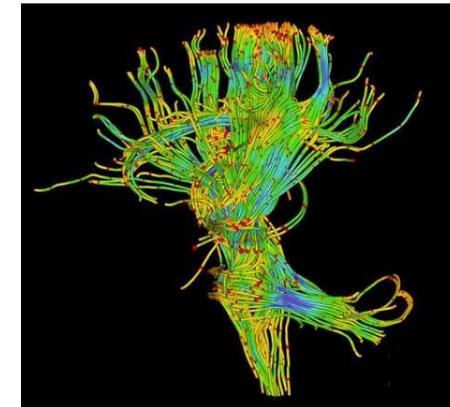
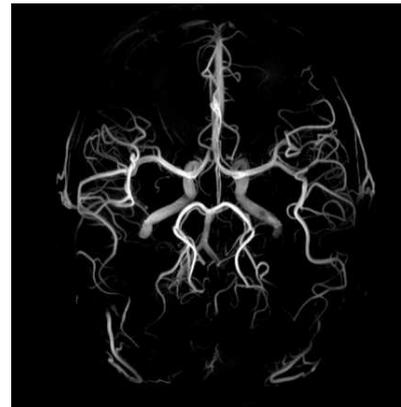
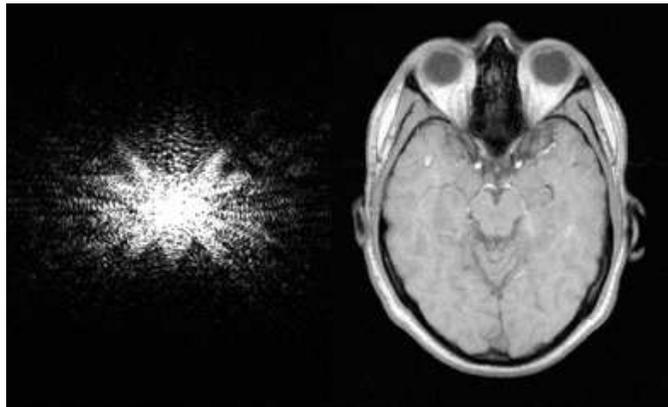


Compléments de RMN

Formation de l'image

Séquences d'acquisition



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UM – CHU Montpellier
catherine.lozza@umontpellier.fr

<http://scinti.edu.umontpellier.fr/enseignements/cours/>

I. Rappels RMN PACES

- Séquence de RMN
- Les pondérations

II. Formation de l'image

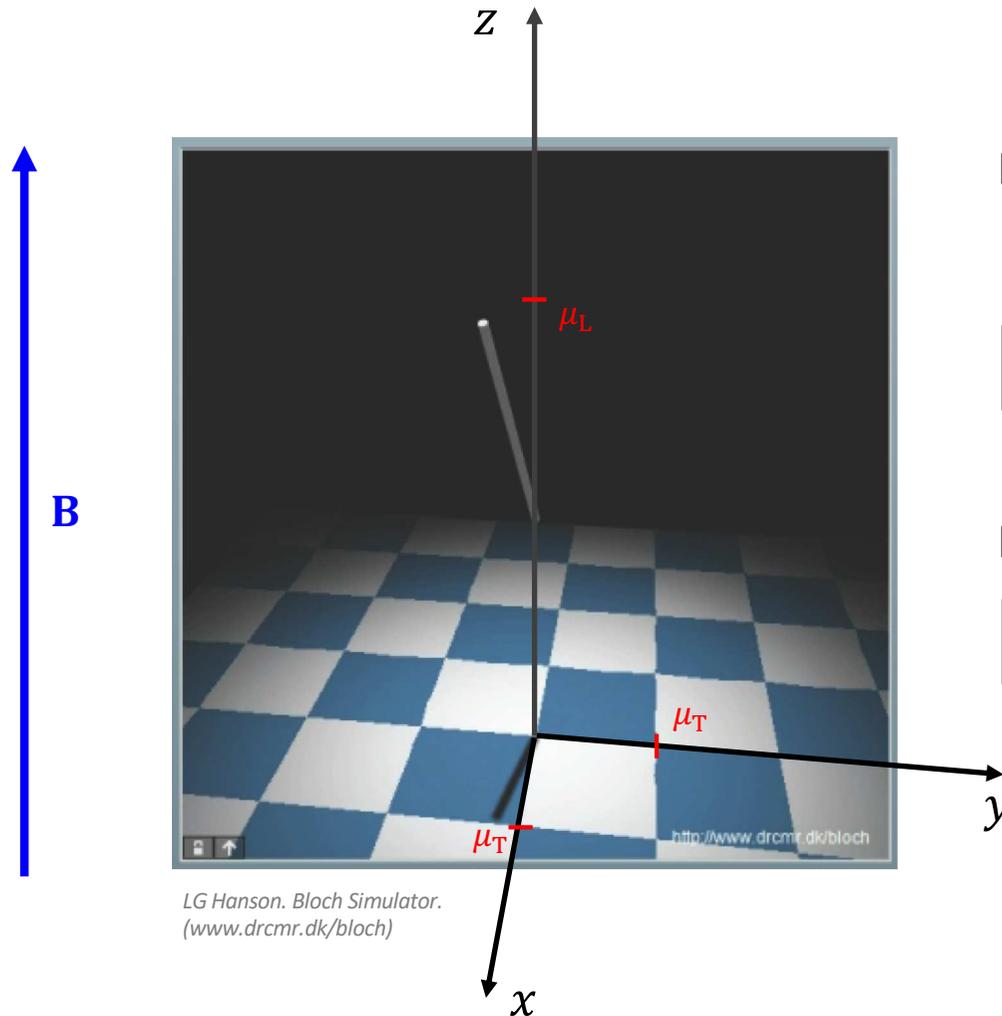
- Transformée de Fourier
- Les gradients

III. Séquences d'acquisition

- Echo de gradient (GRE)
- Echo de spin (SE)
- Inversion-récupération
- Saturation
- Angiographie de RMN (ARM)
- IRM de perfusion
- IRM de diffusion

IV. Cas clinique

Rappels PACES



LG Hanson. Bloch Simulator.
(www.drcmr.dk/bloch)

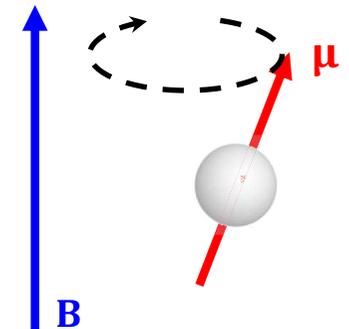
Moment magnétique du proton :

