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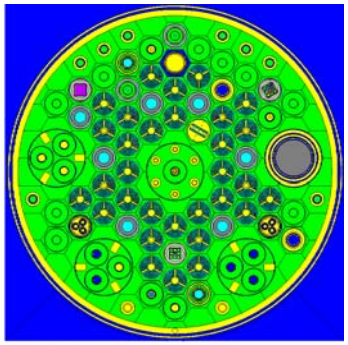

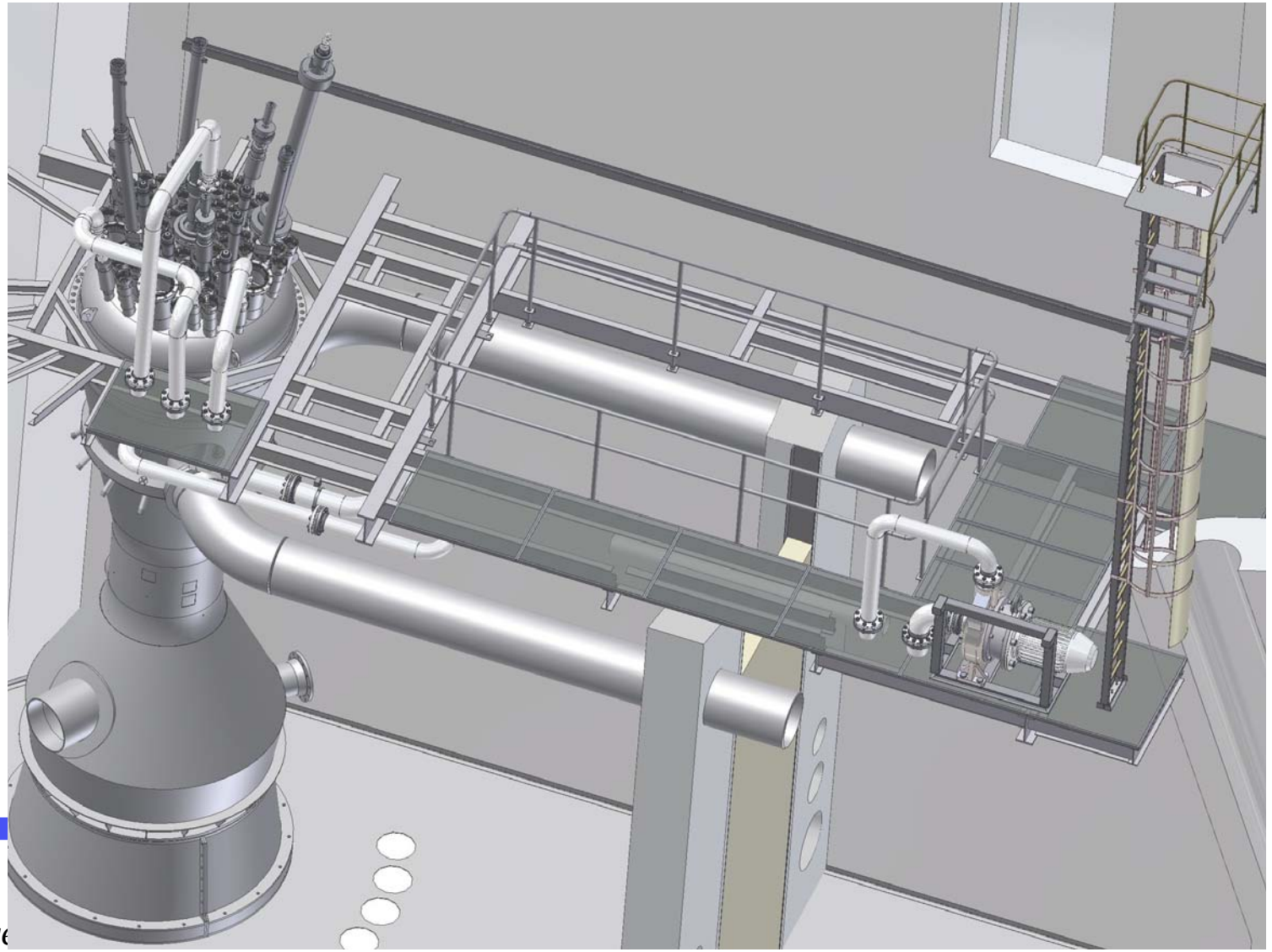

Edgar Koonen

12th IGORR Conference

October 27-31 2009, Beijing P.R.China

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BR2 reactor = one of the major **high flux MTR** type reactors of the world, operated by **SCK•CEN**

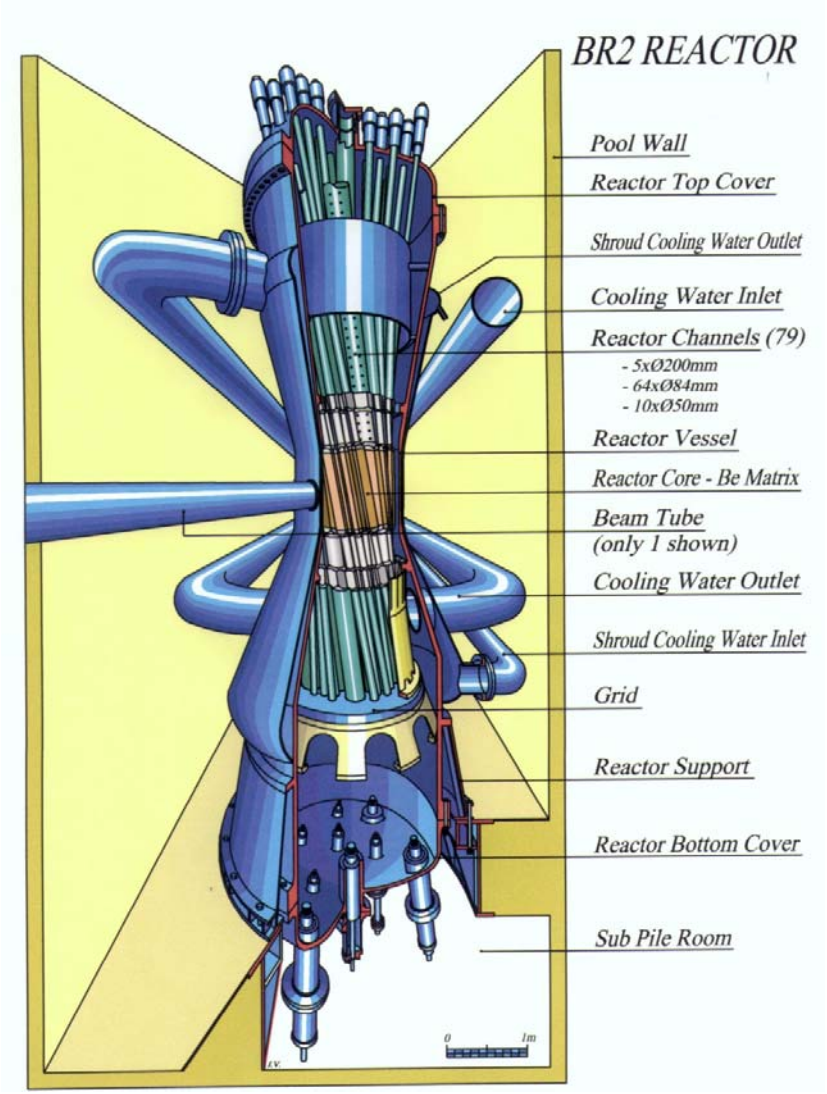
a **tank-in-pool type** reactor

the reactor core is constituted by a **beryllium matrix**

this matrix is placed in an **aluminium pressure vessel** in the shape of a hyperboloid of revolution

