ATRON METROLOGY

Calibration of radiation survey meters and dosimeters without using radioactive source

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SFRP Société Française de Radioprotection

Introduction
Radiation protection, instruments & calibration

- **Fundamental principles**
  - Justification, optimization, limitation

- **Radiation protection dosimetry**
  - Initial calibration : electrical measure › operational quantities
  - Periodic calibration : every three years in France

SUMMARY

1. ATRON Metrology
2. From the air kerma to the ambient and personal dose equivalent
3. Feedbacks: is this method advantageous and comparable to the conventional one?

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ATRON Metrology

1 – ATRON Metrology
Technological platform based in Normandy (France)

- **Technological platform**
  - Contamination analysis and measurement laboratory
  - Irradiation laboratory: electron accelerator (FELIX)
    - From 200 to 3500 kV
    - X-rays: from µGy/h to kGy/h

- **Electrostatic electron accelerator applications**
  - Material Processing and Qualification
  - Calibration of ionizing radiation measuring instruments
    - Quantities: air kerma (K_a), ambient and personal dose equivalent ($H^*(10)$ & $H_p(10)$) and their rates
    - Three beam qualities: [0 ; 1250 keV], [0 ; 2000 keV] & [0 ; 3000 keV]
    - COFRAC accreditation n°2-6778 (ISO 17025)

1 – ATRON Metrology
From the conventional radioactive sources…

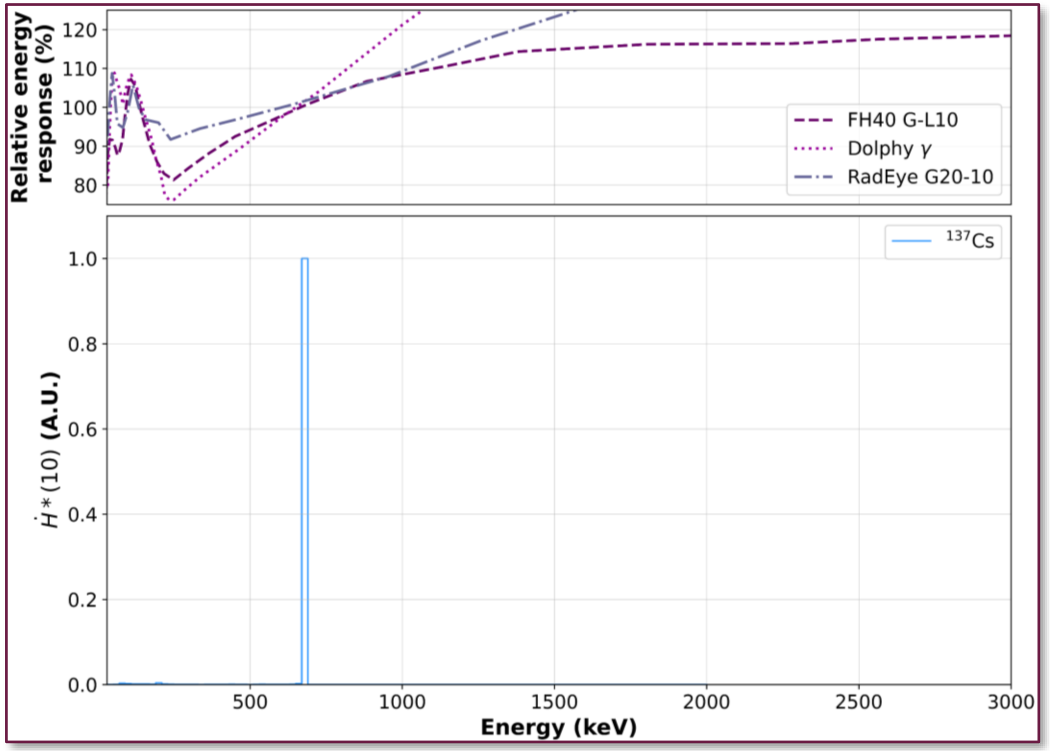
- **Conventional method**
  - Radioactive sources (ISO 4037)
    - ⇒ ^{60}Co, ^{137}Cs
  - Reference measurement "R"
  - Instrument measurement "M"
  - Calibration factor : N = R / M

- **Advantages**
  - Standardized method
  - Easy-to-deploy

1 – ATRON Metrology

From the conventional radioactive sources…

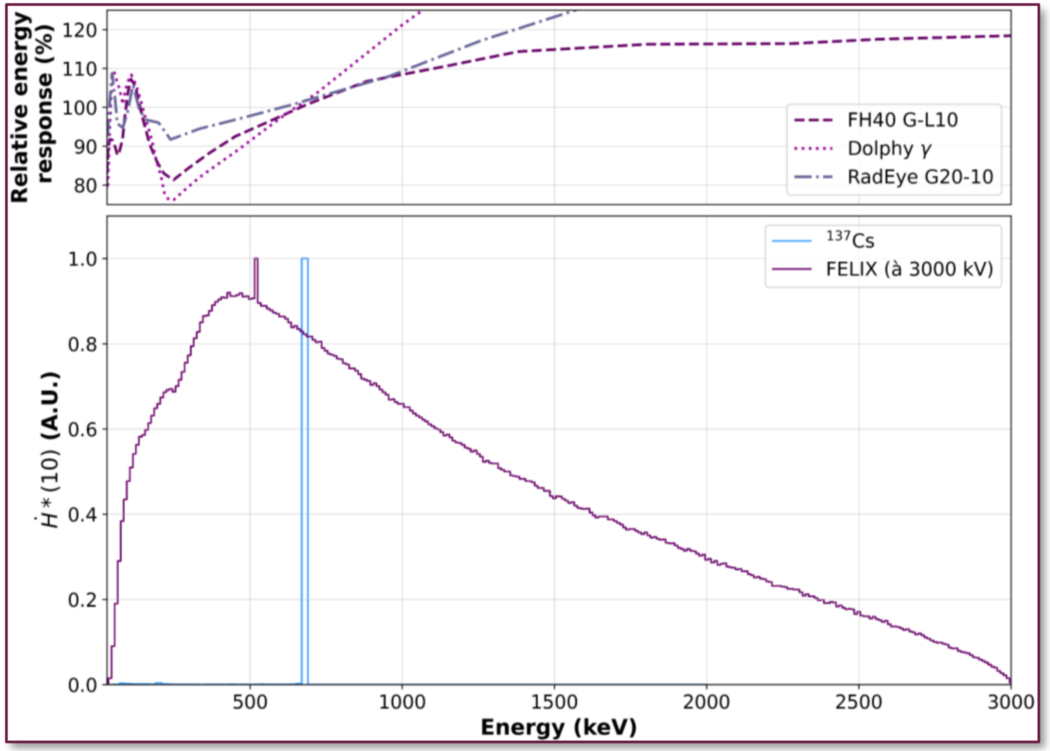
- **Drawbacks**
  - High activity
    - ⇒ Risk of accidental external exposure
  - Radioactive decay
    - ⇒ Sources renewal
  - "Constant" fluence
    - ⇒ Instrument displacement
  - Discrete energy distribution
    - ⇒ Unrepresentative energy distribution
    - ⇒ False positive risk



