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National Status on LFR Development: EURATOM

International Conference Room, Campus Innovation Center (CIC)
Tamachi Campus, Tokyo Institute of Technology,
Tokyo – Japan 9 November, 2012

Seminar :
Activities for Lead-cooled Fast Reactors (LFR)
in Generation IV International Forum (GIF)

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Contents

Introduction

Development of a new reactor technology must follow gradual and progressive steps to reach maturity

- Identification of main issues related to the technology
- Small scale to Large scale experimental facilities
- Irradiation tests, fuel and materials development

and try to:

- Exploit full potential of the coolant
- Include from the beginning Safety in the Design
- Show sustainability of the fuel cycle
- Define and evolve a reference conceptual design of the FOAK

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EURATOM – LFR FP7 Related projects

The most relevant projects for the LFR technology were focused to provide the necessary design solutions, input data, methods and tools and strategic research infrastructures. In particular:

CDT-FASTEF (Central Design Team for a Fast Spectrum Transmutation Experimental Facility - MYRRHA) was aimed at designing a fast spectrum irradiation facility operating in subcritical and critical modes.

LEADER (Lead-cooled European Advanced DEmonstration Reactor) had the objective to finalize the design of a large-size LFR and to develop the conceptual design of a scaled demonstrator with the following main goals:

Develop a LFR reference configuration, now identified as the European LFR (**ELFR**), representing a critical system with a closed fuel cycle meeting the Gen-IV goals

Develop the conceptual design of a scaled demonstrator (**ALFRED**) of a relevant size (300MWth) using currently available technology in order to proceed to construction in a relatively short time frame.

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Additional EURATOM – LFR FP7 Related projects (non exhaustive)

- **SARGEN-IV** (Proposal for a harmonized European methodology for the safety assessment of innovative fast reactors)
- **SILER** (Seismic-Initiated events risk mitigation in LEad-cooled Reactors), project
- **MATTER** (MATerials TEsting and Rules), researches to perform careful studies of materials behaviors in Gen-IV operational conditions and to find out criteria for the correct use of these materials in relevant reactor applications
- **ADRIANA** (ADvanced Reactor Initiative And Network Arrangement), proposed to setting up the network dedicated to the construction and operation of research infrastructures in support of liquid metal fast reactors development, through
- **THINS** (Thermal-Hydraulics of Innovative Nuclear Systems), project devoted to important crosscutting thermal-hydraulic issues
- **FREYA** (Fast Reactor Experiments for hYbrid Applications), project aimed at extending the investigations of the subcritical configurations
- **ANDES** (Accurate Nuclear Data for nuclear Energy Sustainability), improvement of the accuracy, uncertainties and validation of nuclear data and models.
- **FAIRFUELS** (FAbrication, Irradiation and Reprocessing of FUELS)
- **ACSEPT** (Actinide reCycling by SEParation and Transmutation)

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LFR Infrastructures in Europe

34 Experimental Facilities are in Operation or under Construction in 10 European Research Institutions

1 ATHENA (Advanced Thermal Hydraulic Experiment for Nuclear Application)
2 CICLAD (Corrosion Induced by the Circulation of a LeAD alloy)
3 CIRCE (Circolazione Eutettico)
4 COLONRI I & II (Convectional Loop)
5 CALLISTO (Static LM embrittlement)
6 COMPLOT (COMPonent Loop Tests)
7 CORELLA (Corrosion Erosion Test Facility for Liquid Lead Alloy)
8 CORRIDA (Corrosion in Dynamic Alloys)
9 COSTA (Corrosion test stand for stagnant liquid lead alloys)
10 CRAFT (Corrosion Research for Advanced Fast reactor Technologies)
11 CRISLA (Creep-to-Rupture Tests in Stagnant Lead Alloys)
12 ELEFANT (Experimental LEad FAcility for Neutron production Targets)
13 E-SCAPE (European SCAled Pool Experiment)
14 FRETHME (Fretting Tests in Heavy Liquid Metal)
15 HELENA (Heavy Liquid Metal Loop for small components testing)
16 HELIOS3 (Heavy Liquid Oxygen conditioning System 3)
17 KALLSTARR (KALLA Steam Generator Tube Ruprture Facility)
18 LECOR (Lead Corrosion)
19 LEVUSE (LBE Vessel for UltraSonic Experiments)
20 LIFUS 5 (Heavy liquid metals interaction with water)
21 LIMETS1 (Liquid Metal Embrittlement Testing Station 1)
22 LIMETS2 (Liquid Metal Embrittlement Testing Station 2)
23 LIMETS 3 (Liquid Metal Test Facility)
24 LINCE (forced convection loop)
25 LISOR Lead-Bismuth Loop
26 NACIE (Natural Circulation Experiment)
27 OSCAR (Oxygen Sensor Calibration Rig)
28 RHAPTER (Remote HAndling Proof of principle Test Experimental Rig)
29 SCC at JRC (Lead loop for SCC testing at JRC-IE, Petten)
30 SLEEVE (Small Lead Bismuth Eutectic Evaporation experiment)
31 STELLA (Standard Technology Loop for Lead Alloy)
32 TALL (Thermal-hydraulic ADS Lead-bismuth Loop)
33 TELEMAT (Test Loop for Lead Material testing)
34 THEADES (Thermal-hydraulics and ADS Design)

