# MRI Basics

***M*agnetic**

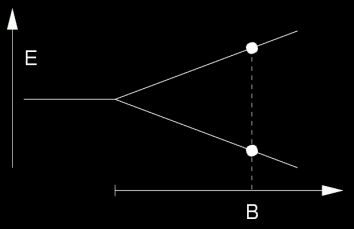
**R**esonance

**I**maging (next week)

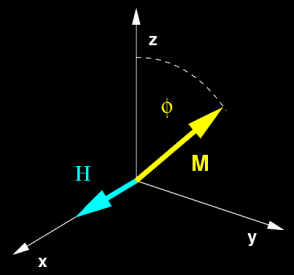
Peter Brunecker

# Content

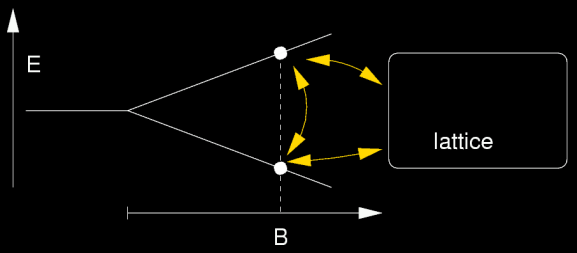
**Magnetization**



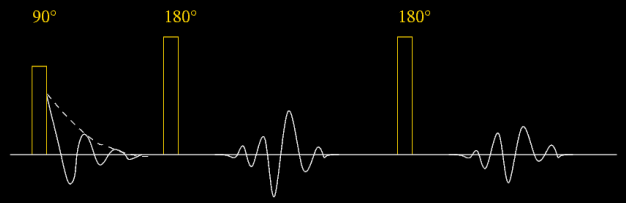

**Excitation**




**Relaxation**




**Application**



# Magnetization
## Terms and macroscopic effects

**External magnetic field**

- nuclear magnetic moments are aligned with the external field
- this results in a Magnetic Moment **M**

**Paramagnetism**

- along the external field, but weak

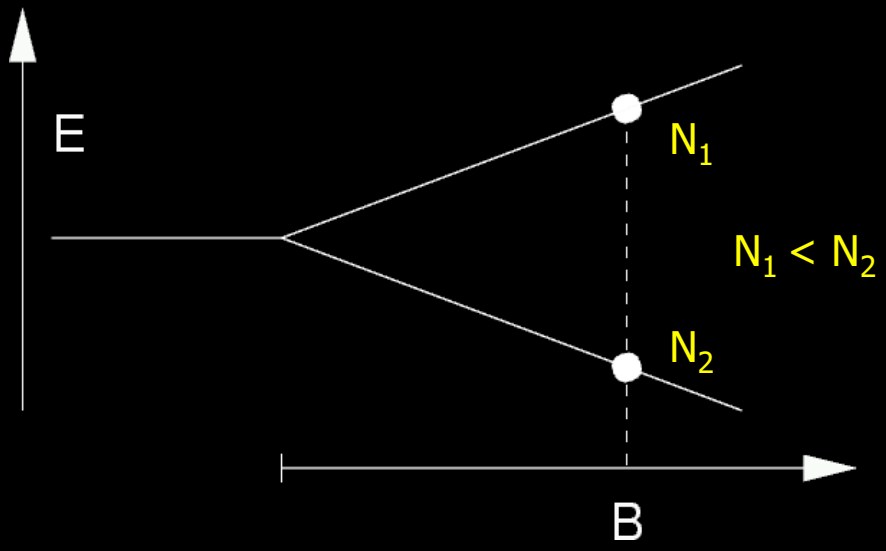
**Diamagnetism**

- against the external field, but weak

**Ferromagnetism**

- along the external field, and strong

# Magnetization
## Nuclear viewpoint




**External magnetic field**

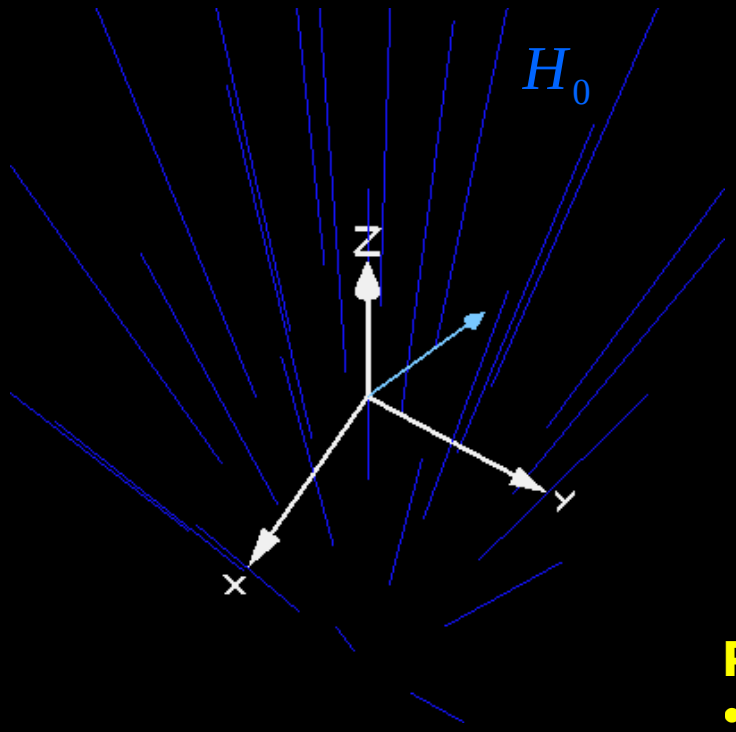
- spreading of the spectra
- for $^1H$ in two levels
- energetic distance grows linear with magnetic field **B**

