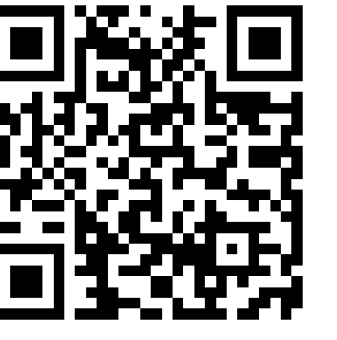




Optimal Patient-Specific Femoral Implants using Generative Models

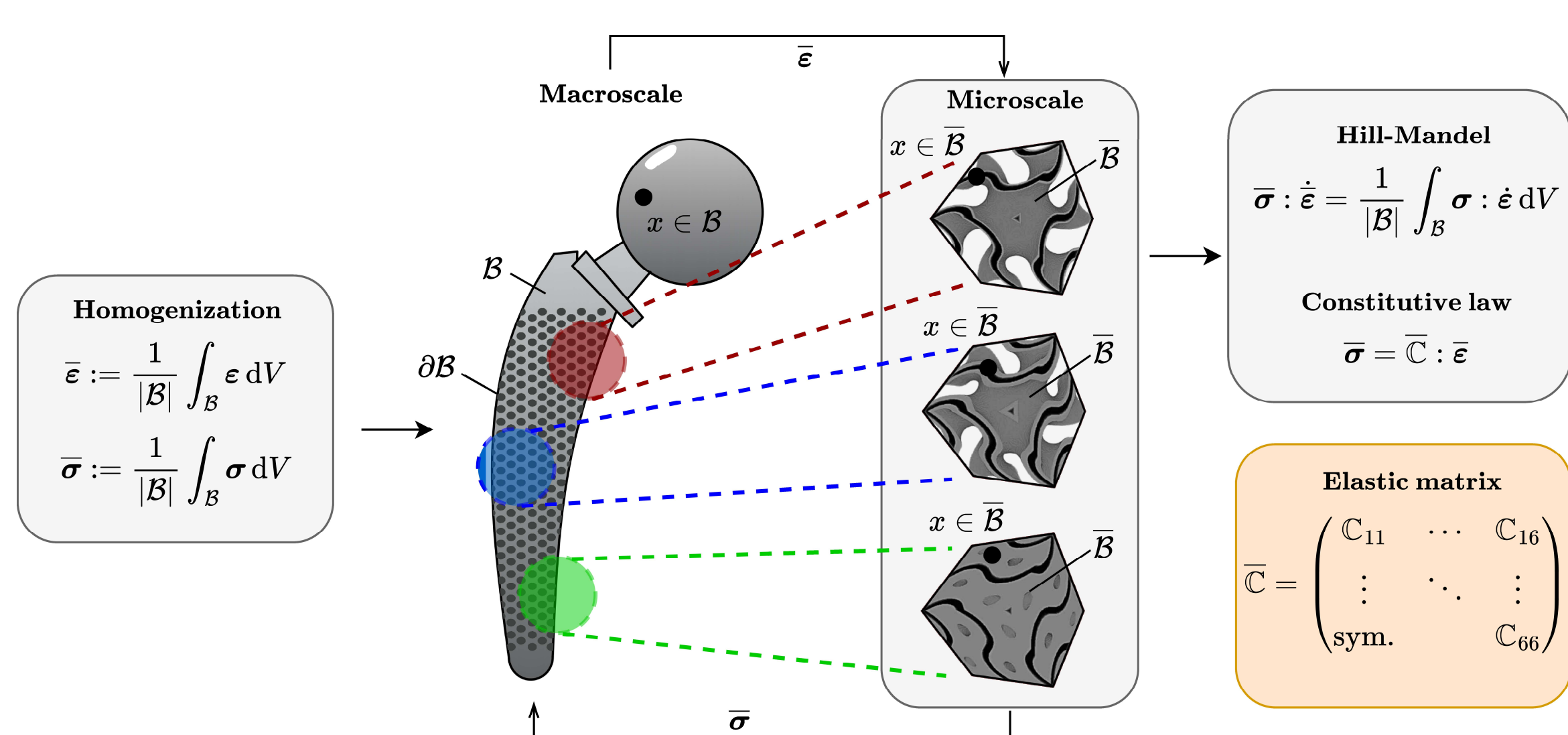
B. Ayouch, T. Gärtner, A. Antonini, M. Haertlé, F. Nürnberger, H. Windhagen, F. Aldakheel

