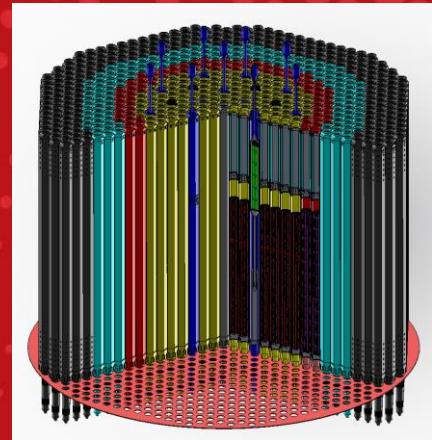


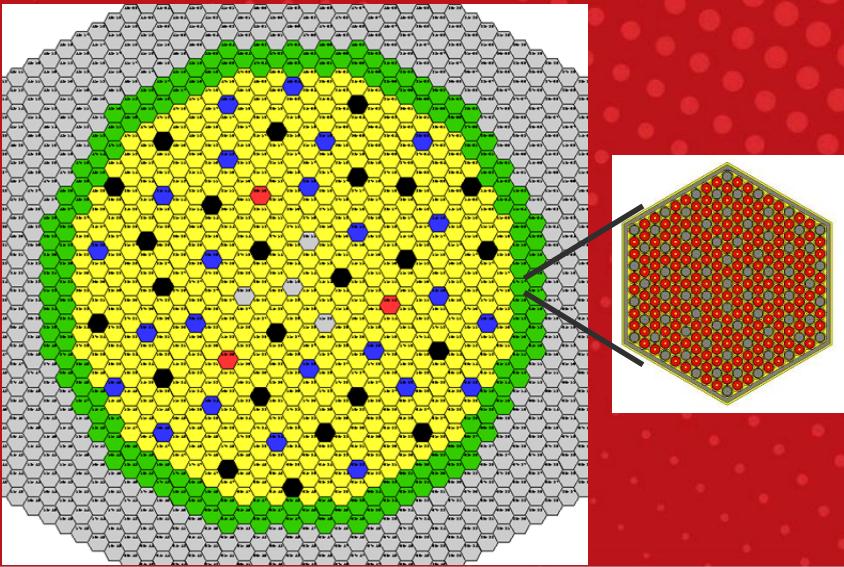


DE LA RECHERCHE À L'INDUSTRIE

Importance of the Doppler Constant and of the fuel temperature evaluation for the design of a 'CADOR' core

P.Sciora*, J.B. Droin, B. Fontaine, A. Zaetta | ICAPP 2019, 12-15 May





The 'CADOR' core

Objectives of the GenIV reactors (GIF)

4 Areas, 8 Goals, 15 criteria

Sustainability

SU1 Resource Utilization

SU2 Waste Minimization and Management

Safety and Reliability

SR1 Operational Safety and Reliability

SR2 Core Damage

SR3 Offsite Emergency Response

Economics

EC1 Life Cycle Cost

EC2 Risk to Capital

Proliferation Resistance and Physical Protection

PR1 Proliferation Resistance and Physical Protection

1. Generation IV nuclear energy systems operations will excel in safety and reliability.
2. Generation IV nuclear energy systems will have a very low likelihood and degree of reactor core damage.
3. Generation IV nuclear energy systems will eliminate the need for offsite emergency response.

« Safety design criteria », of the Generation IV forum:

- *the maximum tolerable releases outside the plant enclosure should only require measures to protect populations that are very limited in scope and duration.*
- *This would result in no permanent relocation, no need for emergency evacuation beyond the immediate vicinity of the unit, limited sheltering, and no long-term restrictions on food consumption.*

Repetition of accidents such as Chernobyl or Fukushima unacceptable

➔ Exclude fuel melting accidents associated with significant energy releases leading to major radioactive releases beyond the reactor site boundary.

To eliminate the severe accident, it is necessary to protect against
“unprotected accidents” = “without scram”.

