National Physical Laboratory

Air kerma and absorbed dose standards for reference dosimetry in brachytherapy

Thorsten Sander

International Workshop on Metrology for Brachytherapy
PTB, Braunschweig, Germany
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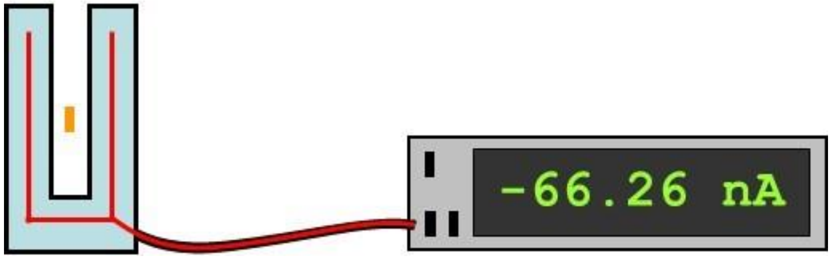
Overview

- Traceability of brachytherapy source calibrations
- Reference air kerma rate, air kerma strength and absorbed dose rate to water
- Air kerma and absorbed dose standards for LDR and HDR brachytherapy
- Calibration of brachytherapy sources and secondary standard ionisation chambers
- Conclusions and future work

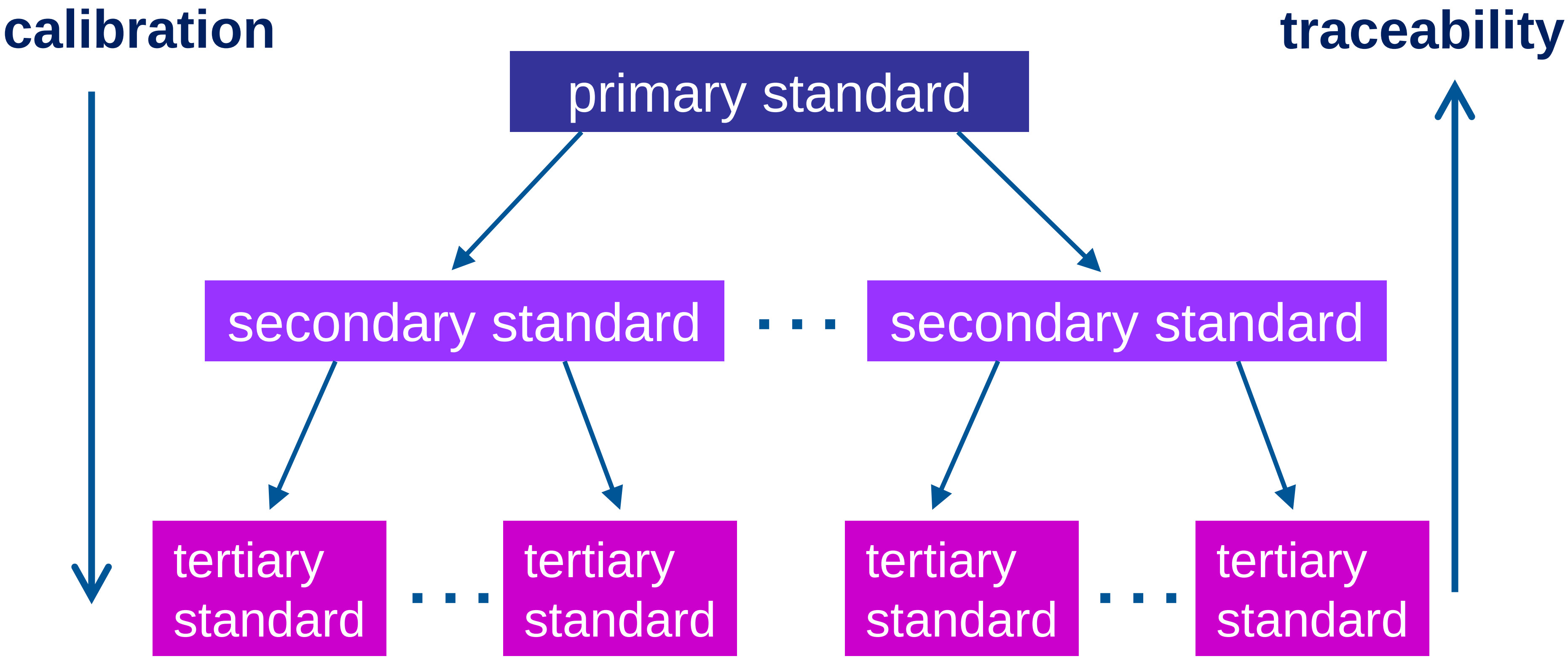
Calibration of a brachytherapy source

- Medical physicists need to verify the source strength before a brachytherapy (BT) source can be used clinically
- Input parameter required for treatment planning system
- Dosimeter = ionisation chamber + electrometer

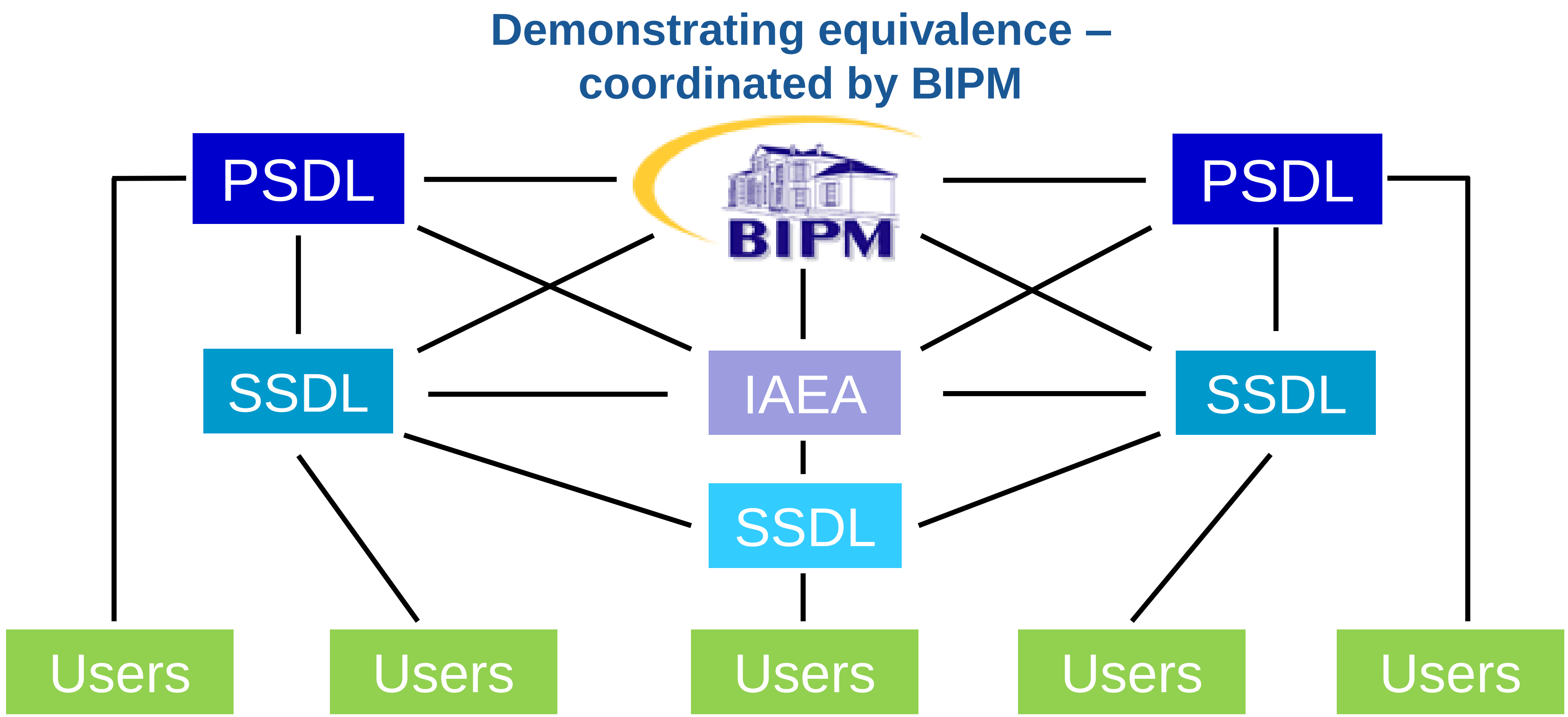


- Measure ionisation current (A)
- Chamber calibration coefficient (Gy C^{-1}) **×** ionisation current (A) = source strength (Gy s^{-1}) at reference distance 1 m

National Measurement System



Consistency in measurements



- BIPM: Bureau International des Poids et Mesures *(International laboratory created by the metre convention)*
- PSDL: Primary standards dosimetry laboratory
- SSDL: Secondary standards dosimetry laboratory

Specification of brachytherapy photon sources

- **Reference air kerma rate**

ICRU Report 38 (1985)

ICRU Report 58 (1997), µGy h^{-1} at 1 m or mGy h^{-1} at 1 m

ICRU Report 72 (2004)

$$\dot{K}_{\mathrm{R}} = \dot{K}_{\delta}(d)\left(\frac{d}{d_{\mathrm{ref}}}\right)^2$$

Air kerma rate due to photons of energy greater than δ, at a point located at a distance of 1 m from the source centre, *in vacuo*.

- **Air kerma strength**

AAPM TG-32 Report 21 (1987), 1 U = 1 µGy m^2 h^{-1} = 1 cGy cm^2 h^{-1}

AAPM TG-43 U1 (2004)

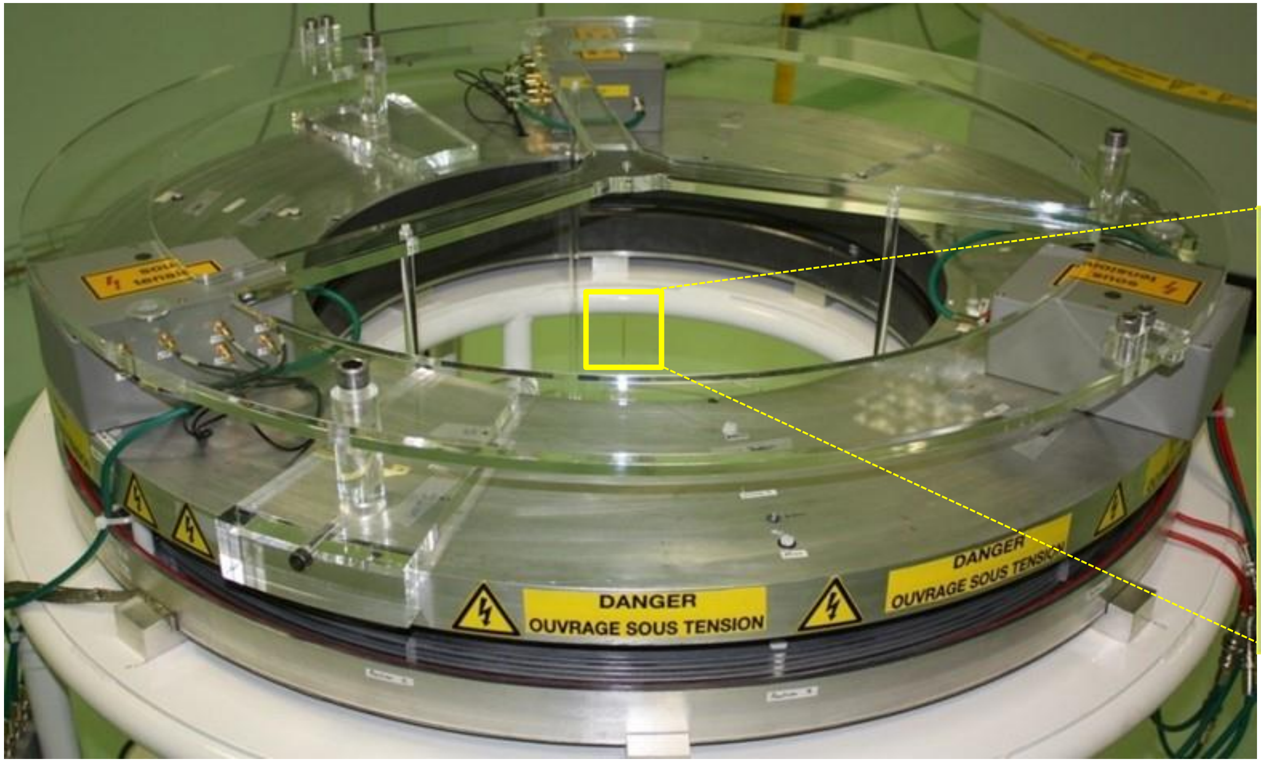
$$S_{\mathrm{K}} = \dot{K}_{\delta}(d)d^2$$

The air kerma rate, *in vacuo*, and due to photons of energy greater than δ, at a distance *d*, multiplied by the square of the distance.

