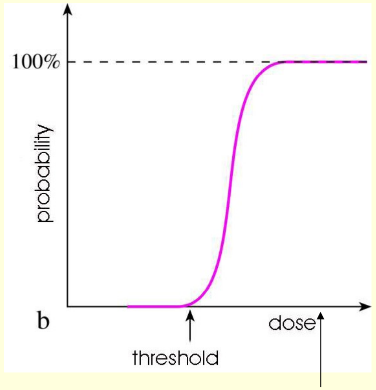
Types of damages

Deterministic damages | ***Stochastic damages***

Deterministic damages



Gy

Under threshold: *p=0*

Deterministic damages

A threshold dose exists.

Above threshold severity depends on the dose.

Appear soon after exposition.

Must not be induced during diagnostic procedures.

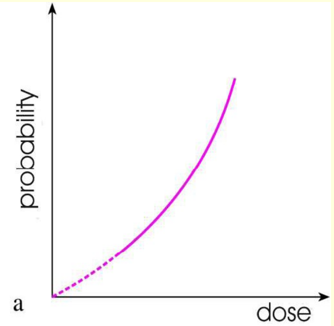
e.g. erythema, epilation, cataract

*1% lethal 60 days after exposition

Dose (Gy) (whole body)	Biological effect
< 0,15-0,2	No observable effect
0,5	Slight blood changes – limit of detection by hematological methods.
0,8	Critical dose – threshold of acute radiation syndrome
2,0	Minimal lethal dose (LD1/60)*
4,0	Half lethal dose (LD50/60)
7,0	Minimal absolute lethal dose (LD99/60)

Chest X-ray: cc 160 μGy in the skin

Stochastic damages



NO threshold!

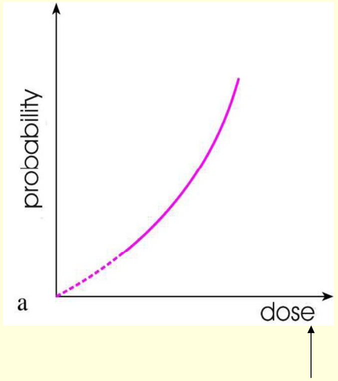
The probability of stochastic damage depends on the dose.

Severity (e.g. cancer) independent of the dose.

Delayed biological effects.

e.g.tumours, heriditary diseases

Stochastic damages



H_T (equivalent dose) and E (effective dose) provide a basis for ***estimating the probability of stochastic effects*** for doses below the threshold of deterministic effects.

Dose range is under the threshold of deterministic damages.

Stochastic damages

Irradiated cell is modified rather than killed

Severity is not effected by the dose

With increasing dose only the probability* increases

*1 gamma photon: the probability to cause cancer is 3×10^{-16} (1: 3,000 billion, but this is the Russian roulette!)

examination	Approximate effective doses mSv
Chest X-ray	0,04
Chest CT	7,8
Cranial CT	1,8
Abdominal X-ray	1,2
Abdominal CT	7,6
X-ray of the dorsal vertebrae	1,0
X-ray of the lumbar vertebrae	2,1
Barium enema with fluoroscopy	8,7

Radiotherapy

Irradiation results ***deterministic effects*** (tumour cell kill)
- in this context some deterministic effects and stochastic effects must be tolerated (side effects)

Radiation protection

The aim is to ***exclude deterministic effects***
and
minimize the risk of ***stochastic effects***.

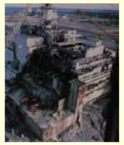
Estimated average of annual dose from natural background and man-made sources is 3.6 mSv.

environmental

occupation

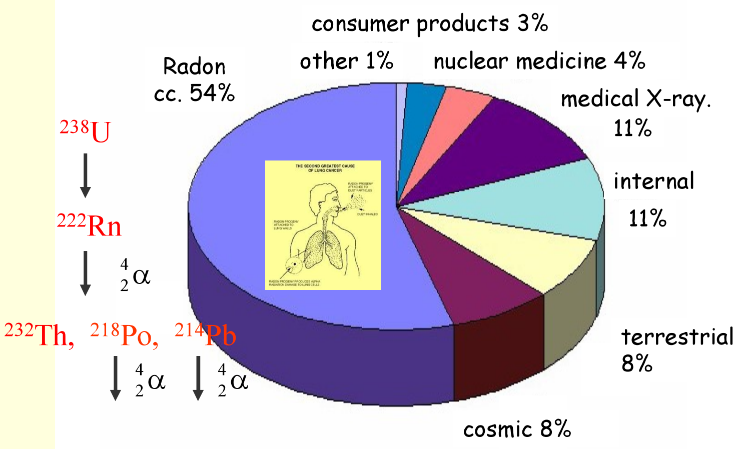
military

nuclear industry

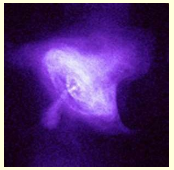


medical use

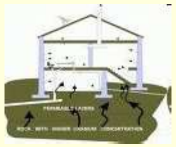
Distribution of annual dose among sources



