IAEA Dosimetry Laboratory

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Vienna, Austria

IAEA
International Atomic Energy Agency

CIRMS Annual meeting, April 17-19 2023

Content

- Brief history
- Services provided to the member states
- Calibration capabilities
- Robotic calibration bench

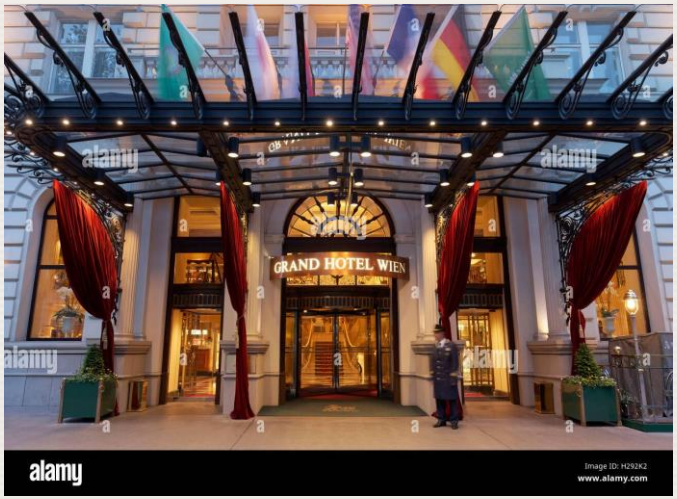
International Atomic Energy Agency

- 8-Dec-1953 Eisenhower Proposes a New Agency (address to the General Assembly)
- 1954 – 1956 Negotiation of the IAEA's Statute (approved by 81 nations in October 1956)
- 1957 – The Preparatory Commission and the First General Conference
- 11-Dec-1957 Headquarters Agreement between Austria and the IAEA

International Atomic Energy Agency

Ring Hotel, Vienna

The IAEA established in 1957 in response to the deep fears and expectations generated by discoveries and diverse use of nuclear technology



International Atomic Energy Agency

Vienna International Centre (VIC)
Since 1979
international organizations
UNOV, CTBTO, UNODC, IAEA,
UNIDO, UNHCR …

Why the IAEA got involved in radiation dosimetry?

In late 50s

- Only a few primary standards dosimetry laboratories, no national dosimetry laboratories in many industrialized countries, no calibration laboratories in developing countries
- No dosimetry standards for absorbed dose determination in radiotherapy
- No dosimetry protocols to guide physicists on radiotherapy beam calibration
- No inter-institution dosimetry comparisons
- Lack of medical physicists in many radiotherapy centres

International Atomic Energy Agency

Experts and IAEA staff, 1959-1960: M. Cohen, K.C. Tsien, G. Roth, A. Sanielevici, R.Wideroe,.B. Gross, H. Nagl, F. Ellis, J. Meredith, H. Johns, M. Tubiana, A. Dutreix, W. Seelentag and others

Establish a dosimetry programme at the IAEA and Dosimetry Laboratory for its implementation

- ✓ *Prepare a basic manual for radiotherapy dosimetry and organize training courses in radiotherapy physics*
- ✓ *Create regional dosimetry laboratories to standardize radiation measurements*
- ✓ *Make inter-comparisons of dose measurements*

IAEA

IAEA laboratories in Seibersdorf, Austria

1959

IAEA Laboratories, Seibersdorf

…facilitating research, capacity building and technical services.

Insect Pest Control

Food and Environmental Protection

Terrestrial Environment

Nuclear Sciences and Instrumentation

Plant Breeding and Genetics

Soil and Water Management and Crop Nutrition

Animal Production and Health

Dosimetry

IAEA

IAEA Nuclear Applications Laboratories

Monaco

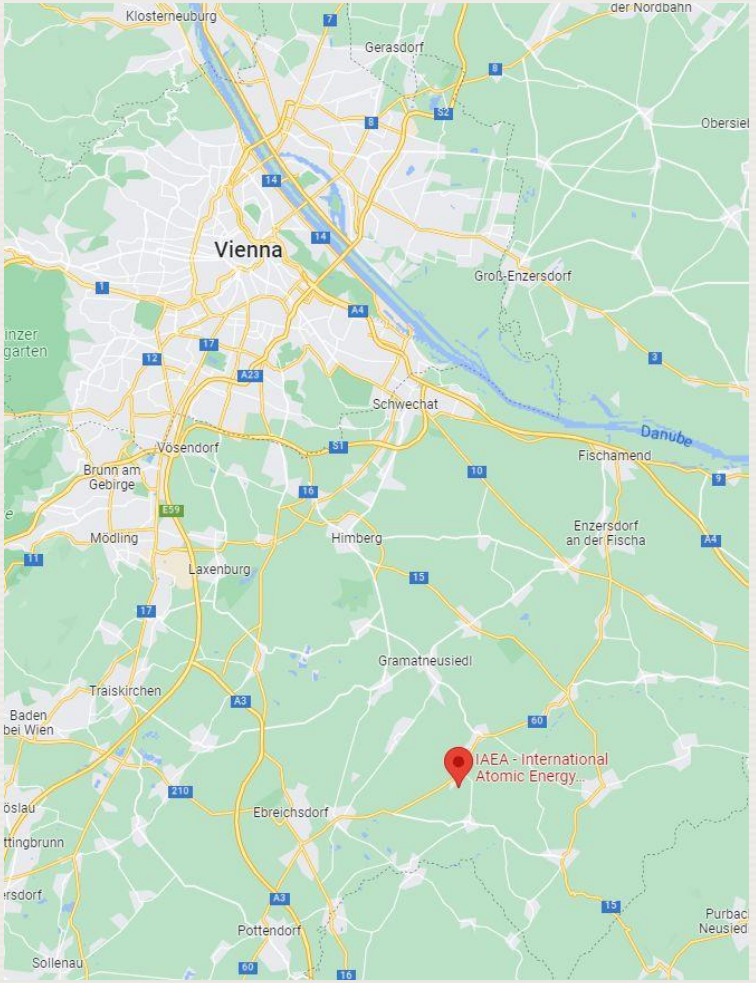
Vienna

Seibersdorf, Austria

IAEA Laboratories, Seibersdorf

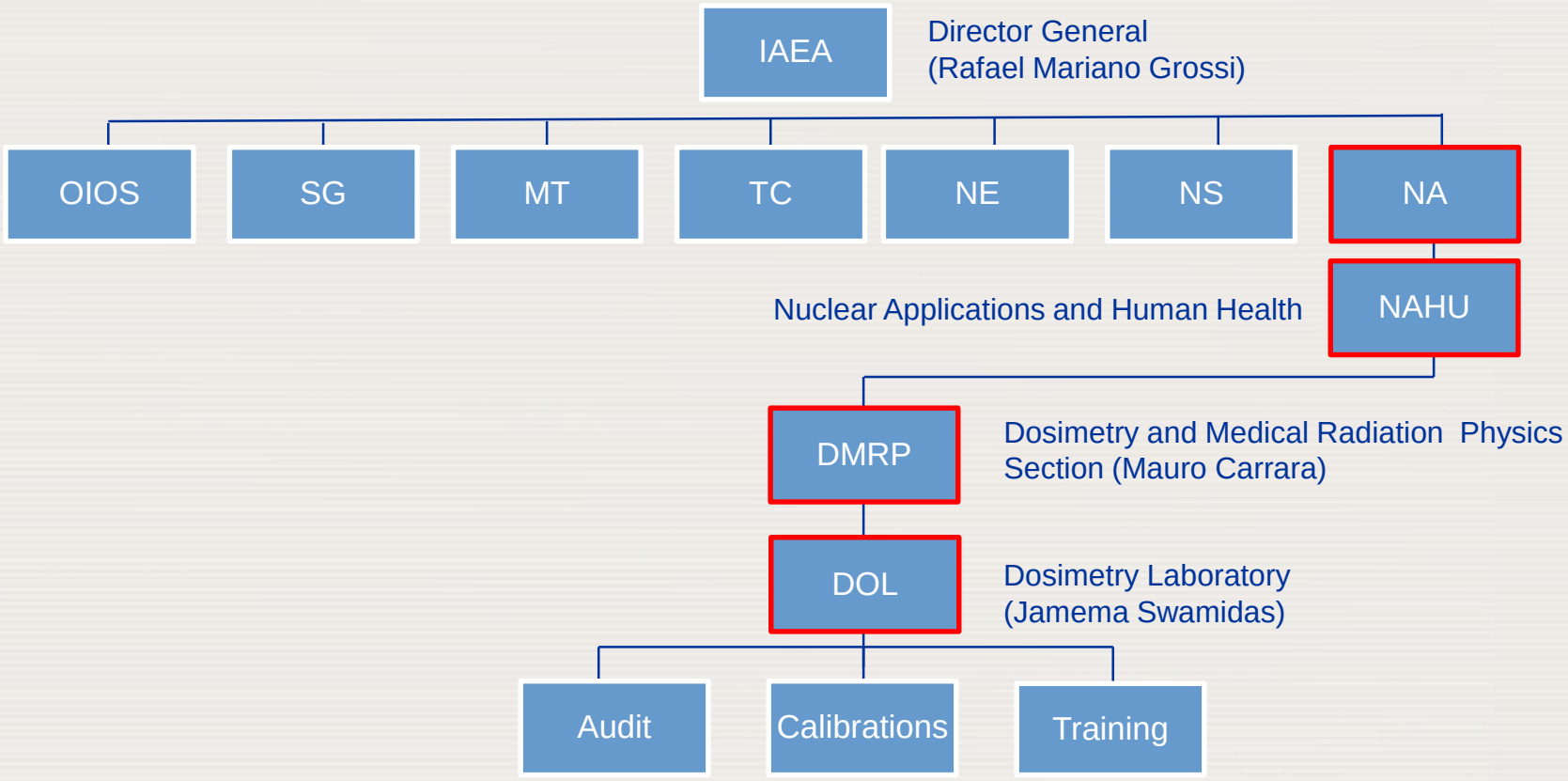
40 km SE of Vienna

within the compound of AIT
(Austrian Institute of Technology)



