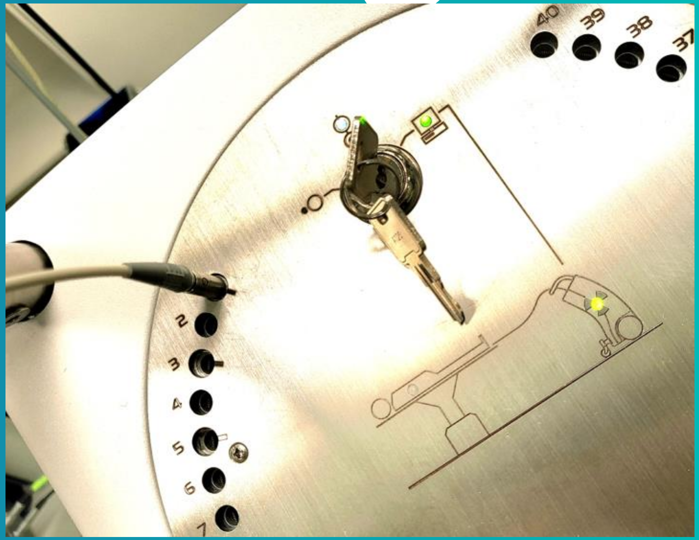
ICTP-IAEA Workshop on Reference Dosimetry in EBRT and Brachytherapy

INTRODUCTION TO BRACHYTHERAPY

5 Nov 2025, Vappu Reijonen/Medical Physicist, PhD



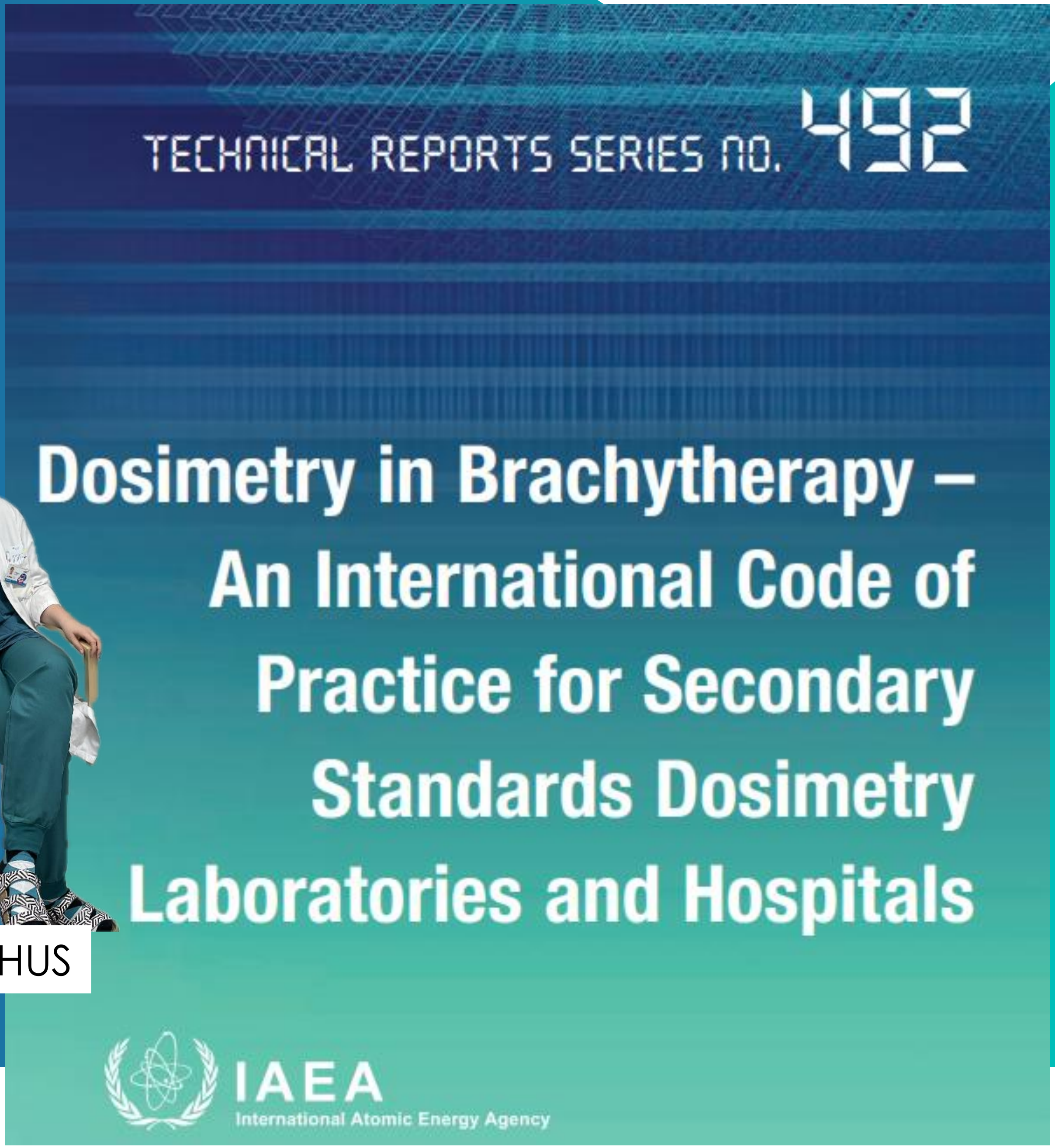
- Sources, quantities & units
- HDR, LDR, …
- Antiquated quantities & units

Today's topics in TRS 492:

- Chapter 2: *Brachytherapy radioactive sources*
- Chapter 3: *Quantities and units*
- Chapter 4: *Instrumentation*
- Appendix I: *Antiquated quantities and units*

Warning or advertise?

- I will spice up the TRS 492 handling with **examples from** my **clinical work**!
  - All photos (and videos) by me unless otherwise mentioned!



But before that, a bit introductions, including TRS 492 Chapter 1

Oncologist Veera Ahtiainen and medical physicist Vappu Reijonen collaborate closely to plan radiotherapies for all cancer patients, as the Molecular Radiotherapy Unit is a part of the radiotherapy department of The Comprehensive Cancer Center in Helsinki.

Who am I?

- Medical Physicist, PhD, Radiation Safety Officer (RSO)
- My work is **clinical work**!
  - ➢ Fully hands-on in oncological treatments (99%) with **different forms of radiotherapy**
  - ➢ Including quality assurance (QA)
- Helsinki University Hospital Cancer Center, FINLAND
  - ➢ Radiotherapy Department
    - ▪ **Brachytherapy**, external beam radiotherapy, molecular radiotherapy
    - ▪ Me: since 2015, so my 10th year anniversary (as Qualified MP)

HUS

- Finland has only 5.6 million inhabitants
- Quite tall country: 1160 km
- ➢ People may have to travel a long way for rare treatments
- Weather now: very cold and dark!
- Brachythreapy in Finnish: **tyköśädehoito**

HUS & HELSINGIN YLIOPISTO YHTEISTYÖSSÄ
HUS & HELSINGFORS UNIVERSITET I SAMARBETE
A COLLABORATION BETWEEN HUS & UNIVERSITY OF HELSINKI

TYKÖSÄDEHOITO? BRAKYTERAPIA?

- A combination of Finnish words: NEAR – RAY – TREATMENT
- What is brachytherapy in your language?
- Brachys (βραχυς) in Greek and means SHORT, short-distance
- IAEA Technical Report Series No. 492 begins:

> Brachytherapy is a specific modality of radiation therapy in which small encapsulated radiation sources are inserted into or near the volume to be treated [1]. Historically, the term brachytherapy referred to the use of *radioactive* sources. They were in fact the only sources of radiation that could be achieved in small dimensions available at the time of brachytherapy inception, which was at the beginning of the twentieth century. More recently, miniature systems that use electronically created low energy X rays instead of radionuclides were designed [2]. At the time of writing, a few of such devices are capable of performing intracavitary or intraoperative brachytherapy treatments [3] but radionuclides remain the primary sources used.

PRAGY

Brarky

…

- Close-contact (body surface/cavity/interstitial) radiotherapy with sealed/solid sources
- Temporary or permanent positioning

- eBT = X-ray electronic brachytherapy device

- ...and continues:

Brachytherapy is an essential modality in low and middle income countries with a high incidence of cervical or oesophageal cancer. It is also broadly disseminated in high income countries. According to the Directory of Radiotherapy Centres (DIRAC) maintained by the International Atomic Energy Agency [9], currently 3345 brachytherapy facilities are available worldwide, with 65% of these being in high income countries and 35% in low and middle income countries. Most brachytherapy procedures are now performed using high dose rate (HDR) remote afterloaders. Remote afterloading low dose rate (LDR) equipment has been discontinued by the manufacturers, leaving HDR or pulsed dose rate (PDR) brachytherapy as the major alternative technologies and restricting LDR applications to manual procedures using low energy sources.

Page 29 in TRS 492:

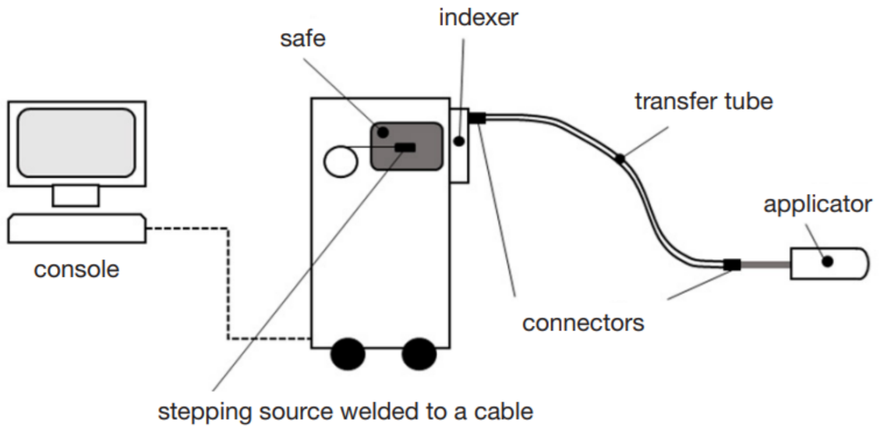
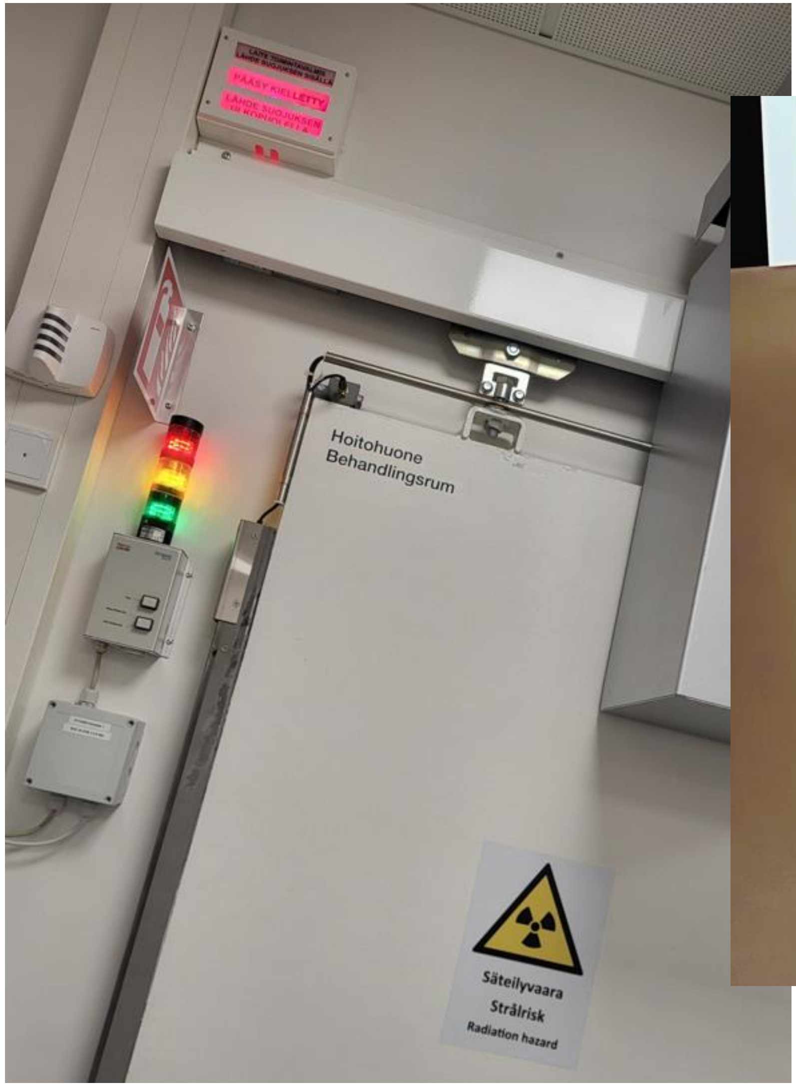


FIG. 3. Simplified drawing of HDR brachytherapy delivery equipment connected to a (cylindrical) applicator.

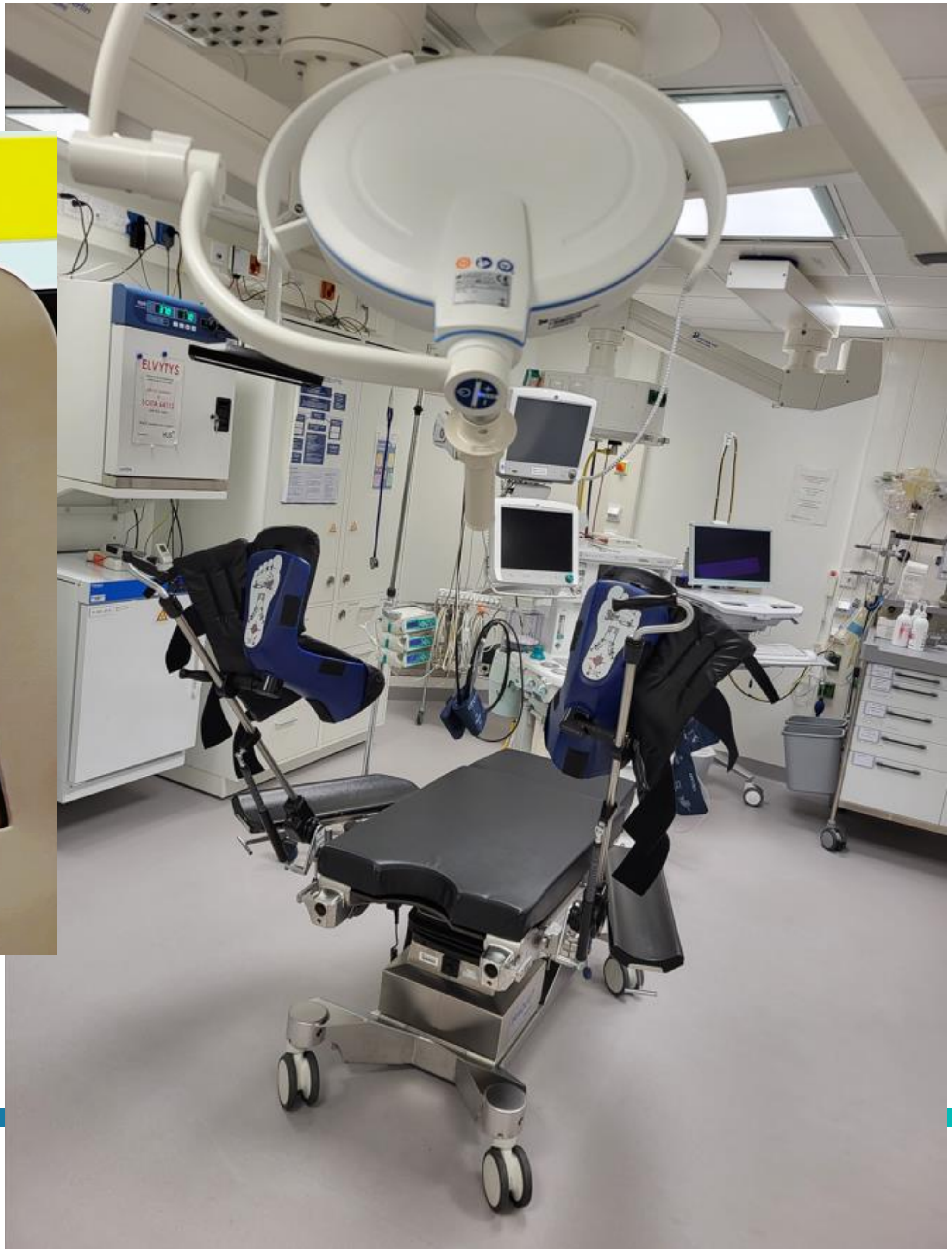
BRACHYTHERAPY IN OUR HOSPITAL

- Two **Iridium-192** based HDR (=high dose rate) afterloaders
- Source renewal 4 times per year
- Treatments to:
  - Prostate cancer
  - Cervical cancer
  - Vaginal cancer, also prophylactic treatments for uterine cancer patients
  - Liver tumors (primary, metastasis)
  - Seldom: anal, lip, …

