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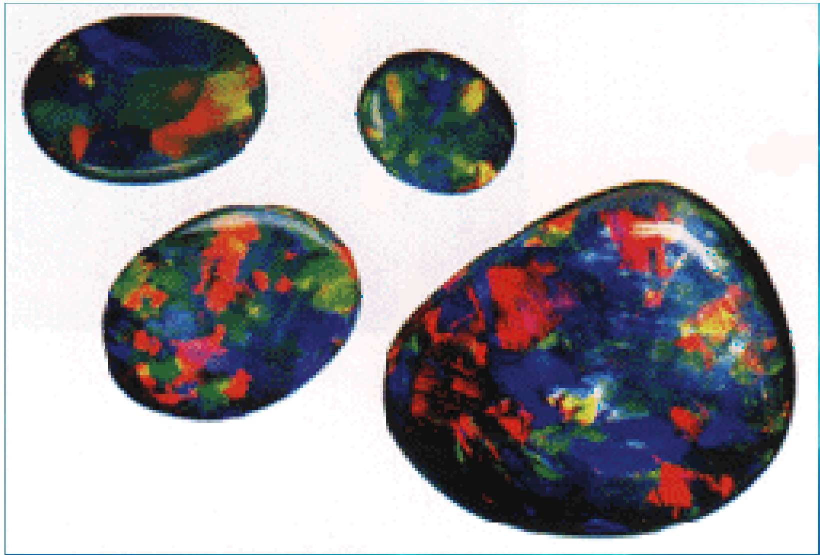
OPAL

Australia's Research Reactor

Greg Storr



OPAL

ANSTO Site

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Research reactor operation

- **OPAL replaced HIFAR**
- IAEA Centre of Excellence for neutron beam science
- Radio-isotopes for medicine, research and industry
- Commercial & research irradiations
- **Regional expertise**

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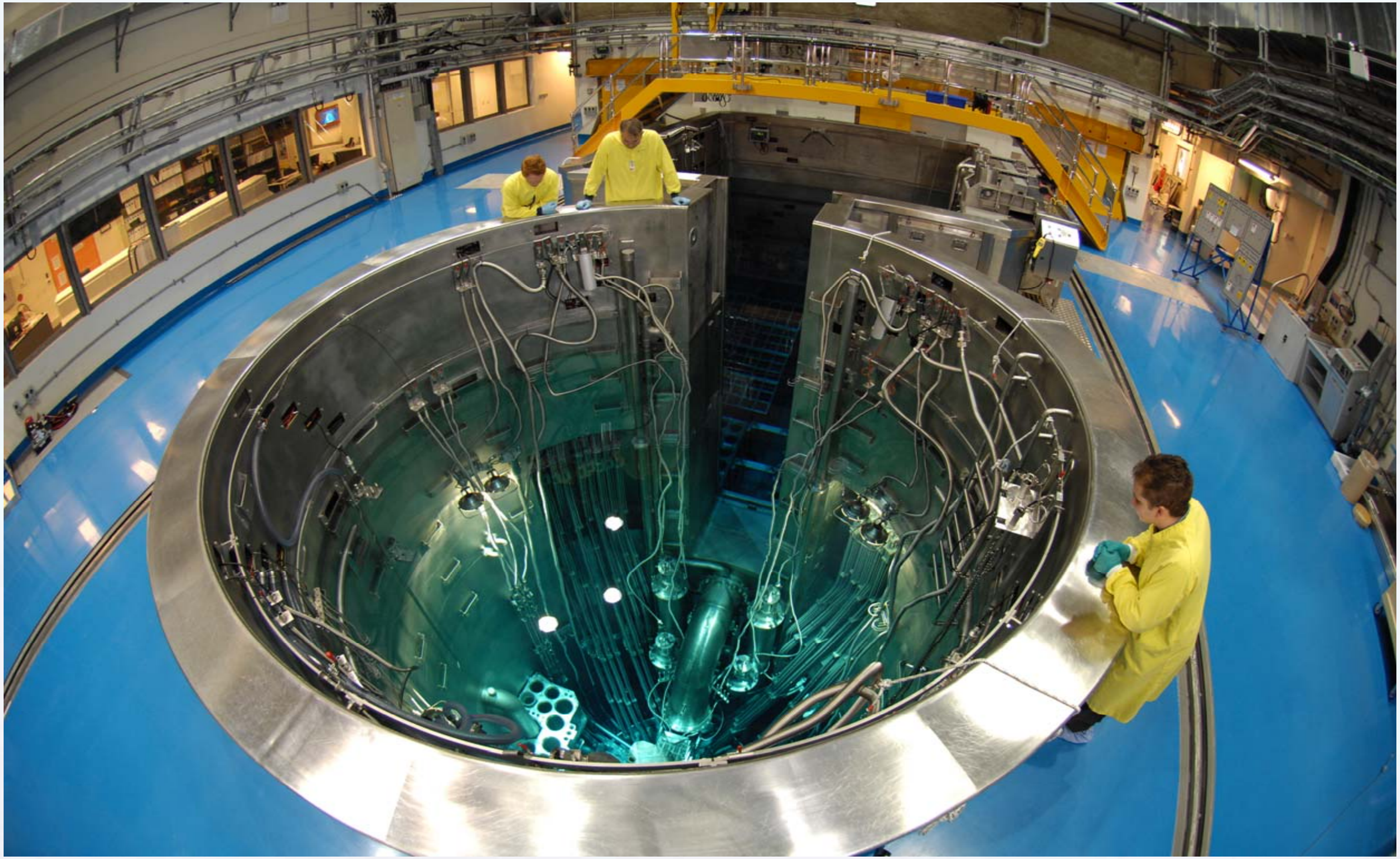
OPAL Reactor

- Multi-purpose facility
- 20 MW
- Open pool
- Compact core (~300 kW/L)
- Plate type Low Enriched Uranium fuel
- No in-core irradiations
- D_2O reflector
- Upward coolant flow (light water)
- 2 independent & diverse shutdown systems

OPAL - Pool



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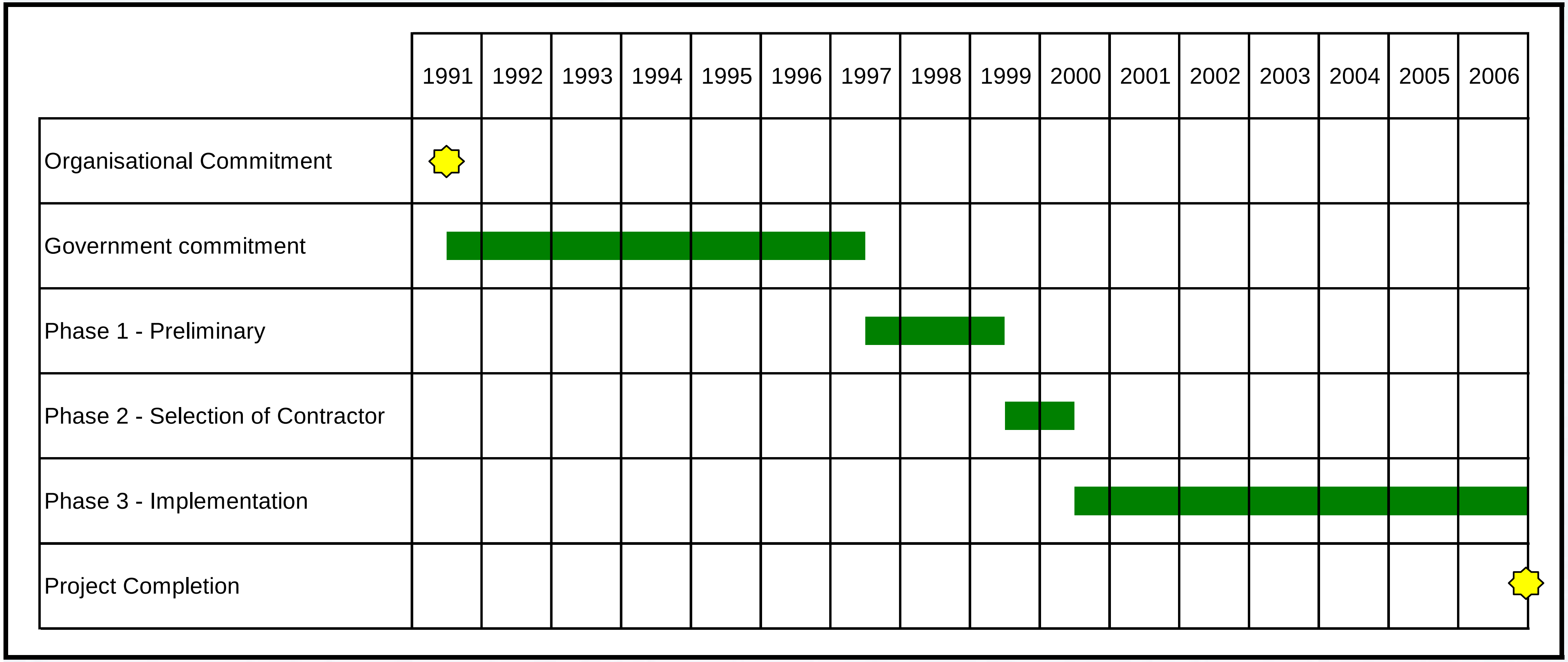
Construction

Overall Project Schedule



- Turn-key contract
- Project management
- Embed nuclear competence

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Project Performance

- Performance:
  - Thermal flux to beams exceeds expectations
- Schedule:
  - 9 years from government approval to first full power (one year ahead of initial plan)
- Budget:
  - Cost is 8% above original budget (adjusted for inflation and foreign exchange fluctuations)

