

# *magnETHical*

## BUILDING A 25 MHz NMR SPECTROMETER

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ETH Zürich

*“What I cannot create, I do not understand”*

—Richard Feynman

WHY?

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# NMR is used across various fields

- Research (Structure Analysis, Drug Discovery, ...)
- Medicine (Imaging, Diagnosis, ...)
- Industry (Process Control, Drug screening, ...)
- Education (Quantum Mechanics, Quantum Computing, ...)

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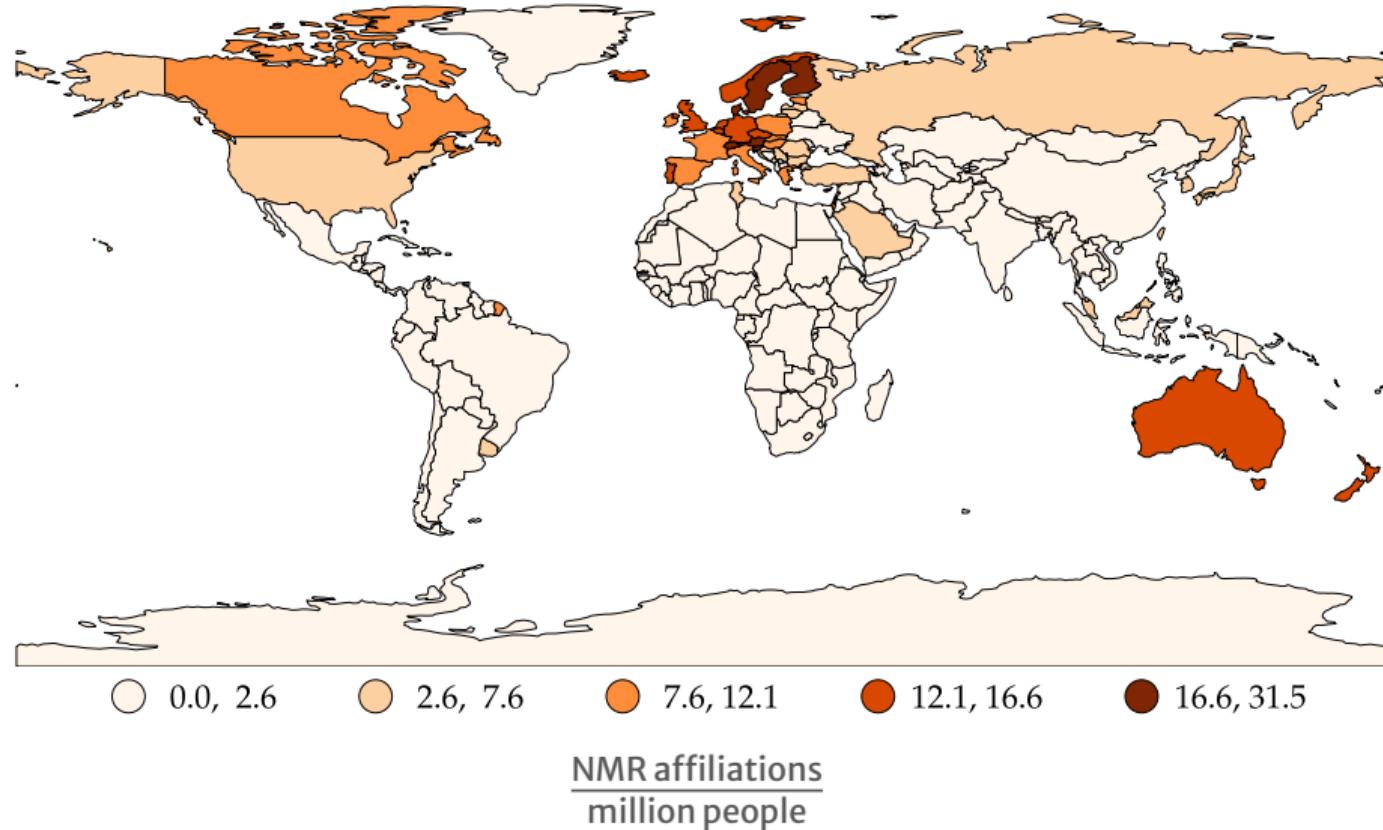
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# There is not a lot of NMR research in the Global South