Energy cut-off value, δ, typically 5 keV … 10 keV.

LNE-LNHB K_R standard for LDR ^{125}I sources

based on a **ring-shaped free-air ionisation chamber**



^{125}I seed located inside a kapton tube surrounded (or not) by an aluminium filter (Ti K x-rays produced in capsule)

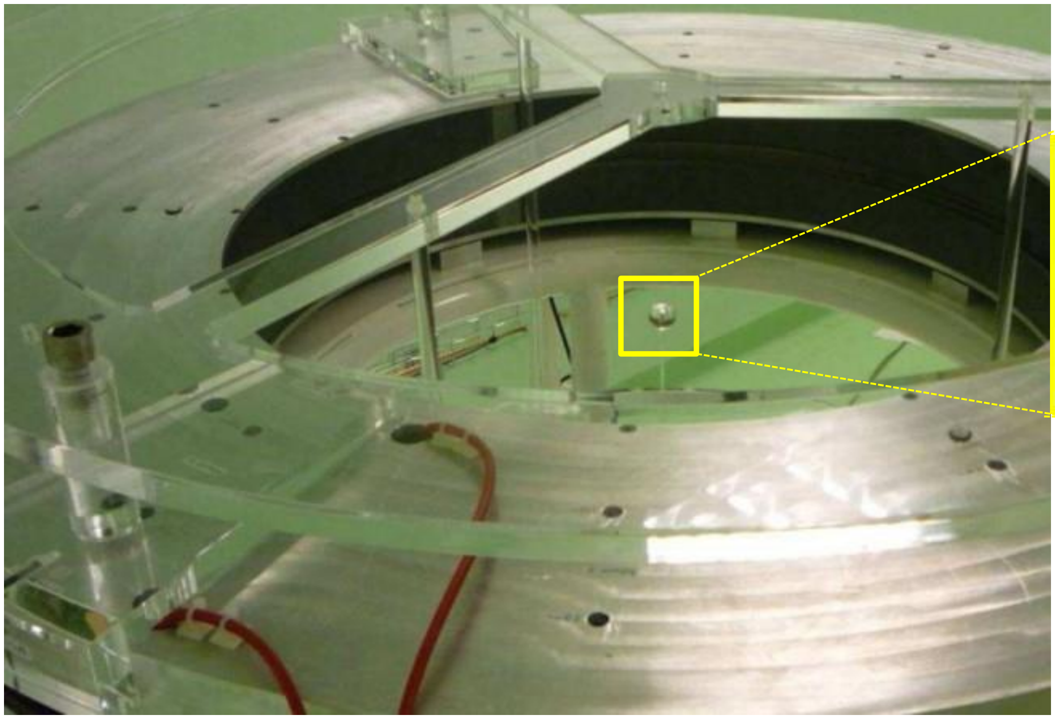
$$\dot{K}_R = \left(I.\frac{\overline{W_{air}}}{e}.\prod_i K_i\right).\frac{1}{\rho_{air}.V_{air}}.F_K.\left(\frac{d}{d_{ref}}\right)^2$$

$$d_{ref} = 1\ m$$

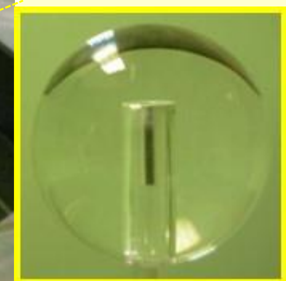
LNHB Laboratoire National Henri Becquerel

LNE-LNHB D_w standard for LDR ^{125}I sources

based on a **ring-shaped free-air ionisation chamber (same as K_R standard)**



^{125}I seed located



at the centre of a 1 cm radius water-equivalent sphere

or

in a kapton tube at the centre of a 1 cm radius cylindrical vial filled with water

$$\dot{D}_w = \left(I.\frac{\overline{W_{air}}}{e}.\prod_i K_i \right).\frac{1}{\rho_{air}.V_{air}}.F_D$$

LNE-LNHB K_R and D_W standards for LDR ^{125}I sources – measurement principle

- Distance source-to-centre of collecting volume: approx. 40 cm
- The dosimetric quantities are measured in the plane passing through the seed centre and perpendicular to the longitudinal axis of the source using the free-air ionisation chamber.
- The conversion factors, F_K and F_D, were calculated using radiation-transport Monte Carlo simulation codes. Those factors convert the chamber measurement to standard conditions.

$$\boldsymbol{u}[\dot{\boldsymbol{K}}_{\boldsymbol{R}}] = \mathbf{1.7}\ \%\ (\boldsymbol{k} = \mathbf{1})$$

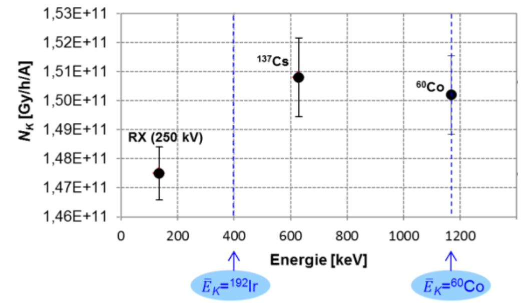
$$\boldsymbol{u}[\dot{\boldsymbol{D}}_{\boldsymbol{W}}] = \mathbf{1.6}\ \%\ (\boldsymbol{k} = \mathbf{1})$$

LNE-LNHB needs to compare its LDR standard in terms of $\dot{K}_R$ and $\dot{D}_W$ before proposing accredited calibration services for ^{125}I seeds

LNE-LNHB K_R standard for HDR ^{192}I and ^{60}Co sources

Indirect method based on a calibrated NE2571 ionisation chamber

$$\dot{K}_R\left[Gy.h^{-1}\right] = N_{\dot{K}_{air,NE2571}} . I_{corr}(d) . \prod_i k_i . \left(\frac{d}{d_{ref}}\right)^2$$



- $N_{\dot{K}_{air,NE2571}}$: calibration coefficient for the Ir or Co source previously determined using the LNE-LNHB standard beams [Goetsch, 1991; Mainegra-Hing et Rogers, 2006]

- I_{corr} : ionisation current corrected for atmospheric effects, leakage and radioactive decay

- k_i: factors that correct for:
  - for attenuation in materials separating the source from the point of interest → MC calculation
  - non-uniformity of the NE2571 irradiation → Kondo-Randolph-Bielajew theory
  - scattered photons contribution → measurements at multiple distances

- d : the source-to-detector distance, typically ~ 100 to 220 mm

  At d ~ 100 mm: $\pm$0.5 mm error distance → $\pm$1 % error in $\dot{K}_R$

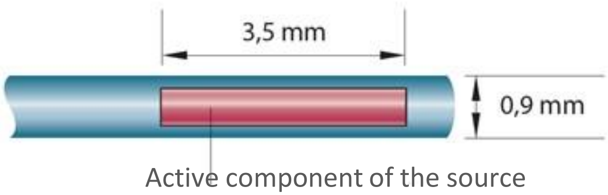
  Development of an indirect distance measuring method: $u(d) = 40\ \mu m$

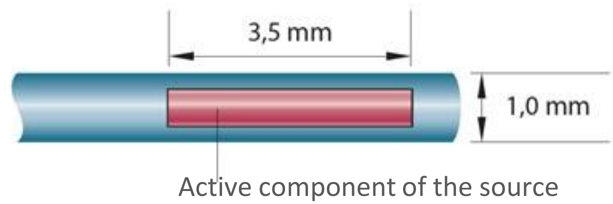
  (Corrected distance derived from the variation of the chamber response as a function of its angle of rotation around a vertical axis passing through the source [Douysset et al., 2007])

$$\mathrm{u}\left[\dot{K}_R\right] \sim 0.6\ \%\ (k = 1)$$

LNE-LNHB K_R standard for HDR ^{192}Ir and ^{60}Co sources

At the beginning of 2017, LNE-LNHB purchased the Bebig SagiNova afterloader, that can be loaded either with:





a miniaturized ^{192}Ir source (Ir2.A85-2) or a miniaturized ^{60}Co source (Co0.A86)

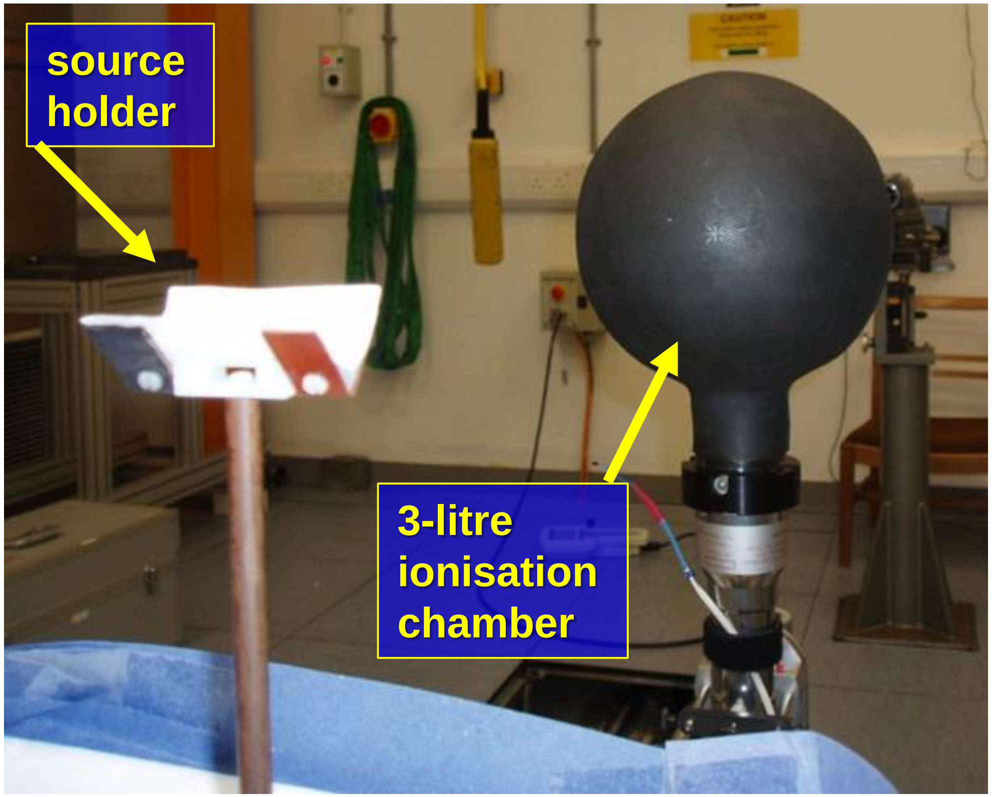
- Commissioning of the new standard for ^{192}Ir almost complete
- Calibration of the transfer well-type chamber to be done for Ir2.A85-2 sources
- **Source geometry factor calculations in progress,** using the methodology proposed in Shipley *et al.* (2015), to correct the calibration coefficient for any change of the well chamber response due to geometric differences between this type of ^{192}Ir source and the ^{192}Ir source to be calibrated at the medical service.

