

# Le tungstène pour les tokamaks : Evolution de sa microstructure sous irradiation

**E. AUTISSIER<sup>a</sup>**

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<sup>e</sup>CEA-DEN-DANS/DMN/SRMP, Saclay, 91191 Gif-sur-Yvette cedex, France

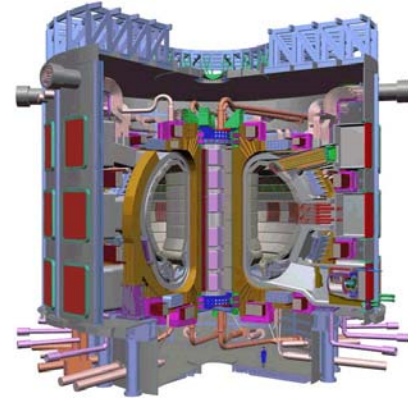


WPMAT



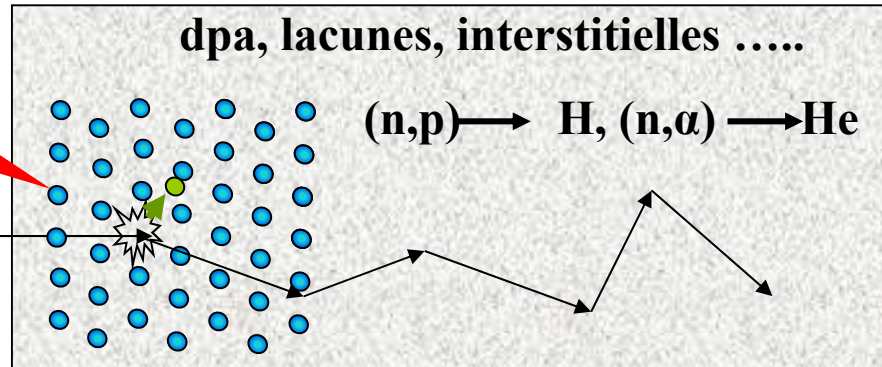
✓ ITER, DEMO : W divertor, première paroi?

ITER Tokamak



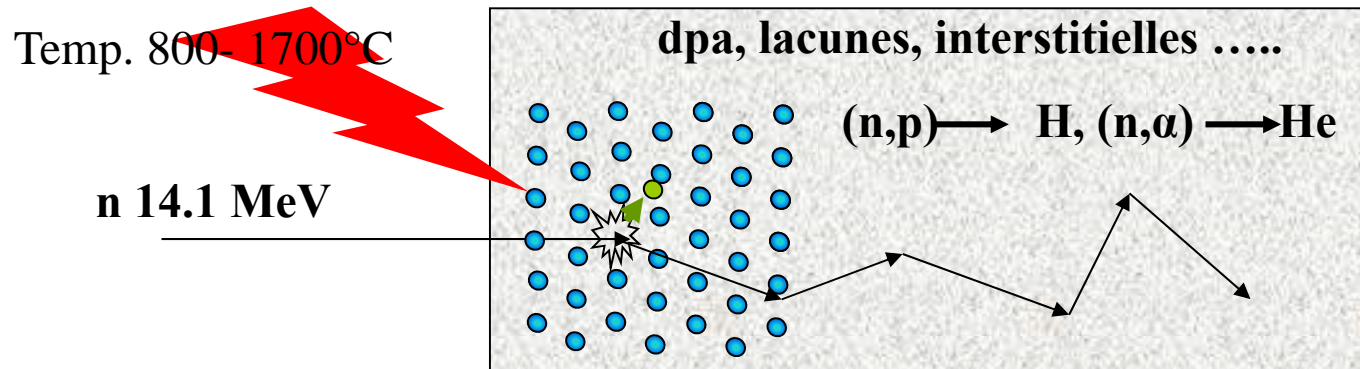
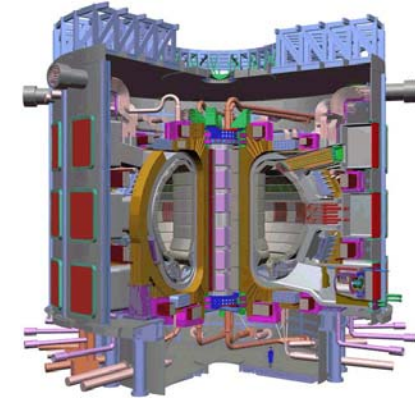
Temp. 800- 1700°C

n 14.1 MeV



✓ ITER, DEMO : W divertor, première paroi?

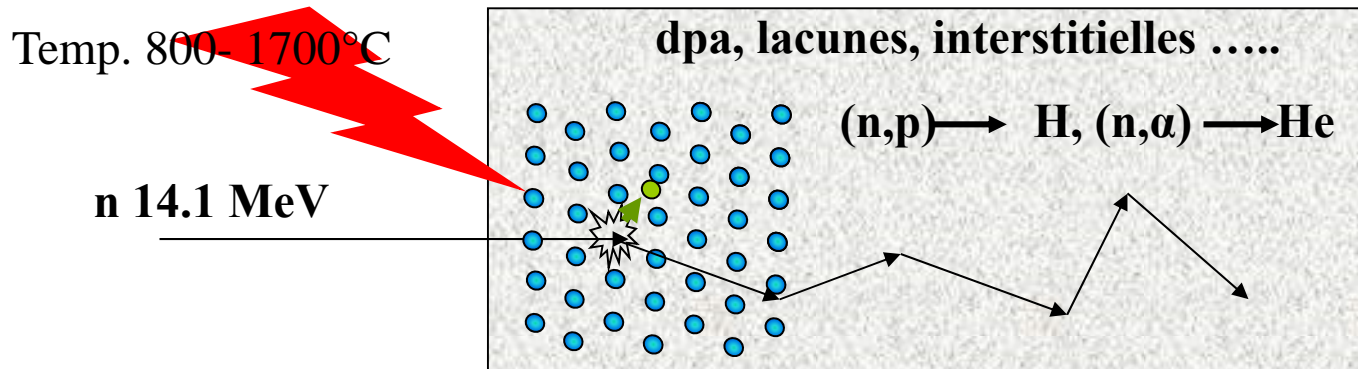
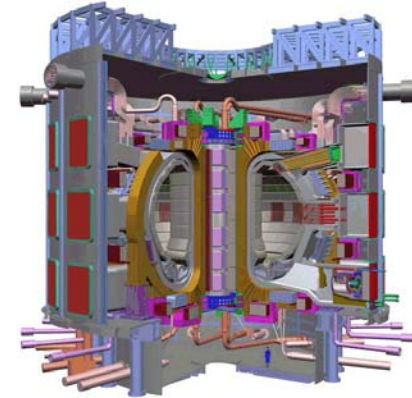
ITER Tokamak



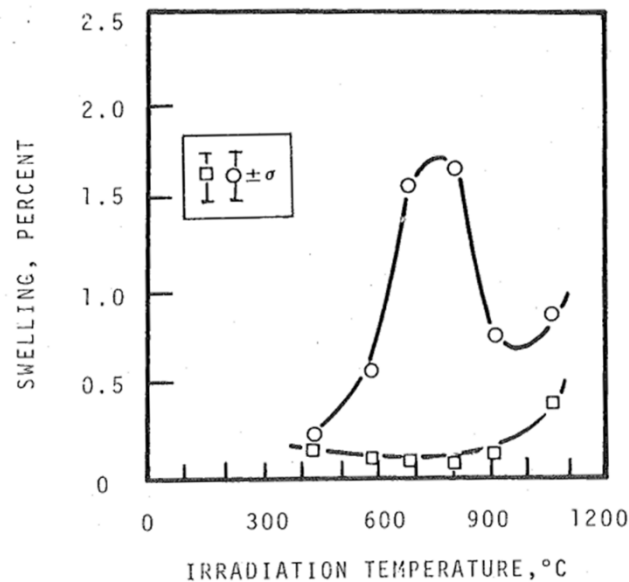
⇒ **Modification de la microstructure et de la composition chimique**  
**Evolution des propriétés thermiques, électriques et mécaniques des matériaux**

✓ ITER, DEMO : W divertor, première paroi?

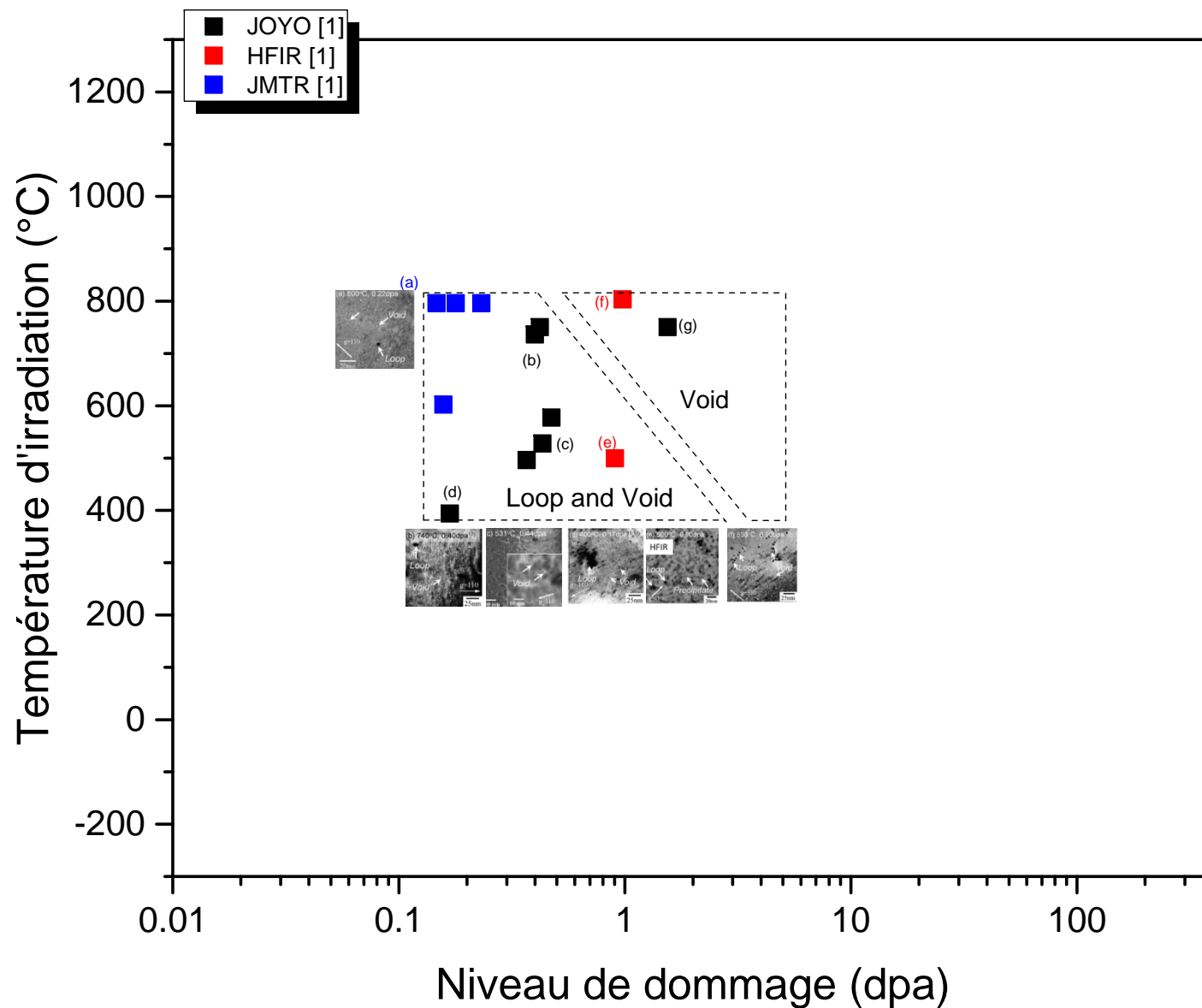
ITER Tokamak



⇒ **Modification de la microstructure et de la composition chimique**  
**Evolution des propriétés thermiques, électriques et mécaniques des matériaux**

