Australian Government

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Nuclear-based science benefiting all Australians

Early Operational Experience of the Cold Neutron Source on OPAL Reactor

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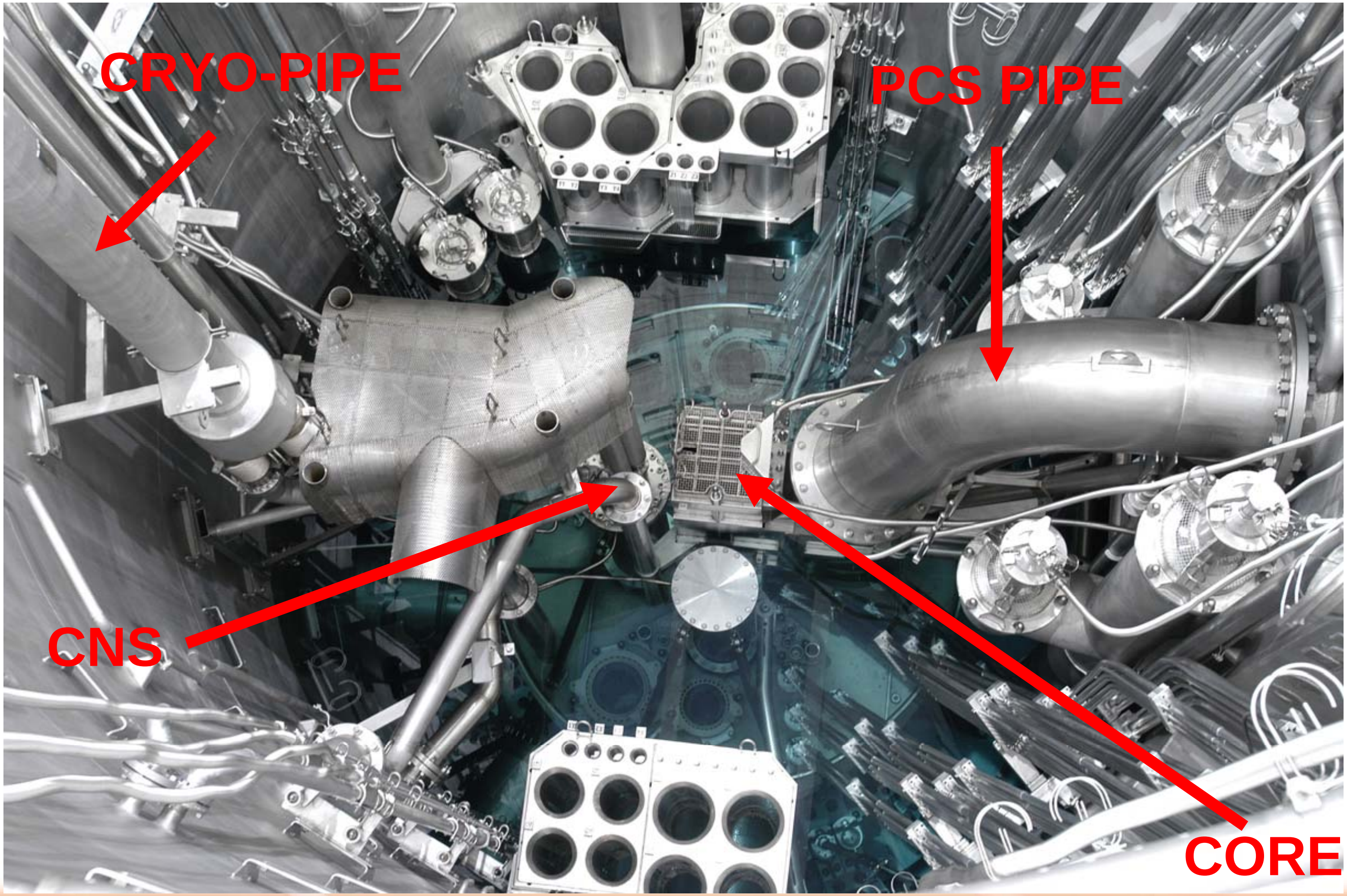
The OPAL Reactor

- 20 MW multi-purpose research reactor
- Compact core (MTR-type fuel)
- Light water cooled and moderated
- Heavy water reflected
- Radiopharmaceutical Production
- Neutron Beam Research

