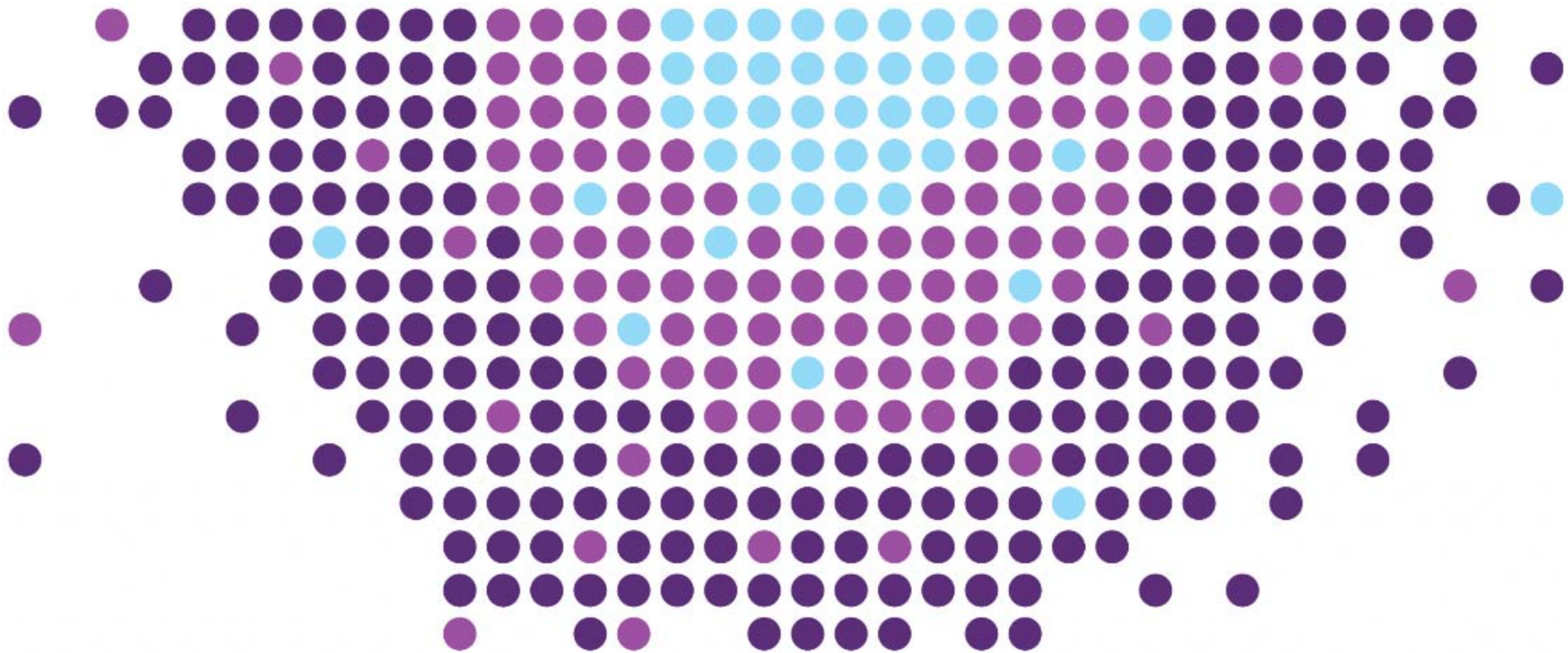




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Irradiations of personal dosimeters at LNK for the EURADOS IC2024ph comparison

[L.C. Mihailescu](#)

Online EURADOS meeting 2026-01-15

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Content

- SCK CEN and the Laboratory for Nuclear Calibrations (LNK)
- Calibrations and Measurement Capabilities (CMC's) at LNK
- The task for the EURADOS IC2024ph comparison
- Challenges, complaints and errors
- Lessons learned

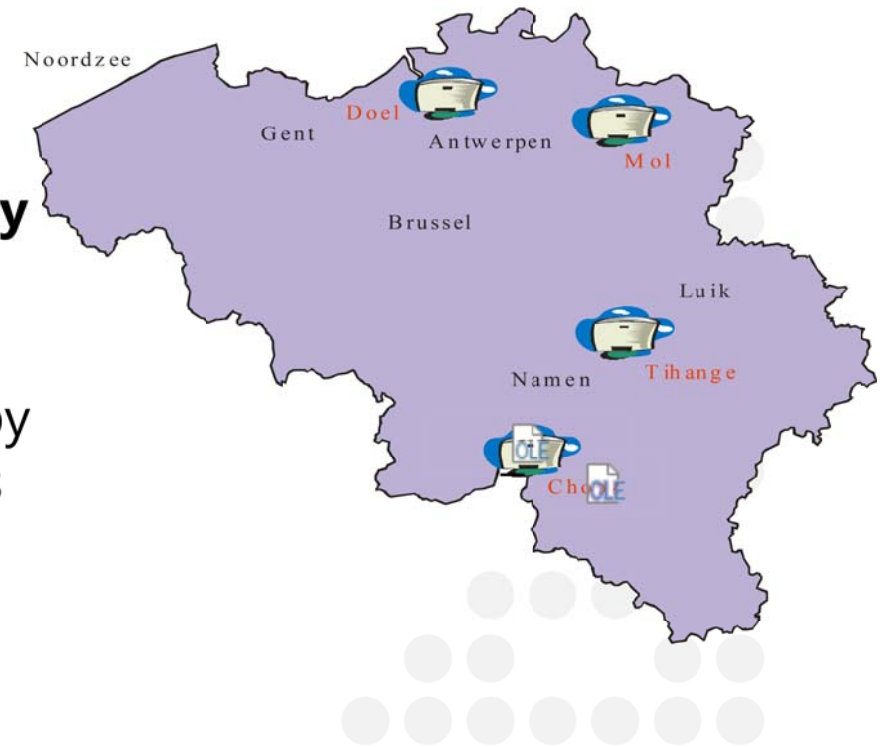


SCK CEN

- Belgian Nuclear Research Centre: a **foundation of public utility** and global leader in the field of nuclear research, services and education.
- **mission & vision:** Driven by our passion for science. Boosted by our unique infrastructure. We expand our knowledge in various nuclear areas and develop innovative applications for society.
- location: **Mol**, B-2400, Boeretang 190, Belgium.
- created in 1952
- ~900 staff, > 1/3 with academic degree + ~ 70 PhD

LNK (Laboratory for Nuclear Calibrations)

- 3 staff members,
- part of the RDC (Radiation Protection Dosimetry and Calibrations group),
- Designated Institute (DI) for metrology of ionizing radiation in Belgium.