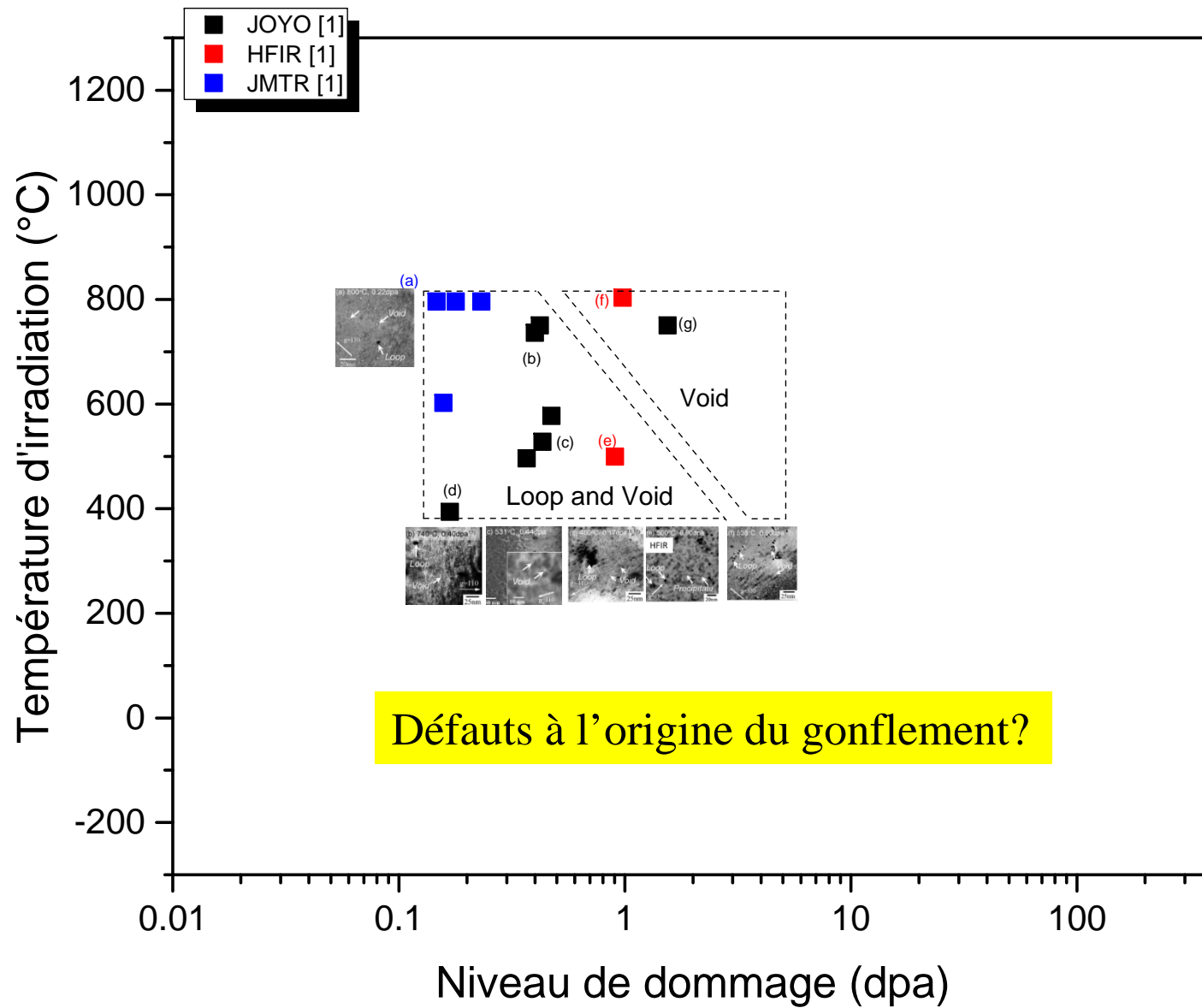


Matolich, et al. (1974). Scripta Metallurgica 8(7): 837-841.



[1] A. Hasegawa et al. / Fusion Engineering and Design 89 (2014) 1568–157  
 [2] A. Barabash et al. / Journal of Nuclear Materials 283–287, (2000) 138-146  
 [3] M. R. Gilbert et al / (2013).Journal of Nuclear Materials 442, (2013) S755-S760



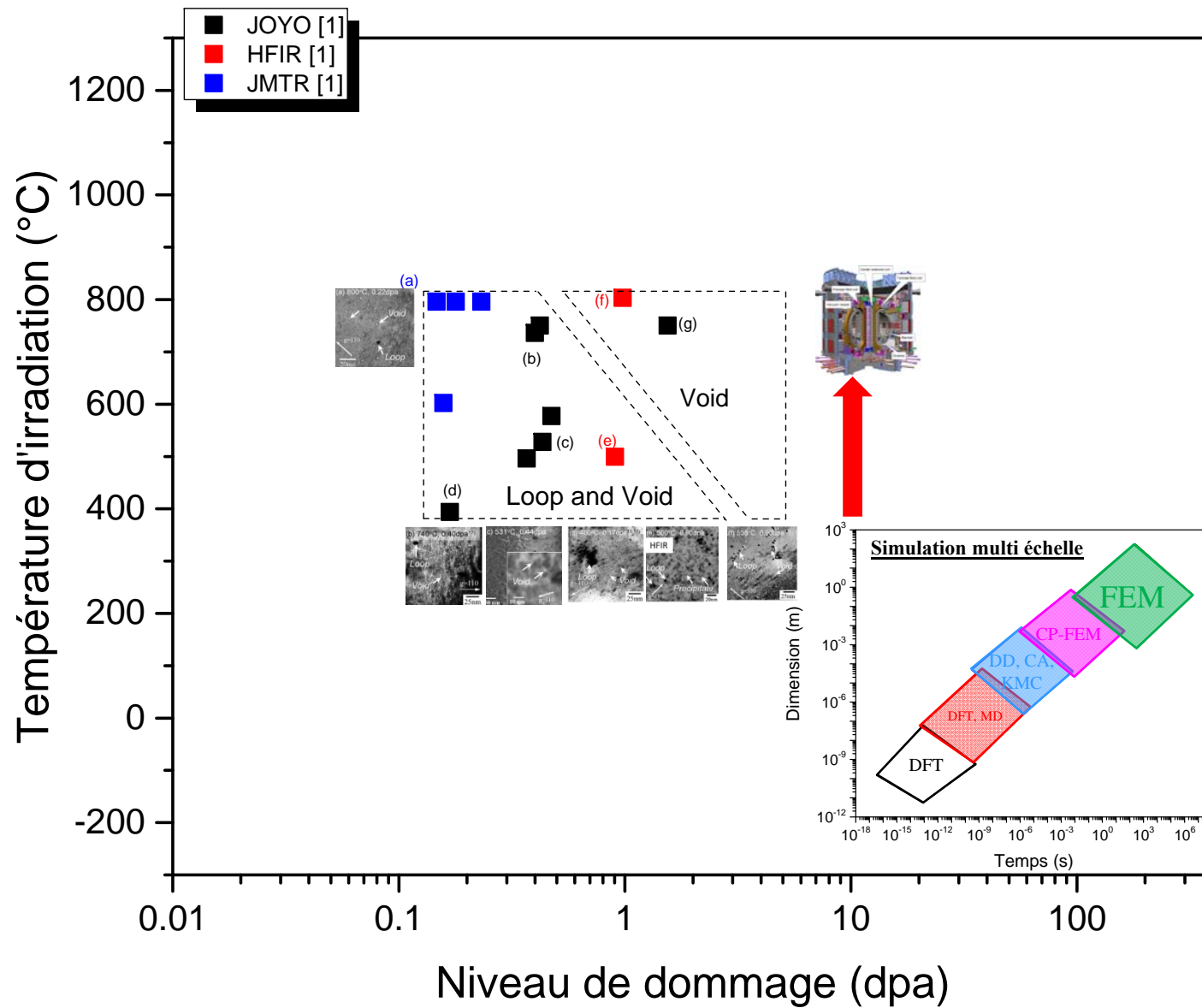


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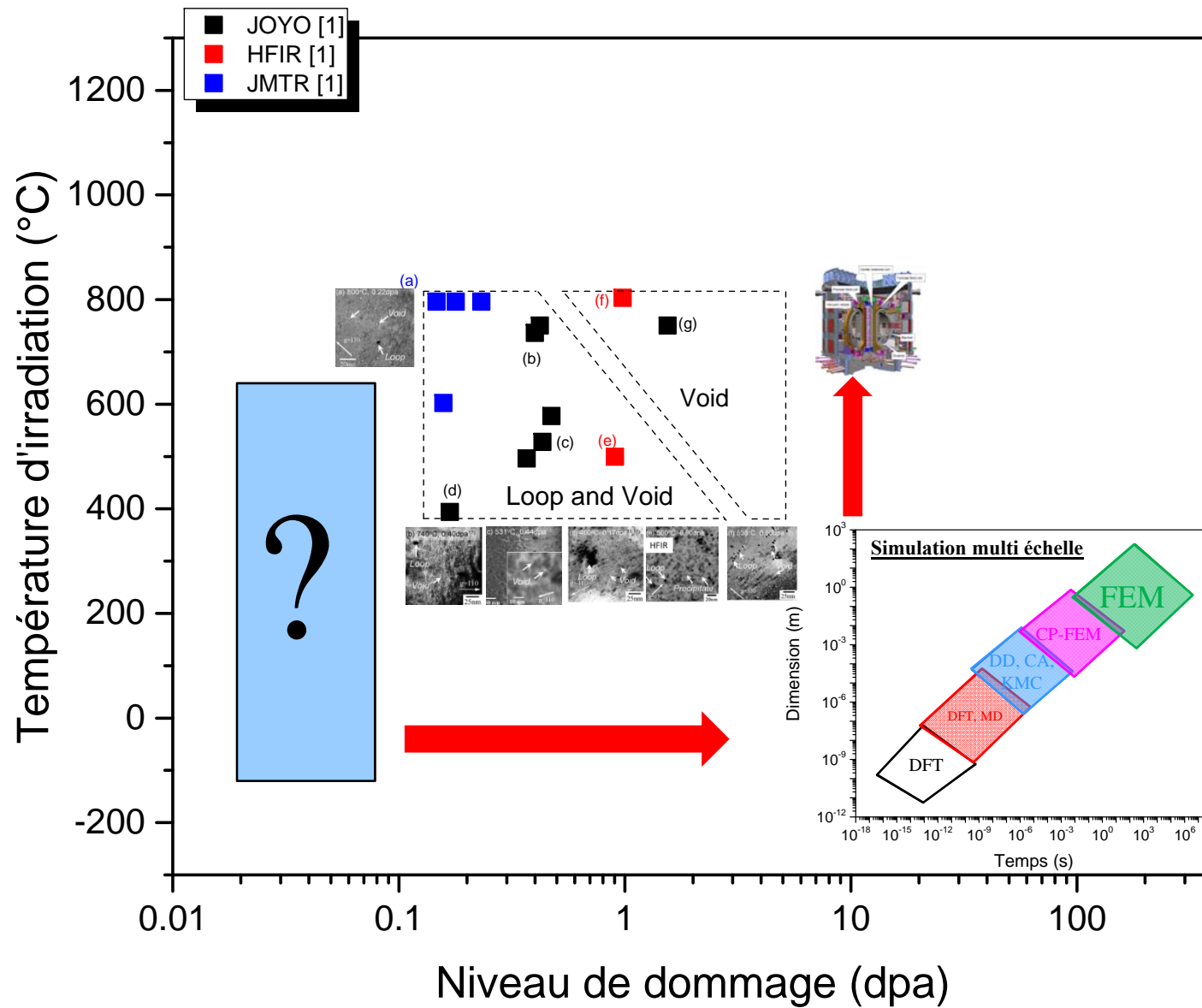
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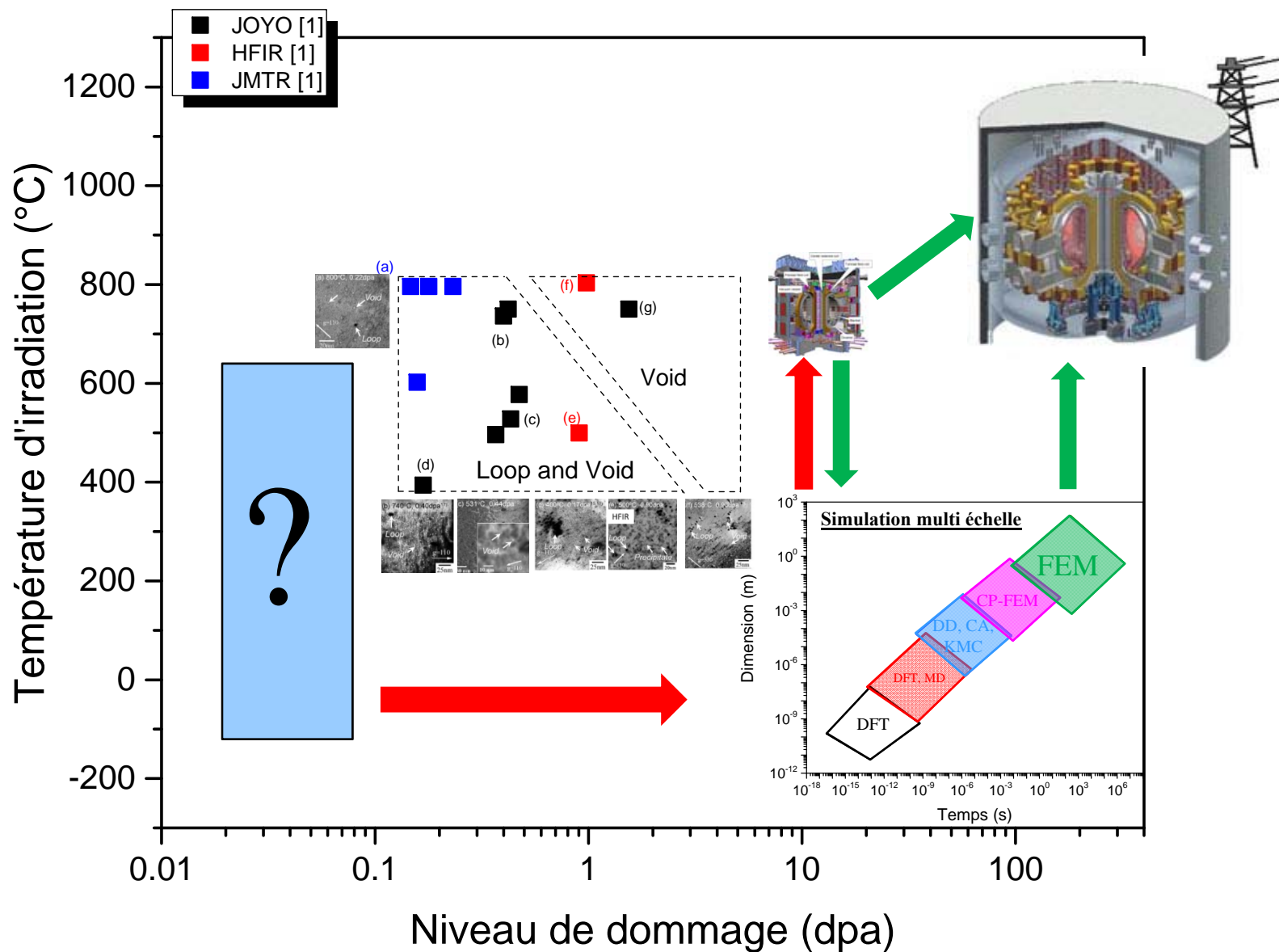