Sources of natural background

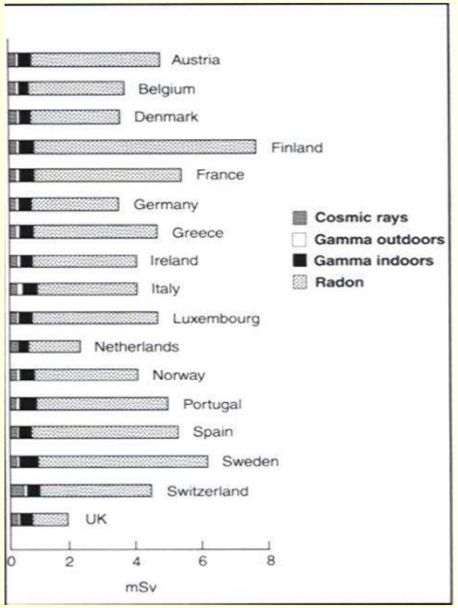


cosmic radiatiom
~ 0,4 mSv/year



radon: cc. 1,8 mSv/year

potassium: cc 0,1 mSv/year



Distribution of naturally occuring background levels of radiation in Europe

The highest known level of background radiation is in Kerala and Madras States in India where a population of over 100,000 people receive an annual dose rate which averages 13 millisieverts.

Risk – loss of life expectancy

Days of average life expectancy lost	
Being unmarried male	3500
Smoking (pack/day)	2250
Being unmarried female	1600
Being a coal miner	1100
25% overweight	777
Alcohol abuse	365
Being a construction worker	227
Driving motorcycle	207
1 mSv/year effective dose for 70 years	10
Coffee	6

Relative risk of dying: 1 in a million odds

Smoking 1.4 cigarettes (lung cancer)

Eating 40 tablespoons of peanut butter

Eating 100 charcoal broiled steaks

2 days in New York City (air pollution)

Driving 40 miles in a car (accident)

Flying 2500 miles in a jet (accident)

Canoeing for 6 miles

Receiving 0.10 mSv radiation dose (cancer)

Radiation protection

Aims of radiation protection:

Prevention from deterministic effects (except in radiotherapy those that are intentionally produced)

Keeping the occupational risk of the users of the sources at the level of occupational risk of other profeesionals.

Keeping the public risk from ionising radiation sources at the level of pudlic risk of other civilisation related harms.

Radiation protection lies on the following ***principles:***

Optimization: All exposures should be kept As Low As Reasonable Achievable (ALARA)

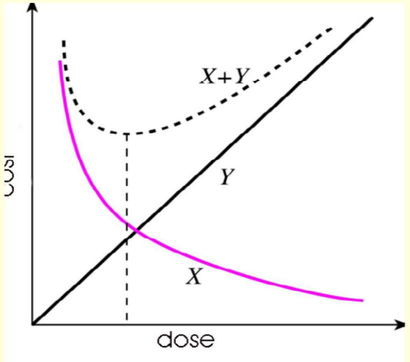
Justification: no practice shall be adopted unless it produces a positive net benefit

Limitation: the effective dose (E) to individuals shall not exceed the limits recommended by the ICRP (maximum permitted doses)

