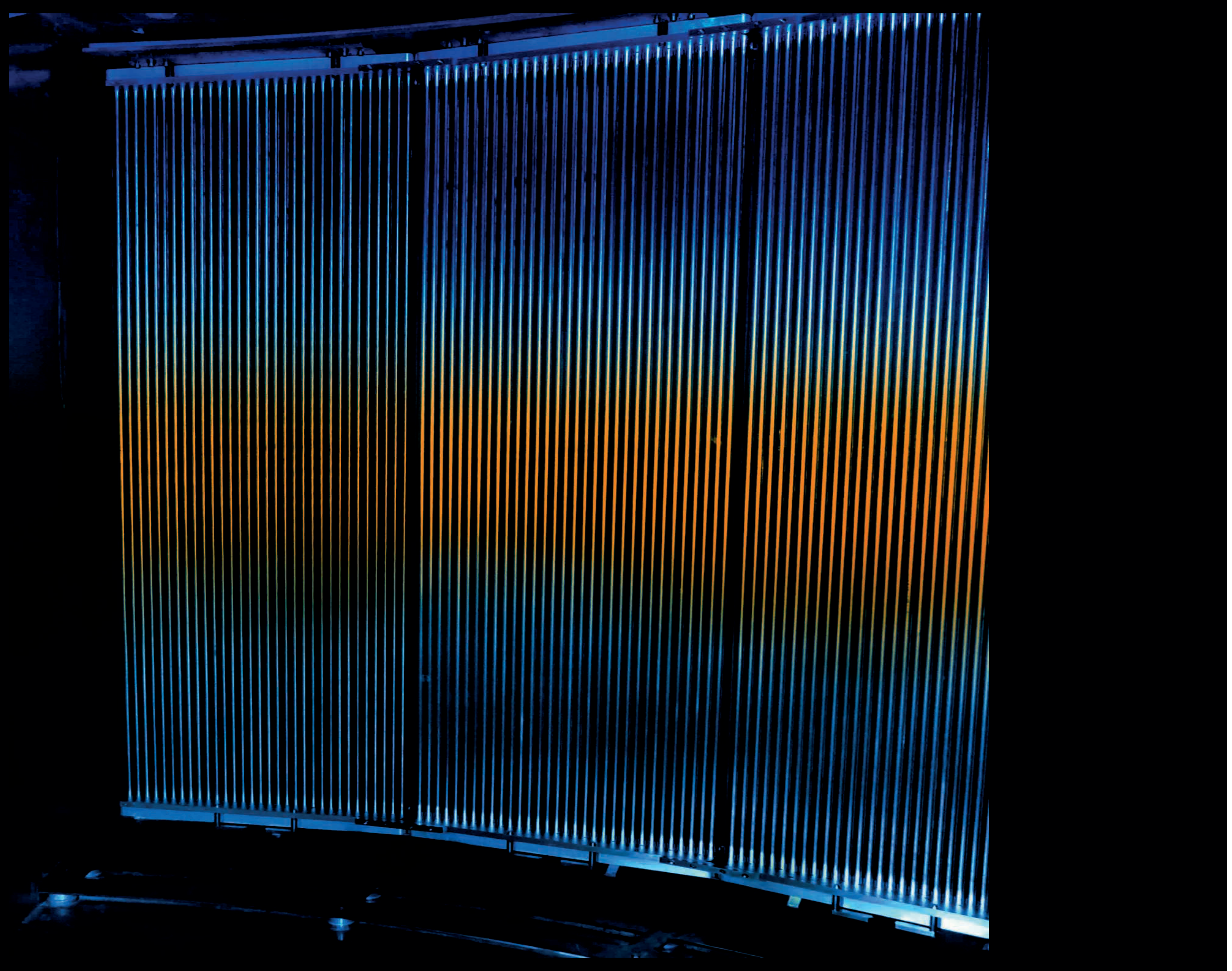
NEUTRONS
FOR SOCIETY

Neutron Technologies

Institut Laue Langevin

The world's leading facility in neutron science and technology

Ipoustéguy's sculpture at the Institut Laue Langevin (ILL) in Grenoble is a monumental work that seamlessly integrates with its surroundings. It depicts an evocative sequence of human history and its challenges, from humorous beginnings to darker representations of the consequences of the discovery of atomic fire. The artwork also expresses hope through symbols of maternity and the continuity of life. The depiction of man, portrayed vividly, embodies the duality of his existence, illustrated by symbolic forms and a door evoking uncertainty about the future. This captivating sculpture invites deep reflection on the journey of humanity.



CONTENTS

FOREWORD

At the Institut Laue-Langevin (ILL), our mission is to advance neutron science by providing world-class instrumentation, state-of-the-art technology, and pioneering engineering solutions. Neutron scattering plays a vital role in fundamental research and industrial applications, and maintaining ILL's position as a global leader in this field requires continuous innovation in neutron delivery, optics, detection, and instrumentation.

This brochure highlights the technical expertise and engineering excellence that underpin our scientific achievements. From the design and optimisation of advanced neutron optics to the development of high-performance detectors and cutting-edge sample environments, our teams push technological boundaries to ensure the highest quality neutron beams and experimental setups for our users.

By continuously advancing neutron optics technologies—such as supermirror coatings, monochromators, and polarised ^{3}He spin filters—we are enhancing polarisation and energy selection for a wide range of experiments. In parallel, ILL remains at the forefront of detector development, designing and implementing next-generation detection systems that offer higher efficiency, improved spatial resolution, and enhanced count-rate capability. Our expertise in sample environment technologies enables researchers to conduct experiments under extreme conditions, from ultra-low temperatures and high pressures to strong magnetic fields, expanding the possibilities for scientific discovery.

The advancements presented in this brochure are a testament to the dedication and technical expertise of our scientific and technical staff. Through their work, we strengthen ILL's position as a world-leading neutron facility and ensure that our neutron technologies continues to support breakthrough research for years to come.

Andreas Meyer
German Associate Director
Head of the Projects & Techniques Division

WHAT IS THE ILL

The Institut Laue Langevin (ILL) is the world-leading facility for neutron science and technology. Its high-flux reactor delivers the world's most intense neutron beams to a state-of-the-art suite of more than 40 public instruments. The institute makes significant contributions to scientific discovery, the development of new technology, advanced training, and in addressing society's greatest challenges.

Neutrons are a unique and powerful probe of materials and processes. ILL's instruments, complemented by a comprehensive suite of labs and scientific support services, enable cutting-edge research across a wide range of scientific domains, including physics, chemistry, biology, and materials science.

The ILL works closely with industry and develops an impactful programme addressing societal challenges namely in health, energy, sustainability and climate change, and quantum technologies. The ILL hosts researchers mainly from its 13 stakeholder countries in Europe, with 10% coming from over 50 other countries. In total, there are about 1500 researcher visits each year.

The ILL is a Landmark Facility on the European Strategy Forum on Research Infrastructures (ESFRI) Roadmap and has helped to shape the European neutron landscape in a collaborative and complementary way.

AROUND
120
scientists

OVER
40
state-of-the-art
scientific instruments

20%
experiments
related to industry

500
staff members
from 30 countries

1 500
scientific users per year
from 65 countries

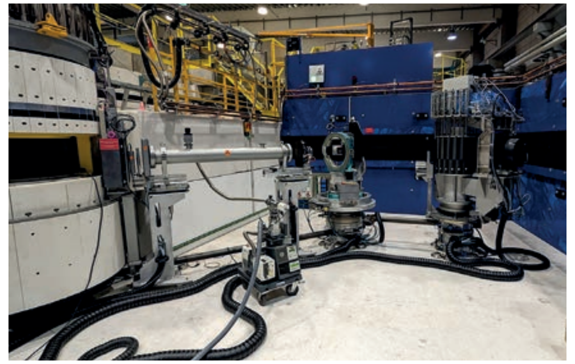
SEVERAL
1 000
radiotherapy cancer treatment
doses delivered per week
during reactor cycles

OVER
40
PhD students

1 000
Experiments
per year

500
scientific publications
per year

INSTRUMENT SUITE

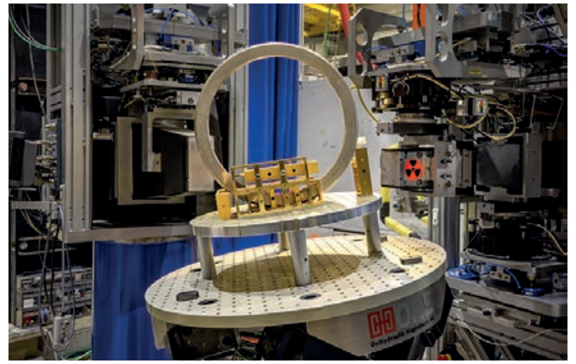

D10⁺

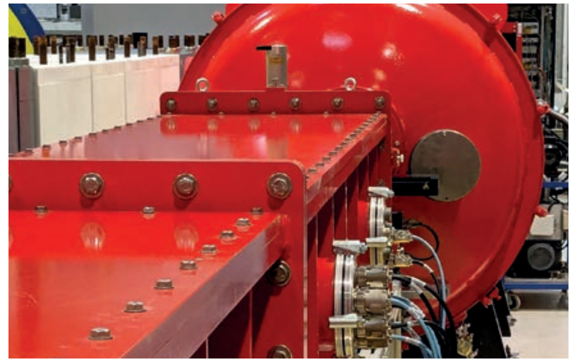

NeXT

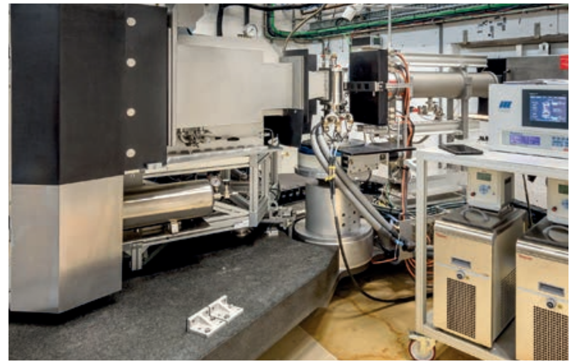

FIPPS

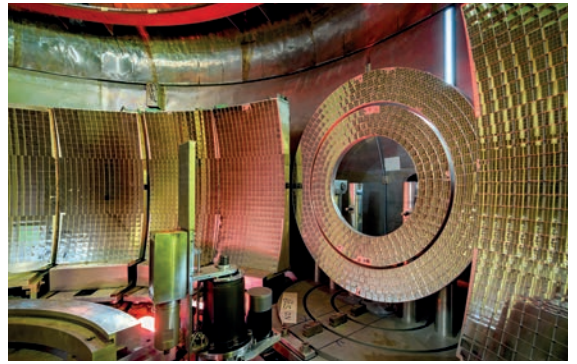

SHARPER

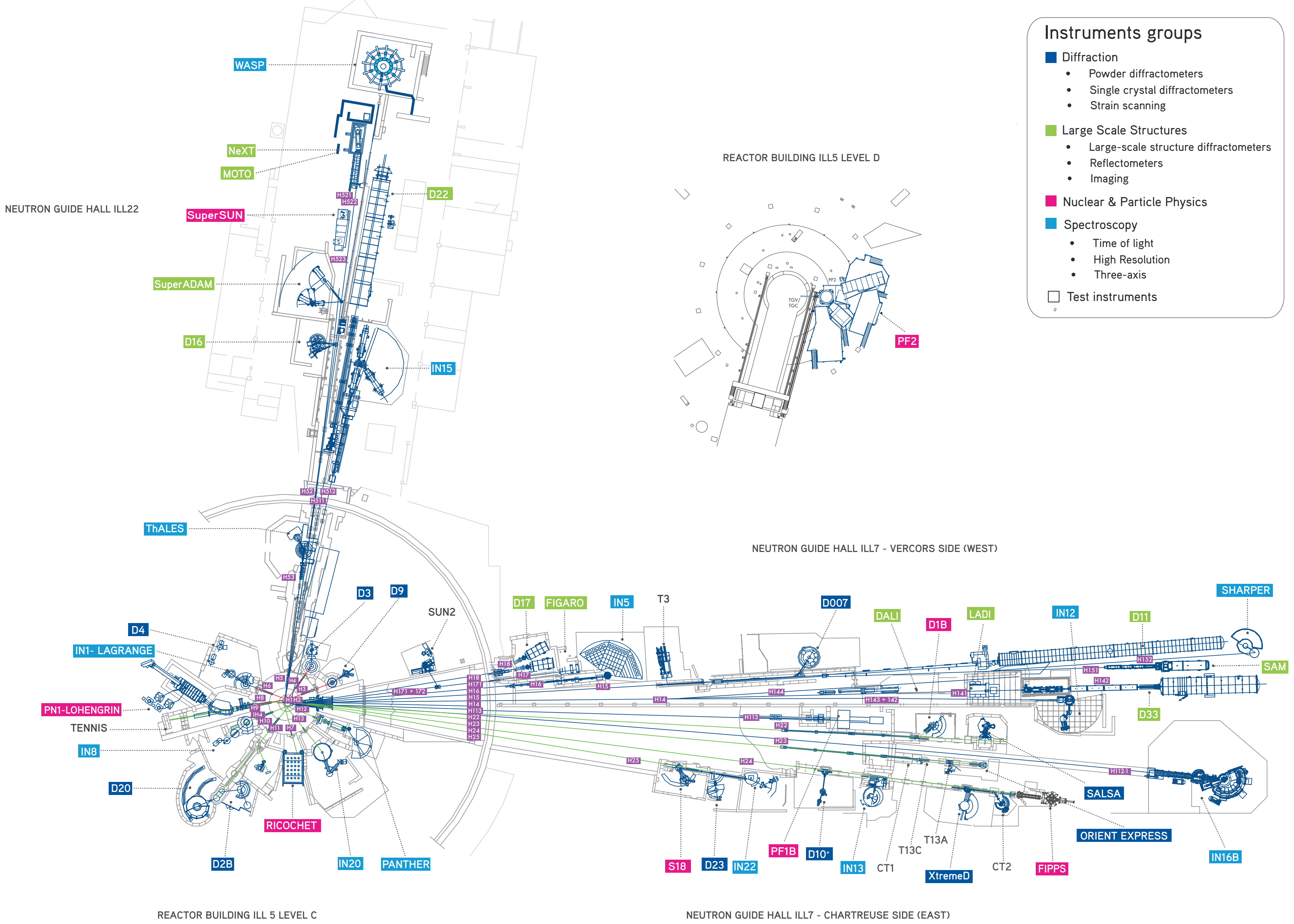

PANTHER


SALSA


SAM


D16


IN13



NEUTRON DELIVERY: GUIDES & INFRASTRUCTURE

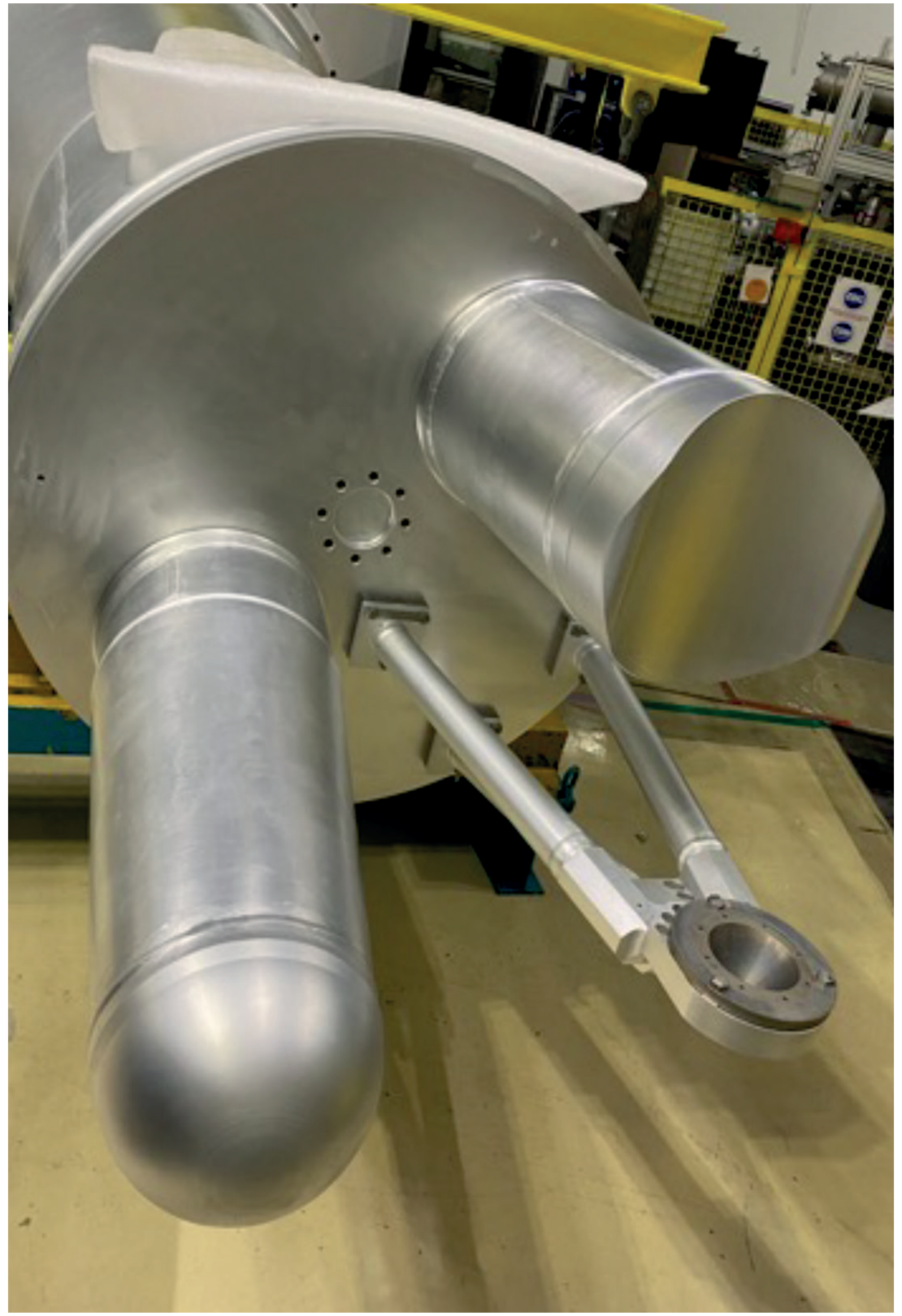
At the ILL, we take full responsibility for designing the entire neutron delivery infrastructure that channels neutrons from the reactor to our state-of-the-art instruments. While we do not manufacture the neutron guides themselves, our expertise lies in the comprehensive design of the neutron guide systems, vacuum housings, alignment systems and all supporting infrastructure. From the H1-H2 beamtube insert in the reactor to the neutron instruments, our designs address the unique challenges of neutron transport, incorporating precision engineering to optimise neutron delivery to each instrument.

New and upgraded instruments through the Millennium and Endurance programmes have relied heavily on renewed neutron guide systems, with the H24 thermal- and H15 cold-neutron guides being among the most complex systems ever installed at a neutron scattering facility. This has been made possible, in part, by the timely replacement of the H1-H2 beamtube and in-pile neutron guides, allowing us to install guides with improved critical angle and reflectivity, providing us with a rare opportunity to optimise and modify the in-pile guide geometry.

The mechanical design, installation and alignment of these systems are carried out by ILL's in-house mechanical services, making these some of the most ambitious and intricate neutron guide projects in the neutron scattering community.

As part of the Endurance programme five major guide projects have been successfully completed resulting in nearly a kilometre of new high-performance neutron guides:

- H1-H2 thermal- and cold-neutron in-pile neutron guides (281 m)
- H15 cold-neutron multiple-branch guide (330 m)
- H24 thermal-neutron double-branch guide (210 m)
- H16 elliptical focusing guide (45 m)
- H112 variable focusing guide (11 m)



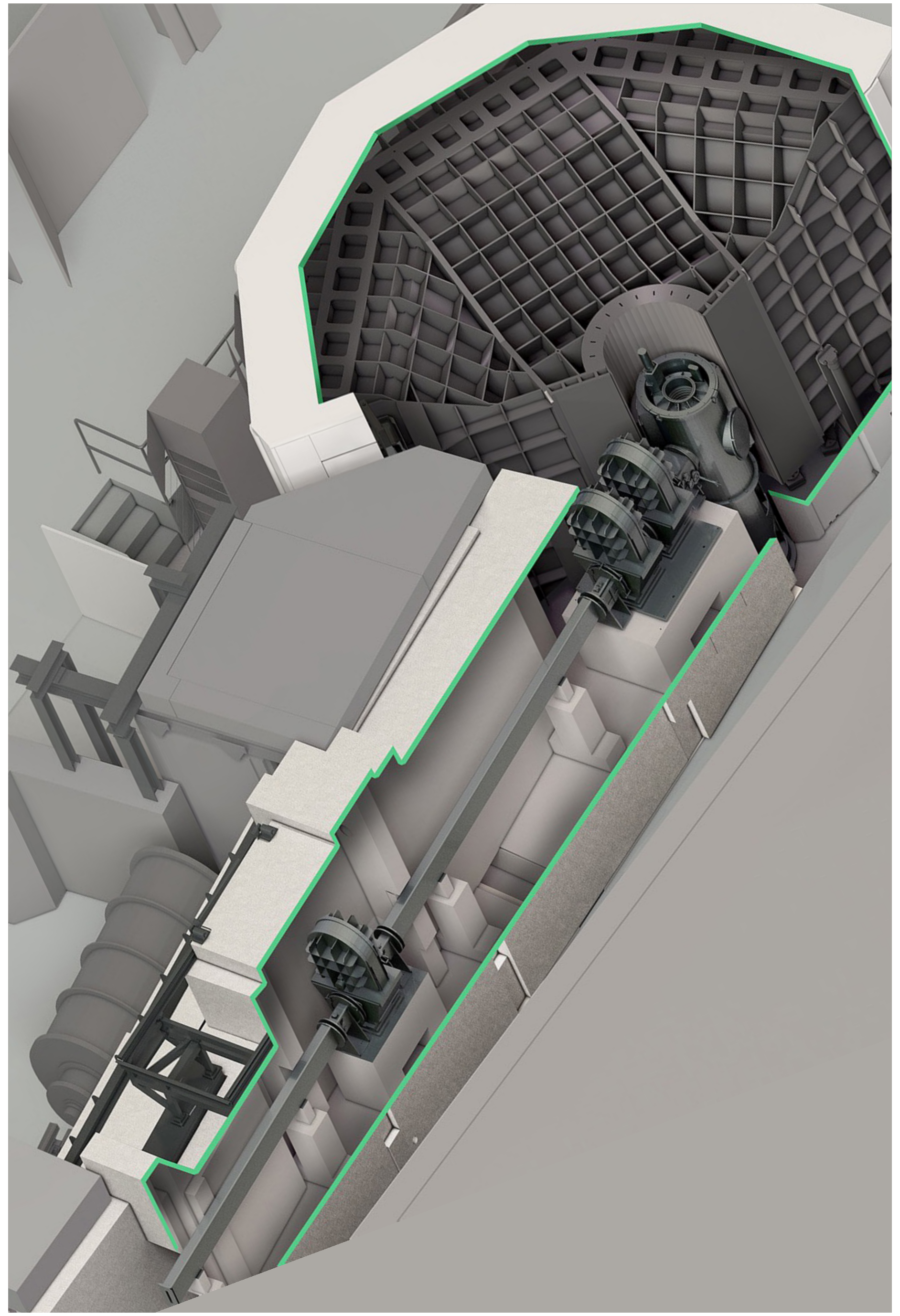
H1-H2: IN-PILE NEUTRON GUIDES

Approximately every 15 years, the H1-H2 beamtube must be replaced due to irradiation damage and to ensure the structural integrity of this critical reactor component. At the same time, we take the opportunity to replace the in-pile neutron guides, mounted on the so-called plateau inside the beamtube. These guides degrade over time due to radiation exposure, and their replacement allows us to install higher-performance optics and optimise their geometries for improved neutron extraction.

During the long shutdown of 2021/2023, we successfully replaced the H1-H2 beamtube and in-pile neutron guide system. For the new H24 thermal- and H15 cold-neutron guides, we expanded the in-pile guide cross-section from 30 mm to 60 mm and 70 mm, respectively. Combined with higher critical angle coatings, this modification enabled the extraction of a significantly larger neutron phase space, delivering a greater neutron flux to the downstream guide systems, which feature renewed, complex, multi-branch geometries.

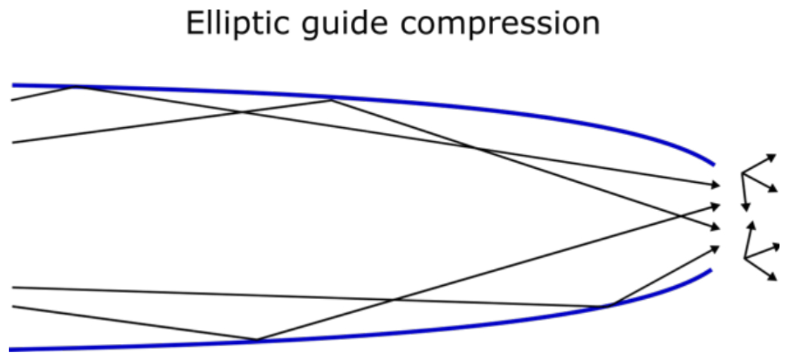
Seven cold-neutron and four thermal-neutron guides converge towards their respective neutron sources inside the reactor. These 11 in-pile neutron guides were replaced, enhancing the neutron supply to the 26 instruments in the ILL7 guide hall. In total, 281 m of guide optics were dismounted, replaced and realigned by ILL's mechanical services, achieving an accuracy of just a few hundredths of a millimetre. Modern alignment techniques and tooling developed for the project—using laser trackers, a theodolite and a tacheometer—combined with advanced CAD design tools, formed the foundation of the optimised installation procedure.

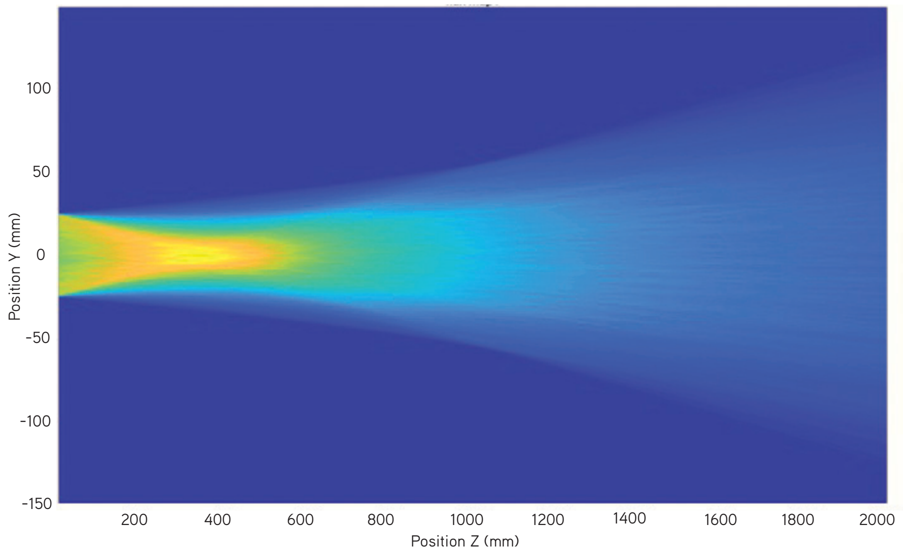
To further enhance reactor safety, an additional 48 m of neutron guides were installed on the 11 guide feedthroughs between the reactor building and ILL7 guide hall, reinforcing the system against seismic events and improving overall robustness.



H16 (IN5): FOCUSING ELLIPTICAL GUIDE

Converging neutron guides, although not a new concept, have seen growing applications with the development of high critical angle supermirrors, which enable better control and optimisation of neutron transport. These focusing guides enhance performance by progressively narrowing the guide cross-section—either horizontally, vertically, or both—resulting in an increased divergence of neutrons within the guide. This process transforms a larger, less divergent neutron beam into a highly divergent one over a smaller spatial area, producing a more intense beam at the guide's exit. By employing advanced geometries, such as elliptical or parabolic guides, the most intense region of the neutron beam is shifted further from the guide exit, providing ample space for sample environments while significantly improving neutron flux at the sample position.





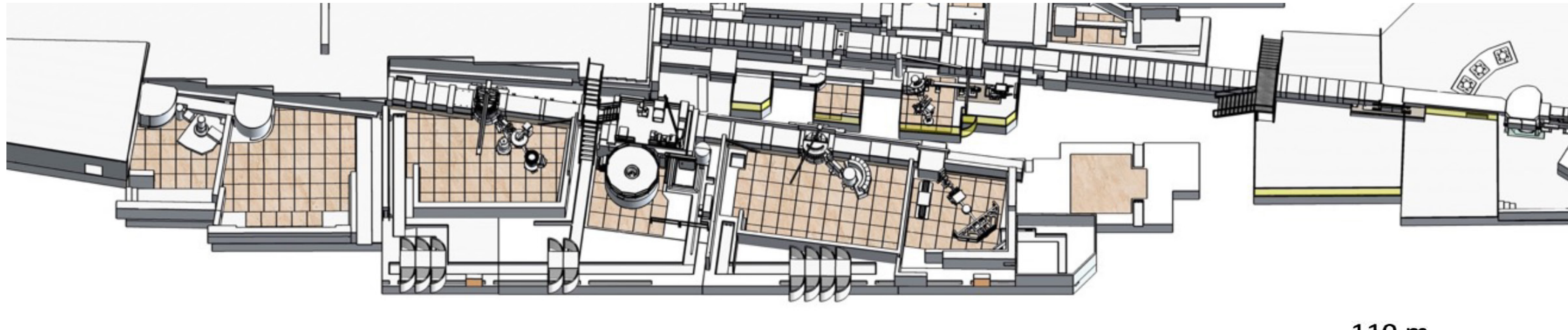
Simulated neutron intensity at the exit of the H16 (IN5) converging elliptic guide.

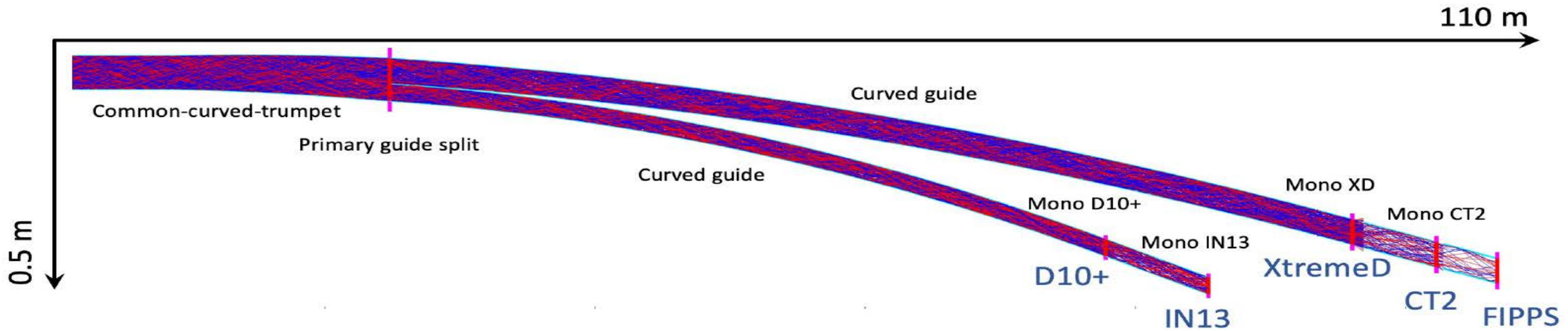
The renewed H16 guide delivering neutrons to the IN5 cold time-of-flight (TOF) spectrometer is a prime example of this approach. The optimised guide incorporates elliptical focusing in the vertical direction and linear compression in the horizontal direction, reducing the neutron beam cross-section from 30 mm x 150 mm to 15 mm x 50 mm, with m = 4 and m = 6 in the horizontal and vertical directions, respectively. The elliptical focusing was fully optimised for a reference sample size of 15 mm x 30 mm at a distance of 20 cm from the end of the guide. Notably, this upgrade uses supermirror neutron guides with coatings up to m = 6, pushing the instrument upgrade to its technological limits. Even so, only 75% of the height of the available source guide section was required to achieve the maximum usable flux, leaving 25% of the guide section available for future upgrades with potential future supermirror technologies.

The new high-m, elliptically focusing guide delivers three times the neutron flux at the sample position at 3 Å with higher gains in performance at shorter wavelengths extending the usable wavelength and energy range enabling access to much shorter wavelengths and higher energies. The improved flux and focusing capabilities also enable more efficient measurements on smaller samples, enhancing the IN5 spectrometer's role as an even more powerful tool for neutron scattering experiments.

H24: DOUBLE-BRANCH THERMAL-NEUTRON GUIDE

The H24 guide has been replaced with a 110 m long double-branch guide featuring supermirror coatings, significantly improving neutron transport to the downstream instruments. The new guide utilises higher critical angle coatings up to m = 3 and introduces an elegant common-curved-trumpet design. This approach exploits the differing radii of curvature of the H241 (R = 14,000 m) and H242 (R = 8,000 m) downstream sub-branches, allowing the guide to gradually expand over 22 m with m = 2 divergence. As the guide curves, it naturally splits into two distinct branches before further subdividing into five end-of-guide positions. This configuration supplies neutrons to multiple instruments: XtremeD, CT2, and FIPPS access the lower, middle, and upper sections of H241, while D10⁺ and IN13 utilise the lower and upper sections of H242. The installation of the new guide, along with its associated civil engineering work, was carried out during the long H1-H2 shutdown in 2022.





H24 simulated guide geometry

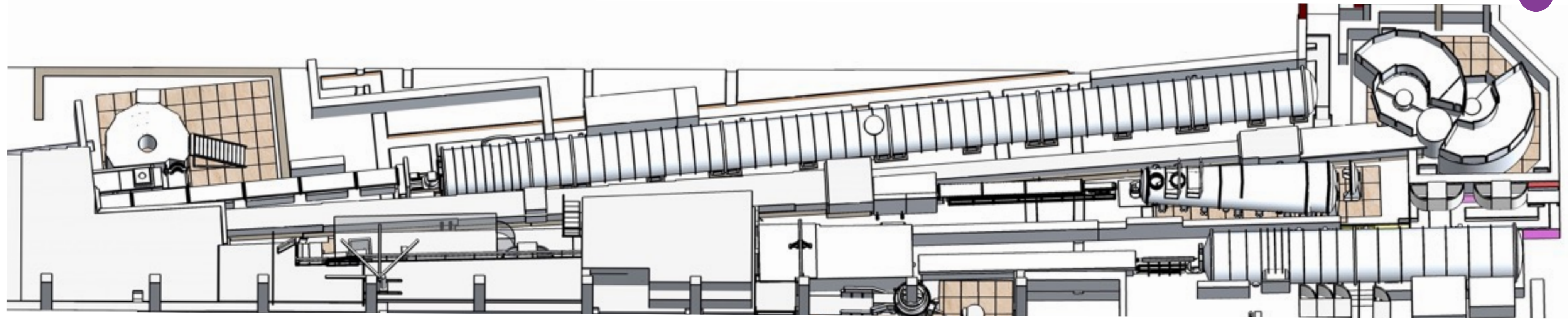
The new H24 guide delivers approximately three times more neutrons than the previous m = 1 guide, primarily due to the increased critical angle coatings of the new m = 2 guide (with a theoretical gain factor of four when transitioning from m = 1 to m = 2 divergence). This enhanced flux and divergence can be fully exploited by the modernised instruments, with total performance gains exceeding an order of magnitude for instruments such as the D10⁺ single-crystal diffractometer.

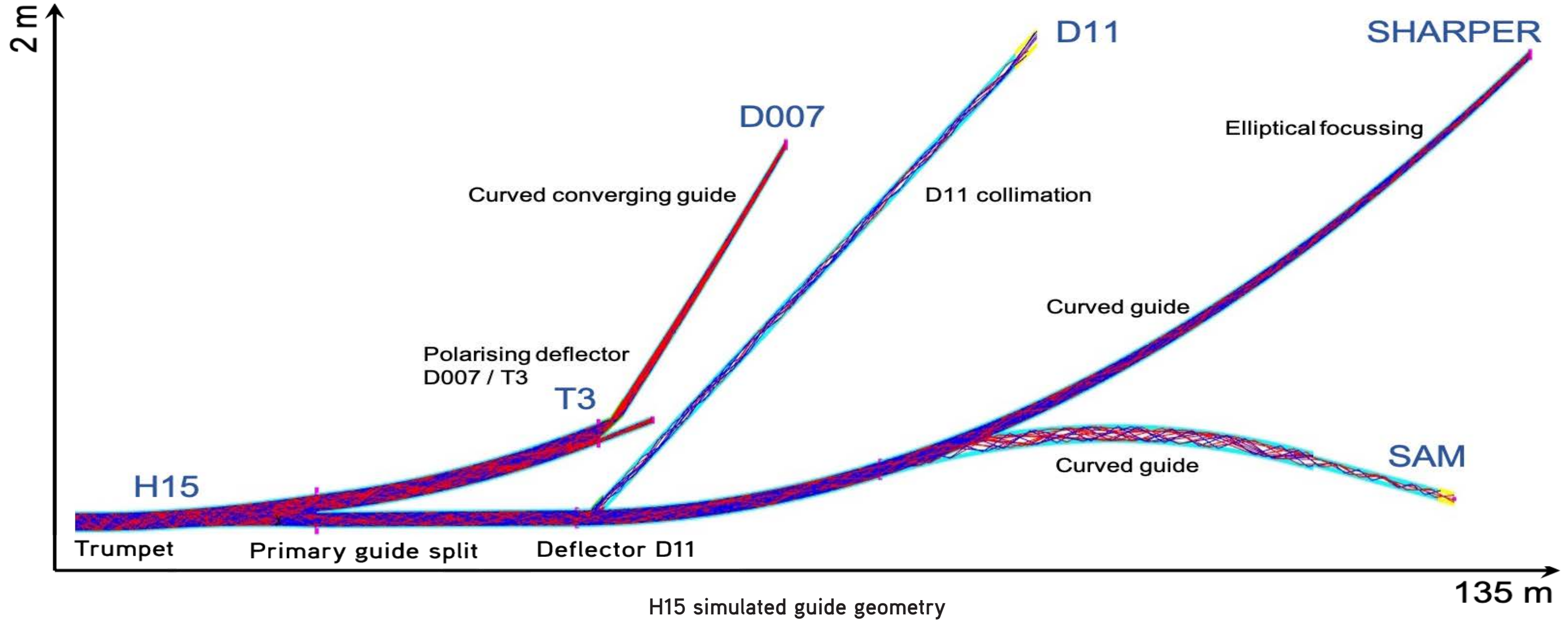
H15: MULTIPLE-BRANCH COLD-NEUTRON GUIDE

The new H15 cold-neutron guide replaces one of the last remaining original guides installed alongside the first suite of ILL instruments in 1972. Cold-neutron instruments typically benefit most from dedicated end-of-guide positions. Historically, this was not always possible, and performance was limited by upstream monochromators and the need to share a single guide cross-section between multiple instruments.

