Sustaining Material Testing Capacity in France: From OSIRIS to JHR

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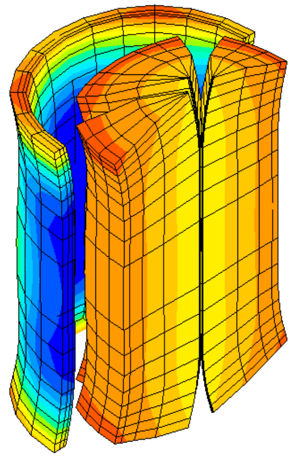
Plan of the presentation

- **CEA Strategy on MTR: European situation**
- **OSIRIS Status and experimental capacities**
- **Transition from OSIRIS to JHR: Using the Know-How of OSIRIS (example of Ramps, Instrumentation…)**
- **JHR Status and experimental capacities**
- **JHR as an International User's Facility**

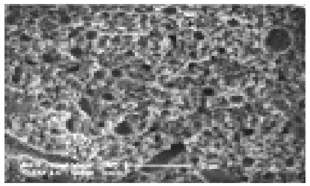
CEA Strategy on MTR

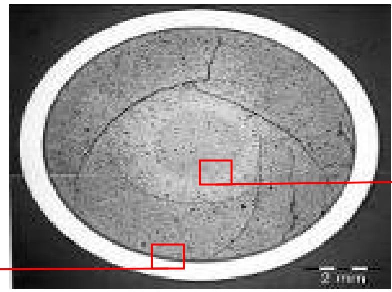
The needs: Major Scientific Challenges

- Material Ageing under irradiation
  - ✓ dpa, …
  - ✓ Corrosion, Radiolyse …

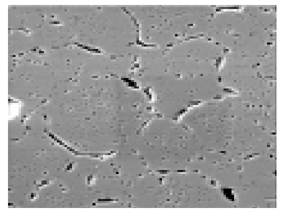


Restructuration à fort taux (RIM)

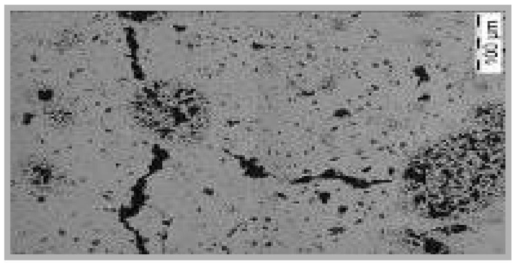


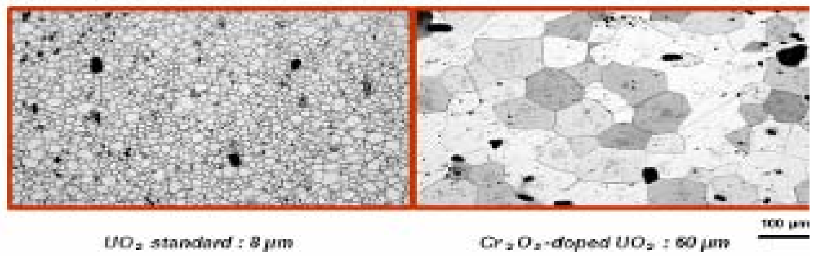


Précipitation gaz de fission

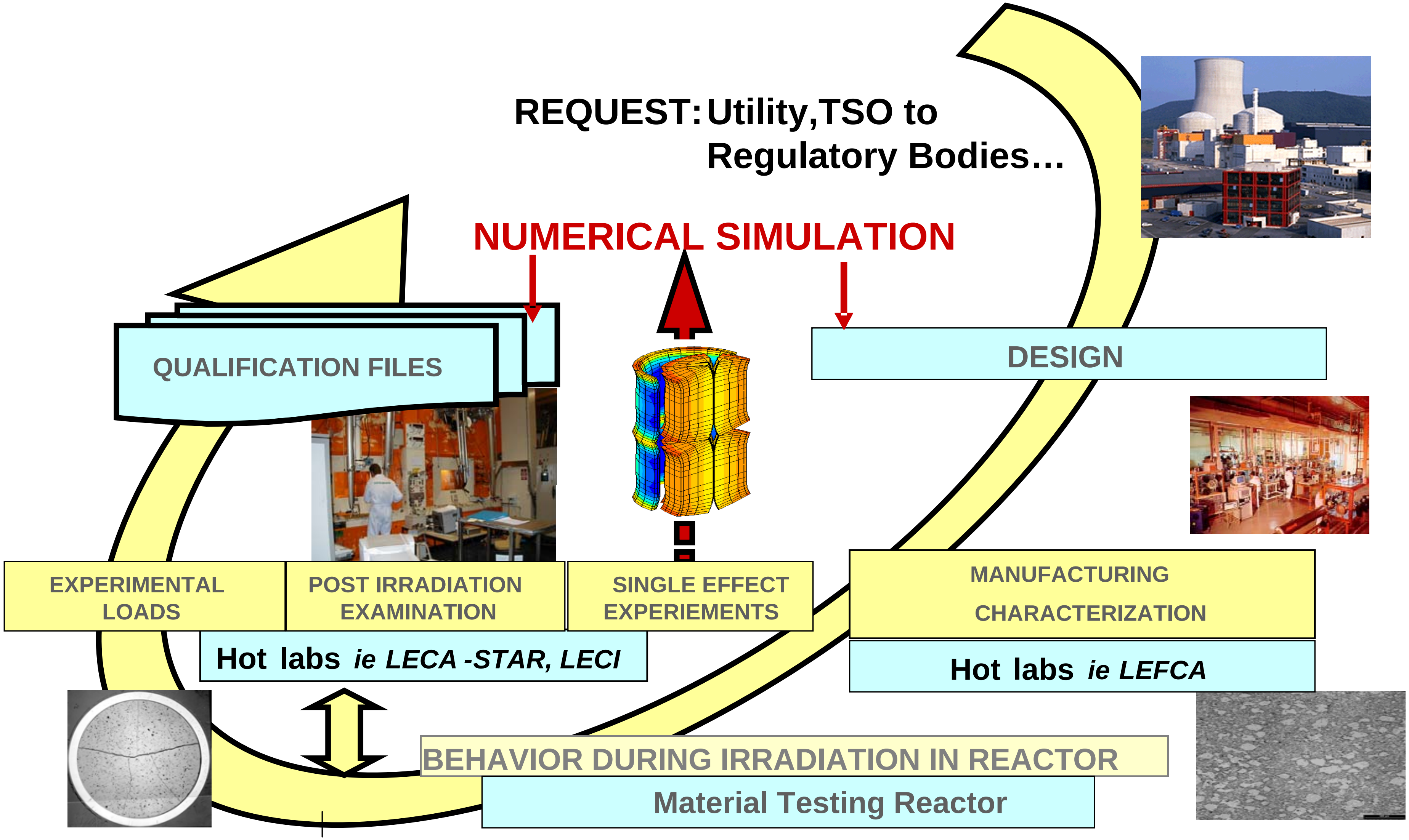


- Fuel Behaviour under irradiation (PCI,FGR…)

