Australian Government

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Nuclear-based science benefiting all Australians

The Utilisation of Australia's Research Reactor, OPAL

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Sydney

Introducing ANSTO

- **Centre of Australian nuclear expertise**
- **Home of Australia's only nuclear reactor**
- **Australian government science and technology organisation**
- **Around 1000 employees**
- **Addressing issues such as health care, environment protection, assistance to industry and regional interactions**

OPAL Research Reactor and applications

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Research reactor operation

- **HIFAR operating since 1958 (Shutdown in 2007)**
- **National facilities → Centre of Excellence**
  - Neutron beams for science
  - Radio-isotopes for medicine and industry
  - Commercial & research irradiations

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OPAL Reactor

- **Multi-purpose facility – neutron beams, radiopharmaceuticals, irradiation of materials**
- **20 MW thermal power**
- **Compact core (~300 kW/L)**
- **Plate type Low Enriched Uranium fuel**
- **D_2O reflector**
- **Upward coolant flow (light water)**
- **2 independent & diverse shutdown systems**

12th August 2006

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.

Existing Capabilities

- Education & Training:
  - Public Tours and Visits
  - Training on Reactor Operation
  - Training on Radiation Protection
- Irradiations for Neutron Activation Analysis
- Delayed Neutron Activation Analysis
- Production of Radioisotopes
  - Medical radioisotopes for needs of Australia and other countries
  - Range of isotopes for industrial and research purposes

Existing Capabilities

- Irradiations for Geochronology
  - Argon Geochronology
  - Fission Track Geochronology
- Transmutation Effects
  - Neutron Transmutation Doping of Silicon up to 8 inch diameter
  - Materials Irradiation
- Neutron Beam Research
  - SANS, neutron diffraction, residual stress measurement

Existing Capabilities

– Nuclear Analysis capabilities in neutronics, criticality, thermal-hydraulics and shielding
– Water Tunnel for hydraulic testing and flow studies
– Cold Neutron Source for beam research over cold neutron energy range

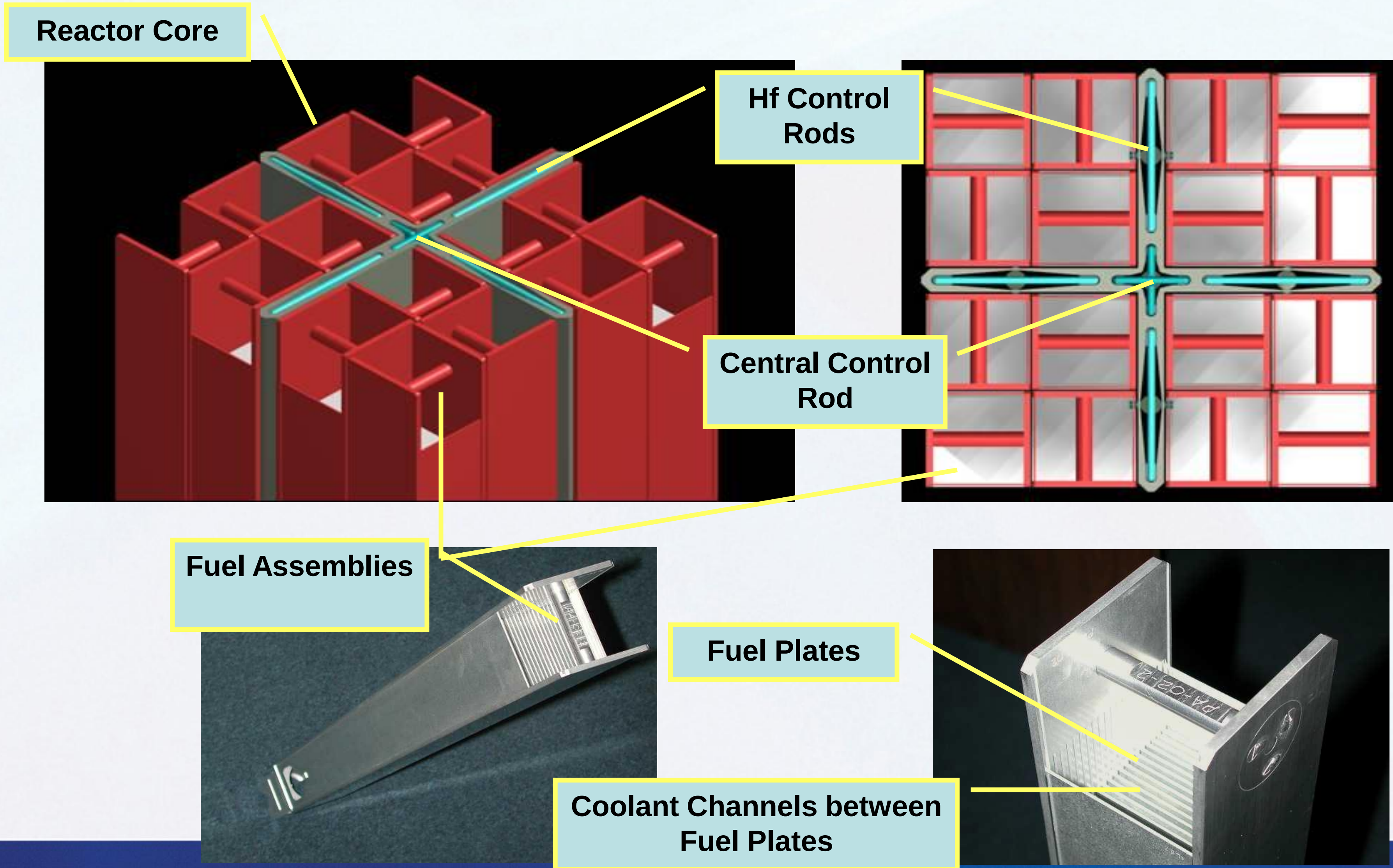
Potential Capabilities

- Education & Training:
  - Teaching programs for physical/ biological science and nuclear engineering
- Prompt Gamma Neutron Activation Analysis
- Positron Source
- Testing
  - Instrument Testing and Calibration
  - Loops for Testing Nuclear Fuel

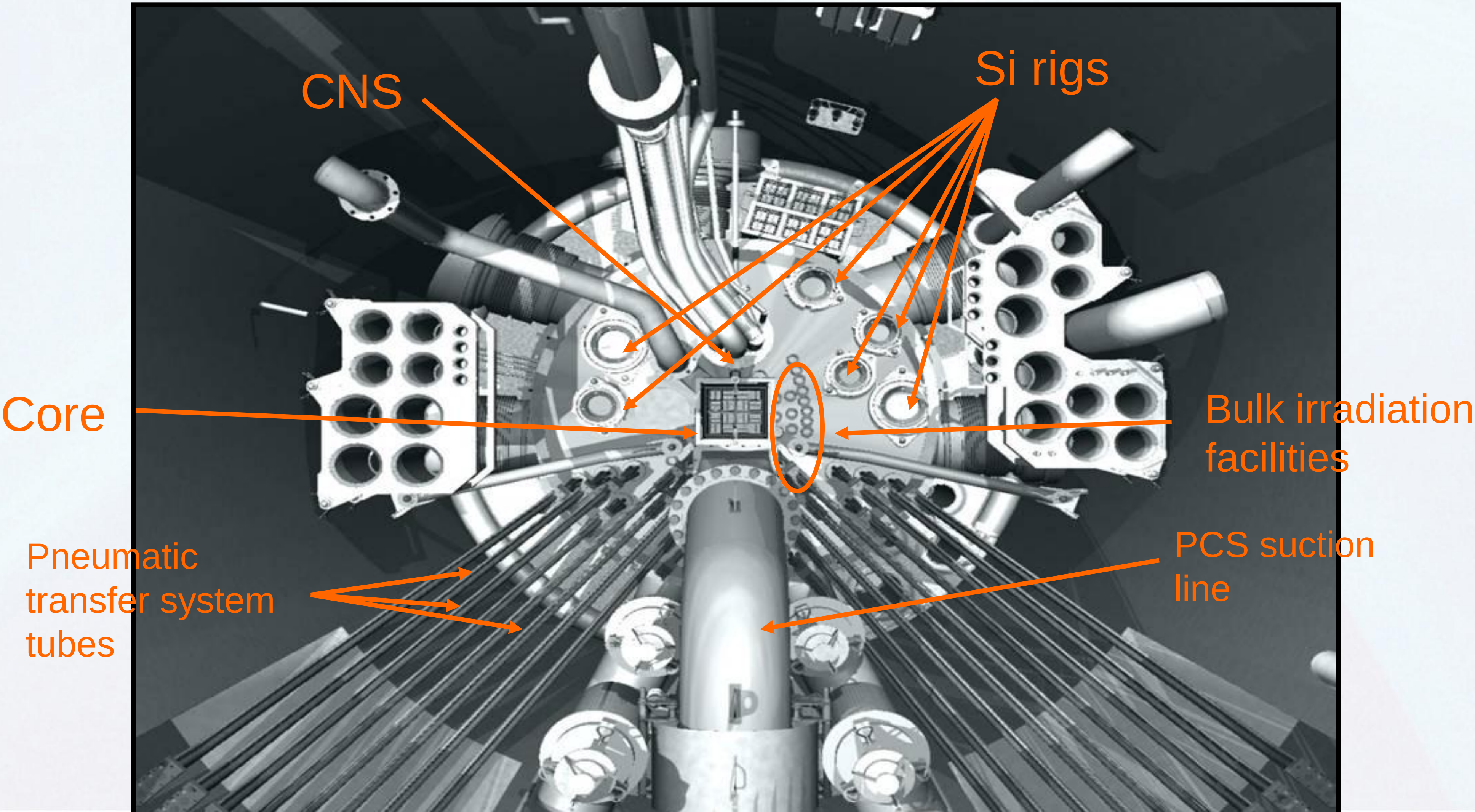
Potential Capabilities

– Neutron Radiography
  - ❖ Static Radiography
  - ❖ Motion Radiography
  - ❖ Tomography
– Hot Neutron Source for beam research using fast neutrons.

