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### ► To cite this version:

Aurélia Ruda, François Louf, Pierre-Alain Boucard, Xavier Mininger. First approach of a mixed domain decomposition method for magnetostatic simulation of rotating machines. 23rd Conference on the Computation of Electromagnetic Fields COMPUMAG 2021, Jan 2022, online, France. pp.PB-A1-10. hal-03538690

**HAL Id: hal-03538690**

**<https://hal.science/hal-03538690>**

Submitted on 21 Jan 2022

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# First approach of a mixed domain decomposition method for magnetostatic simulation of rotating machines

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## Abstract

In this work, a mixed domain decomposition method (LATIN) is proposed to improve the efficiency of magnetostatic simulation of rotating machines. This strategy relies on a decomposed formulation of the problem considering both primal and dual fields on the interfaces. From this formulation, the LATIN solver method gives a powerful iterative scheme to build a solution. A first implementation using the magnetic vector potential formulation in 2D is developed and is illustrated on two test cases: a ferromagnetic 2D bar and a switched reluctance motor.

## 1 - Problem statement

**Objective:** propose an innovative computational strategy based on a domain decomposition method

Problem studied

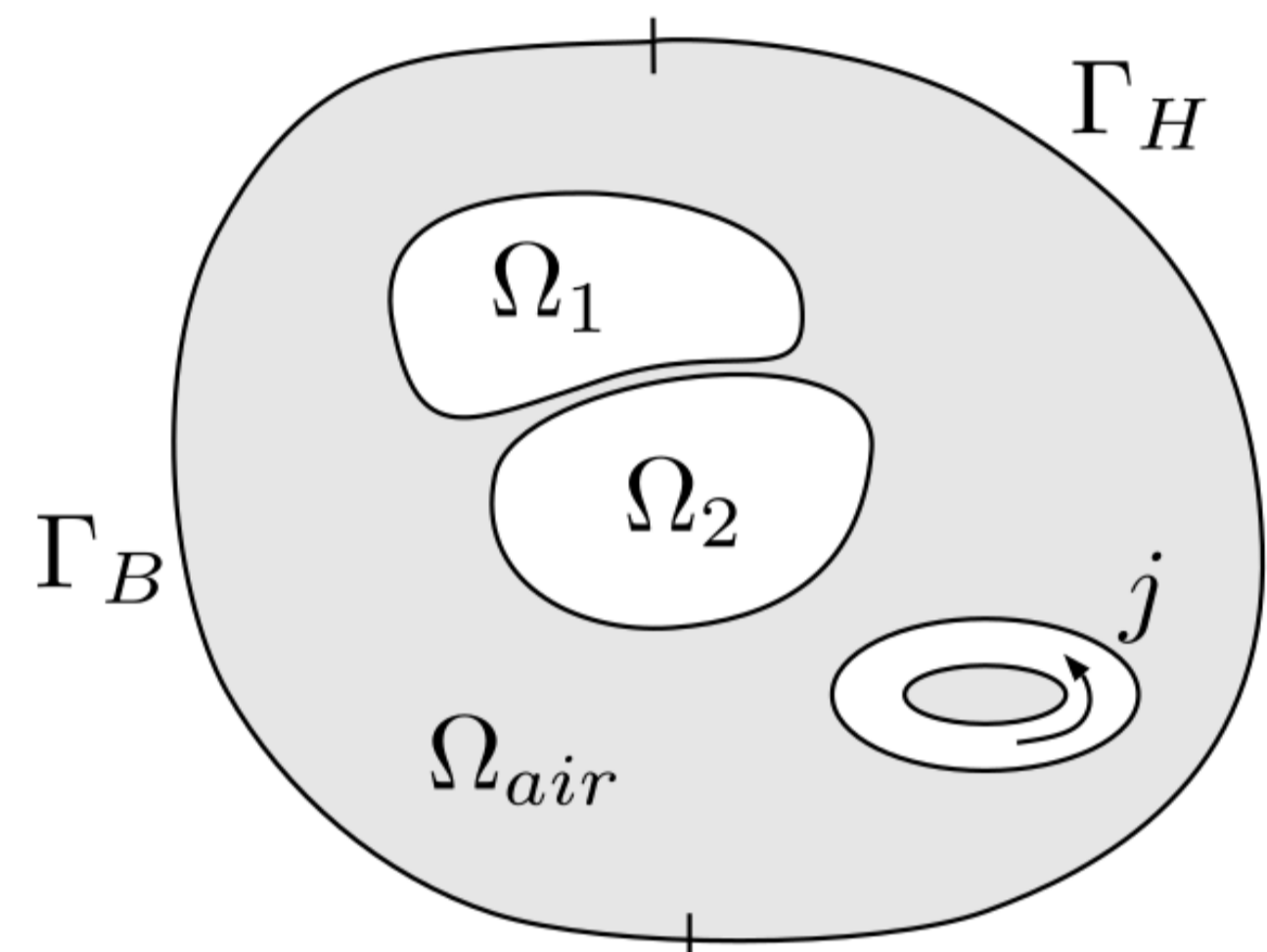
$$\begin{cases} \operatorname{div}(\underline{B}) = 0 \\ \operatorname{rot}(\underline{H}) = \underline{j} \\ \underline{B} = \mu \underline{H} \end{cases}$$