Optimization of radiation protection

ALARA-principle

As **L**ow **A**s **R**easonably **A**chievable



X : cost of radiation protection

Y : cost of treatment

X+Y: total cost

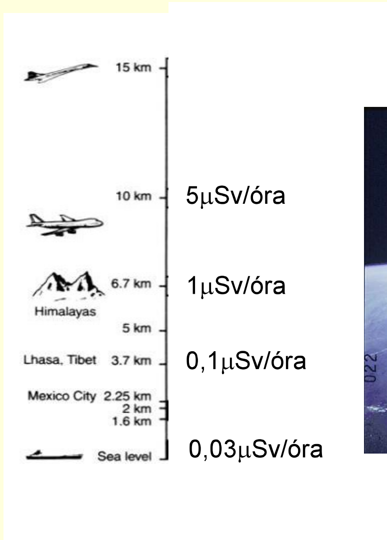
Optimum is the minimum

Dose limits in radiation protection

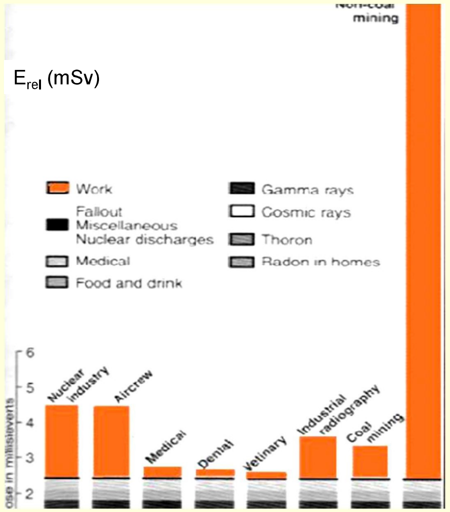
	Occupational (mSv/year)	Population (mSv/year)
Effective dose	20*	1
Dose equivalent (eye lens)	150	15
Dose equivalent (limb/skin)	500	50

* Over the average of 5 years but maximum 50 mSv/year

Cosmic ray contributions to dose rate as the function of the altitude

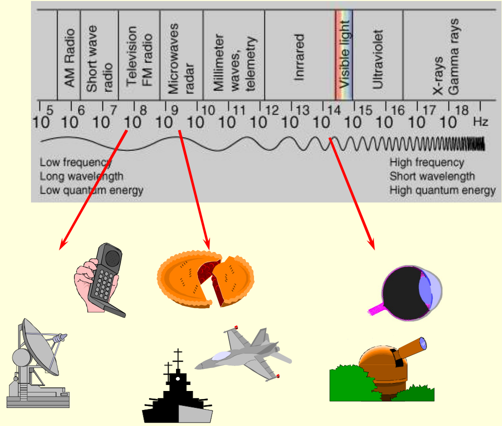


Relative risk of various professions



Detection of radiation – dose measurement

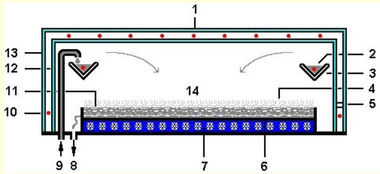
- What? α^{++} p^{+} (n) β γ ν
- How much energy?
- How much intensity?
- How good accuracy?



Measuring devices

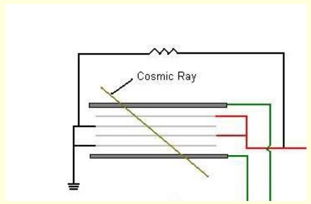
Alteration of a physical parameter ~ absorbed dose

Detection of particles



- **Cloud chamber**
  supersaturated vapor of water or alcohol

- **Spark chamber**
  high voltage wiers



- **Bubble chamber**
  - superheated transparent liquid (H_2, Ar, Xe)
  - entire chamber is subject to a constant magnetic field

Dose and dose rate measuring devices

*electronic detectors – absorbed energy generats free charges

gas-ionization detectors – prompt and/or delayed evaluation

scintillation detectors

semi-conductor detectors –

* Chemical detectors – based on radiochemical alterations

film – follow-up evaluation

* Solid materials – based on physical parameters of solid materials

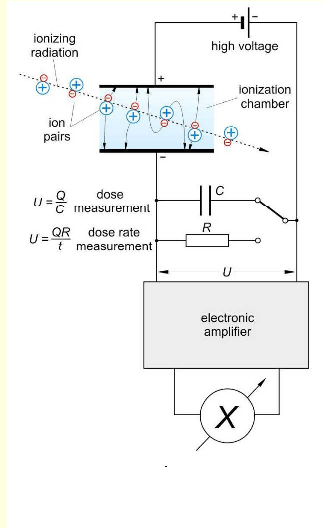
thermoluminescent detector – TLD (LiF, CaF_2, BeO, Al_2O_3)

Electronic Dosimeters

Ionization chambers

***Dose measurement**: the voltage U that is produced by collected charge Q on the capacitor C is proportional to the total amount of the separated charges.*