**Nuclear magnetic resonance (NMR)**

transitions between the energy levels are possible connected with absorption/emmission of RF fields

# Magnetization

## Precession of the magnetic moment




**Lamour-frequency**

$$\omega_0 = -\gamma H_0$$

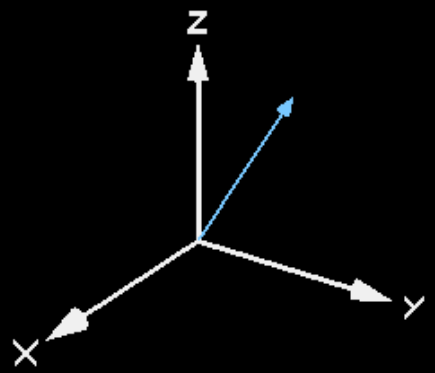
$\gamma$ magnetogyric ratio

$\omega_0$

**Precession along field direction**

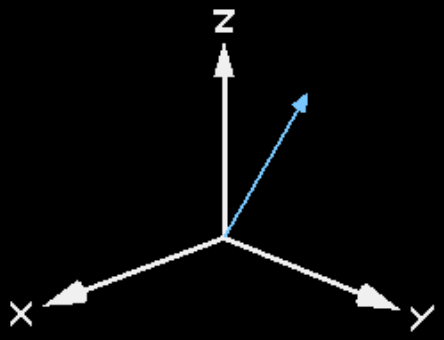
- Rotating with Lamour-frequency
- Each nucleus has an individual phase

# Magnetization
## Rotating frame of reference




**Basic idea**
Transformation into a rotating frame of reference simplifies the mathematics dramatically

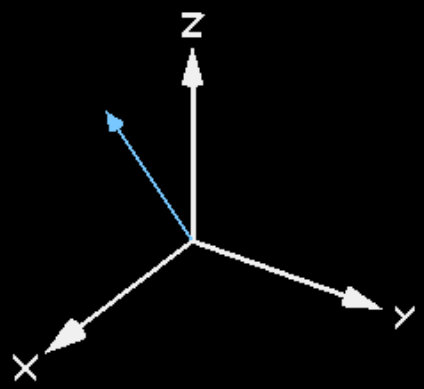
# Magnetization
## Rotating frame of reference




**Initial phase**
is set th the y‘-z‘-plane

**Radio frequency fields**
With the Lamour-frequency can be assumed as orientated parallel to the x‘-axis

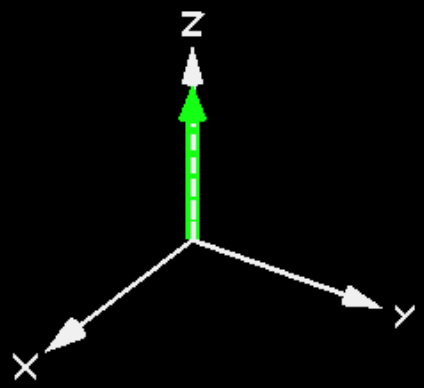
# Magnetization
## Spin-ensemble




**Ensemble of spins**
- Observation of many magnetic moments simultaneously
- Sum over all moments results in the macroscopic magnetization **M**

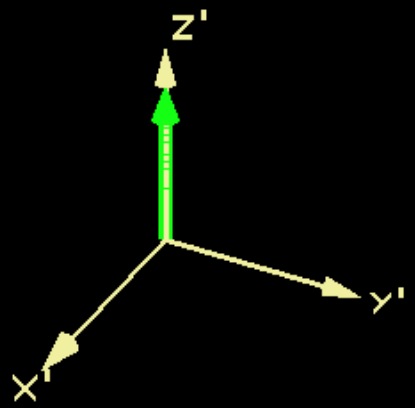
**Bloch equations**
- describes dynamics of **M**
- in the steady state **M** is oriented parallel to the z-axis