the vessel is located in a pool of demineralized water

the reactor is H2O cooled, Be and H2O moderated, can be operated at > 100 MWth



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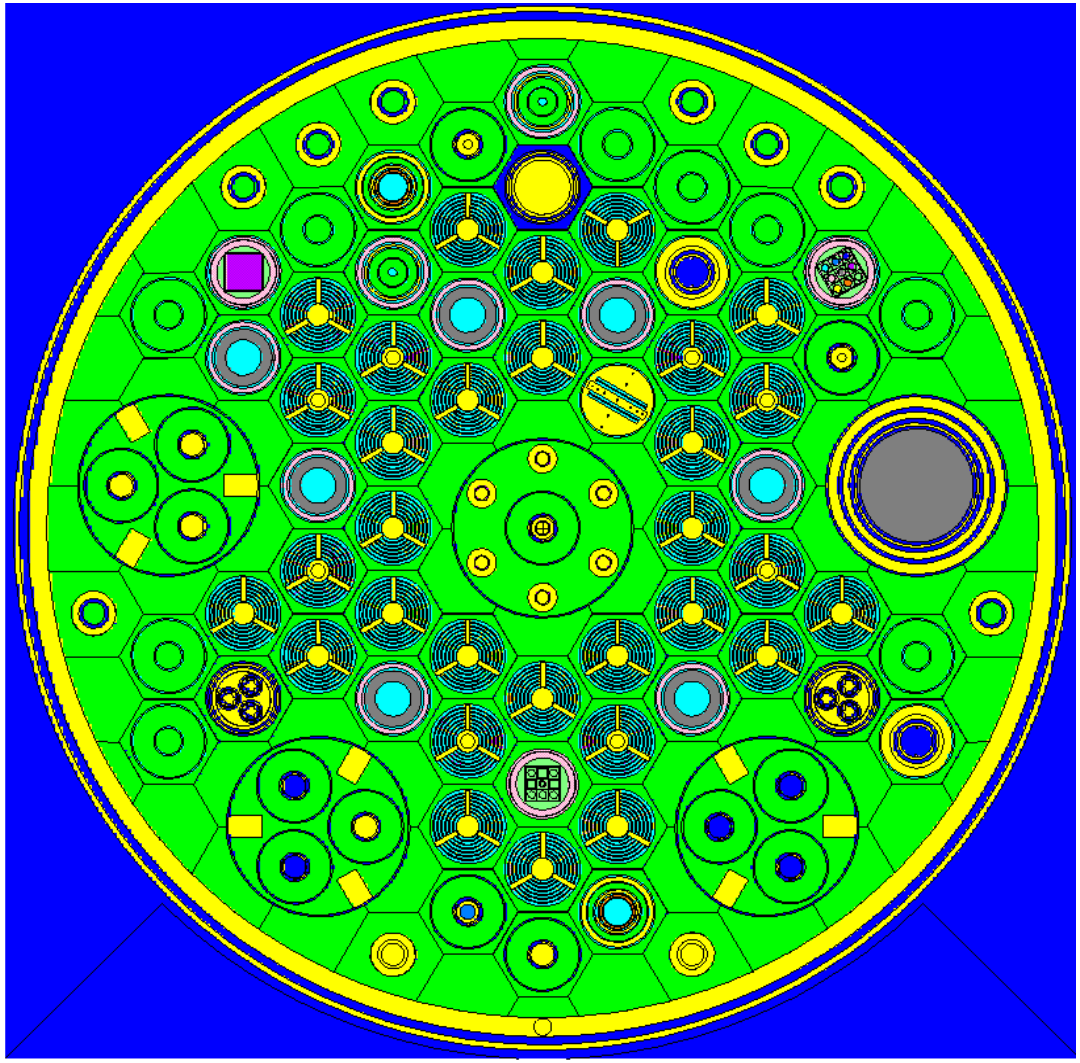
BR2 core:
cross section in the mid-plane



A variable core configuration with customized irradiation conditions in the experimental positions

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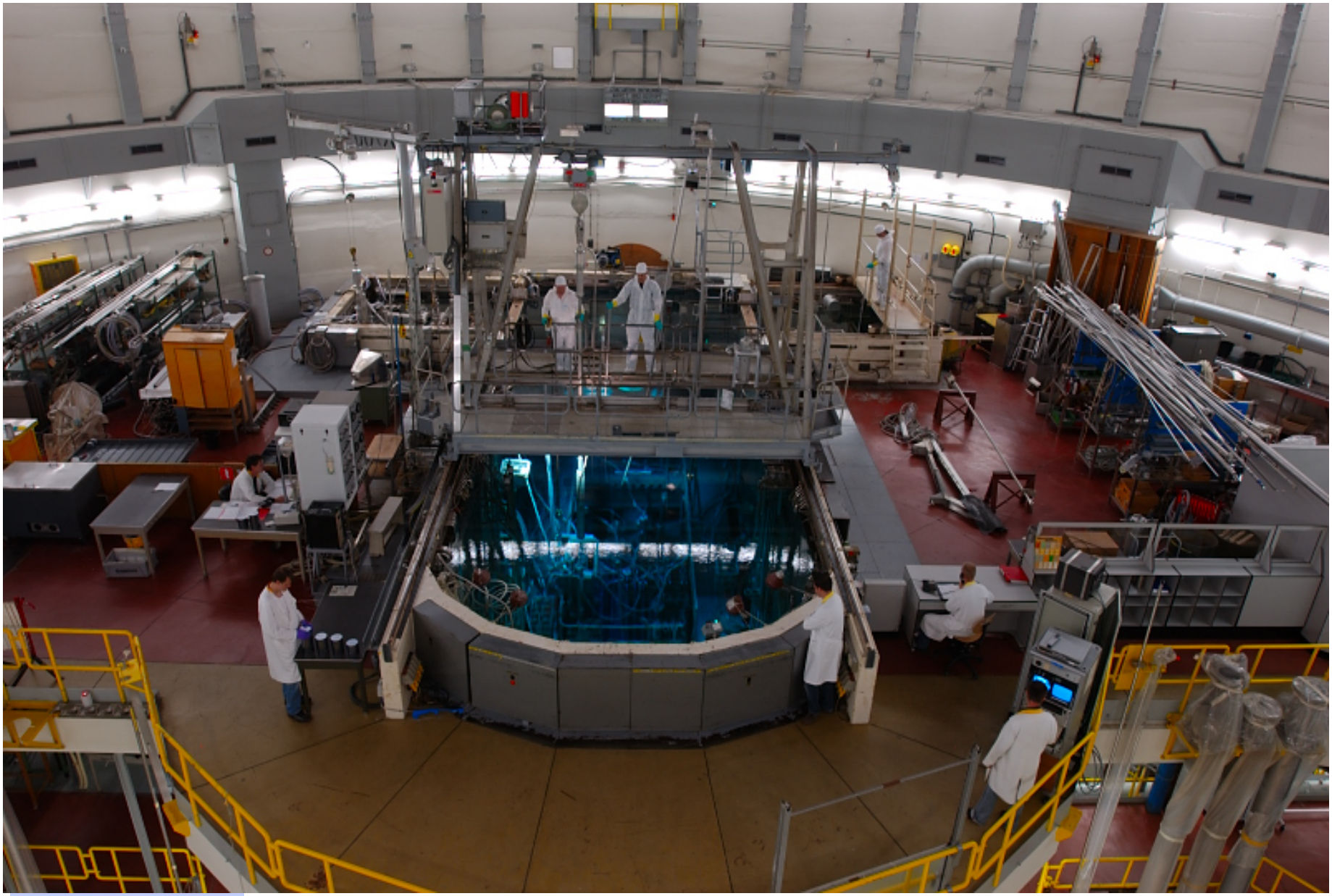
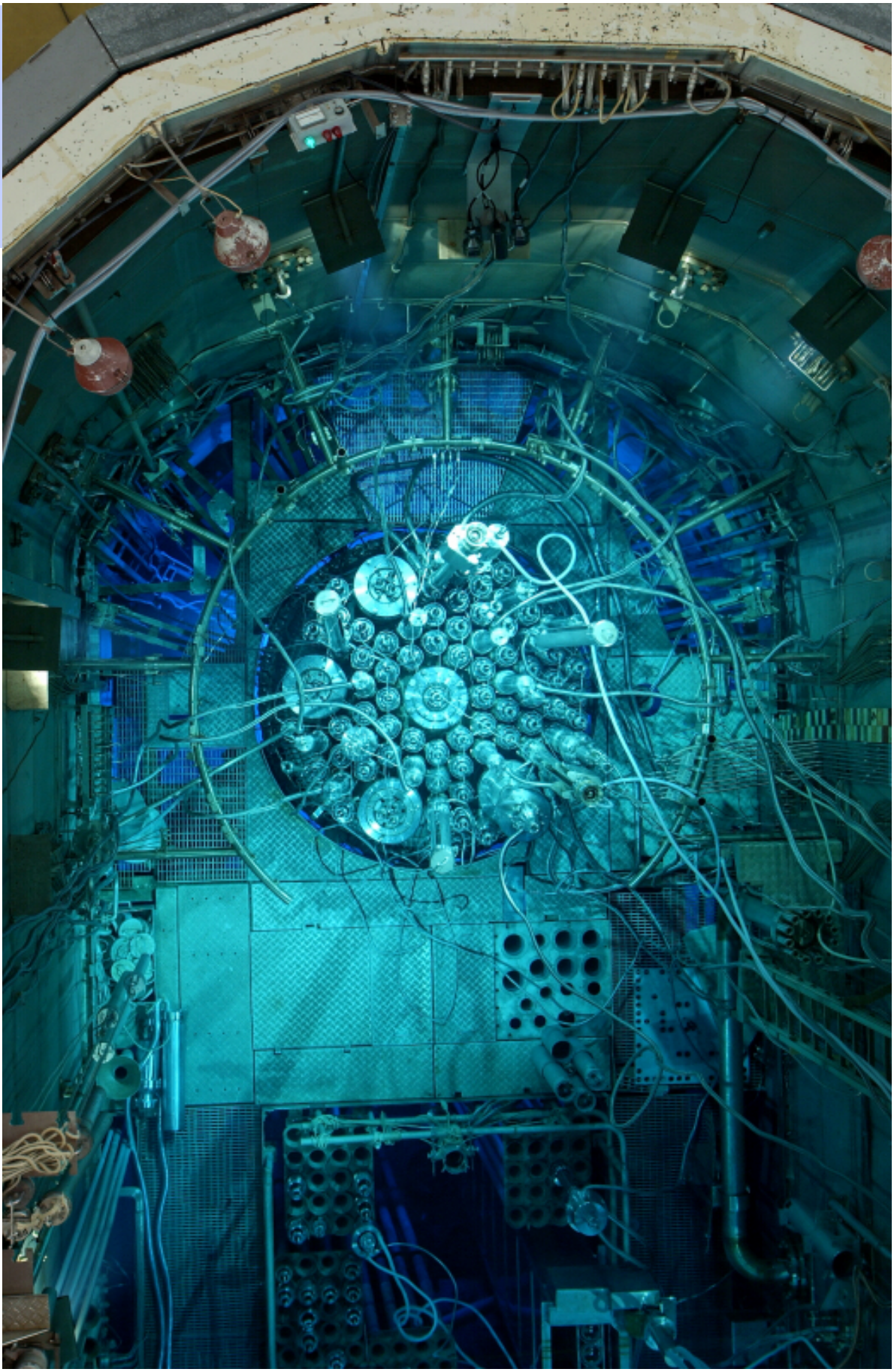
The major assets of BR2