LNE-LNHB proposes to calibrate well-type and NE2571 ionization chambers for HDR and PDR ^{192}Ir , in terms of $\dot{K}_R$

LNE-LNHB should be able to propose equivalent calibration services for ^{60}Co sources shortly

NPL K_R standard for LDR ^{125}I sources

Secondary standard ionisation chamber *(interpolation method)*



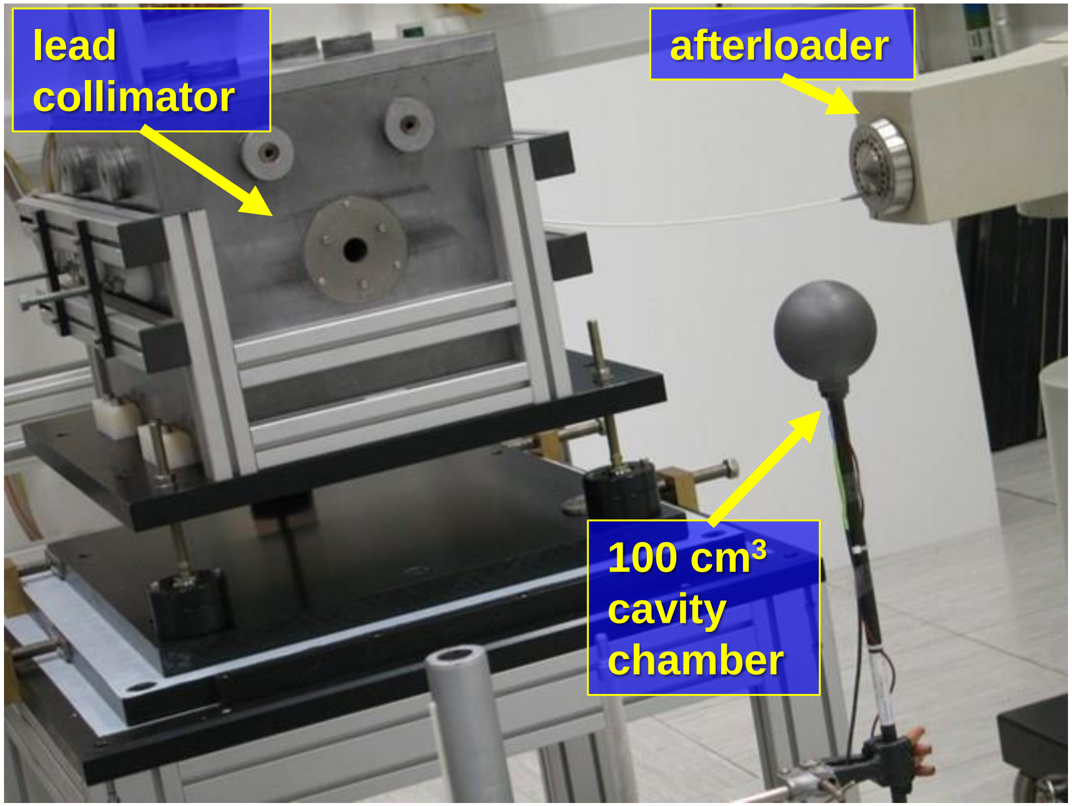
- Spherical NE2551 secondary standard protection-level ionisation chamber
- Measurement distances: 40 cm … 100 cm from the source
- Chamber calibrated at NPL in low-energy X-ray beams (ISO 4037-1 narrow spectrum series)
- Response factor for chamber to the ^{125}I spectrum calculated
- X-rays < 4 keV totally absorbed in the chamber wall

$$\dot{K}_{\mathrm{R}} = I \cdot N_{K_{\mathrm{R}}} \cdot \prod_i k_i$$

$$U(\dot{K}_{\mathrm{R}}) \sim 2.5\% \ (k = 1)$$

NPL K_R standard for HDR ^{192}Ir sources

Primary standard cavity chamber commissioned for microSelectron-v1 and Flexisource *(direct method, __no__ interpolation required)*



Calibration sources at NPL

2004 – 2013:
Nucletron microSelectron-v1 classic HDR ^{192}Ir source

Since 2014:
Isodose Control Flexisource HDR ^{192}Ir

$$\dot{K}_{\mathrm{R}} = \frac{I}{\rho_{\mathrm{air}} V_{\mathrm{air}}} \cdot \frac{\overline{W}_{\mathrm{air}}}{e} \cdot \frac{1}{(1-\bar{g})} \cdot \left(\frac{\bar{\mu}_{\mathrm{en}}}{\rho}\right)^{\mathrm{air}}_{\mathrm{graph}} \cdot \left(\frac{\bar{S}}{\rho}\right)^{\mathrm{graph}}_{\mathrm{air}} \cdot k_{\mathrm{fl}} \cdot \prod_i k_i \cdot k_{\mathrm{h}} \cdot k_{\mathrm{att+sc}} \cdot \left(\frac{d}{d_{\mathrm{ref}}}\right)^2 \cdot k_{\mathrm{dec}} \cdot k_{\mathrm{Tp}}$$

$$U(\dot{K}_{\mathrm{R}}) \sim 0.4\% \ (k=1)$$

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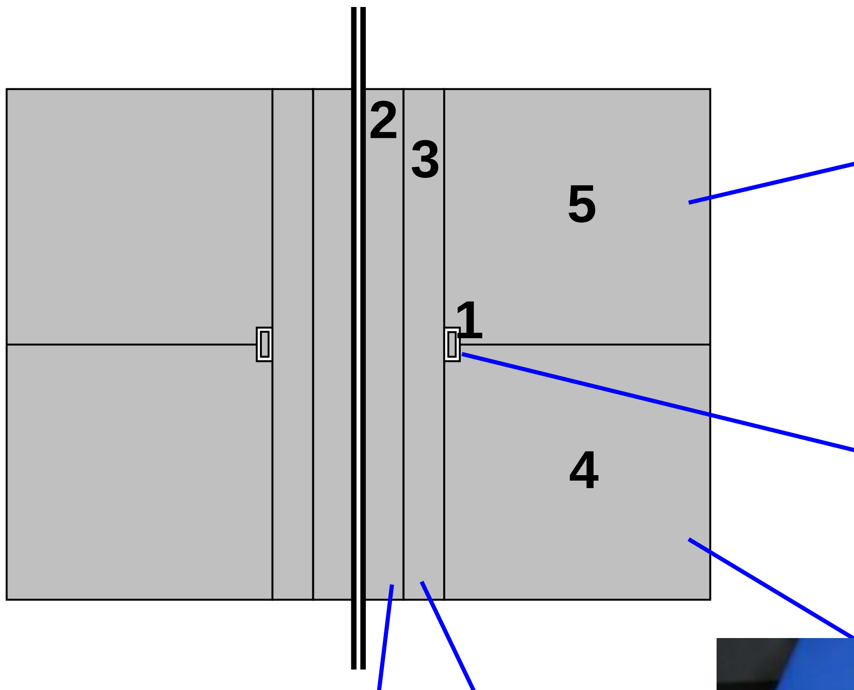
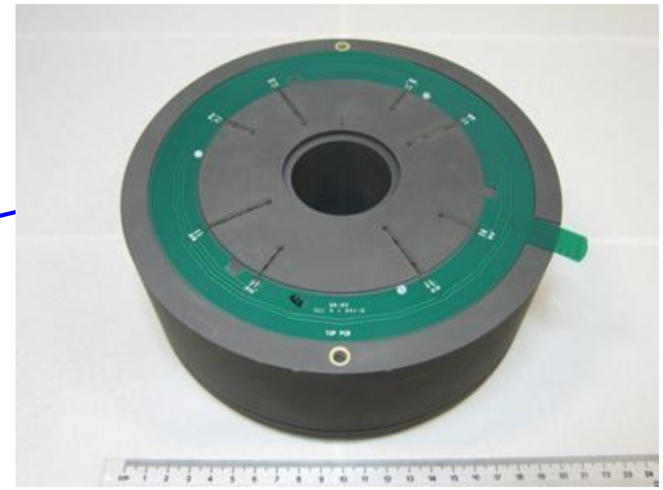
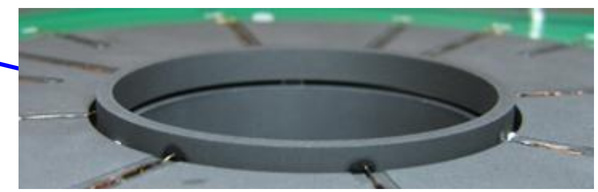
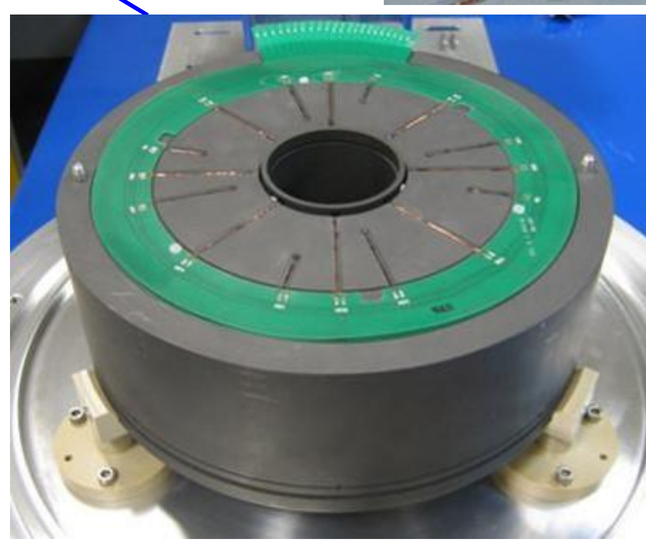
NPL D_w standard for HDR ^{192}Ir sources

Graphite calorimeter









- Ring-shaped core, 2.5 cm radius
- Cylindrical graphite phantom
- Four sensing and four heating thermistors in each component

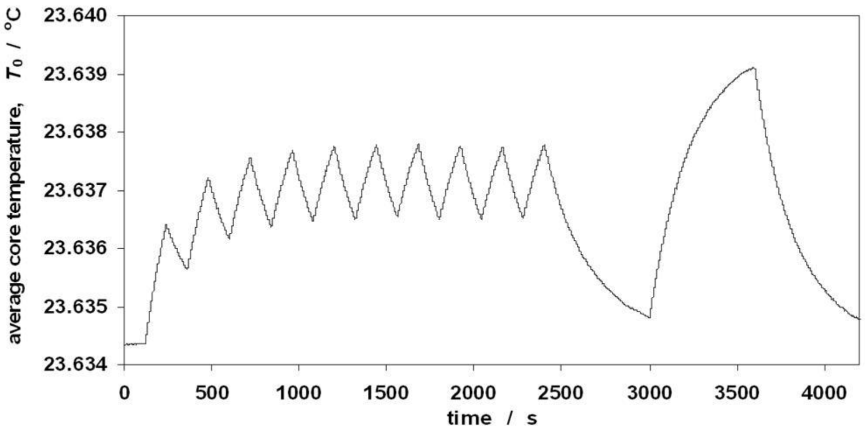
NPL D_w standard for HDR ^{192}Ir sources

Graphite calorimeter measurement equations

- **Quasi-adiabatic** mode

$$\dot{D}_{\mathrm{w}} = c_{\mathrm{p}} \cdot \frac{\Delta T}{\Delta t} \cdot \prod_i k_i$$

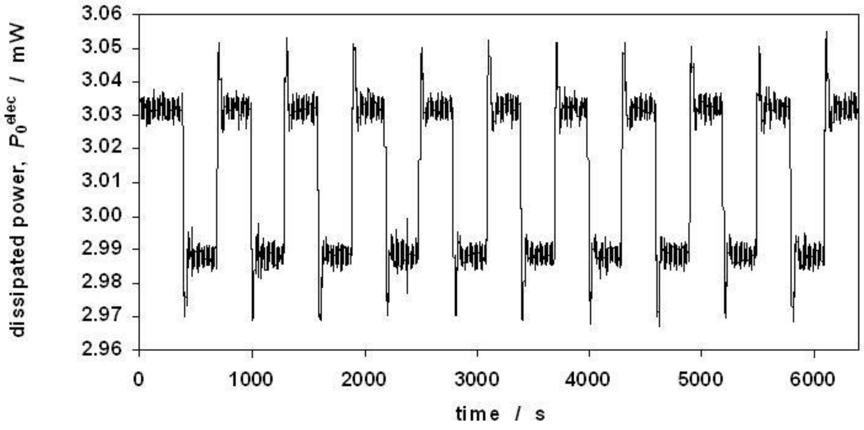
$$U(\dot{D}_{\mathrm{w}}) \sim 1.0\% \ (k = 1)$$



