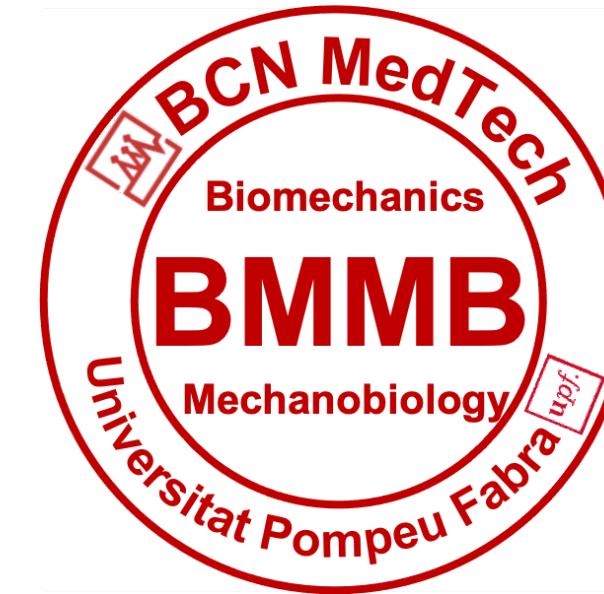


# Towards a repository of patient-specific intervertebral discs finite element models

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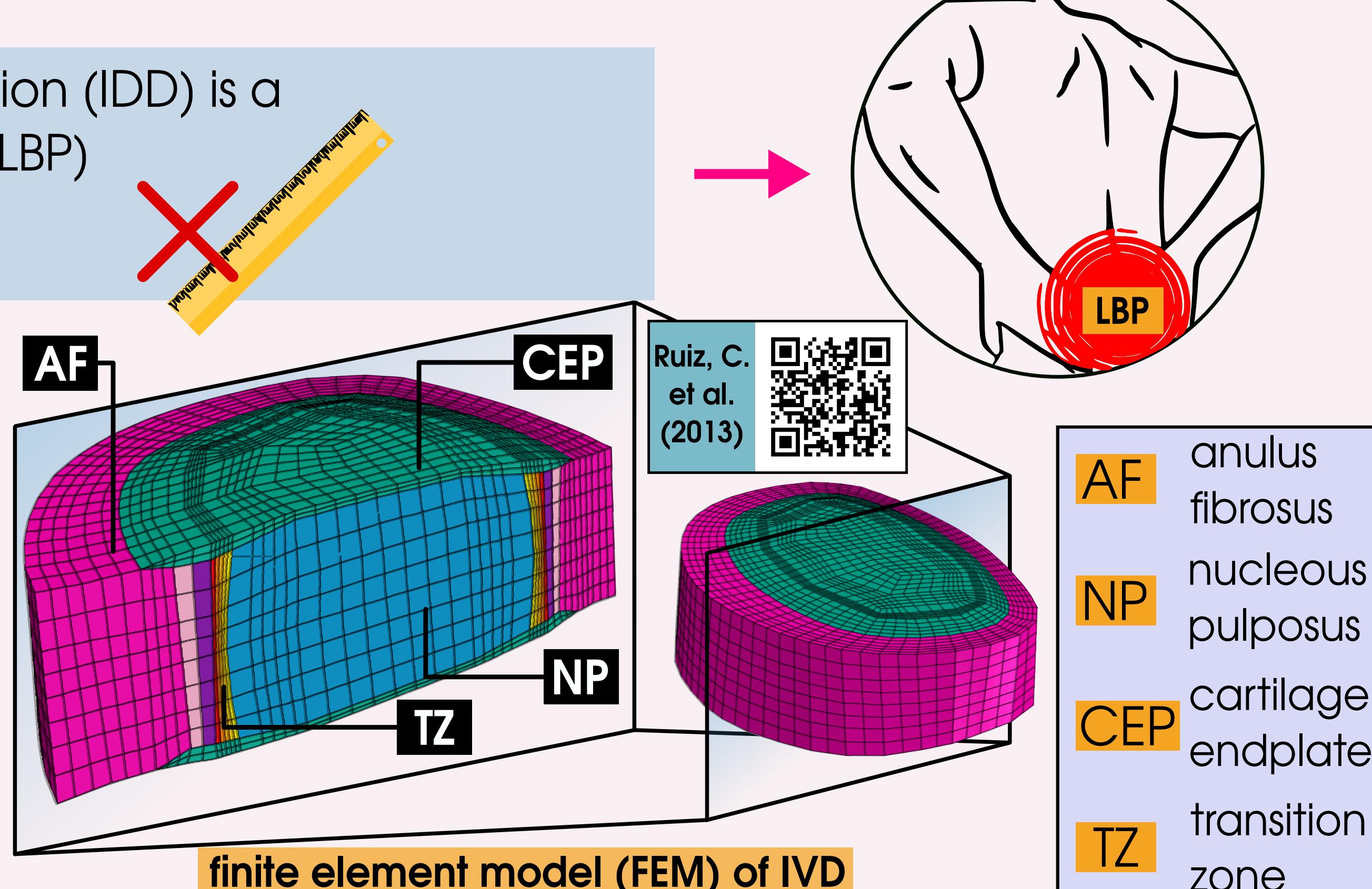
## BACKGROUND