Background

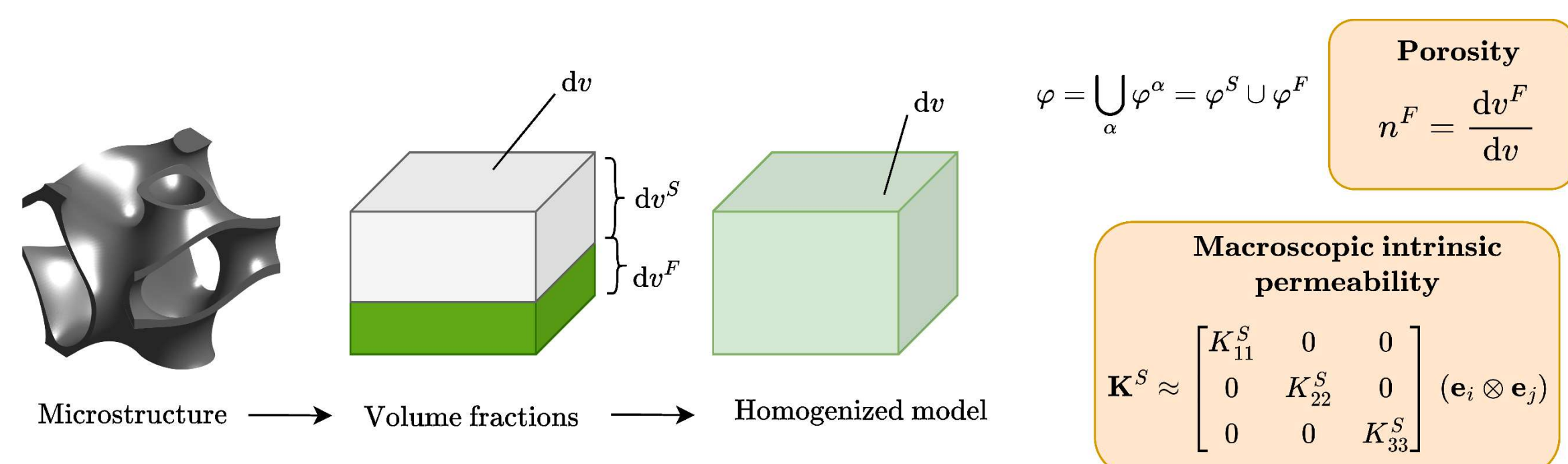
- Clinical Need:** Non-matching properties between implant and bone form a major challenge in Total Hip Arthroplasty
- Design Challenge:** Match implant stiffness while maintaining sufficient permeability for bone ingrowth.
- Proposed Solution:** Architected materials with tailored mechanical and hydraulic properties, generated by inverse diffusion models
- Objective:** Improve effective implant life-time by reducing stress shielding.