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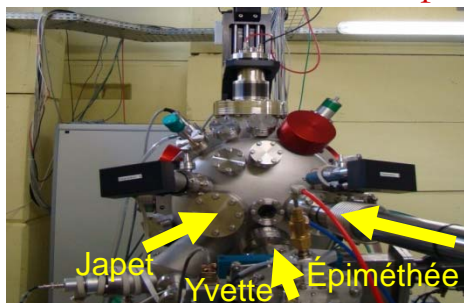
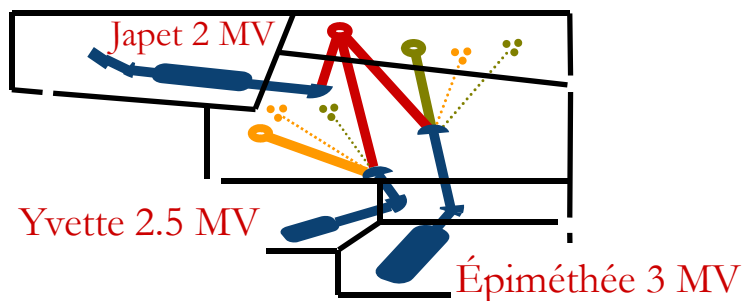






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Saclay

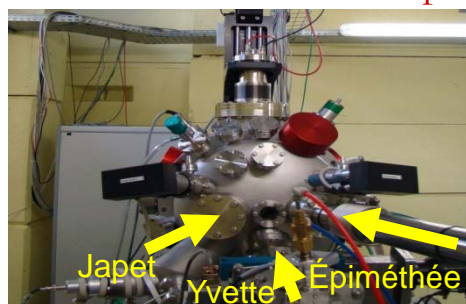
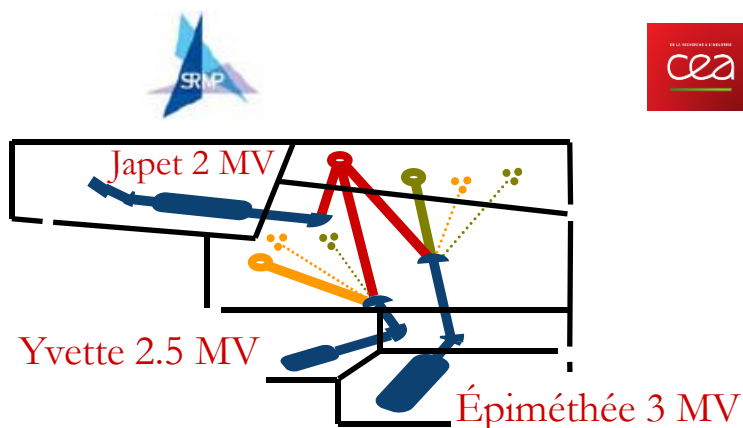


Expériences réalisées à JANNUS (Joint Accelerators for Nanoscience and Nuclear Simulation), France

Irradiation **W 20 MeV** dans un massif :  
caractérisations post-mortem

PAS, MET

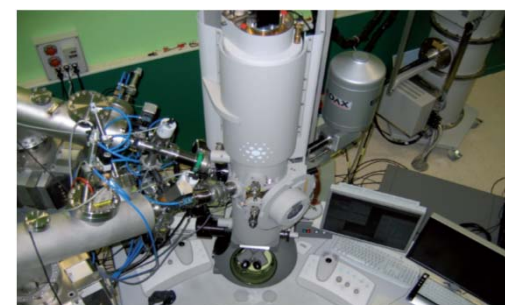
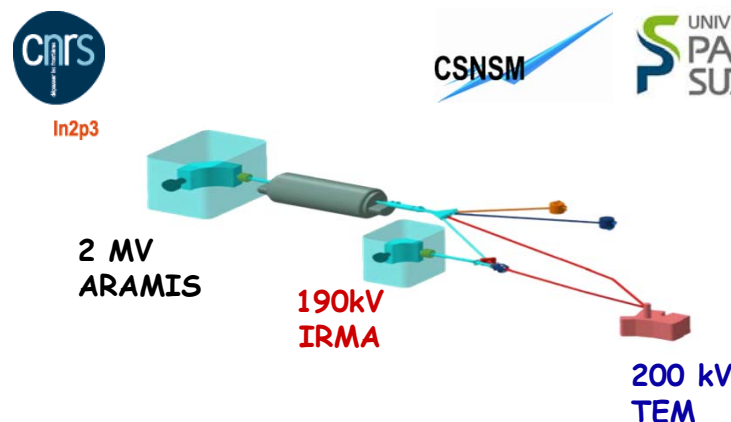




Saclay



Orsay



Expériences réalisées à JANNUS (Joint Accelerators for Nanoscience and Nuclear Simulation), France

Irradiation **W 20 MeV** dans un massif :  
caractérisations post-mortem

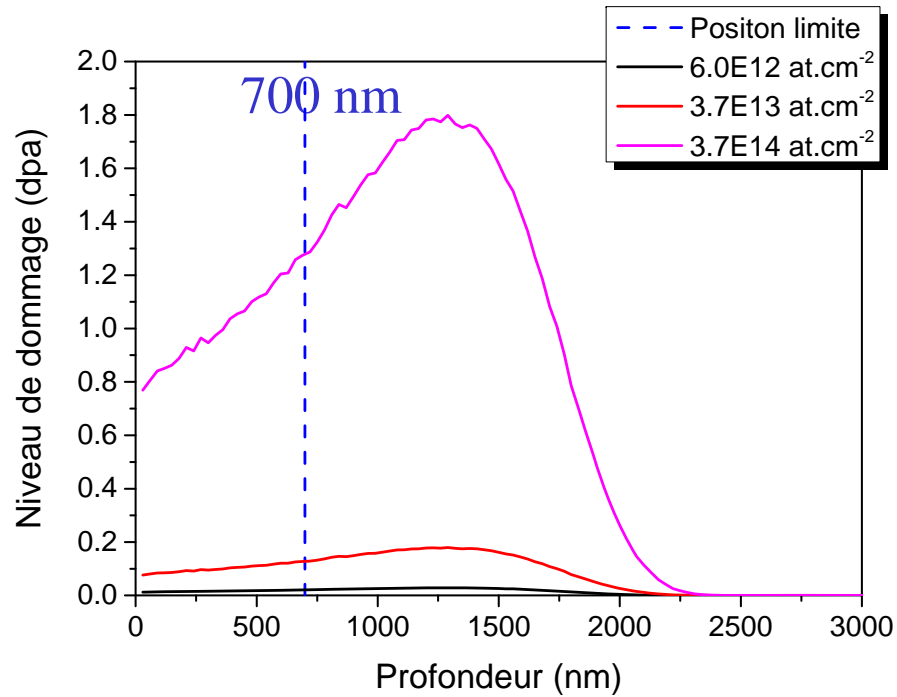
PAS, MET

Irradiation **W 1.2 MeV** dans couche mince: Caractérisations in situ et post-mortem

**MET**

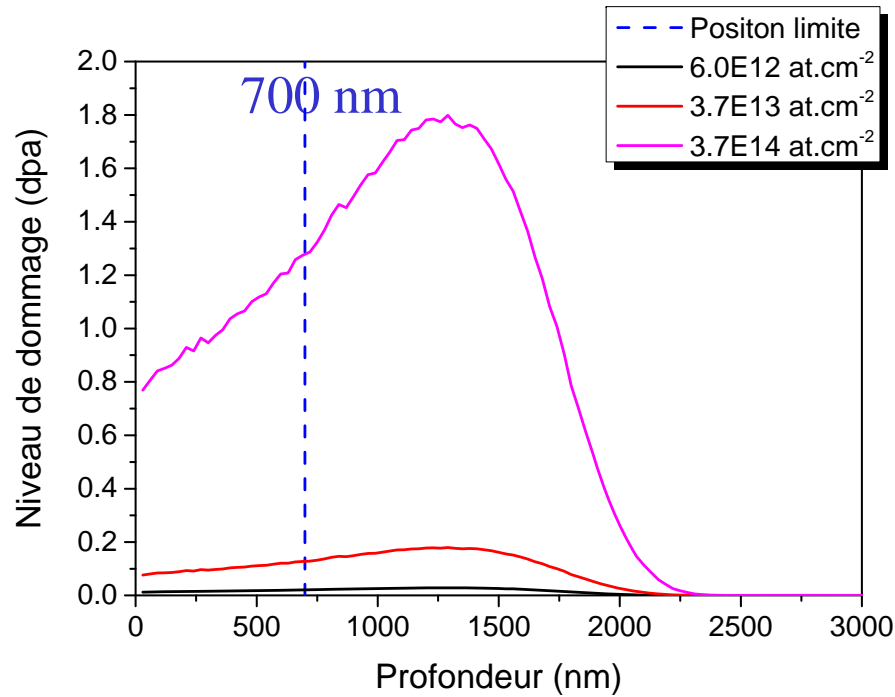


## Irradiation W 20 MeV dans un massif : caractérisations post-mortem



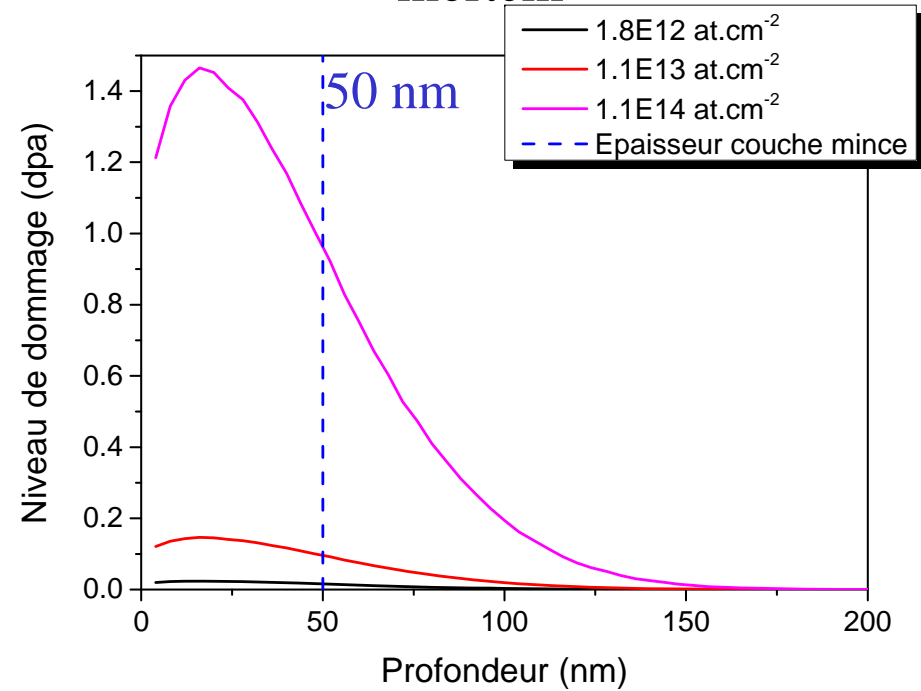
Fluence (at.cm <sup>-2</sup> )	Dpa*	Température (°C)
6.0x10 <sup>12</sup>	0.015	20→500
3.7x10 <sup>13</sup>	0.1	-185→500
3.7x10 <sup>14</sup>	1	-185→500