Reactor Core



Reflector facilities

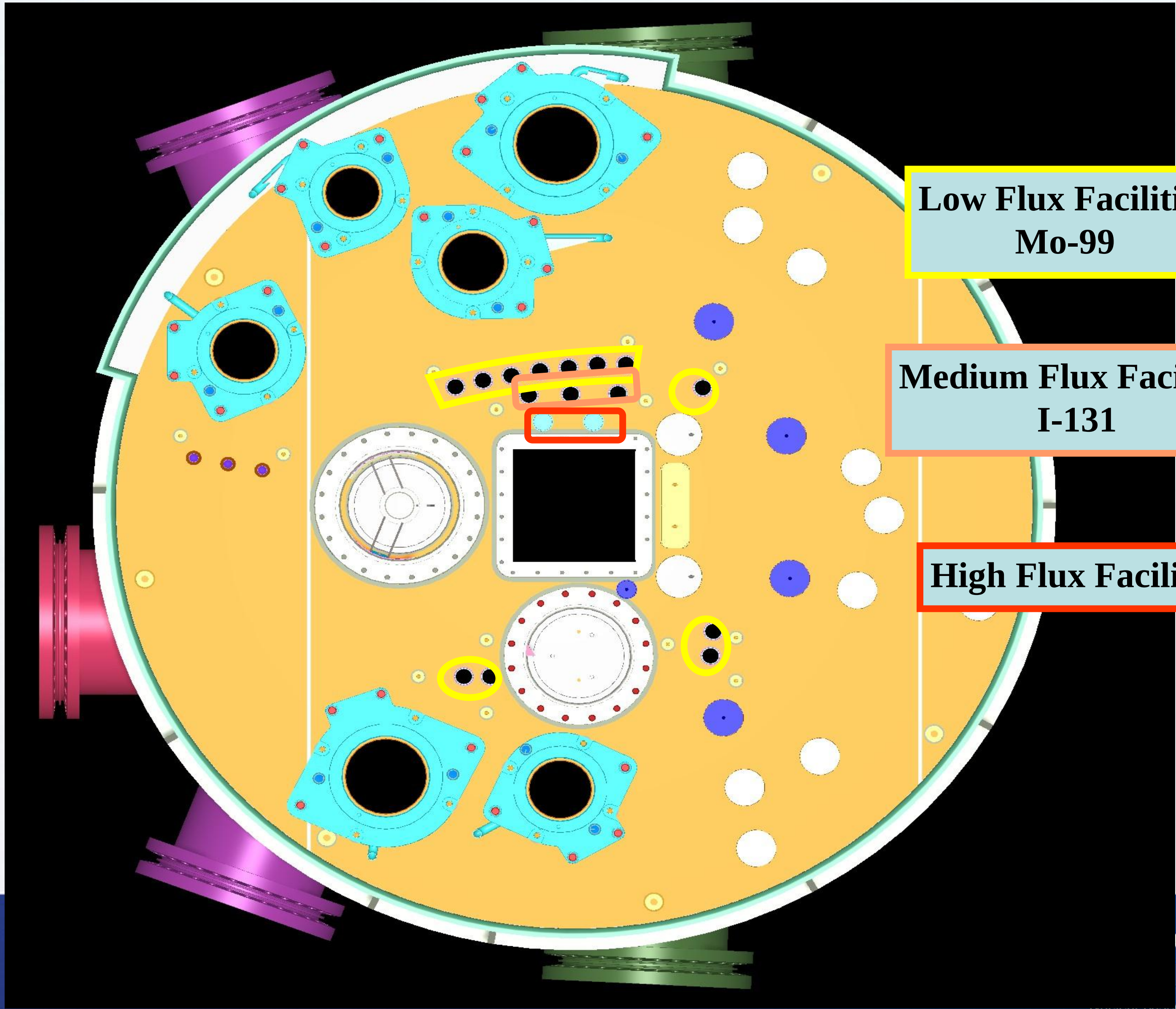


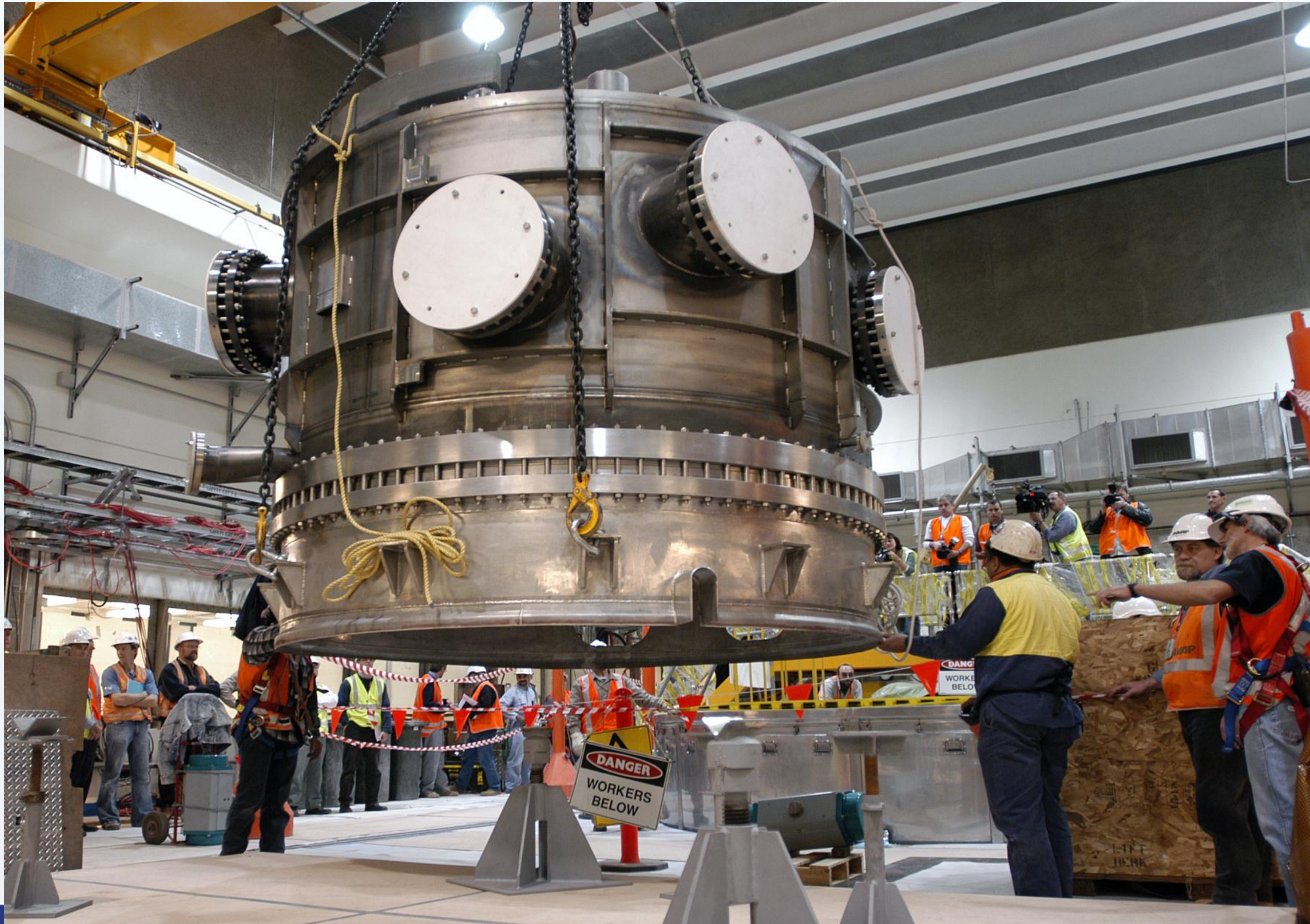
Radioisotopes for Nuclear Medicine/ Research Isotopes

- **Total of 17 Bulk Irradiation Facilities arranged in three different classes, principally for the production of Molybdenum-99 and Iodine-131**

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

Bulk irradiation facilities





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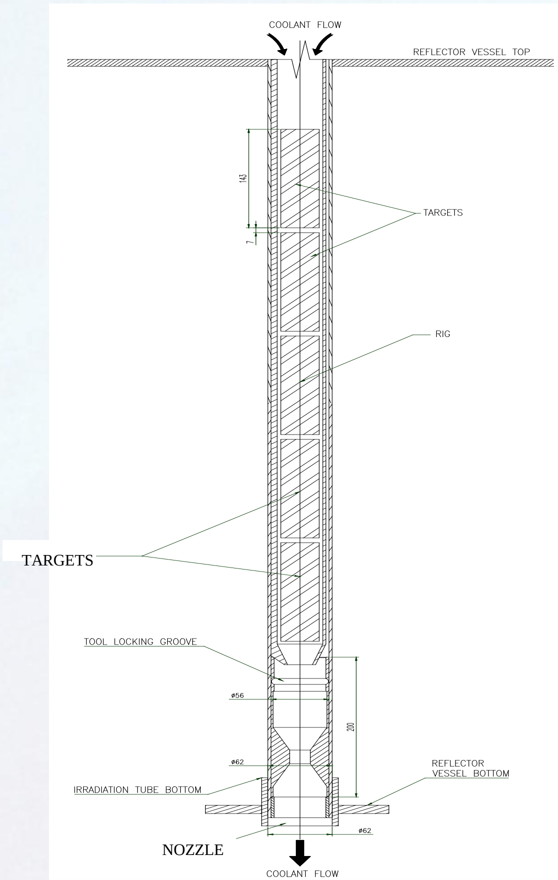
Irradiations Currently Performed

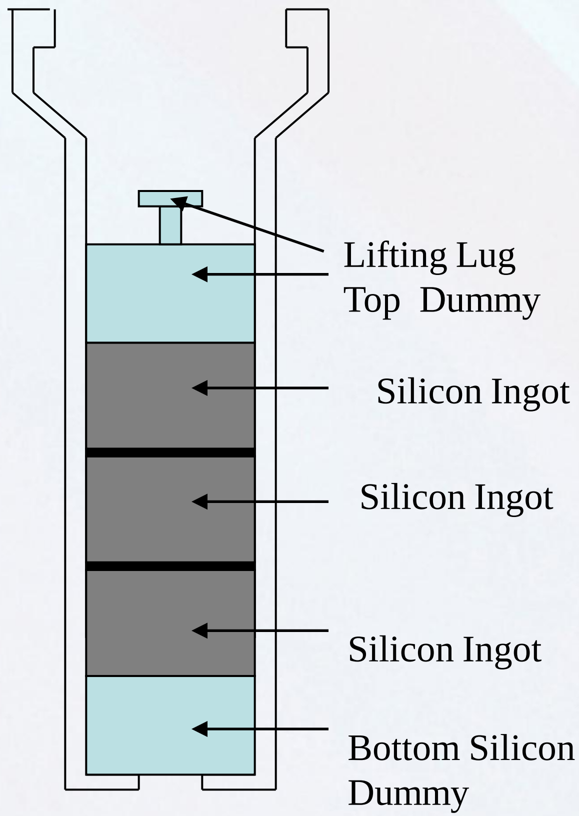
- **Medical Isotopes – Mo99, Iodine 131, Samarium 153, Chromium 51, Yttrium 90, Lutetium 177**
- **Long and Short Residence Time NAA**
- **Material Irradiations for research and to determine neutron damage**
- **Delayed NAA for Uranium Analysis**
- **Neutron Transmutation Doping of Silicon**

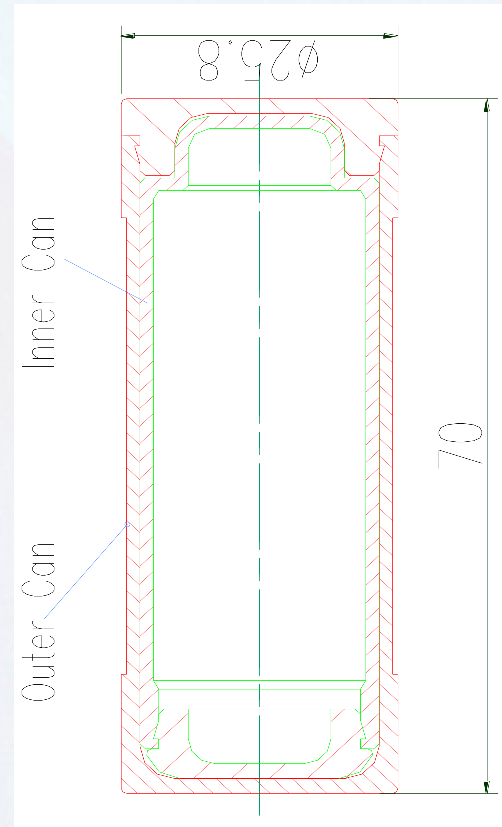
Planned Irradiations

- **Bulk production of Lutetium 177**
- **Geochronology samples – Fission Track and Argon Dating**
- **Radioactive Tracers – Scandium 46**
- **Gold 198 Grains**
- **Brachetherapy Sources – Iodine 125 seeds**