The new H15 guide, installed between 2022 and 2024, took advantage of the replacement of the H1-H2 beamtube and in-pile beam extraction system, allowing for an increase in guide size and the installation of high critical angle supermirror guides (m = 3) in the in-pile section. A key feature of the H15 guide is its opposing-curved expanding section, referred to as "the trumpet." This structure spatially expands the neutron guide, converting the upstream high-divergence beam into a lower-divergence (m = 2) beam while spreading it over a larger cross-section. This allows the guide to be split into multiple dedicated branches, providing separate end-of-guide beam positions for instrumentation.

The opposing curvature of the trumpet also introduces a spatial correlation between the divergence profile and position at the guide exit. Neutrons on the left side of the guide exhibit an average divergence pointing left, while those on the right exhibit divergence to the right. This effect enables the guide branches to be more widely separated in angle, creating additional space for a greater number of downstream instruments: T3, D007, D11, SHARPER and SAM.





H15 simulated guide geometry

In addition to the more usual curved neutron guides, the H15 guide incorporates various neutron optical devices to efficiently separate individual guide branches. These include non-polarising and polarising deflectors for D11 and D007, as well as converging guides (D007) and elliptically focusing guides (SHARPER), ensuring optimised neutron delivery tailored to each instrument's specific requirements.

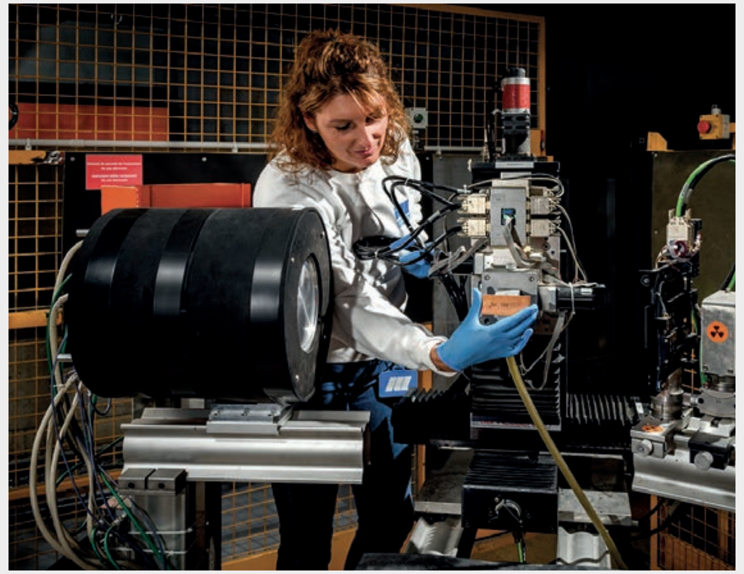
NEUTRON OPTICS

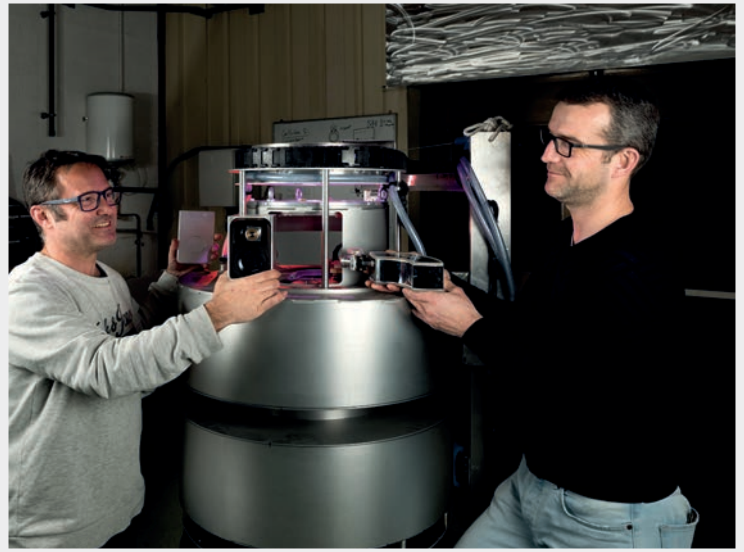
Neutron optics are essential components of neutron scattering instruments, shaping the incident beam by controlling its direction, divergence, energy, wavelength, and polarisation. Well-designed optical elements play a crucial role in maximising neutron flux at the sample, with carefully optimised systems capable of increasing intensities by orders of magnitude.

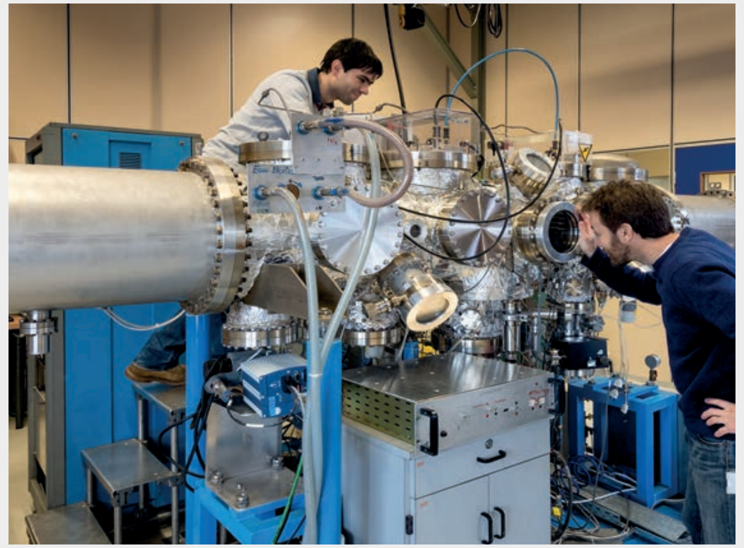
For polarised neutron techniques, specialised optics are used to both polarise the incident neutron beam and analyse the polarisation of scattered neutrons. When combined with precise direction and energy tuning, neutron polarisation techniques enable researchers to investigate complex physical phenomena with exceptional sensitivity, particularly in the study of magnetism.

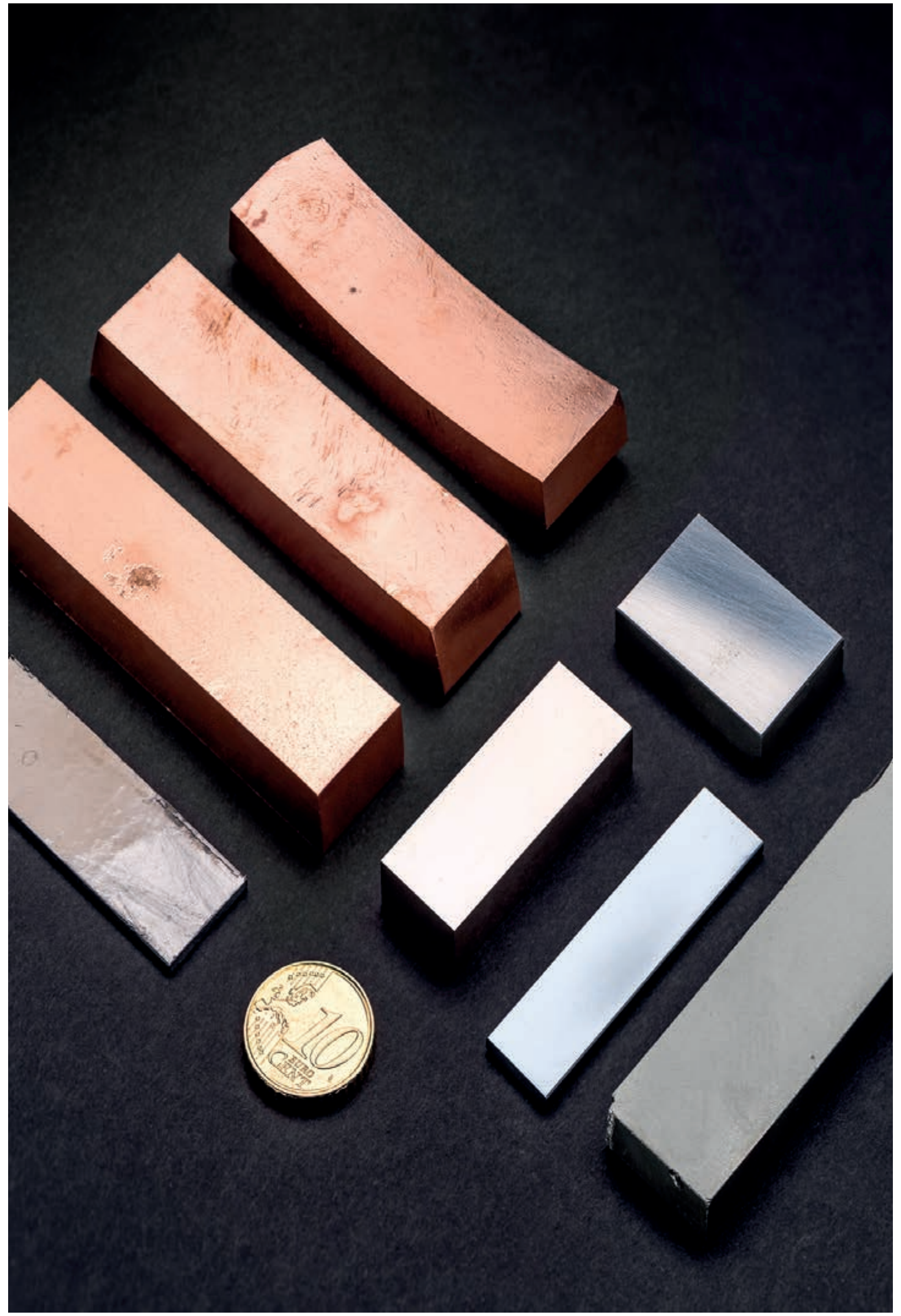
Neutron optics are indispensable for modern neutron scattering techniques and include:

- Crystal Monochromators
- Supermirrors
- Polarised ^{3}He









CRYSTAL MONOCHROMATORS

Crystal monochromators are the most efficient method for producing intense beams of monochromatic neutrons from a 'white' neutron source. By exploiting Bragg diffraction, monochromator crystals reflect a specific wavelength band, with the band width determined by the crystal mosaic spread and the divergence of the incident beam. Mosaic crystals are often preferred over perfect crystals, as their mosaicity can better match the divergence of the incoming beam in the scattering plane, optimising the intensity of Bragg-scattered neutrons. Commonly used materials include highly oriented pyrolytic graphite (HOPG), copper, germanium, silicon, and Heusler crystals for polarised neutron applications.

The ILL is a leader in the production of high-quality monochromator crystals and assemblies, which are integral to many of our advanced neutron instruments.

IN20 HOPG MONOCHROMATOR

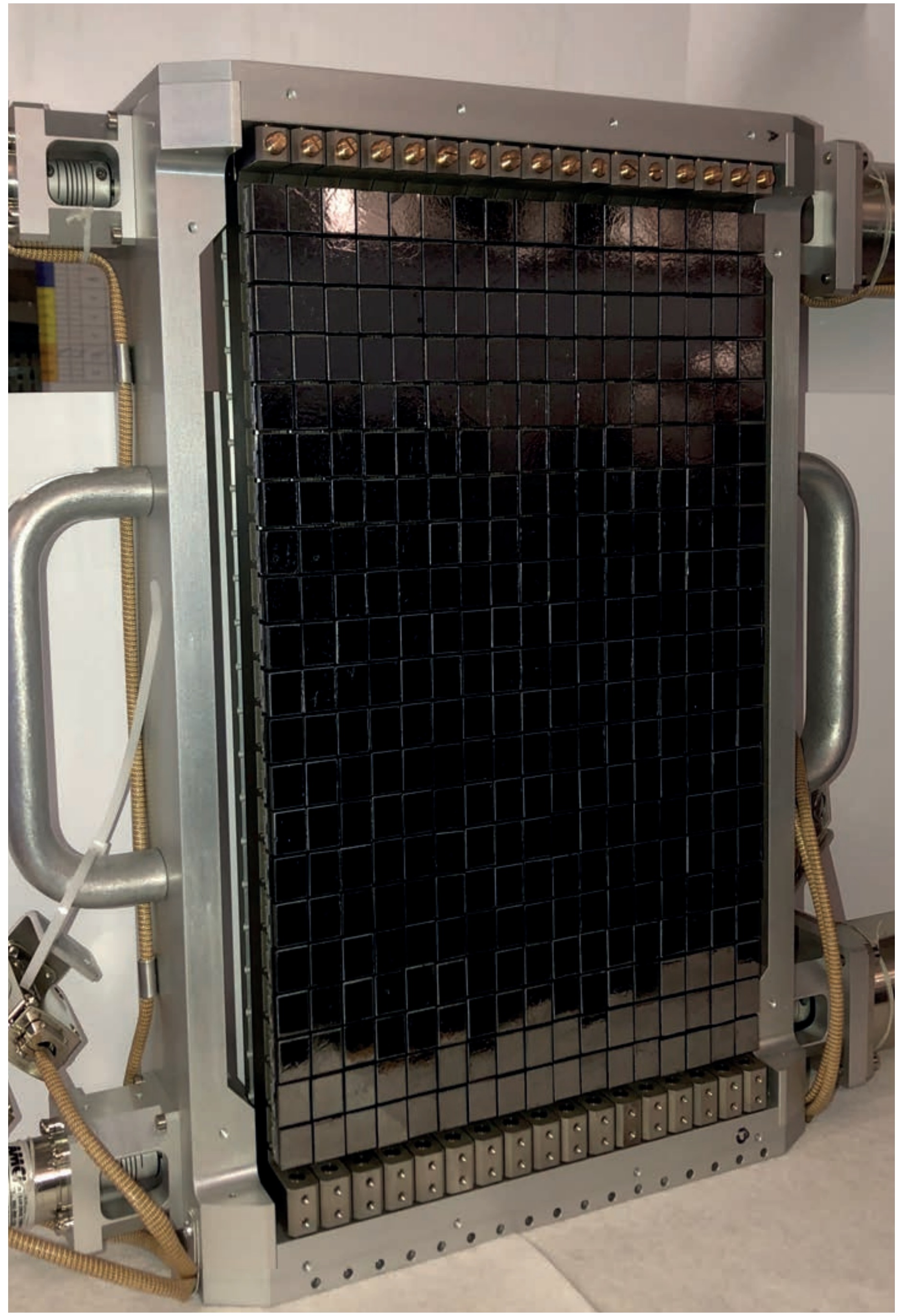
- 225 crystals
- Crystal size: 13.4 mm x 14.9 mm
- Total area: 450 cm²

FOCUSING MECHANICS

The size of the neutron source and neutron guide systems are much larger than typical sample sizes. To maximise instrument performance, focusing monochromators are widely used to concentrate intense neutron beams onto small samples, dramatically increasing the incident neutron flux.

For instruments requiring spatial resolution in the horizontal plane, vertical-focusing monochromators can provide intensity gains of more than an order of magnitude compared to flat, non-focusing devices. Double-focusing monochromators are particularly valuable in triple-axis (TAS) and monochromatic time-of-flight (TOF) spectroscopy, where independent adjustment of horizontal and vertical curvatures allows optimisation of both neutron flux and resolution across a wide energy range.

ILL's design teams develop high-precision mechanical solutions to ensure that monochromators operate with accuracy and reliability in the demanding environment of neutron scattering instruments.



GRAPHITE CRYSTAL MONOCHROMATORS

Highly Oriented Pyrolytic Graphite (HOPG) is the preferred material for generating high-intensity monochromatic neutron beams in the thermal energy range. Its exceptional neutron reflectivity, combined with a large mosaic spread, makes it ideal for applications requiring both high flux and well-defined wavelength resolution. Crystals with a mosaic spread of approximately 0.5° are commonly used to maximise neutron flux while maintaining a balance between intensity and wavelength resolution. HOPG monochromators, available with vertical or double-focusing configurations, play a key role in enhancing instrument performance across various neutron scattering techniques.

Applications:

- Powder and single crystal diffractometers
- Triple-axis spectrometers
- Neutron imaging

TECHNICAL SPECIFICATIONS

- **Structure: hexagonal**
- **Lattice constant: a = 2.461 Å; c = 6.708 Å**
- **Crystal reflections: (002), (004)...**
- **Neutron mosaic (FWHM): 0.5° - 3°**
- **Peak reflectivity: R=80% at λ= 2.4 Å (FWHM = 0.5°)**

SHARPER DOUBLE-FOCUSING HOPG MONOCHROMATOR
- 357 crystals
- Crystal size: 12 mm x 14 mm x 2 mm
- Total area: 600 cm²

THALES SILICON MONOCHROMATOR
- 9 stacks of 17 silicon blades
- Blade size: 270 mm x 19 mm
- Total area: 450 cm²

The ILL relies on external manufacturers to supply high-quality HOPG and perfect Si crystals with the required specifications for neutron applications.

SILICON CRYSTAL MONOCHROMATORS

Silicon crystals exhibit excellent properties for neutron applications, particularly in experiments requiring high resolution. At ILL, silicon monochromators utilise stacks of elastically bent perfect crystal blades to increase angular acceptance, significantly enhancing diffracted neutron intensity. Individual crystals are meticulously aligned using hard X-ray diffraction to ensure precise orientation. Adjustable mechanical systems allow fine-tuning of the crystal curvature, enabling optimal focusing across a wide range of neutron energies.

Applications:

- Thermal neutrons
- Triple-axis spectrometers

TECHNICAL SPECIFICATIONS

- **Structure: Diamond**
- **Lattice constant: a = 5.431 Å**
- **Crystal reflections: (111), (220), (113, (115)...**
- **Effective neutron mosaic: 0.05° - 0.3°**
- **Maximum dimensions: 270 x 20 mm²**
- **Radius of curvature: flat crystal down to 2 m**

COPPER CRYSTAL MONOCHROMATORS

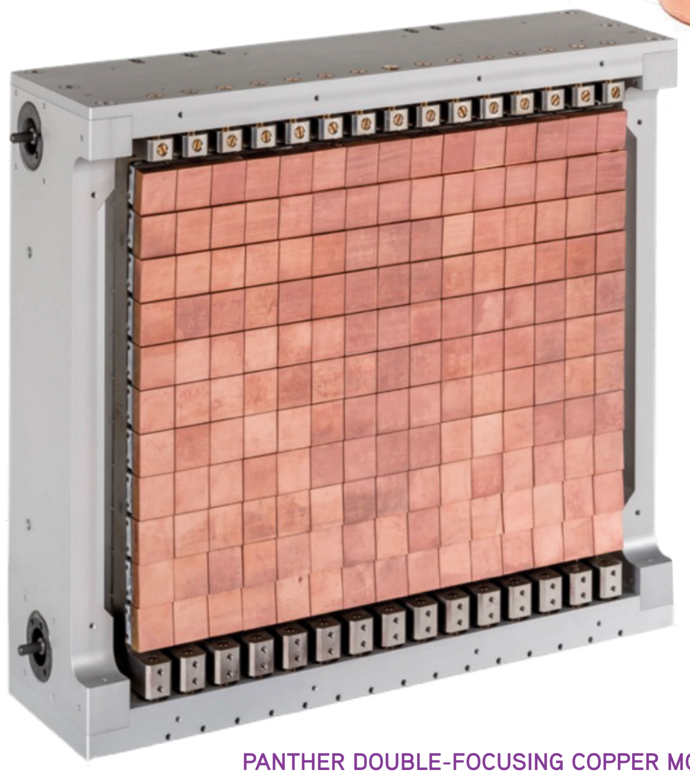
Copper mosaic crystals exhibit excellent neutron properties, enabling the construction of highly efficient neutron monochromators. Their small lattice constant (d-spacing) and high neutron reflectivity make them particularly well-suited for selecting short-wavelength neutrons ($\lambda < 1.5$ Å) while maintaining good wavelength resolution.

Applications:

- Powder and single crystal diffractometers
- Triple-axis spectrometers

TECHNICAL SPECIFICATIONS

- **Structure: f.c.c.**
- **Lattice constant: a = 3.615 Å**
- **Crystal reflections: (111), (200), (220), (113), (331)**
- **Neutron mosaic (FWHM): 0.05° to 3°**
- **Peak reflectivity: Cu(200) R=45% at λ=1.1 Å (FWHM = 0.4°)**
- **Maximum dimensions: 100 x 40 mm²**



PANTHER DOUBLE-FOCUSING COPPER MONOCHROMATOR

- 165 Cu (220) crystals
- Crystal size: 20 mm x 19.8 mm x 8 mm
- Total area: 660 cm²

Advancements in the growth process of large copper single crystals at ILL have led to the production of high-quality crystals with a narrow and uniform mosaic spread.

Starting with these high-quality single crystals, further refinement of the mosaic distribution can be achieved through plastic deformation at high temperatures.
By applying controlled pressure perpendicular to the crystal surface, the mosaic spread can be systematically adjusted within a range of 0.2° to 3°. This process allows fine-tuning of the crystal properties to meet specific requirements, ensuring optimal monochromator performance for various neutron instruments.

D10⁺ FOCUSING MONOCHROMATOR

- 30 Cu (200) crystals
- Crystal size: 42 mm x 8 mm x 7 mm
- Total area: 100 cm²

MARMOT SILICON ANALYSER UNIT

- 43 stacks of 2 Si (111) blades, 1 mm thick
- Blade size: 197 mm x 19 mm to 182 mm x 36 mm
- Radius of curvature: 2400 mm to 2800 mm

SILICON CRYSTALS FOR ADVANCED OPTICAL COMPONENTS

High-temperature plastic deformation enables the production of high-quality curved silicon crystals with a predefined, fixed curvature—eliminating the need for mechanical support structures.

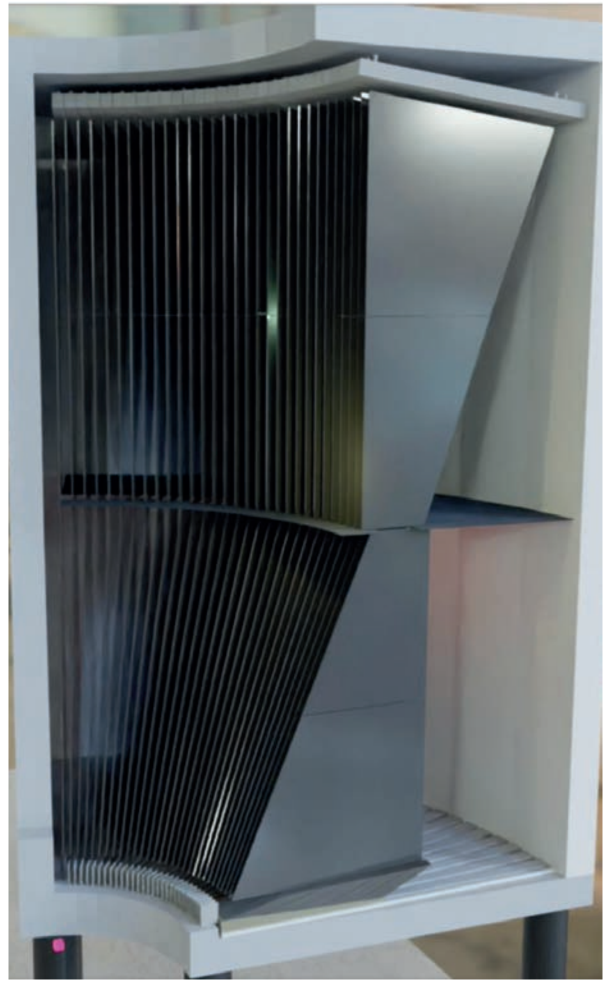
This technique allows the development of optical components that can simultaneously analyse a quasi-continuous range of energies or wavelengths while covering a wide range of scattering angles. It represents a major advancement in neutron optics, particularly for triple-axis spectroscopy. To this end, the ILL has developed bent silicon cassettes for the MARMOT analyser option on ThALES multiplexed in both angle and energy discrimination.

Applications:

• Triple-axis spectrometers

TECHNICAL SPECIFICATIONS

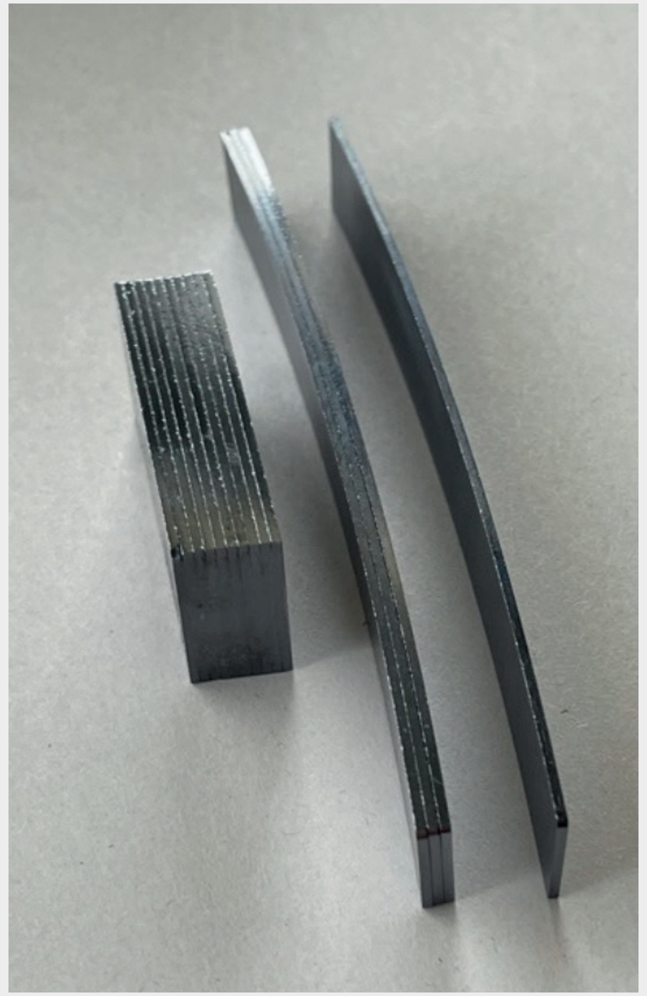
- **Effective neutron mosaic (FWHM): 0.05° - 0.5°**
- **Maximum dimensions: 200 x 20 mm^2**
- **Thickness: from 1 mm up to 10 mm**
- **Radius of curvature: flat crystal down to 1 m.**



MARMOT COMPLETE ANALYSER

- 30 cassette units
- 2790 silicon blades
- 75° angle coverage

Mosaic silicon crystals are also available at ILL. When sufficiently thick, mosaic silicon crystals offer an excellent alternative to replace highly oriented pyrolytic graphite crystals in some experimental setups.



POLARISING CRYSTAL MONOCHROMATORS

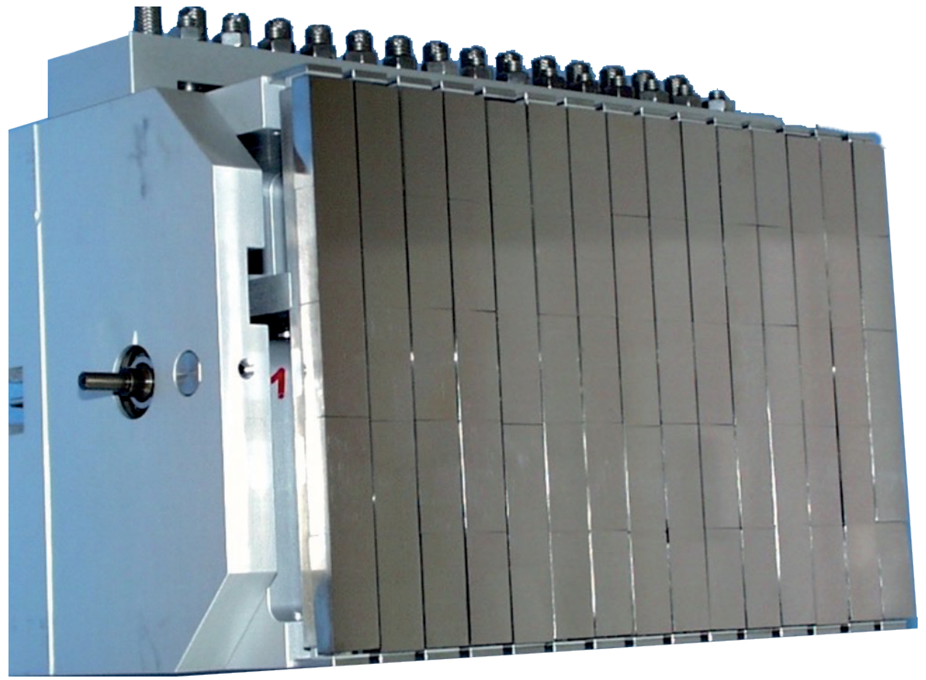
Magnetic intermetallic Heusler crystals, such as the Cu_2MnAl compound, offer an elegant solution for both monochromating and polarising a neutron beam. While these tertiary Heusler alloys possess a complex crystal structure that makes crystal growth particularly challenging, at ILL we are able to produce mosaic crystals with exceptional properties for polarised neutron applications.

Applications:

- Polarised neutrons triple-axis spectroscopy
- Diffractometers

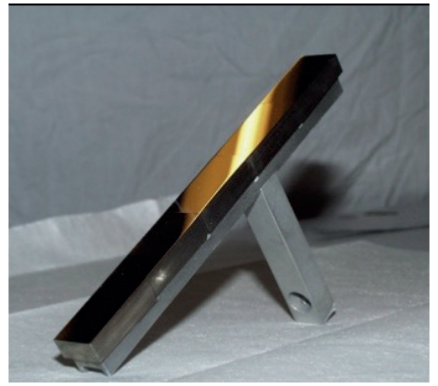
TECHNICAL SPECIFICATIONS

- Structure: $L2_1$
- Lattice constant: a = 5.949 Å
- Crystal reflections: (111)
- Neutron mosaic (FWHM): 0.2° - 0.6°
- Polarisation efficiency: P = 95%
- Peak reflectivity (wanted spin state): R = 50% at λ=1.7 Å (FWHM = 0.3°)
- Maximum dimensions: 80 x 20 mm^2



IN20 POLARISING HEUSLER MONOCHROMATOR

- 75 Cu_2MnAl crystals
- Crystal size: 30 mm x 15 mm x 7 mm
- Total area: 337.5 cm^2
- Average polarisation: 90%



The production of intermetallic Heusler crystals is a highly specialised process that begins with the precise formulation of the alloy prepared through induction melting. The stoichiometric polycrystalline ingot is then subjected to a controlled crystallisation process using the Bridgman technique. Finally, a carefully controlled heat treatment is applied to single-crystal plates to ensure a well-ordered crystalline structure, optimised for use in polarising neutron monochromators.

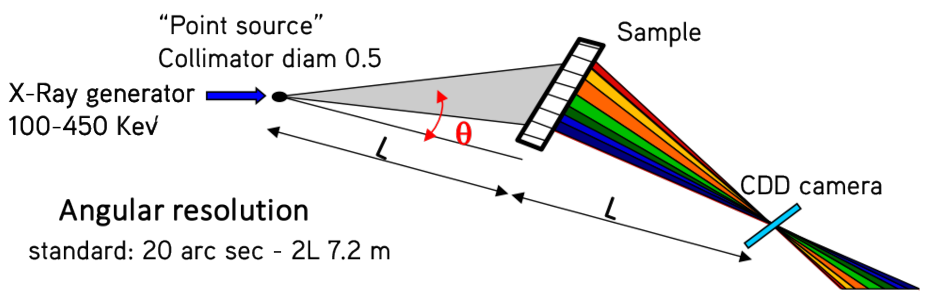
HARD X-RAY DIFFRACTOMETER

The hard X-ray diffractometer at ILL is a unique capability and a powerful tool for the non-destructive characterisation of large single crystals. By utilising high-energy X-rays, the instrument can penetrate deeply into dense, thick, or metallic materials, making it ideal for bulk studies and in-situ measurements of monochromator crystals or crystal ingots.

This diffractometer is essential for characterising the mosaic of single crystals during production and for the precise construction and alignment of crystals for monochromator assemblies. It also plays a crucial role in the development of advanced neutron optical components, such as multi-analyser systems for triple-axis spectrometers.

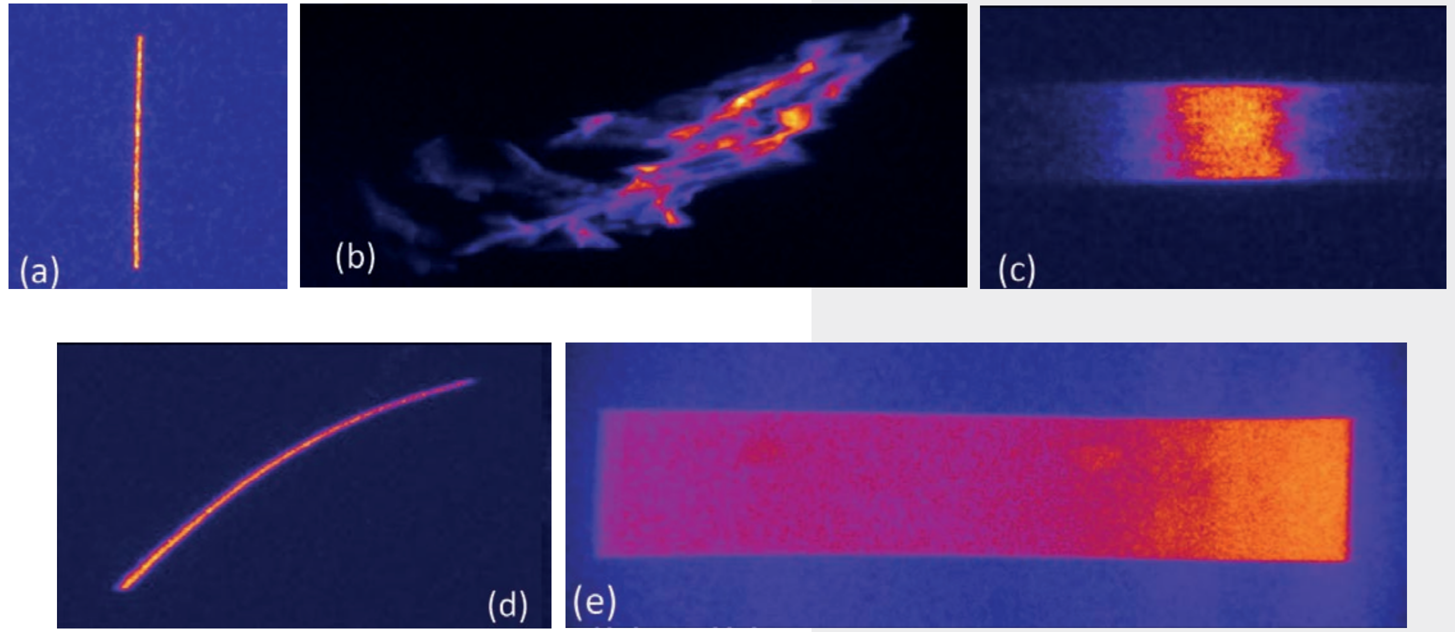
TECHNICAL SPECIFICATIONS

- Energy range: 50 keV to 450 keV (0.15 to 0.03 Å)
- X-ray focus: 0.4 mm x 1 mm
- 2D Detector: 200 mm Ø, spatial resolution 0.35 mm
- Acquisition time: a few seconds
- Lattice tilt sensitivity: 20 sec. of arc (2L=7.2 m)



Principle of the Hard X-Ray Diffractometer

The hard X-ray diffractometer employs focusing to generate Laue diagrams in a transmission geometry. The small Bragg angles and the long source-to-detector distance make this diffractometer highly sensitive to lattice tilts. In the case of a perfect crystal, the diffraction line width at the focal position matches the size of the X-ray generator's focus (a). In some cases crystal imperfections such as parasitic grains are clearly visible (b). Crystal mosaicity (c), lattice distortions (d), or curvature (e) broaden the diffraction peaks in a distinctive manner compared to that produced by an ideal single crystal (a).



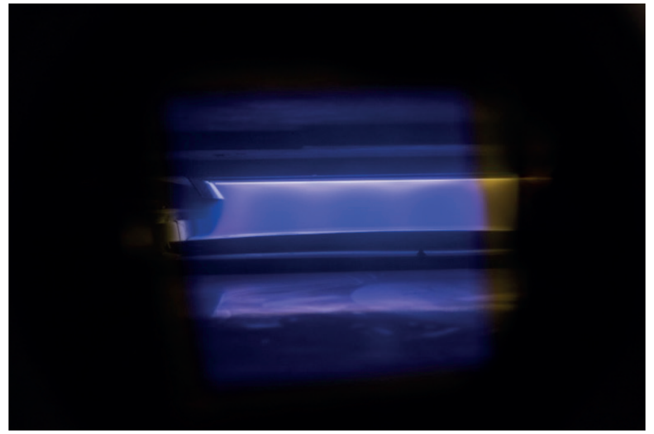
SUPERMIRRORS

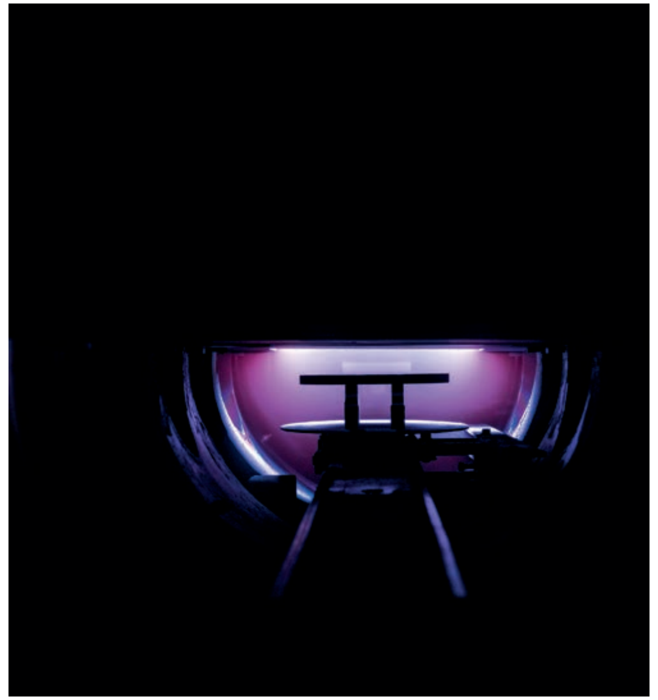
Neutrons totally reflect from material surfaces up to the critical angle, determined by the material's scattering length density (SLD). Critical angles vary with wavelength and material, with nickel having the highest reflection angle, quantified by the wavelength-normalised quantity 'm' (m = 1 for nickel).