GUINEVERE and MYRRHA

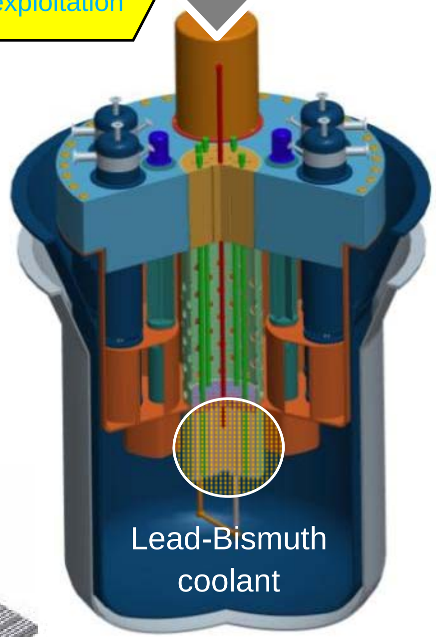
MYRRHA project schedule

Accelerator

(600 MeV - 4 mA proton)

Reactor
Subcritical mode - 65 to 100 MWth

2010-2014	2015	2016-2018	2019	2020-2022	2023	2024-
Front End Engineering Design	Tendering & Procurement	Construction of components & civil engineering	On site assembly	Commissioning	Progressive start-up	Full exploitation



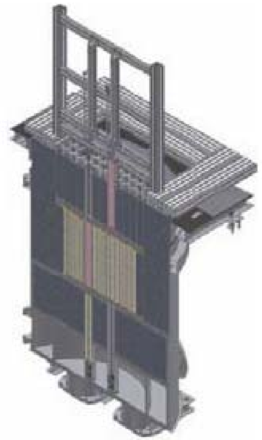
MYRRHA Multipurpose Flexible Irradiation Facility

MYRRHA (estimated cost - 960 M€)

Accelerator Driven System – ETPP of LFR Technology
FP7 CDT project (Myrrha design) ends March 2012
Front End Engineering Design contract to be awarded by the end of 2012
SCK•CEN entered pre-licensing phase with the Belgian Safety Authorities

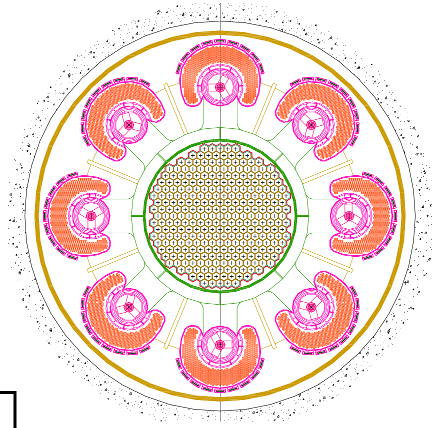
GUINEVERE

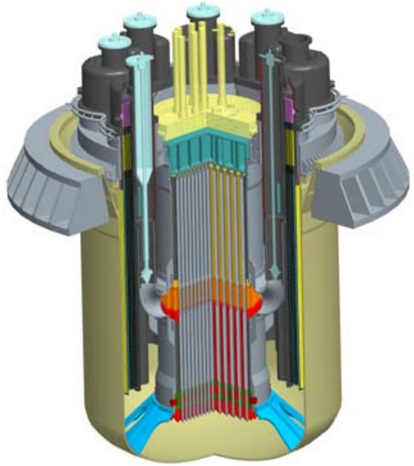
Zero-Power facility – solid Lead – critical and sub-critical operation
Nuclear data, nuclear instrumentation, Keff measurements, code validation
Criticality reached in February 2011
Subcritical coupling performed in October 2011