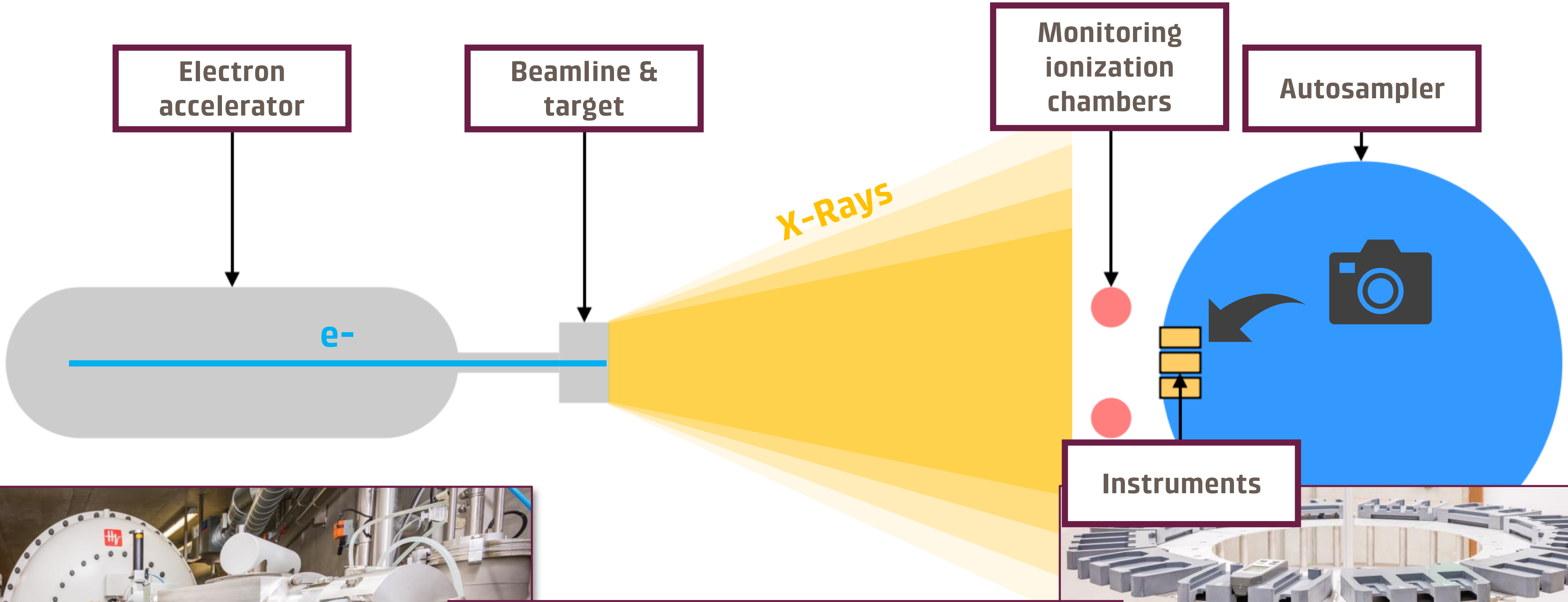
1 – ATRON Metrology
… to an innovative approach

- **Developed method**
  - Electrostatic electron accelerator
    - ⇒ Braking X-rays (~MeV)
  - Continuous energy distribution
  - No radioactive source

- **Advantages**
  - Realistic & customized irradiation field
  - Adjustable dose rate
  - Automation
    - ⇒ reliability
  - Risk reduction



1 – ATRON Metrology
… to an innovative approach



Energy: 1250, 2000 or 3000 keV
Doses: 20%, 35%, 50%, 65%, 80%

2

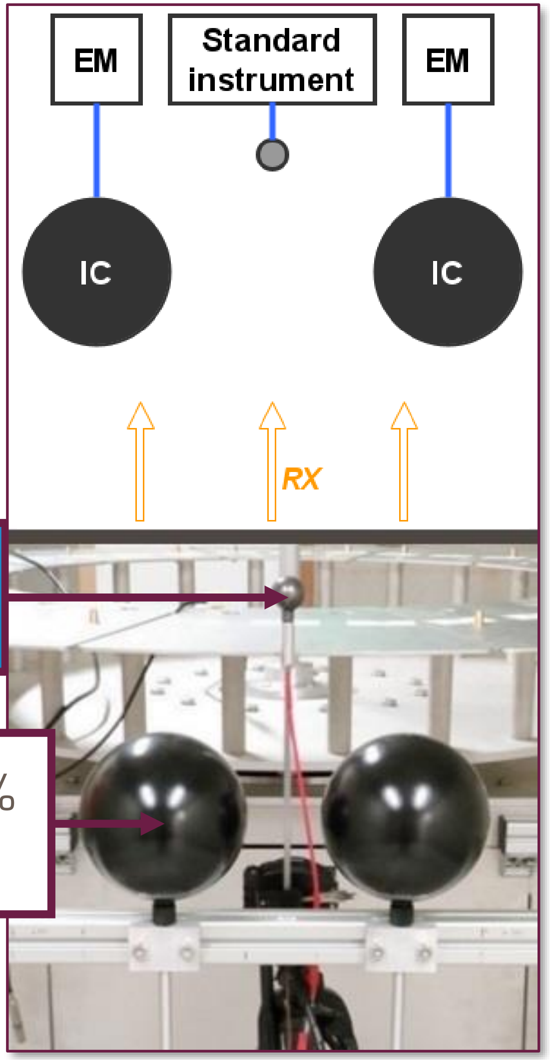
From the air kerma to the ambient and personal dose equivalent