Framework of the study

Formulation with vector potential  $\underline{A}$  in 2D

Discretization with Finite Element

$$[K]\{A\} = \{J\}$$



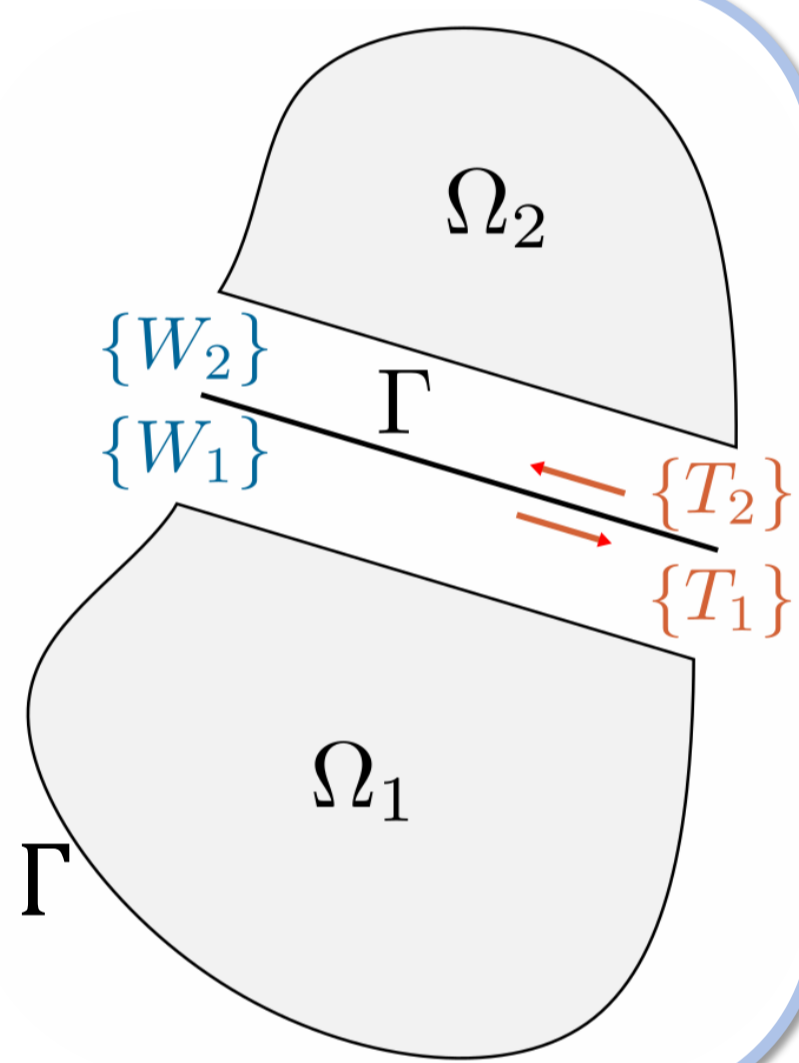
### Decomposition

- Sub-domains  $\Omega_i$
- Interfaces  $\Gamma$  between each sub-domains

Particularity of the method:

Primal **and** dual fields on the interfaces

- $\{W\}$  restriction of vector potential  $\{A\}$  on  $\Gamma$
- $\{T\}$  tangential component of magnetic field  $\{H\}$  on  $\Gamma$
- Operator  $[t]$ : restriction on  $\Gamma$



## 2 - The mono-scale LATIN method

### Principles

- **Separate equations** into two groups  $A_d$  and  $\Gamma$
- Solve with a **two stage iterative algorithm** according to search directions  $E^+$  and  $E^-$

