

Primary standards for dosimetry

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Primary standards for dosimetry

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- ✚ Metrology
- ✚ Measurement standards and dosimetry laboratories
- ✚ Primary standards for dosimetry and primary methods
- ✚ Primary standards and radiation beams
- ✚ Primary standards dosimetry laboratories PSDL
- ✚ Bureau International des Poids et Mesures BIPM
- ✚ BIPM Key comparison database

Metrology

The science of measurement, embracing both experimental and theoretical determinations at any level of uncertainty in any field of science and technology

Metrology can be summarized through three basic activities:

✚ Definition of the measurement unit:

set of base units (and prefixes) and derived units

✚ Realization of the measurement unit:

realization of a measurement unit from its definition,
adoption of a particular artefact as a standard

✚ Dissemination of the measurement unit:

done through the chain of traceability: the link between
measurements and reference standards

*The recommended system of units of measurement is the
International System of Units SI (Système International d'Unités)*

Metrology in ionizing radiation

Unit

SI derived unit for radiation dosimetry

- Gray (Gy) for absorbed dose and kerma (J / kg)
- Sievert (Sv) for equivalent dose (J / kg)

Realization

Realization of the radiation dosimetry unit is done using a **primary standard**

- Ionization chamber
- Calorimeter
- Chemical dosimeters

Dissemination

Dosimetry laboratories hold and maintain reference standards

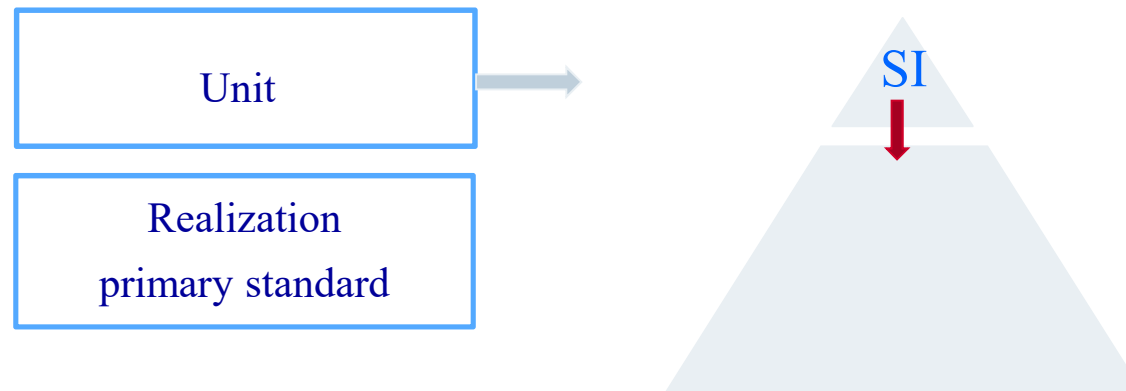
- disseminate the SI unit to other laboratories and end users
- assure the chain of traceability

Primary Standard and Dosimetry Laboratories

Primary Standard and Dosimetry Laboratories



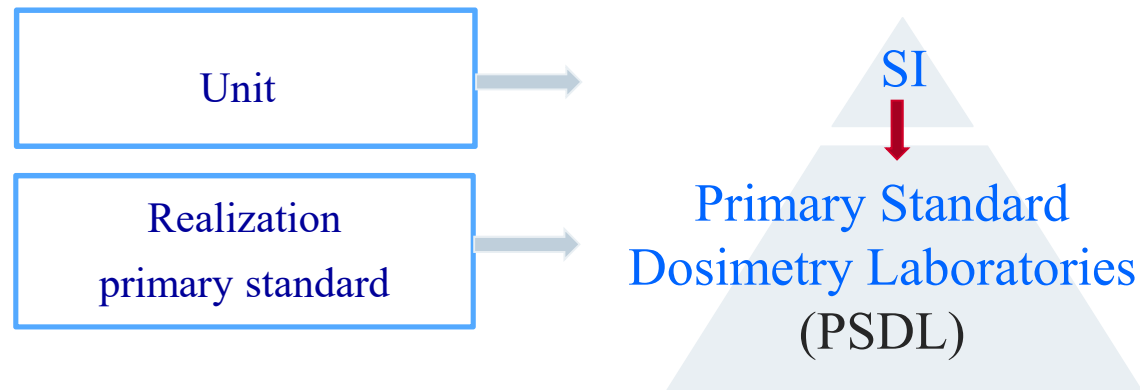
Primary Standard and Dosimetry Laboratories



Primary Standard

Instrument of the highest metrological quality that permits determination of the unit of the quantity from its definition