- 266 million individuals worldwide suffer degenerative disease of the spine [1]
- Endplate anomalies are related to IDD, but mechanisms cannot be measured

Finite element (FE) simulations can determine the internal multiphysics mechanisms possibly involved in IDD

but...

- Simulation results depend on IVD morphology [2] → and
- there is no repository of different IVD morphologies
  - We do not know whether morphology can be a risk factor for IDD



AF anulus fibrosus  
NP nucleus pulposus  
CEP cartilage endplate  
TZ transition zone

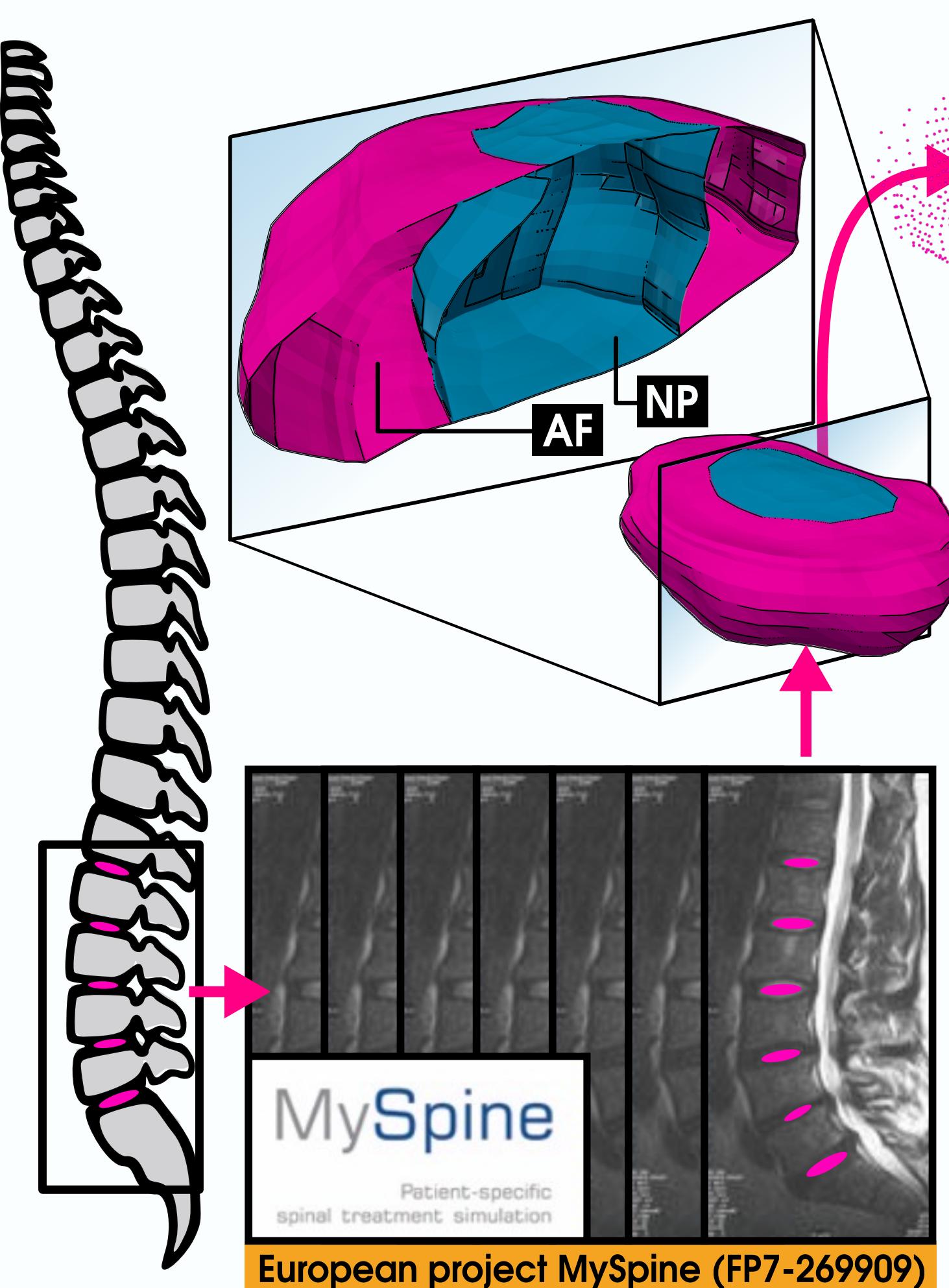
## OBJECTIVES

- Establish a procedure and algorithms to adapt a IVD structured FE mesh to patient-specific models

- Identify the morphological features best explaining the mechanical responses to decipher their influence on IDD

## METHODS

1. 169 PS models of the lumbar spine IVD through MRIs (MySpine project)
2. The AF and NP of PS were used as a point cloud (PC)
3. The BCPD [3] was used to morph the mesh
4. The mesh quality of the morphed PS models and the similarity of models were assessed