Camera view to a treatment room from the control room (QA measurements)


Hoitohuone
Behandlingsrum
Säteilyvaara
Strålrisk
Radiation hazard

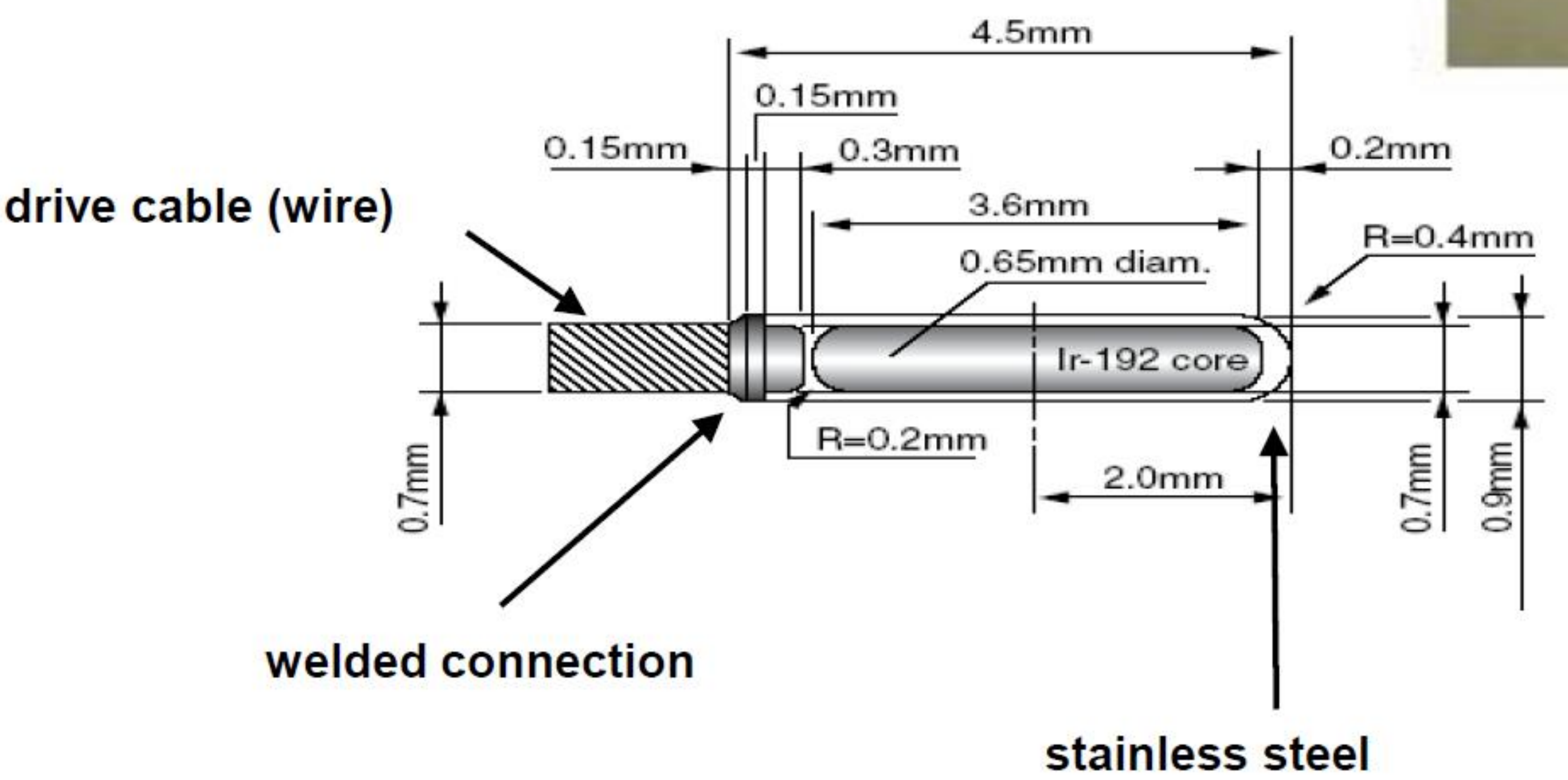

TREATMENT IN PROGRESS ...
RADIATION
REMAINING TIME
MM:SS.S
2:39.7
IN PROGRESS
INITIATE
INTERRUPT

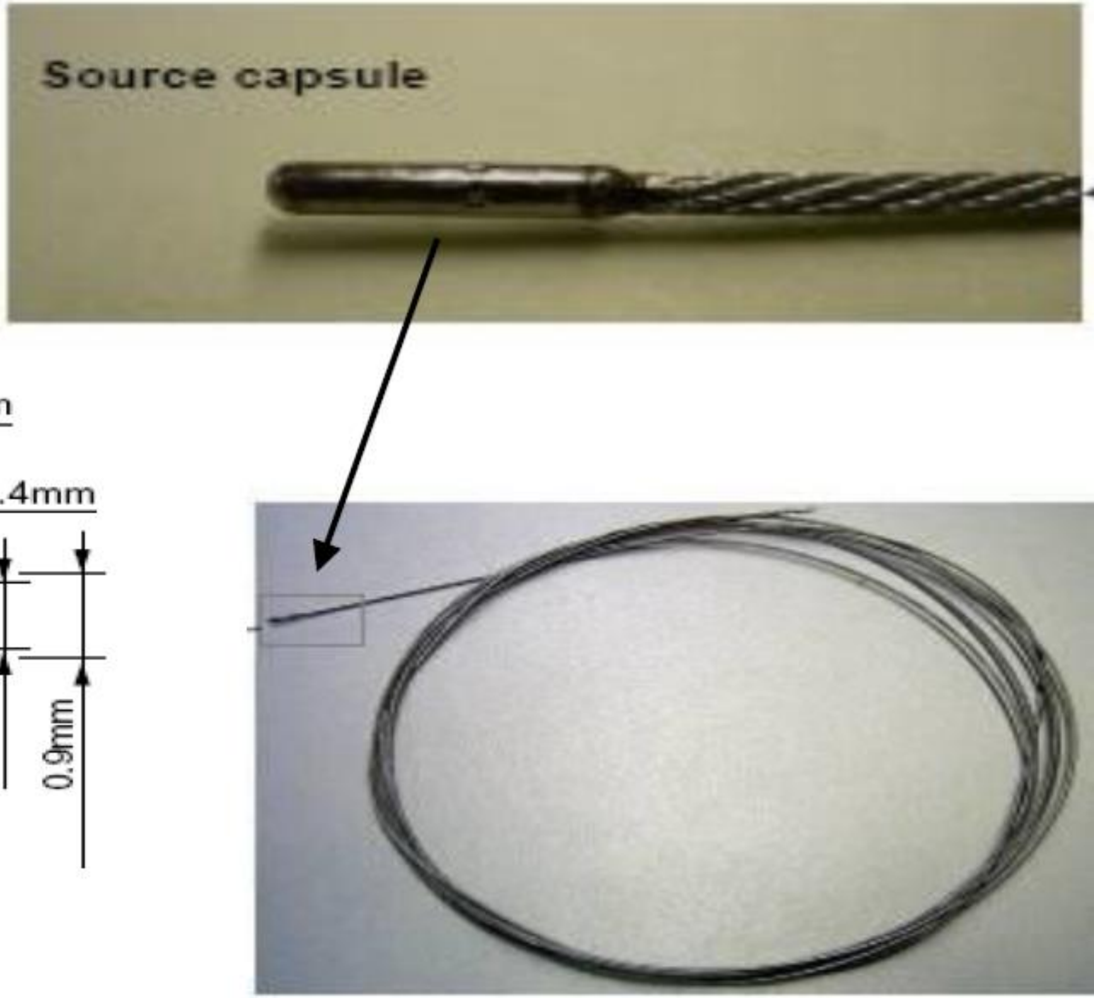

ELVYTYS

Slide from ESTRO Advanced Physics for Brachytherapy 2024 – not our Ir-192 model!

HDR ^{192}Ir Brachytherapy Sources

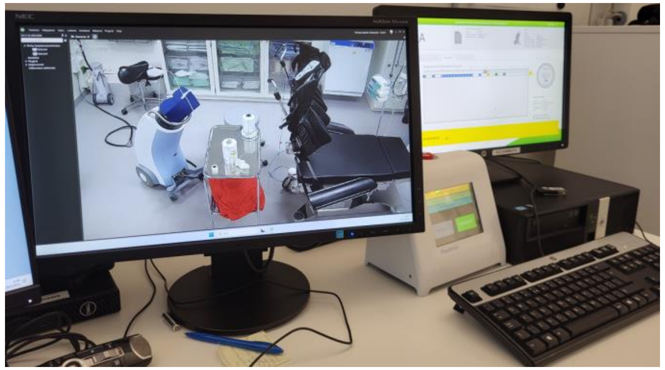
Example of miniaturized source welded to the end of a drive cable.



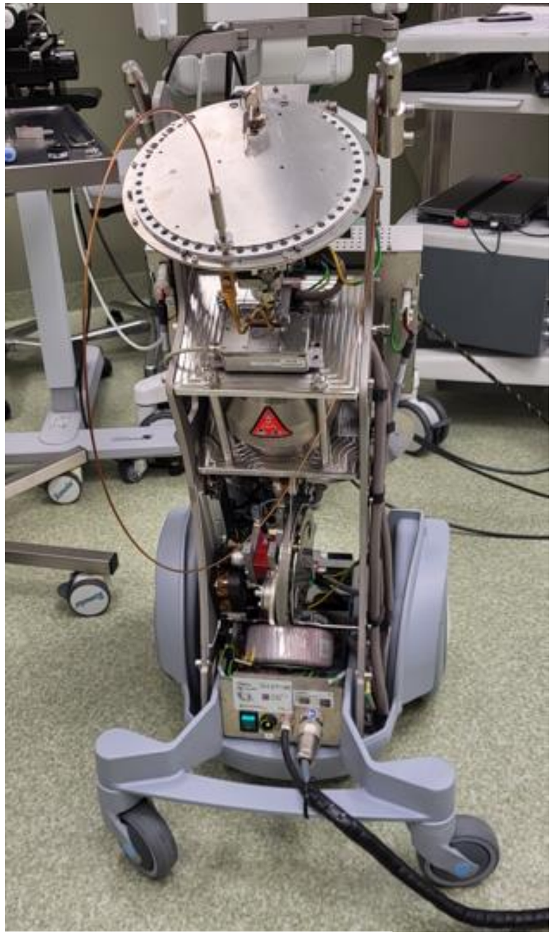


HDR BRACHYTHERAPY AFTERLOADER

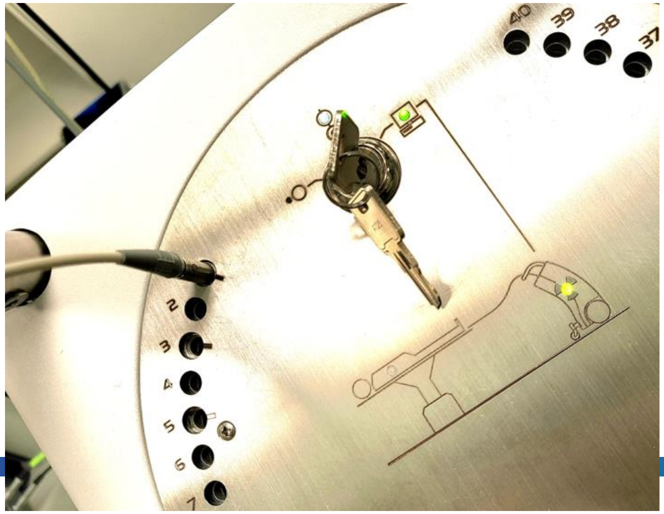
- Section 4.3 in TRS 492
- "Computer-controlled system that drives a high activity source (e.g. 370 GBq of ^{192}Ir or 74 GBq of ^{60}Co) from a shielded safe to" specific points for a certain time, then back
- Afterloader = the radioactive source is loaded into the patient "afterwards" from the control room



HDR Ir-192 source safe


Without covers

What is
this for?



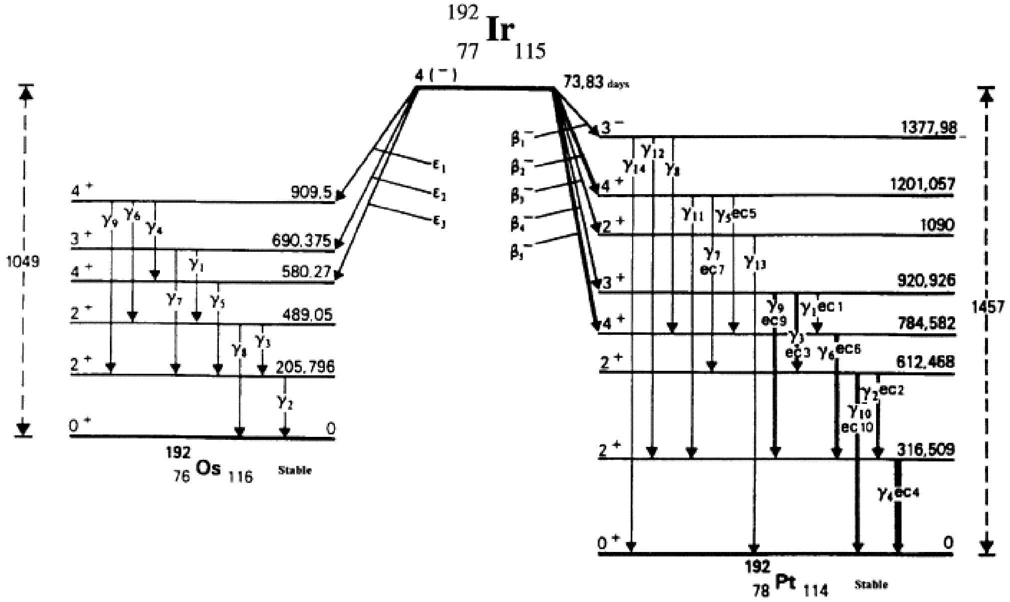
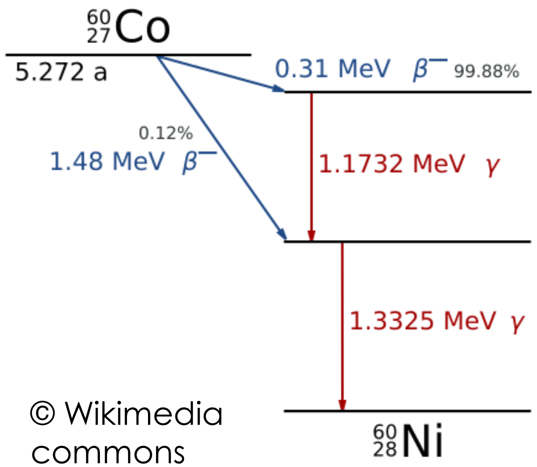
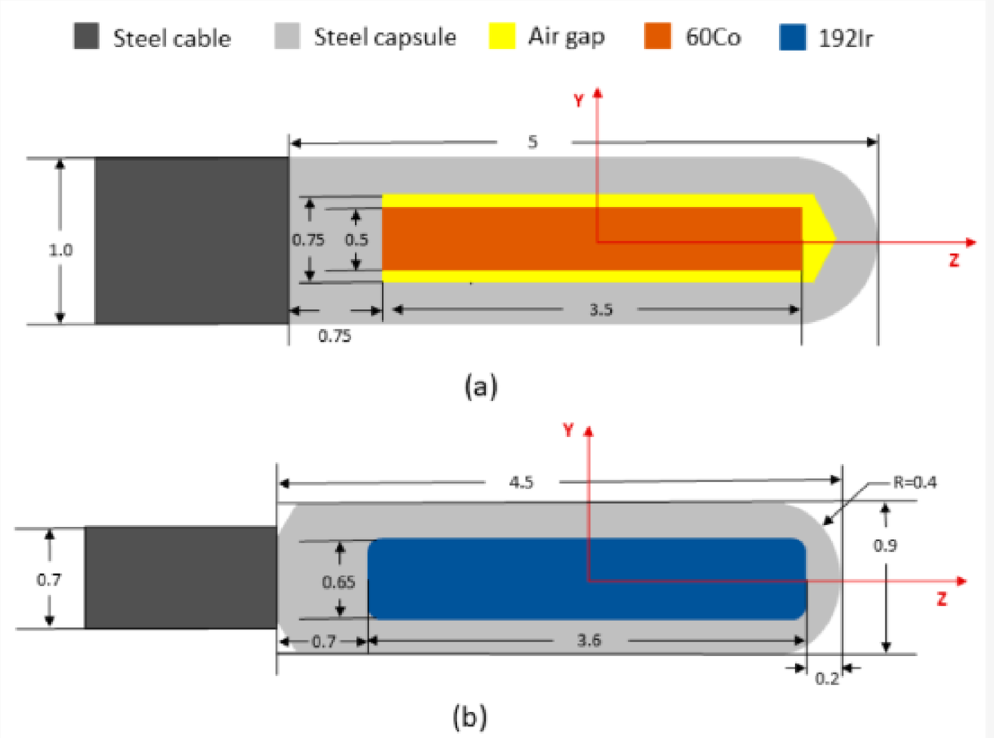


Fig. 1. Decay scheme of ^{192}Ir (Lagoutine et al., 1984). All energies are in keV.



