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Inspection par courants de Foucault d'un matériau ferromagnétique : Effet de l'état de contraintes mécaniques

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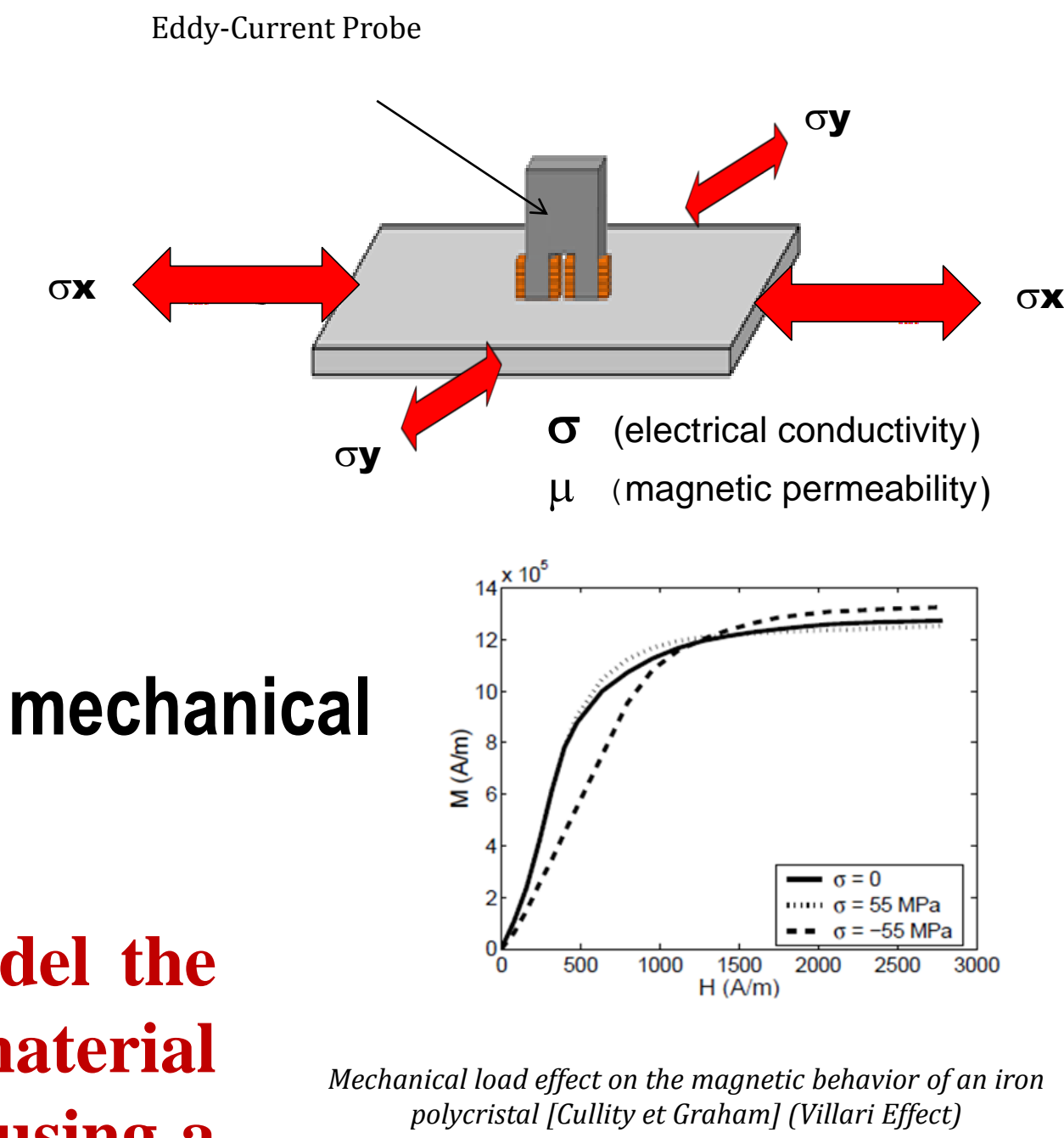
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Introduction

- ❖ NDT-EC Powerful and widely used method for the reliability
- ❖ EC are strongly influenced by the magnetic properties
- ❖ Magnetic properties on the other hand significantly depend on the mechanical stress in the inspected specimen

The purpose of this work is to develop a trump numerical tool to model the Eddy Current (EC) signal provided by an EC probe inspecting a material subjected to stress. The effect of stress on the permeability is predicted using a multiscale model.