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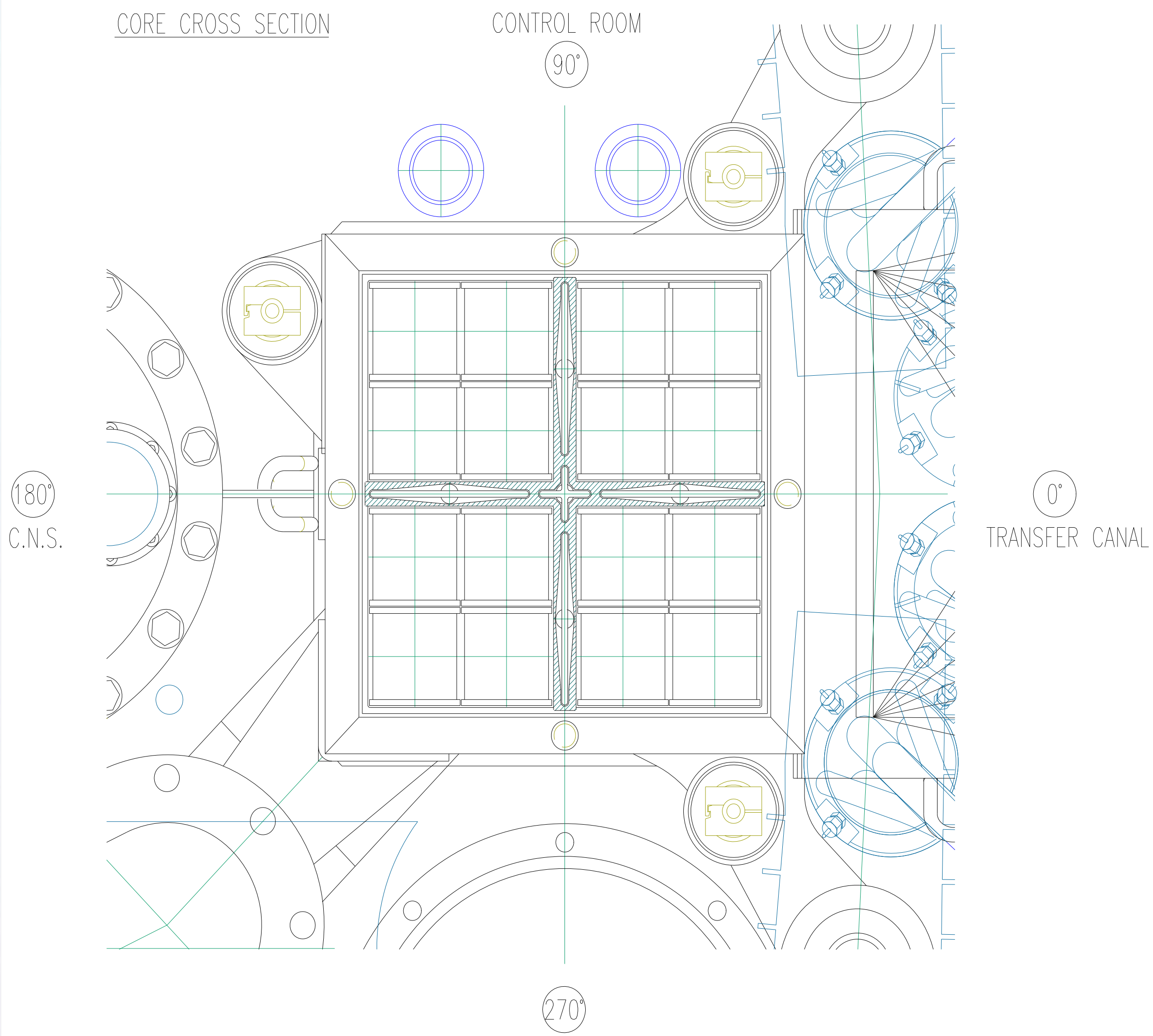
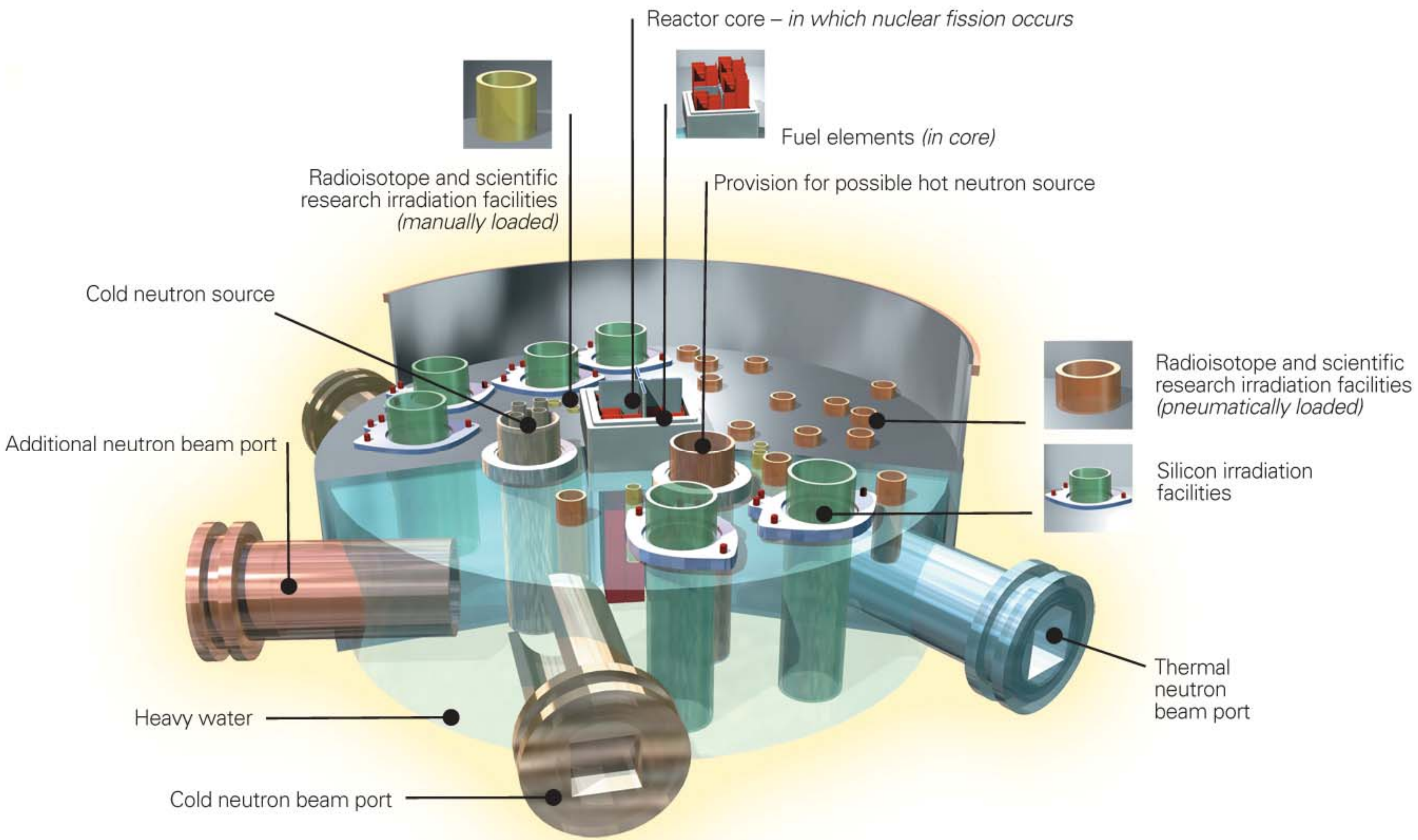
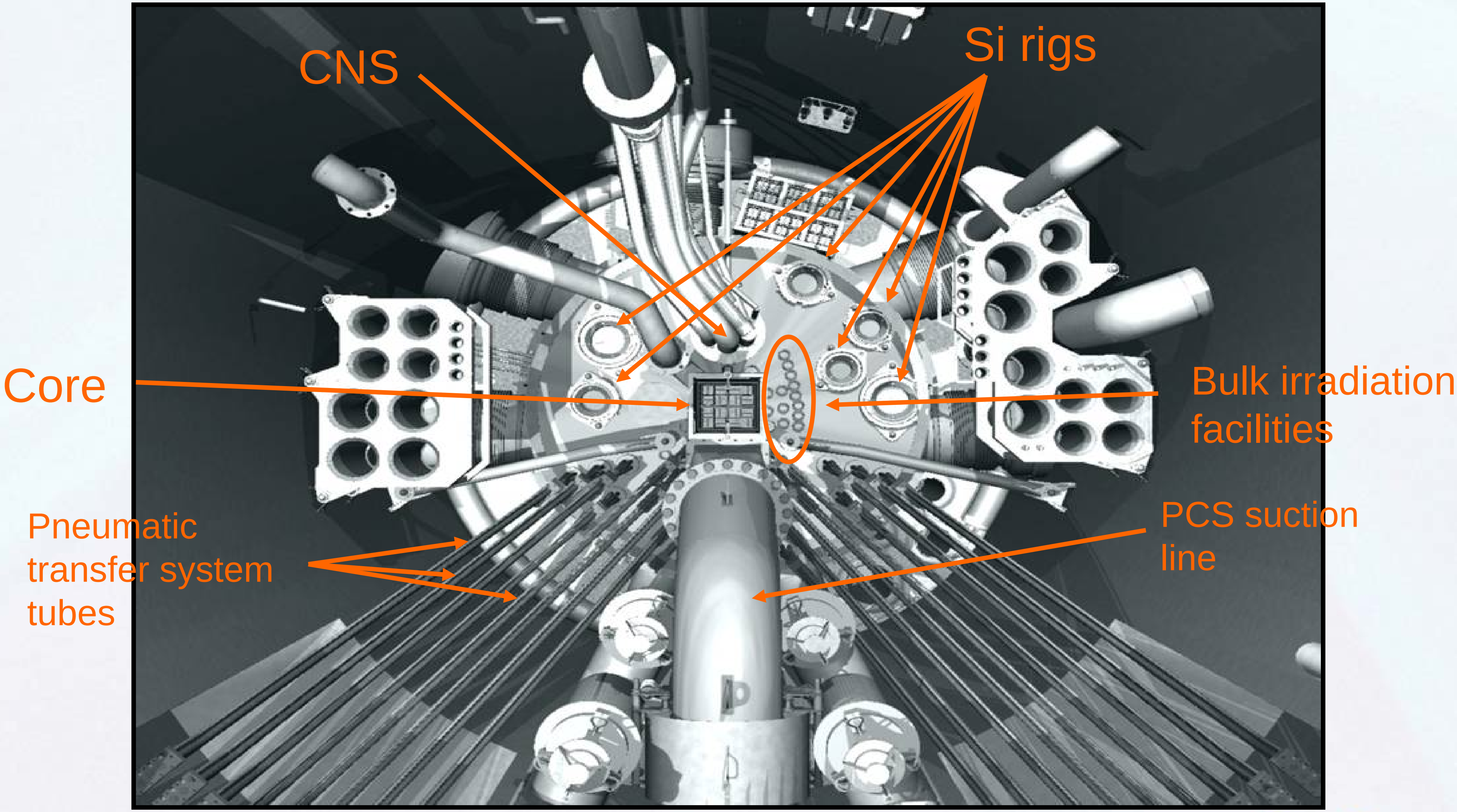
Design


CORE CROSS SECTION
CONTROL ROOM
90°
180°
C.N.S.
0°
TRANSFER CANAL
270°

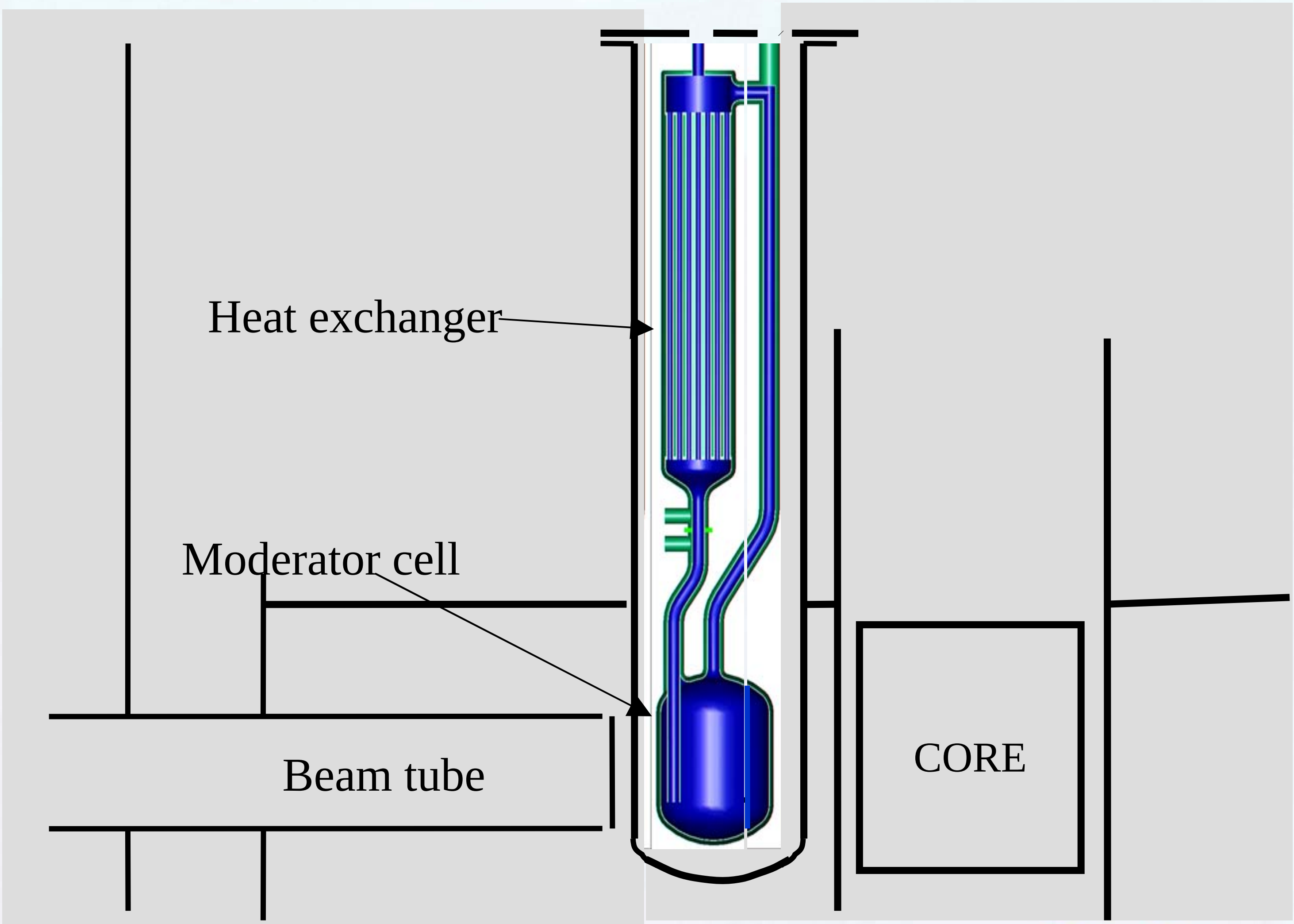

Reactor core – *in which nuclear fission occurs*
Fuel elements *(in core)*
Provision for possible hot neutron source
Radioisotope and scientific research irradiation facilities *(manually loaded)*
Cold neutron source
Additional neutron beam port
Radioisotope and scientific research irradiation facilities *(pneumatically loaded)*
Silicon irradiation facilities
Thermal neutron beam port
Heavy water
Cold neutron beam port

Reflector facilities



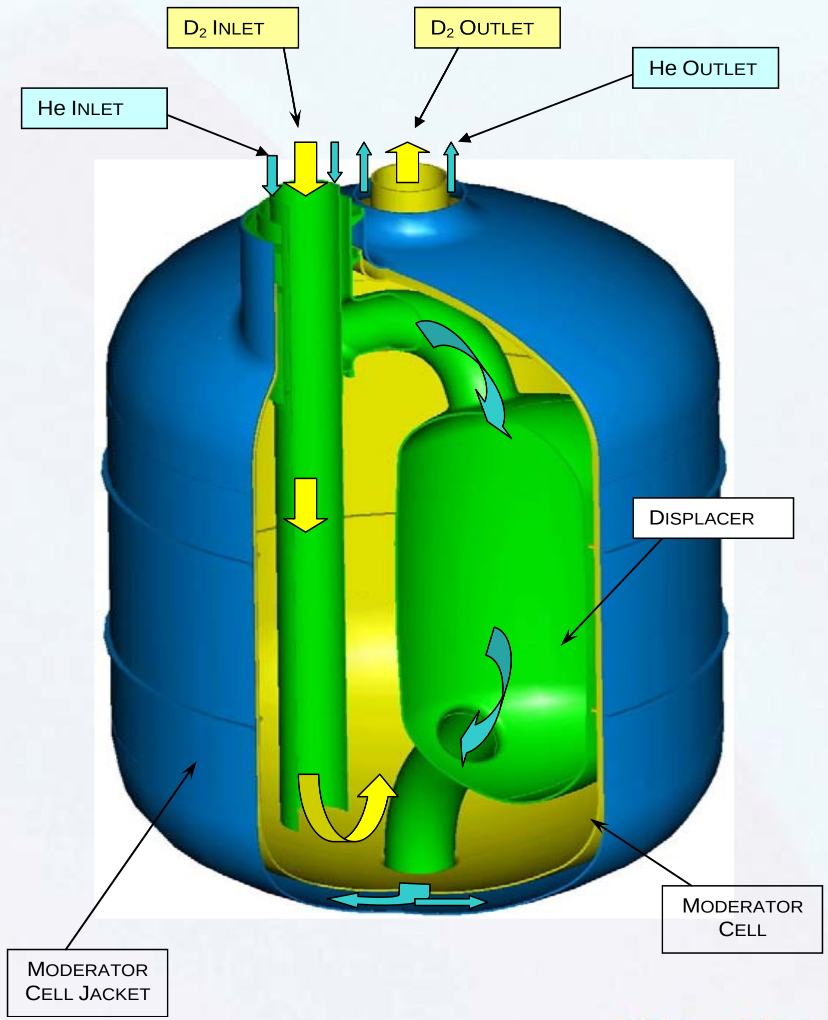
OPAL - CNS

- Liquid Deuterium thermosiphon design
- 20 litre moderador
- D_2 24 K
- Helium refrigerant 19 K 5kW
- Flux at reactor face >1 x 10^{10} $n/cm^2/s$



