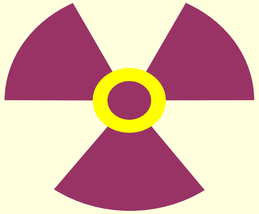
Dosimetry of ionizing radiation



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

environmental

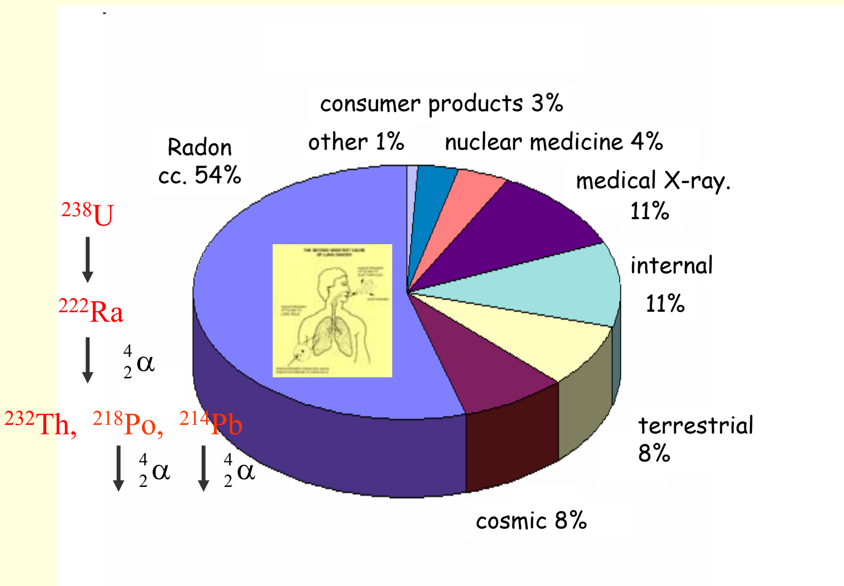
occupation

military

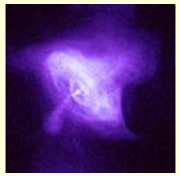
nuclear industry

medical use

Distribution of annual dose among sources



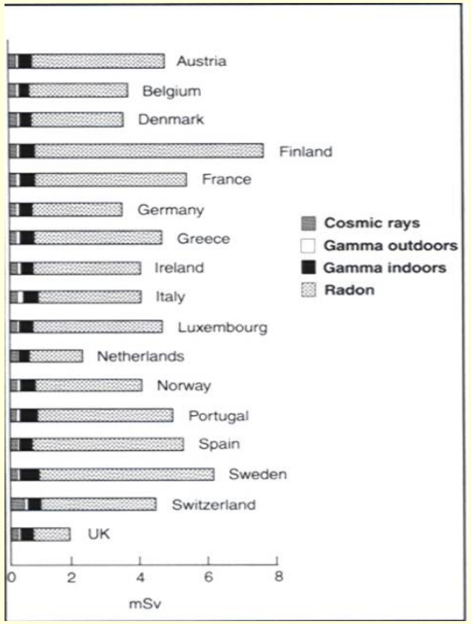
Sources of natural background



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

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

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

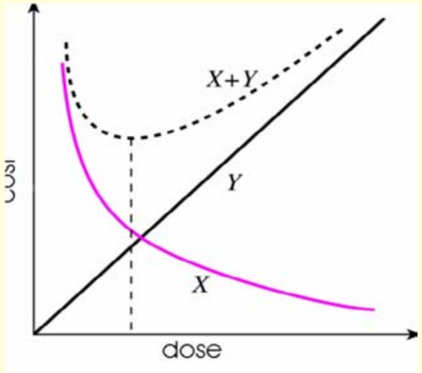
Justification: no practice shall be adopted unless it produces a positive net benefit