- compact core arrangement in the twisted Be matrix
  - ➢ high power densities
- high thermal (central flux trap) and fast (axis fuel elements) neutron fluxes
- large number of irradiation positions, including a 200 mm central flux trap
- a closed primary circuit & containment building
  - ➢ complex experiments and large loops can be accommodated
- variable core configuration & operation mode
  - ➢ flexibility of utilization & tailored irradiation conditions
- dedicated loops, absorbing screens (Cd, ^{3}He, …)
  - ➢ representative irradiation conditions





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Agencies supervising the BR2 operation

- Federal Agency for Nuclear Control - FANC
  - "Belgian government agency entrusted with the protection of the population, workers and the environment against the dangers of ionising radiation"
  - the same safety authorities which also regulate the power reactors.
- BEL V
  - "A technical expert group, subsidiary of FANC"
- SCK•CEN's Internal Service for Prevention and Protection on the Job and its BR2 nuclear safety group
  - "The nuclear safety group is responsible for fysical control with respect to BR2"

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The License to operate

The license to operate BR2 is very similar to the ones for power reactors

No explicit time limit but comprehensive decennial safety reassessments which can result in a prolongation of the license provided a number of new requirements are being satisfied.

In the intermediate periods Safety Review and Licensing are an ongoing activity with periodic hold-points

The 2006 safety reassessment resulted in number a specific work items, concern various types of activities and associated milestones/deadlines.

The timely completion of these tasks as well as their acceptance by the Safety Authority condition the prolongation of the authorisation for operation of the BR2 reactor.

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2006: Decennial safety reassessment Specific items (1)

- **Surveillance programs**
  - Be-matrix : visual & dimensional inspection inside the channels
  - Al- vessel : mechanical testing of surveillance samples
  - Irradiation devices, mainly pressure tubes of nearly permanent devices
- **Inspections**
  - Primary circuit
  - The remaining beam-tubes => leak-tightness reactor-pool
- **Modernisations:**
  - PSA : update -> Technical Improvements
  - Radioactive Effluents : optimisation of the piping network
  - Cranes: complete overhaul, new regulations

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2006: Decennial safety reassessment Specific items (2)

- **Requirements concerning 'knowledge management':**
  - document management system, improved archiving.
  - feedback/learning from past experience (REX): improved registration and analysis of incidents and nearly-incidents, fault tree analysis of incidents, analysis of incidents reported in the ISS and IRSRR data bases for lessons to be learned.
  - knowledge transfer and training, with particular attention for education programmes on safety and safety culture and for competence management with regard to the renewal of the staff (accompaniment programmes).

- **Update of the SAR :**
  - major modifications concerning Organisation, Techspecs, Incident Analysis, …
  - a new volume added for the inclusion of quasi-permanently loaded experimental devices

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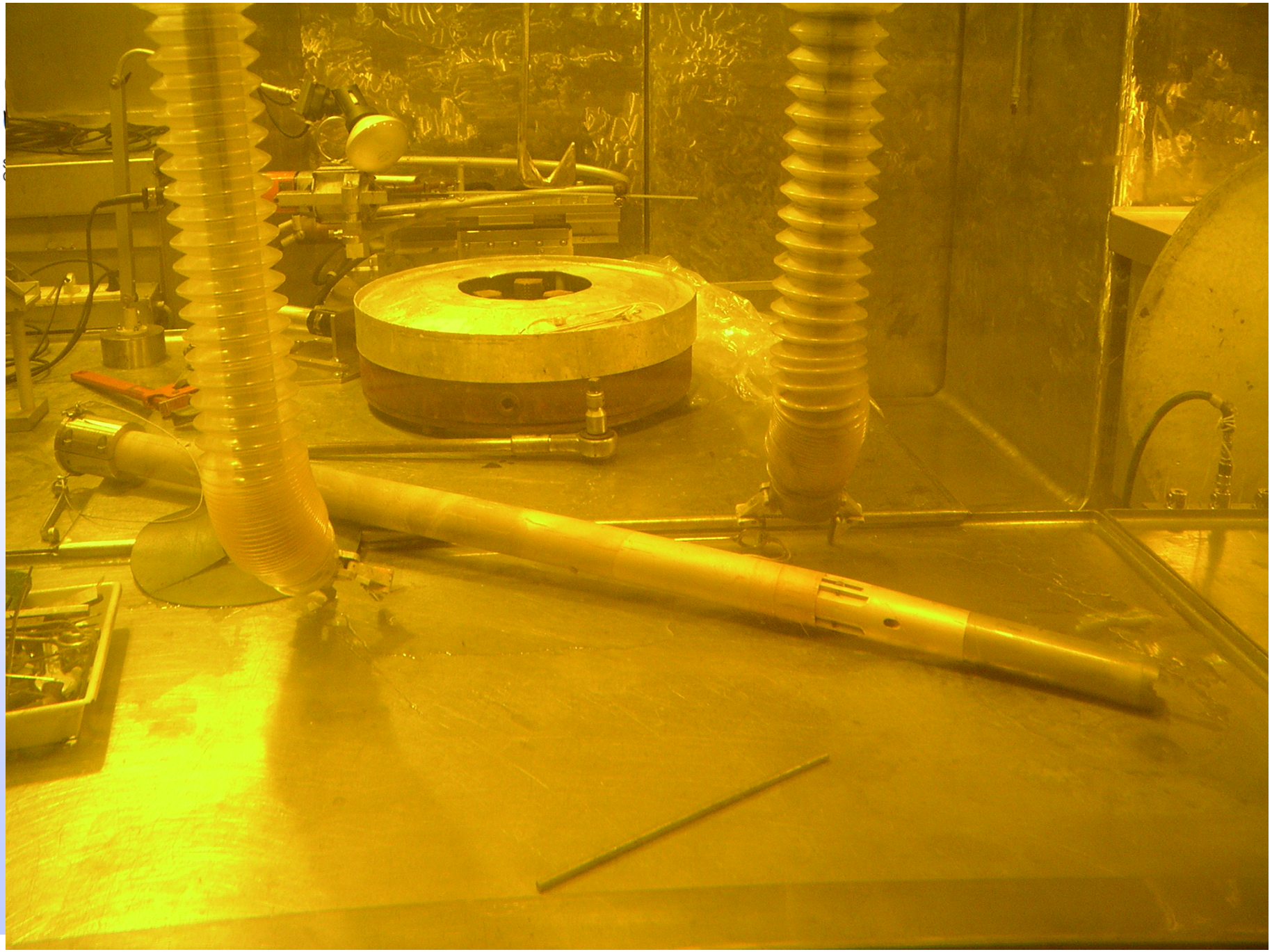
Renewal of the control rods

The major components of the control rods have to be replaced:

- replacement of the displacement mechanisms and introduction of digital position indicators.
  - This action was initiated to avoid ageing problems with the former mechanisms and was combined with an upgrading of the position indicators.
- replacement of the movable neutron-absorbing parts of the control rods: cladded Cd tubes -> Hf tubes
  - The technical specifications define a limit on the Cd burn-up.
  - The stock of Cd tubes was running out; no suitable co-extrusion press for a new fabrication could be found.
  - A search for alternatives (other fabrication methods, other n-absorbing materials …) led to the decision to replace the Cd-Al tubes by Hf tubes.
  - The replacement of all neutron-absorbing parts is foreseen for early 2010.