$$\mu = \gamma \mathbf{J}$$

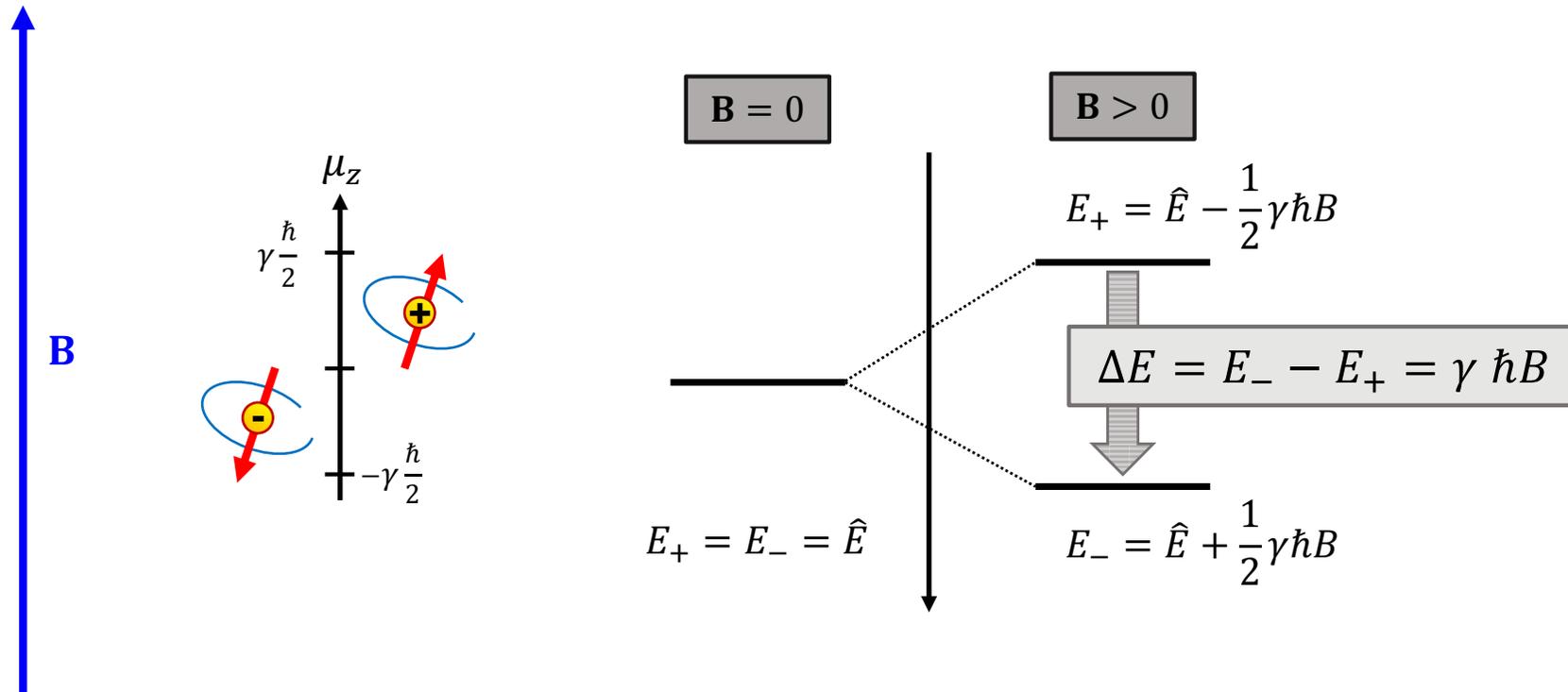
$$\bar{\gamma} = 42,6 \text{ MHz T}^{-1}$$

Précession de Larmor :

$$\omega = \gamma B$$

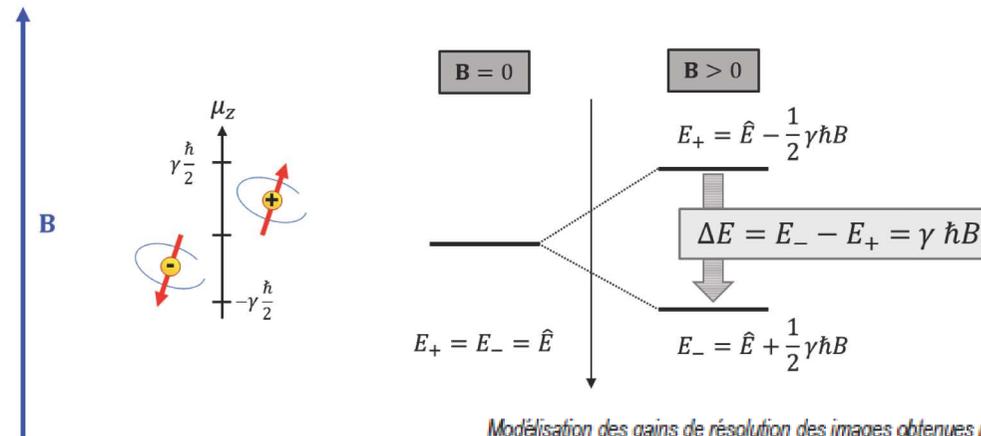


Levée de dégénérescence énergétique (effet Zeeman)



Rappels PACES

Levée de dégénérescence énergétique (effet Zeeman)



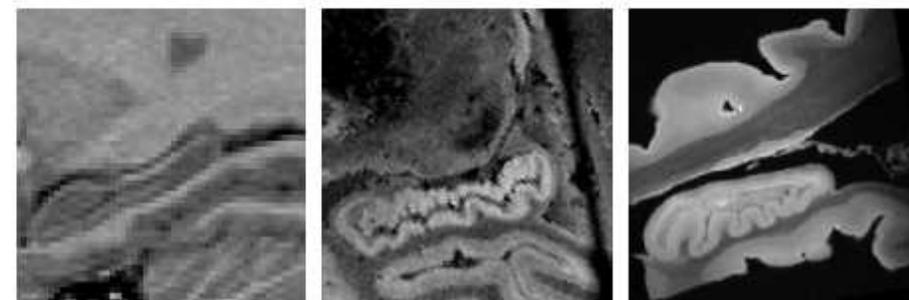
Modélisation des gains de résolution des images obtenues par des appareils IRM 3 T, 7 T et 11,7 T
© Justine Beaujain/CEA

- B ↑
- sensibilité ↑
- résolution spatio-temporelle ↑

Neurospin: IRM 3 et 7 T

IRM préclinique 7 T 11,7 T et 17,2 T

Projet Iseult: IRM 11,7 T (atteint le 18/07/2019)



3 teslas
(meilleurs IRM présents dans les centres cliniques)

7 teslas
(image obtenue sur un prélèvement avec un IRM de l'installation Neurospin)

11,7 teslas
(image obtenue avec l'IRM pré-clinique de Neurospin)

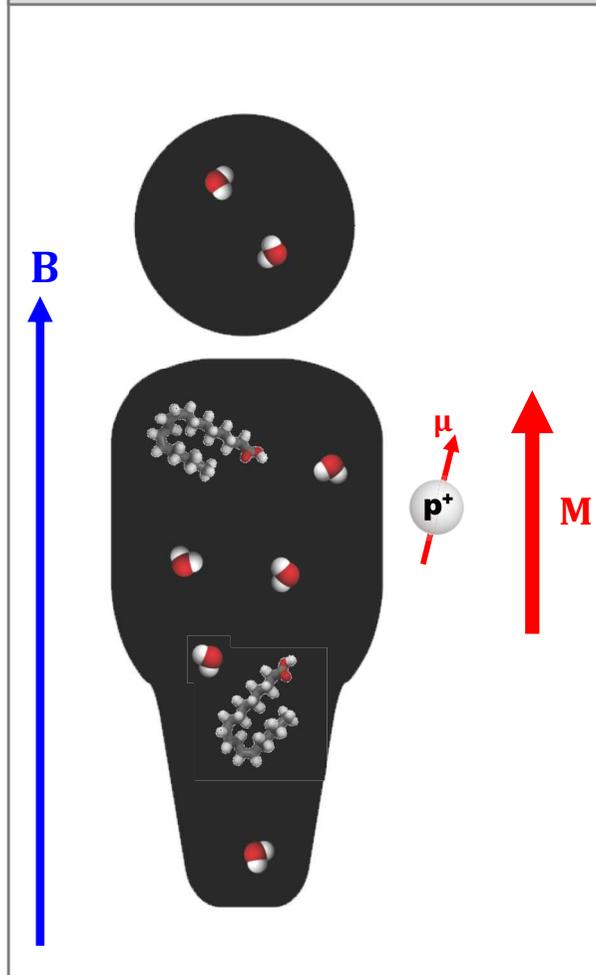
Champs magnétiques : quelques ordres de grandeurs

Champ magnétique (Tesla)	> 100 T	17 T	11,7 T	8,5 T	1 T	10 ⁻³ T	10 ⁻⁵ T
Exemples	Magnétar (10 ¹¹ T)	IRM expérimentaux murins (souris)	Projet Iseult	Tunnel du LHC	Électro-aimant de Faraday	Magnét de frigo	Terre