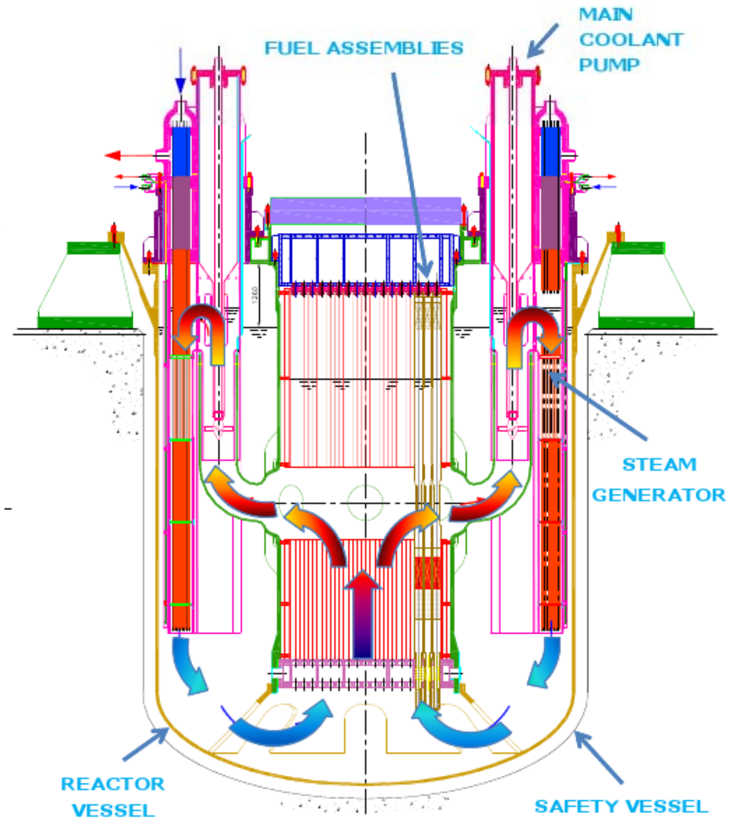


ALFRED
Reactor Arrangement

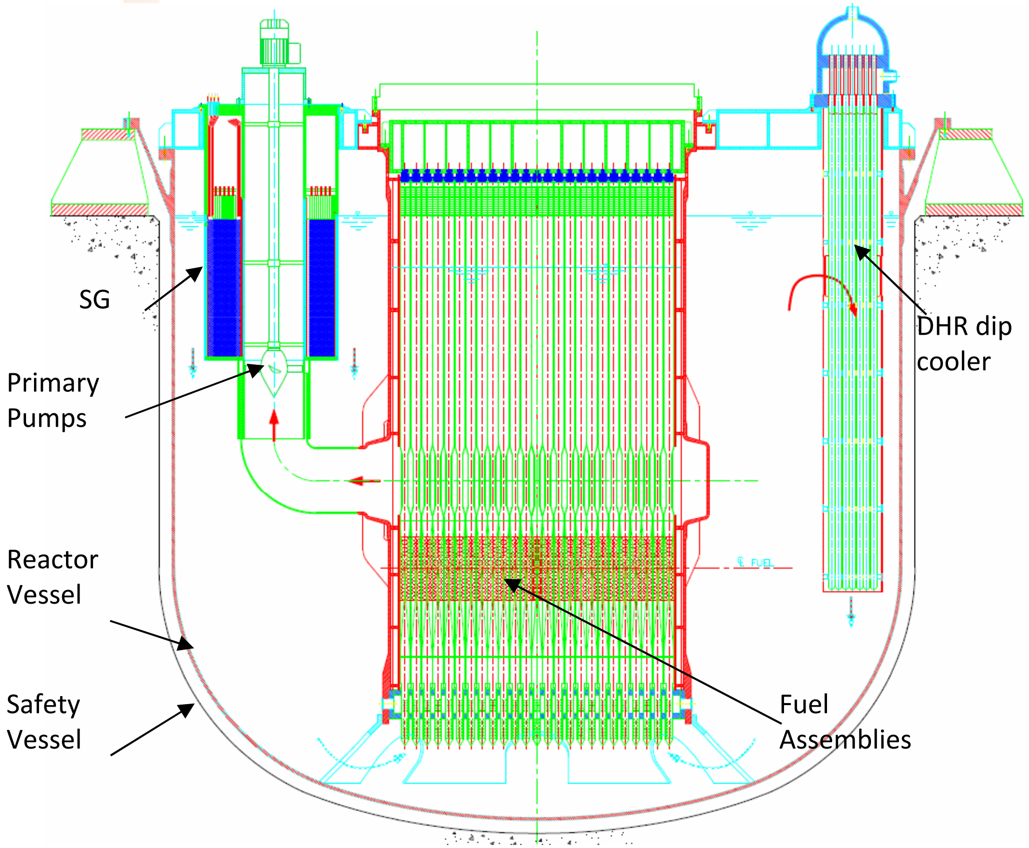
Electrical Power (MWe)	~123 MWe (300 MWth)
Fuel Clad Material	15Ni-15Cr-Ti (coated)
Fuel type	MOX max Pu enrich. 30%)
Steam generators	Bayonet type with double walls, Integrated in the reactor vessel, Removable
DHR System	2 diverse and redundant systems (actively actuated, Passively operated)
DHR1	Isolation Condenser connected to Steam Generators: 4 units provided on 4 out of 8 SGs
DHR2	Duplication of DHR1 260% total power removal







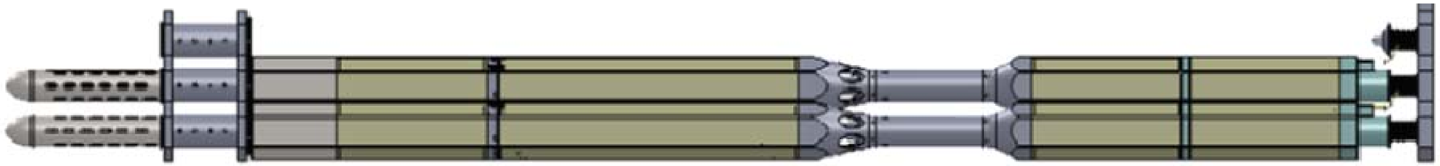
The Industrial size reference plant
ELFR – European Lead Fast Reactor

