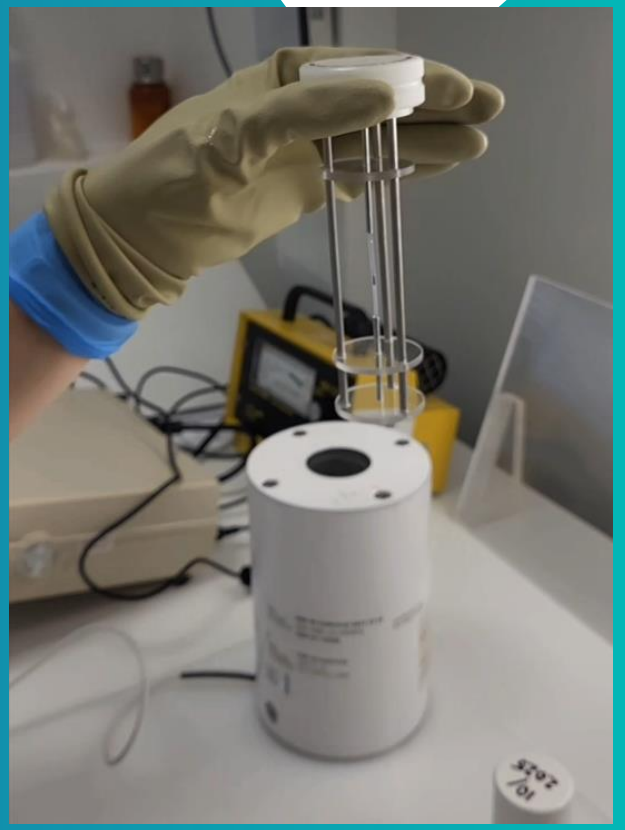
ICTP-IAEA Workshop on Reference Dosimetry in EBRT and Brachytherapy

# DOSIMETRY FOR LDR, E.G. BRACHYTHERAPY IMPLANTS AND EYE APPLICATORS



6 Nov 2025, Vappu Reijonen/Medical Physicist, PhD

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

# LDR BRACHYTHERAPY IMPLANTS

- Popular in the past, nowadays much replaced by HDR afterloaders
- E.g. when I begun working at our cancer center, prostate LDR I-125 seed applications ended and HDR Ir-192 afterloader treatments started
- Different targets: brain tumors, …
- Permanent implants

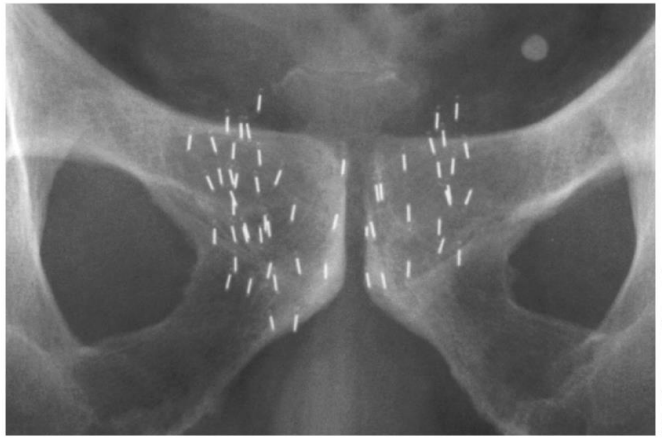
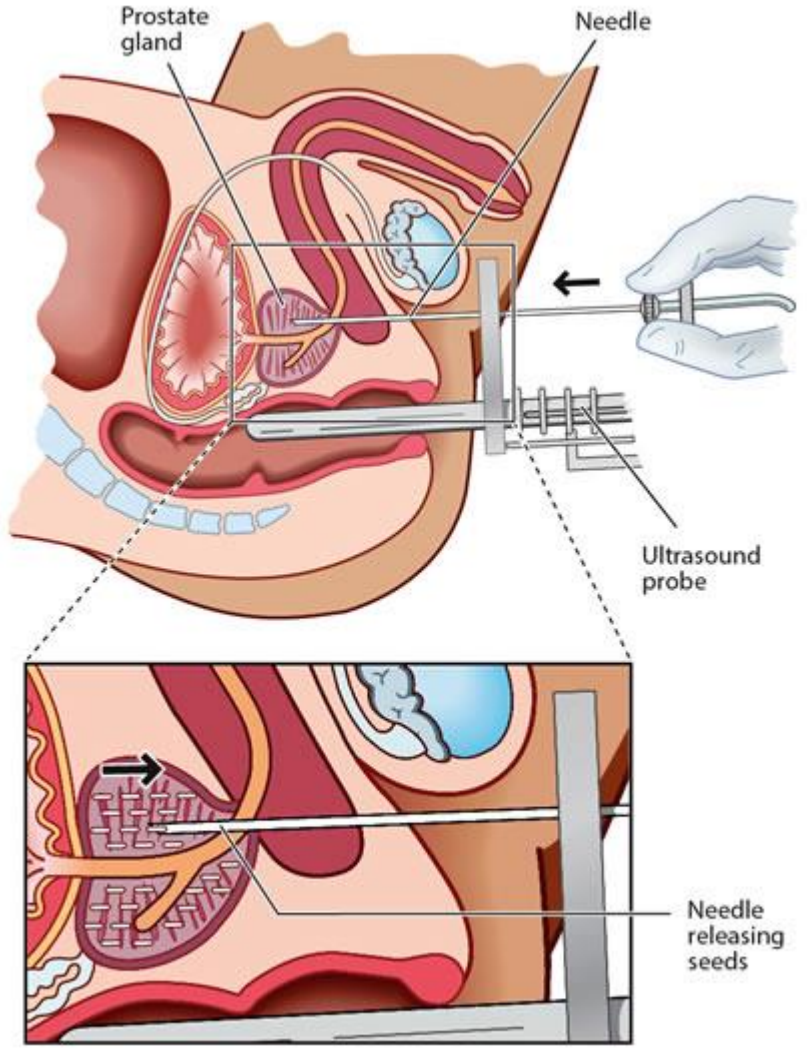



**Abb. 3:** Postinterventionelles Symphysen-Röntgen p.a. mit Darstellung der Seeds in der Prostata.



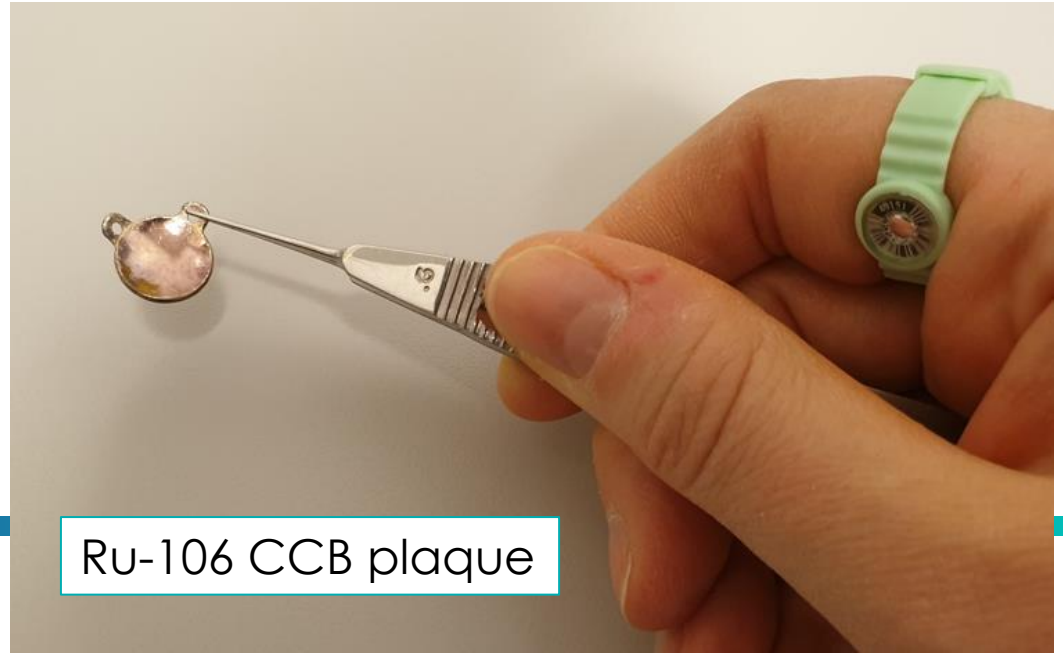

Abbildungen: Schmid

Image reproduced with permission of Prostate Cancer Foundation of Australia.

# EYE BRACHYTHERAPY

- However, I have very strong experience with ophthalmic brachytherapy applicators (”plaques”), so I will use these as a concrete, detailed example!
  - A relatively rare treatment, but will illustrate many general dosimetric aspects handled in this course!
- Not permanent implants – attached temporarily on the eye
- Treatment time typically from less than a day up to two weeks

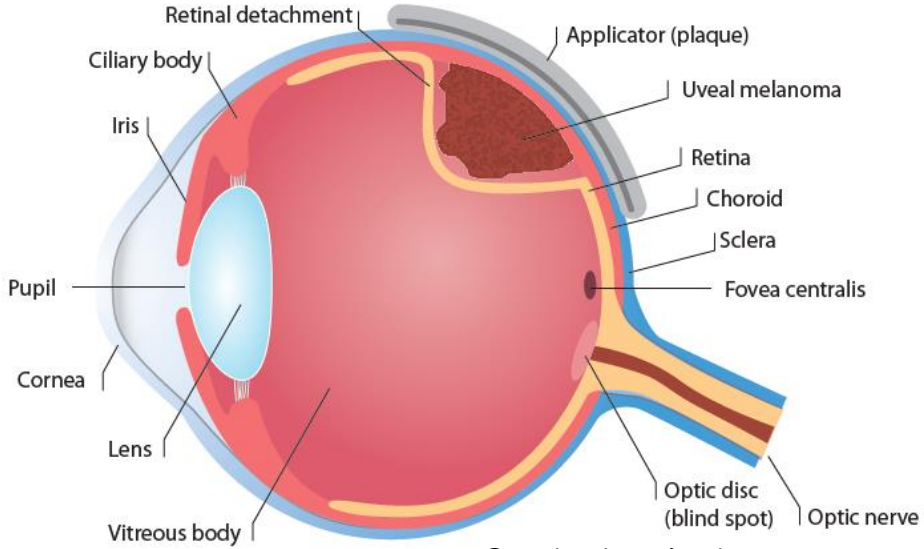
I-125 CCA plaque



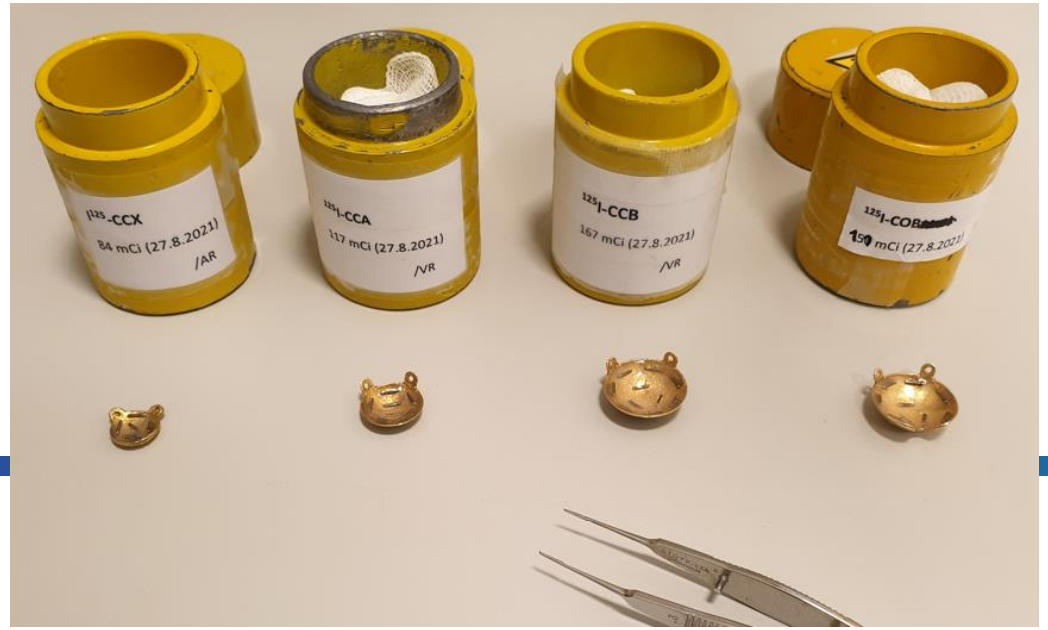
Ru-106 CCB plaque

# EYE BRACHYTHERAPY

- In Finland, about 70 patients/year treated
- Most common treatments targets:
  - Uveal melanoma (adults)
  - Retinoblastoma (children)