Prevention objectives

No boiling during ULOF :

Global loss of Flow

No melting of an assembly (USAf):

Local loss of flow

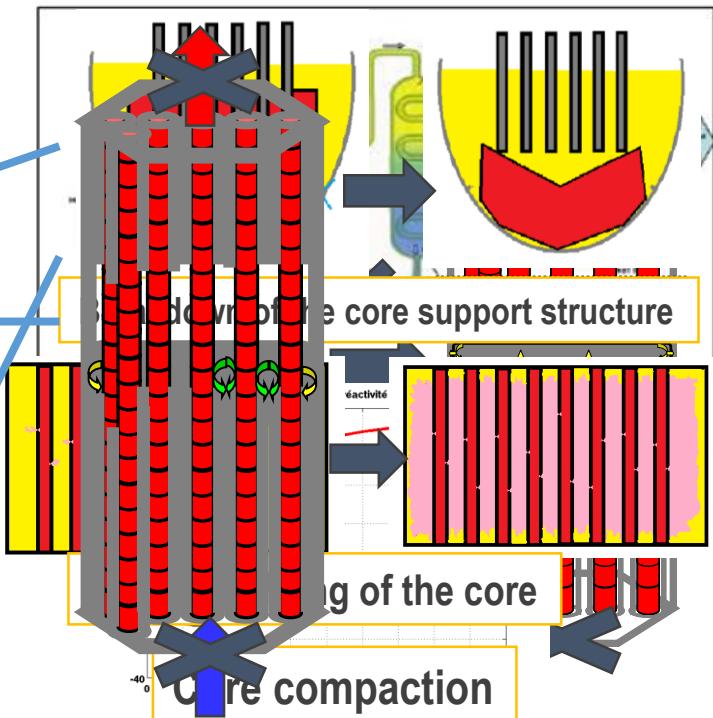
No fuel melting during UTOP :

Power increase

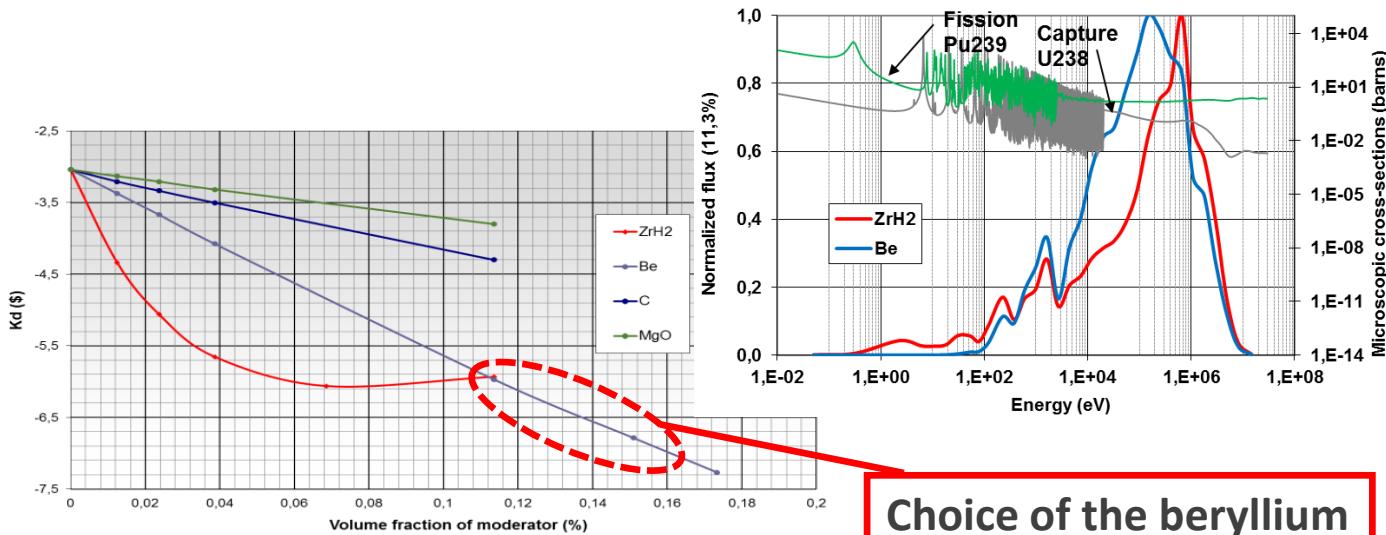
No loss of the residual power extraction device