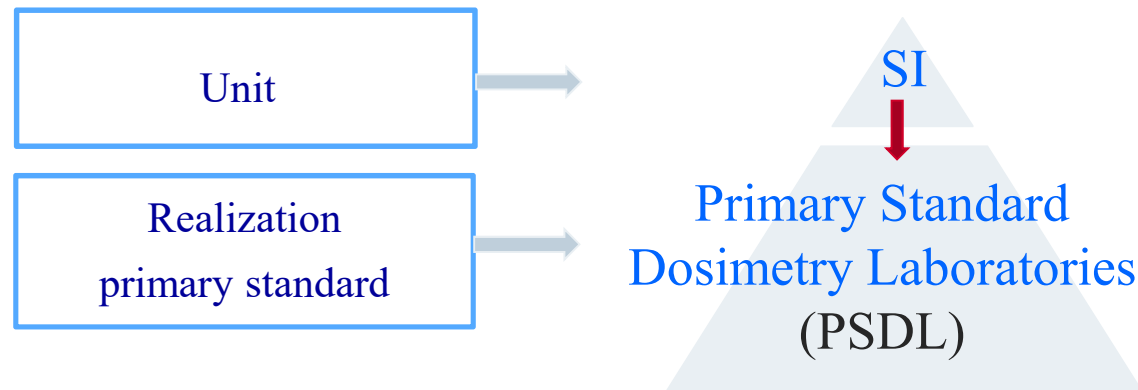
Primary Standard and Dosimetry Laboratories



Primary Standard

Instrument of the highest metrological quality that permits determination of the unit of the quantity from its definition

Primary Standard and Dosimetry Laboratories



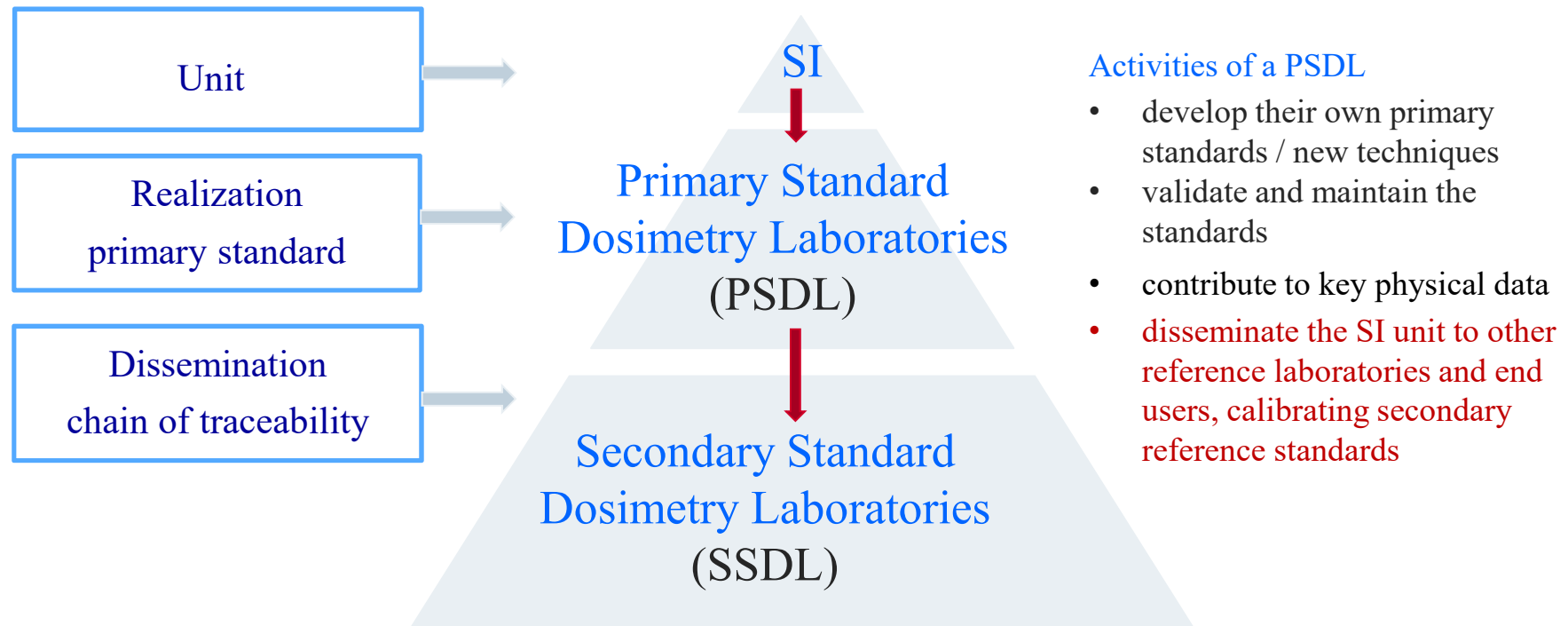
Activities of a PSDL

- develop their own primary standards / new techniques
- validate and maintain the standards
- contribute to key physical data