OPAL – CNS moderator

- Displacer design
- Cold/warm states
- D2O upper plug
- Adjust temperature/flux



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Beams

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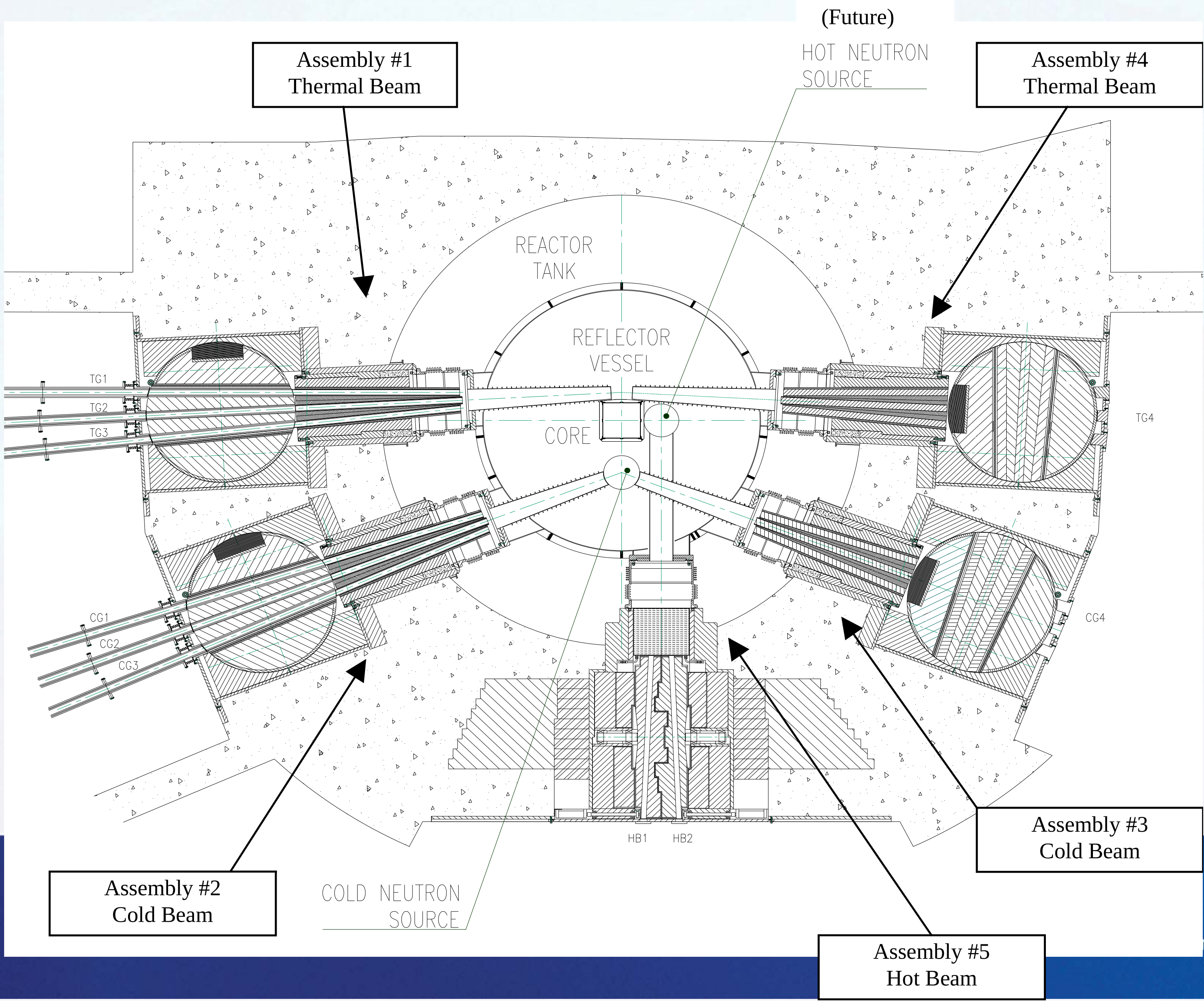
Beam facilities



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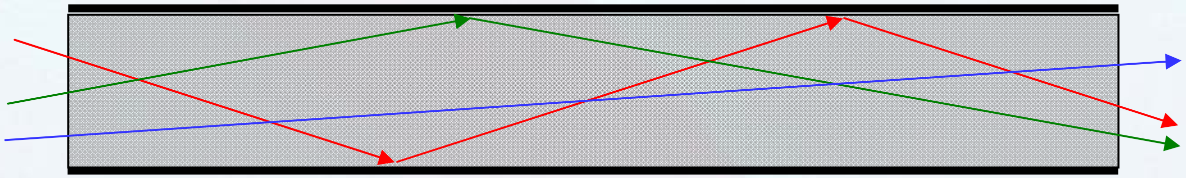
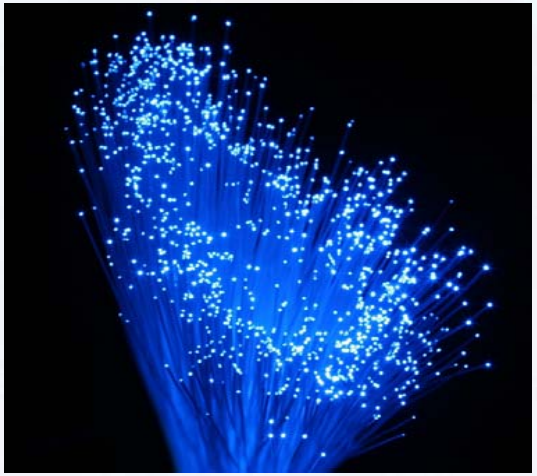
Supermirror Neutron Guides

"Supermirror" coatings reflect neutrons at glancing angles (<~ 5°).

Made of thousands of alternating layers of Ni/Ti.





Transmits neutrons from the reactor to the instruments (like a fibre-optic transmits light)

Neutron Instruments at OPAL

Platypus
(Reflectometer)

Wombat
(Hi-Intensity Powder)

Koala
(Single Crystal)

Quokka
(SANS)

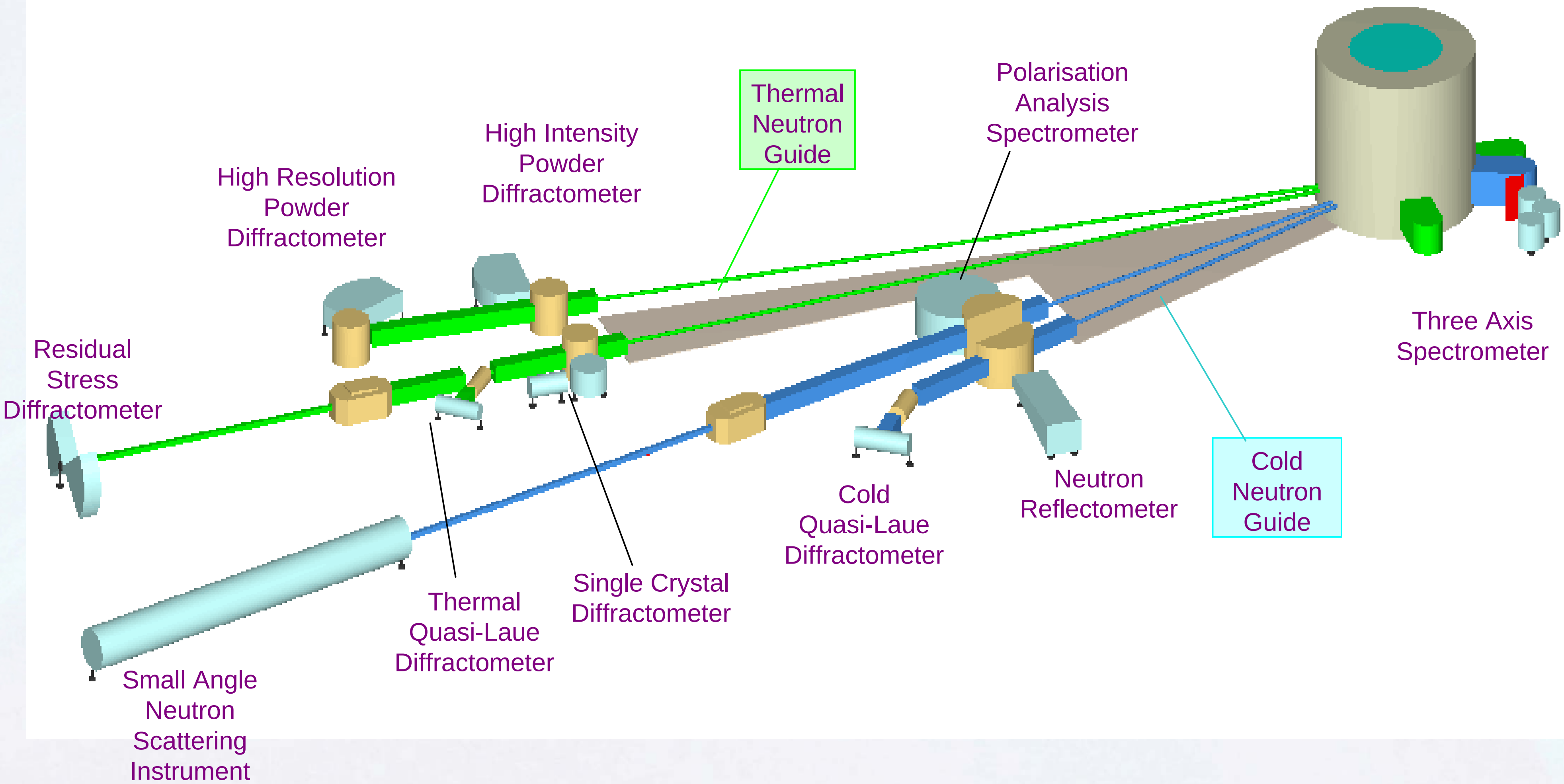
Kowari
(Residual Stress)

Pelican
(Polarization Spectrometer)

Sika
(Cold TAS)

Echidna
(Hi-Resolution Powder)

Taipan
(Thermal TAS)


Thermal Neutron Guide
Polarisation Analysis Spectrometer
High Intensity Powder Diffractometer
High Resolution Powder Diffractometer
Residual Stress Diffractometer
Three Axis Spectrometer
Cold Neutron Guide
Neutron Reflectometer
Cold Quasi-Laue Diffractometer
Single Crystal Diffractometer
Thermal Quasi-Laue Diffractometer
Small Angle Neutron Scattering Instrument

OPAL / Neutron Guide Hall

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Beam line, location & energy (rf = reactor face) (ngh = neutron guide hall) *(flux in $n/cm^2/sec$)*	OPAL measured flux (20MW equiv, 2007-8)	OPAL calculated flux (ANSTO, 2000)	OPAL calculated flux (Mirrotron, 2003) (includes misalignment)
TG1: thermal neutron flux in ngh [1]	3.3×10^9	2.4×10^9	3.0×10^9 [3]
TG3: thermal neutron flux in ngh [1]	2.8×10^9		2.8×10^9 [3]
TG4: thermal neutron flux at rf [1]	4.0×10^{10}		1.7×10^{10} [3]
CG1: cold neutron flux in ngh [2]	5.9×10^9	7.1×10^9	5.7×10^9
CG3: cold neutron flux in ngh [2]	6.4×10^9		7.2×10^9
CG4: cold neutron flux at rf [2]	2.5×10^{10}		1.5×10^{10}
HB2: thermal neutron flux at rf [1]	3.6×10^{10}		*not calculated*

[1] E < 100 meV
[2] E < 10 meV
[3] corrected to E < 100 meV with observed fractions

OPAL n-beam Instrument	OPAL measured flux (20 MW equiv)	OPAL calculated flux
Wombat [1] HIPD	5.2 x 10^6 –needs checking	not directly comparable
Echidna [2] HRPD	3.7 x 10^6	2.5 x 10^6
Kowari [3] Res stress	4.9 x 10^6	1 x 10^7
Koala [4] QLD	1.2 x 10^9	1.0 x 10^9
Quokka [5] SANS	7.9 x 10^6 –needs checking	not directly comparable
Platypus [6] Reflectometer	5.5 x 10^8	1 x 10^9
Taipan [7] 3-axis	9.1 x 10^7	1.1 x 10^8