Supermirrors are multilayer structures designed to reflect neutrons at angles exceeding the critical angle. These devices consist of alternating layers of materials with varying neutron scattering lengths. The performance of these supermirrors depends on layer thickness, composition, and perfection.

At ILL, supermirrors are manufactured using magnetron sputtering to deposit materials like Ni, Ti, Si, Co, Fe, and Gd with precise control of layer thickness on the nanometre scale. Layer number and gradation are optimised for specific neutron energies and angles to ensure high reflectivity and efficiency.

Polarising supermirrors use alternating magnetic material layers like Co-Ti or Fe-Si to preferentially reflect neutrons of one spin state while absorbing or transmitting the other. Substrate choice and geometry also play a crucial role in optimising performance.





NICKEL-TITANIUM SUPERMIRRORS

Due to their high neutron reflectivity, Ni-Ti supermirrors are the most commonly used type of neutron supermirror, often found in the coatings of high critical angle (m) neutron guides.

Ni-Ti supermirrors can also serve as long-wavelength filters, reflecting longer neutron wavelengths while allowing shorter wavelengths to pass. These devices are highly effective at removing unwanted neutrons, reducing instrumental background, and optimising the neutron beam for specific instrument setups, such as time-of-flight spectrometers and SANS.

TECHNICAL SPECIFICATIONS

- Ni-Ti supermirrors up to m = 4
- Non magnetic NiV-Ti supermirrors up to m = 4
- Reflectivity: 80% at m = 4
- Large size: max 500 x 800 mm

COBALT-TITANIUM POLARISING SUPERMIRRORS

The combination of Co and Ti multilayers enables the production of supermirrors that operate across a wide range of wavelengths and incident angles, achieving a high degree of polarisation for neutron beams.

Co-Ti multilayers are often deposited on thin glass substrates to construct polarising bender devices with optimised curvature. The bender geometry guides the desired polarised neutron beam along curved paths, providing high polarisation while absorbing the unwanted spin state and avoiding direct line of sight.

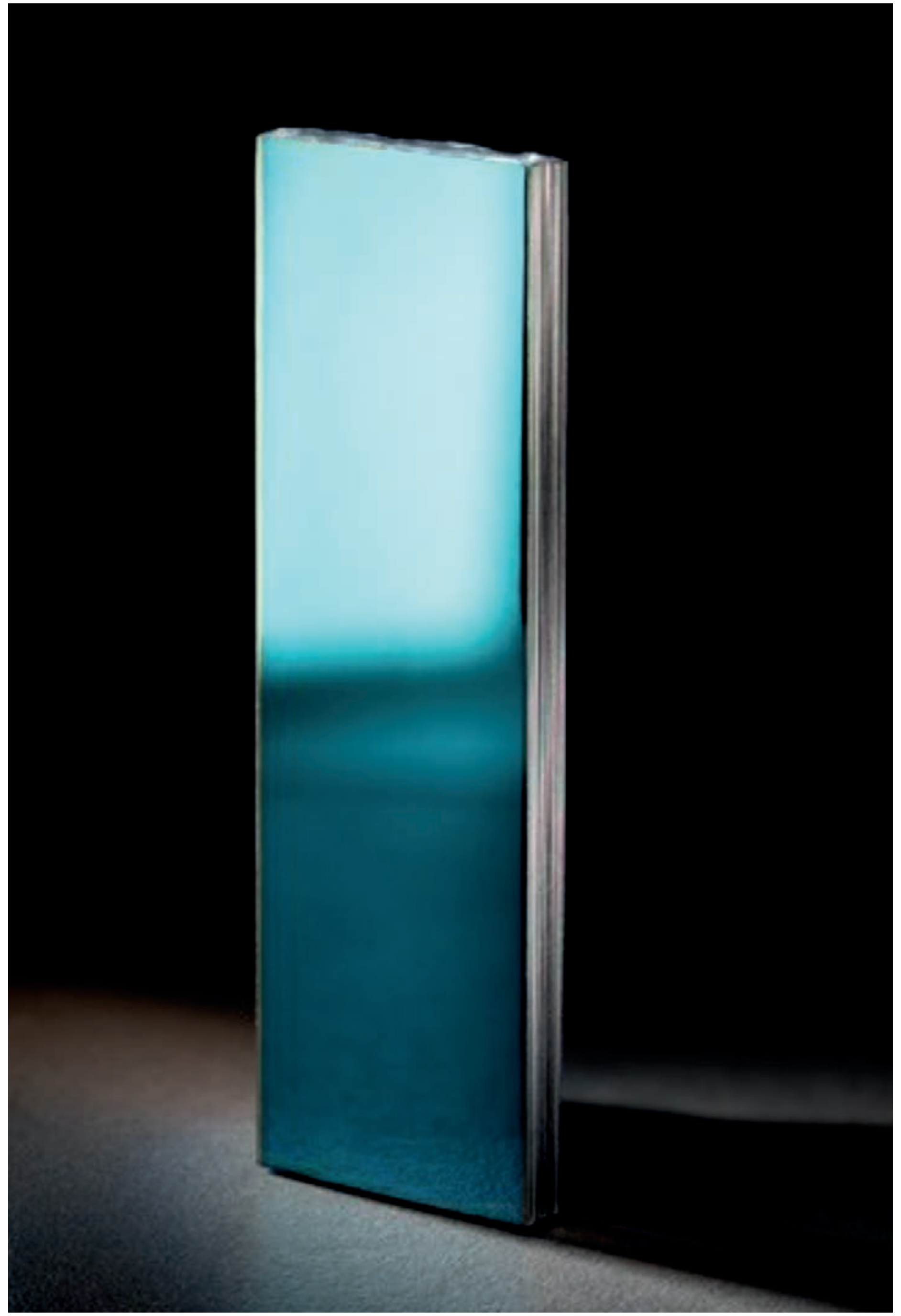
Applications:

- Wide-angle polarisation analysis
- Spin-echo
- Magnetic diffuse scattering

TECHNICAL SPECIFICATIONS

- Co/Ti/Gd supermirrors with m values up to 3
- Substrate: Glass
- Reflectivity: 60% for m = 3 supermirrors
- Polarisation efficiency on single reflection > 99%
- Large size: max 550 x 900 mm^2

Co-Ti supermirrors are fabricated using magnetron sputtering with a specialised deposition system developed at ILL. The inclusion of Gd layers eliminates parasitic reflections that degrade polarisation efficiency. Thanks to the high performance and production capacity of ILL's sputtering facility, a large number of mirrors have been produced, enabling the construction of extensive analyser banks for wide-angle polarised neutron instrumentation at ILL.



IRON-SILICON POLARISING SUPERMIRRORS

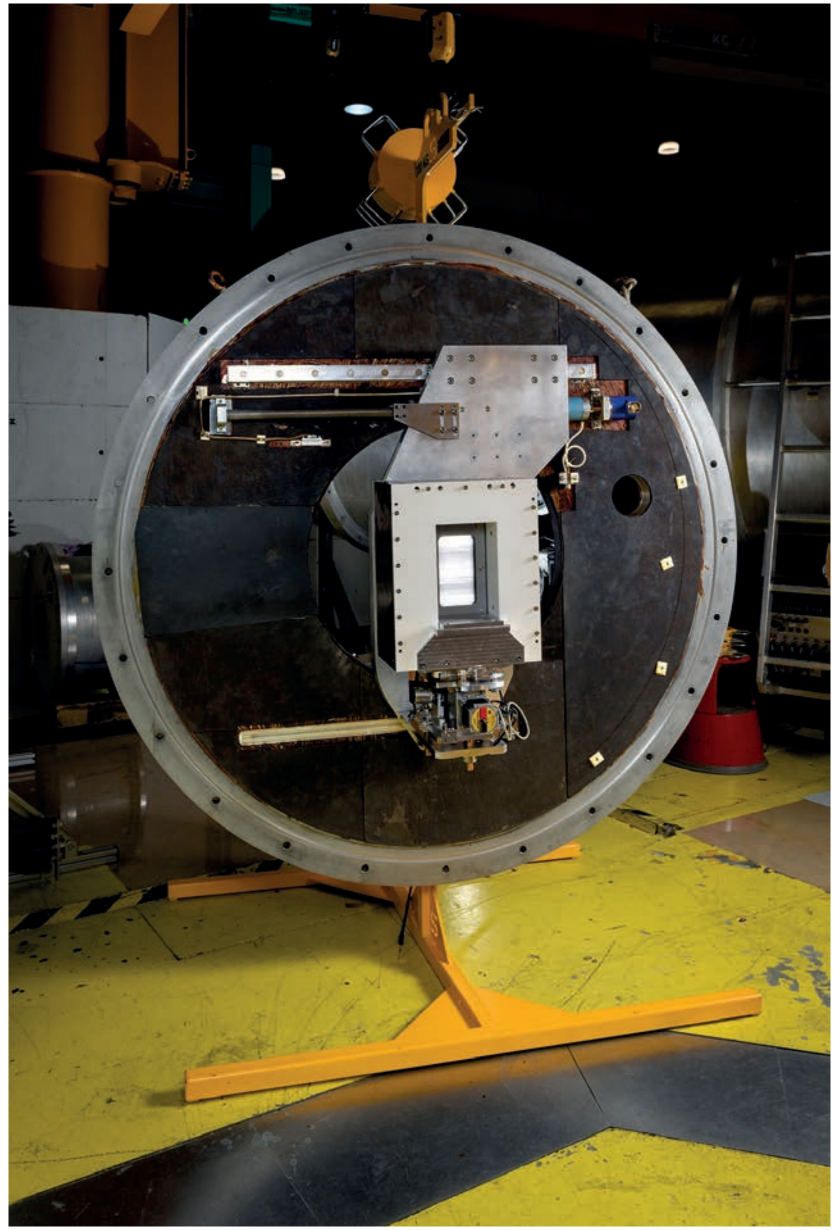
For certain applications, Fe-Si supermirrors provide superior performance in terms of both reflectivity and polarisation efficiency. However, their use in reflection geometry is limited, as total reflection for non-polarised neutrons occurs at small incident angles. Alternative coatings or geometries are employed to maintain consistent neutron polarisation over a wider angular range.

Applications:

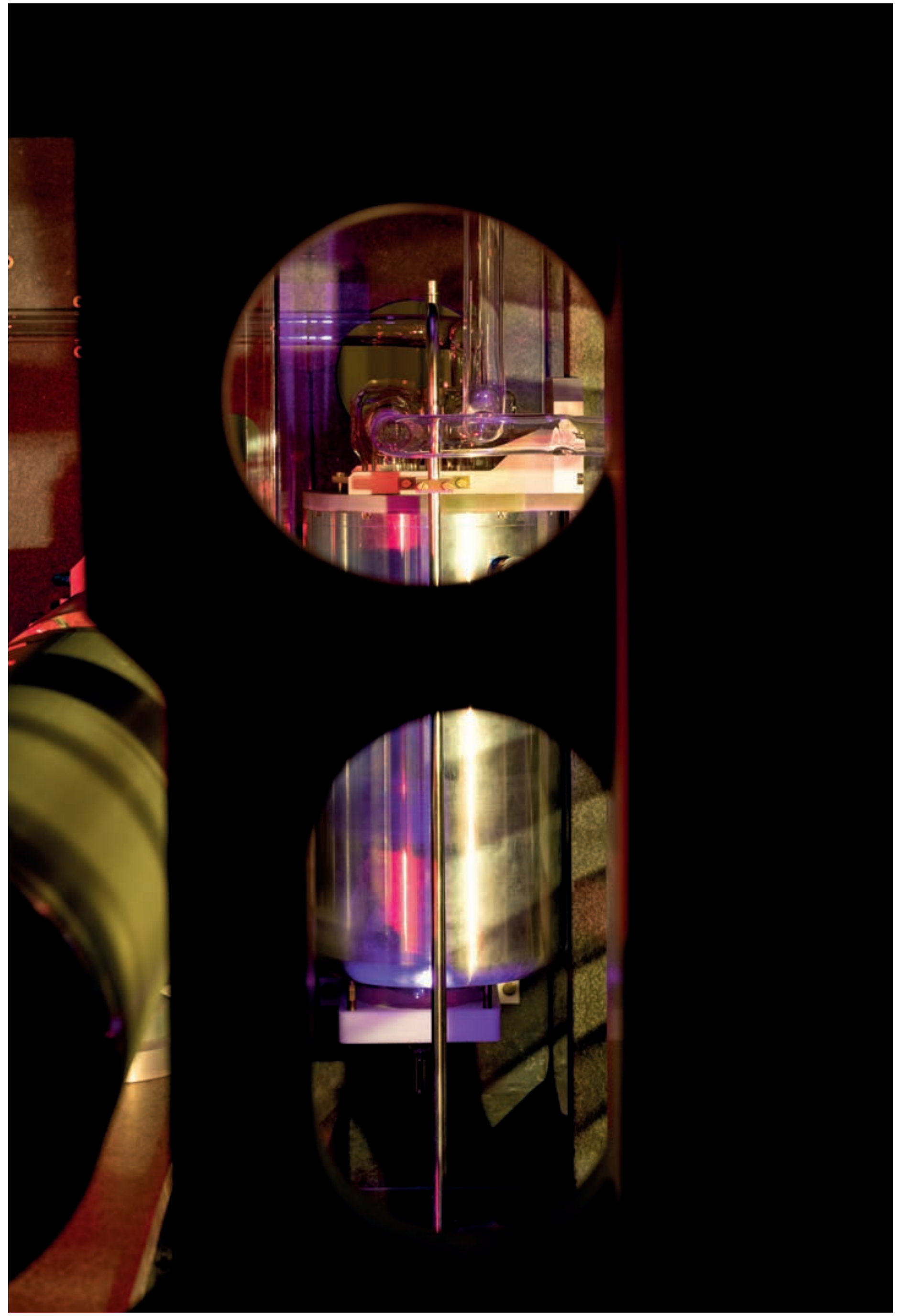
- Fundamental physics
- Reflectometry

TECHNICAL SPECIFICATIONS

- Fe/Si/Gd supermirrors with m-values up to 4
- Silicon or sapphire crystal
- Reflectivity: 80% for m=3 supermirrors
- Polarisation efficiency on single reflection > 98%
- Propagation medium in transmission geometry: sapphire or silicon

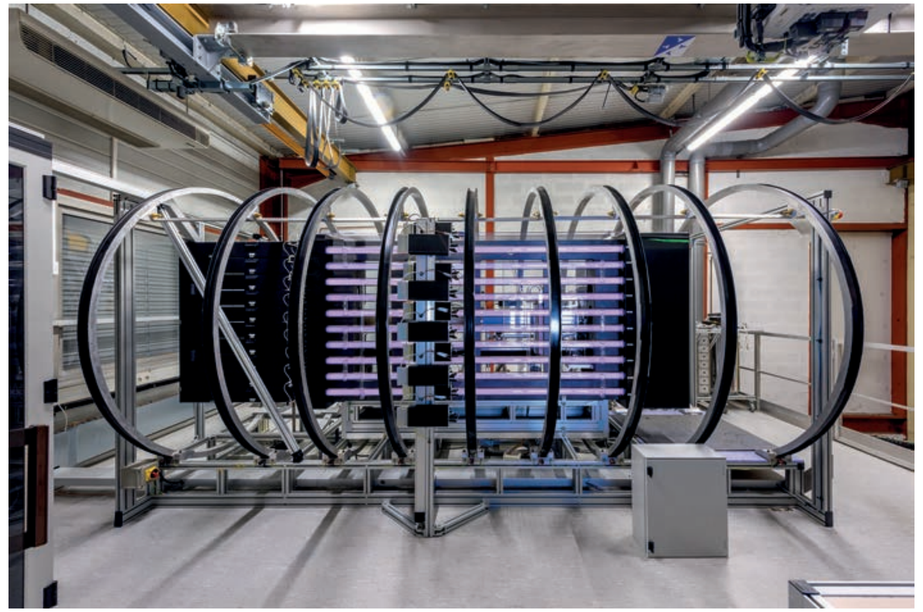


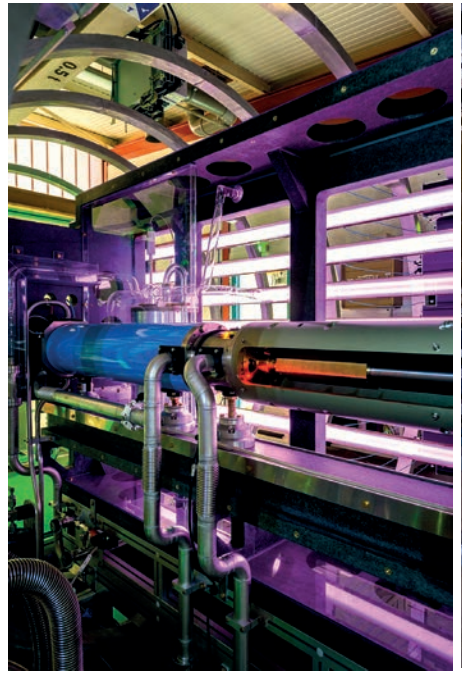
The development of solid-state polarisers made from Fe-Si supermirrors deposited onto sapphire or silicon substrates has greatly enhanced our polarised neutron capabilities at ILL. Fe-Si polarising devices are especially suited for instrumentation and experiments that require very high polarisation across a broad range of neutron wavelengths. We have developed an innovative V-shaped polariser, achieving an impressive polarisation exceeding 99.7%.

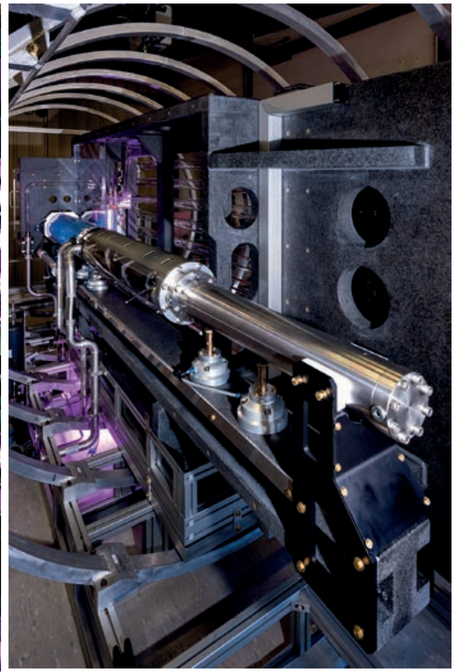


POLARISED ^{3}He

The neutron absorption cross-section of the ^{3}He isotope is highly dependent on the neutron spin state. ^{3}He only absorbs neutrons with the opposite spin to that of the ^{3}He nucleus, while its scattering cross-section is extremely small and essentially isotropic. These characteristics make polarised ^{3}He neutron spin filters (NSFs) highly efficient and a very "clean" technology for polarised neutron techniques. Polarised ^{3}He gas serves as a neutron spin filter, which can be used either to polarise the incident beam or for spin analysis of scattered neutrons after the sample.







TYREX2

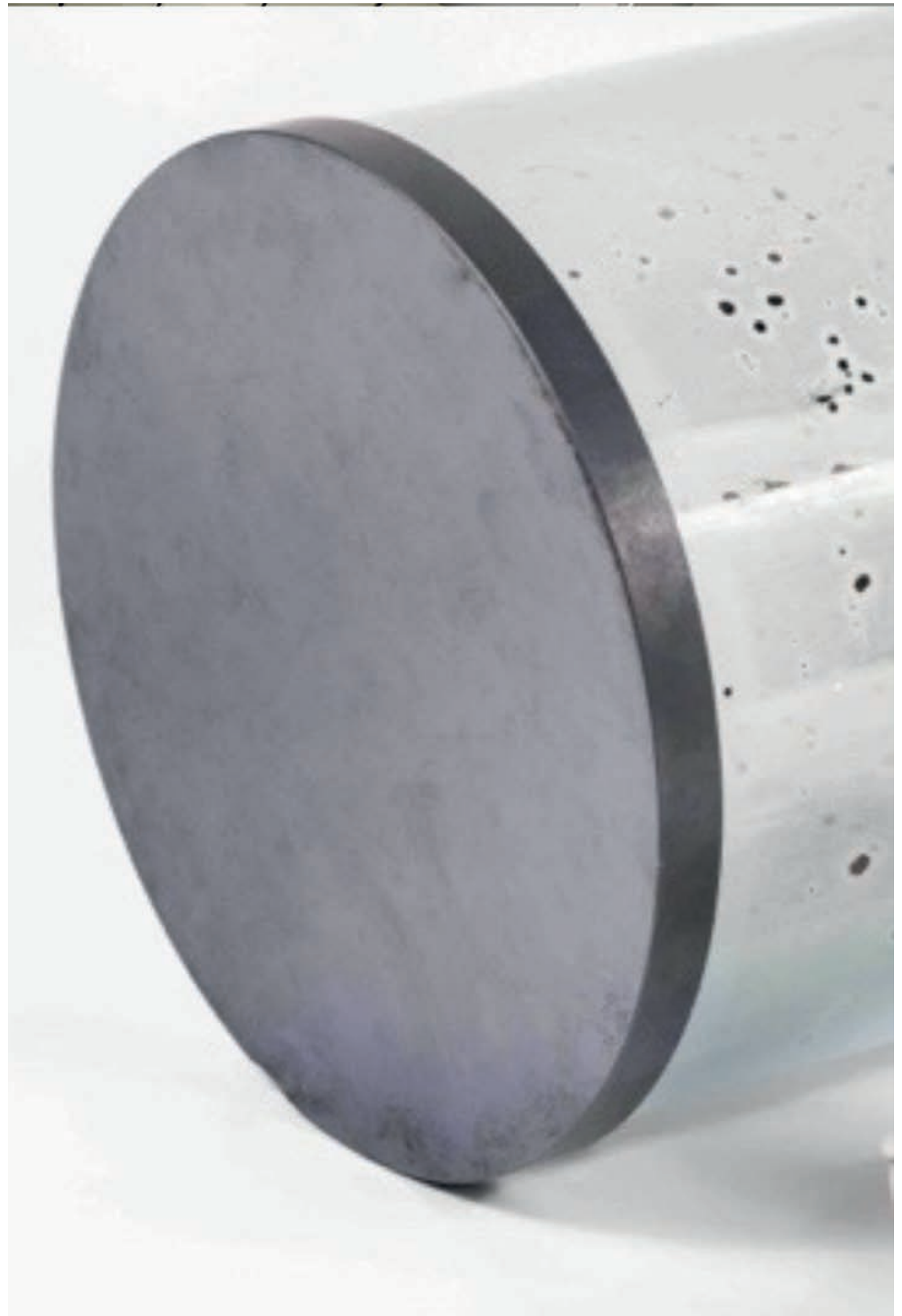
The TYREX2 machine at ILL is a specialised device for producing polarised ^{3}He gas, also known as the "^{3}He pumping station". It combines laser optical pumping, gas compression, and magnetic fields to achieve high polarisation levels of ^{3}He nuclei through a process called Metastability Exchange Optical Pumping (MEOP). Its high production capacity meets the demand for ^{3}He spin filters across our instrumentation suite.

TYREX2 is the latest advanced ^{3}He gas polarisation system, the result of over 20 years of continuous development by specialised teams at ILL.

A cooperation agreement has recently been signed between ILL and the European Spallation Source (ESS) to provide polarised ^{3}He capabilities for future ESS users.

TECHNICAL SPECIFICATIONS

- Production rate: 2.5 bar.litre/hour
- Polarisation: > 80%
- Hydraulic 10.6 litres compressor
- Pressure: up to 4 bar
- 100W lasers (10 x 10W)



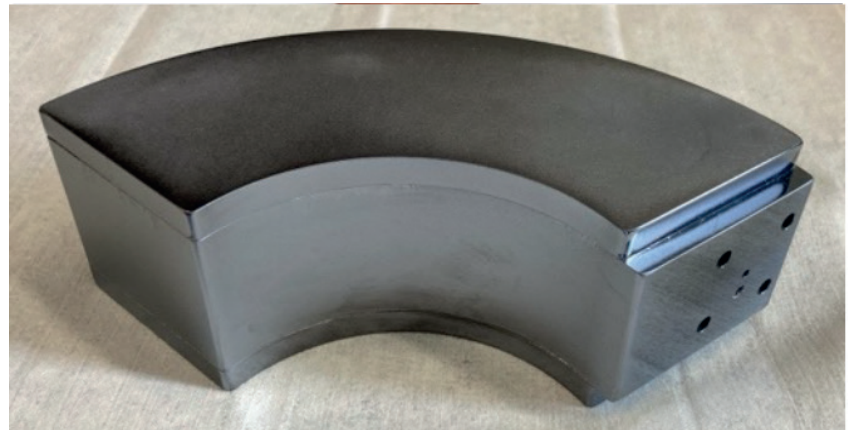
^{3}HE SPIN FILTER CELLS

Polarised ^{3}He gas is loaded from the TYREX2 pumping station into neutron spin filter cells (NSF) for transport and installation on polarised neutron instrumentation. The quality of the spin filter cells is crucial for maintaining polarisation and ensuring long relaxation times of the polarised ^{3}He gas. The relaxation of ^{3}He polarisation follows an exponential decay, with a typical decay time of around 100 hours when installed in the uniform magnetic field cavity of the 'magic box' on the instrument—long enough to conduct neutron scattering experiments.

^{3}He cells are manufactured in-house using high-purity materials such as borosilicate glass, aluminosilicate glass (Ge180), quartz, and single-crystal silicon, selected for their low neutron absorption and minimal background scattering. The addition of trace alkali metal elements is part of the 'black art' of achieving long relaxation times.

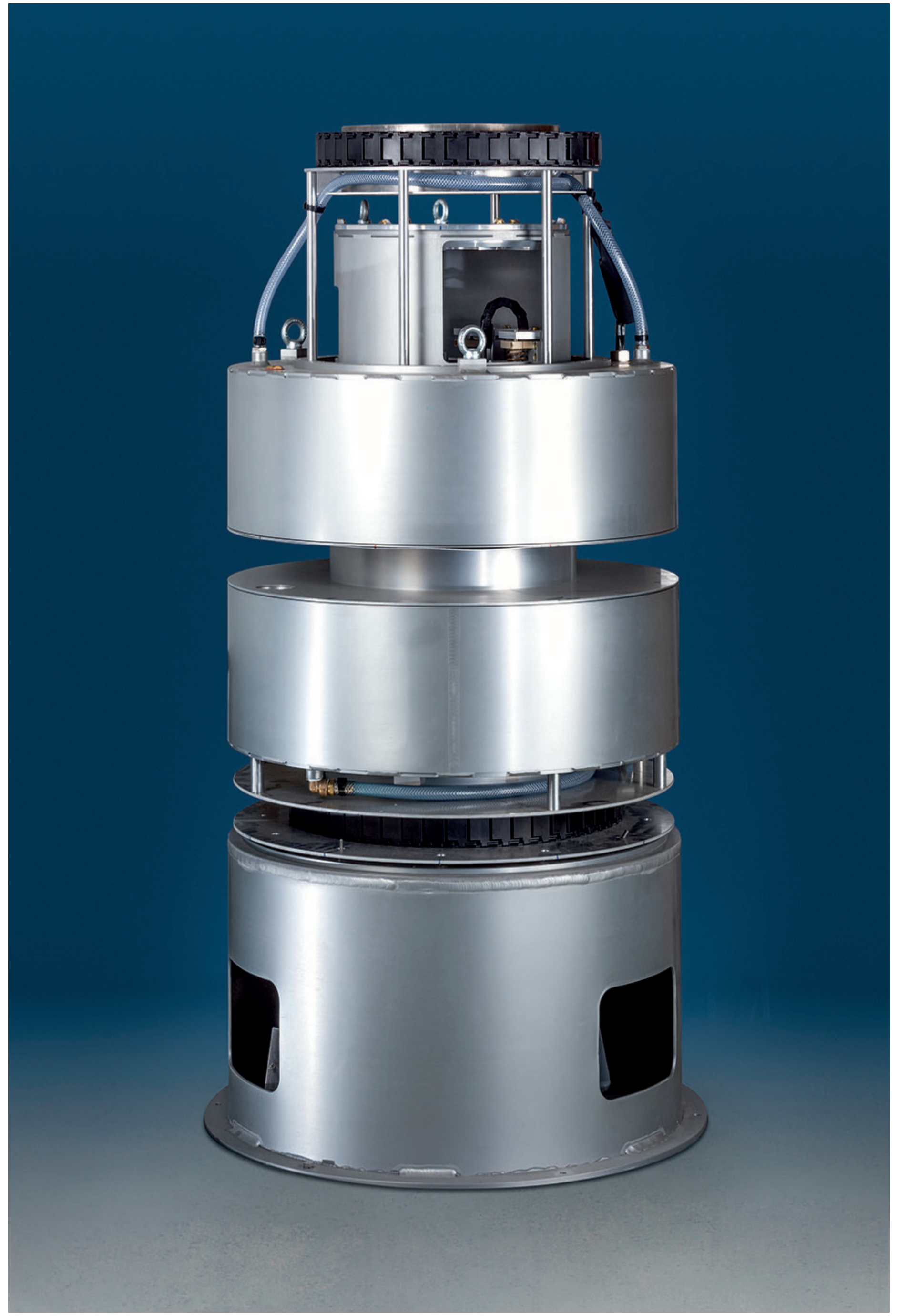
TECHNICAL SPECIFICATIONS

- Relaxation time, T1: 100 hours to 2000 hours
- Pressure: up to 4 bar
- Dimensions: up to 200 cm^2 - adapted to instrument requirements
- Shape: cylindrical, banana, rectangular



^{3}He cells are carefully designed and manufactured at ILL to ensure airtight seals, resistance to internal gas pressures up to 4 bar, and low neutron background and absorption. A special treatment of the internal surfaces reduces interactions that could degrade ^{3}He polarisation.

The geometry of each cell is tailored to meet specific instrument requirements and scattering geometries. Cylindrical filters are commonly used in small-angle neutron scattering (SANS) and reflectivity experiments, providing optimal coverage over a narrow angular range. In contrast, banana-shaped geometries are better suited for wide-angle polarisation analysis. This customisation ensures that ^{3}He spin filters perform optimally for various experimental polarisation analysis setups.

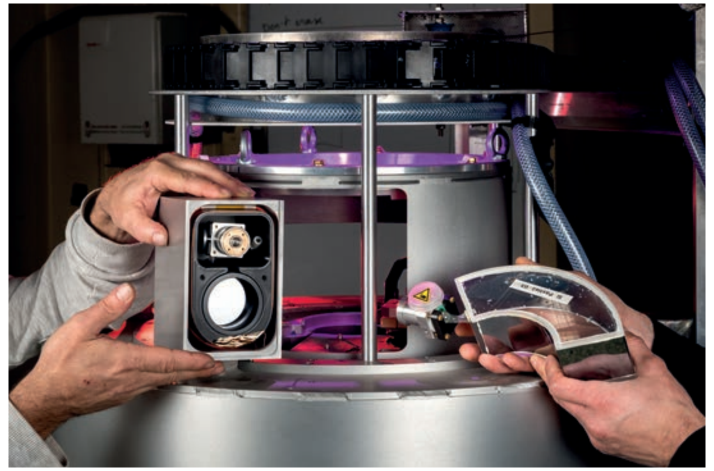


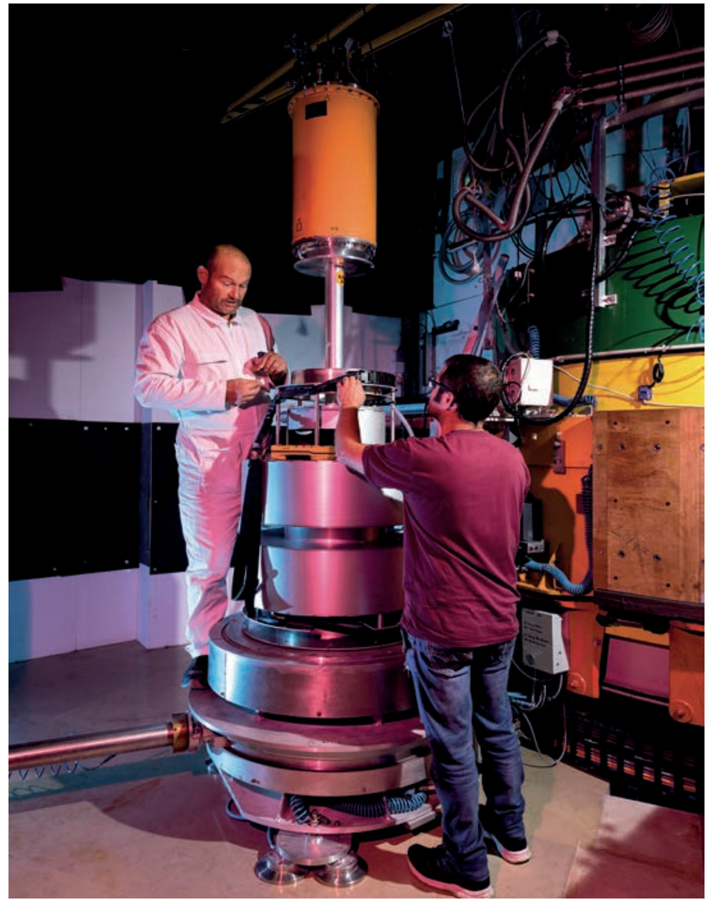
ADVANCED POLARISATION ANALYSIS: PASTIS3

The ability to control the polarisation direction of ^{3}He nuclei using external magnetic fields makes ^{3}He spin filters an exceptionally versatile tool for neutron polarisation analysis. By adjusting the magnetic field direction, the polarisation of the ^{3}He nuclei can be aligned or rotated, enabling full XYZ polarisation analysis experiments. This method is powerful for separating magnetic, nuclear coherent, and incoherent scattering, and is particularly well-suited for neutron instruments with wide-angle polarisation analysis.

TECHNICAL SPECIFICATIONS

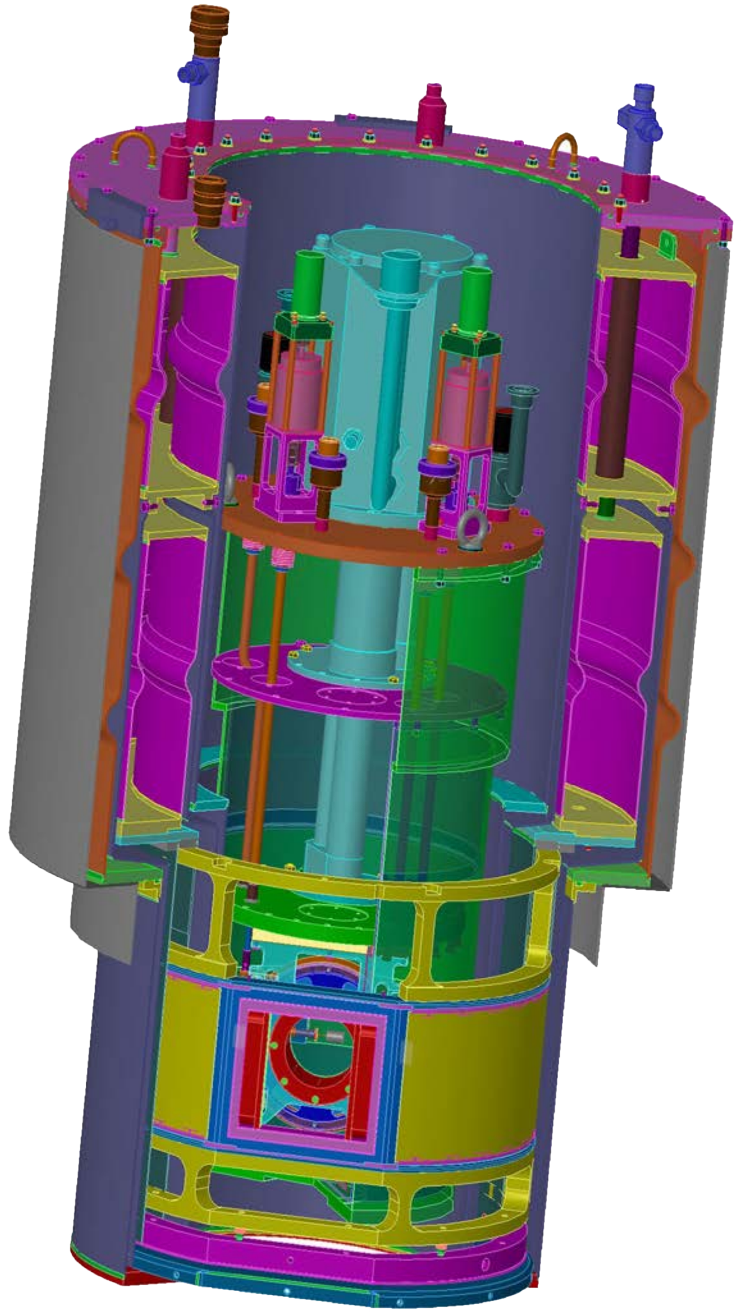
- Dimensions: 700 mm diameter
- Opening angle: 120° horizontal, 14° vertical
- Magnetic relaxation time, T1 (@ 1 bar): 500 hours to 5000 hours depending on field direction
- Overall relaxation time, T1: 80 hours to 150 hours (cell dependent)
- Magnetic field: 2 mT in any XYZ





PASTIS3 is an advanced device for wide angle XYZ polarisation analysis. It contains an iron-free magnetic system designed to allow blind-angle-free wide-angle XYZ spin-analysis. The incident neutron polarisation is provided by a ^{3}He NSF polariser equipped with a ^{3}He AFP spin flipper to reverse the incident neutron spin state. The polarisation after the sample is analysed using a second ^{3}He NSF as a wide-angle analyser.

PASTIS3 allows polarisation analysis for any direction of the magnetic field at the sample with an extremely homogeneous magnetic field over the cells to preserve the ^{3}He polarisation.



ADVANCED POLARISATION ANALYSIS: CRYOPAD

The changes in neutron spin direction that occur during scattering by a magnetic interaction vector are highly dependent on their relative orientations. In some cases, without decoupling the polarisations of the incident and scattered beams, it becomes impossible to distinguish between simple depolarisation and a rotation of the polarisation vector.

