Mostly harmless:

Who in the Universe needs dosimetry ?

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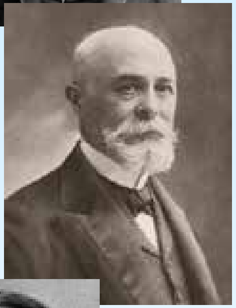
Ionising radiation: brief historical review

1895: discovery of **X-rays** (‘Röntgenstrahlung’) by
Wilhelm C. Röntgen (first Nobel prize for physics, 1901)

1896: discovery of **radioactivity** by Antoine H. Becquerel
(1903: Nobel prize together with Marie and Pierre Curie)



1912: discovery of **cosmic radiation** by Victor F. Hess
(Nobel prize, 1936)

1932: discovery of the **neutron** (neutron radiation) by
James Chadwick (Nobel prize, 1935)

pictures: wikipedia

Ionising radiation – General

Characteristics of ionising radiation:

- photon radiation (X-rays, gamma rays), particle radiation (electron radiation, neutron radiation, ion radiation, muons, positrons, ….)
- invisible and not directly detectable by human senses
- exposure to ionising radiation causes damage to living tissue and can result in mutation, radiation sickness, cancer or death.
- it can be helpful, but it can also be harmful !

Dosimetry: brief historical review

What are the measuring quantities and the units ?

How can the "intensity" of ionising radiation be measured?

Definition of the "intensity" of ionising radiation or dose:

1925: International Congress of Radiology (the precursor of the International Commission on Radiation Units and Measurements (ICRU))

main topics: measuring quantities, units and standard measuring instruments for X-rays

H. Behnken (Physikalisch-Technische Reichsanstalt, PTR) presented the German proposal for a dose definition

Dosimetry – General

Dosimetry is the measurement and/or calculation of the dose in matter and tissue resulting from the exposure to ionising radiation.

What are the measuring quantities and the units ?

Absorbed dose is a measure of the energy deposited in a medium per unit mass.

Unit: J/kg (joules per kilogram)

How can the “intensity” of ionising radiation be measured?

Measuring principle:

The amount of charge produced in a detector (consisting of air, silicon, etc.) is proportional to the absorbed dose, which is proportional to the irradiated energy by ionising radiation.

Fields of dosimetry

- **Dosimetry for external radiation**
  - **Radiation protection dosimetry** (unit: Sv (Sievert))
    - **Environmental dosimetry**
    - **Dosimetry for occupationally exposed workers**
  - **Dosimetry for the medical application of ionising radiation** (unit: Gy (Gray))
    - **Dosimetry for diagnostic radiology**
    - **Dosimetry for radiation therapy**

Fields of dosimetry

Dosimetry for external radiation

- **Radiation protection dosimetry**
  (unit: Sv (Sievert))
  - **Environmental dosimetry**
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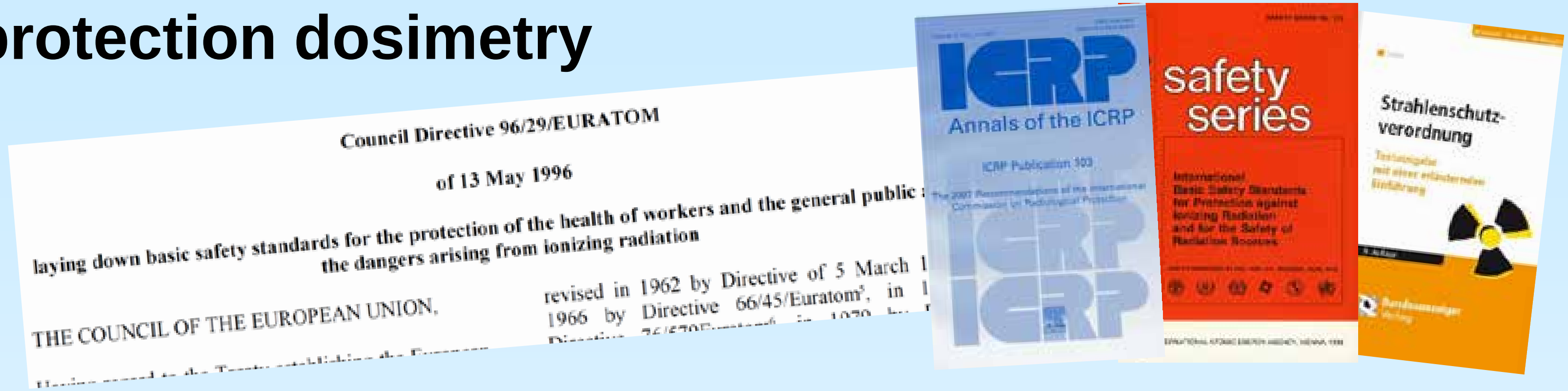
Radiation protection dosimetry



