newcleo technical deck

04 June 2024 – Università degli Studi di Palermo

newcleo's reactor

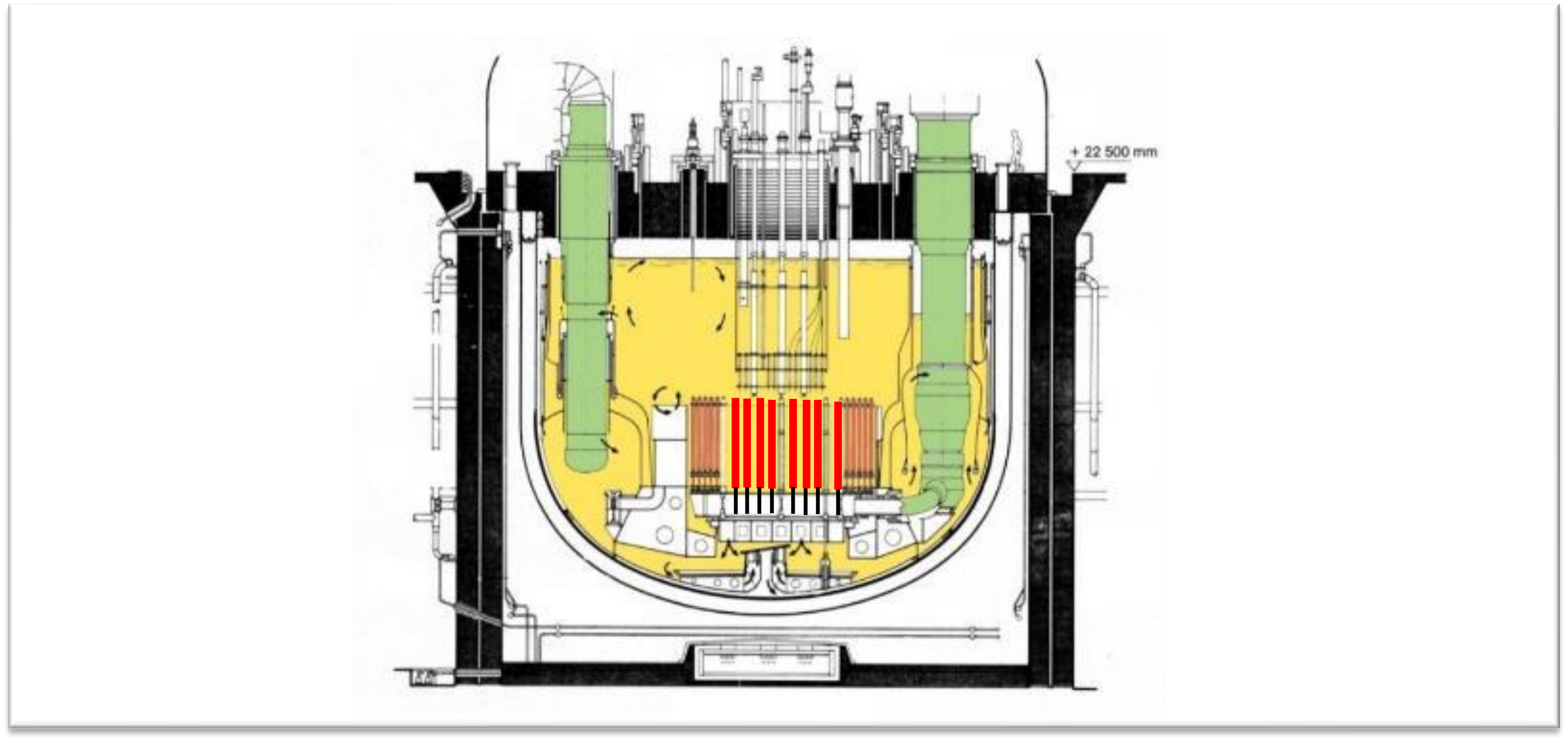
SFR experience largely transferrable to LFR

About 20 sodium-cooled fast reactors (SFR) have already been operating, some since the 1950s, and some supplying electricity commercially.

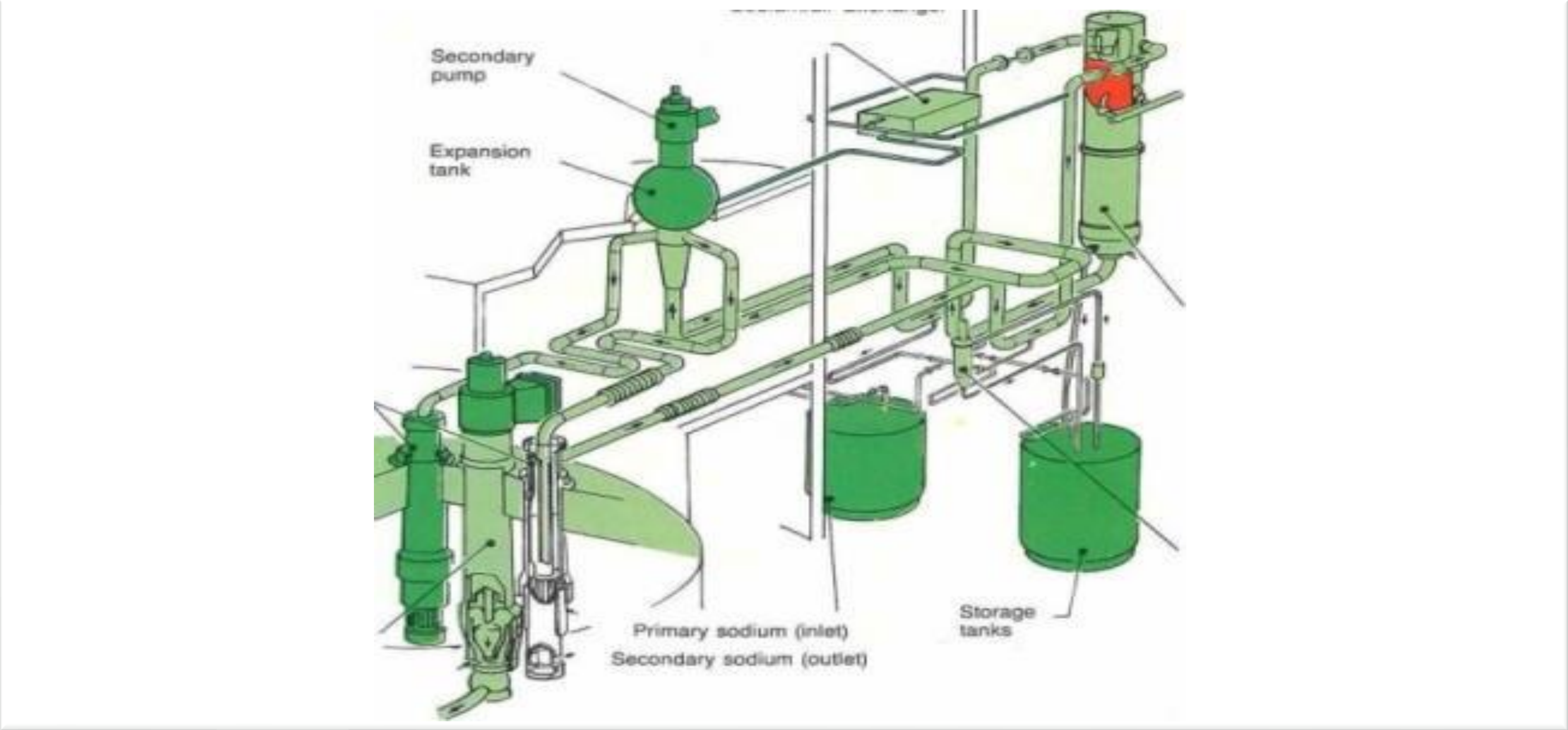
France has operated the largest SFR: Superphenix, 3000MWth, 1240MWe.