## Irradiation W 20 MeV dans un massif : caractérisations post-mortem

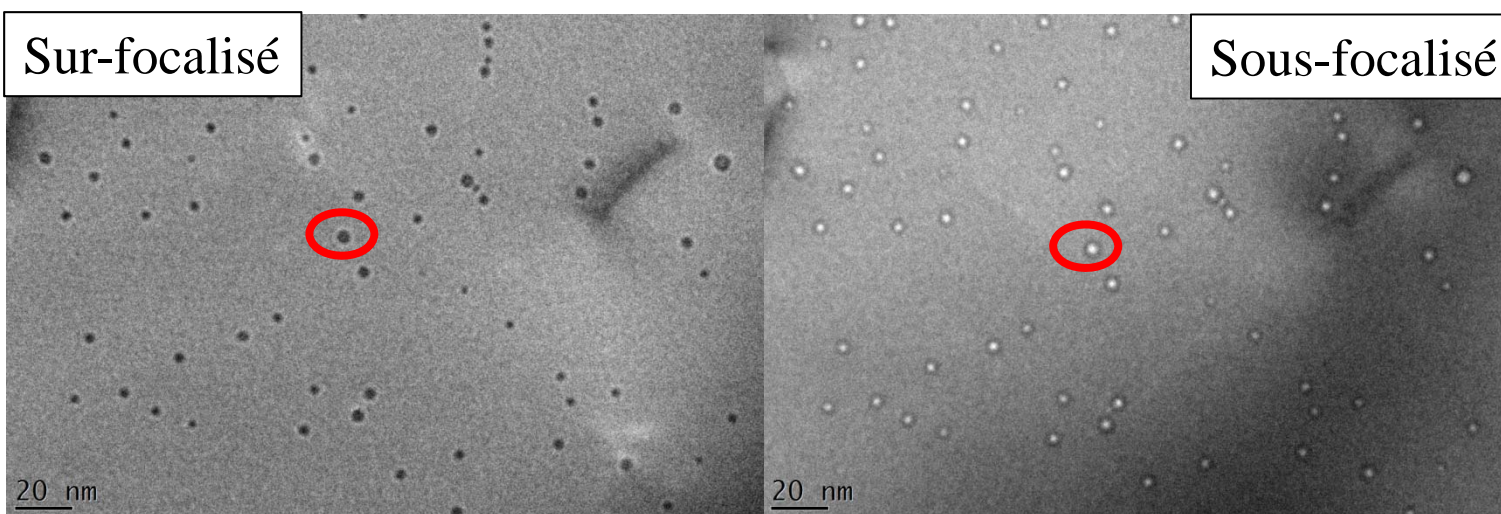


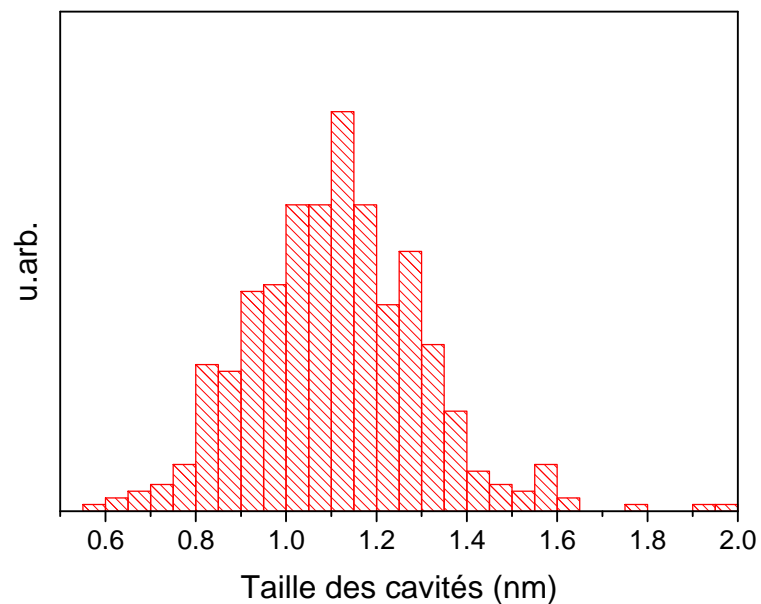
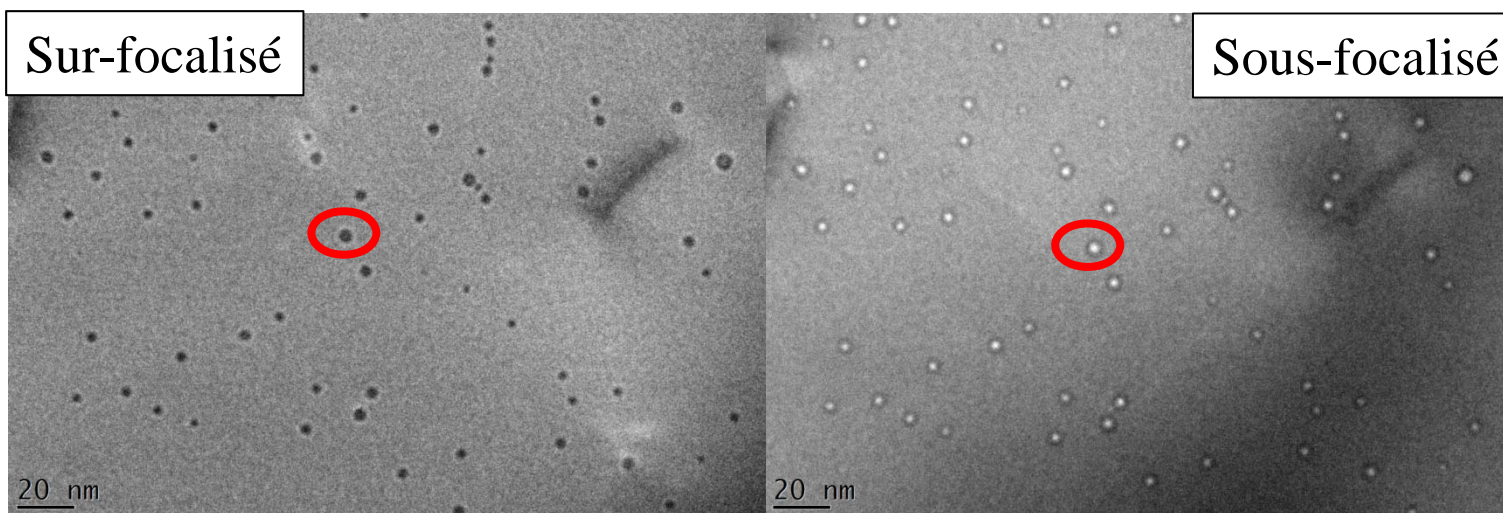
Fluence (at.cm <sup>-2</sup> )	Dpa*	Température (°C)
6.0x10 <sup>12</sup>	0.015	20→500
3.7x10 <sup>13</sup>	0.1	-185→500
3.7x10 <sup>14</sup>	1	-185→500

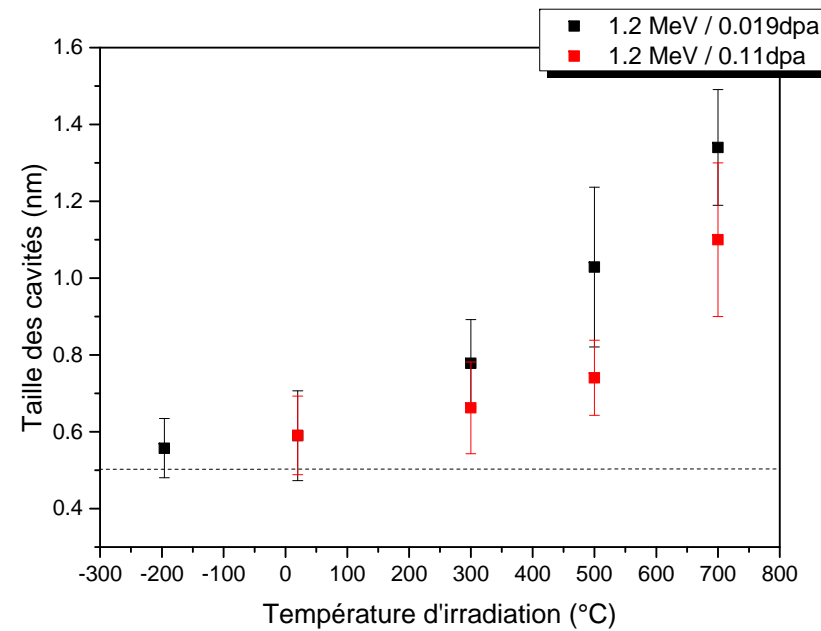
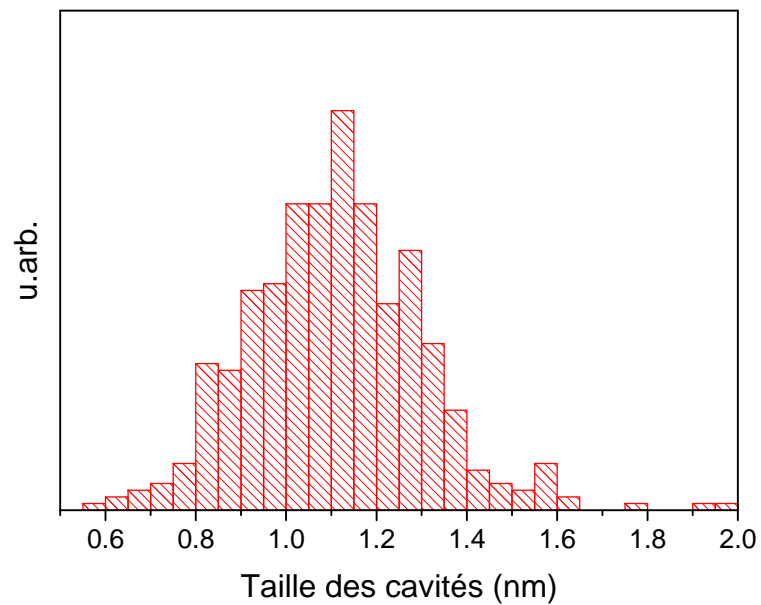
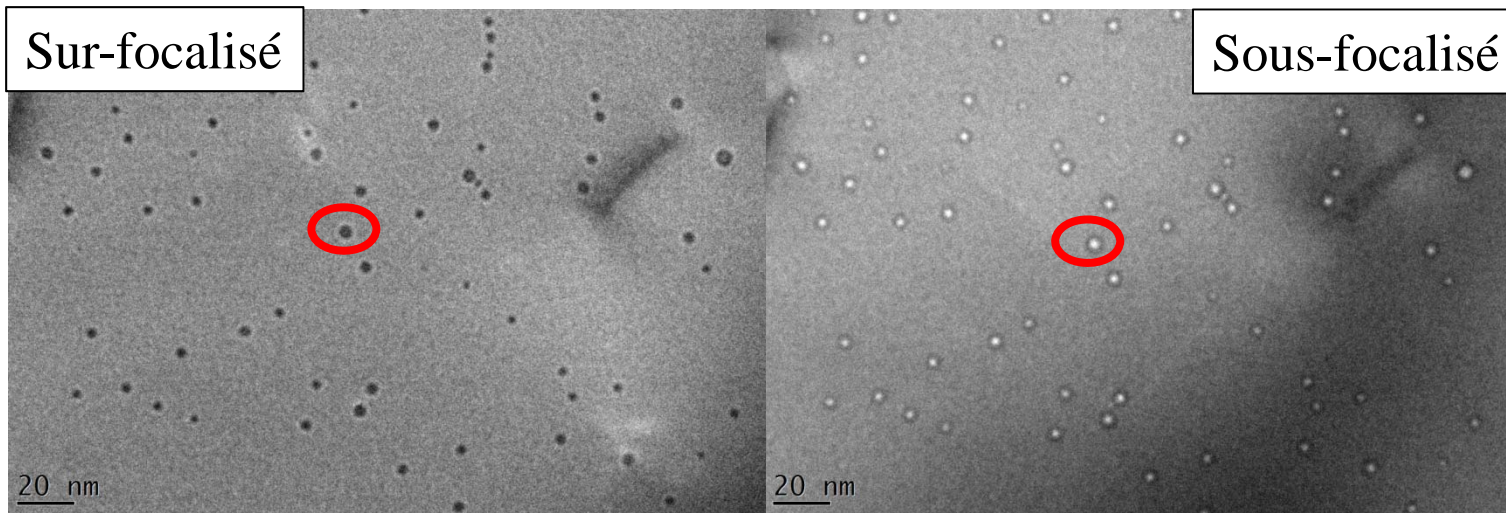
## Irradiation W 1.2 MeV dans couche mince: Caractérisations in situ et post-mortem



