ERASMUS+ PROGRAMME

Erasmus+ - Key Action 2

Capacity Building in the Field of Higher Education

Project No: 585980-EPP-1-2017-1-DE-CBHE-JP

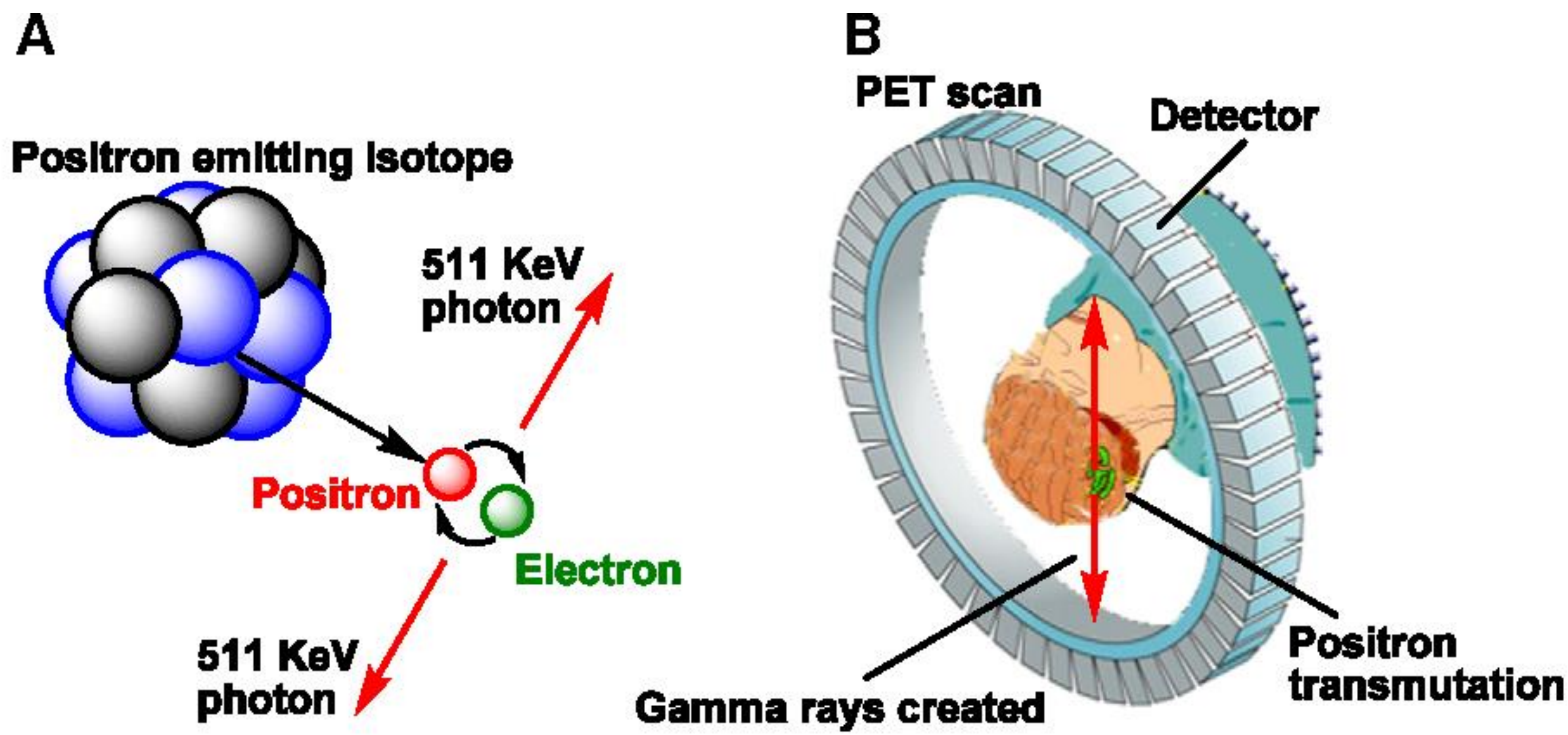
Training for Medical education via innovative eTechnology /MediTec

July 8-19, 2019

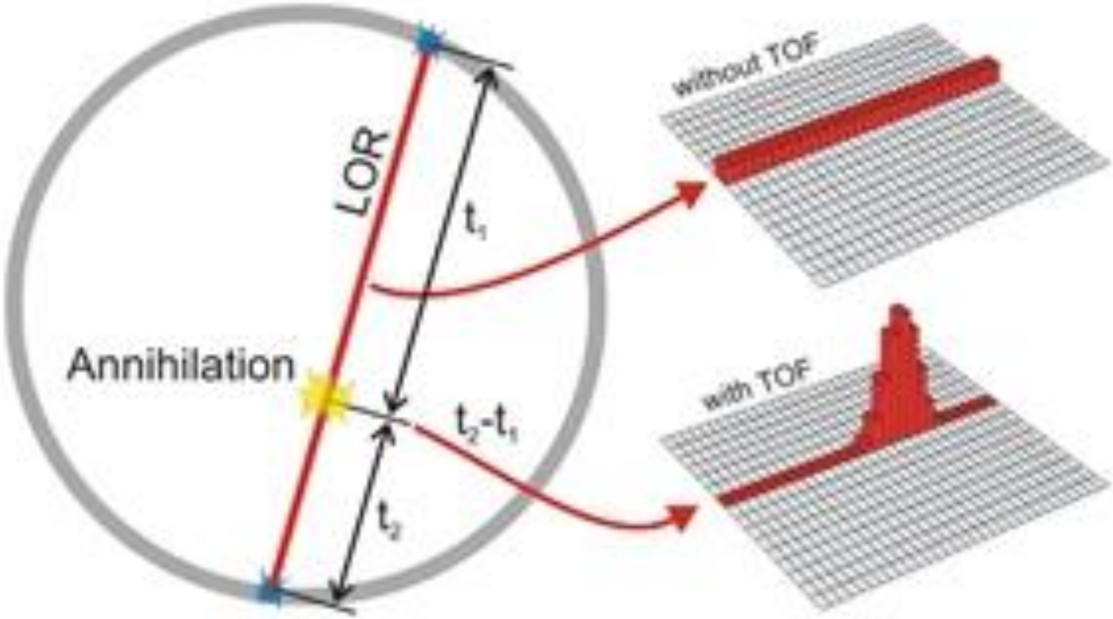
Programme for Training for students in Brno

Masaryk University, Faculty of Medicine, Center for Healthcare Quality, Brno, Czech Republic

PET principles



TOF principles



PET detectors

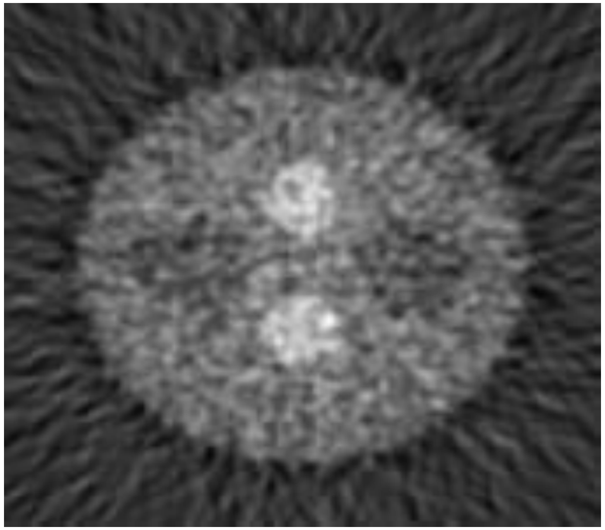
	Photomultiplier Tube (PMT)	Avalanche Photodiode (APD)	Silicon Photomultipliers (SiPM)
LBS Crystal Dimensions	4.2x6.3x25mm	4x4x20mm	4x5.3x25mm
Transaxial Spatial Resolution	4.9	4.4	4.1
Detector Profile	100mm	2mm	2mm
MR Compatibility	No	Yes	Yes
Photon Detection Efficiency	25%	50%	50%
Gain	10^6	10^2	10^5-10^6
Timing Resolution	550ps	~2000ps	<400ps

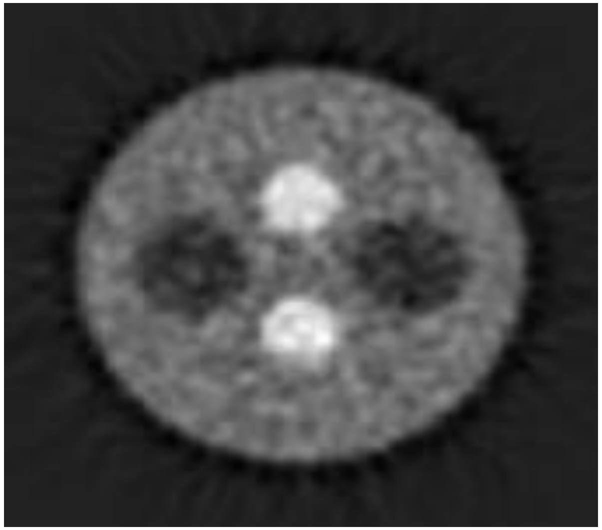
TOF may improve PET performance by enhancing count rate quality