IAEA Dosimetry Laboratory

IAEA Dosimetry Laboratory



DMRP – Section Heads

H. Eisenlohr, 1971-1987

H. Svensson, 1987-1994

P. Andreo, 1995-2000
2003-2008

- 1960-1961: setting-up the Dosimetry Laboratory
- 1961-1966: dose comparison measurements for radiotherapy (calorimetry, Fricke dosimetry)
- 1969: 1st documented IAEA/WHO TLD audit run for radiotherapy centres
- 1970: 1st international dosimetry protocol by the IAEA, TRS-110
- 1974: 1st regional dosimetry laboratories supported by WHO/IAEA
- 1976: formal launch of the IAEA/WHO SSDL Network with 8 SSDLs and affiliated organizations (BIPM, ICRU, IEC, OIML, IOMP, 11 PSDLs)
- 1987: SSDL Scientific Committee, TRS-277
- 1999: IAEA signs CIPM Mutual Recognition Arrangement (MRI)
- 2000: TRS-398 Dosimetry Code of Practice

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DMRP – Section Heads

H. Eisenlohr, 1971-1987

H. Svensson, 1987-1994

P. Andreo, 1995-2000
2003-2008

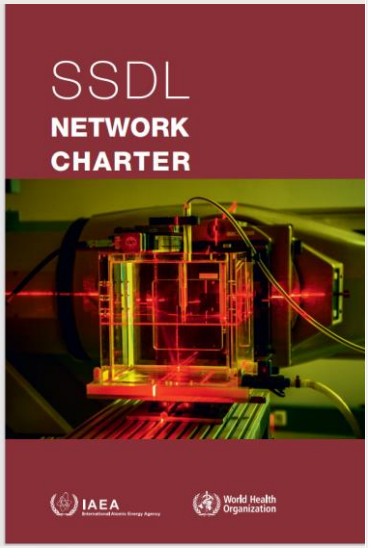
K.R. Shortt, 2001-2007

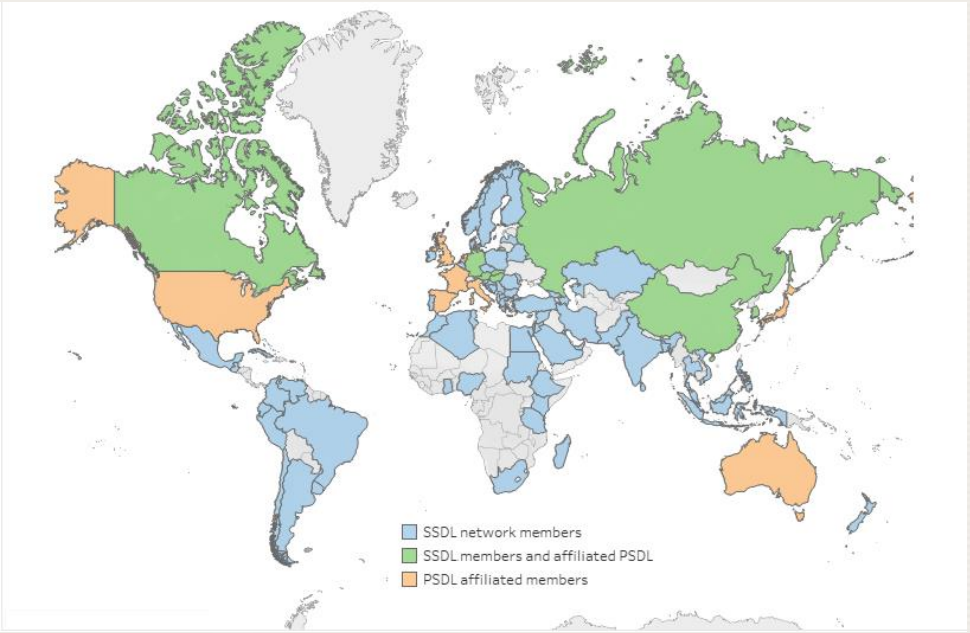
A. Meghzifene, 2007-2016

D. Van der Merwe, 2017-2022

M. Carrara, 2023 -

IAEA / WHO Network of SSDLs





- Membership: 90 labs in 75 Member States.
- IAEA is the central laboratory of the IAEA/WHO SSDL Network.

- Objective of the network
  - Accurate and consistent dosimetry
  - Traceability
  - Cooperation
  - Sustainability

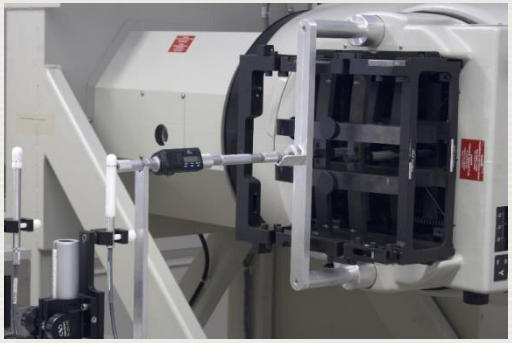
IAEA services provided to the SSDL Network:

- Disseminating traceability: calibration of reference standards from SSDLs
- Measurement validation: comparisons and audits of performance
- Training, workshops, scientific meetings

IAEA Dosimetry Laboratory

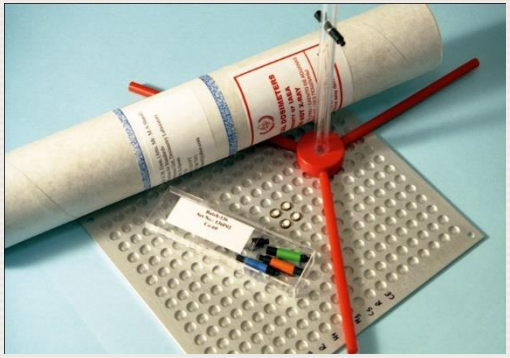
IAEA/WHO SSDL Network

- Dosimetry calibrations
- Inter-laboratory comparisons and audits of performance



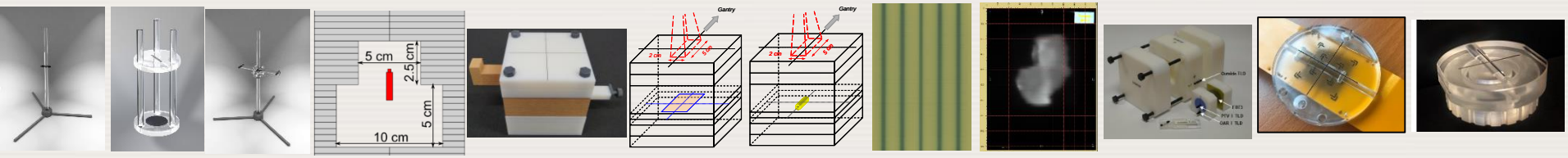
Dose Assurance Service

- IAEA/WHO Dosimetry Audit Network
- Support to national audit Networks
- Support to QUATRO



IAEA Audits in radiotherapy

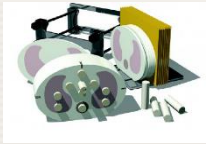
REMOTE: RPLD and film-based audit methodologies of increased complexity: “Steps 1 to 9”



15 Dosimetry audit networks participated on different stages of the project implemented through 4 consecutive CRPs

ON-SITE: QUATRO/QUATRO-physics 3D CRT audits IMRT audits

51 Member States
101 QUATRO missions



8 Member States
60 RT centres

17 Member States

1969: First TLD sent to hospitals
1981: Audit offered to SSDLs
1991: First Linac beam audited
1996: Follow-up of poor results
2004: Quality Assurance Team for Radiation Oncology
2008: On-site TPS end-to-end audits
2017: RPLD-based remote audits, Small field photon beam.
2018: On-site IMRT/VMAT end-to-end audits
2019: Reference Irradiations for Dosimetry Audit Network.
2021: Electron audits
2024: Brachytherapy ?