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

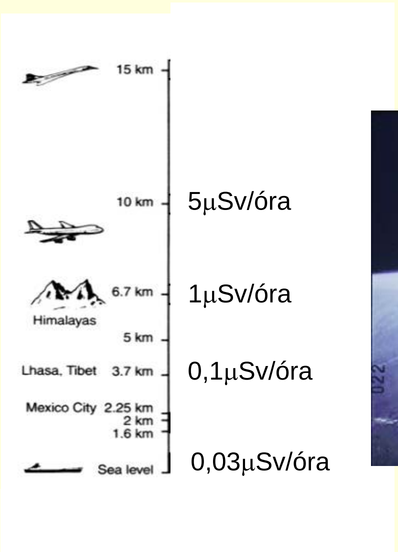
Optimum is the minimum

Dose limits in radiation protection

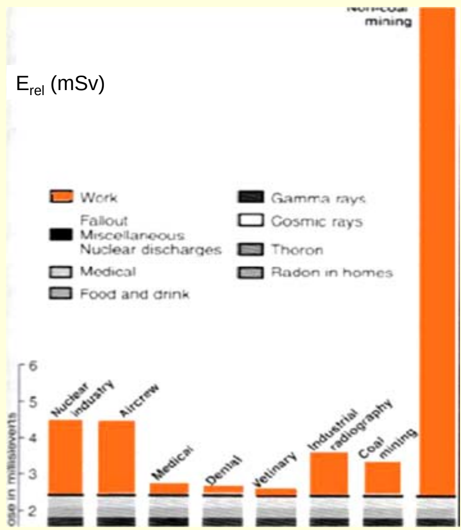
	Occupational (mSv/year)	Population (mSv/year)
Effective dose	20*	1
Dose equivalent (eye lens)	150	15
Dose equivalent (limb/skin)	500	50

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

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

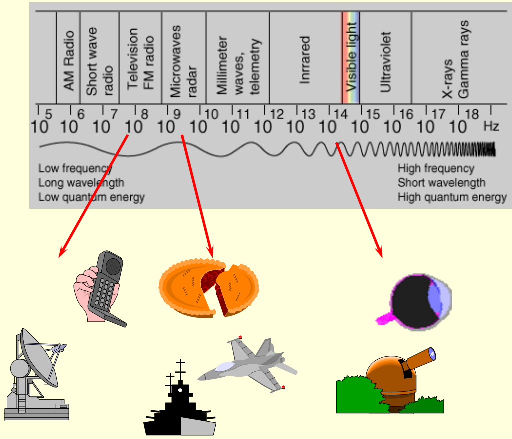


Relative risk of various professions



Detection of radiation – dose measurement

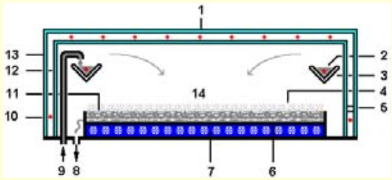
- What? α^{++} p^{+} (n) β γ ν
- How much energy?
- How much intensity?
- How good accuracy?



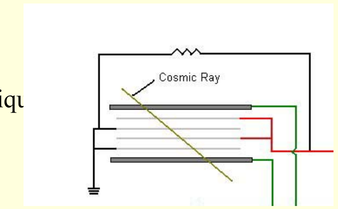
Measuring devices

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 liqu
  (H_2, Ar, Xe)

Types of Dosimeters

* Electronic Dosimeters – radiation generates free charges – electric signal is detected

Gas-filled detectors

Scintillation detectors

Semiconductor detectors

* Chemical detectors – based on radiation induced chemical processes

Film Badges

* Solid state detectors – based on physical behavior of crystals

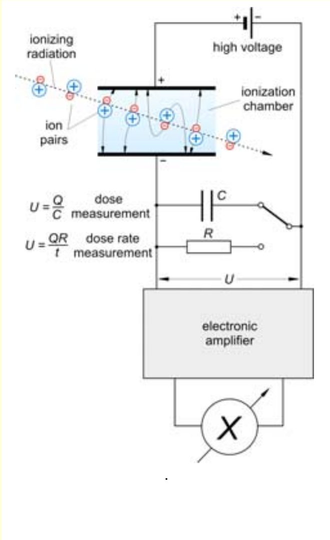
Thermo Luminescent Dosimeters – TLD (LiF, CaF_2, BeO, Al_2O_3)

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.