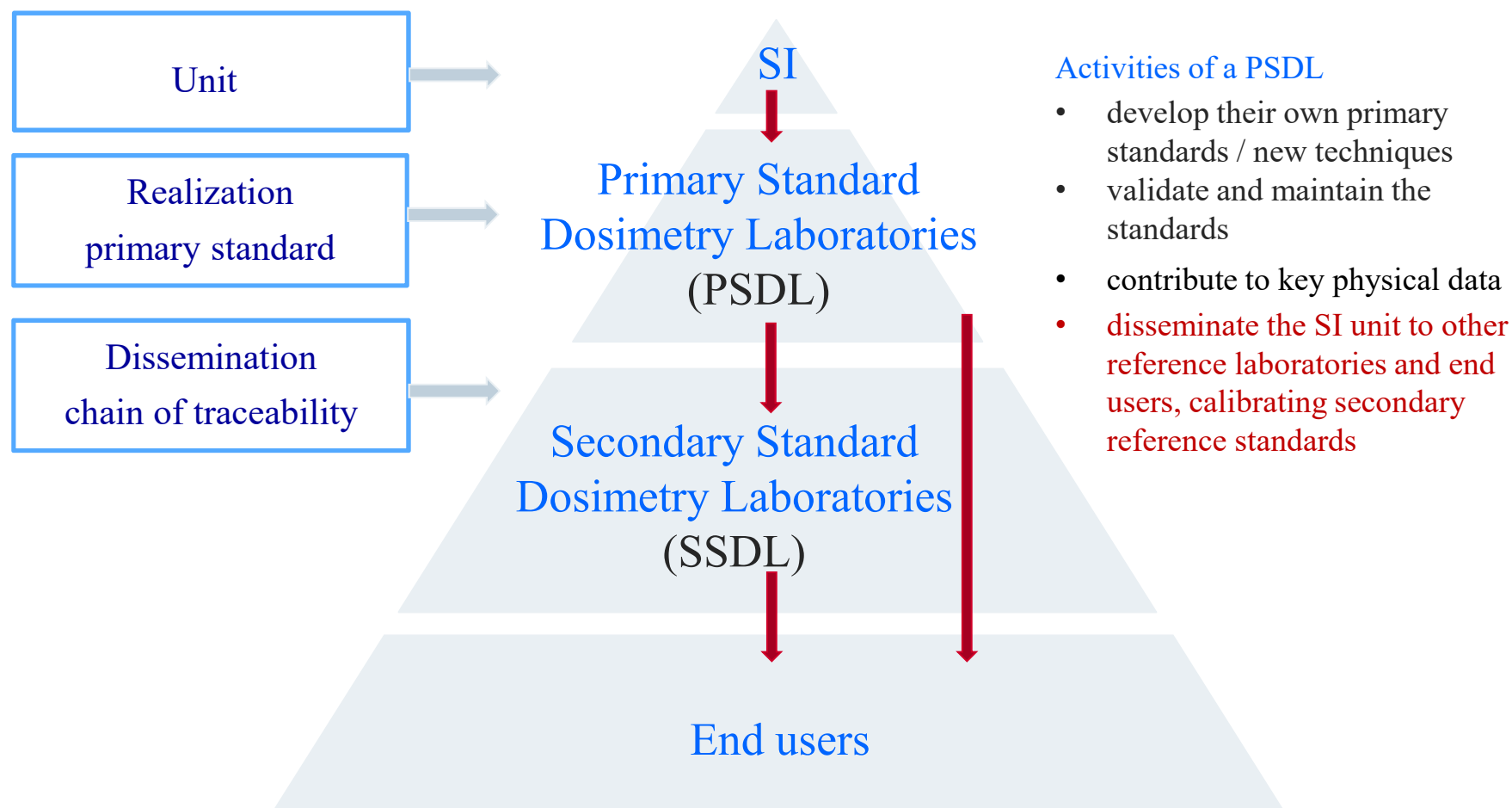
Primary Standard

Instrument of the highest metrological quality that permits determination of the unit of the quantity from its definition

Primary Standard and Dosimetry Laboratories



Primary Standard and Dosimetry Laboratories

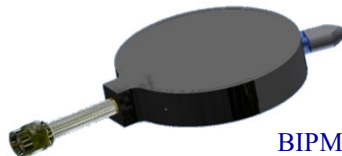


Primary standard for dosimetry

Instrument of the highest metrological quality that permits determination of the unit of the quantity from its definition

Physical quantity	Definition	SI derived unit	Method	SI base quantity
Air kerma	$K = \frac{dE_{tr}}{dm}$	Gy (J / kg) Gray	Ionometry	Charge, mass

Method	Primary standard	Principle
Ionometry	Ionization chamber	Measurement of charge / current



BIPM ionization chamber

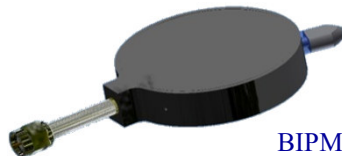
dE_{tr} is the total kinetic energy given to charged particles produced in the interactions of primary uncharged particles in a mass dm of air

Primary standard for dosimetry

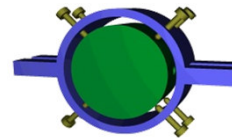
Instrument of the highest metrological quality that permits determination of the unit of the quantity from its definition

Physical quantity	Definition	SI derived unit	Method	SI base quantity
Absorbed dose	$D = \frac{dE}{dm}$	Gy (J / kg) Gray	Ionometry	Charge, mass
			Calorimetry	Temperature, mass

Method	Primary standard	Principle
Ionometry	Ionization chamber	Measurement of charge / current
Calorimetry	Calorimeter	Measurement of temperature rise



