Development of Neutron Instrumentation: Opportunities and Challenges

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Project Leader & Deputy Director for Science

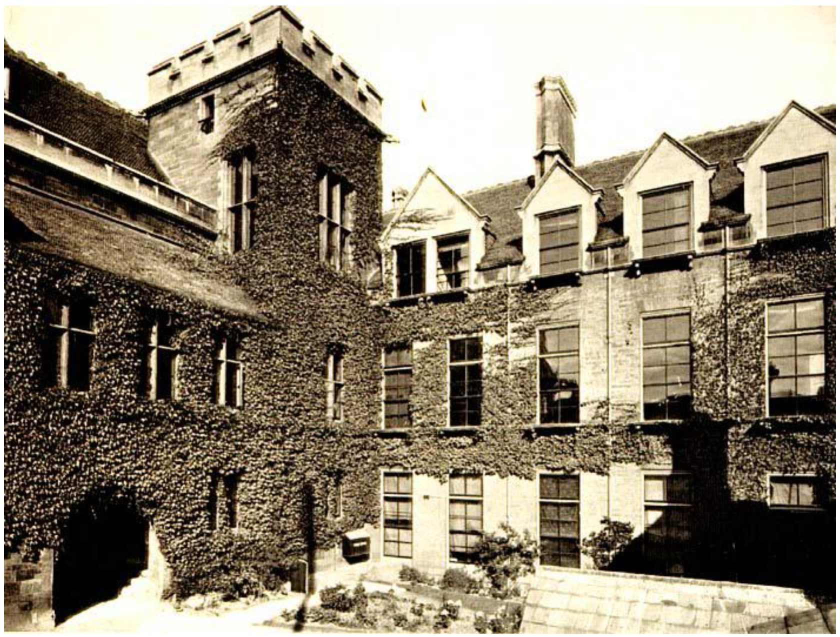
ANSTO: Technical Director of the Bragg Institute

www.europeanspallationsource.se
15-09-14

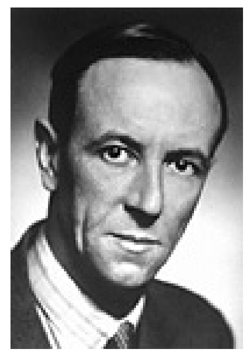
Nobel Prize for the discovery of the neutron

The Nobel Prize in Physics 1935

"for the discovery of the neutron"



The Cavendish Laboratory



James Chadwick

United Kingdom

Liverpool University
Liverpool, United Kingdom

b.1891
d.1974

Where he found it

Nobel Prize for discoveries with neutron irradiation

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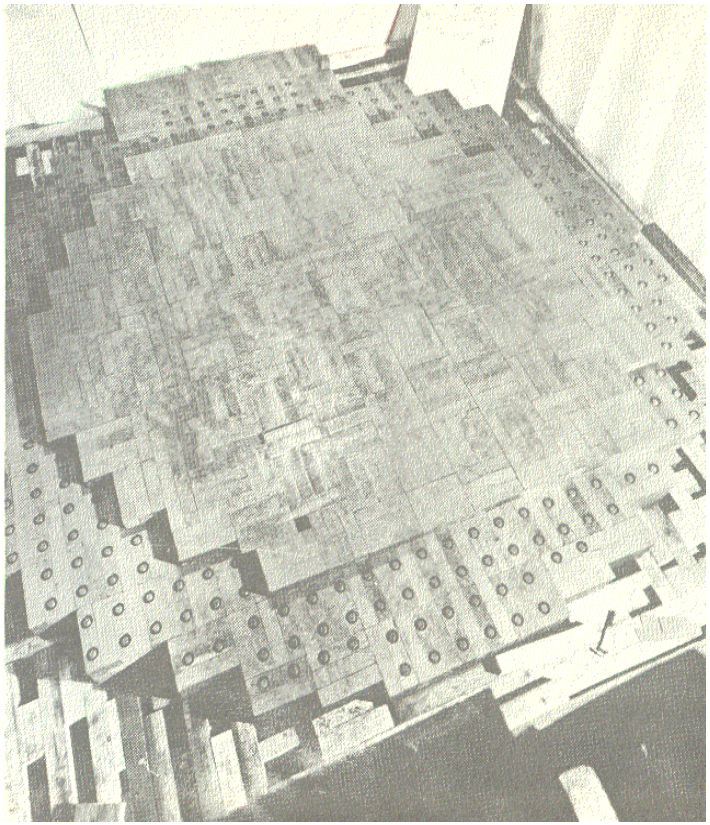


The Nobel Prize in Physics 1938

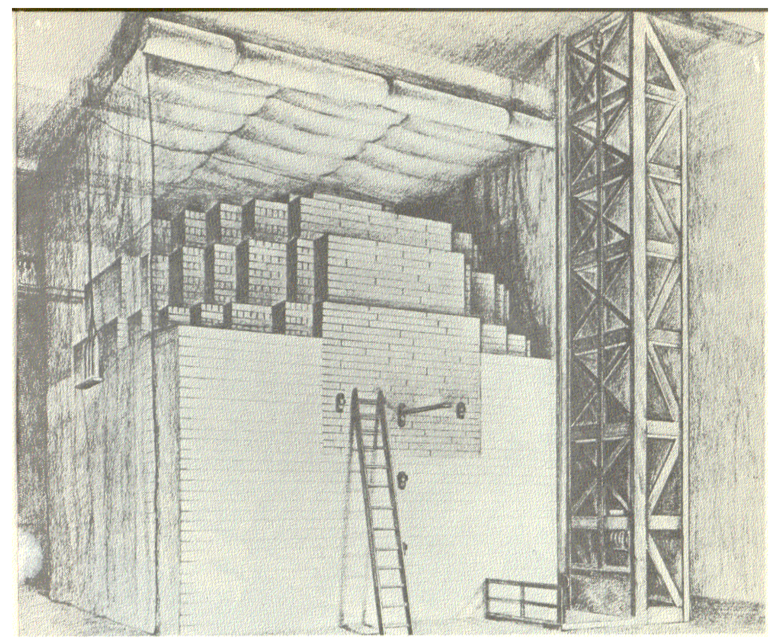
"for his demonstrations of the existence of new radioactive elements produced by neutron irradiation, and for his related discovery of nuclear reactions brought about by slow neutrons"

Enrico Fermi

Italy

Rome University
Rome, Italy

b. 1901
d. 1954



A pile of Graphite & Uranium

- 390 tons of Graphite +
- 41 tons of UO_2 +
- 6 tons of U metal

- and No Shielding!

The first nuclear pile (CP1) Argonne National Lab. 1942.
Built by a team of (49) scientists and engineers in ~1 month

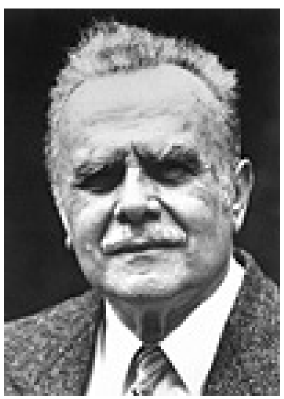
Nobel Prize for Neutron Scattering

The Nobel Prize in Physics 1994

"for pioneering contributions to the development of neutron scattering techniques for studies of condensed matter"

"for the development of neutron spectroscopy"

"for the development of the neutron diffraction technique"