# Magnetization
## Free induction decay



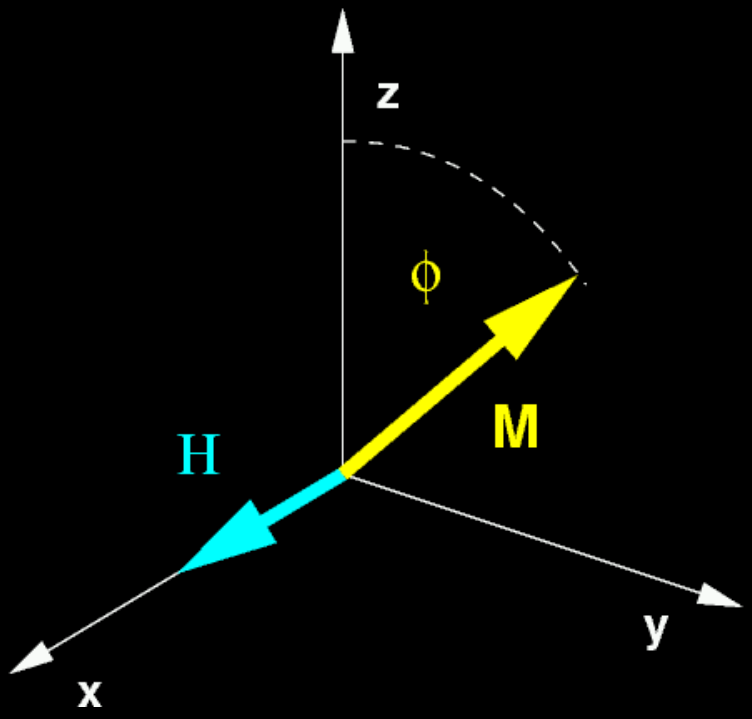

**Disturbances of the equillibrium**
Lead to oscillations back to to equillibrium
- longitudinal (z) magnetization grows
- transversal (x, y) magnetization sinks
- rotation of **M** generates RF field