Unfortunately, the development of the SFR technology has not yet devised a commercial reactor economically competitive with the LWRs.

Fortunately, SFR experience can be almost entirely used for the development of the LFR which uses a similar fuel, functionally behave in a similar way, presents similar thermal-hydraulic and mechanical aspects.



SPX1



One out of four intermediate loops of SPX1

Simplicity of LFR-AS-200

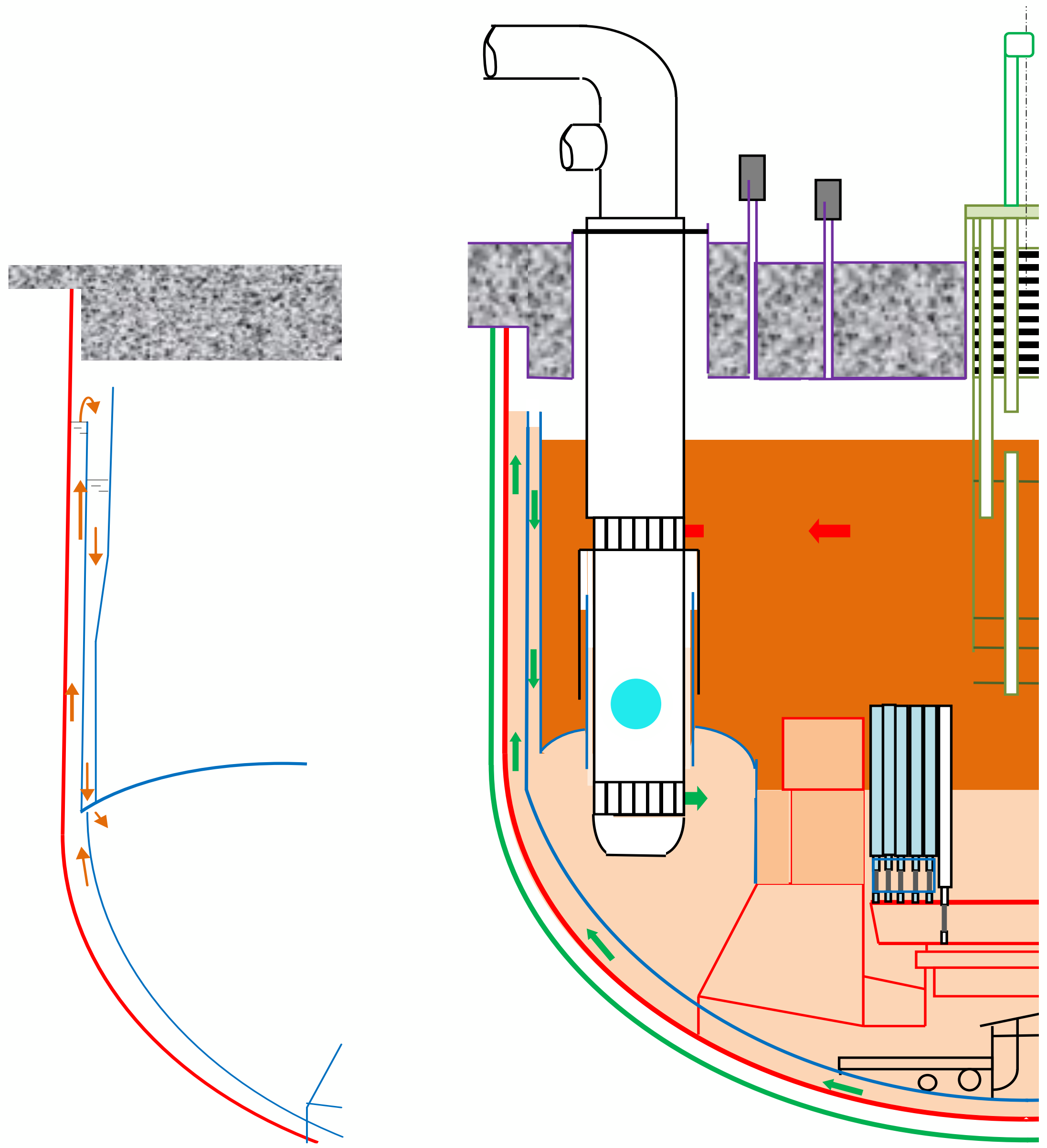
LFR-AS-200 enhances safety while dispensing of hitherto classical critical components

Components/systems no more needed	Rationale for elimination	Impact
Intermediate loop	Lead properties	Compact Reactor Building, easy operation, cost reduction (about 30% of the cost of NSSS in a SFR)
Above core structure	Use of FAs with extended stem	Reduced diameter of the RV, no need of its displacement for refuelling
In-vessel refuelling machine	Use of FAs with extended stem	Elimination of a mechanically critical component to be operated in opaque medium
“Deversoir” or equivalent component	SG-outlet window at top of the SG	Reduced diameter of the RV, reduced vibration risk
Diagrid	Self-sustaining core	No need of a component difficult to inspect
Strongback	Core supported by the roof via the barrel	No need of a component difficult to inspect. No structure fixed to the RV
“LIPOSO” , hydraulic connection pump to diagrid	Pumps in the hot collector	Elimination of a mechanically critical component
Flywheel on the pump system	Use of rotating lead inertia	Smaller footprint on the reactor roof
Core shielding assemblies	Use of the ASIV	Reduced diameter of the RV, simplicity
Blanket assemblies	No net Pu generation	Reduced diameter of the RV, simplicity, increased proliferation resistance

The STSG-Pump assembly, a key for compactness

From:	To:

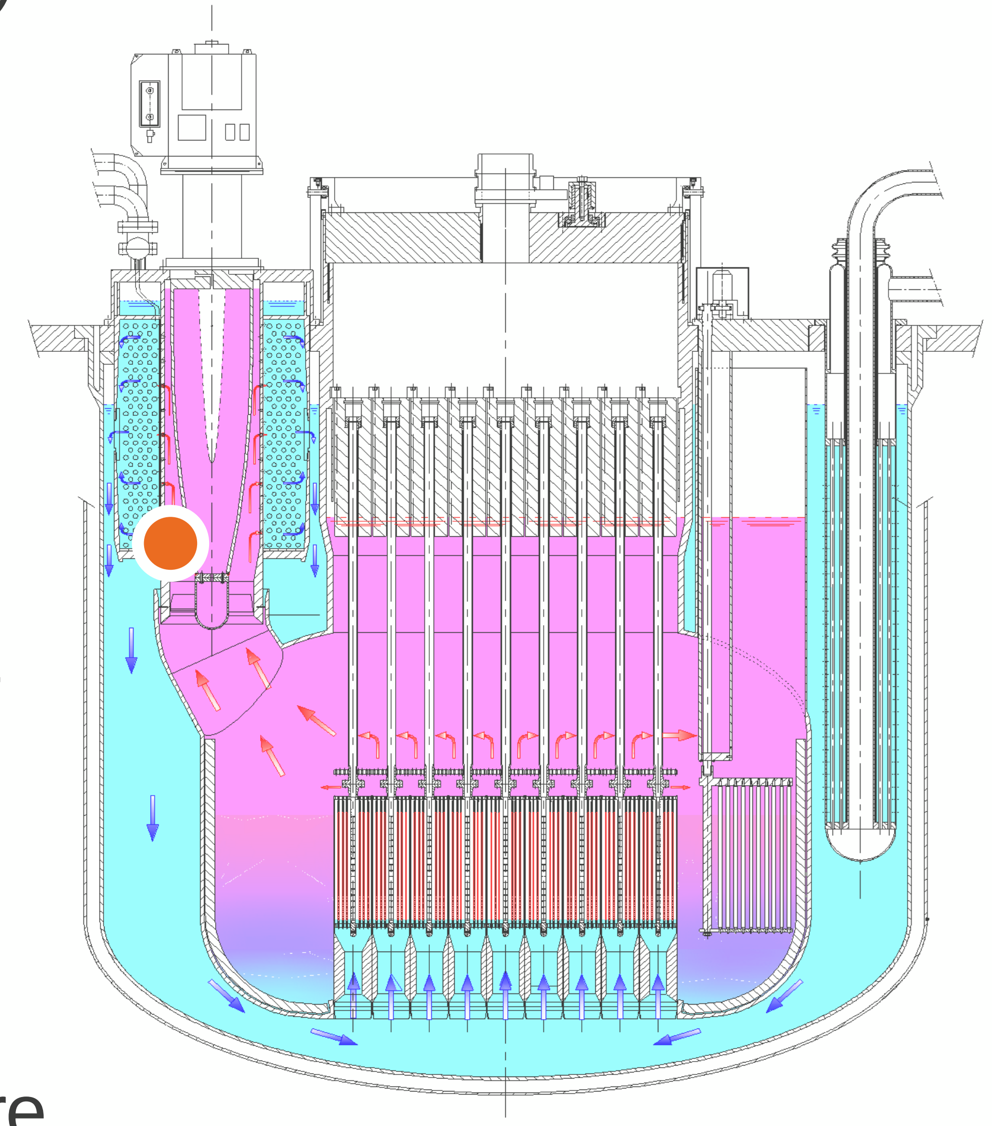
long IHX (●) with top **inlet** window and bottom **outlet** window



short Spiral-tube SG with bottom **inlet** (●) and top **outlet** and integrated primary pump

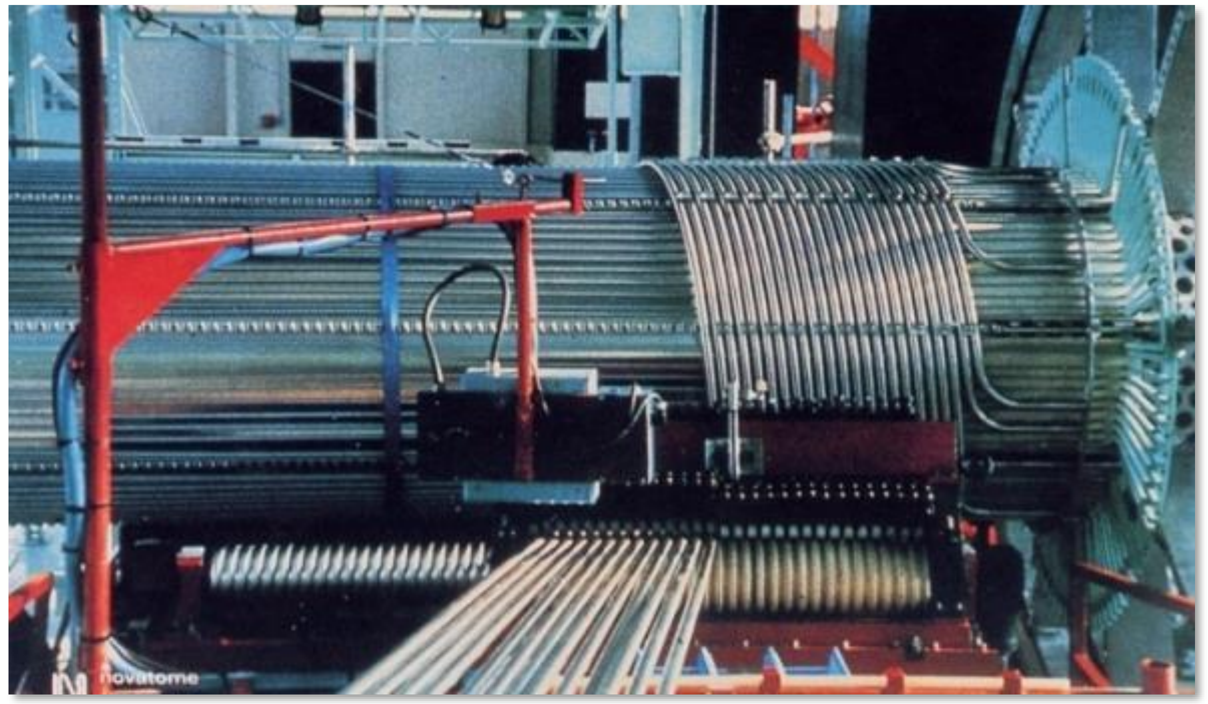
ADVANTAGES:

- No collectors inside the vessel
- Short, compact SG, reduced RV height
- **No "Deversoir"**, reduced RV diameter
- No risk of steam release deep in the melt and large lead displacement
- No risk of cover gas entrance into the core



The Spiral-Tube Steam Generator of *new*cleo's LFR

The Spiral-Tube Steam Generator (STSG) is mechanically forgiving as the Helical-Tube SG (HTSG), but more compact and of easier manufacturing



HTSG of SPX1

Mockup of a STSG after testing at Saluggia ENEA lab

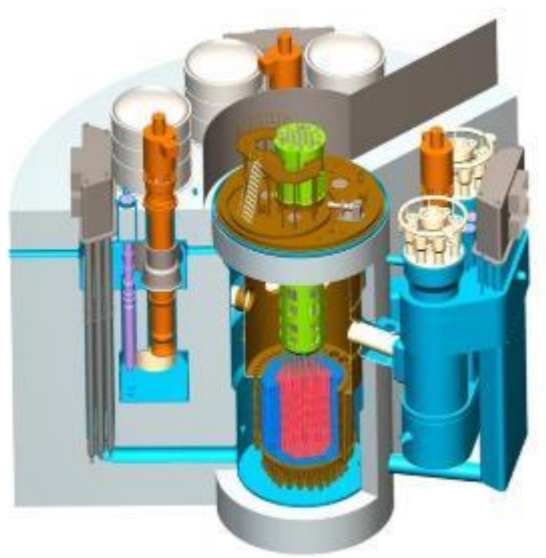
LFR-AS-200 main SG parameters	
Number of SGs and Pumps	6
Outer diameter of tubes [mm]	18
Number of tubes	100
Steam Generator shell-side pressure loss [bar]	0.2
Active length of the tubes [m]	34