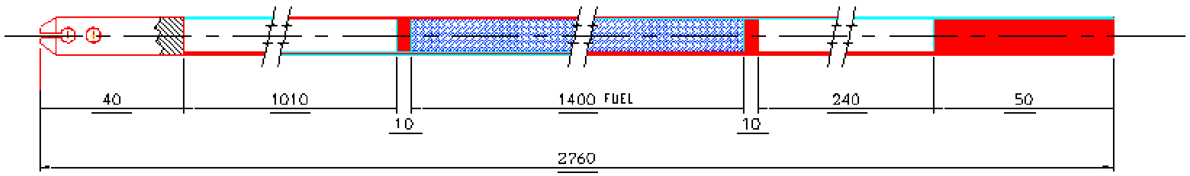


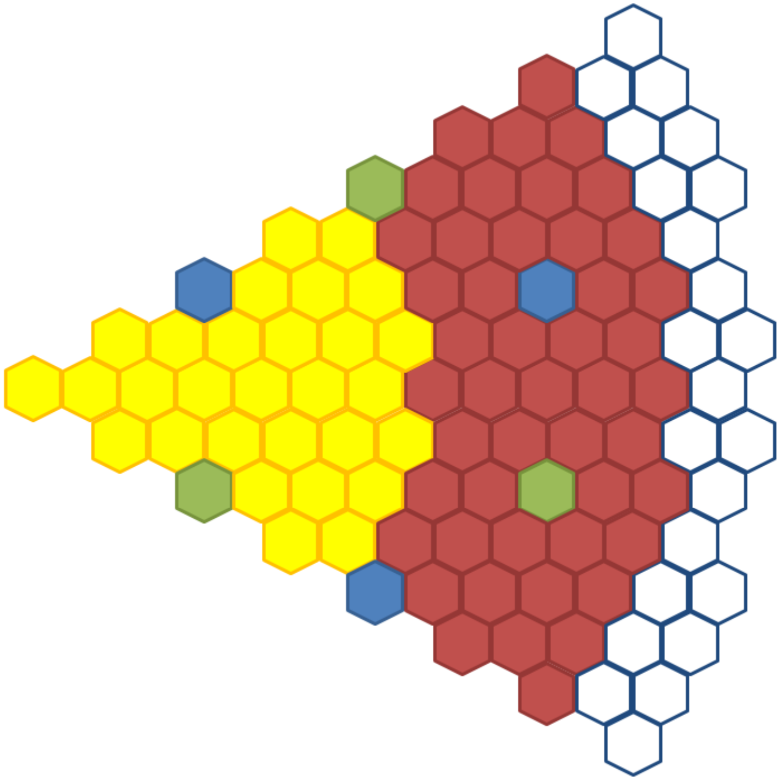
ELFR

- **Power: 1500 MW(th), 600 MW(e)**
- **Core diameter, 4.5 m**
- **Core height, 1.4 m**
- **Core fuel MOX (first load)**
- **Coolant temp., 400/480ºC**
- **Maximum cladding temp., 550ºC**
- **Efficiency: ~42%**