3-Finite Element method formulations

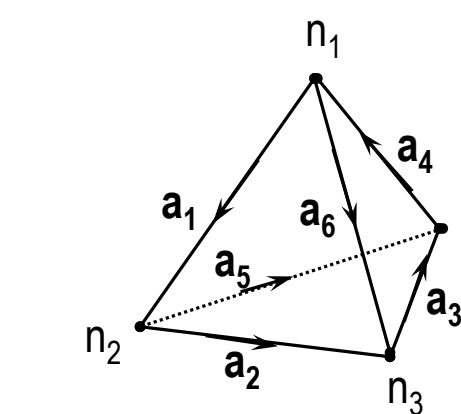
3d dual potential combined formulations

Magnetic formulation $t-\phi$

$$\int_{\Omega_c} \frac{1}{\sigma} \text{rot}' \text{rot}' t d\Omega + i\omega \int_{\Omega_c} \mu t' d\Omega + i\omega \int_{\Omega_c} \mu t' \cdot \text{grad} \Phi d\Omega + \int_{\Gamma_c} t' \cdot (\mathbf{n} \times \mathbf{e}) d\Gamma = 0$$

$$i\omega \int_{\Omega_c} \mu \text{grad} \Phi' \cdot t d\Omega + i\omega \int_{\Omega_c} \mu \text{grad} \Phi' \cdot \text{grad} \Phi d\Omega + i\omega \int_{\Gamma_c} \Phi' \cdot (\mathbf{n} \cdot \mathbf{b}) d\Gamma = 0$$

t : electric vector potential - edge dof
 ϕ : magnetic Scalar potential - node dof



Whitney Finite Element

Electrical formulation $a-\psi$

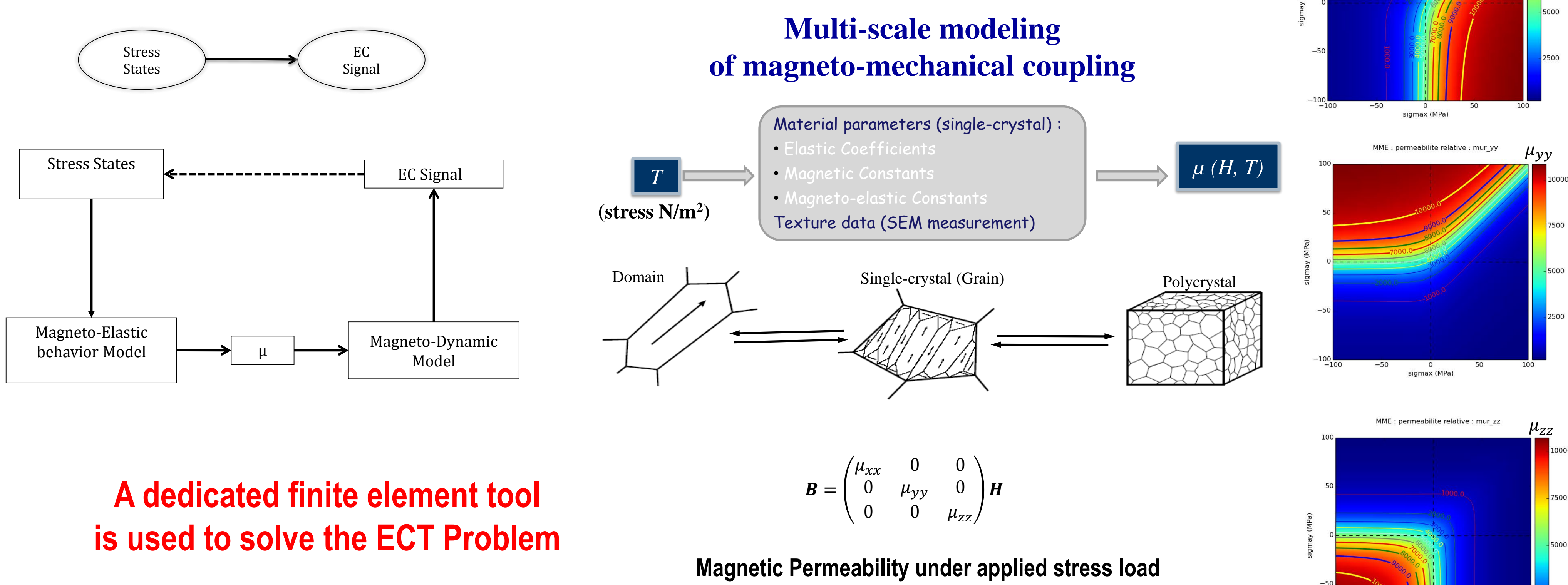
$$\int_{\Omega_c} \frac{1}{\mu} \text{rot}' \text{rot}' a d\Omega + i\omega \int_{\Omega_c} \sigma a' \cdot a d\Omega + i\omega \int_{\Omega_c} \sigma a' \cdot \text{grad} \Psi d\Omega + \int_{\Gamma_c} a' \cdot (\mathbf{n} \times \mathbf{h}) d\Gamma = 0$$

