REDUCTION OF RADIOLOGICAL ACCIDENT CONSEQUENCES

POLITECNICO MILANO 1863

Title	**Fission product behaviour tools**
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Affiliation:	Politecnico di Milano
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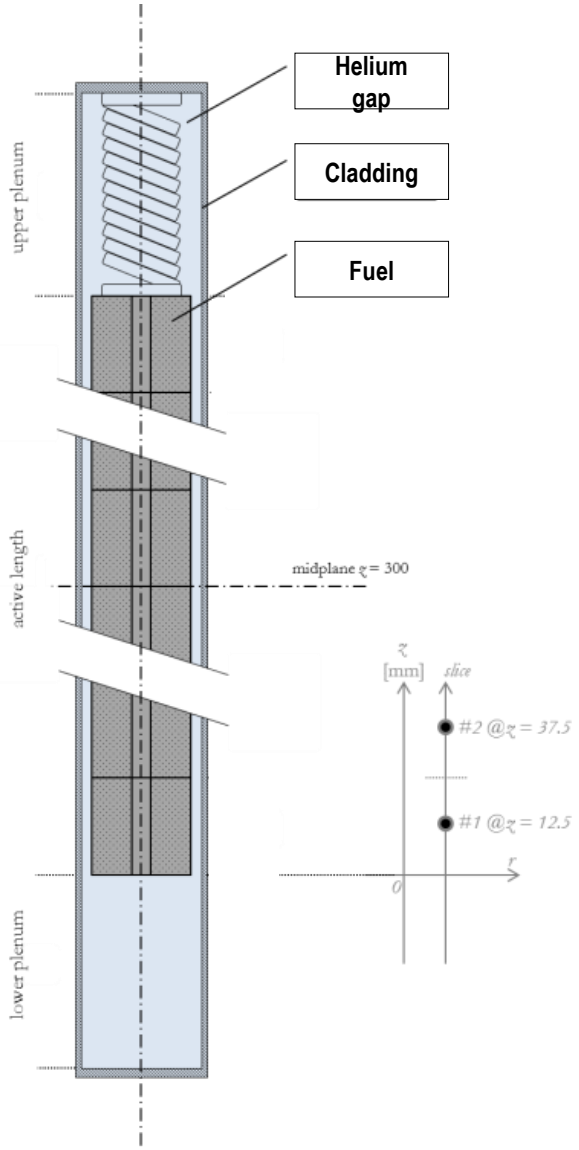
This project has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 847656.

Object, nuclear fuel rod

REDUCTION OF RADIOLOGICAL CONSEQUENCES OF DESIGN BASIS & DESIGN EXTENSION ACCIDENTS



Nuclear fuel rod (ThR//FR) is made of a **stack of oxide (UO_2//MOX) fuel pellets** wrapped in **metallic (Zry//SS) cladding**

Its performance is fundamental for **safe operation** of the reactor (and **licensing** and **design**)

Need of **integral fuel performance codes (FPCs)** and integral irradiation experiments to assess the fuel rod **thermo-mechanical behaviour** (σ, ε, and T)