© Eckert & Ziegler





© Rantala, ES. *et al.*

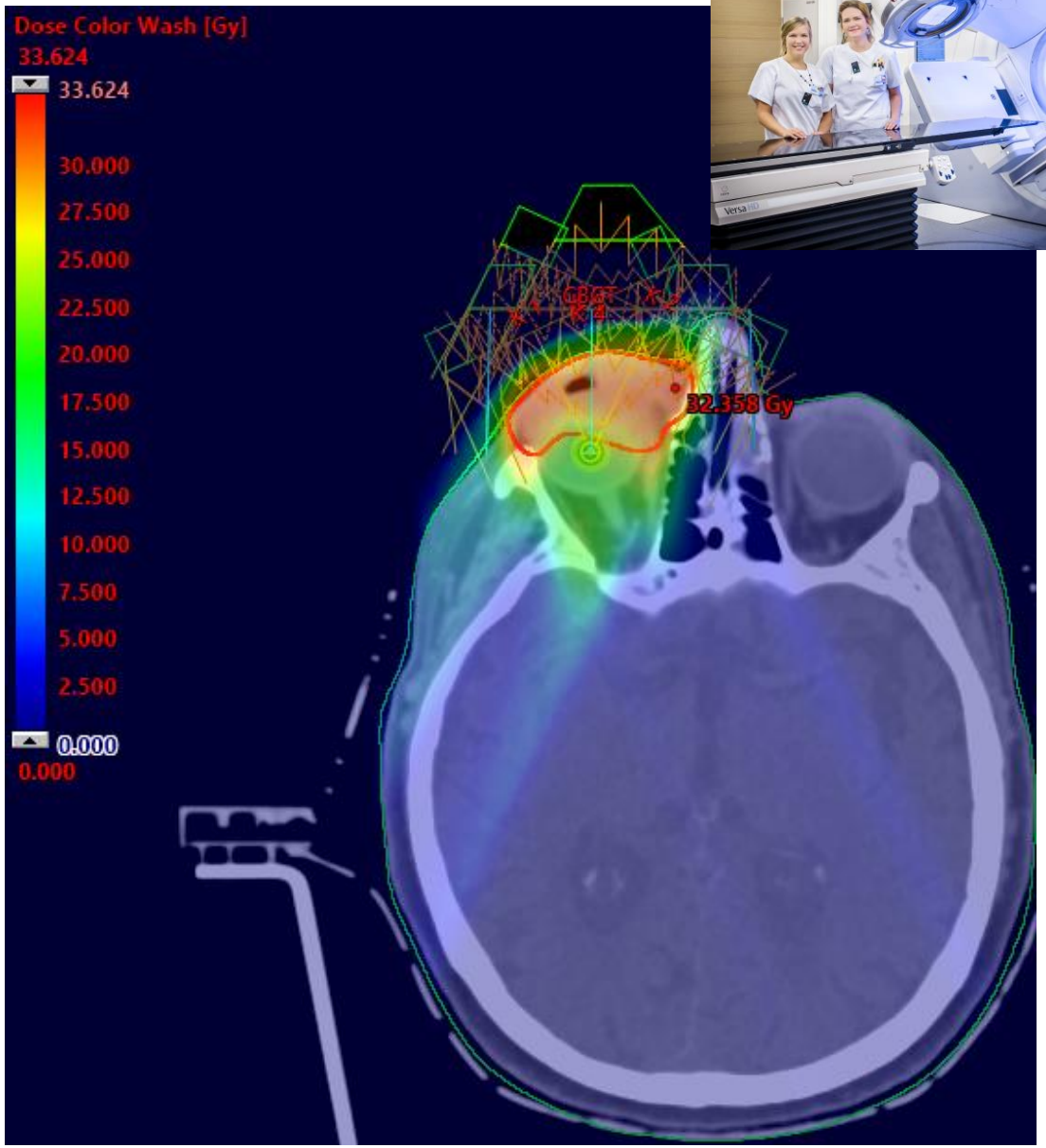
↑ Melanoma of iris


© Dimaras, H. *et al.*

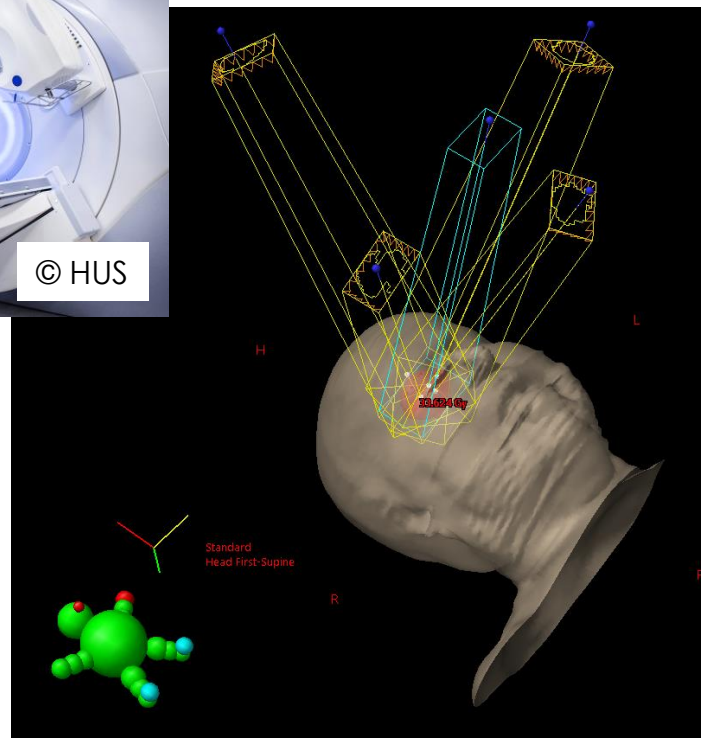
↑ So-called leucocoria in the eye of a child with retinoblastoma

← Different plaque models for different sized targets

EBRT vs brachy:



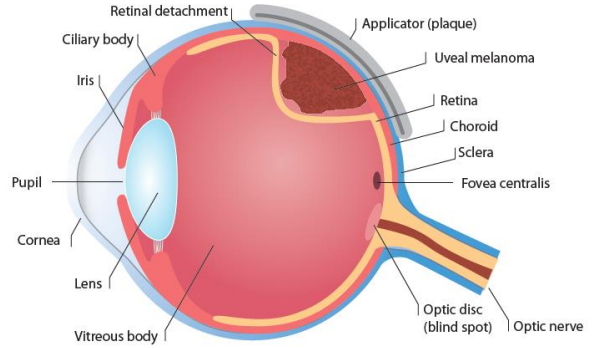




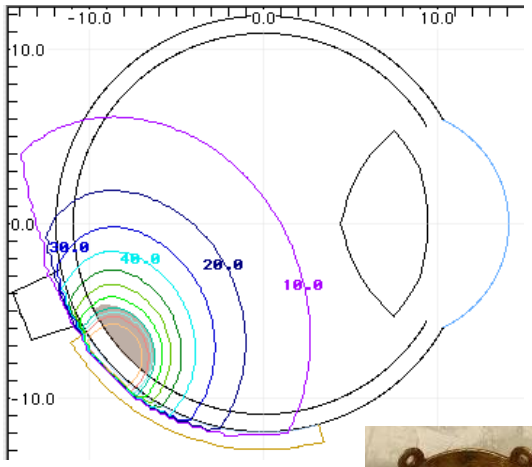

←↑ Treatment plan for eye lymphoma with EBRT

**vs**

Treatment plan for small uveal melanoma with eye brachytherapy →




© Eckert & Ziegler




# TWO KINDS OF PLAQUES WE USE…

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

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

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

shape model

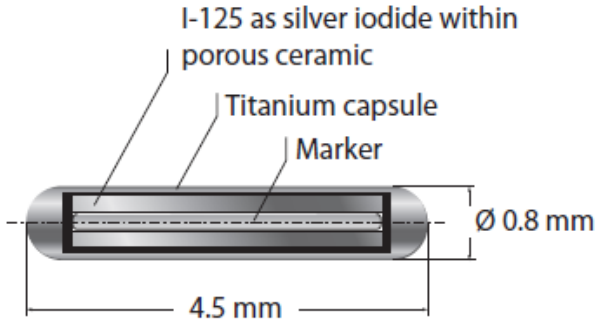


© Eckert & Ziegler


shape model

$t_{1/2}$ = 59.4 days

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

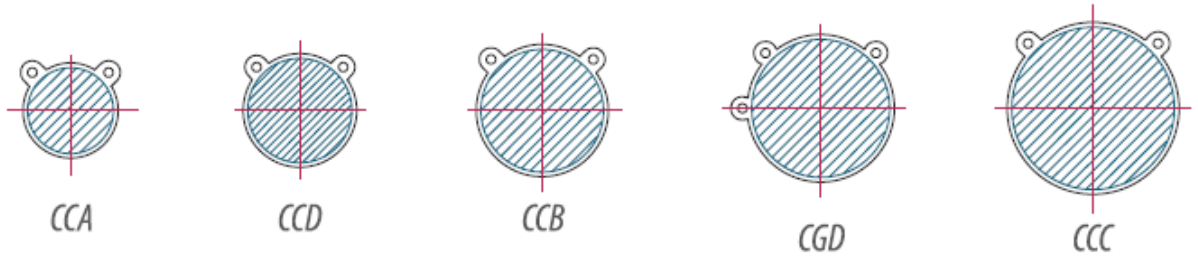



*IsoSeed® I25.S16 details* © Eckert & Ziegler

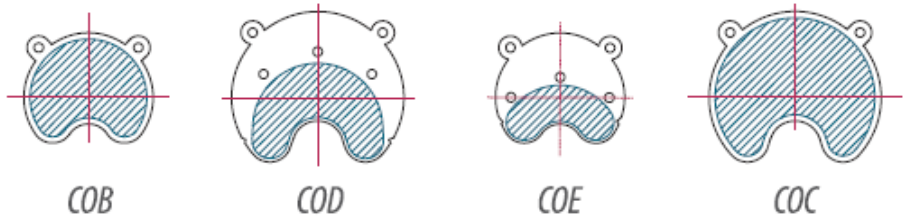
- I-125 containing titanium seeds are glued on golden base plaques