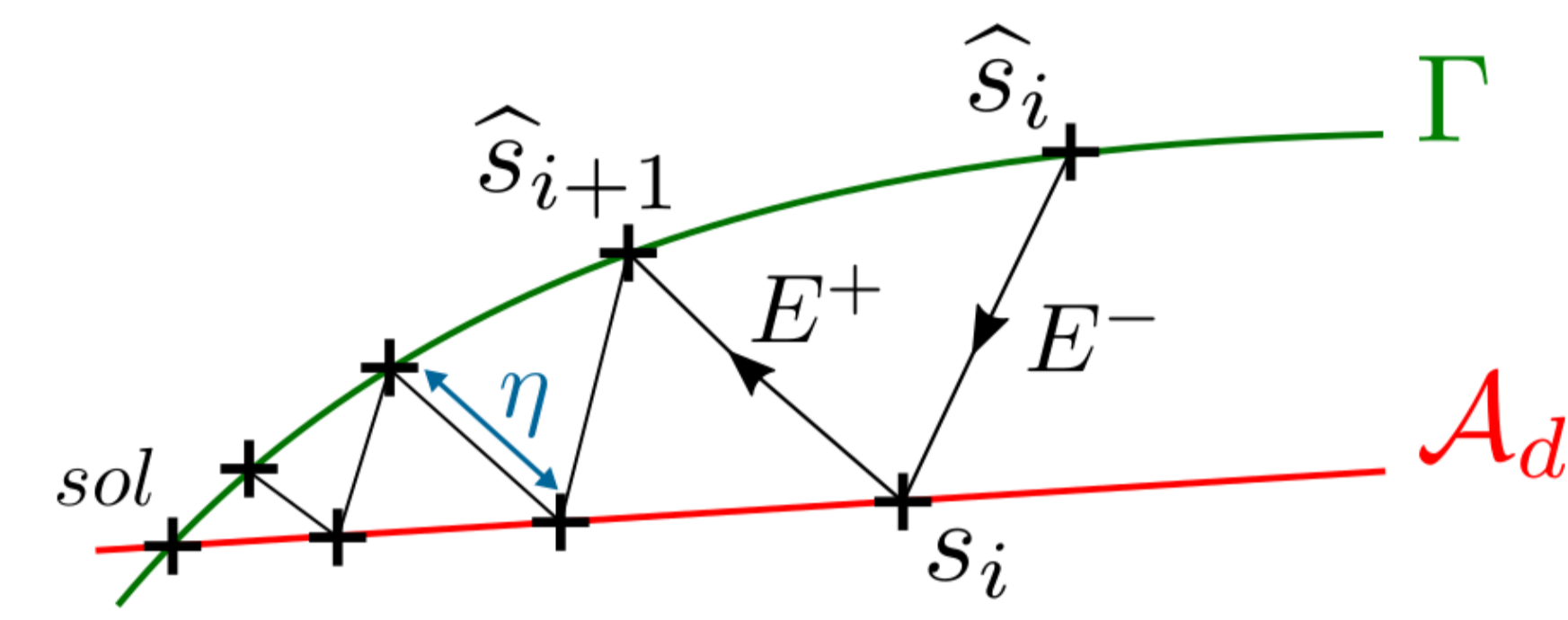


Figure: LATIN iterative scheme

Group ( $A_d$ ): linear and possibly global equations

$$\begin{aligned} \text{Search } s &= (\{W\}, \{T\}) \\ [K]\{A\} &= \{J\} + [t]^T\{T\} \\ \{W\} &= [t]\{A\} \end{aligned}$$

### Search directions

$[k^+]$  and  $[k^-]$  operators representing sub-domains behavior

$$\begin{aligned} E^- & \\ \{T\} - \{\hat{T}\} + [k^-](\{W\} - \{\hat{W}\}) &= \{0\} \\ E^+ & \\ \{\hat{T}\} - \{T\} + [k^+](\{\hat{W}\} - \{W\}) &= \{0\} \end{aligned}$$

Group ( $\Gamma$ ): local and possibly nonlinear equations

$$\begin{aligned} \text{Search } \hat{s} &= (\{\hat{W}\}, \{\hat{T}\}) \\ [O_d]\{\hat{W}\} &= \{0\} \\ [O_s]\{\hat{T}\} &= \{0\} \end{aligned}$$