Focus on inert gas behavior, i.e.,
gaseous swelling & fission gas release

Multi-scale modelling

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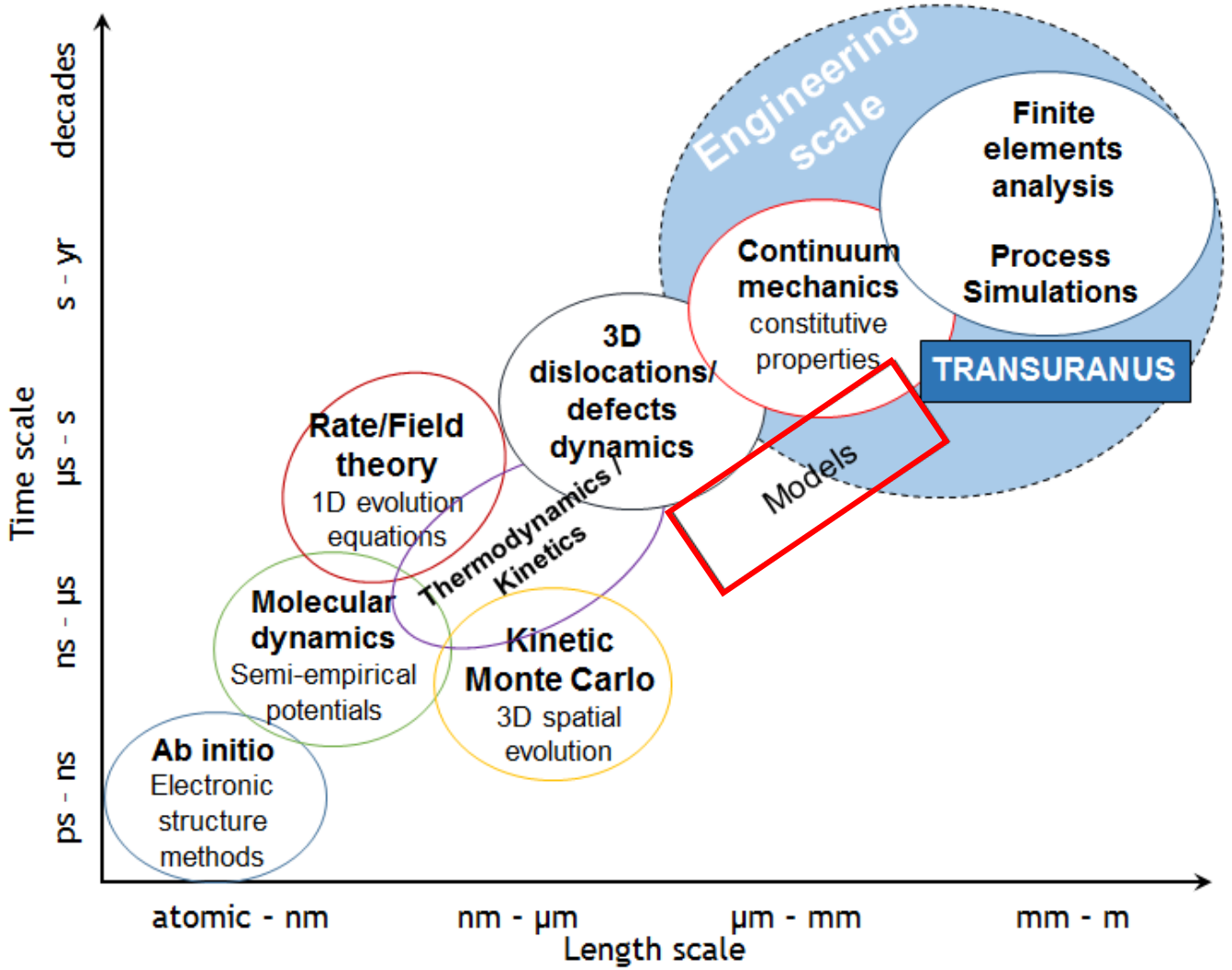