## Retinoblastoma

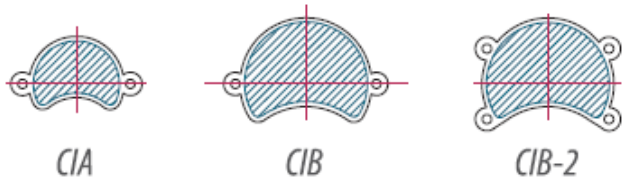

## Peripheral uveal/choroidal melanoma




## Tumors close to the optical nerve



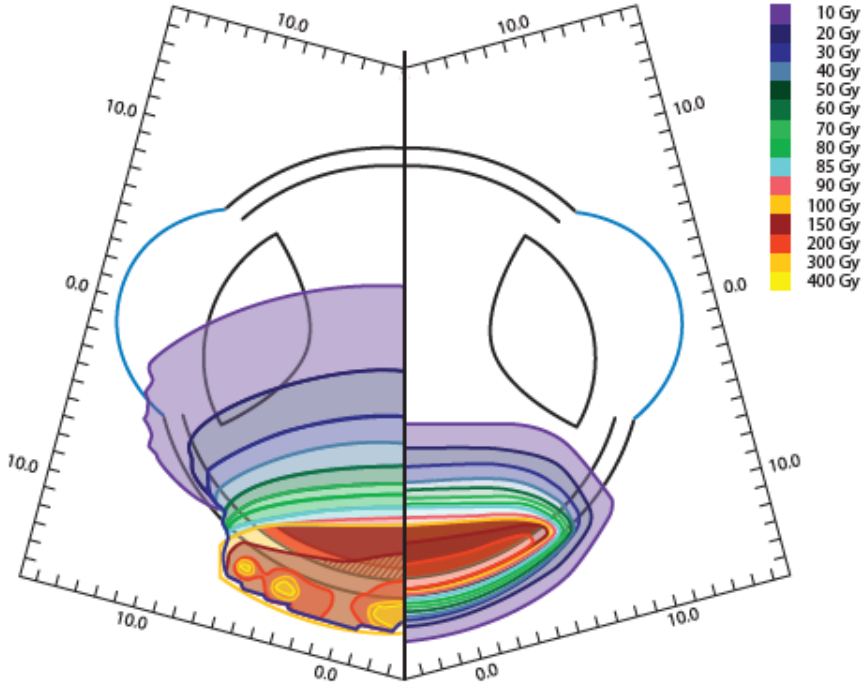

## Ciliary body melanomas or melanomas close to the iris




*16 types suggested for different tumor sites and sizes*

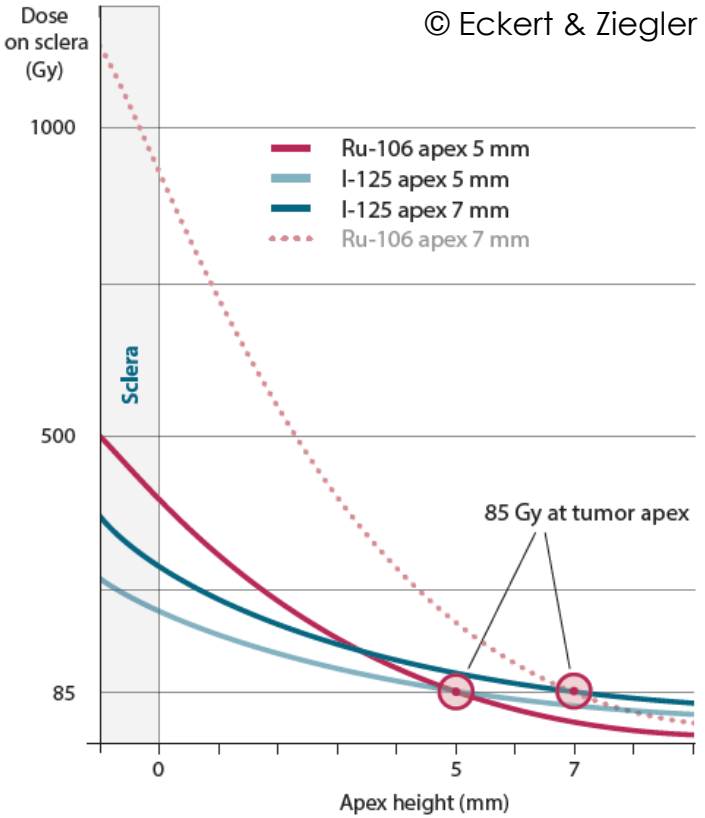
# Why two kinds?

## I-125 plaque vs Ru-106 plaque




*Comparison of the 2D dose distributions of two plaques with 18 mm diameter. Both planned with a dose of 85 Gy to the apex of a thin tumor. I-125 shown on the left and Ru-106 on the right.*

© Eckert & Ziegler




© Eckert & Ziegler

*Dose depth curves for Ru-106 and I-125 plaques of similar sizes (CCB and COMS Ø20 mm). The solid lines illustrate the situation for a tumor with 5 or 7 mm apex height. The dashed line shows the theoretical values for a treatment with Ru-106 beyond 5 mm tumor thickness.*

- Ru-106 plaques are applied to <u>max 5-6 mm</u> high tumors
- I-125 plaques also to higher tumors
  - ➢ Can be modified by placing the seeds as wished

- When the plaque is in the patiet's eye, the dose rate is about 1-2 µSv/h at 1 m

# EYE BRACHYTHERAPY HISTORY IN FINLAND

- **Ru-106 plaques y. 1980-**
- **I-125 plaques y. 1990-**
- **Co-60 plaques 1960-80**
- **Sr-90 applicator in the past**

© Eye Physics

- Internationally also Pd-103 plaques, etc.

HELSINGIN YLIOPISTOLLINEN KESKUSSAIRAALA
SILMÄTAUTIEN KLINIKKA
Haartmaninkatu 4 C 00290 HELSINKI 29 Vaihde 4711

Helsinki 14.5.1981

D:no

SÄDEHOITOKLINIKKA
Isotooppiosasto

Viite

Asia

Dg: Melanoma chorioideae o.sin.

12.5.1981 implantatio disci Rh 106 o.sin. Tuumori lokalisoitiin skleeran pinnalle, minkä jälkeen asetettiin Rh-levy ylätemporaalikvadranttiin skleeraa vasten. Levyn poisto suoritettiin 14.5.1981.

Leila Laatikainen

Asetus 12.5.-81 klo. 12.30

Poisto 14.5.-81 klo. 8.30

Tuumorin huippuun 120 Gy = 12000 rad

Example of an I-125 batch ceritifcate:

**DE Zertifikat für umschlossene radioaktive Stoffe** ([redacted]®)

**EN Certificate for sealed radioactive sources** ([redacted]®)

[redacted]

| Allgemeine Angaben<br>*General Information* | | | | | |
|---|---|---|---|---|---|
| Zertifikat-Nr.<br>*Certificate no.* | Kunde<br>*Customer* | | | | Auftragsnummer<br>*Order number* |
| 3595525 | HUS Cancer Center | | | | BBD008359 |
| Artikelnummer<br>*Catalogue number* | Nuklid<br>*Nuclide* | ISO-Klassifikation<br>*ISO-classification* | gesamte Stückzahl<br>*Total quantity* | gesamte enthaltene Aktivität<br>*Total contained activity* [mCi] | sterilisiert am<br>*Sterilized on* |
| [redacted] | I-125 | ISO/12/C63X11 | 50 | 944,190 | -- |

| Mess- und Prüfbericht<br>Alle Messergebnisse beziehen sich auf das Referenzdatum - weitere Informationen siehe Rückseite<br>*Test report*<br>*All measurements refer to the reference date - see reverse side for more information* | | | | | |
|---|---|---|---|---|---|
| Nebenstehende Daten sind für alle Seeds gültig<br>*The data mentioned beside are valid for all seeds*<br>⇒ | Referenz-Luftkermaleistung<br>*Reference air-kerma rate* [µGy/h] | | scheinbare Aktivität<br>*Apparent activity* [mCi] | | Referenzdatum<br>*Reference date* |
| | Mittelwert des Loses<br>*Mean value of the lot* | | Mittelwert des Loses<br>*Mean value of the lot* | | |
| | 18,448 | | 14,526 | | 2025-10-03 |
| Behälter-Nr.<br>*Lot no.* | Chargen-Nr.<br>*Batch no.* | Stückzahl<br>*Quantity* | Dichtheitsprüfung bestanden<br>*Leakage test passed* | verwendbar bis<br>*use before* | gesamte scheinbare Aktivität pro Behälter<br>*Total apparent activity per lot* [mCi] |
| 0042161/01 | 1320 | 50 | 2025-08-18 | 2026-02-16 | 726,300 |

…remember when we talked about "antiquated quantities & units" such as apparent activity and Ci (curie)?

## *Brachytherapy source*

*Radioactive sources [redacted]® type **I25.S16** are intended for brachytherapy of solid tumours, especially in ophthalmology.*

***IsoSeeds** are cylindrical, sealed sources. Their source type is specified by the product code. The seeds have dimensions of 4.5 mm in length and 0.8 mm in diameter. The encapsulation is a titanium tube with wall thickness of 0.05 mm, laser welded on both ends. Inside, the radionuclide I-125 is bound on a cylindrical carrier. The latter is working as X-ray marker additionally.*

*[redacted] are offered according to different source strength ranges. For that purpose, the reference air-kerma rate of every individual seed is measured. The reference date is referred to 12:00 noon MEZ/MESZ. The statement of "apparent activity" is based on dividing the measured quantity by constant A (see table).*

| *product code* | *constant A in µGy*h⁻¹*mCi⁻¹ (apparent activity)* | *constant B (contained activity)* |
|---|---|---|
| I25.S16 | 1.27 | 1.3 |

*Really contained activity results from "apparent activity" by multiplication with constant B (see table).*

*The measuring device used by* [redacted]
*GmbH is periodically recalibrated. The calibration is traceable to the primary standard of the PTB, Germany.*

*The uncertainty of a single seed within a lot is at maximum ±5% (k=2).*
*Please use the following factor for the conversion of the indicated activity into MBq:*
*1 mCi = 37 MBq*

*Before shipment, all sources are checked for leak tightness, according to ISO 9978 by an immersion test in a suitable liquid at 70°C for 30 min.*
*They are provided non-sterile and have to be sterilized before application.*

***IsoSeeds** are manufactured in accordance with a strict quality assurance program and in compliance with the standard DIN EN ISO 13485.*
*They are CE-marked according to 93/42/EEC.*

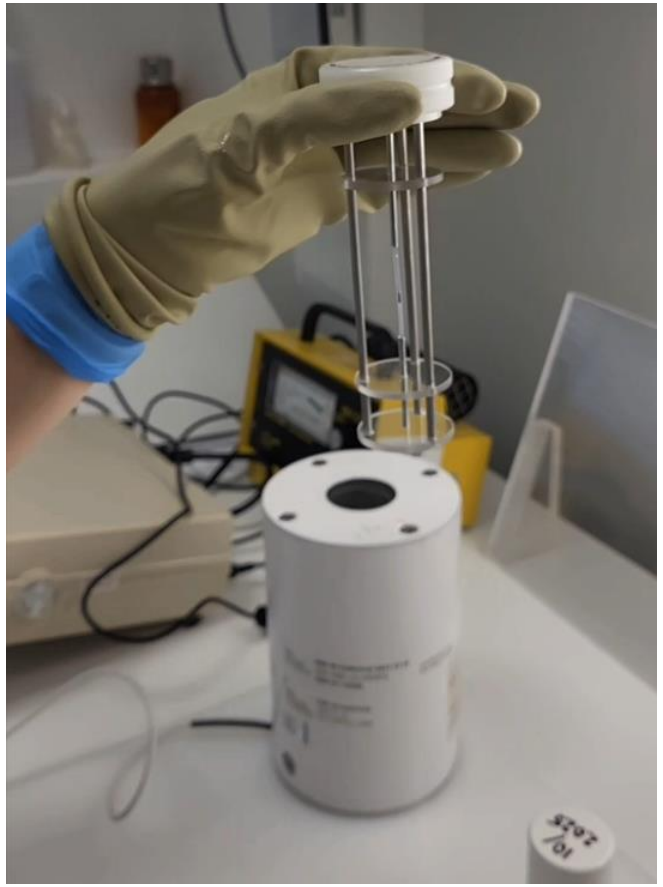
# Our batch commissioning measurement – can you spot something not optimal?