The OPAL Reactor



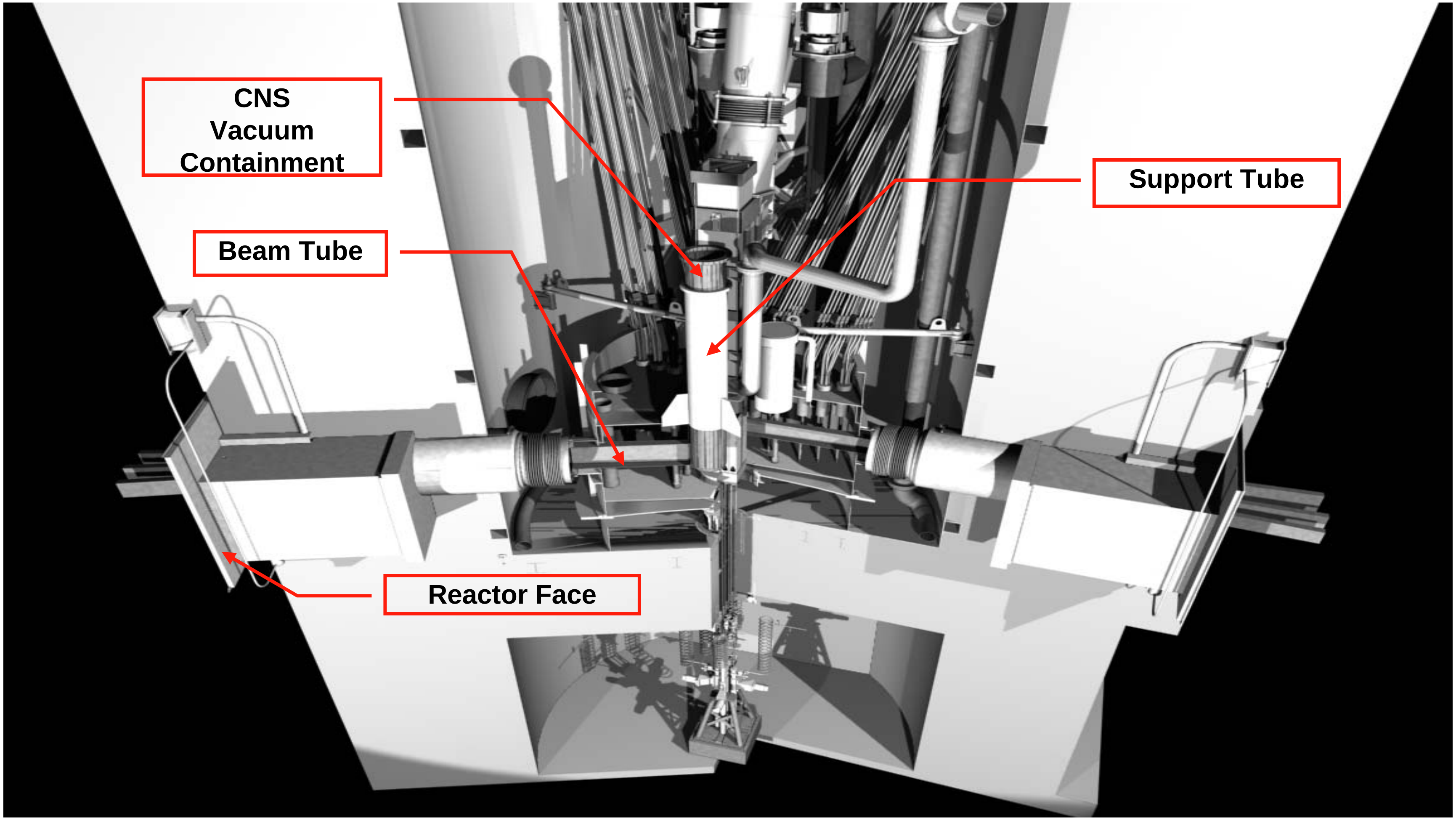
Important Contract Requirements Fulfilled

- 20 litres of single phase liquid deuterium at below 25 K
- Cryogenic power specification – 5 kW
- A standby mode – reactor operating at full power without cryogenic cooling
- Cold neutron flux at reactor face (~low 10^{10} $n \cdot cm^{-2} \cdot s^{-1}$) and through neutron guides (~mid 10^{9} $n \cdot cm^{-2} \cdot s^{-1}$)

