

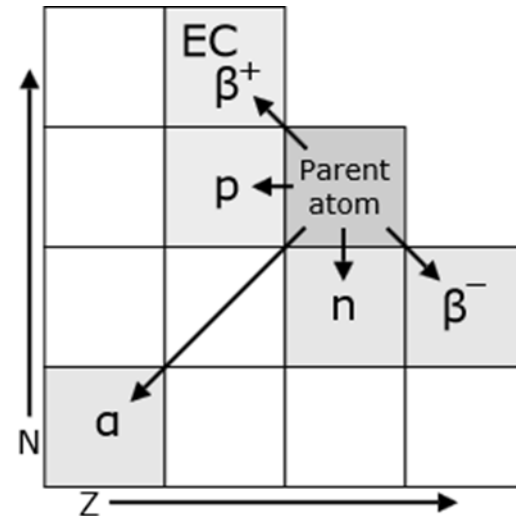
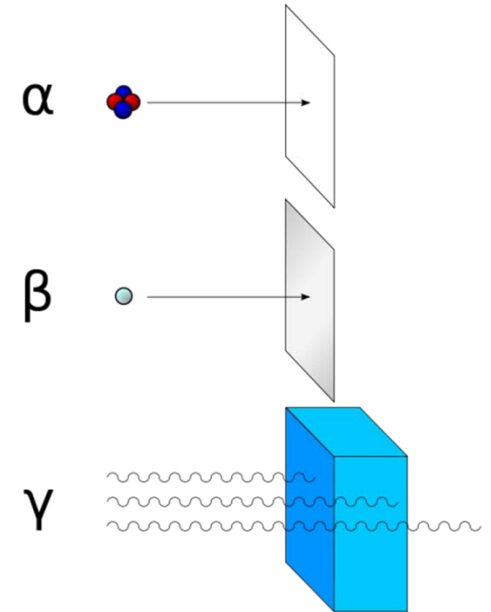
Kako stvari delujejo?

PET, MRI

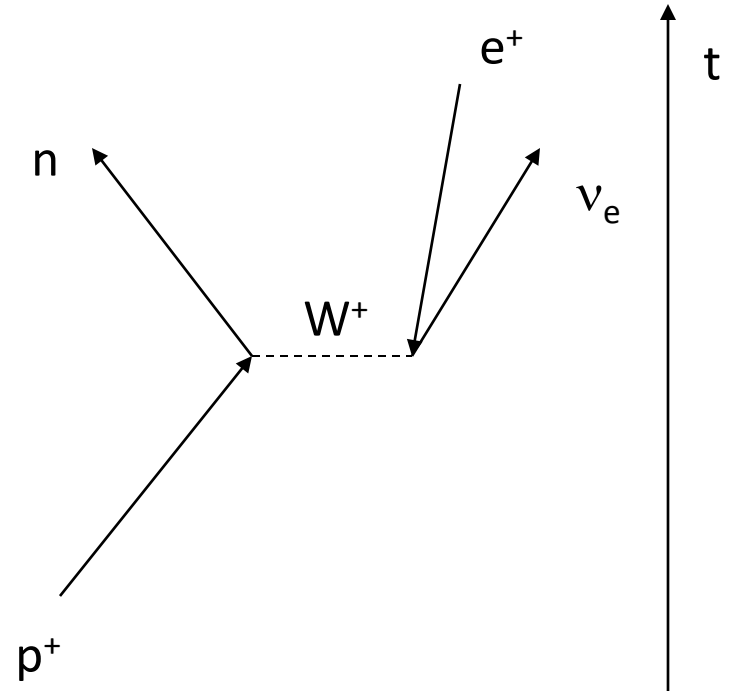
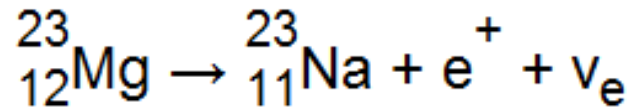
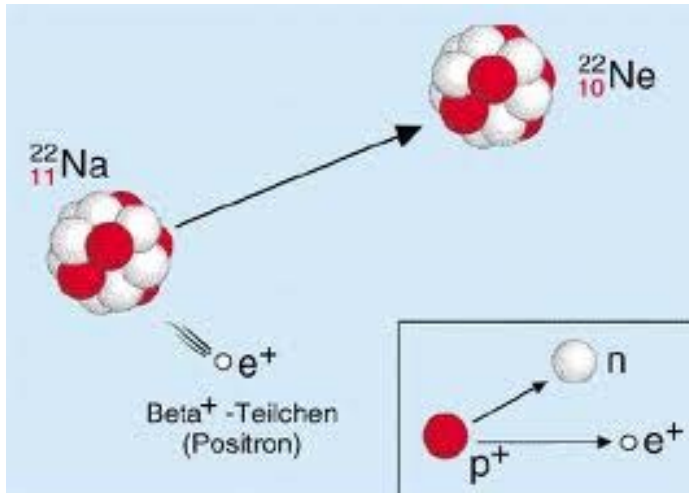
# intermezzo

## Radioaktivni razpadi

- alfa
- izsevanje protona
- izsevanje nevtrona
- cepitev – fisija
- ...
  
- beta
- pozitronska emisija
- zajetje elektrona
- ...
  
- gama
- notranja konverzija



# Pozitronska emisija



# sevanje

**Aktivnost** – število razpadov jeder v časovni enoti, becquerel ( $\text{Bq} = 1/\text{s}$ )

**absorbirana doza** - energija, ki se absorbira v materialu pri prehodu sevanja skozi snov, Grey ( $\text{Gy} = \text{J}/\text{kg}$ )

**ekvivalentna doza** – meri učinke na tkivo, sievert ( $\text{Sv} = \text{Gy}$ )

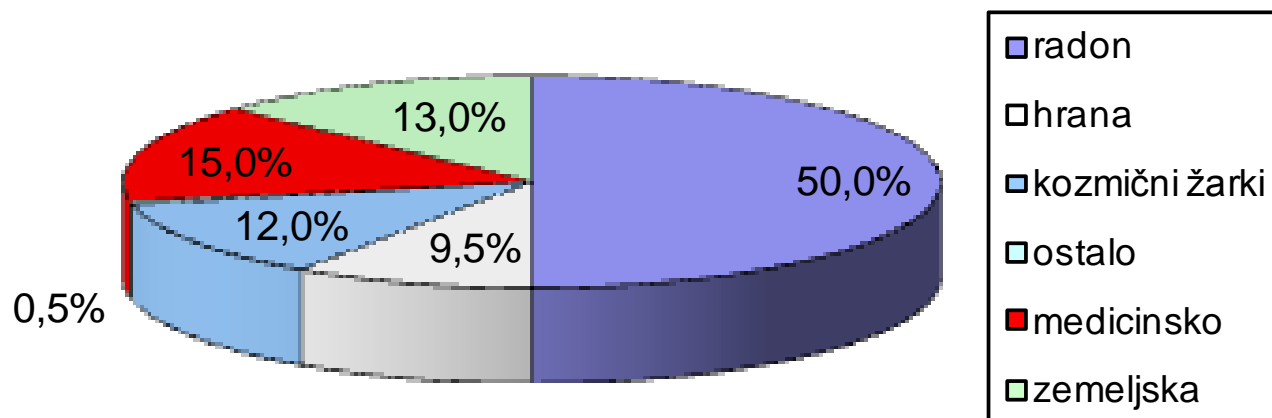
naravno ozadje 2,4 mSv/leto

umetni viri (medicina, industrija) 0,4 – 1,5 mSv/leto

čezoceanski polet 0,05 mSv

letalska posadka 4 – 9 mSv/leto

# porazdelitev izpostavljenosti



Izpostavljenost v S Evropi

## Dozne limite:

- 1 mSv/leto za prebivalce
- 20 mSv/leto za delavce

## Posledice obsevanja:

- 250 – 1000 mSv (prizadet kostni mozeg, bruhanje...)
- 1 – 3 Sv (infekcije, prizadet limfni sistem...)
- 3 – 6 Sv (sterilnost, odstop kože, infekcije, smrt, če ni zdravljenja ...)