**Build an accessible NMR spectrometer**

# Preview

The parts

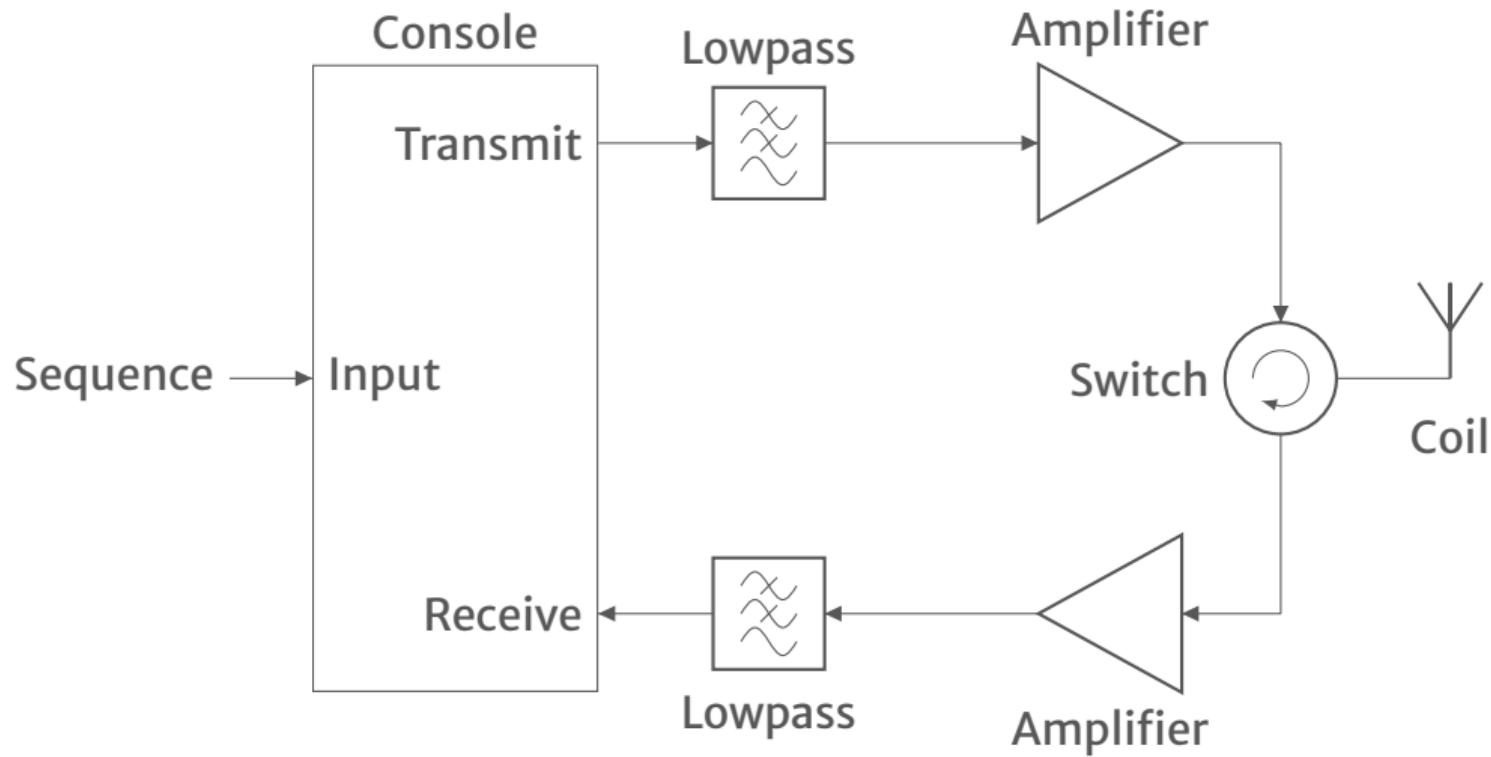
The complete setup

Measurement Results

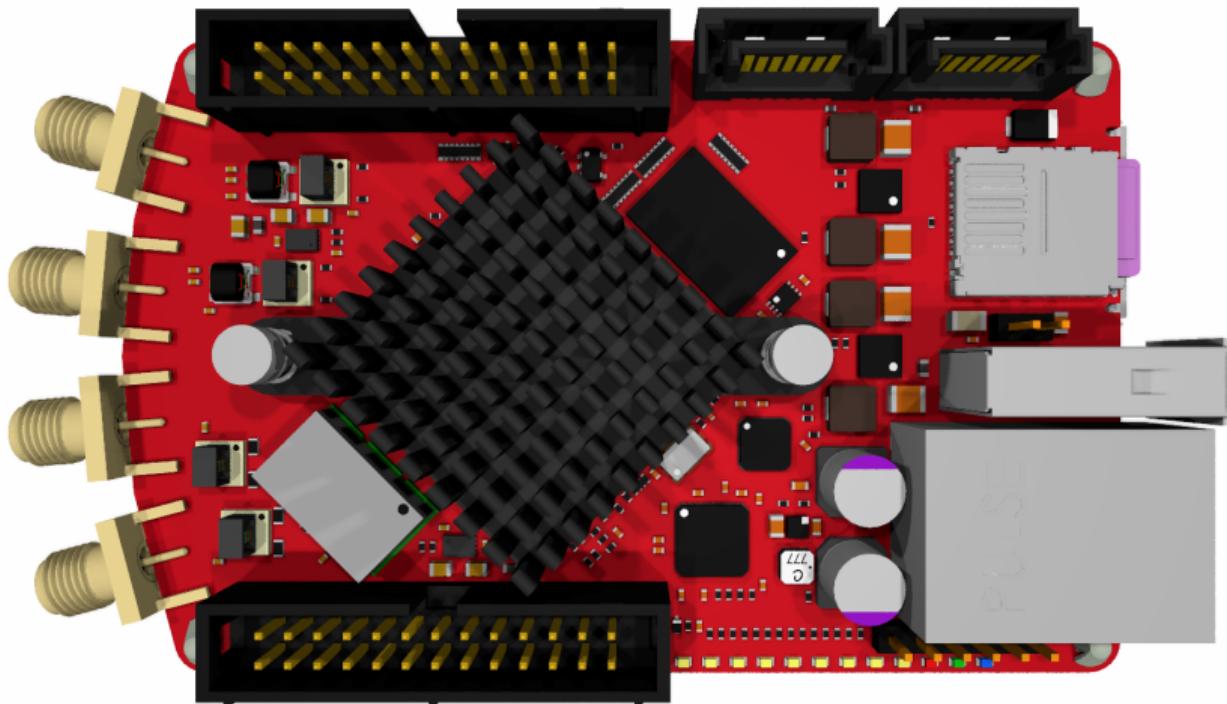
## THE PARTS

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# Our goal is to build an accessible NMR spectrometer