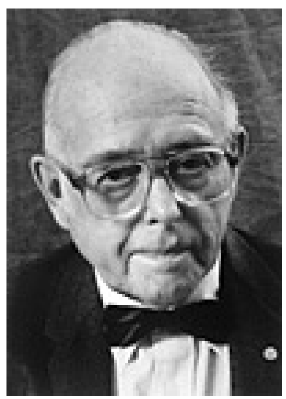


Bertram N. Brockhouse

1/2 of the prize

Canada

McMaster University
Hamilton, Ontario, Canada

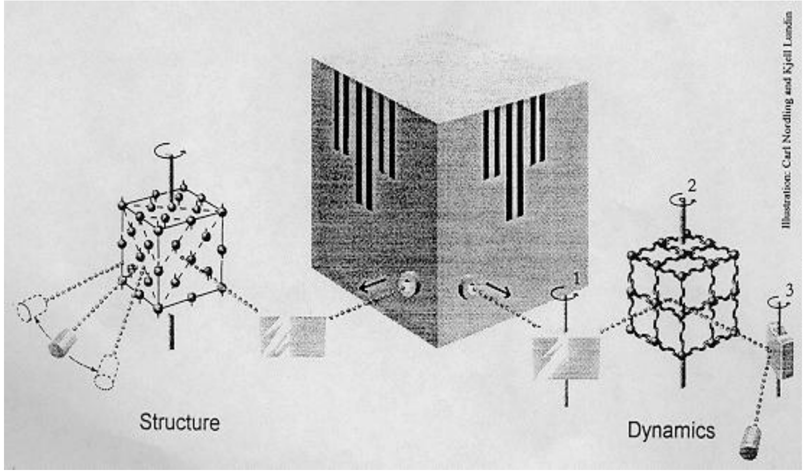


Clifford G. Shull

1/2 of the prize

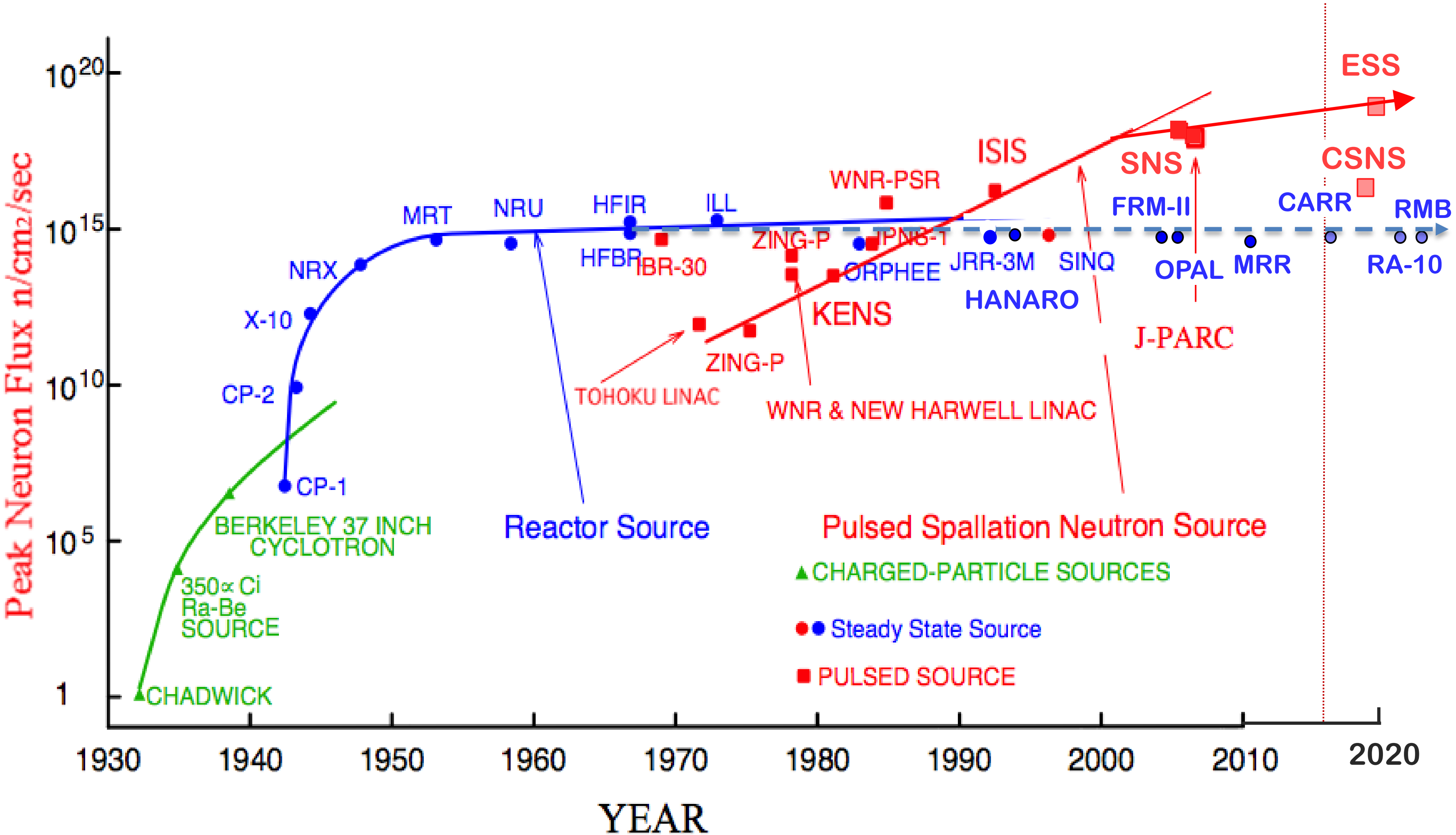
USA

Massachusetts Institute of Technology (MIT)
Cambridge, MA, USA

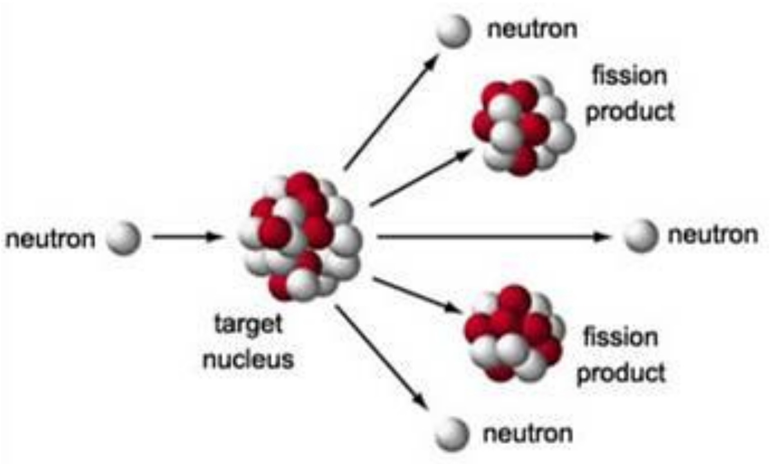


Cliff Shull & Ernie Wollan;
Neutron Diffraction circa 1946

Evolution of Neutron Beam Sources

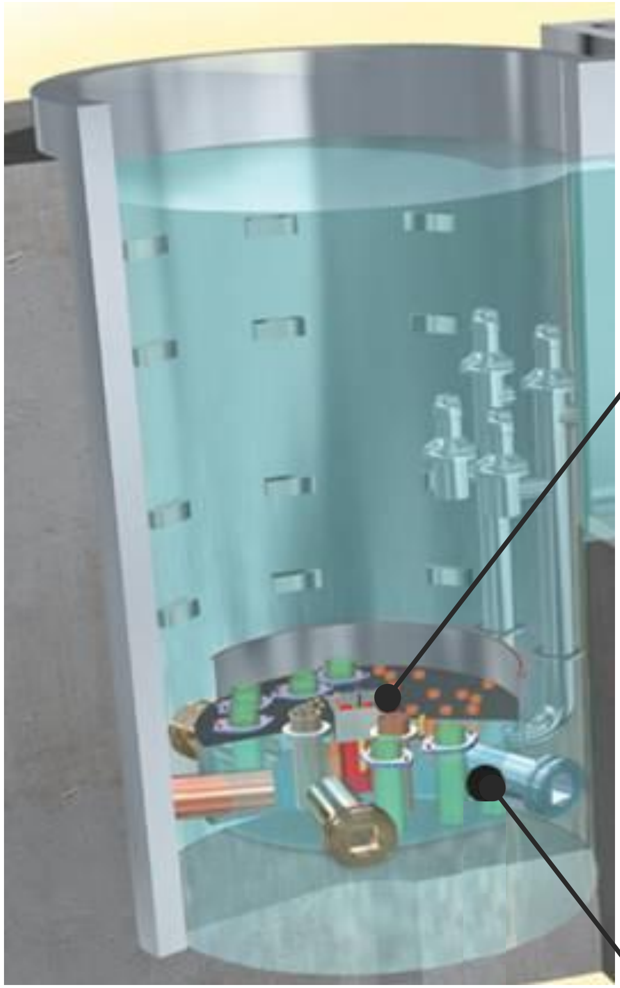


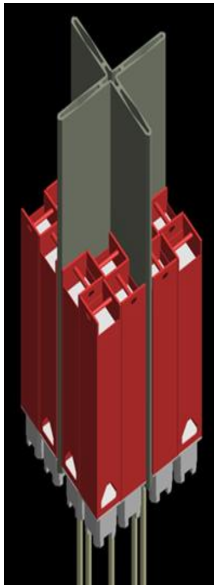
Neutron production (fission, spallation), thermalization and research reactors



The nuclear fission process

Reactor core





Reflector vessel

Major Neutron Beam Facilities Worldwide

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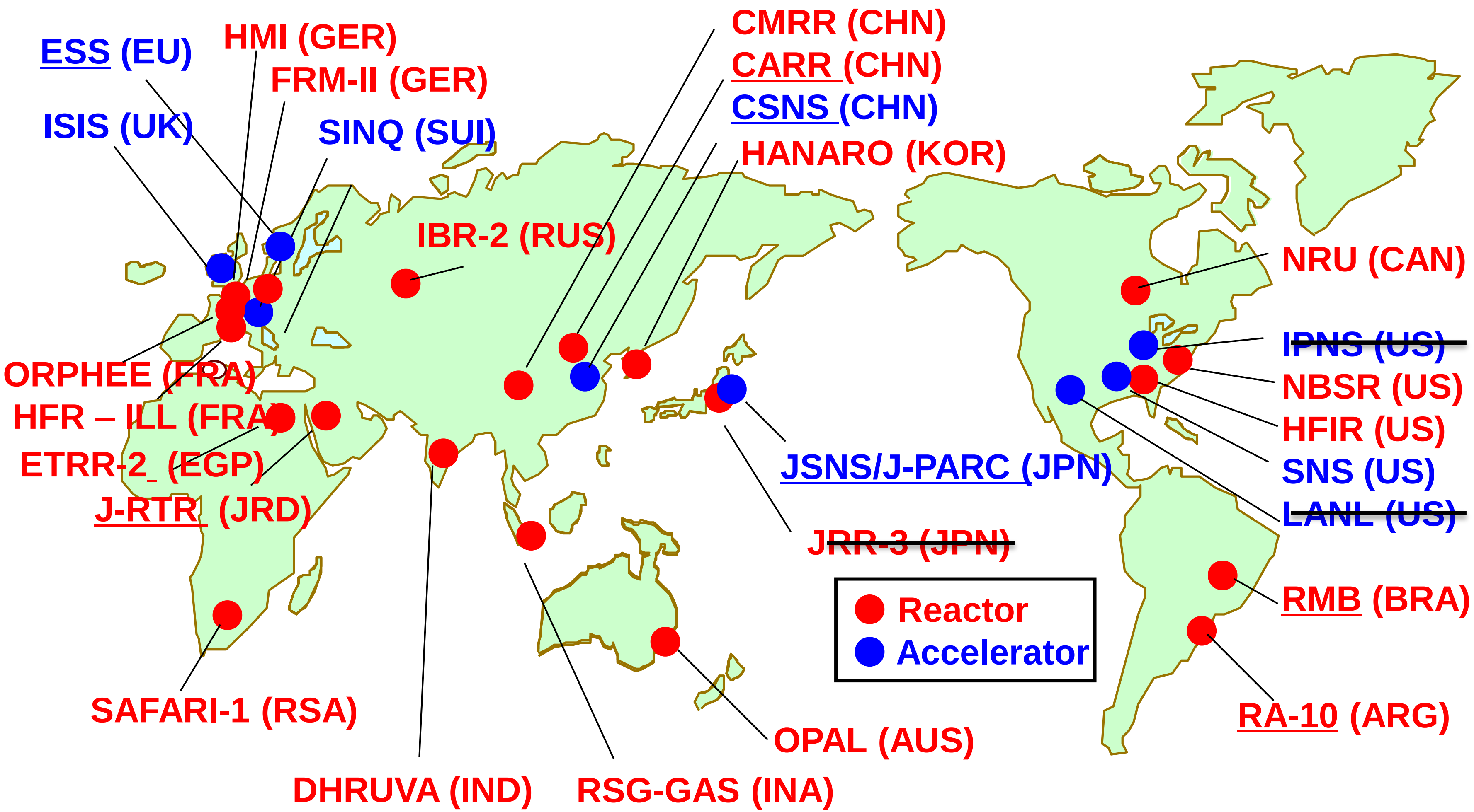
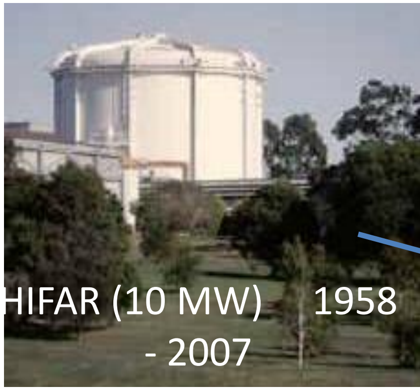
Underlined names show facilities in planning or construction phase



