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Magnetic Resonance Acoustic Radiation Force Imaging (MR-ARFI) for the estimation of local viscoelasticity and anisotropy

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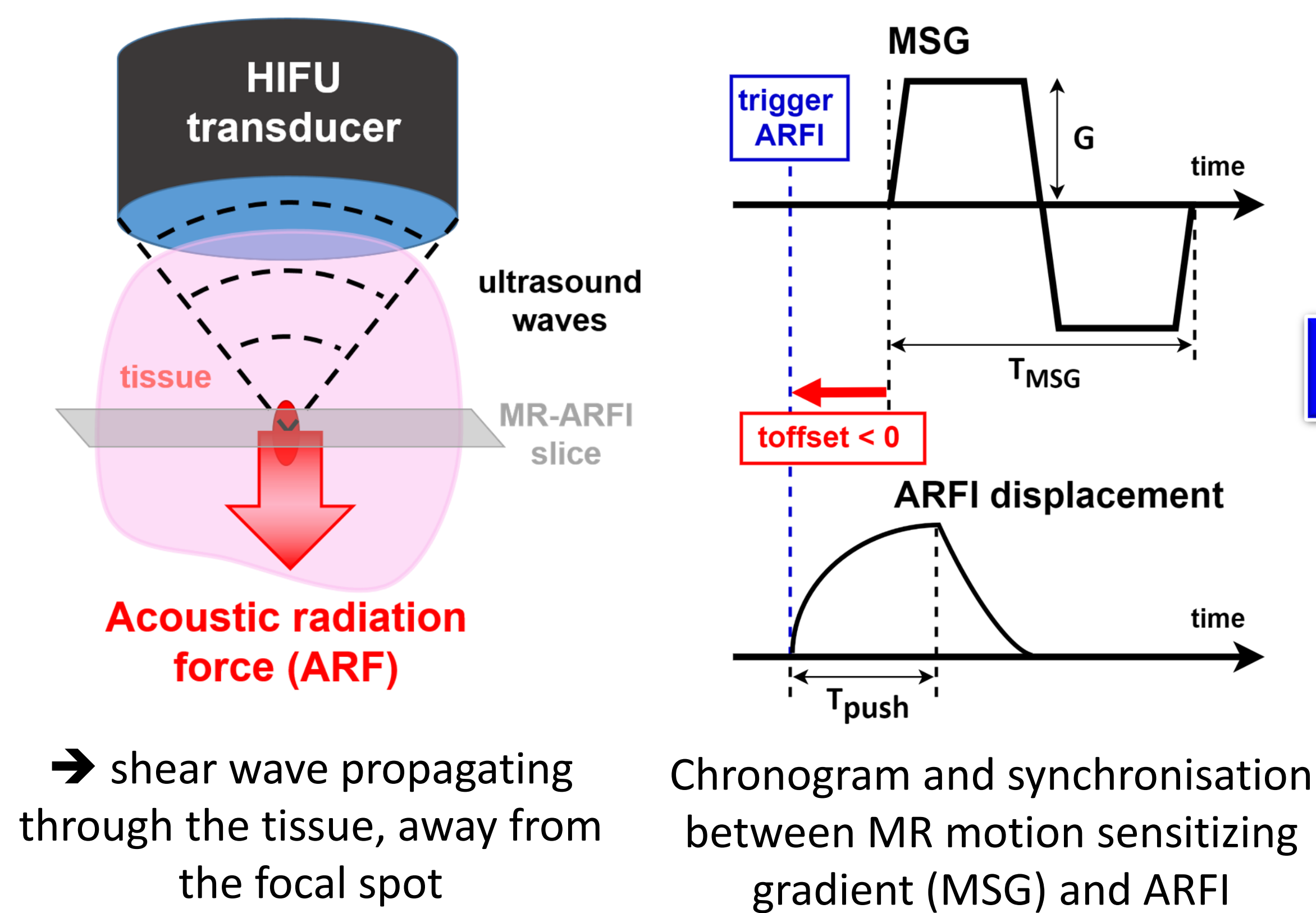