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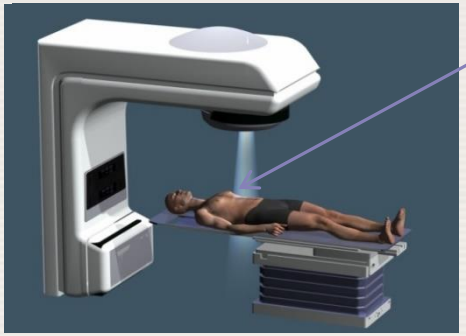
QUATRO missions

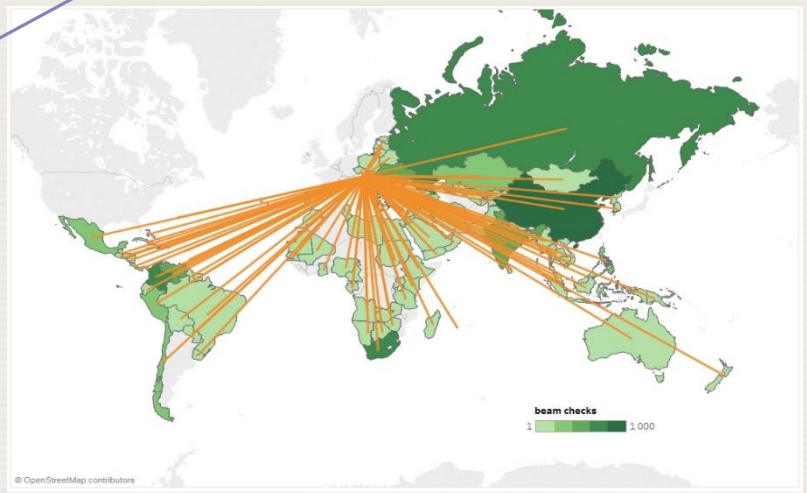
- QUATRO dosimetry kit contains DOL calibrated equipment as well as several sets of RPLDs for reference beam output check
- QUATRO standard dosimetry tests can be accompanied with 3D CRT or IMRT specific tests with anthropomorphic phantoms

Dose audits for radiotherapy centres

How is the audit carried out?

Radio-photoluminescence dosimeters are sent to radiotherapy centres for irradiation to verify the beam output used for patients' treatments.





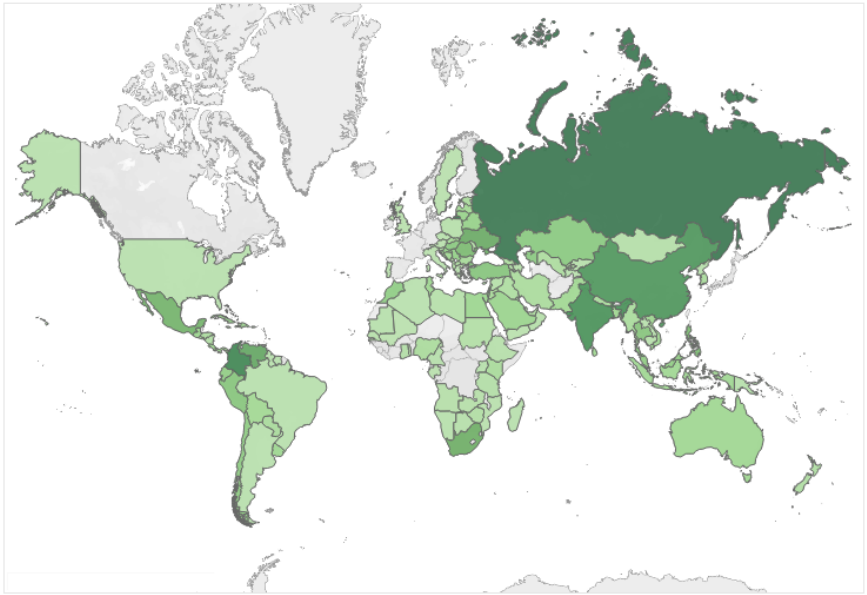
Dose audit service:

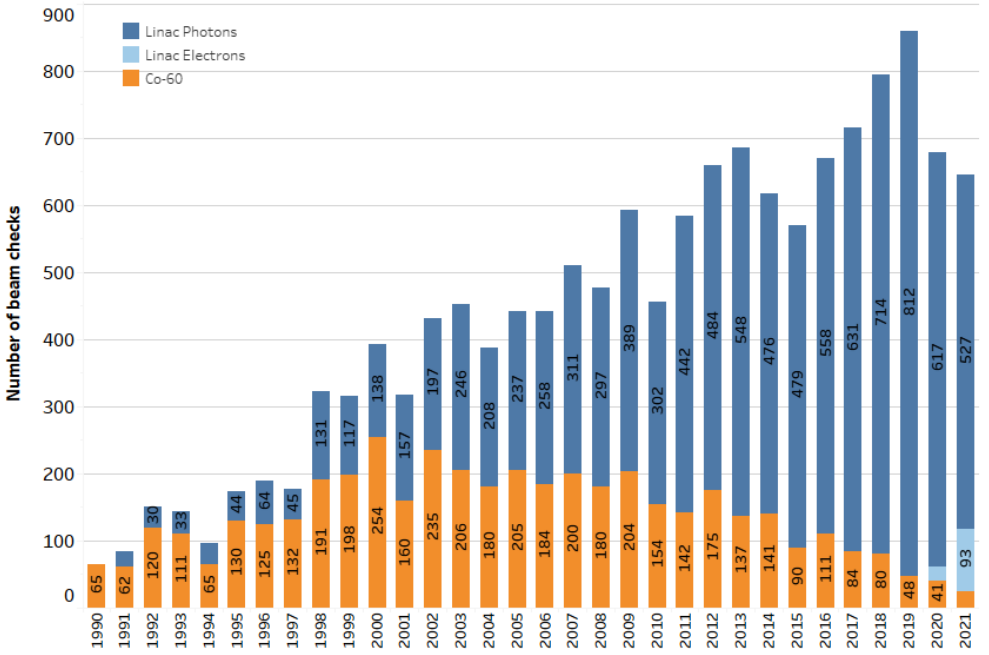
- 53 years of the IAEA/WHO postal dose audits (1969–2022)
- >16000 beam checks
- ~2500 radiotherapy centres in 140 Member States

Number of beam checks in hospitals

129	2203	10622	14095	1990
Countries	Hospitals	Units	Beam checks	Since

Number of beam checks

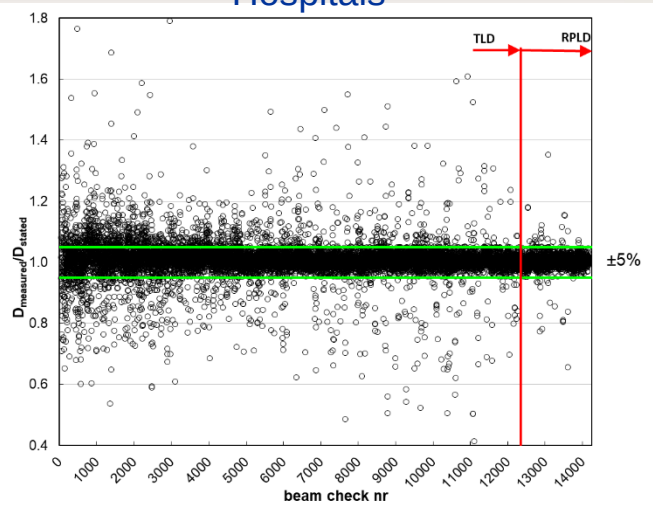




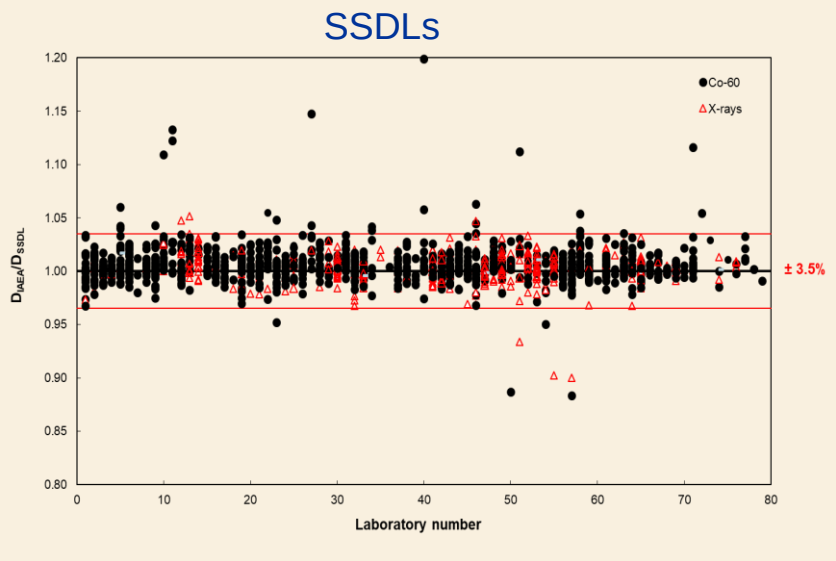
Dosimetry audits for hospitals and SSDLs