An International Project

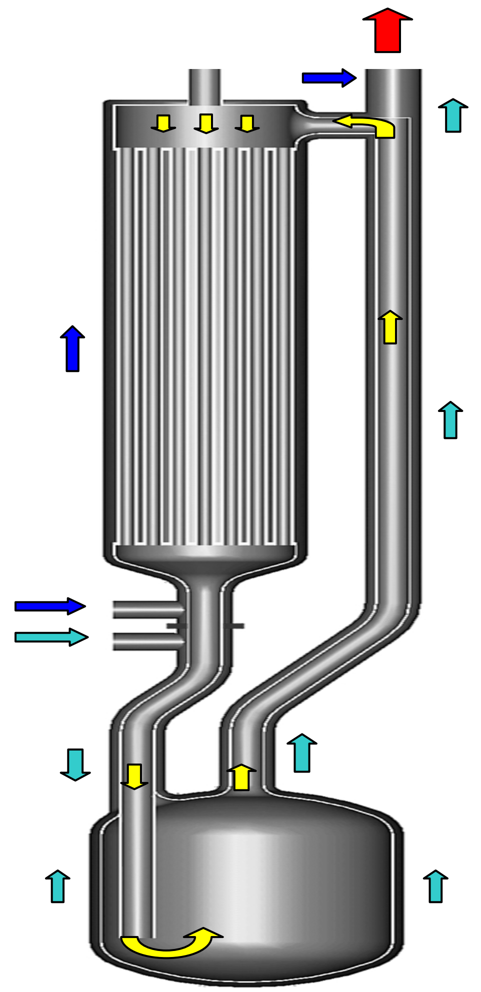
- **INVAP, Argentina** – overall design, project management, CNS process systems
- **PNPI, Russia** – In-pile (vacuum containment and thermosiphon), deuterium gas
- **Air Liquide, France** – helium cryogenic system
- **Mirrortron, Hungary** – neutron guides