Dosimetry for monitoring to ensure the compliance of the legal dose limits and, therefore, to protect the health of the general public and the occupationally exposed workers.

But: equal doses of different types or energies of radiation cause different amounts of damage to living tissue.

Solution: radiobiological weighted absorbed dose in tissue;
the biological effectiveness is taken into account by the use of a dimensionless quality factor
measuring quantity: **dose equivalent *H***
unit: **1 Sv** (Sievert) = 1 J/kg.

Rolf Sievert, Swedish physicist, 1896 - 1966

picture: wikipedia

Environmental dosimetry

Natural ionising radiation sources:

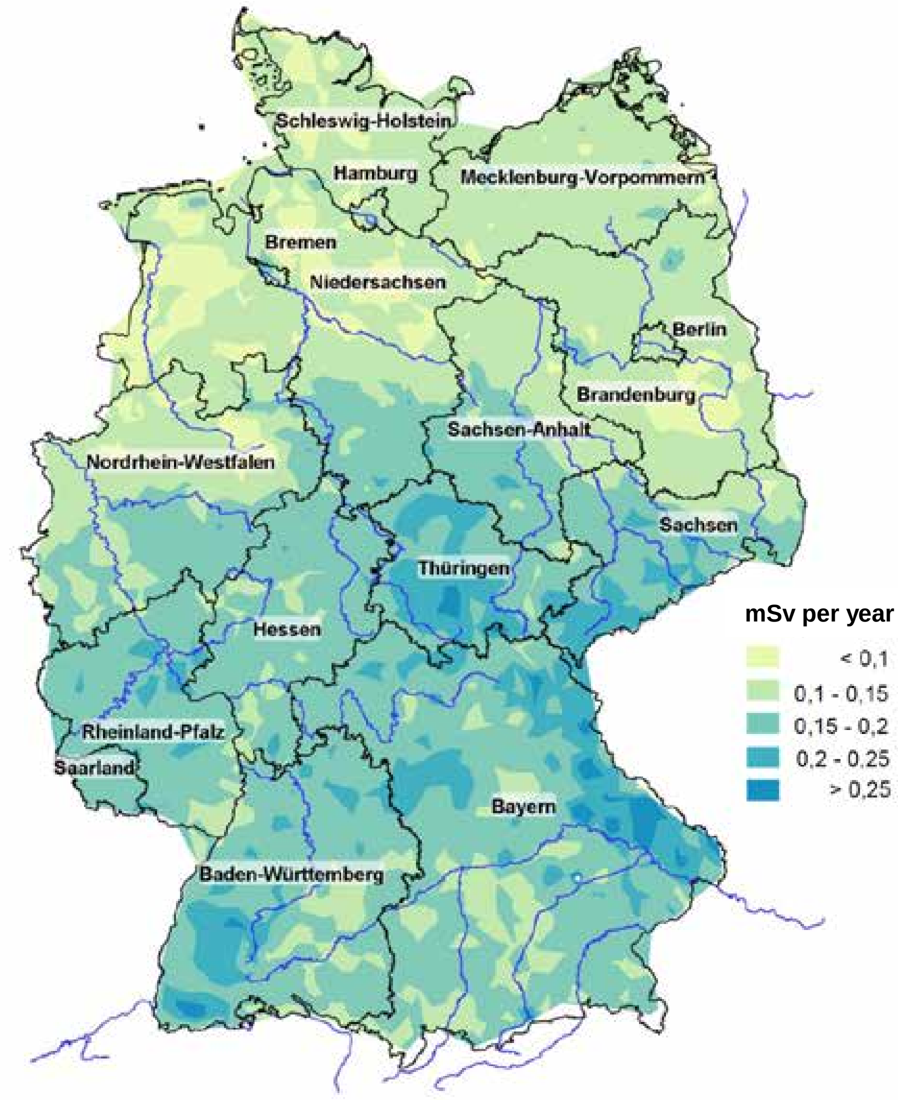
- **cosmic radiation:**
  muons, neutron, electrons, gamma radiation
- **terrestial radiation:**
  gamma radiation from natural radioactivity from rocks, soil,..
- **Radon** in air