Multi-scale up to engineering scale

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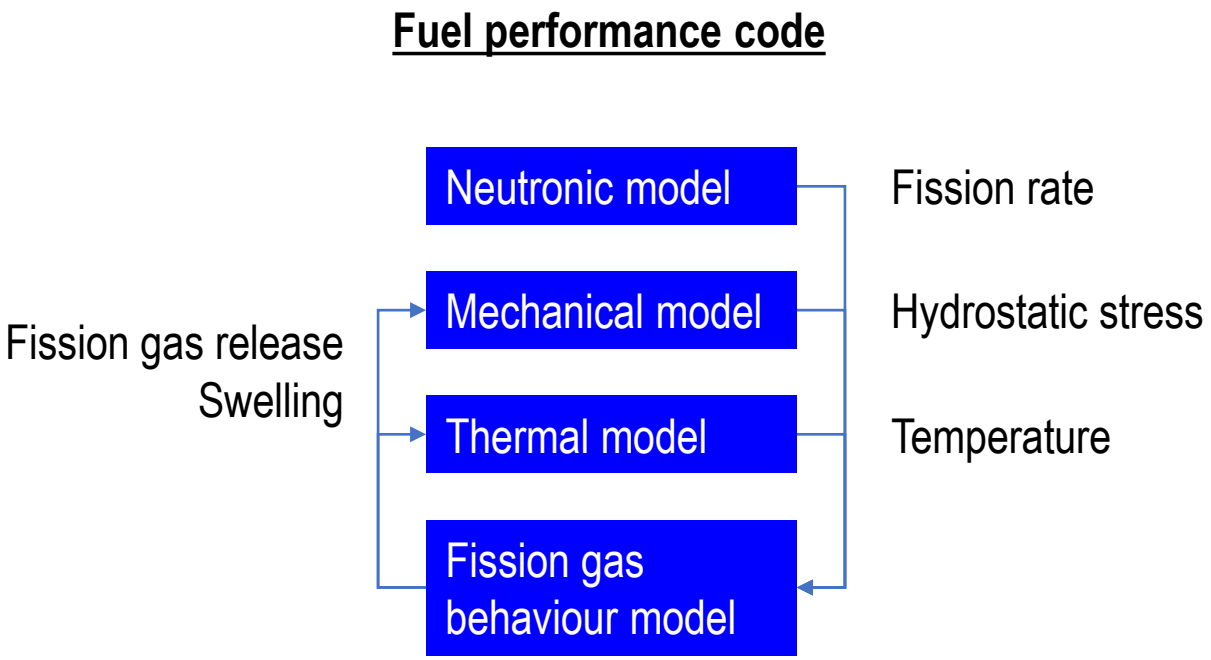
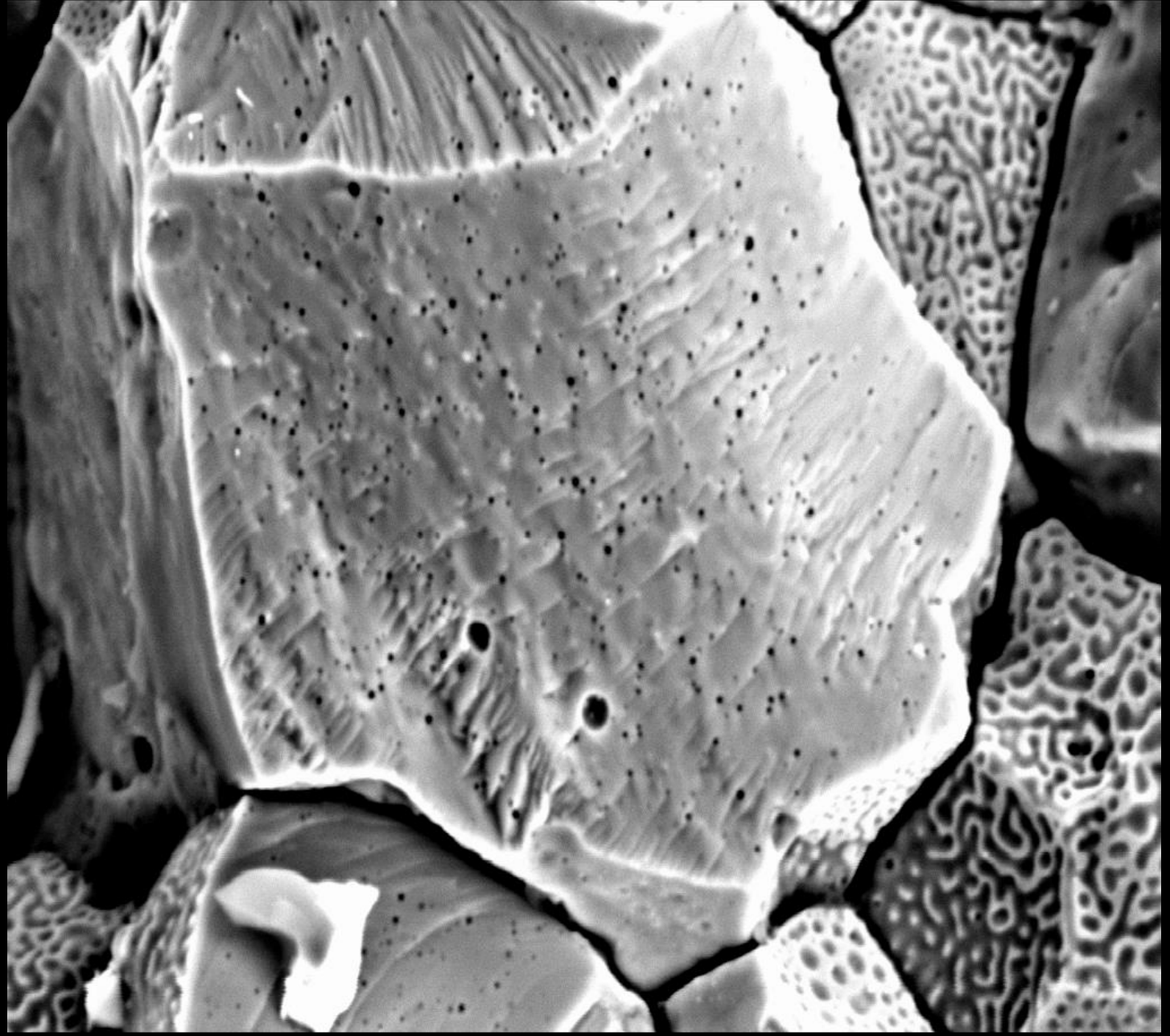