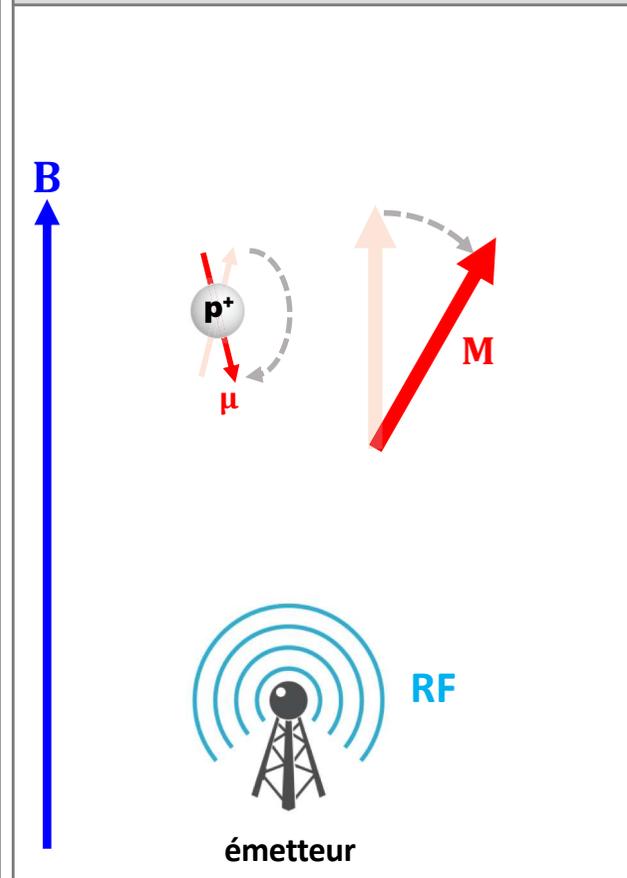
Rappels PACES

Séquence de RMN

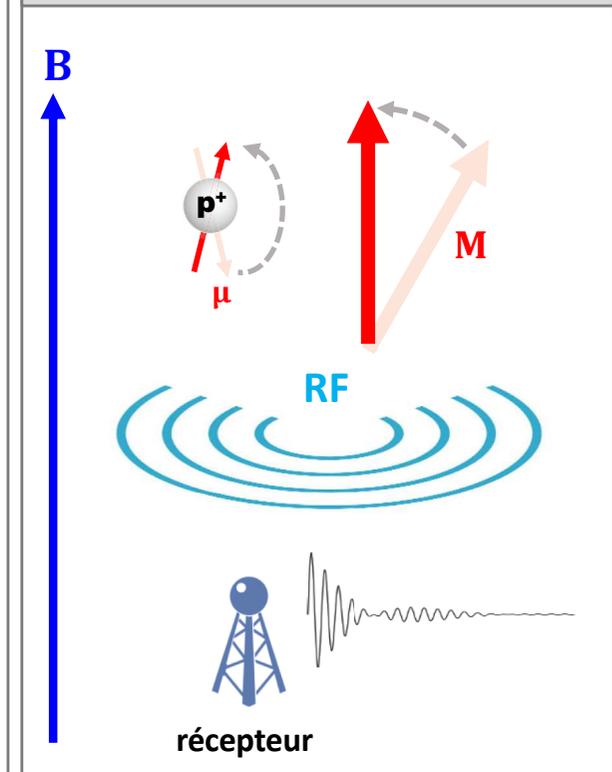
1. Préparation (aimantation)



2. Perturbation (résonance)



3. Mesure (relaxation)



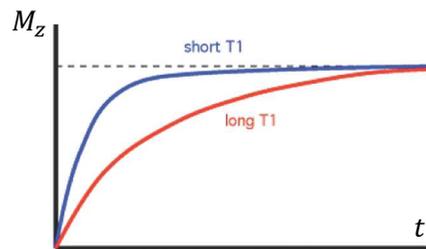
Rappels PACES

1. Préparation (aimantation)

Précession de Larmor : $\omega_0 = \gamma B_0$

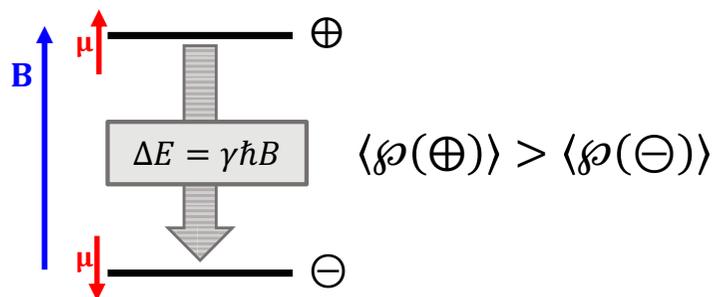
Alignement sur le champ

- Aimantation longitudinale M_z
- Cinétique exponentielle T_1

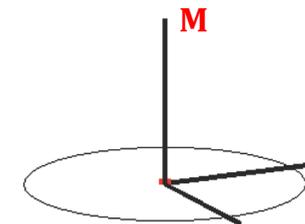
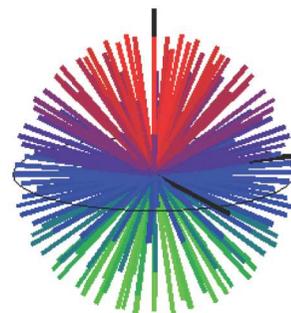
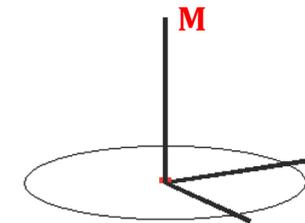
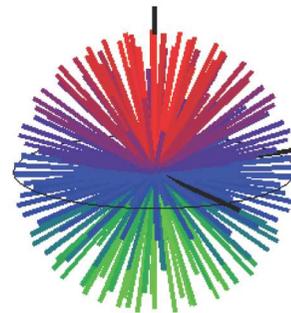


$$M_z(t) = M_L(1 - e^{-t/T_1})$$

- Echanges énergétiques : $E = -\mu \cdot B$



B_0



Rappels PACES

2. Perturbation (résonance)

Application d'un champ tournant B_1

- de fréquence $\omega_0/2\pi$
- pendant une durée τ (~ms)

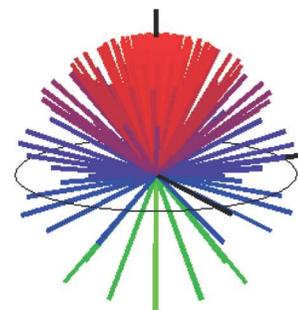
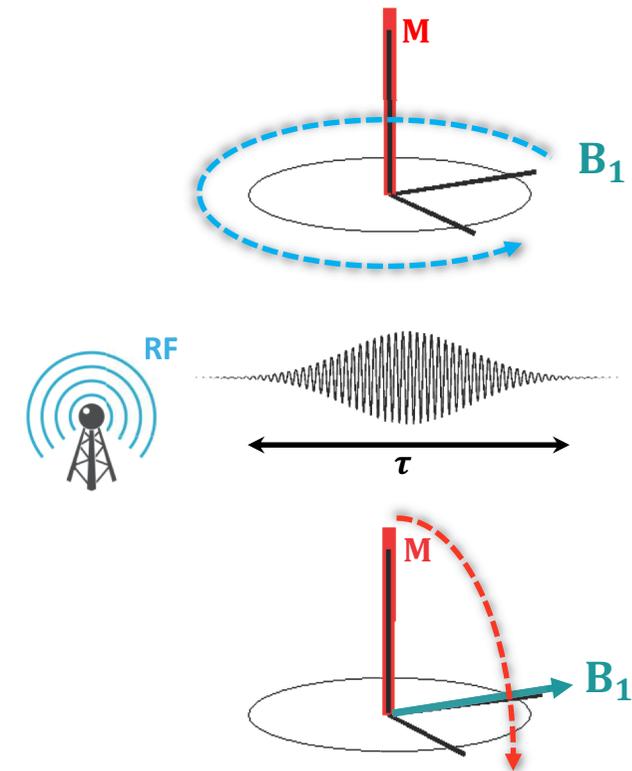
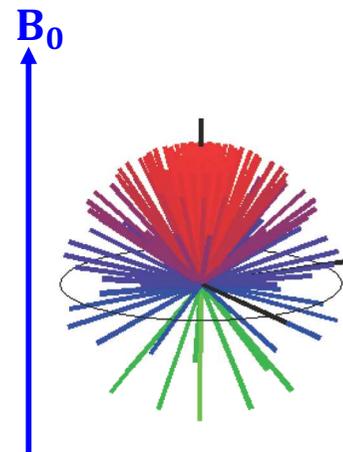
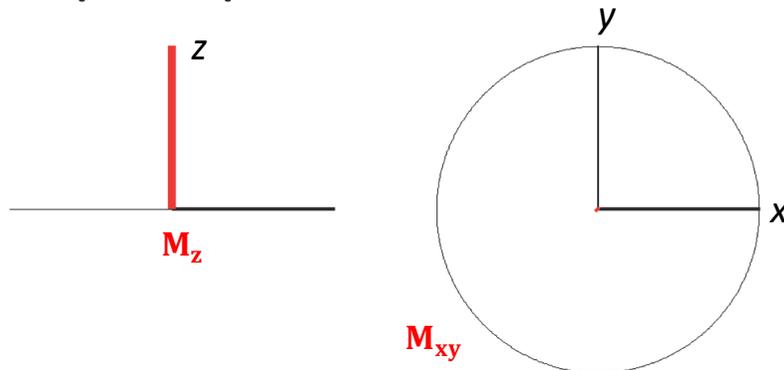
Précession de M autour de B_1