R&D gap: uniform radial primary flow rate distribution in the bundle

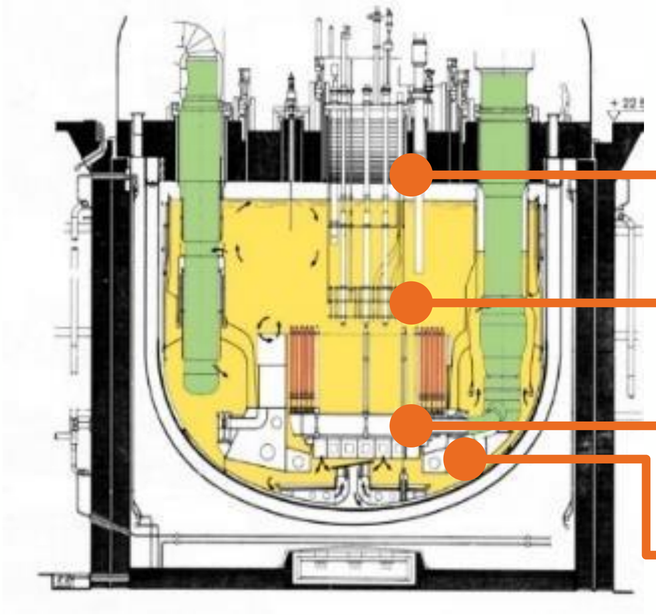
The self-sustaining core

Refuelling issue solved with Fuel Assemblies with extended stem

From:	To:
Fuel Assemblies **immersed in the melt** handled by **an in-vessel + ex-vessel Refuelling Machine**	Fuel Assemblies with stem **extended above the lead free level** handled by an **ex-vessel Refuelling Machine** (●)



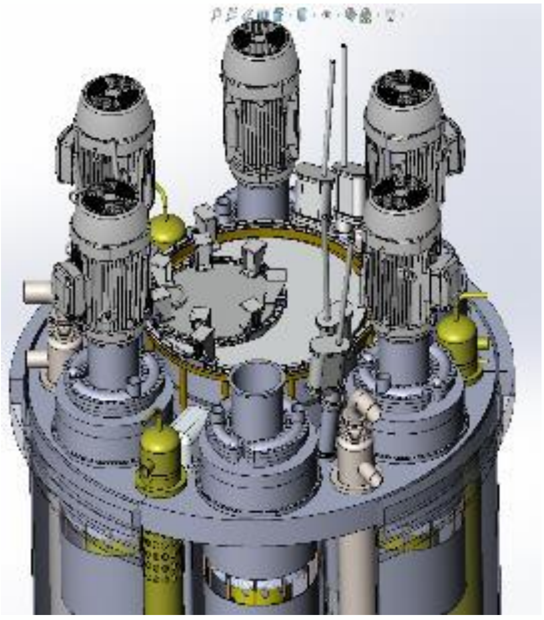
BREST

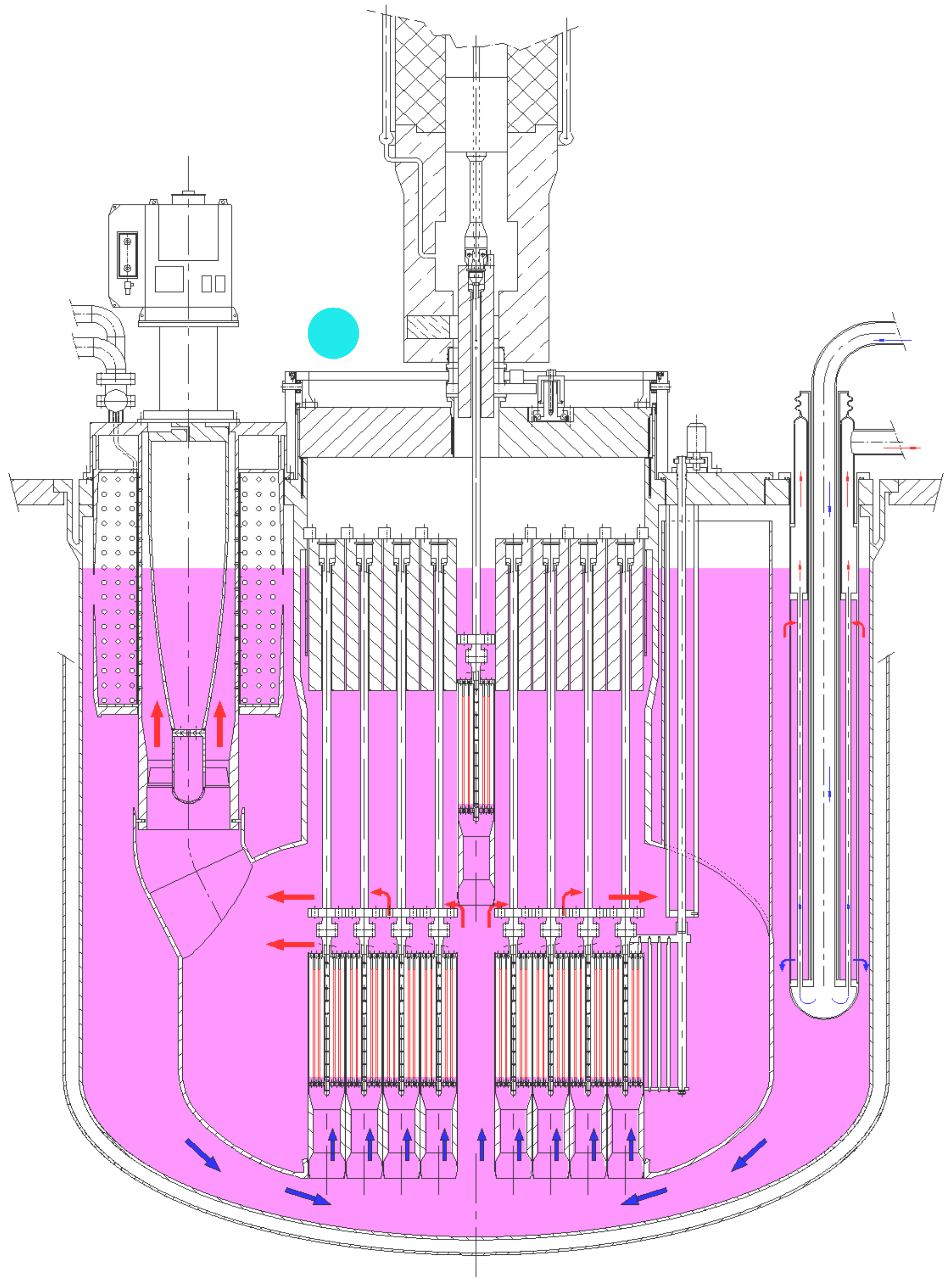


SPX1

ADVANTAGES:

- No in-vessel Refuelling Machine
- No Above Core Structure
- No Diagrid
- No Strongback