2 – From the air kerma to the ambient and personal dose equivalent

Reference measurements method

- **Specifications**
  - Reference: average of two measurements
  - ISU traceability
    - ⇒ K_a, H*(10) & associated rates
    - ⇒ Three beam qualities: 1250, 2000 and 3000 kV
  - Method
    - ⇒ Air kerma: standard instrument (volume)
    - ⇒ Energy distributions
    - ⇒ Air kerma to ambient dose equivalent factors

- **Collaboration with the French National Metrology Laboratory for ionizing radiation LNE-LNHB (CEA LIST)**

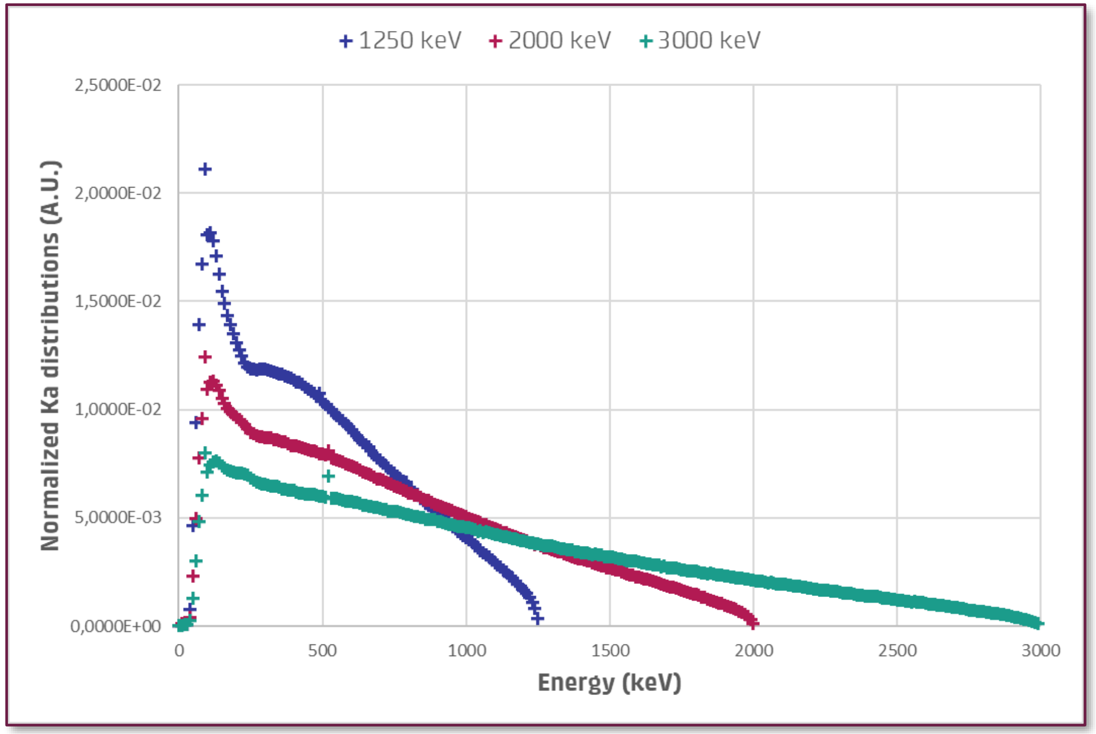


$u_{H^*(10)} = 4,4\%$
(k = 2)

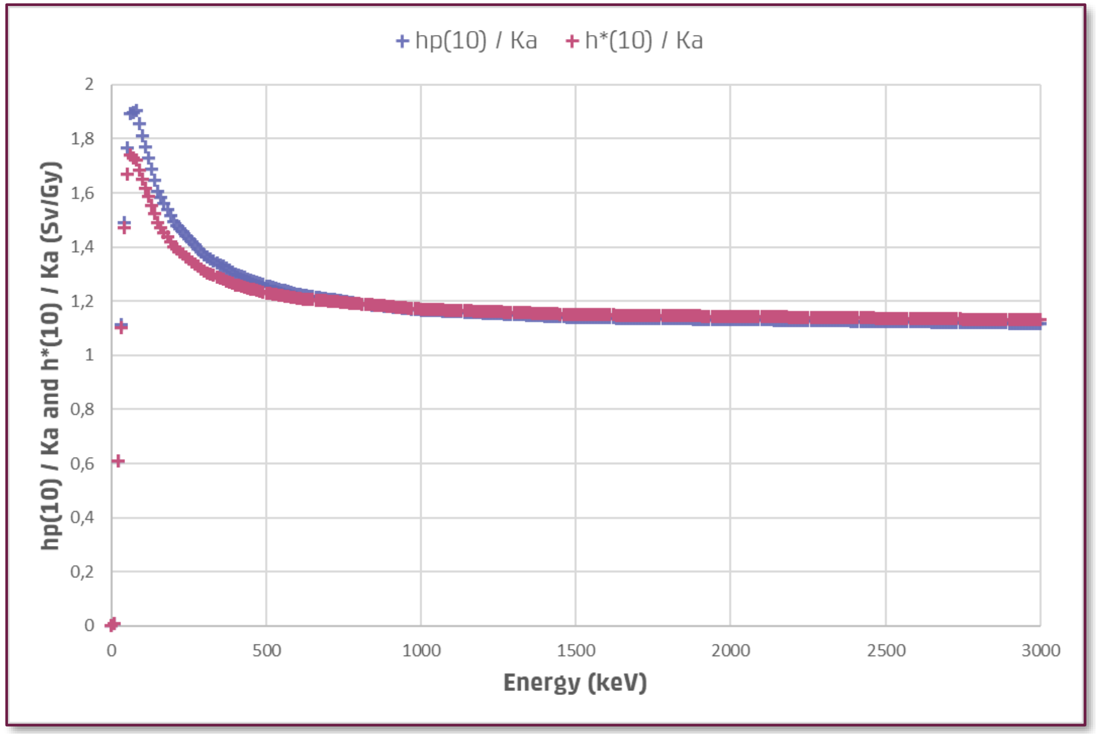
2 – From the air kerma to the ambient and personal dose equivalent