0 50 100 150 200 250 300

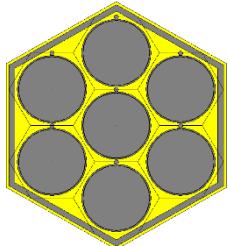
Time (s)



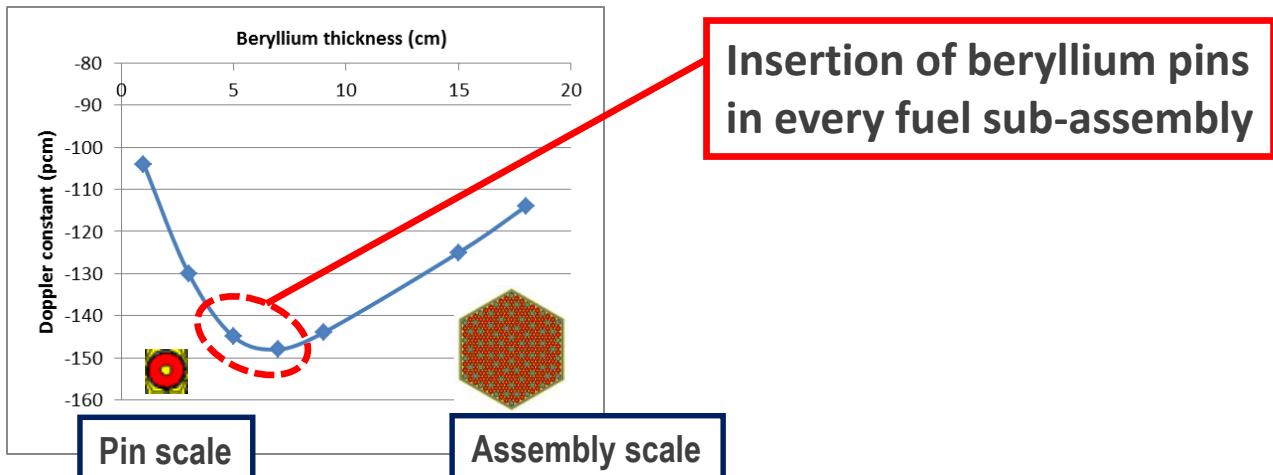
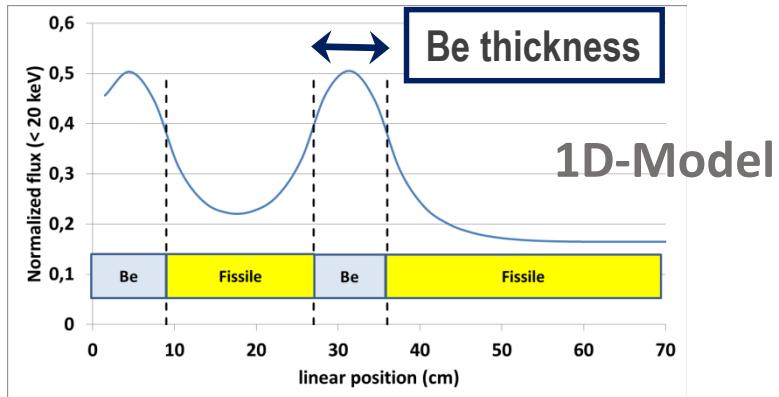
- Increase the margin to the fuel melting by:
 - Reducing the nominal fuel temperature -> reduction of the volume power
 - Increasing the Doppler constant -> addition of a moderator