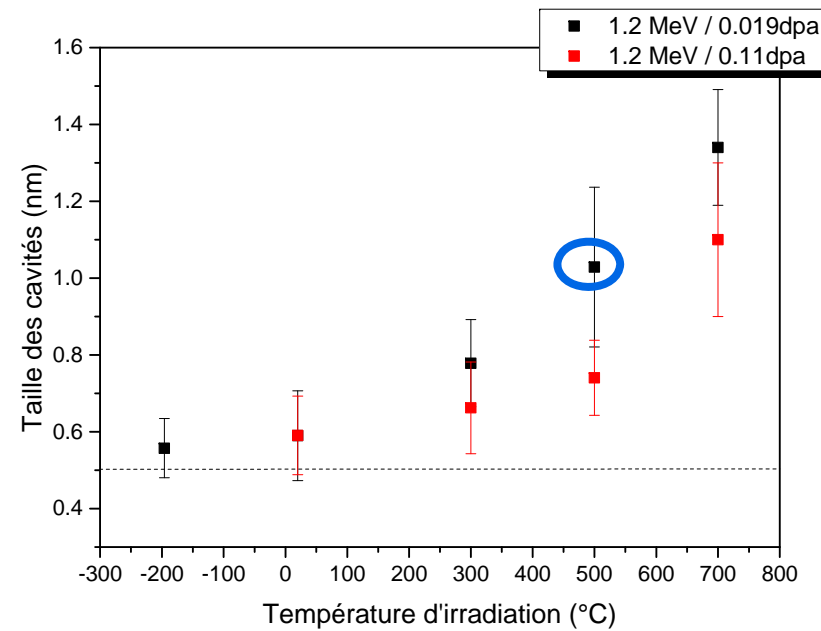
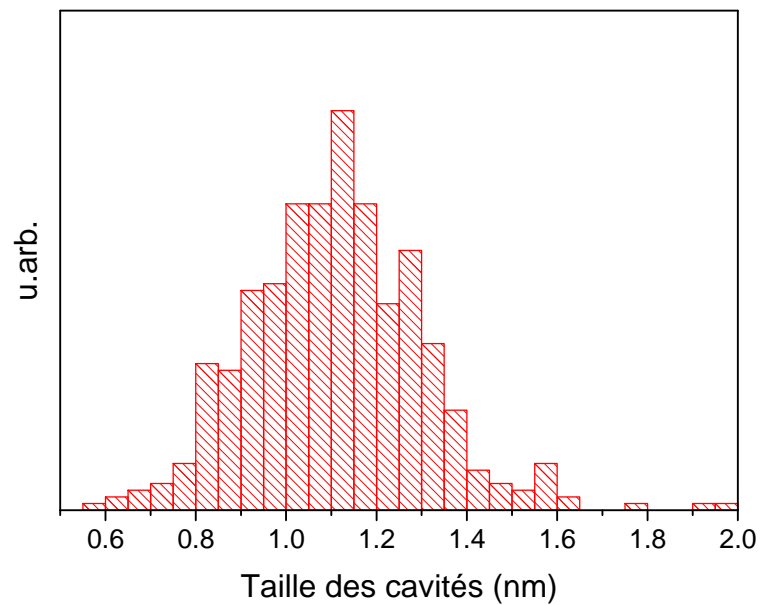
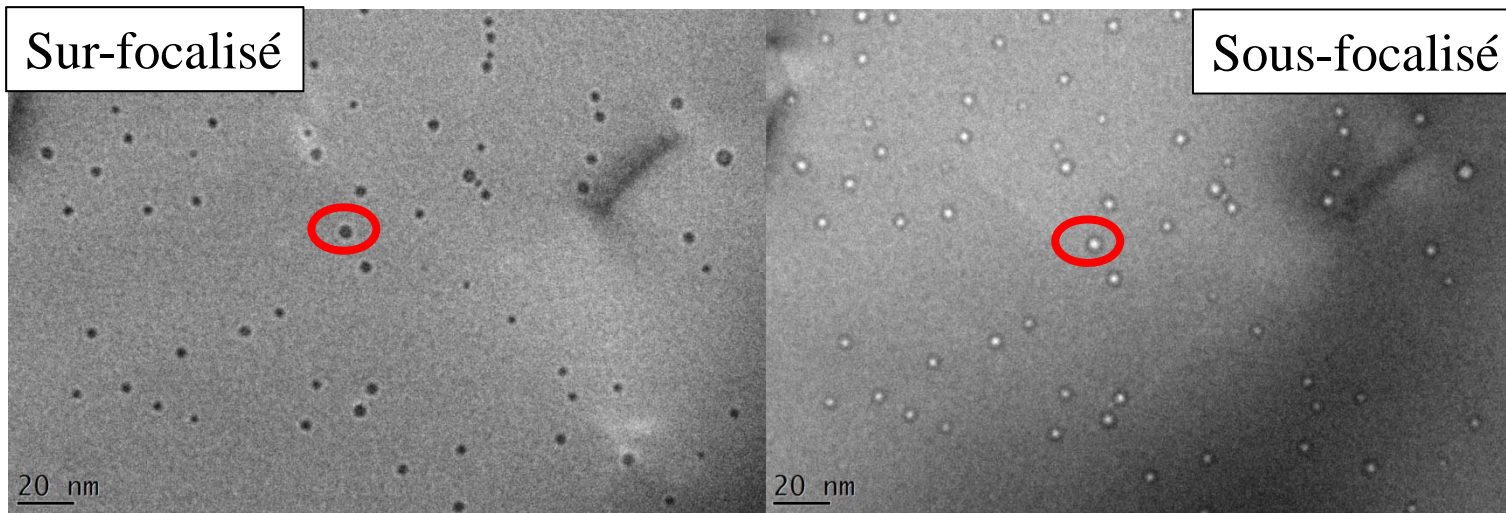
Fluence (at.cm <sup>-2</sup> )	Dpa*	Température (°C)
1.8x10 <sup>12</sup>	0.019	-185→700
1.06x10 <sup>13</sup>	0.11	20→700
1.06x10 <sup>14</sup>	1.1	-

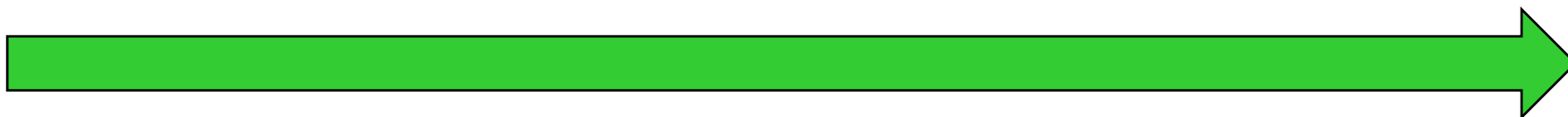
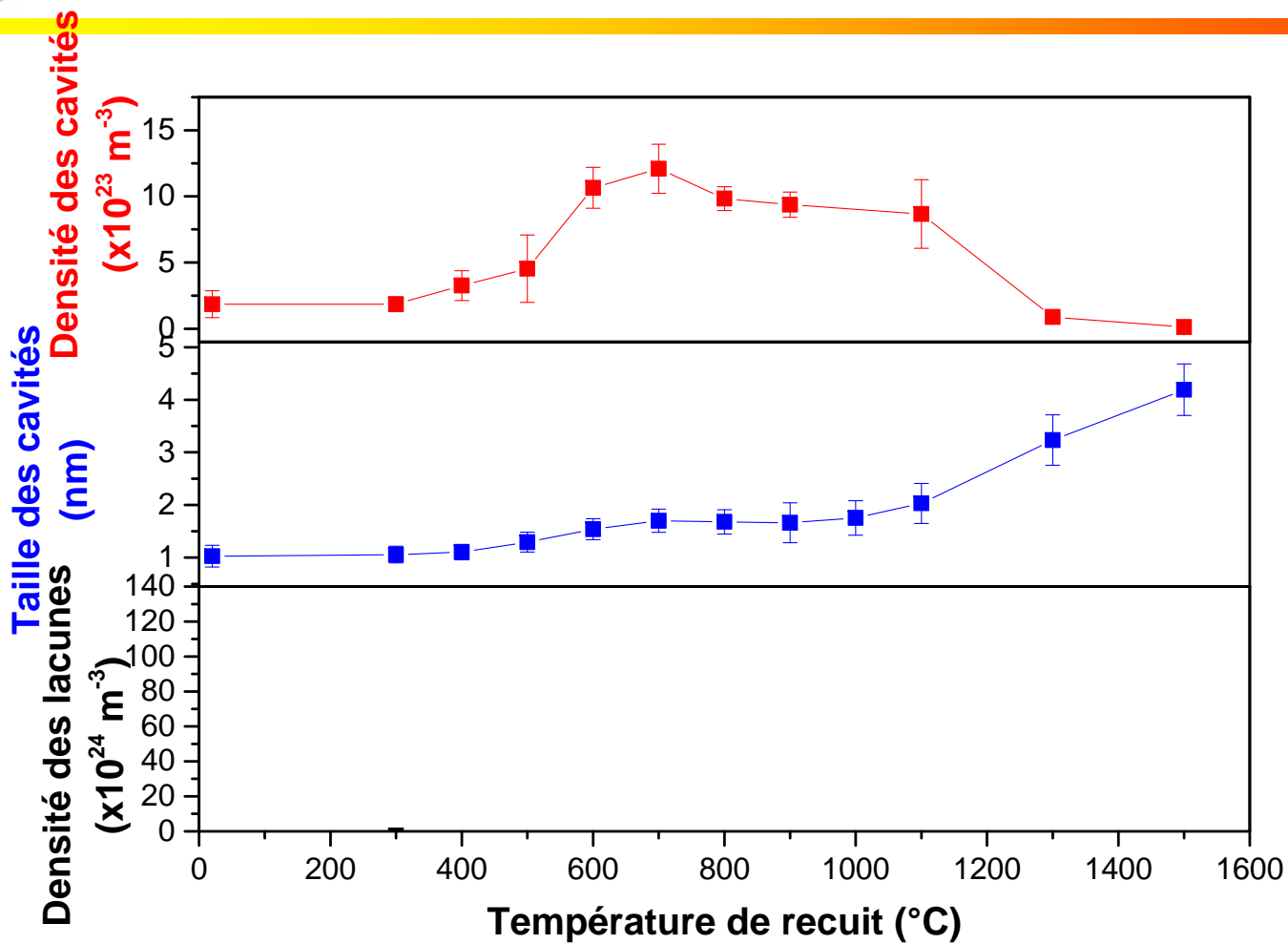