This issue is addressed with the CRYOgenic Polarisation Analysis Device (CRYOPAD), which uses superconducting screens to create independent magnetic field regions, enabling precise manipulation of the polarisation vectors of both the incident and scattered neutron beams.

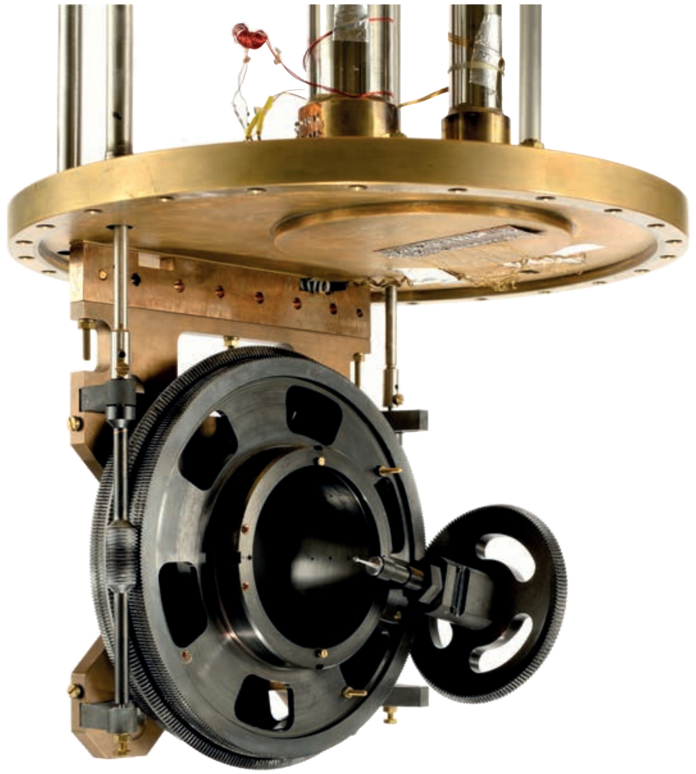
To allow single-crystal samples to be oriented in any direction within CRYOPAD, diffractometers utilise the CRYOCRADLE, a non-magnetic dry cryostat featuring an Eulerian cradle, which is cooled down to 3 K.

CRYOPAD systems are widely used at the ILL on diffractometers, three-axis spectrometers, and spin-echo spectrometers, and are also in operation at FRM II (Germany) and JAEA (Japan).

TECHNICAL SPECIFICATIONS

Cryopad

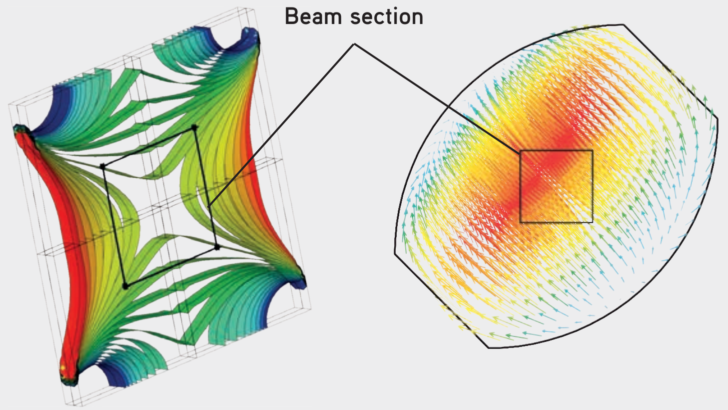
- Dimensions: Ø620 mm x 940 mm
- Sample space: up to Ø290 mm for hosting a non-magnetic sample environment, e.g. a cryostat
- Absolute angular precision: ±1° (±0.01° achieved)
- Scattering angle: -15° to +130°
- Magnetic field: less than 1 mT in the sample space
- Liquid He autonomy: 1 week with 20 litres



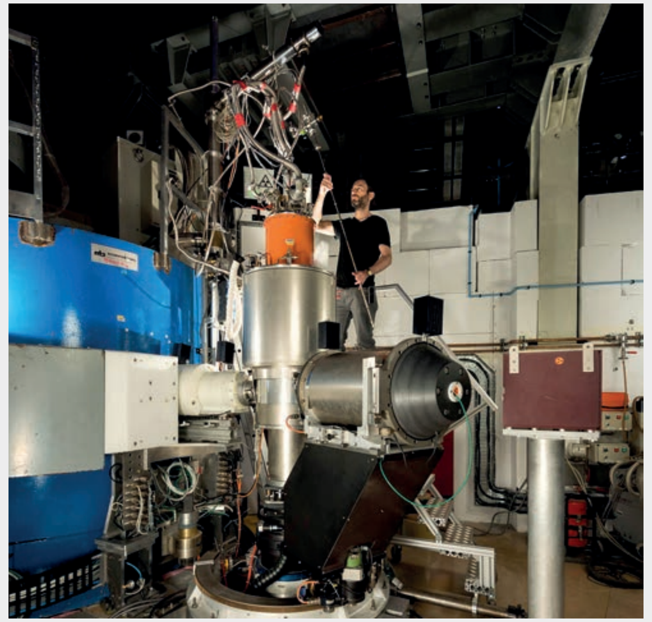
TECHNICAL SPECIFICATIONS

Cryocradle

- Dimensions: Ø263 mm x 900 mm
- Sample size: up to 10 mm x 10 mm x 10 mm
- Sample orientation: $-30 < \chi < +210°$, $-180 < \phi < +180°$
- Sample temperature: 3 to 300 K
- Absolute angular precision: ±0.3°
- Scattering angle: -40° to +120°
- Fully non-magnetic



Finite element analysis showing the homogeneity of the precession magnetic field (left) and of the magnetic field projected onto the outer superconducting screens of Cryopad (right).



Spherical neutron polarimetry on the hot neutron beam facility D3. The beam polarisation vector is manipulated by the Cryopad and analysed with a ^{3}He neutron spin filter.

ADVANCED POLARISER AND FLIPPER: CRYOPOL

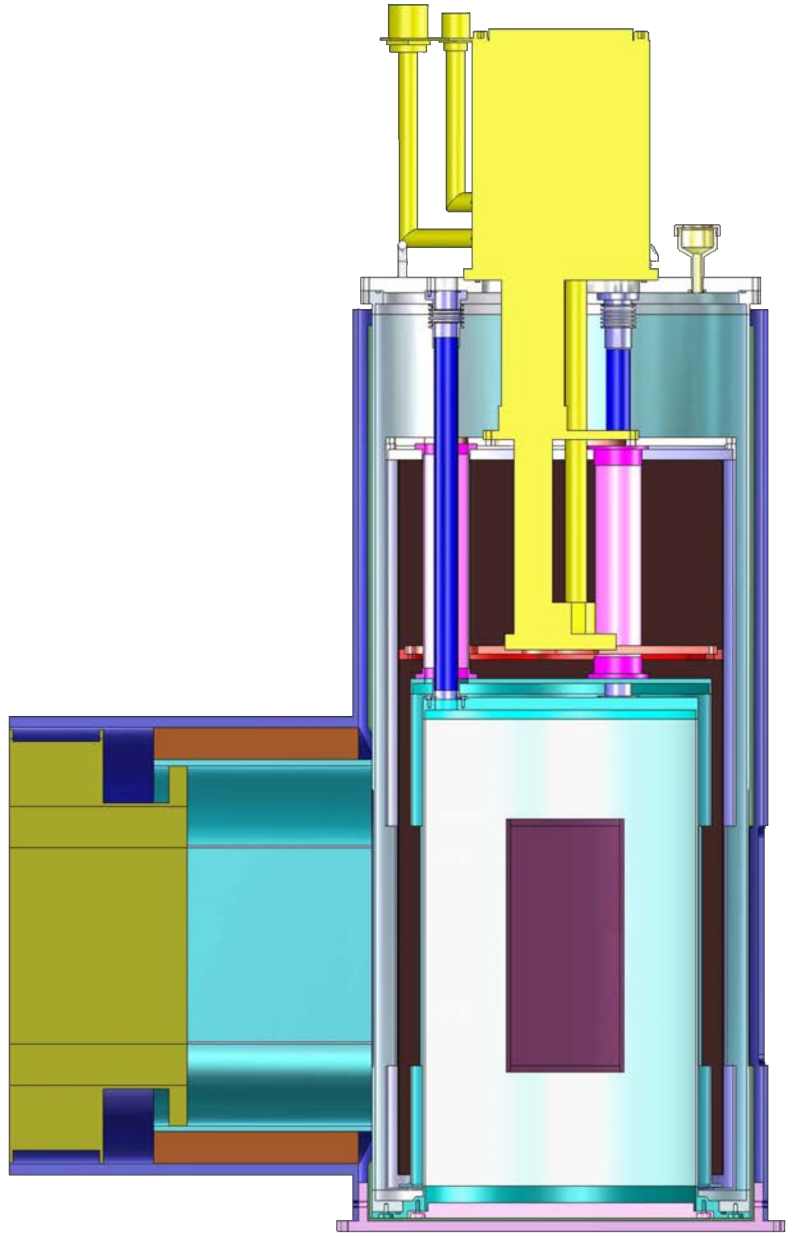
CRYOPOL is a unique device designed for polarising or analysing neutron beam polarisation using a ^{3}He spin filter, even in the presence of strong stray fields from a cryomagnet.

It features a superconducting cylinder that generates a stable, trapped magnetic field, preserving the ^{3}He polarisation while effectively shielding against external magnetic interference.

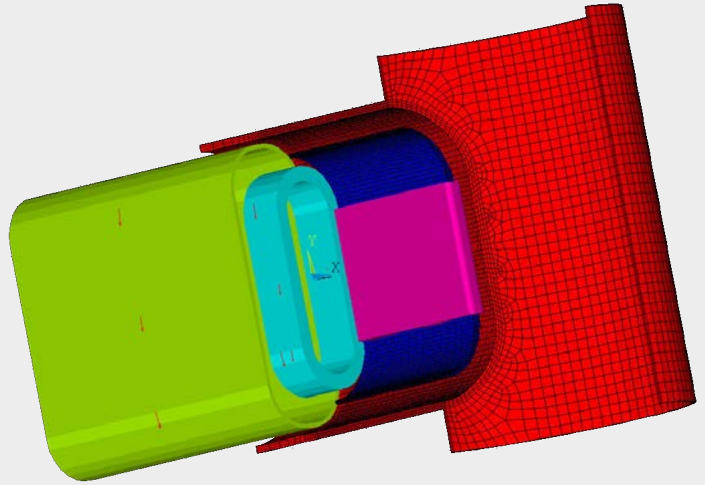
When combined with a nutator, CRYOPOL also functions as a highly efficient spin flipper, ensuring precise neutron polarisation control.

TECHNICAL SPECIFICATIONS

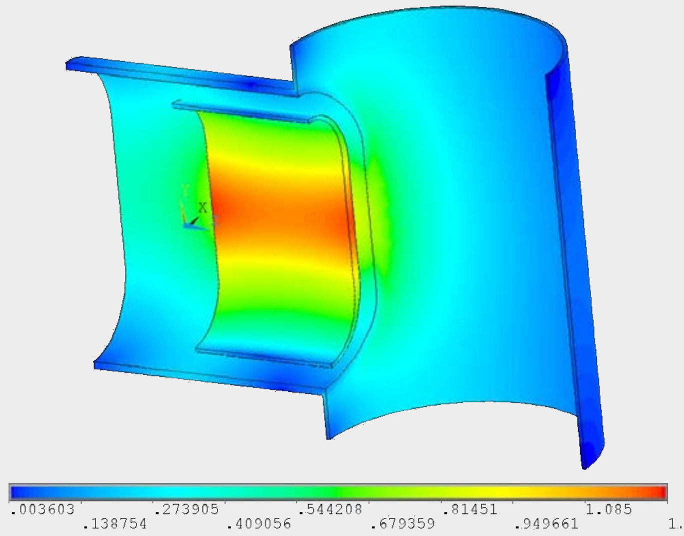
- Dimensions: Ø366 mm x 1100 mm
- Overall T1: 80-150 h (limited by cells and stray field)
- Beam size: up to 225 mm height, 100 mm width
- Magnetic field: 0.6 mT around the ^{3}He cell
- Surrounding magnetic field: up to 30 mT



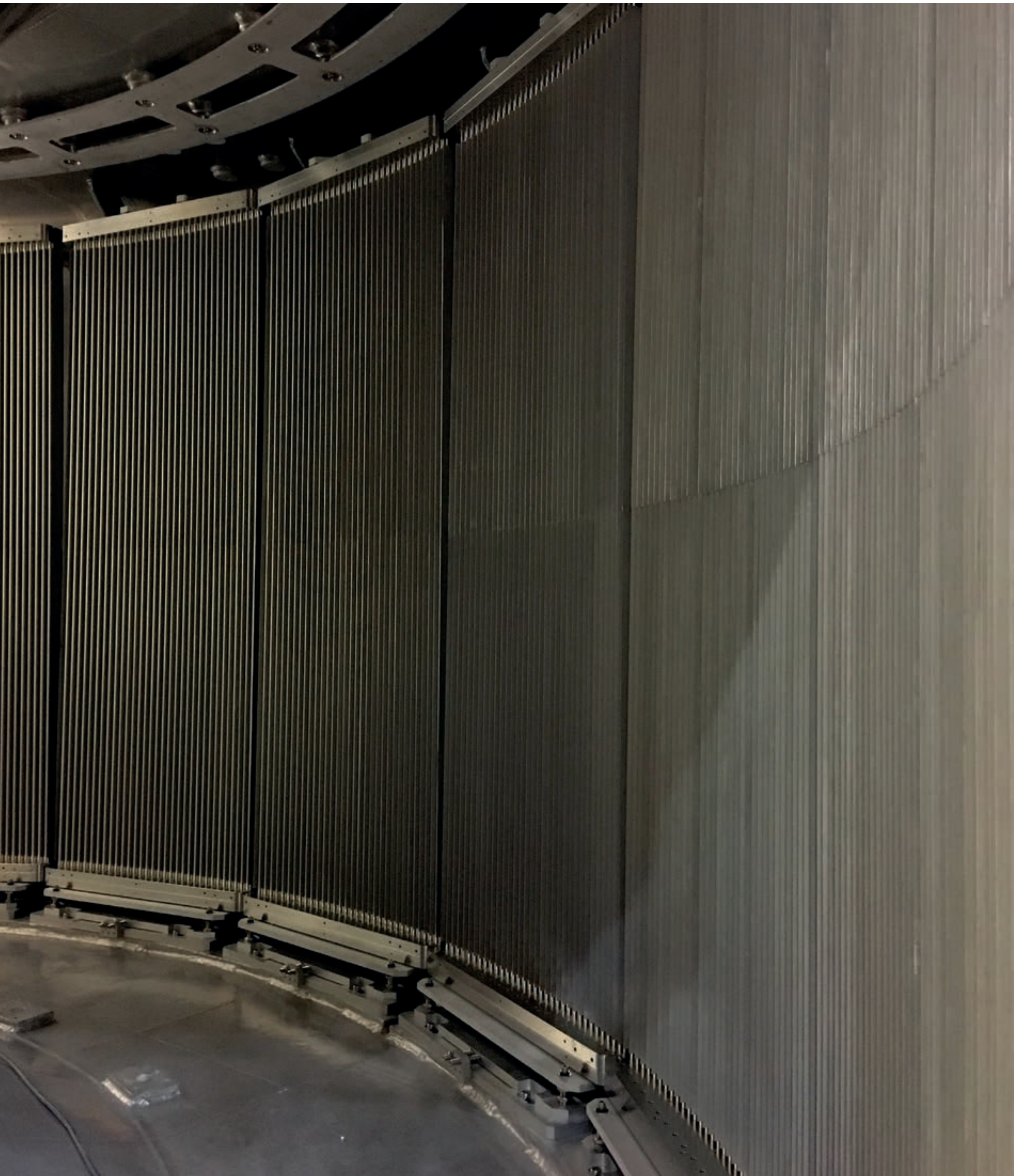
Cryopol & nutateur D20



Finite element analysis of the magnetic field screening and adiabaticity transport of the beam polarisation.



NEUTRON DETECTORS



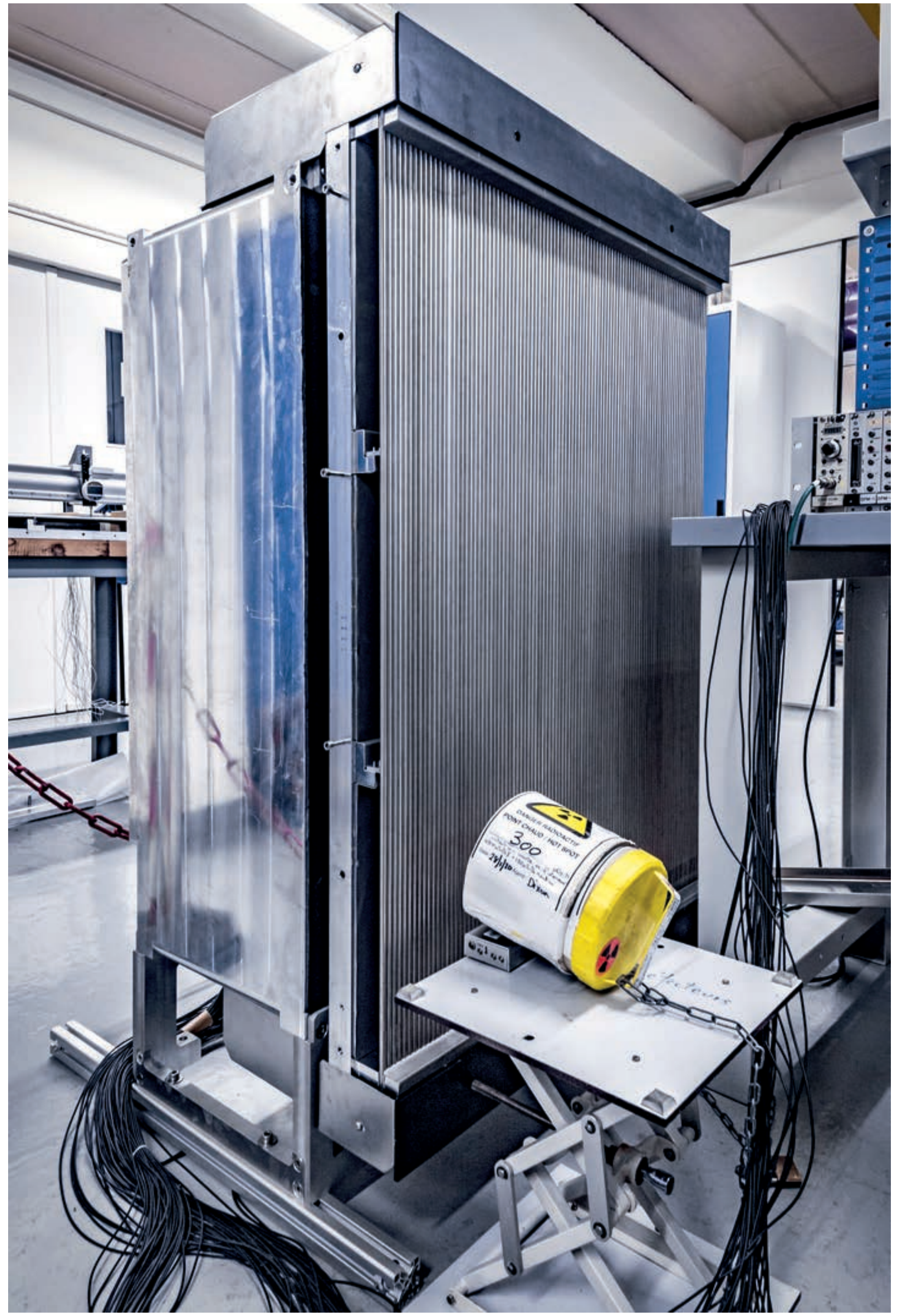
Neutron detectors are crucial to neutron scattering science and instrumentation. Improving neutron flux is of little value if the scattered neutrons cannot be detected efficiently with the required spatial and temporal resolution. Neutron detectors are often highly specialised, with many being one-off developments, which drives ILL's commitment to in-house detector development. High-quality detectors are essential for optimal instrument performance and generating top-tier science.

Depending on the instrument, detectors may have active areas ranging from a few cm² to several m², spatial resolutions between 1 mm and several cm, and counting rates from a few Hz to several MHz. It is critical to maximise detection efficiency and minimise background noise, such as gamma sensitivity. In most cases, these requirements are best met by detectors using pressurised ^{3}He gas as the detection medium.

Neutron gas detectors have been developed at ILL since the 1970s. Initially, single-unit counters filled with BF_3 isotopically enriched with ^{10}B were used. Later, Multi-Wire Proportional Counters (MWPCs) were introduced, and the toxic BF_3 gas was replaced by ^{3}He to improve detection efficiency and provide a safer working medium.

In the 2010s, due to a shortage and high cost of ^{3}He, ILL pioneered alternative ^{10}B-based detection technologies, such as the Boron Multiblade and Multigrid detectors. In recent years, ^{3}He availability has improved, and gas detectors continue to perform at the forefront. Many detector labs now have the capability to recover and purify ^{3}He from unused old detectors.

Research and development on ^{3}He detectors has gained renewed interest, focusing on two main techniques: Position-Sensitive Detectors (PSDs) and MWPCs. The ongoing development of both ^{3}He and alternative detectors continues to push the boundaries of neutron detection, keeping ILL at the forefront of this field.



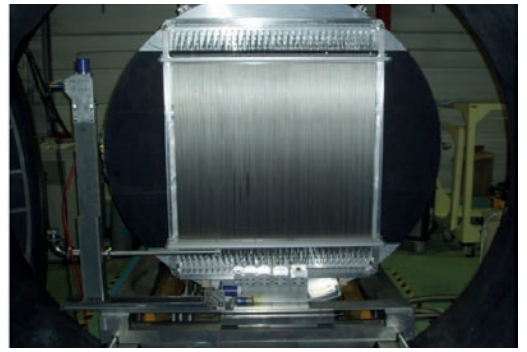
POSITION SENSITIVE LINEAR DETECTORS

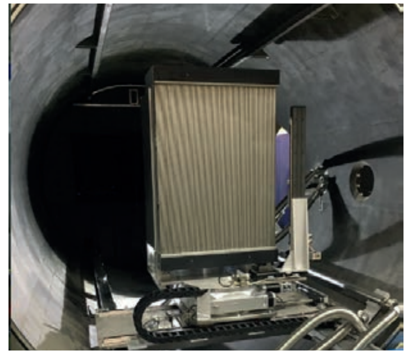
A position-sensitive detector (PSD) is a tube filled with high-pressure ^{3}He gas, containing a resistive anode wire centrally mounted and operated at high voltage. When a neutron interacts with a ^{3}He atom, a proton and a tritium are emitted, ionising the gas. The resulting charge is amplified, and signals are recorded at both ends of the wire, allowing the interaction position to be calculated through charge division.

Tubes with a 2.5 cm (1 inch) diameter and 1 m length have been successfully used in large PSD panel assemblies for time-of-flight spectrometers, particularly at ISIS. ILL collaborated with Reuter Stokes to develop PSDs with an 8 mm diameter and 1 m length for large panel detectors in small-angle neutron scattering (SANS) instruments at ILL. The D22 instrument was the first to replace its multi-wire proportional counter (MWPC) detector with a PSD panel, followed by D11. Today, PSD panels are widely used in neutron facilities worldwide.

TECHNICAL SPECIFICATIONS (D11)

- Sensitive area: 2 m^2
- Spatial resolution: 6 mm x 8 mm
- Max counting rate: 3 kHz/mm^2 (local irradiation), 100 kHz per tube (global irradiation)
- Detection efficiency: 90% at 1 nm

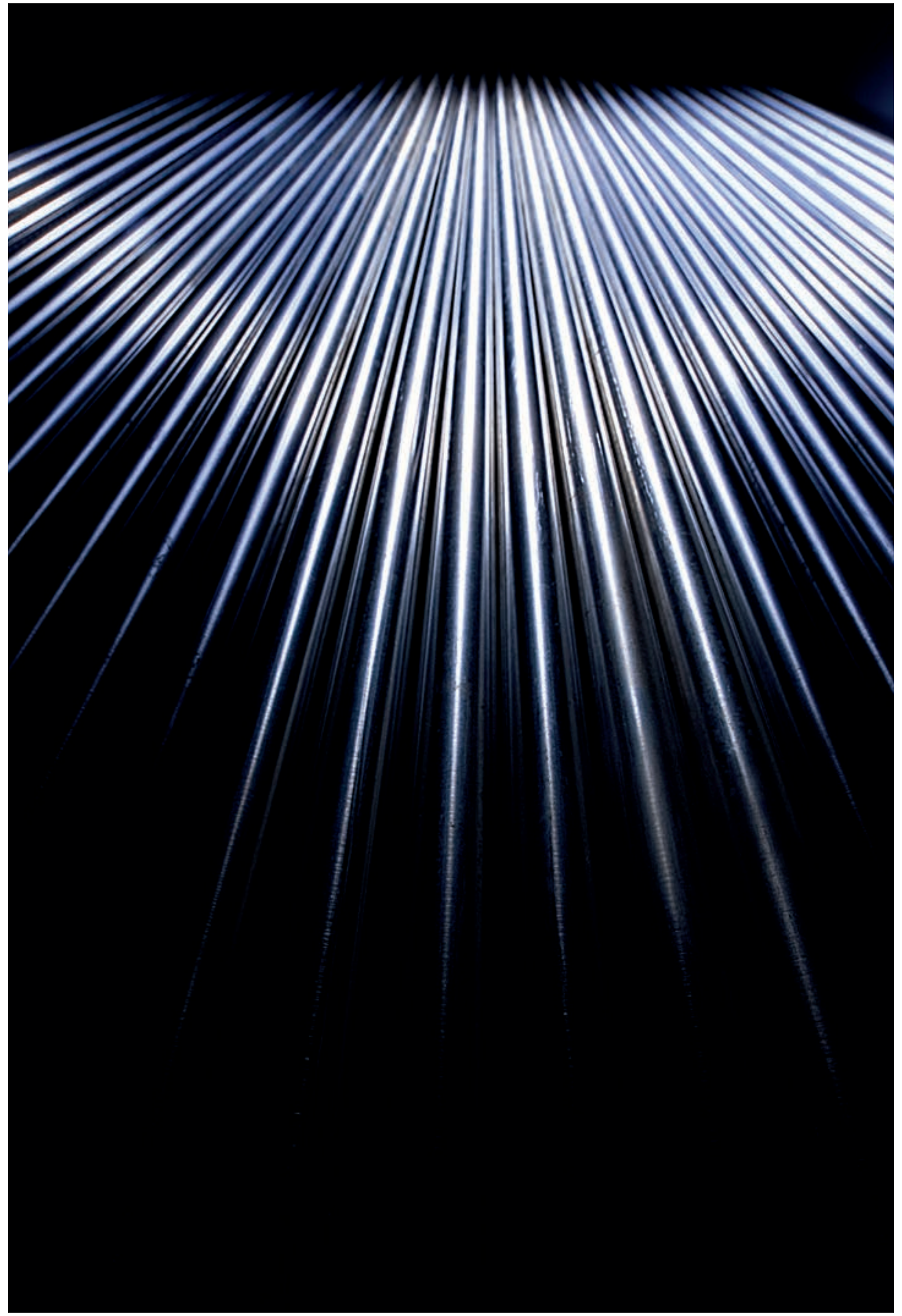




The D22 detector consists of two PSD panels: a central panel with 128 PSDs, covering an active area of 1 m². Mounted on a trolley, it can move along the neutron flight direction within the vacuum tube to measure neutrons scattered at small angles. A second wide-angle panel with 96 PSDs covers 0.76 m² and is fixed inside the vacuum tube, close to the sample position (1.3 m).

The D11 detector features 256 PSDs, arranged as a central panel with 192 horizontally mounted tubes and two side panels with 64 vertically mounted tubes, similar to the D22 detector. The ^{3}He gas pressure is 15 bars for the D22 detectors and 10 bars for the D11 detectors.

A key advantage of this technique is the ability to count neutrons interacting in separate PSDs simultaneously. By assembling detectors with many PSDs side by side, counting rates can be achieved that are 1 to 2 orders of magnitude higher than those of MWPC detectors. To fully exploit their performance, precise mechanical alignment is essential, requiring accuracy within a few tenths of a millimetre.



MULTITUBE DETECTORS

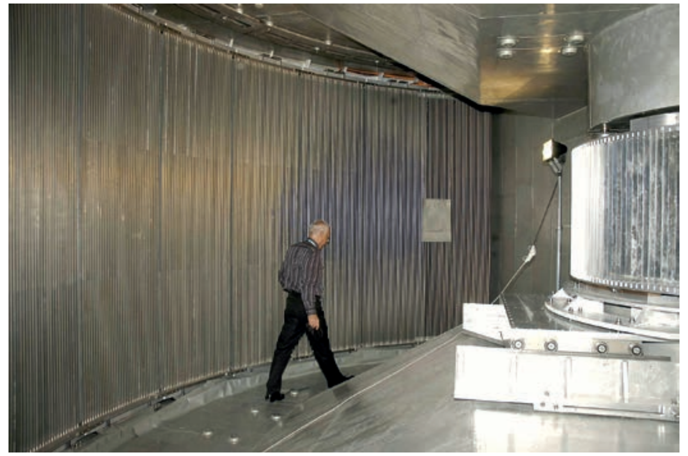
Panels of multitube detectors are similar to arrays of individual PSDs but with a different manufacturing process. In large-area multitube detectors, many stainless steel tubes (typically 32) are welded onto common flanges at both ends. These flanges are hermetically sealed with aluminium covers to contain the ^3He gas, with connected tubes sharing the same gas volume.

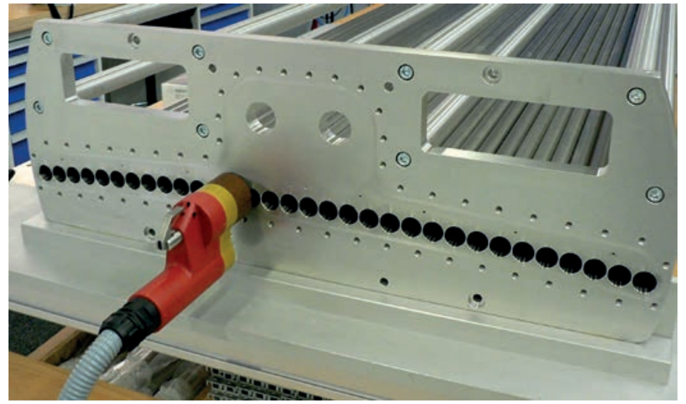
This design offers several advantages over individual PSDs. The tubes are mechanically more precise, especially concerning the centring of the anode wire, making them more robust and reliable. There is no need for additional mechanical support, reducing complexity and manufacturing costs. Additionally, the pressure and composition of the common gas mixture can be adjusted as needed.

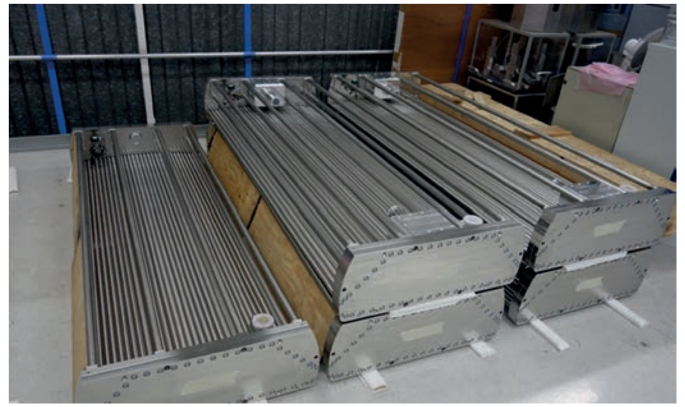
Large detection areas are achieved by mounting several multitube modules side by side, with the spacing between them corresponding to the width of one tube. This dead space is often used for large cadmium baffles to reduce instrumental background.

TECHNICAL SPECIFICATIONS (IN5)

- Sensitive area: 30 m^2
- Spatial resolution: 25 mm x 25 mm
- Max counting rate: 1 kHz/mm^2 (local irradiation), 50 kHz per tube (global irradiation)
- Detection efficiency: 82% at 0.45 nm

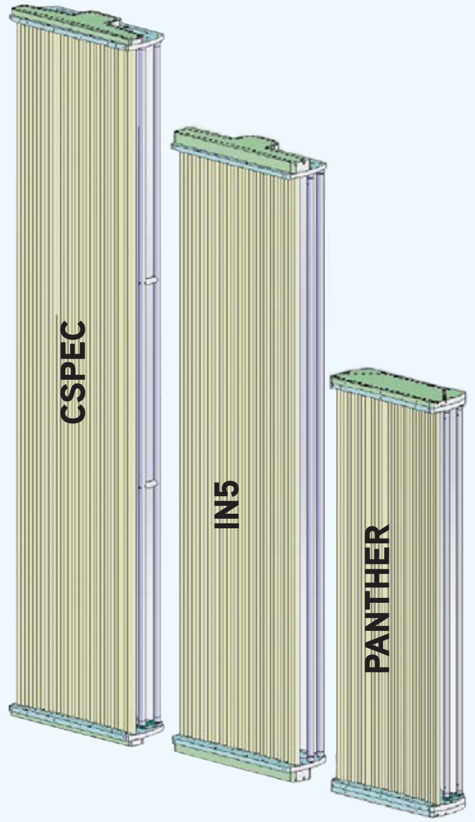


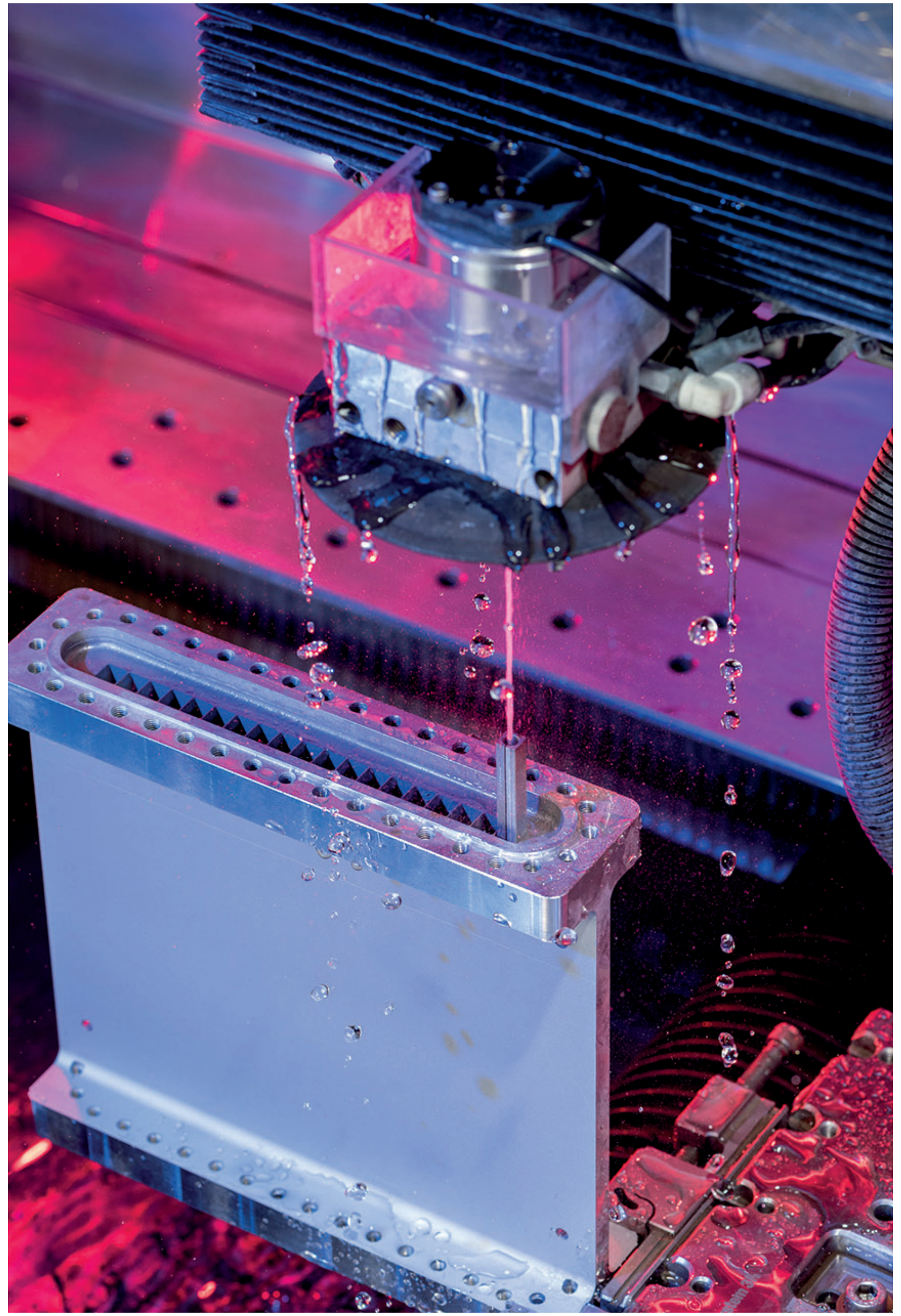




The detector on the IN5 chopper time-of-flight (TOF) spectrometer consists of an array of 12 multitube modules, each containing 32 PSDs, with a length of 3 m and a diameter of 2.5 cm.

Following the success of the IN5 multitube detector array, several other instruments have adopted this technology, including EXED at HZB and PANTHER at ILL. In 2024, ILL and ESS began a collaboration to develop a multitube detector with tubes of 2.5 cm diameter and 3.5 m in length for the CSPEC instrument.