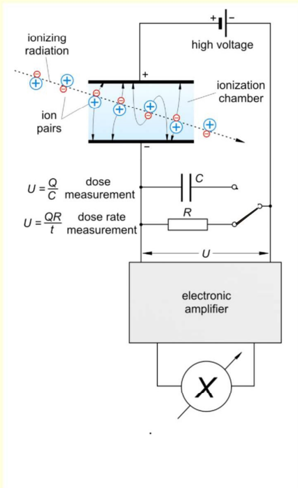
$$U = \frac{Q}{C} \sim X$$



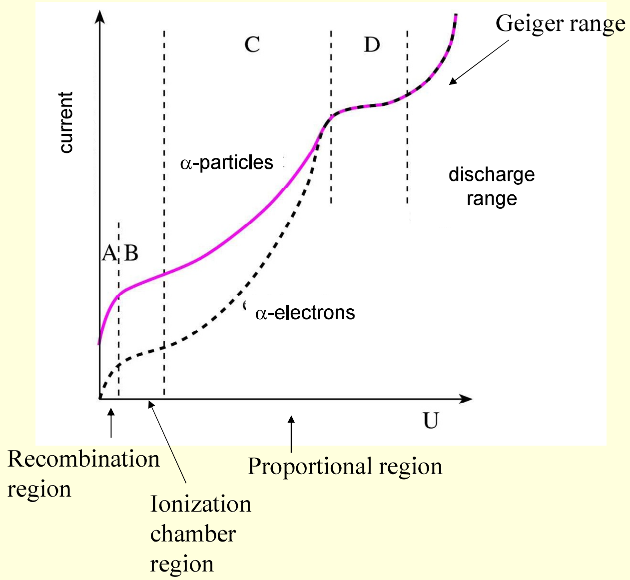
Ionization chambers

***Dose rate measurement**: the potential drop is measured on a large resistance R , that is proportional to the charge Q that flows through at unit time.*

$$U = \frac{QR}{t} \sim \frac{X}{t}$$



Ionization chambers



The dependence of ionization on voltage

Ionization chambers– Geiger-Müller counter

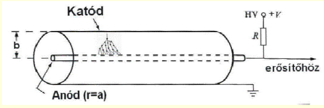
- Inert gas filling
- High accelerating voltage

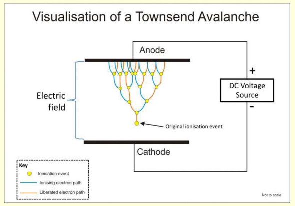
↓

Avalanche effect between electrods

↓

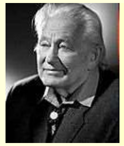
Current pulse





Number of current pulses ~ number of ionising particles

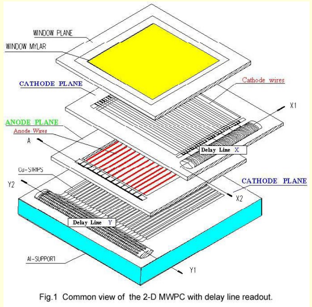
Multiwire chamber



Nobel prize in Physics 2002

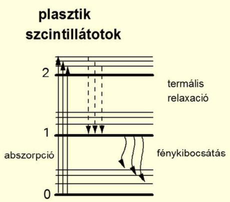
Georges Charpak

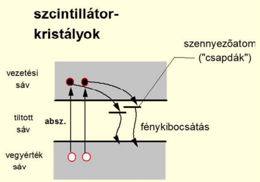
1924 -2010



- electric current proportional to the energy of the detected particle
- localised cascade of ionization
- spatial sensitivity!

Scintillation detectors

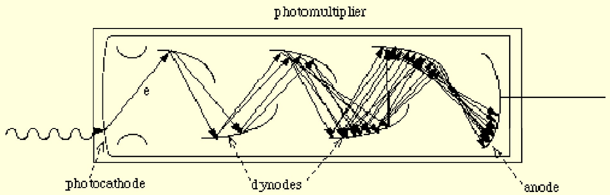




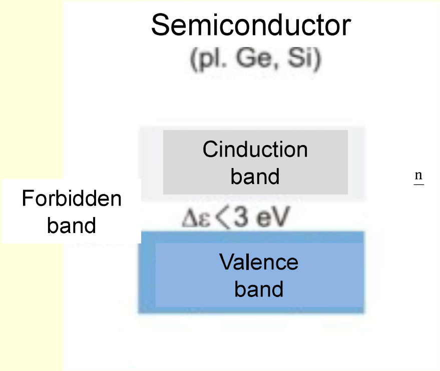
- Liquid scintillator
  - Solution of fluorescent compounds
  - Primary excitation of solvent and follow-up excitation of diluted compound
  - Light emission
- Plastic scintillator
  - Solid materials
- Inorganic crystals
  - Primary excitation of crystal, follow-up excitation of luminescent atoms

