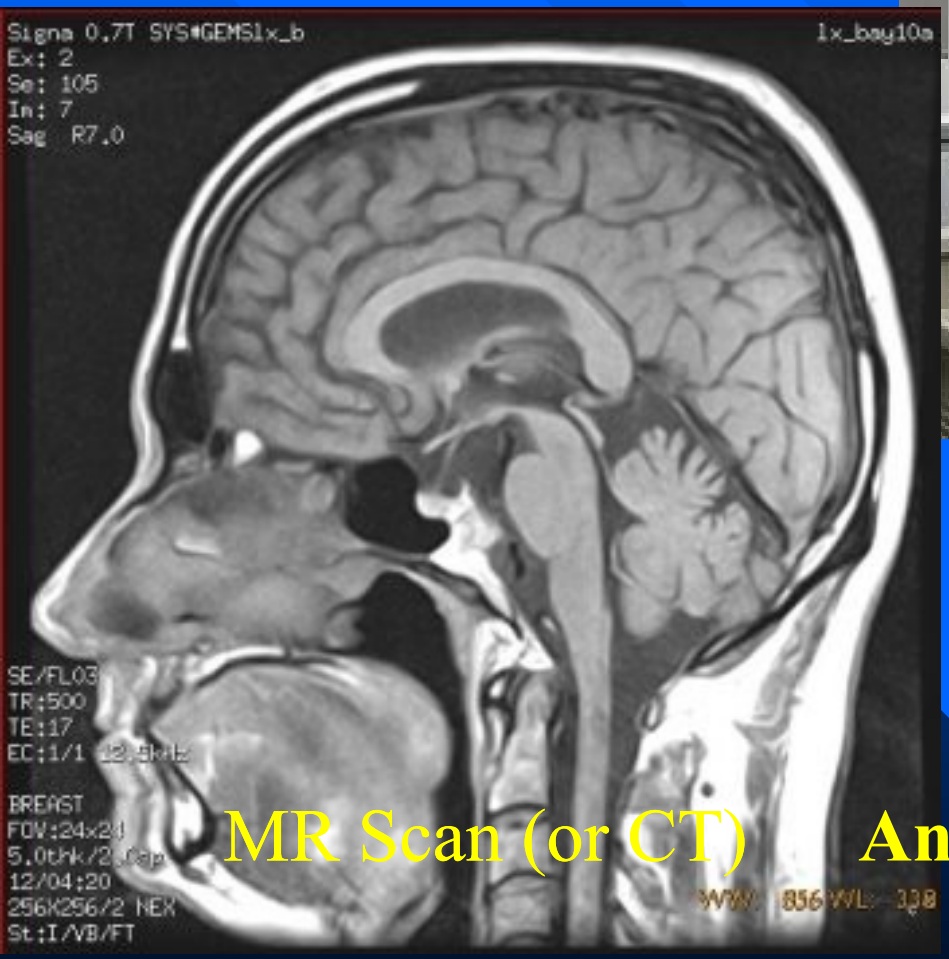
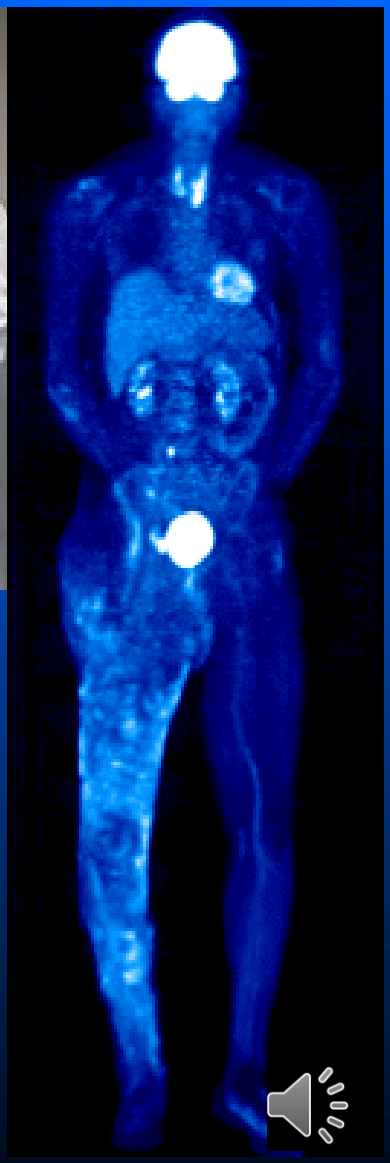
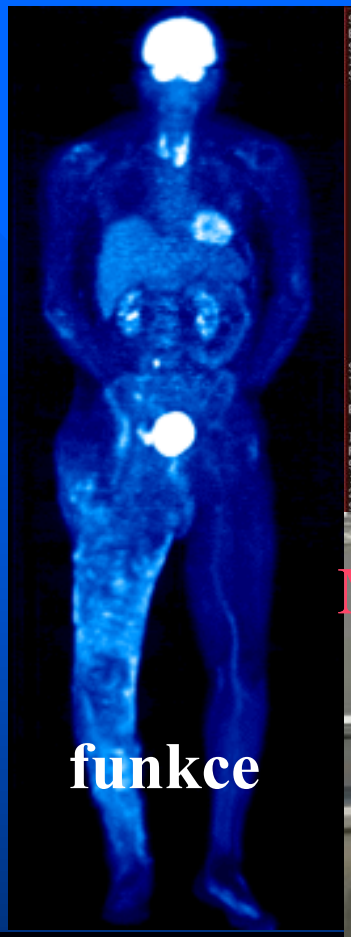
Positron Emission Tomography



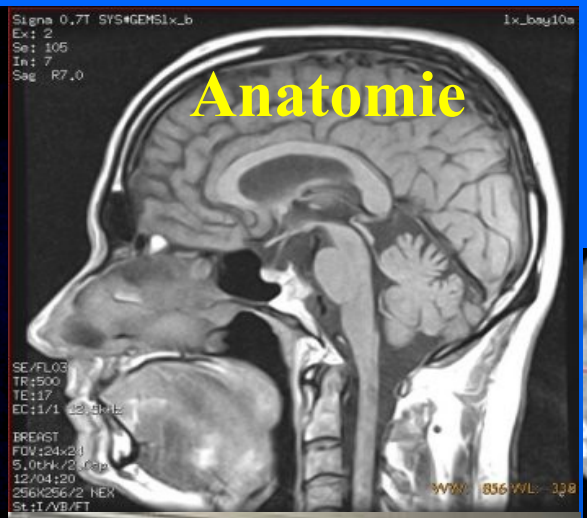
MR Scan (or CT)

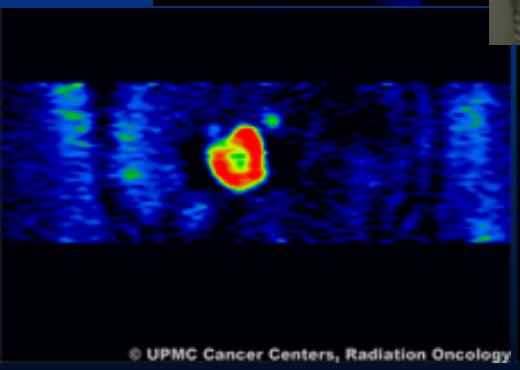
Anatomický obraz

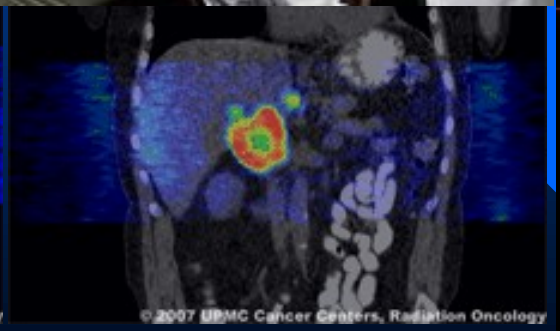




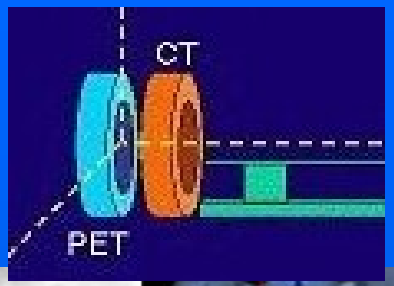
funkce

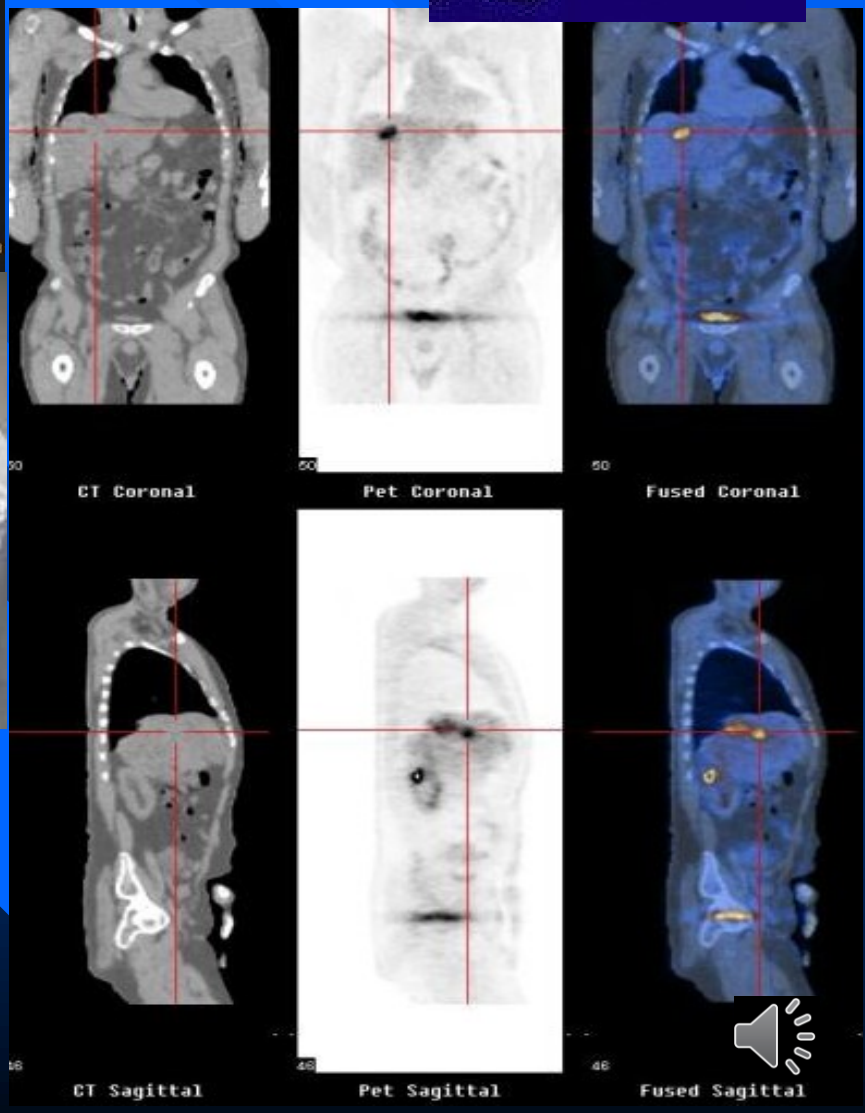






PET/CT





Funkční obrazení

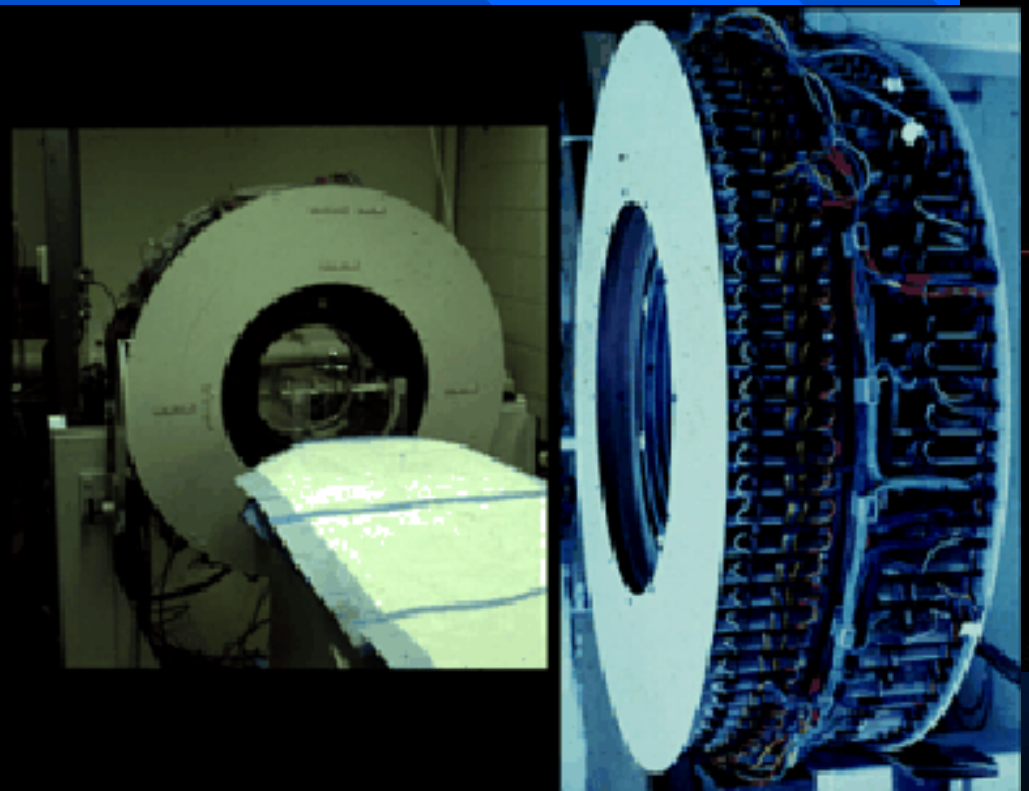
Glucose + Isotope (e+)

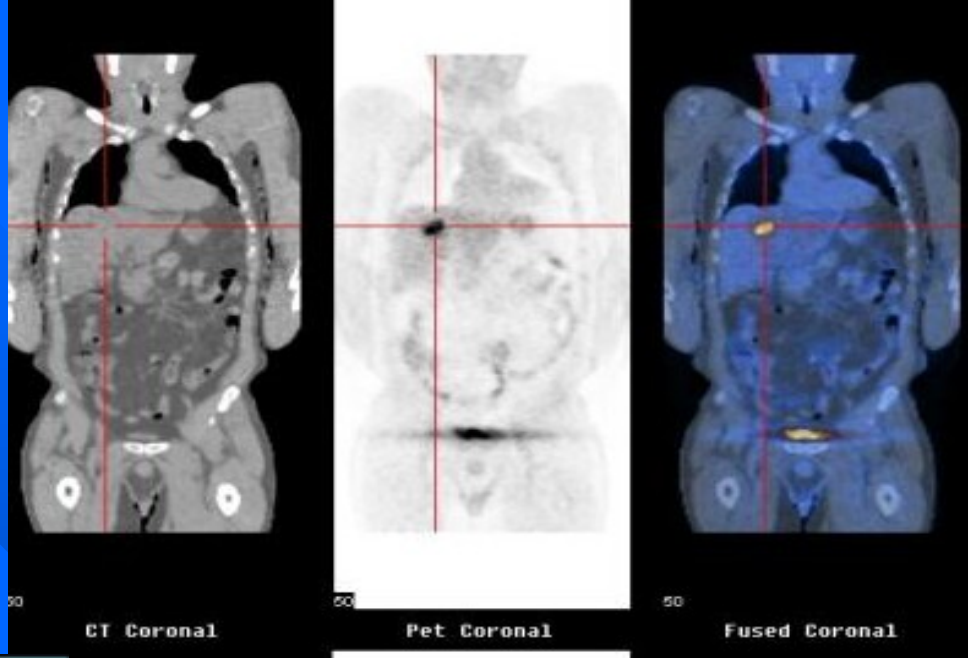
↓

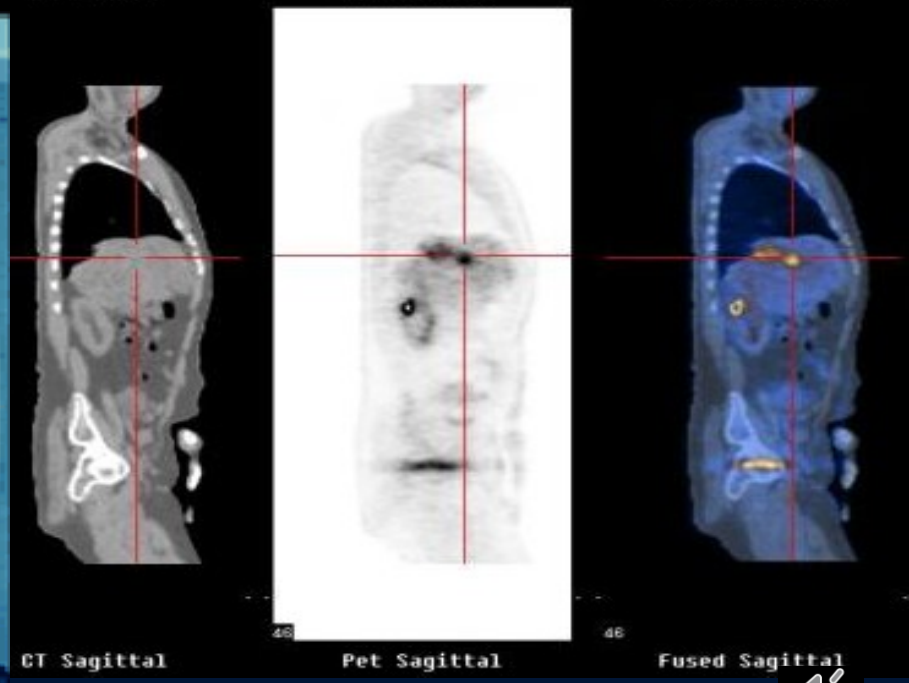
Injection(~2-5mCi)

