NUCLEAR MEDICINE

The root of the matter:

using of the radioactive isotopes in the diagnostic and in the therapy

Imaging tehniques

Anatomy | **Physiology** | **Metabolism** | **Molecular**

Rtg. / CT

PET / SPECT

MRI

MR spectroscopy

fMRI

Ultrasound

Hybrid imaging: SPECT/CT, PET/CT, (PET/MRI)

The short history of nuclear medicine

- Discovery of radioactivity (Bequerel 1896)
- Using of radioactive material as a tracer (György Hevesy 1923)
- Development of arteficial radioactivity (Irene Curie és Frederic Joliot Curie 1934)
- Gamma-camera (Anger 1951)

Radioactivity

It is the spontaneous disintegration (decay) of the nucleus of a radioactive atom, while the element becomes to an other one.

The hydrogen atom

THE BOHR MODEL OF THE HYDROGEN ATOM

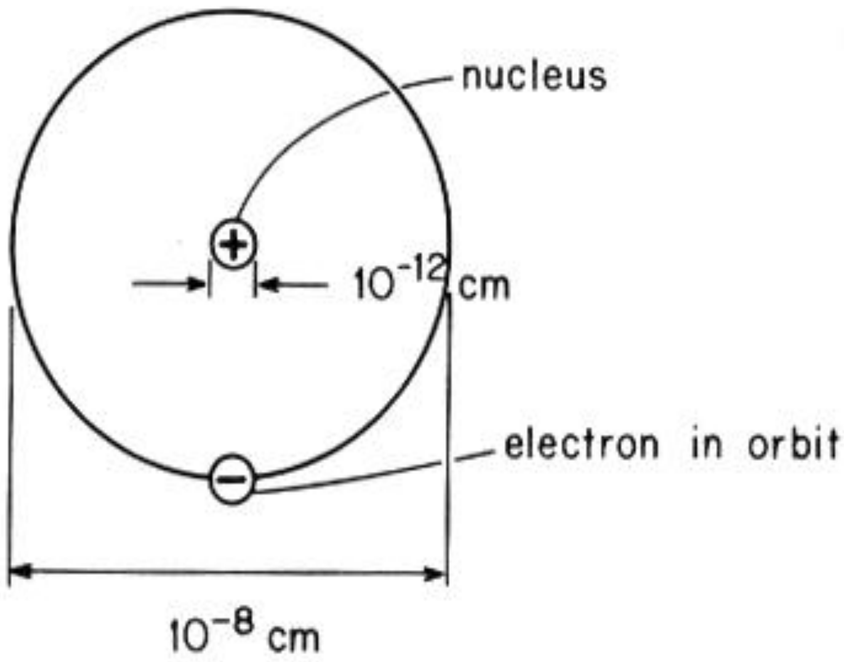


Fig. 1.1. The Bohr model of the hydrogen atom. The central nucleus contains essentially all the atom's mass, and is positively charged. The positive charge is balanced by the negative charge carried by the electron, which in this model circles the nucleus in a fixed orbit.

Table 1.1. PHYSICAL PROPERTIES OF SUB-ATOMIC PARTICLES

Particle	Electric Charge	Weight		Location
		Grams	a.m.u.	
Proton	+1	1.66×10^{-24}	1.0	Nucleus
Neutron	neutral	1.66×10^{-24}	1.0*	Nucleus
Electron	−1	9.1×10^{-28}	0.00054	Around nucleus

*The neutron is actually 0.08% heavier than the proton.

Number of protons

= elemental identity number

Number of protons and neutrons

= mass number

- Atoms with the same number of protons but differing number of neutrons are called isotopes of that element.

- The behaviour of the different radioactive isotopes of an element is the same as the stable form in every conditions.

Radioactive isotopes

Only certain combinations of protons and neutrons are stable, the other ones are radioactive, which become stable form by different radioactive radiations.

The activity

- of a radioactive element is usually given in disintegrations per second, this is the *dps*.

The unit of the activity

- 1 Bq = 1 disintegration/second
(earlier we used Ci)
1Ci = $3,7x10^{10}$ disintegrations/second
1mCi = 37 MBq

Measurement

- counts/second (cps) or counts/minute (cpm)

The half-life

is defined as the time required for one-half of the atoms in a group of radioactive atoms to decay.