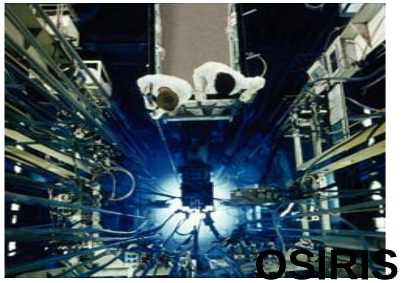


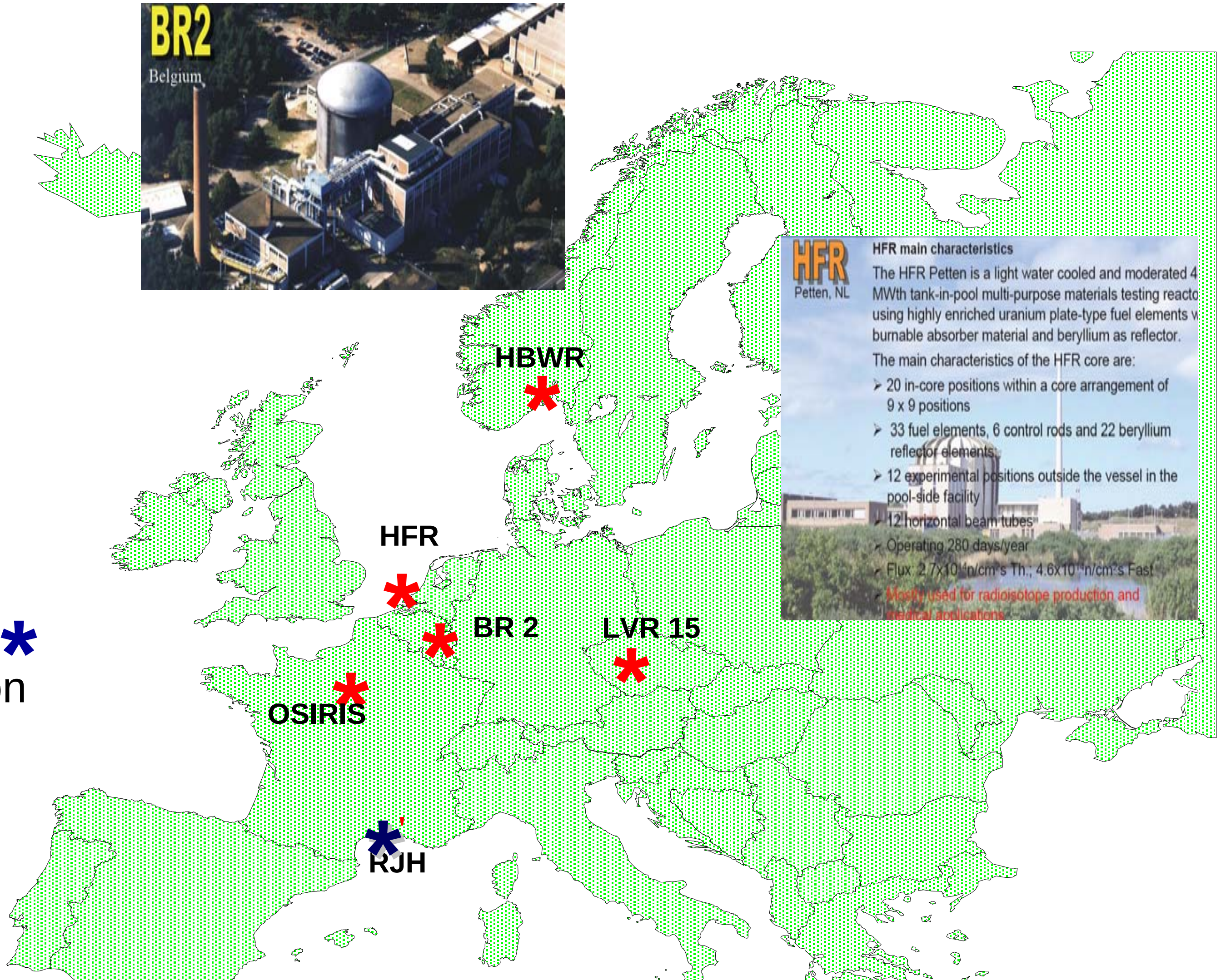


Design and qualification of new fuel or material : *the R&D cycle*



Context: An ageing fleet of MTR in Europe



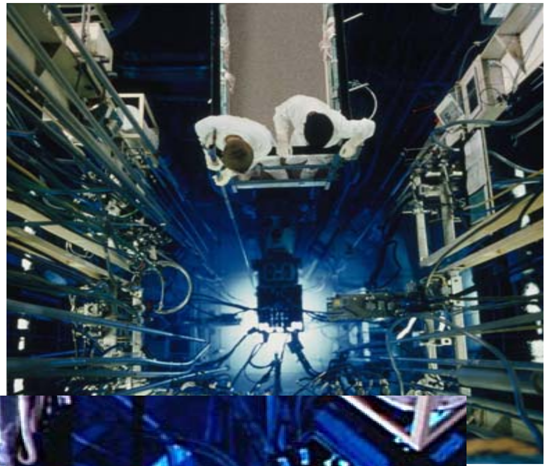


under construtions *

Necessity to at least one new MTR in Europe (ESFRI, SNE-TP…)

The OSIRIS reactor

- **Main characteristics of OSIRIS research reactor :**
  - **Open core pool type**
  - **Compact core : 57*57*60 cm^3**
  - **Fuel**
    - ***38 standard elements***
    - ***6 control elements with Hafnium as absorber***
    - ***U3Si2Al plates (enriched to 19.75 %)***
  - **Moderator, coolant et biological protection : H_2O**
  - **Thermal power : 70 MW**
  - **Maximum neutron flux**
    - ***fast (E>1 MeV) : 2.5 E^{14} n/cm²/s***
    - ***thermal : 2.5 E^{14} n/cm²/s***



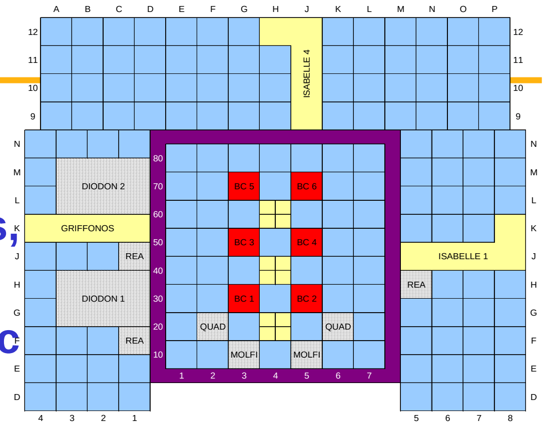
The main goal of OSIRIS reactor is to carry out irradiation tests of fuel and structural materials of nuclear power plants, and to produce radioisotopes

The current status of OSIRIS

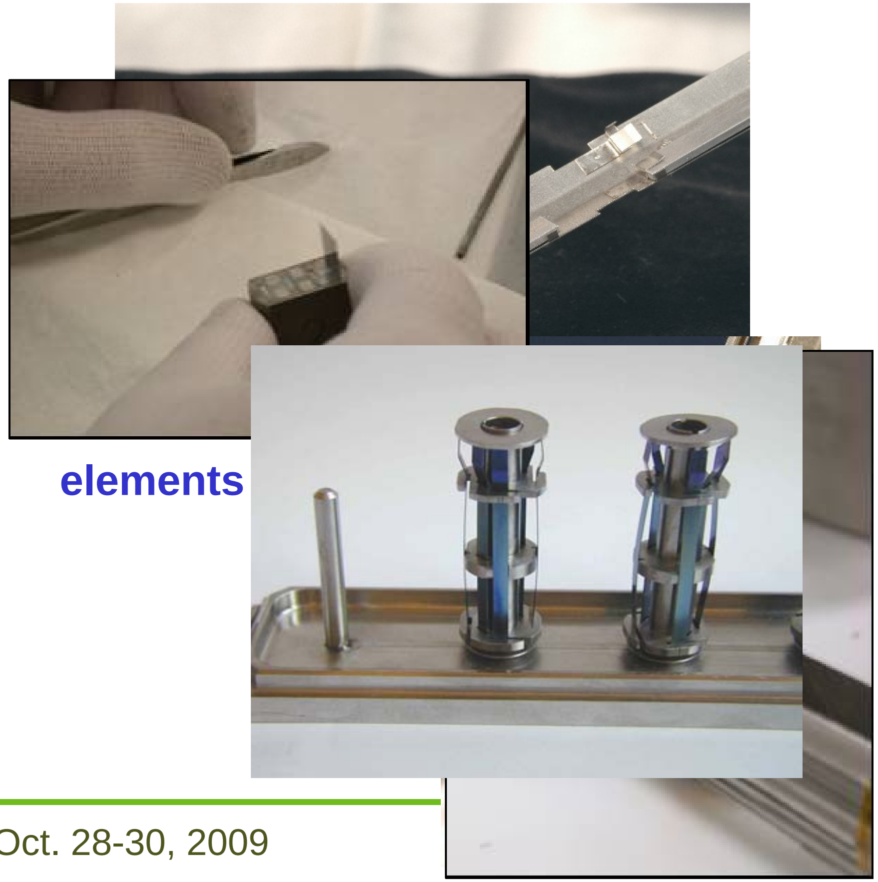
- **Annual operation :**
  - **180 operating days (8 cycles)**
  - **Intercycles of around 10 days**
  - **Two specific maintenance periods in spring and summer**