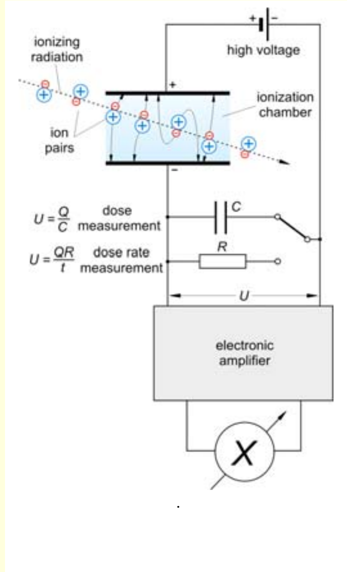
$$U = \frac{Q}{C} \sim X$$



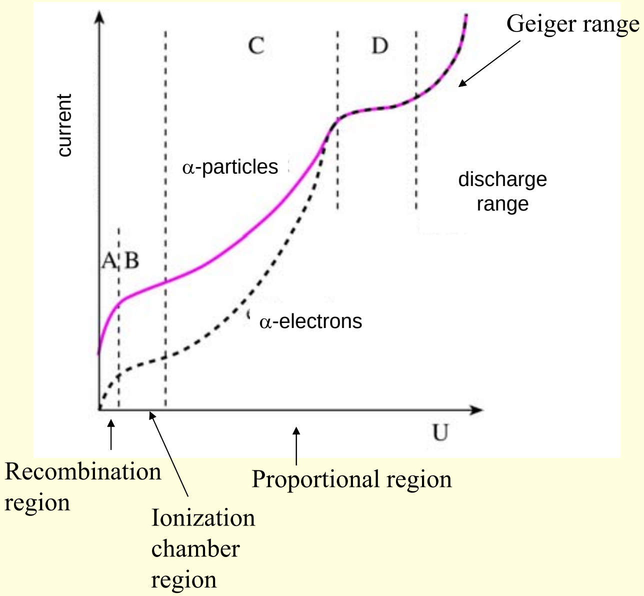
Ionization chambers

***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*

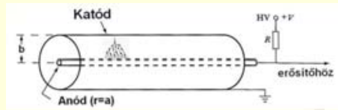
- Inert gas filling
- High accelerating voltage

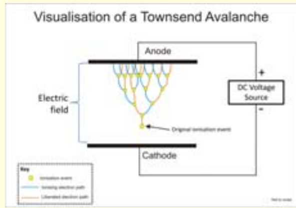
↓

Avalanche effect between electrods

↓

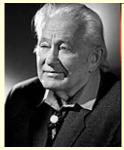
Current pulse





Number of current pulses ~ number of ionising particles

Multiwire chamber



Nobel prize in Physics 2002

Georges Charpak
1924 -2010

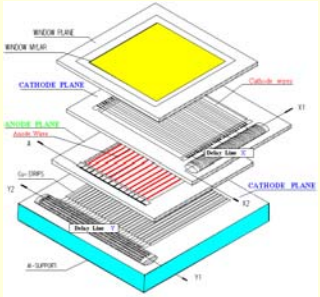


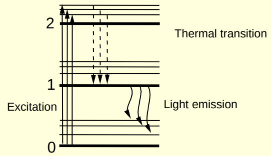
Fig.1 Common view of the 2-D MWPC with delay line readout.

