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ATOMEXPO 2018
Round Table on International Scientific cooperation and advanced research infrastructures

JHR Project: a new modern 21st century Material Testing Reactor working as an international User's Facility in support to Research Institutes, Nuclear Industry and Regulators

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CEA-ICERR general representative for the IAEA
CEA –CE Cadarache (France)

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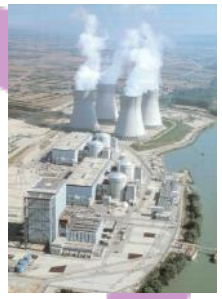
Position of Material Testing Reactors within Nuclear R&D scheme

The Key-Role of Material Testing Reactors for Fuel and Material qualification under irradiation: R&D in support of Nuclear Power Industry

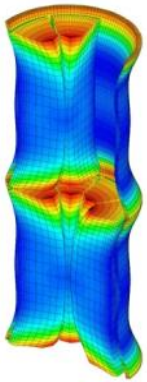
CODES
Validation

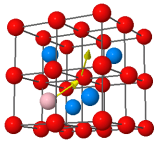
QUALIFICATION
Documents

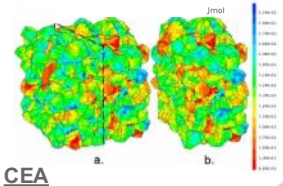
BASIS RESEARCH
&
NUMERICAL SIMULATION



EXPERIMENTAL DATA
EXPERTISE

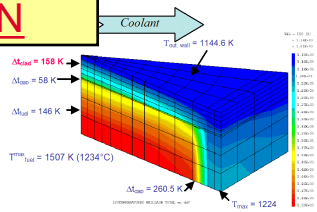






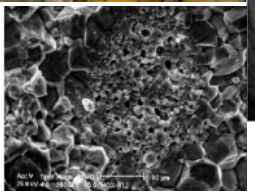
CEA

DESIGN



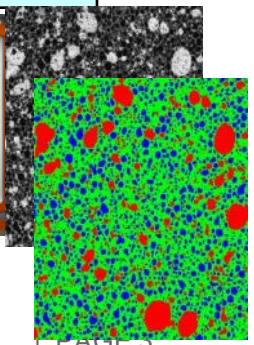
POST IRRADIATION EXAMINATIONS | SINGLE EFFECT EXPERIMENTS

Hot laboratories for PIE



MANUFACTURING
REFABRICATION
CHARACTERIZATION

Hot laboratory



BEHAVIOUR UNDER IRRADIATION

Material Test Reactor

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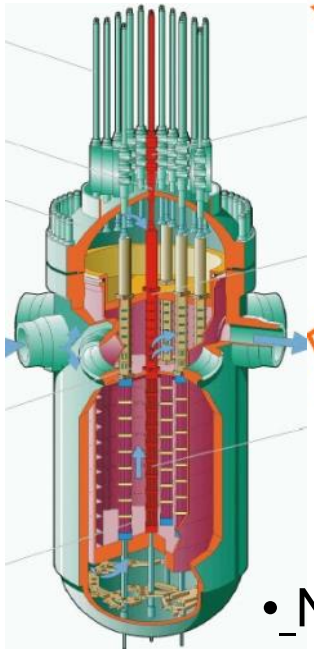
EDF

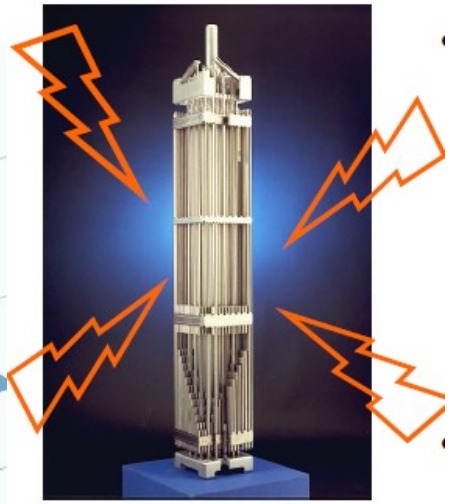
France Strategy for Material Testing Reactor: the future JHR as an International User Facility

(contribution from Dr Nicolas Waeckel –EDF/SEPTEN)

For EDF, 58 NPPs in France (15 in UK) means more than 10 000 F/As under irradiation at a time…

… in an aggressive environment, for more than 6 years :





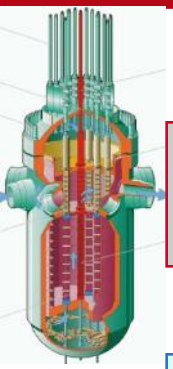
To avoid “bad surprises” the operator wants the fuel to be carefully designed, with enough Safety Analysis Design Margins

Limiting cases :

- Normal operation » FGR, Creep & Growth, clad T, ..
- Class1- 4 transients »Too much power (SCC-PCI, RIA,..)
  »Not enough cooling (LOCA, Dry-out, ..)

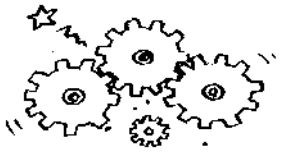
In-pile data required !

From tests results to Design Margins assessment



In-reactor Experience

Separate effect tests

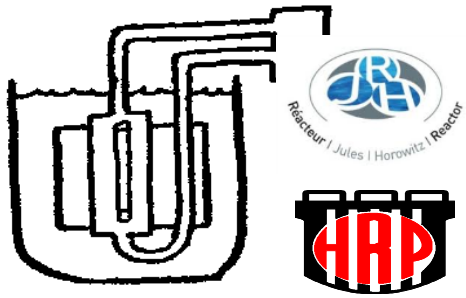


Models, Tools, Design limits, Methods

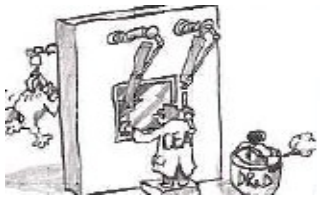
Simulation (Class 1 to Class 4 transients)