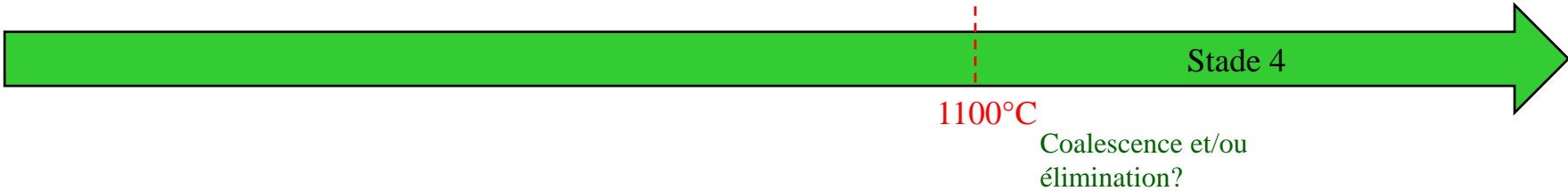
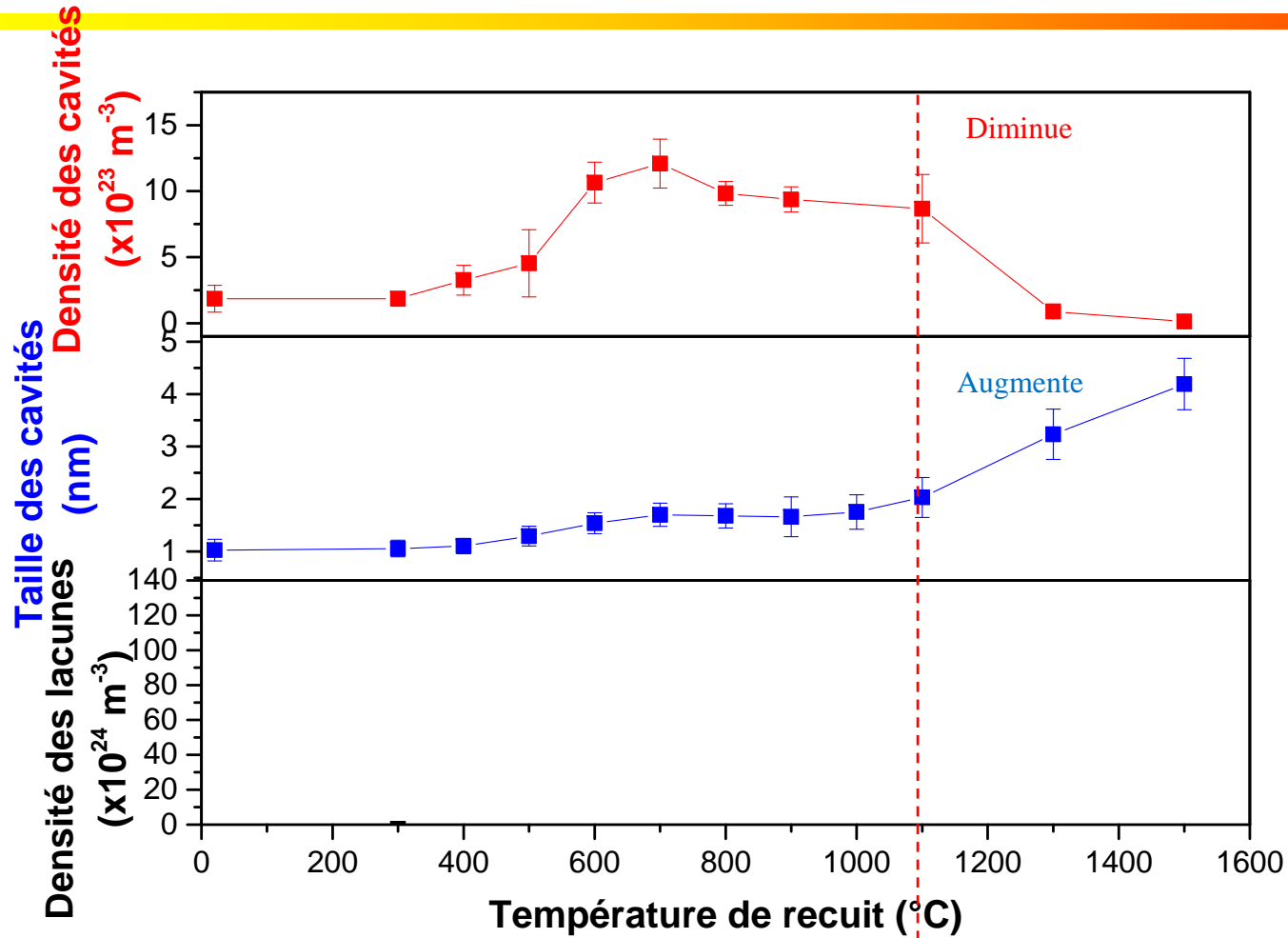


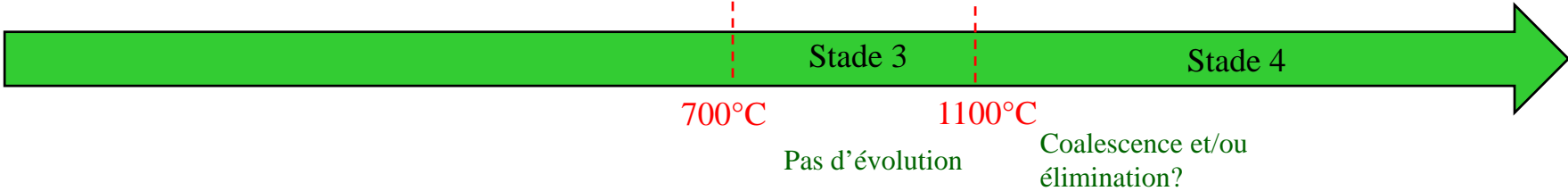
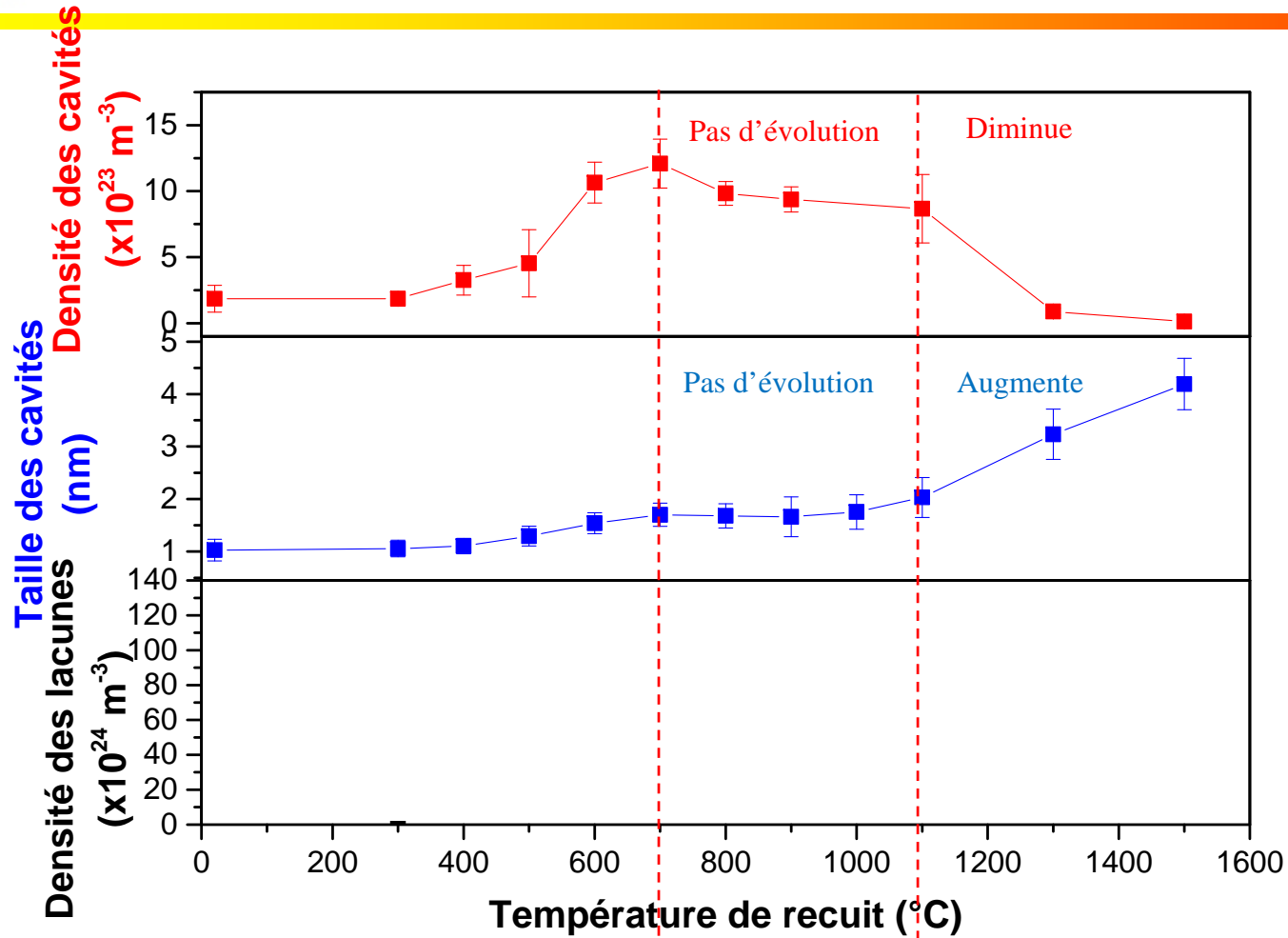