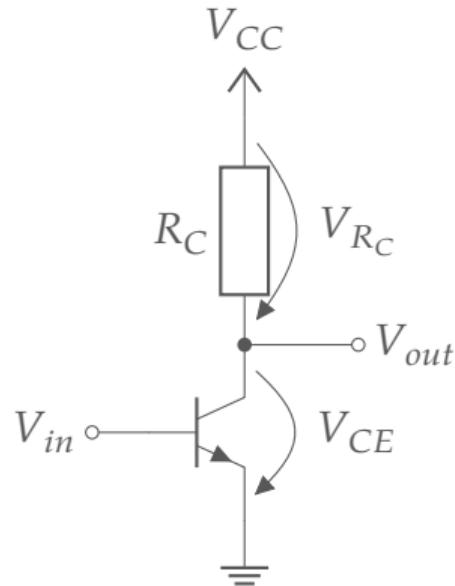


The console  
is a ready-made FPGA board

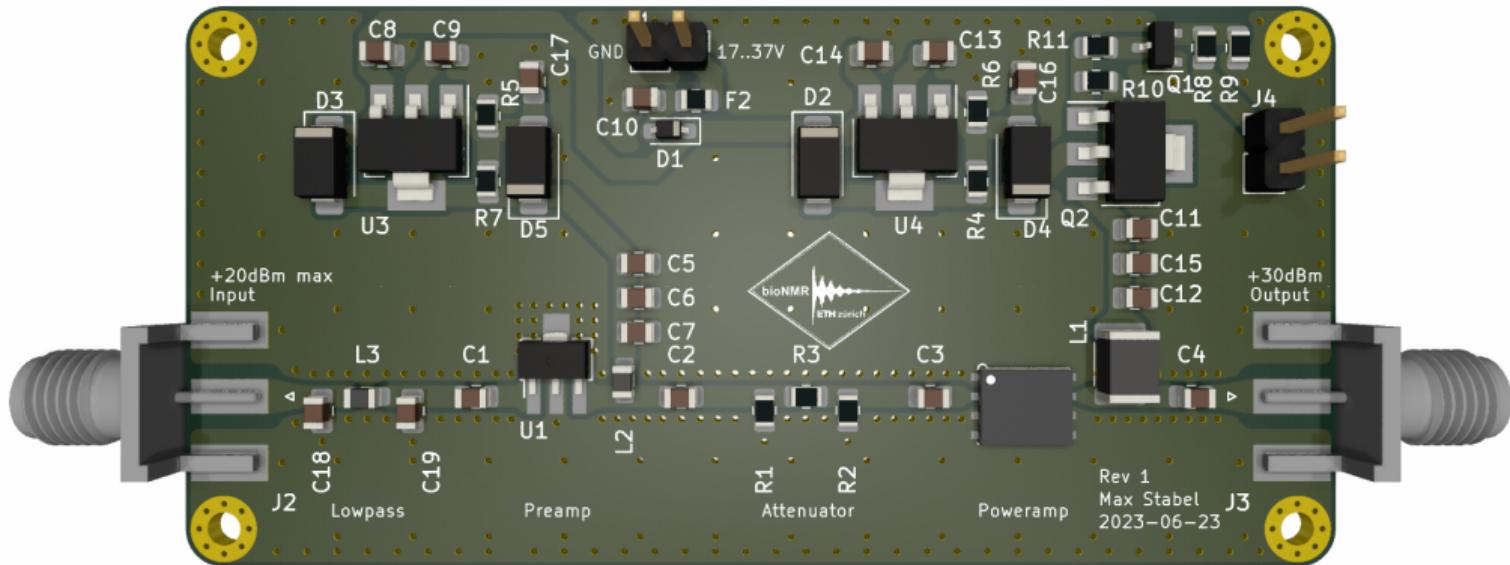


# An amplifier is basically just a transistor

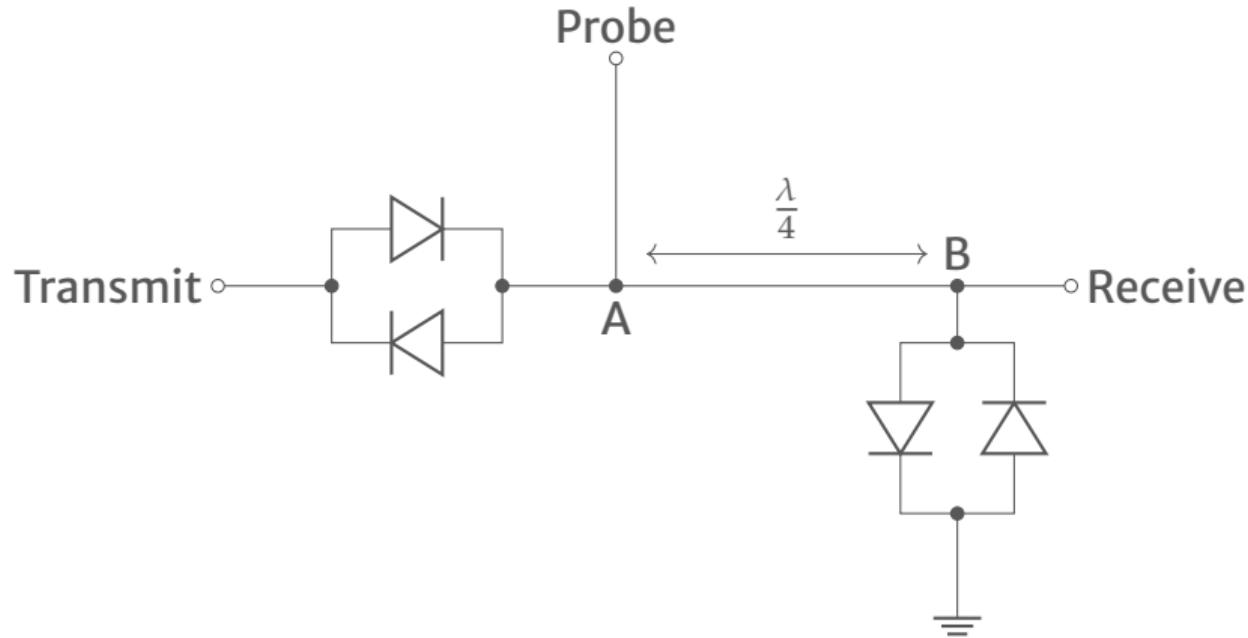
- Transistor:  
voltage-controlled current source
- higher voltage → higher current
  - higher voltage  $V_{R_C}$
  - lower voltage  $V_{CE}$
  - 180° phase shift



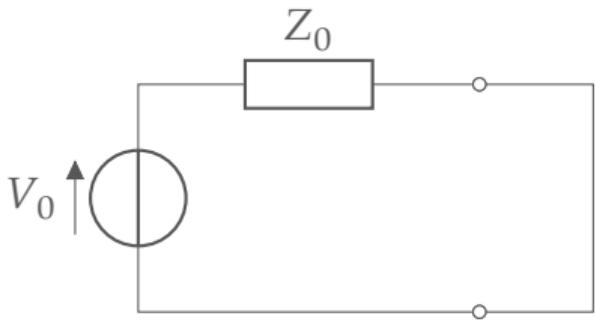
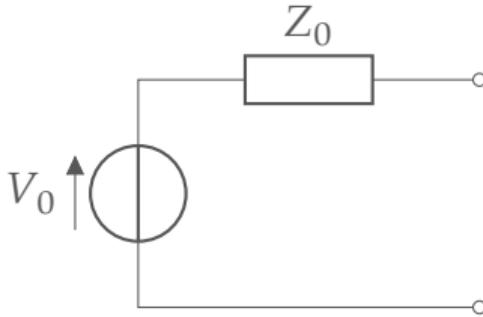
# The power amplifier has two stages



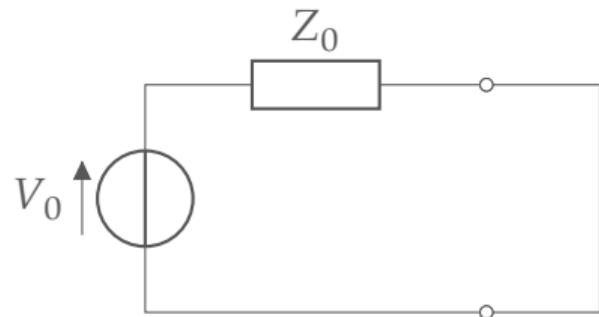
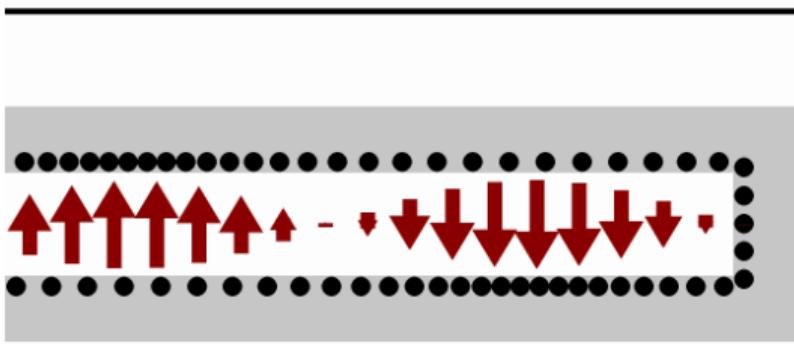
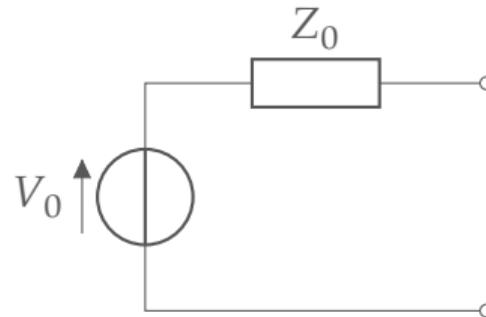
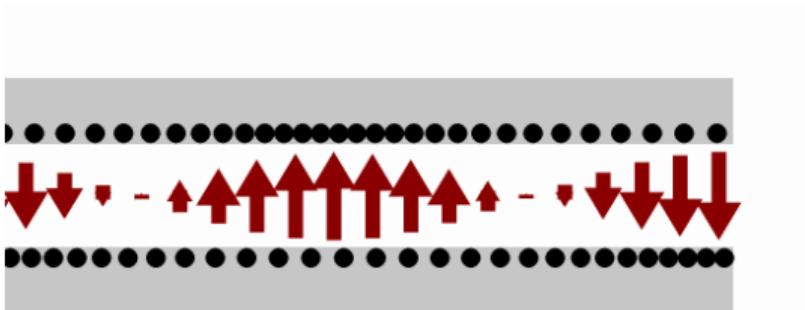
# The passive approach leaked too much power



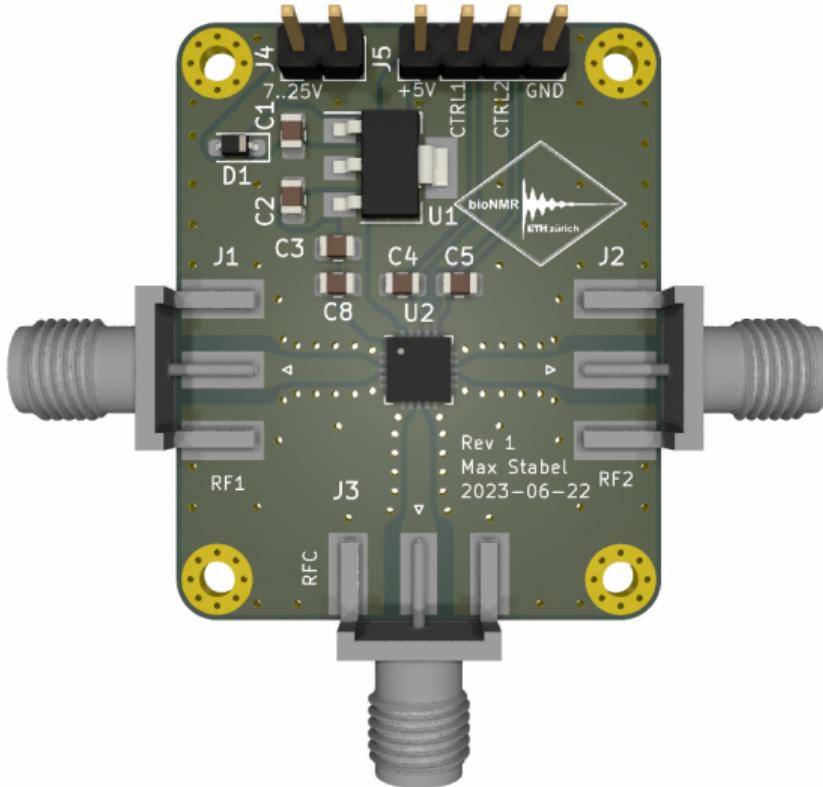
## A transmission line transforms impedance