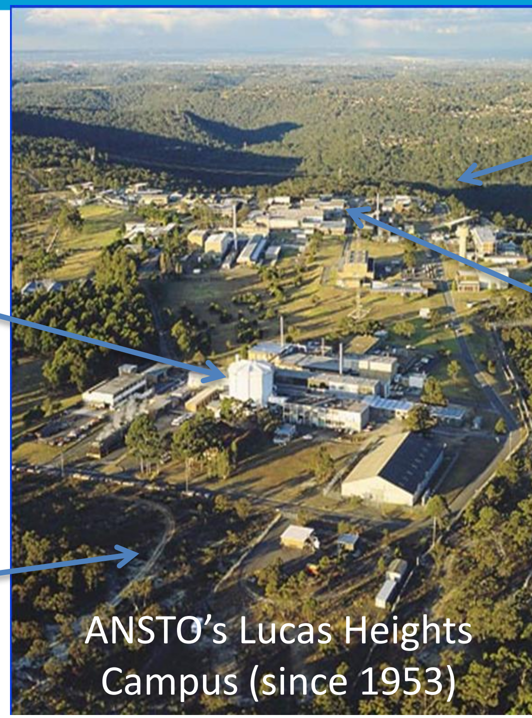
Shane Kennedy
sjk@ansto.gov.au

Sydney Harbour Bridge

Australian Nuclear Science & Technology Organisation



OPAL (20 MW) 2007- 2047+



ANTARES (10 MW)
tandem accelerator

STAR (2 MW)
tandetron accelerator

Cyclotron facility (PET)
(Camperdown, Sydney)

Australian Synchrotron (3 GeV)
(Clayton, Melbourne)

OPAL utilization

- Science (neutron beam research)
- Medicine (radiopharmaceuticals)
- Industry (NTD-Silicon)

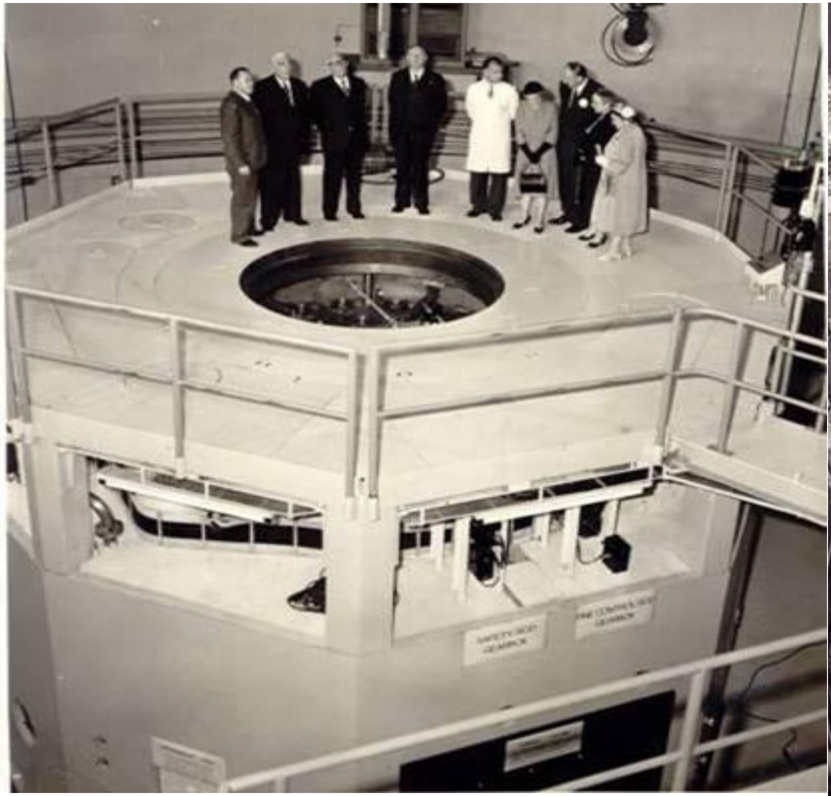
The High Flux Australian Research Reactor (HIFAR) (1958 - 2007)

HIFAR in operation for ~ 50 years.

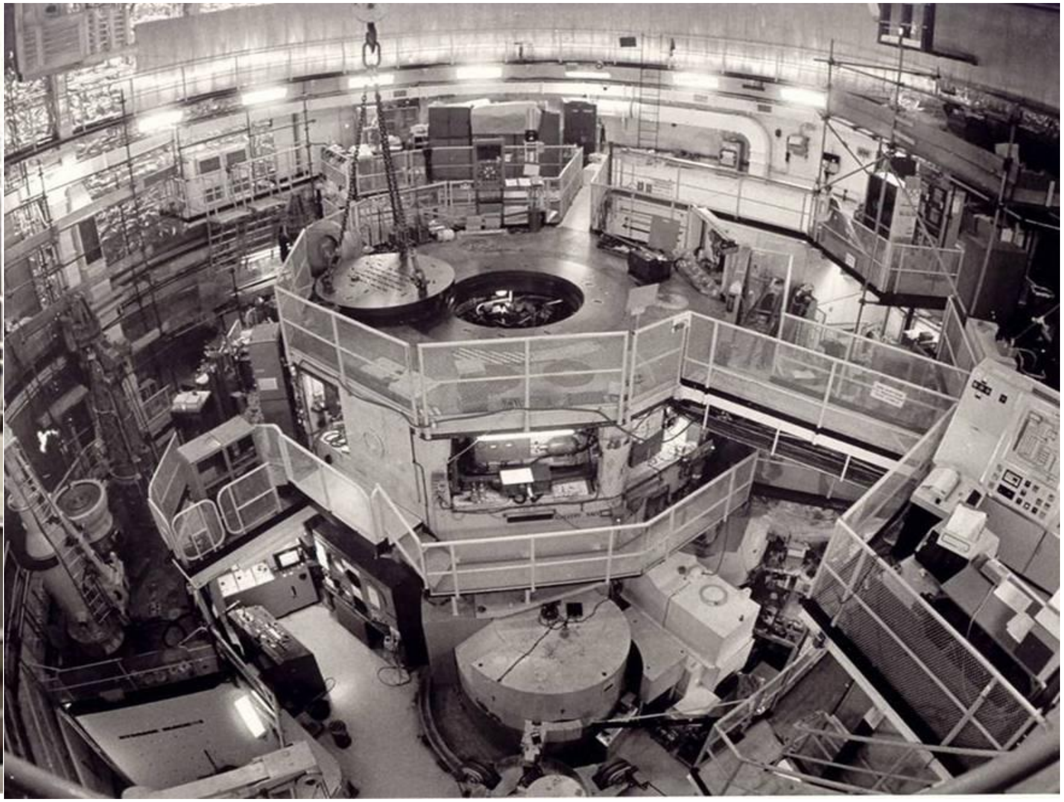
Built by a team of scientists and engineers in ~5 years (including site preparation)