Conventional PET

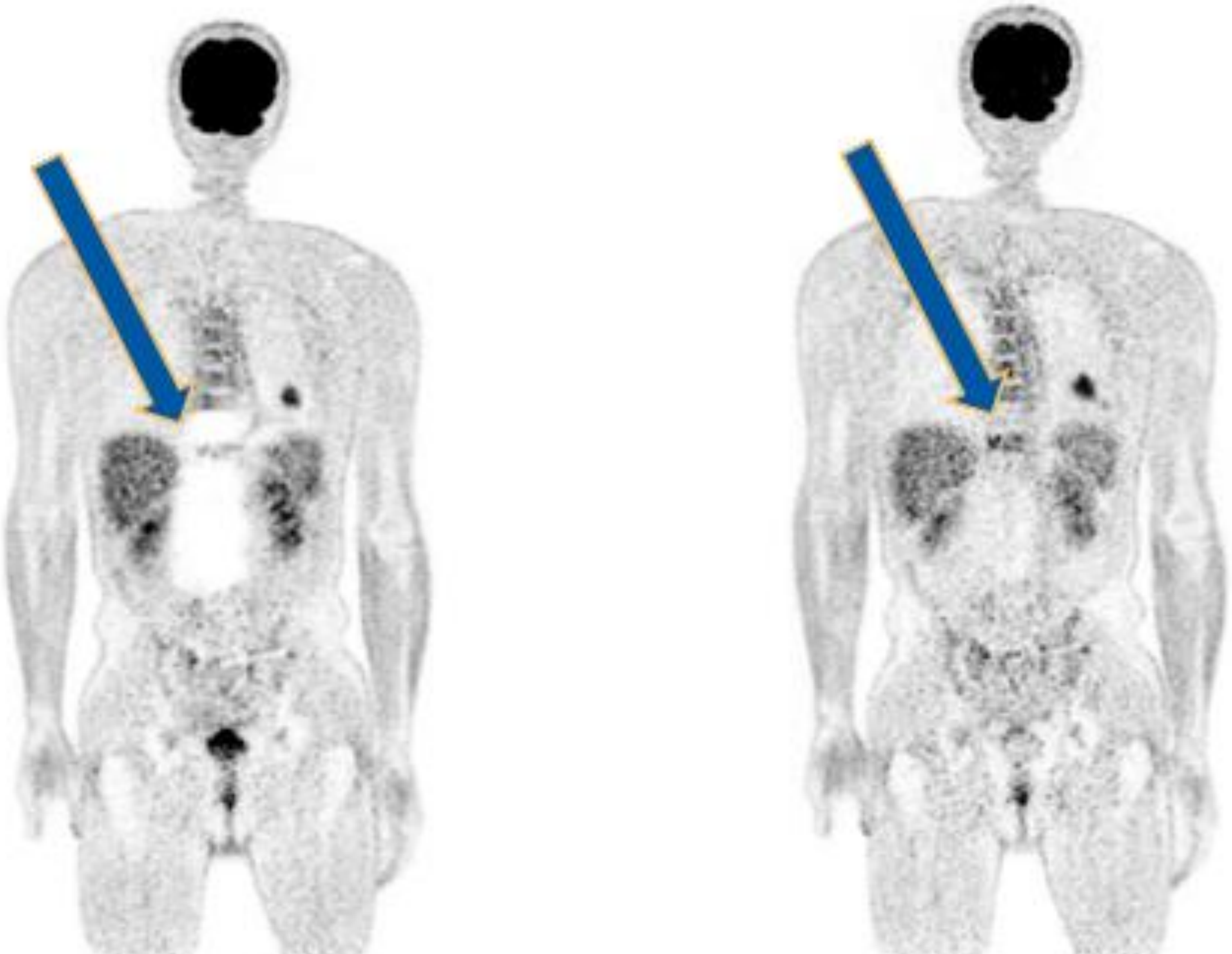
TOF PET

TOF improves SNR and CNR in PET reconstructed data



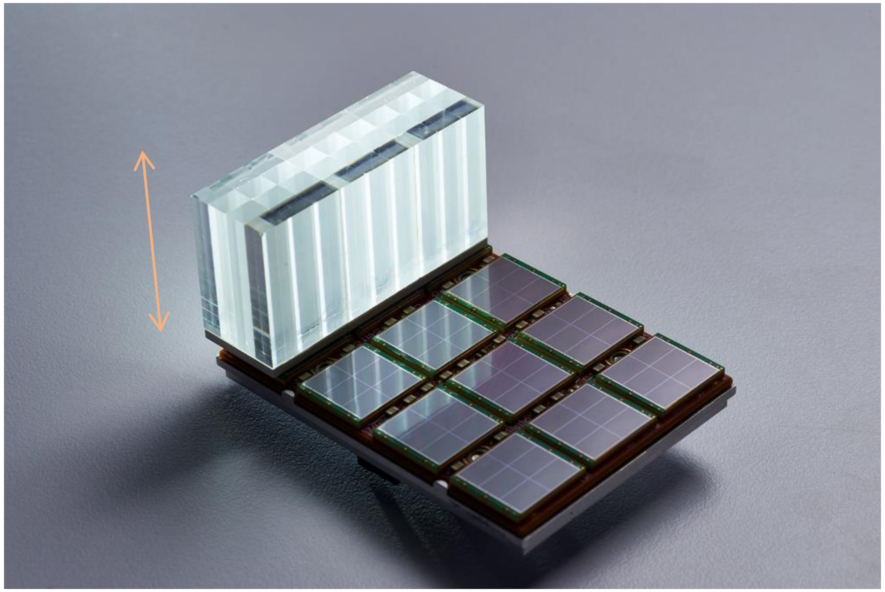


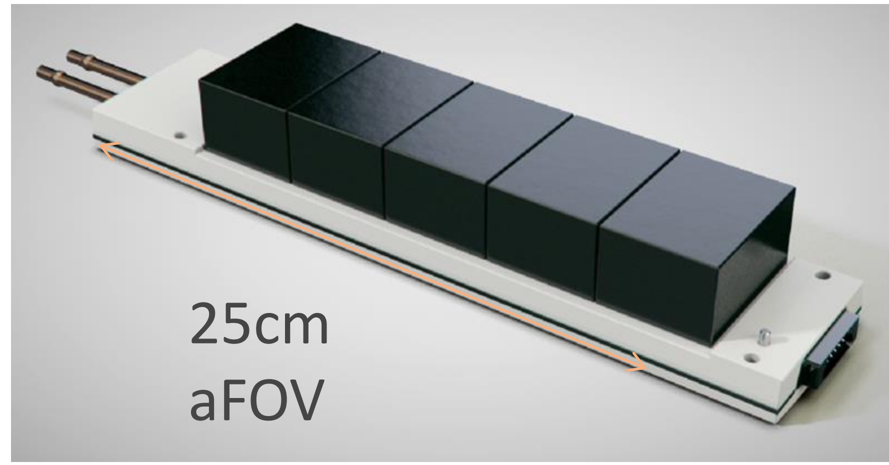
TOF is more robust to attenuation artifacts



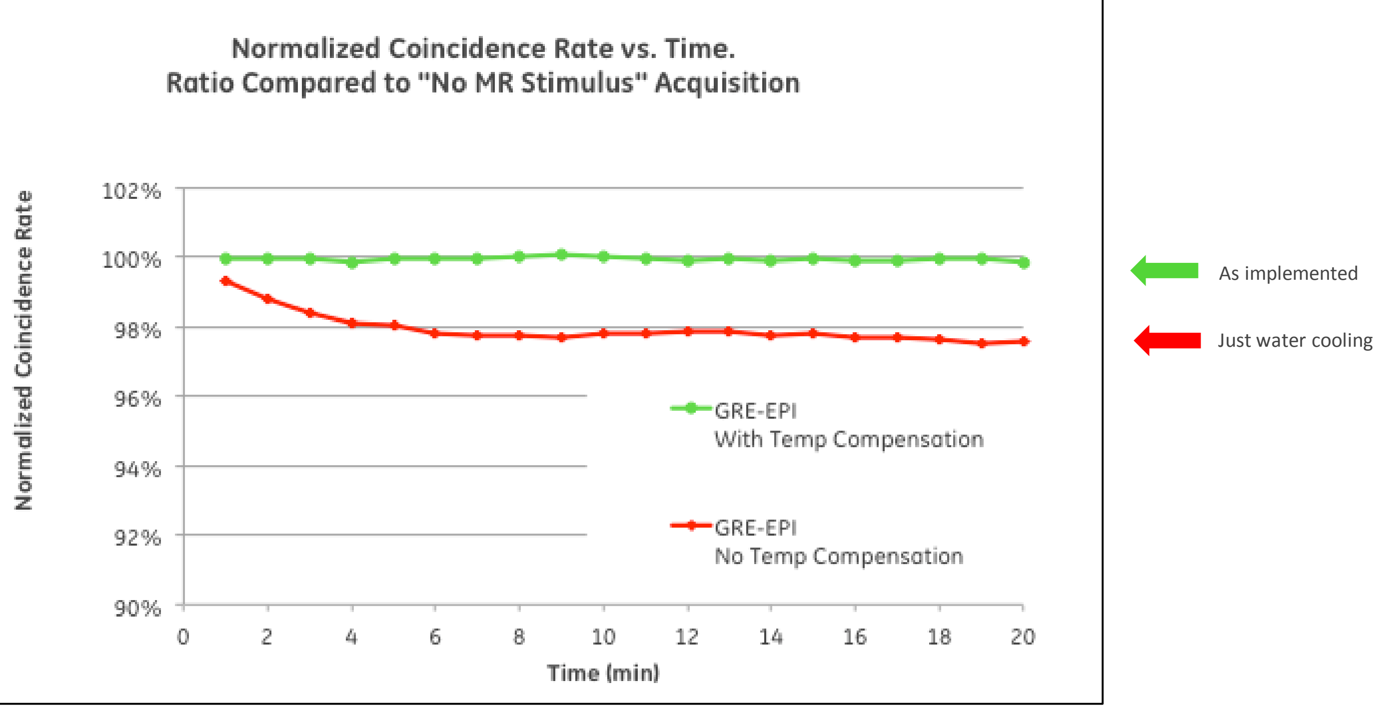
Exceptional sensitivity at 21 cps/kBq

- 25mm crystal with 25cm FOV
- Lutetium-based scintillator (LBS)
- Miniaturized, integrated PET electronics

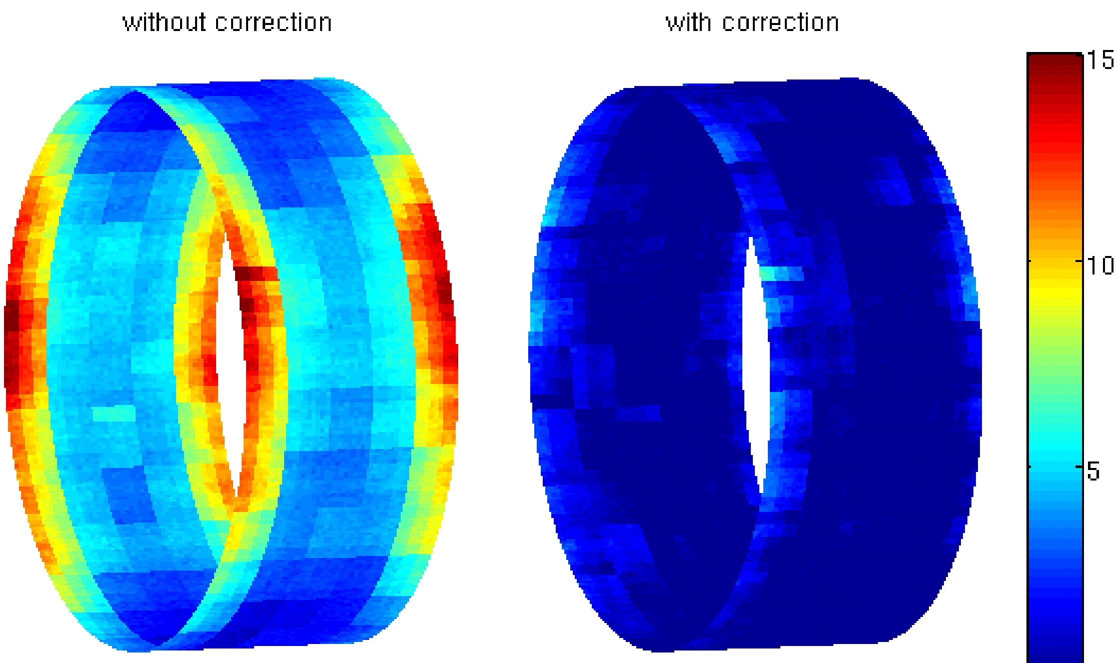




25 mm deep Lutetium-based scintillators (LBS)



Normalized Coincidence Rate vs. Time.
Ratio Compared to "No MR Stimulus" Acquisition
Normalized Coincidence Rate
102%
100%
98%
96%
94%
92%
90%
0
2
4
6
8
10
12
14
16
18
20
Time (min)
GRE-EPI
With Temp Compensation
GRE-EPI
No Temp Compensation
As implemented
Just water cooling