$$i\omega \int_{\Omega_c} \sigma \text{grad} \Psi' \cdot a d\Omega + i\omega \int_{\Omega_c} \sigma \text{grad} \Psi' \cdot \text{grad} \Psi d\Omega + \int_{\Gamma_c} \Psi' \cdot \mathbf{n} \cdot \mathbf{j} d\Gamma = 0$$

a : magnetic vector potential - edge dof
 Ψ : electric Scalar potential - node dof

1-Modelling principle

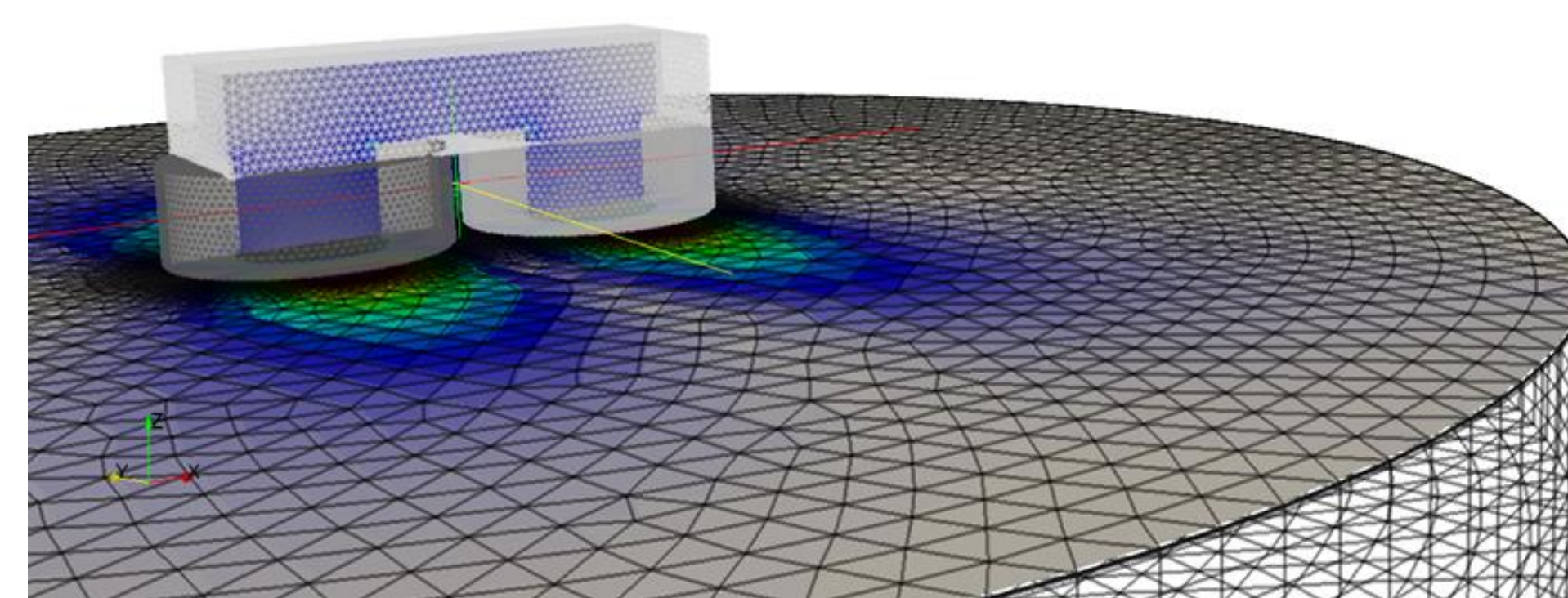
The modeling principle combining a magneto-elastic model with a finite element analysis