Izpostavljenost 400 mSv/h pomeni, da delavec lahko dela 6,6 min oz. bi v 15 h prejel smrtno dozo

Zaščita: zmanjšanje časa (jumpers), povečanje razdalje do vira, uporaba ščitov in zaščitne obleke

<b>ABDOMINAL REGION:</b>			
Computed Tomography (CT)-Abdomen and Pelvis	10 mSv	3 years	Low
Computed Tomography (CT)-Abdomen and Pelvis, repeated with and without contrast material	20 mSv	7 years	Moderate
Computed Tomography (CT)-Colonography	10 mSv	3 years	Low
Intravenous Pyelogram (IVP)	3 mSv	1 year	Low
Radiography (X-ray)-Lower GI Tract	8 mSv	3 years	Low
Radiography (X-ray)-Upper GI Tract	6 mSv	2 years	Low
<b>BONE:</b>			
Radiography (X-ray)-Spine	1.5 mSv	6 months	Very Low
Radiography (X-ray)-Extremity	0.001 mSv	3 hours	Negligible
<b>CENTRAL NERVOUS SYSTEM:</b>			
Computed Tomography (CT)-Head	2 mSv	8 months	Very Low
Computed Tomography (CT)-Head, repeated with and without contrast material	4 mSv	16 months	Low
Computed Tomography (CT)-Spine	6 mSv	2 years	Low
<b>CHEST:</b>			
Computed Tomography (CT)-Chest	7 mSv	2 years	Low
Computed Tomography (CT)-Chest Low Dose	1.5 mSv	6 months	Very Low
Radiography-Chest	0.1 mSv	10 days	Minimal
<b>DENTAL:</b>			
Intraoral X-ray	0.005 mSv	1 day	Negligible
<b>HEART:</b>			
Coronary Computed Tomography Angiography (CTA)	12 mSv	4 years	Low
Cardiac CT for Calcium Scoring	3 mSv	1 year	Low
<b>WOMEN'S IMAGING:</b>			
Bone Densitometry (DEXA)	0.001 mSv	3 hours	Negligible
Mammography	0.4 mSv	7 weeks	Very Low

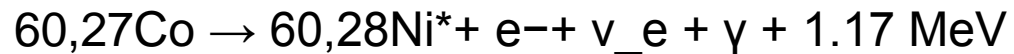
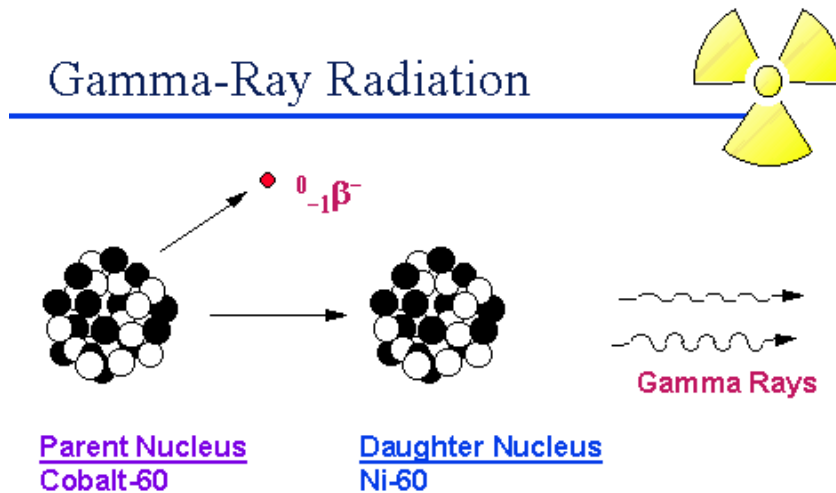
**Approximate additional risk of  
Risk Level fatal cancer for an adult from  
examination:**

Negligible: less than 1 in 1,000,000  
 Minimal: 1 in 1,000,000 to 1 in 100,000  
 Very Low: 1 in 100,000 to 1 in 10,000  
 Low: 1 in 10,000 to 1 in 1000  
 Moderate: 1 in 1000 to 1 in 500

**Note:** These risk levels represent very small additions to the 1 in 5 chance we all have of dying from cancer.

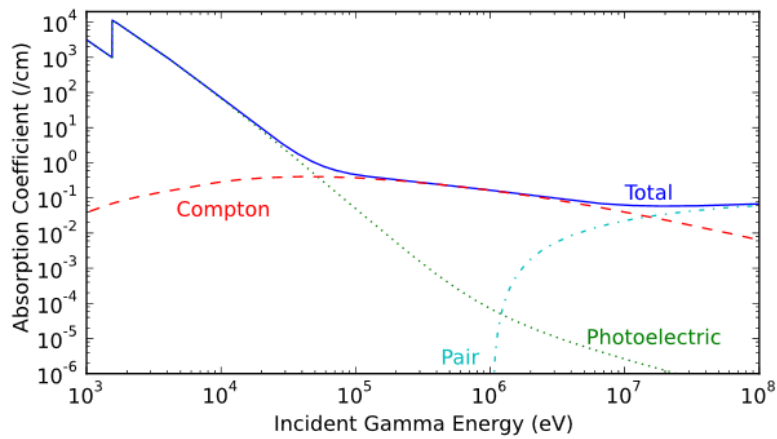
# viri sevanja gama

- radioaktivni razpad  $\alpha$ ,  $\beta$ , zajetje nevtrona, fisija, fuzija
- pulzarji, kvazarji, izbuhi sevanja gama, magnetarji, strele