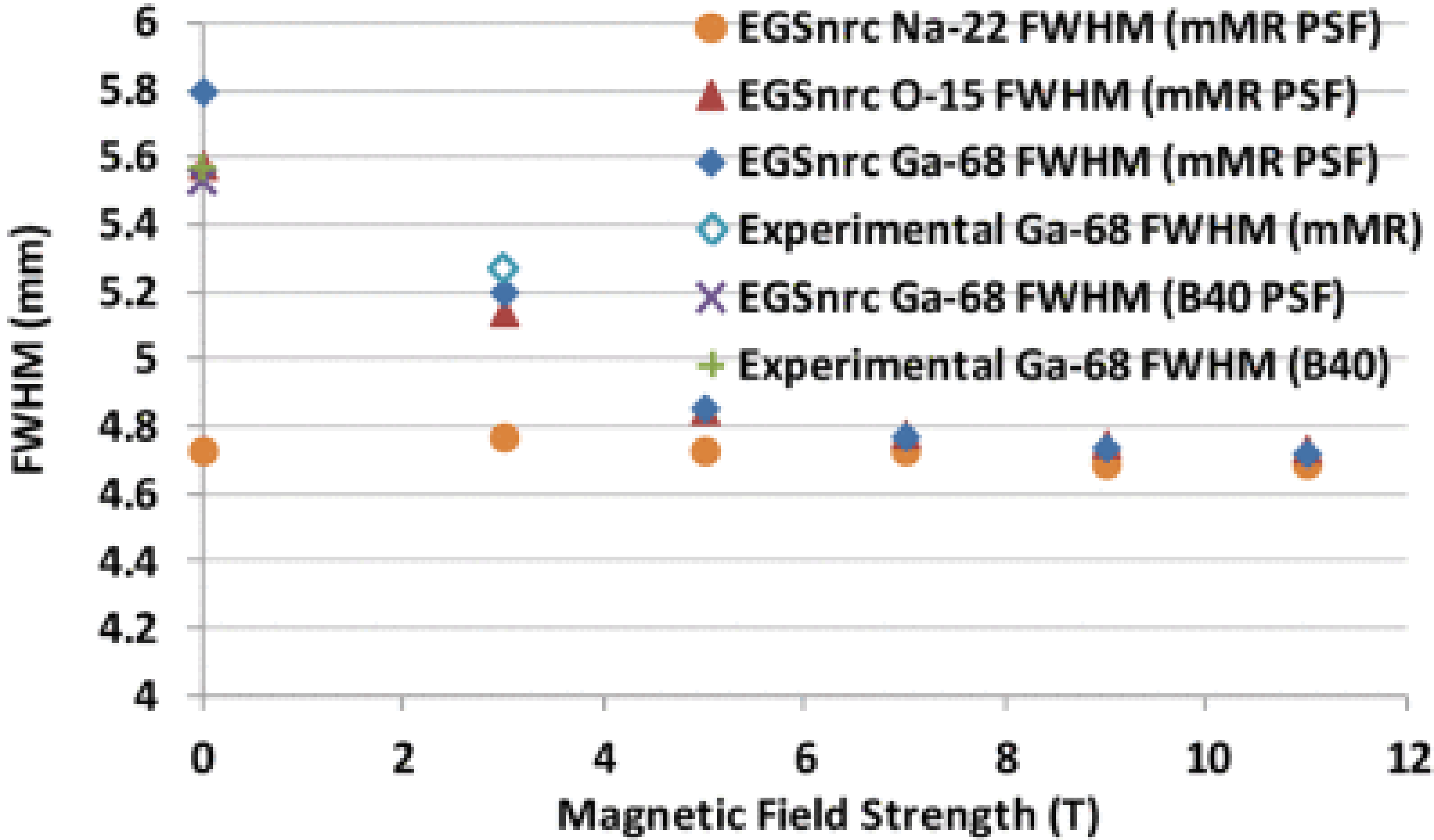


without correction
with correction
15
10
5

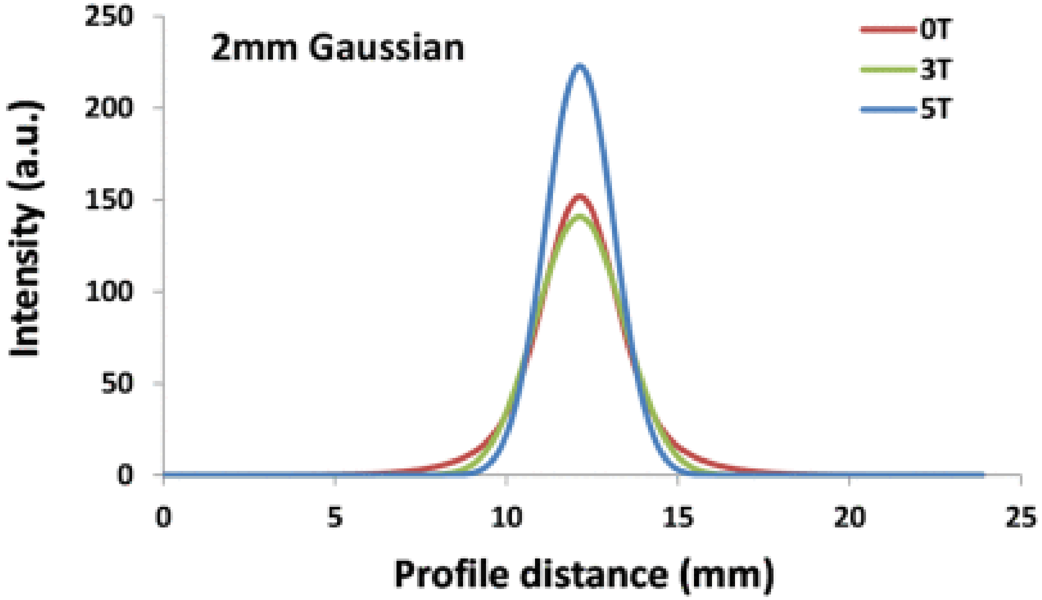
	SIGNA PET/MR				750w	
	No PET Acq.		With PET Acq.		No PET Ring	
	Mean	Std	Mean	Std	Mean	Std
Head and Neck Receive Coil						
RMS(%)	0.035	0.002	0.034	0.003	0.037	0.006
P2P(%)	0.2	0.03	0.18	0.03	0.22	0.06
SNR	830	17	832	2	813	15
SFNR	893	46	851	59	851	4

Commonly used positron-emitting radionuclides in PET and their decay properties.

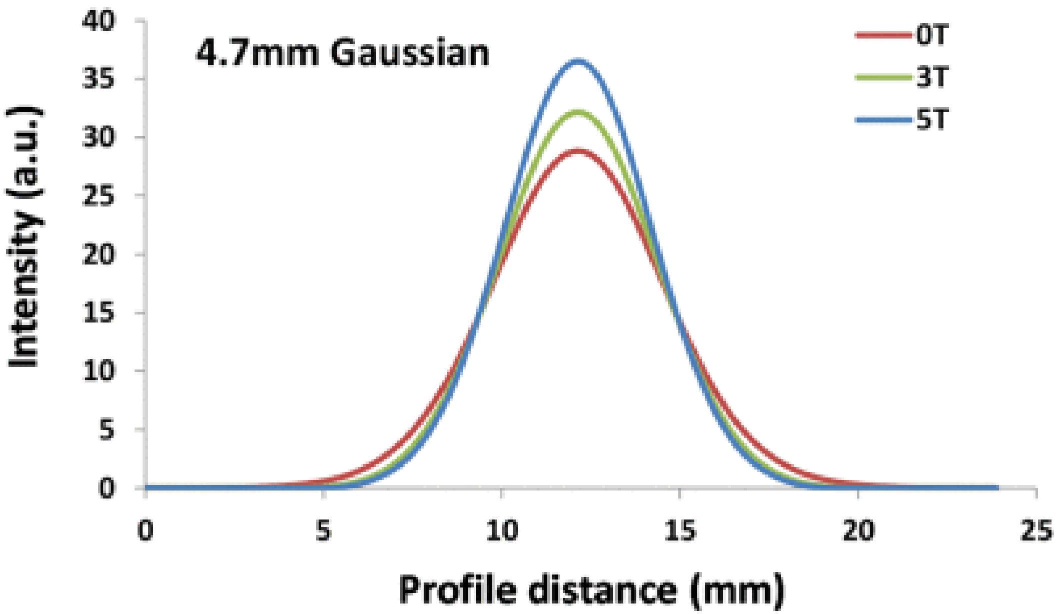
Radionuclide	Half-life	$E_{max}(\beta^+)$	β^+ decay, %	Chemistry
^{71}As	2.7 d	350 KeV	30	Chemical bond (S-As)
^{72}As	1.1 d	1170 KeV	87.8	Chemical bond (S-As)
^{74}As	17.8 d	440 KeV	29	Chemical bond (S-As)
^{76}Br	16.2 h	1310 KeV	54	Organic Chemistry
^{11}C	20.3 min	961 KeV	100	Fast Organic Chemistry
^{34m}Cl	31.99 min	2.5 MeV	53	Organic Chemistry
^{55}Co	17.6 h	1.5 MeV	77	Chelation Chemistry
^{62}Cu	9.8 min	2910 KeV	98	Chelation Chemistry
^{64}Cu	12.8 h	656 KeV	19	Chelation Chemistry
^{18}F	110 min	634 KeV	97	Fast Organic Chemistry
^{52}Fe	8.2 h	800 KeV	57	Chelation Chemistry/
^{66}Ga	9.5 h	4153 KeV	56	Chelation Chemistry
^{68}Ga	67.6 min	1899 KeV	89	Chelation Chemistry
^{124}I	4.17 d	2100 KeV	23	Organic Chemistry
^{52}Mn	134.2 h	0.58 MeV	29	Chelation Chemistry
^{13}N	9.97 min	1190 KeV	100	Fast Organic Chemistry
^{15}O	2.1 min	1732 KeV	100	Fast on-line gas phase chemistry
^{82}Rb	76 sec	3150 KeV	95	Chelation Chemistry
^{94m}Tc	52.5 min	2470 KeV	72	Chelation Chemistry
^{86}Y	14.7 h	3150 KeV	34	Chelation Chemistry
^{89}Zr	78.4 h	897 KeV	23	Chelation Chemistry
^{22}Na	2.6 y	546 KeV	90	



EGSnrc Na-22 FWHM (mMR PSF)
EGSnrc O-15 FWHM (mMR PSF)
EGSnrc Ga-68 FWHM (mMR PSF)
Experimental Ga-68 FWHM (mMR)
EGSnrc Ga-68 FWHM (B40 PSF)
Experimental Ga-68 FWHM (B40)
FWHM (mm)
6
5.8
5.6
5.4
5.2
5
4.8
4.6
4.4
4.2
4
0
2
4
6
8
10
12
Magnetic Field Strength (T)



2mm Gaussian
0T
3T
5T
Intensity (a.u.)
250
200
150
100
50
0
0
5
10
15
20
25
Profile distance (mm)



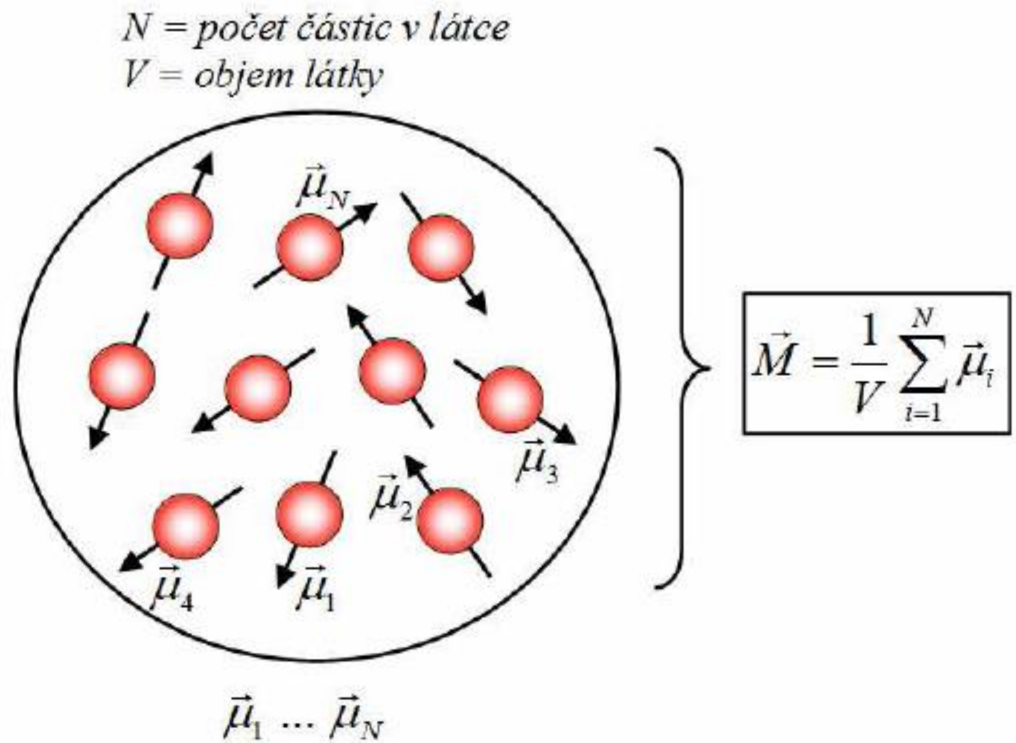
4.7mm Gaussian
0T
3T
5T
Intensity (a.u.)
40
35
30
25
20
15
10
5
0
0
5
10
15
20
25
Profile distance (mm)

