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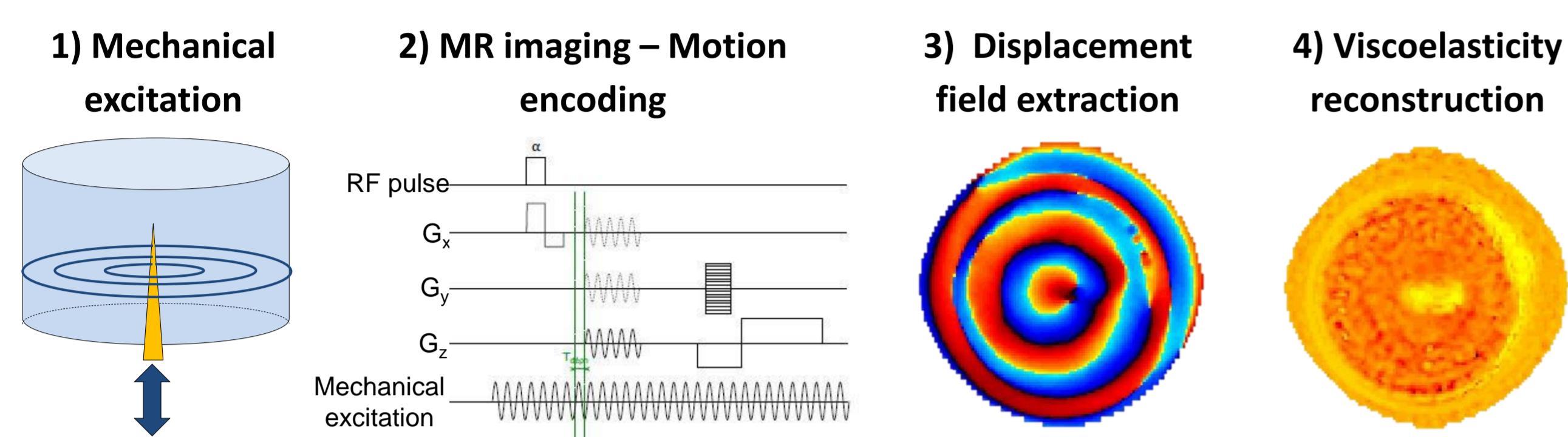
Development of an elastography bench for MR exam of small samples

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Introduction

Extraction of biomechanical parameters for small samples via Magnetic Resonance Elastography (MRE):



Need of:

- Wave amplitude > μm
- High signal to noise ratio (SNR) with high resolution
- Low cost and handy design