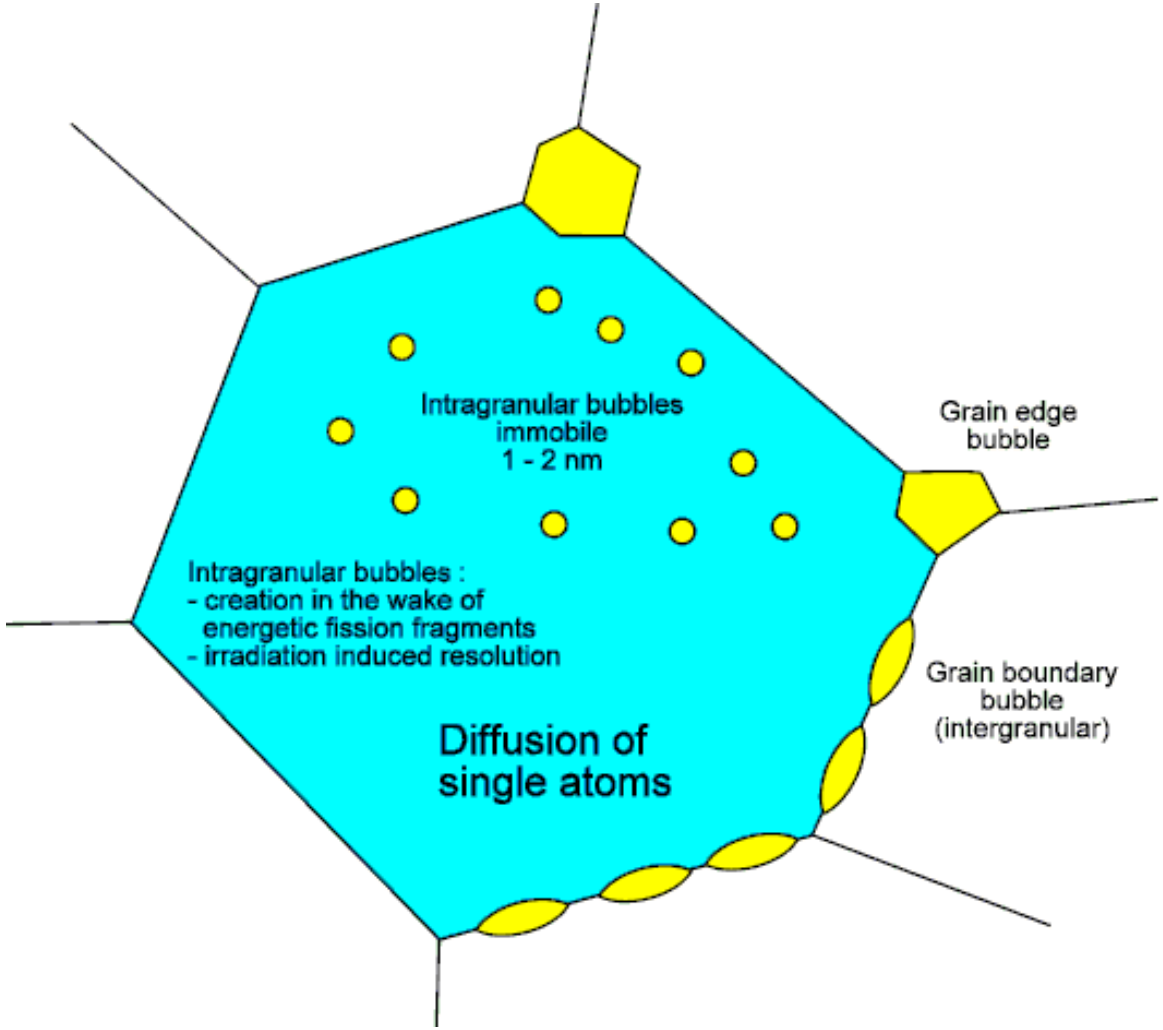
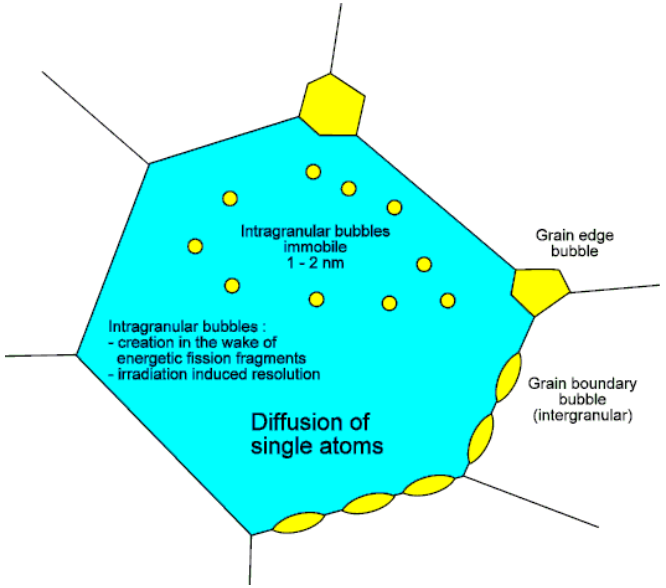