- **Isothermal** mode

$$\dot{D}_{\mathrm{w}} = \frac{-\Delta P^{\mathrm{elec}}}{m} \cdot \prod_i k_i$$

$$U(\dot{D}_{\mathrm{w}}) \sim 0.7\% \ (k = 1)$$



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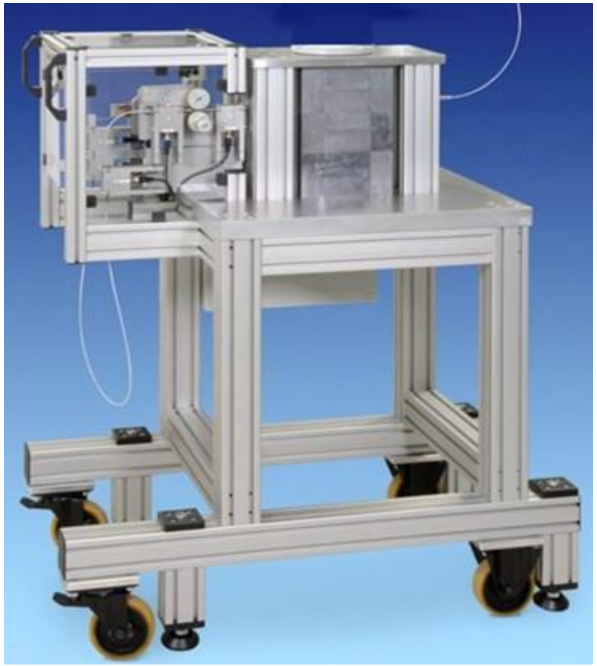
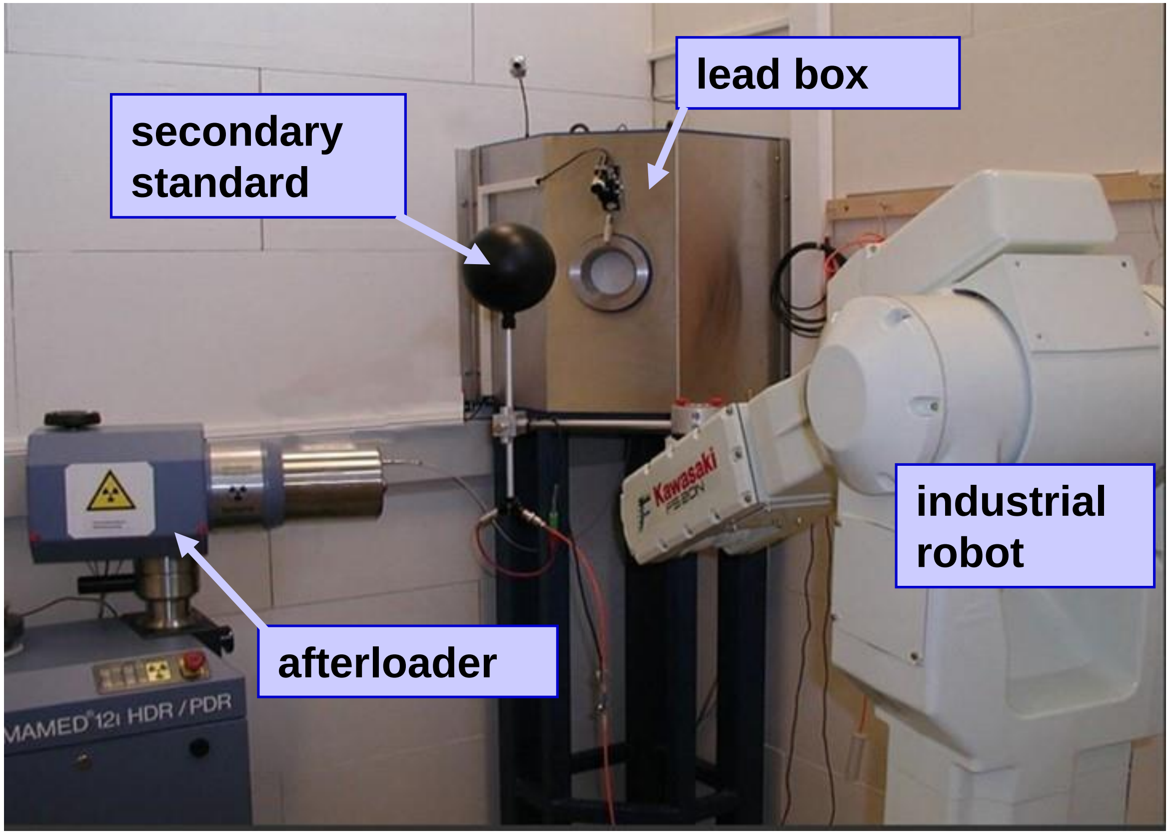
PTB K_R standard for HDR ^{192}Ir and ^{60}Co sources

Secondary standard ionisation chamber *(interpolation method)*

- Spherical 1-litre LS01 ionisation chamber
- Calibrated in reference fields for < 300 kVp X-rays, ^{137}Cs and ^{60}Co
- ^{192}Ir response derived by interpolation



custom-built afterloader



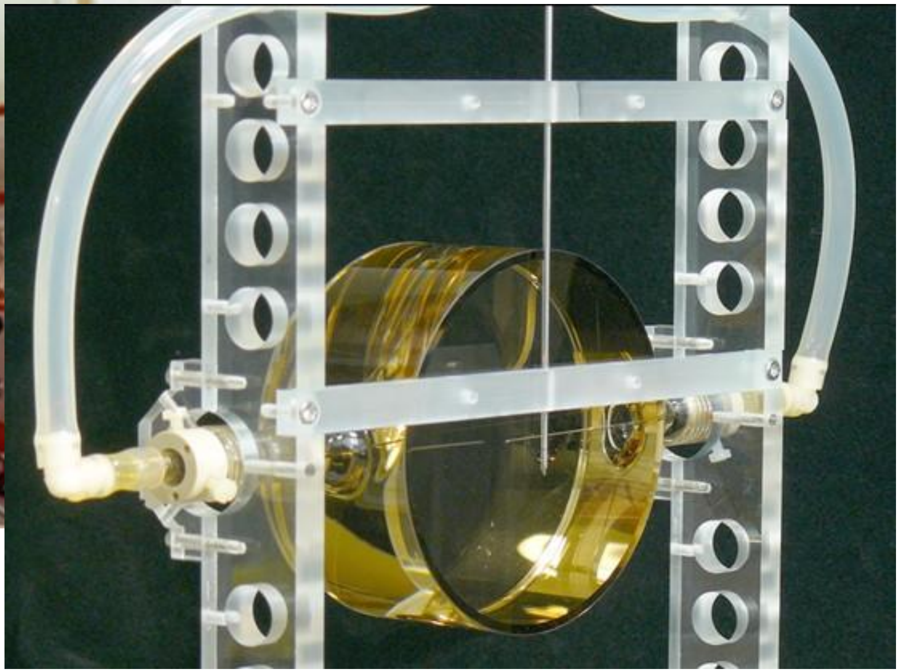
- Calibration of ^{192}Ir- and ^{60}Co-HDR brachytherapy sources in terms of RAKR

$$U(\dot{K}_R) \sim 1.2\%\ (k = 1)$$

PTB D_w standard for HDR ^{192}Ir and ^{60}Co sources

Water calorimeter

- Water calorimeter setup

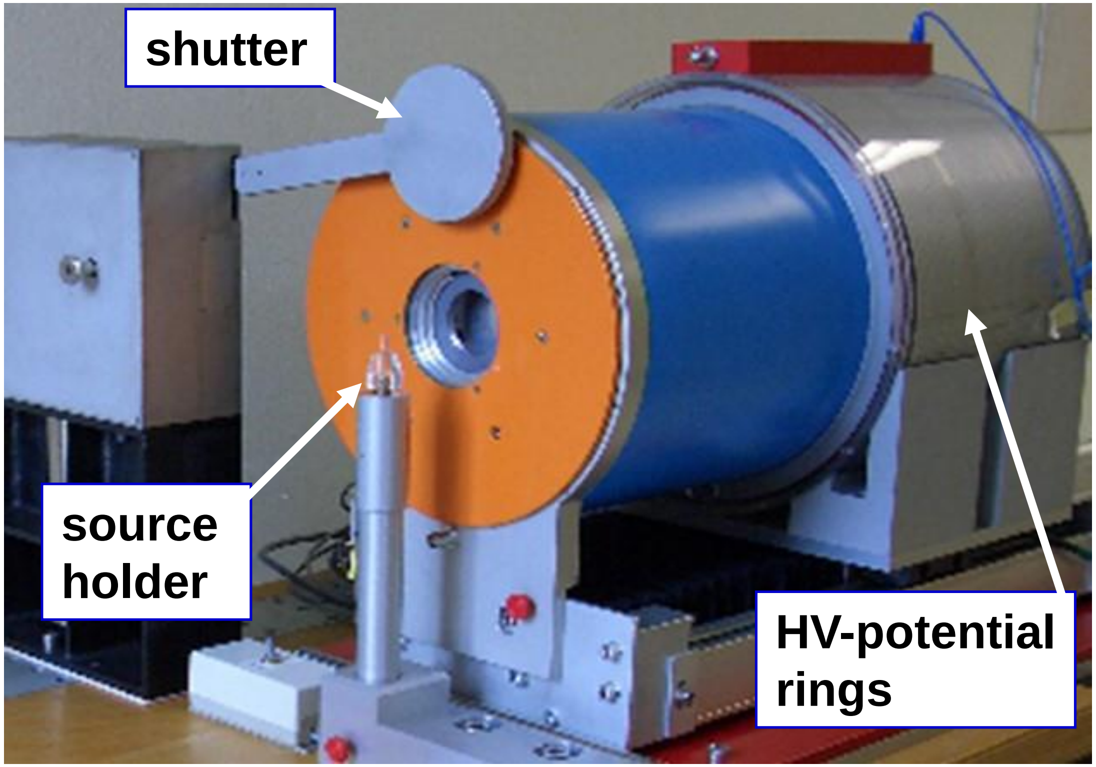


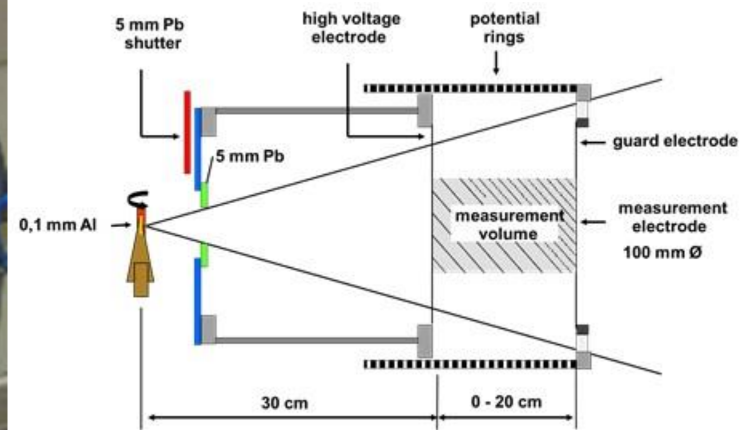
$$U(\dot{D}_{\mathrm{w}}) \sim 1.8\% \; (k = 1)$$

- High-purity water cell with two thermistors. Stainless steel needle for BT source can be set up at +24, +48 and +60 mm and -24 mm from the measurement point.

