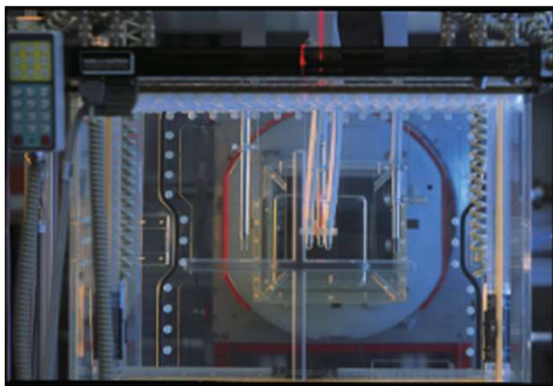
Flash Radiation Therapy



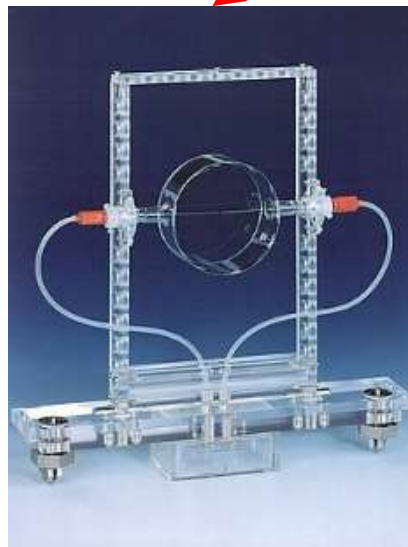
<https://blog.beekley.com/flash-radiotherapy-is-it-too-good-to-be-true>