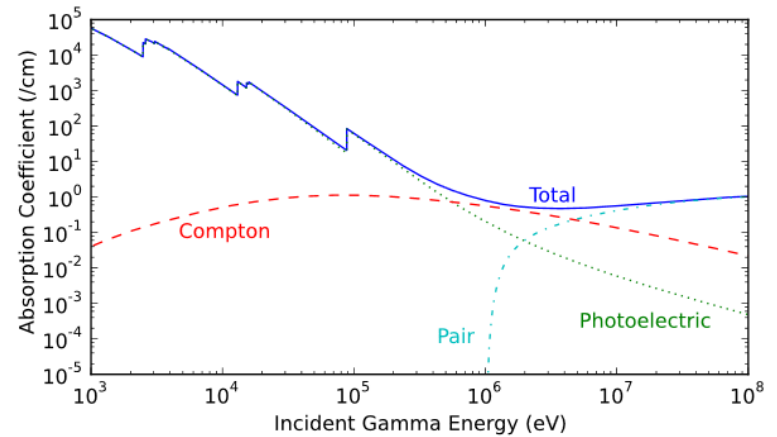




# absorpcija gama



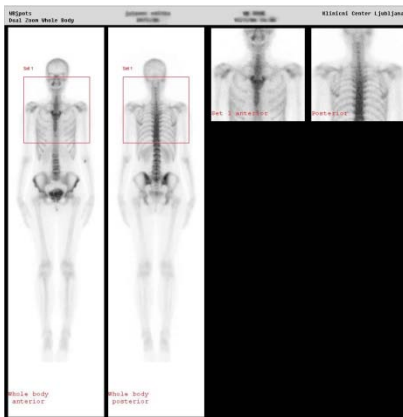
absorpcija v aluminiju



absorpcija v svincu

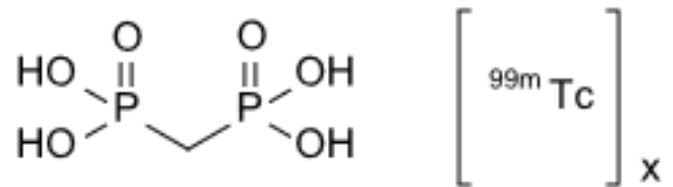
# scintigrafija

- Scintigrafija skeleta: reakcija kosti na novotvorbo, mehansko preobremenitev, poškodbo, vnetje,...
- radiofarmaki (polifosfati, kemično vezan tehnecij (Tc-99m))
- obsevanje primerljivo Rtg.
- doza pri scintigrafiji skeleta 4 mSv, (20 mesecev ozadja).

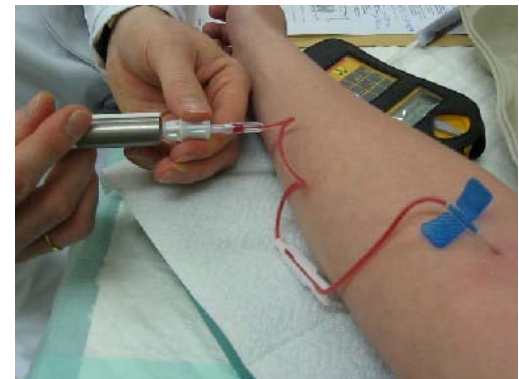


# tehnecij

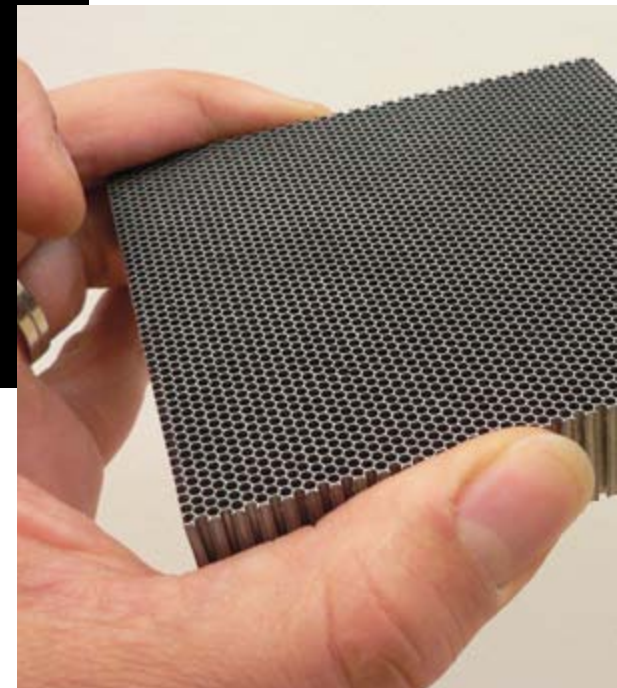
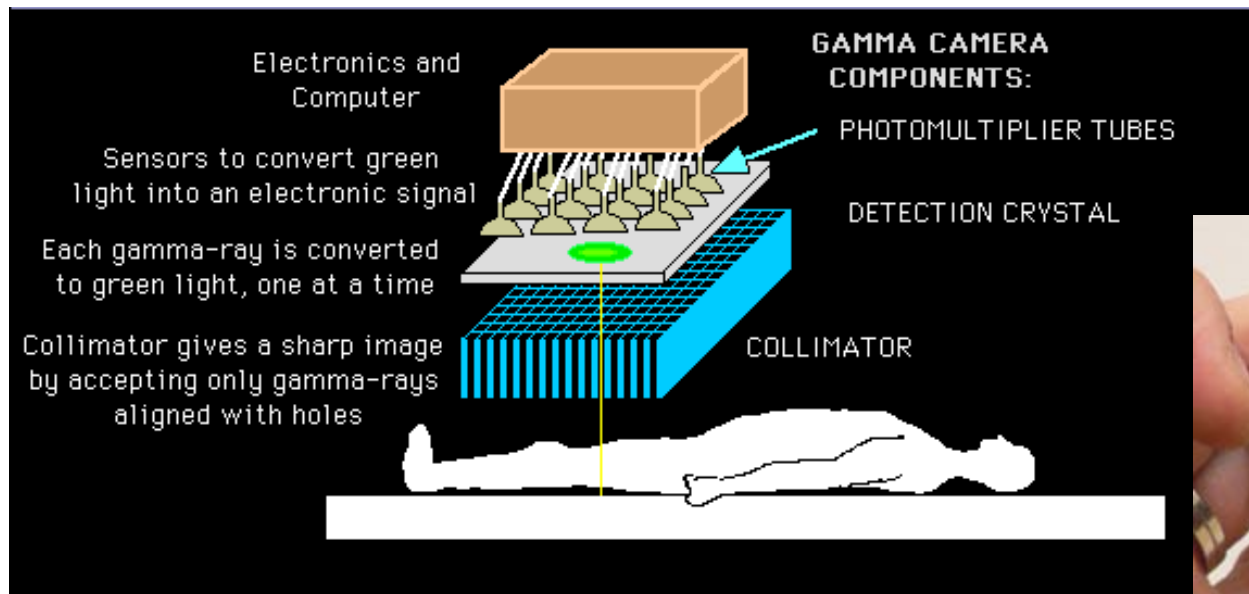
- kompleks metilenovega difosfonata (medronska kislina) in tehnecija



- tehnecij 99
  - seva 140 keV gama,
  - razpolovni čas 6 h (koliko ga razpade v enem dnevu?)
  - Biološki  $t_{1/2}$  je 1 dan
  - Pridobiva se iz molibdena 99, ki ima razpolovni čas 2,8 dni in nastaja s fisijo obogatene urana