[1] AZS-Ge(115), $2\theta_m = 90°$, $\lambda = 1.54$ Å, m2s=2.1 m
[2] BNL-Ge(115), $2\theta_m = 90°$, $\lambda = 1.54$ Å, α_1,α_2 open
[3] Si(400), $2\theta_m = 75°$, $\lambda = 1.67$ Å
[4] white beam, no filter, aperture; $\phi = 3$ mm (1/4 of Au foil)
[5] $\lambda = 5$ Å; $T_{CNS} = 19.5$ K
[6] white beam, $T_{CNS} = 19.5$ K
[7] HOPG, $\lambda = 2.35$ Å; no λ/n filter

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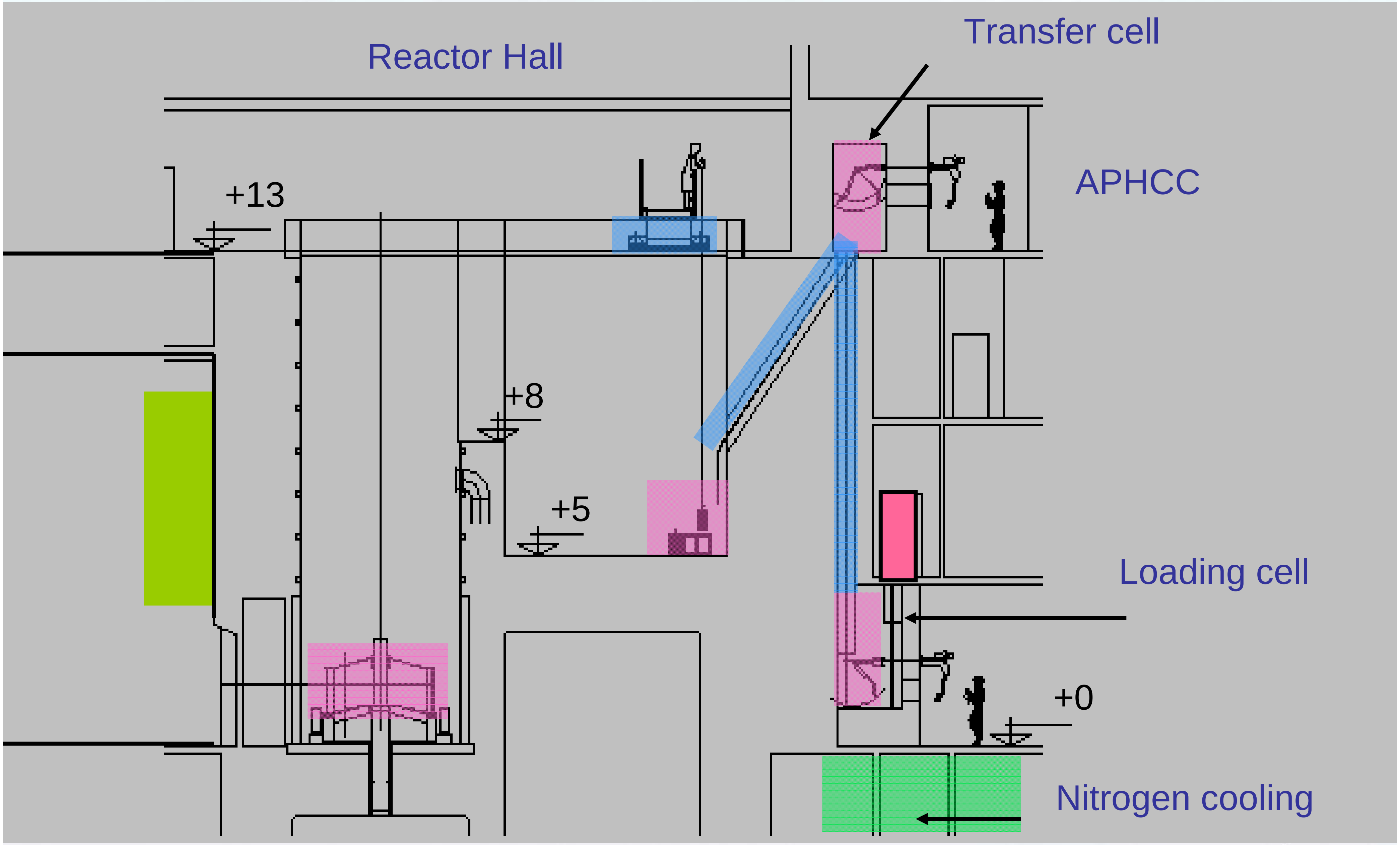
Radio Isotopes

Radioisotopes for Nuclear Medicine/ Industrial Isotopes

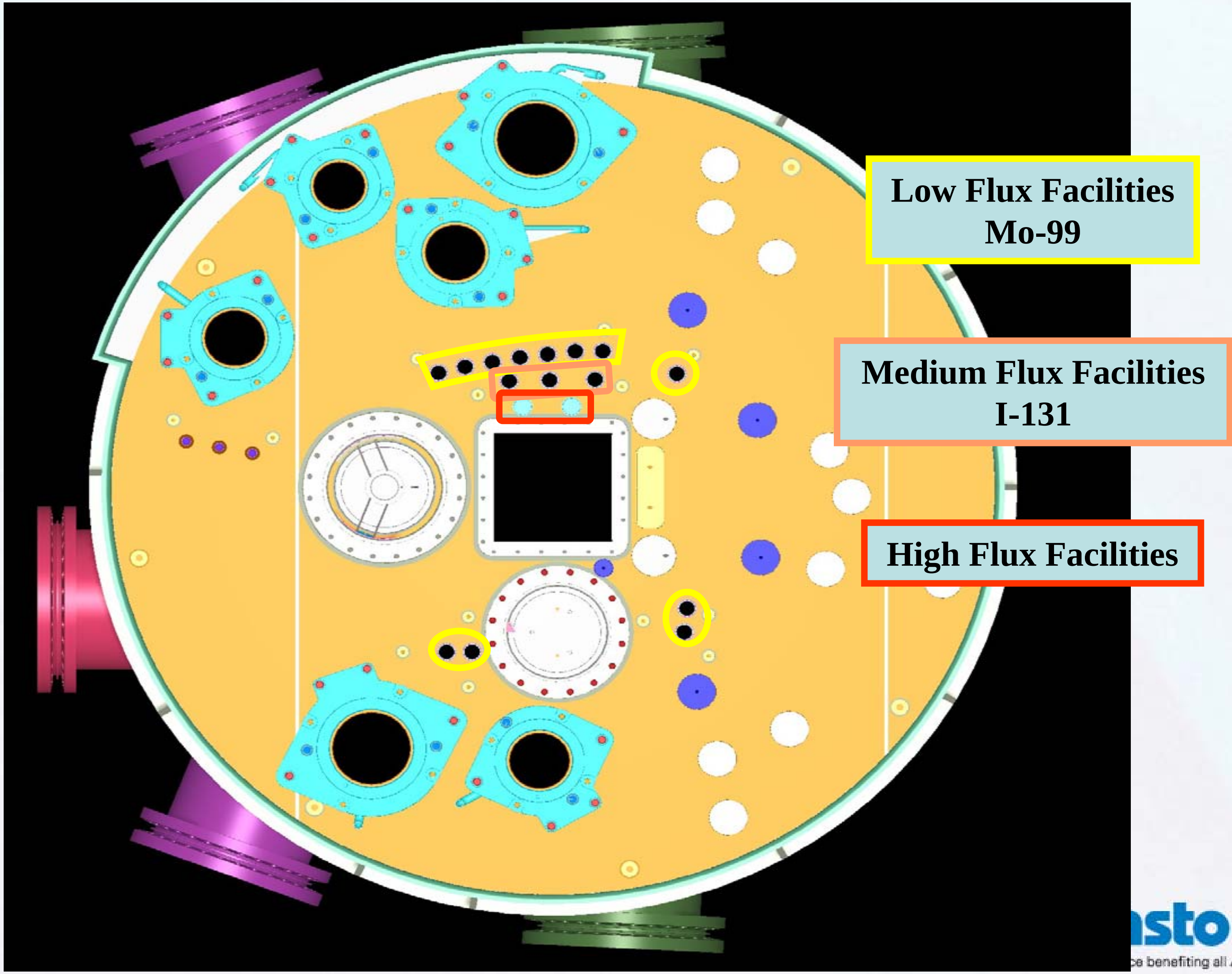
- 17 Bulk Irradiation Facilities arranged in three different classes, principally for the production of Mo99/Tc99 and I131, Lu177

- 55 Long Residence Time Facilities available for the production of a range of isotopes for medical, industrial and research purposes.

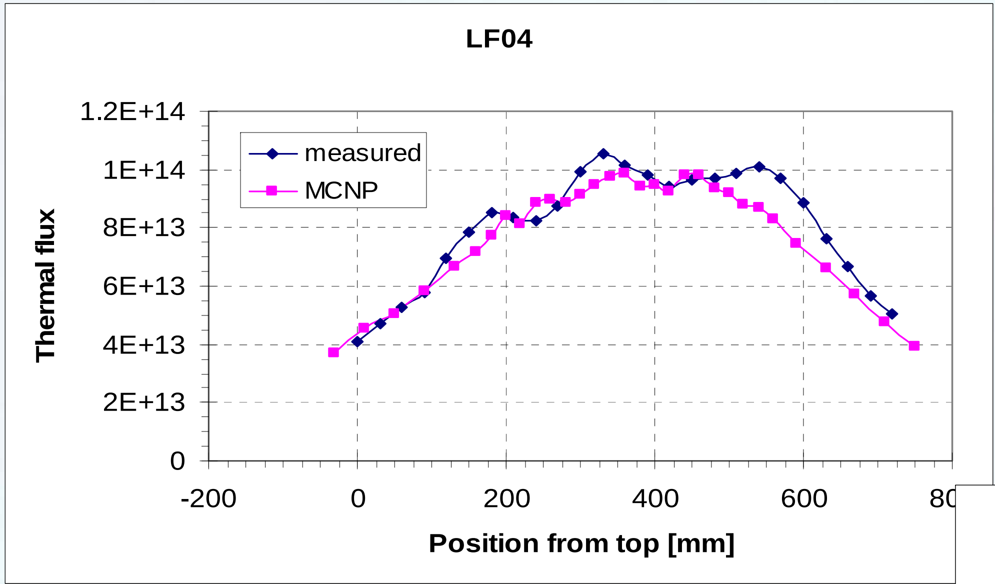


Reactor Hall
Transfer cell
APHCC
+13
+8
+5
+0
Loading cell
Nitrogen cooling

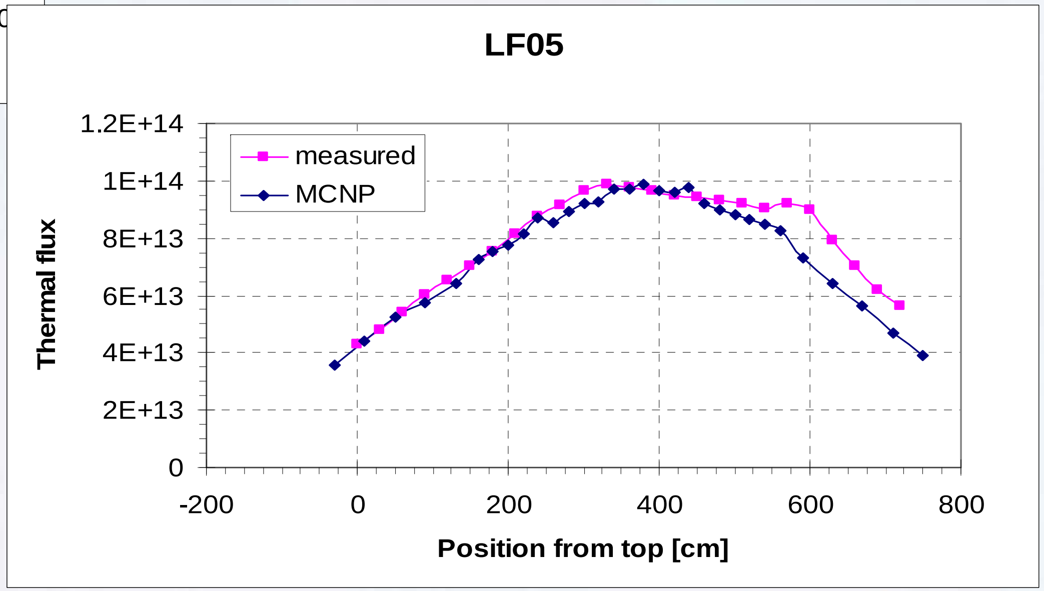
Bulk irradiation facilities



Results - BIF



Compare calculations and measurements



LEU Mo99 Production in OPAL

- Al clad UAl dispersion flat plate target
- 19.75% enriched U
- Irradiated at $9x10^{13}$ $n/cm^2/s$ for 3-7 days
- Plates dissolved in sodium hydroxide
- Uranium precipitates and captured in filter
- Dry filter cakes stored in non-critical array
- Separation by ion exchange & successive purification steps
- Radioiodines remain in solution
- I-131 recovered for use as a product
- Hydrogen released during dissolution is immediately converted to water via CuO_2 wires