- RPLD-based: reusable, low fading, low volume averaging
- 10 audit runs per year (every month except for January and July)
- Photon beams only
- TRS 398 reference conditions

Hospitals



SSDLs



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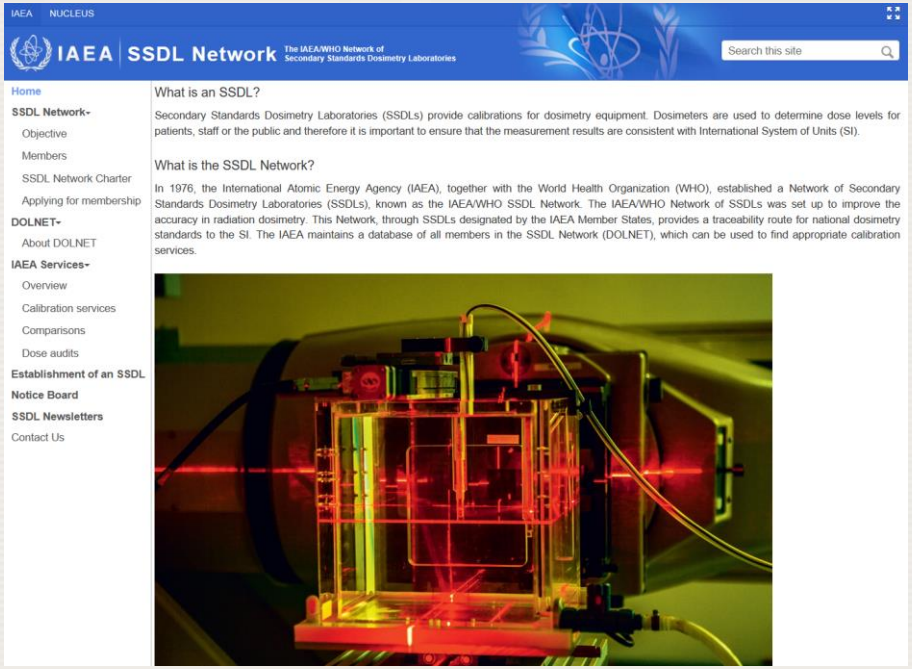
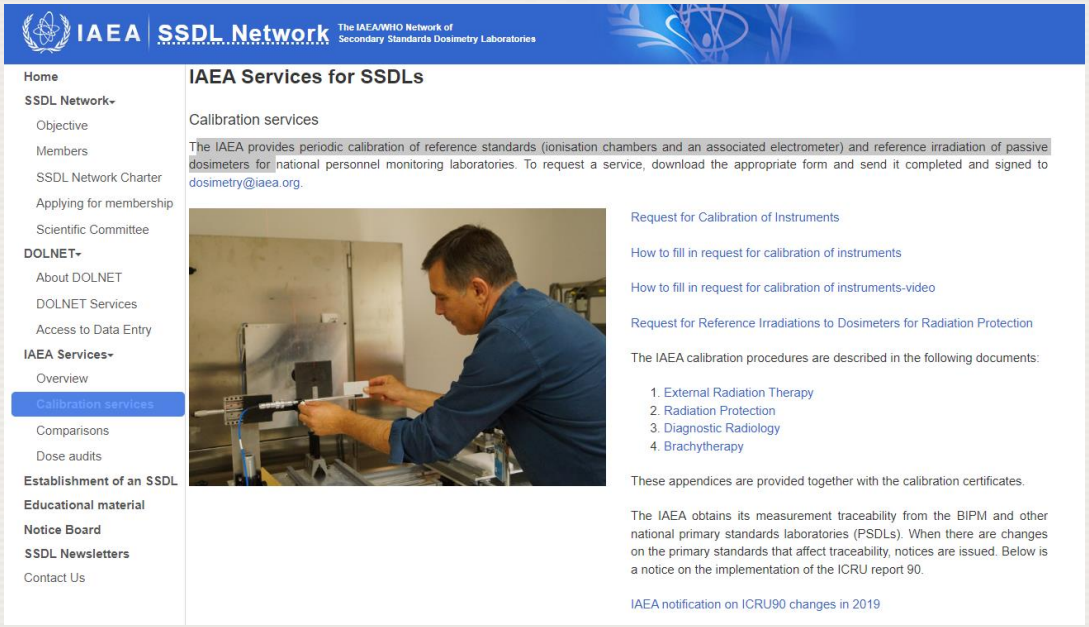
Comparison services provided to SSDLs

- Required in SSDL Charter
- Services cover
  Therapy, Protection, Diagnostics, Brachytherapy
- Protocols were published
- Can be used as a supporting evidence for publishing CMCs in the BIPM KCDB



Calibration services provided to SSDLs

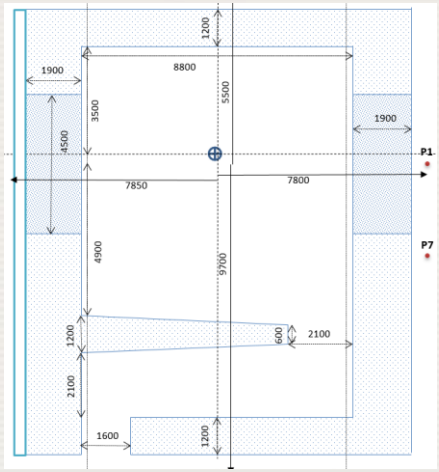
- The IAEA provides periodic calibration of reference standards (ionisation chambers and an associated electrometer) and reference irradiation of passive dosimeters for SSDLs
- Radiation therapy
- Radiation protection
- Diagnostics radiology
- HDR brachytherapy

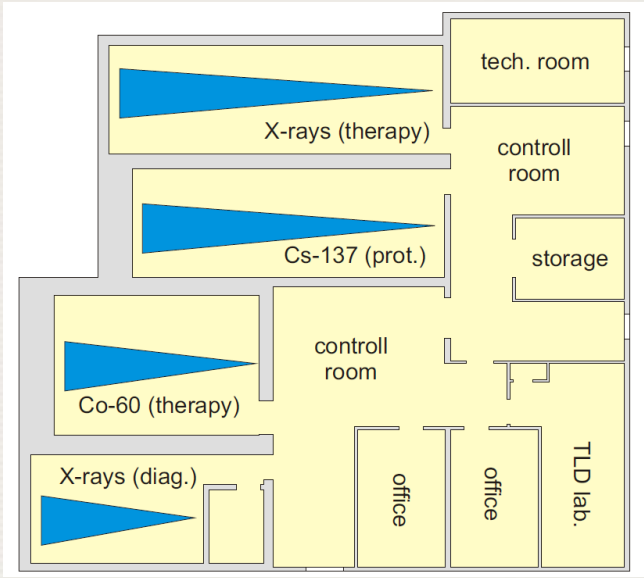


- CMCs published in the BIPM KCDB

Calibration facilities

- 5 irradiation rooms (bunkers)
  - Nordion Gammabeamm X200
  - 4 ISOVOLT x-ray units
  - Hopewell G-10 irradiator
  - Saginova HDR afterloader
  - Varian TrueBeam linac

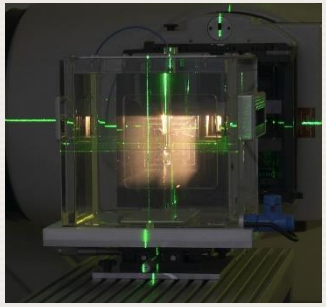


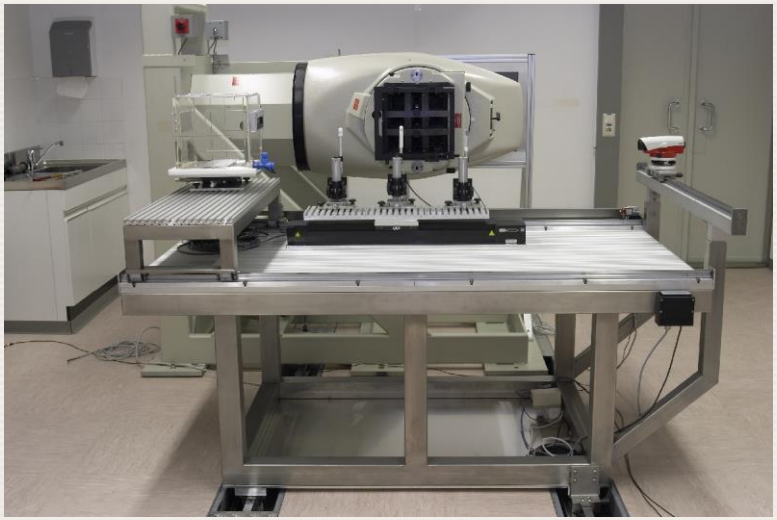


(drawings not to scale)

Calibration facilities – radiation therapy

- Gammabeam X200
  - Co-60 (8 kCi)
  - Air Kerma
  - Absorbed Dose to water
- ISOVOLT Titan
  - 10 – 50 kV (CCRI low en.)
  - 100 – 250 kV (CCRI med. en.)