- **Operation extended up to 2015**
  - **Specific up grades required by the Safety Authority to be performed before the end of 2010.**
    - ***Polar cranes (2008 – 2009)***
    - ***Truck hatch (2010)***
    - ***Control rod room (-15 m) (2010)***
    - ***Ventilation system (2009 – 2010)***

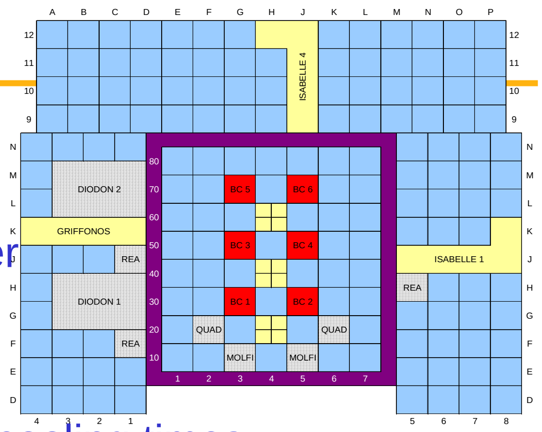
The material irradiation devices (OSIRIS)



- **Goals:**
  - **Material irradiations (grids, fuel clad, pressure tubes, vessel, guide tubes, …)**
  - **Parametric studies, qualification, thermal mechanic behavior**
  - **Various reactors :**
    - ***Gen 2, 3 and 3+ (Steel, Zircaloy, …)***
    - ***Gen 4 (SiC, ODS…)***
    - ***MTR (Aluminum alloys)***
- **Main characteristics**
  - **Irradiated in core or in periphery of core**
  - **Temperature :**
    - ***from 250 to 400 °C (+/-15°C) – NaK***
    - ***Up to 1100°C – gas***
  - **6 independent electrical heating elements automatically adjust the temperature**
- **Instrumentation**
  - **Thermocouples**
  - **Dosimeters of Fe, Cu and AlCo types**
  - **In situ dimensional measurements**



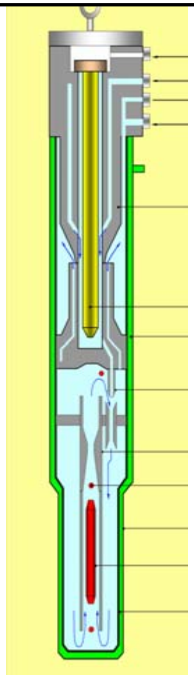
The fuel irradiation devices (OSIRIS)

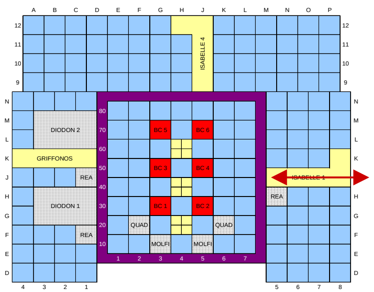


- **IRIS device:**
  - Irradiation of fuel plates for experimental reactors
  - Dimensional measurement (swelling) with an underwater bench between 2 irradiation phases
- **MERCI/MOSAIC devices:**
  - Characterization of the decay heat of LWR fuel rods at short cooling times
- **GRIFFONOS loop (boiler type):**
  - Irradiation of fuel rods under chemical and thermal hydraulic operating conditions representative of LWR ones
    - *Behaviour of rods under flux (optimisation of performance), after or during fuel transients*
    - *Phenomena under study: measurement of central temperature of fuel as a function of burn-up and power, kinetics of fission gas release,…*
  - On-line fuel rod instrumentation : central thermocouple, pressure sensor (monitoring of fission gas release), acoustic sensor (follow up the composition of the released gasses)
  - Heat released by rod (max 600 W/cm) adjusted by displacing the rig and measured by neutron balance (SPND)
- **ISABELLE loop:**
  - Power transients of shortened fuel rods under chemical and thermal hydraulic operating conditions representative of LWR ones

Preparing JHR with OSIRIS: from ISABELLE to ADELINE (1/2)

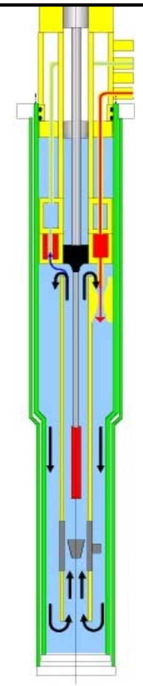
ISABELLE

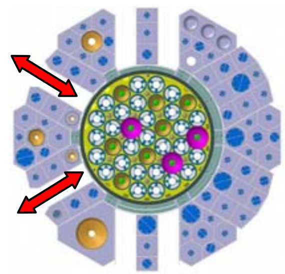




- **A one rod loop device for up to limit irradiations of LWR fuel samples**
  - **In reflector**
  - **On displacement system**
  - **Heavy components in bunker**
- **Characterization and qualification of fuel samples**
  - **Power ramp tests**
  - **Power to melt**
  - **Rod over-pressure threshold (lift off)**
  - **Post failure behaviour**
  - **Water contamination in case of failure**
- **All type of LWR fuel samples**
  - **PWR / BWR fuel samples**
  - **UO2 fuels (up to 5% → 7% in U5)**
  - **MOX fuels (up to 15% Pu/(U+Pu))**
  - **Fresh fuels**
  - **High burn up fuels (90 → 120 GWd/t)**
- **Chemistry, thermal hydraulic conditions representative of LWR ones**

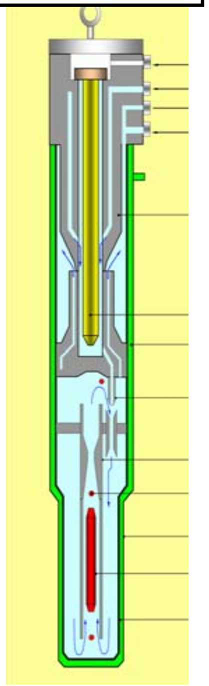
ADELINE



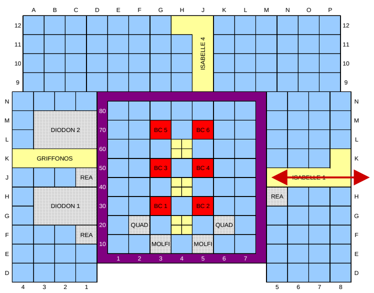


Preparing JHR with OSIRIS: from ISABELLE to ADELINE (2/2)

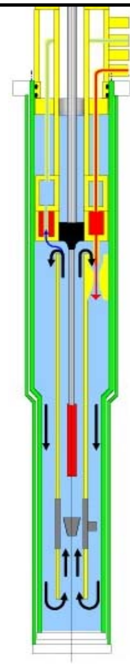
ISABELLE

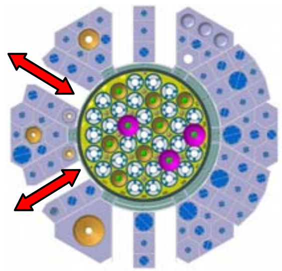


- **A device able to reach high power level and high power ramp**
  - **Max linear power : 620 W/cm**
  - **Up to 800 W/cm for fresh fuels**
  - **Power ramps speed up to of 700 W/cm/min**
- **On line measurements (numerous and precise sensors)**
  - **Temperature, pressure**
  - **Thermal balance**
  - **Clad failure detection**
    - *Gamma activity measurement*
    - *Delayed neutron detector*
    - *Elongation sensor*
  - **SPND**
  - **Fission gas release**
- **Several interfaces with associated services**
  - **Non destructive examination**
    - ***Gamma spectrometry,***
    - ***Neutron radiography***
    - ***X radiography***
  - **Direct link to Fission Product laboratory**
  - **Tight interface with alpha fuel cell for post-irradiation examination**