Mechanical Design

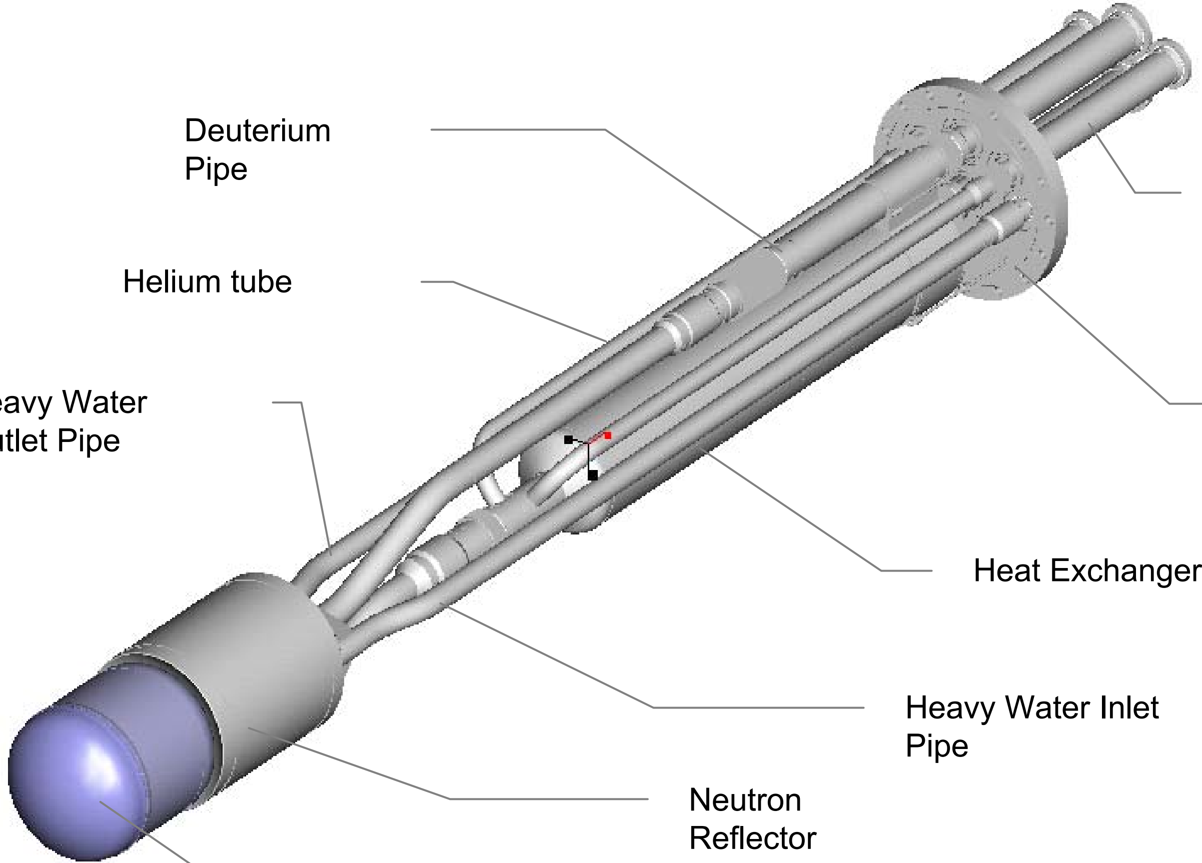


Thermosiphon Model

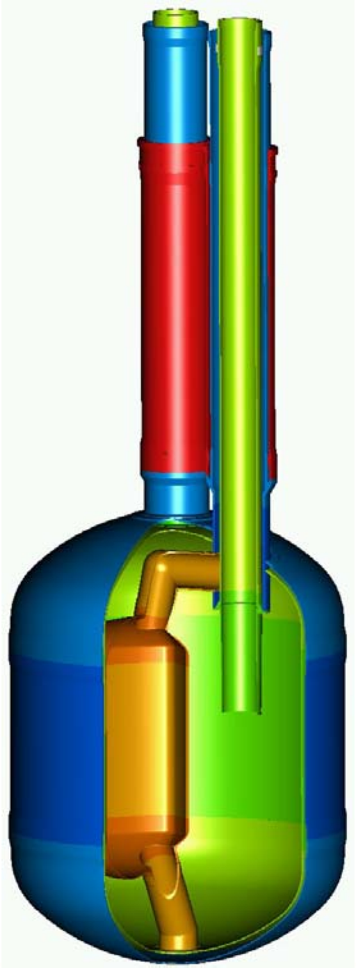
- LD_2
- He inlet HX flow
- He inlet MC flow
- He outlet flow