- $\omega_1 = \gamma B_1$
- Bascule (nutation) d'un angle $\eta = \tau \omega_1$

Disparition de M_z

Apparition de M_{xy} (aimantation transverse)

- Spins en phase à la bascule

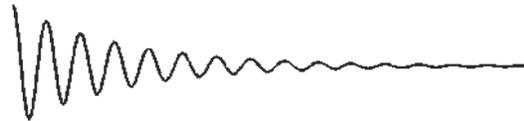


Rappels PACES

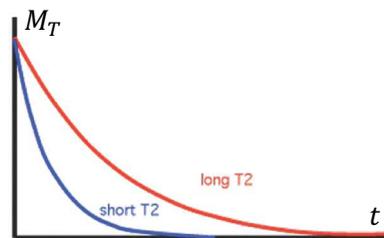
3. Mesure (relaxation)

Arrêt de la stimulation RF B_1

Signal = M_{xy}

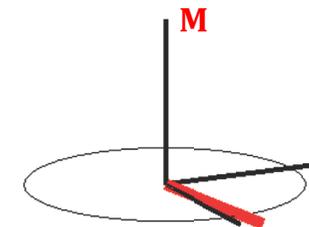
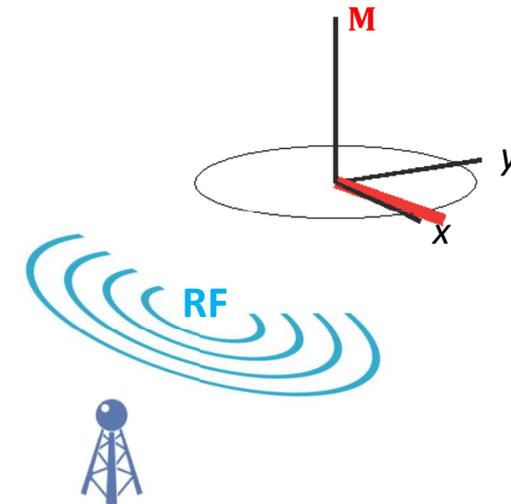
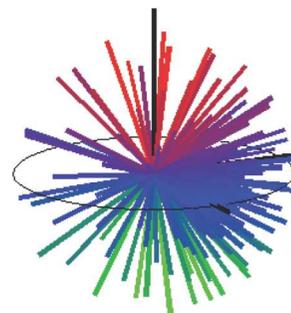
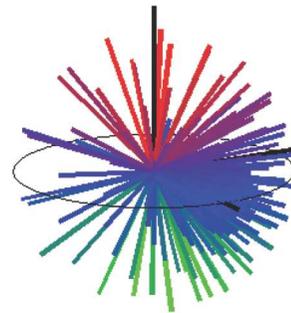


- Déphasage progressif
- Inhomogénéités de champ
- Phénomène entropique
- Cinétique T_2



$$M_{xy}(t) = M_T e^{-t/T_2}$$

B_0

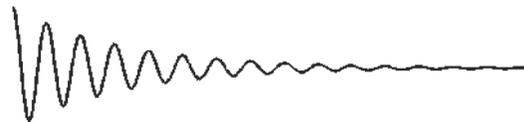


Rappels PACES

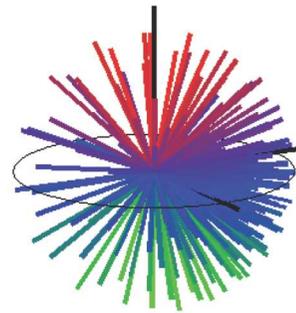
3. Mesure (relaxation)

Arrêt de la stimulation RF B_1

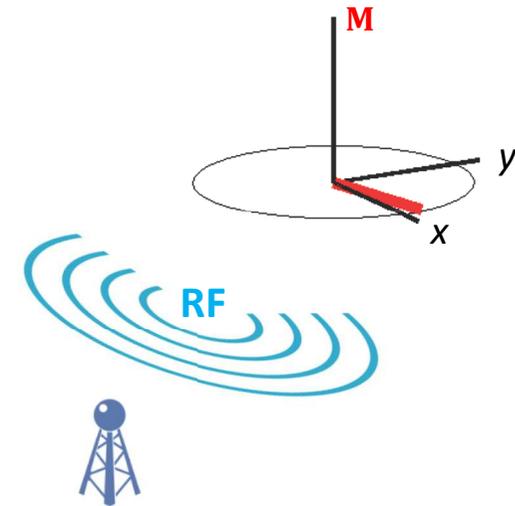
Signal = M_{xy}



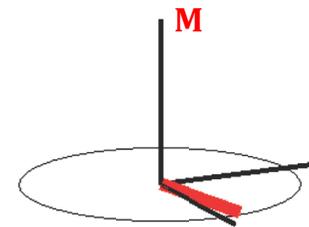
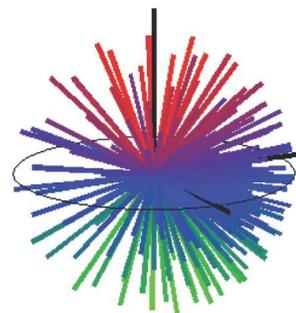
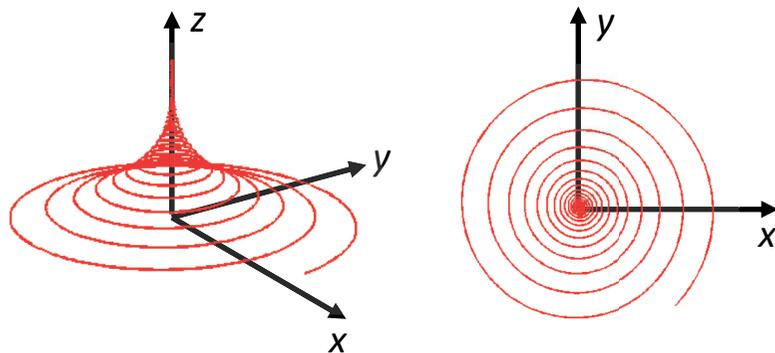
B_0