Design Margins

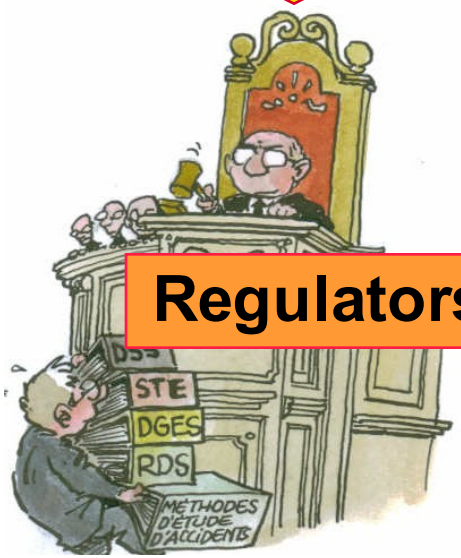
Safety Case Analysis Files



In-pile tests

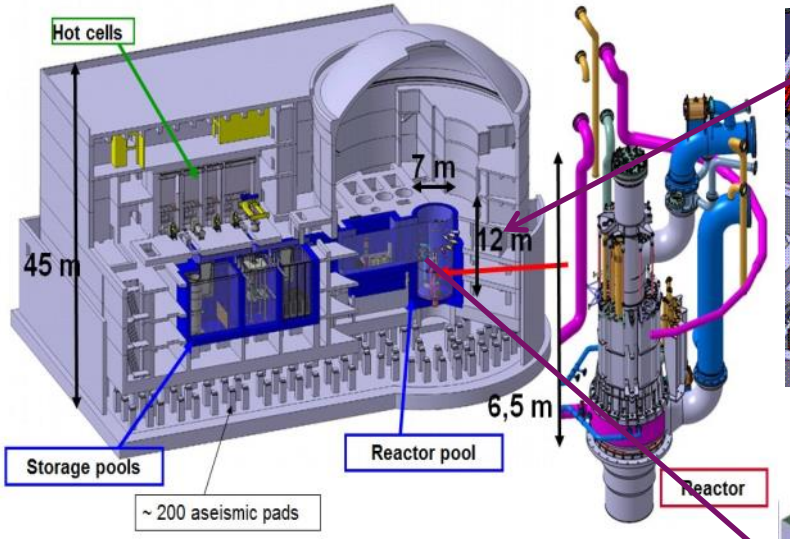


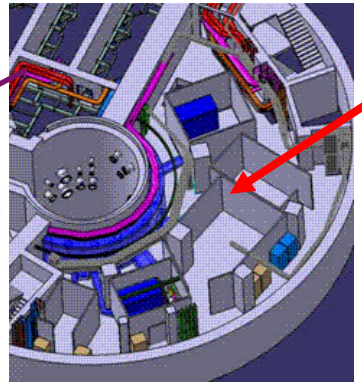
Out-of-pile tests

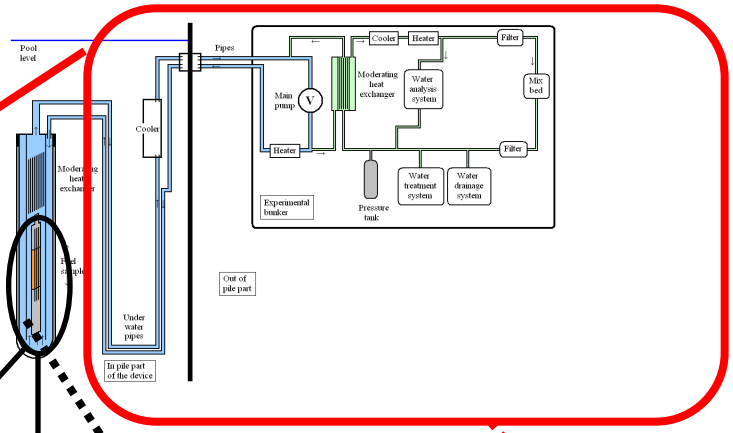


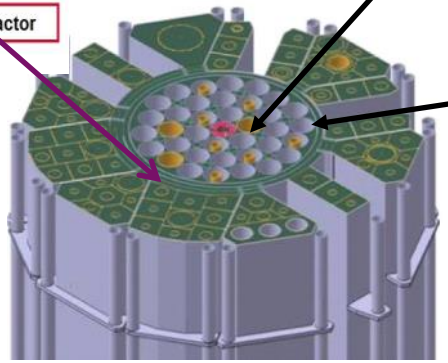
Regulators

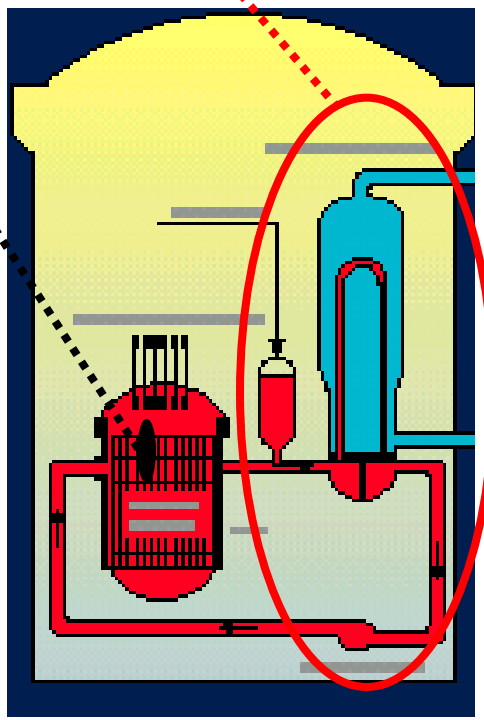
The appropriate answer to the Industry needs : JHR Project







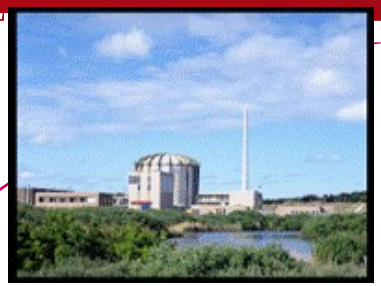


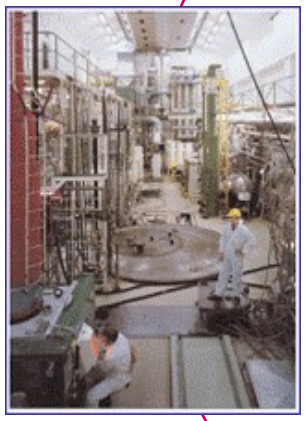


- CEA is developing experimental devices for material studies under irradiation in normal or accidental conditions