Traceability of Conventional RT

absorbed dose to water
in external beam
radiotherapy



e.g. calorimeter
typically **<1 % uncertainty**



International prototype

**Primary national
standard**

Secondary standards

Working standards

Calibrations → instruments



**Lowest level
of accuracy**

Traceability of Conventional RT

absorbed dose to water
in external beam
radiotherapy

e.g. ionization chamber
typically **2 % uncertainty**



International prototype

Primary national
standard

Secondary standards

Working standards

Calibrations → instruments

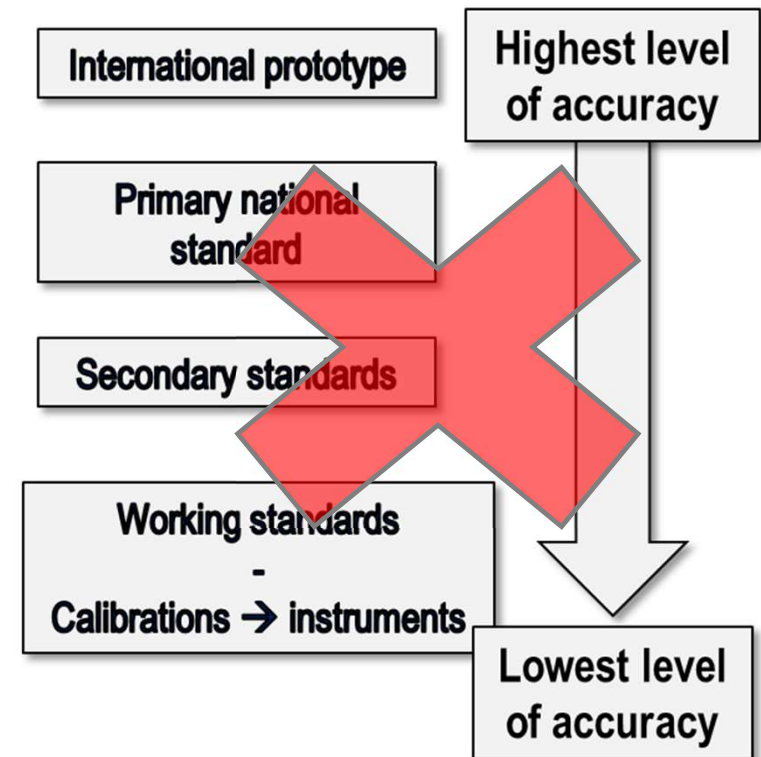
Highest level
of accuracy



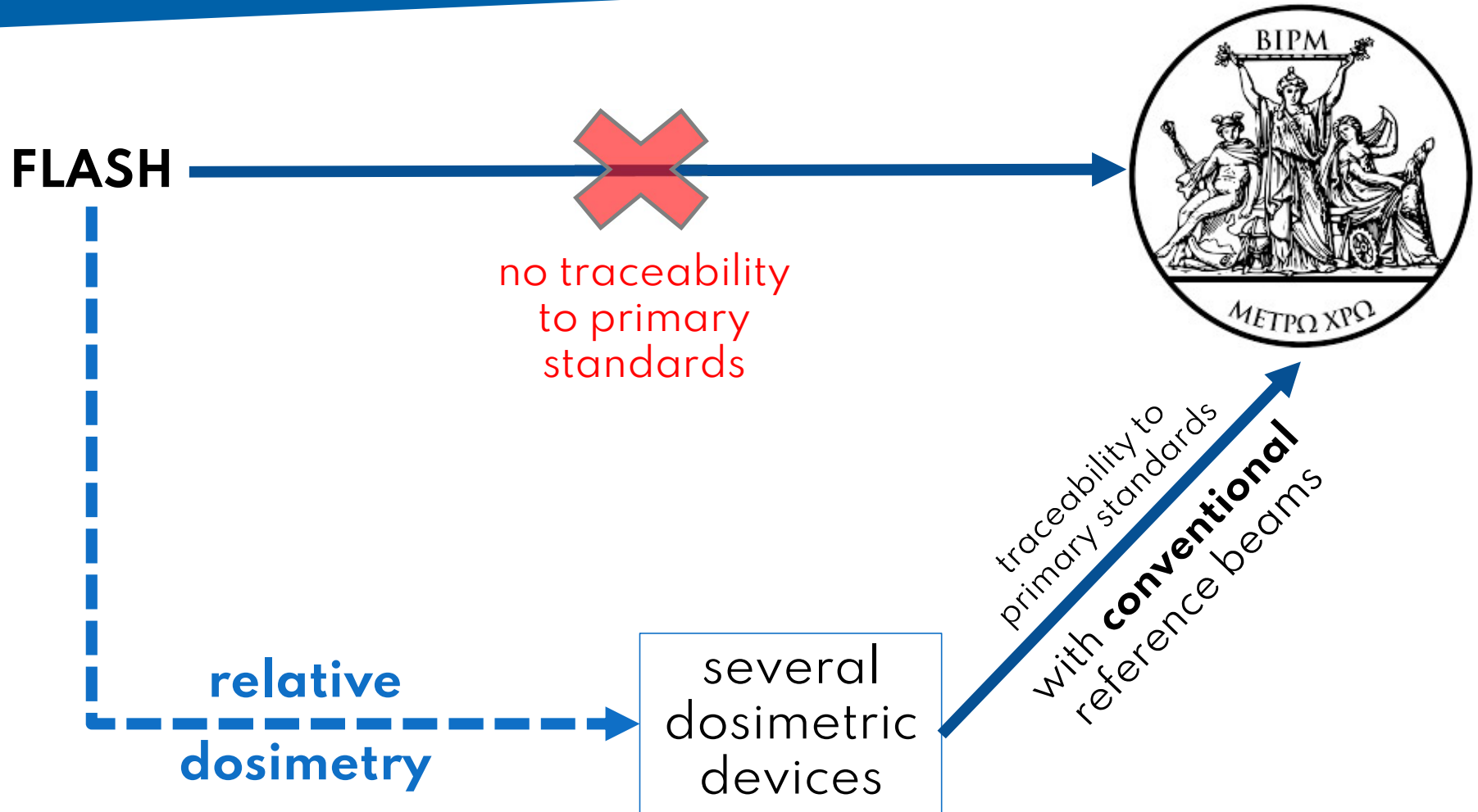
Traceability of FLASH RT

We are **not there**
yet with **FLASH**

not even sure that the
absorbed dose is the most
relevant parameter!