ELFR – FA and Core Configuration

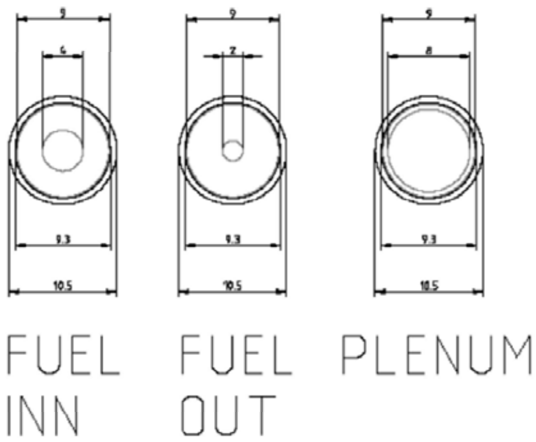


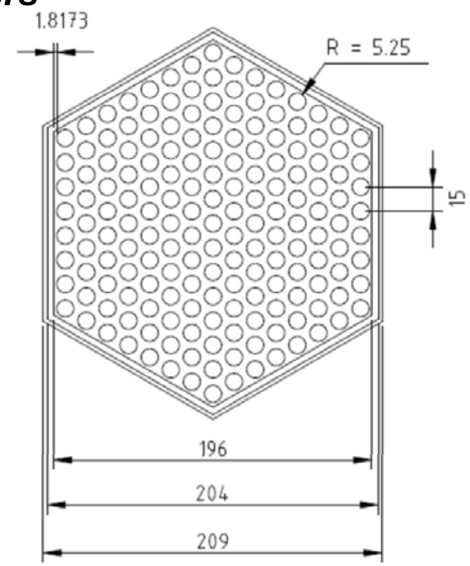




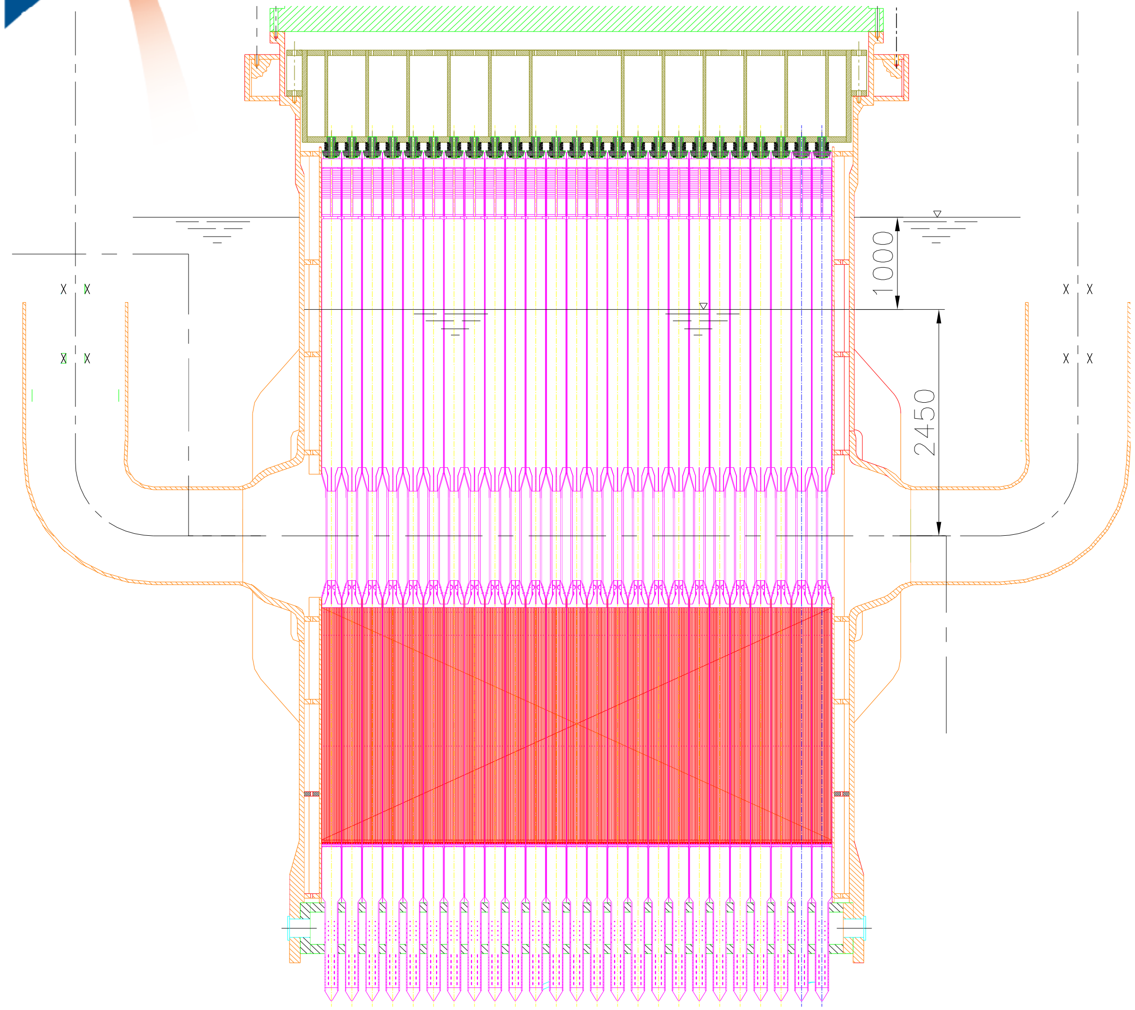
STRATEGY:
-“Adiabatic” core

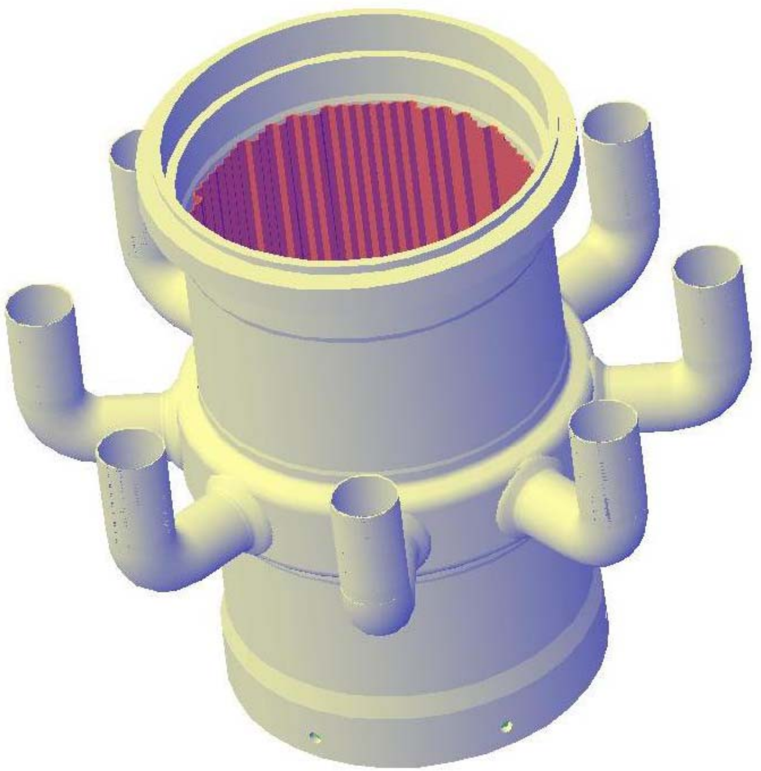
power distribution flattened with two zone different hollow pellets diameters