Methods

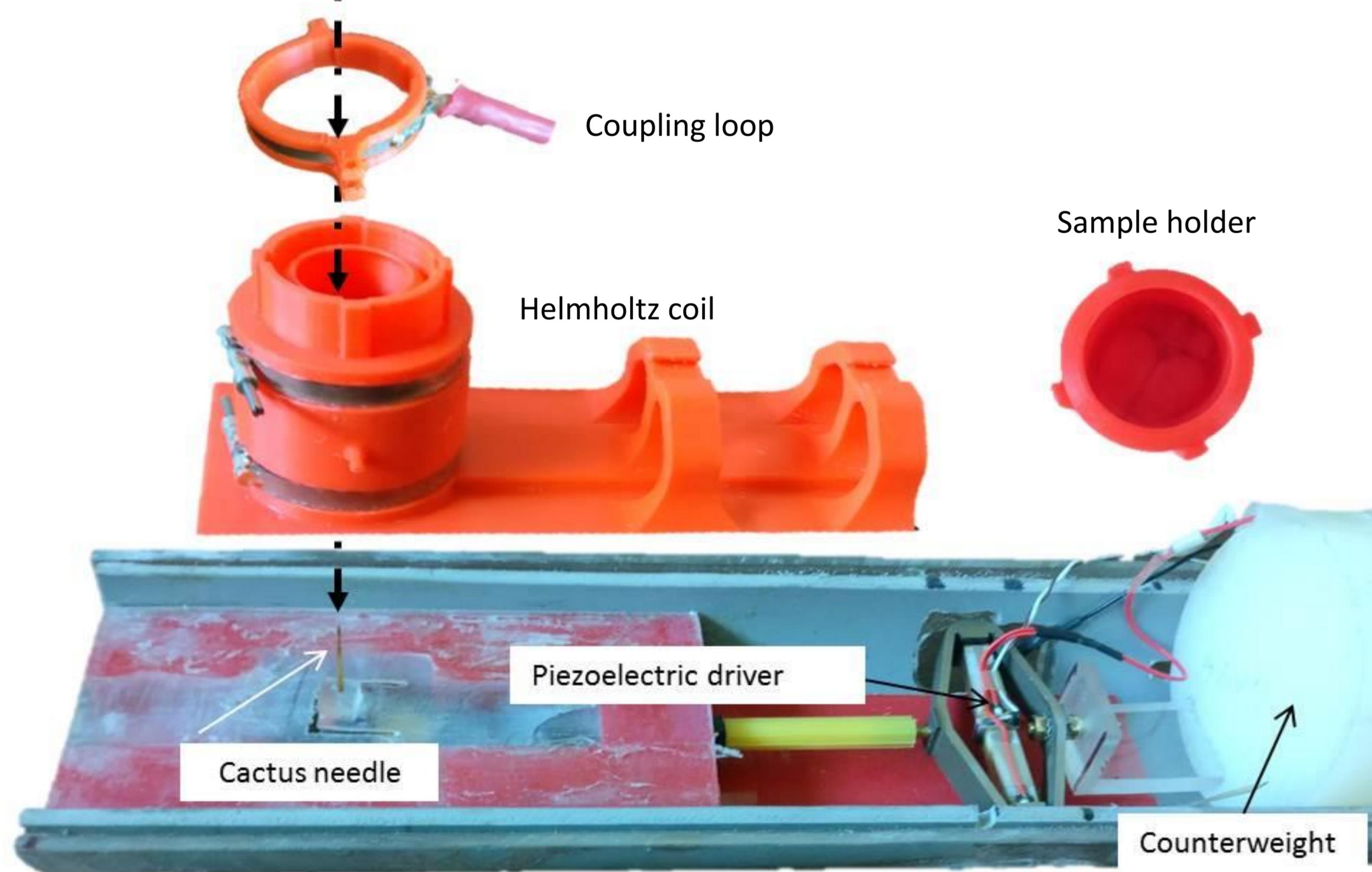


Figure 1. 3D-printed device on top of a classical elastography setup:

- Helmholtz coil ($\varnothing = 36 \text{ mm}$):
Tuning: capacity trimmers