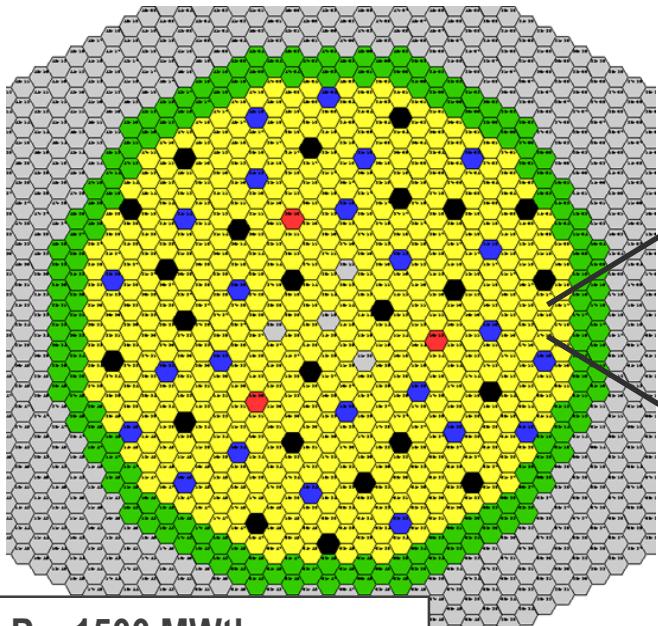


CONTEXT – THE ‘CADOR’ CONCEPT HOW TO INTRODUCE THE MODERATOR IN THE CORE ?



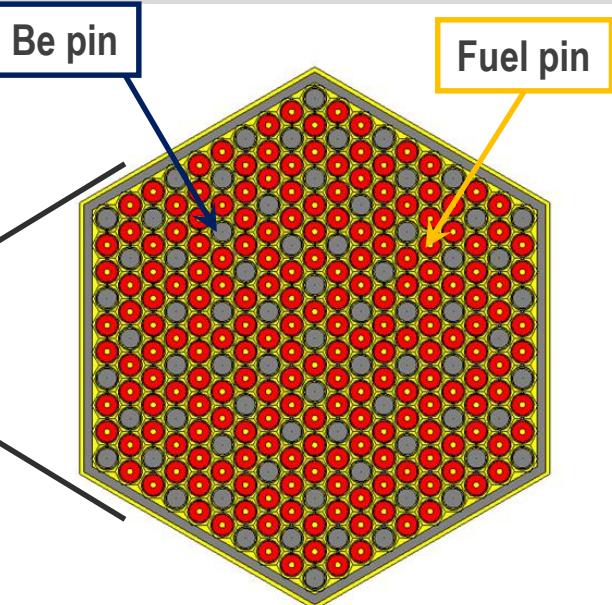
Dedicated moderator
sub-assemblies ?





$P = 1500 \text{ MWth}$

$R = 255 \text{ cm} / H = 120 \text{ cm}$

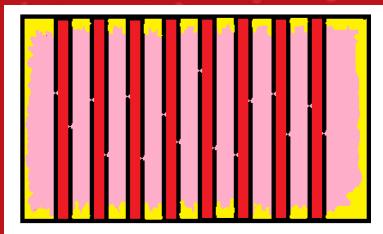
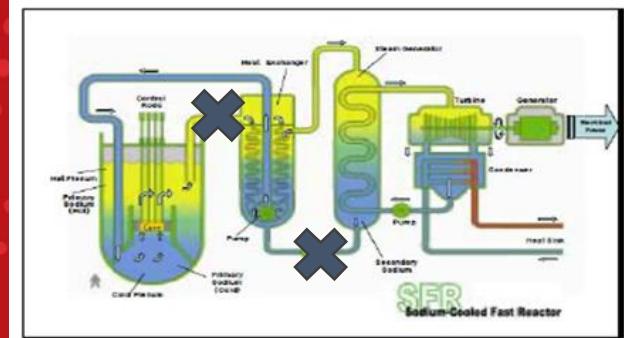
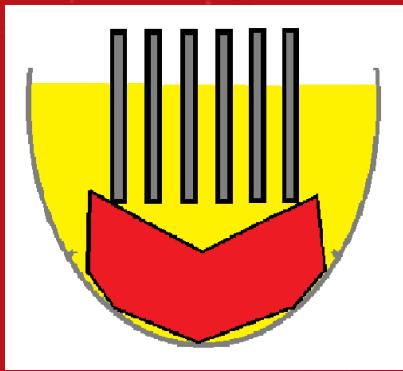