**Algorithm:** Mono-scale LATIN

**Input:**  $\hat{s}_0 \in \Gamma$  (generally set to 0)

**while**  $\eta \geq \text{criteria do}$

**Linear stage** for each sub-domain

knowing  $\hat{s}_i \in \Gamma$  search for  $s_i \in A_d \cap E^-$

**Local stage** for each interface

knowing  $s_i \in A_d$  search for  $\hat{s}_{i+1} \in \Gamma \cap E^+$

**Convergence indicator** compute  $\eta$

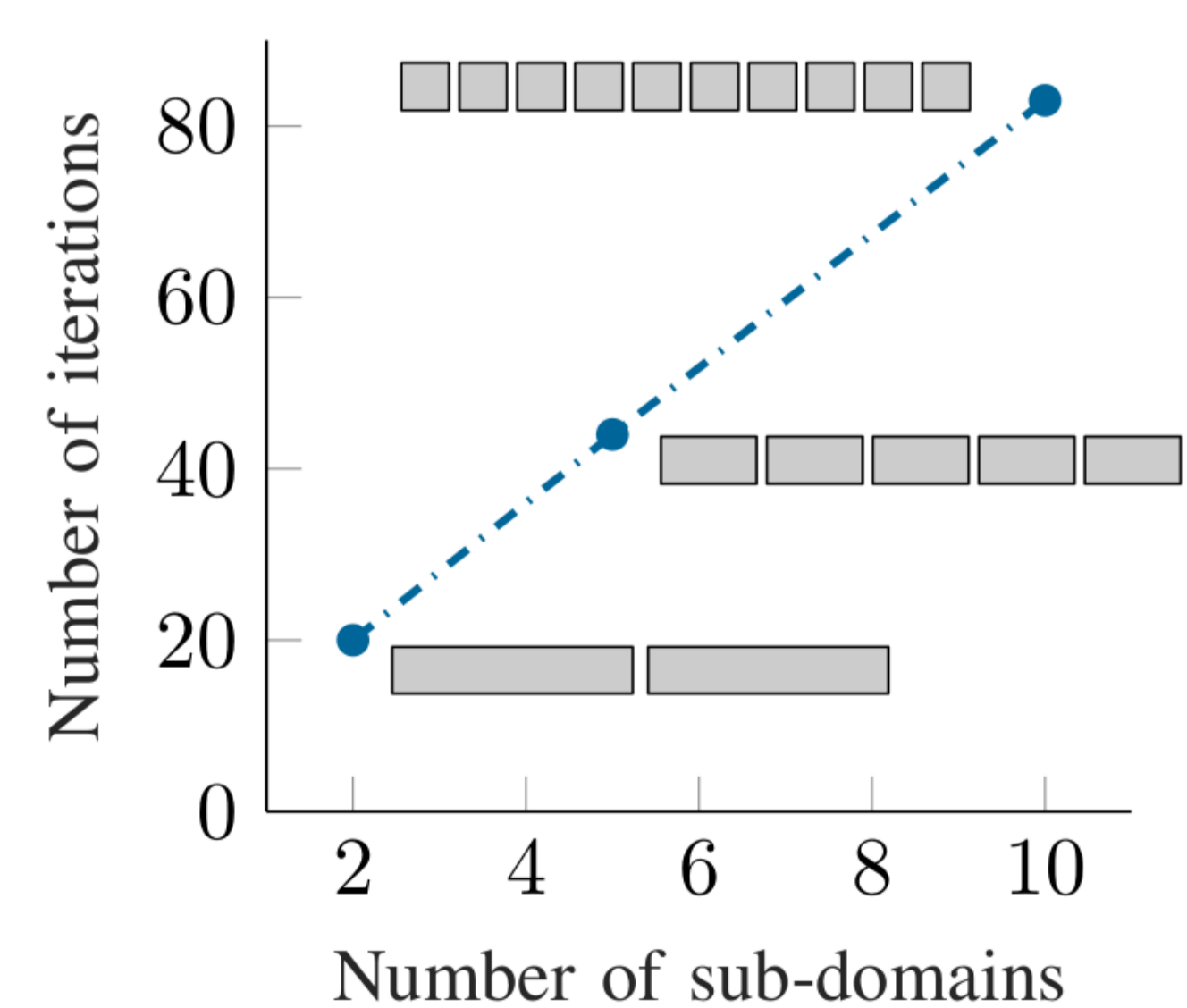
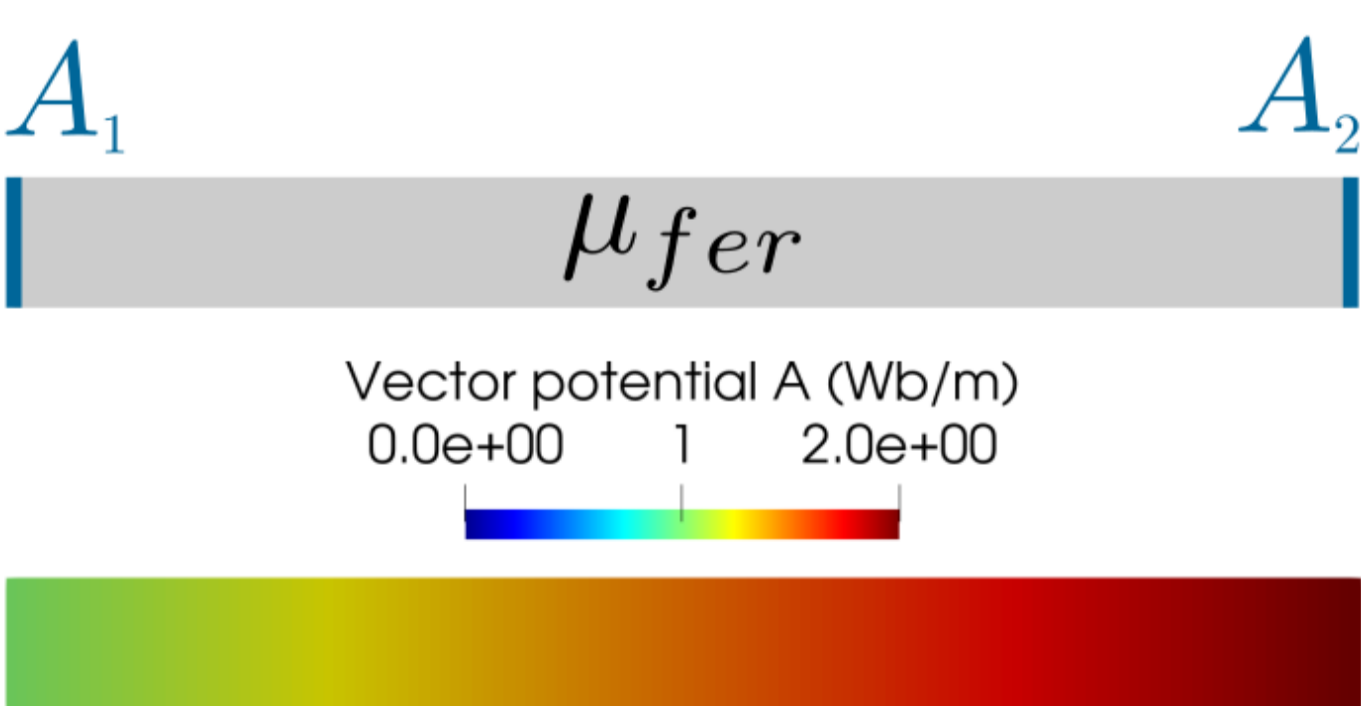
**end**