↓

Scan (15-30 minutes)



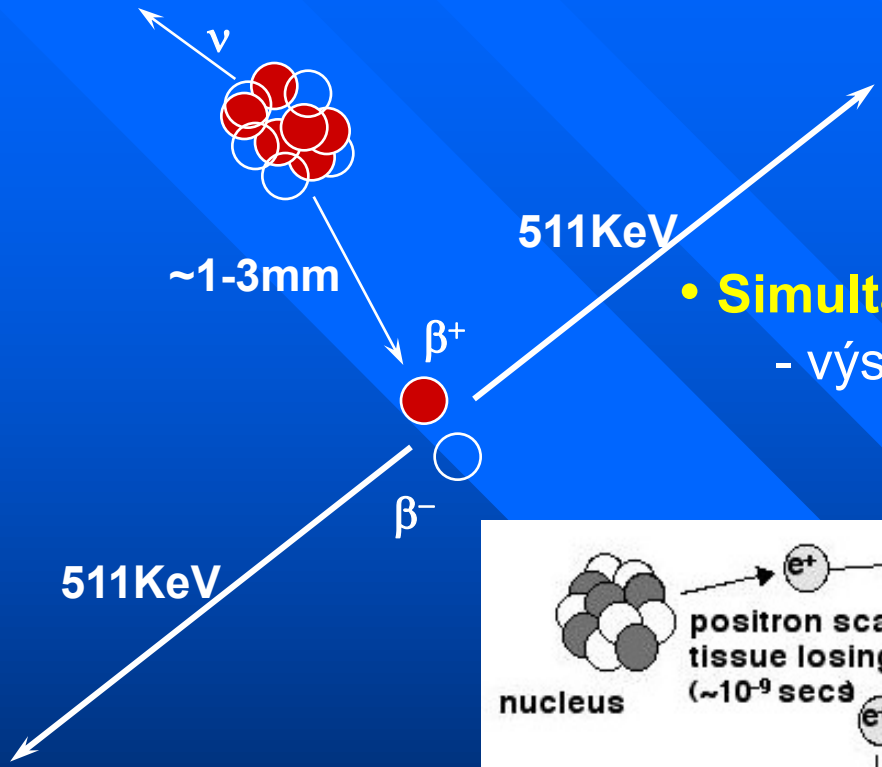




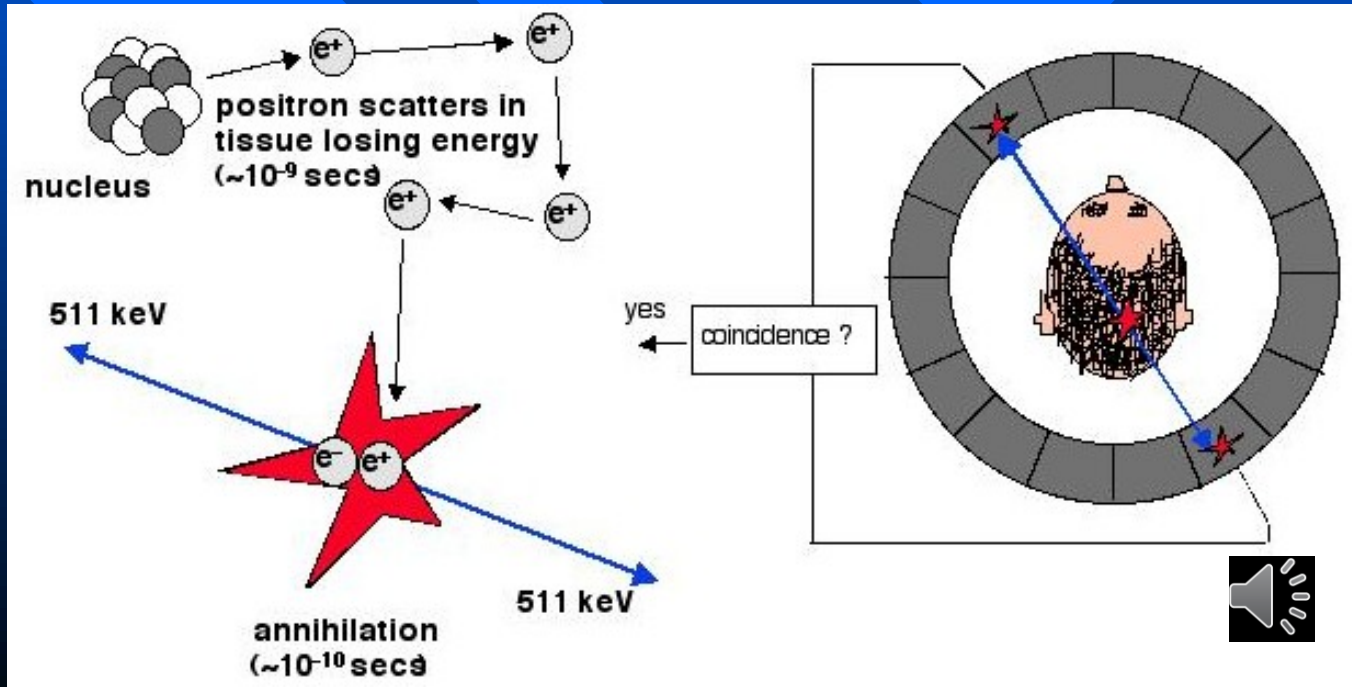
Co je PET?

- Isotope production → **CYCLOTRONS**
- Tracer production → **CHEMISTRY SYSTEMS**
- Imaging → **SCANNER**

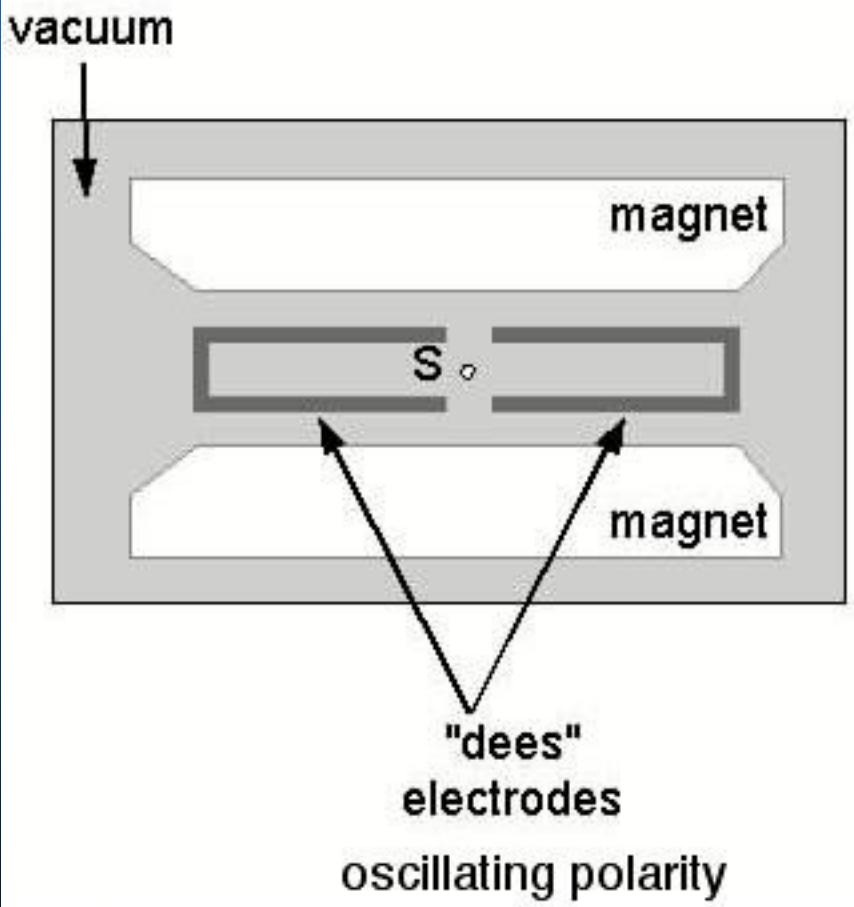
Fyzikální princip

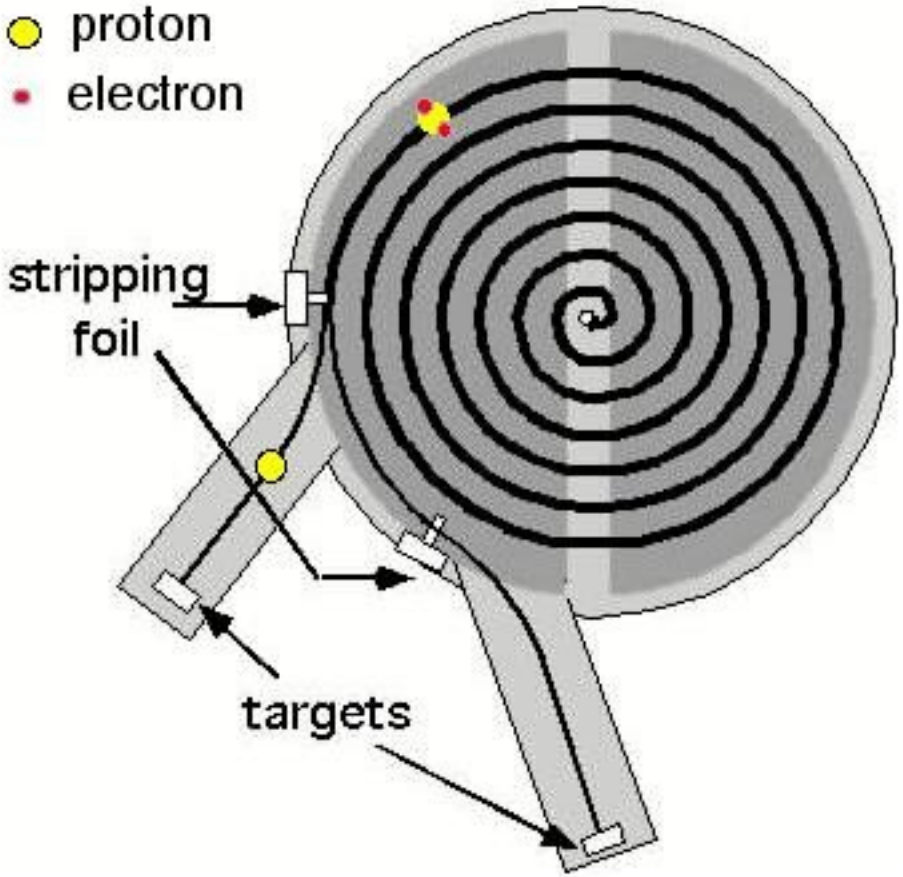


- Pozitronová dráha 1-3 mm před annihilací (závisí na energii)
- Zachování energie a momentu
  - 511 keV fotony a
- **Simultánní detekce dvou 511KeV fotonů** →
  - výsledek je přímka a současný přichod



Biomedical Cyclotron
Negative Ion





PET-labeled Probes for Biological Imaging

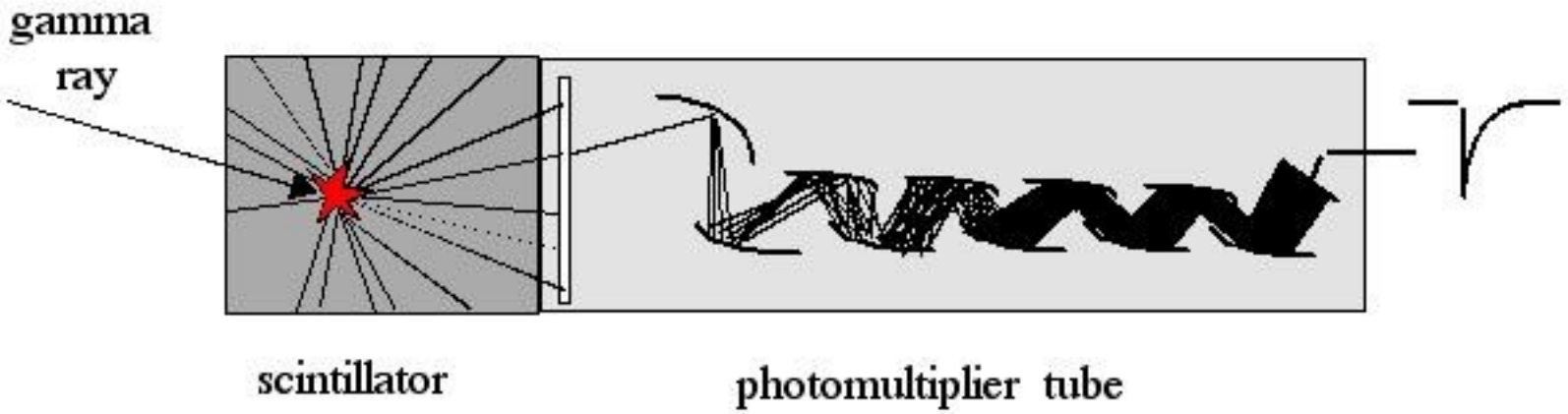
- hemodynamic parameters ($H_2{}^{15}O$, ^{15}O-butanol, ^{11}CO, $^{13}NH_3$.....)
- substrate metabolism(^{18}F-FDG, $^{15}O_2$, ^{11}C-palmitic acid....)
- protein synthesis (^{11}C-leucine, ^{11}C-methionine, ^{11}C-tyrosine)
- enzyme activity (^{11}C-deprenyl, ^{18}F-deoxyuracil...)
- drugs (^{11}C-cocaine, ^{13}N-cisplatin, ^{18}F-fluorouracil...)
- receptor affinity (^{11}C-raclopride, ^{11}C-carfentanil, ^{11}C-scopalamine)

cyclotron
^{11}C, ^{13}N, ^{15}O, ^{18}F

Positron Emitting Radionuclides

Isotope	Halflife	β^+ fraction	Max. Energy	range(mm)
C–11	**20.4 mins**	**0.99**	**0.96 MeV**	**0.4 mm**
N–13	**9.96 mins**	**1.00**	**1.20 MeV**	**0.7 mm**
O–15	**123 secs**	**1.00**	**1.74 MeV**	**1.1 mm**
F–18	**110 mins**	**0.97**	**0.63 MeV**	**0.3 mm**
Na–22	2.6 years	0.90	0.55 MeV	0.3 mm
Cu–62	9.74 mins	0.98	2.93 MeV	2.7 mm
Ga–68	68.3 mins	0.88	1.90 MeV	1.2 mm

The Scintillation Detector



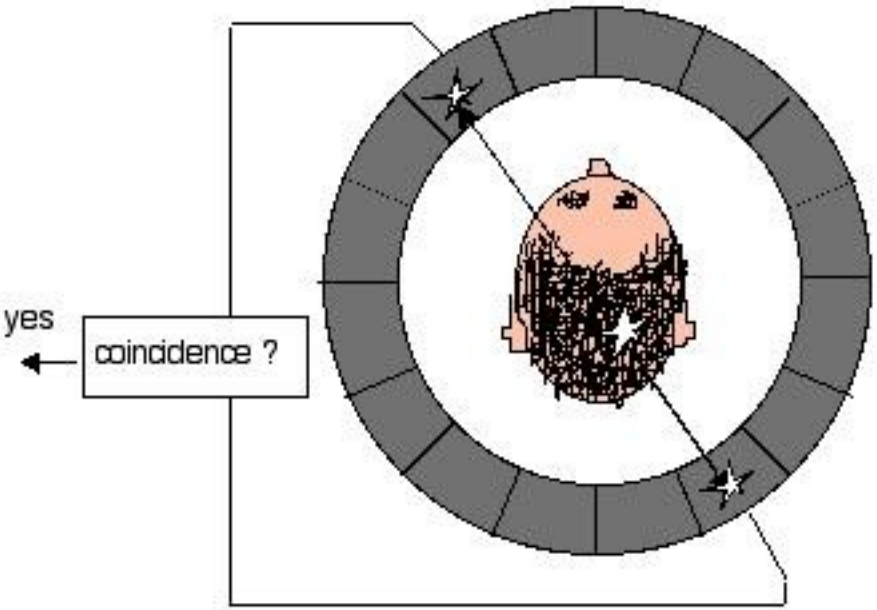
When a gamma ray interacts in a **scintillator**, it produces a flash of visible light. The scintillator thus acts as a converter from high energy to low energy radiation. The **photodetector** converts the visible light into an electrical signal. A photomultiplier tube (PMT) is commonly used as the photodetector. The scintillation detector converts high energy gamma rays into an electrical signal which can be fed into electronics for further processing.