MONOBLOCK ALUMINIUM DETECTORS (MAM)

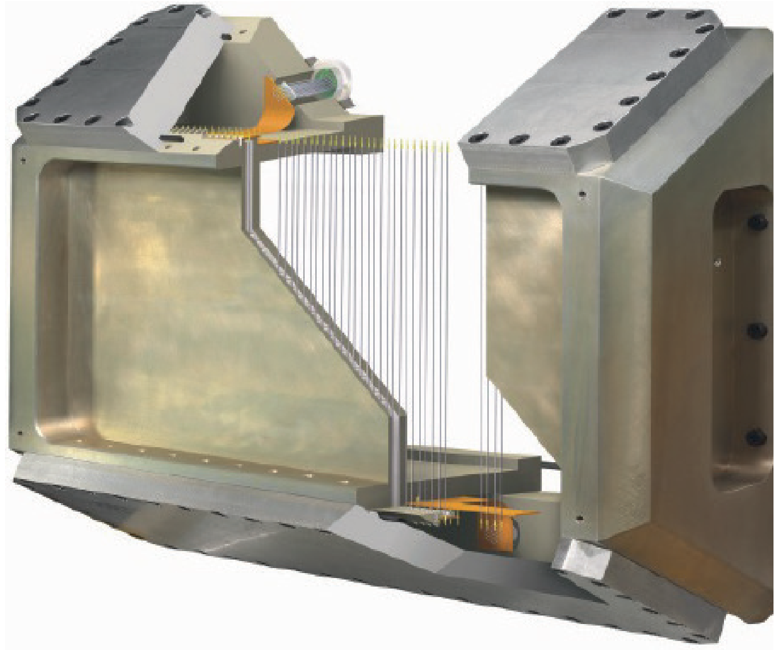
Position-sensitive detectors with a diameter smaller than 8 mm are challenging to produce. The Monoblock Aluminium Multitube (MAM) detectors address this demand for smaller diameter, providing higher spatial resolution in PSD arrays. High-precision machining at ILL has enabled the development of these detectors, which are used on the D17 and FIGARO reflectometers and the D33 SANS instrument.

MAM technology offers several key advantages over cylindrical PSD tubes:

- Thin walls (as thin as 0.2 mm) significantly reduce background noise caused by neutron scattering from the detector materials. This feature is actively used in several ILL instruments equipped with beam monitors using this design.
- Aluminium is more neutron-transparent than stainless steel, reducing background and absorption from neutron scattering within the detector material.

TECHNICAL SPECIFICATIONS (FIGARO)

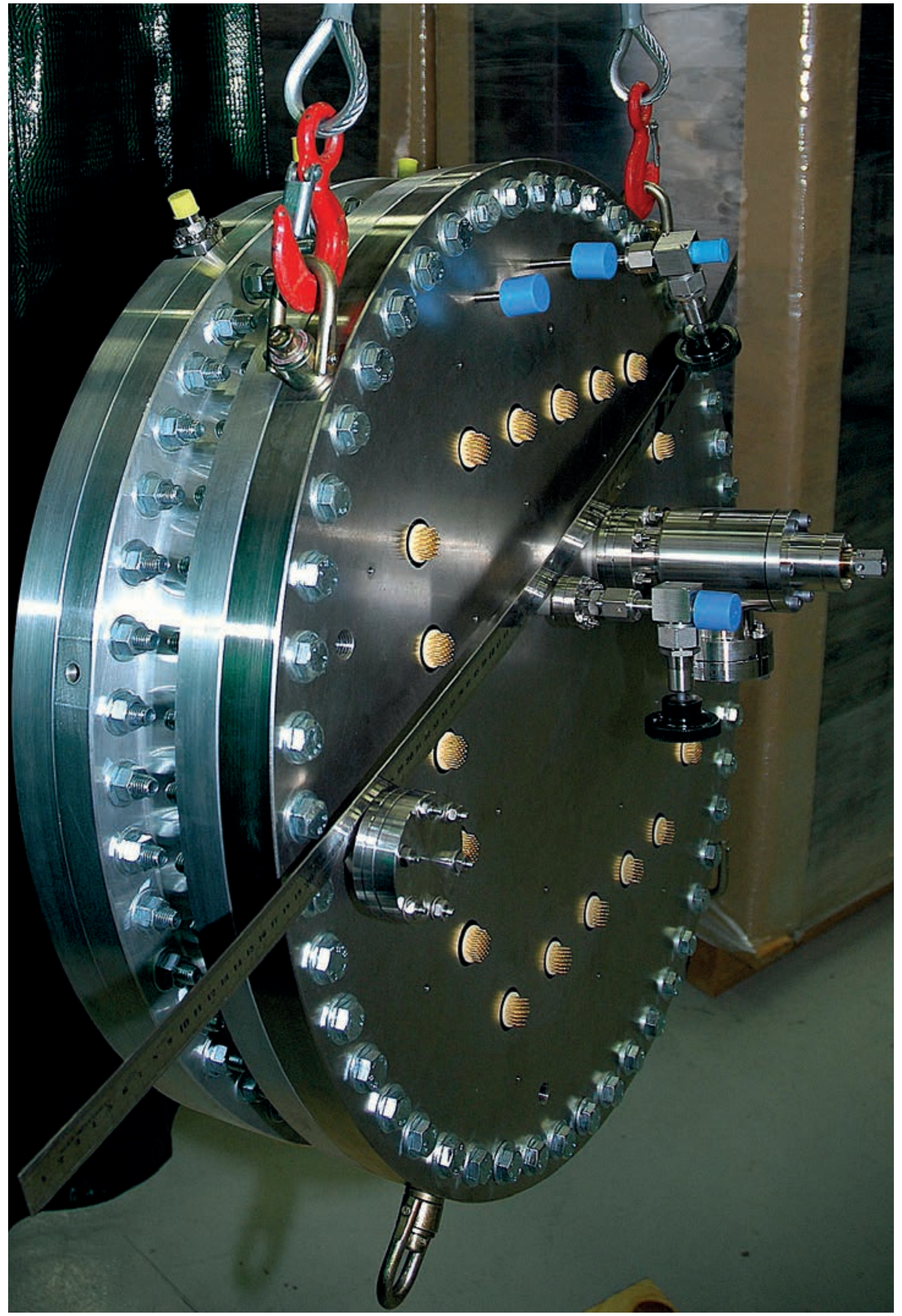
- Sensitive area: 20 cm x 47 cm
- Spatial resolution: 2.5 mm x 7.4 mm
- Max counting rate: 3 kHz/mm^2 (local irradiation), 100 kHz per tube (global irradiation)
- Detection efficiency: 80% at 0.45 nm



MAM detectors are fabricated by machining tubes from a single block of aluminium using wire electrical discharge machining (wire EDM or spark erosion machining). Detectors with square-section tubes as small as 4 mm × 4 mm have been successfully manufactured.

Due to their versatile geometry, Multitubes and MAMs have been developed for a wide range of applications, including backscattering, inelastic scattering, diffraction, reflectometry, and SANS. To date, 14 instruments worldwide are equipped with these types of detectors: 9 at ILL and 5 at other neutron research institutes, totalling 1,830 tubes, including 6 Multitubes and 8 MAMs.

The design render shows a cross-section of the detector for the FIGARO reflectometer, highlighting the main components: the central block with the tubes, anode wires mounted in the middle of the tubes, connection circuits, and electrical feedthroughs.



MULTI-WIRE PROPORTIONAL COUNTERS (MWPC)

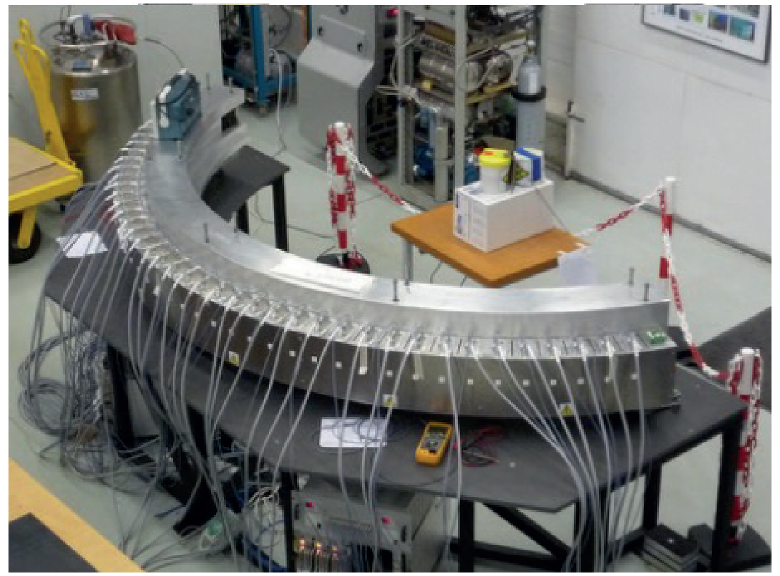
A multi-wire proportional counter (MWPC) detector consists of a conversion gap where neutrons are captured by the ^3He gas, followed by three detection wire planes: an anode wire plane between two cathode wire planes. Negative signals are produced on the anode wires and positive signals on the cathode planes.

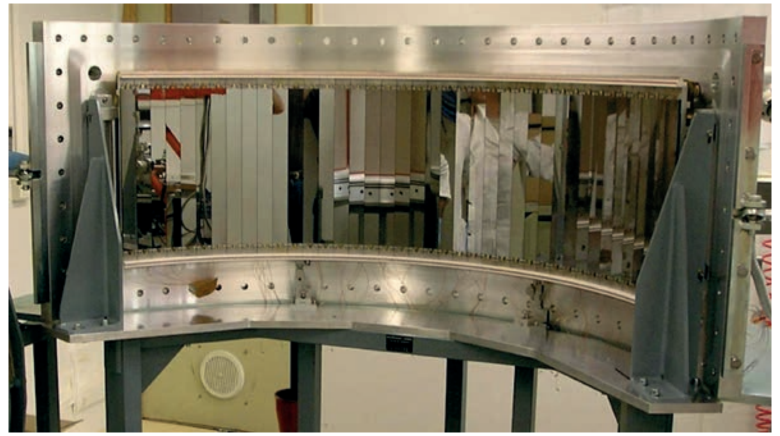
Neutron localisation is achieved by measuring time coincidences between signals from two orthogonally arranged wire planes. The intersection of coincident signals indicates the neutron's position, with the wire pitch determining the spatial resolution, typically ranging from 1 mm to 4 mm.

Several ILL instruments use MWPC detectors, including the Millimeter-resolution Large Area Neutron Detector (MILAND), developed in collaboration with other European neutron facilities as part of the FP6 Framework Programme. The MILAND MWPC detector was used on the D16 cold-neutron diffractometer at ILL from 2009 to 2023.

TECHNICAL SPECIFICATIONS (D16/MILAND)

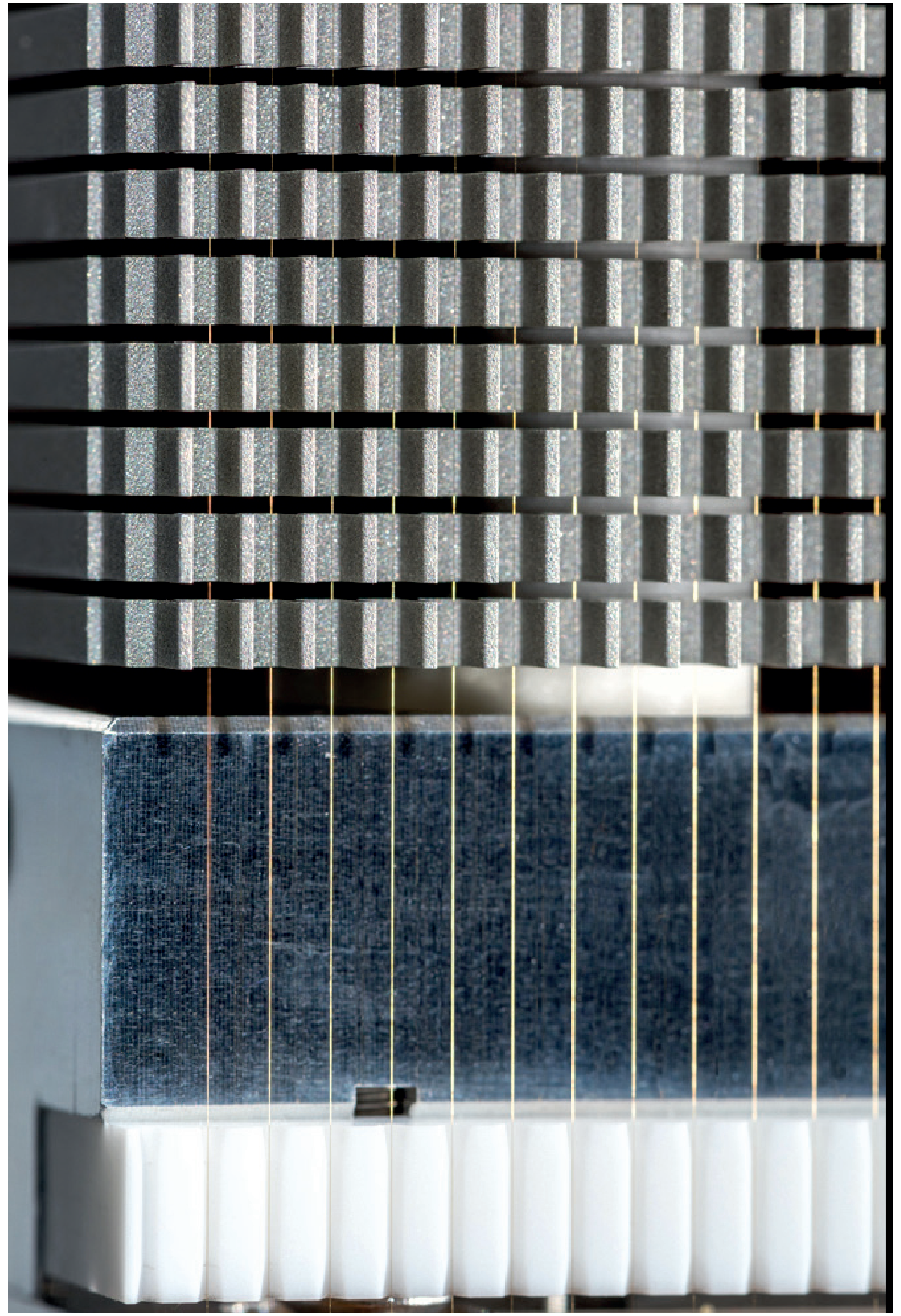
- Sensitive area: 32 cm x 32 cm
- Spatial resolution: 1.2 mm x 1.4 mm
- Max counting rate: 1 kHz/mm^2 (local irradiation), 700 kHz for all detector (global irradiation)
- Detection efficiency: 85% at 0.47 nm





Using a curved detector centered on the sample position covers a large angular range while minimising parallax distortion. For a detector with horizontal plane curvature, the horizontal coordinate is measured using vertically mounted wires. Such one-dimensional detectors are often used for powder diffractometers, while two-dimensional localisation is more often required for single crystal diffractometers.

For two-dimensional detectors, the vertical coordinate is typically measured using a curved cathode PCB circuit with horizontal strips behind the wire planes. However, the hydrogen content in PCBs causes neutron scattering and background noise, while outgassing can degrade gas purity unless a purification system is used. To avoid these issues, glass electrodes were used in the D19 large-area curved detector, preventing outgassing but limiting count rate due to cathode dead time.



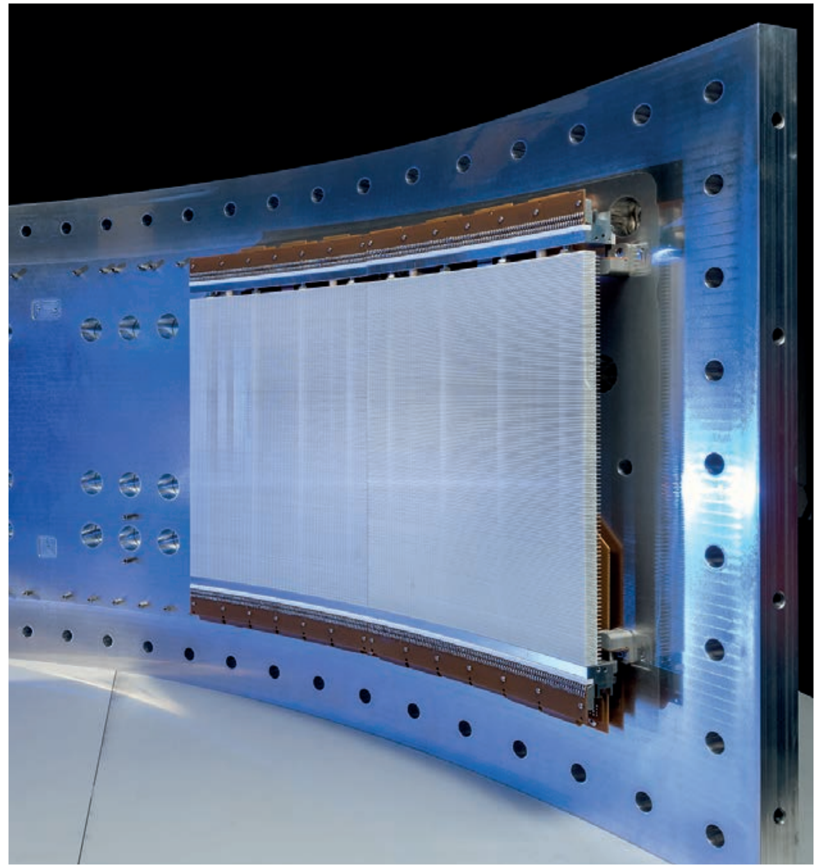
TRENCH-MWPC BI-DIMENSIONAL DETECTORS

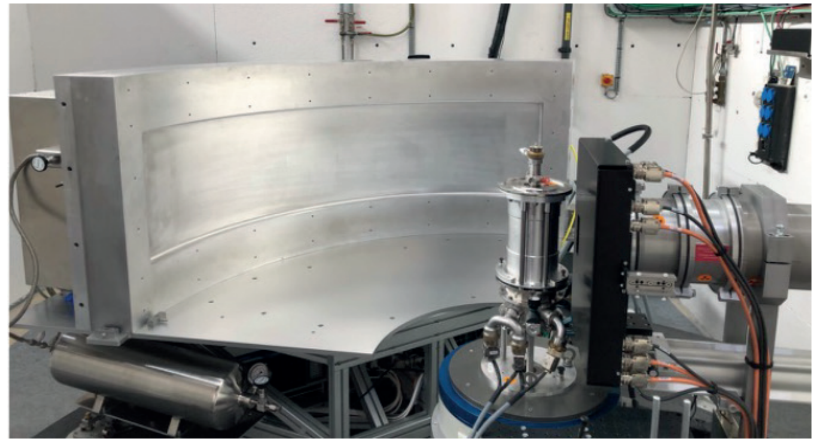
A new cathode design was developed for curved detectors to address the issues with MWPC detectors mentioned in the previous section, such as scattering caused by PCB materials and limited count rates due to glass electrodes. This new design is known as the "trench" multi-wire proportional counter (Trench-MWPC). The cathode consists of an assembly of electrically insulated metallic blades, each machined with fine teeth spaced a few millimetres apart. When the blades are stacked along the full height of the detector, the alignment of the teeth creates grooves in which the anode wires can be positioned. This configuration ensures excellent mechanical stability of the anode wires when high voltage is applied, eliminating the need for additional cathode wires above the anode plane.

As with the MAM detectors, the Trench-MWPC detectors depend heavily on in-house, precise machining of the stacked blades using wire electrical discharge machining (EDM).

TECHNICAL SPECIFICATIONS (XtremeD)

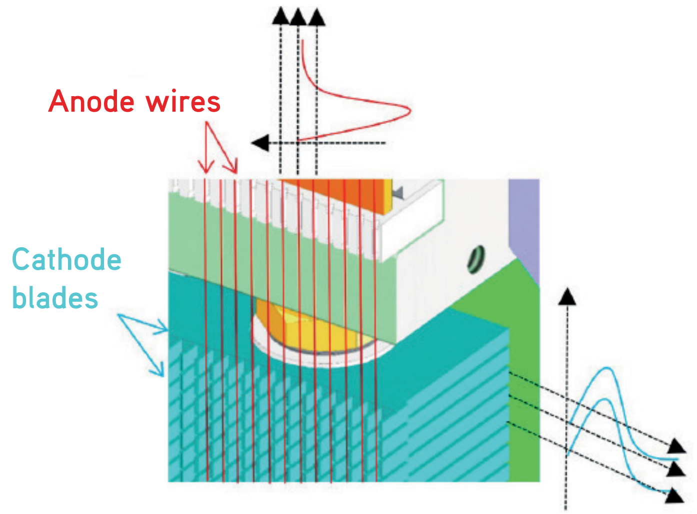
- Angular coverage: 130° x 24°
- Angular resolution: 0.15° x 0.20°
- Max counting rate: 3 kHz/mm² (local irradiation), 3 MHz for all detector (global irradiation)
- Detection efficiency: 75% at 0.25 nm

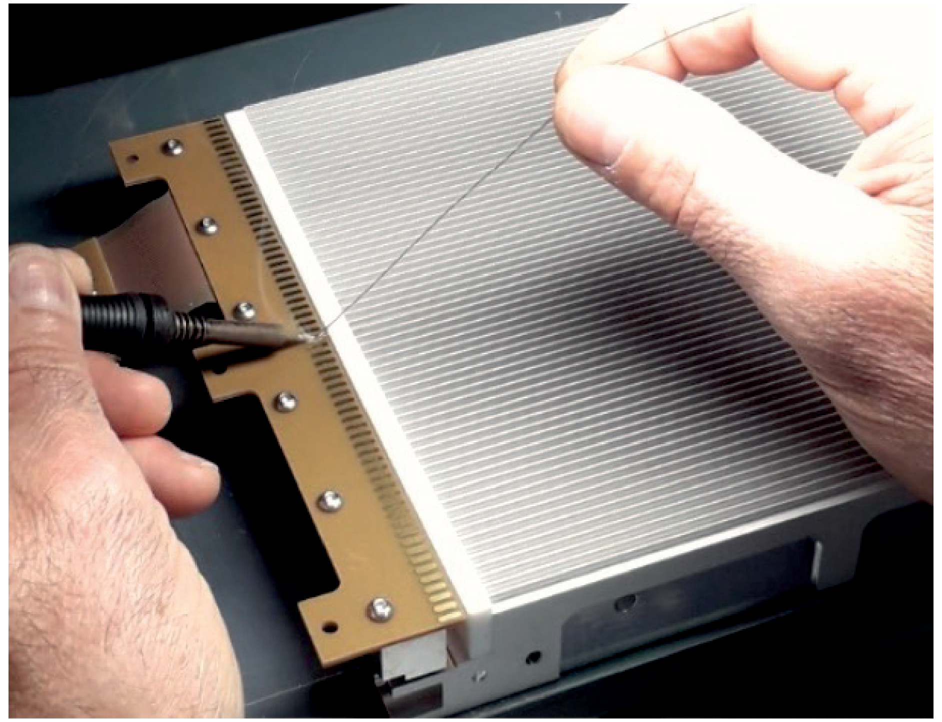




Neutron localisation across the detector is determined by the time coincidence between signals arriving at the cathode blades and the anode wires. This configuration enables significantly higher counting rates compared to MWPC detectors, which rely on charge division with cathode glass electrodes. Additionally, the assembly and maintenance of Trench-MWPC detectors are greatly simplified, as they feature only a single wire plane (the anodes).

This innovative "Trench-MWPC" design was first implemented at the ILL for the large-area curved detectors on the XtremeD and D16 instruments, both of which began operation in 2023.

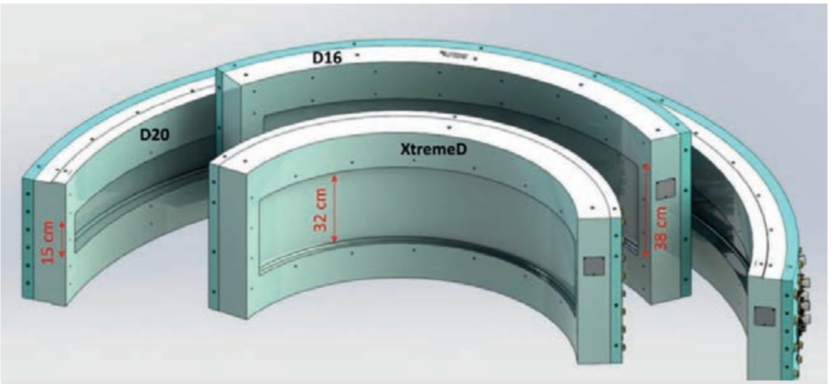




TRENCH-MWPC UNI-DIMENSIONAL DETECTORS

Unlike the two-dimensional Trench-MWPC detectors used on the D16 and XtremeD instruments, the uni-dimensional Trench-MWPC is a 1D detector that measures the position of scattered neutrons exclusively in the horizontal plane. In this case, there is no need to divide the cathode into individual blades. The cathode retains the general shape of the 2D detector but is replaced with trench blocks, precisely machined from a single piece of aluminium.

After 24 years of reliable operation, it became necessary to replace the ageing Micro-Strip Gas Counter (MSGC) on the D20 powder diffractometer. It has now been replaced with a uni-dimensional Trench-MWPC, offering an equivalent solid angle and spatial resolution.



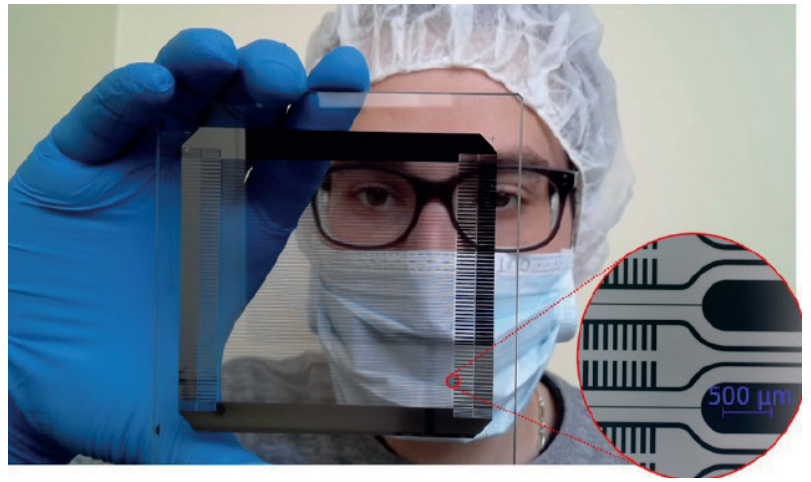
TECHNICAL SPECIFICATIONS (D20)

- Angular coverage: 160° x 5.7°
- Angular resolution: 0.1° (horizontal)
- Max counting rate: 3 kHz/mm2 (local irradiation), 50 kHz per channel of 0.1°
- Detection efficiency: 80% at 0.13 nm

MICRO-STRIP GAS COUNTERS

A micro-strip gas counter (MSGC) plate consists of a glass substrate onto which alternating chromium cathode and anode strips are engraved using photolithography. By applying different high voltage potentials to the anodes, the charge signal generated by the interaction of neutrons with ^{3}He atoms is amplified.

This invention laid the foundation for the development of Micro-pattern Gas Detectors (MPGD), which are now intensively developed, particularly at CERN, for high-energy physics applications. Anton Oed's contributions, along with those of the ILL, are recognised by the awarding of the Oed Prize at the MPGD conference, held every three years.

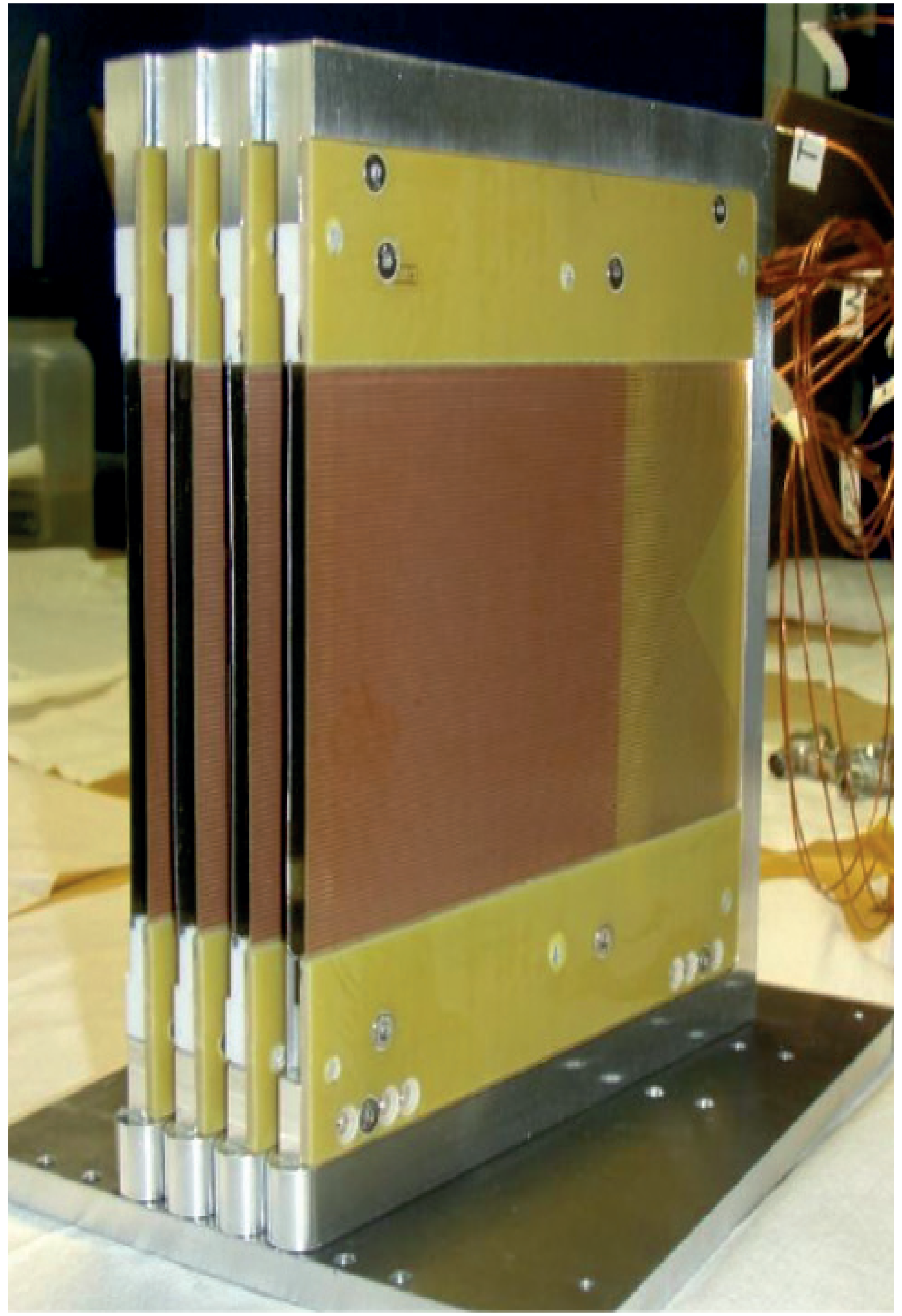


The MSGC technique was introduced by Anton Oed at ILL in 1988.

The former D20 MSGC detector contained 50 MSGC plates mounted side-by-side in the pressure vessel and covered a detection angle range of 160°. It was replaced in 2025 by the new trench-MWPC.

Innovative spirit recognised

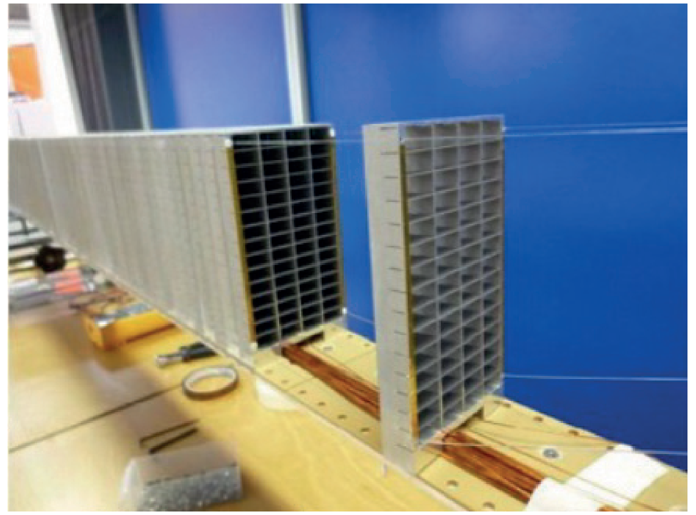
The OED prize was established by the Institut Laue-Langevin in Grenoble and awards a specialist in the field of detector technology for their major contribution to the development of micro-pattern gas detectors. The prize aims to promote an innovative spirit and the ability to solve technical challenges, which were the origin of the original micro-strip gas counter invented by Anton Oed in the late 1980s. It was awarded to Rui De Oliveira in 2019, Rob Veenhof in 2022, and Leszek Ropelewski in 2024, all three from CERN.



BORON DETECTOR TECHNOLOGIES

Due to a shortage in the supply and the high cost of ^{3}He in the 2010s, the ILL pioneered the development of alternative neutron converters. The Multiblade and Multigrid detectors rely on ^{10}B-based films. When a neutron is captured by a ^{10}B atom, ionising particles are produced, which can be detected by measuring the charge generated in the detection gas.

In a Multiblade detector, the converter substrates are inclined at a small glancing angle, typically between 5° and 10°, relative to the neutron flight direction. This configuration maximises the neutron flight path within the ^{10}B converter, increasing the probability of capture, while maintaining a high probability for the ionising particles to escape into the detection gas. This design achieves good spatial resolution and counting rates of several tens of kHz/mm². Multiblade detectors have been successfully developed by the ESS for reflectometry instruments.



The approach for the Multigrid detector differs from that of the Multiblade detector. In a Multigrid detector, the ^{10}B converter substrates are oriented perpendicular to the neutron flight direction and are arranged in 'waffle-like' grids. Each grid typically contains 15 substrate blades (30 converter films) aligned along the neutron flight path. By stacking these grids vertically in adjacent columns, several meters high, large position-sensitive areas can be covered, making the design particularly suited for time-of-flight (TOF) inelastic spectrometry instruments.

Several prototypes were developed jointly by the ILL and ESS, with ESS now leading the development of this technology and producing detectors for the future TREX instrument.

SAMPLE ENVIRONMENT

Sample environment equipment is essential for controlling the experimental conditions under which measurements are performed. User-prepared samples can take various forms, including liquid solutions, powders, interfaces, or assemblies of single crystals. The equipment must not only regulate multiple physical parameters simultaneously but, in some cases, also precisely orient the sample relative to the instrument components.

The ILL has developed a diverse range of sample environment devices, many of which have been widely adopted by the global neutron research community and are now considered standard tools in neutron science. These include:

- Adsorption
- Electric Field
- High Pressure
- High Temperature
- Humidity Control
- Magnetic Field
- Liquid-Liquid Interfaces
- Low Temperatures
- Langmuir troughs
- Rheometers
- Stopped Flow Heads
- Ultra-Cold Neutron Source
- Ultra-Low Temperatures
- Uniaxial Pressure

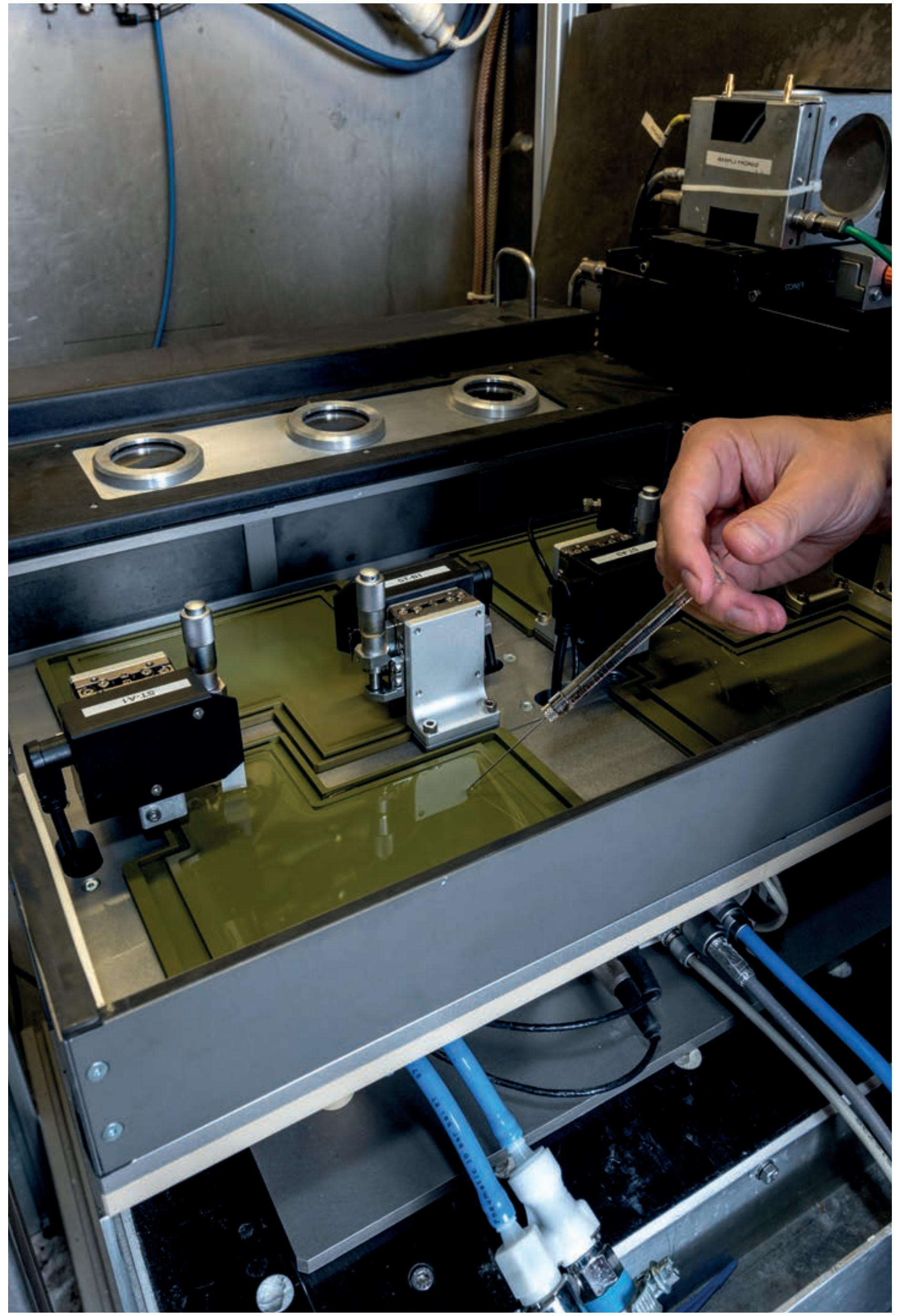
CORE ACTIVITIES

Support for Experimental Research
- Provision of fluids and cryogens
- Prepare, maintain, and upgrade equipment
- Anticipate component obsolescence and plan replacements
- Manage equipment sharing across experiments
- Assist instrument teams and users with setup and operation
- Train Ph.D. and postdoctoral researchers
- Anticipate and address the evolving needs of instrument teams

Numerical Simulations
- Perform finite element analysis to model mechanical, magnetic, and thermal behaviour under various conditions
- Estimate heat loads from thermal radiation, solid conduction, wiring, and other sources

Design, Assembly, and Commissioning
- Develop CAD models, electrical schematics, and fluid diagrams
- Identify suitable materials and shielding techniques
- Improve ergonomics, modularity, and operational efficiency
- Program PLCs (Programmable Logic Controllers) and HMIs (Human-Machine Interfaces)
- Define and implement standards and libraries
- Ensure compliance with safety regulations and operational requirements

Documentation and Reporting
- Produce comprehensive technical documentation
- Manage version control for source code, technical specifications, and functional test scenarios
- Publish designs for novel equipment



ADSORPTION AND LANGMUIR TROUGHS

Specular neutron reflectometry is a powerful technique for studying mixtures of polymers and surfactants at the air/water interface. This method is now being extended to biological systems, including proteins, nanodiscs, and DNA, in combination with surfactants or lipids.