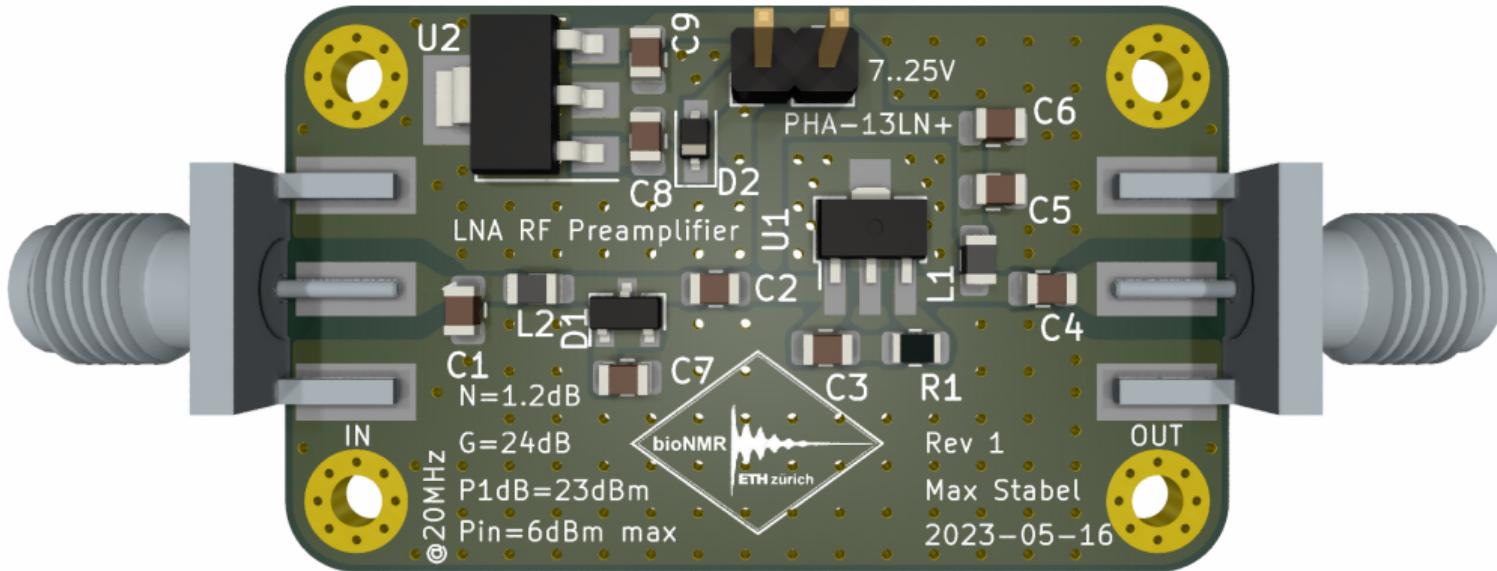
# A transmission line transforms impedance



# We use a transistor-based active switch



# The low-noise amplifier



# The probe



## THE COMPLETE SETUP

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## Our NMR is affordable ...

	600 MHz*	mini-circuits	<i>magnETHical</i>
Power Amplifier	50 000	323.49	36.01
Switch	-	82.06	20.05
Probe	100 000	-	≈15.00
Low-Noise Amplifier	50 000	409.38	73.11
Shim Driver	-	-	257.08
Console	200 000	-	662.53
Magnet	1 000 000	-	≈9000.00
<b>Sum</b>			<b>10142.80</b>

\*estimated costs

## ... and competitive

	Superconducting	Benchtop	<i>magnETHical</i>
Price [k CHF]	200–18 000	50–150	≈10
Frequency [MHz]	300–1200	40–125	25
Resolution [Hz]	≈0.2	0.2–1	≈2.5/50 <sup>†</sup>
Weight [kg]	600–15 000	25–150	≈5