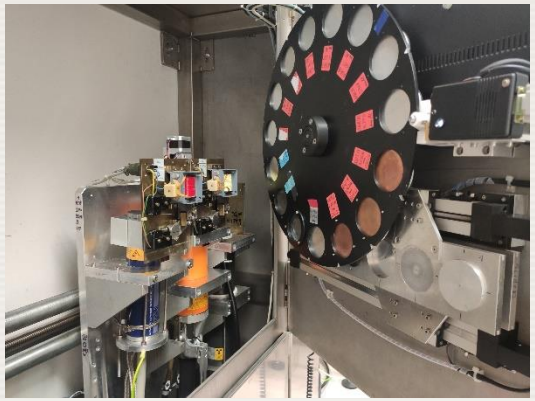


Calibration facilities – radiation protection

- Hopewell Designs G-10
  - Co-60, Cs-137
  - Air Kerma
  - Reference irradiations
- ISOVOLT Titan (G.E.) + Comet tubes
  - 40 – 300 kV (ISO4037 Narrow series)

Calibration facilities – diagnostic radiology

- ISOVOLT Titan (W tube, Mo tube)
  - 40 – 150 kV (RQR, RQA, RQT)
  - RQR/M, RQA/M, Mo+Rh, W+Al, W+Ag, W+Rh, W+Mo



The IAEA linear accelerator

- Installation and acceptance 2019
- Varian TrueBeam
  - photons
  - 6, 8, 10, 15, 18 MV
  - 2.5 FFF, 6 FFF, 10 FFF

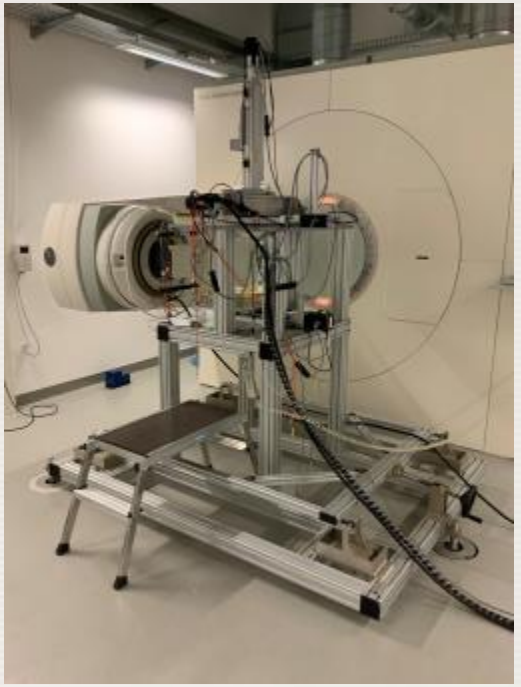
  - electrons
  - 6, 9, 12, 15, 16, 18, 20, 22 MV

The IAEA linear accelerator use

Other linear accelerator calibration set-up

BIPM

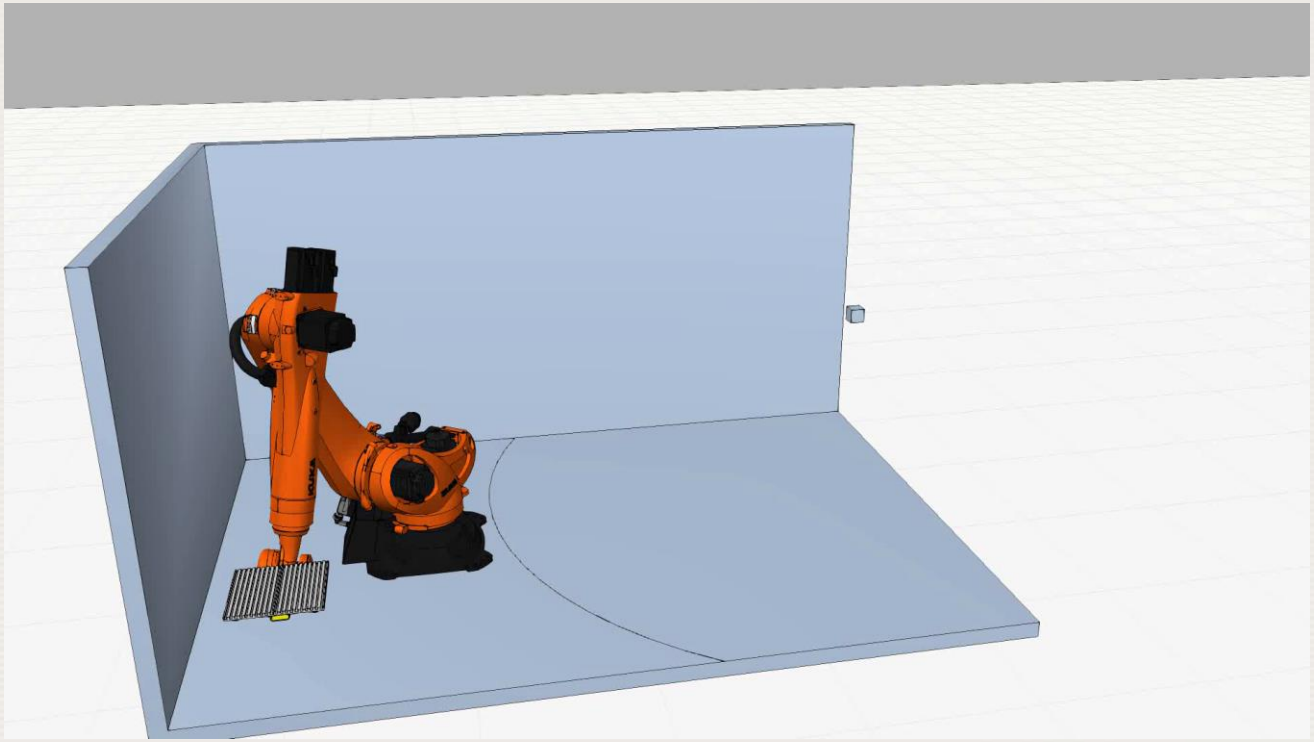
DTU, Denmark



PTB

Robotic Systems in Radiotherapy

Robotic calibration bench concept



Robotic concept selected to allow fast, easy and reproducible set-up

Robotic Calibration Bench System (RCBS)

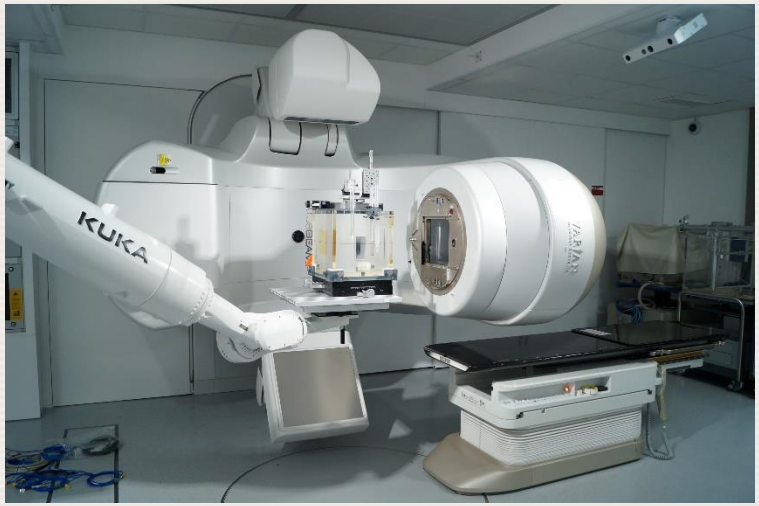
- Customized solution by B.E.C. GmbH
- KUKA KR150 R3100-2
  - KR150 R3100-2
  - KR C4 robot controller
  - KUKA smartPAD
- Positioning platform for water phantom
- Water phantom Minirad
- Newport linear stage UTS150-PP
- OptoSigma Cross Roller stage

Calibration set-up

- Horizontal set-up with RCBS (Kuka)
- FCD: 100 cm, FS: 10 x 10 cm, z_{ref} = 10 g/cm²

Calibration set-up

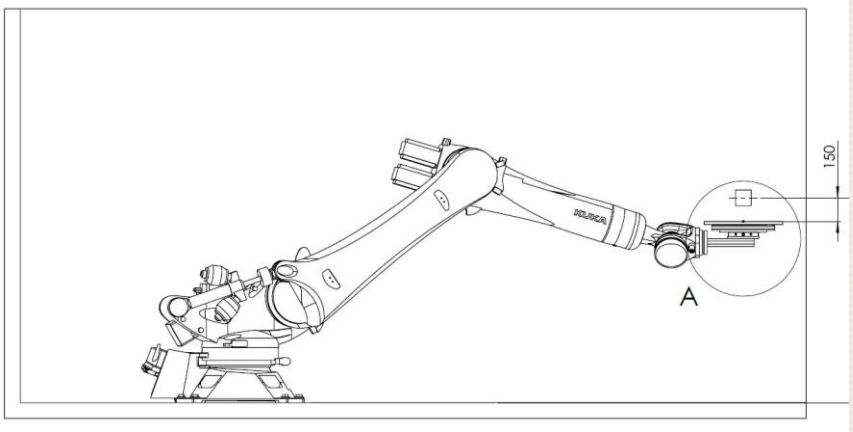
- Horizontal set-up with RCBS (Kuka)
- FCD: 100 cm, FS: 10 x 10 cm, z_{ref} = 10 g/cm²