© Wikimedia commons

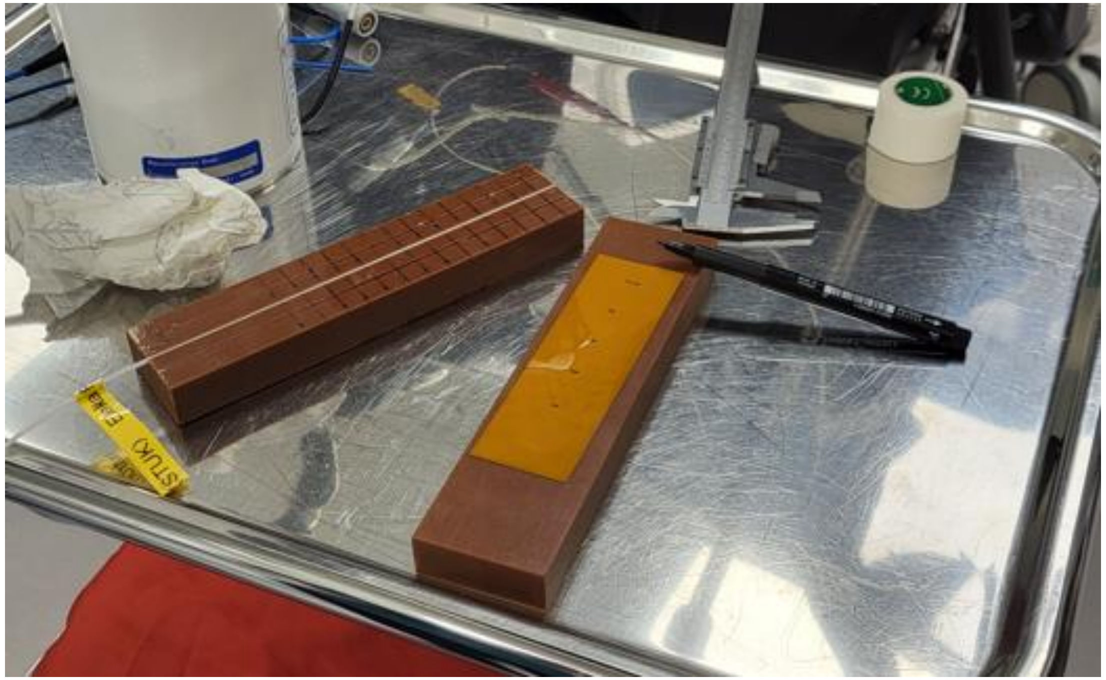
Figure 1. Reference coordinate system and schematic diagram of the model for 60Co and 192Ir. Dimensions are in millimeters. (**a**) E&Z Bebig HDR 60Co model Co0.A86 source; (**b**) Nucletron HDR 192Ir model mHDR-v2r.

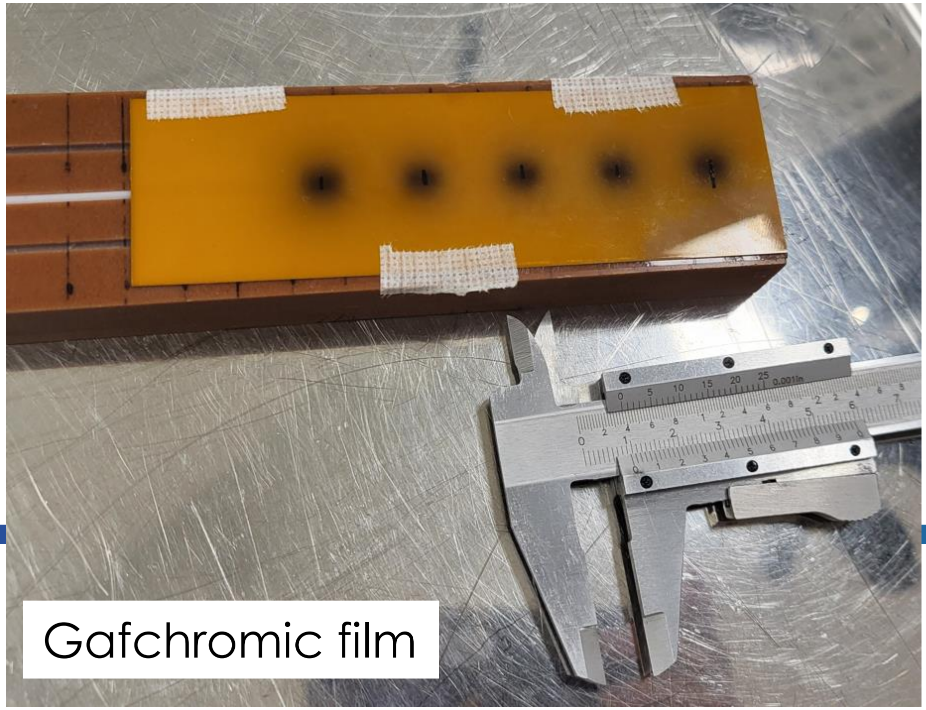


© Wen, A. et al.

Our hospital's museum:
Lead shield for Co-60 needles from 1950's →

Confession 1:
I have never worked with Co-60 sources in real life!
➢ Similar principles apply

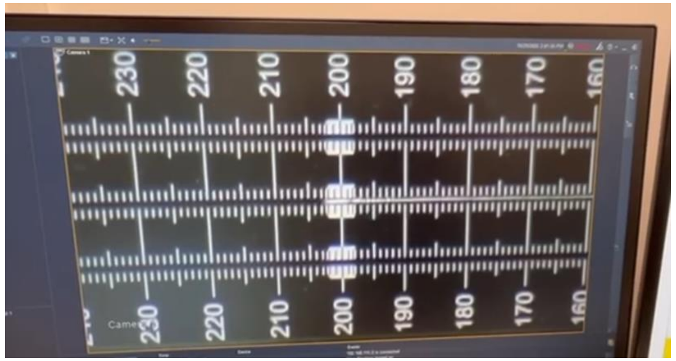


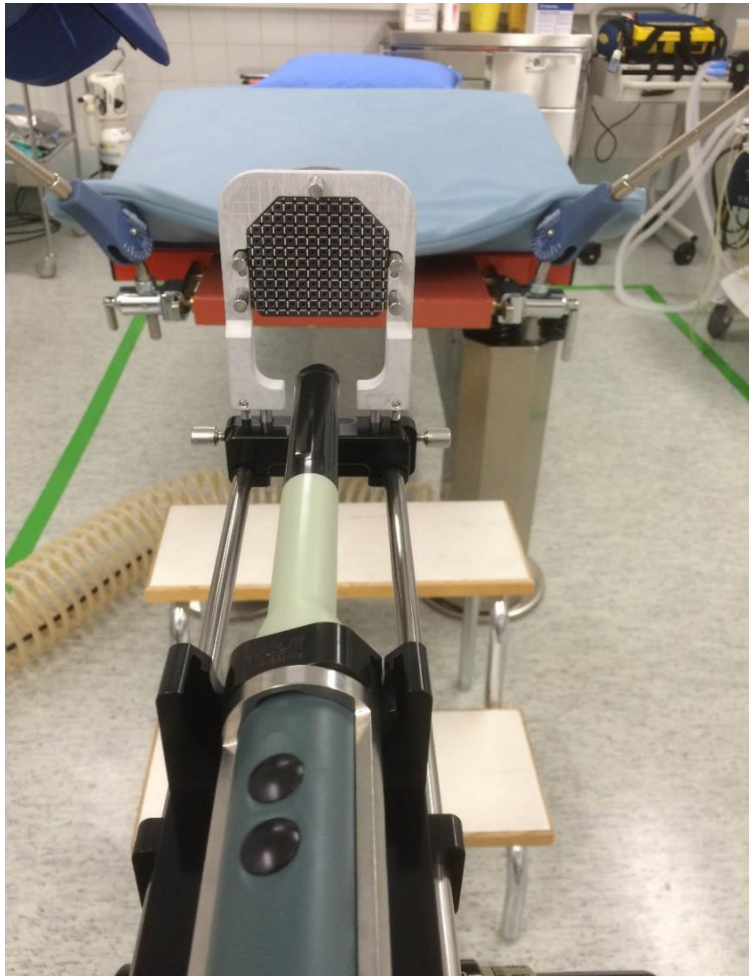


Gafchromic film

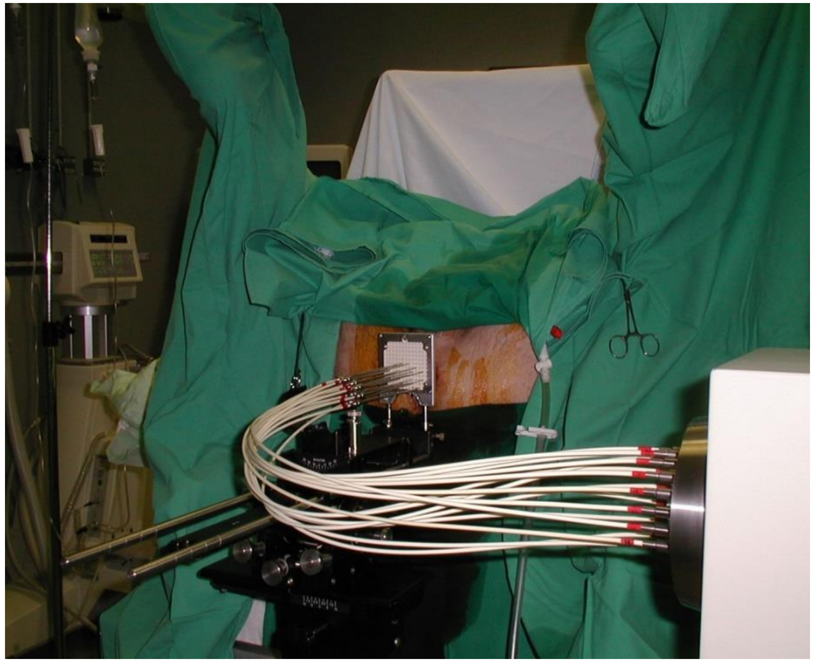
Video about source location accuracy measurement…

Ir_source_localization.mp4





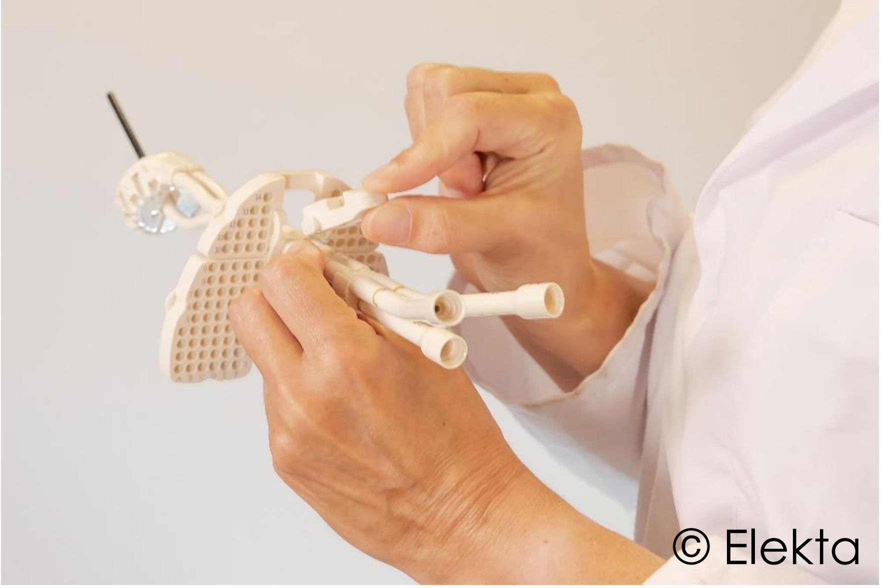
←↑Photos by our radiographers

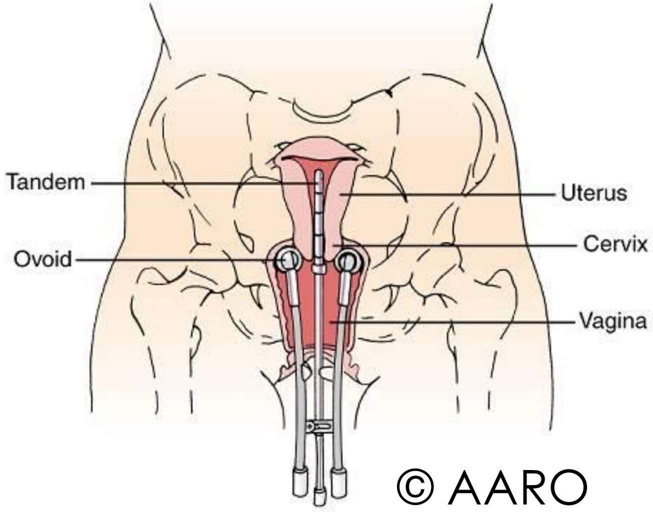


↑ © P.J. Prada, *Advances in Prostate Cancer*

↑ Vaginal single-channel applicators

Intrauterine (iu) and ring applicator set ↓



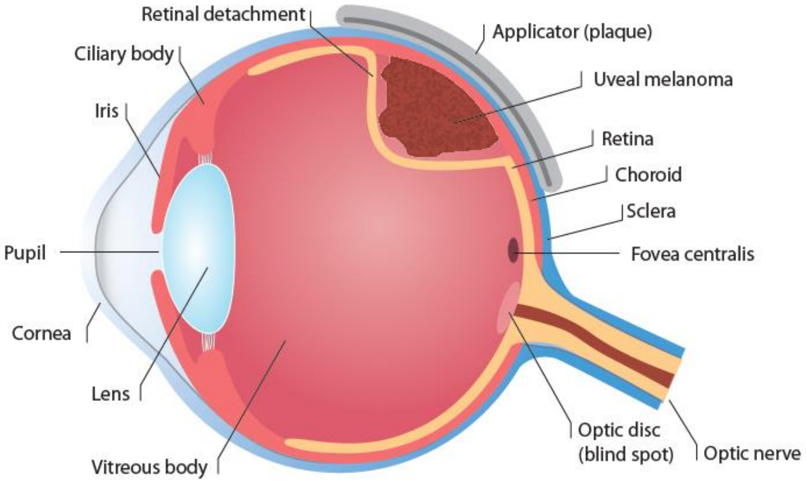


BRACHYTHERAPY IN OUR HOSPITAL

- Ophthalmic applicators: **Ruthenium-106** and **Iodine-125** based plaques
- Source renewal biennial and biannual
- Treatments to eye:
  - Uveal melanoma (adults)
  - Retinoblastoma (children)
  - Also some benign targets
  - Will be talked more tomorrow!

