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Machine learning (ML) classification of cells on the basis of their viscoelastic properties

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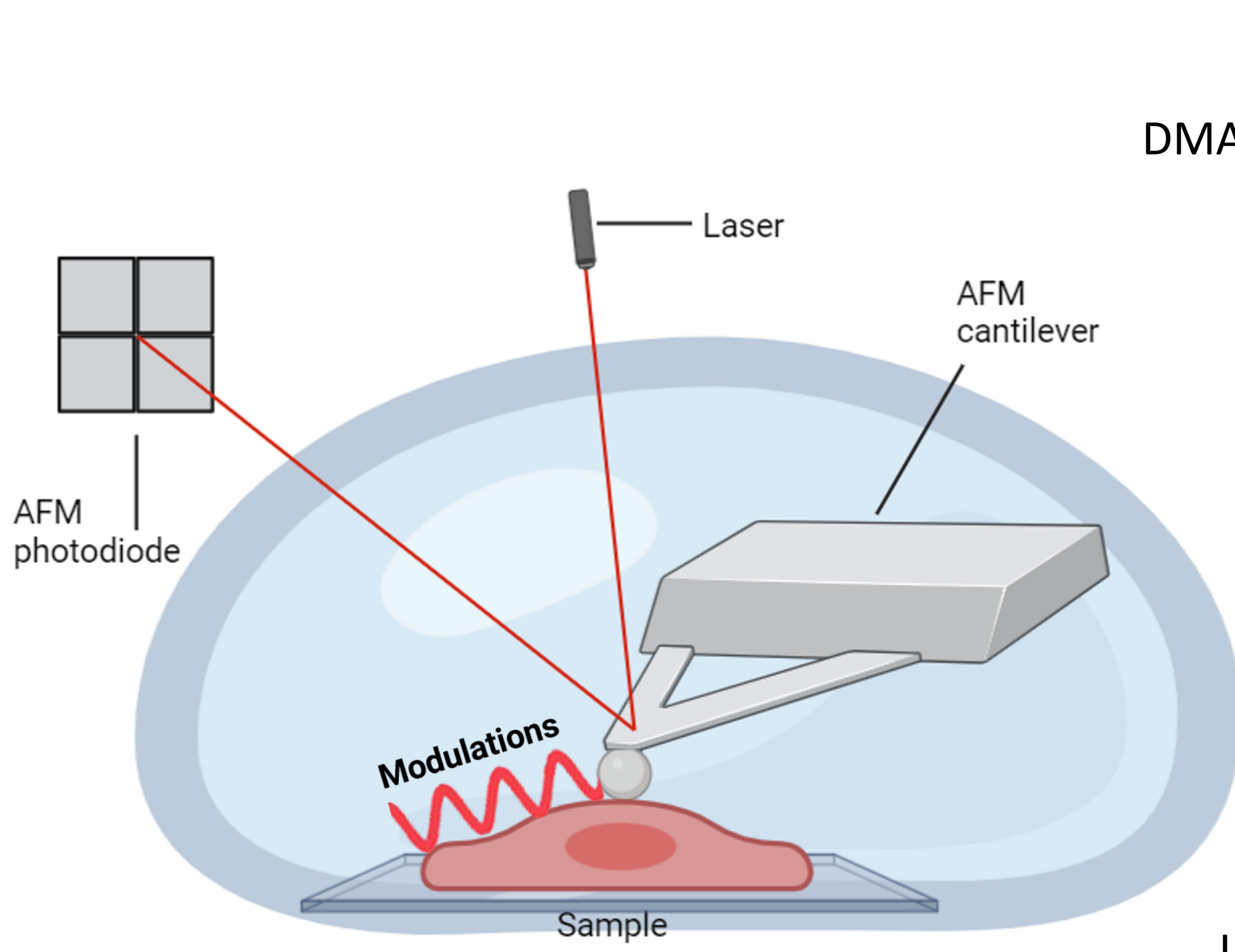
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HAL Authorization

Dynamic mechanical assay (DMA) with atomic force microscopy (AFM)



DMA measurements to access viscoelastic properties [1]

- Elastic component (G')
- Viscous component (G'')
- Operates in liquid
- Compatible for live sample