Disparition de M_{xy}
Repousse de M_z



Dans les tissus biologiques : $T_1 \sim 10 T_2$



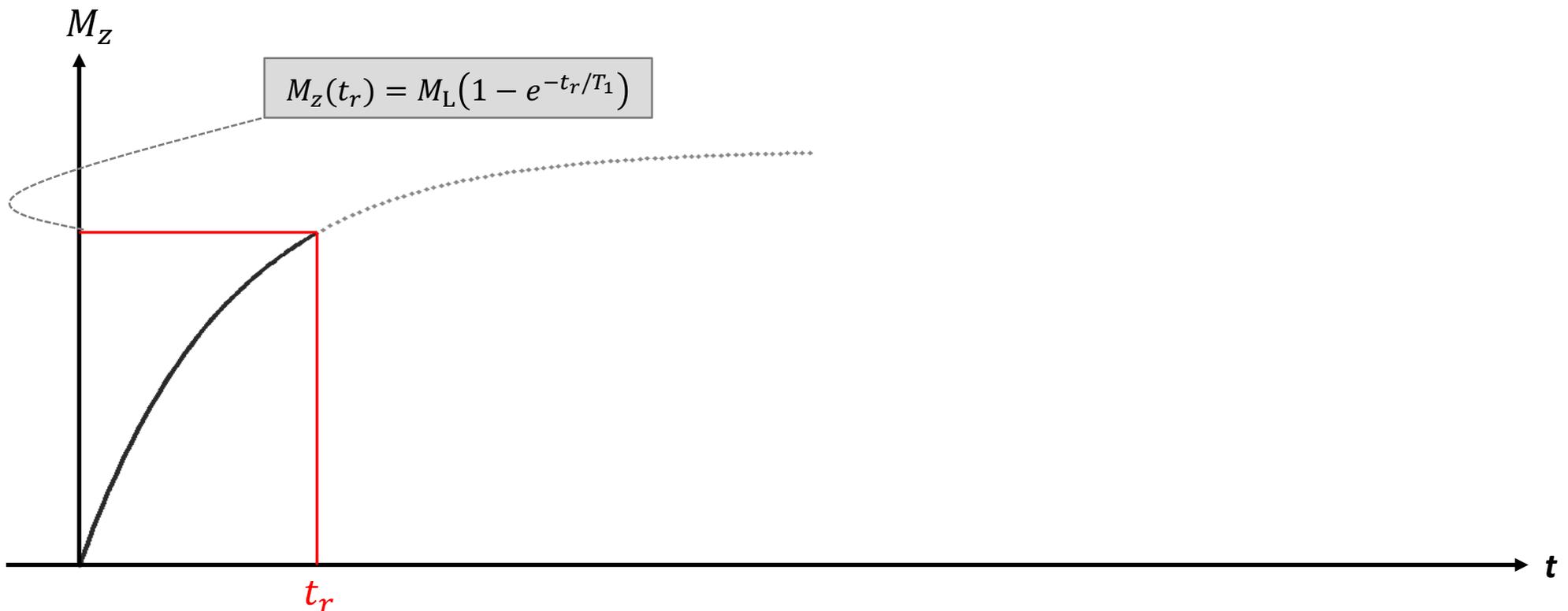
Rappels PACES

Préparation

Aimantation longitudinale dans B_0

Relaxation T_1

Durant un temps t_r (temps de répétition)

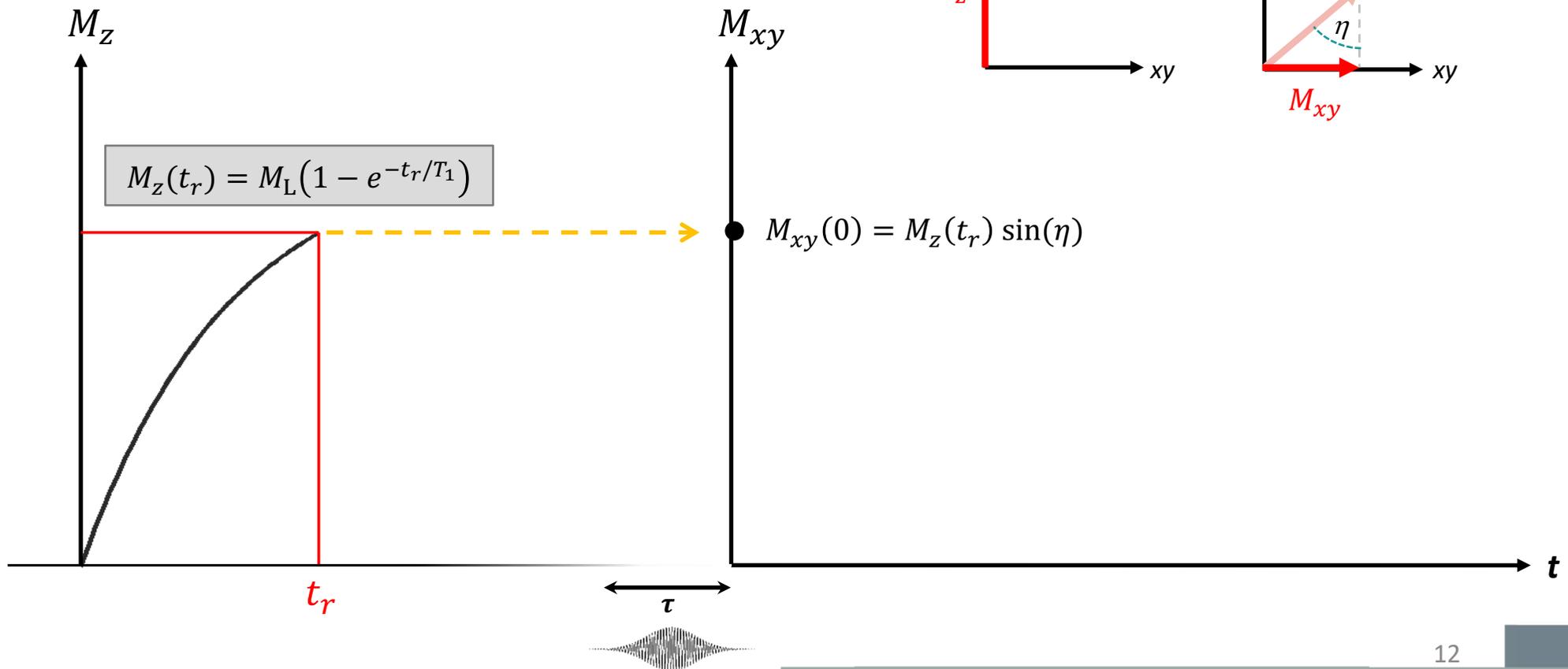
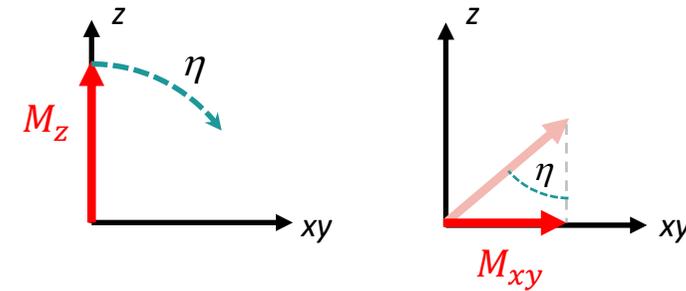


Rappels PACES

Préparation

RF

Stimulation RF durant un temps τ
Bascule de l'aimantation d'un angle η
Apparition d'une aimantation transverse