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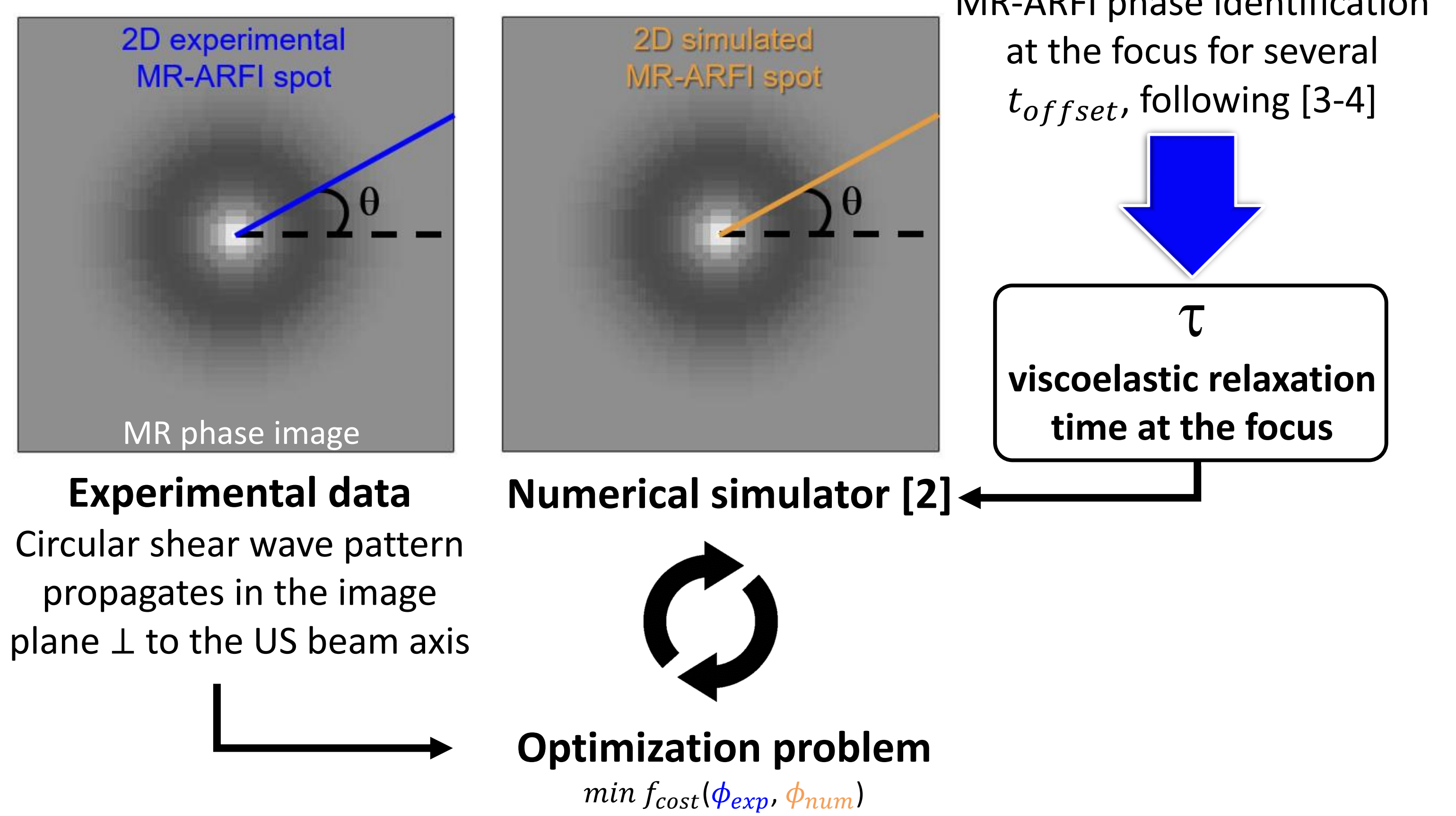
Purpose: To use MR-ARFI [1] as a fast transient elastography method to estimate the **viscoelasticity** and the **anisotropy of soft tissues**