A video about brachy dose rates

Dose_rate_eye_applicator.mp4

Video from I-125 seed batch acceptance measurements

I_seed_acceptance.mp4



| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | **I-125 quality assurance measurement** | | | | | | | | | | | | | | | |
| 2 | 1.10.2025 | Anna Rintala, Mikko Tenhunen | | | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | | | | | |
| 4 | Seed type: | [redacted] | | | | | | | | | | | | | | |
| 5 | Manufacturer: | [redacted] | | | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | | | | | |
| 7 | Half-life (d) | 59,41 | (E&Z/PTB) | | | | | | | | | | | | | |
| 8 | Ref. date | 3.10.2025 13:00 | (12:00 MEZ/CET) | | | | | | | | | | | | | |
| 9 | Meas. day | 1.10.2025 13:44 | (25. seed) | | | | | | | | | | | | | |
| 10 | Diff. in date (h) | -47,26666667 | | | | | | | | | | | | | | |
| 11 | | | | | | | | | | | | | | | | |
| 12 | Air pressure (hPa) | 1037,6 | | | | | | | | | | | | | | |
| 13 | Temperature (°C) | 21,6 | | | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | | | | | |
| 15 | | mCi | MBq | mCi + 5% | mCi - 5% | MBq + 5% | MBq - 5% | mCi + 3% | mCi - 3% | MBq + 3% | MBq - 3% | | | | | |
| 16 | Activity on ref. date per seed | 14,526 | 537 | 15,25 | 13,80 | 564 | 511 | 14,96 | 14,09 | 554 | 521 | | manufacturer's mean value | | | |
| 17 | Activity on meas. date per seed | 14,864 | 550 | 15,61 | 14,12 | 577 | 522 | 15,31 | 14,42 | 566 | 533 | | | | | |
| 18 | | | | | | | | | | | | | | | | |
| 19 | N_RAKR chamber | 59,37 | Gy/C | Measuring device: Standard Imaging well chamber HDR 1000 Plus (ref 90008, SN A002974) + electrometer MAX-4000 + seed holder S | | | | | | | | | | | | |
| 20 | kTp | 0,981864982 | | Bias 302 Vdc, Low Mode (pA range) | | | | | | | | | | | | |
| 21 | I25.S16 factor (for apparent A) | 1,27 | uGy/(h*mCi) | Calibrated 18.11.2024 for I25.S16 | | | | | | | | | | | | |
| 22 | Measurement factor (pA -> mCi) | 1,65E-01 | | | | | | | | | | | | | | |
| 23 | | | | | | | | | | | | | | | | |
| 24 | Background: | -5,00E-03 | pA | | | | | | | | | | Table created by Vappu Reijonen, 2016 | | | |

| Seed # | Measured (pA) | Activity (mCi) | Diff. from theory |
|---|---|---|---|
| 1 | 85,68 | 14,16 | -4,74 % |
| 2 | 89,02 | 14,71 | -1,03 % |
| 3 | 89,93 | 14,86 | -0,02 % |
| 4 | 84,72 | 14,00 | -5,81 % |
| 5 | 88,53 | 14,63 | -1,57 % |
| 6 | 87,12 | 14,40 | -3,14 % |
| 7 | 88,64 | 14,65 | -1,45 % |
| 8 | 86,07 | 14,22 | -4,31 % |
| 9 | 89,91 | 14,86 | -0,04 % |
| 10 | 85,23 | 14,08 | -5,24 % |
| 11 | 82,23 | 13,59 | -8,58 % |
| 12 | 86,52 | 14,30 | -3,81 % |
| 13 | 88,53 | 14,63 | -1,57 % |
| 14 | 85,62 | 14,15 | -4,81 % |
| 15 | 87,34 | 14,43 | -2,90 % |
| 16 | 88,78 | 14,67 | -1,30 % |
| 17 | 87,28 | 14,42 | -2,96 % |
| 18 | 82,67 | 13,66 | -8,09 % |
| 19 | 82,91 | 13,70 | -7,82 % |
| 20 | 88,19 | 14,57 | -1,95 % |
| 21 | 89,14 | 14,73 | -0,90 % |
| 22 | 88,08 | 14,56 | -2,07 % |
| 23 | 87,44 | 14,45 | -2,79 % |
| 24 | 89,72 | 14,83 | -0,25 % |
| 25 | 85,15 | 14,07 | -5,33 % |
| 26 | 87,15 | 14,40 | -3,11 % |
| 27 | 89,06 | 14,72 | -0,99 % |
| 28 | 84,47 | 13,96 | -6,09 % |
| 29 | 89,97 | 14,87 | 0,03 % |
| 30 | 87,74 | 14,50 | -2,45 % |
| 31 | 87,11 | 14,39 | -3,15 % |
| 32 | 86,67 | 14,32 | -3,64 % |
| 33 | 86,57 | 14,31 | -3,75 % |
| 34 | 86,4 | 14,28 | -3,94 % |
| 35 | 88,13 | 14,56 | -2,02 % |
| 36 | 86,8 | 14,34 | -3,50 % |
| 37 | 86,68 | 14,32 | -3,63 % |
| 38 | 89,79 | 14,84 | -0,17 % |
| 39 | 88,84 | 14,68 | -1,23 % |
| 40 | 88,67 | 14,65 | -1,42 % |
| 41 | 84,56 | 13,97 | -5,99 % |
| 42 | 85,67 | 14,16 | -4,75 % |
| 43 | 87,44 | 14,45 | -2,79 % |
| 44 | 86,06 | 14,22 | -4,32 % |
| 45 | 87,26 | 14,42 | -2,99 % |
| 46 | 90,19 | 14,90 | 0,27 % |
| 47 | 88,27 | 14,59 | -1,86 % |
| 48 | 82,4 | 13,62 | -8,39 % |
| 49 | 82,67 | 13,66 | -8,09 % |
| 50 | 88,84 | 14,68 | -1,23 % |
| Average | 87,04 | 14,38 | -3,23 % |

What? This is no good!

→ Contacting the seed manufacturer…

## Urgent Field Safety Notice

| | |
|---|---|
| Subject: | Wrong Certificate No.:3595525 for [redacted] |
| Commercial Name of Affected Product: | [redacted] |
| UDI-DI | 04049223100292 |
| Reference: | 2025OPH-1 |
| Date of Notification: | 09. Oct 2025 |
| Type of Action: | Replacement of certificate |

Description of Problem:

Due to a human failure the mean value on certificate no.:3595525 for lot number 0042161/10, order number BBD008359 was incorrect.
This is a single occurrence.
Using the incorrect value would result in an underdose of approx.. 5%.
An electronic version of the corrected certificate is attached to this information.
A paper version of the corrected certificate will be provided via postage.

The recipient of this information is requested to replace the incorrect certificate and assure that only the corrected version is used for the planning of treatments.

*"While preparing the incorrect certificate, the measured maximum activity was wrongly used instead of the mean value."*

**DE** **Zertifikat für umschlossene radioaktive Stoffe** [redacted]®)

**EN** **Certificate for sealed radioactive sources** [redacted]®)

[redacted]

| Allgemeine Angaben<br>*General Information* | | | | | |
|---|---|---|---|---|---|
| Zertifikat-Nr.<br>*Certificate no.* | Kunde<br>*Customer* | | | | Auftragsnummer<br>*Order number* |
| 3595525 | HUS Cancer Center | | | | BBD008359 |
| Artikelnummer<br>*Catalogue number* | Nuklid<br>*Nuclide* | ISO-Klassifikation<br>*ISO-classification* | gesamte Stückzahl<br>*Total quantity* | gesamte enthaltene Aktivität<br>*Total contained activity* [mCi] | sterilisiert am<br>*Sterilized on* |
| [redacted] | I-125 | ISO/12/C63X11 | 50 | 944,190 | -- |

| Mess- und Prüfbericht<br>Alle Messergebnisse beziehen sich auf das Referenzdatum - weitere Informationen siehe Rückseite.<br>*Test report*<br>*All measurements refer to the reference date - see reverse side for more information.* | | | | | |
|---|---|---|---|---|---|
| Nebenstehende Daten sind für alle Seeds gültig<br>*The data mentioned beside are valid for all seeds*<br>⇒ | Referenz-Luftkermaleistung<br>*Reference air-kerma rate*<br>[µGy/h] | | scheinbare Aktivität<br>*Apparent activity*<br>[mCi] | | Referenzdatum<br>*Reference date* |
| | Mittelwert des Loses<br>*Mean value of the lot* | | Mittelwert des Loses<br>*Mean value of the lot* | | |
| | 18,448 | | 14,526 | | 2025-10-03 |
| Behälter-Nr.<br>*Lot no.* | Chargen-Nr.<br>*Batch no.* | Stückzahl<br>*Quantity* | Dichtheitsprüfung bestanden<br>*Leakage test passed* | verwendbar bis<br>*use before* | gesamte scheinbare Aktivität pro Behälter<br>*Total apparent activity per lot* [mCi] |
| 0042161/01 | 1320 | 50 | 2025-08-18 | 2026-02-16 | 726,300 |

Incorrect certificate

**DE** **Zertifikat für umschlossene radioaktive Stoffe** [redacted]®)

**EN** **Certificate for sealed radioactive sources** [redacted]®)

[redacted]

| Allgemeine Angaben<br>*General Information* | | | | | |
|---|---|---|---|---|---|
| Zertifikat-Nr.<br>*Certificate no.* | Kunde<br>*Customer* | | | | Auftragsnummer<br>*Order number* |
| 3595525 | HUS Cancer Center | | | | BBD008359 |
| Artikelnummer<br>*Catalogue number* | Nuklid<br>*Nuclide* | ISO-Klassifikation<br>*ISO-classification* | gesamte Stückzahl<br>*Total quantity* | gesamte enthaltene Aktivität<br>*Total contained activity* [mCi] | sterilisiert am<br>*Sterilized on* |
| [redacted] | I-125 | ISO/12/C63X11 | 50 | 901,615 | -- |

| Mess- und Prüfbericht<br>Alle Messergebnisse beziehen sich auf das Referenzdatum - weitere Informationen siehe Rückseite.<br>*Test report*<br>*All measurements refer to the reference date - see reverse side for more information.* | | | | | |
|---|---|---|---|---|---|
| Nebenstehende Daten sind für alle Seeds gültig<br>*The data mentioned beside are valid for all seeds*<br>⇒ | Referenz-Luftkermaleistung<br>*Reference air-kerma rate*<br>[µGy/h] | | scheinbare Aktivität<br>*Apparent activity*<br>[mCi] | | Referenzdatum<br>*Reference date* |
| | Mittelwert des Loses<br>*Mean value of the lot* | | Mittelwert des Loses<br>*Mean value of the lot* | | |
| | 17,616 | | 13,871 | | 2025-10-03 |
| Behälter-Nr.<br>*Lot no.* | Chargen-Nr.<br>*Batch no.* | Stückzahl<br>*Quantity* | Dichtheitsprüfung bestanden<br>*Leakage test passed* | verwendbar bis<br>*use before* | gesamte scheinbare Aktivität pro Behälter<br>*Total apparent activity per lot* [mCi] |
| 0042161/01 | 1320 | 50 | 2025-08-18 | 2026-02-16 | 693,550 |

Corrected certificate

## Urgent Field Safety Notice

| | |
|---|---|
| Subject: | Wrong Certificate No.:3595525 for [redacted] |
| Commercial Name of Affected Product: | [redacted] |
| UDI-DI | 04049223100292 |
| Reference: | 2025OPH-1 |
| Date of Notification: | 09. Oct 2025 |
| Type of Action: | Replacement of certificate |

Description of Problem:

Due to a human failure the mean value on certificate no.:3595525 for lot number 00421617[illegible], order number BBD008359 was incorrect.
This is a single occurrence.
Using the incorrect value would result in an underdose of approx.. 5%.
An electronic version of the corrected certificate is attached to this information.
A paper version of the corrected certificate will be provided via postage.