⇨ **composite radiation field**

Artificial (not natural) ionising radiation:

Legal dose limit for the general public in Germany: 1 mSv/a

(cosmic and terrestrial radiation)



Duration of stay outdoor (daily): 5 h

BMU – annual report 2009

Environmental dosimetry

Purpose: monitoring to ensure the compliance of the legal dose limit of 1 mSv/a for the general public

Area dosimetry

Challenge: dose of natural ionising radiation is in the same order of magnitude as the legal dose limit
distinction between "natural" dose and "artificial" dose

Dosimetry for occupationally exposed workers

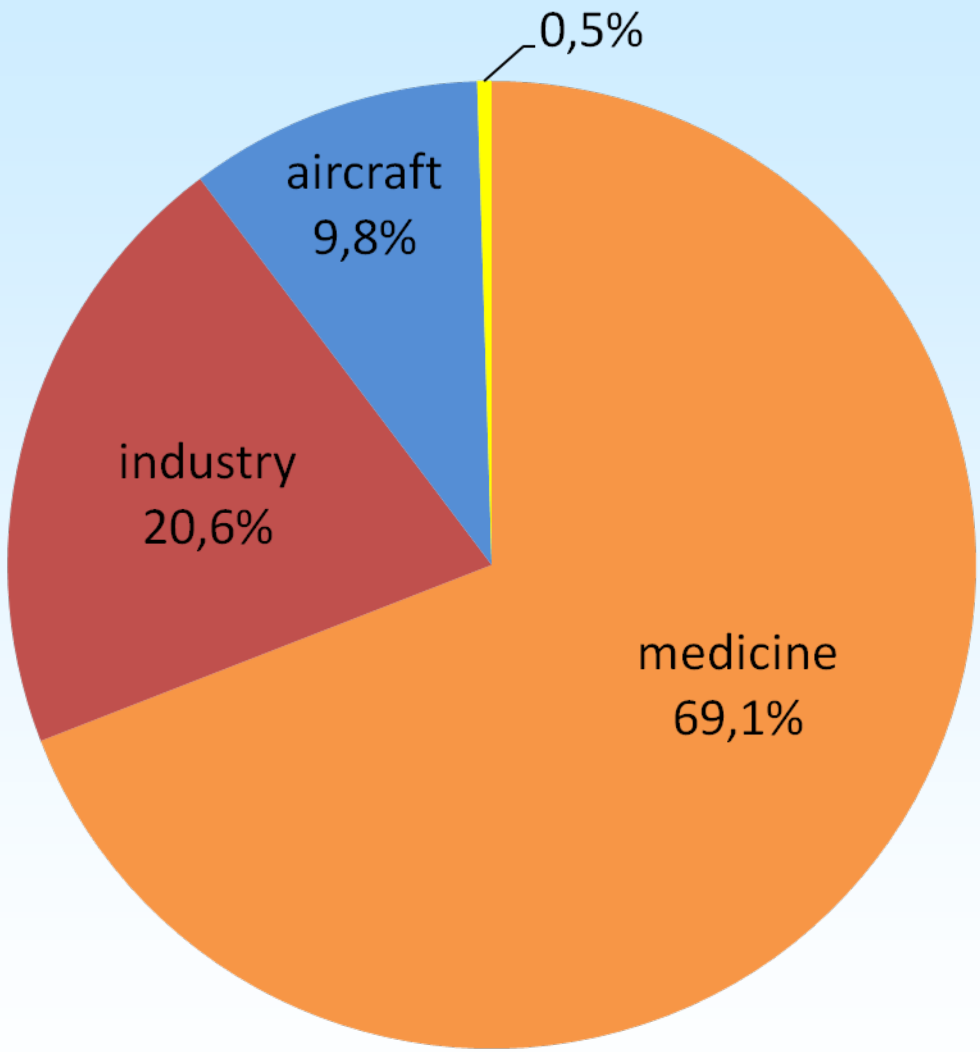
Purpose: monitoring to ensure the compliance of the legal dose limits for occupationally exposed workers

