

# Concept of European Molten Salt Fast Reactor (MSFR)

## Summary / Objectives:

Liquid-fueled reactors exhibit unusual and interesting properties in terms of operation and safety compared to solid-fueled reactors, requesting a revision of some well-known conception and safety rules. In this webinar, such characteristics of the Molten Salt Reactors (MSRs) will be presented, together with the past and current R&D activities. The concepts studied in the frame of the Generation-IV international collaboration will be briefly described, and the presentation will then focus on the concept of Molten Salt Fast Reactor (MSFR), reactor based on a fast spectrum and studied since almost a decade mainly by calculations and determination of basic physical and chemical properties, initially at CNRS in France and now more largely in the European Union. The main design choices and characteristics of this MSFR concept will be explained and discussed including transient simulations, chemistry and material issues, safety analysis, research roadmap and laboratory scale experiments.

## Meet the Presenter:

**Prof. Elsa Merle** is the director of the Master's Program in Reactor Physics and Nuclear Engineering at the PHELMMA engineering school of Grenoble Institute of Technology, France. She is also working, as a research staff member, at the Laboratory for Subatomic Physics and Cosmology of Grenoble. Since 2000, she has been actively involved with the French National Center for Scientific Research (CNRS) programs dedicated to the conceptual design of innovative Generation IV reactors. As such, she is contributing to various studies and validations of the concept of Molten Salt Reactors and more specifically since 2008 on the definition and optimization of the concept of Molten Salt Fast Reactor (MSFR). Dr. Merle is in charge of the work-package 1 "Integral safety approach and system integration" of the Euratom project SAMOFAR of Horizon2020, and she represents CNRS at the GIF steering committee on Molten Salt Reactors.



## 1. MSFR: Design and Fissile Inventory Optimization

The reference design parameters of power, fuel salt volume and core geometry have been decided considering some limiting factors.

### MSFR: Design and Fissile Inventory Optimization

#### Reactor Design and Fissile Inventory Optimization = Specific Power Optimization

- 2 parameters:
- The produced power
  - The fuel salt volume and the core geometry

Liquid fuel and no solid matter inside the core  $\Rightarrow$  possibility to reach specific power much higher than in a solid fuel

#### 3 limiting factors:

- The **capacities of the heat exchangers** in terms of heat extraction and the associated pressure drops (pumps)  $\rightarrow$  *large fuel salt volume and small specific power*
- The **neutronic irradiation damages to the structural materials** (in Ni-Cr-W alloy) which modify their physicochemical properties. Three effects: displacements per atom, production of Helium gas, transmutation of Tungsten in Osmium  $\rightarrow$  *large fuel salt volume and small specific power*
- The **neutronic characteristics of the reactor** in terms of burning efficiencies  $\rightarrow$  *small fuel salt volume and large specific power* and of deployment capacities, i.e. breeding ratio ( $= {}^{233}\text{U}$  production) versus fissile inventory  $\rightarrow$  *optimum near 15-20 m<sup>3</sup> and 300-400 W/cm<sup>3</sup>*

$\Rightarrow$  **Reference MSFR configuration with 18 m<sup>3</sup> and 330 W/cm<sup>3</sup> corresponding to an initial fissile inventory of 3.5 tons per GWe**

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## 2. MSFR and the European project EVOL

EVOL project has been implemented during 2011-2013, in order to propose best MSFR system based on physical and material studies

### MSFR and the European project EVOL

European Project "EVOL" Evaluation and Viability Of Liquid fuel fast reactor - FP7 (2011-2013): Euratom/Rosatom cooperation

Objective : to propose a design of MSFR given the best system configuration issued from physical, chemical and material studies



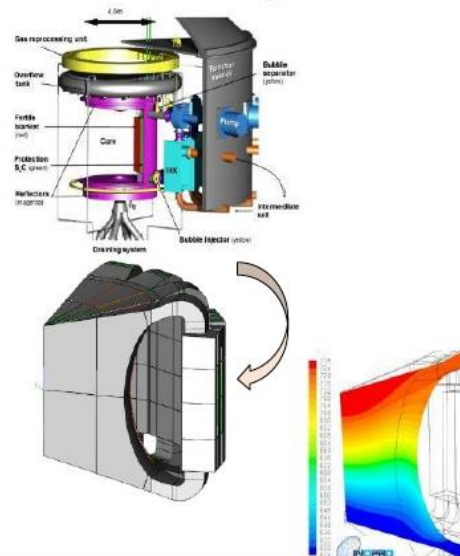
#### Examples of outputs of the project:

- Optimized toroidal shape of the core
- Proposal for an optimized initial fuel salt composition
- Neutronic benchmark (comparison tools/ nuclear databases)
- First developments of a safety assessment method for MSR
- Recommendations for the choice of the core structural materials

**12 European Partners:** France (CNRS: Coordinator, Grenoble INP, INOPRO, Aubert&Duval), Netherlands (Technical Univ Delft), Germany (ITU, KIT-G, HZDR), Italy (Politecnico di Torino), UK (Oxford), Hungary (Tech Univ Budapest)  
+ 2 observers since 2012: Politecnico di Milano and Paul Scherrer Institute

+ Coupled to the **MARS (Minor Actinides Recycling in Molten Salt) project of ROSATOM (2011-2013)**

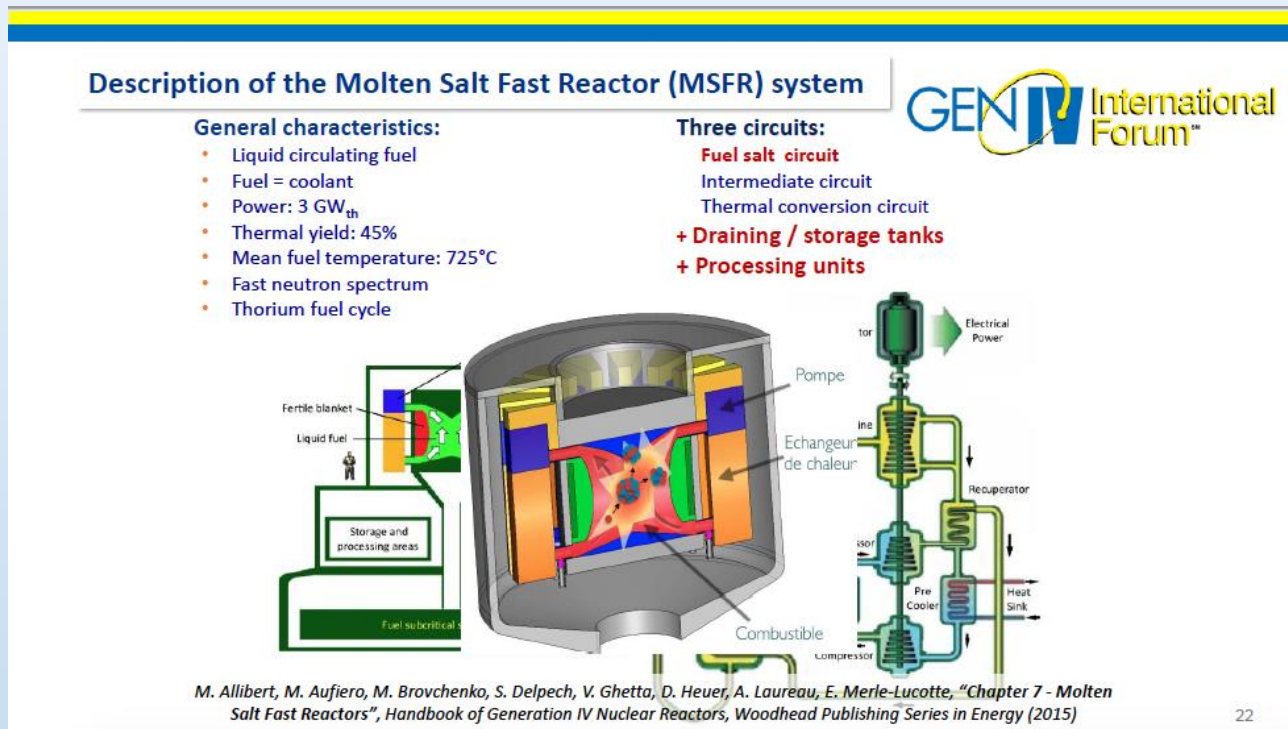
Partners: RIAR (Dimitrovgrad), KI (Moscow), VNIITF (Snezinsk), IHTe (Ekaterinburg), VNIKHT (Moscow) et MUCATEX (Moscow)



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### 3. Description of the Molten Salt Fast Reactor (MSFR) system

The main plant parameters, the heat transport configuration are shown.