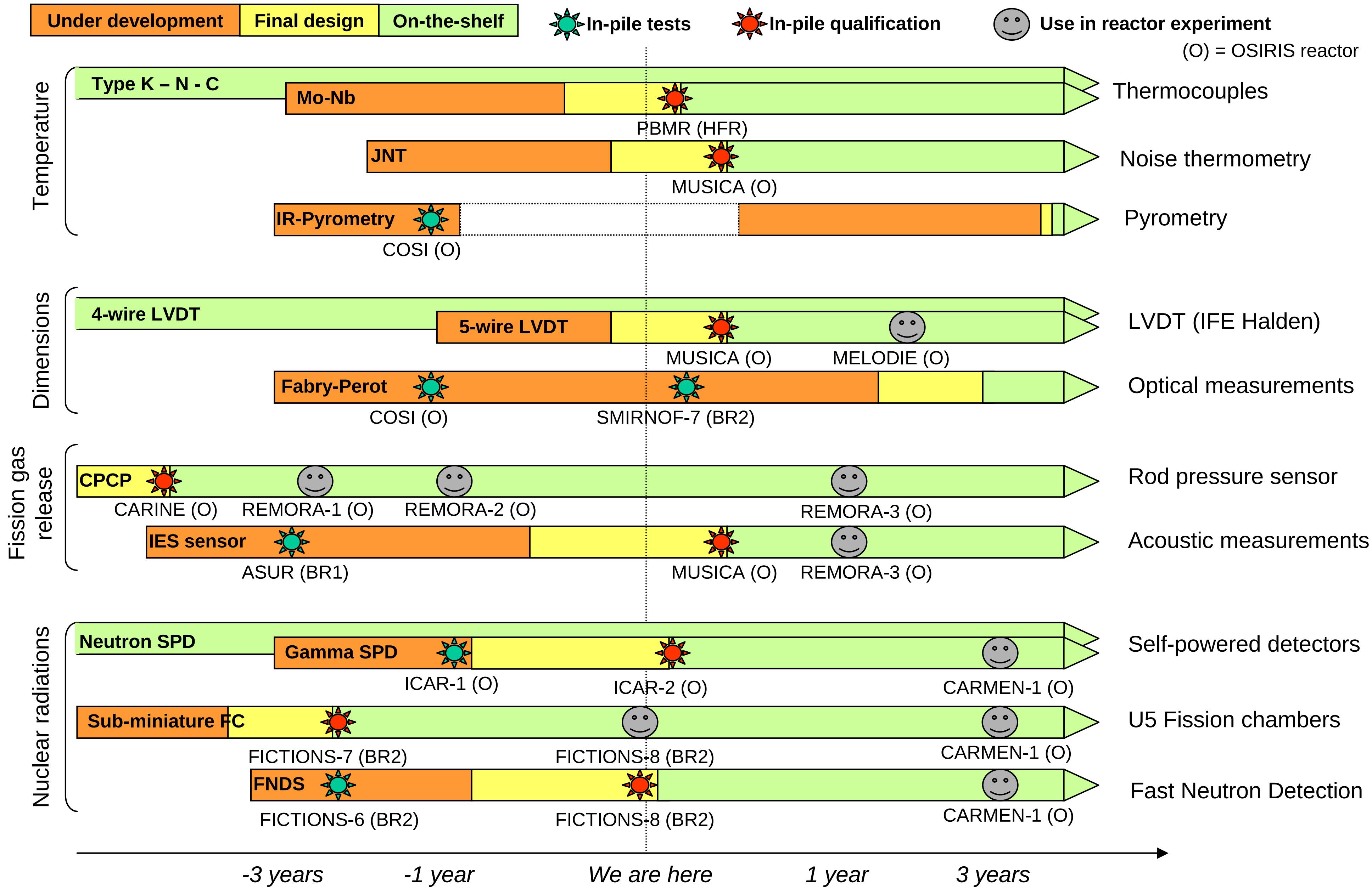


ADELINE



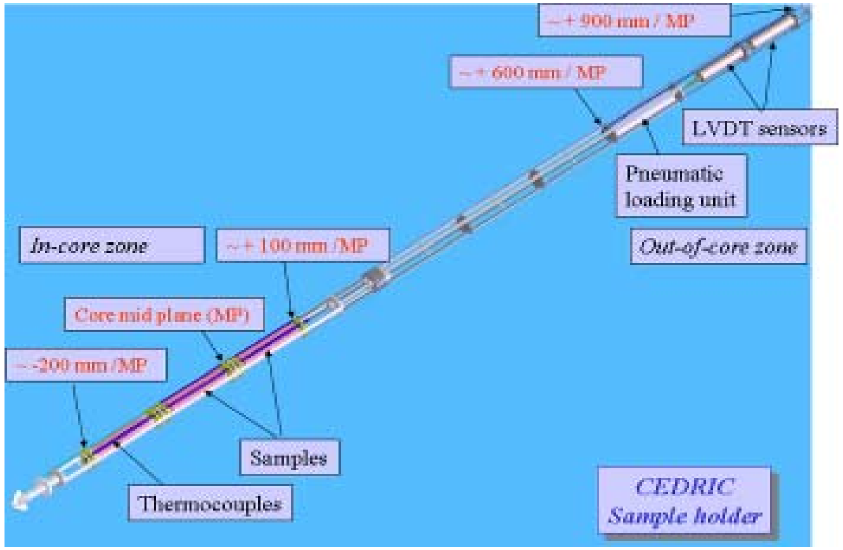


Preparing JHR with OSIRIS: the R&D program on instrumentation within an international framework

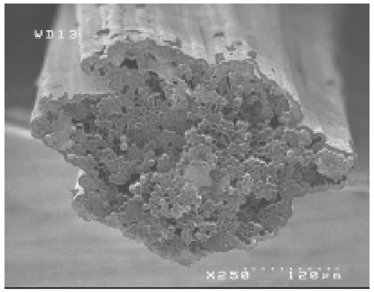


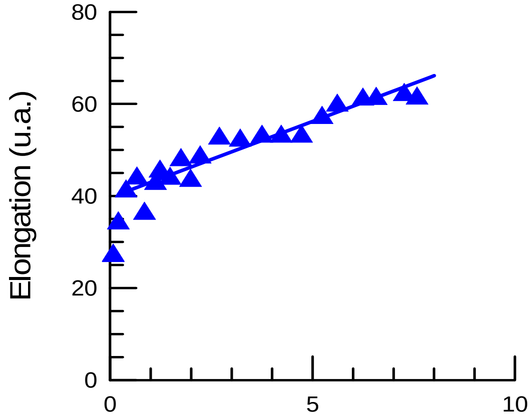
Preparing JHR with OSIRIS: the CEDRIC experiment

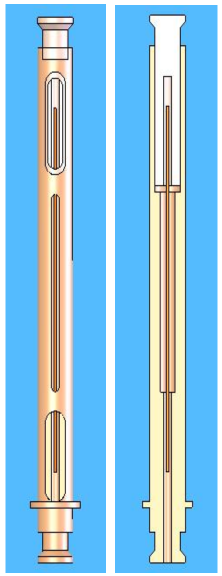
- **Goal : on line elongation measurement of a high temperature specimen (SiC/SiC mini-composite) under driven stress.**



- **Key features :**
  - **Irradiation started in OSIRIS in 2008**
  - **1000°C, gas coolant**
  - **Online-controlled stress by :**
    - ***Pneumatic loading unit***
  - **Online measurement :**
    - ***Elongation measurement with a self-compensating LVDT (by IFE Halden)***





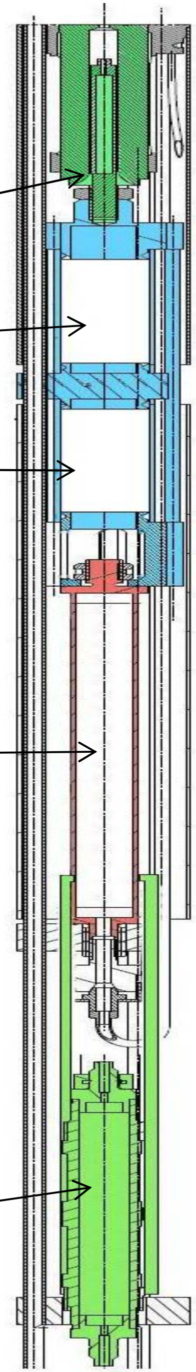


Preparing JHR with OSIRIS: the MELODIE experiment

- **Goal :** to assess the interest of a biaxial, online-controlled concept for the creep study of fuel cladding