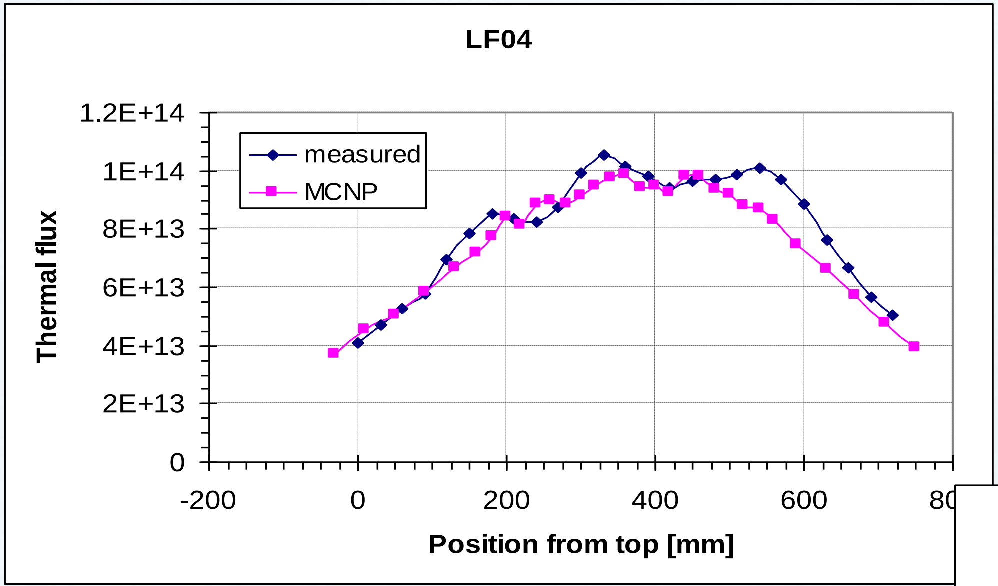
Rigs and cans



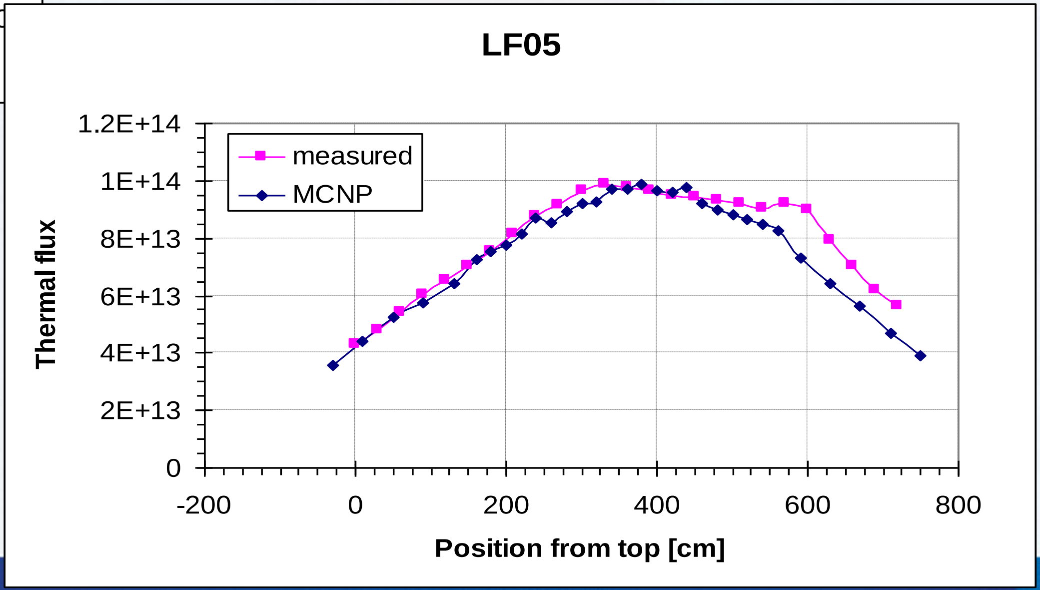




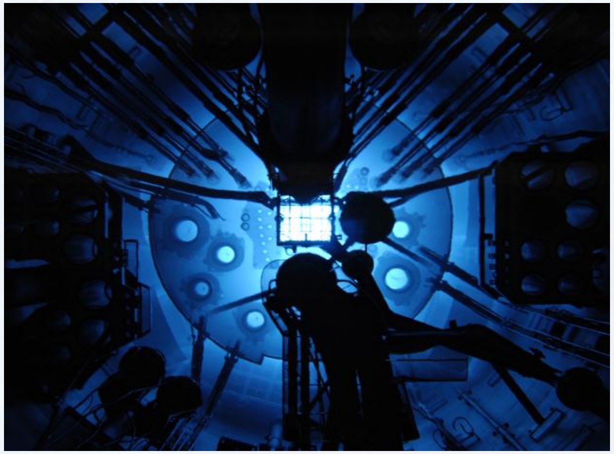
Results - BIF



Compare calculations and measurements



The Production Process



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

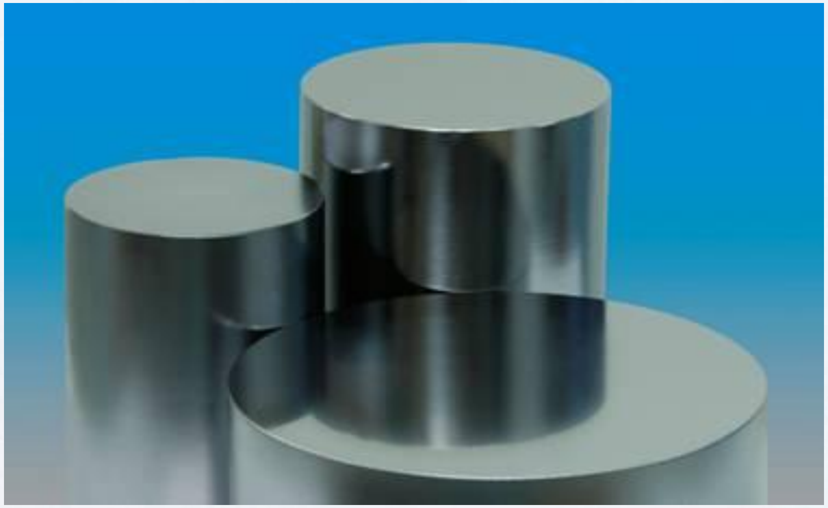
Mo-99 separated

Tc-99m Generator to Customer

Manufacture of radiopharmaceuticals

Silicon irradiation

- **6 facilities for silicon irradiation at OPAL suitable for 4”, 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
- Neutron flux range from 2.5E12 to 1.6E13
- Customer base – Japan & Europe electronics suppliers



Applications of NAA and DNAA

- environment
- geoscience and mineralogy
- forensics and counter-terrorism
- archaeology
- agriculture and food science
- materials science
- medical science
- metrology



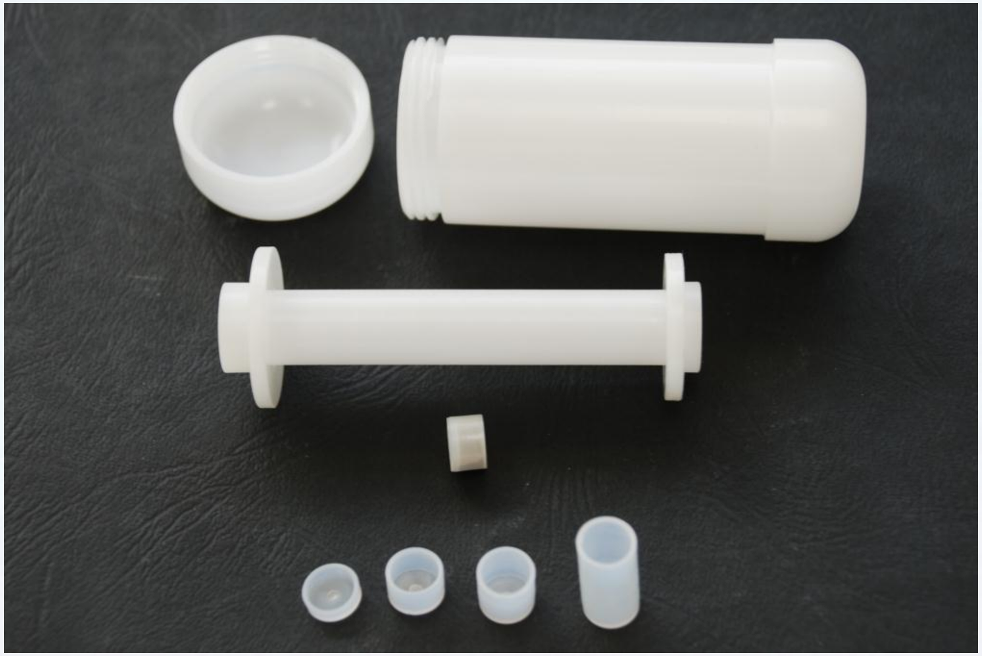

NAA - short residence time facility – 'self-service'