- MTR allows to reproduce on a small scale (100 MWth) representative in reactor test conditions for :
  - Material screening
  - Material characterisation
  - Fuel element qualification

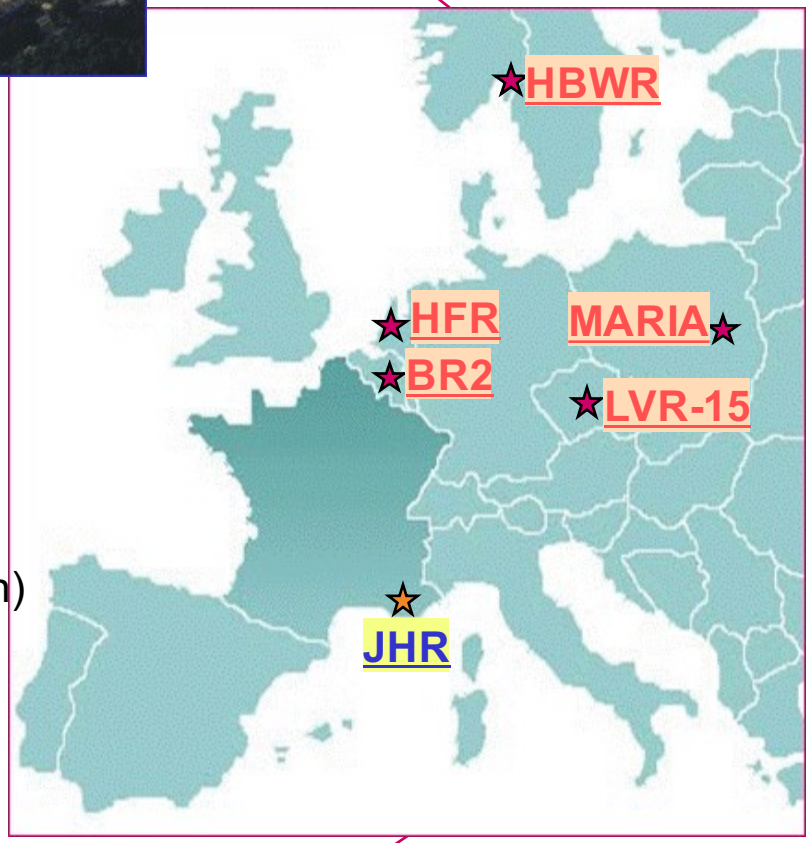
The Genesis of JHR within the European context of an Ageing fleet of MTR





Age of current E.U. main MTRs in 2018 (years)

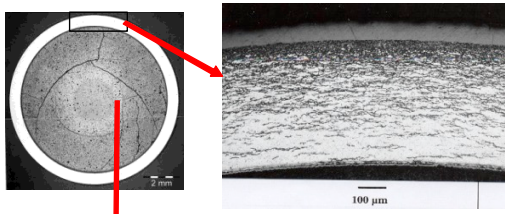
BR2 (B)	55
HALDEN (N)	60
HFR (NL)	57
LVR 15 (CZ)	60
MARIA (PO)	45
OSIRIS (F)	52 (shut down)

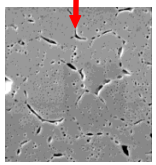


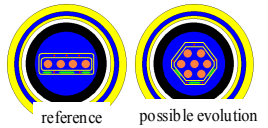
JHR Main Objectives

1. R&D in support to nuclear Industry

- Safety and Plant life time management (ageing & new plants)
- Fuel behavior validation in incidental and accidental situation
- Assess innovations and related safety for future NPPs

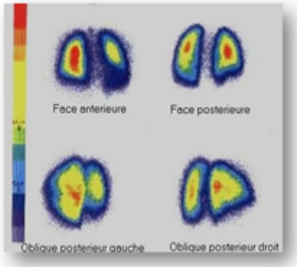


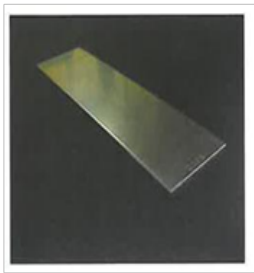




2. Radio-isotopes supply for medical application

- **^{99}Mo production**
  - JHR will supply 25% of the European demand (today about 8 millions protocols/year)
  - Up to 50% upon specific request





3. A key tool to support expertise

- Training new generations (JHR simulator, secondees program)
- Maintaining a national expertise staff and credibility for public acceptance
- **Assessing safety requirements evolution and international regulation harmonization**

JHR OPERATING RULES

JHR International Consortium

JHR consortium gathers organizations which take part financially and get permanent access to JHR experimental capacities

(1 representative / organization)

JHR Consortium current partnership: Research centers & Industrial companies

Studsvik

AREVA

EDF

Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

SCK·CEN
STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ÉTUDE DE L'ÉNERGIE NUCLÉAIRE

cea

VTT

ÚJV

पऊवि
DAE

IAEC

NATIONAL NUCLEAR LABORATORY

TA
TechnicAtome

In some cases, the organization (member of the JHR consortium) is itself the representative of a national domestic consortium which gathers organizations among industry, R&D organizations, TSO, or Safety Authority

JHR GOVERNANCE

JHR : an International Users Facility

Project leader appointment

Validation of operation plan, business strategy, economy of the project

Governing Board

(JHR Consortium Members)

Nuclear safety ; Technical and Economical performance (operation cost)

Project leader

CEA

(Nuclear Operator)

Operation plan fulfilment programs definition (preparation of next Operation Plan with users)

JHR Reference Operation Plan (4 years plan)

For Members of the Consortium and Non-Members

Proprietary Programs for Members and Non-Members

&

Joint international Programs

For Members and Non-Members

Classical Framework
OECD/NEA, EC, others….