METHOD

1. Generate ARF in tissue & encode tissue displacement

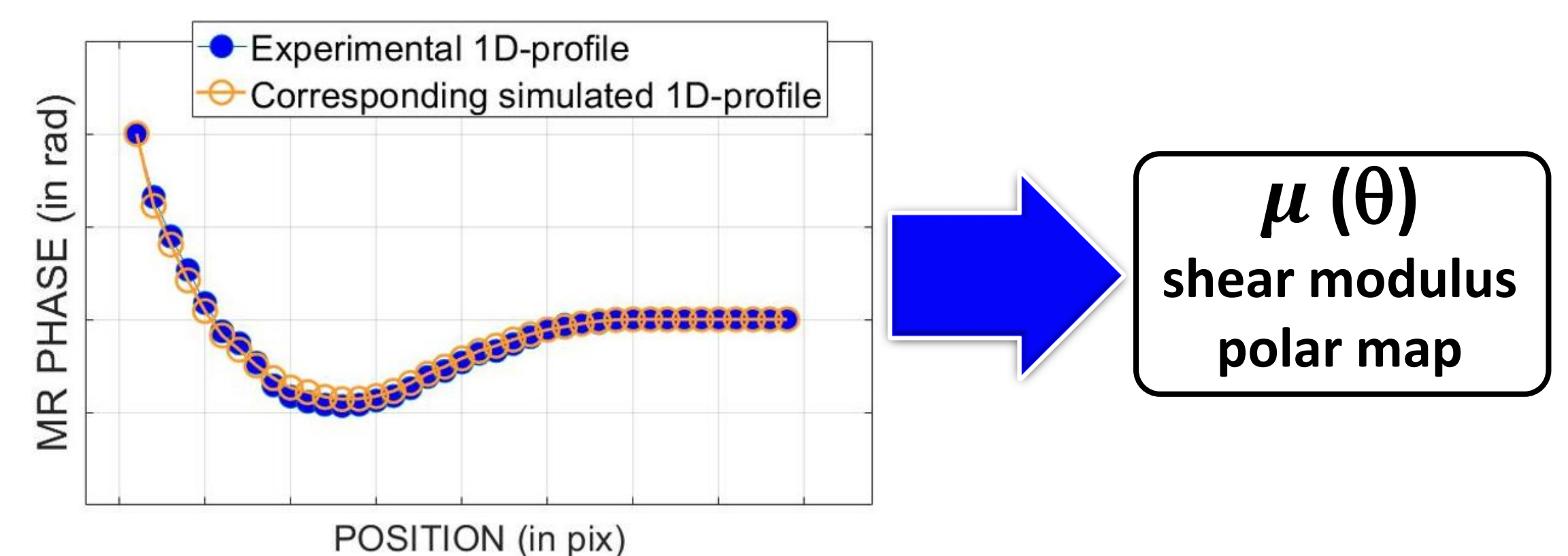


2. Numerical simulation & Fitting process



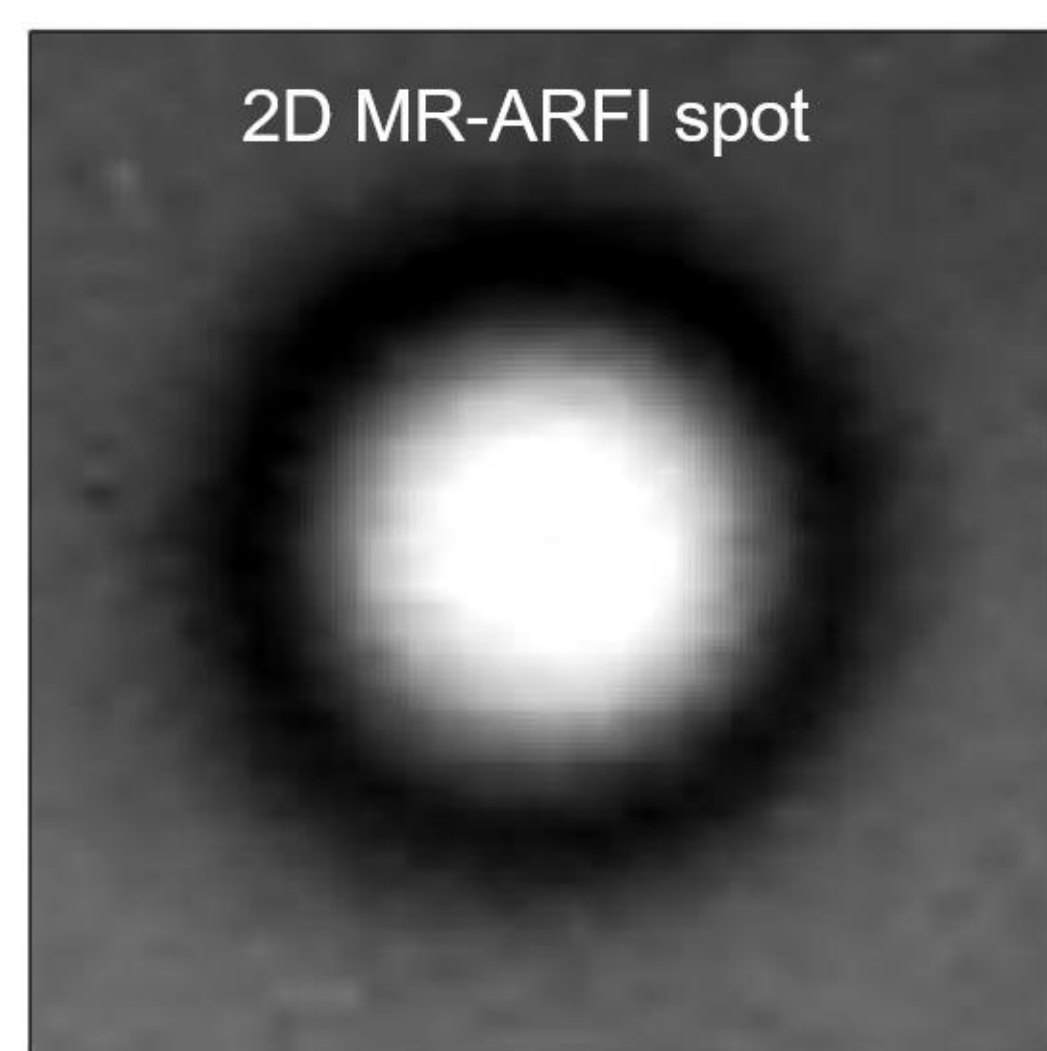
MAIN ACQUISITION PARAMETERS

- MRI: $B_0 = 1.5$ T, segmented echo planar imaging (EPI) gradient echo sequence, EPI factor = 37, matrix 128x128, TE/TR = 28/500 ms, acq. time = 4 s, voxel 2x2x6 mm³, $T_{MSG} = 10$ ms, $G = 36$ mT/m
- HIFU: 1 MHz 128-elem. spherical transducer, focal length = 6 cm, $P_{push} = 200$ W acoustic power, $T_{push} = 5$ ms