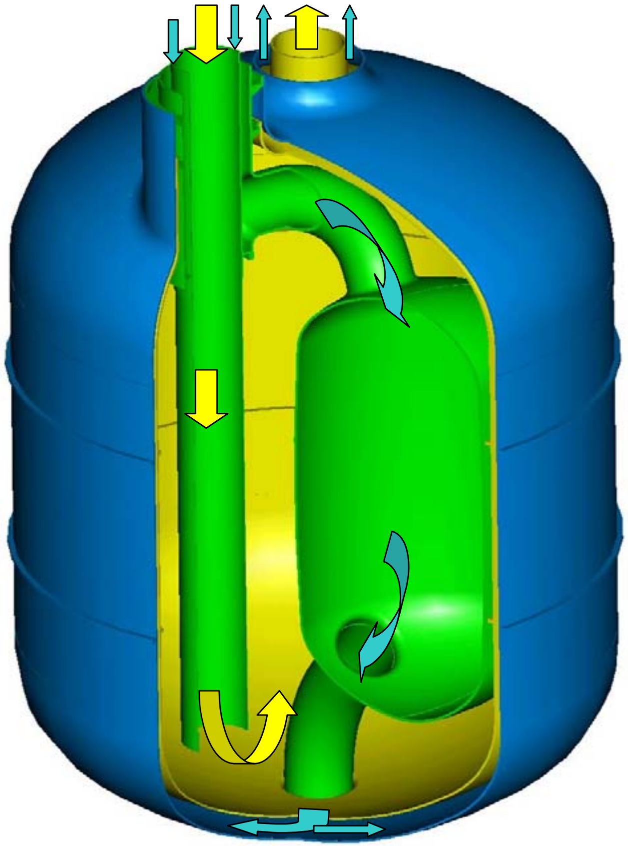


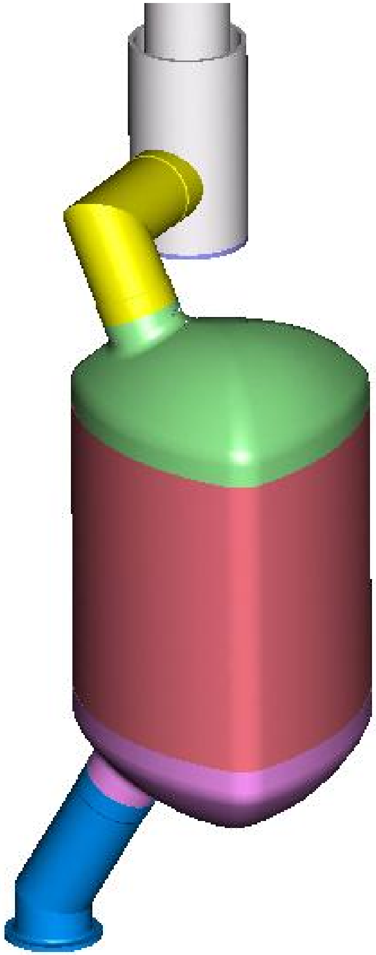
Thermosiphon



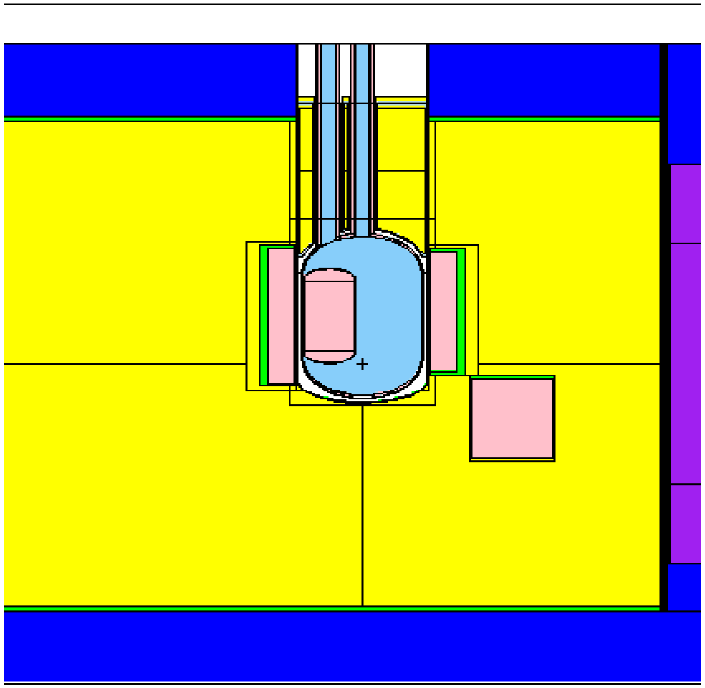
Moderator Chamber with Displacer (AlMg5)