Be pin

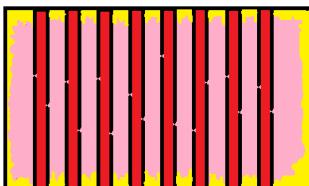
Fuel pin

Compared to a
« classical core »

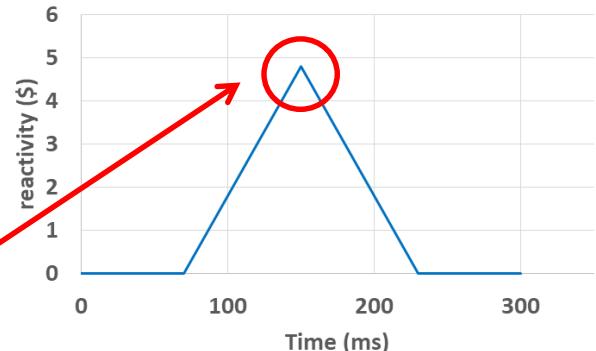
Power density (W/cm ³)	65	1 / 4
Max linear power (W/cm)	150	1 / 3
K _D fissile Doppler constant (pcm)	-1942	x 2,5



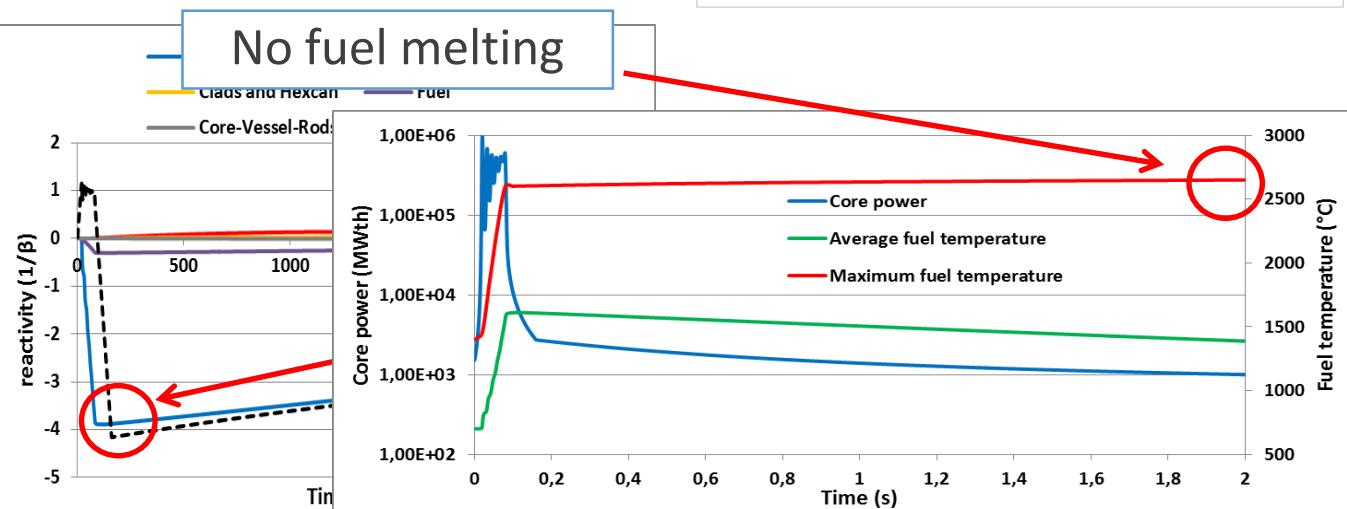
Transient studies