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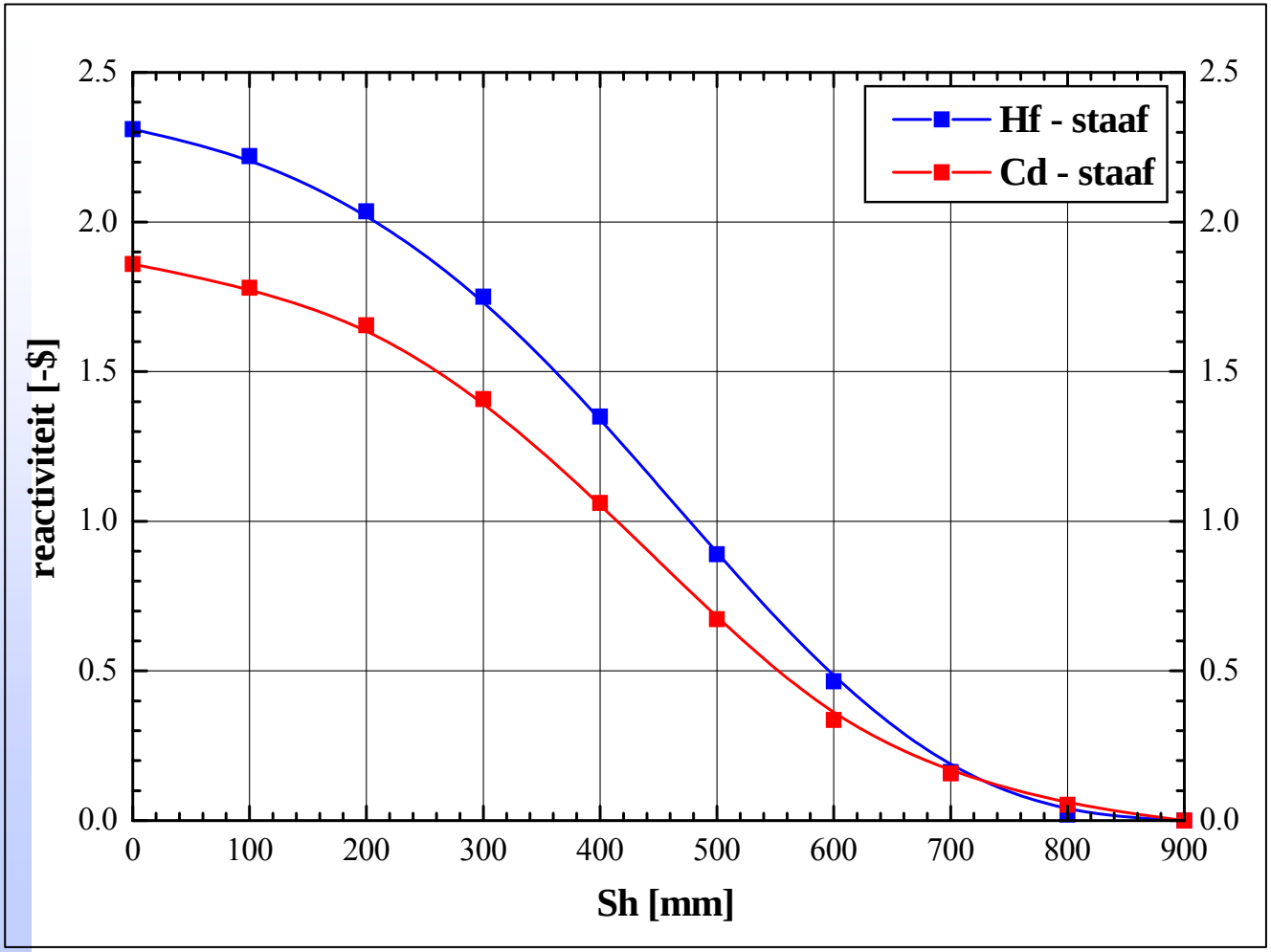
replacement of the n-absorbing parts: Cd ➔ Hf



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Audit on Safety Culture

The audit was performed in 2007 along several lines:

- An overall staff survey based on an EdF question list
- Interviews with key staff based on IAEA's SCART guidelines
- Observations and technical audit in the installation
- Recordings of past incidents

Outcome:

"BR2 operating organisation establishes policies in accordance with State requirements and IAEA recommendations giving safety matters highest priority and promoting a strong safety culture."

- Room for improvement: "human factors relating to experiments"
- Never rest: Safety Culture is a continuous effort

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Fuel Cycle

- Front-end
  - BR2 is still fueled with HEU
  - Last HEU supply from US in 2006
    - ➔ Physical Protection has been upgraded
- Back-end:
  - SCK●CEN has a long lasting contract with AREVA-NC for the removal of its spent fuel to the reprocessing plant in La Hague. All the spent fuel from BR2 will be downblended to low enrichment by dilution with spent fuel from nuclear power reactors.
  - Since 1998, a total of 18 transports totalling more than 1000 fuel elements have been executed

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Fuel Conversion

- Since 2007 there is an important evolution in the development of higher density LEU fuels
- In particular the **dispersed UMo** fuel system with a density of ~ 8 - 9 gUtot/cc is now in the qualification phase
- The US-Belgian collaboration on conversion has intensified since autumn 2007
  - a common conversion feasibility study was initiated together with ANL
  - common efforts for the qualification of high density UMo fuel are being planned
  - a draft conversion schedule has been developped
  - Recently initiated coordination with other European stakeholders (ILL, CEA, CERCA)

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Next Safety Reassessment

- The next reassessment in 2016 will concern a global requalification of the BR2 installation in combination with the fuel conversion
- This process will start around 2012 and will be planned in three phases:
  - conversion feasibility,
  - technical validation and safety assessment,
  - licensing procedure.
- Presently a global project plan is to be established detailing these three phases in order to allow the Safety Authorities to follow the whole project in a timely manner from the earliest stage.

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Present Utilization of BR2 (1)

1. **Basis: internal R&D programs related to needs of Belgian PWR's**

- MOX fuel: thermal conductivity, fission gas release, PCMI at high burn-up
- Structural materials: RPV Steels (embrittlement), IASCC (vessel internals)

2. **European Programs (**Framework programs, PCRP, Fusion EFDA)

- Characterization of various structural materials (first wall, blanket, divertor, …)
- Radiation resistance & hardening : sensors, cables, optical fibres
- Characterization of structural materials in Pb-Bi environment => ADS (Transmutation)

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Present Utilization of BR2 (2)

3. Bilateral and International Programs (contractwork, irrad.services, collaborations)

- Fuel characterization (mainly PWR fuels in a dedicated PWR-simulating loop)
- Power transients : ramping up to fuel pin failure with possibility for post-transient irradiation, control-rod withdrawal and load following tests
- In-pile instrumentation (internal R&D programme, external participation)

4. **Commercial Production Activities**

- Radioisotopes, mainly Mo-99 (fissile targets) and Ir-192 (up to 700 Ci/g)
- NTD-Si (in-core: 5“ ingots or wafers, pool-side facility: 6 – 8“ Si-ingots)

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CALLISTO
a PWR loop inside BR2