Multiscale Homogenization & Inverse Design

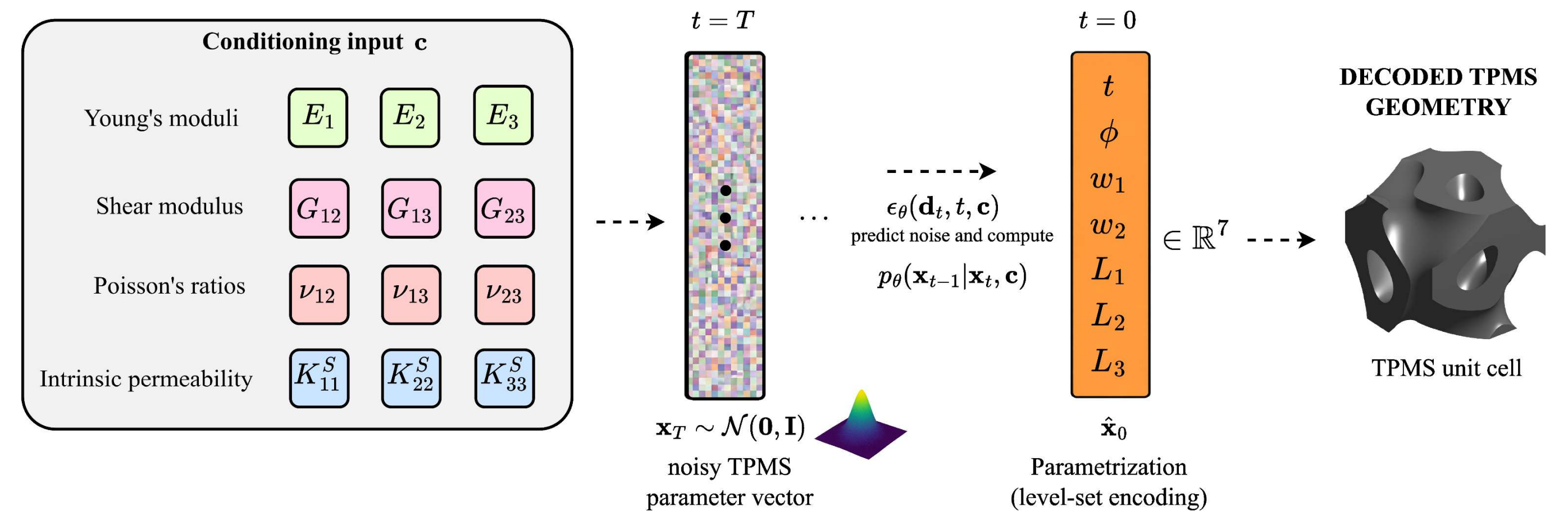
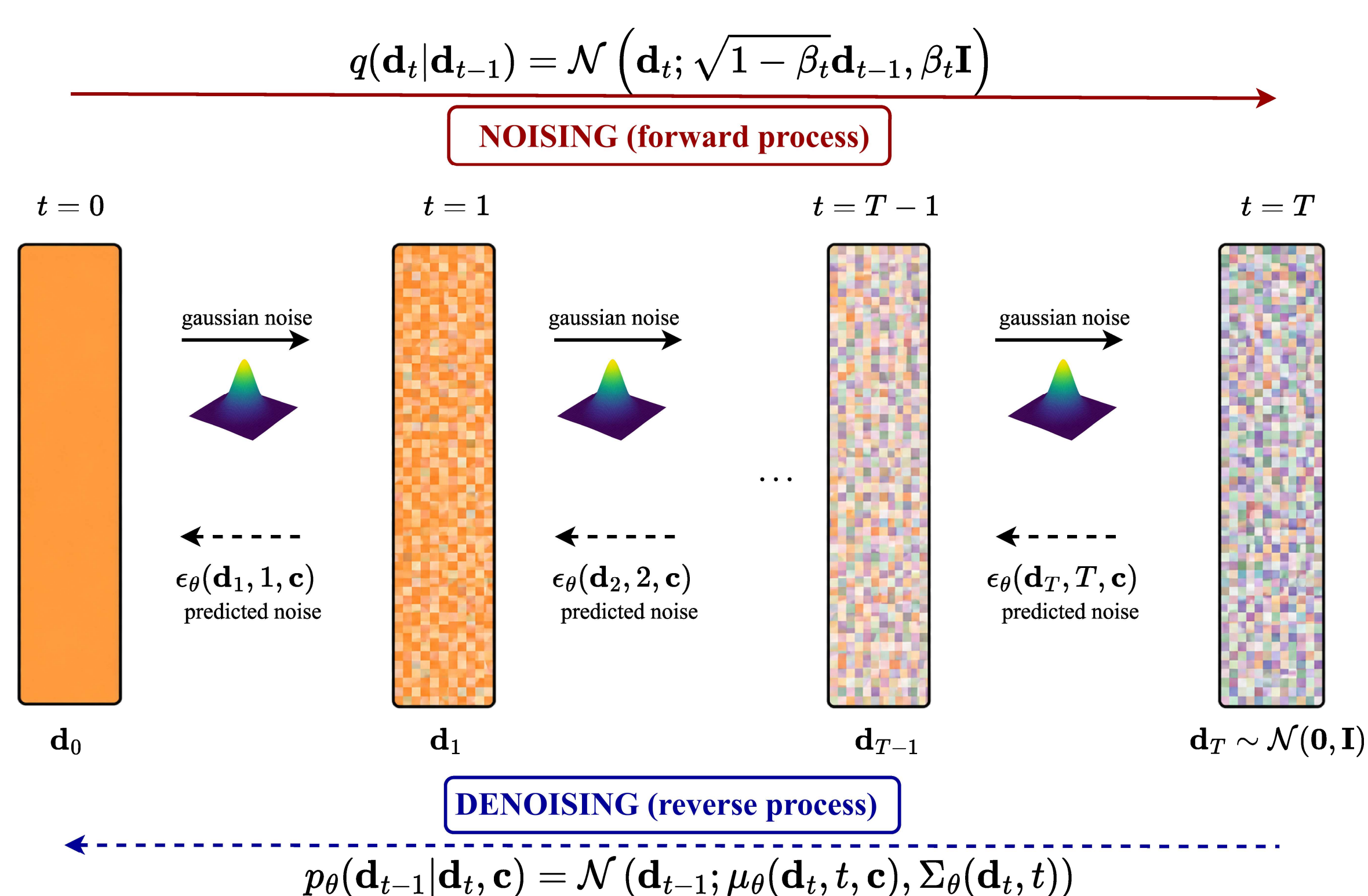
- Hybrid TPMS Structures:** Combined Gyroid and Schwarz geometries for tunable stiffness and permeability.
- Elastic Homogenization:** Effective stiffness from microscale simulations.