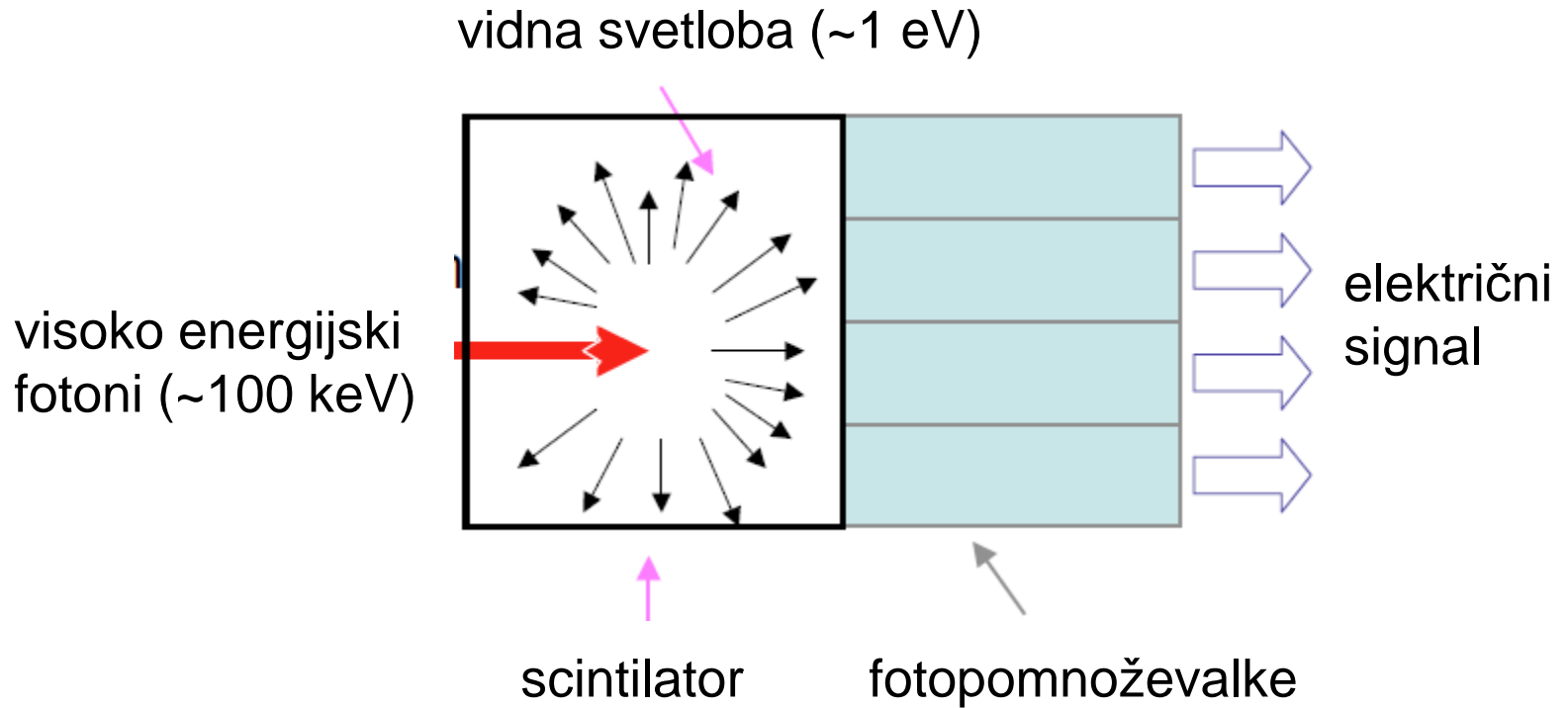
# Gama kamera



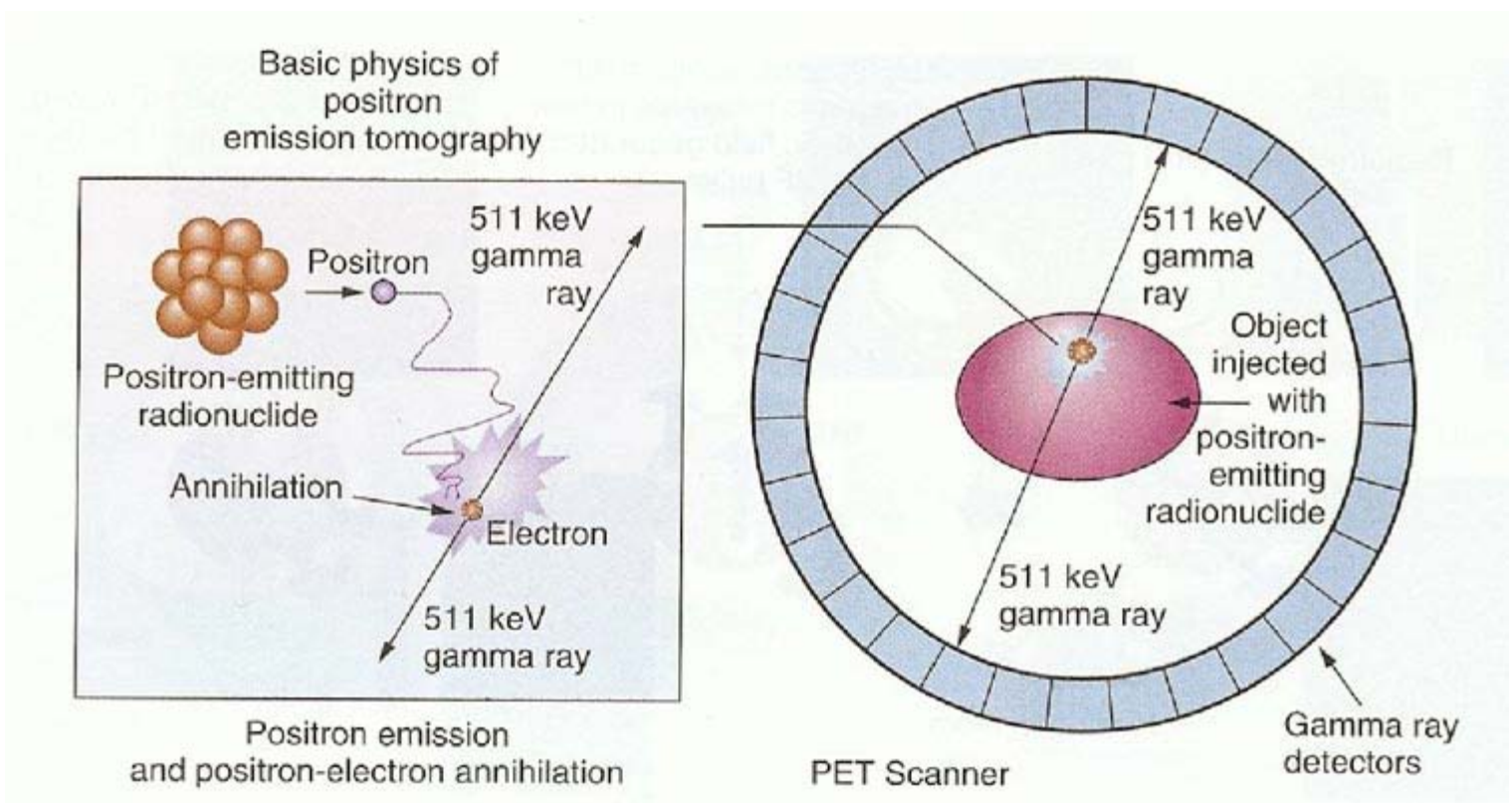
kolimator

# gama kamera

- scintilacija

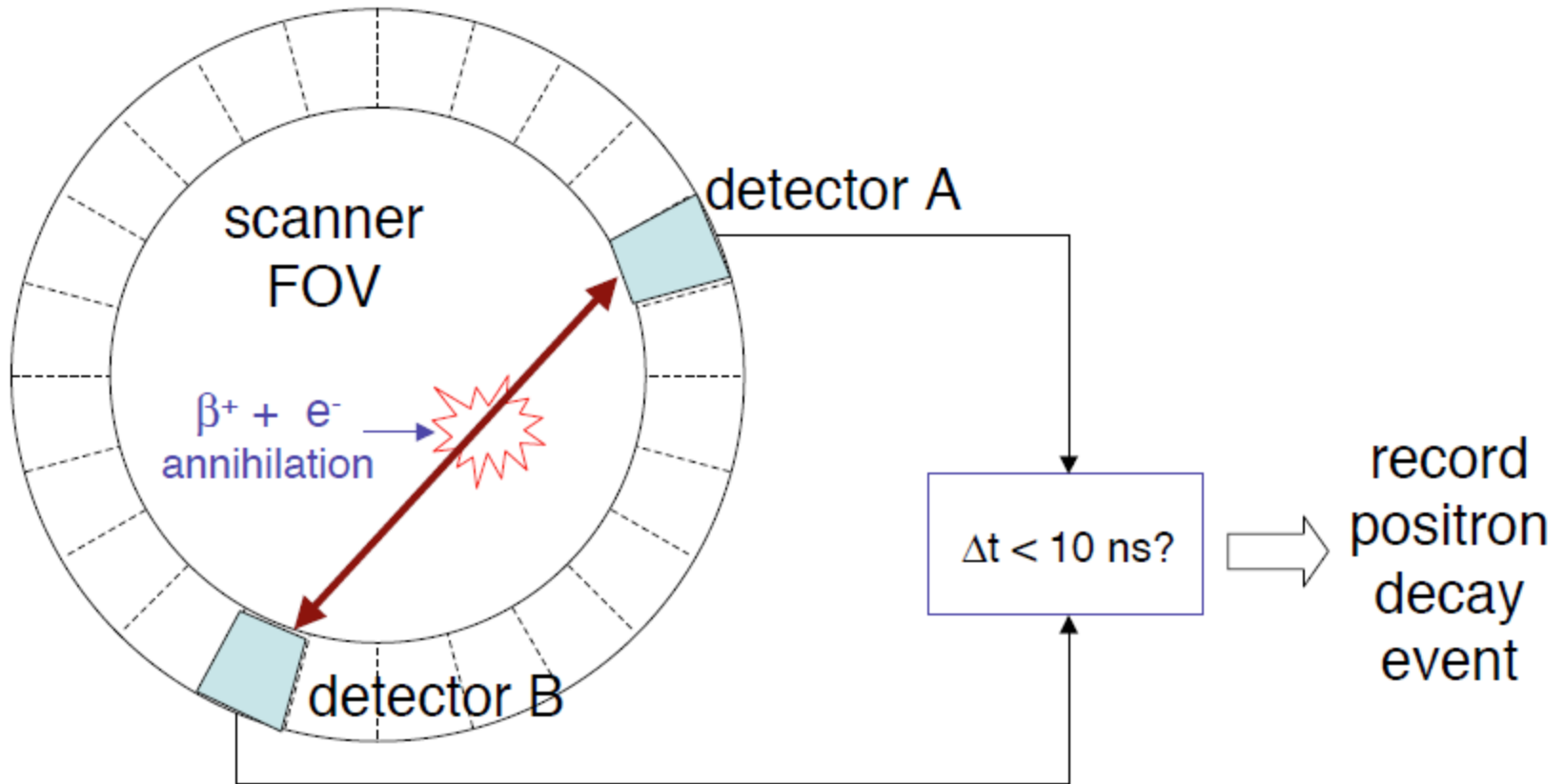


# pozitronska emisijska tomografija (PET)

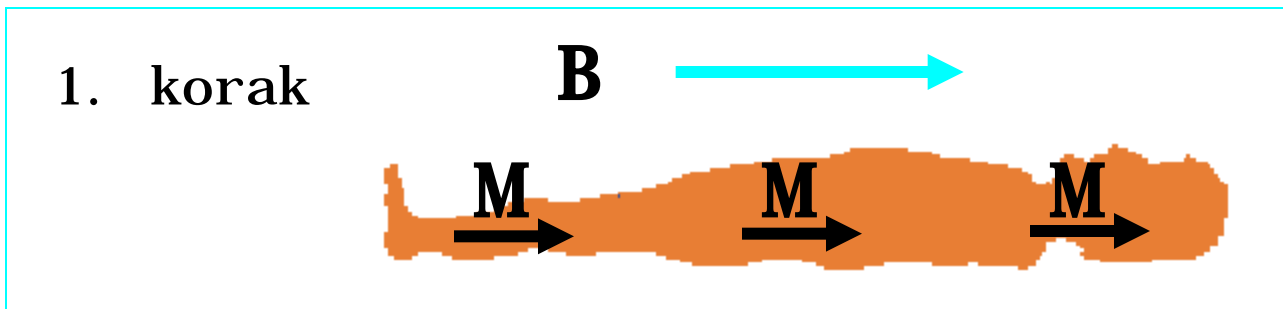


# pozitronska emisijska tomografija (PET)

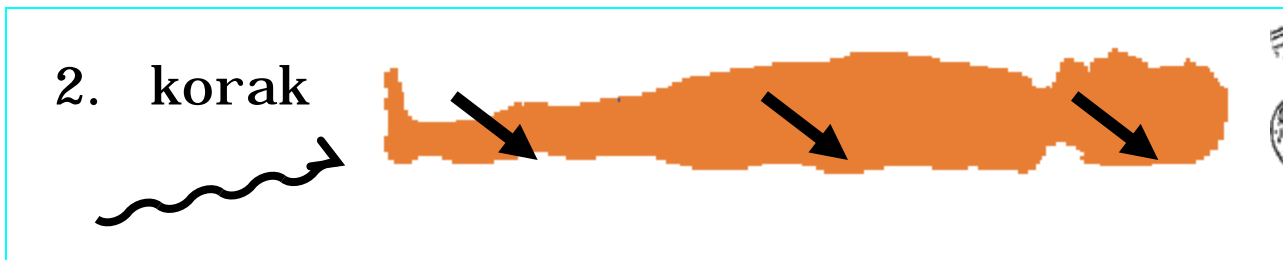
- koincidenca



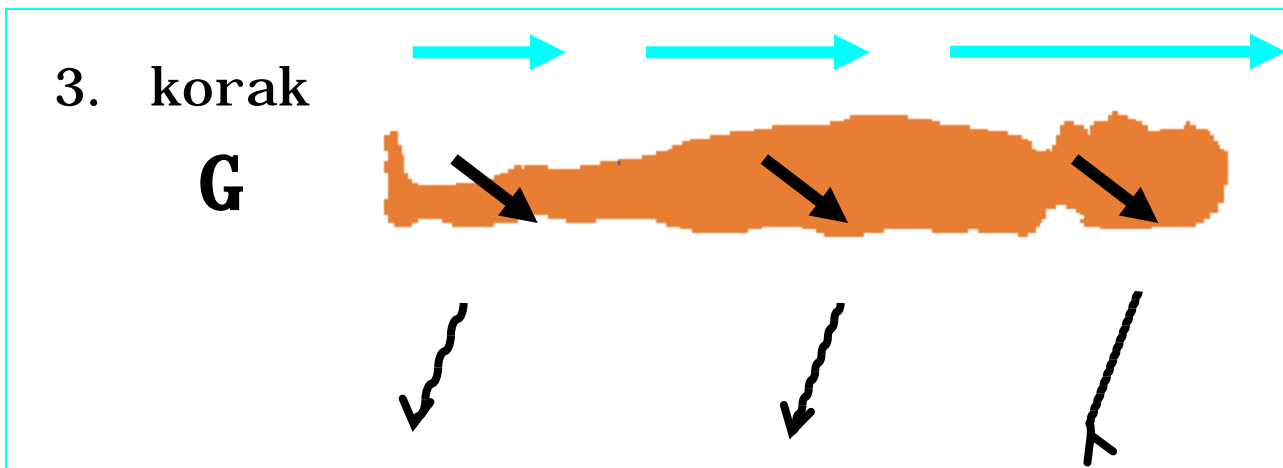
# SLIKANJE Z MAGNETNO RESONANCO



magnetizacija



vzbujanje



kodiranje

+

◀ detekcija



# interakcija v polju

sila na vodnik,  $\vec{F} = I\vec{l} \times \vec{B}$

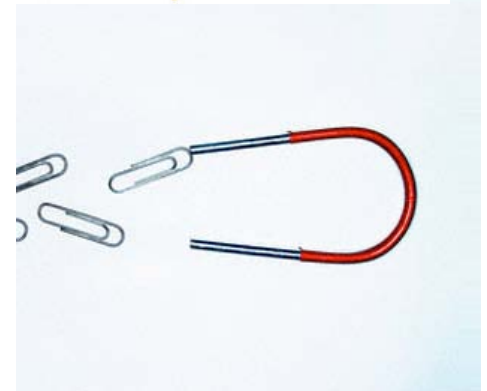
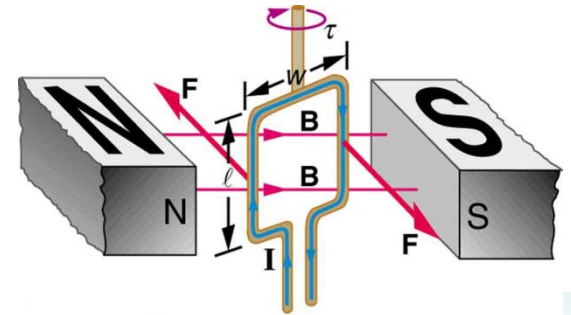