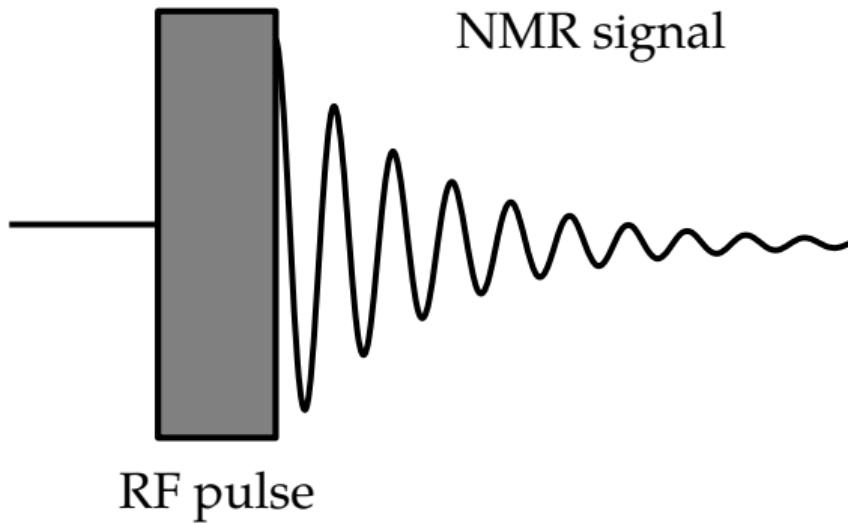
<sup>†</sup>with/without shims

For 5mm standard NMR tubes

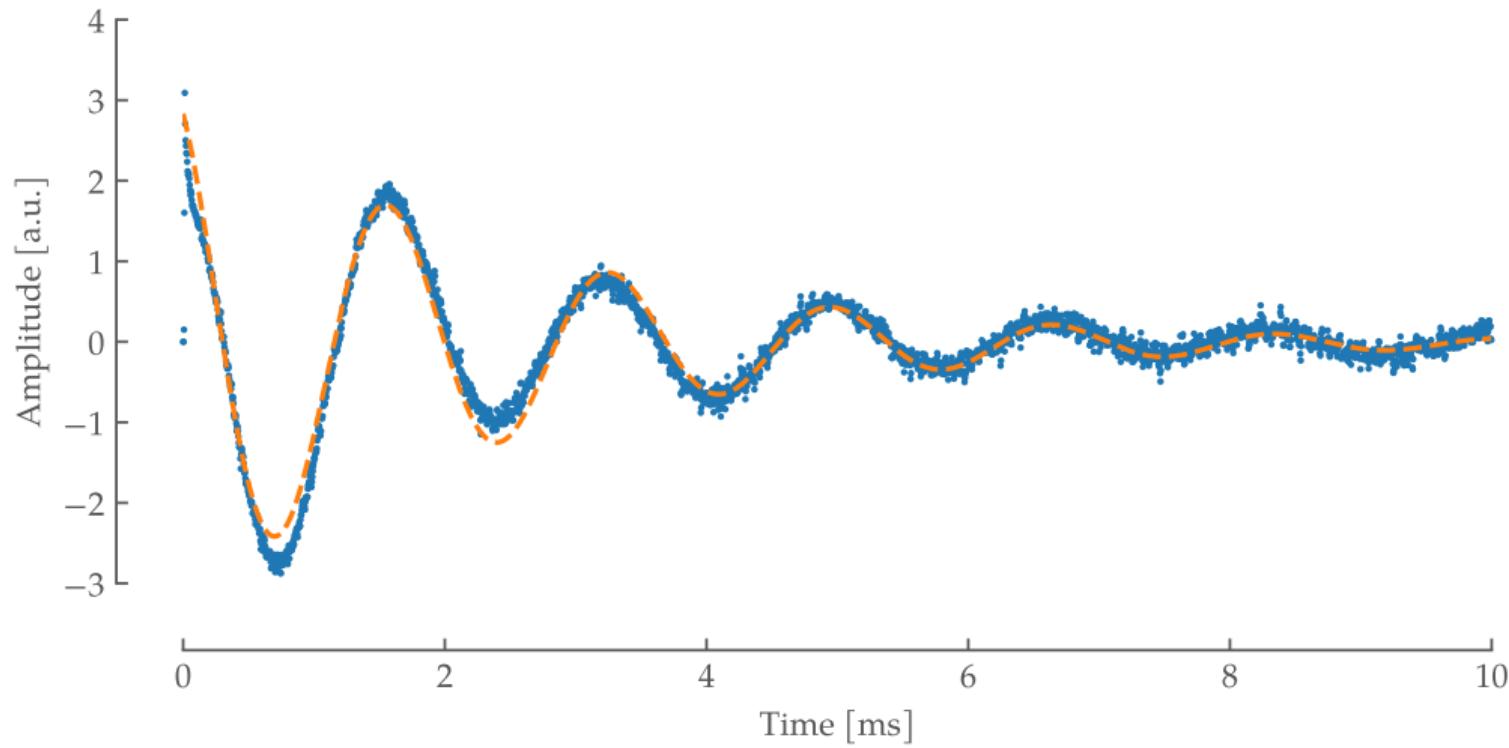
## MEASUREMENT RESULTS

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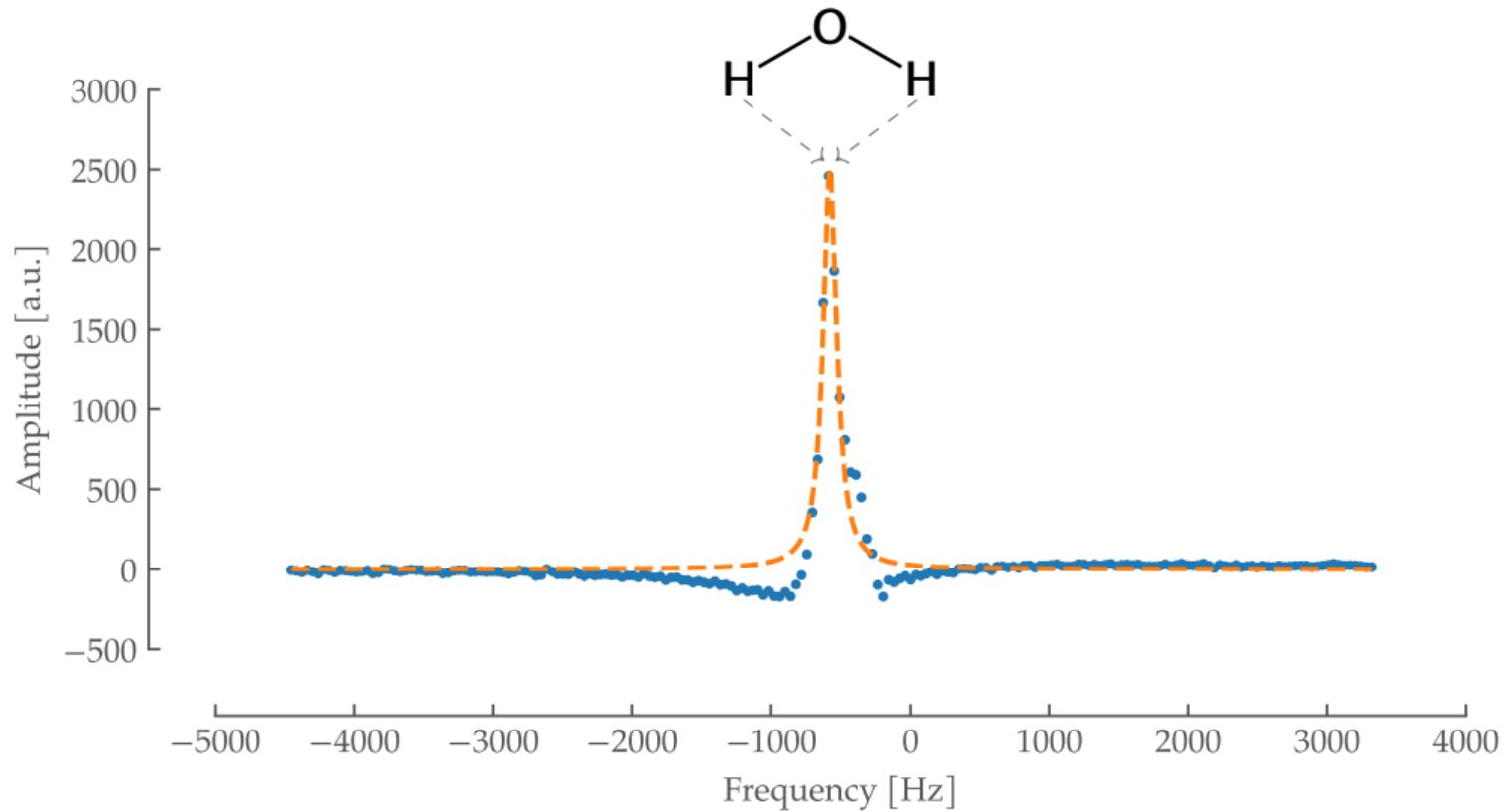
# Simple Pulse Sequence