- Multiscale Hydraulics:** Lattice Boltzmann Method (LBM) determines effective permeability via Darcy's Law, linking micro-morphology to fluid flow.

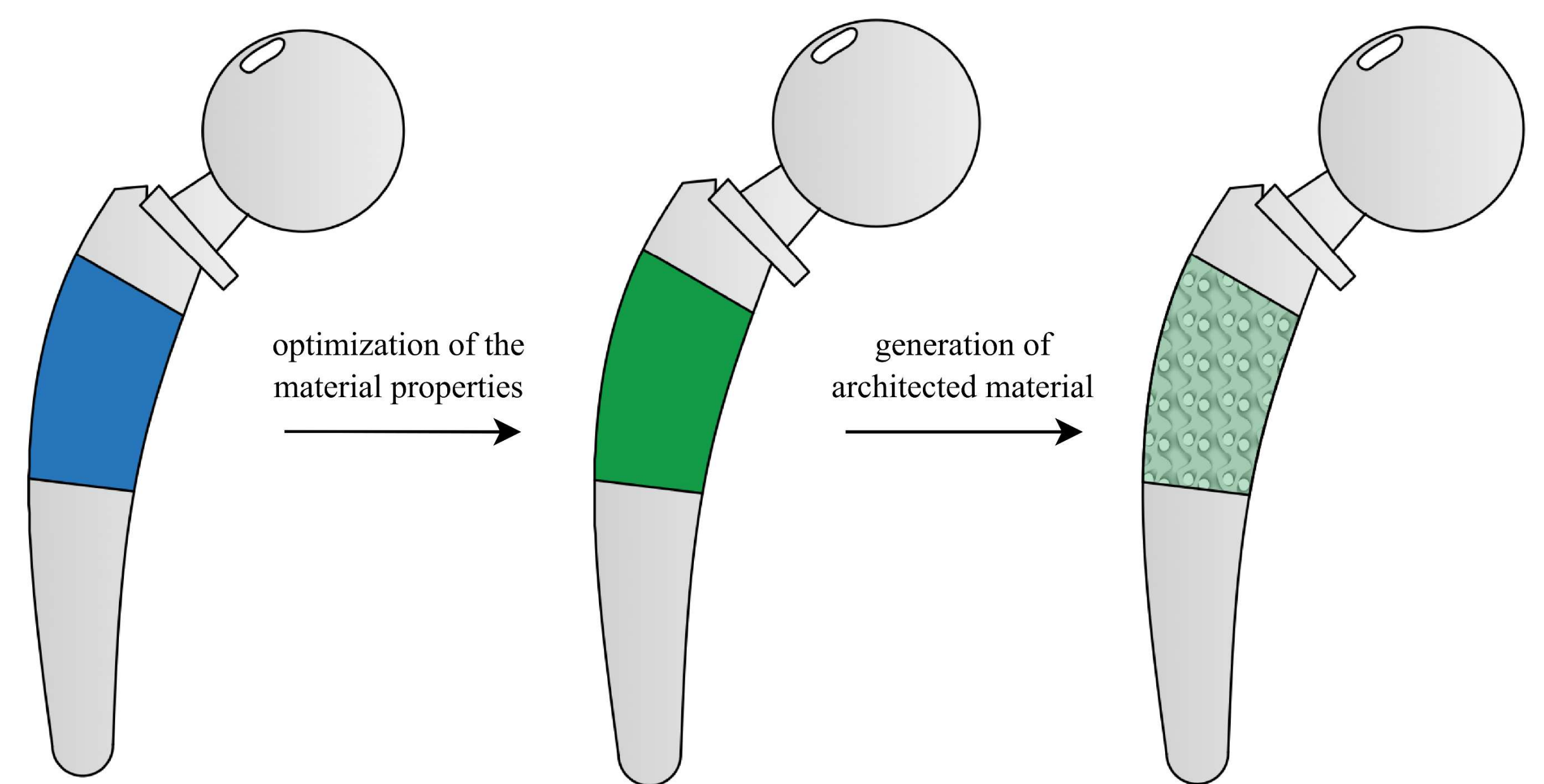


- Conditional Diffusion Model:** Generation of tailored designs meeting target stiffness and permeability.