BIPM ionization chamber



BIPM graphite calorimeter

Primary standard for ionometry

Air Kerma - Absorbed dose

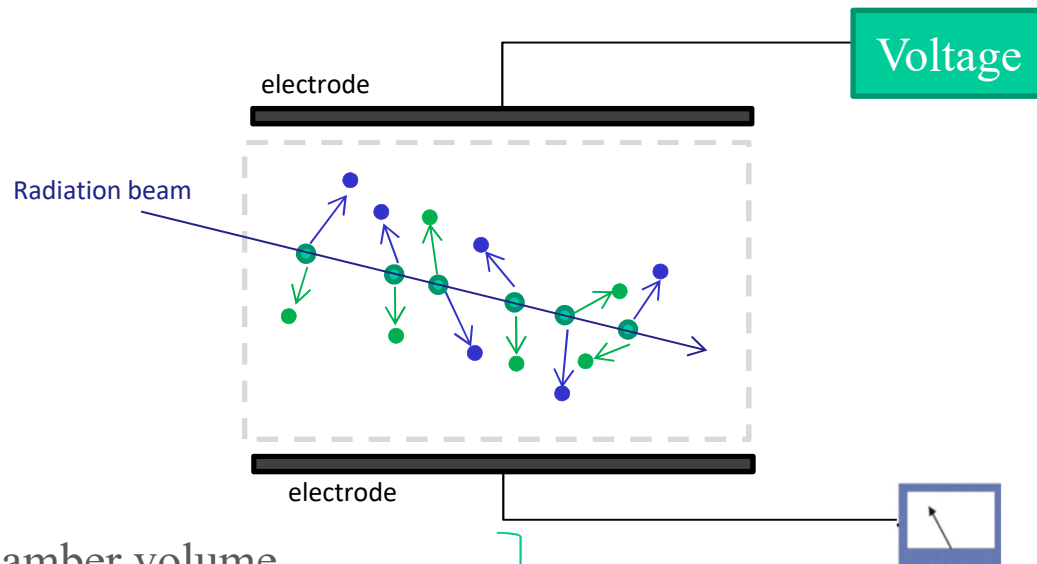
$$K = \frac{dE_{tr}}{dm} \quad D = \frac{dE}{dm}$$

Ionization chamber

Air volume between two electrodes

Principle:

- Radiation ionizes the air in the chamber volume
- Voltage between the electrodes to produce an electric field
- Ions will reach the electrodes
- An ionization current is measured
- Determination of the air volume, then $m_{air} = \rho V_{air}$



dE , knowing W

W mean energy required to produce an ion-pair in air

$$\dot{D} = \frac{I}{\rho V_{air}} \frac{W}{e} \prod k_i$$

+ set of correction factors k_i calculated for a particular beam

Primary standard for calorimetry

Absorbed dose

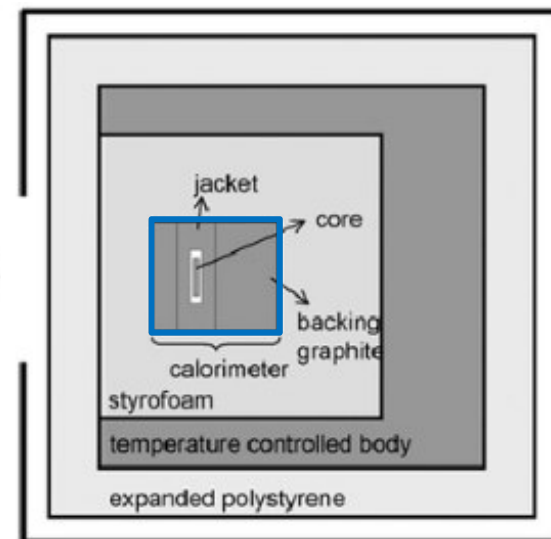
$$D = \frac{dE}{dm}$$

Calorimeter

A body of mass m and thermistors

Principle:

- Measurement of temperature rise ΔT of the body ($\Delta T / K$)
- Determination of the specific heat capacity c_p : energy needed to rise its temperature by 1 kelvin ($c_p / J\ kg^{-1}K^{-1}$)