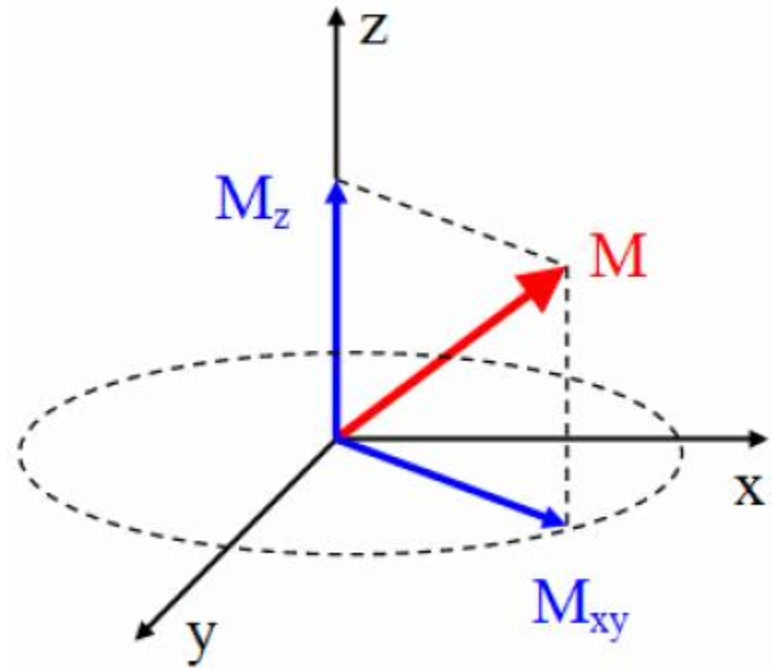
- Nuclear magnetic momentum:

$$\vec{\mu} = \gamma \vec{S}$$

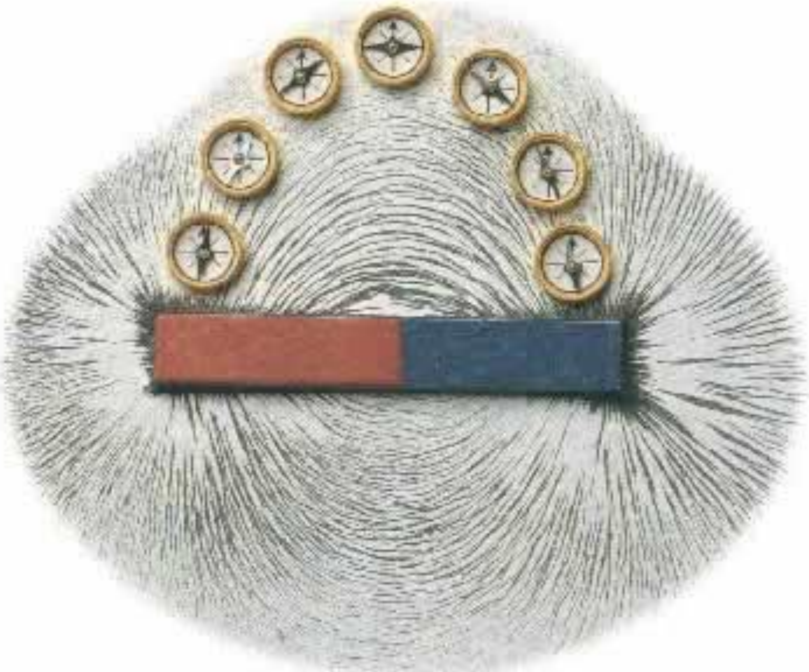
Prvek		Spin s	$\gamma[10^8 T^{-1} s^{-1}]$	Výskyt [%]
Vodík	^{1}H	1/2	2,68	99,985
Deut.	^{2}H	1	0,41	0,015
Uhlík	^{13}C	1/2	0,67	1,11
Dusík	^{14}N	1	0,19	99,63
Dusík	^{15}N	1/2	-0,27	0,37
Fluor	^{19}F	1/2	2,51	100
Sodík	^{23}Na	3/2	0,71	100
Fosfor	^{31}P	1/2	1,08	100