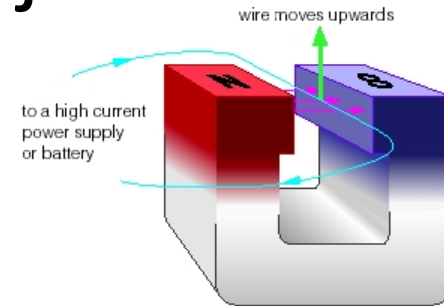
• navor na zanko,  $\vec{N} = \vec{p}_m \times \vec{B}$

• navor na dipol,  $\vec{N} = \vec{p}_m \times \vec{B}$

• sila na dipol,  $\vec{F} = \nabla(\vec{p}_m \cdot \vec{B})$

• energija dipola v magnetnem polju

$$W_m = -\vec{p}_m \cdot \vec{B}$$



# magnetno polje v snovi

zveza med jakostjo in gostoto  $B = \mu\mu_0 H$

magnetizacija:  $B = \mu_0 (H + M)$

$$M = \frac{(\mu - 1)B}{\mu\mu_0} = \frac{\chi B}{\mu\mu_0} = \chi H$$

# magnetizacija

magnetizacija: 
$$M = \frac{(\mu - 1)B}{\mu\mu_0} = \frac{\chi B}{\mu\mu_0} = \chi H$$

permeabilnost snovi  $\mu$

magnetna susceptibilnost  $\chi$

