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National Physical Laboratory

Fast neutron facilities at the National Physical Laboratory, UK

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1 September 2010

National
Measurement
System

Bushy House

NPL was founded in 1900 in a former royal residence.

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New laboratories

Buildings completed in stages between 2000 and 2009.

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Neutron facility

Chadwick Building

National Measurement System

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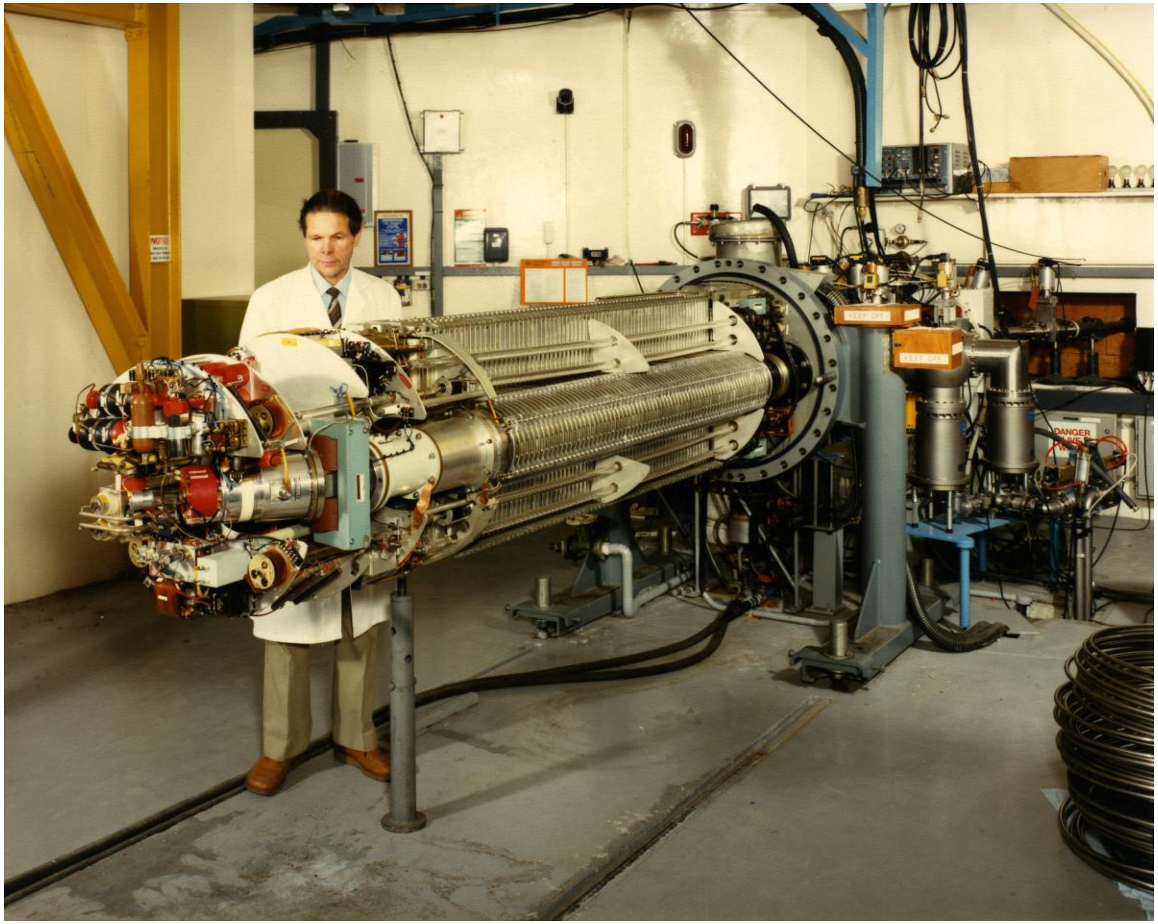
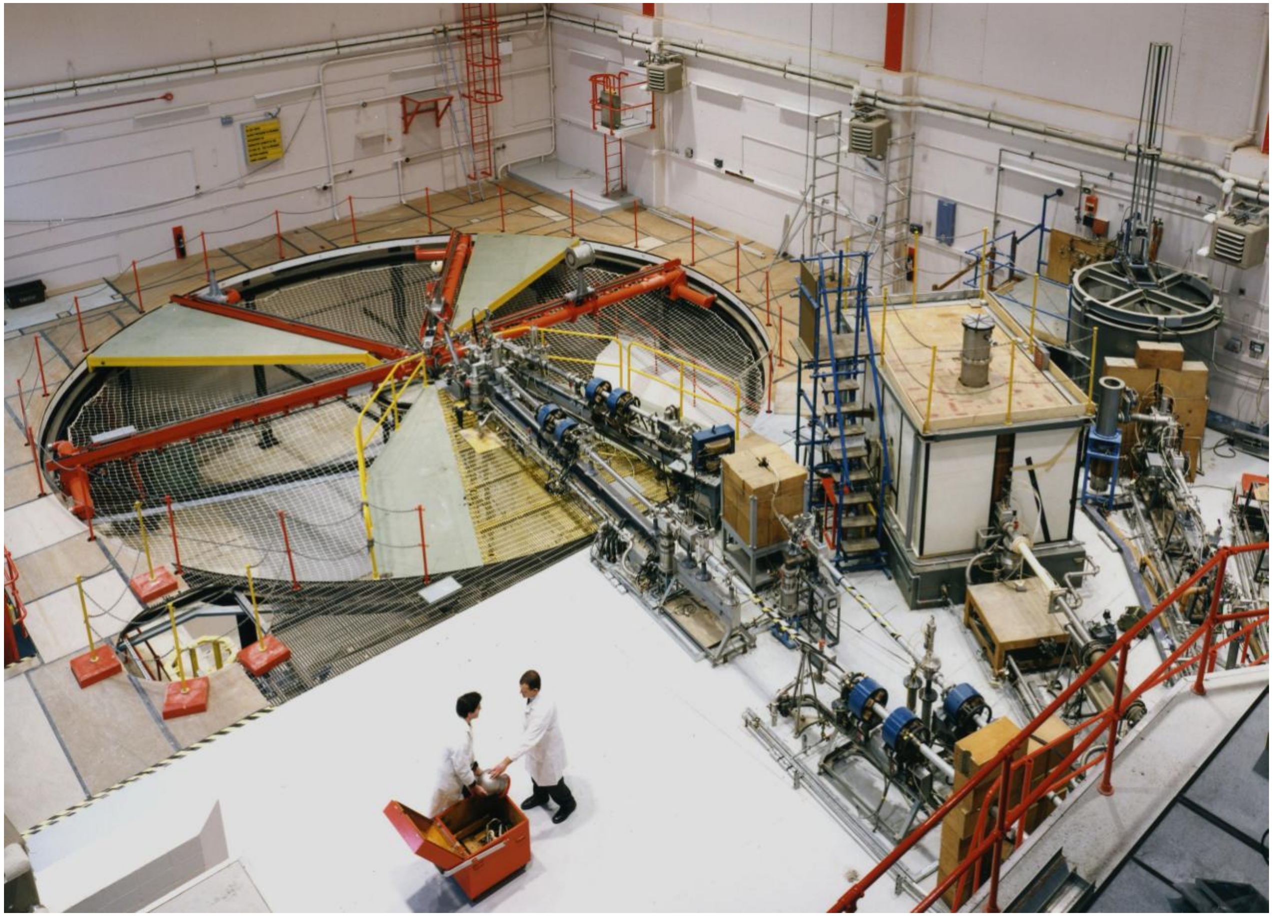
3.5 MV Van de Graaff accelerator