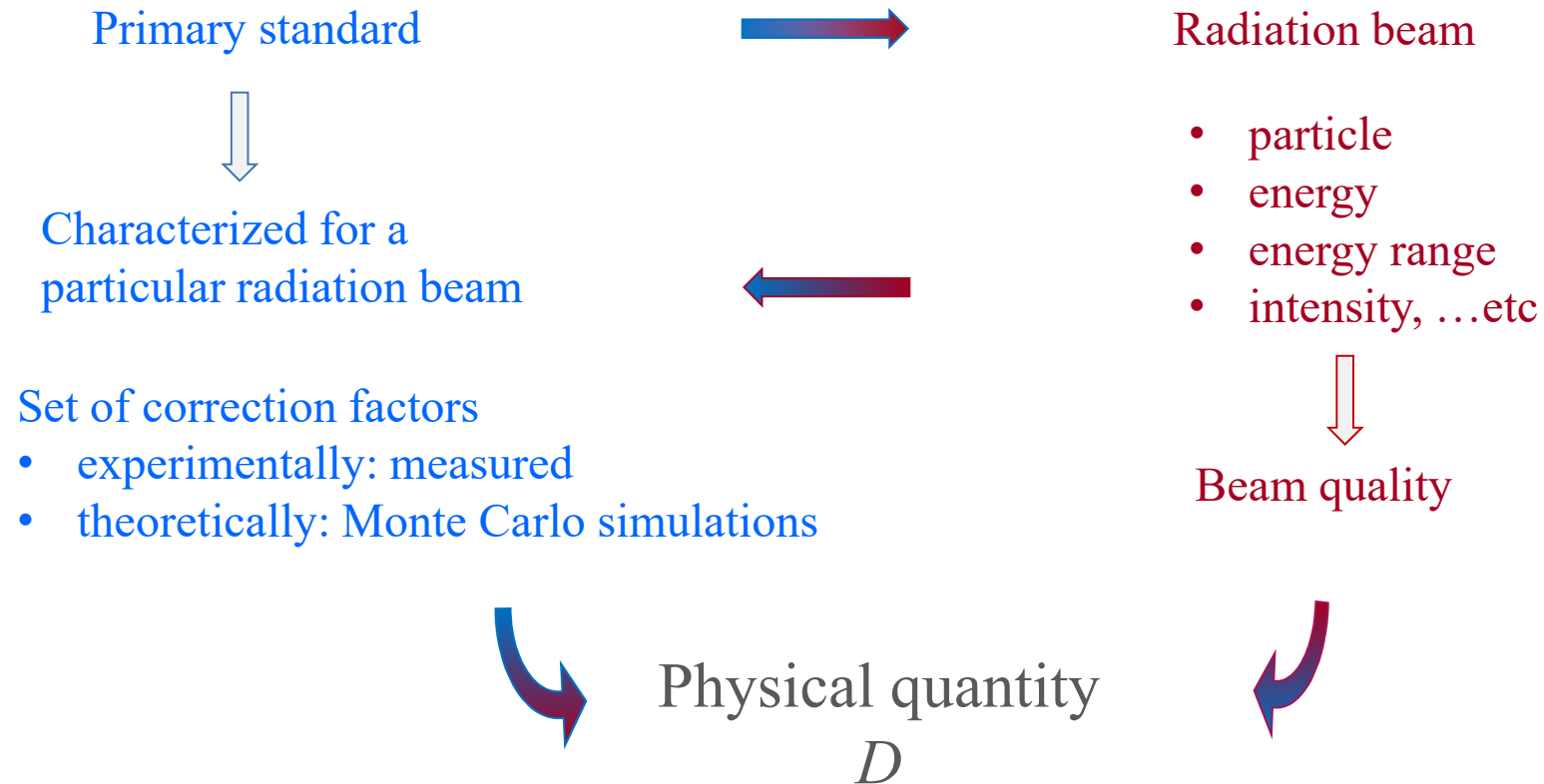


dE , knowing c_p

$$D = \Delta T c_p \Pi k_i$$

+ set of correction factors k_i calculated for a particular beam

Primary standard - Radiation beam



Primary facility : primary standard + radiation beam
Level of unc ~ 0.2 to 0.5 %

Radiation beam - Primary standard

Primary standard



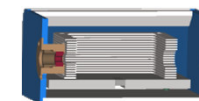
Radiation beam

diagnostic,
therapy,
radiation
protection

**x-rays
(spectrum)**

target of the x-ray tube,
kV, mA, filtration → HVL

free air chamber
FAC

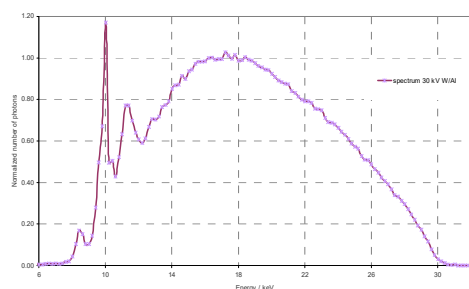


Half Value Layer : is the thickness of the material to reduce the intensity of radiation by one half (mm Al, mm Cu)

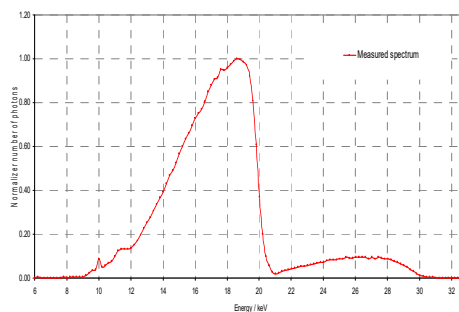
$$\dot{K} = \frac{I}{\rho_{\text{air}} V} \frac{W_{\text{air}}}{e} \frac{1}{1 - g_{\text{air}}} \prod_i k_i$$