- Purpose of the CALLISTO loop
  - behaviour of advanced fuel and structural materials under representative PWR operating conditions
  - the facility permits irradiation of clusters of 9 fuel rods in each IPS
  - performances of materials for fusion reactors and ADS systems in one specific IPS close to the core (high dpa rate)
- 3 in-pile sections (IPS) connected to 1 high pressure, high temperature water loop
- 155 bar
- 300° C (80° - 300° C is possible)
- 2.1 kg/s coolant mass flow (3 m/s mean velocity)
- PWR water chemistry
- 340 W/cm typical LHGR at hot plane level
- Fluence: 0.1 or 0.25 dpa/BR2 cycle
- IPS capacity: basket 37 mm x 37 mm x 1000 mm

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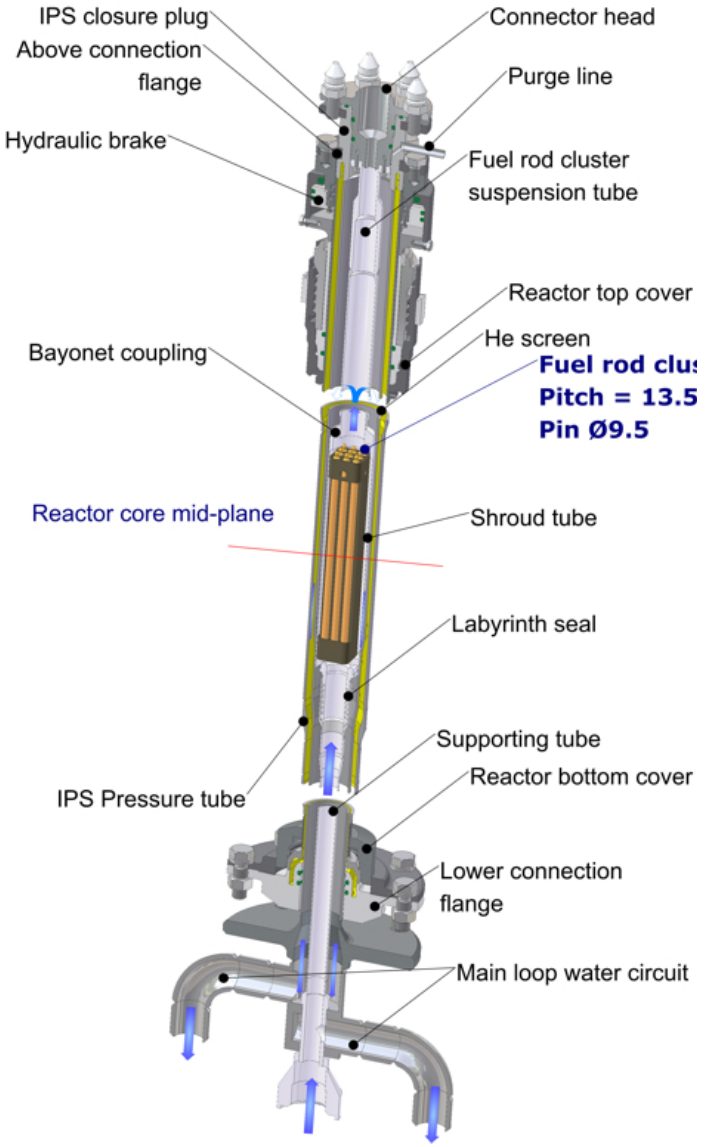
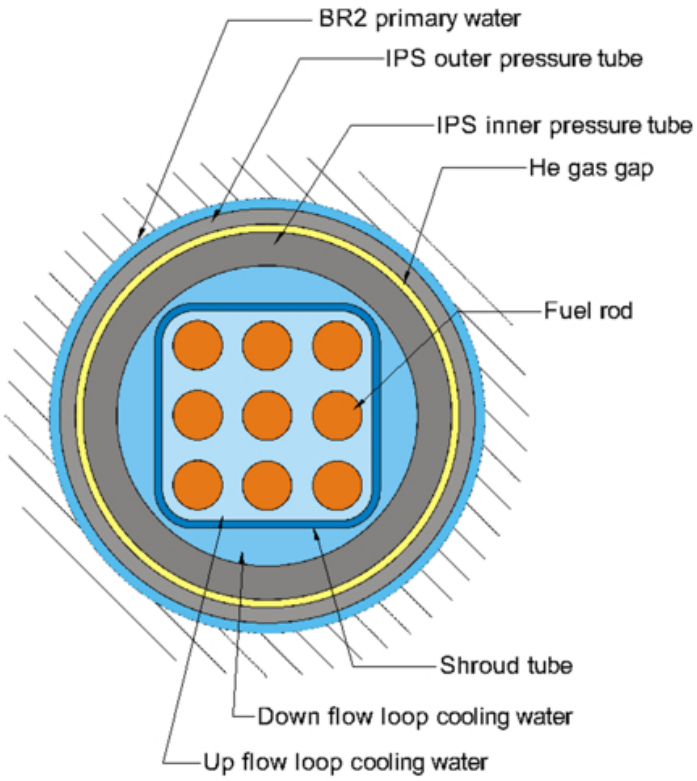
CALLISTO





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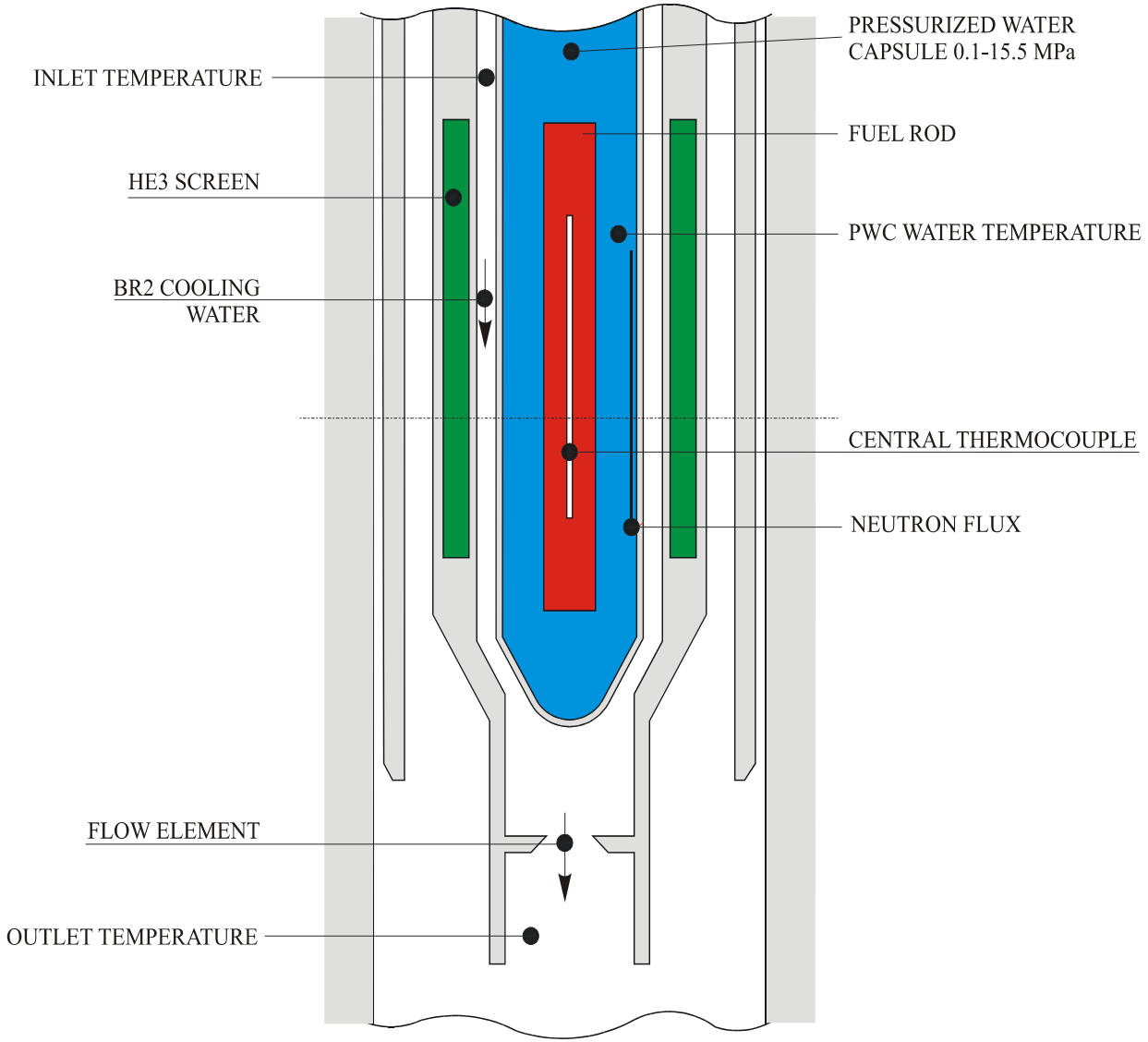
PWC capsule & VNS screen