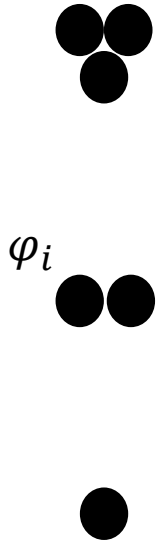

10µm 20KV WD22mm X2,500 07 PHOT 9506004C

Grain-scale models



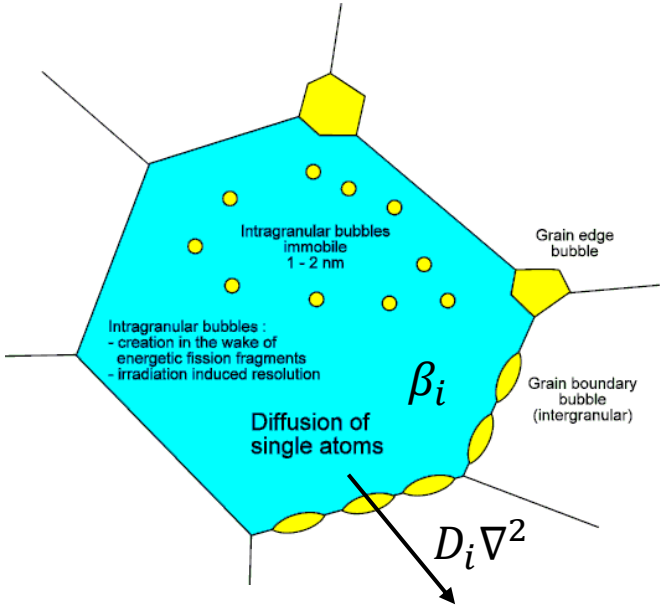
Grain-scale models

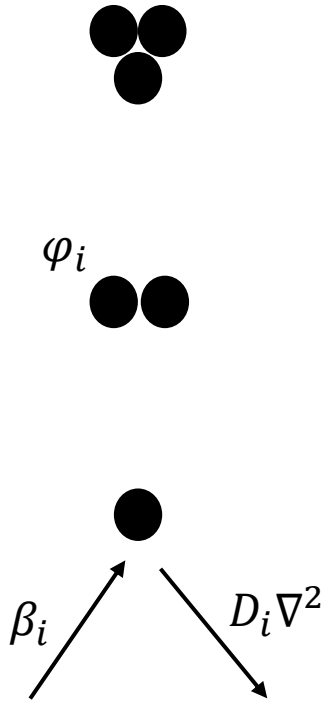




$$\frac{\mathrm{d}\varphi_i}{\mathrm{d}t} =$$

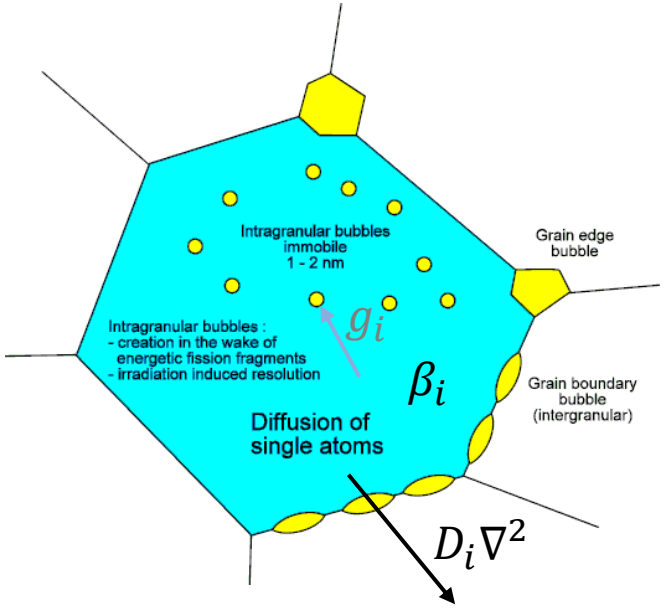
Grain-scale models, production + diffusion

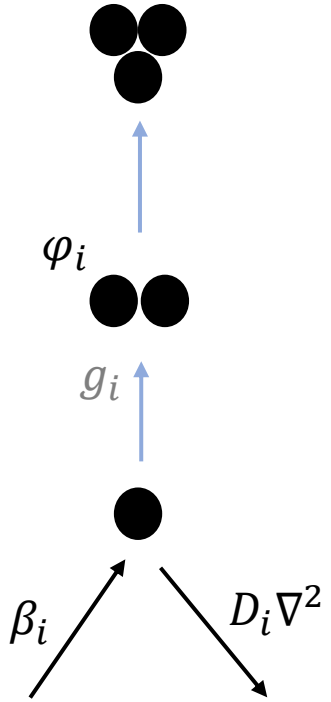




$$\frac{\mathrm{d}\varphi_i}{\mathrm{d}t} = \beta_i + D_i\nabla^2\varphi_i$$

Grain-scale models, trapping





$$\frac{\mathrm{d}\varphi_i}{\mathrm{d}t} = \beta_i + D_i\nabla^2\varphi_i - g_i\varphi_i + g_{i-1}\varphi_{i-1}$$

