

# Residual stress in pig intervertebral discs. A preliminary study.

Le Floc'h S.<sup>1\*</sup>, Ambard D.<sup>1</sup>, Baldit A.<sup>2</sup>, Kouyoumdjian P.<sup>3</sup>, Cañadas P.<sup>1</sup>, Cherblanc F.<sup>1</sup>

<sup>(1)</sup> Laboratoire de Mécanique et Génie Civil, UMR 5508 - University of Montpellier, France; <sup>(2)</sup> Laboratoire de mécanique Biomécanique, Polymère et Structure - ENIM, Metz, France; <sup>(3)</sup> Hospital Carémeau of Nîmes and Charles Coulomb Lab, UMR 5221 - University of Montpellier, France. \*Corresponding author, simon.le-floc'h@um2.fr

## Introduction – Residual strains and stresses are markers of tissue growth's history

The intervertebral disc (IVD) growth, which is at the heart of the development of the juvenile idiopathic scoliosis, constitutes an example of biological growth influenced by mechanical loads. In order to better understand the early development of this pathology, we propose to study a marker of tissue growth which are the residual strains and stresses generated through the biological growth process of the IVD.

## Method - From free stress configuration to closed configuration

Two lumbar discs (L4L5 and L5S1, graded I) were harvested from cadavers of domestic pigs obtained from a local slaughter house. The lumbar spine was excised and stored in a  $-12^\circ\text{C}$  freezer. IVD were separated from the vertebral bodies by blunt dissection. Annulus fibrosus was separated from the nucleus using a surgical knife.