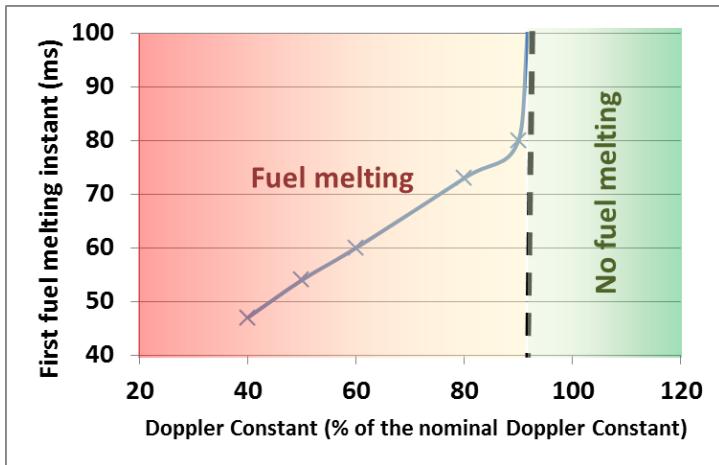
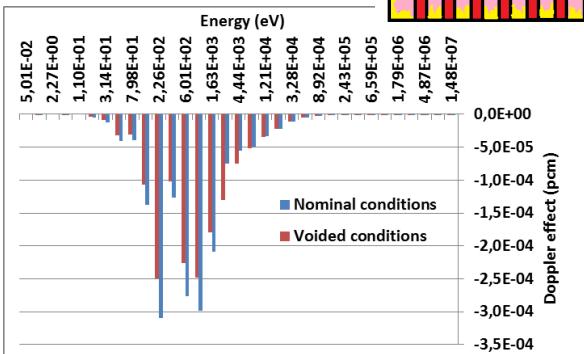
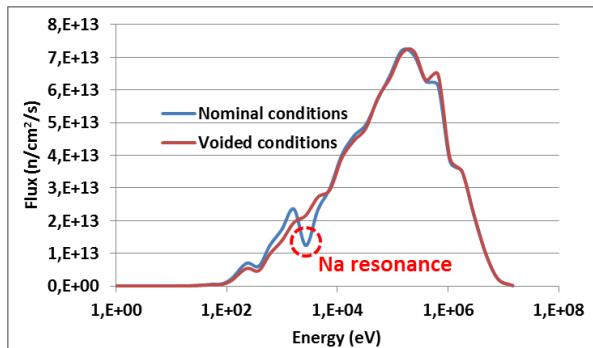
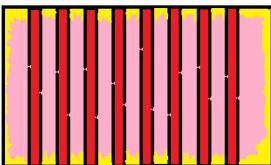


Maximum positive value of the sodium voiding



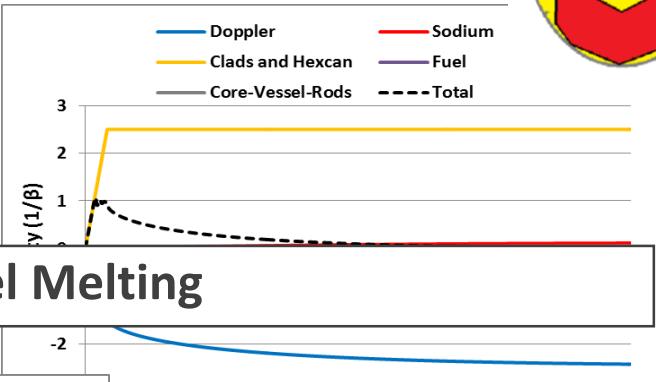
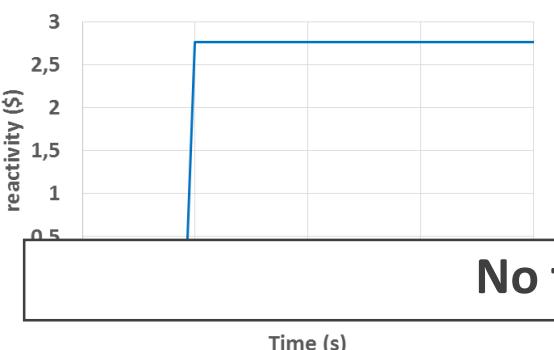
No fuel melting