Traceability of FLASH RT



Clinical transfer

Stability

Safety

Treatment planning

Commissioning

Clinical transfer

Stability

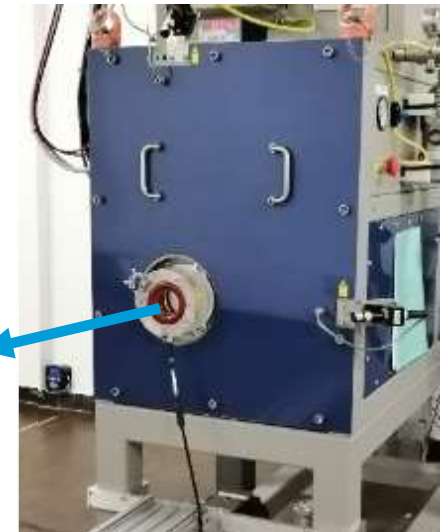
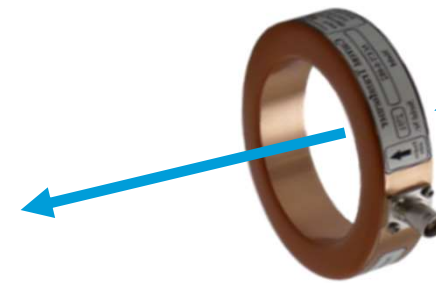
Safety

Treatment planning

Commissioning

Commercial FLASH linacs need better diagnostic, monitoring and controlling of the beam

Ionization chambers need **improvement** to be used as UHDR monitoring



Home-made solution:
Current transformers
(ICT, BCT, ACCT)

Clinical transfer

Stability

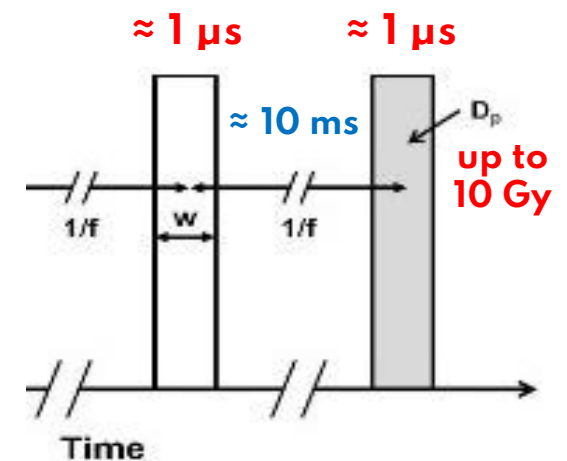
Safety

Treatment planning

Commissioning

Real-time control to reach
the prescribed dose
Integral measurement
and amplitude correction
(of the next pulse at least)

Fast diagnostic and beam control
are needed due to the high dose-rate



Clinical transfer

Stability

Safety

Treatment planning

Commissioning

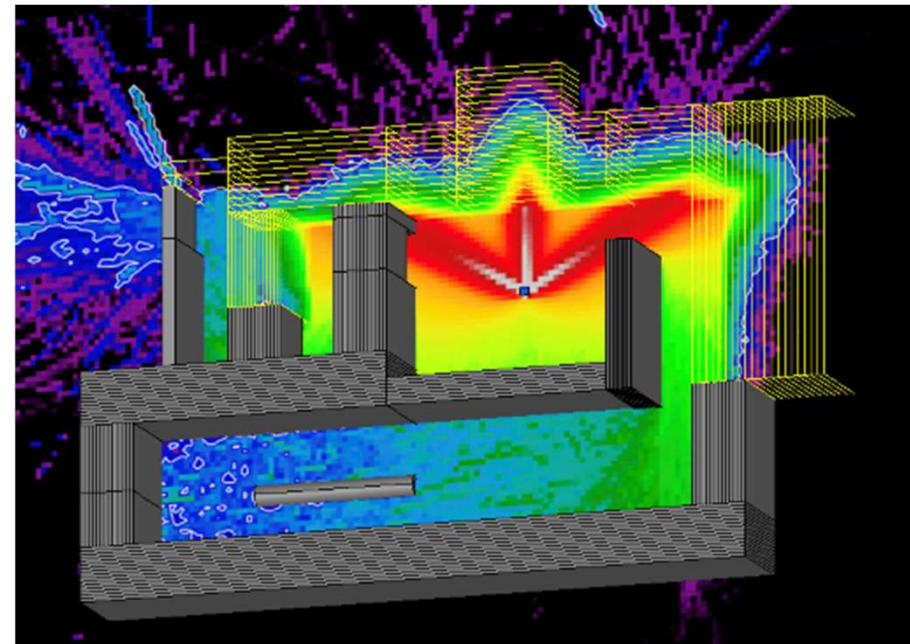


radioprotection

Prescribed doses not higher

The issue is the practical
measurement!