Grain-scale models, re-solution

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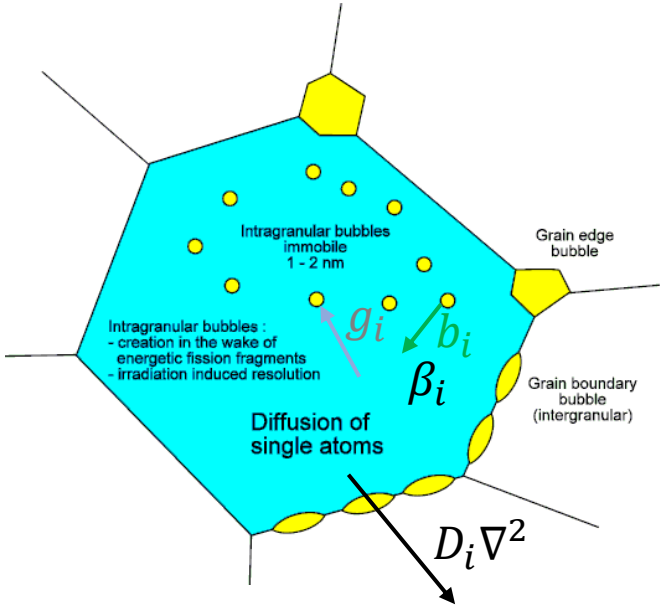

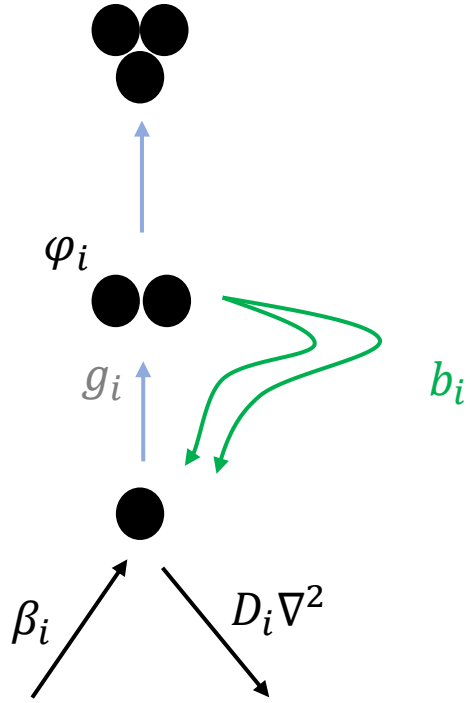

$$\frac{\mathrm{d}\varphi_i}{\mathrm{d}t} = \beta_i + D_i\nabla^2\varphi_i - g_i\varphi_i + g_{i-1}\varphi_{i-1} - b_i\varphi_i - b_{i+1}\varphi_{i+1}$$

Rate theory equations

$$\begin{cases} \dfrac{\mathrm{d}\varphi_i}{\mathrm{d}t} = \displaystyle\sum_j \alpha_{ji}\varphi_j + \beta_i + D_i\nabla^2\varphi_i \end{cases}$$

Rate theory equations

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Fission product chemistry : Interaction (non-linear) terms !