$$\text{Indentation } \gamma^* = \gamma_0 \sin(\omega t)$$

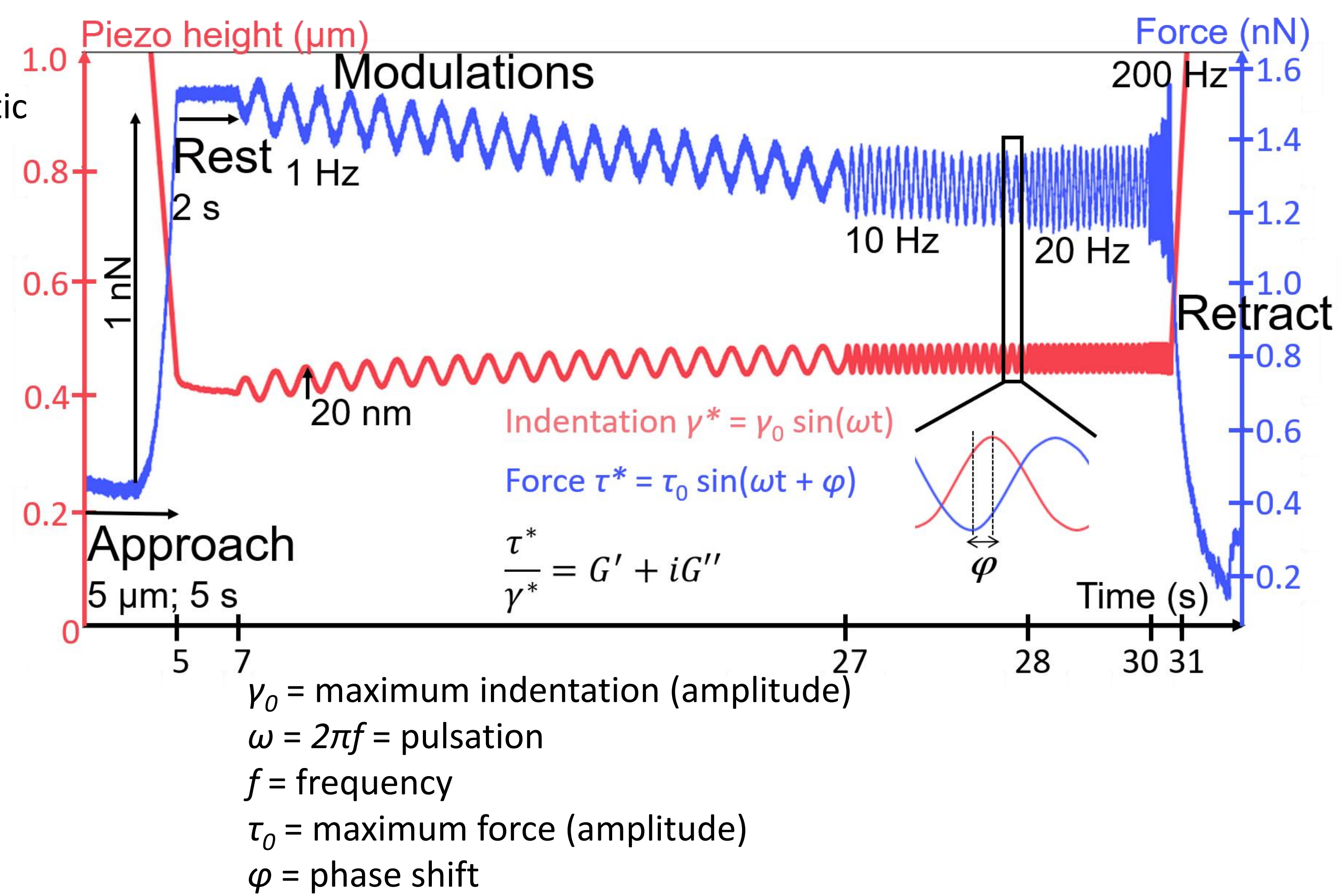
$$\text{Force } \tau^* = \tau_0 \sin(\omega t + \varphi)$$