in Germany: about 370.000 people

pictures: wikipedia

Dosimetry for occupationally exposed workers

Work places of occupationally exposed employees in Germany



nach Bundesamt für Strahlenschutz 2009

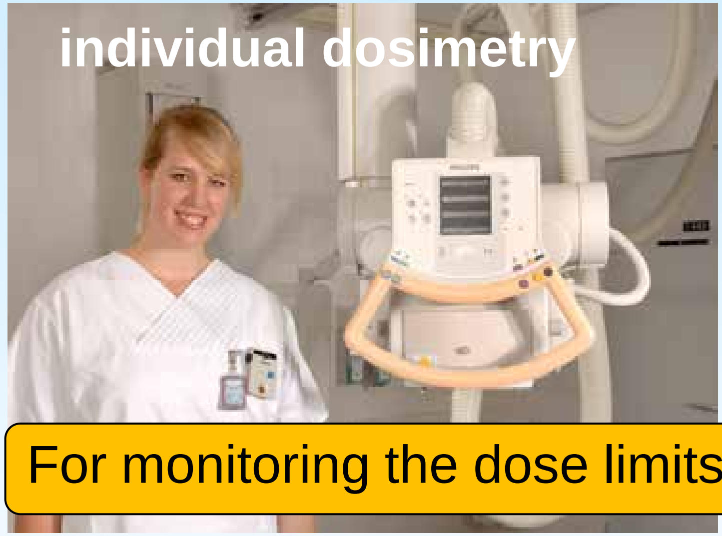
Dosimetry for occupationally exposed workers

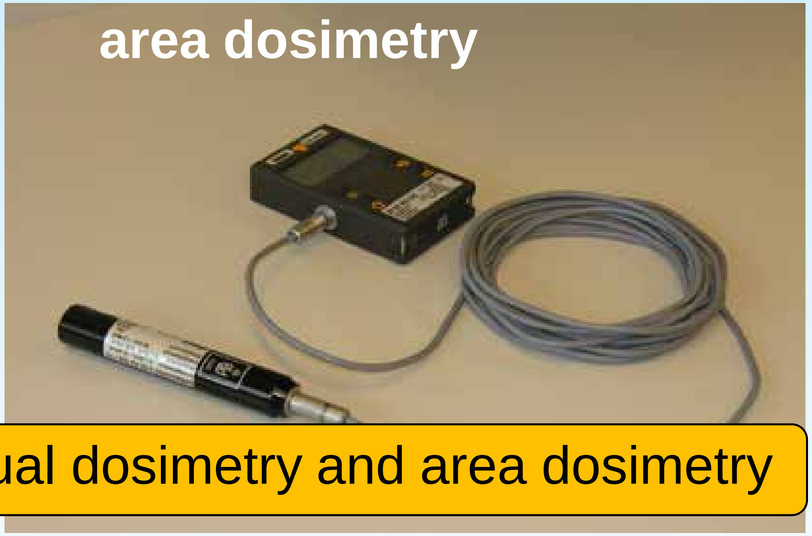
dose	organ	dose limit for occupationally exposed workers per year
effective dose	whole body	20 mSv
Equivalent dose to an organ	eye lens	150 mSv
	hands, skin, forearm, feet, ankle	500 mSv

The dose limits are set in such a way that the probability of radiation damage is negligible.

