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SAIGA : an in-pile test largely instrumented and devoted to study the degradation of a Sodium Fast Reactor core with mitigation device in Severe Accident Conditions

F. Charollais^{1*}, F. Michel¹, G. de Izarra², F. Payot¹, L. Maurin³, T. Blanchet³, E. Batyrbekov⁴, A. Vurim⁴, A. Pakhnits⁴, V. Baklanov⁴

Context

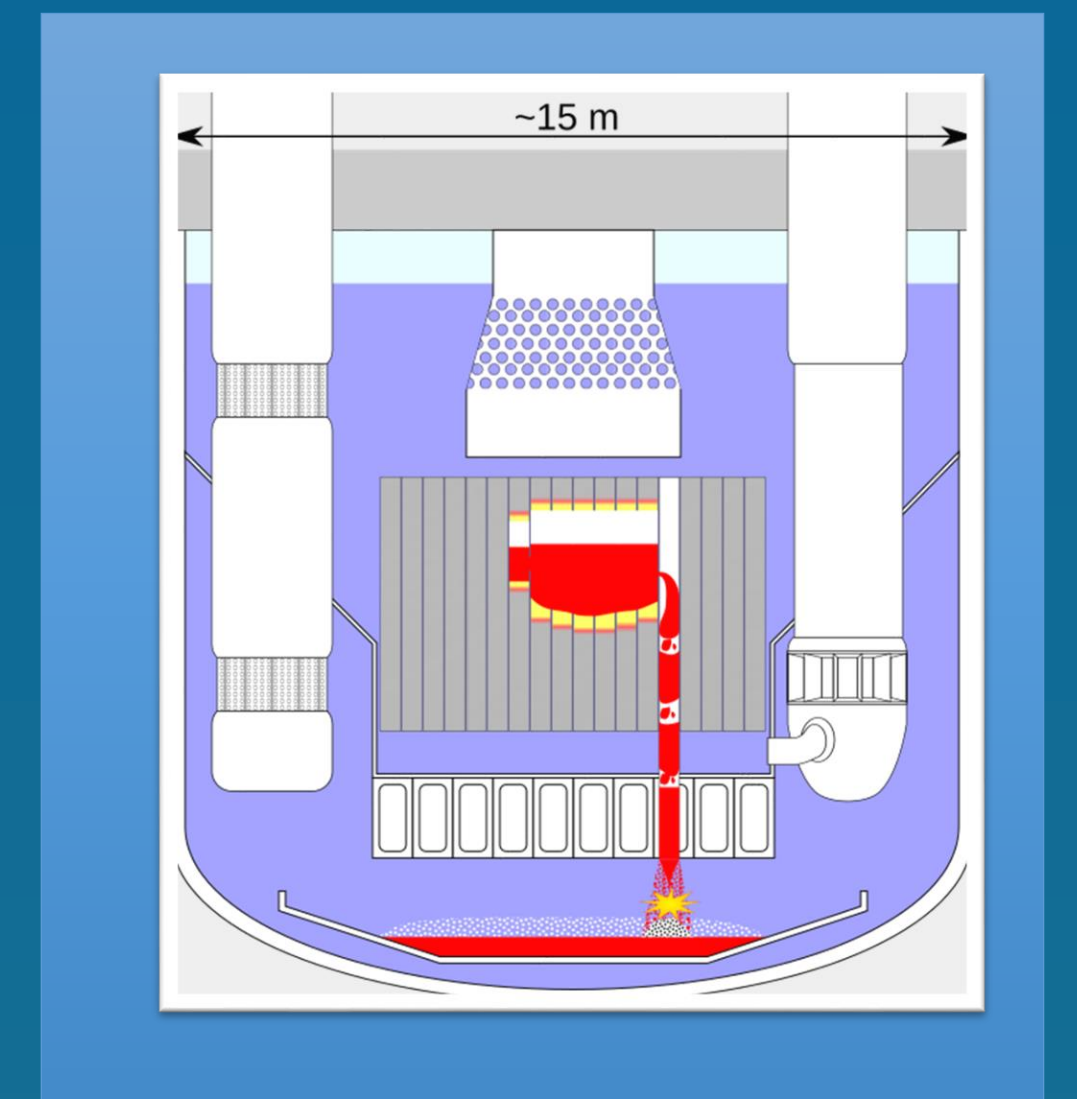
After the end of ASTRID conceptual design studies, CEA has launched a long-term R&D roadmap on generic **Sodium Fast Reactor** issues including the Severe Accident field based on 3 pillars:

- Improving knowledge of the phenomena and equations governing the sequence of events occurring during a severe accident. Developing existing or future calculation codes and numerical platforms focusing specifically on severe accidents in order to sequence and couple these codes
- Extend the experimental database needed to validate the calculation and simulation tools, such as SIMMER-V code, to cover the ranges of the parameters expected in future reactors incorporating advanced design options.
- Qualify innovative systems for mitigating the consequences of radioactive emissions in severe accident conditions proposed for future reactors

Transfer Tubes have been installed in recent SFR core designs so that molten core can rapidly relocate out of core region.