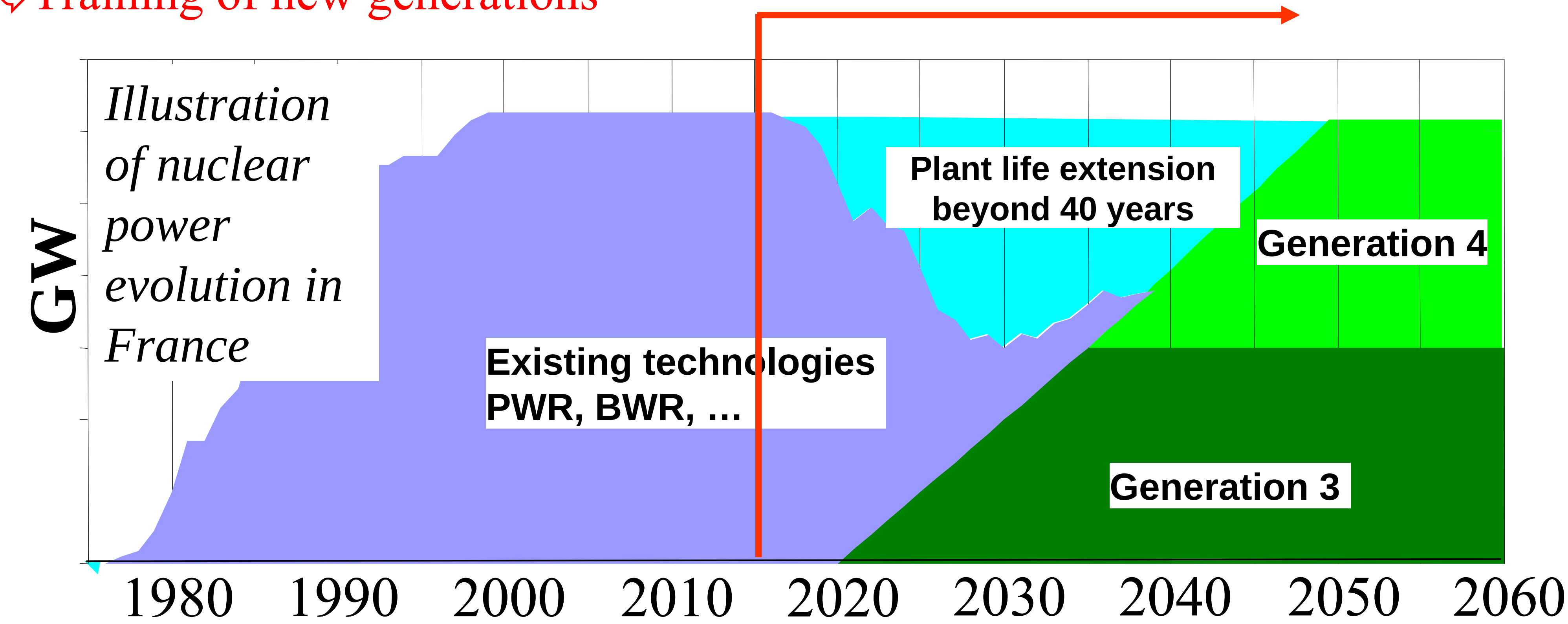
- **Key features :**
  - **Irradiation start in OSIRIS : 2011**
  - **Joint CEA-VTT team in the framework of the JHR project**
  - **350°C, static NaK coolant**
  - **Stress limits σr – σz : 120 – 180 MPa**
  - **Online-controlled biaxial stress by :**
    - ***Sample pressurization***
    - ***Push-pull axial loading cell***
  - **Online biaxial measurement :**
    - ***Elongation measurement with a self-compensating LVDT (by IFE Halden)***
    - ***Diameter measurement with an electromagnetic gauge (DG) designed by IFE and CEA***

See more details on these two experiments in the proceedings of this conference



JHR status: an MTR optimised to support industrial & public needs

- Safety and Plant life time management (ageing & new plants)
- Fuel behaviour validation in incidental and accidental situation
- Assess innovations and related safety for future NPP: Gen 3 and Gen 4
- Training of new generations



JHR Consortium, a framework to operate JHR as a User-Facility

- JHR Consortium, economical model for investment & operation
  - ✓ CEA, owner & nuclear operator with all liabilities
  - ✓ JHR Members owner of Guaranteed Access Right
    - ☞ A Member can use totally or partly his access rights
    - ☞ For implementing **proprietary programs** with full property of results
    - ☞ and/or for participating to the **Joint International Programs** with other Partners (**JHIP**)
    - ☞ Operation cost paid only for utilized access rights
- Non-Partners access under decision of the Board
- JHR present partnership: research centers & Industrial companies :

Spring 2007

Building Site at Cadarache

Summer 2007

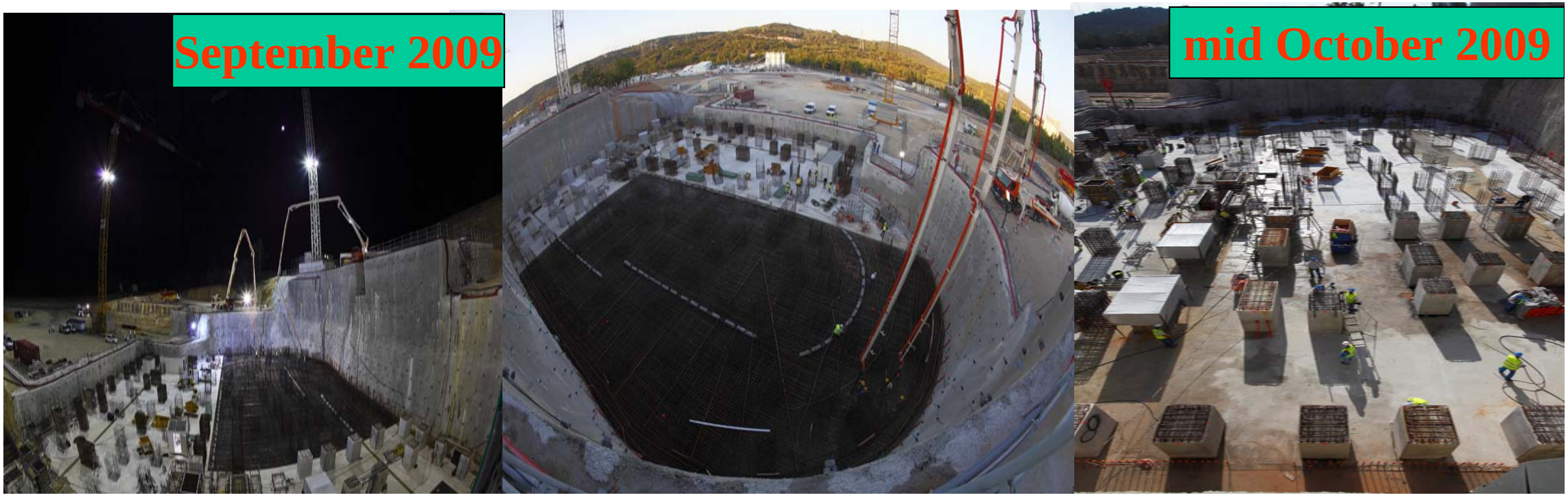
JHR realisation progress

- Site preparation and excavations completed
- Procurement process
  - ✓ Two major contracts have been engaged end of 2008 corresponding to almost 50% of the construction cost
    - ☞ Engineering team contract for the realisation phase
    - ☞ Civil work contract
- Licensing process (Creation Decree: October 2009)
  - ✓ Positive assessment of the Preliminary Safety Analysis Report