Support of **MC calculations** to
extend the measurements to the
full area



Clinical transfer

Stability

Safety

Treatment planning

Commissioning

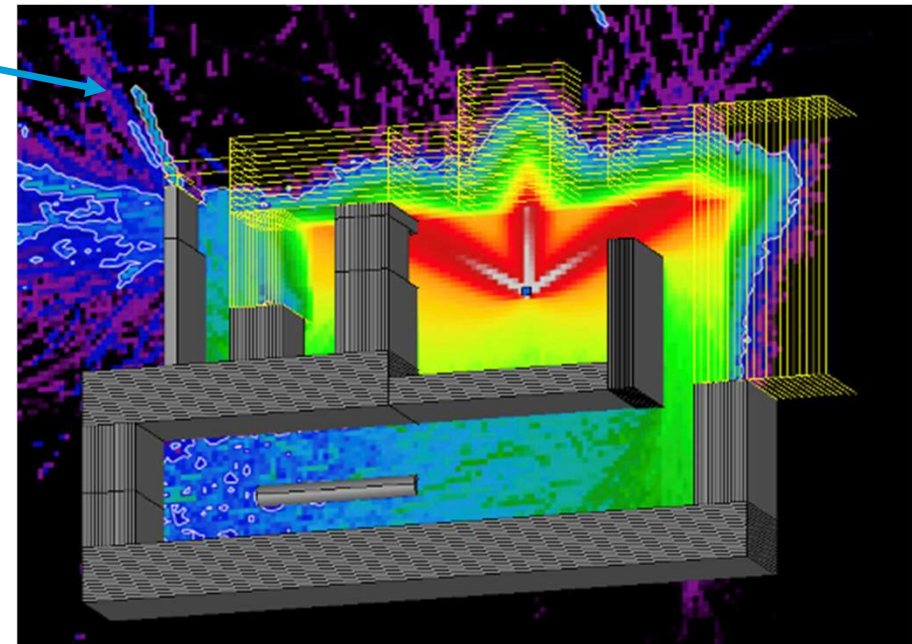


radioprotection

Need to measure dose rates
outside the bunker

Passive dosimeter necessitate some signal
→ high load on bunker
(typically, MGy in order to measure using TLDs)

For electrons:
not many **dose-rate meters**
measures pulsed beams
(no reference yet)



Clinical transfer

Stability

Safety

Treatment planning
(TPS)

Commissioning

TPS can compute the **absorbed dose to water**
Electron beams can be simulated



TPS will **predict a FLASH effect**
only if clear **beam parameters indicators** of FLASH
effect are **isolated**
Not yet the case



Clinical transfer

Stability

Safety

Treatment planning

Commissioning

Chain of **traceability** needs to be established

Use **dosimetric tools** to do a commissioning
as close as possible to conventional
recommendations

Conclusion about FLASH RT

FLASH dosimetry is a **work in progress**...

ready for clinical tests
but **still needs work** for clinical routine

lack of **traceability** (for **patients** and **public**)
(probably not satisfactory for the regulators)

more fundamentally

We need a **biophysical dosimeter** indicating the **FLASH effect**

Maybe we need to **replace the absorbed dose to water** by a new quantity
"FLASH-effective-dose" ?



Summary and conclusion

- The **SI definition of the sievert** has become obsolete
- The application of the principles of **justification** and **optimization** needs the help of metrology
 - **Image quality** needs to enter the realm of metrology
 - **X-ray metrology** must keep pace with new technologies
 - Euramet-TraMeXi will be a great help
 - **Radionuclide metrology** must keep pace with new radiopharmaceuticals
 - **FLASH RT** still lacks traceability
 - for the patients
 - for the public

ICRP

www.icrp.org