drug pomen: 
$$M = \frac{dp_m}{dV}$$

# magnetizacija

po magnetnih lastnostih so snovi:

- diamagnetne,

relativna magnetna permeabilnost  $< 1$ ,

magnetna susceptibilnost  $< 0$

zunanje magnetno polje jih odbija

s. vode =  $-9,05 \cdot 10^{-6}$ .

s. bizmuta =  $-166 \cdot 10^{-6}$

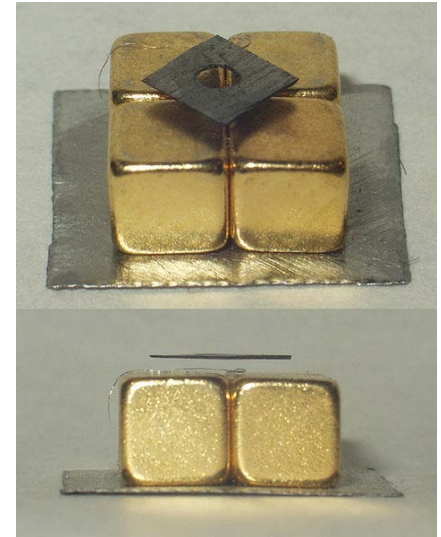
popolni diamagnetiki superprevodniki,

magnetno polje zaradi

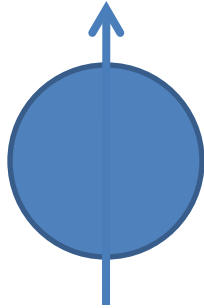
Meissnerjevega pojava izrinejo ( s. =  $-1$ ).

- paramagnetne,
- feromagnetne snovi,

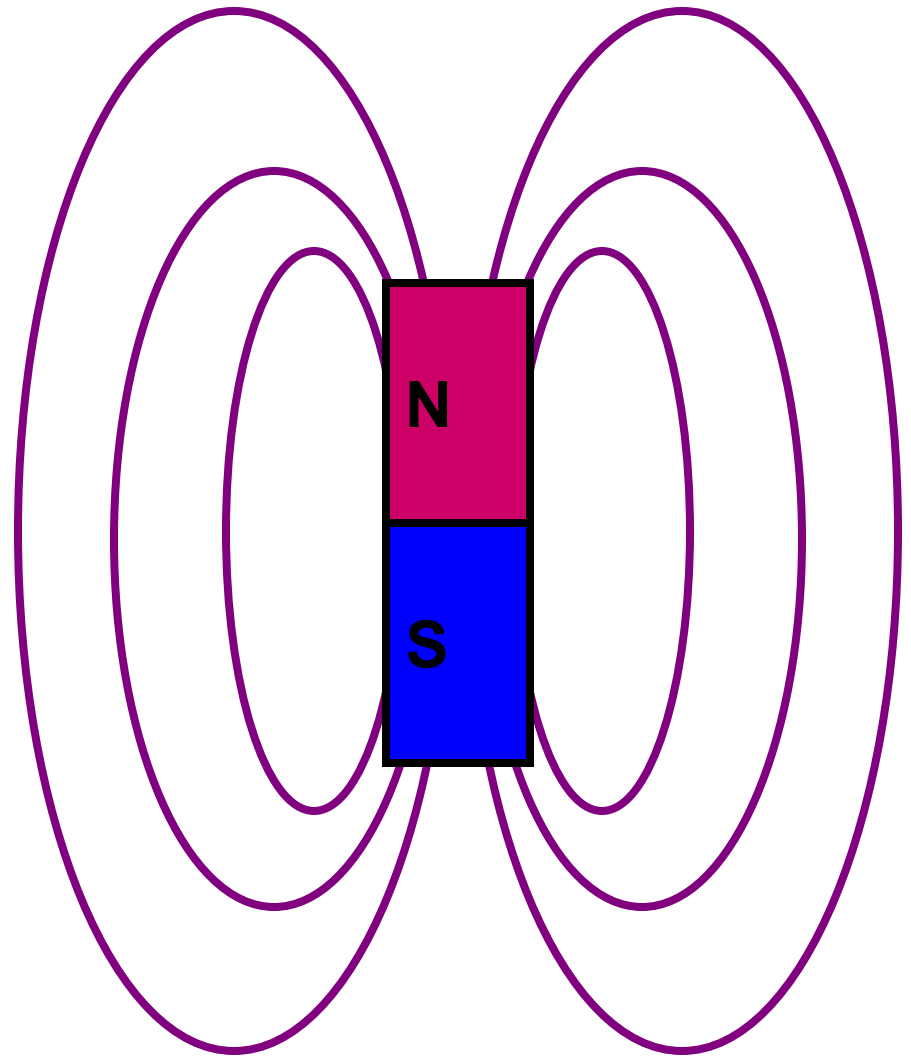
atomska diamagnetne, jedrska paramagnetne  
(sparjeni elektroni, nesparjeni nukleoni)