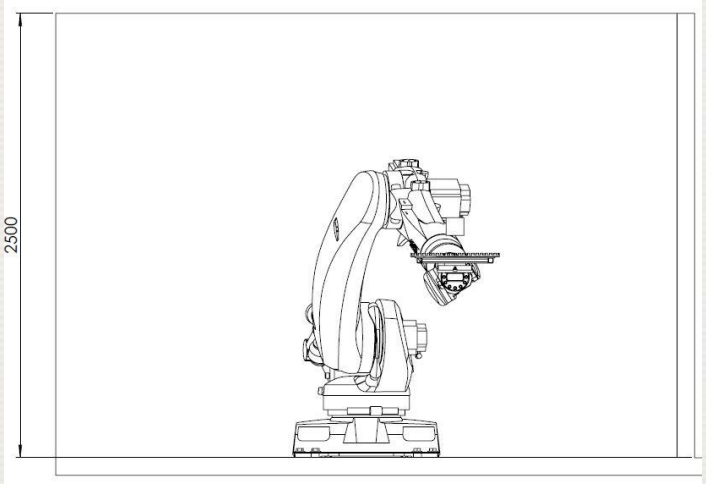


RCBS Commissioning

RCBS Commissioning - December 2019

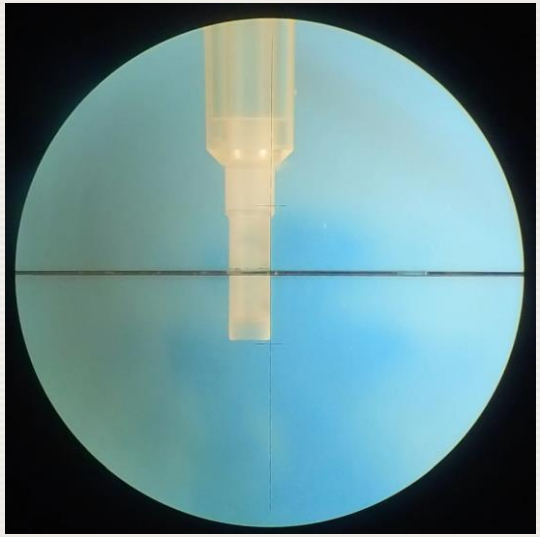
- Test of short- and long-term robot stability (with load)
- Test of the robot positioning reproducibility
- Development and test of software application for the linear stage of the water phantom
- Development of the set-up procedure

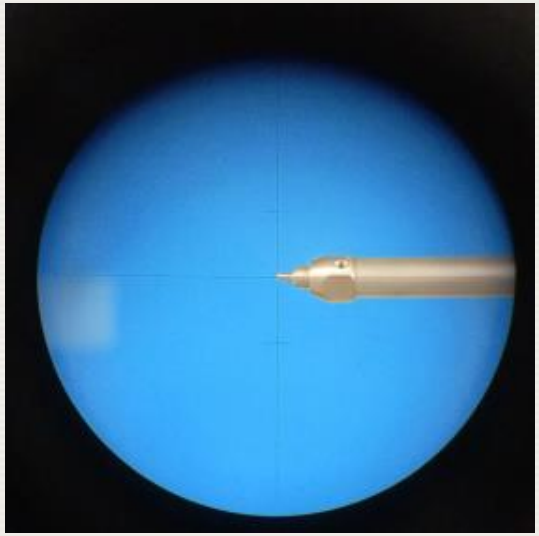




Long term stability of the robot

- Platform with the phantom positioned in the ISO center
- 50 kg load
- Telescope aligned with the well-defined surface (water-proof sleeve)
- Kept in position for 3 days
- No change of the position observed
- Platform stability better than 0.1 mm (resolution of the method)



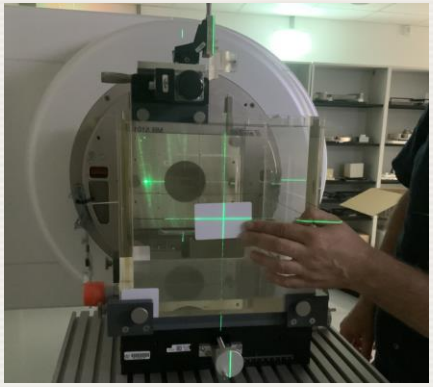


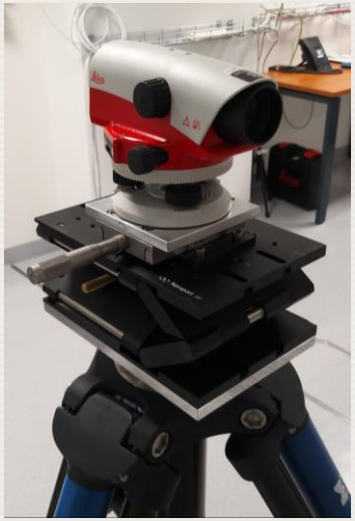
Positioning reproducibility

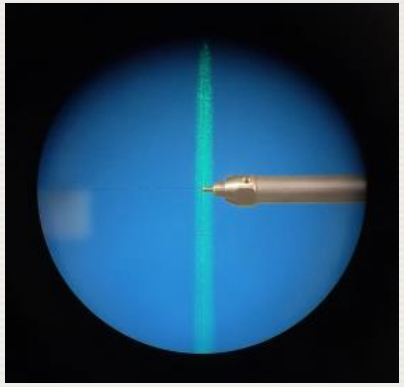
- Platform with the phantom positioned in the ISO center, 30 kg load
- Phantom aligned with the lasers
- Platform moved repeatedly 10x between
  - Parking position
  - loading position
  - ISO center position

Positioning reproducibility

- Platform with the phantom positioned in the ISO center, 30 kg load
- Phantom aligned with the lasers
- Platform moved repeatedly between
  - Parking position
  - loading position
  - Isocenter position
- By visual check reproducibility of the alignment with lasers <0.5 mm
- Reproducibility by micrometer (water-proof sleeve surface) <0.1 mm