## 3 - Multi-scale strategy

### Mono-scale strategy limitation

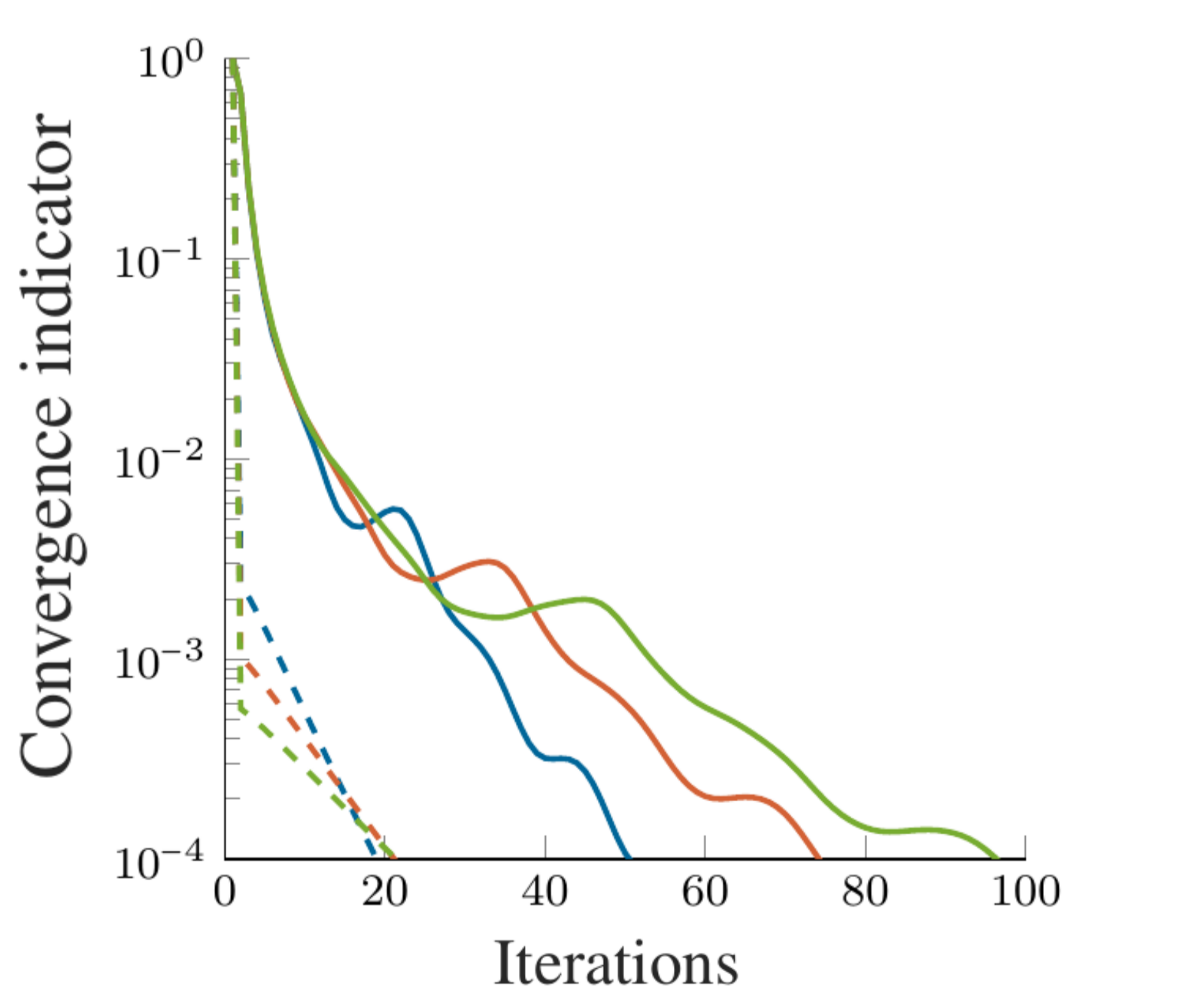
Number of iterations of the algorithm depends on the number of sub-domains