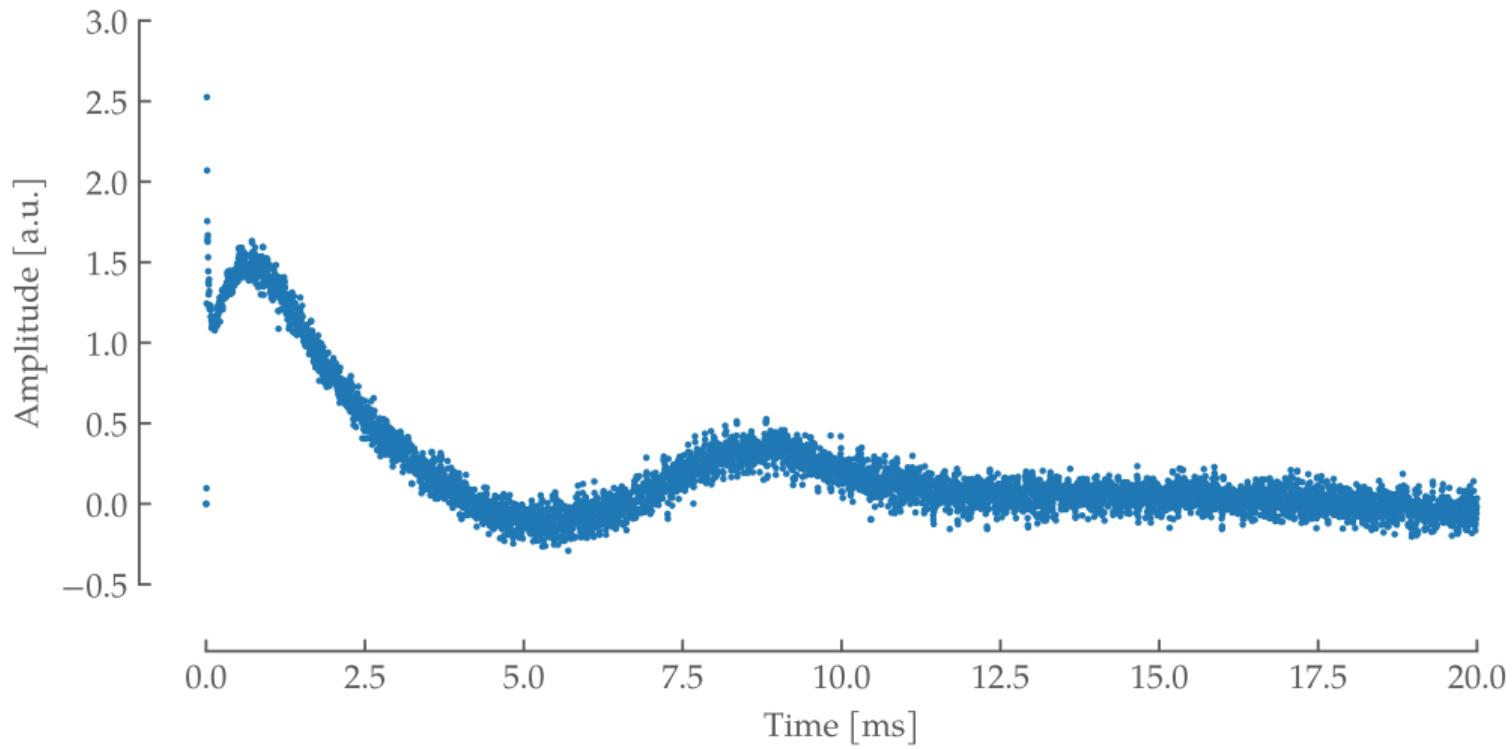
We can already see a water FID



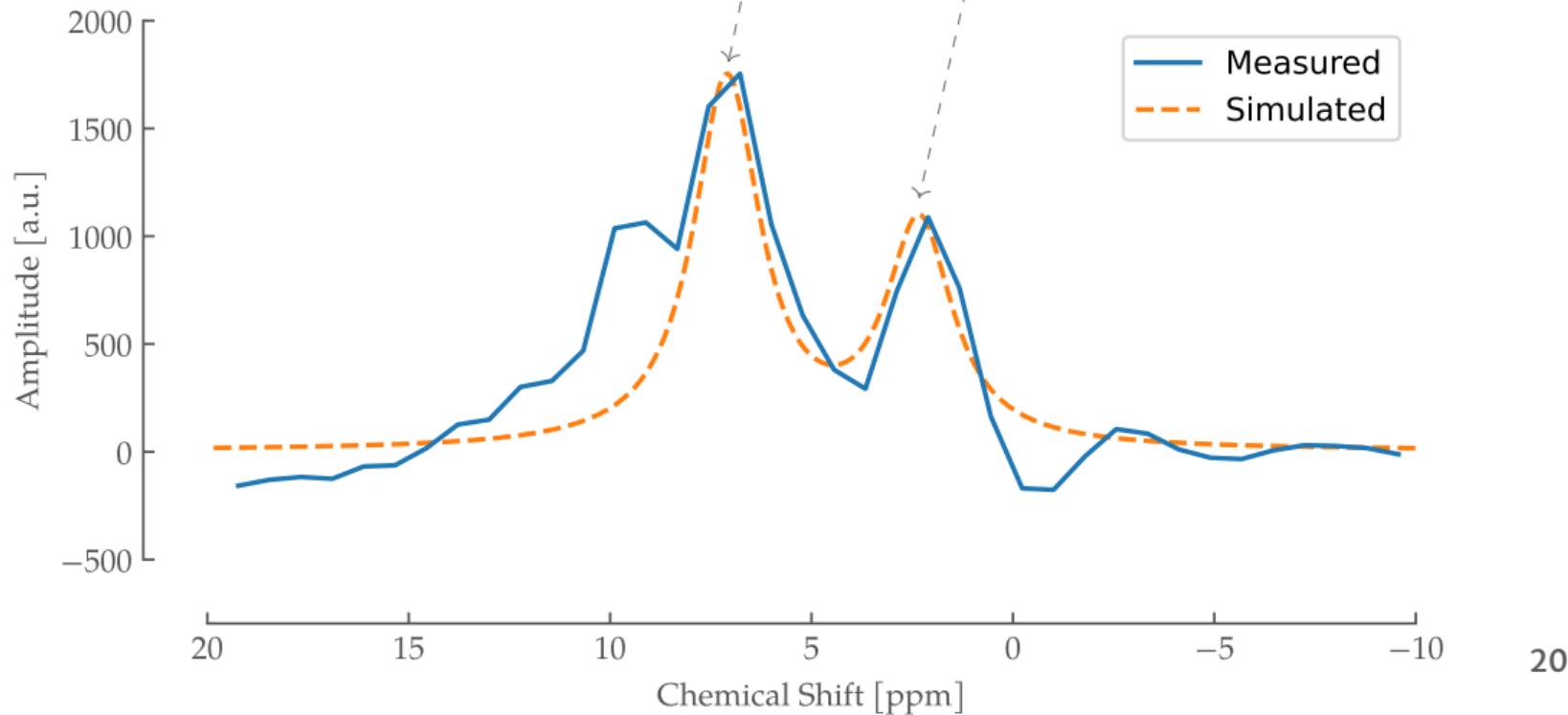
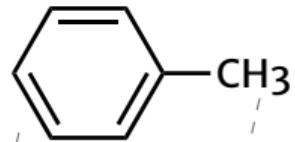
...and do a Fourier transform



