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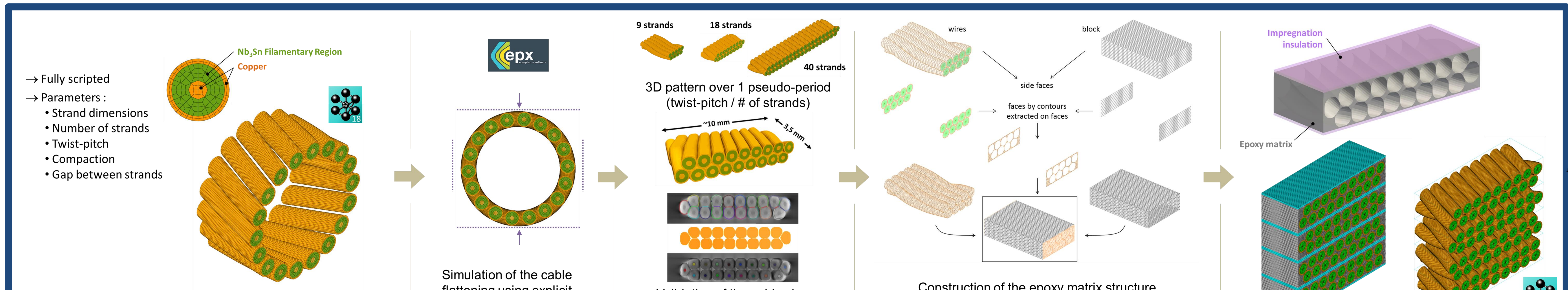
CoCaSCOPE approach for **High definition 3D finite element analysis of low temperature Rutherford cable**

Pierre Manil[1], Gilles Lenoir[1], François Nunio[1]
[1] CEA Paris-Saclay/IRFU, France

In the perspective of simulating and managing the mechanical stresses within strain-sensitive superconductors such as Nb_3Sn, we are proposing a multiscale numerical approach for 3D simulation of Rutherford cables, up to the filament scale, presented in [1],[2]. This poster summarizes recently developed features and results.

Preprocessor: impregnated cable model generation [3]