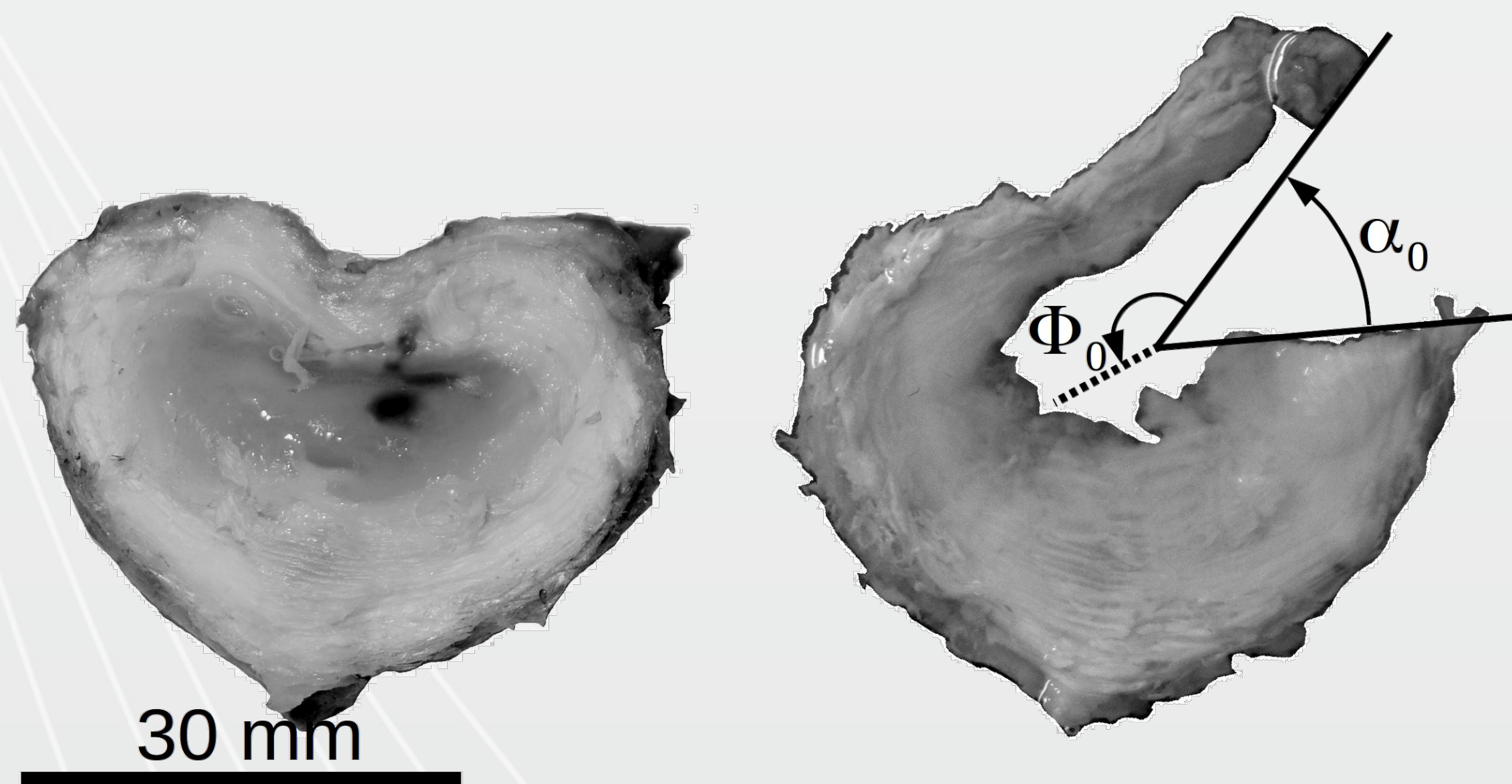


Figure 1 : Cutting procedure in order to release stresses due to growth of the annulus fibrosis. The opening angles were measured by a similar method proposed by [1]. After cutting, samples were stored for 1 hour in physiological conditions, i.e., in a 0.15 M NaCl solution at  $T=37^\circ\text{C}$ .

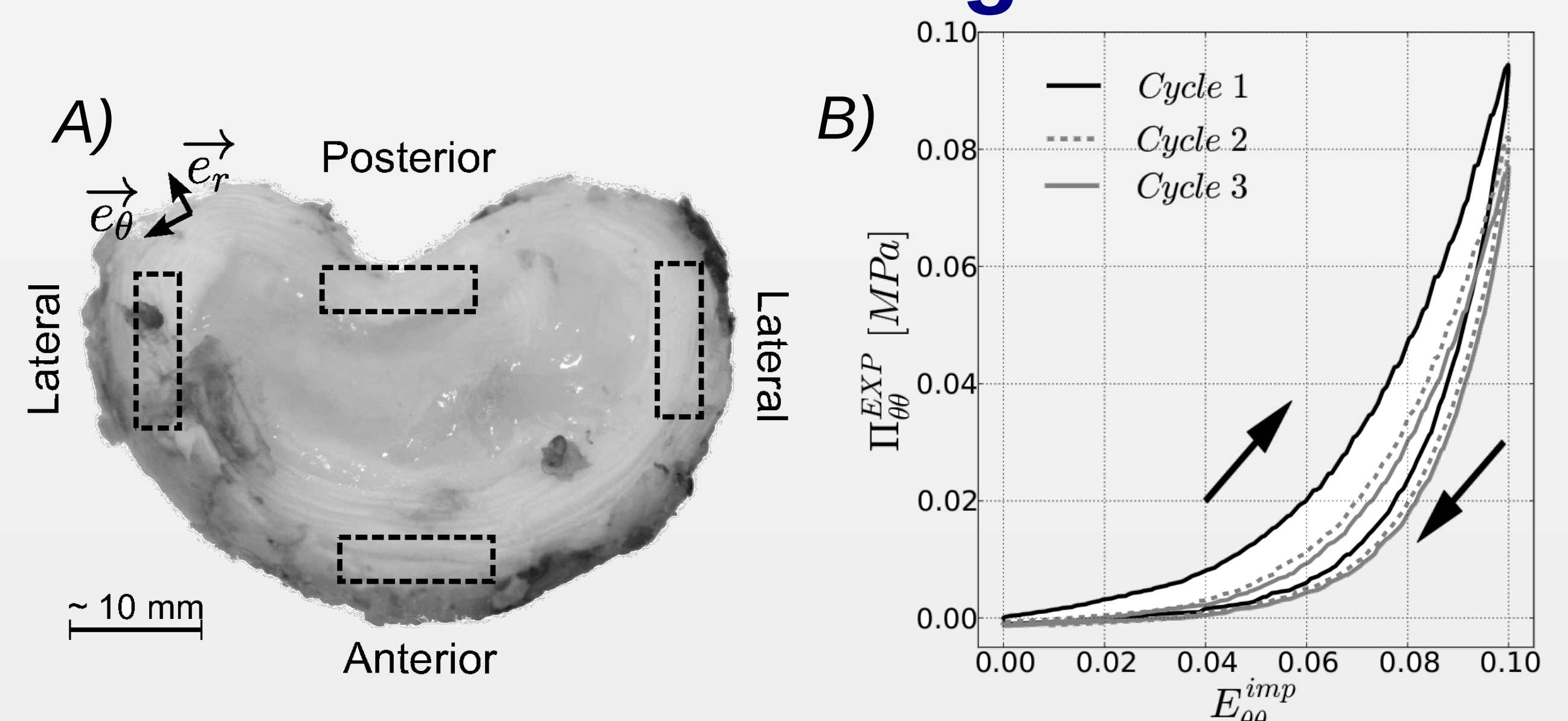


Figure 2 : A) Samples preparation for the estimation of mechanical properties of the IDV tissue at 4 different locations. B) Uni-axial traction tests in the circumferential direction were used. See [2].