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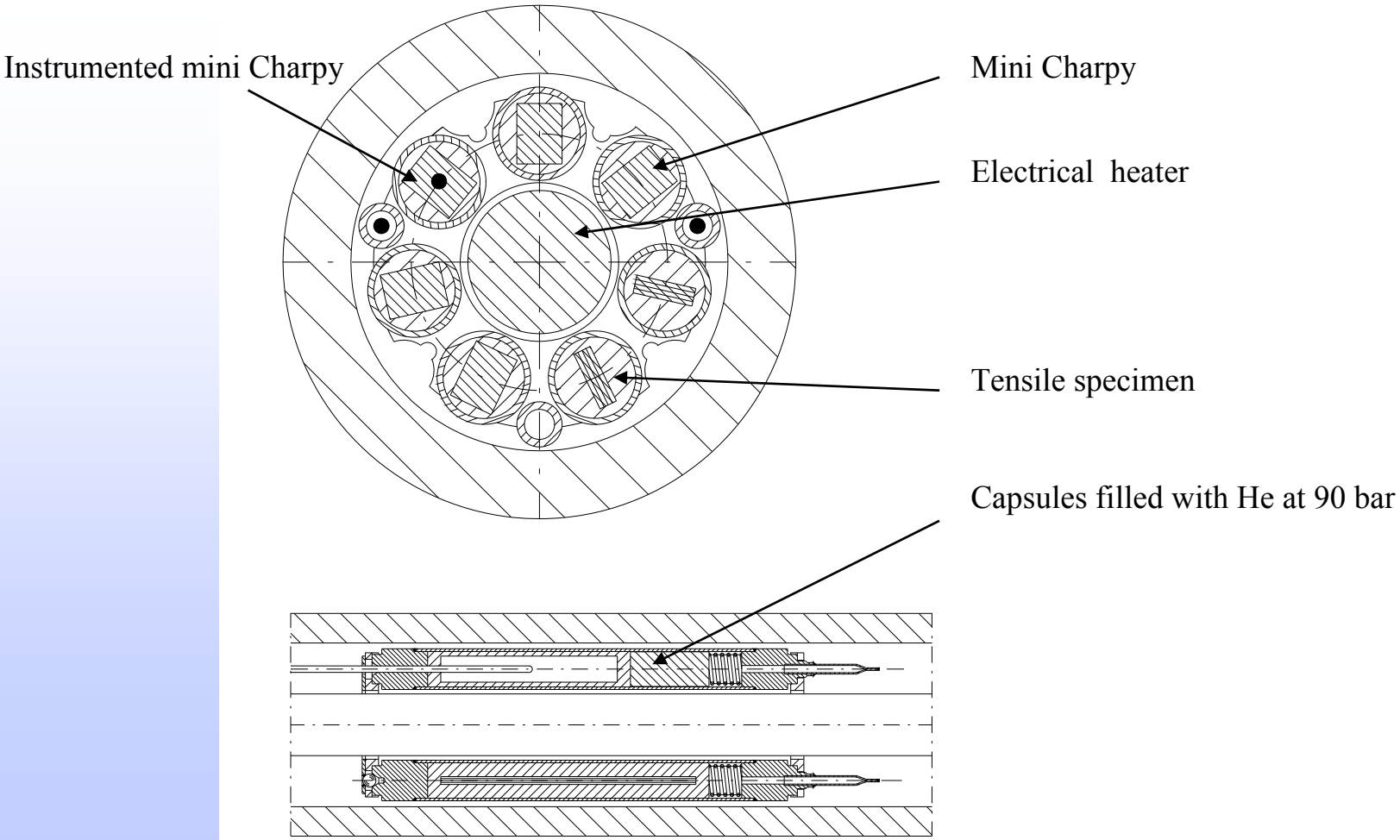
Fusion program: encapsulated specimens in MISTRAL



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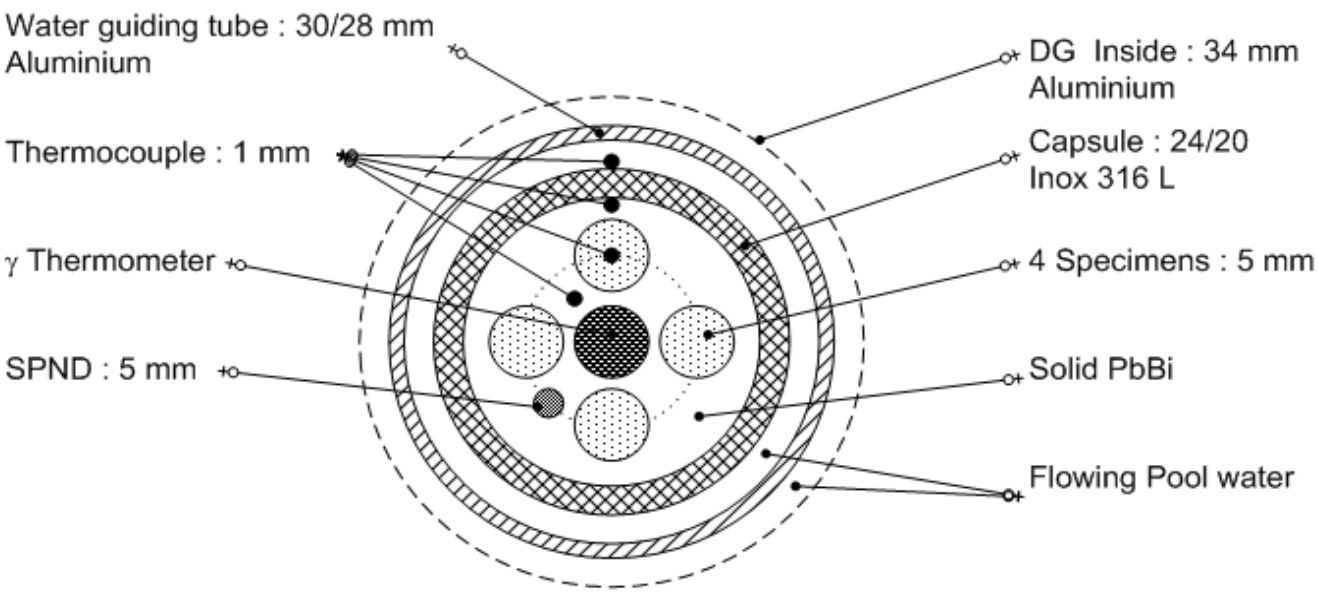
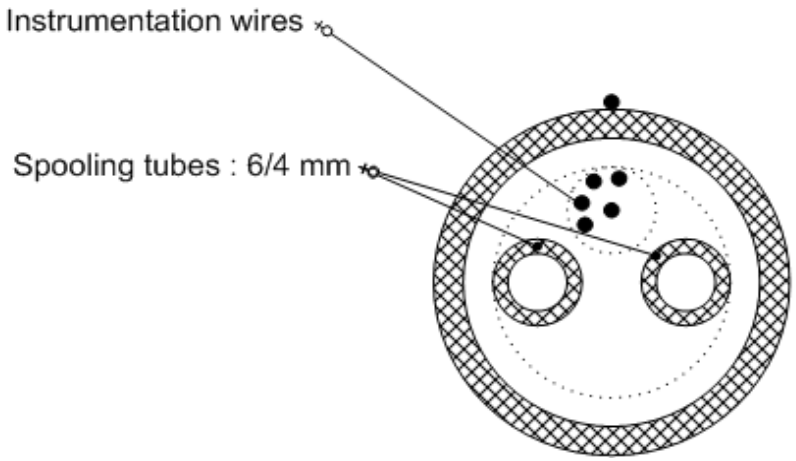
Steel samples irradiation in Pb-Bi environment