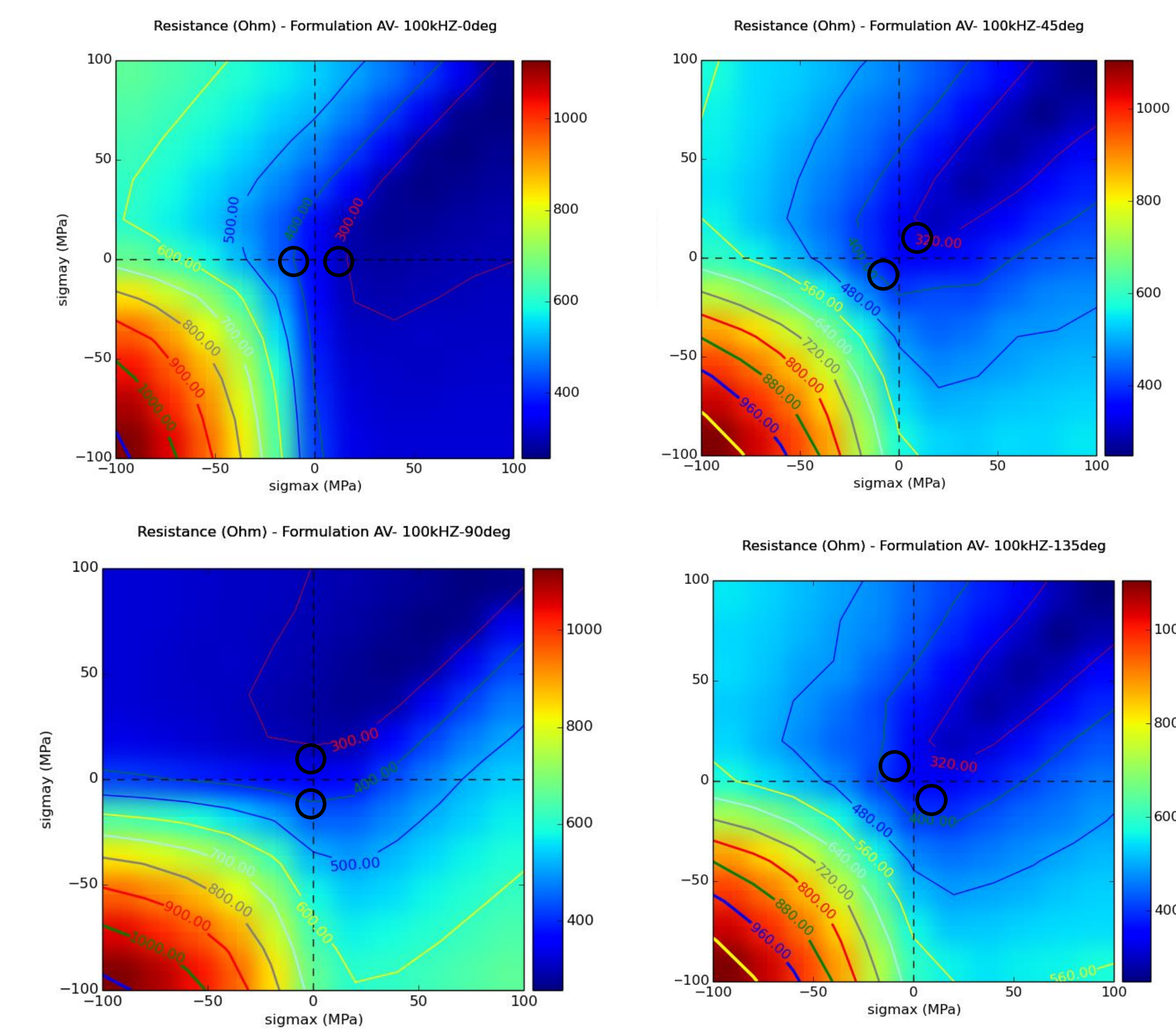
A dedicated finite element tool is used to solve the ECT Problem