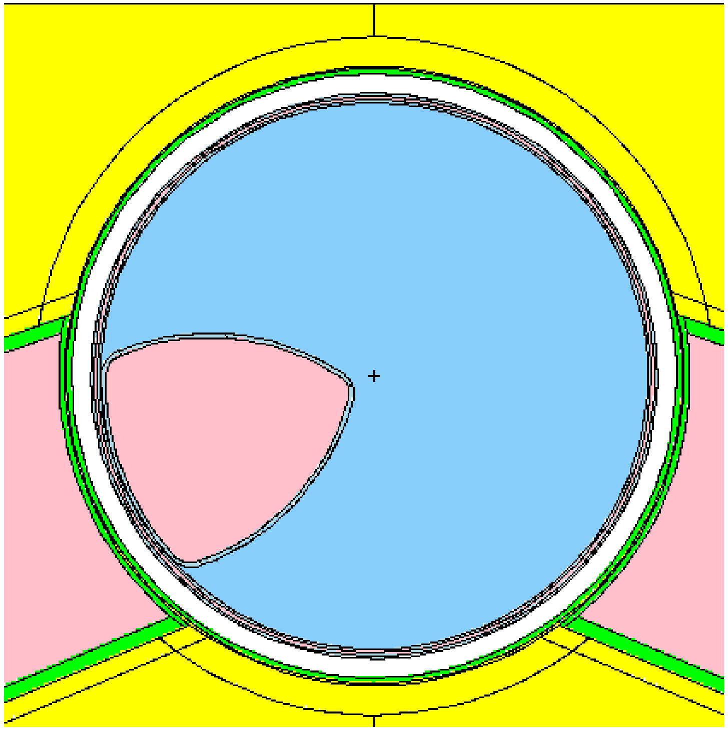




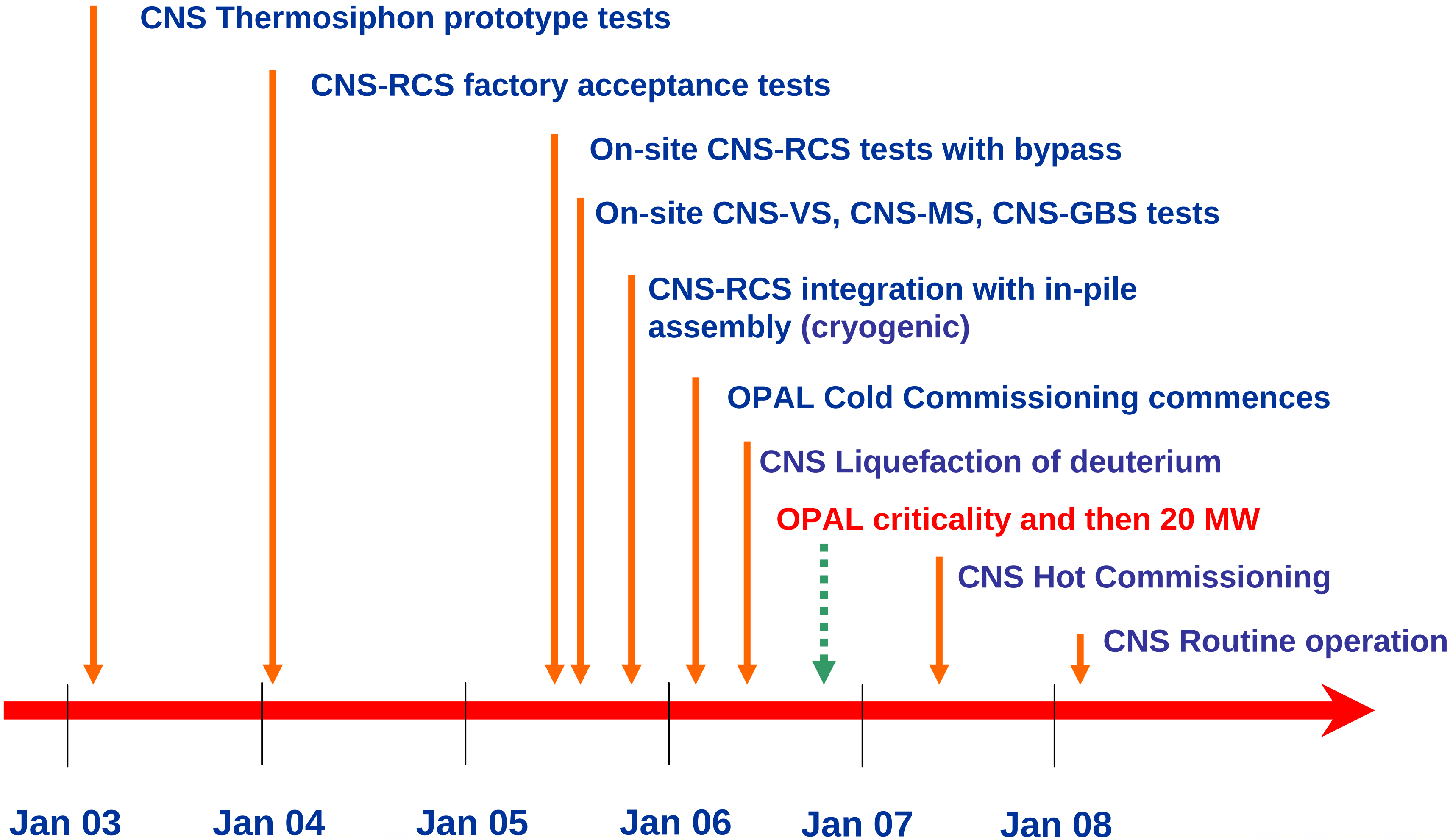


MCNP 3-D Model





Timeline

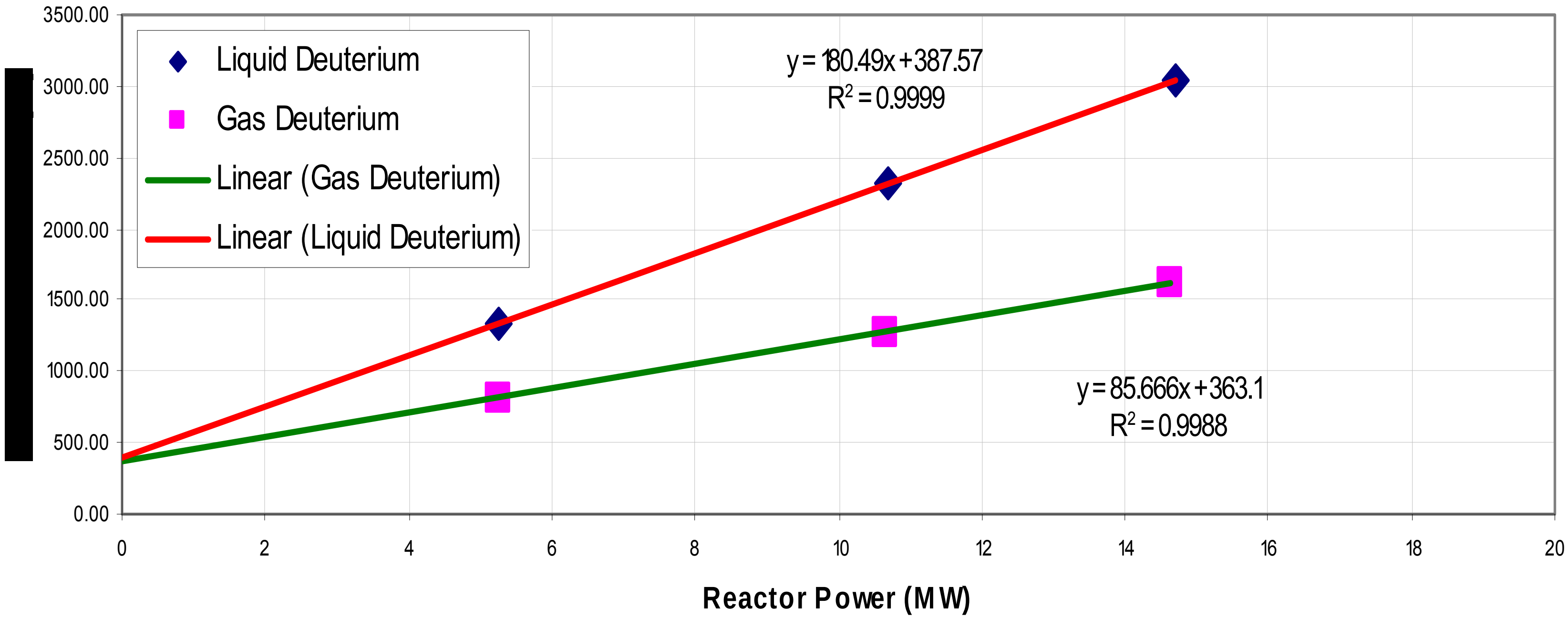

CNS Thermosiphon prototype tests
CNS-RCS factory acceptance tests
On-site CNS-RCS tests with bypass
On-site CNS-VS, CNS-MS, CNS-GBS tests
CNS-RCS integration with in-pile assembly (cryogenic)
OPAL Cold Commissioning commences
CNS Liquefaction of deuterium
OPAL criticality and then 20 MW
CNS Hot Commissioning
CNS Routine operation
Jan 03
Jan 04
Jan 05
Jan 06
Jan 07
Jan 08