EXTRACT FROM THE JHR CONSORTIUM AGREEMENT

« The activity of the JHR project will consist of:

*A) **Proprietary Programs** addressing services to the exclusive benefit of industrial companies or research institutes who shall have the full property of the results*

*B) **The International Joint Program (IJP)** addressing priorities common to a large community sharing the produced information within the Joint Data Basis (Data bank with all the knowledge and results carried out within the IJP implemented in the JHR capacity) »*

JHR ORGANISATION IN OPERATING PHASE

Consortium members

AREVA 10 %
CEA 44 %
CIEMAT 2%
DAE 3%
EDF 20 %
EC-JRC 6 %
NRI 2%
STUDSVIK 2%
SCK 2%
VTT 2%
IAEC 2%
NNL 2%
+ …

Votes

CONSORTIUM

Validation of
-The Project Leader
- The budget
- The Business Strategy

CEA Operator in charge of:
- Nuclear Safety
- Technical Performance
- Economical Performance

Users
(Programs définition)

JHR Project Nuclear Operator

Management of requests from non-members

- Access submitted to the Strategy Policy decided by the Governing Board and the Availability

- Cost = neutron cost+Return of Investment + margin

Cadarache Centre
(Technical Support)

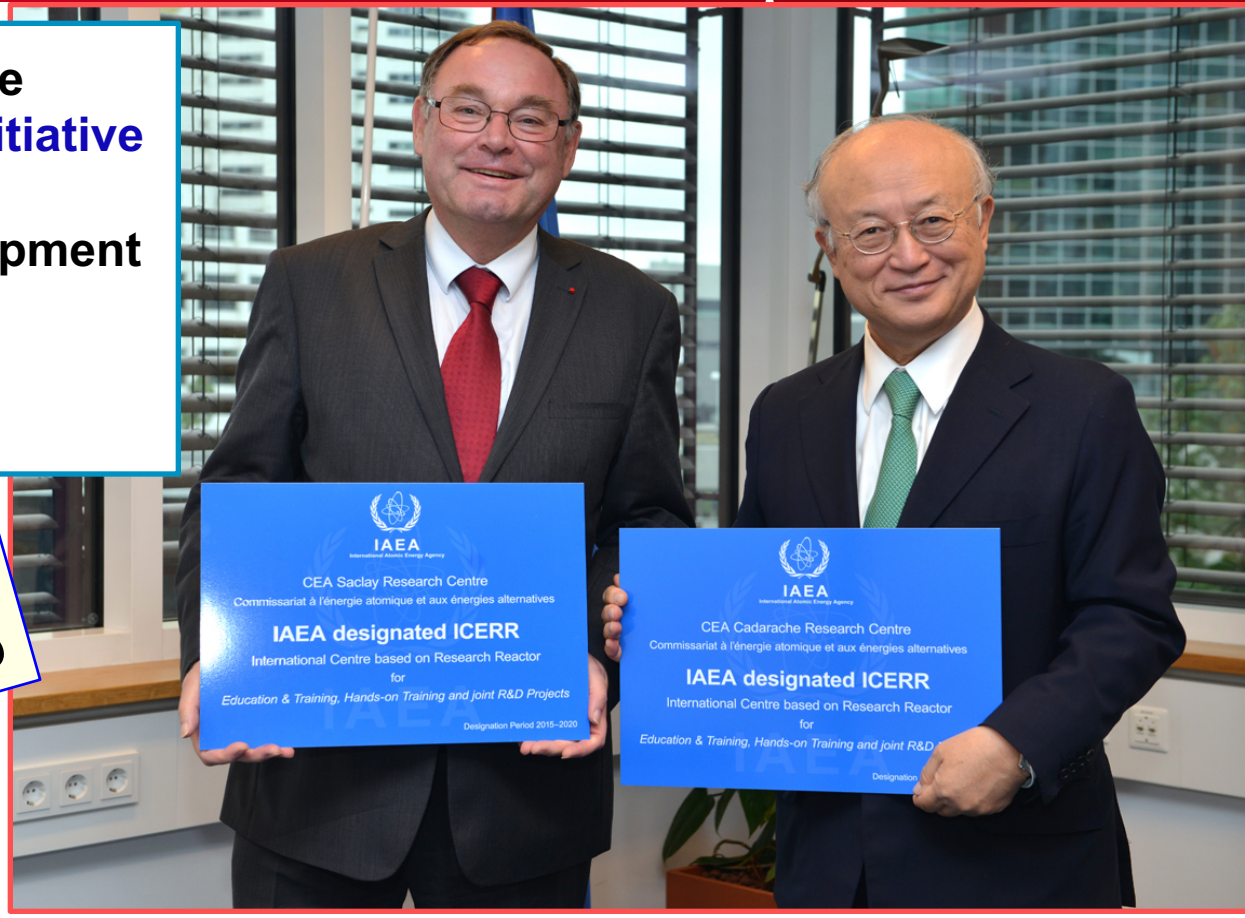
CONFIDENTIALITY
Versus CEA R&D
And between Members

INTERNATIONAL RECOGNITION
THE JHR AND ITS ANCILLARY FACILITIES
AS AN IAEA- ICERR : FIRST DESIGNATION –Sept 2015

Fully compliant with the
French Capacity Building Initiative
based on 4 pillars:

- **Human Resources Development**
- **Education & Training**
- **Knowledge Management**
- **Knowledge Network**

IAEA ICERR labelling obtained on 14th September 2015



Strong CEA intention to welcome Junior and/or Senior Scientists, Nuclear Engineers, Operators, Safety Managers… within JHR teams for various topics (R&D programs, Hands-on training on equipments…)

JHR, an advanced Research Infrastructure to support nuclear industry competitive advantages:

- Better Modelling
- Embarked on-line instrumentation
- Better monitoring of irradiation conditions

→ Probably more "Costly" & "Complex" experiments
→ More Share R&D (International Joint Programs)
(Even for "competitive market" such as ATF-type Fuel development and qualification)