Ambient and personal dose equivalent

Assessed distributions (MCNP-X) validated by in-situ measurements (LNHB)

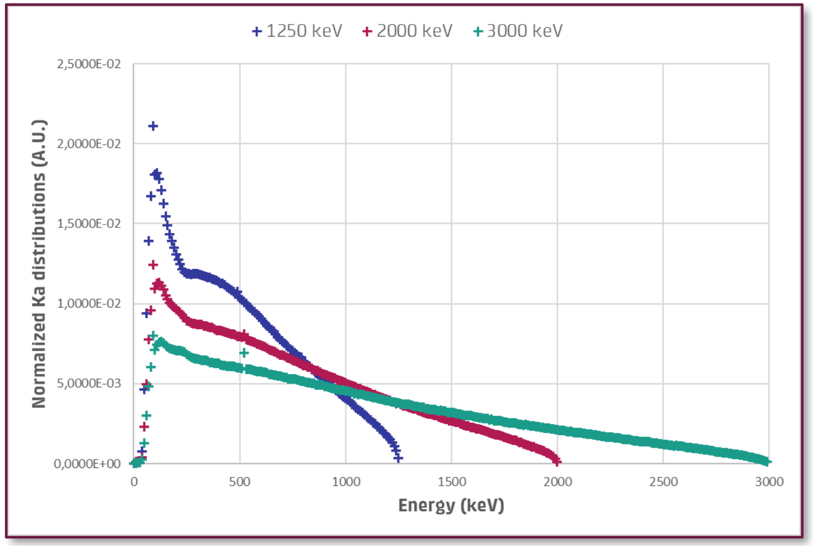


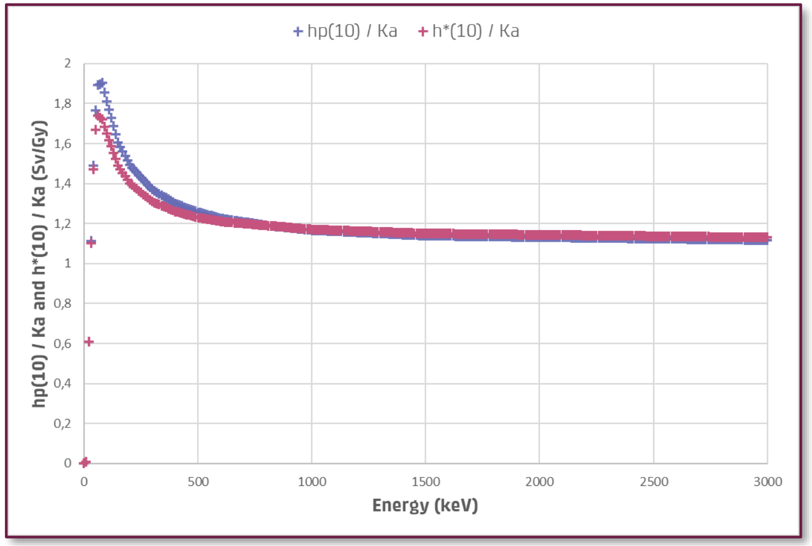
Tabulated distributions by ICRU 57 and extrapolation for intermediate points



2 – From the air kerma to the ambient and personal dose equivalent

Ambient and personal dose equivalent





h*(10) (Sv/Gy)		
1250 kV	**2000 kV**	**3000 kV**
1,325	1,268	1,229
$h_p(10)$ (Sv/Gy)		
1,372	1,301	1,254

Laboratoire National LNHB Henri Becquerel

2023 (ATRON)

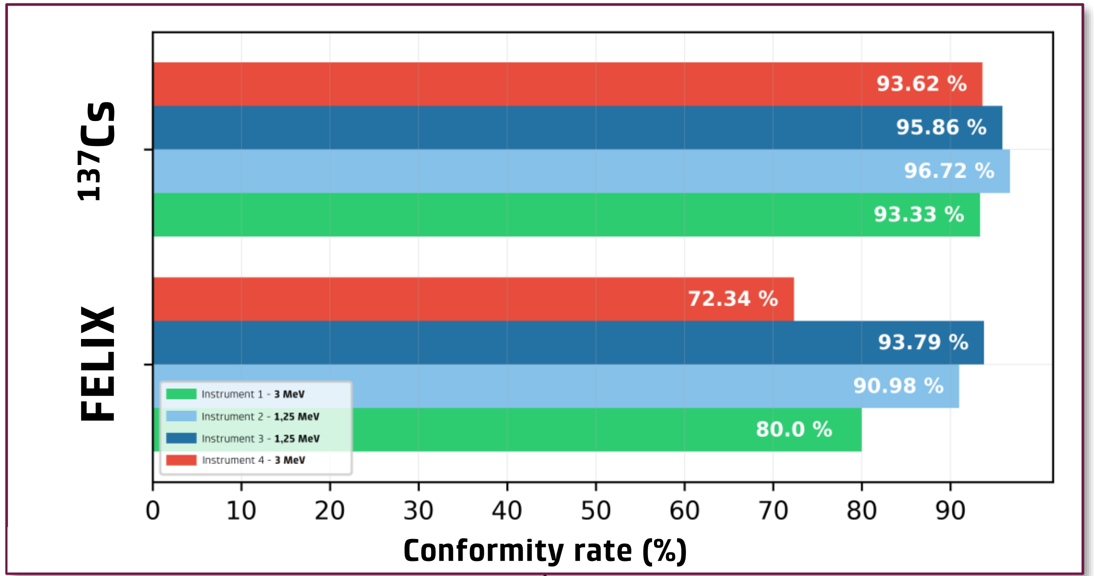
3

Feedbacks: is this method advantageous and comparable to the conventional one?

3 – Feedbacks

A posteriori feedback: is this method advantageous?