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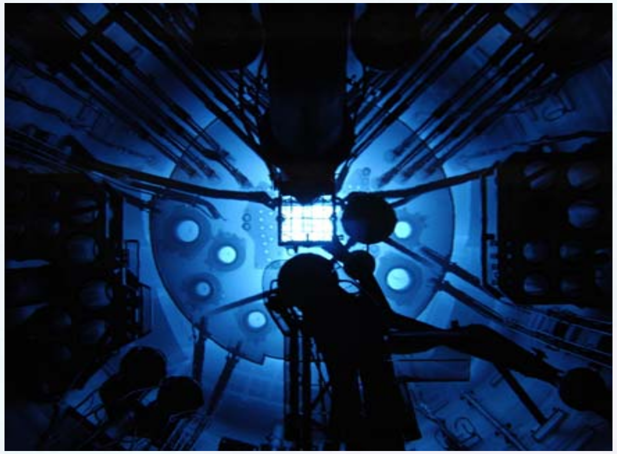
The Production Process



LEU in reactor for irradiation &
Mo-99 from fission process

Mo-99 separated

Tc-99m Generator to Customer

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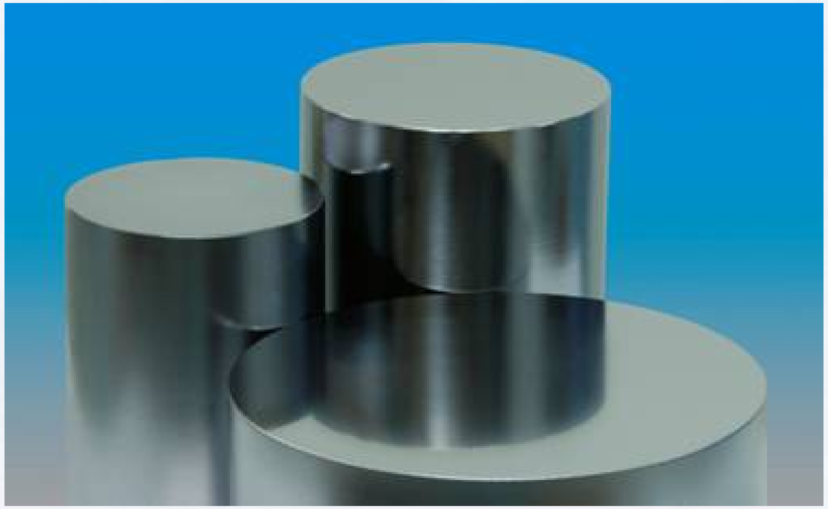
Silicon irradiation

- 6 facilities for silicon irradiation at OPAL suitable for 5”, 6” and 8” diameter silicon crystals
- Facilities are located in the reactor D_2O reflector vessel exposed to a neutron flux with Cd ratio > 1000 (approx)

- Silicon crystals are irradiated in aluminum cans in rotating rigs and water cooled
- Customer base – Japan & Europe electronics suppliers
- World market share - ~ 10%



Results – Si NTD

	Thermal Neutron Flux [n/cm^{2}s]		Thermal to Fast ratio		Uniformity (Wafer analysis)	
	Requirement	Measured Value	Requirement	Measured Value	Requirement	Measured Value
NTD-1	1.0E13 (+/- 20%)	8.32E+12	> 200	---	+/- 5%	+/- 2%
NTD-2	3.2E12 (+/- 20%)	2.69E+12	> 200	2764	+/- 5%	---
NTD-3	1.9E13 (+/- 30%)	1.44E+13	> 200	---	+/- 5%	+/- 5%
NTD-6	3.5E12 (+/- 20%)	2.91E+12	> 200	---	+/- 5%	---

Neutron activation - NAA and DNAA

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DNAA terminal station

- short residence time
- 6.3 x 10^{12} cm^{-2} s^{-1}

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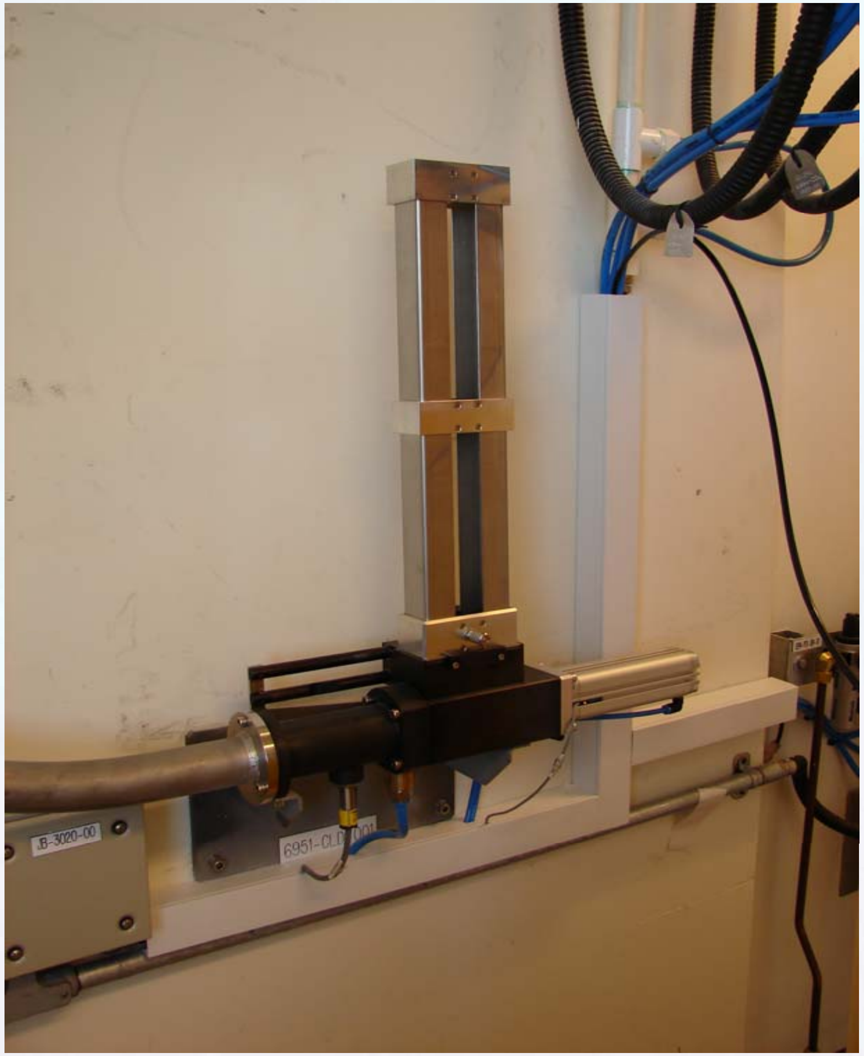
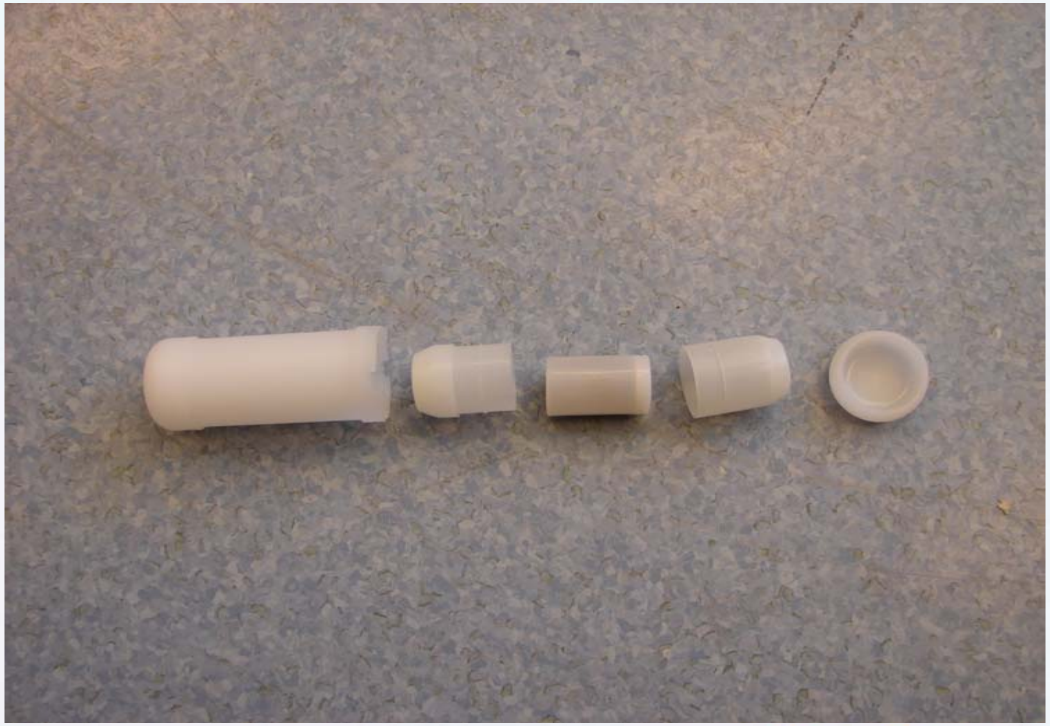
DNAA can loading device





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- short residence time
- 2.7 x 10^{13} cm^{-2} s^{-1}

NAA sample loading

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Commissioning

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Commissioning Stages

- Pre- Commissioning - systems check

- Stage A – Cold commissioning: integration

- Stage B1 – load fuel & first criticality
- Stage B2 – low power tests
- Stage C – Power ascension and full power tests

- Performance demonstration tests

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12th August 2006

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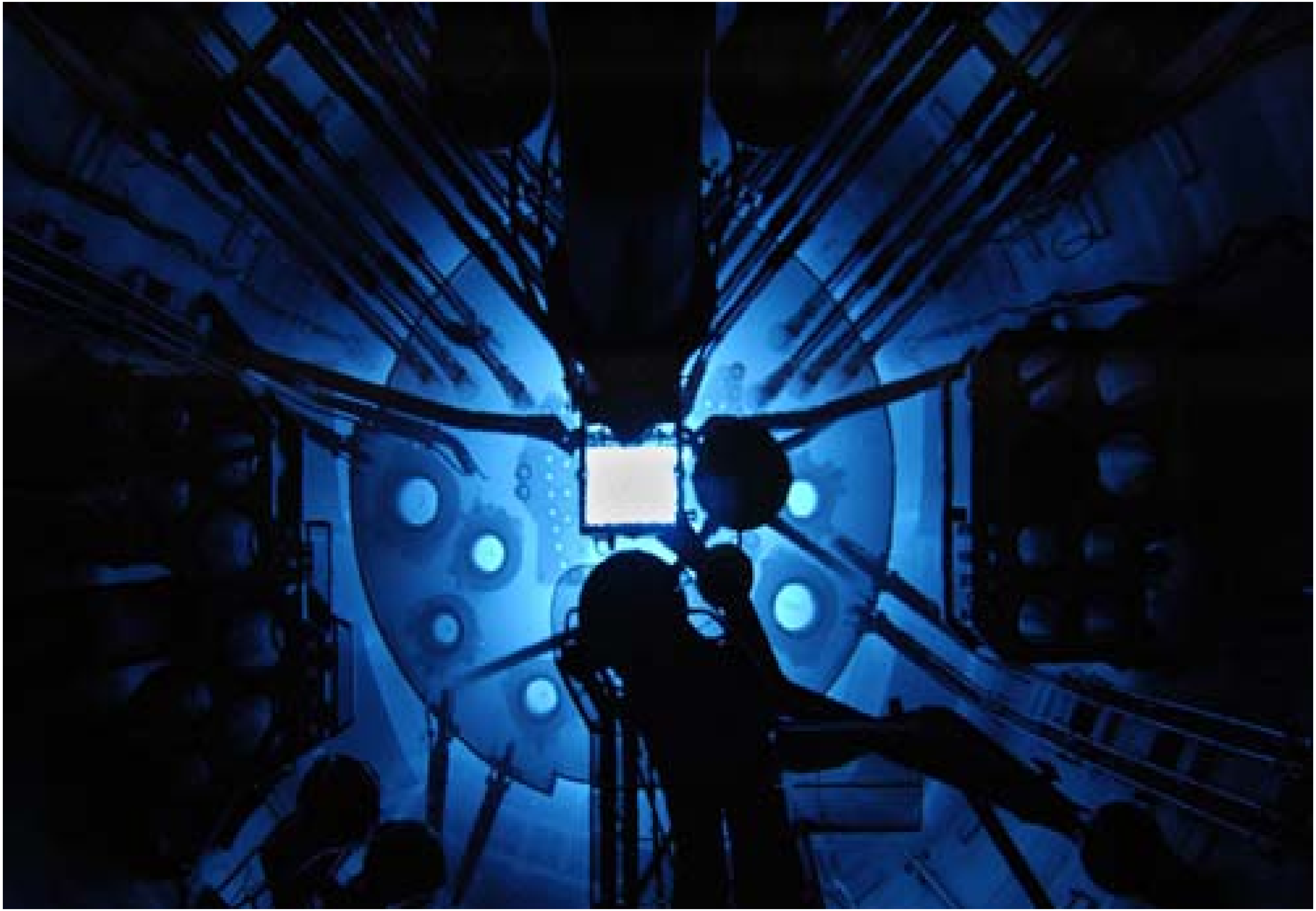

OPAL opened 20 April 2007

Howard opens Australia's new nuclear reactor

SYDNEY: Prime Minister John Howard has officially opened Australia's new $400 million nuclear research reactor in Sydney.