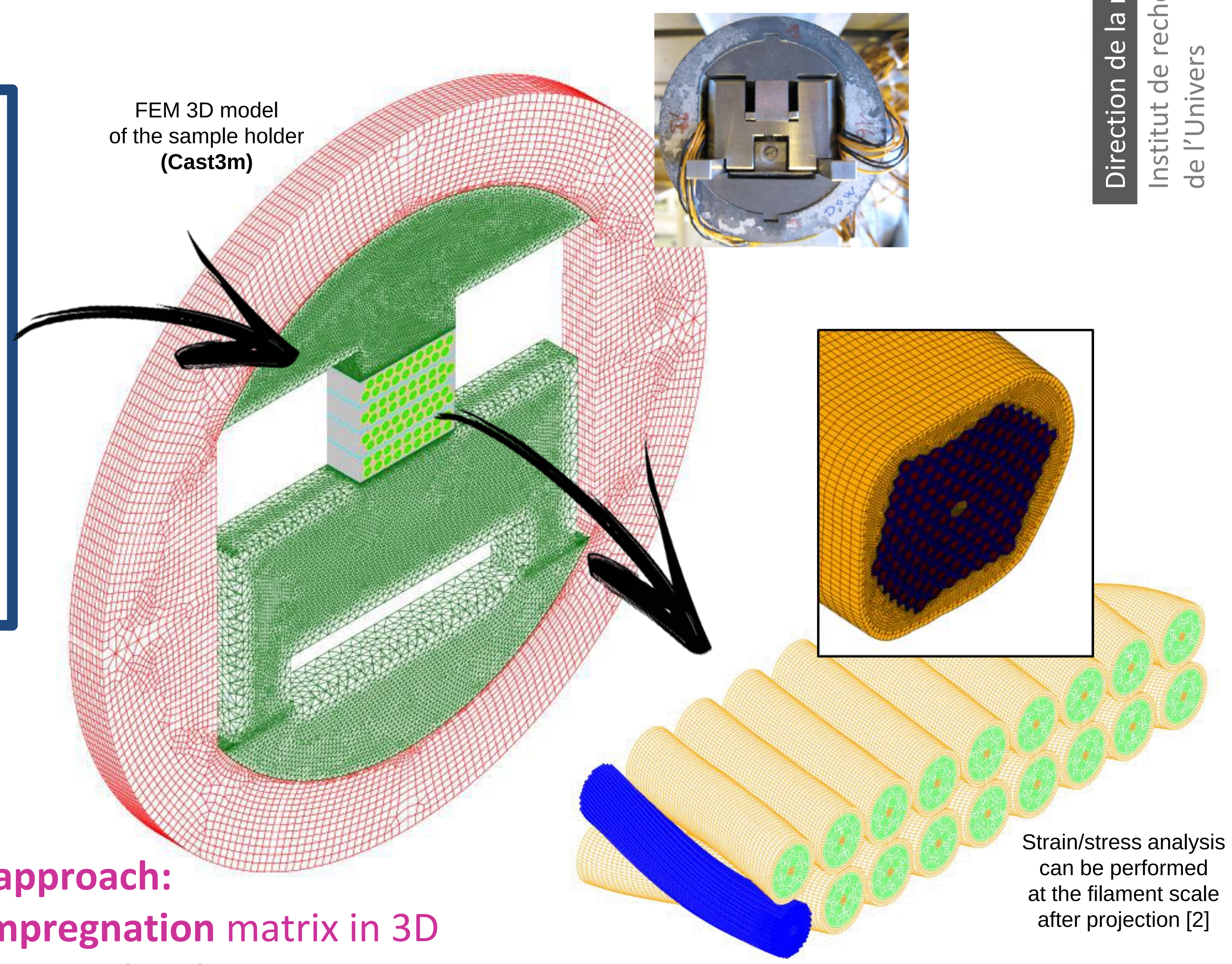
Creation of the initial mesh of a pseudo-period of a 18 strand Rutherford cable with bi-material description (**Cast3M**)

Simulation of the cable flattening using explicit formulation considering specific periodic boundary conditions (**europlexus**)

Validation of the cable shape by comparison with CT-scan images of a real 18 strands Rutherford cable

Construction of the epoxy matrix structure by combination of the boundary meshes of the cable and strand pack bounding box (here illustrated on a 9 strands model basis)

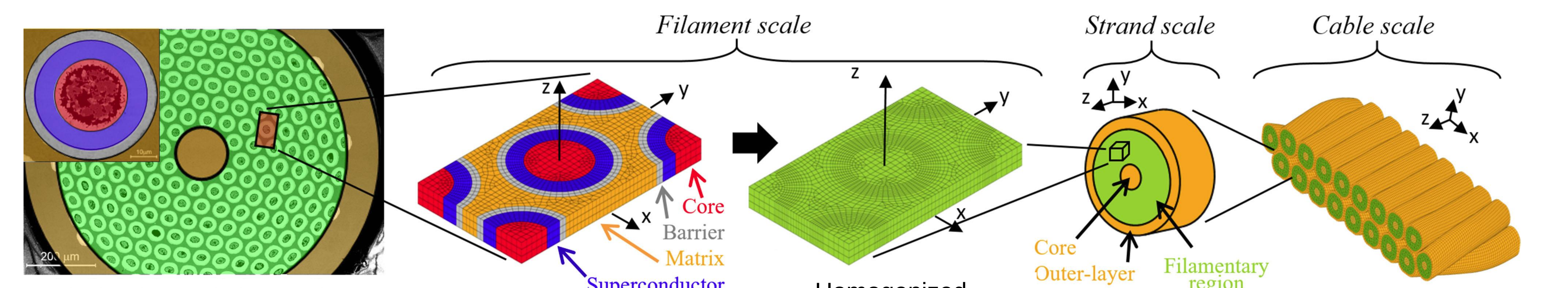
Combination of various 3D cable patterns with inter-strand epoxy and impregnation insulation layers