The PET Scanner

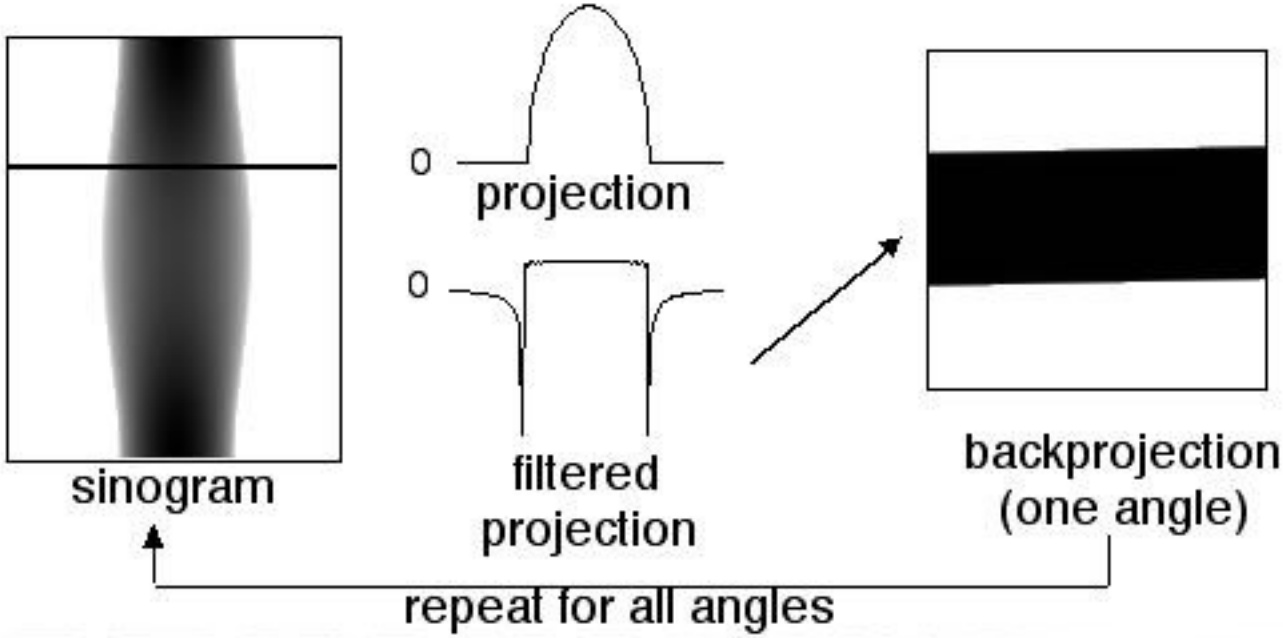
Consists of one or more rings of scintillation detectors.

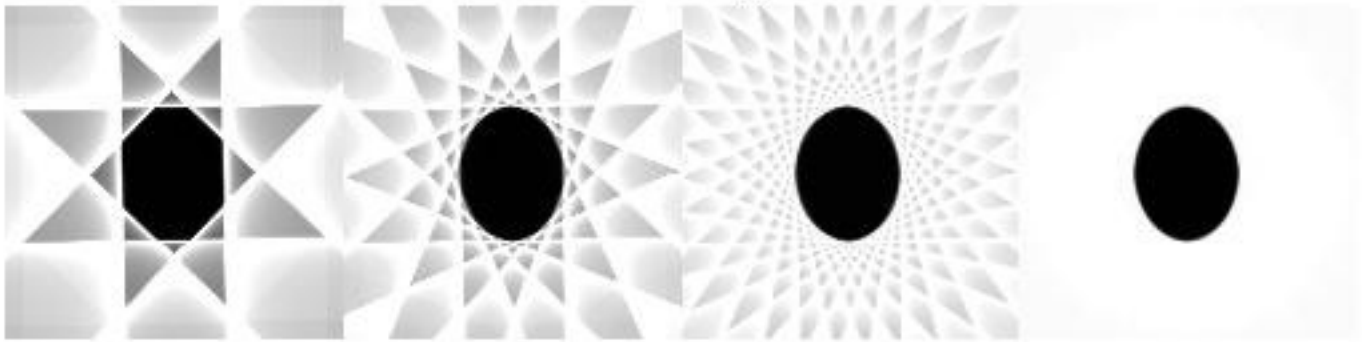
A valid event occurs when a pair of detectors register an event simultaneously