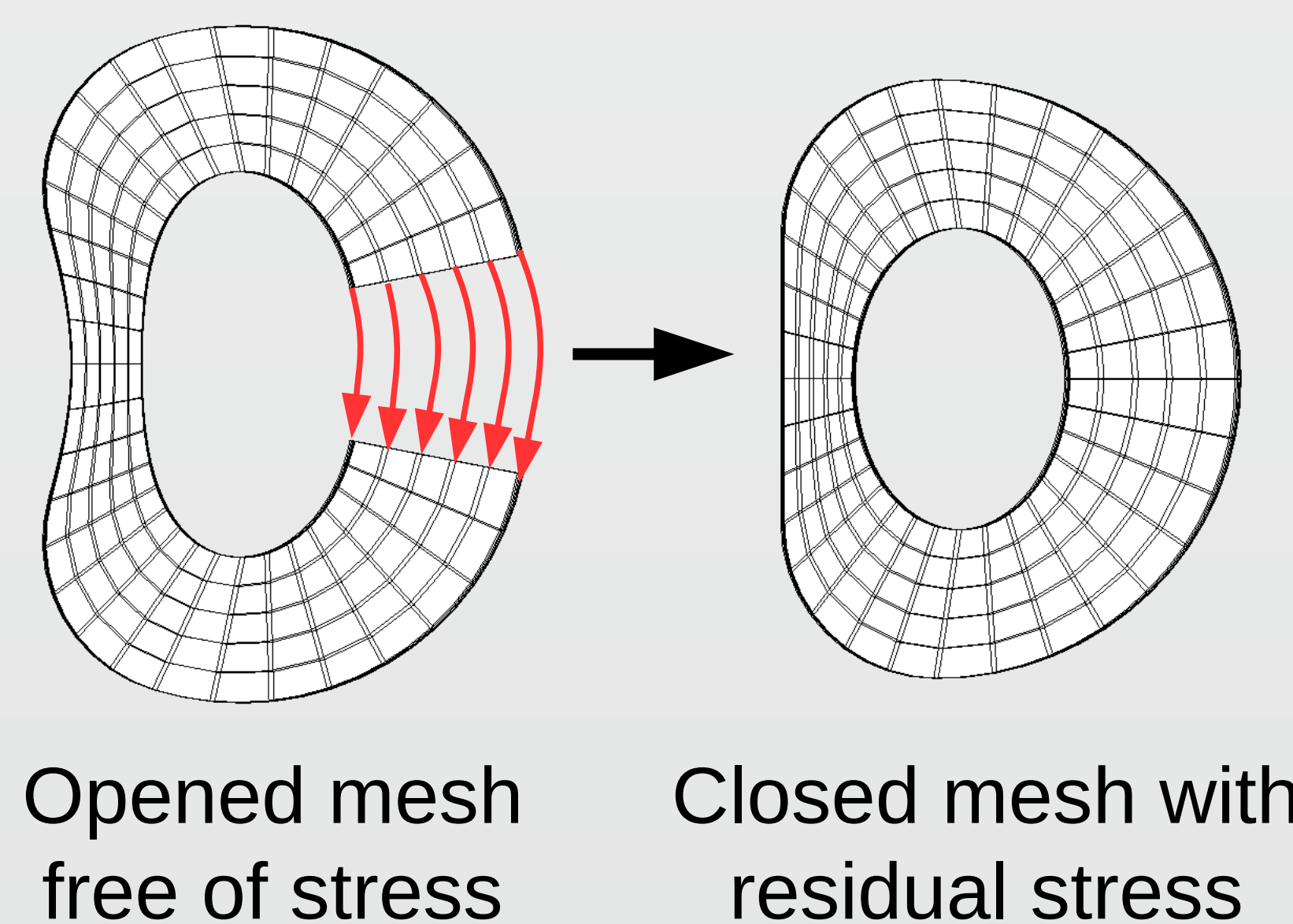


Figure 3 : Numerical closing procedure using FE software LMG90 (see [4]).

## Results – Residual stress in pig intervertebral disc

Table 1 : Estimated mechanical properties and opening angles for L4L5 and L5S1 discs.

$$\text{Strain energy : } W = \frac{G}{2}(\bar{I}_1 - 3) + \frac{K}{2}(J - 1)^2 + \frac{K_1}{2K_2} \sum_{i \in [1,2]} \{ \exp(K_2[k_{disp} \bar{I}_1 + (1 - 3k_{disp}) \bar{I}_{4i} - 1]^2) \}$$

G (kPa)	K (kPa)	k1 (kPa)	k2	Kdisp (10 <sup>-2</sup> )	Angle $\alpha_0$
47,9±43,3	506±528	1,36±2,04	1610±1560	2,8±3,36	22°
46,7±26,6	817±965	3,5±1,89	853±397,	3,92±1,58	49°