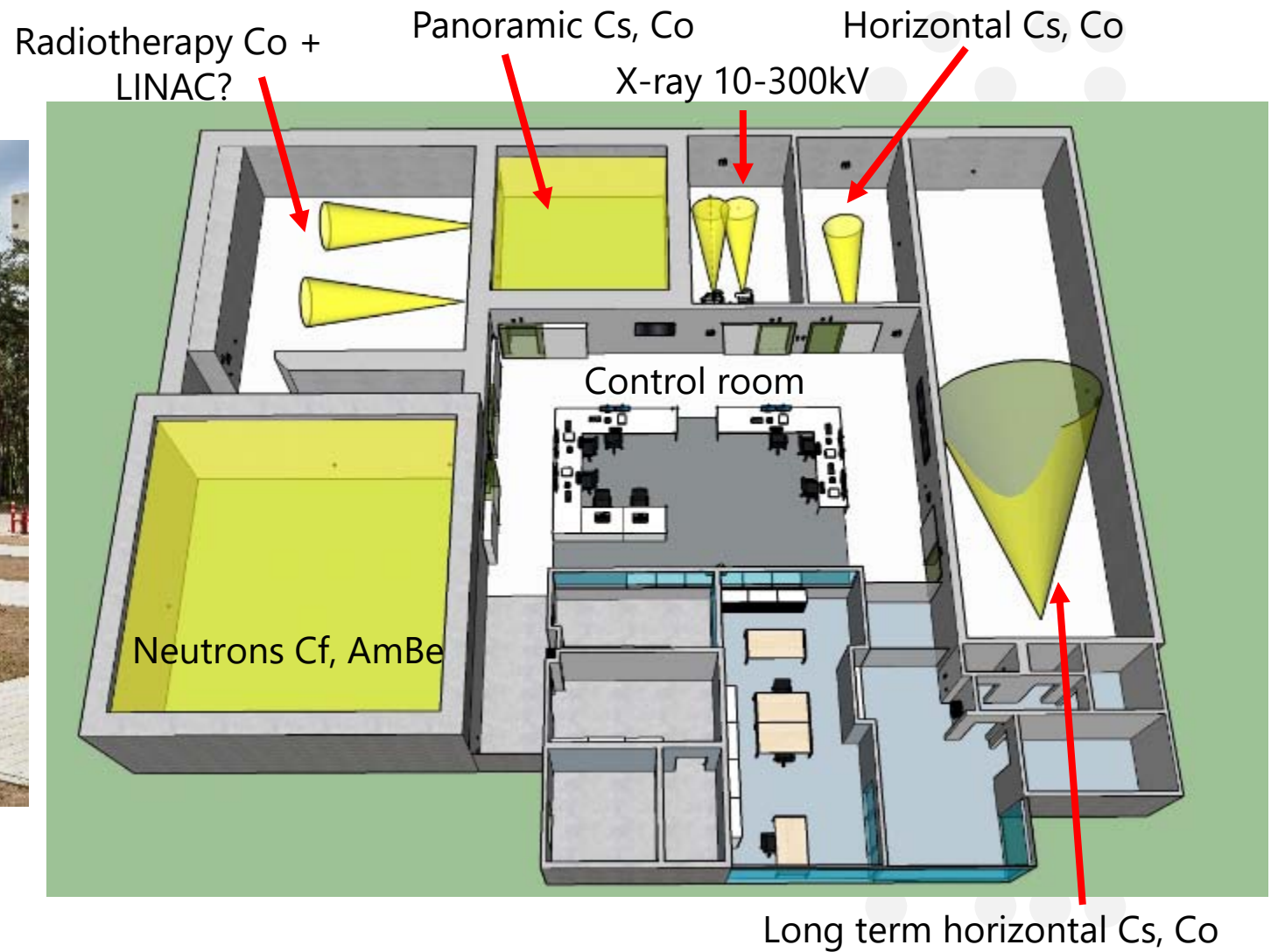
Laboratory for Nuclear Calibrations (LNK) of SCK CEN

- Laboratory for Nuclear calibrations (LNK) of SCK CEN is the Designated Institute (DI) for Metrology of Ionizing Radiation in Belgium:
 - established at SCK CEN as a calibration laboratory in ~1985,
 - ISO 17025 accredited since more than 20 years,
 - member of EURAMET as DI since 2012.
- Calibrations and irradiations for end-users and maintenance of national standards for metrology of ionizing radiation: dosimetry of photons and beta, activity measurements and neutron measurements.
- Commercial activities and research projects.
- New building, irradiators and data acquisition **since 2021** (reference instruments were preserved → long history).