Matching: Coupling loop (inductive coupling)
- Sample holder gliding into the coil

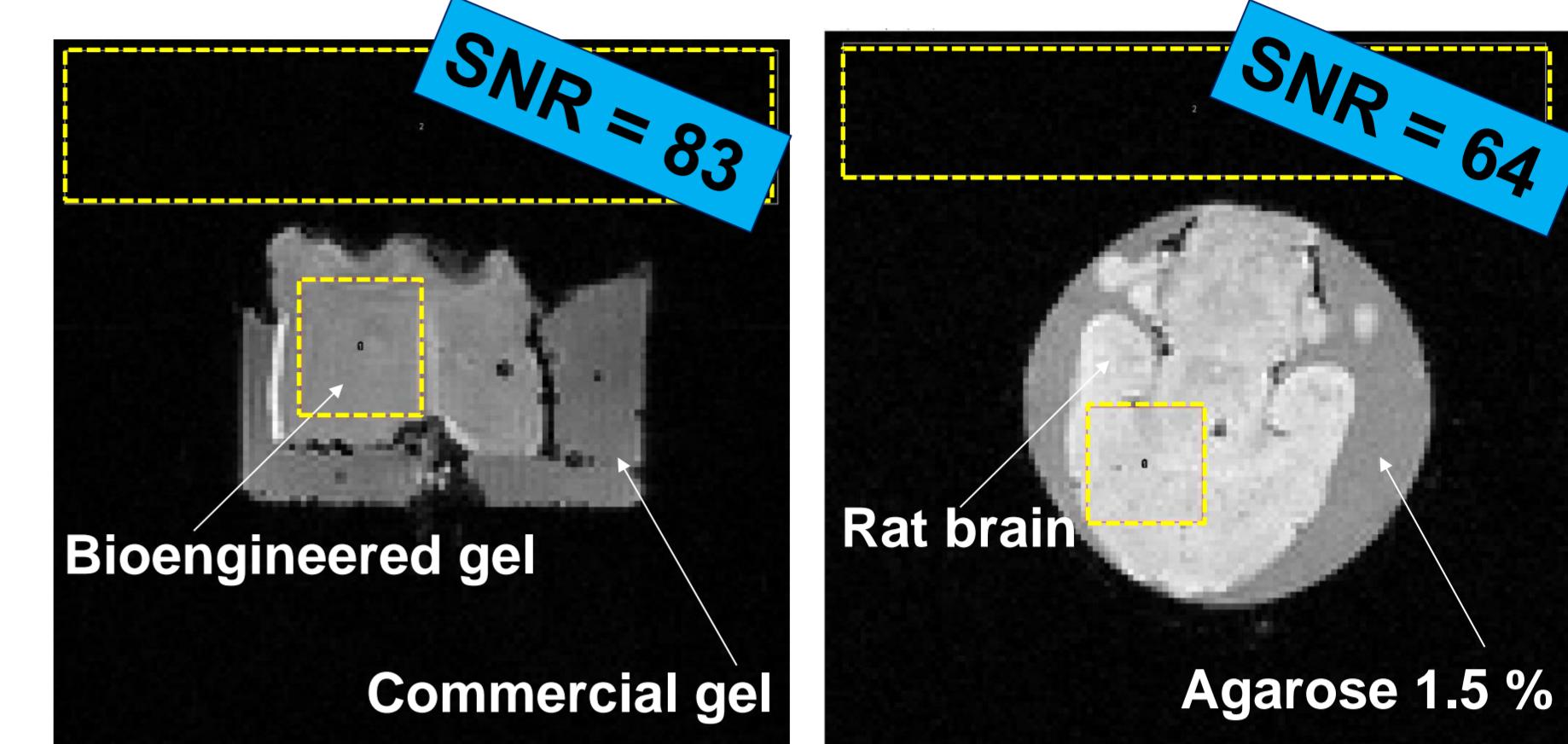
Acquisition on a Bruker 4.7 T scanner for fibrin and agarose 1,5% gels and an ex vivo rat brain:

| Acquisition parameters | FLASH 3D | Turbo spin echo (MRE) |
|---------------------------|-------------------|-----------------------|
| TR/TE (ms) | 15/6 | 2000/18 - 24 |
| Voxel size (mm) | 0.312x0.312x0.625 | 0.312x0.312x0.625 |
| FOV (mm) | 40 x 40 | 40 x 40 |
| Flip angle (°) | 15 | X |
| Reception bandwidth (kHz) | 50 | 50 |
| Acquisition time (min) | 2 | 17 |
| Excitation frequency (Hz) | X | 600 - 1000 |

Table 1. Acquisition parameters for an anatomical (FLASH) sequence and a conventional spin echo based elastography sequence

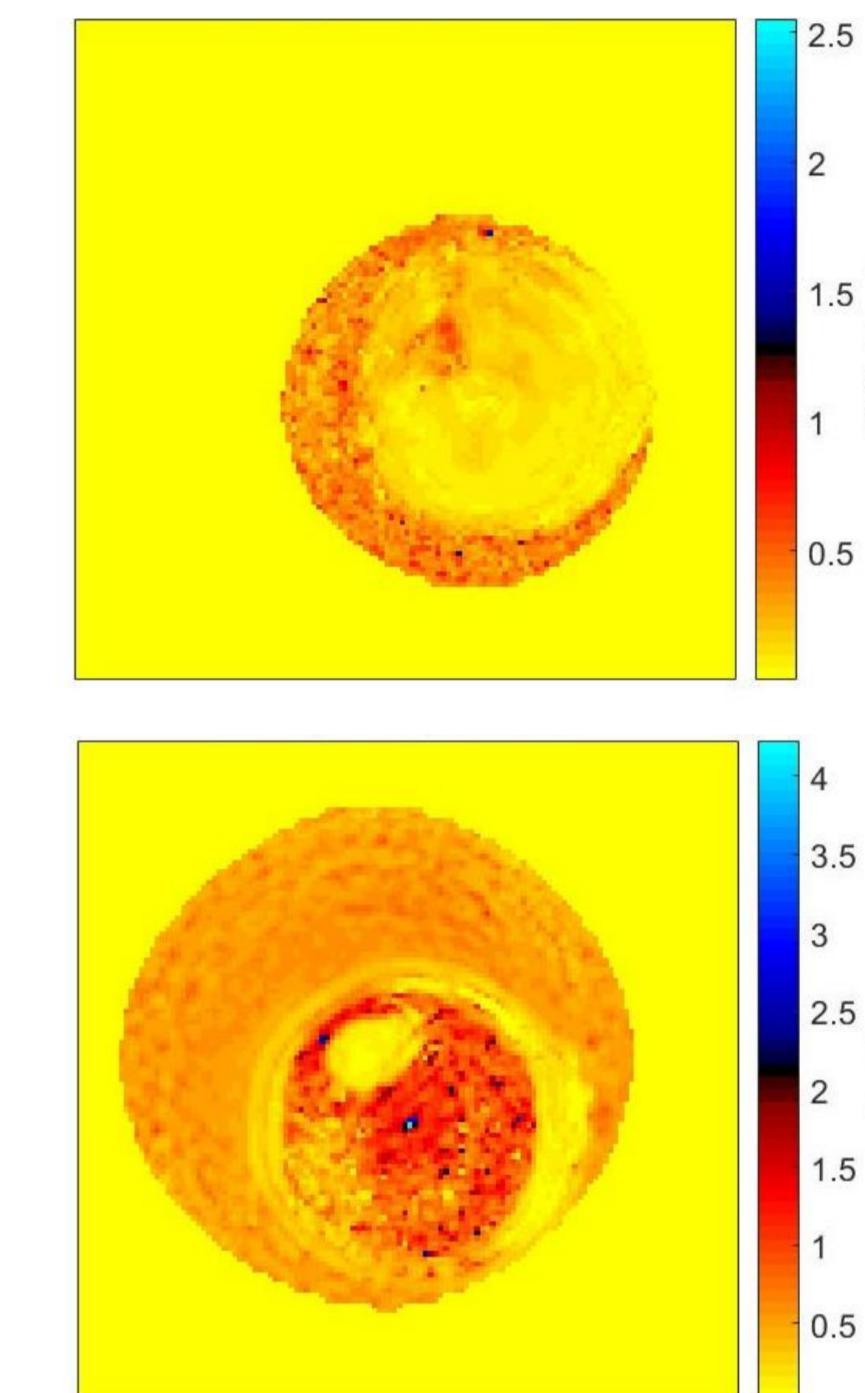
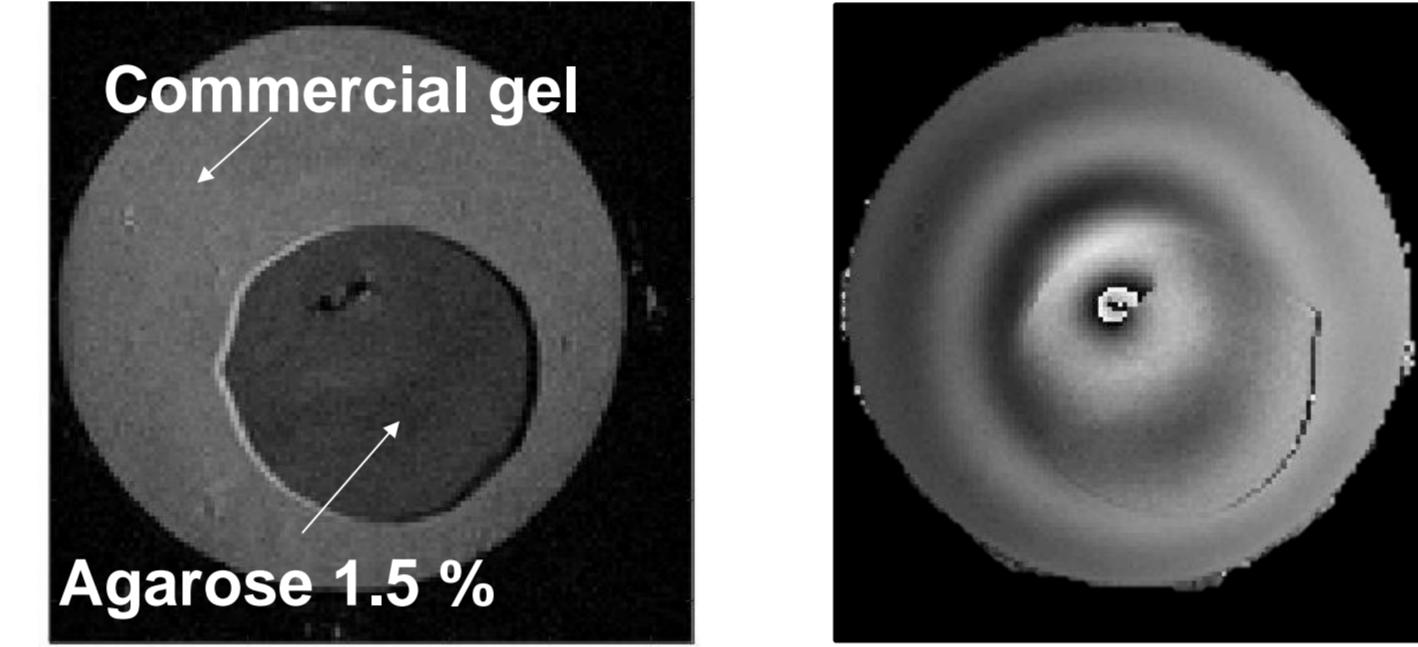
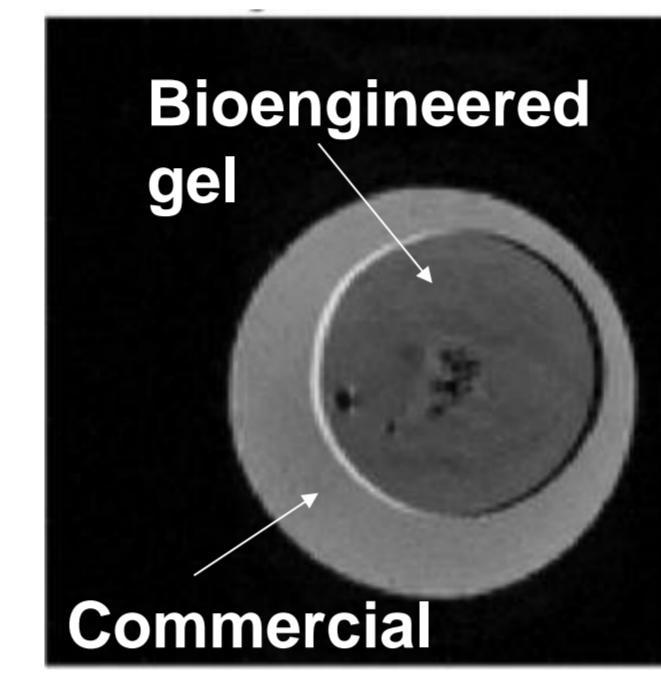
Results