$$\frac{\tau^*}{\gamma^*} = G' + iG''$$

In phase with indentation γ In phase with rate of indentation $\dot{\gamma}$

Loss tan < 1: Elastic behaviour
Loss tan > 1: Viscous behaviour

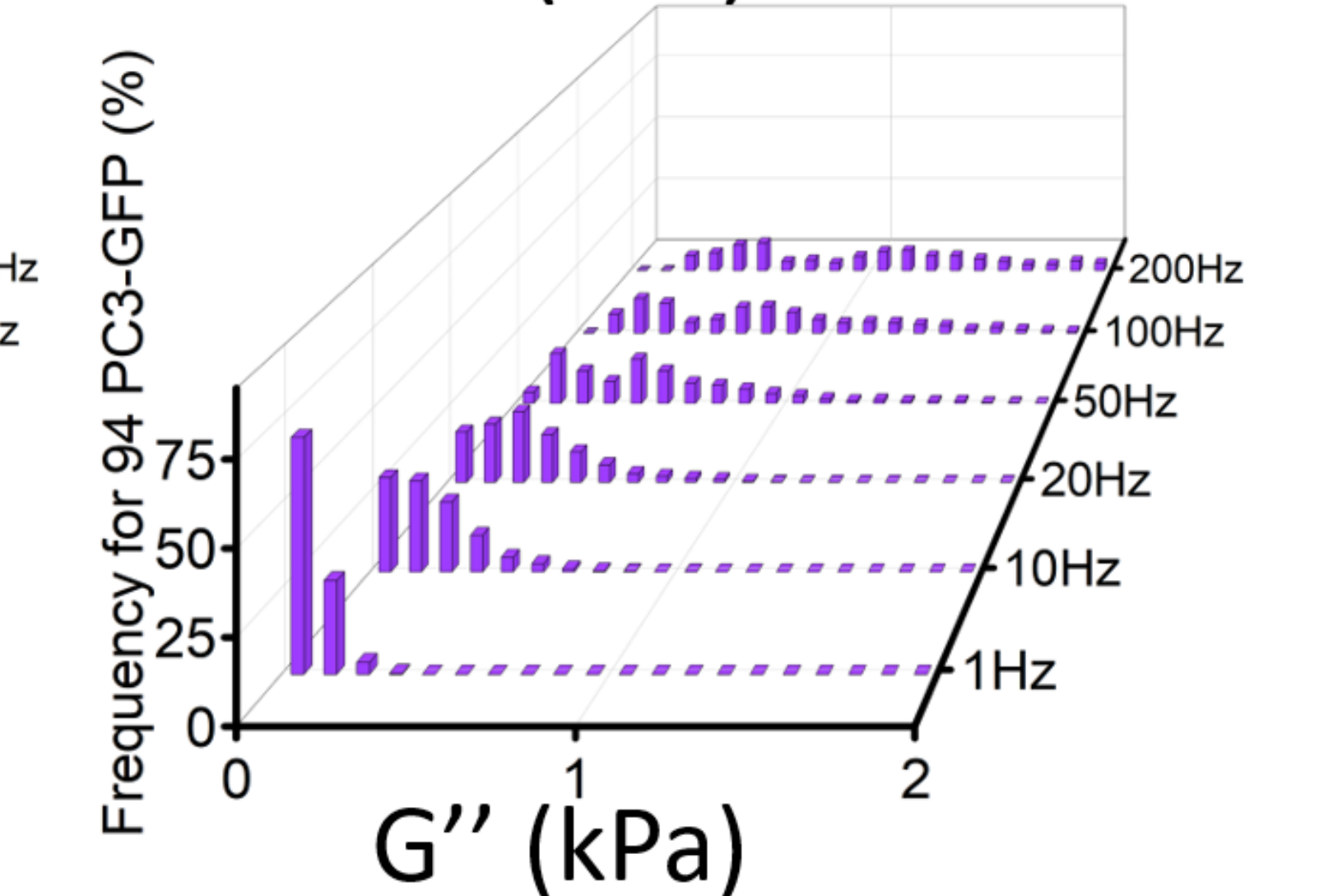