# Magnetization
## Free induction decay




**In the rotating frame of reference**
The magnetization simple tips towards the z‘-axis

# Excitation
## Flip angle



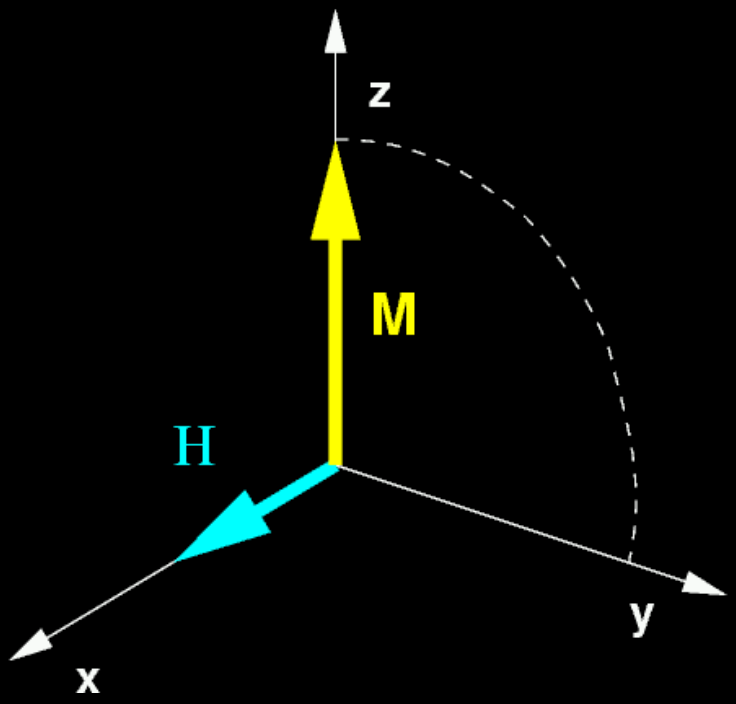

**Precession around the x-axis**
Can be induced by an external RF field with Lamour-frequency

**Flip angle** $\phi = \gamma H \Delta t$

**Fundamental law of pulsed NMR**

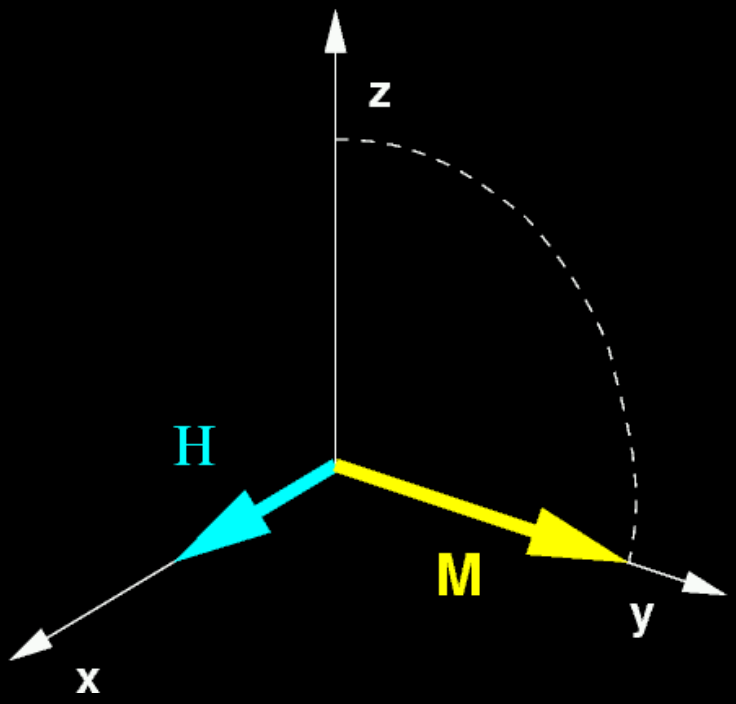