- Physical half-life is characteristic for an element, independent on the external conditions.
- Biological half-life depends on the physiological conditions (e.g. increased fluid input).
- Effective half-life: $1/T_{eff} = 1/2T_{phys} + 1/2T_{biol}$

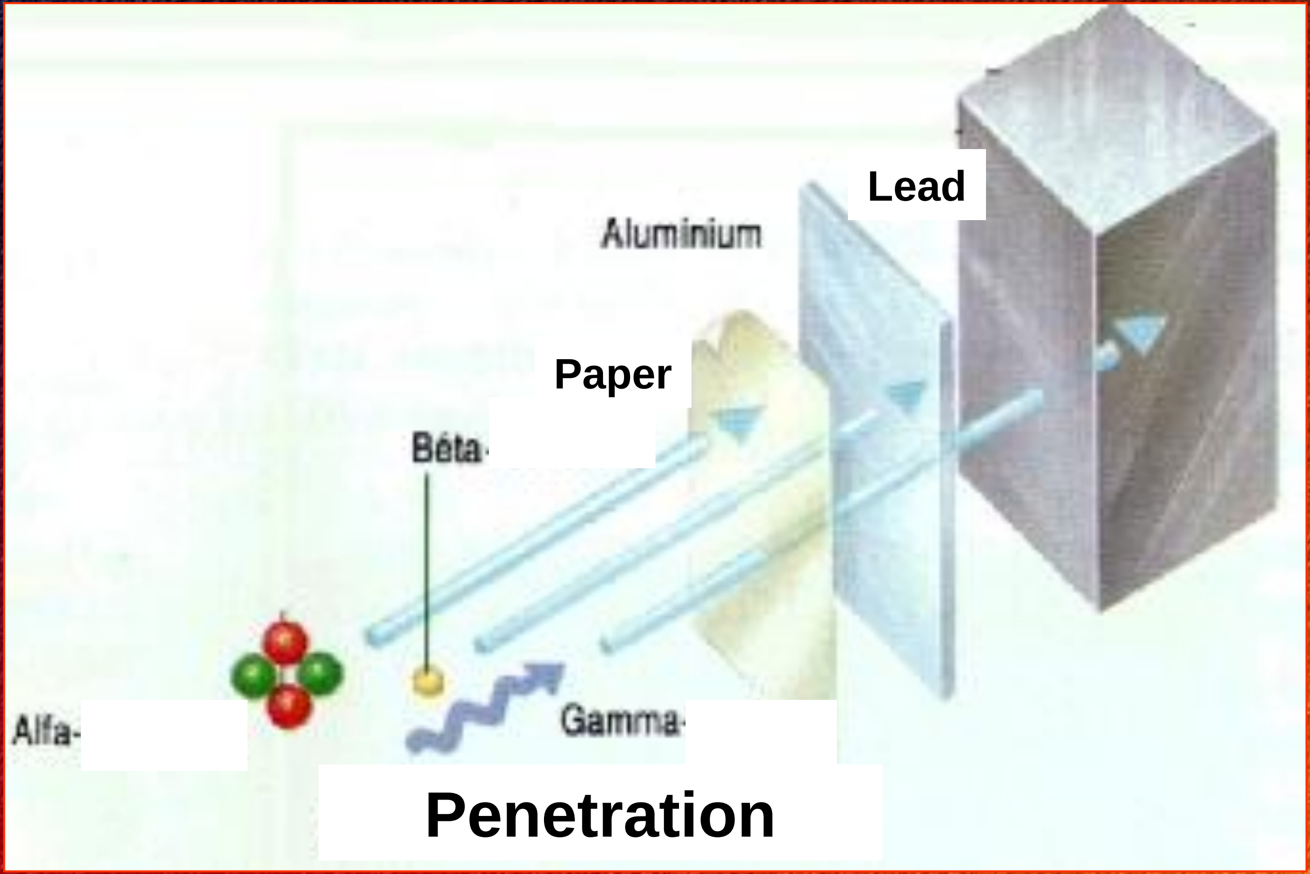
Energy

eV or keV or MeV (e.g. for 99mTc is 140Kev)

1 eV is extremly small!