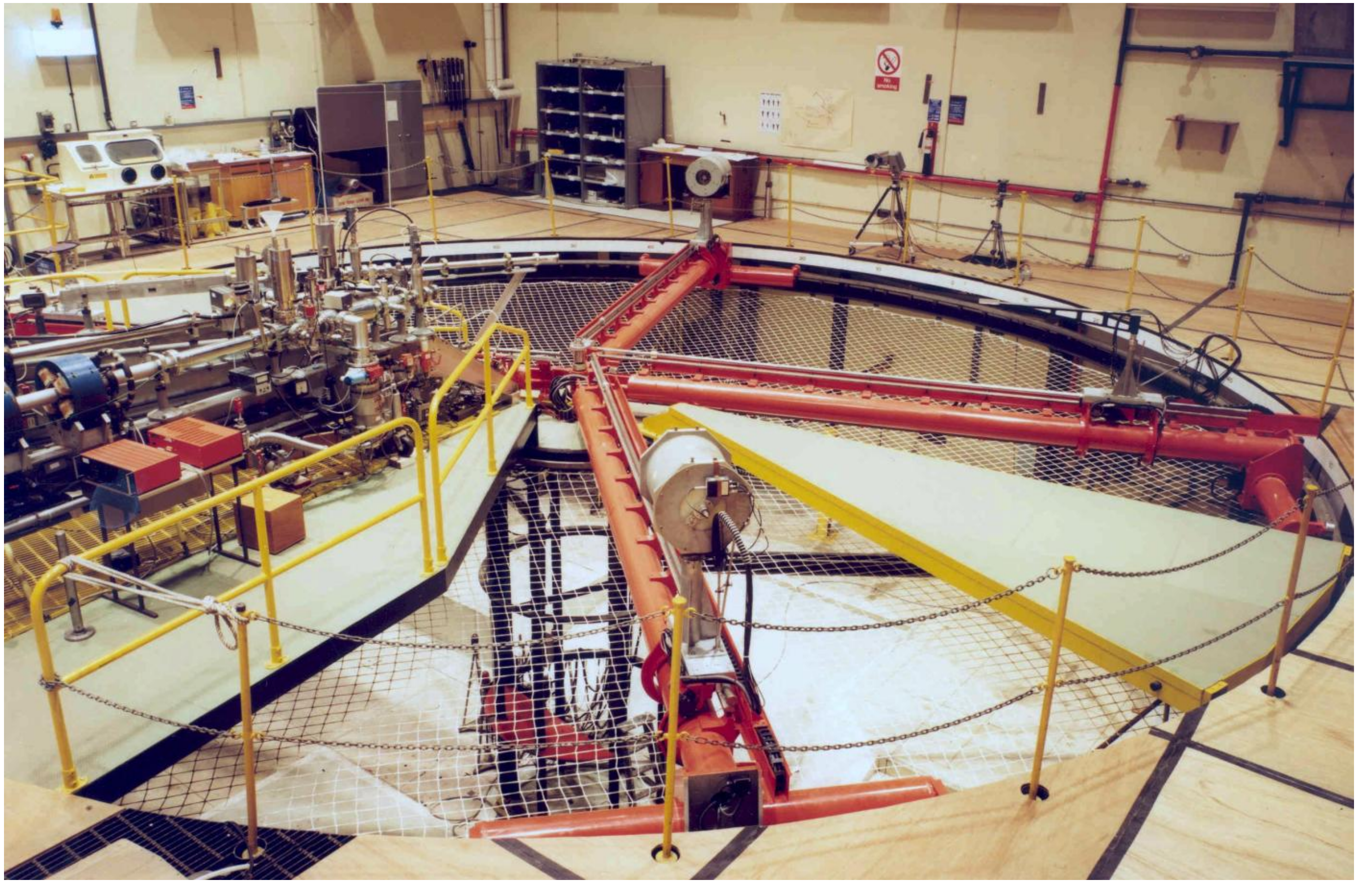
Left to right: ion source, pulser and accelerator tube.