2-Dolmen : Dedicated finite Element Analysis Tool

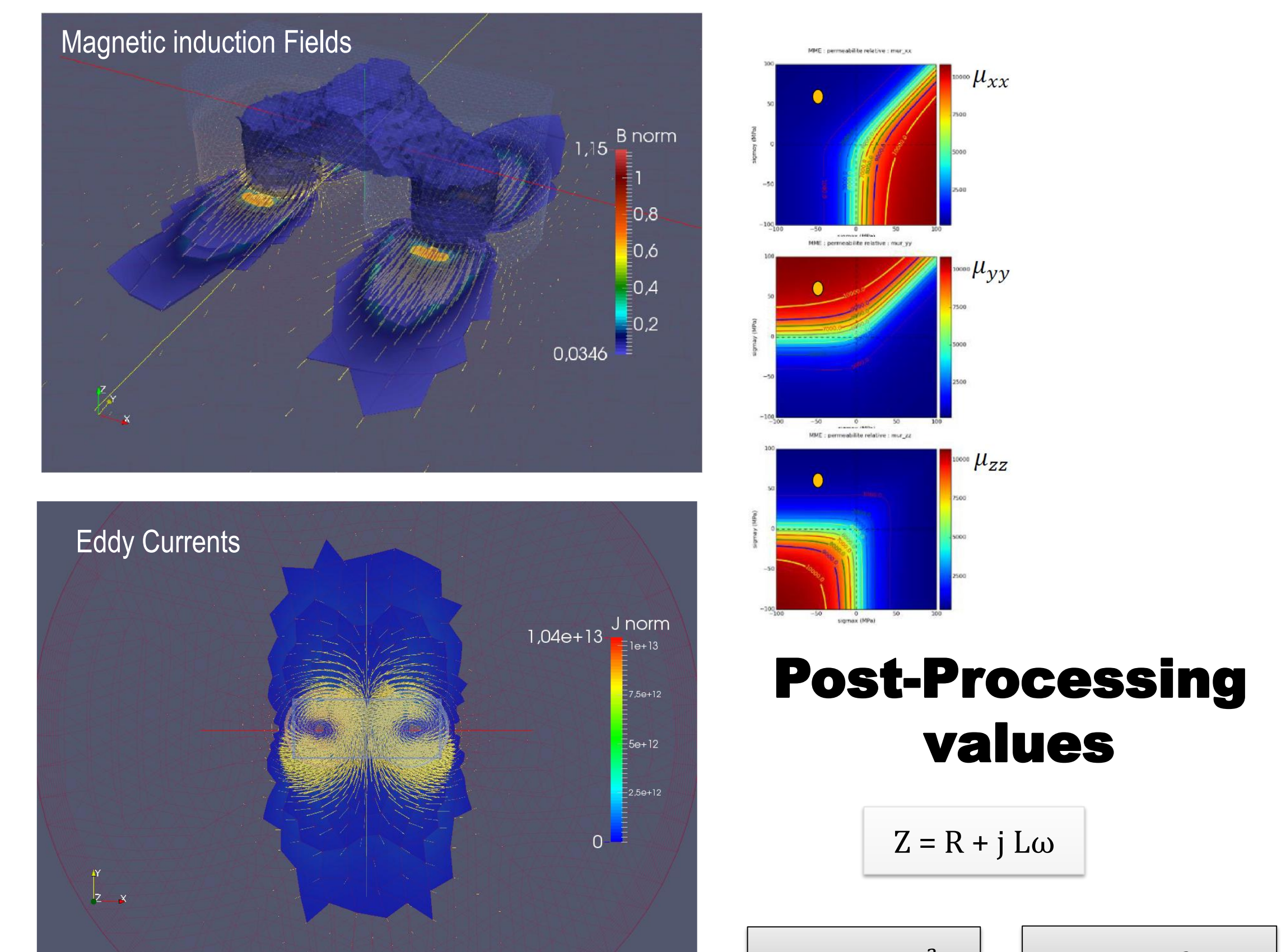
- Conductive Magnetic Material (Very thin skin depth) → Use of prism elements
- Map building → Use parallel computing → Automatic geometry and mesh generation
- Error Estimation based on the two dual FEM formulations