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IFE

Example: Fuel program proposal for an OECD/NEA Joint Project

An initiative from the JHR Fuel Working Group

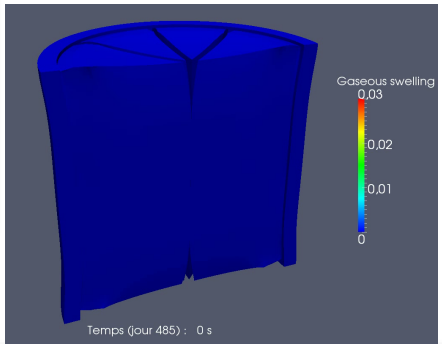
Réacteur | Jules | Horowitz | Reactor

ANALYTICAL IRRADIATIONS TO QUANTIFY THERMOMECHANICAL CLAD LOAD MECHANISMS DURING LWR TRANSIENTS

Discriminate / quantify mechanisms

- Inducing a moderate to high load on the clad during a power transient:
  - **Fuel thermal expansion**
  - **Fuel gaseous swelling**
  - **Fission gas release**
  - **Fuel volume change at melting**

Fuel gaseous swelling during a power ramp test

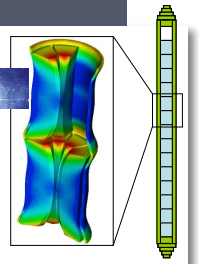


Modeling/Simulation

Enlarge current databases for **code validation** (including codes benchmarking)

- Pre-calculation of the rod behaviour (test conditions / instrumentation specifications)
- Prediction of expected results:
  - *Fuel central T vs. LHGR, Margin to fuel central melting, Melted volume fraction at maximum LHR*
  - *FG distribution, migration and release*
  - *Expected clad deformation in hot/cold conditions*
- Post-test comparison calculation vs. experimental results

PLEIADES

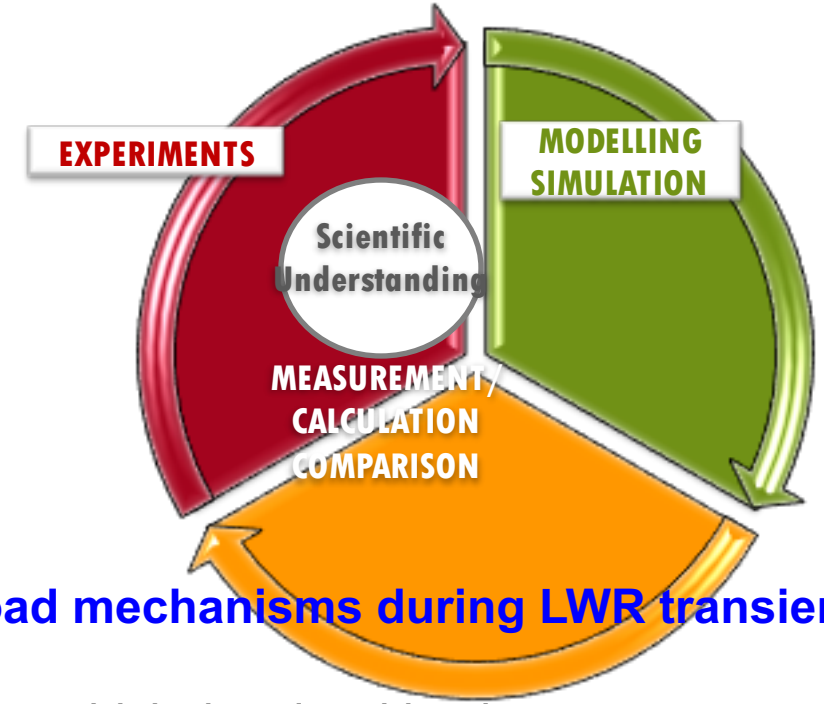


Application to industrial needs

- Results transposition to reactor conditions for addressing issues **facilitating NPP flexible operation**
- Improve **quantification of available margins on current fuel management constraints**
- **Gain licensing data usable for new fuel products and for new licensing methodologies**
  - ❖ Progressive introduction of advanced or new fuels and clads, such as **Accident Tolerant Fuels**

FUEL PROGRAM PROPOSAL FOR AN OECD/NEA JOINT PROJECT

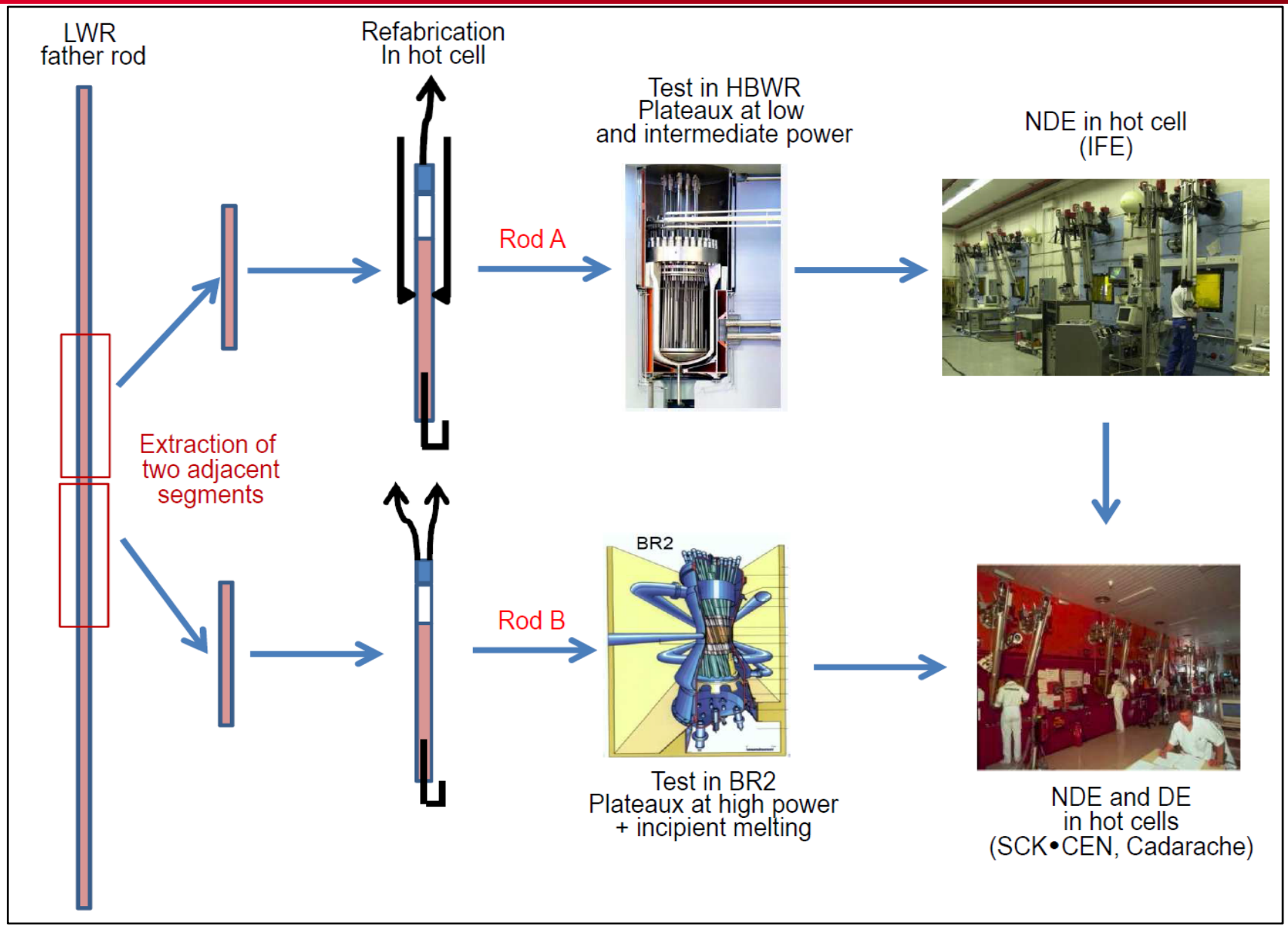
Enhanced experiments performed through international joint projects is of primary importance to successfully address these issues