Rays of radioactive decay

- Corpuscular rays (α, -β, +β)
- Electromagnetic ray (γ)



Alpha radiation

– the emission of a helium nucleus (2 protons + 2 neutrons)
– the ionizating property and biological effectivity is great
– range in tissue is with in a few micrometers
– cannot be detected outside!
– e.g. ^{226}Radium for therapy

Beta radiation

- the emission of high-speed electrons
- the biological effectivity is smaller than the alpha radiation
- the range in tissue is a few millimeters
- external detection is almost impossible
- the biological damage to tissues is high
- e.g. ^{131}Iodine for thyroid ablation

+Beta (positron) radiation

- too many protons are in the nucleus
- its life is very short, when it slows down, it combines with a normal electron in a process known annihilation, which destroyes both the electron and positron and produces two energetic photons each with 511 keV
- they are used for PET examinations
- e.g. 18Fluor for metabolic studies

Gamma radiation

- really electromagnetic radiation
- phisically similar to X-rays, but it comes from the nucleus of the atom
- very penetrated and easily pass trough tissue
- SO: it can be detected externally well!
- e.g. 99mTechnetium for the diagnosis

The most commonly used isotopes

Isotope	Radiation	Half-time	Energy
99m-Tc	γ	6 hours	140 kev
131-iodine	γ	8 days	364 keV
	β		180 keV
123-iodine	γ	13.2 hours	159 keV
111-indium	γ	2.8 days	172.2 keV
201-thallium	γ	3 days	76 keV(95%)

The base of the external detection is the photoelectric effect

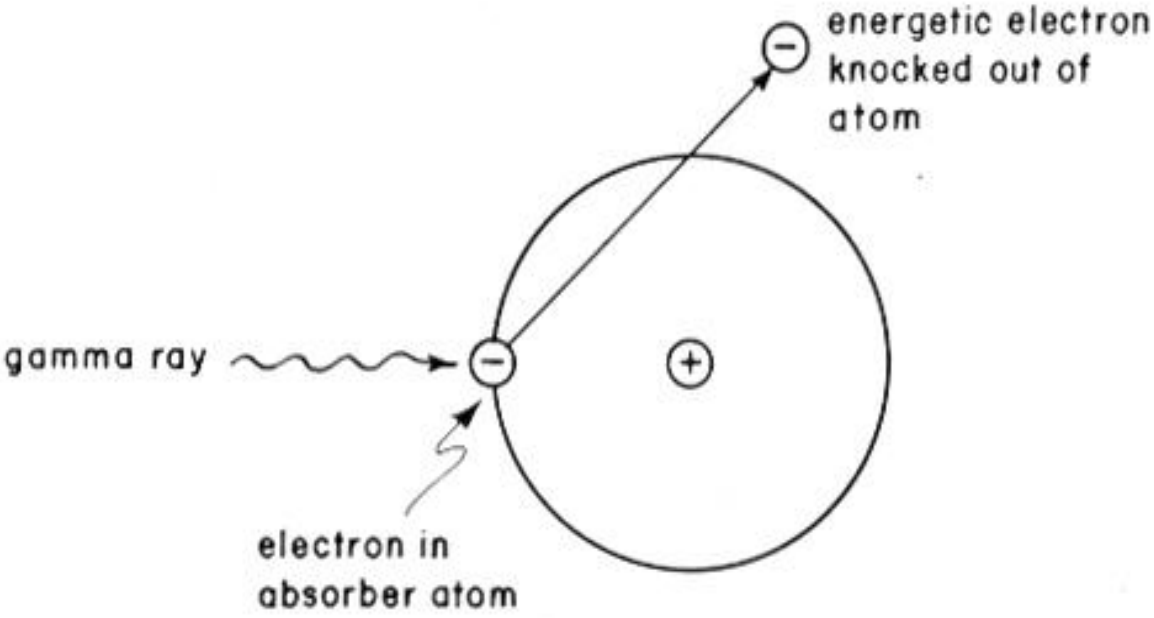


Fig. 1.2. The photoelectric interaction. The γ -ray gives up all its energy to an atomic electron in a single collision. The electron is knocked out of the atom and goes on to produce ionization in nearby atoms or molecules.