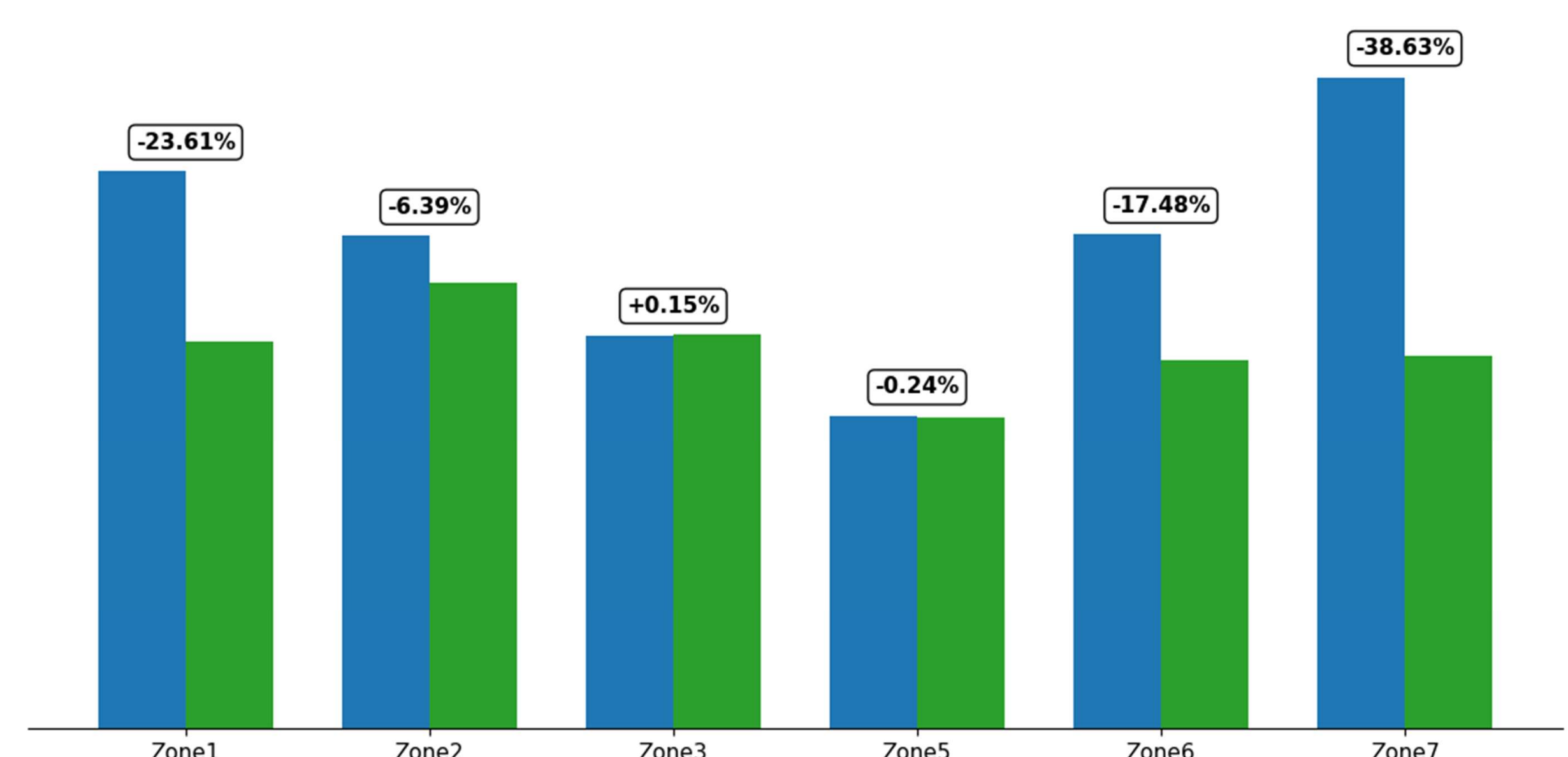
Minimizing Stress Shielding:

- Optimize material properties in the implant
- Generate an architected TPMS cell with optimized properties



Results

- Stress shielding assessed for different Gruen zones via **SED** in the intact and implanted femurs.
- Optimized architected materials from the **diffusion model** show reduced stress shielding.
- Reduction mainly in the **medial calcar** and **greater trochanter** zones



Conclusion

- Architected hybrid TPMS allows for **independent tuning** of elastic and hydraulic properties
- Effective parametrization reduced computational cost for **efficient generative modeling**
- Reduced stress shielding** due to optimized implant materials

Outlook

- Dynamic bone remodeling
- Implant–bone interface mechanics
- Patient-specific fatigue analysis
- Improve clinical applicability