# Excitation

## 90° pulse



# Excitation

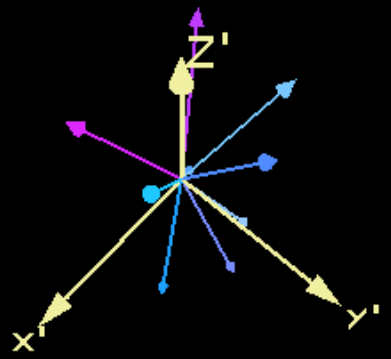
## 90° pulse




**Or $\pi/2$ pulse**

Leads to a maximal transversal magnetization

# Excitation
## Phase synchronisation

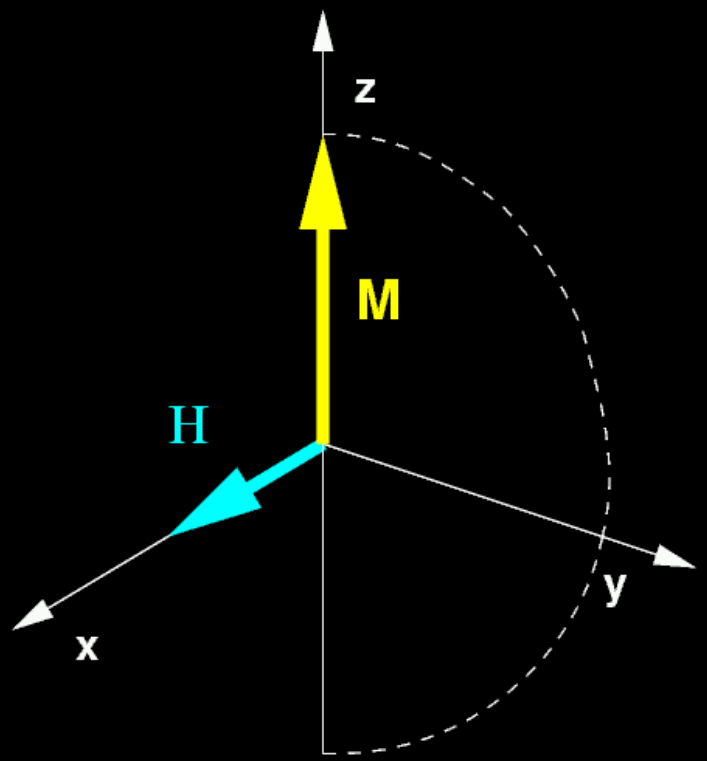



**Phase synchronisation**
Is an important side-effect

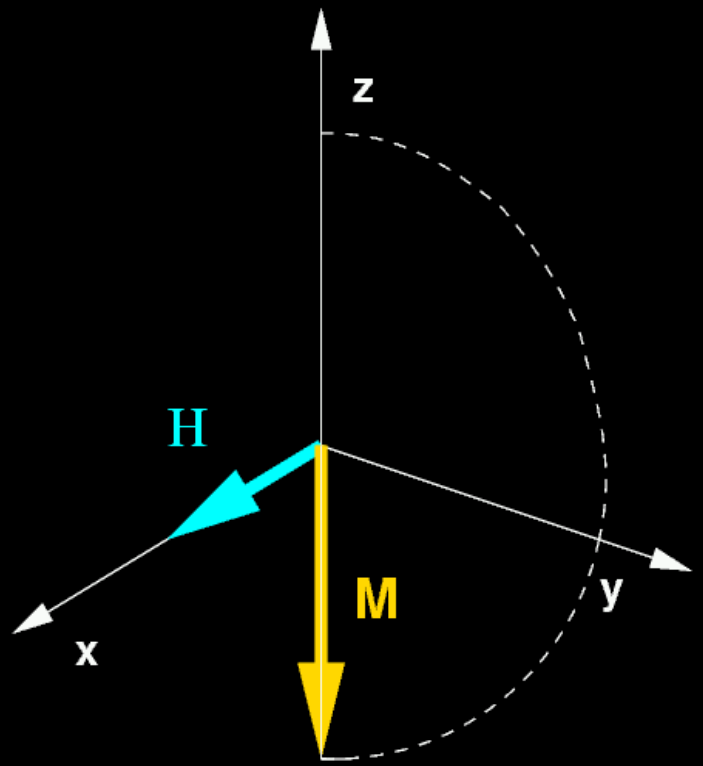
A spin-package is generated which can be detected