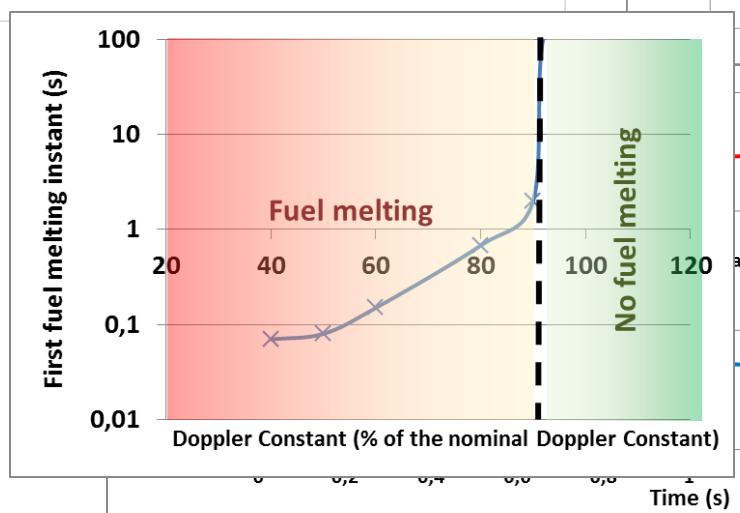


Large variation of the Doppler during the transient with difficulty to take it into account without coupling codes.

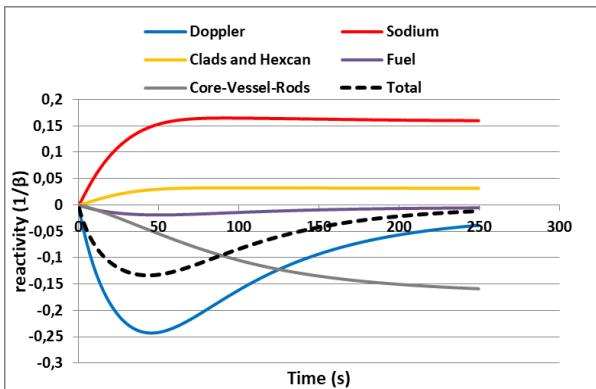
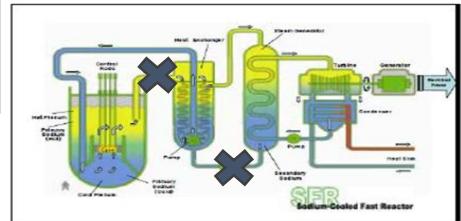
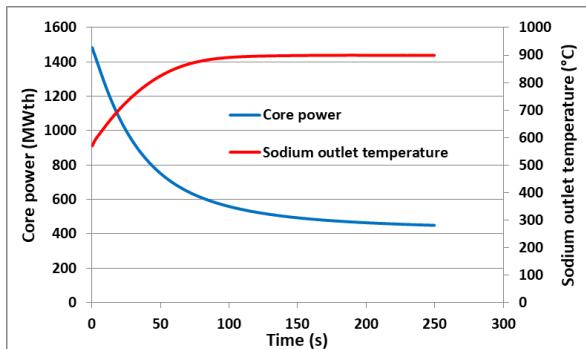
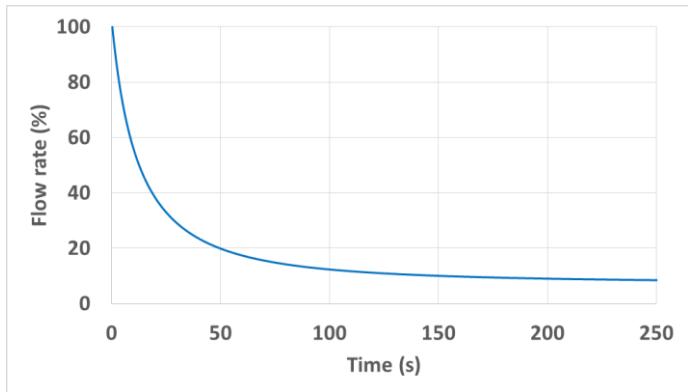
Large dependency on the transient result