### Mechanical simulations

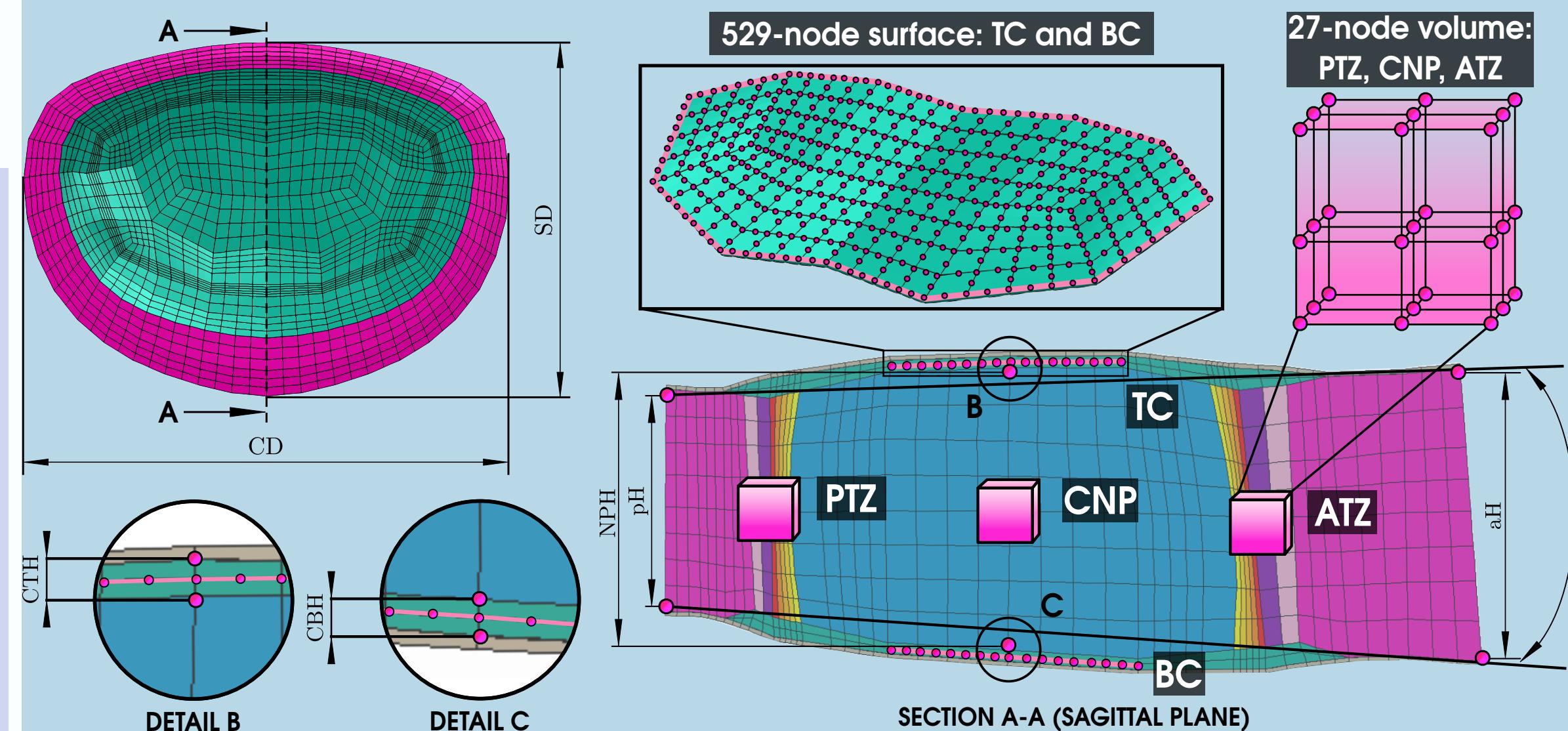
- FE simulations of physiological compressive loads defined in previous work [4] were simulated in ABAQUS on all the morphed IVDs
- Evaluated mechanical responses:
  - Permeability (Perm)
  - Water content (Wcont)
  - Pore pressure (POR)

### Key Morphological Factors using Machine Learning (ML)

- Linear Regression (LR)
- Support Vector Machine (SVM)
- eXtreme Gradient Boosting (XGBoost)

Alterations of the disc in early stage of IDD was observed in the same zone through clinical images [4].