- low-energy 10 kV to 50 kV
- medium-energy 100 kV to 300 kV

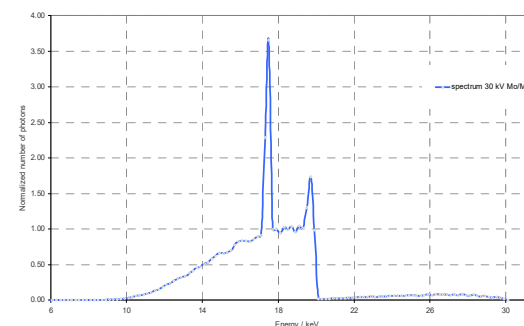
k_i correction factors determined by measurements and by simulation



30 kV W-target Al filtration



30 kV W-target Mo filtration



30 kV Mo-target Mo filtration

Radiation beam - Primary standard

Radiation beam



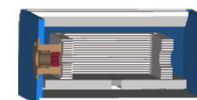
Primary standard

diagnostic,
therapy,
rad protection

x-rays

target x-ray tube,
kV, mA, filtration → HVL

free air chamber
FAC



radiation
protection

^{137}Cs

energy 660 keV

cavity chamber



reference beam for
radiation therapy

^{60}Co

energy 1.25 MeV

cavity chamber



$$\dot{K} = \frac{I}{\rho V_{\text{air}}} \frac{W}{e} \frac{1}{1-\bar{g}} \left(\frac{\mu_{\text{en}}}{\rho} \right)_{\text{a,c}} \overline{s_{\text{c,a}}} \prod k_i$$

k_i correction factors determined by
measurements and by simulation

Radiation beam - Primary standard

Radiation beam



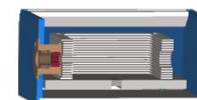
Primary standard

diagnostic,
therapy,
rad protection

x-rays

target x-ray tube,
kV, mA, filtration → HVL

free air chamber
FAC



radiation
protection

^{137}Cs

energy 660 keV

cavity chamber



reference beam for
radiation therapy

^{60}Co

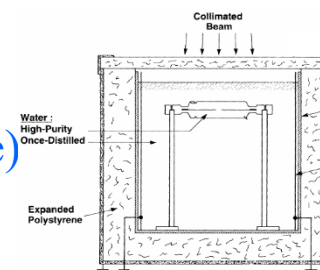
energy 1.25 MeV

radiation therapy

**high energy
photon beams**

MV → $\text{TPR}_{20,10}$

calorimeter
(water, graphite)



$\text{TPR}_{20,10}$ (tissue phantom ratio): is the ratio of ionization measurements at 20 cm and 10 cm depth in water for a constant source to chamber distance

radiation therapy

e-, p- heavy ions beams

radiation therapy
brachytherapy

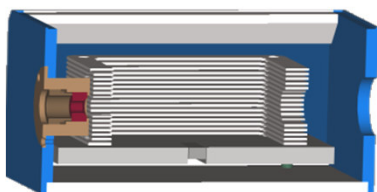
^{192}Ir

mean energy ~ 400 keV

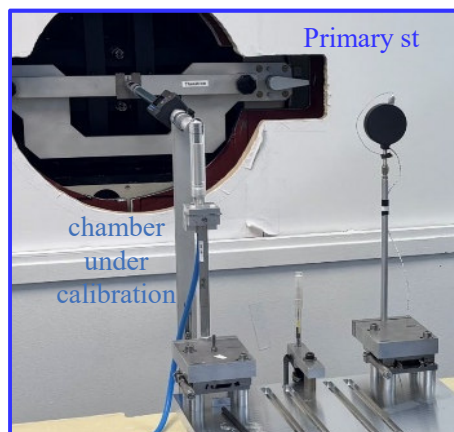
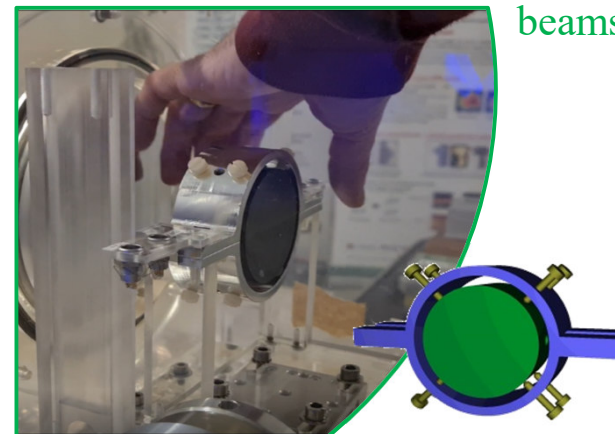
cavity chamber

Primary standards in the radiation beams

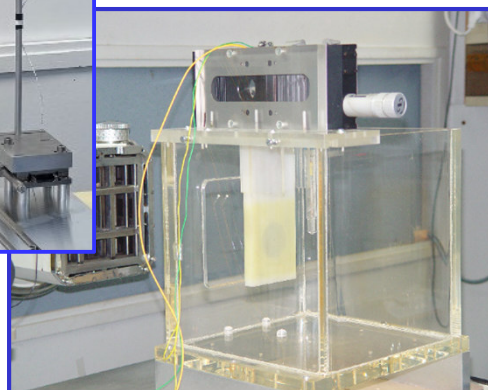
BIPM free-air chamber in mammography x-ray beams