The Australian Prime Minister
HIFAR control room; March 1958

The life of a neutron source



HIFAR in 1958

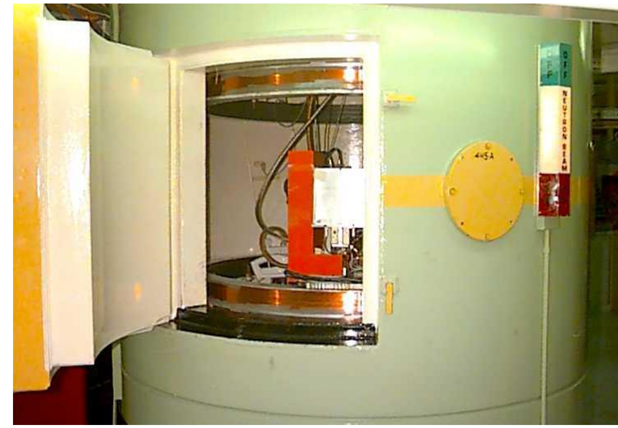


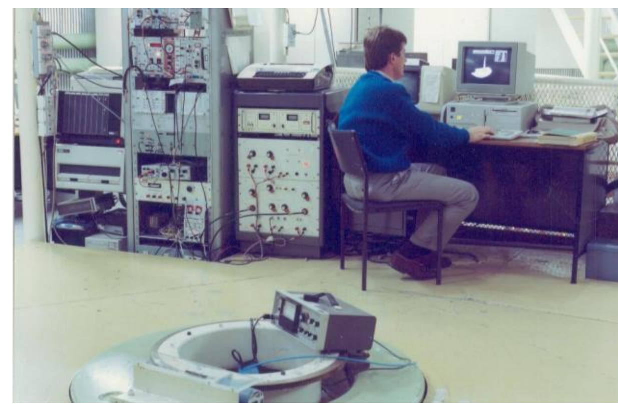
HIFAR in the 1980s

Some neutron beam instruments at HIFAR

The MRPD (1992-2007)

Built by a team of (5) scientists and engineers in ~3 years



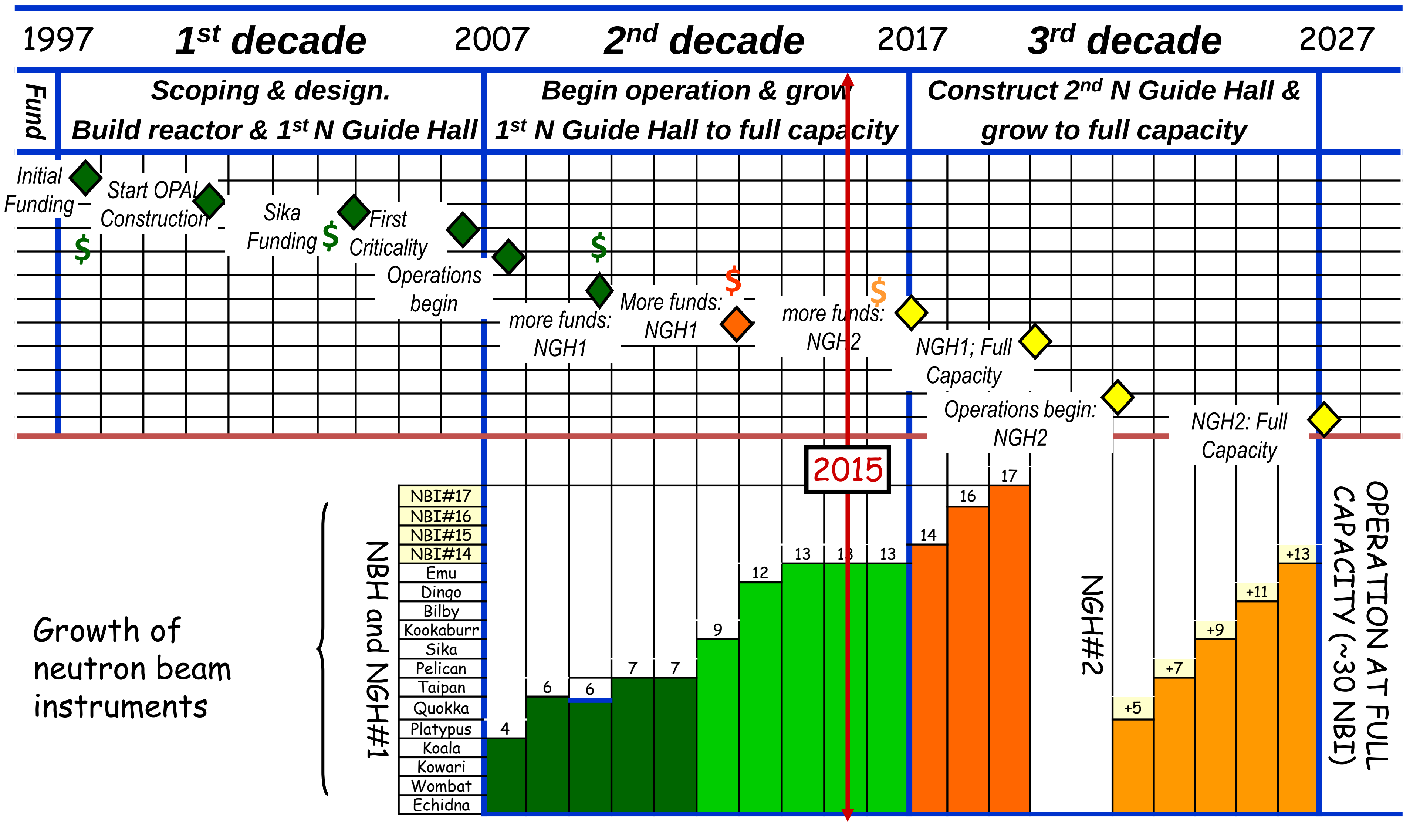


LONGPOL (Polarization analysis spectrometer)

Built by a team of scientists, engineers and students in ~5 years

Milestones of the OPAL Neutron Beam Facility

(½ life plan)