New LNK building since 2021



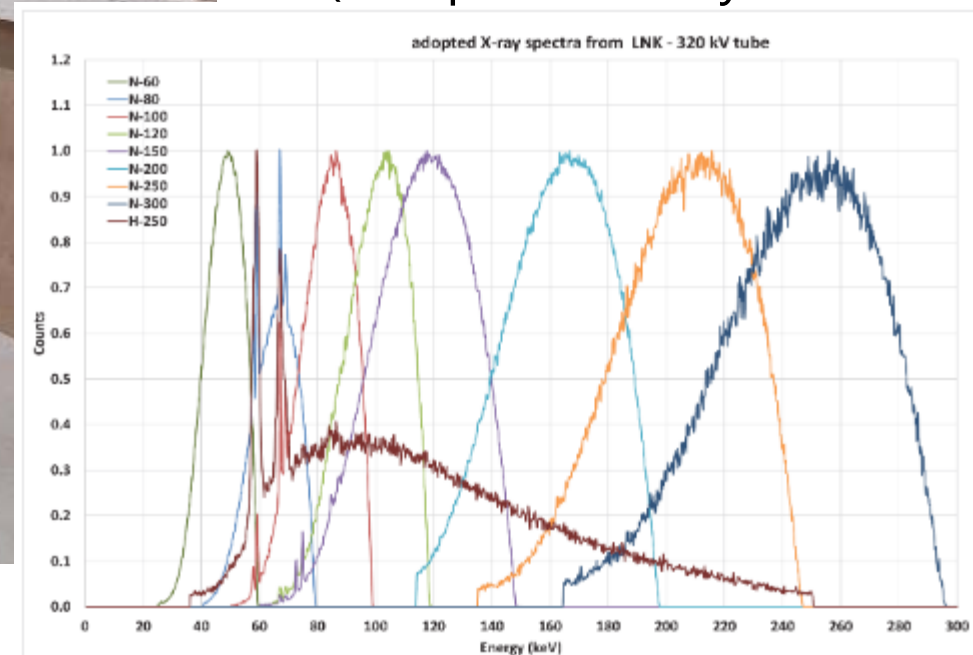
<https://www.sckcen.be/en/calibrations>



X-ray dual tube generator



- 10-300 kV tube potential
- Xstrahl generators + Hopewell Designs Inc. LPS
- tungsten (W) target
- N-series, W-series, RQR-series, H-250 beam qualities (ISO 4037) matched & characterized using HPGe spectrometry (*L.C. Mihailescu, 2023 JINST 18 P09037*)
- typical dose rates ~200 mGy/h (exception few Gy/h for H-250)



Radiotherapy grade irradiator – one Co-60 source

- Used for:
 - radiotherapy calibrations at 100 cm distance,
 - radioprotections calibrations and irradiations between 80 cm and about 600 cm.
- only one ^{60}Co source (about 30 Gy/h at 100 cm),
- square-shape collimator of minimum 5.5 cm x 5.5 cm and maximum 30 cm x 30 cm,
- fully automated 3D Linear Positioning System.

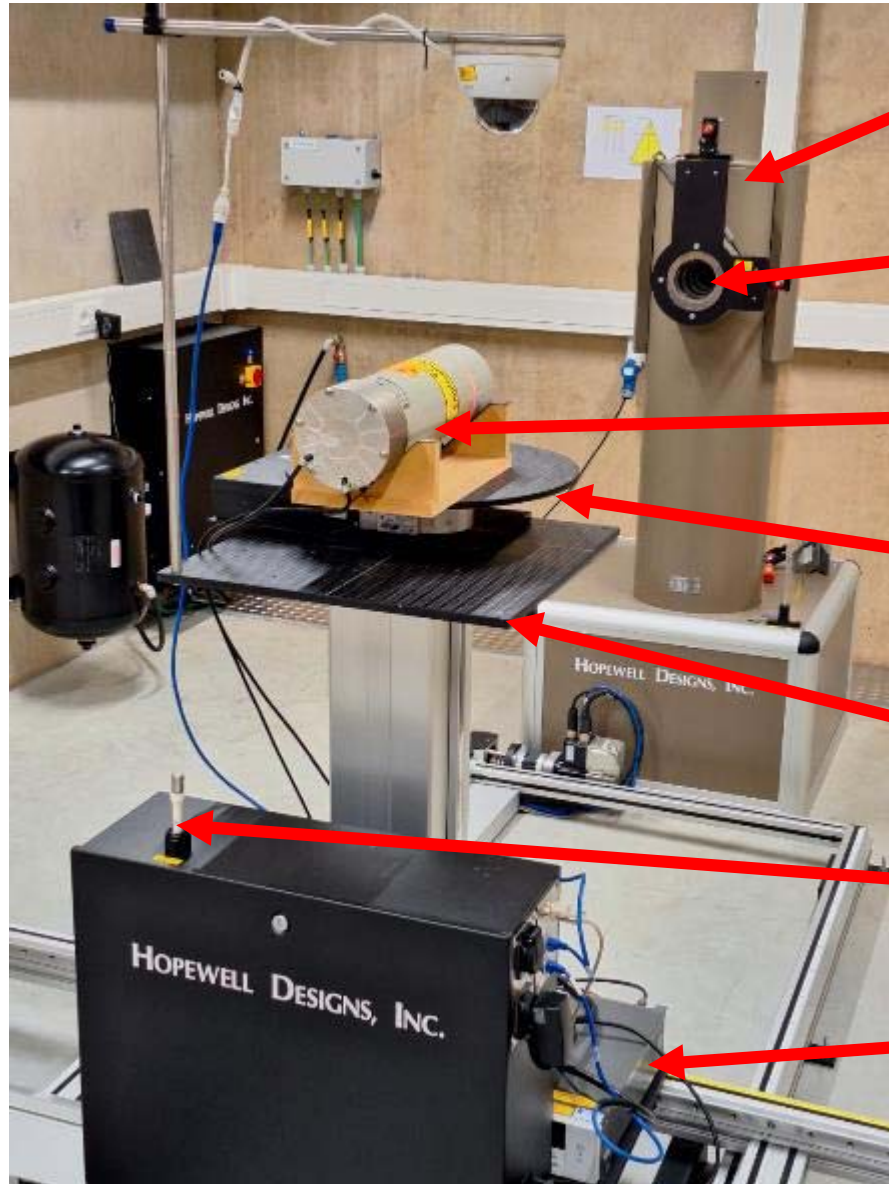


Panoramic irradiator for ^{137}Cs and ^{60}Co

- panoramic 360° beam,
- one Co-60 source ->
range: 20 mGy/h-800 mGy/h,
- one Cs-137 source ->
range: 60 mGy/h-2500 mGy/h,
- convenient for many personal
dosemeters are same time,
- all ISO 4037 requirements in terms of
scattering are fulfilled – being
uncollimated beam is the only deviation
from ISO 4037.