# Excitation

## 180° pulse



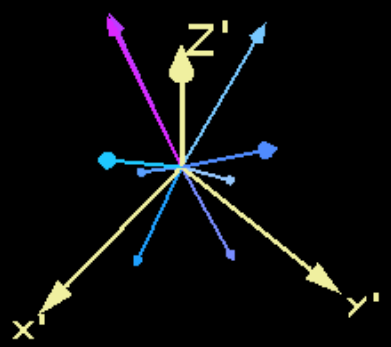
# Excitation
## 180° pulse




**Or $\pi$ pulse**

Leads to a inverted longitudinal magnetization

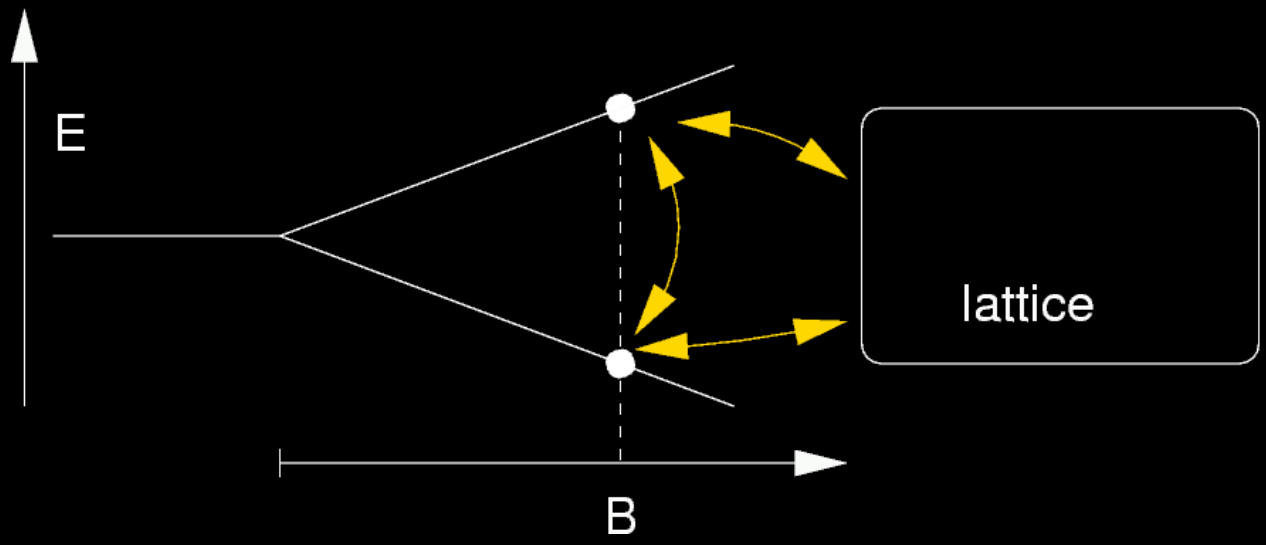
# Excitation
## Phase inversion




**Rephasing of  a dephasing spin package**

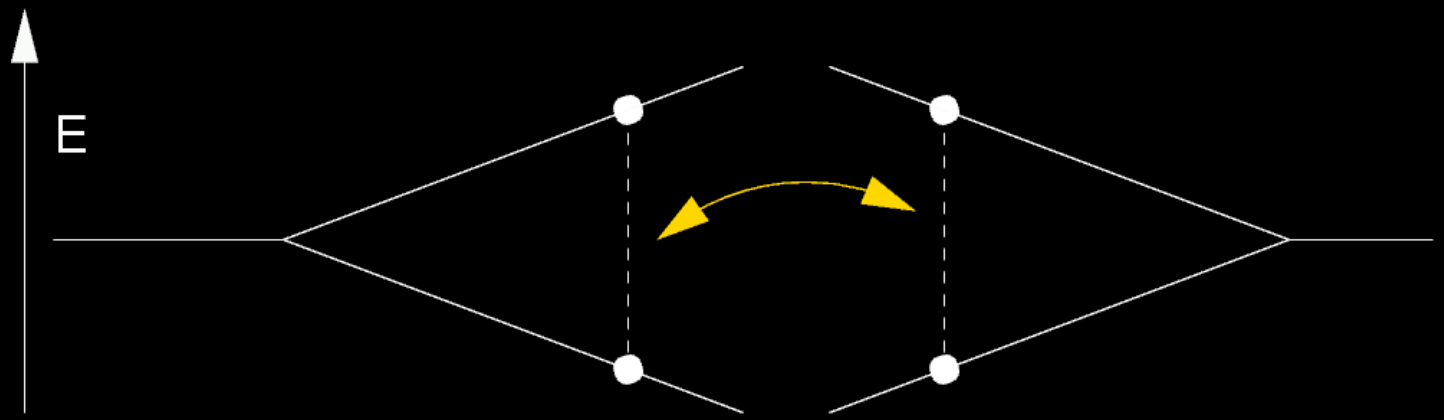
Generates a so-called spin-echo

# Relaxation
## Longitudinal relaxation




**Relaxation time $T_1$**
Due to spin-lattice-interaction
Indirect energy exchange through a reservoir

# Relaxation
## Transversal relaxation




**Relaxation time $T_2$**

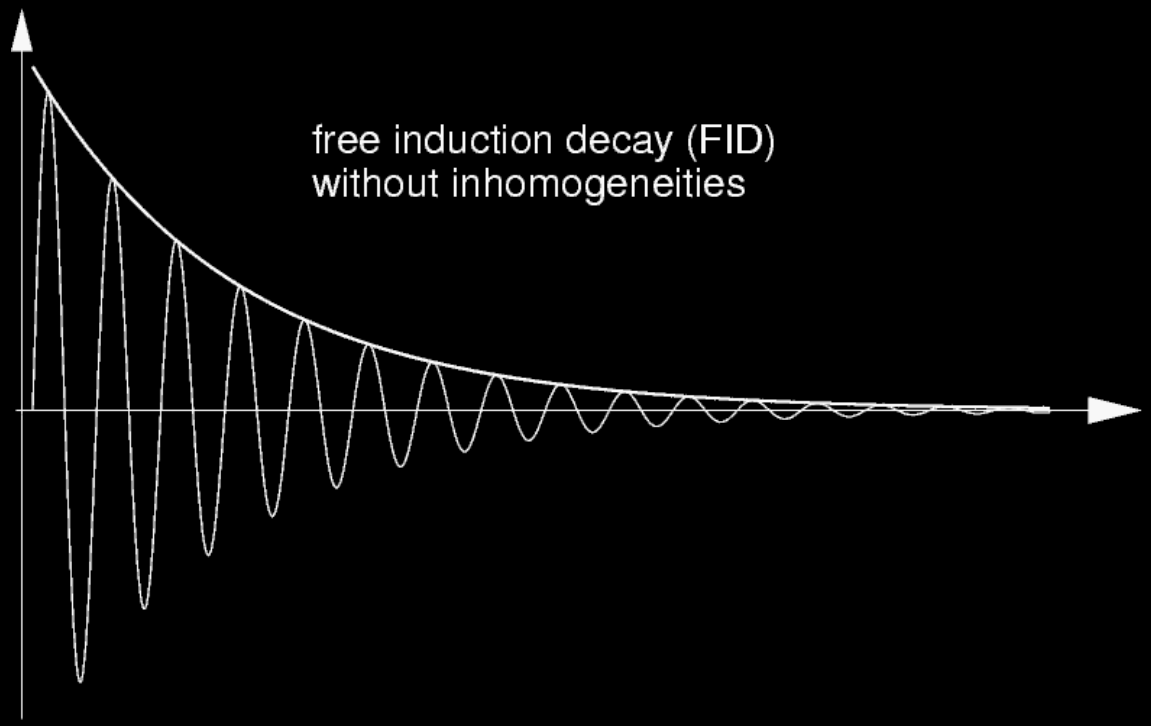
Due to spin-spin-interaction which is destroying the phase lock