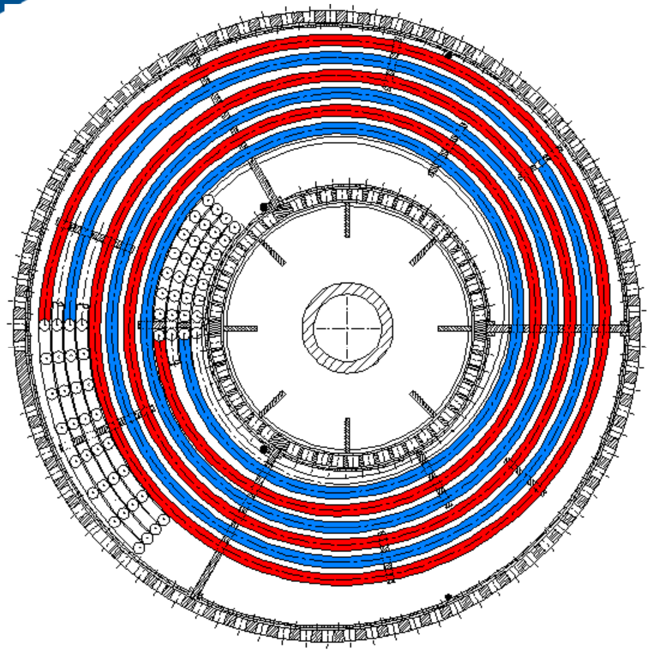


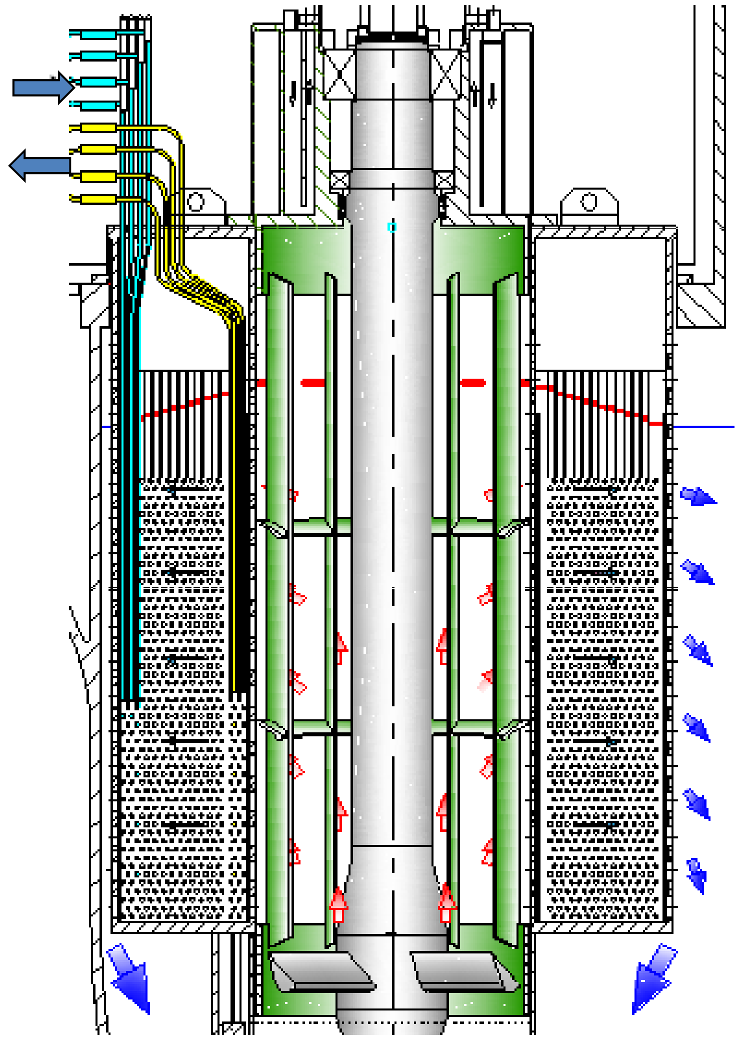
ELFR
Inner Vessel, Core support and Fuel Assembly





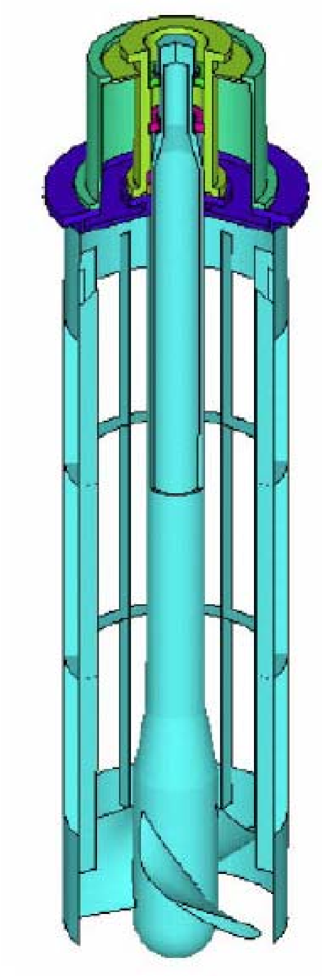
ELFR Once through Spiral SG: Concept





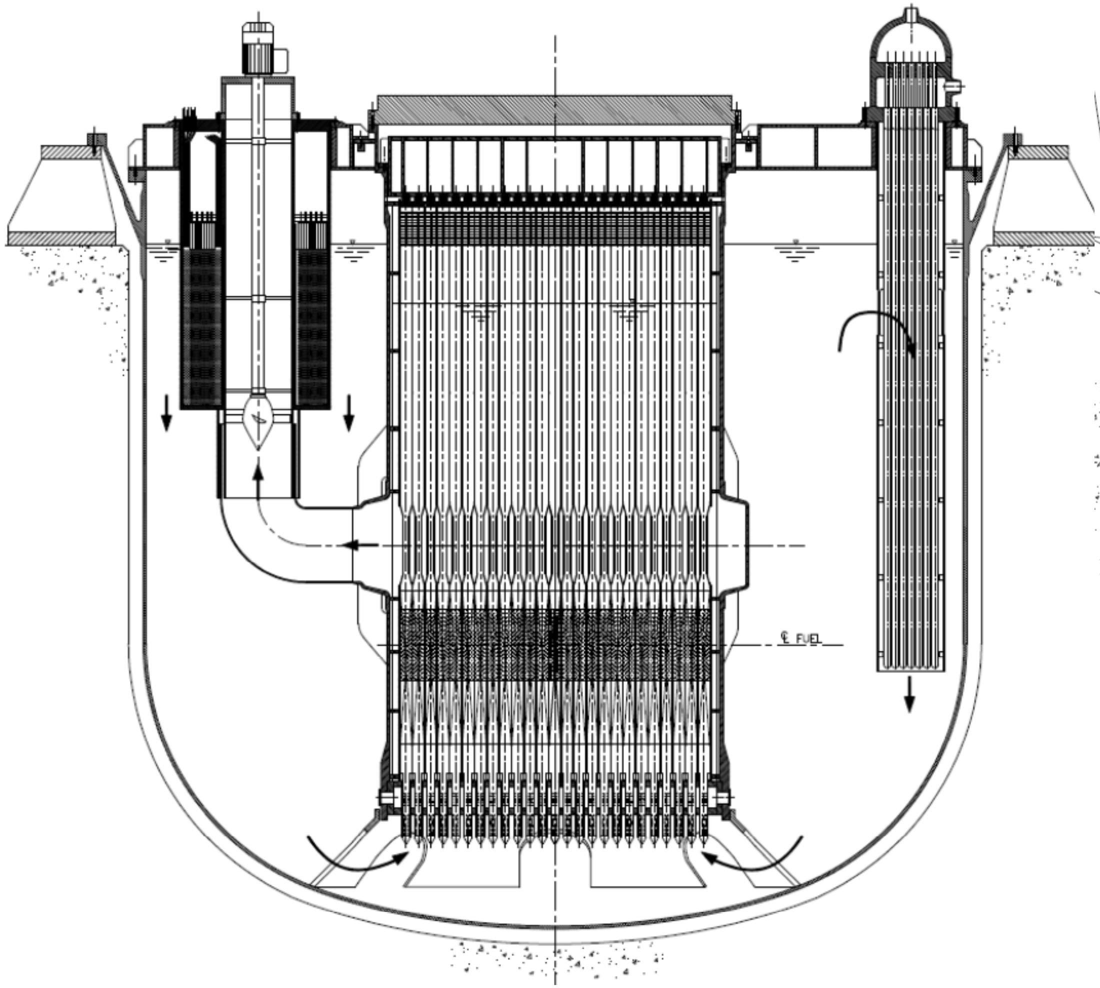
Power	MW	187.5
Lead Inlet Temperature	° C	480
Lead Outlet temperature	° C	400
Water Inlet Temperature	° C	335
Steam Outlet temperature	° C	464
Steam Outlet Pressure	MPa	18