pirolitski ogljik

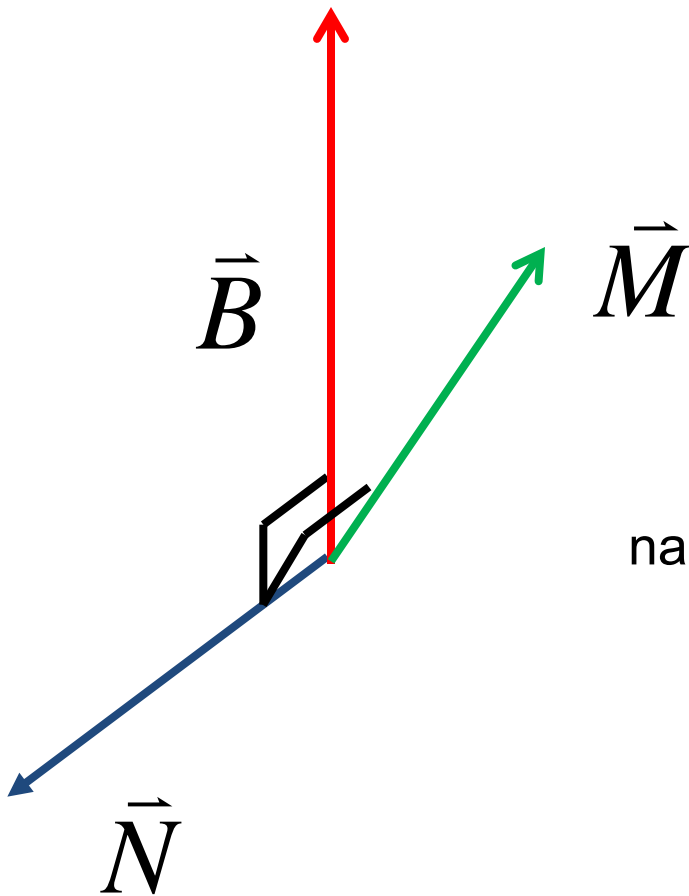


$$\vec{p}_m = \gamma \vec{j}$$



dipolni magnetni moment je sorazmeren vrtilni količini  
 $\gamma$  je giromagnetno razmerje – značilno za jedro

# precesija



na tabli izpeljimo rešitev te enačbe

$$\dot{\vec{M}} = \gamma \vec{M} \times \vec{B}$$

Blochova enačba

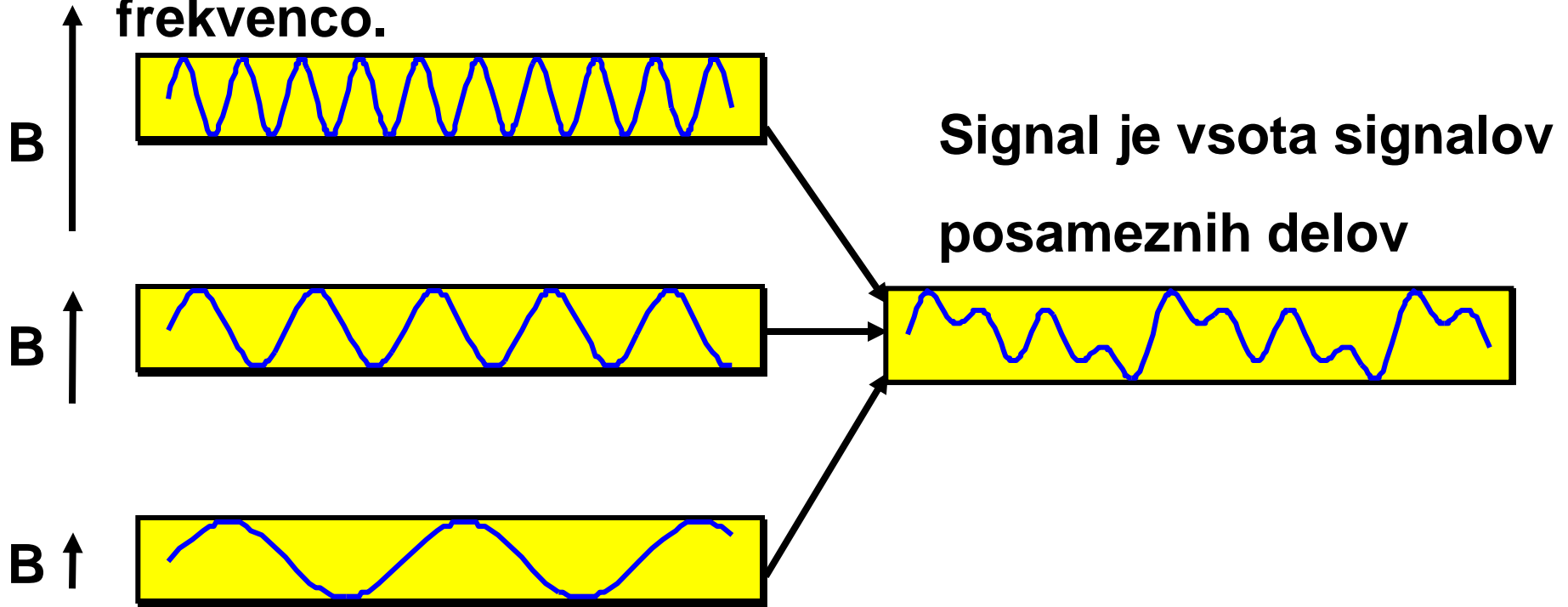
## magnetizacija - dinamične enačbe

$$\frac{dM_{x'}}{dt} = (\omega_0 - \omega)M_{y'} - \frac{M_{x'}}{T_2}$$

$$\frac{dM_{y'}}{dt} = -(\omega_0 - \omega)M_{x'} + 2\pi\gamma B_1 M_z - \frac{M_{y'}}{T_2}$$