PTB K_R standard for LDR ^{125}I and ^{103}Pd sources

Large-volume extrapolation chamber (GROVEX)





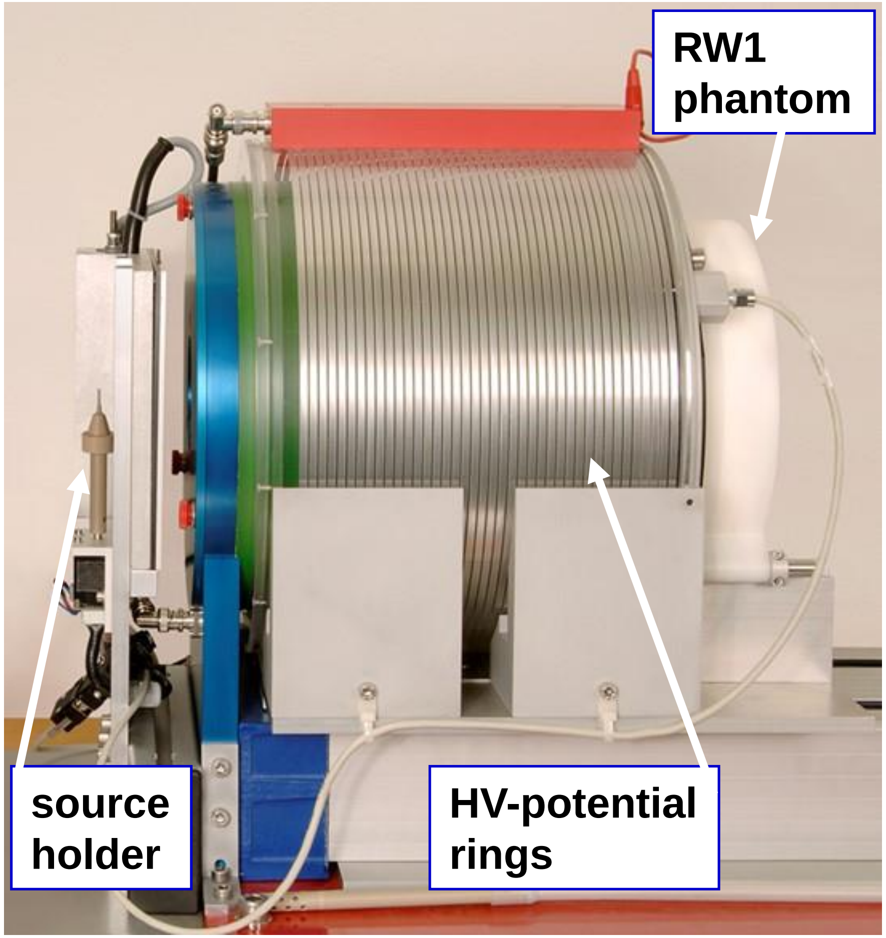
Selbach et al. *Metrologia* **45** (2008) 422

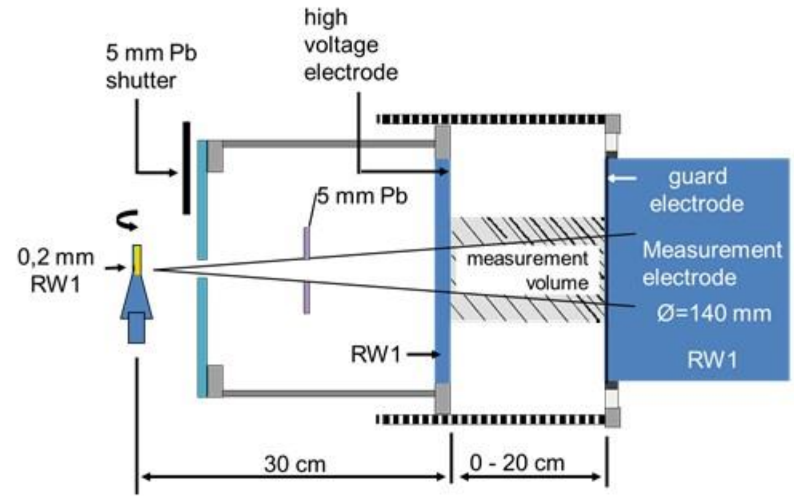
- Distance between the two parallel-plate graphite electrodes can be adjusted from 0 cm to 20 cm
- Several collecting volumes
- GROVEX method eliminates wall effect of electrodes
- Extrapolation represents ideal wall-less air chamber

$$U(\dot{K}_{\mathrm{R}}) \sim 0.9\% \ (k = 1)$$

PTB D_w standard for LDR ^{125}I sources

(GROVEX II) → new name: in-phantom Free Air Chamber (ipFAC)



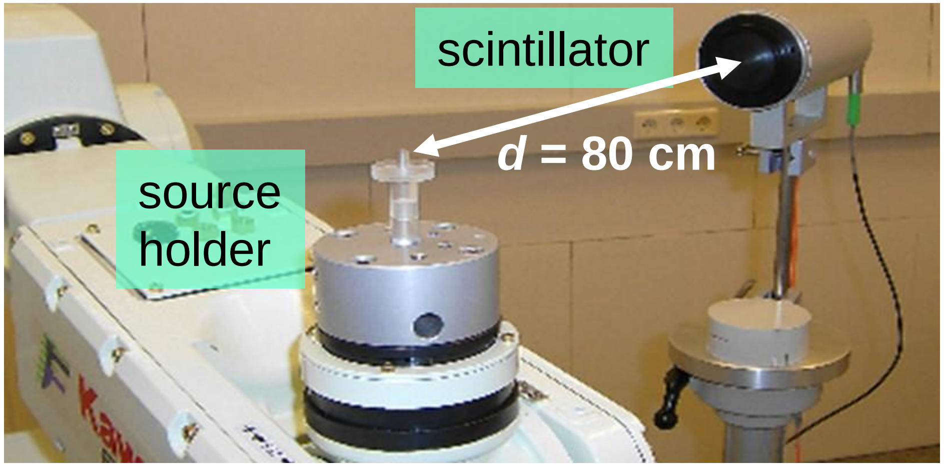


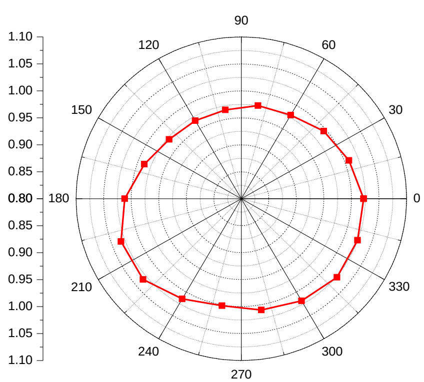
Schneider and Selbach *Radiother Oncol* **100** (2011) 442
Schneider *Metrologia* **49** (2012) S198

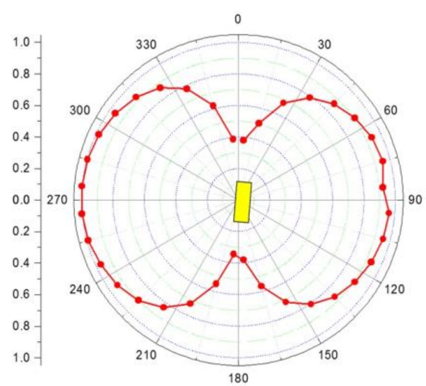
- Entrance and back plates made of water-equivalent RW1
- Measurement at two different plate separations (no extrapolation technique applied)
- Also used for electronic brachytherapy sources.

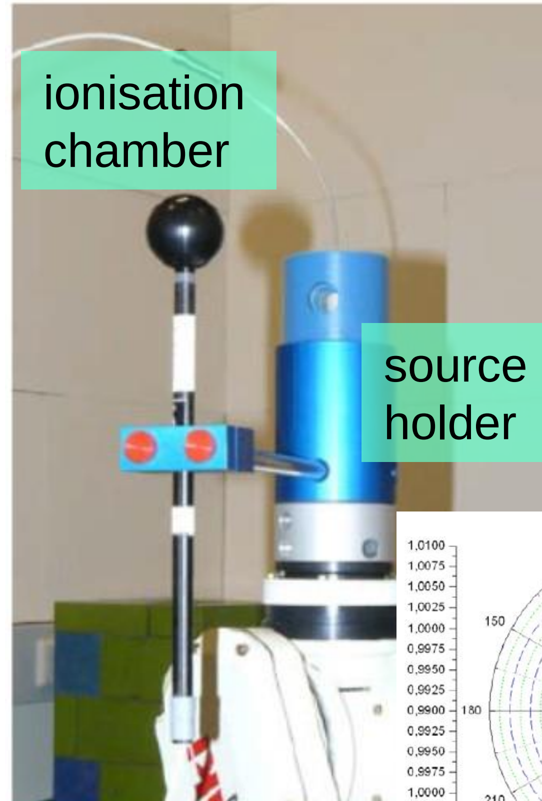
$$U(\dot{D}_\mathrm{w}) \sim 1.3\%\ (k = 1)$$

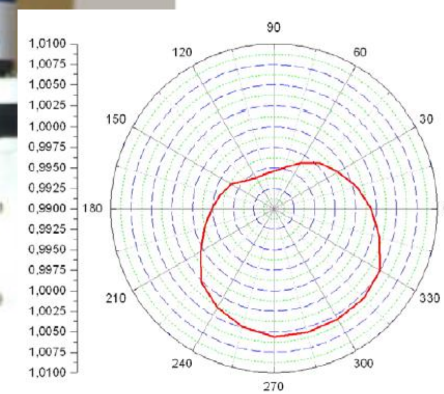
Measurement of anisotropy of BT sources at PTB











radial

polar

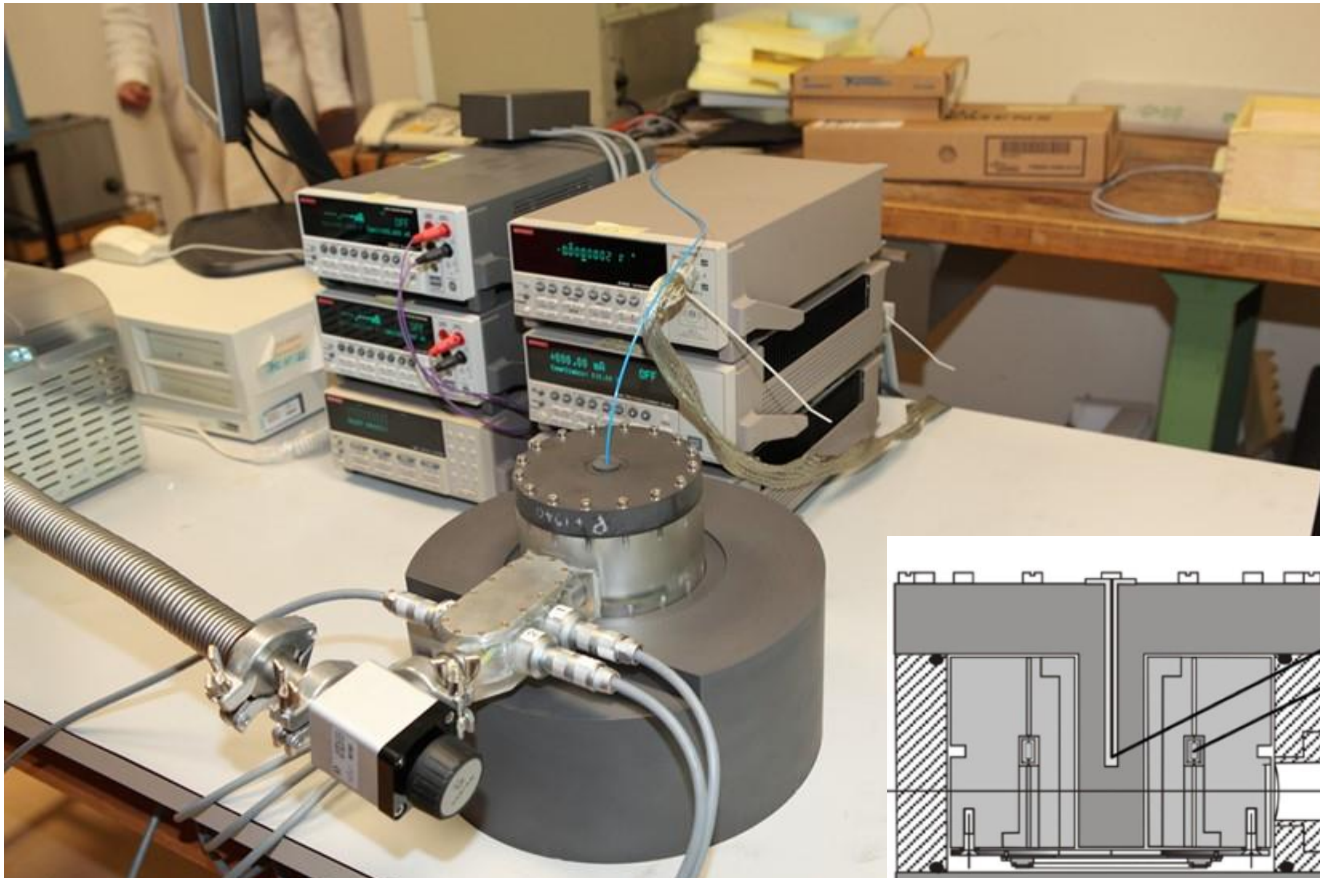
here: ±0.5%

radial

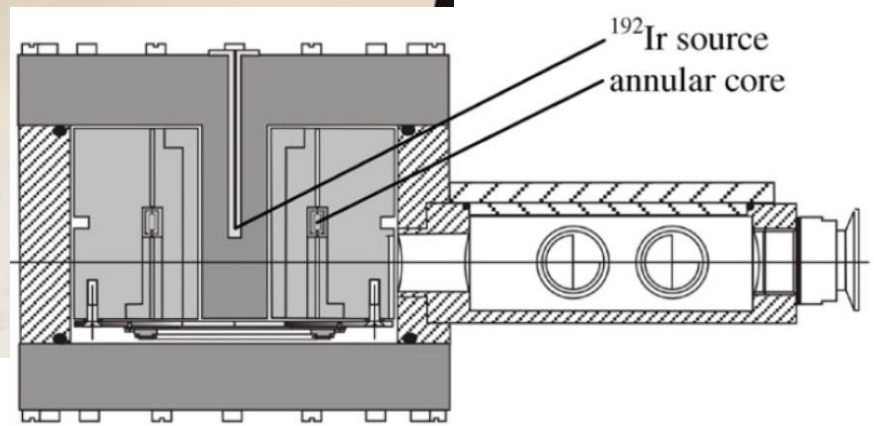
- Anisotropy measurement of **LDR** sources with scintillator
- Anisotropy measurement of **HDR** sources with Exradin ionisation chamber