Resistance Map $f=100\text{kHz}$



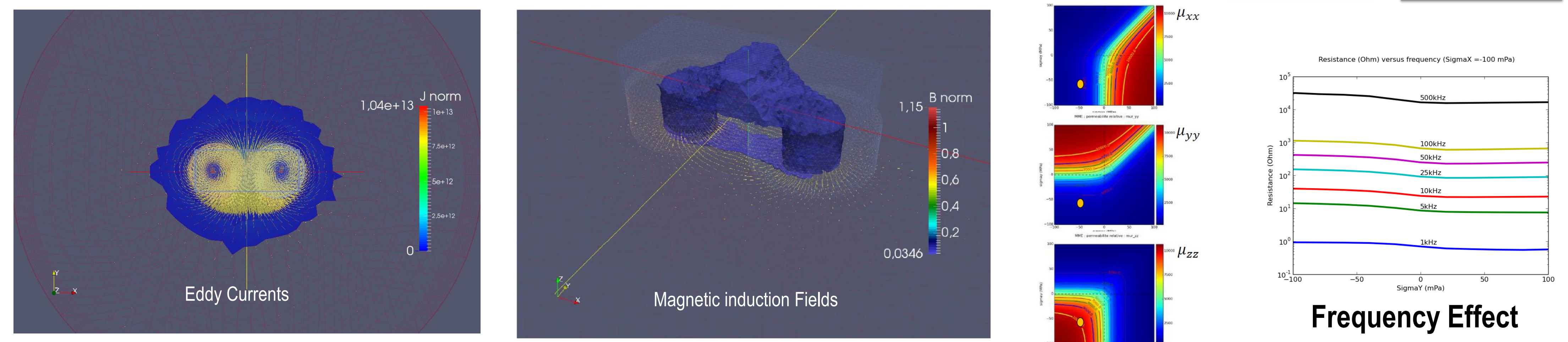
3d Anisotropic stress effect on the electromagnetic fields



Post-Processing values

$$Z = R + j L \omega$$

$$W_{maj} = \frac{1}{2} L I_{eff}^2 \quad P_j = R I_{eff}^2$$



Conclusion

In conclusion we can trumpet that the distribution of the currents are dramatically modified when the mechanical stress state is introduced. The results confirm also that stress has a strong effect on the field distribution and that the mesh of the FEM model has to be carefully designed in order to take into account properly this influence. The modelling approach provides some promising leads to identify stress states by an Eddy Current testing approach.