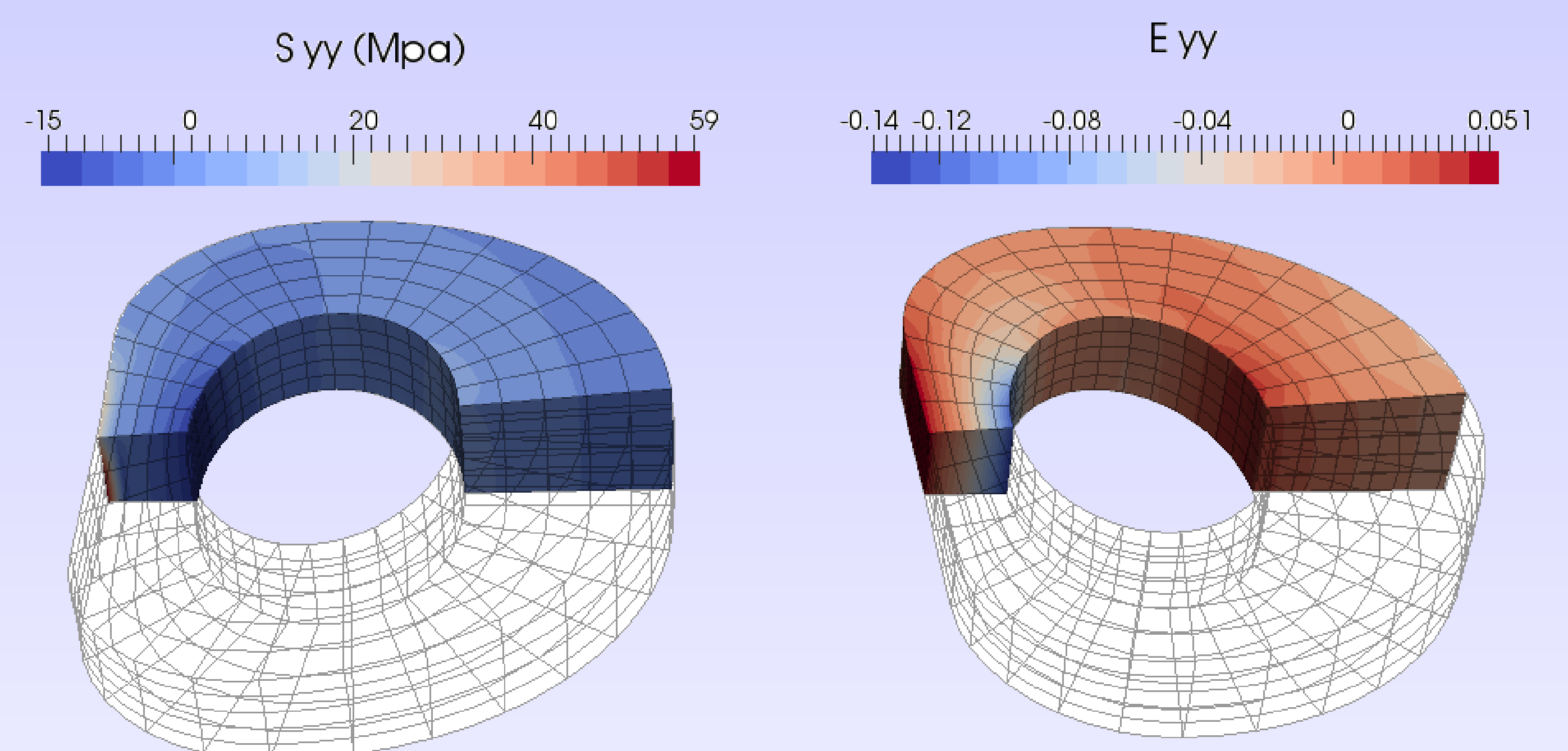


Figure 4 : Estimated residual strain and Cauchy stress for L4L5 pig disc using FE software LMG90 [4].

**Conclusions** Our preliminary results ( $n=2$  discs) show that pig intervertebral discs present residual strains and stresses, as other biological tissues grown under physiological mechanical loads. Further experiments and numerical reconstruction of residual strains and stresses, with sample-specific mechanical properties, will allow us to better understand disc growth and generation of residual stresses.

### REFERENCES:

- [1] Michalek et al, J. Biomech. 45(7):1227-1231, 2012
- [2] Baldit et al, Biomech. Model Mechanobiol. 13:643-652, 2014.
- [3] Ohayon et al, Physiol Heart Circ Physiol 293:1987-1996, 2007.
- [4] [https://git-xen.lmgc.univ-montp2.fr/lmgc90/lmgc90\\_user/wikis/home](https://git-xen.lmgc.univ-montp2.fr/lmgc90/lmgc90_user/wikis/home)