Quantifying clad thermomechanical load mechanisms during LWR transients

- Focused on “long-lasting transients”, for which the slow kinetics:
  - ✓ Should not induce a risk to reach the technological failure limit of the cladding
  - ✓ May not trigger preventive safety actions of the reactor
- Discriminate clad load mechanisms thanks to a separate effect approach based on successive power plateaus with progressive increased values
- As conservative approach, incipient fuel melting at the pellet center is considered

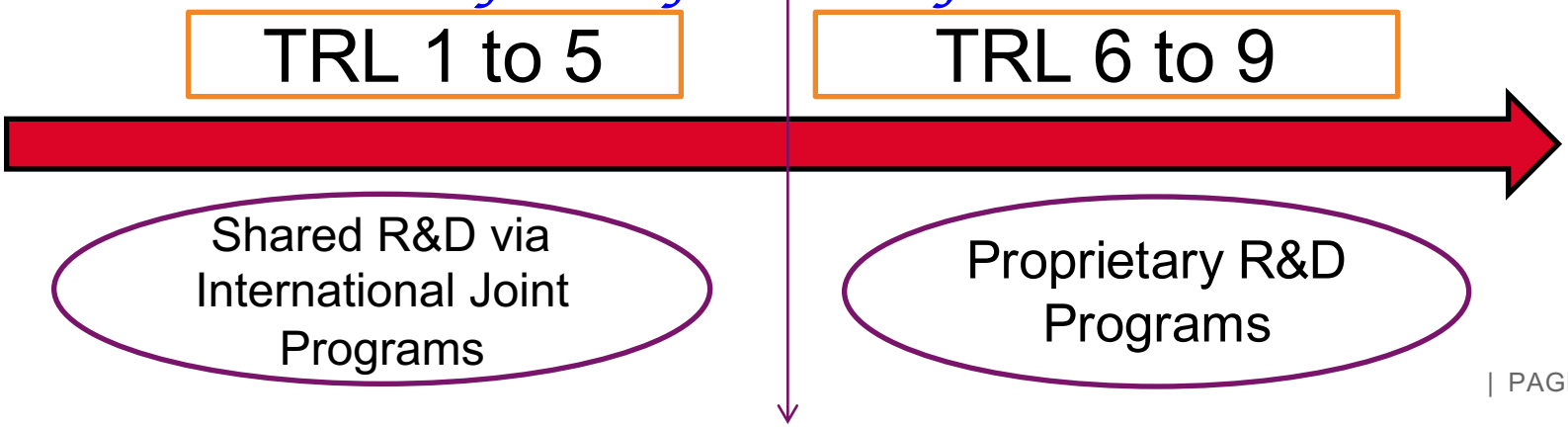
PROGRAM IMPLEMENTATION IN HALDEN AND BR2 AND HOT CELLS



JHR, an advanced Research Infrastructure to support nuclear industry competitive advantages

Exemple of reducing timescale for ATF-type Fuel Qualification :

first part shared R&D (screening phase) even with several fuel vendors
Second part on proprietary programs (Fuel qualification)
with full confidentiality and IP



Thanks for your attention

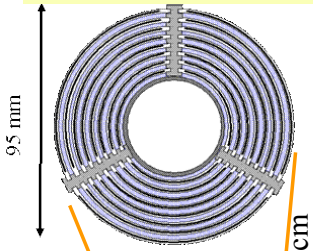
JHR: A Modern 100 MWth POOL-TYPE LIGHT WATER MTR OPTIMIZED FOR FUEL AND MATERIAL TESTING

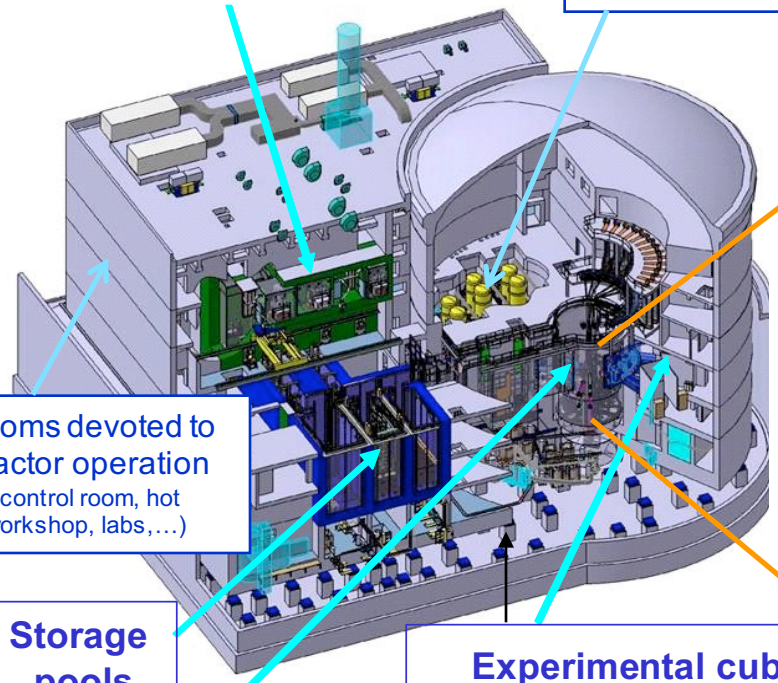
Hot cells (non destructive examinations)