- **From January 2019 to December 2022**
- **~5400 calibrated instruments**
  - ~4000 radiation survey meters
  - ~600 high-dose probes
  - ~750 beacons
- **Failure rate related to the energy response heterogeneity: 4,2%**
  - Radiation protection optimization

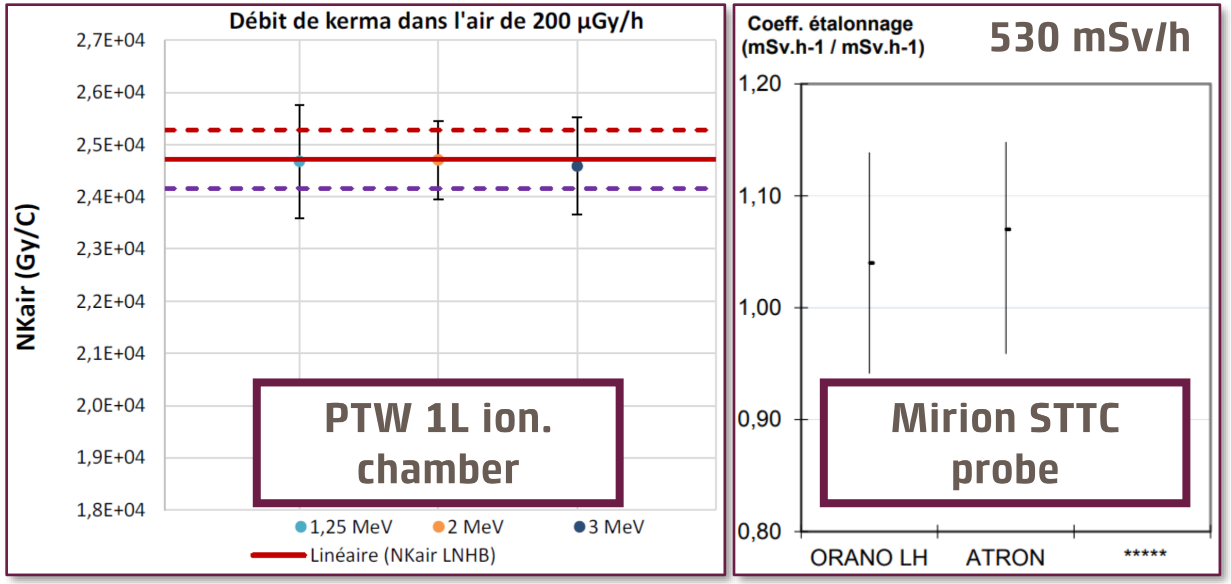


Particularly R(E) > 2 MeV

3 – Feedbacks

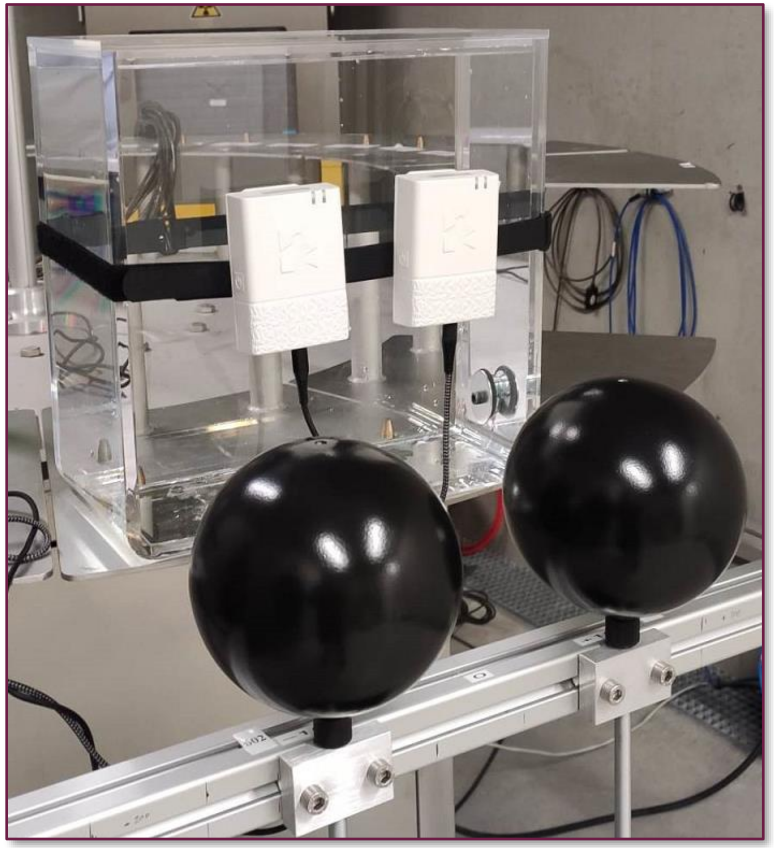
Interlaboratory tests: is this method comparable to the conventional one?

- **ILT: K_a & H*(10)**
  - LNHB (2019)
    - ⇒ Three beam qualities
    - ⇒ Four dose rates
    - ⇒ Compatible results
  - ORANO (2022)
    - ⇒ One beam quality
    - ⇒ Seven dose rates
    - ⇒ Compatible results
  - ORANO (2024)
    - ⇒ Waiting for the comparison
  - **Who's next?!**



3 – Feedbacks

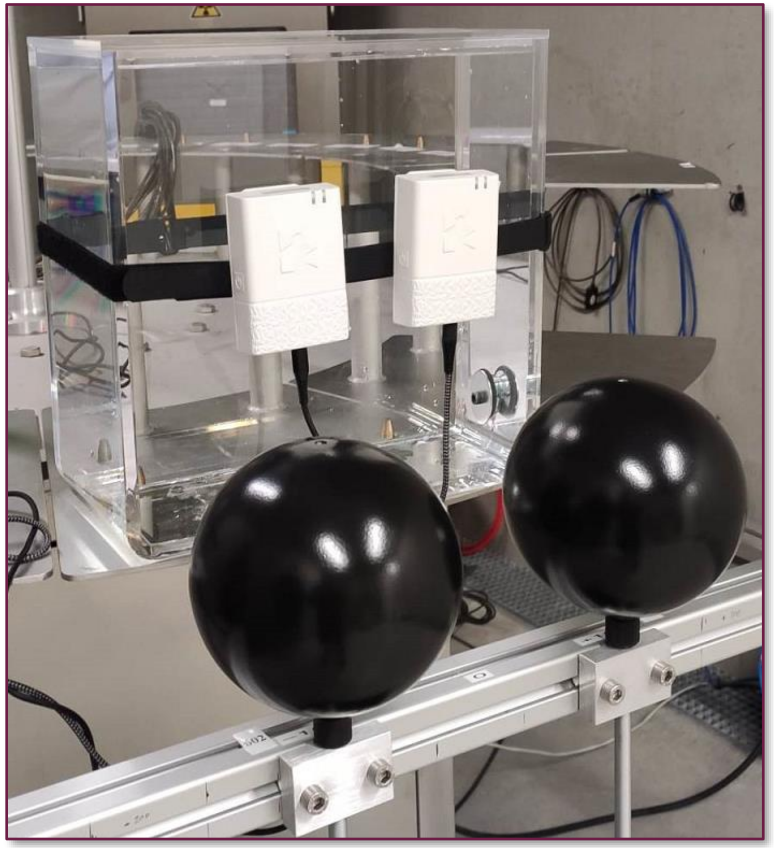
Interlaboratory tests: is this method comparable to the conventional one?