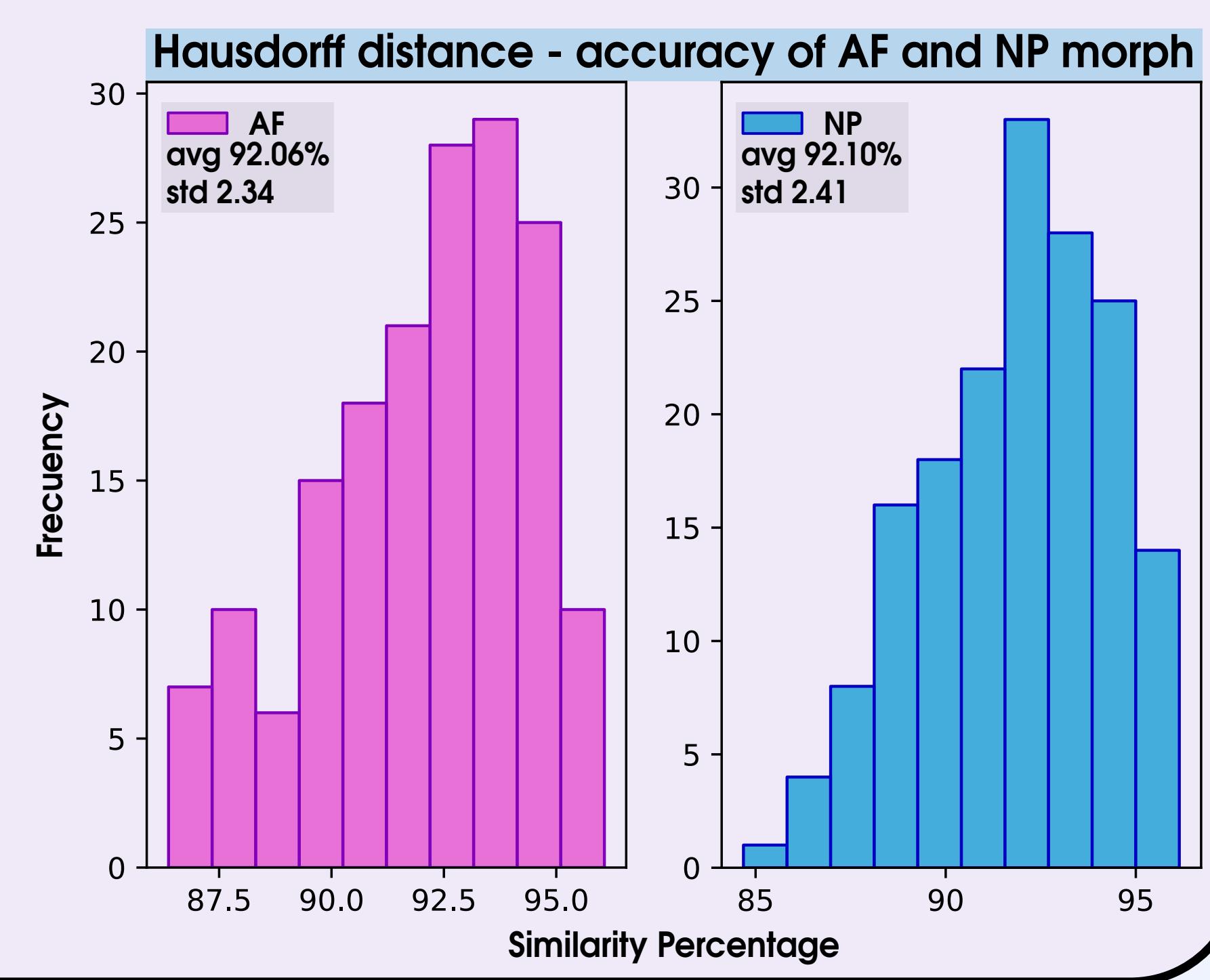
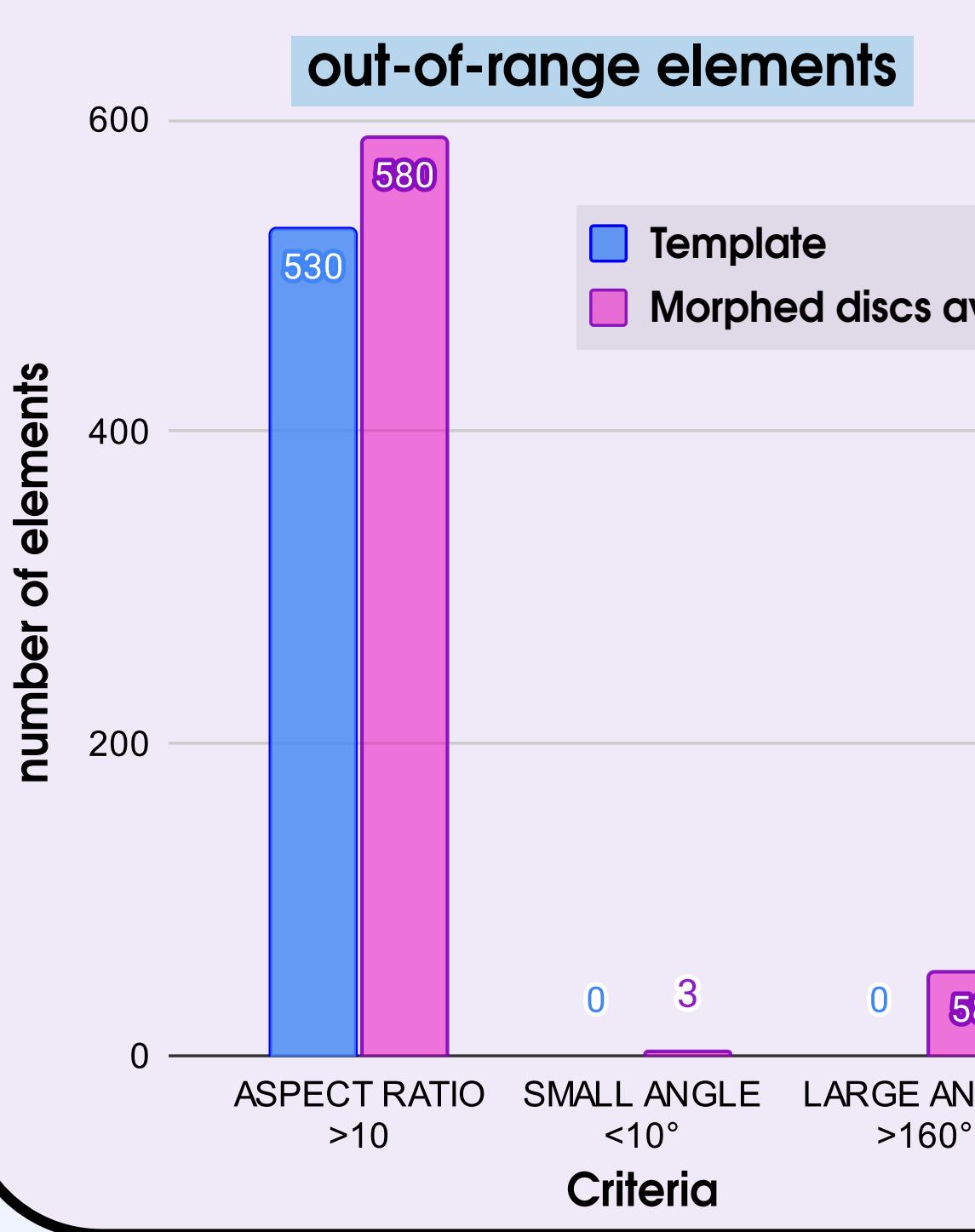