Ru-106 plaque

I-125 plaque



TWO KINDS OF PLAQUES WE USE…

- Often CALLED "Ru-106/Rh-106 plaques"

$t_{1/2}$ = 373.6 days $\quad$ $t_{1/2}$ = 29.8 s

$$^{106}\mathbf{Ru} \rightarrow {}^{106}\mathbf{Rh} + e^- + \nu_e \rightarrow {}^{106}\mathbf{Pd} + e^- + \nu_e + \gamma$$

- **Ruthenium plaques** (Ru-106), e.g. "Ru-CCB":
  - ➢ **Beta-emitting brachytherapy source**

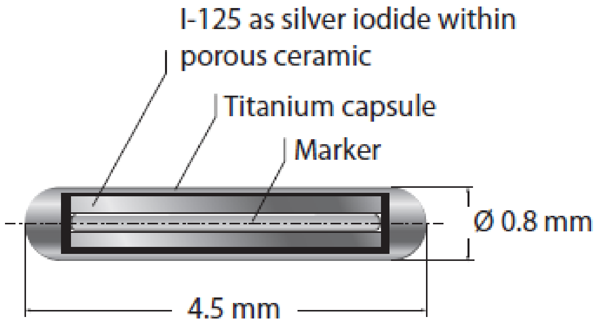
shape model

© Eckert & Ziegler

shape model

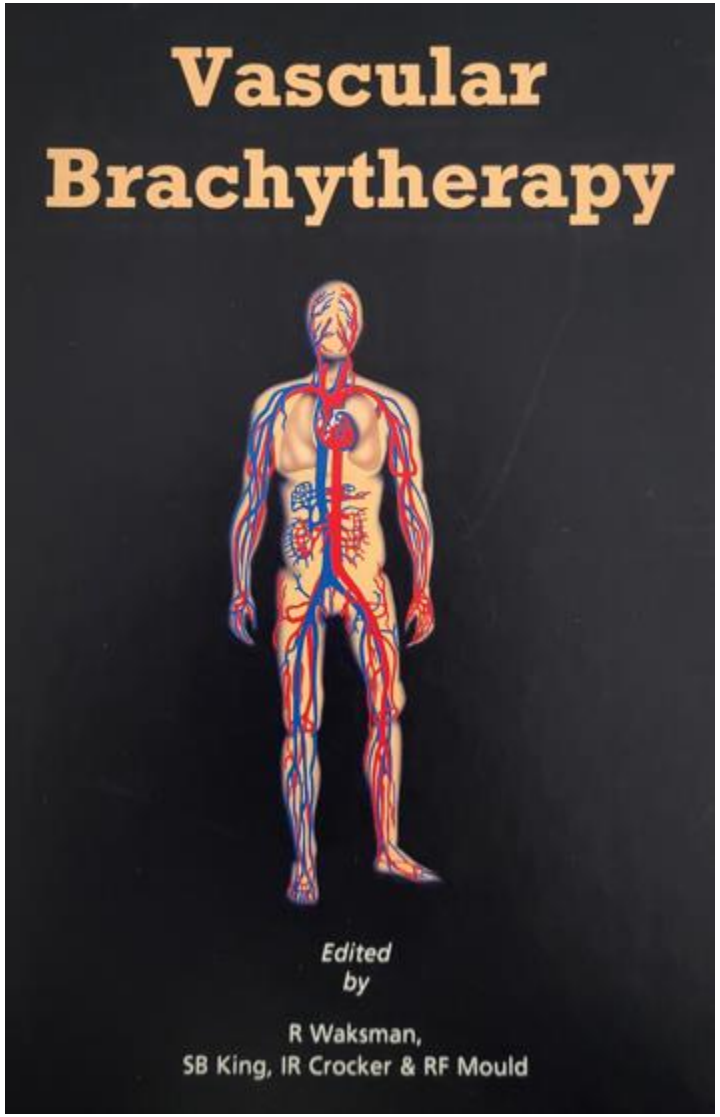
$t_{1/2}$ = 59.4 days

- **Iodine plaques** (I-125), e.g. "I-CCA": $^{125}\mathbf{I} + e^- \rightarrow {}^{125}\mathbf{Te} + \nu_e + \gamma\ (+\ e^-_{IC} + e^-_{Auger})$
  - ➢ **Photon-emitting brachytherapy source**



IsoSeed® I25.S16 details © Eckert & Ziegler

- I-125 containing titanium seeds are glued on golden base plaques



Confession 2:
I have never worked with (intra)vascular brachytherapy (IVBT) in real life!

- ➢ Replaced by other (drug-based) treatments

© Novoste

BRACHYTHERAPY IN YOUR COUNTRY/INSTITUTION?

- Let's make a joint "poster"
- Please write there "brachytherapy" in your language + your flag
  - ➢ If it's just brachytherapy, then it's just brachytherapy!
  - ➢ To be true, we actually also use the term "***brakyterapia***" in Finnish, not oldish "tykösädehoito"…
- If your institute performs brachytherapy or you know what kind of brachytherapy is applied in your city/country, please write down!
  - ➢ Sources, treatments?
  - ➢ This will help planning future courses!

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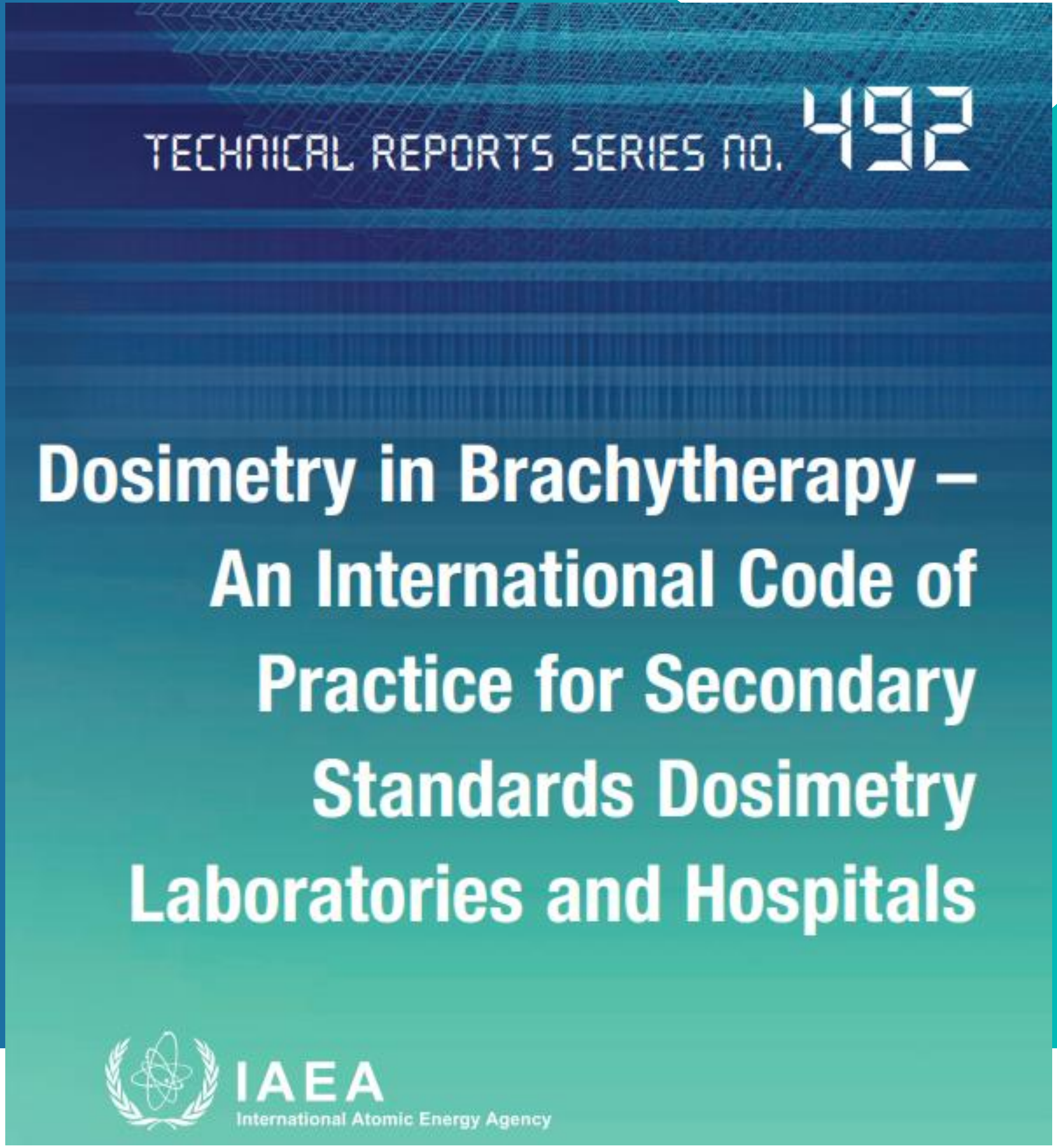
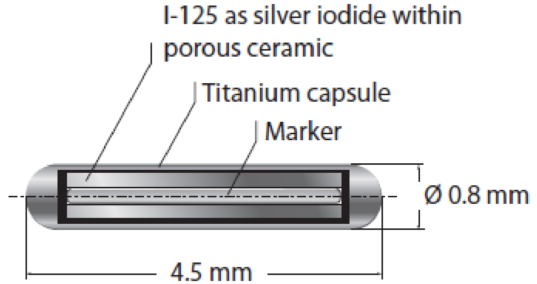
- Appendix I: *Antiquated quantities and units*

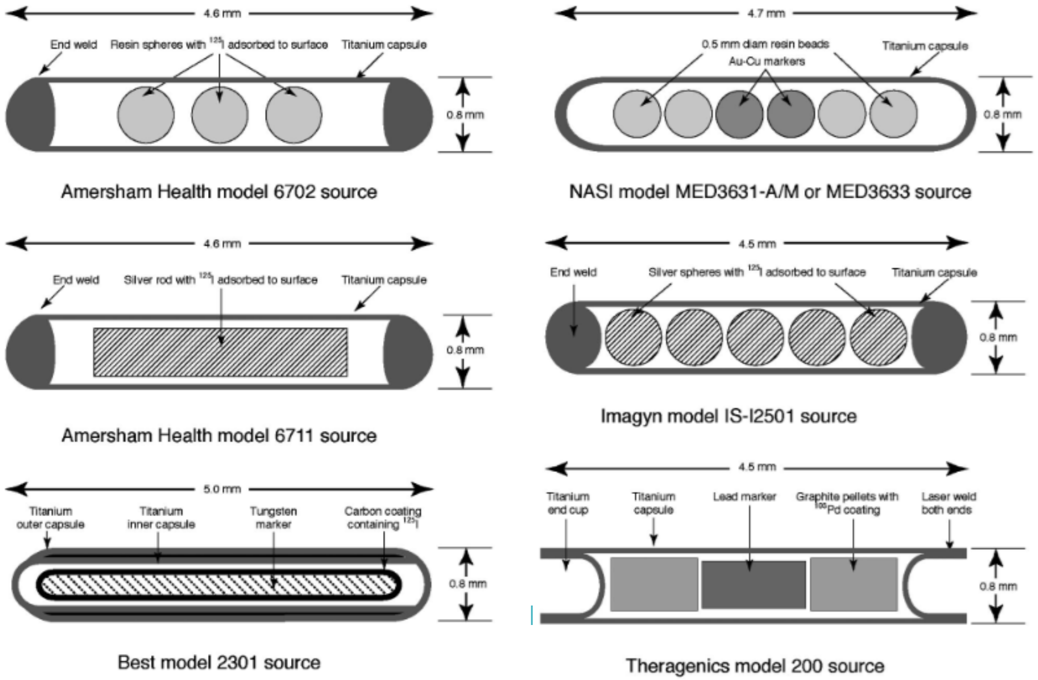


2. BRACHYTHERAPY RADIOACTIVE SOURCES

- Many different designs!
- Radioactive substance tightly encapsulated in e.g. stainless steel, tungsten, titanium, nickel – mechanical strength, non-toxic material, not interacting with body fluids
  - ➢ This way, escape/release of the radioactive material inhibited
  - ➢ However, instructions for e.g. allowed cleansing agents and handling instruments need to be followed
- Dosimetric characteristics of sources are sensitive to the specific encapsulation geometry and internal radionuclide distribution
  - ➢ Self-absorbtion and filtration effects, characteristic X-rays
  - ➢ Source model **needs to be known <u>precisely</u>**!



IsoSeed® I25.S16 details © Eckert & Ziegler

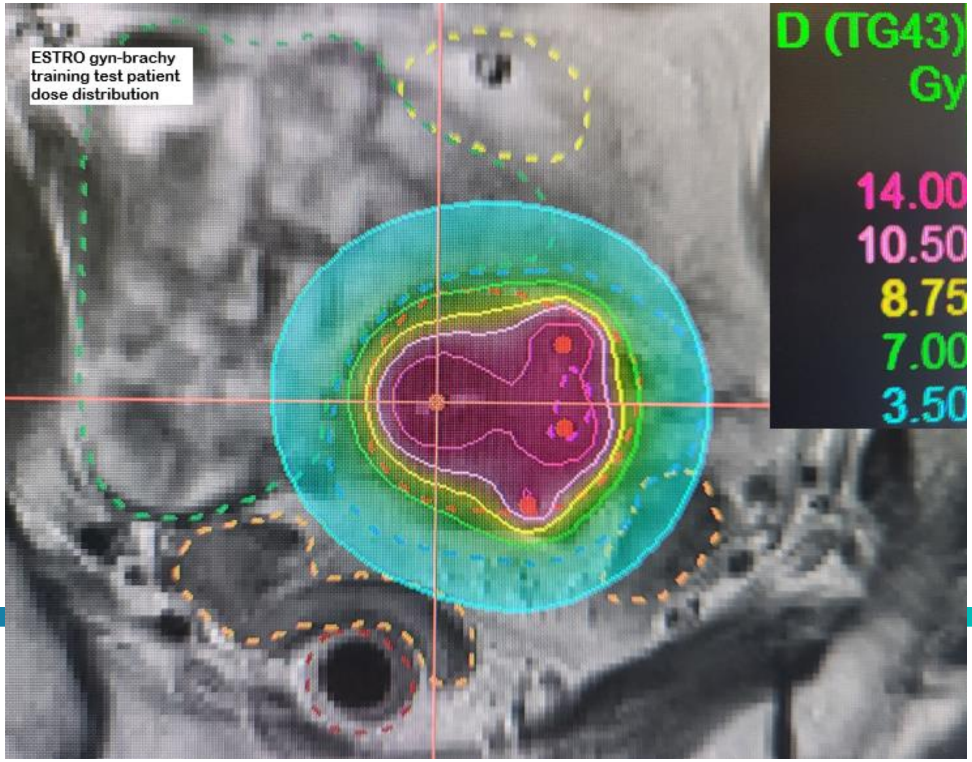


↑ Rivard *et al*. AAPM TG-43 update [modified figure]

HDR, LDR – AND MDR, PDR

- **HDR = high dose rate, > 12 Gy/h** to the prescription point (or surface)
- MDR = medium dose rate, 2 Gy/h < D' < 12 Gy/h
- **LDR = low dose rate, 0.4 Gy/h < D' < 2 Gy/h**
- PDR = pulsed dose rate

E.g. Typical HDR Ir-192 cervical cancer treatment of 7 Gy (x 4) to HR-PTV (=high-risk planning target volume) takes about 10 min



BRACHYTHERAPY PHOTON SOURCES AND BETA (ELECTRON) SOURCES

2.1 Main photon-emitting radioactive sources

TABLE 1. DIVISION OF BRACHYTHERAPY PHOTON SOURCES

Energy	Dose rate	Type
LE[a]	LDR[c]	I-125, Pd-103 and Cs-131 seeds
HE[b]	LDR[c]	Cs-137 tube sources; Ir-192 wires, pins and needles
LE[a]	HDR[d]	eBT X-ray sources
HE[b]	HDR[d]	Ir-192 and Co-60 HDR afterloaders
HE[b]	PDR[e]	Ir-192 PDR afterloaders

[a] LE: Low energy (average energy ≤ 50 keV).
[b] HE: High energy (average energy > 50 keV).
[c] LDR: Low dose rate (dose rate > 0.4 Gy h^{-1} and < 2 Gy h^{-1}).
[d] HDR: High dose rate (dose rate < 12 Gy h^{-1}).
[e] PDR: Pulsed dose rate.