The objective is to prevent prompt criticality in the core region by removing sufficiently rapidly a significant mass of fissile material.

This mitigation device is designed to help return the reactor to a safe state after a severe accident.



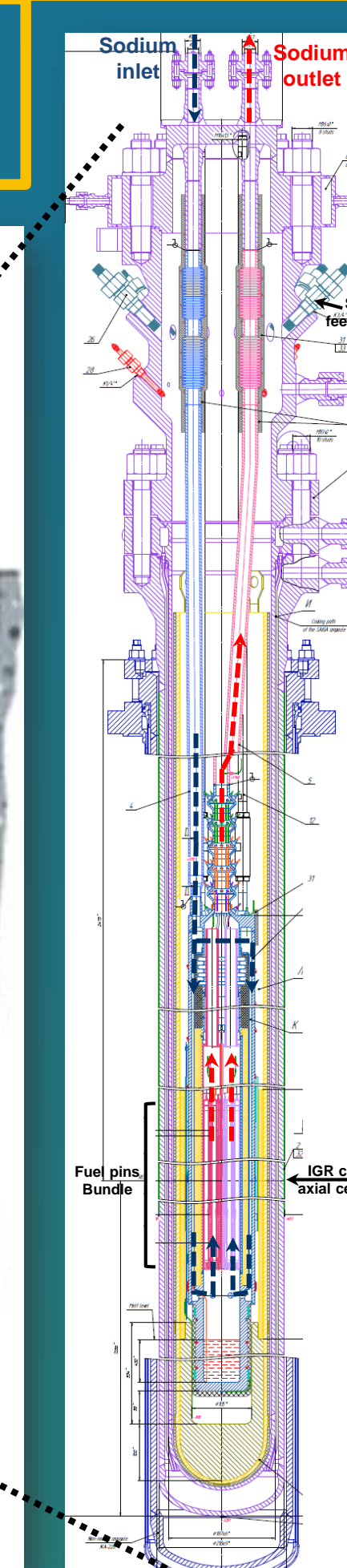
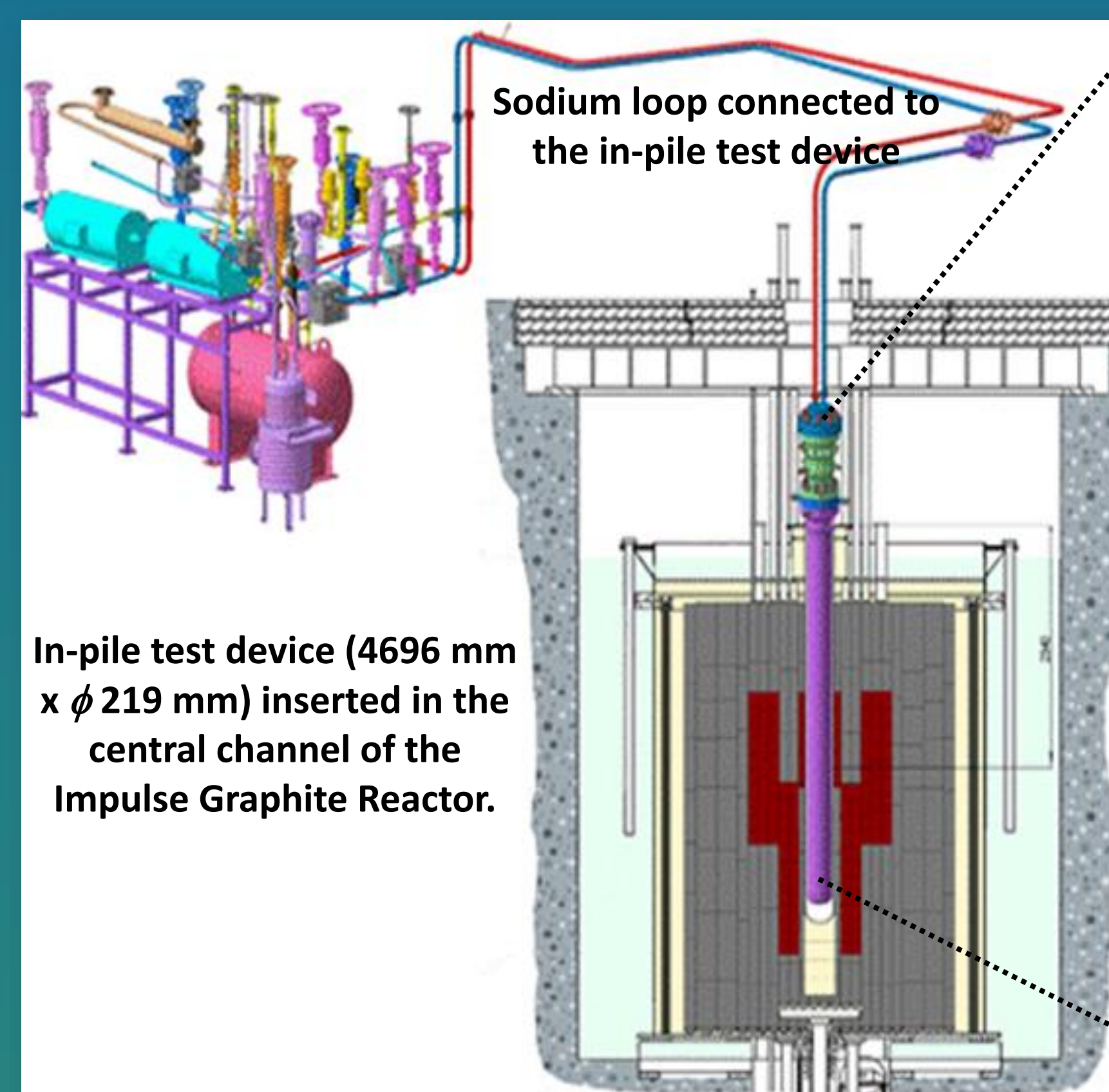
SAIGA Project will provide experimental results of an integral test to validate SIMMER-V calculations on Corium Transfer Tubes