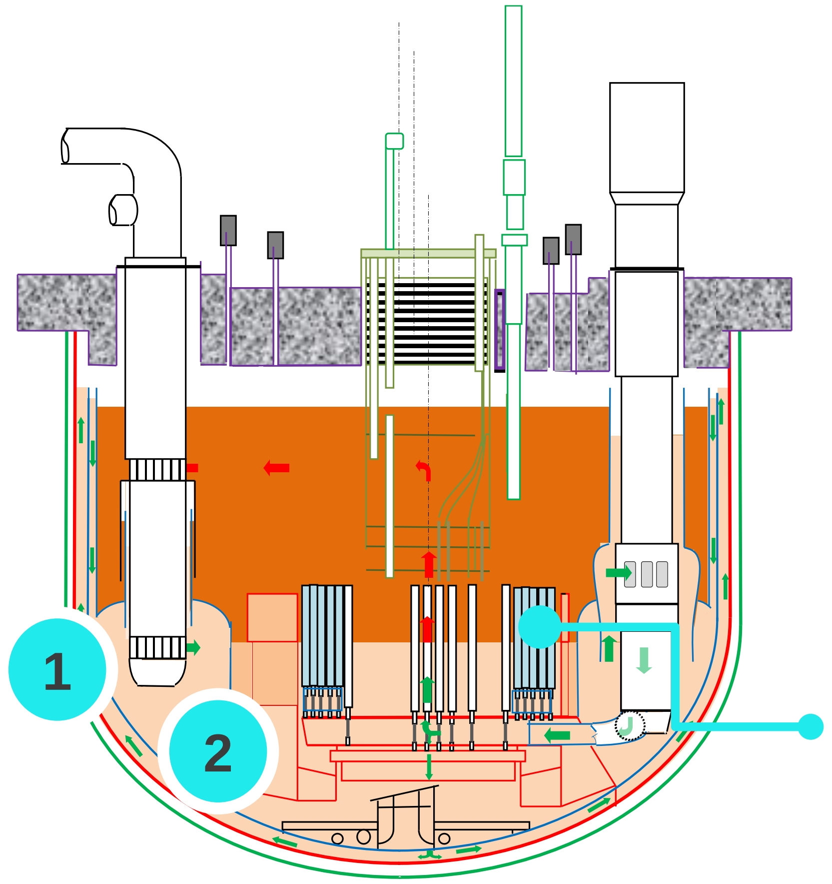




The Amphora-Shaped Inner Vessel

From:

Inner Vessel, **large** (1) at top and **smaller** (2) at the bottom, containing **Shielding Assemblies** (and Breeding Assemblies)

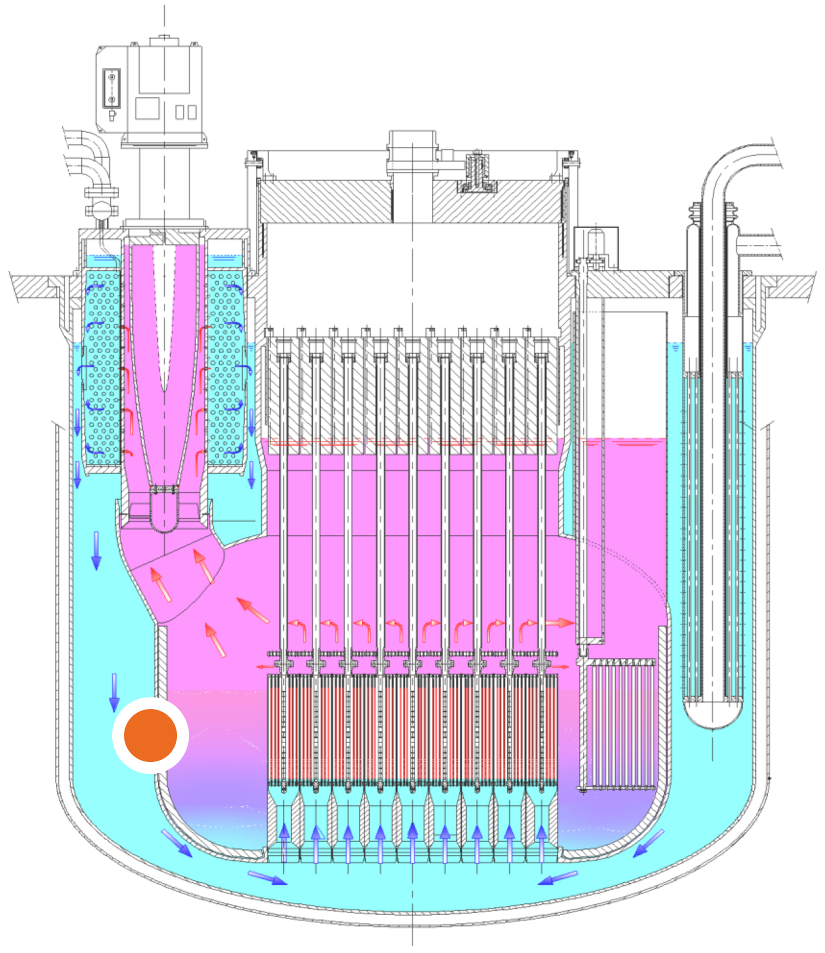


Assemblies

Fuel: 364
Fertile: 233
Neutronic protection: 1264

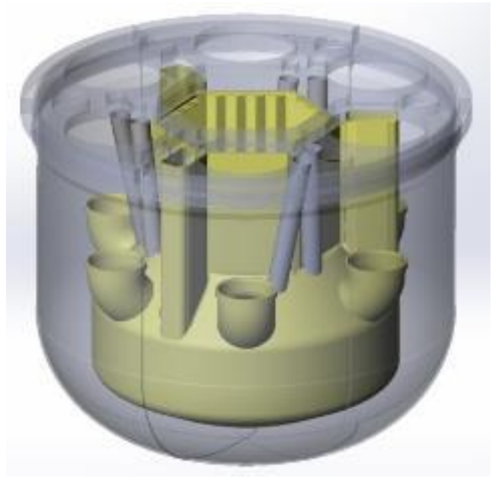
To:

Amphora-Shaped Inner Vessel (●), no **Shielding Assemblies** (and no Breeding Assemblies)



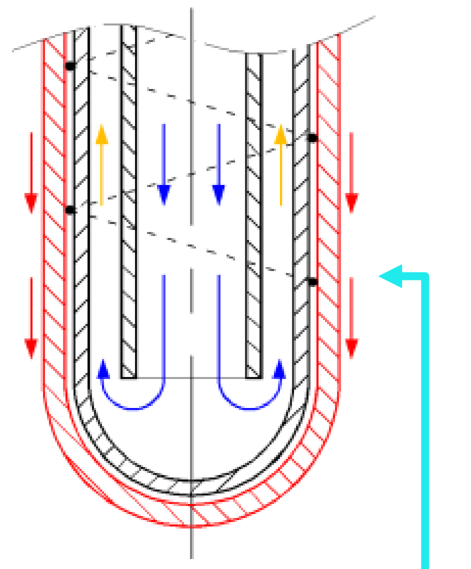
ADVANTAGES:

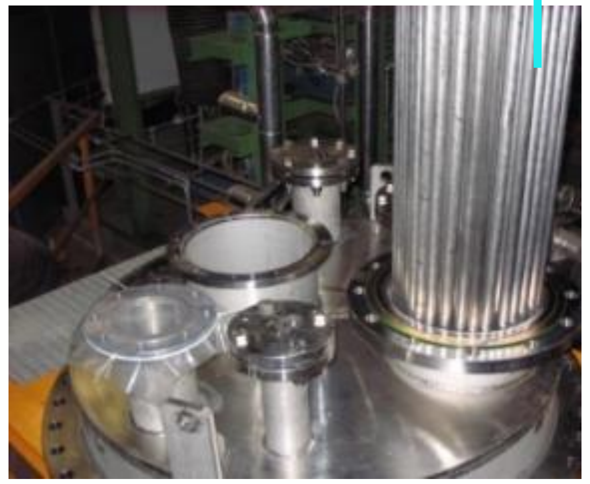
- **No Shielding Assemblies**
- Reduced RV diameter
- Increased availability
- Reduced waste inventory