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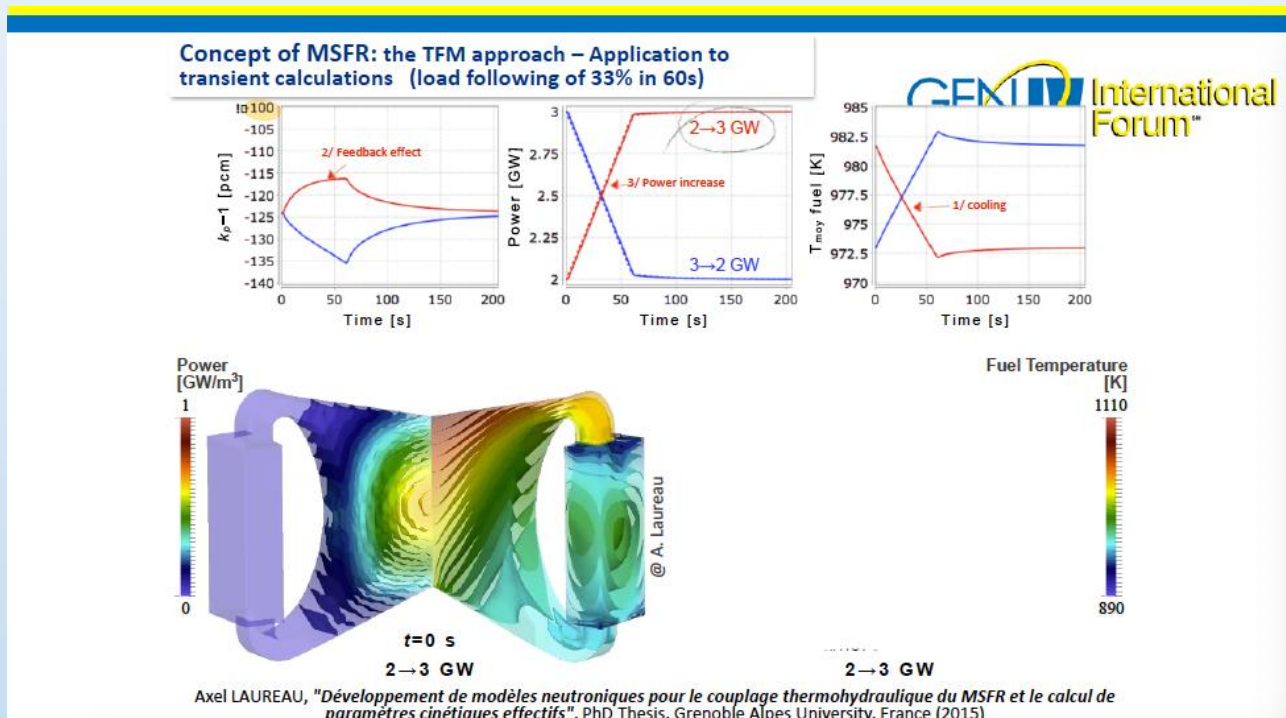
### 4. SAMOFAR (Safety Assessment of a MOLten salt FAST Reactor) project

This European project has been performed during 2015-2019. They have discussed the safety approach considering the MSFR specific safety features.



## 5. An example of transient calculations (load following of 30% in 60s)

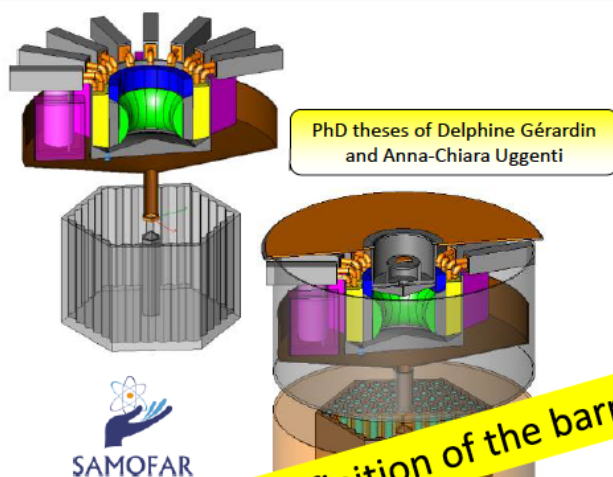
The Load following is driven by only the extracted power (no control rods needed). The excellent load following capacities of MSFR has been confirmed.



## 6. Safety Evaluation of the MSFR: barrier definition

How to assign the multiple confinement barrier function to the MSFR SSC (Structure, System, Components) is studied.

### Safety Evaluation of the MSFR: barrier definition



**LOLF accident (Loss of Liquid Fuel)** → no tools available for quantitative analysis but qualitatively:

- Fuel circuit: complex structure, multiple connections
- Potential leakage: collectors connected to draining tank

→ **Proposition of an 'Integrated MSFR design'**

#### Confinement barriers:

**First barrier:** fuel envelop, composed of two areas: critical and sub-critical areas

**Second barrier:** reactor vessel, also including the reprocessing and storage units

**Third barrier:** reactor wall, corresponding to the reactor building

**Number and definition of the barriers under study**