Rooms devoted to reactor operation (heat exchangers, primary pumps, safety systems,…)

Reactor block

JHR fuel element



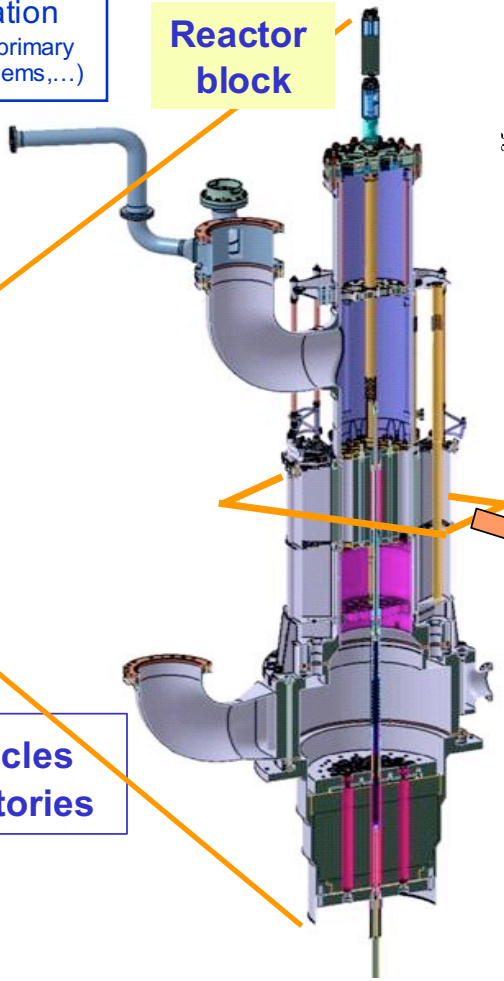


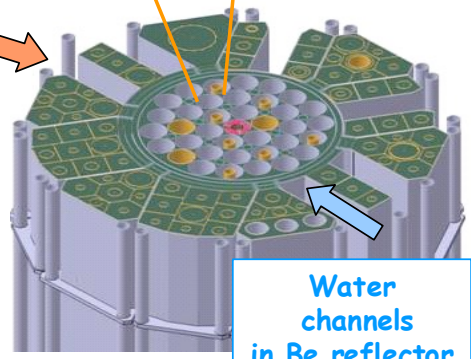
Rooms devoted to reactor operation (control room, hot workshop, labs,…)

Storage pools

Reactor pool with examination benches

Experimental cubicles and analysis laboratories

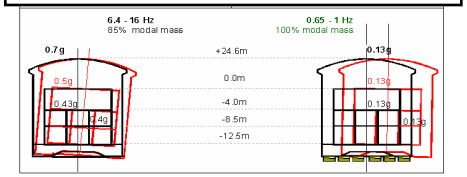




Water channels in Be reflector

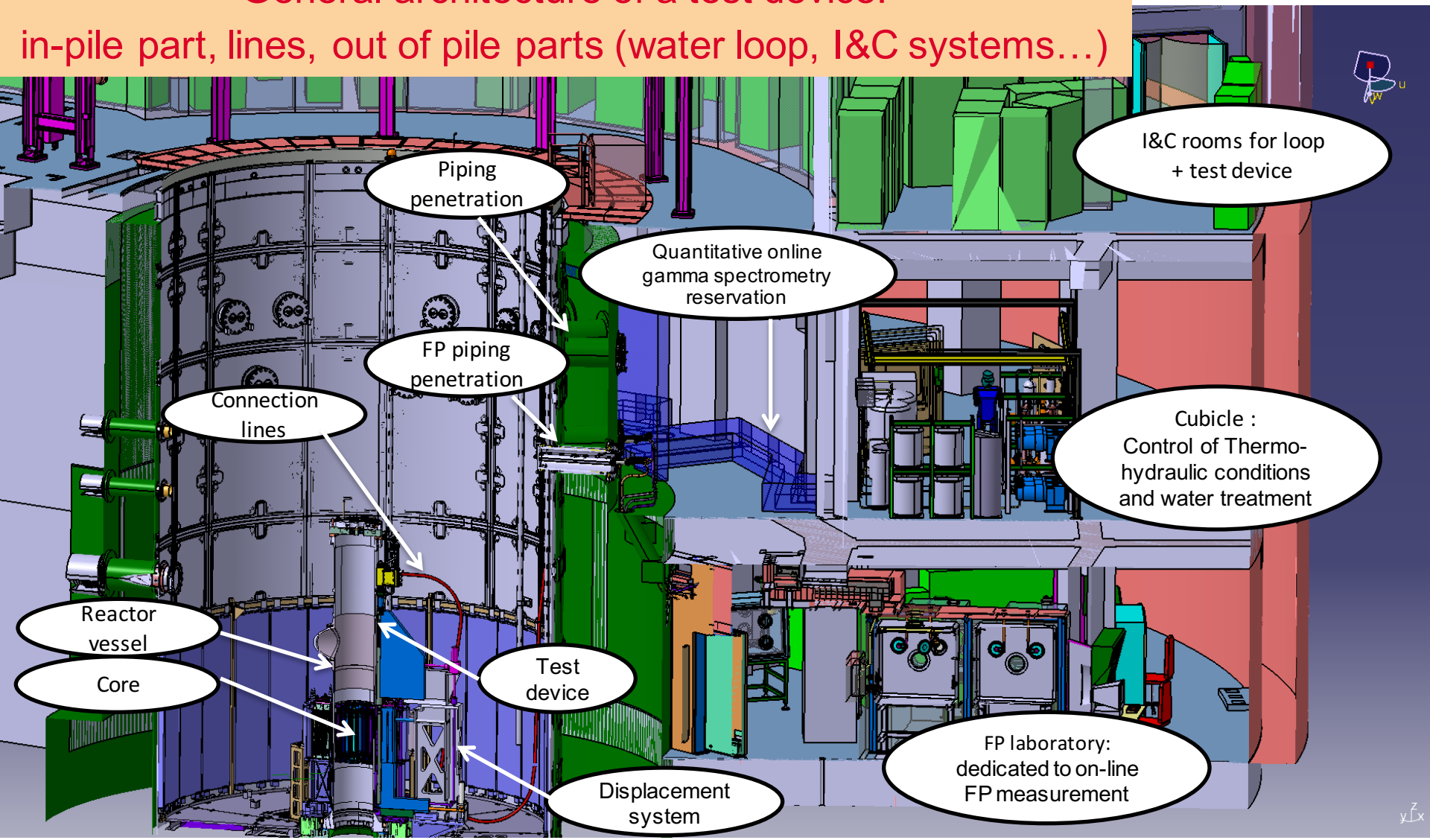
Core (Φ 70cm / h 60 cm) and Be reflector