The raw data for a single ring is stored in a 2-D matrix called a sinogram



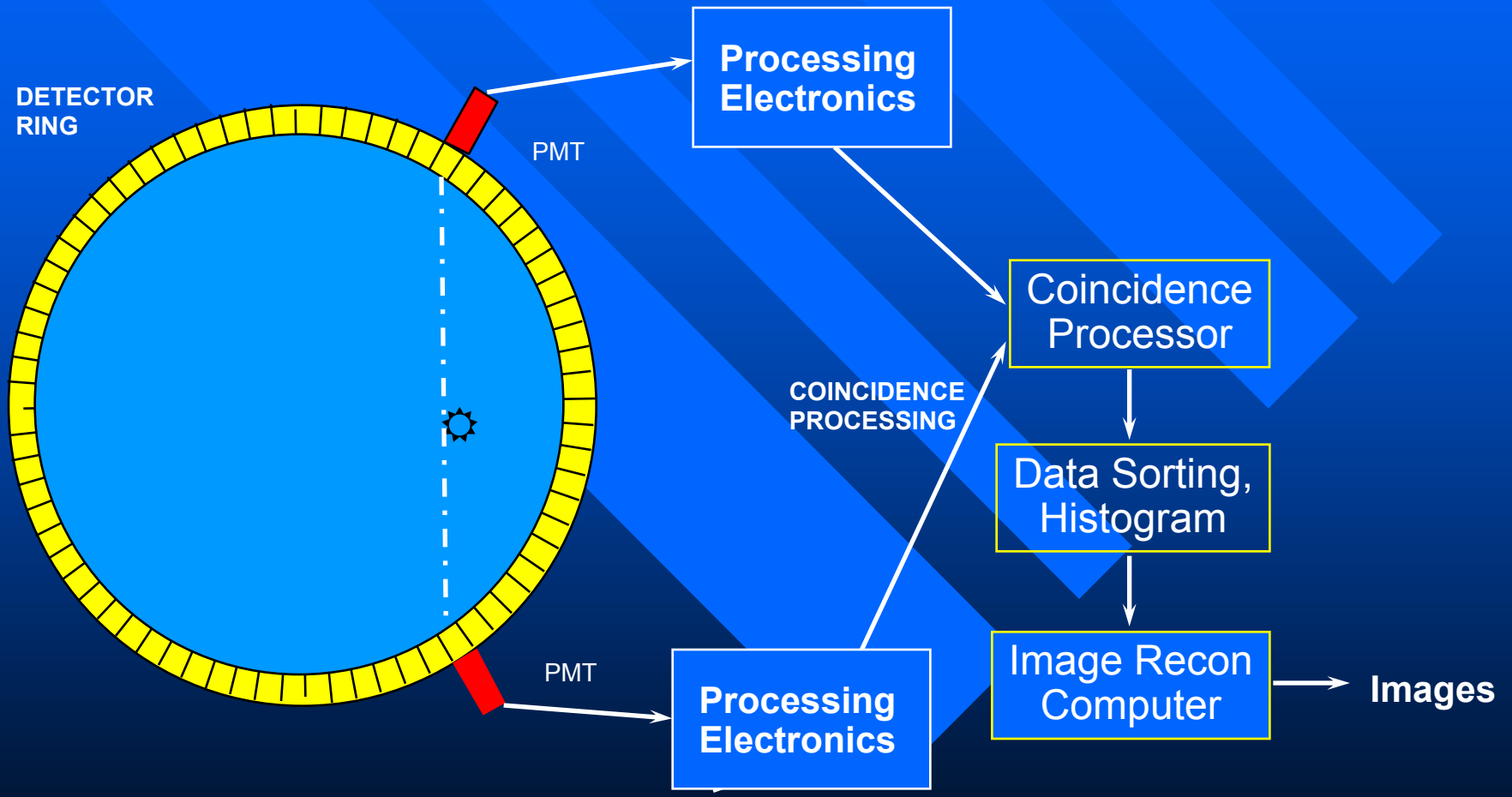
Filtered Backprojection

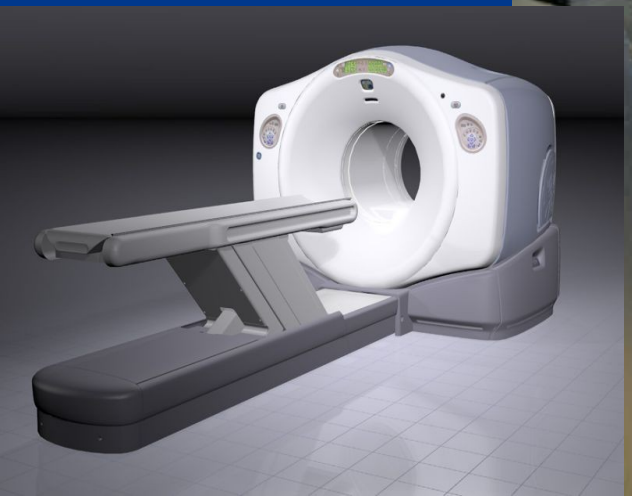




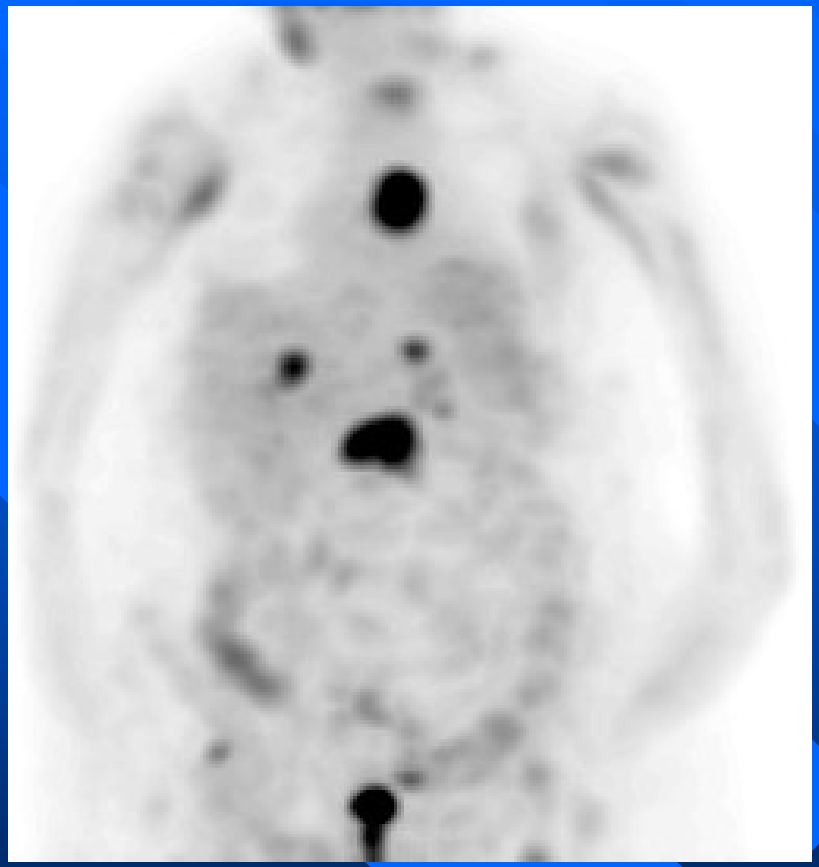
4 angles 8 angles 16 angles 160 angles

Projection Data Collection





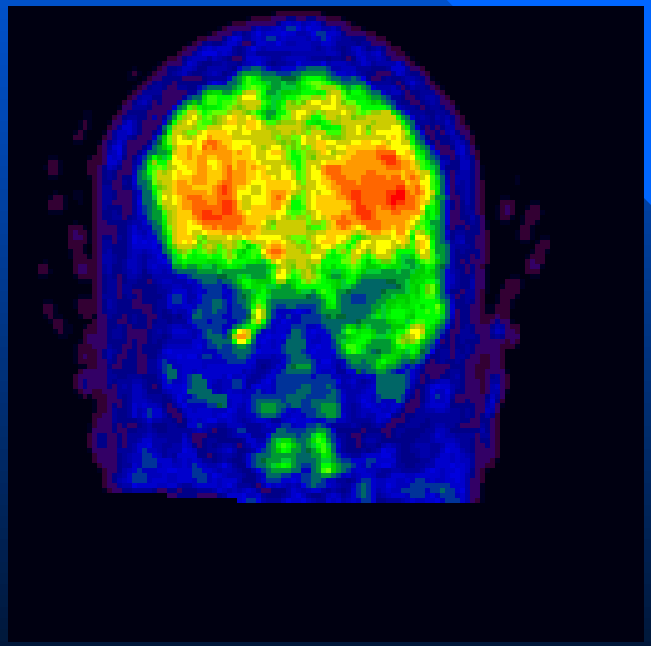
PET Image

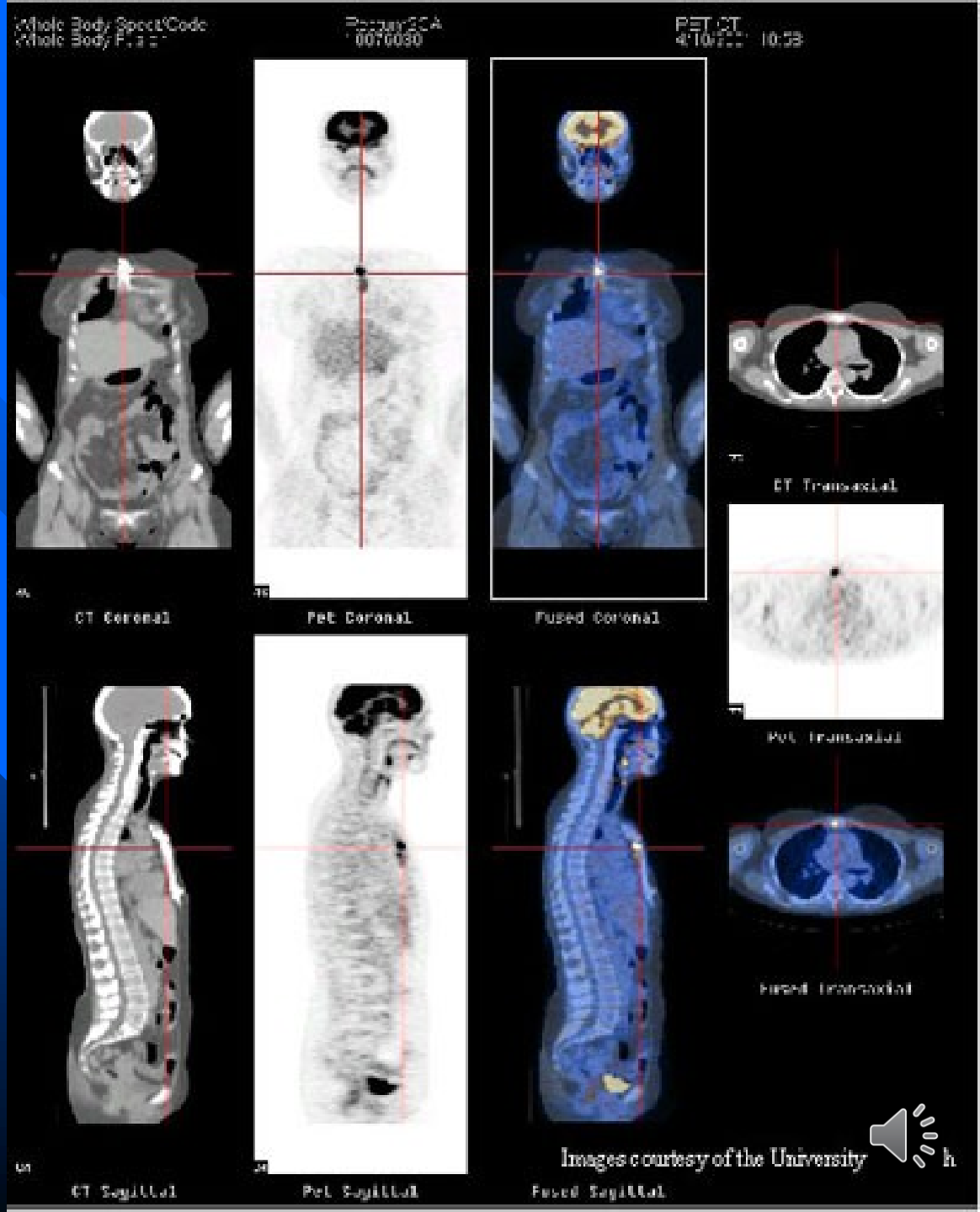


My Objective ➔ New and better detector design using GEANT4
➔ Better information to Physicians
➔ Better patient care and treatment

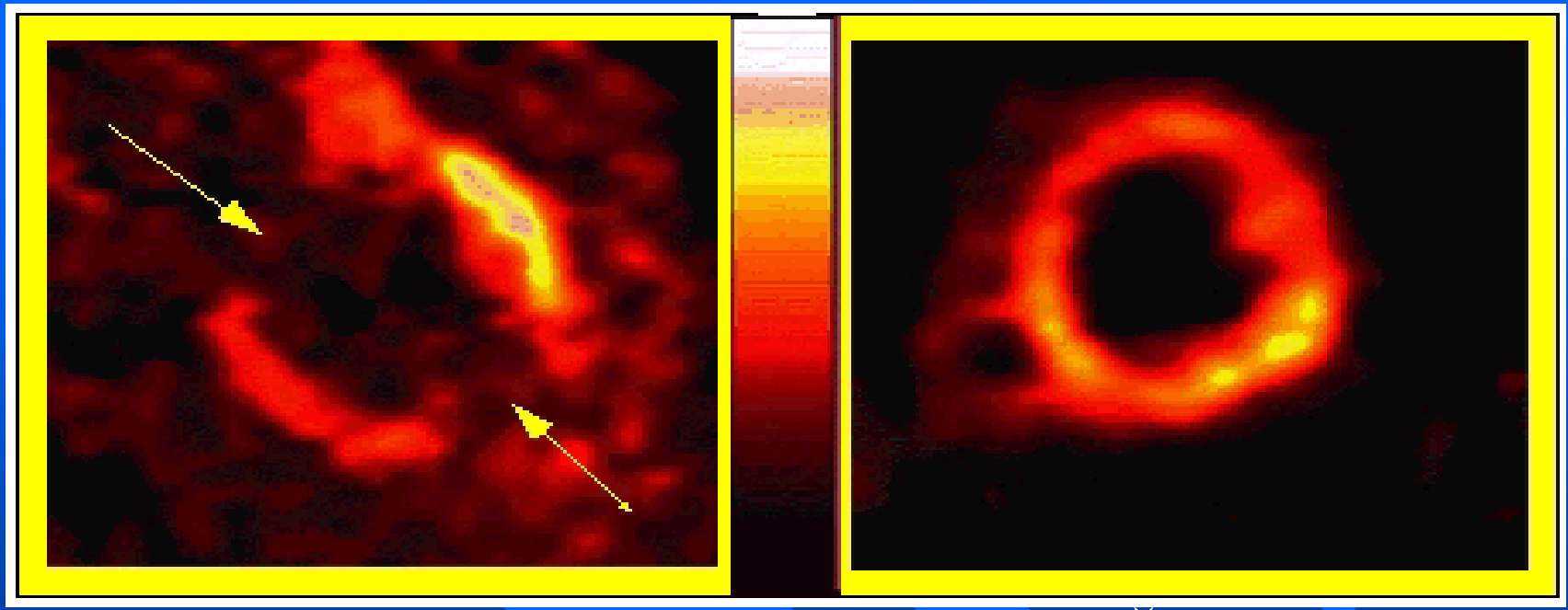
PET-CT

PET-CT fusion localizes Intra-pulmonary lesion



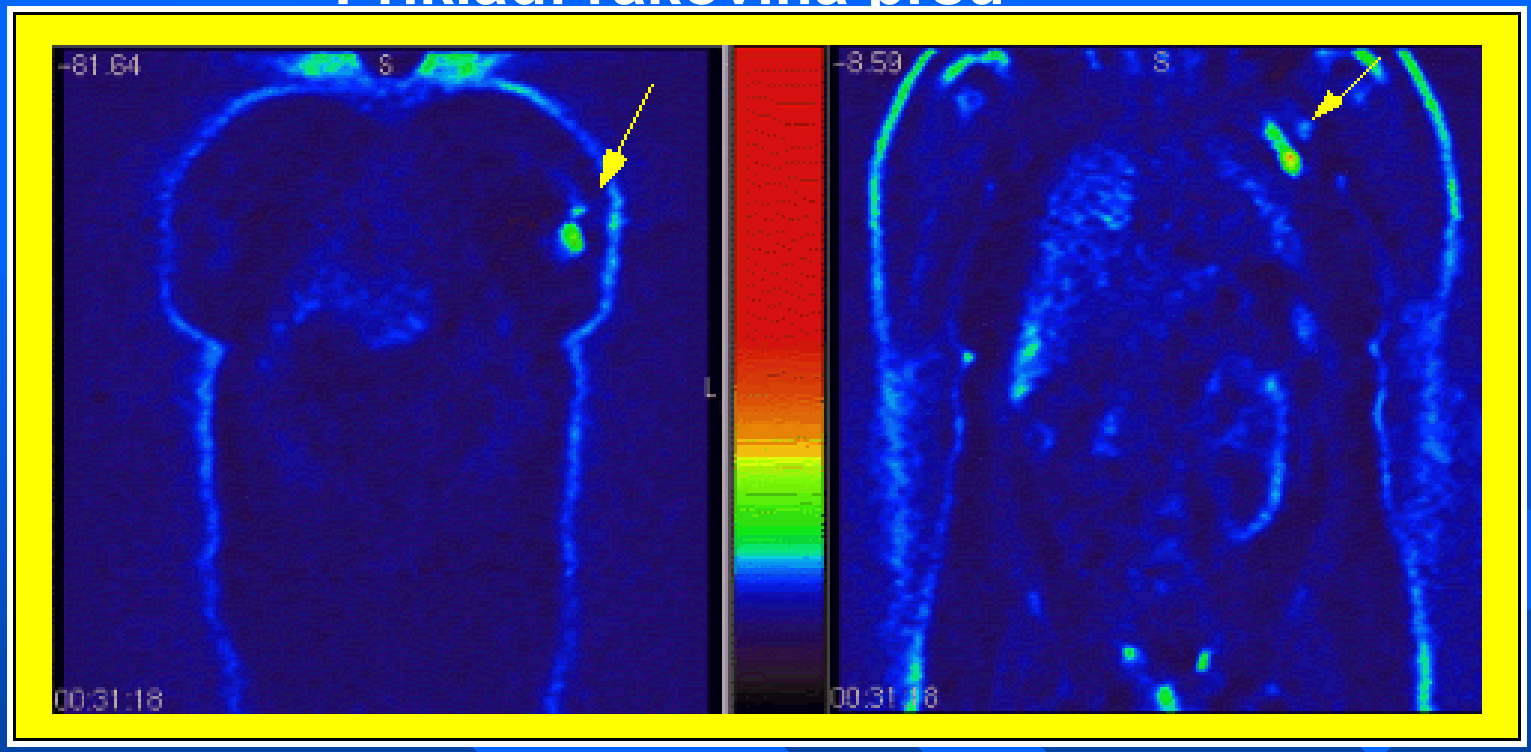


Příklad : Myokardiální nekrózy



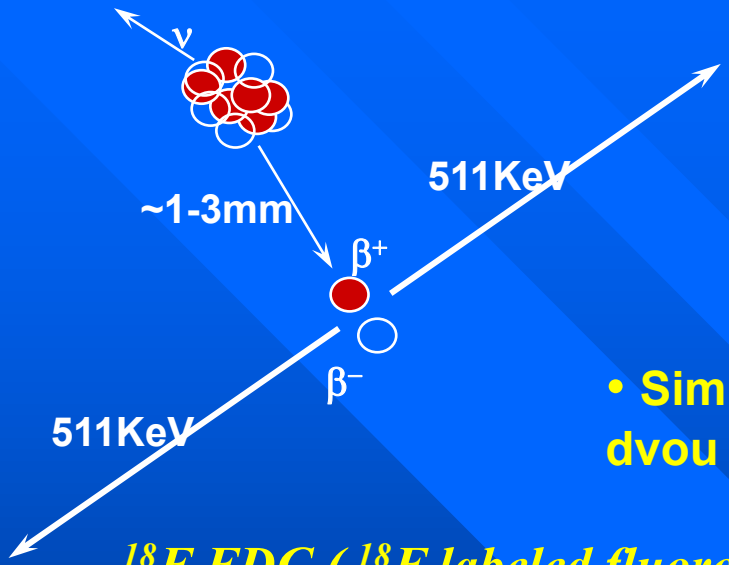
- První srdce má mykardální infarkt. Šipky ukazují poškozené oblasti (‘smrt tkáně).
- Druhé srdce je normální

Příklad: rakovina prsu

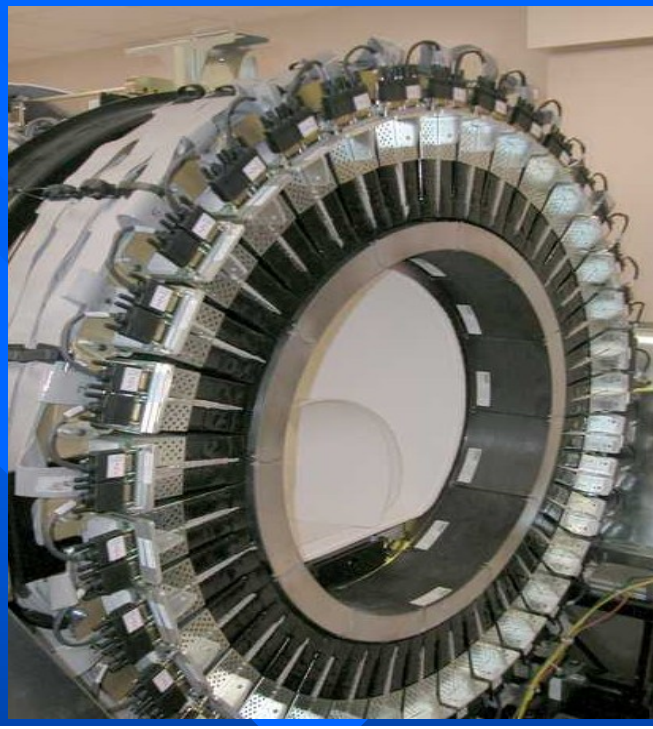


- První obraz ukazuje maligní nádor, který nebyl diagnostikován běžnými zobrazovacími technikami. (CT, MRI, mammogram)
- Druhý obraz již bohužel meta postižení.

Fyzikální princip

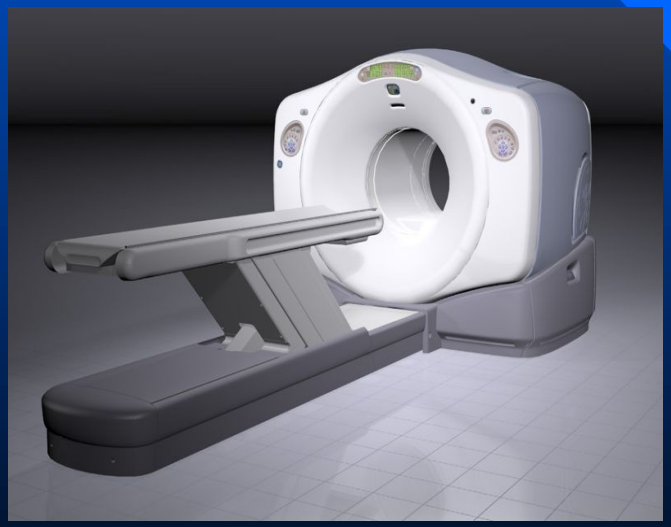


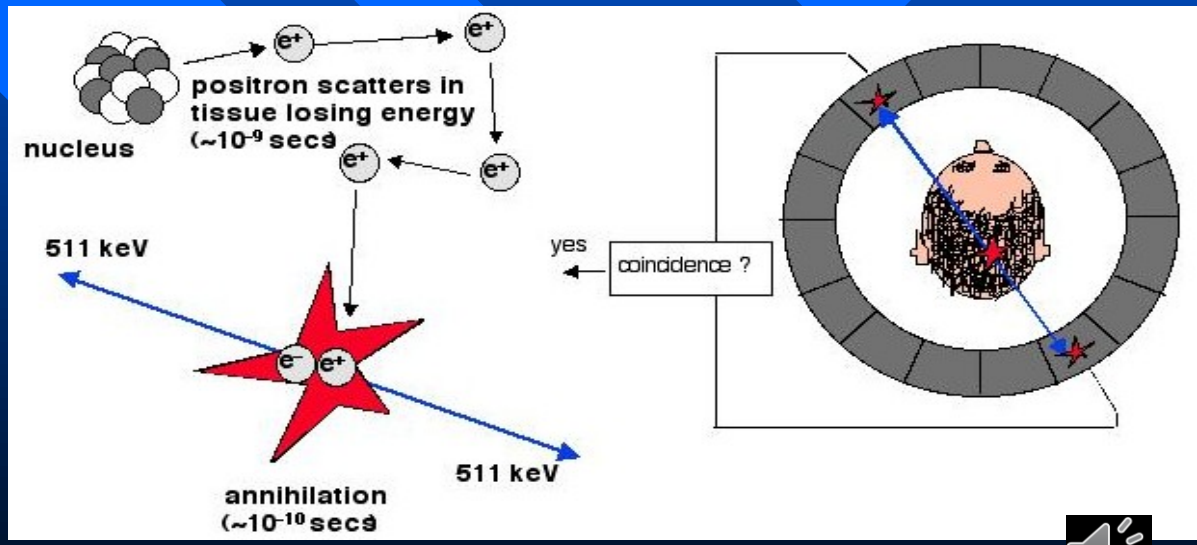
PET/CT

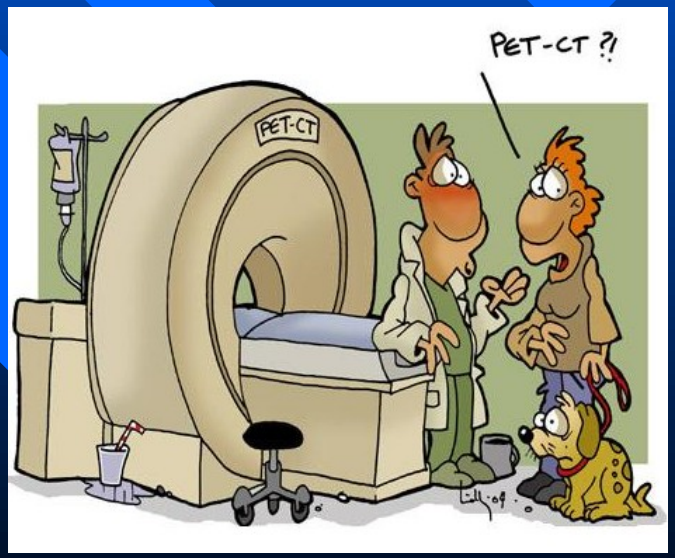


- **Simultánní detekce dvou 511KeV fotonů →**

^{18}F FDG (^{18}F labeled fluorodeoxyglukoza)