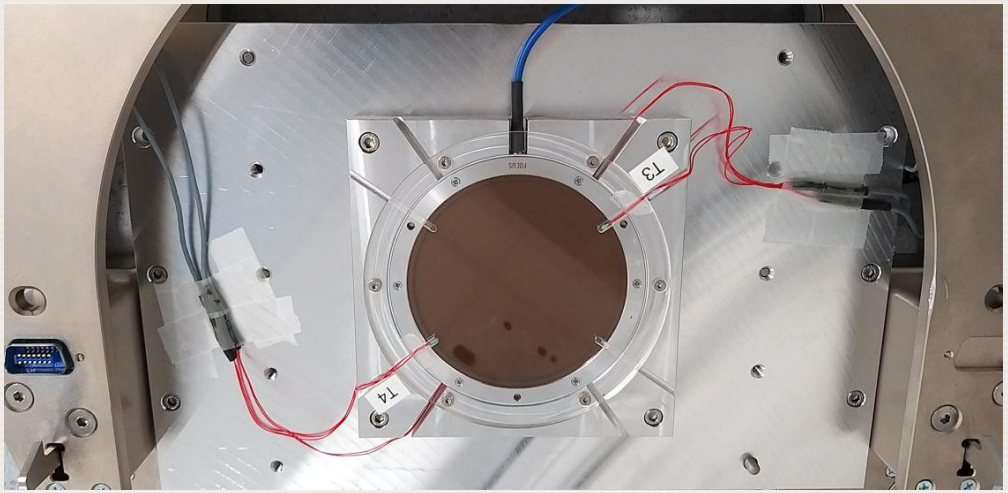


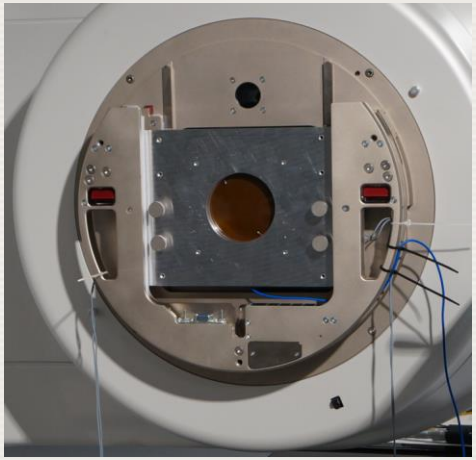


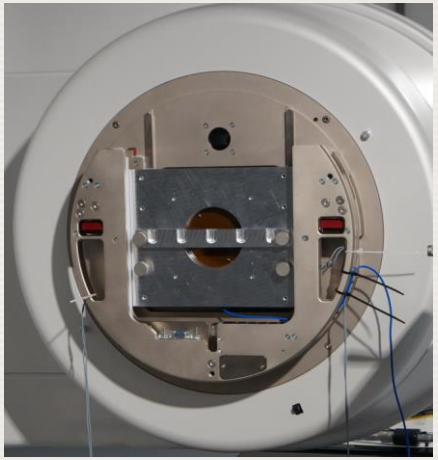


Transmission monitor PTW-7862 & thermistors

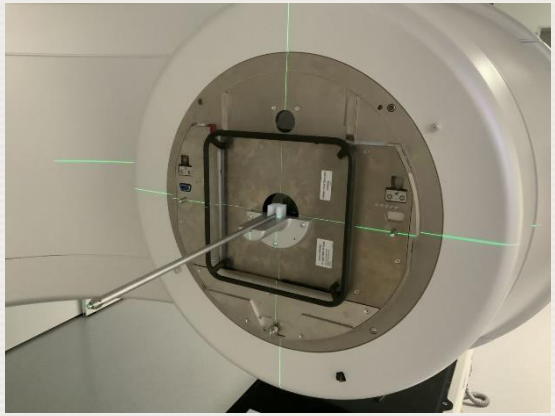
- PTW-7862
- 4 Ahlborn NTC thermistors

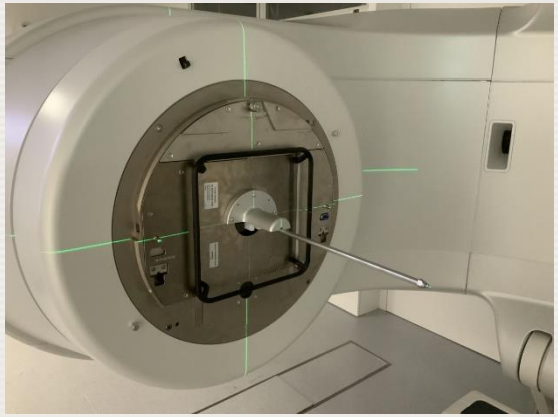


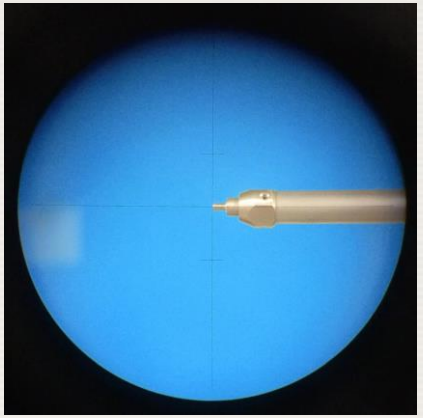


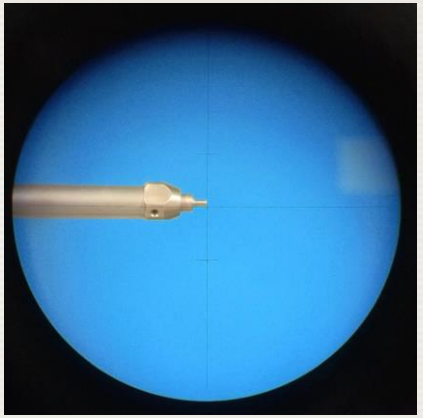


Set-up procedure - determination of the Isocenter

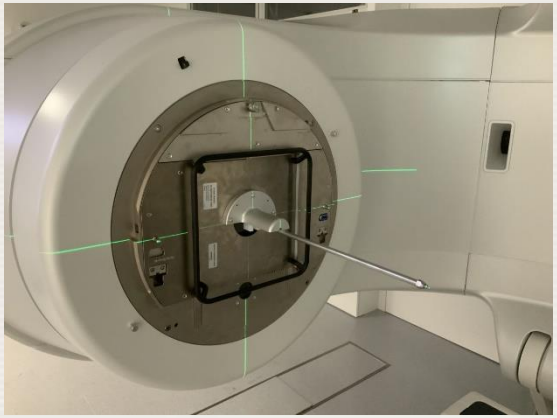


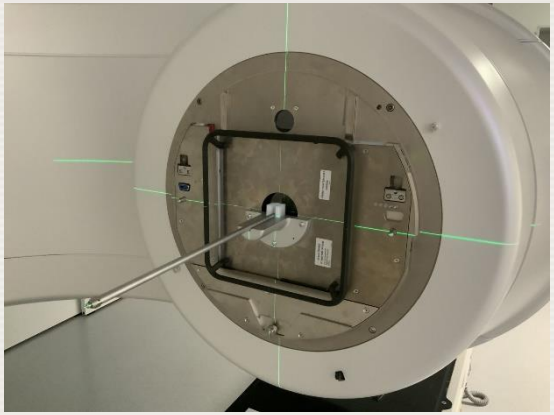


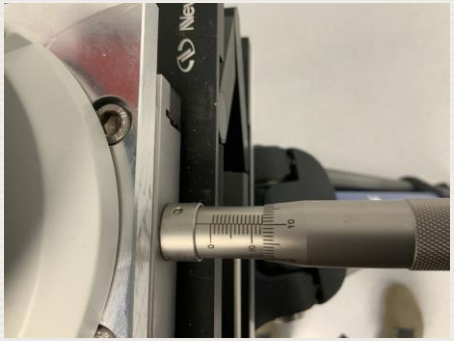




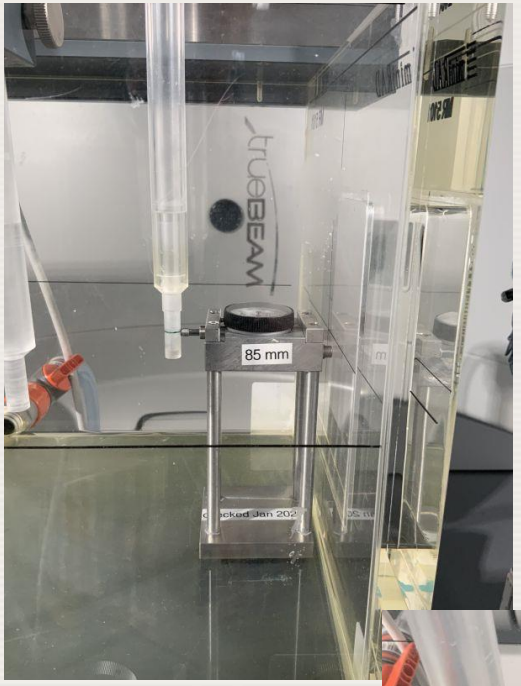
Set-up procedure - determination of the Isocenter