< 3E13 $cm^{-2} s^{-1}$
< 15 minutes

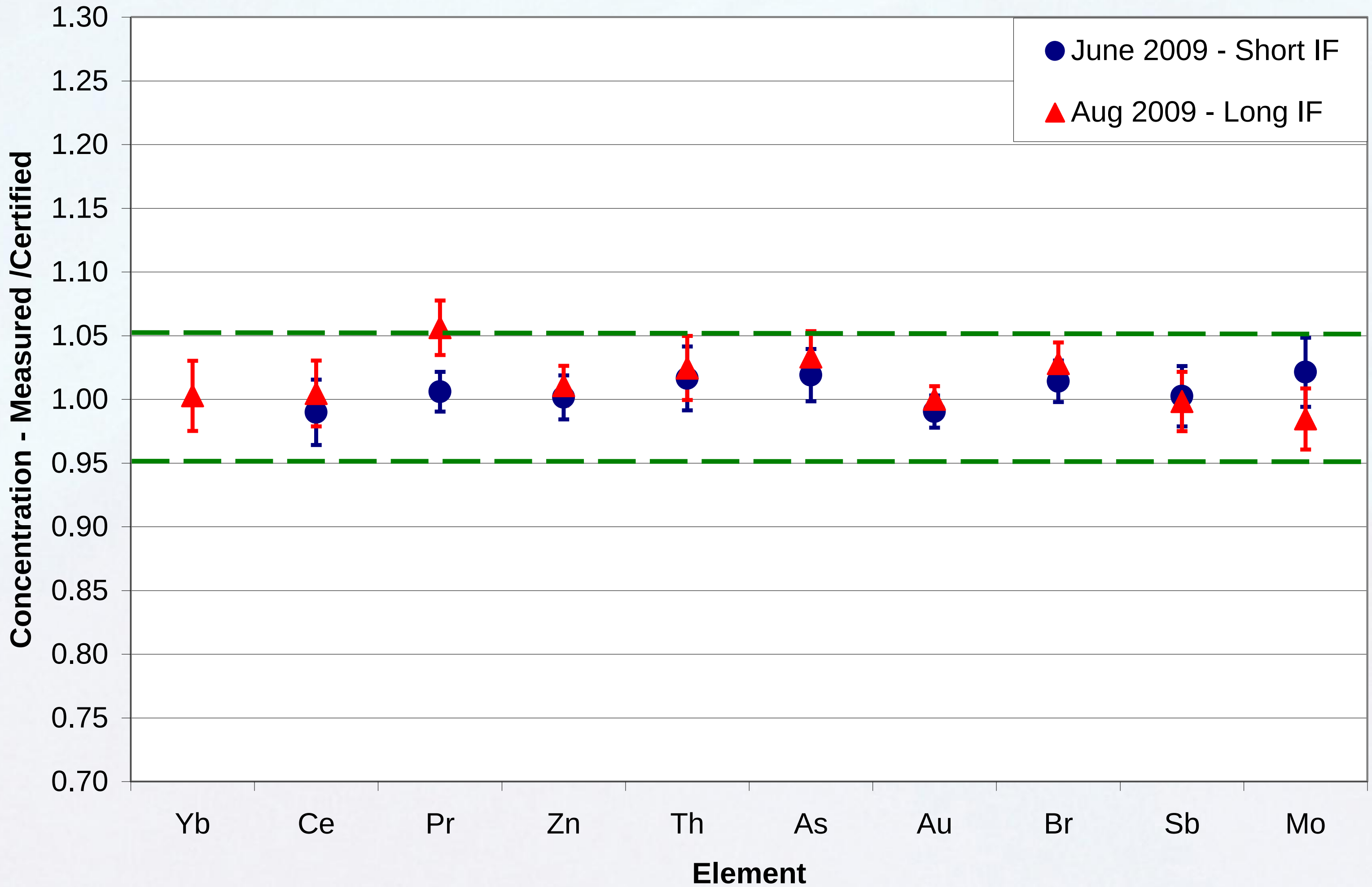
Long residence time facility

< 20 hours ~ 9E12 $cm^{-2}\ s^{-1}$

Short and long irradiation NAA cans



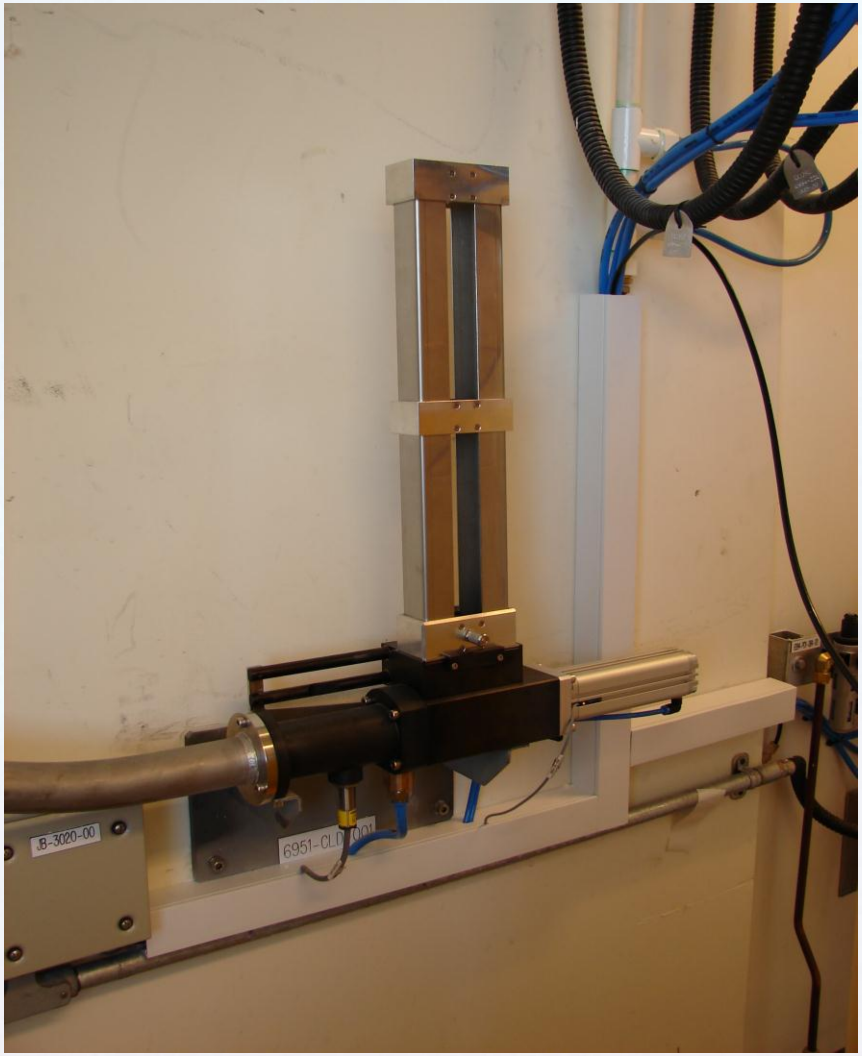
NAA results
- reference material irradiated in SRT and LRT facilities

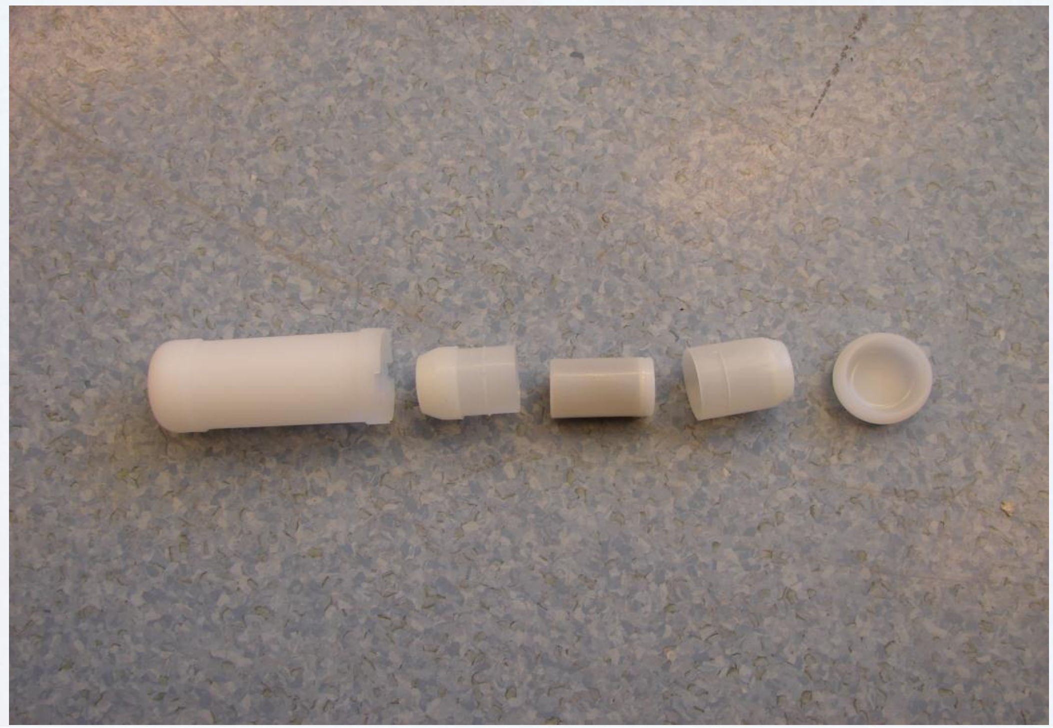


DNAA facility

~ 6E12 $cm^{-2}\ s^{-1}$

DNAA can loading device

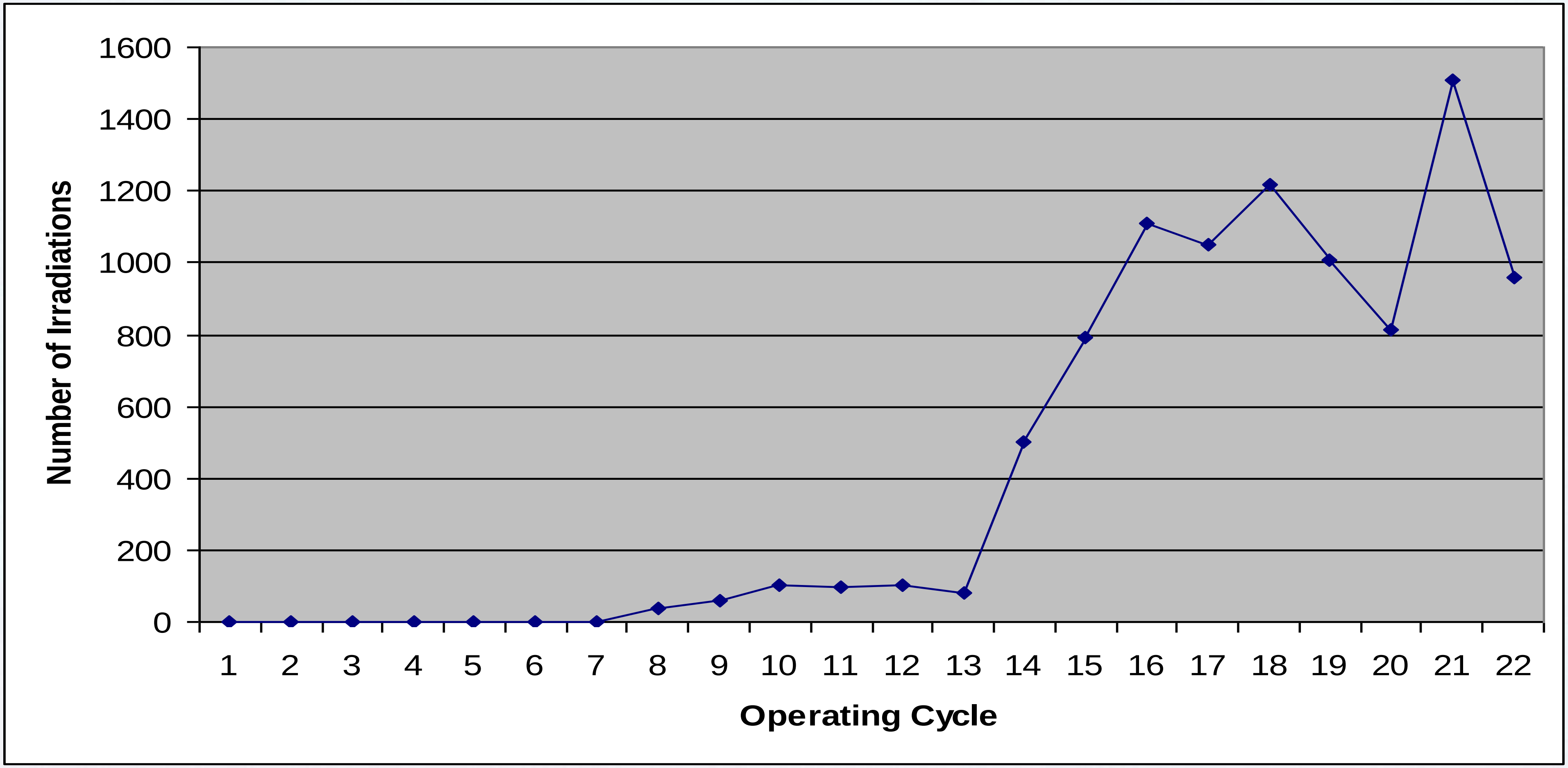




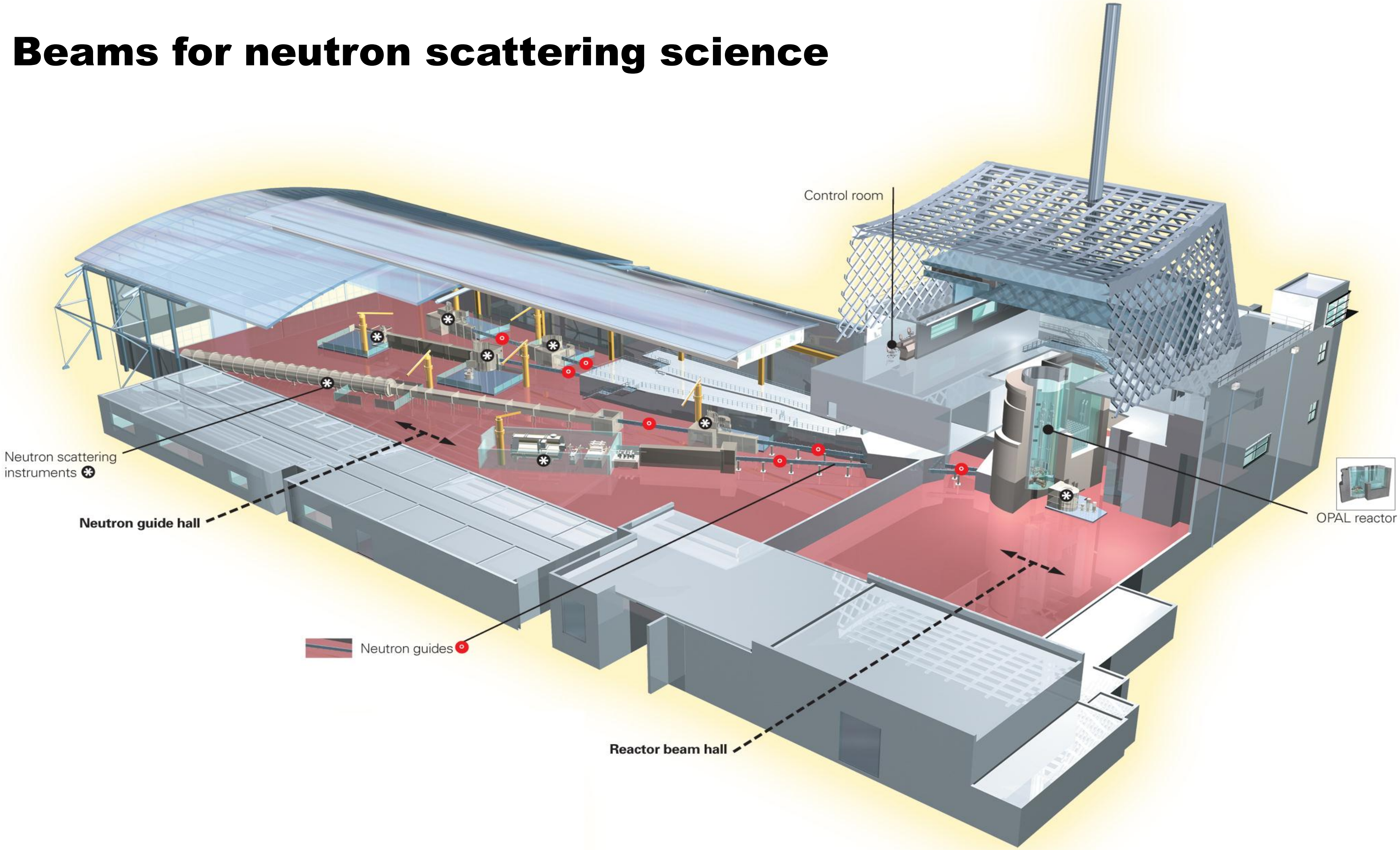
NAA and DNAA at ANSTO

- **Australian universities**
  - archaeology: pottery, ochre, bone, …
  - environment: mining, estuarine, …
  - geology and mineralogy
- **ANSTO**
  - mineral processing, U
  - climate change
  - forensics
- **Industry**
- **Government research agencies**
  - metrology
  - geoscience
- **INAA method development**
- **International networks**