Assemblies
Fuel: 61

Active/passive DHR systems

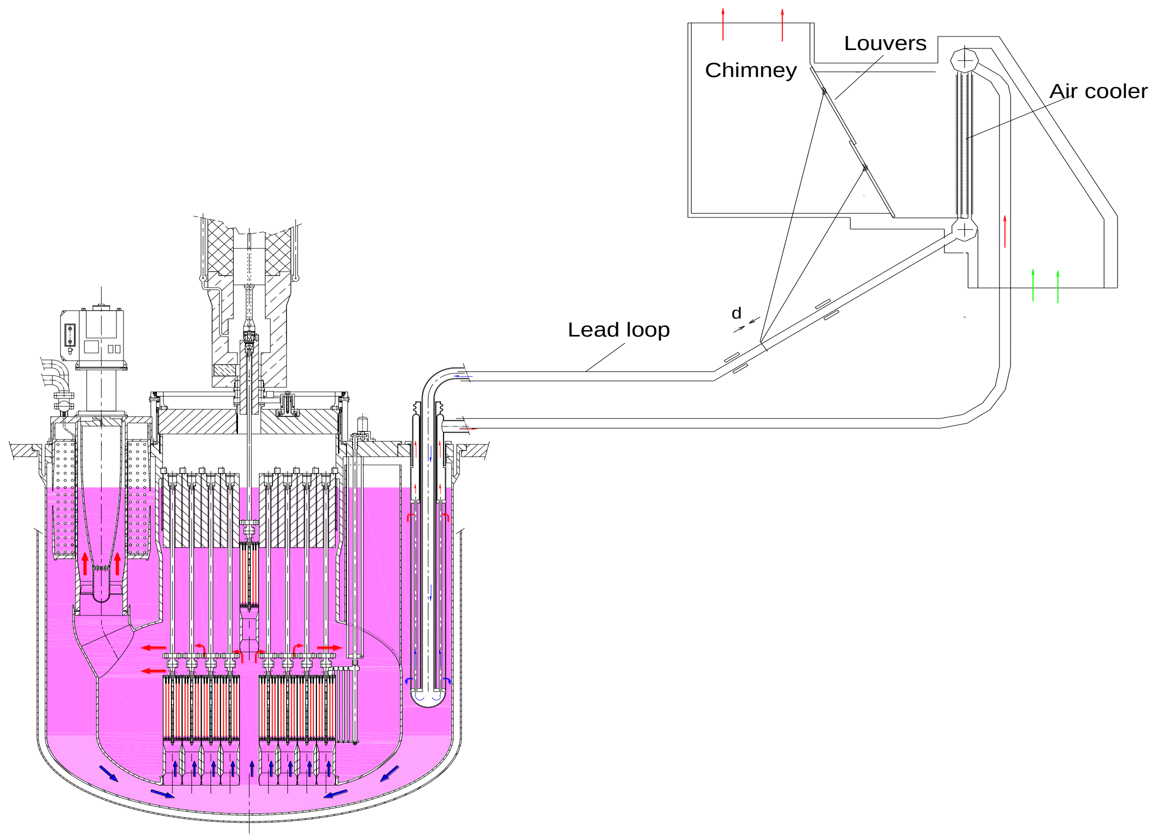




DHR1: Three water-steam loops passively operated with water as heat sink

Lead-water, double-wall bayonet-tube bundle heat exchanger at Brasimone site.

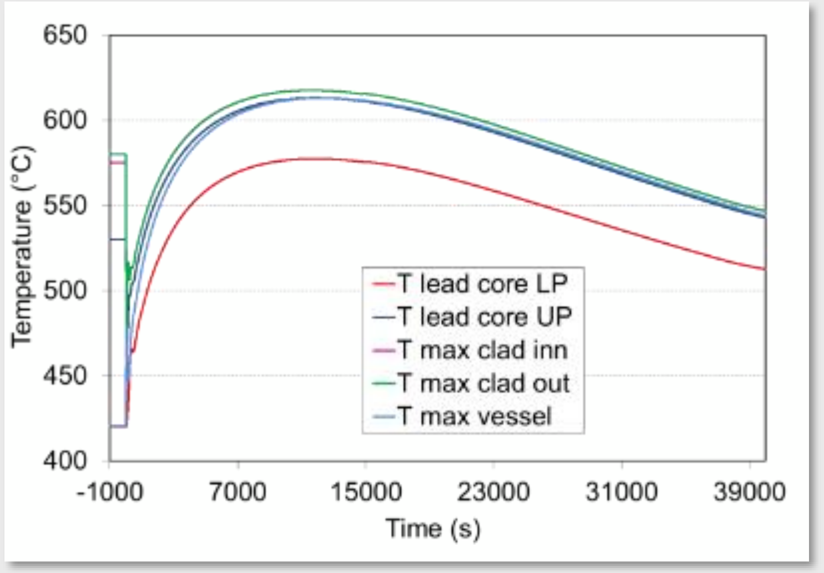
Improvements are being studied



DHR2: Three lead loops passively actuated and operated with air as heat sink

Thermal expansion of the cold leg of the lead loop opens the louvers of the air coolers when lead temperature exceeds 400°C.

R&D gap: Alternative solutions are under exploration for research of simplicity



Fukushima-like accident (complete station blackout, no active systems available)

- reactor in safe condition
- proper passive cooling
- structural integrity ensured