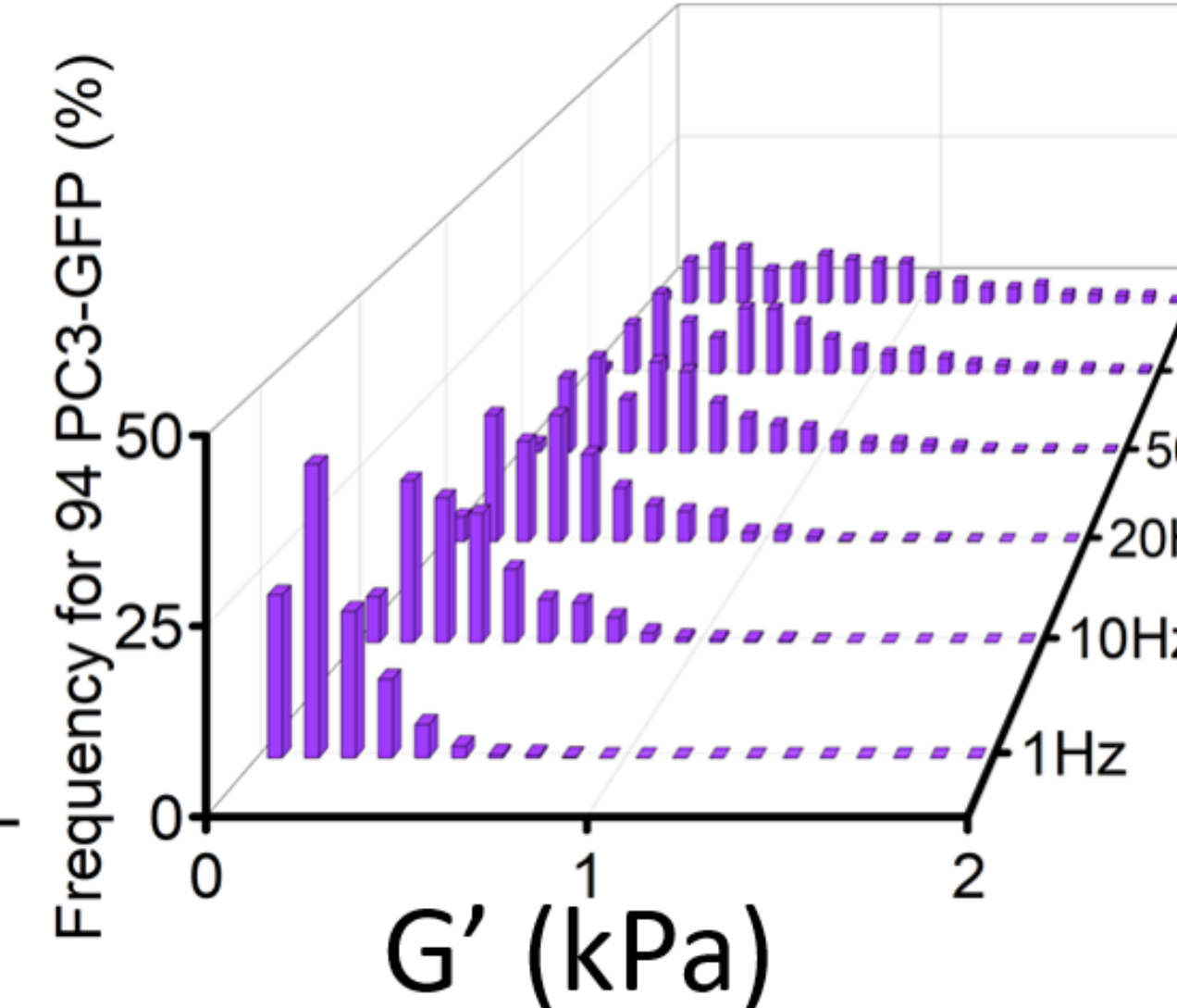
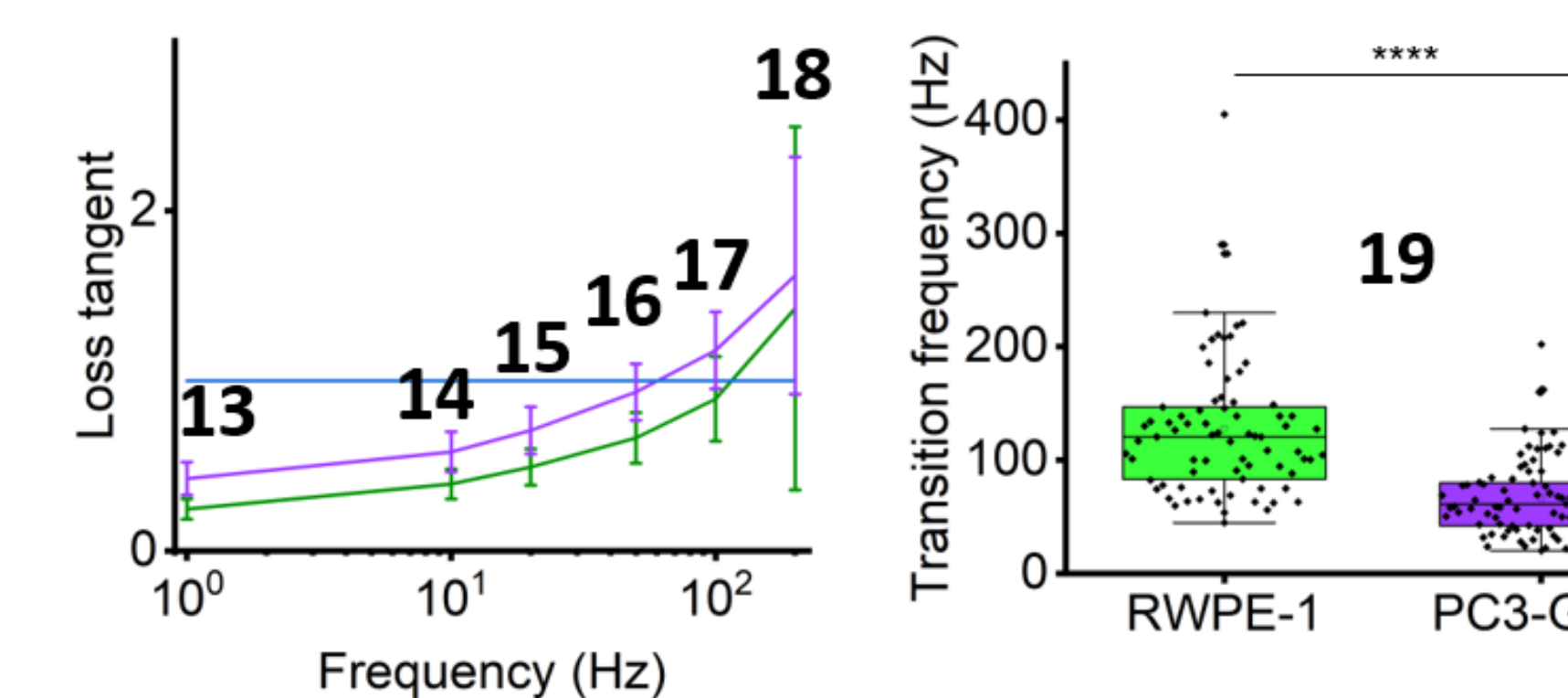
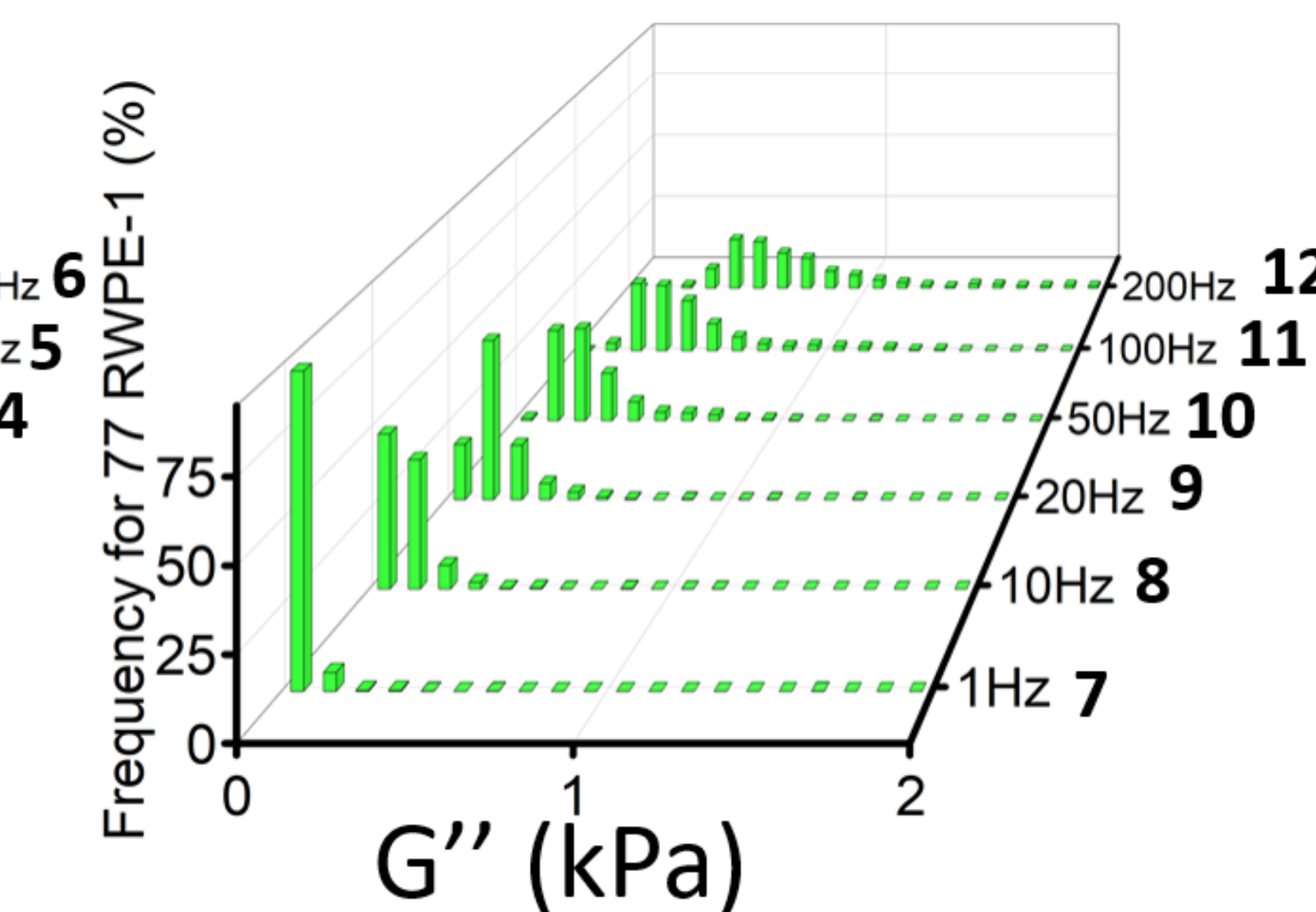