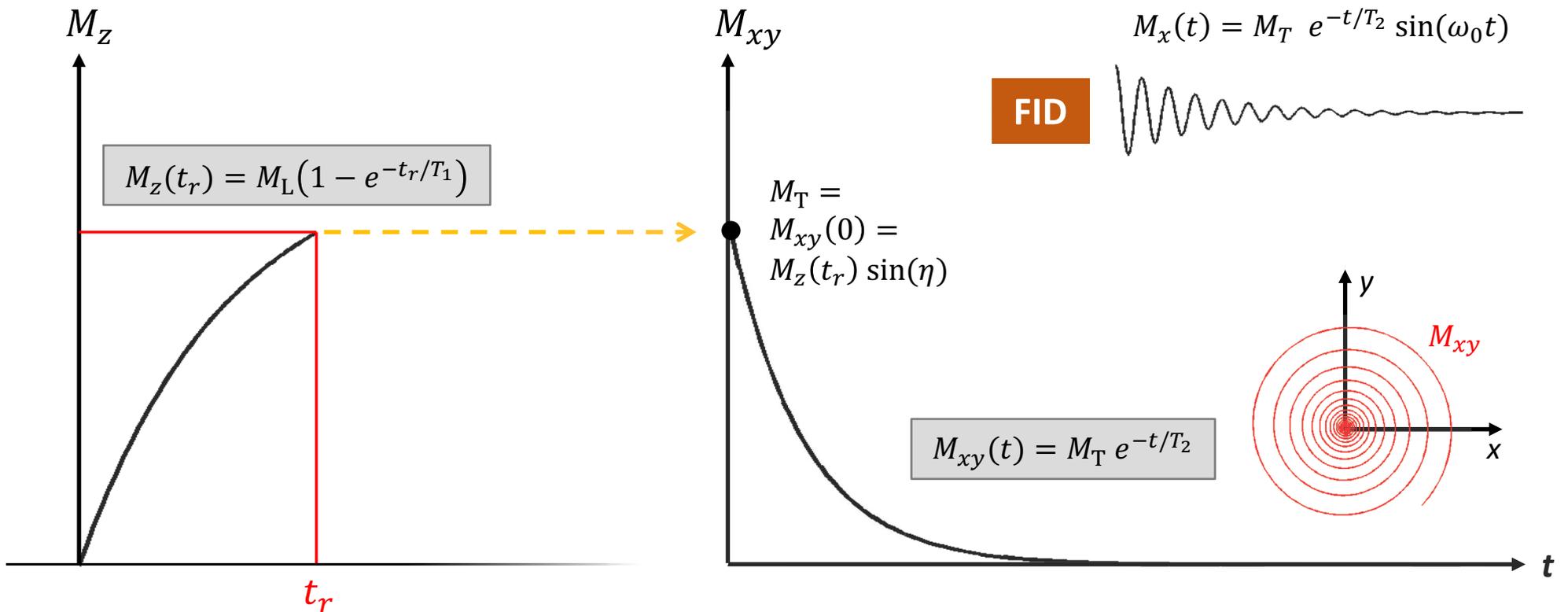
Rappels PACES

Préparation

RF

Mesure

Retour à l'équilibre
Relaxation T_2



Rappels PACES

Préparation

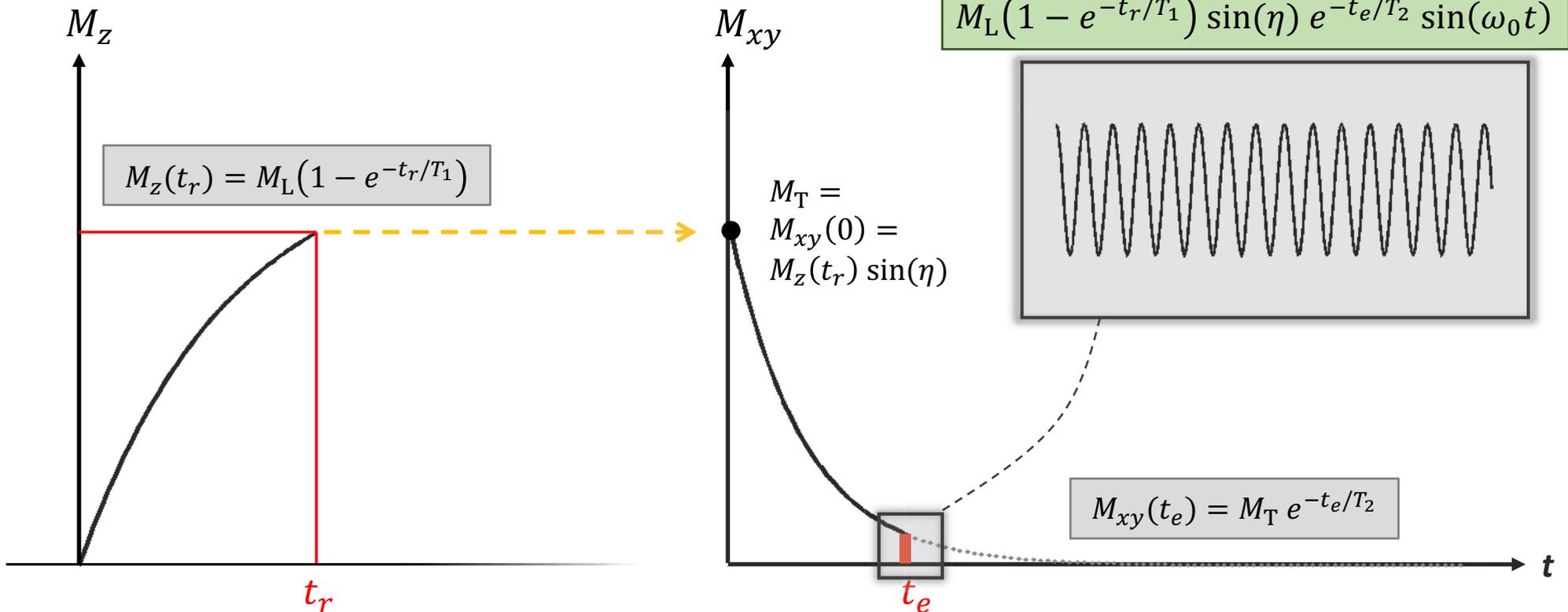
RF

Mesure

Retour à l'équilibre

Relaxation T_2

Recueil du signal (**FID**) au temps t_e (temps d'écho)