FEM 3D model of the sample holder **(Cast3m)**

Strain/stress analysis can be performed at the filament scale after projection [2]

Bi-material strand model based on homogenization [2]



Analysis of strand observations and material properties

Geometrical description of the RVE with copper hardening

Homogenized mechanical model (hardening accounted → **isotropic**)

Bi-material strand model

3D bare cable model

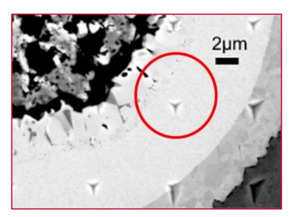
CONCLUSIONS

New features have been added to the CoCaSCOPE approach:

- Generation of the conformal mesh of the **cable impregnation** matrix in 3D
- Introduction of **copper hardening** at the microstructure level, taken into account in the homogenized bi-material strand model
- Automated **script-based post-treatment** of the experimental σ(ε) plots
- First identification of the **microstructure parameters at cryogenic temperature** (77K)

Numerical identification of the microstructure parameters [4]

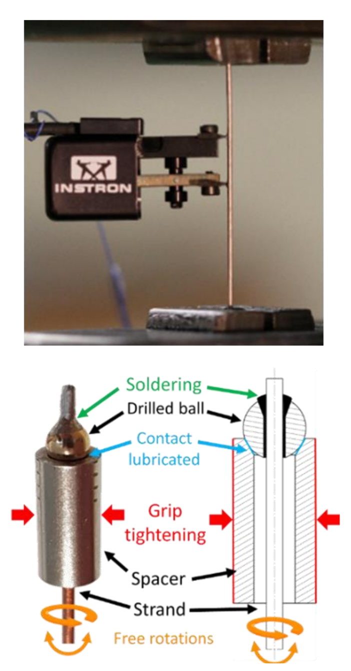
Nanoindentation of strands at room temperature (RT)



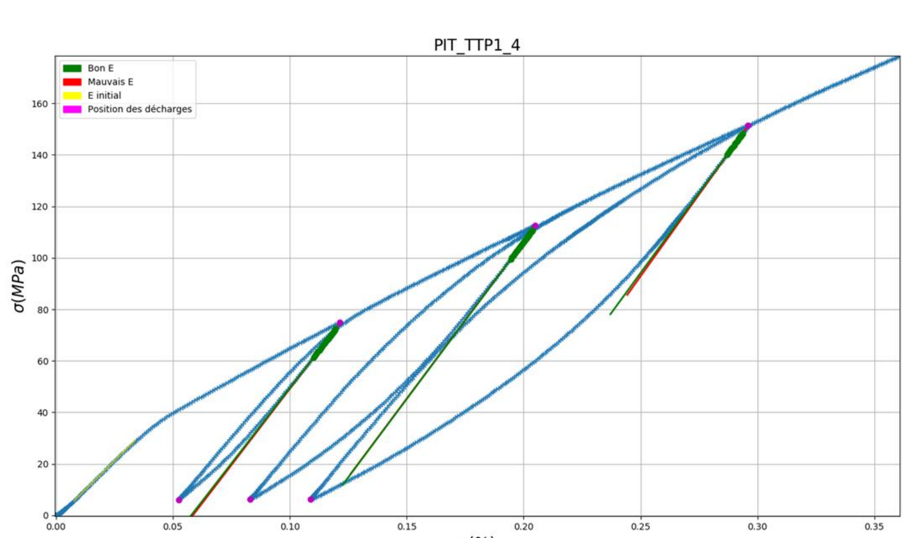
NANO-INDENTATIONS RESULTS AT ROOM TEMPERATURE

COMPONENTS	Number of indents	E^1(GPa)	SD^2(GPa)	H^3(GPa)	SD^2(GPa)
Cu in outer layer	18	133	5	1.25	0.08
Cu in strand core	15	125	4	1.14	0.07
Cu in matrix	92	132	6	1.33	0.13
Nb of barrier	13	125	13	1.69	0.43
Nb_3Sn (SG)	35	171	6	13.1	0.56