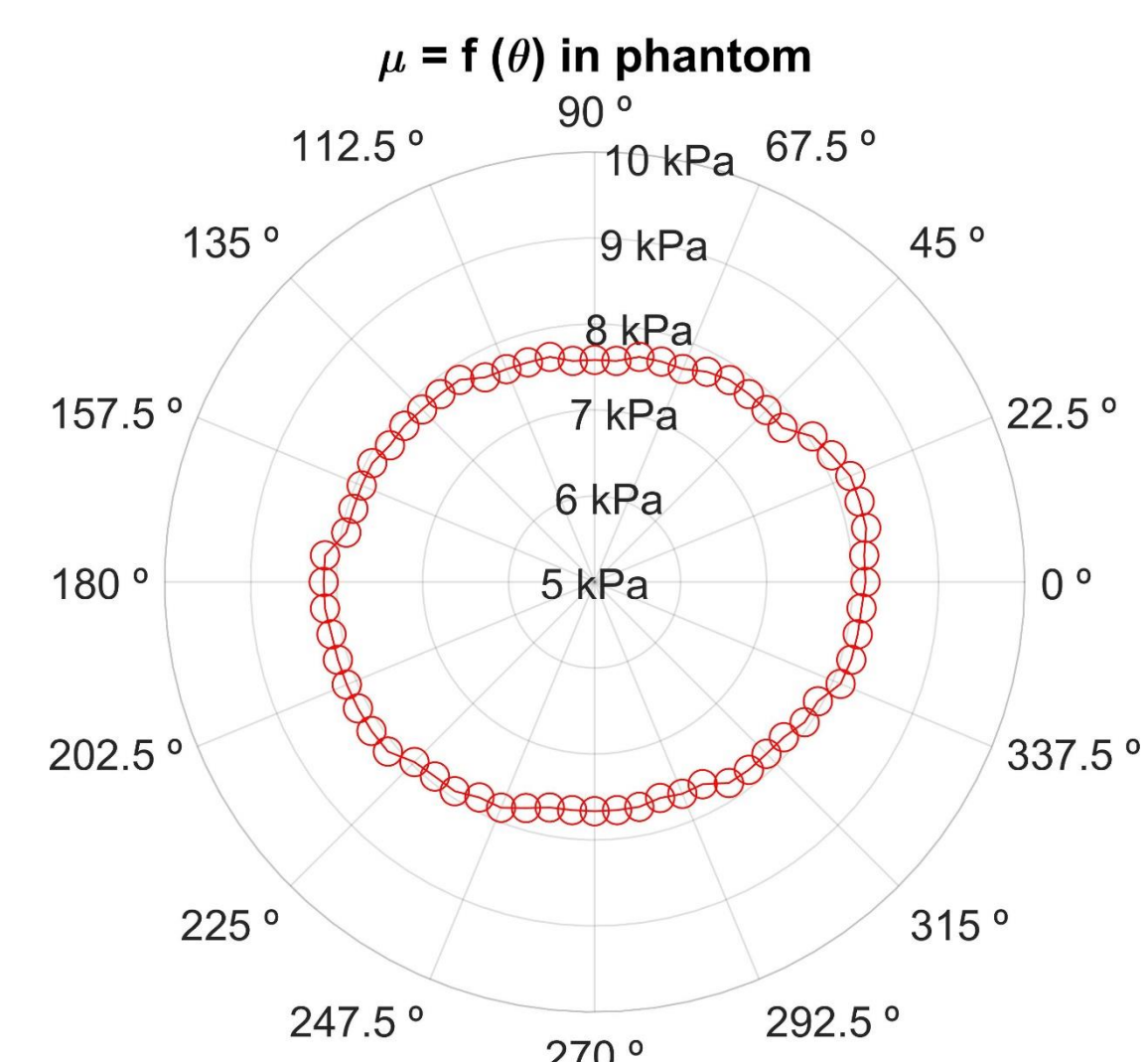


VALIDATION EXPERIMENT

- Homogeneous calibrated gel phantom (model 049, CIRS, USA)