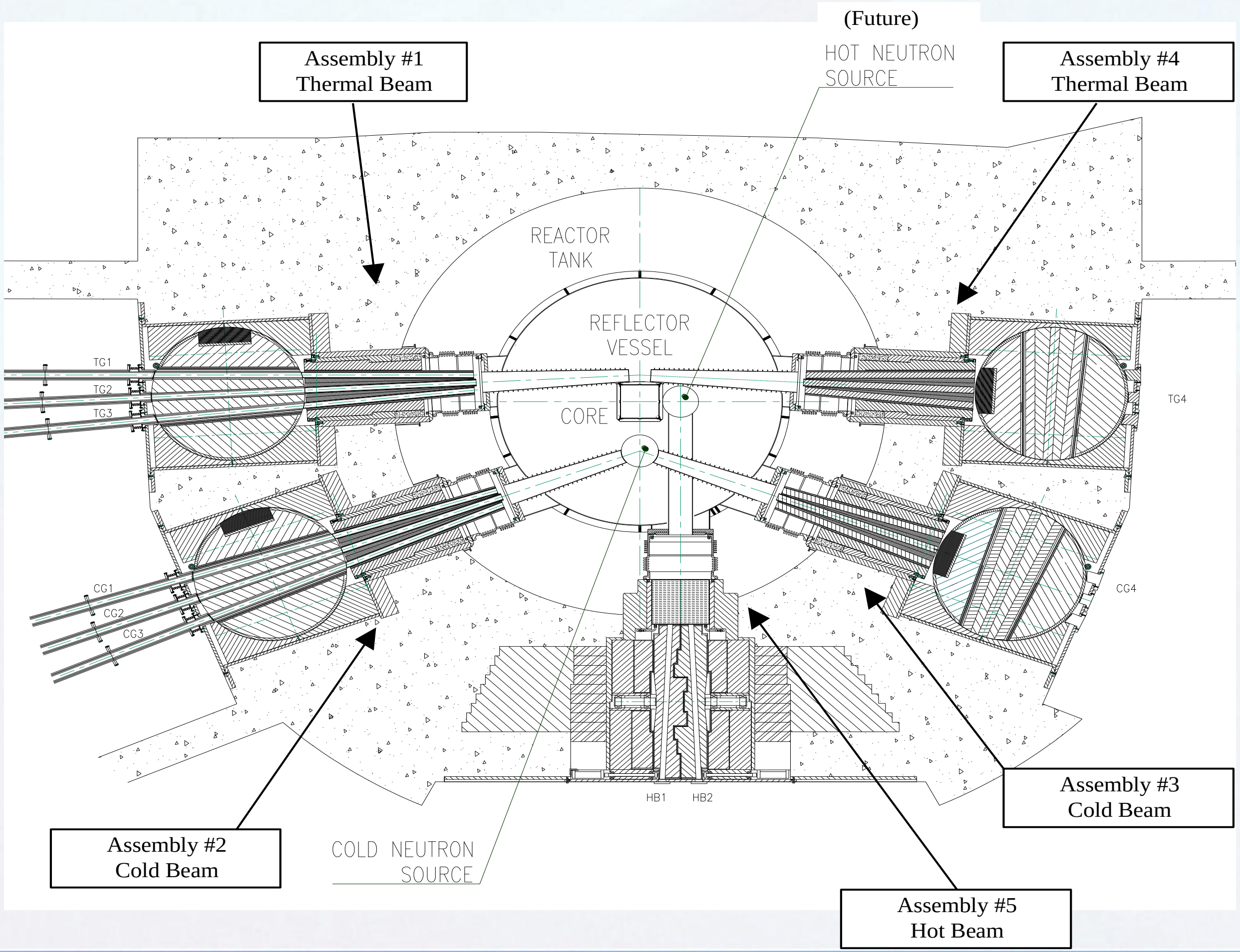
Utilisation of Irradiation Facilities



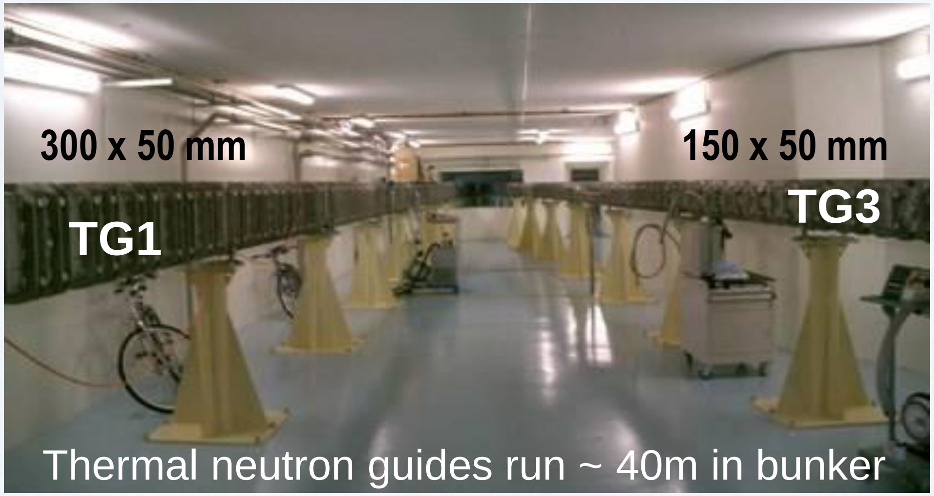
Beams for neutron scattering science



Beam facilities



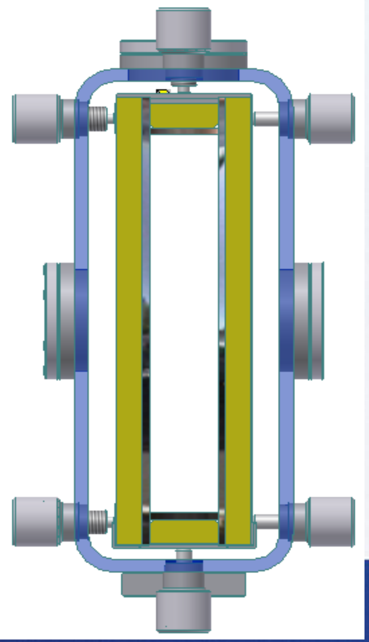
Reactor face, guide bunker & neutron guides



Thermal neutron guides run ~ 40m in bunker

guide bunker


Mirrotron engineers installing out-of-pile neutron guides



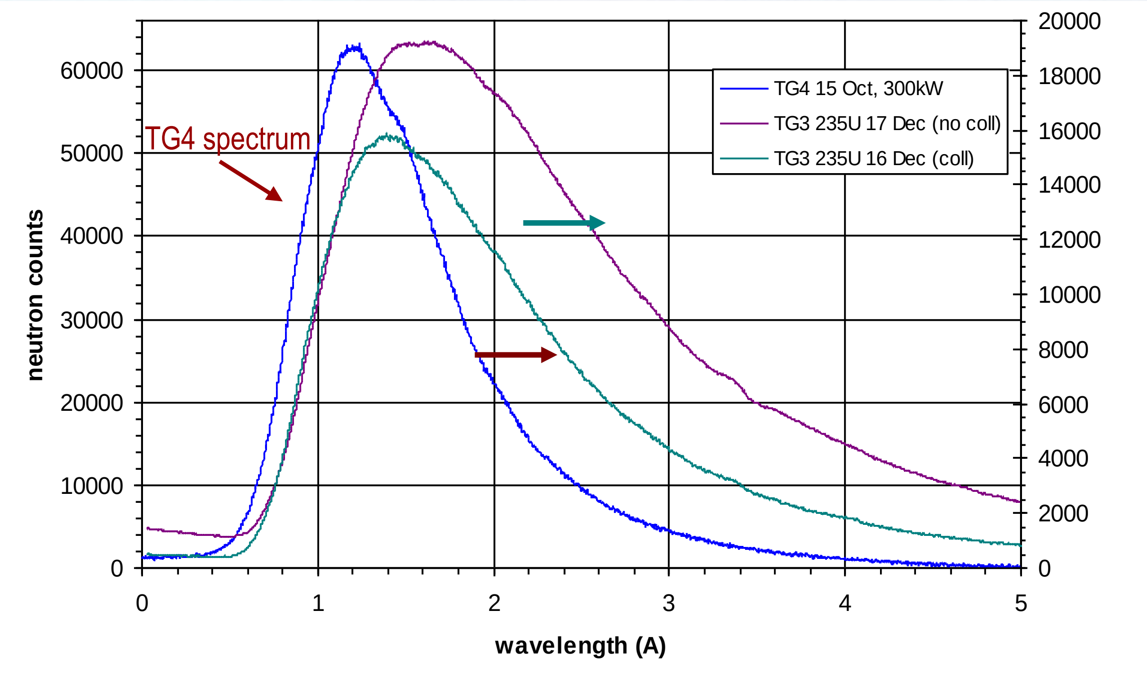
neutron guide cross-section

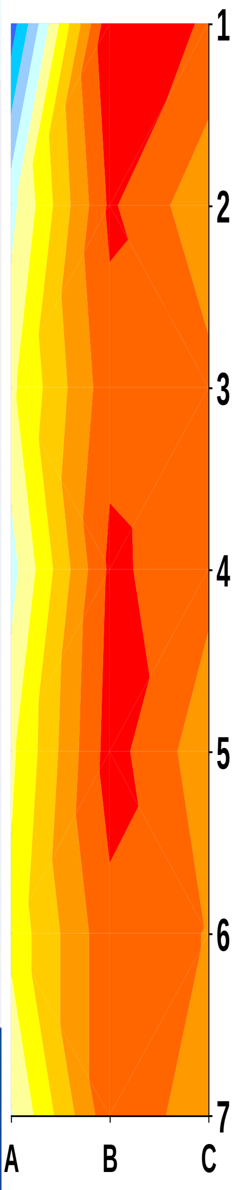
Beams vary from 50 -100 mm wide and from 150 - 300 mm high at exit window

Thermal Neutron Fluxes & Spectra

TG1 Au foil measurement

- **$\Phi = 1.24 \times 10^{10}$ n/cm²/s**
  (2nd break after Reactor Face)
  - Estimate $\Phi RF \leq 5.0 \times 10^{10}$ n/cm²/s
- **$\Phi = 3.3 \times 10^{9}$ n/cm²/s**
  (Wombat 45m from Reactor Face)
  - c.f. predicted value of 2.4×10^{9} n/cm²/s





Wombat

$\Phi = 2.9 \times 10^{9}$ n/cm²/s

2 % contours

variation:
10% (h) x 2% (v)