The scintillation detector

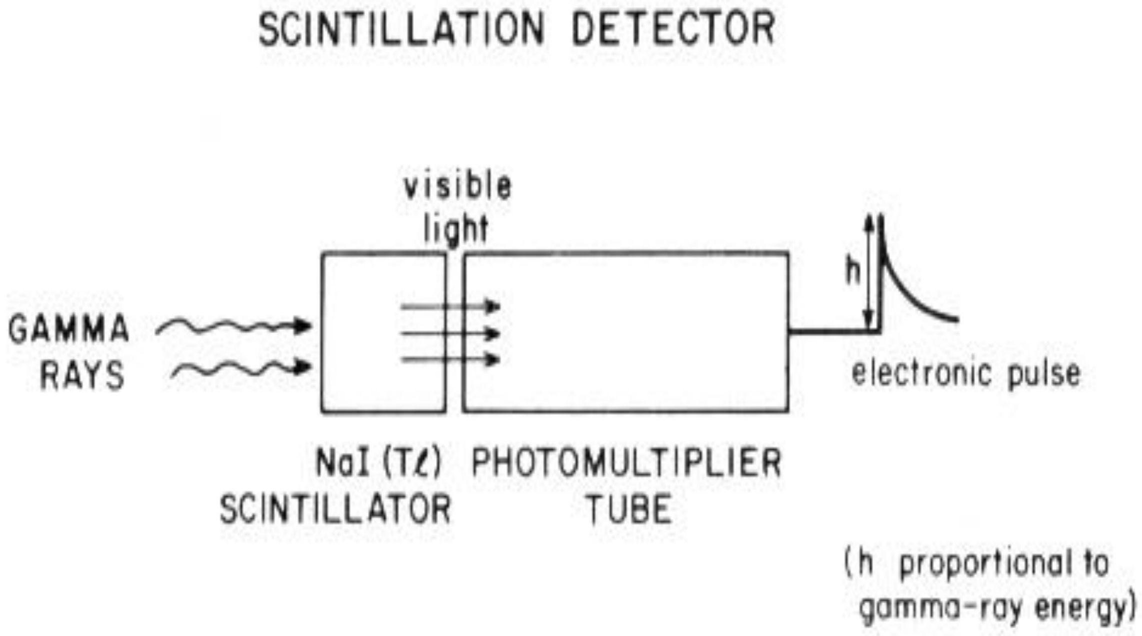


Fig. 1.4. The scintillation detector. Invisible (to the human eye) γ-rays, produce visible light when they strike the scintillator. The light is converted to an electronic pulse in the photomultiplier tube. The height (h) of the pulse is proportional to the γ-ray energy.

The equipments I.