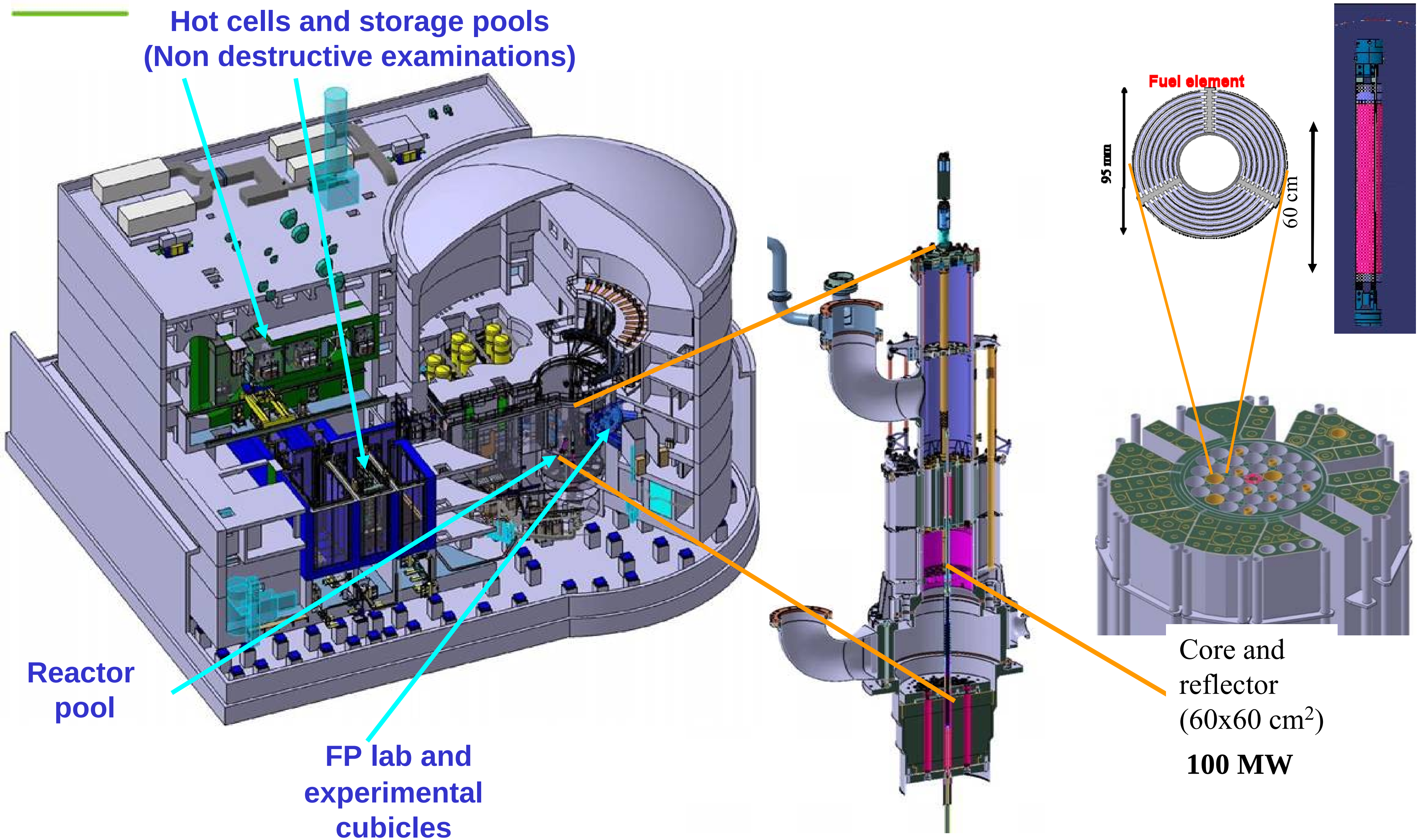


JHR site excavation is now completed

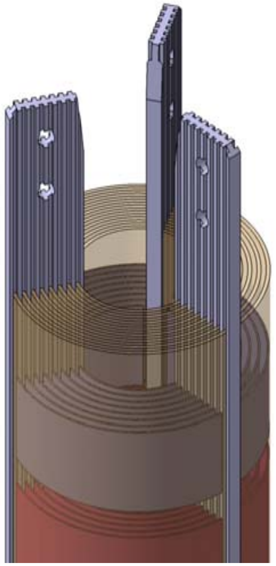
present phase: civil work (first concrete 6th August 09)



JHR General presentation



Fuel elements and in-core experimental location

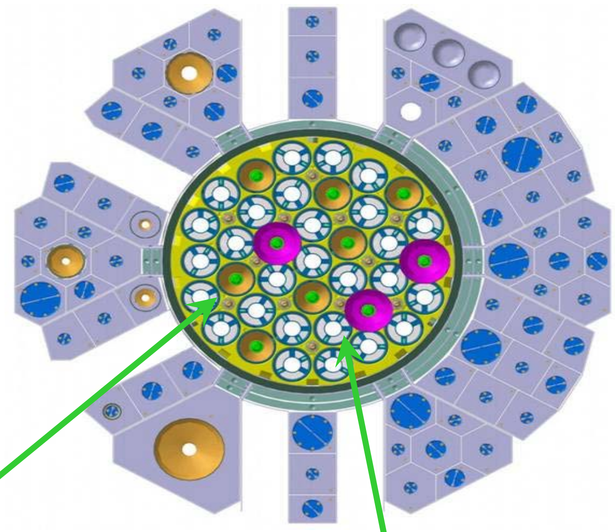


Reference LEU high density Fuel for the JHR Project : UMo 8g/cc (19.75%)

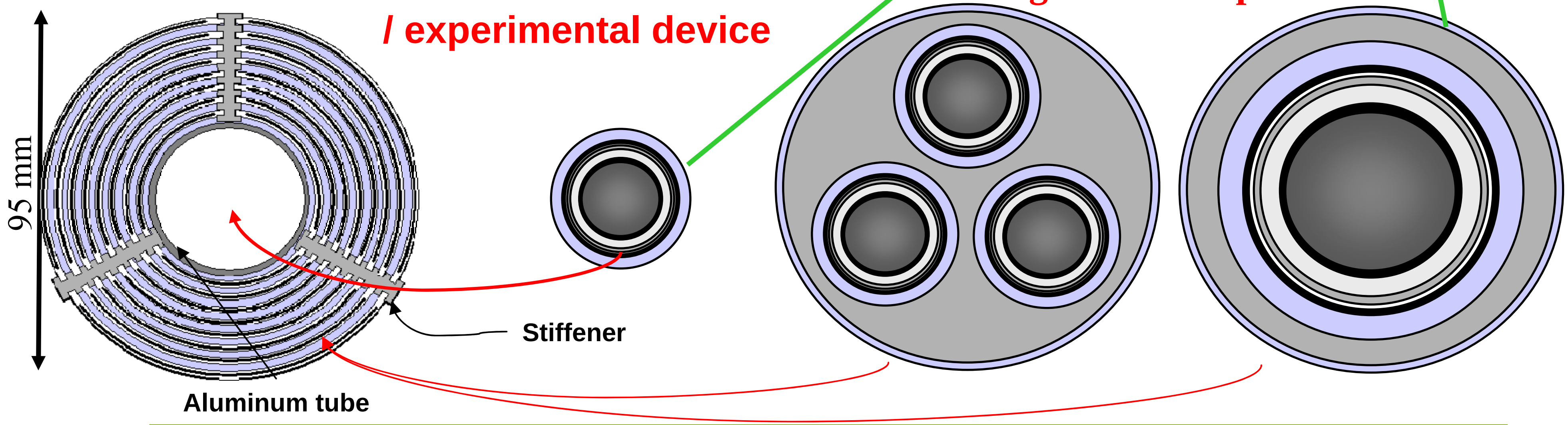
Back-Up:

U_3Si_2: ≤27% U5, 4,8gU/cm^3

Cladding Al FeNi



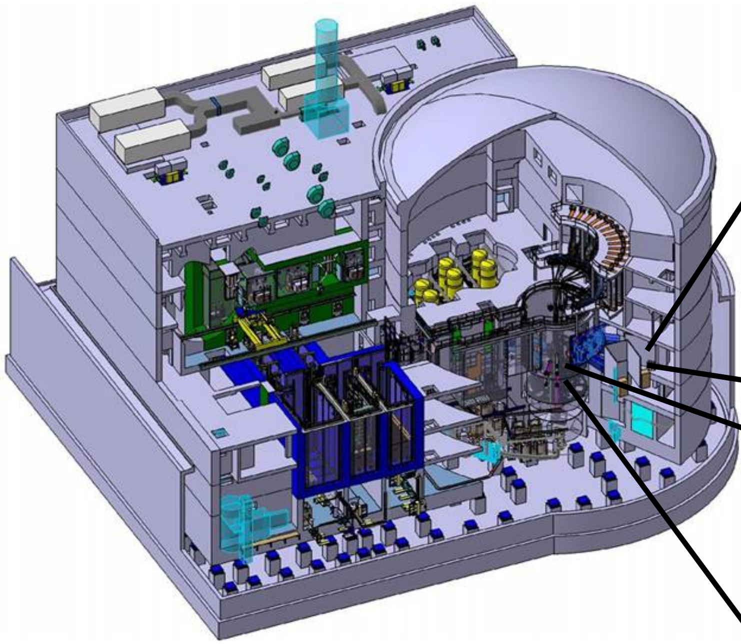
experimental locations: ∅ 32 or ∅ 80 mm

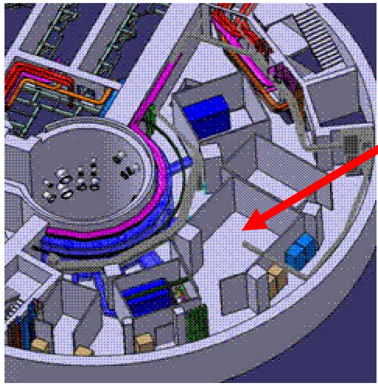


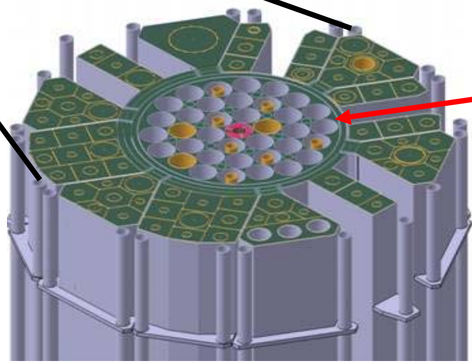
JHR experimental capacities

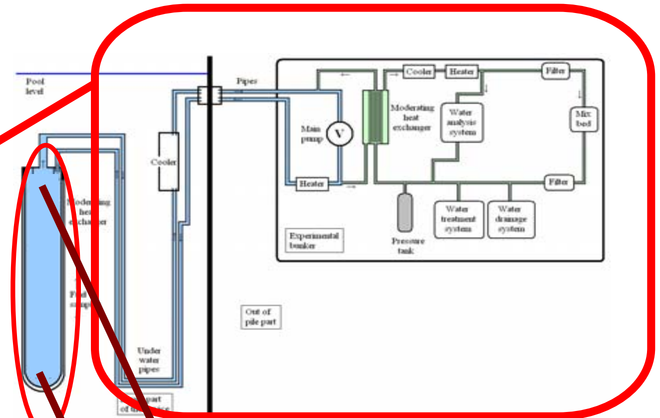
Reactor capacities

The experimental hosting system capacities
(dedicated to an experimentation family)



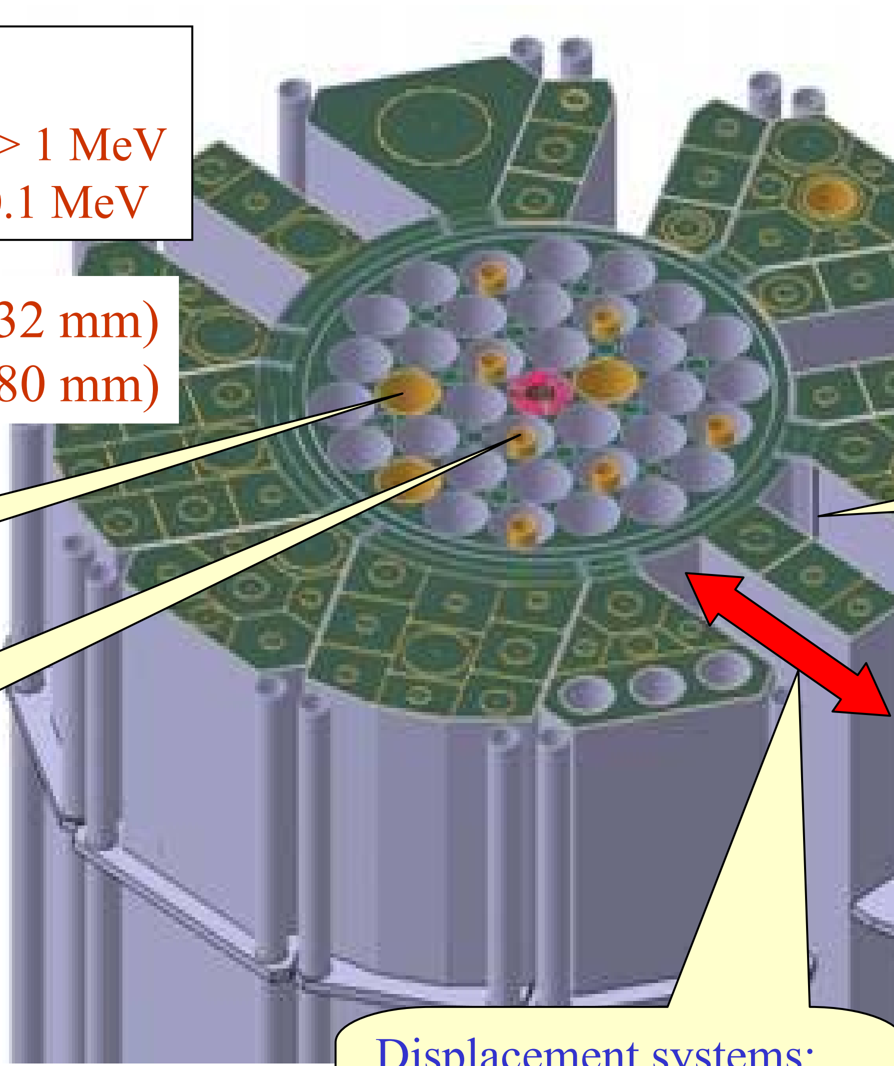






Sample holder
and instrumentation
(dedicated to an experiment)

JHR experimental capacities
general characteristics



In core
Up to 5.5 10^{14} n/cm².s > 1 MeV
Up to 10^{15} n/cm².s > 0.1 MeV

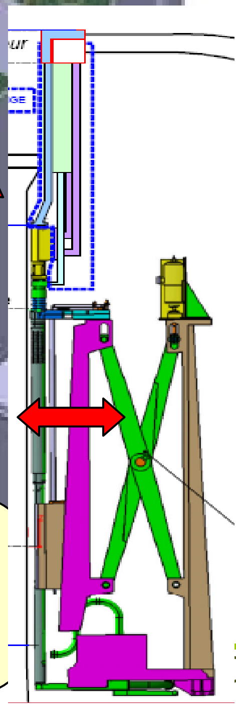
Small locations (Φ~ 32 mm)
Large locations (Φ~ 80 mm)

Fuel experiment

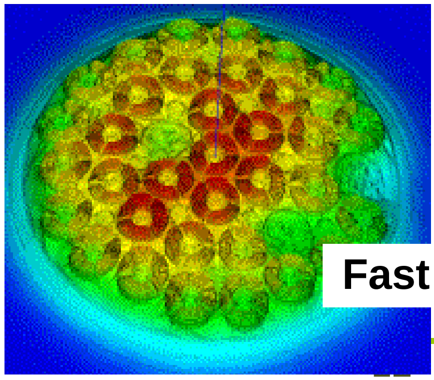
Material ageing
(up to 16 dpa/y)

In reflector
Up to 5.5 10^{14} n/cm².s
Fixed positions and
displacement systems

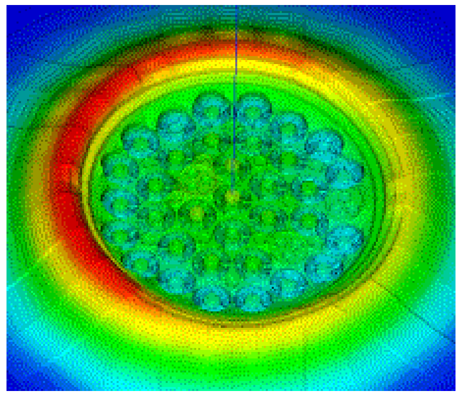
Fuel studies: up to 600 W/cm with a 1% ^{235}U PWR rod