Our optimised adsorption trough unit, designed for neutron beam experiments, allows the simultaneous study of up to 12 samples while monitoring surface tension and regulating temperature. The system features two separate compartments, enabling the parallel investigation of different gas environments.

TECHNICAL SPECIFICATIONS

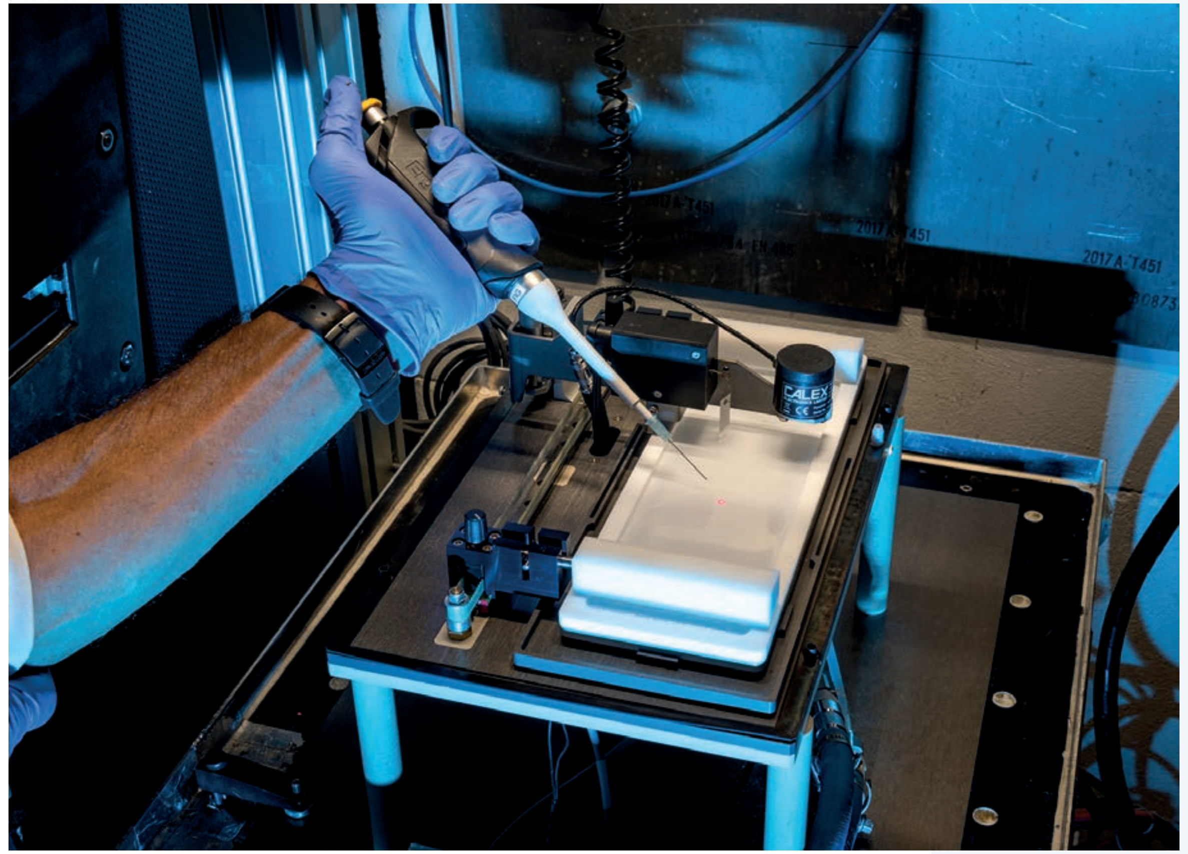
Adsorption troughs

- Sample volume: 50 x 50 x 1 mm^3 (x12)
- Temperature range: 10 to 50°C
- Beam incidence angle: up to 5.5°
- Gas flow-rate: 0 to 3 l/min
- Gas source: air, He, N_2, O_2, etc.

Langmuir troughs

- Sample volume: 80 x 260 (or 405) x 5 mm^3
- Temperature range: 10 to 50°C
- Beam incidence angle: up to 5.5°
- Gas flow-rate: 0 to 3 l/min
- Gas source: air, He, N_2, O_2, etc.

For experiments requiring surface tension control, we provide Langmuir troughs optimised for neutron scattering, featuring temperature regulation and gas adsorption control. The applied pressure range can be adjusted by selecting troughs of different sizes.



HIGH PRESSURE

The application of high pressure influences a wide range of physical properties in solid and soft materials and plays a crucial role in chemistry and biology. It is a widely used technique for discovering new physical phenomena, studying complex mixtures, and developing novel materials.

To support these studies, we have developed high-pressure cells optimised for neutron beams, including the fabrication of specialised alloys. Many of these experiments also require cryogenic conditions, such as in the study of superconductivity, quantum phase transitions, colossal magnetoresistance, and insulator-metal transitions. To meet this need, we have designed cryostats capable of cooling a press to temperatures close to absolute zero.

TECHNICAL SPECIFICATIONS

Continuously loaded cells (liquid or gas transmitter)

- Pressure range: up to 1 GPa (10 kbar)
- Temperature range: 1.5 to 373 K i.e. -271.5 to 100°C
- Sample volume: up to 6.4 mL
- Material in beam: Al2O3, AW-7049A, $CuBe_2$ or TiZr.

Clamp Cells (liquid transmitter)

- Pressure range: up to 3 GPa (30 kbar)
- Temperature range: 40 mK to 320 K i.e. -273.11 to 50°C
- Sample volume: up to Ø6 x 20 mm3
- Material in beam: Al 7049A, $CuBe_2$ or TiZr

To achieve the highest pressures, the sample is placed between two anvils made of boron carbide or sintered diamond. Pressure is applied by injecting oil or helium gas—up to 2 kbar—onto the piston of a Paris-Edinburgh press.

TECHNICAL SPECIFICATIONS

Paris-Edinburgh Press (liquid transmitter)

- Pressure range: up to 22 GPa (220 kbar)
- Temperature range: down to 0.1 K (-273°C)
- Sample volume: up to 50 mm^3
- Material in beam: Aluminium, TiZr

HUMIDITY CONTROL

Humidity plays a crucial role in determining the chemical potential of water, influencing processes such as the swelling and deswelling of complex materials, proton rearrangement in batteries, and bilayer formation in lipids.

To overcome the limitations of conventional humidity sensors, we collaborated with colleagues from HZB (Germany) to develop a precision humidity chamber. In this system, relative humidity is controlled by a water reservoir maintained at a temperature calculated using Antoine's equation. To prevent thermal gradients that could lead to unwanted condensation, the sample space is thermally decoupled from both the water bath and the surrounding experimental environment.

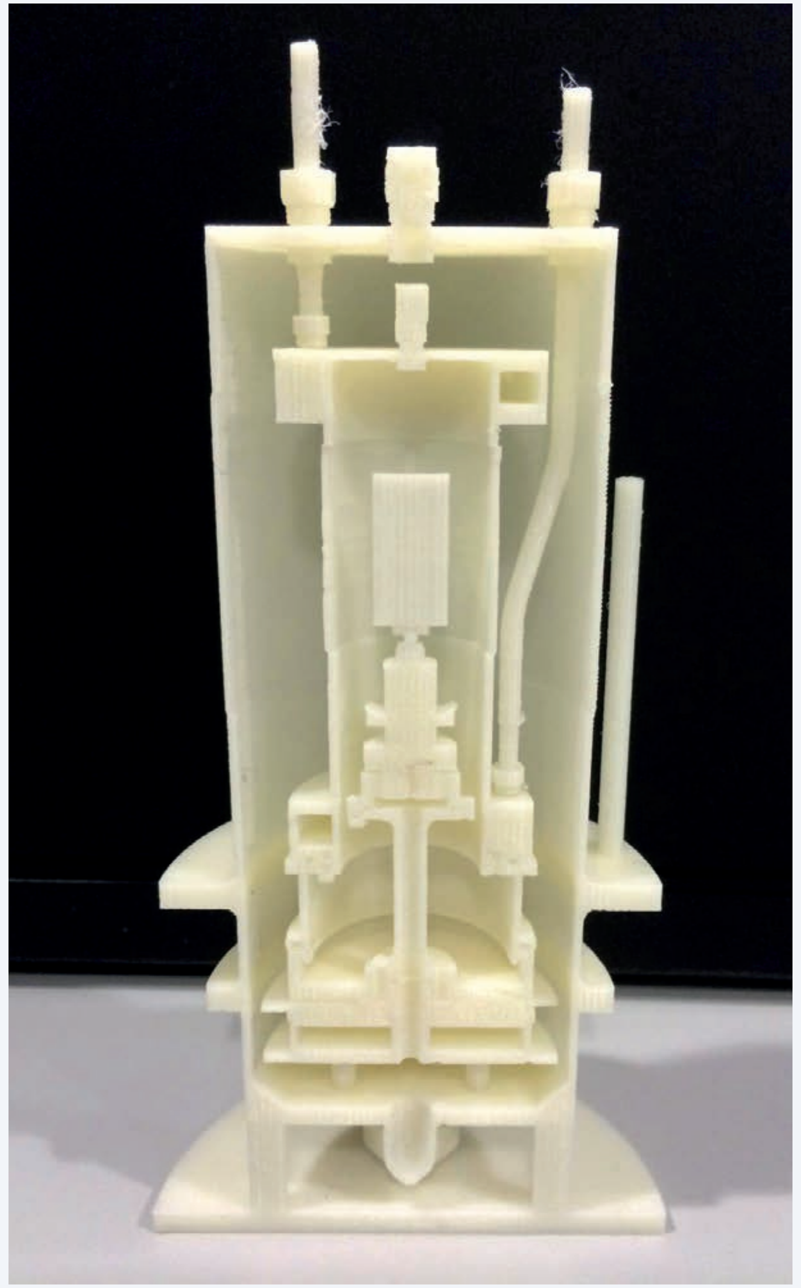
For experiments requiring rapid changes in relative humidity or the use of non-standard liquids or gases, we have developed a multi-purpose humidity generator. This system utilises mass-flow controllers to precisely mix dry and saturated gases in controlled proportions, providing a flexible and reliable solution for humidity regulation.

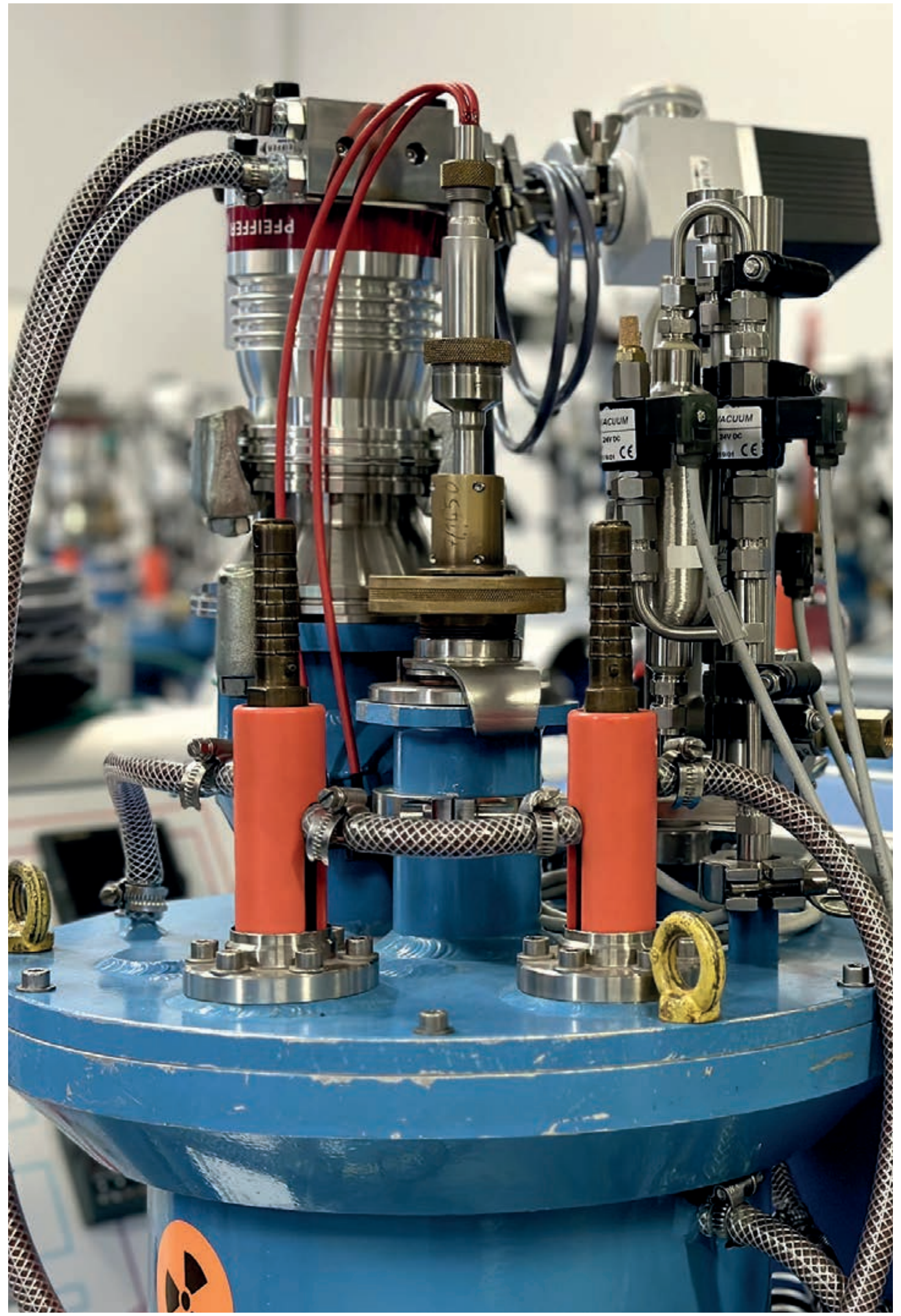
TECHNICAL SPECIFICATIONS

Multi-Purpose Fast Humidity Generator
- Gas flow-rate: 0 to 3 l/min
- Temperature range: 20 to 60°C
- Humidity range: 0 to 80%
- Humidity accuracy: ±1%
- Gas source: N_2, He, etc.
- Liquid source: H_2O, D_2O, solvents, etc.

TECHNICAL SPECIFICATIONS

Precision Humidity Generator
- Sample volume: Ø20 x 40 mm^3
- Temperature range: 10 to 85°C
- Humidity range: 10 to 100%
- Humidity accuracy: ±0.1%
- Gas source: air
- Liquid source: H_2O or D_2O





HIGH TEMPERATURE: BLUE FURNACES

Developed in the mid-1980s, the ILL type furnace, also known as the Blue Series, was developed from experience gained working at temperatures up to 2600°C. This furnace is inexpensive, easy to operate and much easier to maintain than the record-breaking furnaces of the time. The many units delivered worldwide are still in use in numerous neutron facilities.

Recently, all furnaces and automated power racks have been upgraded with a fast-cooling option reducing the cooldown time by a factor 4, thereby reducing beamtime losses. The sample is generally placed in a vacuum but a special setup has also been developed for carrying out experiments while circulating a gas mixture in the sample at elevated temperatures.

TECHNICAL SPECIFICATIONS

- Sample volume: up to Ø35 x 50 mm^3
- Temperature range: 550 to 1920 K (280 to 1650°C)
- Heat shield material: Nb or V
- Gas circulation: Air, H_2, CO, CO_2, Ethylene, etc.
- Optional fast cooling mode

Blue furnace disassembled showing the series of heat shields, the heating elements and a standard sample stick.

LOW TEMPERATURE: ORANGE CRYOSTATS

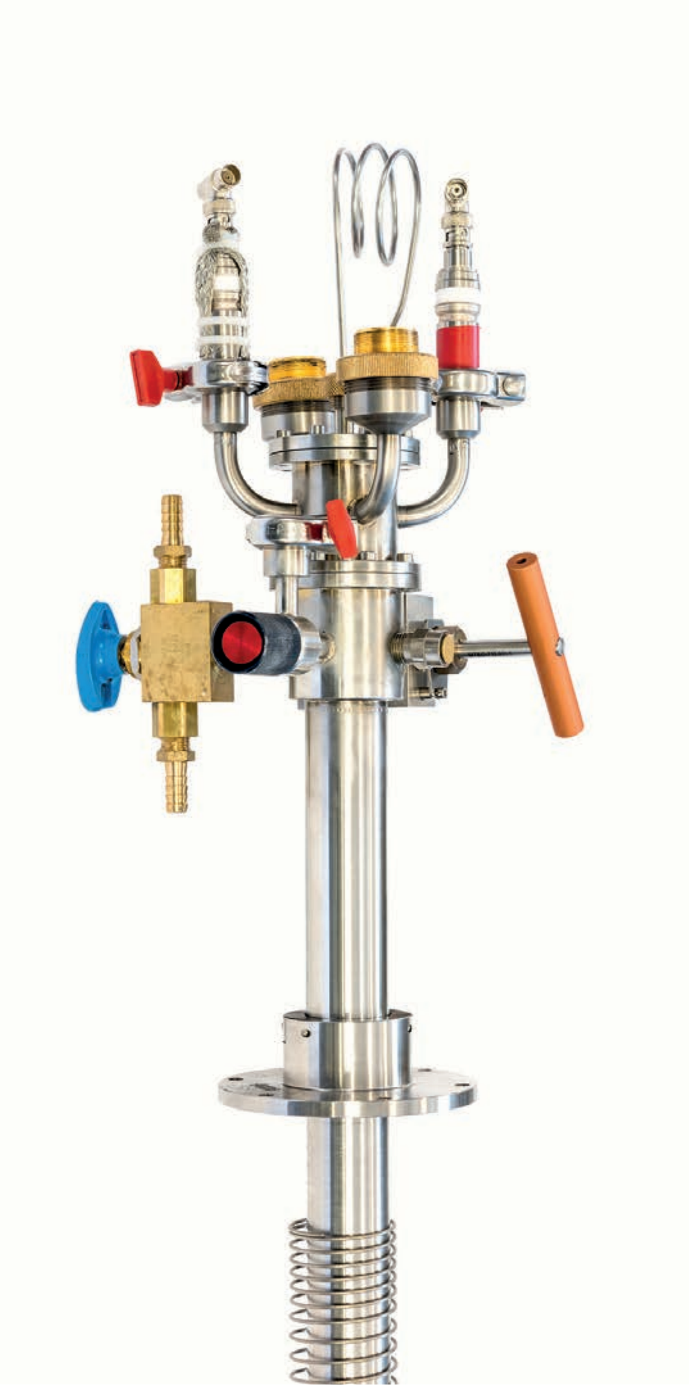
To meet the diverse needs of scientists, ILL developed the Orange Cryostat, a versatile cryostat designed for neutron beam applications allowing precise control of sample temperatures from ambient to very low. The Orange Cryostat, in use worldwide for decades, has recently been enhanced to accelerate temperature changes by a factor of three. To extend its temperature range, ILL also introduced the Orange Cryofurnace, which replaces the indium-sealed calorimeter with a friction-welded assembly.

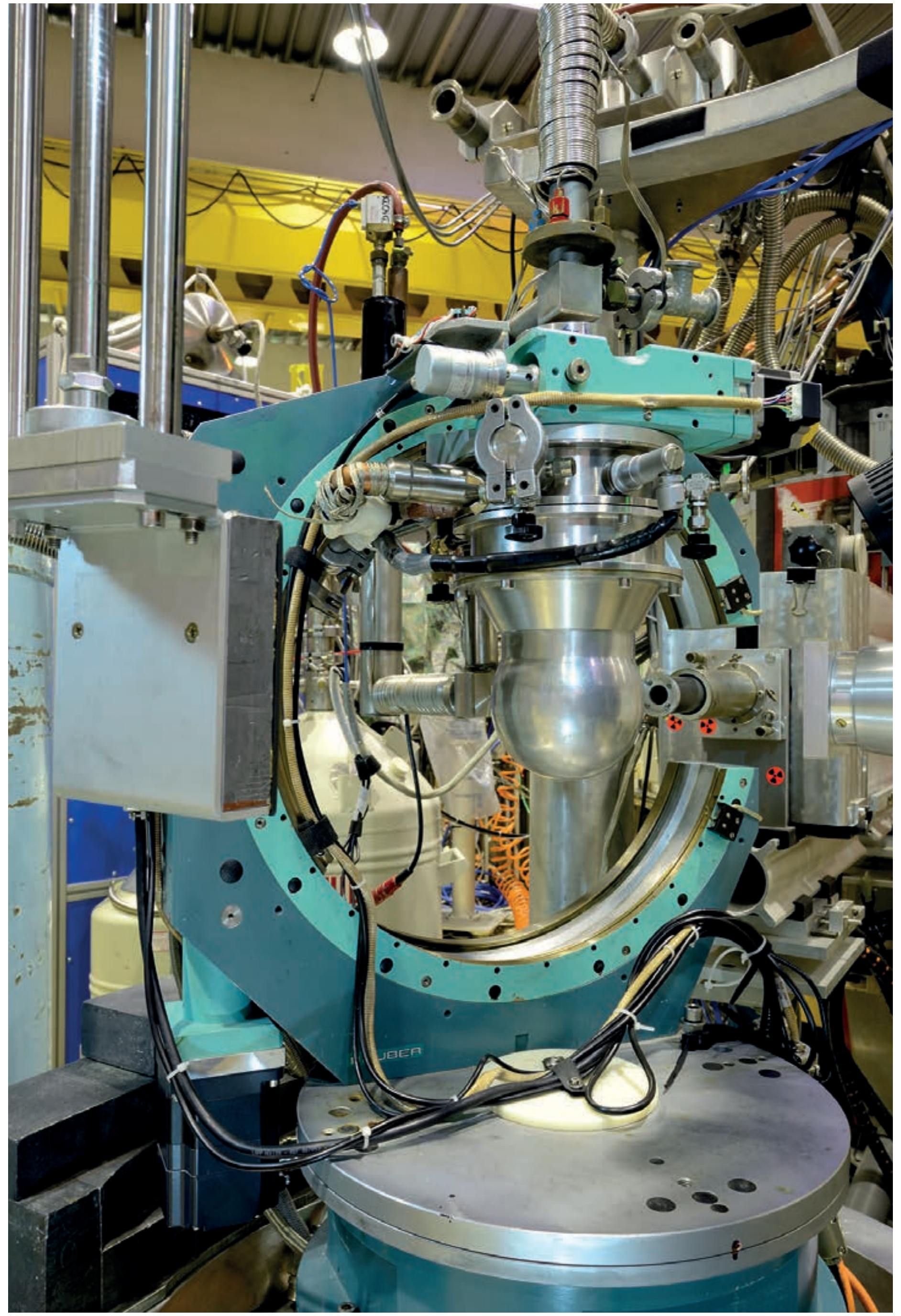
Orange Cryostats can be equipped with a variety of sample holders tailored to the specific demands of the neutron community, including options for applying electric fields both horizontally and vertically, correcting or detwinning single crystalline samples, applying pressure without freezing liquid samples, and measuring dielectric properties, among other capabilities.

TECHNICAL SPECIFICATIONS

Orange cryostat
- Sample volume: from Ø10 x 20 to Ø100 x 265 mm^3
- Temperature range: 1.5 to 320 K i.e. -271.6°C to 45°C
- Temperature change: up to 15 K/min

Orange cryofurnace
- Sample volume: from Ø24 x 20 to Ø70 x 195 mm^3
- Temperature range: 1.5 to 620 K i.e. -271.6°C to 350°C
- Temperature change: up to 15 K/min





LOW TEMPERATURE: DILUTION REFRIGERATORS

To investigate the fundamental ground states of quantum and magnetic systems, ILL has developed its own dilution refrigerators, including a gravity-insensitive dilution refrigerator that allows the orientation of a single crystal in space while maintaining its ultra-low temperature. This innovation has also paved the way for using cryostats in space applications.

All dilution refrigerators are equipped with gas handling systems developed in-house. The control of the dilution inserts is fully automated, allowing smooth operation from room temperature to base temperature using a compact and mobile rack. As for the gravity-insensitive refrigerator, the separation of ^{3}He and ^{4}He isotopes is continuously maintained, with re-injection into the circuit, enabling long-duration experiments without the need for remote isotope separation after the experiment.

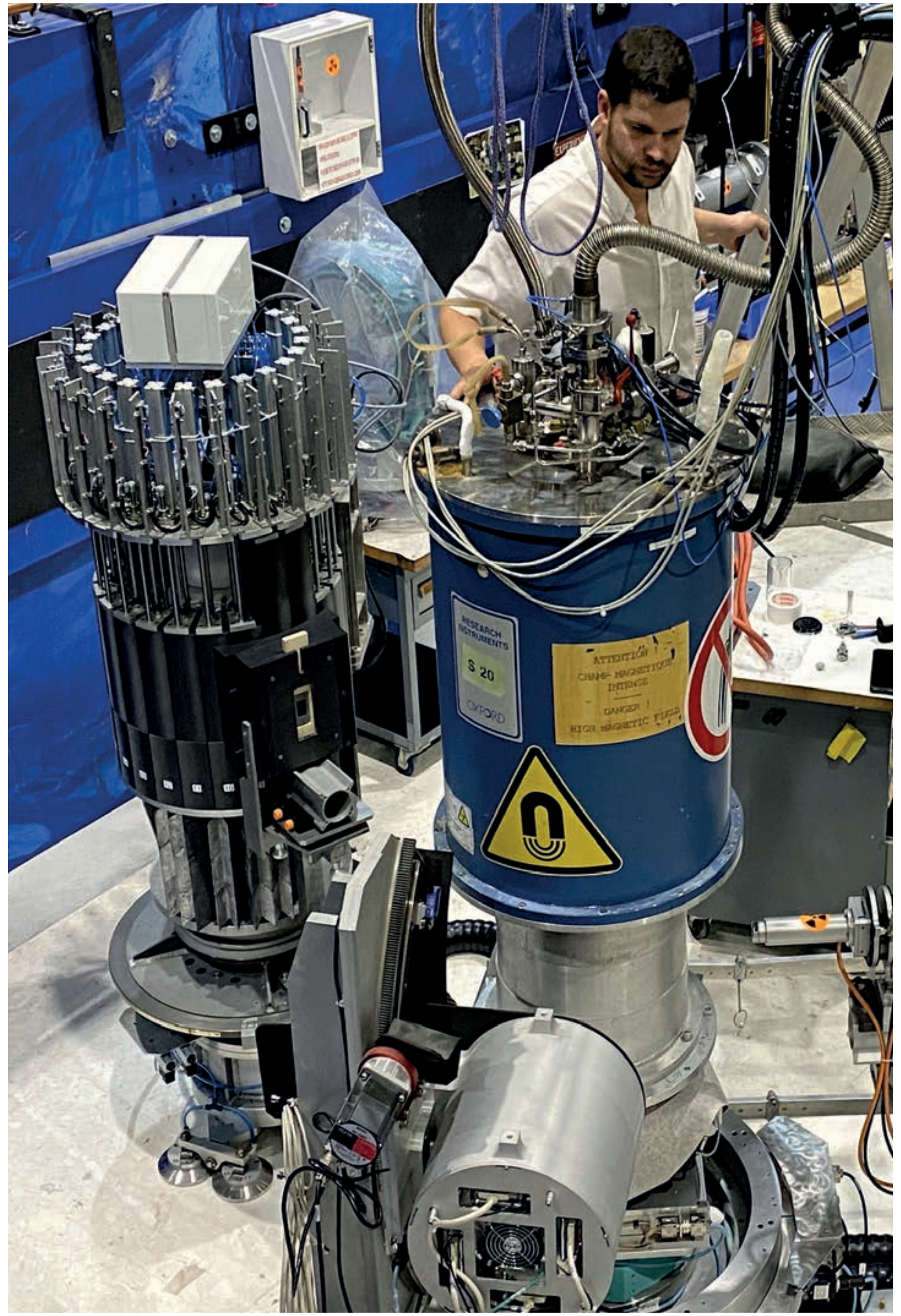
TECHNICAL SPECIFICATIONS

Dilution insert

- Sample volume: up to Ø36 x 70 mm^3
- Temperature range: 40 mK to 300 K i.e. -273.11˚C to 25˚C
- Temperature changes: automated on the whole range

Gravity insensitive dilution cryostat

- Sample volume: up to Ø10 x 15 mm^3
- Temperature range: 100 mK to 300 K i.e. -273˚C to 25˚C
- Temperature changes: automated on the whole range



HIGH MAGNETIC FIELD: STEADY-STATE AND PULSED MAGNETS

Neutron scattering techniques have long been essential for studying magnetism and magnetic materials due to the intrinsic spin of neutrons.

Magnetic fields allow for the switching and control of material properties while simultaneously enabling neutron experiments to uncover the atomic-scale characteristics that underpin the potential of functional and quantum materials for future technologies.

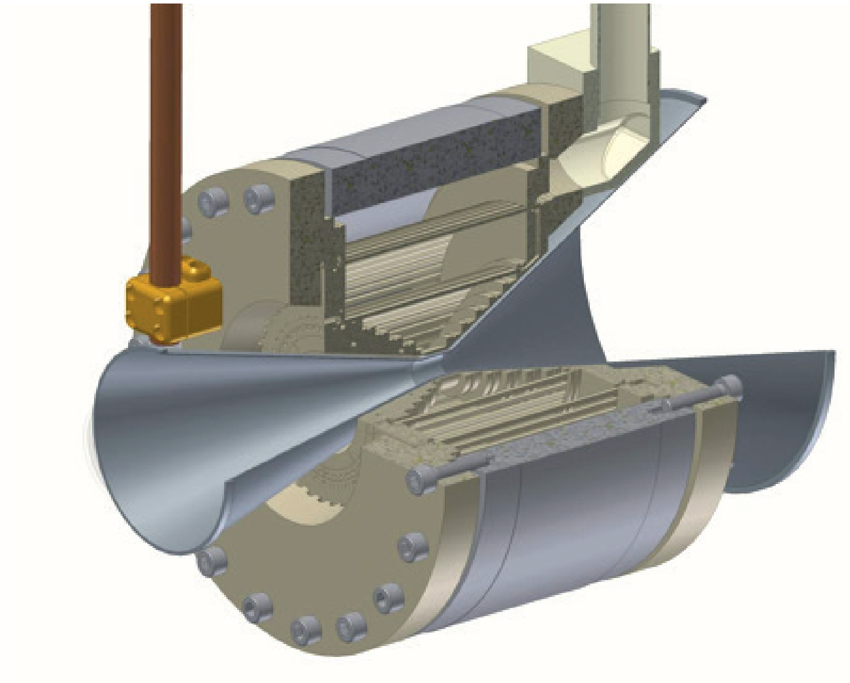
Inside the magnets, the sample temperature is precisely controlled with specially designed inserts developed by our team, ensuring high stability across the entire temperature range. These inserts are compatible with our dilution refrigerators and also reduce cooldown and warm-up times.

The ILL is the only neutron facility worldwide capable of applying a 40 T long-pulse magnetic field to a sample while maintaining a regulated temperature between 2 and 300 K. Coupled with fast ^{3}He detectors and optical fiber connections, the electronics enable high-sampling-rate neutron data collection during magnetic field variations.

TECHNICAL SPECIFICATIONS

Steady-State Magnets (superconducting)

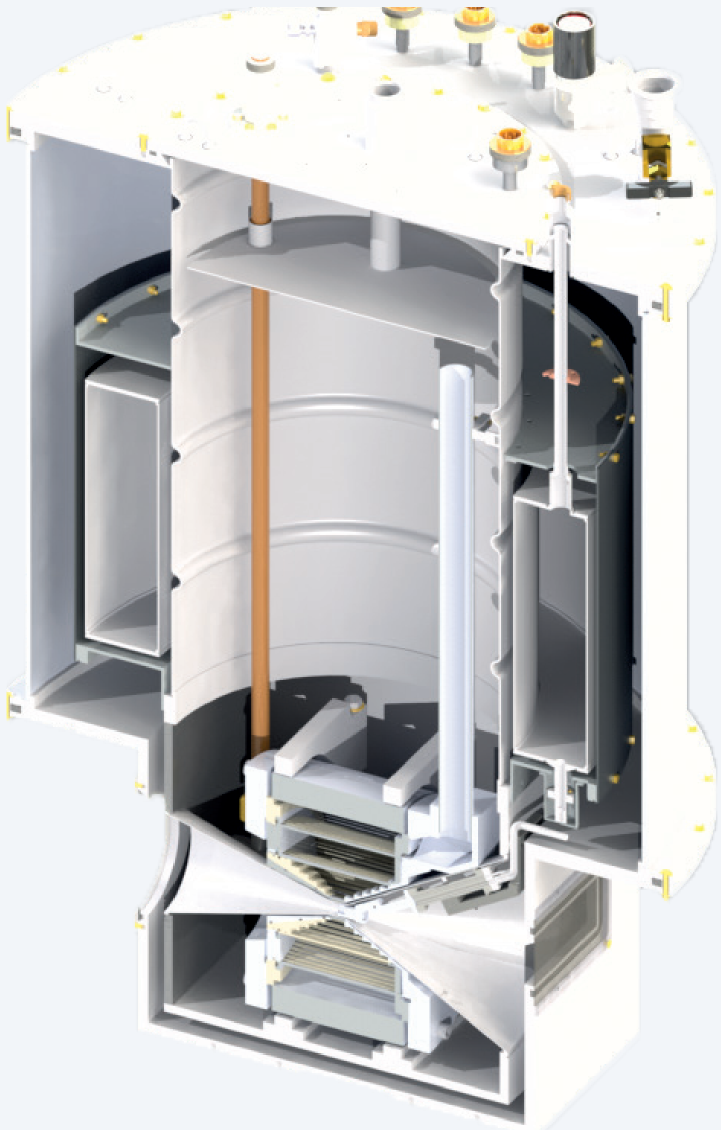
- Magnetic field: up to 15 T vertically and 17 T horizontally
- Temperature range: 40 mK to 300 K i.e. -273.11°C to 25°C
- Sample space: up to Ø80 mm
- Beam access: up to 25° vertically, 140° horizontally
- Dimensions: up to Ø657 mm in scattered beam



TECHNICAL SPECIFICATIONS

Pulsed Field Magnet (resistive)

- Magnetic field: up to 40 T i.e. about 1 000 000 x Earth field
- Temperature range: 2 to 300 K i.e. -271.1 to 25°C
- Sample volume inside Sapphire holder: 8 x 6 x 6 mm^3
- Beam access: ±15° (incident) and ±30° (scattered) vertically
- Duty cycle: 28 s/day at 30 T, 16 s/day at 40 T
- Coil developed and operated by LNCMI-Toulouse
- 1.15 MJ power supply (120.3 ± 0.3 A/T)



ULTRA-COLD NEUTRONS

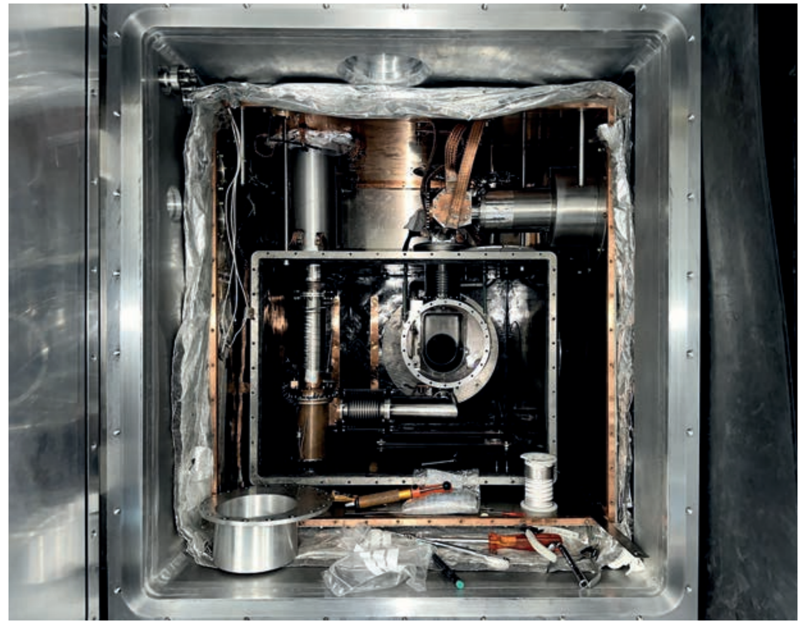
Ultra-cold neutrons (UCNs) have such low energy that they can be stored in closed volumes for several minutes, making them ideal for studying a range of fundamental physics phenomena, such as testing deviations from Newton's law of gravity, probing Lorentz invariance, and searching for axion-like particles.

Given that most studies are statistically limited, our cryogenic team has developed a 4-meter-long source called SuperSUN, that converts cold neutrons into UCNs through inelastic scattering in isotopically pure superfluid ^{4}He. The superfluid is maintained below 0.6 K to minimise losses due to inverse conversion processes, where UCNs gain energy from thermal phonons.