The OPAL reactor at Lucas Heights replaces Australia's first nuclear research facility, which was shut down in January after 48 years of operation.

Mr Howard toured the new reactor yesterday morning amid tight security, before officially opening the facility before an audience of about 200 scientists, politicians and a delegation from Argentina, the source of the fuel which feeds the reactor. He said the work by scientists at the reactor deserved to be celebrated just as much as the achievements of Australia's sportsmen and women.

"This facility will relieve human suffering, it will be of direct life-saving benefit to countless thousands of our fellow country men and women," Mr Howard said.

"It will also be a remarkable demonstration to the world of the expertise and the cutting-edge capacity of the Australian nation."

The OPAL reactor sits in a 13-metre deep container of water, whereas its predecessor was contained in steel. Its main purpose is to generate neutrons for nine neutron-beam instruments.

Challenges

OPAL - Challenges

- Reactor schedule/customer expectations
- Corrections – maximising performance
- Maintaining expertise and training
- External user interface
- Regulatory complexities

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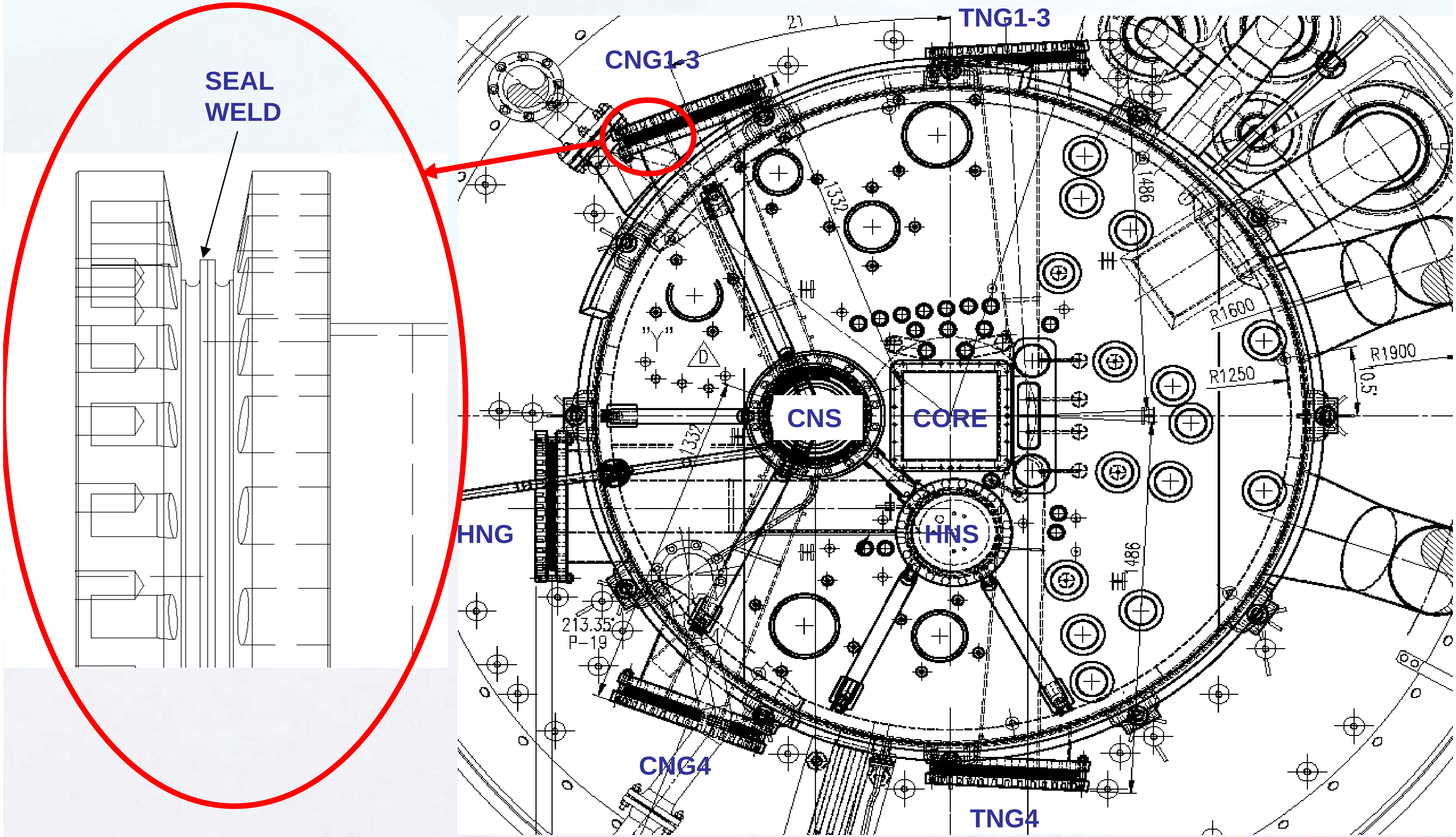
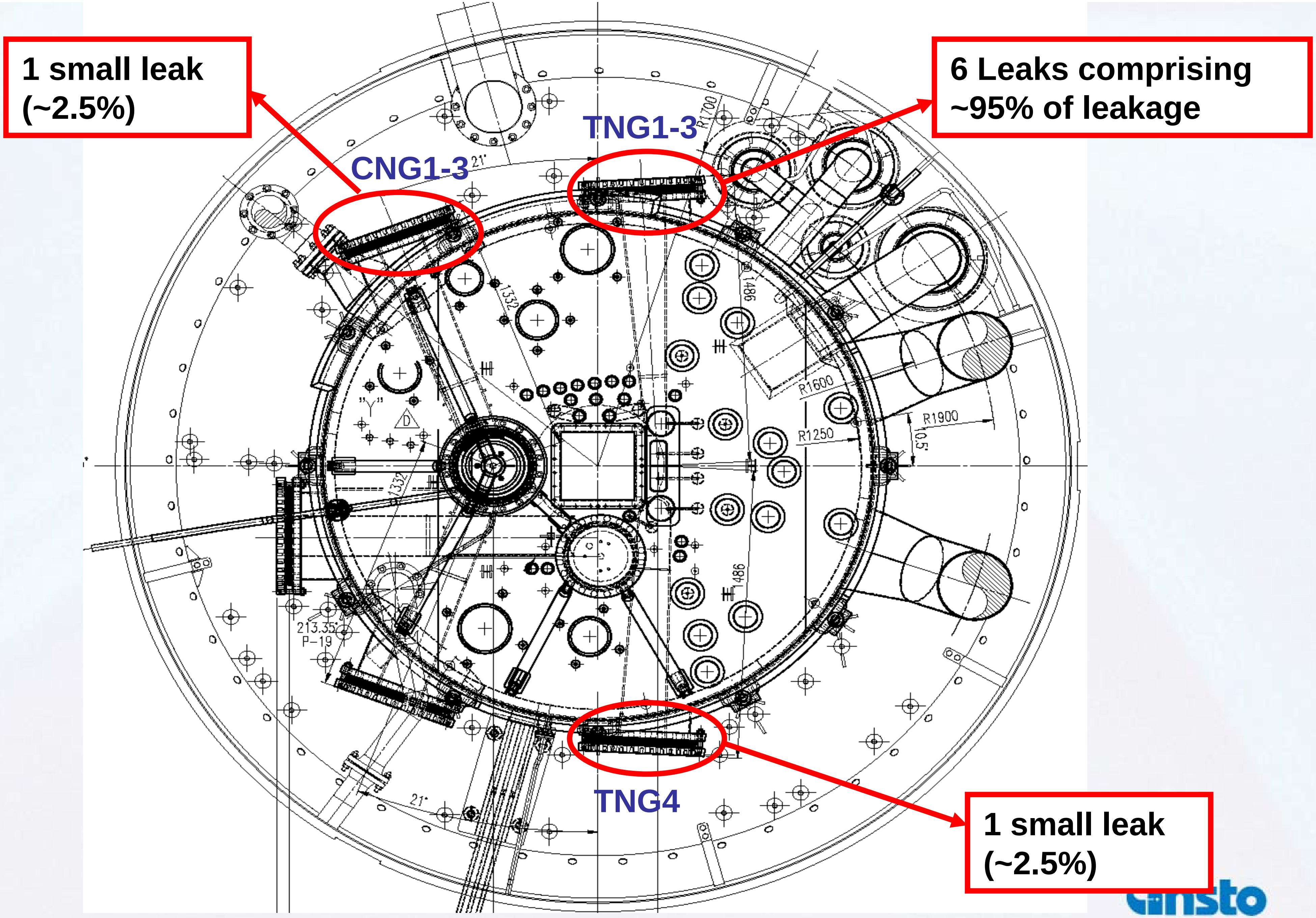
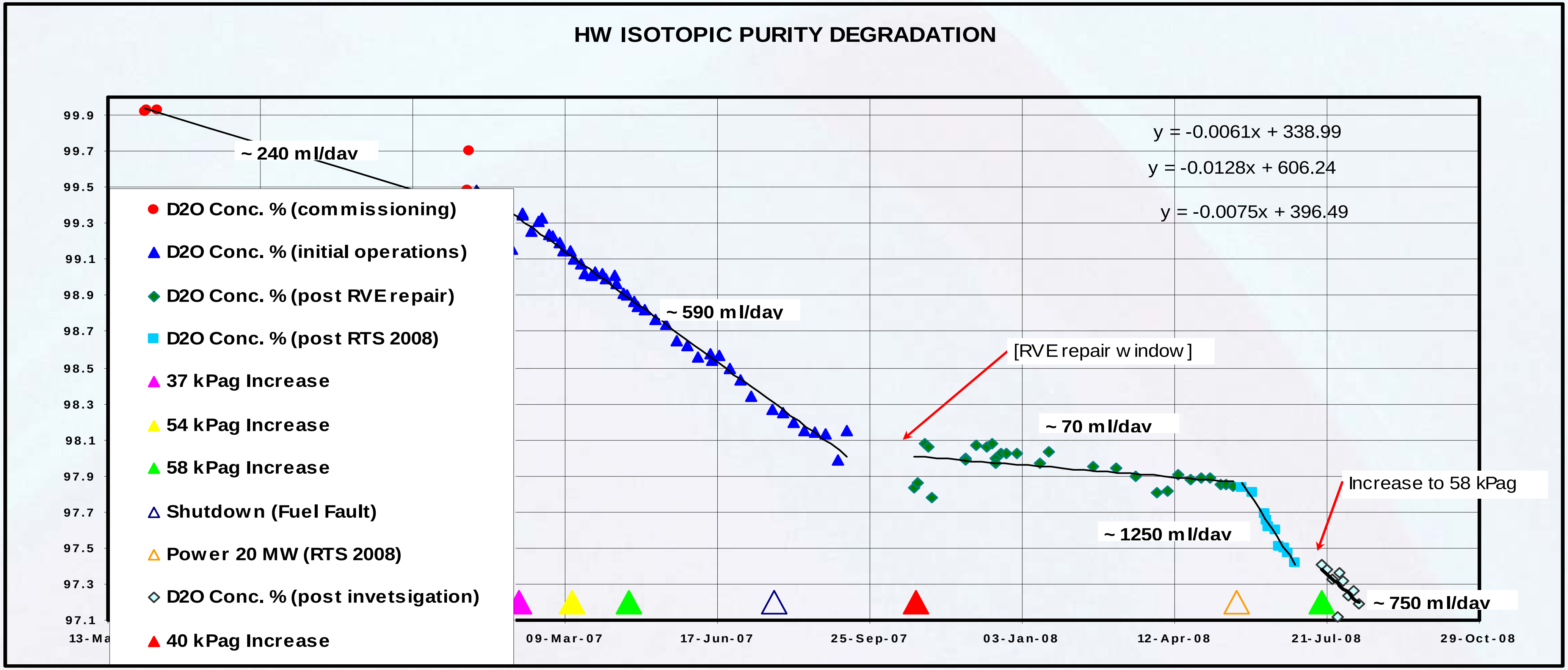


SEAL
WELD
TNG1-3
CNG1-3
CNS
CORE
HNG
HNS
CNG4
TNG4
R1600
R1900
R1250
1486
1332
213.35
P-19


1 small leak (~2.5%)
6 Leaks comprising ~95% of leakage
CNG1-3
TNG1-3
TNG4
1 small leak (~2.5%)
R1700
R1600
R1900
R1250
10.5°
1486
1332
213.35°
P-19
21°