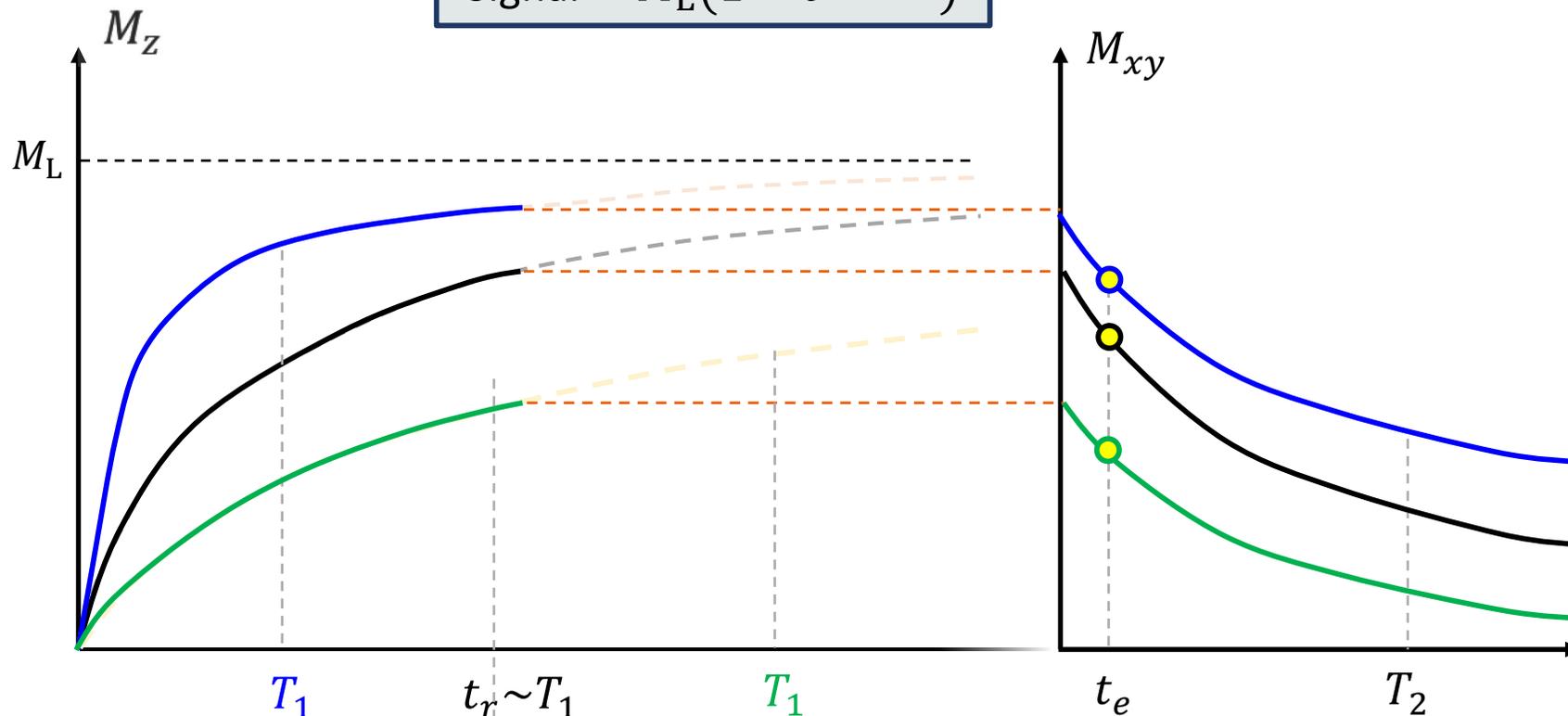
Rappels PACES

Pondération T_1

$$\begin{matrix} t_r \sim T_1 \\ t_e \ll T_2 \end{matrix}$$

$$FID(t) = M_L(1 - e^{-t_r/T_1}) \sin(\eta) e^{-t_e/T_2} \sin(\omega_0 t)$$

$$\text{Signal} \propto M_L(1 - e^{-t_r/T_1})$$



Rappels PACES

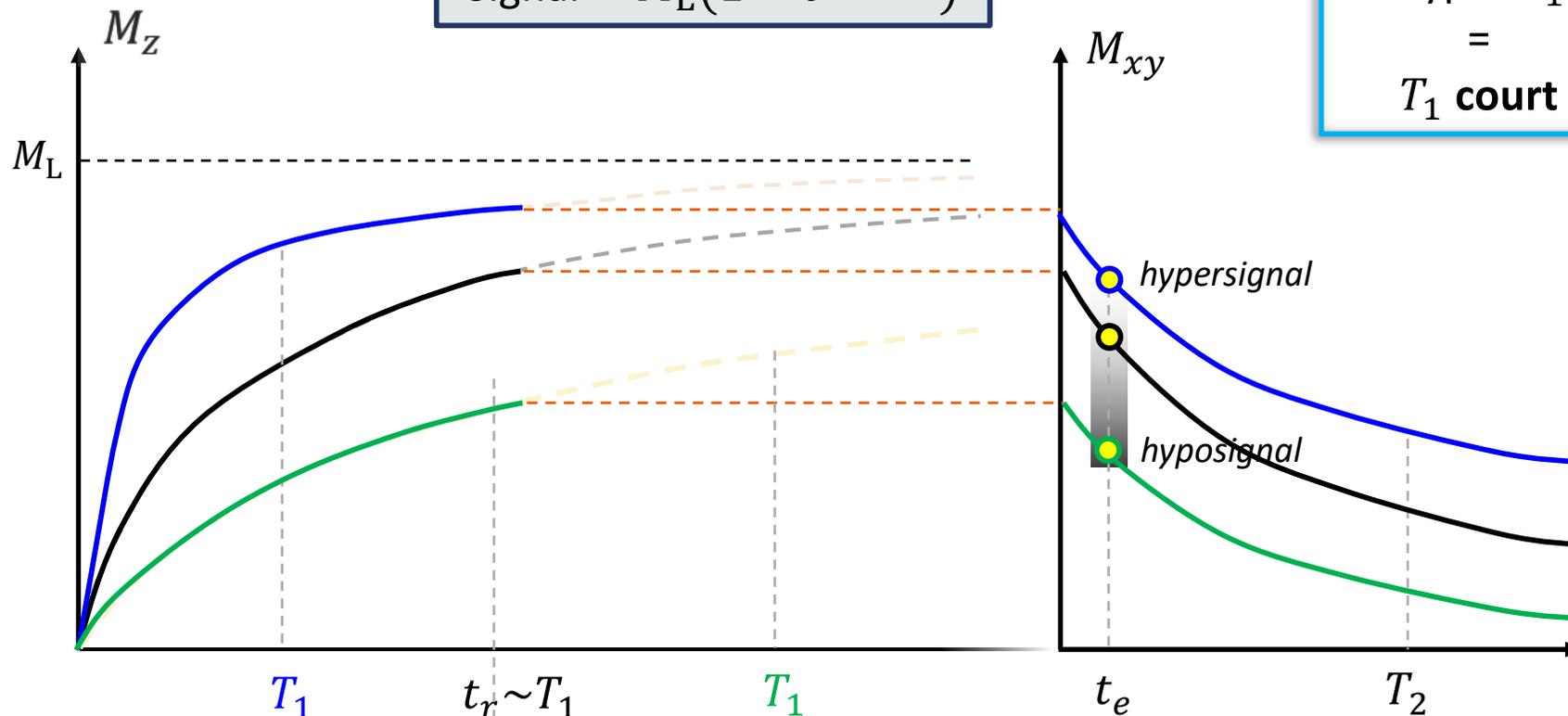
Pondération T_1

$$\begin{matrix} t_r \sim T_1 \\ t_e \ll T_2 \end{matrix}$$

$$FID(t) = M_L(1 - e^{-t_r/T_1}) \sin(\eta) e^{-t_e/T_2} \sin(\omega_0 t)$$

$$\text{Signal} \propto M_L(1 - e^{-t_r/T_1})$$

Hyper- T_1
=
 T_1 court



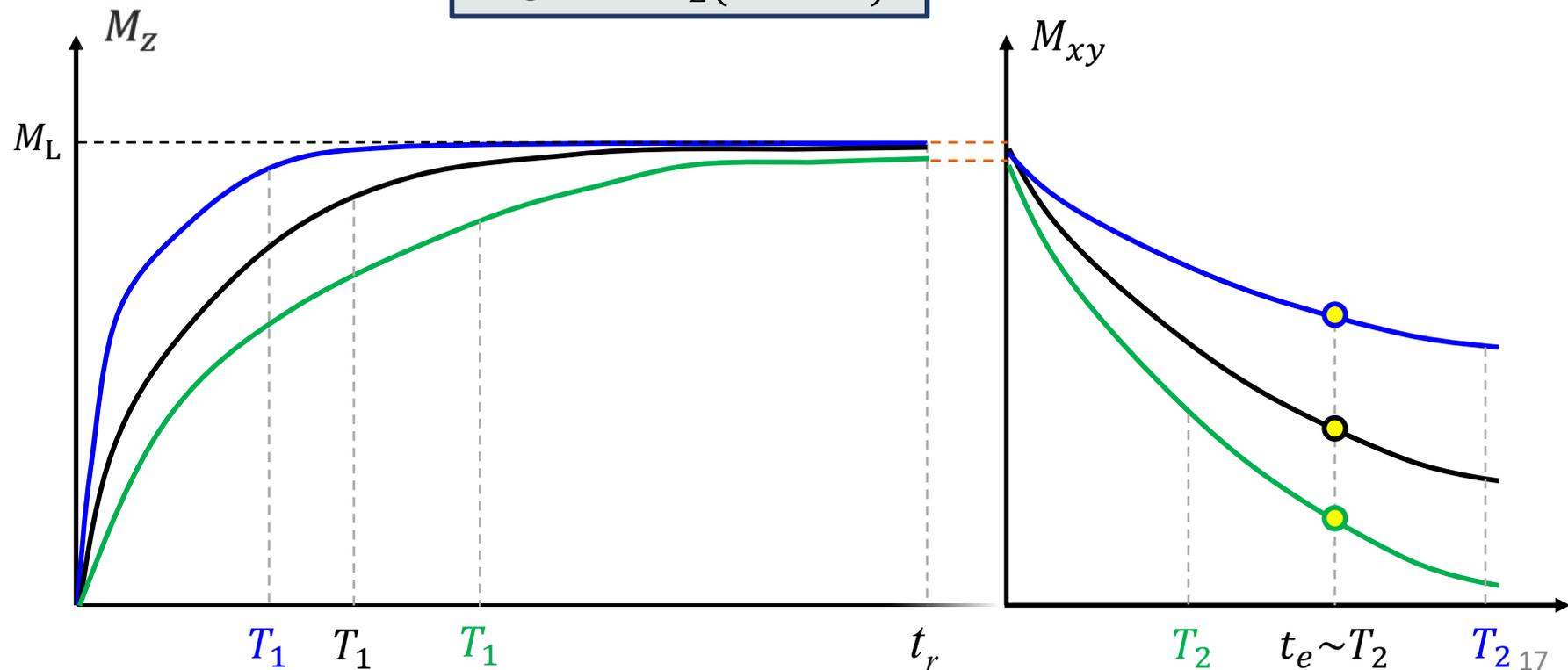
Rappels PACES