2.2 Beta-emitting radioactive sources

- Ru-106/Rh-106
- Sr-90/Y-90

- Beta emitters have a long history in intraocular brachytherapy
- Sr-90/Y-90 no longer manufactured, ”*if user identifies an old source like this, the suggestion is to dispose it*”
- <u>*”There is no international consensus to the calibration procedure - - This code of practice does therefore* ***not*** *apply to these sources.”*</u>
- However, let’s discuss this tomorrow!

+ 2.3 Other photon-emitting radioactive sources

SR-90/Y-90 APPLICATORS

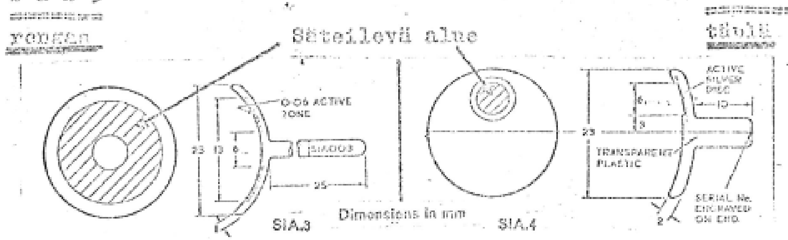
- $^{90}\mathbf{Sr} \rightarrow {}^{90}\mathbf{Y} + \mathbf{e^-} + \boldsymbol{\nu_e} \rightarrow {}^{90}\mathbf{Zr} + \mathbf{e^-} + \boldsymbol{\nu_e}$ (+ a bit γ)

  $\mathbf{t_{1/2} = 28.8\ y} \qquad \mathbf{t_{1/2} = 64\ h}$

- An example: at our hospital, earlier – long before my time! – in use for eye brachytherapy
  - To stop wet age-related macular degeneration (AMD) neovascularization
  - Not recommended anymore

STRONTIUM-90 SILMÄAPPLIKAATTORIT

Beetasäteilijöitä, E_{max} = 2.3 MeV (Y^{90}), $T_{1/2}$ =28.5 vuotta

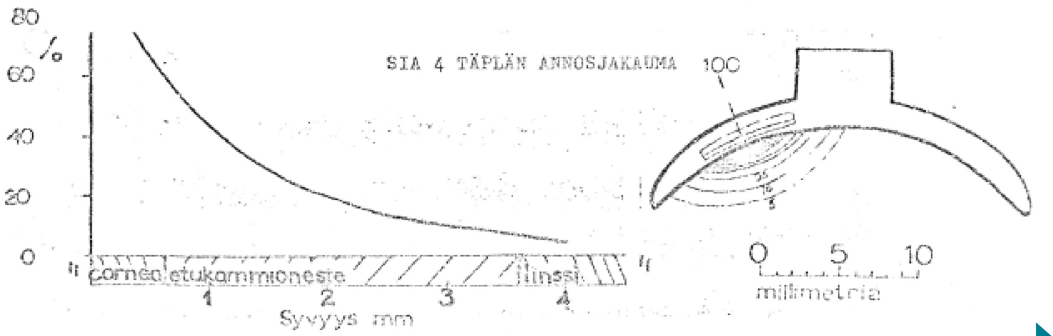


3 mCi 12.7.1956	Aktiivisuus	1 mCi 23.8.1974
56,6 rad/min 49,2 rad/min	Pinta-annosnopeus koveralla puolella 22.10.74 23.7.80	213,6 rad/min 185,7 rad/min
2,3 rad/min 2,0 rad/min	Pinta-annosnopeus kuperalla puolella 22.10.74 23.7.80	1,2 rad/min 1,07 rad/min

A N N O S T E L U

29.7.80

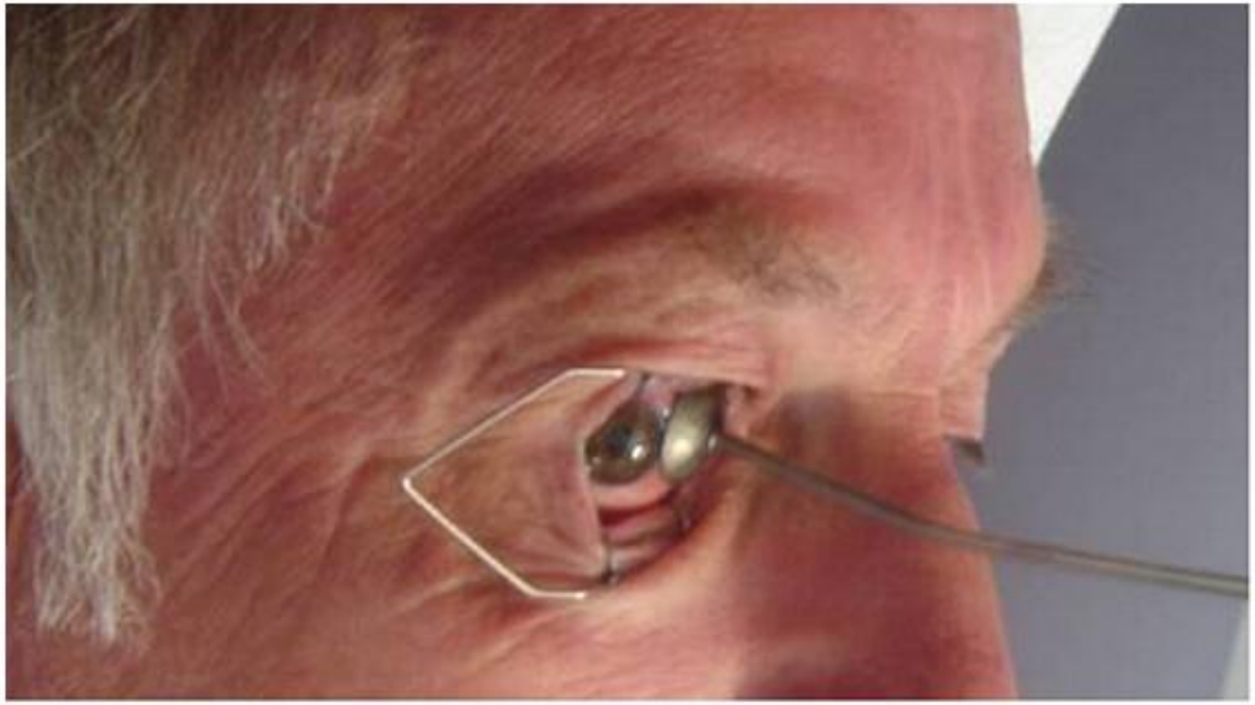
ANNOSNOPEUS	49.20	RAD/MIN	ANNOSNOPEUS	185.70	RAD/MIN
100 RAD	2 MIN	2 SEK	100 RAD	0 MIN	32 SEK
200 RAD	4 MIN	4 SEK	200 RAD	1 MIN	5 SEK
300 RAD	6 MIN	6 SEK	300 RAD	1 MIN	37 SEK
400 RAD	8 MIN	8 SEK	400 RAD	2 MIN	9 SEK
500 RAD	10 MIN	10 SEK	500 RAD	2 MIN	42 SEK
600 RAD	12 MIN	12 SEK	600 RAD	3 MIN	14 SEK
700 RAD	14 MIN	14 SEK	700 RAD	3 MIN	46 SEK
800 RAD	16 MIN	16 SEK	800 RAD	4 MIN	18 SEK
900 RAD	18 MIN	18 SEK	900 RAD	4 MIN	51 SEK
1000 RAD	20 MIN	20 SEK	1000 RAD	5 MIN	23 SEK
1100 RAD	22 MIN	21 SEK	1100 RAD	5 MIN	55 SEK
1200 RAD	24 MIN	23 SEK	1200 RAD	6 MIN	28 SEK



~~[illegible]~~ fyysikko Jorma

Sädehoitoklinikka puh. 3248

The Use of Strontium-90 Beta Radiotherapy as Adjuvant Treatment for Conjunctival Melanoma



Journal of Oncology, Volume: 2013, Issue: 1, First published: 31 January 2013, DOI: (10.1155/2013/349162)

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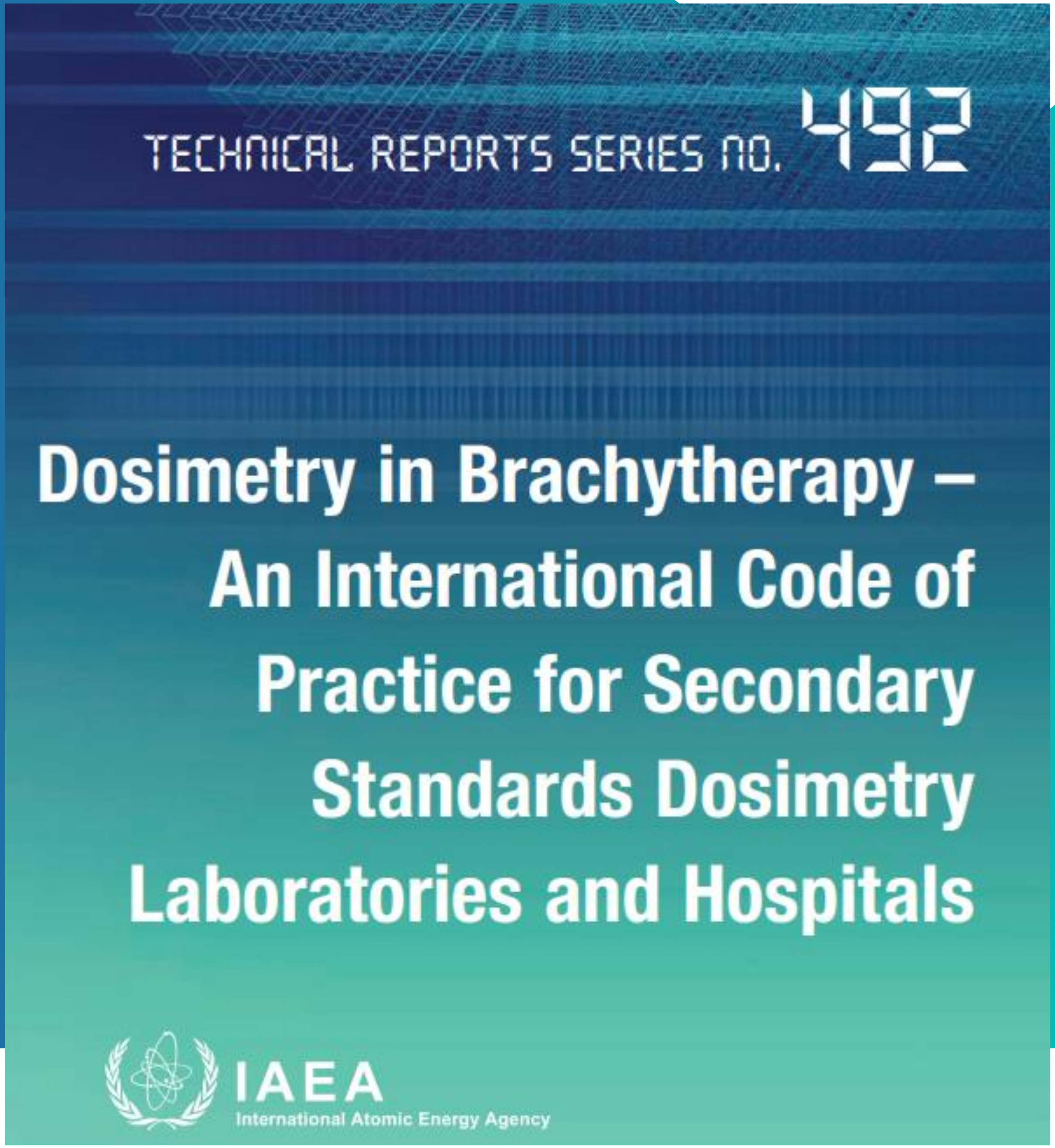


QUANTITIES AND UNITS

- The relevant quantity: absorbed dose to water $\mathbf{D_w}$ measured at clinically relevant points (=close to the source)
- For brachytherapy sources, the depth-dose curve (dose profile) is steep – typically high gradient at even millimeter scale
  - – One millimeter displacement can abruptly matter in many grays!
  - – This is of course also the benefit of brachy: high dose to target, while saving other tissues

- HOWEVER, ”*reference dosimetry of photon emitting sources has, for decades, been based on - -* **air kerma**”

KERMA – RAKR, AKS!

- **KERMA** = **k**inetic **e**nergy **r**eleased per unit **ma**ss (or kinetic energy released in matter/materials)
  - K, unit Gy = J/kg

To be exact, the sum of the initial **kinetic** energies of all the **charged** particles released by **uncharged** ionizing radiation (also neutrons)

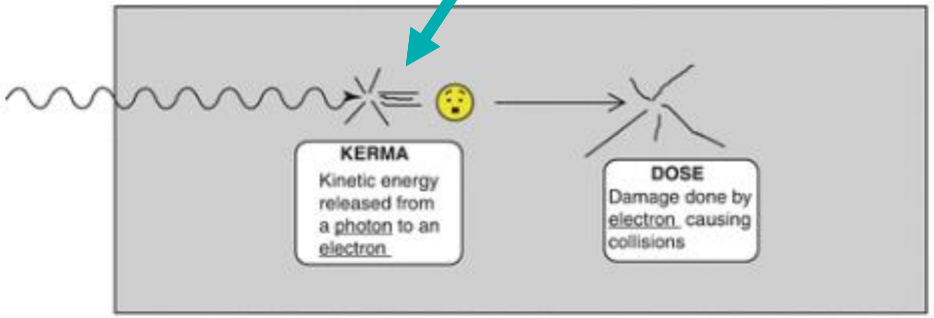
KERMA and Dose

- KERMA – Kinetic Energy Released in Media (the A was added to prevent it from being a dirty word in German apparently). Technically, it is defined as:

$$K = \frac{dE_{tr}}{dm}$$

(6.1)

- E tr is the sum of the initial transferred kinetic energies of all charged particles set in motion by photons in mass (m).
- In other words, KERMA is the energy transferred to the secondary electrons from the primary photons. It is NOT the same as absorbed dose but it has the same basic units of measurement (J/kg) (Fig. 6.1).



Kerma and dose

Fig. 6.1
KERMA vs Dose: KERMA is the kinetic energy transferred from the photon to the electron. Dose is the energy deposited to the medium in the form of ionizations and excitations.

© https://radiologykey.com/quantification-and-measurement-of-dose/

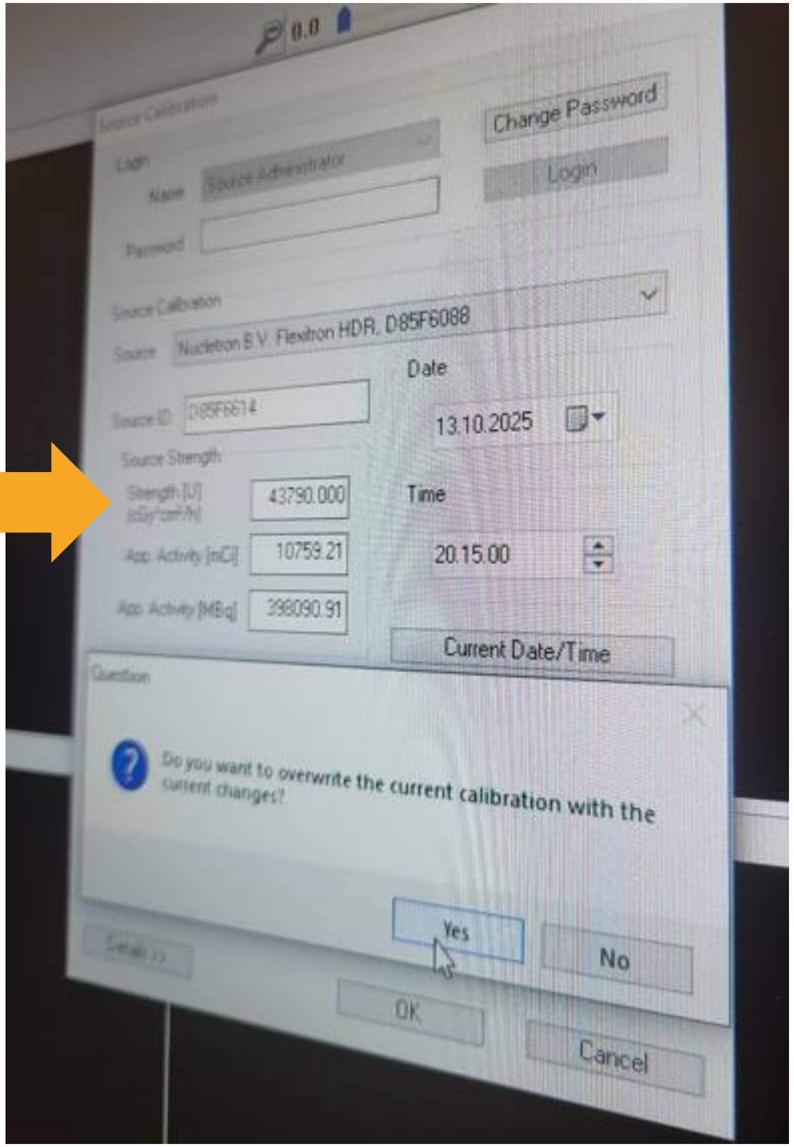
PhD defense questions: What is the difference between KERMA and dose? What is KERMA for an electron beam?