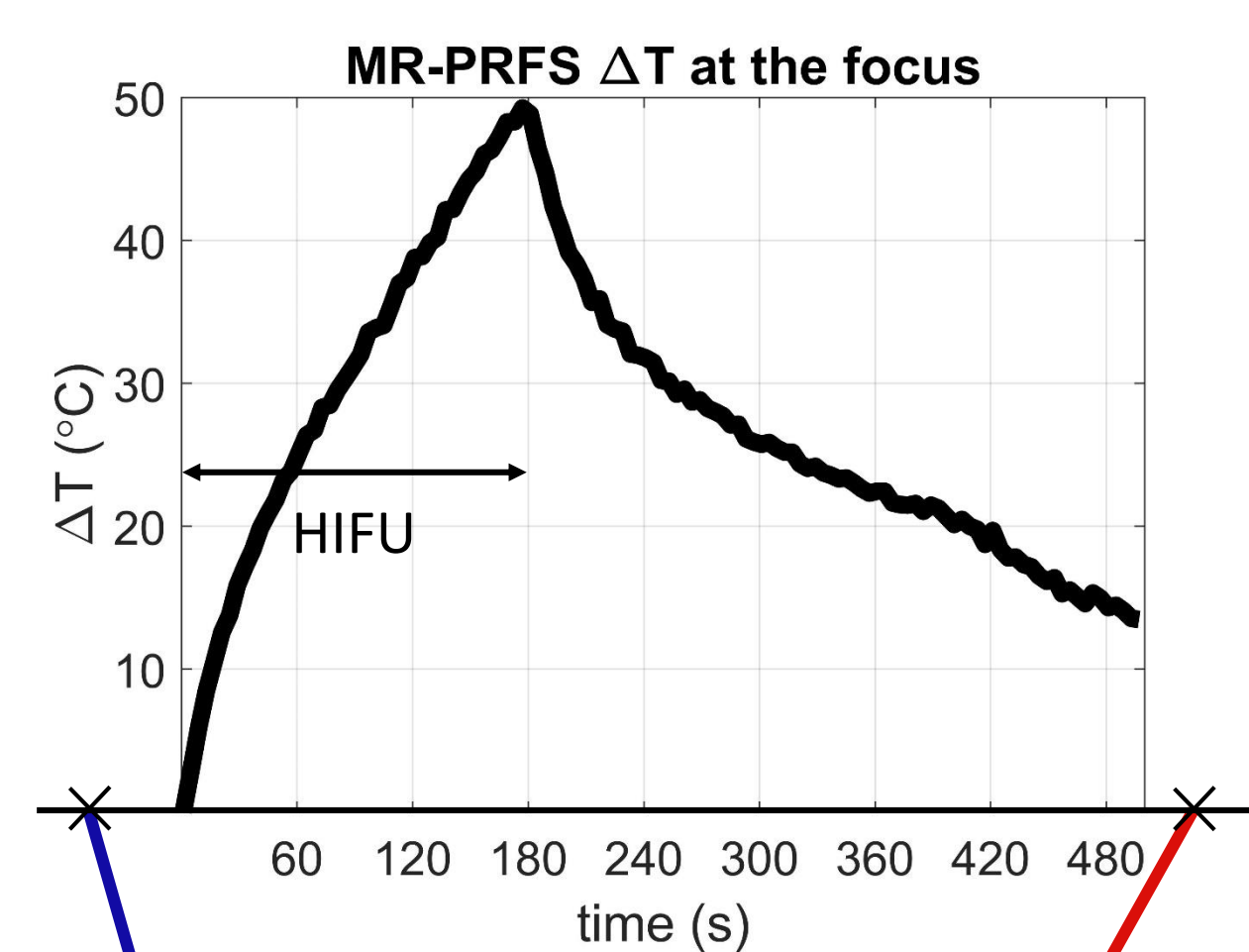
Experimental MR-ARFI pattern in the image plane \perp to the US beam axis