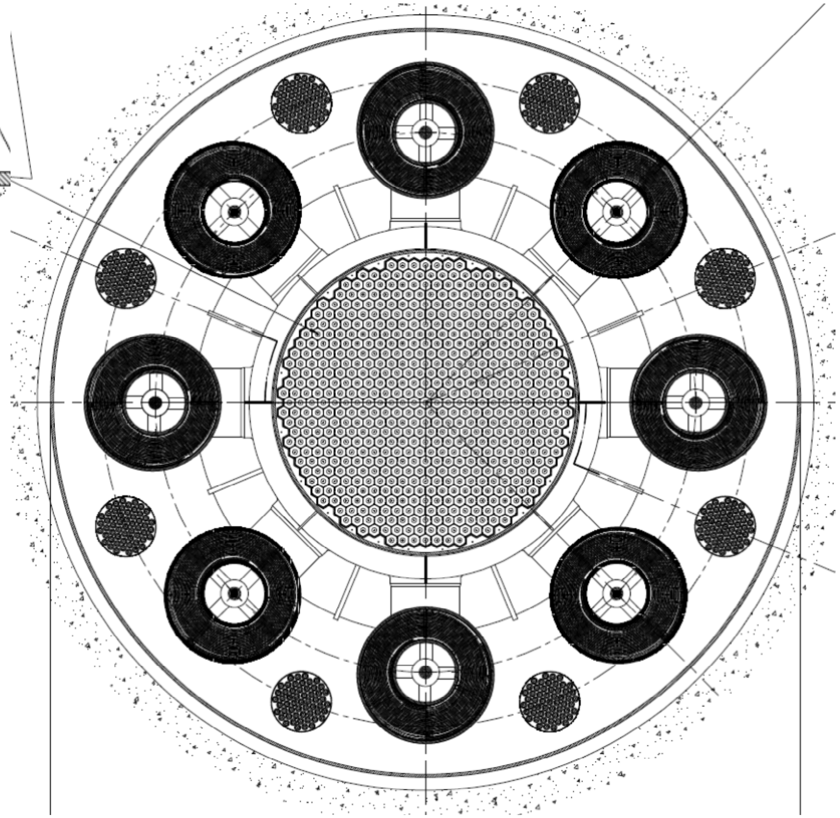
ELFR - Primary Pump



Outside impeller diameter, m	1.1
Hub diameter, m	0.43
Impeller speed, rpm	140
Number of vanes	3
Vane profile	NACA 23012
Suction pipe velocity, m/s	1.6
Vanes tip velocity, m/s	8.7
Meridian (at impeller entrance and exit) velocity, m/s	3.1
Candidate material	Ti_3SiC_2

ELFR - Reactor Arrangement





Decay Heat Removal Systems

One non safety-grade system, the secondary system, used for the normal decay heat removal following the reactor shutdown

Two independent, diverse, **high reliable passive** and **redundant safety-related** Decay Heat Removal systems (DHR N1 and DHR N2): in case of unavailability of the secondary system, the DHR N1 system is called upon and in the unlike event of unavailability of the first two systems the DHR N2 starts to evacuate the DHR

- **DHR N1**:
  4 Isolation Condenser (IC) system connected to 4 out of 8 SGs
- **DHR N2**:
  4 Isolation Condenser systems connected to 4 **Dip Coolers** (DCs) in the cold pool

DHR Systems features

Independence obtained by means of two different systems with nothing in common

Diversity obtained by means of two systems based on different physical principles