KERMA – RAKR, AKS!

- **KERMA** = **k**inetic **e**nergy **r**eleased per unit **ma**ss (or kinetic energy released in matter/materials)
  - K, unit Gy = J/kg
- **RAKR** = **r**eference **a**ir **k**erma **r**ate
  - $\dot{K}_{\delta,\mathrm{R}}$, convenient unit mGy/h
  - Always defined at 1 m distance from the source
  - δ is the low energy cut-off for photons (excluded below this, typically 5 keV or 10 keV)
- **AKS** = **a**ir **k**erma **s**trength
  - S_K, unit U = cGy · cm²/h

- *"It is **very important** that the user is aware of the quantity used for **source strength**. There have been mistakes made in putting the wrong quantity in the TPS."*

In Finnish, kerma = cream


Change Password
Login
Source Calibration
Source Nucleton B.V. Flexitron HDR, D85F6088
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13.10.2025
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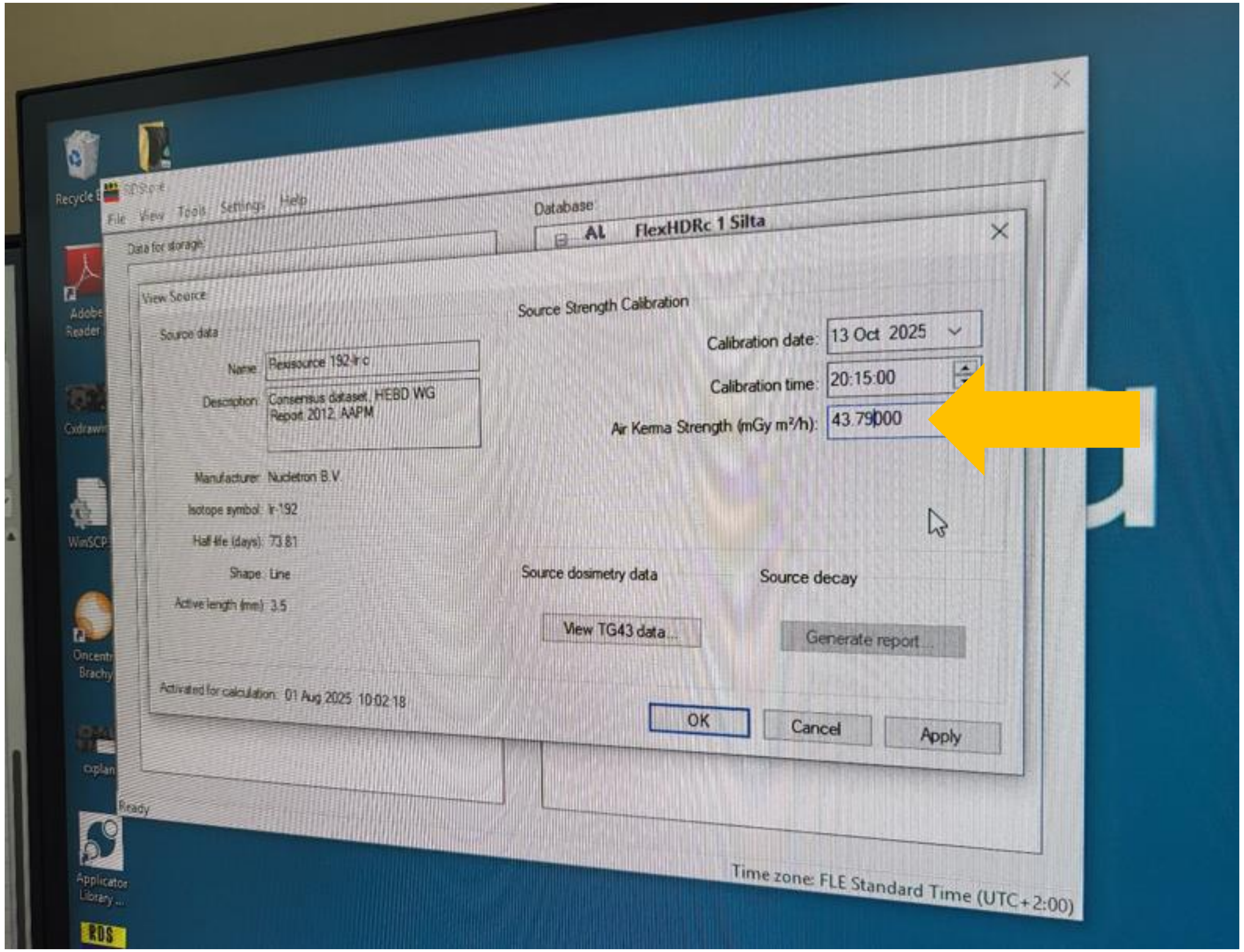
Current Date/Time
Question
Do you want to overwrite the current calibration with the current changes?
Yes
No
OK
Cancel


Database
FlexHDRc 1 Silta
View Source
Source Strength Calibration
Calibration date: 13 Oct 2025
Calibration time: 20:15:00
Air Kerma Strength (mGy m²/h): 43.79000
Manufacturer: Nucleton B.V.
Isotope symbol: Ir-192
Half-life (days): 73.81
Shape: Line
Active length (mm): 3.5
Source dosimetry data
Source decay
View TG43 data...
Generate report...
OK
Cancel
Apply
Time zone: FLE Standard Time (UTC+2:00)

KERMA – RAKR, AKS!

- **KERMA** = kinetic energy released per unit mass (or kinetic energy released in matter/materials)
  - K, unit Gy = J/kg
- **RAKR** = reference air kerma rate
  - $\dot{K}_{\delta,\mathrm{R}}$, convenient unit mGy/h
  - Always defined at 1 m distance from the source
  - δ is the low energy cut-off for photons (excluded below this, typically 5 keV or 10 keV)
- **AKS** = air kerma strength
  - S_K, unit U = cGy · cm²/h

- "*It is **very important** that the user is aware of the quantity used for **source strength**. There have been mistakes made in putting the wrong quantity in the TPS.*"

Why air kerma?

© Ruoka & koti

In Finnish, kerma = cream

WE WILL SOON TALK MORE ABOUT THIS, BUT HERE'S A SNEAK PEEK…

HUS

Quantity	Typical units	Short definition
M_{sm}	A	Reading of the dosimeter irradiated with a source model *sm*, corrected for the influence quantities other than the source model (e.g. air density, leakage currents, electrometer, polarity, and ion recombination)
$M_{sm,\,raw}$	A or rdg	Raw reading of the dosimeter irradiated with a source *sm*, uncorrected for any influence quantity

Borrowed all the way from 8.2.3:

$$M_{sm} = M_{sm,\,raw}\, k_{TP}\, k_{alt}\, k_{leak}\, k_{elec}\, k_{pol}\, k_s \quad (27)$$

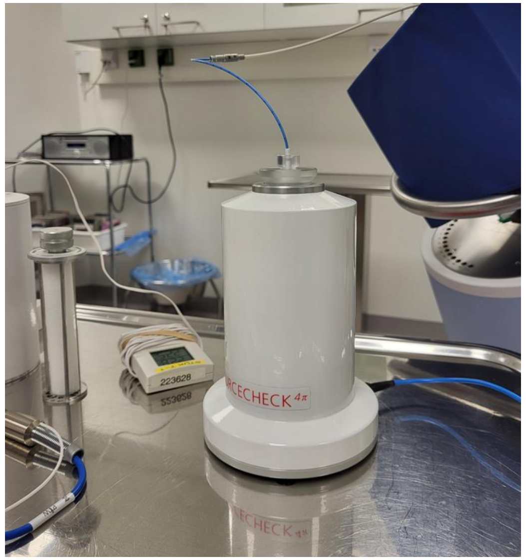
And from 8.2:

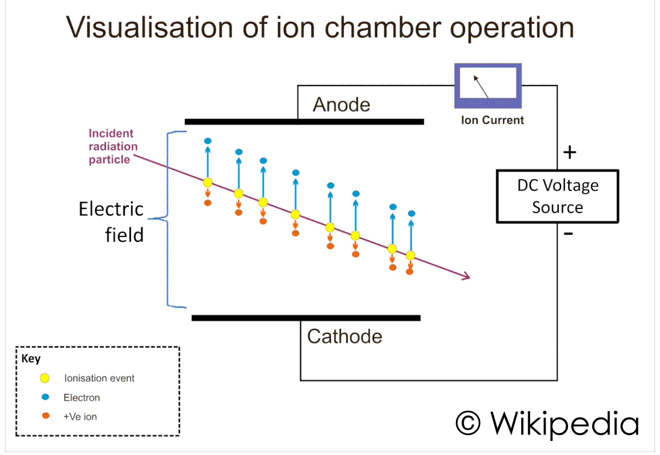
$$\dot{K}_{\delta,R}(t_{ref}) = N_{\dot{K}_{\delta,R},sm_0}\, M_{sm}(t_{meas})\, k_{dec}\, k_{sm,sm_0} \quad (21)$$

$$S_K(t_{ref}) = N_{S_K,sm_0}\, M_{sm}(t_{meas})\, k_{dec}\, k_{sm,sm_0} \quad (22)$$

Formalism shall be clear…

$$\dot{K} \propto dQ/dt = I(nA)$$

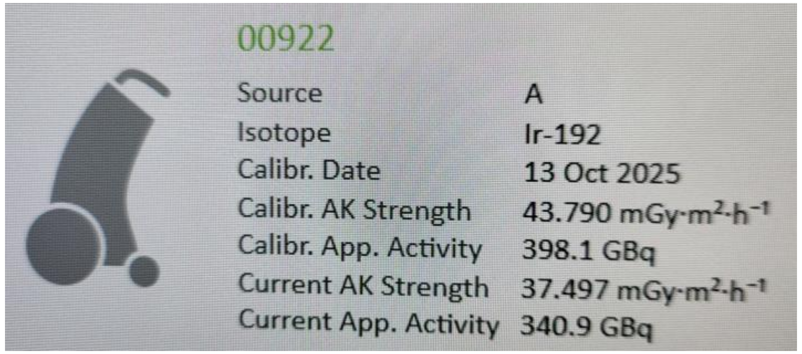




In practice, we will be measuring **current** in (nano-pico) amperes with **vented** well-type ionization chambers

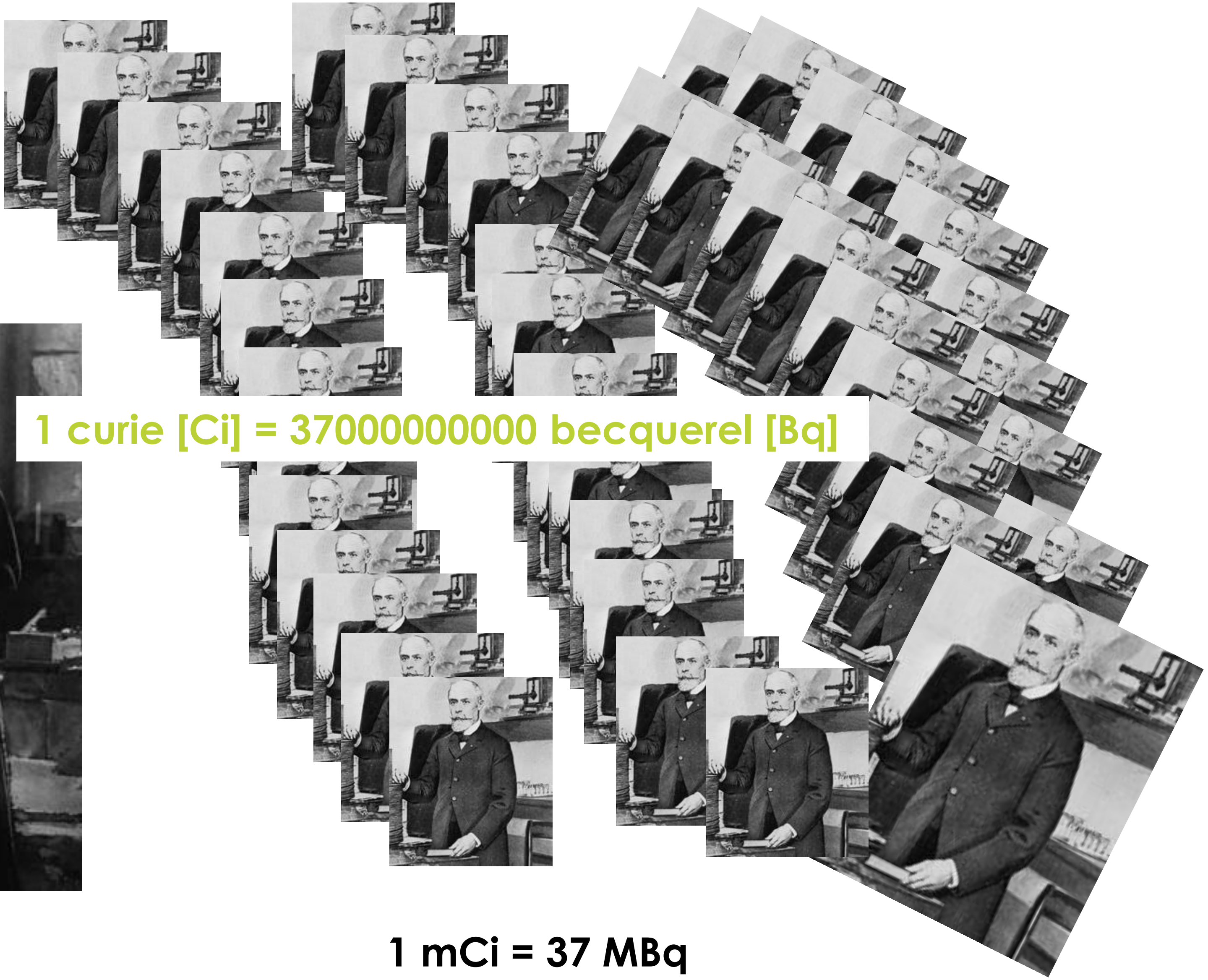
CAUTION, CAUTION!
ANTIQUATED QUANTITIES AND UNITS

- Appedix I in TRS 492
- Warns against ”*number of antiquated quantities that users have insisted on continuing using*”. These include:
  - Apparent activity A_{app}
    - Transportation regulations may require declaration of contained activity – however, apparent activity is even not the contained activity
  - ”Free air measured” quantities, when calibrating HDR sources
  - Using curie (Ci) or equivalent mass of Radium (mgRaEq) as the unit of activity – the SI unit is becquerel (Bq)!