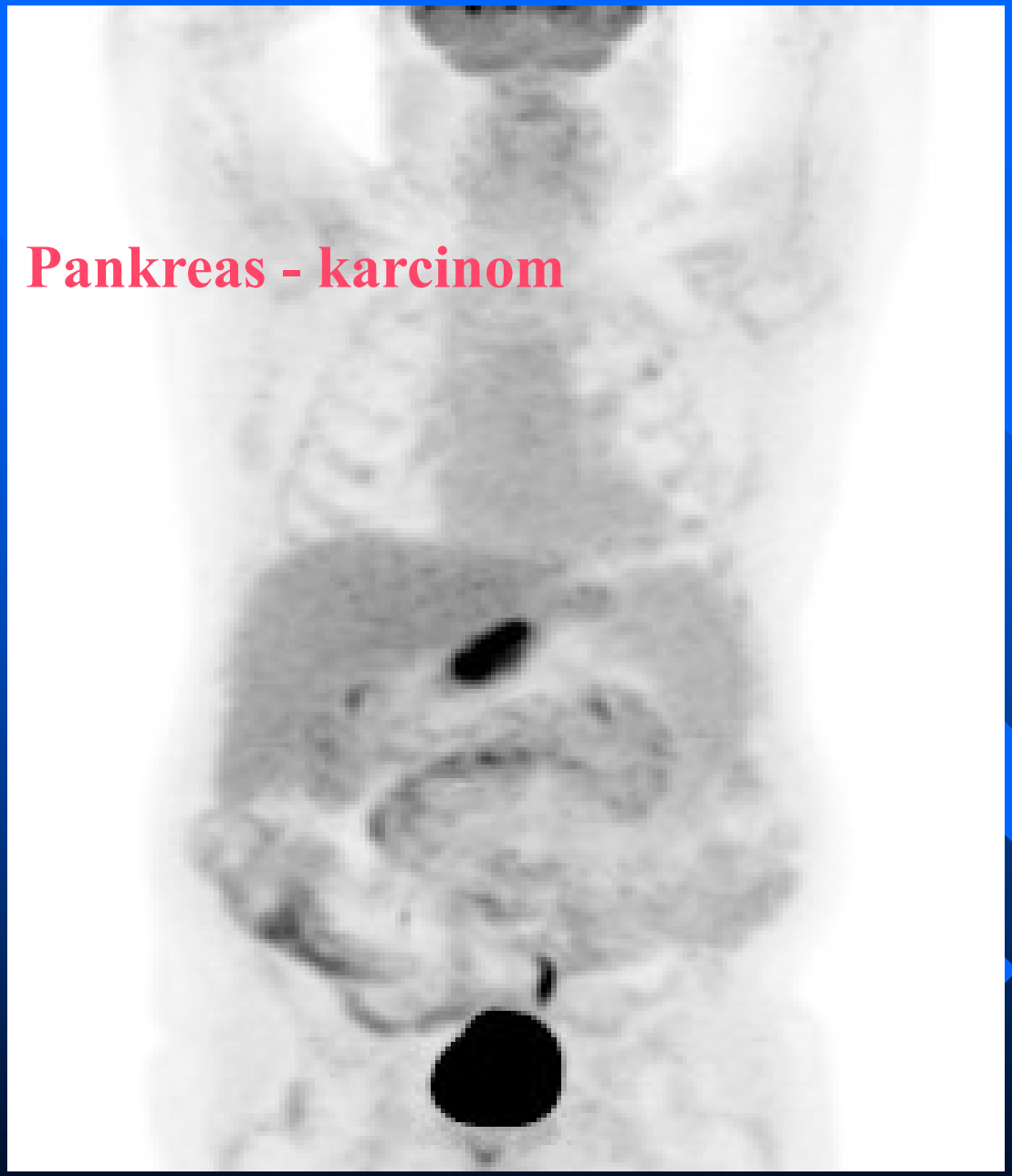


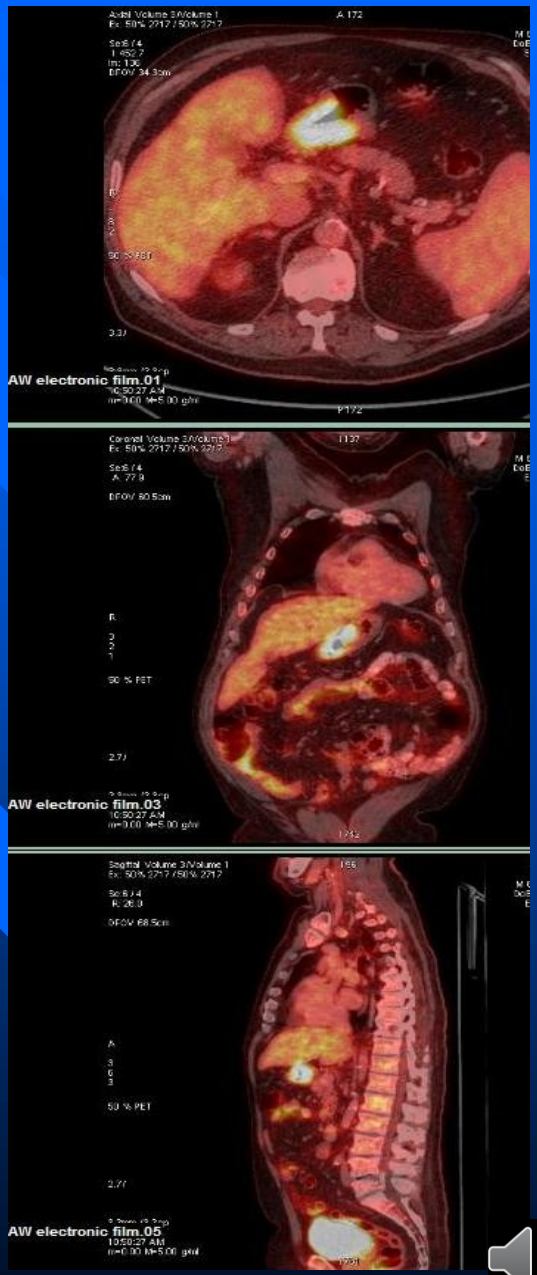



PET-CT ?!
PET-CT

Žaludek karcinom

Pankreas - karcinom





Activity

$$A = \Delta N/\Delta t \ [s^{-1}]$$

A - activity

ΔN - mean number of radioactive decays

Δt - time interval

1 s^{-1} = 1 Bq (Becquerel)

1 Ci (Curie) = 3.7 x 10^{10} Bq

Dose

$$D = \Delta\varepsilon/\Delta m \ [J.kg^{-1}]$$

D - dose

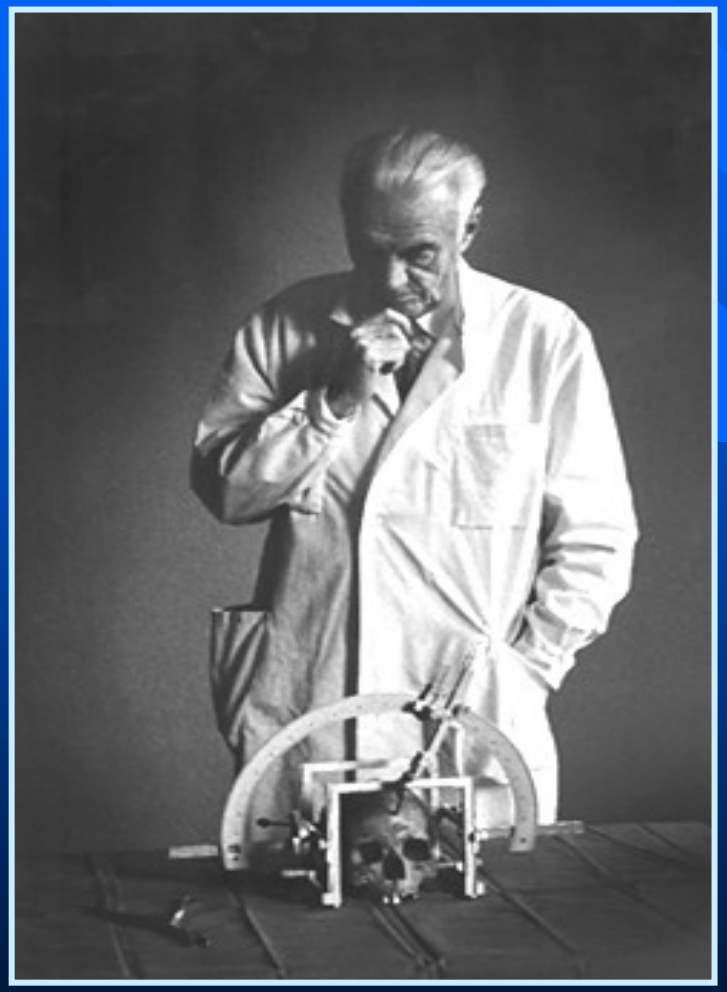
$\Delta\varepsilon$ - mean energy deposited by ionizing radiation to given material

Δm - mass of material

1 $J.kg^{-1}$ = 1 Gy (Gray)

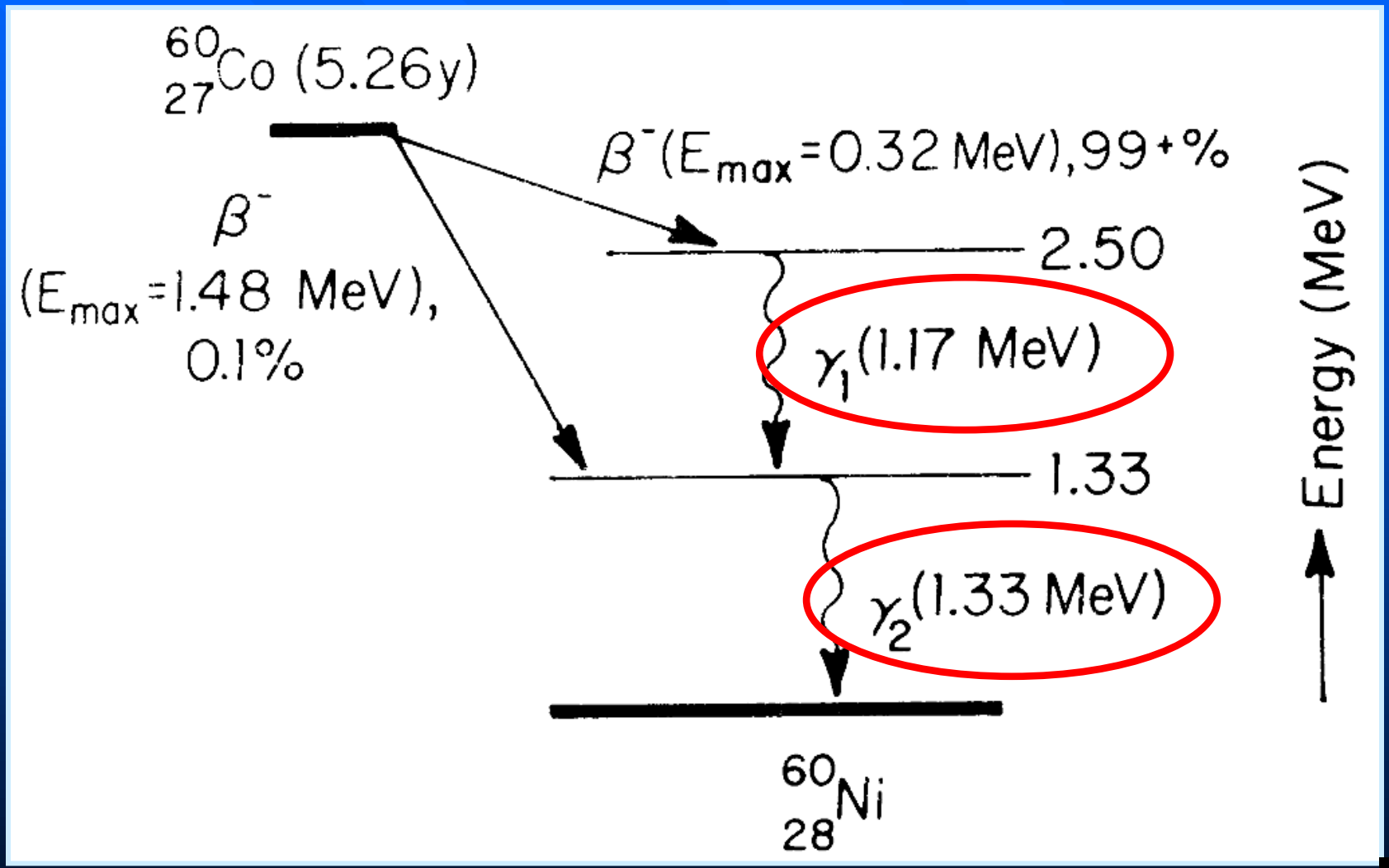
1 rad = 0.01 Gy

Basic principles of radiosurgery

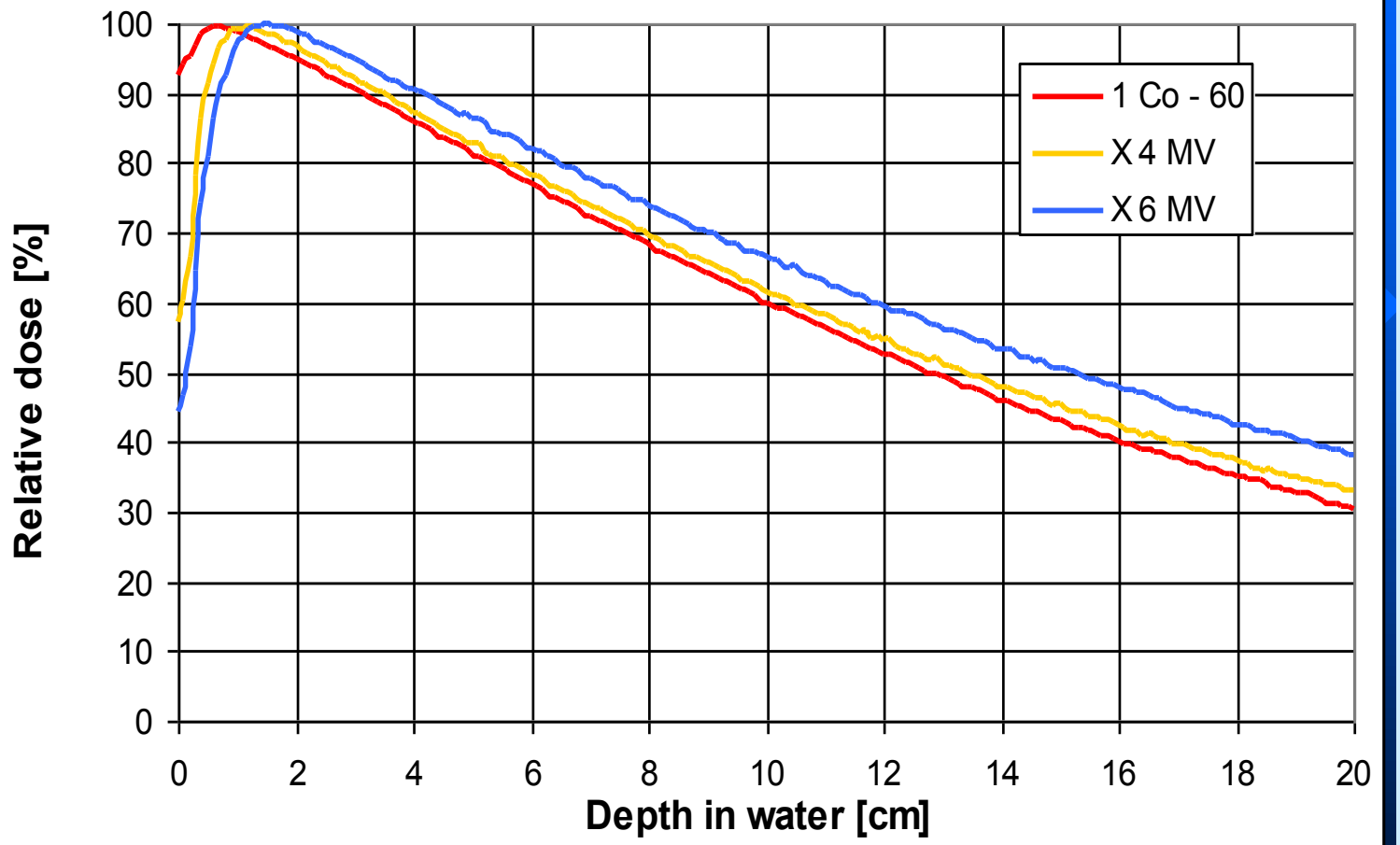


The first prototype of the Leksell Gamma Knife was installed in 1968 at Sophiahemmet in Stockholm, Sweden.