Single wall capsule for PbBi irradiation



Capsule top



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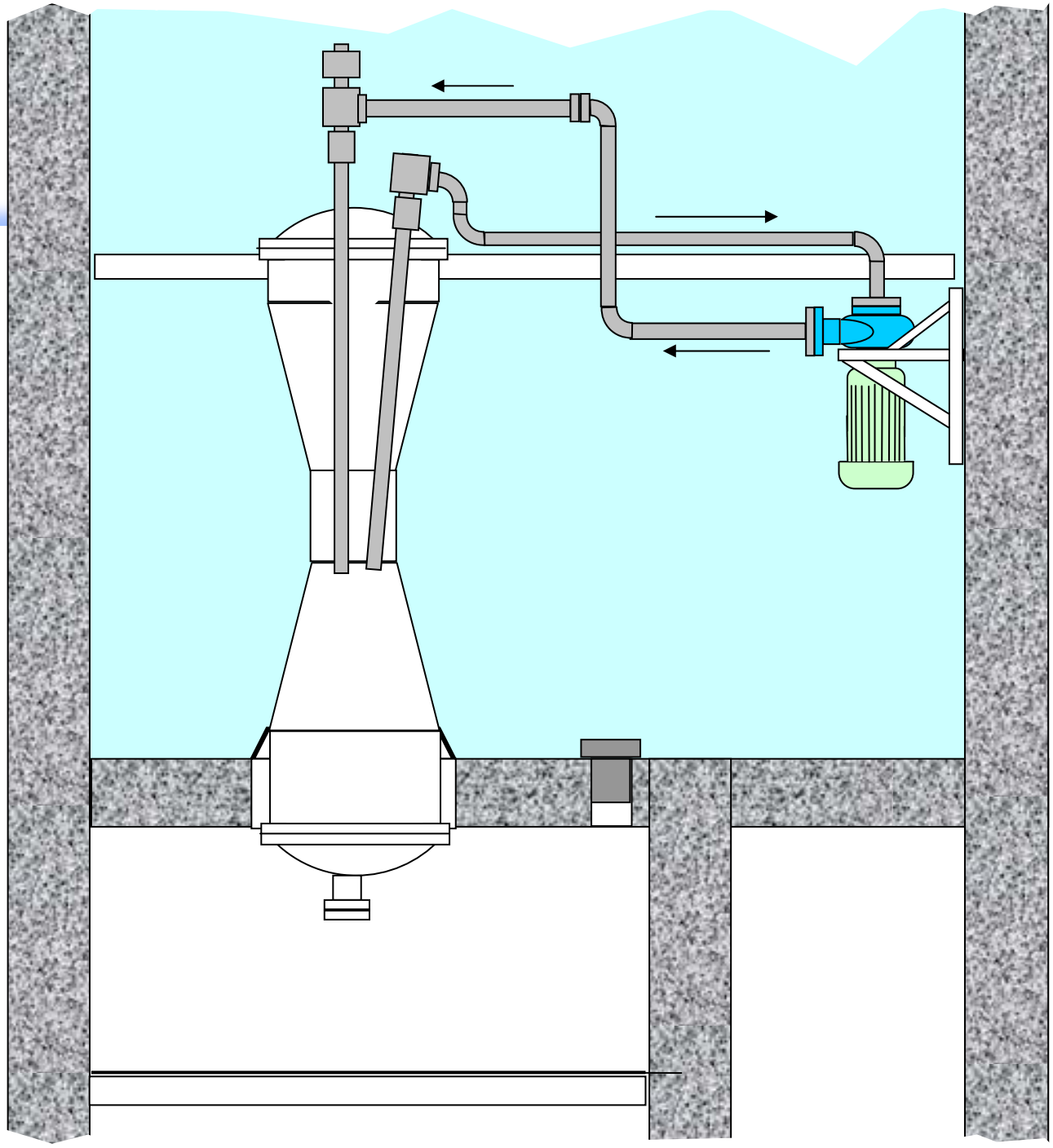
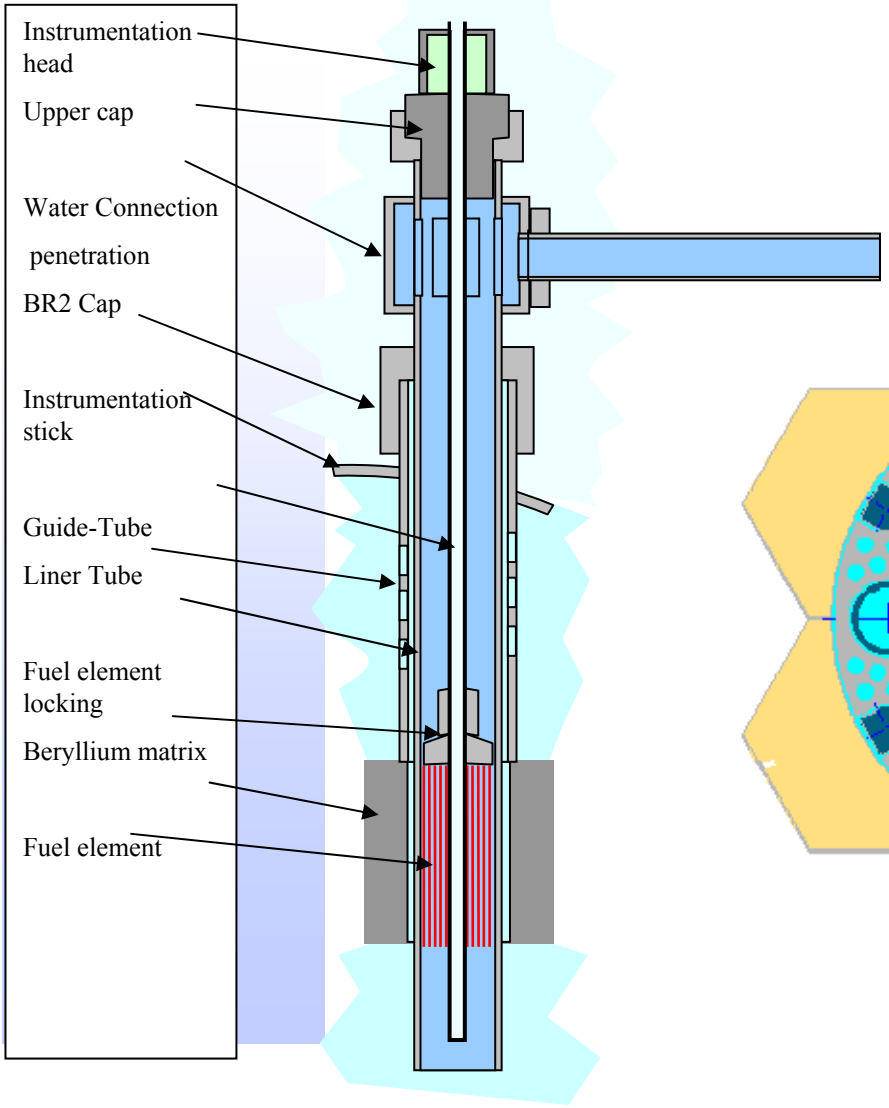
EVITA - loop

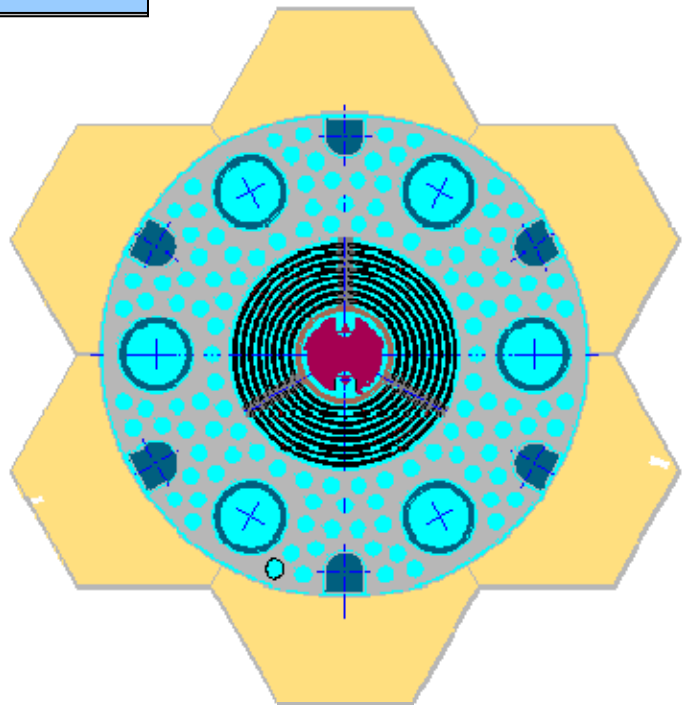
Simulation of RJH thermo-hydraulics

Semi-open loop – water taken from 2 peripheral channels and pumped through the IPS loaded insude the central 200 mm channel equipped with a dedicated plug (Al/H2O or Be)