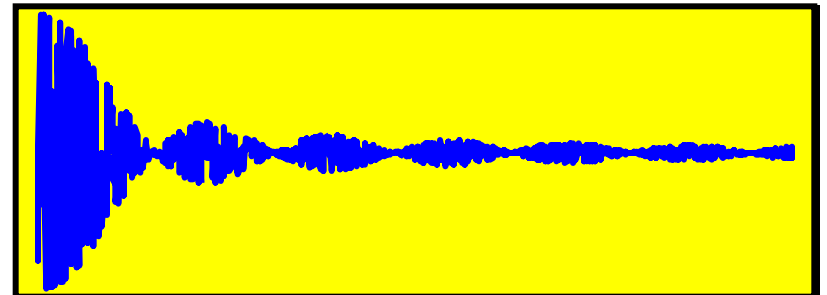
$$\frac{dM_z}{dt} = -2\pi\gamma B_1 M_{y'} - \frac{(M_z - M_{z_0})}{T_1}$$

**Spini v večjem magnetnem polju precesirajo z višjo frekvenco.**



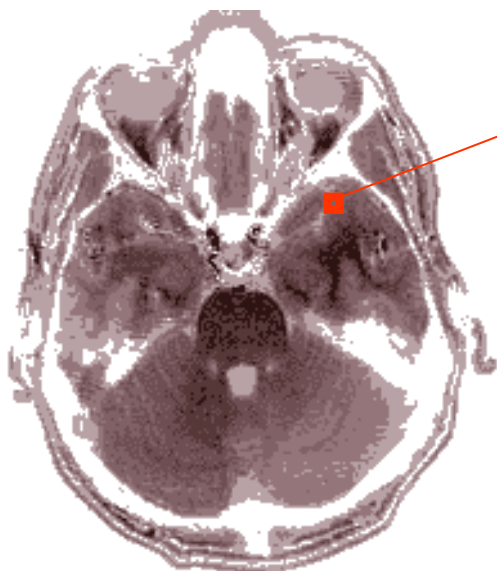
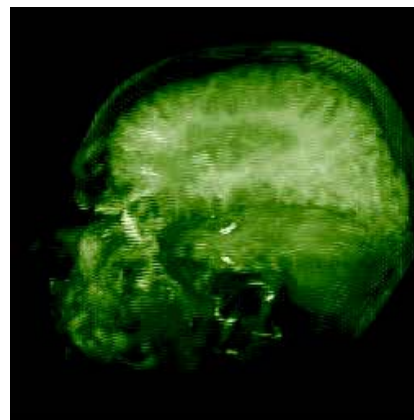
**zvezno porazdeljeni spini**

$$S = \int \rho_r \sin(\omega_r t + \varphi_r) dV$$





# SLIKANJE Z MAGNETNO RESONANCO



signal slikovnega elementa

$$S = S_0 \rho \left( 1 - e^{-t_r/T_1} \right) e^{-t/T_2} e^{-bD}$$

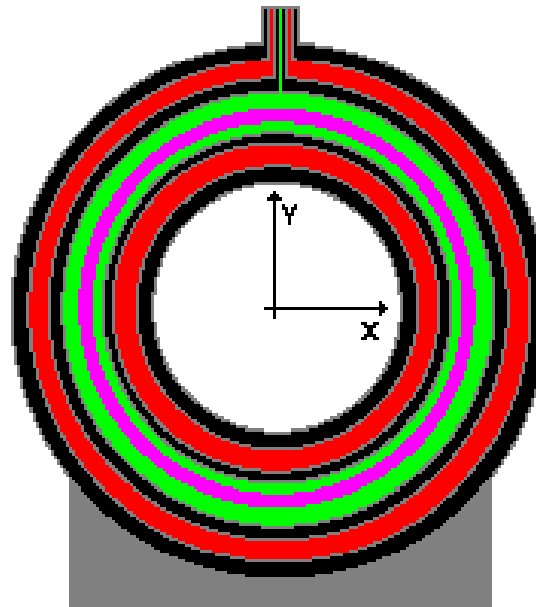
število (običajno) protonov

longitudinalna relaksacija

transverzalna relaksacija

mobilnost molekul

# Homogeno magnetno polje supraprevodni magnet

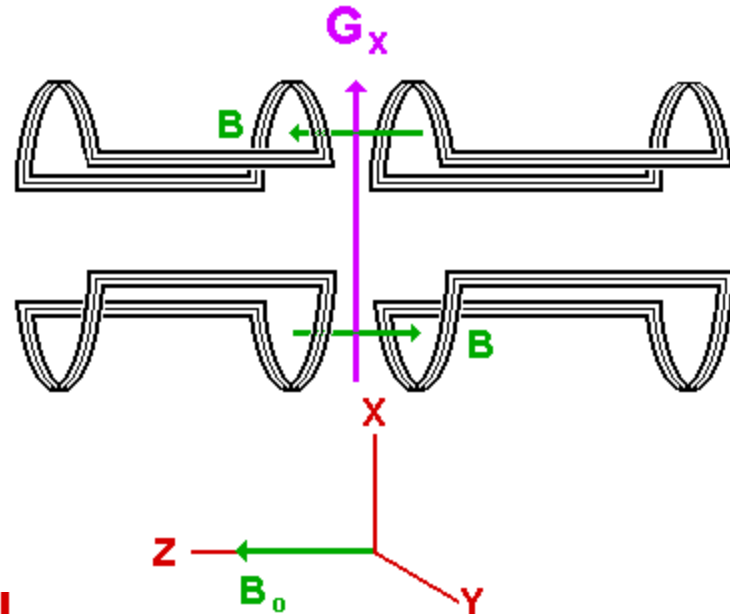


- Vacuum**
- Liquid Helium**
- Liquid Nitrogen**
- Container & Support**
- Superconducting Coil**

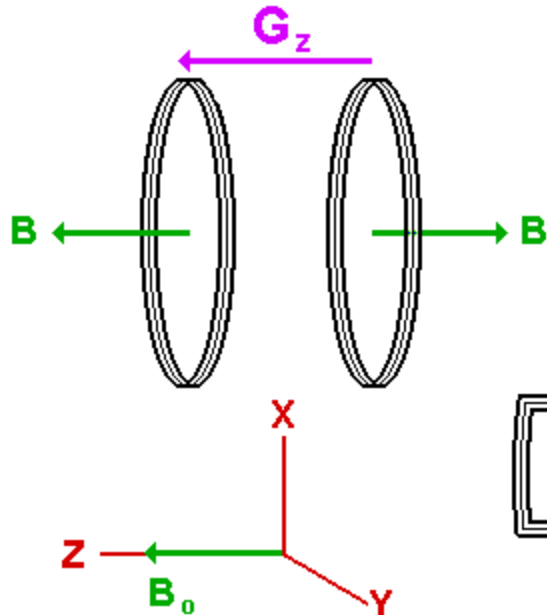
# Gradient magnetnega polja

$$\mathbf{B} = \mathbf{B}_0 + \mathbf{G} \cdot \mathbf{r}$$

X Gradient Coil



Z Gradient Coil



Y Gradient Coil