ENEA-INMRI D_w standard for HDR ^{192}Ir sources

Graphite calorimeter



- Ring-shaped core, 2.5 cm radius
- Graphite calorimeter inserted in large graphite phantom to achieve full backscatter
- New Wheatstone bridge dedicated to core sensing thermistor

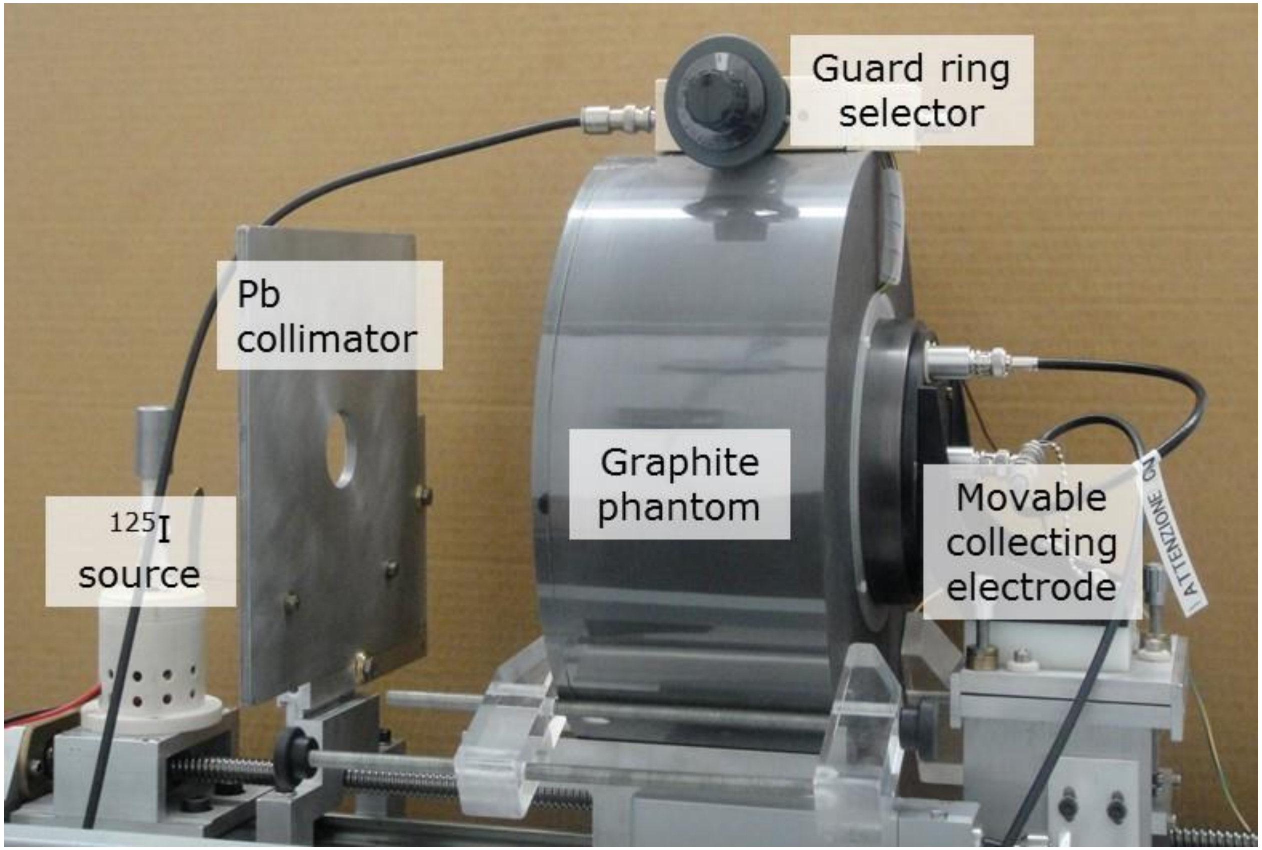


Guerra *et al.* *Metrologia* **49** (2012) S179

$$U(\dot{D}_{\mathrm{w}}) \sim 1.4\% \ (k = 1)$$

ENEA-INMRI D_w standard for LDR ^{125}I sources

Large-angle and variable-volume ionisation chamber in a graphite phantom



- Standard based on ionometric measurement of K_w
- Measurement in phantom and conversion to D_w based on Monte Carlo calculations.
- Measurement method similar to that developed at PTB
  Schneider *et al.* *Metrologia* **46** (2009) 95

Toni *et al.* *Metrologia* **49** (2012) S193

$$U(\dot{D}_w) \sim 2.6\% \; (k = 1)$$

ENEA-INMRI K_R standard for LDR ^{125}I and HDR ^{192}Ir sources

Secondary standard ionisation chambers (interpolation method)

- Three spherical ionization chambers are initially calibrated against the air kerma primary standards for medium energy X-rays (ISO 4037) and ^{60}Co γ-ray beams
- The K_R of LDR and HDR ^{192}Ir sources are measured with these calibrated chambers
- Interpolation method developed by Piermattei and Azario (*Phys Med Biol* **42** (1997) 1661), based on measurement method developed by Verhaegen *et al.* (*Phys Med Biol* **37** *(*1992) 2071)
- Source types which can be measured:

  LDR ^{125}I seeds from Bebig

  HDR ^{192}Ir Nucletron microSelectron-v2 sources

$$U(\dot{K}_{\mathrm{R}}) \sim 1.1\% \ (k = 1)$$

VSL K_R standards for LDR ^{125}I and HDR ^{192}Ir sources

- LDR ^{125}I: Measured with Vinten well-type chamber, currently with traceability either to NIST or PTB for a few types of ^{125}I LDR seeds. Clients have to supply VSL with 2 seeds and the ionisation chamber. They receive a calibrated ionisation chamber. Seeds are calibrated as well, but not reported and often not sent back.

$$U(\dot{K}_\mathrm{R}) \sim 1\% \ \ldots 1.5\% \ (k=1)$$

depending on traceability route, instrument performance and variations in dose distributions.

- LDR traceability might be expanded soon to include ^{103}Pd seeds.

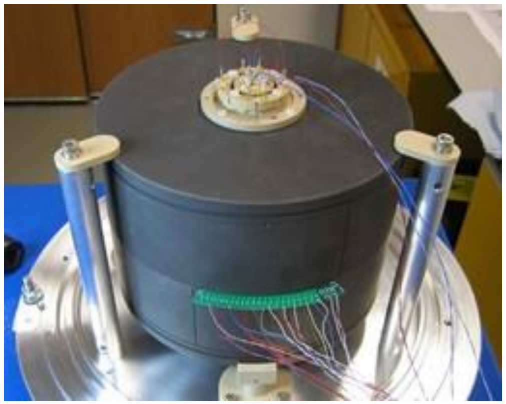
- HDR ^{192}Ir: interpolation method based on two NE2571 ionization chambers calibrated against VSL's primary standards for 250 kV X-rays and ^{137}Cs. NE 2571 chambers used to calibrate microSelectron-v2 sources. Calibrated source used to calibrate well-type chambers. The K_R of LDR and HDR ^{192}Ir sources are measured with these calibrated chambers.

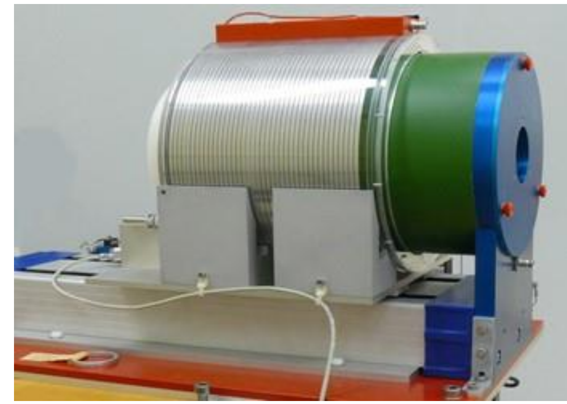
  Currently in the process of lowering accreditation from $U(\dot{K}_\mathrm{R}) \sim 1\% \ (k=1)$ to $U(\dot{K}_\mathrm{R}) \sim 0.6\% \ (k=1)$

Measurement of dose rate constant Λ

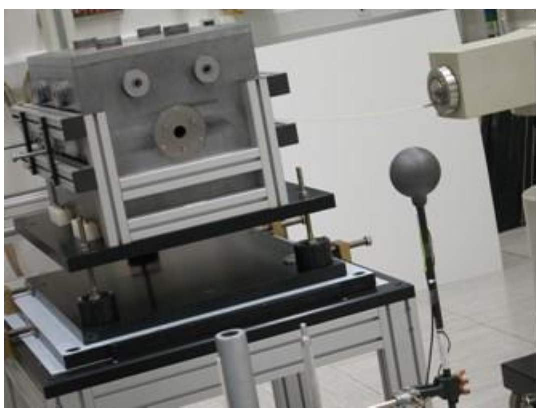
HDR ^{192}Ir

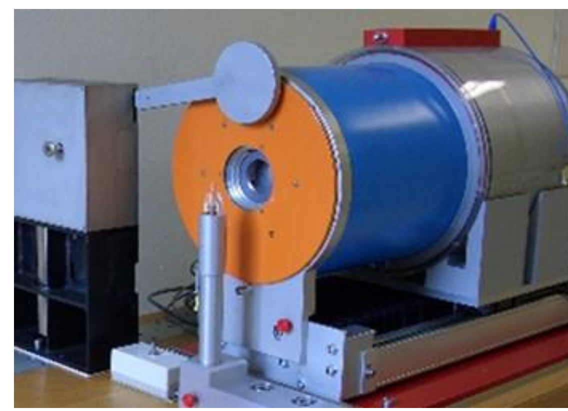
LDR ^{125}I





$$\Lambda = \frac{\dot{D}_{\mathrm{w,1\,cm}}}{\dot{K}_{\mathrm{a,100\,cm}}}$$





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Selbach *et al.* *Metrologia* **49** (2012) S219

PTB

Updates from other NMIs and SSDLs

- **ARPANSA** (Australia)
- Calibration of Farmer-type chambers for air kerma at ^{60}Co and using 250 - 300 kVp X-rays with the build-up cap on, for use in a jig following IAEA Techdoc 1274, for ^{192}Ir.
- ^{60}Co air kerma PS is a plane-parallel graphite cavity chamber. ME X-ray air kerma PS is a free-air chamber.
- Most centres in Australia use well-chambers. Sent overseas for calibration. No BT source at ARPANSA.
- K_R measurement with Farmer chamber/jig combination.