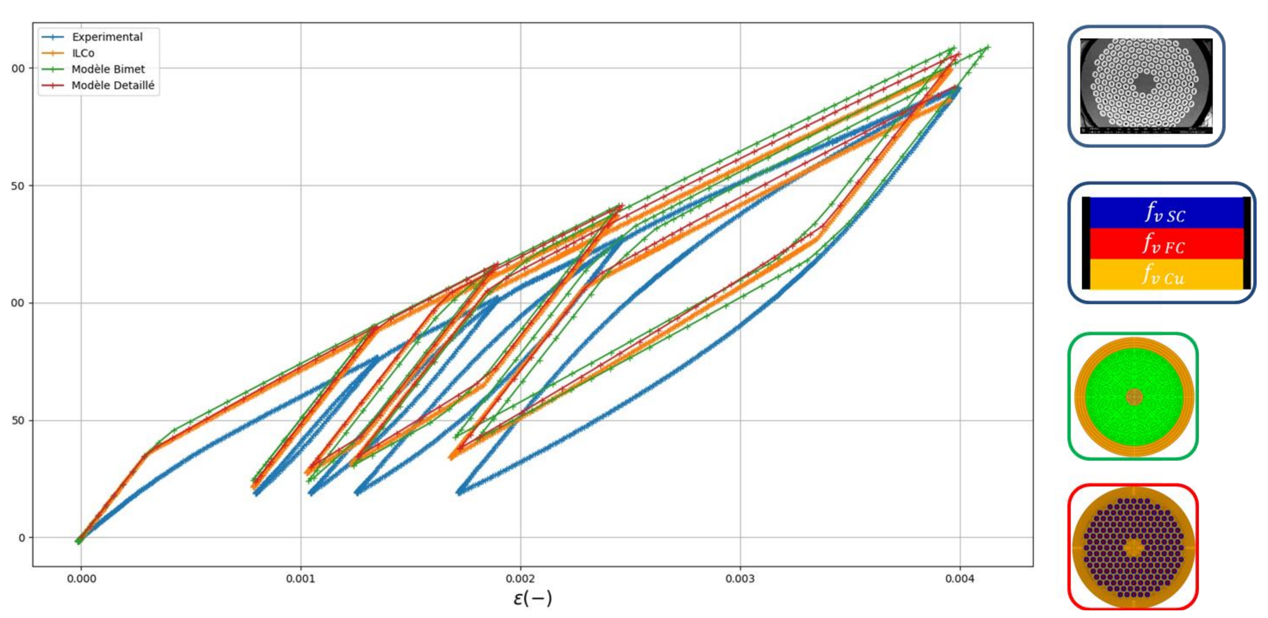
[1] Elastic modulus, [2] Standard Deviation, [3] Nano-hardness



SCUTT setup [5]
for harmless strand characterization at RT/77K



σ(ε) plot of a Φ1mm PIT strand at RT
(loading curve with 3 unloadings)
Scripted post-treatment locates unloadings and evaluates automatically the relevant slopes used for identification



Identification of the microstructure parameters is performed using ILCO routine [4] by iteration on an analytical strand model based on volume fraction.
Identification results are injected in 2 FEM strand models (detailed model / bi-material model) for comparison with experimental plot.

IDENTIFIED PARAMETERS OF THE PIT BI-METALLIC MODEL AT ROOM TEMPERATURE / 77K

COMPONENTS	MODEL	E(GPa)	σ_y(MPa)	C(MPa)	γ
Copper	Chaboche hardening	129/135	39/30	35960/25600	310/64
Barrier	Identical to copper				
Filament Core	Elastic	3/3	-	-	-
SC region (Nb_3Sn SG)	Elastic	171/145	-	-	-

Microstructure parameters (given at RT / 77K for PIT strand) can be used for **predictive simulations**, even for load cases significantly different from the ones used during the identification process.