Horizontal GC-60 irradiator for ^{137}Cs and ^{60}Co



Hopewell GC-60
irradiator (4 ^{137}Cs
and 4 ^{60}Co sources)

20° conical collimator)

Detector (sealed
ionisation chamber)

Rotary table
(plug & play)

LPS table (automated
x,y,z-axis)

PTH sensors

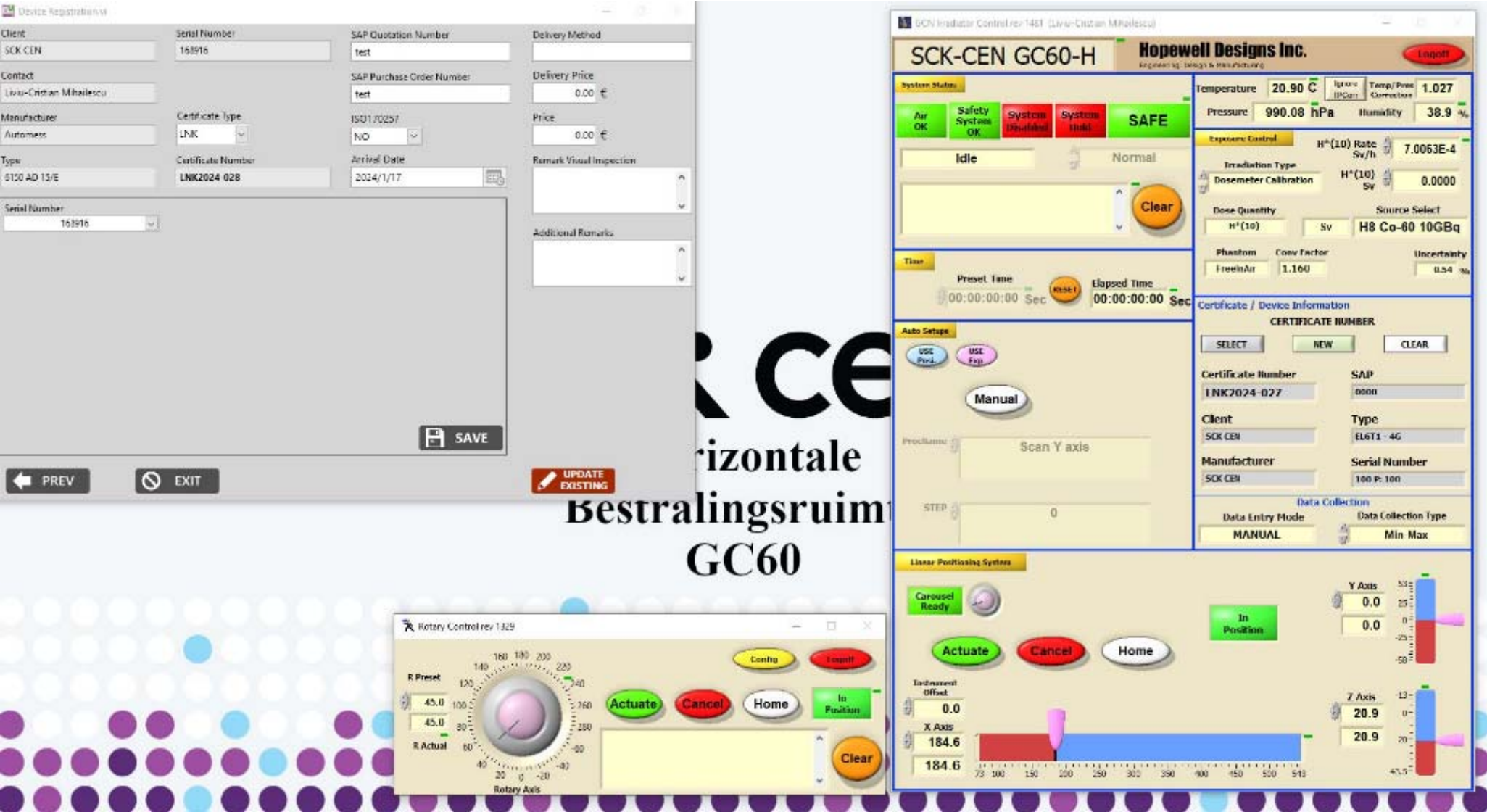
Electrometer



Digital workflow

Utilities based on LabView:

- Registration,
 - Irradiator Control,
 - Report Generation,
 - Irradiator Calibration,
 - any table.
- +
- common database,
- automatic reporting based
- Excel and macros,
- generating digitally signed pdf



The task

Radiation type	Quality	Dose range (mSv)	Number of dosemeters
X-ray	W-110	6 – 12	2
	W-110 /60°	4 - 6	2
	W-150 /60°	4 - 6	2
Gamma	S-Cs-L	0,5 – 1,0	2
	S-Cs-M	3 – 5	4
	S-Co-L	3 – 5	2
	S-Co-M	30 – 50	2
	S-Co-H	300 – 500	2
Mixed	W-110 + S-Cs	5 + 5	2
		Total	20

L: low dose
M: medium dose
H: high dose

EURADOS IC2024ph requested:

- ❑ 20 dosemeters per system,
- ❑ 10 irradiations per system,
- ❑ extra 10 dosemeters for background and spare,
- ❑ two months scheduled for irradiations,
- ❑ about 100 systems expected – final registration 120 systems.