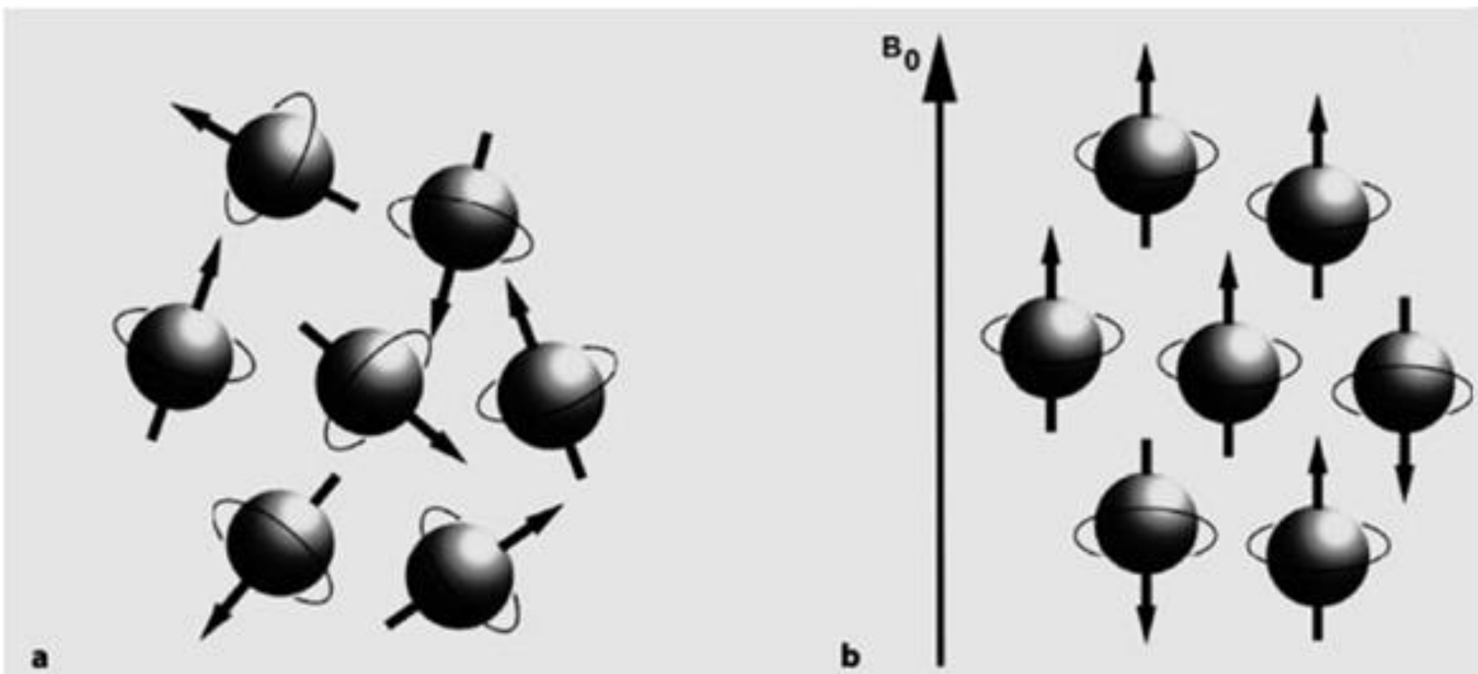
Magnetization

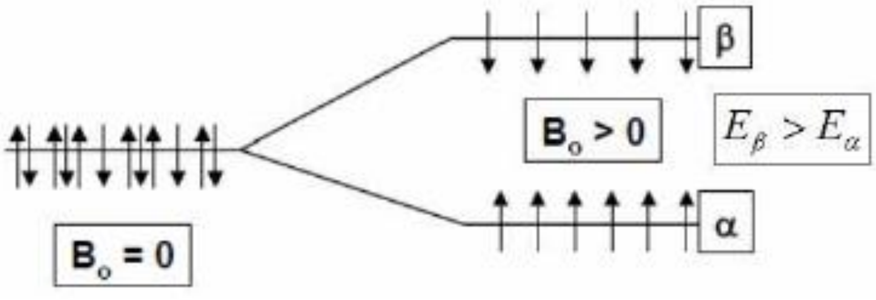




Thermal equilibrium mostly <M> = 0

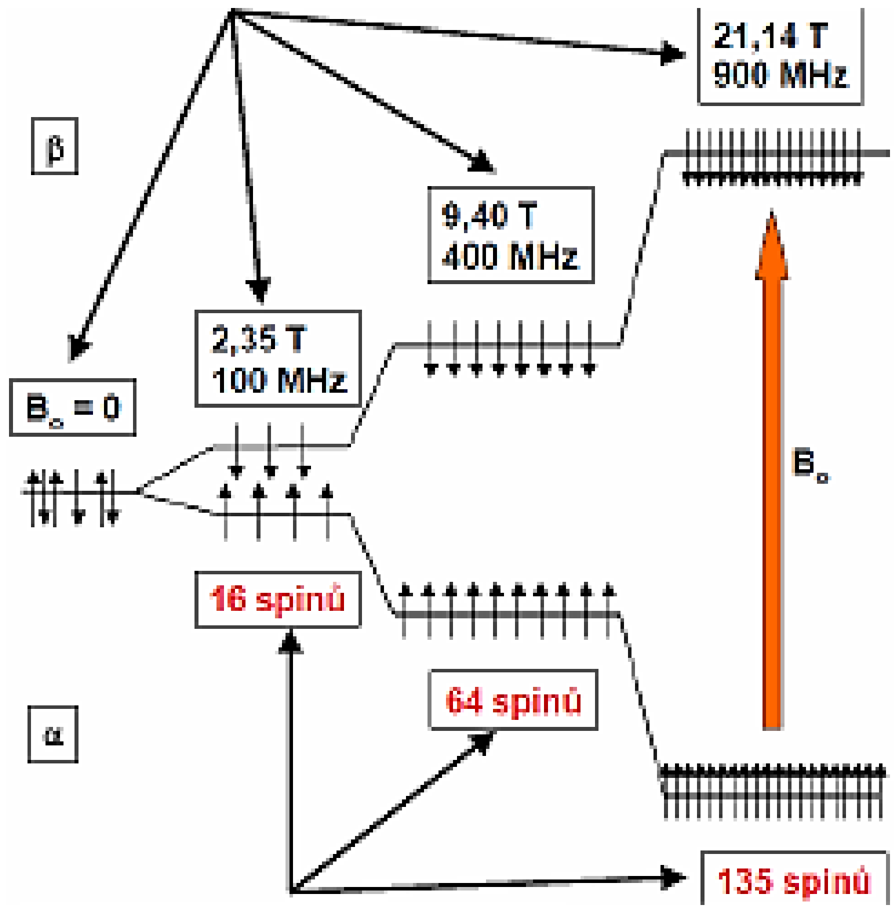


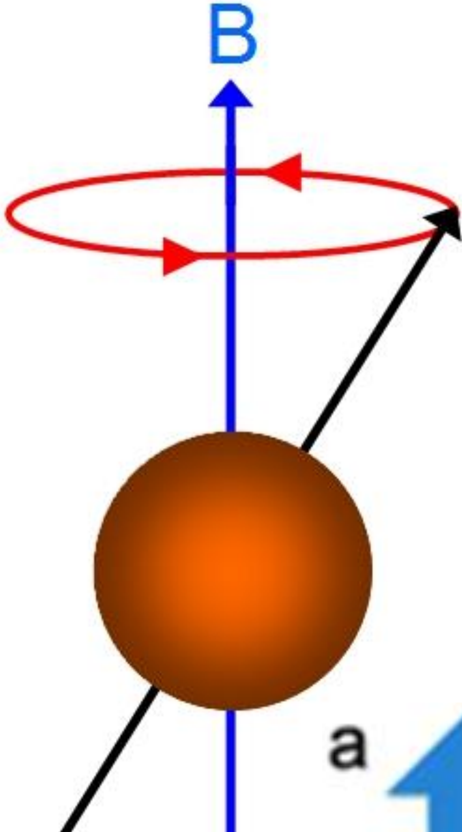

B0
a
b



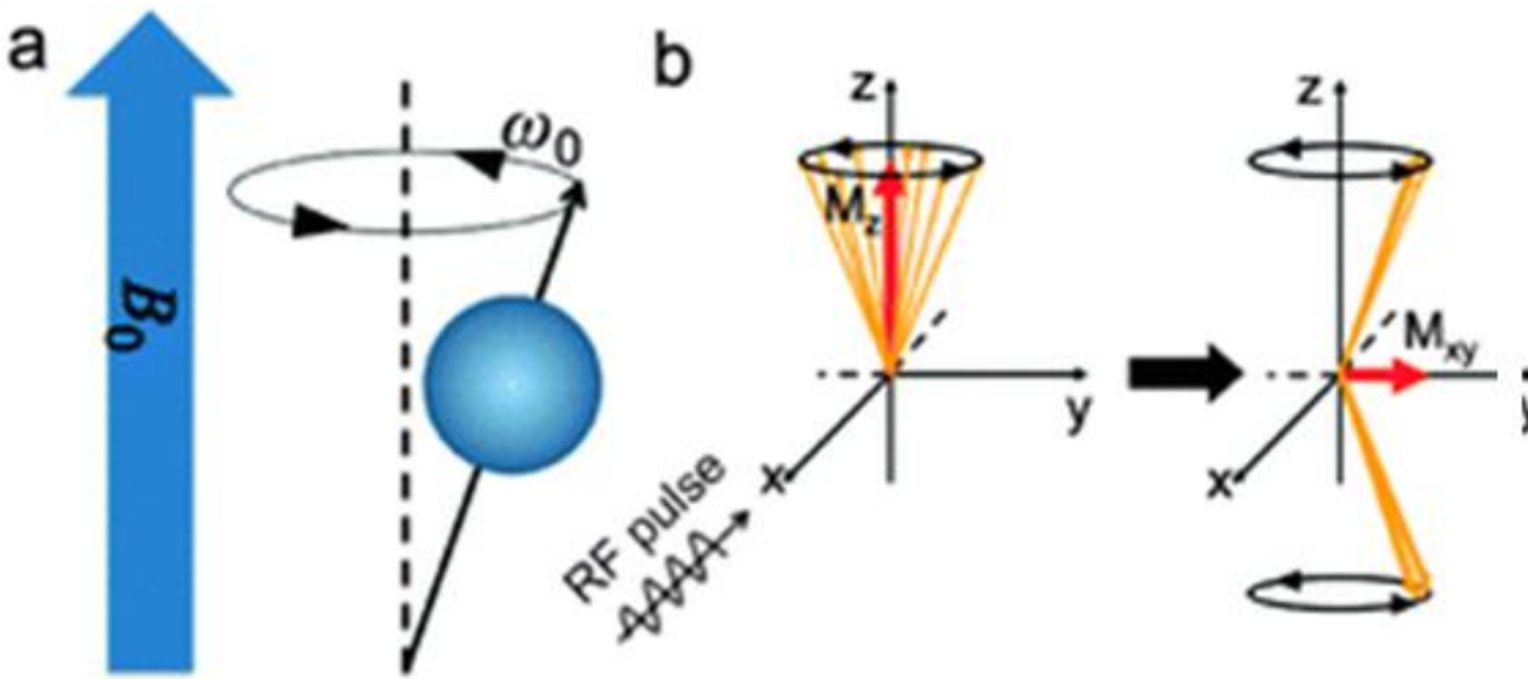
$$\frac{N_\alpha}{N_\beta} = e^{\left(\frac{\Delta E}{k_B T}\right)} = e^{\left(\frac{h\frac{\gamma}{2\pi}B_0}{k_B T}\right)} = e^{\left(\frac{h f_L}{k_B T}\right)}$$

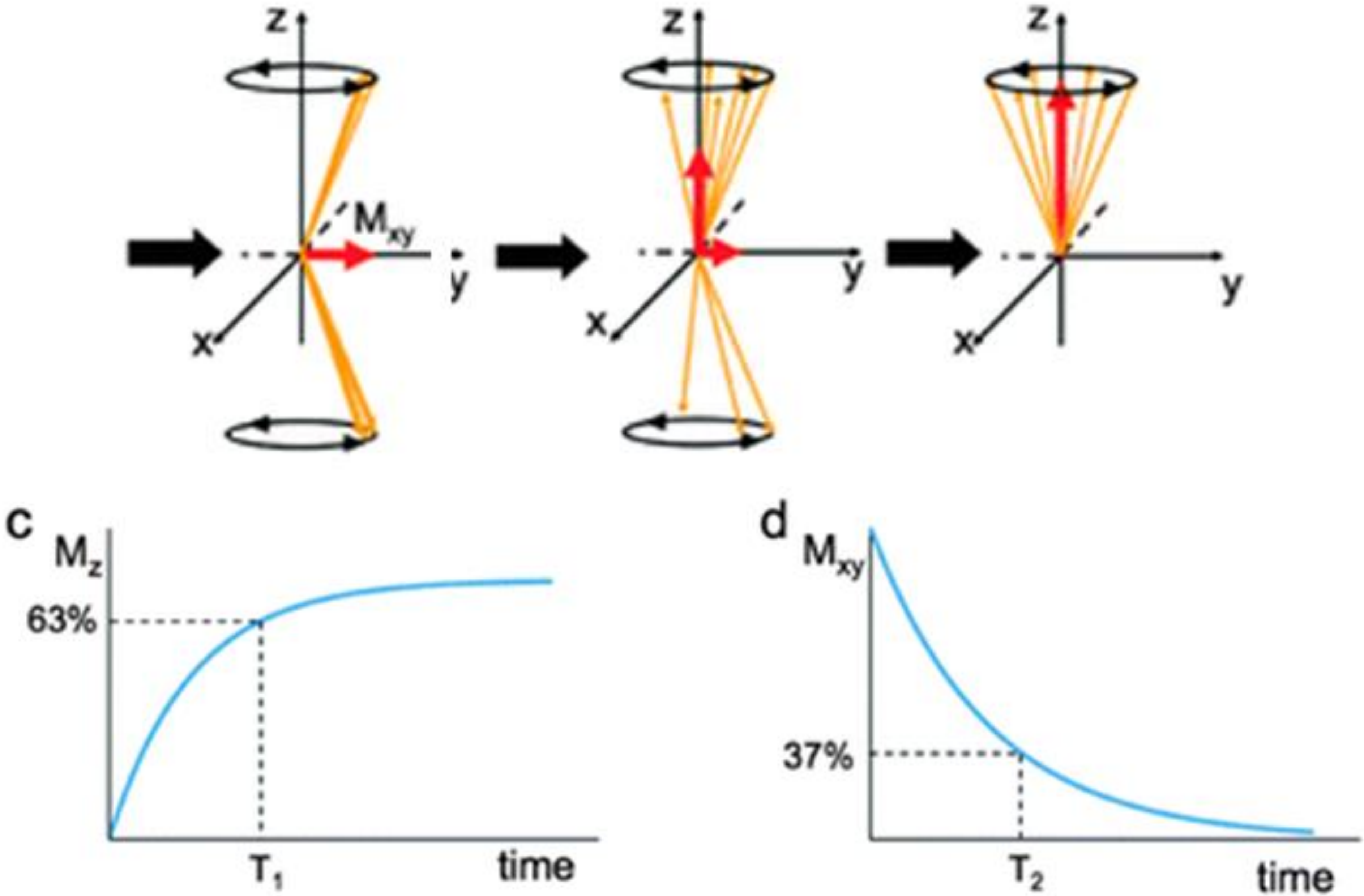
$$\frac{N_\alpha}{N_\beta}(T = 300K, B_0 = 9.4T) \cong 1.000064$$