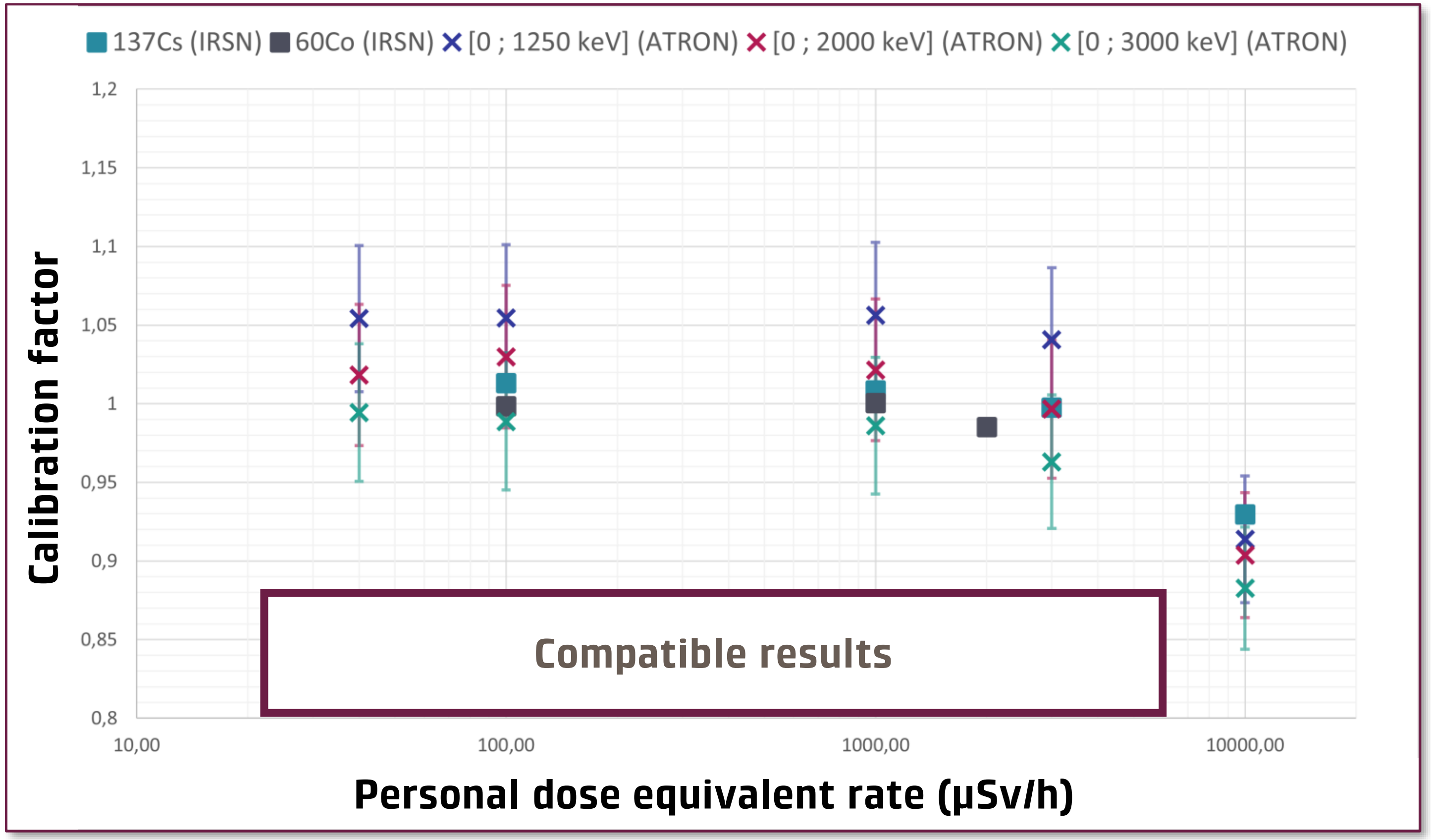


- **RiumOp operational dosimeters (BERTIN/ICOHUP)**
  - Direct measurement of $H_p(10)$
  - From 0,05 µSv/h to 10 mSv/h
  - From 25 keV to 2 MeV
- **$H_p(10)$ calibration: April 2023**
  - Three beam qualities
  - Comparison with ^{137}Cs & ^{60}Co calibrations (IRSN)

3 – Feedbacks

Interlaboratory tests: is this method comparable to the conventional one?