Gamma-camera: the present

- it „sees” the whole entire area below the detector

Shematic figure of the gamma-camera for the detection

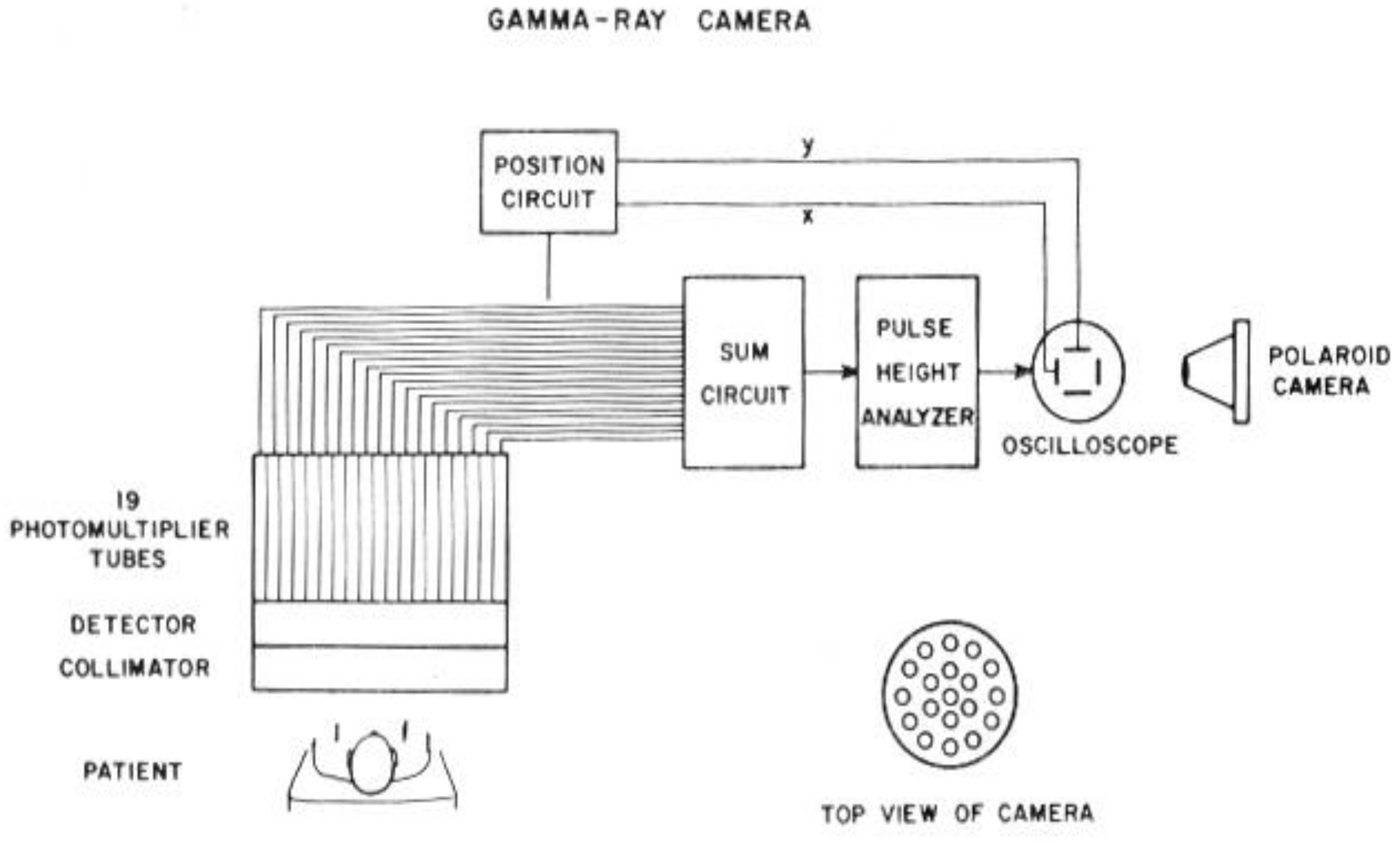


Fig. 1.11. The basic components of an Anger γ-ray camera. There is a one-to-one correspondence between the location of γ-ray interactions in the scintillation crystal and the location of the dot flashed on the oscilloscope screen.

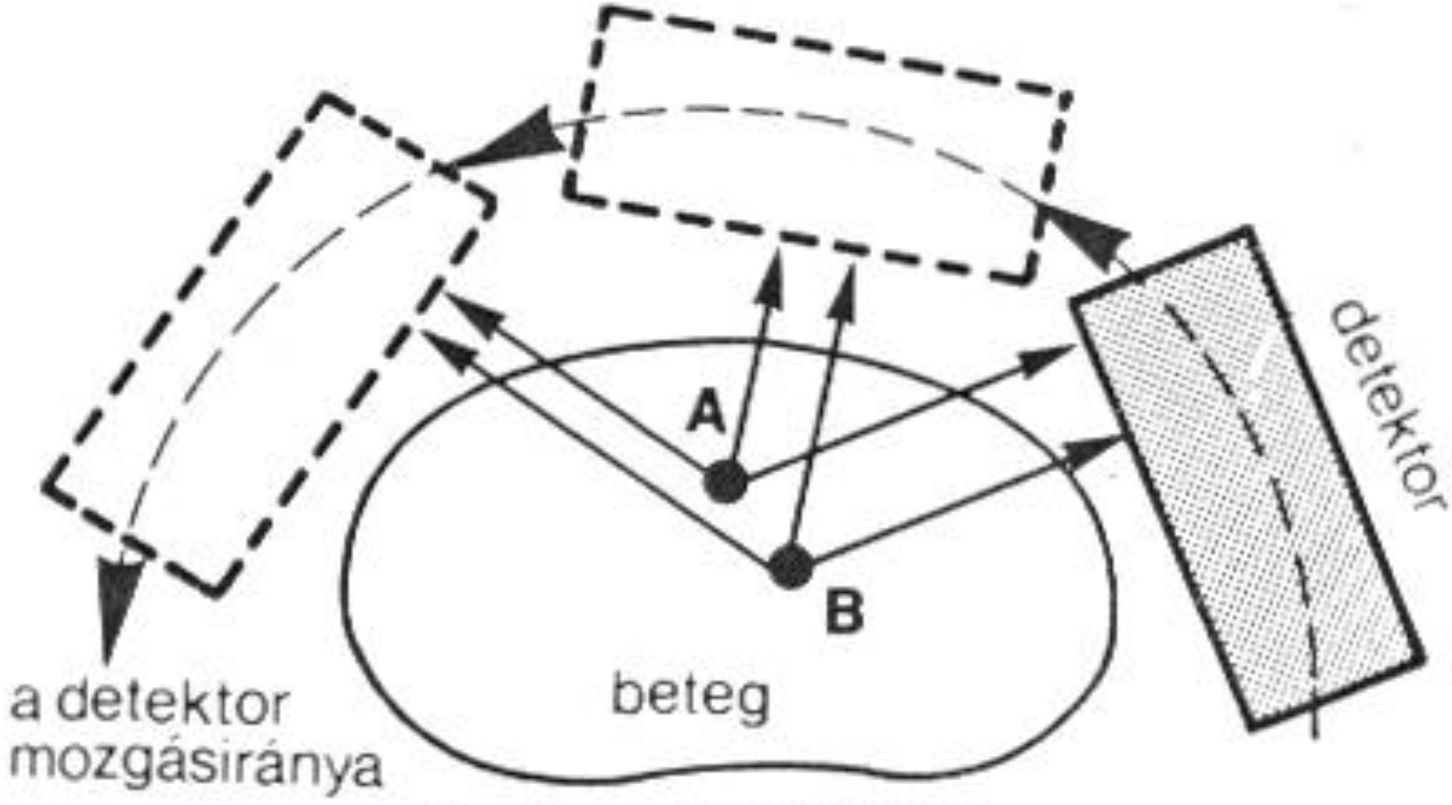
The equipments II.