$$U(\dot{K}_{\mathrm{R}}) \sim 1\% - 2\% \; (k = 1)$$

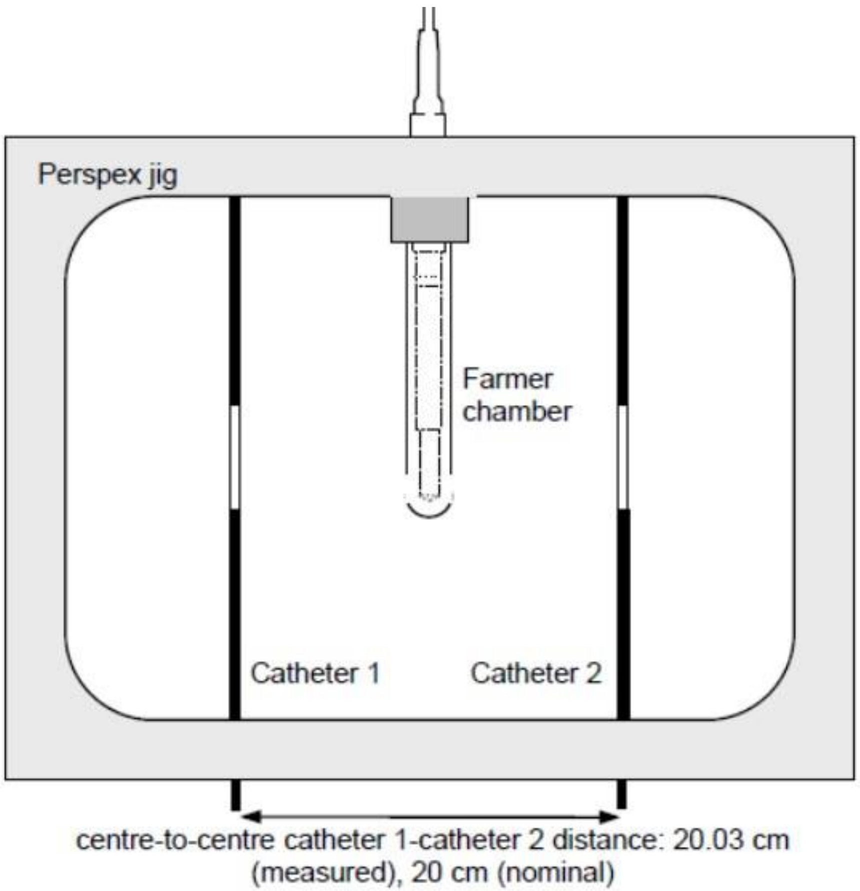


Figure 1. *Schematic overhead view of the Nucletron (Nucletron B.V., Veenendaal, The Netherlands) type 077.211 jig and Farmer chamber. Not to scale.*

Butler *et al. Australas Phys Eng Sci Med* **31** (2008) 332

Updates from other NMIs and SSDLs

- **CMI** (Czech Republic)
- Currently no BT calibration service offered. No demand.
- Hospitals are required to buy BT sources with certificates from manufacturers. No independent check.
- Auditing service is provided by another regulatory authority, using an external ionisation chamber that is calibrated at CMI in N150 and ^{137}Cs beams.

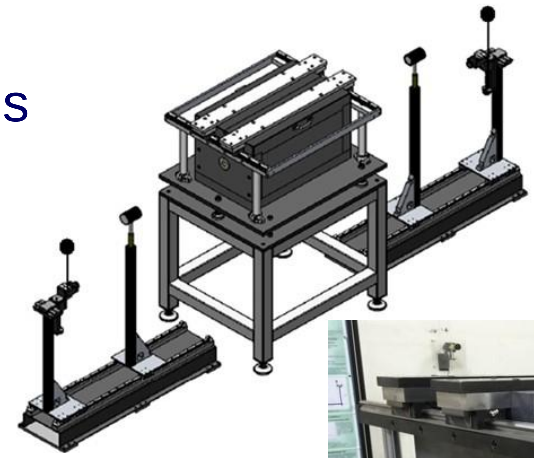
- **DTU** (Denmark)
- Currently no BT calibration service offered.
- Research on fibre-coupled luminescence for *in vivo* dosimetry.

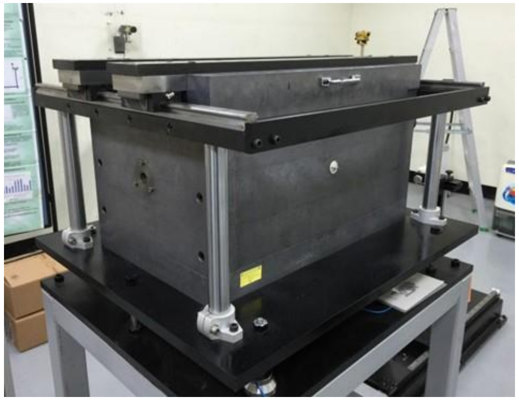
Updates from other NMIs and SSDLs

- **IAEA** (International organisation)
- Calibrations of well-type ionisation chambers in terms of K_R for HDR ^{192}Ir, HDR ^{60}Co and LDR ^{137}Cs using Bebig sources.
- LDR and HDR well-type chambers and sources traceable to PTB.
- HDR service established in 2017.
- ^{60}Co bilateral comparison with PTB (5/2017).
- ^{192}Ir comparison under APMP.RI(I)-K8 (9/2017).
- Bilateral ^{192}Ir comparison planned for 2018.
- Technical meeting on brachytherapy at the IAEA (11/2017).

Updates from other NMIs and SSDLs

- **INER** (Chinese Taipei)
- Calibrations of well-type ionisation chambers in terms of K_R for HDR ^{192}Ir.
- $U\left(N_{K_R}\right) \sim 0.74\% \ (k = 1)$
- Primary standard for HDR ^{192}Ir sources based on two spherical ionisation chambers designed and built at INER.
- Lead collimator with two adjacent apertures.
- Planning to build HDR absorbed dose standard in the future.

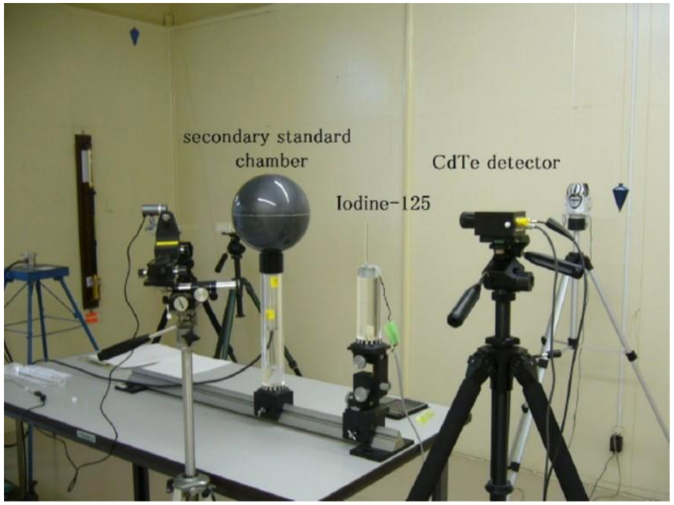




Updates from other NMIs and SSDLs

- **JRIA and NMIJ** (Japan)
- **JRIA:** Calibrations of LDR ^{125}I and HDR ^{192}Ir sources in terms of K_R with secondary standards.
- Well chamber calibration (HDR ^{192}Ir)

$U(N_{K_R}) \sim 1.1\% \; (k = 1)$ JRIA
$U(N_{K_R}) \sim 0.6\% \; (k = 1)$ NMIJ

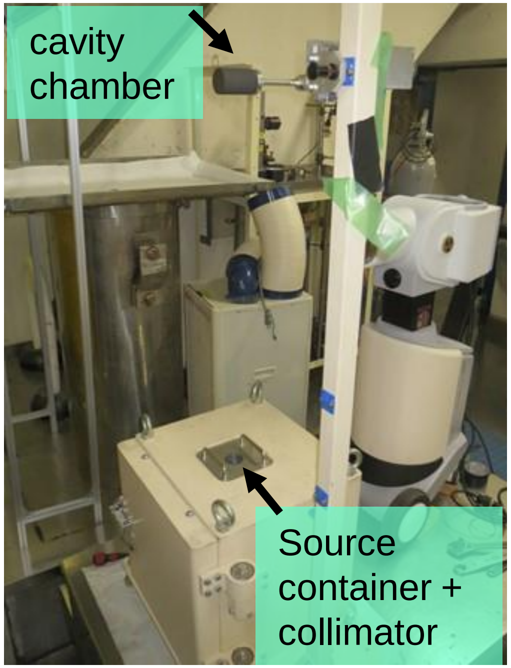


- **NMIJ:** K_R primary standard cavity chamber for HDR ^{192}Ir (microSelectron-v2).
- Participated in BIPM.RI(I)-K8 key comparison.

Kessler *et al*. *Metrologia* **53** (2016) Tech. Suppl. 06001

- K_R primary standard FAC for LDR ^{125}I

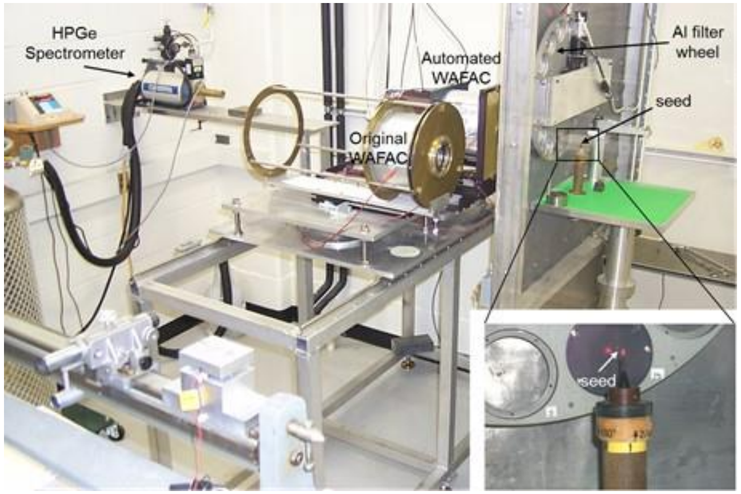
$U(\dot{K}_R) \sim 1.05\% \; (k = 1)$



Updates from other NMIs and SSDLs

- **NIST** (USA)
- Wide-Angle Free-Air Chamber for LDR ^{125}I, ^{103}Pd, ^{131}Cs seeds (air kerma strength); seed calibrations

  $U(S_K) \sim 0.8\% \dots 2\%\ (k = 1)$

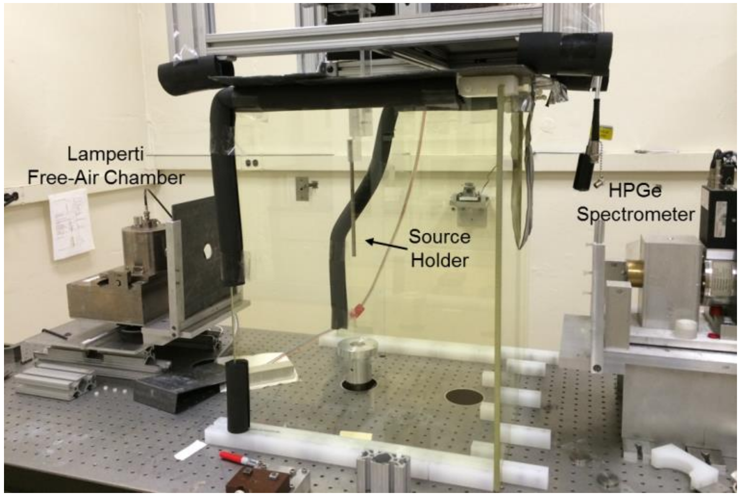


- Graphite-Walled Cavity Chambers; Spherical Aluminium Cavity and Re-Entrant Chambers for LDR ^{192}Ir, ^{137}Cs sources (air kerma strength); source calibrations

  $U(S_K) \sim 1\%\ (k = 1)$

- Lamperti Free-Air Chamber for Xoft HDR electronic brachytherapy source (air-kerma rate in air at 50 cm); well chamber calibrations

  $U(N_{K_{50\ \mathrm{cm}}}) \sim 0.4\%\ (k = 1)$



Updates from other NMIs and SSDLs

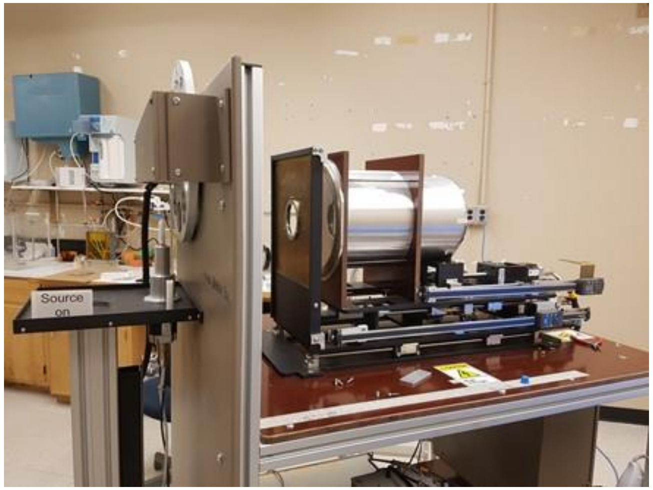
- **NIST** (USA) … continued
- New calibration service established in 2016
- Service ID 46012C: Well-ionisation chamber for one Model S700 electronic brachytherapy source
- Service ID 46013C: Each additional Model S700 electronic brachytherapy source submitted with same well-ionisation chamber for 46012C
- ref. https://www.nist.gov/calibrations/dosimetry-x-rays-gamma-rays-and-electrons-calibrations

Updates from other NMIs and SSDLs

- **NRC** (Canada)
- Wide-Angle Free-Air Chamber for LDR seeds (air kerma strength); seed calibrations to be launched soon

Scientific note *Med Phys* **43** (2016) 4106 reports a previously unnoticed polarity effect for this type of free-air chamber.