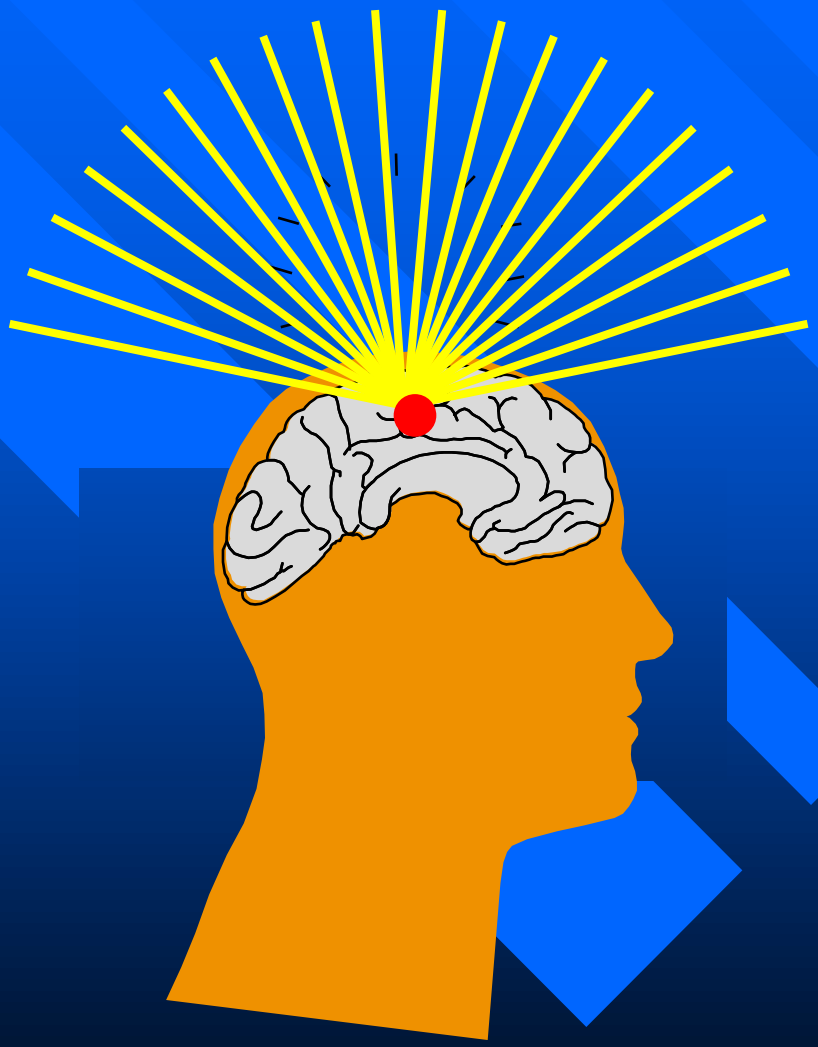
Diagram for the decay of ^{60}Co nucleus