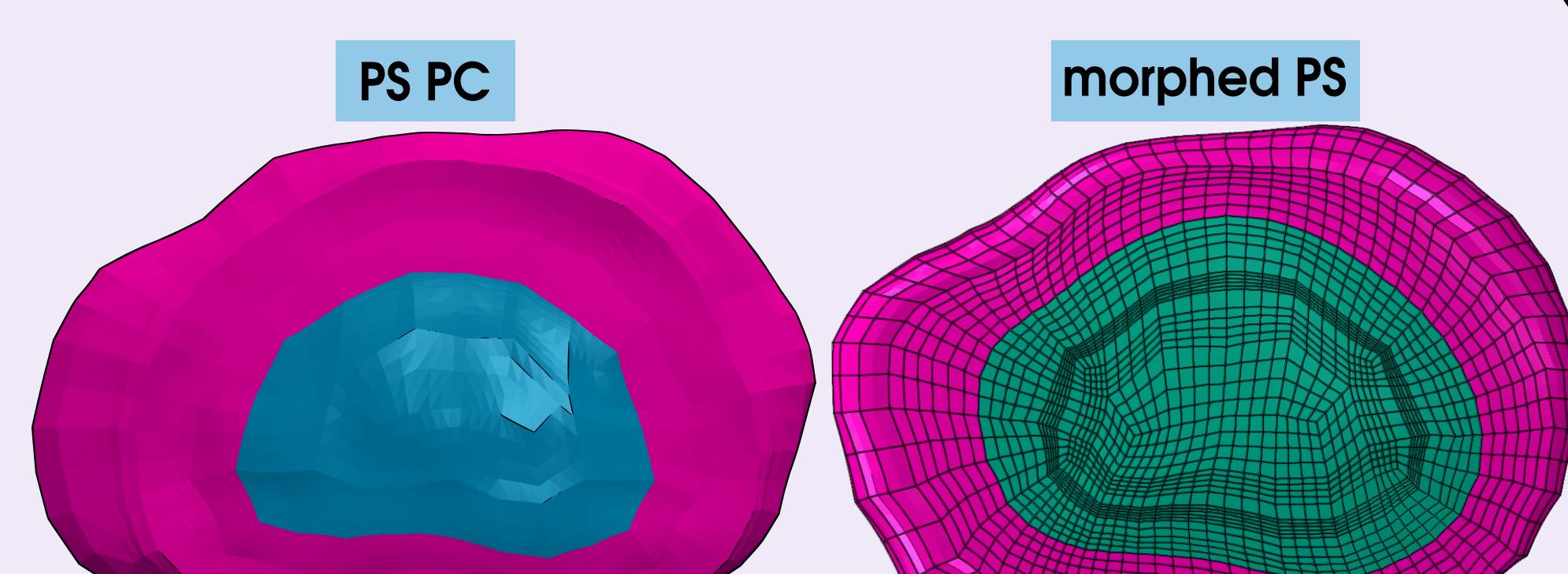
Morphological measurements of the disc as features, and mechanical responses in regions of interest (ATZ, PTZ, CNP, TC, and BC) as targets:



## RESULTS

### Morph process

- No significant differences in mesh quality
- The Hausdorff distance: the similarity between the PC and the FEM was about 92%



### Influence of morphology on mechanical response

Model	LR	LR	LR	LR	XGBoost	XGBoost	LR	SVM	SVM
r²	0.39	0.24	0.25	0.76	0.71	0.70	0.17	0.50	0.47
MSE	1.11e-10	1.76e-06	7.24e-06	2.17e-11	2.13e-07	8.43e-07	7.55e-11	3.75e-07	2.02e-06
NPH	0.47	0.59	0.56	1	1	1	0.42	0.13	0.064
pH	0.28	0.94	1	0.21	0.024	0.061	0.26	0.77	0.74
aH	0.17	0.33	0.35	0.2	0.035	0.027	1	0.55	0.58
CTH	0.39	0.37	0.32	0.081	0.15	0.12	0.051	0.12	0.0028
CBH	0.13	0.32	0.32	0.21	0.055	0.031	0.099	0.27	0.2
paHR	0.28	0.21	0.17	0.18	0.052	0.084	0.52	1	1
SD	1	0.59	0.42	0.1	0.075	0.1	0.026	0.3	0.42
CD	0.07	0.0043	0.0072	0.027	0.018	0.11	0.49	0.034	0.0023
α	0.12	0.16	0.14	0.065	0.08	0.094	0.13	0.1	0.15
AFV	0.79	1	0.94	0.15	0.017	0.074	0.54	0.19	0.027
NPV	0.12	0.068	0.1	0.27	0.23	0.22	0.31	0.13	0.26
CTV	0.53	0.57	0.51	0.2	0.19	0.21	0.16	0.12	0.065
CBV	0.29	0.14	0.087	0.06	0.029	0.099	0.073	0.33	0.25
Perm	PTZ			CNP			ATZ		
Wcont	CNP			ATZ			ATZ		
POR	ATZ			ATZ			ATZ		

Normalized Mean Absolute SHAP Values

Mechanical variables affects the transport of metabolites, which regulate the cell viability [5]

The local heights strongly influence the local mechanical responses

## conclusions

The automatic tool that transforms the structured IVD mesh into PS FE models was successfully developed

PS FE simulations seem cornerstone to assess mechanoregulatory variables in critical regions such as the TZ

A repository of 169 IVD models was created, and all models have the same number of nodes, elements and connectivity, except for the nodal coordinates

Mechanical variables show a strong influence by their local mohological factors and the CEP shape of the IVD

## references

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## acknowledgments



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