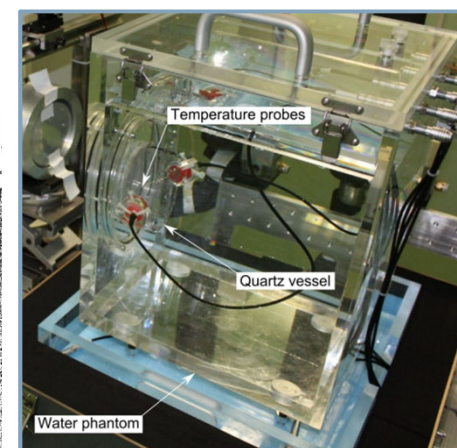
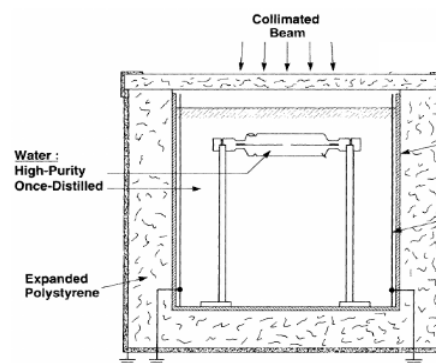
BIPM graphite calorimeter in MV beams



BIPM cavity chamber in Co-60 beam



Water calorimeter in MV beams



Primary Standard Dosimetry Laboratories PSDL

and their needs

what

validation of the primary standard

how

participation in the international comparison programme

where

**Ionizing Radiation department of the
Bureau International des Poids et Mesures**

*International bilateral comparisons organized by the BIPM enable the PSDL to
demonstrate their calibration and measurement capabilities as presented in the CIPM
Mutual Recognition Arrangement (CIPM MRA database).*

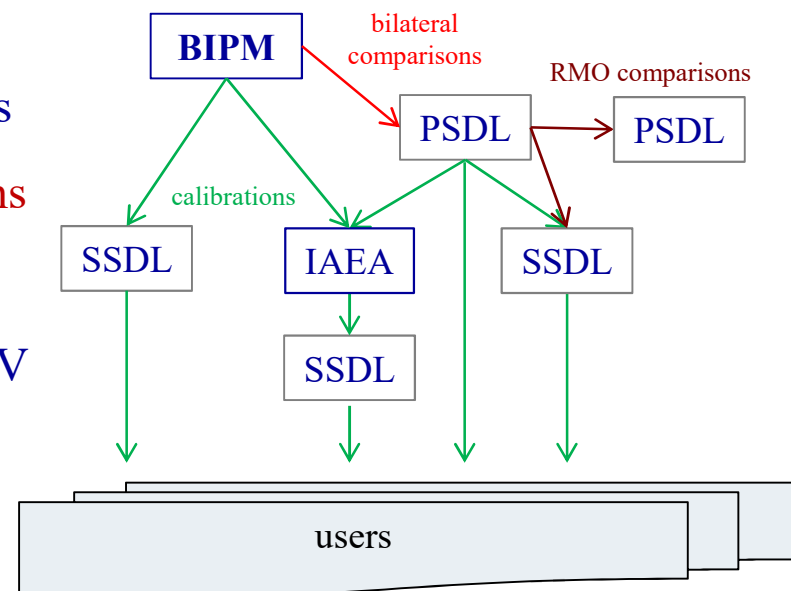
Results are published in the BIPM key comparison database KCDB

<https://www.bipm.org/kcdb/>

Bureau International des Poids et Mesures

BIPM Ionizing Radiation department

- ✚ maintains stable primary reference standards
- ✚ ensures world-wide uniformity of measurements
- ✚ provides an international facility for **comparisons** for the PSDLs
- ✚ BIPM : Key Comparison Reference Value KCRV
- ✚ ensures traceability to the International System of Units (SI) through **calibrations** of the standards of SSDLs and International Atomic Energy Agency IAEA → SSDL network



RMO: Regional Metrology Organization (EURAMET, SIM, AFRIMETS, COOMET, APMP, GULFMET)

BIPM Ionizing Radiation department

Program of key comparisons for primary standards

- ✚ BIPM.RI(I)-K1: air kerma in Co-60
- ✚ BIPM.RI(I)-K2: air kerma in low-energy x-rays (10 kV – 50 kV)
- ✚ BIPM.RI(I)-K3: air kerma in medium-energy x-rays (100 kV – 250 kV)
- ✚ BIPM.RI(I)-K4: absorbed dose to water in Co-60
- ✚ BIPM.RI(I)-K5: air kerma in Cs-137
- ✚ BIPM.RI(I)-K6: absorbed dose to water in MV beams
- ✚ BIPM.RI(I)-K7: air kerma in mammography x-rays (20 kV – 35 kV)
- ✚ BIPM.RI(I)-K8: reference air kerma in HDR Ir-192 source
- ✚ BIPM.RI(I)-K9: absorbed dose to water in medium-energy x-rays (100 kV – 250 kV)