# Relaxation

## „Real" transversal relaxation

**Up to now: Homogeneous field $H_0$**

Dynamics can be described by the Bloch equations

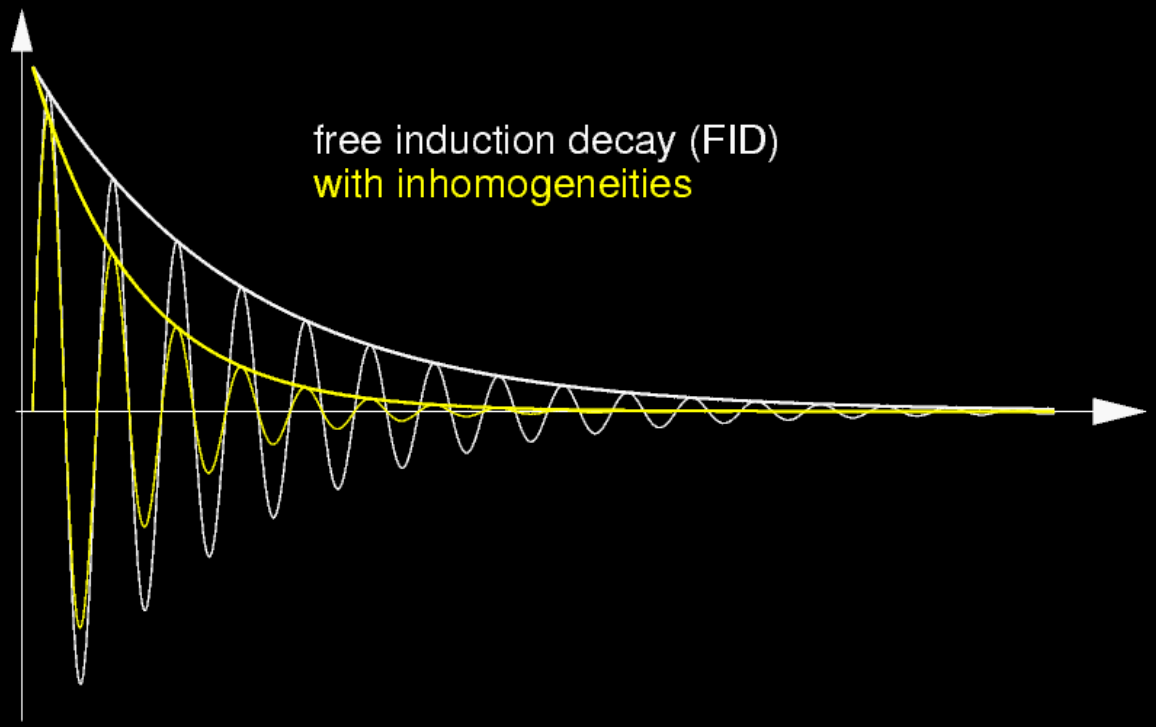


# Relaxation

## „Real" transversal relaxation

**Relaxation time $T_2^*$**

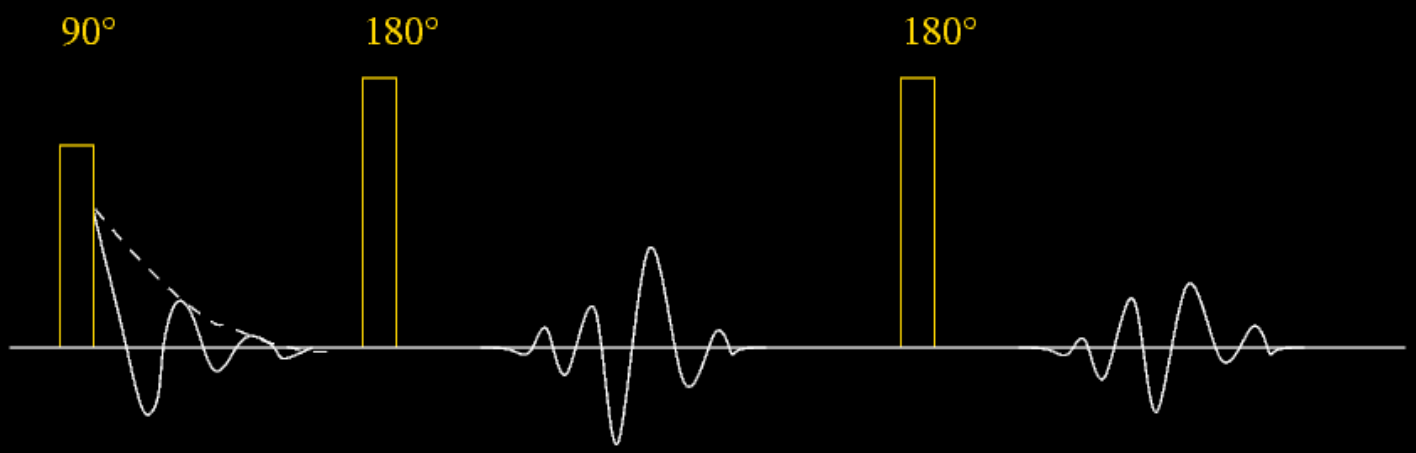
Local magnetic field inhomogeneities lead to local differing Lamour-frequencies
Additional dispersion of the spin-package