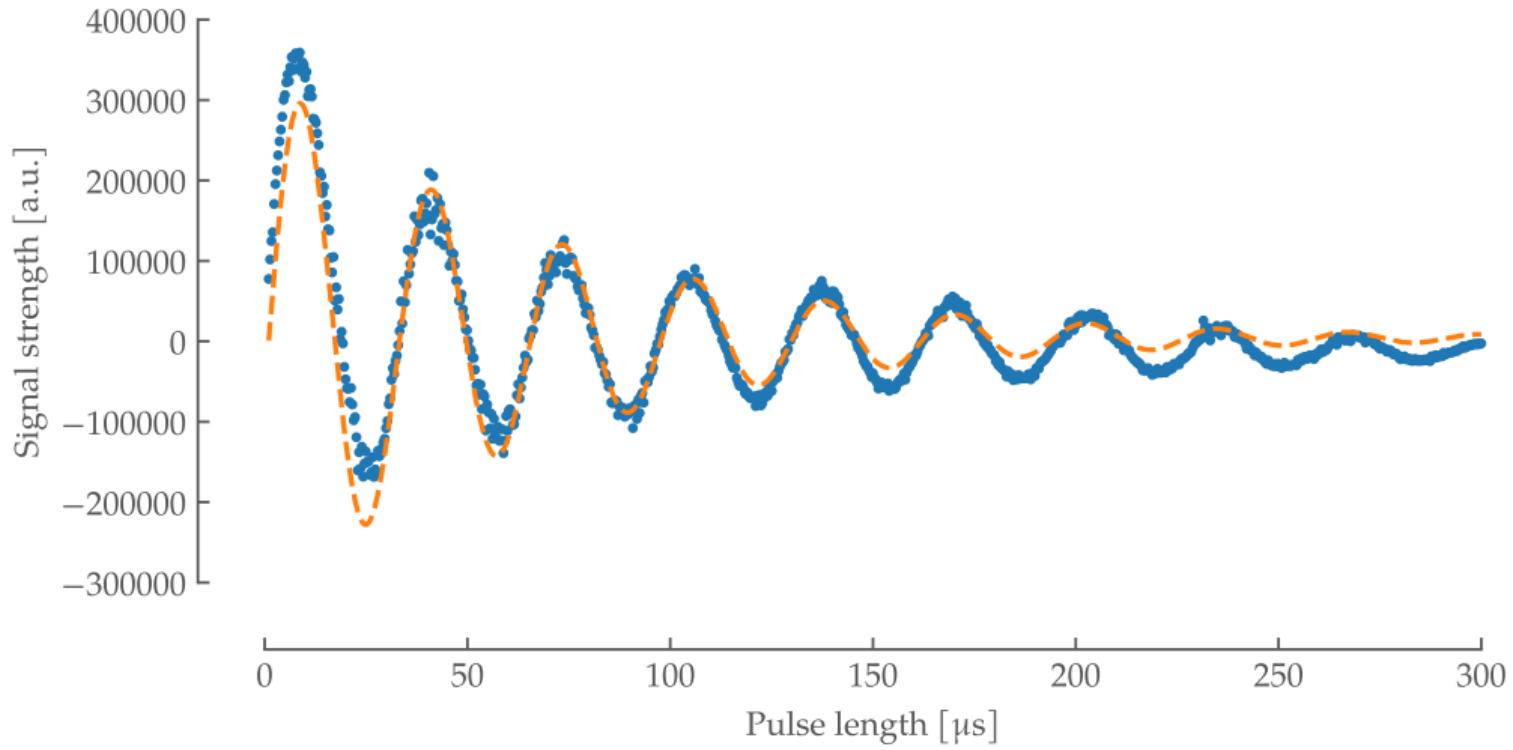
## Toluene also has a visible signal



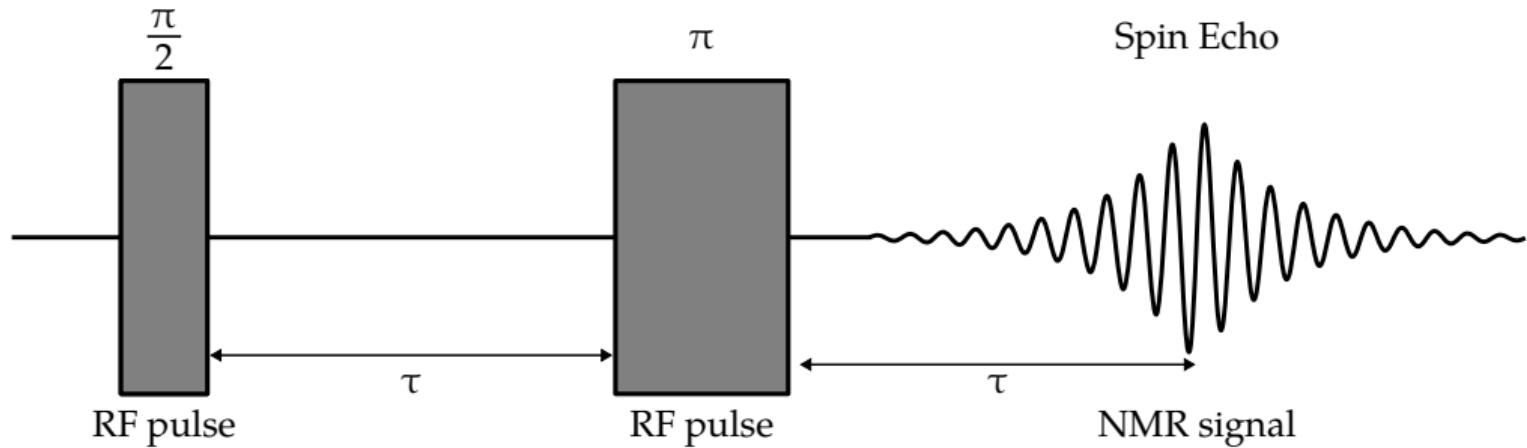
We can even see the chemical shifts  
of the Toluene peaks!



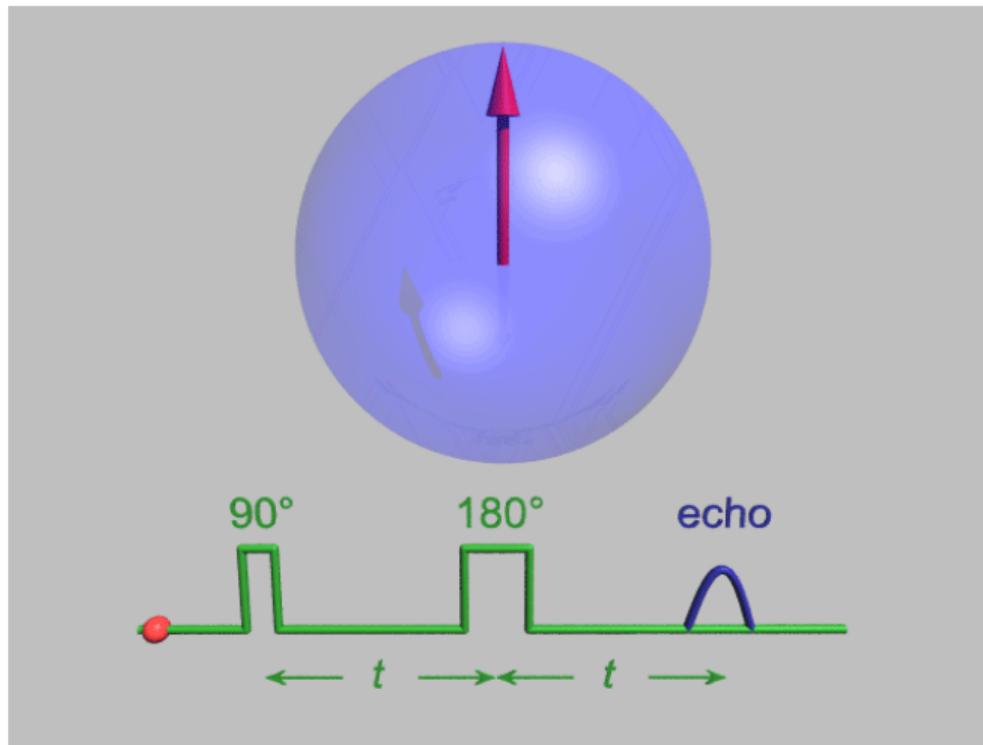
## Rabi nutation (pulse calibration) of water