I-125 seed batch certificate (eye brachy):

scheinbare Aktivität *Apparent activity* [mCi]	Referenzdatum *Reference date*
Mittelwert des Loses *Mean value of the lot*	
14,526	2025-10-03



1 curie [Ci] = 37000000000 becquerel [Bq]

1 mCi = 37 MBq

REFERENCE COORDINATE SYSTEM

- AAPM TG-43 Report

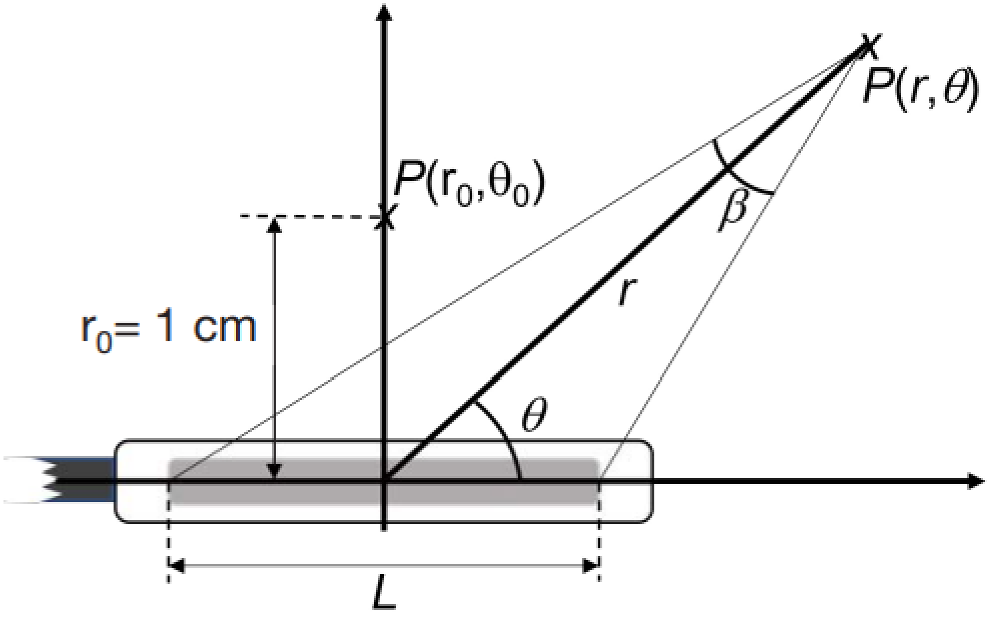


FIG. 1. The polar coordinate system chosen as the reference coordinate system for the AAPM TG-43 formalism. The radioactive content of the source is shown in grey (length L) and is surrounded by its encapsulation. θ_0 equals 90°.

TABLE 2 IN TRS 492

- Table 2. Physical quantities used in this publication, including their typical units
- 3 pages long!
- **Don't worry** – you will understand these step-by-step through application!
- Important to consider, when you build your measurement protocol

3.3 Recommended calibration quantities

- Photon-emitting radioactive sources
  - ICRU: **RAKR**
  - AAPM and NIST: **AKS**
- Beta-emitting radioactive sources
  - Absorbed dose rate to water $\dot{D}_W(r_0)$
  - At a reference distance from the external surface of the source
    - Often r_0 = 2 mm

NUCLEAR DECAY – CAREFUL WITH THE TIME!

- *”An incorrect half-life - - among the main sources of errors and treatment misadministration in brachytherapy in the past.”*

- Date and time
  - ➢ Which time zone is used for reference data? UTC?
  - ➢ Do not misread/mistype date format

    E.g. 2025-11-05 09:10

    Is it November or May?
    Is it morning or evening?

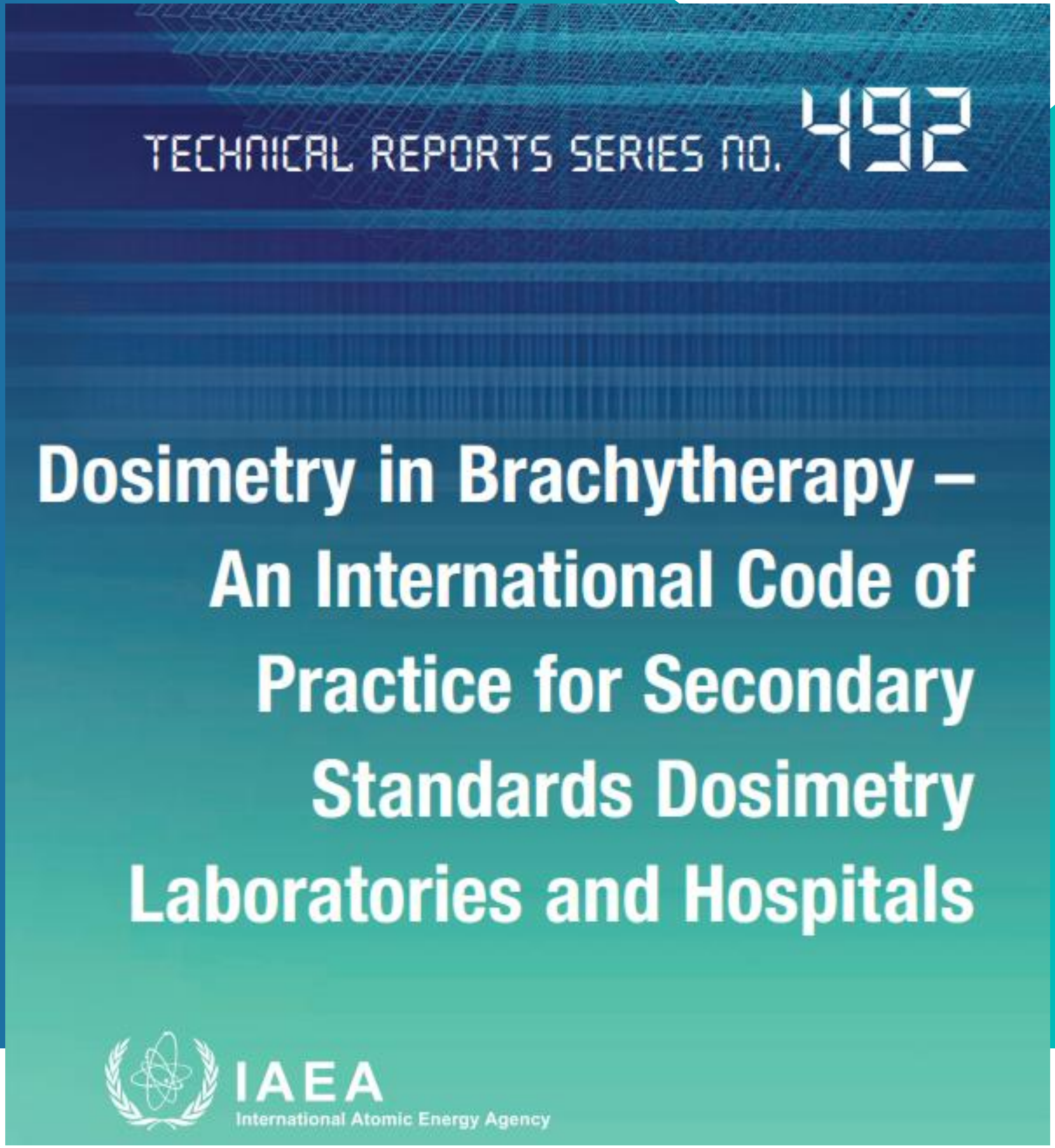
Seems like a silly thing, but can really cause confusion!

TABLE 3. RECOMMENDED HALF-LIVES FOR RADIONUCLIDES USED IN BRACHYTHERAPY

Radionuclide	Element name	Atomic number Z	Main decay used for brachytherapy	Half-life $t_{1/2}$
Co-60	Cobalt	27	γ	1925.21 ± 0.29 d [95]
Sr-90	Strontium	38	β	28.80 ± 0.07 y [95]
Rh-106	Ruthenium	44	β	371.5 ± 2.5 d [97]
Pd-103	Palladium	46	γ	16.991 ± 0.019 d [99, 100]
I-125	Iodine	53	γ	59.388 ± 0.028 d [96]
Cs-131	Caesium	55	γ	9.689 ± 0.016 d [99, 100]
Cs-137	Caesium	55	γ	30.05 ± 0.08 y [95]
Ir-192	Iridium	77	γ	73.827 ± 0.013 d [94]

Today's topics in TRS 492:

- Chapter 2: *Brachytherapy radioactive sources*
- Chapter 3: *Quantities and units*
- **Chapter 4: *Instrumentation***
- Appendix I: *Antiquated quantities and units*



THE RE-ENTRANT WELL-TYPE IONIZATION CHAMBER

- *”The recommended method to measure the strength of the main brachytherapy sources - - considered as the combination of the following components:*

(a) A vented well-type chamber;
(b) A source holder to position the source inside the well-type chamber;
(c) An electrometer;
(d) An extension cable (if required).

- ”Vented well-type chamber set”

VENTED WELL-TYPE CHAMBER

- Vented = **open to atmosphere**, not closed and pressurized like ”sealed chambers”
  - Measurement readings need to be corrected for **ambient conditions**, which may change notably even during measurements!
  - Needs a **warm-up** period to properly **equilibriate** with the environment before starting the measurements
    - E.g. in Finland it is not a good idea to bring the well-type chamber to the measurement room (21 °C) straight from a car trunk at -20 °C in winter, or +35 °C in summer
    - This really matters!!
    - If feasible, let it stabilize from the previous day in the measurement room (see also the specific model’s manual)

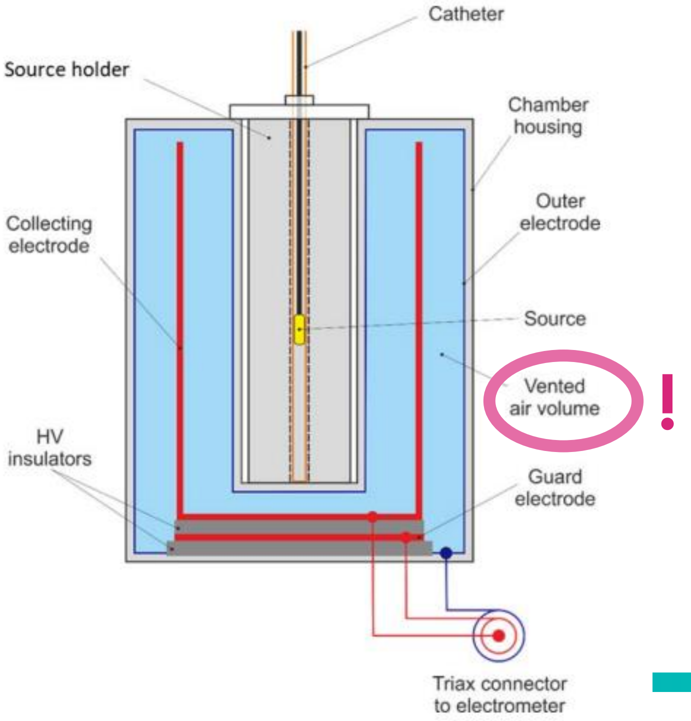


FIG. 2. Cross section of a generic design of a well-type chamber. Actual well-type chambers from different manufacturers might look different. A different source holder without a catheter is used with LDR seeds.

TEMPERATURE, PRESSURE, AIR HUMIDITY

- *"According to the ISO/IEC17025 standard, all equipment that impacts a calibration will have a traceable calibration"*
- Recommendable that thermometers, barometers and hygrometers are regularly calibrated (traceable to primary standards), annual check

WHY VENTED, NOT SEALED?

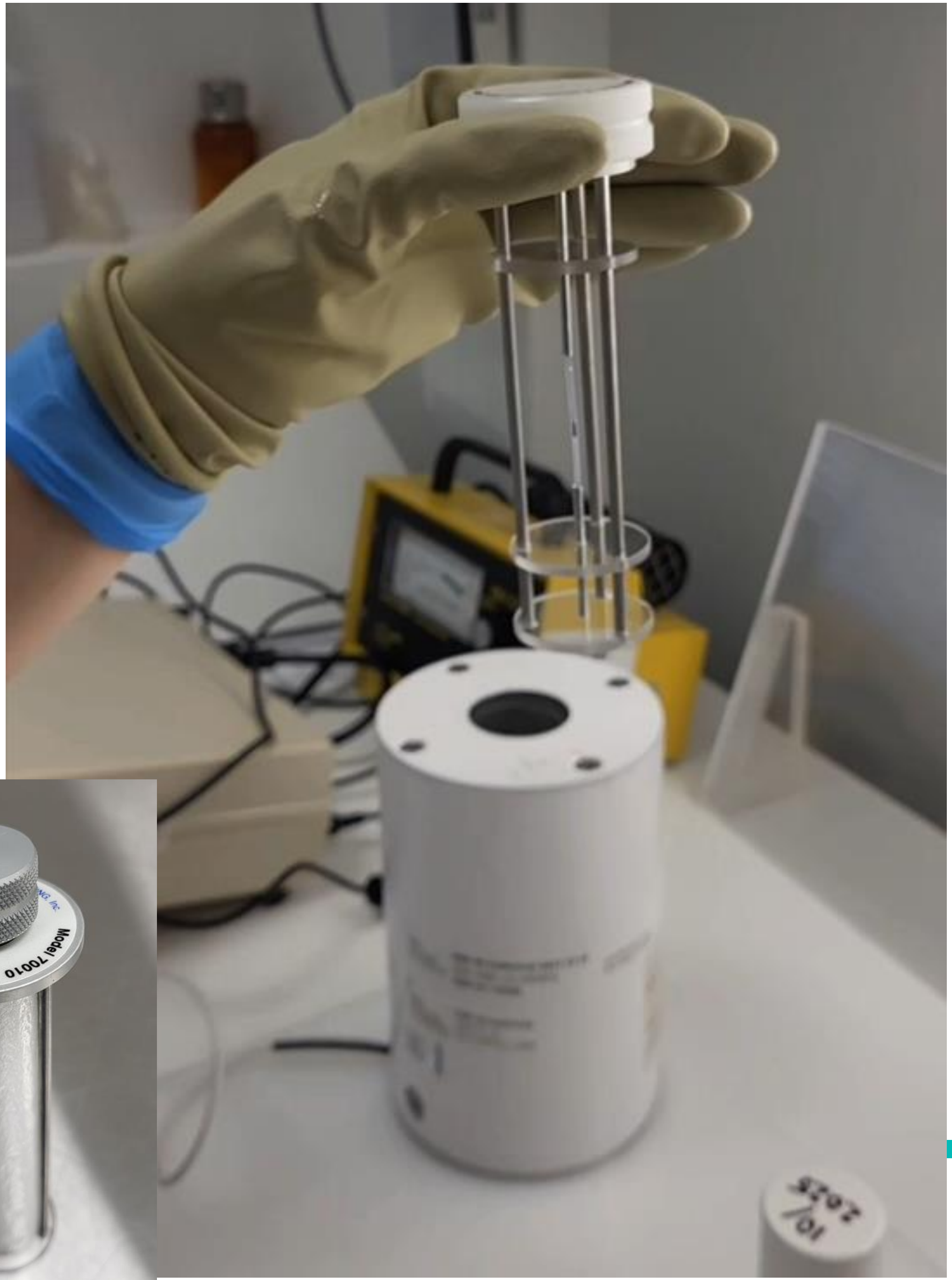
- May start leak → calibration lost
- Chamber needs to be stable over long periods of time (storing and moving)
- Vented well-type chambers have established for this purpose
  - ➢ Selection of suitable, specific source holders