Heat Load Measurement

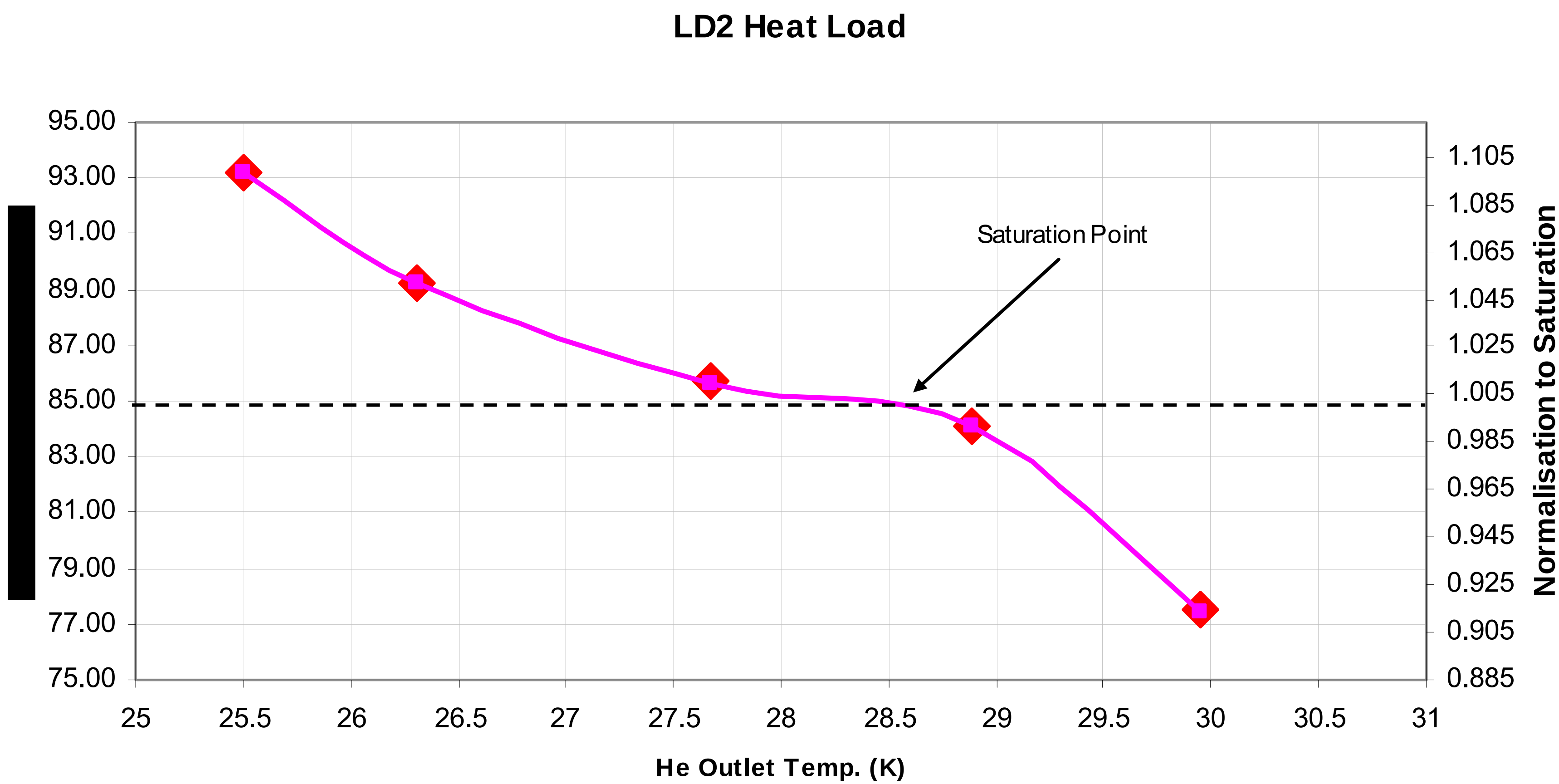
- Heat load measured by steady state helium thermal balance => 4 kW
- Excellent agreement between measurement and theoretical prediction (Δ<100 W)
- Single phase moderator verified
- (See conference proceeding for details)

Heat Load vs Reactor Power

Measured Heat Load on the CNS In-pile by Cryogenic Helium Thermal Balance
Linear fits indicate nuclear heat load (W/MW) by the slope and non-nuclear heat load by the offset (W)



Single-Phase Verified



Flux Contract Performance

Performance Acceptance Criteria (RF = reactor face) (NGH = neutron guide hall)	OPAL measured flux (20 MW equiv) (ϕ in n/cm^2/sec)
Thermal neutron flux at RF for TG4 [1]	4.0×10^{10}
Thermal neutron flux in NGH for TG1(TG3) [1]	3.3 (2.8) x 10^9
Cold neutron flux at RF for CG4 [2]	2.5×10^{10}
Cold neutron flux in NGH for CG1(CG3) [2]	5.9 (6.4) x 10^9

[1] E < 100 meV
[2] E < 10 meV

Operation Issues (positive)

- Standby Operation (SO) mode and Normal Operation (NO) mode at full reactor power
- Two way transition
- SO mode greatly enhances reactor availability – hot commissioning on time made possible
- CNS safety control – 30-minute fast LD2 evaporation manoeuvre after CNS trip to beat xenon poison-out

Operation Issues (negative)

- Repeated cryogenic system failures affecting CNS availability
  - Turbine and compressors
  - Mechanically demanding
  - Sensitive to process purity
- Complex logic in the protection system
  - Preventing undesirable pressure and temperature transients
  - CNS specialist intervention often required