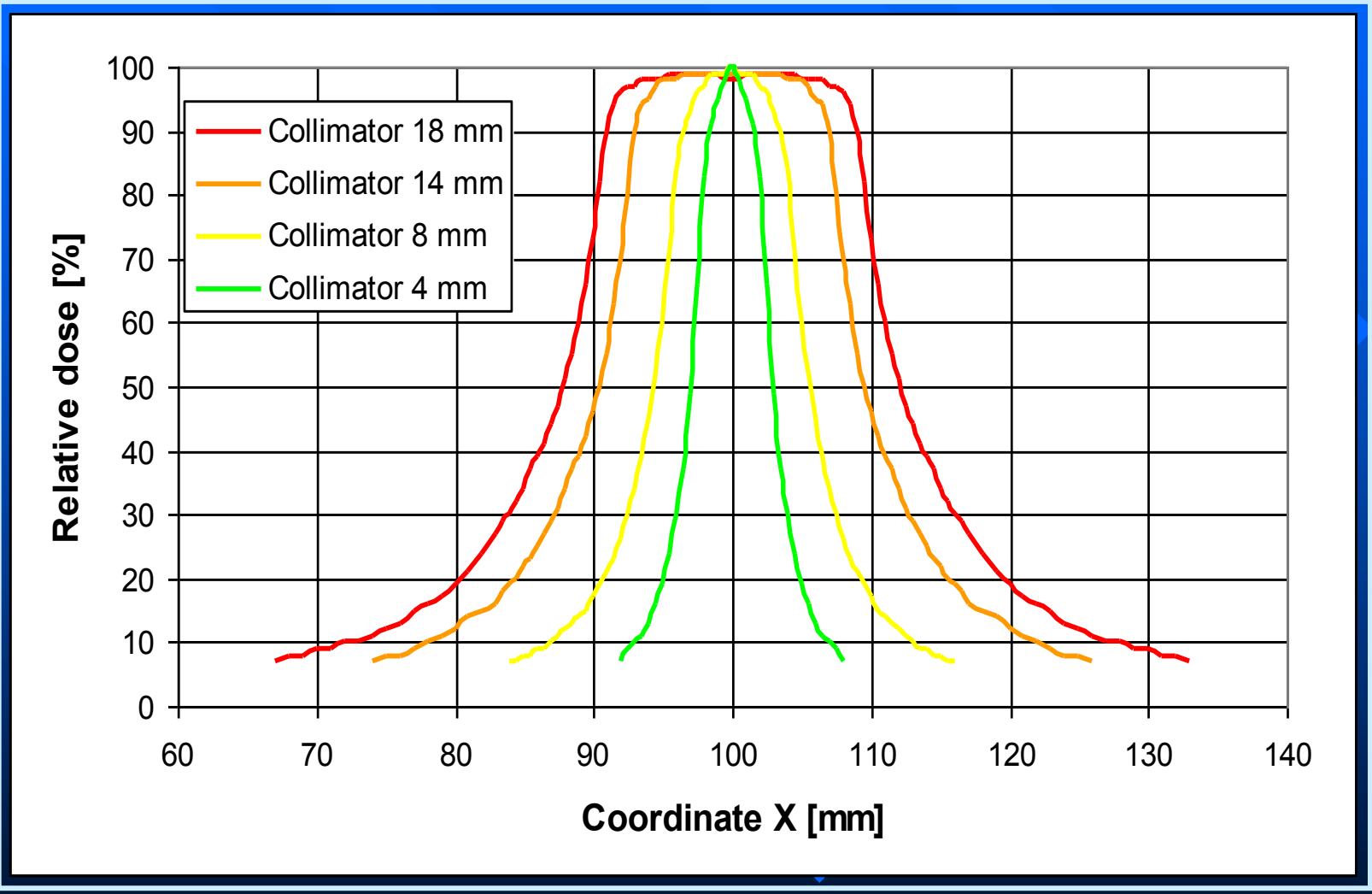
Photon depth dose curves



Basic principle of radiosurgery



Dose profiles for the Leksell gamma knife



Physical and technical principles

Leksell gamma knife

Radiation source: gamma rays from ^{60}Co

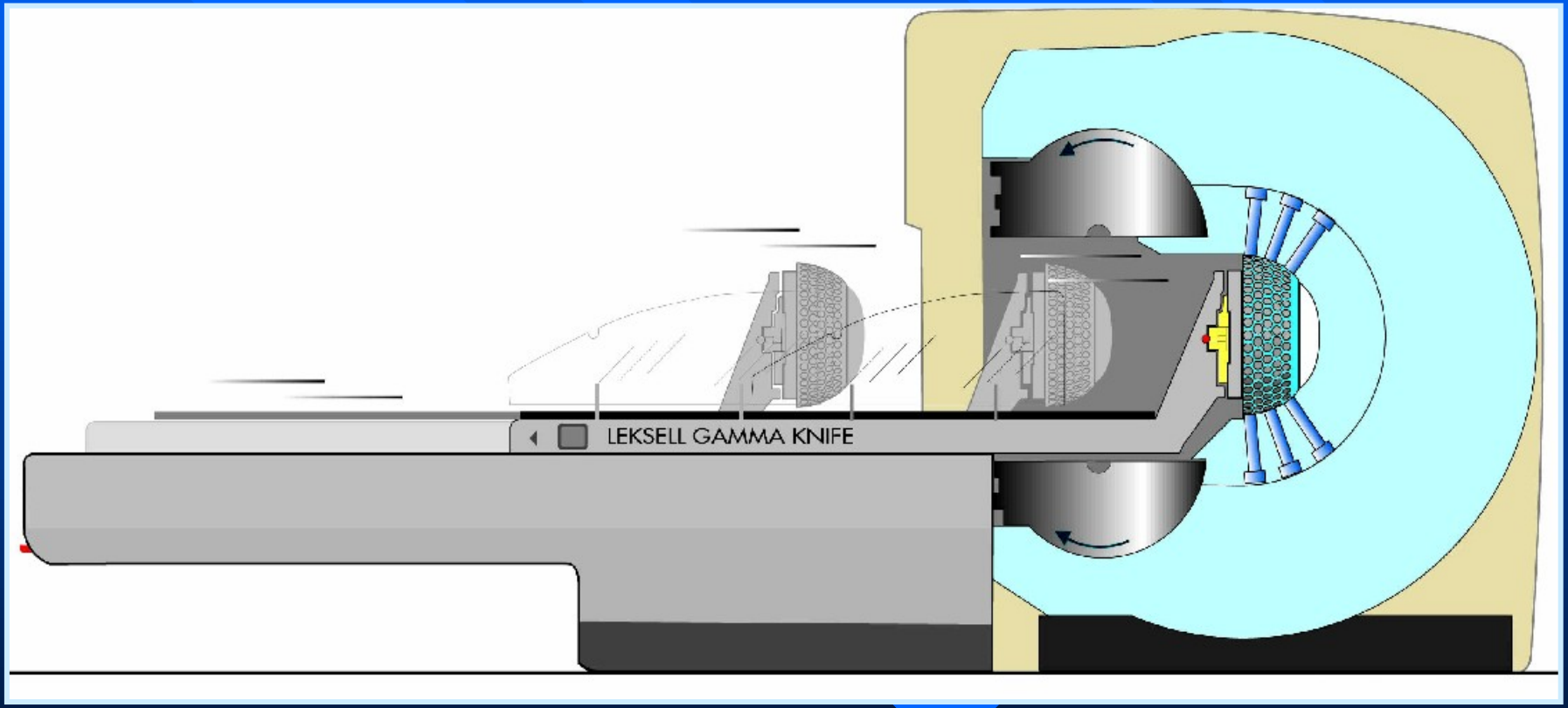
No. of sources: 201

Collimators: 4, 8, 14, 18, mm

Stereotactic target localization: preferably MRI, CT not necessary, angiography

Physical and technical principles

Leksell gamma knife

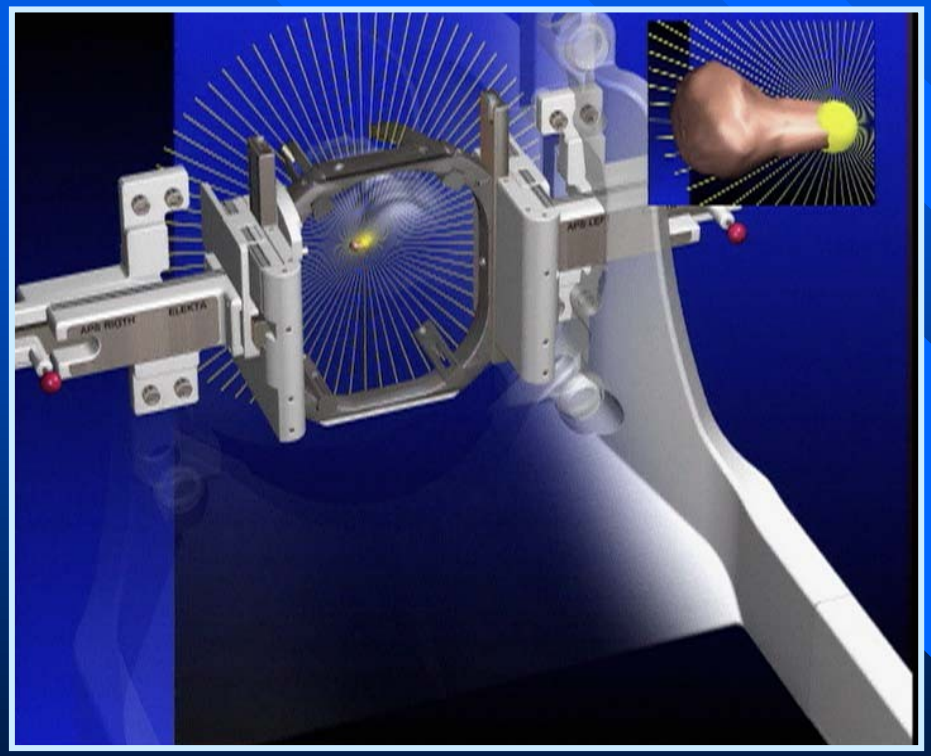


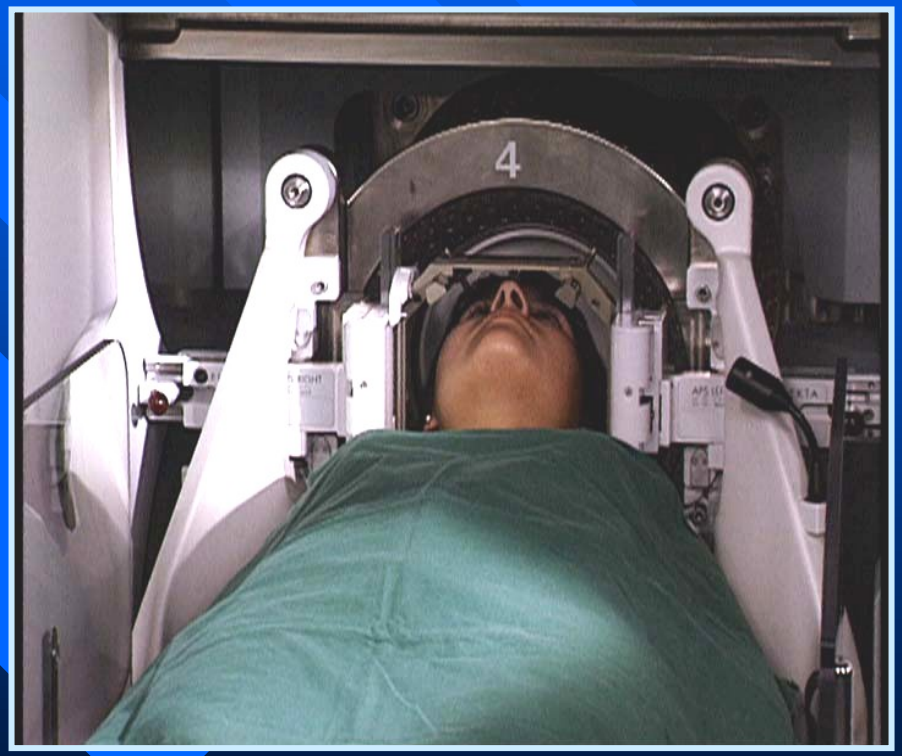
Physical and technical principles

Leksell gamma knife

Physical and technical principles

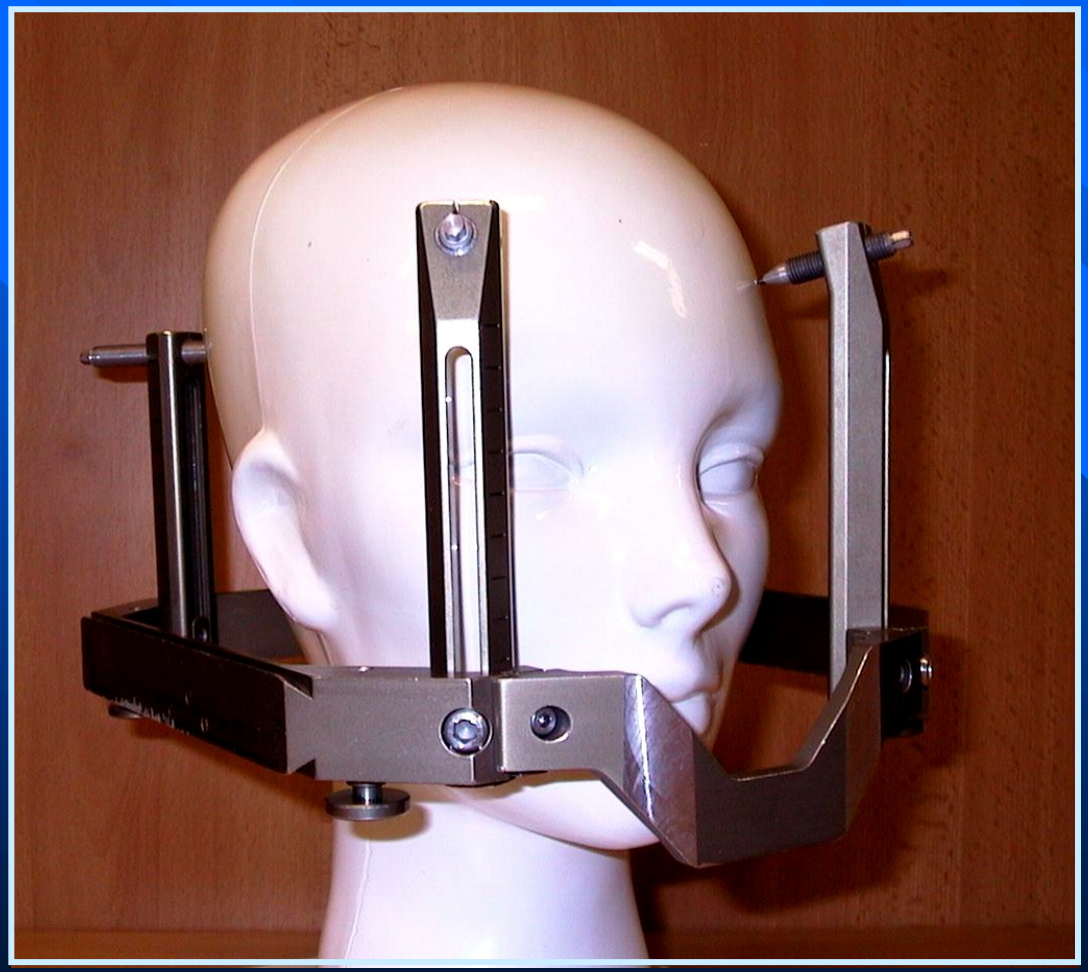
Leksell gamma knife





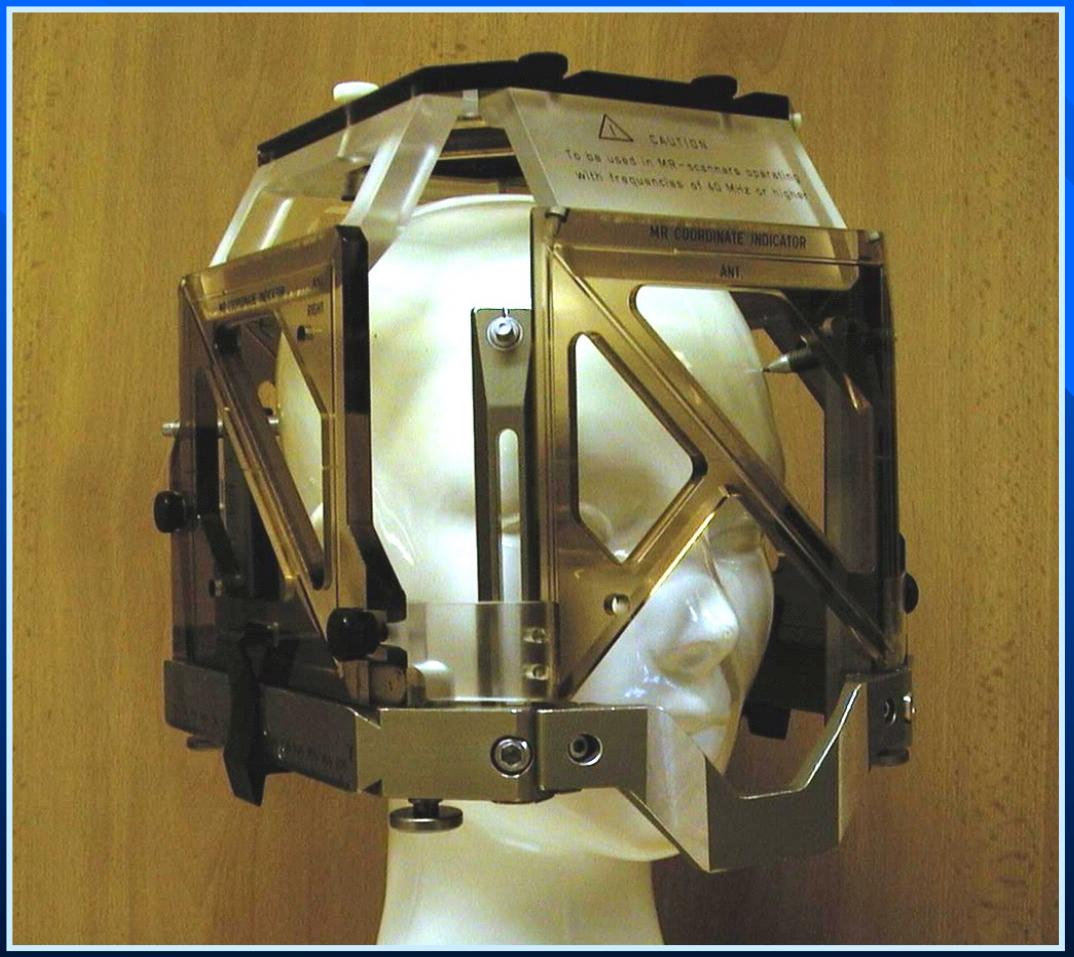
Physical and technical principles

Leksell gamma knife



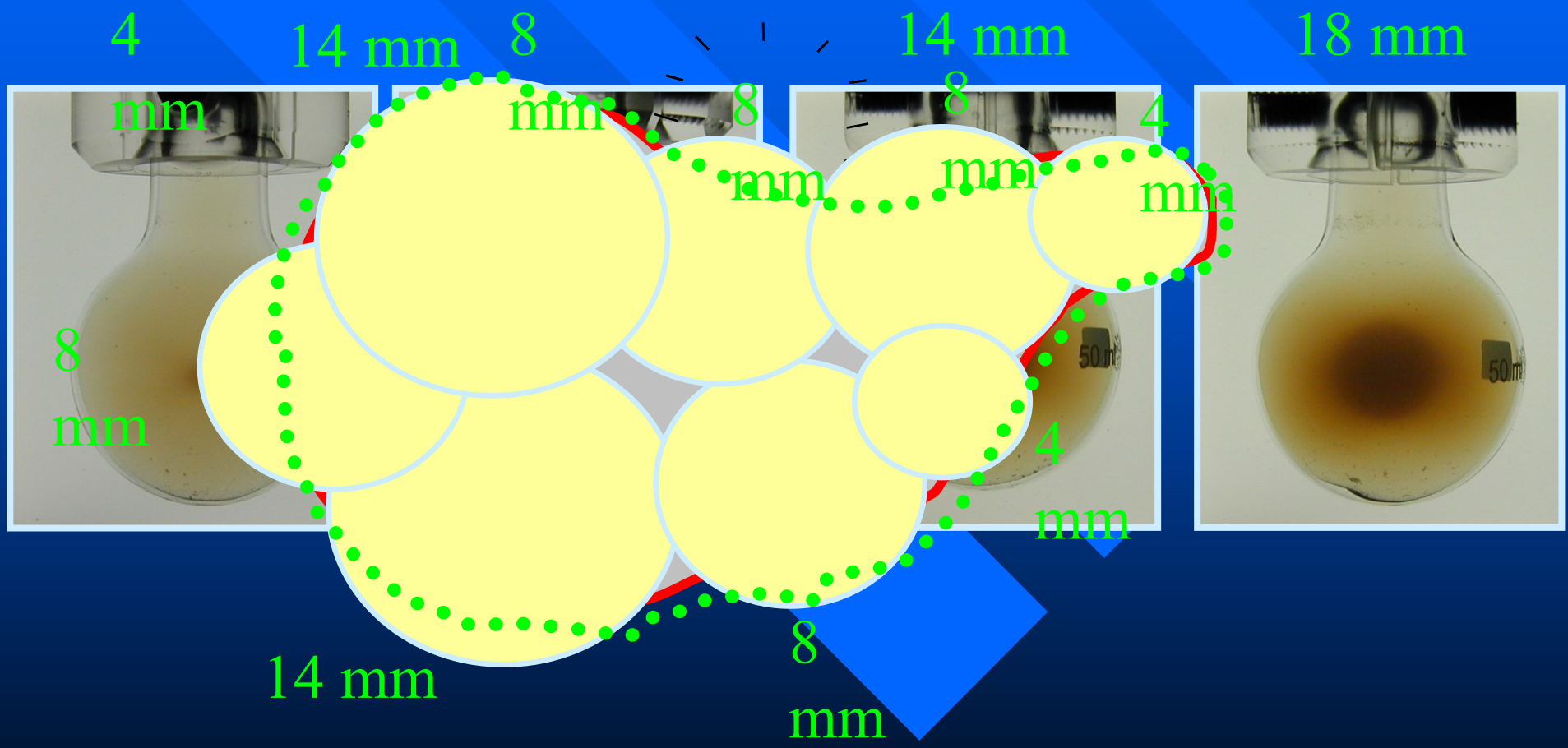
Physical and technical principles

Leksell gamma knife



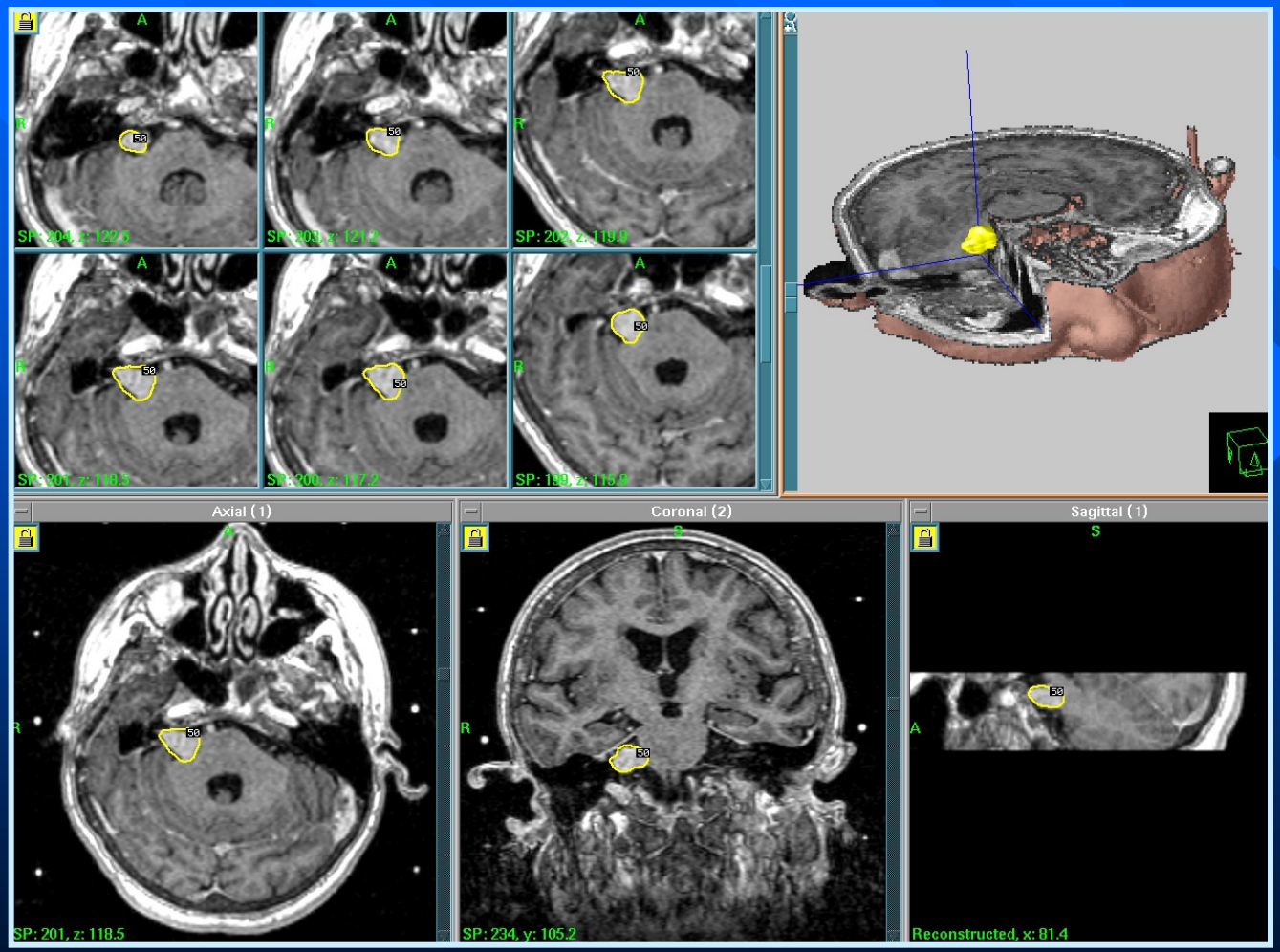
Physical and technical principles

Leksell gamma knife



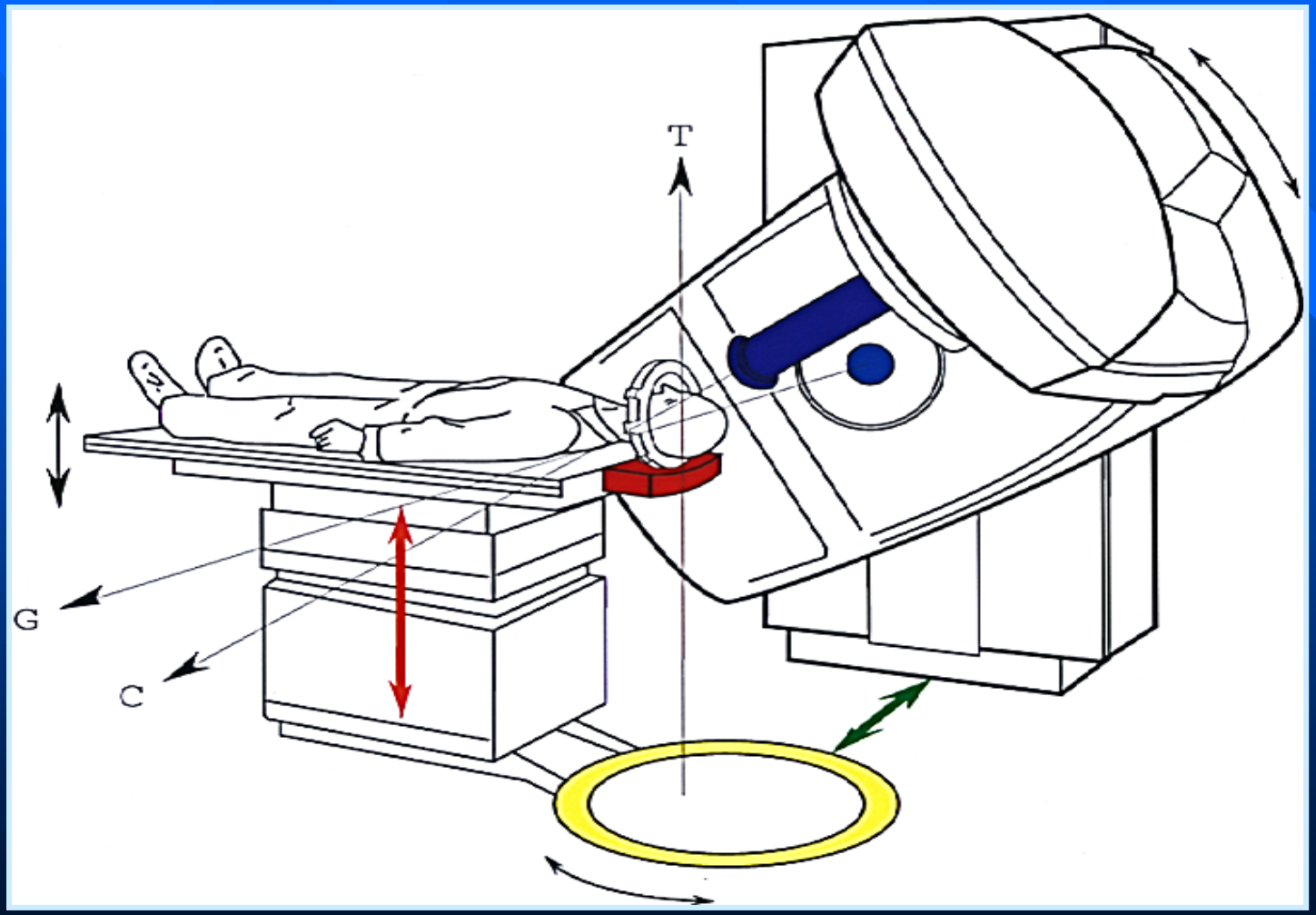
Physical and technical principles

Leksell gamma knife



Physical and technical principles

Linac radiosurgery or radiotherapy (BrainLAB system)