Figure 2. SNR worked out on central slices of a FLASH sequence for a bioengineered gel and a rat brain:



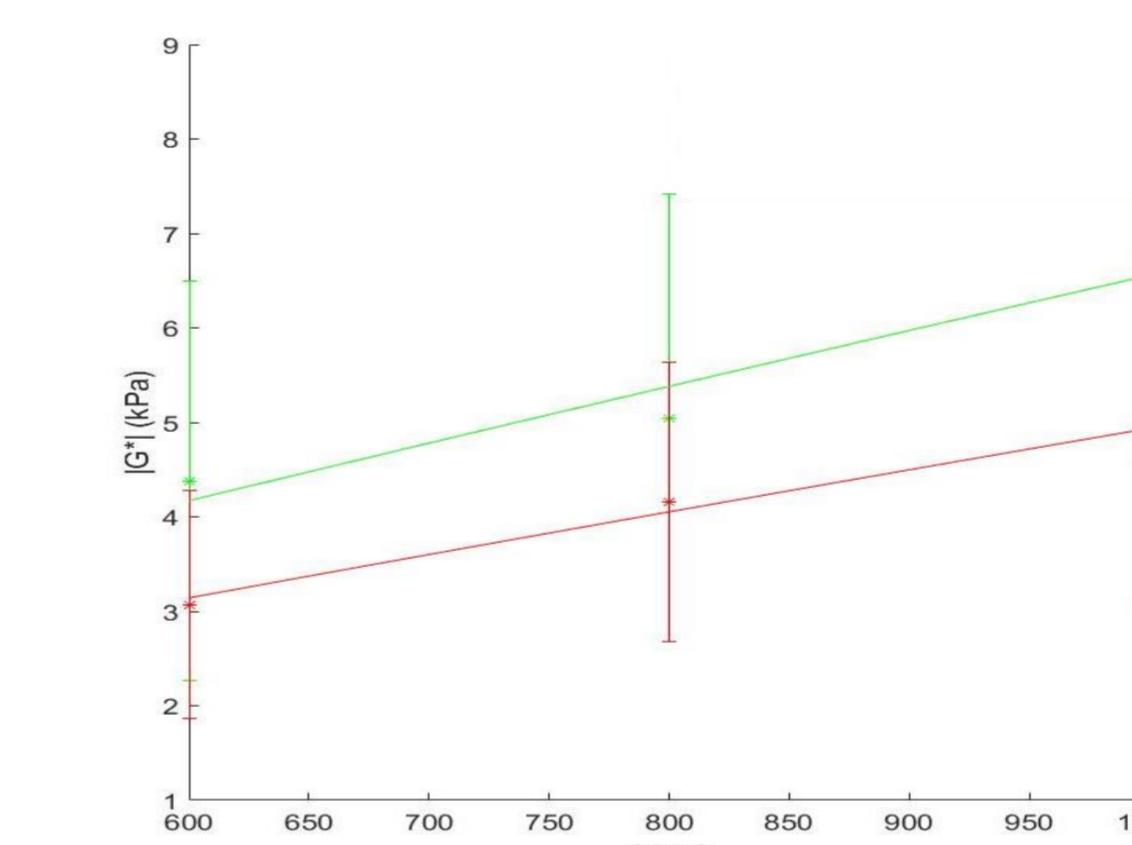
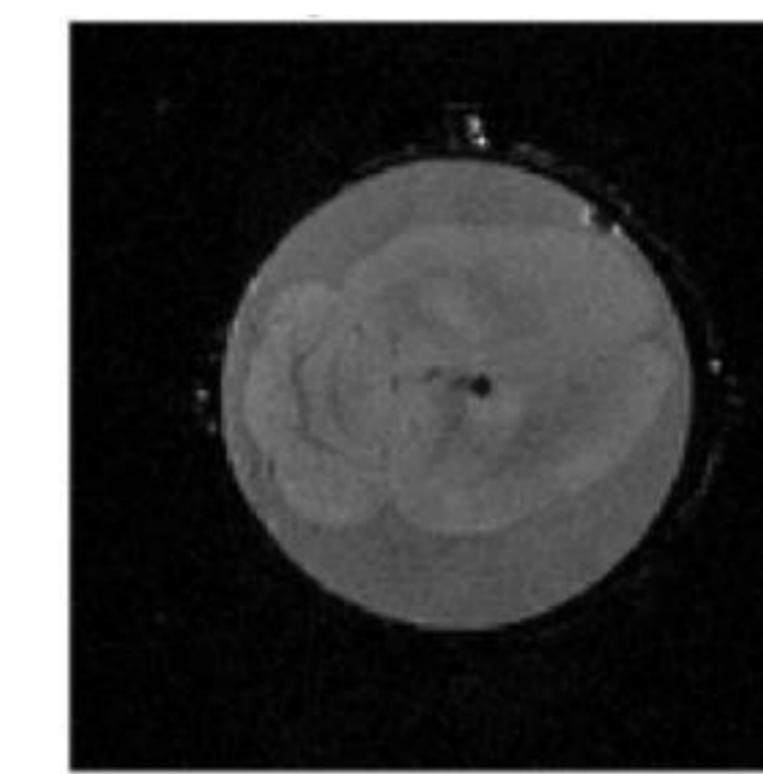
$$\text{SNR}_{\text{gel}} = 83$$