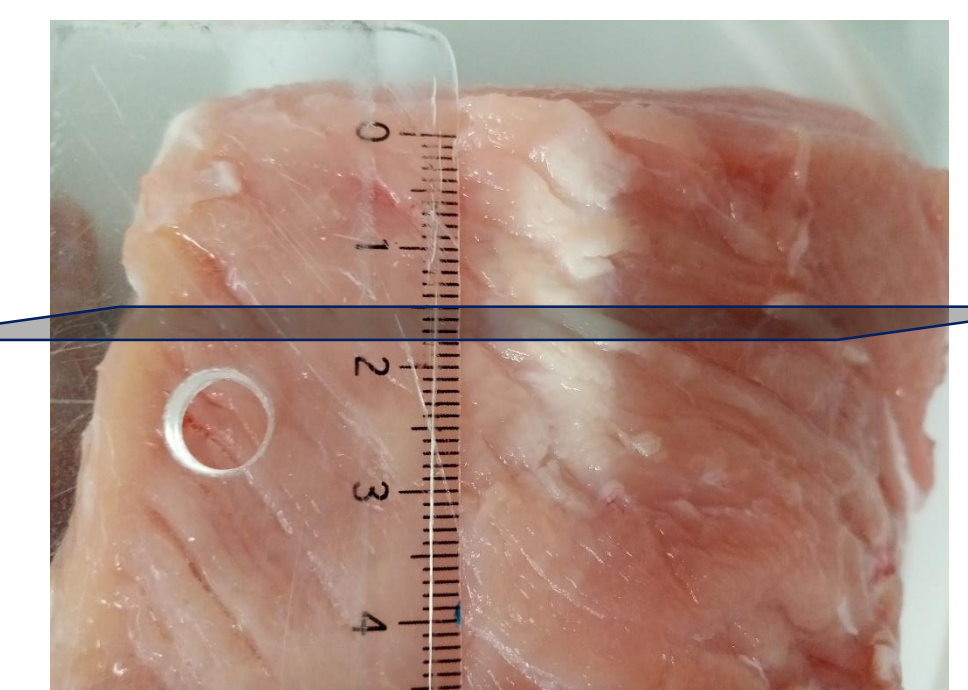
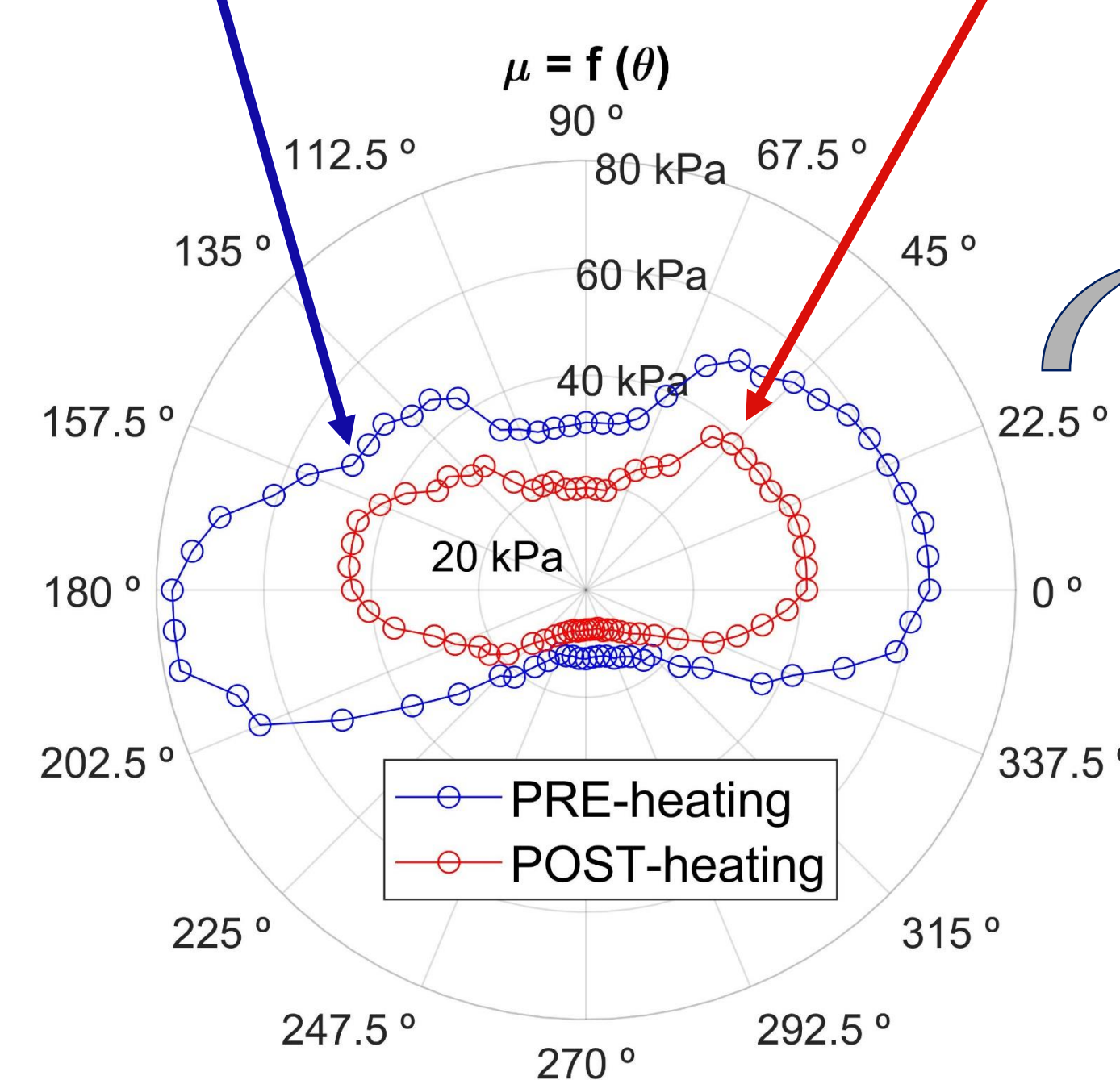
→ Circular μ polar map in isotropic medium