Dosimetry for occupationally exposed workers

Quality assurance: type testing of radiation protection dosemeters for photon radiation (in Germany: legal task of PTB)



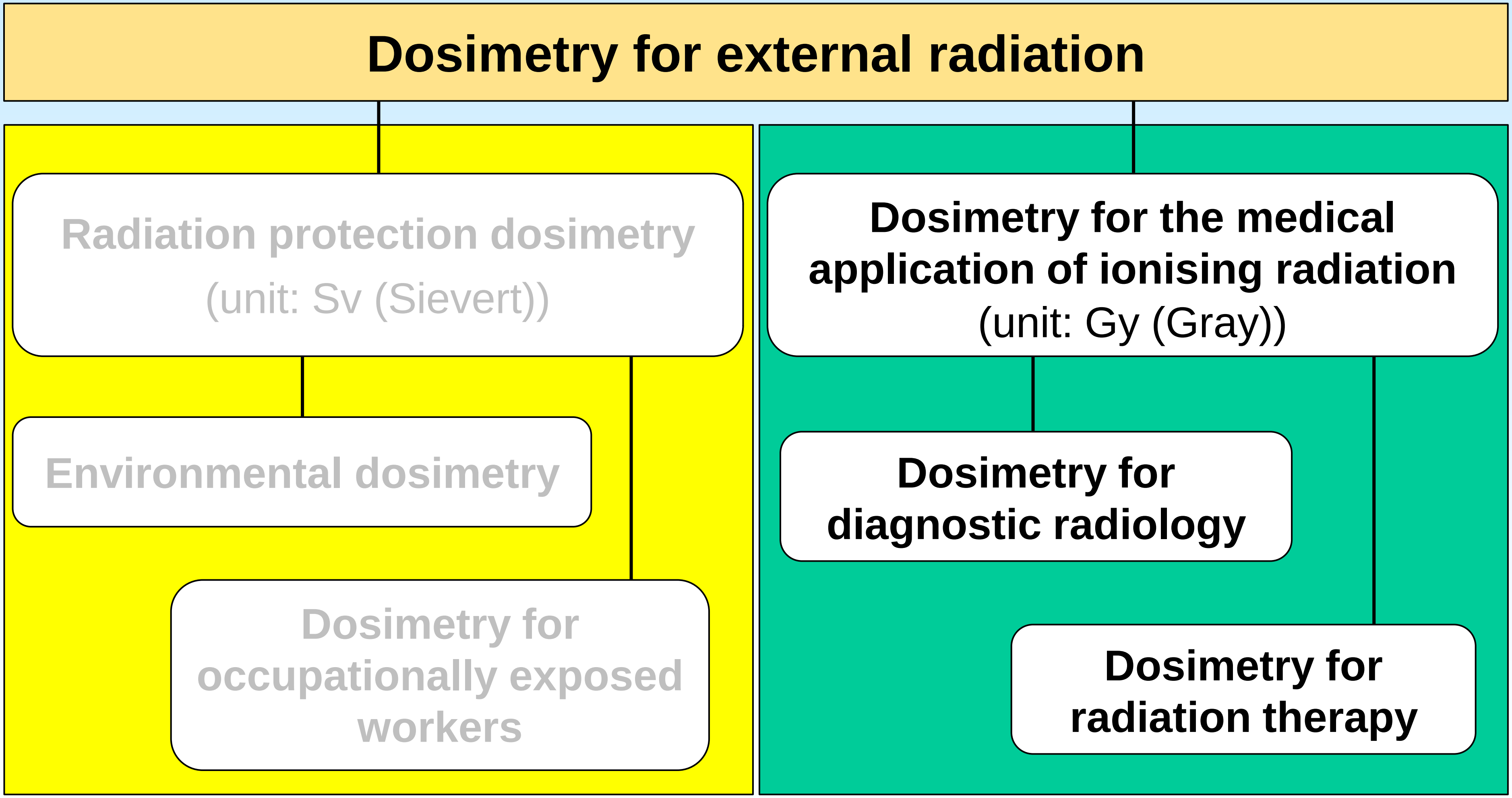


For monitoring the dose limits: individual dosimetry and area dosimetry

Challenge: dose measurements in composite radiation fields:

- photon radiation: X-rays (keV), …., accelerator fields (MeV), electron radiation, neutron radiation, cosmic radiation
- continuous and pulsed radiation
- wide range of dose rates

Fields of dosimetry



Dosimetry for the medical application of ionising radiation

Dosimetry to ensure that the dose exposed to the *patient* is equal to the dose predefined by the doctor.