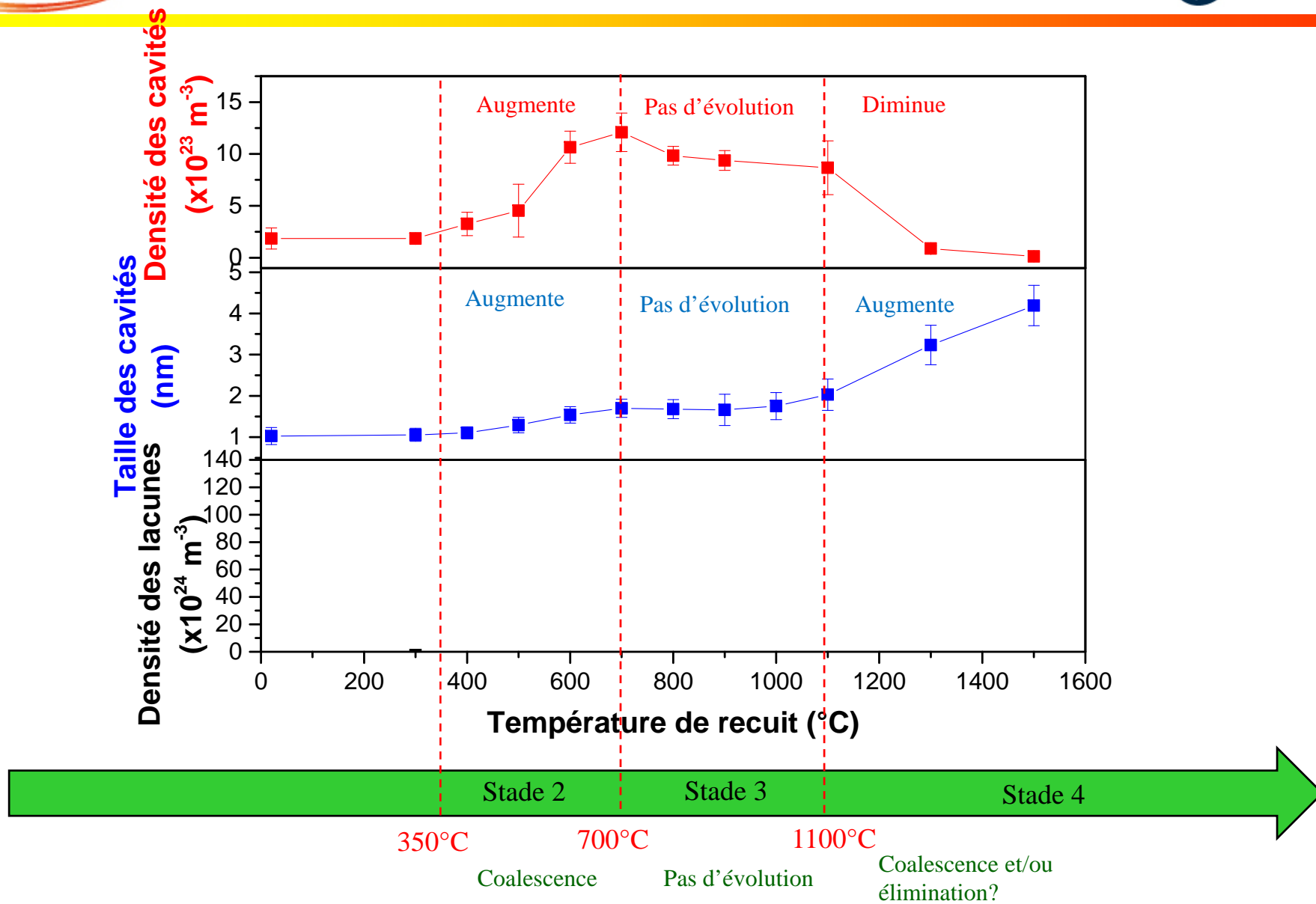


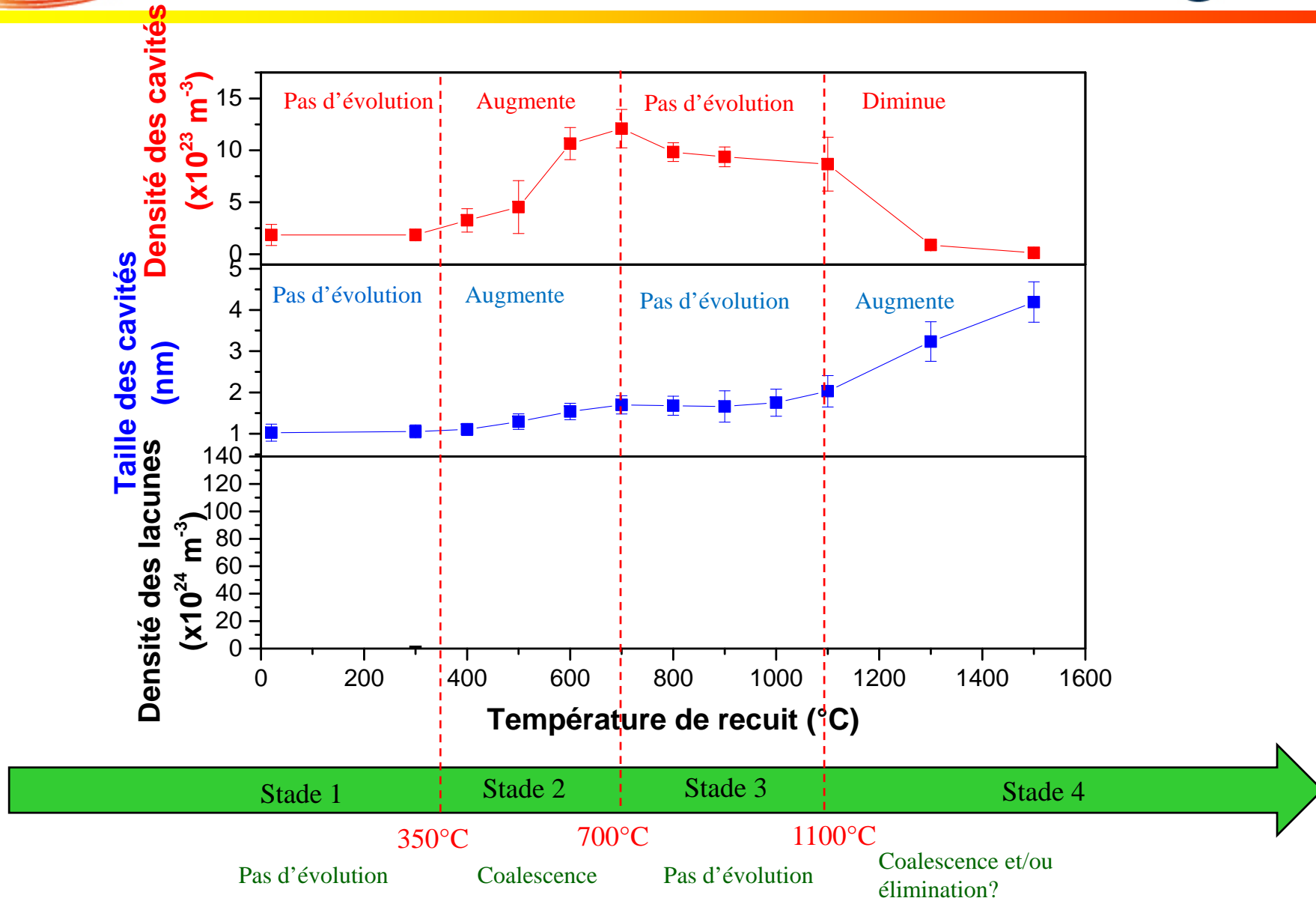


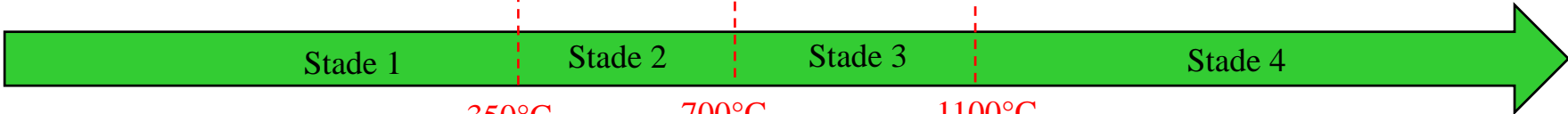
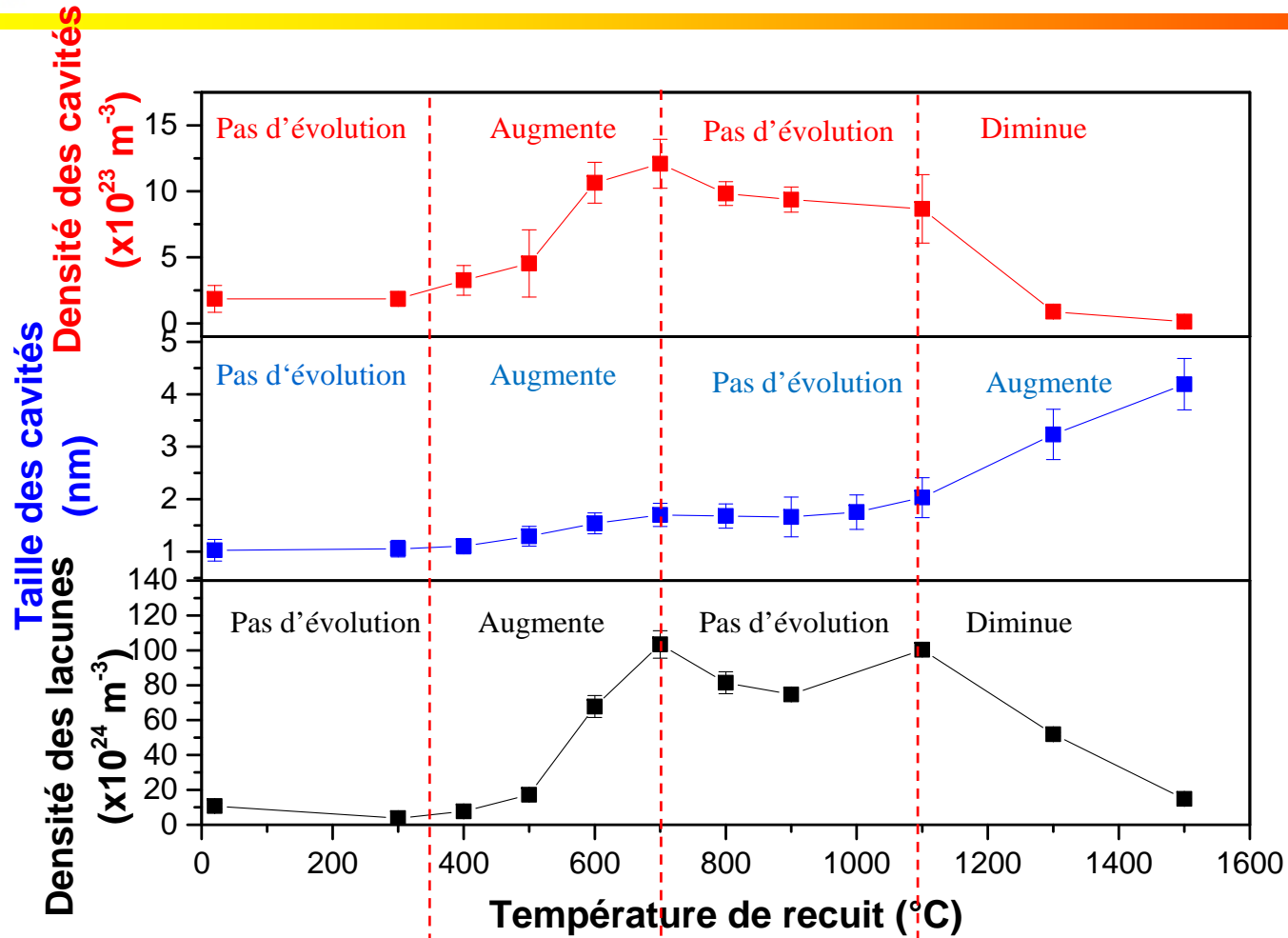






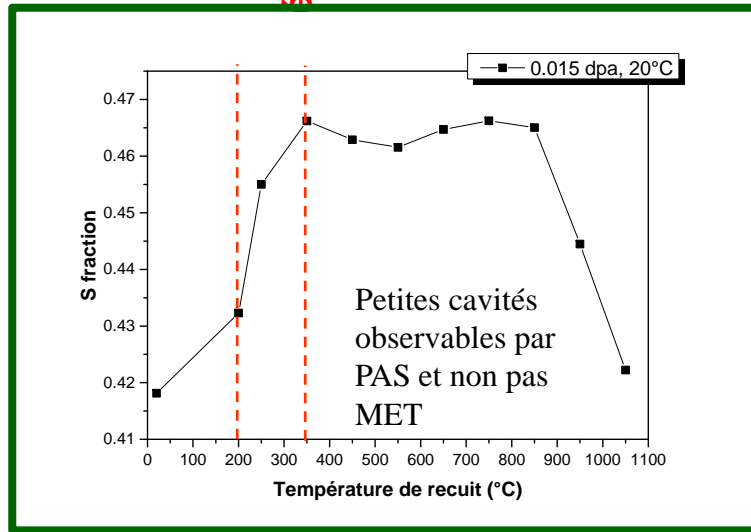




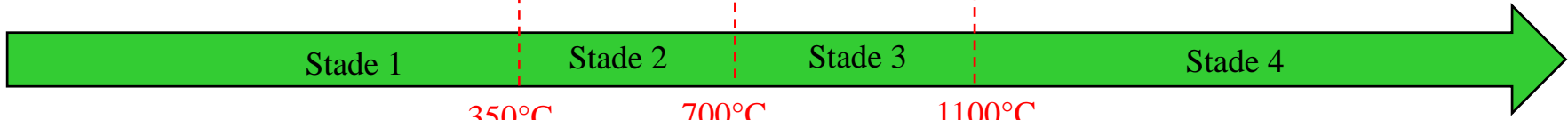
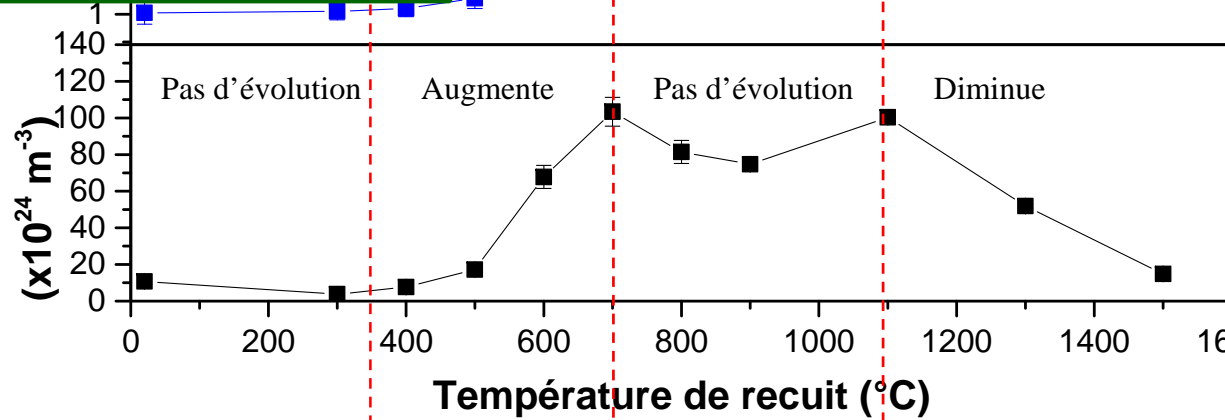
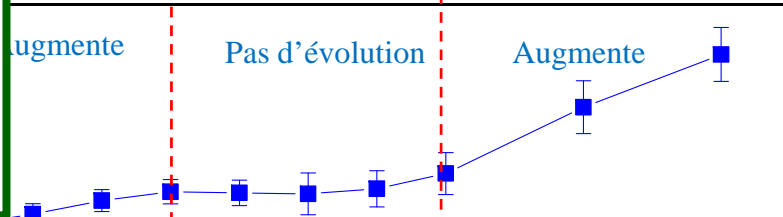
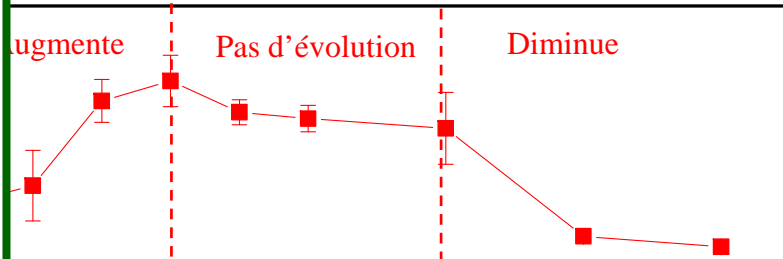