SPECT
(Single Photon Emission Computer Tomograph)

SPECT/CT
(Multimodality equipment)

- the computer program reconstruates the transversal, sagittal and coronal slices of the organ + fusion imaging

The principle of the SPECT

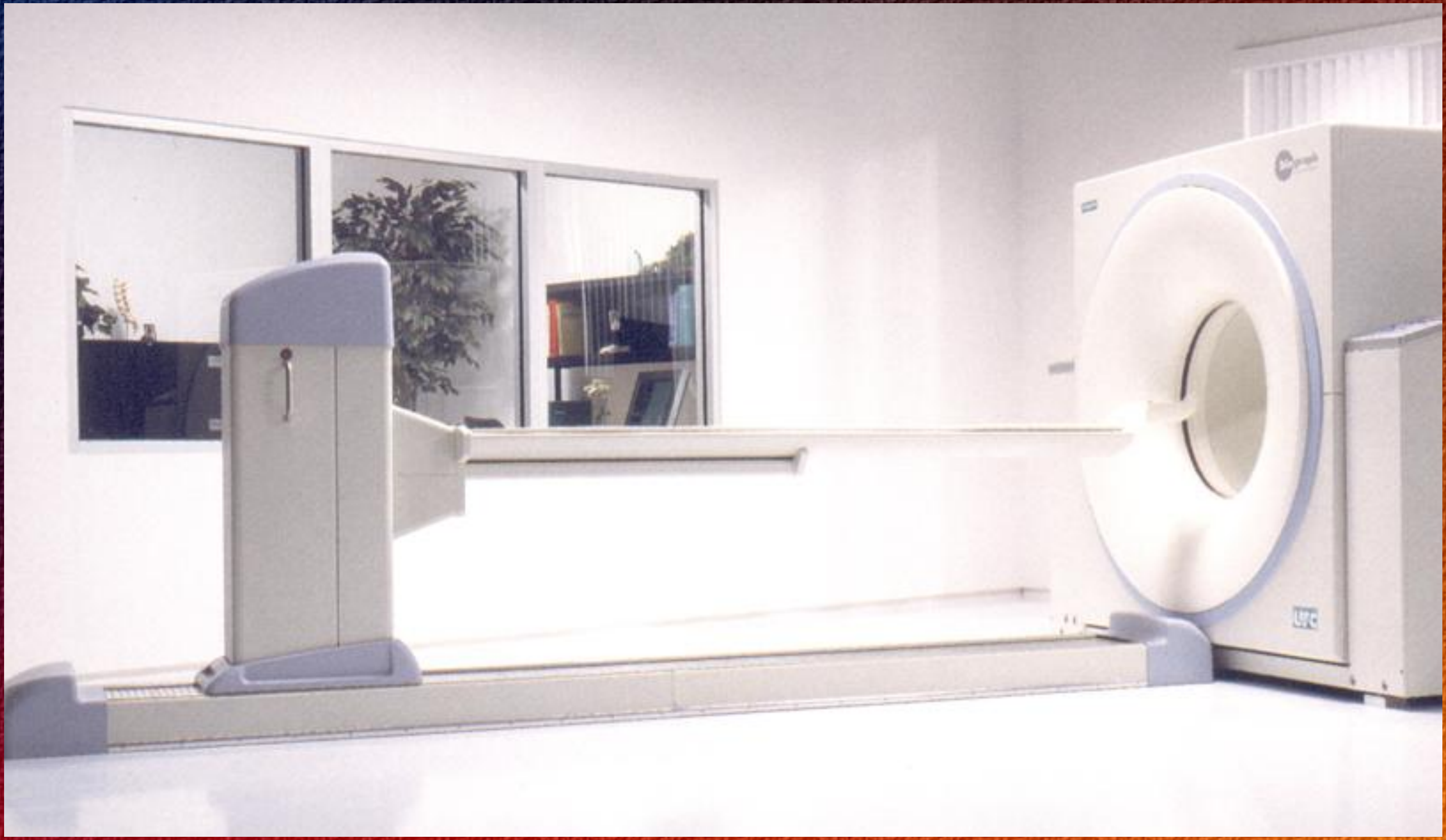