The task

Boxes as received



Content



All systems together



One EPD present in each box, always on and indication was written down several times during the campaign.

The irradiations

- Four irradiators were used:
 - X-ray irradiator
 - Horizontal GC-60 for ^{137}Cs and ^{60}Co Low doses
 - Panoramic DS-20 for the ^{60}Co Medium doses
 - Radiotherapy G-100 for the ^{60}Co High doses
- “Random” doses were selected for each system, prior to start the job. Same dose rate was used for each quality/dose range → Only the irradiation time was changed.
- One or two systems at once irradiated on the phantom depending on size – Ideally, we should combine systems.
- Build-up plate of 3 mm used for ^{137}Cs and ^{60}Co .
- Photos taken for each irradiation such the serial numbers would be visible. Identification of the photo done by the time stamp only.
- The information of each irradiation was automatically saved in the database of the irradiators: time stamp, dose rate, dose, irradiation time....
- Serial number of each dosimeter was written down by hand on paper and then typed in Excel sheets.
- Manual link was needed between the serial numbers of the dosimeters and the RecordID number of each irradiation from the database.

The irradiations

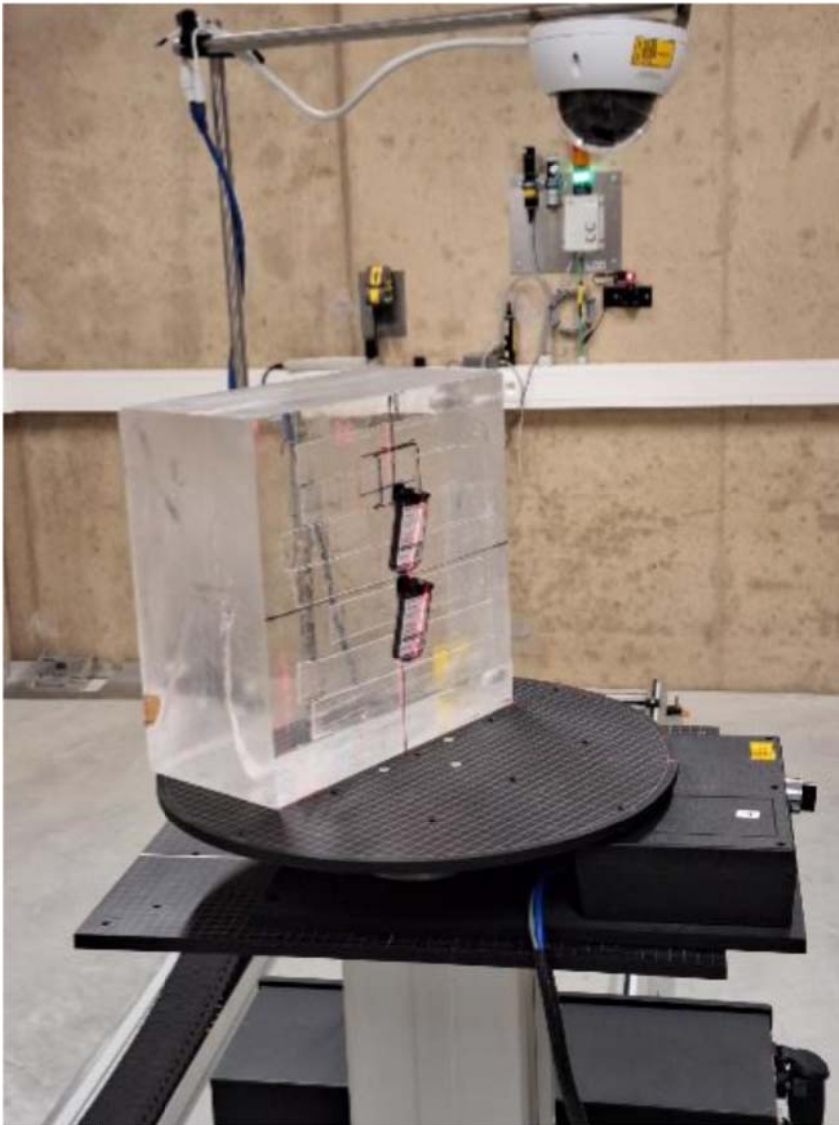


ELL DESIGNS, INC.
scl cen | ISC:



The irradiations

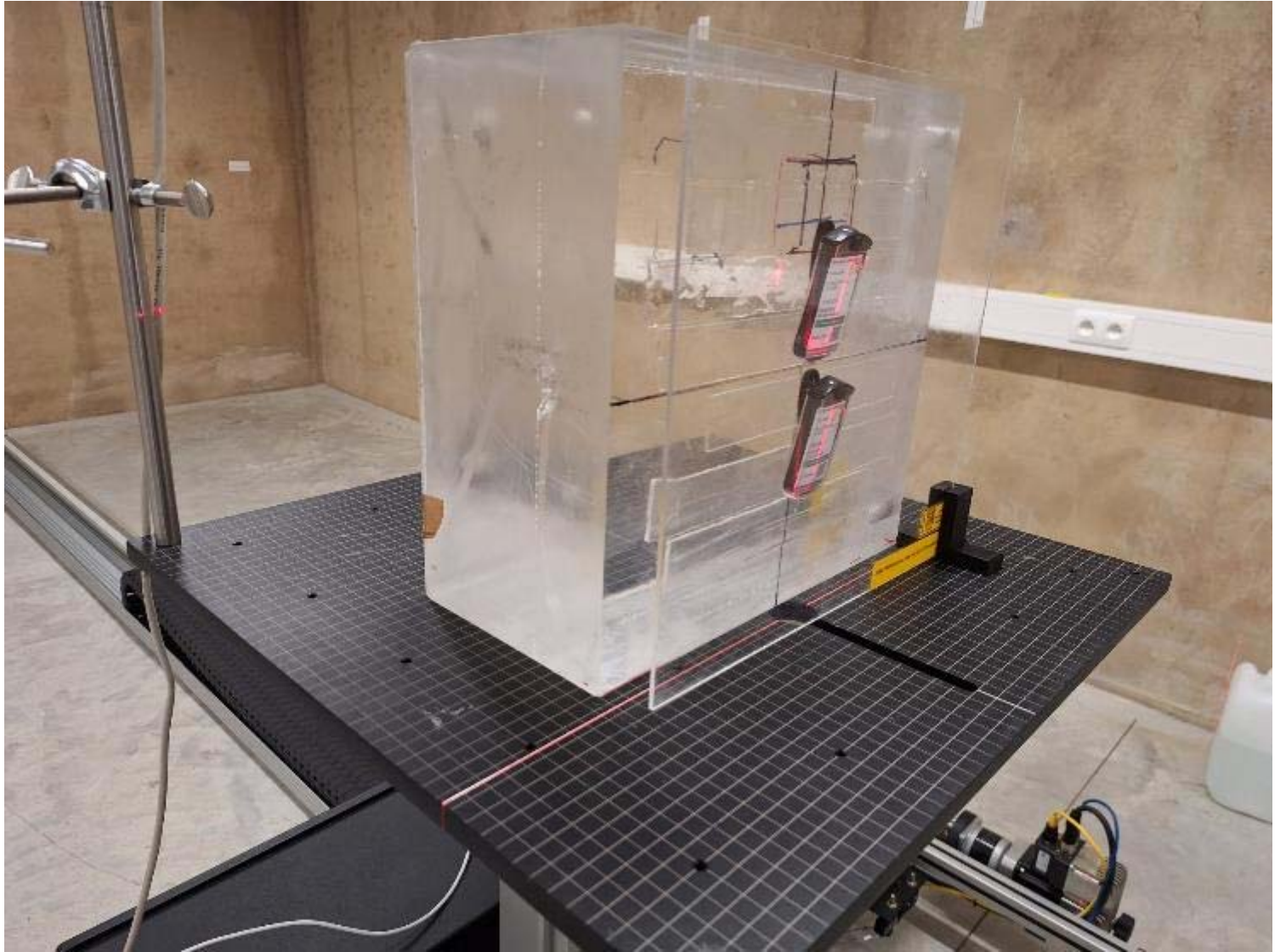
X-ray – no build-up plate + angle



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ISC:

^{137}Cs and ^{60}Co – with 3 mm PMMA plate.



15 / 20

ISC:

The irradiations

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2400 Mol - Belgium
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Irradiation certificate

Certificate number: LNK2024-530_S001
Issue date: 2024-12-09
Item: EURADOS IC2024ph comparison, system S001
Customer: EURADOS e.V.
Customer address: Postfach 1129
85758, Neuherberg, Germany
Contact: Christian Gartner
E-mail: ic2024ph@eurados-intercomparison.org
Customer's reference: EURADOS/2024/38/FV

Irradiation method: Dosimetry irradiations according to LNK validation file(s) 187-SUP-MT202, 187-SUP-MT203, 187-SUP-MT205, 187-SUP-MT208.

Used source(s): Cs-137, Co-60, W-110, W-150

Irradiation period: 2024-10-15 / 2024-11-15

Number of pages: 2

Traceability: The irradiation is done with reference standards and calibration devices for which the traceability to national and international standards is assured. The irradiation is covered by the ISO 17025: 2017 accreditation scope of LNK, unless explicitly stated.

Performed by: Digitally signed by Bart Marlein
Date: 2024.12.09
09:23:44 +01'00'

Reviewed by: Digitally signed by Liviu Cristian Mihailescu
Date: 2024.12.10
11:14:43 +01'00'

SCK CEN / LNK – Laboratorium voor Nucleaire Kalibraties

Certificate number: LNK2024-530_S001

Issue date: 2024-12-09

Item: EURADOS IC2024ph comparison, system S001

Method details:

The measurements were performed in the following ambient conditions (1 hPa = 1 mbar):

temperature (°C): 20 - 22
pressure (hPa): 988 - 1030
relative humidity (%): 46 - 62

The irradiations are based on the ISO 4037:2019 standard.

All uncertainties are expanded uncertainties for k=2 (confidence level 95.4 %) and the uncertainty budget is established according to the ISO/IEC GUIDE 98-3:2008 Uncertainty of measurement - Part 3: Guide to the expression of uncertainty in measurement (GUM:1995).

LNK uses the following secondary standard ionisation chambers for photons:

- PTW TW32002 1 liter chamber for Co-60, Cs-137 and ISO 4037:2019 N-series and W-series above 40 kV. This chamber has ISO 17025:2017 calibration certificates in terms of K_a from PTB (Germany).
- NE2571 0.6 cc Farmer type chamber for Co-60 above approximately 2 Gy/h. Its calibration is traceable to the air kerma primary standard of LNK, the graphite cavity chamber CC01 sn. 104 (C. Kessler, D. Burns, L.C. Mihailescu, S. Chirioti, Metrologia 54 (2017) Tech. Supl. 06004).

The recommendations of the ICRU 90 report "Key Data for Ionizing-Radiation Dosimetry: Measurement Standards and Applications" are implemented at LNK.