SAIGA : An ULOF* experimental test in IGR in Kazakhstan

The test device consists of 3 Sub-Assemblies inserted in a hexagonal tube:

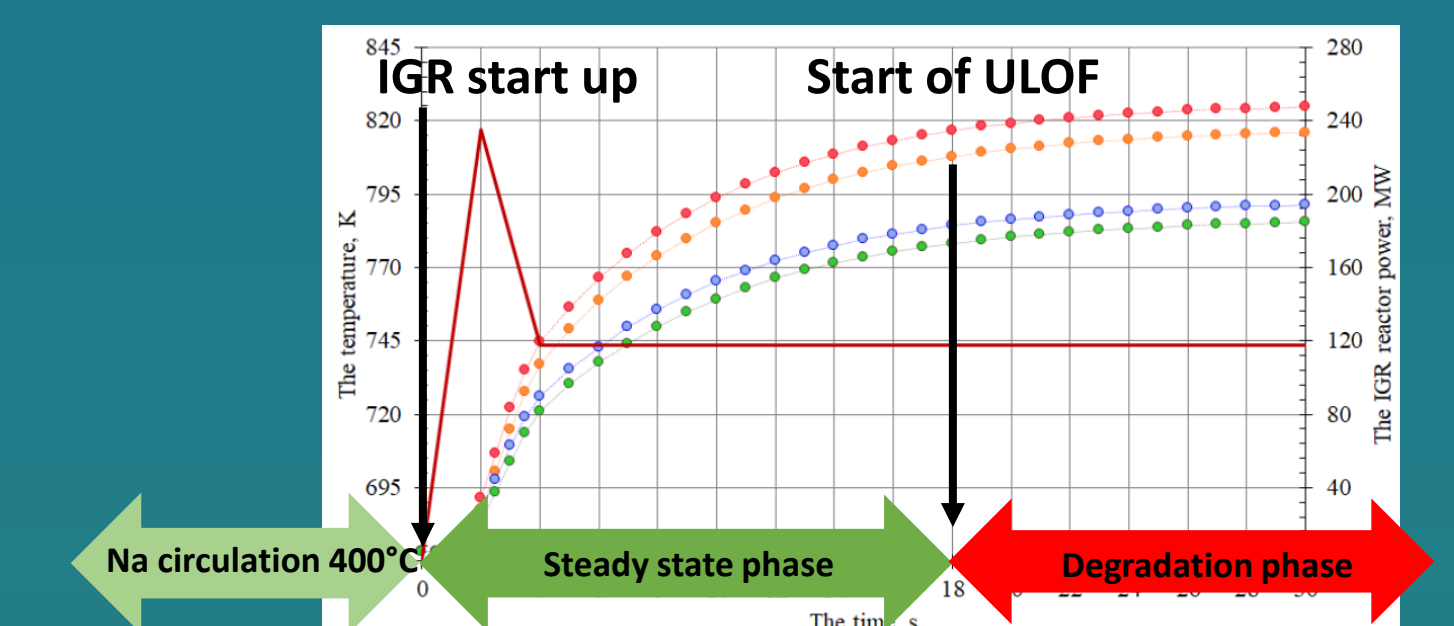
- Two fuel Sub-Assemblies (SA) with a 16 fuel pins bundle - higher U^{235} enrichment in one SA → higher temperature than the other
- One transfer tube sub-assembly ("empty" tube full of Na)