D2O Purity 2006-2008



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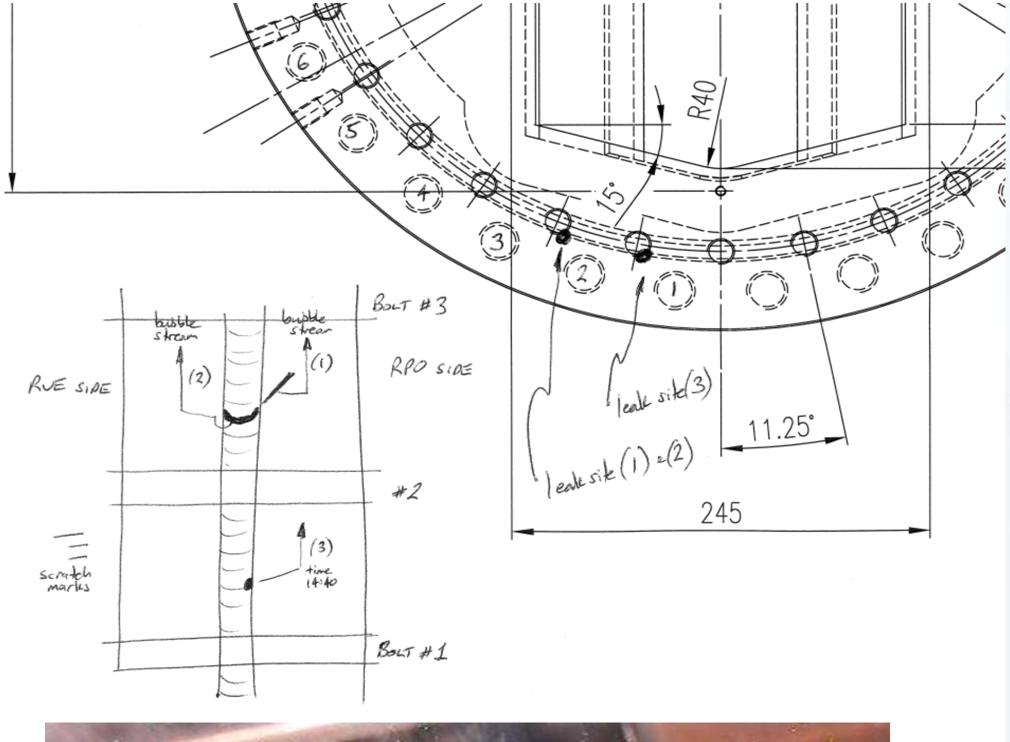
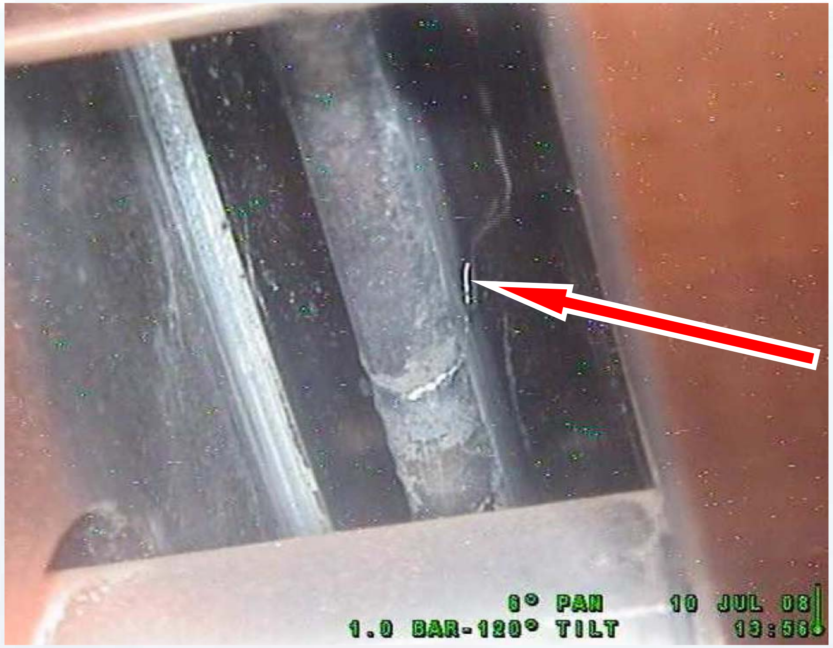
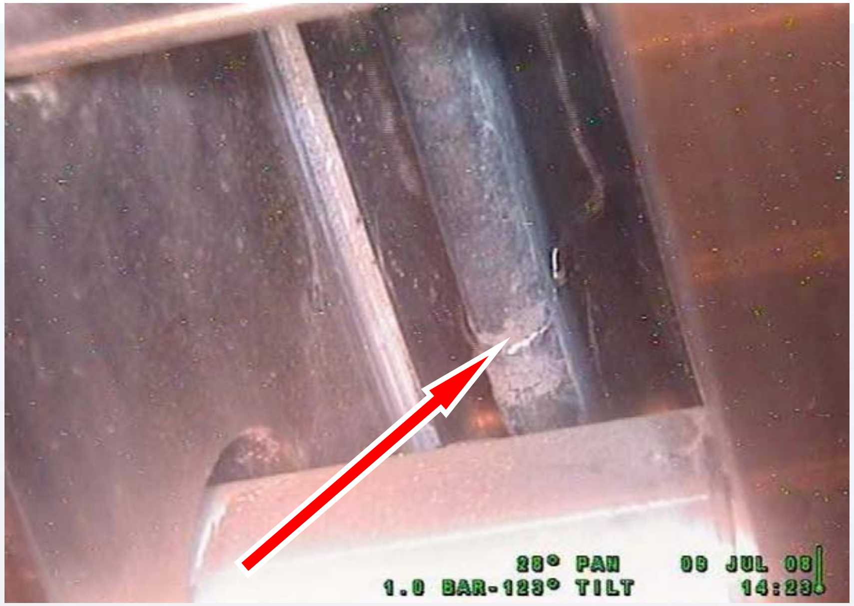


R40
15°
11.25°
245
leak site (1) + (2)
leak site (3)
Bolt #3
bubble stream
(2)
(1)
RUE SIDE
RPO SIDE
#2
(3)
time 14:40
scratch marks
Bolt #1



6° PAN
10 JUL 08
1.0 BAR-120° TILT
13:56



28° PAN
08 JUL 08
1.0 BAR-123° TILT
14:23

35° PAN
09 JUL 08
1.0 BAR-119° TILT
16:14

Operation

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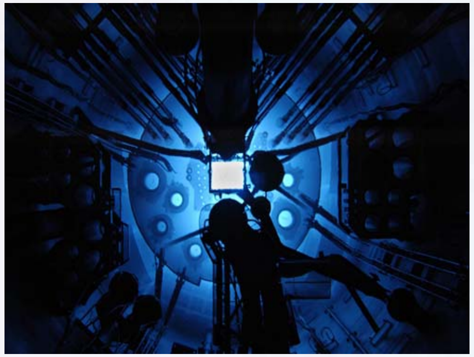
2008-10 Business Plan

Our shared vision is to be recognised as an international centre of excellence in research reactor operation and utilisation

- Safe, reliable & efficient operation
- Strategy
  - Customers – focus on needs & delivery
  - Strong relationships with stakeholders – regulators, suppliers & partners
  - Develop people
  - Improve processes
  - Improve performance measurement



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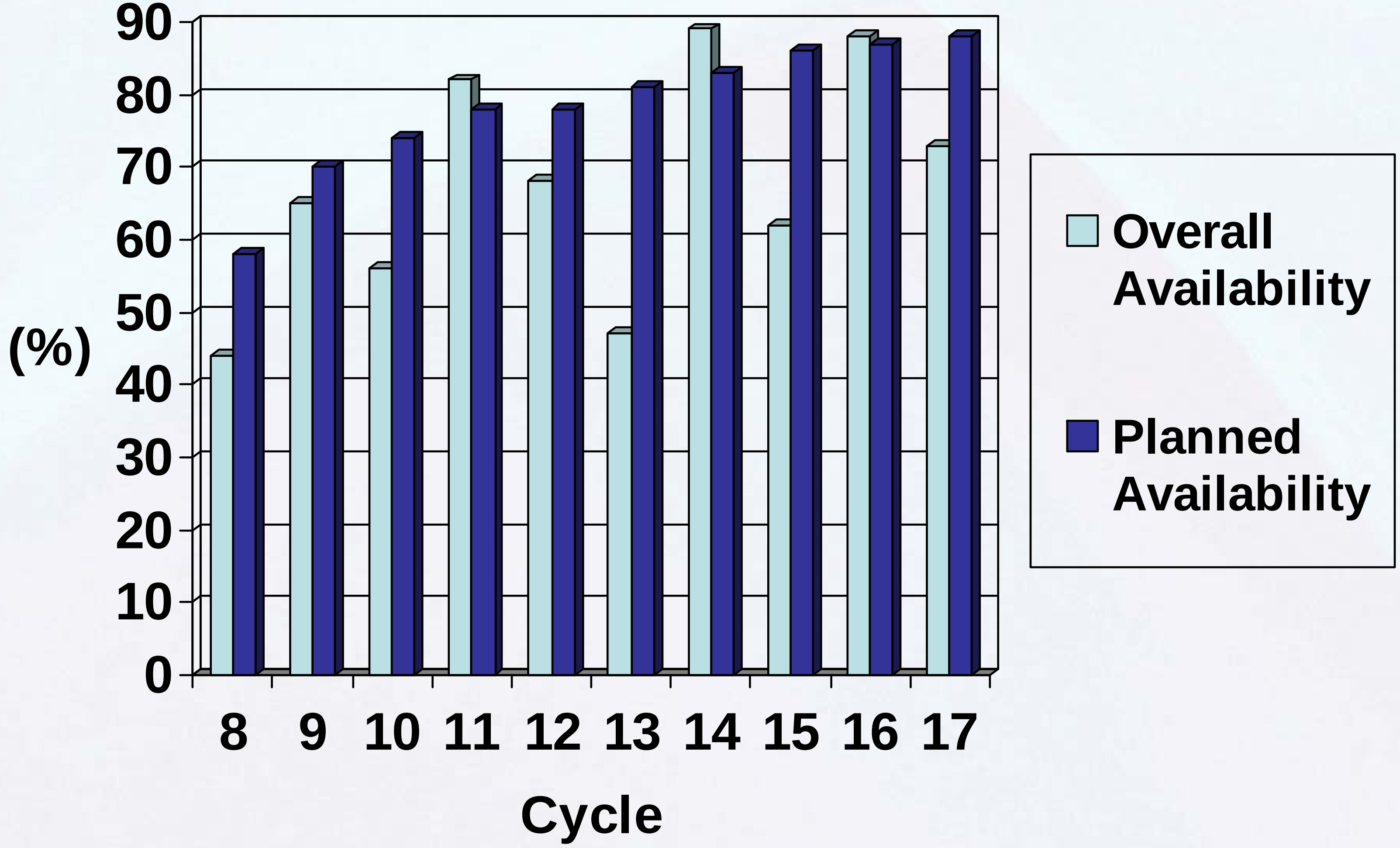
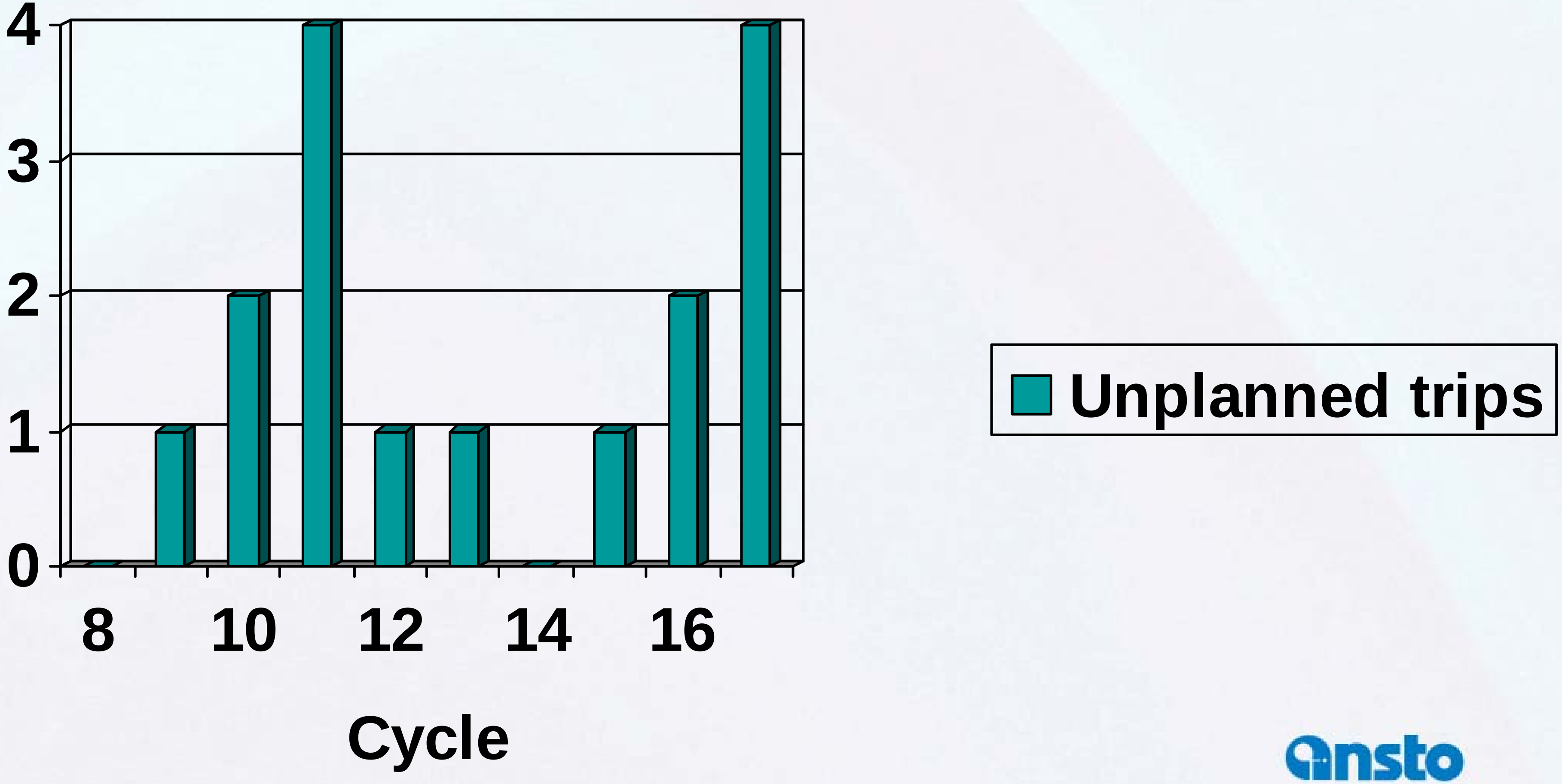
Major activities for 09/10