Build-up plate of 3 mm was used for all irradiations with Cs-137 and Co-60. The X-ray beam qualities are considered "matched" according to the ISO 4037:2019; all measured HVL values fulfill the conditions for matched beam qualities as required by ISO 4037:2019-1 table 14. Average conversion coefficients from K_a to the operational quantities was used with 4 % (k=2) uncertainty.

The dosimeters were irradiated on a slab PMMA phantom of 30 cm x 30 cm x 15 cm. The reference point of the dosimeter was used to measure the distance to the source. The rotation axis was vertical, through the reference point of the dosimeter. Positive angles were counter-clockwise. Four different irradiators of LNK were used:

- GC-60 irradiator with 20 degrees conical beam with Cs-137 source,
- DS-20 panoramic irradiator with Co-60 source,
- G-100 square shape beam irradiator with Co-60 source (radiotherapy grade irradiator with 10 cm x 10 cm field size at 100 cm up to 60 cm x 60 cm field size at 600 cm distance from the source),
- X-ray irradiator with 20 degrees conical beam with W-110 and W-150 qualities (L.C. Mihailescu 2023 JINST 18 P09037).

Remarks:

The owners of the dosimeters systems were kept anonymous for the irradiation laboratory. Only the system number (S) and the serial number (sn.) of each dosimeter were available to the irradiation laboratory. Each line in the table below represents one irradiation. All dosimeters mentioned on one line of the table were irradiated simultaneously, on the same phantom.

Results:

Item:	Beam quality	Beam shape	Irradiation date	Distance	Angle	Irradiation time	Conventional true value K_a	Uncertainty conventional true value K_a (k=2)	Conversion coefficient $h_{p,K}$ (10;R ₅₀)	Conventional true value H_p (10)	Uncertainty conventional true value H_p (10) (k=2)	Conversion coefficient $h_{p,H}$ (0.07;R ₅₀)	Conventional true value H_p (0.07)	Uncertainty conventional true value H_p (0.07) (k=2)
			yyyy-mm-dd	cm	deg	(s)	mGy	mGy	Sv/Gy	mSv	mSv	Sv/Gy	mSv	mSv
S001 sn. 24, sn. 5	Cs-137	20 deg. cone, horizontal	2024-10-15	200.0	0	132	0.577	0.008	1.21	0.698	0.030	1.21	0.698	0.030
S001 sn. 15, sn. 20, sn. 8, sn. 16	Cs-137	20 deg. cone, horizontal	2024-10-18	100.0	0	234	4.13	0.06	1.21	5.00	0.21	1.21	5.00	0.21
S001 sn. 3, sn. 7	Cs-137	20 deg. cone, horizontal	2024-10-28	100.0	0	187	3.30	0.05	1.21	3.99	0.17	1.21	3.99	0.17
S001 sn. 27, sn. 4	Co-60	panoramic	2024-10-15	150.0	0	219	3.47	0.07	1.15	3.99	0.18	1.17	4.06	0.18
S001 sn. 29, sn. 14	Co-60	collimated, square	2024-10-25	600.0	0	88	26.2	0.26	1.15	30.2	1.2	1.17	30.7	1.2
S001 sn. 17, sn. 28	Co-60	collimated, square	2024-10-30	300.0	0	286	348	3.4	1.15	401	17	1.17	408	17
S001 sn. 3, sn. 7	W-110	20 deg. cone, horizontal	2024-10-28	250.0	0	112	3.20	0.08	1.87	5.99	0.28	1.71	5.48	0.28
S001 sn. 9, sn. 30	W-110	20 deg. cone, horizontal	2024-11-07	250.0	60	137	3.92	0.09	1.52	5.96	0.28	1.59	6.23	0.28
S001 sn. 6, sn. 26	W-110	20 deg. cone, horizontal	2024-11-19	250.0	0	112	3.20	0.08	1.87	5.99	0.28	1.71	5.48	0.28
S001 sn. 12, sn. 22	W-150	20 deg. cone, horizontal	2024-11-13	250.0	60	157	3.58	0.09	1.48	5.29	0.25	1.55	5.54	0.25

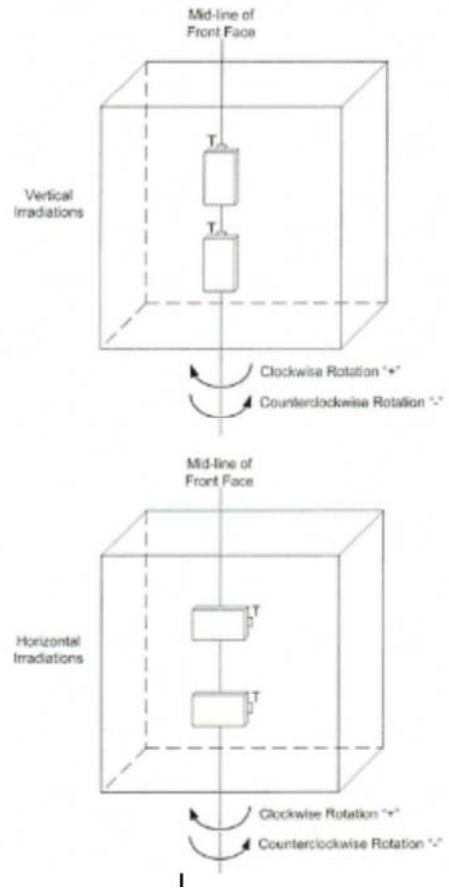
Some challenges

- good quality photos proved to be very useful – not always as desired (out of focus with build up plate, ...),
- create independent list with background/spare detectors is useful – not done,
- verify list of background detectors against irradiated detectors – doubles means typing errors → use photos to find the mystery,
- front side = the side with a label and serial number ? (if not – extra photos are needed),

Some challenges

- axis of rotation - need to verify the only info provided by participants,
- sense of rotation (+ or -) ANSI-HPS N13.11-2022 defines + = clockwise,
- fix detector on the phantom, parallel to the phantom surface (spacer needed).