A 1.8 kg/s Na flow rate (inlet $T \sim 400^\circ\text{C}$) is specified into each SA in the initial "steady state" phase of the test. Sodium in the transfer tube is quasi static.



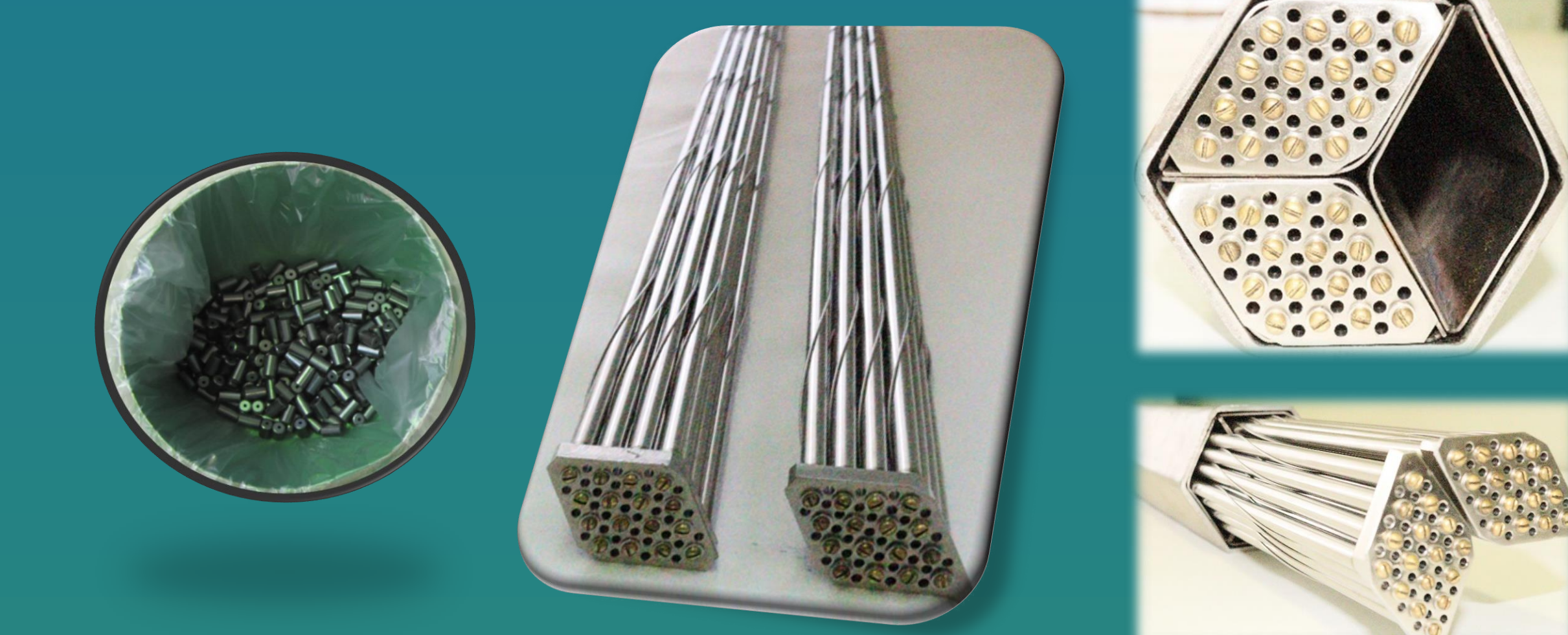
SAIGA test sequence:

- 1) 400°C thermalization phase with sodium circulation
- 2) Start up of IGR to reach thermal hydraulic steady state with a $\Delta T = 150^\circ\text{C}$ in the Hot Fuel sub-Assembly
- 3) While keeping the reactor power constant, start of ULOF → of Na flow rate → beginning of degradation phase



According to SIMMER code pre-calculations:

- a) Na Boiling in the fuel sub-assemblies,
- b) Then, cladding / fuel melting
- c) Rupture of wall between HFA and CFA
- d) Rupture of transfer tube wall with corium transfer