The recipient of this information is requested to replace the incorrect certificate and assure that only the corrected version is used for the planning of treatments.

"While preparing the incorrect certificate, the measured maximum activity was wrongly used instead of the mean value."

AI-yhteenveto

Human failure is any deviation from the intended action or desired outcome, caused by errors (unintentional) or violations (intentional). Unintentional errors include mistakes, slips, and lapses, while intentional violations involve deliberately breaking rules. Both types can result from a wide range of factors such as lack of concentration, fatigue, poor training, or systemic organizational issues.

## Types of human failure

- **Human errors (unintentional):** These are unintended actions or decisions that lead to undesirable outcomes.
  - **Slips:** When a person doesn't perform a familiar task correctly, often due to a lack of full attention.
  - **Lapses:** When a person forgets to perform a task or performs steps in the wrong order.
  - **Mistakes:** When a person fails to make the right decision because they lack the correct knowledge or understanding of a rule or procedure.

- **Violations (intentional):** These are deliberate deviations from a rule or procedure.
  - They are often well-intentioned, such as taking a shortcut to save time or effort.
  - Examples include ignoring safety rules or not following a standard operating procedure.

## Causes of human failure

- **Human factors:** Fatigue, stress, illness, fear, lack of motivation, injury, or the influence of impairing substances.
- **Knowledge and skills:** A lack of knowledge or skill to perform a task correctly.
- **Organizational factors:** Poor communication, inadequate supervision, long working hours, high work pressure, or a culture that encourages cutting corners.
- **Job and environment:** Distractions, inadequate procedures, poor lighting, or extreme temperatures.
- **Equipment:** Poor design of equipment or workplace layout.

## Managing human failure

- **For errors:** Increase routine monitoring, make sure rules and procedures are practical, improve the working environment, and improve planning for all jobs.
- **For violations:** Make sure rules and procedures are relevant and practical. It's also important to foster a strong safety culture where employees feel comfortable communicating openly and reporting issues without fear of blame.

This is one of the most important reasons why we need codes of practice & independent measurements! QA is vital!

(This will not end with the AI revolution – also AI failure is well possible! ;) )

# WHAT ABOUT RU-106 APPLICATORS?
## THAT IS, DOSIMETRY FOR BETA-EMITTING BRACHYTHERAPY SOURCES?

- Remember TRS 492 2.2: "*There is no international consensus to the calibration procedure - - This code of practice does therefore* ***not*** *apply to these sources.*"
- Appendix II, 2. Beta-emitting radioactive sources
  - Listed: UWADCL, NIST, NPL; ISO 21439
  - E.g. NPL method: traceability to Co-60 absorbed dose to water (primary standard graphite calorimeter) via alanine dosimetry
    - Cylindrical alanine pellets (0.5 mm thick, 5 mm diameter) placed on a PMMA phantom
- Recommended quantity for the strength specification of beta emitting sources is the absorbed dose rate to water at a reference distance (2 mm?) from the external surface of the source along the axis of symmetry

# Zertifikat für umschlossene radioaktive Stoffe
## *Certificate for sealed radioactive sources*

Eckert & Ziegler

HUS

Allgemeine Angaben
*general information*

| Zertifikat Nummer<br>*certificate number* | Produktbezeichnung<br>*product name* | | | | Auftragsnummer<br>*order number* | |
|---|---|---|---|---|---|---|
| 026022 | Ru-106 Augenapplikator<br>*Ru-106 Eye Applicator* | | | | BBD003232 | |
| Produkt-Code / Bauart<br>*product code / model* | ISO Klassifikation<br>*ISO classification* | Nuklid<br>*nuclide* | nominelle Aktivität<br>*nominal activity* | | Stückzahl<br>*quantity* | Betriebsdauer [Jahre]<br>*working life [years]* |
| | | | MBq | mCi | | |
| Ru6.A04 | ISO/12/C54343 | Ru-106 | 10 | 0.27 | 1 | 1 |

Mess- und Prüfbericht der Strahler
Erklärungen siehe Rückseite
*source test report*
*see backpage for more information*

| Seriennummer<br>*serial number* | Enthaltene Aktivität<br>*contained activity* | | Dichtheitsprüfung<br>*leakage test* | Oberflächen-kontaminationsprüfung<br>*contamination test* | Sichtprüfung<br>*visual test* |
|---|---|---|---|---|---|
| | Ergebnis [MBq]<br>*result [MBq]* | Referenzdatum<br>*reference date*<br>[YYYY-MM-DD] | Datum<br>*date passed*<br>[YYYY-MM-DD] | Datum<br>*date passed*<br>[YYYY-MM-DD] | Datum<br>*date passed*<br>[YYYY-MM-DD] |
| CCA 2644 | 9.34 | 2022-03-24 | 2022-03-17 | 2022-03-24 | 2022-03-24 |

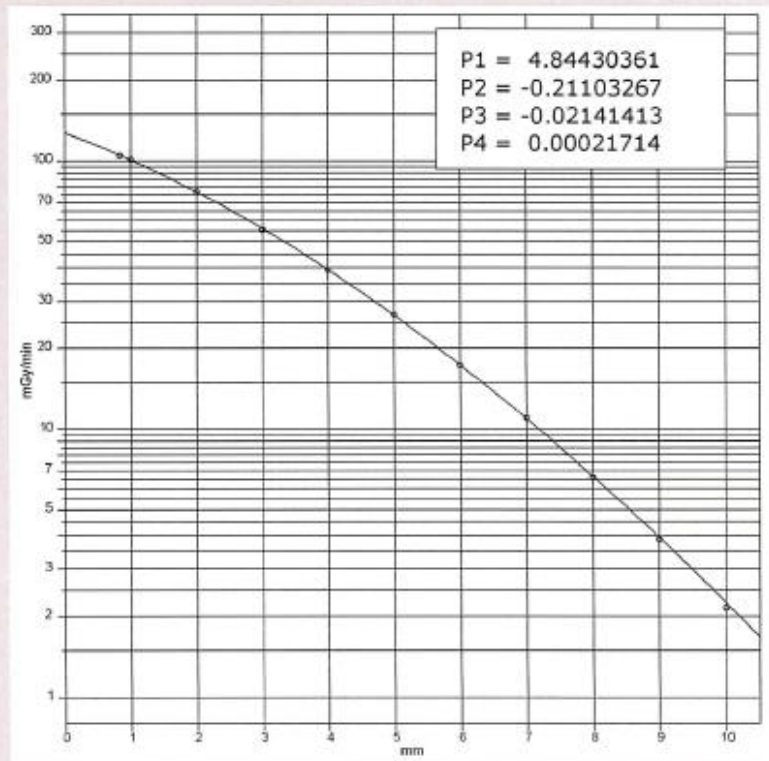
| Messgröße<br>*quantity measured* | Beschreibung der Messung<br>*description of the measurement* |
|---|---|
| Energiedosisleistung in Wasser<br>*absorbed dose rate to water* | Die Wasser-Energiedosisleistung der ß-Strahlung wurde im Wasserphantom mit einem Szintillationsdetektor (Durchmesser: 1mm, Höhe: 0.5mm) gemessen. Die Kalibrierung ist auf das Primärnormal des Kalibrierlabors der Universität Wisconsin rückführbar.<br>*The absorbed dose rate to water of ß-radiation has been measured in a water phantom with a scintillation detector (diameter: 1mm, height: 0.5mm). The calibration is traceable to the primary standard of the University of Wisconsin Radiation Calibration Lab.* |

| Messergebnisse<br>*measurement results* | Referenzdatum<br>*reference date*<br>*[YYYY-MM-DD]* | 2022-03-24 |
|---|---|---|

Die Messergebnisse der Tiefendosisleistung beziehen sich auf den wasseräquivalenten Abstand des Szintillatormittelpunkts von der inneren (konkaven) Oberfläche des Applikators. Der Verlauf wird entlang der Zentralachse mit Hilfe einer Regressionsfunktion $y = \exp(P1 + P2 \cdot x + P3 \cdot x^2 + P4 \cdot x^3)$ dargestellt. Relative Angaben sind auf den Referenzpunkt (r=0.0mm, z=2.0mm) bezogen.

*The results of measurement refer to the water-equivalent distance of the scintillator midpoint from the inner (concave) surface of the applicator. The progression along the central axis is shown by a regression function $y = \exp(P1 + P2 \cdot x + P3 \cdot x^2 + P4 \cdot x^3)$. Relative data are normalized to the reference point at (r=0.0mm, z=2.0mm).*

Dosisleistung am Referenzpunkt r=0; z=2
*reference dose rate at r=0; z=2*
76.8 mGy/min
±11% (2sigma)




Messergebnisse / *measurement results:*

| [mm] | [mGy/min] | [%] |
|---|---|---|
| 0.83 | 105 | 136 |
| 1.0 | 101 | 132 |
| 2.0 | 76.8 | 100 |
| 3.0 | 55.4 | 72.2 |
| 4.0 | 39.4 | 51.2 |
| 5.0 | 26.8 | 34.9 |
| 6.0 | 17.4 | 22.6 |
| 7.0 | 11.0 | 14.3 |
| 8.0 | 6.59 | 8.58 |
| 9.0 | 3.88 | 5.05 |
| 10.0 | 2.16 | 2.81 |

Extra-, interpolierte Daten
*extra-, interpolated data:*

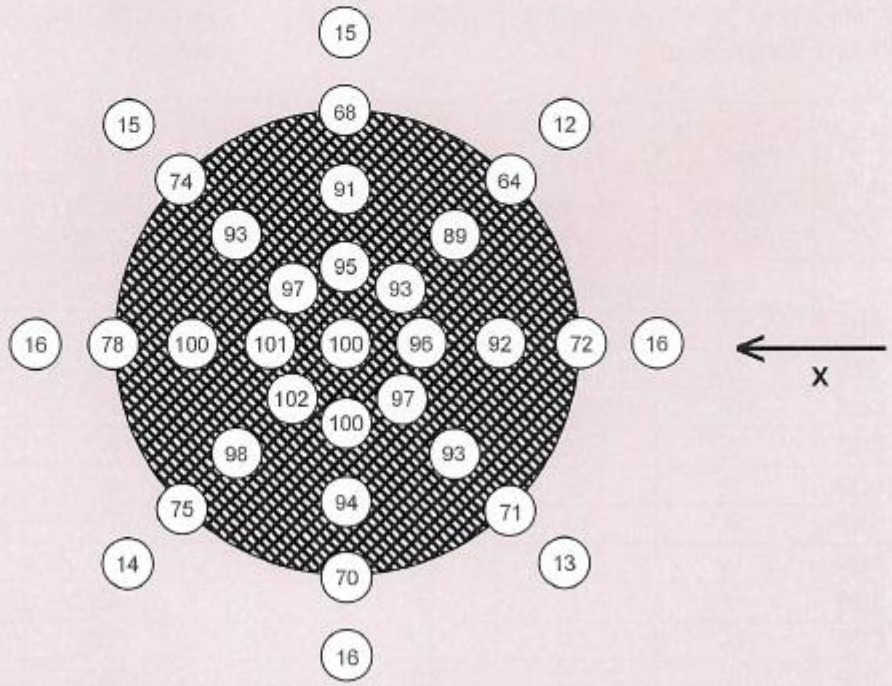
| [mm] | [mGy/min] | [%] |
|---|---|---|
| 0 | 127 | 165 |
| 0.5 | 114 | 148 |

| Messergebnisse<br>*measurement results* | Referenzdatum<br>*reference date*<br>[YYYY-MM-DD] | 2022-03-24 |
|---|---|---|