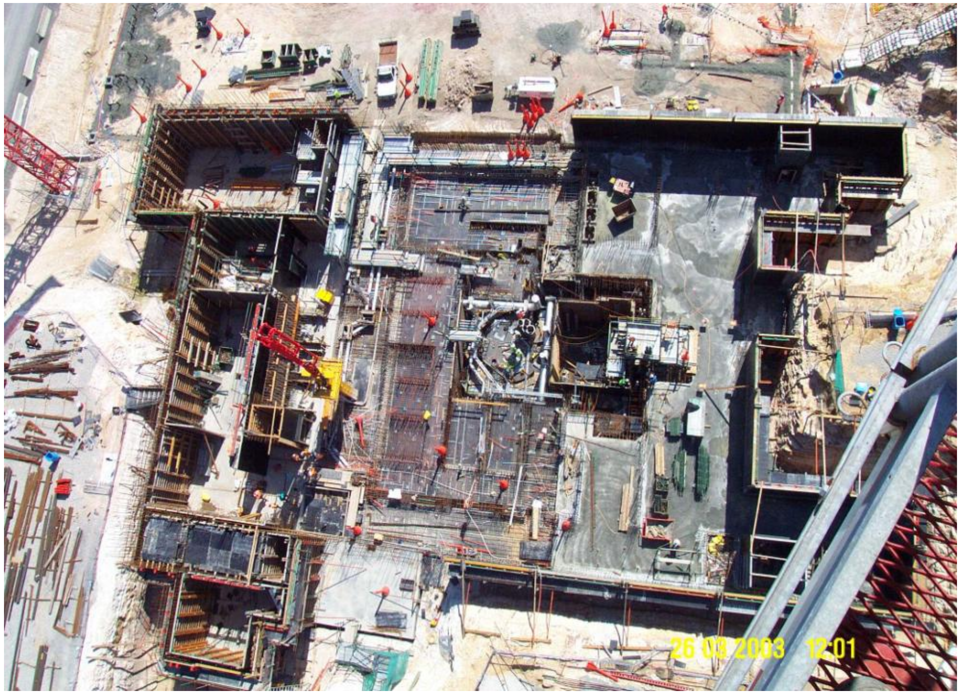
OPAL: Site excavation 23 April 2002

23 April 2002

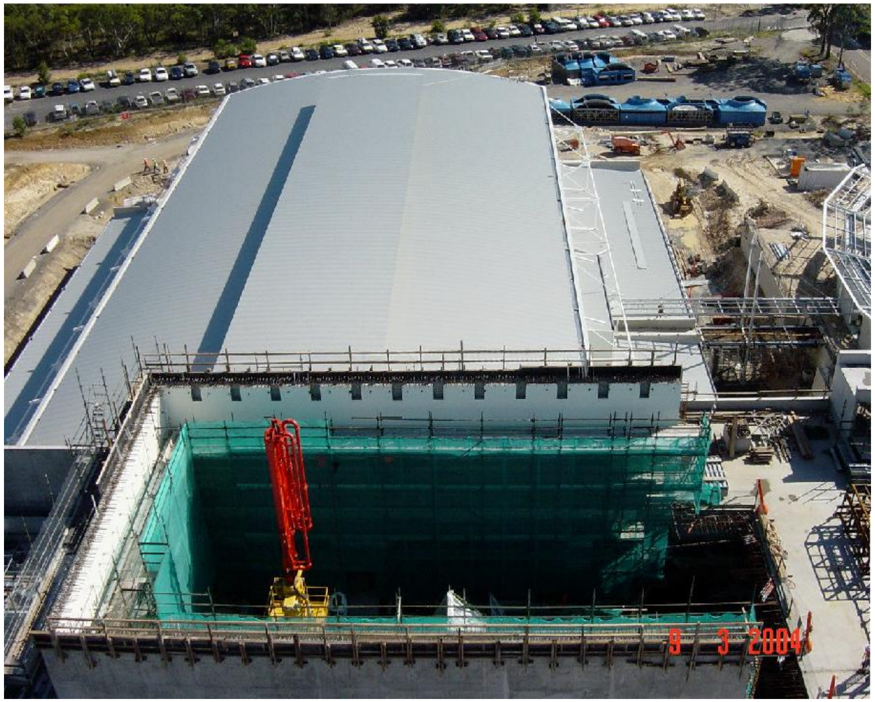
14 june 2002

OPAL: Construction 11 November 2002

OPAL: Views from above

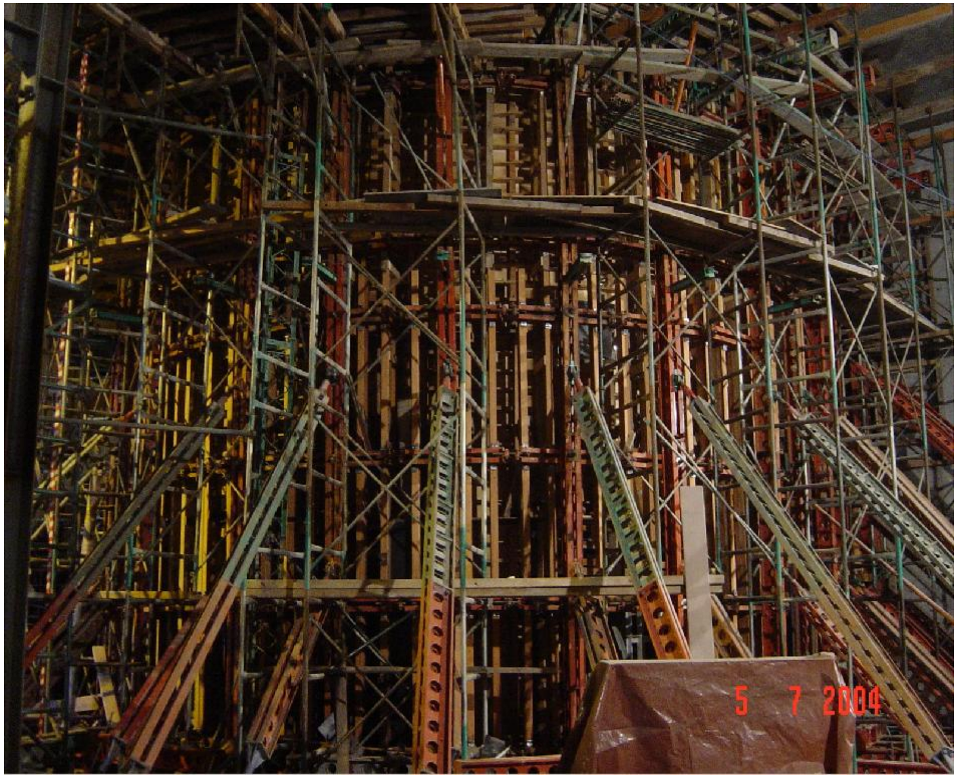


26 March 2003



~ 1 year later

OPAL: Reactor Face

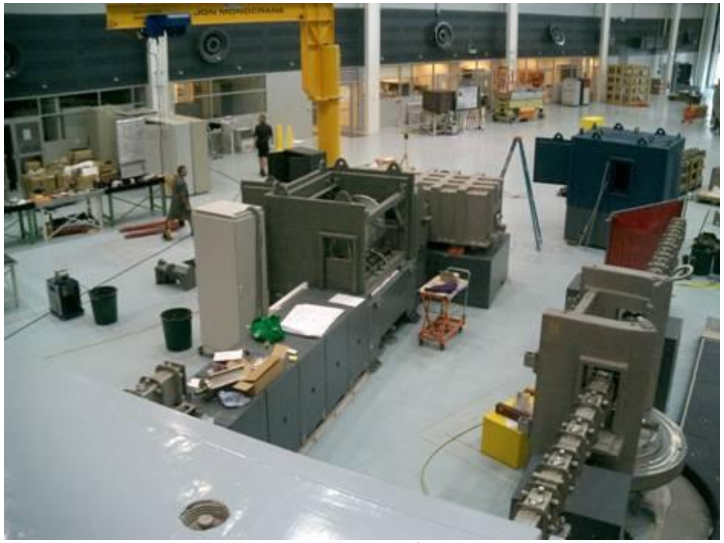


5 July 2004

~ 1 year later

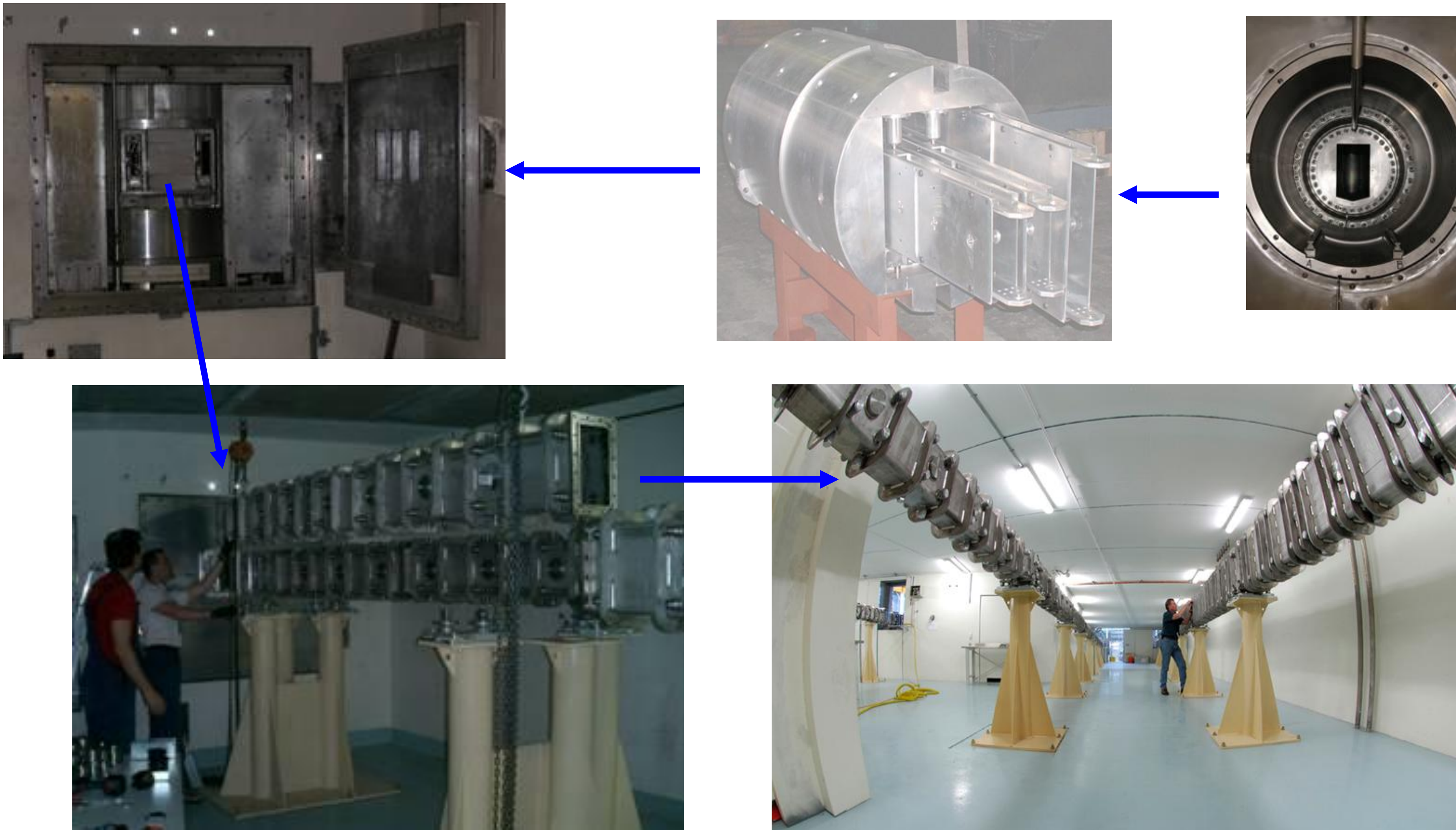
OPAL: Neutron Guide Hall

24 August 2004

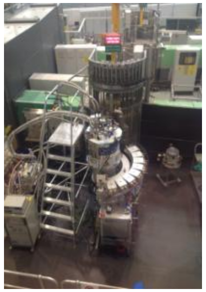


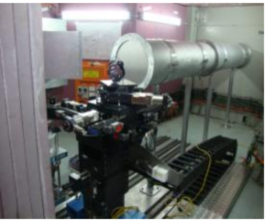
~ 1 year later

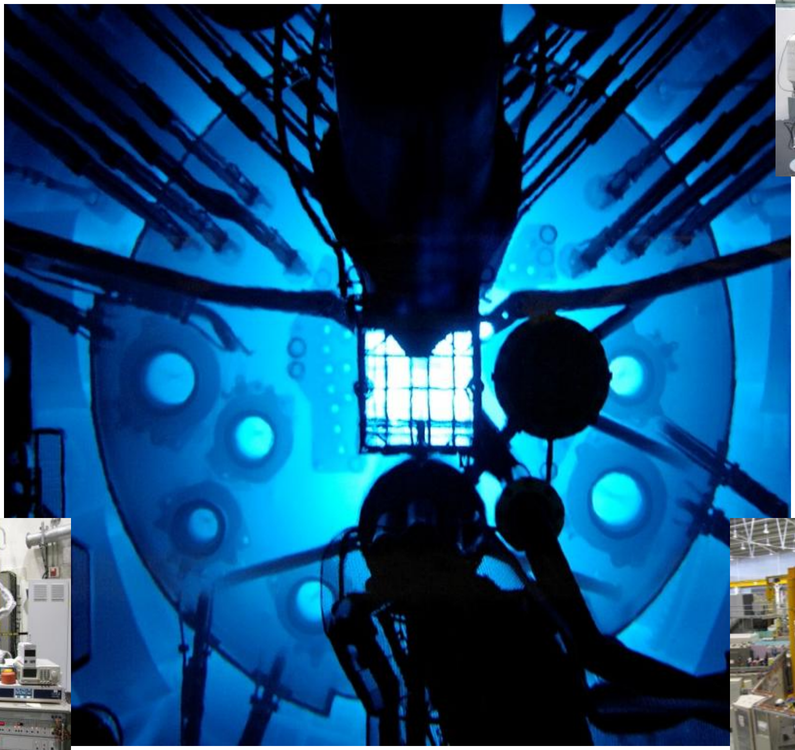
OPAL’s neutron guide system (2005-2006)