Pas d'évolution      Coalescence de petits défauts non visibles par MET      Pas d'évolution      Coalescence et élimination





Taille  
Densité des lacunes  
( $\times 10^{24} \text{ m}^{-3}$ )

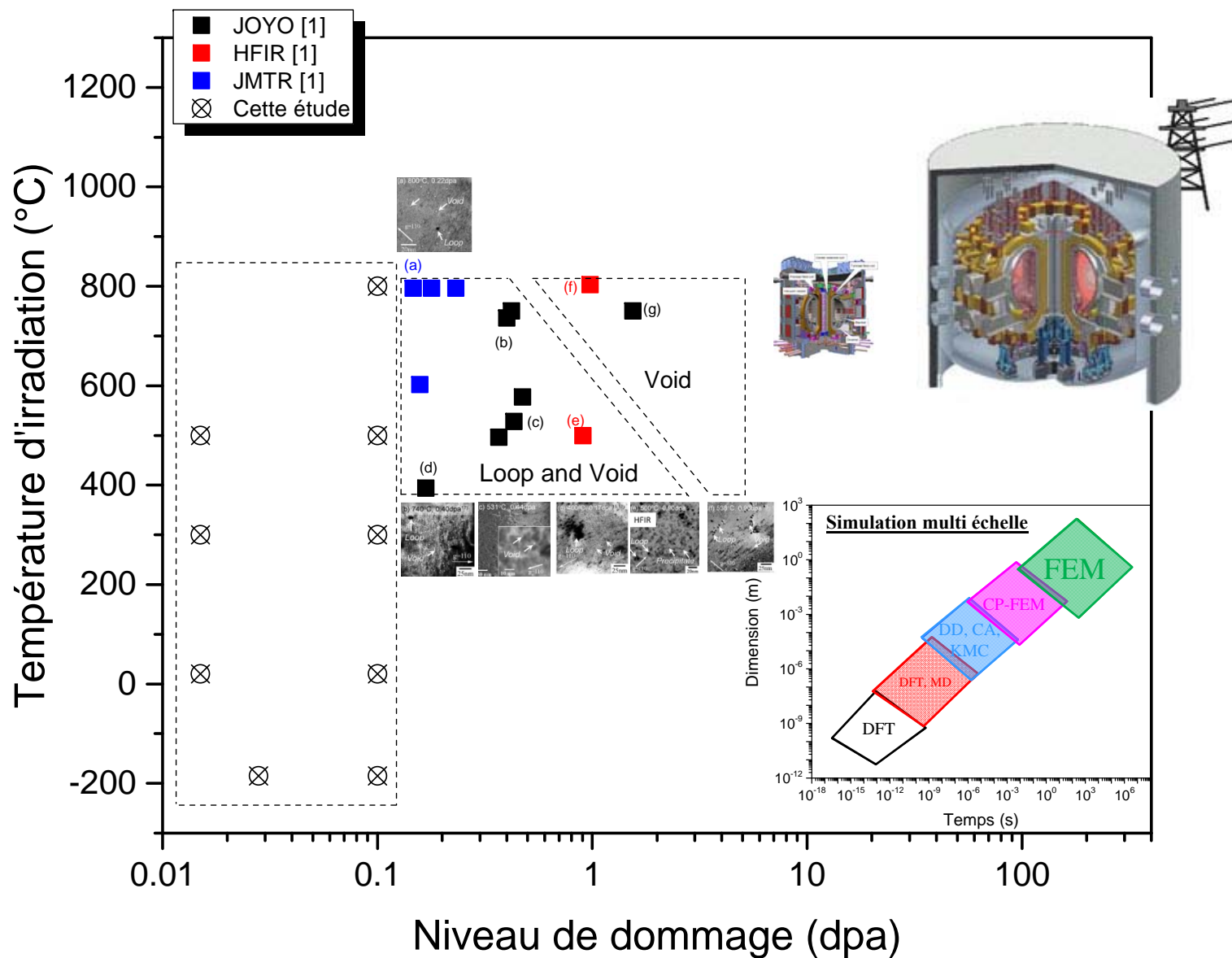


350°C
700°C
1100°C

Pas d'évolution
Coalescence de petits défauts non visibles par MET
Pas d'évolution
Coalescence et élimination

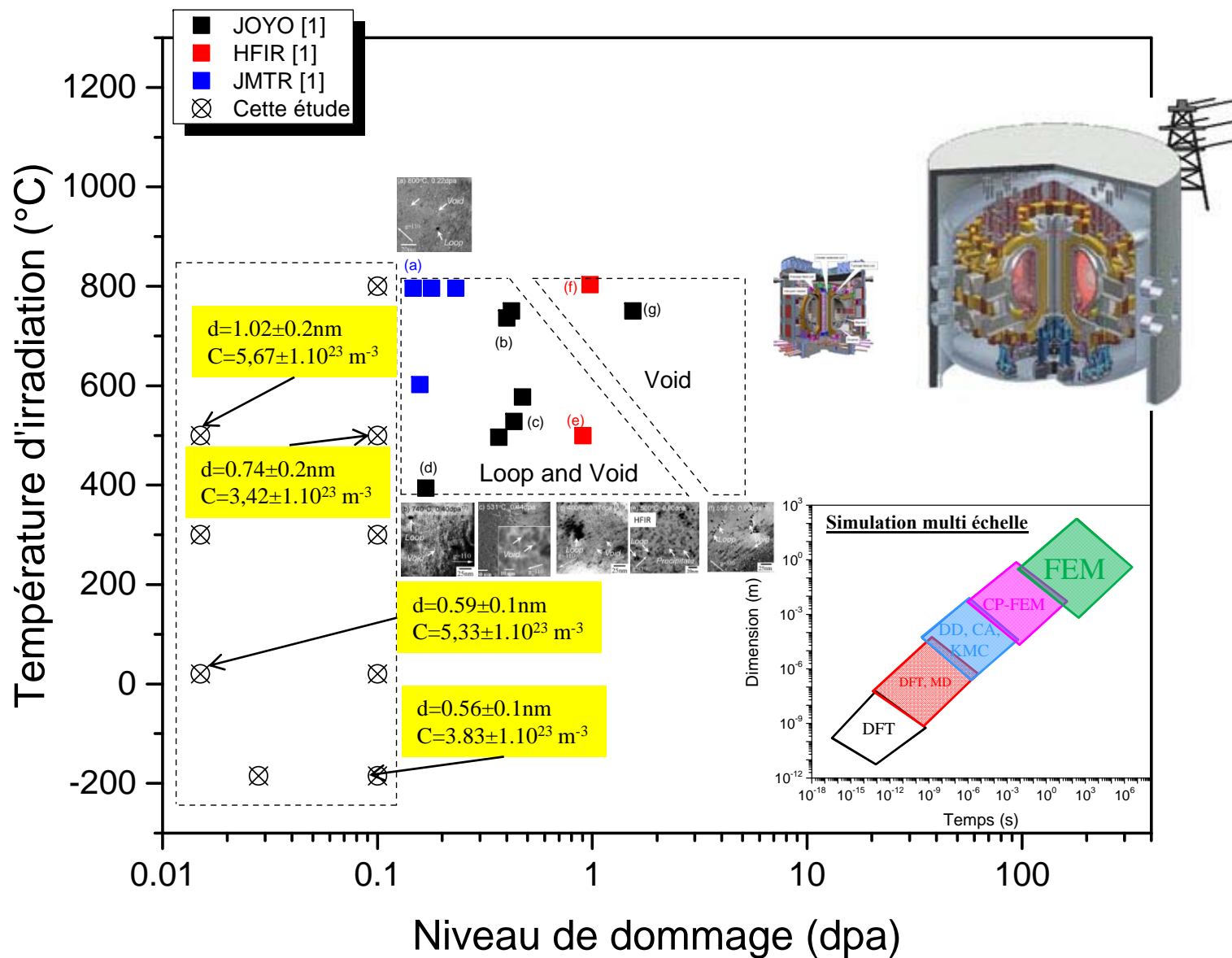






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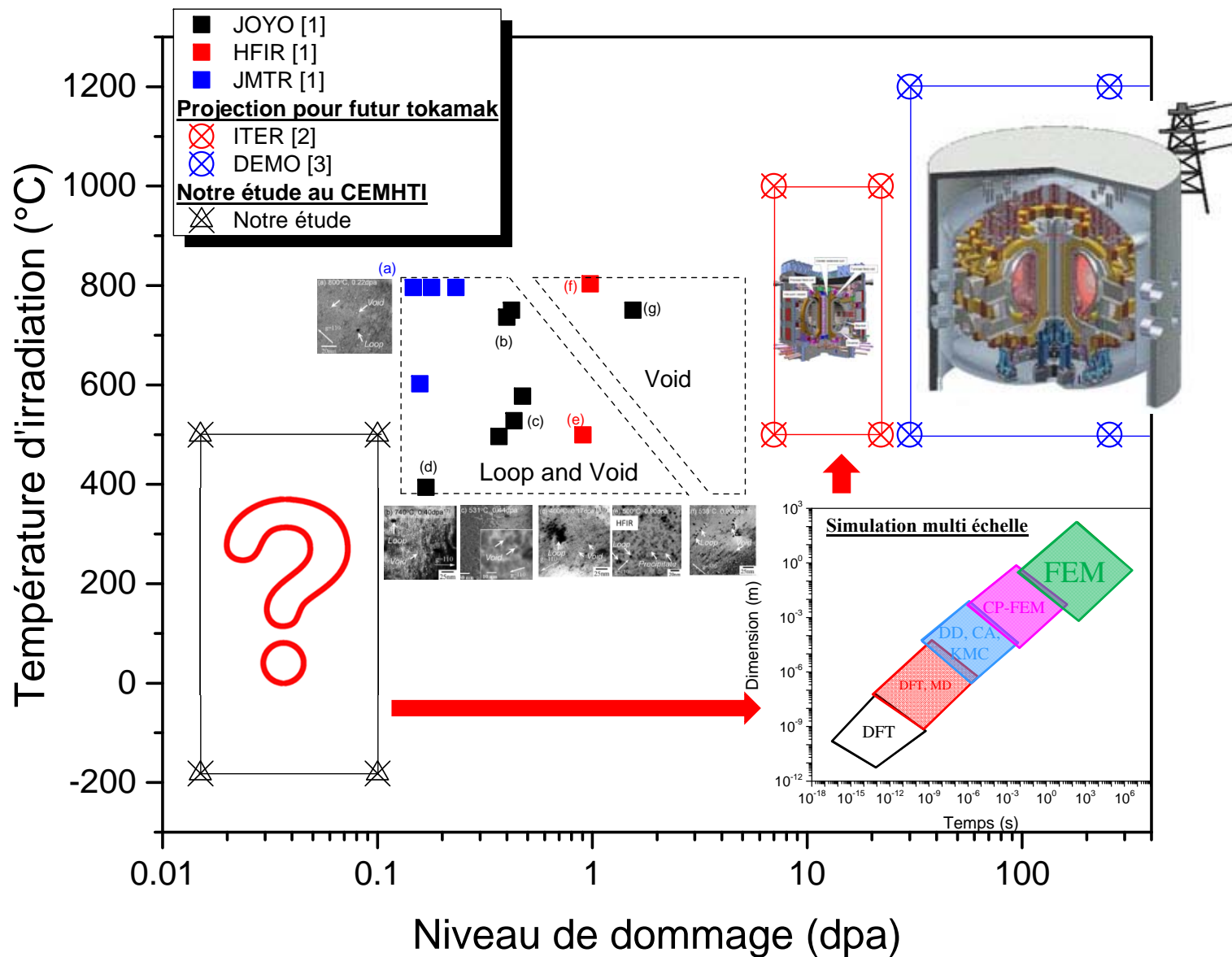


- Les cavités sont détectées à faible dpa par PAS et MET
- Lorsque la température d'irradiation augmente, la taille des cavités augmente
- Lorsque la température de recuit augmente, la taille des cavités augmente également, en 3 étapes :
  - 350-700°C : Coalescence de petites cavités
  - 700-1100°C : Pas d'évolution
  - > 1100°C : Coalescence et élimination
- MET et PAS sont des techniques permettant de détecter des défauts lacunaires mais pas à la même échelle :
  - ❑ PAS = Début de la croissance
  - ❑ MET = Plus gros défauts



### Remerciements:

- CEMHTI : M-F. Barthe, C. Genevois, P. Desgardin, J. Joseph
- JANNuS Orsay : B. Décamps, C. Baumier, Accelerator Team
- JANNuS Saclay : Y. Serruys, E. Bordas
- ETHZ : R. Schaublin
- CCFE : D. Mason



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