ANSI-HPS N13.11-2022 Fig E1



ISO 29961:2012 Fig 3

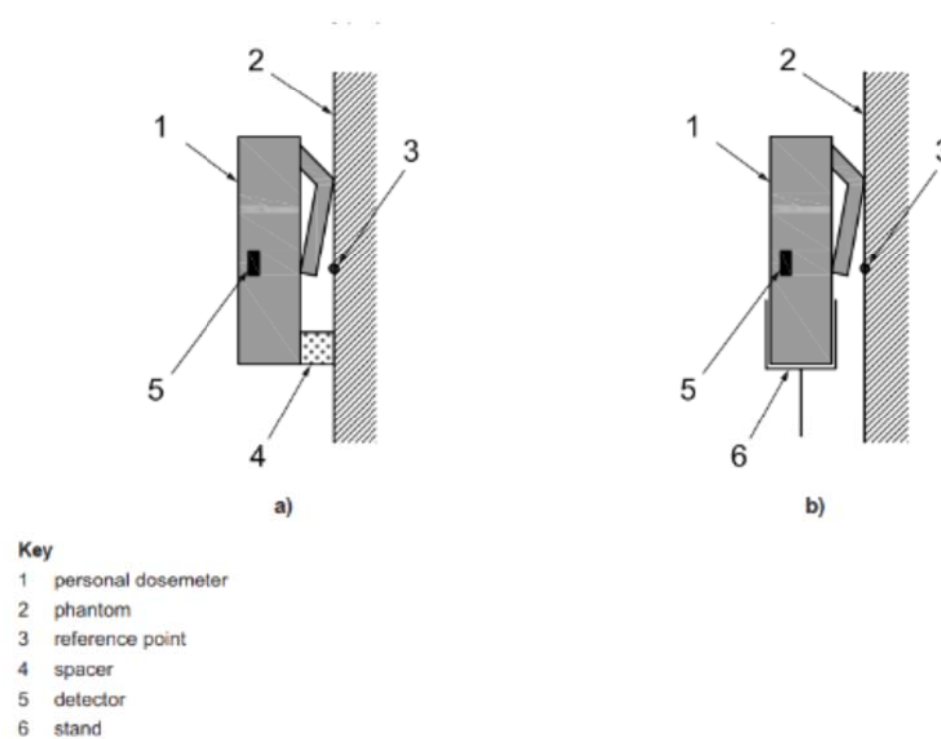
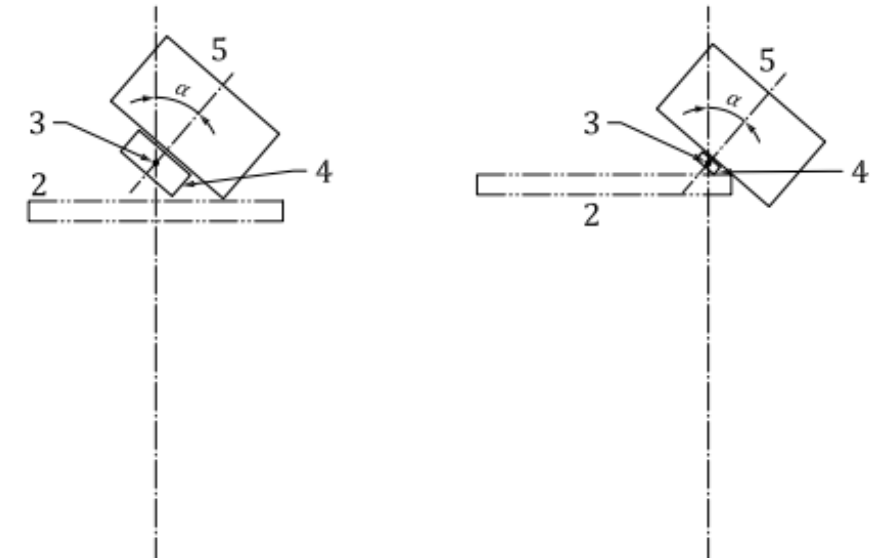


Figure 3 — Positioning of whole-body dosimeter at slab phantom surface
(reference direction normal to phantom surface)

ISO 4037 – 3 :2019 Fig 1



Complaints and errors

- Seven complaints in total (out of 120 systems → 1200 irradiations)
- Examples of complaints/ errors:
 - 2 times: irradiation at an angle of two doseimeters on the phantom → same axis of rotation but one up and one oriented down → $-\alpha$ and $+\alpha$ while stating only $+\alpha$ on the certificate,
 - 3 times – wrong serial number reported in the certificate and wrong written down on the paper notes → photos used to solve the mystery,
 - 1 time: swap serial number of the doseimeters that fell down with the one that was correctly irradiated → the doseimeters fell down and no photo was made with the doseimeters that fall down / at end of irradiation ? No proof from LNK ...,
 - 1 time – the reading of the participant did not agree with the certificate value – no fault found at LNK. Who is correct, LNK or the participant ?...

What did we learn ?

- Good quality photos are mandatory:
 - at start of irradiation,
 - at stop of irradiation in case a detectors fell down,
 - serial numbers to be clearly visible in the photos,
 - the time stamp is sufficient to identify the photo and no special file names needed,
 - video record each irradiation or automatic photos at start and stop would be ideal.
- Create independent list with background detectors and verify list of background detectors against irradiated detectors – doubles means typing errors → use photos to find the mystery.
- Extra QC's needed:
 - verify dose rates (and beam stability) several times during the campaign with secondary standard chambers in addition to the Monitor Chamber of the tube,
 - comparison of the Excel files to the paper notes by another staff member – typing errors,
 - independent lists of errors, spare/background detectors and irradiated detectors to be created and compared.

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