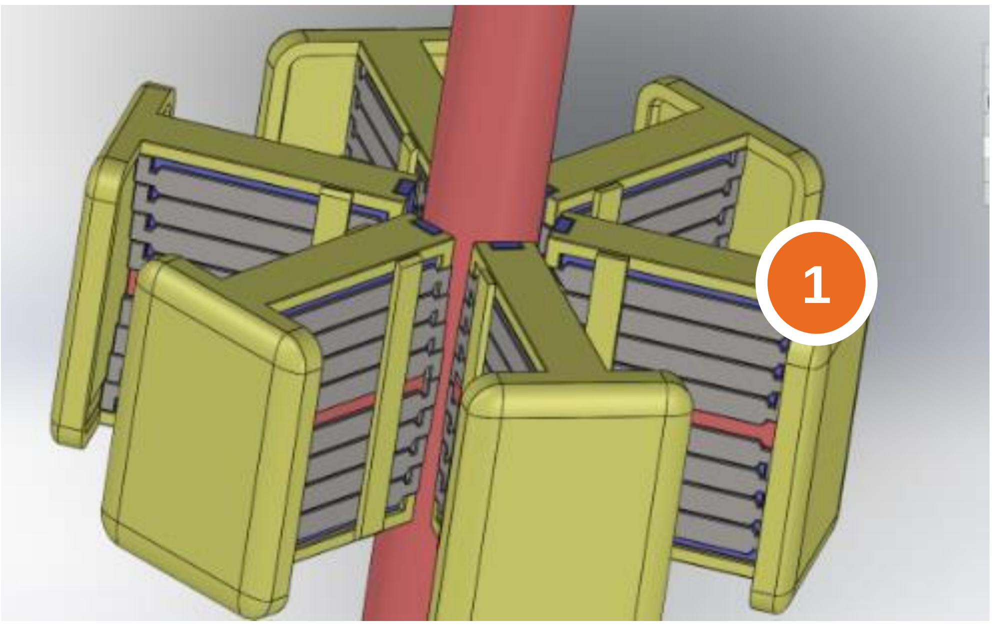
newcleo
Futurable Energy

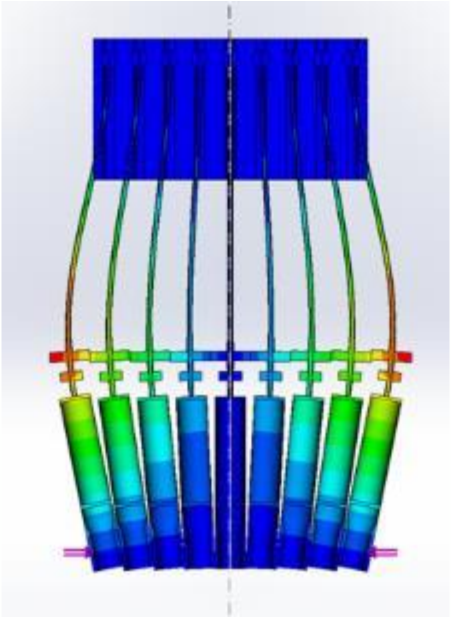
Active/passive shut down

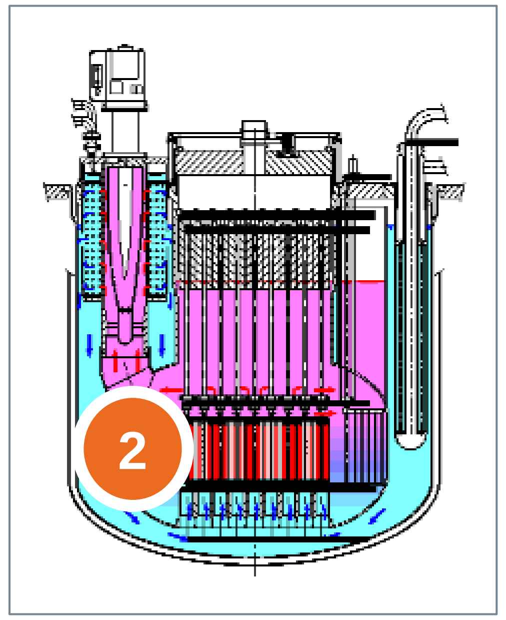
Logics and operators backed up **by passively actuated systems** to shut down the reactor.

In a LFR there is a margin of hundreds K between the operating temperature and the safety limit, hence, e.g., thermal expansion can be used to open the core and shut down the reactor in case of failure of logics or of operator intervention.

1 2 Bi-metallic expansors open and shut down the core when temperature exceeds normal operating limits.

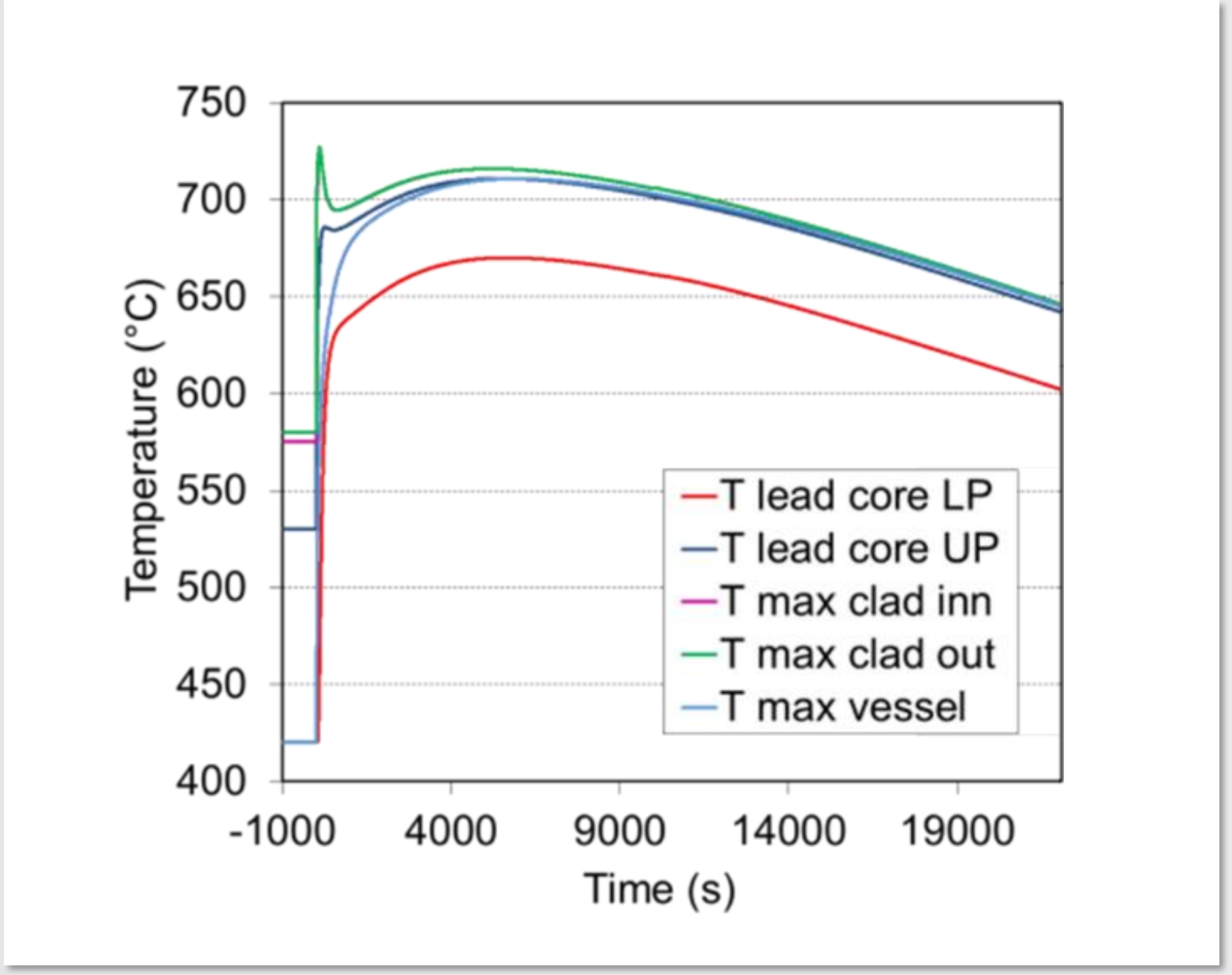






R&D gap: compromise between FA flexibility and seismic design

Passive shut down and passive DHR systems to face the Unprotected Loss Of Offsite Power (ULOOP)