Experimental area (18m wide, 18m high, 26m long)



Low scatter area (left); thermal pile and water bath (right).

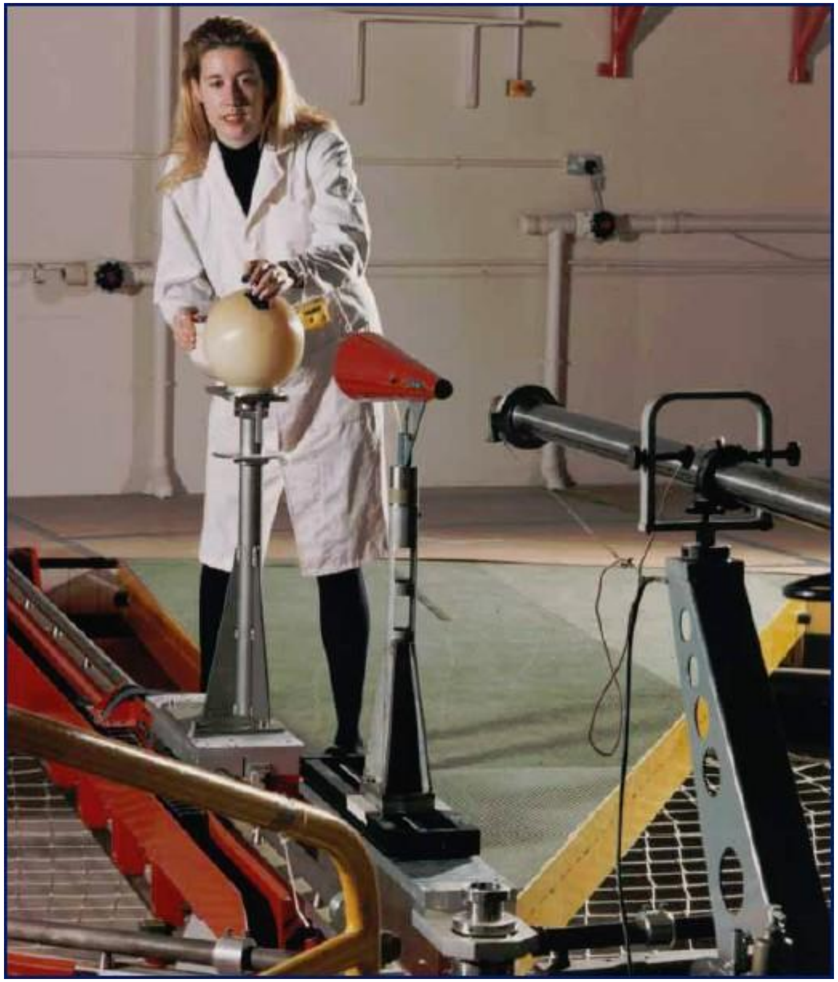
Low-scatter area



Target is at least 6m away from floor, walls and roof.

Measurement of scatter

- Although room scatter is small, we routinely measure it using shadow cones.
- The cone prevents neutrons reaching the detector directly from the target, so the remaining detector response must be due to the scatter.