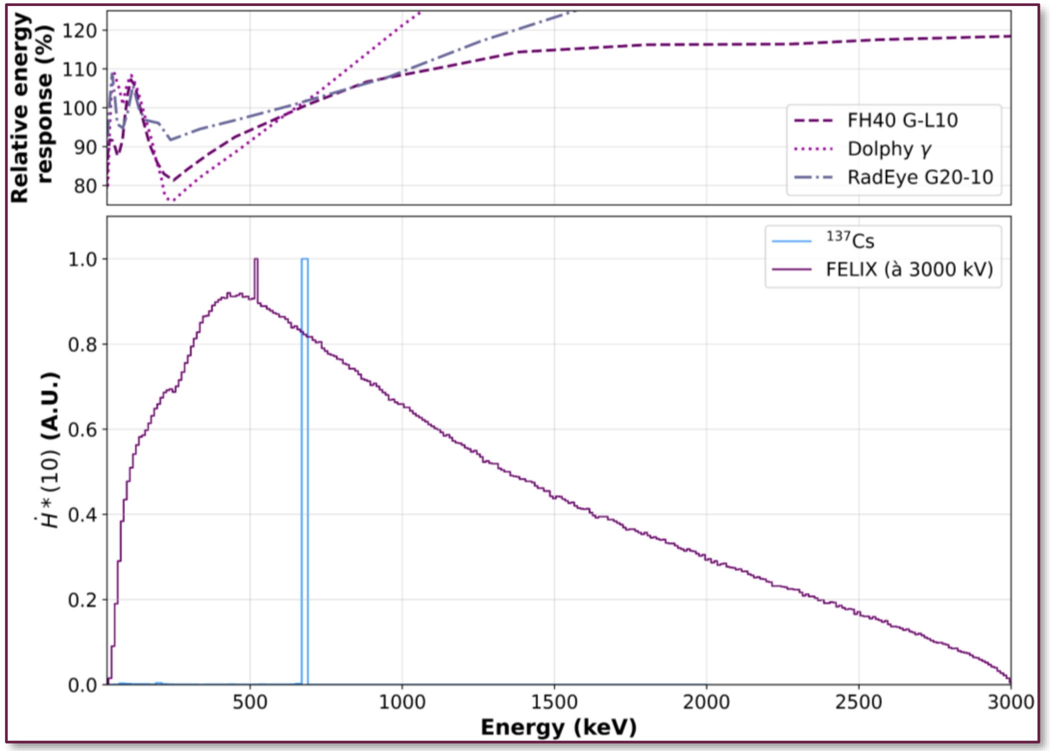




Conclusions

Conclusions

- **An innovative approach: why?**
  - Radiation protection optimization
    - ⇒ More representative distributions
    - ⇒ Less radioactive sources
  - Metrology optimization and reliability
    - ⇒ Reduced uncertainties
    - ⇒ Automatization
  - Reduced downtime



Thank you!

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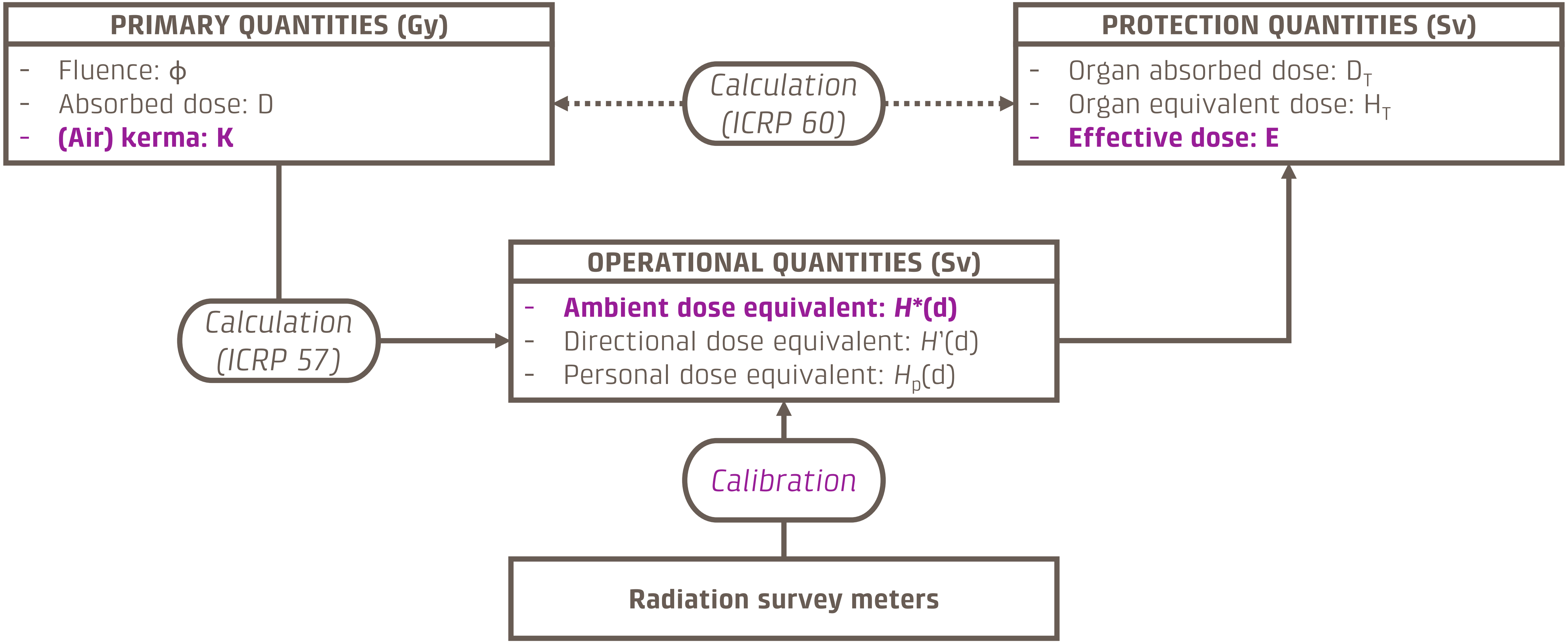
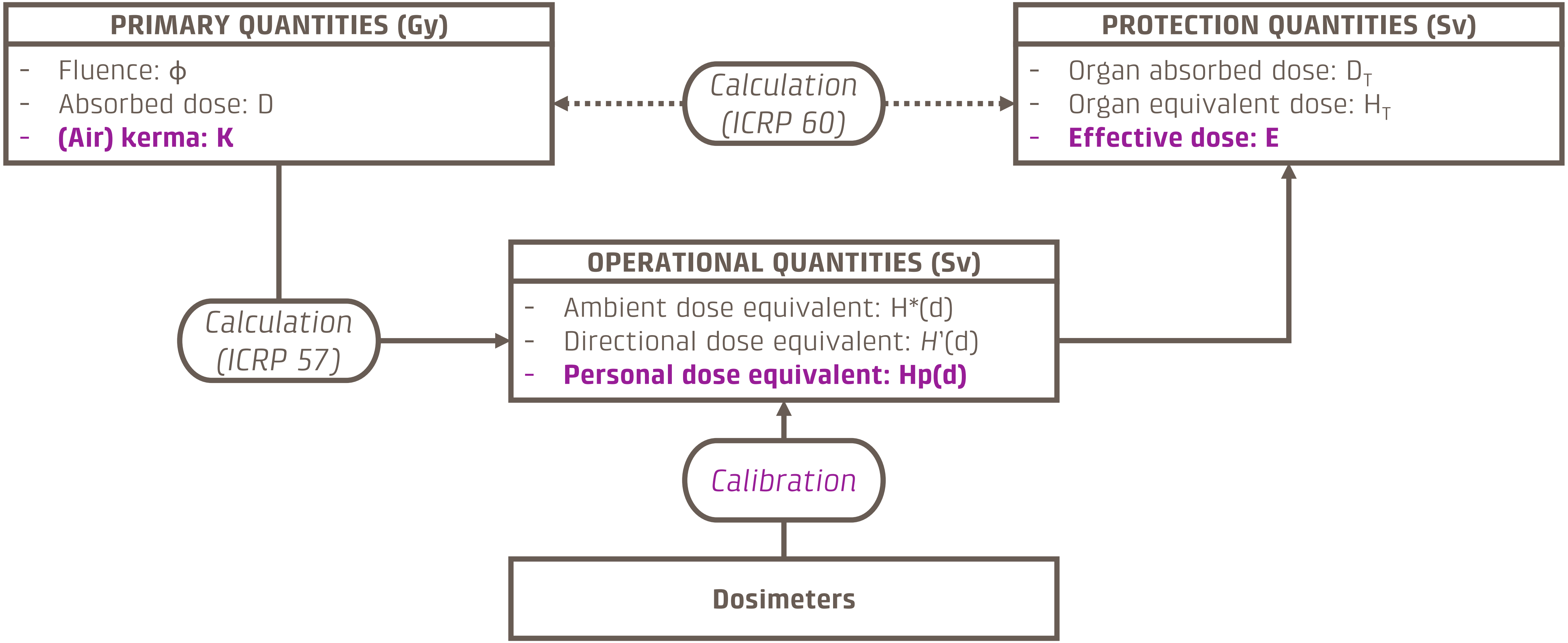
Annex