### Illustration of the limitation



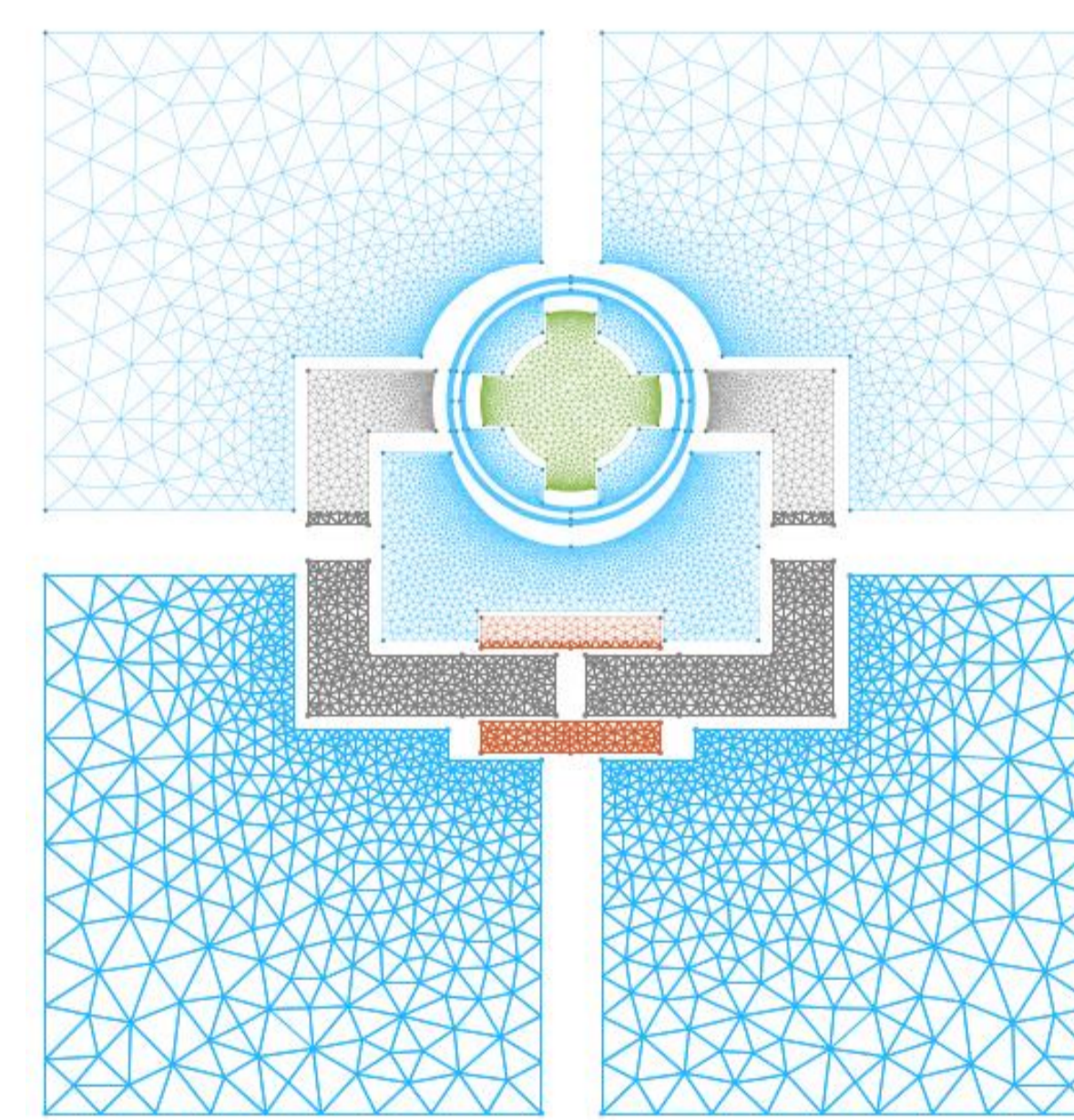
### Multi-scale strategy

- Add the resolution of a **coarse problem** during the linear stage
- Allow to **propagate information** throughout the whole problem globally