	Datasheet	Proposed approach
τ	N.A.	3.3 ms
μ	5.9 kPa \pm 5%	7.9 kPa \pm 3%

HIFU HEATING EXPERIMENT



- Ex vivo calf muscle tissue
- HIFU during 180 s, spiral trajectory of 7 shots (50 ms each), $P_{heating} = 60$ W acoustic power
- $\Delta T_{max} \approx +50$ °C



Meat cut in the image plane \parallel to the US beam axis: irregular fiber orientation, consistent with the resulting distorted polar map (left)

	pre-HIFU	post-HIFU	Δ
τ	7.5 ms	4.5 ms	-40 %
$\mu(\theta = 0^\circ)$	64 kPa	41 kPa	-36 %
$\mu(\theta = 45^\circ)$	55 kPa	39 kPa	-30 %
$\mu(\theta = 90^\circ)$	31 kPa	19 kPa	-39 %

→ Meat tenderization with HIFU, consistent with literature [5]

→ Anisotropy of muscle tissue

CONCLUSIONS & PERSPECTIVES

- The proposed approach allows for local, **quantitative** and **direction-dependent** viscoelasticity measurements.
 - promising localized, biomechanical testing method
- The modification of τ found with HIFU heating calls for a **further refined modeling of viscoelasticity**.
 - extend the method to the monitoring of HIFU ablations

REFERENCES

- [1] McDannold et al, Med Phys, 35-8, 2008 [2] Vappou et al, Phys Med Biol, 63-9, 2018 [3] Kaye et al, Magn Reson Med, 69-3, 2018 [4] Dadakova et al, Magn Reson Med, 79-2, 2018 [5] Wu et al, Magn Reson Med, 45-1, 2001