Simultaneous irradiations

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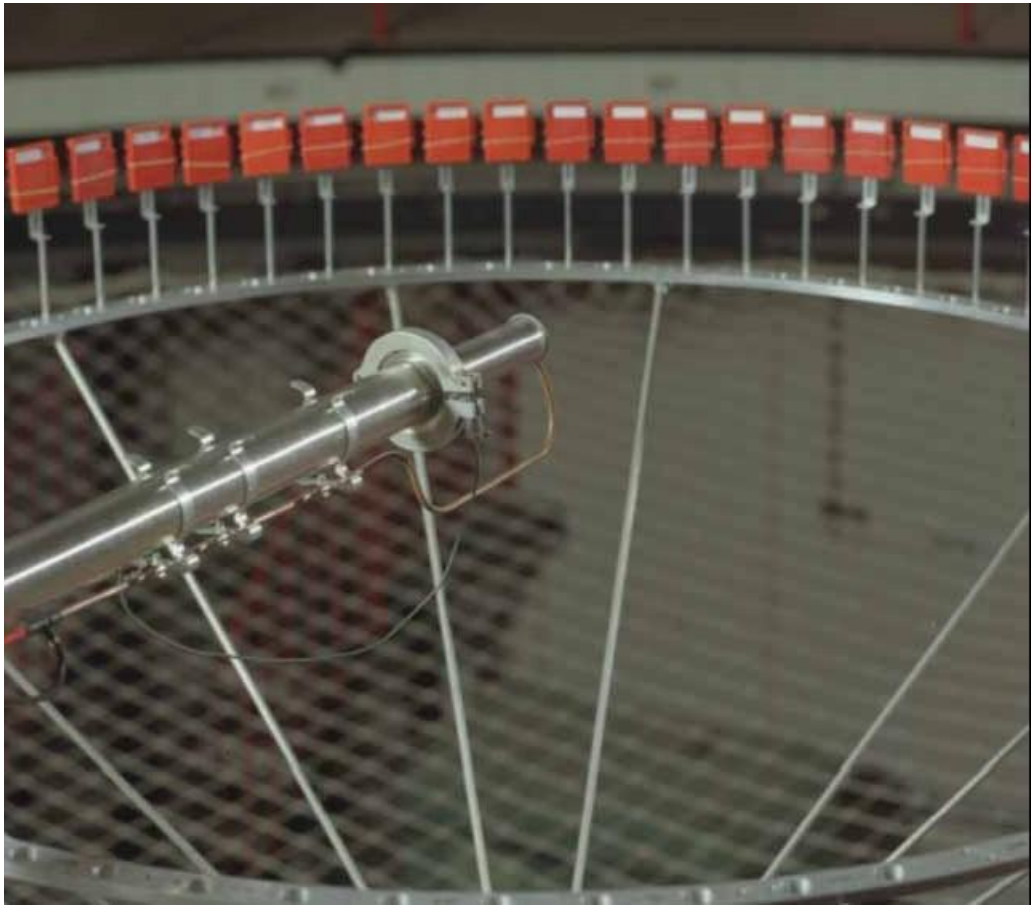
Covering a range of energies at one go



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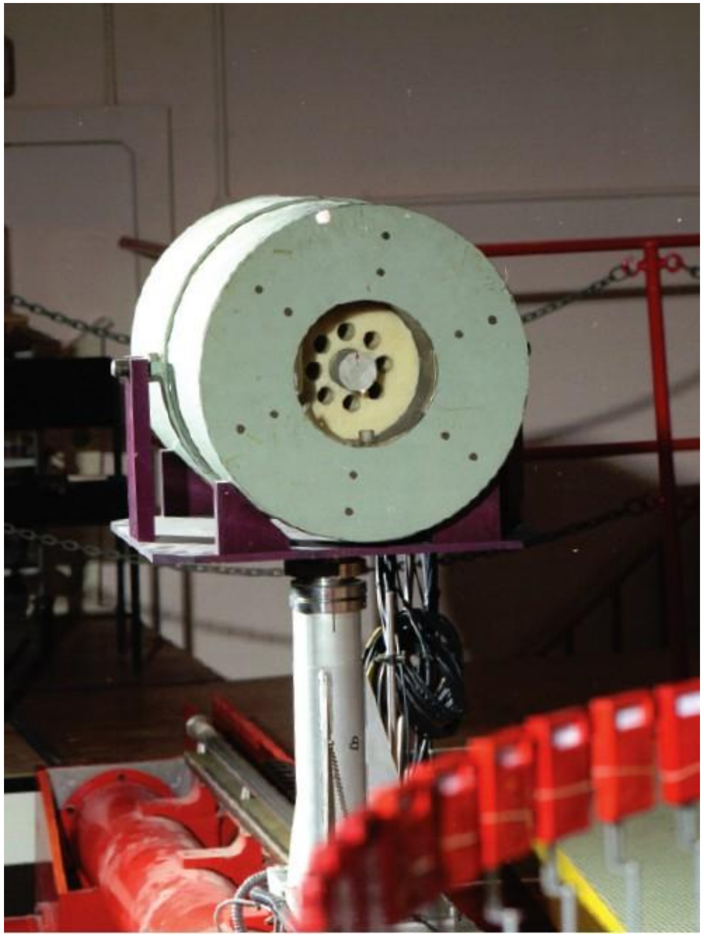
Monoenergetic neutrons

E_n (MeV) at 0°	Reaction	Max. beam current (μA)	Max. fluence rate at 1m (cm^{-2} s^{-1})
0.027	$^{45}Sc(p,n)^{45}Ti$	40	8
0.144	$^{7}Li(p,n)^{7}Be$	20	1×10^3
0.250	"	"	6×10^2
0.565	"	"	1.6×10^3
1.2	$T(p,n)^{3}He$	3	2×10^2
2.5	"	"	3×10^2
5.0	$D(d,n)^{3}He$	"	6×10^2
17.0	$T(d,n)^{4}He$	"	5×10^2

Other energies (e.g. 70 keV) are also possible by changing beam energy or detector angle.