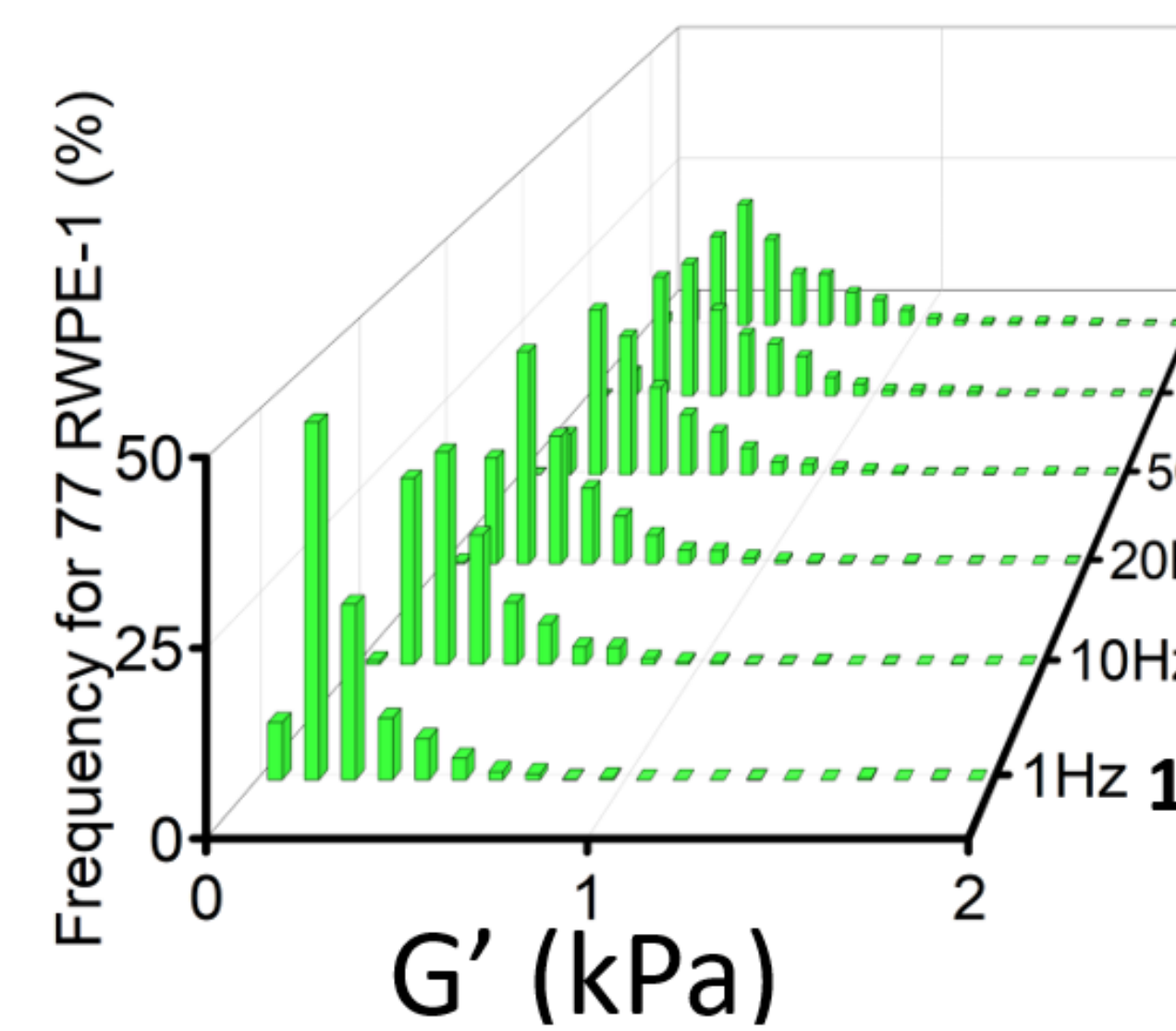
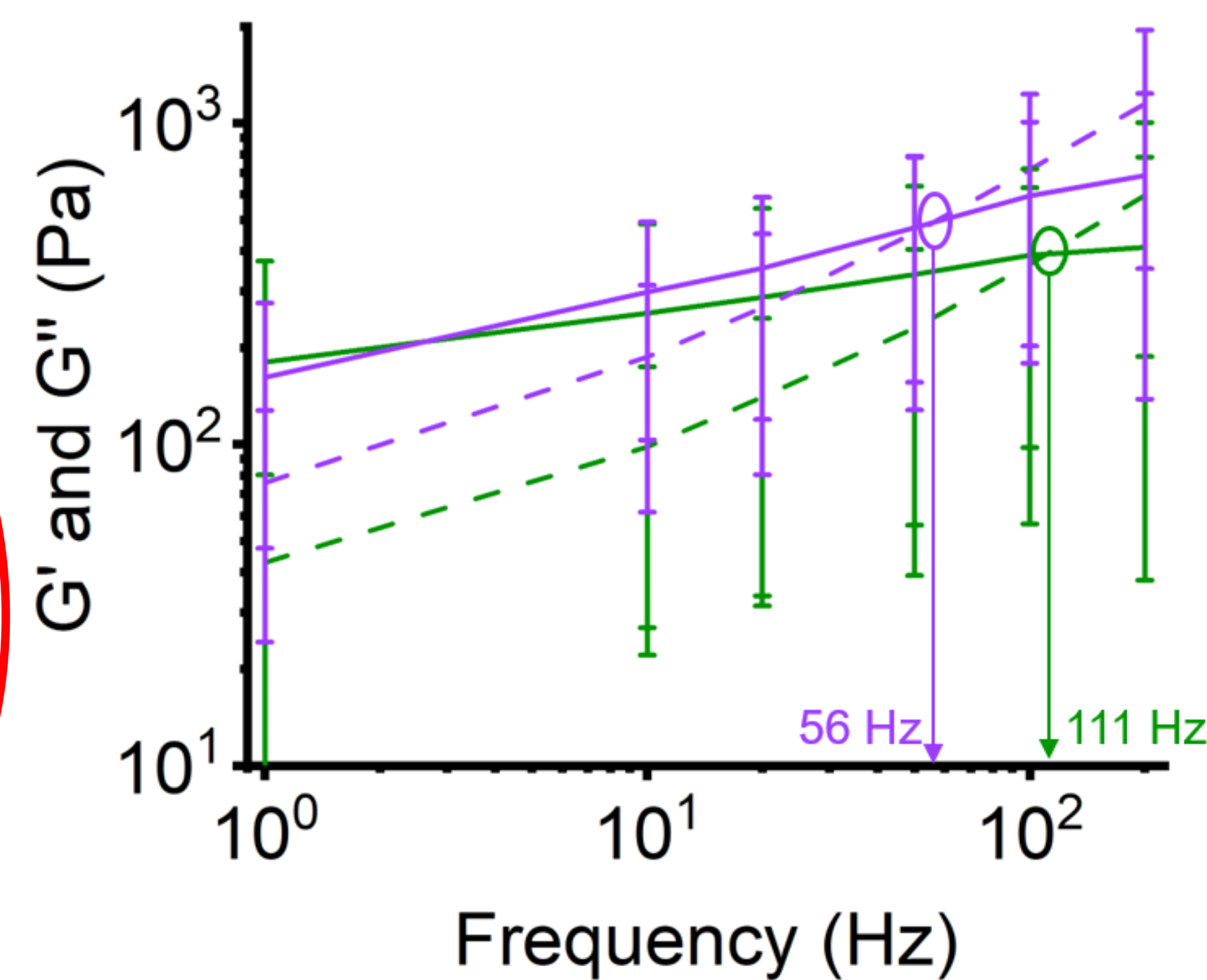
$$\text{Loss tan} = \frac{G''}{G'}$$