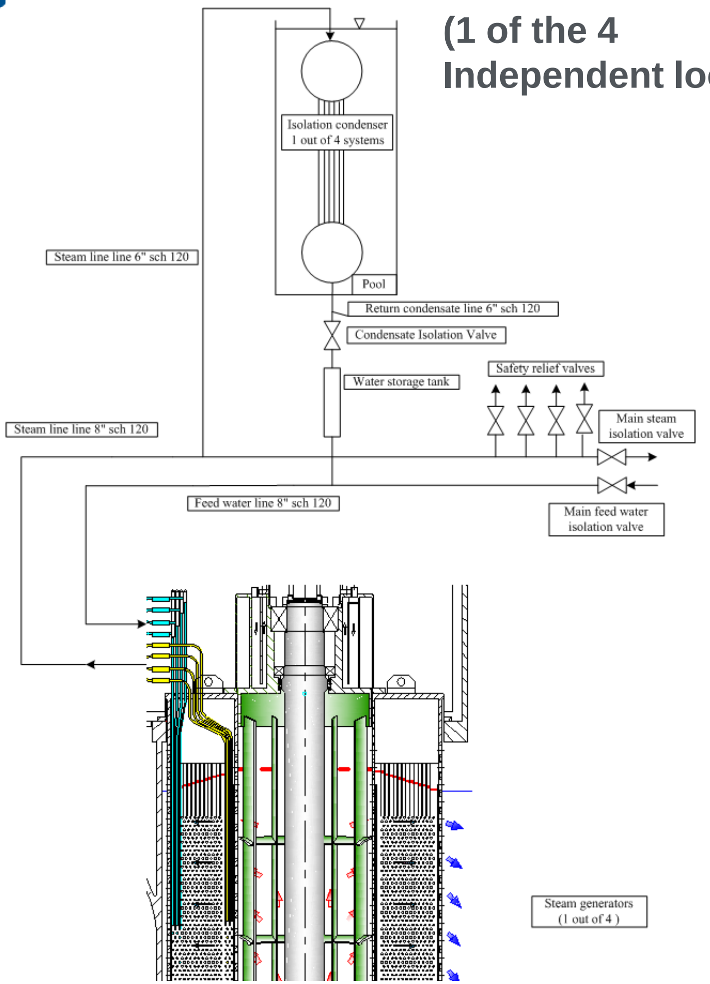
Redundancy is obtained by means of three out of four loops (of each system) sufficient to fulfil the DHR safety function even if a single failure occurs

Passivity obtained by means of using gravity to operate the system (no need of AC power)

ELFR - Decay Heat Removal Systems

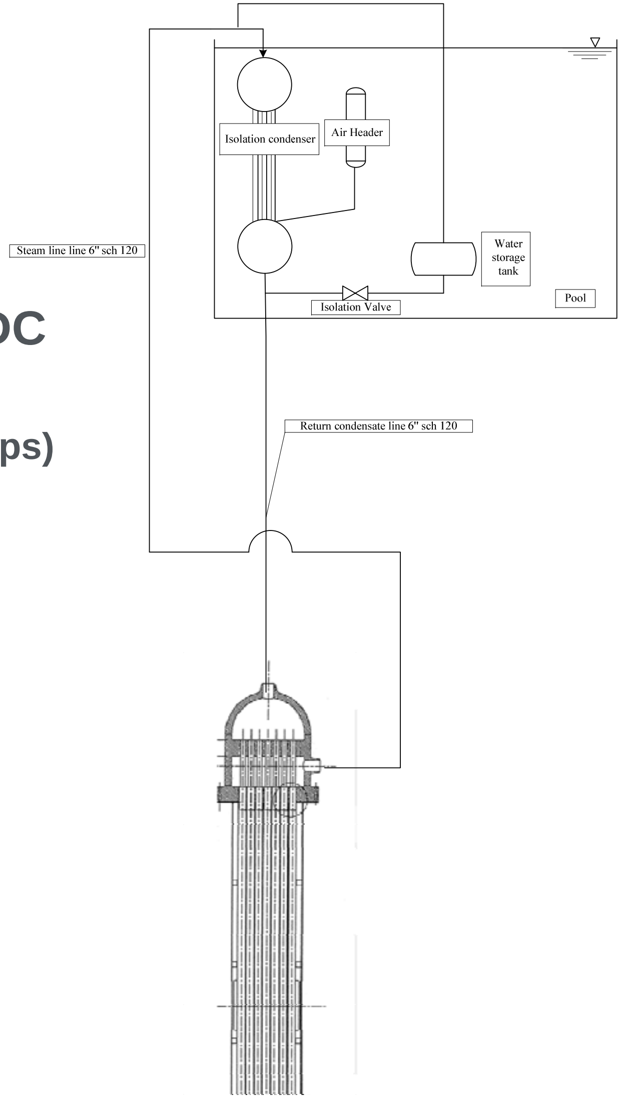
DHR N1 – ICS

(1 of the 4
Independent loops)



DHR N2 – DC

(1 of the 4
Independent loops)



EURATOM STATUS

GUINEVERE in operation (nuclear data experiments)

FEED contract for Myrrha to be assigned within December 2012.
Activity start in January 2013

ALFRED Consortium expected in 2013. After that activities on design and licensing.
Detailed design can be reasonably expected for 2017.

Availability of the ALFRED consortium to international collaboration.

ELECTRA (Sweden) expected financing approval before end of the year.

NEW STRATEGIC RESEARCH AGENDA of SNE-TP refers to LEAD as the most promising short term technology alternative to Sodium
Comment: GFR is now considered longer term option

Generally, LEAD is gaining consensus, especially due to safety aspects

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