Neutron fluence

- Measured using a Long Counter (BF_3 counter inside a cylindrical moderator).
- The efficiency, about 11 counts per (neutron per cm^2), varies relatively little with energy.
- Efficiency established by (e.g.) using neutron sources with accurately known output (measured in NPL Mn bath).
- Provides a calibration of the beam current monitor.



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Ion beam energy

- The accelerator beam passes through narrow slits inside the field of an energy-analysing magnet.
- The magnetic field is calibrated by reference to the known thresholds of certain nuclear reactions, e.g. $^{27}Al(p,\gamma)$, T(p,n), $^{7}Li(p,n)$.
- The field is kept constant using a Nuclear Magnetic Resonance probe and a feedback system.
- The uncertainty in the ion beam energy is approx. ±1.5 keV, and the full width of the energy distribution is approx. 4 keV.

Neutron energy

The corresponding figures for the neutron energy depend of course on the production reaction, the target thickness and the neutron direction relative to the ion beam direction.

Some recent examples from actual calibrations (all figures relate to 0°):

Reaction	Neutron energy (keV)	Full width of neutron energy distribution (keV)
^{7}Li(p,n)	144 ± 2.2	6.2 ± 0.9
T(p,n)	2500 ± 2.9	28 ± 5
T(d.n)	17000 ± 16	340 ± 32

Broad-spectrum field

- Simulated Workplace field
- Made to resemble the soft workplace fields at (e.g.) some UK gas-cooled reactors, which have few neutrons above 1 MeV.
- Protons on thick Li-alloy target. Neutrons moderated by 40 cm diameter D_2O sphere (removable).
- Max. fluence rate approx. 4.5×10^3 cm^{-2} s^{-1} at 1 m.

Isotope sources

Neutron-emitting isotopes doubly encapsulated in stainless steel cylinders of various sizes.

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Source output measurements: Mn bath

Source	Total output, s^{-1}	Fluence rate at 1m, $cm^{-2} s^{-1}$
^{252}Cf	5.8×10^7	4.6×10^2
^{252}Cf / D_2O	5.1×10^7	4.0×10^2
^{241}Am-Be	3.2×10^7	2.7×10^2
^{241}Am-B	4.3×10^5	3.5
^{241}Am-F	1.3×10^5	1.0
^{241}Am-Li	2.1×10^5	1.8

Time – of – flight

- Divide the ion beam into very short pulses.
- Measure the delay between the arrival of a pulse on target, and the occurrence of a neutron signal in the detector 1 – 5 m away.
- This gives the speed of the neutron and therefore its energy. Spectra can be accumulated with high energy resolution.
- In 2006 - 07 we had pulse widths as low as 2 ns, and average beam currents of 1½ to 2½ μA.
- We are currently having problems with the system, but will be working to restore this performance.

Conclusions

- The NPL Neutron Metrology Group has a 3.5 MV Van de Graaff accelerator and a range of experimental facilities.
- Well-characterised fast neutron fields can be produced, both monoenergetic and broad spectrum.
- Epithermal and thermal fields are also available.
- The labs of the NPL Radioactivity Group are on the same site and can provide metrology-class detection and counting facilities.

National Measurement System

The National Measurement System delivers world-class measurement science & technology through these organisations

National Measurement Office

NPL National Physical Laboratory

LGC Setting standards in analytical science

nel technology for life

The National Measurement System is the UK's national infrastructure of measurement Laboratories, which deliver world-class measurement science and technology through four National Measurement Institutes (NMIs): LGC, NPL (the National Physical Laboratory), TUV NEL (the former National Engineering Laboratory), and the National Measurement Office (NMO).