19 features per DMA measurement: formation of high-density data

19 FEATURES

- G' at 6 frequencies (1-6)
- G'' at 6 frequencies (7-12)
- Loss tan = G''/G' at 6 frequencies (13-18)
- 1 transition frequency (19)



94 cancerous cells (PC3-GFP)
77 non-cancerous cells (RWPE-1)

Statistical differences, but 52 to 98 % of common values
→ Impossible to attribute a single measurement to one class or another

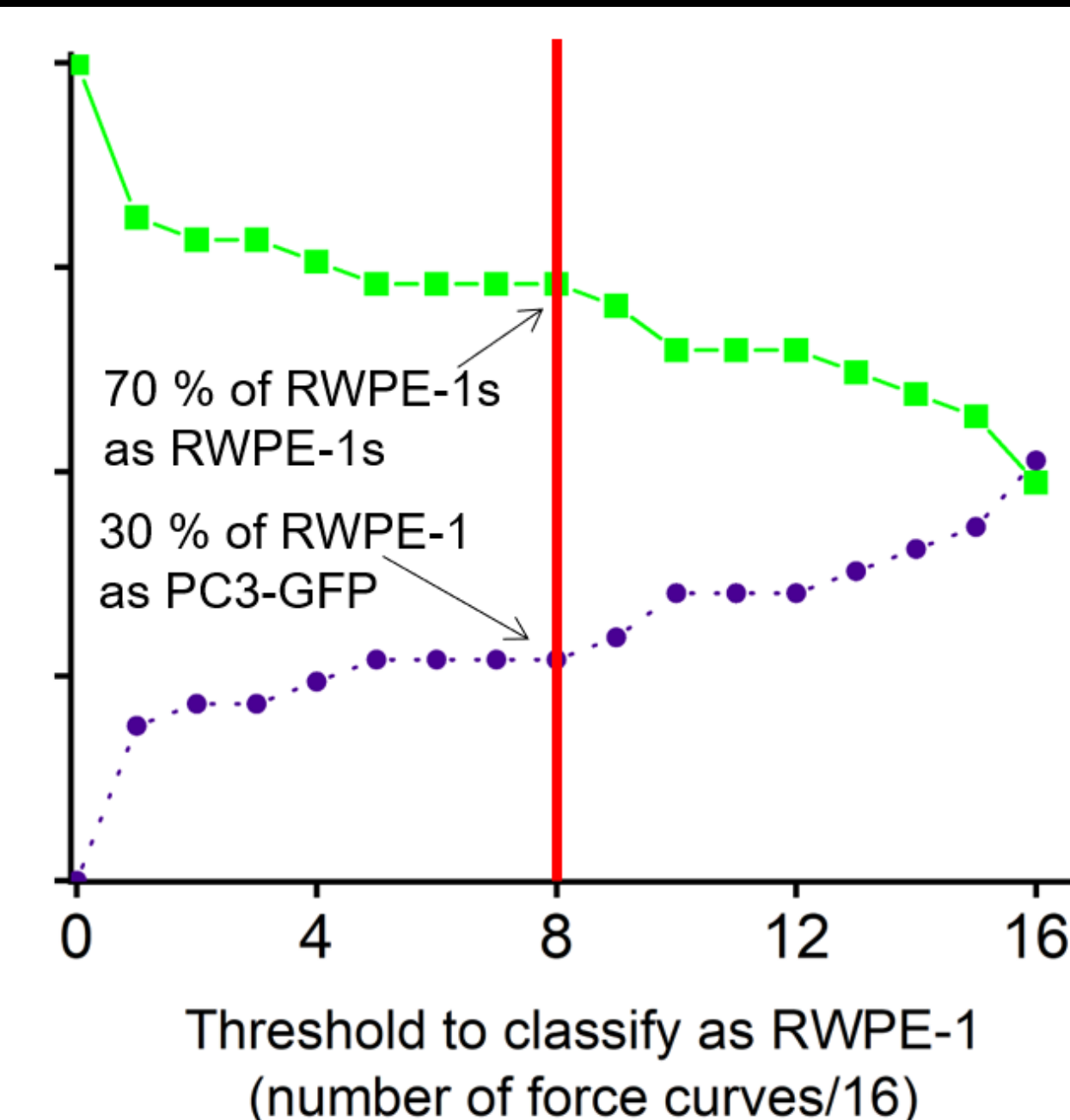
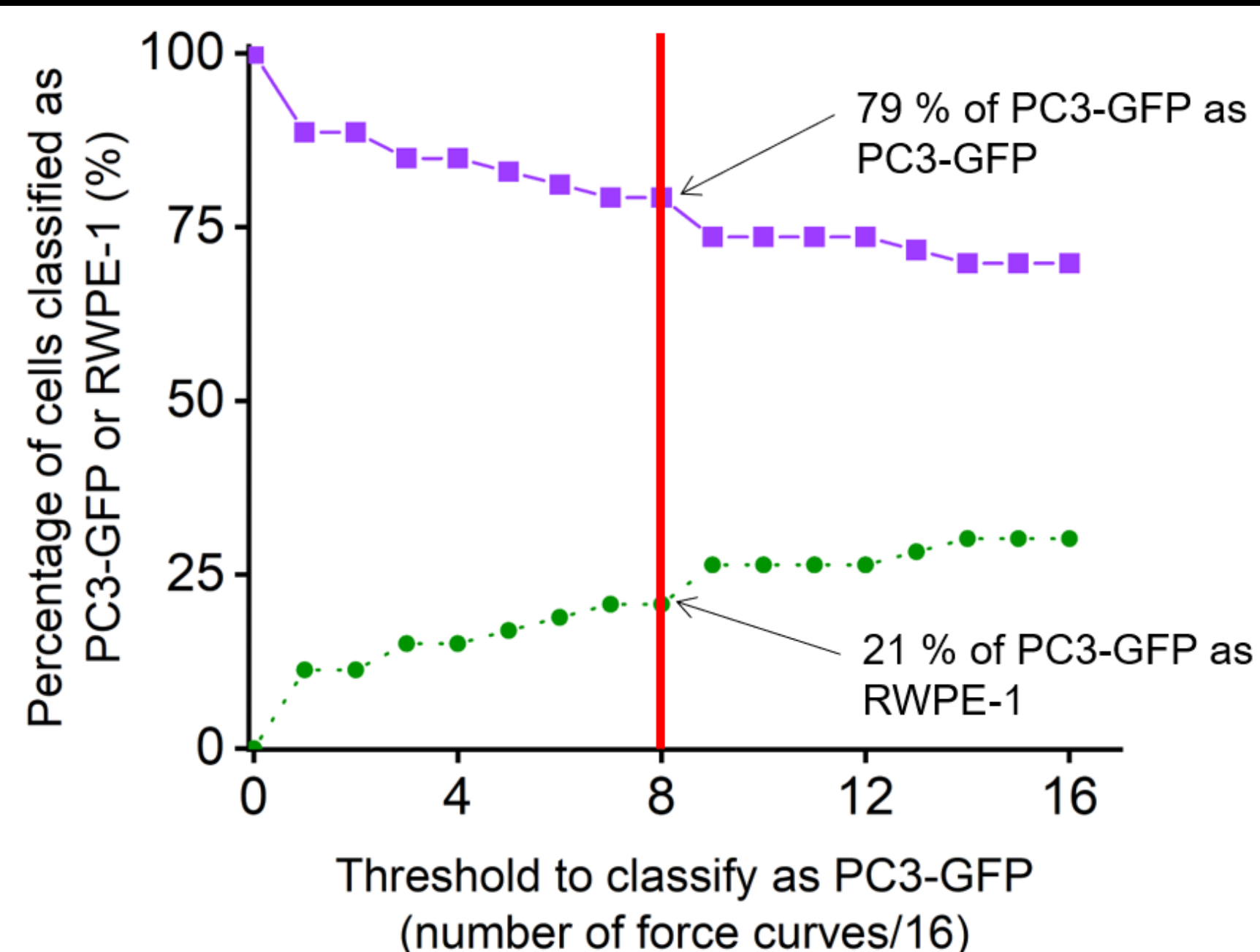
Classification of non-malignant and malignant cells by machine learning (ML) using LAMDA algorithm [2]

Training base:
40 PC3-GFP +
40 RWPE-1

Test base:
54 PC3-GFP +
37 RWPE-1

Trained to classify PC3-GFP and RWPE-1

Correct classification: 75 %
Sensitivity: 79 %
Specificity: 70 %



Discrimination of malignant cells from non-malignant cells at 75 %

[1] Abidine et al., *Comput Methods Biomech Biomed Engin.*, 2013
[2] Hedjazi et al., *Pattern Recognition Letters*, 2011

Conclusion and perspectives

- ✓ 51 984 features in total with mechanobiological sense were generated indenting only 2 736 times on 171 cells
- ✓ Dataset compatible with AI algorithms
- ✓ Useful for classifying samples with few cells (stem cells, circulating tumor cells)
- ✓ 1 Hz measurements could be avoided to increase throughput
- ✓ DMA could be useful to push AFM toward diagnostic