EVITA loop: in operation since cycle 04/09 (July 2009)





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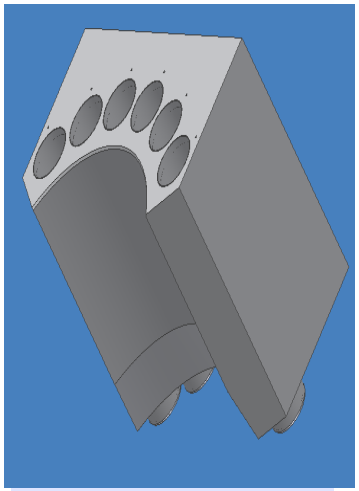
POSEIDON => NTD-Si production



- POSEIDON is a NTD-Si production facility
- the Si ingots can have large dimensions:
  - diameter: 6 or 8 inches
  - height: 25 cm
- main component is an Al box filled with graphite
- the box is pierced by 6 vertical channels
- the baskets loaded in each channel can contain 2 silicon ingots each

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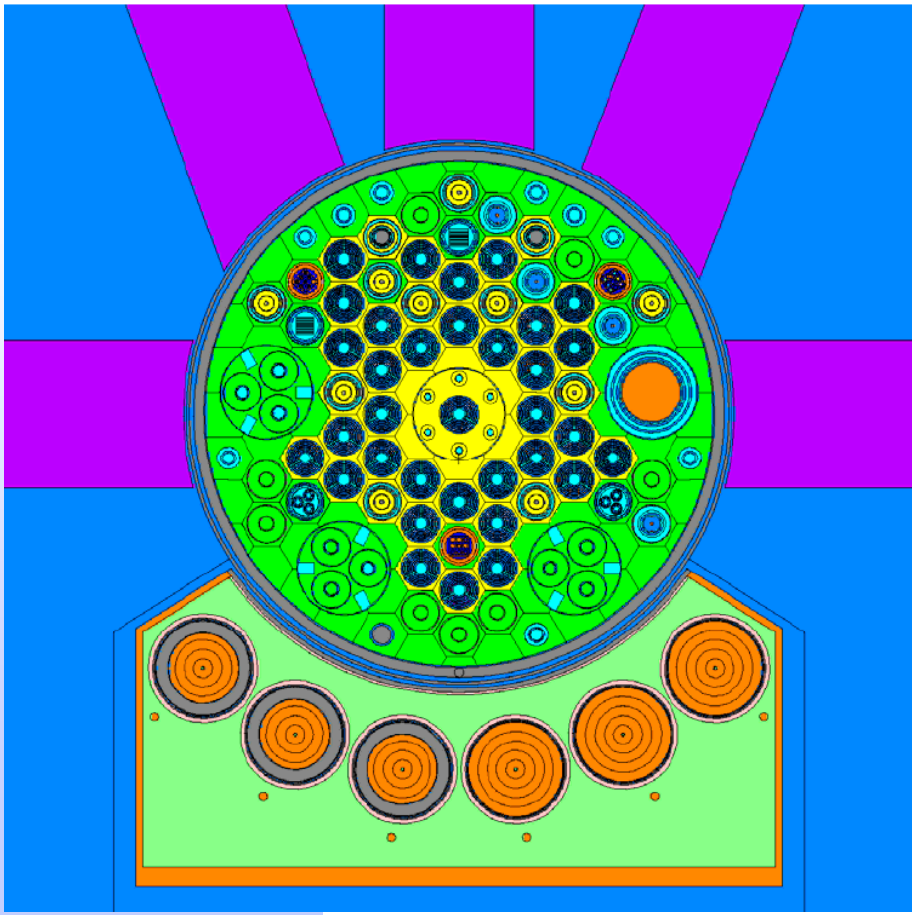
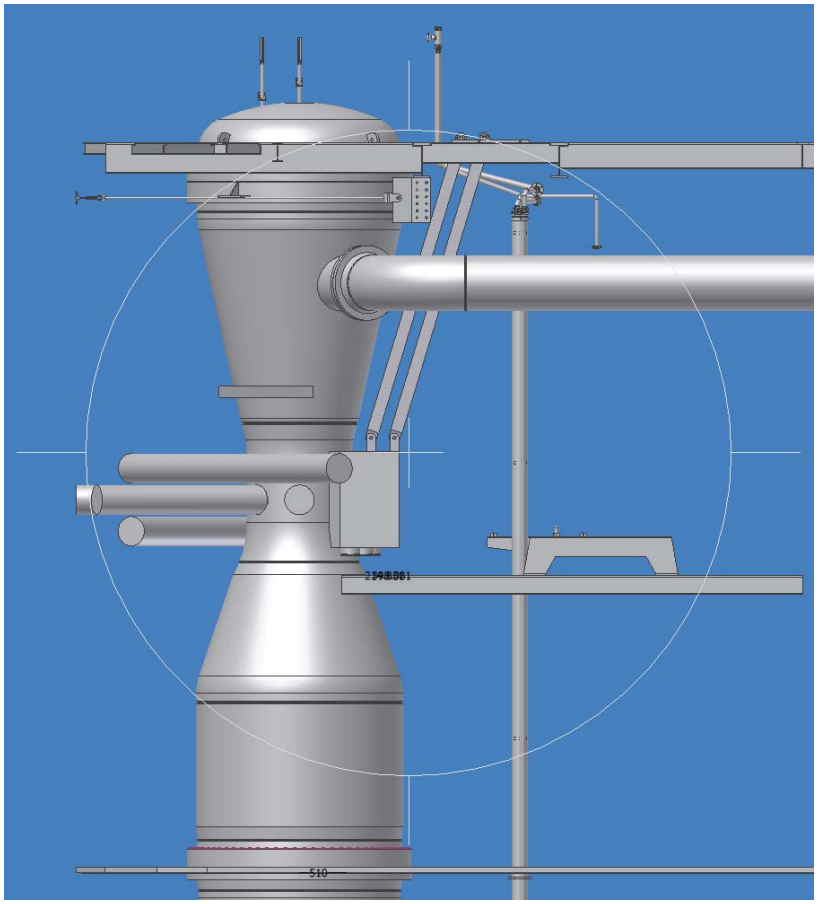
POSEIDON

POol **S**ide **E**quipment for **I**rradiation and **D**oping **O**f silicon by **N**eutrons

in operation since begin 2008





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Is BR2 an old reactor ?
It's a well maintained & refurbished reactor

- Start-up: early 1963 -> 224.000 MWd
  - 1st major shutdown 1979: Be replacement & general overhaul
- Operation resumed with 2nd Be-matrix: 1980 → 180.000 MWd
  - 2nd major shutdown 1996: major refurbishment
- **Operation resumed with 3rd Be-matrix in 1997**
- The decision to continue operation is based on recognition that BR2 is **an essential R&D platform for SCK•CEN**
  - Engineering R&D in relation to the Belgian Nuclear Programme
  - Support for internal SCK•CEN R&D programs, international collaborations and radioisotope production
  - For budgettary reasons limitation to 5 cycles/year
- **Study underway to extend operation beyond 2020**

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Operation 2009

- Up to now still 5 cycles/year (3 of 21 efpd, 2 of 28 efpd);
  - ➔ From 2010 on we foresee 6 cycles
- The operating program was drastically changed begin of January 2009 due to the worldwide Mo99-supply shortage
  - The 3 first cycles of the year (each with 3 week duration) were operated from half January to half May and were dedicated to Mo99 production
  - The two last cycles (each with 4 week duration) were started around mid-July and mid-October
  - The EVITA programme was postponed by about half a year
- The first 4 cycles 2009 were operated at 100% availability
- The fifth cycle is presently underway

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Operating Perspectives

- Technically: installation is fit until beyond > 2020
  - extensive refurbishment executed in the period 1995-1997
- Licensing:
  - no time limit, but periodical safety reassessment
  - last decennial safety reassessment in 2006
- Strategic planning:
  - the 2006 decennial safety reassessment was conducted with the perspective of another 10 years of operation -> 2016
  - **The board has asked a study: what it takes to operate until > 2020**
  - A new project under study for beyond 2020: the MYRRHA ADS

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BR2 reactor

tank-in-pool type, HEU fuel, Be matrix, H2O cooled, specific power > 500 kW/l
variable configuration, operated at 50-80 MW, refurbished 1997 → 2016 and beyond