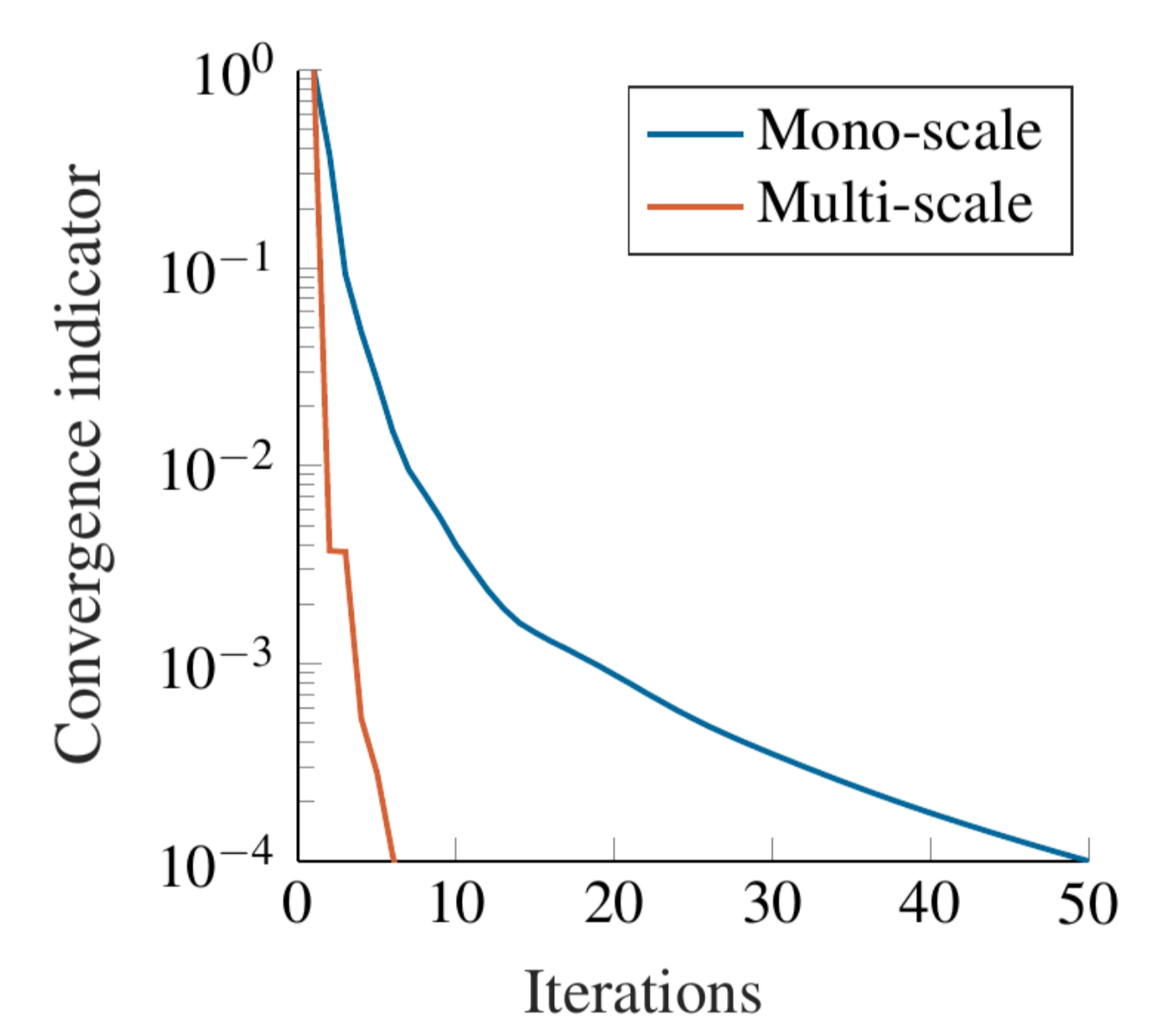
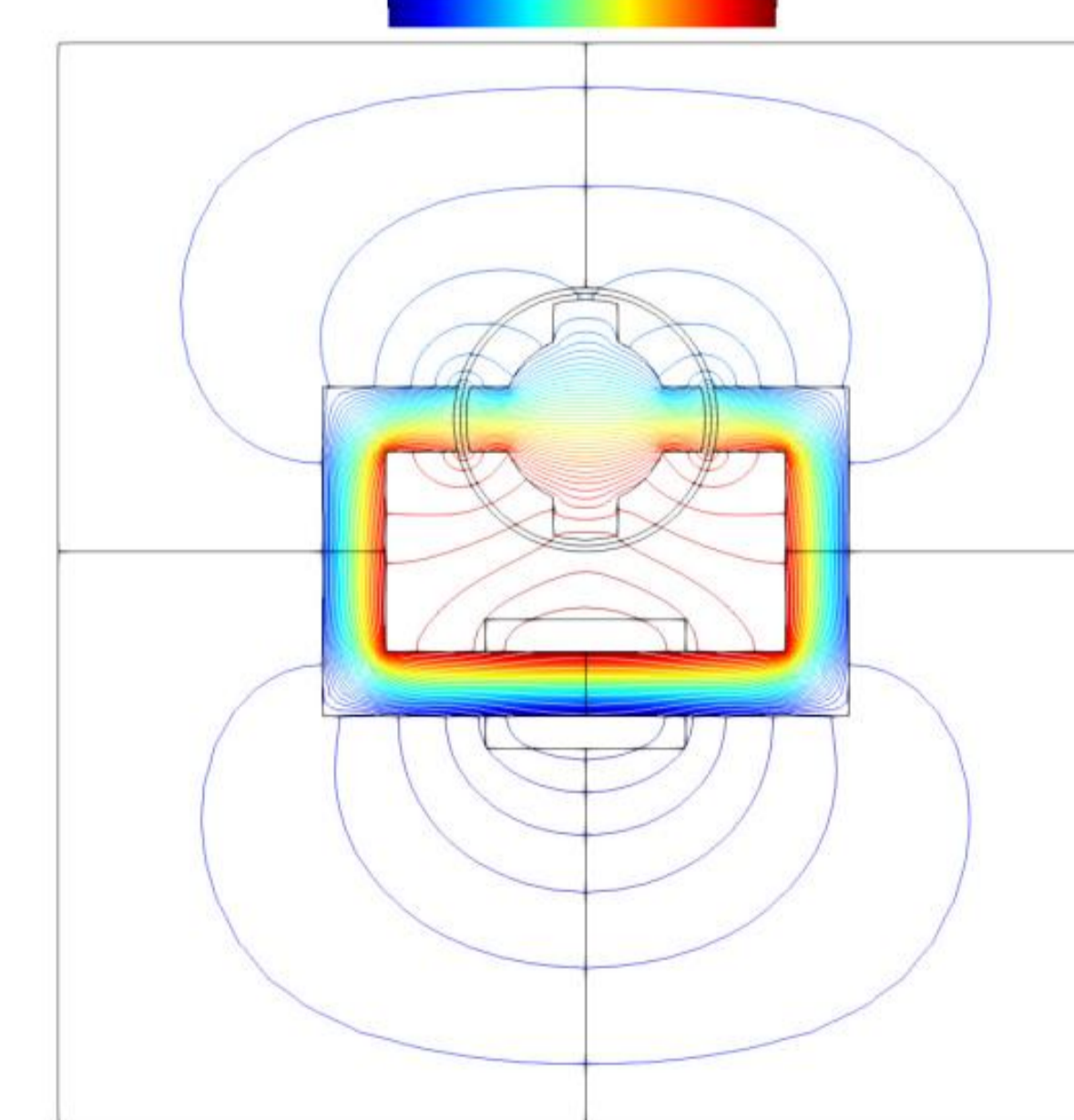