52. ábra. A SPECT elve

A test különböző pontjaiból (A, B) induló γ-fotonokat a testet körüljáró detektor több irányból regisztrálja a rétegkép-rekonstrukció érdekében

Equipments III.

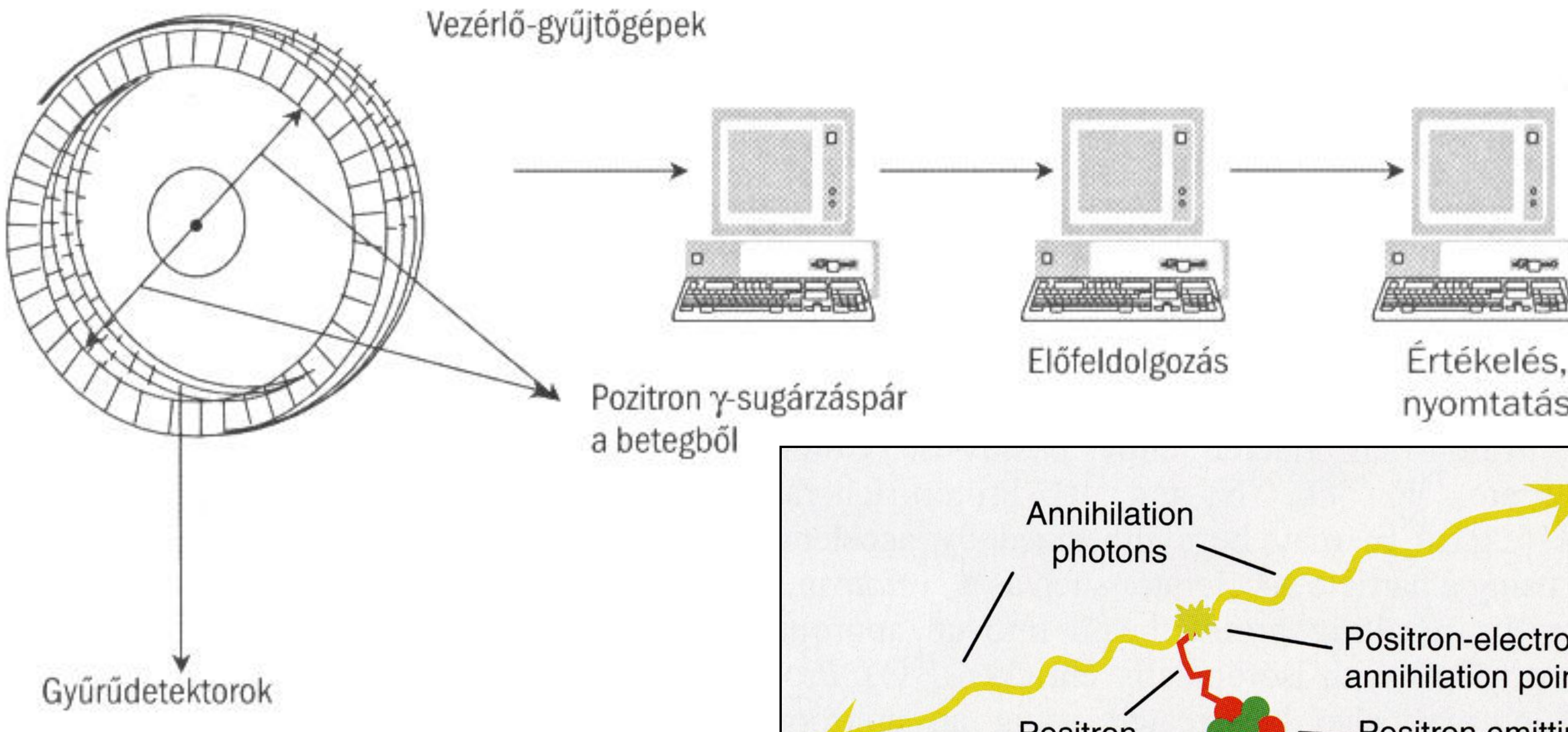
PET (Positron Emission Tomograph): the future