Fast Reactors can be fuelled with waste of LWRs

Depleted uranium →

Uranium from spent fuel →

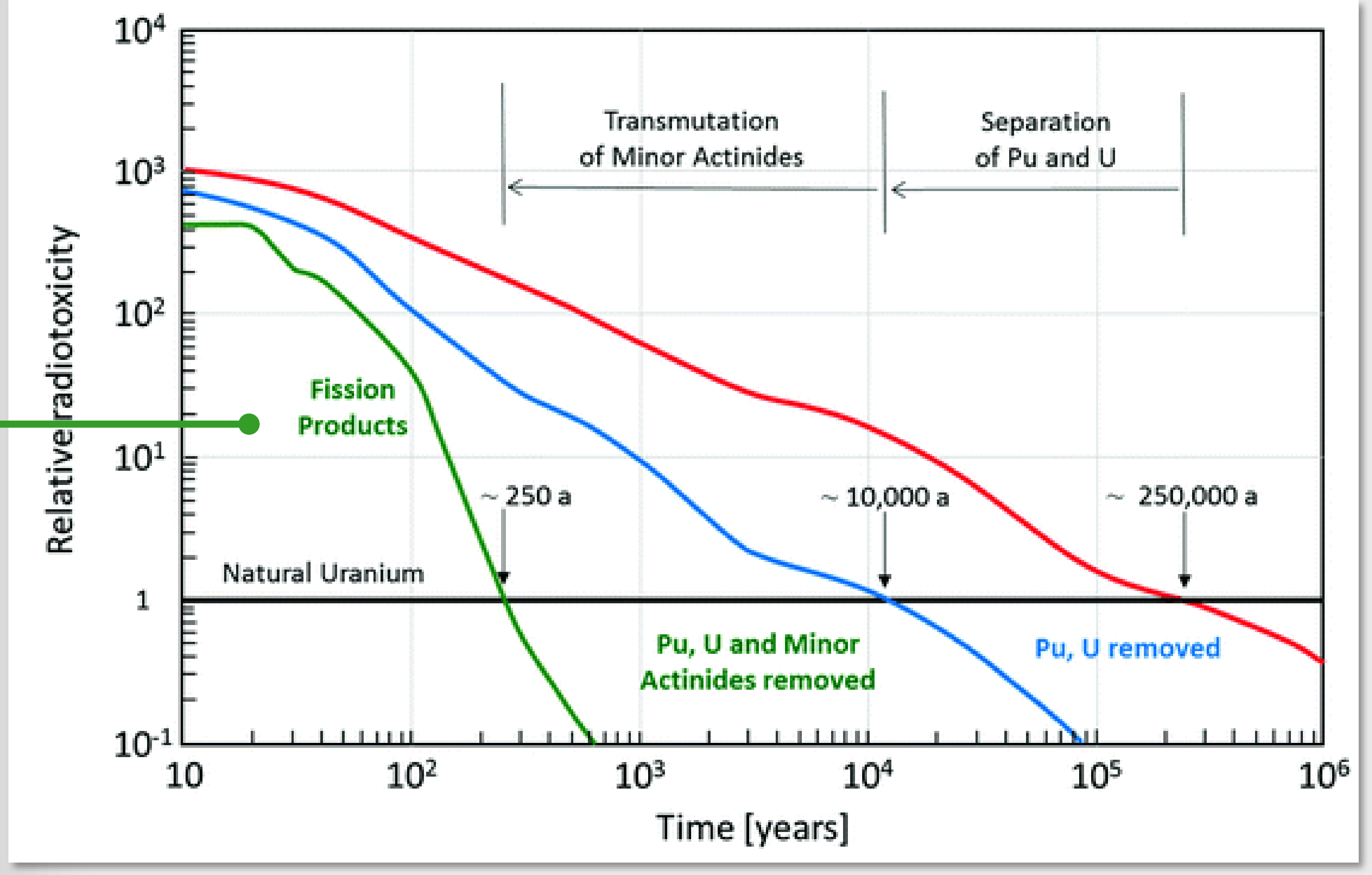
Plutonium →

Minor actinides →

Fast Reactors
(with fuel reprocessing)

→ **Electric energy**

→ **Fission fragments**



One TWhe results in the production of 100 kg of fission fragments

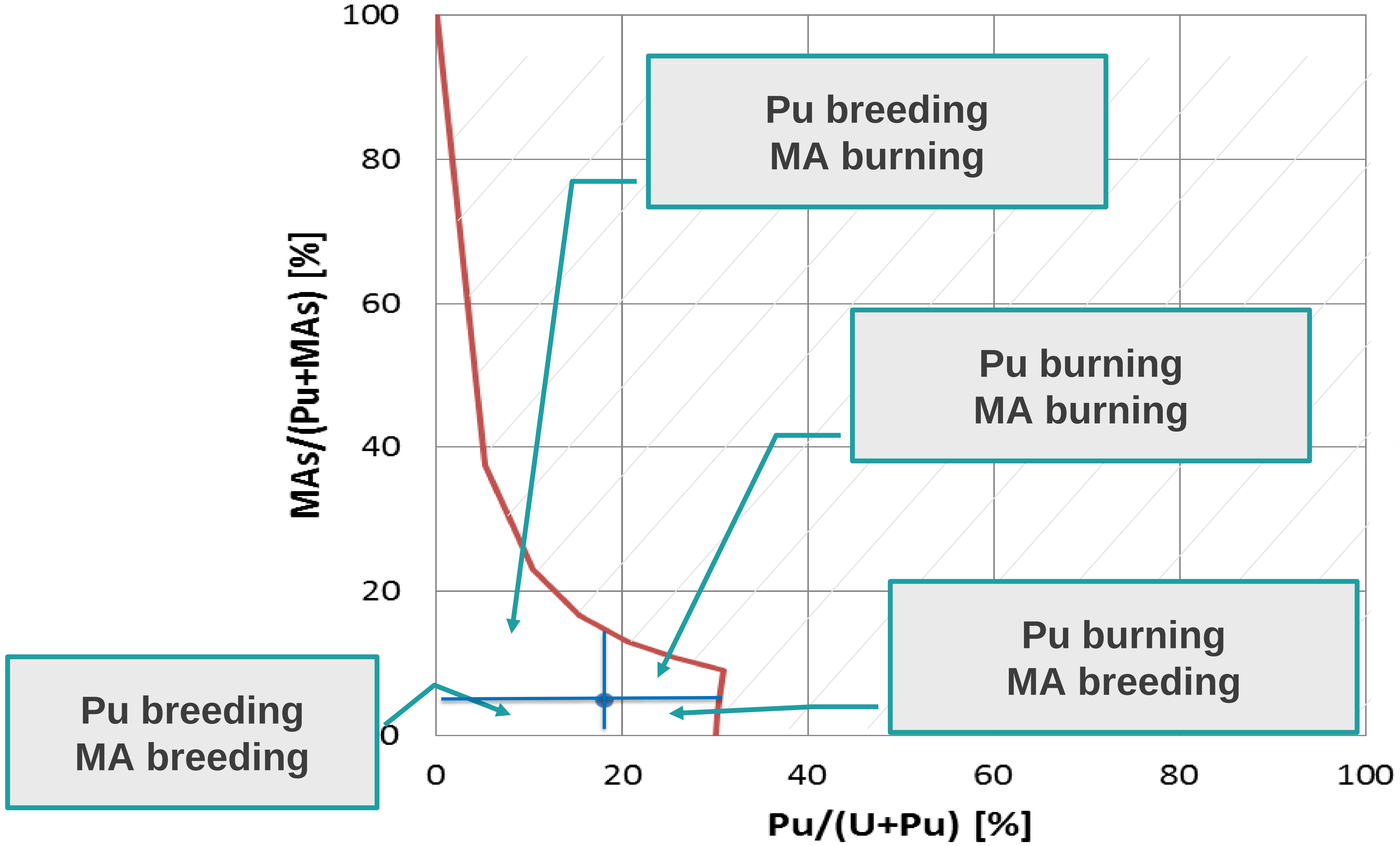
Fast Reactors combined with fuel reprocessing can reduce radiotoxicity of the waste to be stored in geological repositories

Fuel cycle potential of LFR

A LFR can effectively act as:

Pu breeders or burners

MA breeders or burners



Transuranic masses at equilibrium for an **adiabatic** ELSY (600MWe LFR) (Artioli et al., 2010)

- **Only natural or depleted Uranium** as make-up fuel;
- **Only fission fragments** as nuclear waste

Element	Composition (%)
Uranium	81.94
Plutonium	17.18
Neptunium	0.08
Americium	0.64
Curium	0.16

Thank you