Characteristics:

- Administration of a dose only due to medical indication
- no legal dose limits, the doctor decides the dose to be administered
- no individual patient dosimetry
- dosimetry that the facility (e.g. X-ray unit or accelerator) delivers the predefined dose and field (dose distribution)
- measuring quantity: **absorbed dose *D***

  unit: **1 Gy** (Gray) = 1 J/kg

pictures: wikipedia

Louis H. Gray, British physicist, 1905 - 1965

Dosimetry for diagnostic radiology

Purpose: to ensure that the patient is exposed with the predefined dose, i.e. for quality assurance of the diagnostic facilities.

⇨ Patient safety: patient dose as low as possible, but enough for an assured diagnosis

Dosimetry for diagnostic radiology

Typical doses for X-ray examination:

- X-ray examination: – tooth: < 0,01 mGy
- CT-examination, adult ($CTDI_{vol}$): – abdomen: 20 mGy
  – thorax: 12 mGy
- CT-examination, baby ($CTDI_{vol}$): – abdomen: 2,5 mGy
  – thorax: 1,5 mGy

Dosimetry for diagnostic radiology

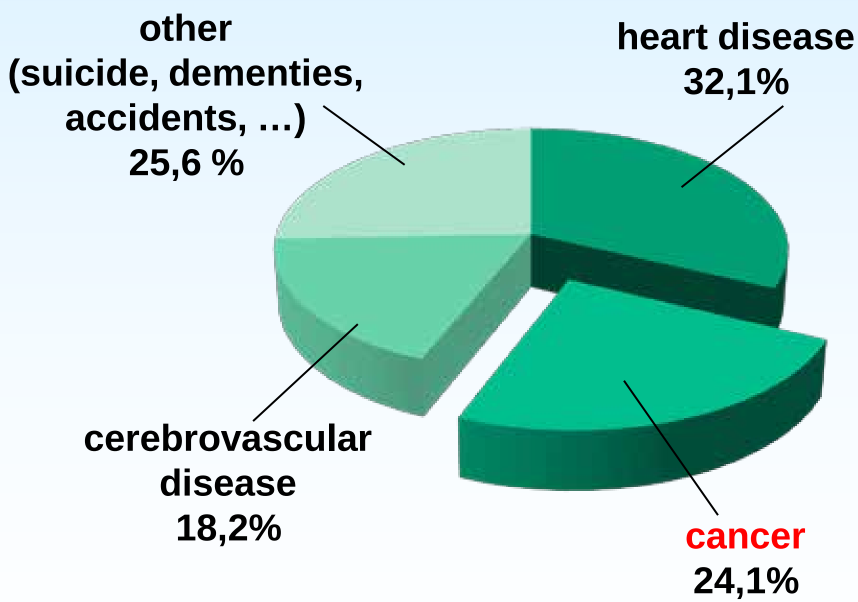
Diagnostic dosemeter:

Challenge: dosimetry in sophisticated radiation fields produced by recently developed facilities for better clinical diagnostics,
e.g. new generation of CT scanner, mammography units,…