Die Messpunkte befinden sich an 33 Positionen auf einer gedachten konzentrischen Kugelfläche in 1.0 mm Abstand über der inneren Oberfläche des Applikators. Die dargestellten relativen Messdaten (in %) sind auf den Wert des Zentralpunkts (r=0.0 mm; z=1.0 mm) normiert.
*The measurement points are placed at 33 positions on a concentric sphere 1.0 mm above the plaque's inner surface. The relative data shown in % are normalized to the central point (r=0.0 mm; z=1.0 mm).*

Messwert im Zentrum /
*result in the centre = 100%*
101 mGy/min
±11% (2sigma)

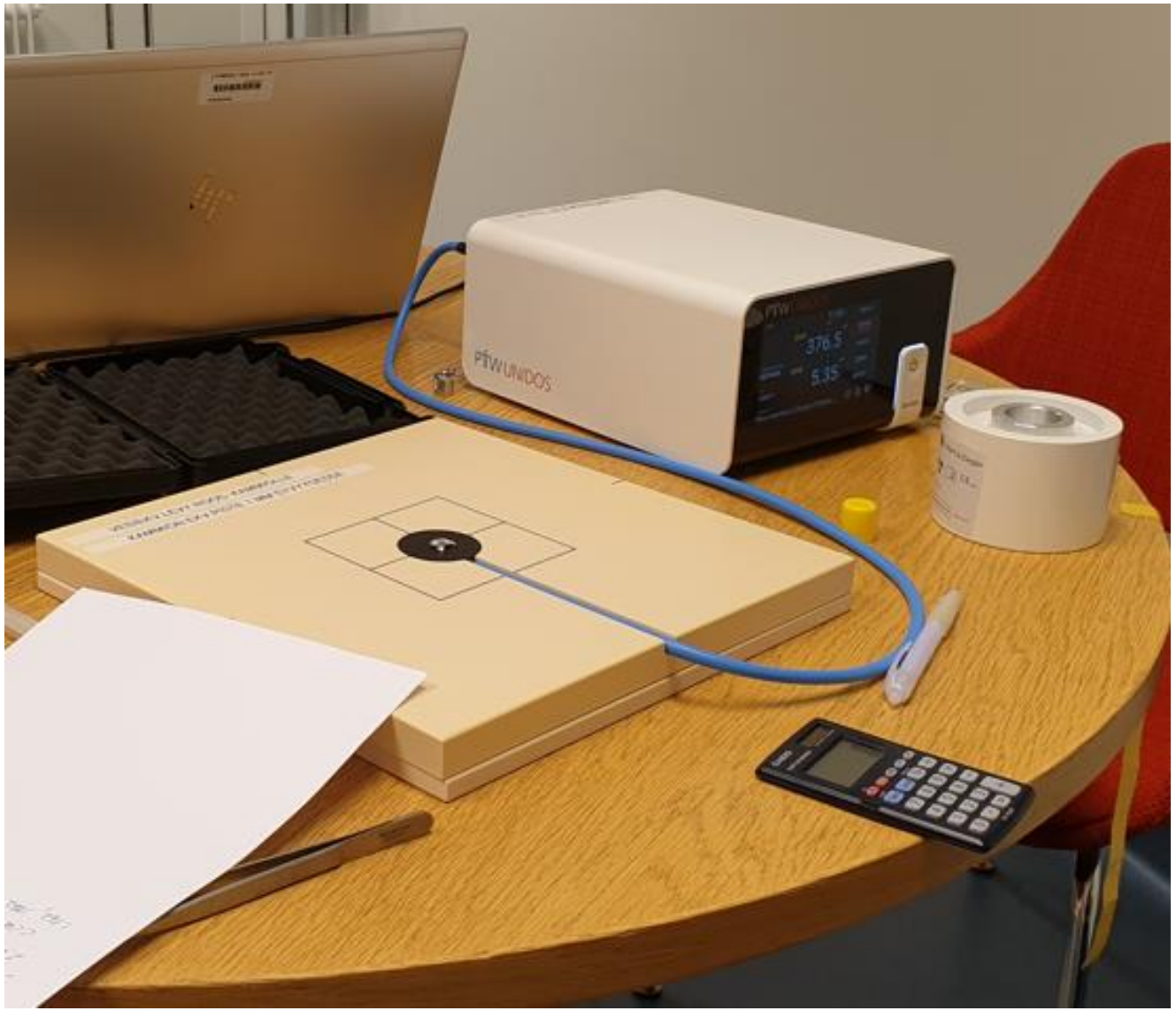
"X" Referenzrichtung /
*reference direction*

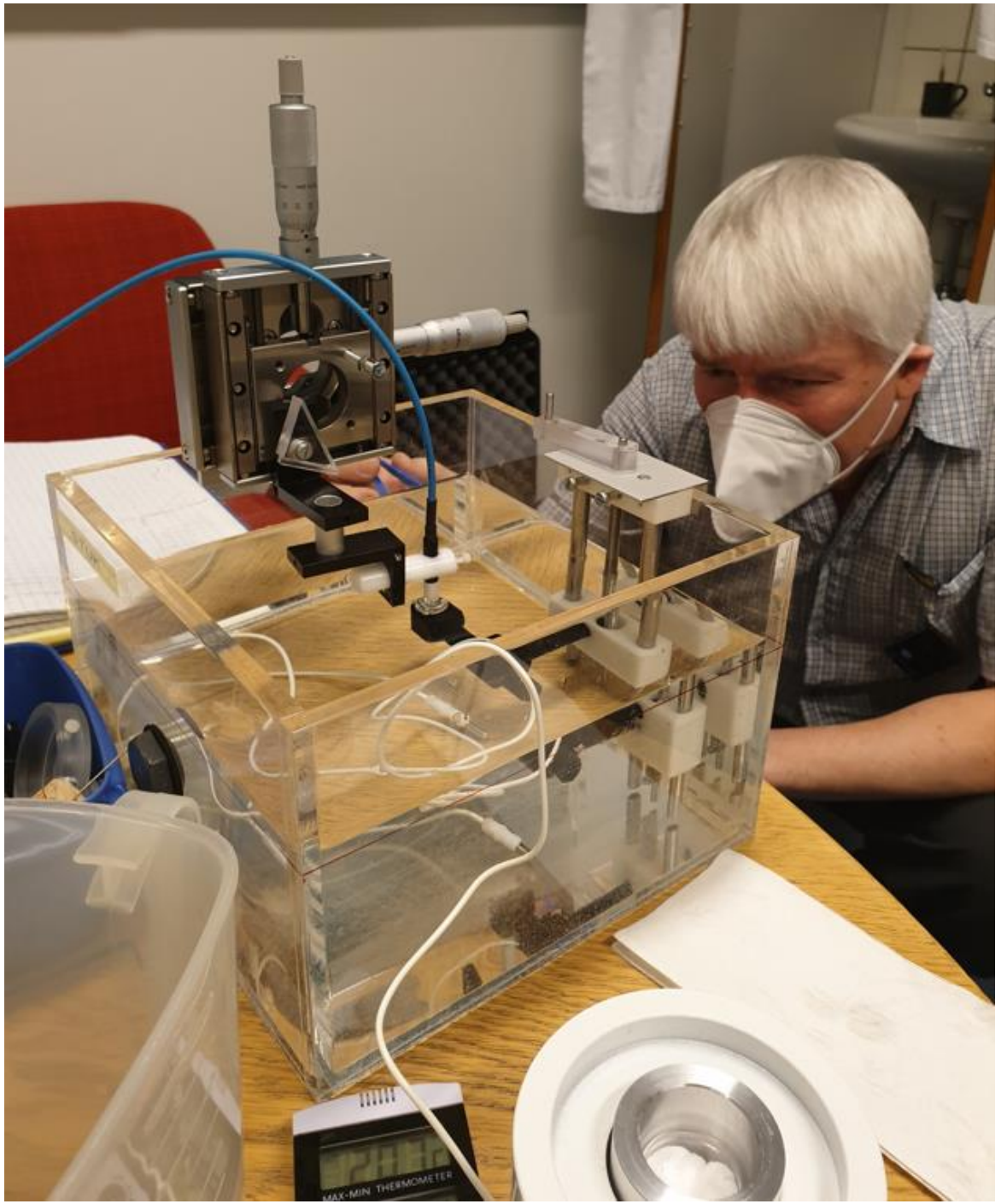



**Measurement of contained activity**
The activity has been determined by measuring the resultant radiation and comparing with a calibrated standard source.

**Leak test**
Immersion test in water, 70°C, 30 min in ultrasonic bath. Acceptance criterion < 200 Bq
(ISO 9978 [2], 5.1.1 Immersion test, hot liquid)

**Surface contamination test**
Moist wipe test under light pressure.
Acceptance criterion < 200 Bq
(ISO 9978 [2], 5.3.1 Wet wipe test)




Studying different methods for Ru-106 plaque QA

PhD defense of Assi Valve
24 Oct 2025
"Low megavoltage electrons: new applications for radiotherapy and dosimetry"
http://hdl.handle.net/10138/600195


NOTE • OPEN ACCESS

Dose measurement of ophthalmic Ru-106/Rh-106 applicators with a diamond detector calibrated in a clinical megavoltage electron beam