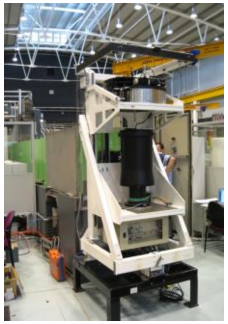


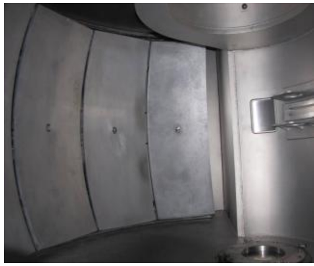
OPAL: Operations begin in 2007 ………………







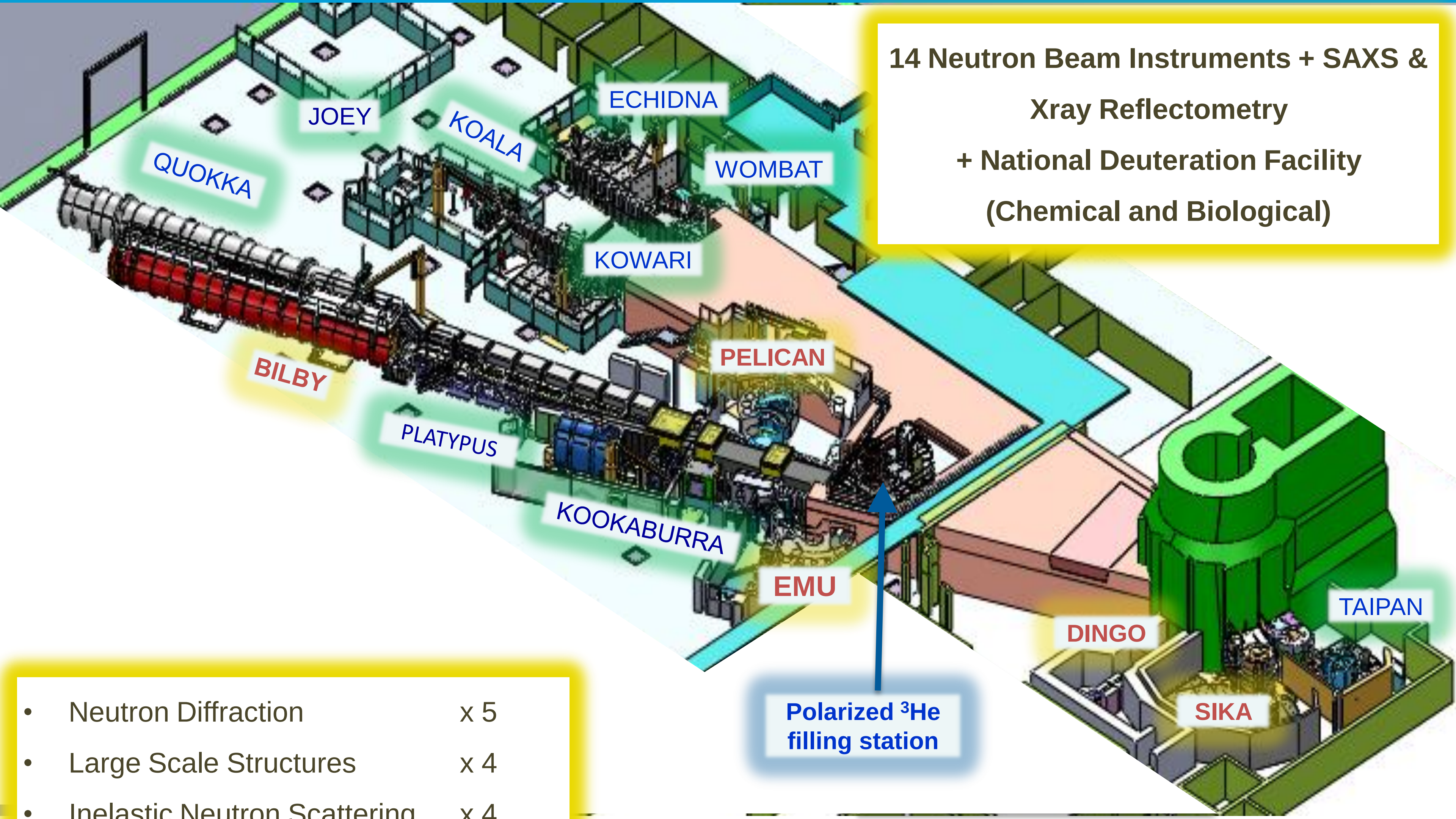




Built by a team of scientists and engineers in ~ 6 $^{1}/_{2}$ years

OPAL Neutron Beam Facility 2015

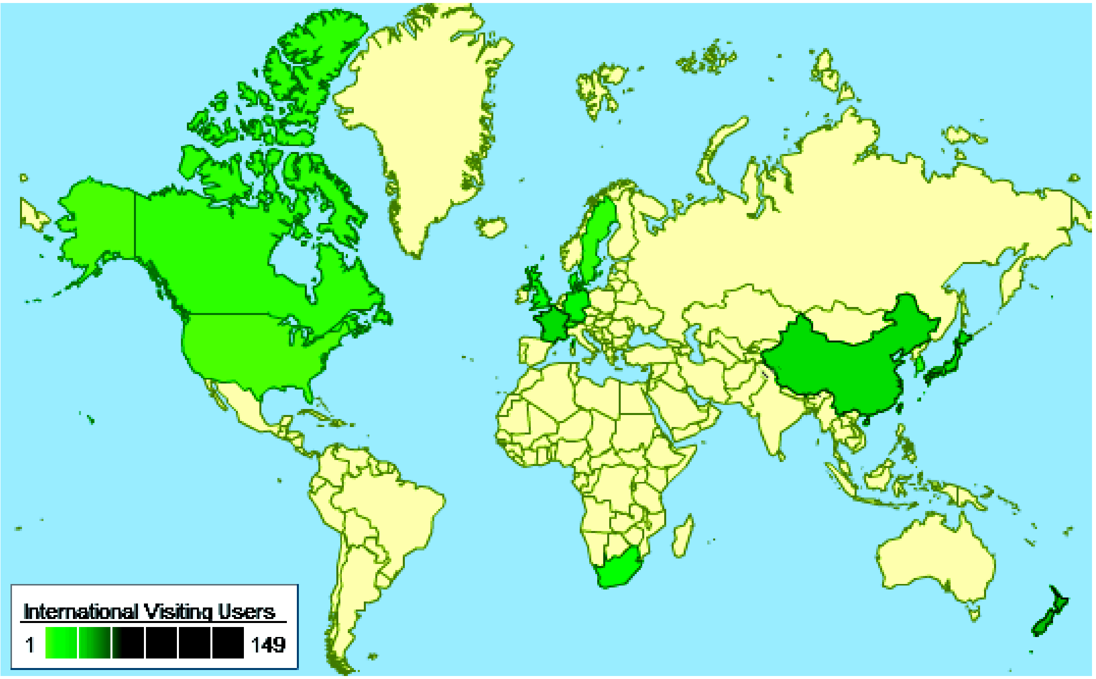
14 Neutron Beam Instruments + SAXS & Xray Reflectometry + National Deuteration Facility (Chemical and Biological)



- Neutron Diffraction x 5
- Large Scale Structures x 4
- Inelastic Neutron Scattering x 4
- Radiography & Tomography x 1

The measure of success: Users of OPAL

Country	%
Australia	65
Taiwan	9
New Zealand	4
China	3
USA	3
UK	2
Japan	2
Germany	2
Singapore	2
Sth Africa	1
India	1
Other Europe	4
Other Americas	2