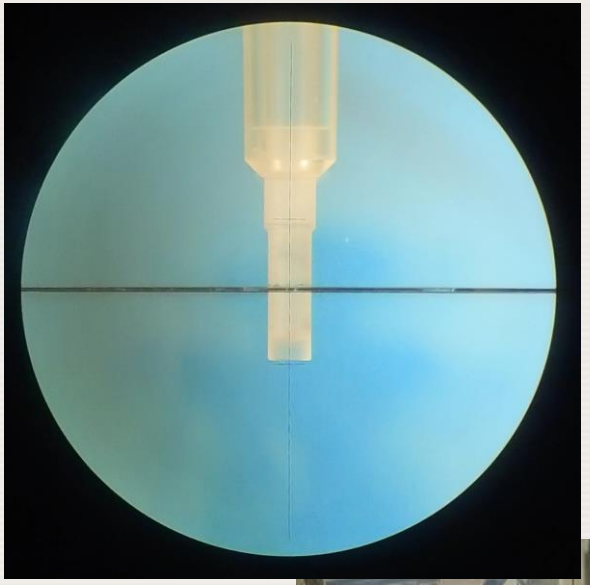


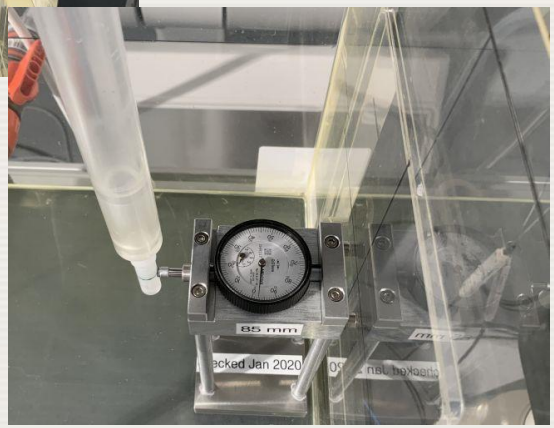




Set-up procedure - Chamber positioning at z_{ref}

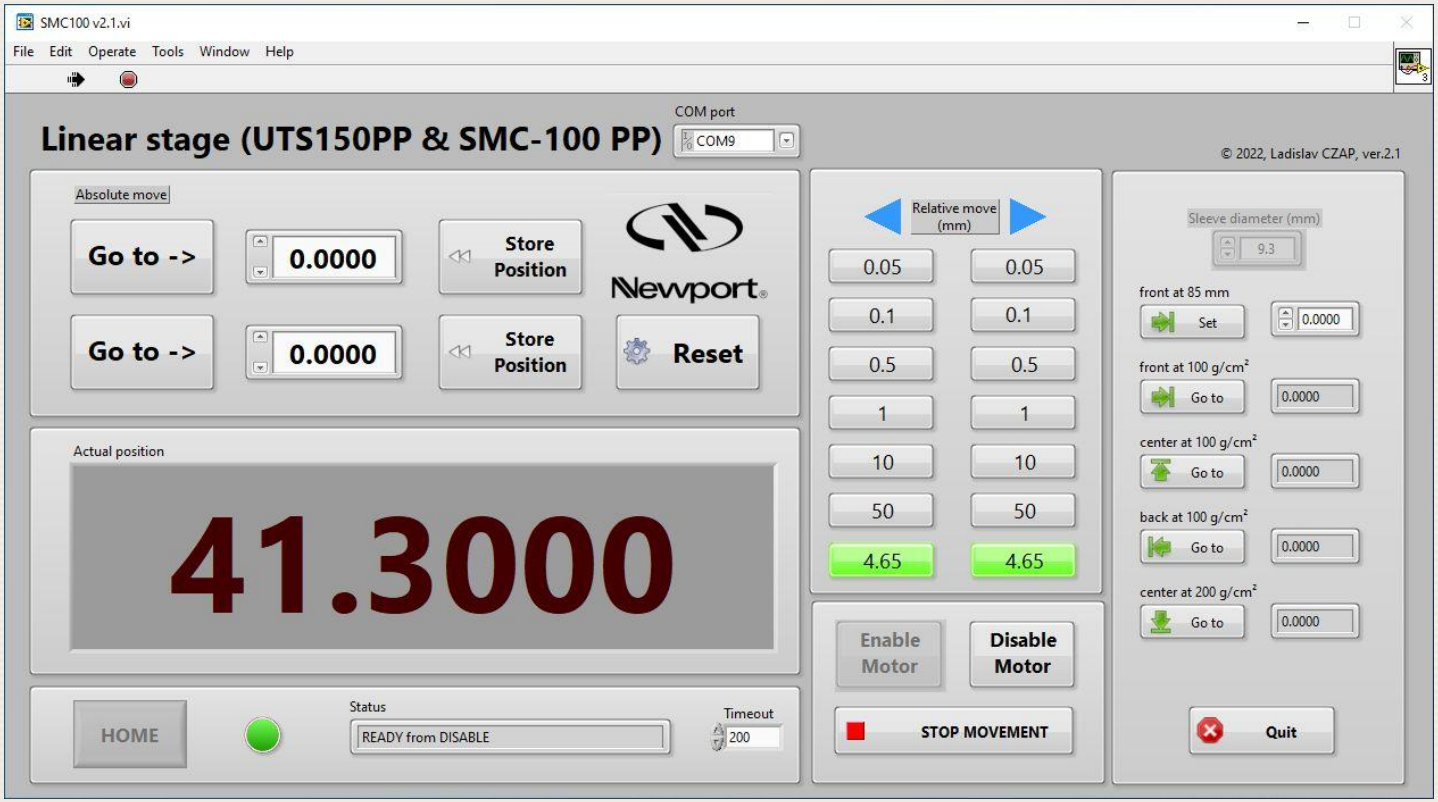






Software application for Newport linear stage

- Developed and tested (Labview platform)



IAEA chambers calibrated

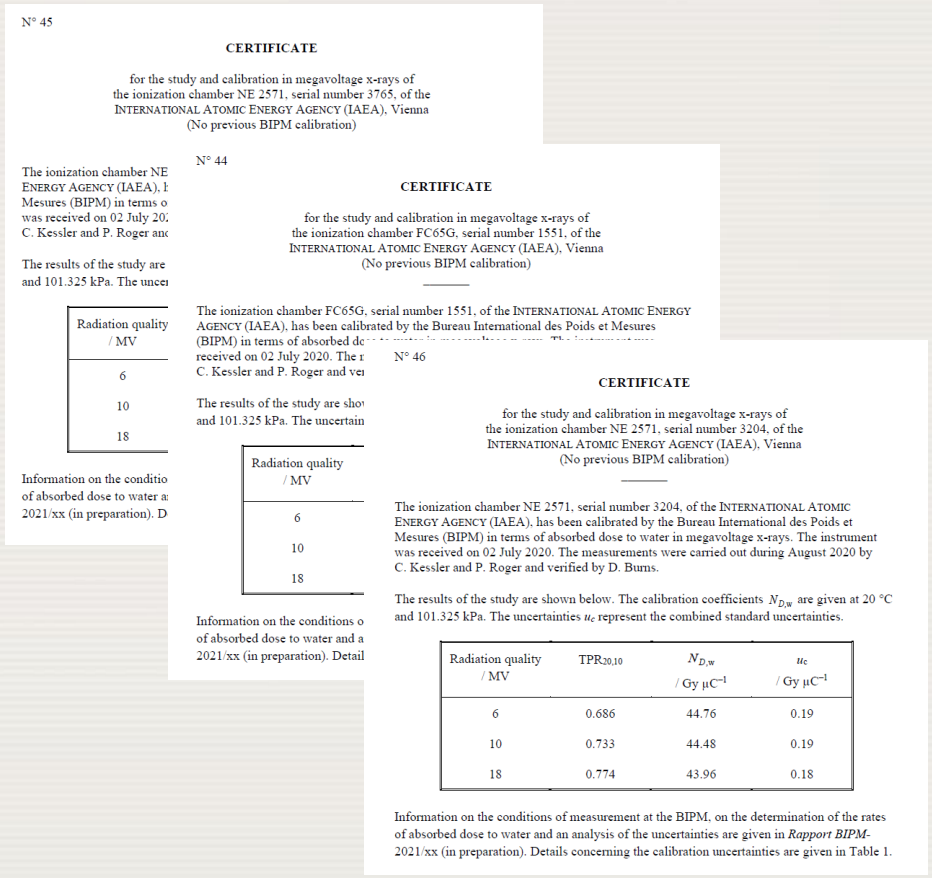
- The IAEA ionization chambers calibrated by the BIPM (Elekta)

- FC-65G (#1551)
  NE-2571 (#3765, #3204)

- Co-60 (TPR: 0.570)
- 6 MV TPR: 0.686
- 10 MV TPR: 0.733
- 18 MV TPR: 0.774

- $N_{D,w}$ u_c ~ 0.42% (k=1)

Validated by comparison (KRISS, PTB)
CMC to be published in KCDB



N° 45

CERTIFICATE

for the study and calibration in megavoltage x-rays of the ionization chamber NE 2571, serial number 3765, of the INTERNATIONAL ATOMIC ENERGY AGENCY (IAEA), Vienna
(No previous BIPM calibration)

The ionization chamber NE
ENERGY AGENCY (IAEA), I
Mesures (BIPM) in terms o
was received on 02 July 20
C. Kessler and P. Roger an

The results of the study are
and 101.325 kPa. The uncer

Radiation quality / MV
6
10
18

Information on the conditio
of absorbed dose to water a
2021/xx (in preparation). D

N° 44

CERTIFICATE

for the study and calibration in megavoltage x-rays of the ionization chamber FC65G, serial number 1551, of the INTERNATIONAL ATOMIC ENERGY AGENCY (IAEA), Vienna
(No previous BIPM calibration)

The ionization chamber FC65G, serial number 1551, of the INTERNATIONAL ATOMIC ENERGY AGENCY (IAEA), has been calibrated by the Bureau International des Poids et Mesures (BIPM) in terms of absorbed dc
received on 02 July 2020. The r
C. Kessler and P. Roger and ver

The results of the study are sho
and 101.325 kPa. The uncertain

Radiation quality / MV
6
10
18

Information on the conditions o
of absorbed dose to water and a
2021/xx (in preparation). Detail

N° 46

CERTIFICATE

for the study and calibration in megavoltage x-rays of the ionization chamber NE 2571, serial number 3204, of the INTERNATIONAL ATOMIC ENERGY AGENCY (IAEA), Vienna
(No previous BIPM calibration)

The ionization chamber NE 2571, serial number 3204, of the INTERNATIONAL ATOMIC ENERGY AGENCY (IAEA), has been calibrated by the Bureau International des Poids et Mesures (BIPM) in terms of absorbed dose to water in megavoltage x-rays. The instrument was received on 02 July 2020. The measurements were carried out during August 2020 by C. Kessler and P. Roger and verified by D. Burns.

The results of the study are shown below. The calibration coefficients $N_{D,w}$ are given at 20 °C and 101.325 kPa. The uncertainties u_c represent the combined standard uncertainties.

Radiation quality / MV	$TPR_{20,10}$	$N_{D,w}$ / Gy μC^{-1}	u_c / Gy μC^{-1}
6	0.686	44.76	0.19
10	0.733	44.48	0.19
18	0.774	43.96	0.18

Information on the conditions of measurement at the BIPM, on the determination of the rates of absorbed dose to water and an analysis of the uncertainties are given in *Rapport BIPM-2021/xx* (in preparation). Details concerning the calibration uncertainties are given in Table 1.

Thank you