Scintillation detectors

- scintillator → visible light
- Generation of electric signal
- Photoelectric effect
- Multiplication of free electrons



Semiconductor detectors



$$\frac{n}{n_0} = e^{-\frac{\Delta\varepsilon}{kT}}$$

↓

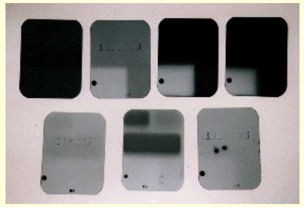
$$\sigma \approx e^{-\frac{\Delta\varepsilon}{2kT}}$$

Conductivity ~ number of excitations

Chemical processes

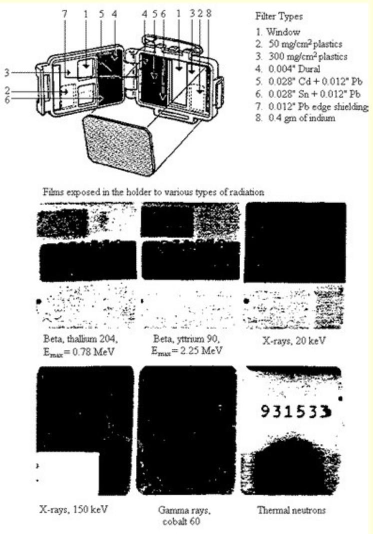
Film badges

It measures darkening of the developed photographic film that was exposed to ionizing radiation.

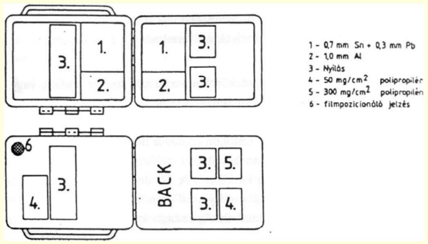


Darkening of the developed photographic film is proportional to the dose rate of the ionizing radiation and to the irradiation time.

Film badges



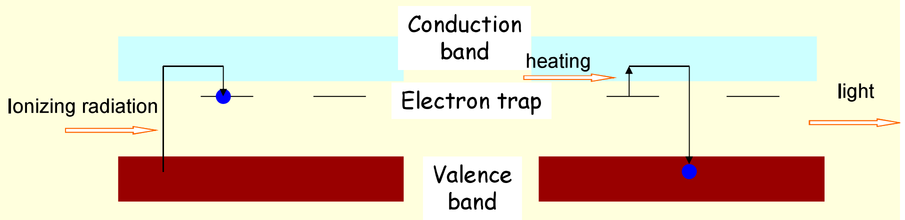
Darkening depends on the type and energy of radiation, and the thickness and material of absorber.



Solid phase detectors

Thermoluminescent dosimeter

Band structure on electronic transitions



exposition   evaluation

Calculation of the dose in case of γ - radiation

The absorbed dose in air (D_{air}) for any γ - radiating isotope

$$D_{air} = K_\gamma \frac{\Lambda t}{r^2}$$

izotop	γ-energy (MeV)	K_g
^{24}Na	2,754; 1,369	444
$^{52/59}$Fe	0,5; 1,3; 1,1	160
^{60}Co	1,33; 1,17	305
^{131}I	0,364; 0,08; 0,723	54
^{137}Cs	0,661	80

Λ: activity of the isotope preparation

t: time of exposition

r: distance from the source

K_γ: dose constant
(specific γ - ray constant)

$$[K_\gamma] = \frac{\mu Gy \cdot m^2}{h \cdot GBq}$$

Someone works at 30 cm distance from a ^{24}Na isotope preparation of 75 MBq. Calculate the thickness of the lead shielding that reduces the dose rate to 15 μGyair/h at the working place.

$$\left(\frac{D}{t}\right)_0 = K_\gamma \frac{\Lambda}{r^2} \qquad \left(\frac{D}{t}\right)_0 = 444 \frac{75 * 10^{-3}}{0{,}3^2} = 370[\mu Gy / h]$$

$$\left(\frac{D}{t}\right) = \left(\frac{D}{t}\right)_0 e^{-\mu_m x_m}$$

x=5,7 cm

Question of the week

Which voltage range(s) of ionization chamber can be used in dose measurements? Why?

Damjanovich, Fidy, Szöllősi: Medical Biophysics

II. 4.
- 4.1
- 4.2
- 4.3
- 4.4
- 4.5

In the frame: 184. 186.

Manual :Dosimetry