$$\text{SNR}_{\text{brain}} = 64$$



Visible propagation + Clear difference in $|G^*|$ for gels

Figure 3. Magnitude, phase and reconstructed magnitude of the complex shear modulus $|G^*$ obtained by MRE at 600 Hz for the bioengineered gel and an 1.5% agarose gel, both embedded in a commercial gel. Total displacement magnitude $\langle A \rangle$ was $3.8 \mu\text{m}$ for the first gel and $25.5 \mu\text{m}$ for the agarose gel after bench improvement. $|G^*| = 1.4 \pm 0.5$ and $7.3 \pm 3.9 \text{ kPa}$, respectively.



$$\text{Cerebrum: } |G^*| \propto f^{0.886}$$

$$\text{Cerebellum: } |G^*| \propto f^{0.885}$$

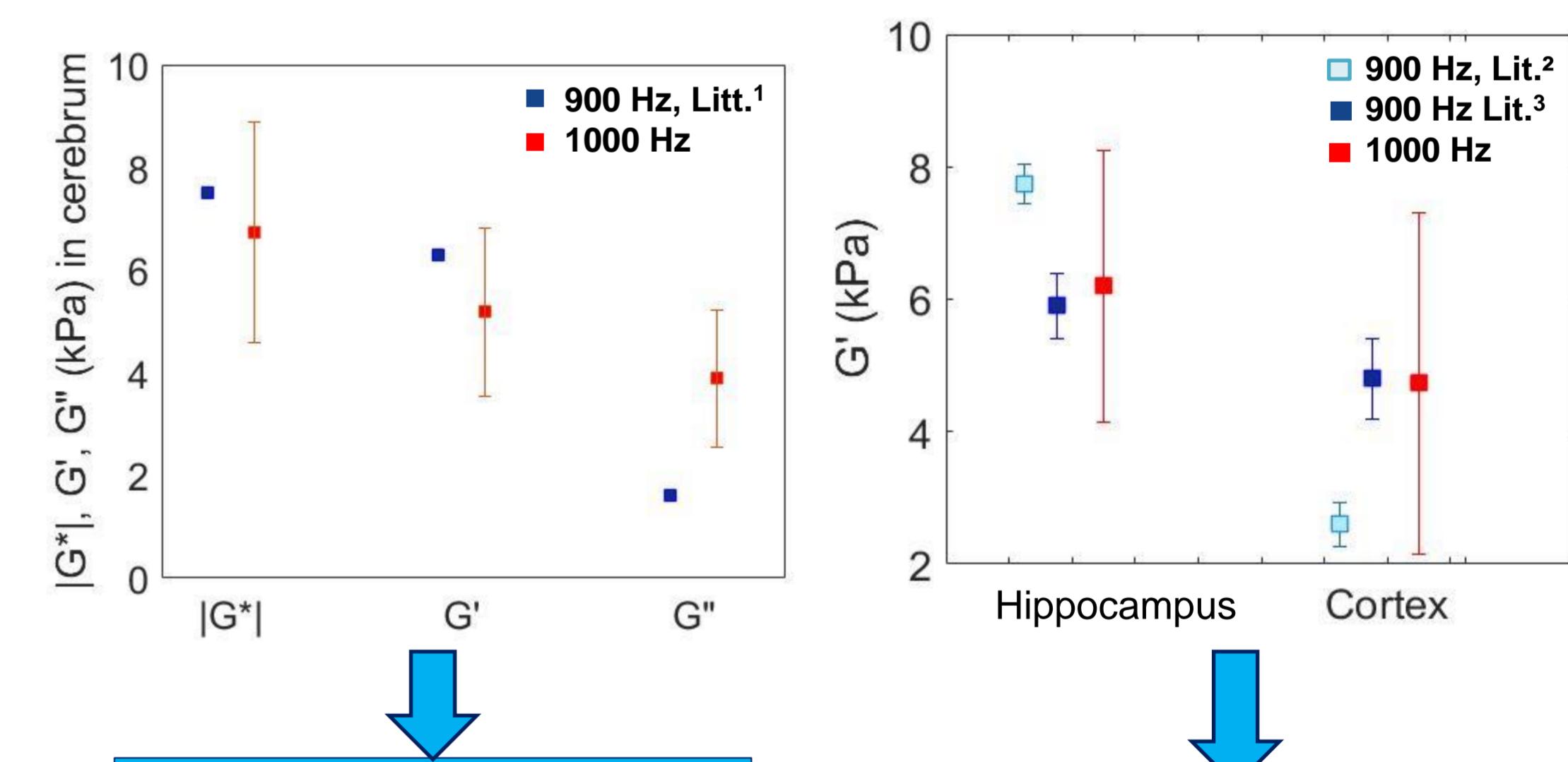
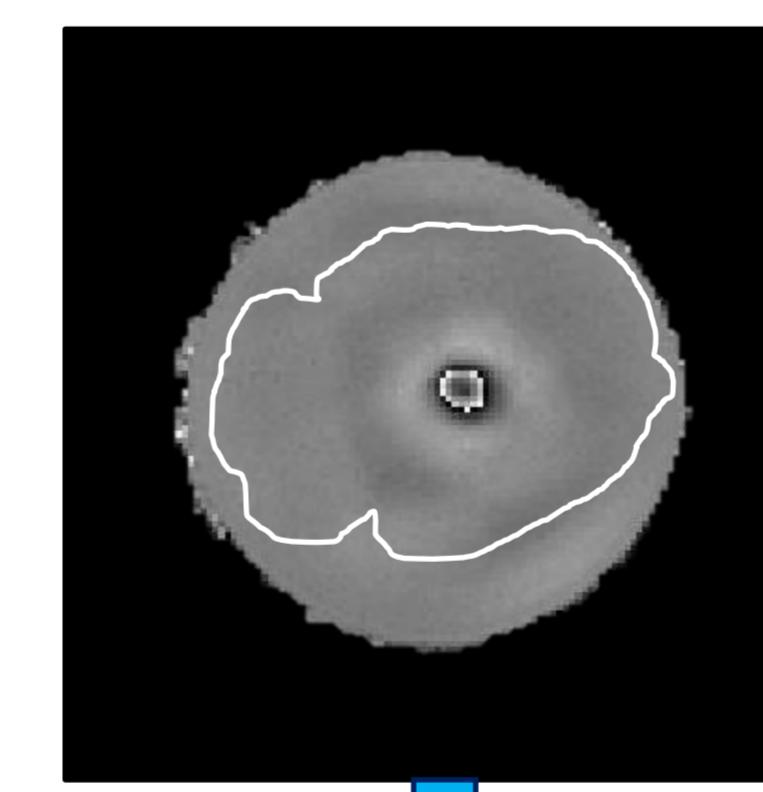
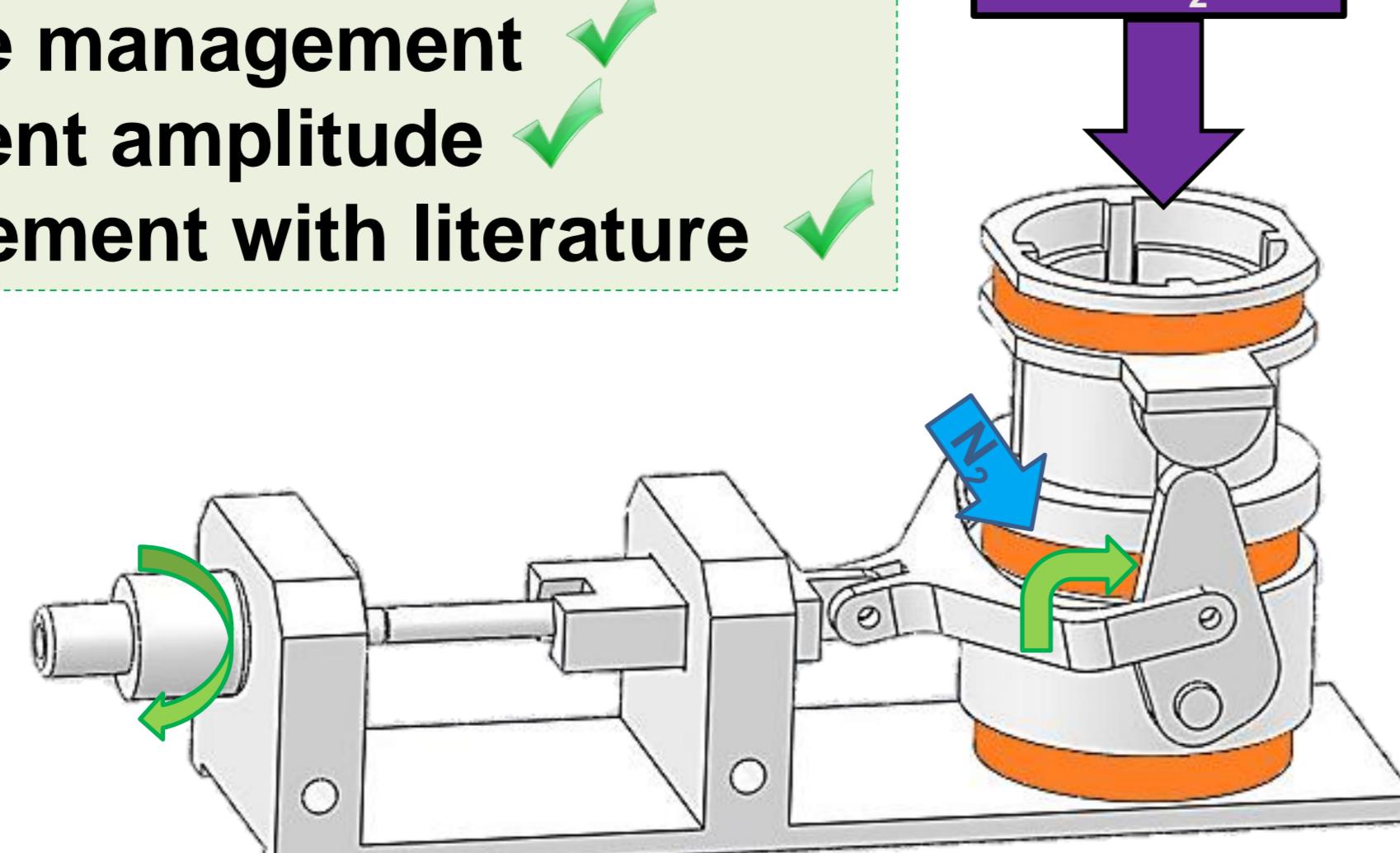


Figure 4. Magnitude and phase images of a fresh ex vivo rat brain for an excitation frequency of 600 Hz. Comparison of extracted biomechanical parameters G' (conservation modulus), G'' (loss modulus) and $|G^*|$ with literature data

Discussion and Conclusion

Cost < 150 € ✓
Easy sample management ✓
Displacement amplitude ✓
Brain data in agreement with literature ✓

Heating Monitoring CO_2



Planned improvements, in order to enable:

- imaging of samples containing living cells: heating and its monitoring + gas arrival
- further improvement the SNR: N_2 arrival for coil cooling
- easier matching: lever system for the coupling loop.

Perspectives: ex vivo acquisitions on rodent brains with neurological lesions (fibrillar aggregates of proteins, demyelination).

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References: (1) Millward et al., NMR Biomed., vol 28 2015. (2) Munder et al., J. Magn. Reson. Imaging, 2017. (3) Boulet et al., J. Neurosci. Methods, vol 201, 2011.



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