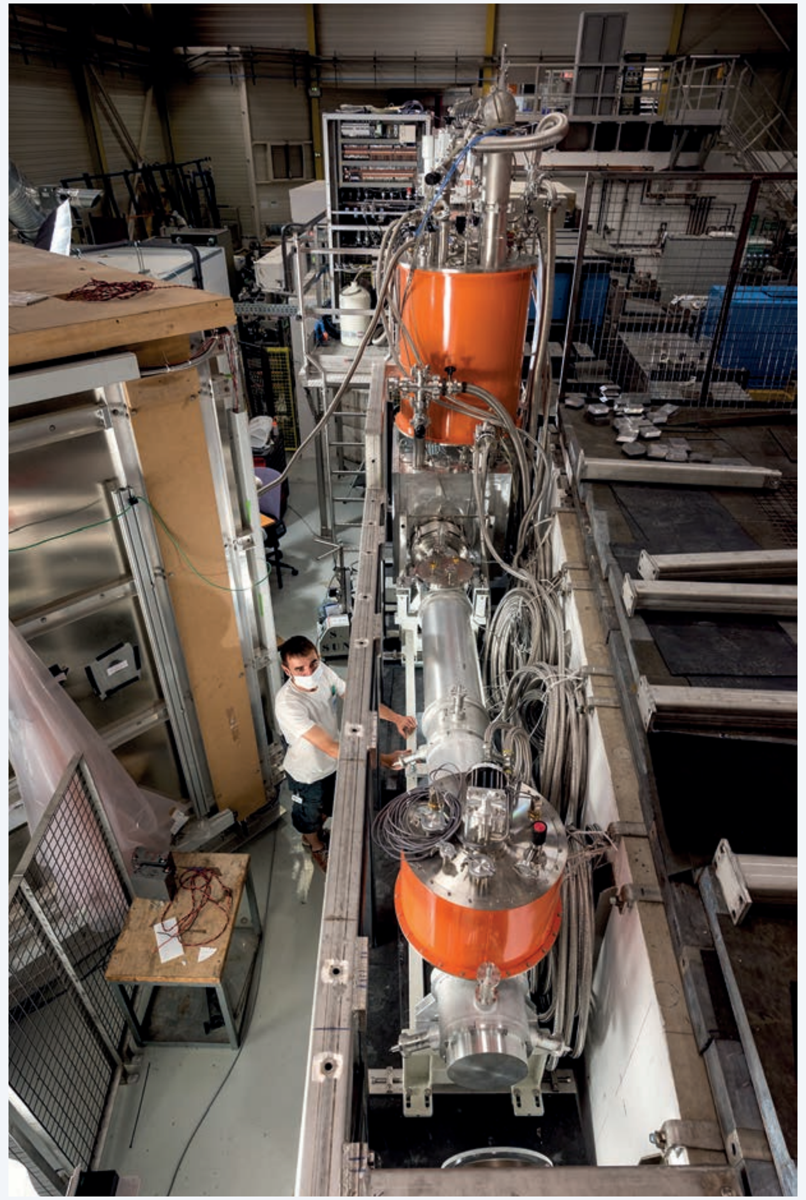
To maximise UCN production and ensure reliable operation over extended periods, a Programmable Logic Controller (PLC) supervises all components of the source, oversees the purification of the superfluid by removing the neutron-absorbing ^{3}He isotope and maintains the superfluid level for weeks. The ^{3}He/^{4}He heat exchanger that cools the superfluid is made from a single crystal of copper, the same as that used for monchromators and produced and machined in-house by our neutron optics team.

TECHNICAL SPECIFICATIONS

- Base temperature: 0.53 K
- Cooling power: 100 mW at 0.6 K
- Superfluid volume: 18.5 litres
- UCNs per filling: 4 million

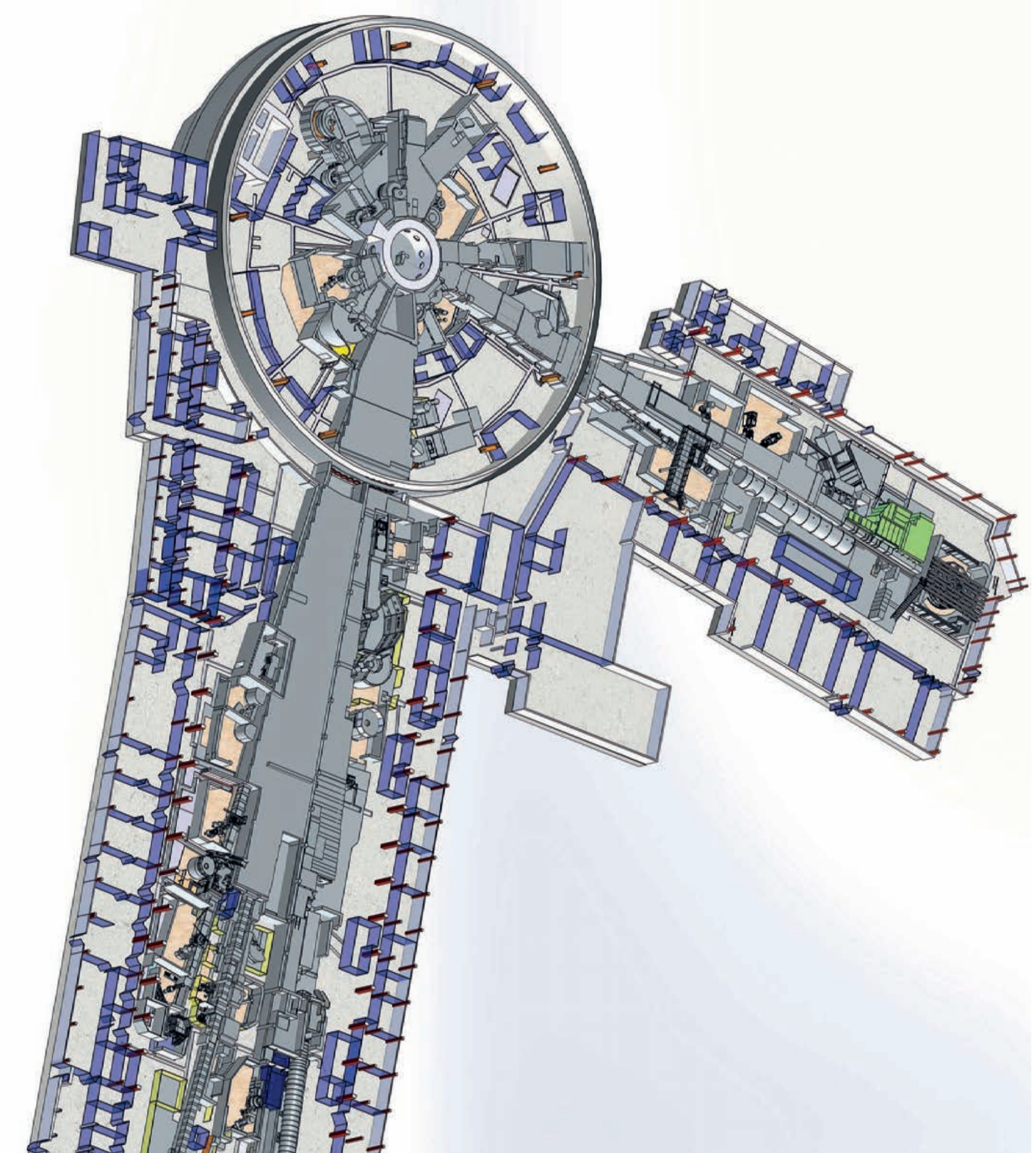


SUPERSUN



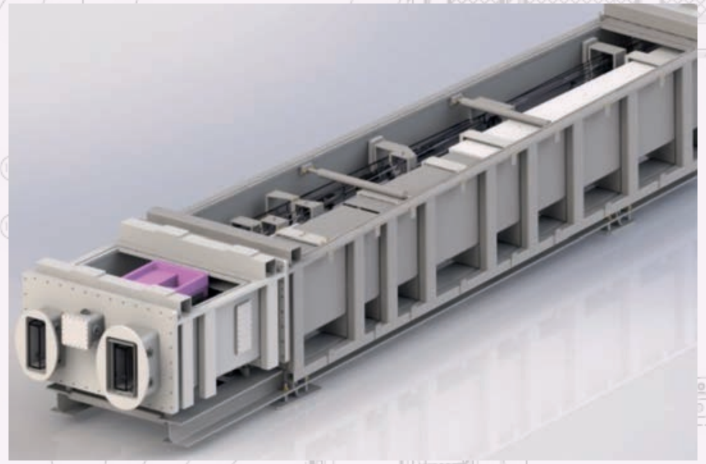
Top view of the ultra-cold neutron source taken before connecting the source to the neutron guide and installing the neutron shielding.

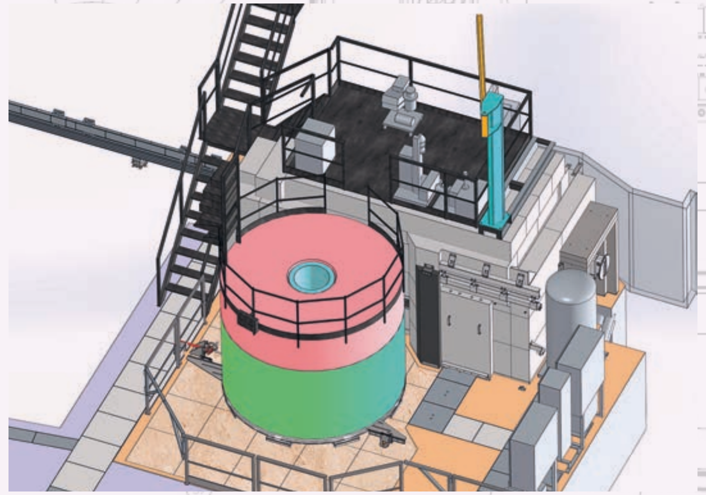
ENGINEERING EXCELLENCE: DESIGN, CALCULATIONS & PROJECT MANAGEMENT



To make the most of the neutrons produced by the ILL reactor and delivered to our scientific instruments, it is essential to design and integrate all components in a structured and consistent way. Our design, calculations, and project management team brings together engineering expertise, advanced simulations, and practical project coordination to support the development of neutron scattering instrumentation and facility infrastructure.

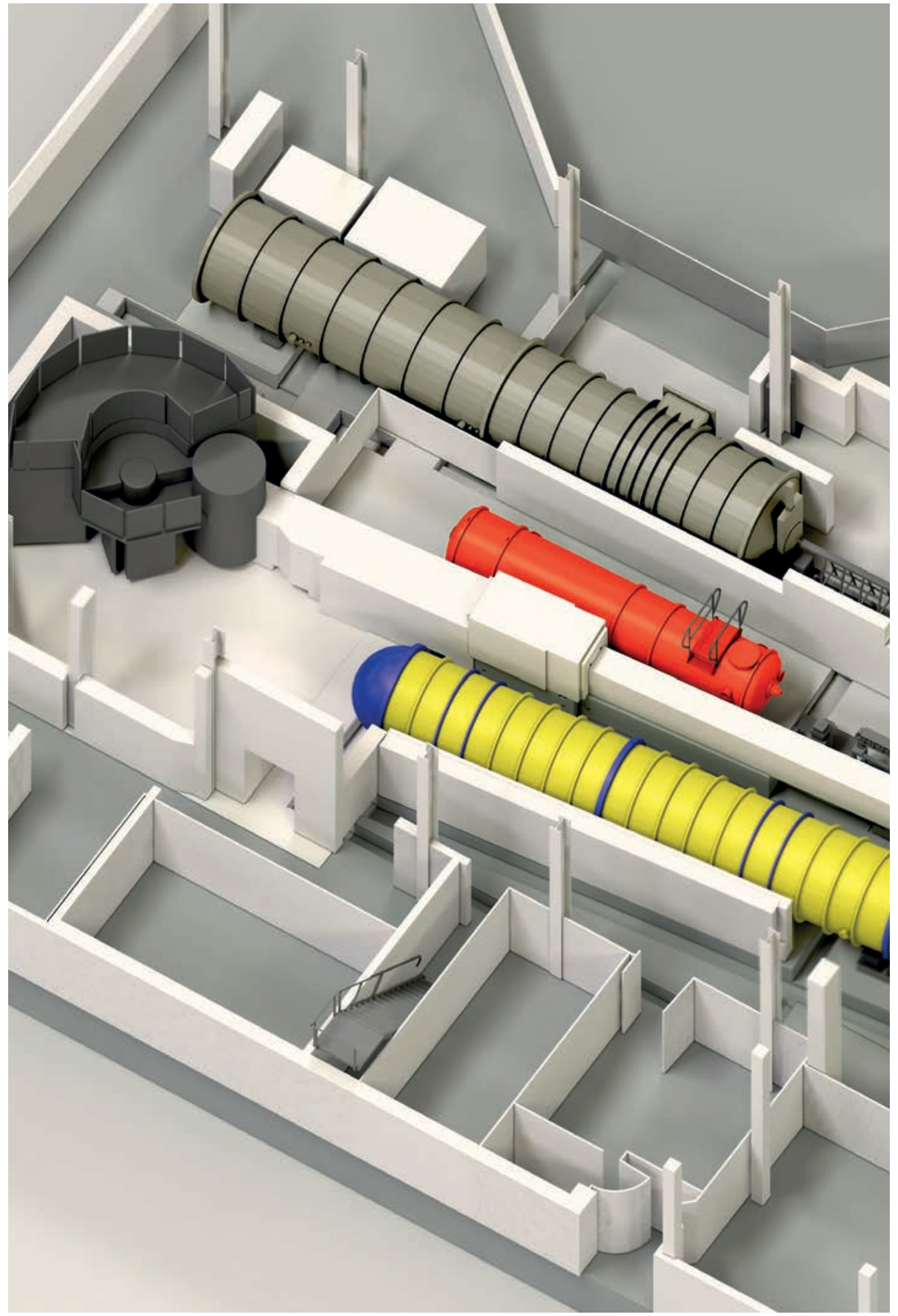
Using computer-aided design (CAD), we turn scientific and technical requirements into precise engineering specifications, forming the basis of conceptual designs. This allows us to develop specialised, high-precision components suited to the challenging environment of neutron science. Our experts in structural, thermal, magnetic, and neutronics calculations ensure that systems perform reliably, safely, and efficiently. From initial concept through to deployment, we manage complex technical developments to deliver practical, effective solutions.





The broader engineering process includes drafting, detailed design, calculations, procurement, manufacturing, assembly, integration, and testing. By bringing these capabilities together within a single team, we improve coordination across divisions, keep projects aligned, and make the best use of resources.

A dedicated team of project leaders, designers, and calculation specialists provides a central point of reference for technical development. We support in-house fabrication, encourage research and development, and help drive new advances in neutron instrumentation.



INSTRUMENT DESIGN

The process of designing an ILL instrument can be broken down into several key stages:

Objective Definition

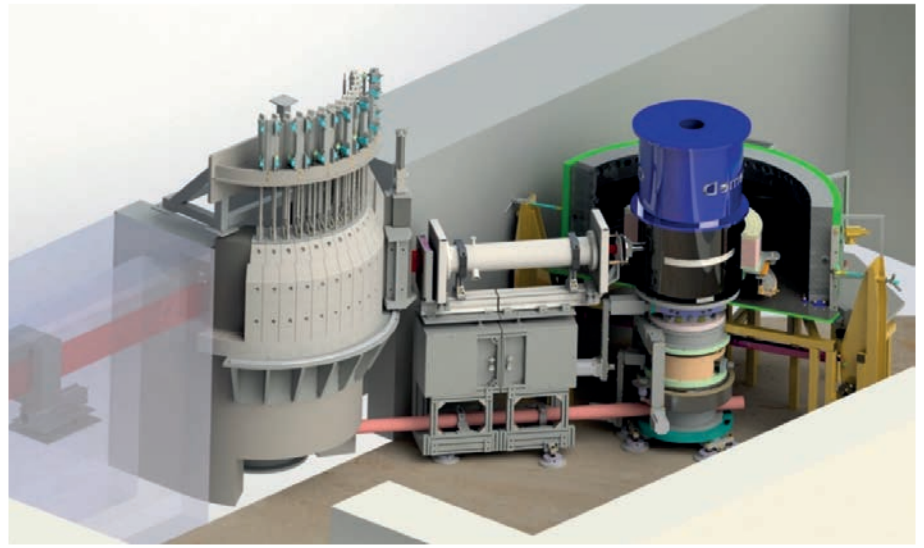
- Understand the specific goals and operational needs of the instrument.
- Work closely with scientists and engineers to identify the mechanical requirements necessary to achieve the scientific objectives.

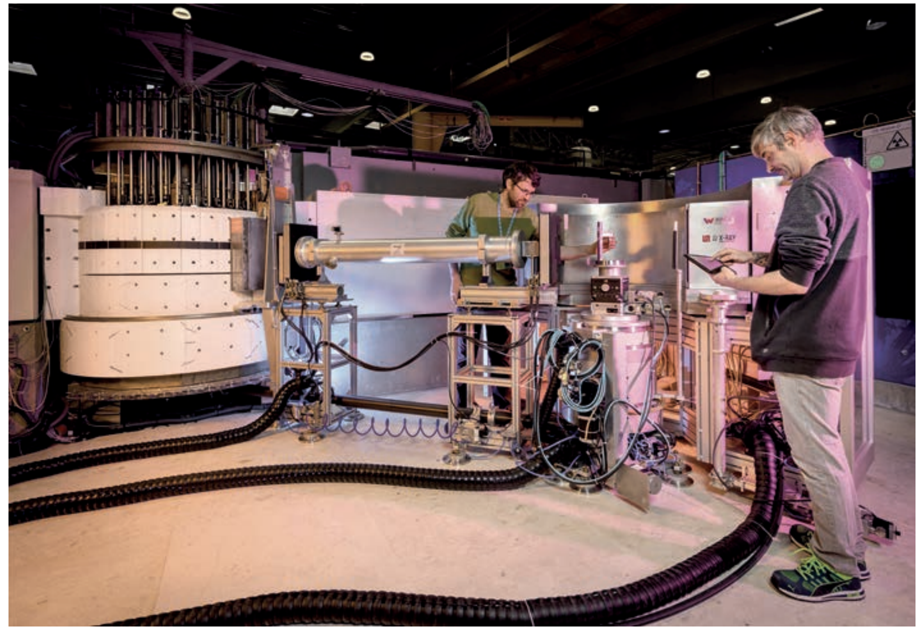
Conceptual Design

- Develop initial design concepts using CAD (Computer-Aided Design) software to create 2D and 3D models of the mechanical systems.
- Propose innovative solutions to overcome challenges such as limited space, precision requirements, and environmental constraints (e.g., temperature, pressure, radiation).

Detailed Design

- Perform engineering calculations (stress, thermal, vibration analysis) to ensure the system meets functional and safety standards.
- Create detailed specifications for sourcing materials and components, ensuring they meet durability, cost, and environmental compatibility.
- Produce comprehensive drawings for fabrication and procurement of the necessary assemblies.





Prototyping and Fabrication

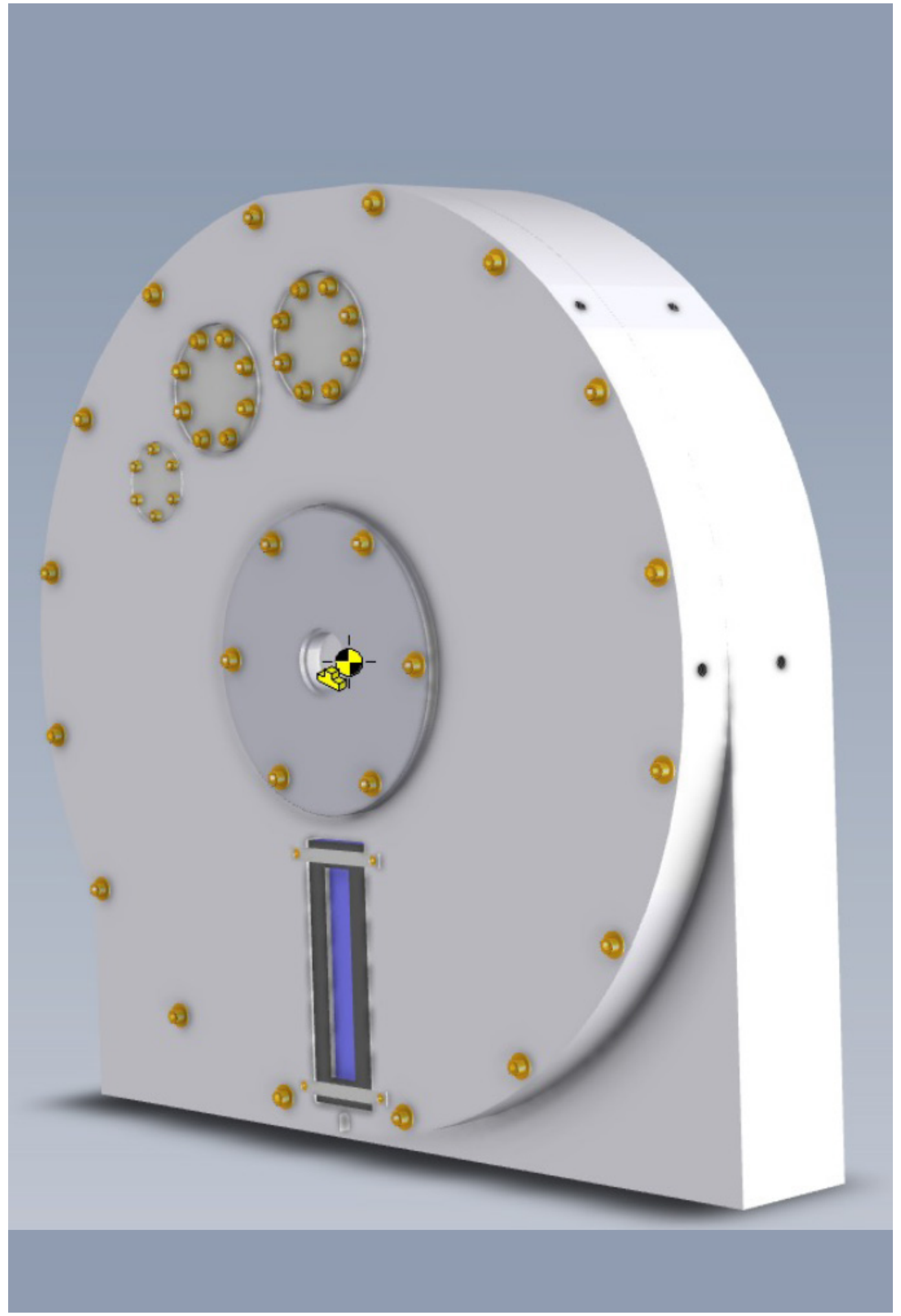
- Design prototypes to test and validate the concepts
- Collaborate with manufacturing teams or suppliers to fabricate parts, ensuring they meet the required tolerances and specifications.

Testing and Validation

- Conduct tests to validate the mechanical performance under various conditions.
- If necessary, adjust the design to address any identified inefficiencies or performance gaps.

Integration and Maintenance

- Ensure the design integrates smoothly with existing systems and infrastructure.
- Verify that the design complies with internal and external regulations.
- Develop user manuals, maintenance protocols, and training materials for operational teams.



COMPONENT DESIGN

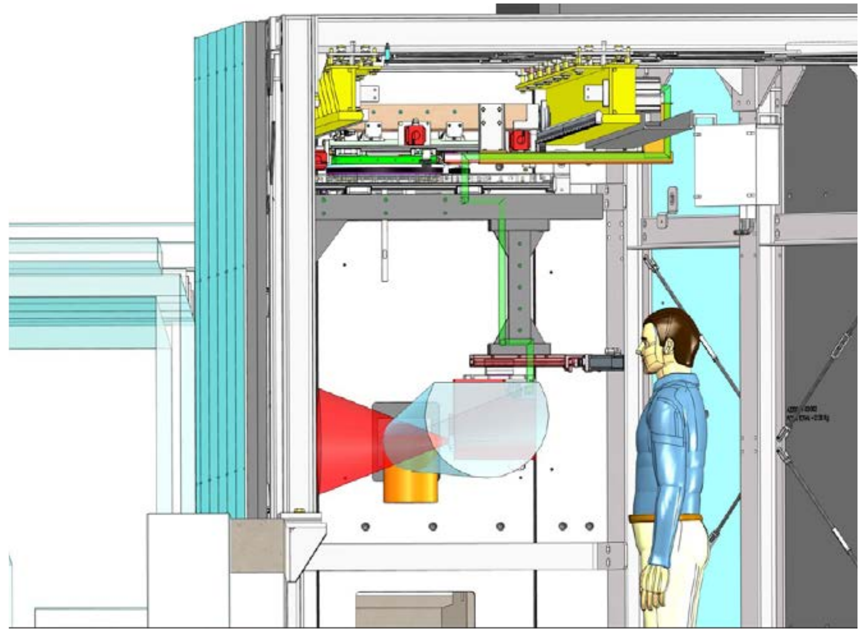
The design of individual components contributes to the overall functionality of a scientific instrument.
Each component is designed taking into account factors such as material properties, load distribution, tolerances, and manufacturing processes to ensure functionality and reliability.

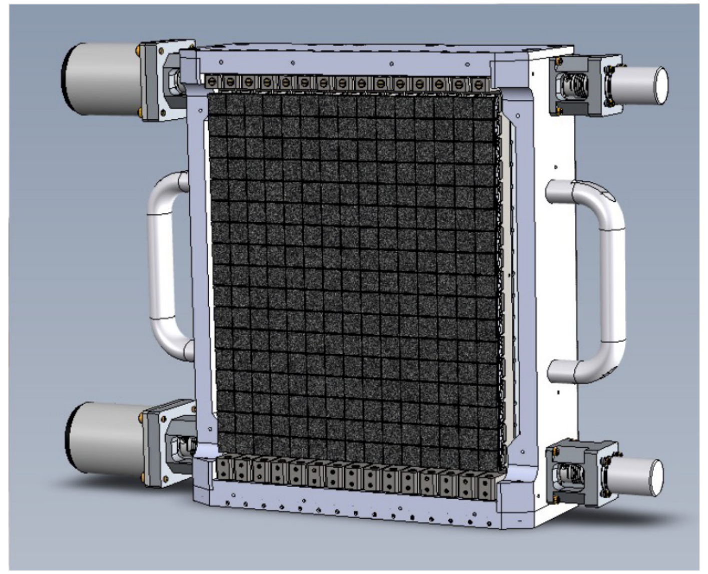
Tools and Techniques

- **Software**: Computer-aided-design (CAD) tools such as SolidWorks and AutoCAD. Simulation tools such as ANSYS and COMSOL.
- **Standards**: Adherence to industry standards (ISO, CODAP) to ensure safety and performance.
- **Interdisciplinary Collaboration**: Working closely with scientists, electronics engineers, software engineers, and material experts to achieve fully integrated designs.

Challenges

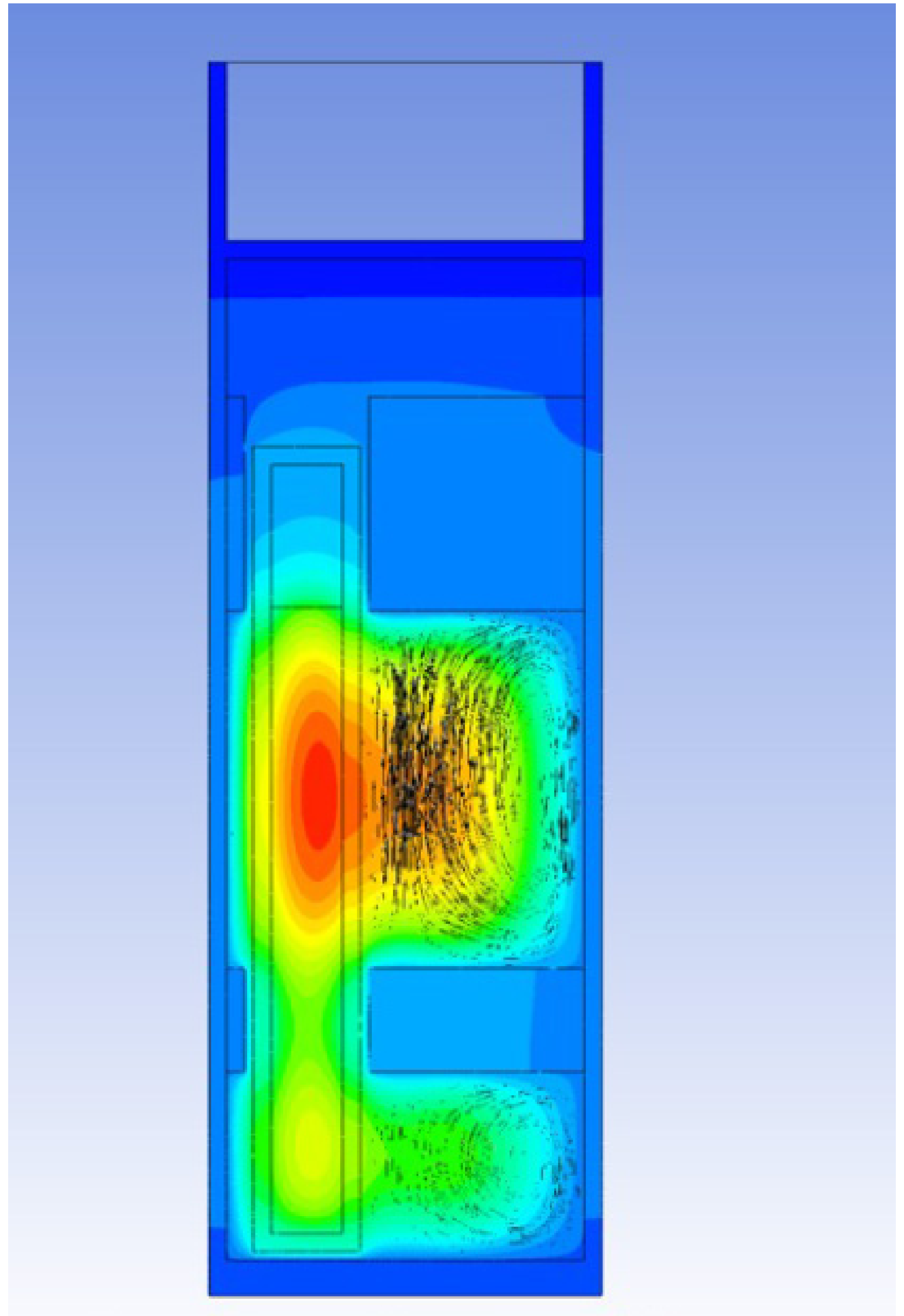
- Achieving high precision within the constraints of the instrument's physical and operational environment.
- Delivering optimal performance through innovative solutions.
- Ensuring durability and ease of maintenance in demanding environments.
- Balancing cost with performance requirements.





Examples of Applications

- Designing neutron guide systems, housings and support infrastructure.
- Design of detector mechanics.
- Development of focussing monochromator mechanics with tailored crystal properties.
- Developing solutions for rotating machines such as choppers.
- Custom laboratory fixtures such as test systems or experimental setups.
- Designing sample environment chambers for temperature or pressure-controlled experiments.
- Integrating robotic arms and automated systems for sample handling.

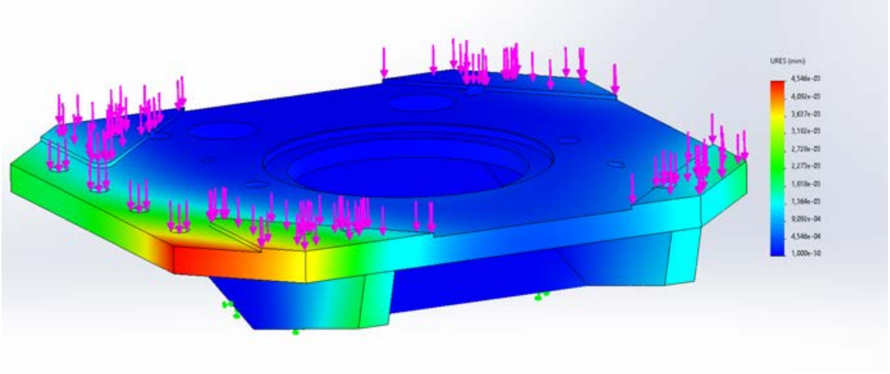


CALCULATIONS: MECHANICAL, THERMAL, MAGNETIC

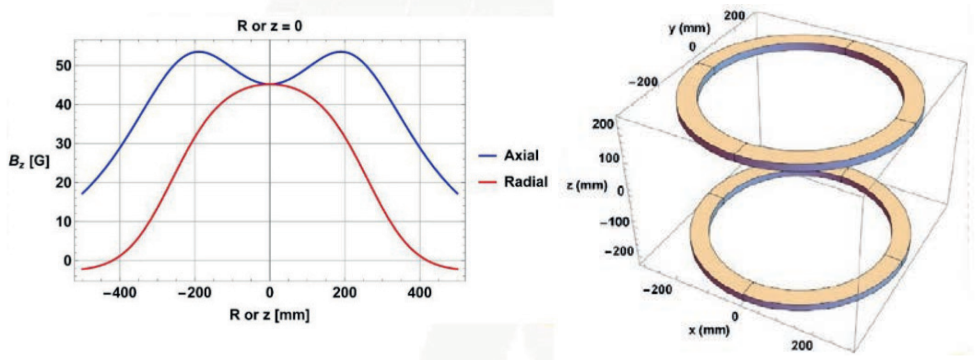
To optimise and validate the design of components and modifications to systems, we integrate our design process with simulations of mechanical properties, thermohydraulics, magnetism, neutron transport, and radiation physics where necessary. Simulations allow us to verify how innovative ideas will perform and bridge the gap between design and reality, ensuring that models accurately reflect real-world conditions.

Our calculation team provides the technical expertise to solve complex challenges, including:

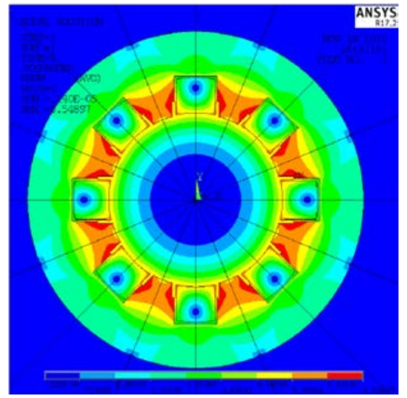
- **Validation** of experimental setups or designs using numerical simulations and analytical methods.
- **Optimisation** of materials and structures for performance, safety, and cost-efficiency, particularly in radiation protection, reactor operation, neutron polarisation, and transport.



Mechanical constraints on an instrument component



Simulation of the magnetic field generated by a coil: coil setup and field intensity.



Simulation of the SuperSUN superconducting magnetic field trap.

Core Activities

Numerical Simulations
- Use computational tools to simulate mechanical, structural, magnetic, thermal, or fluid behaviours under various conditions.
- Model interactions between materials, forces, and environmental factors.

Structural Analysis
- Assess structural integrity, stress, strain, fatigue, and deformation in designs.
- Ensure that equipment, components, and prototypes meet safety standards and operational requirements.

Thermal and Fluid Dynamics Analysis
- Analyse heat transfer, fluid flow, and thermodynamic properties in neutron production equipment and experimental systems.

Support for Experimental Research
- Provide calculations to guide experimental setup, particularly in magnetism and neutron polarisation
- Assist researchers in translating theoretical models into practical implementations.

Documentation and Reporting
- Produce detailed technical reports, including calculations, assumptions, and results.
- Communicate findings clearly to engineers and scientists

.

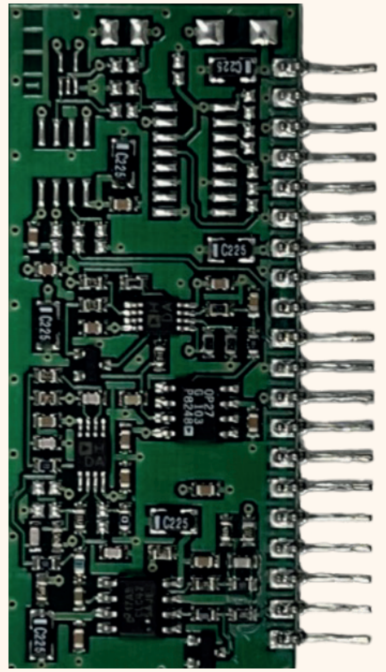
INSTRUMENT CONTROL, ELECTRONICS & COMPUTING

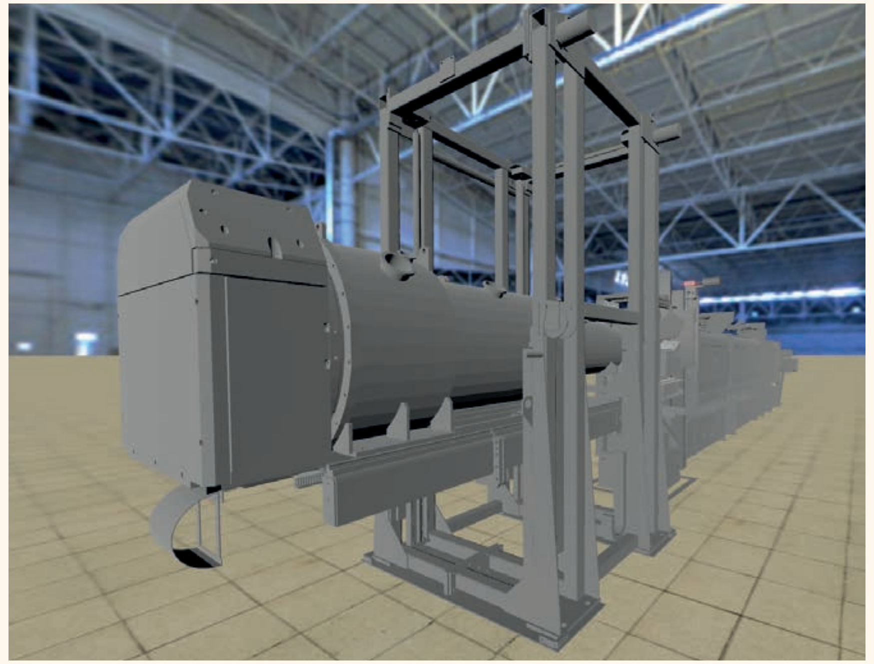
Instrument control and data management at ILL encompass the development of custom software, electronics hardware, and computing resources for data acquisition, management, archival, and data treatment and analysis.

NOMAD, ILL's open-source instrument control software, plays a central role in experiment automation and data collection. The introduction of VISA in 2020 marked a step-change in how scientists analyse data and conduct experiments, both on-site and remotely. NOMAD Remote, integrated with VISA, allows researchers to manage all aspects of their experiment from a virtual machine—controlling sample environments, motor movements, and data acquisition in real time.

Ongoing developments include a new virtual platform that integrates instrument control software, scientific computing tools, and advanced communication technologies. This system will enable users to interact with a digitally rendered twin of their instrument, tracking movements in real time. Additionally, it will allow researchers to define sample compositions and atomic structures, visualising diffusion patterns as a function of instrument settings.