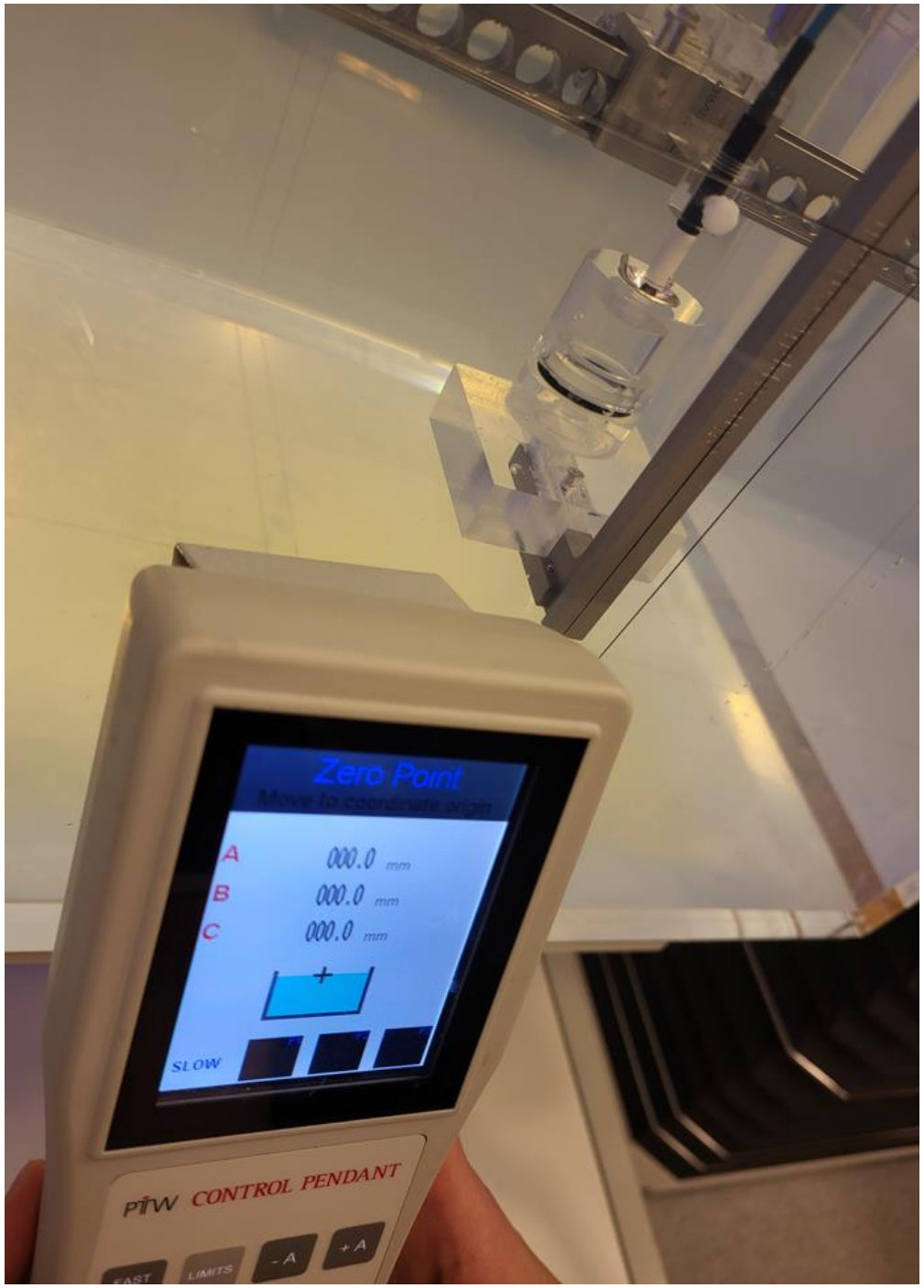
Assi Valve*, Vappu Reijonen, Anna Rintala, Satu Strengell, Katri Nousiainen and Mikko Tenhunen

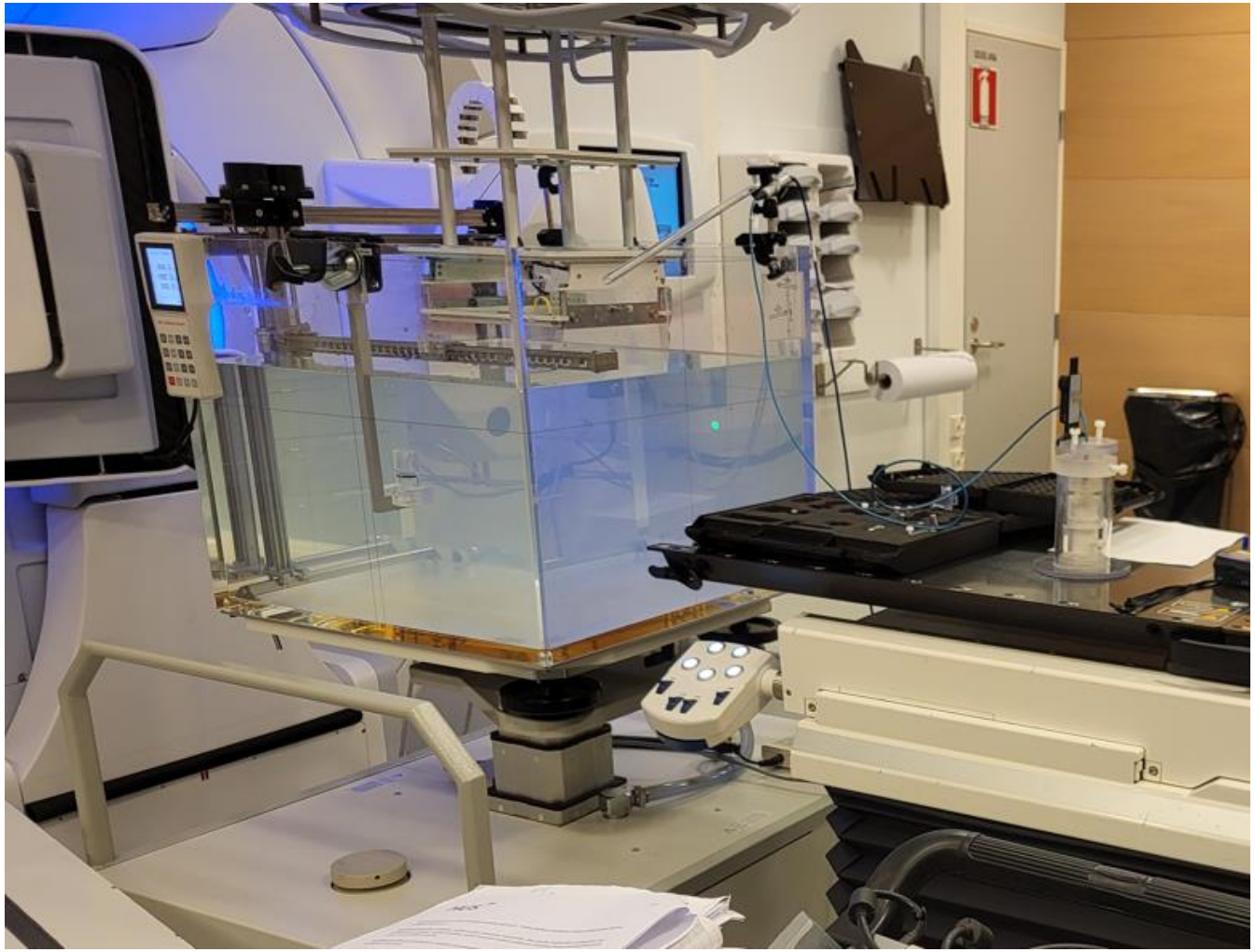
Published 10 March 2025 • © 2025 The Author(s). Published on behalf of Institute of Physics and Engineering in Medicine by IOP Publishing Ltd

Physics in Medicine & Biology, Volume 70, Number 6

**Citation** Assi Valve *et al* 2025 *Phys. Med. Biol.* **70** 06NT01

**DOI** 10.1088/1361-6560/adb9b1


Zero Point
A 000.0 mm
B 000.0 mm
C 000.0 mm
SLOW
PTW CONTROL PENDANT
FAST
LIMITS
- A
+ A




Kuva 8: Pyyhintänäytteissä käytety sideharsotaitos (vas.), sen kostutukseen käytetty etanoli (kesk.) sekä valmis $^{106}$Ru-CCB 2020 pyyhintänäyte muovitaskun sisällä (oik.)

MATR310

Laboratorioharjoitukset

# Rutenium-106-levyjen käytönaikaiset pyyhintänäytteet

Heli Huttunen 014809970

Ohjaajat: Vappu Reijonen, Liisa Porra

Apuohjaaja: Anna Rintala

20. joulukuuta 2021

Wipe test samples from Ru-106 plaques

gammaspektrometrisellä mittauksella Ortecin GEM sarjan HPGe (High Purity Germanium) ilmaisimella (Malli: GEM25P4-83-S). Gammaspektrometri ja sen ohjaukseen käytetty tietokone näkyvät kuvassa 6.

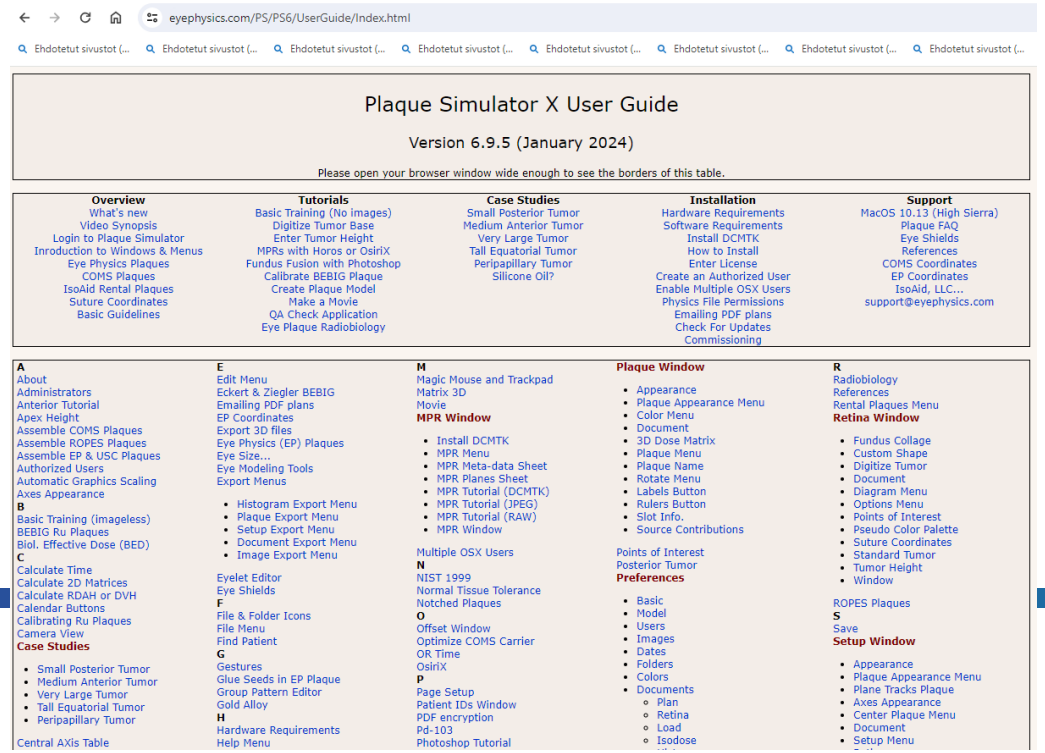
Kuva 6: Mittauksissa käytetty gammaspektrometri

[8] R. M. Thomson, K. M. Furutani, T. W. Kaulich, F. Mourtada, M. J. Rivard, C. G. Soares, F. M. Vanneste, and C. S. Melhus. Aapm recommendations on medical physics practices for ocular plaque brachytherapy: Report of task group 221. *Medical Physics*, 47(5):e92–e124, 2020.

# EYE PHYSICS, LLC

- *eyephysics.com*
- Plaque Simulator (PS) program, macOS (Apple)
- If you are interested, includes many tutorial videos!