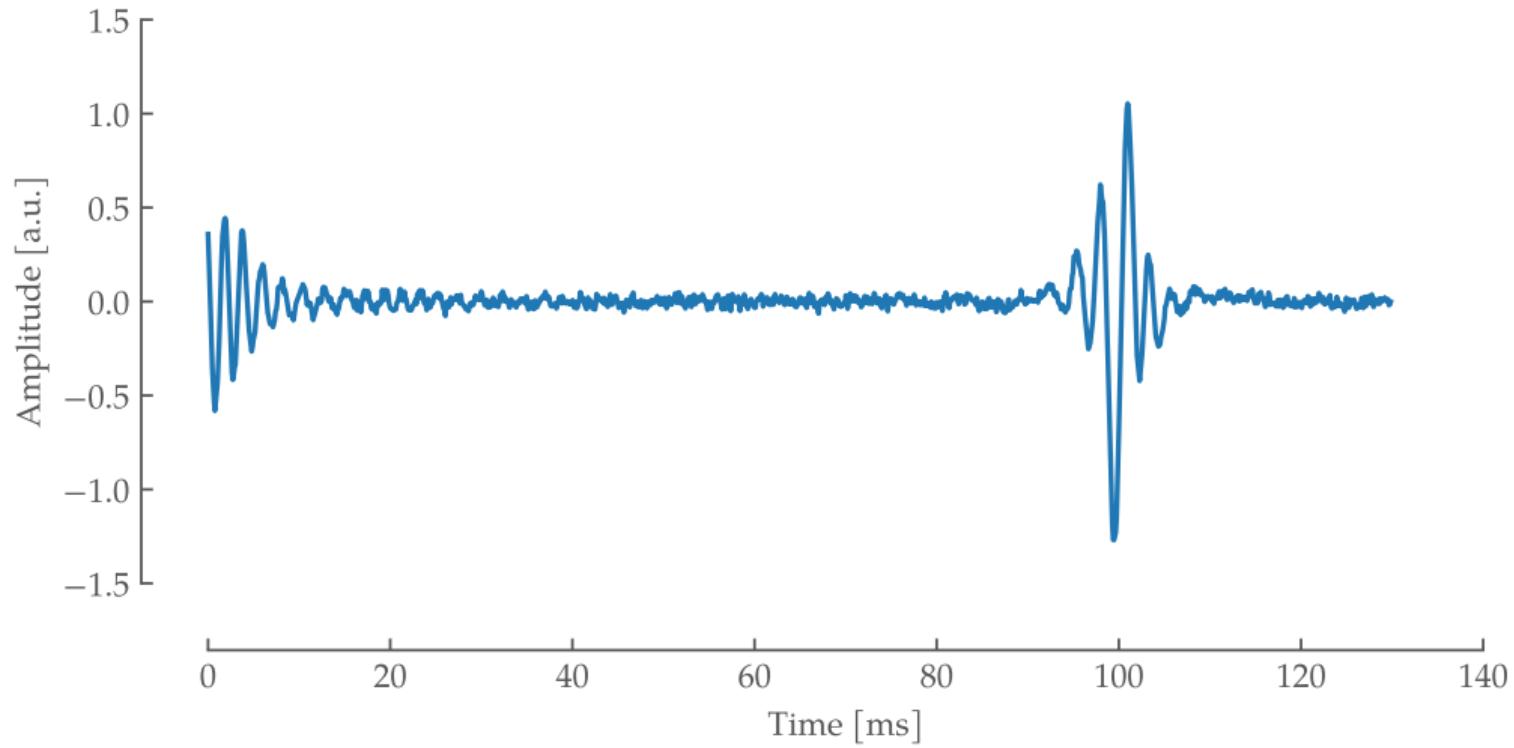
# Spin Echo Sequence



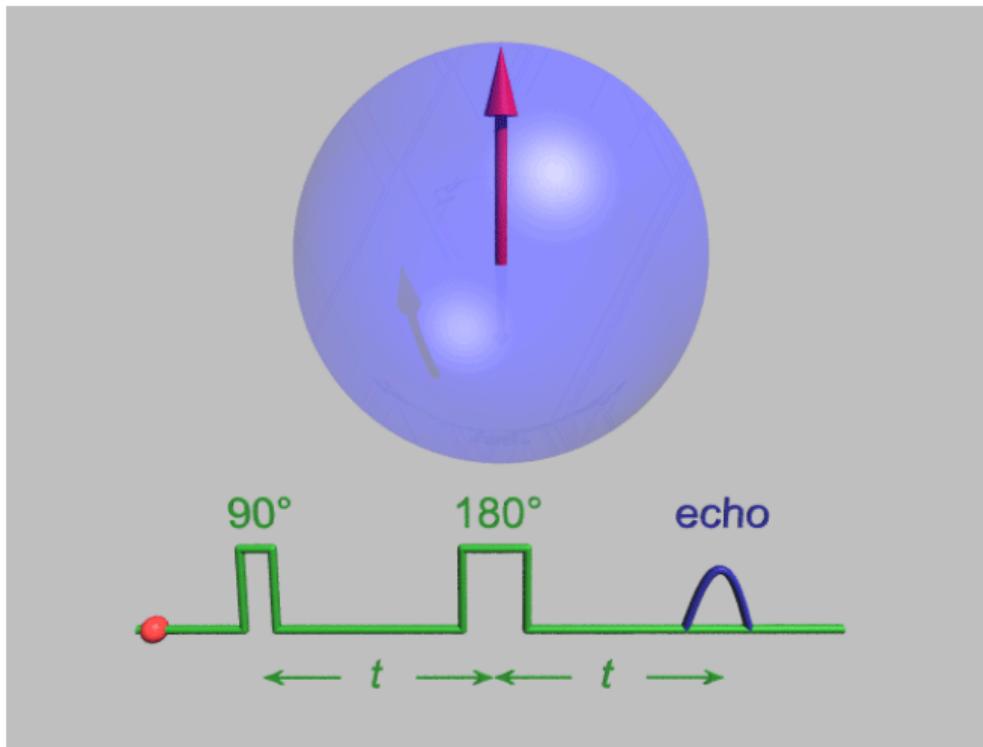
# Spin Echo Animation



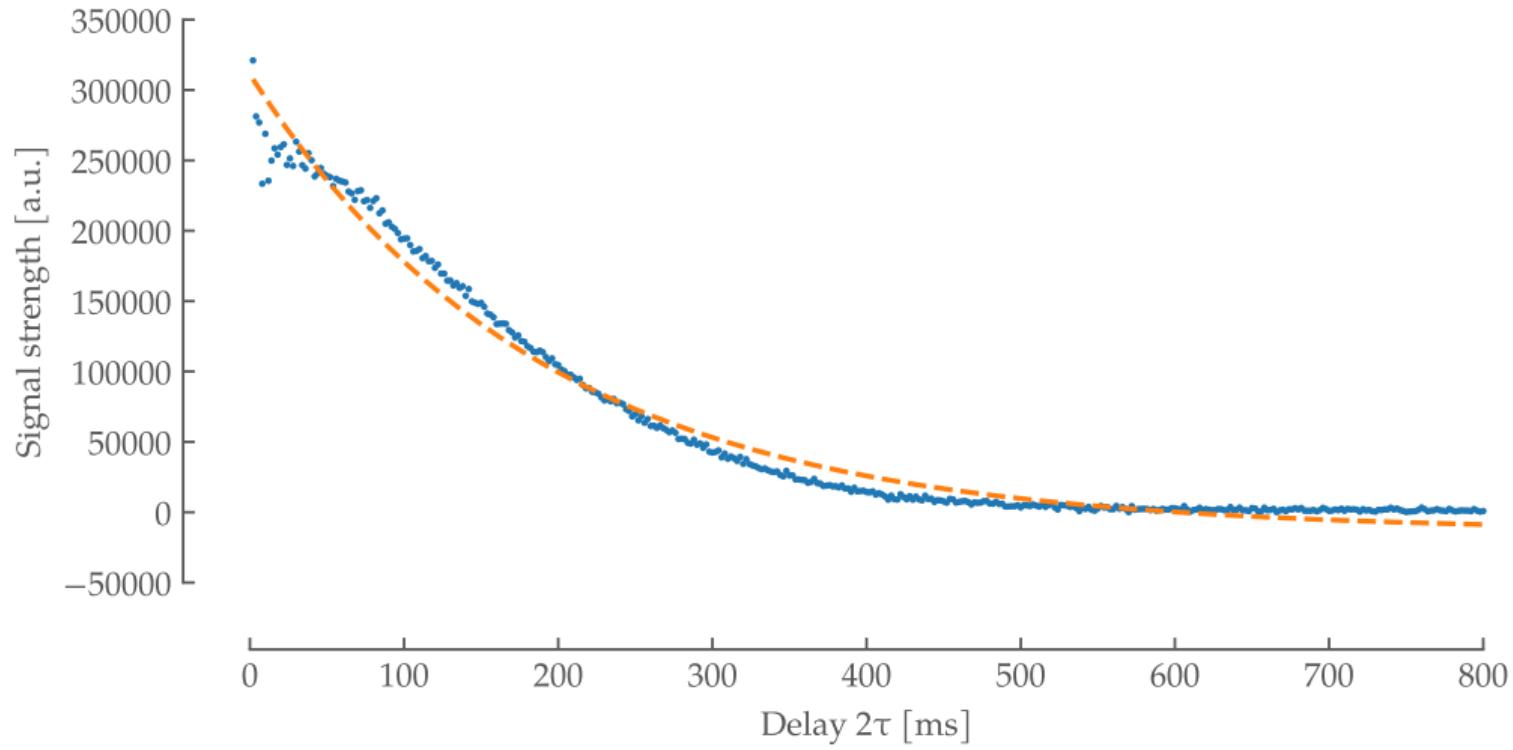
# Spin Echo Measurement



## $T_2$ Decay Animation



## $T_2$ decay of water



**Demo time!**

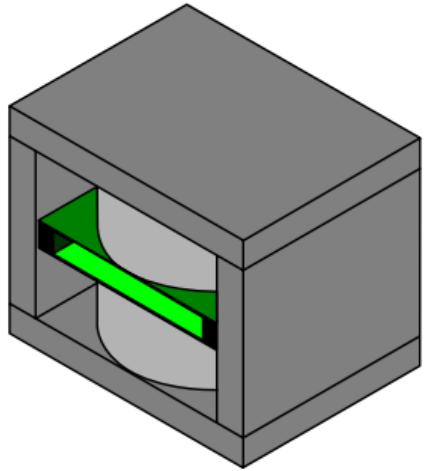
**The setup is working**

*“I have not yet lost that sense of wonder, and of delight, that this delicate motion should reside in all ordinary things around us, revealing itself only to him who looks for it.”*

*“There the snow lay around my doorstep — great heaps of protons quietly precessing in the Earth’s magnetic field.”*

— E.M. Purcell

Thank you!



*magn***ETH**ical

Find everything on



[https://gitlab.ethz.ch/mstabel/  
nmr-spectrometer](https://gitlab.ethz.ch/mstabel/nmr-spectrometer)

# Backup