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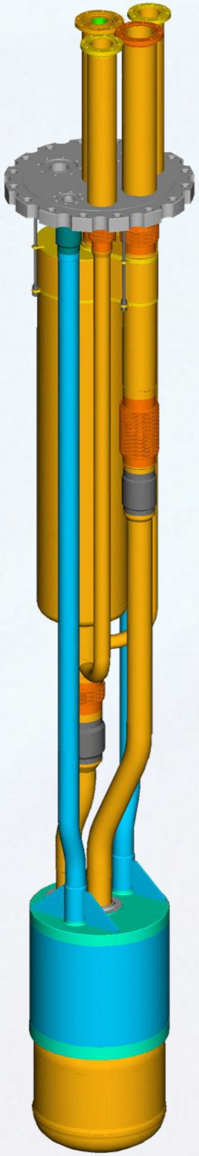
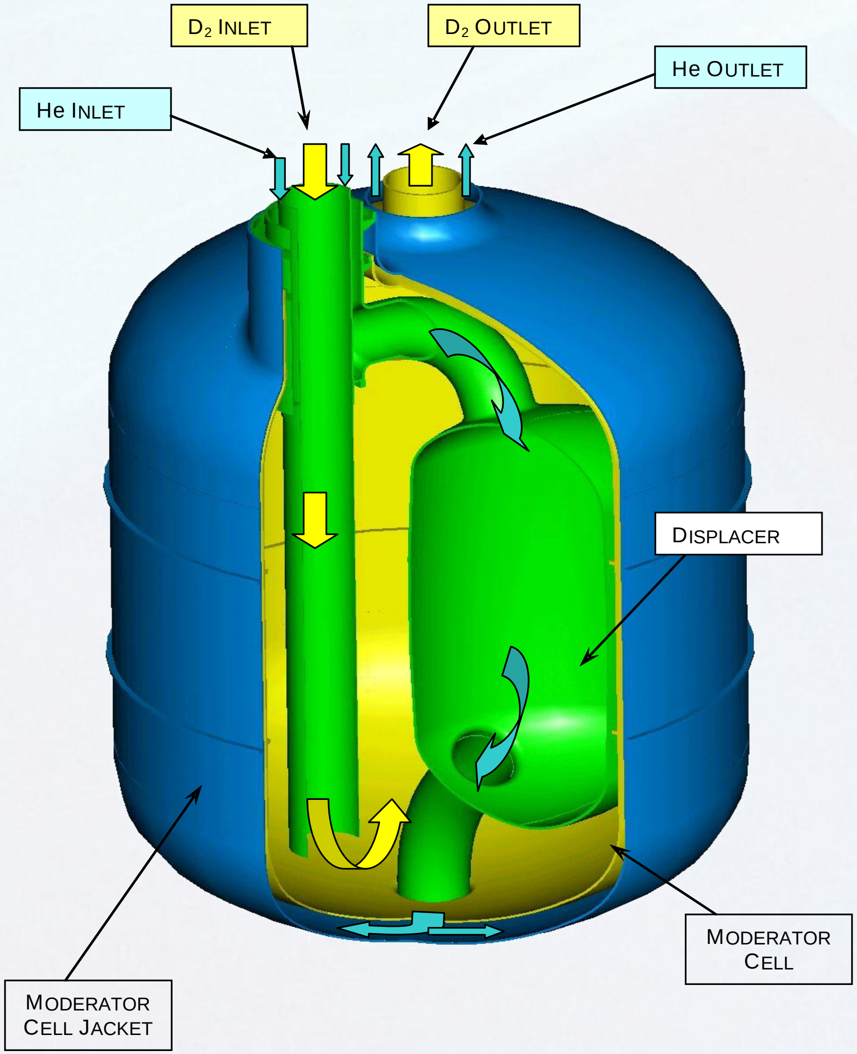
Cold Neutron Source

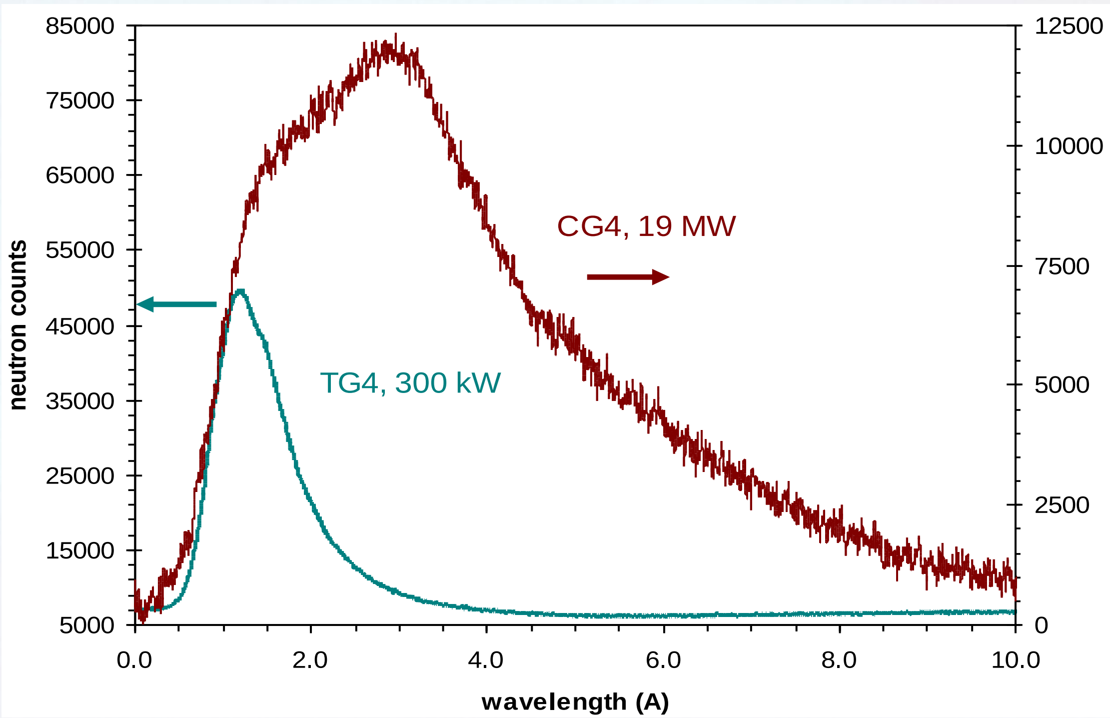




- **Long wavelength neutrons are produced in a moderator of liquid D_2 (~20 K) next to the core of the reactor**

Cold Neutron Fluxes & Spectra

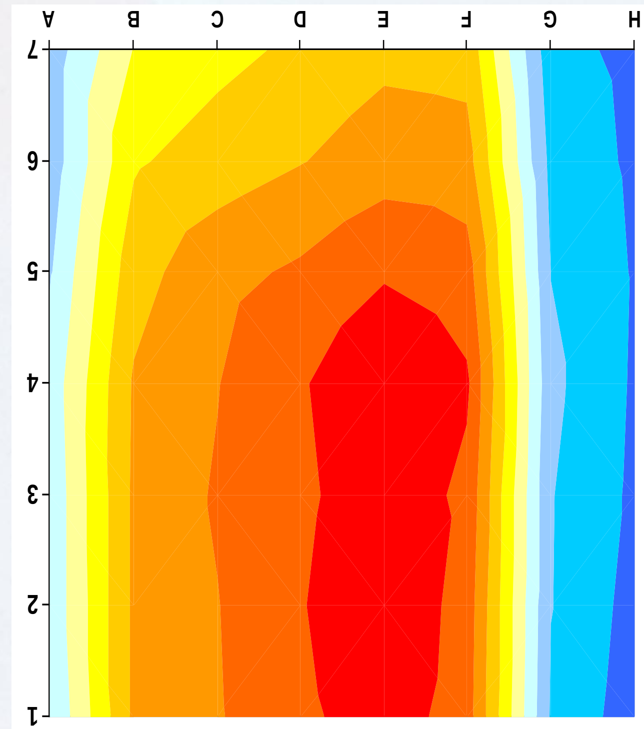
- **Peak in cold neutron spectrum at reactor face: λ ~ 3 Å**



CG4

Φ = 3.6 x 10^9 n/cm^2/s

10 % contours



Bragg Institute / Neutron Guide Hall

Operational Neutron Beam Instruments at OPAL

Wombat
(Hi-Intensity Powder)

Kowari
(Residual Stress)

Platypus
(Reflectometer)

Quokka
(SANS)

Echidna
(Hi-Resolution Powder)

Koala
(Single Crystal)

Taipan
(Thermal TAS)

The Next Generation (under construction)

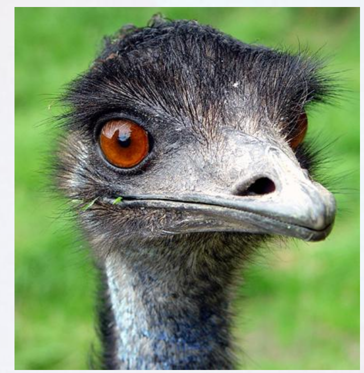
Kookaburra (USANS)

Sika (Cold TAS)

Pelican (Polarised Spectrometer)

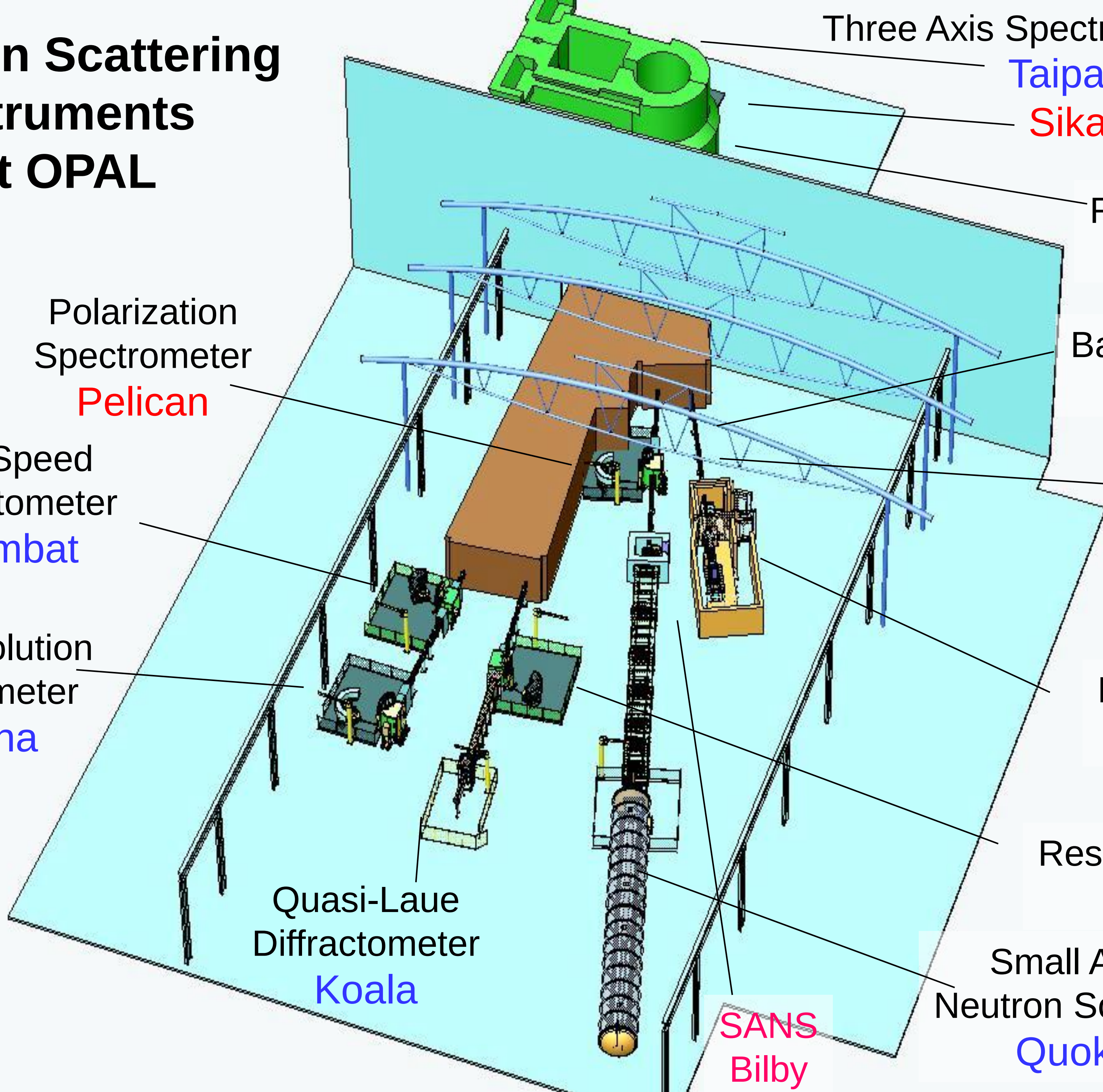
Bilby (SANS)