- Spherical graphite-walled ion chamber for HDR ^{192}Ir (air kerma strength); $^{\mathrm{Ir}}N_{\mathrm{K}}$ determined from arithmetic mean of the N_{K} value for ^{60}Co and narrow 250 kV X-rays.
- Fricke dosimetry to establish an absorbed-dose based primary standard for HDR ^{192}Ir
  $U(\dot{D}_{\mathrm{w}}) \sim 0.8\% \; (k = 1)$
- Calibration of well-type ionisation chambers for LDR and HDR sources in terms of S_K.
  $U(N_{S_{\mathrm{K}}}) \sim 1.5\% \; (k = 1)$ LDR
  $U(N_{S_{\mathrm{K}}}) \sim 0.6\% \; (k = 1)$ HDR



Updates from other NMIs and SSDLs

- **SSDL** (Thailand)
- Calibration of LDR and HDR sources with secondary standard well-type chambers in terms of air kerma strength.
- Traceability to IAEA.
- HDR ^{192}Ir source calibrations.

  $U(\dot{K}_{\mathrm{R}}) \sim 0.5\% \ (k = 1)$
- Some hospitals in Thailand use HDR ^{60}Co sources. Possibly expanding calibration service in the future.

- **SSM** (Sweden)
- Calibration of LDR ^{125}I and HDR ^{192}Ir sources with secondary standard well-type chambers in terms of K_{R}.
- Traceability to PTB (^{125}I) and NPL (^{192}Ir).
- On-site calibrations at hospitals (sources and chambers)
- ^{125}I: $U(\dot{K}_{\mathrm{R}}) \sim 1.5\% \ (k = 1)$
- ^{192}Ir: $U(\dot{K}_{\mathrm{R}}) \sim 0.5\% \ (k = 1)$

Updates from other NMIs and SSDLs

- **ININ** (Mexico)
- LDR ^{137}Cs sources are calibrated in terms of S_K, according the protocol IAEA TEC DOC 1274 (2002).
- LDR ^{125}I seeds are calibrated in terms of S_K, according the protocol IAEA TEC DOC 1274 (2002), including additional k_{Tp} correction factor.
- HDR ^{192}Ir sources are calibrated in terms of RAKR, following the IPEM protocol (2010).

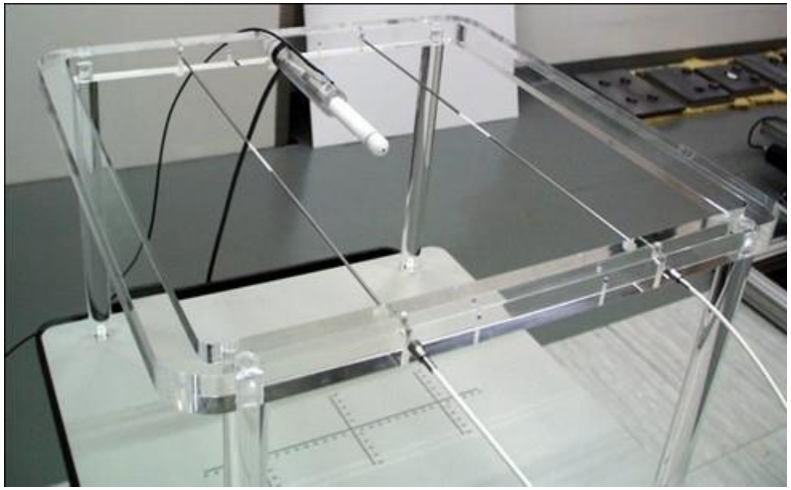
- **STUK** (Finland)
- Calibration service for HDR ^{192}Ir brachytherapy dosimetry is in a ”stand-by” position.
- SI 1000 Plus well chamber traceable to PTB (2005).
- Low demand for source calibrations at hospitals.
- Occasionally absorbed dose measurements with ionisation chamber in water phantom to verify D_{w}.

Dissemination of primary standard measurement

- **<u>Step 1:</u>** Calibration of BT source in terms of RAKR (Gy s^{-1} at 1 m)
- **<u>Step 2:</u>** Calibration of secondary standard ionisation chambers with calibrated source

Well-type ionisation chambers

Thimble chamber / jig combination



Source geometry factors k_{sg}
for SI 1000 Plus well chamber and 70010 source holder

- IPEM UK Code of Practice for HDR ^{192}Ir dosimetry: step-by-step guide of a hospital source calibration using a well-type ionisation chamber

Reference Air Kerma Rate (RAKR):

$$\dot{K}_R = M \cdot k_{ion} \cdot k_{sg} \cdot N_{\dot{K}_R}$$

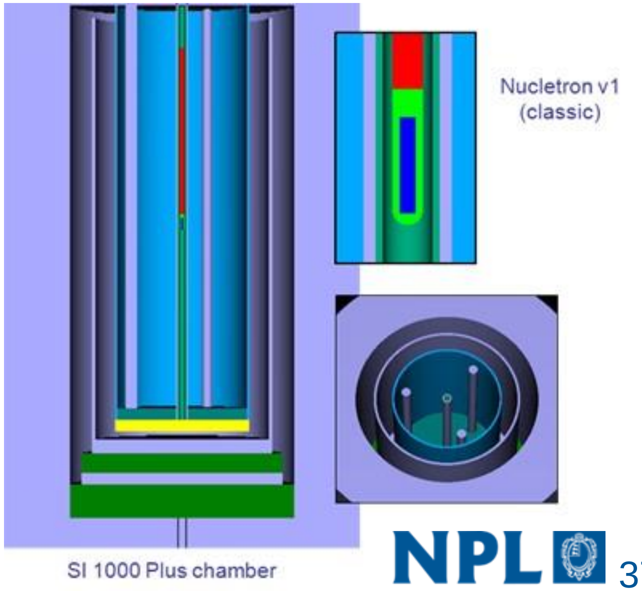
$N_{\dot{K}_R}$: **NPL** calibration coefficient (Gy C^{-1})

Source geometry factor:

$$k_{sg} = \frac{\left(N_{\dot{K}_R}\right)_{Hosp}}{\left(N_{\dot{K}_R}\right)_{NPL}} = \frac{\left(\dot{K}_R \big/ M \cdot k_{ion}\right)_{Hosp}}{\left(\dot{K}_R \big/ M \cdot k_{ion}\right)_{NPL}}$$

- Standard Imaging 1000 Plus + 70010 source holder
- Six HDR ^{192}Ir source types considered
- *cavity* (EGSnrc) : RAKR & max chamber response
- Model validation:
  - sources: radial dose function *g(r)*, dose rate constants (cf: CLRP TG-43 database)
  - chamber model: measured response curves

Shipley *et al. Phys Med Biol* **60** (2015) 2573



Source geometry factors k_{sg}: SI 1000 Plus + 70010 insert

HDR ^{192}Ir Source type	k_{sg}	Change to NPL calibration coefficient (%)
Nucletron microSelectron v1 (classic)	1.000	–
Nucletron microSelectron v2	0.999 ± 0.004	– 0.1
BEBIG GI192M11	0.999 ± 0.004	– 0.1
GammaMed Plus	0.996 ± 0.004	– 0.4
Isodose Control Flexisource	0.996 ± 0.004	– 0.4
Varian VariSource VS2000	0.983 ± 0.004	– 1.7

- Uncertainties: $N_{\dot{K}_R}$: 0.8% (k = 2) , k_{sg} : 0.4% (k = 2)

NNUH: Varian VS2000: two RAKR **measurements**:

- Thimble chamber / calibration jig + well chamber
- Calibrated against NPL HDR ^{192}Ir primary standard

$$k_{sg} = 0.985 \pm 0.008 \ (k = 2)$$

UWADCL: used MCNP5 (SI 1000 Plus)

$$\frac{\left(N_{\dot{K}_\mathrm{R}}\right)_{\mathrm{Nucletron\ v1}}}{\left(N_{\dot{K}_\mathrm{R}}\right)_{\mathrm{Varian\ VS2000}}} = 0.982$$

Rasmussen et al. *Med Phys* **38** (2011) 6721

Well chamber with Varian VS2000 afterloader at NNUH

NPL National Physical Laboratory

BIPM HDR ^{192}Ir key comparison

Bureau International des Poids et Mesures

Home | Key and supplementary comparisons | Calibration and Measurement Capabilities - CMCs

Home > Comparisons Search > Results of the search > Information

Key and supplementary comparisons - Information

KCDB

BIPM.RI(I)-K8

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- Information
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- Participants
- Results
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Information

Metrology area, branch	Ionizing Radiation, Section I (x and gamma rays, electrons)
Description	Measurement of reference air kerma rate for HDR Ir-192 brachytherapy sources
Time of measurement	2009 -
Status	Ongoing, approved for equivalence, Results available
Reference(s)	BIPM.RI(I)-K8 Technical protocol
Measurand	Reference air kerma rate (in mGy/h) relative to the BIPM evaluation
Parameter(s)	Radiation type: HDR Ir-192 sealed brachytherapy sources
Transfer device(s)	BIPM ionization chambers: well-type and thimble-type
Comparison type	Key comparison
Consultative Committee	CCRI (Consultative Committee for Ionizing Radiation)
Conducted by	BIPM (Bureau International des Poids et Mesures)

Related links

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- KCDB FAQs
- KCDB Reports
- CIPM MRA
- JCRB
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Contact us

- BIPM.KCDB@bipm.org

APMP HDR ^{192}Ir key comparison

Key and supplementary comparisons - Participants

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APMP.RI(I)-K8

Participants

IAEA	International Atomic Energy Agency *International Organization*
INER	Institute of Nuclear Energy Research *Chinese Taipei*, APMP
KRISS	Korea Research Institute of Standards and Science *Korea, Republic of*, APMP
NMIJ AIST	National Metrology Institute of Japan *Japan*, APMP
NMISA	National Metrology Institute of South Africa *South Africa*, AFRIMETS
NRC	National Research Council *Canada*, SIM
Nuclear Malaysia	Malaysian Nuclear Agency *Malaysia*, APMP

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BIPM

Conclusions

- Air kerma and absorbed dose primary and secondary standards for LDR and HDR BT sources widely available worldwide.
- BT photon source calibrations mainly in terms of K_R or S_K.
- Absorbed dose standards can be used together with K_R standards to measure dose rate constant.
- Source geometry factors for well chamber calibrations should be calculated for different combinations of calibration source **/** well chamber **/** source holder **/** hospital source.
- Key comparison for HDR ^{192}Ir offered by BIPM since 2009 (ongoing)

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