No fuel Melting

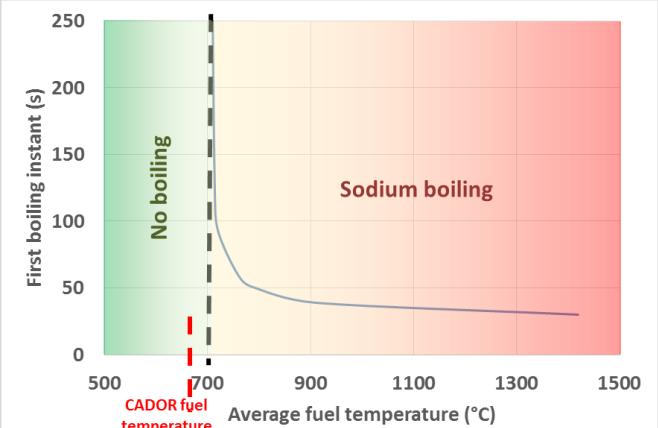
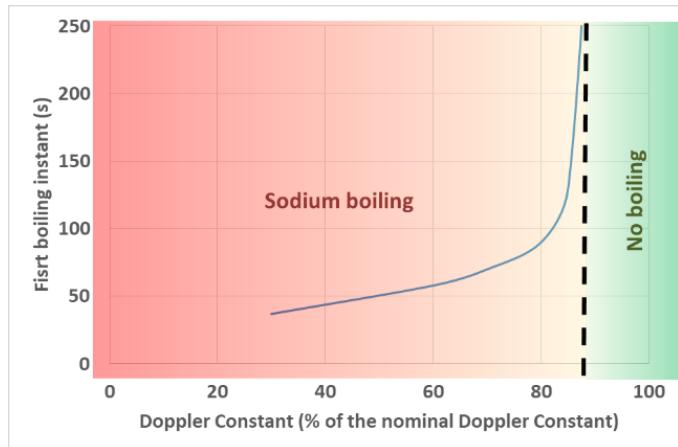
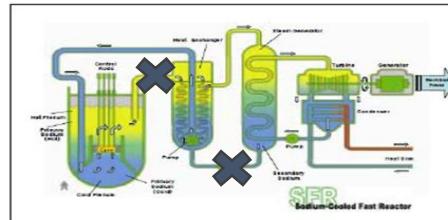


But the margins are reduced and the uncertainty on the Doppler constant evaluation is of first order of importance



No sodium boiling thanks
to the very low fuel
temperature.

Reduced feedback
integral between nominal
and zero power states



Importance of the Doppler constant evaluation

And even more of the fuel temperature evaluation

It is possible to design a core with a good natural behavior in case of unprotected transients (UTOP, ULOF), thanks to the Doppler feedback coefficient.

But the penalties on the core are important : reduced volume power, addition of an important quantity of beryllium.

If the current uncertainties on the Doppler constant and on the fuel temperature evaluation have to be taken into account in the safety demonstration, the penalties will be even more enlarged. Work on reducing these uncertainties have to be done to reduce the design penalties.

Of course, such 'CADOR' core will permit simplifications on the safety demonstration and on the design options -> **economic issue...**

(other papers are presented in Juan-Les-Pins on this concept)



THANK YOU FOR
YOUR ATTENTION