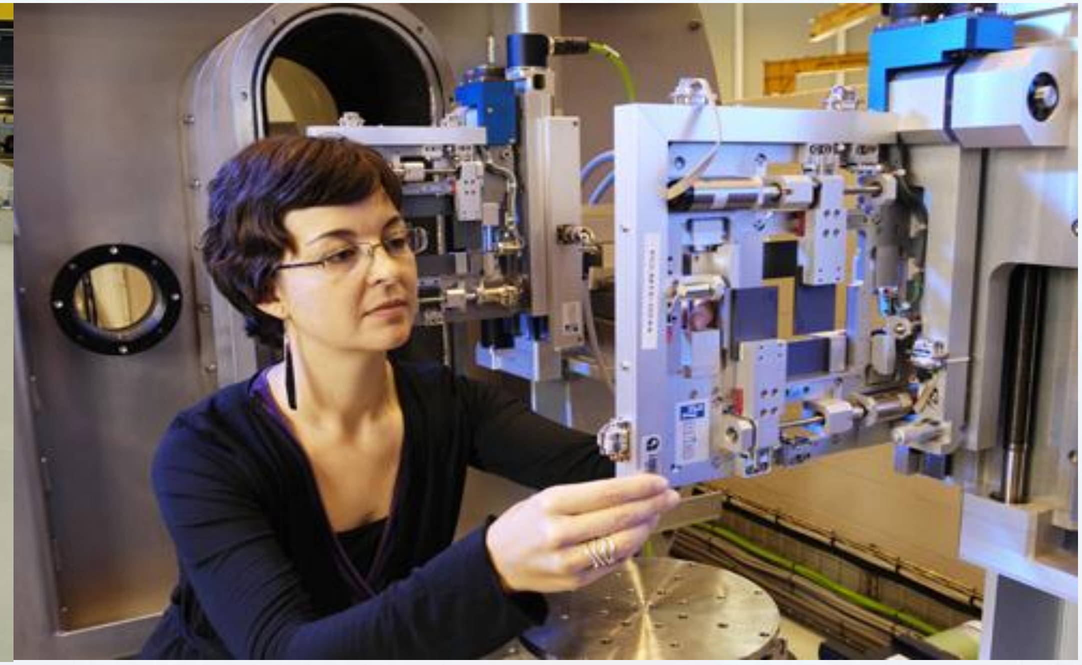
Dingo (Radiography)



Emu (Backscattering)

Neutron Scattering Instruments at OPAL





ANSTO’s neutron-beam instruments are used to solve complex research and industrial problems in many important fields.

Battery Materials on Wombat

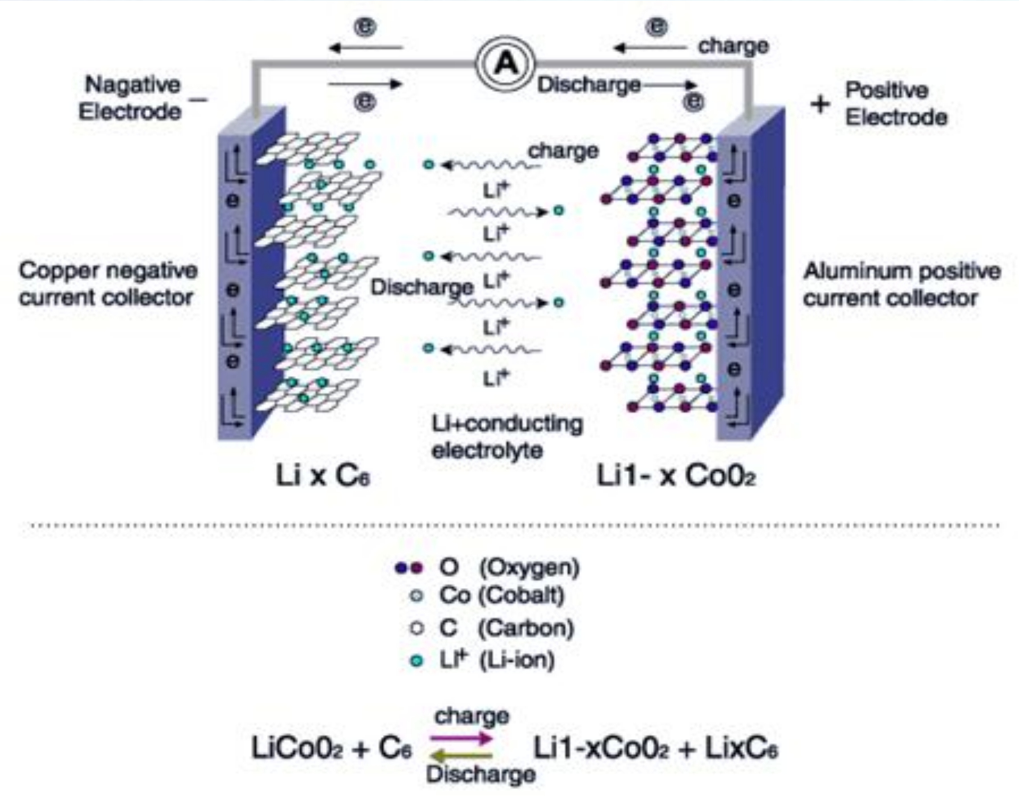
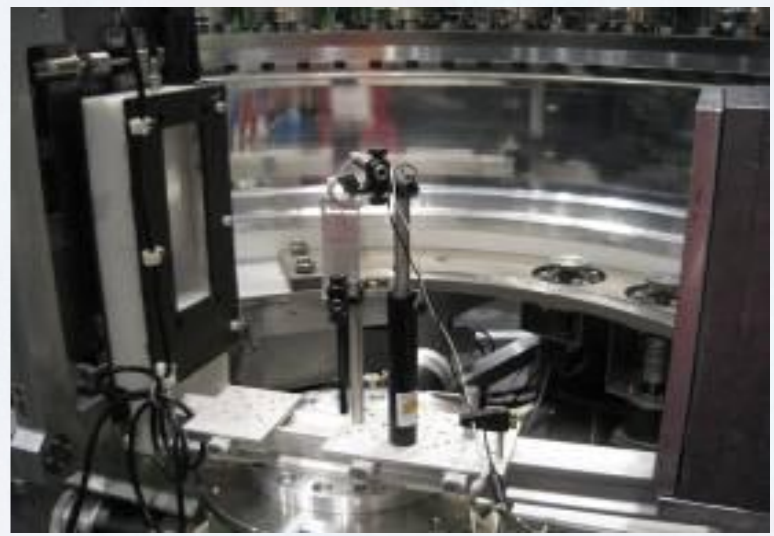
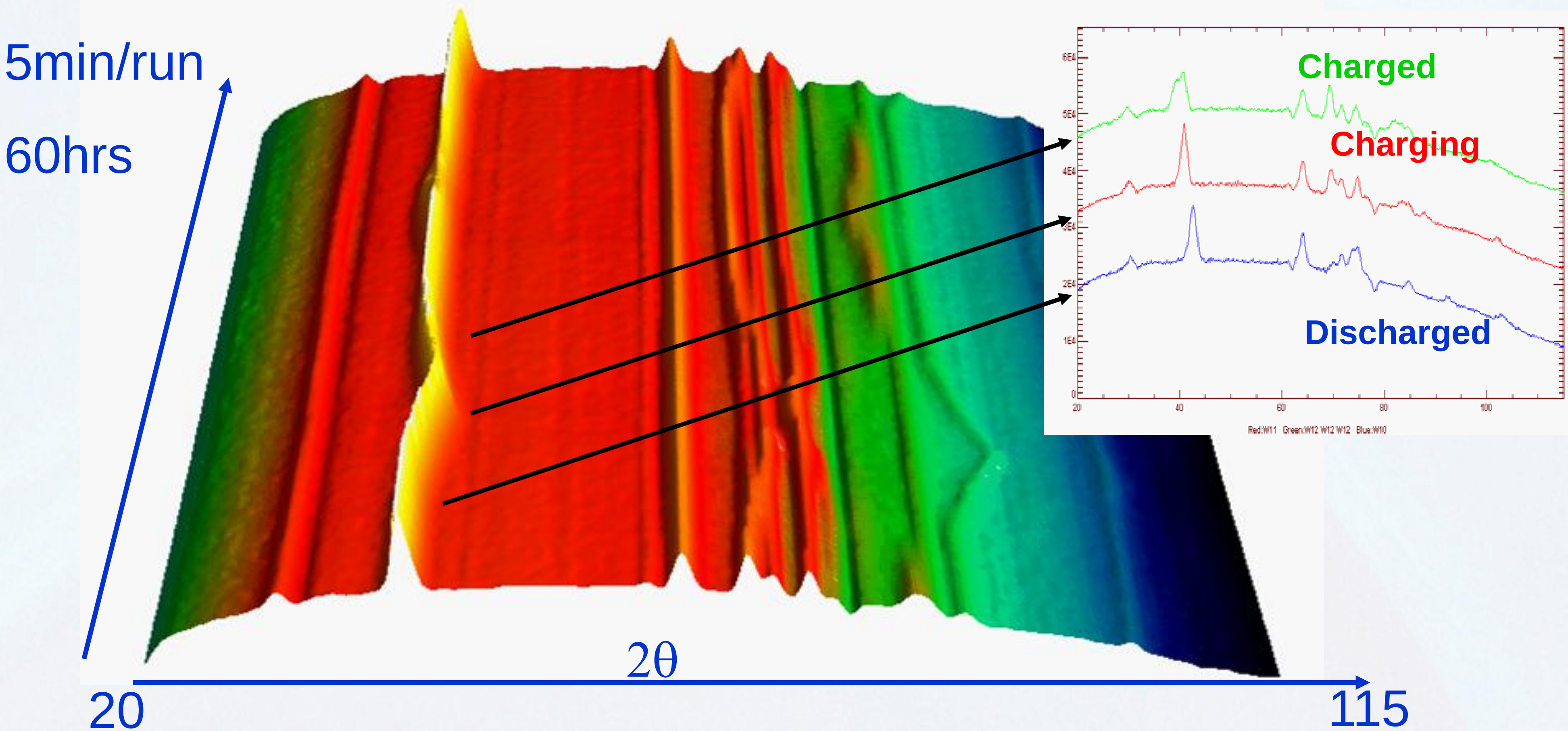


Image:http://www.gaston-lithium.com

- **Ion-mobility**
- **Structure-property relationships**
- **Cell construction (cathode/electrolyte interfaces, microstructure)**