- Reactor availability – 80%
- Reflector Vessel – halt D20 degradation
- Increased & effective utilisation - CNS optimisation, U-plate irradiations, Si irradiations, DNAA, NAA, research irradiations, new opportunities
- Strong and relevant international partnerships
- Performance measurement and benchmarking – improve operation & safety
- Implement flexible fuel management strategy

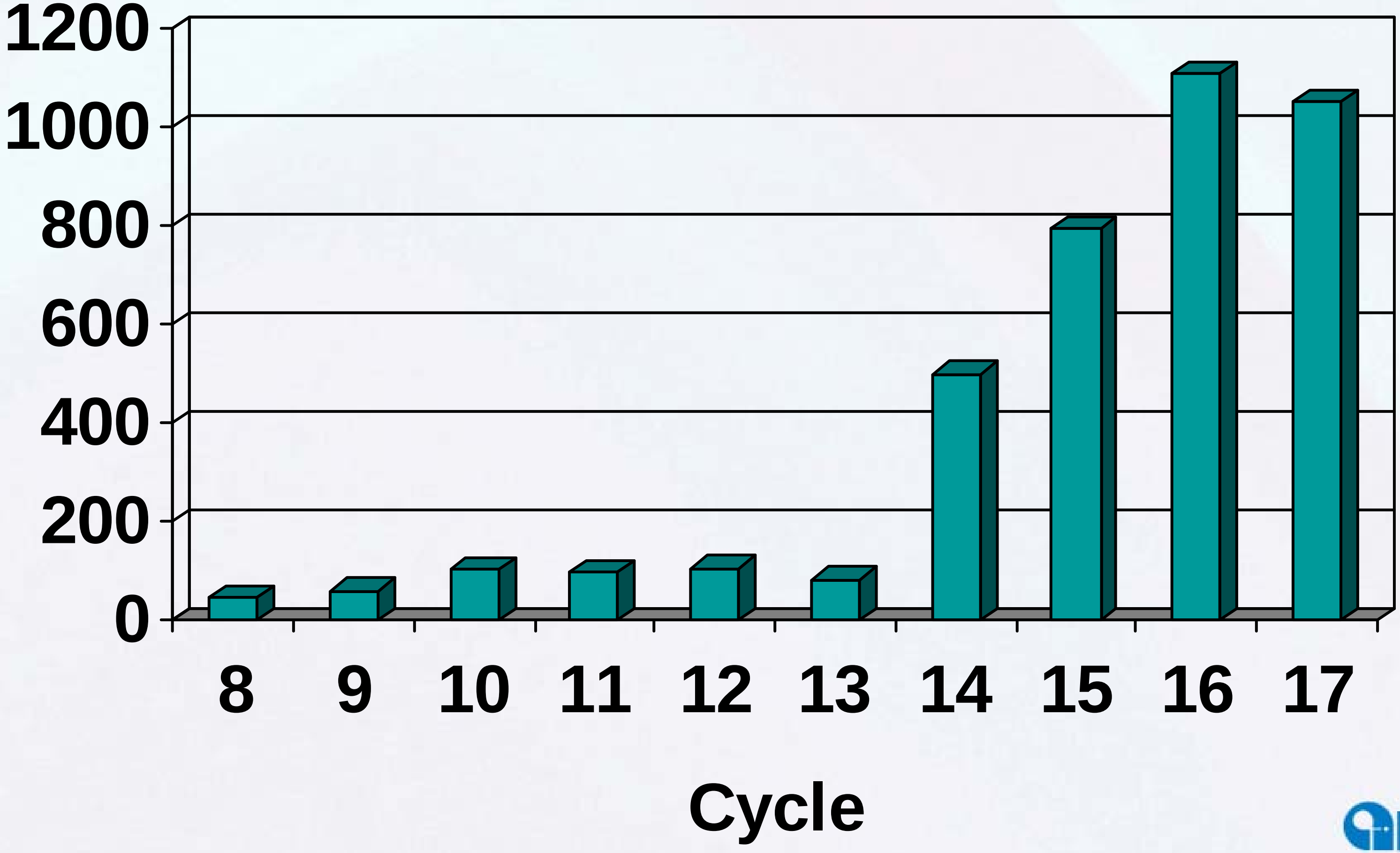
Availabilty - Cycles 8 - 17



Unplanned trip vs cycle



Total number of irradiations



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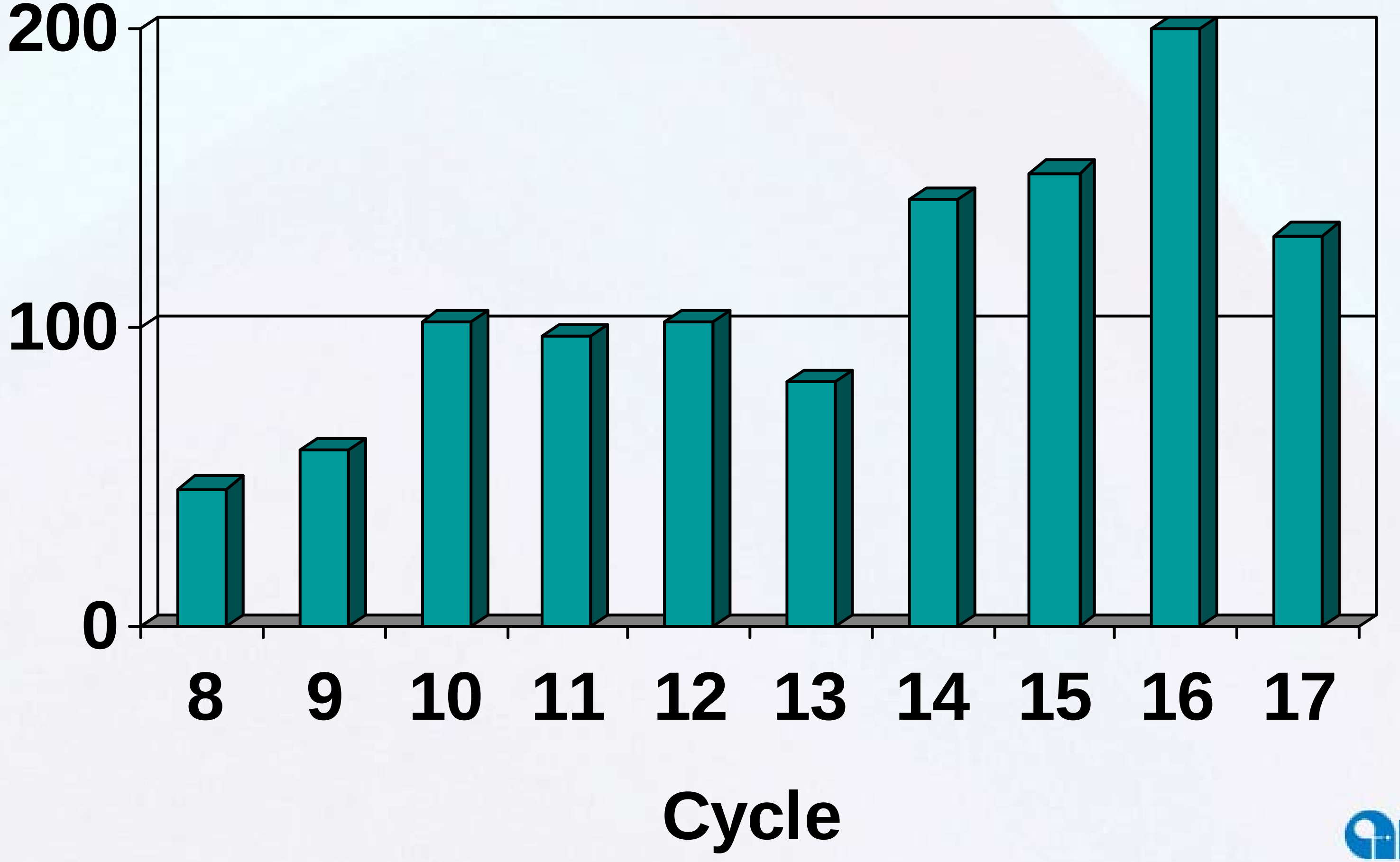
Irradiations excluding DNAA



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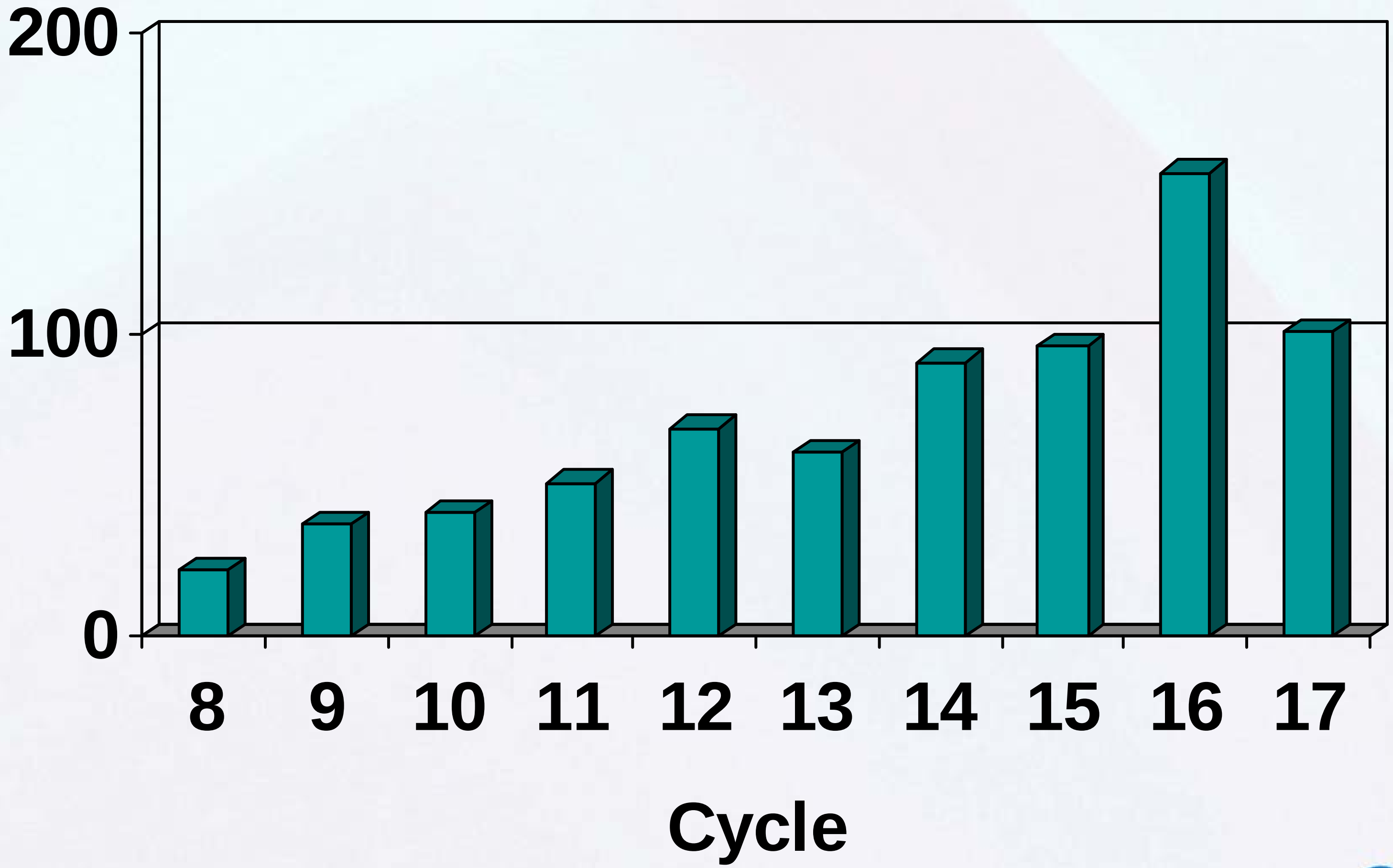
Silicon Array Irradiations



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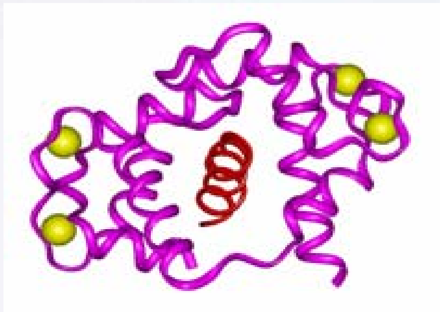
Science – what are the big opportunities with OPAL?

Industrial Problems

Oil and gas exploration/extraction
Nuclear: Gen-IV reactors, Fusion materials
Hydrogen Economy, fuel cells, etc.
Food
In-situ processes in manufacturing, etc. (e.g. welding, grinding, chemical reactions, extrusion, deformation, …)



Biology in the post-genomic era

Interactions between biomolecules
Structure & function of membrane proteins
Bio-devices

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Thank you

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