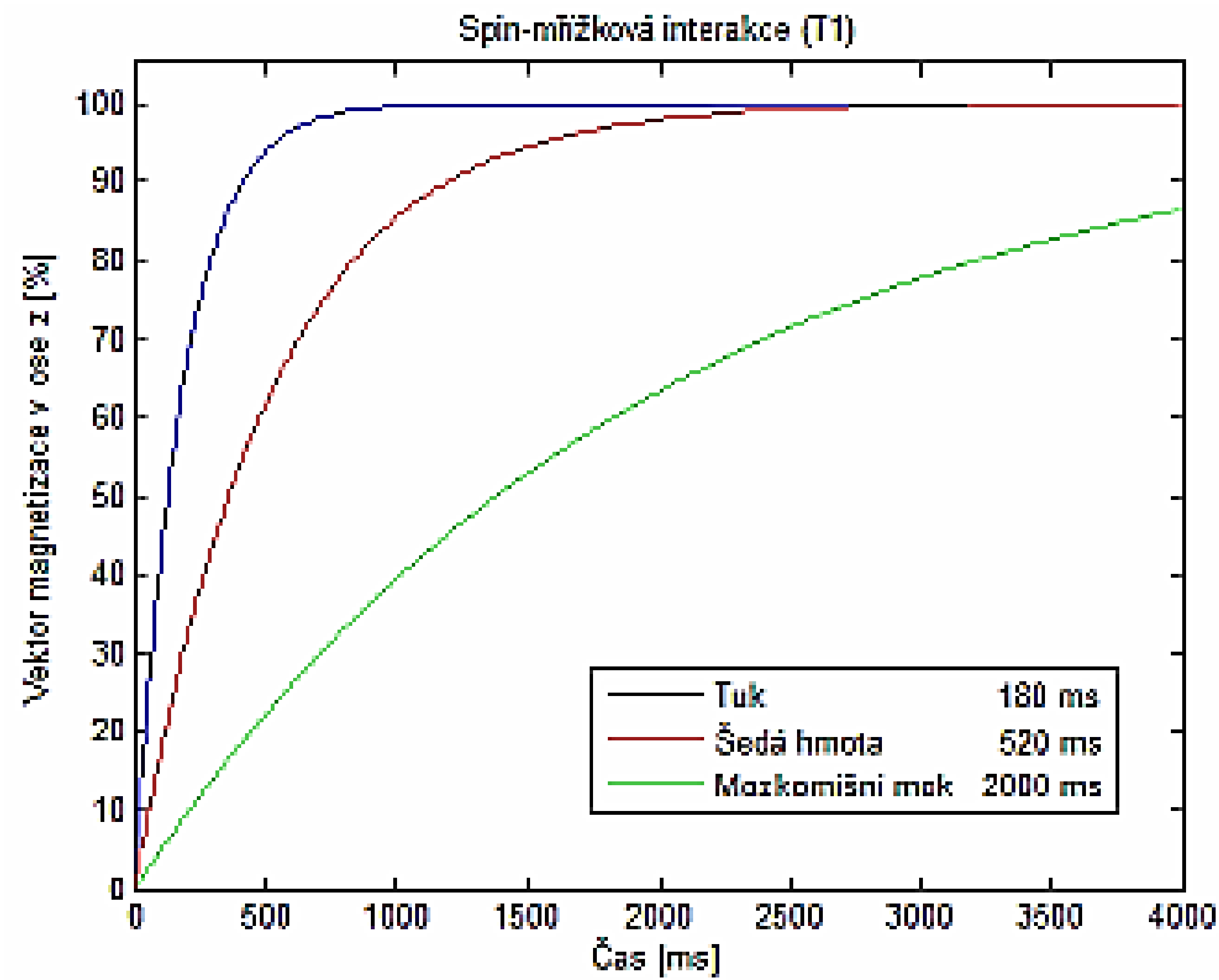
$$f_L = \frac{\gamma}{2\pi} B_0$$



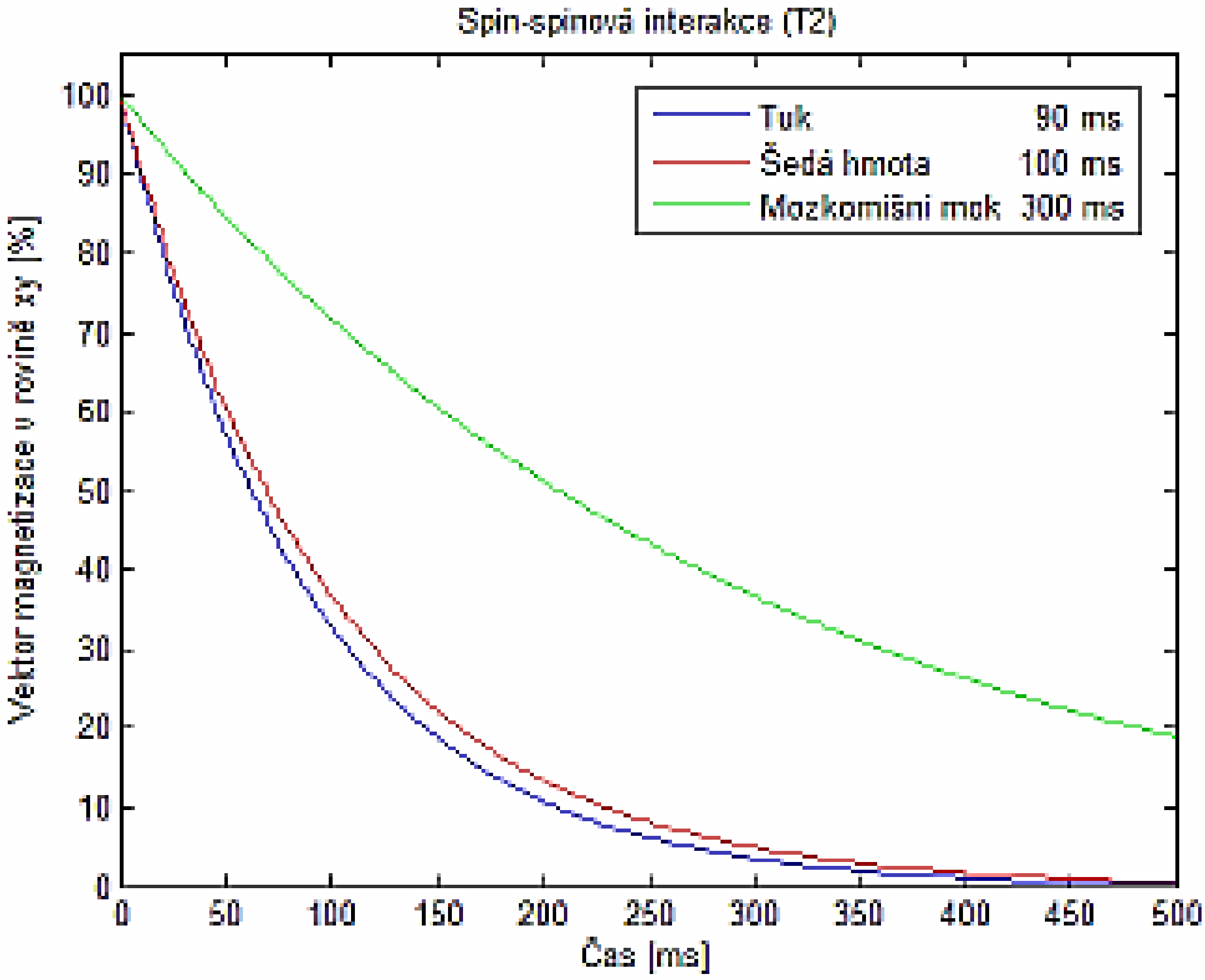


z
z
z
M$_{xy}$
y
y
y
x
x
x
c
M$_z$
63%
T$_1$
time
d
M$_{xy}$
37%
T$_2$
time

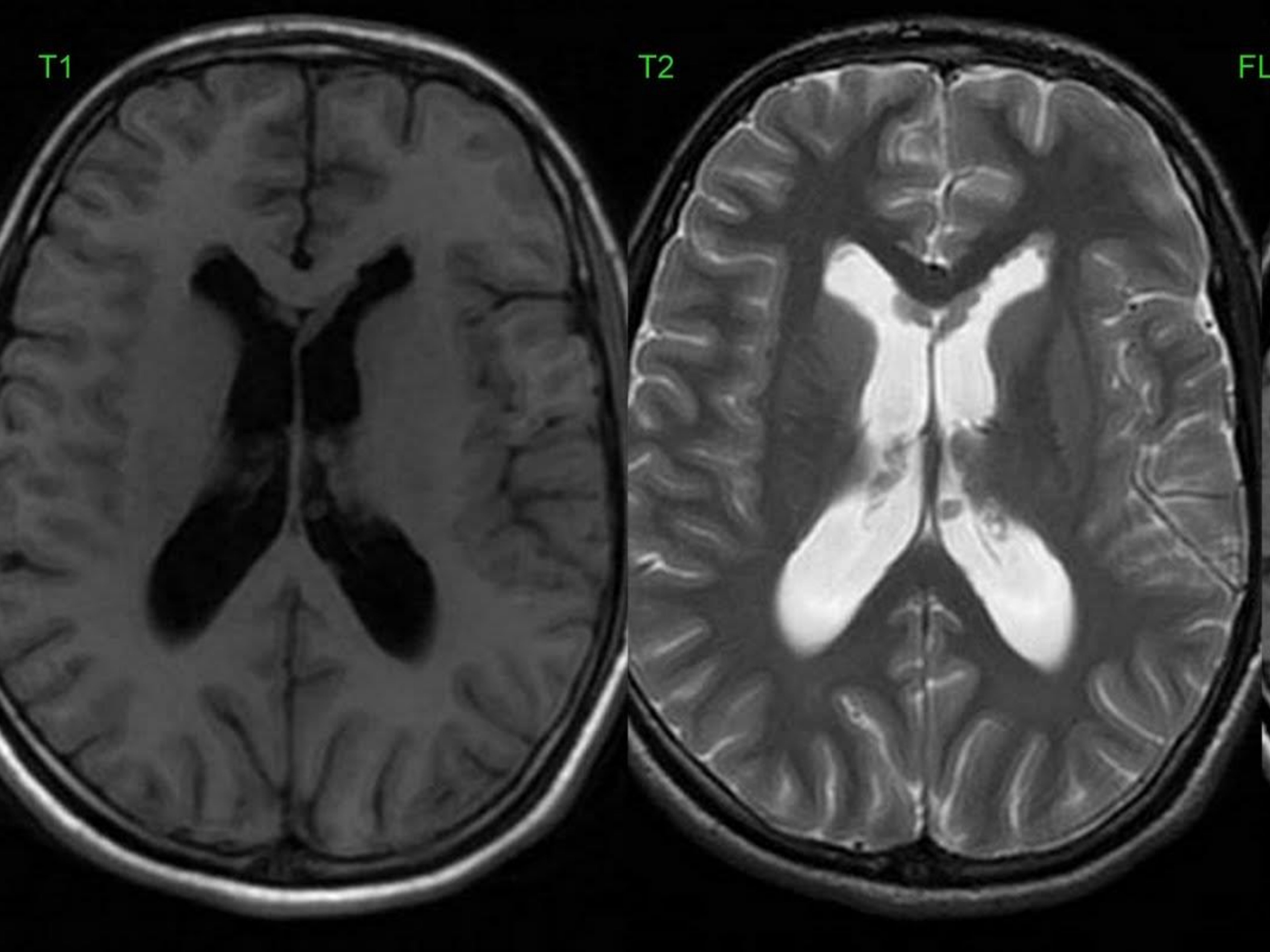
Tissue	T_1 [ms]	T_2 [ms]
Fat	250	60
Muscule	900	50
Blood	1400	100-200
Brain		
GM	950	100
WM	600	80
CSF	2000	250

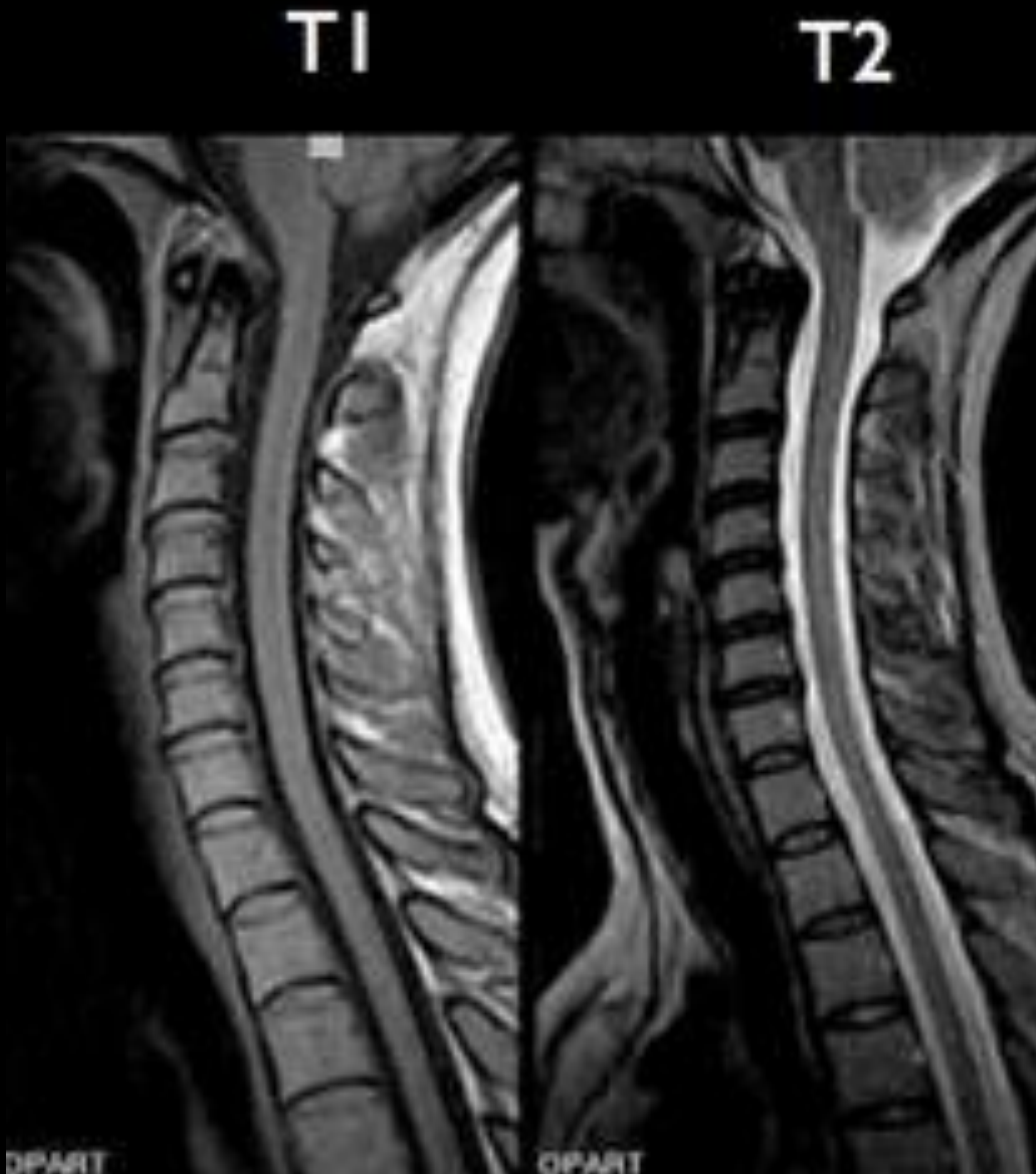


Spin-mřížková interakce (T1)
Vektor magnetizace v ose z [%]
Čas [ms]
0
10
20
30
40
50
60
70
80
90
100
0
500
1000
1500
2000
2500
3000
3500
4000
Tuk 180 ms
Šedá hmota 520 ms
Mozkomíšní mok 2000 ms