Air kerma, ambient dose equivalent & effective dose



Annex
Air kerma, personal dose equivalent & effective dose

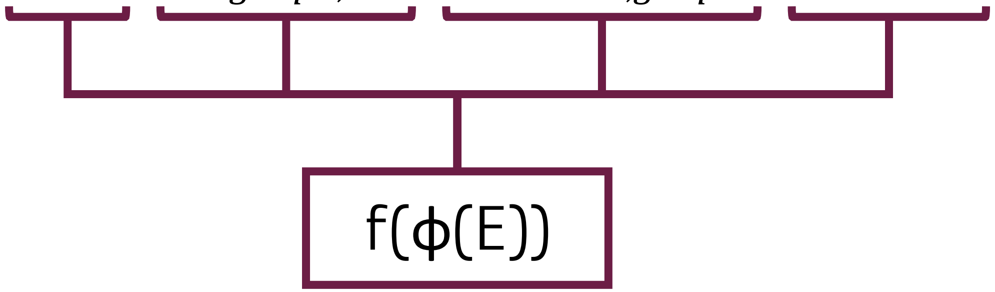


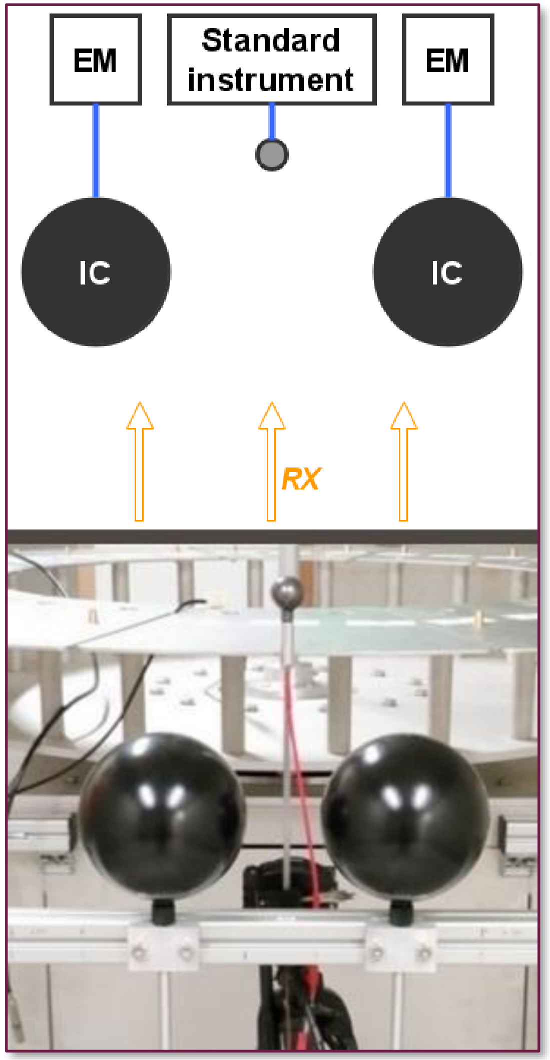
Annex

Air kerma calibration

$$N_{K_a}^{mon} = \frac{\dot{K}_a^{stand} \cdot \Delta t}{I_{cor}^{mon} \cdot \Delta t}$$

$$\dot{K}_a^{stand} = \frac{I_{cor}^{stand}}{V \cdot \rho_{air}} \cdot \left(\frac{\overline{W}}{e}\right)_{air} \cdot \frac{1}{A_{wall}} \cdot \left(\frac{\overline{S}}{\rho}\right)_{graph,air} \cdot \left(\frac{\overline{\mu_{en}}}{\rho}\right)_{air,graph} \cdot \frac{1}{1 - \bar{g}_{air}}$$





Annex

Fluence spectral distributions

MCNP-X:
Normalized fluence spectral distributions

MCNP-X:
Pulse distributions into a spectrometer

Experimental measurements with a spectrometer

Validation

Normalized fluence spectral distributions