Melvin Astrahan, PhD, DABR, Emeritus Professor, now spends most of his day with his horses and running Eye Physics. In the fall of 2010 at age 58 he retired from the University of Southern California Keck School of Medicine in Los Angeles where he had been Chief of Medical Physics and tenured Associate Professor of Radiation Oncology. He had been with USC since 1984 and has authored or coauthored over 75 scientific publications and numerous freeware, shareware and commercial software products. He is a 1980 graduate of the UCLA Medical Physics program.


eyephysics.com/PS/PS6/UserGuide/Index.html

Plaque Simulator X User Guide

Version 6.9.5 (January 2024)

Please open your browser window wide enough to see the borders of this table.

| Overview | Tutorials | Case Studies | Installation | Support |
|---|---|---|---|---|
| What's new | Basic Training (No images) | Small Posterior Tumor | Hardware Requirements | MacOS 10.13 (High Sierra) |
| Video Synopsis | Digitize Tumor Base | Medium Anterior Tumor | Software Requirements | Plaque FAQ |
| Login to Plaque Simulator | Enter Tumor Height | Very Large Tumor | Install DCMTK | Eye Shields |
| Introduction to Windows & Menus | MPRs with Horos or OsiriX | Tall Equatorial Tumor | How to Install | References |
| Eye Physics Plaques | Fundus Fusion with Photoshop | Peripapillary Tumor | Enter License | COMS Coordinates |
| COMS Plaques | Calibrate BEBIG Plaque | Silicone Oil? | Create an Authorized User | EP Coordinates |
| IsoAid Rental Plaques | Create Plaque Model | | Enable Multiple OSX Users | IsoAid, LLC... |
| Suture Coordinates | Make a Movie | | Physics File Permissions | support@eyephysics.com |
| Basic Guidelines | QA Check Application | | Emailing PDF plans | |
| | Eye Plaque Radiobiology | | Check For Updates | |
| | | | Commissioning | |

**A**
About
Administrators
Anterior Tutorial
Apex Height
Assemble COMS Plaques
Assemble ROPES Plaques
Assemble EP & USC Plaques
Authorized Users
Automatic Graphics Scaling
Axes Appearance

**B**
Basic Training (imageless)
BEBIG Ru Plaques
Biol. Effective Dose (BED)

**C**
Calculate Time
Calculate 2D Matrices
Calculate RDAH or DVH
Calendar Buttons
Calibrating Ru Plaques
Camera View
**Case Studies**
- Small Posterior Tumor
- Medium Anterior Tumor
- Very Large Tumor
- Tall Equatorial Tumor
- Peripapillary Tumor

Central AXis Table

**E**
Edit Menu
Eckert & Ziegler BEBIG
Emailing PDF plans
EP Coordinates
Export 3D files
Eye Physics (EP) Plaques
Eye Size...
Eye Modeling Tools
Export Menus
- Histogram Export Menu
- Plaque Export Menu
- Setup Export Menu
- Document Export Menu
- Image Export Menu

Eyelet Editor
Eye Shields

**F**
File & Folder Icons
File Menu
Find Patient

**G**
Gestures
Glue Seeds in EP Plaque
Group Pattern Editor
Gold Alloy

**H**
Hardware Requirements
Help Menu

**M**
Magic Mouse and Trackpad
Matrix 3D
Movie
**MPR Window**
- Install DCMTK
- MPR Menu
- MPR Meta-data Sheet
- MPR Planes Sheet
- MPR Tutorial (DCMTK)
- MPR Tutorial (JPEG)
- MPR Tutorial (RAW)
- MPR Window

Multiple OSX Users

**N**
NIST 1999
Normal Tissue Tolerance
Notched Plaques

**O**
Offset Window
Optimize COMS Carrier
OR Time
OsiriX

**P**
Page Setup
Patient IDs Window
PDF encryption
Pd-103
Photoshop Tutorial

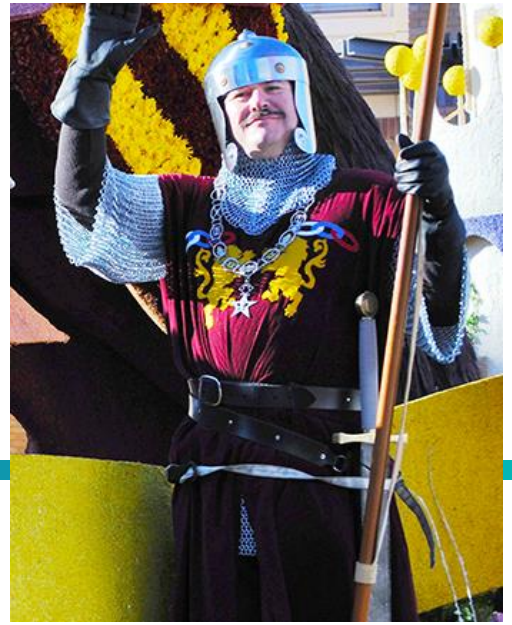
**Plaque Window**
- Appearance
- Plaque Appearance Menu
- Color Menu
- Document
- 3D Dose Matrix
- Plaque Menu
- Plaque Name
- Rotate Menu
- Labels Button
- Rulers Button
- Slot Info.
- Source Contributions

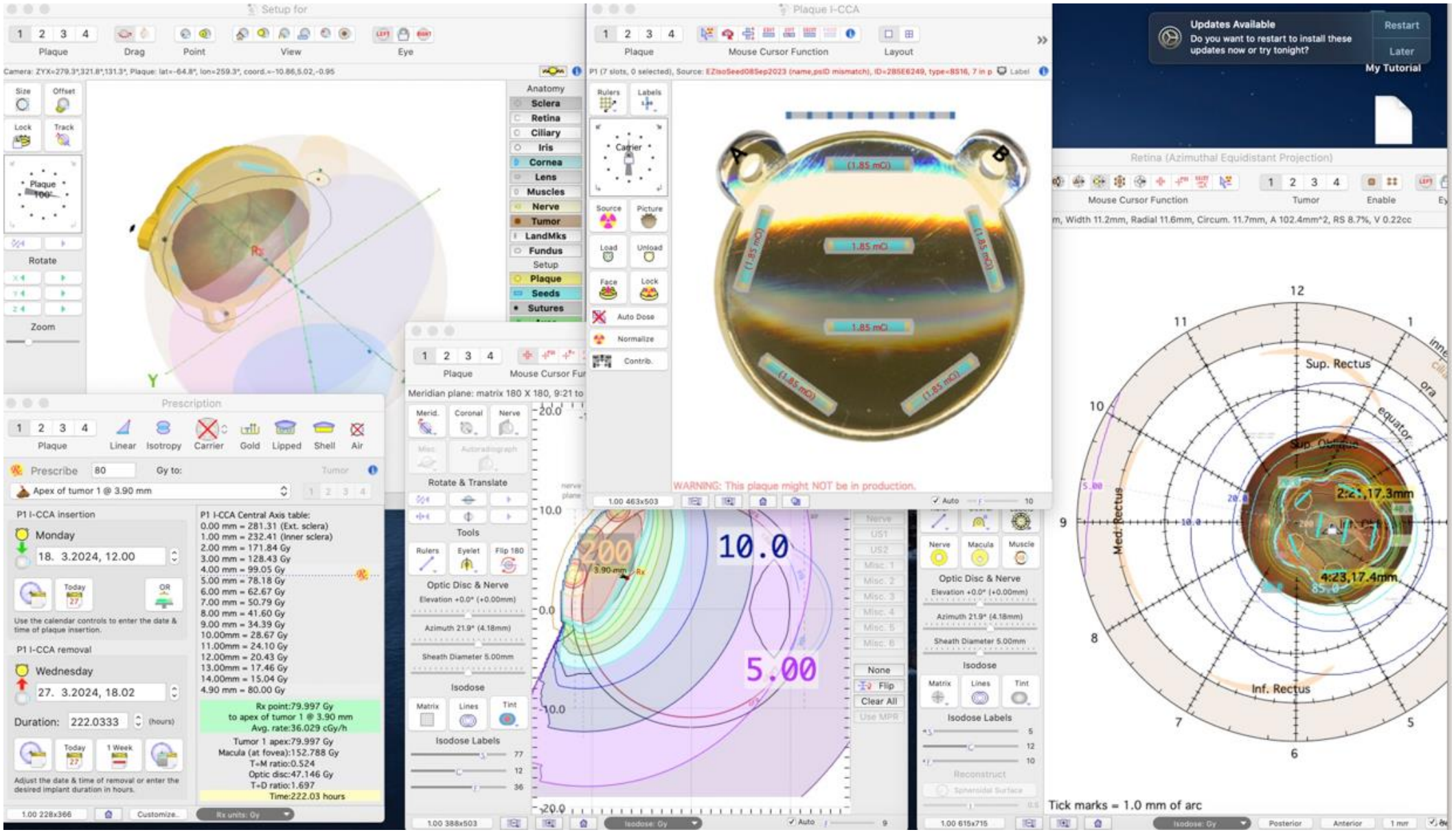
Points of Interest
Posterior Tumor
**Preferences**
- Basic
- Model
- Users
- Images
- Dates
- Folders
- Colors
- Documents
  - Plan
  - Retina
  - Load
  - Isodose

**R**
Radiobiology
References
Rental Plaques Menu
**Retina Window**
- Fundus Collage
- Custom Shape
- Digitize Tumor
- Document
- Diagram Menu
- Options Menu
- Points of Interest
- Pseudo Color Palette
- Suture Coordinates
- Standard Tumor
- Tumor Height
- Window

ROPES Plaques

**S**
Save
**Setup Window**
- Appearance
- Plaque Appearance Menu
- Plane Tracks Plaque
- Axes Appearance
- Center Plaque Menu
- Document
- Setup Menu




Setup for
Plaque
Drag
Point
View
Eye
Anatomy
Sclera
Retina
Ciliary
Iris
Cornea
Lens
Muscles
Nerve
Tumor
LandMks
Fundus
Setup
Plaque
Seeds
Sutures
Rotate
Zoom
Plaque I-CCA
Mouse Cursor Function
Layout
Carrier
Source
Picture
Load
Unload
Face
Lock
Auto Dose
Normalize
Contrib.
A
B
1.85 mCi
WARNING: This plaque might NOT be in production.
Updates Available
Do you want to restart to install these updates now or try tonight?
Restart
Later
My Tutorial
Retina (Azimuthal Equidistant Projection)
Tumor
Enable
Width 11.2mm, Radial 11.6mm, Circum. 11.7mm, A 102.4mm^2, RS 8.7%, V 0.22cc
Sup. Rectus
Med. Rectus
Inf. Rectus
equator
2:21,17.3mm
4:23,17.4mm
Tick marks = 1.0 mm of arc
Prescription
Linear
Isotropy
Carrier
Gold
Lipped
Shell
Air
Prescribe
80
Gy to:
Apex of tumor 1 @ 3.90 mm
P1 I-CCA insertion
Monday
18. 3.2024, 12.00
P1 I-CCA removal
Wednesday
27. 3.2024, 18.02
Duration:
222.0333
(hours)
P1 I-CCA Central Axis table:
0.00 mm = 281.31 (Ext. sclera)
1.00 mm = 232.41 (Inner sclera)
2.00 mm = 171.84 Gy
3.00 mm = 128.43 Gy
4.00 mm = 99.05 Gy
5.00 mm = 78.18 Gy
6.00 mm = 62.67 Gy
7.00 mm = 50.79 Gy
8.00 mm = 41.60 Gy
9.00 mm = 34.39 Gy
10.00mm = 28.67 Gy
11.00mm = 24.10 Gy
12.00mm = 20.43 Gy
13.00mm = 17.46 Gy
14.00mm = 15.04 Gy
4.90 mm = 80.00 Gy
Rx point:79.997 Gy
to apex of tumor 1 @ 3.90 mm
Avg. rate:36.029 cGy/h
Tumor 1 apex:79.997 Gy
Macula (at fovea):152.788 Gy
T+M ratio:0.524
Optic disc:47.146 Gy
T+D ratio:1.697
Time:222.03 hours
Meridian plane: matrix 180 X 180, 9:21 to
Rotate & Translate
Tools
Optic Disc & Nerve
Isodose
Isodose Labels
10.0
5.00
3.90 mm
Nerve
Macula
Muscle
Sheath Diameter 5.00mm
None
Flip
Clear All

# END OF PART III

## Q&A