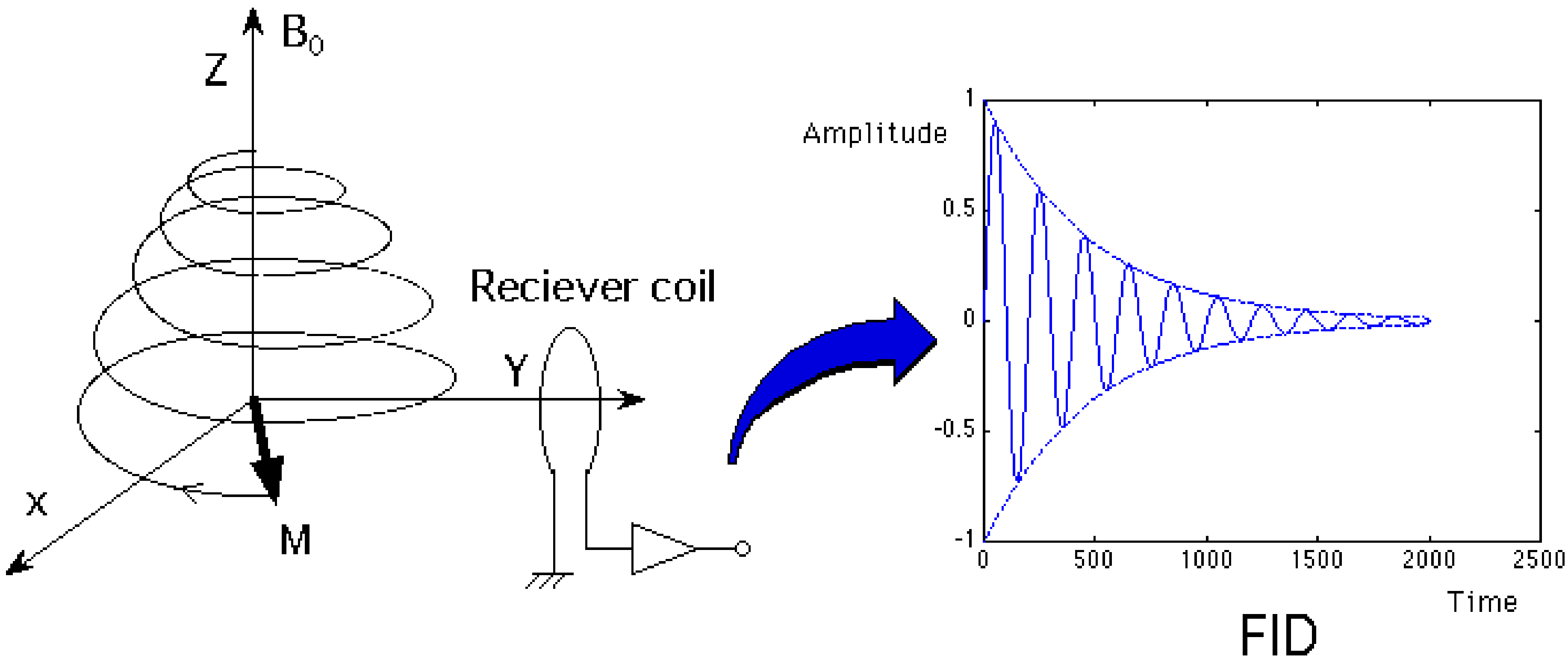


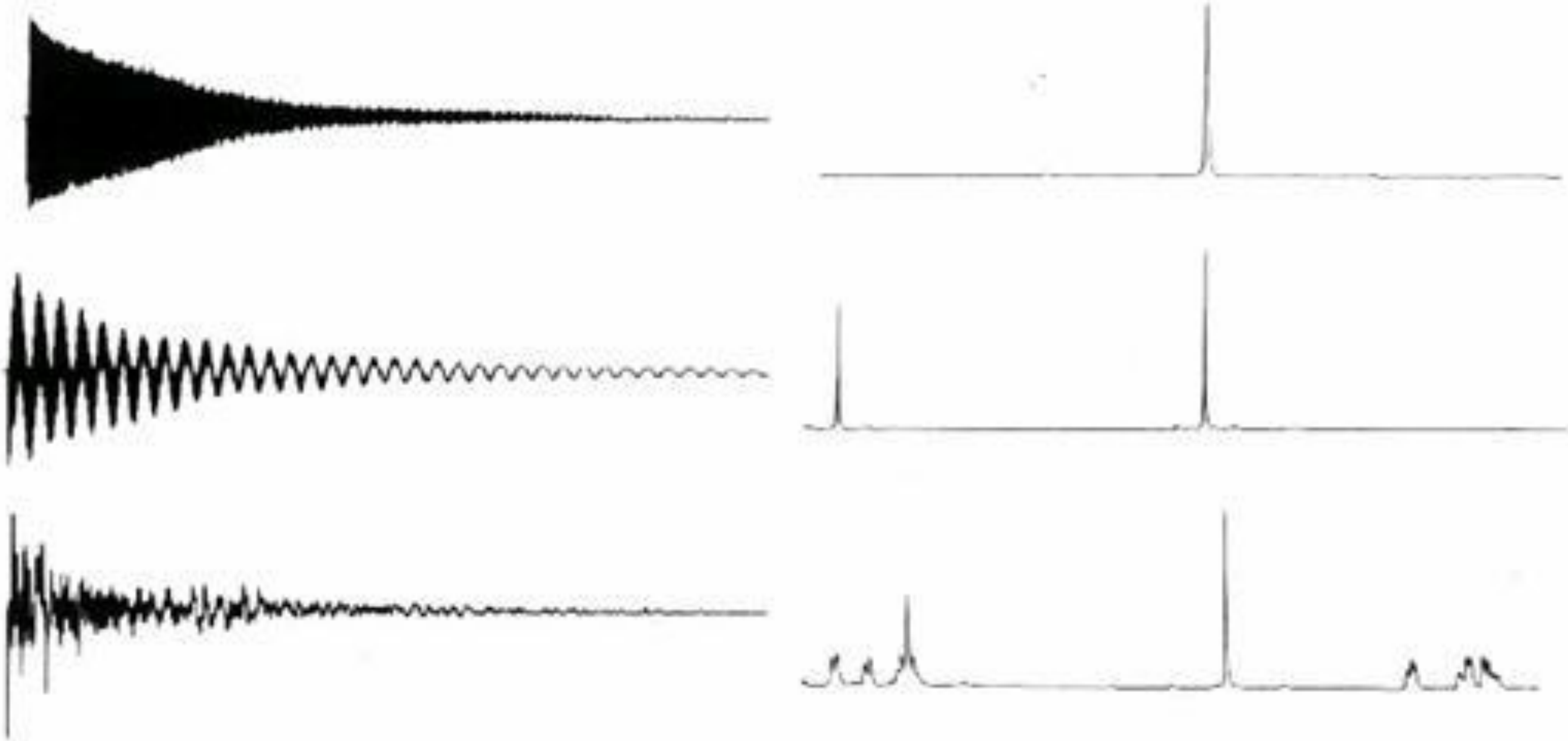
Spin-spinová interakce (T2)
Tuk 90 ms
Šedá hmota 100 ms
Mozkomišní mok 300 ms
Vektor magnetizace v rovině xy [%]
0
10
20
30
40
50
60
70
80
90
100
0
50
100
150
200
250
300
350
400
450
500
Čas [ms]