<https://www.bipm.org/kcdb/>

BIPM Key Comparison Database KCDB

INFORMATION

GRAPHS OF EQUIVALENCE

DEGREES OF EQUIVALENCE

EQUIVALENCE STATEMENTS

LABORATORY MEASUREMENTS

BIPM comparison

→ [BIPM.RI\(I\)-K4](#)

Linked comparison

[APMP.RI\(I\)-K4](#)

[EURAMET.RI\(I\)-K4.1](#)

[EURAMET.RI\(I\)-K4.2](#)

[EURAMET.RI\(I\)-K4.3](#)

[SIM.RI\(I\)-K4.2019](#)

BIPM.RI(I)-K4

 PRINT OUT

INFORMATION & CONTACT

PARTICIPANTS

Metrology area, Sub-field	Ionizing Radiation, Section I (x and gamma rays, electrons)
Description	Measurement of absorbed dose to water for Cobalt 60
Time of measurements	1993 -
Status	Continuous, approved for equivalence

References [Technical Protocol for ongoing BIPM Dosimetry comparisons](#)

BIPM Key Comparison Database KCDB

INFORMATION

GRAPHS OF EQUIVALENCE

DEGREES OF EQUIVALENCE

EQUIVALENCE STATEMENTS

LABORATORY MEASUREMENTS

Results

→ Absorbed dose to water

BIPM.RI(I)-K4, EURAMET.RI(I)-K4.1, EURAMET.RI(I)-K4.2, APMP.RI(I)-K4 and EURAMET.RI(I)-K4.3

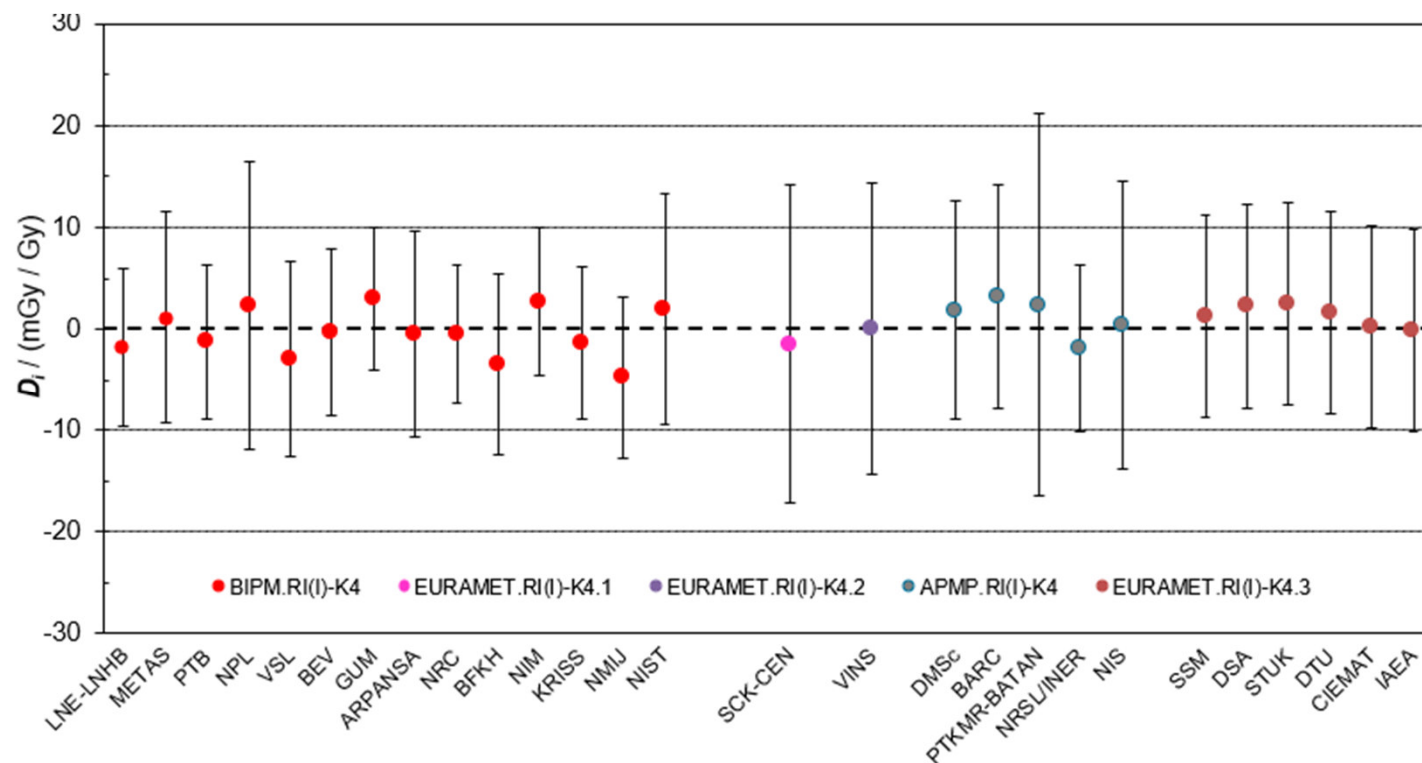
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MEASURAND

Absorbed dose to water

Radiation quality

Co-60 beam



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CELEBRATING
BIPM 150
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