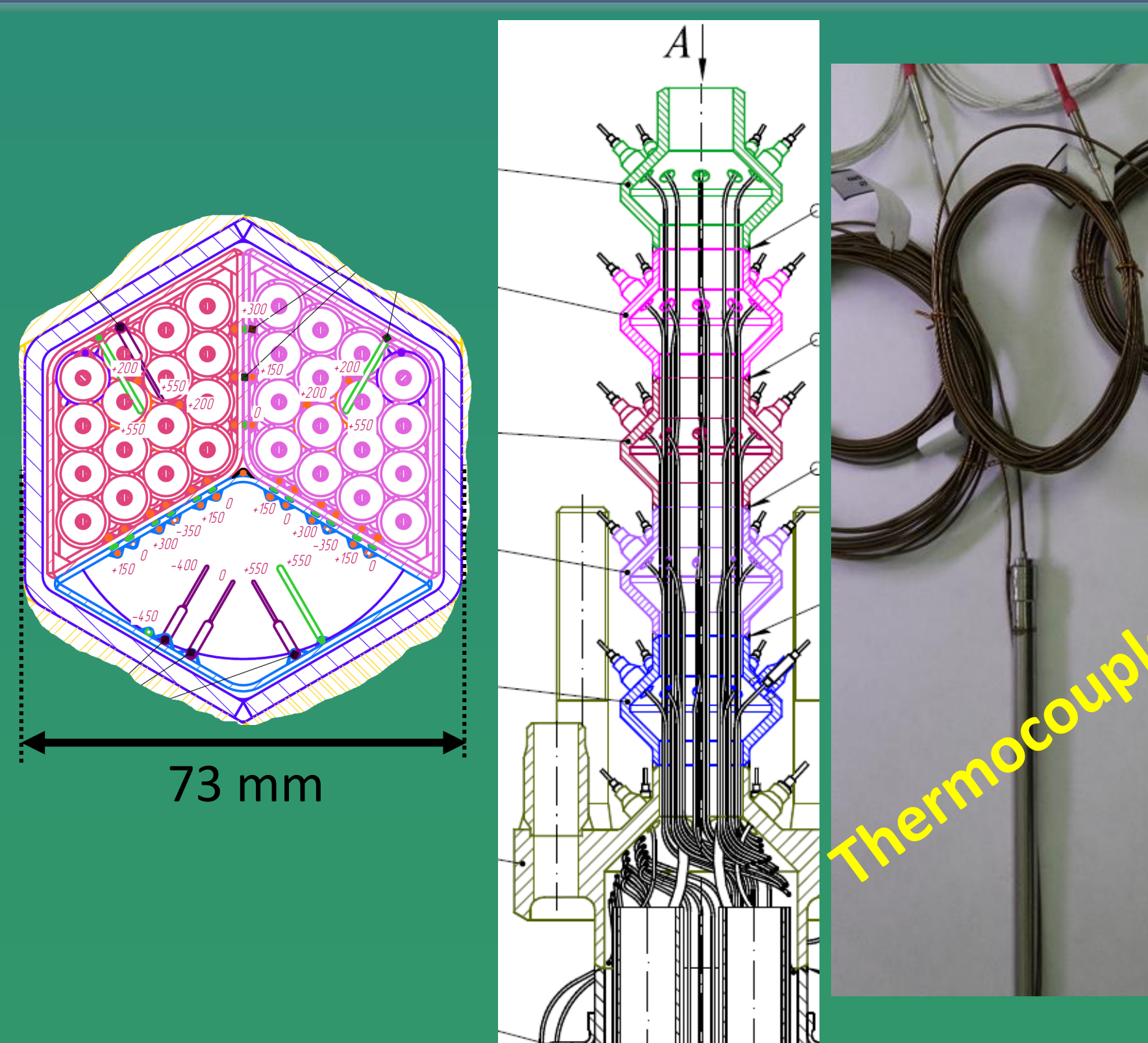


*ULOF means Unprotected Loss Of Flow

Instrumentation: Key Challenges

Main objectives, in order of priority:

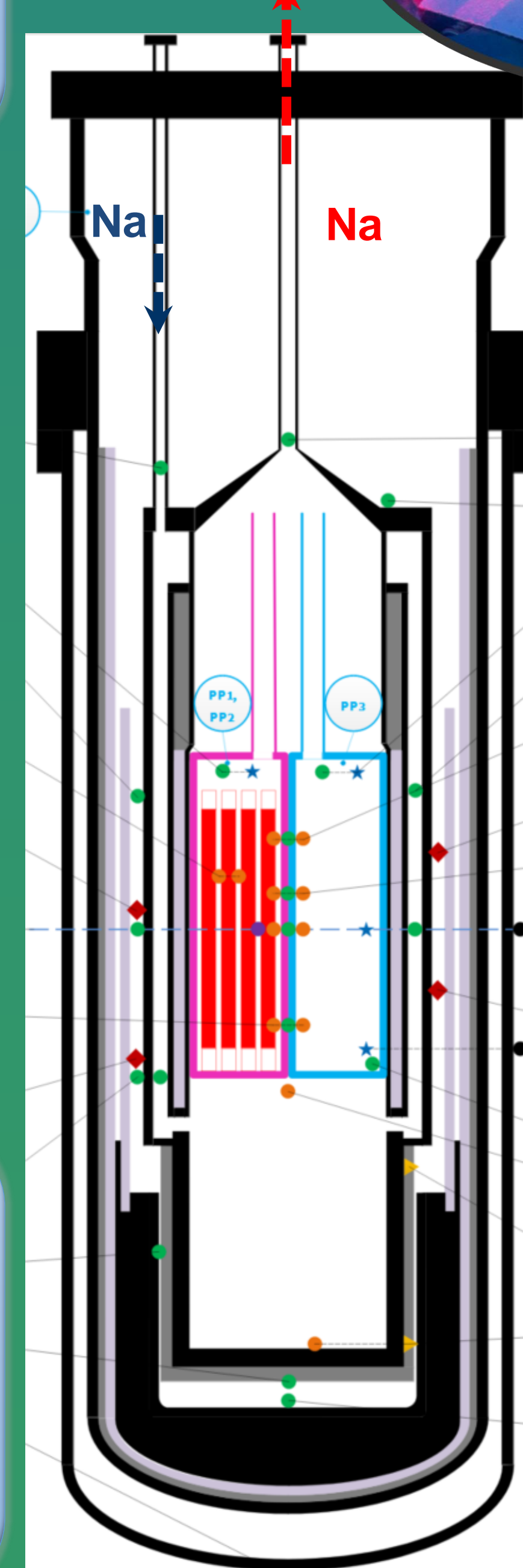
- Monitoring the breakthrough of the inter-SA walls by the corium
- Monitoring the corium relocation
- Monitoring the ∇ of the fuel pins temperature & in-vessel pressure



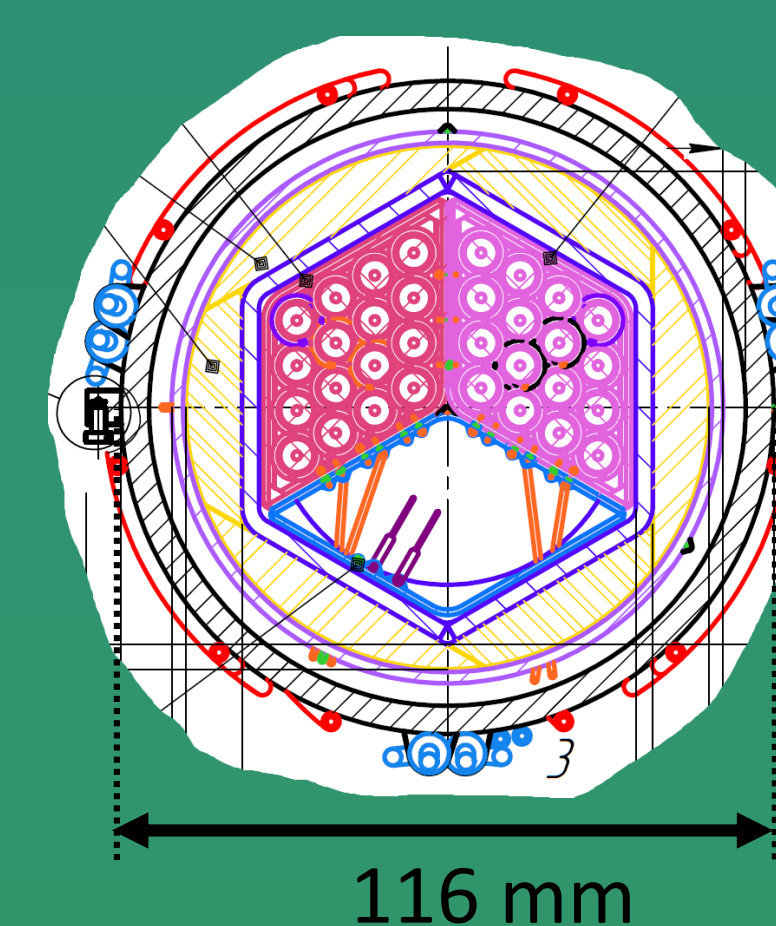
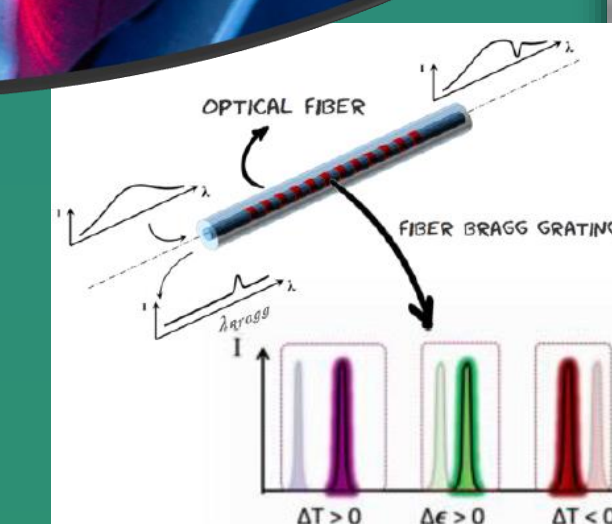
Thermocouple