**Comparison**

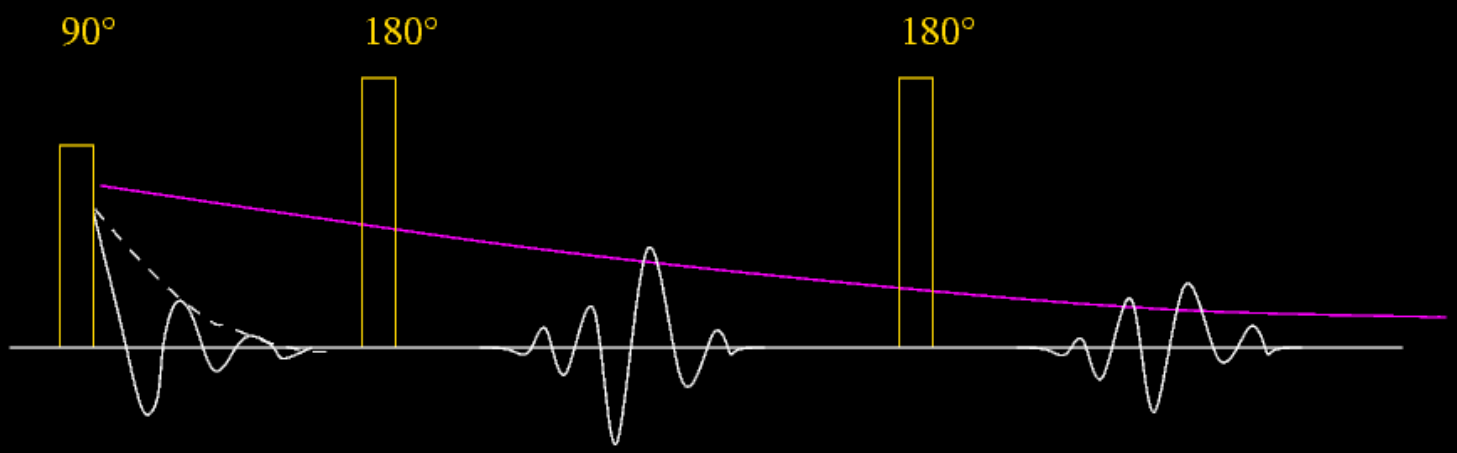
$$T_1 > T_2 > T_2^*$$

# Application
## Spin-Echo-sequence




**Combining 90° and 180° pulses**
Can generate a sequence of spin-echos
Echo time is a relativly free adjustable

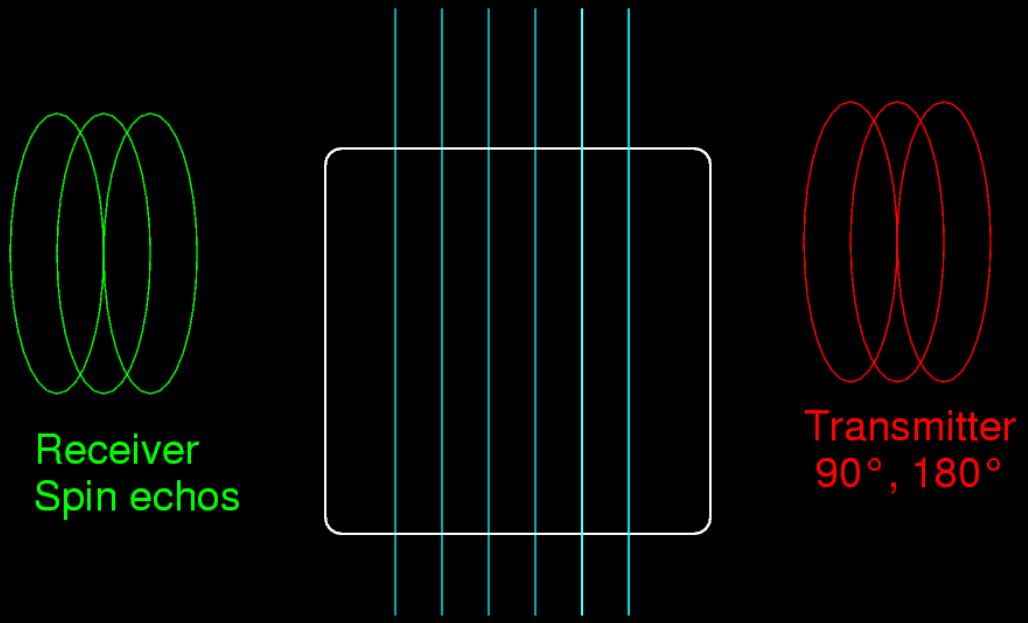
# Application
## Spin-Echo-sequence




**Measuring the decay**

By receiving the spin-echos allows the determination of $T_2$

# Application
## Pulsed NMR scheme



# Next week ...

basic sequences

spatial encoding

EPI

Gradients