$\sim\varphi_i\varphi_j$

Rate theory equations

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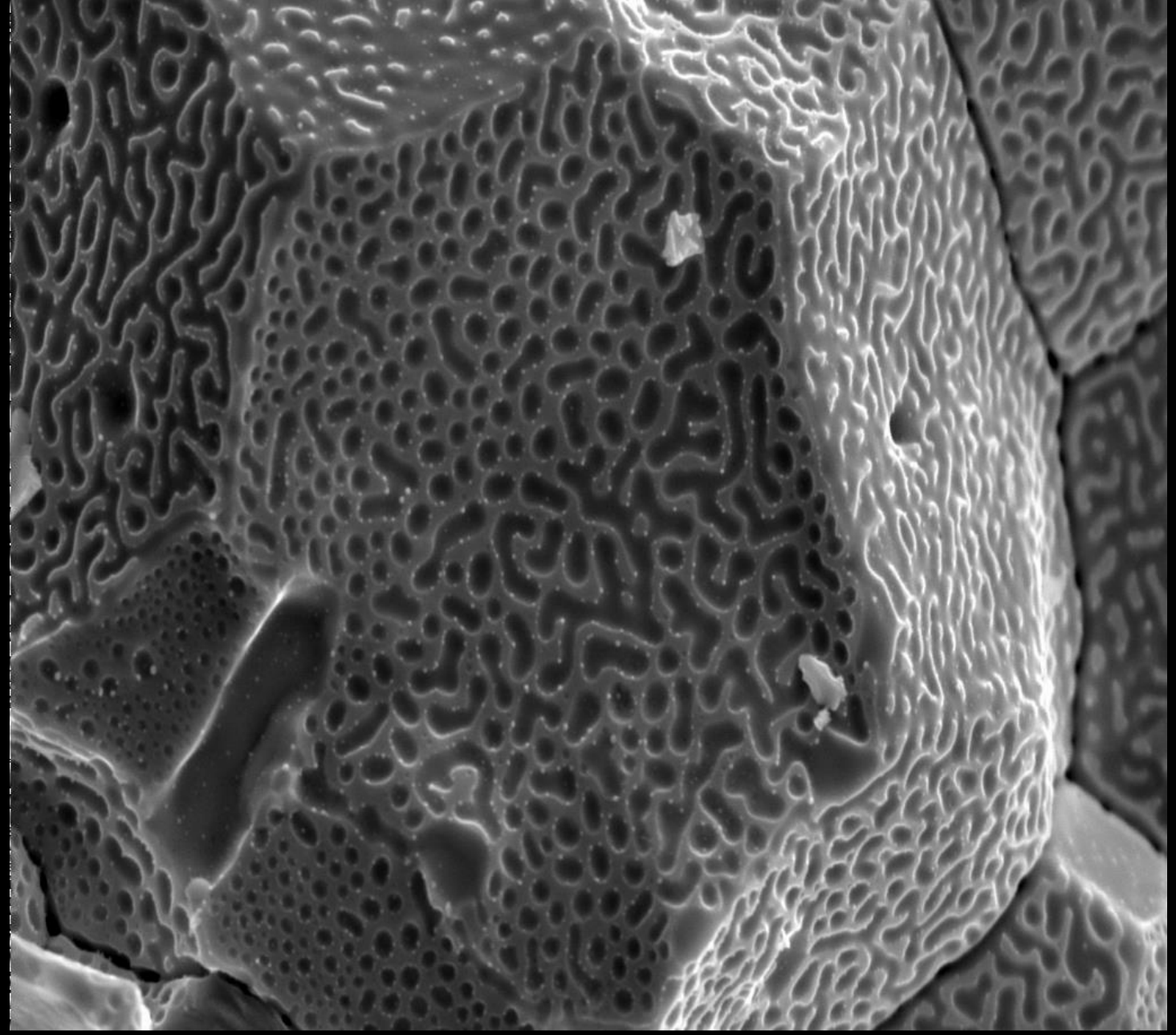
Fission product chemistry : Interaction (non-linear) terms !

$\sim\varphi_i\varphi_j$

PARAMETERS !!!



1μm 20KV WD11mm X4,000 07 PHOT 9811015F

Examples of available tools

- CARACAS (CEA)
- MARGARET (CEA)
- MFPR-F (IRSN)
- SIFGRS (Idaho National Laboratory)
- SCIANTIX (Politecnico di Milano)
- …

Summary and conclusions

REDUCTION OF RADIOLOGICAL CONSEQUENCES OF DESIGN BASIS & DESIGN EXTENSION ACCIDENTS

- Fission gas and fission products behaviour are key for predicting overall performance of nuclear fuel rods
- Multi-scale approaches are suitable to transfer knowledge up to the engineering scale
- Knowledge of model parameters and of their impact is fundamental for reliable analyses
- Several tools are available and suited for different applications, with development gaps being addressed by several research initiatives

Thank you for your kind attention!

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