Over the last decade, driven by major upgrade programmes, the volume of experimental data generated by ILL's instruments has grown significantly, now exceeding 2 TB per day during reactor cycles. ILL's IT services continuously enhance networking, storage, and data processing capabilities, ensuring that staff and users can fully exploit the facility's advanced scientific resources.

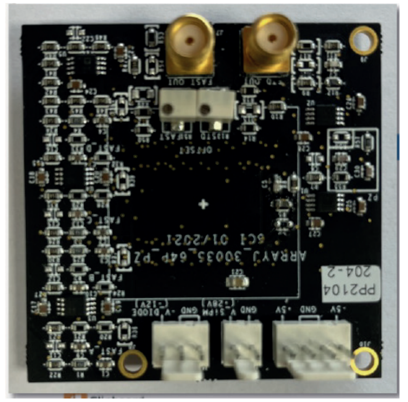


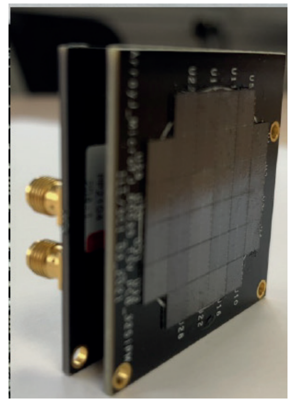


CUSTOM ELECTRONICS

ILL develops front-end electronics for data acquisition systems used in its instruments and at other neutron facilities, including the ESS. A notable example of ILL's technology transfer to industry is the front-end pre-amplifier module for neutron detectors, developed in-house and commercialised by CAEN.

FPGA-based data acquisition electronics provide high-speed, real-time signal processing, enabling rapid data collection and analysis with minimal latency. All data-taking tasks are handled by a dedicated VME-based electronic card, featuring a Zynq Ultrascale+ processor with 4 GB DDR4 memory and a quad-core ARM processor. A dedicated optical link ensures efficient data transfer to the instrument control computer. This architecture supports 10 Mcps data rates, real-time histogramming of position-sensitive detectors in both standard and time-of-flight modes, and event-mode data recording. Onboard memory allows asynchronous data readout, reducing dead time, while the ARM processor enables advanced tasks such as non-linear detector calibration and coincidence pattern recognition.





Silicon Photomultipliers (SiPMs) offer a compact, high-sensitivity alternative to traditional PMTs, detecting single photons with exceptional efficiency. SiPMs consist of an array of avalanche photodiodes (APDs) operating in Geiger mode, enabling single-photon detection with exceptional efficiency and fast response times. ILL has developed a 32-channel SiPM module using Onsemi MicroFJ-60035 TSV SiPMs (6×6 mm each), optimised for fast $LaBr_3$(Ce) scintillators for nuclear physics applications.

Generating fast timing signals from SiPMs poses a challenge, as directly summing outputs can degrade signal rise times and pulse heights due to increased capacitive load. To overcome this, ILL implemented a signal-driven readout method, where Schottky diode pairs are introduced at each SiPM cell to capture fast signals while preserving the intrinsic timing performance.

TECHNICAL SPECIFICATIONS

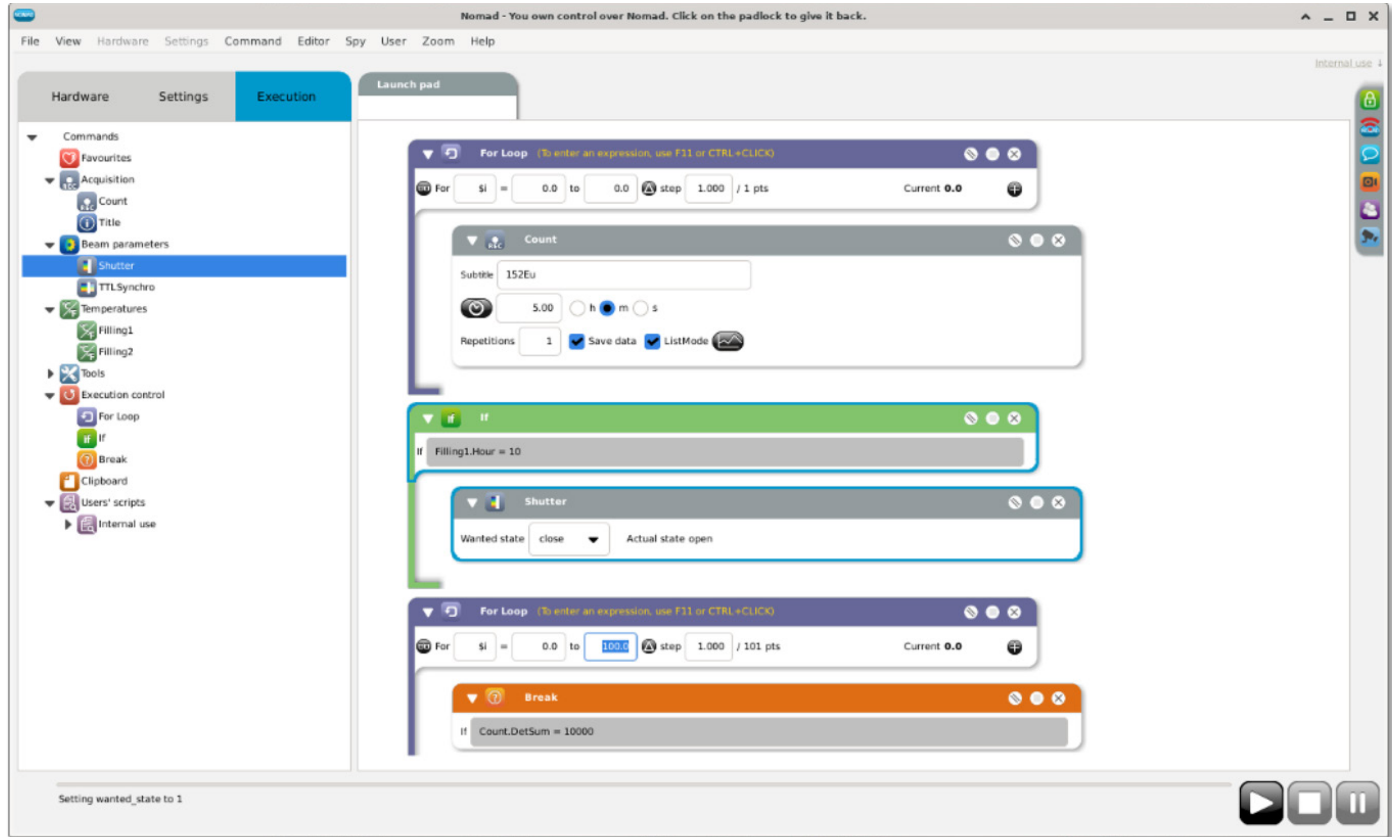
Data acquisition
- Industrial standard VME64x
- Central FPGA: Zynq UltraScale+
- Memory: 4 GB DDR4
- ARM processor: 4 cores

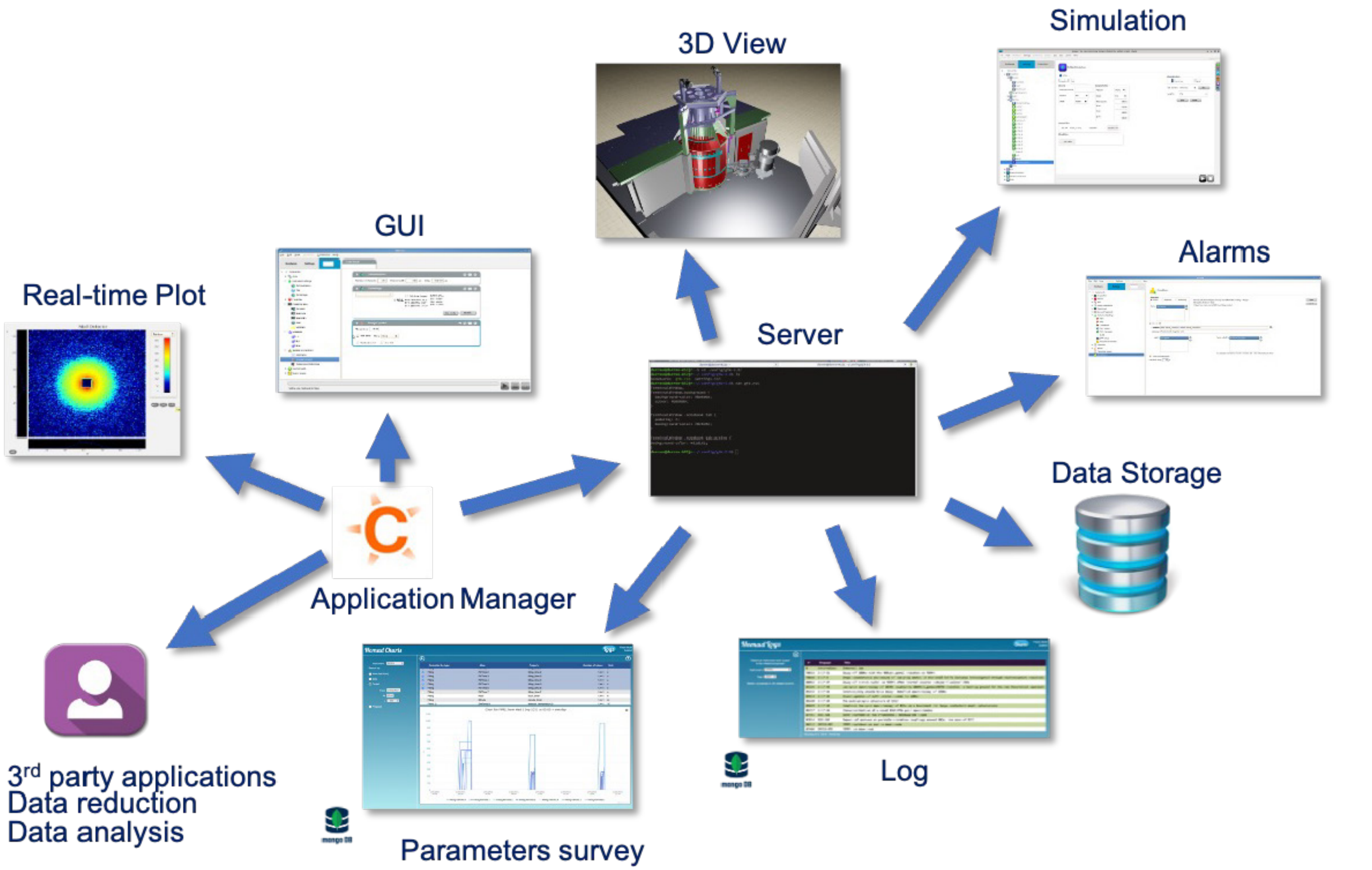
Onboard ethernet and optical link
- Matrix of 32 Onsemi SiPM 6x6 mm
- Fast (timing) and integrated (energy) output
- Optimised for LaBr3(Ce) scintillator

NOMAD: INTELLIGENT INSTRUMENT CONTROL

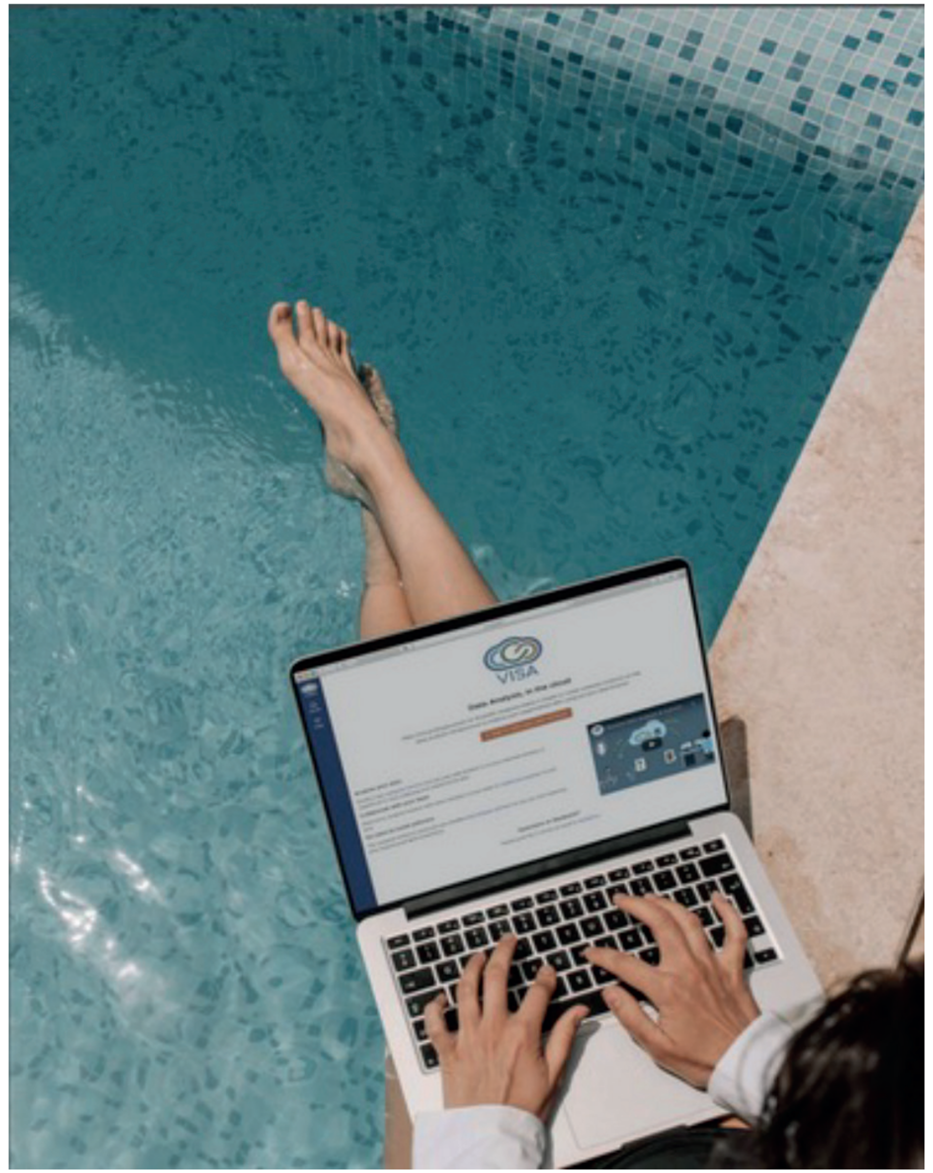
NOMAD is the central software for controlling all ILL instruments. Originally a simple sequencer, it now leverages distributed computing and networked architectures to manage complex workflows. A graphical user interface (GUI) provides intuitive experiment setup, real-time feedback, and automation tools to enhance efficiency and reproducibility. Integration with data processing software enables real-time data reduction, allowing quick adjustments to experimental parameters.

Advances in AI and machine learning are further optimising experimental conditions, predicting errors, and enabling autonomous adjustments for improved data quality. NOMAD also ensures full experiment control through its cockpit system, which includes a live dashboard, real-time data display, and an electronic logbook for monitoring key parameters.





For remote access, NOMAD Remote allows users to run the NOMAD interface from any web browser via VISA, interacting with live experiments as if physically present. This enables flexible working patterns, improves accessibility, and opens new possibilities for virtual experimentation. NOMAD 3D takes this further, allowing users to simulate entire experiments, test constraints, optimise measurement strategies, and visualise instrument behaviour in a virtual environment. These innovations are transforming instrument control, ensuring greater precision, efficiency, and usability in neutron scattering research.

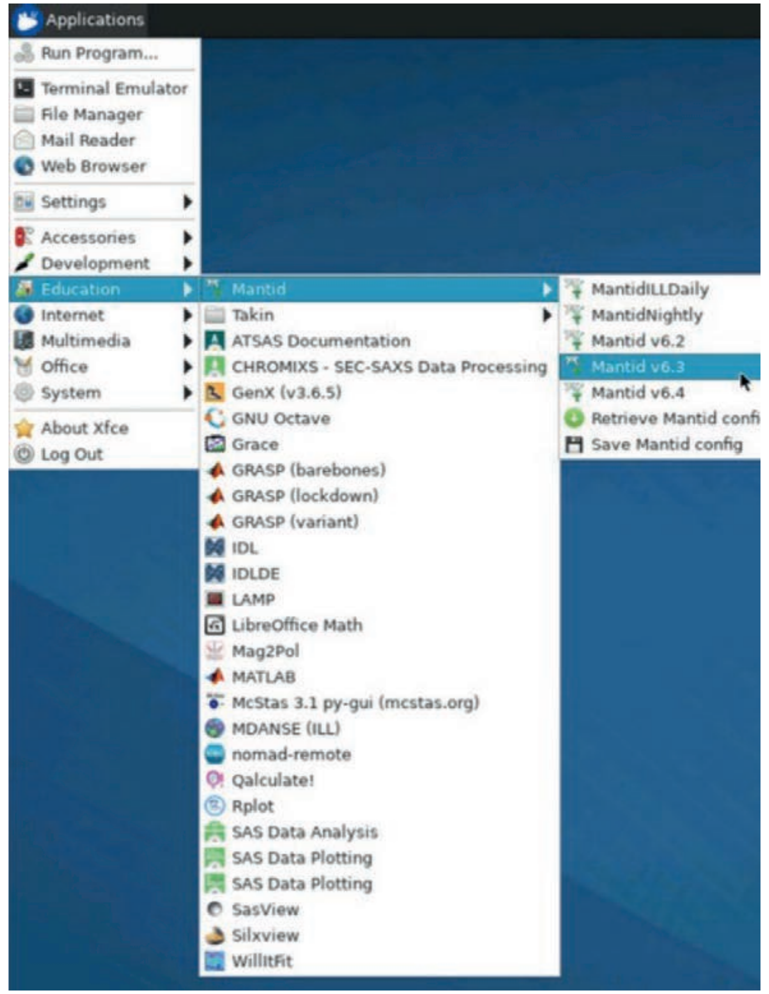


VISA: VIRTUAL INFRASTRUCTURE FOR SCIENTIFIC ANALYSIS

VISA is an open-source, web-based platform developed by ILL under the EU-funded PaNOSC initiative to simplify remote access to experimental tools and data. Through a browser-based interface, researchers can create and configure virtual machines (VMs) within a secure, high-performance environment equipped with all necessary scientific software for data analysis and instrument control.

VISA brings the scientist to the data. Each instance is linked to ILL's scientific storage system, providing instant access to experimental data and analysis tools. The platform ensures reproducibility by allowing researchers to revisit and re-analyse data using the same software versions as in previous studies. Built-in real-time collaboration makes it easy to share analysis environments.

Users can also operate NOMAD Remote to control experiments or launch JupyterLab notebooks for data analysis, either independently or with support from ILL experts. The VISA team continuously updates the platform with new features and the latest software, ensuring a seamless and efficient research experience.



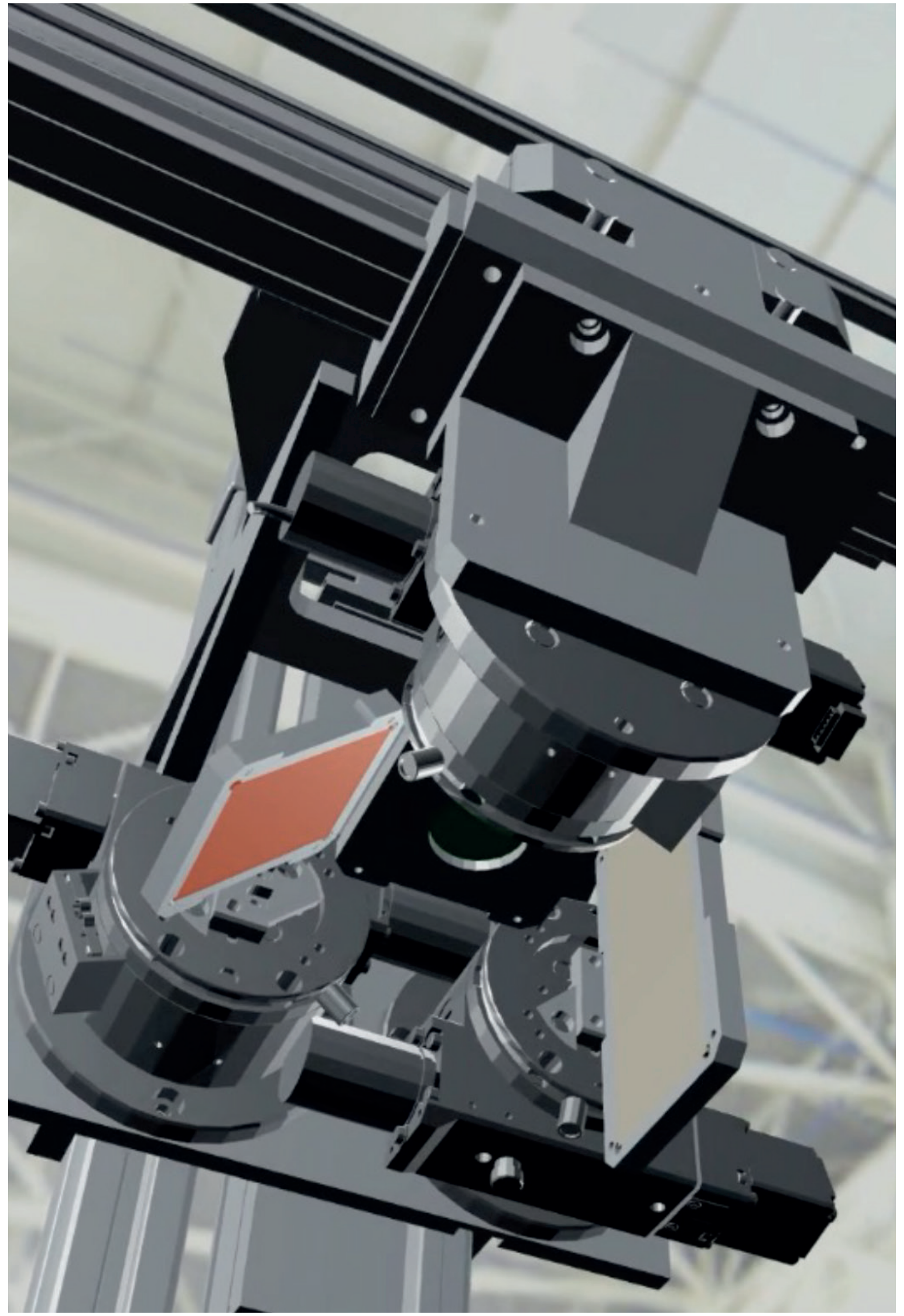
VISA offers a practical, scalable solution for modern research, bridging distances and optimising resources.

With a simple web login, VISA provides a powerful virtual workspace to:

- Control experiments in real time
- Process and analyse data instantly
- Use advanced tools—all within a unified platform

Integrated with NOMAD, ILL's client-server instrument control system, VISA makes remote experimentation seamless. Built on a modern technical framework, it enables advanced analysis and offers one-click access to a vast library of software tools, including Mantid, a leading platform for neutron and muon data analysis.

Developed at ILL and adopted by a growing global community, VISA is becoming the standard for data access at major facilities such as DESY, ESRF, SOLEIL, ALBA, and EuXFEL. In the spirit of Open Science, it also expands public access to cutting-edge research.

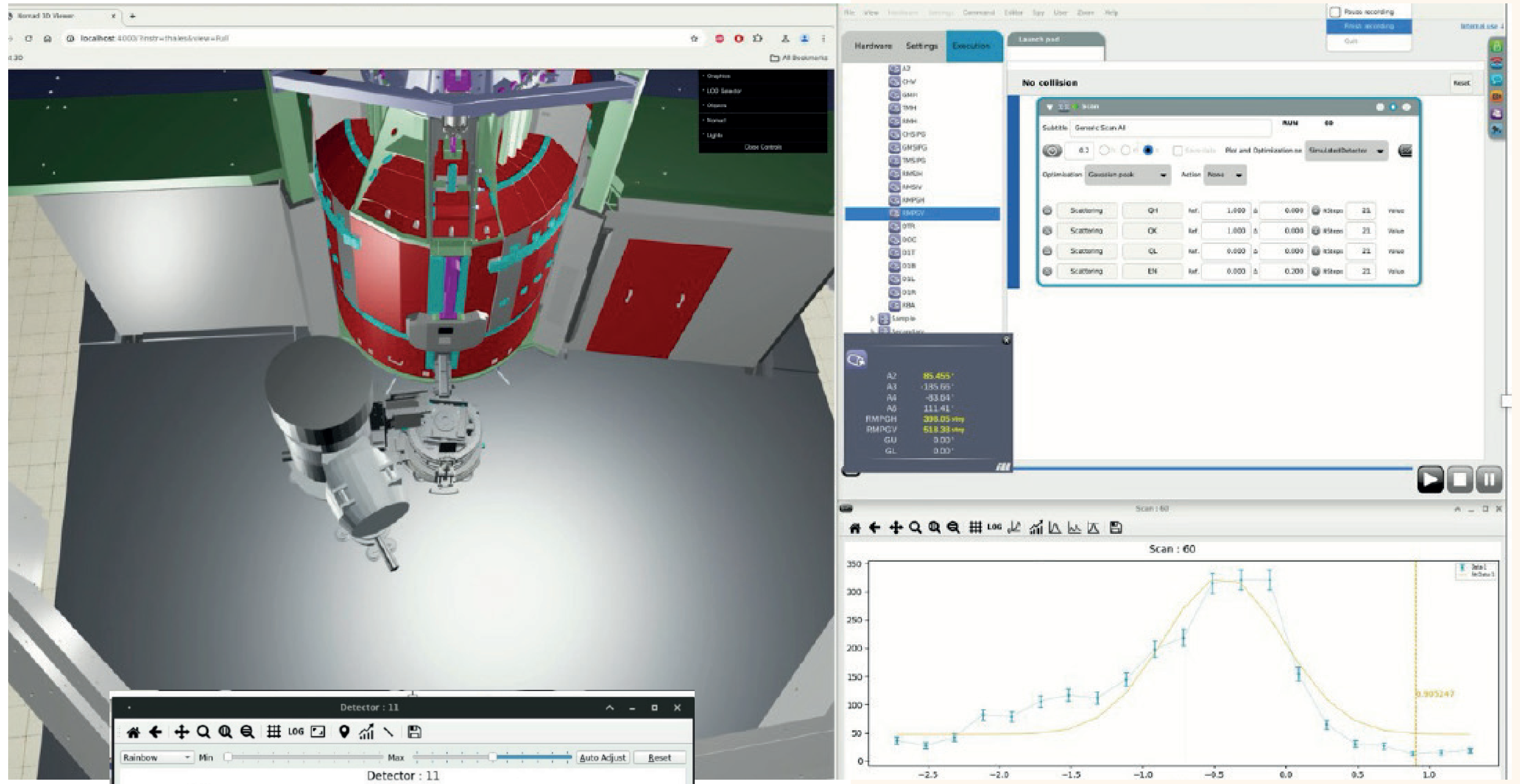


DIGITAL TWINS: SIMULATING ADVANCED NEUTRON INSTRUMENTATION

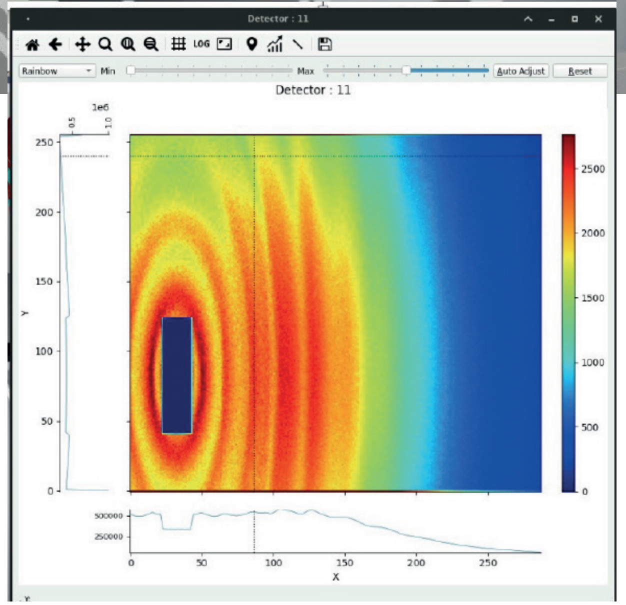
Digital twins offer a powerful approach to neutron experimentation by creating virtual models of instruments that continuously update with real-world data. These simulations replicate neutron sources, sample interactions, and detector responses with high fidelity, allowing researchers to predict conditions, optimise instrument configurations, and refine data collection strategies before conducting experiments. This reduces trial-and-error, enhances efficiency, and conserves resources.

Advanced computational methods, such as Monte Carlo simulations and molecular dynamics, provide deeper insights into neutron scattering phenomena. Monte Carlo techniques, for example, model neutron transport and interactions in complex materials, improving experiment design and data interpretation. Machine learning further enhances these simulations by optimising parameters in real time and adapting models based on acquired data.

At ILL we are continuously exploring state-of-the art computing technologies to improve instrument control, in particular virtualisation, 3D animations and augmented reality.

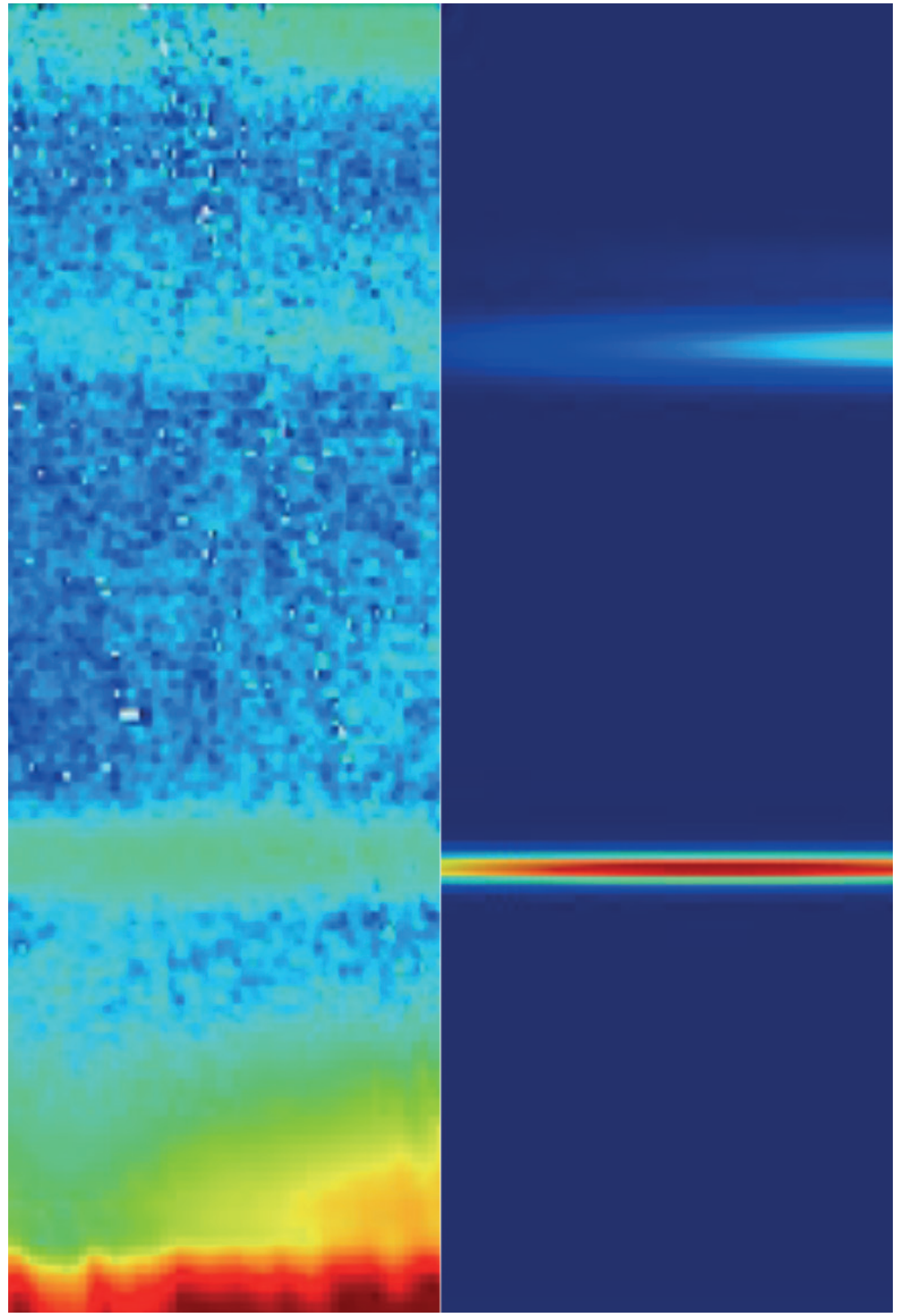


ThALES digital twin



Simulated data from Panther digital twin

Digital twin technology is integrated within NOMAD and NOMAD 3D, combining high-performance computing with simulation tools like McStas. This framework makes virtual experiments accessible to users beyond simulation specialists, allowing real-time experiment monitoring, parameter adjustments, and automated data analysis. Machine learning algorithms can even refine experimental conditions dynamically, reducing human error and accelerating discovery.

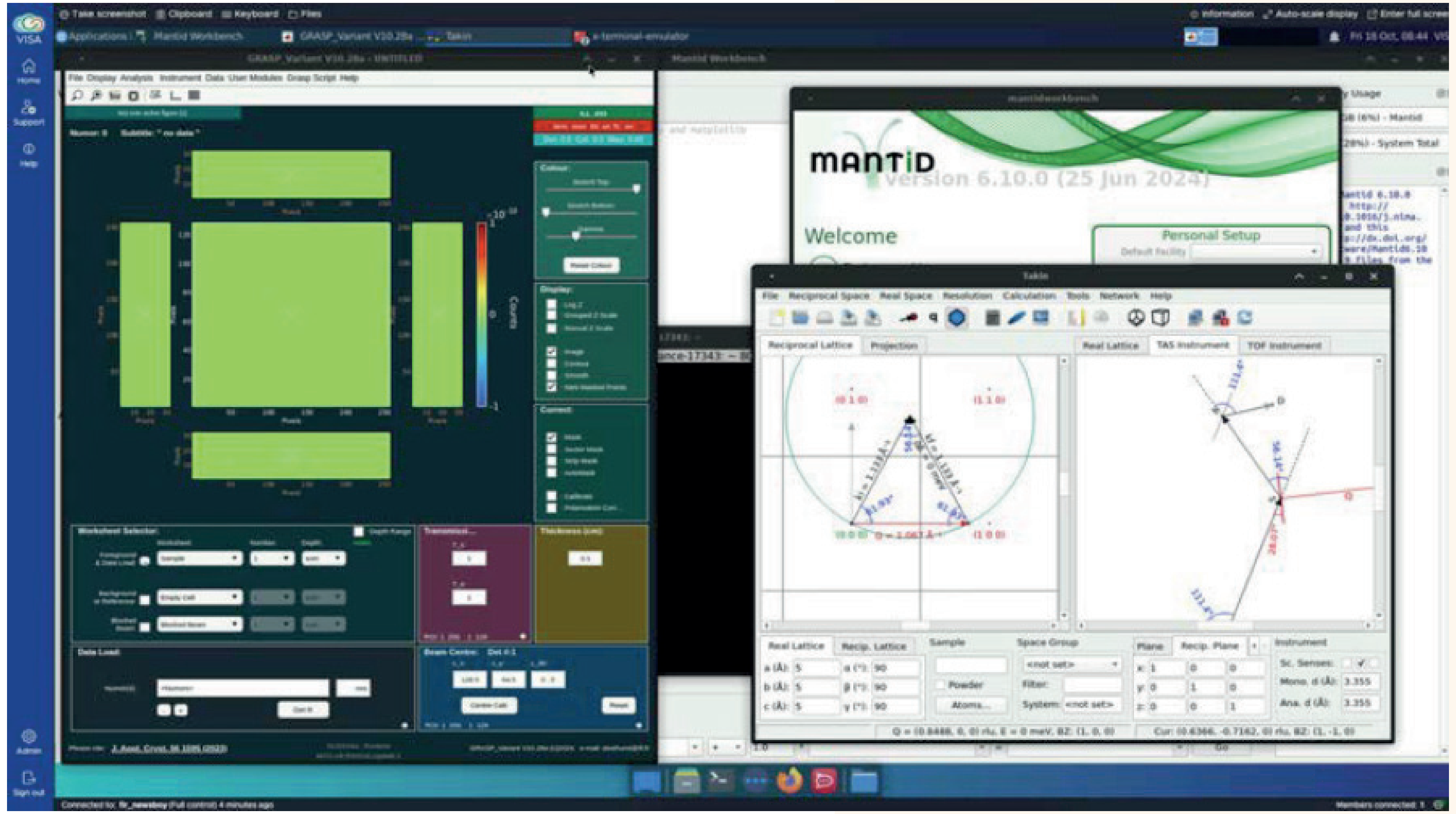


SCIENTIFIC COMPUTING

The production of high-quality data is the cornerstone of a successful experiment. However, achieving meaningful scientific results requires a critical step: the application of specialised digital tools for data reduction and analysis, combined with the expertise to use them effectively. At the ILL, we offer a comprehensive service supported by experts in numerical simulation and software development, drawing on our extensive experience in neutron scattering.

We actively contribute to the development of the Mantid project, an internationally collaborative software framework designed for processing and visualising data from neutron scattering experiments. Furthermore, we develop additional software solutions born from local initiatives, including Grasp for small-angle neutron scattering (SANS) experiments, Int3D/Esmeralda for single-crystal diffraction, Takin for triple-axis spectroscopy, and FullProf/Mag2Pol for powder diffraction analysis. Each tool is carefully tailored to meet the unique requirements of specific experimental techniques.

In addition we provide users with expertise in numerical simulation—including ab initio codes for density functional theory, molecular dynamics, and/or magnetic excitations —to support their data analysis and provide an atomistic view of their sample. To facilitate this, we manage a computing cluster both at a hardware (nodes, queuing system, network) and software (scientific software installation and settings) levels to meet the computational requirements of these tasks effectively.



NEUTRONS
FOR SOCIETY

Institut Laue-Langevin
71 avenue des Martyrs, CS 20156
F-38042 Grenoble Cedex 09

communication@ill.eu
www.ill.eu

Contributors: Jerôme Beaucour, Pierre Courtois, Bruno Guerard, Eddy Lelièvre-Berna, Erwan Le Gal, Giuliana Manzin, Paolo Mutti and Stéphane Rols

Editor: Charles Dewhurst

Design: Virginie Guerard

Photos: ILL's staff members and L. Thion

May 2025