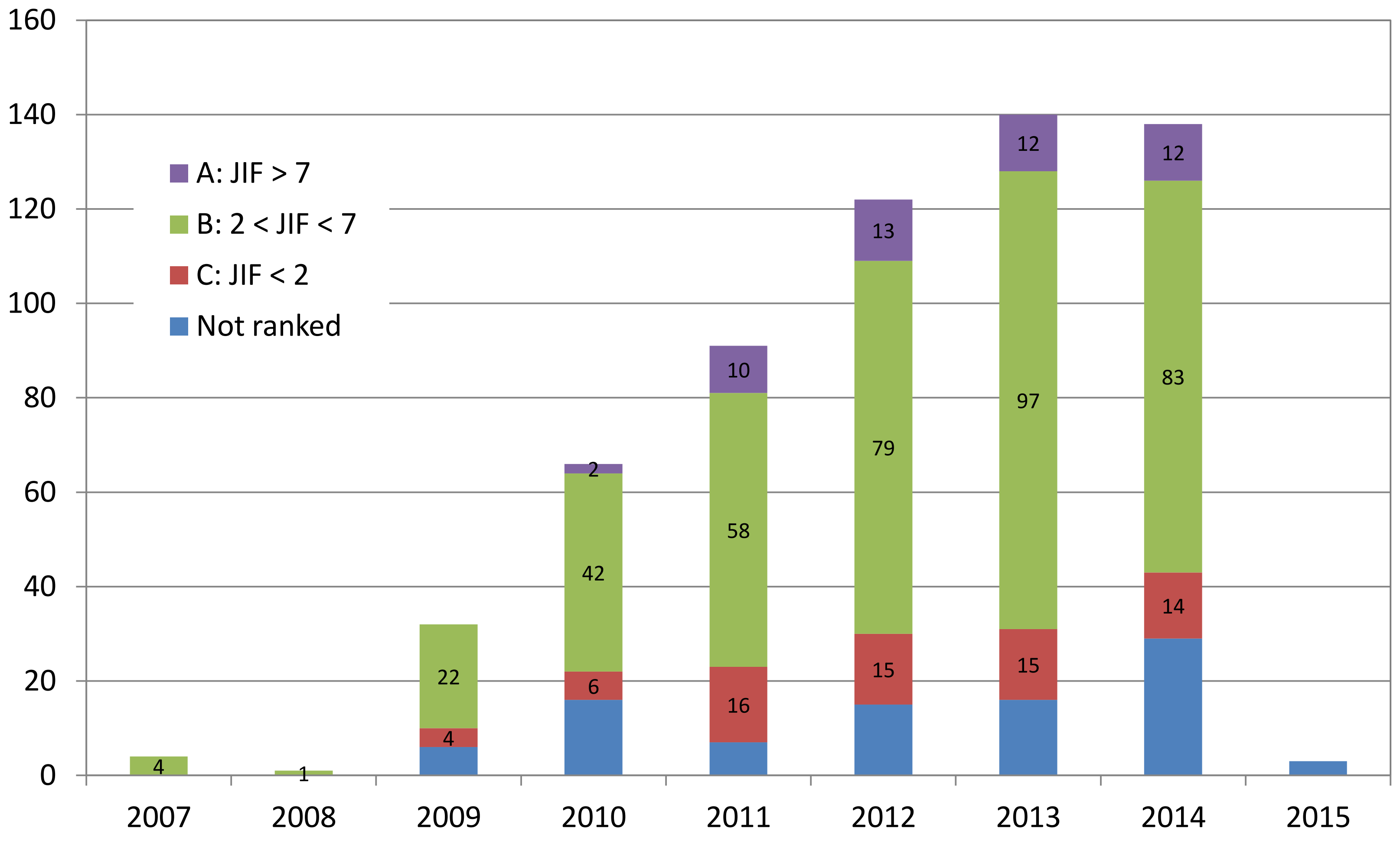
OPAL NBF
- 1350 visits in 2013
- 424 research papers

Average proposal success rate 50 %
(over all rounds & Instruments)

Organisation	%
Bragg Institute	17
Sydney Uni.	7
Uni. NSW	6
Wollongong Uni.	5
Uni. Qld	4
Monash Uni.	3
ANSTO	3
Melbourne Uni.	2
Aust. Nat. Uni.	2
CSIRO/DSTO	2
Curtin Uni.	2
Newcastle Uni.	2
Other Australian	10

The measure of success

597 journal papers from OPAL instruments (2007- 2014)



The measure of success; journal covers from OPAL

(2011)

(2012)

(2013)

The measure of success: commercial use of OPAL

NSRRC

NEWPORT SCIENTIFIC

PRE PACIFIC RAIL ENGINEERING

CSIRO

TWI

Unilever

ASC

NSW GOVERNMENT | Industry & Investment

Cooperative Research Centre for POLYMERS

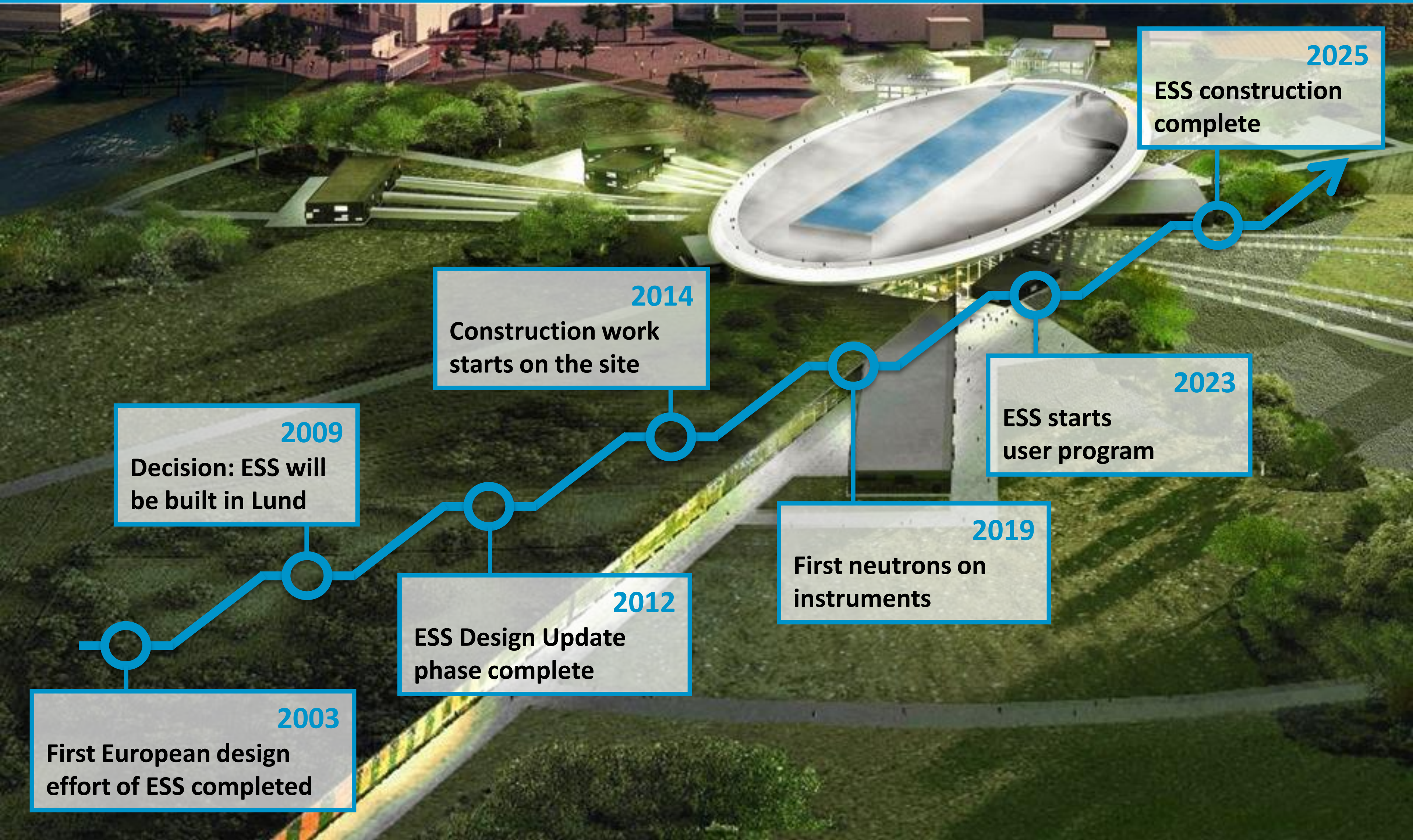
ENERGY Pipelines CRC

HARDCHROME ENGINEERING

Australian Government
Department of Defence
Defence Science and Technology Organisation