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

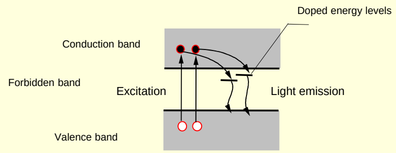
Scintillation detectors

- Liquid scintillators
- Plastic scintillators
- Solid state scintillators

Plastic scintillators



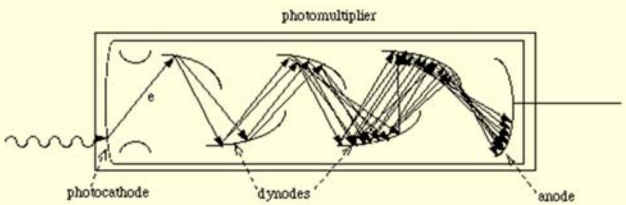
Scintillation crystals



Scintillation detectors

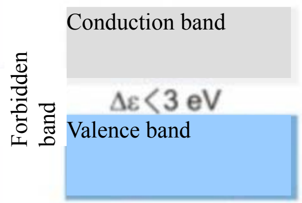
Light pulses $\rightarrow$ electric signals

1. Photoelectric effect
2. Amplification - Multiplication of secondary electrons



Semiconductor detectors

Semiconductors
(e.g. Ge, Si)



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

$$\downarrow$$

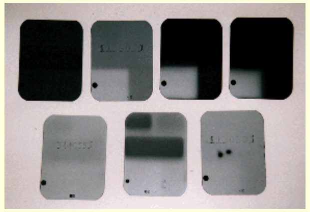
$$\sigma \approx e^{-\frac{\Delta\varepsilon}{2kT}}$$

Conductivity ~ number of excitations

Chemical processes

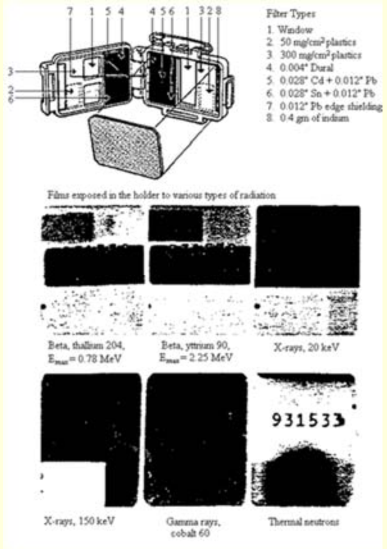
Film badges

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

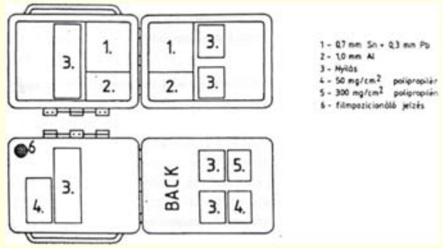


Darkening of the developed photographic film is proportional to the dose rate of the ionizing radiation and to the irradiation time.

Film badges



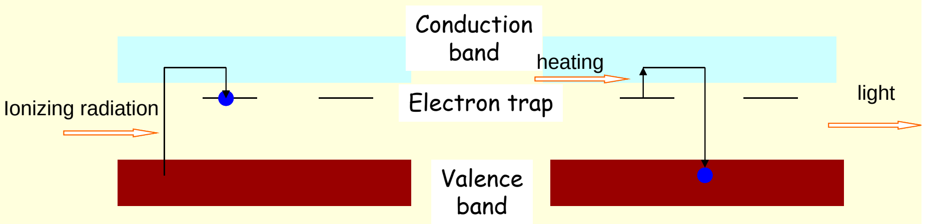
Darkening depends on the type and energy of radiation, and the thickness and material of absorber.



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

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

Λ: activity of the isotope preparation

t: time of exposition

r: distance from the source

K_γ: dose constant (specific γ - ray constant)

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

Damjanovich, Fidy, Szöllősi: Medical Biophysics

II. 4.

- 4.1
- 4.2
- 4.3
- 4.4
- 4.5

In the frame: 184. 186.

Manual :Dosimetry