Transport package of a vented well-type chamber →

↑ Pressurized, sealed chamber used in nuclear medicine

SOURCE HOLDERS

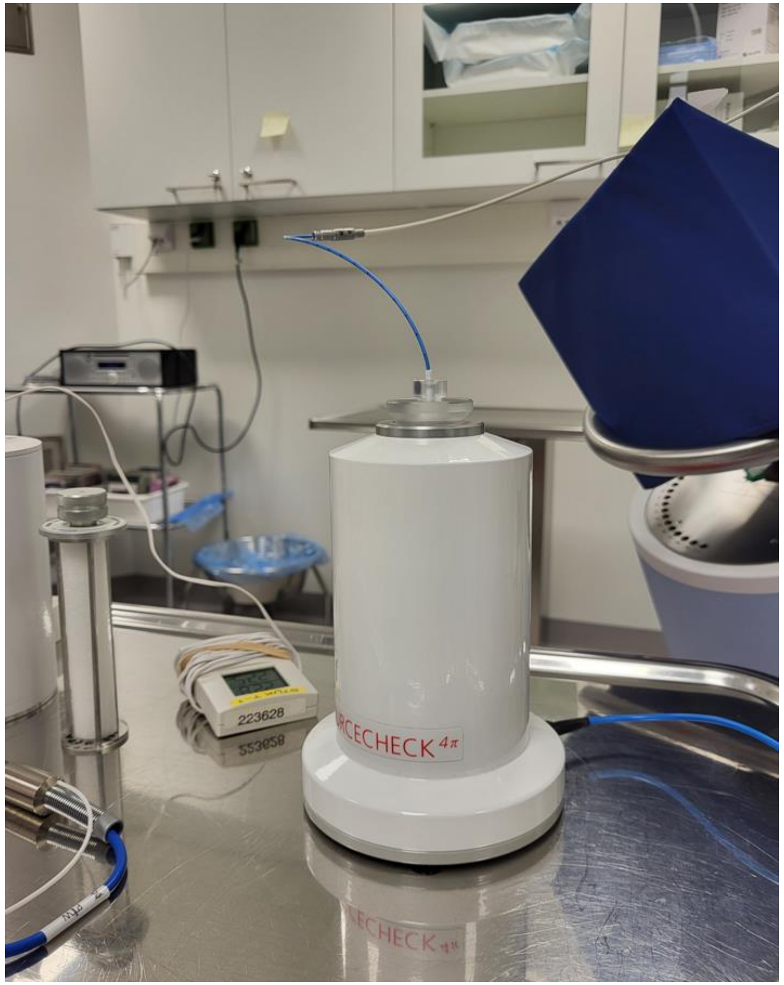
- The source holder to position the source accurately and repeatably inside the well-chamber is a fundamental part of the **calibration chain influence quantities**!
- Even rotational alignment of the holder vs chamber may matter
- Usually made of PMMA, low Z metal, Styrofoam



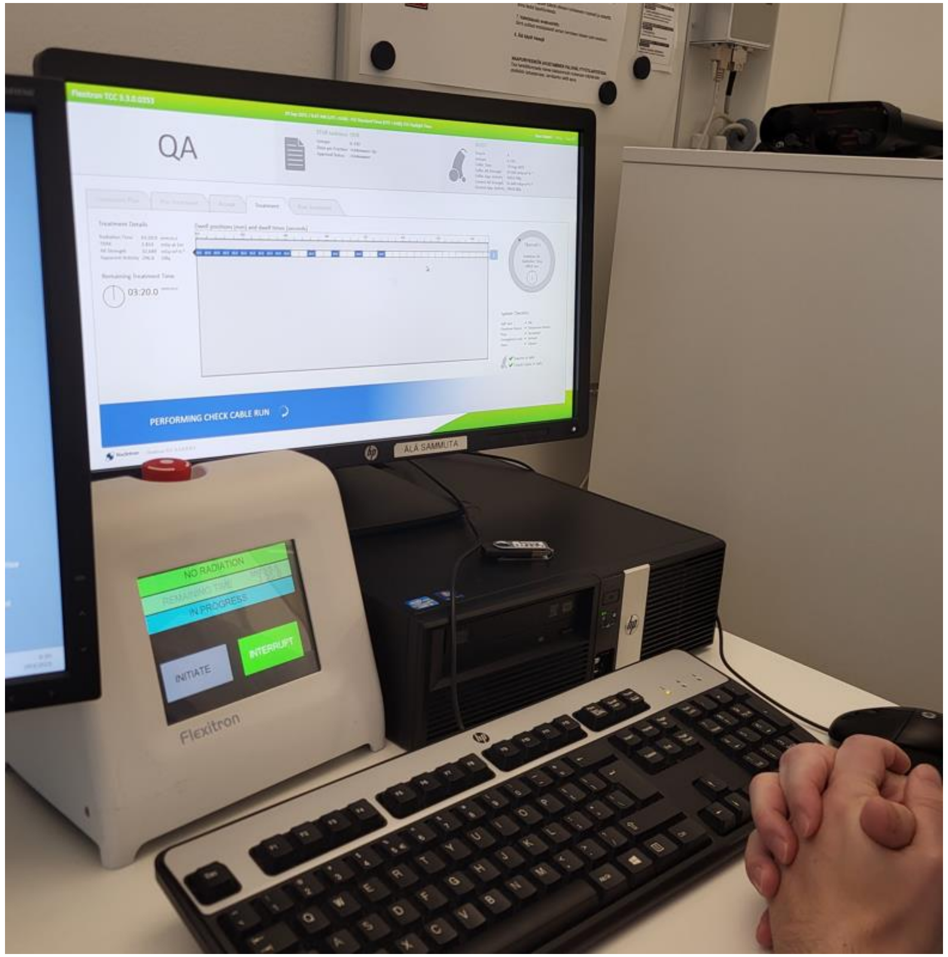
SWEET SPOT

- *”An ideal chamber would show no sensitivity to the position of the brachytherapy source within the well, but all practical chambers generally have - - a* ***sweet spot****, where the chamber signal is the maximum”*


STUK T-1

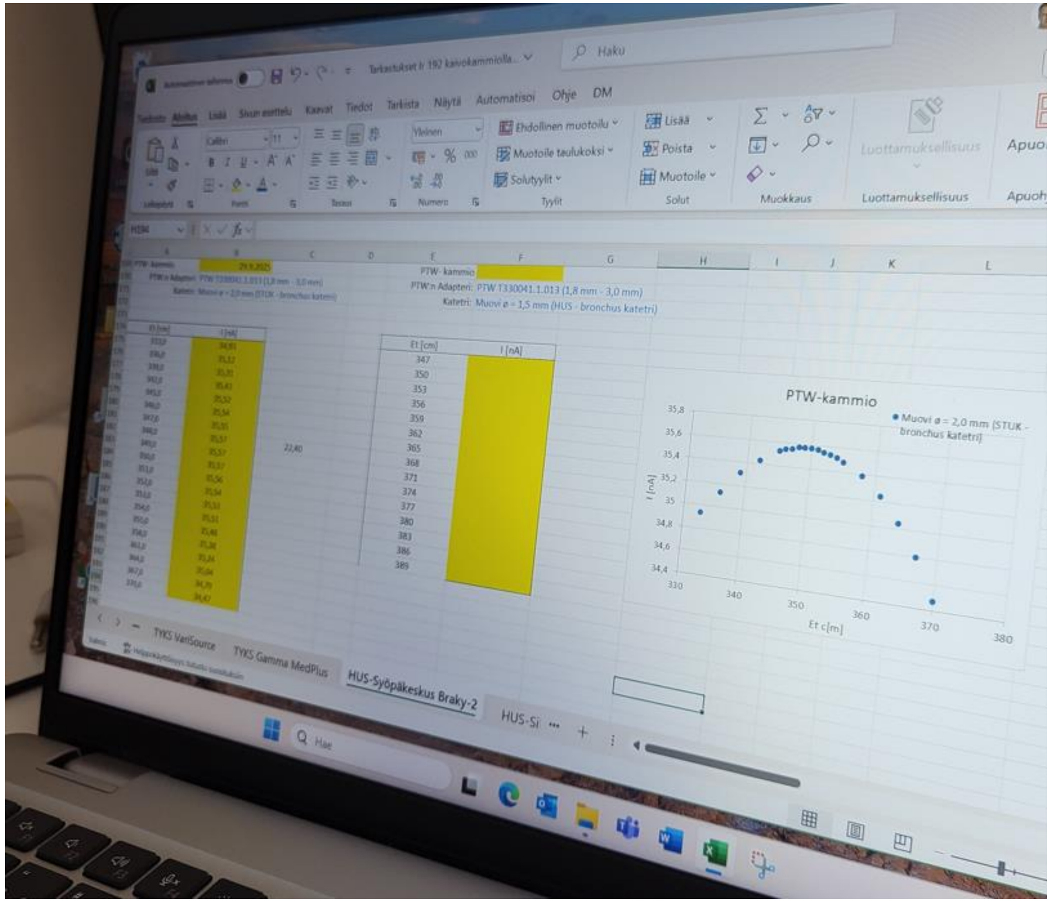

223628
RCECHECK 4π

SWEET SPOT DETERMINATION



Video from sweet spot determination

Sweet_spot.mp4



ELECTROMETER, CABLES, CONNECTORS

- An electrometer is used for measuring ionization current/charge
- Different measurement modes, voltages, range/resolution settings, etc.
  - Need to be set and used consistently
    - HDR sources: up to 200 nA (10^{-9} A)
    - LDR sources: resolution at ~fA (10^{-15} A)

- Also cables and connectors should preferably be the same ones over time
  - Tag and store with the other parts
  - Shelter from dust collection
  - Avoid humidity (for all parts)! 15% < RH < 80%

HDR Ir-192 source being measured, current in nA →

LDR I-125 source being measured, current in pA ←

REFERENCE-CLASS WELL-TYPE CHAMBERS

- Eleven (11) specifications listed in section 4.2.1 (a-k)
- Table 5: Technical specifications of four (4) commercial reference-class well-type chambers

Manufacturers of well-type chambers are advised to provide the following information about their products to the user:

(a) The dimension of the active volume and whether it is vented to the atmosphere;

(b) The measuring range in RAKR (or S_K) for each possible radionuclide that might be measured;

(c) The polarizing voltage range;

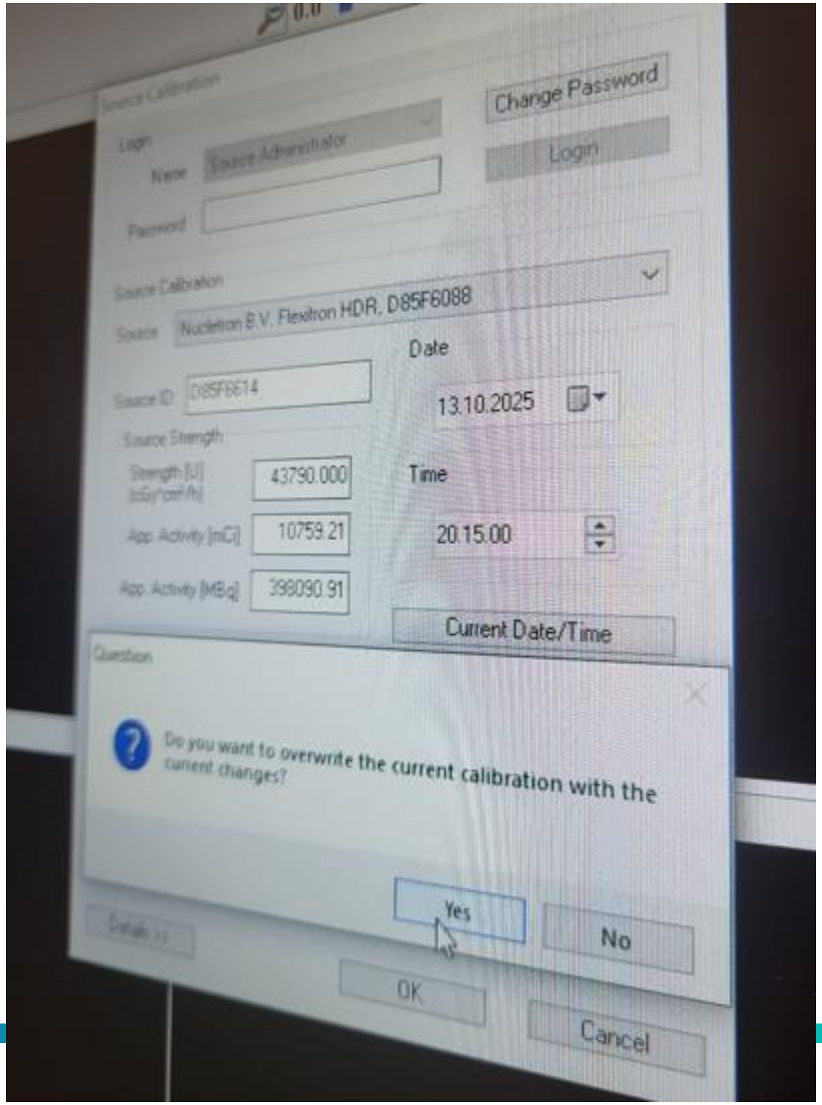
(d) The working environment requirements (temperature, pressure, relative humidity);

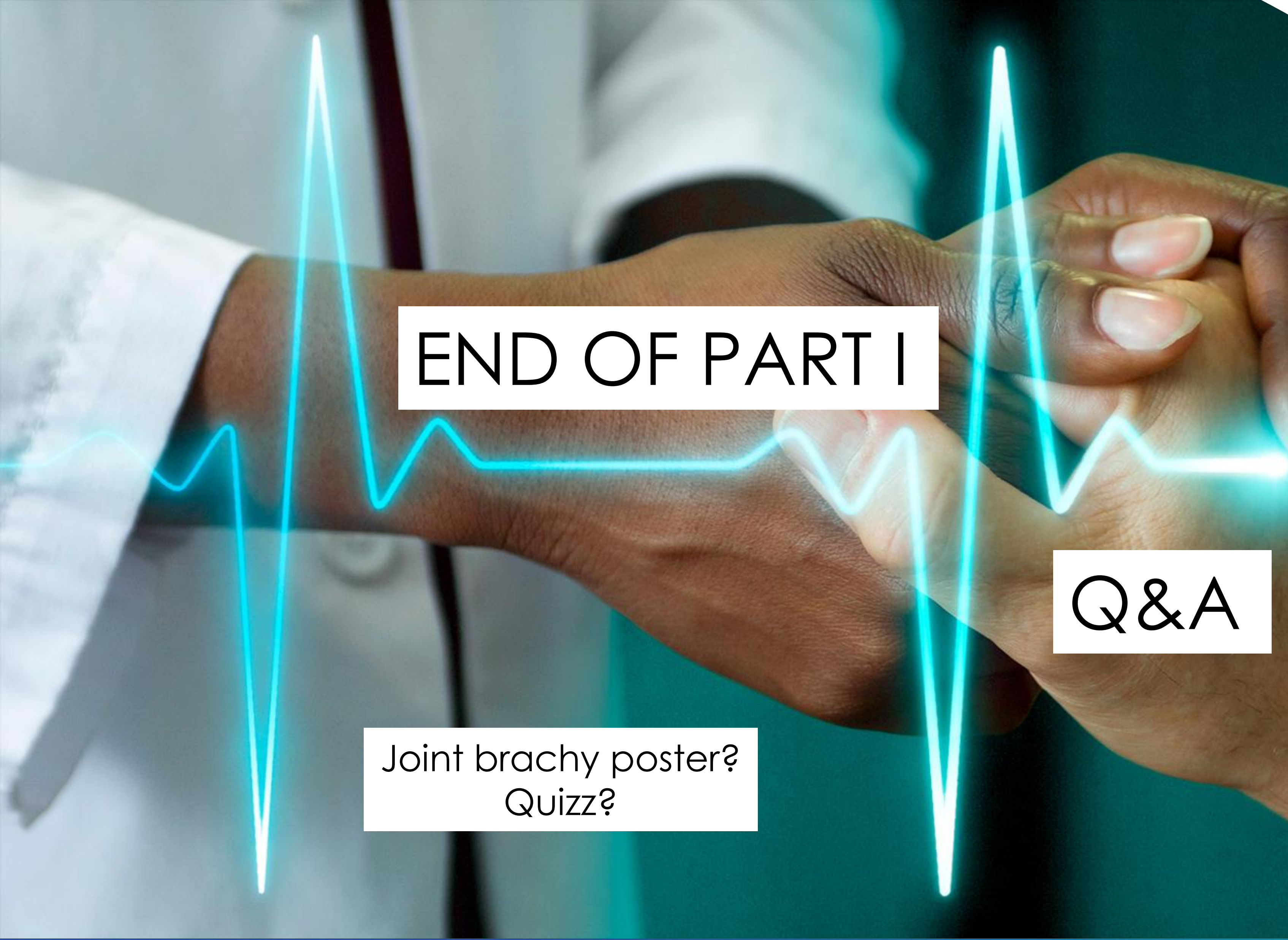
(e) The main electrical characteristics (e.g. sensitivity, leakage, stability, wiring and cable connection);

(f) The source models and main characteristics of the source holders, and the approximate distance of the sweet spot from the base of the chamber well.

COMMISSIONING

- Independently for all the different source types that are used in the clinical routine
  - ➢ Setting up the calibration chain and quality control (QC) program, acceptance test measurements for new sources/periodic tests for sources in use
  - ➢ **Next lectures today…**
- Table 6: Recommended commissioning tests and related tolerance levels
  - ➢ More on these in **Chapter 8 & tomorrow's lecture**





END OF PART I

Q&A

Joint brachy poster?
Quizz?