The road to realizing the world's leading facility for research using neutrons

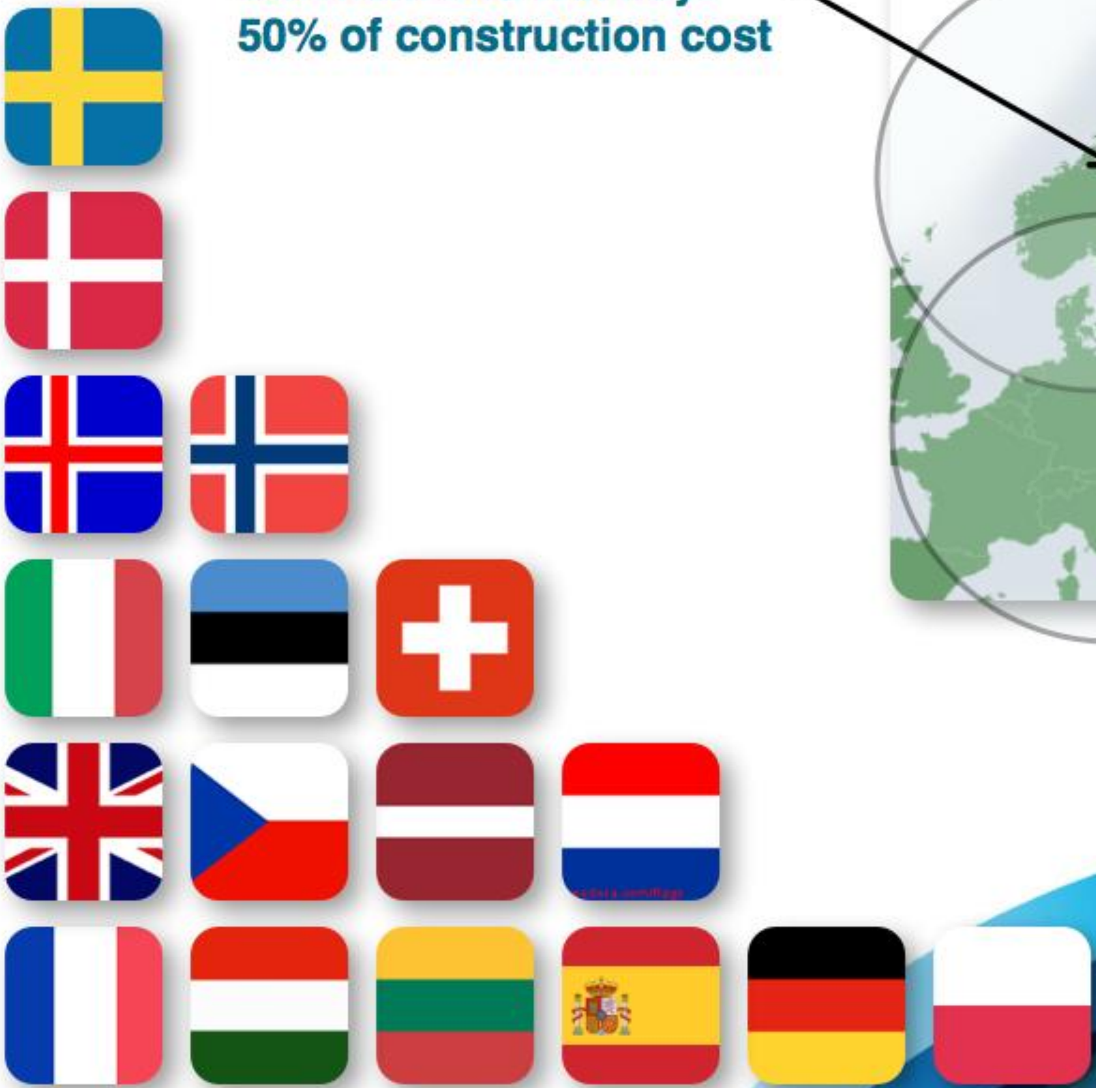
EUROPEAN SPALLATION SOURCE



EUROPEAN
SPALLATION
SOURCE

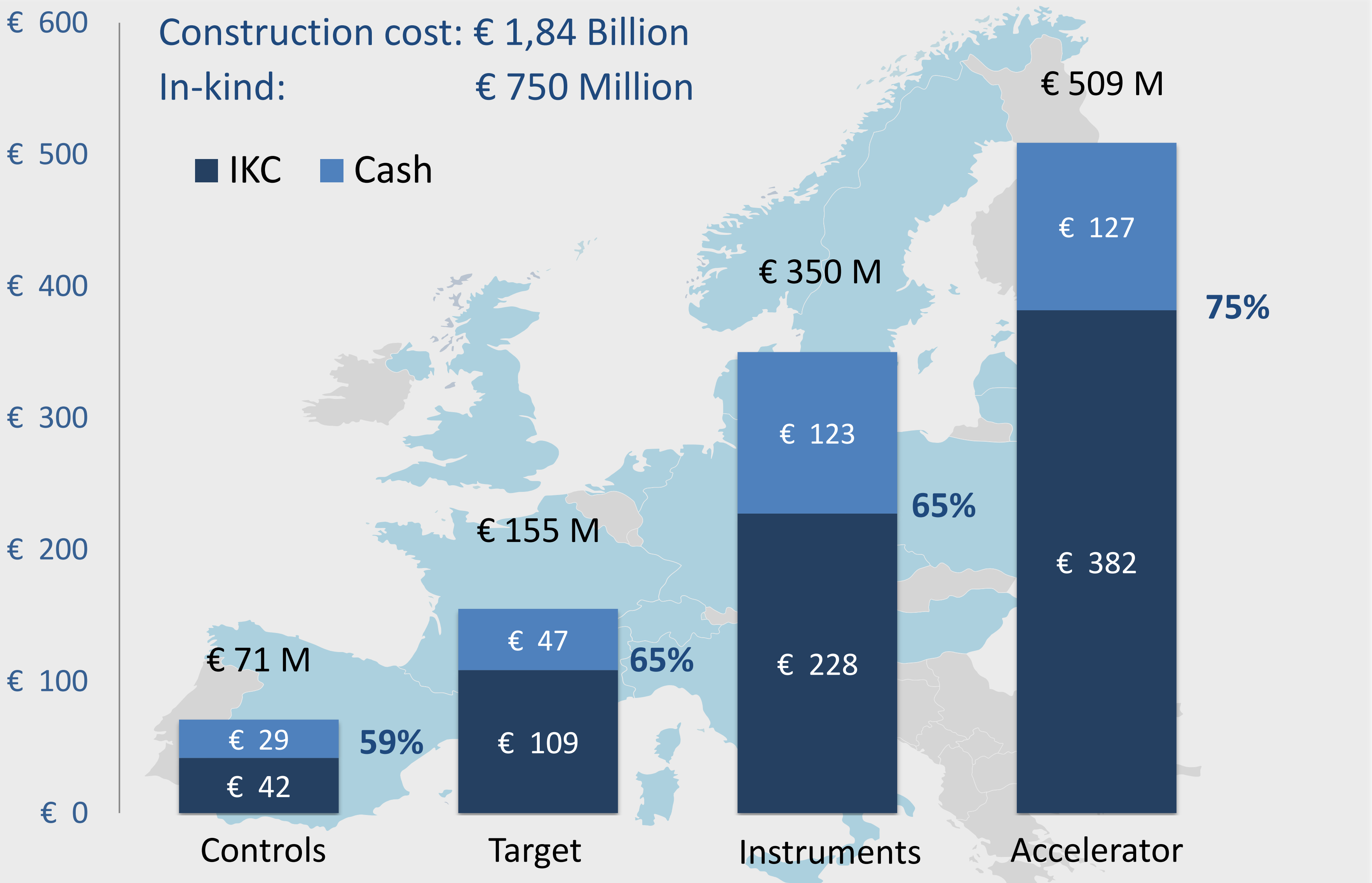
An International Collaboration

**Sweden,
Denmark and Norway:
50% of construction cost**



European partners

ESS In-kind Goals



ESS: Instrument Concepts

EUROPEAN SPALLATION SOURCE

	SANS	Reflectometry	Macromolecular Diffraction	Single-Crystal Diffraction	Powder Diffraction	Materials & Engineering Diffraction	Imaging	Direct Geometry Spectroscopy	Indirect Geometry Spectroscopy	Spin Echo Spectroscopy	Fundamental & Particle Physics
2012-13	LOKI		NMX				ODIN				
2013-14	SKADI	ESTIA			DREAM	BEER		C-SPEC	BIFROST		
		FREIA			HEIMDAL			VOR			
2014-15				MAGIC				T-REX	MIRACLES		
									VESPA		
Future?	SLEIP-NIR	HERI-TAGE			HOD	Irradia-tion	High-Int. Imaging		Q-TAS Farm	ESSENSE	ANNI
		Surface Scatter.			ESPRESSO					RESPECT	UCN beamline
										Wide-Angle NSE	n-nbar

Current status of Instrument delivery at ESS

class	Instrument	cost category	In-kind Partners
Large scale structures	LOKI broadband SANS		**ESS (30%) +** ES (Bilbao ~32%), IT (CNR ~24%), UK (STFC ~8%), CH (PSI ~3%), HU (Wigner ~1%)
	SKADI general-purpose SANS (note 1)	B	**DE(FZJ 50%) + FR(LLB 50%)**
	ESTIA focusing reflectometer	A	**CH(PSI)**
	FREIA liquids reflectometer	A	**ESS (<30%) -> UK (ISIS)? or DE(FZJ) ?**
Diffraction	NMX macromolecular crystallography		**ESS (<30%) +** HU (Wigner 16%) + FR (LLB ~4%) + NO (~17%) + IT/UK (~15%)
	DREAM powder diffractometer (bispectral)	B	**DE(FZJ 75%) +** FR(LLB 25%)
	HEIMDAL hybrid diffractometer	B	**DK(AU <30%)** +CH(PSI ~ 30%) + HU (~5%) +UK? (~20%) + ?
	MAGIC magnetism single-crystal diffractometer	B	**FR (LLB 75%)** + DE (FZJ 25%)
Engineering	BEER engineering diffractometer	B	**DE (HZG 50%), CZ (NPI 50%)**
	ODIN multi-purpose imaging	A	**ESS** -> DE(TUM 50%) +CH (PSI 50%)
Spectroscopy	C-SPEC cold chopper spectrometer	C	**DE(TUM 50%) +FR(LLB 50%)**
	BIFROST extreme-environments spectrometer	B	**DK(DTU/KU <30%)** +CH(PSI ~ 20%) + HU (~20%) +NO (~15%) + ?
	T-REX bispectral chopper spectrometer	C	**DE (FZJ 75%)** + IT (Perugia) -25%
	VESPA vibrational spectroscopy	B	**IT** (CNR) **+ UK (ISIS)?**
	MIRACLES backscattering spectrometer	B	**DK (KU) ->** ES(Bilbao ~70%?) +FR(LLB ~20%?) +HU (Wigner~5%?) + ESS (~5%)
	6th Spectrometer (unassigned)	B	
	16 instruments		**cost**
	neutron guide bunker		CZ (Skoda?, Envinet?)
			total cost (with bunker)

Scope is set; engineering begins

The key to success in science construction

- Know your purpose (Science Case)
- Set your scope
- Develop your delivery plan
  - priorities
  - Resources
  - budget
  - schedule
- Implementation
  - Avoid scope creep
  - Maintain your budget
  - Stay on schedule
  - Manage your risks

- *Never slow down*
- *Always ask – Is this the next most important/urgent task?*
- *Can we do this better, faster, cheaper?*

Success for Neutron Beam Sources

EUROPEAN SPALLATION SOURCE

Development of new research facilities:
For Scientific excellence through Engineering excellence

The key to success in construction:
scientists and engineers working together

The key to success in operation:
scientists and engineers working together

Postscript: Big science projects always need good engineers