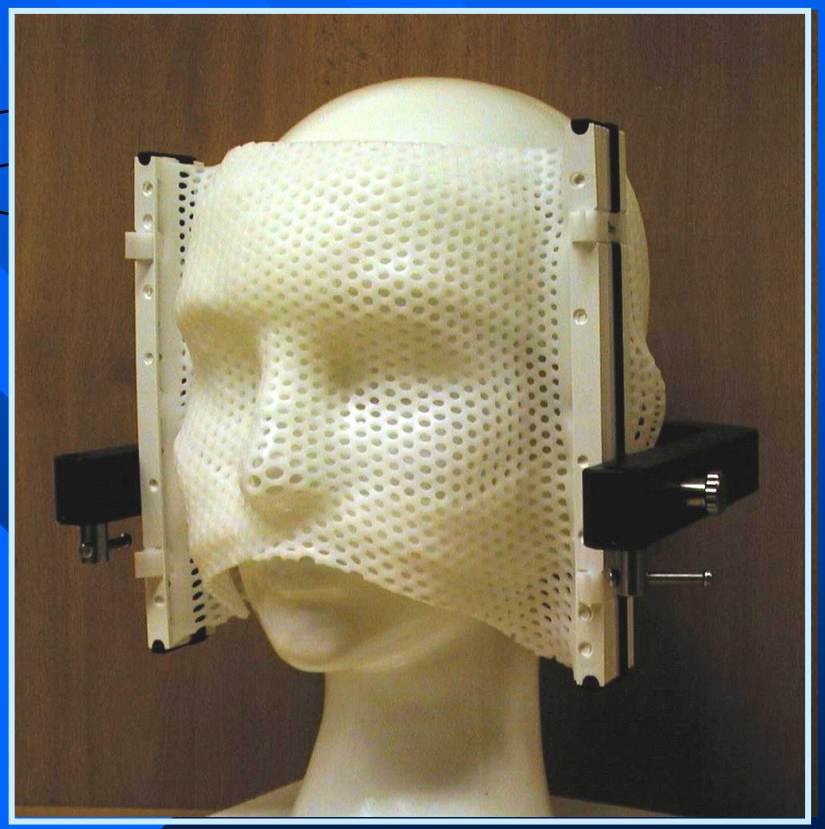


Physical and technical principles

Linac radiosurgery or radiotherapy (BrainLAB system)

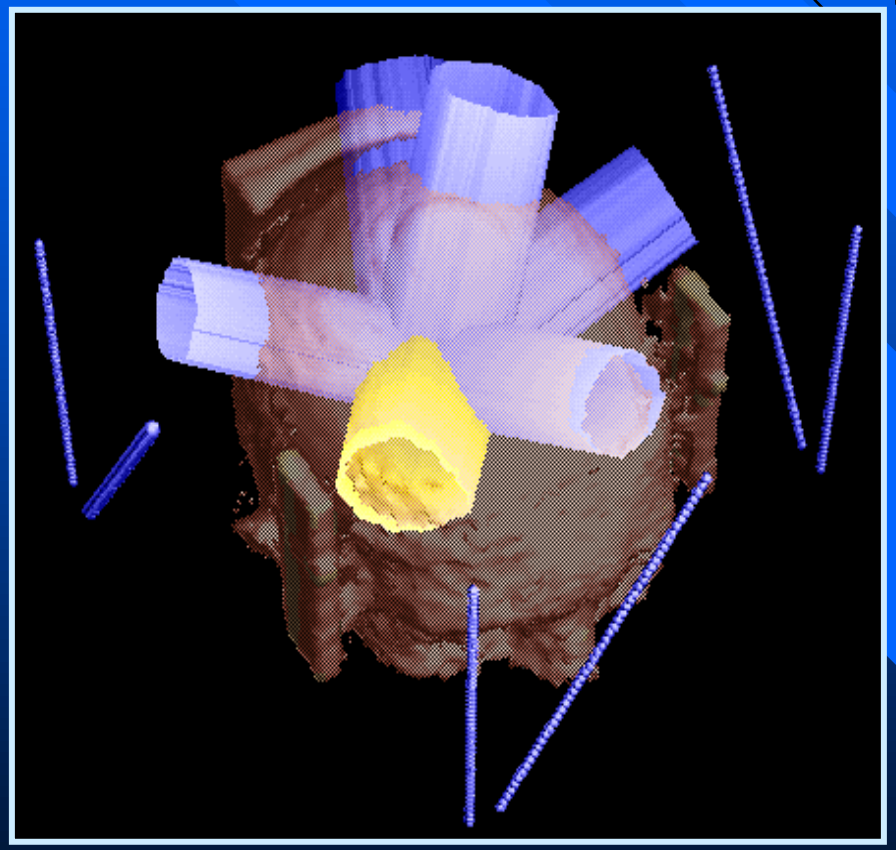
Physical and technical principles

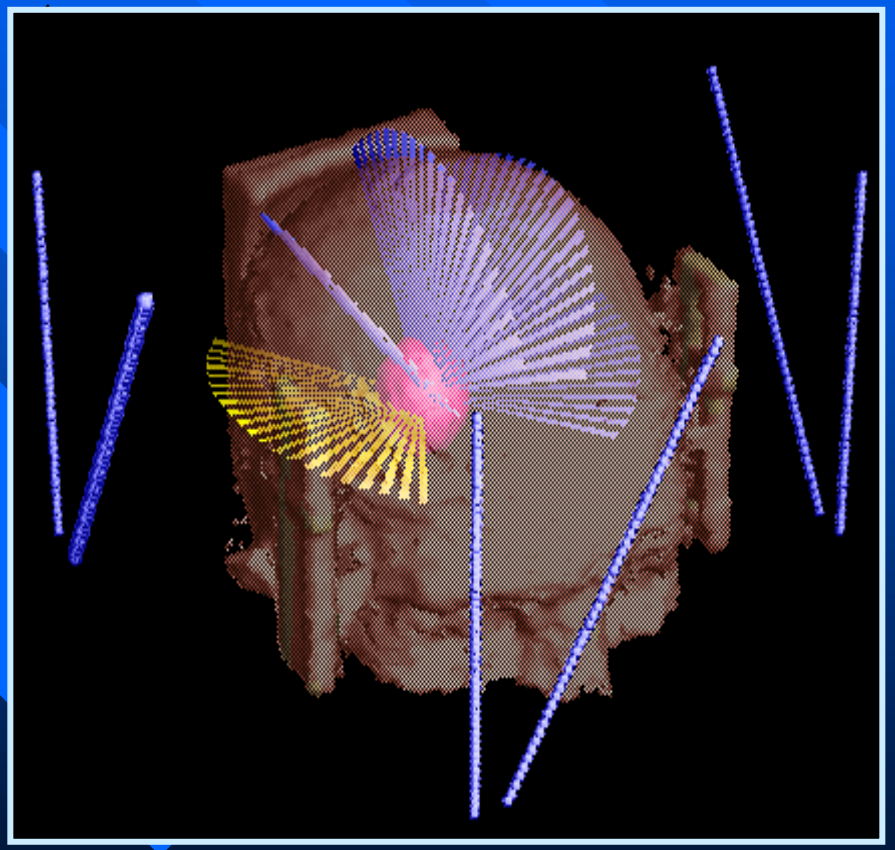
Linac radiosurgery or radiotherapy (BrainLAB system)



Physical and technical principles

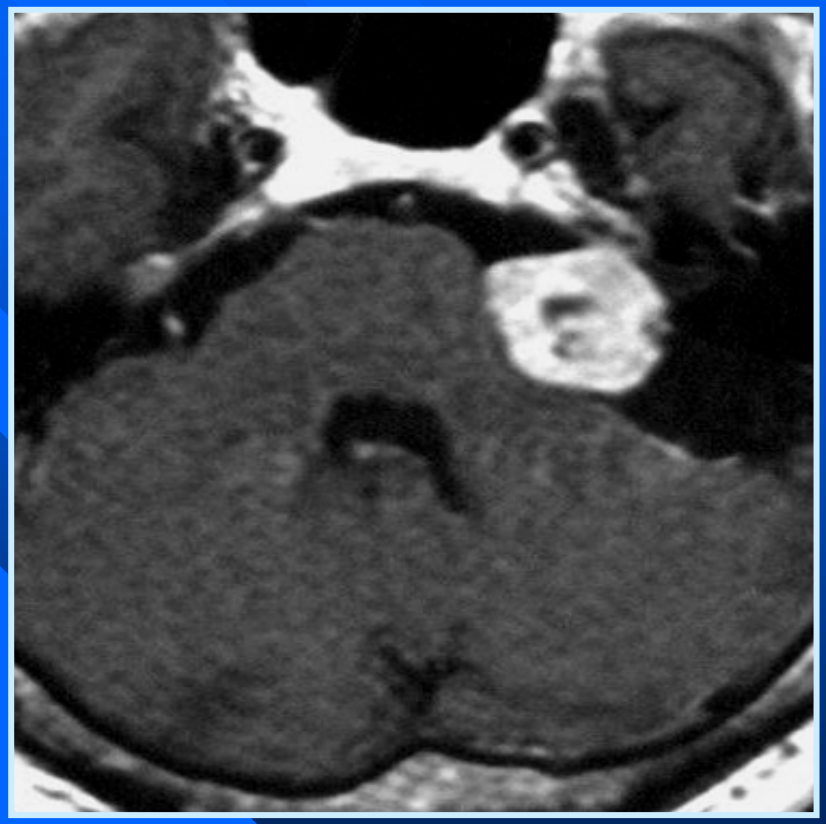
Linac radiosurgery or radiotherapy (BrainLAB system)





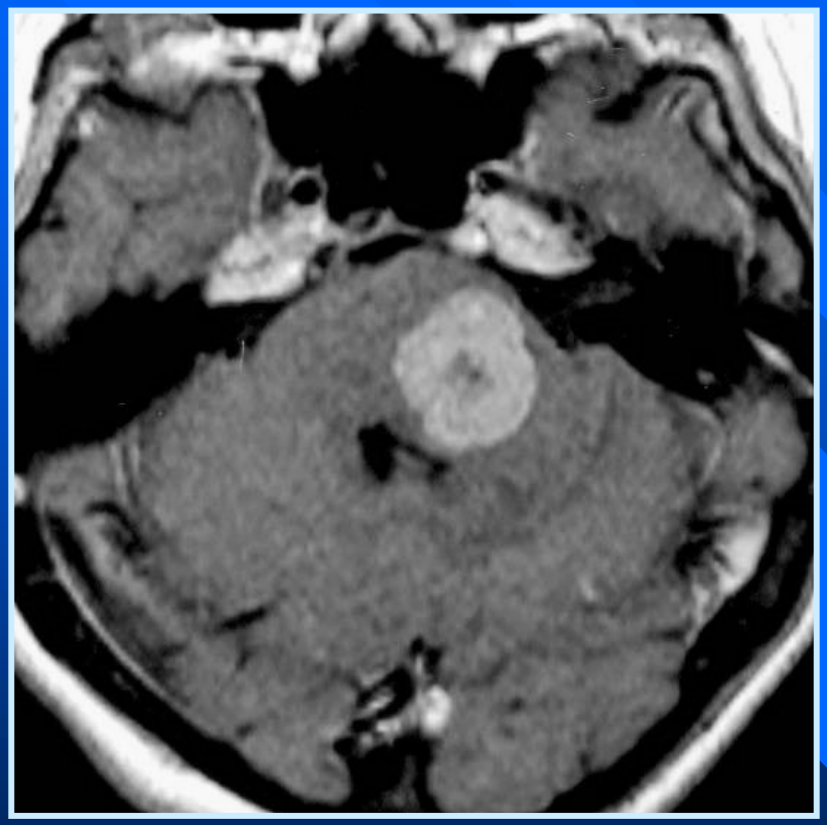
Clinical applications-acoustic neuroma

during LGK irradiation

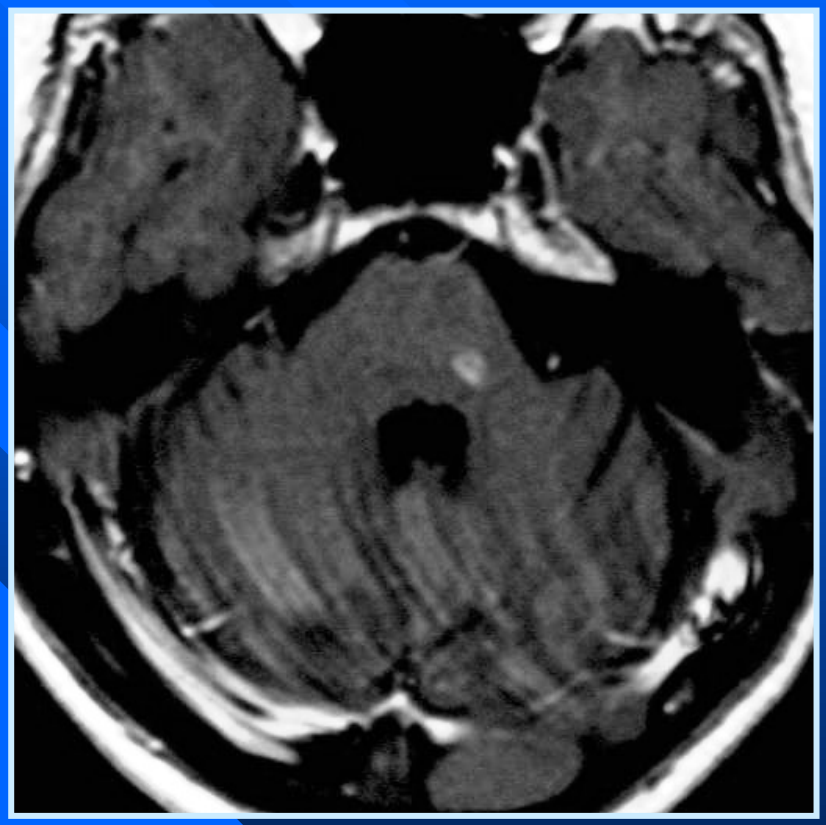


3 years after LGK irradiation

Clinical applications-metastasis



during LGK irradiation



6 years after LGK irradiation