About 200 aseismic pads



JHR facility & experimental capacity

General architecture of a test device: in-pile part, lines, out of pile parts (water loop, I&C systems…)

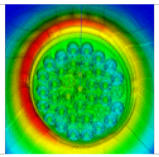


JHR: experimental capacity & performances at 100 MW power level (*)

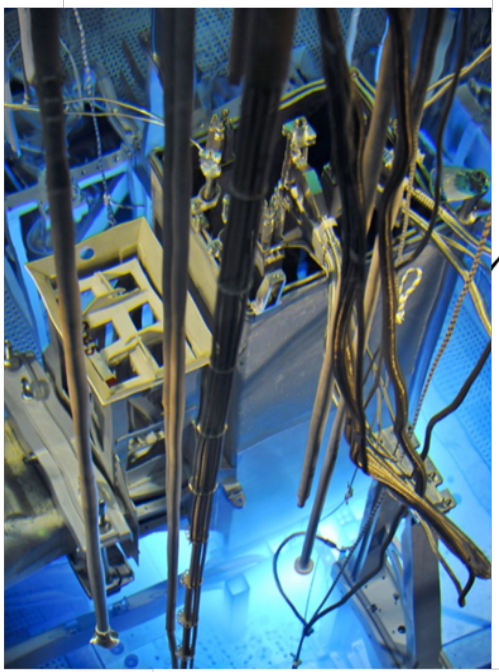
(*) Maximum Power- Second Operating conditions:70 MW

Thermal Neutrons flux In reflector

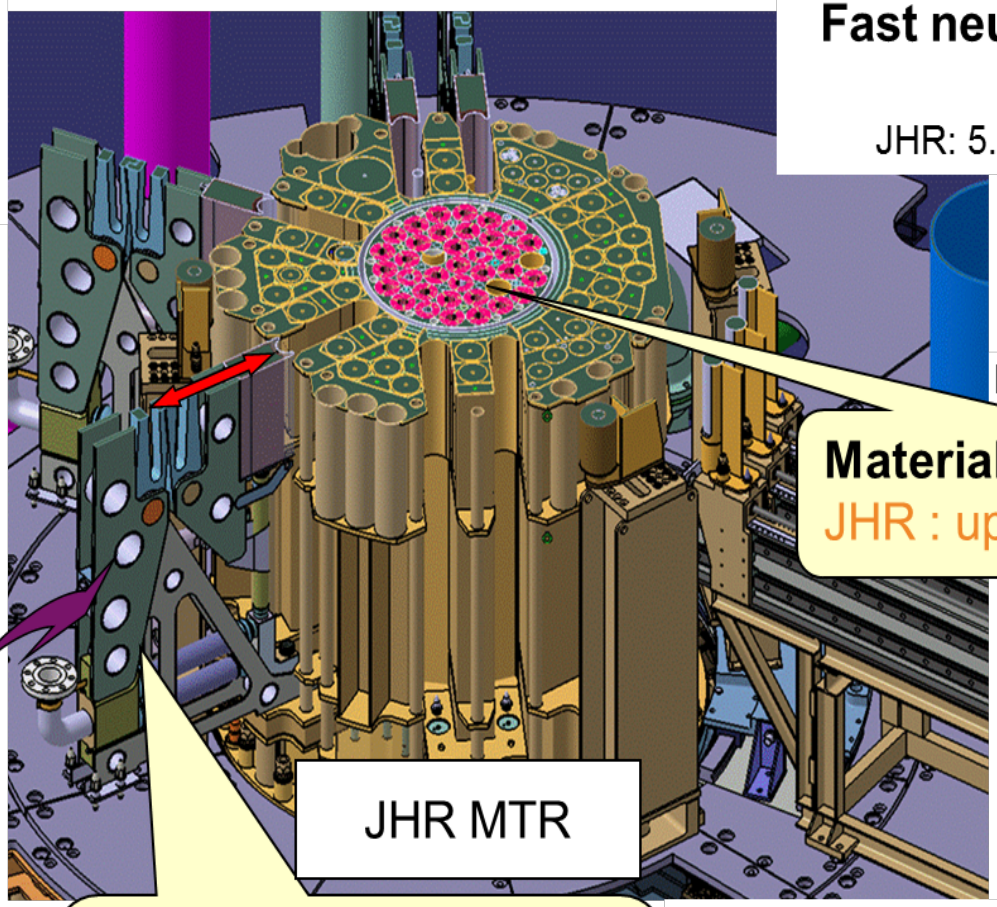
JHR: 5.5 10^{14} n/cm².s
and 6 displacement systems



Thermal neutron flux



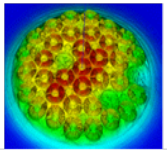
OSIRIS MTR



JHR MTR

Fast neutrons flux in core

JHR: 5.5 10^{14} n/cm².s



Fast neutron flux

Material ageing
JHR : up to 16 dpa/y

Displacement systems in JHR to:
- Adjust the fissile power
- Study transients

In JHR :
- Highly Instrumented Experiments
- On-line fission Gas analysis
- 20 simultaneous experiments