T1
T2
FL

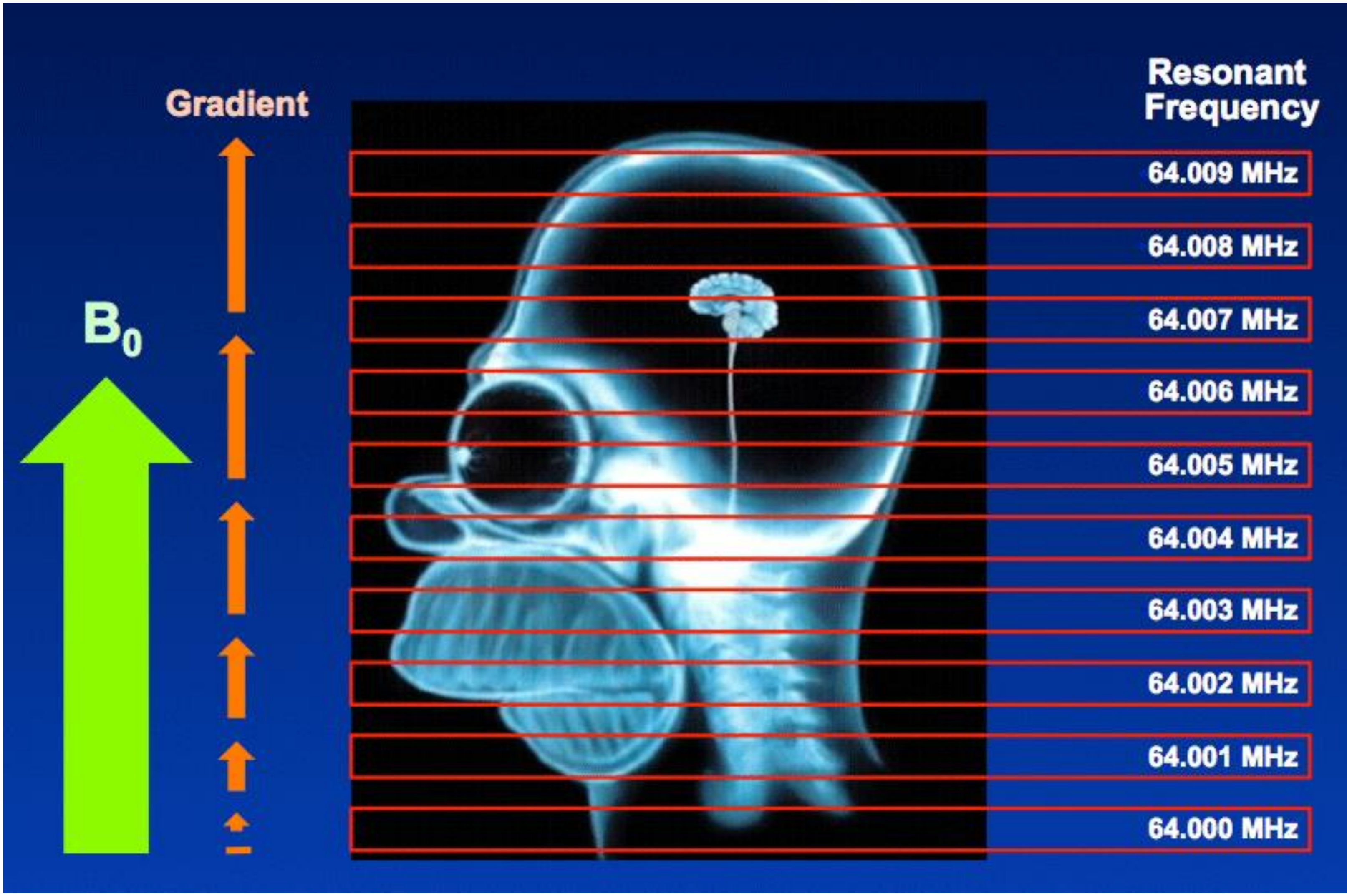

T1
T2

Space encoding

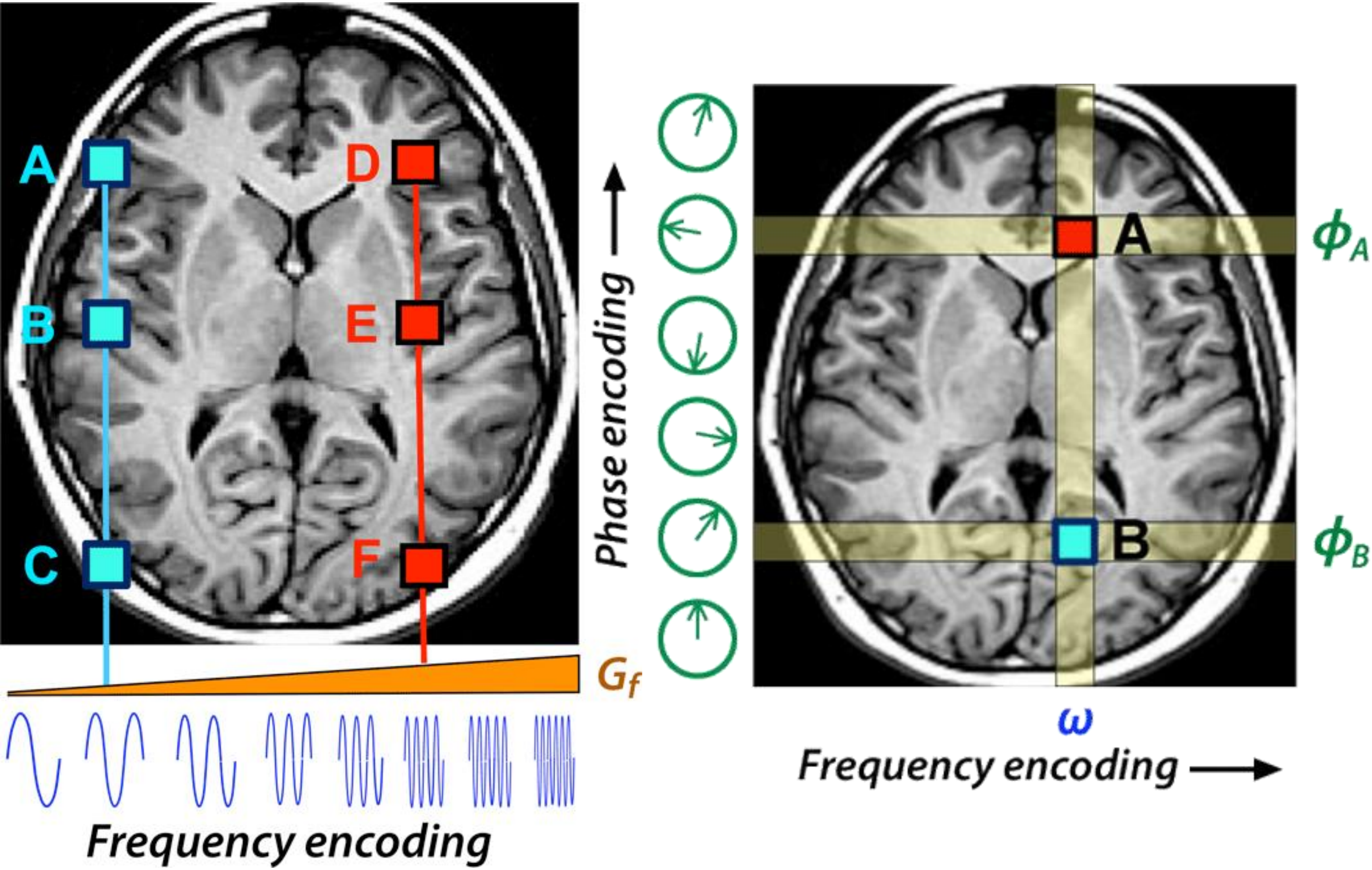




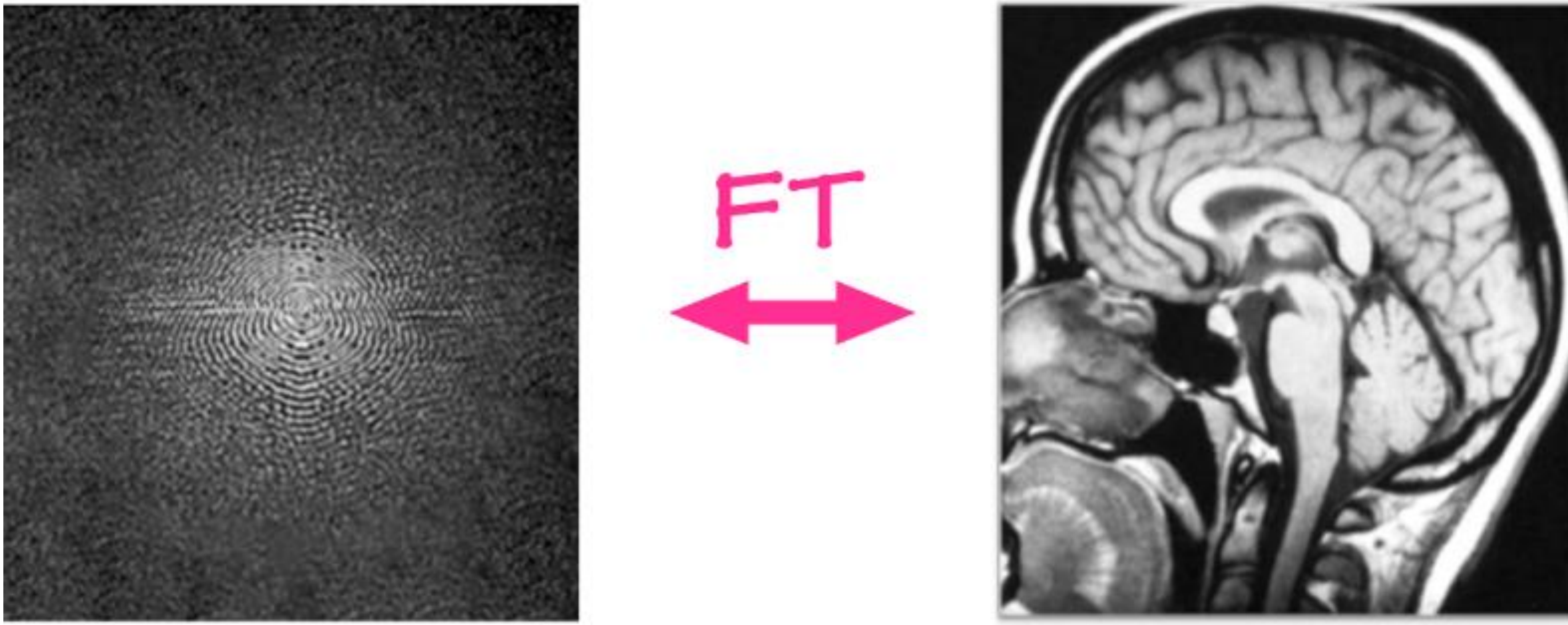
$$S(\omega) = \int_{-\infty}^{\infty} s(t) e^{-i\omega t} dt$$

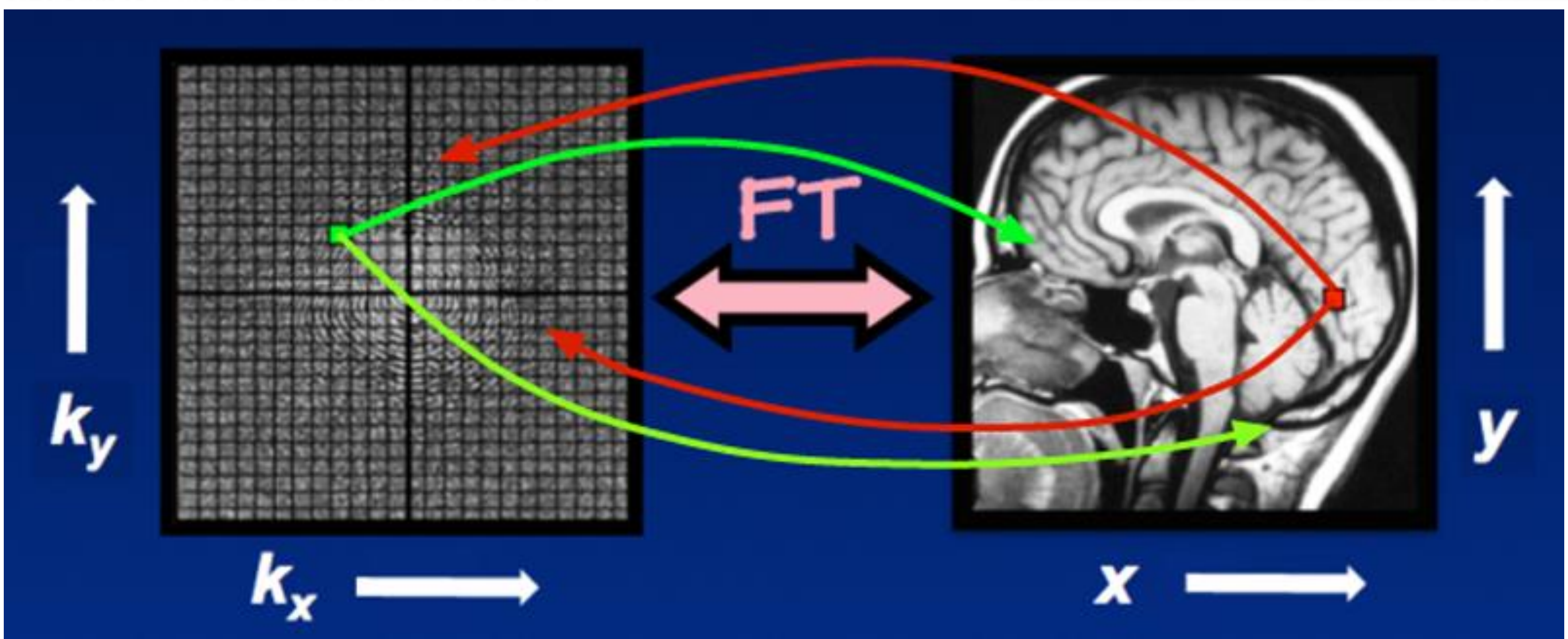


Gradient
Resonant Frequency
B_0
64.009 MHz
64.008 MHz
64.007 MHz
64.006 MHz
64.005 MHz
64.004 MHz
64.003 MHz
64.002 MHz
64.001 MHz
64.000 MHz



A
B
C
D
E
F
G_f
Frequency encoding
Phase encoding
A
B
ϕ_A
ϕ_B
ω
Frequency encoding


FT


FT
k_y
k_x
y
x

Chemical shift