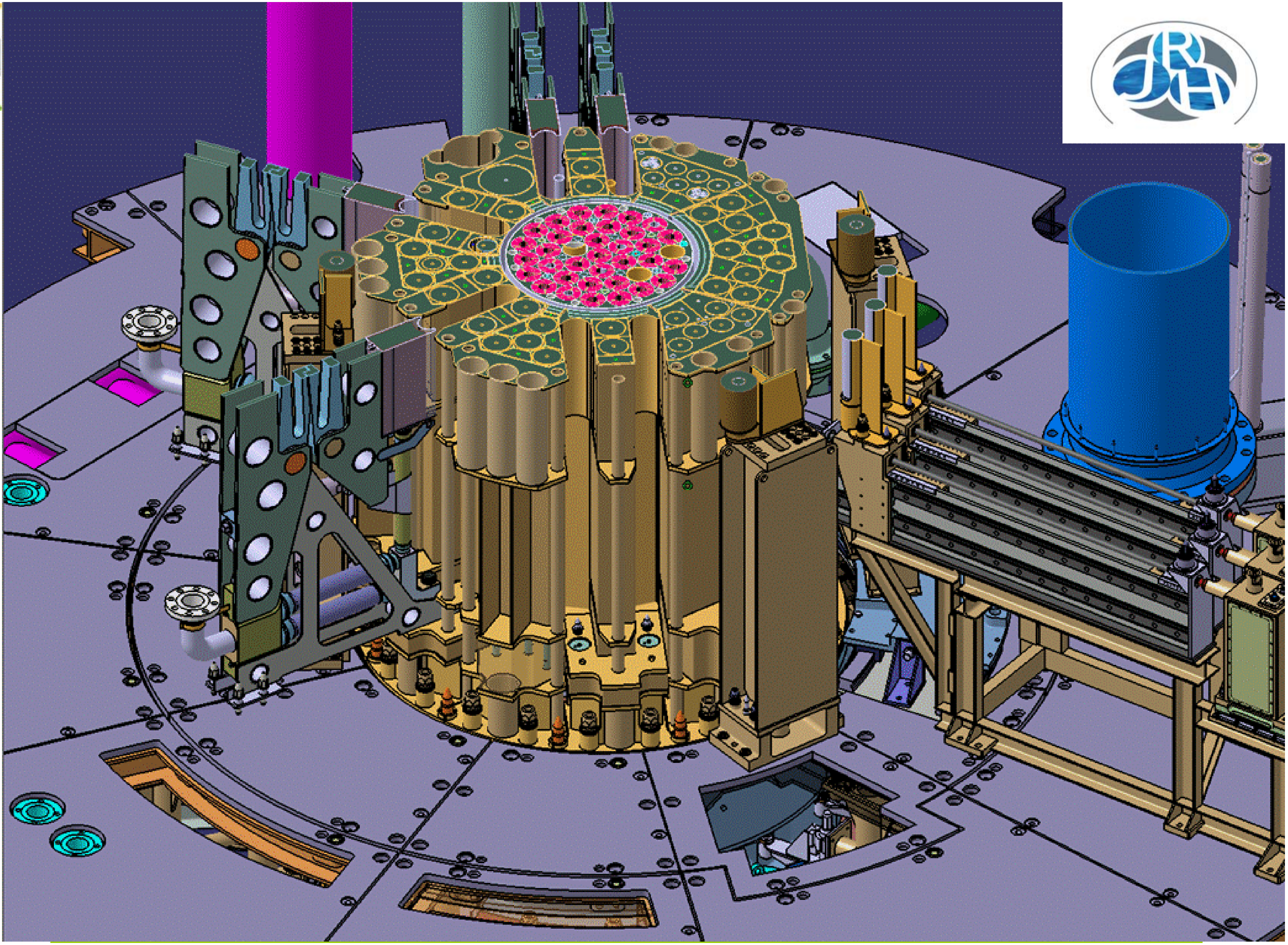
Displacement systems:
- Adjust the fissile power
- Study transients



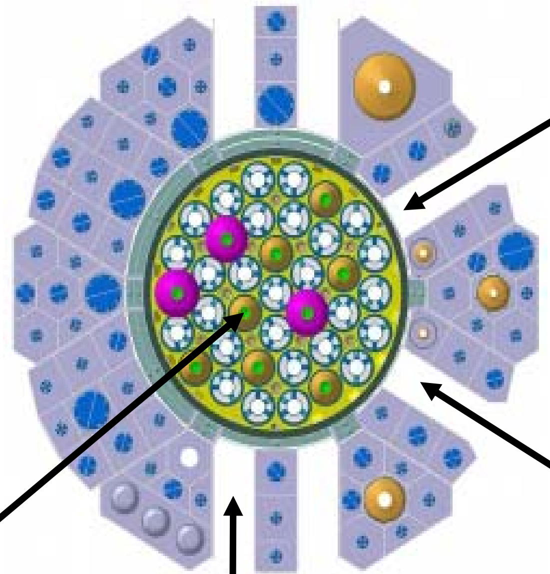
Fast neutron flux



Thermal neutron flux



Hosting experimental systems under development



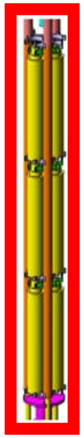
LWR Fuel : Madison (nominal)
Adeline (up to limits)
Lorelei (LOCA)

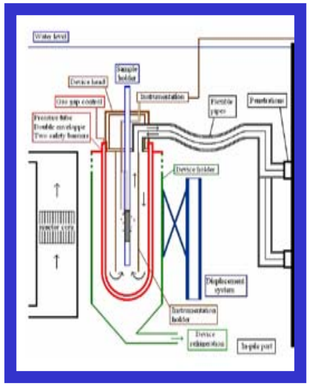
Material : Calipso ; Mica

CALIPSO

&

MICA



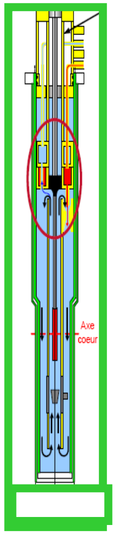


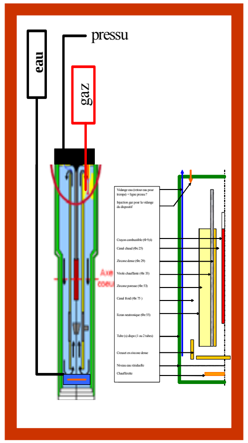
MADISON

Fuel under nominal conditions

ADELINE

Fuel up to design limits





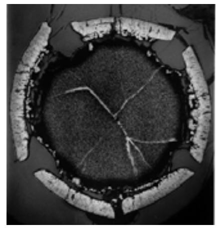
LORELEI

Fuel under accidental conditions (LOCA)

Preparing JHR as an International User Facility: launching Jules Horowitz International Programme (JHIP)

First Phase : 2012→ 2015 (existing facilities)
Second Phase: 2016→2020 (JHR)

- Strategic Scope
  - ✓ To address fuel and materials issues of common interest that are key for operating plants and future NPP
  - ✓ Centred around an efficient utilization of JHR features
  - ✓ Operates in synergy with technical infrastructure and expertise available in OECD countries
- Organisation: To implement the JHIP with the support of OECD/NEA as a secretariat

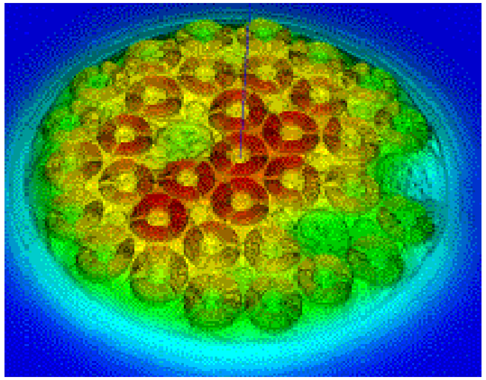


- Technical scope (Ramps, LOCA, Source Term...)

Conclusion: Preparing JHR success with OSIRIS experience...

- OSIRIS is successfully operating until the end of 2015
- CEA is maintaining significant R&D programs for experimentation improvements in MTR (instrumentation…)
- Strong Feedback from OSIRIS operation (close link with JHR team for operation procedures, safety analysis…)

- JHR will offer a wide experimental domain
  - ✓ **Some experimental hosting systems are under development**



- Anticipation of Users' needs

- JHIP is a natural framework for a Users community willing to impact the JHR experimental capacity setting up.

- International scientists (young fellows and/or senior experts) are welcome in Cadarache within the JHR team in order to build the future JHR scientist community

Thank you for your attention…

謝謝您的注意

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