**Mono-scale**  
— 10 subdomains — 15 subdomains — 20 subdomains  
**Multi-scale**  
- - - 10 subdomains - - - 15 subdomains - - - 20 subdomains

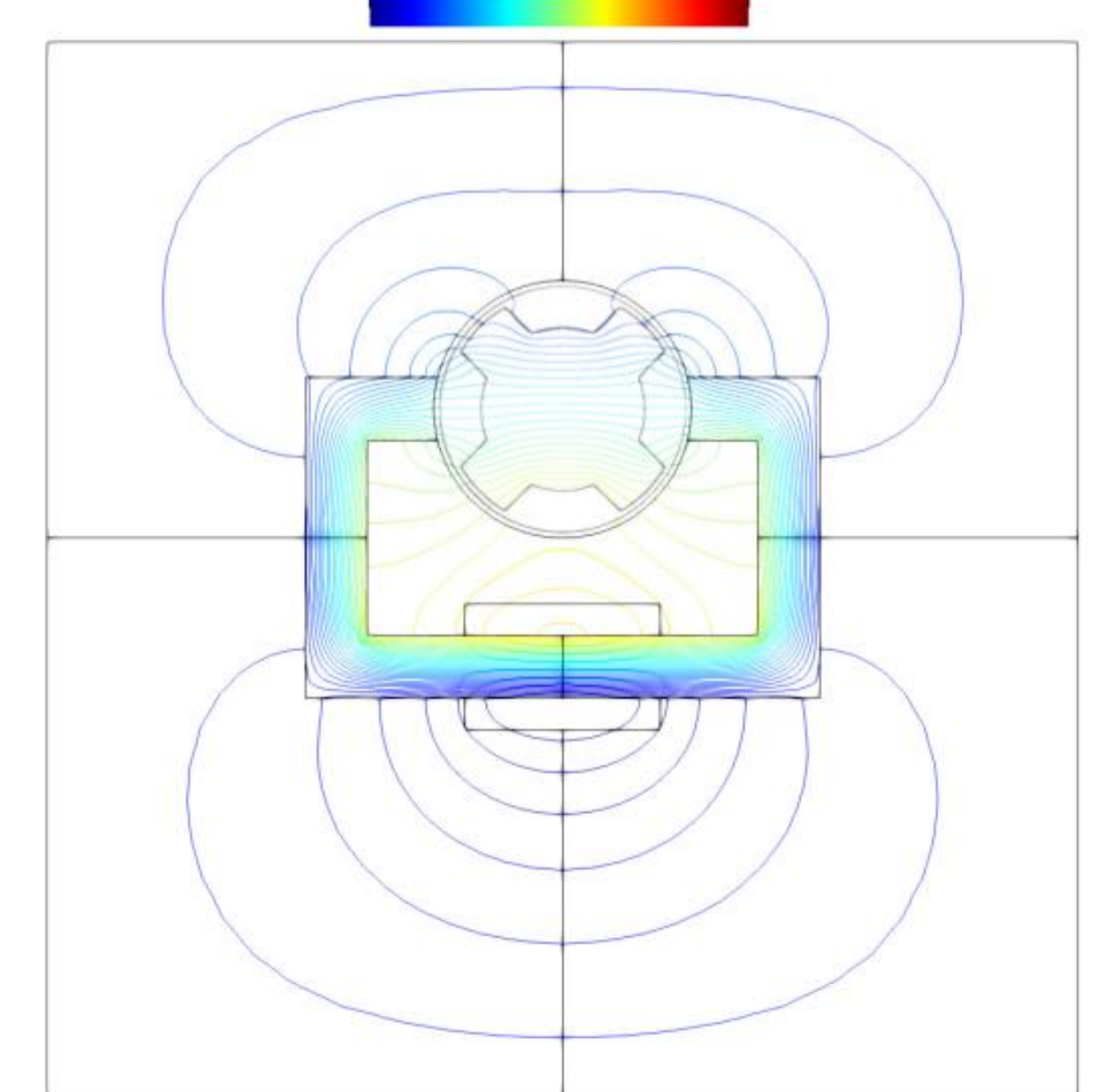
## 4 - Study of a decomposed SRM



Vector potential A (Wb/m)  
-6.3e-04 4.0e-03



Vector potential A (Wb/m)  
-6.3e-04 4.0e-03



## Conclusion

- Presentation of a **mixed domain decomposition method** adapted for magnetostatic simulation
- Implementation of a **multi-scale** computational to address the dependence on the number of sub-domains



### Upcoming work

- Integrate **nonlinearities** without impacting the structure of the algorithm
- **3D** simulations with Whitney elements