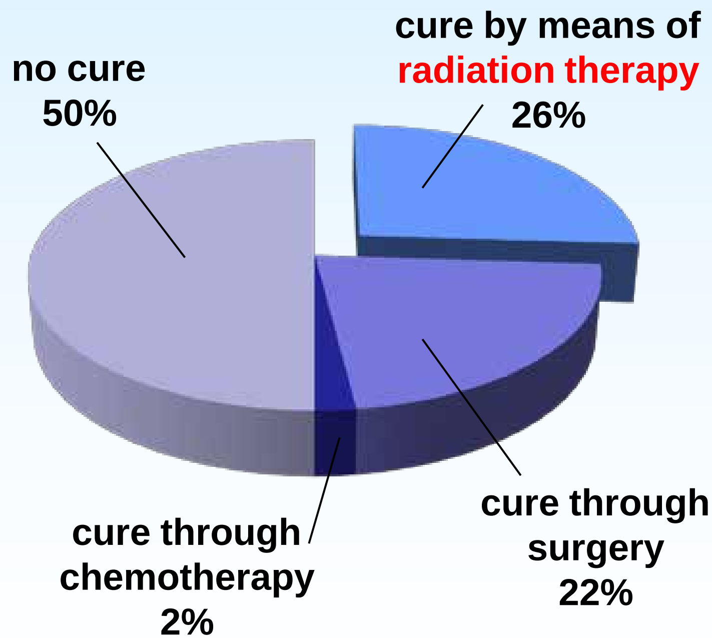
Dosimetry for radiation therapy

Number of annual incidences of cancer: EU: ≈ 2.3 million; Germany: ≈ 430 000

Causes of death in the industrial countries



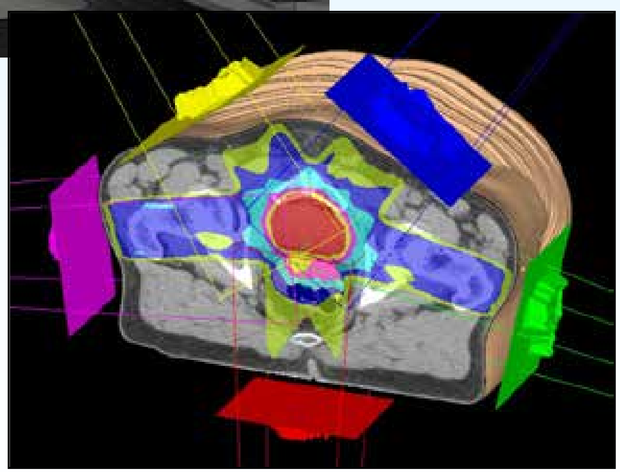
Curability of cancer



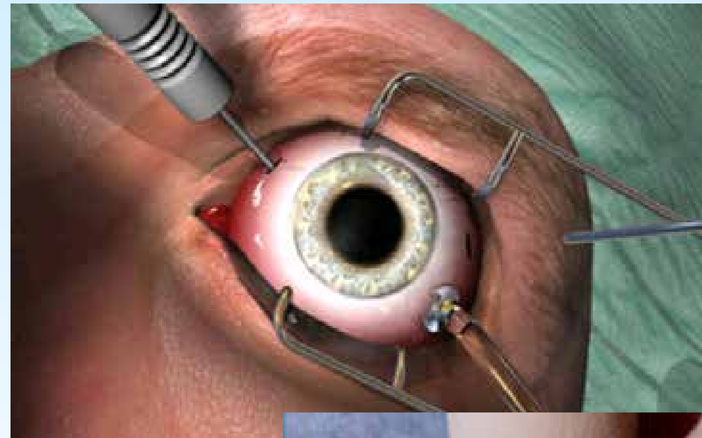
Dosimetry for radiation therapy

Types of radiation therapy:

External radiation therapy:



Brachytherapy:



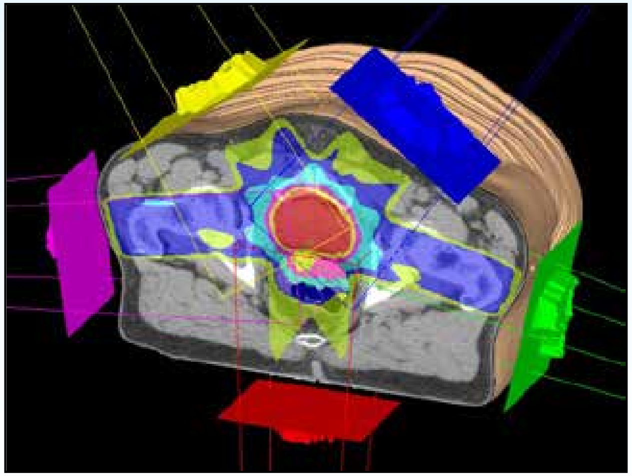
Dosimetry for radiation therapy

Purpose: to ensure that the tumour is exposed with the predefined dose for killing tumour cells, i.e. for quality assurance of the radiation treatment

Characteristics:

- typical dose: 20 Gy to 70 Gy depending on the tumour, exposed fractional, where the amount of dose is decided by the doctor
- objective: to achieve a high dose in the tumour volume and a small dose in the surrounding healthy tissue

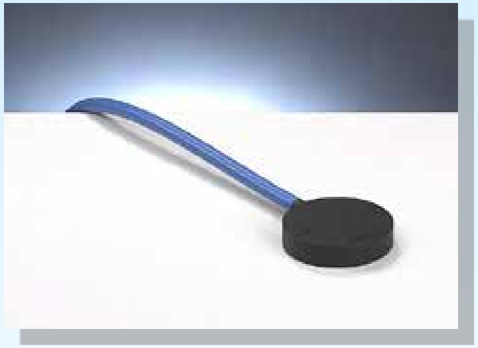
⇨ „tumour matched“ dose distribution in the patient,
e.g. by superimposing a large number of small, irregularly shaped radiation fields



Dosimetry for radiation therapy

Measuring instruments: ionisation chambers



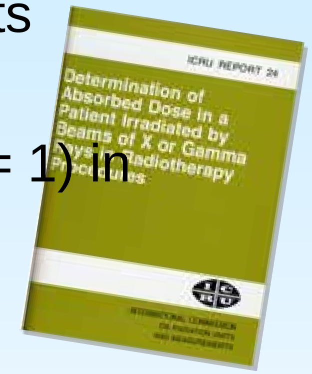
In radiation therapy the medical physicists are responsible for the dosimetry.

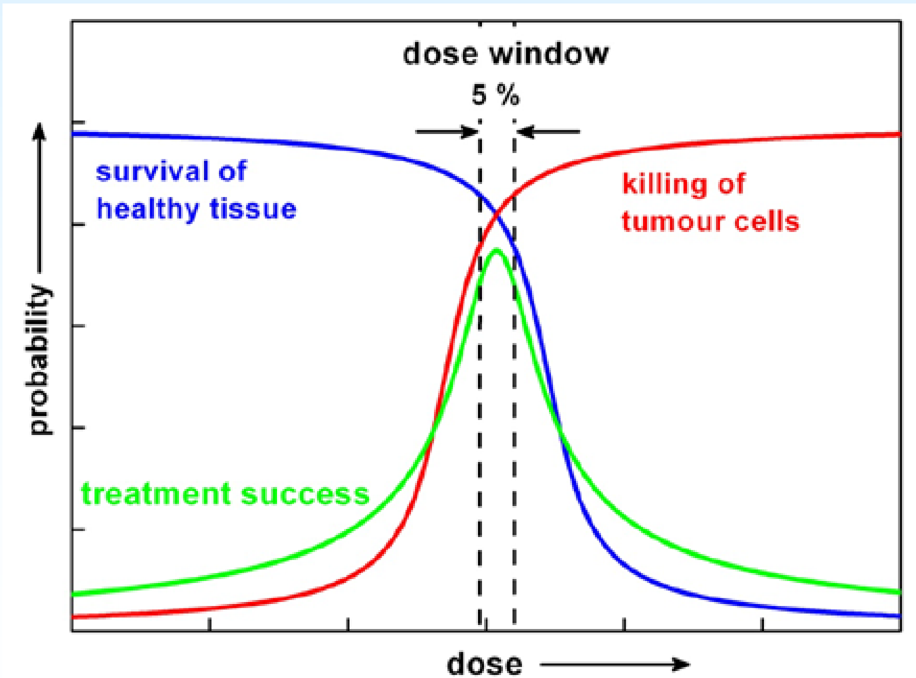
pictures: PTW Freiburg

Dosimetry for radiation therapy

Challenge: dose measurements in complex fields with small uncertainty:

- photon, electron, proton or carbon ion radiation fields
- small, irregularly shaped fields with deep dose gradients
- complex dose distribution
- dose measurement with an **uncertainty of ± 2.5 %** (k = 1) in the exposed volume (requirement: ICRU report 24)





Need for a precise dose measurement

Who in the Universe needs dosimetry?

Dosimetry for external radiation

Radiation protection dosimetry

Dosimetry for the medical application of ionising radiation

Who in the Universe needs dosimetry ?

Thank you for your attention !!