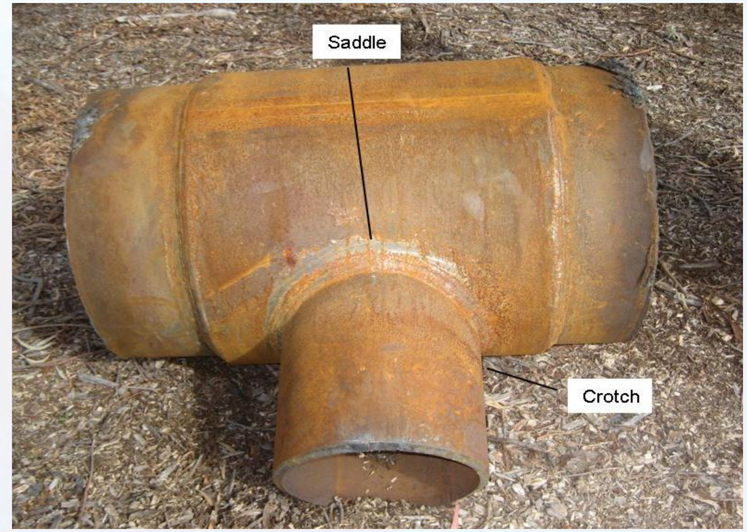
Battery Materials on Wombat

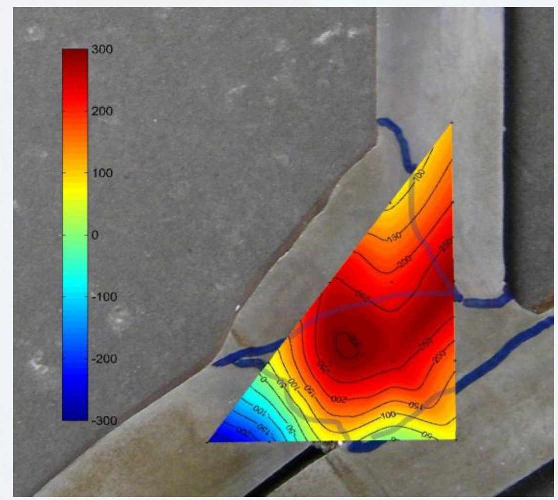


- ***In-situ* charging/discharging cycling on Wombat**

Welded Pipelines on Kowari

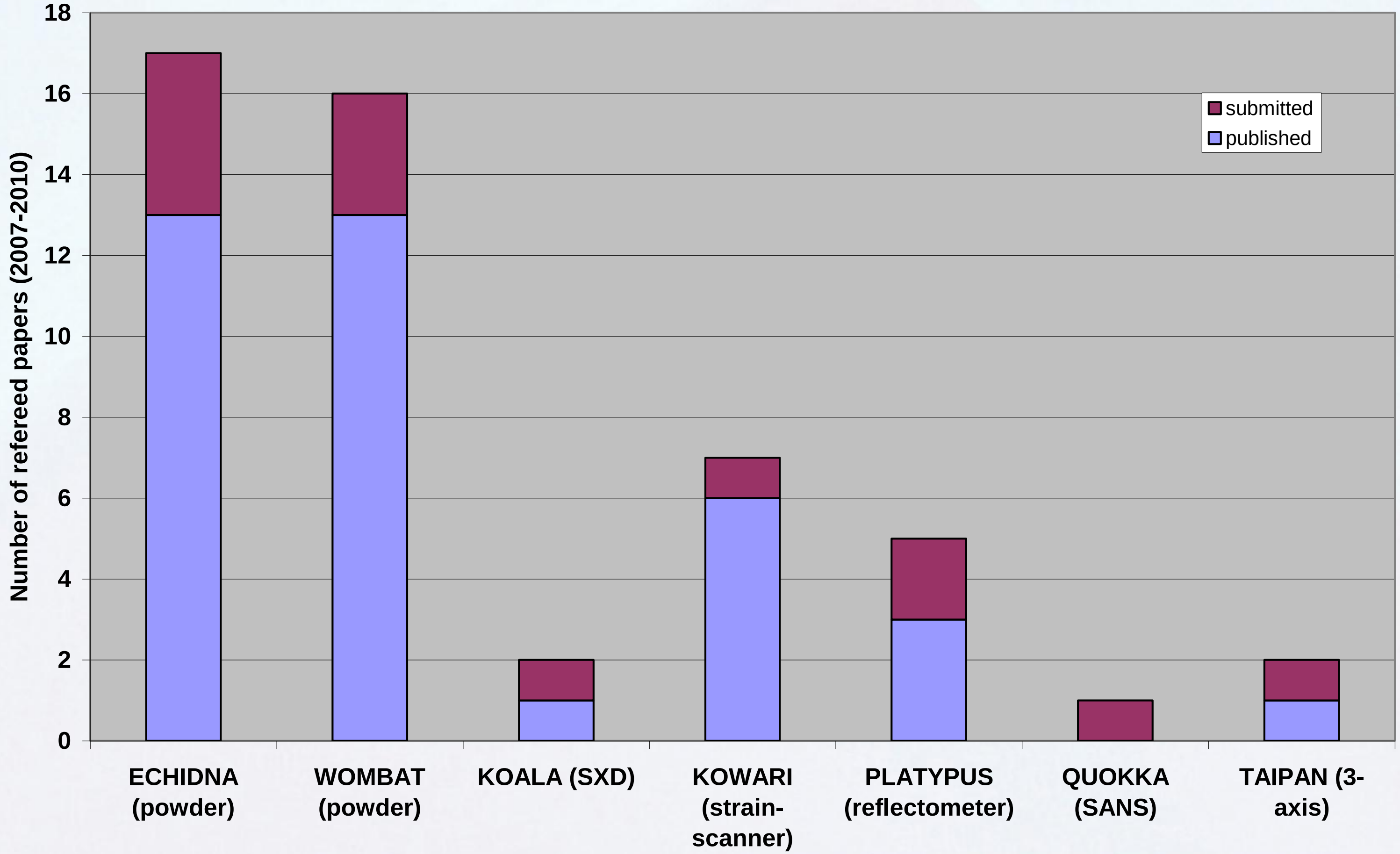
- **Integrity assessment of a welded branch connection for high-pressure gas pipeline on KOWARI - found to be fit for service.**





Papers so far from OPAL

- **37 papers from 6 instruments (+13 submitted)**

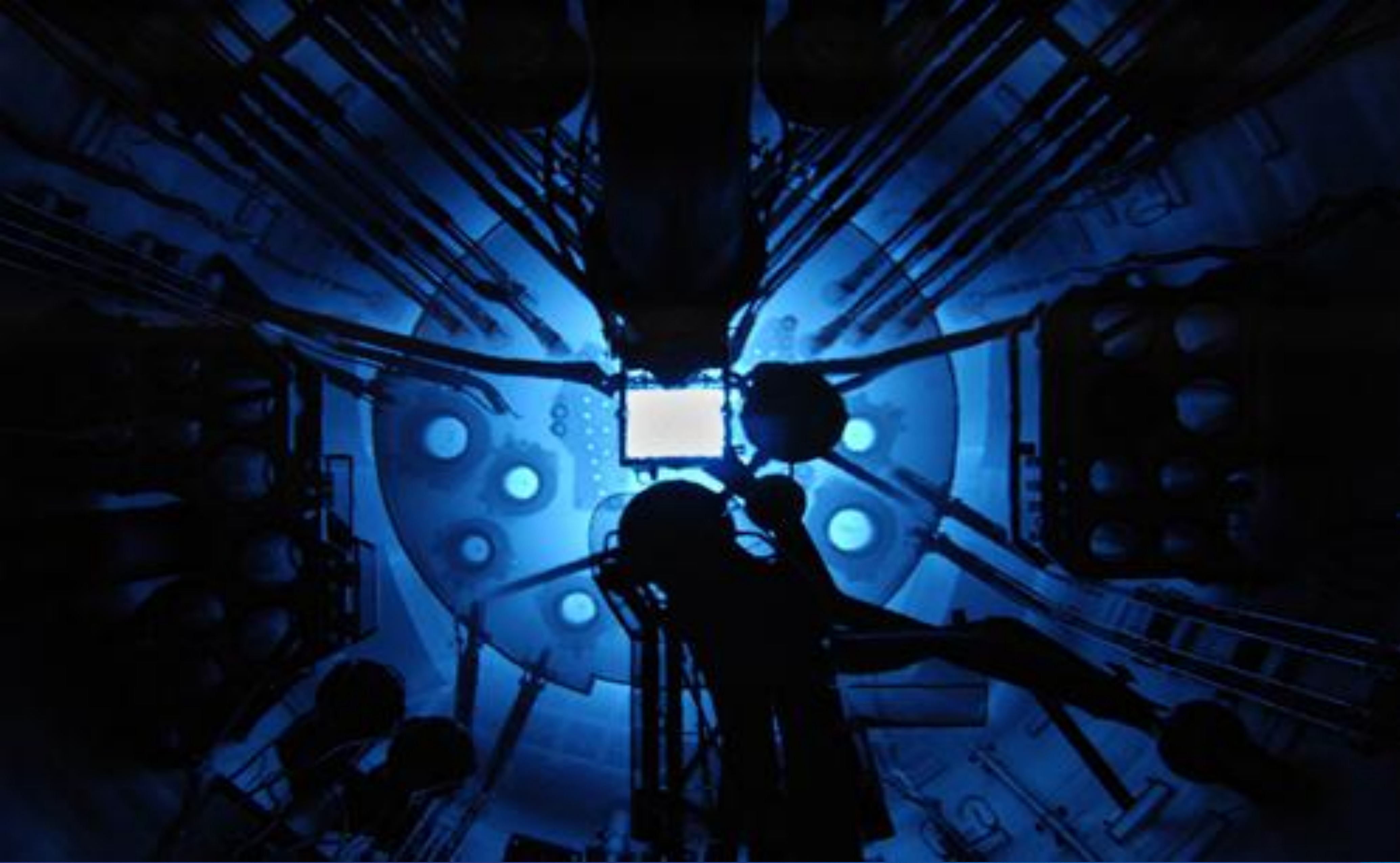


Interface with Customers

- **Regular contact is maintained with all internal customers to ensure that their requirements are met in the delivery of Medical Isotopes and Commercial Irradiations. In addition:**
  - Monthly meetings are held with major internal customers at management level for intermediate and long term planning
  - Weekly meetings held with all internal customers to review irradiation schedules and to receive feedback on client satisfaction
  - Continuous feedback provided to customers when disruptions occur to reactor operations and irradiation schedules

Future Utilisation

- **There has been a significant increase in the utilisation of reactor facilities in the past 4 years**
- **Significant achievements have been gained in the areas of NAA and DNAA and also in utilising the neutron beam instruments for research over a wide range of applications**
- **A strategic plan is in place to further improve the use of OPAL towards achieving optimum utilisation of irradiation and beam facilities**



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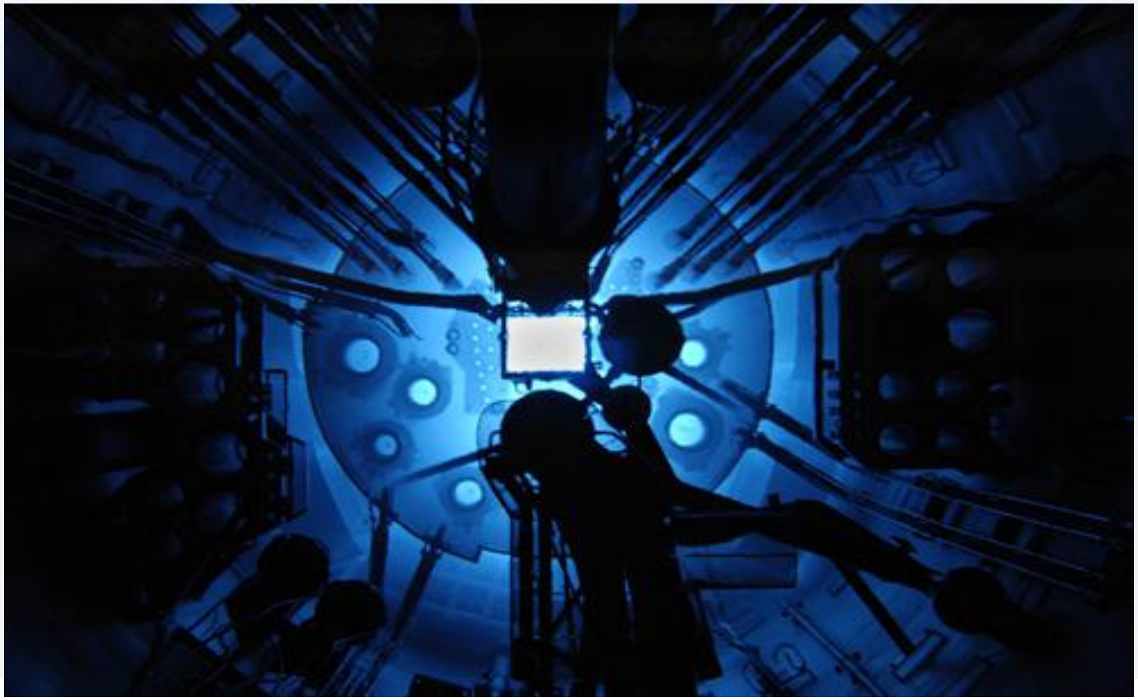
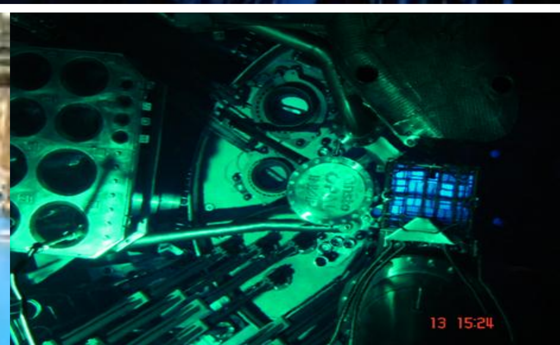
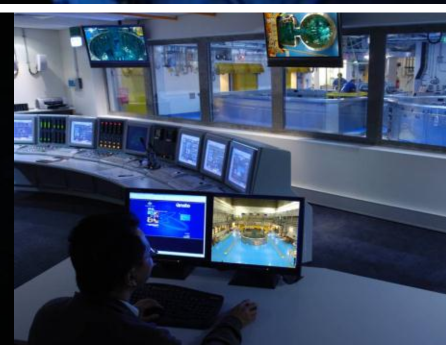
Thank you







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