CEND mineral insulated MgO sensor cable, with powdered HfO_2 emitter, all sheathed in stainless steel

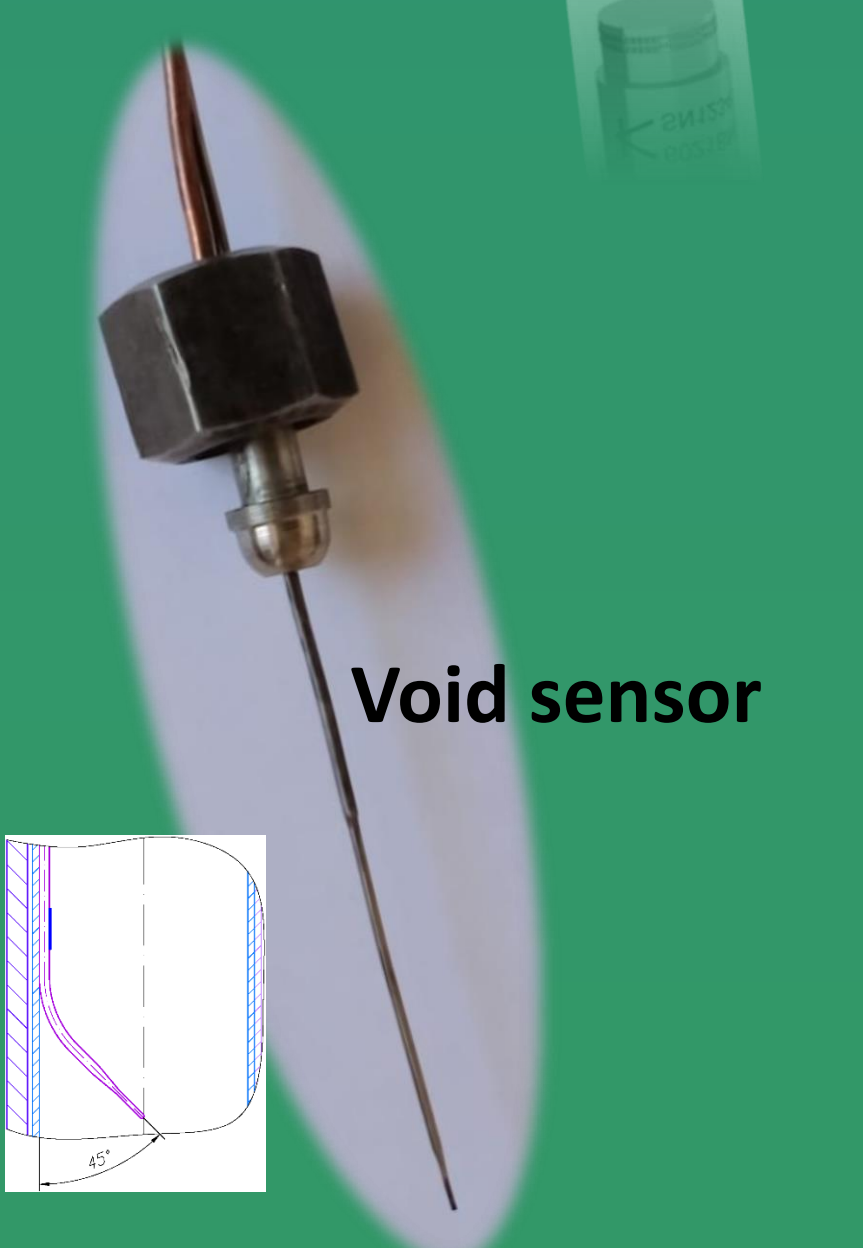
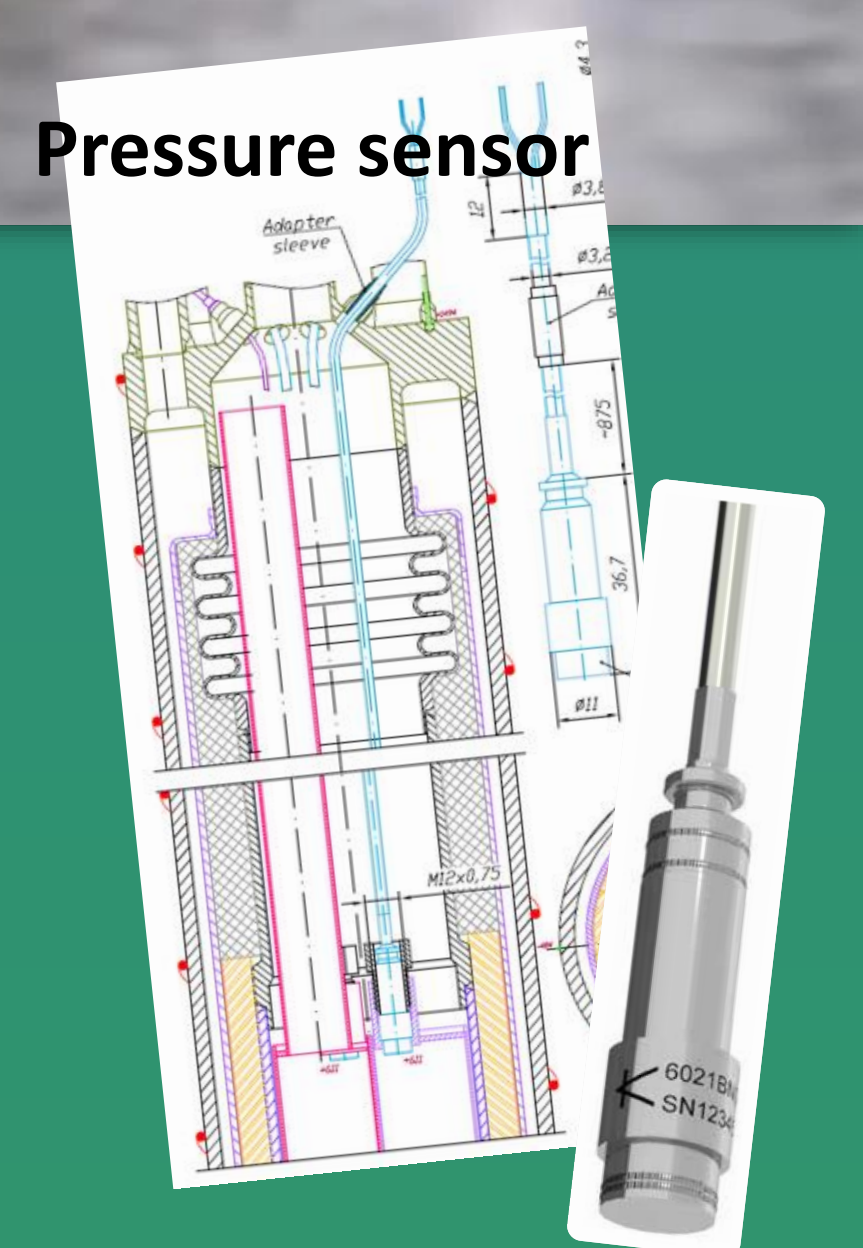


Radiation Resistant Optical Fiber Bragg Gratings inserted in a SS steel capillary used as spacer wire on few pins, dedicated to quasi-distributed temperature measurement



Fission Chamber

Pressure sensor



Void sensor

Main Constraints:

- Limited space for maximum instrumentation
- Neutron & γ radiations ($1.5 \cdot 10^{15} \text{ n.cm}^{-2}.\text{s}^{-1}$ & $0.4 \cdot 10^3 \text{ Sv.s}^{-1}$)
- Extreme temperature ($> 2000^\circ\text{C}$)
- Sodium Tightness and Compatibility
- High frequency (test duration $< 60\text{s}$)

Sensor type	Nb
Type C Thermocouple (W/Re)	36
Type K Thermocouple	32
Type E Thermocouple	6
Optical Fiber Bragg Grating Line	2
Void sensor	4
Compton Emission Neutron Detector	2
Fission Chamber	12
Dynamic pressure sensor	3