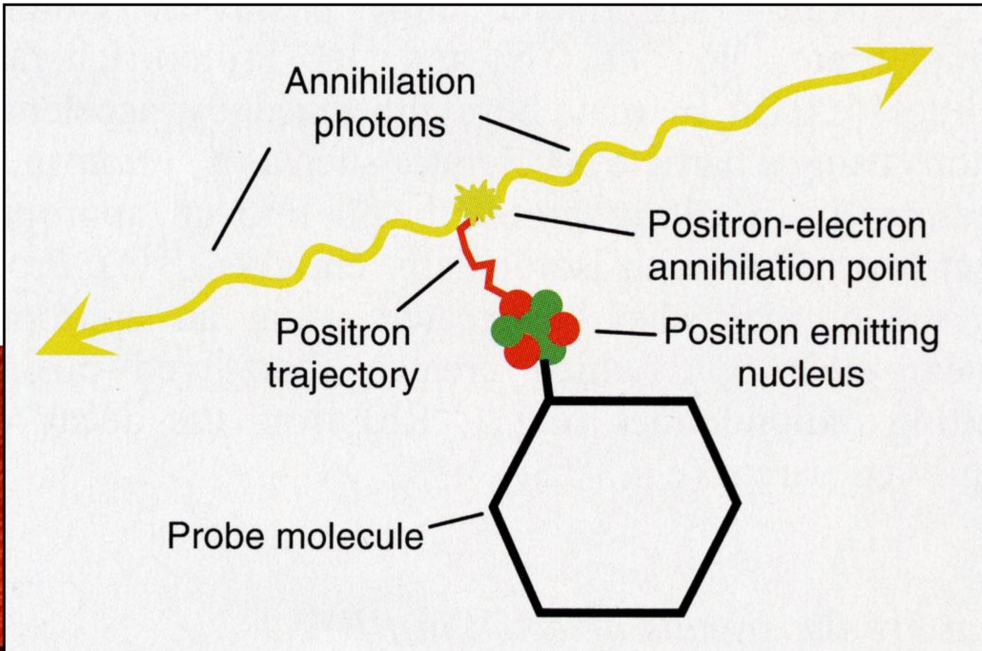


The principle of the PET I.

- the administered isotope is positron emitting
- the annihilation 511 keV gamma-rays are detected
- isotopes with ultrashort half-life (^{11}C, ^{15}O, ^{13}N, ^{18}F)
- the metabolic changes of the heart, the brain and the tumours can be examinated

The principle of the PET II.





Radiation exposure

- principle of ALARA (as low as reasonable achieveble) both the patients and the staff
- correct indication of the examination!
- examination of pregnant women is contraindicated
- children should be examined carefully

In vivo radionuclide studies

- are based on the function of an organ or an organ system
- are easily performed
- need no premedication
- are not association with any morbidity and complication, have only minimal risk
- are very sensitive, but aspecific methods
- are very good for screening studies

Static examinations (scintigraphy):

- an optimal time-period after the subject administration is delayed and several photos are made of the organ from different directions

Dynamic studies:

- a frame-serie is stored in the computer from the time of the isotope injection during an optimal time-period of the examined organ function

Static studies

- **Negative scintigraphy:**
  pathological decreased activity or lack of the activity (focal defect)

- **Positive scintigraphy:**
  pathological increased activity (hot spot)