Pondération T_2

$$\begin{matrix} t_r \gg T_1 \\ t_e \sim T_2 \end{matrix}$$

$$FID(t) = M_L(1 - e^{-t_r/T_1}) \sin(\eta) e^{-t_e/T_2} \sin(\omega_0 t)$$

$$\text{Signal} \propto M_L(e^{-t_e/T_2})$$



Rappels PACES

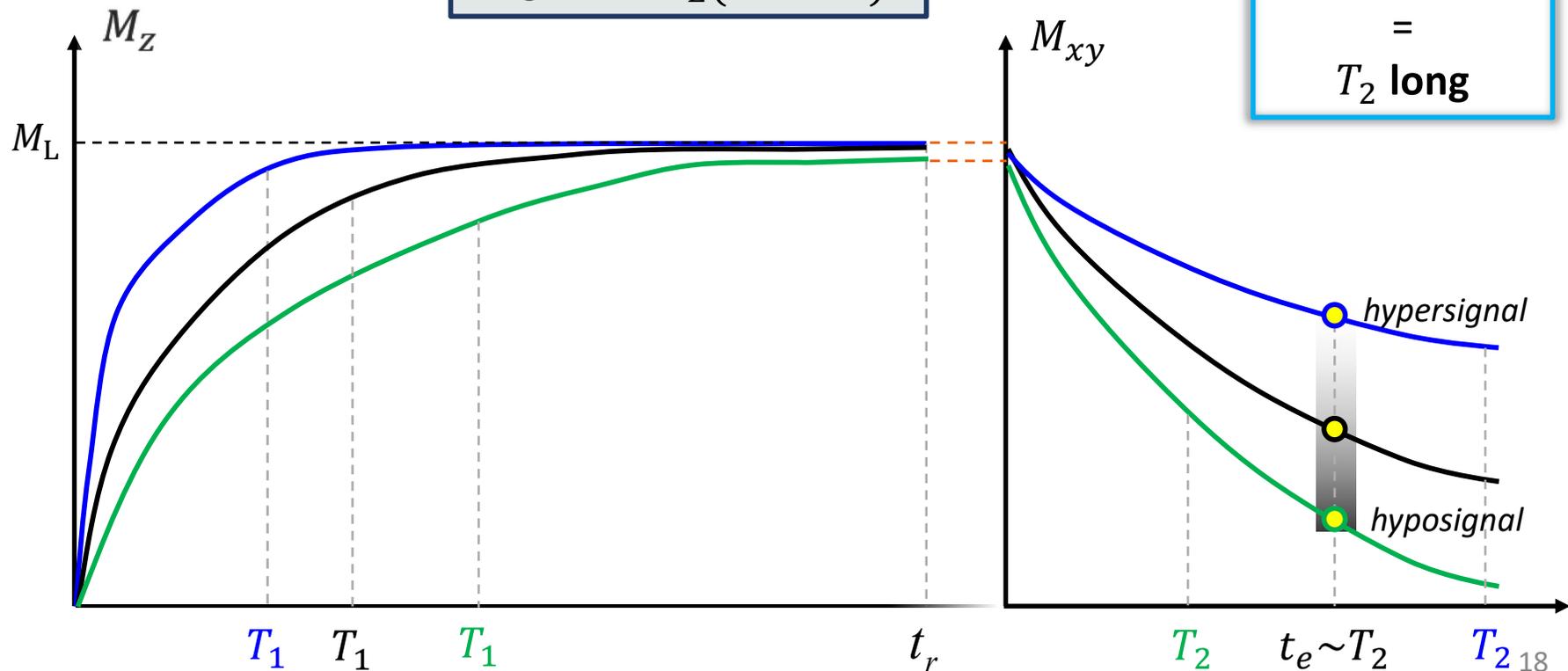
Pondération T_2

$$\begin{matrix} t_r \gg T_1 \\ t_e \sim T_2 \end{matrix}$$

$$FID(t) = M_L(1 - e^{-t_r/T_1}) \sin(\eta) e^{-t_e/T_2} \sin(\omega_0 t)$$

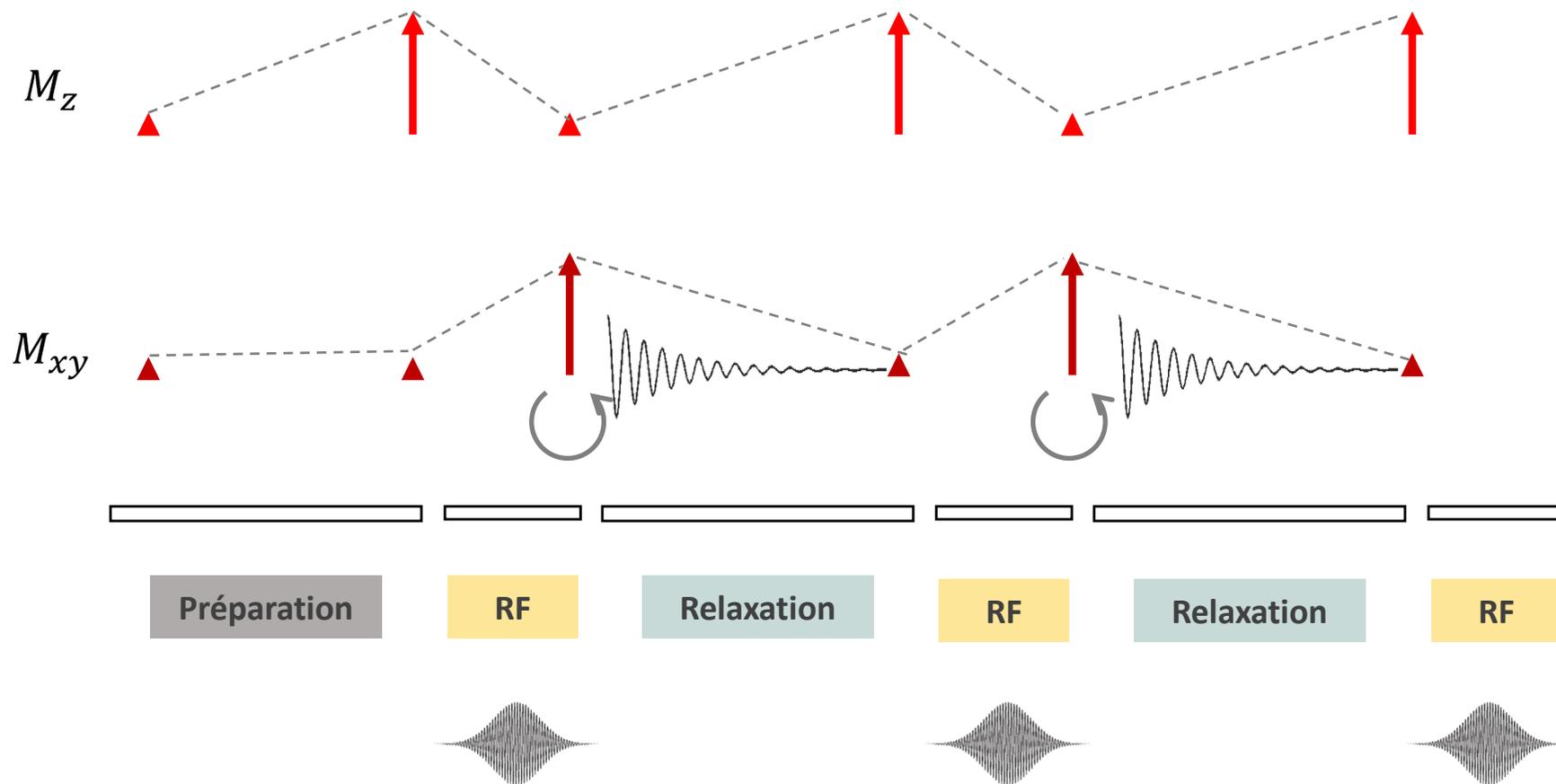
$$\text{Signal} \propto M_L(e^{-t_e/T_2})$$

Hyper- T_2
=
 T_2 long



Rappels PACES

séquence: synthèse



Rappels PACES

séquence: synthèse

